ECT*

Annual Report 2011

European Centre for Theoretical Studies in Nuclear Physics and Related Areas
Trento

Institutional Member of the European Science Foundation Expert Committee NuPECC

FONDAZIONE BRUNO KESSLER

Edited by
Susan Driessen and Gian Maria Ziglio

1 Preface

The European Centre for Theoretical Studies in Nuclear Physics and Related Areas (ECT*) is one of the smaller Research Centres of the Fondazione Bruno Kessler (FBK) and an Institutional Member of the European Science Foundation Expert Committee NuPECC (Nuclear Physics European Collaboration Committee). Its objectives – as stipulated in its statutes – are:

- to arrange in-depth research on topical problems at the forefront of contemporary developments in nuclear physics
- to foster interdisciplinary contacts between nuclear physics and neighboring fields such as astrophysics, condensed matter physics, particle physics and the quantal physics of small systems
- to encourage talented young physicists to participate in the activities of the ECT* and
- to strengthen the interaction between theoretical and experimental physics

As is shown in the figure on p.5 of this Annual Report altogether 869 scientists from 38 countries of the world have visited the ECT* in 2011 and have participated in the activities of the Centre. Since its foundation in 1993 this number is a record high and the steady increase of it from 2008 – the year I have taken over the Directorship of ECT* - with 535 visitors, 640 in 2009, 782 in 2010 up to 869 in 2011, illustrated in the figure on p.6, demonstrates impressively ECT*'s high visibility and important coordinating function in the European and international scientific community.

In 2011 ECT* has held

- 19 Workshops and 1 Collaboration Meeting, like in the year 2010, on new developments in nuclear and hadronic physics from the lowest to the highest energies – two Workshops alone were devoted to physics problems posed and investigated by the Large Hadron Collider (LHC) at CERN and another two dealt with interdisciplinary topics in condensed matter, gravitation and cosmology and the origin of the elements, respectively
- a Doctoral Training Programme on "Neutrinos in Nuclear-, Particle- and Astrophysics" lasting for 10 weeks and attended by 16 students

and has in addition to these 20 scientific events supported

- fundamental research on low energy nuclear theory, models of nuclear structure, reaction dynamics and phase transitions, nuclear many-body wave functions, pion-nucleon interactions, chaos in hadrons, structure of the nucleon, partons, quarks and gluons, non-perturbative QCD, lattice QCD, hadron-nucleus and nucleus-nucleus collisions at high energy and QCD in hot and dense matter. The research was performed by the in-house group of 6 Junior Postdoctoral Fellows and 4 Senior Research Associates having interacted scientifically closely among themselves, with the Director of the Centre, scientific visitors and collaborating physicists elsewhere. All this is documented in detail in Chapter 4 of the Annual Report, and it is gratifying to note that the 27 scientific publications of the ECT* Researchers in refereed (impact factor) journals in 2011 amounts to about 20% of all publications produced within the Fondazione Bruno Kessler in the same year.

Finally, ECT* has

- administered scientifically the AuroraScience project which is a direct collaboration of the FBK with the Istituto Nazionale di Fisica Nucleare (INFN) and several local and national institutions. It utilizes the high performance computing (HPC) system AURORA – a joint research and development project of Eurotech and AuroraScience – optimized for a number of highly relevant scientific computing applications in physics. The first phase of the project has ended on July 31st in 2011. Currently, the system has a peak performance of about 15TFlops. We are now in an intermediate phase looking forward to a decision of the continuation of this important HPC project which has already produced important scientific results.

Maintaining ECT*'s high scientific activity and visibility in 2011 has only been possible through a stable operating budget. We are therefore very grateful for the local support from the FBK/PAT, for the considerable third party funds from European funding agencies and research centres in Belgium, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, the Netherlands, Poland, Romania, Spain and the UK and for funds provided through the European FP7 projects ENSAR, QUIE2T and Hadron Physics. In the latter ECT* has an important role as a Trans-National Access (TNA) facility. ECT* also acknowledges partial support of its workshops from the ExtreMe Matter Institute EMMI in Darmstadt/Germany.

This Annual Report of 2011 is the last one prepared under my responsibility. On October 31st, 2012 I will leave ECT* after having directed the Centre for four years. ECT* is now fully integrated in, respected and carried by the Fondazione Bruno Kessler. I am convinced that this is highly beneficial to both partners and will strengthen their status as European institutions. I thus thank both, President Massimo Egidi and General Secretary Andrea Simoni, for their continuous support of the Centre and the FBK staff for its steady assistance in all administrative matters.

Finally, it is a great pleasure for me to thank the members of the Scientific Board, the coordinator of the Doctoral Training Programme, Georges Ripka, the scientific staff – and last but not least – the very competent administrative and technical staff of the ECT* for their trustful cooperation.

As its predecessors the Annual Report of 2011 is also available on the ECT* web site (www.ectstar.eu).

Achim Richter

Trento, May 17, 2012

Achim Richter
Director of ECT*

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2 ECT* Scientific Board, Staff and Researchers

2.1 ECT* Scientific Board and Director

Mauro Anselmino (until October 2011)	University of Torino, Italy
Baha Balantekin (from January 2010)	University of Wisconsin, Madison, USA
Jens Jørgen Gaardhøje (from January 2010)	Niels Bohr Institute, Copenhagen, Denmark
Pawel Haensel (until January 2011)	N. Copernicus Astronomical Center, Poland
Simon Hands (from January 2008, Chairman)	Swansea University, UK
Kris Heyde (from January 2009)	University of Gent, Belgium
Jean-Yves Ollitrault (from January 2009)	CEA Saclay, France
Arturo Polls (from June 2011)	University of Barcelona, Spain
Günther Rosner (until October 2011)	NuPECC and University of Glasgow, UK
Achim Schwenk (from October 2010)	TU Darmstadt, Germany

Honorary Member of the Board

Ben Mottelson	NORDITA, Copenhagen, Denmark

ECT* Director

Achim Richter	ECT*, Italy and TU Darmstadt, Germany

2.2 ECT* Administrative and Technical Staff

Ines Campo (part time)	Technical Programme Co-ordinator
Serena degli Avancini	Technical Programme Co-ordinator
Barbara Curro' Dossi	Systems Manager
Susan Driessen (part time)	Assistant to the Director
Tiziana Ingrassia (part time)	Accounting Assistant
Mauro Meneghini	Maintenance Support Manager
Gian Maria Ziglio (part time)	Technical Programme Co-ordinator and Web Manager

2.3 Resident Postdoctoral Researchers

- **ECT* Postdocs**

Massimiliano Alvioli, Italy

Daniele Binosi, Italy

Alexis Diaz-Torres, Germany (from 16/08/11)

Cesar Fernandez-Ramirez, Spain (01/01/11-28/02/11 and 03/07/11-16/09/11)

Lorenzo Fortunato, Italy (until 31/08/11)

Vincent Mathieu, Belgium (from 01/10/11)

Stefano Melis, Italy

Pavel Stransky, Czech Republic (from 01/11/11)

Laura Muñoz, Spain

Dionysis Triantafyllopoulos, Greece

- **AuroraScience**

Michele Brambilla, Italy (from 17/01/11)

Marco Cristoforetti, Italy

Marco Grossi, Italy (from 21/02/11)

Fabio Pozzati, Italy

Michele Schimd, Italy (from 01/08/11)

Luigi Scorzato, Italy

Tatjana Skrbic, Serbia (from 15/02/11)

Enrico Tagliavini, Italy (from 28/02/11)

Francesco Versaci, Italy (from 01/08/11)

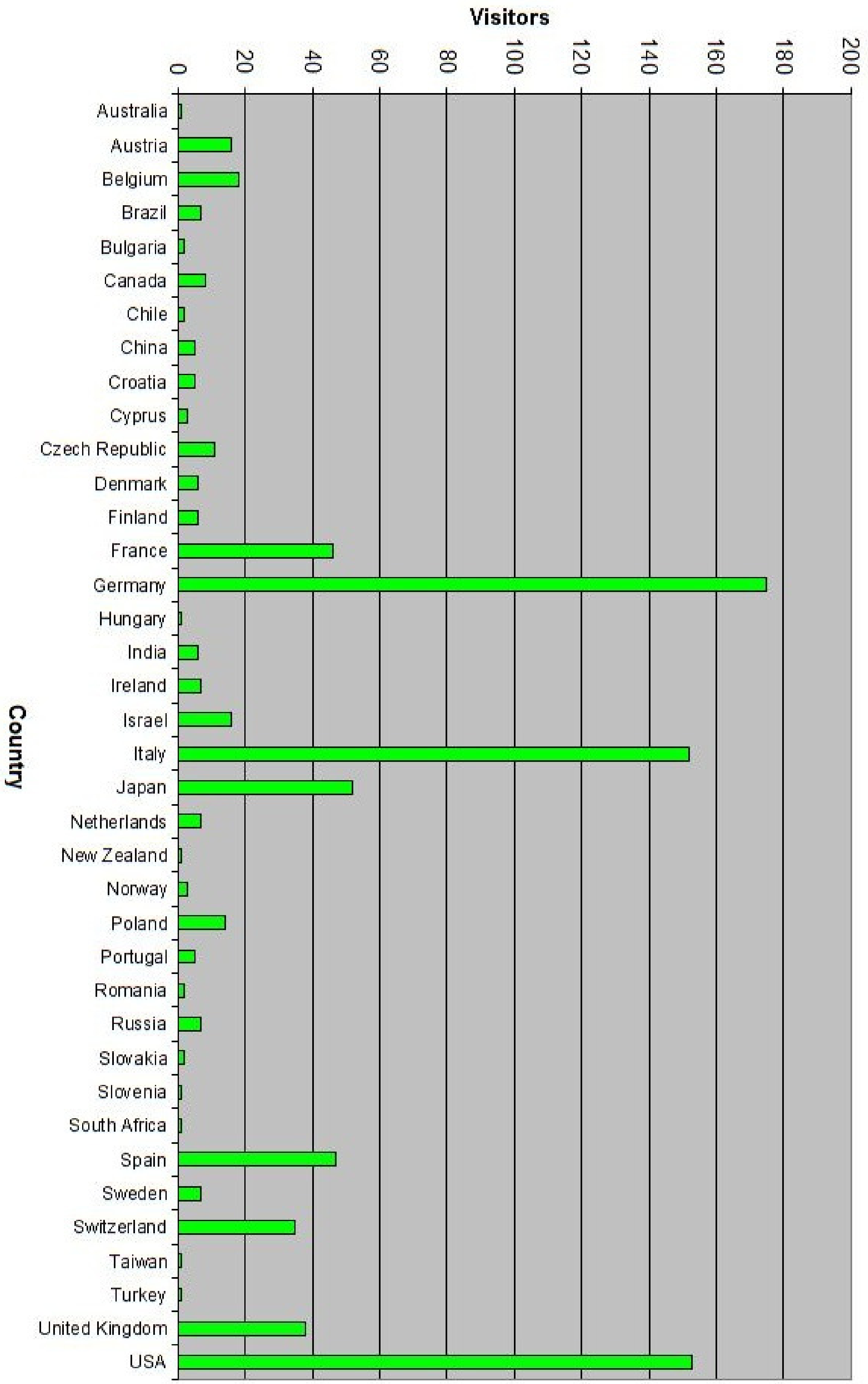
2.4 Visitors in 2011

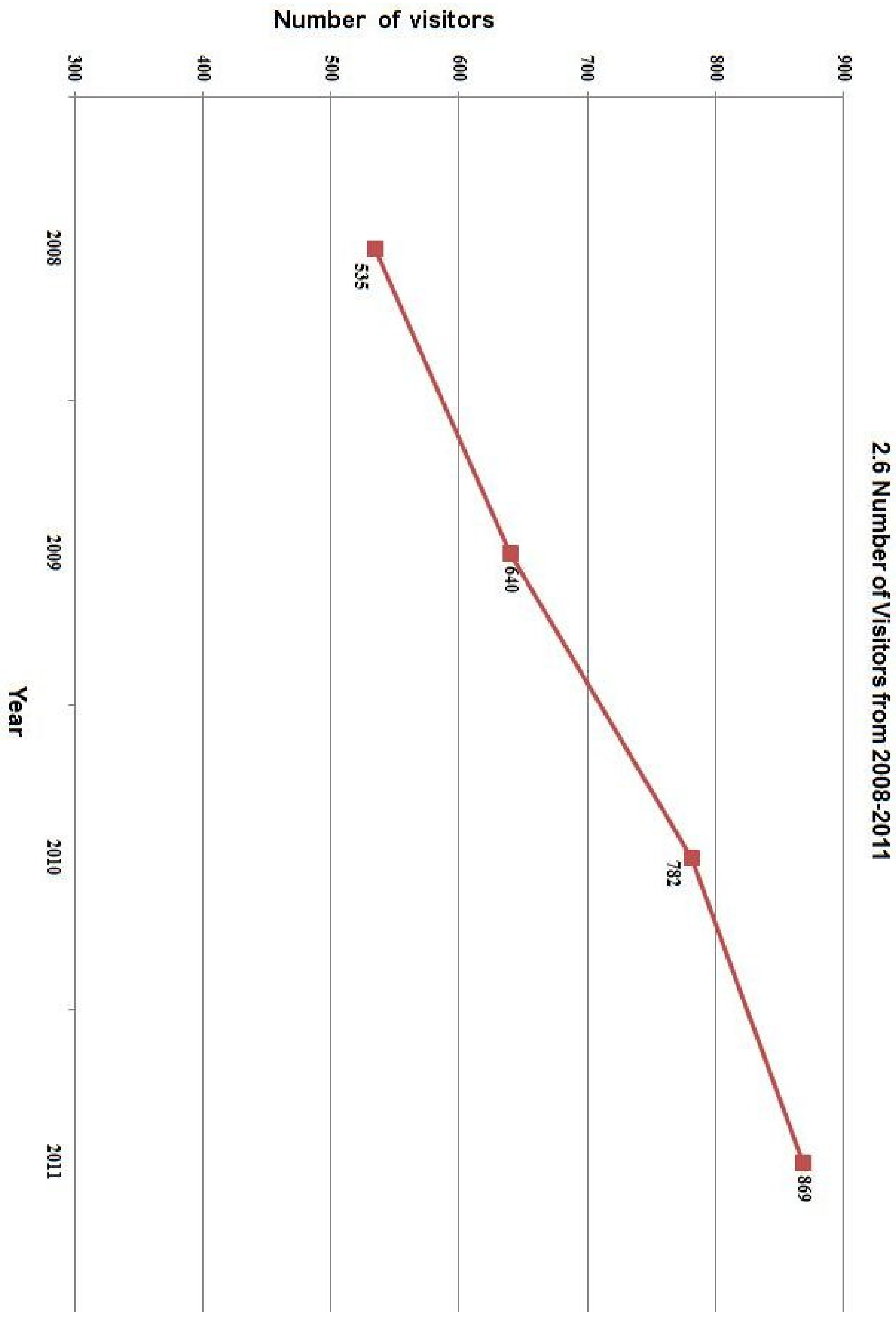
This list includes Visiting Scientists (VS) who typically have spent time from days up to several weeks at the Centre, as well as participants and lecturers of the Doctoral Training Programme (TP).

Arlene Cristine Aguilar (04-16/09)	Federal University of ABC, Brasil (VS)
Baha Balantekin (10-16/04, 15-25/05)	University of Wisconsin, USA (TP)
Heinrich Behrens (06-09/06)	Karlsruhe Institute of Technology, Germany (VS)
Andrea Beraudo (06-11/06)	INFN Torino, Italy (VS)
José Bernabeu Alberola (25/04-01/05)	Universitat de Valencia, Spain (TP)
Jean-Paul Blaizot (28/05-12/06)	CEA Saclay IPhT, France (VS)
Radu Budaca (10/04-18/06)	Horia Hulubei Institute, Bucarest (TP)
Petrica Buganu (10/04-18/06)	Horia Hulubei Institute, Bucarest (TP)
Giovanni Chirilli (09-21/05)	LBL Berkeley, USA (VS)
Claudio Ciofi degli Atti (02-31/05)	INFN Perugia, Italy (VS)
Mattia Dallabrida (23-31/05)	University of Dublin, Ireland (VS)
Rastislav Dvornicky (24/04-28/05)	University Mlynska, Bratislava, Slovak Republic (TP)
Victor Efros (16/02-16/06)	Kurchatov Institute Moscow, Russia (VS)
Amand Faessler (30/05-03/06)	University of Tübingen, Germany (TP)
Livio Fano (19-22/12)	CERN, Switzerland (VS)
Marco Filipuzzi (14-17/06)	INFN Trieste, Italy (VS)
Ettore Fiorini (10-12/04)	University of Milano Bicocca, Italy (TP)
Harald Fritzsch (11-16/07)	University of Munich, Germany (VS)
George Fuller (15-27/05)	University of California, San Diego, USA (TP)
Harald Genz (06-09/06)	TU Darmstadt, Germany (VS)
Carlo Giunti (06-10/06)	INFN Torino, Italy (TP)
Mario Gravina (09-15/01)	University of Nicosia, Cyprus (VS)
Rajiv Gupta (09/04-18/06)	Guru Nanak Dev University, Amritsar, India (TP)
Huma Haider (10/04-18/06)	Aligarth Muslim University, India (TP)
Morten Hjorth-Jensen (17-18/11)	University of Oslo, Norway (VS)
Budimir Klicek (09/04-18/06)	Ruder Boskovic Institute Zagreb, Croatia (TP)
Marek Kowalski (20-23/04)	Universität Bonn, Germany (TP)
Saskia Kraft-Bermuth (12-16/06)	Universität Giessen, Germany (TP)
Thierry Lasserre (05-11/06)	CEA Saclay, France (TP)
Manfred Lindner (09-13/05)	MPI Heidelberg,Germany (TP)

Annalise Malkus (10/04-17/06)	University of Wisconsin, Madison, USA (TP)
Susanne Mertens (10/04-18/06)	Karlsruhe Institute of Technology, Germany (TP)
Lothar Oberauer (31/05-03/06)	TU München, Germany (TP)
Vishvas Pandey (09/04-19/06)	Ghent University, Belgium (TP)
Joannis Papavassiliou (04-16/09)	University of Valencia, Spain (VS)
Francesco Pederiva (17-18/11)	UNITN, Italy (VS)
Carlos Pena Garay (08-13/05)	Universitat de Valencia, Spain (TP)
Marek Ploszajczak (17-18/11)	GANIL, France (VS)
Alfredo Poves Paredes (02-07/05)	Universidad Autonoma de Madrid, Spain (TP)
Andrea Quadri (25-26/09, 16-17/10)	INFN Milano, Italy (VS)
Armando Relaño Pérez (07-13/02)	UCM Madrid, Spain (VS)
Georges Ripka (29/03-17/06)	CEA Saclay IPhT, France (VS)
Sophia Schaefer (21-22/04)	University Duisburg-Essen, Germany (VS)
Achim Schwenk (15-20/05)	TU Darmstadt, Germany (TP)
Marcello Sega (15-17/02)	University of Stuttgart, Germany (VS)
Hale Sert (10/04-18/06)	Izmir Institute of Technology, Turkey (TP)
Elena Shcherbakova (10/04-17/06)	DESY / University of Hamburg, Germany (TP)
Edward Shuryak (25-29/09)	SUNY at Stony Brook, USA (VS)
Jagjit Singh (09/04-18/06)	Maharishi Markandeshwar University Mullana, India (TP)
Hartmut Spalt (06-09/06)	TU Darmstadt, Germany (VS)
Nicola Tamanini (27/04-17/06)	UNITN, Italy (TP)
Jian Tang (10/04-18/06)	University of Würzburg, Germany (TP)
Christian Toepffer (04-07/04)	University of Erlangen, Germany (VS)
Daavid Vaananen (15-28/05)	IPN Orsay, France (TP)
Petr Vogel (02-07/05)	Caltech, Pasadena, USA (TP)
Maria Cristina Volpe (17-21/04, 15-20/05)	IPN Orsay, France (TP)
Christian Weinheimer (13-17/06)	University of Münster, Germany (TP)
Wolfram Weise (03/10)	TU Munich, Germany (VS)
Yvonne Wong (24-30/04)	RWTH Aachen, Germany (TP)
Meng-Ru Wu (15-27/05)	University of Minnesota, USA (TP)
Zhi-zhong Xing (12-19/06)	Chinese Academy of Sciences Beijing, China (VS)
Kai Zuber (21-27/05)	TU Dresden, Germany (TP)

2.5 Visitors at ECT* per Country in 2011




2.6 Number of Visitors from 2008-2011
Number of visitors
300
400
500
600
700
800
900
2008
2009
2010
2011
Year
535
640
782
869

3 Scientific Projects Run in 2011

3.1 Summary

Altogether 21 scientific projects have been run in 2011: 19 workshops, one collaboration meeting, and a Doctoral Training Programme. This chapter contains the scientific reports written by the organizers of each project. Georges Ripka, who assisted the Director in running the long Doctoral Training Programme, prepared the corresponding report for it.

3.2 Workshops, Collaboration Meetings and Schools (Calendar)

Jan 24 - 28	**Amplitude Analysis in Hadron Spectroscopy** A. Szczepaniak *(Indiana University)* C. Hanhart *(Institut fuer Kernphysik Forschungszentrum Jülich)* M. Pennington *(Jefferson Laboratory)* E. Santopinto *(INFN, Genova)* U. Wiedner *(Ruhr University)*
Mar 07 - 11	**Effective Theories and the Nuclear Many-Body Problem** T. Papenbrock *(University of Tennessee / Oak Ridge National Laboratory)* H.-W. Hammer *(HISKP Universität Bonn)* M. Hjorth-Jensen *(University of Oslo)*
Apr 11 - Jun 17	**Neutrinos in Nuclear-, Particle- and Astrophysics (Doctoral Training Programme)** B. Balantekin *(University of Wisconsin, Madison)* C. Volpe *(IPN, Orsay)* C. Weinheimer *(University of Münster)* F. Nunes *(NSCL)* J. Piekarewicz *(Florida State University)*
May 09 - 13	**Recent Developments in Transfer and Knockout Reactions** E. Rehm *(Argonne National Laboratory)* B. Back *(Argonne National Laboratory)*

J. Schiffer *(Argonne National Laboratory)*

May 16 - 20 **The Origin of the Elements: A Modern Perspective**

Y. Qian *(University of Minnesota)*

G. Fuller *(University of California, San Diego)*

W. Haxton *(University of California, Berkeley)*

G. Martinez-Pinedo *(GSI Darmstadt)*

F.K. Thielemann *(University of Basel)*

May 30 - Jun 02 **Standard and Novel QCD Phenomena at Hadron Colliders**

D. Triantafyllopoulos *(ECT*)*

F. Gelis *(IPhT, CEA Saclay)*

E. Iancu *(IPhT, CEA Saclay)*

C. Marquet *(CERN)*

Jun 06 - 10 **Nuclear Many-Body Open Quantum Systems: Continuum and Correlations in Light Nuclei**

C. Forssén *(Chalmers University)*

H. Fynbo *(University of Aarhus)*

G. Hagen *(Oak Ridge National Laboratory)*

L. Platter *(University of Washington)*

H. Simon *(GSI Darmstadt)*

Jun 28 - 30 **Clusters in Nuclei and Nuclear Matter: Nuclear Structure, Heavy Ion Collisions, and Astrophysics**

D. Blaschke *(University of Wroclaw)*

G. Roepke *(University of Rostock)*

T. Klahn *(University of Wroclaw)*

S. Typel *(GSI Darmstadt)*

S. Shlomo *(Texas A&M University)*

Jun 27 - Jul 01 **New Trends in the Physics of the Quantum Vacuum: from Condensed Matter to Gravitation and Cosmology**

I. Carusotto *(BEC-CNR-INFM, Trento)*

R. Balbinot *(Università di Bologna and INFN)*

C. Ciuti *(LMPQ, Paris)*

A. Fabbri *(Universidad de Valencia-CSIC)*

Jul 04 - 08	**Not so Few, but not too Many** N. Barnea *(The Hebrew University, Jerusalem, Israel)* M. Gattobigio *(Université de Nice-Sophie Antipolis)* A. Kievsky *(INFN, Pisa)* B. Esry *(Kansas State University)*
Jul 11 - 15	**Three-Nucleon Forces in Vacuum and in the Medium** C. Barbieri *(University of Surrey)* E. Epelbaum *(Ruhr-Universität)* T. Otsuka *(University of Tokyo)* K. Sekiguchi *(Tohoku University)*
Aug 29 - Sep 02	**Speakable in Quantum Mechanics: Atomic, Nuclear and Subnuclear Physics Tests** C. Curceanu *(LNF - INFN)* J. Marton *(SMI-Vienna)* E. Milotti *(Università di Trieste and INFN)* J. Stroth *(Goethe University Frankfurt)*
Sep 05 - 09	**QCD Green's Functions, Confinement, and Phenomenology** D. Binosi *(ECT*)* A. C. Aquilar *(Federal University of ABC)* J. M. Cornwall *(University of California at Los Angeles)* J. Papavassiliou *(University of Valencia)* P. Verrocchio *(University of Trento)*
Sep 12 - 16	**LC11: Understanding QCD at Linear Colliders in Searching for Old and New Physics** L. Pancheri *(INFN Frascati)* S. De Curtis *(INFN Firenze)* S. Moretti *(University of Southampton)* A. De Roeck *(CERN)* F. Richard *(Université de Paris-Sud)*

Sep 26 - 30	**Strange Hadronic Matter** J. Pochodzalla *(Universität Mainz)* A. Feliciello *(INFN-Torino)* O. Hashimoto *(Tohoku University)* H. Lenske *(Universität Gießen)* A. Ramos *(Universitat de Barcelona)*
Oct 03 - 07	**STRONGnet 2011m** F. Di Renzo *(Università di Parma & INFN)* L. Scorzato *(ECT*)* R. Schiel *(University of Regensburg)* G. Bali *(University of Regensburg)*
Oct 17 - 21	**Nuclear Structure Seen Through Ground-State Properties of Exotic Nuclei** M. Kowalska *(CERN)* K. Blaum *(MPIK – Heidelberg)* P. van Isacker *(GANIL)*
Oct 24 - 26	**The Shell Evolution and the Role of Correlations in Very Neutron Rich Nuclei** **(Collaboration Meeting)** P.H. Heenen *(Université Libre de Bruxelles)* J. Dobaczewski *(Warsaw University)* H. Leeb *(Technical University of Vienna)* F-K.Thielemann *(University of Basel)* A. Richter (*ECT**)
Oct 24 - 28	**Chiral Dynamics with Wilson Fermions** K. Splittorff *(The Niels Bohr Institute, Copenhagen)* P. Henrik Damgaard *(The Niels Bohr International Academy)* J. Verbaarschot *(SUNY at Stony Brook)*
Nov 14 - 18	**Short Range Correlations in Nuclei and Hard QCD Phenomena** C. Ciofi Degli Atti *(University of Perugia)* M. Strikman *(Penn State University)*

Dec 12 - 16 **Modeling Charge-Changing and Neutral-Current Neutrino Reactions with Nuclei**

M. B. Barbaro *(Universita' di Torino and INFN)*

W. Donnelly *(MIT)*

A. Molinari *(Universita' di Torino and INFN)*

3.3 Reports on all Workshops and Collaboration Meetings

3.3.1 AMPLITUDE ANALYSIS IN HADRON SPECTROSCOPY

DATE: January 24-28, 2011

ORGANIZERS:

A. Szczepaniak *(Indiana University, USA)*

C. Hanhart *(Institut für Kernphysik Forschungszentrum Jülich, Germany)*

M. Pennington *(Jefferson Laboratory, USA)*

E. Santopinto *(INFN, Genova, Italy)*

U. Wiedner *(Ruhr University, Germany)*

NUMBER OF PARTICIPANTS: 31

MAIN TOPICS:

Information about the meson spectrum has been collected and collated from many different experiments over the past three decades using different probes and targets. The physics programs of all the experimental nuclear and particle physics laboratories round the world (BES, CERN, JLab, KEKB, SLAC), together with the planned experimental facilities that are being, or will be, built in the near future (FAIR, JLAB12, JPARC, Super-B), have an important component devoted to light and heavy hadron spectroscopy. Discoveries at such facilities, whether of exotic hadrons or of *CP* violation, depend crucially on the production of data of unprecedented statistics and precision. In order to access signatures of physics beyond the standard model, it is critical to be able to analyze these hadronic observables with high and controlled accuracy. In this context *CP* violating contributions to multi-particle decays of heavy flavored mesons (i.e. *B* and *D* mesons) are of great interest, since *CP* signals reveal themselves in phase differences between particle and antiparticle decays that become most visible in Dalitz--plot analyses of their resonant rich decays. This visibility is provided by a non--trivial pattern of phase motions. This type of analysis requires a very high level of control over the hadronic multi-particle final states.

The main topics discussed at the Workshop were:

Characterization of resonance properties. What is the value of Breit-Wigner parameters? What are the ways to extract the corresponding pole positions and residues from data?

Partial Wave Analyses with the least bias. How much theoretical input is necessary/appropriate?

Role of multi-particle final state interaction, in particular what is the effect of successive rescatterings in a three particle environment?

Model independence. What kind of analysis is of sufficient sophistication to deserve the label *model independent*? Especially, how one can quantify the uncertainty induced by the tools used to do the analysis?

SPEAKERS:

Marco Battaglieri *(IFN, Genoa, Italy)*
Diego Bettoni *(Ferrara, Italy)*
Kamal K. Seth *(Chicago, USA)*
Adam Szczepaniak *(Bloomington, USA)*
Christoph Hanhart *(Juelich, Germany)*
Albrecht Gillizer *(Juelich, Germany)*
Miriam Fritsch *(Mainz, Germany)*
Michael Doering *(Bonn, Germany)*
Bingsong Zou *(IHEP, Beijing, China)*
Alfred Svarc *(Zagreb, Croatia)*
Mark Paris (*GWU, Washington, USA)*
Jose Pelaez *(Complutense, Spain)*
Bachir Moussallam *(Paris, France)*
Leonard Lesniak *(INP, Krakow, Poland)*
Tobias Frederico *(Sao Jose dos Campos, Brazil)*
Bastian Kubis *(Bonn, Germany)*
Michael Pennington *(Jefferson Lab, USA)*
Satoshi Nakamura *(Jefferson Lab, USA)*
Sebastian Schneider *(Bonn, Germany)*
Brian Meadows *(Cincinnati, USA)*
Tim Gershon *(Warwick, UK)*
Klaus Peters *(GSI, Germany)*
Raffaella De Vita *(INF, Genoa, Italy)*
Derek Glazier *(Edinburgh, UK)*
M. Shepherd *(Bloomington, USA)*
Nik Berger *(Beijing, USA)*
Bertram Kopf *(Bochum, Germany)*
Lothar Tiator *(Mainz, Germany)*

SCIENTIFIC REPORT:

The presentations largely followed the outline given above. Amongst the presentations there were experimentalists discussing both data-taking as well as data analysis and analysis tools, as were the theoreticians.

The first day was devoted to overview talks (about experimental plans as well as results achieved with special focus on physics in the charm sector and a talk explaining what needs to be done theoretically on the path to high accuracy analyses of heavy meson decays to three light hadrons) and two talks demonstrating the power of dispersion theory to extract resonance properties from data with minimal bias.

The focus of the second day was on dynamical models applied to pion-nucleon scattering as well as meson decays. The main theme of this day was how to characterize resonance properties. The discussions stressed the importance of pole positions and residues as the only process-independent guide.

On the third day the theme was on high accuracy studies of hadronic three body decays. Various speakers talked about the possible influence of rescattering effects --- those were shown to show up as mildly energy dependent differences between scattering phases extracted from the true scattering process and those found in production reactions. The role of effective field theories, as well as dispersion theory, in quantifying these effects was discussed in detail.

The fourth day was devoted to partial wave analyses. New techniques were presented on the theory side, while the efficacy of using graphical processing unit clusters for such analyses was illustrated. These developments show that multi-dimensional fitting of high precision data is within reach. What is especially important is that tools that are presently being developed should be accessible to a broader community.

A higher than expected number of participants cancelled for health reasons just before the week started. Consequently, the formal program was consolidated on the first four days, leaving Friday entirely for informal discussions and collaborative working.

To summarize, the main subjects were

1. On the theoretical side the focus is on the construction of amplitudes, which can be used with as little model dependence as possible, to be used to study multi--hadron final states. This rests on the development of analytical parameterizations constrained by model-independent features such as unitarity, crossing symmetry, and where appropriate, gauge invariance, and chiral symmetry.

2. Standards need to be identified and methods developed to quantify the theoretical uncertainties encoded in such amplitudes. A discussion in this direction should be initiated at a future workshop.

3. A key to making the theoretical and phenomenological efforts directly applicable to experiment is to develop a common interface with easy access and utility. This includes the use of a common language to avoid misunderstandings in the interpretation of data. It is therefore essential to discuss how to implement the amplitudes (mentioned in point 1) within data analysis software packages, and how to disseminate the results interactively.

4. Finally the resonance parameters need to be compared with predictions of QCD and the feasibility of accurate non-perturbative QCD studies in the resonance region has to be evaluated.

Results and Highlights

What was very much appreciated was the goal of the workshop of bringing experimental and theoretical physicists together to consider problems of mutual interest. The discussions highlighted the need for the two groups to interact considerably more strongly in the future, so that a joint community with expertise in all aspects of Amplitude Analyses needs to be built. To push this further, a group of participants came together to organize a summer school this year that is meant to be the start of a series – the first being in Germany, with a summer school next year in the US already envisaged.

The workshop was characterized by very intense, but at all times constructive discussions, with strong participation by experimental as well as theoretical colleagues. Thus indeed the community moved closer together, which was a major success of the meeting.

We will now present the main topics of the discussions in some detail:

- it became clear that parametrizations that are a considerable improvement on standard Breit-Wigner forms are essential for an accurate and meaningful representation of data on hadronic resonances. Constraints from unitarity, for instance using *K*-matrix parametrizations, are essential. A simple method to improve the analytic properties of the *K*-matrix was discussed. This is implemented by replacing the phase space term by the expression for the scalar loop. It became clear that a compact parametrization of the amplitudes that is directly expressed in terms of the pole positions is desirable.

- there are plans to extract meson properties from high energy photon-nucleus reactions. The possible influence of nuclear intermediate states was discussed. Theorists promised to support the analysis to quantify this.

- more theoretical work is necessary to quantify the role of three-body and four-body unitarity on experimental spectra. One might hope that further study might allow such effects to be either more simply parametrized or included in a sophisticated way. This is of particular importance when considering what kind of Amplitude Analyses is appropriate for extracting *CP* violation parameters from anticipated precision data. In analyzing the relevant Dalitz plots a controlled knowledge of hadronic phases is crucial, if the results are to be meaningfully sensitive to physics beyond the Standard Model.

- there are clear theoretical indications that structure beyond the naive, static quark model should be present in both the meson and baryon spectra. A series of future experiments, the plans for which were presented at this meeting, aim to address these issues. With the appropriate Amplitude Analysis tools to be refined over the next 5 years definitive conclusions on these predictions should be possible.

- part of the discussion focused on the question of what is a complete experiment. How many observables are necessary to allow for an unambiguous partial wave analysis? It became clear that exploiting the polarization degree of freedom is very important in constraining the partial wave content.

- the idea came up to form a group to collect and collate pole properties from world analyses - some kind of *'resonance properties averaging group'* was proposed, though this will not happen in the very near future. Moreover, at various occasions in the workshop, participants expressed the desire that in the future there should be more intense and direct contact between the Particle Data Group about ongoing developments in analysis and their results.

- Probably the most central topic of the many discussions was on what is the best way to make experimental data accessible to theorists. The discussion especially focused on the way the information contained in Dalitz plots could be communicated. It was recognised that it is non--trivial to communicate the systematic uncertainties of the individual Dalitz plot bins. From the experimental side, three possible interactions with theorists were proposed
    a) theorists make predictions that could be compared with the data by the experimental group.
    b) the theorists can directly ask representatives of the experimental collaborations for particular pieces of data --- that would allow the experimentalists to communicate potential problems in the use of the data, while allowing theorists to test predictions themselves.
    c) a true collaboration between theory and experiment in the context of making use of a particular set of data.

It was agreed that c) was the best option when appropriate.

- The discussion made clear that there is a desire that the availability of data needs to be improved. However, the appropriate compromise between 'open access' and the current situation is still to be found.

3.3.2 EFFECTIVE THEORIES AND THE NUCLEAR MANY-BODY PROBLEM

DATE: March 7-11, 2011

ORGANIZERS:

Thomas Papenbrock *(U of Tennessee, Knoxville & Oak Ridge National Laboratory)*
Hans-Werner Hammer *(U of Bonn)*
Morten Hjorth-Jensen *(U of Oslo)*

NUMBER OF PARTICIPANTS: 31

MAIN TOPICS:

Effective theories and the nuclear many-body problem

SPEAKERS:

A. Schwenk *(TU Darmstadt, Germany)*
K. Hebeler *(Ohio State, USA)*
J. D. Holt *(U of Tennessee, USA)*
H. Krebs *(U of Bochum, Germany)*
J. Menendez *(TU Darmstadt, Germany)*
R. Roth *(TU Darmstadt, Germany)*
I. Stetcu *(U of Washington, USA)*
B. van Kolck *(Arizona, USA)*
J.-W. Chen *(Taiwan)*
J. Drut *(Los Alamos National Lab, USA)*
K. Tsukiyama *(Tokyo University, Japan)*
H.-W. Hammer *(U of Bonn, Germany)*
D. Lee *(North Carolina State, USA)*
C. Urbach *(U of Bonn, Germany)*
A. Y. Illarionov *(U of Trento, Italy)*
G. Hagen *(Oak Ridge National Laboratory, USA)*
G. Jansen *(U of Oslo, Norway)*
T. Duguet *(IPhT, CEA Saclay, France)*
T. Lesinski *(U of Washington, USA)*
E. Ruiz Arriola *(Spain)*
M. Horoi *(Central Michigan, USA)*
L. Coraggio *(U of Naples, Italy)*
N. Tsunoda *(Tokyo University, Japan)*
W. Leidemann *(U of Trento, Italy)*
D. Lo Bianco *(U of Naples, Italy)*
L. Fortunato *(ECT* Trento, Italy)*

SCIENTIFIC REPORT:

The workshop “Effective theories and the nuclear many-body problem” was held from March 7-11, 2011 at the ECT*. This meeting consisted of 26 30-minute talks (with ten minutes of discussion time after each talk), and brought together about 30 experts in effective field theory, first-principles computations, and nuclear structure theory. Among the speakers were four PhD students and eight postdoctoral researchers. It was the aim of this workshop to inform the participants about the most recent progress in the field, and to allow for intensive discussions about new results, open problems, and challenges. To this purpose, the organizers allocated one hour of additional discussion time at the end of each three-talk session. Many speakers presented unpublished and very exciting and new results, which naturally led to stimulating discussions. In practice, much of the time of the discussion session was in fact used for in-depth discussions after each of the 30-minutes talks. Many participants expressed their satisfaction with the workshop atmosphere.

The first day was dedicated to the role of three-nucleon forces and two-body currents. The talks and discussions taught us about the role of three-nucleon forces in the location of the neutron drip lines in isotopes of oxygen and calcium, the constraints of the equation of state in neutron stars, and the construction the two-body currents which enter the nuclear matrix elements of double beta decay. The discussions clarified the role of these forces and currents in the nuclear shell model, and how they can explain long-standing problems regarding monopole corrections and quenching factors. Open questions concern the possible generation of four-body forces within similarity renormalization group transformations, and an understanding of deep inelastic electron-nucleus scattering via similarity transformations.

The second day focused on effective field theories. The pion-less effective theory has been implemented at leading and subleading orders within the harmonic oscillator, and applications include light nuclei and ultracold atomic gases. Within effective theory, one also studies the dependence of nuclear observables on the quark mass (i.e. in leading order the mass of the pion). Such studies are important to extrapolate lattice QCD results to observables and to constrain the impact of the possible time variation of fundamental constants. The afternoon discussion focused on unsolved issues with the forces from chiral effective field theory (EFT) due to problems with the non-perturbative renormalization in the Weinberg power counting. It was, however, also pointed out that forces from chiral EFT are – in spite of these deficiencies – the most consistent approach available, and unique in their ability to systematically generate consistent two-nucleon, three-nucleon forces, and currents.

The third day dealt with ab initio methods. The morning was dedicated to the impressive progress of lattice Monte Carlo methods in nuclear physics. The most recent result regarding the computation of the Hoyle state was one of the highlights. Other new results include the computation of the equation of state of neutron matter and the first-principles computation of elastic neutron scattering off oxygen within the coupled-cluster method. Discussions focused on the role of omitted three-nucleon forces, and the possibility to treat higher-order corrections perturbatively.

Nuclear density functional theory, effects of pairing, and the nuclear shell model were the focus of the fourth day. We learned about progress in ab-initio computations of semi-magic nuclei within a Gorkov-Green's function approach, and about the explicit construction of a nuclear density functional for a given nucleus by links to first-principles computations. Interesting results were also reported regarding the realization of Wigner and Serber symmetries in nucleon-nucleon potentials. Discussions focused on the restoration of symmetries, the representability problem of densities and currents, and on various aspects of effective interactions.

The last day consisted of a morning session. The participants learned about the treatment of nonlocal potentials in few-body methods and new ideas regarding the solution of the quantum many-body problem.

To summarize, the workshop was very productive thanks to the high quality of the presentations, the novelty of the presented material, and the clarifying discussions that ensued. The workshop format which included fewer talks but plenty of discussion time proved to be very successful. The organizers thank the ECT* and its staff for their support and the efficient organization of this workshop.

Results and Highlights

The workshop fully served its purpose to inform its participants about the most recent developments in the field. Thanks to the generous amount allotted for discussions, all talks received in-depth discussions and critical points such as renormalization-group invariance of chiral effective field theory, technical details in ab initio approaches, and the role of three-nucleon forces could be clarified.

3.3.3 RECENT DEVELOPMENTS IN TRANSFER AND KNOCKOUT REACTIONS

DATE: May 7-13, 2011

ORGANIZERS:

Birger B. Back *(Argonne National Laboratory, USA)*
Karl E. Rehm *(Argonne National Laboratory, USA)*
John P. Schiffer *(Argonne National Laboratory, USA)*

NUMBER OF PARTICIPANTS: 37

MAIN TOPICS:

Direct particle-adding and removing reactions have been extremely useful in understanding nuclei and the mean field in which nucleons arrange themselves. With these reactions, the nuclear wave functions can be decomposed into their single-particle components and the skeleton of single-particle states that define the mean field can be determined, both for the empty and occupied states. For stable nuclei, such investigations were carried out extensively in the 1960-s and 70-s. This technique is now again an essential tool in the difficult task of probing the most basic characteristics of exotic, short-lived nuclei away from the valley of stability. A new generation of investigators is learning, applying, advancing and modifying the method as needed, and examining critically what was 'well known' a generation ago. Progress is being made both in experiments and in theoretical understanding. Beams of short-lived nuclei, with intensities just sufficient to carry out such studies, are becoming available at several laboratories. In addition, nucleon knockout reactions, relevant in the study of nucleon removal from occupied states, can be used at lower intensities and, especially, in lighter nuclei. On the theoretical side new insights have emerged: for instance the influence of the tensor force on the patterns of single-particle states and on the effective interaction and the ability of ab initio calculations predicting the properties of nuclei are being tested. Experimentally, the measurement of reactions on exotic nuclei are complicated by the fact that they have to be performed in 'inverse kinematics', i.e. by bombarding a lighter-mass target with a heavier-mass beam. Techniques involving highly segmented detectors have been used and new concepts in magnetic devices, and 'active targets' have emerged.

The main topics discussed in this Workshop were:

1. Extraction of spectroscopic information
   Spin assignments, *Spectroscopic factors*
2. Structural information
   Systematics of Single particle and single-hole excitations, sum rules, astrophysical applications
3. Experimental methods and recent results
   Techniques to work with inverse kinematics, x-ray coincidences, newest results

SPEAKERS:

B. Back *(Argonne National Laboratory, USA)*
D. Bazin *(MSU, USA)*
D. Bardayan *(ORNL, USA)*
A. Bonaccorso *(U of Pisa, Italy)*
I. Brida *(Argonne National Laboratory, USA)*
R. Broglia *(U of Milan, Italy)*
D. Carbone *(INFS Catania, Italy)*
W. Catford *(U of Surrey, UK)*
C. Deibel *(Argonne National Laboratory, USA)*
J. Diriken *(U of Leuven, Belgium)*
B. Dominguez *(U of Santiago de Compostella, Spain)*
J. Escher *(LLNL, USA)*
S. Freeman *(U of Manchester, UK)*
A. Idini *(U of Milan, Italy)*
R. Johnson *(U of Surrey, UK)*
R. Kanungo *(U of St. Marys, Canada)*
B. Kay *(U of York, UK)*
S. Kubono *(U of Tokyo, Japan)*
J. Lee *(RIKEN, Japan)*
T. Motobayashi *(RIKEN, Japan)*
F. Nunes *(MSU, USA)*
T. Otsuka *(U of Tokyo, Japan)*
R. Raabe *(U of Leuven, Belgium)*
D. Radford *(ORNL, USA)*
K. E. Rehm *(Argonne National Laboratory, USA)*
J. P. Schiffer *(Argonne National Laboratory, USA)*
I. Thompson *(LLNL, USA)*
R. Tribble *(TAMU, USA)*
I. Sick *(U of Basel, Switzerland)*
E. Vigezzi *(INFN Milano, Italy)*
K. Wimmer *(MSU, USA)*
A. Wuosmaa *(U of Western Michigan, USA)*

SCIENTIFIC REPORT:

The subject of the Workshop was transfer and knockout reactions, in particular:

- to review the techniques for determining the single-particle structure of nuclei that had been developed and utilized to explore the properties of stable nuclei, primarily in the period from about 1960 to 1990.
- to discuss new data obtained for transfer and knockout reactions on nuclei that are not stable, and whose properties are not well understood.

The Workshop had a mix of people cutting across generations (of the 38 participants 10 were within 5 years of their Ph.D. degrees). There were those who had been practioners of studies on stable nuclei and reaction theorists who helped develop the techniques, as well as scientists who are beginning the investigation of short-lived nuclei with the capabilities that are becoming available at facilities such as Rex-Isolde at CERN, GANIL, the Radioactive Beam Factory at RIKEN in Japan, and the Holifield Facility, the National Superconducting Cyclotron Laboratory, and the ATLAS facility in the United States.

In addition to overview talks establishing the framework, a number of young researchers, students and postdocs, presented their results at the workshop. Since the talks were reasonably well confined, the discussions were vigorous and at times passionate, particularly regarding reaction mechanisms. The group was sufficiently small that the pros and cons of the various perspectives could be argued out, and give participants, overall, a reasonably balanced view of the issues. There was a good mixture of experimentalists (27) and theorists (10), and there was enough discussion of new experimental techniques and of new theoretical methods, to give the flavor of these to the participants.

The nuclear structure implications of the emerging single-particle structure were reviewed, particularly in terms of the role of the tensor interaction in causing the shell structure to change with neutron excess, sometimes quite dramatically.

Results and Highlights

The goal of the proposed Workshop was to bring together active participants of this field, from both the experimental and the theoretical side. This goal was well achieved as shown by the vigorous discussions during this Workshop. Other applications of transfer reactions were also discussed, particularly in helping place constraints on matrix elements for neutrinoless double beta decay. In nuclear astrophysics transfer reactions on nuclei away from stability provide also an important surrogate method for indirect measurements of nuclear reactions, which presently can not be studied experimentally due to the limits in beam intensity. Attempts at applying transfer reactions as surrogates for neutron-induced reactions were also described.

The exchange of information between long-term practioners of the field and younger researchers was extremely useful, since it will benefit ongoing and future experimental programs and the planning of devices at the next generation radioactive beam facilities.

3.3.4 THE ORIGIN OF THE ELEMENTS: A MODERN PERSPECTIVE

DATE: May 16-20, 2011

ORGANIZERS:

Y.-Z. Qian *(U of Minnesota, USA)*

G. M. Fuller *(U of California, San Diego, USA)*

W. C. Haxton *(U of California, Berkeley, USA)*

G. Martinez-Pinedo *(GSI, Germany)*

F.-K. Thielemann *(U of Basel, Switzerland)*

NUMBER OF PARTICIPANTS: 46

MAIN TOPICS:

The general theme of the workshop concerned recent progress in our understanding of the origin of the elements, which had been brought about by great improvements in modelling nucleosynthesis and stellar evolution through decades of theoretical works with crucial inputs from nuclear experiments and astronomical observations. We hoped that a broad community of theorists, experimentalists, and observers would be exposed to the major advances in the dynamic field of nuclear astrophysics, interact with each other on topics of mutual interest, and find opportunities of collaboration to make further progress.

The main topics were

- Recent progress in stellar evolution, explosion, and nucleosynthesis
- Big bang nucleosynthesis, star formation, and chemical evolution
- Nuclear physics input for nucleosynthesis
- Special session on nuclear physics, nucleosynthesis, and chemical evolution
- Neutrinos and the origin of the elements

SPEAKERS:

T. Abel *(U of Stanford, USA)*
A. Arcones *(U of Basel, Switzerland)*
M. Asplund *(MPA, Garching, Germany)*
B. Balantekin *(U of Wisconsin, Madison, USA)*
A. Bauswein *(MPA, Garching, Germany)*
K. Blaum *(MPI, Heidelberg, Germany)*
M. Busso (*U of* Perugia, Italy)
N. Christlieb *(U of Heidelberg, Germany)*
C. Chiappini *(AIP, Potsdam, Germany)*
T. Fischer *(GSI, Germany)*
C. Fröhlich *(North Carolina State University, USA)*
C. Fryer *(Los Alamos National Laboratory, USA)*
M. Hass *(Weizmann Institute of Science, Israel)*
A. Heger *(U of Minnesota, USA)*
R. Hirschi *(U of Keele, UK)*
R. Hix *(Oak Ridge National Laboratory, USA)*
H.-T. Janka *(MPA, Garching, Germany)*
J. Kneller *(North Carolina State University, USA)*
D. Lamb *(U of Chicago, USA)*
K. Langanke *(GSI, Germany)*
M. Liebendörfer *(U of Basel, Switzerland)*
C. Lunardini *(Arizona State University, USA)*
T. Lund *(MPA, Garching, Germany)*
A. MacFadyen *(New York University, USA)*
G. McLaughlin *(North Carolina State University, USA)*
B. Mueller *(MPA, Garching, USA)*
N. Nishimura *(U of Basel, Switzerland)*
S. Nishimura *(RIKEN, Japan)*
I. Panov *(ITEP, Russia)*
M. Pignatari *(U of Basel, Switzerland)*
T. Rauscher *(U of Basel, Switzerland)*
T. Rodriguez *(GSI, Germany)*
F. Roepke *(U of Würzburg, Germany)*
A. Serenelli *(Institute for Space Sciences, Bellaterra, Spain)*
I. Tamborra *(MPP, Munich, Germany)*
J. Truran *(U of Chicago, USA)*
S. Typel *(GSI, Germany)*
D. Tytler *(U of California, San Diego, USA)*
F. Villante *(U of L'Aquila, Italy)*
C. Volpe *(IPN, Orsay, France)*
S. Wanajo *(MPA, Garching, Germany)*

SCIENTIFIC REPORT:

Since the pioneering works of Burbidge et al. and Cameron more than five decades ago, there has been major progress in our understanding of the origin of the elements. Two outstanding examples are big bang nucleosynthesis and the solution to the solar neutrino problem. BBN together with observed abundances of D at high redshifts gives a baryonic content of the universe that coincides with what is derived independently from measurements of the cosmic microwave background. This then allows big bang nucleosynthesis to probe fundamental physics such as the number of active neutrino flavors using the observed He abundances at low metallicities. Precise nuclear cross sections and understanding of the evolution and structure of the sun improved by helioseismology lead to a confident conclusion that neutrino oscillations are the solution to the missing solar neutrinos, which are confirmed spectacularly by various solar neutrino experiments and the KamLAND experiement. In both cases, nucleosynthesis/nuclear burning serves as diagnostics of the cosmological/astrophysical environment and probes of fundamental physics.

Other major advances include: (1) the realization that neutrinos play many important roles in stellar evolution, explosion, and nucleosynthesis, (2) discoveries of new astrophysical phenomena such as gamma ray bursts and the associated hypernovae, (3) a large number of data on abundances in globular clusters, the Milky Way, dwarf galaxies, damped Lyman alpha systems, and Lyman alpha forests provided by large telescopes, and (4) the emergence of a firm cosmological framework for understanding structure formation, the making of the first stars, and chemical evolution.

The workshop focused on two main themes: (1) the rapid advance in our observational knowledge of galactic chemical evolution - from the first stars to today - and the implications of these observations for nuclear physics, which must explain the micro-physics of the stellar and explosive environments where the nucleosynthesis takes place; and (2) the role of neutrinos in such processes, including both their effects on the astrophysical environments (e.g., in powering winds and controlling the neutron-to-proton ratios of those winds) and the influence of oscillations and other new physics.

The workshop consisted of 38 invited and 3 contributed talks. The topics covered included

- big bang nucleosynthesis;
- the formation of the first stars and subsequent chemical evolution of the early universe in the current cosmological framework;
- the evolution of massive stars, core-collapse supernovae (including hypernovae) and

neutron star mergers, as well as the associated neutrino emission and nucleosynthesis;

- the evolution of low and intermediate mass stars and the associated nucleosynthesis;
- roles of neutrinos in big bang nucleosynthesis, core-collapse supernovae, and stellar nucleosynthesis, as well as the effects of neutrino oscillations in cosmological and astrophysical environments;
- comparison of models with observational data on elemental abundances; and
- the nuclear physics required for understanding the origin of the elements and the needs for future theoretical and experimental works, including low-energy facilities like LUNA and higher energy facilities in which various rare isotopes of astrophysical interest might be produced and studied.

Results and Highlights

The workshop was an excellent venue to bring together a broad community of nuclear theorists and experimentalists, as well as astrophysicists, cosmologists, and astronomers. All participants found the atmosphere stimulating and had a useful experience that broadened their perspectives. The most significant results presented and discussed at the workshop were:

1. Primordial Li problems

The workshop talks (e.g., Asplund, Tytler, Fuller, Volpe, Haas, and others) and the lively discussions resulting from these served to frame a key problem in Big Bang Nucleosynthesis (BBN) and cosmology: The primordial abundances of the lithium isotopes, as currently derived from the observational data, do not fit the Standard BBN picture. Moreover, much of the uncertainty surrounding this picture has been removed because of the precise determination of the baryon-to-photon ratio, first from the measurement of the primordial deuterium abundance from isotope-shifted hydrogen absorption lines along lines of sight to high redshift QSO's, and then in the last ten years from cosmic microwave background (CMB) anisotropy measurements, specifically the ratio of the amplitudes of the CMB acoustic peaks. The Planck satellite promises to provide sub-one percent uncertainties on this quantity. Likewise, future measurements of the Silk Damping tail in the CMB power spectrum may give us better than two percent precision on the primordial ^{4}He abundance. Together, these measurements constitute a revolutionary advance. In short, BBN considerations are becoming a much finer instrument for probing cosmology and fundamental particle, neutrino and nuclear physics.

The lithium problems stand out all the more because of the advances in these observational determinations of the fundamental cosmological parameters. BBN predictions are now quite robust: ^{7}Li is predicted to be 3 to 4 times higher than the measurements (the Spite plateau) on hot, old halo stars suggest; the claimed abundance of ^{6}Li (1/30 of ^{7}Li) on the surfaces of some of these same stars is 300 times larger than the BBN-predicted abundance!

^{7}Li: This species is made during BBN as ^{7}Be, principally via ^{3}He$(\alpha,\gamma)^7$Be. Discussions during the workshop of laboratory probes of this reaction suggest that nuclear physics uncertainties are *not* likely to resolve the discrepancy between BBN predictions and observations. This leaves two possibilities. First, the observationally-determined abundance of ^{7}Li is wrong. This explanation would necessarily invoke a stellar destruction mechanism for ^{7}Li, for example by rotationally-driven turbulent diffusive mixing of the stellar surface layers down to a temperature where ^{7}Li$(p,\alpha)\ \alpha$ can destroy it. The problem here is that suggested mechanisms do not match the observations in star clusters where we know the distribution of stellar rotation rates. Second, maybe BBN itself is missing important input physics. A decaying particle (e.g., a Super-WIMP) could produce high-energy photons which induce non-thermal nuclear reaction processes, destroying some ^{7}Li, but also making the requisite amount of ^{6}Li. The problem here is that the particle decay properties must be relatively finely tuned to make this work.

^{6}Li: The measurements of the abundance of this species on the surface of the hot, old halo stars involve identifying the isotope-shifted absorption lines of lithium. This is tricky. Professor Asplund provided an insightful explanation of the possible uncertainties involved, especially as regards radiation transport issues. The workshop was fortunate to have Tytler and Asplund, both leaders in this field, to lead the discussions on these issues.

2. Challenges from solar photospheric abundances to solar models

The program included talks by Aldo Serenelli and by Francesco Villante on the current tension between the best model of the solar surface (a 3D treatment of solar photosphere absorption lines that indicates a low-metallicity surface) and the best model of the solar interior (the sound speed profile deduced from heliosesismology, which indicates a higher metallicity core). The talks focused on astrophysical observables, such as the surface helium abundance, the depth of the convective zone, and the various solar neutrino fluxes, that are also sensitive to solar model input parameters such as metallicity. Villante's talk described the degeneracies that exist between opacities and metallicities, as well as the radial sensitivity of helioseismology to specific metals. Serenelli described an ambitious program to build nonstandard solar models with metal-rich or metal-poor accretion, to test whether metal segegration associated with the planetary disk might be responsible for solar model discrepancies. The nonstandard models were solved with the boundary condition of reproducing the observed low-metallicity photosphere.

The experimental nuclear astrophysics talk by Michael Hass was also quite relevant to the discussions, describing recent experimental and theoretical efforts to quantify the uncertainties for cross sections important to hydrogen burning and to assess the impact of these uncertainties on the standard solar model.

3. State-of-the-art simulations of core-collapse and Type Ia supernovae

Core-Collapse Supernovae: While this topic has lingered for more than 40 years with periodically changing results (starting with the first attempts by Colgate and White in 1967), depending on the improvements in the nuclear equation of state, neutrino physics and their interaction with matter, as well as multi-dimensional effects and numerical methods, there seems to be a real light at the end of the tunnel. So-called electron capture supernovae, i.e. stars in the mass range 8-10M_{sun} which start their collapse due to electron capture on core carbon burning products, result already in clear explosions in 1D simulations. Multi-D simulations confirm this as well. For more massive progenitor stars which experience Fe-core collapse, the onset of hydrodynamic instabilities (e.g. SASI, the standing accretion shock instability) permits to deposit neutrino energies from the proto-neutron star core and the accreted matter into the shock. It is important that “cold, dense matter” is mixed to smaller radii where it is heated by outstreaming neutrinos. While final explosions have not been obtained yet, at this point in time, all participating groups reported outward moving (averaged) shock radii for times followed up to 600-800 ms. This is clearly promising and in the near future successful explosions are expected. It is now time to attack then also those more massive events which do not have central neutron stars as a final outcome, but lead either after fallback or already during the accretion to central black holes and events like failed supernovae, hypernovae, gamma-ray bursts. For nucleosynthesis purposes it was pointed out at several occasions that one expects clearly new features in multi-D simulations. A specific feature of the equation of state, the quark-hadron phase transition, was also discussed. While it is hard to constrain the density (for the astrophysical temperatures) at which this transition occurs, in a certain parameter range this would lead to a second collapse just in time to energize the shock sufficiently for causing an explosion. Such events would be accompanied by two neutrino bursts, and if observed, this could give supporting evidence.

Type Ia Supernovae: The increasing number of Type Ia supernova light-curve surveys, utilized for cosmological distance determination, has led also to the discovery of specific subclasses of super- and subluminous cases which do not belong to the (dominant) so-called Branch-normal sample. The search for the progenitor systems of such explosions caused a re-evaluation of previously considered models, e.g. white dwarf collisions and mergers, as well as He-accreting white dwarfs, exploding via double detonations. The first type of event (although rare) can occur in the center of galaxies or globular clusters, where the density of stars is sufficiently high for such encounters. The shock wave of the collision, passing through high-density matter, causes a detonation and large production of ^{56}Ni. Less violent binary mergers can also encounter hot spots which cause a detonation but at smaller densities, only leading to small amounts of ^{56}Ni production, being responsible for the light-curve luminosity. Thus, in the first case [(central) collisions] one produces superluminous, in the second case (mergers) subluminous Type Ia events. If He-accretion in binary mass transfer onto one white dwarf proceeds at low rates, He is not burned steadily in the accretion and causes a layer of unburned He on the surface of a C+O white dwarf. Once a critical mass (base density) of this shell is attained, ignition will occur, leading to a density wave focusing at the white dwarf center, which causes not only a detonation at the base of the He-shell but also in the center. Such double-detonation models were discarded in the 1980s, as they led to a complete burning of the outer He-layer and too much Fe-group matter at high velocities. Recent speculations that instabilities can cause He-ignition already at much lower than critical He-layer masses, avoid the before-mentioned problem. However, the colors and spectra of such models still have problems to match observations and it requires further investigations to see whether these hypothetical sub-Chandrasekhar models are viable candidates for Type Ia supernova explosions. High accretion rates onto C+O white dwarfs in binary systems lead to steady H- and He-burning in the accretion and an increasing mass of the central C+O white dwarf. When attaining a total mass close to the critical Chandrasekhar mass, the object becomes unstable against contraction and ignites (first in simmering C-burning and later in explosive runaway burning under degenerate conditions, when initially increasing temperatures do not cause increasing pressures under degenerate conditions, which avoids an expansion of matter until the degeneracy is lifted). Such systems are the basis for the typical Branch-normal Chandrasekhar mass models of Type Ia supernovae. There exist a few open questions: (a) how and where is the ignition occurring? and (b) how does the burning front propagate? With present multi-D explicit codes the ignition phase cannot be simulated and a distribution of ignition points is assumed.

(However, if implicit codes could handle this phase, it is not obvious whether they would smear out temperature fluctuations, which could cause ignitions). Assumptions on the ignition point distribution result either in central or in off-center ignition. Central ignitions propagate via turbulent motion and mixing of hot matter as a deflagration wave. In order to obtain results which match observations a transition to detonations is required (for typical luminosities). Off-center ignitions propagate outward, then encompassing the surface of the white dwarf, before this leads to a focusing density wave and a complete ignition and detonation (in that sense similar to double detonations). Such so-called gravitationally confined detonations can also explain typical Type Ia observations. Variation of ignition point distributions in both cases, can match the family of Branch-normal Type Ia events, although a self-consistent understanding is still missing.

4. Nucleosynthesis in early rapidly-rotating massive stars

Rotation is an important and common feature of stars. Due to their compact structure, low-metallicity stars formed at early times are expected to be fast rotators. Evolution of rotating low-metallicity massive stars was discussed by Hirschi. An important consequence of rotation is new modes of stellar nucleosynthesis due to the increased efficiency of mixing. For example, ^{12}C produced by core He burning can be mixed into the H envelope to produce ^{14}N, which can be mixed back into the core later to produce ^{22}Ne. Finally, neutrons produced by $^{22}Ne(\alpha,n)\,^{25}Mg$ can be captured by ^{56}Fe, which was incorporated into the star at its birth, to produce s-process nuclei from ^{88}Sr to ^{208}Pb. Chiappini presented observational evidence for greatly-enhanced s-process nucleosynthesis in early rapidly-rotating massive stars from abundances in the oldest globular cluster in the Galaxy. However, the actual nucleosynthetic contributions from such stars remain to be quantified by more detailed analyses of available and future observational data.

5. Sources for the elements from Sr to Ag at low metallicities

The classical mechanisms for producing elements heavier than Fe are the r-, s-, and p-processes, with the first two being dominant. Over the past few decades, at least two more processes have been added to the list: the α - and νp-processes. Both these processes occur at relatively high entropy and are associated with neutrino-heated outflows in core-collapse supernovae. The former operates under neutron-rich conditions and the latter under proton-rich ones. Fischer presented models of neutrino-heated outflows in supernova simulations, Arcones discussed nucleosynthesis in such outflows, and Fröhlich focused on the νp-process in particular. The variety of processes capable of producing elements heavier than Fe has led to quite some confusion in interpreting the abundances observed in metal-poor stars. For example, elements from Sr to Ag can be produced by the r-, s-, α -, and νp-processes associated with massive stars. The uncertainties in predicting conditions in the core-collapse supernovae resulting from such stars make it rather difficult to separate the contributions from the above four processes. The α - and νp-processes are almost certain to occur if a neutron star is produced from the core collapse: the difficulty is in predicting the exact yield pattern for either process from individual supernovae. In particular, the neutron- or proton-richness of the neutrino-heated outflows crucially depends on the neutrino emission characteristics and flavor oscillations. Thus, the puzzle of sources for the elements from Sr to Ag at low metallicities is intimately related to neutrino physics.

6. Sites of the r-process

Talks by Shinja Wanajo and Wick Haxton focused on the current status of searches for the r-process site or sites. There were also relevant talks by Almudena Arcones and by Tobias Fischer on the physics and nucleosynthesis of neutrino-driven winds. Wanajo described the history of the hot-bubble r-process, which may not produce significant yields of heavy elements, and then explored the possibility that neutron star mergers might be a robust site for r-process nucleosynthesis. One of the arguments that suggests multiple r-process sites is the observation that neutron star mergers are an unlikely explanation of the r-process enrichment seen in very-metal-poor stars as few mergers are expected in the early galaxy, and because observations of Eu and other r-process elements suggest an r-process frequency in the early galaxy typical of the supernova rate, not the merger rate. Haxton described a possible mechanism for r-process synthesis in metal-poor stars that is driven by neutrons from neutrino interactions in the progenitor star's outer helium envelope. This mechanism has unusual properties because it is cold, requiring relatively long times to complete. The two talks raised the possibility that a low-metallicity supernova-associated r-process operating at low metallicity combined with the turn-on of neutron star mergers at higher metallicity might yield a multi-site explanation for heavy element synthesis.

7. Supernova neutrino oscillations

Much of the discussions about supernova nucleosynthesis at the workshop involved the role of neutrinos. At issue is the expected set of fluxes and energy spectra appropriate for each of the six neutrino species at a number of different supernova epochs where neutrino-affected nucleosynthesis proceeds. We now know from the laboratory that neutrinos have rest masses and that they mix in vacuum (the propagation, or energy, eigenstates are not coincident with the weak interaction, or flavor states). This means that the neutrinos can in principle change their flavors as they propagate through the envelope of the supernova. Since at many epochs in the history of the post-bounce supernova environment the expected fluxes and energy spectra of the various neutrino flavors may be different, neutrino flavor transformation may affect these and thereby also affect key nucleosynthesis parameters, like the neutron-to-proton ratio.

However, a key uncertainty in neutrino flavor transformation calculations has been the role of nonlinearity. Namely, the supernova environment has large fluxes of neutrinos and this implies that neutrino-neutrino forward scattering can be a significant contributor to the potential that governs how neutrinos change their flavors. The potential that governs neutrino flavor transformation itself depends on the flavor states of neutrinos. During the last few years the advent of readily available supercomputers has allowed solutions to this nonlinear problem. The results were startling: even though the measured neutrino mass-squared differences are small and the supernova matter densities above the neutron star surface relatively large, large scale collective transformation of neutrino flavors can occur. Moreover, these collective oscillations can occur deep enough in the supernova envelope to affect nucleosynthesis processes. The supernova neutrino signal will almost certainly be affected.

Researchers have identified different modes of collective neutrino flavor transformation and discovered a feature of this collective behavior, the spectral swap/split, that could be a dead giveaway for the neutrino mass hierarchy. At the workshop Y.-Z. Qian discussed how precession- and nutation-driven resonances can give a straightforward explanation for many of the features seen in the large-scale numerical simulations, including issues associated with adiabaticity and swaps. C. Volpe, J. Kneller and others discussed other aspects of the neutrino flavor transformation problem, CP-violation and turbulence-generated neutrino flavor de-polarization, respectively. W. Haxton and Y.-Z. Qian discussed a neutrino spallation-induced neutron source in the helium layer as a promising route for production of the r-process nuclei. A key issue in this model is the input electron and neutrino and antineutrino energy spectra and fluxes and these, in turn, may be sensitive to neutrino oscillations.

The workshop discussions on this topic brought out the relatively primitive state of the supernova neutrino oscillation calculations at present. Qian, Fuller and Balantekin emphasized the point that so-called single-angle calculations of neutrino flavor evolution are frequently inadequate, demonstrably so in recent large-scale numerical simulations of, e.g., O-Ne-Mg core-collapse supernovae. Moreover, none of the large core-collapse and explosion simulations (e.g., including the one discussed by H.-T. Janka at the workshop) at present organically include neutrino mixing physics. A consensus of the flavor transformation community is that this is a problem that must be remedied, if for no other reason than that many of the neutrino mixing parameters are either measured outright or the target of ongoing or future laboratory experiments.

8. Progress in nuclear physics input for nucleosynthesis

Recent years have witnessed a tremendous progress in the nuclear physics input for nucleosynthesis studies driven both by experiment and theory. Thanks to upgrades in existing facilities and to the set up of new facilities, it has become possible to access new regions of the nuclear chart. Particularly important has been the progress in measurements of nuclear masses. Most of the masses of neutron-deficient nuclei participating in explosive nucleosynthesis processes (e.g. rp-process, νp-process, p-process) are currently known experimentally. The situation is more demanding for the many neutron-rich nuclei that participate in the r-process. Here experimental efforts have to be supplemented with theoretical progress. The most relevant nuclear inputs for dynamical r-process calculations were presented and discussed during the workshop. Additionally the development of nuclear models that include correlations beyond mean field opens the possibility of improving our understanding of nuclear masses for r-process nucleosynthesis. These efforts are being supplemented by an improved modeling of neutron-induced reactions including fission channels that are important for trans-lead nuclei.

A highlight of the workshop was the recent measurement at RIKEN of 38 beta-decay half-lives for neutron-rich nuclei between $_{36}$Kr and $_{43}$Tc. The data clearly show that the Finite Range Droplet Model, commonly used in r-process nucleosynthesis calculations, overestimates the half-lives by more than a factor of 2. Similar differences have also been found in other regions of the nuclear chart suggesting that the flow of matter in the r-process may be faster than currently thought. This is an important aspect to constrain the yet unknown astrophysical site for the r-process. From the theoretical point of view, there are strong indications that first-forbidden transitions can play a very important role for the determination of beta-decay half-lives of heavy r-process nuclei.

3.3.5 STANDARD AND NOVEL QCD PHENOMENA AT HADRON COLLIDERS

DATE: May 30 – June 2, 2011

ORGANIZERS:

Dionysis Triantafyllopoulos *(ECT*, Italy)*
Francois Gelis *(Saclay, France)*
Edmond Iancu *(Saclay, France and CERN, Switzerland)*
Cyrille Marquet *(CERN, Switzerland)*

NUMBER OF PARTICIPANTS: 35

MAIN TOPICS:

The workshop was mainly centered on high energy hadronic and nuclear collisions in the semi-hard region, and on their QCD description as this emerges from the Color Glass Condensate (CGC) which is the effective theory for parton saturation. In particular, it was of crucial interest the experimental results and the theoretical understanding of single and double inclusive cross-sections and of dijet correlations in such collisions. NLO corrections of this effective theory were clearly considered as necessary to achieve more quantitative explanations. We also hoped to address the problem of thermalization and its relationship with the special initial conditions of ultra relativistic heavy ion collisions. Related to that, and assuming that a Quark Gluon Plasma (QGP) is formed, we also emphasized on the evolution of a jet, initiated by a hard produced particle, in such a dense medium.

The main topics were:

a) Experimental Review of QCD studies from high energy collisions
b) Applications of the Color Glass Condensate to heavy ion collisions
c) NLO corrections and Monte Carlo event generators at small-x
d) Thermalization in gauge theories
e) Jet evolution in a dense QCD medium

SPEAKERS:

Massimiliano Alvioli *(ECT*, Italy)*
Ian Balitsky *(Old Dominion University and JLAB, USA)*
Valerio Bertone *(Freiburg University, Germany)*
Guillaume Beuf *(Brookhaven National Laboratory, USA)*
Mario Campanelli *(University College London, UK)*
Giovanni Chirilli *(Lawrence Berkeley National Laboratory, USA)*
Fabio Dominguez *(Columbia University, USA)*
Kevin Dusling *(North Carolina State University, USA)*
Gosta Gustafson *(Lund University, Sweden)*
Yoshitaka Hatta *(U of Tsukuba, Japan)*
Edmond Iancu *(Saclay, France and CERN, Switzerland)*
Yuri Kovchegov *(Ohio State University, USA)*
Alex Kovner *(U of Connecticut, USA)*
Piotr Lebiedowicz *(INP Cracow, Poland)*
Rafal Maciula *(INP Cracow, Poland)*
Magdalena Malek *(U of Illinois at Chicago, USA and CERN, Switzerland)*
Yacine Mehtar-Tani (*U of Santiago de Compostela, Spain)*
Beau Meredith *(U of Illinois at Urbana-Champaign, USA)*
Jose Guilherme Milhano *(CENTRA-IST, Portugal and CERN, Switzerland)*
Akihiko Monnai *(U of Tokyo, Japan)*
Philipe Mota *(ITP Frankfurt, Germany)*
Alfred Mueller *(Columbia University, USA)*
Thomas Peitzmann *(Utrecht University, Netherlands)*
Amir Rezaeian *(Universidad Tecnica Federico Santa Maria, Chile)*
Martin Rybar *(Charles University, Czech Republic)*
Soeren Schlichting *(Darmstadt Technical University, Germany)*
Anna Stasto *(Penn State University, USA)*
Naoto Tanji *(KEK, Japan)*
Dionysis Triantafyllopoulos *(ECT*, Italy)*
Konrad Tywoniuk *(Lund University, Sweden)*
Raju Venugopalan *(Brookhaven National Laboratory, USA)*

The following participated for the full period without contributing with a talk:

Jean-Paul Blaizot *(Saclay, France)*
Francois Gelis *(Saclay, France)*
Koichi Hattori *(KEK, Japan)*
Cyrille Marquet *(CERN, Switzerland)*

SCIENTIFIC REPORT:

Quantum Chromodynamics (QCD), the theory of strong interactions, predicts that in semi-hard processes occurring in high energy hadronic or nuclear collisions, gluon densities become large and a new phenomenon, known as parton saturation, starts to play an important role. A characteristic scale, the saturation momentum, is dynamically generated and, if sufficiently above the confinement scale, permits the application of weak coupling techniques. There is an elaborated QCD framework, the effective theory of the Color Glass Condensate, which can serve as a central tool in understanding many aspects of the experiments carried out at the LHC, especially those related to its own existence and the formation of the Quark Gluon Plasma. The exploration of these phases has already started at HERA and RHIC and the important jump in collision energy at the LHC provides new opportunities for a systematic study of these phases and also for new discoveries.

Appropriate observables for studying the CGC are mainly related to total, diffractive, single inclusive and double inclusive cross sections. Furthermore, correlations that can shed light to the particular high density, in terms of quarks and gluons, nature of hadronic and nuclear wavefunctions are typically explored. Is is clear that we aimed for a comprehensive review of recent experimental data and at the same time for a thorough analysis of the theoretical techniques that have been available to this moment and on those to be anticipated.

For a more quantitative description of parton saturation and the initial state of ultra relativistic heavy ion collisions one needs to go beyond the leading order non-linear evolution equations and/or use appropriate Monte Carlo event generators which incorporate the correct physics and such tools have been partially available over the recent years. The next to leading order (NLO) corrections have been calculated, but there are issues. In phenomenological studies only those related to the running of the QCD coupling are used, mostly due to technical difficulties. However a systematic description would require the inclusion of all corrections, which are also suspected to be unphysically large and thus leading to instabilities. Therefore, it was natural to address a question on how to use and make sense of the NLO corrections.

The CGC also provides a natural framework to study the initial stages of heavy ion collisions. It has been used in particular to compute the initial spectrum of the produced gluons, or to compute initial conditions for the subsequent hydrodynamical evolution. In this context, the main outstanding problem that remains to be understood is that of the thermalization of the matter produced in these collisions. Indeed, experimental results suggest that the quark-gluon plasma is close to local thermal equilibrium, while the gluons produced initially are rather far from equilibrium. It is believed that equilibration is driven by the instabilities that exist in anisotropic gluonic systems, but a precise understanding of this mechanism is still missing.

The QGP created in the intermediate stages of a heavy ion collision is an ephemeral state with an estimated lifetime of about 10 fm/c. One of the main observables allowing one to explore this phase, known as jet quenching, refers to the energy and momentum deposited by a partonic jet propagating through the plasma. The theoretical study of this observable is complicated because it involves many scales and the medium effects are non-perturbative even if the coupling is weak. It is presently unclear whether the jet quenching measured in the Au+Au collisions at RHIC can be explained within perturbative QCD: the calculations appear to underestimate the data, a feature sometimes seen as evidence for strong-coupling behavior (sQGP), but which could also reflect the incompleteness of the current perturbative approaches. This mystery has been sharpened by the advent of the first heavy ion data at the LHC, which revealed a new phenomenon known as di-jet asymmetry: a strong suppression of the recoil jet in Pb+Pb collisions as compared to p+p collisions. In this context, the workshop proposed to review both the experimental situation at RHIC and the LHC, and the state of the art of the theoretical approaches within perturbative QCD.

Results and Highlights

There were 35 participants, out of which 5 experimentalists representing main collaborations (2 from ATLAS, 1 from CMS, 1 from STAR and 1 from PHENIX) and 30 theorists many of which are leading experts of the field worldwide. The workshop lasted three and a half days and 31 participants contributed with a talk; 9 for each of the first three days and 4 for the last day. Experimental talks were distributed in the first three days, typically in the beginning of a session. All talks lasted 35 + 10 minutes and thus, being in accord with the style of ECT* workshops, there was plenty of time for vivid discussions without suppressing the time allocated to each speaker.

There was a strong interest on the results of the RHIC experiment in single and double inclusive cross section, and furthermore in the correlations emerging from the latter. For both cases it has been by now accepted that one needs to go beyond k_T factorization but this is hardly a problem and in fact it is well under control. For the single inclusive cross section in d+Au collisions one can get quantitative results by using the BK equation. The double inclusive cross section and when the two-jets are produced forward is by far more interesting due to the attenuation of the away-side peak in the transverse plane. But it is also technically more difficult since one needs to solve a more complicated functional equation, the JIMWLK equation. On can do this on a lattice and preliminary results were presented. Much progress in that direction is to be expected in the near future.

Not only in technical talks, but also in phenomenologically oriented ones, it was a recurring theme the importance of NLO corrections. By now, it has been unanimously agreed that one has to use and properly incorporate the running of the strong coupling constant in the evolution equations. It was argued that a better prescription, than the current one, for the momentum scale determining the argument of the coupling could be found. The full NLO equation, whose derivation was a formidable task, was presented and then it was demonstrated that it suffers from large negative terms related to the collinear emission of partons. The proper way to eliminate those unphysical contributions was discussed and preliminary estimates for the rate of evolution were given. Still, more elaborate analysis is needed, and in particular the interplay with the initial conditions needs to be examined more thoroughly. It is to be appreciated that the outcome of these analyses should also influence the correct implementation of Monte Carlo event generators dedicated to high energy scattering; since it is difficult in practice for them to include all the NLO corrections, one should provide the most dominant ones to capture the correct physics mechanisms.

In this workshop, there were several talks reporting on recent results on the problem of thermalization in heavy ion collisions. In the CGC approach, the main progress is the computation of the spectrum of vacuum fluctuations immediately after the collision. These fluctuations are the seeds of the instabilities that are expected to lead to thermal equilibrium, and a precise knowledge of their spectrum is therefore necessary in order to perform numerical simulations of the post-collision evolution of the system. A numerical study of the effect of these instabilities was also presented in the simpler case of an O(N) scalar model, showing that when the system expands longitudinally one usually gets different pressures in the transverse and longitudinal directions. Whether this conclusion remains true in the QCD case remains to be checked.

The presentations and discussions of jet quenching were naturally focused on the recent data on di-jet asymmetry at the LHC and on the first theoretical attempts towards understanding these data from first principles. Given the relatively hard momentum scales involved by this phenomenon, it is likely that this is controlled by weak coupling dynamics. Yet, explicit calculations are complicated due to the non perturbative aspects inherent at high density. Recent progress, as reported at the workshop, refers to the first studies of interference phenomena for medium-induced gluon radiation by several sources. These studies show that the interference effects are washed out by the medium, thus opening the way towards Monte Carlo generators for the in-medium jet evolution.

3.3.6 NUCLEAR MANY-BODY OPEN QUANTUM SYSTEMS: CONTINUUM AND CORRELATIONS IN LIGHT NUCLEI

DATE: June 6-10, 2011

ORGANIZERS:

Christian Forssén *(Chalmers University of Technology, Gothenburg, Sweden)*
Hans Fynbo *(Department of Physics and Astronomy, Aarhus University, Denmark)*
Gaute Hagen *(Oak Ridge National Laboratory, USA)*
Lucas Platter *(Chalmers University of Technology, Gothenburg Sweden)*
Haik Simon *(GSI, Darmstadt, Germany)*

NUMBER OF PARTICIPANTS: 37

MAIN TOPICS:

The aim of the workshop was to address the description of nuclear systems that are close to the breakup threshold and whose properties are determined by a combination of many-body correlations and couplings to the continuum.

The main topics were:

- General properties of open quantum systems
- Interface between clustering and continuum in nuclear structure and reactions
- Cluster models for nuclear structure and reactions
- Halo effective field theory
- Bound-state techniques for scattering
- Ab-initio theory for nuclear structure and reactions

SPEAKERS:

C. Barbieri *(Surrey, UK)*
N. Barnea *(Hebrew University, Israel)*
D. Baye *(Brussels, Belgium)*
V. Efros *(Trento, Italy and Kurchatov, Russia)*
P. Fallon *(LBNL, USA)*
A. Gade *(MSU, USA)*

E. Garrido *(CSIC, Madrid)*

M. Golovkov *(Dubna, Russia)*

D. Heiss *(Stellenbosch, South Africa)*

R. Higa *(Gronigen, Netherlands)*

W. Horiuchi *(GSI, Germany)*

A. Jensen *(Aarhus, Denmark)*

A. Kievsky *(Pisa, Italy)*

J. Kirscher *(Ohio, USA)*

M. Kowalska *(CERN, Switzerland)*

M. Marques *(Caen, France)*

U. Meissner *(Bonn, Germany)*

M. Michel *(Jyväskylä, Finland)*

A. Mukhamedzhanov *(Texas, USA)*

P. Navrátil *(TRIUMF, Canada)*

W. Nazarewicz *(UT, USA)*

T. Neff *(GSI, Germany)*

T. Papenbrock *(ORNL, USA)*

M. Ploszajczak *(GANIL, France)*

S. Quaglioni *(LLNL, USA)*

G. Rogachev *(FSU, USA)*

J. Rotureau *(Arizona, USA)*

A. Schwenk *(Darmstadt, Germany)*

S. Typel *(GSI, Germany)*

M. Viviani *(Pisa, Italy)*

A. Volya *(Florida State, USA)*

M. Zhukov *(Chalmers, Sweden)*

SCIENTIFIC REPORT:

The workshop was organized with generous support from the ECT*, the ExtreMe Matter Institute EMMI, and the HIC for FAIR. The workshop had 37 participants. Most people came from Europe and North America, but there were also participants from Asia, and Africa. During the five-days workshop we had 33 presentations on different aspects of the topics listed above. We had 7 experimental talks and 26 theory presentations focusing on recent achievements and future challenges.

The contributions were arranged in 45-minute time slots. Discussions during the presentations were highly encouraged and turned out to become lively. The workshop format worked out very well and interaction among participants was dynamic. We had 2-3 special contributions with the instructions of reviewing some key concepts (in particular, E. Garrido on the Complex scaling method and D. Baye on the R-matrix method). These contributions were paired with presentations of recent progress in these fields, and turned out to be very enlightening.

The workshop program lasted for five days with one half-day free on Wednesday afternoon and the conclusion on Friday at lunchtime. The topics were deliberately mixed during the five days to keep the interest of all workshop participants. Some groups of talks with common themes were identified:

Day 1: Nuclear reactions and spectroscopic information; Cluster models;

Day 2: Open quantum systems; Halo effective field theory;

Day 3: Effects of correlations;

Day 4: Microscopic reaction theory; Bound-state techniques;

Day 5: Gamow shell model;

Most participants were nuclear structure and reaction physicists, but we had a couple of talks to broaden the scope of the workshop in the spirit of the Open Quantum Systems series of meetings. In particular, D. Heiss was giving a talk on the Physics of Exceptional Points (that triggered interesting discussions on the signatures of such phenomena in nuclear physics) and S. Typel provided a bridge to the next workshop at the ECT*: “Clusters in Nuclei and Nuclear Matter”.

Results and Highlights

The main achievement of the workshop was probably the cross-fertilization of knowledge from different subfields. In particular:

- Various sources of uncertainties in the results of theoretical calculations were discussed in quite some detail. This was mainly, but not exclusively, in the context of effective field theories for which the magnitude of errors can be estimated from uncertainties in determining the parameters of the effective Lagrangian and from the order of the diagrammatic expansion. Sensitivity of various results to the inclusion or not of the delta-resonance, continuum effects and model space was also discussed.

- On the experimental side there was most discussion on the meaningfulness of extracting spectroscopic factors. From a theoretical point of view this quantity, being an off-shell property, is not directly observable. Instead, the extraction of asymptotic normalisation coefficients was advertised.

- Data needs were mentioned in several contributions. Examples are precise phase shift measurements for light nuclei (in particular elastic scattering), scattering and absolute normalisation of photo-dissociation data for light nuclei.

- Various methods to include the continuum in theoretical structure models were presented. Either through the use of the Berggren basis, by an expansion in cluster states as in the Resonating Group Method, or using bound-state techniques such as integral transforms or integral relations.

It is clear from these discussions that our workshop dealt with a very demanding field of nuclear physics. On the experimental side we have all the complications that follow from dealing with unstable elements: production and handling, detection methods, data analysis, etc. On the theoretical side, the challenge might be best summarized by the diagram shown in the presentation by Witold Nazarewicz, see Figure 2. Three ingredients have to be properly treated for a complete description of nuclear open quantum systems: The nuclear Hamiltonian (or the selection of the appropriate degrees of freedom), a method to solve the many-body problem and treat correlations, and the description of the continuum. The physics of light, exotic nuclei is just at the intersection of these components.

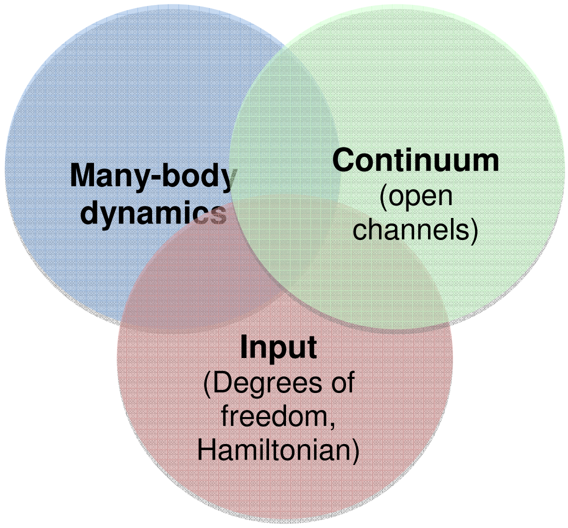


Figure 1. The proper description of nuclear open quantum systems requires a proper treatment of three challenging ingredients. Adapted from the workshop presentation by Witold Nazarewicz.

It was clear that different theoretical approaches discussed at the workshop have different strengths and limitations in terms of these three ingredients. Some methods include the continuum explicitly and others through configuration interaction type mixing. The former type of method has problems dealing with realistic interactions and short-range (many-body) correlations when studying systems with more than 3-4 particles. The latter type of methods is usually related to the shell model. Continuum channels can be included using e.g. the Berggren basis, as in the Gamow shell model, or by treating selected channels explicitly as in the resonating group method. Finally we have to mention the novel development of doing nuclear physics on the lattice employing chiral effective field theory for computing the action. These methods are very promising and interesting results from first calculations of the Hoyle state in ^{12}C were shown.

For all these calculations a discussion on theoretical error bars is very important. In particular, the identification of uncertainties originating from different ingredients of the method is relevant. Such identification can be used to decide on the most relevant avenue for continued efforts. An interesting question is at what stage a difference between theory and data is significant? This discussion also includes the question of what observables that can be directly compared with theory. Some data needs were mentioned above: precise phase shift measurements for light nuclei (in particular elastic scattering), scattering and absolute normalisation of photo-dissociation data for light nuclei.

As an outlook we have tried to characterise different avenues for which we expect several projects to develop in the coming years, partly as a result of this workshop:

- Collaborations at early planning stages of experiments as well as theory method development to identify experimental observables that can be directly compared with theory;

- Efforts to estimate error bars on theoretical results for more relevant comparisons with experimental data;

- The development of halo effective field theory and the transfer of knowledge from existing cluster models and few-body methods;

- The development of nuclear lattice methods in conjunction with progress in chiral perturbation theory;

- The opportunity to extract continuum properties from bound-state techniques adapted to modern state-of-the-art ab initio approaches;

Needless to say, we look forward to exciting years to come and to additional workshops on this topic in the near future.

3.3.7 CLUSTERS IN NUCLEI, NUCLEAR MATTER, HEAVY ION COLLISIONS AND ASTROPHYSICS

DATE: June 13-17, 2011

ORGANIZERS:

Gerd Roepke *(U of Rostock, Germany)*
David Blaschke *(U of Wroclaw, Poland; JINR Dubna, Russia)*
Thomas Klahn *(U of Wroclaw, Poland)*
Shalom Shlomo *(Texas A&M University, USA)*
Stefan Typel *(GSI Darmstadt and LMU Munich, Germany)*

NUMBER OF PARTICIPANTS: 32

MAIN TOPICS:

Correlations in nuclear systems are of fundamental interest for different phenomena in nuclear structure and reaction physics, but also for the nuclear matter equation of state which is crucial for the modeling of astrophysical systems. Our aim of this workshop was to bring together scientists from these different fields in physics. For all of them a better understanding of correlations and more realistic descriptions are crucial since usually the described systems are very complex and subject to many uncertainties. Therefore, understanding and applying state of the art techniques with respect to cluster formation promise to give much better insight into the physics of the investigated phenomena.

The main topics were:

- Correlations in nuclear matter
- Clusters and the equation of state
- Heavy ion collisions
- Alpha clusters in nuclei
- Clusters in nuclei and astrophysics

SPEAKERS:

Z. Basrak *(Boskovich Institute Zagreb, Croatia)*
P. Danielewicz *(Michigan State University, USA)*
J. De *(Saha Institute, India)*
E. Epelbaum *(U of Bochum, Germany)*
Y. Funaki *(U of Tsukuba, Japan)*
M. Hempel *(U of Basel, Switzerland)*
H. Horiuchi *(RCNP Osaka, Japan)*
C. Horowitz *(Indiana University Bloomington, USA)*
A. Illarionov *(U of Trento, Italy)*
S. Kubis *(IFJ PAN Cracow, Poland)*
H. Lenske *(U of Giessen, Germany)*
P. Marini *(Texas A&M University, USA)*
M. Milin *(Boskovich Institute Zagreb, Croatia)*
J. Natowitz *(Texas A&M University, USA)*
W. Reisdorf *(GSI Darmstadt, Germany)*
P. Schuck *(IPN) Orsay, France)*
J. Stone *(Oxford University, UK)*
K. Sumiyoshi *(NCT, Japan)*
A. Tohsaki-Suzuki *(RCNP Osaka, Japan)*
W. Trautmann *(GSI Darmstadt, Germany)*
K. Vantournhout *(GSI Darmstadt, Germany)*
X. Vinas *(U of Barcelona, Spain)*
P. von Neumann-Cosel *(TU Darmstadt, Germany)*
A. Wierling *(U of Rostock, Germany)*
H. Wolter *(LMU Munich, Germany)*
T. Yamada *(Kanto Gakuin University, Japan)*

SCIENTIFIC REPORT:

Nuclear systems are important examples for strongly interacting quantum liquids. New experiments in nuclear physics and observations of compact astrophysical objects require an adequate description of correlations, in particular with respect to the formation of clusters and the occurrence of quantum condensates in low-density nuclear systems. An important task is to join different approaches such as virial expansions and the nuclear statistical equilibrium, valid in the low-density limit, with approaches that are applicable near the saturation density, such as Dirac-Brueckner-Hartree-Fock or relativistic mean-field approximations. A quantum statistical approach has been elaborated that allows to include few-nucleon clusters like deuterons, tritons, ^{3}He, and ^{4}He embedded in nuclear matter, but can also be extended to describe the formation of larger nuclei in low-density matter. The final goal is the formulation of a unified approach which describes the properties of nuclear matter and bound states over the whole range of relevant temperatures, densities and asymmetries.

Meeting Programme:

The workshop programme was concerned with three important fields where correlations in nuclear systems are of fundamental interest: nuclear structure and reaction physics, heavy-ion collisions and the structure and evolution of compact astrophysical objects.
Experimentalists and theorists working in these fields were brought together to discuss different phenomena and to check the used approaches, as well as to draw consequences for astrophysical processes. The comparison between theory and experiment gave valuable new insights and new directions of research were identified. To account for this goal the workshop was organised such that besides a discussion period after each presentation there was room for further communication between the participants, either in form of panel sessions or informal meetings. The discussion helped to identify new possibilities for experiments and improvements of models and interpretation. The main focus was on bound states (clusters) in nuclear matter.

Results and Highlights

It was possible to attract leading groups in the different fields of research relevant for the workshop.

In particular, we would like to summarize some results and highlights of the workshop which serve as motivations for further work:

- Correlations, in particular cluster formation, has to be considered in low-density nuclear systems. Any single-nucleon quasiparticle approach fails in that region. A possible approach is the introduction of clusters as effective degrees of freedom in the model description. The full antisymmetrization (Pauli blocking) is indispensable at increasing densities.

1. Nuclear structure: pairing is well accepted. We need a theory that includes quartetting, i.e. four-particle correlations. First steps have been done for ^{8}Be and ^{12}C (Hoyle state) and related light low-density nuclei. Similar to Hartree-Fock-Bogoliubov theory, we need an approach that joins shell structure calculations and alpha cluster-like correlations. Promising approaches such as Fermionic Molecular Dynamics were presented at the workshop. At present, one can use a local density approach to estimate the role of four-nucleon correlations.

2. Heavy ion collisions: the formation of light elements is a nonequilibrium process that has to be described with adequate equilibrium approaches as inputs (freeze-out, coalescence, transport codes).

The extraction of thermodynamic parameters, including the symmetry energy, should go beyond the nuclear statistical equilibrium (NSE) taking into account in-medium effects.

3. Astrophysics: we need improved equations of state (EOS) to analyse the evolution of supernovae, including neutrino transport.

At present, different attempts are performed to include few-nucleon correlations (light elements) as well as the full table of all known nuclei. The unification of mean-field approaches and NSE (in-medium description of clusters) as well as the contribution of continuum states (virial coefficients) has to be implemented.

We expect that there will be some progress in these directions during the next years. The workshop initiated discussions an collaborations that result in cross-fertilisation between the different attempts to include nucleonic correlations in the low-density regions. Very important is the interaction of theory and experiments/observations.

3.3.8 NEW TRENDS IN THE PHYSICS OF THE QUANTUM VACUUM: FROM CONDENSED MATTER, TO GRAVITATION AND COSMOLOGY

DATE: June 26 - July 1, 2011

ORGANIZERS:

Iacopo Carusotto *(INO-CNR BEC Center, Trento, Italy)*

Roberto Balbinot *(Università di Bologna, Italy)*

Alessandro Fabbri *(Univ. de Valencia-CSIC, Spain)*

Cristiano Ciuti *(Université Paris 7, France)*

NUMBER OF PARTICIPANTS: 49

MAIN TOPICS:

The workshop had a very interdisciplinary focus and addressed a number of aspects of the "quantum vacuum" concept through its manifestations in the different contexts of gravitational physics, cosmology and condensed matter physics. The aim was to establish a common language and identify useful connections between originally distinct research lines.

More specifically, the main covered subjects were:

- Quantum field theories on curved space-time
- Physics of astrophysical black holes and Hawking radiation
- Quantum fluctuations in cosmology
- Dynamical Casimir effect
- Condensed matter analogue models
    - Bose-Einstein condensates of ultracold atoms and of exciton-polaritons in semiconductor devices
    - Nonlinear optical systems
    - Circuit QED in superconducting devices
    - Ultrastrong light-matter coupling and sub-optical-period modulations
- Quantum hydrodynamics of analogue black/white holes in a flowing fluid, black hole lasing

SPEAKERS:

Bill Unruh *(U of British Columbia, Canada)*
Renaud Parentani *(U of Orsay, France)*
Marc Jaekel *(LPT-ENS, France)*
Cristiano Ciuti *(U of Paris 7, France)*
Sandro Stringari *(U of Trento, Italy)*
Chris Westbrook *(U of Orsay, France)*
Luis Garay *(U of Complutense, Madrid, Spain)*
Ruth Durrer *(U of Geneva, Switzerland)*
Jerome Martin *(IAP Paris, France)*
Nemanja Kaloper *(U.C. Davis, USA)*
Jeff Steinhauer *(Technion, Haifa, Israel)*
Caterina Braggio *U of Padova, Italy)*
Simone De Liberato *(U of Paris 7, France)*
Iacopo Carusotto *(INO-CNR BEC Center, Trento, Italy)*
Carlos Mayoral *(U of Valencia, Spain)*
Nicolas Pavloff *(LPTMS Orsay, France)*
Victor Fleurov *(U of Tel Aviv, Israel)*
Francesco Marino *(U of Firenze, Italy)*
Silke Weinfurtner *U of British Columbia, Canada)*
Pasquale Calabrese *(U of Pisa, Italy)*
Stefano Liberati *(SISSA, Italy)*
Robert Johansson *(RIKEN, Japan)*
Rupert Huber *(U of Regensburg, Germany)*
Per Delsing *(Chalmers Univ., Sweden)*
Daniel Faccio *(U of Insubria, Italy)*
Sergio Cacciatori *(U of Insubria, Italy)*
Alberto Bramati *(LKB-Paris 6, France)*
Daniele Sanvitto *(CNR, Lecce, Italy)*
Alberto Amo *(LPN, Paris, France)*
Carlos Barcelo *(U of Granada, Spain)*
Susanne Kehr *(U of St. Andrews, UK)*
Piero Nicolini *(U of Frankfurt, Germany)*
Stefano Giovanazzi *(U of Heidelberg, Germany)*
Stefano Finazzi *(SISSA, Italy)*
Simon Horsley *(U of St. Andrews, UK)*
Ivar Zapata *(U of Complutense, Madrid, Spain)*
Ariel Guerreiro *(U of Porto, Portugal)*
Scott Robertson *(U of Pavia, Italy)*

SCIENTIFIC REPORT:

The main objective of the present workshop was to establish long-lasting scientific links among scientists working on different aspects of the physics of the quantum vacuum. Although a huge number of conferences focussed on specific topics are already taking place on a regular basis, an interdisciplinary forum was still missing. The goal of the present workshop was to fill this gap bringing together distinguished scientist active in the different fields and stimulating the establishment of new collaborations. The numerous and active participation of a number of top-level scientists with very different backgrounds is a good witness of the interest of such an initiative for a broad community.

The workshop was organized with a restricted number of long talks by world-class experts giving tutorial overviews of the different fields, followed by shorter talks by younger fellows on more specific subjects of present-day research. This organization turned out very efficient in conveying to a broad audience both the general concepts of each field and a glimpse of the presently hottest problems. All speakers were strongly encouraged to make a specific effort in order for their presentations to be understandable by the whole audience: the outcome of these efforts was remarkable, with people from very different backgrounds being constantly active in discussing the different topics during the sessions as well as in informal discussions during the free time. A crucial contribution in this direction was the structure and organization of ECT*, which favoured socialization and scientific exchanges during coffee-breaks as well as during meals.

The simultaneous presence of theorists and experimentalists allowed a fruitful and bidirectional exchange of ideas: theorists discussed the fundamental problems and the conceptual framework that can be used to understand them; experimentalists presented a number of systems where these problems are being investigated and pointed out the new questions that the experiments are raising.

The success of the workshop has opened the discussion on how to continue the series of these quantum vacuum workshops after the first edition of the workshop in Valencia in early 2009 and the present second edition at ECT*. We indeed expect that the rapid advances in the experimental study of analogue black holes will soon raise a number of new questions on the physics of quantum fields on curved space times as applied to condensed matter systems and that new perspectives in quantum field theories will be opened by the developments in the realization and manipulation of solid-state QED devices on sub-optical-period timescales. A third edition of the workshop will be the ideal forum for a broad community to continue discussing this physics from an interdisciplinary point of view.

Results and Highlights

Atomic Bose-Einstein condensates are among the most promising analogue models to which quantum field theories in curved space times can be applied in a condensed matter context. At the workshop, the general concepts of QFT on curved space times were reviewed by W. Unruh, one of its founders.

Two recent experiments were then reported where a black hole configuration in a flowing atomic condensate is created and where peculiar density correlations are detected after suitable manipulation sequences. According to theoretical work, a combination of these two features is likely to be essential in view of getting a conclusive evidence of analogue Hawking radiation in a condensed matter system.

A number of theoretical talks have addressed the rich dynamics of artificial black and white holes in atomic condensates at both classical and quantum level: the peculiar properties of white holes have been illustrated in connection to on-going experiments in classical hydrodynamical systems and in nonlinear optics. The black hole lasing instability in paired black and white hole horizons has been characterized.

The overview on quantum fluids was completed by a long review talk on the hydrodynamics of Bose-Einstein condensates of exciton-polaritons in semiconductor devices, which efficiently stimulated the discussion on the promise of these novel quantum fluids in order to create and study artificial black hole configurations. Several theoretical groups are presently undertaking the challenge of pushing forward this research direction.

Another class of systems that hold strong promise in view of experimental studies of analogue Hawking radiation are based on ultra-fast optics techniques: by means of a suitable short and intense pulse of light, a moving perturbation of the refractive index is generated in a nonlinear optical medium, which is expected to give rise to a pair of horizons. Two groups have presented their experimental observations and the theoretical interpretation of their data in a sequence of four talks. These presentations triggered intense exchanges on the actual meaning of the observations and on the next steps to be performed in order to obtain more conclusive results: all these discussions will be of extreme utility in order for the new generation of experiments to focus onto the clearest signatures of quantum vacuum physics.

The session was closed with two more theoretical talks investigating other possible configurations to generate artificial black holes in nonlinear optical systems.

The interest in the dynamical Casimir effect has received a strong boost in the last year thanks to on-going experiments using superconducting circuits. A first claim of an observation of the effect has been presented at the workshop together with the corresponding theoretical model: the presence of several experts in the dynamical Casimir physics has made the workshop the ideal location where to discuss those few features of the experiment that are still under debate. This discussion was completed by a series of talks on QED effects in the so-called ultra-strong coupling regime of light-matter interaction: the peculiar properties of the QED quantum vacuum beyond the rotating wave approximation have been illustrated as well as the observation of novel physical behaviours when the properties of an optical systems are modulated in time on a sub-optical-period time-scale. The scientific contacts that have been creaed between experts in the Casimir effect and condensed matter physicists exploring novel regimes of electrodynamics of material media is expected to open new angles to the research on Casimir effects and, more generally, on the quantum physics of the electromagnetic field.

Several talks were finally dedicated to illustrating different scenarios where quantum vacuum effects lay an important role in cosmology and in particle physics. The conversion of quantum fluctuations into real modulations during the inflationary age is the main candidate to explain the largest scale structures of the universe as observed from the anisotropies of the CMB radiation: the underlying mechanism appear very similar to the one that is active in the above-mentioned experiments with ultracold atoms. The cosmological counterpart of the trans-Planckian features of Hawking radiation from black holes were also discussed, as well as the behaviour of mini-black holes that may be created in elementary particle accelerators. After all these talks, the low-energy part of the audience has got aware of the kind of fundamental questions that condensed-matter analogue models may help to address in the next future, from the non-Gaussianities of the CMB spectrum due to back-reaction effects, to the actual signatures of the UV "trans-Planckian" physics onto the Hawking spectrum from black holes.

3.3.9 NOT SO FEW, BUT NOT TOO MANY

DATE: July 4 - 8, 2011

ORGANIZERS:

Nir Barnea *(The Hebrew University, Jerusalem, Israel)*
Brett Esry *(Kansas State University, USA)*
Mario Gattobigio *(Université de Nice-Sophie Antipolis, France)*
Alejandro Kievsky *(Istituto Nazionale di Fisica Nucleare, Italy)*

NUMBER OF PARTICIPANTS: 33

MAIN TOPICS:

The intention of the workshop was to get an overview regarding the theoretical description of systems with more than four particles in atomic, molecular and nuclear physics. To this aim physicist belonging to both communities have been invited.

The main topics treated were:

- Strengths and limitations of the various theoretical approaches used in the description of bound and scattering states
- Discussion of convergence criteria
- Evolution of Efimov physics with the number of particles
- Focus on open problems in A>4 systems
- Discussion of excited states, resonances and clusterization
- Bound state techniques in the description of scattering states
- Exchange of ideas between the different communities

SPEAKERS:

V. Aquilanti *(Perugia, Italy)*
S. Aoyama *(Niigata, Japan)*
S. Bacca *(TRIUMF, Canada)*
D. Baye *(Brussels, Belgium)*
D. Blume *(WSU, USA)*
D. Fedorov *(Aarhus, Denmark)*
M. Gattobigio *(INLN, Nice)*
H. Gharibnejad *(Reno, USA)*
Ch. Greene *(Boulder, USA)*
E. Hiyama *(Riken, Japan)*
H. Han *(WIPM, China)*
W. Horiuchi *(GSI, Germany)*
A. Kupperman *(Caltech, USA)*
D. Lee *(NCSU, USA)*
W. Leidemann *(Trento, Italy)*
J. Mitroy *(CDU, Australia)*
P. Navratil *(TRIUMF, Canada)*
T. Neff *(GSI, Germany)*
G. Orlandini *(Trento, Italy)*
S. Quaglioni *(LLNL, USA)*
F. Pederiva *(Trento, Italy)*
A. Rinat *(Rehovot, Israel)*
Y. Suzuki *(Niigata, Japan)*
N. Timofeyiuk *(Surrey, UK)*
K. Varga *(Vanderblit, USA)*
M. Viviani *(Pisa, Italy)*
Z.-Ch. Yan *(UNB, Canada)*

SCIENTIFIC REPORT:

The first years of the new millennium have been successful in the application of specific theories to few-body systems. We refer for example to the description of three- and four-nucleon systems in terms of the modern two- and three-nucleon interactions. We also refer to the universal behaviour appearing in A=3,4 boson systems when the short-range interaction between the components produces a large scattering length. Both fields have benefited from developments using effective field theories. In the first case chiral perturbation theory has been used to consistently determine two-nucleon and three-nucleon forces. In the second case the presence of a large scattering length allows for an effective field theory built up using only contact interaction terms. Both theories have to some extent a predictive power. In order to corroborate their predictions and judge their accuracy, a detailed description of the A=3,4 system was needed. This goal was achieved thanks to the enormous work done during the nineties dedicated to solve the A=3,4 quantum mechanical problem. This include bound and scattering state solutions of the Schroedinger equation. We can extract a first conclusion: although specific discrepancies between theory and experiment can be observed, an overall agreement is obtained in the description of such systems.

Systems with A>4 have a very rich structure and their description present particular challenges. Even the simple problem of constructing an expansion basis having a well defined behaviour under particle permutation is a difficult task. On the other hand in these systems there is a particular competition between the statistics and the underlying interaction. Strange structures can appear, as halo nuclei, which are particularly difficult to describe using "ab initio" methods. At present different groups are studying the extension of their methods, used in the A=3,4 systems, or are developing new methods to describe systems with A>4. Among the methods we can mention the Green Function Monte Carlo (GFMC), the No Core Shell Model (NCSM), the Hyperspherical methods, the Effective Interaction Hyperspherical Harmonics (EIHH), the Coupled Cluster expansion (CC), the Stocastic Variational Method (SVM), the Coupled-Rearrangement-Channel Gaussian (CRCG) and, more generally, expansions of Gaussian functions, the Fermionic Molecular Dynamics, discretization methods and calculations on the lattice. World experts on these methods have participated in the workshop.

Results and Highlights

One of the main objectives of the workshop was to encourage discussions between the participants belonging to the fields of atomic, molecular and nuclear physics. Accordingly, the talks were allocated mostly in the mornings allowing for discussion time in the afternoons. The arguments covered in the morning triggered the afternoon discussions in the following topics: Hyperspherical methods were discussed the first day, Efimov physics in the second day, Gaussians expansions the third day and bound state methods applied to the continuum the last day. The different communities were very active in stimulating discussions after the talks and during the discussion time.

From the presentations it is now clear that systems with more than four particles can be treated by different methods not only in the description of the ground state properties but also excited states . However the methods present a good convergence when the interaction is soft. To this respect, it is important to notice that part of the effort in nuclear physics is devoted to derive soft-core interactions well suited to describe p-shell nuclei. Different examples have been discussed during the workshop. In the case of atomic physics, Efimov physics is intensively studied, in particular the consequences of large scattering lengths between two atoms in systems with more than four particles. In addition exotic systems presenting an Efimov spectrum have been discussed. Much of the methods treating systems with more than four particles are based on Gaussian expansions. Matrix elements between Gaussians can be calculated analytically, moreover permutational symmetry between particles is easy to consider with Gaussians. Different tricks to implement this kind of basis have been discussed during the workshop. Finally we have to mention methods based on discretization techniques as the Lagrange-mesh method and nuclear physics on the lattice. These methods are very promising and interesting results from first calculations of the Hoyle state in ^{12}C have been shown.

3.3.10 THREE-NUCLEON FORCES IN VACUUM AND IN THE MEDIUM

DATE: July 11-15, 2011

ORGANIZERS:

C. Barbieri *(U of Surrey, UK)*
E. Epelbaum *(U of Bochum, Germany)*
T. Otsuka *(U of Tokyo, Japan)*
K. Sekiguchi *(Tohoku University, Japan)*

NUMBER OF PARTICIPANTS: 42

MAIN TOPICS:

Topics discussed included:

- Derivation of the nuclear Hamiltonian: chiral effective field theory and phenomenological models.
- Experimental verification of models for the nuclear Hamiltonian.
- Calculations of three- and four-nucleon scattering.
- Signature of 3NFs from three- and four-nucleon scattering.
- Future application of 3NFs in many-body calculations with A>12.
- "Effective" nuclear forces in the medium.
- Possible signatures of 3NFs in exotic nuclei.

SPEAKERS:

S. Aoyama *(U of Niigata, Japan)*
S. Bacca *(TRIUMF, Canada)*
C. Barbieri *(U of Surrey, UK)*
B. Barrett *(U of Arizona, USA)*
T. Duguet *(CEA Saclay, France)*
E. Epelbaum *(U of Bochum, Germany)*
D. Gazit *(The Hebrew University of Jerusalem, Israel)*
R. Machleidt *(U of Idaho, USA)*
T. Otsuka *(U of Tokyo, Japan)*
A. Rios *(U of Surrey, UK)*
R. Roth *(TU Darmstadt, Germany)*
K. Sagara *(Kyushu)*
H.-J. Schulze *(INFN Catania, Italy)*
A. Schwenk *(TU Darmstadt, Germany)*
K. Sekiguchi *(Tohoku University,*

J. Holt *(U of Munich, Germany)*

J. Holt *(ORNL, USA)*

S. Ishikawa *(Hosei University, Japan)*

E. Jurgenson *(Livermore National Lab, USA)*

N. Kalantar-Nayestanaki *(KVI, Netherland)*

R. Kanungo *(U of Halifax, Canada)*

A. Kievsky *(U of Pisa, Italy)*

S. Kistryn *(Cracow University, Poland)*

J. Langhammer *(TU Darmstadt, Germany)*

D. Lee *(U of North Carolina, Italy)* A. Lovato *(SISSA, Trieste, Italy)*

D. Mac Gregor *(U of Glasgow, UK)*

Japan)

V. Somà *(CEA Saclay, France)*

O. Sorlin *(GANIL, France)*

E. Stephan *(U of Silesia, Katowice, Poland)*

T. Suzuki *(Nihon University, Japan)*

W. Tornow *(TUNL, USA)*

N. Tsunoda *(U of Tokyo, Japan)*

J. Vary *(Iowa State University, USA)*

K. Sekiguchi *(Tohoku University, Japan)*

SCIENTIFIC REPORT:

Three-nucleon forces are a key element to explain phenomena such as the binding of light nuclei and the saturation point of nuclear matter. At present, several sophisticated phenomenological models of three-nucleon forces (3NFs) are available. However, applications to the structure of medium-heavy nuclei are still at an infant stage.

The workshop was organized to cover both two main fields of research addressing 3NF's effects. In the vacuum, one tests directly the nuclear Hamiltonian by comparing rigorous numerical calculations (e.g. with the Faddeev-Yakubovsky method) of three- and four-nucleon scattering observables with available experimental data. Important advances came from the measurements of most previously unknown data at intermediate energies, which was achieved during the last decade. In this energy regime the effects of NN forces (2NF) becomes less important and new data gives strong evidence for 3NFs. A closer look at polarized scattering data shows that there remain subtle discrepancies with the theoretical models.

The second field addresses applications of 3NFs in the nuclear many-body problem. Rigorous studies along this line have so far been limited to p-shell nuclei using Green's function Monte Carlo and no-core shell model (NCSM). Another promising approach utilizes a lattice formulation of chiral effective field theory to obtain the ground state energies of nuclei with up to 12 nucleons.

Rigorous calculations become progressively difficult in larger systems. In this case 3NFs are still present but usually considered as "hidden" in the effective interactions used, for example, in the phenomenological shell-model. To address this problem a part of the workshop was dedicated to studies aiming at disentangling links between such effective forces and the underlying nuclear interactions. Recently, it has been possible to show the connection between the basic properties of 3NFs (e.g. for the Fujita-Miyazawa term) to those of the interaction in the medium. This has important implications for the position of the oxygen dripline. 3NF are also expected to affect spin-orbit splitting and the separation of major nuclear shells (which is related to the saturation density of nuclear matter). Experimental information on exotic nuclei is also important to further investigate these Issues.

Results and Highlights

The workshop brought together researches from both few- and many-body communities to further help cross fertilization, and emphasis was given to the above questions.

The Workshop was a very useful opportunity to discuss signatures of 3NFs and the inclusion of 3NFs in many-body calculations. The program was in fact highly considered as by all the participants from whom we received enthusiastic comments. A number of participants did not have new research on 3NF to present but still wanted to attend the workshop and actively contributed to the discussions. These were mostly many-body theorists, as 3NF are not yet fully implemented in most many-body nuclear structure calculations but people are now seeking for technical advances to fill this gap.

For the part relative to the construction of realistic forces, highlights were the discussion on the construction of interaction from chiral effective field theory. Chiral lagrangians are now also applied in afore mentioned lattice calculations up to 12 nucleons.

A number of experimental talks and few-body calculations have covered several issues related to testing the chiral theories of 3NF. Extracting polarization observables is now the frontier for the experimental programs around the world.

As far as the application to larger systems are concerned. New results have been reported on two relevant approaches. First, the evolution of ‘bare’ 3NF to lower cut-off are now making possible to appliey low momentum interactions consistently evolved in the 2N and 3N sectors together. At the same times, application of Fujita-Miyazawa terms into shell model calculations have shown the importance of 3NF effects in medium-heavy nuclei. And in particular on the position of dripliines and on evolution of shell closures.

New methods are now being developed to achieve calculations of open-shell nucleon in the mid-mass region. A main example is the extension of many-body Green’s function to the Gorkov formalism (which was discussed in during the workshop). Such methods will possibly rely on the use of low momentum interaction, including evolved 3NF.

For nuclear matter, calculation including 3NF are already available and were reported by several groups. It was seen once again how these effects are a crucial role in reproducing the saturation point of nuclear matter.

A complete and detailed discussion of the results of the topics above, would be too lengthy; we will simply say that a global picture of the roles that 3NF play trough out the nuclear chart (from few-bodies to heavy elements) is beginning to take shape out of the various research efforts being carried out by the participants to the workshop.

Enthusiastic discussions among scientists from all the different subfields were another important highlight of the meeting.

3.3.11 SPEAKABLE IN QUANTUM MECHANICS: ATOMIC, NUCLEAR AND SUBNUCLEAR PHYSICS TESTS

DATE: 29 August – 2 September, 2011

ORGANIZERS:
Catalina Curceanu Petrascu (*LNF–INFN, Frascati, Italy*)
Johann Marton (*SMI Vienna, Austria*)
Edoardo Milotti (*U of Trieste and INFN Trieste, Italy*)

NUMBER OF PARTICIPANTS: 39

MAIN TOPICS:
Quantum Mechanics (QM) has been with us for more than 100 years now, and some long-standing debates are still more alive than ever. The aim of the present workshop, was to realize a "constructive interference" between theoreticians and experimentalists to discuss possible new tests of the QM predictions, as well as the interpretation of the experimental existing results in the fields of atomic, nuclear and subnuclear physics: indeed these are the natural testing grounds of QM, from particles to the nuclei and molecules.

Main topics of discussion were:

- Foundations of quantum mechanics and open problems
- Spin-statistics theorem: the Pauli Exclusion Principle: present status of theory, and discussion of theories presenting small violations; nuclear and subnuclear physics tests;
- Bell inequalities: status of the theory and of the experimental tests in nuclear and subnuclear physics
- Decoherence in quantum mechanics: theory and experiments
- CPT and Lorentz symmetry violation: theory and experimental tests
- Neutral meson interferometry
- Quantum vacuum: present status of understanding and experiments
- The measurement problem and possible experimental tests (collapse of the wave-function) in nuclear physics
- Experimental results of tests of quantum mechanics and fundamental symmetries in nuclear and subnuclear physics:

- VIP experiment is checking Pauli Exclusion Principle Violation for electrons at Gran Sasso
- LIBRA/DAMA, checks dark matter and Pauli Exclusion Principle Violation for nucleons
- BOREXINO, checks Pauli Exclusion Principle Violation for nucleons
- KLOE and KLOE2 – tests of quantum mechanics using entangled neutral kaons from phi-decay at the DADNE accelerator at LNF-INFN (interference, re-generation, CTP)
- PVLAS – checks on quantum vacuum
- Towards tests of CPT with antihydrogen

- Next-generation experiments
  - Future of PVLAS
  - Future of experiments at Gran Sasso (VIP, DAMA/LIBRA, BOREXINO…)
  - Experiments at DAFNE
  - A facility for low-energy antiproton and ion research: FLAIR at GSI

SPEAKERS:

A. Bassi *(U of Trieste and INFN Trieste, Italy)*
P. Belli *(Tor Vergata Univ. and INFN, Roma, Italy)*
A. Clozza *(LNF-INFN, Italy)*
C. Curceanu *(LNF-INFN, Italy)*
G.M. D'Ariano *(U of Pavia, Italy)*
B. Dakic *(Institute for Quantum Optics and Quantum Information, Austrian Academy of Science, Vienna, Austria)*
F. de Martini *(Univ. "La Sapienza" Roma, Italy)*
A. di Domenico *(Univ. "La Sapienza" Roma, Italy)*
A. di Marco *(Tor Vergata Univ. and INFN, Roma, Italy)*
A. Diaz-Torres *(ECT*, Trento, Italy)*
L. Ferialdi *(U of Trieste and INFN Trieste, Italy)*
R. Floreanini *(U of Trieste, Italy)*
K. Fomenko *(LNGS-INFN, Italy)*
S. Gerlich *(U of Vienna, Austria)*
M. Guanere *(IPNL, Lyon, France)*
A. Hayrapetyan *(MPIK and PI, Heidelberg, Germany)*
B. Hiesmayr *(U of Vienna, Austria)*
N. Kiesel *(U of Vienna, Austria)*
Y.C. Liang *(U of Geneva, Switzerland)*
N. Mavromatos *(King's College, London, UK)*
S. Mayburov *(Lebedev Institute of Phys., Moscow, Russia)*

F. Piacentini *(INRIM, Torino, Italy)*
H. Rauch *(Atominstitut, Vienna Univ. of Technology, Austria)*
A. Rauschenbeutel *(U of Vienna, Austria)*
A. Rizzo *(LNF-INFN, Italy)*
B. Vacchini *(U of Milano, Italy)*

N. Vona *(LMU, München, Germany)*
L. Wellmann *(KVI Groningen, Holland)*
E. Widmann *(SMI-Vienna, Austria)*
P. Zanghi *(U of Genova, Italy)*
G. Zavattini *(U of Ferrara and INFN Ferrara, Italy)*

SCIENTIFIC REPORT:

Items such as: the spin-statistics connection, decoherence, locality, entanglement, quantum interference with atomic, nuclear and subnuclear probes, as well as other intriguing aspects of QM, such as the measurement problem were discussed.

The spin-statistics connection, and the Pauli Exclusion Principle (PEP) in particular, is one of the basic principles of modern physics and, even if there are no compelling reasons to doubt its validity, it is still debated today because an intuitive, elementary explanation is still missing, and because of its unique standing among the basic symmetries of physics. This very reason has prompted several theorists to build models (such as parastatistics; quon-theory; existence of multidimension; non-commutativity- etc) where a possible tiny violation of PEP is allowed. These theories were discussed, together with experimental tests in atomic and nuclear physics. Experimental results from the VIP (searching for atomic transitions in copper from 2p to 1s level, with 1s already occupied by 2 electrons, so manifestly violating the PEP principle), DAMA and BOREXINO (searching for nuclear transitions violating PEP) experiments were presented and discussed in an unique framework, together with theoretical implications and future perspectives.

Entanglement, decoherence and the Bell inequalities are also important elements of QM, giving specific predictions strictly related to its very nature. As such, the newest theoretical developments were presented, with special emphasis on experimental tests in nuclear and subnuclear physics. The Bell inequalities and their relation to nonlocality, which until now have been mostly studied in systems of photons (such as the experiments performed by Alain Aspect and al.), have recently been tested in kaon systems as well. In fact, with the advent of facilities such as the DAFNE-factory at LNF-INFN, where $K^0 - \bar{K}^0$ pairs are copiously produced in an entangled 1^{--} state, it is now possible to test the predictions of quantum mechanics in massive systems, i.e., systems where quantum gravity effects might became important and alter the predictions of non-relativistic quantum mechanics. At microscopic level, in the framework of quantum gravity, space-time might be subject to inherent non-trivial quantum metric and topological fluctuations at the Planck scale. This space-time structure might induce a pure state (as suggested by Hawking) to evolve in a mixed one, i.e. decoherence of apparently isolated matter systems, with applications to the understanding of processes of formation and evaporation of black-hole. This decoherence implies CPT violation in the sense that the quantum mechanics operator generating CPT transformations cannot be consistently defined. The information-loss paradox generated a

lively debate during the last decades with no generally accepted solution. The treatment of entangled kaon-antikaon state can constrain these theories, with intriguing possible consequences, such as the loss of particle-antiparticle identity which induces a breakdown in the correlation imposed by Bose statistics.
Bell inequalities can also be checked in such systems. Experimental tests werediscussed, such as those planned in the KLOE upgrade at DAFNE, together with other types of experiments which could be proposed in the future in nuclear and subnuclear physics.

The mystery that still shrouds the collapse of the wave function has been addressed in recent years by novel theories like the GRW model: no experimental tests have been performed to date, and part of the discussion in the workshop was focused on this important topic, with many ideas for possible future experimental check.

Unlike many other meetings on the Foundations of QM we casted the QM problems in the wider context of modern physics, including discussions on field theories and fundamental symmetries such as CPT and Lorentz symmetry. This included also a section on the structure of quantum vacuum, where theories were discussed along with active experiments such as PVLAS, and other planned experiments.

Results and Highlights

About 40 scientists participated in our workshop exhibiting a synthesis of theory and experiment in quantum mechanics and related topics with specific attention in atomic, nuclear and particle physics sectors. Many young scientists were attracted and contributed to the success.

The fascinating topics list comprehended many questions of modern physics and searches for new physics spanning from quantum effects with photons to massive particles like neutrons, kaons and even heavier systems like buckyballs. Important questions like the validity of the Pauli principle and CPT/Lorentz symmetry were addressed. Items as the decoherence or the “measurement problem” in its Bohmian and collapse of the wave function versions were debated, together with possible experimental checks.
Contacts between persons working in different sectors was established for the first time – and will potentially bring to important progress in the field.

Certainly *the nature likes to hide* but the discovery potential assisted by frontier technologies is always unveiling many of the existing mysteries – this spirit characterized the workshop.

The achievements of the workshop will be published in a „Mini-Proceedings“ of all presentations, to be published on arXiv.

During the workshop few actions, apart of regular talks given both by theoretician experts in the field and experimentalists, were as well organized. The EU COST Action 1006 on Quantum Mechanics was presented by A. Bassi – the Coordinator of the project.

Dedicated discussions on specific items were realized, with original ideas put forward.The workshop gathered together world-leading experimental and theoretical experts in the field and young scientists and students, providing a state-of-the-art overview of the field of quantum mechanics and related symmetries, with special focus on possible tests in atomic, nuclear and particle physics. The young participant's percentage was more than 50%, which is one of the successes of the Workshop.

The future of the field looks bright and promising – in good health, with an ideal mixing of experts and young, theoreticians and experimentalists, understood items and still-to-be-solved puzzles.

The organization of these type of Workshops in the ideal environment of ECT* contributes to the progress of the field.

Last but not least a note of merit: the organization of the Workshop by ECT (special thanks to the ECT* Director, Professor A. Richter, and to Ines Campo, the Workshop secretary) was excellent.*

3.3.12 QCD-TNT: INTERNATIONAL WORKSHOP ON QCD GREEN'S FUNCTIONS, CONFINEMENT, AND PHENOMENOLOGY

DATE: September 5 - 9, 2011

ORGANIZERS:

D. Binosi *(ECT*-FBK, Italy)*

J. Papavassiliou *(U of Valencia, Spain)*

A.C. Aguilar *(Federal University of ABC, Brasil)*

J.M. Cornwall *(U of California at Los Angeles, USA)*

NUMBER OF PARTICIPANTS: 54

MAIN TOPICS:

QCD-TNT-II addressed critically the hard problems that remain unsolved in QCD, connecting non-perturbative continuum and lattice ideas in new and original ways. The general themes of the second edition of the workshop include the understanding confinement, chiral symmetry breakdown, and the nature of topological charge, for all of which there is more than one plausible scenario. All these phenomena are non-perturbative and probe the strongly-coupled infrared region of QCD. We looked for ways to reconcile apparent discrepancies in various schools of thought, with an emphasis on enforcing gauge invariance, and for lattice simulations in specially-constructed scenarios that can accurately compare and contrast the proposed non-perturbative mechanisms of QCD.

Topics included:

- Lattice calculations in different covariant gauges
- Center vortices and confinement
- Chiral symmetry breaking
- Green's functions in the background of vortices and condensates
- Bethe-Salpeter equations
- QCD phenomenology and the gluon mass
- Yang-Mills theories in lower space-time dimensions
- QCD at Finite temperature and density

SPEAKERS:

Arlene Aguilar *(Federal University of ABC, Brasil)*
Reinhard Alkofer *(U of Graz, Austria)*
Natalia Alkofer *(U of Graz, Austria)*
Dmitri Antonov *(Instituto Superior Tecnico, Lisboa, Portugal)*
Daniele Binosi *(ECT*-FBK, Trento, Italy)*
Igor Bogolubsky *(JINR, Dubna, Russia)*
Stan Brodsky *(SLAC, USA)*
Marco Cardoso *(CFTP, Lisboa, Portugal)*
John Cornwall *(U of California at Los Angeles, USA)*
Aurore Courtoy *(INFN - Sezione di Pavia, Italy)*
Michael Creutz *(Brookhaven National Laboratory, USA)*
Attilio Cucchieri *(IFSC, Brasil)*
Philippe de Forcrand *(ETHZ, Switzerland)*
David Dudal *(U of Ghent, Belgium)*
Dietmar Ebert *(Humboldt University, Germany)*
Gernot Eichman *(U of Giessen, Germany)*
Bruno El-Bennich *(Universidade Cruzeiro do Sul, Brasil)*
Ruggero Ferrari *(U of Milan, Italy)*
Christian Fischer *(U of Giessen, Germany)*
Leonard Fister *(U of Heidelberg, Germany)*
Hilmar Forkel *(HU Berlin, Germany)*
John Gracey *(U of Liverpool, UK)*
Jeff Greensite *(San Francisco State University, USA)*
David Ibanez *(U of Valencia, Spain)*
Kei-Ichi Kondo *(Chiba University, Japan)*
Kurt Langfeld *(U of Plymouth, UK)*
Axel Maas *(Friedrich-Schiller-University Jena, Germany)*
Vincent Mathieu *(U of Valencia, Spain)*
Tereza Mendes *(IFSC, Brasil)*
Parameswaran Nair *(City College of New York, USA)*
Adriano Natale *(Instituto de Física Teórica – UNESP, Brasil)*
Stefan Olejnik *(Inst. Phys., Slovak Acad. Sci., Bratislava, Slovakia)*
Giulia Pancheri *(INFN, Frascati, Italy)*
Joannis Papavassiliou *(U of Valencia, Spain)*
Owe Philipsen *(U of Frankfurt, Germany)*
Carina Popovici *(U of Coimbra, Portugal)*
Andrea Quadri *(U of Milan, Italy)*
Hugo Reinhardt *(U of Tübingen, Germany)*
Craig Roberts *(Argonne National Laboratory, USA)*
Josè Rodriguez-Quintero *(U of Huelva, Spain)*
Helios Sanchis-Alepuz *(U of Graz, Austria)*
Francesco Sannino *(CP3-Origins, Denmark)*
Vladimir Sauli *(INP Rez, CAS, Czech Republic)*
Hideo Suganuma *(U of Kyoto, Japan)*
Adam Szczepaniak *(Indiana University, USA)*
Terry Tomboulis *(U of California at Los Angeles, USA)*
Jos Van Doorsselaere *(U of Ghent, Belgium)*
Vicente Vento *(U of Valencia, Spain)*
David Vercauteren *(U of Valencia, Spain)*

Peter Watson *(U of Tübingen, Germany)*
David Wilson *(Argonne National Laboratory, USA)*
Daniel Zwanziger *(New York University, USA)*

SCIENTIFIC REPORT:

This is the second Workshop on the general subject of non-perturbative aspects of quantum chromodynamics (QCD) with an emphasis on the methodologies of calculating QCD Green's functions, including lattice simulations; various pictures of confinement, including center vortices; and on fundamental investigations of chiral symmetry breaking. The stated goal was to connect continuum and lattice ideas in new and original ways. In some sense, the final arbiter of the success or failure of any particular theory of non-perturbative aspects of QCD is the outcome of lattice simulations, and there were a large number of workers in this field reporting their results at the Workshop.

In addition to theoretical and lattice studies of the fundamentals of QCD, there was considerable emphasis at the Workshop on phenomenological results, based on various approximations that do not necessarily have a heritage in fundamental principles, but that still may be quite useful. Such results were reported for chiral symmetry breaking and bound states of heavy and light quarks, among other topics.

The investigation of QCD Green's functions is complicated by the fact that many workers use techniques that are not gauge-invariant, and that lattice simulations of these Green's functions must be done with specific choices of gauge-fixing. By far the most common is Landau gauge, followed by Coulomb gauge, on which many workers reported at the Workshop both for lattice simulations and for theoretical studies of the QCD Schwinger-Dyson equations (SDEs). There was also some discussion of the maximal Abelian gauge. In all these gauges the behavior of the ghost sector is critical, and received much attention.

A number of Workshop participants reported their work on the Gribov phenomenon (the fact that standard gauge-fixing mechanisms, notably for the Landau gauge, do not completely fix the gauge, allowing for multiple QCD configurations that differ only by gauge transformations that stay within the partly-specified gauge) and the subsequent Gribov-Zwanziger (GZ) program for exploiting this phenomenon. Others spoke on ways to realize the so-called BRST symmetry non-perturbatively, using various effective actions and other techniques. There were also talks on a holographic view of QCD in the light-cone gauge; on gauge-theory solitons; on subtleties of light quark masses; on nuclear physics from strong-coupling lattice simulations; on finite-temperature and finite-density problems; on holographic approaches to QCD; and several talks on various approaches to d=2+1 QCD. Others spoke on particular approximations to QCD SDEs; on including background field back-reaction in the pinch technique; and on theoretical lattice studies that went beyond straightforward simulation.

It is fair to say that every major field of study of non-perturbative QCD was well-represented at the Workshop. All the participants to whom the organizers talked were enthusiastic about the Workshop as an excellent venue for balanced discussion of competing views, and virtually unanimously suggested that a follow-on Workshop be held in two years at ECT*. There were a number of world leaders in their areas at the Workshop, a good fraction of whom had attended the 2009 Workshop. It seems that a Workshop size of some 50 people is big enough so that all contending points of view can be heard, yet small enough so that everyone can give a talk and thrash out the important issues in private discussions.

Results and Highlights

QCD is both the only self-contained and experimentally-confirmed field theory that we have, and the hardest field theory ever attempted. Its high-energy features were well-understood within a few years of its founding in the 1970s, but its low-energy behavior is still under vigorous investigation; it is in this low-energy sector that contains all the spectacular non-perturbative aspects of QCD, such as confinement, chiral symmetry breaking, and topological manifestations.

For many years, two particular issues have—implicitly or explicitly—dominated the problems of non-perturbative, or low-energy, QCD. The first is whether, as suggested by one of the organizers more than thirty years ago and further investigated and confirmed by the other three, the gluon of QCD has a dynamical mass. (Naively, the gauge invariance of the classical Lagrangian of QCD forbids any mass, but there is no prohibition on generation of a mass by quantum effects.) A consequence of the finite gluon mass is that the strong coupling constant of QCD is finite at zero momentum and changes but little at momenta less than a few hundred MeV, in distinction to other approaches (for example, perturbation theory yields an infinite charge at zero momentum, and others have argued for zero charge at zero momentum). The second issue is that both the standard Feynman-graph approach to, and gauge-fixed lattice simulations of, QCD lead to indeterminate and ambiguous results for off-shell Green's functions, because they depend on choosing a gauge, an arbitrary and unphysical choice.

At the time of the previous Workshop there was an ongoing controversy over whether the so-called decoupling solutions of the SDEs in the Landau gauge (favored by the organizers and others) was correct in its prediction of a dynamical gluon mass, or whether an alternate set of solutions, called the scaling solutions and effectively predicting a massless gluon, was nature's choice. Aside from these theoretical investigations, lattice simulations in the Landau gauge over the last two years have solidly confirmed a body of evidence growing over the last several years that the gluon of QCD has a dynamical mass of approximately 600 MeV. It now seems that decoupling and a finite gluon mass is the correct view, and many workers reported on ways of incorporating a dynamical gluon mass into their particular framework (Gribov-Zwanziger mechanism, BRST structure, dimension-two condensates,...).

Concerning the issue of gauge-invariant calculations, there is a technique, invented by one of the organizers and thoroughly exploited by the other three, for recombining standard Feynman graphs so as to produce QCD Green's functions that are entirely gauge-invariant: The pinch technique. Among many other applications, this technique connects Landau-gauge calculations with truly gauge-invariant pinch technique results, allowing for comparison with Landau-gauge lattice simulations. New pinch-technique results were presented strongly supporting the decoupling solution with a finite gluon mass, and showing a surprisingly-large influence of ghosts in the Landau gauge. Also reported was a simple way to enforce renormalization-group invariance for pinch-technique Green's functions.

Of course, pinch technique calculations are far from the only path to understanding QCD. The long-standing GZ program held for many years that the gluon could not have a conventional mass, predicting a form of a Green's function that now is clearly not supported by lattice simulations. As a result, GZ workers are now trying various modifications to incorporate a dynamical gluon mass, with the goal of reconciling GZ with the lattice simulations.

The program of Coulomb-gauge investigations is currently quite productive, with new results on finite-temperature QCD and on chiral symmetry breaking presented at the Workshop to go along with somewhat older results demonstrating a form of confinement in this gauge. Several proposals for the wave functional for the QCD functional Schrodinger equation were presented, along with numerical tests comparing them to lattice simulations. A satisfactorily coherent picture is emerging of how non-perturbative QCD works in this gauge, but it remains to understand these Coulomb-gauge results in a broader gauge-invariant framework; for example, exactly how center vortices emerge in Coulomb gauge.

There is not space here to go into detail about the many other subjects covered at the Workshop. The general consensus is that there has been substantial progress in resolving controversies of the last Workshop; much hard work still remains; and a Workshop such as the present one is an ideal venue to continue the discussion two years from now.

3.3.13 LC11 WORKSHOP: UNDERSTANDING QCD AT LINEAR COLLIDERS IN SEARCHING FOR OLD AND NEW PHYSICS

DATE: September 12 - 16, 2011

ORGANIZERS:

Stefania De Curtis *(INFN Firenze, Italy)*

Albert De Roeck *(CERN Geneva, Switzerland)*

Stefano Moretti *(U of Southampton, UK)*

Giulia Pancheri *(Coordinator - INFN Frascati, Italy)*

Orlando Panella *(INFN Perugia, Italy)*

Francois Richard *(Laboratoire de l'Accélérateur Linéaire, Orsay, IN2P3, France)*

NUMBER OF PARTICIPANTS: 46

MAIN TOPICS:

This Workshop was part of a series of workshops on physics at Linear Colliders, which is organized in Italy every year with two objectives: to contribute to the international effort for studies and developments of future Linear Colliders and to stimulate and gather together the Italian community interested in Linear Colliders. The workshop, like all the others in the series, invited scientists from everywhere in the world to discuss together topical arguments directly and indirectly related to Linear Colliders. Previous editions have taken place in Florence, Perugia and Frascati. Every year the Workshop addresses a different theme, on which to place special emphasis. This year the main topic chosen was QuantumChromodynamics, QCD, in order to study new physics and to increase the precision of Standard Model physics.

The main topics discussed were:

- Status of the LC projects and their connections with the LHC
- Results from LHC at 7 TeV
- Future Medium energy project in e+e-
- Precision measurements at e+e- colliders
- The structure of QCD from the multi-TeV to the GeV scale
- QCD: from partons to hadrons

- Higgs and Top physics
- Physics beyond the Standard Model
- Dark Matter searches
- Photon-photon physics
- The future of QCD in e+e- physics

SPEAKERS:

Nestor Armesto *(U of Santiago de Compostela, Spain)*
Andrea Banfi *(ETH, Zurich, Switzerland)*
Sergey Barsuk *(LAL, Orsay, France)*
Francesco Becattini *(U of Firenze and INFN Firenze, Italy)*
Giorgio Bellettini *(U of Pisa and INFN Pisa, Italy)*
Stefano Bianco *(INFN, Frascati, Italy)*
Francesco Bigazzi *(INFN, Pisa, Italy)*
Marco Cirelli *(IPhT, Saclay & CERN, Geneva, Switzerland)*
Marco Ciuchini *(U of Roma and INFN, Roma III, Italy)*
Francesco Coradeschi *(U of Firenze and INFN Firenze, Italy)*
Roberto Corsini *(CERN, Geneva, Switzerland)*
Andreas Crivellin *(ITP, U of Bern, Switzerland)*
Leticia Cunqueiro Mendez *(INFN, Frascati, Italy)*
Wilfrid Da Silva *(LPNHE, Paris, France)*
Riccardo Di Sipio *(U of Bologna and INFN Bologna, Italy)*
Estia Eichten *(FNAL, Batavia, USA)*
Ruggero Ferrari *(U of Milano and INFN Milano, Italy)*
Alex Finch *(Lancaster University, UK)*
Rikkert Frederix *(Zurich University, Switzerland)*
M. Godbole Rohini *(CTS/IISC, Bangalore, India)*
Gaston Gutierrez *(FNAL, Batavia, US)*
Fred Jegerlehner *(Humboldt University, Berlin, Germany)*
Frederic Kapusta *(LPNHE, Paris, France)*
Nicolas Kauer *(NExT, Royal Holloway University of London, UK)*
Stefan Kluth *(MPI, Munich, Germany)*
Michael Kraemer *(RWTH, Aachen, Germany)*
David Lopez-Val *(U of Heidelberg, Germany)*
Nancy Marinelli *(U of Notre Dame, USA)*
Alan D Martin *(IPPP, U of Durham, UK)*
Antonio Masiero *(Uof Padova and INFN Padova, Italy)*
Pier Francesco Monni *(U of Zurich, Switzerland)*
Margarete Mühlleitner *(ITP, Karlsruhe, Germany)*
Daisuke Nomura *(Tohoku University, Japan)*
Giulia Pancheri *(INFN Frascati, Italy)*
Francois Richard *(LAL, Orsay, France*

Stefano Rosati *(U of Rome and INFN Rome Italy)*
Marc Ross *(FNAL, Batavia, USA)*
Ignatio Scimemi *(U of Madrid, Spain)*
Michael Spira *(PSI, Villingen, Switzerland)*
Graziano Venanzoni *(INFN, Frascati, Italy)*
J-C. Winter *(CERN, Geneva, Switzerland)*

SCIENTIFIC REPORT:

The particle physics community has recently entered into the the LHC era. Both new and old phenomena are probed with higher precision and at higher energies. Together with a study of what is being measured and discussed, it is now the time to look at the future of particle physics and envisage what will be studied twenty or thirty years from now. Thus the question of which machine can be best to go beyond the LHC and its upgrades, wheher it be a linear collider, or a new higher energy electron-proton option, or others. Within the linear collider options, the energy of the possible accelerator and hence the required technology is still an open question, whose answer will depend on what we learn from LHC experiments. A light Higgs for instance would encourage the community to build a linear collider wth a moderate beam energy, as the best option to study with high precision the Higgs boson properties. On the other hand, if no Higgs is discovered at LHC, the scenario would become very confused and probably require a higher energy machine like CLIC. Other questions facing particle physics now concern both the potential discoveries as well how optimal is the present understanding of the background out of which one needs to disentagle the unknown. One example is the search for the Higgs boson, another is the search for exotic fermions, or technipions, for instance. Some rare processes are characterized by the observation of two, three or more W-bosons. In order to distinguish between the Standard Model production of a number of W-bosons, some of which decay in jets, and the new physics, it is necessary to have the tools for such calculations, which include not only QCD estimates to higher orders, but also a control of jet phenomenology including the soft part of the event. However, the study of hadronic interactions is not simply a question of background. Indeed, an adequate understanding and description of the hadronic dynamics rely on modelling the large distance behaviour of QCD. There are many ways to approach the problem. Simulation programs exist which include inputs from many models for the very soft component of the interaction. Together with QCD calculations at various next-to-leading orders to describe the part of the interaction leading to observable jets in the final state, the MonteCarlo codes simulate the complexity of LHC events and test different hadronic models. Thus LHC allows tuning of the MonteCarlo programs, while at the same time testing the modelling of the very soft component. Other approaches might include the study of total cross-sections, the inelastic part measured by all the LHC experiments, or the elastic differential cross-section where the interplay and the transition between the perturbative and non perturbative part dictates the dependence of the cross-section on the momentum transfer. Another subject where QCD plays a crucial role, both through the known perturbative as well as through the lesser known threshold behaviour, is physics of the top and other heavy flavours. The top quark is still a rather mysterious particle and not all of its behaviour is fully understood. The intense LHC studies will certainly establish some of its properties, as such they will be a guidance in the choice of which future collider to build. To summarize the major questions which were to be addressed at this Workshop were:

- What is the status of the projects for the future of particle physics?
- Are the LHC experiments giving indications for new directions?
- Which are the possible scenarios for new physics to be discovered either at accelerators or through cosmology?
- What is the state-of-the-art of QCD concerning our ability to disentangle new physics from Standard Model processes?
- What messages can we expect from LHC concerning the large distance behaviour of QCD?

Results and Highlights

Through speakers who are leaders in the field, the LC11 Workshop presented the state-of-the-art of the different sub-disciplines of particle physics: accelerators, experiments, theory and phenomenology. All the participants agreed that the workshop succeeded in presenting, in a unique combination of varied talks, the exciting present, i.e., the LHC results, and the planning for future machines, from the viewpoint of both experiment and theory.

Although not all the questions posed to the workshop could be answered yet, a very good overview of the various problems discussed above was given.

Question 1: Status of future projects for particle physics, theoretical and experimental tools

The workshop started with a grand view of the research priorities nowadays in particle physics as perceived by one of the worldwide experts in beyond the Standard Model (BS) physics (Masiero), spanning from the understanding of the origin of mass and flavour, as testable at particle accelerators and in several underground experiments, to the cosmological implications of the results expected at these machines and their interplay with the observations being gathered by several space probes in the attempt to resolve the mystery of the matter-antimatter asymmetry. The talks transmitted a sense of urgency that made it clear to the audience that we are about to unravel the next layer of particle physics in the upcoming decade or so.

The other talks delivered during the first day (Richard, Corsini and Ross) were extremely important as they put into context the possible landscape of future Linear Colliders (LCs), by highlighting the synergies and complementarities existing between the two front-runner projects presently: the International Linear Collider (ILC) and the Compact Linear Collider (CLiC). The physics of these machines was highlighted particularly in view of their potential in accessing new physics signals. Special attention was devoted to the case of a 1 TeV ILC option. Several testable features of QCD in the TeV regime were discussed in particular. These talks were useful in balancing the often partisan views about either machine in the direction of recognising that it will be the LHC results that will indicate which LC prototype is best pursuing and that in the mean time sharing and thus cross-fertilisation of ideas across the two communities is of the outmost importance.

Of great relevance was also the following talk (Eicthen) as it recapped the status of the muon collider project, an alternative (or possibly a successor) to an electron positron collider, offering the unique opportunity of directly and copiously producing the Higgs boson as a single resonance, thereby affording the possibility of solving a puzzle of current particle physics, i.e., whether Electro-Weak Symmetry Breaking (EWSB) and the ensuing generation of mass is indeed due to the Higgs mechanism and, if so, to which realisation of it.

Complementary information to the highest energy frontier available would come from lower energy, yet higher precision, experiments only recently planned, such as the new g-2 experiment (Jegerlehner, Nomura, Venanzoni) and a SuperB factory (Ciuchini).

Questions 2 and 3: LHC results and future scenarios

All the LHC experiments presented their results. Great attention was focused on results from ATLAS and CMS and the exclusion limits on the Higgs mass (Rosati), released shortly before this Workshop, indicating the preference for a light Higgs. Scenarios for a no-Higgs discovery situation were presented (Kraemer and Ferrari), highlighting possible strategies for searches for New Physics and alternative theoretical frameworks in which to reconcile Electro-Weak (EW) precision measurements with such scenarios like, for example, the composite Higgs scenario proposed by Coradeschi. Of particular relevance was also the contribution by Crivellin, who considered the appearance of peculiar new signals in top and stop hadro-production in the presence of flavour violation.

To stay with Higgs scenarios, the Workshop enjoyed the review presentations on SM and BSM Higgs by Spira and Muhlleitner, chiefly of QCD effects in Higgs boson hadro-production, as well as the illustration of new Higgs production channels available in photon-photon scattering (Lopez-Val).

One important player in any discussion of New Physics is Dark Matter. Since a previous workshop had been dedicated to this subject, the present workshop only included one review talk on Dark Matter (Cirelli), focusing on the tools for its detection. It was shown that only few multiplets, containing a lightest neutral component automatically stable, can be added to the SM. The ingredients and the recipes for computing signals of TeV-scale Dark. Matter annihilations and decays in the Galaxy and beyond where deeply discussed. For each DM channel, it was shown the energy spectra of electrons and positrons, antiprotons, antideuterons, gamma rays, neutrinos and antineutrinos e, mu, tau at production, computed by high-statistics simulations. The energy spectra of electrons and positrons, antiprotons and antideuterons at the location of the Earth was given. All results are available in numerical form and ready to be consumed.

Question 4: State of Perturbative QCD : top and jet physics

Top quark, from both theoretical and experimental point of views, was thoroughly discussed in the LC11 workshop. We had reviews on the latest results from both Tevatron (Gutierrez) and LHC (Di Sipio) experiments, along with discussions on the latest calculations, at fixed order and resummed, as well as Monte Carlo codes on top quark production and decay at both lepton and hadron colliders (Frederix). Particular attention was paid to the extraction of the top mass, the forward-backward asymmetry and the top Yukawa coupling. We even had a presentation reviewing the latest results on Soft Collinear Effective Theories (SCET), taking particular care about the application of the SCET approach to extract the top mass from jet distributions and its relation to the mass parameter implemented in Monte Carlo generators.

As for resummations, a recent computation of the thrust distribution in electron-positron collisions was also presented and compared with the SCET predictions and experimental data from the ALEPH collaboration (Monni). Furthermore, progresses in the implementation of parton distributions (Martin), parton showers (Winter) as well as NLO Monte Carlo tools (Kauer) were also reported. From the experimental side, we heard about the most recent QCD analyses carried out by the LHC experiments, i.e. ATLAS/CMS (Marinelli), LHCb (Barsuk) and ALICE e^+e^- (Cunqueiro), and by the D0 and CDF collaborations at the Tevatron

(Bellettini).

The last three talks of the workshop were devoted to theoretical and experimental reviews of the present status of QCD, following the lessons learnt from previous and current e e^+e^{V-} experiments, DIS and hadronic machines. Two talks addressed traditional issues of QCD, from both the theoretical (Banfi) and experimental (Kluth) side, as developed over the years by adopting a perturbative approach formulated within gauge theory, essentially aimed at testing the SU(3) structure of the strong interactions. The third presentation (Bigazzi) gave instead an overview of recently developed theoretical approaches in describing QCD by exploiting dualities between supersymmetric gauge theories and string theories, chiefly the AdS/CFT correspondence applied to phenomenological aspects of a strongly coupled theory like QCD, including the description of AdS/QCD models of mesons and their application to hadronisation at colliders.

Question 5: Large distance behaviour of QCD

QCD at large distance was discussed in the context of total hadronic cross-sections. For the linear colliders, the highlight is on photon-photon interactions, where hadronic production both in beam-beam interactions and particle-beam interactions can obscure the processes one wants to observe. Progress was reported concerning simulation of both beamsstrahlung and bremsstrahlung effects at CLIC (Godbole), using a model developed for proton scattering, where a large role is played by emission of infrared gluons (Pancheri), for which a singular but integrable effective coupling is proposed. The infrared region was discussed also by a different angle (Martin) in a unified description of both soft and hard interactions, in a framework where the appropriate formalism for high-energy soft interactions is based on Reggeon Field Theory with a phenomenological (soft) Pomeron, whereas for hard interactions a QCD partonic approach is used in which the (QCD) Pomeron is associated with the BFKL vacuum singularity. In this unified vision the two approaches appear to merge naturally into one another. That is, the partonic approach seems to extend smoothly into the soft domain. Other approaches to the soft interaction region were discussed within a statistical model (Becattini). These different approaches indicate a growing awareness in trying to probe the large distance QCD regime of QCD and its transition to the perturbative region.

Summary

In essence, the workshop succeeded in giving an overview of future projects in particle physics, and of what to expect from precision physics either from e^+e^- or from new experiments. Higgs-less scenarios were discussed, different approaches to the long distance dynamics problem were presented. Although it is clear that QCD is not yet a complete tool, many excellent presentations showed that progress in perturbative QCD, and in modelling the non-perturbative regime both theoretically and phenomenologically, is being made. The format of these Workshop has proved to be very effective in bringing together theorists and experimentalists for planning the future of particle physics. In addition to the high level of scientific presentations, the success of this workshop is also due to a very efficient organization by the part of the ECT*, the very beautiful settings of the Center, and the generous support by both the ECT* and INFN.

Outcomes

The appreciation of this Workshop by all the participants is encouraging and we plan to continue our efforts to explore the physics of future machines within this format.

Proceedings of the Workshop will be published on line as part of the Frascati Physics Series and thus made accessible to interested researchers worldwide.

3.3.14 STRANGE HADRONIC MATTER

DATE: September 26 - 30, 2011

ORGANIZERS:

Josef Pochodzalla *(U of Mainz, Germany)*
Alessandro Feliciello *(INFN-Torino, Italy)*
Osamu Hashimoto *(Tohoku University, Japan)*
Horst Lenske *(U of Gießen, Germany)*
Angels Ramos *(Universitat de Barcelona, Spain)*

NUMBER OF PARTICIPANTS: 63

MAIN TOPICS:

The workshop “Strange Hadronic Matter” was intended to focus on new developments of strange nuclear physics and its adjacent fields. Considering that hypernuclei are unique in their potential of improving our knowledge on the strange particle-nucleon and nucleus interaction, the latter in turn are essential for a more general and self-consistent description of the baryon-baryon interaction and its role in cold nuclei, ultra-relativistic heavy ion collisions as well dense stellar objects. The possible existence of quasibound antikaonic-nuclear clusters is linked to the low-energy interaction of antikaons with nucleons and its modification due to the nuclear medium.
The workshop “Strange Hadronic Matter” was focused on new developments in theory and experiment and on future opportunities in this frontier field of research. Thus the scope of the workshop did lay solidly at the intersection of hadron-, nuclear- and astrophysics and even cosmology.

SPEAKERS:

Patrick Achenbach *(U of Mainz, Germany)*
Elena Botta *(INFN Torino, Italy)*
Alexander Botvina *(FIAS/U of Frankfurt/GSI, Germany)*
Stefania Bufalino *(INFN Torino, Italy)*
Petr Bydzovsky *(Nuclear Physics Institut, Rez, Czech Republic)*
Ales Cieply *(Nuclear Physics Institut, Rez, Czech Republic)*
Anselm Esser *(U of Mainz, Germany)*
Laura Fabbietti *(TU München, Germany)*

Alessandro Feliciello *(INFN Torino, Italy)*
Eli Friedman *(The Hebrew University Jerusalem, Israel)*
Theodoros Gaitanos *(U of Giessen, Germany)*
Avraham Gal *(The Hebrew University Jerusalem, Israel)*
Daniel Gazda *(Nuclear Physics Institut, Rez, Czech Republic)*
Ben Gibson *(Los Alamos Laboratory, USA)*
Toshiyuki Gogami *(Sendai University, Japan)*
Johann Haidenbauer *(FZ-Juelich, Germany)*
Emiko Hiyama *(RIKEN, Japan)*
Kenichi Imai *(J-PARC, Japan)*
Takatsugu Ishikawa *(Tohoku University, Japan)*
Daisuke Kawama *(ELPH, Tohoku University, Japan)*
Horst Lenske *(U of Giessen, Germany)*
Kazushige Maeda *(Tohoku University, Japan)*
Tomofumi Nagae *(U of Kyoto, Japan)*
Sho Nagao *(Tohoku University, Japan)*
Satoshi Nakamura *(Tohoku University, Japan)*
Anika Obermann *(U of Giessen, Germany)*
Makato Oka *(Tokyo Institute of Technology, Japan)*
Shinji Okada *(INFN Frascati, Italy)*
Eulogio Oset *(U of Valencia, Spain)*
Assumpta Parreno *(U of Barcelona, Spain)*
Josef Pochodzalla *(U of Mainz, Germany)*
Takehiko Saito *(GSI Darmstadt, Germany)*
Lorente Sanchez Alicia *(U of Mainz, Germany)*
Susumu Sato *(JAEA, Japan)*
Jürgen Schaffner-Bielich *(U of Heidelberg, Germany)*
Florian Schulz *(U of Mainz, Germany)*
Hans-Josef Schulze *(U of Catania, Italy)*
Reinhard Schumacher *(Carnegie Mellon University, USA)*
Nina Shevchenko *(Nuclear Physics Institut, Rez, Czech Republic)*
Vitaly Shklyar *(U of Giessen, Germany)*
Tamura Hirokazu *(Tohoku University, Japan)*
Liguang Tang *(U of Hampton, USA)*
Laura Tolos *(U of Barcelona, Spain)*
Kyo Tsukuda *(Tohoku University, Japan)*
Krzysztof Wisniewski *(U of Heidelberg Germany)*

SCIENTIFIC REPORT:

The workshop was well received by the community. With more than 60 participants the interest was overwhelming. Special thanks are given to the ECT* staff, in particular to Ines Campo who did an outstanding job as our workshop secretary, supporting the organization and preparation of the meeting in an excellent manner. At the workshop we could gather a representative selection of the internationally most active and leading researchers in the fields of low energy strangeness physics and hypernuclear reaction and structure physics. Particular strong groups came from Japan, Germany, Spain, and Italy. The workshop program included 46 scientific presentations from researchers at all levels of experience. Special care was taken that also younger scientists could report on their work.

Talks have included subjects ranging from

- neutron stars to baryon resonances to lattice QCD and the H dibaryon;
- kaonic systems, hyperatoms, antikaonic clusters, KbarNN, K in matter;
- hadronic production of strangeness, heavy-ion production of strangeness, electroproduction of strangeness;
- weak decay of hypernuclei, photoproduction of strangeness, pion spectroscopy of hypernuclei, anti-proton strangeness production;
- baryon-baryon interactions in terms of chiral EFT, YN and YY meson-exchange models, G-matrix approaches;
- hypernuclear structure in the shell model, clustering aspects of light nuclei, observation of ${}^{6}_{\Lambda}H$, Hall C and Hall A results, and many more

The speakers represented all leading experimental facilities such as J-PARC, DAFNE, JLab, FINUDA, MAMI-C, COSY, GSI, and FAIR(PANDA).

Results and Highlights

A few scientific topics, their status and perspectives as discussed at the workshop are listed below.

- The long accepted physical properties of the $\Lambda(1405)$ have been experimentally determined; the spin is ½ and the parity is positive.

- Using Saclay-Lyon A and Kaon-MAID model results outside the region in which they have been checked can be dangerous; the K^0 channel provides an important test. Photoproduction amplitudes tend to agree but differences arise for electroproduction.

- J-PARC pentaquark signal is fading under the weight of increased statistics; a stringent limit will hopefully be obtained by the 2012 Barcelona meeting.

- Lattice QCD suggests that the H di-baryon may rise again from the ashes of the quark model. In both Lattice QCD calculations and the chiral potential approach the H appears to possibly lie above the $\Lambda\Lambda$-threshold but below the threshold for ΛN. The significance for $\Lambda\Lambda$ hypernuclei is unclear.

- Neutron star maximum mass calculations appear to limit the role of hyperons, because the additional degrees of freedom soften the Equation of State. One solution is to convert the neutron star core into quark matter; that would limit hyperons and other baryons to an outer shell or crust.

- Heavy ion production of hypernuclei offers a means to reach far off the drip line to very neutron rich Λ hypernuclei. Heavy ion reactions also provide a possibility to explore hypernuclei with strangeness < -2. Peaks for ${}^{3}_{\Lambda}H$ and ${}^{4}_{\Lambda}He$ have been observed in peripheral collisions by the HypHI collaboration.

- J-PARC will return to operation in 2012. The results from Hall A and Hall C were reviewed. The apparent charge symmetry breaking in the A=7 isospin triplet seems not agree with current cluster model calculations. The effort and analysis in the FINUDA observation of 3 events identified as ${}^{6}_{\Lambda}H$ was impressive.

A selected number of about 30 contributions will be published as original papers in a special issue of Nuclear Physics A, edited by Avraham Gal, Osamu Hashimoto and Josef Pochodzalla.

The workshop schedule was set up such that there was time for individual discussion sessions and group meetings, respectively. Integrated into the workshop program were sessions of the SPHERE FP6-IH3P-initiaitve and the JSPS collaboration, led by the research group at the Tohoku University at Sendai/Japan.

We thank the ECT* for the local support at Trento and the outstanding hospitality. In addition, the workshop was financially supported by external contributions from SPHERE, JSPS, and the Helmholtz International Center for FAIR. The marvellous, inspiring atmosphere at the ECT* during the days of the workshop will be remembered by all participants.

3.3.15 STRONGnet 2011 SCIENTIFIC REPORT

DATE: October 3-7, 2011

ORGANIZERS:

G. Bali *(U of Regensburg, Germany)*
F. Di Renzo *(U of Parma, Italy)*
R. Schiel *(U of Regensburg, Germany)*
L. Scorzato *(ECT*, Italy)*

NUMBER OF PARTICIPANTS :68

MAIN TOPICS:

The workshop was part of the activities of the (Marie Curie) Initial Training Network STRONGnet (the first day was actually dedicated to the Midterm Review Meeting; the network fellows were the only scientific speakers on Monday the 3rd). The main topics of the workshop were all in the field of Computational Hadron Physics.
The lattice regularization is one the major theoretical tools to tackle the many subtleties of the non-perturbative regime of QCD; since this regularization is viable to computer simulations, computational techniques open a broad range of opportunities. The workshop was both a way to communicate recent developments and results obtained within the network, and a chance (in particular for the network fellows) to present the current status in both longstanding problems and more recent trends.

The main topics were:

- Spectroscopy including multiquark and scattering states
- Hadron structure calculations and electroweak decays
- Simulations of QCD at finite temperature and density
- Theories beyond QCD: technicolor, large N or SUSY on the lattice
- New algorithms and methods in lattice simulations
- Computer architecture and its challenges in software design and algorithms

SPEAKERS:

Constantia Alexandrou *(U of Cyprus, Cyprus)*
Andrei Alexandru *(U of Washington, USA)*
Paul Arts *(Eurotech SpA, Italy)*
Ashley Cooke *(U of Edinburgh, UK)*
Gunnar Bali *(U of Regensburg, Germany)*
Matthias Bolten *(U of Wuppertal, Germany)*
Nemanja *Bozovic (U of Wuppertal, Germany)*
Michele Caselle *(U of Turin, Italy)*
Luca Castagnini *(U of Regensburg, Germany)*
Gennaro Cortese *(U of Madrid, Spain)*
Mattia Dalla Brida *(Trinity College Dublin, Ireland)*
Ydalia Delgado *(U of Graz, Austria)*
Francesco Di Renzo *(U of Parma, Italy)*
Matthias Ehrhardt *(U of Wuppertal, Germany)*
Eric Endress *(U of Madrid, Spain)*
Gergely Endrody *(U of Regensburg, Germany)*
Alessandra Feo *(U of Parma, Italy)*
Andreas Frommer *(U of Wuppertal, Germany)*
Margarita Garcia-Perez *(U of Madrid, Spain)*
Pietro Giudice (U of Swansea, UK)
Mario Gravina *(U of Cyprus, Cyprus)*
Simon Hands *(U of Swansea, UK)*
Masayasu Hasegawa *(U of Parma, Italy)*
Dirk Hesse *(U of Parma, Italy)*
James Hetrick (U of the Pacific, USA)
Narjes Javadi Motaghi *(U of Regensburg, Germany)*
Karsten Kahl *(U of Wuppertal, Germany)*
Sandor Katz *(Eotvos University, Budapest, Hungary)*
Liam Keegan *(U of Madrid, Spain)*
Eoim Kerrane *(U of Edinburgh, UK)*
Pan Kessel *(U of Edinburgh, UK)*
Francesco Knechtli *(U of Wuppertal, Germany)*
Edwin Laermann *(U of Bielefeld, Germany)*
Christian Lang *(U of Graz, Austria)*
Laurent Lellouch *(CPT Marseille, France)*
Liuming Liu *(Trinity College Dublin, Ireland)*
Biagio Lucini *(U of Swansea, UK)*
Vidushi Maillart *(U of Regensburg, Germany)*
Nilmani Mathur *(Tata Institute Mumbai, India)*
Raffaele Millo *(U of Liverpool, UK)*
Hartmut Neff *(Amplitude Capital, Zug, Switzerland)*
Junichi Noaki *(KEK, Japan)*
Elisabetta Pallante *(U of Groningen, Holland)*
Michael Peardon *(Trinity College, Dublin, Ireland)*
Carlos Pena *(U of Madrid, Spain)*
Owe Philipsen *(U of Frankfurt, Germany)*
Sasa Prelovsek *(Jozef Stefan Institute, Slovenia)*
Fabrizio Pucci *(U of Bielefeld, Germany)*
Paul Rakow *(U of Liverpool, UK)*

Joern Rank *(d-fine GmbH, Frankfurt, Germany)*
Sinead Ryan *(Trinity College, Dublin, Ireland)*
Heiko Joerg Schick *(IBM Germany)*
Rainer Schiel *(U of Regensburg, Germany)*
Mario Schröck *(U of Graz, Austria)*
Andreas Schäfer *(U of Regensburg, Germany)*
Luigi Scorzato *(ECT* Trento, Italy)*
Dmitry Shcherbakov *(U of Wuppertal, Germany)*
Karthee Sivalingam *(U of Edinburgh, UK)*Ion-Olimpiu Stamatescu *(U of Heidelberg, Germany)*
Carsten Urbach *(U of Bonn, Germany)*
Pol Vilaseca *(Trinity College Dublin, Ireland)*
Michèle Wandelt *(U of Wuppertal, Germany)*
Frank Winter *(U of Edinburgh, UK)*
Kyoko Yoneyama *(U of Wuppertal, Germany)*
James Zanotti *(U of Edinburgh, UK)*

SCIENTIFIC REPORT:

Computational Hadron Physics is by now a well established field in Particle Physics. Since their introduction in the seventies, Lattice Gauge Theories substantially enlarged the number of topics under investigation. This is the time of high precision lattice simulations. New evidences and novel understanding are being put forward for longstanding problems: e.g., the hadron spectrum is by now reconstructed with an impressive control on systematic errors; we have stringent numerical tests on the effective string picture of confining gauge theories; results in flavor physics are getting more and more precise. At the same time, the lattice is aiming at deep insight in other challenging problems: e.g., tremendous efforts are being devoted to attack not only hot, but also dense baryonic matter, exploring the many phases of QCD; the lattice is also providing original insight into theories behind QCD, like the new technicolor scenarios, which ask for exploring non Abelian theories in a large range of number of colors and flavors. All these scientific tasks require a lot of computational resources. The advances in computer technology gave a tremendous contribution. On top of this, algorithmic developments and novel numerical techiques have been in recent years giving us the chance to make full profit of the increased computer capabilities.

Within such a broad range of interests, the workshop collected several contributions. As already said, a key goal was to give the network fellows a chance to grasp the state of the art. A few questions that were addressed were the following:

- What is the current status of Lattice QCD study of the baryonic spectrum and what are the major improvements in the control of systematics? What can we now say about exotic states? Is the lattice study of tetraquarks viable?
- What is the status of the QCD phase diagram, in particular with respect to the limitations in dealing with baryon chemical potential due to the so-called sign problem? What can we learn from simpler theories or from Random Matrix Theories?
- Is a picture of Technicolor candidate theories emerging from the lattice studies? What is the current lattice contribution to understanding the large-N limit of gauge theories? Can the lattice say anything on scenarios of extra-dimensions?
- What are the novel features in large-scale simulations by the big lattice collaborations?
- Can we expect new algorithmic progresses in the immediate future?
- What are the issues in tackling higher and higher computational resources?

Results and Highlights

The Workshop was a very useful opportunity to have a broad overview of Computational Hadron Physics. This was true in particular for the network fellows, who had the chance to better understand how their research is part of a much larger scenario. We provide here a selection of presented results, out of many interesting ones.

- The lattice determination of the QCD spectrum has really entered the stage of high precision physics; e.g. an BMW Collaboration claims an impressive control on systematics, with even interpolation (as opposed to extrapolation) on the pion mass value. Resonances are not yet accesible comprehensively: new techniques as distilation and dilution are expected to give important contributions. As for tetraquarks, while admittely nothing has yet been tackled with rigorous techniques (like the Luescher finite volume method), pionering efforts are going on to study quarkonium like XYZ states.
- A solution of the sign problem for hot and dense QCD is still far to come, even if we are gaining insight from techniques like imaginary chemical potential and series expansions or from scenarios emerging from Random Matrix Theories. The status of the Langevin approach is still under debate; in principle it could be a breakthrough, but currently we can only rely on criteria to assess the correctness of results.
- Quite remarkably, hot QCD is now being tackled also with Wilson fermions, with an indeed valuable opportunitiy to test results which came from the cheaper (but theoretically less reliable) staggered fermions formulation. Also, the phenomenologically interesting presence of an external magnetic field is now being taken into account in studying the QCD finite temperature transition.
- An interesting project is going on within the network to assess the status of a 5d theory by lattice simulations and there are indeed signals for dimensional reduction and even for spontaneous symmetry breaking with orbifold geometry.
- Out of the many efforts put in studying technicolor scenarios on the lattice, indications of the opening of a conformal window at N_f~12 are well establishing.
- Large-N studies seem to point to small $1/N^2$ corrections for many obervables; quite remarkably, including the effects of fermions is by now on the agenda.
- The test of the string picture of the interquark potential is by now controling (at least on numerically less demanding theories) next to leading effects and even the T-dependent increase of the flux tube thickness.

- N_f=2 is no more the only unquenched setting of lattice QCD: different approaches (2+1, 2+1+1) are by now well established, with complementary control on systematics.
- GPU programming is getting close to a more friendly software environment, with interesting contributions coming from STRONGnet activities.
- Our industrial partners (IBM and Eurotech) made us grasp problems put by current trends to higher computer powers, e.g. data reliability on large scale projects and machines. The participants had the chance to visit the AURORA installation in Trento.

It was interesting to have a couple of sessions interely dedicated to informal discussions: the presence of many young researchers (the network fellows) made them lively.

3.3.16 NUCLEAR STRUCTURE SEEN THROUGH GROUND-STATE PROPERTIES OF EXOTIC NUCLEI

DATE: October 17-21, 2011

ORGANIZERS:

Magdalena Kowalska *(CERN, Switzerland)*

Klaus Blaum *(MPIK, Germany)*

Piet Van Isacker *(GANIL, France)*

NUMBER OF PARTICIPANTS: 29

MAIN TOPICS:

The aim of the workshop was to overview the contribution of ground-state observables to our present understanding of the nuclear structure, and to review how our experimental knowledge is reflected in theoretical descriptions. For this reason this workshop brought together experimentalists and theorists addressing the ground-state properties of nuclei. We intended to discuss recent key experimental results as well as the current status of theoretical approaches, and the paths for their improvement. We also hoped to formulate concrete proposals for possible future measurements, based on requests from the theory side and taking into account the progress in experimental techniques and access to new facilities.

The main topics were:

- Ground-state observables and the underlying nuclear structure
- Properties of very heavy and superheavy nuclides
- Experimental developments in laser and storage techniques
- Nuclear theory: agreement with data and predictive power (mean field and beyond, shell model, ab initio approaches)

SPEAKERS:

J. Billowes *(U of Manchester, UK)*

G. Bollen *(MSU-NSCL, USA)*

G-L. Colò *(U of Milano, Italy)*

J. Dobaczewski *(U of Warsaw, Poland)*

S. Goriely *(Université libre de Bruxelles , Belgium)*

P-H. Heenen *(Université de Bruxelles, Belgium)*

E. Khan *(IPN-Orsay, France)*

D. Lunney *(CSNSM-Orsay, France)*

P. Möller *(Los Alamos National Lab, USA)*

P. Müller *(Argonne National Lab, USA)*

G. Neyens *(U of Leuven, Belgium)*

K. M. Nollett *(Argonne National Lab, USA)*

W. Nörtershäuser *(U of Mainz, Germany)*

P. Ring *(TU München, Germany)*

D. Vretenar *(U of Zagreb, Croatia)*

M. Block *(GSI, Germany)*

B. Cakirli *(MPIK, Germany)*

R. Casten *(Yale University, USA)*

L. Dieperink *(KVI, Holland)*

T. Eronnen *(MPIK, Germany)*

M. Kowal *(U of Warsaw, Poland)*

S. Kreim *(MPIK, Germany)*

V. Manea *(CSNSM-Orsay, France)*

J. Menendez *(TU Darmstadt, Germany)*

Y. Utsuno *(JAEA, Tokai, Japan)*

P. Van Duppen *(U of Leuven, Belgium)*

D. Yordanov *(CERN, Switzerland)*

SCIENTIFIC REPORT:

Our present understanding of nuclear structure is based to a large extent on the precise knowledge of the ground-state properties of nuclei, here especially masses, radii, spins and moments of radionuclides. In the beginning of the workshop overview talks have been given on the precise and most important model independent determination of these ground-state properties by, among others, high-resolution laser spectroscopy and high-precision Penning trap and storage ring mass spectrometry. Nowadays, experiments far from the valley of stability, where the production rate at existing radioactive beam facilities is only a few ions per second or even per minute, can be performed, demonstrating the high sensitivity of these experiments.

However, in the past, not much effort has been put into the investigation of the correlations of mass and spectroscopy observables, although extensive data on nuclei have been accumulated over the past decades. In this workshop a series of talks have been dedicated to the study of correlations between various observables and to the inspection of nuclear data over a large area of the nuclear chart, mainly along isotopic chains spanning a large fraction of major neutron shells.

Last but not least, numerous theory talks have been dedicated to the latest developments in nuclear structure theory in order to interpret the existing data and to allow for the prediction of yet unknown ground-state properties of nuclei far from stability. These developments include among others new mean-field and shell models for the description of nuclear masses, relativistic Hartree-Fock Bogoliubov descriptions of the ground state of deformed nuclei, as well as three-body forces and energy density functionals.

Results and Highlights

The workshop was a very useful and successful event to bring together leading scientists in the field of nuclear structure seen through ground-state properties of exotic nuclei. Numerous recent experimental developments like the octupolar excitation of the ion motion in a Penning trap allowing for a hundred-fold improved resolving power or the first application of laser-induced nuclear orientation for high-accuracy isotope shift measurements have been highlighted and demonstrated that especially modern atomic physics based techniques will give us access to even more exotic nuclei in order to study their properties with highest sensitivity and accuracy. Nowadays, e.g., masses of short-lived nuclides can be measured with a relative uncertainty of well below 10^{-8} even for nuclides with half-lives of less than 100 ms and production rates of only a few hundred ions per second.

Breathtaking results have been reported on in-source laser spectroscopy in the lead region, collinear laser and beta-NMR spectroscopy in the region of the island of inversion, direct mass measurements and the discovery of new isotopes in the heavy mass region.
On the theory side, besides an overview talk on the status of nuclear structure theory, highlights included an outline of a comprehensive programme to construct an energy density functional for nuclei, an in-depth discussion of current mass formulas (with ideas for improvement and applications), a report on the current status of relativistic mean-field descriptions, a critical analysis of our present understanding of superheavy nuclei and a discussion on shell structure in the nuclear shell model and possible evidence for three-body forces, and a progress report of ab initio quantum Monte Carlo calculations of light nuclei.
Talks successfully bridged the gap between theory and experiment. For example, a lively discussion session took place on the usefulness of mass filters around the theme: Can mass filters be applied to isolate specific components of the nuclear interactions or, conversely, are the latter too much intertwined to allow for such decomposition? The discussion is still ongoing. Several experimenters also ended their presentation with a clear request in the direction of theorists by pointing out pieces of unexplained data, for example, concerning radii and nuclear mass data.

3.3.17 THE SHELL EVOLUTION AND THE ROLE OF CORRELATIONS IN VERY NEUTRON RICH NUCLEI (COLLABORATION MEETING OF THE THEXO JOINT RESEARCH ACTIVITY)

DATE: October 24-26, 2011

ORGANIZERS :

P-H. Heenen *(Université Libre de Bruxelles)*

J. Dobaczewski *(U of Warsaw)*

H. Leeb *(Technical U of Vienna)*

F. Thieleman *(U of Basel)*

A. Richter *(ECT*)*

NUMBER OF PARTICIPANTS: 26

MAIN TOPICS :

- Effective nucleon-nucleon interactions
- Correlations beyond mean-field for nuclei far from stability
- Odd nuclei
- Confrontation between different models to describe exotic nuclei
- Definition of key quantities for a meaningful comparison between theory and experiment

SPEAKERS:

J. Aysto (*U of Jyväskylä, Finland*)

M. Bender (*CENBG, France*)

T. Duguet (*CEA, France*)

P. Greenlees (*U of Jyväskylä, Finland*)

S. Lenzi (*U of Padova, Italy*)

A. Poves (*UAM Madrid, Spain*)

P.-G. Reinhard (*University Erlangen, Germany*)

P. Ring (*Technical University Munich, Germany*)

P. Van Isacker (*GANIL, France*)

SCIENTIFIC REPORT :

The aim of this collaboration meeting was to review the status of the joint research activity on low-energy nuclear theory (THEXO) and to discuss the next steps to be performed in order to achieve the goals of THEXO. We also wanted to present our work to experimentalists who are active in the field of neutron-rich nuclei and to have presentations on experiments that are of special interest for our work.

During the meeting, we discussed in detail the significance of single-particle states as defined in different models (mainly the mean-field methods and the shell model) and their relation to specific experimental data. A breakthrough in the description of odd nuclei by beyond mean-field methods was presented. These nuclei are crucial to link theory and experiment on single-particle energies without ambiguity. These new developments will also permit to confront the results of beyond mean-field methods and the shell model in regions of the nuclear chart that should be well described by both models. During the discussions, nuclei in the N=28 mass region (Cr, Ti…) have been suggested as an optimal choice.

The effect of specific terms in the nucleon-nucleon interaction has been largely discussed. In particular, a tensor term seems to be an important ingredient for some models (Skyrme energy density in particular) but do not seem necessary for the Gogny interaction or the relativistic mean-field method. In the same way, some shell model interactions can only explain the position of the island of inversion and of the drip line (N=20 mass region in particular) as an effect due to the tensor interaction. In other shell model calculations, the same effects are obtained thanks to the T=1 NN interaction. Very detailed comparisons with experimental data are required to better fix the role of the different terms of the interaction

How to develop the THEXO collaboration has also been discussed. Although there are already some established collaborations between theoretical and experimental groups, these collaborations must be extended and experimentalists and theoreticians should interact more closely to define on which key data they should focus.

Among developments that still require to be performed before the end of the European project, the participants agreed on the importance on making available to the community fully documented state of the art codes. Such publication is particularly important for the task of THEXO devoted to nuclear structure, since these codes will be used by the participants of the two other tasks, devoted to reactions and to nuclear astrophysics.

3.3.18 CHIRAL DYNAMICS WITH WILSON FERMIONS

DATE: October 24-28, 2011

ORGANIZERS:

Kim Splittorff *(The Niels Bohr Institute, Denmark)*
Poul Henrik Damgaard *(The Niels Bohr International Academy, Denmark)*
Jac Verbaarschot *(SUNY at Stony Brook, USA)*

NUMBER OF PARTICIPANTS: 40

MAIN TOPICS:

The two main discretizations used in lattice QCD are staggered ferminons and Wilson fermions. Although a remnant of chiral symmetry is present in the staggered fermion action, the study of chiral dynamics, i.e. the study of QCD for small quark masses, requires very small lattice spacings because of taste violations. Wilson fermions, on the other hand, explicitly violate the chiral symmetry at nonzero lattice spacing, but the flavor symmetry is closer to that of the continuum limit. In this workshop we discussed chiral dynamics with Wilson fermions which has become possible because of remarkable recent developments in computational and analytical methods. The main topics where:

a) Phases of Lattice QCD with Wilson Fermions
b) Spontaneous breaking of Chiral Symmetry
c) Wilson Chiral Perturbation Theory
d) Spectrum of the Wilson Dirac operator

SPEAKERS:

Martin Lüscher (CERN)
Stephen Sharpe (U of Washington)
Sinya Aoki (U of Tsukuba)
Rainer Sommer (DESY)
Karl Jansen (DESY)
Urs Heller (American Physical Society)
Maarten Golterman (San Francisco State University)
Leonardo Giusti (Universitá di Milano Bicocca)
Pilar Hernandez (IFIC - Edificio Institutos de Investigación, Valencia)
Gernot Akemann (U of Bielefeld)
James Osborn (Argonne National Laboratory)
Mike Creutz (BNL)

SCIENTIFIC REPORT:

The study of the deep chiral limit, remains one of the main challenges for lattice QCD. The limit of massless quarks is not only essential in order to fully understand spontaneous breaking of chiral symmetry, it is also central for the study of the phase structure at non zero temperature and of QCD like theories as a function of the number of flavors. In particular, the interplay between the continuum and the chiral limit leads to several challenges. For example, lattice QCD with Wilson fermions may enter the Aoki phase or the Sharpe-Singleton scenario.

The small eigenvalues of the Wilson-Dirac operator are central for the breaking of chiral symmetry and the Aoki phase. Understanding the behavior of these small eigenvalues is also crucial for establishing a stable domain for numerical simulations. Moreover, it is also essential for understanding the chiral dynamics in the twisted mass formalism. In the twisted mass formalism the mass sets a strict lower limit on the eigenvalues at the price of breaking isospin symmetry.

Several of these issues have been addressed in the low energy effective theory of lattice QCD with Wilson fermions known as Wilson Chiral Perturbation Theory. In this framework the effect of the discretization errors are incorporated into new low energy constants. Determining the magnitude and sign of these constants is central for extracting continuum physics from the lattice. Most recently studies of the microscopic spectrum of the Wilson Dirac operator has cast new analytic light on the Aoki phase.

Results and Highlights

The workshop brought together the main players in this dynamical field for a week at ECT*. The aim was to foster new computational strategies and analytical methods for lattice QCD with Wilson fermions in the deep chiral limit.

There where several highlights of the workshop. The two opening talks by Steve Sharpe and Sinya Aoki set the stage with the two different phases (baring the names of the respective speakers) and the possible realizations in lattice simulations with Wilson fermions. The workshop brought together scientists of different backgrounds and the opening talks greatly helped the communication between experts in the different topics. During the week many most interesting new results where presented and at the end of the workshop a general new understanding of the low energy constants of Wilson chiral perturbation theory emerged.

The main highlight of the workshop was no doubt the many deep discussions triggered by the talks. We had deliberately left ample time for discussions and collaboration in the workshop program and it was a pleasure to participate in and observe the continued discussions throughout the week.

The workshop has already resulted the publication of ideas conceived during the week at the ECT*.

3.3.19 SHORT RANGE CORRELATIONS IN NUCLEI AND HARD QCD PHENOMENA

DATE: November 14-18, 2011

ORGANIZERS:

Claudio Ciofi degli Atti *(Istituto Nazionale Fisica Nucleare, Perugia, Italy)*
Mark Strikman *(Penn State University, University Park, PA, USA)*

NUMBER OF PARTICIPANTS: 40

MAIN TOPICS:

The Workshop was aimed at reviewing theoretical and experimental advances in the study of short range correlations (SRC) in nuclei and their effects in various fields, with a special focus on hard QCD phenomena. Although the main focus was on theoretical issues, an active participation of experimentalists involved in programs on existing electron and hadron facilities took place. Particular emphasis was placed on the presentation of the broad program of studies planed at Jlab after the 12 *GeV* upgrade, as well as on possible related programs, which could be feasible using hadron facilities (e.g. PANDA detector at FAIR and JPARC), and the electron-ion collider which is currently under discussion at Jlab, BNL and GSI. The Workshop brought together an active community interested in the above fields, which have been addressed, during the last two years, at four International Workshops held in Seattle, Miami, Munich, and during the APS Annual Meeting, in Denver. The main topics were:

- Theoretical predictions and experimental evidences of SRC in nuclei.
- Current methods for the calculation of wave functions, momentum distributions and spectral functions of bound nucleons.
- SRC and dense nuclear matter in laboratory and cosmos.
- Role of QCD dynamics in understanding the properties of dense cold nuclear matter.
- QCD factorization theorems for hard exclusive processes.
- Color transparency dynamics in quasi-elastic and coherent phenomena.
- Recent results on deep inelastic scattering of nuclei and hadron propagation and formation in medium.
- Experimental perspectives.

SPEAKERS:

M. Alvioli *(ECT*)*
M. Anselmino *(U of Torino, Italy)*
J. Arrington *(Argonne National Laboratory, USA)*
O. Benhar *(INFN Roma, Italy)*
W. Boeglin *(FIU, Miami, USA)*
W. Brooks *(UTFSM, Valparaiso, Chile)*
C. Ciofi degli Atti *(INFN Perugia, Italy)*
W. Cosyn *(Gent Univ, Belgium)*
D. Day *(Charlottsville Univ,USA)*
R. Ent *(Jlab, USA)*
E. Epelbaum *(U of Bochum, Germany)*
N. Fomin *(Los Alamos National Lab, USA}*
L. Frankfurt *(Tel Aviv Univ, Israel)*
M. Gaidarov *(NPI, Sofia, Bulgaria)*
K. Gallmeister *(U of Frankfurt, Germany)*
S. Gilad *(MIT, Boston, USA)*
R. Gilman *(Rutgers Univ, USA)*
A. Gillitzer *(Forschungszentrum Juelich, Germany)*
C. Granados *(FIU, Miami, USA)*
K. Hafidi *(Argonne National Laboratory, USA)*
R. Hen *(Tel Aviv Univ, Israel)*
A. Kievsky *(INFN Pisa, Italy)*
A. Kaptari *(U of Perugia, Italy)*
I. Korover *(Tel Aviv Univ, Israel)*
S. Kumano *(KEK, Tsukuba, Japan)*
C. B. Mezzetti *(U of Perugia, Italy)*
G. Miller *(U of Washington, Seattle, USA)*
U. Mosel *(U of Giessen, Germany)*
N. Muagma *(MIT, USA)*
E. Piasetzky *(Tel Aviv Univ, Israel)*
J. Ryckebusch *(Gent Univ, Belgium)*
G. Ron *(Jerusalem Univ, Israel)*
M. Sargsian *(FIU, Miami, USA)*
S. Scopetta *(U of Perugia, Italy)*
S. Strauch *(U of South Carolina, USA)*
M. Strikman *(Penn State Univ, USA)*
V. Sulkosky *(Jlab, USA)*
D. Treleani *(U of Trieste, Italy)*
L. Weinstein *(Old Dominion Univ and Jlab, USA)*

SCIENTIFIC REPORT:

The presence and structure of the short-range nucleon-nucleon correlations (SRC) in nuclei was considered as one of the key issues of the microscopic nuclear physics for more than a half a century. The knowledge of the details of SRC is necessary for building microscopic theories of nuclei and understanding the structure of dense extended objects like, e.g., neutron stars. However SRC were considered a very elusive feature of nuclear structure, since there existed no solid experimental evidence on them, due to the difficulty to separate the effects from SRC from the contribution of competing multistep processes, like e.g. final state interaction and meson exchange currents, in various scattering processes off nuclei. The situation changed radically with the advent of high energy machines which enable to study high momentum-energy transfer processes on nuclei, in particular nucleon knock-out experiments with leptons and hadrons probes. These experiments were performed at the Brookhaven National Lab with proton beams and, more extensively, with electron beams at Thomas Jefferson National Facility (Jlab). A parallel progress was achieved in the calculation of the characteristics of nuclei related to SRC, in particular high momentum components of the nuclear wave function and the spectral function. Studies of SRC with high energy high momentum transfer probes required also a better understanding of novel features of hard processes, like the color transparency phenomenon. The primary aim of the workshop was to review theoretical and experimental results in several fields, in particular the structure and probes of the SRC, the hard exclusive nuclei phenomena, the dynamics of the modification of the bound nucleon wave function, the mechanism of hadron formation in deep inelastic scattering.

Results and Highlights

New calculations of the double momentum distribution were reported, which demonstrated the validity of the two nucleon approximation with the inclusion of the motion of the pair in the mean field. First steps to modelling three nucleon SRC were illustrated and new data were reported for the scaling of the inclusive A(e,e')X cross sections at x> 1, which confirmed the prediction of a scaling behaviour of the ratio of the cross section on a nucleus A to the cross section on a lighter nucleus, like deuteron or ^{3}He. At the same time, detailed analyses of the final state interaction (FSI) were presented, which demonstrated that at large distances they tend to vanish in kinematics characterised by large values of Q^2 and x> 1, so that the the scaling behaviour of the ratios is practically not affected by FSI. It was also shown that the large long distance FSI effects found in some of the early papers originate from inadequate treatment of the off-mass-shell effects.

Further plans of the studies of SRC at Jlab were reviewed in great detail. A special attention was paid to the near future plans of “data mining” the old CLAS data. The first results of the data mining reported at the meeting appear to provide a complementary evidence for the presence of SRC. It was also pointed out that complementary studies of SRC would be possible at the FAIR facility at GSI, which is now under construction with the PANDA project, optimal both for the SRC and color transparency studies.

An important issue which has been discussed concerned the problem as to whether and to what extent nucleon parton degrees of freedom affect SRC. At the meeting it was pointed out that the non-nucleonic effects, as appearing in the EMC effect, are likely to originate mostly from SRC and are related to rare configurations in which one of the partons of the short range correlated nucleons has $x> 0.5$. Evidence of the deformation of the bound nucleon wave function was shown to follow from electron-^{4}He scattering. New measurements performed at Jlab appear to contradict those models where the experimental data were explained in terms of FSI effect and, on the contrary, support the prediction that the features of the data depend upon the virtuality of the nucleon, which reaches its maximum value in a short range correlated nucleon.

One of the key directions for the future studies at the Jlab is the measurement of the nucleon generalized parton distributions. Determining kinematics where such measurements are possible requires the study of the color transparency phenomenon in the exclusive meson production. The observation of color transparency in rho-meson exclusive production channel was reported at the meeting. The results of the experiment are in agreement with the theoretical predictions. When combined with the rate of hadron absorption in deep inelastic scattering a new effect is demonstrated, namely the duality of two effects: the expansion of color singlet dipole and hadronization of quarks into hadrons.

A complete and detailed discussion of the status of the field and plans for the future were also subject of two- hour long panel discussions. The general feeling was that: (i) the idea of using high energy probes for the investigation of nuclear structure is by now demonstrated both by theoretical and experimental studies, and (ii) there is a clear path for further progress in the field.

3.3.20 MODELING CHARGE-CHANGING AND NEUTRAL-CURRENT NEUTRINO REACTIONS WITH NUCLEI

DATE: December 12 - 16, 2011

ORGANIZERS:

Maria Benedetta Barbaro *(U of Turin, Italy)*
Thomas William Donnelly *(M.I.T., USA)*
Alfredo Molinari *(U of Turin, Italy)*

NUMBER OF PARTICIPANTS: 28

MAIN TOPICS:

The workshop was focused on the modeling of change-changing neutrino (CCv) and neutral-current neutrino (NCv) reactions with nuclei at GeV energies, namely, for kinematics of relevance for ongoing experimental studies with neutrinos. Importantly this regime implies the need for relativistic modeling and this was emphasized during the meeting. In recent studies of electroweak interactions with nuclei the roles played by 2-body currents through their effects on correlations and meson-exchange contributions have been seen to be significant. Several different approximations have been invoked in modeling these effects (see below) and these were inter-compared during the meeting.

We take as given that electron scattering must be understood before one can hope to interpret the weak interaction processes and accordingly the status of contemporary modeling of electromagnetic nuclear response functions and the degree to which these reproduce the well-known electron scattering data in the quasielastic regime were also emphasized. Here both ab initio modeling and phenomenology, including scaling analyses, were discussed.

Various approaches were compared and contrasted:

e) relativistic mean-field theory and semi-relativistic modeling
f) Green function studies
g) random phase approximation
h) inclusion of correlation effects and meson-exchange currents
i) scaling approaches
j) pion production

The degree to which these approaches successfully reproduce electron scattering data and what this implies for CCv and NCv reactions were central themes of the meeting.

SPEAKERS:

Luis Alvarez-Ruso *(U of Valencia, Spain)*
Jose E. Amaro *(U of Granada, Spain)*
Artur Ankowski *(U of Rome, Italy)*
Omar Benhar *(U of Rome, Italy)*
Damiano Berardo *(U of Turin, Italy)*
Juan A. Caballero *(U of Seville, Spain)*
Gerald Garvey *(Los Alamos, USA)*
Carlotta Giusti *(U of Pavia, Italy)*
Marek Gozdz *(U of Lublin, Poland)*
Martin Ivanov *(U of Sofia, Bulgaria)*
Natalie Jachowicz *(U of Ghent, Belgium)*
Davide Meloni *(U of Rome, Italy)*
Andrea Meucci *(U of Pavia, Italy)*
Ulrich Mosel *(U of Giessen, Germany)*
Juan Miguel Nieves *(U of Valencia, Spain)*
Ronald Ransome *(Rutgers University, USA)*
Rex Tayloe *(Indiana University, Bloomington, USA)*
Jose Manuel Udias *(U of Madrid, Spain)*
Alfons Weber *(U of Oxford and STFC/RAL, UK)*
Jakub Zmuda *(U of Wroclaw, Poland)*

SCIENTIFIC REPORT:

Neutrino reactions with nuclei have several different motivations, specifically, exploration of the properties of the neutrinos themselves including their masses and accordingly the oscillations that occur between the various flavor eigenstates together with the properties of the hadronic form factors that are accessible via the weak interaction. Since most of the ongoing experiments of this type involve scattering from complex nuclei (especially ^{12}C and ^{16}O) it is important to have state-of-the-art knowledge of the underlying nuclear structure issues involved. This is essential if the hadronic form factors, for instance the axial isovector form factor in CC reactions or the strangeness form factors in NC reactions, are to be isolated. And even for studies of neutrino oscillations, issues of nuclear structure are not completely absent: the effective neutrino energy $\langle E \rangle$ is required in forming the ratio with the oscillation length L, namely, $L/\langle E \rangle$, and this energy depends on nuclear modeling.

These observations motivated the workshop on modeling charge-changing and neutral-current neutrino reactions with nuclei. A group of theorists working in this area were brought together with a few experimentalists representing some of the ongoing neutrino experiments to review the current status of modeling the relevant reactions. The goals were to inter-compare the various approaches being taken by the different theorists and to engage in a dialog between the theorists and experimentalists to attempt to sharpen the understanding of the uncertainties both in the theoretical studies and in the data, the latter typically having undergone some model-dependent analysis before being modelled. This latter issue is one that needed clarification, a goal that was met to some degree during the workshop.

Specific areas of theoretical study were discussed, including:

- Relativistic modeling – At the energies of interest (typically a few 100 MeV to a few GeV) relativistic modeling is essential. Various approaches were discussed including relativistic mean field theory, relativistic Green's function modeling, modeling based on the random phase approximation and the use of spectral functions. Where the modeling is able to compare a relativistic approach with a corresponding non-relativistic approximation the need for the former is seen to be apparent.
- Scaling approaches – Phenomenological scaling approaches both to the QE part of the cross section, but now most recently to pion production as well are seen to be quite successful, setting a baseline for the types of modeling summarized above. These approaches are obtained specifically by making detailed analyses of electron scattering results for kinematics that are similar to those of interest in the neutrino

reaction studies. A central theme that was emphasized by several speakers at the workshop was the fact that any such successful approach to the modeling must produce agreement with the (e,e') data before being acceptable for A analyses.

- Inclusion of 2p2h meson-exchange and correlation contributions – Various alternative approaches to the modeling of these contributions were discussed. While the various approaches differ in detail, they all agree that such contributions are important for what is called "CCQE" by the neutrino community, that is the sum of true quasi-elastic (QE effects arising from 1-body operators) and the effects of such 2p2h excitations (effects arising from 2-body operators) – really the "no-pion" neutrino cross section.
- Pion production – Several speakers emphasized throughout the workshop that pion production must be better understood. What is presented as CCQE data has a contribution from pion production followed by absorption of the produced pion, thereby passing the "no-pion" test. The subtraction of such effects being done in the analysis of the experiments to leave the true QE plus 2p2h contributions being modelled by the theory community is clearly model dependent.
- Other topics – Presentations were also made on related subjects including coherent kaon production, gamma-ray production in NC interactions, Majorana magnetic moments and the leptonic CP phase, scaling and short-range correlations, plus a talk on the OPERA experiment suggesting that neutrinos are superluminal.

Results and Highlights

The theoretical talks at the workshop gave a good representation of many of the theoretical approaches being pursued. As mentioned above, the importance of 2p2h effects was emphasized by many of the theorists present. Each speaker was able to bring out the special merits of the approach he/she was taking and the discussions that occurred during the workshop were very fruitful in that they highlighted the issues that might require a combination of the techniques employed. For instance, clearly the RPA (which leads to the observed collective effects at modest excitation energies) is missing from any mean-field or scaling approach, the latter having their strengths in the required relativistic modeling at higher excitation energies. On the other hand, the Green's function approach gives one special insights into the flux conservation issue, but (so far) only explicitly addresses the 1p1h sector. The requirements of the various approaches with regard to computation of total cross sections where complete specification of the final state is less important than it is when computing the cross section assuming detection of some final-state hadron(s) were highlighted by some of the speakers and constituted one of the topics selected for the dedicated discussion session held during the meeting.

The experimental talks at the workshop provided an excellent summary of some of the on-going efforts in this field. Considerable discussion centered around the merits of having the various types of cross sections, namely the double-differential cross section for CCQE reactions (differential in T and) versus cross sections as functions of <E> which is model-dependent and clearly to some extend not being evaluated correctly, given both the asymmetry in the underlying nuclear responses (seen in electron scattering analyses) and the fact that the CCQE cross section has both true QE and 2p2h contributions. Additionally, some discussion revolved around the differences between what is called by theorists "inclusive" and what is called "semi-inclusive", the former being a total cross section as far as the hadronic physics is concerned, while the latter assumes that some hadron (or even a photon, in the case of one study presented at the workshop) is also detected. While the latter is more selective for the measurements and helps to identify specific processes in the reaction, it also requires much more of the theory and almost certainly brings with it increased theoretical uncertainties. This issue may be of some relevance for future experiments where a greater degree of exclusivity may be achieved, but with much more severe demands being placed on the modeling.

3.4 Doctoral Training Program in 2011
"Neutrinos in Nuclear-, Particle- and Astrophysics"

The 2011 ECT* Doctoral Training Program on Neutrinos in Nuclear-, Particle- and Astrophysics started on April 11 and ended June 17, 2011. The lectures lasted 10 weeks with 2 lectures given every morning. The afternoons were free except for one or two student seminars given each week. The fact that the afternoons were free and the lecturers present at ECT allowed many students to discuss with the lecturers.

The coordinators of this Doctoral Training Program were Baha Balantekin, Cristina Volpe and Christian Weinheimer.

The Doctoral Training Program was attended by 16 students. The list of students is appended at the end of this report. The students were all working on their PhD. Among the students, 2 were experimentalists. There were 19 invited lecturers. The finance, lodging and other administrative tasks of both the students and the lecturers were taken care of by Serena Degli Avancini.

A most welcome change in this year's Doctoral Training Program was the frequent presence of the program coordinator, Baha Balantekin. Not only did he attend many lectures but he also spent much time in the afternoons to discuss with the students. Professors Baha Balantekin and Cristina Volpe also rightly advised the invited lecturers to write on the board rather than to make PowerPoint presentations, which, no matter how pretty and animated the slides may be, are very inefficient pedagogically. As a result of this advice, far more lecturers used the board than in the previous Doctoral Training Programs. Some lecturers however took no notice of the advice.

This and last year's Doctoral Training Program differed from the previous ones by the presence of 2 lecturers each week, except for week 6 which had one lecturer. Although a small number of lecturers stayed for a whole week, most of them stayed for only two or three days. As a result, many lectures were similar to invited (albeit introductory) talks delivered in meetings, instead of being lectures designed to give the students a solid theoretical background. The large number of lecturers and the correspondingly small number of lectures which they had time to give, made it difficult to coordinate the lectures. As a result, there were numerous repetitions of subjects which were rarely exposed in detail. This made the

Doctoral Training Program all too often more similar to a meeting than to a school, and this may not be what students, still working on their PhD, need most.
It is a pity that no book was suggested, such as, for example, “Physics of neutrinos and applications to astrophysics” by Fukugita and Yanagida, Springer 2003, or the book by one of the lecturers, Carlo Giunti, “Fundamentals of Neutrino Physics and Astrophysics”. In previous programs books were often suggested in time to be available in the ECT library. Future Doctoral Training Program coordinators should be advised to suggest such books.

At the end of the program, the students were asked to write an informal report about the program. The reports, which were not required to be signed, have been delivered to the ECT Director .

3.4.1 The Lecture Programme

Except during one week, 2 lecturers were invited to lecture each week, giving 5 lectures each during the mornings. Most lecturers put their slides on internal Web site, thereby making them accessible to students but only from within ECT. Some lecturers placed scanned hand written notes there.

E. Fiorini
E. Fiorini gave a purely descriptive PowerPoint presentation of various past and present experiments designed to detect neutrinos. He spoke of superheated and superconducting granules, double beta-decay, and more. He gave the students his PowerPoint file.

A. B. Balantekin
The lectures of B. Balantekin were all done carefully on the board and were very pedagogical. He distinguished Dirac and Majorana particles. He discussed helicity, chirality and charge conjugation of massless particles. He explained how to generate massive Majorana neutrinos with 2 Higgs fields and a dimension 5 mass-term which is divided a large mass scale parameter.

C. Volpe
The lectures of C. Volpe were done on the board and she explained in some detail the mass and flavor matrices of neutrinos, their parameterizations and relations. She also discussed symmetry breaking in weak interactions.

M. Kowalski

The lectures of M. Kowalski were very instructive. He explained neutrino detection and measurement. He insisted on orders of magnitude (the earth's atmosphere is equivalent to 10 meters of water, for example) and units used (parsec et al.) He discussed the possible origin of very energetic cosmic rays (with energies way beyond the reach of the LHC) and possible acceleration mechanisms outside our galaxy. He detailed the IceCube detector at the South Pole.

J. Bernabeu

J. Bernabeu gave very rich, condensed and instructive lectures on the board. He discussed the seesaw mechanism, Dirac and Majorana particles, mass matrices and flavor matrices, possible terms beyond the standard model which allows massless neutrinos, how one can generate Majorana massive particles with a dimension 5 Lagrangian involving Higgs fields and divided by a large mass scale parameter. He made explicit calculations of oscillations of neutrino flavors.

Y. Wong

The lectures of Y. Wong were exceptionally good and instructive, all given on the board. It is a great pity that she was allotted only 2 days to lecture, instead of being present for a full week. She explained the Friedman equations describing the expansion of the universe, the time-dependent Hubble parameter and how they are expressed in general relativity. She estimated the contribution of massless (photons) particles, massive particles and dark matter to the energy momentum tensor. She estimated the density of these particles and their temperature at the present time. She made numerous order of magnitude estimations of energy densities, entropy and temperatures of matter in the universe. She left hand-written notes.

P. Vogel

P. Vogel gave excellent descriptions of estimates of possible processes which can determine the masses and magnetic moments of either Dirac or Majorana neutrinos. The lectures were pure PowerPoint presentations, but very carefully worded and presented. He explained qualitatively RPA vibrations of BCS states used to calculate nuclear matrix elements, with the aim of estimating the lifetimes of neutrinoless double beta decay and in different nuclei, in order to find the best suited nucleus to observe it.

A. Poves

A. Poves talked about shell model calculations of Gamov Teller nuclear matrix elements (and their associated quenching factors) as well as shell model evaluations of nuclear matrix elements for either neutrinoless or 2 neutrino double beta decays. He described the problems with the evaluation of neutrinoless double beta decay, when the parent and granddaughter nuclei are quite different, differing in deformation and/or seniority for example. He compared QRPA and shell model calculations. The lectures were rather qualitative: matrix elements of Fermi, Gamov-Teller transitions were evoked but he never wrote down what they were.

C. Garay

C. Garay gave incredibly detailed and well prepared lectures entirely on the blackboard, experimental results included. He left hand-written notes. The lectures included estimates and evidence for the age of our sun, and a detailed analysis of neutrinos emitted by the sun, an analysis of the creation (nuclear physics) and the escape (scattering) of neutrinos created in the sun.

M. Lindner

M. Lindner discussed models beyond the standard model. All was done by PowerPoint. It was the first time that the standard model Lagrangian was in fact displayed (during week 5 of the program). The lectures were entirely descriptive, transparencies from other talks were used and the lectures, albeit interesting, were extremely difficult to follow. He indicated mostly what students should learn, rather than teaching them the matter.

A. Schwenk

A. Scwenk was the only lecturer during week 6 of the Doctoral Training program. He gave remarkable lectures on the board. He explained the collapse and explosion of stars, he gave exercises to solve the Tolman-Oppenheimer-Volkov equations in order to establish numerically the relation between the mass and radius of a star. He discussed the star crust, pasta, and more generally systems of constant neutron and proton density, their equilibrium composition (neutron, proton and electron densities). He discussed dilute systems with large scattering lengths (and therefore strongly interacting) and their response functions. He also gave a qualitative description of chiral perturbation theory with a discussion of the effect of 3 body forces on the stability of oxygen isotopes.

K. Zuber

K. Zuber gave a purely PowerPoint presentation of experiments designed to detect, and measure the mass of neutrinos. He made useful estimates of counting rates which, for neutrinos are extremely low. He described neutrino detectors and their required performances, in view of the low number of events.

G. Fuller

The lectures of G. Fuller were displayed on slides with frequent excursions on the board. His lectures began with unexplained assertions concerning neutrinos in supernovae. But the following lectures became increasingly instructive. He estimated the amount of energy and entropy carried away by neutrinos during star evolutions. He discussed the neutrinos produced after the big bang, how and when they decouple to the extent of having a mean free path larger than the visible horizon. He also discussed nucleo-synthesis in the universe (as opposed to nucleo-synthesis in stars). Although the lectures were full of barely explained assertions, questions raised were always very carefully answered.

A. Faessler

A. Faessler spoke of the calculation of nuclear matrix elements responsible for double beta decay. He also supplied the students with a series of exercises.

L. Oberauer

L. Oberauer decribed the experiments performed with BOREXINO in Gran Sasso, Italy. He also described the future LENA detector and the possible detection of proton decay and galactic supernova neutrino bursts. These were carefully presented powerpoint lectures.

C. Giunti

C. Giunti gave excellent lectures on neutrino oscillations, neutrino mixing and their possible observations, different possible schemes of sterile neutrinos and their detection by the disappearance of active neutrinos. The lecturers were partially given on the board.

T. Lasserre

T. Lasserre gave very good, detailed and pedagogical lectures on the detection of neutrinos emitted by nuclear reactors.

C. Weinheimer

C. Weinheimer gave a series of remarkably good lectures on present and future experiments designed to search for neutrino masses. Very precise evaluations were made on the board of possible counting rates, and on their meaning. A detailed account of the KATRIN experiment was given.

S. Kraft-Bermuth

S. Kraft-Bermuth lectured on neutrino physics using calorimeters. She gave a rather detailed description of present and future experiments.

3.4.2 List of the Participants

Budaca Radu	Horia Hulubei National Inst. of Physics and Nuclear Engineering, Bucarest
Buganu Petrica	Horia Hulubei National Inst. of Physics and Nuclear Engineering, Bucarest
Dvornicky Rastislav	University Mlynska, Bratislava, Slovak Rep.
Gupta Rajiv	Guru Nanak Dev University, Amritsar, India
Haider Huma	Aligarth Muslim University, India
Klicek Budimir	Rudjer Boskovic Institute, Zagreb, Croatia
Malkus Annelise	U of Wisconsin, Madison, USA
Mertens Susanne	Karlsruhe Institute of Technology, Germany
Pandey Vishvas	Ghent University, Belgium
Sert Hale	Izmir Institute of Technology, Turkey
Shcherbakova Elena	DESY / U of Hamburg, Germany
Singh Jagjit	Maharishi Markandeshwar University Mullana, India
Tamanini Nicola	Unitn, Trento, Italy
Tang Jian	Inst. of Theoretical Physics and Astrophysics, U of Würzburg, Germany
Vaananen Daavid	IPN Orsay, France
Wu Meng-Ru	U of Minnesota, USA

3.4.3 Seminars delivered by the students

Hale Sert

Higgs bosons of gauge-extended super-symmetric U(1)’ model at the LHC

Huma Haider

Nuclear medium effects in deep inelastic neutrino-nucleus scattering

Jian Tang

Phenomenology of neutrino oscillations at the neutrino factory

Ratislav Dvornicky

Neutrino mass estimation in tritium and rhenium beta decay

Annelise Malkus

Can we use solar neutrinos to measure θ_{13} ?

Petrica Buganu

Nuclear shape phase transitions

Budimir Klicek

OPERA experiments

Susanne Mertens

Background processes at the KATRIN experiment

Meng-Ru Wu

Resonances of collective neutrino oscillations in supernovae

Radu Budaca

Closed formulas for ground rotational band energies of nuclei with various symmetries

Elena Scherbakova

Z-boson production in the Drell-Yang mechanism

4 Research at ECT*

In this chapter the activities of the Scientific Researchers at ECT* in 2011, i.e. of the Postdoctoral Fellows, the Director, the long-term Visitors and of their collaborators are briefly summarized. The different contributions are listed in alphabetical order of the Researchers. It can be seen that on the one hand there existed collaborations amongst the Researchers at the ECT*, but on the other hand all Researchers have collaborated also strongly with colleagues outside the Centre. The main reason for the latter is of course the particular structure of ECT* with few senior scientists present. All four – Daniele Binosi, Alexis Diaz-Torres, Luigi Scorzato and Dionysis Triantafyllopoulos – are, however very essential for creating a lively scientific atmosphere amongst the nuclear and hadron physicists of the in-house group. Daniele besides his research in QCD continued his efforts on coordinating European projects in the field of quantum information for which ECT* has been in the past and will also be in the future a special host. Luigi is a very experienced researcher in LQCD and is spending a tremendous effort in coordinating the projects within the AuroraScience collaboration at the newly installed HPC facility AURORA, and Dionysis is mainly concerned with QCD in matter of high density and temperature as it is being produced experimentally at RHIC and LHC. Finally, Alexis has just arrived at the ECT* and will with his work on nuclear reaction dynamics at low energies open at the centre a research line into the field of nuclear astrophysics.

4.1 Projects of ECT* Researchers

Massimiliano Alvioli

High energy hadron-nucleus and nucleus-nucleus collisions with correlated nuclear configurations

In collaboration with M. Strikman (Pennsylvania State University, USA)

In Ref. [1] we started a program for the inclusion of short range nucleon-nucleon correlations in nuclear configurations to be used in hadron-nucleus and nucleus-nucleus high-energy collisions [2], motivated by the recent observation of effects of correlations [3], ascribed to the action of the tensor operator on the nuclear wave function [4]. The use of realistically correlated configurations has been shown to produce large fluctuations [1,5] on observables and we recently extended the implementation from central to realistic correlations [6]. We also developed a model to describe the beam fragmentation process in heavy ion collisions within a novel approach which accounts for the detailed centrality dependence of several key quantities such as directed flow of nucleons and their momentum distributions [6]. In a recent collaboration with the group of Professor Eskola (University of Jyvaskyla, Finland) we studied the effects of NN correlations and NN interactions on the fluctuations of initial-state asymmetries of participant matter in ultrarelativistic heavy-ion collisions [7]. (Work supported by a mobility grant under the program HPC-Europa2 [8]).

Realistic many-body wave functions of medium-heavy nuclei

In collaboration with C. Ciofi degli Atti, S. Scopetta, L. P. Kaptari (University of Perugia) and H. Morita (Sapporo University, Japan)

In Ref. [9] we developed a many-body description of nuclei, within the cluster expansion method, which provides the expectation value of a given operator over the realistically correlated wave function. In particular, we produced basic one- and two-body quantities of interest in the calculation of nuclear reactions, namely one- and two-body densities and, most notably, momentum distributions [4,9]. These quantities have been shown to be relevant in many kind of reactions at medium- and high-energies [6,10,11]. Universality of NN correlations and their A dependence are the object of current experimental investigations at JLab (USA) and other world facilities. We have recently shown that universal features can be found in one- and two-body quantities of few- and many-body nuclei [12,13]. One of the next goals of the collaboration is the extension of the method of Glauber multiple scattering in order to have a comprehensive description of final state interactions in A(e,e'p)X and A(e,e'pN)X reactions, with A ranging from few-to many-body nuclei and using realistic wave functions.

Parton correlations and multiple partonic interactions

In collaboration M. Filipuzzi and D. Treleani (University of Trieste & INFN)

L. Fano' Illic (University of Perugia & INFN)

Multiple Partonic Interactions [14] are the tool to obtain information on the correlations between partons in the structure of hadrons. Partons may be correlated in all degrees of freedom and all different correlation terms contribute to the cross section. In the case of high energy proton-proton collisions, the effects of correlations in the transverse coordinates and in fractional momenta are mixed in the final observables, while the investigation of proton-nucleus collisions present advantages in order to disentangle such correlations [15]. It has been shown in [16] that the effects of longitudinal and transverse correlations may be studied through investigations of double parton interactions in high energy proton-deuteron collisions. The collaboration during the past year has led to a Master Thesis at University of Trieste co-supervised by Professor Treleani and Dr. Alvioli [17], in which calculations have performed for the p-D reaction with usual parton distribution functions and modeling double-parton distribution functions. Work is in progress for the calculation of p-D to p-p cross ratios and their x-dependence [18] at possible kinematic conditions of the LHC. The implementation of the model in a Pythia-based Monte Carlo simulation is also in progress.

High energy QCD evolution of the small x hadronic wave functions

In collaboration with D.N. Triantafyllopoulos (ECT)*
and G. Soyez (IPhT, Saclay, France)

The high-energy QCD evolution of the small-x components of a generic hadronic wave function is one of the main topics investigated at ECT*. We were interested in the numerical solutions of these nonlinear evolution equations, and in particular in the Balitsky-Kovchegov equation [19,20] which describes the evolution of the dipole-hadron interaction at high-energy. The solution of such an equation, which is integro-differential and nonlinear, is rather involved, so we spent time in reproducing some known analytic and numerical solutions under particular conditions in order to test our codes and optimize their implementation with parallel codes. We recently moved to the core of our project which is to find the solution of new, approximate equations [21,22] which serve as a direct test of the Gaussian approximation [23]. This will allow to calculate easily higher-point correlations in the hadronic wave functions and it is furthermore of direct phenomenological interest, for example in calculating di-hadron correlations in proton-lead collisions at LHC.

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Daniele Binosi

Gluon mass through ghost synergy

In collaboration with A. Aguilar (Federal University of ABC, Brazil) and J. Papavassiliou (University of Valencia, Spain)

In this work we have computed, at the “one-loop-dressed” level, the nonperturbative contribution of the ghost loops to the self-energy of the gluon propagator in the Landau gauge. This is accomplished within the PT-BFM formalism, where the contribution of the ghost-loops is inherently transverse, by virtue of the QED-like Ward identities satisfied in this framework. At the level of the “one-loop dressed” approximation, the ghost transversality is preserved by employing a suitable gauge-technique Ansatz for the longitudinal part of the full ghost-gluon vertex. Under the key assumption that the undetermined transverse part of this vertex is numerically subleading in the infrared, and using as nonperturbative input the available lattice data for the ghost dressing function, we show that the ghost contributions have a rather sizeable effect on the overall shape of the gluon propagator, both for $d=3,4$. Then, by exploiting a recently introduced dynamical equation for the effective gluon mass, whose solutions depend crucially on the characteristics of the gluon propagator at intermediate energies, we show that if the ghost loops are removed from the gluon propagator then the gluon mass vanishes. These findings suggest that, at least at the level of the Schwinger-Dyson equations, the effects of gluons and ghosts are inextricably connected, and must be combined suitably in order to reproduce the results obtained in the recent lattice simulations.

The dynamical equation of the effective gluon mass

In collaboration with A. Aguilar (Federal University of ABC, Brazil) and J. Papavassiliou (University of Valencia, Spain)

In this article we have derived the integral equation that controls the momentum dependence of the effective gluon mass in the Landau gauge. This is accomplished by means of a well-defined separation of the corresponding “one-loop dressed” Schwinger-Dyson equation into two distinct contributions, one associated with the mass and one with the standard kinetic part of the gluon. The entire construction relies on the existence of a longitudinally coupled vertex of nonperturbative origin, which enforces gauge invariance in the presence of a dynamical mass. The specific structure of the resulting mass equation, supplemented by the additional requirement of a positive-definite gluon mass, imposes a rather stringent constraint on the derivative of the gluonic dressing function, which is comfortably satisfied by the large-volume lattice data for the gluon propagator, both for $SU(2)$ and $SU(3)$. The numerical treatment of the mass equation, under some simplifying assumptions, is presented for the aforementioned gauge groups, giving rise to a gluon mass that is a non-monotonic function of the momentum. Various theoretical improvements and possible future directions are briefly discussed.

Slavnov-Taylor constraints for non-trivial backgrounds

In collaboration with A. Quadri (University of Milan & INFN, Italy)

In this paper we have devised an algebraic procedure for the evaluation of Green's functions in SU(N) Yang-Mills theory in the presence of a non-trivial background field. In the ghost-free sector the dependence of the vertex functional on the background is shown to be uniquely determined by the Slavnov-Taylor identities in terms of a certain 1-PI correlator of the covariant derivatives of the ghost and the anti-ghost fields. At non-vanishing background this amplitude is shown to encode the quantum deformations to the tree-level background-quantum splitting. The approach only relies on the functional identities of the model (Slavnov-Taylor identities, b-equation, anti-ghost equation) and thus it is valid beyond perturbation theory, and in particular in a lattice implementation of the background field method. As an example of the formalism we analyze the ghost two-point function and the Kugo-Ojima function in an instanton background in $SU(2)$ Yang-Mills theory, quantized in the background Landau gauge.

Gauge invariant Ansatz for a special three-gluon vertex

In collaboration with J. Papavassiliou (University of Valencia, Spain)

In this paper we have constructed a general Ansatz for the three-particle vertex describing the interaction of one background and two quantum gluons, by simultaneously solving the Ward and Slavnov-Taylor identities it satisfies. This vertex is known to be essential for the gauge-invariant truncation of the Schwinger-Dyson equations of QCD, based on the pinch technique and the background field method. A key step in this construction has been the formal derivation of a set of crucial constraints (shown to be valid to all orders), relating the various form factors of the ghost Green's functions appearing in the aforementioned Slavnov-Taylor identity. When inserted into the Schwinger-Dyson equation for the gluon propagator, this vertex gives rise to a number of highly non-trivial cancellations, which are absolutely indispensable for the self-consistency of the entire approach.

Marco Cristoforetti

Tetraquark spectroscopy

M. Cristoforetti and L. Scorzato

The computation of multi-hadron correlators and, more in general, correlators involving annihilation diagrams, have always been a great challenge for the Lattice approach to QCD. A new technique has been recently proposed in Ref. [1] that leverages on a long experience of previous attempts of challenging lattice QCD computations.

Given the high relevance of these calculations for Nuclear Physics we have implemented this method in the twisted mass LQCD code (tmLQCD), in collaboration also with the University of Cyprus, the Goethe-Universitaet Frankfurt am Main and the Rheinische Friedrich-Wilhelms-Universitaet Bonn.

In particular we have started applying this technique to the study of systems of two heavy-light mesons in order to determine whether or not they may form bound-states (tetraquarks). In the future we plan to extend this kind of analysis to the study of the hadron scattering like for example the case of the pion-pion and the pion-baryon systems.

For this project we are currently performing calculations using the HPC facility AURORA stationed at the Interdisciplinary Laboratory for Computational Science of the Fondazione Bruno Kessler and the Università di Trento.

The IR sector of QCD: lattice vs Schwinger-Dyson equations

M. Cristoforetti and D. Binosi

Important information about the infrared dynamics of QCD is encoded in the behavior of its (off-shell) Green's functions, most notably the gluon and the ghost propagators. We are approaching the study of such quantities both through lattice calculations and solving Schwinger-Dyson equations. Recent years have witnessed a lot of progress in both methods [2,3], at least in the pure gauge sector of the theory. A comparison between the results obtained in the two frameworks is possible projecting the lattice configurations in the Landau gauge.

We are extending the tmLQCD code in order to include the possibility to perform calculation in the Landau gauge. As a first step we will calculate the gluon propagator, for the first time in full QCD with Nf=2+1+1. After that we will move to the case of the unquenched ghost dressing function.

Also in this case the use of a supercomputer facility like the Aurora machine is mandatory.

KvBLL calorons and dyons

In collaboration with E. Shuryak (SUNY at Stony Brook, USA) and P. Faccioli (University of Trento)

Calorons are classical solutions of the Yang-Mills equation of motions that generalize instantons in the finite temperature region. The existence of calorons with nontrivial holonomy (KvBLL calorons), as aggregates of Nc chromo-electro-magnetic dyons is supposed to play a significant role in the emergence of confinement of quarks in QCD. Developing a consistent model of dyon-dyon dyon-quark interactions, could give us a semi-classical approximation of QCD where effects due to chiral symmetry breaking and confinement are both taken into account simultaneously. The active collaboration with Professor E. Shuryak (SUNY at Stony Brook), and our previous experience on instanton calculus [4], provide us with the ideal knowledge background in order to complete this program.

Polyakov extended Nambu Jona-Lasinio model

In collaboration with W. Weise, B. Klein (TU Munich, Germany) and C. Ratti (University of Torino)

In this model not only chiral symmetry breaking but also effects connected with confinement are included. Mean field calculations of QCD thermodynamics quantities in the PNJL model reproduce surprisingly well lattice data. To compare more properly the results obtained by the model with lattice data, we need to include also fluctuations in the PNJL model. In this direction we have considered standard Monte-Carlo techniques to compute thermodynamics quantities taking into account zero mode fluctuations of the considered fields [5,6]. As a further step forward, we are currently studying the possibility to include also non-zero modes to the calculation involving in this way the full dynamics of the mesons appearing in the formulation of the model, making finally the comparison with lattice data fully consistent.

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Alexis Diaz-Torres

Quantum decoherence in low-energy nuclear collision dynamics

In collaboration with M. Dasgupta and D.J. Hinde (ANU, Canberra, Australia)

In Ref. [1] an investigation of quantum decoherence effects on low-energy heavy-ion fusion cross sections was initiated. It has been motivated by systematic disagreements between high-precision measurements of sub-Coulomb fusion cross sections and calculations based on the standard coupled-channel model [2]. An innovative approach [3] that is based on the time propagation of a coupled-channel density matrix (CCDM) is being developed, which includes decoherence and dissipation. These are caused by a high-density of single-particle states that affect the dynamics of low-lying collective states of the colliding nuclei. Decoherence is not included in the widely used optical potential model [4]. The developments allow to quantify decoherence effects on both fusion and scattering [3]. Extensive CCDM calculations are planned for explaining very recent precision measurements of fusion and quasi-elastic barrier distributions [5]. The microscopic foundation of the employed (phenomenological) Lindblad operators will be investigated. The model will also be developed for treating reaction dynamics of weakly-bound rare-isotopes [6].

Reaction dynamics of weakly-bound nuclei at near-barrier energies

In collaboration with experimenters in France (GANIL & IPHC-Strasbourg), India (BARC), Brazil (USP) and Australia (ANU)

In Refs. [7,8] a classical-trajectory Monte-Carlo model for treating low-energy reaction dynamics of weakly-bound nuclei was developed, which is implemented in an user-friendly code [9]. This is being exploited for planning, guiding and interpreting particle-gamma coincidence measurements as well as fusion measurements in reactions induced by weakly-bound nuclei at energies near the Coulomb barrier. The model will be developed further and fine tuned with the measurements. A unified quantum description of relevant reaction processes of weakly-bound nuclei (breakup, transfer, complete and incomplete fusion) will be pursued.

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César Fernández Ramírez

D waves in low - energy pion photoproduction from the proton

In collaboration with A.M. Bernstein and T.W. Donnelly
(Laboratory for Nuclear Science, Massachusetts Institute of Technology)

The standard approach to describe near-threshold pion photoproduction from the proton employing chiral perturbation theory has relied in the approximation that only S and P waves are meaningful in the description of the observables and that higher partial waves can be neglected. In Refs. [1,2,3] it was proved that the inclusion of D waves in the analysis makes a sizeable impact in the extraction of the E_{0+} electromagnetic multipole (S wave) from data, affecting the magnitude of the unitary cusp that appears when the charged pion production channel opens [1,2], the extraction of the low-energy constants [1,2], and the prediction of several double spin polarization observables [3]. A recent experiment at MAMI (Mainz) that measured the photon beam asymmetry has preliminary results [4] and we are providing theoretical support to the understanding of the data.

Theoretical input for the PrimEx experiment

In collaboration with A.M. Bernstein and T.W. Donnelly
(Laboratory for Nuclear Science, Massachusetts Institute of Technology)

The PrimEx experiment is aimed to extract the neutral pion to two photons decay width and henceforth the neutral pion mean life in order to have direct evidence of the modification of this mean life due to quark mass effects (chiral symmetry breaking) [5,6]. This is done measuring the differential cross section of neutral pion photoproduction from carbon and lead at close-to-zero angles and 5 GeV photon energy in the laboratory frame, where the scattering by the Coulomb field dominates (Primakoff effect). In doing so an accurate reaction model is mandatory to extract from the data the pion-photon-photon coupling constant that is related to the decay width. We are currently developing a reaction model for the process based upon one photon exchange (Primakoff part) and Regge exchanges (meson exchanges) [7] which accounts for nuclear structure, in particular the effects of excited states. Model dependencies are thoroughly considered and estimated in order to reliably account for all the sources of error.

Chaos in hadrons

In collaboration with L. Muñoz (ECT), A. Relaño (Instituto de Estructura de la Materia, CSIC, Spain) and J. Retamosa (Universidad Complutense de Madrid, Spain)*

In the last decade quantum chaos has become a well established discipline with outreach to different fields, from condensed-matter to nuclear physics. The most important signature of quantum chaos is detected from the statistical analysis of the energy spectrum, which distinguishes between systems with integrable and chaotic classical analogues [8]. In recent years, spectral statistical techniques inherited from Random Matrix Theory have been applied successfully to the baryon spectrum [8,9] revealing its likely chaotic behaviour even at the lowest energies, despite of the low statistics involved. This result implies that the baryonic low-energy spectrum is highly correlated at low energy. We extended the work in [10] to mesons [11] and other statistics that can be meaningful as well as studying how unknowns in the spectra affect the conclusions.

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Lorenzo Fortunato

The research activity has been conducted along several lines in parallel. In nuclear structure I have investigated the rise of triaxiality by adding a cubic-order term in the quadrupole degree of freedom within the consistent-Q Hamiltonian approach. This has led to an improved shape phase diagram that displays a tiny triaxial region (first topic). In nuclear reactions I have collaborated with an experimental group operating at the Legnaro National Laboratories (second topic) on breakup reactions near the Coulomb barrier and with another group based in Camerino that operates at the LNS in Catania, furnishing theoretical calculations about E0 transitions in rare-earth nuclei (sixth topic). The fruitful collaboration (borne out at the ECT*) with W. de Graaf (Department of Mathematics of the University of Trento) has led to a couple of publications in the field of application of nilpotent orbits to algebraic models of nuclear and molecular physics (third topic). I have completed a long work with F.Pérez-Bernal on the full characterization of the shape phase diagram for ABBA-type molecules using an U(3)xU(3) algebraic model (fourth topic). Finally I have started new research on a coordinate systems and solution method for the non-relativistic many-body Schrödinger equation (fifth topic).

Triaxiality in the potential energy surface of the (QxQxQ) operator and cubic consistent Q Hamiltonian

In collaboration with A. Vitturi (University of Padova, Italy), J.M. Arias and C. Alonso (University of Seville, Spain), J.E.Garcia-Ramos (University of Huelva, Spain)

The potential energy surface for the cubic order quadrupole interaction (QxQxQ) has been calculated within the coherent state formalism. It is found to be compatible with the prolate axially deformed behaviour observed in the IBM spectra by several authors [1,2]. Our calculation gives a geometric interpretation and a confirmation of these results. In addition, we propose that the simple consistent Q Hamiltonian can be extended with a cubic term that allows for several interesting possibilities. The associated phase diagram shows a narrow region of triaxiality, together with spherical, prolate and oblate shapes [3].

Reaction dynamics for the system ^{17}F + ^{58}Ni at near-barrier energies

In collaboration with M.Mazzocco et al. (University of Padova, Italy)

We have collaborated with an experimental group on the interpretation of the break-up channel for fluorine in the reaction $^{17}F + ^{58}Ni$ that shows a moderate enhancement with respect to that of the more standard system $^{16}O + ^{58}Ni$. The loosely bound nature of the last unpaired proton is the crucial feature of this system that strongly influences its reaction dynamics [11,12].

Angular momentum non-conserving symmetries

In collaboration with W. de Graaf (University of Trento)

Algebraic models have been applied to several quantum systems [4] such as nuclei (Interacting Boson Model and extensions [5]), polyatomic molecules (Vibron model [6]) and many-body models. Using the theory of nilpotent orbits and weighted Dynkin diagrams [7], in connections with classical Lie algebras, we show that several interesting subalgebra chains, that are not commonly used, can be associated with angular momentum non-conserving symmetries. We have classified them in the cases of u(2), u(2)xu(2), u(3) and u(4) and we have given a physical interpretation, where possible, that leads to insightful speculations about the vibron model [8,9]. This study has been presented at a conference in Newcastle and we have published on my website several files that can be run in the GAP4 system.

Phase diagrams of tetra-atomic ABBA molecules in an algebraic model

In collaboration with F. Perez-Bernal (University of Huelva, Spain)

We have completed a study on the phase diagram of tetra-atomic ABBA molecules within an algebraic formalism [6] based on U(3)xU(3) that allows for the calculation of the potential energy surface. The characterization of this surface through coherent states leads to a phase diagram that displays four phases: linear, cis-bent, trans-bent and non-planar. We have fully characterized this phase diagram and its phase transitions [10].

Diagonalization of the many-body Schrödinger equation

We are studying a new diagonalization method for the many-body Schrödinger equation. This is a notoriously difficult problem that we handle with appropriate kinematic rotations and with the aid of the Löwdin alpha-function technique. This allows the calculation of matrix elements, in a totally uncoupled basis, that are necessary for a complete *ab initio* diagonalization. We will try to apply this method to the benchmark Helium atom problem and subsequently to nuclear systems such as three alpha particles with Ali-Bodmer or Buck potentials or to few-body nuclear systems with N-N interactions.

E0-transitions in rare-earth nuclei

In collaboration with A.Saltarelli, S.Das Gupta (University of Camerino, Italy) and N. Blasi (University of Milano, Italy)

The branching between the $E0(0_2^+ \to 0_1^+)$ and the $E2\ (0_2^+ \to 2_1^+)$ transitions in ^{156}Dy and ^{160}Er have been measured following the beta-decay of ^{156}Ho and ^{160}Tm. A potential of the 4*th* order of the deformation parameter *beta* (the "Lo Bianco potential") was chosen to describe the $U(5) \to SU(3)$ first order shape phase transition, covering the whole transitional path. The comparison of the excitation spectra and the measured ratios of reduced transition probabilities, $X(E0/E2)$, with the calculations, indicates that ^{156}Dy is in the spherical region, while ^{160}Er is located in the deformed region, but quite close to the critical point.

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Vincent Mathieu

Background processes for nucleon+meson->nucleon+2mesons

In collaboration with A. Szczepaniak (Indiana University, USA)

The COMPASS experiment [1] is devoted to hadron spectroscopy. One of its main goals will be to identify the presence (or the absence!) of exotic mesons. But before drawing conclusions concerning the extraction of any signal one has first to understand background processes. We are presently working on a model based on effective field theories to compute amplitudes associated to non-resonance processes. Those backgrounds have already proven their relevance in the vector meson sector [2]. We aim to generalize the approach to all partial wave and various final states.

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Stefano Melis

Transverse Momentum Dependent (TMD) distribution and fragmentation functions

In collaboration with M. Anselmino (University of Torino), M. Boglione (University of Torino), U. D'Alesio (University of Cagliari), F. Murgia (University of Cagliari), A. Prokudin (Jefferson Lab, USA)

The study of spin dependent observables is crucial in order to fully understand the internal structure of nucleons. In high energy processes, in the so called “collinear parton model”, a fast moving nucleon is described as a collection of constituents moving collinearly with it. The objects describing the structure of the nucleon in high energy processes are the parton distribution functions (PDFs). They represent the number density of quarks (or gluons) with a certain polarization and momentum inside a moving nucleon at some given energy scale. In the usual QCD “collinear” approach there are three fundamental PDFs: 1) the unpolarized PDF interpreted as the probability to find an unpolarized parton (with given momentum) inside an unpolarized nucleon; 2) the helicity PDF describing a longitudinally polarized parton in a longitudinally polarized nucleon; 3) the transversity function describing a transversally polarized parton inside a transversally polarized nucleon.

At the next level of sophistication one allows for the transverse motion of the constituents. Taking into account the parton transverse motion one has more degrees of freedom and new possible correlations between the nucleon and parton spin and the parton momenta are allowed. Thus five new Transverse Momentum Dependent PDFs (TMDs) are necessary to describe the nucleon structure. Among them we find the so called “Sivers function” interpreted as the probability to find an unpolarized parton inside a transversally polarized nucleon and the so called “Boer-Mulders function” describing a transversally polarized parton inside an unpolarized nucleon. The TMDs usually exhibit highly non-trivial QCD properties (for instance, some of them are “naively T-odd”). Their theoretical definition and their QCD evolution are still largely unknown. In spite of that there are many experimental evidences on the existence of these functions provided by several experimental collaborations in many facilities in the world (HERMES at DESY, COMPASS at CERN, RHIC, JLAB, BELLE). For a theoretical and experimental review see Ref. [1].

Our collaboration studies TMDs from a theoretical and phenomenological point of view. In Ref. [2] we analysed the polarized SIDIS processes in a formal way, in the context of a generalized parton model by means of the helicity formalism. We showed that there is a full equivalence (at leading twist) between the helicity formalism and the “hadron correlator” approach. Similarly in Ref. [3] we presented a decomposition of the polarized DY hadronic tensor by means of the “Lam and Tung”' helicity formalism.

Finally, we analysed the role of partonic transverse motion in unpolarized SIDIS processes [4]. Imposing appropriate kinematical conditions, we found some constraints which fix an upper limit to the range of allowed transverse momentum values, obtaining a better description of some observables like the cosΦ and cos2Φ azimuthal asymmetries.

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Laura Muñoz Muñoz

Chaos in hadrons

In collaboration with C. Fernández-Ramírez, A. Relaño and J. Retamosa (Universidad Complutense de Madrid, Spain)

Recently, spectral statistical techniques inherited from quantum chaos have been applied successfully to the baryon spectrum revealing its likely chaotic behaviour even at the lowest energies [1,2]. However, the theoretical spectra present a behaviour closer to the statistics of integrable systems which makes theory and experiment statistically incompatible. The usual statement of missing resonances in the experimental spectrum when compared to the theoretical ones cannot account for the discrepancies [2]. We have extended the work to mesons, with similar results, and also taking into account the uncertainties in the experimental data, thus giving stronger support to the result [3]. We aim to get insight into the quark models to investigate the origin of this “lack of chaos” with respect to the experiment. This can be done by modelling the Hamiltonian with a random ensemble of matrices with which the transition from order to chaos can be studied by varying some parameter which controls the strength of the interaction. If the strength needed to complete the transition is much bigger than the typical one of quark models, then we can state that the changes which are needed in the models in order to get a correct description of the experiment are not minor.

New gamma-hadron separation method based on RMT

In collaboration with E. Faleiro (Universidad Politécnica de Madrid, Spain), and J. Retamosa (Universidad Complutense de Madrid, Spain)

Extensive air showers (EAS) result from the interaction of high altitude atmospheric constituents with very high energy particles, mainly atomic nuclei and photons, arriving from any direction of space and collectively called primary cosmic rays. New particles, commonly called secondaries, are created as a consequence of these interactions, and interact again leading to a multiplicative cascade through the atmosphere. From the experimental measurement of lateral distributions of secondary particles on earth detectors, or the precise detection of individual impacts, it is possible to determine several properties of EAS. In particular, the nature of the primary cosmic ray, i.e. whether it is a high energy gamma ray or a hadronic particle, can be inferred. The precise identification of primary gamma rays is very important for Cosmic Ray Astronomy, since only these particles retain information on the position of the emitting source. We have published a series of works dealing with gamma-hadron separation methods, based on multifractal characterization, bidimensional power spectra and principal components analysis [4].

Recently we have proposed a new gamma-hadron separation method based on Random Matrix Theory (RMT): we consider an analogy between the individual impacts of secondary particles, and the complex eigenvalues of a matrix. Then we perform a RMT statistical analysis in two dimensions and the differences encountered between the statistics in each case (gamma or hadron) indicate that we can define a cutting parameter for a separation method. It seems that the separation power is at least as good as for other well established methods [5]. We have preliminary results on an improvement based on an appropriate combination of the statistics used in [5], which seems to yield larger quality factors, that is, higher separation power. We continue developing this method, its properties, possible advantages and disadvantages, application to experimental data.

Correlation structure of embedded ensembles

In collaboration with J. Retamosa (Universidad Complutense de Madrid, Spain), and A. Relaño (Instituto de Estructura de la Materia, CSIC, Spain)

Embedded ensembles are Random Matrix ensembles to model many-body quantum systems in the context of quantum chaos. As the classical ensembles, they properly reproduce the spectral statistics but in addition have the advantage of correctly modeling the

Hamiltonian, that is, taking into account parameters like the rank of the interaction or the number of particles. They are also a good framework to study the transition from integrability to chaos in quantum many-body systems [6]. Precisely, because they are more realistic models they are also more complicated, meaning that correlations between the matrix elements make a theoretical approach much more difficult than for the classical ensembles. As the origin of the relation between statistical properties of the spectra and chaotic dynamics is not well understood it is interesting to study the properties of the ensembles to try to get deeper insight into the issue. We aim to investigate the correlation structure of the embedded ensembles by means of δ_n, a newly proposed statistic based on time series analysis [7].

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Achim Richter

In my third year at the ECT I have – as in the former years – continued working closely with collaborators from my home institution, the Institute of Nuclear Physics at the Technical University of Darmstadt, and from institutions elsewhere mainly on problems in nuclear structure and nuclear astrophysics, in accelerator physics, and in quantum and wave dynamical chaos. The names of the respective collaborators are listed in the references cited at the end of this section.*

The ^{8}Li + ^{2}H reaction studied in inverse kinematics

This nuclear reaction has been studied at a relatively low incident energy of 3.15 MeV/nucleon using the REX–ISOLDE post-accelerator at CERN. Ground and low-lying excited states in $^{7\text{-}9}$Li were studied through the (d,p), (d,d) and (d,t) reactions, respectively. Measured angular distributions have been analysed with distorted-wave Born approximation (DWBA) and coupled-channels calculations in order to extract information on the nuclei studied [1].

Fine structure of the isoscalar giant quadrupole resonance in ^{40}Ca and level density of 2^+ states

The analysis of the high-resolution inelastic proton scattering spectra on ^{40}Ca described already in the ECT* Annual Report of 2010 and the comparison of the results to those obtained by Random Phase Approximation (RPA) and second-RPA calculations with an effective interaction derived from a nucleon-nucleon interaction by the Unitary Correlation Operator Method (UCOM) has yielded evidence for the mechanism of Landau damping [2]. Furthermore nuclear level densities of 2^+ states at excitation energies between 11 and 19 MeV in ^{40}Ca were extracted from a fluctuation analysis of the same data set and compared to predictions from widely used phenomenological and microscopic nuclear models [3].

An analytic approach to rotational states in deformed nuclei

Ongoing work for some time within a field theoretical model on the consequences of the spontaneous breaking of rotational symmetry in deformed nuclei has been finalized. The so called Ward-Takahashi identities play a crucial role in describing the rotational states, and it is shown explicitly how the rotor picture emerges from the isoscalar Goldstone modes and the two-rotor model from the isovector scissors modes [4]. The formalism has been applied to magnetic dipole sum rules in deformed nuclei [5]. The work is presently being extended to spin magnetic dipole excitations.

The complete electric dipole response and the neutron skin thickness in ^{208}Pb

In a recent benchmark experiment on the doubly magic nucleus ^{208}Pb it was demonstrated that polarized proton inelastic scattering at high energies and under very forward angles including zero degree is a powerful tool to study the electric dipole and spin dipole response in nuclei over a wide range of excitation energies for stringent tests of up-to-date nuclear models. The extracted electric dipole strength converted into a polarizability has led – using advanced mean-field model predictions [6] – to a neutron skin thickness r_{skin} = $0.156^{+0.021}_{-0.025}$ fm in ^{208}Pb. This value constrains the nuclear symmetry energy and its density dependence relevant to the description of neutron stars [7].

Single and double slit experiments with microwave billiards

For these experiments two microwave billiards with the shape of a rectangle and a quarter Bunimovich stadium, respectively, were used. The classical dynamics of the former is regular, whereas that of the latter is chaotic. Microwaves coupled into the billiards could leave them via slits in the boundary, leading to interference patterns on a screen. The aim of the experiments has been to determine the effect of the billiard dynamics on their structure. It was found that the interference patterns depend not only sensitively on the billiard dynamics but also on the initial position and direction of the wave packet inside the billiard [8].

Parity-time reversal (PT) spontaneous symmetry breaking in a microwave billiard

Flat microwave billiards are analogues of quantum billiards and can hence be used to study properties of eigenvalues and eigenfunctions of quantum systems. In the present work we have investigated theoretically and experimentally that with a special type of quantum billiards dissipative quantum systems which have a **PT** symmetry, i.e. are invariant under the simultaneous action of a parity operator (**P**) and a time-reversal operator (**T**), reveal interesting properties. We have in particular looked at a dissipative microwave billiard described by a non-Hermitian two-state Hamiltonian and find at a so called exceptional point defined as the coalescence of at least two eigenvalues and the corresponding eigenvectors that a phase transition occurs indicating spontaneous symmetry breaking. These results have just been published [9].

Semiclassical approaches for the treatment of dielectric resonators

Lately we have extended our experiments with microwave resonators also to dielectric resonators. The physics in the latter is dominated by the interplay between ray and wave dynamics, i.e. by semiclassical phenomena [10]. Recently the length spectra of flat three-dimensional dielectric resonators of circular shape were determined and compared to predictions from a semiclassical trace formula obtained within a two-dimensional model based on an effective index of refraction approximation. After taking the dispersion of the effective index of refraction into account good agreement was found. The methods developed enable also the application of the trace formula to realistic, flat three–dimensional microcavities and –lasers, allowing for the interpretation of their spectra in terms of classical periodic orbits. These results have just been published [11].

Transmission of microwaves through a photonic crystal and detection of edge states in a Dirac billiard

We have continued our experiments described in the ECT* Annual Report of 2010 on the properties of microwaves propagating in an unbounded and bounded photonic crystal consisting of metallic cylinders that are arranged in a triangular lattice. The transmission at the Dirac point, i.e. an isolated conical singularity of the photonic band structure, shows a pseudo-diffusive 1/L dependence, with L being the crystal thickness, i.e. a phenomenon also observed in graphene. Furthermore, we also measured the eigenmode intensity distribution of a relativistic Dirac billiard. Close to the Dirac point, states were detected that are localized at the straight edge of the photonic crystal embedded into the billiard corresponding to a zigzag edge in graphene. The results have just been published [12].

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Pavel Stránský

Regular and chaotic dynamics and phase transitions in collective models of nuclei

In collaboration with P. Cejnar (Charles University in Prague, Czech Republic) and M. Macek (Racah Institute of Physics, The Hebrew University, Jerusalem, Israel)

It has been shown in recent years that simple models of nuclear collective dynamics – the geometric collective model (GCM) and the interacting boson model (IBM) – exhibit a high degree of variability in regular and chaotic features with energy and control parameters

[1,2,3]. The complex dynamics encoded in relatively simple Hamiltonians well position these systems to be laboratories for detailed investigation into classical-quantum correspondence and for testing different approaches of measuring and visualizing chaos [4]. In addition, it appears that the study of chaos can help in understanding the dynamical structure of the systems and allows for observation of new phenomena, such as the quantum phase transitions [5] and the separation of intrinsic and collective dynamics induced by increased regularity [6]. In future work, we shall intend to follow three branches. (i) Elaborate the method of associating a classical Hamiltonian with an appropriate metric tensor of a Riemannian space [7]. This method can be successively used as an indicator of the dynamical stability and can bring better understanding of the order-chaos-order transition in the parametric space of the system under study. (ii) Continue the investigation of the quantum phase transitions, focusing mainly on the changes in the exited spectra (the so called excited state phase transitions). (iii) Adopt the phenomenon of entanglement, known from solid-state physics [8], and apply it to study the quantum phase transition in nuclear physics.

Prolate shape predominance in nuclear deformation

In collaboration with A. Frank and R. Bijker (Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México)

In Ref. [9] we used the volume-conserving deformed liquid drop model to study quantitativly the experimentally observed strong predominance of prolate over oblate shapes of nuclei. We perform an analysis using up-to-date experimental data for electric quadrupole moments and B(E2) transition probabilities and show that, for a significant number of well-deformed nuclei, the prolate-oblate difference in binding energy reaches values of the order of 500-800 keV. We are planning to include microscopic effects in order to reveal the condition for an oblate nucleus to appear.

Study of well-deformed nuclei by means of the Bohr Hamiltonian with different mass parameters for the rotational and vibrational modes

In collaboration with M.J. Ermamatov (Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México, and Institute of Nuclear Physics, Tashkent, Uzbekistan), P.R. Fraser (School of Physics, University of Melbourne, Australia), and P.C. Srivastava (Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México)

In recent works [10] it has been shown that taking into account the difference in the mass parameters of the rotational and the two vibrational modes in the Bohr Hamiltonian of the nuclear collective dynamics is very important when describing the properties of axially symmetric, well-deformed nuclei, especially for the interband $E2$ transition probabilities. Choosing the Davidson potential to characterize the β vibrations, the excited-state energies and $E2$ transitions have been calculated for several even and odd nuclei [11]. Future work on this topic will explore the situation where K (the angular momentum projection onto the third symmetry axis) and Ω (the angular momentum projection of the external nucleon) are not conserved, as this leads to the inclusion of the Coriolis force. In order to determine the correct value of the angular momentum of the external nucleon, large-scale shell-model calculations, using the ANTOINE code [12], will be performed.

Study of time series in complex physical and medical systems

In collaboration with A. Frank, E. Landa, I.O. Morales, J.-C. López Vieyra (Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México), V. Velázquez (Facultad de Ciencias, Universidad Nacional Autónoma de México), and R. Fossion (Instituto de Geriatría de la Secretaría de Salud, México)

Many dynamical systems from different areas of knowledge can be studied within the theoretical framework of time series, where the system can be considered as a black box. Certain dynamical systems auto-organize in a critical state that is characterized by 1/f noise in the power spectrum of the time series (for example the time series of the human heart inter-beat intervals of a healthy individual follows 1/f noise [13]). This noise has been also observed in physics both in classical and quantum systems [14-16], and could possibly offer a unifying bridge between the macroscopic and the quantum world. Besides the power spectrum, which assumes the time series to be stationary and periodic, and which uses an *a priori* given Fourier basis, we have adopted the Empirical Mode Decomposition (EMD) [17]. It decomposes a general nonstationary time series into few modes that can be regarded also as an *a posterior* determined basis. The EMD method has been applied to improve the unfolding procedure [18], necessary for studying the fluctuating part of the quantum spectra. In addition, it has revealed a scaling law in the spectra of random matrices [19]. In the future, this method will be used to analyse time series originated from the spectra of diverse complex systems including collective (GCM and IBM) and microscopic (Shell model) models of atomic nuclei.

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Luigi Scorzato

Aurora

In collaboration with the University of Trento, INFN, IASMA, ATreP, the University of Padova, Eurotech, Intel

The Aurora project is presented with more details below. I am involved in many aspects of this project: I am responsible of porting LQCD algorithms and code to the new architecture, and I am also advising the various groups to port their applications to the new architecture.

Numerical stochastic perturbation theory

In collaboration with F. Di Renzo and M. Brambilla (University of Parma)

I am computing renormalization factors and improvement coefficients in lattice perturbation theory. These quantities are needed to improve the precision of phenomenological predictions that can be extracted from non-perturbative QCD lattice calculations.

Exotic mesons and tetraquarks on the lattice

In collaboration with M.Cristoforetti (ECT), M.Dalla Brida (University of Trento), C.Alexandrou, M.Gravina (University of Cyprus), C.Urbach (University of Bonn)*

We are computing the contribution of tetraquark states to the meson spectrum. We are using various noise reduction methods in which we are experts. The next step will be the extension of the method to the baryonic spectrum and later to the computation of hadron scattering.

Computation of renormalization constants lattice QCD

Together with the ETMC collaboration

We are doing simulations of Nf=4 lattice QCD in the twisted mass regularization, near the chiral limit in order to compute the renormalization constants that are needed for the computations of hadronic quantities with u, d, s, c dynamical quarks in the twisted mass regularization.

Lefshetz thimbles and the sign problem of QCD at finite baryonic density

In collaboration with F. Di Renzo (University of Parma), M.Cristoforetti (ECT), R.Ghiloni (University of Trento)*

We are studying a new regularization of QCD, which enables the definition of an algorithm for studying QCD at finite baryonic density with no sign problem. The idea is based on representing the path integral as a sum along the manifold defined by the curves of steepest descent (Lefshetz thimbles).

Dionysis Triantafyllopoulos

Radiation in strongly coupled gauge theories

In collaboration with Y. Hatta (University of Tsukuba, Japan), E. Iancu (IPhT, Saclay, France) and A.H. Mueller (Columbia University, USA)

It is possible to study the strong coupling limit of particular conformal gauge field theories by using the AdS/CFT correspondence [1]. Working in the supergravity approximation, we managed to compute the energy density radiated by a heavy quark undergoing some arbitrary motion in the vacuum of the strongly coupled N=4 supersymmetric Yang-Mills theory [2], thus extending previous results obtained in [3,4]. We found that the energy is fully generated from the near-boundary endpoint of the dual string attached to the heavy quark and because of that, the energy distribution shows the same space-time localization as the classical radiation that would be produced by the heavy quark at weak coupling. In fact, up to a term which is a total (time) derivative and up to a multiplicative constant, the weak and strong coupling results coincide. An analytical understanding of the generalization to finite temperature [5] would be useful, since this problem corresponds to the energy loss of a heavy quark propagating in a strongly coupled Quark Gluon Plasma.

Next to leading order corrections in the Color Glass Condensate

In collaboration with E. Avsar, A. Stasto and D. Zaslavsky (Penn State University, USA)

At sufficiently high energy, and/or for large nuclei due to the large number of valence quarks, the gluon density can reach its asymptotic limit and the hadronic wavefunction will exhibit saturation. As energy increases, more and more gluonic modes saturate, the dynamically generated “saturation scale” increases, the QCD coupling becomes smaller and the problem can be approached by weak coupling methods. The effective theory of the Color Glass Condensate (CGC) aims to describe this phenomenon of parton saturation and finds applications in deep inelastic scattering at small-x, in giving the initial conditions for ultra-relativistic heavy-ion collisions and in various semi-hard processes [6]. The NLO equation which gives the evolution of the dipole-hadron scattering amplitude was derived in [7] but it is expected to have pathologies, like its linearized version, the NLO BFKL equation. Correcting these type of equations and thus providing the phenomenologists with more accurate tools is essential. As a first step we investigated the effects of a saturation boundary on BFKL evolution at NLO and beyond. We demonstrated that the instabilities of the NLO BFKL evolution are not cured by the presence of the nonlinear saturation effects, and a resummation of the most dominant higher order corrections is therefore needed. A reduction of the saturation scale was found, and we also observed that the onset of the saturation corrections is somewhat delayed to higher rapidities. Most probably this is a manifestation of the fact that the resummed gluon splitting function at moderately small values of x possesses a minimum. More precise studies using the full NLO equations should be performed and various types of initial conditions should be considered in order to draw more accurate conclusions.

Higher-point correlations and di-hadron production in heavy ion collisions

In collaboration with E. Iancu (IPhT, Saclay, France)

In light with heavy ion collisions at high energy, single and multi particle production at moderate momenta can be expressed in terms of Wilson lines [9]. These represent higher point-correlations in the Color Glass Condensate, and evolve according to the JIMWLK equation. For any value of the number of colors, we showed why and how we can approximate the JIMWLK Hamiltonian by a Gaussian one [10,11], thus explaining the numerical findings of [12]. This facilitates significantly the calculation of any higher-point correlation function which can be expressed in terms of the kernel of the Gaussian and opens the way for easier but more precise phenomenology than the one of [13].

Testing the Gaussian approximation in the Color Glass Condensate

In collaboration with M. Alvioli (ECT, Trento, Italy) and G. Soyez (IPhT, Saclay, France)*

In the numerical solution in [12] only a couple of representative configurations and correlators were studied. It would be more convincing if one can extend to more general configurations, and/or test the aforementioned Gaussian approximation in an independent way. This is what we have undertaken in [14] by solving appropriate mean-field equations [11].

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4.2 Publications of ECT* Researchers and ECT* Visitors

Massimiliano Alvioli

M. Alvioli and M. Strikman

Beam fragmentation in heavy-ion collisions with realistically correlated nucleon configurations

Phys. Rev. ***C83,*** *044905 (2011)*

M. Alvioli, C. Ciofi degli Atti, L.P. Kaptari, C.B. Mezzetti, H. Morita and S. Scopetta

Universality of nucleon-nucleon short-range correlations: two-nucleon momentum distributions in few-body systems

arXiv: 1112.2651 [nucl-th]; accepted by Phys. Rev. C, Rapid Communications

M. Alvioli, H. Holopainen, K.J. Eskola and M. Strikman

Initial state anisotropies and their uncertainties in ultrarelativistic heavy-ion collisions from the Monte Carlo Glauber model

arXiv: 1112.5306 [hep-ph]; accepted by Phys. Rev. C

M. Alvioli, H. Holopainen, K.J. Eskola and M. Strikman

Monte Carlo Glauber modeling of initial state anisotropies in ultrarelativistic heavy-ion collisions

Presented at the annual HPC-Europa meeting (Barcelona, June 2011); to appear in "Science and Supercomputing in Europe – report 2011"

Daniele Binosi

D. Binosi and J. Papavassiliou

Infrared properties of the gluon mass equation

To appear in the proceedings of the "International Workshop on QCD Green's Functions, Confinement and Phenomenology" (September 2011, Trento, Italy)

A. Aguilar, D. Binosi and J. Papavassiliou

Gluon mass through ghost synergy

JHEP ***1201****, 050 (2012)*

A. Aguilar, D. Binosi and J. Papavassiliou

The dynamical equation of the effective gluon mass

Phys. Rev. ***D84,*** *085026 (2011)*

To appear in the proceedings of the conference “Light Cone 2010: Relativistic Hadronic and Particle Physics” (June 2010, Valencia, Spain)

D. Binosi and A. Quadri

Slavnov-Taylor constraints for non-trivial backgrounds

Phys. Rev. ***D84,*** *065017 (2011)*

D. Binosi and J. Papavassiliou

Gauge invariant Ansatz for a special three-gluon vertex

JHEP ***1103*** *121, (2012)*

Marco Cristoforetti

M. Cristoforetti

Instanton fermionic zero mode at finite temperature and chemical potential

Phys. Rev. ***D84,*** *114016 (2011)*

Alexis Diaz-Torres

A. Diaz-Torres

Platypus: a code for reaction dynamics of weakly-bound nuclei at near-barrier energies within a classical dynamical model

Computer Physics Communications ***182,*** *1100 (2011)*

D.H. Luong, M. Dasgupta, D.J. Hinde, R. du Rietz, R. Rafiei, C.J. Lin, M. Evers and A. Diaz-Torres

Insights into the mechanisms and time-scales of breakup of ^{6,7}Li

Phys. Lett. ***B695,*** *105 (2011)*

A. Diaz-Torres

Coupled-channels density-matrix approach to low-energy nuclear reaction dynamics
AIP Conference Proceedings **1377**, *136 (2011)*
Proceedings of the 3rd International Conference "Frontiers in Nuclear Structure, Astrophysics and Reactions (FINUSTAR 3)" (August 23-27, 2010, Rhodes, Greece)

A. Diaz-Torres
Quantum decoherence in low-energy muclear reaction dynamics?
Proceedings of the 34th Brazilian Workshop on Nuclear Physics (June 5-10 2011, Foz do Iguazu, Brazil)
Proceedings of Science (PoS), http://pos.sissa.it

C. Beck, N. Rowley, P. Papka, S. Courtin, M. Rousseau, F.A. Souza, N. Carlin, F. Liguori Neto, M.M. De Moura, M.G. Del Santo, A.A.I. Suade, M.G. Munhoz, E.M. Szanto, A. Szanto de Toledo, N. Keeley, A. Diaz-Torres and K. Hagino
Cluster model for reactions induced by weakly-bound and/or exotic halo nuclei with medium-mass targets
Int. J. Mod. Phys. ***E20,*** *943 (2011)*
Proceedings of the 2nd International Workshop "State-of-the-Art in Nuclear Cluster Physics (SOTANCP 2)" (May 25-28 2010, Brussels, Belgium)

Victor D. Efros

Luping Yuan, Winfried Leidemann, Victor D. Efros, Giuseppina Orlandini, Edward L. Tomusiak
Transverse electron scattering response function of ^{3}He in the quasi-elastic peak region and beyond with Δ isobar degrees of freedom
Phys. Lett. ***B706,*** *90 (2011)*

Victor D. Efros
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ArXiv: 1110.3468 (2011)

César Fernández-Ramírez

A. Antonov et al. (143 authors)

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Nucl. Instr. Meth. ***A637****, 60 (2011)*

Lorenzo Fortunato

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J.Phys.Conf.Ser. ***312****, 082032 (2011)*

F.Pérez-Bernal and L.Fortunato

Phase diagram of coupled benders within a U(3)xU(3) algebraic approach

Phys.Lett. ***A 376,*** *236 (2012)*

Victor V. Flambaum and S.G. Karshenboim

S.G. Karshenboim and Victor V. Flambaum

Constraint on axionlike particles from atomic physics

Phys. Rev. ***A84****, 064502 (2011)*

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Gen. Relativ. Gravit. ***43****, 2673 (2011)*

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Stefano Melis

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Partonic transverse motion in unpolarized semi-inclusive deep inelastic scattering processes

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ETM Collaboration

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Aspects of the UV/IR correspondence : energy broadening and string fluctuations

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Zhi-zhong Xing

Zhi-zhong Xing

The T2K indication of relatively large Θ_{13} and a natural perturbation to the democratic neutrino mixing pattern

arXiv:1106.3244 [hep-ph] (2011)

4.3 Talks by ECT* Researchers presented outside of ECT* and at ECT* workshops

Massimiliano Alvioli

Realistic many-body wave functions and heavy-ion collisions simulation
Seminar given at FIAS, Frankfurt Institute for Advanced Studies
March 2011, Frankfurt, Germany

Correlations and fluctuations in a Glauber Monte Carlo approach
Seminar given at University of Jyvaskyla
April 2011 Jyvaskyla, Finland

Correlations and fluctuations studies in heavy-ion collisions
Talk given at the annual HPC-Europa meeting
April 2011, Technical University of Catalonia, Barcelona, Spain

Correlations and fluctuations studies in Glauber Monte Carlo approach
Talk given at the ECT* workshop on “Standard and Novel QCD Phenomena at Hadron Colliders”
June 2011, ECT, Trento, Italy*

Realistic wave functions of nuclei and their applications
Seminar given at the PINTS meeting
June 2011, LISC/FBK, Trento, Italy

One- and two-body momentum distributions (and universality of NN short-range correlations)
Talk given at the ECT* workshop “Short-range correlations in nuclei and hard QCD phenomena”
November 2011, ECT, Trento, Italy*

Realistic wave functions of nuclei and their applications (universality of NN short-range correlations)
Seminar given at the University of Pavia

November 2011, Pavia, Italy

Daniele Binosi

The dynamical equation of the effective gluon mass
Talk given at the ECT* Workshop on “QCD Green’s Functions, Confinement and Phenomenology”
September 2011, Trento, Italy

Schwinger-Dyson equations: from theory to applications - Part 1: Theory
Invited talk given at the workshop “Strongly Coupled QCD: The Confinement Problem”
November 2011, Rio de Janeiro, Brazil

Dynamical gluon mass generation and the IR sector of QCD
Invited talk given at the Federal University of ABC
December 2011, Sao Paulo, Brazil

Alexis Diaz-Torres

Quantum decoherence in low-energy nuclear reaction dynamics?
Invited seminar at the Max Planck Institute for the Physics of Complex Systems
January 2011, Dresden, Germany

Reaction dynamics of weakly-bound nuclei at near-barrier energies
Invited seminar at a number of places:

University of Sao Paolo
June 2011, Brazil

IPHC Strasbourg
March 2011, France

IPN Orsay
March 2011, France

CENBG Bordeaux

March 2011, France

ATOMKI Debrecen

February 2011, Hungary

Decoherence in low-energy nuclear collision dynamics?

Invited talk given at "Brazilian Physics Meeting 2011: Integration of Physics in Latin America"

June 2011, Foz do Iguacu, Brazil

Quantum decoherence in low-energy nuclear reaction dynamics?

Invited talk given at the ECT* Workshop on "Speakable in Quantum Mechanics: Atomic, Nuclear and Subnuclear Physics Tests"

August 2011,Trento, Italy

Reaction dynamics of weakly-bound nuclei at near-barrier energies

Invited talk given at the series "Selected Topics in Nuclear and Atomic Physics"

September 2011, Fiera di Primiero, Italy

Lorenzo Fortunato

A new method to solve the many - body Schrödinger equation

Talk given at the ECT* Workshop on "Effective Theories and the Nuclear Many-Body Problem"

March 2011, Trento, Italy

Introduzione ai modelli collettivi e algebrici del nucleo

Invited lecture at the University of Camerino, Italy

May 2011, Camerino, Italy

Recent developments in quantum shape phase transitions

Invited talk at the University of Padova, Italy

June 2011, Padova, Italy

Stefano Melis

New extraction of the Sivers distribution functions

Talk given at the XIX International Workshop on Deep-Inelastic Scattering and Related Subjects, DIS2011

April 2011, JLAB, Newport News, Virginia (USA)

Phenomenology of TMDs

Invited talk given at PINAN 2011

September 2011, Marrakesh, Morocco

Extraction of PDFs with global fits

Talk given at Transversity 2011

September 2011, Veli Losinj, Croatia

Laura Muñoz Muñoz

Chaos in hadrons

Talk given at the “Rutherford Centennial Conference on Nuclear Physics”

August 2011, Manchester, UK

Caos en hadrones

Talk given at “XXXIII Reunión Bienal de la Real Sociedad Española de Física ”

September 2011, Santander, Spain

Achim Richter

Playing billiards with microwaves - quantum manifestations of classical chaos

Physics Colloquium at the University of Milano, Italy

May 17, 2011

Simulating graphene with a microwave photonic crystal

Invited talk presented at the 5th International Workshop on “Quantum chaos and localization phenomena”

May 20-22, 2011, Warsaw, Poland

Exceptional points in microwave billiards: eigenvalues and eigenfunctions

Invited talk presented at the International Seminar and Workshop on Quantum Physics with Non-Hermitian Operators at the Max-Planck-Institut für Physik Komplexer Systeme (MPIPKS) in Dresden, Germany
June 15-26, 2011

Playing billiards with microwaves - quantum manifestations of classical chaos
Physics Colloquium at the George Washington University, Washington DC, U.S.A.
October 20, 2011

Playing billiards with microwaves - quantum manifestations of classical chaos
Physics Colloquium at the National University of Singapore
November 23, 2011

Transnational access to ECT*
Final Report presented at the HadronPhysics2 Collaboration Committee Meeting, Frascati, Italy
December 02-03, 2011

Dipole response in ^{208}Pb: Polarizability, fine structure and level density
Seminar at The Henryk Niewodniczański Institute of Nuclear Physics of the Polish Academy of Sciences, Krakow, Poland
December 07, 2011

Playing billiards with microwaves - quantum manifestations of classical chaos
Physic Colloquium at the Henryk Niewodniczański Institute of Nuclear Physics of the Polish Academy of Sciences, Krakow, Poland
December 08, 2011

Luigi Scorzato

Renormalization constants of fermionic operators in lattice QCD with Nf=4 dynamical Wilson quarks
Presentation at the XXIst International Europhysics Conference on High Energy Physics
July 2011, Grenoble, Rhône Alpes, France

AuroraScience

Talk given at the Workshop "Computational Science in Trento"

November 2011, Trento, Italy

Dionysis Triantafyllopoulos

Forward and Mueller-Navelet jets

Talk given at “Excited QCD 2011”

February 2011, Les Houches, France

NLO BFKL with saturation boundary: pathologies and solutions

Talk given at “Standard and novel QCD phenomena at hadron colliders”

June 2011, Trento, Italy

Parton saturation in Quantum Chromodynamics

Seminar given at University of Cyprus

June 2011, Nicosia, Cyprus

Higher-point correlations in the Color Glass Condensate

Seminar given at IPhT, Saclay

December 2011, Paris, France

4.4 Lectures and Seminars at ECT*

4.4.1 Lectures

An Introduction to Neutrino Physics
Lecturer: Baha Balantekin (University of Wisconsin, USA)

Determination of the Neutrino Mass
Lecturer: Ettore Fiorini (University of Milano Bicocca, Italy)

Leptonic CP Violation: from Earth-based Experiments to Astrophysics and Cosmology
Lecturer: Cristina Volpe (IPN, Orsay, France)

Neutrino Astronomy
Lecturer: Marek Kowalski (Universität Bonn, Germany)

Neutrino Properties
Lecturer José Bernabeu (Universitat de Valencia, Spain)

Cosmological Neutrinos
Lecturer: Yvonne Wong (RWTH Aachen, Germany)

Weak Decays of Nuclei (β, ββ2v, ββ0v)
Lecturer: Alfredo Poves (Universidad Autonoma de Madrid, Spain)

Double Beta Decay
Lecturer: Petr Vogel (Caltech Pasadena, USA)

Neutrinos and Dark Matter as Probes of New Physics
Lecturer: Manfred Lindner (MPI Heidelberg, Germany)

Neutrino-Nucleus and Neutrino-Electron Scattering Cross Sections
Lecturer: Carlos Pena Garay (Universitat de Valencia, Spain)

Neutron-rich Matter, Neutrinos and Effective Field Theory
Lecturer: Achim Schwenk (TU Darmstadt, Germany)

Neutrinos in Supernovae and Cosmology
Lecturer: George Fuller (University of California, San Diego, USA)

Solar Neutrinos and Neutrino Oscillations
Lecturer: Kai Zuber (TU Dresden, Germany)

Neutrino Masses, Double Beta Decay, and Nuclear Structure
Lecturer: Amand Faessler (University of Tübingen, Germany)

Neutrino Detection with BOREXINO and Prospects of LENA
Lecturer: Lothar Oberauer (TU München, Germany)

Reactor Neutrinos
Lecturer: Thierry Lasserre (CEA Saclay, France)

Theory of Neutrino Oscillations and Sterile Neutrinos
Lecturer: Carlo Giunti (INFN Torino, Italy)

Neutrino Physics with Low Temperature Microcalorimeters
Lecturer: Saskia Kraft-Bermuth (Universität Giessen, Germany)

Direct Neutrino Mass Searches
Lecturer: Christian Weinheimer (University of Münster, Germany)

4.4.2 Seminars

Ghost-gluon coupling power corrections and $\Lambda_{\overline{MS}}$ from twisted-mass lattice QCD at $N_f=2$
January 13
Mario Gravina

Approaching the sign problem in lattice QCD using complex Langevin dynamics
February 09
Marco Cristoforetti

Thermalization in isolated quantum many-body systems
February 10
Armando Relaño

Some relativistic aspects of nuclear dynamics in electrodisintegration of nuclei
May 12
V.D. Efros

Nonlinear dynamics of the hadronic matter at high-energy
May 19
Giovanni Chirilli

Investigation of the EMC effect and hadronization mechanisms by semiinclusive deep inelastic scattering off nuclei
May 26
Claudio Ciofi degli Atti

Composite weak bosons and the LHC
July 12
Harald Fritzsch

The second act of hydro: the sounds of the "Little Bang"
September 28
Edward Shuryak

Transverse Momentum Dependent (TMD) distribution functions
November 17
Stefano Melis

Properties of exotic hadrons
December 16
Vincent Mathieu

QCD measurements and the role of multiple parton interactions with the CMS detector at LH
December 20
Livio Fano' Illic

Modeling partonic correlations with double-parton interactions in proton-deuteron collisions
December 20
Massimiliano Alvioli

5 Quantum Information Processing at ECT*

As explained in detail in previous reports, ECT* has been involved in the field of Quantum Information Processing (QIP) over the last decade. Specifically, the QIP field has been a so-called Proactive Initiative of the Future and Emerging Technologies Unit in DG Information Society and Media of the European Commission in the Framework Programme FP5 (1999-2002), FP6 (2003-2006) and FP7 (2007-2013), and ECT* researchers have been constantly represented in QIP consortia.

This continues to be true at present, since during 2011 Senior Research Associate Daniele Binosi actively worked on the following projects:

- The Coordination Action QUIE2T (Quantum Information Entanglement-Enabled Technologies) in which, in addition to contributing to Work-Package 2 and 3 (Dissemination activities), he acts also as QUIE2T Executive Secretary (the funding for the ECT* node is 89k€).
- The ERA-NET initiative CHIST-ERA in which he acts as the leader of Work-Package 3 (Definition of Countours and Joint Call Topics)

6 Aurora Science

AuroraScience is a project partially managed by ECT* and has been already outlined in the ECT* section of this document. Here we provide more details. AuroraScience is a research project at the crossroad of Computational Science and Computer Architecture. It builds on the combined know-how collectively available to the members of the collaboration on:

- design, development and operation of application-driven high-performance computer systems (e.g., the series of APE machines, developed by INFN).
- algorithm development and physics analysis in computational areas of physics (Lattice Gauge Theory, Computational Fluid-Dynamics, Molecular Dynamics), Quantitative Biology (Protein Folding), Bioinformatics (Gene Sequencing) and Medical Physics.

AuroraScience is thus a scientific project based on leading-edge computational systems and driven by specific competences in the useful operation of these systems. The project started formally on July 31st, 2009. The first phase ended on July 31st, 2011. Application for the second phase was submitted to INFN and PAT on April 28th, 2011. We are now in an intermediate phase looking forward to a decision on the prosecution of the project. The accomplishment of the project in 2011 are summarized here:

1. Development of the Aurora computing system. A prototype AURORA system has been procured and installed. It implements the special communication network developed by the AuroraScience collaboration. Currently, the system has a peak performance of almost 15TFlops and is producing results for the AuroraScience collaboration and other scientific groups. A high performance parallel file system has also been installed and tuned, and a larger storage system has been aqcuired.

2. Lattice QCD. Three codes of LQCD have been ported and optimized for the AURORA architecture. New algorithms have been developed and tested. The most performing algorithm employs the dedicated AuroraScience communication network. Lattice QCD calculations performed on Aurora have produced a number of publications and others are in preparation.

3. Nuclear Physics. The AURORA system has also been used for studies in nuclear physics by employing the algorithms and codes developed in 2010 both for so called

Auxiliary Field Diffusion Monte Carlo and for few-body calculations. hese computations are now producing results for a number of publications.

4. Protein Folding. The code based on the so called Dominant Reaction Pathway (DRP) method is now running on the AURORA system and has produced already results for a number of publications.

5. Bioinformatics. A new algorithm for Gene Sequencing, suitable for the data produced by the new generation sequencing machine, has been developed and tested.

6. Radiotherapy. The basic libraries relevant for Monte Carlo simulations of radiotherapy have been tested on the AURORA system.

7. Parallel Algorithms. The group at the Department of Electronics and Informatics of the University of Padova has been leading activities in the development of new parallel algorithms for gene sequencing and on the extension of the AuroraScience custom network to general patterns of communication.

More details about the AuroraScience project can be found in the report of the first phase that is now available ont the web: www.ectstar.eu -> AuroraScience -> "Report on the first phase of the AuroraScience project".

7 ECT* Computing Facilities

Available computing resources

HARDWARE	
Servers:	1 Virtual Server DELL PowerEdge R900
Superc omputation:	1 Supercomputer AURORA compounded by 106 Node Card (NC): Each AURORA NC provides two Intel Xeon (Nehalem or Westemere) at ~ 3GHz for a peak performance of 92/150 GFlops/NC. Each processor has three banks of ECC-enabled DDR3 memory running at 1333 MHz (6 or 12 GB/NC). The NC ere interconnected by an APE-like interconnection network based on FPGA hardware. The calculation power reached in 2011 was 15 TFlops
19 PCs for staff and local research:	Workstation DELL Precision T1500 Workstation DELL Precision 390 Workstation DELL Optiplex GX620 Workstation DELL Optiplex 755 Workstation DELL Optiplex SX270 Apple iMac 27”
35 PCs for workshops and schools:	Workstation DELL Precision T1500 Workstation DELL Optiplex GX280 Workstation DELL Optiplex GX620 Workstation DELL Optiplex 755
SOFTWARE	
License servers:	1 Mathematica network server [3 concurrent users] 1 Mathematica network server [7 concurrent users]