ECT*

Annual Report 2009

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

Institutional Member of the European Science Foundation Expert Committee NuPECC

FONDAZIONE BRUNO KESSLER

Edited by
Silvia Tomasi and Gian Maria Ziglio

1 Preface

The objectives of the European Centre for Theoretical Studies in Nuclear Physics and Related Areas (ECT*), which is an Institutional Member of the European Science Foundation Expert Committee NuPECC, concern fundamental research. With 648 visiting scientists in 2009 from all over the world spending from a week to several months at the Centre, ECT* has maintained and increased its high visibility and coordinating function in the European and international scientific community by holding during the year

- 17 Workshops and Collaboration Meetings on topical problems at the forefront of contemporary developments in nuclear physics and related fields like astrophysics, condensed matter physics and quantal physics of small systems,
- a Doctoral Training Programme on “The physics of strongly correlated systems: from quark matter to ultra cold atoms” lasting 3 months for 16 talented young physicists selected out of a large number of applicants,and by fostering
- basic 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 and the Vice-Director of the Centre and visitors and collaborating physicists elsewhere.

Furthermore, in 2009 ECT* has started to administer scientifically a new research project named

- AuroraScience, which consists of interdisciplinary proposals that explore the architectural opportunities for high performance computing (HPC) systems optimized for a number of highly relevant scientific computing applications in physics, biology, fluid dynamics, molecular dynamics, protein folding, genomics and medical physics. The project is a joint research and development project of Eurotech and the AuroraScience collaboration and funded by the Provincia Autonoma di Trento (PAT) and by the Istituto Nazionale di Fisica Nucleare (INFN). The PAT has therefore, through the Fondazione Bruno Kessler (FBK), provided a significant contribution for the integration of the initiative in a large framework, where innovation bridges theoretical and applied science. AuroraScience involves several local and national institutions and is furthermore embedded into the European scene of HPC.

The operating budget of ECT* in 2009 amounted to 1,152 Mio €, 46% of this amount has been provided by the FBK/PAT and 54% by outside funds mainly from funding agencies in various European countries – Belgium, Czech Republic, Denmark, Finland, France, Germany, Hungary Italy, The Netherlands, Poland, Romania, Spain and the UK – and through the European FP7/Hadron Physics 2 programme. We are extremely grateful for this support which has allowed to operate ECT* at the highest scientific level.

As its predecessors this Annual Report for 2009 contains details of the mission and the numerous scientific and other achievements of the ECT*. It is also available on the ECT* web site (www.ect.it/TheECT/Whatis_ECT/annualreports.htm). I thank all members of the internationally composed Scientific Board, the coordinators Gordon Baym, Chris Pethick, George Ripka and Sandro Stringari of the Doctoral Training Programme and the Staff and Researchers of the ECT* for their dedicated work and effort which has led to the fact that ECT* in 2009 has been able to take up new opportunities and challenges within the gradual emergence of a European Research Area and growing international coordination. It is and will continue to be an established research centre for theoretical nuclear physics in a broad sense which – through its Workshops and Collaboration Meetings – furthers the mobility of frontline researchers, both through its Doctoral Training and Visiting Scientists Programmes and its vivid in-house Research Group. Thereby ECT* generates continuously future leaders of research, and its fixed-term faculty forms indeed a talent pool for universities and research laboratories for Europe and worldwide.

Trento, April 14, 2010

Achim Richter

Director of ECT*

Contents

2 ECT* Scientific Board, Staff and Researchers

2.1 ECT* Scientific Board, Director and Vice - Director

Mauro Anselmino (from September 2008)	University of Torino, Italy
Bengt Friman (from October 2006)	GSI, Darmstadt, Germany
Hans-Ake Gustafsson (from June 2006)	Lund University, Sweden and CERN, Switzerland
Pawel Haensel (from January 2008)	N. Copernicus Astronomical Center, Poland
Simon Hands (from January 2008)	Swansea University, UK
Wick Haxton (from June 2006)	University of Washington, USA
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

Honorary Member of the Board

Ben Mottelson — NORDITA, Copenhagen, Denmark

ECT* Director

Achim Richter — ECT*, Italy and TU Darmstadt, Germany

ECT* Vice – Director

Marco Traini (until October 2009) — ECT* and University of Trento, Italy

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	System Manager
Susan Driessen (part time)	Assistant to the Directors
Tiziana Ingrassia (part time)	Accounting Assistant
Mauro Meneghini	Driver and Maintenance Support Manager
Donatella Rosetti (part time, until June 2009)	Secretary Eurons
Gianmaria Ziglio (part time)	Web Manager

2.3 Resident Postdoctoral Researchers

- **ECT* Postdocs**

Daniele Binosi, Italy (part time 2009)
Cesar Fernandez-Ramirez, Spain (from October 2009)
Lorenzo Fortunato, Italy (from September 2009)
Vadim Lensky, Russia (until 15th October 2009)
Bingwei Long
Javier Lopez Albacete, Spain (until May 2009)
Dionysis Triantafyllopoulos Greece (from October 2009)

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

Daniele Binosi, Italy (from February 2005)
Tommaso Calarco, Italy (from June 2003)

- **Teraflop Cluster (special Fellow)**

Luigi Scorzato, Italy

- **AuroraScience**

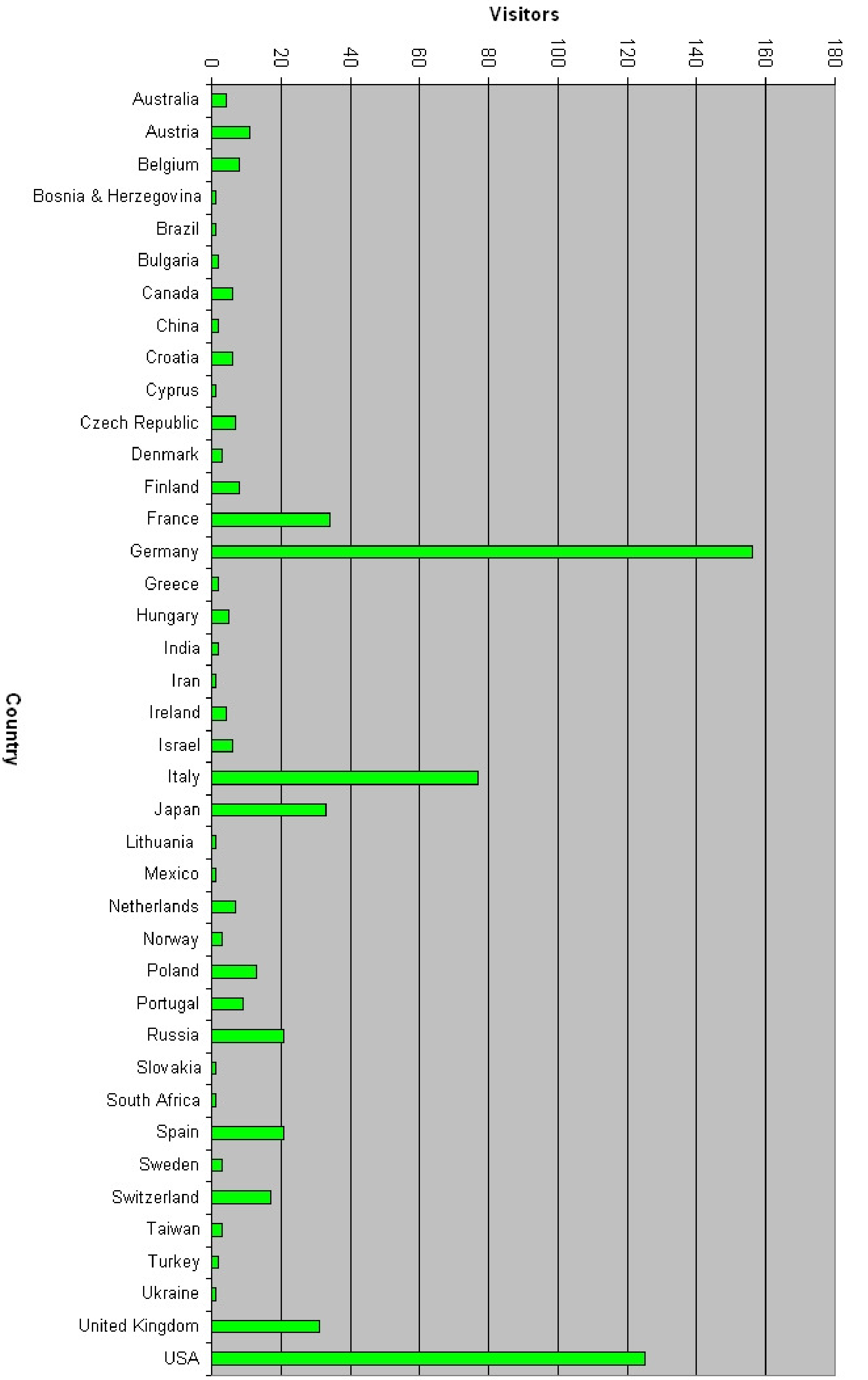
Luigi Scorzato, Italy (from April 2009)

2.4 Visitors in 2009

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).

Alberto Accardi (25-28/05)	JLab, USA (VS)
David Edwin Alvarez Castillo (27/03-21/06)	Inst. of Nuclear Physics, Krakow, PL (TP)
Gordon Baym (28/03-05/04, 02-13/06)	University of Illinois, USA (TP)
Andrea Beraudo (01-07/03, 14-18/09)	INFN Torino, Italy (VS)
Gianluca Bertaina (29/03-19/06)	University of Trento, Italy (TP)
Jean-Paul Blaizot (22/02-08/03, 06/02/09)	CEA Saclay SPHT, France (VS)
Eugene Bogomolny (09-10/08)	CNRS Orsay, France (VS)
Peter Braun-Munzinger (27-30/04)	GSI, Darmstadt, Germany (TP)
Juan Francisco Castillo Hernandez (27/03-21/06)	GSI, Darmstadt, Germany (TP)
Bhaswar Chatterjee (25/03-25/06)	Physics Research Laboratory, Ahmedabad, India (TP)
Ignacio Cirac (18-19/05)	Max-Planck Institut für Quantenoptik Garching, Germany (VS)
Giuseppe Congedo (25-31/05)	University of Trento, Italy (TP)
Barbara Dietz (25-27/11)	TU Darmstadt, Germany (VS)
Jacek Dobaczewski (14-19/06)	University of Warsaw, Poland (TP)
Torleif Ericson (25-28/11)	CERN, Switzerland (VS)
Stefano Fantoni (05-08/05)	SISSA, Trieste, Italy (TP)
Victor Flambaum (24/07-18/08)	University of New South Wales, Australia (VS)
Lorenzo Fortunato (06/05)	INFN, University of Padua, Italy (VS)
Jens-Joergen Gaardhøje (19-22/04)	University of Copenhagen, Denmark (TP)
Thierry Giamarchi (07-12/06)	University of Geneva, Switzerland (TP)
Stefano Giorgini (06-30/04)	University of Trento, Italy (TP)
Tetsuo Hatsuda (31/05-06/06)	University of Tokio, Japan (TP)
Paul Hoyer (11/10-06/12)	University of Helsinki, Finland (VS)
Andreas Ipp (25-28/02)	Max Planck Institut Heidelberg, Germany (VS)
Dario Jukic (27/03-21/06)	University of Zagreb, Croatia (TP)
Johannes Kirscher (05-13/09)	George Washington University, USA (VS)
Jussi Kajala (27/03-21/06)	University of Helsinki, Finland (TP)
Tommaso Macri (11-17/05, 08-14/06)	SISSA, Trieste, Italy (TP)
Kenji Maeda (03/04-21/06)	University of Tokio, Japan (TP)
Agne Masalaite (27/03-21/06)	Vytautas Magnus University, Lithuania (TP)

Michael Merkl (28/03-21/06)	Herriot-Watt University, UK (TP)
Tomoki Ozawa (25/03-25/06)	University of Illinois, USA (TP)
Marco Panero (25-28/05)	ETH, Zurich, Switzerland (VS)
Chris Pethick (29/03-04/04, 15-20/06)	NORDITA, Copenhagen, Denmark (TP)
Francesco Raimondi (10/05-21/06)	University of Jyvaskyla, Finland (TP)
Claudia Ratti (25-28/05)	SUNY at Stony Brook, USA (VS)
Georges Ripka (15/03-30/06)	CEA Saclay SPHT, France (VS)
Florian Schaefer (25-27/11)	TU Darmstadt, Germany (VS)
Sandro Stringari (30/03-29/04)	University of Trento, Italy (TP)
Pekka Toivanen (09/05-14/06)	University of Jyvaskyla, Finland (TP)
Dionysis Triantafyllopoulos (01-09/09)	University of Vienna, Austria (VS)
Shun Uchino (27/03-21/06)	University of Tokio, Japan (TP)
Jasper Jacobus Van Heugten (30/05-06/06)	University of Utrecht, NL (TP)
Anna Watts (24-29/05)	University of Amsterdam, Netherlands (TP)
Daniel Zablocki (28/03-21/06)	University of Wroclaw, Poland (TP)
Martin Zwierlein (10-13/05)	MIT, Cambridge, USA (TP)



Visitors at ECT* per Country 2009

3 Scientific Projects Run in 2009

3.1 Summary

Altogether 18 scientific projects have been run in 2009: 16 workshops, 1 collaboration meeting and 1 doctoral training programme. This chapter contains the scientific reports written by the organizers of each project. Georges Ripka, who assisted the Director in the running of the doctoral training programme, prepared the corresponding report for it.

3.2 Workshop and Collaboration Meetings in 2009 (Calendar)

Jan 07-10	**Collaboration Meeting SFB/TR55** T. Hemmert (Coordinator) *(Uni. Regensburg)* A. Schäfer (*Uni. Regensburg*)
Mar 02-06	**Sign Problems and Complex Actions** G. Aarts (Coordinator) (*Swansea Uni.*) S. Chandrasekharan *(Duke Uni.)*
May 11-15	**Simulations of Low and Intermediate Energy Heavy Ion Reactions** J. Aichelin (Coordinator) (*Uni.Nantes*) H. Wolter (*Uni. Munich*)
May 25-29	**Heavy Quarkonia Production in Heavy-Ion Collisions** D. Blaschke (Coordinator) (*Uni. Wroclaw*) P. Crochet (*Uni. Clermond-Ferrand*) R. Rapp (*Texas A.& M. Uni.*)
Jun 01-05	**The 5th International Pion-Nucleon PWA Workshop and Interpretation of Baryon Resonances** M. Giannini (Coordinator) (*Uni. Genova*) L. Tiator (*Uni. Mainz*)
Jun 15-19	**Atomic Effetcs in Nuclear Excitation and Decay** P. Walker (Coordinator),*(Uni. Surrey)* F.J. Currel *(Queen's Uni., Belfast UK)* J. Carroll *(Youngstown State Uni.)*
Jul 06-10	**Linking Nuclei, Molecules, and Condensed Matter: Computational Quantum Many-Body Approaches** R. Roth (Coordinator) (*TU Darmstadt*) J. Schnack (*Uni. Bielefeld*) J. Richter (*Uni. Magdeburg*)

Jul 20-25	**Recent Advances in Perturbative QCD and Hadronic Physics** A. Belitsky (Coordinator, (*Arizona St. Uni.*) K. Goeke (*Ruhr Uni. Bochum*) D. Mueller (*Ruhr Uni. Bochum*) O. Teryaev (*Joint Inst. for Nucl. Research, Dubna*) A. Radyushkin (*Jefferson Lab.*)
Jul 27-31	**Confrontation and Convergence in Nuclear Theory** A. Brown (Coordinator) *(Michigan State Uni.)* M. Hjorth-Jensen (*Uni. Oslo*) R. Janssens (*ANL*) J. Tostevin (*Uni. Surrey*) T. Papenbrock (*Uni. Tennessee at Knoxville*)
Aug 03-07	**The Lead Radius Experiment and Neutron Rich Matter in Astrophysics and in the Laboratory** C. Horowitz (Coordinator) (*Indiana Uni.*) P.G. Reinhard (*Uni. Erlangen*) C.W. de Jager (*Jefferson Lab.*)
Sep 07-11	**QCD Green's Functions, Confinement, and Phenomenology** D. Binosi (Coordinator) (*ECT**) J. Papavassiliou (*Uni. de Valencia*) A.C. Aguilar (*Uni. de Valencia*) J.M. Cornwall (*Uni. of California at Los Angeles*)
Sep 14-18	**Flow and Dissipation in Ultrarelativistic Heavy Ion Collisions** C. Greiner (Coordinator) *(Uni. Frankfurt)* M. Bleicher *(Uni. Frankfurt)* P. Huovinen *(Uni. Frankfurt)* R. Snellings *(NIKHEF)* P. Petreczky *(Brookhaven National Lab.)*
Sep 28 - Oct 03	**Strong, Weak and Electromagnetic Interactions to probe Spin-Isospin Excitations** A. Rubio (Coordinator) (*CSIC*) Y. Fujita (*Uni. Osaka*) W. Gelletly (*Uni. Surrey*)
Oct 12-16	**Hadronic Atoms and Kaonic Nuclei - Solved Puzzles, Open Problems and Future Challenges in Theory and Experiment** C.O. Curceanu (Coordinator) (*LNF-INFN Frascati*) C. Guaraldo (*LNF-INFN Frascati*) J. Marton (*SMI Vienna*) P. Kienle *(TUM* Garching) W. Weise (*TUM Garching*)
Oct 19-23	**Relativistic Description of Two- and Three-body Systems in Nuclear Physics** G. Salme' (Coordinator) (*INFN Roma*) T. Frederico (*Inst. Tecnologico de Aeronautica*) M. Viviani (*INFN Pisa*)

Oct 26-30	**Electroweak Interactions with Nuclei : Superscaling and Connections Between Electron and Neutrino Scattering** M.B. Barbaro (Coordinator) (*Uni. Torino*) T.W. Donnelly (*MIT*) A. Molinari (*Uni. Torino*)
Nov 09-13	**Orbital Angular Momentum of Partons in Hadrons** M. Burkardt (Coordinator) (*New Mexico State Uni.*) G. Schnell (*DESY*)

3.3 Reports on Projects and Collaboration Meetings

3.3.1 SFB/TR 55 COLLABORATION MEETING

DATE: January 07-10, 2009

ORGANIZERS:

Thomas R. Hemmert *(Co-ordinator)* (*U Regensburg*)
Andreas Schäfer (*U Regensburg*)

NUMBER OF PARTICIPANTS:37

MAIN TOPICS:

- Hadron physics from lattice QCD
- Algorithms for lattice QCD simulations
- QPACE computer project

SPEAKERS:

W. Bietenholz (*U Regensburg*)
M. Günther (*U Wuppertal*)
M. Gürtler (*TU München*)
R. Horsley (*U Edinburgh*)
A. Jakovac (*U Wuppertal*)
K. Kahl (*U. Wuppertal*)
V. Maillart (*U Bern*)
F. Niedermayer (*U Bern*)
A. Nobile (*U Regensburg*)
H. Perlt (*U Leipzig*)
P. Rakow (*U Liverpool*)

SCIENTIFIC REPORT:

Aim and Purpose

The SFB/TR55 ”Hadron physics from Lattice QCD” was inaugurated on July 1st, 2008 and is still in its start-up phase, e.g. several postdoc-positions connected with this SFB have only been filled during fall 2008. The collaboration meeting at ECT* in early January 2009 therefore had the following goals:

a) Researchers of the four universities involved i.e. Bern, Graz, Regensburg and Wuppertal and especially the new postdocs would get to know each other and their respective work/expertise.
b) A setting in a place like ECT* outside one of the universities involved allows for un-interrupted focused discussion/planning of the concrete research goals to be realized in 2009.
c) Identification of research projects that will be worked upon in close collaboration between researchers from different universities within the SFB.

Results and Highlights

In the mornings we had presentations both from SFB members and from SFB-associates reporting the status of their sub-projects within the SFB. The afternoons were reserved for small working group meetings which took place both in the Rustico (offices, seminar room) as well as in seminar rooms of the Villa Tambosi. Given that our SFB members/associates typically work scattered over several European countries (e.g. the international QCDSF lattice QCD collaboration which is part of the SFB), the small-group afternoon meetings formed the most important parts of this collaboration meeting. As mandated by the by-laws of the SFB we also held a general assembly of all the SFB members during the collaboration meeting at ECT*

Conclusions

The majority of participants at this collaboration meeting at ECT* were Ph.D. students and postdocs of the new SFB who interacted lively throughout these four days, so we are confident that goal a) has been achieved. Quite certainly, the specific setting of this collaboration meeting at ECT* with the possibilities to interact (goal b)) both during the afternoons and also informally in the evenings during/after dinner was also helpful in creating a sense of community among the many new researchers in this SFB. As far as goal c) is concerned, we are aware of at least two new projects involving researchers both from Wuppertal and Regensburg that got initiated during this meeting in Trento, and we are looking forward to the outcome.

3.3.2 SIGN PROBLEMS AND COMPLEX ACTIONS

DATE: March 02-06, 2009

ORGANIZERS:

Gert Aarts *(Co-ordinator)* (*Swansea University*)
Shailesh Chandrasekharan (*Duke University*)

NUMBER OF PARTICIPANTS: 26

MAIN TOPICS:

- Nature of sign problems
- Worldline formulations
- Complex Langevin methods
- Diagrammatic Monte Carlo
- Extrapolation methods
- Reweighting methods

SPEAKERS:

Gert Aarts (*Swansea University*),
Bartolome Alles (*INFN Pisa*),
Jacques Bloch (*Universität Regensburg*),
Barak Bringoltz (*University of Washington*),
Shailesh Chandrasekharan (*Duke University*),
Philippe de Forcrand (*ETH Zürich and CERN*),
Massimo D'Elia (*University of Genova*),
Francesco Di Renzo (*University of Parma*),
Shinji Ejiri (*Brookhaven National Labs*),
Gergely Endrodi (*Eötvös University*),
Dean Lee (*North Carolina State University*),
Maria-Paola Lombardo (*Frascati*),
Atsushi Nakamura (*Hiroshima University*),
Owe Philipsen (*Universität Münster*),
David Reeb (*University of Oregon*),
Erhard Seiler (*Max-Planck Institute Munich*),
Denes Sexty (*Universität Darmstadt*),
Kim Splittorff (*NBI Copenhagen*),

Ion Stamatescu (*Universität Heidelberg*),
Boris Svistunov (*University of Massachusetts Amherst*),
Urs Wenger (*Bern University*).

SCIENTIFIC REPORT

Aim and Purpose

The understanding of strongly interacting matter and a variety of strongly correlated materials requires a nonperturbative analysis employing numerical simulations. In the conventional formulations of these problems, introduction of a chemical potential makes the action complex. Hence, the standard Monte Carlo method to evaluate the path integral through importance sampling fails, since there is no clear probability distribution to sample from. This problem is commonly known as the sign problem and is an outstanding problem in field theory and many-body physics. One prime example of a theory in particle physics where the sign problem arises is QCD at nonzero baryon density. There are also many condensed matter materials of interest where sign problems have hindered progress. This includes frustrated quantum spin systems and strongly correlated electronic systems away from half filling. Fortunately, in recent years radical new approaches have been developed which can handle the sign problem or even eliminate it altogether. For a class of field and many-body theories, these methods are based on rewriting the partition function in a dual set of variables, similar to worldline (WL) representations. In many cases, the WL-approach suggests new solutions to the sign problem. Promising results have also been obtained using stochastic quantization and complex Langevin dynamics. In this case the sign problem is potentially circumvented by complexifying all degrees of freedom, so that the theory's phase space is explored in an inherently di different fashion. The aim of this workshop was to learn about sign problems that arise in lattice field theory, understand what has been done in recent years and explore what can be done in the future.

Results and Highlights

The format of the workshop was chosen to optimize two requirements often lacking in larger-scale conferences: sufficient time for speakers to explain their ideas and maximal discussion time. In practice this meant that we scheduled four talks per day, with the opening talks being semi-introductory in nature. The morning sessions concluded with a half hour discussion. For the afternoons we organized discussion sessions of at least one hour, moderated by a chair who prepared a 10 minute introduction and list of open questions. This format was well-appreciated by all participants and allowed for lively discussion continuing into the night.

We had in mind an interdisciplinary yet technical meeting, giving participants the opportunity to learn developments outside their own field of expertise. This goal was achieved by having among the participants several researchers from the nuclear and condensed matter physics community (the majority of the participants are interested in the physics of QCD at nonzero baryon density). In combination with the discussion sessions, this allowed the workshop to be constructive and interdisciplinary. Moreover, many participants used the meeting to advance existing collaborations and possibly start new ones.

Two days were spent on the most promising directions to tackle the sign problem: complex Langevin dynamics and worldline methods. The possibility to focus a full day on one approach, with extensive discussions throughout, has allowed us to clarify aspects of the methods which were more obscure before. Two important insights have emerged from this conference: (1) In the context of complex Langevin dynamics, the possible relevance of stochastic gauge fixing was emphasized by several participants, (2) In the context of world line formulations, the sign problem in QCD with a finite baryon density may be alleviated through a partial averaging over gauge field configurations especially in relation to the Polyakov loop fluctuations.

In conclusion, the workshop was considered a success, by many of the participants and the organizers.

3.3.3 SIMULATIONS OF LOW AND INTERMEDIATE ENERGY HEAVY ION REACTIONS

DATE: May 11-15, 2009

ORGANIZERS:

Joerg Aichelin *(Co-ordinator) (Subatech, Ecole de Mines, Nantes, France)*
Hermann Wolter *(Ludwig-Maximilians University, Munich, Germany)*

NUMBER OF PARTICIPANTS: 21

MAIN TOPICS:

- Comparison of benchmark calculations of simulation codes for heavy ion reactions at low and intermediate energy
- Investigations into reasons for different results for identical physical input, and planning of further tests
- Current topics in heavy ion reactions in the low and intermediate energy range (see speakers)
- Lecture: Transport of resonances with a continuous mass spectrum

SPEAKERS:

J. Aichelin(*Subatech, Nantes*)

M. Colonna (*University and INFN-LNS, Catania*)

P. Danielewicz (*Michigan State University*)

T. Gaitanos(*Giessen University*)

C. Hartnack (*Subatech, Nantes)*

S. Leupold (*Giessen University*)

A. Ono (*Tohoku University in Sendai*)

W. Reisdorf (*GSI, Darmstadt*)

B. Tsang(*Michigan State University*)

G. Verde (*Catania University and INFN*)

H. Wolter (*Ludwig-Maximilians University in Munich*)

Y. Zhang (CIAE, China)

SCIENTIFIC REPORT:

Aim and Purpose

Heavy ion collisions are the principal tool to learn about the properties of hadronic matter in all its aspects. However, these properties are not directly observed in a collision, rather one obtains any information only by comparing experimental observables with predictions of non-equilibrium transport calculations by varying the assumptions on the equation-of-state, on in-medium cross sections or on other input variables. For a successful approach the non-equilibrium transport calculations have to be sufficiently accurate that their inherent systematic errors are smaller than the expected signal.

At higher energies the combined efforts of different groups have succeeded in the identification of unambiguous and robust signals for the hadronic equation of state. At lower energies, between 100 AMeV and 1 AGeV, the range in which we can hopefully identify the origin of the in-plane flow and functional form of the symmetry energy the situation is more complicated. The longer reactions times require a longer time evolution until the final values of the observables are obtained. The simulations are therefore more sensitive to the variety of choices have to be made on the programming level (how to initialize the collision partners, how to realize the Fermi motion and the Pauli blocking, to decide when and how a collision takes place, etc.), which are solved by different strategies in the different codes.

The workshop was motivated by the idea to improve this situation by making a direct comparison between the various codes existing in the field, and trying to assess in a way the systematic uncertainties of theoretical predictions. This required that the programs are tested for the same reactions and the same physical input and that all refinements and unnecessary features like experimental filters are discarded. Thus to achieve a meaningful comparison we succeeded to engage the main players in the field, who agreed to test the programs under identical conditions, and who were willing to cooperate in the resolution of the difficulties.

Thus this workshop was of a different nature than usual workshops, since the main objective was of a computational nature. It was therefore classified by the board of the ECT* as a collaboration meeting. But the attendants of the workshop do not form a collaboration with a budget of its own. However, with the support of the ECT* and the willingness of some of the participants, including the organizers, to support themselves, the workshop could be held successfully.

An important concept of the workshop was to do some work already before the meeting, a kind of homework assignment. This allowed to eliminate some trivial problems before the meeting and provided a starting basis for the work on the workshop. These comparisons were presented by Th. Gaitanos and H. Wolter at the beginning of the meeting. From the discussions new test calculations were agreed upon which were performed during the meeting and analyzed and discussed in several sessions.

We found generally a good agreement of the results for bulk variables, such as stopping and flow. In this respect the situation had considerably improved since the earlier workshop. On the other hand, this agreement is still not good enough relative to the variations due to different physical assumptions, e.g. on the symmetry energy. We therefore discussed in particular the behaviour of the collision term (frequency, energy and density distributions). Here we found rather large differences, showing that the strategy to simulate this term is critical for further progress. Thus at the end of the meeting a continuing activity was planned with further benchmark calculations. The aim is to write a report in a quotable journal to allow to assess the accuracy of such simulations. To settle the remaining questions the participants agreed to plan a second workshop. With a sufficient preparation by homework assignments it should allow to elucidate the interplay between collision term and mean field which is presently the largest source of the systematic error of these programs.

In addition, since many of the foremost experts on transport calculations in heavy ion collisions were present, we also took the opportunity to have a series of lectures and extended talks on the physics problems of heavy ion collisions in this energy range, on the status and the open questions. We followed the principle to have essentially one review talk (of about one hour length) for a given subfield, which should not only cover the results of the reviewer, and then to have a thorough and unhurried discussion. We believe, that this plan worked very well and led to many suggestions on further work. Also several experimentalists, who work in the field of intermediate energy heavy ion collisions had been invited, and they contributed very useful views and reviews of their perception of the state of the theory and the demands and requirements to theorists. Also we had invited one lecturer (S. Leupold from Giessen) to give a 3-hour lecture on transport of particles with finite width ("off-shell transport"), which led beyond the current practice of transport calculations.

Results and Highlights

We believe that with this meeting we made real progress in the understanding of simulation programs for heavy ion collisions. In particular, we identified the various procedures chosen in the different implementations of the stochastic collision term as the main source of the remaining differences. After the meeting we have collected more test calculations to further elucidate this problem. As said above, we aim at writing an article, which we believe would give a sort of systematic theoretical error in the prediction of the various simulation codes, which took part in the comparisons.

It also proved to be very useful to have included experimentalists into the presentations and discussions at Trento. We think that this will make the theorists more aware of the needs of the experimentalists. There was an agreement that the various codes should be better documented and also more usable by a similar input and output structure. Also the presentations and discussions of theoretical issues in an unhurried and cooperative atmosphere proved to be very useful for further work. In fact, the files of the presentations on the website of the ECT* have been useful repeatedly.

A highlight of the meeting was the friendly support of the director and staff of the ECT*, in particular of Cristina Costa, and the conference dinner at Rifugio Bindesi.

3.3.4 HEAVY QUARKONIUM PRODUCTION IN HEAVY-ION COLLISIONS

DATE: May 25-29, 2009

ORGANIZERS:

David Blaschke *(Co-ordinator) (University of Wroclaw)*
Philippe Crochet *(LPC CNRS/IN2P3)*
Ralf Rapp *(Texas A&M University)*

NUMBER OF PARTICIPANTS: 43

MAIN TOPICS:

- Experimental Programs for Quarkonia at CERN-SPS, CERN-LHC, RHIC and FAIR-CB
- Cold nuclear matter effects
- Production process of heavy quarkonia
- Models and phenomenological approaches
- Hot and dense medium effects
- Statistical models
- Kinetic approaches
- Lattice QCD for heavy-quark potential and quarkonium correlators

SPEAKERS:

Anton Andronic *(GSI Darmstadt)*
Roberta Arnaldi *(INFN Torino)*
Andrea Beraudo *(Universita' di Torino)*
Hamza Berrehrah *(Subatech-Nantes)*
Nora Brambilla *(Technische Universität München)*
Elena Bratkovskaya *(ITP, Uni. Frankfurt)*
Peter Braun-Munzinger *(GSI Darmstadt)*
Daniel Cabrera *(UCM, Madrid)*
David D'Enterria *(Universitat de Barcelona)*
Hengtong Ding *(Bielefeld University)*
Elena Ferreiro *(Univ. Santiago)*
Anthony Frawley *(Florida State Univ.)*
Taku Gunji *(University of Tokyo)*
Olaf Kaczmarek *(University of Bielefeld)*
Che-Ming Ko *(Texas A&M University)*
Mikko Laine *(Bielefeld University)*

Philippe Lansberg *(SLAC - Stanford)*
Mike Leitch *(Los Alamos National Laboratory)*
Carlos Lourenco *(CERN)*
Gines Martinez *(SUBATECH)*
Amruta Mishra *(Indian Institute of Technology)*
Peter Petreczky *(BNL)*
Dariusz Prorok *(University of Wroclaw)*
Krzysztof Redlich *(University of Wroclaw)*
Felix Riek *(Texas A&M University)*
Helmut Satz *(Univ. Bielefeld)*
Enrico Scomparin *(INFN Torino)*
Peter Senger *(GSI)*
Jonivar Skullerud *(NUIM)*
Thomas Ullrich *(BNL)*
Ramona Vogt *(LLNL and UC Davis)*
Hermine Woehri *(LIP)*
Cheuk-Yin Wong *(Oak Ridge National Laboratory)*
Yongbin Zhao *(TAMU)*

SCIENTIFIC REPORT:

Aim and purpose

Significant progress has been made recently in the field of charmonium (or more general heavy quarkonium) production in heavy-ion collisions, both theoretically (lattice QCD and effective models at finite temperature, phenomenological implementations for A-A collisions) and experimentally (most notably in the understanding of “cold nuclear matter" effects at RHIC and the CERN-SPS). It was therefore an ideal time to revisit these developments and update the understanding of charmonium properties in medium and their consequences for heavy-ion collisions, also in view of upcomning experiments at CERN-LHC and the new domain of dense matter to be probed at FAIR-CBM.
The following topics have been selected for lectures and topical discussions at the workshop:

a) Quarkonium spectral functions and correlators: potential/T-matrix models versus lattice QCD (lQCD)
b) Quarkonia (nonequilibrium) statistics: kinetics of dissociation vs. recombination processes in the medium.
c) Data from CERN-SPS and RHIC; prospects for future experiments.
d) Cold nuclear matter (CNM) effects on heavy quarkonia production in nuclear collisions.

The workshop has served its goal of bringing together at the ECT* theorists and experimentalists fostering a fruitful exchange leading to significant progress in identifying central problems in heavy-quarkonia production in heavy-ion collisions, and advance viable avenues of solution. The forefront of the experimental status has been pushed forward, and theoretical concepts have been presented, discussed and scrutinized. By the end of the workshop and within the two weeks following it we have received many positive feedback from participants and from colleagues who followed the talks online on the website.

Contacts among leading researchers in the field have been facilitated, new projects have been initiated, and existing collaborations (e.g., Frawley, Leitch, Lourenco, Vogt, Woehri) have worked on joint publications. The workshop can thus be considered a successful one providing a step forward in the physics of heavy quarkonia in medium.

Results and Highlights

Progress has been made in the main directions defined above:

1. Exchanges between experts in lQCD, effective field theory and potential models have been organized; one of the central topics, the extraction of heavy-quark potentials from thermal lQCD (“$F(r,T)$ vs. $U(r,T)$"), has been addressed in depth (Beraudo, Brambilla, Cabrera, Kaczmarek, Laine, Petreczky, Riek, Satz, Wong and others), including a dedicated discussion session (convener: Rapp).
   The problem has not been resolved, but arguments and problems to distinguish different quantities have been better identified and sharpened.

2. The role and relations of different inelastic reaction rates have been clarified. The nonequilibrium aspects of quarkonia creation and evolution within kinetic approaches including dissociation and/or recombination in the medium have been discussed. The role of hadronic states, the relation of timescales (heavy-quark vs. quarkonium vs. plasma formation) and their role at different collisions energies have been elaborated (Andronic, Bratkovskaya, Braun-Munzinger, Ko, Redlich, Zhao and others).

3. New experimental results, in particular from p-A and d-Au collisions at RHIC (Frawlez, Leitch) and SPS (Arnaldi, Scomparin), have led to a highlight of this workshop: a systematic evaluation of CNM effects has been used to isolate a centrality-dependent ``anomalous suppression" factor, S_{J/psi}. Albeit not fully

model-independent, the resulting S_{J/psi} exhibits, within exp. errors, universal behavior in system size and collision energy when plotted as a function of charged-particle multiplicity, dN_ch/d eta.

Moreover, S_{J/psi}(dN_ch/deta) seems to feature an “onset-behavior" for suppression at approximately $dN_{ch}/d\eta\simeq 300$. It is tempting to associate this with an energy-density variable and thus relate it to the onset of Quark-Gluon Plasma formation in A-A reactions. Current model predictions overestimate the suppression at low centralities (partly due to the updated CNM baseline), but several theoretical questions will have to be revisited (e.g., variations in the QGP formation time, magnitude of J/ψ binding and dissociation in both QGP and hadron gas, etc.). This will further tighten the connection with the theoretical developments discussed above.

3.3.5 THE 5TH INTERNATIONAL PION-NUCLEON PWA WORKSHOP AND INTERPRETATION OF BARYON RESONANCES

DATE: June 01-05, 2009

ORGANIZERS:

Lothar Tiator *(Co-ordinator) (Universität Mainz)*
Mauro Giannini *(Universita' di Genova)*
Alfred Svarc *(Rudjer Boskovic Institute, Zagreb)*
Michael Sadler *(Abilene Christian University)*

NUMBER OF PARTICIPANTS: 40

MAIN TOPICS:

- Status of πN and electroproduction experiments
- Phenomenological analyses: SAID, MAID, EBAC
- Inelastic partial wave amplitudes
- Coupled-channels approaches
- Isobar models, dynamical models and dynamically generated resonances
- Bare versus dressed resonance poles
- Effective field theories and chiral corrections to nucleon resonance masses and form factors
- Nucleon resonances in quark models and lattice QCD

SPEAKERS:

C.M. Alexandrou *(University of Cyprus, Nikosia)*
J. Arends *(University of Mainz)*
R.A. Arndt *(George Washington University, GWU)*
S. Capstick *(Florida State University in Tallahassee)*
S. Ceci *(Rudjer Boskovic Institute)*
M. Döring *(Institut für Kernphysik and Jülich Center for Hadron Physics in Jülich)*
D. Drechsel *(University of Mainz)*
E. Friedman *(Hebrew University of Jerusalem)*
G. Galata *(University of Genova)*
J. Gegelia *(University of Mainz)*
M.M. Giannini *(University and INFN)*

H. Haberzettl *(George Washington University,GWU)*
M. Hadzimehmedovic *(University of Tuzla)*
B. Julia-Diaz *(University of Barcelona)*
S.S. Kamalov *(Joint Institute for Nuclear Research, JINR, Dubna)*
A. Kiswandhi *(University of Taiwan in Taipei)*
M. Kirchbach *(Universidad Autonoma de San Luis Potosi, Mexico)*
C. Lorce *(University of Mainz)*
T. Melde *(University of Graz)*
K. Nakayama *(University of Georgia in Athens, USA)*
B. Pasquini *(University of Pavia and INFN)*
V. Pascalutsa *(University of Mainz)*
A. Ramos *(University of Barcelona)*
D. Richards *(Jefferson Laboratory)*
M. Ripani *(University of Genova and INFN)*
M. Sadler *(Abilene Christian University, USA)*
M. Sainio *(University of Helsinki)*
E. Santopinto *(University and INFN of Genova)*
A. Sarantsev *(HISKP, University of Bonn)*
S. Scherer *(University of Mainz)*
V. Shklyar *(University of Giessen)*
J. Stahov *(University of Tuzla)*
I. Strakovsky *(George Washsington University,USA)*
A. Svarc *(Rudjer Boskovic Institute of Zagreb)*
L. Tiator *(University of Mainz)*
U. Thoma *(University of Bonn)*
M. Vanderhaeghen *(University of Mainz)*
H. Wittig *(University of Mainz)*
S.N. Yang *(University of Taiwan,Taipei)*
B. Zauner *(Rudjer Boskovic Institute of Zagreb)*

SCIENTIFIC REPORT:

Aim and Purpose

The aim of the planned workshop was three-fold:

First we wanted to bring the people together who are presently involved in the partial wave analysis of pion nucleon scattering and electromagnetic meson production. This part is in close connection to the previous PWA workshops starting in 2004 at Abilene and continued in Zagreb, Tuzla and Helsinki. Besides the techniques to be exchanged (e.g. how to get the resonance poles from the partial wave amplitudes), an important question is to determine which further experiments are needed to be done in the near future, in order to get precise and convergent results for partial waves.

Second we wanted to continue and extend the discussion on the physical interpretation of resonance poles started at BRAG2007. We wanted to have all opinions formulated, expressed, presented in a checkable and reproducible form and widely discussed. At this point we also wanted to discuss the mechanism of dynamically generated nucleon resonances as an alternative to genuine resonances, typically described within quark models.

Third we wanted to discuss recent developments in Effective Field Theory (EFT) and Lattice QCD to describe the structure and decay of nucleon resonances. The most prominent candidates are the P11(1440)and the S11(1535) resonances and their coupling to the pion and photon fields.

Results and Highlights

All topics were presented. We succeeded to get the experts of the different fields together during the week. The presentations were followed by lively discussions. The themes of our proposal were addressed and the following questions discussed in detail.

- What is a resonance? How can we distinguish between genuine 3q resonances and dynamically generated resonances?

- What are the model independent resonance properties? Are Breit-Wigner positions still meaningful or is it better to discuss only T-matrix pole positions and residues? How are the K-matrix poles related to them?

- What is the best procedure to obtain pole positions? Is the speed-plot technique sufficient, or the improved regularization technique should be applied?

- What is the role of coupled channels in pole extraction procedure? How sensitive the pole parameters are with respect to the number of channels? What is the role of coupled channels for stable production of K-matrix amplitudes?

- Is there a unique definition of bare parameters? What is the interrelation between bare and dressed poles on one side, and QCD quark models and lattice QCD calculations on the other?

- What is the present understanding of the issue of unmeasurability of the off-shell effects?

- The detailed overview of constituent quark models, quark-diquark models, quark-soliton models, unquenched quark models is given.

- How well can we understand the lowest nucleon resonances with lattice QCD? Masses and transition form factors can be calculated for Delta, Roper and S11 resonances. How well can we understand the correct ordering of the masses?

- What are the most recent experiments which have given information on the resonance production? And what are the future experiments to be expected in the near future? Various laboratories in Europe and abroad (USA, Japan, ...) are going to continue and increase this kind of activity.

Conclusions

Our immediate goals were met. We carried out many fruitful discussions on controversial aspects of proper resonance parametrization, and almost a consensus is achieved that our future work should be more and more oriented towards obtaining the T-matrix pole positions and residues. Different techniques have been discussed, how to reliably obtain these pole positions and residues. Analytical continuation into the complex plane seems to be the most straightforward way to go, but it was shown that also in this case various analyses can give conflicting results, especially, when the structure of the Riemann sheets becomes very complicated or when poles move far away from the physical axis. On the other hand it was also demonstrated, that at least the pole parameters of four-star resonances can reliably be obtained by improved speed-plot techniques and the regularization method. Both of them only use the PWA information along the physical axis, which is less influenced by model dependence. A very interesting exception seems to be the S11(1535) resonance. Even also kept as a four-star resonance by the PDG, different models give important hints that this resonance may not be a genuine 3q state, but rather a dynamically generated state by Kλ and KΣ dynamics. This is similar to the also discussed λ 1405) state, which is the most established dynamically generated resonance. Electromagnetic transition moments and transition form factors should also be analyzed in the future at the T-matrix pole, because they will provide additional information about the dynamical structure, i.e. the meson cloud contribution. This is in full agreement with effective field theoretical aspects and probably also with future lattice QCD calculations. It has been shown that lattice QCD is on the verge of getting the realistic nucleon resonance spectrum, and that in spite of still non-adequate pion masses and cell volume, the results tend to show resemblance to the experiment.

Presentations

All talks of the workshop are available at the ECT* website: http://www.ect.it

3.3.6 ATOMIC EFFECTS IN NUCLEAR EXCITATION AND DECAY

DATE: June 15-19, 2009

ORGANISERS:

Philip M. Walker *(Co-ordinator) (University of Surrey, Guildford, UK)*

James J. Carroll *(Youngstown State University, Ohio, USA)*

Fred J. Currell *(Queen's University, Belfast, UK)*

NUMBER OF PARTICIPANTS: 41

MAIN TOPICS:

- Isomer excitations
- Laser-plasma interactions
- Atomic-nuclear coupling
- Storage rings
- Ion traps
- Solid-state environments

SPEAKERS:

Bret Beck *(LLNL California)*
Lee Bernstein *(LLNL California)*
Fritz Bosch *(GSI Darmstadt)*
Carsten Brandau *(GSI Darmstadt)*
James Carroll *(YSU Ohio)*
Jos´e Crespo *(MPI Heidelberg)*
Dave Cullen *(Manchester University)*
George Dracoulis *(ANU Canberra)*
Ladislav Drska *(CTU Prague)*
Victor Flambaum *(UNSW Sydney)*
Georgi Georgiev *(CSNSM Orsay)*
Franck Gobet *(CENBG Bordeaux)*
Gilbert Gosselin *(CEA Bruy`eres)*
Igor Izosimov *(JINR Dubna)*
Sarkis Karamian *(JINR Dubna)*
Tibor Kibedi *(ANU Canberra)*
Shunji Kishimoto *(KEK Tsukuba)*
Filip Kondev *(ANL Chicago)*
Alain Lapierre *(TRIUMF Canada)*
Yuri Litvinov *(MPI Heidelberg)*
Peter Mohr *(Schwäbisch Hall)*
Iain Moore *(JYFL Jyvaskyla)*
Pascal Morel *(CEA Bruy`eres)*
Adriana Palffy *(MPI Heidelberg)*
Zygmunt Patyk *(SINS Warsaw)*
Götz Ruprecht *(TRIUMF Canada)*
Klaus Spohr *(UWS Scotland)*

SCIENTIFIC REPORT:

Aim and Purpose

It is well known that atomic electrons have keyroles to play in weak and electromagnetic decays (electron capture and electronconversion, respectively). However, their influence in nuclear excitation processes has hardly been studied. Meanwhile, technological advances with production and storage of highly charged ions, in rings and traps, open new opportunities to study the atomic-nuclear interface. This workshop explores relevant theoretical and experimental issues, and addresses the question: to what extent can atomic manipulations give control over nuclear transitions? An important consideration, which makes this workshop particularly timely, is the new and emerging capability to generate intense beams of short-lived nuclei. This not only opens up a wide range of nuclear ground states, but also enables a large number of nuclear isomers to be stored and studied.
An experimental opportunity that arises with isomer beams is the exploitation of their potentially large de-excitation signal (such as a 1 MeV gamma ray) when the initial interaction may be of relatively low energy (< 100 keV). Furthermore, the isomeric nuclei can be prepared as highly charged ions (HCI). These may open up the study of, for example, nuclear excitation by electron capture (NEEC), a process which has yet to be identified experimentally.
Even though few-electron or bare ions appear to be exotic states to study in the laboratory, they have wide application to plasmas, e.g. stellar environments. Indeed, NEEC and other atomic-nuclear interactions have been predicted to have large effects in plasmas. Such theoretical developments, combined with new ion-storage, laser-plasma and radioactive-beam techniques, give rise to a high discovery potential. Nevertheless, the interdisciplinary nature of the subject area leads to the need to bring together an appropriate range of different specialists.

Results and Highlights

The workshop succeeded in attracting an excellent cross section of speakers, including theorists and experimentalists from both sides of the atomic-nuclear divide. Nuclear isomers were able to act as a “cement” to hold together the different specialist communities. The search for isomers in exotic nuclei depends strongly on an understanding of what makes these states so long lived, and so too does the quest for their production and how this can be enhanced by the atomic environment. Here the role of HCI proved to be another unifying theme, since the resonant capture of electrons into vacant atomic orbitals is potentially a good means to 2 excite the nucleus (i.e. the NEEC process). Three specific HCI-generating methods were presented and discussed in detail: high-power lasers; storage rings coupled to heavy-ion accelerators - specifically the experimental storage ring (ESR) at GSI, which can store highly-charged radioactive ions; and electron beam ion traps (EBIT). The theoretical presentations demonstrated that there is a good understanding of the NEEC process, though, of course, it will be important to demonstrate its effect experimentally. The sister process of nuclear excitation by electron transition (NEET) is also now on a good theoretical footing, and has even been observed - but only in two nuclides thus far, 197Au and 193Ir. As described at the workshop, those observations (yet to be confirmed independently) made use of the SPring-8 synchrotron in Japan to generate appropriate atomic vacancies. NEET should also be important in HCI conditions. Both NEET and NEEC are expected to play significant roles in astrophysical environments where HCI conditions are common, but as yet there is no consensus on the specification of those environments, and no consensus on the most promising way to measure the corresponding NEET and NEEC effects. The workshop generated lively discussion about these issues, and several plans were hatched, from which experimental results may be anticipated in the not-too-distant future. The workshop included several other issues related to isomers and the atomic-nuclear interface, among them neutron acceleration caused by isomer de-excitation; the production of purified isomer beams; photoactivation of isomers; the influence of solid-state environments on nuclear decay rates; the exceptional case of the 7 eV (?)isomer in 229Th; the potential to probe the constancy of the physical constants; and the remarkable decay-rate oscillations observed in the ESR, associated with the electron capture of single-electron ions. To some extent, the workshop seemed like a whirlwind of challenging processes that take place on the borderland between atomic and nuclear physics. It was an exciting time in a number of ways. Participants departed with bold plans in mind.

Conclusions

The bringing together of experts from both the atomic and nuclear physics communities was highly successful in terms of generating lively discussion, debate, and ideas. An example of lingering questions was: can NEEC be observed? However, while there was plenty of optimism, there was no clear consensus regarding a single “best” method. Many new associations between participants were initiated, and the future holds much in store.

3.3.7 LINKING NUCLEI, MOLECULES, AND CONDENSED MATTER:COMPUTATIONAL QUANTUM MANY-BODY APPROACHES

DATE: July 06-10, 2009

ORGANIZERS:

Robert Roth *(Co-ordinator) (TU Darmstadt)*
Jürgen Schack *(Univ. Bielefeld)*
Johannes Richter *(Univ. Magdeburg)*

NUMBER OF PARTICIPANTS: 37

MAIN TOPICS:

The description of strongly correlated quantum many-body systems is a common challenge in nuclear structure physics, condensed matter theory, and quantum chemistry. By bringing together experts from these fields, the workshop highlights and promotes new developments and applications of a set of many-body techniques including

- Large-Scale Diagonalization Approaches
- Coupled-Cluster Method
- Density Matrix Renormalization Group
- Variational and Monte-Carlo Techniques

and also addresses computational aspects and codes.

SPEAKERS:

Bishop, Raymond *(Univ. Manchester, UK)*
Chan, Garnet *(Cornell Univ., USA)*
Dukelsky, Jorge *(CSIC Madrid, Spain)*
Farnell, Damian *(Univ. Manchester, UK)*
Forssén, Christian *(Chalmers Univ., Sweden)*
Gauß, Jürgen *(Univ. Mainz, Germany)*
Honecker, Andreas *(Univ. Göttingen, Germany)*
Kinder Jesse, *(Cornell Univ., USA)*
Jürgen Schnack *(Univ. Bielefeld)*
Läuchli, Andreas *(MPI Dresden, Germany)*
Lester, William *(Univ. California, Berkeley, USA)*

Navrátil, Petr *(LLNL, USA)*
Papenbrock, Thomas *(ORNL, USA)*
Pederiva, Fancesco *(Univ. Trento, Italy)*
Piecuch, Piotr *(Michigan State Univ., USA)*
Pittel, Stuart *(Univ. of Delaware, USA)*
Richter, Johannes *(Univ. Magdeburg)*
Roth, Robert *(TU Darmstadt)*
Ruedenberg, Klaus *(Iowa State Univ., USA)*
Schmitt, Felix *(TU Darmstadt)*
Schnalle, Roman *(Univ. Bielefeld)*
Schulenburg, Jörg *(Univ. Magdeburg, Germany)*
Sorella, Sandro *(SISSA, Italy)*
Taioli, Simone *(Univ. Trento, Italy)*
Tsukerblat, Boris *(Ben-Gurion Univ., Israel)*
Walet, Niels *(Univ. Manchester, UK*

SCIENTIFIC REPORT:

Aim and Purpose

Computational quantum many-body approaches are at the forefront of theoretical research activities in a number of different fields of physics and chemistry. The description of strongly correlated quantum systems composed of tens or hundreds of indistinguishable particles, mostly fermions, is at the heart of nuclear structure theory, quantum chemistry, and certain areas of condensed matter theory. Consequently similar theoretical methods for tackling the many-body problem have been adopted and developed in the respective fields – often in parallel and without much interaction.

The general aim of this workshop, therefore, was to bring together experts and practitioners for selected computational many-body methods from the different communities to (i) discuss the methodical advances in their respective fields, (ii) identify similar developments and connections to other fields, and (iii) explore prospects for the transfer of new methodologies to other fields.

In order to promote this discussion and coordinate efforts towards understanding and exploiting the methodical links, we have focussed on four classes of many-body approaches: (a) large-scale diagonalization techniques, e.g. exact diagonalization (ED), configuration interaction (CI), and no-core shell model (NCSM), (b) coupled-cluster methods (CC), (c) density matrix renormalization group (DMRG), and (d) quantum Monte Carlo methods (QMC) and variational approaches. Furthermore, we had a special session discussing several open-source program libraries, e.g. the ALPS and SPINPACK packages.

All of these methods are actively applied and constantly improved in the three fields covered by our workshop. Each field has its own specific requirements and difficulties, which drive innovative developments.

In nuclear theory, the solution of the many-body problem is only the second stage of the nuclear structure problem. The first stage is the construction of a realistic Hamiltonian, i.e. the derivation of a realistic nuclear interaction. Prompted by the advent of soft interactions derived consistently in the framework of chiral effective field theory and the development of transformation methods, which lead to phase-shift equivalent interactions with superior convergence properties, there is an increased interest in ab initio methods for the nuclear many-body problem. Established ab initio methods in the nuclear structure context are, e.g., the Green's function Monte Carlo method and the NCSM, which are limited to the p-shell for computational reasons. For heavier systems first attempts have been made to adopt alternative many-body approaches: The CC method has been applied successfully to nuclei beyond the p-shell. First successful applications of the DMRG have also been reported. At these frontiers, nuclear structure theory benefits enormously from the input from other fields of many-body theory, which this workshop shall provide.

For the field of condensed matter theory we are focusing on quantum spin systems and strongly correlated quantum gases. Both infinitely extended (lattices) as well as finite-size systems (e.g. magnetic molecules) are of interest. Although in most cases the appropriate Hamiltonian is clear, e.g. Heisenberg or Hubbard, the solution of the many-body problem is challenging especially in cases of geometrically frustrated antiferromagnets. Their non-trivial and highly correlated ground states might change under variation of external parameters giving rise to quantum phase transitions. The relation to high temperature superconductivity is a long-standing hypothesis. In order to achieve the necessary high numerical precision that is needed for instance to obtain correlation functions several large-scale numerical methods have been devised and improved, among them ED, DMRG, and CC. Recent developments include for instance the use of time-dependent DMRG for the evaluation of spectral densities, the development of a massively parallel code for numerical diagonalization as well as the combined use of spin rotational and point group symmetries. The possibility of experimental investigations with highly accurate spectroscopic methods stimulates further improvements on the methodological side.

In quantum chemistry a wealth of high-precision tools for the solution of the electronic many-body problem have been developed. Many of these developments are driven by the extraordinary requirements regarding the accuracy of the electronic structure predictions (“chemical accuracy”). The two major working horses for Hamiltonian-based problems are CC and CI methods and there have been amazing methodical advances and refinements driven by the chemistry community. Other methods, like DMRG and QMC have also been established and further developed. All these advances are a treasure trove for other fields and this workshop shall identify connections, overcome language barriers, and promote the methodical transfer between the fields.

Results and Highlights

The structure of the workshop and the invited key-participants were chosen to provide a balanced view of the many-body approaches we focussed on with contributions from all three fields of quantum science. Throughout the workshop week each day was devoted to one many-body methodology – i.e. “Diagonalization”, “Monte Carlo”, “Coupled Cluster”, and “DMRG” – plus a special session on “Codes & Co” (see Appendix: Workshop Program). We were able to attract a significant number of outstanding scientists presenting the general framework and recent methodological developments from the point of view of the different disciplines. For these major talks we allocated one hour of time including discussion. All speakers were encouraged to focus on methodical aspects of interest for practitioners outside their own community.

As a result of the methodological grouping of the program and of a number of excellent presentations, which addressed in particular researchers outside of the own community, we had very lively and productive discussions across disciplinary boarders. A lot of questions were geared towards understanding the specific problems and approaches in other fields and possible avenues for transferring ideas and methods to the own field of research. This type of discussion shows that the major goals of the workshop, as defined in the second paragraph of the preceding section, were successfully accomplished.

During and after the workshop we got very positive feedback from the participants confirming that communication between the different disciplines, which has often been neglected in the past, is of vital importance and holds great potential for new and innovative developments. It was also remarked that a broader view on the many-body methods and their applications outside of the own field of activity is of increasing importance, particularly for young researchers. As a result of the workshop and to further promote the discussion in a trans-disciplinary setting, several invitations to seminar talks at different Universities were arranged.

3.3.8 RECENT ADVANCES IN PERTURBATIVE QCD AND HADRONIC PHYSICS

DATE: July 20-25, 2009

ORGANIZERS:

Andei Belitsky *(Co-ordinator)* (*Arizona St. Univ)*
Klaus Goeke (*Ruhr Univ. Bochum*)
Dieter Mueller (*Ruhr Univ. Bochum)*
Oleg Teryaev (*Joint Inst. for Nucl. Research*)
Anatolij Radyushkin (*Jefferson Lab.*)

NUMBER OF PARTICIPANTS: 28

MAIN TOPICS:

- QCD factorization
- Spin Physics in QCD
- Non-perturbative models
- QCD evolution
- Generalized Parton distribution

SPEAKERS:

D. Shirkov (*JINR, Dubna*)
A. Bakulev (*Bogolyubov Lab. Theor. Phys., JINR*)
S. Mikhailov (BLTPh, JINR)
D. Ivanov (Sobolev Institute of Mathematics)
N. Stefanis (ITP- II, Ruhr University Bochum)
F. Ceccopieri (Universita' di Parma & INFN)
A.Manashov (*Univ.Regensburg*)
G.Kortchemsky (*IPhT, Saclay)*
E.Sokatchev (*LAPTH – Annecy*)
I.Ginzburg (*Sobolev Inst. of Mathematics SB RAS, Novosibirsk*)
A.Efremov (*JINR, Dubna*)
G.Chirilli (*JLAB & ODU*)
B.Ermolaev (*Ioffe Phys-Tech Institute*)
L.Gamberg (*Penn State University-Berks*)
O.Denisov (*CERN / INFN sez. di Torino*)
A. Schaefer (*Universität Regensburg*)
J. Riedl (*Universität Regensburg*)
S. Boffi (*Univ. Pavia*)
P. Ratcliffe (*Università degli Studi dell'Insubria*)
A. Metz (*Temple Univ.)*
P. Schweitzer (*Univ. of Connecticut*)

F. Bradamante (*Univ.Trieste and INFN*)
T. Teckentrup (*Bochum University*)
O. Teryaev (*JINR*)
M. Anselmino (*Univ. Torino & INFN*)
B. Pasquini (*U. Pavia & INFN, Pavia*)
P. Kroll (*University of Wuppertal*)
D. Mueller (*Ruhr-University Bochum)*

SCIENTIFIC REPORT:

Aim and purpose

The aim of the meeting was to collect the experts in the field of QCD factorization and its applications, in particular, for a description of exclusive and spin-dependent processes.
These subjects were consistently developed by A.V. Efremov and his collaborators in the past and receive currently a special attention because of the vast amount of experimental data on spin-dependent semi-inclusive deep inelastic scattering, deeply virtual Compton scattering, hard exclusive meson production and meson transition formfactors.
The latter are especially interesting because of recent puzzling BABAR data. The relevant non-perturbative QCD inputs constitute the nucleon and meson spin structure. At the same time, the QCD evolution of higher twist matrix elements manifest the remarkably hidden symmetries, integrability and relations to string dynamics. The scope of the Workshop was to discuss these issues and find possible relations between them.

Results and Highlights

The Workshop contained a detailed overview of all important theoretical and selected experimental issues. All the fields were covered extensively and caused vivid discussions.
The talks of Efremov and Ginzburg presented the original approach to QCD factorization and showed its modern implications, in relation to the talk of Ermolaev. The role of BABAR data for factorization was analyzed by Mikhailov.

One of the highlights which should have further implications was the discussion of Transverse Momentum Dependent QCD factorization, presented by Yuan as a discussion leader and its relation to other types of factorization. In this discussion the experts from all fields present at the Workshop took part, including the more mathematical issues represented by Kortchemsky, whose presentation of Sudakov effects put a common view on many of the discussed subjects. The talk of Kroll presented new results on Generalized Parton Distributions (GPD) which were understood as the non-forward analogs of transversity. Complementary views for non-perturbative models were presented by Boffi, Pasquini and Schweitzer. Various aspects of evolution were put forward by Ceccopieri, Ratcliffe, Yuan and Stefanis. Some discrepancies in colour structure were found and discussed. The distribution of orbital momentum was discussed by Mueller and Teryaev. In general, the aim to find relations between different subjects was achieved and the outcome should affect the development of the field.

3.3.9 CONFRONTATION AND CONVERGENCE IN NUCLEAR THEORY

DATE: July 27-31, 2009

ORGANIZERS:

Alex Brown *(Co-ordinator) (NSCL,USA)*

Morten Hjorth-Jensen *(Oslo, Norway)*

Robert Janssens *(ANL, USA)*

Jeff Tostevin *(Surrey, UK)*

Thomas Papenbrock *(ORNL, USA)*

NUMBER OF PARTICIPANTS: 30

MAIN TOPICS:

- Connections between ab-initio methods and CI methods
- Special problems and methods for drip line nuclei
- Single-particle properties from stability to the drip line
- Approaches to heavy nuclei, CI vs EDF
- Approaches to double-beta decay

SPEAKERS:

C. Barbieri *(RIKEN, Japan)*

S. Bogner *(NSCL, USA)*

A. Covello *(Napoli, Italy)*

T. Duguet *(Saclay, France)*

D. Frekers *(Muenster, Germany)*

A. Gade *(NSCL, USA)*

M. Gorska *(GSI, Germany)*

R. Gryzwacz *(ORNL, USA)*

G. Hagen *(ORNL, USA)*

P.H. Heenen *(Brussels, Belgium)*

M. Horoi *(Central Michigan, USA)*

J. Holt *(TRIUMF, Canada)*

S. Kvaal *(Oslo, Norway)*

F. Nowacki *(Strasbourg, France)*

E. Ormand *(LLNL, USA)*

T. Otsuka *(Tokyo, Japan)*

A. Poves *(Madrid, Spain)*

V. Rodin *(Tuebingen, Germany)*

R. Roth *(Damstadt, Germany)*

J. Schiffer *(ANL, USA)*

K. Sieja *(GSI, Germany)*

A. Signoracci *(MSU, USA)*

O. Sorlin *(GANIL, France)*

N. Timofeyuk *(Surrey, UK)*

J. Toivanen *(Jyväskylä, Finland)*

K. Tsukiyama *(Tokyo, Japan)*

E. van Dalen *(Teubingen)*
A. Volya *(Florida State, USA)*
P.Vogel *(Caltech, USA)*
B. Walters *(Maryland, USA)*

SCIENTIFIC REPORT:

Aim and Purpose

Day 1 of the workshop set the scene for a very rewarding meeting, with several interesting talks on progress in our understanding of various many-body methods and their link in particular to the nuclear shell model. The latter has been very successful in understanding the structure of a large body of nuclear data. However, due to the dramatic increase in dimensionality, it is normally limited to studies of systems with single-particle degrees of freedom. With upcoming facilities that will study the limits of nuclear stability it becomes imperative to study, understand and develop many-body methods that can tackle systems with huge dimensionalities. A proper understanding of the mathematical properties of such methods is also crucial in order to progress. The first day was thus devoted to presentations of recent progress in nuclear many-body theory, starting with Scott Bogner from Michigan State University. He gave an excellent overview of the progress made in renormalization group approaches, in addition to providing theoretical links to theories such as Green's function and coupled cluster approaches. Applications of the renormalization group method was presented in the afternoon by Koshiroh Tsukiyama, with an emphasis on applications to light nuclei. Along these lines, Simen Kvaal from the University of Oslo, presented rigorous mathematical convergence criteria for large-scale shell-model calculations, with an emphasis on quantum dots. These findings can easily be transferred to nuclear physics studies or studies of trapped atoms. A preliminary understanding of convergence criteria for coupled-cluster was also presented. Erich Ormand from Lawrence Livermore lab gave an excellent overview over recent progress in no-core shell-model calculations with interesting applications on how to derive effective two and three-body interactions from large-scale shell-model calculations. These effective interactions can in turn be used in smaller space, in order to attack nuclei where a no-core approach becomes prohibitive. Calculations with three-body interactions are under way, similarly, Jason Holt from Triumf presented shell-model studies of the oxygen isotopes using three-body interactions from chiral perturbation theory, showing that these are crucial in order to understand the stability of these isotopes. These findings were much debated, and discussed by other speakers as well, see both Sorlin's, Otsuka's and Hagen's talks. Finally, an importance-truncating scheme for the no-core shell-model was presented by Robert Roth from GSI in Germany, with interesting applications to closed-shell nuclei like 16O and 40Ca.

The second day of the workshop focused on discussions of "Special problems and methods for drip line nuclei". This started with O. Sorlin providing an excellent experimental perspective on the state of knowledge of single-particle strength determinations and corresponding observed shell evolution near traditional (20,28) magic shell closures, interpreted as evolution of the monopole and spin-orbit interactions in neutron-rich systems. The binding of the oxygen isotopes, as a benchmark of theoretical calculations, was a pervasive theme. N. Timofeyuk discussed of calculation of spectroscopic factors (SF) via single particle overlap functions (OF) and their pre-asymptotic behavior when nucleon removal results in halo-like residues, making comparison of few-body and Gamow shell model results and suggesting testing in mirror systems. The relative merit of derivations of SF and OF by direct overlap or source-term techniques was also introduced. A. Volya led an excellent pedagogical discussion of the time-dependent continuum shell model formulation and its direct connection to observables, allowing tuning to known structures. Successful recent applications (and R-matrix comparisons) of a number of topical problems with one nucleon (neutron and proton) in the continuum were presented. G. Hagen discussed the rapidly-developing capabilities of the (CCSD, J-coupled) coupled cluster methodology (low-k/Chiral EFT interactions) for heavier asymmetric systems (including the oxygen isotopes to 28O). Center of mass motion was clarified. Considerations in going to the Sn region were outlined. Finally, E. van Dalen discussed the use of low-k interactions in HF(B) calculations of lighter nuclei, with an emphasis of the use of non-oscillator bases.

The third day of the workshop considered the topic of "single-particle properties from stability to the drip line". It started off with a theoretical talk by Taka Otsuka. He showed how the proton-neutron tensor interaction provides a way to understand the observed changes of shell gaps for neutrons as protons are added or for protons as neutron are added. He also showed that other problems associated with like-nucleons interactions might be understood by three-body interactions that originate from Delta-particle admixture in the nucleus. The next four presentations by Robert Gryzwacz (ORNL), Alexandra Gade (MSU), Magda Gorska (GSI), Bill Walters (Maryland) John Schiffer (ANL) showed recent experimental results. New results for a wide range of nuclei were presented including neutron-rich nuclei near the N=20 island of inversion (A=28-36), the neutron-rich nuclei near N=28 (A=44-50), the neutron-rich Ni, Cu, Zn and Ga (A=66-82) and near the closed-shell heavier nuclei 100Sn, 132Sn and 208Pb. These observations are crucial for tests and constraints of the various theoretical model discussed at this workshop. The session ended with a theoretical talk by Kamila Sieja who showed CI results for the pf-sdg model-space applied to neutron-rich nuclei from 64Cr to 100Sn. New predictions for a new island of inversion around 64Cr were presented that will require experimental verification.

The fourth day of the workshop was dedicated to "Approaches to heavy nuclei: configuration interaction vs. Energy-density functionals," and consisted of five 60-minutes talks by seasoned researchers and one 30-minutes student presentation. F. Nowacki presented results from recent large-scale shell-model calculations, including a discussion of the island of inversion, 50<Z<82 nuclei, and Xe-110. He also pointed out the need for more spectroscopic data in the Sn-132 region. A. Covello reported on the quality of shell model calculations that employ low-momentum interactions for nuclei around Sn-132 and Pb-208, respectively. C. Barbieri presented the status of an ab-initio description of single-particle energies in Ni isotopes within an ab-initio approach. The talks by P.-H. Heenen and T. Duguet focused on energy density functionals (EDF). Heenen presented impressive results based on fully projected single-particle wave functions, and its effect of the proton and neutron shell gaps. Duguet showed how an EDF augmented with microscopic matrix elements in the pairing channel yields a much-improved description of pairing properties in semi-magic nuclei. Finally, the PhD. student A. Signoracci presented new ideas to constrain the shell-model interaction by EDF.

The workshop was capped off on Friday with a session on "approaches to double-beta decay". Petr Vogel gave an introduction to the problems in neutrino physics and the new physics required for the observation of neutrino-less double beta decay. He presented results for the QPRA approach to two-neutrino (2nu) and zero-neutrino (0nu) decay. Vadim Rodin presented results from the QRPA method and also explained them in terms terms of broken SU(4) symmetry. John Schiffer presented data on nucleon transfer observables near A=76 that serve as a test of the CI models. The change of occupations as one adds two protons or two neutrons require a rather diffuse Fermi surface for the nucleon occupancies. Dieter Frekers presented data on charge exchange reactions and how they are used to understand the role of the intermediate 1+ states in 2nu decay. Mihai Horoi and Alfredo Poves discussed CI calculations. Horoi discussed the problem of increasing dimensionality for heavy nuclei and what models might be used to truncate CI. Poves showed the role of high seniority states in the 0nu calculations and how they might explain the difference (about a factor of two) between the QRPA and CI methods. There was much discussion about other problems that need to be addressed including the role of quenching in 2nu and 0nu matrix elements.

Results and Highlihts

All in all, the contributions spanned over several many-body methods, providing mathematical rigorous approaches and understandings as well as presenting several interesting links between the various methods. Ab initio approaches are now in the position where one can attack a large body of nuclei, in particular we expect to be able to study with a given Hamiltonian rather precisely most closed-shell nuclei in the near future. One can then use methods like coupled-cluster or Green's function based methods to derive better effective interactions for the nuclear shell model, in particular for regions close to the stability of a given chain of isotopes.

All presentations received considerable comments and questions from the audience, and discussions led to a 30-minutes "overtime" at the end of the day. Some of the highlights were the impressive results of large-scale shell-model calculations and modern nuclear EDF. It is clear that theory is making significant project regarding precision, and that experimental data for neutron-rich regions close to doubly magic shell closures are needed to calibrate and test current models.

The workshop was of immense value in disseminating theoretical advances in a format that allowed discussions to explore in detail the theoretical foundations of the methodologies used. The ECT* logistical support was excellent and the facilities and environment provided at ECT* were ideal for the planned workshop format. All presentations stimulated considerable comments, questions and debate. The one-hour discussion format was very effective in delivering this aim.

All of the formal presentations of the Workshop have been made available at http://www.nscl.msu.edu/~brown/ECT-2009/ECT.html, available also through the ECT* website.

3.3.10 THE LEAD RADIUS EXPERIMENT AND NEUTRON RICH MATTER IN ASTROPHYSICS AND IN THE LABORATORY

DATE: August 03-07, 2009

ORGANIZERS:

Charles J. Horowitz *(Co-ordinator) (Indiana U.)*
Kees de Jager *(JLAB)*
Paul Gerhard Reinhard *(U. Erlangen)*

NUMBER OF PARTICIPANTS: 38

MAIN TOPICS:

- The PREX Parity Violating Experiment
- Neutron densities and Nuclear Structure
- Atomic Parity Violation and Neutron Densities
- Neutron rich matter in Astrophysics

SPEAKERS:

M. Baldo *(Catania)*
M. Bender *(Gradignan)*
D. Blaschke *(Wroclaw)*
K. Blaum *(Heidelberg)*
A. Bracco *(Milano)*
A. Brown *(East Lansing)*
E. Brown *(East Lansing)*
N. Chamel *(Brussels)*
P. Danielewicz *(East Lansing)*
L. Dieperink *(Groningen)*
V. Flambaum *(Sydney)*
M. Gorshteyn *(Bloomington)*
G. Gwinner *(Winnipeg)*
I. Jones *(Southampton)*
B. Krusche *(Basel)*
K. Kumar *(Amherst)*
J. Lattimer *(Stony Brook)*
Bao-An Li *(Commerce, Texas)*
W. Lynch *(East Lansing)*
R. Michaels *(Newport News)*
P. Møller *(Los Alamos)*
O. Moreno *(Madrid)*
B. Owen *(Penn State)*
P. Ring *(Munich)*
L. Robledo *(Madrid)*
R. Rutledge *(Montreal)*
I. Sick *(Basel)*
P. Souder *(Syracuse)*
A. Steiner *(East Lansing)*
M. Stoitsov *(Oak Ridge)*
K. Tsigutkin *(Berkeley)*
G. Urciuoli *(Rome)*
N. Van Giai *(Orsay)*
L. Wansbeek *(Groningen)*

SCIENTIFIC REPORT:

Aim and Purpose

The Lead Radius Experiment (PREX) uses parity violation to accurately determine the radius of the neutron distribution in 208Pb. This measurement has remarkably broad implications for nuclear structure, astrophysics, atomic parity violation, and low energy tests of the Standard Model. The purpose of this workshop was to review final plans for PREX and to discuss the experiment's many implications. In addition, we aimed to improve communication between electron scattering, nuclear structure, astrophysics, and atomic parity communities and between North American and European researchers. The program involved many experimentalists, in addition to theorists, and emphasized the close interplay between theory and experiment. We thank the participants for their excellent talks and for the intensive discussions.

Results and Highlights

Many predictions were made for the neutron skin thickness (difference between neutron and proton radii) of 208Pb including those based on antiproton-nucleus scattering, semi-empirical mass formula fits, the strength of the Pygmy resonance, and a review of proton-nucleus scattering. In addition, extracting matter radii from electro-pion production was discussed. The skin thickness in 208Pb was shown to be strongly correlated with skin thicknesses in nuclei of interest for atomic parity experiments. In addition, it was shown that while deformation can increase both neutron and proton radii, it has very little effect on the skin thickness. Advances in nuclear structure were presented including more accurate microscopic mass formulas and a more systematic construction of a universal energy density functional. In a previous workshop at Jefferson Laboratory in 2008 (see http://conferences.jlab.org/PREX) the neutron radius of 208Pb was shown to have implications for many neutron star properties such as the transition density between solid crust and liquid interior, and the possibility of rapid neutrino cooling via the direct URCA process. In the present workshop, updates were presented on measuring neutron star radii, which may require more sensitive X-ray telescopes, and on possibilities to extract properties of neutron rich matter from neutron star shear oscillations, crust cooling, and gravitational wave observations. Possibilities for a follow on measurement to the planned 208Pb experiment were discussed, including other nuclei, a higher momentum transfer, or measuring with improved precision. Measurements for both 48Ca and120Sn appear feasible. Measurement of the neutron radius in 208Pb with an improved accuracy of ± 0.03 fm, compared to the planned ± 0.05 fm, may be possible with a large experimental effort.

Conclusions

The Lead Radius Experiment (PREX) impacts an extraordinary variety of research areas in nuclear physics, atomic physics, and astrophysics, and its results could have significant impact. A follow on measurement that increases the accuracy of the original experiment beyond the planned 0.05 fm, could increase the physics payoff even further, and should be considered. Nuclear physicists and astrophysicists have important common interests in the study of neutron rich matter and measurements in both areas of research will help to constrain theoretical predictions in either regime. This requires close contact between the two groups. Thus some kind of electronic community should be established to improve communication and foster collaborations. New astrophysical facilities, such as the International X-ray Observatory (IXO) or the Advanced Laser Interferometer Gravitational Wave Observatory (LIGO), promise unique and exciting information on neutron rich matter, while advances in nuclear structure promise improved descriptions of neutron stars and their crusts.

The workshop talks can be browsed from the website: http://www.ect.it or at http://cecelia.physics.indiana.edu/ECT-PREX/Talks

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

DATE: September 07-11, 2009

ORGANIZERS:

Daniele Binosi *(Co-ordinator) (ECT*, Italy)*

Joannis Papavassiliou *(Univ. of Valencia, Spain)*

Arlene C. Aguilar *(Federal Univ. of ABC, Brazil)*

John M. Cornwall *(Univ. of California at Los Angeles, US)*

NUMBER OF PARTICIPANTS: 55

MAIN TOPICS:

The general theme of the workshop concerned techniques for gauge-invariant calculations of off-shell Green's functions in non-Abelian gauge theories such as Quantum Chromodynamics (QCD), and their relationship to other approaches to QCD, including lattice simulations and phenomenology. Of critical interest was the infrared behavior of such gauge theories, where all non-perturbative phenomena (confinement, chiral symmetry breakdown, non-integral topological charge) have their roots. We especially hoped that the lattice and the continuum communities would find at the Workshop, and later explore, new ways of this most difficult problem of non-perturbative QCD.

The main topics were

- Aspects of confinement
- Center vortices
- Background field method and the pinch technique
- Chiral symmetry breaking
- Finite temperature
- Phenomenology
- Bound states, hybrids, glueballs

SPEAKERS:

Aguilar, C *(Federal Univ. of ABC, Brazil)*
Antonov, D *(Univ. Bielefeld, Germany)*
Bicudo, P *(CFTP, Technical Inst., Portugal)*
Binosi, D *(ECT*, Italy)*
Blaizot, J-P *(IPhT – Saclay, France)*
Chiu, T-W *(National Taiwan Univ., China)*
Cornwall, J M *(Univ. of California at Los Angeles, US)*
Creutz, M, *(Brookhaven Nat. Lab., US)*
Cucchieri, A *(Univ. of São Paulo, Brazil)*
D'Elia, M *(Univ. Genoa & INFN, Italy)*
de Forcrand, Ph. *(ETH Zuerich, Switzerland)*
Dudal, D. *(Ghent Univ., Belgium)*
Ferrari, R *(MIT & Univ. Milano, Italy)*
Forkel, H *(Univ. Humboldt Berlin, Germany)*
Giusti, L *(CERN & Univ. Milano-Bicocca, Italy)*
Gracey, J *(Liverpool, Univ., UK)*
Greensite, J *(San Francisco State Univ., US)*
Hands, S *(Swansea Univ., UK)*
Ilderton, A *(Dublin Trinity College, Ireland)*
Ilgenfritz, E-M *(Univ. Heidelberg, Germany)*
Kondo, K-I *(Univ. Chiba, Japan)*
Langfeld, K *(Univ. Plymouth, UK)*
Lavelle, M *(Univ. Plymouth, UK)*
Mathieu, V *(Univ. Mons, Belgium)*
Mehta, D *(Nat. Univ. of Ireland Maynooth, Ireland)*
Mendes, T *(Univ. São Paulo, Brazil)*
Millo, R *(Univ. Trento, Italy)*
Minkowski, P *(Univ. Bern, Switzerland)*
Nair, V. P. *(City College of New York, US)*
Natale, A *(Univ. Estadual Paulista, Brazil)*
Olejnik, S (*Slovak Acad. Sci., Bratislava, Slovakia)*
Oliveira, O *(Univ. Coimbra, Portugal)*
Papavassiliou, J *(Univ. Valencia, Spain)*
Pene, O *(LPT Orsay, France)*
Philipsen, O *(Univ. Münster, Germany)*
Quadri, A *(Univ. Milano & INFN, Italy)*
Ratti, C *(Univ. Stony Brook, US)*
Reinhardt, H *(Univ. Tübingen, Germany)*
Rodriguez-Quintero, J *(Univ. Huelva, Spain)*
Sauli, V *(CFTP IST Lisbon, Portugal)*
Semenoff, G W *(Univ. British Columbia, US)*
Simonov, Y *(ITEP, Moscow, Russia)*
Skullerud, J *(Nat. Univ. of Ireland Maynooth, Ireland)*
Suganuma, H *(Univ. Kyoto, Japan)*
Szczepaniak, A *(Univ. Indiana, US)*
Tandy, P *(Kent State Univ., US)*
Trusov, M *(ITEP, Moscow, Russia)*
Vandersickel, N *(Univ. Gent, Belgium)*
Weise, W *(TU Munich, Germany)*

SCIENTIFIC REPORT:

Aim and Purpose

Non-Abelian gauge theories have been at the centre stage of elementary particle physics for the last four decades, since the establishment of electroweak gauge theory and, a few years later, QCD, the theory describing strong interactions. Unlike quantum electrodynamics, which yields with spectacular success to perturbation theory and Feynman-diagram techniques, only the ultraviolet (high-energy) regime of QCD is amenable to a perturbative treatment, due to the characteristic property of asymptotic freedom. The infrared sector of QCD, on the other hand, is the host of several non-perturbative phenomena, which most famously encompass quark confinement and dynamical mass generation, and powerful methods must be employed for their quantitative treatment.

The basic building blocks of QCD are the Green's (correlation) functions of the fundamental physical degrees of freedom, gluons and quarks, and of the unphysical ghosts. Even though it is well-known that these quantities are not physical, since they depend on the gauge-fixing scheme and parameters used to quantize the theory, it is widely believed that reliable information on their non-perturbative structure is essential for unravelling the infrared dynamics of QC. In addition to their relevance for phenomenology, the QCD Green's functions encode information on confinement, albeit in a rather subtle way.

The two basic non-perturbative tools that permit the exploration of the infrared domain of QCD are (i) the lattice, where space-time is discretized and the quantities of interest are evaluated numerically, and (ii) the infinite set of integral equations governing the dynamics of the QCD Green's functions, known as Schwinger-Dyson equations (SDE). While the lattice calculations are limited by the lattice size used, the problem of the Gribov copies, and the extrapolation of the numerical results to the continuous limit, the fundamental conceptual difficulty in treating the SDE resides in the need for a self-consistent truncation scheme, i.e., one that does not compromise the gauge-invariance of the quantities studied.

These two methods are actively applied in all the areas which were covered by the workshop; in fact about half the attendees of QCD-TNT worked in continuum theory and half in lattice simulations. The multiple QCD competing themes addressed in the workshop can be summarized as follows.

- Does the QCD gluon have a dynamical mass, coming from solving Schwinger-Dyson equations (sometimes called the "decoupling" solution) for the gauge propagator and ghost and yielding finite gauge and ghost dressing functions at zero momentum? Or do the gauge and ghost propagators of the equations show a power-law behaviour for small momentum, including a ghost dressing function diverging at zero momentum (called the “scaling” solution)?

- Is the Gribov-Zwanziger (GZ) picture, emphasizing the Landau gauge and gauge copies of the gauge potential, consistent with either or neither of the above views? How is the GZ picture realized non-perturbatively?
- What do lattice simulations say about the previous two topics?

In addition to these main themes there were a number of other subjects covered in the Workshop, represented by one or a few speakers each, including:

- Continuum and lattice studies of the Coulomb gauge; three-dimensional QCD and the functional Schrodinger equation; five-dimensional QCD simulations; calculations and lattice simulations in QCD at finite temperature and density; fermions and chiral symmetry breaking in QCD; the role of calorons or other topological solitons; glueballs; the AdS/CFT view of QCD; and QCD phenomenology.

Results and Highlights

The Workshop was a very useful opportunity to balance the aforementioned competing views, and this was in fact perceived by all the participants.

Notwithstanding the fact that consensus on the decoupling vs scaling issue (first three topics above) has not been achieved, and that at the Workshop there were dissenters, it is fair to say the participants were leaning toward the decoupling picture of a massive gluon and non-singular ghost dressing function, and that lattice simulations probing the region of near-zero propagator momentum are largely in support of this picture.

The GZ scenario is currently in a confused state, with different authors making different claims at the Workshop. In view of the growing support from lattice simulations of the decoupling" picture, some are trying to incorporate a massive gluon into the original GZ effective action, with varying degrees of success. Others claim that a confinement criterion due to Kugo and Ojima is wrong and needs to be revised; the revision would favour the “decoupling” scenario. Yet others claim that this revision is incorrect. It appears now that lattice simulations support the revision rather quantitatively; on the other hand claims were made that this agreement may be coincidental.

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 topics.

3.3.12 FLOW AND DISSIPATION IN ULTRARELATIVISTIC HEAVY ION COLLISIONS

DATE: September, 14 – 18, 2009

ORGANIZERS:

Pasi Huovinen *(Co-ordinator) (Frankfurt)*
Marcus Bleicher *(Frankfurt)*
Carsten Greiner *(Frankfurt)*
Peter Petreczky *(BNL)*
Raimond Snellings *(NIKHEF)*

NUMBER OF PARTICIPANTS: 41

MAIN TOPICS:

- Transport coefficients and equation of state
- Relativistic viscous hydrodynamics
- Parton and hadron cascades
- Measurement of flow
- Measurement of two- and three-particle correlations
- Ridges and Mach cones

SPEAKERS:

Barbara Betz *(Frankfurt)*
Marlene Nahrgang *(Frankfurt)*
Ante Bilandzic *(Nikhef)*
Harri Niemi *(Frankfurt)*
Ioannis Bouras *(Frankfurt)*
Chiho Nonaka *(Nagoya)*
Piotr Bozek *(Krakow)*
Robert Peschanski *(Saclay)*
Laszlo Csernai *(Bergen)*
Robert Peschanski *(Saclay)*
Gabriel Denicol *(Frankfurt)*
Andre Peshier *(Frankfurt)*
Andrej El *(Frankfurt)*
Hannah Petersen *(Frankfurt)*
ShinIchi Esumi *(Tsukuba)*
Peter Petreczky *(BNL)*
Francois Gelis *(Saclay)*
Scott Pratt *(MSU)*
Clement Gombeaud *(Saclay)*
Dirk Rischke *(Frankfurt)*

Ulrich Heinz *(OSU)*
Yuri Sinyukov *(Kiev)*
Tomoi Koide *(Frankfurt)*
Huichao Song *(OSU)*
Roy Lacey *(Stony Brook)*
Derek Teaney *(Stony Brook)*
Mike Lisa *(OSU)*
Giorgio Torrieri *(Frankfurt)*
Matt Luzum *(Saclay)*
Josh Vredevoogd *(MSU)*
Mauricio Martinez *(Frankfurt)*
Sergei Voloshin *(Wayne State)*
Denes Molnar *(Purdue)*
Fuqiang Wang *(Purdue)*
Akihiko Monnai *(Tokyo)*
Klaus Werner *(Subatech)*
Azwinndini Muronga *(Cape Town)*
Zhe Xu *(Frankfurt)*

SCIENTIFIC REPORT:

Aim and Purpose

The success of ideal-fluid hydrodynamics in reproducing the observed azimuthal anisotropy of particles produced in heavy-ion collisions at RHIC gave rise to the notion of quark-gluon plasma as a perfect fluid. As a matter with extremely low shear viscosity coefficient to entropy ratio. Since then there has been a great interest in the heavy-ion physics community to measure and determine how large the shear viscosity coefficient actually is, and the there has been a tremendous effort to develope viscous hydrodynamical and parton cascade models capable of describing dissipative processes in heavy ion collisions. In this workshop we aim to summarise what we do know from theory and experiment about the matter at high temperature: degrees of freedom, EoS and transport coefficients. What the present state of development of dissipative hydro and parton cascade is and what we can expect to learn in the near future, especially what are the prospects of achieving quantitative instead of qualitative understanding of hot QCD matter.

Results and Highlights

A general opinion among the participants was that the workshop was very successful with many excellent talks, which provided a state-of-the-art view of the theory and experiment. Among the recurring themes in the talks and discussions were

- The necessity to model thermalization and the possible buildup of flow during thremalization
- The need to check the different formalisms of relativistic dissipative hydrodynamics against kinetic theory, i.e. transport model calculations

• The urgent need to understand the dissipative corrections to thermal distribution functions
• The poorly understood mechanism of hadronization

Conclusions

There has been tremendous development in the viscous hydrodynamics and transport models, but a lot of work still remains to be done before the uncertainties of our models are under control and it is possible to extract the shear viscosity to entropy ratio of strongly interacting matter from the data. Nevertheless, the general opinion was that this task is doable and many new projects and collaborations were initiated.
The talks are available at the websites http://www.ect.it and http://th.physik.uni-frankfurt.de/huovinen/ect.html

3.3.13 STRONG, WEAK AND ELECTROMAGNETIC INTERACTIONS TO PROBE SPIN-ISOSPIN EXCITATIONS

DATE: September 28 - October 02, 2009

ORGANIZERS:

Berta Rubio *(CSIC)*

Yoshitaka Fujita *(Osaka Univ, Japan)*

William Gelletly *(University of Surrey)*

Alex Brown *(Michigan State University)*

NUMBER OF PARTICIPANTS: 31

MAIN TOPICS:

- CE reactions and theoretical calculations
- B(GT) and M1 calculations
- Spin-isospin related experiments. Reactions
- Spin-isospin related experiments. Decay
- M1 related experiments
- Nuclear astrophysics

SPEAKERS:

S. Austin *(Michigan State University)*

H. Sagawa *(Univ. of Aizu, Japan)*

N. Paar *(University of Zagreb)*

P. Sarriguren *(CSIC, Madrid)*

A. Brown *(Michigan State University)*

T. Otsuka *(Univ. Tokyo)*

K. Muto *(Tokyo Institute of Technology)*

S. Lenzi *(Universita' di Padova)*

H. Fujita *(Osaka Univ, Japan)*

Y. Shimbara *(Niigata University, Japan)*

H. Sakai *(University of Tokyo)*

D. Frekers *(University Muenster)*

Y. Fujita *(Osaka Univ, Japan)*

A. Krasznahorkay *(Institute of Nuclear Research of the Hungarian Academy of Sciences)*

B. Blank *(CEN Bordeaux-Gradignan)*

J. Luis Taín *(IFIC, Valencia)*

J. Aysto *(Univ. Jyvaskyla)*

F. Montes *(NSCL Michigan State University)*

J. Pereira *(NSCL/MSU)*

A. Tamii *(Osaka Univ.)*

P. von Neumann-Cosel *(TU Darmstadt)*

A. Dewald *(IKP Univ. Köln, Germany)*

A. Zilges *(Univ. Cologne, Germany)*

G. Martínez Pinedo *(GSI)*

B. Balantekin *(University of Wisconsin-Madison)*
R. Hix *(ORNL)*
F. Molina *(IFIC-CSIC)*

SCIENTIFIC REPORT:

Aim and Purpose

This workshop was concerned with a number of interlinked processes of importance in spin-isospin excitations in atomic nuclei. The nuclear states involved can be excited with probes involving the strong, weak and electromagnetic interactions. The workshop had two principal objectives. Firstly the aim was to capture a picture of both our present state-of-knowledge of spin-isospin excitations and the current theoretical approaches to the analysis and interpretation of the data. Secondly to look at the limitations and constraints on both the experimental and theoretical approaches and try to determine how we can improve our understanding in the future. Such excitations can also be important in supernovae explosions and by extension in understanding nucleosynthesis. It was also the intention to explore this topic as well.

Results and Highlights

Experimentally spin-isospin excitations and spin excitations can be studied in beta decay, charge exchange reactions, inelastic scattering and electromagnetic excitation. The operators involved are closely related. We have at least three strong reasons to try to understand these processes. Firstly they carry significant information about nuclear structure. Secondly if the nuclear matrix elements involved in double-beta decay are to be calculated with precision we need information from such studies. Thirdly as already indicated they also play an important role in nucleosynthesis in the r- and rp-processes of nuclear astrophysics and must be understood in this context as well. Amongst the many aspects of such excitations discussed at some length were a) differences in detail between excitations of this kind with different probes including differences observed in studies with (p,n) and (^{3}He,t) reactions, b) the long-standing problem that the strengths derived from experiment do not satisfy the model-independent sum rule and c) effects due to various components of the nuclear force.

In terms of nuclear astrophysics too many nuclear species are involved to contemplate studying all of them in this context. Accordingly one major conclusion of the workshop was that we must concentrate on validating theoretical approaches by paying particular attention experimentally to critical cases. A second conclusion was that differences in these excitations as observed in beta decay and (p,n) and (^{3}He,t) reactions may crudely be ascribed to differences in the part of the wavefunction which is sampled in each approach. There was also considerable discussion of the sum-rule problem and it was agreed that the elements of a solution are at hand.

In terms of a forward look it is clear that some of the information required to understand spin-isospin excitations will come from new and improved techniques at the radioactive beam facilities under construction. The experimental methods needed are in their infancy and will require long and determined effort if they are to be carried out with success, this applies particularly to charge exchange reactions. On the theoretical side little effort has been expended on charge exchange in recent times. A major theoretical effort is required here which needs a champion if it is to be a success. There is a considerable need for data on charge exchange reactions and beta decay in nuclear astrophysics and double beta decay and these developments will help to satisfy that demand.

3.3.14 HADRONIC ATOMS AND KAONIC NUCLEI SOLVED PUZZLES, OPEN PROBLEMS AND FUTURE CHALLENGES IN THEORY AND EXPERIMENT

DATE: October, 12-16, 2009

ORGANIZERS:

Catalina Curceanu *(Co-ordinator)(LNF-INFN, Italy)*
Carlo Guaraldo *(LNF-INFN, Italy)*
Paul Kienle *(TU München, Germany)*
Johann Marton *(SMI-Vienna, Austria)*
Wolfram Weise *(TU München, Germany)*

NUMBER OF PARTICIPANTS: 46

MAIN TOPICS:

This workshop brought together international experts in the research area of hadronic atoms and kaonic nuclear states, 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 – theory and phenomenology
- Cascade calculations for hadronic atoms transitions
- Meson (in particular kaon)-nucleon scattering status
- Low-energy effective theories
- Deeply bound meson-nuclear states: theoretical status
- Antiprotons as hadronic probes
- Experimental results:
    - DEAR and SIDDHARTA at DAFNE
    - Kaonic Helium by E570 at KEK
    - Deeply bound mesonic nuclear states:
    - E471 at KEK
    - E549 and E570 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: upgrade of FOPI and HADES
- Experiments at DAFNE-upgrade: AMADEUS and future plans;
- E15and E17at J-PARC
- Facility for low-energy antiproton and ion research: FLAIR at GSI

SPEAKERS:

Y. Akaishi *(RIKEN, Nihon Univ., Japan)*
P. Aslanyan *(JINR Dubna, Russia)*
A. Cieply *(NPI Rez, Czech Republic)*
C. Curceanu *(LNF-INFN, Italy)*
J. Donoval *(NPI Rez, Czech Republic)*
E. Epple *(TU, Munich, Germany)*
L. Fabbietti *(TU Munich, Germany)*
M. Fayfman (*Kurchatov Inst., Moscow, Russia)*
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)*
C. Guaraldo *(LNF-INFN, Italy)*
O. Hartmann *(SMI Vienna, Austria)*
H. Herrmann *(Univ. Heidelberg, Germany)*
T. Ishiwatari *(SMI, Vienna, Austria)*
A. Ivanov *(Vienna Univ. of Technology, Austria)*
M. Iwasaki *(RIKEN, Japan)*
S. Kalantari *(Isfahan Univ. of Tech., Isfahan, Iran)*
P. Kienle *(TU Munich, Germany)*
V. Krejcirik *(NPI Rez, Czech Republic)*
V. Magas *(Univ. Bercelona, Spain)*
J. Mares *(NPI Rez, Czech Republic)*
J. Marton *(SMI Vienna, Austria)*
H. Outa *(RIKEN, Japan)*
S. Piano *(Sez. Trieste, INFN, Italy)*
A. Romero Vidal *(LNF.INFN, Italy)*
P. Salvini *(INFN, Sez. Pavia, Italy)*
M. Sato *(Univ. Tokyo, Japan)*
A. Scordo *(LNF.INFN, Italy)*
N. Shevchenko *(NPI Rez, Czech Republic)*
T. Suzuki *(Univ. Tokyo, Japan)*
O. Vazquez Doce *(LNF-INFN, Italy)*
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:

Aim and Purpose

The hadronic atoms and the kaonic nuclear states are extremely valuable tools for studying fundamental interactions and symmetries in a fairly direct way, complementing the 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 experiments. 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 or the quest for kaonic nuclear clusters) and to extract new hadronic atom 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 and a deepening of the very successful 2006 ECT* Workshop on “Exotic hadronic atoms, deeply bound kaonic nuclear states and antihydrogen”. The present Workshop brought together international experts in the research area of hadronic atoms and kaonic nuclear states, 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 in detail into the physics motivations, the low-energy interactions of the lightest pseudoscalar mesons (pions and kaons) with nuclear systems are basically dictated by the spontaneous chiral symmetry breaking of QCD. Important information related to the mechanism of chiral symmetry breaking (spontaneous and explicit) can be obtained from the study of exotic hadronic atoms and from exploring the possible existence of bound antikaon-nuclear states, the latter being a very hot issue presently.

An exotic hadronic atom is formed whenever a hadron (pion, kaon, antiproton) from a beam enters a target, is stopped inside and replaces an orbiting electron. Such exotic atoms are usually formed in a highly excited state; a process of de-excitation through the respective atomic levels follows. The X-ray transitions to the lowest orbits (1s) are affected by the presence of the strong interaction between the nucleus and the hadron. This is translated into a shift of the 1s level with respect to the purely electromagnetic-based calculated value and by a limited lifetime (width) of the level. Extracting these quantities, via the measurement of the X-ray emitted in the transitions, provides fundamental information on the low-energy hadron-hadron and hadron-nuclear interactions. Quantities such as kaon-nucleon scattering lengths turn out directly accessible by measuring properties of exotic atoms. Further on, these quantities are important milestones to deal, in a unique way, with some important aspects of chiral symmetry breaking. Although the field of exotic atoms has a long history, it is very active, both from the experimental and from the theoretical point of view. On the experimental side, new "hadronic" beams became available recently (kaons at DAFNE) or will become available in 2010 (J-PARC facility), while new detectors with improved performance (better energy resolution, stability, efficiency, trigger capability) are starting to operate. On the theoretical side the field has advanced significantly through recent developments in chiral effective field theories and their applications to hadron-nuclear systems.

Experiments at GSI, KEK and DAFNE and (re)analyses of existent data from experiments performed years ago at CERN or JINR are delivering yearly new results with steadily increasing precision, so that theoreticians can cope with items not accessible till very recently and realize important progress in the understanding of basic features of low-energy QCD.

The kaonic hydrogen was measured by the DEAR Collaboration (on DAFNE) with an unprecedented precision, leading to a lively debate on the kaon-proton scattering length extraction procedure, and on the compatibility with existent kaon-nucleon scattering data. The SIDDHARTA experiment is performing in 2009 an even more precise measurement and will complement it with an exploratory measurement of the kaonic deuterium; the results were presented and discussed at the Workshop. Kaonic helium was measured at KEK (E570 experiment) and SIDDHARTA – solving the "kaonic helium puzzle", while new experiments are planned at JPARC in the near future (E17) to measure kaonic Helium on 3He. Future experiments are already planned at existent and/or future machines (GSI, J-PARC, DAFNE-upgraded). The future of exotic hadronic atoms will reach new horizons – in precision and in dealing with new types of exotic atoms, never measured before, such as kaonic deuterium, or sigmonic atoms.

Another hot item intensively discussed at the present Workshop deals with the recently studied "Kbar -mediated bound nuclear systems", with (contradictory) experimental indications being produced at KEK, LNF, BNL and GSI, or signals being present in older data

(OBELIX, DISTO) – recently reanalyzed. It was originally suggested that in the few-body nuclear systems the (strongly attractive) isospin I=0 Kbar-N interaction can favour the formation of discrete and narrow Kbar- nuclear bound states with large binding energy (100 MeV or even more). Recent theoretical works suggest, however, that such deeply bound kaonic nuclear states do not exist: antikaon-nuclear systems are only weakly bound and very short-lived. Different interpretations for the existing experimental results are given, based for example on the interaction of negative kaons with two or more nucleons. This topic is related to a new puzzle in the physics of kaon-nucleon interaction: the nature of the (1405) – single or double pole? Lively discussion were dedicated to this item in the workshop. All these topics have important consequences in astrophysics as well – in the physics of the neutron stars for example.
The presently available experimental results were reviewed (KEK experiments. FINUDA at DAFNE, FOPI, BNL, OBELIX, Dubna experiments, DISTO at Saturne), together with a critical discussion of current theories/models. Future perspectives at J-PARC (E15, E17); GSI (upgrade of FOPI and HADES) and DAFNE (AMADEUS experiment), together with the possibility to use antiprotons to create single and double strangeness nuclei (CERN, J-PARC or FLAIR) were discussed in the framework of an integrated strategy in which complementary facilities should bring together the various pieces of the puzzle.

Results and Highlights

The field of Hadronic atoms and kaonic nuclei is a very active one, as it 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 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 indeed solved puzzles, as kaonic hydrogen and kaonic helium ones – which were understood, both due to the newer experiments (E570 and DEAR and SIDDHARTA at DAFNE) and to the 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. Important questions were targeted and formulated, but they still need both experimental results and and deeper theoretical understanding. So future challenges in experimental and theoretical sectors are many and were, for the first time, focussed and formulated in an unitary framework. If the 2006 Workshop helped to formulate a series of important questions, it basically remained not-structured; the 2009 Workshop helped to arrive, for the first time, at a mutual and agreed formulation of solved problems, open ones and future strategies!

During the workshop few actions, apart of regular talks given both by theoretician experts in the field and experimentalists, were organized. A round-table (lead by A. Gal) dealt with the search of the K- nuclear bound state; it proved to be extremely useful, since a common ground has been achieved on what information (i.e. experimental results) could bring light in the field in the future – and this is important, since new experiments are just about to be performed (AMADEUS, E15, HADES and FOPI upgrades…). A visit to the FBK centre for scientific and technological research was organized, so the capacity of FBK to perform research in the field of detectors for future experiments was presented and contacts established with those experiments potentially interested in these types of development (AMADEUS, FOPI, just to name some). The EU FP7 framework programs were as well presented (HadronPhysics2, by C. Guaraldo); in particular a talk was dedicated to the LEANNIS Network (HadronPhysics2 FP7), 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 of making the LEANNIS web-site an active centre of information exchange and storage).

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 participants percentage was about 50%, which is one of the successes of the Workshop.

Moreover, participants from many countries took part (Israel and Iran, just to name two) – 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 this type of Workshops in the ideal environment of ECT* contributes to the progress of the field. Since many experiments are just undergoing or about to start, and since theories and methods are evolving in parallel, we plan to organize another workshop in this field very soon (2010 or 2011), at ECT*.

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

3.3.15 INTERNATIONAL WORKSHOP ON RELATIVISTIC DESCRIPTION OF TWO- AND THREE-BODY SYSTEMS IN NUCLEAR PHYSICS

DATE : October 19-23, 2009

ORGANIZERS:

Giovanni Salme' *(Co-ordinator)(INFN, Rome Italy)*

Tobias Frederico *(Sao Jose dos Campos, Brazil)*

Michele Viviani *(INFN Pisa, Italy)*

NUMBER OF PARTICIPANTS: 39

MAIN TOPICS:

- Nucleon-nucleon interaction
- Non relativistic calculations of light nuclei
- Comparisons with experimental data and present challenges
- New approaches for solving the Bethe-Salpeter equation in Minkowski and Euclidean spaces
- Three-dimensional reductions of the Bethe-Salpeter equation
- Higher order effects in the Fock space

SPEAKERS:

A. Arriaga *(CFN, Lisbon, Portugal)*

B.L.G. Bakker *(Vrije Universiteit, Amsterdam, The Netherlands)*

N. Barnea *(Hebrew Univ., Israel)*

B.V. Carlson *(ITA - CTAS. Jose` dos Campos, Brazil)*

J. Carbonell *(LPSC, Grenoble, France)*

W. Cosyn *(Gent Univ., Belgium)*

A. Deltuva *(Univ. of Lisbon, Portugal)*

C. Elster *(Ohio Univ., USA)*

C. Forssen *(Chalmers Univ., Gőteborg, Sweden)*

T. Frederico *(ITA, Sao Jose dos Campos, Brazil)*

L. Girlanda *(Pisa Univ., Italy)*

F. Gross *(William & Mary, USA)*

N. Ishii *(Tokio Univ., Japan)*

S. Jeschonnek *(Ohio State Univ., USA)*

H. Kamada *(KIT, Kitakyushu, Japan)*

L. Kaptari *(JINR, Dubna, Russia)*

V. Karmanov *(Lebedev Physical Institute, Russia)*

A. Kievsky *(INFN - Pisa, Italy)*

W.H. Klink *(Univ. of Iowa, USA)*

H. Krebs *(Bonn Univ. and Forschungszentrum Jülich, Germany)*
W. Leidemann *(Trento Univ., Italy)*
P. Maris *(Iowa Univ., USA)*
J.-F. Mathiot *(LPC, Univ. Blaise Pascal, Clermont-Ferrand, France)*
D. Nicmorus *(Karl-Franzens-Universität Graz, Austria)*
M.T. Pena *(CFTP, Lisbon, Portugal)*
W. Polyzou *(Iowa Univ., USA)*
E.P. Rogochaya *(JINR, Dubna, Russia)*
R. Rosenfelder *(PSI, Villigen, Switzerland)*
V. Sauli *(NPI , Rez near Prague, Czech Republic)*
R. Schiavilla *(JLAB, Newport News and ODU, Norfolk, USA)*
W. Schweiger *(Graz Univ., Austria)*
A.V. Smirnov *(Lebedev Physical Institute, Moscow, Russia)*
A. Stadler *(Univ. of Evora and CFN, Univ. of Lisbon, Portugal)*
N. Tsirova *(Samara S. U., Samara, Russia)*
A. Vairo *(Phys. Dept., Technische Univ. Munchen, Garching,Germany)*
M. Viviani *(INFN - Pisa, Italy)*
H. Witala *(Jagellonian Univ., Krakow, Poland)*

SCIENTIFIC REPORT:

Aim and Purpose

The possibility of extending the realm of investigation of the accurate non relativistic approaches, by including, possibly in a non perturbative way, the fulfilment of general properties, as the Poincare' invariance, or even the full covariance by dealing with antiparticle degrees of freedom, appears to become a tractable issue. The driving force for pursuing such an effort is twofold: on one hand, already there exists a number of challenging experimental puzzles (see, e.g. the neutron-deuteron analysing power at low-energy or the detailed behaviour at high momentum transfer of the electromagnetic deuteron form factors); on the other hand, new experimental facilities are forthcoming (as the approved 12 GeV upgrade of the electron accelerator at the Thomas Jefferson National Laboratory) and this makes desirable the relativistic treatment of the nuclear systems involved in the proposed experiments. In view of this, our compelling motivation has been to set up an appropriate place for both discussions and cross-fertilizations between the non relativistic few-body community and the relativistic one.

The Workshop has been aimed at bringing together experts of both relativistic and non relativistic approaches, in order to stimulate new investigations and to propose applications through detailed discussions of: i) new techniques for solving the Bethe-Salpeter Equation for both bosonic and fermionic systems, ii) approaches relying or inspired from field theory

for reducing the 4D Bethe-Salpeter Equation to a 3D problem (e.g., the Covariant Spectator equation, the light-front projection, instant-form boosted potentials and the point-form approach), iii) the present stage of the calculations of observables, that could be a potential target of investigations within relativistic approaches.
Another very important aim of the Workshop has been the fruitful interaction between experts in the different topics and younger colleagues, in order to widen their expertise, getting acquainted with the most accurate and/or recent approaches.

Results and Highlights

Review talks and topical presentations have been alternated, in order to make the audience fully aware of the most significant results achieved within both the non relativistic and relativistic approaches for describing processes involving few-hadron systems. In particular, it has been possible to compare the modern theory of the Nucleon-Nucleon interaction, developed within a chiral effective field theory, with the successful description obtained through a fully covariant approach (namely the Covariant Spectator one). It is worth noting that the Covariant Spectator approach leads to a surprising result, once it is applied to the three-nucleon system (no contributions from three-body forces are needed in order to reproduce the binding energy of the triton). This achievement poses an immediate challenge for the community, namely the necessity i) to have a confirmation through calculations of the binding energy of the four-body system or even of nuclear matter, and ii) to clarify the true nature of the three-nucleon forces, as a genuine three-body interaction or as relativistic effects or both.

Another relevant issue has been the detailed discussion of new classes of solutions of the Bethe-Salpeter Equation, both in ladder and cross-ladder approximations, and for both bosons and fermions. Their applications to actual cases (e.g. deuteron momentum distribution, electromagnetic form factors, etc.) has been also illustrated. Finally, with respect to the general approaches, the Relativistic Hamiltonian Dynamics, with a fixed number of degrees of freedom, has been presented in several talks. In particular, the three different forms: Instant form, Front form and Point form, have been analysed, emphasizing benefits and drawbacks of each of them. Moreover it has been pointed out the role of the Relativistic Hamiltonian Dynamics as an intermediate step, between the non relativistic approaches and the ones based on the field theory, in its full-glory.
The presentations of calculations, elaborated either within accurate non relativistic frameworks or applying the relativity to large extent, have shown that existing experimental puzzles could represent stringent tests for the different relativistic approaches. Given this

remark, during the working-group sessions, there has been a wide agreement on tackling the calculations of some observables that appear particularly promising for an analysis of the relativistic effects, e.g. the electromagnetic deuteron form factors and the n-d inclusive cross section. Moreover, from the general point of view, it has been proposed to calculate observables within the different relativistic approaches but using a “simple”, realistic field theoretical model, the Σ - Ω model. In conclusion, all these well-defined issues, that the community has singled out, could represent the reachable (in a reasonable time) milestones toward the construction of a relativistic description of few-nucleon systems. Finally, it should be mentioned that, following a recommendation of the participants, the Organizers are elaborating a proposal to be submitted to the International Journal “Few-Body Systems” for publishing, as regular papers, both minireviews and topical articles, spanning the issues discussed during the Workshop.

3.3.16 ELECTROWEAK INTERACTIONS WITH NUCLEI: SUPERSCALING AND CONNECTIONS BETWEEN ELECTRON AND NEUTRINO SCATTERING

DATE: November 25-30, 2009

ORGANIZERS:

Maria Benedetta Barbaro *(Co-ordinator) (Torino University)*

Thomas William Donnelly *(MIT)*

Alfredo Molinari *(Torino University)*

NUMBER OF PARTICIPANTS: 23

MAIN TOPICS:

- Scaling and superscaling
- Modeling the nuclear EW response
- CC/NC neutrino reactions

SPEAKERS:

J.E. Amaro *(Granada University)*

O. Benhar *(Rome University)*

A. Beraudo *(Turin University)*

J.A. Caballero *(Sevilla University)*

D. Day *(Virginia University)*

T.W. Donnelly *(MIT)*

C. Giusti *(Pavia University)*

C. Maieron *(CNRS LPSC Grenoble)*

M. Martini *(Lyon University)*

A. Molinari *(Turin University)*

A. Rinat *(Weizmann Institute)*

J. Sobczy *(Wroclaw University)*

J.M. Udias *(Madrid University)*

C. Williamson *(MIT)*

SCIENTIFIC REPORT:

Aim and Purpose

In the proposal for the workshop the focus was placed on studies of electroweak (EW) interactions with nuclei at energies which are high enough that scaling is known to work. The central theme centered around research being undertaken by several theory groups in the research areas that include inclusive electron scattering in the quasielastic region, the

resonance region, and above, together with predictions for both charge-changing and neutral current neutrino reactions with nuclei. A basic starting point was assumed to be that electron scattering must be understood before one can hope to interpret the weak interaction processes, including present and future neutrino oscillation experiments. Accordingly, part of the workshop goals was to provide a review of the status of both the scaling approach and of contemporary modeling of the relevant nuclear response functions. In particular, recent studies have been focused on scaling violations and the degree to which these imply modifications of existing predictions for neutrino reactions; accordingly one of the themes was to assess what is being done with regard to this central issue.
Furthermore, new models have been developed
in the two years since the last ECT* meeting held by this collaboration and cross-comparisons of these provided the motivation for some of the discussions.

The main themes of the meeting were the following:

a) Scaling of the 0th, 1st, 2nd and 3rd kinds;

b) The structure of the superscaling function and modeling;

c) Sources and magnitudes of the scaling violations: meson-exchange currents, short-range correlations, final-state interactions;

d) Emphasis on similarities and differences between electron scattering and neutrino reactions;

e) Transition from y- to x-scaling.

Results and highlights

As summarized above, the themes of the workshop were focused on two related areas of research in medium-to-high-energy electroweak interactions with nuclei, namely, scaling of inclusive response functions and implications for using the known properties of the electromagnetic response to obtain predictions for charge-changing and neutral current neutrino reactions. The former has continued to see progress in the two years since the last ECT* workshop held by many of the same participants as in the recent workshop. Scaling of the first kind (independence of momentum transfer) and violations thereof have been explored, leading to a heightened awareness of the importance of how in the scaling region scaling is approached with increasing momentum transfer, namely, from above rather than below. Most models produce an approach from below and only a small set has the correct qualitative behaviour, implying that in most cases such scaling violations are not being controlled correctly.

Indeed, the role of final-state interactions is clearly an important one and this may call for a new paradigm for inclusive EW reactions.Of specific interest is the deep scaling region (very negative scaling variable) where short-range physics is thought to play a dominant role. Presentations and discussions emphasized the issues of interest in this region.

In all of the EW modeling in the energy ranges of interest it is clear that relativistic approaches are essential; this was stressed in talks which specifically addressed this point.

In contrast to scaling of the first kind, scaling of the second kind (independence of nuclear species) continues to be very well obeyed, both by the data and by essentially all state-of-the-art models. Scaling of the zeroth kind (universality of longitudinal and transverse quasi-elastic (QE) responses), on the other hand, is obeyed in modeling using either non-relativistic wave functions with a semi-relativized response or relativistic wave functions where only the upper components are employed. However, when the full relativistic mean field approach is followed including, in particular, effects from the lower components of the final-state high-energy particle, scaling of the zeroth kind is broken and the transverse QE response is found to be higher than the longitudinal one. Tests of this using existing data are being attempted.

The above scaling and scaling violations are focused on the QE response. Of course, other processes are present which entail different scaling properties. Clearly, for the excitation region above the QE peak one finds large contributions from non-QE effects (pion production, both non-resonant and via excited baryons including the Delta, merging into DIS at high W). These do not (and should not) have the same scaling properties as the QE response. Recently, new studies of these inelastic contributions have been undertaken, including detailed comparisons with experiment, leading to much better understanding of their properties as functions of the kinematics. The outcome of these studies is that there is evidence for still more in the non-QE response. Indeed, while not conclusive at present, it appears likely that the residual arises from 2p-2h MEC effects. When all three types of contributions are added together (QE, inelastic and MEC) relatively successful agreement with experiment is obtained. As presented in several of the talks at the workshop and elaborated in the discussions that followed, there are still, however, issues to be clarified in such syntheses. In particular, in the above-mentioned study it was necessary to invoke

scaling of the zeroth kind, while, on the other hand, as stated above, this is broken in some specific models. The relativistic mean field (RMF) modeling produces a transverse response that is larger that the longitudinal one, whereas in past and recent work on 1p-1h MEC effects one sees the opposite behaviour, a lowering of the transverse response at the peak due to a destructive interference between one- and two-body 1p-1h contributions. These seem to roughly compensate and restore the zeroth-kind scaling, although more study is needed to be sure. Interesting, in the talk where the recent study of 1p-1h MEC effects was presented, a new feature was also reported, namely, an enhancement at higher excitation energy which may play a role in the detailed comparisons with experiment. Several approaches to the inelastic contributions referred to above were discussed, including specific modeling of coherent and incoherent pion production in neutrino interactions with nuclei.
Finally, at the highest energies where these types of scaling are relevant one also has the possibility of approaching the problem from the point of view of “x”-scaling rather than scaling of the first kind (“y”-scaling). Some discussions took place on the inter-relationships between the two approaches.

In summary, much new progress on studies of scaling and scaling violations has been made in the two years since the last ECT* workshop held by this collaboration. In all areas there are ideas for further investigations and one anticipates stimulating renewed discussions when the next meeting of this group takes place.
The second theme of the workshop focused on applications of scaling ideas and modeling to both charge-changing and neutral current neutrino reactions with nuclei. Many discussions centered around what is common to both electromagnetic and weak interaction responses or not, and to what degree the inevitable uncertainties in scaling analyses, on the one hand, or use of specific models, on the other, lead to uncertainties in predictions for neutrino-induced processes. As just one example, the role played by two-particle emission MEC effects in the vector current that enters in electron scattering clearly provides roughly 15-20\% of the response in the QE region, whereas these contributions are absent in the axial-vector response that provide typically half of the charge-changing neutrino cross section.
Accordingly the inclusion or not of such effects may lead to a significant error in the predictions for the weak interaction reactions.
Finally, presentations were made of the state-of-the-art Monte Carlo
generators of neutrino reaction events, together with discussions of modeling issues involved in such simulations.

Conclusions

In conclusion, our feeling is that this was a very useful one-week workshop. The participants had the opportunity to hear about the progress being made outside of their own local collaborations and also to have some discussions of experimental issues to place the theoretical work in context. Our intent is to propose to have the next in this series of workshops (this was the fourth of its type) in two years, namely in 2011.

3.3.17 ORBITAL ANGULAR MOMENTUM OF PARTONS IN HADRONS

DATE: November, 09-13, 2009

ORGANIZERS:

Matthias Burkardt *(Co-ordinator) (NMSU)*
Gunar Schnell (*DESY, Zeuthen*)

NUMBER OF PARTICIPANTS: 23

MAIN TOPICS:

- Angular momentum decomposition
- Generalized parton distributions
- Transverse momentum dependent parton distributions

SPEAKERS:

M.Aghasyan *(INFN Frascati)*
A.Bacchetta *(University of Pavia)*
L.C.Bland *(BNL)*
M.Burkardt *(NMSU)*
I.O.Cherednikov *(JINR Dubna)*
P.F.Dalpiaz *(INFN Ferrara)*
D.Fields *(University of New Mexico)*
L.Gamberg *(Penn State University)*
G.R.Goldstein *(Tufts University)*
P.Hägler *(TU München)*
D.Hasch *(INFN Frascati)*
P.Hoyer *(University of Helsinki/ECT*)*
E.-M.Kabuß *(University of Mainz)*
P.Kroll *(University of Wupperta)*
E.Leader *(London Imperial Colleg)*
S.Liuti *(University of Virginia)*
A.Rostomyan *(DESY)*
F.Yuan *(LBNL, Lawrence Berkeley National Laboratory)*

SCIENTIFIC REPORT:

Aim and Purpose

The primary topic of this workshop was the decomposition of the nucleon's spin "budget" into the various contributions stemming from quarks and gluons, in particular the role of orbital angular momentum from these constituents. The aim was to review the state of the art in the experimental investigation of orbital angular momentum, to clarify the theoretical understanding of these complementary data, and to help define what might be learned about partonic orbital angular momentum from present and upcoming high precision experiments. The workshop was timely, in order to help interpret recent data on DVCS and semi-inlcusive DIS data from HERMES, COMPASS, and JLab, as well as anticipated data from JLab@12GeV and the EIC.

Results and Highlights

The workshop program contained several review talks on the experimental status as well as various contributions aiming at clarifying the role of angular momentum. In addition ample time was allocated for discussions. This approach proved to be quite successful and let to several important outcomes.
One of the note-worthy results was homogenizing the understanding of various subtleties in the decomposition of the nucleon spin. The validity of the transverse-spin sum rule was questioned and crucial tests in model calculations were formulated to clarify this issue. Another important result was the realization that final-state interactions needed to describe, e.g., the *Sivers function*, can be absorbed in the nucleon's wave function, allowing a parton interpretation of such PDFs. Continuing in the spirit of the previous transversity ECT* workshop (2004), a roadmap was laid out with short- and long-term goals in both the theoretical and the experimental efforts to quantify the role of orbital angular momentum. A council has been formed to follow up on the progress and to coordinate upcoming workshops and conferences to achieve these goals.

Conclusions

Several initiatives emerged from the workshop: as part of the roadmap formulated during the workshop, a set of concrete questions were formulated whose answers will help clarify the role of orbital angular momentum of partons in hadrons. For example, a model calculation was formulated to check the transverse spin sum rule; a manifestly gauge invariant definition of the Jaffe-Manohar parton orbital angular momentum should be constructed; the physical meaning of sign and magnitude of each tarnsverse momentum dependent PDF should be identified; a physical meaning of the ‘soft factor’ in TMD factorization should be provided.

It should be realistic to find answers to most of these questions on a timescale of one or a few years.

3.4 Doctoral Training Programme in 2009

"The physics of strongly correlated systems: from quark matter to ultra cold atoms".

The 2009 ECT* Doctoral Training Programme on "The physics of strongly correlated systems: from quark matter to ultra cold atoms" lasted 12 weeks, from March 30 to June 18, 2009. The coordinators of the programme were Gordon Baym, Chris Pethick and Sandro Stringari.

It was attended by 13 full time and 5 part time students, among which 2 were from the University of Trento. In addition, one mathematician, working in FBK, attended several of the lectures and a post-doc in Povo also attended a few lectures. The list of students is appended at the end of this report. The students were lodged in the guest house in San Dona, an apartment which ECT* rents year round, four students were in an apartment in Dosso Dossi and two in the Foyer College in Gardolo. As in previous Doctoral Training Programmes, the students from Trento only attended a few of the lectures.

The 2009 Doctoral Training Programme, on the subject of Strongly Correlated Systems, was initiated by the Board in 2007. The programme differed from previous ones in that it covered strongly interacting systems in a number of seemingly different fields, namely quantum liquids, high energy heavy ion reactions, trapped cold atoms, the physics of neutron stars, nuclear physics, and low-dimensional systems. Several lecturers pointed out some common features in the theory of the different fields. The students were already engaged in their PhD projects in particular fields and generally had little knowledge of other areas. The programme offered the students a unique opportunity to discover other fields which, according to reports from the students, should serve to expand their perspectives and tools within their own fields.

The group of lecturers included an important number of experimentalists (see the list of lecturers below). Generally the lecturers, aware of the fact the majority of students had no familiarity with other subjects than their own, tailored their lectures to a broader audience. The upshot is that the students were taught a broad range of physics, rather than theoretical techniques.

The lectures were delivered in the mornings and the afternoons were kept free except for student seminars and occasional exercise sessions. The presence at ECT* of the lecturers in the afternoons is a great asset for the students who can discuss with them. The students are also expected to work on their PhD in the afternoons. Several lecturers, who had accepted to

lecture for a full week, either arrived on Monday of left on Friday, thereby lecturing one day less. Fantoni was scheduled for one week and lectured during only two days. Such occurrences should be avoided.
Most of the lecturers left lecture notes which were put onto the Wiki page which allowed the students to download them. Two students (Zablocki, Merkl and Maeda) volunteered to write up the lectures of Baym, Giorgini and (most probably) Hatsuda, thereby making them available to the other students.

Each student was required to give a seminar on his ongoing research. This proves to be useful in so far as it develops contacts and discussions between the students. The list of seminars is given below. The seminars are announced on the ECT Web page. Some of the seminars were very informative. A suggestion was made, which might be applied in future Doctoral Training Programmes, namely to group all the student seminars into, say, the first 10 days so as to stimulate more discussion between the students.

The lecturers were encouraged by the coordinators to lecture on the blackboard, and those who did so were the most successful at conveying information to the students. But not all abided by this request. Of course, experimental and computational results need to be projected and a projector was always available.

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

3.4.1 The Lecture Programme

(The asterisks ** stais indicate lecturers who are experimentalists.)

<u>During week 1</u>

Chris Pethick (NORDITA) **and Gordon Baym** (University of Illinois in Urbana Champaign) gave an overview of the forthcoming lectures. They specified carefully the orders of magnitude of the phenomena, which differ widely when going from cold atoms to RHIC and LHC physics. The lectures were entirely written on the board. The handwritten lectures of Pethick were scanned. The lectures of Baym were written up by Zablocki, one of the students.

Weeks 2 and 3 (which included an Easter break) and part of week 4

were devoted to lectures of **Sandro Stringari and Stefano Giorgini**, both from the physics Department of the University of Trento. The Stringari lectures covered much of present theory of trapped cold atoms. It was a pure PowerPoint presentation with the result that equations were more displayed than derived. Giorgini gave remarkable series of detailed lectures on the board on sampling and Monte Carlo calculations. One of the students Kenji Maeda wrote them up.

During week 4

Jens Jörgen Gaardhoje (Niels Bohr Institute and University of Copenhagen) described high energy heavy ion reactions, explaining what could be observed experimentally. The lectures were a useful account of the experiments and were delivered entirely on the board.

During week 5

Peter Braun-Munzinger (GSI Darmstadt and Technische Universität Darmstadt) lectured during three days and gave essentially descriptive Powerpoint lectures on the experimental aspects of relativistic heavy ion reactions. He also evoked elliptic flow and fluid dynamics with insistence that the fireball is a strongly correlated fluid. His aim was, to use his own words, to give the students "a taste" of the subject.

During week 6

Stefano Fantoni (SISSA and INFN) came for only two of the originally planned five days. He spoke about Monte Carlo calculations of nuclear matter and nuclei. The lectures were qualitative Powerpoint presentations.

Week 7

was devoted to lectures by **Martin Zwierlein** (MIT, Cambridge, USA) and **Achim Richter** (ECT* and Technische Universität, Darmstadt). Martin Zwierlein gave a detailed and very useful description of the experimental observations of trapped cold atoms. Achim Richter gave a Powerpoint presentation of collective excitations of nuclei (giant resonances, scissors mode, pygmy resonances, and more) as well as of nuclear astrophysics experiments performed with the electron beam of the Superconducting Electron Linear Accelerator S-

Dalinac in Darmstadt. He stressed correspondences of nuclear structure with super-fluidity and pairing and discussed possible connections with Bose-Einstein condensation.

Week 8

was a vacation.

During week 9

Anna Watts (University of Amsterdam) described the observations made on pulsars and neutron stars. She insisted on the recent new data coming from satellite based counters as well as from radio telescopes. She gave students reports which they prepared in groups comprising three students and presented at the end of the course.

Week 10

was devoted to lectures of **Tetsuo Hatsuda** (University of Tokyo) and **Gordon Baym** (University of Illinois). Tetsuo Hatsuda described the symmetries of the QCD lagrangian, as well as broken symmetries of the physical vacuum. He also discussed the Nambu Jona-Lasinio model and phenomenological descriptions of QCD phase diagrams. Gordon Baym gave a very informative description of our understanding of conditions which prevail on a neutron star.

During week 11

Thierry Giamarchi (University of Geneva) lectured on the physics of low dimensional (mostly one-dimensional) systems, on the Hubbard, Lieb-Liniger models in particular. The lectures were entirely written on the board.

During Week 12

Jacek Dobaczewski (University of Warsaw, University of Jyvaskyla) discussed density functional methods in nuclear physics.

3.4.2 List of the Participants

David Edwin Alvarez Castillo	Institute of Nuclear Physics PAN, Krakow
Gianluca Bertaina	University of Trento, Italy
Juan Francisco Castillo Hernandez	GSI, Darmstadt
Chatterjee Bhaswar	Physics Research Laboratory, Ahmedabad, India
Giuseppe Congedo	University of Trento, Italy
Dario Jukic	University of Zagreb, Croatia
Jussi Kajala	Helsinki University of Technology, Finland
Tommaso Macri	SISSA, Trieste, Italy
Kenji Maeda	University of Tokio, Japan
Agne Masalaite	Vytautas Magnus University, Kaunas, Lithuania
Michael Merkl	Heriot-Watt University, Scotland
Tomoki Ozawa	University of Illinois, Urbana Champaign, US
Francesco Raimondi	University of Jyvaskyla, Finland
Pekka Toivanen	University of Jyvaskyla, Finland
Shun Uchino	University of Tokio, Japan
Daniel Zablocki	University of Wroclaw, Poland

3.4.3 Seminars Delivered by the Students:

The full-time students were required to give a seminar, which was announced on the ECT* Web site. The seminars prove to be quite useful for the students and also provide useful information on the work they are doing. The seminar programme is listed below:

Thursday, April 2

Michael Merkl (Heriot-Watt University, Scotland): *Non-abelian gauge fields and cold atoms: Zitterbewegung, solitons and vortices.*

Thursday, April 16

Jussi Kajala (Helsinki University of Technology): *Josephson effect in a Fermi gas.*

Wednesday, April 22

Tomoki Ozawa (University of Illinois, Urbana-Champaign): *Do photons exist? --- Niels Bohr's argument.*

Tuesday, April 28
Shun Uchino *(*University of Tokyo*)*: *Dynamical symmetry in spinor Bose-Einstein condensation.*

Friday, May 8

Agne Masalaite (Vytautas Magnus University, Lithuania*): Quark confinement and the nucleon-nucleon interaction.*

Thursday, May 14

Bhaswar Chatterjee (Physics Research Laboratory, Ahmedabad, India): *Variational approach to relativistic BCS-BEC crossover with two species of fermions.*

Thursday, May 28
Juan Francisco Castillo Hernandez (GSI, Darmstadt): *Multiplicity fluctuations and forward-backward correlations in proton-proton collisions at LHC energies.*

Tuesday, June2

Daniel Zablocki (University of Wroclaw) *Anomalous propagator contributions to mesonic decays - a signature of chiral symmetry restoration?*

Wednesday, June 3

Kenji Maeda (University of Tokyo) *Phases of attractively interacting boson-fermion mixtures.*

Tuesday, June 9

Dario Jukic (University of Zagreb): *Free expansion of a Lieb-Liniger gas.*

Thursday, June 11

David Edwin Alvarez Castillo (Institute of Nuclear Physics, Krakow): *Noise powered glitches in neutron stars.*

4 Research at ECT*

In this chapter the activities of the scientific researchers at ECT* in 2009, i.e. of the Postdoctoral Fellows, the Director, the Vice - Director 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 ECT*. The main reason for the latter is of course the particular structure of ECT* with few senior scientists present. Dyonisis Triantafyllopoulos, hired late in 2009 as a senior scientist, has already been essential, however, for creating a remarkable scientific life amongst the hadron and nuclear physicists of the in-house group. As before, Luigi Scorzato who has held a special INFN fellowship until the end of March 2009 has been responsible for the operation of Teraflop cluster BEN at ECT* as well as for the planning of its much more powerful successor machine AURORA beside his scientific work mainly on lattice QCD. Finally, Daniele Binosi beside his scientific activity in QCD continued his efforts on coordinating large European projects on quantum information processing and communication for which ECT* has been and will also be in the future a special host.

4.1 Projects of ECT* Researchers

Daniele Binosi

Quantum Information Processing and Communication

In 2009, I have been continuing the activity related to the European project QUROPE. In particular the Trento node of this coordination action is involved in the following two work-packages:

- **WP2: Develop a common vision, strategy and goals**
  WP leaders: T. Calarco (Ulm) and P. Zoller (Innsbruck);
  WP members: D. Binosi (Trento)
  WP2 is designed to develop a common European vision, strategy and goals. It formally takes over the development and regular updates of the European QIPC Strategic Report from the ERA-Pilot QIST WP1 described earlier. Other reports and position papers are also within the scope of work. The goal is to provide input for the

preparation of the upcoming 7th Framework Program, and of other strategy/policy documents which could help the EC to shape the research programme in the field of IST. The organization of working Expert groups in various sub-fields, their interaction and integration is also an important part of the work.

- **WP4: Electronic Information Infrastructure and Information Exchange**
  WP leaders: E. Polzik (Copenhagen) and D. Binosi (Trento);
  WP members: L. Theussl (Copenhagen)
  QUROPE WP4 is in charge of establishing and maintaining an Electronic In- formation Infrastructure to support the efficient service of all the coordination action objectives. The centerpiece is a comprehensive website constituting (i) the project portal through which all the relevant information are distributed, exchanged and disseminated, and (ii) the feedback channel that the QIPC community uses to provide direct input to the QUROPE members thus influ- encing on the fly the future actions taken by the coordination action. The QUROPE website http://www.qurope.net is hosted at the Niels Bohr Institute in Copenhagen with part of the database infrastructure hosted in the ECT* servers.

Finally, in November 2008 the European Commission has opened an FP7 call in Quantum Information Foundations and Technologies (Call 4: FP7-ICT-2009-4, Objective ICT-2009.8.2). I have been actively involved in the writing of three projects (two coordination actions and one integrated project) submitted to the aforementioned call; all three of them have been funded (see the section “Quantum Information Processing Group at ECT*” in this report).

Non-perturbative Quantum Chromo-Dynamics

As in the past year, during 2009 my research activity has focussed on exploring the properties of the new truncation scheme for the Schwinger-Dyson equations of QCD that we have developed in 2007. In particular this year we have fully concentrated on explaining the picture of the infrared sector of QCD that is emerging from lattice simulations using huge lattices. In this spirit, we have also organized the “International workshop on QCD Green’s functions, confinement and phenomenology” held at ECT* (September 7 - 11) in which the lattice and the Schwinger-Dyson community exchange their views on the new and exciting developments of the field (see the corresponding report).

We have also continued 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) which will be published next year by Cambridge University Press (the manuscript expected delivery date is March 2010).
The main scientific results reached this year include:

Non-perturbative Comparison of QCD Effective Charges

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

In this paper we study the non-perturbative behavior of two versions of the QCD effective charge, one obtained from the pinch technique gluon self-energy, and one from the ghost-gluon vertex. Despite their distinct theoretical origin, due to a fundamental identity relating various of the ingredients appearing in their respective definitions, the two effective charges are almost identical in the entire range of physical momenta, and coincide exactly in the deep infrared, where they freeze at a common finite value. Specifically, the dressing function of the ghost propagator is related to the two form factors in the Lorentz decomposition of a certain Green's function, appearing in a variety of field-theoretic contexts. The central identity, which is valid only in the Landau gauge, is derived from the Schwinger-Dyson equations governing the dynamics of the aforementioned quantities. The renormalization procedure that preserves the validity of the identity is carried out, and various relevant kinematic limits and physically motivated approximations are studied in detail. A crucial ingredient in this analysis is the infrared finiteness of the gluon propagator, which is inextricably connected with the aforementioned freezing of the effective charges. Some important issues related to the consistent definition of the effective charge in the presence of such a gluon propagator are resolved. We finally present a detailed numerical study of a special set of Schwinger-Dyson equations, whose solutions determine the non-perturbative dynamics of the quantities composing the two effective charges.

Indirect Determination of the Kugo-Ojima Function from Lattice Data

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

In this paper we study the structure and non-perturbative properties of a special Green's function, $u(q^2)$, whose infrared behavior has traditionally served as the standard criterion for the realization of the Kugo-Ojima confinement mechanism. It turns out that, in the Landau gauge, $u(q^2)$ can be determined from a dynamical equation, whose main ingredients are the gluon propagator and the ghost dressing function, integrated over all physical momenta.

Using as input for these two (infrared finite) quantities recent lattice data, we obtain an indirect determination of $u(q^2)$. The results of this mixed procedure are in excellent agreement with those found previously on the lattice, through a direct simulation of this function. Most importantly, in the deep infrared the function deviates considerably from the value associated with the realization of the aforementioned confinement scenario. In addition, the dependence of $u(q^2)$, and especially of its value at the origin, on the renormalization point is clearly established. Some of the possible implications of these results are briefly discussed.

On the Dynamics of the Kugo-Ojima Function

In this work, after reviewing the dynamical gluon mass generation mechanism within the pinch technique framework and its phenomenological predictions, we 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 $q^2 = 0$.

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 is currently under analysis [4] and theoretical input has been provided. An experiment aimed to extract the imaginary part of the E0+ multipole and to assess the impact of D waves in the F asymmetry (target-beam asymetry) was approved this year [5] and theoretical input was provided for the development of the proposal and will be provided for the run of the experiment and the data analysis.

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) [6,7]. 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) [8] 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.

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Lorenzo Fortunato

After joining the ECT* in September 2009, in addition to the collaborations I had already undertaken before coming here, I have started to investigate several new research themes with a common mathematical substrate: the application of symmetry principles to many-body quantum physics as detailed in the following sections.

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)

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

Physical Interpretation of New Non-Canonical Chains in Bosonic Models

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

Algebraic models have been applied to several quantum systems [3] such as nuclei (Interacting Boson Model and extensions[4]), polyatomic molecules (Vibron model[5]) and many-body models. Using the theory of nilpotent orbits and weighted Dynkin diagrams [6] in connections with classical Lie algebras we show that there are many more subalgebra chains that the ones commonly used. We are currently trying to give a physical interpretation to these chains for A_3, that might lead to insightful speculations regarding the vibron model. In future we plan to extend our research to A_5, to treat the IBM.

Phase Diagrams of Tetra-Atomic ABBA Molecules in Algebraic Model

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

We have described the phase diagram of tetra-atomic ABBA molecules within an algebraic formalism [5] that allows for 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.

Coordinate Transformations that Separate the Center of Mass Motion

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 are found and discussed. It is found that the suitable transformations, depending on the number of particles, have a certain number of free parameters and this allows for the generalization of the Jacobi coordinates to a much larger class of coordinates with the same properties and that there is a new, uncommon, additive group structure hidden in the transformation matrices that is connected to certain geometric properties of the set of coordinates [7].

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Vadim Lensky

Compton Scattering off Protons within Baryon Chiral Perturbation Theory

In collaboration with V. Pascalutsa (Johannes Gutenberg Universität Mainz)

We studied low-energy nucleon Compton scattering in the framework of baryon chiral perturbation theory with pion, nucleon, and Δ(1232) degrees of freedom, up to and including the next-to-next-to-leading order (NNLO) [1], [2]. We found that uncertainty of such a NNLO result is comparable to the uncertainty of the present experimental data for low-energy Compton scattering. We find an excellent agreement with the experimental cross section data up to at least the pion-production threshold. Nevertheless, the obtained value for the proton's magnetic polarizability is in significant disagreement with the current PDG value. Unlike the previous ChPT studies of Compton scattering, we perform the calculations in a manifestly Lorentz-covariant fashion, refraining from the heavy-baryon expansion. The difference between the lowest order HBChPT and BChPT results for polarizabilities was found to be appreciable. We discussed the chiral behavior of proton polarizabilities in both HBChPT and BChPT with the hope to confront it with lattice QCD calculations in a near future. In studying some of the polarized observables, we identify the regime where their naive low-energy expansion begins to break down, thus addressing the forthcoming precision measurements at the HIGS facility.

Pion Production in Nucleon-Nucleon Collisions

In collaboration with V. Baru, E. Epelbaum, J. Haidenbauer, C. Hanhart, U.-G. Meißner (Forschungszentrum Jülich), and A. E. Kudryavtsev (ITEP, Moscow)

Pion production in nucleon-nucleon collisions is studied in chiral effective field theory. Our previous results on this project include a discussion on how to properly identify the irreducible contribution of loop diagrams in such type of reaction [3]. We also studied the role of the dispersion and absorption corrections in the pion-deuteron scattering length [4], and also the role of the Δ(1232) isobar in low-energy pion-deuteron scattering [5]. These findings allowed for a precision calculation for the pion-deuteron scattering length [6]. Our recent results on the reactions $NN \to NN\pi$ concern the p-wave pion production, which is closely related with the electroweak and nuclear few-body processes. We showed that it is possible to describe simultaneously the p-wave amplitudes in the $pn \to pp\pi^-$, $pp \to pn\pi^+$, $pp \to d\pi^+$ channels by adjusting a single low-energy constant accompanying the short-range operator which is available at this order [7]. This study provides a non-trivial test of the applicability of chiral effective field theory to reactions of the type $NN \to NN\pi$, and also a connection between various few-body reactions.

Construction of Heavy-Baryon Lagrangians Using Small-Velocity Boosts

In collaboration with B. Long (ECT)*

We used a bottom-up approach, based on the generalized Foldy-Wouthuysen representation, to construct the heavy-baryon chiral Lagrangian with explicit Δ(1232) degrees of freedom. Unlike formalisms utilizing the Rarita-Schwinger field, ours is free of
any unphysical degrees of freedom from the beginning. As an example, we worked out the chiral index-2 πNΔ vertex, which includes $1/m_N^2$ corrections and terms that have undertermined low-energy constants [8]. We also pointed out that one of the terms usually considered to be a part of chiral index-1 πNΔ vertex is in fact redundant, and discussed the implications of this. In particular, we showed that this redundant term should be dropped if one wants to use low energy constants fitted from πN scattering in calculations of NN→NNπ reactions.

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Bingwei Long

Exclusive Decays of χ_{bJ} and η_b into Two Charmed Mesons

In collaboration with R.S. Azevedo and E. Mereghetti (University of Arizona)

We develop a framework to study the exclusive two-body decays of bottomonium into two charmed mesons and apply it to study the decays of the C-even bottomonia [1]. Using a sequence of effective field theories (EFT), we take advantage of the separation between the scales contributing to the decay processes, $2m_b \gg m_c \gg \Lambda_{QCD}$. We prove that, at leading order in the EFT power counting, the decay rate factorizes into the convolution of two perturbative matching coefficients and three non-perturbative matrix elements, one for each hadron. We calculate the relations between the decay rate and non-perturbative bottomonium and D-meson matrix elements at leading order, with next-to-leading log resummation. The phenomenological implications of these relations are discussed.

π N Scattering in the Resonance Regions in an Effective Field Theory

In collaboration with U. van Kolck (University of Arizona)

We study the lowest two baryon resonances through pion-nucleon scattering, Δ(1232) and N^*(1440), using a generalized version of heavy-baryon chiral perturbation theory that describes pion-nucleon scattering in a kinematic domain that extends continuously from threshold to the resonance regions. As the first study, the delta-isobar peak is considered [2]. The P-wave phase shifts are used to illustrate this framework. We also compare our approach with those in the literature that concern the delta resonance.

Heavy-Particle Formalism with Foldy-Wouthuysen Representation

In collaboration with V. Lensky (ECT)*

It is nontrivial to preserv Lorentz invariance in an EFT in which the particles appearing in the initial and final states have a mass, m, as large as the break-down scale of the EFT. An infinite series of interactions in powers of ∂/m is needed in order to improve the Lorentz invariance of the S-matrix. We use the Foldy-Wouthuysen representation to construct Lorentz-invariant Lagrangians. The couplings obtained this way feature a straightforward 1/m expansion [3].

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Javier López Albacete

Global Analysis of Electron-Proton Data from Non-Linear QCD Evolution Equations

In collaboration with N. Armesto and C. A. Salgado (University of Santiago de Compostela) and J.G. Milhano (Instituto Superior Tecnico, Lisbon)

In [1] we have performed a global fit to the structure function F_2 measured in lepton-proton experiments at small values of Bjorken-x for all experimentally available values of the photon virtuality. We show that the recent improvements resulting from the inclusion of running coupling corrections [2] allow for a description of data in terms of non-linear QCD evolution equations. In this approach F_2 is calculated within the dipole model with all Bjorken-x dependence described by the running coupling Balitsky-Kovchegov equation. Two different initial conditions for the evolution are used, both yielding excellent fits to data. Data for the proton longitudinal structure function F_L, not included in the fits, are also well described. We provide predictions for F_2 and F_L in the kinematical regions of interest for future colliders and ultra-high energy cosmic rays. Our analysis allows to perform a first principle extrapolation of the proton-dipole scattering amplitude. A numerical implementation of our results down to $x=10^{-12}$ is released as a computer code for public use [3].

AdS/CFT Correspondence in Heavy Ion Collisions

In collaboration with Y. Kovchegov and A. Taliotis (Ohio State University)

In this project we study the applicability of the AdS/CFT correspondence to study strongly coupled aspects of heavy ion collisions. In [4] we consider high energy collisions of two shock waves in AdS_5 as a model of ultra-relativistic nucleus-nucleus collisions in the boundary theory. We first calculate the graviton field produced in the collisions in the NLO and NNLO approximations, corresponding to three- and four-graviton exchanges with the shock waves. We then consider the asymmetric limit where the energy density in one shock wave is much higher than in the other one. In the boundary theory this setup corresponds to proton-nucleus collisions, with the nucleus being the denser of the two shock waves and the proton being the less dense one. Employing the eikonal approximation we find the exact high energy analytic solution for the metric in AdS_5 for the asymmetric collision of two delta-function shock waves. The solution resums all-order graviton exchanges with the "nucleus" shock wave and a single-graviton exchange with the "proton" shock wave. Using the holographic renormalization prescription we read off the energy-momentum tensor of the matter produced in proton-nucleus collisions. We show in explicit detail that in the boundary theory the proton is completely stopped by strong-coupling interactions with the nucleus, in agreement with our earlier results [5].

In a related work [6], we study the heavy quark potential at strong coupling and finite temperature. In order to do so we exploit the relation between Wilson loops in gauge theories and semiclassical solutions in supergravity. Our most important result is that, at large quark-antiquark separations, the potential follows a power-law falloff rather than the expected Debye exponential suppression. Moreover, at large separations the potential develops an imaginary part, which is physically related to the decay probability of heavy quarkonia in a Quark Gluon Plasma.

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Luigi Scorzato

Aurora

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

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

Instantons Liquid Model and Stochastic PT

In collaboration with P.Faccioli, R.Millo (Trento U.) and F.Di Renzo (Parma U.)

By means of Stochastic Perturbation Theory we are computing the quantum corrections around a background of diluted Instantons and/or Instantons pairs. This would allow to promote the Instantons Liquid Model into a systematic expansion, where QCD corrections are computed in PT via NSPT. In a first work we have proposed a method to analyse the instanton content of non perturbatively generated configurations and applied it to the double well problem in Quantum Mechanics.

Numerical Stochastic Perturbation Theory

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

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..

Computation of B_K with Overlap Quarks on a Twisted Mass Sea

In collaboration with K.Cichy, (Poznan U.) K.Jansen, G. Herdoiza (DESY)

We use a mixed action approach, employing dynamical twisted-mass fermions in the sea sector and overlap valence fermions, with the aim of testing the continuum limit scaling behaviour of physical quantities. The pion decay constant is the first test example. Interesting physical applications include the computation of the Kaon bag parameter B_K

Computation of Meson-Baryon Scattering with Lattice QCD

In collaboration with Bingwei Long (ECT) Xu Feng, Karl Jansen, Dru Renner (DESY)*

We are studying the possibility to compute meson-baryon scattering length with Lattice QCD and twisted mass fermions. This poses more difficulties than meson-meson scattering, but it is very much relevant in connection with HBChPT.

Achim Richter

In my first full year at ECT I have – as in 2008 – continued working closely with colleagues at the Technical University of Darmstadt and elsewhere on both, problems in nuclear structure and nuclear astrophysics and in quantum chaos studied through microwave billiards. The names of the respective collaborators are listed in the references cited.*

Properties of the ^{7}He Ground State from ^{8}He Neutron Knockout

The unbound light nucleus ^{7}He, produced in a neutron knock-out reaction from a 240 MeV/u ^{8}He beam hitting a liquid-hydrogen target has been studied at the heavy-ion accelerator facility SIS at GSI Darmstadt. From an R-matrix analysis the resonance parameters for ^{7}He as well as the spectroscopic factor S for the ^{6}He(0$^+$)+n configuration were obtained. The value S = 0.61 confirms that ^{7}He is not a pure single-particle state. Furthermore, a possible low-lying excited state in ^{7}He observed in an earlier neutron knock-out experiment from ^{8}He in a carbon target could not be observed in the present experiment [1].

Global Investigation of the Fine Structure of the Isoscalar Giant Quadrupole Resonance

Fine structure in the region of the isoscalar giant quadrupole resonance (ISGQR) in medium-heavy and heavy nuclei has been observed in high-resolution inelastic proton scattering experiments at medium energy at the accelerator facility iThemba LABS. Calculations of the corresponding quadrupole excitation strength functions performed within models based on the random-phase approximation (RPA) reveal similar fine structure when the mixing of one-particle one-hole states with two-particle two-hole states is taken into account. A detailed comparison of the experimental data is made with results from the quasiparticle-phonon model (QPM) and the extended time-dependent Hartree-Fock (ETDHF) method. For the nucleus ^{208}Pb, additional theoretical results from second RPA and the extended theory of finite Fermi systems (ETFFS) are discussed. A continuous wavelet analysis of the experimental and the calculated spectra is used to extract dominant scales characterizing the fine structure. Although the calculations agree with qualitative features of these scales, considerable differences are found between the model and experimental results and amongst different models. Within the framework of the QPM and ETDHF calculations it is possible to decompose the model spaces into subspaces approximately corresponding to different damping mechanisms. It is demonstrated that characteristic scales mainly arise from the collective coupling of the ISGQR to low-energy surface vibrations [2].

Scales in the Fine Structure of the Magnetic Dipole Resonance: a Wavelet Aproach to the Shell Model

Wavelet analysis is applied as a tool for the examination of magnetic dipole (*M*1) strength distributions in *pf*-shell nuclei by the extraction of wavelet scales. Results from the analysis of theoretical *M*1 strength distributions calculated within the shell model with the KB3G interaction are compared to experimental data from (*e*, *e'*) experiments and good agreement of the deduced wavelet scales is observed. The influence of the number of Lanczos iterations on the development and stability of scales and the role of the model space in terms of the truncation level are studied. Moreover, differences in the scales of spin and orbital parts of the *M*1 strength are investigated as well as the use of different effective interactions (KB3G, GXPF1 and FPD6). The results have just been published [3].

The "^{138}La-^{138}Ce-^{136}Ce Nuclear Cosmochronometer of the Supernova Neutrino Process"

We have commented on if the nuclear cosmochronometer suggested by Hayakawa *et al.* [Phys. Rev. C 77, 065802 (2008)] based on the ^{138}La-^{138}Ce-^{136}Ce abundance ratio in presolar grains would be affected by the existence of a hitherto unknown low-energy 1^+ state in ^{138}La. Results of a recent high-resolution study [4] of the $^{138}Ba(^3He, t)$ reaction under kinematics selectively populating 1^+ states in ^{138}La through Gamow-Teller transitions provides strong evidence against the existence of such hypothetical state [5].

Magnetic Dipole Excitations in Nuclei: Elementary Modes of Nucleonic Motion

A review article has been written about this topic within the general frame of nuclear magnetism which is one of the fascinating faces of the nucleus. We have not limited ourselves to presenting the by now very large data set that has been obtained using various probes, electromagnetic and hadronic alike, and that presents ample evidence for a low-lying orbital scissors mode, albeit fragmented over an energy interval of the order of 1.5 MeV, and higher-lying spin flip strength in the energy region 5 – 9 MeV in deformed nuclei, nor to the presently discovered evidence for low-lying proton-neutron isovector quadrupole excitations in spherical nuclei. To the contrary, we have put the experimental evidence in the perspectives of understanding the atomic nucleus and its various structures of well-organized modes of motion and have thus enlarged our discussion to more general fermion and bosonic many-body systems [6].

Friedel Oscillations in Microwave Billiards

Friedel oscillations of electron densities near step edges have an analog in microwave billiards. A random plane-wave model, normally only appropriate for the eigenfunctions of a purely chaotic system, can be applied and is tested for non-purely-chaotic dynamical systems with measurements on pseudointegrable and mixed dynamics geometries. It is found that the oscillations in the pseudointegrable microwave cavity match the random plane-wave modeling. Separating the chaotic from the regular states for the mixed system requires incorporating an appropriate phase-space projection into the modeling in multiple ways for good agreement with experiment [7].

Nonperiodic Echoes from Quantum Mushroom-Billiard Hats

Nonperiodic tunable quantum echoes have been observed in experiments with an open microwave billiard whose geometry under certain conditions provides Fibonacci-like sequences of classical delay times. These sequences combined with the reflection at the opening induced by the wave character of the experiment and the size of the opening allow to shape quantum pulses. The pulses are obtained by response of an integrable scattering system [8].

Experimental Test of a Two-Dimensional Approximation for Dielectric Microcavities

Open dielectric resonators of different shapes are widely used for the manufacture of microlasers. A precise determination of their resonance frequencies and widths is crucial for their design. Most microlasers have a flat cylindrical geometry, and a two-dimensional approximation, the so-called method of the effective index of refraction, is commonly employed for numerical calculations. Our aim has been an experimental test of the precision and applicability of a model based on this approximation. We performed very thorough and accurate measurements of the resonance frequencies and widths of the two passive circular dielectric microwave resonators and found significant deviations from the model predictions. From this we conclude that the model generally fails in the quantitative description of three-dimensional dielectric resonators [9].

Avoided-Level Crossing Statistics in Open Chaotic Billiards

We have investigated a two-level model with a large number of open decay channels in order to describe avoided level crossing statistics in open chaotic billiards [10]. This model allows us to describe the fundamental changes in the probability distribution of the avoided level crossings compared with the closed case. Explicit expressions are derived for systems with preserved and broken time-reversal symmetry. We find that the decay process induces a modification at small spacings of the probability distribution of the avoided level crossings due to an attraction of the resonances. The theoretical predictions are in complete agreement with the recent experimental results of Dietz *et al*. [Phys. Rev. E 73, 035201 (2006)].

Induced Violation of Time-Reversal Invariance in the Regime of Weakly Overlapping Resonances

We have measured the complex scattering amplitudes of a flat microwave cavity (a “chaotic billiard”). Time-reversal (T) invariance is partially broken by a magnetized ferrite placed within a cavity. We extend the random-matrix approach to T violation in scattering, determine the parameters from some properties of the scattering amplitudes, and successfully predict others. Our work constitutes the most precise test of the random-matrix theoretical approach to T violation so far available [11].

Cross-Section Fluctuations in Chaotic Scattering

For the theoretical prediction of cross-section fluctuations in chaotic scattering, the cross-section autocorrelation function is needed. That function is not known analytically. Using experimental data and numerical simulations, we show that an analytical approximation to the cross-section autocorrelation function can be obtained with the help of expressions first derived by Davis and Boosé. Given the values of the average *S*-matrix elements and the mean level density of the scattering system, one can then reliably predict cross-section fluctuations. This work has just been published [12].

Quantum Chaotic Scattering in Microwave Resonators

In a frequency range where a microwave resonator simulates a chaotic quantum billiard, we have measured moduli and phases of reflection and transmission amplitudes in the regimes of both isolated and of weakly overlapping resonances and for resonators with and without time-reversal invariance. Statistical measures for *S*-matrix fluctuations were determined from the data and compared with extant and/or newly derived theoretical results obtained from the random-matrix approach to quantum chaotic scattering. The latter contained a small number of fit parameters. The large data sets taken made it possible to test the theoretical expressions with unprecedented accuracy. The theory is confirmed by both, a goodness-of-fit-test and the agreement of predicted values for those statistical measures that were not used for the fits, with the data. This work has just been published [13].

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Marco Traini

Radiative Partons from Quark Models

In collaboration with P. Faccioli (University of Trento)
and M. Cristoforetti (Technische Universität, Müunchen)

A radiative parton model implemented up to Next-to-Leading-Order (NLO) has been proposed and discussed in the past [1]. The model is based, at low resolution scale, on the structure functions (twist-2 part) calculated within a relativistic quark model of the nucleon. The approach can be implemented for unpolarized and polarized partons, including longitudinal and transverse partons, as well as off diagonal responses (Generalized parton Distributions (GPDs)) [2]. The recent calculations of Next-to-Next-Leading-Order (NNLO) coefficients and splitting functions challenges the approach to demonstrate the convergence of the procedure. We are implementing a new code for the calculation of unpolarized NNLO partons starting from the response of a light-cone quark model [3].

Sum Rule Approach to the Electric Polarizability of Neutral Atoms, Ions and Clusters

In collaboration with R. Leonardi (University of Trento)

The electric polarizability of atoms and ions is calculated within a sum rule approach which can constrain the actual values of the polarizabilty in a self-consistent way. The approach has been applied to nuclei and nucleons [4], the atomic application is a severe test of the method [5].

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4.2 Publications of ECT* Researchers

Daniele Binosi

D. Binosi

On the dynamics of the Kugo-Ojima function.

To appear in PoS, e-Print: arXiv:0911.0315 [hep-ph]

D. Binosi and J. Papavassiliou

Pinch Technique: Theory and Applications

Phys. Rept. 479:1-152, 2009, e-Print: arXiv:0909.2536 [hep-ph]

A. C. Aguilar, D. Binosi and J. Papavassiliou

Indirect determination of the Kugo-Ojima function from lattice data.

JHEP 0911:066,2009, e-Print: arXiv:0907.0153 [hep-ph]

A. C. Aguilar, D. Binosi and J. Papavassiliou

Non-perturbative comparison of QCD effective charges.

Phys. Rev. D80:085018, 2009, e-Print: arXiv:0906.2633 [hep-ph]

César Fernández-Ramírez

C. Fernández-Ramírez, A.M. Bernstein, T.W. Donnelly

Unexpected impact of D waves in low-energy neutral pion photoproduction from the proton and the extraction of the multipoles

Phys. Rev. C 80 065201 (2009) [*arXiv:0907.3463 [nucl-th]*] [ECT*-09-21]

Lorenzo Fortunato

L.Fortunato

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

To appear in J.Phys. A [*arXiv:0910.2811 [nucl-th]*]

ECT preprint number: ECT*-09-10*

L.Fortunato and L.Sartori

Detailed analysis of quantum phase transitions within the $u(2)$ algebra

arXiv:0910.2341 [nucl-th]

Vadim Lenski

V. Baru, E. Epelbaum, J. Haidenbauer, C. Hanhart, A. E. Kudryavtsev, V. Lensky and U.-G. Meißner

p-Wave pion production from nucleon-nucleon collisions

Phys. Rev. C 80, 044003 (2009), e-Print: arXiv:0907.3911 [nucl-th]

V. Lensky and V. Pascalutsa,

Predictive powers of chiral perturbation theory in Compton scattering off protons

Eur. Phys. J. C 65, 195 (2010), e-Print: arXiv:0907.0451 [hep-ph]

V. Lensky and V. Pascalutsa

Predictions of chiral perturbation theory for Compton scattering off protons

PoS(EFT09)033, e-Print: arXiv:0905.3861 [nucl-th]

Bing Wei Long

R.S. Azevedo, B. Long, and E. Mereghetti

Exclusive decays of χ_{bJ} and η_b into two charmed mesons

*Phys. Rev. D*80*, 074026 (2009), e-Print: arXiv:0909.1995 [hep-ph] [ECT*-09-09]*

B. Long and U. van Kolck

π N Scattering in the Δ(1232) region in an Effective Field Theory

Submitted to Nucl. Phy. A, e-Print: arXiv:0907.4569 [hep-ph] [ECT-09-08]*

B. Long

Pion-nucleon scattering around the delta resonance

To appear in PoS, e-Print: arXiv:0911.4308 [hep-ph] [ECT-09-19]*

Javier López Albacete

J. L. Albacete

Heavy Quark Potential at Finite Temperature in AdS/CFT

Nucl. Phys. A830, 311 C-314C (2009) [arXiv:0908.2541 [hep-ph]]

J. L. Albacete, Y. Kovchegov and A. Taliotis

AdS/CFT correspondence in heavy ion collisions

*In *Hamburg 2008, Multiparticle dynamics (ISMD08)* 135-139*

J. L. Albacete, N. Armesto, J. Guilherme Milhano and C. Salgado

A Global Analysis of DIS data at Small-x with Running Coupling BK evolution

To appear in the proceedings of 17th International Workshop on Deep-Inelastic Scattering and Related Subjects (DIS 2009), Madrid, Spain, 26-30 Apr 2009. [arXiv:0906.2721 [hep-ph]]

Javier L. Albacete, Y. Kovchegov and A. Taliotis

Asymmetric Collisionof Two Shock Waves in AdS(5)

JHEP 0905:060 (2009) [arXiv:0902.3046 [[hep-th]]. Preprint number: ECT-09-02*

Javier L. Albacete, N. Armesto, J. Guilherme Milhano and C. Salgado

Non-linear QCD meets data: A Global analysis of lepton-proton scattering with running coupling BK evolution

Phys. Rev D80:034031 (2009), e-Print: arXiv:0902.1112 [[hep-ph]]. Preprint number: ECT-09-01*

Achim Richter

A. Bäcker, B. Dietz, T. Friedrich, M. Miski-Oglu, A. Richter, F. Schäfer, and S. Tomsovic

Friedel oscillations in microwave billiards

Phys. Rev. E 80, 066210 (2009)

C. Poli, B. Dietz, O. Legrand, F. Mortessagne, and A. Richter

Avoided-level-crossing statistics in open chaotic billiards

Phys. Rev. E 80, 035204 (2009)

S. Bittner, B. Dietz, M. Miski-Oglu, P. Oria Iriarte, A. Richter, and F. Schäfer

Experimental test of a two-dimensional approximation for dielectric microcavities

Phys. Rev. A 80, 023825 (2009)

B. Dietz, T. Friedrich, M. Miski-Oglu, A. Richter, F. Schäfer, and T. H. Seligmann

Nonperiodic echoes from quantum mushroom-billiard hats

Phys. Rev. E 80, 036212 (2009)

Yu. Aksyutina, H.T. Johansson, T. Aumann, K. Boretzky, M. J. G. Borge, A. Chatillon, L. V. Chulkov, D. Cortina-Gil, U. Datta Pramanik, H. Emling, C. Forssén, H. O. U. Fynbo, H. Geissel, G. Ickert, B. Jonson, R. Kulessa, C. Langer, M. Lantz, T. LeBleis, A. O. Lindahl, K. Mahata, M. Meister, G. Münzenberg, T. Nilsson, G. Nyman, R. Palit, S. Paschalis, W. Prokopowicz, R. Reifarth, A. Richter, K. Riisager, G. Schrieder, H. Simon, K. Sümmerer, O. Tengblad, H. Weick, and M.V. Zhukov

Properties of the ^{7}He ground state from ^{8}He neutron knockout

Phys. Lett. B 679, 191 (2009)

B. Dietz, T. Friedrich, H. L. Harney, M. Miski-Oglu, A. Richter, F. Schäfer, J. Verbaarschot, and H. A. Weidenmüller

Induced violation of time-reversal invariance in the regime of weakly overlapping resonances

Phys. Rev. Lett. 103, 064101 (2009)

P. von Neumann-Cosel, A. Richter, and A. Byelikov

Comment on "^{138}La-^{138}Ce-^{136}Ce nuclear cosmochronometer of the supernova neutrino process"

Phys. Rev. C 79, 059801 (2009)

A. Shevchenko, O. Burda, J. Carter, G. R. J. Cooper, R. W. Fearick, S. V. Förtsch, H. Fujita, Y. Fujita, Y. Kalmykov, D. Lacroix, J. J. Lawrie, P. von Neumann-Cosel, R. Neveling, V. Y. Ponomarev, A. Richter, E. Sideras-Haddad, F. D. Smit, and J. Wambach
Global investigation of the fine structure of the isoscalar giant quadrupole resonance
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Luigi Scorzato

M. Brambilla, F. Di Renzo and L. Scorzato
High loop renormalization constants for Wilson fermions/Symanzik improved gauge action.
PoS LAT2009:211,2009 [*arXiv:1002.0446 [hep-lat]*]

R. Baron, Ph. Boucaud, P. Dimopoulos, F. Farchioni, R. Frezzotti, V. Gimenez, G. Herdoiza, K. Jansen, V. Lubicz, C. Michael, G. Muenster, D. Palao, G.C. Rossi, L. Scorzato, A. Shindler, S. Simula, T. Sudmann, C. Urbach, U. Wenger
Light Meson Physics from Maximally Twisted Mass Lattice QCD
arXiv:0911.5061 [hep-lat] ECT-09-23*

R. Millo, P. Faccioli, L. Scorzato
Quantum Interactions Between Non-Perturbative Vacuum Fields
arXiv:0911.3021 [hep-lat] ECT-09-22*

4.3 Seminars and Presentations at International Conferences by ECT* Researchers

Daniele Binosi

On the dynamics of the Kugo-Ojima function

Talk given at the "International workshop on QCD Green's functions, confinement and phenomenology".

September 2009, Trento, Italy

Lorenzo Fortunato

Applications of Lie algebras to physical problems: Dynamical Symmetries at the crossroad between mathematics and physics

Invited talk at the Department of Mathematics, University of Trento

15 October 2009, Trento, Italy

Interacting Boson approximations in nuclear many-body models

ECT*-Coffee Talks

December 2009 (moved to 8 January 2010), Trento, Italy

Vadim Lensky

Predictions of Chiral Perturbation Theory for Compton Scattering off Protons

Talk given at the International Workshop on Effective Field Theories "From the Pion to the Upsilon".

February 2009, Valencia, Spain

Bingwei Long

Pion-nucleon scattering around the delta-isobar resonance

Talk given at "Effective Field Theories and the Many-Body Problem" INT program,

April 2009, Seattle, US

Javier López Albacete

Unitarity Effects at HERA

Seminar given at the Departamento de Fisica, Universita degli Studi de Milano.

April 2009, Milano, Italy

The Thermalization Problem in Heavy Ion Collisions from AdS/CFT

Seminar given at Technische Universität München.

June 2009, München, Germany

Aspects of Gluon Saturation

Seminar given at the Technische Universität München.

June 2009, München, Germany

Dipole models beyond HERA data

Talk given at the Low-x Meeting 2009.

September 2009, Ischia, Italy

Heavy Quark Potential in AdS/CFT

Talk given at the 21st International Conference on Ultra-Relativistic Nucleus-Nucleus Collisions (QM08).

April 2009, Knoxville (TN), USA.

A global analysis of DIS data with running coupling BK evolution.

Talk given at the XVII International Workshop on Deep-Inelastic Scattering and Related Subjects (DIS 2009).

April 2009, Madrid, Spain.

Phenomenological applications of BK with running coupling

Talk given at Workshop on High-Density QCD at the LHC and in Cosmic Rays, Universidade de Santiago de Compostela

January 2009, Santiago de Compostela, Spain.

Achim Richter

Chaotic scattering in microwave billiards: isolated and overlapping resonances
Invited talk presented at the international workshop on “Resonances in mathematical physics”.
January 12-16, 2009, CIRM, Luminy, France

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
Lectures given in the Doctoral Training Programme on “Strongly correlated quantum systems”.
March 29 – June 19, 2009, ECT, Trento, Italy*

Playing billiards with microwaves – quantum manifestations of classical chaos
Talk presented in the joint Colloquium of the ECT* and the Physics Department of the University of Trento.
April 08, 2009, UNITN, Trento, Italy

Double slit experiments in microwave billiards with regular and chaotic dynamics
Invited talk presented at the 4th international workshop on “Quantum chaos and localization phenomena”.
May 22-24, 2009, Warsaw, Poland

Microwave experiments with circular and square dielectric billiards
Invited talk presented at the international workshop on “Microcavities and their applications” at the Seoul National University.
August 25-28, 2009, Seoul, South Korea

Spectral properties and scattering in chaotic billiards and nuclei
Invited talk presented at the “ISOLDE workshop and users meeting 2009” at CERN.
November 18-20, 2009, Geneva, Switzerland

Spectral properties and scattering in chaotic billiards and nuclei
NIF & Photon Science Invited Guest Seminar at the Lawrence Livermore National Laboratory.
December 14, 2009, Livermore, U.S.A.

Luigi Scorzato

Aurora: Scientific Applications
Talk given at the Workshop introducing the Aurora project
May 2009, FBK-Povo, Italy

AuroraScience: High performance computing for Scientific Applications
Talk given at the ETM Collaboration meeting
September 2009, Groningen, The Netherland

Quark Masses from Lattice QCD
Talk given at ECT* Board meeting
October 2009, ECT-Villazzano, Italy*

4.4 Lectures and Seminars at ECT*

4.4.1 Lectures

Introduction and overview

March 30 - April 5

Lecturers: G. Baym (University of Illinois) and C. Pethick (NORDITA)

Physics of ultracold atomic gases

April 6 - 8, April 15 – 19, April 23 – 24, April 27 – 29

Lecturer: S. Stringari (University of Trento)

Introduction to Monte Carlo methods

April 6 - 8, April 15 – 19, April 23 – 24, April 27 – 29

Lecturer: S. Giorgini (University of Trento)

Experimental aspects of relativistic heavy-ion reactions

April 20 – 22, April 27 – 29

Lecturer: P. Braun-Munzinger

Microscopic many-body theory

May 4 – 10

Lecturer: S. Fantoni (SISSA, Trieste)

Making, Probing and Understanding Ultracold Atomic Fermi Gases

May 11 – 17

Lecturer: M. Zwierlein (MIT)

Topics in correlations in nuclei

May 12 – 15

Lecturer: A. Richter (TU Darmstadt and ECT*)

Observational aspects of neutron stars

May 25 – 31

Lecturer: A. Watts (University of Amsterdam)

Physics of quark-gluon plasma

June 1 – 7

Lecturers: T. Hatsuda (University of Tokio) and G. Baym (University of Illinois)

Physics of low dimensional systems

June 8 – 14

Lecturer: T. Giamarchi (University of Geneva)

Density functional methods in nuclear physics

June 15 – 19

J. Dobaczewski (University of Warsaw and University of Jyvaskyla)

4.4.2 Seminars

Universality in Pion-less EFT with the Resonating Group Model: Three, Four, and Six Nucleons

September 9

J. Kirscher

Non-linear QCD at high energies

May 13

J. L. Albacete

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.
T. Calarco and D. Binosi have jointly applied for two 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) representing the successor of the currently running QUROPE. In QUIE^{2}T, T. Calarco is the leader of Work-Package 2 (Strategy, vision and sustainability), while D. Binosi, in addition to having laid the foundations of this new enterprise and contributing to Work-Package 2 and 3 (Dissemination activities), will act as QUIE^{2}T Executive Secretary. The funding requested for the ECT* node is 89k€.

Finally they have been involved in the preparation of an ERA-NET initiative (**CHIST-ERA**) led by the French funding agency ANR, that has as one of its main deliverables a joint transnational call in the QIP field funded by the Austrian, German, Italian and Polish governments.
All three projects have been funded with CHIST-ERA starting the 1st of January 2010 while AQUTE and QUIE^{2}T starting on the 1st of February 2010. As far as the ERA-NET initiative is concerned D. Binosi will be the leader of Work-Package 3 (Definition of Countours and Joint Call Topics) acting as a consultant for the Italian MIUR.

6 BEN, the ECT* Teraflop Cluster

The teraflop cluster BEN at ECT* is the result of a joint ECT*-INFN-PAT-Eurotech Supercomputing initiative that was started in order to create a nucleus of supercomputing initiatives aimed at serving both the local and international scientific communities.

The main goals of the project were the design, development and operation of an experimental supercomputing facility with a significant performance level (1 teraflop), including a low latency network designed for grand challenges tasks as LQCD; the creation of a team that could deliver a number of services to the users community; the development of a network of researchers with heterogeneous interests that could share their experiences and needs within the framework of the supercomputing environment; the production and publication of high quality, peer refereed scientific results.

The Joint Supercomputing Initiative has now been in force for more than 5 years has achieved most of its goals. In particular the BEN supercomputer has been in production for all these years and it is still serving the international scientific community. The low latency APE3D network has been deployed and used for LQCD calculations. A team has been formed and has supported the users of the cluster. A network of researchers coming from very different and complementary
research areas and institution has been using the system to develop a number of scientific projects that have resulted in many published papers.

As it can be expected in any experimental project, there have also been some difficulties, that have been fully reviewed by the ECT* Scientific Board in 2009.

The experience of BEN showed clearly that HPC is a crucial requirement for competitive Science and ECT* can play an primary role by supporting innovative ideas. This experience help ECT* to shape the new project AURORA, that takes advantage of the lessons of BEN and is described elsewhere in this report.

7 Aurora Science

Aurora-Science 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 compute-based areas of physics (Lattice Gauge Theory, Computational Fluid-Dynamics, Molecular Dynamics), quantitative-biology (protein folding), Bio-Informatics (Gene-Sequencing) and medical physics.

Aurora-Science can be seen as a scientific project enabled by leading-edge computational systems and by specific competences in the useful operation of these systems. The main goals of the Aurora-Science Project are the following:

- Tailor the architecture of a massively parallel computer system to the specific needs of a large class of regular computational problems. This is done by assembling a large number of latest generation multi-core CPUs (Intel Nehalem, to be soon replaced by Intel Wesmere) and interconnecting them with a low-latency 3-D toroidal grid. The project uses the hardware recently introduced by Eurotech in their Aurora class of machines and re-designs and optimize the (FPGA-based) network processors of the torus network.
- Procure and operate a medium size Aurora prototype machine, optimized for Aurora-Science. The envisaged installation will have in excess of 100 processing nodes with a target peak performance of some tens of TeraFlops. The project considers the prototype as a convincing test proof that large scale systems can be efficiently operated by a combination of off-the-shelf hi-end processors and application-driven interconnects. Following successfull operation of the prototype, the project will consider enlarged collaboration options, with the main goal of developing a PFlops class machine optimized for scientific applications and fully available to basic science.
- Modify, tune, port and optimize for the Aurora-Science prototype key computational algorithms in the scientific areas described above, and show effectiveness for state-of-the-art scientific simulations.

7.1 The structure of the project

AuroraScience is operated on the basis of a research agreement between IstitutoNazionale di Fisica Nucleare (INFN) and the Provincia Autonoma di Trento(PAT). INFN and PAT jointly provide the Aurora-Science budget. The project started officially by August 1, 2009 and will continue till the end of January 2011. A further phase of the project (stretching over 18 more months) is forecast but not yet approved by INFN and PAT.

The project is managed by ECT* in Trento. The scientific team of the project includes members from:

- ECT* - Project coordination, Lattice QCD and Nuclear Physics
- INFN (Ferrara, Milano Bicocca, Parma) - Torus network architecture, Application-specific system software, LQCD, Fluid-Dynamics
- Physics Department, University of Trento, Trento - Molecular Dynamics, Nuclear Physics
- DEI (Department of Information Engineering, University of Padova) - Network architecture, application-independent algorithmic optimization
- ATreP (Agenzia Provinciale per la Protonterapia) - Medical physics
- FEM (Fondazione Edmund Mach, San Michele all' Adige) - Bio-informatics, gene sequencing.

8 ECT* Computing Facilities

Available computing resources

HARDWARE	
Servers:	6 DELL Intel XEON 3GHz 1 DELL Power Edge 1600SC [firewall]
Supercomputation:	1 Supercomputer EXADRON: 1 front/end and 99 computers Communication band-width Gbit/sec 1 cluster ALPS: 1 front/end and 36 CPUs Communication band-width Gbit/sec
18PC for staff and local research:	Pentium IV up to 2.8 GB Workstation DELL Optiplex SX270 Workstation DELL Optiplex GX280 Workstation DELL Optiplex GX520 Workstation DELL Optiplex GX620 Workstation DELL Optiplex 755 Workstation DELL Precision 390
35 PCs for guests:	Pentium IV up to 3 GB 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] 1 MATLAB server [2 concurrent users]