ECT*

Annual Report 2010

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

ECT*

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 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

With 782 visiting scientists in 2010 – as compared with 648 in 2009 – from 37 countries of the world spending from a week up to several months at the Centre, ECT* has maintained and even increased its high visibility and important coordinating function in the European and international scientific community. The distribution of visitors in 2010 at the ECT* over the various countries is shown in the graph on page 6 of this Annual Report. It is interesting to note that after Germany with the highest number of visitors (ever since the existence of the Centre), Italy with the second highest number has now overtaken the USA followed by Japan, the UK, France and the Netherlands. It is gratifying to note, however, that the continuously increasing promotion of European research efforts is preventing isolation of smaller research groups, particularly in the peripheral and less-favored regions of the Community, who turn up more frequently at the ECT* than in former years and hence put themselves in a strong worldwide competitive environment.

In 2010 ECT* has held

- 18 Workshops and Collaboration Meetings, like in the year before, on topical problems at the forefront of new developments in nuclear and hadronic physics from the lowest to the highest energies – three Workshops alone were devoted to LHC physics, three to interdisciplinary topics in atomic and condensed matter physics and one Collaboration Meeting on the application on theoretical physics methods in biology
- a Doctoral Training Programme on "Nuclear structure and astrophysics with radioactive ion beams" dealing with physics investigated at the major heavy ion accelerator facilities in Europe and elsewhere – the 9 weeks programme was attended by 18 full time and 7 part-time graduate students (10 experimentalists and 8 theoretical physicists)
- a School on High Performance Computing (Aurora School) and its application in various scientific fields including nuclear, hadronic and particle physics as well as

statistical physics and biophysics – about 30 students attended the 2 weeks programme

and has supported

- fundamental research on low energy nuclear theory, effective field theory, the pion-nucleon interaction and the nuclear force, non-perturbative QCD, the colour glass condensate and the quark gluon plasma done by an in-house group of Postdoctoral Fellows and Senior Research Associates having interacted closely scientifically with the Director of the Centre and visitors and collaborating physicists elsewhere.

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 increased scientific activity in 2010 – especially through the realization of the HPC project AURORA - has naturally resulted also in an increase of the operating budget of ECT* in 2010. We are therefore very grateful for the local support from the FBK/PAT, for the considerable third party funds from various European funding agencies and research centres in Belgium, 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/Hadron Physics 2 project, in which ECT* has an important role as a Trans-National Access (TNA) facility.

Finally, it is a great pleasure for me to thank the members of the Scientific Board, the coordinators of the Doctoral Training Programme and the Aurora School, the scientific and administrative staff for their strong and dedicated contributions for the scientific well-being of the Centre and its further development. This is also the place to thank Administrative Assistant Cristina Costa who has been responsible for the Workshop programme from 1993 – the year of the foundation of ECT* - until her retirement at the end of 2010 for her strong commitment and dedication to her work.
As its predecessors the Annual Report of 2010 is also available on the ECT* web site (www.ect.it).

Achim Richter

Trento, May 9, 2011

Achim Richter
*Director of ECT**

Contents

2 ECT* Scientific Board, Staff and Researchers

2.1 ECT* Scientific Board and Director

Mauro Anselmino (from September 2008)	University of Torino, Italy
Baha Balantekin (from January 2010)	University of Winsconsin, Madison, USA
Bengt Friman (until June 2010)	GSI, Darmstadt, Germany
Jens Jørgen Gaardhøje (from January 2010)	Niels Bohr Institute, Copenhagen, Denmark
Pawel Haensel (from January 2008)	N. Copernicus Astronomical Center, Poland
Simon Hands (from January 2008)	Swansea University, UK
Kris Heyde (from January 2009)	University of Gent, Belgium
Jean-Yves Ollitrault (from January 2009)	CEA Saclay, France
Günther Rosner (from January 2009)	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* Staff

Ines Campo	Technical Programme Co-ordinator
Cristina Costa	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	Driver and Maintenance Support Manager
Gian Maria Ziglio (part time)	Web Manager

2.3 Resident Postdoctoral Researchers

- **ECT* Postdocs**

Massimiliano Alvioli, Italy (from September 2010)
Cesar Fernandez-Ramirez, Spain
Lorenzo Fortunato, Italy
Bingwei Long, China (until October 2010)
Stefano Melis, Italy (from October 2010)
Laura Muñoz, Spain (from October 2010)
Dionysis Triantafyllopoulos, Greece (from October 2009)

- **Quantum Computing Group (post-docs)**

Daniele Binosi, Italy
Tommaso Calarco, Italy (from November 2010 until December 2010)

- **AuroraScience**

Marco Cristoforetti, Italy (from April 2010)
Fabio Pozzati, Italy (from May 2010)
Laura Sartori, Italy (from April 2010 until September 2010)
Luigi Scorzato, Italy (from April 2009)

2.4 Visitors in 2010

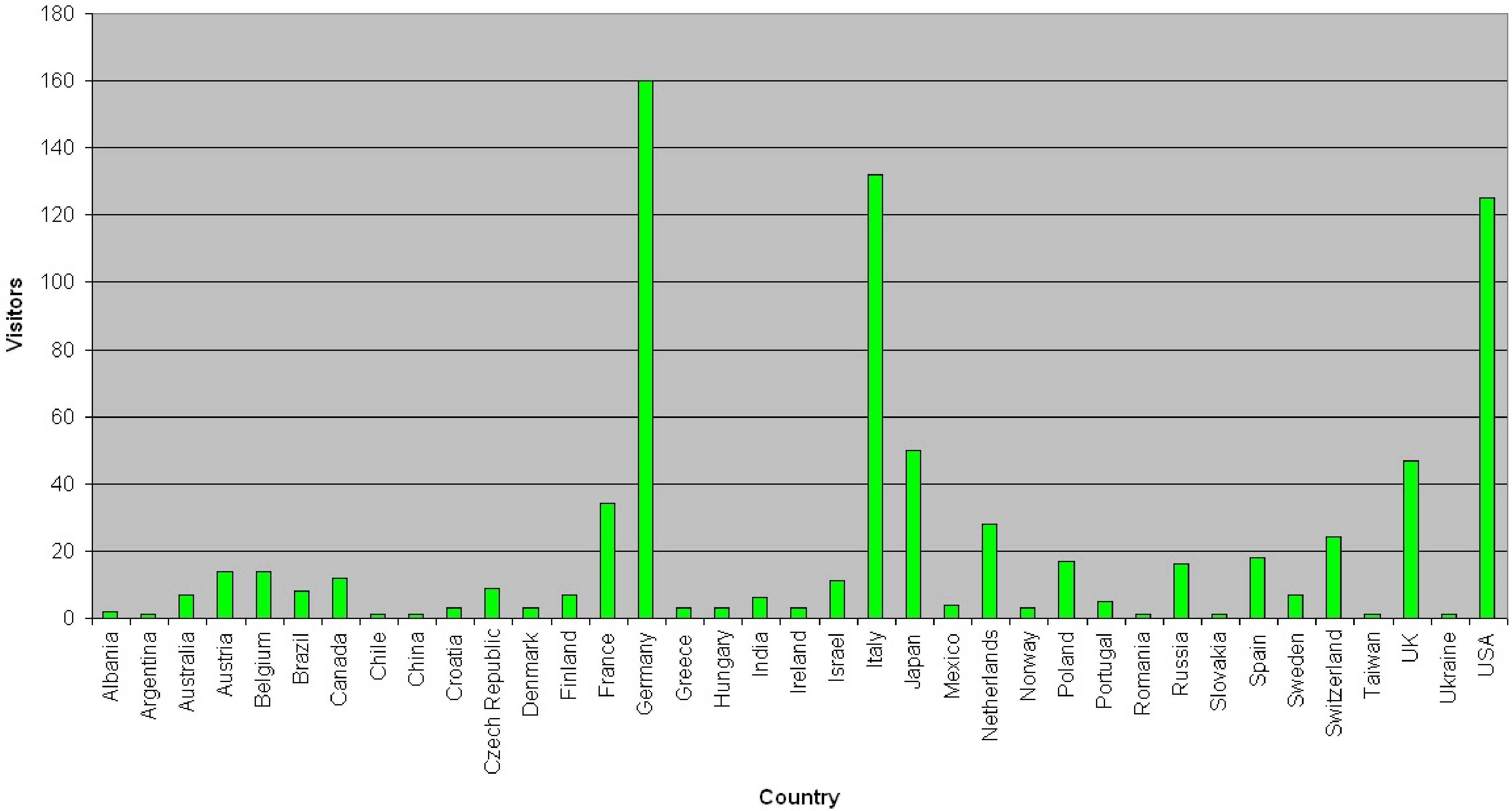
This list includes Visiting Scientists (VS) who typically spent up to several weeks at the Centre, as well as participants and lecturers of the Doctoral Training Programme (TP) and of the Aurora School (AS).

Costantia Alexandrou (26/09 - 02/10)	Cyprus Institute, Greece (AS)
Roberto Alfieri (27/09 - 30/09)	University of Parma, Italy (AS)
Maria Luisa Aliotta (23/04 – 27/04)	University of Edinburgh, UK (TP)
Paolo Armani (13/09 - 05/10)	University of Trento, Italy (AS)
Tom Aumann (02/05 – 05/05)	Universitè Libre de Bruxelles, Belgium (TP)
Nir Barnea (19/09 - 02/10)	The Hebrew University, Israel (AS)
Benjamin Bally (10/04 - 13/06)	CNRS/IN2P3, University of Bordeaux, France (TP)
Daniel Baye (27/04 – 01/05)	Universitè Libre de Bruxelles, Belgium (TP)
Andrea Beraudo (26 - 30/04)	INFN Torino, Italy (VS)
Jean-Paul Blaizot (24/04 - 01/05)	CEA Saclay SPHT, France (VS)
Piefrancesco Bortignon (19/04 – 22/04)	INFN, Milano, Italy (TP)
Michele Brambilla (20 - 24/09)	University of Parma, Italy (AS)
Inva Buzi (19/09 - 02/10)	University of Tirana, Albania (AS)
Arianna Carbone (19/09 - 01/10)	University of Barcelona, Spain (AS)
Nuno Cardoso (19/09 - 02/10)	Istituto Superior Tecnico, Portugal (AS)
Dimitros Christras (13/09 – 05/10)	University of Cyprus, Cyprus (AS)
Gennaro Cortese (13/09 – 05/10)	University of Calabria / INFN Cosenza, Italy (AS)
Mattia Dalla Brida (20/09 - 01/10)	University of Trento, Italy (AS)
Shinjinee Das Gupta (14 - 16/07)	University of Camerino, Italy (VS)
Andrei Derevianko (01 - 29/09)	University of Nevada, USA (VS)
Paloma Diaz Fernandez (02 - 08/05)	University Santiago de Compostela, Spain (TP)
Roland Diehl (10/06 – 12/06)	MPE, Garching, Germany (TP)
Francesco Di Renzo (20 - 27/09)	University of Parma, Italy (AS)
Thomas Druet (10 - 24/04)	Université Libre de Bruxelles, Belgium (TP)
Jytte Elseviers (23/05 - 02/06)	Catholic University Leuven, Belgium (TP)
Maurits Evers (10/04 - 13/06)	The Australian National University, Canberra, Australia (TP)
Hans Feldmeier (11/04 – 28/04)	GSI, Darmstadt, Germany (TP)
Juan Manuel Figueira (11/04 - 13/06)	Tandar Laboratory, National Atomic Energy Commission, Buenos Aires, Argentina (TP)
Victor Flambaum (10/09 - 09/10)	University of New South Wales, Australia (VS)

Jacob Finkenrath (19/09 - 02/10)	Bergische Universitaet, Wuppertal, Germany (AS)
Avraham Gal (12/09 - 11/10)	The Hebrew University, Jerusalem, Israel (VS)
Elena Garcia Ramos (19/09 - 02/10)	DESY Zeuthen, Germany (AS)
Andrea Gottardo (03 - 07/05)	Laboratorio Nazionale Legnaro, Padova, Italy (TP)
Marco Grossi (08 - 10/04)	INFN, Parma, Italy (VS)
Matthias Hackstein (11/04 - 12/06)	Universitaet Köln, Germany (TP)
Masayasu Hasegawa (19/09 - 02/10)	Kanazawa University, Japan (AS)
Alexey Illarionov (24/09 - 01/10)	University of Trento, Italy (AS)
Ron Johnson (25/04 – 01/05)	University of Surrey, UK (TP)
Konstantin Kanishev (19/09 - 02/10)	Novosibirsk State University, Russia (AS)
Savely Karshenboim (26 - 29/09)	MPQ Garching, Germany (VS)
Yeunjin Kim (15/05 - 08/06)	University of Chicago, USA (TP)
Istvan Kuti (10/04 - 13/06)	ATOMKI, Hungary (TP)
Winfried Leidemann (19/09 - 02/10)	University of Trento, Italy (AS)
Vadim Lensky (16 - 30/10)	University of Manchester, UK (VS)
Diego Lonardoni (20 - 28/09)	University of Trento, Italy (AS)
Cristina Losa (19/09 - 01/10)	Niels Bohr Institute, Denmark (AS)
Alessandro Lovato (20/09 - 01/10)	SISSA-ISAS, Italy (AS)
Duc H. Luong (10/04 - 13/06)	The Australian National University, Canberra, Australia (TP)
Tomislav Marketin (11/04 - 13/06)	University of Zagreb, Croatia (TP)
Gabriel Martinez Pinedo (16/05 – 21/05)	GSI, Darmstadt, Germany (TP)
Rhiannon Meharchand (12/04 - 14/06)	NSCL/MSU, USA (TP)
Joel Mendoz-Temis (10/04 - 13/06)	GSI, Darmstadt, Germany (TP)
Bradley Meyer (13/05 – 23/05)	Clemton University, USA (TP)
Raffaele Millo (20/09 - 01/10)	University of Trento, Italy (AS)
Kohtaroh Miura (19/09 - 02/10)	LNF, INFN, Italy (AS)
Laura Muñoz (10 - 21/07)	University of Madrid, Spain (VS)
M. Ali Najafi (10/04 - 13/06)	KVI, Groningen, The Netherlands (TP)
Thomas Neff (06/06 – 09/06)	GSI, Darmstadt, Germany (TP)
Nir Nevo-Dinur (19/09 - 02/10)	Hebrew University, Israel (AS)
Ivan Ursin Nikolaisen (19/09 - 02/10)	University of Oslo, Norway (AS)
Kosuke Nomura (10/04 - 13/06)	University of Tokio, Japan (TP)
Filomena Nunes (06/04 – 13/04)	NSCL, Michigan State University, USA (TP)
Bruno Olaizola (10/04 - 13/06)	Universidad Complutense de Madrid, Spain (TP)
Francesco Pederiva (19/09 - 02/10)	University of Trento, Italy (AS)
Andrea Pelissetto (19/09 - 02/10)	University La Sapienza, Roma, Italy (AS)

Francisco Perez-Bernal (05 - 11/12)	Universidad de Huelva, Spain (VS)
Axel Perez-Obiol (19/9 - 02/10)	University of Barcelona, Spain (AS)
Takaharu Otsuka (05/05 – 07/05)	University of Tokio, Japan (TP)
Edna Carolina Pinilla (10 - 24/04)	Université Libre de Bruxelles, Belgium (TP)
Marcello Pivanti (20 - 24/09)	University of Ferrara, Italy (AS)
Mauricio Porto Pato (09/07 - 07/08)	Universidade de São Paulo, Brasil (VS)
Andrea Quadri (06/12)	INFN Milano, Italy (VS)
Paola Rangel Pestana Allegro (10/04 - 12/06)	Universidade de São Paulo, Brasil (TP)
Ernst Rehm (29/05 – 05/06)	Argonne National Laboratory, USA (TP)
Georges Ripka (01/04 - 30/06)	CEA Saclay SPHT, France (VS)
Alessandro Roggero (20/09 - 01/10)	University of Trento, Italy (AS)
Valentina Rolando (19/09 - 01/10)	University of Ferrara, Italy (AS)
Alessandro Saltarelli (14 - 15/07)	University of Camerino, Italy (VS)
Hendrik Schatz (19/05 – 26/05)	MSU, USA (TP)
David Scheffler (19/09 - 02/10)	TU Darmstadt, Germany (AS)
Fabio Schifano (19 - 25/09)	University of Ferrara, Italy (AS)
Kevin Schmidt (19/09 - 02/10)	Arizona State University, USA (AS)
Tatjana Skrbic (24/09 - 01/10)	University of Trento, Italy (AS)
Konrad Steiger (11/04 - 08/05)	TU Muenchen, Germany (TP)
Andrè Sternbeck (08 - 09/06)	Regensburg Universitaet, Germany (VS)
Lukas Theussl (07 - 10/09)	RCQI, Bratislava, Slovakia (VS)
Jeff Tostevin (25/04 – 01/05)	University of Surrey, UK (TP)
Stephan Typel (02/06 – 06/06)	GSI, Darmstadt, Germany (TP)
Naofumi Tsunoda (10/04 - 13/06)	University of Tokio, Japan (TP)
Piet van Isacker (24/05 – 29/05)	GANIL, France (TP)
Giorgios Vernardos (10/04 - 13/06)	Université Libre de Bruxelles, Belgium (TP)
Paolo Verrocchio (19/09 - 02/10)	University of Trento, Italy (AS)
Andrea Vitturi (08/06 – 12/06)	INFN, Padova, Italy (TP)
Vasily Volkov (10/04 - 13/06)	TU Darmstadt/GSI, Germany (TP)
Dennis Weber (11/04 - 12/06)	GSI, Darmstadt, Germany (TP)
Kyoko Yoneyama (19/09 - 02/10)	Bergische Universitaet, Wuppertal, Germany (AS)
Remco Zegers (23/05 – 29/05)	MSU, USA (TP)
Rudina Zeqirllari (19/09 - 02/10)	University of Tirana, Albania (AS)
Zhenxiang Zu (10/04 - 15/05)	AlbaNova University Center, Royal Institute of Technology Sweden (TP)

2.5 Visitors at ECT* per Country in 2010



3 Scientific Projects Run in 2010

3.1 Summary

Altogether 20 scientific projects have been run in 2010: 17 workshops, one collaboration meeting, a Doctoral Training Programme and an AuroraSchool on High Performance Computating. 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. Francesco Pederiva summarized the aim and success of the first Aurora School on high performance computing and its application in science.

3.2 Workshops, Collaboration Meetings and Schools (Calendar)

Jan 04-08	**Diffractive and Electromagnetic Processes at the LHC** R. Schicker *(University of Heidelberg)* L. Jenkovszky *(BITP, Kiev)* M. Machado *(Universidade Federal do Pampa, Bage')* R. Orava *(Helsinki Inst. of Physics)* K. Piotrzkowski *(Louvain-la-Neuve)* A. Szczurek *(Inst. Nucl. Physics, Cracow)*
Feb 22-26	**Many-Body Open Quantum Systems: From Atomic Nuclei to Quantum Dots** J. Vaagen *(University of Bergen)* W. Schleich *(University of Ulm)*
Apr 06-10	**Reactions and Nucleon Properties in Rare Isotopes** W. Dickhoff *(Washington University in St. Louis)* T. Aumann *(GSI, Darmstadt)* C. Barbieri *(RIKEN)* F. Nunes *(NSCL)* J. Piekarewicz *(Florida State University)*

Apr 12-14	**New Frontiers in Graphene Physics** I. Carusotto *(BEC - CNR - INO)* B. Trauzettel *(University of Wuerzburg)* S. Hands *(Swansea University)* A. Richter *(TU Darmstadt, ECT*)* S. Stringari *(University of Trento)*
Apr 12-June 11	**Nuclear Structure and Nuclear Astrophysics with Radioactive Ion Beams** **(Doctoral Training Programme)** H. Feldmeier *(GSI, Darmstadt)* H. Schatz *(Michigan State University)* J. Tostevin *(University of Surrey)*
Apr 26-30	**Decoherence in Quantum Dynamical Systems** A. Diaz-Torres *(University of Surrey)* I. Burghardt *(École Normale Supérieure, Paris)* J. Tostevin *(University of Surrey)* C. Martens *(University of California)*
Jun 21-25	**TMD 2010 - Workshop on Transverse Momentum Distributions** A. Bacchetta *(University of Pavia)* F. Yuan *(Lawrence Berkeley National Laboratory)* C. Aidala *(Los Alamos National Laboratory)* M. Contalbrigo *(INFN - Ferrara)*
Jun 28-30	**2nd Collaboration Meeting on the Applications of Theoretical Physics Methods in Biology** P. Faccioli *(University of Trento)*
Jul 05-10	**Confining Flux Tubes and Strings** O. Aharony *(Weizmann Institute)* B. Bringoltz *(University of Washington)* M. Teper *(Oxford University)*

Jul 19-23	**Chiral Symmetry and Confinement in Cold, Dense Quark Matter** L. Glozman *(Institute for Physics, University of Graz)* K. Fukushima (*University of Kyoto)* L. McLerran *(BNL)* R. Pisarski *(BNL)*
Aug 02-06	**QCD from the Bound States' Perspective** B. El - Bennich *(UNICSUL São Paulo)* C. D. Roberts *(ANL)* P. H. Hägler *(TU München)* M. Pennington *(Durham University)*
Sep 13-17	**Electromagnetic Probes of Strongly Interacting Matter: Status and Future of Low-Mass Lepton-Pair Spectroscopy** T. Galatyuk *(Goethe University)* J. Kapusta *(University of Minnesota)* R. Rapp *(Texas A&M University)* J. Stroth *(Goethe University)*
Sep 20-Oct 01	**Aurora School 2010** F. Pederiva *(University of Trento)* F. Di Renzo *(University of Parma)* W. Leidemann *(University of Trento)* L. Scorzato (ECT*) P. Verrocchio *(University of Trento)*
Sep 27-Oct 01	**QCD at the LHC** J. Blümlein *(DESY, Hamburg)* H. Fritzsch *(LMU, Munich)* M. Mangano *(CERN, Geneva)*

Oct 04-08	**Strangeness in Nuclei**
	T. Bressani *(University of Torino and INFN)*
	C. Curceanu *(LNF, INFN)*
	P. Kienle *(Technische Universität München)*
	T. Yamazaki *(University of Tokyo / RIKEN)*
	J. Zmeskal *(SMI Vienna)*
Oct 11-15	**Hard Meson and Photon Production**
	N. D'Hose *(CEA-Saclay)*
	P. Kroll *(University of Wuppertal)*
	R. Kaiser *(University of Glasgow)*
Oct 25-30	**The Limits of Existence of Light Nuclei**
	C. Bertulani *(Texas A&M University)*
	T. Aumann *(GSI Darmstadt)*
	A. Bonaccorso (*University of Pisa)*
	U. van Kolck *(University of Arizona)*
Nov 08-12	**Precision Tests of the Standard Model: from Atomic Parity Violation to Parity-Violating Lepton Scattering**
	W.T.H. van Oers *(Manitoba / TRIUMF)*
	R.D. Carlini *(Jlab)*
	J.Erler *(UNAM)*
	K. Kumar *(University of Massachusetts)*
	F. Maas *(University of Mainz)*
Nov 15-19	**Searches for CP-and T-Violation in Atoms and Nuclei**
	L. Willmann *(University of Groningen)*
	P. Butler *(Univ. Liverpool, UK)*
	J. Martin *(Univ. Winnipeg, US)*
Nov 29-Dec 03	**Hadron-Hadron and Cosmic-Rays Collisions at multi-TeV Energies**
	D. d'Enterria *(CERN, and LNS, MIT)*
	R. Engel *(Karlsruhe Inst. of Technology)*
	T. Sjostrand *(Lund University)*

3.3 Reports on all Workshops

3.3.1 DIFFRACTIVE AND ELECTROMAGNETIC PROCESSES AT THE LHC

DATE: January 4 - 8, 2010

ORGANIZERS:

R. Schicker *(Phys. Inst., University of Heidelberg, Germany)*
L. Jenkovszky *(BITP, Kiev, Ukraine)*
M. Machado *(Universidade Federal do Pampa, Brazil)*
R. Orava *(Helsinki Inst. of Physics, Finland)*
K. Piotrzkowski *(U Louvain, Belgium and CERN, Switzerland)*
A. Szczurek *(Inst. Nucl. Physics, Cracow, Poland)*

NUMBER OF PARTICIPANTS: 45

MAIN TOPICS:

- Soft diffraction
- Hard diffraction
- Electromagnetic processes
- Instrumentation/Monte Carlo Tools

SPEAKERS:

Mike Albrow *(Fermilab)*
Alessia Bruni *(Bologna)*
Armen Bunyatyan *(DESY)*
Anna Cisek *(Cracow)*
Frank Close *(Oxford)*
Jean-Rene Cudell *(Liege)*
Carlo Ewerz *(Heidelberg)*
Laura Fabbri *(Bologna)*
Salvatore Fazio *(Calabria)*
Michele Gallinaro *(Lisbon)*
Krzysztof Golec-Biernat *(Cracow)*
Jacob Groth-Jensen *(Lund)*
Wlodek Guryn *(BNL)*
Lucian Harland-Lang *(Cambridge)*
Jonathan Hollar *(Louvain)*

Laszlo Jenkovszky *(Kiev)*
Mariola Klusek *(Cracow)*
Piotr Lebiedowicz *(Cracow)*
Emerson Luna *(Pelotas)*
Magno Machado *(Bage)*
Vladimir Magas *(Barcelona)*
Eric Malmi *(Helsinki)*
Dermot Moran *(Dublin)*
Dieter Mueller *(Bochum)*
Michael Murray *(Kansas)*
Sparsh Navin *(Birmingham)*
Kenneth Oesterberg *(Helsinki)*
Fredrik Oljemark *(Helsinki)*
Risto Orava *(Helsinki)*
Giulia Pancheri *(Frascati)*
Kornelija Passek-Kumericki *(Zagreb)*
Andrew Pilkington *(Manchester)*
Krzysztof Piotrzkowski *(Louvain)*
Martin Poghosyan *(Torino)*
Sergio Ricciarini *(Florence)*
Christophe Royon *(Saclay)*
Wolgang Schaefer *(Cracow)*
Laurent Schoeffel *(Saclay)*
Nicolas Schul *(Louvain)*
Valeriy Serbo *(Novosibirsk)*
Antoni Szczurek *(Cracow)*
Korinna Zapp *(Durham)*

SCIENTIFIC REPORT:

Aim and Purpose

The Large Hadron Collider LHC at CERN has recently begun operation and the experiments have started taking data and have shown first results. This workshop was therefore a timely opportunity to bring together the experimentalists working in the areas of diffractive and electromagnetic measurements at the LHC in order to have discussions with the theorists working on different aspects of diffractive/electromagnetic physics at high energies. In this workshop, the lessons learned from the diffractive and electromagnetic physics programs at the SPS, HERA, TEVATRON and RHIC accelerators have been discussed in order to get ready for diffractive and electromagnetic measurements at the LHC. In particular, the aim of this workshop was to present and discuss issues which are of common interest for all the LHC experiments for developing a successful diffractive/electromagnetic physics program.

The following topics have been selected for presentations:

- Soft diffraction: Review of existing data, discussion of planned measurements at the LHC
- Hard diffraction: Review of existing data, discussion of planned measurements at the LHC
- Electromagnetic processes: Review of existing data, discussion of $\gamma\gamma$-induced reactions at the LHC, prospects of DVCS measurements in the time-like regime at the LHC
- Instrumentation/Monte Carlo Tools: Plans on very forward proton tagging in CMS (HPS) and ATLAS (AFP), status of event generators for diffractive physics at the LHC (Pythia, Sherpa)

Results and Highlights

The main outcome of this workshop can be summarized in the following topical list:

- Review talks from the HERA, TEVATRON and RHIC programs (A. Bruni, L. Schoeffel, M. Gallinaro, W. Guryn)

- Presentations of various diffractive physics topics which are of interest for a diffractive physics program at the LHC (M. Machado, W. Schaefer, E. Luna, G. Pancheri)
- Review of leading baryon production at HERA (A. Bunyatyan) and a presentation of planned measurements at the LHC (M. Murray)
- New analysis techniques for analyzing diffractive topologies at the LHC (R. Orava, E. Malmi)
- Overview talks of the planned measurements of diffractive/electromagnetic observables at ALICE (S. Navin), at ATLAS (L. Fabbri, J. Groth-Jensen, A. Pilkington), at CMS (K. Piotrzkowski, S. Amaral, J. Hollar), at LHCb (D. Moran), at LHCf (S. Ricciarini) and at TOTEM (K. Oesterberg, F. Oljemark),
- Discussion of various diffractive reaction channels and predictions of cross sections at LHC energies (M. Poghosyan, M. Klusek, P. Lebiedowicz, A. Cisek)
- Status of event generators for diffractive physics channels (S. Navin, K. Zapp)

The highlights of this workshop are the following:

- Presentations of results on central exclusive production at the SPS (F. Close, WA102) and at the TEVATRON (M. Albrow, CDF) and a critical discussion of the formalism for central exclusive production (A. Szczurek, J.R. Cudell) as well as a discussion of the prospect for such measurements at the LHC, in particular for the chi_c (L. Harland-Lang)
- Discussion of physics topics which are of high interest for a diffractive physics program at the LHC, in particular the possible measurement of the Odderon (C. Ewerz) as well as tests for the gap survival probability and flavour symmetric diffractive PDFs by measuring the rapidity asymmetry of diffractively produced W bosons (K. Golec-Biernat)
- Presentations on the use of the LHC as γγ-collider (K. Piotrzkowski), a discussion of selected topics in lepton and photon production in p-p and Pb-Pb collisions (V. Serbo) as well as discussions of beyond standard model physics searches by looking for anomalous photon interactions (Ch. Royon) and supersymmetric pairs (N. Schul)
- An in-depth discussion of DVCS and GPDs with the ultimate goal of a feasibility study of DVCS measurements in the time-like regime at LHC energies (K. Passek-Kumericki, D. Mueller, L. Jenkovszky, S. Fazio, V. Magas)

Conclusions

This workshop at ECT* has been successful in bringing together theorists and experimentalists working in the area of diffractive and electromagnetic physics at the LHC. The multitude of physics topics which was presented and discussed illustrates the many aspects of diffractive/electromagnetic physics at high energies. We consider this workshop to be a great success since representatives of all the six LHC experiments participated and the status of all the six LHC experiments was presented. Moreover, the participation of 15 theorists reflects the interest from the theoretical community for data coming in the near future from the diffractive/electromagnetic physics program at the LHC. The participation of these theorists resulted in fruitful discussions of all the presentations. Since the LHC has barely started operation, we expect a continuation of this workshop within a time period of 1-1.5 years to review the progress in this field.

Optional

We thank Barbara Curro' Dossi for setting up the infrastructure for two remote talks by phone connection.

3.3.2 WORKSHOP ON MANY-BODY OPEN QUANTUM SYSTEMS: FROM ATOMIC NUCLEI TO QUANTUM DOTS

DATE: 22 - 26 February, 2010

ORGANIZERS:

Jan Vaagen *(Univ. of Bergen, Norway)*

Wolfgang Schleich *(Univ. of Ulm, Germany)*

NUMBER OF PARTICIPANTS: 27

MAIN TOPICS:

- Exotic structure and response in atomic and nuclear systems under extreme conditions
- Entanglement, condensates and universality
- Laser - BEC analogy
- Continuum dynamics of nuclei
- Efimov states, halos and few-body resonances
- Ab-initio no-core shell model and light nuclei
- Gamow-shell model for open quantum systems
- Coupled-cluster calculations for neutron rich nuclei

SPEAKERS:

H. Ahlers *(Hannover, Germany)*
V.S. Bagnato *(São Paulo, Brasil)*
J. Bergou *(New York, USA)*
R. Id Betan *(Oak Ridge, USA)*
A. Bonaccorso *(INFN Pisa, Italy)*
D. Fedorov *(Aarhus, Denmark)*
C. Forssén *(Gothenburg, Sweden)*
U. Guenther *(FZ-Dresden-Rossendorf, Germany)*
G. Hagen *(Oak Ridge, USA)*
I. Jex *(Prague, Czech Republic)*
R. Kaiser *(Nice, France)*
W. Leidemann *(UNITN, Italy)*
H. Lenske *(Giessen, Germany)*

N. Michel *(Jyväskylä, Finland)*
P. Navez *(Duisburg, Germany)*
N. Orr *(Caen, France)*
S. Orrigo *(Coimbra, Portugal)*
M. Ploszajczak *(Caen, France)*
A. Sadreev *(Krasnoyarsk, Russia)*
W. Schleich *(Ulm, Germany)*
M.O. Scully *(Texas A&M and Princeton, USA)*
H. Simon *(GSI Darmstadt, Germany)*
M. Štefaňák *(Prague, Czech Republic)*
M. Zaccanti *(Firenze, Italy)*
M. Zhukov *(Gothenburg, Sweden)*

SCIENTIFIC REPORT:

Aim and Purpose

Small Many-body Open Quantum Systems (MBOQS), whose properties are profoundly affected by environment, i.e. continuum of decay channels, are intensely studied in various fields of physics (nuclear physics, atomic and molecular physics, quantum optics, etc.). These different many-body systems, in spite of their specific features, have generic properties which are common to all weakly bound/unbound systems close to threshold.

The workshop started with a talk by Marlon Scully on fluctuations of a Bose-Einstein condensate (BEC) and its description in a master equation approach having much in common with the quantum theory of the laser. In follow-up talks on BEC's V.S. Bagnato discussed turbulence and fragmentation, P. Navez gap and screening effects and H. Ahlers described a planned experiment in which a BEC is created in a capsula dropped in a tower. The benefit of exploiting microgravity lies in extending evolution times of condensates in an environment unperturbed by trapping potentials. With an increasing sensitivity of interferometers, tests in fundamental physics of gravity, relativity, and theories beyond the Standard Model will thus eventually become possible. The discussion of ultracold gases has been rounded up by a presentation of M. Zaccanti on an exploration of Efimov physics in ultracold gases. The Efimov effect, Feshbach resonances, recombination reactions and other phenomena were also looked at by D. Fedorov from the standpoint of universality in few-body systems of particles with short-range interactions, where certain properties of the system do not depend on the details of the interactions.

A major fraction of the workshop on MBOQS was devoted to a thorough discussion of phenomena in nuclear structure and nuclear reactions. Talks on recent experiments studying single-neutron unbound states of light nuclei (N. Orr) and correlations in light exotic systems at relativistic velocities (H. Simon) were accompanied by talks from nuclear theorists on unbound nuclei studied by projectile fragmentation (A. Bonaccorso), on nuclear halo formation and breakup (M. Zhukov), on continuum spectroscopy of light exotic nuclei (S. Orriga), on continuum dynamics of nuclei (H. Lenske), and on the calculation of continuum reactions without continuum wave functions (W. Leidemann). These considerations of primarily nuclear reaction aspects were complemented by a consideration of particular features of nuclear structure in talks on the ab-initio no-core shell model applied to light nuclei (C. Forssén), on coupled-cluster calculations for medium-mass and neutron-rich nuclei (G. Hagen), on the interacting shell model for open quantum systems (M. Ploszajczak), on the description of weakly bound and resonant nuclei with the Gamow shell model (N. Michel), and on a calculation of alpha decay using a complex energy basis (R. Id Betan).

Finally, the workshop was rounded up with talks on a critical overview of the concept of entanglement (J. Bergou), on quantum networks and random unitary interactions (I. Jex), on quantum walks, localization and recurrences (M. Štefaňák), on cooperative scattering and disorder (R. Kaiser), on resonances induced by bound states in the continuum in a two-level nonlinear Fano-Anderson model (A. Sadreev), and on mathematical models of PT quantum mechanics and their behavior in the vicinity of spectral singularities (U. Guenther).

The workshop ended with a general talk by Wolfgang Schleich on the role of the inertial and gravitational mass in quantum mechanics. He showed that in complete agreement with classical mechanics the dynamics of any quantum mechanical wave packet in a linear gravitational potential is solely governed by the ratio of the gravitational and the inertial mass. In contrast, the spatial modulation in the corresponding energy wave function, that is the wave vector, is determined by the third root of the product of the two masses. Only in the semiclassical limit and appropriately away from the turning point is the equivalence principle retrieved, that is the velocity of the particle is governed by the ratio of the two masses. Moreover, the discrete energy spectrum of a particle constrained in its motion by a linear gravitational potential and an infinitely steep wall depends on the inertial as well as the gravitational mass with different powers.

Results and Highlights

The workshop did not only have the character of an interdisciplinary meeting but has shown a sustained growth and dynamics of the wide field of open quantum systems. The topics discussed within five days ranged from the physics of ultra cold gases and Bose-Einstein Condensation (BEC), the laser-BEC analogy, entanglement, quantum networks and random unitary interactions to the physics of nuclei. A thorough discussion of the latter clearly constituted the major part of the workshop and has shown how the growing interest into the theory of MBOQS is associated with experimental efforts in producing weakly bound/unbound nuclei close to the particle drip-lines and studying structures and reactions with those nuclei. The workshop was full of lively discussions between the participants from different communities in the wide field of small MBOQS and the success achieved in understanding generic properties of those systems since the last ECT* workshop on this topic has become evident.

3.3.3 REACTIONS AND NUCLEON PROPERTIES IN RARE ISOTOPES

DATE: April 6 - 10, 2010

ORGANIZERS:

Willem Dickhoff *(Washington U, St. Louis, USA)*
Thomas Aumann *(GSI Darmstadt, Germany)*
Carlo Barbieri *(RIKEN, Japan)*
Filomena Nunes *(NSCL/Michigan State, USA)*
Jorge Piekarewicz *(Florida State)*

NUMBER OF PARTICIPANTS: 46

MAIN TOPICS:

- Systematics of single-particle properties (that is both energies and spectral strength) along isotopic chains.
- Comparison of different reaction methods for extracting information on spectroscopic factors—including discussions of reaction model dependence.
- Charge-exchange reactions and collective modes in Z/N asymmetric nuclei.
- Implications of collective response to stability and symmetry energy.
- Theory at the drip lines: evolution of quasiparticle properties, coupling between single nucleons and collective modes
- Experiments at the drip lines: discussion of possible future experiments.

SPEAKERS:

Omar Benhar *(Univ. Roma)*
Konstanze Boretzky *(GSI Darmstadt)*
Ricardo Broglia *(Univ. Milano)*
Luciano Canton *(INFN Padova)*
Bob Charity *(Washington StL)*
Gianluca Colo *(Univ. Milano)*
Matthias Degroote *(Univ. Ghent)*
Arnas Deltuva *(Univ. Lisbon)*
Lex Dieperink *(KVI Groningen)*
Umesh Garg *(Notre Dame)*
Chuck Horowitz *(Indiana Univ)*
Mushin Harakeh *(KVI Groningen)*

Ron Johnson *(Univ. Surrey)*
Ritu Kanungo *(Saint Mary's U.)*
Jose Lay *(Univ. Sevilla)*
Roy Lemmon *(Daresbury)*
Antonio Moro *(Univ. Sevilla)*
Akram Mukhamedzhanov *(Texas A&M U)*
Tetsuo Noro *(Kyushu Univ.)*
Alexandre Obertelli *(CEA-Saclay)*
Taka Otsuka *(Univ. Tokyo)*
Arturo Polls *(Univ. Barcelona)*
Arnau Rios *(Univ. Surrey)*
Jan Ryckebusch *(Univ. Ghent)*
Hide Sakai *(Univ. Tokyo)*
Susumu Shimoura *(CNS Tokyo)*
Ingo Sick *(Univ. Basel)*
Toshio Suzuki *(Nihon Univ.)*
Isao Tanihata *(RCNP Osaka)*
Jon Taylor *(Liverpool)*
Natasha Timofeyuk *(Univ. Surrey)*
Betty Tsang *(NSCL/MSU)*
Tomohiro Uesaka *(CNS Tokyo)*
Yutaka Utsuno *(JAEA)*
Dimitri Van Neck *(Univ. Ghent)*
Enrico Vigezzi *(Univ. Milano)*
Tomotsugu Wakasa *(Kyushu Univ.)*
Seth Waldecker *(Washington StL)*
Freddy Flavigny *(CEA-Saclay)*
Alain Gillibert *(CEA-Saclay)*
Corinne Louchart *(CEA-Saclay)*

SCIENTIFIC REPORT:

Aim and Purpose

One of the goals of this workshop was to start the process of evaluating the uncertainties in the data analysis related to reaction models with the intent to identify necessary developments in reaction theory. For this reason several sessions were devoted to various aspects of reaction theory and a large number of experimental talks were included in the workshop. Another prominent goal was to discuss theoretical questions related to exotic isotopes that can further motivate future experiments so the emphasis on the theory side was to have talks that concentrate on generating results relevant for rare isotopes.

Results and Highlights

We summarize the main points of the various sessions in the following.

Tuesday morning session

After an introduction to the ECT by the director Achim Richter, Willem Dickhoff reminded participants of the workshop of the goals and topics and introduced the speakers of the first session. One of the future tools to investigate proton properties in rare isotopes is the (p,2p) reactions in inverse kinematics. It was therefore appropriate to start this workshop with an update on the status of this reaction with stable targets by Tetsuo Noro. As a possible bridge between the description of nuclear reactions and structure, the dispersive optical model, developed by Mahaux and Sartor, deserves considerable attention since it allows data-driven extrapolations to the drip lines. The latest progress extending it to chains of isotopes was reported by Bob Charity. The puzzling results of knockout reactions with Be targets were scrutinized by Alexandre Obertelli. The contrast with the results for transfer reactions remains large and the workshop provided several opportunities to discuss these issues.

Tuesday afternoon and Saturday morning sessions

An area of intense research activity that cuts across a variety of disciplines is the symmetry energy. The poorly-constrained density dependence of the symmetry energy impacts nuclear properties as diverse as the energetics of neutron-rich nuclei, the neutron-skin thickness of heavy nuclei, and the radii of neutron stars. The ongoing parity violating electron-scattering experiments on ^{208}Pb (PREx) along with measurements of the monopole (Umesh Garg), dipole, and Gamow-Teller responses are important tools to link the properties of finite nuclei to those of infinite matter.

Two important open questions were identified in this area. The first is the rapid softening of the monopole response observed in the Tin isotopes (Umesh Garg). This behavior appears inconsistent with the one displayed in other nuclei, such as in the doubly-magic nuclei ^{90}Zr and ^{208}Pb. The second one relates to the nature of the observed low-energy dipole strength---the so-called *Pygmy dipole resonance*. At present it is even unclear if the Pygmy resonance represents a collective excitation of the neutron-rich skin against the symmetric core that may be used to constrain the density dependence of the symmetry energy.

Various experiments were discussed to shed light on these questions. First, the community awaits with great anticipation the report of the 1% measurement of the neutron radius of ^{208}Pb, likely to become available by the end of 2010 (or beginning of 2011) and discussed by Chuck Horowitz. Further, we had discussions on the merit of a more precise measurement of the neutron radius of ^{208}Pb and/or measurements on other neutron-rich nuclei, such as ^{48}Ca. Despite the enormous experimental challenges, there was general agreement that these experiments should be performed as they will be invaluable in calibrating future hadronic experiments on radioactive nuclei. Second, a measurement of the giant monopole resonance on various Cadmium (Z = 48) isotopes has been conducted at the RCNP to confirm (or dismiss) the rapid softening observed in the Tin isotopes. A preliminary analysis seems to confirm the rapid softening observed in these open-shell nuclei. Finally, the LAND collaboration will measure the distribution of low-energy isovector dipole strength in various Ni-isotopes in an attempt to elucidate the nature of the Pygmy dipole resonance.

Several nuclear structure topics were discussed in these sessions like electron capture reactions related to astrophysics (Toshio Suzuki, how to apply the shell model in heavier nuclei (Yutaka Utsuno), and an overview of finite nuclear constraints from the dipole response on the symmetry energy. Nuclear matter results were presented by Arnau Rios focusing on the isospin dependent depletion of the Fermi sea, by Arturo Polls who presented at a microscopic approach for the calculation of the density dependence of the symmetry energy, and by Omar Benhar who discussed the limits of the impulse approximation.

<u>Wednesday morning session</u>

A lively discussion occurred on using transfer reactions to extract spectroscopic information. First an overview of the reaction models was presented by Ron Johnson, followed by an update on the experimental status by Betty Tsang. Akram Mukhamedzhanov presented the combined method and finally Natasha Timofeyuk closed the session with a suggestion as to how to connect the many-body structure calculations to the reaction data and in particular proposed a new method for extracting overlap functions necessary for transfer calculations.

There was strong participation of the audience with many comments and questions. Participants enjoyed the session particularly because it unveiled differences in how results are presented and allowed for a more transparent discussion of the sort of information one can hope to extract from transfer reactions.

Wednesday afternoon session

The physics of ^{11}Li received considerable attention both experimentally and theoretically (Ritu Kanungo, Enrico Vigezzi, and Ricardo Broglia) with special emphasis on the role of the continuum for pairing in this neutron halo system. The puzzling results from high energy transfer reactions on ^{16}O and the hunt for further evidence of tensor correlations were discussed by Isao Tanihata.

Thursday morning session

The discussion included a review of issues related to the evolution of single particle states influenced by the nuclear tensor force and three-body interactions (Taka Otsuka), a report on advances in developing of polarized proton targets for rare isotope experiments (and first results for elastic scattering in inverse kinematics at RIKEN) by Tomohiro Uesaka. Ingo Sick presented a historical overview of experiments aimed at elucidating high-momentum components associated with short-range correlations. On the one hand, it covered past experience (and mistakes) and know-how important for future experiments. On the other hand, the quasiparticles and short-range correlations, discussed together, gave a general overview of the properties of the spectral function. Lex Dieperink discussed developments of the liquid drop model to constrain neutron radii.

Thursday afternoon session

Thursday afternoon was dedicated to progress reports on a variety of ongoing reaction studies, demonstrating that there are a number of promising new developments. The session opened with Antonio Moro reporting from the latest results in analyzing elastic scattering with two-neutron halo nuclei, including ^{6}He and ^{11}Li. Arnas Deltuva gave us a summary of the various activities of the Lisbon group and the use of momentum space Faddeev formalism to address the nuclear reaction problem. Luciano Canton presented the latest results on the multi channel algebraic approach to scattering, which uses a sturmian basis, showing predictions for resonances in various halo systems. The Ryckebusch talk was a nice continuation of Ingo Sick's presentation. He discussed further the difficulties analyzing electron knockout at high energy and how much of the density is actually probed in the reaction. Finally, a short talk by Jose Lay addressed the use of pseudo states in describing resonances in the breakup of loosely bound nuclei.

Friday morning session

General issues including experimental ones of collective giant resonances in exotic nuclei were discussed by Muhsin Harakeh. New results for the pygmy dipole response in Ni isotopes were presented by Konstanze Boretzky as already mentioned above. Spin-isospin response functions in connection with pionic enhancements were discussed by Tomotsuga Wakasa. New results for the isovector spin dipole response in ^{208}Pb were presented as well. Roy Lemmon and his student Jon Taylor presented experimental issues related to (p,2p) experiments performed in inverse kinematics at GSI.

Friday afternoon session

A brief talk by the coordinator was devoted to the recent scientific accomplishments of Hide Sakai who recently retired from the University of Tokyo followed by a presentation of the retiree of the first results involving the SHARAQ spectrometer in the search of the IVSM resonance resulting in a lively discussion. Experimental work with transfer reactions like (α,t), (α,^{3}He) for exotic nuclei was discussed by Susumu Shimoura.

Technical developments on the understanding of the self-energy were also discussed on Friday afternoon. The DOM (its phenomenological version) is being improved to include non-locality discussed by Dimitri Van Neck and the correct isospin dependence to improve extrapolations to the drip line (Seth Waldecker). Microscopic calculations based on the Faddeev random phase approximation (FRPA) are now successfully extended to molecules, as discussed by Matthias Degroote. This work is based on the experience gained in nuclear structure and furthermore provides microscopic insight into the results of the empirical DOM analysis.

Conclusions

It is the opinion of the organizers backed-up by numerous comments of participants that the workshop was very successful and exposed lots of participants to a much broader range of topics than is usual at such meetings. We summarize the main points of the various sessions in the following.

3.3.4 NEW FRONTIERS IN GRAPHENE PHYSICS

DATE: April 12 - 14, 2010

ORGANIZERS:

Iacopo Carusotto *(BEC Trento, Italy)*
Bjoern Trauzettel *(Univ. Wuerzburg, Germany)*
Simon Hands *(Swansea University)*
Achim Richter *(TU Darmstadt, Germany and ECT*, Italy)*
Sandro Stringari *(Univ. Trento, Italy)*

NUMBER OF PARTICIPANTS: 43

MAIN TOPICS:

The main objective of the workshop "New Frontiers in Graphene Physics" held at the ECT* in Trento (Italy) in April 2010 was to favor the establishment of an interdisciplinary community of scientists interested in the physics of graphene from different points of view. The issues that were addressed can be classified as follows:

- Experiments in graphene
- Many-body theory of graphene
- Lattice gauge theories applied to graphene
- Analogs of graphene in condensed-matter systems, in ultracold atomic gases, and with light

SPEAKERS:

Kostya Novoselov *(Manchester, UK)*
Klaus Ensslin *(ETH Zürich, CH)*
Antonio Castro-Neto *(Boston, US)*
Bjoern Trauzettel *(Wuerzburg, D)*
Gordon Semenoff *(UBC Vancouver, Canada)*
Igor Herbut *(Simon Fraser University, Canada)*
Dimitri Khveshchenko *(Chapel Hill, US)*
Andrea Ferrari (UK ,Cambridge)
Sophie Gueron *(Orsay, France)*
Ed McCann *(Lancaster, UK)*
Joel Moser *(Barcellona, Spain)*
Mihai Popinciuc *(Groningen, Netherlands)*
Mrkaus Muellre (ICTP Trieste Italy)
Chang-Yu Hou *(Leiden, Netherlands)*

Pietro Faccioli *(Trento, Italy)*
Simon Hands *(Swansea, UK)*
Timo Lahde *(Aalto, Finland)*
Oskar Vafek *(Tallahassee, US)*
Yasufumi Araki *(Tokyo, Japan)*
Vittorio Pellegrini *(NEST, Pisa, Italy)*
Maksim Miski-Oglu *(Darmstadt, DE)*
Cristiane Morais-Smith *(Utrecht, Netherlands)*
Christian Miniatura *(Nice, France and Singapore)*
Patrik Ohberg *(Edinburgh, UK)*
Johannes Otterbach *(Kaiserslautern)*

SCIENTIFIC REPORT:

The main objective of the workshop "New Frontiers in Graphene Physics" held at the ECT* in Trento (Italy) in April 2010 was to favor the establishment of an interdisciplinary community of scientists interested in the physics of graphene from different points of view. Graphene is a two-dimensional allotrope of carbon. Its peculiar properties have been theoretically studied since 1947 but first graphene samples were experimentally realized for the first time at the University of Manchester in the year 2004.

Condensed-matter physicists are amazed by its peculiar electronic properties, that mostly stem from its semi-metal nature with massless electrons: instead of the usual Schroedinger equation for electron and holes, a (2+1)-dimensional Dirac equation has in fact to be used to describe its carrier dynamics. As a result, unusual half-integer sequences are observed in the quantum Hall effect, as well as remarkable Klein tunneling effects in the scattering on defects. More recent activity is addressing the properties of more complex geometries with several graphene layers juxtaposed. The use of graphene as the basic constituents for electronic devices such as quantum dots is also an active direction of research.

The fast experimental advances in the realization of free-standing graphene sheets are expected to address in the next future crucial questions on the insulator vs. conductor nature of its ground state: theoretical work have in fact anticipated that a spontaneous breaking of chiral symmetry could take place as a consequence of Coulomb interactions and lead to a gapped chiral condensate state in place of the usual semi-metallic ground state. A number of researchers with a background in high-energy quantum field theories are presently very active in investigating these features using a variety of analytical and numerical Monte Carlo methods inspired from gauge theories.

At the same time, a number of other fields are taking inspiration from the advances in graphene physics to investigate a similar physics in completely different systems. Among the most active research directions, we can mention the on-going work on ultracold atomic gases. After the realization of degenerate Bose and Fermi atomic gases, researchers are now starting to address the physics of atoms trapped in optical lattices with a honeycomb geometry. In this configuration, atoms are expected to behave as electrons in graphene. Given the extreme cleanness of atomic systems, these experiments are likely to provide crucial understanding of the fundamental physical effects that determine their many-body properties. In turn, this deeper understanding of fundamental physics will be of great utility in designing new graphene-based devices.

Honeycomb geometries are presently being investigated also in the framework of photonic crystals: the typical Dirac-like dispersion is in this case shown by photons in a periodic dielectric geometry and leads to peculiar transmission and reflection properties that have been recently measured in the microwave frequency window. Applications to photonic devices are presently under development. Including a nonlinear optical medium in the photonic crystal will open the way to studies of the dynamics of a novel model of an interacting Dirac-like field.

More exploratory research is presently trying to apply the concepts of the physics of relativistic fields to slow-light propagation in Electromagnetic Induced Transparency media and to the motion of atoms in artificial gauge fields.

Results and Highlights:

The workshop at ECT* has allowed researchers that are active in all these different research fields to enter into contact with each other and has tried to stimulate active collaborations. In spite of the very different backgrounds, the effort in finding a common language has generally been successful: due to the high quality of the talks and the willingness of the speakers to explain their expertise in an understandable way to physicist from other areas of research, the workshop definitely increased the interdisciplinary interaction of all participants.

On a short term, the main achievement of the workshop has been the inspiration of different fields from each other: it became clear during the three days of the workshop that the interdisciplinary flow of information already inspired several of the participants to explore and develop new ideas and perspectives. On the long run, the establishment of direct collaborations between some of the participants can be expected. As a clearest example, it is reasonable to think that the many-body effects predicted by the condensed matter community will soon be measured using cold atom systems in optical lattices: disentangling the interesting many-body properties from spurious effects due to e.g. the substrate and sample disorder will be of course much easier in atomic systems, but the resulting understanding will be of great utility to condensed-matter systems as well. The remarkable results that have been obtained by applying the numerical and analytical methods of lattice gauge field theories to graphene suggests that a similar procedure can be fruitfully implemented for other condensed-matter systems, in particular ultracold atomic gases.

3.3.5 DECOHERENCE IN QUANTUM DYNAMICAL SYSTEMS

DATE: 26 - 30 April, 2010

ORGANIZERS:

Alexis Diaz-Torres *(Univ. Surrey, UK)*
Irene Burghardt *(ENS, Paris, France)*
Jeffrey Tostevin *(Univ. Surrey, UK)*
Craig Martens *(Univ. California, Irvine, USA)*

NUMBER OF PARTICIPANTS: 29

MAIN TOPICS:

The main topics were:

1. What are the relative merits of alternative formulations of the quantum dynamical evolution in the presence of environmental couplings, in particular with reference to nuclear dynamical systems
2. How does the effective decoherence time and the entropy production depend on the collision energy, and how does this affect considerations in item above?
3. How does the environment affect the reaction dynamics and which observables are needed to quantify the effects of environment-induced quantum decoherence? What specific or classes of measurements on nuclear dynamical systems might provide additional insights?

SPEAKERS:

Franz Hasselbach *(Univ. Tuebingen)*
Stefan Gerlich *(Univ. Vienna)*
Klaus Hornberger *(MPIPKS, Dresden)*
David Hinde *(ANU, Canberra)*
Lorenzo Corradi *(INFN Legnaro)*
Alexis Diaz-Torres *(Univ. Surrey)*
Mahir Hussein *(USP, São Paulo)*
Marek Ploszajczak *(GANIL, Caen)*
Aurelian Isar *(NIPNE, Bucharest)*
Peter Saalfrank *(Univ. Potsdam)*
Ulrich Kleinekathoefer *(Jacobs Univ., Bremen)*
Jyrki Piilo *(Univ. Turku)*
Barry Garraway *(Univ. Sussex)*

Irene Burghardt *(ENS, Paris)*
David Coker *(UCD, Dublin)*
Angelo Bassi *(Univ. Trieste)*
Guillaume Hupin *(GANIL, Caen)*
Denis Lacroix *(GANIL, Caen)*
Takashi Nakatsukasa *(RIKEN, Japan)*
Arnau Rios Huguet *(Univ. Surrey)*
Walter Strunz *(TU Dresden)*
Ronnie Kosloff *(Hebrew Univ.)*
Baha Balantekin *(Univ. Wisconsin)*
Mahananda Dasgupta *(ANU, Canberra)*
Kouichi Hagino *(Tohoku Univ.)*

In addition to the above speakers, Ronald Johnson (Univ. Surrey), Alahari Navin (GANIL, Caen), Luca Ferialdi (Univ. Trieste) and Jeffrey Tostevin (Univ. Surrey) actively contributed to the discussions.

SCIENTIFIC REPORT:

Nuclear physics research has entered a new era with the recent developments of facilities that provide access to high intensity radioactive nuclear beams; an area in which Europe is a major stakeholder (GSI, HIE-ISOLDE, GANIL). At these facilities it is nuclear collisions and reactions that provide the primary probes of the new physics, such as novel structural changes, through dynamical excitations of nucleonic, collective and cluster degrees of freedom. In parallel, new and innovative detection systems are allowing measurements of unprecedented exclusivity and precision, including those using intense stable beams. These and the increased intensity rare radioactive beam capabilities require investigations of the role of hitherto inaccessible degrees of freedom and new dynamical considerations in the nuclear structure and collision dynamics. Combining fully reaction dynamics and many-body structure information is a major outstanding problem across disciplines.

Quantifying the role and the importance of decoherence in quantum many-body systems is now pervasive in modern science and studies of quantum measurement and quantum information. The concept of a reduced (but not closed) quantum system evolving in the presence of weak couplings to complex states is common throughout disciplines. Collisions of composite nuclei have conventionally been treated as closed quantum systems, assuming a state-truncated model space. In reality however their evolution involves intrinsic excitations to innumerable available open channels. The assumed model space for any practical, conventional calculation is inevitably limited to a number of most relevant excitations, defining the reduced quantum system. All other states (each individually very weakly coupled to the reduced system by residual interactions) constitutes the external environment in this case - and which may be specific to particular degrees of freedom of the system and the collision dynamics, such as weak binding or isospin asymmetry, and the collision energy. Among such environments are (i) high level-densities of one- and multi-nucleonic excitations, (ii) the breakup continua of decay channels (e.g. for weakly-bound nuclei).

Many of the key questions posed are common across disciplines and applicable techniques have been advanced very significantly in other areas of few- and many-body physics and chemistry. Molecular physics, for example, covers a wide range of regimes involving ultrafast electronic and vibrational decoherence, as well as situations where collective environmental modes create approximate decoherence-free subspaces. Recent experiments on photosynthetic light-harvesting systems provide strong evidence for the protection of excitonic coherence by the protein environment. Accordingly, the available theoretical approaches include Markovian and non-Markovian master equations as well as explicit, high-dimensional quantum and mixed quantum-classical calculations of the combined system and environment.

The main aims of the Workshop are:

a) To both review and assess methods, recent investigations and implications of quantum decoherence in atomic, molecular and other areas, and to relate these to the nuclear physics context; providing both theoretical and experimental perspectives.
b) To create essential links between the nuclear physics community and practitioners in other areas of science aimed at understanding fundamental aspects of quantum physics, such as the role of decoherence and the quantum-to-classical transition.
c) To initiate inter-disciplinary exchanges and the transfer of expertise, to foster collaborations, and facilitate the formation of younger- researcher networks.

Results and Highlights

The workshop brought together researchers (both theorists and experimenters) from a wide range of disciplines (electron and molecular interferometry, quantum optics, atomic and molecular physics, quantum information, quantum biology and nuclear physics) that span the subject of quantum decoherence in dynamics of few- and many-body quantum systems.

Researchers from fields other than nuclear physics presented methodologies and experiments for the study of decoherence in quantum dynamics. Nuclear scientists reported on theoretical methods and experimental capabilities in nuclear structure and reaction dynamics. They discussed, with researchers of other disciplines the use of specific techniques (their strengths and weaknesses) that might be used to identify nuclear scenarios where quantum decoherence may play a crucial role. E.g. complex atomic nuclei have proven to be outstanding laboratories for researching quantum decoherence effects, with the interplay of multiple, complicated degrees of freedom in the processes involved.

Conclusions

The workshop was a great success, as expressed by many delegates. While quantum decoherence is topical across various disciplines, it is hardly investigated at all in low-energy nuclear physics phenomena. Thus, the workshop has opened a new window for the nuclear physics community. In the workshop, the communication between the participants was impressive, reflected in deep and stimulating discussions during and after the daily presentations. The workshop has been a very positive experience for everyone. New collaborations and exchange of ideas have been initiated, for instance, between nuclear theorists and researchers from other areas regarding methodologies for investigating the open (nuclear) system dynamics. A collaboration meeting on nuclear fusion (involving theorists and experimenters) has been planned, which could take place in 2011. It is expected that such a meeting will help tackle urgent (unsolved) problems in low-energy nuclear collision dynamics. It could also access, through realistic quantitative models, the usefulness of a consistent treatment of open (nuclear) system dynamics that includes quantum decoherence effects.

3.3.6 TMD2010 - WORKSHOP ON TRANSVERSE MOMENTUM DISTRIBUTIONS

DATE: 21 - 25 June 2010

ORGANIZERS:

Alessandro Bacchetta (Univ. of Pavia and INFN Pavia, Italy)
Feng Yuan (Lawrence Berkeley National Laboratory, USA)
Christine Aidala (Los Alamos National Laboratory, USA)
Marco Contalbrigo (INFN Ferrara, Italy)

NUMBER OF PARTICIPANTS: 56

MAIN TOPICS:

The subject of the workshop was the study of Transverse Momentum Distributions (TMDs). They extend the concept of parton distribution function (PDF) and describe a new dimension of the partonic structure of the nucleon: the transverse momentum dimension. Intuitively, they represent multi-dimensional images of the distribution of partons in the nucleons in momentum space. Similarly to standard PDFs, TMDs are invaluable objects to understand the physics of hadrons as well as to make predictions for any hard scattering processes involving hadrons.
The main topics were

- EXPERIMENT: new and updated measurements involving TMDs;
- THEORY: new results concerning the theoretical framework and the evolution of the TMDs, new calculations of TMDs on the lattice and in models;
- PHENOMENOLOGY: updates on TMD fits.

SPEAKERS:

Piet Mulders *(Vrije U. Amsterdam)*
John Collins *(Penn State U.)*
Gunar Schnell *(DESY)*
Mauro Anselmino *(U. Torino)*
Haiyan Gao *(Duke U.)*
Christian Weiss *(Jefferson Lab)*
Philipp Haegler *(TU Munich)*
Giuseppe Bozzi *(U. Milano)*
Dennis Sivers *(Portland Physics Institute)*
Hrayr Matevosyan *(U. of Adelaide)*
Anna Martin *(U. Trieste)*
Armine Rostomyan *(DESY)*
Igor Cherednikov *(INFN Cosenza and JINR Dubna)*
Ted Rogers *(Vrije U. Amsterdam)*
Michal Deak *(U. Madrid)*
Stefano Melis *(U. Piemonte Orientale)*
Alexander Manashov *(U. Regensburg)*
Bernhard Musch *(Jefferson Lab)*
Gary Goldstein *(Tufts U.)*
Simonetta Liuti *(U. Virginia)*
Isabella Garzia *(U. Ferrara)*
Harut Avakian *(Jefferson Lab)*
Xiaodong Jiang *(Los Alamos Lab)*
Ralf Seidl *(RIKEN)*
Marco Stratmann *(U. Regensburg)*
Aurore Courtoy *(U. Pavia)*
Peter Schweitzer *(U. Connecticut)*
Cedric Lorcé *(U. Mainz)*
Marco Radici *(INFN Pavia)*
Barbara Pasquini *(U. Pavia)*
Asmita Mukherjee *(IIT Bombay)*
Sucheta Jawalkar *(College of William and Mary)*
Akio Ogawa *(Brookhaven National Lab)*
Matthias Burkardt *(New Mexico State U.)*
Andrea Bianconi *(U. Brescia)*
Oleg Teryaev *(JNR Dubna)*
Petr Zavada *(Institute of Physics, Prague)*
Frank Rathmann *(Forschungszentrum Juelich)*
Marc Schlegel *(U. Tuebingen)*
Cristian Pisano *(U. Cagliari)*
Oleg Shevchenko *(JINR Dubna)*
Oleg Denisov *(INFN Torino)*
Jen-Chieh Peng *(Jefferson Lab)*
Matthias Grosse Perdekamp *(U. Illinois)*
Andreas Metz *(Temple U.)*

SCIENTIFIC REPORT:

Aim and purpose

The general aim of the workshop was to bring together a group of experts to discuss the best ways to measure and analyze observables related to TMDs as well as to better understand the physical information contained in these objects.

In the last years, there has been flourishing activity on TMDs, thanks to pioneering experimental measurements and novel theoretical ideas. The field has grown and evolved from a phase of exploration to its present phase of intense development.

Several new experimental results have been presented from the following collaborations: HERMES (DESY), COMPASS (CERN), BELLE (KEK), STAR (RHIC), BRAHMS (RHIC), PHENIX (RHIC), CLAS (JLab), Hall A (JLab), E866 (Fermilab). Perspectives for measurements by the BABAR (SLAC) collaboration were also discussed. Future plans of measurements at COMPASS, JLab, NICA and a future Electron-Ion Collider (EIC).

The status of TMD theory has been reviewed and discussed, especially focusing on the impact of theoretical concepts on the phenomenology (e.g., different definitions of TMDs, universality properties, evolution equations, resummations, relation to collinear PDFs).

Results obtained in model calculations of TMDs have been reported and discussed, with a particular attention on (model-dependent) relations between TMDs and generalized parton distributions (GPDs), and between different TMDs. A model calculation of fragmentation functions has also been presented.

Recent calculations of TMDs in lattice QCD have been described, trying to clarify to which extend the lattice results can be compared with the TMDs extracted from experimental measurements.

The latest updates on TMD parametrizations has been presented and discussed, trying to understand to which extent they can be considered to be reliable and how they can be improved.

Results and Highlights

The workshop fostered a productive interaction between theorists and experimentalists, which has been a distinctive feature of this field of research in the last years.

From the point of view of the TMD formalism, there have been several discussions on different ways to define TMDs. A first interesting point of discussion was the possibility of defining TMDs so that they include the so-called soft factor appearing in factorization proofs. This would simplify their phenomenological study, but has to be done in a consistent way. Another important question is to compare the different ways to regularize the divergences appearing in TMDs (rapidity divergences). There are a few alternatives (e.g., non-light-like Wilson lines, non-light-like gauges, pole prescriptions). It is not clear if all of them are formally acceptable and convenient, and if choosing different prescriptions simply amounts to different scheme choices. Clarifying this question would be extremely useful.

Some discussion has been devoted to Lattice QCD calculations of TMDs. At present, these calculations refer to objects with a Wilson line that does not correspond to any of the definitions suggested in factorization theorems. In practice, what is computed on the lattice is not what is measured experimentally. It is not clear if it is possible to quantify the differences between the two. It is important to address this problem, also because these “exploratory” lattice studies have already displayed certain nontrivial features of TMDs that would be interesting to check experimentally (for instance, flavor dependence of TMDs, Gaussian shapes).

A talk addressed the question of the evolution of the collinear twist-3 function that is connected to the evolution of the first transverse moment of the Sivers function. In particular, it has been stressed that there are some discrepancies between the calculations of three different groups. A related subject was the inclusion of transverse-momentum resummation into TMDs studies. State-of-the-art studies using the so-called Collins-Soper-Sterman formalism are available for unpolarized cross sections, but not yet for azimuthal asymmetries. This will be an important goal for the near future.

Several talks were devoted to model calculations of TMDs, fragmentation functions, twist-3 collinear functions. They show widely different behaviors, also qualitatively, and are also different from the behavior usually assumed in present-day parametrizations. Some discussion was devoted to the relations that models predict between TMDs and GPDs as well as between different TMDs. Some of these relations are due to specific symmetries imposed on the model, which are probably not valid in full generality, but may work well in practice and be therefore useful to inspire the way TMDs are parametrized.

The most recent parametrizations of the Sivers and Boer-Mulders functions were presented and discussed. TMD fits are still far away from the quality of collinear PDF fits (presented in an overview talk), it is clear that there is still a long way to go and we are just at the beginning. The most crucial shortcomings that need to be overcome are: the lack of a proper treatment of evolution, an improved treatment of error correlations, an estimate of systematic theoretical uncertainties and biases. On the other hand, it seems that we can trust the qualitative features emerging from these first fits, e.g., the existence of a nonzero, negative up Sivers function, and a down Sivers function of similar size and opposite sign.

From the experimental point of view, the HERMES collaboration presented the final data on the Sivers and Collins asymmetries on the proton, together with preliminary measurements of all other azimuthal asymmetries for transversely polarized protons. The COMPASS collaboration presented new data on the Sivers asymmetry for protons. A preliminary analysis with limited statistics seemed to be inconsistent with the HERMES data, but further studies reduced the differences. At present the two data sets seem to be compatible. New studies on the Q and W dependence of the asymmetries were reported: they could be useful for a better understanding of the underlying physics.

A few talks were devoted to illustrating future experimental measurements related to TMDs at Fermilab, BaBar, COMPASS, J-Parc, PAX, as well as at a future Electron Ion Collider (EIC). In particular, it seems clear that a machine with the luminosity and kinematic span of EIC will be a precision machine for the study of TMDs and will push the whole field to an entirely new level of accuracy.

In summary, the workshop has been fruitful and successful and gave important inputs for further achievements and advances in the field.

3.3.7 (SECOND COLLABORATION MEETING ON THE) APPLICATION OF THEORETICAL PHYSICS METHODS TO BIOLOGY

DATE: June 28 - 30, 2010

ORGANIZER:

Pietro Faccioli *(Dipartimento di Fisica, Università di Trento, Italy)*

NUMBER OF PARTICIPANTS: 14

MAIN TOPICS:

The general theme of the workshop concerned the application of advanced theoretical and computational physics techniques to the investigation of the dynamics of macromolecules of biological interest. In particular, the meeting focused on the possibility of investigating the long-time dynamics of the protein folding reaction and of the protein-protein interaction, in the context of stochastic path integral approaches.

Along with theoretical contributions, the meeting included a number of experimental talks. The purpose was to discuss the possibility of establishing direct collaboration between theory and experiment. In particular, a specific attention has been given to the experimental investigation of reaction pathways, under topological or special constraints.

The main topics were

- Stochastic dynamics, path integral methods for molecular dynamics
- Coarse-grained description of macromolecular systems
- Experimental characterization of conformational transitions of proteins, protein-protein and protein-membrane systems

SPEAKERS:

C. Micheletti *(SISSA, Italy)*
C. Cammillon *(Cambridge Univ., UK)*
C. Bejac *(Univ. Texas at Austin, USA)*
P. Faccioli *(Trento Univ., Italy)*
S. a Beccara *(Trento Univ., Italy)*
T. Skrbic *(Trento Univ., Italy)*
F. Valle *(CNR, Italy)*
M. Dalla Serra.*(CNR, Italy)*
G. Tiana *(Milan Univ., Italy)*

SCIENTIFIC REPORT:

The investigation of the conformational dynamics of biopolymers is one of the fastest developing fields of research at the interface between physics, biochemistry and biology.

From the experimental point of view, the field is experiencing a revolution, due to the development of powerful optical techniques such as optical tweezers, or single-molecule laser-jump fluorescence experiments, to name a few. These methods, along with the development of nano-scale devices (such as nano-pores, nano-tubes) offer the possibility of investigating the dynamics of biomolecular processes under a wide range of external conditions, such as under confinement or topological constraints. Such a body of new-generation experiments is beginning to provide information about the thermodynamics and the kinetics of molecular processes, at an unprecedented level of accuracy, both under equilibrium and (most notably) non-equilibrium conditions. In particular, much insight is being gained in reconstructing the pathways of intermediate conformational transitions involved in the folding of proteins and in the aggregation of bio-molecules.

From the theoretical point of view, the problem of investigating the dynamics of biomolecules is strongly limited by its intrinsic computational complexity. The origin of such difficulties is rooted in the large number of degrees of freedom involved and in the co-existence of widely separated time scales, ranging from ps (vibration of covalent bonds) to ns (rotation of dihedral angles) to ms or even seconds (protein folding time).

The decoupling of time scales makes Molecular Dynamics (MD) simulations of large systems very computationally inefficient and often impracticable. On the other hand, theoretical physicists and in particular nuclear physicists have a long-time experience in exploiting gaps in energy-momentum scales to device low-resolution effective theories for many-body systems.

In recent years, it has been realized that the dynamics of macromolecular transitions in a solvent can be rigorously formulated using the path integral formalism. Clearly, such a formulation opens the doors to the application of the arsenal of nuclear physics tools to macromolecular dynamics. For example, in the last few years, progress has been made in the application of instanton theory to investigate rare thermal activated transitions, and in the use of renormalization group methods to integrate out the fastest molecular dynamics.

Results and Highlights

The main purpose of the meeting was to bring together theoretical physicists and experimental biophysicists in order to explore the potential for applying path integral techniques to interpret the results of new-generation experiments. The event was organized in the form of a small collaboration meeting (with participation under invitation) to encourage the discussion and the planning of future joint-works.

The meeting consisted of joint morning sessions with oral presentations and afternoon round-table discussions. The latter were organized in the form of two working-groups, which focused on different projects.

As a result of these sessions, a collaboration project between the Trento University and the Texas University at Austin has been established, which aims at developing path integral approaches to protein-protein interaction dynamics, based on multi-scale modelling of macromolecular complexes. In addition, a collaboration between two experimental CNR groups, the SISSA and Trento theory groups has been established which aims at studying the dynamics of protein folding under confinement conditions in nano-structure. Finally, three scientists affiliated to the Cambridge University, Milan University and Trento University had the opportunity to progress on their on-going projects aiming at the development of a high-performance sampling technique to investigate rare biomolecular transitions in the context of biased-molecular dynamics and kinetic Monte Carlo.

In view of this network of collaborations, it is possible to argue that the workshop has successfully accomplished its main goals.

3.3.8 CONFINING FLUX TUBES AND STRINGS

DATE: 5 - 9 July, 2010

ORGANIZERS:

O. Aharony *(Weizmann Institute, USA)*

B. Bringoltz *(University of Washington, USA)*

M. Teper *(University of Oxford, UK)*

NUMBER OF PARTICIPANTS: 28

MAIN TOPICS

Understanding the low-energy behaviour of strong nuclear interactions (QCD) is a long-standing problem. A key role in this behaviour is played by flux tubes, which form `confining strings' connecting quarks and anti-quarks when they are separated to long distances. The goal of the workshop is to bring together different communities which study confining flux tubes from various points of view, in order to understand better their behaviour, and to see what they teach us about the more general problem of confinement. In particular, the workshop will include talks by people from the lattice gauge theory community who perform numerical simulations of flux tubes, by people from the string theory community using holographic models in string theory to study flux tubes, by field theorists who study flux tubes in more general, often supersymmetric, field theories, by string/field theorists studying general constraints on the effective string action for flux tubes, and talks on various other approaches as well.

The main topics were

- Gauge-gravity duality
- Confinement
- Flux tubes
- Effective string actions
- Flux tubes and strings - lattice

SPEAKERS:

O. Aharony *(Weizmann Institute, Israel)*

A. Armoni *(Swansea University, UK)*

R. Auzzi *(Hebrew University, Israel)*

M. Baker *(University of Washington, USA)*

M. Bertolini *(SISSA/ICTP, Italy)*

M. Caselle *(University of Turin, Italy)*

J. Drummond *(LAPTH, France)*

R. Falcone *(University of Bielefeld, Germany)*

F. Gliozzi *(University of Turin, Italy)*

J. Greensite *(San Francisco University, USA)*

D. Karabali *(CUNY, USA)*

K. Konishi *(University of Pisa, Italy)*

B. Lucini *(Swansea University, UK)*

Y. Makeenko *(ITEP, Russia)*

V. Vyas *(Delhi University, India)*

H. Meyer *(University of Mainz, Germany)*

V.P Nair *(CUNY, USA)*

R. Narayanan *(University of Miami, USA)*

S. Necco *(CERN, Switzerland)*

C. Nunez *(Swansea University, UK)*

L. Pando-Zayas *(University of Michigan, USA)*

A. Rajantie *(Imperial College, UK)*

V. Rodgers *(University of Iowa, USA)*

M. Shifman *(University of Minnesota, USA)*

J. Sonnenschein *(Tel Aviv University, Israel)*

M. Stephanov *(University of Illinois, USA)*

K. Stiffler *(University of Iowa, USA)*

M. Teper *(University of Oxford, UK)*

SCIENTIFIC REPORT:

The idea that the strong interactions may be described by a string theory grew out of the Veneziano amplitude and is even older than Quantum Chromodynamics, and the idea that SU(N) gauge theories, at least in 't Hooft's planar limit, may have such a description is only a little younger. The more recent and radical version of this idea is Maldacena-Witten-... gauge-string (AdS/CFT) duality. To learn something about this string theory it is natural to start by focusing upon any degrees of freedom that are manifestly string-like and, in linearly confining theories such as SU(N) gauge theories, whether in 2+1 or 3+1 dimensions, these are long confining flux tubes.

One can ask what effective string theory describes the dynamics of these flux tubes. Recently there has been substantial analytic progress towards answering this (old) question which, roughly speaking, tells us that the dynamics governing very long flux tubes is, to a certain approximation, that of a Nambu-Goto free bosonic string theory. Simultaneously, numerical lattice calculations of the low-lying excitations of closed flux tubes in D=2+1 and D=3+1 SU(N) gauge theories have been telling us that their energies are typically remarkably close to those of the free bosonic string theory even for shorter flux tubes, where the flux tube length is on the order of its (expected) intrinsic width and, naively, they look nothing like strings.

The apparent universality of the string description has motivated calculations in simpler theories (certain spin models etc.) where dualities can be exploited to allow very accurate calculations of very long flux tubes. These reveal clearly the logarithmic growth of the flux tube, now also being seen in gauge theories. The effective string description is also being extended to finite temperature where novel features arise and are being observed. The universality also motivates theoretical calculations, in the context of gauge-gravity duality, where using suitable confining backgrounds it has been successfully checked, and more detailed properties, such as those to do with the intrinsic flux tube width, have begun to be calculated. On the lattice side, there have also been recent lattice calculations that are beginning to give useful information on this intrinsic width.

In related field theories flux tubes can be visible already semiclassically, and in certain cases, given enough supersymmetry, analytic calculations are feasible. Again in the last few years there has been substantial progress on understanding such flux tubes, which are in calculable universality classes that are different from QCD.

On the field theory side, the dynamics of confinement is not yet under analytic control and, indeed, one hopes that an effective string action for the large N theory will eventually either encode (or at least illuminate) that dynamics. But in any case, this dynamics is certainly expected to play a role in determining interesting non-universal aspects of the effective string theory as well the apparent precocious onset of its universal aspects. There have been many ideas tested using lattice gauge theory calculations and there has also been significant progress in understanding non-Abelian solitonic objects that may be dynamically generated and may drive confinement in certain gauge theories. Simultaneously significant progress has been made in reproducing the confining vacuum of SU(N) gauge theories in D=2+1 within a Hamiltonian approach.

In our workshop we had many of the leading figures in all these developments and in some related areas. The main purpose was to inform these different communities of the progress being made in all these related areas and hence to focus attention on problems that were interesting and where progress was being made using different conceptual frameworks and techniques. The focus was therefore on a substantial number of review talks, often reviewing the work done in a particular area over the last decade, together with a detailed presentation of the most recent work (some unpublished) where significant progress was being made. To make this really work we had extended discussion sessions in the afternoons, led by discussion leaders who had been asked to prepare a number of topics for discussion that arose from the morning and early afternoon talks. These discussions proved very useful -- often being animated and involving many of the participants. In this way this Workshop has helped to set the agenda for these problems amongst these overlapping communities of theoretical high energy physics.

Results and Highlights:

The workshop included many interesting talks and discussions on the topic of flux tubes and confinement. The main goal, which was to bring together different communities working on this topic, and to teach each community the methods and results found by the other communities, was definitely achieved, and we believe that this will have significant influence on the work of the people who attended the workshop in the coming years. A number of specific, often controversial, topics were analysed at some length in the discussion sessions. These included: the proper definition of the width of the flux tube and what it teaches us; the general form of the corrections to the Nambu-Goto action for long strings and the prospects for measuring them by lattice simulations; the behavior of k-strings; and the validity of various descriptions of confinement.
A significant measure of agreement was reached on some of these, including:

a) On the subject of the flux tube's "intrinsic width", a distinction was established with the width generated by the usual massless transverse oscillations. Explicit lattice calculations, using e.g. products of local operators separated (only) in the transverse direction, illustrated these ideas. However different definitions and lattice set-ups yield different widths, and without some more universal definition of an "intrinsic width" for a flux tube, it is not clear if this can be turned into a useful concept.

b) The current status of attempts to analytically construct the vacuum state for 2+1 dimensional gauge theories is not yet sufficiently clear. The most formal and precise such approach produces a `leading' result for string tensions which is known to be very close to lattice values. However significant success is also reached by much simpler and more heuristic approaches. The former formalism being exact offers the advantage of a framework in which, in principle, systematic corrections may be calculated. However, while a way of organising corrections does indeed give the very small corrections that the success of the `leading term' requires, this comes from a cancellation of several terms, each quite large, that appears accidental and, for now, leaves it unclear how readily this might generalises to a real approximation scheme with control over corrections.

c) The question whether corrections to k-string tensions in the large N limit can scale as 1/N while being consistent with the usual large N counting was answered, in principle, in the affirmative: through explicit arguments based on quantum mechanical mixing of degenerate states, or looking explicitly at Euclidean correlators, or on the string side through the possible long range character of string-string interactions mediated by the massless modes. Such arguments are in the well-defined large N limit where all parameters, including the length l, are kept fixed as N grows to infinity. If one increases l with N, which may be a relevant limit in the context of a string tension calculation where one may want to take l large compared to any possible scale in the theory, then it appeared possible that these arguments could break down, but the standard large N counting also becomes more subtle. While lattice calculations can determine the power of these 1/N corrections if they set in at moderate N and l, it does not seem possible for them to access the truly large l and N limits that may be of greater interest.

d) Most lattice results on flux tubes so far agree with the general expectations from the effective string action. This includes the growth of the width with l, at zero and finite temperature, corrections to the ground state energy, and the low-lying spectrum of excited flux tube states. However Gliozzi reported one case of an apparent disagreement, in a 2+1 dimensional Z2 theory, for which no explanation has yet been found.

3.3.9 EMMI WORKSHOP CHIRAL SYMMETRY AND CONFINEMENT IN COLD, DENSE QUARK MATTER

DATE: July 19 - 23, 2010

ORGANIZERS:

L.Ya. Glozman *(University of Graz, Austria)*
K. Fukushima *(Kyoto University, Japan)*
L. McLerran *(BNL, USA)*
R. Pisarski *(BNL, USA)*

NUMBER OF PARTICIPANTS: 41

MAIN TOPICS:

- Experimental situation and systematics in the temperature-chemical potential plane.
- Implications of large Nc for the QCD phase diagram.
- Beyond large Nc.
- Solvable models with confinement and chiral symmetry.
- Implications for heavy ion collision programs and astrophysics.

SPEAKERS:

R. Alkofer *(Graz U, Austria)*
D. Blaschke *(Wroclaw U, Poland)*
N. Bratovic *(Tech. U of Muenchen, Germany)*
P. Braun-Munzinger *(GSI, Germany)*
P. Buescher *(Darmstadt Tech. Univ. Germany)*
T. Cohen *(Maryland U, USA)*
M. Cristoforetti *(ECT*, Italy)*
K. Fukushima *(Kyoto U, Japan)*
P. de Forcrand *(Zürich, ETH, Switzerland)*
L. Glozman *(Graz U, Austria)*
K. Hashimoto *(RIKEN, Japan)*
S. Hands *(Swansea U, UK)*
T. Hell *(Tech. U of Muenchen, Germany)*
Y. Hidaka *(Kyoto U, Japan)*
S. Imai *(RCNP, Japan)*
J. Jankowski *(Wroclaw U, Poland)*
T. Kojo *(RIKEN BNL, USA)*
T. Kunihiro *(Kyoto U, Japan)*
K. Langfeld *(Plymouth U, UK)*
L. McLerran *(RIKEN BNL, USA)*

A. Nakamura *(Hiroshima U, Japan)*

J. Papavassiliou *(Valencia U, Spain)*

J. Pawlowski *(Heidelberg U, Germany)*

R. Pisarski *(BNL, USA)*

F. Preis *(Vienna Tech.U, Austria)*

K. Redlich *(Wroclaw U, Poland)*

M. Rho *(Hanyang U, South Korea)*

M. Sadzikowski *(Krakow U, Poland)*

C. Sasaki *(FIAS, Germany)*

J.-I. Skullerud *(NUIM, Maynooth, Ireland)*

B.-J. Schaefer *(Graz U, Austria)*

I. Zahed *(Stony Brook U, USA)*

P. Sorensen *(BNL, USA)*

J. Stachel *(Heidelberg U, Germany)*

M. Stephanov *(Illinois U, USA)*

S. Stricker *(Vienna Tech. Univ. Austria)*

A. Szczepaniak *(Indiana U, USA)*

M. Thies *(Erlangen-Nuremberg U, Germany)*

H. Toki *(RCNP, Japan)*

J. Wambach *(Darmstadt Tech. U, Germany)*

W. Weise *(Tech. U of Muenchen, Germany)*

SCIENTIFIC REPORT:

Results and Highlights

The purpose of the workshop was to gather about 40 theorists to attack problems related to confinement, chiral symmetry and their interrelations in cold, dense matter in QCD. This included those who work on phenomenology in QCD, those working in numerical simulations on the lattice, string theorists, and experimentalists. Understanding these issues has a direct impact on the proper formulation of planned experimental programs to explore the QCD phase diagram at large baryon density at BNL, GSI and JINR. It also impacts our understanding of different astrophysical phenomena in neutron stars and the like.

On Monday, there was an introductory talk on Quarkyonic matter by L. McLerran. There were then further talks on Quarkyonic matter by Y. Hidaka, and on the large Nc limit by T. Cohen. In the afternoon, M. Stephanov talked about signatures of a critical endpoint. Then there were two people who work on the Schwinger-Dyson approach to QCD, R. Alkofer and J. Papavassiliou, who were specifically invited. Cold, dense quark matter is a real opportunity for this approach. Unfortunately, there still is not agreement on a standard method, which was clear from these two talks: Alkofer used a skeleton expansion, whilst Papavassiliou used the "pinch" technique.
The last talk on Monday was by L. Glozman, who discussed parity doubling in the meson and baryon spectra.

On Tuesday, A. Szczepaniak gave a very nice discussion of using Coulomb gauge to compute non-perturbatively, using various ansatzes for the gluon propagator. Then M. Thies gave an excellent talk, summarizing his work on exactly soluble models in 1+1 dimensions. The work is very technical, but his talk was clear, to the point, and very useful. T. Kojo then gave a talk on how Quarkyonic matter forms patches which cover the Fermi surface. After lunch, J. Skellerud and S. Hands discussed their work on dense quark matter for two colors. They studied this numerically, as it is free of the sign problem. This was fascinating, and will surely serve as a real benchmark for effective models. There were various details, especially a peak in the energy density in the confined (quarkyonic) phase, that were most perplexing and intriguing. K. Langfeld then gave a nice discussion of how an approximate Z(3) symmetry is present even in theories with dynamical quarks. H. Toki gave a talk on the "FWpPNJL" model (Fukushima-Weise-Pisarski-Polyakov-Nambu-Jona-Lasino) model.

On Wednesday, A. Nakamura gave a talk on his recent lattice work, especially of lattice propagators at nonzero temperature. J. Pawlowski discussed the Functional Renormalization Group analysis of the deconfining phase transition. His results, especially on the renormalized Polyakov loop, were very interesting, and do not agree with lattice calculations. They may indicate a finite renormalization not yet accounted for on the lattice. P. Sorensen gave a nice summary of the low energy run at RHIC. P. Braun-Munzinger and J. Stachel gave extremely interesting discussions of the applicability of statistical models to heavy ion collisions. The former emphasized that they do not work for e+e-, nor pp collisions, while the latter showed how they can explain the "Matterhorn", the peak in the K/pi ratio at sqrt s of 10 GeV.

On Wednesday and Thursday, Redlich, Fukushima, Weise, and Schafer talked about dense quark matter in the FWpPNJL model. Also on Thursday were talks by T. Kunihiro, on how a pseudogap arises in a color superconductor; M. Rho, on dense nuclear matter in the Skyrme model; and I. Zahed, on the same in holographic models. Lastly, K. Hashimoto gave a masterful summary of results on dense nuclear matter in the Sakai-Sugimoto model. It was most impressive and informative.

Friday ended with talks by P. de Forcrand, on dense quark matter in a strong coupling expansion on the lattice, and D. Blaschke, on the pPNJL model. R. Pisarski gave the summary talk.

Relation to EMMI

From the above, it is clear that the workshop directly addresses two of the four main research areas of EMMI, namely:

1. Properties of the quark-gluon plasma and the phase structure of strongly interacting matter.

2. Structure and dynamics of neutron matter.

Expenditure of funds from EMMI

We hereby certify that the EMMI funds were used for travel and accommodation of speakers and young participants of the workshop. More than half of the EMMI funds were used for supporting young participants.

3.3.10 QCD FROM THE BOUND STATES' PERSPECTIVE

DATE: August 2 - 6, 2010

ORGANISERS:

B. El-Bennich *(Universidade Cruzeiro do Sul & IFT State University of São Paulo, Brazil)*
C. D. Roberts *(Argonne National Lab, USA)*
Ph. Hägler *(TU Munich, Germany)*
M. Pennington *(Durham University, UK)*

NUMBER OF PARTICIPANTS: 22

MAIN TOPICS:

- Nonperturbative methods in QCD
- QCD-inspired models
- Structure of bound states in QCD
- Hadron spectrum
- Electromagnetic and hadronic probes of mesons and nucleons

SPEAKERS:

B. El-Bennich *(Univ. Cruzeiro do Sul & IFT São Paulo, Brazil)*
G. Engel *(Univ. Graz, Austria)*
M. Giannini *(Univ. & INFN Genova, Italy)*
R. Gothe *(Univ. South Carolina, USA)*
M. Guidal *(IPN, Orsay, France)*
Ph. Hägler *(TU Munich, Germany)*
A. Hosaka *(Osaka Univ., Japan)*
A. Kizilersu *(Univ. Adelaide, Australia)*
T.-S. Lee *(Argonne National Lab, USA)*
F. Llanes-Estrada *(Univ. Compl., Spain)*
T. Nagae *(Kyoto Univ., Japan)*
D. Renner *(DESY Zeuthen, Germany)*
S. Riordan *(Jefferson Lab, USA)*
C. D. Roberts *(Argonne National Lab, USA)*
J. Rodriguez-Quintero *(Univ. Huelva, Spain)*
G. Salmè *(INFN Roma, Italy)*
H. Ströher *(FZ Jülich, Germany)*
T. Takahashi *(Gunma CollegeTech., Japan)*
P. Tandy *(Kent State Univ., USA)*
V. Vento *(Univ. Valencia, Spain)*

R. Williams *(TU Darmstadt, Germany)*
Q. Zhao *(IHEP, Chin. Acad. Sciences, China)*

SCIENTIFIC REPORT:

Aim and Purpose

The five-day workshop was attended by more than 20 participants, among them several early-career researchers, from Europe, Asia, and North and South America. Approximately one-half of the speakers had never before participated in a Trento workshop.

The attendees gathered to address outstanding questions in contemporary hadron physics, amongst them: the understanding of confinement and dynamical chiral symmetry breaking and their expression in hadron observables; the covariant calculation of the hadron spectrum, electromagnetic and strong form factors; the computation rather than parametrisation of parton distribution functions; lattice-QCD and the effective field theories necessary in order to make precise predictions; the cross-fertilisation of Dyson-Schwinger equations and lattice-QCD to elucidate the properties of QCD's gauge- and ghost-field Schwinger functions; and the development of a reaction theory that can reliably be used to connect hadron structure calculations with features observed in hadron production cross-sections.

One objective of the workshop was the immediate communication of re- cent results in hadron physics via fruitful exchanges between experimentalists and theorists. This exposed theorists to the experimental issues involved in these measurements, as well as to the details of form factor extractions that are relevant to their calculations. It also gave the experimentalists the opportunity to appreciate and compare contemporary theoretical tools.

Results and Highlights

A key goal of modern studies in QCD is to develop an understanding of the spectrum and interactions of light-quark hadrons, whose masses lie in the range 1-2 GeV, and connect this with a description of excited states and putative exotics and hybrids in the charm and bottom sector. Theory, phenomenology, and experimental goals and results in this area were presented. The framework, 45 minute talks followed by a 15-minute question session, nurtured many discussions and comparison between theoretical approaches; the most prolific and widely employed of these are the relativistic quark models, in their various manifestations, Dyson-Schwinger equations and lattice-regularised QCD. The communication between experimentalists and theorists stimulated discussions about how future measurements can most effectively provide additional constraints on theory. In this respect, the talks highlighting recent progress and future programmes at experimental facilities dedicated to hadron physics in Europe, Japan and North America were excellent.

Recent progress in the following areas was described: solving the QCD bound-state problem via Bethe-Salpeter equations and the impact of a newly derived Ward-Takahashi relation for the Bethe-Salpeter kernel; calculations of quark-gluon vertices and mass functions beyond the rainbow-ladder approximation; the role of a pion cloud in nucleon structure and interactions; the large x behaviour of pion, kaon and nucleon parton distribution functions; a conjectured understanding of relations between the rest-frame features of a hadron and properties determined on the light-front; the high-Q^2 behaviour of the nucleon form factor ratios in the space-like region; the behaviour of the nucleon form factor ratios in the time-like region; non-perturbative effects in charmonium and B-meson decays; and lattice-QCD results on the nucleon resonance and exotic mass spectrum, the pion form factor and parton distribution functions.

Conclusions

The workshop brought together practitioners with expertise in:

- the diverse nature and challenges of contemporary experiments in hadron physics;
- the application of QCD- and symmetry-preserving models to the spectrum and dynamics of light-quark hadrons as well as to elucidate the deep connection between analytical properties of Schwinger functions and confinement;
- the extension of these approaches to excited states, exotics and hybrids, and to charmed and beauty mesons;
- pion-nucleon reaction theory and its application to calculations of hadron structure and hadron production cross sections;
- the numerical simulations of lattice-regularised QCD in connection with the hadron spectrum and experimental observables.

The practitioners elucidated the strengths of, and challenges for, their chosen tools. The presentations stimulated other participants, and got them thinking and talking about the interplay between dynamical quarks and the problem of quark confinement within light and heavy mesons, nucleons and their excited states. Each of the key participants addressed this charge element.

The immediate goal of communication was met through vigorous debate during, between and after presentations. In the longer term, we anticipate more discussion and collaboration between the participants. It was recognised that there is ample room for cross-fertilisation.

3.3.11 ELECTROMAGNETIC PROBES OF STRONGLY INTERACTING MATTER: STATUS AND FUTURE OF LOW-MASS LEPTON-PAIR SPECTROSCOPY

DATE: September 13 - 17, 2010

ORGANIZERS:

T. Galatyuk *(Goethe-University of Frankfurt, Germany)*
J. Kapusta *(University of Minnesota, USA)*
R. Rapp *(Texas A&M University, USA)*
J. Stroth *(Goethe-University of Frankfurt, Germany)*

NUMBER OF PARTICIPANTS: 41

MAIN TOPICS

The main topics were:

- Electromagnetic probes of hot and dense matter
- In-medium modifications of hadrons
- Quark-Gluon Plasma radiation
- Phases of strongly interacting matter
- Future facilities

SPEAKERS:

Elena Bratkovskaya *(Frankfurt)*
Markus Bleicher *(Frankfurt)*
Oliver Busch *(Heidelberg)*
Olena Linnyk *(Frankfurt)*
Daniel Cabrera *(Madrid)*
Payal Mohanty *(VECC)*
Sanja Damjanovic *(Gent)*
Kazunori Nakayama *(Athens)*
Charles Gale *(Montreal)*
Marina Nanova *(Giessen)*
Masayasu Harada *(Nagoya)*
Massimiliano Procura *(Muenchen)*
Claudia Hoehne *(Giessen)*
Lijuan Ruan *(Brookhaven)*
Romain Holzmann *(Darmstadt)*
Elvira Santini *(Frankfurt)*
Olaf Kaczmarek *(Bielefeld)*
Gianluca Usai *(Cagliari)*
Stefan Leupold *(Uppsala)*
Janus Weil *(Giessen)*

Volker Metag *(Giessen)*
Gyuri Wolf *(Budapest)*
Piotr Salabura *(Cracow)*
Christian Baumann *(Frankfurt)*
Radhey Shyam *(Calcutta)*
Gennady Lykassov *(Dubna)*
Hendrik van Hees *(Giessen)*
Tetyana Galatyuk *(Frankfurt)*
Satoshi Yokkaichi *(Tokyo)*
Ralf Rapp *(College Station)*

SCIENTIFIC REPORT:

This workshop was the fourth of the series on “Electromagnetic Probes of Strongly Interacting Matter" at ECT* (March 1999, June 2005, June 2007). Its main purpose was to communicate the newest experimental results and theoretical developments to advance our understanding and develop a coherent picture of the properties of hadrons in hot/dense QCD matter, specifically of the light vector mesons r, w and f. The workshop benefited from discussions between the high- and intermediate-energy heavy-ion communities, as well as from connections to elementary proton- and photo-induced meson-production reactions. The discussion was further stimulated in 4 lively evening sessions following the regular talks (moderated by B. Friman, J. Wambach, V. Koch and I. Tserruya). Inviting the leading scientists in the field ensured a high quality of the meeting.

Results and Highlights

DAY 1:

- Re-analysis of TAPS data on *w* photo-production does not exhibit a significant *w* mass shift in nuclei (revising previous claims); *w* line shape analysis is not sensitive to medium effects, but nuclear transparency ratio suggests a large absorptive *w* width.
- The experimentally suggested large *w* width cannot be explained by theory in linear density approximation; r^2_N effects in the pion cloud of the *w* may resolve this problem.
- CLAS-g7 dielectron mass spectra in nuclear photoproduction show a moderate broadening of the *r*, contradicting KEK-E325 results in p-induced reactions (9% downward *r*-mass shift); the in-medium *w* width inferred from the transparency ratio confirms TAPS results.
- Recent hadronic many-body calculations reproduce CLAS-g7 data on the in-medium *r*, predicting a reduced broadening at large 3-momentum $p > 1GeV$.
- Theoretical and phenomenological analysis of t decay data using chiral Lagrangians for vector/axialvector spectral functions seem to favor a dynamical nature of the a_1 resonance.
- Moment analysis of in-medium QCD sum rules for vector spectral function demonstrated consistency of hadronic many-body effects with Operator Product Expansion; controversial discussion of ramifications for chiral restoration (in-medium pion decay constant).

DAY 2:

- Confirmation of experimental resolution of the longstanding DLS puzzle by HADES: reference spectrum from p+p and n+p accounts for the ^{12}C+C spectrum when scaled by the number of binary N+N collisions.
- Importance of dilepton production in N+N Bremsstrahlung (BS) has been confirmed theoretically; latest OBE-model calculations made progress in qualitatively reproducing the strong isospin dependence, but do not yet describe “quasi-free" n+p collisions satisfactorily.
- The problematics of a full gauge-invariant calculation of BS using realistic N+N T-matrices (rather than OBE amplitudes) has been exhibited; the importance of full gauge invariance (not just transversality of the amplitude) was emphasized.
- In 1.76 GeV/u ^{40}Ar+KCl a substantial contribution of radiation from the dense medium is identified as baryon-resonance contributions to e^+e^- mass spectrum (scaling with pion number). For the first time at these energies vector-meson production has been observed. The m_t slopes for e^+e^- pairs with invariant mass above 500 MeV/c^2 are substantially harder than at lower mass.
- p+p data at 3.5 GeV kinetic beam energy were presented for the first time; no solid theoretical interpretation of data yet, due to poorly known electromagnetic transition form factors of D and other resonances in the time-like region.
- The problem of off-shell transport simulations was reiterated, exhibiting differing treatments in different codes.

DAY 3:

- Presentation of fully acceptance corrected dimuon mass excess spectra in ^{115}In+In collisions at E_{beam} = 158 GeV/u by NA60, achieving (Lorentz-) *invariance* of the mass spectrum for the first time in heavy-ion collisions. Isotropy of angular distribution supports the interpretation of the excess as thermal radiation over the entire mass range ($M=2m_m$-3 GeV).
- Excellent agreement of hadronic many-body calculations for the in-medium r spectral function with acceptance corrected NA60 low-mass spectra ($M\leq 1$ GeV), thus establishing the melting of the r resonance ($m_r \cong G_r$) at temperatures close to T_c; lifetime of the fireball in In(158 AGeV)-In can be determined with unprecedented accuracy at 6-8 fm/c.
- Controversial discussion of the interpretation of the NA60 dimuon excess at intermediate mass ($M=1$-3 GeV); a rather sharp drop of the effective slope parameter

for dimuon m_t spectra around *M≅1 GeV* suggests a transition to a "new" source (other than inmedium r decays) with temperature

T≅160-200 MeV; no consensus on composition of this source ("partonic" or multi-meson annihilation which thus far is not included consistently in all theoretical models); importance of the acceptance-corrected mass spectra in determining the "true" radiation temperature (unaffected by blue shifts due to flow).

- Indirect evidence for in-medium *w* broadening via absorption at low p_t; no effect for the *f.*
- Elliptic flow of thermal dileptons suggested as tool to disentangle their emission history.
- Presentation of high-precision data on the e.m. transition form factors of *h* and *w* Dalitz decays in peripheral In-In, confirming Lepton-G results.

DAY 4:

- New lattice QCD results (quenched) for low-mass thermal dilepton rates at *p=0* show good agreement with hard-thermal loop results, thus supporting the quark-hadron duality scenario with hadronic many-body theory with implied chiral restoration; $w \to 0$ limit allows to extract thermal conductivity; extension to non-zero 3-momentum in near future.
- PHENIX dielectron mass spectra for ^{197}Au+Au at √s = 200 GeV at RHIC show a striking low-mass enhancement for *M=0.2-0.7 GeV* which is a strong function of centrality (concentrated in central collisions), dubbed "PHENIX puzzle".
- Excess reported in central ^{64}Cu+Cu (world premiere) does not reach the level of the one measured in ^{197}Au+Au.
- Measurements of thermal (quasi-real) photon p_t have been reported indicating a temperature of *T≅220 MeV* in Au-Au at RHIC.
- ALICE dielectron and CMS dimuon spectra at LHC energy for p+p at √s = 7 TeV (world premiere) over large mass range look very promising for heavy-ion runs.
- QGP emission (constrained by newest lattice-QCD results, see above) has been shown to be inefficient in explaining the PHENIX puzzle, due to a general interplay of emission temperature and 3-volume; solution to PHENIX puzzle likely residing in hadronic phase, e.g., long-lived pion droplets, possibly Disoriented Chiral Condensate; challenge of consistency with hadronic data at RHIC and dileptons at SPS.
- First calculations of in-medium a_1 spectral function (chiral partner of *r*) in cold nuclear

matter, using dynamically generated a_1 resonance from chiral Lagrangian; a_1 resonance exhibits significant broadening in nuclear medium.

- Presentation of comprehensive approach to parton jet quenching and e.m. emission at high p_t.

DAY 5:

- New results from hybrid model (UrQMD and hydro) for the dynamics of heavy-ion collisions, using a *3+1* ideal hydro evolution for the hot and dense stage of the reaction; first implementation of thermal dilepton radiation into hydrid approach; promising results but NA60 data cannot be quantitatively described; necessity of improving hadronic input rates at both low and intermediate mass.
- Discussion of future theoretical approaches to in-medium vector mesons/chiral restoration.
- Planned experiments for vector-meson measurements through dileptons at J-PARC (cold nuclear matter), NA60* at SPS (critical point!?), and CBM at FAIR (although not a dedicated dilepton spectrometer).

Conclusions

In conclusion, this workshop fully met its goal by bringing together leading theorists and experimentalists working on electromagnetic probes of QCD matter from GSI to RHIC/LHC energies. Lively discussions fostered improved understanding and stimulated new directions for future research projects and “homework" to be conducted. With LHC having started operation in the heavy-ion mode, precision RHIC dilepton data having been collected with the HBD, HADES having completed its upgrade and ready to perform ^{197}Au+Au measurements, we enthusiastically suggest a continuation of this workshop series in 2012 to scrutinize further progress made in the wake of this meeting and take advantage of the building momentum in this field.

3.3.12 QCD AT THE LHC

DATE: September 27 - October 1, 2010

ORGANIZERS:

J. Blümlein *(DESY, Hamburg, Germany)*

H. Fritzsch *(LMU Munich, Germany)*

M. Mangano *(CERN, Geneva, Switzerland)*

NUMBER OF PARTICIPANTS: 45

MAIN TOPICS:

The Large Hadron Collider (LHC) at CERN has started taking data in Autumn 2009 and collected, through the Summer of 2010, a large amount of data, which allowed a first complete assessment of the features of QCD processes at the center of mass energy of 7 TeV. In particular, measurements were available at the time of the Workshop on all key QCD observables:

- global properties of the final state structure of *pp* collisions
- production rates and distributions of high transverse momentum jets
- production rates and distributions of *W* and *Z* gauge bosons
- production rates and distributions of heavy quarks

The Workshop provided therefore a very timely opportunity to discuss, among world-leading experts of the field, these important results, and to plan future efforts for the interpretation and the exploitation of these valuable data. In parallel, the Workshop provided a unique forum for the presentation of recent theoretical calculations, notably of advances in the techniques for the estimates of higher-loop processes, of the theoretical Monte Carlo modelling of *pp* collisions, and of more accurate determinations of the proton structure in terms of parton distributions. These three topics were covered in great detail during the afternoon meetings of the three discussion groups, dedicated to “multilegs and higher-loops”, to “MC modelling”, and to “parton distribution functions” (PDFs).

SPEAKERS:

S. Alekhin *(DESY/ITEP)*

S. Badger *(DESY)*

J. Bluemlein *(DESY)*

M. Botje *(NIKHEF)*

J. Butterworth *(UC London)*

M. Cacciari *(Paris)*

F. Caola *(Milan)*

M. Cooper-Sarkar *(Oxford)*

A. Denner *(PSI)*

C. Diaconu *(DESY)*

G. Dissertori *(ETH Zurich)*

L. Dixon *(SLAC/CERN)*

R. Field *(U. of Florida)*

J. Fleischer *(Bielefeld)*

D. Forde *(CERN)*

H. Fritzsch *(LMU Muenchen)*

V. Gabor *(CERN)*

A. Geiser *(DESY)*

W. Giele *(FNAL)*

A. Vicini *(Milano)*

A. Glazov *(DESY)*

M. Grazzini *(Firenze)*

J. Huston *(East Lansing)*

P. Jimenez-Delgado *(Zürich)*

J. Casalderry *(CERN)*

U. Klein *(Liverpool)*

F. Krauss *(Durham, UK)*

Z. Kunszt *(ETH Zürich)*

E. Laenen *(NIKHEF)*

F. Maltoni *(Louvain-la-Neuve)*

M. Mangano *(CERN)*

S. Moch *(DESY)*

A. Moraes *(CERN)*

P. Nason *(Milan)*

M. Neubert *(Mainz)*

C. Papadopoulos *(Demokritos Athens)*

G. Passarino *(Torino)*

R. Placakyte *(Aachen)*

V. Radescu *(Heidelberg)*

E. Reya *(Dortmund)*

K. Safarik *(CERN)*

N. Skachkov *(JINR)*

B. Spaan *(Dortmund)*

J. Stirling *(Cambridge)*

Z. Trocsanyi *(Debrecen)*

M. Ubiali *(Edinburgh)*

M. Velasco *(North Western University)*

B. Webber *(Cambridge)*

SCIENTIFIC REPORT:

About 50 invited participants attended the Workshop, partly supported by ECT*, partly self-supported. All LHC experiments, as well as experiments from the *ppbar* Tevatron collider and from the *ep* HERA collider, were represented, and contributed by giving detailed reports on the ongoing analyses, as well as by actively participating and steering the discussions of the working groups. Of particular value in promoting the interaction of theorists and experimentalists were some sessions dedicated to the PDFs and to the MC generators, where all outstanding issues in the comparisons of current data with the theoretical QCD calculations were discussed. For example, one session of the MC WG focused on recent measurements, by the CMS experiment, of a "ridge structure" in *pp* final states with large particle multiplicity. This measurement, which indicates important discrepancies between the QCD modelling and the data, and which appears to suggest some connection with similar structures observed in collisions among relativistic nuclei at RHIC, had been reported only few weeks before the Workshop. The discussions that took place at ECT* were the first coherent effort to identify the sources of these discrepancies, and led to several suggestions towards their understanding.

Important discussions took place also in the PDF sessions, where members from all the groups engaged in the parameterization of the parton densities of the proton were represented. The ECT* Workshop, in fact, was used as the occasion for a meeting of the PDF4LHC working group, which is currently preparing a report of a several-year-long activity. The ECT* meeting provided the ideal environment to openly discuss several outstanding issues, ranging from the treatment of heavy quarks in the proton, to the determination of the QCD coupling constant from PDF fits, to the assessment of the systematic uncertainties in these fits.

The landscape of QCD phenomenology at the LHC was completed with reviews of the plans for the forthcoming heavy ion run, and with the discussion of the theoretical issues facing the interpretation of the data on *b*-hadron decays which are being analysed by the LHCb experiment.

Results and Highlights

All key questions that were included in our initial proposal for the Workshop have been covered:

1. What is the outcome of the first comparisons of data and predictions at the LHC? How does the current description of QCD at LHC energy score?
2. Which theoretical predictions about key hard scattering processes to be measured need further improvement?
3. What are the scattering processes for which further, resp. more detailed, theoretical calculations have to be performed?
4. What is the detailed behaviour of parton distributions in the kinematic region at the LHC and which strategies have to be employed to extract these distributions with the highest possible precision?
5. What is needed to improve the main Monte Carlo simulation codes?
6. Did we reach an understanding of the standard candle processes which is sound enough for the luminosity monitoring required?
7. Do we understand the backgrounds to the first important searches for new particles, such as the Higgs boson(s) and supersymmetric signatures?
8. What is the theoretical status to understand key measurements in B-physics?
9. What is the theoretical status to understand key measurements in heavy ion collisions?

In several cases, clear-cut answers have emerged. For example, we can certainly claim that indeed perturbative QCD emerges from this first comparison against LHC data as a robust theoretical framework. The agreement of theory and data is impressive, possibly far better than one could have anticipated. Observables in the non-perturbative regime have also been identified where some theoretical improvement is required (e.g., the ‘ridge” mentioned above, as well as some other global-event properties, such as inclusive multiplicities of strange particles). More accurate estimates of the multi-jet backgrounds to new-physics searches have been presented, for the first time, at this meeting, and many ideas on new observables with reduced theoretical systematic uncertainty have been discussed (e.g. cross-section ratios).

The detailed agenda, as well as the slides of the talks, can be found at the URL http://indico.cern.ch/conferenceOtherViews.py?view=standard\&confId=93790. We had 24 plenary talks, plus 3 plenary WG reports at the end of the meeting. In the discussion sessions we had 36 presentations, triggering ample discussion, which continued during the various coffee breaks and the valuable common dinners.

On behalf of all participants, we would like to acknowledge and thank the secretarial support, which handled very efficiently the logistics of the meeting, both before and during the Workshop. The facilities were impeccable, the accommodations in the Hotels of high quality, and the dinner venues very pleasant.

3.3.13 STRANGENESS IN NUCLEI

DATE: 4 - 8 October, 2010

ORGANIZERS:

Tullio Bressani *(Univ. and INFN Torino, Italy)*
Catalina Curceanu *(LNF-INFN, Italy)*
Paul Kienle *(TU München, Germany)*
Toshimitsu Yamazaki *(Univ. Tokyo and RIKEN Japan)*
Johann Zmeskal *(SMI-Vienna, Austria)*

NUMBER OF PARTICIPANTS: 46

MAIN TOPICS:

This workshop brought together international experts in the research area of strangeness in nuclei physics, working on theory as well as on experiments, to discuss the present status, to develop new methods of analysis and to have the opportunity for brainstorming towards future studies, going towards a deeper understanding of the hot topics in the low-energy QCD in the strangeness sector.

Main topics of discussion were:

- Hadronic atoms
- Hypernuclear physics
- Meson (in particular kaon)-nucleon scattering status
- Low-energy effective theories
- In-medium modification of vector mesons
- Excited hyperons and their interaction with nuclei
- Deeply bound meson-nuclear states: theoretical status
- Antiprotons as hadronic probes
- EU HadronicPhysics FP7 LEANNIS Network and its future
- Experimental results:
    - DEAR and SIDDHARTA at DAFNE
    - Kaonic Helium by E570 at KEK
    - Deeply bound mesonic nuclear states:
    - E549 at KEK

- FOPI and HADES at GSI
    - FINUDA and KLOE at DAFNE
    - OBELIX results
    - Dubna results
    - DISTO at Saturne
- Next-generation experiments
    - Experiments at GSI: future of FOPI and HADES
    - Experiments at DAFNE: SIDDHARTA2, AMADEUS and future plans;
    - E15 and E17 at J-PARC
    - Facility for antiproton annihilation in nuclei physics: JPARC and CERN

SPEAKERS

Y. Akaishi *(RIKEN, Nihon Univ., Japan)*
P. Aslanyan *(JINR Dubna, Russia)*
G. Bonomi *(Univ. and INFN Brescia, Italy)*
T. Bressani *(Univ. and INFN Torino, Italy)*
S. Bufalino *(Univ. and INFN Torino, Italy)*
A. Cieply *(NPI Rez, Czech Republic)*
C. Curceanu *(LNF-INFN, Italy)*
E. Epple *(TU Munich, Germany)*
L. Fabbietti *(TU Munich, Germany)*
A, Filippi *(INFN Torino, Italy)*
E. Friedman *(Racah Institute of Physics, Jerusalem, Israel)*
A. Gal *(Hebrew Univ. Jerusalem, Israel)*
D. Gazda *(NPI Rez, Czech Republic)*
E. Hiyama *(RIKEN, Japan)*
T. Hyodo *(Tokyo Inst. of Technology, Japan)*
F. Iazzi *(Univ. and INFN Torino, Italy)*
Y. Ikeda *(RIKEN, Japan)*
T. Ishiwatari *(SMI, Vienna, Austria)*
A. Ivanov *(Vienna Univ. Of Technology, Austria)*
M. Iwasaki *(RIKEN, Japan)*
P. Kienle *(TU Munich, Germany)*
K. Lapidus *(TU Munich, Germany)*
M. Maggiora *(Univ. and INFN Torino, Italy)*
J. Mares *(NPI Rez, Czech Republic)*
J. Marton *(SMI Vienna, Austria)*
I. Mishustin *(Univ. Frankfurt, Germany)*
R. Münzer *(TU Munich, Germany)*
S. Okada *(LNF-INFN, Frascati, Italy)*
S. Piano *(Sez. Trieste, INFN, Italy)*
J. Pochodzalla *(Univ. Mainz, Germany)*
F. Sakuma *(RIKEN, Japan)*
N. Shevchenko *(NPI Rez, Czech Republic)*
J. Siebenson *(TU Munich, Germany)*
D. Sirghi *(LNF-INFN, Frascati, Italy)*
K. Suzuki *(SMI, Vienna, Austria)*
T. Suzuki *(Univ. Tokyo, Japan)*
T. Uchino *(Tokyo Inst. Of Technology, Tokyo, Japan)*
W. Weise *(TU Munich, Germany)*
S. Wycech *(Soltan Institute for Nuclear Studies, Warsaw, Poland)*
T. Yamazaki *(Univ. Tokyo, Japan)*
J. Zmeskal *(SMI Vienna, Austria)*

SCIENTIFIC REPORT:

Strangeness nuclear physics is an extremely valuable tool for studying fundamental interactions and symmetries in a fairly direct way, complementing high energy physics studies performed at LHC and elsewhere. Important information regarding the low-energy, non-perturbative, regime of QCD can be gained from these types of research. Since the pioneering days, decades ago, new technologies (in accelerators and detectors) were developed in order to perform precision experimental studies to clarify open issues (such as the still existing discrepancies between experiment and theory in kaonic atoms, the quest for kaonic nuclear clusters or studies on hypernuclei with S=-2) and to extract new data with unprecedented accuracy. One can say that the field is experiencing a happy coincidence in which the progress achieved in accelerator physics is paralleled by the advances in detector physics. Theory has, meanwhile, performed equally important steps forward towards a deeper understanding of the involved physics processes.

The Workshop was a continuation, a deepening and an enlargement of physics sectors of the very successful 2006 ECT* Workshop on *"Exotic hadronic atoms, deeply bound kaonic nuclear states and antihydrogen"* and of the 2009 ECT* Workshop *"Hadronic atoms and nuclei - solved puzzles, open problems and future challenges in theory and experiment*".

The present Workshop brought together international experts in the research area of strangeness in nuclei physics, working on theory as well as on experiments, to discuss the present status and the recent important progress, to develop new methods of analysis and to have the opportunity for brainstorming towards future studies.

Going more into detail, the following main items were discussed:

i) *Hypernuclear spectroscopy, including the strangeness S = -2 nuclei and weak decays of hypernuclei* which were new topics and refer to experimental results already existent (as FINUDA) and to experiments proposed for the J-PARC and FAIR facilities for the search for double Λ nuclei and the synthesis of cascade nuclei and their weak decays including their theoretical relevance for the strangeness interaction in nuclei.

ii) *Antikaon-nucleon and -nucleus interactions at low energy* for which we had new results from the analysis of the kaonic hydrogen, deuterium and ^{3}He data from SIDDHARTA at LNF. This new data were at the basis of a very fundamental discussion of the complex nature of the antikaon-nucleon interaction governed by hyperon resonances close to threshold. Future of this sector will see the SIDDHARTA2 and E17 experiments in data taking in the coming years, the first one at DAFNE the second at JPARC. These experiments plan to go to perform even more precise kaonic atoms measurements for more atoms, as required by theoreticians working in the field.

iii) *Excited hyperons and their interactions with nuclei*, especially the double pole property of the Λ(1405/1420) resonance which is crucial for understanding of our central theme "Strangeness in Nuclei". New data for this much discussed topic were shown from HADES at GSI and they gave a key database for a theoretical understanding of the strong attraction mediated by antikaons in nuclei.

iv) S*earch for strongly bound, dense antikaonic light nuclei* predicted by Akaishi and Yamazaki in 2002 were strongly debated at the present workshop where final result of DISTO data analysis were presented and discussed. In addition, FOPI preliminary results from the recent experiment on the search for the K^-pp state in the pp reaction at 3.1 GeV bombarding energy were introduced. Furthermore final results were reported on Λ-n and Λ-p correlations following stopped K^- absorption at rest in ^4He measured in the E549 experiment which give indications of deeply bound tri-baryon systems. E15 at J-PARC is going on line for a search of the K^-pp state using the in flight K^-(3He, n) reaction with a kinematically complete experimental set up - the status of this experiment was discussed. AMADEUS future dedicated experiments for these type of studies at DAFNE were as well discussed.

v) *In-medium modification of strange vector mesons,* such as Φ-mesons with hidden strangeness, has been studied recently using invariant mass spectroscopy in the *p+A* reaction by the KEK-PS experiment E325 to determine its mass shift and width. For the study of bound states of Φ-mesons in nuclei, missing mass spectroscopy using antiproton annihilation reactions with small momentum transfer have been proposed recently by Iwasaki et al to be performed with antiproton beams at J-PARC and at a later stage at FAIR. The status of the proposal was reviewed and new ideas discussed and implemented.

vi) *Study of antiproton annihilation in nuclei at rest* using a 4π-detector system with the capability of detecting and identifying all charged and neutral particles and measuring their four momentum in order to study the reaction mechanisms with high statistics and kinematically complete was proposed. A search for double antikaonic strongly bound and dense nuclear systems, and systems of high energy density produced by antiproton annihilation in nuclei will be proposed at J-PARC.

Moreover, in the framework of the present Workshop two other activities were organized:

1) presentation and discussion of the EU FP7 LEANNIS Network in the framework of HadronPhysics2 program and its continuation in HP3

2) physics conference “La Fisica moderna tra arte e medicina” by Catalina Curceanu at the Galileo Galilei High School of Trento (http://trentinocorrierealpi.gelocal.it/cronaca/2010/10/11/news/la-fisica-moderna-tra-arte-e-medicina-2509188)

Results and Highlights

The field of *Strangeness in Nuclei* is a very active one, as was fully proven during this Workshop. On one side there are many new and important experimental results coming from precision experiments performed or undergoing in GSI, DAFNE, KEK, or from re-analyses of existent older data from OBELIX, DISTO or JINR experiments, just to name a few. On the other side, theoretical tools have performed important steps forward, motivated by the new coming results: not only at technical level, but, even more important, on the understanding of underlying physical processes or questions to be explored in the upcoming experiments.

There are *many solved problems*, as kaonic hydrogen and kaonic helium measurements - which were understood, both due to the newer experiments (as SIDDHARTA at DAFNE) and to theoretical interpretation, but many *open problems* are still present. Actually, the number of open problems is increasing, theories are dealing with one or two (1405), with various potential models below the threshold on kaon-nucleon interaction, having as consequence the possibility or not to create deeply bound kaonic nuclear states. The sector of hypernuclear physics is still long way to go, especially in going towards S=-2 sector. Important questions were targeted and formulated, but they still need both experimental results and deeper theoretical understanding. The future challenges in the sector of strangeness in nuclei physics are many and were, for the first time, focussed and formulated in a unitary framework.

One can rightly say that we can look forward to the future of low-energy QCD with strange quarks as a quantitative, precision science.
This Workshop definitely gave an important contribution in this sector and we plan to apply for a future one eventually in 2012 when more experimental data and theoretical work will become available.

During the workshop few actions, apart of regular talks given both by theoretician experts in the field and experimentalists, were organized. The EU FP7 framework programs was presented; in particular a discussion was dedicated to the LEANNIS Network (HadronPhysics2 FP7) by J. Marton, just dealing with physics discussed in the present workshop; future important contacts and modalities to optimize future contacts were discussed and some decision taken (for example related to the continuation and renewal of this Network in HP3).
Moreover, a physics conference "La Fisica moderna tra arte e medicina" by Catalina Curceanu at the Galileo Galilei High School of Trento was organized with the support of ECT* (in particular of Cristina Costa)

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 hadronic atoms and kaonic nuclear states. The young participant's percentage was about 50%, which is one of the successes of the Workshop.
Moreover, participants from many countries took part, making it an occasion not only of scientific exchange, but of cultural and social ones too, proving once again scientists are part of society, and their role is an important one.

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 puzzles.
The organization of these type of Workshops in the ideal environment of ECT* contributes to the progress of the field. Since many experiments are just going or are about to start, and since theories and methods are evolving in parallel, *we plan to organize other workshops in this field in the coming years, at ECT*.*

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

3.3.14 HARD MESON AND PHOTON PRODUCTION

DATE: 11 - 15 October, 2010

ORGANIZERS:

N. d'Hose *(CEA-Saclay, France)*

P. Kroll *(U. Wuppertal, Germany)*

R. Kaiser *(U. Glasgow, UK)*

NUMBER OF PARTICIPANTS: 38

MAIN TOPICS

- Generalized Parton Distributions
- Deeply Virtual Compton Scattering
- Deeply Virtual Meson production
- GPD models and GPD fits
- Transverse Spin and Transverse Momentum Dependent Parton Distributions
- Parton Distributions and Form Factors

SPEAKERS:

Mauro Anselmino *(Univ. of Torino, Italy)*
Harut Avakian *(JLab, USA)*
Jochen Bartels *(DESY, Germany)*
Vladimir Braun *(Univ. of Regensburg, Germany)*
Jian-Ping Chen *(JLab, USA)*
Valeru Druzhinin *(BINP Novosibirsk, Russia)*
Horst Fischer *(Univ. of Freiburg, Germany)*
Leonard Gamberg *(Penn State Univ., USA)*
Haiyan Gao *(Duke Univ., USA)*
Meinulf Goeckeler *(Univ. of Regensburg)*
Morgan Murray *(Univ. of Glasgow, UK)*
Hervé Moutarde *(CEA Saclay, France)*
Dieter Mueller *(Univ. of Bochum, Germany)*
Wolf-Dieter Nowak *(DESY- Germany)*
Luciano Pappalardo *(INFN Ferrara, Italy)*
Barbara Pasquini *(Univ. of Pavia, Italy)*
Franck Sabatié *(CEA Saclay, France)*
Andrzej Sandacz *(SINS Warsaw, Poland)*
Marc Schlegel *(Univ. of Tuebingen, Germany)*
Gunar Schnell *(DESY, Germany)*
Laurent Schoeffel *(CEA Saclay, France)*
Kirill Semenov *(Ecole Polytechnique Palaiseau, France)*

Gary Goldstein *(Tufts Univ., USA)*
Sergei Goloskokov *(JINR Dubna, Russia)*
Oleg Kouznetsov *(CEA Saclay, France)*
E-M. Kabuss *(Mainz University, Germany)*
Valery Kubarovsky *(JLab, USA)*
K. Kumericky *(Univ. Zagreb, Croatia)*
Elliot Leader *(Imperial College of London, UK)*
Lech Szymanowski *(SINS Warsaw, Poland)*
Oleg Teryaev *(JINR Dubna, Russia)*
Sadaharu Uehara *(KEK Tsukuba, Japan)*
Heiner Wollny *(Freiburg Univ. & Germany-CEA Saclay, France)*
Inti Lehmann *(Univ. of Glasgow, UK)*
Simonetta Liuti *(Univ. of Virginia, USA)*

SCIENTIFIC REPORT:

During the recent years the framework of generalized parton distributions (GPDs) was developed providing a comprehensive description of the partonic structure of the nucleon and containing a wealth of new information. It embodies both, nucleon form factors as observed in elastic lepton scattering and parton distribution functions (PDFs) measured in deep inelastic lepton scattering (DIS). A GPD can be considered as a momentum dissected form factor providing information on the transverse localization of a parton as a function of the fraction it carries of the nucleon's longitudinal momentum. Thus one obtains a "3-dimensional picture" of the nucleon which is often referred to as "nucleon tomography". GPDS also allow access to such a fundamental property of the nucleon as the orbital angular momentum of quarks.

GPDs can be experimentally accessible in exclusive reactions as hard meson and photon production processes. In the last years an enormous activity could be observed on the theoretical as well as experimental side. Data on many hard exclusive reactions as deeply virtual Compton scattering and hard production of rho, omega, phi, J/psi, upsilon at HERA, HERMES and JLab have been published. In the near future COMPASS will investigate the uncharted kinematic domain between the HERA collider experiments H1 and ZEUS and the fixed-target experiments at HERMES and JLab. This is the domain where role of both quarks and gluons are expected. The 11 GeV extension of the JLab accelerator will provide a very detailed study for the valence quarks domain. Reviews and confrontations of all these experiments have been presented during the workshop.

Many theoretical developments have been presented. Numerical lattice QCD calculations predict moments of GPDs and last improvements have been reviewed. GPD models which reproduced very reasonably well the lattice predictions and the first experiment results have been discussed. Moreover several techniques based on "partial wave expansions" providing fitting procedure to extract GPDs from the experimental data have been discussed and will become fundament tools for the community.

In order to calculate hard meson production the meson distribution or light-cone wave functions are required. Our understanding of these functions, in particular those for the pion, has been challenged by a recent BABAR measurement of the pion-photon transition form factor at very large photon virtualities, Q^2. The BABAR data exhibit an unexpectedly strong increase of the form factor, scaled by Q^2 with the photon virtuality. This measurement has immediately provoked a number of theoretical papers in which explanations of this measurement are attempted. However, a convincing explanation which is not in conflict with other results, is still lacking. It was very interesting to watch the disputed developments of this field.

Another interesting topic is the connection between GPDs and transverse momentum dependent distributions (TMDs). In a more general way Wigner distributions encode all the possible correlations between quark transverse position and momentum and the recently introduced generalized transverse-momentum dependent distributions (GTMDs) provide connection with the Wigner distributions, the GPDs and the TMDs. The intrinsic transverse parton momentum effects become visible in hadronic Drell-Yan and semi-inclusive (SIDIS) processes which give access to the TMDS. Many results have also been presented and connections between these two activities (GPDs - TMDs) have been developed.

Results and Highlights:

The presentations at the workshop covered experimental results from all experiments in the field of hard meson and photon production and a broad range of theory presentations, from progress in fundamental questions to GPD model building.
The discussions at the end of each talk were lively and were continued over the lunch and coffee breaks. The central topic of the workshop turned out to be the interface between experimentalists and their data and theorists and their models. A new collaboration between experimentalists and theorists started during the workshop in order to use the most elaborated GPD model not only for meson production but also for photo production where the Bethe-Heitler interference has to be taken into account.

It is clear that GPD models and fits to the experimental data will be one of the key points over the next years. A Collaboration to perform global analysis in order to extract the GPD from all the hard meson and photon production data as the one dedicated to Parton Distribution Functions from DIS and SIDIS data has still to emerge.

3.3.15 THE LIMITS OF EXISTENCE OF LIGHT NUCLEI

DATE: October 25 - 30, 2010

ORGANIZERS:

C. Bertulani *(Texas A&M – Commerce, USA)*

T. Aumann *(GSI, Darmstadt, Germany)*

A. Bonaccorso *(INFN, Pisa, Italy)*

U. van Kolck *(University of Arizona, USA)*

NUMBER OF PARTICIPANTS: 41

MAIN TOPICS:

- Effective interactions and ab-initio models for weakly bound systems.
- Few-body problems. Halo nuclei.
- Effective field theories for loosely bound systems.
- Correlations/decay of unbound systems. Clusterization.

SPEAKERS:

S. Bogner *(Michigan State University, USA)*

L. Chulkov *(RRC KI, Moscow/GSI, Damstadt, Germany)*

C. Forssén *(Chalmers University of Technology, Sweden)*

T. Frederico *(Instituto Tecnologico da Aeronautica, Brazil)*

R. Furnstahl *(Ohio State University, USA)*

D. Gazit *(Hebrew University of Jerusalem, Israel)*

G. Hagen *(Oak Ridge National Lab, USA)*

R. Higa *(KVI, Groningen The Netherlands)*

H.-W. Hammer *(Bonn University, Germany)*

J. Holt *(Oak Ridge National Lab, USA)*

M. Horoi *(Central Michigan University, USA)*

W. Horiuchi *(TU Darmstadt, Germany)*

M. *Hussein (University of Sao Paulo, Brazil)*

A. Jensen *(Aarhus University, Denmark)*

W. Leidemann *(Trento University, Italy)*

V. Lensky *(University of Manchester)*

A. Mukhamedzhanov *(Texas A&M, College Station, USA)*

T. Nakamura *(Tokyo Tech, Japan)*

T. Neff *(GSI, Darmstadt, Germany)*

N. Orce *(TRIUMF, Canada)*

T. Papenbrock *(U. of Tennessee/ORNL/TU Darmstadt)*
S. Ramanan *(Trieste, Italy)*
G. Rogachev *(Florida State University, USA)*
R. Roth *(Technical University, Darmstadt, Germany)*
A. Schwenk *(EMMI/TU Darmstadt, Germany)*
J. Rotureau *(University of Arizona, USA)*
G. Rupak *(Mississippi State University, USA)*
H. Simon *(GSI, Darmstadt, Germany)*
A. Spyrou *(Michigan State University, USA)*
I. Stetcu *(University of Washington, USA)*
M. Viviani *(INFN, Pisa, Italy)*
F. Wamers *(GSI, Darmstadt, Germany)*
D. Weber *(GSI, Darmstadt, Germany)*
M. Zhukov *(Chalmers University of Technology, Sweden)*

SCIENTIFIC REPORT:

Aim and Purpose

Nuclear physics emerges from QCD as the dynamics is fine-tuned to produce a large two-nucleon scattering length. This fine-tuning is most apparent in the existence of weakly bound nuclei as they are coupled to an environment of scattering states. Studies of decays and reactions involving weakly bound nuclei in the vicinity of and even beyond driplines elucidate fundamental questions in nuclear science, astrophysics, and physics of the Standard Model. There is thus a need to develop new theoretical techniques and computational tools that will enable theorists to investigate nuclear decays and reactions with exotic nuclei.

Phenomenological reaction theory and experimental analyses for high-energy reactions at existing and proposed radioactive-beam facilities have been highly developed so far but the link to the underlying inter-nucleon interaction has proven difficult. Also the connection between nuclear forces and QCD is not easy. Beams of light exotic nuclei available at existing radioactive-beam facilities around the world, offer a unique opportunity to test our growing understanding of the QCD basis of nuclear physics and of few body and many body methods needed to pursue this synthesis.

The purpose of the workshop was to bring together experts, especially young scientists from a wide range of research areas concentrated around the physics of light exotic nuclei at the limits of stability in order to exchange ideas between the different approaches and to create possible links between them.

Although the workshop was mainly theoretical, a number of recent experimental results for light exotic nuclei from leading experimental facilities, were presented. This led to active interaction between experimentalists and theorists during the workshop.

Results and Highlights

The workshop was very successful in achieving its aim, bringing together leading scientists, including young scientists, working in the field of light exotic nuclei from Brazil, Europe, Japan and North America. In 36 talks of the participants all of the workshop key topics were covered from effective field theory for loosely bound systems to recent experimental results for light exotic nuclei. All presentations received considerable comments and questions from the audience and intense discussions were continued over the lunch and coffee breaks.

The workshop turned out to be very fruitful from both the scientific and the organizational point of view. The participants commented that the workshop had been very useful for them and they had real opportunity to discuss the issues of interest with other specialists. Such discussions can lead to further collaborations between different groups as well as to more close contacts between theory and experiment in the field of the exotic nuclei.

The ECT* logistical support was excellent and the environment provided at ECT* was ideal for the workshop format.

The Coulomb gauge picture of QCD is in an interesting state of evolution. It is now apparent both in the continuum and on the lattice that Coulomb gauge gluon propagators are very different from those of either the Landau gauge or the Pinch Technique; these Landau or PT propagators support the center vortex picture. Most Workshop practitioners of the Coulomb gauge are strong supporters of the center vortex picture, so the question is how to reconcile Coulomb gauge and center vortices. Some interesting proposals that might do this were made, but they need more work.
A complete and detailed discussion of the results of the fourth topic above, would be too lengthy; we will simply say that taken as a whole they seem to be consistent with the emerging majority view of the work presented for the main three topic.

3.3.16 PRECISION TESTS OF THE STANDARD MODEL: FROM ATOMIC PARITY VIOLATION TO PARITY-VIOLATING LEPTON SCATTERING

DATE: 8 - 12 November, 2010

ORGANIZERS:

Willem T.H. van Oers *(Manitoba/TRIUMF, Canada)*

Roger D. Carlini *(Jlab, USA)*

Jens Erler *(UNAM, Mexico)*

Krishna Kumar *(Massachusetts, USA)*

Frank Maas *(Uni-Mainz, Germany)*

NUMBER OF PARTICIPANTS: 41

MAIN TOPICS

- Parity Violating Lepton Scattering
- Electroweak Measurements at the Energy Frontier
- Electroweak and Flavor Physics at the Intensity Frontier
- Atomic Parity Violation

SPEAKERS:

Masaharu Aoki *(Osaka U.)*

David Armstrong *(William & Mary)*

Sebastian Baunack *(Uni-Mainz)*

Robert Bernstein *(FNAL)*

Roger D. Carlini *(Jefferson Laboratory)*

Alberto Cervelli *(INFN-Pisa)*

We-Fe Chang *(National Tsing-Hua U.)*

Ian C. Cloet *(U. of Washington)*

Andrzej Czarnecki *(U. of Alberta)*

Manfred Daum *(PSI)*

Marten de Kieviet *(Uni-Heidelberg)*

Andrei Derevianko *(U.of Nevada)*

Lex Dieperink *(KVI)*

Jens Erler *(UNAM)*

Fabrizio Ferro *(GSI)*

Peter Fischer *(MIT)*

Susan Gardner *(U. of Kentucky)*

Eduardo Gomez-Garcia *(U. de San Luis Potosi)*

Ulrich Haisch (*Uni-Mainz)*

Klaus P. Jungmann *(KVI)*

Krishna S. Kumar *(U. of Massachusetts)*

Chen-Yu Liu *(Indiana U.)*

Frank Maas *(Uni-Mainz)*

William J. Marciano *(BNL)*

Jeffery W. Martin *(U. of Winnipeg)*

Antonio Masiero *(INFN-Padova)*
Yasuhiro Masuda *(KEK)*
Wally Melnitchouk *(JLab)*
Mikihiko Nakao *(KEK)*
John Ng *(TRIUMF)*
Mark Pitt *(VPI)*
Maxim Pospelov *(U. of Victoria)*
Michael J. Ramsey-Musolf *(U. of Wisconsin)*
Frank Rathmann *(FZ-Juelich)*
Paul E. Reimer *(ANL)*
Michael V. Romalis *(Princeton U.)*
Heidi Schellman *(Northwestern U.)*
Paul Souder *(Syracuse U.)*
Hans Stroeher *(FZ-Juelich)*
Shufang Su *(U. of Arizona)*
Justin Torgerson *(LANL)*
Willem T.H. van Oers *(TRIUMF/Manitoba)*
Lorenz Willmann *(KVI)*

SCIENTIFIC REPORT:

The purpose of the workshop was to review the status of and explore future directions in searches for physics beyond the Standard Model using parity-violating electron scattering that are truly complementary to direct searches of new physics at colliders, e.g. the Large Hadron Collider, but also at SUPER KEKB and SuperB. In order to put the objectives of the workshop in context, a comprehensive span of electroweak experiments covering the full range of energies, from table-top experiments to the highest energy colliders was discussed. Consequently, the workshop addressed the interplay of nuclear and particle physics at intermediate energies with atomic physics and high-energy physics.

The centerpiece of the workshop was the future potential of parity-violating electron scattering to explore new physics manifestations that are difficult to access at existing high-energy colliders. Two ultra-precise experiments are being developed for Jefferson Laboratory upon its upgrade of CEBAF to 12 GeV: one would use Moller scattering and the other would explore deep inelastic scattering. While the workshop in particular studied the theoretical and experimental aspects of precision electroweak measurements, it also addressed the nuclear and particle physics and experimental questions relevant to interpreting the electroweak observables that these two new projects would yield to extract information regarding new physics at the multi-TeV scale.

Another important aspect of the workshop was to discuss precision measurements that are directly related to new physics signatures at the energy frontier, and associated theoretical issues. For example, whereas the highest energy collider experiments will search for new particles, in many models it is low-energy precision weak neutral current observables that can constrain quantum numbers of such new particles. In addition, experiments at future facilities at the precision frontier such as flavor factories and proton drivers can make unique measurements of electroweak observables and search for rare processes with unprecedented precision. The goal was to explore the complementarity of experiments at the energy frontier and at the precision frontier. In addition there are currently extensions of the Standard Model that predict signatures in the low-energy domain. Precision low-energy experiments have a unique role to play.

Finally, the workshop explored the possible electroweak physics topics at a high energy polarized electron-light ion collider, focusing on the luminosity and center-of-mass energy needed to access new parity-violating observables.

The workshop concentrated on the interplay among the following four specific topics:

Parity Violating Lepton Scattering: The precision determination of semi-leptonic and purely leptonic low-energy weak neutral current coupling constants is of tantamount importance in constraining models of new TeV scale physics. Precision parity violating electron scattering measurements have evolved as the tool to determine these weak neutral current coupling constants, from which the weak mixing angle can be deduced. Following the completion of the Qweak experiment and the realization of the 12 GeV upgrade of CEBAF at Jefferson Laboratory, a new pair of parity violating electron scattering experiments is foreseen, for not only testing the electroweak aspects of the Standard Model but also elucidating novel aspects of the QCD structure of nucleons and nuclei.

The Moller scattering project proposes to measure the weak mixing angle with an accuracy comparable to the two best such determinations at high energy colliders. No other comparable technique to reach similar accuracy exists over the next decade. The deep inelastic scattering project would yield information on axial-vector quark couplings which are impossible to measure using other low energy techniques. In addition, the latter project would yield information about the partonic structure of nucleons and nuclei that has been difficult to isolate in other deep-inelastic processes, such as higher-twist effects and charge symmetry violation. Looking far into the future, parity-violating electron scattering will provide access to entirely new structure functions at a high energy polarized electron-light ion collider, as well as provide new observables to measure the weak-mixing angle to ultra-high precision.

Electroweak Measurements at the Energy Frontier: The anticipated LHC data should allow for much improved determinations of the masses of the W boson and the top quark, which in turn will further narrow the range of allowed values of the mass of the Higgs boson. In addition, the forward backward asymmetry for electron final states will provide an independent precise determination of the weak mixing angle in a higher momentum transfer region, competitive possibly with the better determinations of the weak mixing angle at the Z^0 pole. It should be noted that the latter two determinations (one semi-leptonic the other pure-leptonic) differ by three standard deviations.

Electroweak and Flavor Physics at the Intensity Frontier: The discovery of neutrino oscillations has renewed theoretical and experimental interest in exploring violations of approximate flavor symmetries. Many theoretical models that predict 'Beyond the Standard Model' (BSM) signals in weak neutral current observables also predict observable signals in lepton flavor violation and flavor-changing neutral currents searches, which would be tested to unprecedented precision in future facilities such as proton drivers and tau-charm and superB-factories. The workshop discussed the phenomenology, the interpretability, and experimental prospects of such measurements. Additionally, the prospects for intense neutrino beams makes precision measurements of neutrino weak neutral current parameters at very high precision feasible, which would complement similar measurements with electrons. The workshop also had arranged a special discussion session on the theoretical interpretations of the NuTeV experiment.

Atomic Parity Violation: The semi-leptonic weak neutral coupling constants are also accessible in atomic parity violation experiments. The electroweak and new physics in atomic parity violation observables are present through the weak charges of heavy nuclei. At the present the most precisely known weak charge is of cesium, obtained from a single isotope; the weak charge of thallium is known with less precision. Currently, there are efforts to measure the weak charges of barium, ytterbium, rubidium, and of the francium isotopes. Thus, future work involves improved single isotope atomic parity violation measurements, where the difficulty lies in the atomic theory of complex many electron systems, and in atomic parity violation measurements of the ratios of weak charges of an isotope series, where the atomic physics dependence to a large extent cancels.

Program Outline: Each of the topics mentioned were introduced by a more general theoretical overview and an experimental overview, followed by more specific talks where there was ample scheduled time for discussions. The workshop was concluded by a synopsis and evaluation of the physics discussed (by Jens Erler). A formulation of recommendations regarding theoretical and experimental endeavors following the workshop has been attached separately as well as the final scientific program ass it took place.

Conclusions:

A synopsis and analysis of the Workshop towards future directions of precision electroweak physics was presented by Jens Erler in the final discourse. Below are given in a succinct form some conclusions and recommendations.

- The ongoing and planned parity-violating electron scattering experiments need to obtain their stated precision in order to be significant tests of the Standard Model.
- Continued evaluations of the radiative corrections and gamma-Z^0 box diagram contributions for the above are warranted.
- Low-energy precision electroweak experiments are not only fully complementary to the high-energy collider experiments but serve also as benchmarks for possible Standard Model extensions in the low-energy domain.
- Atomic parity-violating experiments require great attention to the intricacies of atomic theory (electron configurations). A comparison of the atoms in an isotopic chain will result in the cancellation of difficult to calculate electronic corrections.

- Electric Dipole Moment searches (ongoing and planned) may depend on advances in high-technology instrumentation. With many years of preparatory efforts timely re-evaluations may be necessary.
- There is a definite role for electroweak tests with an electron-positron collider using polarized electrons.

Proponents of the NuTeV experiment together with theorists involved and with Jens Erler as Chair need to formulate the possible nuclear physics corrections to the NuTeV experimental result for inclusion in the PDG Handbook.

3.3.17 VIOLATIONS OF DISCRETE SYMMETRIES IN ATOMS AND NUCLEI

DATE: 15 - 19 November, 2010

ORGANIZERS:

Lorenz Willmann *(University of Groningen, The Netherlands)*
Peter Butler *(University of Liverpool, UK)*
Jeffry Martin *(University of Winnipeg, Canada)*

NUMBER OF PARTICIPANTS: 41

MAIN TOPICS:

The workshop was focused on the violation of the discrete symmetries time reversal, charge conjugation and parity and their observation at low energy, in particular in atomic systems and in weak decays of nuclei. Here, the interplay between different fields in experimental and theoretical physics is crucial all the way from the conceptual design of experiments to the interpretation within established theoretical theories. The topics are at the interface of atomic and nuclear physics at the precision frontier.

The main topics were

d) Symmetry Violations in the theoretical framework
e) Searches for permanent electric dipole moments in light and heavy nuclei
f) New precision measurements of atomic parity violation in order to constrain the Standard Model
g) Weak decays of nuclei to search for symmetry violating correlations
h) Nuclear and atomic structure relevant for symmetry violations
i) Enabling technologies: State of the art experimental methods and facilities for the experimental programs

SPEAKERS:

Koichiro Asahi *(Tokyo Institute of Technology, Japan)*
Douglas Beck *(University of Illinois at Urbana-Champaign, USA)*
Michael Bender *(CENBG, Gradignan, France)*
Robert Berger *(TU Darmstadt, Germany)*
Jacek Bieron *(Uniwersytet Jagiellonski, Krakow, Poland)*
Klaus Blaum *(MPIK, Heidelberg, Germany)*
Yorick Blumenfeld *(CERN, CH)*
Roberto Calabrese *(University of Ferrara and INFN, Italy)*
Timothy Chupp *(Univ. of Michigan, USA)*
Umakanth Dammalapati *(KVI, University of Groningen, NL)*
Alexander Dieperink *(KVI, Groningen, NL)*
Jacek Dobaczewski *(University of Warsaw, Poland)*
Dimitri Dounas-Frazer *(UC Berkeley, USA)*
Erler, Jens *(IF-UNAM, Mexico)*
Peter Fierlinger *(Excellence Cluster, Munich, Germany)*
Gouri Shankar Giri *(KVI, Univ. Groningen, NL)*
Werner Heil *(U. Mainz, Germany)*
Klaus Jungmann *(KVI, University of Groningen, NL)*
Klaus Kirch *(ETH Zürich, Paul Scherrer Institut, CH)*
Frank Maas *(Mainz, Germany)*
Michael Martin *(JILA, Univ. Colorado, USA)*
Dan Melconian *(A&M University, USA)*
Peter Mueller *(Argonne National Laboratory, USA)*
Oscar Naviliat-Cuncic *(NSCL-MSU, USA)*
Cornelis Onderwater *(KVI, Univ. of Groningen, NL)*
Bijaya Sahoo *(PRL, Ahmedabad, India)*
Yasuhiro Sakemi *(Tohoku University, Japan)*
Marcus Scheck *(IKP, TU-Darmstadt, Germany)*
Yannis Semertzidis *(Brookhaven National Lab, USA)*
Eric Tardiff *(TRIUMF, Canada)*
Lotje Wansbeek *(KVI, Uni. Groningen, NL)*
Henricus Wilschut *(KVI, Uni. Groningen, NL)*

SCIENTIFIC REPORT:

Discrete symmetries are at the core of the theoretical description of physics. Their central role require a careful testing of the range of validity of these concepts. The known symmetry violations in the weak interaction and the requirements of three generations of particles is for CP violation is seen as the invitation to look deeper into this topic. The particular emphasis was on permanent electric dipole moments (EDMs), atomic parity violation (APV) and nuclear beta decay. This necessitated the discussion theoretical framework and developments, as well as experimental techniques and infrastructure. The presentations discussed the possibilities in this field and the ongoing activities. In many cases we expect significant results in the next couple of years.

All topics have been presented and were enthusiastically discussed. The workshop started with an overview of the underlying theoretical framework (J. Erler). It was shown that the different types of research on symmetry violations are complementary, e.g. that different systems test different physical models. All the efforts are needed in order to identify the structure of a fundamental theory beyond the Standard Model. For example a precision measurement of parity violation in atoms provides strong constraints in the Standard Model, which are not accessible by other efforts. This was complemented by an overview on experimental work related to the subject of the workshop (K. Jungmann) with an emphasis on precision measurements and rare decay studies and a summary (F. Maas) on the workshop “Precision tests of the Standard Model: From APV to P Violating Lepton Scattering”, ECT*, Nov. 8-12. 2010, with an emphasis on the lepton scattering activities. On this background the workshop moved to the detailed discussion of the main topics.

The discussions of EDMs ranged from new ideas using ions in storage rings (G. Onderwater, Y. Semertzidis, K. Kirch), ultra-cold neutron in superfluid helium and in neutron bottles (D. Beck, K. Kirch, P. Fierlinger), to single or double species noble gas masers (K. Asahi, T. Chupp, E. Tardiff, P. Fierlinger, W. Heil), and heavy atoms trapped in optical dipole traps (Y. Sakemi, P. Mueller, U. Dammalapati). All developments of new experimental techniques as well as the exploitation of new systems, e.g. use heavy radioactive isotopes, were covered. In the detailed discussion the synergy (development in magnetometry, high electric fields) between the different approaches were brought forward, together with the anticipated improvements of EDM limits.

Atomic parity violation is the only pass to the determination of the weak interaction strength in the limit of low momentum transfer. The outstanding result on cesium APV was brought forward more than a decade ago. The presentations showed the promising directions in the field of APV experiments (D. Dunas-Frazer, G. Giri, R. Calabrese). The emphasis was on the gain in sensitivity in systems with large APV amplitudes, single ion approaches and the use of heavy rare isotopes. At this level of sensitivity improvements of atomic structure calculations and the knowledge of nuclear properties, i.e. nuclear charge radii and neutron skin, become indispensable. An alternate route would be APV determinations in a chain of isotopes. The difference between the APV strength for a pair of isotopes reduced the limitations from atomic and nuclear structure at the cost of a higher experimental precision. Correlations in the parameters in nuclear beta decay provide another route to test symmetry violations (H. Wilschut, D. Melconian, O. Naviliat-Cuncic). Some of the observables can be related to limits from EDMs, while other provide complementary results.

On the theory side the nuclear, atomic and molecular issues were brought forward. The theoretical methods are based on similar descriptions in applications to nuclei, atoms and molecules, but encounter different challenges due to the various types and strength of interactions. The status in theoretical descriptions of symmetry violations in nuclei was presented (M. Bender). Detailed discussions of Schiff moments and magnetic quadrupole moments were presented and the connection of these parameters to observable quantities were investigated (J. Dobaczewski, L. Dieperink). This provides a strong motivation for a better determination of these observables, since currently the data are not present or reliable especially for the heavy isotopes used for EDM searches and APV measurements. Atomic structure calculations were discussed in the context of EDM, APV and parity violation in molecules (J. Bieron, B. Sahoo, L. Wansbeek, J. Bieron, R. Berger). The challenges on the APV calculations arise from the high precision which requires the inclusion of all contributions. This was illustrated by the tour de force of calculations over the last decade for the interpretation of the cesium APV result. The theory presentations were an indispensable complement to the discussion of the experiments.

The described work is closely related to developments in state-of-the-art experimental techniques and the availability of facilities. Precision measurements in atomic systems apart from measurements of discrete symmetry violations are the central issue for optical atomic clock developments (M. Martin). The presentations of the neutron EDM experiments discussed the building of new high flux ultracold neutron sources at different facilities. Intense heavy rare isotopes are available at present and the plans for the future were presented (Y. Blumenfeld). Here, the nuclear structure of relevant isotopes, i.e. Rn, Fr and Ra isotopes, can be determined in dedicated experiments (M. Scheck, E. Tardiff) and state-of-the-art nuclear structure research with trapped isotopes (K. Blaum). All facilities have a strong program in other research fields but they welcome initiatives for fundamental symmetry research.

Results and Highlights:

The workshop brought together different communities to discuss their contribution to the searches for discrete symmetry violations. This created a strong overlap between topics which usually are not presented at the same conferences. The participants appreciated this inclusive approach, and used the workshop to refresh or strengthen the connection activities in neighboring fields. The selection of topics was good and coherent. Overlap between theorists (atomic, molecular and nuclear) was beneficial because of different points of view on the same physical problem. The techniques used in the different fields can cross fertilize. Several new contacts were established which have the potential to lead to future collaborations. Many participants expressed interest in repeating such a meeting at an appropriate time to discuss the anticipated results and to keep the coherence in the field.

All speaker had 45 minutes including discussions. This gave sufficient time to go into detail on a specific aspect to be presented without sacrificing the general overview of the work. This format was highly appropriate for the workshop. The time during coffee break lunches and dinners were used to discuss additional details of the presented work. The staff and the facilities at the ECT* provided the basis for the successful workshop.

The interpretation of experimental results in terms of underlying theories require a detailed knowledge of the system under investigation and additional measurements are needed. In case of EDM searches in heavy atomic systems this triggered questions on tabulated data for nuclear structure. In particular, the investigation of odd radon, francium and radium isotopes is needed. Theoretical calculation have linked the observable B(E3) transition strength to the Schiff moment, which is a representation of the strength of the octupole correlations.

It was pointed out that the interpretation of the results should be done in a more general way. As an example the EDM of Hg sets a limit on the nuclear EDM but also limits the electron EDM in a competitive way. Several speakers felt that the complementarity of the results on APV, EDMs and nuclear beta-decays should be better represented in a description in a common framework. This would make the comparison of limits from different experiments more transparent. Furthermore, in such a framework a global fit analysis would become possible.

Atomic structure calculations envelope two frontiers. On the one hand issues on calculational approaches are shared with nuclear and molecular theory. On the other hand questions always arises on the estimated accuracy of the calculations. The deviation of APV extracted from Cs measurements with the Standard Model has been reduced to zero in the last 15 years. How can we be sure that this is the final result? These can only be tested with the availability of measurements on other calculable observables like isotope shifts, hyperfine structure splitting and transition matrix elements. The first experimental results on theory and experiments were reported for the radium ion. In case of atomic parity the absolute nuclear charge radius and the neutron skin is required for the extraction of a weak charge to a level of 0.1%. Optical hyperfine structure and isotope shift measurements are sensitive to changes of the charge radii and the absolute charge radii are nuclear model dependent parameters. The measurement of gamma cascades from muonic atoms was suggested to solve this problem. No such data are available in the interesting range of isotopes near radium. The discussion started at the workshop may lead to a new collaboration to set up this experiment. The experimental efforts have strong overlap in methods, e.g. neutral atom trapping and manipulation, magnetometry together with shielding of magnetic fields and statistics limited precision measurements. Combining the expertise of the participants is essential to tackle the common issues in this highly challenging field of research.

3.3.18 WORKSHOP ON HADRON-HADRON & COSMIC-RAY INTERACTIONS AT MULTI-TEV ENERGIES

DATE: November 29 – December 3, 2010

ORGANIZERS:

David d'Enterria *(PH Department CERN, Geneva, Switzerland)*

Ralph Engel *(IKP, Karlsruhe Institute of Technology, Karlsruhem, Germany)*

Torbjorn Sjostrand *(Dept. of Theoretical Physics, Lund University, Lund, Sweden)*

NUMBER OF PARTICIPANTS: 39

MAIN TOPICS:

The main topics covered during the workshop were

4. QCD predictions for multiparticle production at very high energy and their implementation in Monte Carlo simulation packages: PYTHIA, HERWIG, SHERPA, PHOJET, DPMJET, QGSJET, SIBYLL, EPOS, QGSM, FLUKA;

- theoretical and experimental developments on diffractive and elastic scattering at multi-TeV energies;
- theoretical approaches to understand multi-parton dynamics and underlying event in hadronic collisions;
- theoretical and experimental developments on low-x QCD and forward particle production;
- theoretical developments on modelling of cosmic-ray showers;
- experimental results on inclusive hadron production at the LHC and other colliders (RHIC, HERA, Tevatron);
- latest experimental measurements of cosmic-rays in the 10^{15} - 10^{20} eV range: Auger, HiRes, TA, KASCADE-Grande, Argo, IceCube.

organized around four main blocks:

1. Hadronic collisions at multi-TeV energies: Experimental results
2. Hadronic collisions at multi-TeV energies: Theory
3. Cosmic-rays at Ultra-High Energies: Experimental results
4. Cosmic-rays at Ultra-High Energies: Theory

SPEAKERS:

Bruno Alessandro *(ALICE, Torino)*
Doug Bergman *(HiRes, Salt Lake City)*
Massimo Bongi *(LHCf, Florence)*
Armen Bunyatyan *(HERA, Yerevan & Hamburg)*
Lorenzo Cazon *(Auger, Lisbon)*
David d'Enterria *(Geneva)*
Ivan de Mitri *(ARGO-YBJ, Lecce)*
Paul Doll *(KASCADE-Grande, Karlsruhe)*
Ralph Engel *(SIBYLL, Karlsruhe)*
Karsten Eggert *(TOTEM, Cleveland)*
Maria Garzelli *(FLUKA, Milano)*
Lisa Gerhardt *(IceCube, Berkeley)*
Stefan Gieseke *(HERWIG, Karlsruhe)*
Rohini Godbole *(Bangalore & Geneva)*
Jan Fiete Grosse-Oetringhaus *(ALICE, Geneva)*
Gosta Gustafson *(Lund)*
Thomas Hebbeker *(CMS, Aachen)*
Katsuaki Kasahara *(Tokyo)*
Yoshio Kitadono *(Tsukuba)*
Lev Kheyn *(CMS, Moscow)*
Joanna Kiryluk *(STAR, Berkeley)*
Paolo Lipari *(Roma)*
Sergey Ostapchenko *(QGSJET, Tromso)*
Tanguy Pierog *(CORSIKA, Karlsruhe)*
Olga Piskounova *(QGSM, Moscow)*
Johannes Ranft *(DPMJET-III, Siegen)*
Amir Rezaeian *(Valparaiso)*
Andrey Rostovtsev *(Moscow)*
Nobuyuki Sakurai *(TA, Osaka)*
Sebastian Sapeta *(Paris)*
Sebastian Schleich *(LHCb, Dortmund)*
Holger Schulz *(Berlin)*
Torbjorn Sjostrand *(PYTHIA 8, Lund)*
Lars Sonnenschein *(Tevatron, Aachen)*
Mark Sutton *(ATLAS, Sheffield)*
Ralf Ulrich *(Karlsruhe)*
Klaus Werner *(EPOS, Nantes)*
Korinna Zapp *(SHERPA, Durham)*

SCIENTIFIC REPORT:

The origin and nature of cosmic rays (CRs) with energies between 10^{15} eV and the so-called Greisen-Zatsepin-Kuzmin (GZK) suppression at about 10^{20} eV, recently measured by the HiRes and Auger experiments, remains a central open question in high-energy astrophysics with very interesting connections to particle physics and, in particular, to Quantum Chromodynamics (QCD) at the highest energies ever studied. One key to solving this question is the determination of the elemental composition of cosmic rays in this energy range. The candidate particles, ranging from protons to nuclei as massive as iron, generate "extensive air-showers" (EAS) in interactions with air nuclei when entering the Earth's atmosphere. The determination of the primary energy and mass relies on hadronic Monte Carlo models, which describe the interactions of the primary cosmic ray in the upper atmosphere.

The bulk of particle production in such high-energy hadronic collisions can still not be calculated within first-principles QCD and general principles such as unitarity and analyticity (as implemented in Regge-Gribov theory) are often combined with perturbative QCD predictions for high-pT processes, constrained by the existing collider data (Elab ~ 10^{15} eV). Important theoretical issues at these energies are the understanding of diffractive and elastic hadronic scattering contributions, the description of hadronic forward fragmentation and multi-parton interactions ("underlying event"), and the effect of high parton densities ("gluon saturation") at small values of parton fractional momentum $x = p_{parton}/p_{proton}$. Indeed, at these energies, the relevant Bjorken-x values are as low as 10^{-7}, where effects like gluon saturation and multi-parton interactions, particularly enhanced with nuclear targets, are expected to dominate the early hadron collision dynamics.

The current energy frontier for hadron collisions in the laboratory is reached at the Large Hadron Collider (LHC), currently under operation at CERN. The measurement of inclusive hadron production observables in proton-proton, proton-nucleus, and nucleus-nucleus collisions, at LHC energies (equivalent to Elab ≈ 10^{17} eV) will provide very valuable information on high-energy multiparticle production, and allow for more reliable determinations of the CR energy and composition around the GZK cut-off. In the high luminosity phase of LHC, each bunch crossing will lead to several proton-proton interactions, increasing even more the importance of understanding the background from diffractive and soft particle production. Semi-hard particle physics will allow one to test the boundaries of the applicability of perturbative QCD in the region where low-x gluon saturation phenomena become increasingly important and may even dominate particle production.

All LHC experiments feature detection capabilities with a wide phase-space coverage without parallel, in particular in the forward direction, compared to previous colliders. Such capabilities allow for a (fast) measurement of global hadron-hadron collision properties (inelastic - including diffractive - cross sections, particle multiplicity and energy flows as a function of pT and pseudorapidity, …) even with the moderate statistics of a first pp and PbPb run. The aim of the Workshop was to discuss theoretical and experimental issues connected to hadronic interactions of common interest for high-energy particle and cosmic-ray physics. With the recent high-quality cosmic-ray results from the HiRes and Auger experiments and the first available LHC data it seemed a timely moment to have such a meeting in autumn 2010. The Workshop brought together experts, both theorists and experimentalists, in QCD and cosmic-ray physics in view of expanding the mutually beneficial interface between two communities currently exploring the physics of strong interactions at the highest energies accessible.

Results and Highlights:

The Workshop was a very useful opportunity to discuss all the aforementioned interdisciplinary physics topics, and this was in fact perceived by all the participants. The fact that three different, yet closely related, communities - such as high-energy particle, high-energy nuclear and particle astrophysics - with a 50%-50% component of theorists and experimentalists each presented their results to an audience which was not always fully aware of the details of the measurements/ calculations resulted in a extremely stimulating environment where illuminating discussions were the rule. Beyond doubt, the central characteristics of the meeting was the very open and live discussions that took place during and after each one of the talks (as a matter of fact, the average time per talk turned out to be about 1 hour in all 4 sessions and the schedule extended systematically 2-3 hours beyond the originally planned timetable every day), that helped clarifying many open issues in the experimental and theoretical field of high-energy hadronic interactions. As a result of the discussions, various scientific collaborations between participants were either strengthened or started up after the workshop.

3.4 Doctoral Training Program in 2010

"Nuclear structure and astrophysics with radioactive ion beams"

The 2010 ECT* Doctoral Training Program on *Nuclear structure and astrophysics with radioactive ion beams* started on April 12 and is scheduled to end on June 11, 2010. The week of May 10-14, 2010 was left free so that the lectures lasted for 8 weeks. The coordinators of the program were Hans Feldmeier (GSI), Hendrik Schatz (National Superconducting Cyclotron Laboratory) and Jeff Tostevin (University of Surrey).

It was attended by 18 full-time and 7 part time students. The list of students is appended at the end of this report. This is an increase of 6-8 students as compared to the past three Doctoral Training Programs which is a positive development. The students were all working on their PhD. Among the full time students, 10 were experimentalists and 8 theoretical physicists, a substantially larger proportion of experimentalists than in the previous Doctoral Training Programs.

The finance, lodging and other administrative tasks of both the students and the lecturers were taken care of by Serena degli Avancini.

The present Doctoral Training Program differs from the previous ones in several aspects.

There were 19 invited lecturers which represents an average of 2 ¼ lecturers per week. This is more than twice the number of lecturers per week, as compared to the previous Doctoral Training Programs. This completely changed the nature of the Doctoral Training Program. Although a small number of lecturers stayed for a whole week, most of them stayed only for 2 or 3 days. As a result, most of the lectures (for the most part PowerPoint presentations, more on this below) were similar to invited (albeit introductory) talks delivered in meetings, instead of being lectures designed to give the students a solid theoretical background. In past Doctoral Training Programs one lecturer was invited for each week. This allowed the lecturer to make a thorough presentation of the theory, to remain at ECT* in the afternoons to either organize exercise sessions or to be available for discussions with the students in the afternoons. In the present Doctoral Training Program, only two lecturers (Bradley Meyer and Hendrick Schatz) organized afternoon exercise sessions. One lecturer (Daniel Baye) told me that he had offered to do so but had been told that it was not necessary. Another lecturer (Rehm) told me that he was simply told that the students were preparing a PhD on astrophysical applications of nuclear physics and had been given no further instructions. The number of lecturers and the relatively small number of lectures which they had time to give, made it difficult to coordinate the lectures. All too often the lecturers referred to previous lectures without realizing how quickly they had been delivered. In short, the program was closer to a meeting than to a school, which may not be what students, still working on their PhD, need most.

Another innovation was the scheduling, during the first week, of 18 half-hour talks, during which the 18 full-time students presented themselves and described their research project. This was an innovation designed to allow the students to get to know each other from the outset and to prompt discussions among them. In past Doctoral Training Programs, during the first week, one afternoon was devoted to roughly 5 minute presentations during which the students introduced themselves. Then, each week, two one-hour seminars were scheduled and given by the students. The seminars were announced on the ECT* Web page and occasionally attended by physicists in the university in Povo for example. Personally, I found that these seminars were much better prepared and instructive for all.

The volcano eruption in Iceland kept Jeff Tostevin and Ron Johnson grounded and prevented them from giving introductory lectures on nuclear reactions during the second week of the Doctoral Training Program. So they shifted their lectures during the afternoons of the third week.

As in all the previous reports, I reiterate the importance of lecturing on the board and of avoiding the use of PowerPoint, except for showing, for example, numerical results. The abuse of PowerPoint is getting worse every year and most lecturers took no notice of the fact that they were encouraged by the coordinators to lecture on the blackboard. Of course it requires more work on their behalf to present their lectures on the board. The fact that they can cover less material on the board is almost an advantage. A few lecturers took the trouble to use the board (Nunes, Baye, Meyer, Schatz, van Isacker) and their lectures were an excellent illustration of this point.

The lecturers made their PowerPoint presentations available on the Web site http://wkserver.wks.ect.it/~gripka/Docs/ which is accessible only from ECT*. Three lecturers (Baye, Feldmeier and Isacker) left lecture notes.

Towards the end of the program, the students were asked to write an informal report on their experience during the Doctoral Training Program. The reports were handed to the director of ECT*.

3.4.1 The Lecture Programme

During week 1 (April 12 - 16)

Filomena Nunes *(NSCL/MSU East Lansing, USA)* gave an overview of the coming lectures and continued with some very useful introductory lectures on nuclear reactions, explaining various ways (cross-sections, phase shifts, T- and S- matrices, resonances,…) to parameterize and to understand experimental results. Most of her lectures were delivered on the board but unfortunately she stayed only two days. In the absence of Feldmeier, who was prevented from coming, **Georges Ripka** (*ECT* and IPhT Saclay*) lectured on some basics tools (second quantization, diagonalization of quadratic hamiltonians, thermal expectation values, pi-exchange and tensor interactions).

During week 2 (April 19 - 23)

Pier Francesco Bortignon (*University of Milan*) evoked Hartree-Fock theory, collective excitations and particle-vibration coupling. **Lorenzo Fortunato** (ECT*) offered to lecture in the absence of Tostevin and Johnson, grounded by the Icelandic volcano. He gave a rather extensive overview of the Interacting Boson Model and of group theoretical methods used to diagonalize the corresponding model hamiltonians.

During week 3 (April 26 - 30)

Marialuisa Aliotta *(University of Edinburgh)* lectured on the synthesis of heavy elements in stars. She explained how rates of fusion in stars were estimated and indicated what experiments could improve these estimates. Too much was crammed into PowerPoint slides. **Hans Feldmeier** (*GSI Darmstadt*) gave one lecture explaining the measurement of neutrino oscillations. He distributed to the students hand-written notes. **Daniel Baye** (*ULB Brussels*) gave detailed lectures on nuclear reactions and on the cluster model. His lectures were entirely on the board except for figures showing results and data. Some lectures were given by **Jeff Tostevin** *(University of Surrey)* and **Ron Johnson** *(University of Surrey)* during the afternoons.

During week 4 (May 3 - 7)

Tom Aumann (*GSI Darmstadt*) described present and future experiments with high energy radioactive beams, mostly the future FAIR facility in GSI. The lectures were descriptive PowerPoint presentations. **Takaharu Otsuka** (*University of Tokyo*) lectured on observed shell closures observed in either neutron or proton rich nuclei far from the stability line. He explained how tensor interactions between nucleons could explain some shell closures. His lectures were completely PowerPoint presentations, mostly qualitative descriptions of his own work.

During week 5 (May 10 - 14) there was a break with no lectures.

During week 6 (May 17 - 21)

Bradley Meyer (*Clemson University*) lectured on nucleosynthesis, and he described codes written to evaluate the distribution of nuclei synthesized in stars. He made the codes available to students and organized afternoon exercise sessions during which they could make them run. He lectured on the black board. **Gabriel Martinez Pinedo** (*GSI Darmstadt*) gave almost completely PowerPoint lectures on nucleosynthesis. Since both Bradley Meyer and Gabriel Martinez Pinedo lectured during the same week, never had there been a better example of how much better lectures are when they are presented on the board.

During week 7 (May 24 - 28)

Hendrik Schatz (*NSCL/MSU East Lansing*) lectured on the r-process and its sensitivity to nuclear reaction processes. He distributed codes for practical exercises in which the students could compute the distribution of nuclei in stars, assuming various parameters. These were most instructive lectures and Schatz made a large effort to communicate with the students. **Piet van Isacker** (*GANIL Caen*) explained how to solve the Bohr hamiltonian which describes quadrupole rotations and vibrations in nuclei. His presentation was carefully written on the board and he left hand-written notes. **Remco Zegers** *(NSCL/MSU East Lansing)* lectured on charge exchange reactions at intermediate energies.

During week 8 (May 31- June 4)

Ernst Rehm (*ANL Argonne*) lectured on direct and indirect methods to measure reaction rates which are important for the abundance of nuclei formed in stars. His 99 % Powerpoint lectures presented new results as they would be in a conference. **Stefan Typel** (*TU Munich*) lectured on the nuclear matter equation of state and astrophysical applications.

The lectures of week 9 were given by **Thomas Neff** (*GSI Darmstadt*), **Andrea Vitturi** (*INFN Padua)*, and **Roland Diehl** (*MPE Garching*) on the following topics: Ab initio nuclear structure models, effective nucleon-nucleon potentials, exotic structures and fermionic molecular dynamics; weakly bound systems, S factors, role of breakup, fusion hindrance at very low energies; Observational high-energy astrophysics.

3.4.2 List of the Participants

Full time students

Bally Benjamin	CNR/IN2P3, Univ. of Bordeaux, France
Evers Maurits	The Australian National Univ., Australia
Figueira Juan Manuel	Tandar Laboratory National Atomic Energy Commission, Argentina
Hackstein Matthias	Instituet fuer Kernphysik, Germany
Kuti Istvan	ATOMKI, Hungary
Luong Duc H.	The Australian National Univ, Australia
Marketin Tomislav	Univ. of Zageb, Croatia
Meharchand Rhiannon	NSCL/MSU, US
Mendoza-Temis Joel	GSI, Darmstadt
Najafi M.Ali	KVI, Groningen, The Netherlands
Nomura Kosuke	Univ. of Tokio, Japan
Olaizola Bruno	Universidad Complutense de Madrid, Spain
Rangel Pestana	Universidade de San Paulo, Brasil
Tsunoda Naofumi	Univ. Of Tokio, Japan
Vernardos Georgios	Université Libre de Bruxelles, Belgium
Volkov Vasily	TU Darmstadt/GSI, Germany
Weber Dennis	GSI, Darmstadt, Germany
Xu Zhenxiang	Albanova University Center Royal Institute, Sweden

Part time students

Diaz Fernandez Paloma	Univ. Santiago de Compostela, Spain
Druet Thomas	Universite Libre de Bruxelles, Belgium
Elseviers Jytte	Catholique University Leuven, Belgium
Gottardo Andrea	Laboratorio Nazionale Legnaro, Italy
Kim Yeunjin	University of Chicago, USA
Pinilla Edna Carolina	Université Libre de Bruxelles, Belgium
Steiger Konrad	TU Muenchen, Germany

3.4.3 Seminar delivered by the students

Bally Benjamin

Odd-A nuclei, HF + projection, Skyrme force

Evers Maurits

Multi-nucleon transfer processes near fusion barrier

Figueira Juan Manuel

Transfer reactions with radioactive beams, 30P (alpha,p) 32S reaction in ATLAS, Argonne

Hackstein Matthias

Inverse coulomb excitation, gamma coincidences, 128Xe to Fe, in Jyvaskyla

Kuti Istvan

3-gamma coincidence experiments, search for chirality in 132La and 134 Pr

Luong Duc H.

Back angle scattering, breakup into alpha or alpha-t

Marketin Tomislav

Neutrino capture rates

Meharchand Rhiannon

7Li, 7Be inverse charge exchange reactions done at MSU. DelatL=0 deltaS=1 Gamov Teller transitions.

Mendoza-Temis Joel
Nuclear mass formulae, monopole Zucker interactions

Najafi M.Ali
Exotic nuclei seen with light ion beams

Nomura Kosuke
IBM models based on HF calculations with skyrme forces
Olaizola Bruno
Measurement of ½ lives 221Fr and 224Fr in ISOLDE and alpha decay

Rangel Pestana
Peletron accelerator, 8 MeV Tandem in San Paolo gamma ray spectroscopy of odd-odd nuclei

Tsunoda Naofumi
Renormalisation of the tensor force in effective interactions, v_low k

Vernardos Georgios
Neutron star crust calculation using local density (Kirkwood) approximation

Volkov Vasily
Mesurement of knock out reactions in GSI at 700 MeV/A and ELISA electron knock out reactions. Design of luminosity detector

Weber Dennis
V_low k and silarity transformations

Xu Zhenxiang
Multistep shell model calculations

3.5 AURORA School in 2010

DATE: September 20 - October1, 2010

ORGANIZERS:

F. Pederiva *(University of Trento, Italy)*
F. Di Renzo *(University of Parma, Italy)*
W. Leidemann *(University of Trento, Italy)*
L. Scorzato *(ECT*, Italy)*
P. Verrocchio *(University of Trento, Italy)*

NUMBER OF PARTICIPANTS: 34

MAIN TOPICS:
The school covered a few selected topics in computational methods commonly employed in nuclear physics, high-energy physics, and statistical physics, with the addition of technical sessions describing the architecture of the novel high performance computing system Aurora, related software and applications. Two seminars were devoted to computational applications in other areas. The detailed list is the following:

- Monte Carlo Methods for Statistical Physics and Critical Phenomena
- Few-body Methods in Nuclear Physics
- Lattice QCD
- Quantum Monte Carlo Methods for Nuclear Physics
- The Aurora Architecture
- Software and Applications for the Aurora System
- Genomics Applications on Aurora
- Nucleon Transport Simulations on Aurora for Proton Therapy

SPEAKERS:

Scientific Sessions:
Alexandrou C. *(University of Cyprus, Cyprus)*
Barnea N. *(Hebrew University of Jerusalem, Israel)*
Pelissetto A. *(University of Rome, "La Sapienza", Italy)*
Schmidt K.E. *(Arizona State University, USA)*

Technical Sessions:

Schifano F. and Pivanti M. *(University of Ferrara and INFN, Italy)*

Alfieri R. and Grossi M. *(University of Ferrara and INFN, Italy)*

Topical Session:

Schwarz M. *(A.Tre.P., Italy)*

Cilia E. *(Edmund Mach Foundation, Italy)*

SCIENTIFIC REPORT:

The First Aurora School was organized in the framework of the AuroraScience collaboration. AuroraScience is a research project at the crossroad of computational sciences 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 compute-based areas of physics (Lattice Gauge Theory, Computational Fluid-Dynamics, Molecular Dynamics, Few- and Many-body Nuclear Physics), Quantitative-Biology (Protein Folding), Bio-Informatics (Gene-Sequencing) and Medical Physics.

The school aimed at educating young scientists, together with high quality short courses on selected topics in computational science given by world class scientists, on the architecture and the possible applications of the Aurora machine. The main goal has been to create a wide basis of possible users in different institutions in Europe and worldwide.

In this first school the focus was kept on algorithms and applications in nuclear physics and high-energy physics. The targeted attendees were graduate students and Ph.D. students working on related topics. The participations of young post-docs was also encouraged.

The level of the scientific courses was meant to be introductory. The first week hosted the classes of Andrea Pelissetto on basic Monte Carlo techniques for statistical physics, with an introduction to specific techniques for improving the sampling of statistical ensembles near a phase transition, which are of common use also in other fields of physics. In the same week Nir Barnea illustrated methods commonly employed in few-body simulations, from a direct

diagonalization of the Hamiltonian to the most sophisticated methods like the Lorentz Integral Transfom.
In the second week Constantia Alexandrou presented an introduction to LQCD methods, and Kevin Schmidt illustrated the advanced Quantum Monte Carlo methods employed nowadays to study non-relativistic nuclear Hamiltonians.
Despite the fact that the topics appear to be spread on a wide range of physical applications, the technical aspects are in many cases very similar, and the participants were stimulated to find the connections between the different topics introduced.

The technical sessions were divided in two sections. The first section dealt with a basic introduction to the architecture of the Aurora system, mainly in order to make the participants familiar with the concept of double data transport network that characterizes the machine. This part was coordinated by Fabio Schifano. In the second week the focus was moved to the software that has been developed to operate the machine. In both sessions the students had the possibility to directly explore and exercise the notions that were presented in the classes.

The presence of two speakers operating in fields not directly covered by the school (Genomics and proton transport) was meant to give to the attendees a sense of the broad range of topics that are covered by the AuroraScience collaboration, and to stimulate the interest towards other possible applications.

General Evaluation

The school characterized itself for a very high standard of lectures and for an active participation of the students. The attendance to all the proposed courses and seminars has been regular and constant. The limited overlap of presence of the various speakers did not foster new interaction. However there have been occasions for an exchange of scientific and technical competences, in particular concerning the peculiar aspects of the Aurora architecture.
The response among the students was rather high. Many of them actively contributed and kept the level of the discussion on a high standard. Also the practical sessions were appreciated, although some of the attendees expected even more focus on practical applications and real programming. This aspect has to be taken into account in view of the possibility of organizing a second edition of the Aurora school

4 Research at ECT*

In this chapter the activities of the scientific researchers at ECT* in 2010, 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 within the researchers at the ECT*, but on the other hand all researchers 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 three – Daniele Binosi, 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.

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 the effects correlations [3], ascribed to the action of the tensor operator in 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]. We recently planned a new collaboration with the group of Prof. Eskola (University of Jyvaskyla, Finland) for the study of the effects of correlations and received a mobility grant under the program HPC-Europa2 to be used in the year to come to establish such a collaboration.

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. [7] 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 [7,4]. These quantities have been successfully used for the calculation of high-energy hadron-Nucleus cross sections, showing the relevance of correlation effects on such reactions. We are now in the process of extending 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 [10,11].

Parton correlations and multiple partonic interactions

In collaboration with D. Treleani (University of Trieste & INFN)

Multiple Partonic Interactions [12] are the tool to obtain information on the correlations between partons in the hadron structure. 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. It has been shown in [13] that the effects of longitudinal and transverse correlations may be disentangled investigating double parton interactions in high energy proton-deuteron collisions. The aim of the collaboration is to perform detailed calculations with a realistic deuteron wave function in order to i) quantitatively evaluate the effect of the smearing due the use of the deuteron ii) describe partonic correlations in a model independent way.

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Daniele Binosi

Quantum information processing and communication

After the ending of the European Coordination Action QUROPE a new project QUIE^{2}T started in February. On top of acting as the Executive Secretary I am actively involved in the following work-packages:

j) **WP2: Strategy Vision and Sustainability**
WP leader: T. Calarco (Ulm)

The aim of WP2 is twofold. On the one hand, it will provide the community with a widely accepted comprehensive strategic vision and future goals of QIPC research; on the other hand it will explore possible ways to ensure the future sustainability of the field. These goals will be mainly achieved through the elaboration of a series of documents and tools serving the WP different purposes, which will be maintained and regularly updated.

k) **WP3: Dissemination activities**

WP leaders: I. Wamsley (Cambridge)

The aim of this work package is to increase the general visibility of QIPC related research in Europe, and to assure a constant information flow within the community and beyond. This will be achieved specifically via

- The setup of a comprehensive web site
- The setup of adequate means for efficient information exchange and dissemination
- An increase of the general public visibility of QIPC related research

The central piece of work to be delivered by this work package is the project web site, which will serve as the main source of information and focal point to represent the project. Besides its representative function, it will also serve as a major information exchange and communication platform for the community.

The second main objective of this work package is the outreach to other communities, in particular industries, the general public and political representatives. This will be achieved by a sustained public relations campaign, including publications in political and popular media and press releases.

One specific aim is targeted at the sustained awareness of the general public to ensure broader acceptance and understanding of QIPC related issues in particular, and science in general. The collected media contributions will also provide a helpful indicator for the excellence of European research in the context of international competition.

Non-perturbative Quantum Chromo-Dynamics

During 2010 my research activity has focussed on exploring the properties of the new truncation scheme for the Schwinger-Dyson equations of QCD we have recently developed, especially in the context of low dimensional QCD. I have been also invited in several international conferences where such aspects were thoroughly discussed.

Finally, we have finished the writing of the monograph on the Pinch Technique written in collaboration with Prof. J. Cornwall (Emeritus Professor of Physics at UCLA, USA) and Prof J. Papavassiliou (University of Valencia) that has been published in December by Cambridge University Press.
The main scientific results are listed below.

The pinch technique and its applications to non-Abelian gauge theories

Book written in collaboration with J. M. Cornwall (UCLA, US)
and J. Papavassiliou (University of Valencia, Spain)

Non-Abelian gauge theories, such as quantum chromodynamics (QCD) or electroweak theory, are best studied with the aid of Green's functions that are gauge invariant off-shell, but unlike for the photon in quantum electrodynamics, conventional graphical constructions fail. The pinch technique provides a systematic framework for constructing such Green's functions and has many useful applications.
Beginning with elementary one-loop examples, this book goes on to extend the method to all orders, showing that the pinch technique is equivalent to calculations in the background-field Feynman gauge. The pinch technique Schwinger-Dyson equations are derived and used to show how a dynamical gluon mass arises in QCD. Applications are given to the center vortex picture of confinement, the gauge-invariant treatment of resonant amplitudes, the definition of non-Abelian effective charges, high-temperature effects, and even supersymmetry. This book is ideal for elementary particle theorists and graduate students.

A dynamical study of the Kugo-Ojima function

As has been recently realized, a certain two-point function Λ -- and its associated form factors G and L -- play a prominent role in the PT-BFM formulation of the Schwinger-Dyson equations used to study gauge-invariantly the gluon and ghost propagators. After showing that in the (background) Landau gauge Λ fully constrains the QCD ghost sector, we show that G coincides with the Kugo-Ojima function u, whose infrared behavior has traditionally served as the standard criterion for the realization of the Kugo-Ojima confinement mechanism. The determination of the behavior of G for all momenta through a combination of the available lattice data on the gluon and ghost propagators, as well as the dynamical equation G satisfies, will be then discussed. In particular we will show that in the deep infrared the function deviates considerably from the value associated with the realization of the Kugo-Ojima confinement scenario; the dependence on the renormalization point of u, and especially of its value at q=0, will be also briefly discussed.

Dynamical gluon mass generation and the IR sector of QCD

We review the Pinch Technique - Background Field Method (PT-BFM) framework for formulating and solving the Schwinger-Dyson equations of Yang-Mills theories. In particular, we show how within this framework it is possible to write a new set of Schwinger-Dyson equations that (i) accommodate the dynamical gluon mass generation through Schwinger's mechanism, and (ii) have much better truncation properties than the conventional equations. The resulting solutions show (in the Landau gauge) an infra-red saturating gluon propagator and ghost dressing function, in agreement with all lattice studies to date for both SU(2) and SU(3) gauge groups as well as 3 and 4 space-time dimensions. We also briefly discuss how a massive gluon enables self-consistently confinement through the condensation of thick vortices, and study other infra-red characteristic quantities such as the Kugo-Ojima function and the effective charge.

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

Important information about the infrared dynamics of QCD is encoded in the behavior of its (of-shell) Green's functions, most notably the gluon and the ghost propagators. Due to recent improvements in the quality of lattice data and the truncation schemes employed for the Schwinger-Dyson equations we have now reached a point where the interplay between these two non-perturbative tools can be most fruitful. In this talk several of the above points will be reviewed, with particular emphasis on the implications for the ghost sector, the non-perturbative effective charge of QCD, and the Kugo-Ojima function.

Nonperturbative gluon and ghost propagators for d=3 Yang-Mills theories

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

We study a manifestly gauge invariant set of Schwinger-Dyson equations to determine the nonperturbative dynamics of the gluon and ghost propagators in d=3 Yang-Mills. The use of the well-known Schwinger mechanism, in the Landau gauge, leads to the dynamical generation of a mass for the gauge boson (gluon in d=3), which, in turn, gives rise to an infrared finite gluon propagator and ghost dressing function. The propagators obtained from the numerical solution of these nonperturbative equations are in very good agreement with the results of SU(2) lattice simulations.

QCD effective charges from lattice data

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

We use recent lattice data on the gluon and ghost propagators, as well as the Kugo-Ojima function, in order to extract the non-perturbative behavior of two particular definitions of the QCD effective charge, one based on the pinch technique construction, and one obtained from the standard ghost-gluon vertex. The construction relies crucially on the definition of two dimensionful quantities, which are invariant under the renormalization group, and are built out of very particular combinations of the aforementioned Green's functions. The main non-perturbative feature of both effective charges, encoded in the infrared finiteness of the gluon propagator and ghost dressing function used in their definition, is the freezing at a common finite (non-vanishing) value, in agreement with a plethora of theoretical and phenomenological expectations. We discuss the sizable discrepancy between the freezing values obtained from the present lattice analysis and the corresponding estimates derived from several phenomenological studies, and attribute its origin to the difference in the gauges employed. A particular toy calculation suggests that the modifications induced to the non-perturbative gluon propagator by the gauge choice may indeed account for the observed deviation of the freezing values.

On the dynamics of the Kugo-Ojima function

After reviewing the dynamical gluon mass generation mechanism within the pinch technique framework and its phenomenological predictions, we will introduce the modern formulation of the pinch technique which makes extensive use of the Batalin-Vilkovisky quantization formalism. In this framework a certain auxiliary function $\Lambda_{\mu\nu}(q)$ - and its associated form factors $G(q^2)$ and $L(q^2)$ - play a prominent role. After showing that in the (background) Landau gauge $\Lambda_{\mu\nu}(q)$ fully constrains the QCD ghost sector, we show that $G(q^2)$ coincides with the Kugo-Ojima function $u(q^2)$, whose infrared behavior has traditionally served as the standard criterion for the realization of the Kugo-Ojima confinement mechanism. The determination of the behavior of $G(q^2)$ (and therefore of the Kugo-Ojima function) for all momenta through a combination of the available lattice data on the gluon and ghost propagators as well as the dynamical equation $G(q^2)$ satisfies, will be then discussed. In particular we will show that (i) in the deep infrared the function deviates considerably from the value associated with the realization of the Kugo-Ojima confinement scenario, and (ii) establish the dependence on the renormalization point of $u(q^2)$, and especially of its value at $q^2 = 0$.

Marco Cristoforetti

Complex Langevin and lattice QCD

In collaboration with L. Scorzato (ECT) and F. Di Renzo (University of Parma)*

It is well known that at finite chemical potential the fermionic term of the QCD Lagrangian becomes complex and Monte-Carlo methods are no longer applicable to lattice QCD. Indeed the failure of the importance sampling prevents the possibility to select the gauge configurations that mostly contribute to the path integral (sign problem). Trying to overcome this obstacle, one of the possibilities that have been recently taken into account is the stochastic quantization of the system described by a complex action, applying Langevin dynamics [1]. As a starting step towards application of this method to QCD, we plan to study the properties of convergence of the complex Langevin dynamics applied to the instanton model.

Improving hadron creation operators on the lattice

In collaboration with M. Dalla Brida (University of Trento), L. Scorzato (ECT), C. Alexandrou and M. Gravina (University of Cyprus)*

In order to study hadron spectroscopy using lattice QCD we need to pay particular attention to the to the operators creating the hadron from the gauge configuration. From the different available solution very promising seems to be the use of the so called Laplacian Heaviside smearing [2]. In the tmLQCD collaboration we are combining this technique with the one-end trick method in the study of meson spectroscopy. As a second step we will move to the baryon sector where of particular interest will be the analysis in this framework of the meson-baryon scattering.

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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] 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 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 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 relates 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 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 quantum chaos 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 are extending the work in [10] by analyzing mesons and other statistics that can be meaningful as well as studying how unknowns in the spectra affect the conclusions.

Electric form factor of the neutron at high momentum transfer

As a member of the GEN and Hall A Collaborations at Thomas Jefferson National Accelerator Facility (Newport News VA, USA)

The GEN Collaboration proposed in 2002 the measurement of the electric form factor of the neutron using the reaction He-3(e,e'n)pp with polarized Helium and incoming electron at Q^2=3.4 GeV^2 and the experiment was performed in 2007. This past year, the first paper regarding this experimental effort was published in Physical Review Letters [11]. To know the electric form factor of the neutron in a wide momentum-transfer range is of great importance in order to fully understand the nucleon in terms of the QCD degrees of freedom and to test our theoretical knowledge. This experiment has been a step further in this research and a longer article with the full details of the experiment and the analysis is currently under elaboration.

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Lorenzo Fortunato

I have continued the investigation of several themes, in particular the study of the spectral features of shape phase transitions in even and odd nuclei and the issue of triaxiality (first and second topics below) and the calculation of observables of interest in break-up reactions involving halo or cluster nuclei. A common mathematical substrate has been the application of symmetry principles to many-body quantum physics with application to nuclear and molecular systems (third and fourth topics below). In addition, I have:

- strengthened the ongoing collaborations and opened new ones with several experimental groups (sixth topic) and with a mathematician from Trento University (third topic).

- started a new research on a coordinate systems and solution method for the non-relativistic many-body Schrödinger equation (seventh and eighth topics).

Shape phase transitions in odd-even nuclei

In collaboration with M. Böyükata (Kırıkkale, Turkey), A. Vitturi (University of Padova), J.M. Arias and C. Alonso (University of Seville, Spain)

Shape phase transitions in odd-*A* nuclei have been investigated within the framework of the interacting boson-fermion model (IBFM). The case of a single $j = 9/2$ fermion coupled to an even-even boson core is considered. This boson core transits from spherical to γ -unstable shapes depending on the value of a control parameter in the boson Hamiltonian. The effect of the coupling of the odd particle to this core along the shape transition and, in particular, at the critical point is discussed [1]. These results have been presented at the Workshop in Kaziemierz Dolny (Poland).

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

In collaboration with A. Vitturi (University of Padova), 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 [2,3]. 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.

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 the conference in Newcastle.

Phase diagrams of tetra-atomic ABBA molecules in algebraic models

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 characterized this phase diagram and its phase transitions.

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].

Coordinate transformations that separate the center of mass motion

We derive and analyse the most general transformations of coordinates that allow for the exact separation of the kinetic energy operator of a quantum many-body system into total center of mass kinetic energy and internal kinetic energy. We have found that the appropriate transformations, depending on the number of particles, have a certain number of free parameters. This allows for the generalization of the Jacobi coordinates to a much larger class of coordinates with the same properties. We find a new, uncommon, additive group structure hidden in the transformation matrices that is related to certain geometric properties of the set of coordinates [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 Lödwin 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.

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Bingwei Long

π N Scattering in the resonance regions in an Effective Field Theory

*In collaboration with U. van Kolck (University of Arizona)
and V. Lensky (University of Manchester)*

Following the previous study on pion-nucleon scattering around the delta-isobar resonance [1], we extend our generalized version of heavy-baryon chiral perturbation theory to include the Roper resonance [2]. The other direction we are pursuing is to refit the low energy constants of pi-pi-N-N "seagull" couplings in the context of explicit delta-isobar degrees of freedom [3]. These low energy constants are important inputs to NNLO two-nucleon and subleading three-nucleon chiral forces.

Heavy-particle formalism with Foldy-Wouthuysen representation

In collaboration with V. Lensky (University of Manchester)

Utilizing the Foldy-Wouthuysen representation, we use a bottom-up approach to construct heavy-baryon Lagrangian terms, without employing a relativistic Lagrangian as the starting point [4]. The couplings obtained this way feature a straightforward 1/m expansion, which ensures Lorentz invariance order by order in effective field theories. We illustrate possible applications with two examples in the context of chiral effective field theory: the pion-nucleon coupling, which reproduces the results in the literature, and the pion-nucleon-delta coupling, which does not employ the Rarita-Schwinger field for describing the delta-isobar, and hence does not invoke any spurious degrees of freedom. In particular, we point out that one of the subleading pi-N-delta couplings used in the literature is in fact redundant, and discuss the implications of this.

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Stefano Melis

Transverse Momentum Dependent distribution and fragmentation functions

In collaboration with M. Anselmino (University of Torino) V. Barone (Universit del Piemonte orientale A. Avogadro), 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 our last papers [2,3] we concentrated our attention to the phenomenological extraction of the

Boer-Mulders and Sivers functions from the HERMES and COMPASS collaborations Semi-inclusive deep inelastic (SIDIS) data. In our analysis we use a simple Gaussian model for the parton transverse motion, a simplified evolution and simple factorized parametrizations. Our analysis shows that the valence Sivers and Boer-Mulders functions are both sizeable. Moreover u and d Sivers function are opposite in sign, while valence Boer-Mulders functions have the same sign. In our fit the Boer-Mulders functions are assumed to be proportional to the Sivers functions. The proportionality factors extracted are in agreement with several theoretical models. We extended our analysis of the Boer-Mulders functions to Drell-Yan processes [4]. We found that the sea Boer-Mulders functions are not negligible. However we also pointed out that the phenomenological extraction of the TMDs done taking into account both SIDS and Drell-Yan data presents some difficulties: the mean parton transverse momentum seems to be different for different processes and energies. Therefore a more accurate phenomenological analysis (or a theoretical answer to the problem of the TMD QCD evolution) is needed.

In Ref. [5] we analyse the polarized SIDIS processes in a formal way, in the context of a generalized parton model by means of the helicity formalism. We show that there is a full equivalence (at leading twist) between the helicity formalism and the “hadron correlator” approach (for a review on the hadron correlator approach see Ref. [1]).

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Laura Muñoz Muñoz

Chaos in hadrons

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

The problem of missing resonances in the low-lying baryon spectrum has been approached from the point of view of Quantum Chaos [1,2]. By using spectral statistics it has been found that the experimental spectrum is compatible with GOE statistics, while the theoretical spectra (from quark models) are quite close to Poisson statistics [2]. But an experimental spectrum with missing resonances should be closer to Poisson statistics than any theoretical one. Thus concluding that quark models, in their present form, may not be suitable to reproduce the low-lying baryon spectrum and therefore to predict missing resonances. We are currently working in an improved analysis to give stronger support to this result. In addition, we are studying how the uncertainties in the experimental data could affect the conclusion and we are extending the analysis to the experimental meson spectrum.

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 [3].

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 particules, and the complex eigenvalues of a matrix. Then we perform 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 [4]. 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 modelling 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 [5]. Precisely because they are more realistic models they are also more complicated, meaning that correlations between the matrix elements make much more difficult a theoretical approach 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 [6].

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Achim Richter

In my second full year at ECT I have - as in 2008 and 2009 before - continued working closely with collaborators from my home institution, the Technical University of Darmstadt, and from elsewhere mainly on problems in nuclear structure and nuclear astrophysics , in accelerator physics, in quantum chaos and in modeling graphene through photonic crystals with microwaves.*

The names of the respective collaborators are listed in the references cited.

Three-body correlations in the decay of ^{10}He and ^{13}Li

The very exotic nuclear resonance systems, ^{10}He and ^{13}Li, produced in proton knock-out reactions from relativistic ion beams of ^{11}Li and ^{14}Be, respectively, at the heavy-ion accelerator facility SIS at GSI Darmstadt, were studied. In particular the measured energy and angular correlations between their decay products, ^{8}He+n+n and ^{11}Li+n+n were analyzed using an expansion of decay amplitudes from a set of spherical harmonics with the result that the ^{8}He+n+n relative energy spectrum provides evidence for two resonances, a 0^+ ground and an excited 2^+ state. The ^{11}Li+n+n spectrum is interpreted as a $3/2^-$ ground state overlapping with excited states of similar structure as the 2^+ state in ^{10}He but with strength spread over several states due to the coupling to the $3/2^-$ core state. The ^{13}Li data furthermore provide evidence for configuration mixing, i.e. the two neutrons occupying partially the d-shell [1].

Dipole strength in the ^{235}U (γ, γ ') reaction up to 2.8 MeV

In a low-energy photon scattering experiment at the superconducting electron linear accelerator in Darmstadt (S-DALINAC) evidence for discrete dipole transitions as well as for unresolved dipole strength has been found in ^{235}U. If the unresolved strength exhibits the electric dipole/magnetic dipole cross section ratio as observed in the even-mass neighboring nucleus ^{236}U, then the energy centroid at 2.5(3) MeV and the total magnetic dipole strength are in good agreement with the systematics of the scissors mode in even-even actinide nuclei [2].

Fragment characteristics from fission of ^{238}U and ^{234}U induced by 6.5-9.0 MeV bremsstrahlung

The fission-fragment mass and energy distribution from (γ,f) reactions on ^{238}U and ^{234}U in the fission barrier region have been measured at the S-DALINAC and interpreted in terms of fission modes of the so called Brosa model. The experiment served primarily as a preparatory experiment for detecting parity non-conservation (PNC). The dominant population of 1^-states interfering with 1^+ states could give rise to PNC indeed, as earlier seen in fission induced by polarized thermal neutrons. To observe PNC in photofission is, however, much harder than in fission with neutrons. Presently a polarized electron source as a prerequisite for the production of polarized bremsstrahlung is put into operation. The results of the preparatory fission experiment with unpolarized photons have just been published [3].

The first $½^+$ state in ^9Be and astrophysical implications

Astrophysically relevant resonance parameters of the first excited $1/2^+$ state in ^9Be, i.e. its energy and width, have been remeasured in a high resolution inelastic electron scattering experiment at the S-DALINAC. These parameters are of particular interest since they determine the importance of ^9Be production for the synthesis of ^{12}C seed material, triggering the r process in type II supernovae. Their values are in good agreement with the ones from a recent photo-disintegration experiment on ^9Be but with considerably improved uncertainties. However, there is still a difference by a factor of two for the reduced electrical dipole transition strength in the two experiments which needs to be explained [4].

Pair decay width of the Hoyle state in ^{12}C and its role for stellar carbon production

The fusion of three alpha particles (the triple-alpha process) for the production of the most abundant stable carbon isotope ^{12}C in the center of stars proceeds through the first excited 0^+ state, the so called Hoyle state. Since the precise knowledge of the pair decay width of this state is mandatory for some key issues in the modeling of supernovae and asymptotic giant branch stars it has been redetermined from (i) a novel analysis of the world data on inelastic electron scattering covering a wide range in momentum transfer, and (ii) new data at low momentum transfers measured at the S-DALINAC. It was thereby possible to reduce the uncertainty of the literature values by more than a factor of three [5].

Fine structure of the isoscalar giant quadrupole resonance in ^{40}Ca and possible evidence for Landau damping

Our former high-resolution inelastic proton scattering experiments at medium energy on heavy nuclei were extended towards medium heavy and lighter nuclei. Thereby considerable fine structure has been found, particularly in the region of the Isoscalar Giant Quadrupole Resonance (ISGQR), and characteristic energy scales were extracted from the experimental data through a wavelet analysis. For the particular case of the ISGQR in the doubly magic nucleus ^{40}Ca the experimental scales are well described by Random Phase Approximation (RPA) and second-RPA calculations with an effective interaction derived from a realistic nucleon-nucleon interaction by the Unitary Correlation Operator Method (UCOM). In the calculations characteristic scales are already present at the mean-field level originating possibly from Landau damping. This is in contrast to observations in heavier nuclei and also to SRPA calculations for ^{40}Ca based on phenomenological effective interactions, where the fine structure is explained by the coupling to (2p-2h) states. The results of this work have just been published [6].

Correlation widths in quantum-chaotic scattering

Quantum-chaotic scattering is an ubiquitous phenomenon emerging whenever Schrödinger waves are scattered by a system with chaotic intrinsic dynamics. Examples are numerous. In condensed matter physics it is the passage of electrons through disordered microscopic samples, in nuclear physics compound nucleus scattering, and on a macroscopic scale it occurs when electromagnetic waves of sufficiently low frequency are transmitted through a microwave cavity with the shape of a classically chaotic billiard. In all these cases, chaotic scattering is due to the numerous quasibound states of the system that appear as resonances in the scattering process and that obey random-matrix statistics. In the generic approach to quantum-chaotic scattering [7] an important parameter to characterize the scattering matrix S is the correlation width Γ_{corr} of the S-matrix autocorrelation function. We have shown that the so called “Weisskopf estimate” $d/2\pi\Sigma T_c$ (where d is the mean resonance spacing, T_c the “transmission coefficient” in channel c and where the sum runs over all channels) provides a good approximation to the correlation widths even when the number of channels is small. That same conclusion applies also to the cross-section correlation function. The results of this work have just been publishes [8].

Observation of a Dirac point in a microwave photonic crystal modeling graphene

We have measured reflection and transmission spectra of a microwave photonic crystal made of 874 metallic cylinders arranged in form of a triangular lattice. The spectra show a cusp structure close to the expected Dirac frequency which can be related to the local density of states of the photonic crystal, providing thereby clear evidence for the existence of a Dirac point. Dirac points are also a peculiar property of the electronic band structure of graphene. Thus, although the Fermi velocity is typically 300 times smaller than that of light, the energy spectrum of the electrons in graphene is similar to that of massless relativistic fermions. We have shown that several features of graphene (dispersion relations, so called edge states, pseudo-diffusive transmission at the Dirac point) can be modeled in microwave photonic crystals [9].

Exceptional points in a microwave billiard with time-reversal invariance violation

We have studied experimentally two nearly degenerate eigenmodes in a dissipative microwave cavity with induced time-reversal (T) violation through a ferrite inside the cavity. The associated two-state Hamiltonian is non-Hermitian and may thus posses a so called exceptional point (EP), where the two eigenvalves and also the associated eigenvectors coalesce. It is also non-symmetric. We determined the Hamiltonian experimentally on a narrow grid in a parameter plane around the EP. At the EP the size of T violation is given by the relative phase of the eigenvector components. The eigenvectors are adiabatically transported around the EP, whereupon they gather geometric phases and in addition geometric amplitudes different from unity. This work has been the first experimental study of an EP under T violation and the results have just been published [10].

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Luigi Scorzato

Aurora

In collaboration with Trento Univ.,INFN, IASMA, ATreP, Padova Univ., Eurotech, Intel

The Aurora project is presented with more details elsewhere in this report. I am involved in many aspects of this project: I am scientific coordinator for FBK, I am responsible of porting LQCD algorithms and codes to the new architecture, I am giving some help to the various groups to port their applications.

Numerical stochastic perturbation theory

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

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..

Improving hadron creation operators on the lattice

In collaboration with M. Cristoforetti (ECT), M. Dalla Brida (U.Trento), C. Alexandrou (Cyprus U.) M. Gravina (Cyprus U.)*

We are computing the meson spectrum by combining the distillation method introduced recently by Peardon et al. (Phys. Rev. D80, 054506 2009) with other noise reduction methods extensively used by us in previous works. The next step will be the extension of the method to the baryonic spectrum and later to the computation of hadron scattering.

Computation of meson-baryon scattering with Lattice QCD

In collaboration 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 factors that are needed for the computations of hadronic quantities with u, d, s, c dynamical quarks in the twisted mass regularization.

Dionysis Triantafyllopoulos

Radiation in strongly coupled gauge theories

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

This year I have started studying the problem of radiation from a quark at strong coupling. The problem is non-perturbative, and one way to approach it is by using the gauge/string duality [1]. Borrowing techniques and ideas from string theory and/or its supergravity limit, it is possible to derive results valid in supersymmetric gauge theories which are similar to QCD in various aspects. A rather surprising result was find in [2], where for the particular case of synchrotron radiation (that is with a quark moving in a uniform circular motion), the radiated energy density at strong coupling, as obtained from the supergravity approximation, looked very similar to the weak coupling one which in turn is given by the classical result. In [3] we managed to show that the same phenomenon occurs for one-dimensional non-relativistic motion and for the decay of a time-like wave-packet and at the same time to give its physical explanation. In [4] we have solved the problem for an arbitrary three-dimensional relativistic motion and gave an explicit expression for the space-time distribution of the energy radiated and the corresponding power. The real merit will be when we generalize to finite temperature, since then we shall be able to calculate the energy loss of a heavy quark propagating in a strongly coupled Quark Gluon Plasma. Such a state of matter might have already been created in heavy-ion collisions at RHIC and the LHC.

Next to leading order corrections in the Color Glass Condensate

In collaboration with E. Avsar (Penn State University) and E. Iancu (IPhT, Saclay)

In the high energy limit, and due to the three-gluon vertex in QCD, the wavefunction of a generic hadron is dominated by a dense system of gluons. At sufficiently high energies, and/or for large nuclei due to the large number of valence quarks, one expects the gluon density to reach its asymptotic limit and the wavefunction to exhibit saturation. With increasing energy, 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. This leads to the effective theory of the Color Glass Condensate (CGC) which aims to describe the 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 [5]. NLO evolution equations which give the evolution of the CGC have been derived [6]. However these NLO equations have serious pathologies (like their linearized version, the BFKL equation at NLO), which I have been able to recognize. I am working to correct these equations and thus provide the phenomenologists with more accurate tools.

Monte Carlo for inclusive and exclusive processes at small-x

In collaboration with M. Alvioli (ECT, Trento)*

Apart from the genuine NLO corrections of resummed perturbation theory, there are also low-density fluctuations of the hadronic wavefunction which eventually lead to the formation of Pomeron loops. A few years ago we found that even though the contributions from these low density fluctuations are parametrically more important, numerically it is the corrections due to the running coupling that dominate, at least when we measure the total cross section [7]. For more exclusive processes like single gluon production, the analysis is currently under progress.

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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 Nuclear Configurations

To appear in Phys. Rev. C [*arXiv:1008.2328 [nucl-th]*]

Daniele Binosi

J. M. Cornwall, J. Papavassiliou and D. Binosi

The Pinch Technique and its Applications to Non-Abelian Gauge Theories

Cambridge University Press, December 2010

ISBN-13:9780521437523

D. Binosi

A dynamical study of the Kugo-Ojima function

arXiv: 1012.0245 [hep-ph]

To appear in the proceedings of the conference "Quark Confinement and the Hadron Spectrum" (September 2010, Madrid, Spain)

D. Binosi

Dynamical gluon mass generation and the IR sector of QCD

arXiv: 1010.5254 [hep-ph]

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

D. Binosi

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

arXiv:1010.2945 [hep-ph]

To appear in the proceedings of the conference "QCD@Work 2010 - International Workshop on QCD: Theory and Experiment" (June 2010, Martina Franca, Italy)

A. C. Aguilar, D. Binosi and J. Papavassiliou
Nonperturbative gluon and ghost propagators for d=3 Yang-Mills
Phys. Rev. ***D81****, 125025, (2010), e-Print: arXiv:1004.2011 [hep-ph]*

A. C. Aguilar, D. Binosi and J. Papavassiliou
QCD effective charges from lattice data
JHEP 1007:002,2010, e-Print: arXiv:1004.1105 [hep-ph]

Marco Cristoforetti

M. Cristoforetti, T. Hell, B. Klein and W. Weise
Thermodynamic quark susceptibilities in the PNJL model
POS (Lattice2010) 175

M. Cristoforetti, T. Hell, B. Klein and W. Weise
Thermodynamics and quark susceptibilities: a Monte-Carlo approach to the PNJL model
Phys. Rev. ***D81,*** *114017,(2010)*

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Thermodynamics of a three-flavor nonlocal Polyakov-Nambu-Jona-Lasinio model
Phys. Rev. ***D81,*** *074034, (2010)*

César Fernández-Ramírez

S. Riordan et al. (118 authors)
Measurement of the electric form factor of the neutron using the reaction 3He(e,e'n)pp up to Q^2=3.4 GeV^2
Phys. Rev. Lett. ***105****, 262302 (2010)* [*arXiv:1008.1738 [nucl-th]*] [ECT*-10-04]

Victor V. Flambaum and A. Derevianko

V.V. Flambaum and A.Derevianko

Comment on "Time modulation of the K-shell electron capture decay rates of H-like heavy ions at GSI experiments"

Phys. Rev. Lett. ***104****, 159201 (2010)*

J.C. Berengut and V.V. Flambaum

Astronomical and laboratory searches for space-time variations of fundamental constants

J. Phys. Conf. Ser. (2010), in press, e-Print: arXiv:1009.3693v1 [physics atom-ph]

V.A. Dzuba and V.V. Flambaum

Current trends in searches for new physics using measurements of parity violation and electric dipole moments in atoms and molecules

arXiv: 1009, 4960v1 [physics.atom-ph]

V.A. Dzuba, V.V. Flambaum, K. Belay, and A. Derevianko

Hyperfine-mediated static polarizabilities of monovalent atoms and ions

Phys. Rev. ***A82****, 062513 (2010)*

Lorenzo Fortunato

L. Fortunato

All transformations of coordinates that separate the center of mass kinetic energy, their group structure and geometry

J.Phys. ***A43,*** *065301 (2010)*

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Phys. Rev. ***C82****, 014317 (2010)*

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Scattering of F-17 nuclei from a Ni-58 target at energies around the Coulomb barrier

Nucl.Phys. ***A834****, 488c-490c (2010)*

Bing Wei Long

B. Long and V. Lensky

Heavy-particle formalism with Foldy-Wouthuysen representation

Submitted to Phys. Rev. C, e-Print: arXiv:1010.2738 [hep-ph] [ECT-10-07]*

Fabio Pozzati

F. Pozzati et al.

The AuroraScience Project

Poster presented at the SC10 conference held in New Orleans (USA), November 13-19, 2010, New Orleans, LA (USA).

Achim Richter

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Luigi Scorzato

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L. Scorzato (for the AuroraScience Coll.)

AuroraScience

PoS(Lattice 2010)039.

F. Di Renzo, M. Brambilla and L. Scorzato

Perturbative vs non-perturbative renormalization: the case of the quark mass

PoS(Lattice 2010)225.

Dionysis Triantafyllopoulos

Y. Hatta, E. Iancu, A.H. Mueller and D.N. Triantafyllopoulos

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

arXiv:1011.3763 [hep-th] [To appear in JHEP]

4.3 Talks by ECT* Researchers presented outside of ECT*

Daniele Binosi

Dynamical gluon mass generation and the IR sector of QCD

Plenary talk given at “Light Cone 2010: Relativistic Hadronic and Particle Physics”

June 2010, Valencia, Spain

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

Invited talk given at “QCD@Work 2010 - International Workshop on QCD: Theory and Experiment ”

June 2010, Martina Franca, Italy

A dynamical study of the Kugo-Ojima function

Invited talk given at “Quark Confinement and the Hadron Spectrum”

September 2010, Madrid, Spain

IR properties of QCD from the Batalin-Vilkoviski framework

Invited talk given at “The many faces of QCD”

November 2010, Gent, Belgium

Marco Cristoforetti

Thermodynamic quark susceptibilities in the PNJL model

Talk given at the conference Lattice 2010

June 2010, Villasimius, Sardinia, Italy

Thermodynamic quark susceptibilities in the PNJL model

Group report given at the DPG conference

March 2010, Bonn, Germany

César Fernández Ramírez

Chaos in baryons

Talk given at Encuentro Nacional de Física Nuclear.

September 2010, El Escorial, Spain

Lorenzo Fortunato

Shape phase transitions & critical points: X(5), related models and E0-transitions

University of Milano, Invited talk

March 19, 2010

Algebraic models and lost chains: the case of the vibron model

Huelva (Spain), Workshop on "Quantum phase transitions in molecular and nuclear structure"

May 17-18, 2010

"Lost chains" in algebraic models - an account on how the complete classification of subalgebras can lead to new unexpected physics

Newcastle Upon Tyne (UK), ICGTMP - GROUP'28 International Conference

July 26-30, 2010

Odd nuclei and shape phase transitions: the role of the unpaired fermion

Kazimierz Dolny (Poland), 17th Nuclear Physics Workshop

September 22-26, 2010

Bingwei Long

Pion-nucleon scattering around the delta-isobar resonance

Seminar given at Jefferson Lab,

February 2010, Newport News, VA, USA

Pion-nucleon scattering around the delta-isobar resonance
Talk given at “Simulations and Symmetries: Cold Atoms, QCD, and Few-hadron Systems” INT program,
April 2010, Seattle, USA

Achim Richter

Playing billiards with microwaves – quantum manifestations of classical chaos
Physics Colloquium at GANIL
March 08, 2010, Caen, France

Microwave experiments with circular and square dielectric billiards
Symposium on the Occasion of Sven Åberg’s 60th Birthday University of Lund
June 11, 2010, Lund, Sweden

Some aspects of collective oscillations and superfluidity in atomic nuclei

Giant resonances – wavelets, scales and level densities

Nuclear structure in astrophysics studied with electromagnetic probes – some examples

Quantum manifestations of classical chaos – universal features of billiards and nuclei
Four lectures presented at the Joint 2010 US National Physics Summer School (NNPSS) and the 2010 TRIUMF Summer Institute (TSI)
June 21-July 02, 2010, Vancouver, BC, Canada

Mit Teilchenbeschleunigen der Entstehung des Universums auf der Spur
Talk presented at the Rotary Club Darmstadt – Bergstrasse
April 21, 2010, Darmstadt, Germany

Transnational access to ECT*
Talk presented at the HadronPhysics2 Collaboration Committee Meeting and Midterm Review at CNRS
September 16, 2010, Paris, France

Quantum chaotic scattering in microwave billiards and Ericson fluctuations revisited
Invited talk at the Symposium on the Occasion of Magda and Torleif Ericson's 80th Birthday
CERN
September 17, 2010, Geneva, Switzerland

Exceptional points in microwave billiards: early experiments (2001-2007)

Exceptional points in microwave billiards: recent experiments (2009-2010)
Two lectures presented at the International Workshop "The Physics of Exceptional Points"
National Institute for Theoretical Physics in South Africa
November 02-05, 2011, Stellenbosch, South Africa

Relativistic physics with a microwave photonic crystal simulating graphene
Invited talk presented at the international Workshop on "Strongly-coupled systems"
Extreme Matter Institute (EMMI)
November 15-17, 2010, Darmstadt, Germany

Luigi Scorzato

Twisted mass QCD and other applications on AURORA
AuroraScience/QPACE/PetaQCD Meeting
April 14-15, 2010, Regensburg, Germany

Quark masses from LQCD
Seminar at the Physics Department, University of Trento
May 6, 2010, Trento, Italy.

AuroraScience: HPC for scientific applications
Convegno Informale di Fisica Teorica
May 26-29, 2010, Cortona Italy.

tmLQCD on AURORA
AuroraScience Meeting
June 10, 2010, Trento, Italy.

ECT* e AuroraScience
Notte dei ricercatori FBK
September 24, 2010, Trento, Italy.

AuroraScience
Talk given at the XXVIII International Symposium on Lattice Field Theory
June 14-19, 2010, Villasimius, Italy.

Dionysis Triantafyllopoulos

Shockwaves and deep inelastic scattering within the gauge/gravity duality
Seminar given at IPhT, Saclay
May 2010, Paris, France

Radiation in strongly coupled gauge theories
Invited talk at the workshop “Strings and QCD”
November 2010, Cagliari, Italy

Parton saturation and the color glass condensate

Invited lecture at the workshop “Strings and QCD”

November 2010, Cagliari, Italy

Mueller-Navelet Jets

Invited talk at the workshop “Structure Functions, Geometric Scaling and Parton Saturation”

November 2010, Darmstadt, Germany

Shockwaves and DIS within the gauge/gravity duality

Talk given at the workshop “Low-x”

June 2010, Kavala, Greece

4.4 Lectures and Seminars at ECT*

4.4.1 Lectures

Nuclear reactions
Lecturer: Filomena Nunes (NSCL/MSU East Lansing, USA)

Basic tools in many-body theory
Lecturer: Georges Ripka (ECT* and IPhT Saclay, France)

Nuclear reactions
Lecturer: Jeff Tostevin (University of Surrey)

Two and three body models of direct nuclear reactions
Lecturer: Ron Johnson (University of Surrey)

HF, RPA, second RPA, dynamical shell model, excitations of exotic nuclei
Lecturer: Pier Francesco Bortignon (University of Milan)

Experimental nuclear astrophysics
Lecturer: Marialuisa Aliotta (University of Edinburgh)

Realistic and effective nucleon-nucleon interactions
Lecturer: Hans Feldmeier (GSI Darmstadt)

Microscopic cluster description of collisions
Lecturer: Daniel Baye (ULB Brussels)

Experiments with high energy radioactive beams
Lecturer: Tom Aumann (GSI Darmstadt)

Shell model and exotic nuclei
Lecturer: Takaharu Otsuka (University of Tokyo)

Nucleosynthesis and introduction to libnucnet
Lecturer: Bradley Meyer (Clemson University)

Nuclear physics input for supernovae evolution and explosive nucleosynthesis
Lecturer: Gabriel Martinez Pinedo (GSI Darmstadt)

Open questions and experimental approaches in nuclear astrophysics: r-process nuclei, X-ray bursts and neutron star crusts
Lecturer: Hendrik Schatz (NSCL/MSU East Lansing)

Collective nuclear structure models
Lecturer: Piet van Isacker (GANIL Caen)

Charge exchange interactions at intermediate energies, supernovae
Lecturer: Remco Zegers (NSCL/MSU East Lansing)

Experimental techniques in nuclear astrophysics
Lecturer: Ernst Rehm (ANL Argonne)

Nuclear matter equation of state, astrophysical applications
Lecturer: Stefan Typel (TU Munich)

Ab initio nuclear structure models, effective nucleon-nucleon potentials, exotic structures and fermionic molecular dynamics
Lecturer: Thomas Neff (GSI Darmstadt)

Weakly bound systems, S factors, role of breakup, fusion hindrance at very low energies
Lecturer: Andrea Vitturi (INFN Padua)

Observational high-energy astrophysics
Lecturer: Roland Diehl (MPE Garching)

4.4.2 Seminars

The Interacting Boson Model: physical motivation, algebraic structures and phenomenology
January 8
Lorenzo Fortunato

Genetic algorithms, or how I stopped worrying about the crocoduck and learned to love Darwin's theory of evolution
February 24
Cesar Fernandez Ramirez

The Riemann hypothesis, prime numbers and quantum mechanics
May 11
Dionysis Triantafyllopoulos

Developments in Landau gauge QCD
June 8
Andre Sternbeck

Investigation of the EO transition of 160Er
July 15
Shinjinee Dasgupta

Quantum chaos and 1/f noise
July 16
Laura Muñoz

Decomposition of spectral density in individual eigenvalue contributions
July 27
Mauricio Pato

Why scientific software fails or what we can learn from software engineers
September 9
Lukas Theussl

Ultracold, precise, and electroweak

September 20

Andrei Derevianko

Evidence for spatial variation of the fine structure constant alpha

September 22

Victor V. Flambaum

Kbar-nuclear interactions and dynamics

September 23

Avraham Gal

Atomic Quantum Technologies

October 8

Daniele Binosi

Nuclear forces by effective field theory - an introduction

October 28

Bingwei Long

A renormalizable gauge free of the Gribov ambiguity: Yang-Mills and Higgs

December 6

Andrea Quadri

Novel results from the two-dimensional limit of the vibron model

December 7

Francisco Perez-Bernal

5 The Quantum Information Processing Group at ECT*

ECT*, owing to its institutional goals, is interested in research on computing technologies for the simulation of complex quantum many-body systems. On a normal (super)computer this requires exponential computational resources; this would not be the case, should the computer itself obey the laws of quantum mechanics. These basic considerations have started some 20 years ago the new research field of Quantum Information Processing (QIP). In this context the Future and Emerging Technologies Unit in DG Information Society and Media of the European Commission acted as a pathfinder and played a crucial role in the development and structuring of this strategic field in Europe by quickly recognizing its potential. In particular, QIP has been a FET Proactive Initiative (PI) in the Framework Programme FP5 (1999-2002) and FP6 (2003-2006).
Since the beginning, the ECT* have been a constant presence in QIP research consortia, through the activity of T. Calarco and later on of D. Binosi. In particular

- In 2000 ECT* has been coordinating the theoretical research of the FP5 Research and Technology Development Network **ACQUIRE** (Atom Chips for QUantum Information REsearch; start: 1/1/2000, end: 31/12/2002; funding: 75k€), aiming at the implementation of an elementary quantum processor on an atom chip (based on an idea of T. Calarco, J.-I. Cirac and P. Zoller);
- ECT* has been a node of the FP5 European QIPC Network of Excellence **QUIPROCONE** (QUantum Information PROcessing and COmmunication Net- work of Excellence; start: 1/1/2000, end: 31/12/2003);
- ACQUIRE has continued under the name **ACQP** (Atom Chip Quantum Processor; start: 1/1/2003, end: 31/12/2005) with ECT* as a consortium member (funding: 150k€);
- In FP6, ECT* has been a partner of the FET Integrating Project **SCALA** (SCAlable quantum computing with Light and Atoms; start: 1/11/2005, end: 31/10/2009; funding: 135k€).

Over the course of these projects, a fruitful collaboration has been established with the University of Trento and with the INFM BEC Centre, including the super- vision of several Laurea and Ph. D. theses, several joint papers on various aspects of QIP implementations using cold neutral atoms, and two one-day workshops, held at ECT* in December 2004 and December 2005. Along this line, T. Calarco has been appointed first as an INFM Researcher (since November 1st, 2004) and later as a Senior Researcher (since March 2005) - while office space for a few members of the QIP group has been provided at the BEC Centre in Povo. Computing resources are a key asset in this context, as they are used quite intensively for simulation of

1quantum processes relevant for QIP; hence, the purchase of two new state-of-the- art computing workstations has been realized whose cost has been equally shared among the ECT* general budget and the ACQP project.

Furthermore, T. Calarco has been appointed also as the responsible of the European QIP Roadmap, in the framework of ERA-Pilot QIST Project, in a joint effort be tween INFM and the Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences. Since then, T. Calarco collaborates with the ECT* researcher D. Binosi. In particular, they have written together the ap- plication for the Coordination Action QUROPE (Quantum Information Processing and Communication in Europe; start: 1/9/2006, end: 31/8/2009; funding 220k€) in which ECT* leads the Work-Package 4, in charge of establishing and maintaining an Electronic Information Infrastructure to support the efficient service of all the coor- dination action objectives. ECT* is also deeply engaged in Work-Package 2 which is designed to develop a common European vision, strategy and goals, formally taking over the development and regular updates of the European QIPC Strategic Report from the ERA-Pilot QIST Work-Package 1 described earlier.

It is the early support and long-term vision offered by the ECT* that has allowed T. Calarco to build a career in QIP physics and get an offer for a full professorship from the University of Ulm that he took up in September 2007.

This did not weaken the strong link of T. Calarco with the ECT* in general and D. Binosi in particular. In fact, T. Calarco and D. Binosi, while planning a joint line of research in Density Matrix Renormalization Group techniques applied to QIP, have been involved in the preparation and/or directly participating to several high profile meeting held at the European Commission in Brussels, intended to shape the future of the QIP field in Europe. In addition, T. Calarco has contributed in the writing of the German roadmap for QIP, while D. Binosi has participated in the working group of the Italian roadmap for QIP lead by M. Inguscio and written the final document presented to the MIUR (Ministero Italiano dell'Università e della Ricerca).

As a result of all these activities (carried out under the QUROPE flagship) and the constant input gathered from the research community and conveyed by the QUROPE Work-Package 2 to the Commission in the preparation process of the Seventh Framework-Programme, QIP is a FET Proactive Initiative also in FP7, under the objective ICT 2009.8.2: Quantum

Information Foundations and Technologies. The call for projects (FP7-ICT-2009-4) is funded for 15M€, and has been opened in November 2008 with a deadline on the 1/4/2009.

Currently T. Calarco and D. Binosi collaborate in three projects:

- The Integrating Project **AQUTE** (Atomic QUantum TEchnologies) involving a Consortium of 24 partners including two Nobel Prize winners (Theodor W. Hansch and William Phillips), and of which T. Calarco is the coordinator (based in Ulm) and D. Binosi the Project Office leader;
- The Coordination Action **QUIE^{2}T** (QUantum Information Entanglement- Enabled Technologies) in which T. Calarco is the leader of Work-Package 2 (Strategy, vision and sustainability), while D. Binosi in addition to contributing to Work-Package 2 and 3 (Dissemination activities), acts also as QUIE^{2}T Exceutive Secretary (the funding for the ECT* node is 89k€).
- The ERA-NET initiative **CHIST-ERA** in which T. Calarco is chair of the Scientific Advisory Board while D. Binosi is the leader of Work-Package 3 (Definition of Countours and Joint Call Topics)

6 Aurora Science

AuroraScience is a project 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 Sciences 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 system (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 a scientific project enabled by leading-edge computational systems and by specific competences in the useful operation of these systems. The project started formally on July 31, 2009. The project is now in its first phase, which will end on July 31st, 2011, and we are applying for the second phase. The accomplishment of the project in 2010 are summarized here:

1. <u>Development of the Aurora computing system</u>. 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 10TFlops and is producing results for the AuroraScience collaboration.

2. <u>Lattice QCD</u>. Three codes of LQCD have been ported and optimized for the AURORA architecture. New algorithms have been developed and tested. Production of LQCD results has started. In particular ECT* is participating in a project to compute the renormalization factors for LQCD with 4 dynamical flavours in the regularization used by the ETM Collaboration. A further project pursued at ECT* makes use of recent techniques for computing hadron correlator functions to improve the determination of mesonic and baryonic masses.

3. <u>Nuclear Physics</u>. The adaptation to the AURORA system of existing algorithms and codes both for Auxiliary Field Diffusion Monte Carlo and for few-body computations has been completed.

4. Protein Folding. The Dominant Folding Pathway (DFP) method is now running on the AURORA system.

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

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

7. High Level Training. The first school for doctoral students organized by AuroraScience at ECT* in the fall 2010 has been very successful.

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

7 ECT* Computing Facilities

Available computing resources

HARDWARE	
Servers:	1 Virtual Server DELL PowerEdge R610
Supercomputation:	1 Supercomputer AURORA compounded by 64 Node Card (NC): Each AURORA NC provides two Intel Xeon 5500 (Nehalem) at 293GHz for a peak performance of 92G Flops/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 2010 was 10 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 guests:	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]