ECT*

Annual Report

2006

European Centre for Theoretical Studies in Nuclear Physics and Related Areas
Trento
Institutional Member of the European Science Foundation Expert Committee NuPECC

Preface

The scientific activities of the ECT* that are summarized in this report concern the international projects (workshops and collaboration meetings), the doctoral training programs, the visitor program, the postdoctoral program and local research. This report also describes the latest developments of the teraflop cluster (BEN) and the activities of the quantum computation group hosted at ECT*.

Eighteen projects were run in 2006 (16 workshops and 2 collaboration meetings). The topics spanned, as usual, a large variety of subfields, ranging from low to high energy nuclear physics; some of the workshops were directly connected to experimental projects, while others were centered on more theoretical subjects. Let us recall that the choice of topics is determined in the first place by the community, the Board of Directors selecting the best projects that it receives; occasionally, however, the Board takes initiatives to encourage activities in areas which are felt important and under-represented. A well appreciated characteristic of ECT* workshops is the strong interaction among the participants; this is favored by our continuing encouragement to the organizers to limit the size to about 40 participants. Let us finally mention that while it has been a tradition at ECT* not to publish proceedings, we have started to collect systematically copies of the talks, and make them available on the ECT* web site. The scientific reports written by the organizers are also available online shortly after each event.

The training of young researchers represents in 2006 an increasing part of ECT*'s activities, with two schools and two training programs, making a total of 17 weeks devoted to training activities. The by-now traditional spring doctoral training program has developed into a very successful format. Such a program offers a unique occasion for students coming from various countries in Europe and beyond, to get basic lectures from top level physicists, interact among themselves, as well as with workshop participants, and present their own work through seminars. The theme of this year's program, computational techniques in strongly interacting systems, was chosen to accompany the recent installation at ECT* of the teraflop cluster, BEN. A second training program was run in the fall, for a shorter period of time (6 weeks). This program, on QCD Spin Physics, was sponsored by the RIKEN-BNL Research Center for half of its total cost. Georges Ripka has, this year again, agreed to come to ECT* and help supervising the training programs, in particular organizing tutorials and the student seminars. I wish to thank him for his help.

The research at ECT* is carried out by the postdocs, the director and the vice director, as well as by long term visiting scientists. Close contacts exist with the Physics Department of the University of Trento and the Center for Bose-Einstein Condensation. In 2006, a common postdoc has been appointed, who shares his time between the Physics Department and the ECT*. Another appointment, that of Vladimir Pascalutsa, represents a major addition to the local research group. Vladimir Pascalutsa occupies a position of a level equivalent to that of an assistant professor, that is jointly funded by ECT* and the European I3 Hadron Physics. He will carry research of his own in hadronic physics, and contribute to the supervision of ECT* postdocs. It would be worthwhile to create another such position, in a different area of nuclear physics, in particular in low energy nuclear physics. This would contribute to the development of a research group at ECT*, providing a broader basis for interactions with the workshop participants, as well as enhancing the attractiveness of the

Center for visitors in various subfields of nuclear physics. I hope this goal can be achieved in the near future.

BEN, the Teraflop cluster has been made fully operational. It is open to outside users. As will be seen from this report, a variety of projects have been run on the cluster: projects in nuclear physics, hadronic physics, gauge theory, but also molecular dynamic calculations applied to systems of biological interest.

Let me conclude this introduction with a word about the future. This coming year, 2007, is an important one for the ECT*. While changes in the local environment are taking place, with the (public) Istituto Trentino di Cultura turning into the (private) Foundation Bruno Kessler, assurance for continuing support of the ECT* have been reaffirmed recently by the local authorities. Our scientific community is well aware of this, and is grateful to the Autonomous Province of Trentino and the Bruno Kessler Foundation for their generous and continuous support, which has made possible the creation of ECT* and its development throughout the years. Recently, with the help of NuPECC, ECT* has taken various initiatives in order to broaden the basis of the support that it gets from various European countries, and we are confident that these efforts will be successful soon. The year 2007 is also the year where we shall start the preparation of the applications for the new European framework program, the FP7. ECT* will join the successors of the two Integrated Infrastructure Initiatives EURONS and Hadron Physics. This offers new opportunities for ECT*, and comfort it in its role of a bridge between two major components of the nuclear physics community. Finally in 2007, the activities of the Center over the years 2003-2006 will be evaluated by an international review committee. Thus, aside from the many exciting scientific projects that will be run during the year, 2007 will be a busy year where much of our efforts will focus on consolidating the basis for a successful development of ECT* in the coming years.

Jean Paul Blaizot
Director, ECT*

Contents

1 ECT* Board of Directors, Staff and Researchers

1.1 ECT* Board of Directors, Director, Vice Director and Scientific Secretary

Wanda Alberico (from September 2005)	University of Torino, Italy
Michael Birse (until January 2006)	University of Manchester, UK
Peter Braun-Munzinger (until June 2006)	GSI, Darmstadt, Germany
Bengt Friman (from October 2006)	GSI, Darmstadt, Germany
Brian Fulton (from June 2006 - NuPECC)	University of York, UK
Hans Åke Gustafsson (from June 2006)	Lund University and CERN
Muhsin Harakeh (until January 2006 - NuPECC)	KVI, Groningen, Netherlands
Wick Haxton (from June 2006)	University of Washington
Paul Hoyer (from October 2004 - chairman)	University of Helsinki, Finland
Frithjof Karsch (from October 2004)	Bielefeld University, Germany
Vijay Pandharipande (until January 2006)	University of Illinois, USA
Friederich-Karl Thielemann (from October 2004)	Univ. of Basel, Switzerland
Piet Van Isacker (from September 2005)	GANIL, Caen, France

Honorary Member of the Board:

Ben Mottelson	NORDITA, Copenhagen, Denmark

ECT* Director:

Jean Paul Blaizot (from September 2004)	ECT* and CNRS, France

ECT* Vice Director:

Marco Traini (from October 2004)	ECT* and University of Trento

ECT* Scientific Secretary:

Renzo Leonardi	ECT* and University of Trento

1.2 ECT* Staff

Ines Campo	Technical Programme Co-ordinator
Stefania Campregher	Programme Assistant
Corrado Carlin	Maintenance Support Manager
Cristina Costa	Technical Programme Co-ordinator
Serena Degli Avancini (from July 2006)	Technical Programme Co-ordinator
Barbara Currò Dossi	System Manager
Susan Driessen (from June 2005)	Assistant to the Directors
Gianni Fattore (from February 2004, part time)	System Manager
Domenico Gonzo (from February 2004, part time)	System Manager
Tiziana Ingrassia	Accounting Assistant
Mauro Meneghini	Driver and Maintenance Support Manager
Donatella Rosetti (part time)	Assistant to the Directors
Gianmaria Ziglio (part time)	Web Manager

1.3 Resident Postdoctoral Researchers and supported Students

- **ECT* postdocs:**

Carlo Ewerz (Germany) (from October 2005)

Andreas Hiroichi Ipp (Austria)(until September 2006)

Taeko Matsuura (Japan) (from April 2006)

Claudia Ratti (Italy) (from August 2005)

Michael Schwamb (Germany)(from June 2006) (Joint position with the Physics Department)

Dionysis Triantafyllopoulos (Greece) (from October 2005)

- **Research Assistant:**

Vladimir Pascalutsa (USA)(from October 2006)(Joint position with I3 Hadron Physics)

• **Quantum Computing Group (post-docs and students):**

Daniele Binosi (Italy) (from February 2005)

Tommaso Calarco (Italy) (from June 2003)

Markus Antonio Cirone (Italy) (until June 2006)

Gabriele De Chiara (Italy) (from March 2006)

• **ECT* supported students:**

Marco Cristoforetti (Italy) (from July 2004)

Sara Della Monaca (Italy) (till fall 2006)

• **Associate researchers:**

Daniele Binosi (from February 2005, part time)

Pietro Faccioli (University of Trento) (from January 2005)

• **Teraflop Cluster (special fellowships):**

Andrea Nobile (Italy) (from November 2005)

Luigi Scorzato (Italy) (from April 2006)

1.4 Visitors in 2006

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

Charalampos Anastasiou	ETH Zurich, Switzerland (VS)
Gert Aarts	University of Swansea, UK (TP)
Mauro Anselmino	University of Turin and INFN, Italy (TP)
Alessandro Bacchetta	DESY, Germany (TP)
Melahat Bayar	Karadeniz Technical University, Turkey (TP)
Andrea Beraudo	University of Turin, Italy (VS)
Rajeev Bhalerao	Tata Institute of Fondamental Research Mumbai, India (VS)
Kieran Peter Boyle	Stony Brook University, USA (TP)
Tomas Brauner	Nuclear Physics Institute Prague, Czech Republic (VS)
Mark Caprio	Yale University, USA (VS)
Pavel Cejnar	Charles University, Czech Republic (VS)
Lukasz Daniel	Jagiellonian University, Poland (TP)
Thomas Alan DeGrand	Univ. of Colorado, USA (TP)
Jishnu Dey	Presidency College, India (VS)
Mira Dey	Presidency College, India (VS)
Sebastian Diehl	University of Heidelberg, Germany (VS)
Thorsten Feldmann	University of Siegen, Germany (TP)
Dominik Daniel Gabbert	DESY - HERMES, Germany (TP)
Giovanni Garberoglio	University of Trento, Italy (TP)
François Roland Gelis	CEA Saclay, France (VS)
Simon Hands	University of Swansea, UK (TP)
Hubert Hansen	University of Turin (VS)
Jiri Hosek	Nuclear Physics Institute Academy of Sciences, Czech Republic (VS)
Francesco Iachello	Yale University, USA (VS)
Edmond Iancu	SPhT CEA Saclay, France (VS)
Matti Oskari Järvinen	University of Helsinki, Finland (TP)
Malvin Howard Kalos	Lawrence Livermore Nat. Lab, USA (TP)
Frithjof Karsh	Brookhaven Nat. Lab, USA (TP)
Anthony David Kennedy	University of Edinburgh, UK (TP)
Maxim Khlopov	University of Rome "La Sapienza" (VS)
Adam Philip Kocoloski	MIT, USA (TP)
John Koster	University of Illinois, USA (TP)
Boris Krippa	University of Manchester, UK (VS)
Elliot Leader	Imperial College, UK (TP)
Andrew Lee	University of Cambridge, UK (TP)
Julio Cesar Leon Luquez	Universidad Nacional de Colombia, Colombia (TP)
Adam Lichtl	Carnegie Mellon University, USA (TP)
Magdalena Luz	Humboldt University Berlin, Germany (TP)
Michal Macek	Charles University Prague, Czech Republic (VS)
Tetsuo Matsui	University of Tokyo, Japan (VS)

Taeko Matsuura	University of Tokyo (VS)
Stephan Meissner	Ruhr-University Bochum, Germany (TP)
Mattia Melis	University of Cagliari, Italy (TP)
Ramon Mendez Galain	University Montevideo, Uruguay (VS)
Alena Moiseeva	BLTP JINR Dubna, Russia (TP)
Astrid Morreale	PHENIX-RHIC University of California, USA (TP)
Swagato Mukherjee	Tata Institute of Fundamental Research, India (TP)
Stephane Munier	Polytechnique, France (VS)
Domhnaill O'Brien	Trinity College Dublin, Ireland (TP)
Oleg Pavlovskiy	Moscow State University, Russia (VS)
Francisco Bartolome Perez-Bernal	Universidad de Huelva, Spain (VS)
Andre Peshier	Giessen University, Germany (VS)
Alexander Pimikov	Irkutsk State University, Russia (TP)
Giovanni Marco Pruna	University of Cagliari, Italy (TP)
Irina Pushkina	Hiroshima University, Japan (TP)
Urko Reinosa	University of Heidelberg, Germany (VS)
Georges Ripka	SPhT CEA Saclay, France (VS)
Simon Rössner	TU Munich, Germany (VS)
Armine Rostomyan	DESY - HERMES, Germany (TP)
Naohito Saito	KEK, Japan (TP)
Tai Sakuma	MIT, USA (TP)
Juan Jose Sanz Cillero	IPN Orsay, France (VS)
Sebastian Scheffler	University of Heidelberg, Germany (TP)
Marcello Sega	University of Trento, Italy (TP)
Peter Douglas Sitch	University of Wales Swansea, UK (TP)
Mikhail Stephanov	University of Illinois, USA (TP)
Pavel Stransky	Charles University Prague, Czech Republic (VS)
Stefan Strauss	University of Rostock, Germany (TP)
Tobias Teckentrup	Ruhr-University Bochum, Germany (TP)
Maria Varanda	DESY - HERMES, Germany (TP)
Alexey Vladimirov	BLTP JINR Dubna, Russia (TP)
Werner Vogelsang	Brookhaven and RIKEN BNL, USA (TP)
Uwe-Jens Wiese	University of Bern, Switzerland (TP)
Nicolas Wschebor Pellegrino	University Montevideo, Uruguay (VS)
Ruizhe Yang	University of Illinois, USA (TP)

2 Scientific Projects run in 2006

2.1 Summary

Altogether, 22 projects have been run at ECT* in 2006: 16 workshops and 2 collaboration meetings, 2 schools,2 doctoral training programmes. This chapter contains the scientific reports prepared by the organizers of each project. G. Ripka, who assisted the Director in the running of the doctoral training programmes, contributed to the preparation of the corresponding reports.

2.2 Workshops and Collaboration Meetings in 2006

16–21 Jan. **The Physics Opportunities with Eurisol**
Organisers: R. Page (Co-ordinator) (*Univ. Liverpool*),
A. Bonaccorso (*INFN Pisa*),
N. Orr (*LPC Caen*) [p. 10]

27 Feb.–10 Mar. **Renormalization Group and Effective Theory Approaches to Many-Body Systems (ECT* School)**
Organisers: A. Schwenk (Co-ordinator) (*Indiana Univ.*),
J. Polonyi (*Univ. Louis Pasteur*) [p. 13]

21–25 Mar. **QCD at Finite Density**
Organisers: S. Gupta (Co-ordinator) (*Tata Inst. of Fund. Research*),
E. Laermann (*Univ. Bielefeld*) [p. 15]

27–31 Mar. **New Directions in Nonperturbative QCD**
Organisers: G. Akemann (Co-ordinator) (*Brunel Univ.*),
P. Damgaard (*Niels Bohr Institute*),
J. Verbaarschot (*State Univ. New York*) [p. 17]

10–14 Apr. **Numerical Simulation of Heavy Ion Reactions in the Fermi Energy Domain**
Organisers: J. Aichelin (Co-ordinator) (*Univ. Nantes*),
P. Danielewicz (*MSU*),
M. Di Toro (*INFN Catania*),

F. Gulminelli (*LPC Caen*),
A. Ono (*Univ. Tohoku*),
W. Herrmann (*LMU Munich*) [p. 19]

8–12 May **Gamma-ray Spectroscopy in Europe: present and future challenges**
Organisers: S. Lenzi (Co-ordinator) (*Univ. Padova and INFN*),
D. R. Napoli (*LNL Legnano*),
G. Sletten (*Niels Bohr Institute*),
W. Korten (*CEA Saclay*) [p. 21]

29 May–2 Jun. **The Physics of High Baryon Density**
Organisers: B. Friman (Co-ordinator) (*GSI Darmstadt*),
V. Koch (*GSI Darmstadt*),
P. Senger (*GSI Darmstadt*) [p. 23]

5–10 Jun. **Generalized Parton distributions - The Present Status**
Organisers: P. Kroll (Co-ordinator) (*Univ. Wuppertal*),
N. d'Hose (*CEA Saclay*),
R. Kaiser (*Univ. Glasgow*) [p. 25]

19–24 Jun. **Exotic Hadronic Atoms, Deeply Bound Kaonic Nuclear States and Antihydrogen**
Organisers: C. Curceanu (Co-ordinator) (*INFN*),
A. Rusetsky (*Helmholtz-Institut, Univ. Bonn*),
E. Widmann (*S.M. Inst. für sub. Phys.*) [p. 27]

26 Jun.–1 Jul. **Heavy Ion Reactions at Ultrarelativistic Energies**
Organisers: M. P. Lombardo (Co-ordinator) (*INFN*),
J. Aichelin (*Subatech*),
C. Greiner (*ITP Goethe Univ.*),
J. Wambach (*GSI Darmstadt*),
P. Levai (*RMKI*) [p. 32]

3–8 Jul. **Observables in Antiproton-Proton Interactions and their Relevance to QCD**
Organisers: H. Koch (Co-ordinator) (*Ruhr-Univ. Bochum*),
M. Anselmino (*Univ. of Turin*),
U. Mosel (*Inst. für Theor. Phys.*),

D.-O. Riska (*Univ. Helsinki*) [p. 33]

17–22 Jul. **Hadrons and Strings**
Organisers: M. Stephanov (Co-ordinator) (*Univ. Illinois Chicago*),
N. Evans (*Univ. Southampton*),
C. Korthals-Altes (*CNRS*),
D. T. Son (*Univ. Washington*) [p. 36]

17–31 Aug. **Heavy Quarkonium and Related Heavy Quark States**
Organisers: T. Mehen (Co-ordinator) (*Duke Univ.*),
N. Brambilla (*Univ. Milan*),
A. Vairo (*Univ. Milan*),
J. Soto (*Univ. Barcelona*) [p. 37]

1–6 Sept. **Jet Physics in Heavy Ion Collisions at the LHC**
Organisers: A. Morsch (Co-ordinator) (*CERN*),
Y. Schutz (*CERN*) [p. 39]

7–10 Sept. **Heavy Flavor Physics in Heavy Ion Collisions at the LHC**
Organisers: G. Martinez (Co-ordinator) (*Subatech*),
F. Antinori (*INFN*) [p. 41]

11–15 Sept. **Summer School on Exotic Nuclear Beams**
Organisers: J. Al-Khalili (Co-ordinator) (*Univ. Surrey*),
A. Vitturi (*INFN*),
P. Van Isacker (*GANIL*),
M. Pfützner (*Univ. Warsaw*),
P. van Duppen (*Univ. Leuven*) [p. 43]

26–28 Sept. **Spin Observables and Spin Structure Functions: Inequalities and Dynamics**
Collaboration meeting
Organisers: J.-M. Richard (Co-ordinator) (*LPSC*) [p. 44]

2–6 Oct. **Lattice QCD, Chiral Perturbation Theory and Hadron Phenomenology**

Organisers: U.-G. Meissner (Co-ordinator) (*Univ. Bonn*),
G. Schierholz (*DESY*) [p. 46]

16–19 Oct. **Electromagnetic properties of the $\Delta(1232)$-resonance Collaboration meeting**
Organisers: V. Pascalutsa (Co-ordinator) (*College of William and Mary*),
M. Vanderhaeghen (*College of William and Mary - JLab*) [p. 47]

30 Oct.–3 Nov. **The Physics of Halo Nuclei**
Organisers: I. Thompson (Co-ordinator) (*Univ. Surrey*),
A. Richter (*Univ. Darmstadt*),
B. Jonson (*Univ. Göteborg*) [p. 49]

2.3 Reports on Projects and Collaboration Meetings

2.3.1 THE PHYSICS OPPORTUNITIES WITH EURISOL

DATE: 16–21 Jan

ORGANISERS:
Robert Page (Co-ordinator) (*University of Liverpool*), Angela Bonaccorso (*INFN Pisa*), Nigel Orr (*LPC Caen*)

NUMBER OF PARTICIPANTS: 43

MAIN TOPICS:

- Nuclear Equation of State
- Resonances
- Nuclear Reactions and Spectroscopy
- Nuclear Astrophysics
- Fundametal Interactions
- Superheavy Elements
- Ground State Properties

SPEAKERS:

C. Angulo (*Louvain-la-Neuve*),
E. Betak (*Bratislava*),
Y. Blumenfeld (*IPN Orsay*),
P. F. Bortignon (*INFN Milano*),
G. Colo (*INFN Milano*),
M. D'Agostino (*INFN Bologna*),
M. Di Toro (*INFN Catania*),
L. Ferreira (*IST Portugal*),
A. Garcia-Camacho (*INFN Pisa*),
F. Gulminelli (*LPC Caen*),
R.-D. Herzberg (*Liverpool*),
E. Khan (*IPN Orsay*),
G. La Rana (*INFN Napoli*),
V. Lapoux (*CEA Saclay*),
D. Lunney (*CSNSM Orsay*),
O. Naviliat-Cuncic (*LPC Caen*),
S. Peru-Desenfants (*CEA Saclay*),
C. Petrache (*Camerino*),
K.-H. Schmidt (*GSI*),
K. Subotic (*Vinca Institute*),
L. Trache (*Texas A&M*),
H. Woertche (*KVI Groningen*)

SCIENTIFIC REPORT:

Aim and Purpose

This workshop was organized as part of the EU 6^{th} Framework Design Study for the proposed EURISOL radioactive beam facility. The aim of this workshop was to identify some of the physics areas in which major scientific breakthroughs can be expected from EURISOL. To achieve this, the workshop set out to attract speakers and participants representing diverse fields at the frontiers of nuclear physics research. The timing of the meeting will allow those working on the "Physics and Instrumentation" Task of the Design Study to

develop these ideas and include them in their final report. Another important aspect was to liase with representatives of other Tasks in the Design Study in order to provide input and guidance driven by the requirements of the EURISOL physics research community.

Results and Highlights

Over 40 scientists from institutions spanning 12 different countries participated in the workshop in the stimulating atmosphere of Trento, including a significant proportion of younger researchers. The topics addressed in the presentations covered a very broad spectrum of nuclear physics research that is likely to figure prominently at the EURISOL facility. Throughout the workshop, a significant portion of the time was spent in lively open discussions of the ideas presented by the speakers.

On the first day, following an introduction to the EURISOL project and an overview of some of the physics questions arising from the 5^{th} Framework Report, the emphasis was on the physics of highly excited nuclei and the role of the isospin degree of freedom. The presentations covered isospin dynamics in heavy ion reactions at Fermi energies, equation of state sensitive observables, the nuclear liquid-gas phase transition with exotic beams and the experimental challenges that lie ahead for EURISOL in investigating the nuclear equation of state. The final talk considered signatures of isospin effects on nuclear level density at rather lower excitation energies.

The second day started with a talk covering giant resonances, exotic resonance modes and the effects these phenomena may have in astrophysics. Example experiments were suggested and discussed. The following presentations considered the dipole strength distribution in unstable nuclei, the two-component (neutron/proton) statistical description of low-energy heavy ion reactions, improved numerical calculations of Coulomb break-up reactions, and isoscalar selective excitations, which was one of the new areas for EURISOL to emerge from the workshop. Part of the afternoon was spent discussing the requirements for the beams from the EURISOL post-accelerator, a topic that was returned to on the final day of the workshop.

The third day of the workshop started by considering some of the experiments that could be performed to search for new physics beyond the Standard Model at low energies. This was followed by a review of the importance of the ground-state properties of nuclei and their systematics in the context of EURISOL. The remaining speakers then concentrated on the physics of very neutron-rich nuclei, starting with a theoretical analysis of the evolution of shell closures in very exotic nuclei, which was then complemented by an experimental perspective on measuring the particle spectroscopy of unbound states in neutron-rich nuclei. The third day's programme of talks was then rounded off by a talk speculating about the prospects of observing the neutron drip line and ground state neutron emission.

The penultimate day started with a presentation considering what can be learnt from vibrational states in exotic nuclei, focusing on the isoscalar and charge exchange excitations. Two talks then followed on superheavy nuclei, the first identifying new opportunities with EURISOL for spectroscopic studies, while second addressed questions regarding the synthesis of such heavy nuclear systems. The final talks then switched the emphasis to some of the nuclear astrophysics questions that could be addressed with EURISOL. The role of the CARINA network was outlined and some of the key studies in nuclear astrophysics were identified. Some interesting ideas on nuclear physics for astrophysics with radioactive beams

were then presented.

The final day started with a short talk on a detector design study, followed by an overview of the production reactions in EURISOL targets, the expected yields of a variety of nuclides and a discussion of the implications for the physics programme. Following a brief review of all the physics that had been presented during the week, the discussion then returned to the topic of the post-accelerator requirements. The next steps in the Design Study were then considered before the final discussion which focused on the possible formation of an ISOL user group to draw together the future EURISOL research community.

Conclusions

We successfully fulfilled our primary aim for the workshop through the diverse physics programme covered during the workshop and the active role played by the participants in the lively discussions. In addition, the participants included people from other Tasks within the EURISOL Design Study, namely those working on the Heavy Ion Post-accelerator design, the Beam Preparation and Handling, and the Beam Intensity Calculations. Furthermore, three of the EURISOL Design Study Management Team were present during the workshop. This allowed us to fulfil our secondary aim of liasing with representatives of other Tasks to provide feedback and input from the EURISOL physics research community.

Optional

The talks will be available in due course on the website: http://www.eurisol.org

2.3.2 RENORMALIZATION GROUP AND EFFECTIVE FIELD THEORY APPROACHES TO MANY-BODY SYSTEMS

DATE: 20 February–10 March

ORGANISERS:
Achim Schwenk (Co-ordinator) (*University of Washington/TRIUMF*), Janos Polonyi (*Université Louis Pasteur Strasbourg*)

NUMBER OF PARTICIPANTS: 46 plus several local students

MAIN TOPICS:

- Introduction to Effective Field Theory and the Renormalization Group
- Effective Field Theory (EFT) for cold atoms and high-density QCD
- EFT for nuclear forces
- EFT and density functional theory
- Renormalization Group (RG) approach to interacting Fermi systems
- Introduction to functional RG and applications to gauge theories
- Functional RG approach to Bose-Einstein condensation
- RG approach to nucleonic matter
- Functional RG approach to low-dimensional Fermi systems
- Functional RG approach to frustrated systems

SPEAKERS:

Jean-Paul Blaizot (*ECT* & CNRS*),
Bertrand Delamotte (*Paris*),
Bengt Friman (*GSI*),
Richard Furnstahl (*Ohio State*),
Holger Gies (*Heidelberg*),
Peter Lepage (*Cornell*),
Walter Metzner (*MPI Stuttgart*),
Andreas Nogga (*FZ Jülich*),
Thomas Schaefer (*NC State*),
R. Shankar (*Yale*)

SCIENTIFIC REPORT:

Over the past five years, there have been important developments based on Effective Field Theory (EFT) and the Renormalization Group (RG) in atomic, condensed matter, nuclear and high-energy physics. These powerful and versatile methods offer novel approaches to study complex and strongly interacting many-body systems in a controlled manner.

The program of the ECT* school was interdisciplinary and was focused on recent applications of EFT and the RG to atomic (Bose-Einstein condensation, resonant Fermi gases, QED in atoms), condensed matter (Fermi liquids, superconductivity, low-dimensional Fermi

systems, frustrated systems), nuclear (chiral interactions, few-body systems, nucleonic matter, density functional theory, neutron stars) and high-energy many-body problems (quark matter, color superconductivity, gauge theories). The school was aimed at graduate students and junior researchers, with the opportunity to develop contacts across physics subfields at an early stage in their career. The structure of the school was two lectures in the morning and two lectures in the afternoon with ample time used for discussions in the coffee breaks between the lectures and the long lunch break.

By all accounts the school was a great success. The lectures were outstanding and pedagogical. All student responses were entirely very positive. The school was also successful in establishing connections and exchanges among the students working in the different physics areas targeted. In addition to the lectures, we had four participant talks by Jens Braun (University of Heidelberg, "The phase boundary of QCD from the functional RG"), Sebastian Diehl (University of Heidelberg, "Universality in the BCS-BEC crossover in cold fermion systems"), Joaquin Drut (University of Washington, "Dilute Fermi gases in the BCS-BEC crossover") and Eiji Nakano (National Taiwan University, "Shear viscocity of a pionic gas"). These talks were well aligned with the topics of the lectures and provided additional example material. A highlight of the school was the interdisciplinary character and the participation of experts from condensed matter and high-energy physics.

Lectures: The lectures are available on-line at the ECT* school website http://www.triumf.info/hosted/ECT/ and they will also be published as a Volume of Springer Lectures Notes in Physics.

2.3.3 QCD AT FINITE DENSITY

DATE: 21–25 March

ORGANISERS:
Sourendu Gupta (Co-ordinator) (*Tata Institute of Fundamental Research, India*), Edwin Laermann (*University of Bielefeld*)

NUMBER OF PARTICIPANTS: 35

MAIN TOPICS:

- QCD at finite chemical potential
- Related theories at finite chemical potential
- Hadrons and glueballs at finite temperature
- Fluctuations, hydrodynamics and transport coefficients

SPEAKERS:
G. Aarts (*Swansea U, UK*),
G. Akemann (*Brunel U, UK*),
B. Alles Salom (*Pisa U, Italy*),
V. Azcoiti (*Zaragoza U, Spain*),
S. Chandrasekharan (*Duke U, USA*),
M. Döring (*Bielefeld U, Germany*),
S. Ejiri (*Tokyo U, Japan*),
Ph. de Forcrand (*ETH Zürich, Switzerland*),
S. Gupta (*TIFR, India*),
S. Hands (*Swansea U, UK*),
B. Kämpfer (*FZ Rossendorf, Germany*),
F. Karsch (*BNL, USA*),
S. Katz (*Wuppertal U, Germany*),
E. Laermann (*Bielefeld U, Germany*),
M. P. Lombardo (*INFN Frascati, Italy*),
H. Malekzadeh (*Frankfurt U, Germany*),
C. Miao (*Bielefeld U, Germany*),
S. Mukherjee (*TIFR, India*),
M. Ohtani (*Tokyo U, Japan*),
A. Nakamura (*Hiroshima U, Japan*),
J. Noronha (*Frankfurt U, Germany*),
P. Petreczky (*BNL, USA*),
M. Prevot (*Bielefeld U, Germany*),
Cl. Ratti (*ECT*, Italy*),
R. Ray (*SINP, India*),
A. Rebhan (*Wien U, Austria*),
A. H. Rezaeian (*Heidelberg U, Germany*),
G. M. Roland (*MIT, USA*),
I. Shovkovy (*FIAS, Frankfurt U, Germany*),
A. Smetana (*AS Prague, Czech Republic*),
M. Stephanov (*UIC, USA*),
A. Vuorinen (*Washington U, USA*),
D. Toublan (*UIUC, USA*),
J. van der Heide (*Bielefeld, Germany*),
F. Zantow (*BNL, USA*)

SCIENTIFIC REPORT:

Aim and Purpose

Progress in lattice simulations of QCD at finite chemical potential was long held up due to the fact that the measure is complex in general, and no methods of Monte Carlo integration could deal with this situation. With the advent of new techniques to go around the problem, results from lattice QCD at finite chemical potential are beginning to accrue.

Interest in these computations presently centers on the phase diagram. With an increased number of variables, the Gibbs phase rule then allows interesting configurations of phase boundaries tied together with multi-critical points. Such expectations are currently under test and quantification on the lattice.

Apart from QCD at finite baryon chemical potential, interest also focusses on allied models like QCD with different numbers of gluons or quarks, and on effective models which describe QCD in some limit.

Experimental observability of the phase diagram would depend, of course, on how medium properties change with parameters. Thus the interest in the equation of state, the nature of fluctuations in conserved quantities, changes in hadron properties, and transport coefficients. Since several of these quantities are extracted from hadron correlations in the medium, we also covered new results and techniques in this area.

Results and Highlights

In the last few years new techniques have been developed to go around the sign-problem of lattice QCD at finite chemical potential. Different approaches to the problem have been tried out by several different groups. There were talks about these approaches by V. Azcoiti, S. Ejiri, Ph. de Forcrand. S. Gupta, S. Katz and M. P. Lombardo. Results obtained by these approaches on the phase diagram, susceptibilities and the equation of state were discussed.

Other approaches have been taken; these include effective models, weak coupling expansions, random matrix theory, large-N expansions, etc. Talks by G. Akemann, B. Kämpfer, C. Ratti, A. Rebhan, I. Shovkovy, M. Stephanov, D. Toublan and A. Vuorinen, discussed these various different methods.

Apart from QCD at finite baryon chemical potential, interest also focusses on allied models like QCD with different numbers of gluons or quarks, and on effective models which describe QCD in some limit. There were several talks on this aspect of physics, including those by S. Chandrasekharan, S. Hands, M. Ohtani and A. Smetana.

Experimental observability of the phase diagram would depend, of course, on how medium properties change with parameters. Thus the interest in the equation of state, the nature of fluctuations in conserved quantities, changes in hadron properties, transport coefficients and other quantities. These topics were discussed in detail by G. Aarts, B. Alles Salom, M. Döring, A. Nakamura, H. Malekzadeh, S. Mukherjee, J. Noronha, P. Petreczky and R. Ray. Finally, experimental issues regarding the prospects of investigating the phase diagram of QCD at finite density were presented by G. Roland.

Conclusions

Discussions threw up interesting points of agreement and disagreement between various different methods which have been adopted for finite density computations in QCD. New

computations will be necessary in order to resolve some of these issues. Computations in simpler models, where the sign problem does not exist, show that many interesting new pieces of physics are within reach. Weak-coupling analysis is exploring regimes of chemical potential which are beyond the present reach of lattice computations. A consistent picture of the phase diagram is under combined test from all these directions.

The nature and properties of the matter at high temperature and densities determines what kind of signals one should expect in experiments. There was discussion of the spectrum and methods of extracting spectral functions from non-perturbative lattice computations. There was interest also in exploring fluctuations in heavy-ion collisions. This is one area where weak-coupling expansions and lattice results are converging, and experimental work has begun.

Optional

Electronic proceedings are available at the website:
http://www.ect.trento.it/

2.3.4 NEW DIRECTIONS IN NONPERTURBATIVE QCD

DATE: 27–31 March

ORGANISERS:
Gernot Akemann (Co-ordinator) (*Brunel University West London*), Poul Damgaard (*The Niels Bohr Institute Copenhagen*), Jac Verbaarschot (*State University of New York*)

NUMBER OF PARTICIPANTS: 34

MAIN TOPICS:

- Theoretical Developments on Lattice Chiral Symmetry
- Effective Field Theory and Chiral Perturbation Theory
- Finite-Temperature and Topology
- Random Matrix Theory and Other Mathematical Tools
- Lattice Supersymmetry

SPEAKERS:
A. D'Adda (*Turin*),
F. Basile (*Brunel/Pisa*),
W. Bietenholz (*HU Berlin*),
B. Bringoltz (*Oxford*),
S. Catterall (*Syracuse*),
G. Cicuta (*Parma*),
A. Feo (*Parma*),
E. Follana (*Glasgow*),
M.T. Frandsen (*NBI Copenhagen*),
Y. Fyodorov (*Nottingham*),
J. Giedt (*Minnesota*),
S. Gupta (*Tata Mumbai*),

P. Hernandez (*Valencia*),
E. Kanzieper (*Holon*),
C. Korthals-Altes (*Marseilles*),
M. Laine (*Bielefeld*),
E. Laermann (*Bielefeld*),
Y. Meurice (*U Iowa*),
H. Neuberger (*Rutgers*),
S. Nonnenmacher (*Saclay*),
S. Shcheredin (*Bielefeld*),
K. Splittorff (*NBI Copenhagen*),
M. Stephanov (*Chicago*),
M. Teper (*Oxford*),
D. Toublan (*U Maryland*),
J. Verbaarschot (*SUNY Stony Brook*),
U. Wenger (*ETH Zurich*),
T. Wettig (*Regensburg*),
U.-J. Wiese (*Bern*),
M. Zirnbauer (*Cologne*)

SCIENTIFIC REPORT:

Aims of the workshop

Our aim has been to highlight exciting recent developments in nonperturbative QCD by selecting specific topics from the areas of Nuclear Theory, High Energy Physics and Mathematical Physics and bringing together people from each of these areas. Part of our motivation for this program has been that such meetings at ECT* have been very fruitful in past. We also benefited from the workshop on QCD at finite density that was organised the week before our workshop. About seven participants contributed actively to both workshops and quite a few more participants have been actively involved in the subjects of both workshop. The connection between both workshops was further strengthen by talks of the organisers of the preceding workshop in our workshop and by a review talk on random matrix theory at nonzero chemical potential by Gernot Akemann in the preceding workshop. Each of the five main topics of this workshop (see list above) were represented by 5-6 speakers each. A balance was kept between world experts and young researchers in the field.

Results and Highlights

Throughout the workshop we have seen nonperturbative phenomena in QCD that can be both analysed numerically by means of lattice QCD and understood analytically in terms of models or by exploiting the symmetries of QCD. Some of the analytical approaches require sophisticated mathematics which gave a natural connection with research in Mathematical Physics. We have seen problems and solutions of QCD at finite density that was the also main topic of the previous workshop with which we shared 7 participants. Strong coupling expansion and reformulations of QCD were discussed. The large-N limit was exposed, including relations to the phase diagram of QCD. The zero momentum regime of chiral perturbation theory was analysed both numerically on the lattice as well as analytically, including its relation to random matrix theory. More formal aspect of matrix models and group integrals were developed, the elimination of colour degree of freedom in favour of flavour degrees of freedom was discussed. Recent results on exact supersymmetry on the lattice were another highlight of the workshop.

Conclusions

The conclusions of the workshop were presented in a summary talk by one of the organisers, Jacobus Verbaarschot, pointing out the connections of the various topics with QCD as

developed in the workshop. Our motivation of bringing together people from the different fields present has been successful. We expect to have initiated new links and bridges by means of common techniques appearing in effective field theory, lattice QCD and mathematical physics.

Weblinks

The talks and program of the workshop are available on the ECT* webpage http://www.ect.it/ following the link "Meetings 2006" under the workshop title New Directions in Nonperturbative QCD. For the workshop webpage including the list of participants see also http://cs.physics.sunysb.edu/verbaarschot/html/trento-2006/index.html

2.3.5 NUMERICAL SIMULATION OF HEAVY ION REACTIONS IN THE FERMI ENERGY DOMAIN

DATE: 10–14 April

ORGANISERS:
Jörg Aichelin (Co-ordinator) (*Subatech*), Pawel Danielewicz (*MSU*), Massimo Di Toro (*Catania*), Francesca Gulminelli (*LPC Caen*), Akira Ono (*Tohoku University*), Herrmann Wolter (*LMU Mnchen*)

NUMBER OF PARTICIPANTS: 16

MAIN TOPICS:

- Simulation of heavy ion reactions
- Symmertry potential
- mean field beyond normal nuclear matter density

SPEAKERS:

J. Aichelin (*Subatech*),
M. Colonna (*Catania*),
P. Danielewicz (*MSU*)
M. Di Toro (*Catania*),
A. Drago (*Ferrara*),
T. Gaitanos (*Munich*),
F. Gulminelli (*LPC Caen*),
C. Hartnack (*Subatech*),
A. Ono (*Tohoku*),
M. Papa (*Catania*),
A. Raduta (*Catania*),
J. Rizzo (*Catania*),
F. Sebille (*Subatech*),
E. Suraud (*Toulouse*),
J.-P. Wieleczko (*Ganil*),
H. Wolter (*LMU Munich*)

SCIENTIFIC REPORT:

Aim and Purpose

To simulate heavy ion reactions at energies of around 100 AMeV is all but an easy task. At that energy mean field dynamics, collisions and Pauli blocking are similar important and, even more, shortcomings in the description of one of them has an immediate influence on the others. Simulation programs have been developed at several places worldwide and have usually been compared with experiments but never among themselves. The world consensus initiative (WCI) has therefore suggested to apply benchmark tests to these simulation programs in order to find optimal solutions for the numerical problems involved and to reinforce their predictive power. It has turned out, that this is not possible by email contacts but that the code owner have to be at the same place to discuss the results and to converge. It was the purpose of the workshop at the ECT* to bring all code owners together and to discuss the differences which have been seen in the homeworks which have been done before the meeting.

Results and Highlights

This comparison has been accompanied by lectures on the details of the quite sophisticated programs as well as on the physics problems which have to be solved. All existing simulation programs but one (Boa An Li from Arkansas State) have been represented. During the meeting we were able to verify that the collisions routines and the Pauli blocking - despite of the very different numerical descriptions - are well implemented and act in a very similar way. We also verified that single nuclei are well described despite of the different potentials (Skyrme, Gogny, relativistic mean field,..) applied.

Conclusions

The next step will be to see how the mean field will act when two nuclei collide. This is presently studied by the different groups as a homework assignment. The ultimate goal is to understand how the chaoticity of the reaction arrives which can be seen in experimental multifragmentation events. Probably a second workshop will be necessary before this goal can be achieved.

2.3.6 GAMMA-RAY SPECTROSCOPY IN EUROPE: STATUS AND PERSPECTIVES

DATE: 8–12 May

ORGANISERS:
Silvia M. Lenzi (Co-ordinator) (*Dipartimento di Fisica and INFN, Padova, Italy*), Daniel R. Napoli (*INFN - Laboratori Nazionali di Legnaro, Legnaro (PD), Italy*), Geirr Sletten (*Niels Bohr Institute, University of Copenhagen, Denmark*), Wolfram Korten (*CEA, Saclay, France*)

NUMBER OF PARTICIPANTS: 59

MAIN TOPICS:

- Nuclear structure of nuclei far from stability
- Spectroscopy with radioactive beams
- Synthesis and spectroscopy of super-heavy nuclei
- Symmetries in nuclear structure and exotic excitations.
- Applications of gamma-ray spectroscopy

SPEAKERS:
F. Azaiez (*IPNO, Orsay, France*),
S. Bhattacharyya (*Ganil, France*),
P. Butler (*U. of Liverpool, UK*),
F. Camera (*U. di Milano, Italy*),
B. Cederwall (*KTH, Sweden*),
R. Chapman (*U. of Paisley, UK*),
G. de France (*Ganil, France*),
A. Dewald (*IKP, Cologne, Germany*),
P. Doornebal (*GSI, Germany*),
L. Egido (*UAM, Madrid, Spain*),
C. Fahlander (*U. Of Lund, Sweden*),
A. Feliciello (*INFN, Torino, Italy*),
A. Gadea (*INFN - LNL, Italy*),
J. Gerl (*GSI, Germany*),
A. Goergen (*CEA, Saclay, France*),
P. Greenless (*JYFL, Finland*),
F. Haas (*IPHC, France*),
I. Hamamoto (*U. of Lund, Sweden*),
J. Jolie (*IKP, Germany*),
P. Jones (*JYKL, Finland*),
D. Joss (*CLRC Daresbury, UK*),
R. Julin (*JYFL, Finland*),
Th. Kroell (*TU Muenchen, Germany*),
A. Lopez Martens (*IN2P3, France*)
N. MUniversityarginean (*INFN LNL, Italy*),
P. Nolan (*U. Liverpool, UK*),
P. Reiter (*IKP, Cologne, Germany*),
T. Saito (*GSI, Germany*),
G. Simpson (*IN2P3, France*),
J. Simpson (*CLRC Daresbury, UK*),
I. Stefanescu (*KU Leuven, Belgium*),
Ch. Theisen (*CEA, France*),
C. A. Ur (*INFN, Padova, Italy*),
N. Warr (*IKP, Cologne, Germany*),
R. Wyss (*KTH, Stockholm, Sweden*)

SCIENTIFIC REPORT:

Aim and Purpose:

Experimental nuclear structure physics is producing a large amount of interesting results in several campaigns using gamma-ray arrays and is facing still better perspectives. The atomic nucleus has been studied far from of stability, expanding the limits of mass, isospin and angular momentum. The continuous development of high resolution gamma-ray detector systems and powerful ancillaries has been of vital importance on this respect, leading to unexpected insights into the nuclear structure. The workshop, organised in the framework of the Gammapool Network, was aimed to the presentation of the status and to the discussion of the perspectives on nuclear spectroscopy research. Sessions have been dedicated to the presentation of recent theoretical developments, the recent results obtained in the different experimental campaigns using Euroball equipment, and the main gamma-ray facilities in Europe, and to the discussion on the future research, the experimental developments and technical challenges.

Results and Highlights:

The achievements obtained using the different experimental set-ups cover a very wide range of physical properties and phenomena. We just list some of the highlights presented in the workshop:

- Spectroscopy of the neutron-deficient ($N = Z - 4$) ^{36}Ca nucleus.
- Measurement of the B(E2) values for the neutron-rich $A \sim 60 - 70$ nuclei in Coulomb excitation reactions with radioactive beams.
- Nuclei at the critical point of shape-phase transitions produced in deep-inelastic collisions.
- Gamma-decay of molecular resonances (^{24}Mg+^{24}Mg).
- Spectroscopy of very heavy elements: ^{254}No, ^{255}Lr, ^{250}Fm.
- Shape coexistence in heavy proton-rich nuclei.
- Spectroscopy at the magic numbers for very neutron-rich O and Si isotopes.
- Isospin symmetry in medium-light nuclei
- Coulomb excitation of nuclei around ^{132}Sn

In almost each session, there was a theoretical talk on a related subject which gave rise to the development of a deeper collaboration between theoretical and experimental researchers. In particular, theoretical predictions on the structure of neutron-rich nuclei, mean-field calculations for high-spin states in $N \sim Z$ nuclei and on proton-rich nuclei were presented. A session was also devoted to the presentation of future developments and another one for the applications of gamma-ray techniques, as for example, the feasibility studies for an animal PET or the construction of devices for the detection of explosive mines.

Conclusions:

The goal of the workshop has been successfully achieved. For the first time it was possible to have a complete vision of the different results obtained with the most important spectrometers in Europe. Bringing together most of the active researchers in the field, the

workshop provided a forum to discuss the experimental methods and results achieved and to explore the perspectives in spectroscopy research in Europe. The success of the workshop induced the participants to ask for a new workshop of the same type in one or two years from now.

Talks:
The talks can be browsed from the website:
http://gammapool.lnl.infn.it/ECT2006/

2.3.7 THE PHYSICS OF HIGH BARYON DENSITIES

DATE: 29 May–2 June

ORGANISERS:
Bengt Friman (Co-ordinator) (*GSI, Darmstadt*), Volker Koch (*LBNL, Berkeley*), Peter Senger (*GSI, Darmstadt*)

NUMBER OF PARTICIPANTS: 45

MAIN TOPICS:

- Properties of strongly interacting matter
- In-medium excitations
- Dynamics of relativistic heavy-ion collisions
- Experimental observables

SPEAKERS:
D. Blaschke (*Univ. Rostock*),
E. Bratkovskaya (*FIAS, Frankfurt*),
W. Cassing (*Univ. Giessen*),
V. Friese (*GSI, Darmstadt*),
Z. Fodor (*Univ. Wuppertal*),
C. Fuchs (*Univ. Tuebingen*),
N. Herrmann (*Univ. Heidelberg*),
C. Hoehne (*GSI, Darmstadt*),
Y. Ivanov (*Kurchatov Inst., Moscow*),
B. Kaempfer (*Research Center Rossendorf*),
C.-M. Ko (*Texas A & M, College Station*),
V. Koch (*LBNL, Berkeley*),
E. Laermann (*Univ. Bielefeld*),
A. Larionov (*Univ. Giessen*),
S. Leupold (*Univ. Giessen*),
P. Petreczky (*BNL, Upton*),
J. Randrup (*LBNL, Berkeley*),
R. Rapp (*Texas A & M, College Station*),
C. Ratti (*ECT, Trento*),
H.-G. Ritter (*LBNL, Berkeley*),
K. Rummukainen (*CERN, Geneva*),
B.-J. Schaefer (*KFU, Graz*),
K. Schweda (*Univ. Heidelberg*),
E. Scomparin (*Univ. Torino*),
E. Shuryak (*SUNY, Stony Brook*),
M. Stephanov (*Univ. Chicago*),
J. Stroth (*Univ. Frankfurt*),
H. van Hees (*Texas A & M, College Station*),
N. Xu (*LBNL, Berkeley*),
E. Zabrodin (*Univ. Oslo*),
G. Zeeb (*Univ. Frankfurt*)

SCIENTIFIC REPORT:

The exploration of the phase diagram of strongly interacting matter is one of the major challenges of modern high-energy physics. Of particular interest are the deconfinement and chiral phase transitions which are expected to occur at high temperatures and high baryon densities. Important goals of both theoretical and experimental efforts are in general the study of the equation-of-state of strongly interacting matter and in particular the determination of the QCD phase diagram. At low net baryon densities, one finds a continuous transition, while at high baryon densities a first order phase transition, which ends in a critical endpoint, is expected. For very high baryon densities color superconducting phases are predicted. These phenomena play an important role for our understanding of strongly interacting hot and dense matter, in particular for the physics of compact stars.

The aim of the workshop was to review the status of the various theoretical approaches, to discuss the relation between the physics of dense baryonic matter and experimental observables, in particular in relativistic heavy-ion collisions, and to map out a strategy for future research. Furthermore, the workshop aimed at a critical confrontation of results of state-of-the-art calculations and recent experimental data.

Recent progress in first-principle calculations of QCD thermodynamics at non-zero net baryon densities, using lattice techniques, is very promising. Nevertheless, large theoretical uncertainties remain. In this context effective theories and phenomenological analyses play an important role in model building as well as in the interpretation of lattice results. Furthermore, such models are necessary for confronting theory with experiment in transport theoretical and hydrodynamic treatments of the dynamics of heavy-ion collisions. Thus, the theory discussions focused on four main topics, lattice results, effective models, phenomenological approaches and modeling of the collision dynamics.

New high-quality experimental data will provide valuable constraints on theory. Therefore, a focal point of the discussions was the future experimental program with heavy-ion beams, in particular with the CBM experiment at the international FAIR facility in Darmstadt.

Presentations of recent theoretical and experimental developments led to numerous fruitful discussions on a wide range of relevant issues. Furthermore, the status of the physics book for the CBM experiment was presented. During the discussion sessions questions relevant for the physics book, both physics and editorial issues, were raised and discussed. Decisions on the form of the book and on a time line were taken and an editorial committee was formed.

The following key topics were presented and extensively discussed during the workshop.

- The QCD phasediagram, lattice results, effective models, phenomenology
- The equation-of-state of strongly interacting matter at high baryon densities.
- Heavy-quark potentials and spectral functions.
- The search for the QCD critical point.

- Signatures of the deconfinement transition and of first-order-transitions in general.
- Properties of hadrons in dense and hot strongly interacting matter.
- Theoretical and experimental aspects of di-lepton production in relativistic heavy-ion collisions.
- Collision dynamics, transport description of in-medium properties, kinetics of charm in medium, collective flow.
- Strangeness and charm production in relativistic heavy-ion collisions.
- Astrophysical aspects of the EOS, constraints from observations.
- Status of the planned low-energy program at RHIC.
- Status of the Compressed Baryonic Matter experiment at FAIR.

2.3.8 GENERALIZED PARTON DISTRIBUTIONS - THE PRESENT STATUS

DATE: 5–10 June

ORGANISERS:
Peter Kroll (Co-ordinator) (*Universitaet Wuppertal, Germany*), Nicole d'Hose (*CEA-Saclay, France*), Ralf Kaiser (*University of Glasgow, United Kingdom*)

NUMBER OF PARTICIPANTS: 43

MAIN TOPICS:

- Properties of generalized parton distributions
- Experimental reviews of hard exclusive processes
- Recent phenomenological studies of hard exclusive processes

SPEAKERS:

H. Avakian (*Jefferson lab*),
A. Belitsky (*Arizona State Uni.*),
P. Bertin (*Uni. Clermont-Ferrand*),
F. Bradamante (*Uni. di Trieste*),
M. Burkhardt (*New Mexico Uni.*),
E. Burtin (*CEA Saclay*),
M. Diehl (*DESY Hamburg*),
M. Dueren (*Uni. Giessen*),
Th. Feldmann (*Uni. Siegen*),
S. Friot (*LMAH-Le Havre*),
F.X. Girod (*CEA Saclay*),
S. Goloskokov (*JINR Dubna*),
V. Guzey (*Uni. Bochum*),
Ph. Haegler (*TU Munich*),
C.C. Kuo (*Nat. Uni. Taiwan*),
S. Liuti (*Uni. of Virginia*),
M. Mazouz (*LPSC Grenoble*),
D. Mueller (*Arizona State Uni.*),
W. Nowak (*DESY Zeuthen*),
A. Osborne (*Uni. of Glasgow*),
B. Pasquini (*Uni. di Pavia*),
D. Robaschik (*Uni. Cottbus*),
G. Rosner (*Uni. of Gasgow*),
A. Rostomyan (*DESY Hamburg*),

A. Sandacz (*Uni. of Warsaw*),
A. Schaefer (*Uni. Regensburg*),
G. Schierholz (*DESY Hamburg*),
L. Schoeffel (*CEA Saclay*),
P. Schweitzer (*Uni. Bochum*),
M. Siddikov (*Uni. Bochum*),
L. Szymanowski (*Uni. de Liege*),
M. Vanderhaeghen (*Will.-Mary*),
C. van Hulse (*Uni. of Gent*),
B. Wojtsekhowski (*Jefferson lab*)

SCIENTIFIC REPORT:

Generalized parton distributions (GPDs) have been discussed by the Lipsia group (Geyer et al) first and, after their rediscovery (Radyushkin, Ji) in 1996, applied to a large number of scattering processes. GPDs, as a generalization of the usual parton distributions (PDFs), provide information on the longitudinal momentum distributions of the partons as well as on their momentum transfer dependence or, after Fourier transforming, on the transversal parton distributions in the impact parameter space. They parameterize soft hadron matrix elements and therefore cannot be calculated from QCD with a sufficent degree of accuracy as yet. First results from lattice QCD are however already available. At present GPDs have to be extracted from experiment as in the case of the PDFs.

GPDs occur in hard exclusive processes. As a consequence of QCD factorization properties, the process amplitudes are represented by convolutions of GPDs and partonic subprocesses. The latter can be calculated by means of perturbation theory. A large number of such processes have been analyzed over the last decade. One class of such reactions is formed by deeply virtual kinematics, i.e. by highly virtual photons but small momentum transfer in the hadronic matrix element. Examples of such reactions are deeply virtual Compton scattering or meson electroproduction. A complementary class of reactions is defined by wide-angle kinematics where the virtuality of the photon is small or even zero while the large scale is provided by the momentum transfer. Examples of such reactions are real Compton scattering, photoproduction of mesons or two-photon annihilations into pairs of hadrons.

The present theoretical knowledge of GPDs has been extensively discussed at the workshop (**Belitsky, Burkardt, Diehl**). **Feldmann** presented first attempts to extract GPDs from data while **Schierholz** and **Schäfer** talked on recent lattice QCD studies of GPDs. Theoretical and phenomenological analyses of various hard exclusive processes in both the kinematical regions, deeply virtual and wide-angle, have been presented for instance by **Müller, Diehl, Szymanowski**. A large fraction of the talks were devoted to new experimental results. Thus, for instance, data on deeply virtual Compton scattering from HERA at low Bjorken-x **Schöffel** and from the complementary large Bjorken-x experiments HERMES **Nowak** and Jlab **Bertin, Avakian** have been discussed. The recent JLab measurements on wide-angle Compton scattering have been presented by **Wojtsekhowski**. The complementary BELLE results on time-like wide-angle processes have been discussed by **Kuo**. The extension of the program at JLab with the future electron beam of 12 GeV has been discussed. The COMPASS program plan with the high energy 100 GeV myon beam has been presented by **Burtin**, and the GSI project FAIR has been introduced by **Düren**.

The talks can be browsed from the website:
http://gpd.gla.ac.uk/gpd2006/

The workshop made it clear that the field of GPDs is expanding. The theoretical understanding of hard exclusive processes is rapidly growing. The experimental information collected for such processes in recent years although not fully analyzed by Theoreticians as yet, as well a large number of future experiments indicate that in the foreseeable future a good knowledge of the GPDs will have been achieved. The theoretical and experimental talks have sharpened the the questions to be answered in the future.

Last not least it should be mentioned that a rather large number of young researchers participated in the workshop and got the opportunity to present their current work in short talks. An introductory lecture on GPDs has been given for them by **Diehl**.

2.3.9 EXOTIC HADRONIC ATOMS, DEEPLY BOUND KAONIC NUCLEAR STATES AND ANTIHYDROGEN: PRESENT RESULTS, FUTURE CHALLENGES

DATE: 19–24 June

ORGANISERS:
Catalina Curceanu Petrascu (Co-ordinator) (*LNF -INFN, Italy*), Akaki Rusetsky (*Helmholtz-Institut für Strahlen und Kernphysik, Universität Bonn, Germany*), Eberhard Widmann (*Stefan Meyer Institut für subatomare Physik, Austria*)

NUMBER OF PARTICIPANTS: 49

MAIN TOPICS:

- Hadronic atoms: status of the theory and of experimental results (including DEAR/SIDDHARTA at DAFNE, DIRAC at CERN, Pionic atoms at PSI)
- Meson-nucleon and meson-nucleus interactions in effective theories, unitarization models of Chiral Perturbation Theory
- Input from lattice QCD: status and perspectives
- $K \to 3\pi$ decay: theory and experimental results (including NA48 at CERN)
- Deeply bound kaonic-nuclear states: status of the theory and experimental results (including E471 and E549/570 at KEK, FINUDA at DAFNE, FOPI at GSI)
- Antihydrogen physics: production mechanisms, precision spectroscopy for testing CPT and QED, gravitation of antimatter
- Next generation experiments at DAFNE2, J-PARC, FAIR

SPEAKERS:

Y. Akaishi (*RIKEN,Japan*),
P. Aslanyan (*Yerevan, Armenia*),
V. Baru (*ITEP, Moscow*),
B. Borasoy (*Univ. Bonn*),
P. Buehler (*SMI, Austria*),
G. Collazuol (*SNS Pisa and INFN Pisa*),
E. Epelbaum (*Jülich, Germany*),
T. Ericson (*CERN*),
E. Friedman (*The Hebrew Univ., Israel*),
A. Gal (*The Hebrew Univ., Israel*),
J. Gasser (*Univ. Bern*),
D. Gotta (*Jülich, Germany*),
R. Hayano (*Univ. Tokyo*),
N. Hermann (*Univ. Heidelberg*),
G. Isidori (*LNF-INFN, Italy*),
K. Itahashi (*RIKEN, Japan*),
A. Ivanov (*Univ. Vienna*),
M. Iwasaki (*RIKEN, Japan*),
B. Juhasz (*SMI Vienna*),
P. Kienle (*SMI Vienna*),
T. Kishimoto (*Osaka Univ.*),
A. Kudryavtsev (*ITEP Moscow*),
N. Kuroda (*RIKEN, Japan*),
R. Lehnert (*MIT, USA*),
R. Lemmer (*Univ. Withwatersand, South Africa*),
V. Magas (*Univ. Barcelona*),
J. Marton (*SMI Vienna*),
N. Mavromatos (*King's College London*),
R. Nissler (*Univ. Bonn*),
H. Ohnishi (*RIKEN, Japan*),
J. A. Oller (*Univ. Murcia*),
E. Oset (*Univ. Valencia*),
J. Prades (*Univ. Granada*),
U. Raha (*Univ. Bonn*),
A. Rusetsky (*Univ. Bonn*),
L. Simons (*PSI, Switzerland*),
L. Tauscher (*CERN*),
D. Trautmann (*Univ. Basel*),
W. Weise (*TU München*),
S. Wycech (*Univ. Warsaw*),
T. Yamazaki (*Univ. Tokyo*),
V. Yazkov (*Moscow, Russia*)
J. Zmeskal (*SMI Vienna*)

SCIENTIFIC REPORT:

Aim and Purpose

The present workshop has been largely inspired by latest theoretical and experimental progress, achieved in the investigation of the exotic hadronic bound systems. These systems offer a unique way for studies of fundamental interactions and symmetries. Low-energy interactions of the lightest pseudoscalar mesons (pions and kaons) with the nucleons are determined by the spontaneous chiral symmetry breaking of QCD. For this reason, one may extract important information, related to the mechanism of chiral symmetry breaking in QCD, from the study of the exotic hadronic atoms and of the deeply bound meson-nuclear states. Antiprotonic atoms and especially antihydrogen are well suited for precision studies of CPT symmetry, and the use of the antiproton as hadronic probe also opens up other possibilities. X-ray spectroscopy of light antiprotonic atoms investigates the nucleon-antinucleon interaction at low energies. i.e. close to threshold. Heavy antiprotonic atoms can be used to study the structure of stable and unstable nuclei.

The aim of the Workshop was to review the latest results in the field, from theoretical and experimental point of view and to fix the main lines of future research. The exchange of ideas between theoreticians and experimentalists was envisaged, with benefits for both communities. In the same time, new ideas which can be checked at the next generation experiments were considered.

Results and Highlights

An exotic hadronic atom, which contains one or several nucleons, 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 states follows. The X-ray transitions to the lowest orbits ($1s$) are affected by the presence of the strong interaction between the nucleon(nucleus) and the hadron. This effect can be further translated into the shift of the $1s$ level with respect to the value calculated in pure QED, and into the lifetime (width) of the level. Extracting these quantities via the measurement of the X-ray transitions enables one to determine hadron-nucleon(nuclear) scattering lengths, which are fundamental characteristics of the hadron-nucleon(nuclear) interactions at low energy. These experiments with exotic atoms provide us with an unique chance to directly access hadronic scattering lengths by measuring bound-state features that is hardly possible by using a different experimental technique. These scattering lengths, in its turn, are further used as an input in the calculations of other fundamental characteristics of QCD at low energy, like meson-nucleon sigma-terms or the strangeness content of the nucleon.

Precision spectroscopy of antiprotonic helium and anti-hydrogen is being actively pursued at the Antiproton Decelerator (AD) of CERN. The study of the metastable three-body system pbar-e-He has, by comparing results of laser and microwave spectroscopy measurements to state-of-the-art three-body QED calculations, led to the most stringent tests of the equality of proton and antiproton charge and mass at a relative precision of 2 ppb. Anti-hydrogen, the simplest atom of antimatter, offers even higher sensitivity to violations of CPT symmetry because the properties of its conjugate system, hydrogen, is known to very high precision (10^{-12} for the ground-state hyperfine structure, and a few parts in 10^{14} for the 1S–2S two-photon transition.

Even the story of exotic atoms is decades old, many developments are taking place now in the field, both from the experimental and from the theoretical points of view. On the experimental side, new "hadronic" beams became available rather recently (as kaons at DAFNE), while new detectors, with improved performance, are becoming available: better energy resolution, stability, efficiency, trigger capability.

Experiments at PSI, DAFNE, CERN are delivering yearly their results, which are becoming more and more precise, so that theoreticians can cope with items not accessible till very recently.

The kaonic hydrogen was recently measured by the DEAR/SIDDHARTA Collaboration on DAFNE with an unprecedented precision, leading to a lively debate on the kaon-proton scattering length extraction procedure, as well as on the compatibility with existent kaon-nucleon scattering data and with the theoretical calculations based on the low-energy effective theory of QCD. The DIRAC Collaboration measured the pionium lifetime, which yields the combination of the S-wave pion-pion scattering lengths $|a_0 - a_2|$. The same quantity was recently measured as well by NA48 in K_{e4} decays and by analyzing the cusps in the decays $K \to 3\pi$. At PSI the series of successful pionic atoms measurements are continued. At CERN, experiments on antiprotonic helium continue by the ASACUSA collaboration, while the formation of cold anti-hydrogen atoms for precision spectroscopy is being developed by the ATRAP, ALPHA and also ASACUSA collaborations.

Future experiments are already planned at existent and/or future machines (GSI, J-PARC, DAFNE2, FAIR). The future of exotic hadronic atoms can 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 item discussed at the workshop is the new paradigm in the strangeness nuclear physics, represented by the recently studied "K-mediated bound nuclear systems," whose first experimental indications are being produced at KEK, LNF and GSI. It turns out that, in the few-body nuclear system the KN interaction with the isopsin $I = 0$ plays an important role: it favors discrete nuclear bound states of K while contracting the nucleus, thus producing a cold dense nuclear system.

Many important implications follow. First, such compact exotic nuclear systems are formed with binding energies so large (100-200 MeV), that their widths turn out very narrow – less than (20-30 MeV) (this happens because the decay channel to $\Sigma\pi$ is closed energetically and in addition the channel $\Lambda\pi$ is forbidden by isospin selection rule). Further, empirical information on the possibility for kaon condensation and strange matter would be obtained. Finally, high-density cold nuclear matter might be formed around K^-, which could provide information about the modification of the kaon mass and the KN interactions in the nuclear medium, as well as about a possible phase transition. The question how the hadrons behave and how their properties change in the nuclear medium could be interesting and important from the viewpoint of spontaneous chiral symmetry breaking of QCD. Namely, the masses of light hadrons are largely of dynamical origin and reflect the symmetry pattern of QCD. Consequently, their change in the nuclear environment may offer insights about the properties of QCD at low energies.

The workshop was aimed at the detailed discussion of the above issues. In particular, for the exotic atoms, the results of the latest measurements by DIRAC, Pionic Hydrogen and DEAR/SIDDHARTA collaborations have been reported and the next generation experiments have been discussed. On the theoretical side, the extraction of the pion- (kaon-) nucleon scattering lengths from the deuterium experiment have been considered, as well as the calculation of the kaon-nucleon scattering lengths within the chiral unitary approach, where differences between various theoretical groups still persist. Moreover, these scattering lengths form an important input in the calculations of the properties of the deeply bound states of kaons on the nuclei. The possibility of formation of such states and their experimental detection have been the subject of intense discussions during the workshop. Future perspectives at J-PARC, GSI, BNL and DAFNE were discussed in the framework of an integrated strategy, in which complementary facilities should bring together the pieces of the puzzle.

Further, the test of the fundamental symmetries of Nature by the anti-hydrogen measurements has obtained an extensive coverage, both on the experimental and theoretical side. In particular, the future experiments on anti-hydrogen physics (related to the FLAIR project): spectroscopy for tests of CPT and QED, the gravitation of antimatter, study of the atomic collisions and the antiprotons as hadronic probes were reviewed.

Last but not least, a separate discussion has been dedicated to the alternative method of a precise measurement of the $\pi\pi$ scattering lengths in $K \to 3\pi$ decays, which has been recently performed by NA48 collaboration at CERN.

Conclusions

The aim of the Workshop was fully achieved. It was proved that the investigation of the exotic hadronic bound systems offers an unique way to study the fundamental interactions and symmetries. Low-energy interactions of the lightest pseudoscalar mesons (pions and kaons) with the nucleons are determined by the spontaneous chiral symmetry breaking of QCD. Their study can bring new and important information concerning the mechanism of the symmetry breaking. The study of the deeply bound kaonic states, might bring a way to study the dense and cold nuclear matter, with important results not only in nuclear and particle physics, but in astrophysics too. Antiprotonic atoms and especially anti-hydrogen are well suited for precision studies of CPT symmetry, and the use of the antiproton as hadronic probe also opens up other possibilities.

A constructive discussion between the theoreticians and experimentalists, experts in the above mentioned field, brought new and important ideas not only for the present experiments/theories, but gave important guiding lines for future experiments, at future facilities, and for future theory developments.

Finally, note that we plan to publish the mini-proceedings of the workshop. These will include 1-page contributions from all speakers, which contain all necessary references on the regular articles. We plan to collet the contributions, combine them into a single file and submit to the hep-ph archive [hep-ph/0610201].

Optional

The talks can be browsed from the website:
http://www.itkp.uni-bonn.de/%7Erusetsky/TRENTO06/talks.html

2.3.10 HEAVY ION REACTIONS AT ULTRARELATIVISTIC ENERGIES

DATE: 25–30 July

ORGANISERS:
Maria Paola Lombardo (Co-ordinator) (*INFN Frascati*), Jörg Aichelin (*Subatech*), Carsten Greiner (*J. W. Goethe Univ. of Frankfurt*), Peter Levai (*KFKI*), Jochen Wambach (*Subatech*)

NUMBER OF PARTICIPANTS: 45

MAIN TOPICS:

- the physics of the quark gluon plasma
- hadrons in matter
- energy loss of particle in matter

SPEAKERS:

J. Aichelin (*SUBATECH*),
M. Attems (*Maximilian*)TU Wien,
R. Baier (*Bielefeld Univ.*),
J.-P. Blaizot (*ECT* and CEA*),
M. Bleicher (*Univ. Frankfurt*),
E. Bratkovskaya (*Univ. Frankfurt*),
M. Buballa (*TU Darmstadt*),
J. Casalderrey Solana (*SUNY - Stony Brook*),
W. Cassing (*Univ. Giessen*),
L. P. Csernai (*Univ. Bergen*),
A. Dumitru (*Univ. Frankfurt*),
G. Fai (*Kent State Univ.*),
G. Ferini (*LNS, Catania*),
L. Ferroni (*Univ. Firenze - INFN*),
H. Hansen (*INFN - Univ. Torino*),
U. Heinz (*Ohio State Univ.*),
A. Ipp (*ECT**),
B. Kämpfer (*Research Center Rossendorf*),
F. Karsch (*Brookhaven Nat. Lab.*),
P. Levai (*KFKI*),
M. P. Lombardo (*INFN Frascati*),
L. McLerran (*BNL*),
Y. Mehtar-Tani (*LPY-Orsay*),
H. Niemi (*Univ. Jyvaskyla*),
S. Peigne (*SUBATECH*),
A. Peshier (*Univ. Giessen*),
G. Purcsel (*KFKI*),
C. Ratti (*ECT**),
P. Romatschke (*Univ. Bielefeld*),
S. Rössner (*TU Munich*),
C. Salgado (*Univ. Roma - La Sapienza*),
C. Sasaki (*GSI*),
B. J. Schaefer (*K.-F. Univ., Graz*),
A. Ster (*RMKI/MFA*),
H. Stöcker (*FIAS, Frankfurt*),
M. Strickland (*Univ. Frankfurt*),
L. Turko (*Univ. Wroclaw*),
K. Werner (*Univ. Nantes*),
F. Zoltan (*Univ. Wuppertal*),
S. Zschocke (*Univ. Bergen*)

SCIENTIFIC REPORT:

Aim and Purpose

This workshop served to discuss the recent results which have obtained in the theory groups of the laboratories which are part of the I3-HP SIM network with the outside world

and with colleagues from the other participation laboratories. A large fraction of the speakers were thesis students and young post docs which reported on their own projects.

Results and Highlights

Since the project started two years ago a remarkable progress has been obtained in several theoretical fields: They include effective meson theories, energy loss and jet quenching, the behavior of heavy mesons in matter as well as lattice gauge approaches. In very lively discussion and a real workshop style these results have been discussed in detail.

Conclusions

It was the general wish of the audience to have another workshop of a similar style in two years from now at the end of the funding period. This shows that the style of the workshop has been appreciated and that useful contacts among the young people have been established.

2.3.11 OBSERVABLES IN PPBAR–INTERACTIONS AND THEIR RELEVANCE TO QCD

DATE: 3–7 July

ORGANISERS:
Helmut Koch (Co-ordinator) (*Bochum*), Mauro Anselmino (*Torino*), Ulrich Mosel (*Giessen*), Dan-Olaf Riska (*Helsinki*)

NUMBER OF PARTICIPANTS: 38

MAIN TOPICS:

- Hadron Spectroscopy
- Hadrons in Matter
- Nucleon Structure

SPEAKERS:
M. Anselmino (*Torino*),
G. Bali (*Regensburg*),
T. Barnes (*Tennessee*),
D. Bettoni (*Ferrara*),
S. Brodsky (*Stanford*),
M. Düren (*Giessen*),
A. Gillitzer (*Jülich*),
M. Große–Perdekamp (*Urbana*),
T. Johansson (*Uppsala*),
P. Kienle (*Wien*),
P. Kroll (*Wuppertal*),
P. Lenisa (*Ferrara*),
S. Leupold (*Giessen*),
M. Lutz (*Darmstadt*),

V. Metag (*Giessen*),
A. Metz (*Bochum*),
C. Morningstar (*Pittsburg*),
U. Mosel (*Giessen*),
P. Mulders (*Amsterdam*),
M. Nikoleav (*Jülich*),
W. Oelert (*Jülich*),
E. Oset (*Valencia*),
J. Pochodzalla (*Mainz*),
F. Rathmann (*Jülich*),
J. Ritman (*Jülich*),
L. S. Szymanowski (*Liege*),
R. Timmermans (*Groningen*),
A. Vairo (*Geneve*),
T. Walcher (*Frascati*),
W. Weise (*Munich*)

SCIENTIFIC REPORT:

Aim and Purpose

Because of the FAIR project GSI will develop in the coming years to one of the leading centres in hadron physics. Antiproton beams of very high quality will allow experiments in various fields: Hadron spectroscopy (up to masses of 5.5 GeV/c^2), investigation of hadron properties in nuclear matter, nucleon structure studies (e.g. General Parton Distributions (GPD)), hypernuclear experiments and a broad program on low energy antiprotons (Antihydrogen, Antiprotonic atoms).The first three topics are intimately related to the progress in understanding QCD at long distances (non perturbative QCD). It was the aim of the workshop to discuss the relation of observables in antiproton induced reactions to QCD. Theorists and experimental physicists have participated, so that close contacts were established and realistic proposals were worked out.

Results and Highlights Three main topics were addressed: Hadron spectroscopy, hadron properties in nuclear matter and nucleon structure functions.
Hadron Spectroscopy: Several new states with hidden and open charm were recently discovered at B–Factories, Cleo–c and BES. Several of them are unexpectedly narrow. However, their total width is often not measurable, the statistics is low and only a few decay modes are known. In order to learn more about the nature of these states, the total widths and as many partial widths as possible have to be measured. That will be the task of the PANDA experiment at FAIR, which will have much better mass resolutions and higher statistics than the present experiments. As far as theory is concerned, Lattice QCD, effective field theories and models were discussed. The LQCD approach is on good track, but more time is needed to get detailed information on the widths and decay modes of the states. Effective field theories yield very good descriptions of the data and give insights, which terms play a decisive role in hadron spectroscopy. A comprehensive overview on the existing models was given, which give very detailed predictions in many cases. The PANDA experiment will be able to check the validity of many theoretical predictions and search for exotic states like Glueballs, Hybrids and Multi-Quark configurations.
Hadron Properties in Matter The experimental and the theoretical status were addressed in a series of talks. In medium changes seem to be established in the light quark sector, showing up in the data of CERES, NA60, TABS/CB and earlier investigations of deeply bound pionic states and K–production in heavy ion reactions. One common feature in all cases is the influence of resonance–hole excitations. The theory has to be further developed.

An essential problem is the link of in–medium properties to observables, where the final state interaction must become part of the theory. In the heavy quark sector particular problems arise. The production mechanisms lead to particles with high momenta counteracting large in-medium effects, and there are qualitative disagreements between theories. The measurement at PANDA will start with a determination of the J/ψ–nucleon absorption cross section, which is of extreme relevance for QGP investigations.
Nucleon Structure As far as theory is concerned, two approaches for hard, exclusive processes were discussed in detail: The hand bag model and the ERBL–approach. $k_\perp$–integrated and $k_\perp$–dependent distribution functions were presented as well as GPD's. The key experiments for FAIR were identified. The most relevant ones for nucleon structure studies will be performed by PAX. Unique is the measurement of the A_{TT}–asymmetry which gives information on the transverse spin distribution of the quarks. In contrast to other experiments, A_{TT} can be directly measured without the knowledge of polarized fragmentation functions. Of interest are also single spin asymmetries (Sivers function) as well as form factor measurements. Also the PANDA–experiment (without polarization observables) can contribute to a deeper understanding of the nucleon structure. Here, the processes $p\bar{p} \to \gamma\gamma$, $\gamma\pi(\rho, \phi)$ and the Drell–Yan Dilepton production are of relevance, where time like GPD's and the Boer–Mulders function can be extracted.

Conclusions

From the discussions it became clear, that the program of PANDA and PAX as outlined in the FAIR–Proposal and the Technical Reports cover the relevant aspects as far as QCD–observables are concerned. However, several new aspects should be added and more stressed, respectively. An important role here play tests of reaction mechanisms, where scaling predictions, dimensional counting and color transparency can be checked. Of relevance is also the study of $p\bar{p}$ elastic reactions with polarization degrees of freedom, where spin mysteries like in pp–scattering may appear. In the case of the PANDA–experiment nucleon structure studies might play a larger role. Also the search for ppK^- and $pnnK^-$–clusters recently seen in several experiments, should be further investigated. The Workshop was very helpful in updating the physics relevant for the FAIR hadron program. It will influence the final design of the detectors and will give input to the Physics Books of the experiments planned for the coming years.

Web Talks

The talks are available at:
http://www.ect.it and
http://www.ep1.ruhr–uni–bochum.de/∼dagmar/Trento.htm

2.3.12 HADRONS AND STRINGS

DATE: 12–17 September

ORGANISERS:
Nick Evans (Co-ordinator) (*Southampton*), Christian Korthals-Altes (*Marseille*), Dam T. Son (*Seattle*), Misha Stephanov (*Chicago*)

NUMBER OF PARTICIPANTS: 33

MAIN TOPICS:

- QCD
- AdS/CFT Correspondence
- AdS/QCD

SPEAKERS:
A. Belitsy, (*Arizona*),
N. Braga (*Rio de Janerio*),
G. de Teramond (*Costa Rica*),
L. Del Debbio (*Edinburgh*),
J. Erdmenger (*Humboldt*),
K. Ghoroku (*Fukuoka*),
E. Iancu (*Saclay*),
I. Kirsch (*Harvard*),
G. Korchemsky (*Orsay*),
M. Kruczenski (*Brandeis*),
B. Lucini (*Swansea*),
A. Mueller (*Colombia*),
L. Pando-Zayas (*Michigan*),
A. Paredes (*Ecole Polytechnique*),
A. V. Ramallo (*Santiago*),
A. Starinets (*Perimeter*),
M. Teper (*Oxford*)

SCIENTIFIC REPORT:

Aim and Purpose

The purpose of the workshop was to discuss recent developments in our understanding of the relationship between field theory and string theory (AdS/QCD), with a focus on the physics of strong interactions and QCD. We wanted to enhance communication between the QCD/lattice and string-theory communities and to accelerate the development of new methodology for QCD based on the recent technical and conceptual advances in string theory. QCD physicists needed to understand the framework of the string-based techniques, and string theorists needed to learn how their efforts would be potentially of most value to QCD theorists. The workshop was intended to help forge new approaches and maximize possible progress in solving QCD.

Achievements

The workshop was very successful. It was attended by about 30 participants who included senior faculty, junior faculty, postdocs and PhD students. Participants included people working in the areas of formal AdS/CFT and string theory, phenomenological AdS/QCD, low x

QCD physics, high temperature and density QCD and lattice gauge theory. There were six talks each day allowing essentially every participant to contribute as well as periods set aside for discussion. The talks generated long question sessions and the different communities all seemed to benefit strongly from their interactions. We are confident, from the feedback we had, that many new directions for research were generated and new collaborations will have been forged.

Web

The talks can be browsed from the website:
http://www.hep.phys.soton.ac.uk/ evans/Trento/schedule.html

2.3.13 HEAVY QUARKONIUM AND RELATED HEAVY QUARK STATES

DATE: 17–31 August

ORGANISERS:
Thomas Mehen (Co-ordinator) (*Duke University*), Nora Brambilla (*University of Milan*), Joan Soto (*University of Barcelona*), Antonio Vairo (*University of Milan*)

NUMBER OF PARTICIPANTS: 15

MAIN TOPICS:

- Quarkonium Production and Decay in NRQCD and SCET
- Heavy Quarks on the Lattice
- Effective Field Theories for Hadronic Bound States
- Charmonium Spectroscopy, including XYZ States
- Resummation and Factorization in SCET

SPEAKERS:

A. Ali-Khan (*Regensburg*),
G. Bodwin (*Argonne*),
X. Garcia i Tormo (*Barcelona*),
A. Idilbi (*U. of Maryland*)
M. Kusunoki (*Arizona*),
A. Leibovich (*Pittsburgh*),
M. Negrini (*Ferrara*),
A. Penin (*Karlsruhe, Moscow*),
H. Sazdjian (*Orsay*),
R. Sommer (*DESY, Zeuthen*),
F. Stancu (*Leige*),
A. Vairo (*Milan*)

SCIENTIFIC REPORT:

Aim and Purpose

The meeting covered recent advances in the study of heavy quarkonium and related heavy quark bound states. The heavy quarks research area has seen recently many interesting developments in both theory and experiment. Theoretically, there has been significant development of effective field theories for heavy quark bound states as well as increasingly accurate lattice QCD simulations. Experimentally, there has been a resurgence in spectroscopy with the discovery of new excited charmed states such as the $D_s(2317)$ and $D_s(2460)$, new regular heavy quarkonium states such as $\eta_c(2S)$, $h_c(1P_1)$ and new resonances in the charmonium sector ($X(3872)$, $X(3940)$, $Y(3940$, $Z(3930)$, $Y(4260)$), some seemingly of a new nature (hybrids, molecular states, four quark states) and candidates for doubly charm baryons. Experiments have also observed striking anomalies in the production of charmonium in e^+e^- collisions at B-factories and in charmonium polarization at high p_t at Fermilab, which pose serious challenges to theories of quarkonium production.

This was therefore high time to organize an extended activity on this research subject.

Results and Highlights

New experimental results, new states, new lattice data, new production and decays results, new developments in effective field theories, new effective field theories, new developments in lattice QCD have been presented and discussed. The goal of the workshop to bring together experts in effective field theories, lattice QCD and experimentalists working on heavy quarks to discuss the latest developments in each field has been reached. New collaborations between different groups may have originated from this institute at ECT, with the goal of achieving a better understanding of heavy quark bound state physics.

Conclusions

We conclude that this is a very lively and expanding research field, where new data, new states, new production mechanisms are expected to come in the next few years from B-factories, CLEO, BES and Fermilab experiments, and in perspective more is expected from LHC-b, Super-B and tau-charm factories. The outcome will depend on the abilities of theory to match the precision of the new data and to pin down the nature and the dynamics of the new states and on the ability of measurements to answer some relevant theory questions. The work and the discussions held at this Institute will constitute a fertile ground for further progress in the field. To structure this workshop as a long activity in two weeks has been very beneficial and appropriate. We foresee the need to organize at the ECT in

the near future another long activity of the same type, either focused on a subfield like e.g. heavy quarks in dense matter, or devoted to monitor and stimulate the progress achieved in one year. We suggest also a three months school activity on the subject of the effective field theories methods used and discussed in this workshop.

Webpage

The talks can be browsed from the website:
http://www.phy.duke.edu/∼mehen/ECT/

2.3.14 JET PHYSICS IN HEAVY ION COLLISIONS AT THE LHC

DATE: 1–6 September

ORGANISERS:
Andreas Morsch (Co-ordinator) (*CERN*), Yves Schutz (*CNRS and CERN*)

NUMBER OF PARTICIPANTS: 34

MAIN TOPICS:

- Lessons from SPS and RHIC
- Gamma-Jet Correlations
- Predictions and Models for Jet Physics in Heavy Ion Collisions the LHC
- Jet Analysis at the LHC

SPEAKERS:

N. Armesto (*U. Santiago de Comp.*),
G. Barnafoldi (*KFKI, Budapest*),
S. Bathe (*UC Riverside*),
H. Buesching (*U. Frankfurt*),
M. Cacciari (*LPTHE Paris*),
G. Conesa Balbastre (*INFN*),
J.G. Contreras (*CINVESTAV*),
A. Dainese (*INFN*),
R. Diaz Valdes (*CEADEN Habana*),
Th. Dietel (*U. Muenster*),
P. Di Nezza Speaker (*INFN*),
N. Grau (*Nevis Labs*),
Ch. Klein-Boesing (*U. Munster*),
S. Kniege (*U. Frankfurt*),
P. Levai (*KFKI, Budapest*),
A.M. Marin Garcia (*GSI*),
Th. Peitzmann (*U. Utrecht*),
D. Perrino (*INFN Bari*),
M. Ploskon (*U. Frankfurt*),
J. Rak (*U. Jyvaskyla*),
D. Roehrich (*U. Bergen*),
Ch. Roland (*MIT*),
C. Salgado (*U. Rome*),
Y. Schutz (*CNRS, CERN*),
M. J. Tannenbaum (*BNL*),
M. van Leeuwen (*LBNL*)

SCIENTIFIC REPORT:

Aim and Purpose

High transverse momentum partons produced in the initial state of a nucleus-nucleus collision are expected to undergo multiple interactions inside the collision region prior to fragmentation and hadronisation. In particular in a quark gluon plasma (QGP) partons will loose energy through medium induced gluon radiation. These interactions give rise to modifications of the structure of the produced jets which probe the properties of the QGP.

At RHIC several striking effects have been observed in heavy ion collisions; among the most prominent the suppression of high transverse momentum particles and the suppression of back to back correlations. They show that the jet structure is strongly modified in dense matter and are consistent with partonic energy loss via medium-induced radiation. However many questions remain still open, like the observation and characterization of the radiated energy or the accurate accounting of the full jet energy. Heavy ion collisions at the LHC will certainly help to clarify them.

As compared to jet physics at RHIC there are two important new features in central Pb-Pb collisions at the LHC: the multi-jet production per event is not restricted to the mini-jet region $p_{\mathrm{T}} < 2$ GeV but extends to 20 GeV and jet rates are high at energies, at which jets can be distinguished from the background energy of the underlying event. Hence, event-by-event jet reconstruction will be possible.

One year before the LHC start-up, this workshop provides a forum to bring together experimentalists and theorist with experience in jet analysis at RHIC with those preparing the data analysis at the LHC. Experimentalists will meet theorists to clarify, which are the remaining open questions and how can they be addressed experimentally at the LHC.

Results and Highlights

The workshop consisted of a series of typically one hour talks covering the above mentioned topics. The participants were invited to interrupt the speakers at any point if they had questions or comments. This lead to very lively discussions throughout the meeting. The format has been very much appreciated by everybody. It lead in particular to an in depth understanding of the various analysis methods used at present at SPS and RHIC.

Very important were the talks on the direct photon analysis. The sensitivities of different analysis techniques which are also relevant at the LHC have been discussed in great detail. A common theme of hadron correlation studies at RHIC and jet reconstruction at the LHC represent the biases introduced through the incomplete measurement of the parton energy. The different biases identified at RHIC (trigger bias, surface bias, ...) can be mitigated using jet reconstruction techniques but will be still relevant.

We profited very much from the free exchange of ideas between the three LHC experiments in particular on their different approaches to optimise jet reconstruction algorithms and to quantify their relative performance in a heavy ion environment. Alternative reconstruction algorithms tuned for application in a high multiplicity environment are emerging. In particular, results for k_T algorithms look very promising. The three LHC experiments agreed to use common simulated data sets for an objective comparison of the various jet finders.

Although new approaches to model jet quenching using MCs have been presented, a

much stronger effort is needed to develop Monte Carlos which have predictive power for the LHC and which can be used by the experiments to optimize their analysis.

References

The talks can be browsed from the website:
http://indico.cern.ch/conferenceOtherViews.py?confId=5144&view=cdsagenda&sho

2.3.15 HEAVY FLAVOR PHYSICS IN HEAVY ION COLLISIONS AT THE LHC

DATE: 6–9 September

ORGANISERS:
Federico Antinori (Co-ordinator) (*INFN, Padova*), Ginés Martinez-Garcia (*Subatech, Nantes*)

NUMBER OF PARTICIPANTS: 56

MAIN TOPICS:

- Lessons from SPS and RHIC;
- Heavy flavour production in heavy-ion collisions;
- Quarkonia production in heavy-ion collisions;
- Analysis framework for heavy flavour analysis in ALICE;

SPEAKERS:

A. Andronic (*Darmstadt*),
N. Armesto (*Santiago*),
R. Arnaldi (*Torino*),
N. Bastid (*Clermont*),
F. Becattin (*Firenze*),
D. Blaschke (*Dubna*),
Ch. Blume (*Frankfurt*),
C. Bombonati (*Padova*),
E. Bruna (*Torino*),
M. Cacciari (*Jussieu*),
F. Carminati (*CERN*),
J. Castillo (*Saclay*),
Z. Conesa (*Nantes*),
A. Dainese (*Legnaro*),
J. Faivre (*Padova*),
S. Gadrat (*Nantes*),
R. Granier (*Palaiseau*),
M. Heinz (*Yale*),
H. Huang (*Los Angeles*),
C. Lourenco (*CERN*),
G. Martinez (*Nantes*),
M. Nardi (*Torino*),
F. Prino (*Torino*),
L. Rosselet (*Geneve*),
C. Salgado (*Roma*),
E. Scomparin (*Torino*),
R. Silvestri (*Salerno*),
D. Stocco (*Torino*),
R. Turrisi (*Padova*),
T. Ullrich (*BNL*)

SCIENTIFIC REPORT:

Aim and Purpose

Heavy ion collisions (HIC) at ultra-relativistic energies are a privileged tool for creating very hot and dense matter in the laboratory. In particular, lattice chromo-dynamics (lQCD) predicts a phase transition toward a new state of matter called Quark Gluon Plasma (QGP) at a temperature of around 170 MeV for vanishing chemical potential. ALICE is the LHC experiment devoted to heavy ion physics; the ATLAS and CMS experiments plan to develop a heavy-ion program in parallel with their main physics goals.

The study of the QGP at LHC energies will be enriched by exploiting new probes which can be efficiently studied in this energy regime. In particular, open charm and open beauty will be exploited as new probes of the strong interacting system of partons. Heavy quarks are produced only in the first stages of the collisions and then they coexist with the surrounding medium throughout its life-time. Production rates, transverse momentum (pT) and rapidity (y) distributions, quarkonia production rates, will allow for probing the properties of the medium. The open charm (beauty) production cross-section will increase by a factor 10 (100) with respect to RHIC energies. It will become possible to study the Debye screening of bottomonium states in QGP.

At RHIC several, some aspects of the heavy quark production in HIC are being addressed in the non-photonic electron channel. The measurement of heavy flavours in HIC at the LHC will certainly help to clarify RHIC measurement.

One year before the LHC start-up, this workshop will provide a forum to bring together experimentalists and theorist with experience in heavy-quark analysis at RHIC with those preparing the data analysis at the LHC.

Results and Highlights

The workshop consisted of a series of one hour talks devoted to the following topics:

- Theory and models of heavy flavour production in proton-proton and heavy-ion collisions;
- Experimental results from RHIC (STAR and PHENIX) and SPS (NA60) on heavy flavour production;
- Physics performances of the LHC experiments.

then there was a series of half an hour talks devoted to specific heavy flavour channels that will be addressed by the ALICE detector.

This led to very useful discussions with experimentalist from other collaborations on the preparation of the physics analysis and with theorist concerning the way to present data related to heavy flavour production. Discussion about latest results on heavy-flavour production at RHIC energies were very interesting:

- the observed disagreement between STAR and PHENIX charm production cross-section, measured in proton-proton collisions at 200 GeV;
- the incoherence of energy-loss models to describe the non-photonic single electron nuclear modification factor in central Au+Au collisions at 200 GeV.

Finally, we discussed about the observed suppression of J/ψ at RHIC energies which is similar to the one observed as SPS. Two alternative hypothesis could explain this experimental observation:

- Suppression of the higher resonances like χ_c and ψ';
- Recombination of $c\bar{c}$ quarks in later stage of the collision.

We conclude that the measurement of J/ψ in Pb+Pb collisions at LHC energies is crucial to disentangle this situation, since recombination is expected to be much more relevant at LHC energies.

We had an in-depth discussion about the analysis strategy of ALICE in general and about the heavy-flavour analysis in particular. A document summarizing our requirement for the ALICE analysis framework was drawn up.

References

The talks can be browsed from the website:
http://indico.cern.ch/conferenceDisplay.py?confId=a055772

2.3.16 SUMMER SCHOOL ON EXOTIC NUCLEAR BEAMS

DATE: 7–11 November

ORGANISERS:
Jim Al-Khalili (Co-ordinator) (*University of Surrey*), Andrea Vitturi (*INFN Padova*), Piet Van Isacker (*GANIL*), Marek Pfützner (*University of Warsaw*), Piet van Duppen (*University of Leuven*)

NUMBER OF PARTICIPANTS: 53

MAIN TOPICS:

- Application of the shell model to nuclei far from stability: effective interactions and shell evolution
- Experimental tools for nuclear astrophysics
- Gamma-ray tracking methods for the spectroscopy of exotic nuclei
- Test of isospin symmetry along the N=Z line
- Testing the structure of exotic nuclei via nuclear reactions
- Physics with antiprotons
- Application of nuclear techniques to cultural heritage studies
- Radioactive beams and advanced nuclear technology: accelerator driven systems and nuclear waste
- Recent developments in AMS (accelerator mass spectrometry) technique

SPEAKERS:
C. Angulo (*Louvain-la-Neuve*),
Y. Kadi (*CERN*),
W. Kutschera (*Wien*),
A. Lopez-Martens (*Orsay*),
S. M. Lenzi (*Padova*),
P. A. Mandó (*Firenze*),
N. Orr (*Caen*),
T. Otsuka (*Tokyo*),
E. Widmann (*Wien*)

SCIENTIFIC REPORT:

The Summer School on Exotic beams has been held at ECT* in the period 11-15 September, 2006. The school, which is part of a series of schools on the same subject started in the early nineties, was intended for PhD students and young post-docs starting to work in the fields related to radioactive ion beams and to the structure of nuclei far from the stability line. These students are trained in view of the new theoretical and experimental challenges opened by the present radioactive beam facilities and those of second generation under construction or study.

The participants to school have been more than 50, from 21 different countries, mainly from Europe or, if not European, from European institutions. The ECT* has offered them an ideal location and atmosphere for a productive interaction with the lecturers, for getting introduced into this new area or deepen their knowledge. A poster session (with short oral presentation) has also allowed them to present their present work.

All the school run completely smoothly thanks to the usual ability of the staff at ECT*. For this, and for the financial support, we are grateful to the ECT*. We have also to acknowledge additional support from different institutions (GSI, Ganil, Isolde, INF-Legnaro, Jyvaskyla, Leuven).

2.3.17. SPIN OBSERVABLES AND SPIN STRUCTURE FUNCTIONS: INEQUALITIES AND DYNAMICS

(Collaboration Meeting)

DATE: 26–28 September

ORGANISERS:
Jean-Marc Richard (Co-ordinator) (*LPSC-IN2P3 and University of Grenoble*)

NUMBER OF PARTICIPANTS: 3

MAIN TOPICS:

- Spin observables in exclusive reactions
- Spin observables in inclusive reactions
- Structure functions and parton distributions

SPEAKERS:

X. Artru (*IPNL-IN2P3, Lyon*),
J. Soffer (*CNRS, Marseille*),
J.-M. Richard (*LPSC-IN2P3 - Univ., Grenoble*)

SCIENTIFIC REPORT:

Aim and Purpose

The aim of this project is to summarise the state of art on the constraints on spin observables. This problem occurs in different domains: low- and high-energy hadronic exclusive reactions, inclusive reactions, and in particular, spin-dependent structure functions and parton distributions. An unified presentation is desirable, this is why this collaboration includes both nuclear physicists and experts of particle physics. Also, the equalities or inequalities on spin observables have sometimes been derived as a purely algebraic exercise. Our review will instead focus on physics aspects, in particular the positivity of the density matrix, and the general properties of the flux of information in quantum processes. It will contain both theoretical considerations, and a survey of the available results on the spin observables, to study how well they fulfil the inequalities.

Results and Highlights

The possibility to meet in the quiet and stimulating atmosphere of ECT*, Trento, gave us the opportunity of long discussions. Several key points have been clarified. The working procedure has been completely reorganised. This meeting was thus extremely useful. We shall be able to finish this review by the end of the year 2006, or early in 2007, and to send it to the editors of Physics Reports.

Web access

The report, when finalised, will be available on the site http://arxiv.org/ and published.

2.3.18 LATTICE QCD, CHIRAL PERTURBATION THEORY AND HADRON PHENOMENOLOGY

DATE: 2–6 October

ORGANISERS:
Ulf-G. Meißner (Co-ordinator) (*University Bonn*), Gerrit Schierholz (*DESY*)

NUMBER OF PARTICIPANTS: 36

SPEAKERS:
D. Alexandrou (*Univ. of Cyprus*),
S. Aoki (*Univ. Tsukuba*),
C. Aubin (*Columbia Univ.*),
O. Bär (*Humboldt Univ.*),
V. Bernard (*LPT Strasbourg*),
W. Bietenholz (*Humboldt Univ.*),
B. Borasoy (*Univ. Bonn*),
D. Brömmel (*DESY*),
P. Damgaard (*Niels Bohr Inst.*),
M. Della Morte (*CERN*),
M. Dorati (*Univ. Pavia*),
S. Dürr (*Bern Univ.*),
E. Epelbaum (*FZ Jülich - Univ. Bonn*),
P. Faccioli (*Univ. Trento*),
T. Gail (*TU Munich*),
M. Göckeler (*Univ. Regensburg*),
C. Haefeli (*Bern Univ.*),
H. Krebs (*FZ Jülich - Univ. Bonn*),
J. Laiho (*Fermilab*),
C. B. Lang (*Univ. Graz*),
M. Lin (*Columbia Univ.*),
K.-F. Liu (*Kentucky Univ.*),
U.-G. Meißner (*Univ. Bonn - FZ Jülich*),
J. A. Oller (*Univ. Murcia*),
D. Pleiter (*DESY*),
D. Richards (*Jefferson Lab*),
A. Rusetsky (*Univ. Bonn*),
A. Schäfer (*Univ. Regensburg*),
G. Schierholz (*DESY*),
M. Schindler (*Univ. Mainz*),
E. Scholz (*Brookhaven Nat Lab*),
W. Schroers (*DESY*),
L. Scorzato (*ECT Trento*),
V. Weinberg (*DESY*),
H. Wittig (*Univ. Mainz*)

SCIENTIFIC REPORT:

As a result of developments in lattice field theory and computer technology, the first full QCD calculations in the chiral regime are becoming available now. An essential tool for extracting hadronic quantities from lattice QCD is chiral perturbation theory. Chiral perturbation theory is the effective field theory of QCD and allows to analyze the quark mass dependendce of observables in a model-independent manner. Since the technologies for large scale lattice calculations and for detailed chiral perturbation calculations are each so different and so demanding, the same theorists generally do not pursue both aspects. Hence, we considered it to be valuable to bring together practioners of both aspects of lattice calculations, and deepen each others' appreciation of the issues involved, thus opening a new era for confronting experiment with solutions of QCD from first principles.

Thus, such a meeting was organized at the ECT* (Trento) from October 2-6, 2006, with

financial support from the ECT* as well as the I3HP networks N2 and N5 and by EURONS. The meeting had 36 participants whose names, institutes and email addresses are listed below. 35 of them presented results in presentations of various lengths. Ample time was left for discussions on the various talks each day. In addition, there was also a special discussion session "Lattice meets chiral perturbation theory" convened by Hartmut Wittig, in which the interplay between the various issues as seen from the two communities were addressed.

We will publish Mini-proceedings of this workshop, these should be available on the web in November 2006.

We would like to thank the ECT*, in particular Serena Degli Avancini, for the excellent organization of the workshop and all participants for their valuable contributions. We believe that this was only the first workshop of this kind and look forward to similar meetings in the future.

2.3.19. ELECTROMAGNETIC PROPERTIES OF THE $\Delta(1232)$-RESONANCE

(Collaboration Meeting)

DATE: 16–19 October

ORGANISERS:
Vladimir Pascalutsa (Co-ordinator) (*College of William and Mary*), Marc Vanderhaeghen (*College of William & Mary - JLab*)

NUMBER OF PARTICIPANTS: 15

MAIN TOPICS:

- Compton scattering and virtual Compton scattering at low Q^2.
- Radiative pion photoproduction and the Δ's electromagnetic moments.
- Chiral effective-field theory vs. model calculations vs. experiment.
- Proposals for future high-precision experiments.

SPEAKERS:
J. Annand (*Glasgow U., UK*),
R. Beck (*U. Bonn, Germany*),
B. Boillat (*Basel U., Switzerland*),
L. Doria (*U. Mainz, Germany*),
E. Downie (*Glasgow U., UK*),
D. Drechsel (*U. Mainz, Germany*),
H. Fonvieille (*Clermont-Ferrand U., France*),
M. Kotulla (*U. Giessen, Germany*),
H. Merkel (*U. Mainz, Germany*),
C. Papanicolas (*IASA Athens, Greece*),
B. Pasquini (*U. Pavia, Italy*),
S. Schumann (*U. Bonn, Germany*),
N. Sparveris (*IASA Athens, Greece*),
D. Watts (*Edinburgh U., UK*),
N. Wies (*U. Mainz, Germany*)

SCIENTIFIC REPORT:

Aim and Purpose

Two-photon processes, such as real and virtual Compton scattering on the nucleon, provide precision information about the nucleon structure (e.g., polarizabilities and electromagnetic form factors). Several recent experiments have been focused on probing the $\Delta(1232)$-resonance region, with the aim of precise extraction of the properties of the nucleon's first excited state. For example, the electromagnetic moments of the Δ are being addressed in Crystal Ball experiments at MAMI, the electromagnetic nucleon-to-Δ transition factors in the current and future measurements of virtual and doubly-virtual Compton scattering at MIT-Bates and MAMI. These experimental programs are being complemented by the theoretical effort to describe these processes from the effective-field theories of QCD.

The intent of this Collaboration Meeting was to (i) discuss the recent and future two-photon experiments in the $\Delta(1232)$-resonance region; (ii) confront theoretical predictions with new experimental results, as well as discuss recent developments in theory; (iii) provide a venue for "brainstorming", exchange of ideas and results; (iv) determine new directions in this field.

Highlights and Conclusions

The meeting was opened with a comprehensive survey of the Δ-resonance properties by Dieter Drechsel.[1] In the following-up talk, Martin Kotulla presented an overview of the current experimental program at MAMI aimed for a precise determination of the electromagnetic properties of the Δ. In particular, Martin showed the preliminary results of the Crystal Ball Collaboration for the radiative pion photoproduction – the reaction which allows for an extraction of the Δ's magnetic dipole moment. The details of these experiments were subsequently discussed in the talks of the three PhD students: Evie Downie, Sven Schumann and Benedicte Boillat. Natalia Wies presented a recent effective-field theoretic (EFT) calculation of the Δ's magnetic dipole moment. The first day ended with a very interesting discussion session led by Reinhard Beck. A substantial part of this discussion centered on the understanding the chiral EFT approach to the problem of extraction of the Δ-resonance magnetic moment from experiment.

The second and third day of the meeting were focused on the virtual Compton scattering (VCS) in the Δ-resonance region. The experimental and theoretical situations were reviewed in the talks of Helene Fonvieile and Barbara Pasquini. Barbara, in particular, demonstrated how the predictions of her approach agreed amazingly well with the new preliminary data from MAMI. These new data were subsequently presented and discussed by Nikos Sparveris. Luca Doria presented some more detail of the VCS experiments in the MAMI setup. Vladimir Pascalutsa gave a talk on the issue of the Δ-resonance contribution to the nucleon polarizabilities within the ChEFT framework. Costas Papanicolas gave a very stimulating talk on a new technique suited to perform an entirely model-independent multipole analysis of observables.

In the last day, Daniel Watts explained in great detail the new Crystal Ball measurement of the charged-pion radiative pion photoproduction. He also demonstrated some preliminary

[1]The talks can be accessed at http://www.ect.it/Meetings/ConfsWksAndCollMeetings/ ConfWksDocument/2006/Talks/16_19_Oct/talks.htm

results for both the differential cross-sections and beam asymmetries. Marc Vanderhaeghen summarized the main points that were addressed during the meeting.

We therefore have discussed the rapidly developing experimental situation in the $\Delta(1232)$-resonance region. Many new data on the processes of radiative pion photoproduction and VCS are becoming available. The dispersion relation approach and the framework of chiral effective-field theory have been adopted as the major theoretical tools for interpreting these data. This interplay of theory and experiment promises to yield new insight in the structure of the nucleon and the nature of its first excited state, the $\Delta(1232)$.

2.3.20 THE PHYSICS OF HALO NUCLEI

DATE: 30 October–3 November

ORGANISERS:
Ian Thompson (Co-ordinator) (*University of Surrey and Lawrence Livermore National Laboratory*), Björn Jonson (*Chalmers University of Technology, Göteborg*), Achim Richter (*Technical University of Darmstadt*)

NUMBER OF PARTICIPANTS: 39

SPEAKERS:
T. Aumann (*GSI*),
D. Baye (*Univ. Bruxelles*),
A. Bonaccorso (*INFN, Pisa*),
P. Capel (*Univ. Bruxelles*),
R. Crespo (*IST, Portugal*),
B. Danilin (*RRC, Russia*),
B. Davids (*TRIUMF*),
P. Descouvemont (*Univ. Bruxelles*),
D. Fedorov (*Aarhus Univ.*),
H. Feldmeier (*GSI*),
A. Fonseca (*CFNUL, Portugal*),
C. Forssén (*Chalmers Univ. Technology*),
M. Hussein (*Univ. Sao Paulo*),
B. Jonson (*Chalmers Univ. Technology*),
M. Marques (*LPC-Caen*),
N. Michel (*Kyoto Univ.*),
T. Nakamura (*Tokyo Inst. Technology*),
P. Navratil (*L.Livermore Nat Lab*),
C. Nociforo (*INFN-LNS, Catania*),
F. Nunes (*Michigan State Univ.*),
K. Riisager (*CERN*),
M. Rodrguez-Gallardo (*Univ. Lisbon*),
R. Roth (*TU Darmstadt*),
H. Simon (*TU Darmstadt*),
J. Tostevin (*University of Surrey*),
J. Vaagen (*Univ. Bergen*)

SCIENTIFIC REPORT:

Nuclear halo states are one of the more fascinating phenomena discovered in the spectrum of light nuclei. They occur close to the drip lines as a threshold phenomenon when one or more weakly bound nucleons tunnel into the surrounding space. The structure of these halo states is by now almost generally understood, but the precise role of intruder states and

pairing in the continuum was discussed theoretically and experimentally. This continuum can be probed in low-energy reactions important in astrophysics, or in breakup reactions of halo projectiles.

In this workshop, the third in a series after 1996 and 2001, we saw a great deal of the more work which has been performed in the last 5 years concerning both the many-body structure underlying halo nuclei, as well as the reactions by which halo nuclei are studied experimentally. Elastic, breakup and transfer reactions were all studied, with both theoretical and experimental programmes.

The theoretical effort in developing few-body reactions is bearing fruit. We saw the great precision that application of Alt-Grassberger-Sandhas few-body methods at Lisbon can treat transfer and breakup reactions in three-body systems, now even including converged results with the Coulomb potentials. Further Coupled Discretised Continuum Channels (Surrey, MSU, Lisbon, Seville) and time-dependent (Brussels) breakup calculations are regularly giving converged results, and the CDCC can now include dynamical core (de)excitation of one of the bodies during breakup reactions. The few-body continuum was explored by hyperspherical harmonics methods by groups at Surrey, Aarhus, Göteborg, Bergen, Moscow and Brussels, and by the Gamow shell model by work at Oak Ridge.

What was particularly impressive on the theory side is the new extensive work on the structure of light nuclei that begins *ab initio* from various nucleon-nucleon and three-body potentials. We heard about work using the V_{UCOM} at Darmstadt and the No-core Shell Model at Tucson and Livermore. Now these theories are shown to reproduce not only the structure of stable nuclei, but also the general features of halo nuclei. More work will be clearly needed to understand the particular halo properties to the precision of few-body models, but indications are that the various approaches are converging.

Recent experimental achievements were presented here, either as work in progress or as newly published results. We saw new distributions for the breakup of ^{11}Li, where great effort was spent in measuring the almost-coincident neutrons that very easily arise from the breakup of two-neutron halo nuclei. Other speakers told of the large number of low-energy elastic and transfer experiments at ISOLDE and TRIUMF, which now reveal the single-particle structures and resonances in new ways. High energy experiments at GSI and medium-energy experiments at GANIL, MSU and RIKEN were reported, and regularly included comparisons with the best reaction theory predictions. It is now widely accepted that good theoretical analyses requires the combination of multistep reaction theory calculations with at least good few-body structure models, or with the microscopic models mentioned above.

Most experiments now routinely include detection of possibly coincident gamma rays, an achievement in recently years which has helped considerably to distinguish from elastic breakup (diffraction dissociation) from other processes which excite the residual nuclei, and this has aided the detailed comparisons between theories and experiments.

We are particularly pleased with the wide ranging and thorough interactions between the theorists and experimentalists. From our earlier meetings we soon realised the necessity of such close collaborations in order to extract accurate structural conclusions from the now-excellent experimental results.

This workshop is a natural followup of the previous workshops with the same title and the same organisers. These were judged by both the theory and experimental participants to provide most instructive, fruitful and informal meeting grounds for the detailed discussion of all the necessary issues. As much has developed in the five years since the last meeting, our successor workshop has proved similarly beneficial.

There were 39 participants (29 theorists and 10 experimentalists) from 14 countries, namely from Belgium, Brazil, Canada, Denmark, France, Germany, Great Britain, Italy, Japan, Norway, Russia, Spain, Sweden and the United States. There were 8 young participants and 8 women. The average participation during the working sessions was around 35.

As can be seen from the appended programme, there was ample time provided for intense discussions amongst the participants, and in fact many commented positively on the friendly atmosphere.

We are fortunate that one of the organiser (BJ) is a member of the Nobel Committee for Physics of the Royal Swedish Academy of Sciences, and was able to report on this years award of the Physics Nobel Prize. This session was well attended, also from the participants of an ongoing course on spin physics, and the management and research staff of the ECT*.

2.4 ECT* Doctoral Training Programme "Computational techniques in strongly interacting systems"

The 2006 ECT* Doctoral Training Programme was held at ECT* during the 11 week period extending from March 13 to May 26, 2006. It was devoted to Computational Techniques in Strongly Interacting Systems. The Programme Coordinator was Simon Hands (University of Wales, Swansea, UK) and he was assisted by Pietro Faccioli (University of Trento). ECT* covered the financial support for 9 lecturers and 11 participants.

The Doctoral Training Programme consisted of 9 lecture series, each (except one) given by one lecturer and lasting for one week. One lecture series was given by two lecturers from the University of Trento. Each student was asked to give a seminar which was announced on the ECT* Web page. In addition some lecturers scheduled occasional afternoon tutorial sessions.

The Doctoral Training Programme was attended by 11 full-time participants. Some lectures were attended by a handful of students from the University of Trento and several lectures were attended by ECT* post-docs. Two students who were participating in an ongoing ECT* workshop, attended one lecture series. Among the full time students, 5 were in the 1st year of their PhD, 1 was in his 2nd year, 2 in the 4th year and 2 had completed their PhD. One student was still preparing his MSc. The list of full time students is given below.

The students were each given a desk to work on and those which did not use their personal laptops were given ECT* desk computers, running either on Unix or on Windows. They all had access to Internet. In addition, they had access to an ECT* wiki page, from which they could download the lecture notes delivered by the lecturers.

During the stay of the students, four workshops were held at ECT*:
- QCD at finite density (March 21-25,2006)
- New directions non-perturbative QCD (March 27-31,2006)
- Numerical Simulation of Heavy Ion Reactions in the Fermi Energy Domain (April 10-14, 2006)
- Gamma-Ray Spectroscopy in Europe: Present and Future Challenges (May 8-12, 2006)

Only the first two workshops were of direct interest to the students. One student (Swagato Mukherjee) gave a talk in the second workshop.

The duration of the course, namely 11 weeks seems to be good. The students had time to work both on the lectures and on their research projects. In addition, the lecturers remained at ECT* in the afternoons, and several students chose that opportunity to discuss with them.

2.4.1 Lecture Series

The following series of lectures were presented at the Centre (see also section 3.4.1):

- **Lattice methods in quantum field theory**
  Lecturer: Simon Hands (University of Wales, Swansea, UK)
- **QCD thermodynamics**
  Lecturer: Frithjof Karsch (Brookhaven National Lab, USA)
- **Algorithms and chiral fermions**
  Lecturer: Anthony David Kennedy (University of Edinburgh, UK)
- **Green's function Monte Carlo in many-body theory**
  Lecturer: Malvin Kalos (Lawrence Livermore National Lab, USA)
- **Quantum field theory out of equilibrium**
  Lecturer: Gert Aarts (University of Wales, Swansea, UK)
- **Molecular dynamics simulations of biological systems**
  Lecturer: Giovanni Garberoglio and Marcello Sega (University of Trento, Italy)
- **Approaches to the sign problem**
  Lecturer: Uwe-Jens Wiese (Bern University, Switzerland)
- **Hadron structure and the QCD vacuum**
  Lecturer: Thomas Alan DeGrand (University of Colorado, USA)
- **Holographic methods in QCD**
  Lecturer: Mikhail Stephanov (University of Illinois, Chicago, USA)

2.4.2 Participants

List of participants:

Melahat Bayar	Karadeniz Technical University,
Lukasz Daniel	Jagiellonian University, Krakow,
Andrew Lee	University of Cambridge,
Julio Cesar Leon Luquez	Universidad Nacional de Colombia,
Adam Lichtl	Carnegie Mellon University,
Magdalena Luz	Humboldt University Berlin,
Swagato Mukherjee	Tata Institute of Fundamental Research,
Irina Pushkina	Hiroshima University,
Sebastian Scheffler	University of Heidelberg,
Peter Sitch	University of Wales, Swansea,
Stefan Strauss	University of Rostock

2.4.3 Further scientific activities of the Training Programme

In addition to the lectures listed above, further scientific activities consisted of seminars given at ECT* by the participants, and various tutorials.

Seminars given at ECT* by the students

Magdalena LUZ: 29th of March, 2006, "Cutoff effects of Wilson fermions in the absence of spontaneus chiral symmetry breaking".

Sebastian SCHEFFLER: 5th of April, 2006, "The phase structure of scalar field model with a non-standard potential ".

Stefan STRAUSS: 11th of April, 2006, "Light-Front field theory of relativistic quark matter ".

Irina PUSHKINA: 13th of April, 2006, "Lattice QCD with chemical potential: Hadron screening masses under extreme conditions".

Swagato MUKHERJEE: 19th of April, 2006, "QCD thermodynamics using modified differential method".

Melahat BAYAR: 24th of April, 2006, "Investigation of the G_{SVY} Coupling constant in three point QCD sum rules and light cone".

Lukasz DANIEL: 1st of May, 2006, "Introduction to Econophysics".

Andrew LEE: 10th of May, 2006, “An introduction to super-symmetry”.

Peter SITCH: 15th of May, 2006, “All to all spectroscopy in Dense two-colour QCD”.

Julio Cesar LEON LUQUEZ: 17th of May, 2006, “The broad histogram method; an extension to continuous systems ”.

Adam LICHTL: 22nd of May, 2006, “Current methods in lattice hadron spectroscopy ”.

2.5 ECT* - RBRC Doctoral Training Programme "QCD Spin Physics"

The Doctoral Training Programme on QCD Spin Physics was held at ECT* during 6 weeks, from October 30 to December 7, 2006. The Programme was organized by Elliot Leader and Werner Vogelsang, who lectured during the first two weeks.

The programme was attended by 13 full time students. In addition, 4 students attended the lectures delivered during the first two weeks and one student attended the lectures during the last week. Among the full-time students:

- 6 students were just beginning their PhD project; however, among these, some had already worked on deep-inelastic scattering for their Diploma;
- 2 students were in the first year of their PhD project;
- 4 students were in the second year of their PhD project;
- 1 student was in the fourth year of his PhD project.

Five of the full-time students were engaged in an experimental research project. The list of students is attached to this report.

The students were each given a desk to work on and those which did not use their personal laptops were given ECT* desk computers, running either on Unix or on Windows. They all had access to Internet. In addition, they had access to an ECT* wiki page, from which they could download the lecture notes delivered by the lecturers.

2.5.1 Lecture Series

The following series of lectures were presented at the Centre (see also section 3.4.1):

- **Introduction to perturbative QCD; the collinear parton model; deep inelastic scattering**
  Lecturer: Werner Vogelsang (Brookhaven and RIKEN BNL, USA)

- **Spin (helicity and transverse) in relativistic theories; polarized deep inelastic scattering; polarized parton densities**
  Lecturer: Elliot Leader (Imperial College, London)

- **The problem of single spin asymmetries; new mechanisms for asymmetries; parton intrinsic transverse momentum; naive extension of the collinear parton model**
  Lecturer: Mauro Anselmino (University Torino and INFN, Italy)

- **The new generation of experiments at RHIC, COMPASS and Jefferson Laboratory**
  Lecturer: Naohito Saito (KEK, Japan)

- **Transverse momentum dependence in parton densities–advanced topics**
  Lecturer: Alessandro Bacchetta (DESY, Germany)
- **Generalised parton distributions; orbital angular momentum**
  Lecturer: Thorsten Feldman (University of Siegen, Germany)

2.5.2 Participants

List of participants:

Kieran Boyle	Stony Brook University,
Dominik Gabbert	DESY - HERMES,
Matti Oskari Järvinen	University of Helsinki,
Adam Kocoloski	MIT,
John Koster	University of Illinois,
Stephan Meissner	Ruhr-University Bochum,
Mattia Melis	University of Cagliari,
Alena Moiseeva	BLTP JINR Dubna,
Astrid Morreale	PHENIX-RHIC,
Donie O'Brien	Trinity College Dublin,
Alexander Pimikov	Irkutsk State University,
Giovanni Marco Pruna	University of Cagliari,
Armine Rostomyan	DESY - HERMES,
Tai Sakuma	MIT,
Tobias Teckentrup	Ruhr-University Bochum,
Maria Varanda	DESY - HERMES,
Alexey Vladimirov	BLTP JINR Dubna,
Ruizhe Yang	University of Illinois

2.5.3 Further scientific activities of the Training Programme

A total of 12 seminars were given by the students during the programme (two seminars each week). They covered research projets which the students were engaged in. Several students placed their seminar presentations on the Wiki page.

Seminars given at ECT* by the students

Stephan MEISSNER: 1st of November, 2006, "Transverse momentum dependent parton distributions and the Sivers effect".

Tai SAKUMA: 2nd of November, 2006, "The di-jet production at 200 GeV polarized pp collisions at STAR".

Tobias TECKENTRUP: 7th of November, 2006, "Dual parameterization of GPDs and description of the DVCS data".

Donie O'BRIEN: 9th of November, 2006, "Spin observables for polarizing antiprotons".

Astrid MORREALE: 14th of November, 2006, "Central rapidity charged pion $A_L L$ measurements at RHIC".

Giovanni Marco PRUNA: 16th of November, 2006, "Contribution of intrinsic charm to SSA in D-meson production in nucleon-nucleon scattering".

John KOSTER: 21st of November, 2006, "The PHENIX Muon Piston Calorimeter".

Alexander PIMIKOV: 22nd of November, 2006, "Self-consistent gaussian model of non-perturbative QCD vacuum".

Ruizhe YANG: 28th of November, 2006, "Muon trigger upgrade for PHENIX experiment at RHIC".

Matti Oskari JÄRVINEN: 30th of November, 2006, "Single spin asymmetry at large x_F and k_T".

Kieran BOYLE: 4th of December, 2006, "Constraining Δg by measuring π_0 A_{LL}.".

Alexei VLADIMIROV: 6th of December, 2006, "Distribution function for effective coordinates of particle creation area".

3 Research at ECT*

This chapter summarizes the scientific activities of researchers who are hosted at ECT*. This concerns the Director and the Vice Director, the postdoctoral fellows and PhD students. The research effort has been strengthened in 2006 by the hiring of Vladimir Pascalutsa, on a joint position supported by the European I3 "Hadron Physics" and the ECT*. Some of the ECT* researchers belong to the "Quantum Information Processing Group" which has been presented in last year's report. Particularly noteworthy in 2006 is the important responsibility taken by Daniele Binosi in the coordination of a large European consortium on quantum computing (see the sections concerning QUROPE and the ERA-pilot).

3.1 Projects of ECT* Researchers

• Daniele Binosi

During the year 2006 my activity has been focused on two fronts.

On the one hand I have continued my activity in coordinating the work of the European coordination action project ERA-Pilot QIST. In particular I have been busy in updating the roadmap-type document "Quantum Information Processing and Communication: strategic report on current status, visions and goals for research in Europ", which has the purpose of promoting QIPC in Europe, strengthening its image and expressing it in a coherent way, unifying the research community, elaborating a common European strategy and setting the agenda for its short- and long-term goals, and, finally, reaching in an appropriate way decision makers. The document is now stable and it has reached version 1.3. At the end of 2005 I have been also appointed responsible for coordinating the writing of a project proposal for a second coordination action called QUROPE. The proposal was filed at the last European FP6 call, where it ranked first and was granted 1 Million euros. QUROPE started the September the 1st of 2006, and I am responsible for developing and maintaining its website, as well as writing all position documents that the community might need.

For more information see the detailed descriptions of the two projects later in this report, as well as the projects' websites

http://qist.ect.it (ERA-Pilot QIST)
and
http://www.qurope.net (QUROPE)

On the other hand I have continued my research in the high energy physics, which included the following projects:

We have studied the impact of CP violation through particle mixing on the line-shape of the CP-even and CP-odd neutral scalars that appear in models with two Higgs doublets, such as the supersymmetric extension of the Standard Model. Our analysis suggests that such observable may provide valuable information on the CP nature of the underlying theory, allowing for a direct experimental determination of the CP-conserving vs CP-breaking models.

In the context of scalar QED we have derived the pinch technique self-energies and vertices directly from the Schwinger-Dyson equations. The construction required the simultaneous treatment of the equations governing the scalar self-energy and the fundamental interaction vertices. The resulting non-trivial rearrangement of terms generates dynamically the Schwinger-Dyson equations for the corresponding Green's functions of the background field method. The general strategy for the generalization of the method in a non-Abelian context is clearer at this point, and we are presently working on solving some technical hurdles to complete this ambitious task.

We have started investigating how the decay properties of an unstable particle are affected by the presence of an external electromagnetic field. The effect on the lifetime can be assessed by observing that the magnetic moment of unstable particle has an absorptive (imaginary) part, which in an external field induces a shift in the absorptive part of the energy, i.e., in the width. This effect is new, and could have potential impact for particle, nuclear and astrophysics processes.

We are currently finishing a work on how noise affects the entanglement in spin chains. The family of models studied is the one-dimensional disordered Potts models, which include also the well-known Ising model. For the first time we have observed a situation in which disorder actually increase the entanglement of a spin chain instead of decreasing it.

Work is in progress on the application of the exact renormalization group to QCD in the Curci-Ferrari gauge.

Finally we have been working on a new version of the code JaxoDraw, which has become by now a standard tool among the physics community (to the point in which several Linux distribution have packaged the code, and that the original article discussing the code usage is ranked in the Elsevier top 25 papers.)

• Jean-Paul Blaizot

Together with Andreas Ipp at ECT*, and collaborators at Montevideo, we have used the non-perturbative renormalization group to clarify some features of perturbation theory in thermal field theory. For the specific case of the scalar field theory with O(N) symmetry, we solved the flow equations within the local potential approximation. This approximation reproduces the perturbative results for the screening mass and the pressure up to order g^3, and starts to differ at order g^4. The method allows a smooth extrapolation to the regime where the coupling is not small, very similar to that obtained from a simple self-consistent approximation. [ECT*-06-15]

Together with E. Iancu and A. Rebhan, we have applied a previously proposed scheme of approximately self-consistent hard-thermal-loop resummations to the entropy of high-temperature QCD to N=4 supersymmetric Yang-Mills (SYM) theories and compare with a (uniquely determined) $R[4,4]$ Padé approximant that interpolates accurately between the known perturbative result and the next-to-leading order strong-coupling result obtained from AdS/CFT correspondence. We find good agreement up to couplings where the entropy has dropped to about 85% of the Stefan-Boltzmann value. This is precisely the regime which in purely gluonic QCD corresponds to temperatures above 2.5 times the deconfinement temperature and for which this method of hard-thermal-loop resummation has given similar good agreement with lattice QCD results. This suggests that in this regime the entropy

of both QCD and N=4 SYM is dominated by effectively weakly coupled hard-thermal-loop quasiparticle degrees of freedom. In N=4 SYM, strong-coupling contributions to the thermodynamic potential take over when the entropy drops below 85% of the Stefan-Boltzmann value. [ECT*-06-22]

Together with D. Triantafyllopoulos at ECT* and E. Iancu, we have investigated a zero-dimensional toy model originally introduced by Mueller and Salam which mimics high-energy scattering in QCD in the presence of both gluon saturation and gluon number fluctuations, and hence of Pomeron loops. Unlike other toy models of the reaction-diffusion type, the model studied in this paper is consistent with boost invariance and, related to that, it exhibits a mechanism for particle saturation close to that of the JIMWLK equation in QCD, namely the saturation of the emission rate due to high-density effects. Within this model, we establish the dominant high-energy behaviour of the S-matrix element $< S^n >$ for the scattering between a target obtained by evolving one particle and a projectile made with exactly n particles. Remarkably, we find that all such matrix elements approach the black disk limit S=0 at high rapidity Y, with the same exponential law: $< S^n > \ exp(-Y)$ for all values of n. This is so because the S-matrix is dominated by rare target configurations which involve only few particles. We also find that the bulk distribution for a saturated system is of the Poisson type. [ECT*-06-09]

We have shown how the Landau-Pomeranchuk-Migdal effect on photon production rates in a quark-gluon plasma can be derived via the usual Boltzmann equation. To do this, we first derived the electromagnetic polarization tensor using linear response theory, and then formulate the Boltzmann equation including the collisions mediated by soft gluon exchanges. We then identified the resulting expression for the production rate with that obtained by the field-theoretic formalism recently proposed by Arnold, Moore and Yaffe. To illustrate the LPM effect we solved the Boltzmann equation in the diffusion approximation.[ECT*-05-22]

We have presented the first numerical application of a method that we have recently proposed to solve the Non Perturbative Renormalization Group equations and obtain the n-point functions for arbitrary external momenta. This method leads to flow equations for the n-point functions which are also differential equations with respect to a constant background field. This makes them, a priori, difficult to solve. However, we demonstrated in [ECT*-05-26] that, within a simple approximation which turns out to be quite accurate, the solution of these flow equations is not more complicated than that of the flow equations obtained in the derivative expansion. Thus, with a numerical effort comparable to that involved in the derivative expansion, we can get the full momentum dependence of the n-point functions. The method was applied, in its leading order, to the calculation of the self-energy in a 3-dimensional scalar field theory, at criticality. Accurate results were obtained over the entire range of momenta.

• Tommaso Calarco

Atom chips combine many important features of a scalable architecture for quantum information processing: long coherence time, accurate control and scalability. Our objective was to propose and investigate on the implementation of a robust two-qubit quantum gates with neutral atoms trapped in atom chips. Robustness and high fidelity of the gate are obtained by means of quantum optimal control techniques.

We tackled our objective by proposing in ["Theoretical analysis of the implementation of a quantum phase gate with neutral atoms on atom chips", E. Charron, M. A. Cirone, A. Negretti, J. Schmiedmayer and T. Calarco, Phys. Rev. A 74, 012308 (2006)] a two-qubit phase gate on atom chips using static currents. We considered the exact potential created on atom chips taking into account the finite size of the current-carrying wires and proximity effects of the surface, like spin flips and decoherence. We specialized our proposal to neutral 87Rb atoms. We considered also an optimized gate which minimizes the effect of leakage from the computational basis due to non-adiabaticity. The results indicate that the optimized gate infidelity is, on average, improved by a factor of 6 when compared to the linear gate. The optimized gate can achieve fidelities of 99% in 6.3 ms and of 99.9% in 10.3 ms.

In ["Microwave potentials and optimal control for robust quantum gates on an atom chip", P. Treutlein, T. W. Hänsch, J. Reichel, A. Negretti, M. A. Cirone, and T. Calarco, Phys. Rev. A 74, 022312 (2006)] we propose a two-qubit collisional phase gate with neutral atoms trapped in atom chips by means of microwave potentials. The qubit states are two internal hyperfine levels, $|0>=|F=2,mF=1>$ and $|1>=|F=1,mF=-1>$, of the 87Rb atom whose energy difference is insensitive to magnetic field fluctuations. To evaluate the fidelity we again solve the time-dependent Schrödinger equation numerically. During the application of the microwave potential, non-adiabatic effects distort the atom wave functions which do not get back to the ground states of the separated wells after the gate. In order to overcome this source of errors we apply optimal control techniques to optimize the gate performance. The results are extremely encouraging: the gate fidelity is F = 0.997 for a time of the gate of 1.1 ms. We discuss possible source of errors such as thermal and transverse excitations, decoherence and loss, two-photon transitions. We estimate the contribution of these source of errors to be of the order of 10-3 leading to a fidelity of F = 0.996.

We discuss the application of quantum control techniques in another setting. In ["Fast Rydberg gates without dipole blockade via quantum control", M. Cozzini, T. Calarco, A. Recati, P. Zoller, Opt. Com. 264, 375 (2006)], in collaboration with the Institute for Quantum Optics and Quantum Information in Innsbruck, we study a fast high fidelity phase gate between optically trapped Rydberg-excited neutral atoms coupled via dipole-dipole interactions. In order to realize a fast gate we employ quantum control techniques, originally proposed in the context of ion-trap quantum gates. The gate is obtained by driving the two-particle system on a closed path in phase space, whose final result is to bring it back to its original state, while at the same time imprinting on it the desired phase. The resulting fidelity is F = 99.9% for a gate time which is a fraction of the trapping period for present day experimental parameters.

Finally in [B. Zhao, Z.-B. Chen, J.-W. Pan, J. Schmiedmayer, A. Recati, G. E. Astrakharchik, T. Calarco: "Deterministic Entanglement via Molecular Dissociation in Integrated Atom Optics", quant-ph/ 0502011], in collaboration with the university of Heidelberg, we present a scheme for deterministic generation of entanglement of neutral atoms trapped in atom chips. The atom entanglement can be manipulated by "linear atom optics elements", which can be integrated on atom chips, such as atomic beam splitters, phase shifters and in-

terferometers. The entanglement can be created in both internal (spin) and external degrees of freedom. Detection of entanglement can be realized using current technologies of single atom detection with almost 100% efficiency.

• Markus Antonio Cirone

In 2006 we have continued and concluded our investigations concerning the implementation of quantum phase gates with neutral atoms on atom chips. We also started investigating the radiation emitted by entangled atoms.

We have presented a detailed, realistic analysis of the implementation of a proposal for a quantum phase gate based on atomic vibrational states, specializing it to neutral rubidium atoms on atom chips. We have shown how to create a double-well potential with static currents on the atom chips, using for all relevant parameters values that are achieved with present technology. The potential barrier between the two wells can be modified by varying the currents in order to realize a quantum phase gate for qubit states encoded in the atomic external degree of freedom. The gate performance has been analyzed through numerical simulations; the operation time is 10 ms with a performance fidelity above 99.9%. For storage of the state between the operations the qubit state can be transferred efficiently via Raman transitions to two hyperfine states, where its decoherence is strongly inhibited. In addition we have discussed the limits imposed by the proximity of the surface to the gate fidelity. This work has been done in close collaboration with E. Charron of the University of Paris Sud and with J. Schmiedmayer of the University of Heidelberg (now at the Technical University of Vienna). The results of these investigations are published in the article "Theoretical analysis of a realistic atom-chip quantum gate", by E. Charron, M. A. Cirone, A. Negretti, J. Schmiedmayer, and T. Calarco, Phys. Rev. A **74**, 012308 (2006).

We have also proposed a two-qubit collisional phase gate that can be implemented with available atom chip technology and have presented a detailed theoretical analysis of its performance. The gate is based on earlier phase gate schemes, but uses a qubit state pair with an experimentally demonstrated, very long coherence lifetime. Microwave near fields play a key role in our implementation as a means to realize the state-dependent potentials required for conditional dynamics. Quantum control algorithms have been used to optimize gate performance. We have employed circuit configurations that can be built with current fabrication processes and extensively discussed the impact of technical noise and imperfections that characterize an actual atom chip. We have found an overall infidelity compatible with requirements for fault-tolerant quantum computation. This work has been done in close collaboration with J. Reichel of the Ecole Normale Superieure of Paris and with P. Treutlein, from the group of T. W. Hänsch at the Max Planck Institut in Munich. The results of these investigations are published in the article "Microwave potentials and optimal control for robust quantum gates on an atom chip", by P. Treutlein, T. W. Hänsch, J. Reichel, A. Negretti, M. A. Cirone, and T. Calarco, Phys. Rev. A **74**, 022312 (2006).

We have analyzed the radiation emitted by entangled atoms. The fluorescent light emit-

ted by pairs of entangled atoms contains information concerning the atomic state: the first- and second-order correlation functions of the radiation emitted by the so-called Ψ and Φ states are significantly different from each other. Therefore a simple analysis of the emitted radiation can be used as a test to check which of the Bell states Ψ or Φ has been realized.

• Marco Cristoforetti

We use the Interacting Instanton Liquid Model to investigate the non-perturbative interaction associated to spontaneous chiral symmetry breaking. In particular, we study how hadrons' structure changes as a function of the quark mass. To support the validity of this model in the chiral regime, the quark mass dependencies of several properties are shown to agree with chiral perturbation theory, including the density of eigenmodes of the Dirac operator and the masses of the pion and nucleon. We identify a natural mass scale m*=80 MeV which sets the boundary of the mass regime where the non-perturbative QCD dynamics is determined by chiral effects.

• Gabriele De Chiara

This year my research, in close collaboration with Tommaso Calarco, has concerned:

- Quantum information processing with neutral atoms trapped in optical lattices. Quantum gates can be produced by bringing two initially separated atoms in the same well. The contact interaction between the two atoms produces the desired phase shift. Since the phase depends on the internal state of the atoms this process can be used as a controlled phase shift, one of the necessary ingredients of a quantum computer. We concentrate on the transport process of the atoms from a double well to a single well configuration. This can be achieved by changing adiabatically the potential ensuring that no spurious excitations are produced during the evolution. Using adiabatic switching, the achievement of a good fidelity requires the gate to be very slow. One possibility to overcome the slowness of this gate is to make use of quantum optimal control methods. This numerical methods iteratively find better time-shape of the potential increasing the fidelity at each step. We have applied this method to an experimental setting by W. P. Phillips, J. Porto and M. Anderlini (NIST, Gaithersburg). The numerical results show that, for a duration of 0.15 ms, a fidelity of the order of 99% can be obtained whereas without optimization the fidelity is less than 70%.
- Quantum information processing with trapped ions. Here we study the implementation of a quantum gates with trapped ions which are subject to a walking standing wave potential as described in Leibfried et al 2003. We are studying the effects of quadratic and high oder contributions to the potential which lead to a decrease in fidelity. We are using numerical simulations in order to take into account the effects of nonlinear forces.
- Scaling of entanglement properties in spin chains. Entanglement is one of the striking consequences of the quantum world. First regarded as a source of paradoxes,

entanglement is now considered as a resource for quantum communication (teleportation, quantum cryptography), quantum computing, high precision measurements (standards, positioning, Heisenberg limited interferometry). Since the seminal paper by Osterloh et al. 2002, a great interest has been devoted to the properties of entanglement in spin chains at criticality. In collaboration with D. Binosi and A. Recati we are studying the scaling properties of the block entanglement in disordered spin chains. Apart from the few cases where an exact solution can be exploited, we use numerical tools such as exact diagonalization and density matrix renormalization group.

• Sara Della Monaca

In collaboration with: G. Orlandini (Trento Univ.), W. Leidemann (Trento Univ.), V. Efros (Russian Research Centre "Kurchatov Institute"), E. L. Tomusiak (Univ. of Victoria -Canada)

My research activity during the last year has focused mainly on the calculation of the inclusive transverse response functions of three-body nuclei with a realistic NN-potential and three-body forces. The calculation of the responses are performed via the application of the Lorentz Integral Transform method.

Two-body nuclear current operators, due to a one-π and a one-ρ exchange between nucleons, have been inserted into the electromagnetic transition operator; the correctness of their analytic expressions and of their implementation into a preexisting code, has been checked. To this aim, a one-π and one-ρ exchange potential fulfilling the continuity equation with the implemented current operators has been adopted as the nuclear Hamiltonian and a check of the validity of the Siegert theorem has been performed successfully.

Calculations of the inclusive transverse function with the realistic Bonn A NN-potential and Tucson Melbourne three body forces are presently performed.

• Carlo Ewerz

In collaboration with O. Nachtmann (Univ. Heidelberg) I have continued to investigate the nonperturbative foundations of the dipole picture of high energy scattering. We have identified the approximations and assumptions required to obtain the dipole picture from a general nonperturbative formulation of photon-hadron scattering. We have further derived bounds on various ratios of deep inelastic nucleon structure functions which follow from the dipole picture. By confronting these bounds with available data from the HERA collider we are able to constrain the range of applicability of the dipole picture.

Also in collaboration with O. Nachtmann I have applied the nonperturbative techniques developed in the study of the dipole picture to more exclusive processes. We have in particular investigated the diffractive photo- and electro-production of a single pion in photon-proton scattering. This process had been advocated in order to discover the elusive Odderon,

that is the leading exchange carrying negative charge parity in high energy scattering. However, previous predictions for the cross section of this process were ruled out by experiments at the HERA collider. We have now shown that the smallness of the cross section can be understood as a consequence of the approximate chiral symmetry of QCD.

I have also continued my work on the conformal properties of Pomeron vertices in high energy QCD in collaboration with T. Bittig (Max-Planck-Institut für Physik komplexer Systeme, Dresden), G. Korchemsky and S. Wallon (both at LPT, Univ. de Paris XI, Orsay). In collaboration with J. Bartels and M. Hentschinski I currently study the high energy limit of $\mathcal{N} = 4$ supersymmetric Yang-Mills theory, in particular concentrating on the perturbative resummation of leading logarithms. Both studies aim at finding a possible relation of perturbative field theory in the high energy limit with conformal field theory and string theory.

• Pietro Faccioli

Theoretical Biophysics

Collaborators: F. Pederiva (Trento Univ.), G. Garberoglio (Trento Univ.), H. Orland (SPhT,CEA Saclay), M. Sega (Trento Univ.), F. Fogolari (Udine Univ.)

We have further developed the joined ECT*-Trento University research line which focuses on applications of theoretical physics techniques to biological systems. The idea of this project is to combine the nuclear physicist's know-how in non-perturbative many-body problems with the ECT* super-computing facility to develop new approaches to the study protein folding, unfolding and bio-molecules aggregation. We have completed the two projects started in year 2005 namely:

- **Study of Aggregation of $\beta - 2$ Microglobulin by Means of Molecular Dynamics Simulations.**

  In this project we performed Molecular Dynamics simulation on BEN of the process of aggregation of several beta-2 micro-globuline molecules both in the folded and misfolded structure. The evolution of the misfolded structures suggested the set-up of an aggregation process.

  Ref: Submitted to J. Mol. Biol. (JMB-D-06-00996), Federico Fogolari, Alessandra Corazza, Paolo Viglino, Pierfrancesco Zuccato, Lidia Pieri, Pietro Faccioli, Vittorio Bellotti, Gennaro Esposito

- **Dominant Protein Folding Pathways**

  We have developed a method to investigate the kinetics of protein folding on a long time-scale and the dynamics underlying the formation of secondary and tertiary structures during the entire reaction. The approach is based on the formal analogy between thermal and quantum diffusion: by writing the solution of the Fokker-Planck equation for the time-evolution of a protein in a viscous heat-bath in terms of a path integral, we derive a Hamilton-Jacobi variational principle from which we are able to compute the

most probable pathway of folding. The method is applied to the folding of the Villin Headpiece Subdomain, in the framework of a Go-model. We have found that, in this model, the transition occurs through an initial collapsing phase driven by the starting coil configuration and a later rearrangement phase, in which secondary structures are formed and all computed paths display strong similarities. This method is completely general, does not require the prior knowledge of any reaction coordinate and represents an efficient tool to perfom ab-initio simulations of the entire folding process with available computers.

Reference: P.Faccioli, M.Sega, F.Pederiva and H.Orland, Phys. Rev. Lett. **97**, 108101 (2006)

• Andreas Hiroichi Ipp

My research followed two distinct trails:

In a project in collaboration with K. Kajantie (Helsinki U.), A. Rebhan (Vienna, Tech. U.), and A. Vuorinen (Washington U., Seattle), we presented a new method to calculate the perturbative equation of state of the quark-gluon plasma for all temperatures and chemical potentials. Previous methods have been limited to either small to moderate temperatures (dimensional reduction) or small chemical potentials (hard dense loop resummation). The new method unifies the perturbative results through fourth order in an expansion in the coupling parameter of the strong interaction.

Another project in collaboration with Jean-Paul Blaizot (ECT*), Ramon Mendez-Galain, and Nicolas Wschebor (Republica U., Montevideo) treats the non-perturbative renormalization flow of a scalar field theory at finite temperature. We show how the flow equations within the so-called local potential approximation reproduce the perturbative expressions for the thermal mass or pressure for small couplings. For larger couplings we obtain numerical results that are not afflicted with the poor convergent behavior of perturbation theory. These results turn out to be compatible with results from a self-consistent approximation.

• Taeko Matsuura

This year I (with prof. Blaizot, Dr. Ipp, and Dr. Krippa) started the project on applying the exact renormalization group approach to the BCS-BEC crossover of the cold dilute fermi gas, which is now under a remarkable progress both theoretically and experimentally. So far we concentrate on the unpolarised fermi gas where two fermion species are mixed 50:50 and calculate the energy gap and the chemical potential flow in terms of the IR cutoff scale. We have tried several regulators and checked whether they have physically meaningful number density as well as fermion spectrum during the flow. We now obtain the adequate method to solve and are starting the numerical calculations.

• Andrea Nobile

Currently I'm working on the new IBM "CELL" processor and on the newest video card processors to implement high performance Lattice QCD computational kernels. I worked in the field of Protein folding.

Reference: **Study of a model for the folding of a small protein** A. Nobile and F. Rapuano, J. Phys.: Condens. Matter 18 5687-5694 (2006)

We describe the results obtained from an improved model for protein folding. We find that a good agreement with the native structure of a 46-residue-long, five-letter protein segment is obtained by carefully tuning the parameters of the self-avoiding energy. In particular we find an improved free-energy profile. We also compare the efficiency of the multidimensional replica exchange method with the widely used parallel tempering.

Administration of the computational facility

- The support requests by the users were satisfied and the continuous functioning of the supercomputer was guaranteed.
- The software collection available on the facility was improved with two new compilers in order to get the maximum performance from the machine.
- The NASM assembler package was installed to give the possibility to users to experiment and use vector instructions to increase even more the machine yeld.
- A collection of scientific software libraries and tools was installed: Openmpi, GSL, Octave, Atlas, Gromacs, Fftw, Grace, Rasmol, Git.
- A web site that provides information about the facility, its resources and its status has been developed and opened to the public for dissemination and monitoring, it is hosted at the address http://benson.ect.it
- The queue and accounting systems were maintained and the correct functioning was guaranteed. We are now planning for an extension to manage the jobs requiring the APE3D communication network.

Development of the APE3D communication technology

- We are in active contact and collaboration with the APE group in Roma.
- I patched various scripts to fit our machine and I'm working to improve the *apelib* low level library.
- The latest firmware (07/2006) developed by INFN was installed on all the cards.
- Low level testing of the cards was successful.

- Test with benchmark codes was successful.
- We are testing the system with scientific code.

• Vladimir Pascalutsa

For the brief time that I have spent at the ECT*, I was focusing my research in the fields of *chiral effective field theory* (EFT) and *lattice QCD*. Primarily I have been working on the chiral EFT in the energy region of the nucleon first excited state, the $\Delta(1232)$ resonance. The results have been reviewed at a plenary talk on the *Chiral Dynamics 2006* Workshop and in a Physics Reports. The most recent experimental and theoretical developments in this field were presented and discussed at a Collaboration Meeting "Electromagnetic Properties of the Delta Resonance" at ECT*, see the report above.

Furthermore, I have worked on the subject of *Generalized Parton Distributions (GDPs)*. Together with M. Vanderhaeghen, have recently derived the large-N_c relations between the nucleon and $N \to \Delta$ GPDs, as well as, have been using such relations to perform a parton-model calculation of the *two-photon exchange* effects in *semi-exclusive electron scattering* at moderate momentum transfers.

• Claudia Ratti

A field theoretical quasiparticle approach for QCD thermodynamics

In collaboration with S. Rößner and W. Weise (Technical University of Munich)

A relevant part of my recent research activity is focused on the study of QCD thermodynamics in the framework of a field theoretical model. This model combines the Nambu Jona-Lasinio type of interaction with the nonlinear dynamics involving the Polyakov loop (PNJL model) [1, 2, 3]. This model represents a minimal synthesis of the two basic principles that govern QCD at low temperatures: spontaneous chiral symmetry breaking and confinement. The respective order parameters (chiral quark condensate and Polyakov loop) are given the meaning of collective degrees of freedom, to which quarks couple according to the symmetry rules dictated by QCD itself.

Once a limited set of input parameters is fitted to lattice QCD in the pure gauge sector and to pion properties in the hadron sector, the $N_f = 2$ QCD thermodynamics above T_c up to about twice the critical temperature is nicely reproduced. The finite μ lattice results which we use for reference are obtained through a Taylor expansion of the thermodynamic grand canonical potential in powers of μ/T around $\mu = 0$ [4, 5]. Within our model, we have performed a comparison between full and truncated results at finite μ; this has allowed us to draw conclusions about the convergence properties of the Taylor series [6]. The model has also been extended to larger chemical potentials, with the incorporation of diquark condensation [7]. The phase diagram in the (T, μ) plane has been obtained, and its quark mass dependence has been investigated, including the position of the critical endpoint [7].

Pure gauge QCD thermodynamics: Polyakov loop and transverse gluonic degrees of freedom

In collaboration with J.-P. Blaizot (ECT)*

One of the shortcomings of the PNJL model is its limited applicability at large temperatures, since it does not involve transverse gluonic degrees of freedom, which are known to play the relevant role at $T \leq 2.5T_c$. In collaboration with Professor Jean-Paul Blaizot, I am presently investigating QCD thermodynamics in the gluonic sector. We are developing an approach obtained by combining the effects due to the Polyakov loop, with transverse gluon thermodynamics.

In our scheme, gluon quasiparticles propagate in a temporal background gauge field representing Polyakov loop dynamics. Their propagator is modified accordingly. The thermodynamic potential obtained in this way exhibits an interplay between the Polyakov loop, which plays the relevant role in describing the physics in the vicinity of T_c, and the gluonic quasiparticles, whose contributions dominate the high temperature region.

Through this approach, we will then obtain a suitable description of pure gauge QCD thermodynamics in the whole temperature range above T_c. The preliminary results that we obtain for the thermodynamics of the pure gauge sector look very promising: the coupling to the Polyakov loop suppresses the gluonic degrees of freedom in the vicinity of the phase transition, thus providing a nice description of the corresponding lattice data. Once the thermodynamics in the gluonic sector is settled, we will proceed to incorporate quarks in the system.

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• Michael Schwamb

My research activities in 2006 at ECT*, in collaboration with the Trento group (G. Orlandini, W. Leidemann), focus on the study of electromagnetic reactions on few-nucleon systems. The latter constitute an ideal test object for state-of-the-art effective approaches of the strong interaction. Moreover, they may serve as effective neutron targets.

Despite the small amount of participating particles, realistic microscopic studies on few-nucleon systems are far from being trivial. Usually, various approximations are used, especially with respect to the treatment of final state interactions (FSI). Moreover, most approaches are constructed only for a specific type of reactions, ignoring their implication for the other ones. Last, but not least, existing rigorous calculations for mass number $A \geq 3$ are only applicable in the low-energy regime, typically below pion threshold.

In my research activities, I intend to overcome these shortcomings. The final aim, in the long term, is the construction of a unified theoretical treatment for electromagnetic reactions on few-nucleon systems up to the Δ-region within the Lorentz Integral Transform (LIT) method developed by the Trento group together with V. D. Efros (Moscow). It permits the explicit calculation of observables with a complete treatment of FSI without requiring the explicit calculation of final state continuum wave functions.

Since the beginning of my work at ECT* in June 2006, I have developed at first the formal framework for these studies within the LIT approach, where I concentrate myself in a first step on inclusive reactions on the three-nucleon-system as the most natural starting point. In order to obtain a realistic description up to the Δ-region, the usual nucleonic Hilbert space is extended by contributions where in addition pions as well as Δ-resonance contributions are taken into account. With the help of appropriate projection operators on the various Hilbert subspaces, a rigorous calculation of observables can be formulated within the LIT approach. With respect to the hadronic Hamilton operator, besides state-of-the-art NN-potentials (e.g. Bonn, Argonne), a suitable NN$\rightarrow$ NΔ-transition potential and an explicit $\pi N\Delta$-vertex is considered. The corresponding electromagnetic current operators comprise the usual nucleonic one- and two-body contributions as well as the $\gamma N \rightarrow \Delta$-transition current fixed by elementary photopionproduction in the Δ-region.

In the meantime, I have started with the explicit realization by means of a partial wave expansion in momentum space. This allows to incorporate straightforwardly nonlocalities in the potentials and currents. The numerical results expected in 2007 will be of specific importance with respect to various experimental activities, e.g. at MAMI in Mainz.

• Luigi Scorzato

Ben cluster with APE3D:

In collaboration with A. Nobile (ECT), INFN-APE group in Roma 2 and Exadron*

I am developing and testing the software interface between MPI the APE3D network cards. This is needed to ensure stability and good performances.

Numerical Stochastic Perturbation Theory:

In collaboration with F. Di Renzo (Parma U.), E. Miccio (Milano Bicocca U.), and C. Torrero (Bielefeld 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.

Unquenched Lattice QCD:

Within the ETM Collaboration

I am doing Lattice QCD calculation of hadron masses and decay constants. We use the "twisted mass" regularization for the sea quarks and also the "overlap" regularization for the valence quarks. This choice is done in order to optimize symmetry properies and computational cost. Computations are done, in part, also on the ECT* BEN cluster.

Study of the Delta-resonance:

In collaboration with K. Orginos, M. Vanderhaeghen (JLab), and V. Pascalutsa (ECT)*

We just started a project to study the properties of the Delta-resonance with Lattice QCD computations. Calculation will be performed on the teraflop cluster BEN of ECT*.

• Marco Traini

in collaboration with M. Cristoforetti (Univ. Trento) and P. Faccioli (Univ. Trento

I have been continuing the research activity in collaboration with Pietro Faccioli and Marco Cristoforetti on the structture of the hadrons. In particular, by means of an Interacting Instanton Liquid Model we have explored the role of instanton induced dynamics on hadron structure. We have investigated the validity of this model in the chiral regime. To this aim the quark mass dependencies of the density of eigenmodes of the Dirac operator and the masses of the pion and nucleon have been esplicitly calculated and shown to agree with chiral perturbation theory. A quark mass m* = 80 MeV emerging naturally from the model is shown to specify the mass scale above which the fermion determinant is suppressed, the zero modes become subdominant, and the density of quasi-zero modes become independent of the quark mass.

• Dionysis Triantafyllopoulos

Quantum Chromodynamics at High Energy

A main active field of research within QCD is the study of its behavior in the high energy limit. In this regime, and due to the triple-gluon coupling, the wavefunction of a hadron is dominated by a dense system of gluons. When the energy of the hadron becomes sufficiently high, one expects the gluon density to reach its asymptotic limit ($1/\alpha_s$) and the wavefunction to exhibit saturation. In particular, but not necessarily, this phenomenon is enhanced for large nuclei due to the large number of valence quarks. With increasing energy, more and more gluonic modes saturate and the dynamically generated "saturation scale" is an increasing monotonic function of the energy. The QCD coupling constant becomes small and the problem can be approach by analytical methods. Over the recent years it has been possible to describe the energy evolution of all the moments of the gluon density through an infinite system of coupled equations.

One of the main features of the equations that we have recently proposed, is the formation of "Pomeron loops" in the course of evolution, an ingredient which is necessary for the correct description of saturation. Together with collaborators from Saclay and BNL, we have shown that this has significant effects on total and single diffractive cross sections; at very high energies, "diffusive scaling" replaces the (well-known) "geometric scaling".

The analysis of these Pomeron loop equations (which hold in two transverse dimensions) has been difficult, even by using numerical methods. As a first step, with collaborators from ECT* and Saclay, we explored a "toy model" in zero dimensions. Even in this seemingly simple case, one is able to see highly non-trivial aspects; for example, the (boost-invariant) S-matrix elements are dominated by different configurations of the wavefunctions, when different reference frames are considered. As a second and more important step, we constructed and studied a model in one dimension. Such a model, whose numerical solution is under way, may be very close to QCD, so long as the scattering between two hadrons at zero impact parameter is considered.

Improvements over the current effective theory (e.g. inclusion of running coupling effects, more elaborate study of its probabilistic structure), deeper understanding of its asymptotic solutions, and more precise applications to the experimental data of deep inelastic lepton-hadron scattering (HERA) and heavy-ion collisions (RHIC, LHC) should be expected in the future.

3.2 Publications of ECT* Researchers

D. Binosi and J.Papavassiliou
Pinch-Technique for Schwinger-Dyson equations
JHEP 0307, 041 (2007) [*arXiv:hep-ph/0611354*]

J. Bernabeu, D. Binosi and J. Papavassiliou
CP violation through particle mixing and the H - A lineshape
JHEP 0609, 023 (2006) [*arXiv:hep-ph/0604046*]

Jean-Paul Blaizot
Theoretical overview: towards understanding the quark-gluon plasma
19th International Conference on Ultra-Relativistic Nucleus-Nucleus Collisions, Shanghai, China on November 14-20, 2006 [*hep-ph/0703150*]

J.-P. Blaizot, E. Iancu, U. Kraemmer, A. Rebhan
Hard thermal loops and the entropy of supersymmetric Yang-Mills theories
[*hep-ph/061139; ECT*-06-22*]

Jean-Paul Blaizot, Andreas Ipp, Ramon Mendez-Galain, Nicolas Wschebor
Perturbation theory and non-perturbative renormalization flow in scalar field theory at finite temperature
Nucl. Phys. A784:376-406,2007 [*hep-ph/0610004; ECT*-06-15*]

J.-P. Blaizot, E. Iancu, D.N. Triantafyllopoulos
A zero-dimensional model for high-energy scattering in QCD
Nucl. Phys. A784:227-258,2007 [*hep-ph/0606253;ECT*-06-09*]

G. Baym, J.-P. Blaizot, F. Gelis, T. Matsui
Landau-Pomeranchuck-Migdal effect in a quark-gluon plasma and the Boltzmann equation
Phys.Lett.B644:48-53,2007 [*hep-ph/0604209;ECT*-05-22*]

Jean-Paul Blaizot, Ramon Mendez-Galain, Nicolas Wschebor
Non-Perturbative Renormalization Group calculation of the scalar self-energy
[*hep-th/0605252;ECT*-05-26*]

B. Zhao, Z.-B. Chen, J.-W. Pan, J. Schmiedmayer, A. Recati, G. Astrakharchik, T. Calarco
Deterministic Entanglement via Molecular Dissociation in Integrated Atom Optics
arXiv:quant-ph/0502011

D. Rossini, T. Calarco, V. Giovannetti, S. Montangero, R. Fazio
Decoherence by engineered quantum baths

arXiv:quant-ph/0605051

Z. Idziaszek, T. Calarco
Analytical solutions for the dynamics of two trapped interacting ultracold atoms
Phys. Rev. A 74, 022712 (2006)

P. Treutlein, T. W. Hänsch, J. Reichel, A. Negretti, M. A. Cirone, T. Calarco
Microwave potentials and optimal control for robust quantum gates on an atom chip
Physical Review A 74, 22312 (2006)

D. Binosi, T. Calarco, R. Fazio, P. Zoller
Quantum Information Classification Scheme
Eur. Phys. J. D 38, 237 (2006)

E. Charron, M. A. Cirone, A. Negretti, J. Schmiedmayer, T. Calarco
Theoretical analysis of the implementation of a quantum phase gate with neutral atoms on atom chips
Physical Review A 74, 12308 (2006)

M. Cozzini, T. Calarco, A. Recati, P. Zoller
Fast Rydberg gates without dipole blockade via quantum control
Optics Comunications 264, 375 (2006)

Z. Idziaszek, T. Calarco
Pseudopotential method for higher partial wave scattering
Physical Review Letters 96, 13201 (2006)

E. Charron, M. A. Cirone, A. Negretti, J. Schmiedmayer, T. Calarco
Theoretical analysis of the implementation of a quantum phase gate with neutral atoms on atom chips
Physical Review A 74, 12308 (2006)

P. Treutlein, T. W. Hänsch, J. Reichel, A. Negretti, M. A. Cirone, T. Calarco
Microwave potentials and optimal control for robust quantum gates on an atom chip
Physical Review A 74, 22312 (2006)

M. Cristoforetti, P. Faccioli, M. C. Traini, J. W. Negele
Exploring the Chiral Regime of QCD in the Interacting Instanton Liquid Model
Phys. Rev. D75 (2007) 034008 [*ECT*-06-06*]

G. De Chiara, M. Rizzi, D. Rossini, S. Montangero
Density Matrix Renormalization Group for Dummies
Eprint: cond-mat/0603842

G. De Chiara, C. Brukner, R. Fazio, G. M. Palma, V. Vedral
A scheme for entanglement extraction from a solid
Eprint: quant-ph/0505107

G. De Chiara, S. Montangero, P. Calabrese, R. Fazio
Entanglement Entropy dynamics in Heisenberg chains
J. Stat. Mech. (2006) P03001 Eprint: cond-mat/0512586

G. De Chiara, R. Fazio, C. Macchiavello, S. Montangero, G. M. Palma
Effect of noise on spin network cloning
Int. J. Quant. Inf. 4, 487 (2006)

A. Romito, G. De Chiara, D. Rossini, S. Montangero
Implementation of quantum communication protocols in Josephson junction arrays
Int. J. Quant. Inf. 4, 519 (2006)

D. Rossini, M. Rizzi, G. De Chiara, S. Montangero, R. Fazio
Anti-ferromagnetic spinor BECs in optical lattices
J. Phys. B: At. Mol. Opt. Phys. 39 (2006) S163-S175

C. Ewerz
Gribov's Picture of Confinement and Chiral Symmetry Breaking
in Gribov-75 Memorial Volume, Budapest 2005, World Scientific, p. 366-378, IFUM-857-FT, ECT-05-20, hep-ph/0601271*

C. Ewerz, O. Nachtmann
Towards a Nonperturbative Foundation of the Dipole Picture: II. High Energy Limit
HD-THEP-04-18, IFUM-790-FT, ECT-05-19, hep-ph/0604087* [*submitted to Annals of Physics*]

C. Ewerz, O. Nachtmann
Chiral Symmetry and Diffractive Neutral Pion Photo- and Electroproduction
ECT-06-10, HD-THEP-06-16, hep-ph/0608082* [*to appear in Eur. Phys. J. C*]

C. Ewerz, O. Nachtmann
Bounds on Ratios of DIS Structure Functions from the Dipole Picture
ECT-06-18, HD-THEP-06-29, hep-ph/0611076* [*submitted to Phys. Rev. Lett.*]

P. Faccioli, M. Sega, F. Pederiva, H. Orland
Dominant Pathways in Protein Folding
Oct 2005. 4pp. Phys.Rev.Lett.97:108101,2006, e-Print Archive: q-bio/0510045

F. Fogolari, A. Corazza, P. Viglino, P. Zuccato, L. Pieri, P. Faccioli, V. Bellotti, G. Esposito
Molecular dynamics simulation suggests possible interaction patterns at early steps of 2-microglobulin aggregation
Biophys. J. BioFAST: First Published December 8, 2006. doi:10.1529/biophysj.106.098483

J.-P. Blaizot, A. Ipp, R. Mendez-Galain, N. Wschebor
Perturbation theory and non-perturbative renormalization flow in scalar field theory at finite temperature
ECT-06-15, hep-ph/0610004 [*accepted for publication in Nuclear Physics A*]

A. Ipp
The Pressure of deconfined QCD for all temperatures and quark chemical potentials
ECT-06-12, hep-ph/0608250 [*For the proceedings of International Conference on Strong and Electroweak Matter (SEWM 2006), Upton, New York, 10-13 May 2006*]

A. Ipp, K. Kajantie, A. Rebhan, A. Vuorinen
The Pressure of deconfined QCD for all temperatures and quark chemical potentials
ECT-06-04, HEP-2006-18-TH, TUW-06-02, hep-ph/0604060, Phys.Rev.D74:045016,2006*

A. Gerhold, A. Ipp, A. Rebhan
Thermodynamics of QCD at large quark chemical potential
TUW-05-21, ECT-05-27, Dec 2005, 19pp, hep-ph/0512273, PoS JHW2005:013,2006 [*Invited talk at 29th Johns Hopkins Workshop in Theoretical Physics: Strong Matter in the Heavens, Budapest, Hungary, 1-3 Aug 2005*]

J.-P. Blaizot, A. Ipp, A. Rebhan, U. Reinosa
The Entropy of hot QCD at large N(f): Successfully testing weak coupling techniques
ECT-05-11, TUW-05-16, hep-ph/0510115, Rom.Rep.Phys.58:043-048,2006* [*Contributed to 18th International Conference on Ultrarelativistic Nucleus-Nucleus Collisions: Quark Matter 2005 (QM 2005), Budapest, Hungary, 4-9 Aug 2005*]

J.-P. Blaizot, A. Ipp, A. Rebhan
Study of the gluon propagator in the large-N(f) limit at finite temperature and chemical potential for weak and strong couplings
ECT-05-07, TUW-05-11, hep-ph/0508317, Annals Phys.321:2128-2155,2006

V. Pascalutsa
Chiral effective field theory in the Delta-resonance region
arXiv:hep-ph/0612303, ECT-06-34*

V. Pascalutsa, M. Vanderhaeghen
The $\gamma N \to \Delta$ transition in chiral effective-field theory
to appear in J. Phys. G, arXiv:hep-ph/0611317, ECT-06-33*

V. Pascalutsa, M. Vanderhaeghen
New large-N_c relations among the nucleon and nucleon-to-Delta form factors
arXiv:hep-ph/0611050, ECT-06-32* [*submitted to Phys. Rev. Letters*]

V. Pascalutsa, M. Vanderhaeghen, S.-N. Yang
Electromagnetic excitation of the $\Delta(1232)$ resonance
Physics Reports (in press), arXiv:hep-ph/0609004, ECT-06-16*

C. Ratti, M. A. Thaler, W. Weise
Phases of QCD: lattice thermodynamics and a field theoretical model
Phys. Rev. D 73 (2006) 014019, ECT-06-07*

C. Ratti, M. A. Thaler, W. Weise
Phase diagram and thermodynamics of the PNJL model
nucl-th/0604025, ECT-06-08* [*To appear in GSI Scientific Report on Compressed Baryonic matter*]

H. Hansen, W. M. Alberico, A. Beraudo, A. Molinari, M. Nardi, C. Ratti
Mesonic correlation functions at finite temperature and density in the Nambu Jona-Lasinio model with a Polyakov loop
hep-ph/0609116, ECT-06-13* [*To appear in Phys. Rev. D.*]

C. Ratti, S. Roessner, M. A. Thaler, W. Weise
Thermodynamics of the PNJL model
hep-ph/0609218, ECT-06-14* [*To appear in Eur. Phys. J. C (2006)*]

S. Roessner, C. Ratti, W. Weise
Polyakov loop, diquarks and the two-flavour phase diagram
hep-ph/0609281, ECT-06-16* [*Submitted to Phys. Rev. D.*]

C. Ratti, M. A. Thaler, W. Weise
Phases of QCD: lattice thermodynamics versus PNJL model
Talk presented at the International Conference "PANIC 2005", Santa Fe, New Mexico, 24-28 October 2005, In "Particles and Nuclei", AIP Conference Proceedings 842 (2006), 104-106, ECT-06-31*

C. Ratti, S. Roessner, W. Weise
Phases of QCD: lattice thermodynamics, quasiparticles and Polyakov loop
Talk presented at the XI Meeting on Problems in Theoretical Nuclear Physics, Cortona, Italy, 11-14 October 2006, ECT-06-30* [*To appear in the Proceedings of the Conference by the World Scientific, Singapore*]

M. Schwamb
Electromagnetic reactions on few-nucleon systems
Proceedings of XI Convegno su Problemi di Fisica Nucleare Teorica (Cortona 2006), ECT-06-29* [*World Scientific, in press*]

F. Di Renzo, A. Mantovi, V. Miccio, L. Scorzato, C. Torrero
3 (And Even 4) Loops Renormalization Constants For Lattice QCD
Nucl. Phys. Proc. Suppl. 153 (2006) 74, ECT-06-23*

O. Bar, K. Jansen, S. Schaefer, L. Scorzato, A. Shindler
Overlap fermions on a twisted mass sea
hep-lat/0609039, ECT-06-24* [*To appear in PoS*]

F. Di Renzo, V. Miccio, L. Scorzato, C. Torrero
Renormalization constants for Lattice QCD: new results from Numerical Stochastic Perturbation Theory
hep-lat/0609077, ECT-06-25* [*To appear in PoS*]

T. Chiarappa, F. Farchioni, K. Jansen, I. Montvay, E.E. Scholz, L. Scorzato, T. Sudmann, C. Urbach
Numerical simulation of QCD with u, d, s and c quarks in the twisted-mass Wilson formulation
hep-lat/0606011, ECT-06-26* [*To appear in Eur. Phys. J C.*]

T. Chiarappa, K. Jansen, K.-I. Nagai, M. Papinutto, L. Scorzato, A. Shindler, C. Urbach, U. Wenger, I. Wetzorke
Iterative methods for overlap and twisted mass fermions
hep-lat/0609023, ECT-06-27* [*To appear in Comput. Sci. Disc.*]

F. Di Renzo, V. Miccio, L. Scorzato, C. Torrero
High-loop perturbative renormalization constants for Lattice QCD (I): finite constants for Wilson quark currents
hep-lat/0611013, ECT-06-28*

M. Cristoforetti, P. Faccioli, M.C. Traini, J.W. Negele
Exploring the Chiral Regime of QCD in the Interacting Instanton Liquid Model
Phys. Rev D75(2007) 034008 [*ECT*-06-06*]

Y. Hatta, E. Iancu, C. Marquet, G. Soyez, D. N. Triantafyllopoulos
Diffusive Scaling and the High Energy Limit of Deep Inelastic Scattering in QCD at Large N_c
Nucl. Phys. **A 773** *(2006) 95 [hep-ph/0601150], ECT*-06-01*

J.-P. Blaizot, E. Iancu, D. N. Triantafyllopoulos
A Zero Dimensional Model for High Energy Scattering in QCD

hep-ph/0606253, ECT-06-09* [*To appear in Nucl. Phys.* **A**]

E. Iancu, J. T. de Santana Amaral, G. Soyez, D. N. Triantafyllopoulos
One-Dimensional Model for QCD at High Energy
hep-ph/0611105, ECT-06-19*

3.3 Seminars and Presentations at International Conferences by ECT* researchers

• Daniele Binosi

QIPC Cluster review
Institute Henry Poincare
Feb. 2006, Paris, France

7th European QIPC workshop
Oct. 2006, The Royal Society, London

• Jean-Paul Blaizot

The quark-gluon plasma
Hadrons, nuclei and stars
June 8, 2006, Darmstadt, Germany

The high temperature phase of QCD
Heavy ion reactions at ultra-relativistic energies
June 26, 2006, ECT, Trento, Italy*

A few topics in hot and dense QCD
Daniel Gogny Jubile
May 30, 2006, Bruyeres Le Chatel, France

The birth of matter: the big bang in the laboratory
Colloquium at the University of Montevideo
October 31, 2006, Montevideo, Uruguay

Theoretical overview: towards understanding the quark-gluon plasma
International Conference Quark matter 2006
November 14, 2006, Shanghai, China

QCD thermodynamics
RHIC Physics in the context of the standard model
June 21, 2006, RIKEN BNL Reasearch Center, USA

The high temperature phase of QCD
Perspectives in hadronic physics
May 26, 2006, Trieste, Italy

Functional renormalization group and the transition temperature of the weakly repulsive Bose gas
International Conference on the exact renormalization group
September 20, 2006, Lefkada, Greece

High temperature Phase of QCD
Strong and electroweak matter
May 10, 2006, BNL, USA

Weak compling approach to the quark-gluon plasma thermodynamics
Yukawa Institute Seminar
November 27, 2006, Kyoto, Japan

- **Tommaso Calarco**

Cluster review report; QUROPE
QIPC Cluster review and Conference 2006
11-13 February 2006, Paris, France

Quantum control theory for decoherence suppression in quantum gates
Quantum 2006: III workshop ad memoriam of Carlo Novero
2-5 May 2006, Turin, Italy

Gordon Research Conference on "Quantum Information Processing"
7-12 May 2006, Castelvecchio Pascoli, Italy

20th international Conference on Atomic Physics
16-21 July 2006, Innsbruck, Austria

Principles and Applications of Control in Quantum Systems 2006
7-12 August 2006, Cambridge (MA) USA

Robust quantum computation via quantum control of atomic systems
XCII Congresso Nazionale Societ Italiana di Fisica
18-23 September 2006, Turin, Italy

- **Marco Cristoforetti**

  Instantons and the non-perturbative quark dynamics in the chiral regime
  Contributed talk, "Cortona 2006. XI Convegno su Problemi di Fisica Nucleare Teorica"
  11-14 October 2006, Cortona, Italy

- **Carlo Ewerz**

  Diffraction at the LHC
  Joint LHC Seminar, Universität Heidelberg
  20 February 2006, Heidelberg, Germany

  Pomeron Interactions, CFT and Strings
  Workshop 'QCD and Strings', DESY
  19 May 2006, Hamburg, Germany

  Conformal Bootstrap and String Amplitudes for Pomeron Interactions
  Workshop 'Hadrons and Strings', Trento
  19 July 2006, Trento, Italy

  On the Dipole Picture and its Nonperturbative Foundations
  Invited talk at Workshop 'Hadronic Physics', Heidelberg
  4 October 2006, Heidelberg, Germany

  Gribov's Picture of Confinement and Chiral Symmetry Breaking
  Scuola Normale Superiore, Pisa
  10 October 2006, Pisa, Italy

- **Pietro Faccioli**

  Talk title
  Poster presentation at XX Sitges Conference on Statistical Mechanics
  5-9 June 2006, Sitges, Barcellona

  Predicting Protein folding Pathways from Quantum Path Integrals
  Invited talk at Center For Theoretical Physics, MIT
  7 Novembre 2006, Cambridge, MA, USA

  Stochastic Theory of Protein Folding
  Invited talk at Dept Chemistry and Chemical Biology, Harvard University
  10 Novembre 2006, Cambridge, MA, USA

- **Andreas Hiroichi Ipp**

  The pressure of deconfined QCD for all temperatures and chemical potentials
  Strong and electroweak matter (SEWM) 2006, Brookhaven National Laboratory
  10-13 May 2006, Upton (New York) USA

  Pressure of deconfined QCD at finite chemical potential
  Workshop "Heavy Ion Reactions at Ultrarelativistic "Energies, ECT* Trento
  26 June - 1 July 2006, Trento, Italy

  Perturbation theory and nonperturbative renormalization flow in scalar field theory at finite temperature
  Conference on Exact Renormalization Group (ERG) 2006
  18-22 September 2006, Lefkada, Greece

- **Vladimir Pascalutsa**

  The Δ-resonance in chiral effective-field theory
  Invited plenary talk at The 5th International Workshop on "Chiral Dynamics: Theory and Experiment"
  18-22 September 2006, Durham/Chapel Hill (NC) USA

  A theoretical issue in Compton scattering on the nucleon
  Talk at the ECT* Collaboration Meeting "Electromagnetic Properties of the Delta(1232) Resonance"
  16-19 October 2006, Trento, Italy

  Chiral Effective Field Theory for the N^* Analysis
  Invited talk at the "N^* Analysis White Paper" Meeting
  5-6 November 2006, Newport News (VA) USA

- **Claudia Ratti**

  Phases of QCD
  Talk at the collaboration meeting "Physics of Heavy-Ion Collisions and Quark-Gluon Plasma"
  16-17 February 2006, Florence, Italy

  Phases of QCD
  Group Report at the Spring meeting of the German Physical Society (DPG)
  20-24 March 2006, Munich, Germany

Phases of QCD
Talk at the International Conference "QCD at finite density", ECT*
21-25 March 2006, Trento, Italy

Phases of QCD in the PNJL model
Invited Seminar at the Technical University of Munich
24 April 2006, Munich, Germany

Phases of QCD
Talk at the International Conference "Hot Quarks 2006"
15-20 May 2006, Villasimius, Italy

Phases of QCD
Invited talk at the International Conference "The Physics of High Baryon Density", ECT*
29 May - 2 June 2006, Trento, Italy

Model Field Theories for QCD thermodynamics
Invited talk at the International Conference "Heavy Ion Reactions at Ultrarelativistic Energies", ECT*
26 June - 1 July 2006, Trento, Italy

Phases of QCD: lattice thermodynamics, quasiparticles and Polyakov loop
Talk at the XI Meeting on Problems in Theoretical Nuclear Physics
11-14 October 2006, Cortona, Italy

A field theoretical model for QCD thermodynamics
Talk at the International Conference "Quark Matter 2006"
14-20 November 2006, Shanghai, China

A field theoretical model for QCD thermodynamics
Invited Seminar at the Department of Physics, Ferrara University
27 November 2006, Ferrara, Italy

- **Michael Schwamb**

Electroweak reactions on few-nucleon systems
XI Convegno su Problemi di Fisica Nucleare Teorica
11-14 October 2006, Cortona, Italy

- **Luigi Scorzato**

Status of the A4 project: progress with tmQCD dynamical fermion simulations
Computer supported Particle Physics
March 2006, Zeuthen, Germany

Results from Lattice QCD simulations with a twisted mass
Seminar at the University of Glasgow
September 2006, Glasgow, UK

Results from Lattice QCD simulations with a twisted mass
Talk at the Workshop "Lattice QCD, Chiral Perturbation Theory and Hadron Phenomenology", ECT*
2-6 October 2006, Trento, Italy

- **Dionysis Triantafyllopoulos**

Pomeron Loops in High Energy QCD
Seminar given at SPhT, Saclay
19 April 2006, Paris, France

Color Glass Condensate (QCD at small-x)
Talk given at the RNM Meeting
11 May 2006, Heidelberg, Germany

Rare Configurations at High Energy
Talk given at the Low-x Workshop
30 June 2006, Lisbon, Portugal

3.4 Lectures and Seminars at ECT*

3.4.1 Lectures

- Lattice methods in quantum field theory
  (March 13 - 17)
  Lecturer: Simon Hands (University of Wales, Swansea, UK)
- QCD thermodynamics
  (March 27 - 31)
  Lecturer: Frithjof Karsch (Brookhaven National Lab, USA)
- Algorithms and chiral fermions
  (April 3 - 7)
  Lecturer: Anthony David Kennedy (University of Edinburgh, UK)
- Green's function Monte Carlo in many-body theory
  (April 17 - 21)
  Lecturer: Malvin Kalos (Lawrence Livermore National Lab, USA)
- Quantum phase transitions: General concepts
  (April 18)
  Lecturer: Francesco Iacchello (Yale University)
- Algebraic models (Bose systems)
  (April 20)
  Lecturer: Francesco Iacchello (Yale University)
- Quantum field theory out of equilibrium
  (April 24 - 28)
  Lecturer: Gert Aarts (University of Wales, Swansea, UK)
- Molecular dynamics simulations of biological systems
  (May 2 - 6)
  Lecturer: Giovanni Garberoglio and Marcello Sega (University of Trento, Italy)
- Approaches to the sign problem
  (May 8 - 12)
  Lecturer: Uwe-Jens Wiese (Bern University, Switzerland)
- Hadron structure and the QCD vacuum
  (May 15 - 19)
  Lecturer: Thomas Alan DeGrand (University of Colorado, USA)
- Holographic methods in QCD
  (May 22 - 26)
  Lecturer: Mikhail Stephanov (University of Illinois, Chicago, USA)
- Introduction to String Theory
  (April 6, 12, 13 - May 2, 3, 8, 9, 23, 31 - June 1, 12, 13)
  Lecturer: Carlo Ewerz (ECT*)
- Introduction to perturbative QCD; the collinear parton model; deep inelastic scattering
  (October 30 - November 3)
  Lecturer: Werner Vogelsang (Brookhaven and RIKEN BNL, USA)

- Spin (helicity and transverse) in relativistic theories; polarized deep inelastic scattering; polarized parton densities
  (November 6 - 10)
  Lecturer: Elliot Leader (Imperial College, London)
- The problem of single spin asymmetries; new mechanisms for asymmetries; parton intrinsic transverse momentum; naive extension of the collinear parton model
  (November 13 - 17)
  Lecturer: Mauro Anselmino (University Torino and INFN, Italy)
- The new generation of experiments at RHIC, COMPASS and Jefferson Laboratory
  (November 20 - 24)
  Lecturer: Naohito Saito (KEK, Japan)
- Transverse momentum dependence in parton densities–advanced topics
  (November 27 - December 1)
  Lecturer: Alessandro Bacchetta (DESY, Germany)
- Generalised parton distributions; orbital angular momentum
  (December 4 - 8)
  Lecturer: Thorsten Feldman (University of Siegen, Germany)

3.4.2 Seminars

09.02
Universality in the BCS BEC Crossover in Cold Fermion Gases
S. Diehl (*University of Heidelberg*)

14.02
Small-x QCD (part 6)
D. Triantafyllopoulos (*ECT*, Trento*)

22.02
Small-x QCD (part 7)
D. Triantafyllopoulos (*ECT*, Trento*)

24.02
On the Nonperturbative Foundation of the Dipole Picture (Part1)
C. Ewerz (*ECT*, Trento*)

28.02
On the Nonperturbative Foundation of the Dipole Picture (Part2)
C. Ewerz (*ECT*, Trento*)

14.03
Particle production in field theories coupled to strong external sources
F. Gelis (*SPhT, Saclay*)

23.03
High energy QCD, selective growth models and spin glasses
S. Munier (*CPT, Ecole Polytechnique, France*)

29.03
Cutoff effects of Wilson fermions in the absence of spontaneus chiral symmetry breaking
M. Lutz (*GSI, Germany*)

30.03
The sQGP as a colored liquid
A. Peshier (*Giessen University*)

05.04
The phase structure of scalar field model with a non-standard potential
S. Scheffler (*University of Heidelberg*)

06.04

Introduction to String Theory (part 1)
C. Ewerz (*ECT*, Trento*)

11.04
Light-Front field theory of relativistic quark matter
S. Strauss (*University of Rostock*)

12.04
Introduction to String Theory (part 2)
C. Ewerz (*ECT*, Trento*)

13.04
Lattice QCD with chemical potential: Hadron screening masses under extreme conditions
I. Pushkina (*Riise-Hiroshima University, Japan*)

13.04
Introduction to String Theory (part 3)
C. Ewerz (*ECT*, Trento*)

18.04
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F. Iacchello (*Yale University*)

19.04
QCD thermodynamics using modified differential method
S. Mukherjee (*TIFR, India*)

20.04
Algebraic models (Bose systems)
F. Iacchello (*Yale University*)

21.04
Chiral dynamics in low-energy QCD
B. Borasoy (*Bonn University, Germany*)

21.04
Factorization and universality of transverse momentum dependent partonic functions
A. Metz (*University of Bochum, Germany*)

21.04
Chiral Effective-Field Theory in the Delta-Resonance Region
V. Pascalutsa (*Jlab, USA*)

21.04
Effective field theories for heavy quarkonium
A. Vairo (*University of Milano*)

27.04
Investigation of the G_SVY Coupling constant in three point QCD sum rules and light cone
M. Bayar (*Karademiz Technical University, Trebzon, Turkey*)

02.05
Introduction to string theory (part 5)
C. Ewerz (*ECT*, Trento*)

03.05
Introduction to Econophysics
L. Daniel (*Jagellonian University, Krakow*)

03.05
Introduction to string theory (part 6)
C. Ewerz (*ECT*, Trento*)

05.05
Dynamical breakdown of Abelian Gauge Chiral simmetry by strong Yukawa interactions
J. Hosek (*INP, Rez, Czech Republic*)

08.05
Introduction to string theory (part 7)
C. Ewerz (*ECT*, Trento*)

09.05
Introduction to string theory (part 8)
C. Ewerz (*ECT*, Trento*)

10.05
An introduction to super-symmetry
A. Lee (*University of Cambridge, UK*)

15.05
All to all spectroscopy in Dense two-colour QCD
P. Sitch (*University of Wales, Swansea*)

16.05
Ginzburg-Landau Approach to colour superconductivity
T. Matsuura (*ECT*, Trento*)

17.05
The broad histogram method; an extension to continuous systems
J. C. L. Luquez (*National University of Columbia, Bogota*)

18.05
Quantum Phase transitions: links to other concepts (part 1)
P. Cejnar (*Charles Univesity, Czech Republic*)

22.05
Quantum Phase transitions: links to other concepts (part 2)
P. Cejnar (*Charles Univesity, Czech Republic*)

23.05
Introduction to string theory (part 9)
C. Ewerz (*ECT*, Trento*)

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Introduction to string theory (part 10)
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24.05
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A. Lichtl (*Carnegie Mellon University, Pittsburg*)

26.05
Challenges for perturbative calculations at the LHC
C. Anastasiou (*ETH, Zurich*)

31.05
Introduction to string theory (part 11)
C. Ewerz (*ECT*, Trento*)

01.06
Introduction to string theory (part 12)
C. Ewerz (*ECT*, Trento*)

12.06
Introduction to string theory (part 15)
C. Ewerz (*ECT*, Trento*)

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C. Ewerz (*ECT*, Trento*)

13.06
Lattice QCD - Foot note (...related areas)
L. Scorzato (*ECT*, Trento*)

04.07
Exact Renormalisation Group and many-fermion systems
B. Krippa (*University of Manchester, UK*)

05.10
Goldstone bosons in systems without Lorentz invariance
T. Brauner (*Department of Theoretical Physics, Rez, Czech Republic*)

09.10
Few Nucleon-Systems: Present achievements and future challenges
M. Schwamb (*ECT*, Trento*)

19.10
Chiral Born-Infeld Theory: from Heisenberg model for hadron-hadron collision to Strong-Coupling Random Lattice QCD
V. Pavlovsky (*Moscow Uninversity, Moscow*)

4 The Quantum Information Processing Group at ECT*

The Quantum Information Processing Group has been presented in the previous reports. Let us recall that T. Calarco is responsible of the European QIP Roadmap for FP7, in the framework of the ERA-Pilot QIST Project, a joint effort between INFM and the Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences. Daniele Binosi has been hired to carry out the job. This section presents the ERA-Pilot Project and the coordination action QUROPE.

4.1 ERA-Pilot QIST

Coordinating Action: Structuring the European Research Area within Quantum Information Science and Technology

QIPC has been a vigorously active cross-disciplinary field drawing upon theoretical and experimental physics, computer science, engineering, mathematics, and material science that has burgeoned in Europe over the last decade, generating a wealth of high-level scientific results, and eventually reaching critical mass in many of its subfields, where European research is currently at the leading edge.

However, notwithstanding the fact that the potential of QIPC was quickly recognized by FET, whose pathfinder activity played a crucial role in the development of the field in Europe, a structuring of the area on a truly European level was lacking. In other countries most notably in the U.S.A. this structuring was much more advanced, with an overall strategy (towards quantum computing) established, a roadmap for quantum computing elaborated in 2002 and updated in April 2004, and another one for quantum cryptography published in July 2004. Since then, public QIPC funding in the U.S.A. has been spent according to the latter generally accepted strategy.

Therefore Europe lagged behind, not from the scientific point of view (Europes researchers are among the leading groups worldwide), but in terms of co-ordinating QIPC research funding and progress, and developing a broadly accepted vision regarding the future of QIPC in Europe according to which strategic decisions on the level of funding and technology focus could be made.

4.1.1 Strategic actions taken

To amend this situation, at the 5th European QIPC Workshop (September 2004 in Rome) a special session was organized by FET, titled Perspectives for QIPC in the Seventh Framework Programme. The main point was that input towards the European Commission (EC) would be needed on the part of the scientific community for the preparation of the Seventh Framework Programme (FP7). There was a general discussion on the actions to be taken with the aim of promoting QIPC research in Europe, strengthening its image in a coherent way, unifying the research community by elaborating a common European strategy and goals, and, especially, providing the required input to the European Commission, reaching decision makers in an appropriate way. It was then decided (i) to write a strategic report including an assessment of current results and an outlook on future efforts, and (ii) to expand the strategic report with a detailed technical assessment, to draw up a summary of long and

medium term goals, and to express visions and challenges for QIPC in Europe. P. Zoller was nominated as the editing author and the co-ordinator of a committee in charge of this. Work on the document started immediately afterwards. Moreover, by the end of the same month the proposal for a QIPC Coordination Action (CA) the ERA-Pilot on Quantum Information Sciences and Technologies was submitted to the European Commission, with the explicit mission of developing the basis for taking strategic decisions in QIPC, through the development of a common vision, the structuring of the community and the establishment of an early dialogue between scientists, policy makers and industries.

During the conference day of the QIPC cluster review (February 2005 in Innsbruck) a follow up discussion took place, together with the kick-off meeting of the ERA-Pilot meanwhile approved and founded. Finally, the first version of the document Quantum Information Processing and Communication: strategic report on current status, visions and goals for research in Europe (now known in the community as the European QIPC roadmap) was published in May 2005. Since then it has been updated regularly as a living document by the work-package 1 (WP1) of the ERA-Pilot QIST, of which it constitutes a true milestone, as it will contribute to determining the QIPC strategic research agenda in Europe for the next decade, serving as a guideline to both scientists and decision makers. This fact makes its continuous update by the ERA-Pilot of pivotal importance.

4.1.2 Recommendations from the initial report

As the substantial list of contributors shows, the document has been a real community effort and it has proven that the QIPC community is able to organise itself and to comprehensively present the major challenges, visions and goals ahead. This unique bottom-up approach is reflected as well in the QIPC roadmap, since it definitely gives to the document a wider perspective of the QIPC research fields rather than just a focus on specific issues, like factoring or quantum key distribution broadening the documents scope and vision (this distinctive feature of the document is known as the European flavour).

As far as the recommendations that have emerged from the initial report are concerned, two are worth a special mention. First of all given that at present there are no fundamental obstacles to the building of quantum information technologies the only risk of slowing down Europe in this race put forward by the authors is the lack of EU and regional funding. In fact, if funding is maintained at present levels we could start to lag behind the US, not to mention other countries that are coming up fast in this area, such as Australia and Japan. This is why foreseeing a higher funding level for QIPC in FP7 is so essential to the maintenance of European research at the forefront in this area. On the other hand, given that it is too early to pick up a winning technology for the implementation of quantum computing devices, the roadmap recommends that the spectrum for research funding should be kept as wide as possible, and even open to blue-sky research, since it might well be the case that the winning technology has not been discovered yet.

As already mentioned, the European QIPC roadmap is updated in the living document spirit; since it first appeared, the ERA-Pilot has sought for as wide a discussion as possible within the community. During all the European QIPC workshops special sessions are organized in which the status report of the document is discussed and reviewed; and for any planned updating of the document, calls for changes/addenda to the reports are sent out to

practically all the European QIPC groups. Moreover, the ERA-Pilot WP1 has supported on its website the consultation procedure for FP7 which was requested by FET: as a result of this consultation forum, the QIPC roadmap has been backed up with the support and the endorsement of virtually all leading European QIPC scientists.

4.1.3 More project results

The QIPC roadmap has clearly paved the way towards a stronger structuring of the European QIPC community; however, there have been other issues (such has the development of a generally accepted classification scheme of QIPC topics, an overview of QIPC related activities and actors within Europe, an overview of funding agencies in the QIPC areas both European and worldwide) that the ERA-Pilot has endeavoured to pinpoint and work out.

In particular, WP1 has delivered a comprehensive Quantum Information Classification Scheme (QICS) a four-level in-depth hierarchical classification scheme of QIPC related topics (with the narrowest term giving the most detailed characterization) which is currently being used by the European Physics Journal D to classify articles in the field of QIPC, and could be used by the EC to classify QIPC related project calls (by the way, notice that all the research projects described in the present publication are classified according to the QICS scheme). Contacts with the American Institute of Physics (AIP) Physics and Astronomy Classification Scheme (PACS) committee have been made, and a proposal for changes in the PACS scheme for accommodating QICS, has been submitted by WP1. The PACS committee has approved the suggested changes, which will appear in the 2008 PACS revision (to be released around September 2007.) The full list of QICS codes is reported at the end of the publication.

In addition, the ERA-Pilot WP3 has endeavoured to complete a task of major importance and urgent need, namely the cartography and analysis of the existing QIST structures (research groups, initiatives, funding agencies and funding schemes) in Europe on national and regional level. In fact, even if it is true that a global European structuring is only beginning to take shape, local structuring has already taken place within some European countries: national funding programmes and clustering of groups with similar and/or complementary research activities have occurred during the last few years, showing that the importance of QIPC research has been recognized by national authorities. It is therefore important to gather intelligence on these existing structures, in order to exploit already existing synergies and elaborate a more effective policy on European QIPC funding (in particular within the upcoming FP7.)

WP2 has a similar task to carry out, but this time on a world-wide level. The point would be in this case to gather intelligence and to analyze how QIPC research areas outside Europe (e.g., in the U.S.A., Japan, Australia and Singapore) are organized, with particular emphasis on the applicability of such structuring to the European situation. Moreover a very important task of this workpackage will be the organization of a small informal bilateral meeting between EU and US representatives of the scientific community and of funding agencies in order to start building up a platform for international cooperation. Last but not least, WP2 has also developed a fresh approach to the way of evaluating high risk scientific projects, which may be useful for the practice of different funding agencies.

4.1.4 The future

The ERA-Pilot has a unique flexible structure that has allowed a continuous adaptation of its workpackages (mainly WP1, WP2 and WP3) in order to meet the new and fast changing needs of the research community; moreover it will also benefit from an extension of its duration of at least at 8 months.

However, as it should be clear from the outset, an important point for all the CA type of projects is the development of proposals on how their outcomes could be maintained in a sustainable way as well as how the success of the suggested measures could be evaluated. To this end the team of WP1 has worked intensively in the preparation and writing of the proposal for a new CA QUROPE (see its description in this same publication) that was submitted in the last FP6 call (September 2005), and scored first among all the proposals submitted. Its work started in September 2006. QUROPE has been partially tailored to complement, expand and gradually (as it ends) take over from the ERA-Pilot QIST project practically all of its crucial tasks (such as that of regularly updating its living documents, or maintaining the databases on QIPC groups and funding agencies). The overlap period between the ERA-Pilot QIST and QUROPE, together with the fact that many of the people involved in the former CA will be also playing leading roles in the latter, building on their valuable experience, will ensure the necessary continuity and smooth transitional phase.

To summarize, the future of the QIPC field in Europe and worldwide critically depends on the ability to identify feasible research directions and goals which, when achieved, will make quantum communication and computing a source of further inspiration for the scientific community at large and will provide clear benefits for society. We think that the ERA-Pilot QIST has paved the way for attaining this goal.

4.2 QUROPE

Coordinating Action: Quantum Information Processing and Communication in Europe

QIPC is by now one of the most active research areas in natural sciences, with a strong interdisciplinary aspect, as it involves such various fields as Experimental and Theoretical Physics, Computer Science, Mathematics, Information Theory, Chemistry and Material Sciences. Just like Quantum Physics has revolutionized science in the 20th century, QIPC may well revolutionize information processing in the 21st century. In fact, it has the potential to influence many areas of science and technology, and we can only speculate about its impact at various levels on society, based on the impact that Quantum Physics had during the last 100 years. Thus, the importance of the emergence of completely new areas of technology for the future European information society can hardly be overestimated.

From the beginning, European researchers have played a major part in setting the agenda of, and leading, the worldwide research efforts in quantum information science, quantum computing and cryptography. This was done in a climate of friendly but strong competition with similar research efforts in other parts of the world, in particular the US, Australia, Canada and Japan. The results so far include pioneering and groundbreaking works that have laid the foundations for future research in the field. A unique feature and strength of the European research landscape is its broad range of activities and expertise, combining basic theoretical investigations with efforts of experimental realization.

It is evident today that QIPC research has matured in the last few years and that it has gained an important European dimension. However, its further development now requires an expansion of its activities at the European level. This has to be brought about in a well-structured and organized way in order to guarantee the further systematic advance of the European QIPC community in an orderly and democratic fashion. The common vision regarding the future of QIPC in Europe (see the corresponding description) that has been established by the ERA-Pilot coordination action, has to be further developed and some strategic decisions have to be made accordingly. This is the main reason for why QUROPE (Quantum Information Processing and Communication in Europe) came into existence.

QUROPE is an FP6 Coordination Action program that aims at harmonizing all efforts at the European level towards a unified, participated and strong community in QIPC research in Europe. Given the current situation, as outlined above, the objectives of the QUROPE project have been formulated as follows:

- Unify, structure and strengthen the QIPC scientific community in Europe
- Develop a common strategy, vision and goals at the scientific level
- Congregate and coordinate all QIPC projects / actions at the EU level
- Support integration and cross-fertilization across disciplines and subfields
- Extend investigations towards emerging new areas, topics and applications
- Encourage promising young researchers in the different QIPC fields
- Increase the general public awareness and visibility of QIPC research in Europe
- Establish international cooperation

These objectives outline a well-defined overall vision: to establish a widely recognized common strategy for the development of QIPC in Europe for the years to come, through an intensified and structured dialogue with and within the community.

The work to accomplish QUROPEs objectives, specifically to develop a common European strategy for research in QIPC, is divided into eight work packages, whose titles and main tasks are briefly outlined in the following list:

- **WP1: Management and coordination** Secure an effective progress of the project towards its various goals. Build a common strategy for QIPC in Europe.
- **WP2: Develop a common vision, strategy and goals** Carry out a complete survey of QIPC research in Europe. Elaborate a comprehensive strategic vision of current directions and future goals. Maintain and enlarge the QIPC strategic report.
- **WP3: Public outreach: increasing the public visibility and awareness of the field** Increase the general media coverage of QUROPE. Strengthen media activities of QUROPE members.

- **WP4: Electronic Information Infrastructure and Information Exchange (with a feedback channel)** Provide a mechanism to distribute information between QUROPE partners. Provide a facility to archive any generated knowledge. Develop, publish and maintain a comprehensive web site.

- **WP5: Structuring and integrating the community: Scientific meetings and dissemination activities** Steer, coordinate and support cross-disciplinary scientific meetings in QIPC in Europe.

- **WP6: Young scientists and training activities** Coordinate and support the organization of training activities in QIPC in Europe.

- **WP7: Collaboration with related well-established R&D and with industry** Initiate a steady information transfer and establish collaborations between the QIPC community and European industries.

- **WP8: International contacts between researchers communities in Europe and overseas** Organize strong and sustained international contacts between the QIPC community in Europe and those overseas. Increase the global visibility of European QIPC.

The main task of the QUROPE project as a whole is the realization of its objectives, as outlined in the list above. By doing so, QUROPE will develop a common European strategy which will be implemented by:

- provide overall coherence and support to the QIPC community

- unify and linking appropriate sub-areas and projects

- support and developing new opportunities

- bring relevant new researchers and groups into the area

- establishing links with relevant industries

It will also provide a common communication platform for its members, as well as a dissemination route to other scientific and technological communities and beyond. Finally, QUROPE will contribute to the visibility of European QIPC research to the general public, through the production of one popular documentary film and the publication of popular folders and brochures.

As already pointed out, QUROPE will complement and extend the work of the currently running FP6 Coordination Action program ERA-Pilot QIST (Structuring the European Research Area with Quantum Information Science and Technology). This program will run until September 2007, at which point QUROPE will take over and carry on with its tasks, which in particular include, but are not restricted to, the maintenance of the various databases (QIPC groups, activities and events), the European QIPC roadmap and the elaborated Quantum Information Classification Scheme (QICS)

5 BEN, the ECT* teraflop cluster

BEN, the ECT* Teraflop cluster, is now fully operational and opened to external users. This section provides a detailed technical status of the machine, as well as the list of the projects that have been running in 2006.

5.1 Report of Cluster Management

5.1.1 Status of the computing nodes

In the first plot below the red line shows that almost all the computing nodes of the BEN cluster were up almost all the time. There have been problems on some computing nodes and have been substituted. Such problems occur periodically and we are in contact with Exadron to provide a fast substitution. The single long period when the machine was unavailable happened from the 26th of August to the 6th of September, when the cooling system was partially broken. The company in charge of the maintainence of the cooling system periodically visits the installation and, in case of a fault, receives an emergency alarm which is active 24h/day. Besides that, the rack 2 has been unavailable from September to December in order to test the Apelink network cards (APE3D). The runs using APE3D communications are now always done in the rack 2.

The global CPU load is on average about 50 %. The history is also shown in the first plot. A 100% load is irrealistic because of the following: many jobs use only one processor per node in order to have more RAM available and/or faster communications; for maintenance reasons (as mentioned above); jobs in the queue are too big to fit in the available nodes; some jobs have large communications or input/output which limits the use of CPU.

The machine has been almost empty during Christmas time. This is probably due to a combined effect of Christmas holidays and new queue system (see below).

The other plot shows the communication flow, which depends very much on the application.

5.1.2 File System

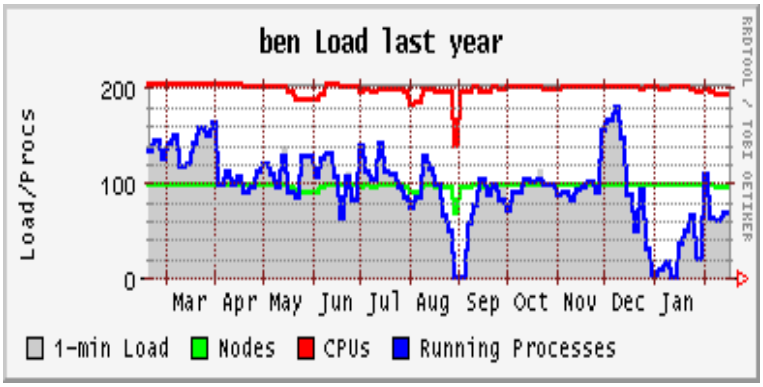
We spent quite some time to understand the origine of a "disk full" problem and to find the correct solution. The problem was difficult because the file system in BEN is unusual (mounting a so called "unionfs" file system) and in some respect unique. Finally, with the help of Alessandro Gervaso (@ exadron), the problem was fixed. We hope that this will also prevent some crashes in the machine.

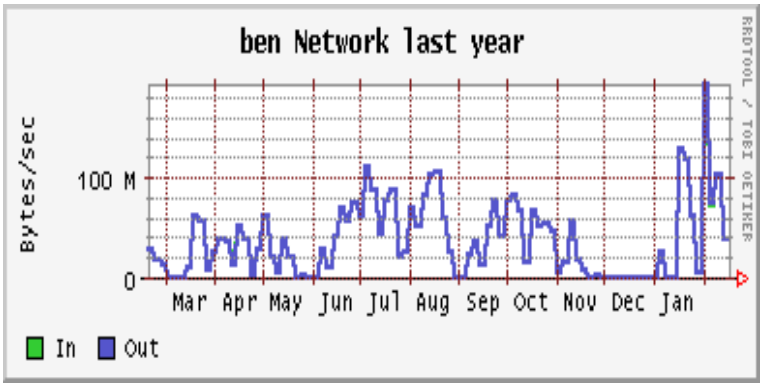
The filesystem was probably also responsible for some crashes of the queue system. After we changed the server of the queue system (from ben to c2-0), the problem disappeared.

5.1.3 Queue System

We decided to introduce an important change to the queue system: there is now a time limit of 12 hours per jobs. This is due to 2 main reasons:

In future the cluster should (hopefully) deal with larger jobs (requiring many more processors than is common now). In order to give large jobs a chance to run, a queue system





typically adopt measures called "help starving". For instance, when a job is waiting in the queue since a long time (typically a big one starving to find a sufficient number of processors), no new job can start until the old (big) one has finally started. However, the procedure works without spoiling too much computer time only if there is enough turn over in the machine.

The second reason has to do with the APElink communications. It became clear (see below) that these net work cards will always be in a "testing" phase. Both for testing and for production the APElink cards require some specific computing nodes and topologies of the connections to be available: this can live together with a normal queue system, only if, again, the turn over in the machine is frequent enough.

We are offering assistance to the users who are unfamiliar with the practice of automatic re-submission of jobs.

5.1.4 New users

We contacted the new users, who are testing their codes. All sucessfully compiled their codes. One of them (Vaccari) found a problem with his code, which is strangely hanging, after a few minutes of execution. We also tested his code under different situations, but deeper investigations need to be done by the author of the code. The second one (Orginos) had some delay in testing it, because his jobs require many processors. The problem was solved with the change of policy in the queue system (see below). He is now trying to use the APE3D network cards. This works quite well for a few hours, but it fails for longer jobs (see the section about the APE3D cards).

5.1.5 New software

We installed various software in the cluster (Openmpi, GSL, Octave, Atlas, Gromacs, Rasmol, tvmet, Arpack). We considered to buy a good debugger for parallel programs. We evaluated "totalview" by etnus, but it is probably not a good choice for our system.

5.1.6 APElink network cards

We successfully used the APElink network cards to run a standard package of linear algebra (HPL), which is commonly used also as a benchmark of supercomputers (for instance the www.top500.org list is based on that). Results are very encouraging in terms of speed. Also the stability improved a lot since the last upgrade of the firmware (december 06): Now we can run real codes on the largest available connected topology ($4 \times 4 \times 2$). However, the stability is still not such to allow jobs which last many hours, which happens in the typical use of such clusters.

The INFN-Roma group and Exadron (who developed together the APE3D cards) are now collaborating to implement a new communication system, which implements Remote Direct Memory Access (RDMA). This will improve the speed. However, since the error rate of the communication is apparently not negligeable, the new system will implement also an error check after each package is sent. This reduces the speed, but it was shown to be very efficient in a custom and stripped version of MPI, developed by the INFN-Roma group. Moreover, the new system should be fully MPI compatible.

5.2 Overview of the projects running in 2006

The table shows the resources used by the jobs running under the queue system (i.e. excluding APE3D). The machine was used essentially by 6 groups: AFDMC, chiral, molcp, NSPT, pH2wave, BECPCF. The others are mainly test runs. I report below some informations about each of these groups.

5.3 Abstracts from the projects

group: AFDMC

people: Francesco Pederiva, Stefano Gandolfi

Title: Study of ground state properties of light nuclei and neutron matter with the Auxiliary Field Diffusion Monte Carlo (AFDMC) method.

Abstract: We plan to compute ground state energies and the low lying energy spectrum of light nuclei by using the Auxiliary Field Diffusion Monte Carlo (AFDMC) method. This algorithm proved itself to be extremely powerful in dealing with pure neutron matter and neutron droplets. The main advantage compared to the standard GFMC calculation is the number of nucleons that it is possible to treat, while maintaining a comparable accuracy of the results. We aim to compute ground state properties of 4He, 16O and possibly 40Ca, and also of some open-shell nucleus. We also plan to start preliminary

Group	No. jobs	days	Percent	Average No. nodes
TOTAL	3565	21492.23	100.00	8.80
AFDMC	1137	7441.56	33.53	7.71
chiral	221	6004.41	27.06	18.05
molcp	740	4003.82	18.04	9.77
NSPT	161	1920.59	8.65	4.94
pH2wave	916	1734.48	7.82	5.60
BECPCF	809	801.23	3.61	8.66
kspg	37	195.68	0.91	13.11
qnsu	47	57.76	0.26	16.90
maxwell	63	24.42	0.11	5.00
scorzato	84	7.21	0.03	15.24
HPLQ	1	1.06	0.00	1.00
Delta	5	0.01	0.00	20.45
biodcv	44	0.00	0.00	1.89

calculations on the nuclear matter, including explicit pairing effects in the wavefunction.
Update (october 2006):
The Teraflop cluster 'ben' at ECT was used to perform calculations of nuclear systems with the Auxiliary Field Diffusion Monte Carlo method. The aim of AFDMC technique is to solve the many-body Schrodinger equation for A nucleons interacting with realistic NN-potential (of the Argonne-type). In particular, we studied the equation of state of symmetric nuclear matter with the Argonne v_6' interaction (nucl-th/0607022, submitted to PRL) and the properties of several nuclei (to be submitted to PRL). We also performed calculations to study properties of neutron rich isotopes of calcium (nucl-th/0605064). At present we are working to include three-body and spin-orbit forces in the nuclear Hamiltonian, and we are studing properties of three-body forces in pure-neutron systems (neutron drops).

group: chiral

people: Pietro Faccioli, Marco Cristofoletti, John Negele, Marco Traini

Title: Study of the Chiral Extrapolation of QCD Observables Using the Instanton Liquid Model

Abstract: The calculation of moments of D.I.S. structure functions requires the evaluation of appropriate ratios of two- and three-point Euclidean hadronic correlation functions. By analyzing two-point hadronic correlation functions it is possible to determine the mass of lowest-lying hadrons with given quantum numbers. Hence, this pro ject offers as a by-product the opportunity to perform a study of the light hadron spectrum, in the Instanton Liquid Model. From such an analysis we expect to obtain important

information about the microscopic dynamics responsible for the binding of quarks and gluons in hadrons. In the Instanton Liquid Model the energy stored in the chromo-electromagnetic field between two static color point- charges does not grow linearly with the distance between the charges. In this sense, one says that instanton-induced interaction do not generate color confinement. On the other hand, in the Instanton Liquid Model the nucleon and the pion are known to be bound and their calculated masses are in excellent agreement with the experimental values. This fact points out that at least such two light hadrons can exist even in the absence of confinement. It is important to find out if also the other lowest-lying hadrons can be bound by instanton forces alone, without confinement. This would represent a strong indication that the binding of hadrons is predominantly driven by chiral dynamics while confinement, in the sense described above, plays only a secondary role.
Update (october 2006):
In this research line we made extensive use of BEN to investigate the dynamical mechansisms involved in the transiton to the chiral regime of QCD This problem is of interest as lattice QCD simulations are presently limited to pion masses greater that (approximatively) 400 MeV.

By computing the nucleon and pion masses for a wide range of quark masses, we have shown that the Interacting Instanton Liquid Model (IILM) reproduces the existing lattice data for pion masses in the range $500 - 600$ MeV. We also shown that fitting the nucleon masses, using covariant Baryon Chiral Perturbation Theory at order $o(p^4)$, we obtain chiral coefficients in good agreement with those extracted from the analysis of pion-nucleon scattering. Moreover the nucleon sigma-term extracted from our study completely agree with recent scattering data analysis. To further explore this model in the chiral regime, we have shown that the spectral density of the Dirac operator and the three-point scalar correlation function agree with the behavior expected from chiral perturbation theory for two flavors. In the IILM, we have identified a characteristic quark energy scale, $m^* = 80$ MeV, which governs the zero-mode zone and thus the scale for instanton mediated chiral symmetry breaking, and discuss its physical significance.

Recently we have started an analysis of the quark mass dependence of the low lying sector of the meson and baryon spectrum. This analysis (which is in progress) has revealed interesting features which require further numerical investigation. We have found that the constituent quark and the scalar diquark mass become degenerate as one approaches the chiral limit. This surprising fact may be the consequence of the underlying symmetry of the microscopic instanton-induced interaction and may therefore lead to new insight on the structure of the non-perturbative interaction.

References:

1) Exploring the Chiral Regime of QCD in the Interacting Instanton Liquid Model. M. Cristoforetti, P. Faccioli, M.C. Traini , J.W. Negele e-Print Archive: hep-ph/0605256 submitted to P.R.D.

2) Hadron spectroscopy in the Interacting Instanton Liquid Model M. Cristoforetti, P. Faccioli, M.C. Traini , J.W. Negele manuscript in preparation

group: molcp

people: Francesco Guerrieri, Sara Furlan, Giovanni La Penna, Silvia Morante, Gian Carlo Rossi

Title: Study of aggregation processes in proteins: Prion Protein and beta-Amyloid peptides

Abstract: By using first principle ab initio Molecular Dynamics simulations of the Car-Parrinello type, the coordination modes of Cu and other metals to the binding sites of the prion and -Amyloid proteins are investigated. Despite the large amount of available experimental data, many details of structural modifications involved in the aggregation process in the presence of metals are still unclear. Ab initio quantum mechanical simulations are a unique tool for a parameter-free investigation of such problems. Since large numbers of atoms with many electrons are involved, investigations of this type are well suited for a Linux Cluster architecture, owing to the existence of high-performance libraries and well adapted codes. The present proposal is the continuation of a previously submitted project on similar systems, whose results are briefly reviewed here.

group: NSPT

people: Y. Schroeder , F. Di Renzo, M. Laine, C. Torrero, V. Miccio

Title: NSPT for 3d gauge theories:

Abstract: Three-dimensional (3d) gauge theories are interesting for several independent reasons. Theoretically, they are simpler than four-dimensional (4d) theories in that they are superrenormalisable, yet equally non-trivial in that they display confinement and other nonperturbative phenomena. Phenomenologically, they describe the thermodynamic properties of 4d physical theories, particularly QCD, at very high temperatures. Motivated by the latter aspect, namely the reliable determination of the pressure of hot QCD at very high temperatures, we wish to make use of the former aspect, namely the possibility to obtain non-perturbative results from lattice Monte Carlo simulations of 3d gauge theories, if the perturbative ultraviolet divergences are computed up to a sufficient loop order. More precisely, we wish to determine the renormalisation constants needed for certain effective gluon condensates, by using numerical stochastic perturbation theory (NSPT). Part I of the project has been completed, and it has demonstrated that BEN meets the demands of this project in an optimal way. In Part II we wish to determine the renormalisation constants for the remaining effective gluon condensates. With the help of BEN, we have published a proof-of-concept of our strategy. For precision results, we would need to run our codes for a larger set of parameters.

group: pH2wave

people: Francesco Pederiva, Francesco Operetto

Title: Study of high pressure properties of defective solid pH2 with Shadow Wave Functions.

Abstract: We employ the SWF formalism in conjunction with variational Monte Carlo methods to study high pressure properties of solid pH2 at temperature T=0 in presence of vacancies and impurities. In particular we want to address the destructuring of the crystal due to the presence of vacancies, the vacancy-vacancy correlation, and the possible phase separation in the solid with impurities when the impuruty concentration increases.

group: BECPCF

people: Daniele Binosi et al.

Title:

Abstract: The main aim of this project is to analyze the behavior of the entanglement of disordered spin chains. In particular the models we will concentrate on comprise N states $|0_i\rangle, |1_i\rangle, \ldots, |N_i\rangle$ per lattice site i, and are described by the hamiltonian

$$\mathcal{H}_N = -\sum_{i=1}^{L-1} J_{i,i+1} \sum_{n=1}^{N-1} \left(\bar{S}_i^z S_{i+1}^z\right)^n - \sum_{i=1}^{L-1} h_i \sum_{n=1}^{N-1} \Gamma_i^n, \tag{1}$$

where L is the length of the chain, Γ represents the ladder operator $\Gamma|s\rangle = |s{+}1, \mathrm{N}\rangle$ and $S^z = e^{2i\pi\ell/N}\delta_{\ell\ell'}$ $(\ell, \ell' = 1, \ldots, N-1)$. The couplings $J_{i,i+1}$ and h_i are positive random numbers to be drawn from a suitable distribution. We will in particular concentrate on generating the aforementioned coupling from correlated distribution functions and study the effect of correlation on the entanglement of the full chain.

group: kspg

people: Antonio Rago, Biagio Lucini

Title: K-stringhe in pure SU(N) gauge theories in infinite N limit.

Abstract:

group: qnsu

people: Andreas Ipp, Maximilian Attems, Anton Rebhan, Paul Romatschke, Michael Strickland

Title: Quark-gluon-plasma instabilities in discretized hard-loop approximation

Abstract: This work will be a memory- and calculation-intensive extension of a work by AR, PR, and MS [1, 2] where the real-time evolution of instabilities in non-Abelian plasmas with a momentum-space anisotropy has been studied using a hard-loop e ective theory that is discretized in the velocities of hard particles. Previous results on the evolution of unstable modes in the gauge groups SU(2) and SU(3) in 1+1-dimensional and 3+1-dimensional simulations were limited only by the main memory of a desktop computer. This constraint shall be avoided by splitting the simulation domain into smaller pieces that t into the main memories of the nodes of a calculation cluster. Finer discretization and larger lattice sizes will allow to more accurately study the late-time behavior of anisotropic systems.

group: Delta

people: Kostas Orginos, Vladimir Pascalutsa, Marc Vanderhaeghen, Luigi Scorzato,

Title: Delta(1232) resonance electromagnetic properties in lattice QCD

Abstract: One of the major efforts in theoretical physics is understanding the properties of hadrons from first principles. The theory describing these systems is Quantum Chromo Dynamics (QCD), yet calculating the consequences of this theory is non trivial. Development of non-perturbative techniques such as lattice QCD and use of effective field theories (EFT) is required. The proposed research emphasizes the synergy amongst lattice QCD, effective field theories and hadron phenomenology, to achieve this goal. We intend to study the Delta (1232) magnetic dipole moment and its electromagnetic and axial form factors using lattice calculations in full QCD. These calculations will be done using domain wall valence quarks and staggered sea quarks, drawing on the expertise of two of us (K.O. and L.S.). Significant improvement on the precision and reliability of the results can be achieved by going beyond present calculations done in the quenched approximation and by studying these quantities close to the physical pion masses. In parallel, following up on previous work by two of us (V.P. and M.V.), we will interpret the results using the chiral EFT framework in the Delta (1232) region, and study the chiral extrapolation to the physical quark mass. The synergy between such lattice studies with chiral EFT calculations may result in reliable computations of the electromagnetic properties of the resonance at the physical point.

group: scorzato

people: Luigi Scorzato, Andrea Nobile

Title: Benchmarks of the APE3D Network.

Abstract: Tests and benchmarks of the APE3D cards.

group: maxwell

people: Alessandro Vaccari, Luca Cristoforetti, Carla Malacarne, Rolando Pontalti

Title: A MPI parallel programming implementation of a subgridding algorithm for FDTD solutions of Maxwell's equations

Abstract: In a previous activity we developed a robust and efficient three-dimensional (3-D) subgridding algorithm for the FDTD solution method of Maxwell's curl PDE system. It manages straight embedding of meshes having refinement factors of 5, 7 and more within coarser ones. In the proposed work we plan to test a MPI parallel programming implementation of that subgridding algorithm. The aim is fully exploiting the speed up capacities, in order to achieve large grid results with a more efficient algorithm.

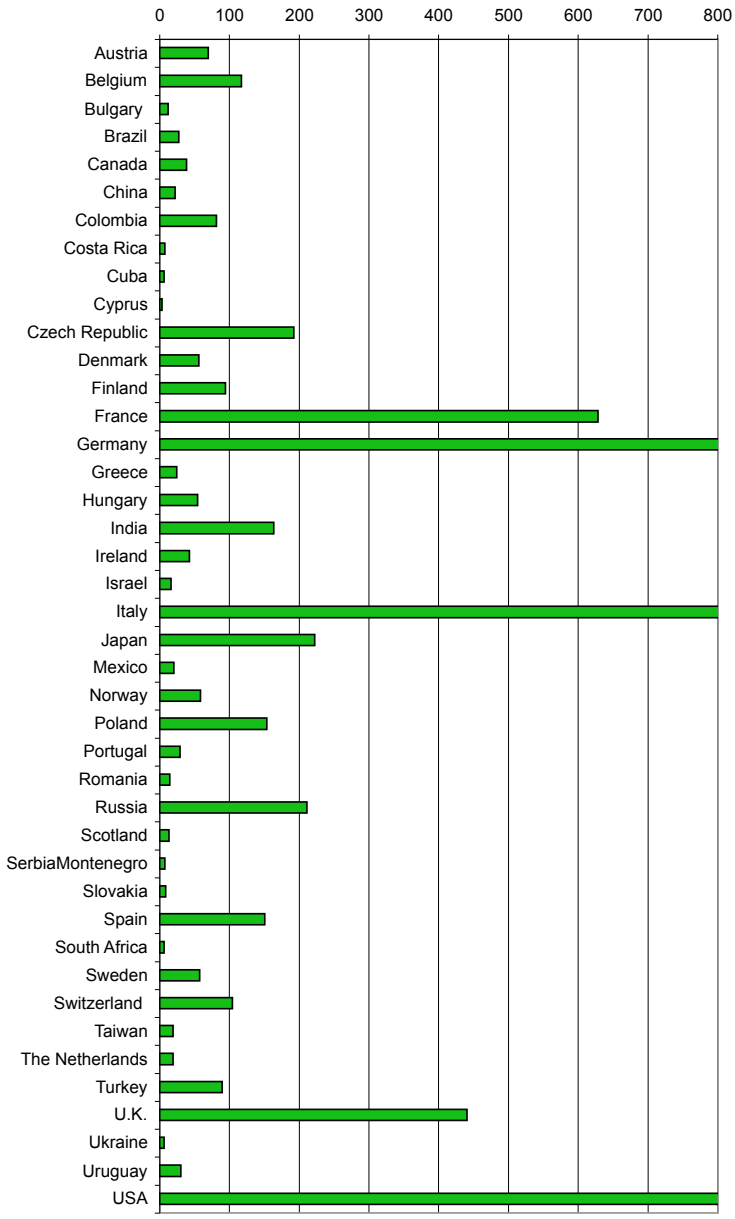
6 ECT* Computing Facilities

6.1 Available computing resources

2 license servers:	2 PC (MATHEMATICA) [10 concurrent users] 1 PC (MATLAB) [2 concurrent users]
server:	6 Dell Intel Xeon 3GHz
computation servers:	1 Alpha Bi-Processor 533 MHz (NAG libraries) 1 Dell Intel Xeon 3GHz 1 AMD Opteron 2GHz
26 PC for staff and local research:	Pentium III up to 866 MHz Pentium IV up to 2.8 GHz BI-PROC. Pentium III up to 1 GHz BI-PROC. Pentium IV up to 1.6 GHz RACK
28 PC for users:	Pentium II up to 400 MHz Pentium III up to 866 MHz Pentium IV up to 3 GHz BI-PROC. Pentium III up to 650 MHz
1 Supercomputer EXADRON:	1 Front/End and 99 computers Communication Band width Gbit/second
1 cluster ALPS:	1 Front/End and 36 CPU Communication Band width Gbit/second
1 APEmille:	128 CPU managed by 4 PC for the Input/Output and 1 Front End (64 GFlops)
1 DELL:	Power Edge 1850 Bi-Processore Xeon 3 GHz

7 Statistics

Visitor Days Spent at ECT*
(total number of visitors in 2006: 837, with France: 87, Italy: 135, Germany: 206, USA: 105)



Includes: Workshop Participants, Visiting Scientists,
Marie Curie Fellows and Lecturers