ECT*

Annual Report 2005

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

Preface

This report gives an overview of the scientific activities run at ECT* in 2005: projects in the form of workshops and collaboration meetings, training of students, local research.

Altogether, sixteen projects were run in 2005 (12 workshops and 4 collaboration meetings, gathering theorists and experimentalists). The topics span, as usual, all subfields of nuclear physics with, however, a heavy weight this year on high energy nuclear physics and hadronic physics. All these activities were quite successful as reflected in the high level of satisfaction expressed in some of the individual reports.

The ECT* advanced training programme was run for three months. The theme of the 2005 session was hadronic physics. This programme was also very successful and a severe selection had to be made among the students who had applied. Unfortunately, the proposal submitted to the EU for a renewal of the support, although rated highly, did not get funded. The Board of ECT* considers however that the training of young people is an essential mission of the Centre, and has decided that some of the ECT* resources should be made available to continue training activities.

The local research is carried out at ECT* by the director, the vice-director and the postdocs, as well as by long term visitors. In 2005 several visitors stayed at ECT* for extended periods, of up to several months. The discussion, that had started a year ago with the Hadron Physics I3, came to a positive conclusion and a joint position in hadron physics could be opened at the end of the year. This will contribute to strengthen the research effort at ECT* in the very near future. Detailed reports concerning the research carried out by ECT* fellows are given in this document.

BEN, the ECT* Teraflop Cluster, has been completed and is now fully operational. Two positions are attached to this project, supported by the Province of Trentino and administered by INFN. One of these positions is occupied since November by Andrea Nobile who succeeded Pierfrancesco Zuccato as a system administrator. We expect the second position to be filled shortly. The opening of BEN to external users requires access to a line with a larger bandwidth than that presently available. Negotiations with INFN are on the way, and we anticipate these to be concluded shortly.

Scientific contacts with the department of physics of the University of Trento have been strengthened by the appointment of Marco Traini as Vice-Director of ECT* at the end of 2004. Regular common activities have started (Joint theoretical physics seminar, regular informal exchanges with the physicists of the Bose-Einstein Condensation Center, etc.). A joint postdoc position is also been considered starting in 2006.

All these activities are made possible thanks to the generous and continuous support of the Istituto Trentino di Cultura, and regular contributions from funding agencies in various European countries, as well as EU grants (in particular EURONS I3 provides substantial support for "transnational access"). While the funding of ECT* has reached a level of stability allowing us to embark in long term actions (e.s. the joint position with Hadron Physics I3), the number of high quality projects submitted to ECT* remains high. Also some resources are fluctuating (e.s. grant supporting the training programme). This invites

us to continue looking for extra resources. Actions to this aim have been undertaken towards various European countries which may be able to support ECT*, but have not done so until now; this effort will be pursued in 2006.

Due to its missions, ECT* welcome each year a large number of visitors. In order to reduce the cost of housing, in particular for the students participating in the various training activities, ECT* has been allowed to rent a large apartment in S. Donà, a small village near Povo. This apartment, which has been completely renovated, can host comfortably nine visitors. We hope that it will become a regular "guest house" for ECT*, and that our visitors will like to stay there.

Finally, I wish to emphasize that the success of ECT* rests also on its diligent and dedicated staff. To all I would like to address my warmest thanks, with special thanks to Stefania Campregher for her assistance in preparing this document.

Jean Paul Blaizot Director, ECT*

PS. While giving the last touch to this report, the very sad news of the death of Vijay Pandharipande reached us. Vijay was a member of the Board of Directors and was still with us at the last meeting in September. We benefited a lot from his profound vision of the field, his sharp remarks on the proposals we had to examine, and appreciated above all his warm personality. Vijay was much loved by his many friends and highly respected by his colleagues. His death represents a great loss for the scientific community.

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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
Marcello Baldo (until June 2005)	INFN, Catania, Italy
Michael Birse (from February 2003)	University of Manchester, UK
Peter Braun-Munzinger (from October 2002 - chairman)	GSI, Darmstadt, Germany
Muhsin Harakeh (from February 2003 - NuPECC)	KVI, Groningen, Netherlands
Paul Hoyer (from October 2004)	University of Helsinki, Finland
Frithjof Karsch (from October 2004)	Bielefeld University, Germany
Elvira Moya de Guerra (until June 2005)	C.S.I.C. Madrid, Spain
Vijay Pandharipande (from February 2004)	University of Illinois, Urbana-Champaign, USA
Friederich-Karl Thielemann (from October 2004)	Department of Physics and Astronomy, Basel, Switzerland
Piet Van Isacker (from September 2005)	GANIL, Caen, France

Honorary Member of the Board:

Professor Ben Mottelson	NORDITA, Copenhagen, Denmark

ECT* Director:

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

ECT* Vice Director:

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

ECT* Scientific Secretary:

Professor Renzo Leonardi	ECT* and University of Trento

1.2 ECT* Staff

Ines Campo	Technical Programme Co-ordinator
Stefania Campregher (from July 2004)	Technical Programme Assistant
Corrado Carlin	Maintenance Support Manager
Cristina Costa	Technical Programme Co-ordinator
Barbara Currò Dossi	System Manager
Susan Driessen (from June 2005)	Assistant to the Directors
Gianni Fattore (from February 2004)	System Manager
Domenico Gonzo (from February 2004)	System Manager
Tiziana Ingrassia	Accounting Assistant
Mauro Meneghini	Driver and Maintenance Support Manager
Donatella Rosetti (Rachel Weatherhead on maternity leave until June 2005)	Assistant to the Directors
Gianmaria Ziglio	Web Manager

1.3 Resident Postdoctoral Researchers and supported Students

- **ECT* postdocs:**

Daniele Binosi (Spain) (from January 2004)

Carlo Ewerz (Germany) (from October 2005)

Luca Girlanda (Italy) (until April 2005)

Andreas Hiroichi Ipp (Austria)(from September 2004)

Olivier Leitner (France) (until December 2005)

Claudia Ratti (Italy) (from August 2005)

Dionysis Triantafyllopoulos (Greece) (from October 2005)

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

Tommaso Calarco (Italy) (from June 2003)

Markus Antonio Cirone (Italy) (from October 2004)

Antonio Negretti (Italy) (from September 2004)

Christian Trefzger (Italy) (until July 2005)

Alessio Recati (Italy) (from October 2004)

- **ECT* supported students:**

Marco Cristoforetti (Italy) (from July 2004)

Sara Della Monaca (Italy) (from January 2004)

- **Associate researchers:**

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

- **Teraflop Cluster:**

Pierfrancesco Zuccato (Italy) (until May 2005)

Andrea Nobile (Italy) (from November 2005)

1.4 Marie Curie Fellows

Cyril Adamuscin (Slovak Republic)	Slovak Academy of Sciences
Adam Bzdak (Poland)	Krakow University
Vicent Mateu Barreda (Spain)	University of Valencia
Stefan Michalski (Germany)	University of Dortmund
Matthias Ralf Schindler (Germany)	University of Mainz
Adam Smetana (Czech Republic)	University of Prague

1.5 Visitors in 2005

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

Shahin Sabir Oglu Aghayev	Baku State University , Azerbaijan (VS)
Deborah Nancy Aguilera	University of Rostock, Germany (TP)
Ziad Jean Ajaltouni	Laboratoire de Physique Corpuscolaire, France (VS)
Bindu Anubha Bambah	University of Hyderabad, India (VS)
Gordon Baym	University of Illinois, USA (VS)
Petr Benes	Nuclear Physics Institute AS CR, Czech Republic (TP)
Michael Charles Birse	University of Manchester, UK (VS)
Mark Anthony Caprio	Yale University, USA (VS)
Frank Close	Oxford University, UK (TP)
John Collins	Penn State University, USA (TP)
Christine T.H. Davies	University of Glasgow, UK (TP)
Magali Estienne	SUBATECH, France (TP)
Teresa Fernàndez-Caramés	University of Valencia, Spain (TP)
Hilmar Forkel	IFT-UNESP, Brasil (VS)
Hirotsugu Fujii	University of Tokyo, Japan (VS)
Charles Gale	McGill University, Canada (VS)
Francois Roland Gelis	CEA Saclay, France (VS)
Ivana Hristova	DESY, Germany (TP)
Francesco Iachello	Yale University, USA (VS)
Edmond Iancu	CEA Saclay, France (VS)
Santosh Kumar Karn	U P Technical University, India (VS)
Maxim Khlopov	University of Rome "La Sapienza"(VS)
Evgueni Kolomeitsev	University of Minnesota, USA (TP)
Olga Lakhina	Oxford University, UK (TP)
Jean-Philippe Lansberg	University of Liége, Belgium (TP)
Dimitris Lenis	Institute of nuclear physics NCSR, Greece (VS)
Vadim Lensky	Institut fr Kernphysik, Germany (TP)
Cédric Serge Corinne Lorcé	University of Liége, Belgium (TP)
Aneesh Manohar	University of California, USA (TP)

Nicholas Stephen Manton	University of Cambridge, UK (VS)
Nicolas Matagne	University of Liége, Belgium (TP)
Jean-François Mathiot	Laboratoire de Physique Corpusculaire (VS)
Testuo Matsui	University of Tokyo, Japan (VS)
Ramon Mendez Galain	University Montevideo, Uruguay (VS)
Piet J. Mulders	Vrije University, Netherlands (VS)
Yusuke Nishida	University of Tokyo, Japan (TP)
Henri Orland	CEA Saclay, France (VS)
Francisco Perez Bernal	Huelva University , Spain (VS)
Massimiliano Procura	TU Munich, Germany (VS)
Claudia Ratti	TU Munich, Germany (VS)
Felix Riek	GSI, Germany (TP)
Georges Ripka	CEA Saclay, France (VS)
Stefan Scherer	University of Mainz, Germany (TP)
Grégory Soyez	SPht, CEA Saclay, France (VS)
Federica Sozzi	University of Trieste, Italy (TP)
Donato Giorgio Torrieri	McGill University, Canada (VS)
Dionysis Triantafyllopoulos	CEA Saclay, France (VS)
Christian Türk	University of Torino, Italy (TP)
Annelies Van Dyck	University of Gent, Belgium (TP)
Marc Vanderhaeghen	College of William and Mary and Jefferson Lab., USA (TP)
Raju Venugopalan	Brookhaven National Laboratory, USA (VS)
José Maria Verde Velasco	University of Salamanca, Spain (TP)
Aleksi Risto Johannes Vuorinen	University of Washington, USA (VS)
Wolfram Weise	TU Munich, Germany (VS)
Wschebor Pellegrino Nicolas	University Montevideo, Uruguay (VS)
Zhenyu Ye	DESY-HERMES, Germany (TP)

2 Scientific Activities in 2005

2.1 Summary

Altogether, 16 projects have been run at ECT* in 2005 (12 workshops and 4 collaboration meetings), in addition to the ECT* advanced doctoral training programme.

This chapter contains the scientific reports prepared by the organizers of each project. G. Ripka, who assisted the Director in the running of the training programme, contributed to the preparation of the corresponding report.

2.2 Workshops and Collaboration Meetings in 2005

21–25 Feb. **Exotic hadrons**
Organisers: S. Kabana (Co-ordinator) (*CERN, Switzerland*),
V. Guzey (*Ruhr-Univ. Bochum*),
M. V. Polyakov (*Univ. of Liege and St Petersburg Nuclear Physics Institute*) [p. 9]

9–14 May **Partonic structure of hadrons (Concepts and Phenomenology)**
Organisers: S. Kretzer (Co-ordinator) (*Brookhaven Nat. Lab.*),
M. Grosse Pederkamp (*Loomis Lab.*),
M. Stratmann (*Univ. of Regensburg*),
W. Vogelsang (*Brookhaven Nat. Lab.*) [p. 11]

19–21 May **Investigation Protein Dynamics with Theoretical Physics Methods Collaboration Meeting**
Organisers: L. Pieri (Co-ordinator) (*Univ. of Stockholm*),
P. Zuccato (*Exadron and ECT**),
F. Pederiva (*Univ. of Trento*),
P. Faccioli (*Univ. of Trento*) [p. 13]

23–28 May **Two-photon physics**
Organisers: M. Vanderhaeghen (Co-ordinator) (*College of William and Mary and Jeffer*
C. Carlson (*College of William and Mary*),
B. Pasquini (*Univ. of Pavia*) [p. 15]

2–11 Jun. **Electromagnetic probes of hot and dense matter**
Organisers: R. Rapp (Co-ordinator) (*Texas A & M Univ.*),
C. Gale (*McGill Univ.*),
P. Braun-Munzinger (*GSI Darmstadt*) [p. 17]

13–17 Jun. **Charge symmetry breaking and other isospin violations**
Organisers: C. Horowitz (Co-ordinator) (*Indiana Univ.*),
C. Hanhart (*Inst. für Kernphysik Jülich*),
G. Miller (*Univ. of Washington*) [p. 20]

20 Jun.–1 Jul. **Nuclear forces and QCD: never the twain shall meet?**
Organisers: J. McGovern (Co-ordinator) (*Univ. of Manchester*),
R. G. E. Timmermans (*Univ. of Groningen*),
B. F. Gibson (*Los Alamos Nat. Lab.*),
U. van Kolck (*Univ. of Arizona*) [p. 22]

4–9 Jul. **Highly excited hadrons**
Organisers: L. Ya. Golzmann (Co-ordinator) (*Univ. of Graz*),
T. D. Cohen (*Univ. of Maryland*),
E. Swanson (*Univ. of Pittsburgh*) [p. 24]

11–16 Jul. **Resonances in QCD**
Organisers: M. F. M. Lutz (Co-ordinator) (*GSI Darmstadt*),
J. Nieves (*Univ. of Granada*),
U. Thoma (*Univ. of Giessen*),
U. Wiedner (*Univ. of Uppsala*) [p. 26]

18–23 Jul. **Effective theories in nuclear physics and lattice QCD**
Organisers: A. Parreño (Co-ordinator) (*Dept. ECM, UB, Barcelona*),
P. F. Bedaque (*Lawrence Berkley Nat. Lab.*),
E. Pallante (*Univ. of Groningen*) [p. 28]

25–30 Jul. **Probing microscopic structure of the lightest nuclei in electron scattering at Jlab energies and beyond**
Organisers: M. M. Sargsian (Co-ordinator) (*Florida International Univ.*),
C. Ciolfi (*Univ. of Perugia*),
M. Strikman (*Pennsylvania State Univ.*) [p. 31]

8–10 Sept. **Weak-coupling expansion for the pressure of hot QCD**
Collaboration Meeting
Organisers: M. Laine (Co-ordinator) (*Univ. of Bielefeld*),
Y. Schröder (*Univ. of Bielefeld*) [p. 34]

12–17 Sept. **The new physics of compact stars**
Organisers: D. Blaschke (Co-ordinator) (*Univ. of Bielefeld*),
J. Margueron (*IPN Orsay*),
J. Trümper (*MPE Garching*) [p. 36]

19–21 Sept. **Understanding the structure of nucleon-deficient Pb nuclei**
Collaboration Meeting
Organisers: K. Heyde (Co-ordinator) (*Dept. of Subatomic and Radiation Physics, Gent*)
P. Van Duppen (*Instituut voor Kernen stralingsfysica, Leuven*),
R. Julin (*Accelerator Lab., Jyväskylä*) [p. 39]

26 Sept.–7 Oct. **Parton propagation through strongly interacting matter**
Organisers: W. K. Brooks (Co-ordinator) (*T. Jefferson Nat. Accelerator Facility*),
B. Z. Kopeliovich (*Max-Planck Inst., Heidelberg*),
U. Mosel (*Univ. of Giessen*),
V. Muccifora (*INFN, Frascati*),
X. N. Wang (*Lawrence Berkeley Nat. Lab.*) [p. 42]

7–11 Nov. **Many-body techniques at high energies:**
electroweak scattering on nuclei versus the physics of the QGP
Collaboration Meeting
Organisers: A. Molinari (Co-ordinator) (*Univ. Turin and INFN Turin*),
M.B. Barbaro (*University of Turin and INFN*),
T. W. Donnelly (*CTP, LNS and Dep. of Phys., MIT, Cambridge, USA*) [p. 45]

2.3 Reports on Projects and Collaboration Meetings

2.3.1 EXOTIC HADRONS

DATE: 10–12 Feb

ORGANISERS:
S. Kabana (Co-ordinator) (*CERN, Switzerland*), V. Guzey (*Ruhr-Universit*), M. Polyakov (*Liege University and St Petersburg Nuclear Physics Institute*)

NUMBER OF PARTICIPANTS: 25

MAIN TOPICS:

- recent experimental results on the Θ^+, Ξ^{--} and Θ_c^+ pentaquark baryons
- status of exotic baryons
- theoretical and phenomenological studies of exotic baryons

SPEAKERS:

T. Anticic (*CERN*),
T. Cohen (*Maryland*),
W. Eyrich (*Erlangen*),
Z. Fodor (*Wuppertal*),
M. Graham (*SLAC*),
V. Guzey (*Bochum*),
K. Hicks (*Ohio*),
E. Klempt (*Bonn*),
V. Kouznetsov (*INR, Moskow*),
K. Lipka (*DESY*),
N. Manton (*Cambridge*),
M. Neubauer (*Fermilab*),
P. Ouyang (*UC, Santa Barbara*),
C. Petrascu (*Frascati*),
P. Pobylitsa (*Bochum*),
M. Polyakov (*Liege and St Petersburg*),
M. Praszalowicz (*Krakow*),
J.-M. Richard (*LPSC, Paris*),
Fl. Stancu (*Liege*),
A. Szczepaniak (*Indiana*)

SCIENTIFIC REPORT:

Aim and Purpose:
The aim and purpose of the workshop was to present most recent experimental and theoretical results addressing the status of pentaquark baryons, the Θ^+, Ξ^{--} and Θ_c^+. By bringing together supporters and critics of the baryon pentaquarks, we attempted to organize a fruitful exchange of ideas which would clarify the experimental and theoretical arguments in favor or against the existence of the pentaquarks.

Results and Highlights
The main results of the workshop include:

- Presentation of positive results on the Θ^+ search at Spring-8 and COSYTOF
- The much expected JLab Θ^+ data could not be yet reported: the existence of the Θ^+ is an open issue

- New analysis and confirmation of the positive result on the Ξ^{--} search by NA49 at CERN
- Presentation of the charmed pentaquark $Theta_c^+$ results by H1 at DESY
- Presentation of null results on the $Theta^+$ search at CDF and BaBar
- An indication of clear experimental prospectives to study non-exotic members of the antidecuplet at several experimental facilities such as GRAAL, COSY-TOF, JLab and CERN
- A rather broad agreement that the existence of narrow baryon pentaquarks does not follow from large-N_c QCD and that a much deeper understanding of effective theories based on QCD is required in order to address the issue of anomalously narrow pentaquarks

Conclusions

Experimental talks at the workshop reflected the current controversy surrounding the Θ^+: while a number of low-energy experiments see the Θ^+ signal, there is a similar number of high-energy experiments which do not see the Θ^+ and other exotics. It is generally hoped that the much anticipated JLab deuterium data will clarify the issue of the Θ^+ existence.

Studies of the pentaquark states on the lattice are extremely difficult. Therefore, it appears that the lattice QCD will not be able to significantly contribute to the pentaquark research.

It is important to note that the Θ^+ must be accompanied by other members of the antidecuplet. The GRAAL experiment observes a new nucleon-like state, whose mass and the fact that it is predominantly photo-excited on neutrons rather than on protons strongly support its antideduplet nature. Other experiments (COSY-TOF, JLab, NA49) also have a potential to study non-exotic members of the antidecuplet.

The main outcome of the theoretical talks at the workshop is a general consensus that the large-Nc QCD does not justify the existence of narrow pentaquark states (one example is the collective coordinate quantization of the Skyrme model). The narrow width of the Θ^+ originally obtained in the quark soliton model is not understood and is probably the most challenging theoretical question in the field. Most likely a much deeper understanding of the large-Nc QCD is required to solve this puzzle.

The talks of the workshop can be browsed from the website:
http://www.tp2.ruhr-uni-bochum.de/vortraege/workshops/trento05/index.shtml?lang=en.

2.3.2 PARTONIC STRUCTURE OF HADRONS (CONCEPTS AND PHENOMENOLOGY)

DATE: 9–14 May

ORGANISERS:
Stefan Kretzer (Co-ordinator) (*Brookhaven National Laboratory*), Matthias Grosse Perdekamp (*University of Illinois*), Marco Stratmann (*University of Regensburg*), Werner Vogelsang (*Brookhaven National Laboratory*)

NUMBER OF PARTICIPANTS: 29

SCIENTIFIC REPORT:

As we enter the era of perturbative QCD calculations at NNLO, the ever-increasing accuracy of pQCD calculations has made the parton model an indispensable tool for collider phenomenology. The ongoing workshop series *HERA and the LHC* (`www.desy.de/~heralhc`) exemplifies such current trends where the "parton model" has become more or less synonymous with the well-established leading twist pQCD formalism modulo, perhaps, traces of low-x asymptotics such as BFKL and, ultimately, saturation.

At the same time, the mature status of QCD as well as the wealth of precision data offer the opportunity to re-investigate the borderline to hadronic phenomenology at comparatively low energies where it is less obvious that hadrons are resolved into their partonic degrees of freedom. In this region, theoretical approaches in terms of quarks and gluons are bound to be conceptually more involved. At the same time they open up a window on aspects of QCD which prove to be rich in structure even in the perturbative regime.

In the past, research along such lines often has been qualitative in nature or model dependent. We have brought together theorists who have done seminal work on the conceptual foundations of pQCD with phenomenologists and experimenters in the field of hadron structure. Our hope was to facilitate and contribute to serious phenomenological assessments, where the underlying theoretical questions are formulated in ways that lend themselves to quantitative answers and experimental tests.

It remains to be said that the presentations and the discussions at the workshop have very satisfyingly met our expectations, and have contributed their share to a firm theoretical basis for the interpretation of recent experimental results such as from COMPASS, HERMES, Jlab and RHIC, as well as for future measurements at GSI.

Numerous students of the *ECT* DOCTORAL TRAINING PROGRAMME 2005* on *HADRON PHYSICS*. have sneaked into the workshop sessions. We are glad to have been able to provide them with an opportunity to pick up some recent research trends and to get a first impression of vivid scientific discourse.

The workshop did assess partonic approaches at subasymptotic energies through a few topics, selected according to their relevance for the interpretation of current experiments. The following topics have particularly profited from synergies at the workshop:

- Inclusive high $p_\perp$ particle production in the small-to-medium GeV range: Based on presentations by Barish and De Florian we had extensive discussions that also involved Vogelsang and Brodsky. Key measurements and analyzes where identified to distinguish perturbative production mechanisms from constituent exchanges.

- Semi-inclusive DIS at COMPASS, HERMES and Jlab: Current measurements, as presented by Aschenauer, Mallot, and Jiang will benefit from a critical analysis as outlined by Christova and ultimately global data analysis of the type suggested by Saito.

- Models for parton densities and fragmentation functions: With respect to the so far limited data, theoretical models are required to advance our understanding of non-standard – in particular non-collinear – partonic structure functions. Such models were presented by Radici, Anselmino, Pijlman, Leader, Mulders, Baccheta, Menzel and Burkhardt, and discussed with respect to their experimental manifestation, see slides by Bland and Grosse Perdekamp. See also Agaev's and Gardi's talk for interesting aspects of parton densities in light and heavy mesons.

- High order QCD: Vogt reported on the impressive recent advances in NNLO QCD perturbation theory.

- Duality: We heard Keppel's overview of duality studies at Jlab, Reno discussed duality and other topics that need to be assessed to understand neutrino interactions.

- Outlook: The workshop topics were introduced by Metz, Brodsky and Lenisa gave us an outlook on theoretical and experimental developments.

The very lively workshop atmosphere stimulated broad and extensive discussions that helped relate the above topics to concepts such as

- Factorization / Resummations / Power corrections

- Duality

- Chiral symmetry breaking

- Light cone wave functions

The generous support through the ECT* and money provided through an NSF grant at the University of Illinois at Urbana-Champagne made it possible to invite several participants who would have been unable to cover their costs through their home institutes.

2.3.3. INVESTIGATION PROTEIN DYNAMICS WITH THEORETICAL PHYSICS METHODS

(Collaboration Meeting)

DATE: 19–21 May

ORGANISERS:
L. Pieri (Co-ordinator) (*Univ. Stockholm*),
P. Faccioli (*ECT* and Univ. of Trento*) F. Pederiva (*ECT* and Univ. of Trento*) P. Zuccato (*ECT* and Exadron*)

NUMBER OF PARTICIPANTS: 40

SPEAKERS:

C. Broglio (*Trento Univ.*),
G. Colombo (*CNR, Milano*),
P. Faccioli (*Trento Univ. and ECT**),
F. Fogolari (*Udine Univ.*),
E. Melloni (*Genoa Univ.*),
C. Micheletti (*SISSA, Trieste*),
F. Pederiva (*Trento Univ.*),
L. Pieri (*Stockholm Univ.*)

SCIENTIFIC REPORT:

Scope of the Meeting

The main purpose of this Collaboration Meeting was to coordinate the research activity of a inter-disciplinary scientific collaboration devoted to the study of protein dynamics. The underlying motivation for bringing theoretical physicists together with experimental and theoretical biologists, biophysicists and biochemists is that of exploiting the nuclear physicists know-how in the theoretical description of strongly correlated many-body systems. In this context, the collaboration has been so far involved in the development of the following two investigations:

- **Path Integral approach to protein folding. (P. Faccioli, T. Garel, H. Orland, F. Pederiva)**
  This research line is based on the observation that the diffusive dynamical evolution in a protein folding process can be formally re-written in terms of a quantum transition amplitude (path integral). Four theoretical physicists in the collaboration are combining functional integral and numerical methods to determine the most probable folding path, which proteins follow, during the folding process.

- **Study of the time-evolution of the fibrillar structures of human β-2m. (G. Esposito, F. Fogolari, L. Pieri, P.Zuccato)**
  This research line aims to study the aggregation through fibrils in the -structures of selected human proteins, associated to amyloidoses diseases, by means of numerical molecular dynamics simulations performed with the E.C.T.* teraflop cluster. In particular, part of the collaboration has simulated the evolution of an ensemble of human

-2m proteins. This is one of the 17 proteins associated to this disease and is being studied experimentally by members of the collaboration (Prof. Esposito group).

Specific Activity Performed During the Meeting

The specific activity planned and performed during the two-day collaboration meeting was the following:

- Presenting and analyzing the results obtained so far in the context of the two main projects in which the collaboration is presently involved.
- Setting-up the next steps of development of the investigations.
- Performing round-table discussions in order to establish possible connections between the two projects.
- Establishing connections with other groups involved in related research, in the Trento area.

The following scientific results were presented in this meeting for the first time:

- Development of the theoretical framework for a path integral approach reaction path ways and application to the study of test problems of diffusion
- Preliminary results of the numerical simulations on beta-2m fibril aggregation performed at E.C.T.*

Summary and Conclusions

An important goal of the meeting was to show that such an interdisciplinary collaboration could lead to cross-fertilizing exchange of ideas and methodology, between theorists and experimentalists coming from different areas of Science. We can say that this goal has been fully achieved: in fact, the participants have immediately managed to establish a common working language, despite their different scientific back-grounds. Each discussion session has been extremely animated and characterized by a remarkable exchange of information between theorists and experimentalists and well as between physicists, bio-chemists and biologists.

Another important goal of the meeting was to allow the project developers to make progress in the specific investigations they are involved. Also this goal has been achieved. More specifically:

- In the context of Project 1 (Path Integral Approach to Protein Folding):
  - A potential problem with the approach under development, related to the failure of the semiclassical-like approach under some conditions has been discussed and solved
  - The choice of the specific theoretical model to be implemented in the study of realistic protein folding has been made
  - The choice of the protein to be studied has been made
  - The next steps of the projects have been discussed and identified
- In the context of Project 2 (Study of the time-evolution of the fibrillar structure of human β-2m):

– The preliminary results on the theoretical simulation of the initial stage of aggregation have been presented and discussed. During the discussion it has been observed that such numerical simulations (which were performed at ECT*) are in agreement with the observations made by the experimental group in the collaboration, lead by Prof. Esposito.

A third goal of the collaboration was the identification of future developments. Also this goal has been achieved. In fact:

- The idea for a new investigation involving the collaboration of Esposito, Fogolari, Pieri, Colombo e Micheletti has been suggested. Such an investigation will begin in the Fall 2005.

- A direct and continuative exchange of results between the developers of project 1 and the group lead by Dr. Micheletti was set-up. The goal of this operation is to compare different approaches to the folding of the CI2 protein in the same dynamical model (Go-Model)

In the view of the above considerations we can definitely say that all the goals we had set for the present collaboration meeting have been accomplished and therefore we can conclude that the meeting was highly successful.

2.3.4 TWO-PHOTON PHYSICS

DATE: 23–28 May

ORGANISERS:
M. Vanderhaeghen (Co-ordinator) (*College of William and Mary and Jefferson Lab.*), C. Carlson (*College of William and Mary*), V. Pascalutsa (*College of William and Mary*), B. Pasquini (*University of Pavia*)

NUMBER OF PARTICIPANTS: 43

MAIN TOPICS:

- Compton scattering, pion and nucleon polarizabilities
- Inelastic Compton scattering, magnetic dipole moment of the $\Delta(1232)$-resonance
- Lattice QCD calculations of polarizabilities and magnetic moments
- Chiral EFT, chiral extrapolations
- Two-photon effects in atomic physics experiments
- Two-photon exchange in elastic electron scattering and in parity-violation experiments
- Two-photon exchange in $N \to \Delta$ transition

SPEAKERS:

A. Afanasev (*Jefferson Lab.*),
C. Alexandrou (*Univ. Cyprus*),
J. Arrington (*Argonne Nat. Lab.*),
T. Averett (*College of William and Mary*),
P. Blunden (*Univ. Manitoba*),
S. Bouchigny (*IPN, Orsay*),
A. Braghieri (*INFN Pavia*),
Y.-C. Chen (*National Taiwan Univ.*),
K. de Jager (*Jefferson Lab.*),
D. Drechsel (*Mainz Univ.*),
H. Fonvieille (*LPC, Clermont-Ferrand*),
M. Gorchtein (*Caltech*),
H. Griesshammer (*TU Munich*),
K. Griffioen (*College of William and Mary*),
R. Hildebrandt (*TU Munich*),
J. R. Hiller (*Univ. Minnesota Duluth*),
B. Holstein (*Univ. Massachusetts*),
C. Kao (*N.C.T.S., Taiwan*),
S. Karshenboim (*Mendeleev Inst.*),
M. Kotulla (*Univ. Giessen*),
P. Kroll (*Univ. Wuppertal*),
F. X. Lee (*George Washington Univ.*),
F. Maas (*J. Gutenberg Univ.*),
R. Miskimen (*Univ. Massachusetts*),
M. Procura (*TU Munich*),
M. Schindler (*J. Gutenberg Univ.*),
O. Scholten (*KVI, Groningen*),
W. Schroers (*DESY Zeuthen*),
I. Sick (*Univ. Basel*),
T. Spitzenberg (*Mainz Univ.*),
L. Tiator (*Mainz Univ.*),
T. Walcher (*Mainz Univ.*),
C. Weiss (*Jefferson Lab.*),
H. Weller (*Duke Univ. and TUNL*),
B. Wojtsekhowski (*Jefferson Lab.*),
J. Zanotti (*NIC/DESY*)

SCIENTIFIC REPORT:

Aim and Purpose:

The new generation of high-precision experiments has made two-photon processes, such as Compton scattering, a major source of information about hadron structure. It also has been recognized that two-photon effects are the leading uncertainty in the interpretation of high-precision electron-scattering experiments. The workshop is aimed at reviewing the latest theoretical and experimental developments in the field of Compton scattering, both elastic and inelastic, real and virtual. Emphasis is put on the extraction of the pion and nucleon polarizabilities and magnetic moments of nucleon resonances, such as the Delta(1232). Recent calculations in lattice QCD and chiral effective field theory for these quantities are reviewed. Additionally, an important part of the program is devoted to the question how two-photon-exchange processes enter in the extraction of electromagnetic form factors and in the interpretation of precision atomic physics experiments, such as the hydrogen hyperfine splitting. The program includes review lectures on central topics as well as more specialized contributions.

Achievements:

- Reviewed current status of experimental investigation of real and virtual Compton scattering processes. Strengthened the cooperation with theorists to extract nucleon polarizabilities from such processes
- Reviewed status of radiative pion production experiments to extract the Delta(1232) magnetic dipole moment

- Identified and discussed the theoretical framework, based on chiral effective field theory, to extract of the Delta(1232) magnetic dipole moment from experimental data
- Reviewed the status of lattice QCD calculation of hadronic structure quantities such as polarizabilities and magnetic moments and discussed theoretical issues, such as the extrapolation in quark mass needed to confront these lattice QCD calculations with experiment
- Identified various direction for future studies; in particular, future experiments to quantify the two-photon exchange contributions to elastic electron nucleon scattering
- Discussed the implications of precision atomic physics experiments (such as the hydrogen hyperfine splitting) for hadron structure
- Brought together researchers working on two-photon processes both at low and high energy electron–beam facilities (JLAB, MIT, MAMI)
- Exchanged ideas and expertise between various areas of specialization in the theoretical description of Compton–like processes: Dispersion relations, chiral perturbation theory, QCD factorization, lattice QCD

Acknowledgement
On behalf of the participants, the organizers express their gratitude for the substantial financial support extended by ECT*. We also thank the staff at ECT*, in particular Cristina Costa, for the very professional local organization of the workshop, and for ensuring the uniquely pleasant atmosphere at ECT*.

2.3.5 ELECTROMAGNETIC PROBES OF HOT AND DENSE MATTER

DATE: 2–11 June

ORGANISERS:
R. Rapp (Co-ordinator) (*Texas A & M Univ.*), C. Gale (*McGill Univ.*), P. Braun-Munzinger (*GSI Darmstadt*)

NUMBER OF PARTICIPANTS: 51

MAIN TOPICS:

- Low-Mass Dileptons, Light Vector Mesons in Medium and Chiral Symmetry Restoration
- Thermal Photons
- Intermediate-Mass Dileptons and non-/perturbative QGP Emission
- E.M. Emission from Color-Glass-Condensate, Pre-Equilibrium and correlated open-charm decays
- Future Perspectives at RHIC, LHC and FAIR

SPEAKERS:

Y. Akiba (*RIKEN*),
G. E. Brown (*Stony Brook*),
D. Cabrera (*Valencia*),
W. Cassing (*Giessen*),
G. Chanfray (*Lyon*),
B. Cole (*Columbia*),
P. Crochet (*Clermond Ferrand*),
S. Damjanovic (*Heidelberg*),
D. Davesne (*Lyon*),
A. David (*Lisbon*),
A. Drees (*Stony Brook*),
C. Fuchs (*Tübingen*),
C. Gale (*McGill*),
F. Gélis (*Saclay*),
K. L. Haglin (*St. Cloud State*),
M. Harada (*Nagoya*),
B. Kämpfer (*Rossendorf*),
F. Karsch (*BNL*),
V. Koch (*LBNL*),
S. Leupold (*Giessen*),
P. Lichard (*Silesian*),
C. Lourenco (*CERN*),
V. Metag (*Giessen*),
S. Mioduszewski (*BNL*),
U. Mosel (*Giessen*),
T. Peitzmann (*Utrecht*),
R. Rapp (*Texas A and M*),
S. Räsänen (*Jyväskylä*),
K. Redlich (*Warsaw*),
T. Renk (*Duke*),
F. Riek (*GSI*),
P. Salabura (*Cracow*),
B. Schenke (*Frankfurt*),
E. V. Shuryak (*Stony Brook*),
H. J. Specht (*Heidelberg*),
J. Stachel (*Heidelberg*),
J. Stroth (*Frankfurt*),
I. Tserruya (*Weizmann*),
S. Turbide (*McGill*),
T. Ullrich (*BNL*),
J. P. Wurm (*MPI Heidelberg*),
M. Zetenyi (*KFKI*)

SCIENTIFIC REPORT:

This workshop was the first ECT* program on the topic of Electromagnetic Probes of strongly interacting matter since the one taking place in March of 1999. Those events serve many purposes. The first is to encourage the announcement and dissemination of recent important scientific results. The quality of the meeting was ensured by inviting (almost all) major scientific players in the field. Second, the workshop represented an ideal forum for detailed discussions and exchanges between the experimental and theoretical communities. Our field has traditionally enjoyed a high level of collaboration between those two groups, owing largely to opportunities like this one. This was further fostered through 4 introductory morning (theory) lectures (which R. Rapp and C. Gale agreed to give upon request from experimental colleagues). The workshop furthermore benefited from contacts between the high-energy (SPS, RHIC, LHC) and intermediate-energy (BEVALAC, HADES) heavy-ion research communities, as well as from connections to elementary pion- and photo-nuclear physics. The timeliness of the workshop is partly due to the fact that we have arrived at a crossroads, regarding electromagnetic observables in relativistic nuclear collisions. Indeed, many experimental collaborations were slated to present groundbreaking results just around the time of our workshop, which also was judiciously chosen to be a few months before the

International Quark Matter 2005 conference (to be held in August in Budapest). The new experimental developments coincided with progress made in theory toward a more comprehensive interpretation of electromagnetic data, both in the regions of low and high transverse momentum.

Results and Highlights

- New NA60 data on low-mass dimuons in In-In collisions at SPS have been disclosed for the first time. This data, of exceptional quality, sparked an intense and lively debate which was (partially) accommodated in 2 separate discussion sessions after the regular talks. It is fair to say that this announcement marks the beginning of an era where a precise characterization of the in-medium spectral density can be made.
- New data from the CERES collaboration on dielectrons from central Pb-Pb collision were shown for the first time which rendered possible a detailed comparison to NA60 data.
- The first data from HADES was shown. This also generated a lot of excitement, as this experiment has been in the development stage for some time and set out to resolve a puzzle left by the last DLS analysis at the Bevalac. The preliminary data indicate a smaller enhancement as compared to DLS data.
- First evidence of a dropping ω-mass in photo-nuclear reactions by the CB-TAPS collaboration was presented. This exciting result might represent the onset of chiral symmetry restoration in nuclear matter.
- A PHENIX analysis confirming the presence of direct photons at RHIC was shown.
- The first calculation that combines parton energy loss and the electromagnetic signature of jets, together with an assessment of the most recent low-p_T photon rates, was discussed.
- The Brown-Rho scaling ansatz was incorporated into a firmer theoretical framework through the vector manifestation of chiral symmetry. Several discussions ensued on the experimental consequences of this scenario.
- The presence of hadronic bound states in the QGP was argued for and shown to lead to an enhancement in the intermediate-mass dilepton regime; later, this scenario has been questioned in terms of a model analysis of fluctuation properties in comparison to lattice QCD results.

Conclusions

The workshop was a resounding success. By all accounts, the quality of the presentations was uniformly high, as was the level of the discussions. The degree of collaboration across the theoretical-experimental boundary was apparent and even noticeably increased. The case of the new NA60 data is a good example. It was emphatically agreed that those workshops should become a regular series on a 2-3 year timescale. Most of the talks can be browsed from the website:
http://cyclotron.tamu.edu/rapp/ECT_EM_Probes.html

2.3.6 CHARGE SYMMETRY BREAKING AND OTHER ISOSPIN VIOLATIONS

DATE: 13–17 June

ORGANISERS:
C. Horowitz (Co-ordinator) (*Indiana University*), C. Hanhart (*Inst. für Kernphysik Jülich*), G. Miller (*University of Washington*)

NUMBER OF PARTICIPANTS: 37

MAIN TOPICS:

- Charge Symmetry breaking in pion production
- Isospin violating meson decays
- Applications of Charge Symmetry

SPEAKERS:

A. Bacher (*Indiana*),
A. Bernstein (*MIT*),
J. Bijnens (*Lund*),
B. Borasoy (*Bonn*),
G. Colangelo (*Bern*),
E. Epelbaum (*JLAB*),
A. Sa Fonseca (*Lisbon*),
A. Gardestig (*Ohio Univ.*),
S. Gardner (*Kentucky*),
D. Gotta (*Jülich*),
V. Hejny (*Jülich*),
R. Kaiser (*Vienna*),
V. Kleber (*Jülich*),
M. Knecht (*Marseille*),
P. Kroll (*Wuppertal*),
B. Kubis (*Bonn*),
K. Kumar (*Univ. Mass*),
V. Lensky (*Jülich*),
J. T. Londergan (*Indiana*),
A. Micherdzinska (*Indiana*),
G. Miller (*Univ. Washington*),
F. Myhrer (*South Carolina*),
H. Neufeld (*Vienna*),
J. Niskanen (*Helsinki*),
A. Nogga (*Jülich*),
A. Opper (*Ohio Univ.*),
D. Phillips (*Ohio Univ.*),
E. Stephenson (*Indiana*),
B. van Kolck (*Arizona*),
W. T. H. van Oers (*Manitoba*),
M. Wolke (*Jülich*),
A. Zuker (*Strasburg*)

SCIENTIFIC REPORT:

Aim and Purpose

The aim of the workshop was to present new charge symmetry breaking results in pion production, review the broad field of isospin violation, discuss theoretical techniques to calculate charge symmetry breaking, and finally to identify promising future experiments and areas for theoretical development.

Results and Highlights

The TRIUMF results for the CSB forward- backward asymmetry in $n + p \to d\pi^0$ were presented along with a discussion of historical calculations and what is needed for a modern chiral perturbation theory calculation of this reaction. Next the Indiana results for the CSB reaction $d + d \to^4 He + \pi^0$ were presented. A very clear pion signal is seen. There followed presentations of the complicated ingredients that go into $d + d \to^4 He + \pi^0$ calculations. A variety of pi, eta and eta prime meson decays were discussed and a number of charge symmetry breaking measurements in nucleon-nucleon and nuclear systems were reviewed. Finally applications of charge symmetry breaking to CP violating studies of B decays, deep inelastic neutrino scattering at NuTeV, and parity violating electron scattering were presented. We identified promising new CSB experiments including $d + d \to^4 He + \pi^0$ at higher energies, $a_0 - f_0$ mixing and parity violating deep inelastic electron scattering.

Conclusions

Charge symmetry provides important insight into QCD and the structure of strongly interacting systems. Charge symmetry breaking interactions are closely related to the up and down quark masses. Calculations of charge symmetry breaking pion production involve a number of open questions including: power counting for the production operator, consistency between wave functions and operators, and a large model dependence for predicted cross sections. However specific plans have been developed to address these theoretical issues. First calculations are needed in chiral perturbation theory for both the CSB and charges symmetry conserving $n + p \to d\pi^0$. Next a paper will be written that collects all of the presently calculated contributions to $d + d \to^4 He + \pi^0$ using realistic wave functions for bound and scattering states. Finally, future experiments including $d+d \to^4 He+\pi^0$ at higher energies, $a_0 - f_0$ mixing, and the study of eta decays can provide important new information.

Web talks

The talks can be obtained from the CSB meeting website:
http://cecelia.physics.indiana.edu/csb

2.3.7 NUCLEAR FORCES AND QCD: NEVER THE TWAIN SHALL MEET?

DATE: 20 June–1 July

ORGANISERS:
J. McGovern (Co-ordinator) (*University of Manchester*), R. G. E. Timmermans (*KVI, University of Groningen*), B. F. Gibson (*Los Alamos National Laboratory*), U. van Kolck (*University of Arizona*)

NUMBER OF PARTICIPANTS: 43

MAIN TOPICS:

- Formulation of two-nucleon and three-nucleon forces and their relation to low-energy pion-nucleon scattering, including the implications of chiral symmetry and coupling constant constraints from large N_C and lattice approaches.
- Few-body and many-body constraints on the nuclear force coming from calculations of the structure of light nuclei plus few-nucleon scattering and reactions.

SPEAKERS:

M. Birse (*Univ. Manchester*),
J. Carlson (*Los Alamos Nat. Lab.*),
T. Cohen (*Univ. Maryland*),
L. Coraggio (*Naples Univ., INFN Naples*),
D. Dean (*Oak Ridge National Lab.*),
A. Deltuva (*Univ. Lisbon*),
E. Epelbaum (*TJNAF*),
G. Erkol (*KVI, Univ. Groningen*),
J. Friar (*Los Alamos Nat. Lab.*),
A. Gardestig (*Ohio University*),
H. Griesshammer (*TU Munich*),
F. Gross (*College of William and Mary*),
T. Hemmert (*TU Munich*),
R. Higa (*TJNAF*),
C. Horowitz (*Indiana Univ.*),
N. Kaiser (*TU Munich*),
A. Kievsky (*Univ. Pisa*),
B. van Kolck (*Univ. Arizona*),
R. Lazauskas (*CEA Bruyeres-le-Chatel*),
R. Machleidt (*Univ. Idaho*),
L. Marcucci (*Univ. Pisa*),
P. Navratil (*Lawrence Livermore Nat. Lab.*),
A. Nogga (*Forschungzentrum Jülich*),
M. Oka (*Univ. Tokyo*),
M. Pavon Valderrama (*Granada Univ.*),
F. Pederiva (*Univ. Trento*),
D. Phillips (*Ohio Univ., Athens*),
S. Quaglioni (*Univ. Trento*),
M. Rentmeester (*Radboud Univ. Nijmegen*),
E. Ruiz Arriola (*Granada Univ.*),
A. Schwenk (*Indiana Univ.*),
I. Stetcu (*Univ. Arizona*),
J. de Swart (*Radboud Univ. Nijmegen*),
R. Timmermans (*KVI, Univ. Groningen*),
E. Truhlik (*Nuclear Physics Inst.*),
T. Thomas (*TJNAF*),
S. Vigdor (*IUCF & Indiana Univ.*),
W. Weise (*TU Munich*),
A. Zuker (*IReS, Strasbourg*)

SCIENTIFIC REPORT:

Aim and Purpose

Nuclear forces form the basis for our understanding of much of nuclear physics, both structure and reactions. In the nearly six decades since the discovery of the pion, progress in comprehending the two-nucleon interaction and consistent few-nucleon forces has been slow. The connection to the 30-years-old theory of the strong interaction, quantum chromodynamics (QCD), has remained an enigma. However, in the last decade, and particularly since the 1999 ECT* workshop entitled "The nuclear interaction: modern developments", important advances have opened new doors to better understanding of nuclear forces. In view of the recent developments, an intense meeting of researchers investigating these issues was timely. The focus on the current situation provided a necessary expansion of the road map to further progress.

Highlights

Energy-dependent partial-wave analysis (PWA) methods, which incorporate the rich two-nucleon scattering data base, provide a sensitive tool to investigate small but important effects such as the two-pion exchange component and isospin violation in coupling constants. An update of the august Nijmegen PWA was presented. Much discussion took place regarding the rationale for excluding data from the analysis on statistical grounds, and about the procedures used by experimentalists to quantify and present systematic errors.

The effective field theory (EFT) approach suggests systematic expansions consistent with QCD; the aim being to overcome renormalizability problems encountered in the 1950s and off-shell ambiguities which can arise in potential models of the two-nucleon force inspired by the PWA results. New results of the pionless EFT were presented. Various implementations of the nuclear EFT with pions were discussed, and the renormalization of pion exchange was a central issue of argument.

Few-body calculations are being performed with unprecedented precision, and can be used as a genuine source of information about the nuclear force. Much progress was reported in dealing with both bound and scattering states.

Even more rapid progress has taken place in the development of methods to deal with nuclei heavier than the alpha particle. Different techniques were discussed by various speakers, some using phenomenological potentials reduced to small model spaces. Applications of EFT are also being extended from few-body systems to many-body nuclei.

The large N_C limit of QCD may shed light upon fundamental aspects of the relation between QCD and nuclear forces. The baryon-meson coupling constants involved in modeling nucleon-nucleon and hyperon-nucleon forces are the target for a number of scientists, even some working with lattice approaches.

Experiments exploring the fundamental aspects of isospin violation are underway at facilities such as COSY and TRIUMF. Progress on the theory of charge-symmetry-breaking reactions was reported.

Conclusions

Based upon the spirited discussion among the proponents, one must conclude that nuclear EFT is not dead. On the other hand, the inclusion of a physical finite effective range in the

nucleon-nucleon force appears to bring the EFT approach and the potential model approach much closer in spirit (except for the important notion of renormalization-group invariance and, thus, model independence) and practicality. Fifty years of shell model physics appears to have identified the need for a three-body force in that approach to resolve such issues as the isospin puzzle in ^{16}O, that ^{48}Ca is the closed shell and not ^{40}Ca, the spectrum of ^{10}B and ^{22}Na. Chiral constraints reduce the number of parameters needed to represent the data in the energy-dependent *pp* and *np* partial-wave analysis. Discussions regarding the *np* database are closed. An effective means of including the Coulomb interaction in the three-body problem with two charged particles appears to be at hand. Despite precision calculations in the three-nucleon and four-nucleon arenas, there are several puzzling features to the data. Vigdor's challenge to the theorists remains unanswered: What low-energy experiments must be performed before the last machine is shuttered?

Supplemental
Thanks to M. Rentmeester, the individual talks can be browsed from the website:
http://nn-online.org/trento-2005/?p=talks

2.3.8 HIGHLY EXCITED HADRONS

DATE: 4–9 July

ORGANISERS:
L. Ya. Golzmann (Co-ordinator) (*University of Graz*), T. D. Cohen (*University of Maryland*), E. Swanson (*University of Pittsburgh*)

NUMBER OF PARTICIPANTS: 30

MAIN TOPICS:

- Chiral symmetry breaking, its restoration in excited hadrons, confinement and quark-hadron duality
- Lattice studies of chiral symmetry breaking, restoration and excited hadrons
- Large N_c, quark, string, solitonic models as well as AdS/QCD description of excited hadrons
- Experimental advances and perspectives for exploring the excited spectrum
- Excited hadrons and high temperature

SPEAKERS:

T. Barnes (*Oak Ridge*),
N. Brambilla (*Milan*),
W. Broniowski (*Cracow*),
D. Bugg (*London*),
S. Capstick (*Florida*),
T. Cohen (*Maryland*),
L. Glozman (*Graz*),
R. Gothe (*South Carolina*),
T. Hatsuda (*Tokyo*),
A. Krassnig (*Graz*),
C. Lang (*Graz*),
F. Lee (*Washington*),
P. Majumdar (*Graz*),
C. Morningstar (*Pittsburgh*),
C. McNeile (*Liverpool*),
A. Nefediev (*Moscow*),
M. Oka (*Tokyo*),
M. Ostrick (*Bonn*),
W. Plessas (*Graz*),
Yu. Simonov (*Moscow*),
V. Shevchenko (*Moscow*),
M. Shifman (*Minnesota*),
Fl. Stancu (*Liege*),
M. Stephanov (*Illinois*),
E. Swanson (*Pittsburgh*),
A. Szczepaniak (*Indiana*),
P. Talavera (*Barcelona*),
V. Zakharov (*Muenchen*)

SCIENTIFIC REPORT:

The purpose of the workshop was to discuss new achievements in the physics of excited hadrons. In particular, a new phenomenon of chiral symmetry restoration in excited hadrons, a possible relation of chiral symmetry breaking, restoration and confinement, developments of lattice QCD for excited hadrons, large N_c, quark and string models, AdS/QCD description of hadrons, as well as experimental results and perspectives were in the focus. Relations of these subjects to our understanding of QCD in different regimes as well as limitations of different models of the hadrons were emphasized. Key world experts from many countries as well as young participants actively took part, including some students participating at the ECT training program.

One of the key tasks for future experimental research is to confirm many of the highly excited states found in $\bar{p}p$ as well as to find some of the missing states which are definitely predicted by $SU(2)_L \times SU(2)_R$ and $U(1)_A$ symmetries. While theoretically in general the phenomenon of chiral symmetry restoration can be considered to be almost established, a detailed microscopical understanding is missing and is a challenging task for theory. Such an understanding would also imply a detailed microscopical picture of confinement and chiral symmetry breaking and hence is a task of primary importance.

A development of lattice QCD for excited hadrons has been discussed in a few talks and a few different methods to extract excited hadrons from the correlation functions have been critically compared. While there is a real hope that in some future with advent of the full QCD calculations one can expect a reliable extraction of the ground states as well as the lowest excitations, the lattice will not help us with respect to the high excitations. Hence this field will be the subject of pure theory (and hence will stimulate analytical methods), modelling and experiment. A few model pictures for excited hadrons, models for confinement and chiral symmetry breaking have been presented in many talks and followed by vivid

discussions during the whole workshop. An extra panel discussion of these subjects has been organized.

The talks can be browsed from the website: http://www.ect.it

2.3.9 RESONANCES IN QCD

DATE: 11–16 July

ORGANISERS:
M. F. M. Lutz (Co-ordinator) (*GSI Darmstadt*), J. Nieves (*University of Granada*), U. Thoma (*University of Giessen*), U. Wiedner (*University of Uppsala*)

NUMBER OF PARTICIPANTS: 36

MAIN TOPICS:

- Quark-model approach
- Effective field theory with coupled channels
- Lattice QCD simulations
- Experimental results

SPEAKERS:

G. Bali (*Univ. Glasgow*),
T. Barnes (*Oak Ridge Nat. Lab.*),
R. Beck (*Univ. Bonn*),
D. Bettoni (*INFN Ferrara*),
S. Capstick (*SCRI, USA*),
P. Colangelo (*Univ. Bari*),
Ch. Gattringer (*Univ. Regensburg*),
J. L. Goity (*Hampton Univ. and JLab*),
E. Klempt (*Univ. Bonn*),
E. E. Kolomeitsev (*Univ. Minnesota*),
J. S. Lange (),
S. H. Lee (*Yonsei Univ.*),
T. S. H. Lee (*Argonne Nat. Lab.*),
Th. Mehen (*Duke Univ.*),
A. Nakamura (*Hiroshima Univ.*),
E. Oset (*I.F.I.C.*),
J. R. Pelaez (*Univ. Complutense*),
K. Peters (*GSI Darmstadt*),
B. A. Raue (*Florida International Univ.*),
D. Richards (*Jefferson Lab.*),
J. Ritman (*IKP Jülich*),
P. Rossi (*INFN Frascati*),
C. Schat (*TANDAR, Argentina*),
H. Schmieden (*Univ. Bonn*),
V. Shklyar (*Univ. Giessen*),
B. Silvestre Brac (*LPSC Grenoble*),
M. Soyeur (*DAPNIA/SPhN Saclay*),
E. Swanson (*Oxford Univ.*),
K. Terasaki (*Kanazawa Univ.*),
L. Tiator (*Univ. Mainz*),
H. Toki (*Osaka Univ.*),
W. Weise (*TU Munich*)

SCIENTIFIC REPORT:

This workshop was aimed at bringing together experimentalists and theoreticians from different communities to foster the exchange of ideas and experience. We successfully gathered people with expertise in the study of meson systems with those specializing on the baryon spectrum. In view of the FAIR project at GSI it is important to predict in detail the spectrum of mesons and baryons involving charm quarks, a rather poorly understood sector of QCD. There are indications that this is a sector of QCD full of structure, which may help to unravel the mysteries of QCD. The community addressing such systems is at present quite small and should benefit from interactions with the people studying meson and baryon systems composed of u, d, s quarks only.

Overview talks on recent results on the meson and baryon spectrum from most facilities were given. The importance of polarization experiments to disentangle the many helicity amplitudes for final states involving vector mesons was emphasized in the context of the electron machines at ELSA or MAMI. Transition form factors of baryon resonances define a challenge which should be taken up by the competing theoretical approaches. The huge impact of B factories on our knowledge of the meson and baryon spectrum was pointed out. There are still many searches for so-far undiscovered states that can and should be performed based on data already collected. The latest developments on the possible existence of the Θ^+ state from SPRING-8 and CEBAF were discussed. Though the new results certainly weaken the evidence for the possible existence of that state, it is too early to draw definite conclusions at this stage. Further experimental efforts are required.

A balance of presentations emphasizing different theoretical approaches was kept. Talks on QCD lattice simulations, QCD sum rules, large-N_c QCD, chiral coupled- channel effective field theory and quark models were presented. For instance, the competing theoretical approaches for the description of the recently discovered narrow open charm states with $J^P = 0^+, 1^+$ were discussed. Are these systems diquark clusters, tetra-quark states or hadronic molecules. To possibly discriminate the approaches it would be important to compute and accurately measure the electromagnetic transitions. An important topic was the relevance of un-quenching the quark-model. Hadronic loop effects are generally found to be large possibly providing an explanation for the success of coupled-channel generation of resonances. Further theoretical developments are needed.

Most of the talks can be browsed from the web-page.

2.3.10 EFFECTIVE THEORIES IN NUCLEAR PHYSICS AND LATTICE QCD

DATE: 18–23 July

ORGANISERS:
A. Parreño (Co-ordinator) (*University of Barcelona*), P. F. Bedaque (*Lawrence-Berkeley National Laboratory*), E. Pallante (*University of Groningen*)

NUMBER OF PARTICIPANTS: 17

MAIN TOPICS:

- EFT description of strong two-baryon interactions.
- Lattice simulations of hadron-hadron interactions.
- Weak matrix elements.
- Quark mass extrapolations.
- Chiral, finite lattice volume/spacing extrapolations.
- Quenched and partially-quenched chiral perturbation theory.

SPEAKERS:
O. Bär (*Tsukuba Univ.*),
P. Faccioli (*Trento Univ.*),
H. R. Fiebig (*Florida International Univ.*),
M. Golterman (*S. Francisco State Univ.*),
H. Griesshammer (*TU Munich*),
D. Lin (*Univ. Washington*),
H. Markum (*TU Vienna*),
K. Orginos (*MIT*),
E. Pallante (*Univ. Groningen*),
D. Phillips (*Ohio Univ.*),
Y. Shamir (*Tel-Aviv Univ.*),
J. Soto (*Univ. Barcelona*),
A. Walker-Loud (*Univ. Washington*)

SCIENTIFIC REPORT:

Aim and Purpose

The theme of the workshop has been Lattice Nuclear Physics, which is Lattice QCD connected to the effective field theory description of nuclear forces. Recent developments in effective theories and lattice QCD make us believe that now is the moment for a renewed attack on the problem of understanding how nuclear forces emerge from QCD. Our aim has been to stimulate a constructive interaction among lattice QCD and nuclear EFT physicists, and to motivate discussions on the formulation of baryon-baryon interactions as derived from QCD.

The computational cost of QCD simulations grows very fast with increasing lattice sizes, smaller lattice spacings and smaller quark masses. This is particularly true in the difficult observables needed in nuclear physics. Extrapolations from numerically accessible ranges of parameters to realistic values are then the only practical way to connect QCD with nuclear phenomenology. Effective field theories, which received so much attention in the last few

years, are the necessary tool used in these extrapolations. This fact has motivated an added interest in the combined EFT and lattice description of nuclear interactions. The effort to understand many physical phenomena has already stimulated world-wide collaborations, motivated the development of sophisticated and dedicated algorithms and massively parallel computers (in the range of tens of Teraflops). Starting the present year, we will see the realization of a European project (apeNEXT), a US project (QCDOC, QCD On-a-Chip), and the IBM BlueGene/L projects at Groningen and Livermore. A theoretical advance in this field will profit from large-scale computing resources as ever before.

Since new lattice calculations with two heavy baryon operators ($\Lambda\Lambda$) have become available very recently, the workshop has taken place at the right time to explore the potentials and limitations of the lattice approach to nuclear problems. Lattice Nuclear Physics as a field is just beginning and it will only prosper if a close connection to the Particle Lattice community is established. This is even more true here than in other overlapping fields, because we have to share not only ideas and motivations, but software, hardware, gauge configurations, etc. The role of the workshop has been to foster this connection, and the cast of participants was carefully chosen to make that happen. Within the present computational limitations, and in view of the next future enormously increased computing capabilities, our aim has been to find a feasible framework for lattice calculations which can help in our understanding of low energy interactions among hadrons.

Results and Highlights

Talks and discussions during the workshop were mainly focused on the feasibility and relevance of lattice simulations of baryon physics. Why baryon physics? Among the reasons are the long list of poorly known observables involving one and two baryons (e.g. low energy scattering parameters in the strangeness -1 and -2 sectors) and the long standing discrepancies between experimental determinations and theoretical predictions of certain quantities (e.g. S- and P-wave amplitudes in the non-leptonic decays of hyperons). Another fundamental reason is the need of understanding nuclear phenomena from first principles. Highlights of the workshop were:

- exploring the feasibility of one- and two-baryons simulations in different regimes of lattice parameters. *One baryon in a tiny box* (known as ϵ regime) was discussed by H. Griesshammer and compared with different regimes (p-regime, δ regime, ϵ' regime) on the lattice. This is the first step towards the more complex simulations of two-baryon interactions. Preliminary results for $\Lambda\Lambda$ scattering were presented by K. Orginos, together with a study of the $I = 2\pi\pi$ phase shifts and scattering lenght. R. Fiebig presented an exploratory lattice study of $K-\Lambda$ systems. In this context relevant issues were discussed, related to the quenched approximation, like the role of the η' in the long range contributions (quenched artifact) to the potential. An analytic investigation of the nucleon-nucleon potential was reported by J. Soto, who pointed out the presence of new non analytic contributions to the potential beyond the static approximation. This mass dependence is especially relevant when performing chiral extrapolations of lattice results.
- various lattice strategies and their improvement were exhaustively reviewed by several participants (O. Bär, M. Golterman, E. Pallante, Y. Shamir and A. Walker-Loud). In particular we focused on staggered fermions, domain-wall fermions and the recently

formulated twistedmass Wilson fermions and their corresponding χPT formulation for mesons and baryons. D. Lin presented a proposal for the implementation of Operator Product Expansion on the lattice to determine the dominant matrix elements contributing to deep inelastic scattering.

- more exotic explorations of QCD phenomenology like the Instanton Liquid Model (ILM) were discussed by P. Faccioli, who presented intriguing results on the neutron electric dipole moment and weak decays of hyperons. Quantum chaos method for generating configurations and its role in simulating hadron physics was reviewed by H. Markum.
- the discussion sessions (chaired by D. Phillips and E. Pallante) played a quite significant role to settle technical issues in lattice simulations of nuclear phenomena, namely which quantities can be extracted from presently available lattices, which strategies are accessible and how they can be improved, and which is the optimal strategy for a given observable. In this respect a guidance was provided by what is known from simulations in the meson sector and in the effective field theory description of baryon interactions.

Conclusions

The aim of the workshop was to stimulate interactions and encourage the exchange of knowledge between two communities, namely experts and practitioners of lattice QCD and Effective Field theorists in nuclear physics. A good balance in the number of participants representing the two fields, the structure of the workshop (a few talks per day and long sessions of discussion designed to cover specific topics) and the active participation of everyone, made possible to achieve this goal.

It was certainly the appropriate time to discuss the feasibility and relevance of lattice simulations of baryon physics. The reason can be found both in the lack of lattice studies in this sector, the urgency in understanding many nuclear physics phenomena from first principles and the enormous progress in large scale parallel computing over the last years.

All these facts make us believe that the organization of more meetings devoted to the same topic and structured in a similar way is highly desirable and it will certainly be extremely useful to both communities.

The talks can be browsed from the following website:
http://www.ecm.ub.es/assum/webpage/ectpage.html

2.3.11 PROBING MICROSCOPIC STRUCTURE OF THE LIGHTEST NUCLEI IN ELECTRON SCATTERING AT JLAB ENERGIES AND BEYOND

DATE: 25–30 July

ORGANISERS:
M. M. Sargsian (Co-ordinator) (*Florida International University*), C. Ciolfi degli Atti (*University of Perugia*), M. Strikman (*Pennsylvania State University*)

NUMBER OF PARTICIPANTS: 33

MAIN TOPICS:

- Generalized Eikonal Approximation in $(e, e'N)$ Reactions
- Diagrammatic Approaches in $(e, e'N)$ reactions
- Relativistic Description of few-nucleon systems
- Role of non-nucleonic degrees of freedom in $(e, e'N)$ reactions
- Current Status of High Q^2 $(e'e, N)$ and $(e, e'NN)$ Experiments with Light Nuclei
- DIS Scattering with fast backward nucleon production
- First results of semi-inclusive DIS experiments from JLab
- Quasi-elastic and DIS scattering at x>1, theory and experiment
- Electroproduction of Vector Mesons from light nuclei at large Q2
- High Energy Break-up of light nuclei at large CM angles
- Probing non-nucleonic degrees of freedom in hard nuclear reactions
- Meson versus Quark Exchange currents

SPEAKERS:
M. Alvioli (*Univ. Perugia*),
H. Arenhovel (*Univ. Mainz*),
J. Arrington (*Argonne National Lab.*),
C. Barbieri (*TRIUMF*),
W. Boeglin (*Florida Int'l Univ.*),
R. Gilman (*Rutgers Univ. & JLab*),
C. Ciofi degli Atti (*Univ. Perugia*),
F. Gross (*Jefferson Lab*),
E. Jans (*NIKHEF*),
S. Jeschonnek (*Ohio State Univ.*),
L. Kaptari (*JINR, Russia*),
A. Kievsky (*Univ. Pisa*),
S. Kuhn (*Old Dominion Univ.*),
J. M. Laget (*Jefferson Lab*),
W. Leidemann (*Univ. Trento*),
G. A. Miller (*Univ. Washington*),
H. Morita (*Sapporo Gakuin Univ. Japan*),
M. Osipenko (*Univ. Genova*),
E. Pace (*Univ. Rome2*),
E. Piasetzky (*Tel Aviv Univ.*),
N. Pivnyuk (*ITEP, Russia*),
T. Rogers (*Pennsylvania State, Univ.*)
P. Rossi (*Univ. Rome*),
J. Ryckebusch (*Univ. Gent*),
G. Salmè (*Univ. Rome*),
M. Sargsian (*Florida Int'l Univ.*),
R. Schiavilla (*Old Dominion Univ. & JLab*),
S. Scopeta (*Univ. Perugia*),
R. Skibinski (*Jagelonian Univ. Poland*),
M. Strikman (*Pennsylvania State Univ.*),
D. Treleani (*Univ. Trieste*),
J. M. Udias (*Univ. Madrid*),
L. Weinstein (*Old Dominion Univ.*)

SCIENTIFIC REPORT:

Aim and Purpose

The aim of the workshop was to perform a comprehensive review of the theoretical calculations of high momentum transfer processes of electron and photon scattering off $A = 2 \div 4$ nuclei at Jefferson Lab energies. We mainly focused on the possibilities of using these processes for the studies of short range nuclear correlations (SRC) in nuclei, relativistic description of high momentum component of the nuclear wave functions, non-nucleonic degrees of freedom, deep-inelastic structure function of bound nucleons and hadron-quark transitions in nuclei.

During the last several years a substantial progress has been made in the development of various theoretical methods aimed at the calculation of high momentum transfer eA reactions off light nuclei. This progress allowed for the first time to establish a research program of probing microscopic properties of nuclei at short space-time separations of nucleons. To achieve such a goal the pressing problem was to establish a baseline calculation upon which different theoretical groups can agree. This will allow further progress in developing theoretical approaches for the description of the reactions involving short-range correlations in nuclei. Thus one of the goals of the workshop was to bring together the theorists active in the field and perform a comprehensive comparison between the theoretical methods used by different groups to calculate high Q^2 semi-inclusive eA reactions.

Since SRCs manifest themselves mostly in the kinematical domain where excitation energies are of the order of the nucleon rest mass, the relativistic description of nuclei become a significant issue in probing SRCs. The purpose of the workshop was also to review the present status of the theoretical description of few nucleon system in the relativistic domain. This would also allowed to understand how the relativistic description of nuclei can be incorporated in the eikonal models used to calculate high momentum transfer semi-inclusive eA reactions.

The third major goal of the workshop was to review the present understanding of the dynamics of hadron-quark transition in nuclei. Discussion of the signatures which unambiguously will indicate on the onset of quark-gluon degrees of freedom in nuclei and prospect of their theoretical description in QCD.

To facilitate the maximally practical discussion the idea was to invite also the leading experimentalist in the field who gave overview talks about the status of the experimental research in the areas corresponding to the subject of the workshop.

Results and Highlights

The program was organized such that each day participants were focused on one major subject covered in the workshop.

The first day was dedicated to the discussion of high energy approximations in calculating semi-inclusive electro-nuclear reactions involving lightest nuclei as deuteron, ^3He and ^4H. Jean Marc Laget, Sabine Jeschonnek, Misak Sargsian and Claudio Ciofi degli Atti gave theory overviews of the diagramatic approach, the Glauber approximation as well as the Generalized Eikonal Approximations and their application in eA reactions. L. Kaptari and H. Morita discussed the application of high energy approximations for electroproduction reactions involving ^3He and ^4He reactions. Werner Boeglin reviewed the experimental status

of high momentum transfer reactions involving lightest nuclei. The first day presentations were followed by a discussion on the need of coordinating efforts in producing baseline calculations upon which all theoretical groups can agree. The discussion allowed to isolate those kinematics where one expects that different approaches should yield a same result. It was decided to establish a web page which will allow to compile all necessary parameterizations and ingredients needed to do a meaningful comparisons within the different models as well as with the emerging experimental data from Jefferson Lab.

The second day program was focused on the discussion of the theoretical approaches to relativistic description of few nucleon systems, the role of the non-nucleonic (meson and isobar) degrees of freedom, as well as probing the short range correlations in nuclei. Franz Gross gave an overview talk about theoretical foundations of relativistic description of few nucleon systems and Mark Strikman reviewed the light cone dynamics of the deuteron and short range correlations. Gerald Miller reviewed the progress in light cone description of nuclei. A comprehensive discussion of the electro-nuclear reactions based on the hadronic picture including meson and Isobar degrees of freedom was given by Rocco Schiavilla and Hartmuth Arenhovel. Roman Skibinski and Alejandro Kievsky discussed the studies of electro-nuclear reactions involving A=3 and A=4 systems and possibilities of using these reactions in probing the microscopic structure of few nucleon systems. The present status of the experimental studies of SRC in few nucleon systems was reported by Larry Weinstein and Eddy Jans.

The third day of the workshop was dedicated to the theoretical and experimental studies of medium to heavy nuclei. Jose Udias, Jan Ryckebusch, Winfried Leidemann, Massimiliano Alvioli and Carlo Barbieri covered major theory aspects related to the nuclear wave functions, reaction dynamics, final state interactions as well as SRCs. Eli Piasetzky reviewed the experimental program of studies of few-nucleon correlations in medium nuclei.

The problem of probing short range correlations were discussed also during the next day by John Arrington who reviewed inclusive large x physics, EMC effects, as well as studies of superfast quarks in nuclei. Mark Strikman reported on the recent progress in probing few nucleon correlations in $x > 1$ inclusive reactions. Possibilities of probing short range correlation in deuteron knock-out reactions from ^3He was discussed by Nikolai Pivnyuk.

A newly emerging subject of of final state interaction in semi-inclusive Deep Inelastic Scattering from Nuclei was discussed in the theoretical presentations of Claudio Ciofi degli Atti and Misak Sargsian and reviews of the experimental results from Jefferson lab by Sebastian Kuhn and Mikhail Osipenko.

The last subject covered in the workshop was the study of quark-gluon degrees of freedom in nuclei. Sergio Scopeta and Daniele Treleani discussed the theoretical framework of description of generalized parton distribution in ^3He and partonic correlations in nuclei while Ted Rogers discussed the high energy approximations in the description of vector meson photoproduction from nuclei.

Patrizia Rossi and Ron Gilman reviewed on the present status and upcoming experimental studies of quark-gluon signatures in nuclei.

Practically all talks were followed by active discussions which significantly complemented the program of the workshop.

Conclusions

Five days of talks and discussions allowed us to reach the following main conclusions on the physics of high momentum transfer electro-nuclear reactions:

- The diagramatic technique and generalized eikonal approximations can be successfully applied to describe high energy semi-inclusive reactions from nuclei covering lightest to medium nuclei.
- The further development of these approaches requires checking current codes. As a way of testing the codes different groups agreed on the need to perform the baseline calculations at the specific kinematics
- The Workshop allowed to establish the necessary kinematics for which one expects similar theoretical predictions from approaches used by different groups
- In many instances the careful consideration of the meson exchange and Isobar contributions are needed for meaningful interpretation of experimental data.
- There is a transition kinematics in which both the partial wave and the eikonal approximations to treat final state interactions yield similar results
- The discussion of relativistic approaches for the description of high momentum components of the nuclear wave function demonstrated that further developments will assume the incorporation of the eikonal approximation with the relativistic approximations used to describe the nuclear wave function
- There are systematic experimental approaches to identify and probe short range nucleon correlations in nuclei
- Combination of the eikonal approximation with QCD aspects of deep-inelastic scattering will allow to describe the FSI in semi-inclusive DIS scattering off nuclei
- Emerging experiments on semi-inclusive DIS will greatly advance our understanding of the dynamics of FSI for DIS kinematics.
- Large angle Center of Mass break-up nuclear reactions provide a unique framework in probing hadron-quark transition in nuclei

Next few years will provide us with data from the several key experiments which may play a significant role in identifying the appropriate theoretical approaches for the description of SRCs as well as quark-gluon degrees of freedom in nuclei. The workshop resulted in several key agreements among theoretical groups which will allow a further progress in high energy electro nuclear theory.

Similar workshop few years from now when data from the several key experiments will be available may help to rectify the present progress and outline the further development in the field.

The talks of the workshop can be browsed at:
http://www.fiu.edu/ sargsian/ect05.html

2.3.12. WEAK-COUPLING EXPANSION FOR THE PRESSURE OF HOT QCD

(Collaboration Meeting)

DATE: 8–10 September

ORGANISERS:
M. Laine (Co-ordinator) (*University of Bielefeld*), Y. Schröder (*University of Bielefeld*)

NUMBER OF PARTICIPANTS: 12

MAIN TOPICS:

- Determination of the pressure of hot QCD up to order g^6T^4.
- Automatised techniques for perturbative computations at finite temperatures and on the lattice.
- Lattice Monte Carlo simulations within effective theories of hot QCD.

SPEAKERS:

M. Laine (*Bielefeld*),
A. Rago (*Milan*),
P. Giovannangeli (*Marsielle*),
A. Vuorinen (*Washington*),
Y. Schröder (*Bielefeld*),
F. Di Renzo (*Parma*),
C. Torrero (*Parma*),
A. Hietanen (*Helsinki*)

SCIENTIFIC REPORT:

Purpose

The free energy density, or pressure, of QCD, as a function of temperature and baryon chemical potential, is of principal relevance to cosmology, the nearly ideal hydrodynamics observed in heavy ion collision experiments, as well as compact star phenomenology. Its study has a long history of more than two decades. The most traditional line of research pursues the weak-coupling expansion, which currently is known up to the order $O(g^6\ln(1/g)T^4)$, where g is the QCD gauge coupling and T the temperature. The purpose of the meeting was to coordinate ongoing parallel projects, whose goal is to determine the pressure of hot QCD at the full order $O(g^6\ln(1/g)T^4)$.

Highlights

The meeting consisted of review talks summarising the current status of the various subprojects; technical reports, attempting to analyse in detail the challenges that lie ahead and to clarify the techniques that are believed to help in solving them; as well as a few topicwise "peripheral" contributions, with the aim of opening new angles and stimulating new approaches. Moreover, there was ample time for discussions during and after the talks. All of the talks appeared to serve their purposes; indeed both the format of the meeting and the

contents of the presentations were deemed a success.

Conclusions

It became apparent during the meeting that while hard work lies ahead if the goals are to be met, there also seem to be good reasons for optimism: certainly at least some of the sub-problems will be solved during the next couple of years. Moreover, the meeting also brought to our knowledge the existence of the BEN supercomputing facility newly installed at the ECT*. We got the impression that it might be most welcome for the computations that we are carrying out, and thus decided to compose a project application for computing time on BEN in the immediate future.

References

Most of the talks presented continue to be electronically available through
http://www.physik.uni-bielefeld.de/ laine/trento/program.html

2.3.13 THE NEW PHYSICS OF COMPACT STARS

DATE: 12–17 September

ORGANISERS:
D. Blaschke (Co-ordinator) (*GSI Darmstadt*), J. Margueron (*IPN Orsay*), C. Pethick (*Nordita*), J. Trümper (*MPE Garching*)

NUMBER OF PARTICIPANTS: 52

MAIN TOPICS:

- EoS, phase transitions, structure of compact stars
- Transport properties, modelling of cooling and supernova evolution
- Implications and future prospects of observations

SPEAKERS:

D. Aguilera (*Rostock Univ.*),
M. Baldo (*Catania Univ.*),
D. Bandyopadhyay (*Saha Institute, India*),
O. Benhar (*INFN Roma*),
J. Berdermann (*Rostock Univ*),
D. Blaschke (*GSI Darmstadt*),
I. Bombaci (*INFN and Univ. Pisa*),
A. Dieperink (*KVI Groningen*),
A. Drago (*Ferrara Univ.*),
C. Ducoin (*GANIL Caen*),
U. Geppert (*MPE Garching*),
H. Grigorian (*Yerevan Univ.*),
P. Haensel (*CAMK Warsaw*),
A. Illarionov (*Pisa Univ.*),
E. Khan (*IPN Orsay*),
T. Klähn (*Rostock Univ.*),
S. Lawley (*TJNAF, USA*),
G. Lugones (*Pisa Univ.*),
G. Lykasov (*JINR Dubna*),
J. Margueron (*IPN Orsay*),
T. Maruyama (*JAERI, Japan*),
P. Napolitani (*GANIL Caen*),
J. Navarro (*IFIC Valencia*),
D. Page (*UNAM Mexico City*),

G. Pagliara (*INFN Ferrara*),
I. Parenti (*Ferrara Univ.*),
J. Pons (*Alicante Univ.*),
S. Popov (*MSU Moscow*),
B. Posselt (*MPE Garching*),
C. Providencia (*Univ. Coimbra*),
E. Regos (*Univ. Budapest*),
P. Reuter (*Univ. Frankfurt*),
L. Rezzolla (*MPIG Golm*),
S. Rosswog (*Bremen Univ.*),
N. Sandulescu (*CEA Saclay*),
M. Hempel (*Univ. Frankfurt*),
A. Schwenk (*Indiana Univ.*),
N. Scoccola (*CNEA Buenos Aires*),
V. Soni (*NPL New Delhi*),
T. Tatsumi (*Kyoto Univ.*),
L. Tolos (*GSI Darmstadt*),
J. Trümper (*MPE Garching*),
R. Turolla (*Padova Univ.*),
E. Van Dalen (*Tuebingen Univ.*),
I. Vidana (*GSI Darmstadt*),
D. Voskresensky (*MEPhI Moscow*)

SCIENTIFIC REPORT:

Aim and Purpose

The understanding of the complex physical phenomena in compact objects requires expertise from virtually all branches of physics, ranging from the Theory of General Relativity, to the low temperature physics of fermion and boson condensation, and to QCD at finite densities. In view of this diversity it was the aim of this workshop to build up bridges between workers in different subfields and to provide a forum for corss-talk in order to gain an overall physical picture of compact stars and confront the actual status of the theory with newest experimental results of high energy physics and astrophysics.

This workshop was timely since we are witnessing now the wake of a new era in compact star physics: the observational data are gaining a precision which is sufficient to put tight constraints to the theory of dense hadronic matter. In this situation it is of utmost importance that theorists talk to those observers producing decisive data points, before they abandon theories which seem not to fulfill observational constraints. On the other hand, the cross-fertilizing theory-meets-experiment experience of this workshop may help to identify flaws of puzzling observations before big efforts are started to develope intricate models in the attempt to explain them. A famous example for the latter was the submillisecond pulsar of the late 1980ies. In the following we pick a few examples for highlights reported at the workshop.

Results and Highlights

Most striking recent results for observations of particular compact objects constraining properties of dense baryonic matter discussed at the workshop are:

- Pulsar PSR J0751+1807 with M=2.1 $M_\odot$, Nice et al. astro-ph/0508050
- z=0.35 surface redshift (EXO 0748-676), Cottam et al. astro-ph/0211126
- M-R constraints from QPOs in LMXBs (4U 0614+09), Miller astro-ph/0312449
- M-R constraints from isolated NS (RXJ 1856-3754), Trümper et al. astro-ph/0312600

The Nice-Pulsar yields a maximum mass constraint of 1.6 $M_\odot$ at the 2-σ level and 1.9 $M_\odot$ at the 1-σ level. At present no hybrid star model with a quark matter core on the market supports 2 solar masses. If observational limits for masses of compact stars settle

at such a high value with sufficient precision, the quark matter phase transition density in beta-equilibrated matter has to occur at rather high densities implying constraints for the critical densities where deconfinement can occur in symmetric compressed baryon matter (CBM experiment at FAIR Darmstadt).

The measurement of the surface redshift z=0.35 would be a direct constraint on the compactness M/R of neutron stars. Serious doubts were raised concerning this datum.

QPOs in LMXBs give constraints for M/R which, however depend on the model used in the analysis. Although the beat frequency model is generally favored, other approaches (Bombaci) suggest that 4U 0614+09 cannot be a hadronic star but is rather a strange star. Model uncertainties are still large.

A rather promising observational constraint was reported by Trümper and concerns Radius measurements from the thermal radiation of the isolated neutron star RXJ 1856-3754. From these measurements strange stars can be excluded and almost all standard EoS are excluded.

Another class of constraints on the properties of dense matter concerns the phenomenology of neutron star cooling, extensively discussed at the meeting (Aguilera, Berdermann, Blaschke, Geppert, Grigorian, Klähn, Lykasov, Page, Pons, Popov, Voskresensky). Since the analysis of cooling data involves the whole complexity of compact star physics definite conclusions can be drawn only when the big variety of possible scenarios is constrained, e.g. by the requiremet of the consistency of inputs to the modeling.

The very low upper limit of the surface temperature for the young ($\sim$ 800 yr) compact object in the supernova remnant 3C58 points to a strong sensitivity of the cooling behavior as a function of the unknown mass of the coolers, suggesting strong in-medium effects on transport properties being typical for superconducting/superfluid matter.

One of the central questions discussed at the meeting concerned speculations about the occurence of quark matter in compact stars and the potential of the deconfinement phase transition in resolvin puzzling phenomena such a bursts phenomena and enhanced cooling. If quark matter is to occur in compact stars a successful cooling phenomenology puts rather tight constraints on possible quark matter phases. In particular, it was argued that quark matter in compact stars has to be color superconducting, but with a rather small pairing gap.

Conclusions

The workshop on "The New Physics of Compac Stars" at the ECT* provided the frame for an extremely useful and timely dialogue between theorists and observers (surrounded by a wonderful landscape). Given a wealth of new observational material from satellite missions such as Chandra, XMM Newton, as well as ground based observatories we have entered an era where astrophysical measurements of compact star properties reach the precision level required to falsify assumptions about the properties of strongly and electroweakly interacting matter at extreme densities. These results complement information from laboratory experiments with heavy-ion collisions which access a different domain in the phase diagram of dense matter. Due to the complexity of the physics involved in this thematics it is ideally suited for both, networking activities of many European (and intenational) groups as well as a comprehensive long-term training course for young scientists. Several groups represented at the workshop have agreed on a European Research and Training Network programme "Physics of Compact Stars" which got meanwhile submitted to Brussels. The participants

would welcome the continuation of meetings on this thematics on an annual basis.

Optional
The talks can be browsed from the website:
http://snns.in2p3.fr/trento2005/program.html

2.3.14. UNDERSTANDING THE STRUCTURE OF NUCLEON-DEFICIENT PB NUCLEI

(Collaboration Meeting)

DATE: 19–21 September

ORGANISERS:
K. Heyde (Co-ordinator) (*University of Gent*), P. Van Duppen (*University of Leuven*), R. Julin (*University of Jyväskylä*)

NUMBER OF PARTICIPANTS: 21

MAIN TOPICS:

- Alpha-decay and general ground-state properties
- Mean-field approaches
- Shape coexistence: microscopic and macroscopic approaches
- In-beam spectroscopy
- Experimental and theoretical fingerprints: round-up

SPEAKERS:

A. Andreyev (*Triumf, Canada*),
M. Carpenter (*ANL, USA*),
A. Dewald (*Univ. Köln, Germany*),
R. Fossion (*Thessaloniki, Greece*),
V. Hellemans (*Univ. Gent, Belgium*),
P.-H. Heenen (*ULB, Brussels*),
K. Heyde (*Univ. Gent, Belgium*),
R. Julin (*JYFL, Jyväskylä*),
D. Karlgren (*R. Inst. Tech., Sweeden*),
W. Korten (*DAPNIA, CEA, France*),
S. Lesher (*IKS, Belgium*),
P. Nieminen (*ANU, Australia*),
M. Nymann (*JYFL, Jyväskylä*),
L. Robledo (*UAM, Madrid, Spain*),
J. Uusitalo (*JYFL, Jyväskylä*),
P. Van Duppen (*IKS, Belgium*),
P. Van Isacker (*GANIL, France*),
A. Wilson (*ANU, Australia*)

SCIENTIFIC REPORT:

Aim and Purpose

Understanding the fundamental excitations of many-fermion systems is of significant current interest. In atomic nuclei with even number of protons and neutrons, the low-lying excitations are in general formed by nuclear pair breaking and nuclear vibrations or rotations, depending on the precise position in the nuclear mass table. However, for certain numbers of protons and neutons, a subtle rearrangement of only a few nucleons among specific orbitals near the Fermi level can result in a different elementary mode: a macroscopic shape change. The first experimental evidence for this phenomenon came from the observation of shape coexistence in ^{16}O. Other unexpected examples came with the discovery of fission isomers and superdeformed nuclei. This research field has "exploded" in recent years due to the highly increased technical capabilities in detecting gamma-radiation emitted during the slowing down of the rapid rotation (Gammasphere, Euroball, ...).

The lead isotopes provide a unique laboratory to study the phenomenon of shape coexistence in nuclei and have been the subject of much experimental and theoretical interest and debate in the last couple of years.

It turns out that the combined effect of the proton shell-gap at $Z = 82$ for the Pb-nuclei and the large number of valence nucleons outside the closed $N = 126$ core (in this case, neutron holes), results in an important lowering of the energy of proton particle-hole excitations. More specifically, near the neutron midshell (at $N = 104$), collective bands have been experimentally observed that extend to high spin (using various experimental techniques like recoil and recoil-decay (RDT) tagging and heavy-ion induced fusionevaporation reactions), and that were totally unexpected to appear because the Pb nuclei are single-closed shell nuclei.

From a theoretical side, the shell-model spaces that include besides the valence neutrons outside the $N = 126$ shell closure also proton particle-hole excitations are beyond reach. Therefore, various approximations have been addressed. From one side one makes use of a spherical basis and keeps the essential low-lying pair excitations (0^+ and 2^+ proton and neutron pairs) within a symmetry-dictated truncation to the shell-model (the interacting boson model). On the other hand, one may address the problem using mean- field methods. In this direction, much has been learned from the use of phenomenological deformed potentials but recently, state-of-the-art HF plus pairing and HFB calculations have become available.

The program aimed at bringing together representatives of the experimental groups that have been advancing the study of the most exotic Pb species and are actively trying to resolve the nature of these collective bands, as well as the theoreticians that have developed the most recent techniques to address these neutron-deficient nuclei. We expected, as an outcome, to define key experiments that can clarify the underlying physics that is at the origin of these bands observed near neutron mid-shell and bridge the gap between the spherical and deformed mean-field studies as to the equivalences that are definitely present.

Results and Highlights

New results on two-neutron separation energies in the Pb region and new results on the radii in this mass region have been presented. Attempts to obtain a quantitative description of alpha-decay hindrance factors in the Pb region have been presented and discussed in depth.

The specific characteristics of the Pb nuclei within the context of the larger mass region was intensively discussed.

State-of-the-art results from Hartree-Fock-Bogolubov (HFB) plus Generator Coordinate Method GCM calculations were presented. Collective bands and the E2 properties are well described starting from a microscopic origin, using both zero-range Skyrme functionals and the finite-range Gogny force. Attempts to describe the structure in the neutron-deficient Pb nuclei using relativistic mean-field methods (RMF) have started and first results were presented.

The shell-model approach for lighter nuclei show the importance of particlehole excitations in order to describe shape coexistence phenomena. The state-of- the-art calculations, using symmmetry-dictated truncations, i.e., the interacting boson model were presented and discussed for the Pb region. Results on both the band structures, E2 and E0 properties and the connection to geometrical methods were presented. A new method of matrix coherent states was presented and solutions for schematic Hamiltonians were presented.

There appeared a wealth of new data on in-beam studies in both the neutron-deficient even-even Pb,Po,Hg en Pt nuclei but, very important, oddmass nuclei have been extensively presented and discussed. Results from the groups using accelerators with in-beam detection techniques (recoil decay tagging methods) at Argonne National Laboratory, ANU at Canberra and JYFL at Jyväskylä have been intensively debated. Many questions have been raised that need a better understanding in these odd-mass systems.

Conclusions

The Pb region clearly forms a unique and rich region in the chart of nuclei to study shape coexistence and the subtle interplay between the singleparticle and collective behavior. Its understanding has immediate consequences for the understanding of nuclear structure throughout the nuclear mass table.

The Pb region of neutron-deficient nuclei has become accessible with different experimental probes ranging over alpha-decay, in-beam methods with sophisticated tagging techniques to extract nuclear structure information even for very exotic nuclei. These high-quality data form a stringent test for present-day theoretical approaches.

During the past 3 years, there has been a substantial improvement of the capabilities in going beyond the deformed mean-field properties, using generator-coordinate methods (GCM) projecting on proton and neutron numbers Z,N and angular momentum J using Skyrme functionals and the finite-range Gogny force. From the side of the interacting boson model, the most advanced calculations have been carried out. Now, the relation to the underlying shell-model needs to be better understood and the connection with geometrical methods persued.

From the workshop, clear projects have been defined for both experimental studies (relating to the study of α and β decay studies, study of neutron and proton pairing gap, two-neutron separation energies, obtaining more data on E0 properties such as radii, tagging for in-beam studies at the lowest cross-section) and advancing the use of theoretical methods (trying to connect mean-field and shell-model approaches to cover even the most exotic species in this mass region).

A final statement from J.Wood (who unfortunately could not participate) condenses a good part of the workshop "The subject has been very active for 30 years. We are about

half way to a reasonably full delineation of the topic. The neutron-deficient Pb region is the most important focus at present, i.e., we will learn more about the phenomenon by fully characterizing the Pb region than anywhere else".

2.3.15 PARTON PROPAGATION THROUGH STRONGLY INTERACTING SYSTEMS

DATE: 26 September–7 October

ORGANISERS:
W. K. Brooks (Co-ordinator) (*Thomas Jefferson Nat. Accelerator Facility*), B. Z. Kopeliovich (*University Santa Maria, Valparaiso*), U. Mosel (*University of Giessen*), V. Muccifora (*INFN, Frascati*), X. N. Wang (*Lawrence Berkeley National Laboratory*)

NUMBER OF PARTICIPANTS: 41

MAIN TOPICS:

- Jet Quenching
- Partonic Energy Loss
- Hadron Formation
- Medium-modified Fragmentation Functions

SPEAKERS:
A. Accardi (*Iowa State*),
F. Arleo (*Paris*),
H. Blok (*NIKHEF*),
W. Brooks (*Jefferson Lab*),
W. Cassing (*Giessen*),
C. Ciofi degli Atti (*Perugia*),
D. d'Enterria (*Columbia*),
T. Falter (*Brookhaven*),
K. Gallmeister (*Giessen*),
S. Gevorkyan (*Dubna*),
P.-B. Gossiaux (*Nantes*),
L. Grigoryan (*Yerevan*),
D. Gruenewald (*Heidelberg*),
A. Hayashigaki (*Frankfurt*),
S. Jeon (*McGill*),
C.-M. Ko (*Texas A&M*),
B. Kopeliovich (*Valparaiso*),
C. Loizides (*MIT*),
A. Morsch (*CERN*),
U. Mosel (*Giessen*),
V. Muccifora (*INFN Frascati*),
J. Nemchik (*Kosice*),
S. Peigne (*Annecy*),
A. Peshier (*Annecy*),
H.-J. Pirner (*Heidelberg*),
J. Qiu (*Iowa State*),
J. Raufeisen (*Heidelberg*),
J. Rykebusch (*Ghent*),
K. Safarik (*CERN*),
M. Sargsian (*Florida International*),
I. Schmidt (*Valparaiso*),
D. Treleani (*Trieste*),
I. Vitev (*Los Alamos*),
K. Wang (*Virginia*),
X.-N. Wang (*Berkeley*),
K. Zapp (*Heidelberg*)
B.-W. Zhang (*Wuhan*)

SCIENTIFIC REPORT:

Aim and Purpose

The interaction of energetic partons passing through strongly interacting systems has been a topic of study for over two decades. Anticipation of the advent of RHIC and LHC stimulated an accelerating amount of activity throughout the 1990's as proposed signatures of the quark gluon plasma appeared to be closely connected to energy loss of propagating partons. The suppression of high-p_T jets observed in the RHIC data offer the strongest evidence to date of energetic partons losing energy in a hot and dense medium. Though the wealth of data on jet quenching at RHIC provides the first glimpse into jet interactions in a very hot medium, it is essential to understand the baseline effect of jet quenching in cold, "normal" nuclear matter.

In the past decade, two new sets of experimental data became available that provide important information on these baseline effects. First, a series of experiments exploiting the Drell-Yan process in high-energy p-A scattering were used to estimate the energy loss of quarks passing through cold nuclear matter. These experiments, using 800 GeV protons incident on a variety of nuclear targets, have lead to an extraction of an estimate for quark energy loss. Additionally, broadening of the transverse momentum distribution of Drell-Yan pairs, charmonia and bottomia produced off nuclei with 800-GeV protons provided crucial information about multiple interactions of high-energy quarks and gluons propagating through the nuclei.

More recently, measurements at HERMES using positron beams of 12 and 27 GeV have provided a rich new data set for deep inelastic scattering on light and medium-mass nuclear targets, with excellent hadron identification in the final state. The attenuation of hadrons in these measurements has been interpreted phenomenologically to yield the formation lengths of hadrons evolving from struck quarks. New theoretical activity has been stimulated by this data. However, the theoretical efforts to date explain the data using a variety of physical pictures which may not be compatible at root.

Finally, experiments at Jefferson Lab are providing deep inelastic scattering data on a range of nuclei, detecting final-state hadrons. The first measurements took place in CLAS in early 2004 with a 5 GeV electron beam; future investigations with an upgraded facility will be feasible with an 11 GeV electron beam. These measurements complement the HERMES data by providing lower energy measurements at high luminosity on targets from carbon to lead.

The primary focus of the workshop was to *understand in-medium hadronization dynamics and partonic energy loss.* This subject is timely because of the convergence of relevant data from four international-scale laboratories: RHIC, Fermilab, HERA, and Jefferson Lab. It is particularly timely in view of its role in interpreting the RHIC data and predicting similar phenomena at LHC. It is interdisciplinary in the sense that it connects to topics in core nuclear physics as well as hadronic physics and high energy physics, and connects to QED in the sense that there exist analogous phenomena in QCD.

Results and Highlights

One important dynamic of the workshop was discussion between members of several communities that ordinarily do not interact at a deep level. For example, the workshop session themes alternated between deep inelastic scattering and jet propagation in hot, dense matter. The talks presented in these two session categories included a number of experimental topics in addition to the theoretical discussions that were the primary focus. A wide variety of energy scales was represented, another traditional divide that was spanned by the workshop. This mixture was very important in identifying common issues in hadronization and quark energy loss, which is a first step toward forming a conceptually consistent view of the processes at work. For instance, an understanding of the state that is intermediate between a propagating quark and a fully formed hadron, referred to as a 'prehadron,' is important in several theoretical formulations addressing nuclear deep inelastic scattering, but the prehadron is not typically an ingredient in the description of relativistic heavy ion collisions. Because both communities were present, there were extended and productive discussions of whether the prehadron could play a role in jet suppression. An alternative example is given by the use of the color flux tube or string model, which gives naive but useful and apparently relevant guidance for deep inelastic scattering. If the hot dense matter produced in relativistic heavy ion collisions really is fully deconfined, then the string concept is likely to be irrelevant, and perturbative QCD is the only resource common to both communities.

New preliminary experimental data were released at the workshop. In the first week, new 5 GeV DIS data from CLAS at Jefferson Lab were shown for hadronic multiplicity ratios and transverse momentum broadening for positive pions in carbon, iron, and lead. In the second week, new 27 GeV HERMES DIS data were released for hadronic multiplicity ratios for several hadron species from a xenon target. The latest status of jet quenching in RHIC data was also reviewed in the second week, including new preliminary results. All of these data were very exciting and stimulated much discussion among the workshop participants. Future prospects for LHC data were also discussed in both weeks, and it is clear that much further progress will come once those data are in hand.

A host of new theoretical ideas surfaced in the workshop presentations. One example was a new approach for estimating an upper bound on the medium-induced partonic energy loss in cold nuclei. Another theme was to explore additional mechanisms for energy loss in hot dense matter, such as the increased role of collisional losses expected in a dense fluid. Further progress in understanding specific features of the medium-induced gluon emission was visible, such as increased evidence supporting the idea that quark energy loss is dominated by emission of hard gluons in small numbers. Further discussion concerned detailed mechanisms of hadronization, e.g., the number of independent time scales involved in the process, on which historically there has not been a consensus. The time scale for DGLAP evolution of an energetic jet was debated at length, concluding that the DGLAP processes could happen on a time scale comparable to the system size for an initial jet with large virtuality. This may have important implications for how partonic multiple scattering is treated in this kinematic domain. In spite of much discussion, consensus was not reached on the order of magnitude of the hadronic formation length. For instance, theoretical studies with a sophisticated coupled-channel final state interaction were presented that indicated the formation length for pions is approximately 0.5 fm in the unboosted frame; this formalism is able to describe many different data sets and therefore offers strong constraints.

Such a formation length would exceed nuclear dimensions for pions of only 2 GeV. On the other hand, well-founded arguments based on the string model and pQCD suggested that hadronic formation lengths are an order of magnitude smaller, as discussed in several talks. The core issue of whether hard or soft scales govern hadron formation was not resolved at the workshop, and the discussions are continuing.

Conclusions
The workshop was a great success. New collaborative efforts are certain to spring from this gathering of experts from diverse fields. Although much work remains to be done, the opportunity to discuss dissenting ideas at length has laid a valuable foundation for ultimately resolving the issues and arriving at a consistent description of parton propagation in strongly interacting systems, both hot and cold.

Many of the talks can be browsed from the workshop website at
http://conferences.jlab.org/ECT/

2.3.16. PARTON PROPAGATION THROUGH STRONGLY INTERACTING MATTER

(Collaboration Meeting)

DATE: 7–11 November

ORGANISERS:
A. Molinari (Co-ordinator) (*University of Turin and INFN Turin*), M.B. Barbaro (*University of Turin and INFN*), W. Donnelly (*CTP, LNS and Dep. of Phys., MIT, USA*)

NUMBER OF PARTICIPANTS: 22

MAIN TOPICS:

- Electroweak interactions with hadrons and nuclei
- The physics of the quark-gluon plasma

SPEAKERS:

M. B. Barbaro (*Univ. Torino*),
A. Beraudo (*Univ. Torino*),
J. P. Blaizot (*ECT* and CNRS*),
J. A. Caballero (*Univ. Seville*),
G. Chanfray (*IPN Lyon*),
S. Chiacchiera (*Univ. Torino*),
P. Czerski (*Niew. Inst., Cracow*),
D. Davesne (*IPN Lyon*),
A. De Pace (*INFN Torino*),
T. W. Donnelly (*MIT*),
M. Ericson (*CERN*),
G. Garbarino (*Univ. Torino*),
H. Hansen (*Univ. Torino*),
C. Martinez (*Ghent Univ.*),
M. Martini (*Univ. Lecce*),
A. Molinari (*Univ. Torino*),

E. Moya de Guerra (*Univ. Madrid*),
F. Palumbo (*INFN and LNF*),
C. Ratti (*ECT**),
I. Sick (*Univ. Basel*),
V. Somà (*Niew. Inst., Cracow*),
J. M. Udias (*Univ. Madrid*)

SCIENTIFIC REPORT:

This collaboration meeting (CM) was prompted from the starting assumption that advancement in science is best achieved through the interbreeding of different fields. Hence this (in some sense "experimental") CM balanced the area of electroweak interactions with hadrons and nuclei against that of ultrarelativistic collisions of heavy ions. This rencontre was not expected to lead immediately to projects of collaboration on specific themes between scientists belonging to the two communities, but rather to pave the way for such an occurrence.

Specifically the purpose was

a) to create the conditions allowing the researchers of one field to understand the issues and theoretical methods employed by the researchers of the other field, and

b) to lead to the recognition that the two fields have much in common — more than one would superficially believe.

Concerning these points, in our view the CM has indeed been quite successful. This is demonstrated by the attendance to the presentations: all the participants (a large fraction of them being young people) were always present. Of course in the short span of time of a week it was not possible even remotely to cover the broad range of items related to electroweak interactions and the QGP. Yet a good selection of the central themes was addressed.

In the area of electroweak interactions considerable attention has been placed on the experimentally established phenomenon of superscaling. In particular, links to the factorization of the single-constituent physics, the information on the many-body dynamics gained both from the superscaling function and from the violations of superscaling, and the relationship between electron and neutrino cross sections were thoroughly explored. Worth stressing is the relevance of the last mentioned item for crucial questions of particle physics, namely, neutrino oscillations and the mass and mixing matrix for neutrinos.

Also investigated (regrettably only briefly) was the evolution of the superscaling function as one approaches the domain of DIS: here indeed the transition from hadronic to QCD degrees of freedom cries out for deeper understanding.

Concerning the QGP, a comprehensive discussion of the various energy scales characterizing the physics at $T > T_c$ was offered. At each scale different aspects of QCD disclose themselves and accordingly studies were presented in the hard thermal loop (HTL) expansion framework (and beyond) and on $q - \bar{q}$ correlations both in space and in imaginary time. It was emphasized that such investigations are relevant both for the interpretation of experimental data and for grasping essential aspects of QCD. On the same footing should

be placed the analysis of the color singlet heavy $q - \bar{q}$ potential and of the solutions of the associated Schrödinger equation for charmonium and bottomonium in the deconfined phase of QCD.

For $T < T_c$ (actually for $T = 0$) attention was focused on the evolution of the quark condensate with density in connection with the restoration of chiral symmetry.

Finally an approach was discussed implementing the Nambu Jona-Lasinio model to account for confinement and for the connection between the physics of alkali atoms confined in a magnetic field and the QGP as far as the asymmetry in the angular distribution of the reaction products, experimentally found at RHIC, is concerned.

In conclusion, we believe from feedback already received that the experience of taking part in this CM has been positive for all: it appears that everyone felt enriched and that future fruitful collaborations prompted by this meeting should be expected.

2.4 ECT* Doctoral Training Programme

The 2005 Marie-Curie Doctoral Training Programme was devoted to "Hadron Physics". It was held at ECT* during the three month period May-July 2005.

The Programme was prepared by Matthias F.M. Lutz (Darmstadt) who was the co-ordinator, together with Michael Birse (Manchester) and W. Vogelsang (New York) who acted as co-organizers. The student applications were examined and selected jointly by the director, the vice director and the organizers. G. Ripka (SPhT - CEA Saclay) was present at ECT* during the entire program. He assisted the director in the daily supervision of the students.

2.4.1 Lecture Series

The following series of lectures were presented at the Centre (see also section 3.5.1):

- **Chiral perturbation theory**
  Lecturer: Stefan Scherer (University of Mainz, Germany)
- **Charm physics on the lattice**
  Lecturer: Christine T. H. Davies (University of Glasgow, UK)
- **Large-N_c QCD**
  Lecturer: Aneesh Vasant Manohar (University of California, San Diego, USA)
- **Photon-hadron interactions and parton distributions**
  Lecturer: John Collins (Penn State University, USA)
- **Parton distributions in exclusive processes**
  Lecturer: Mark Vanderhaeghen (TJNAF, College of William and Mary, USA)
- **Quark model and exotics**
  Lecturer: Francis Close (Oxford University, UK)
- **Spin structure functions**
  Lecturer: Piet J. Mulders (Vrije University, the Netherlands)
- **Hadron-hadron interactions**
  Lecturer: Evgueni Kolomeitsev (University of Minnesota, USA)

2.4.2 Participants

On the basis of their academic and scientific profiles and achievements, 23 advanced doctoral students were selected as participants of the Training Programme. Six of those participants were eligible for Marie Curie Fellowships[1]. These fellowships enabled them to spend extended periods (3 months) at ECT* conducting their own research and entering into new collaborations. All Training Programme participants were furnished with standard working conditions at the Centre, including full access to the ECT* computing facilities.

List of participants (Marie Curie Fellows are indicated by *):

Cyril Adamuscin*	Slovak Academy of Science,
Deborah Nancy Aguilera	University of Rostock,
Petr Benes	Nuclear Physics Institute AS CR,
Adam Bzdak*	Jagiellonian University, Krakow,
Marco Cristoforetti	University of Trento,
Sara Della Monaca	University of Trento,
Magali Estienne	SUBATECH,
Teresa Fernàndez-Caramés	University of Valencia,
Ivana Hristova	DESY,
Olga Lakhina	Oxford University,
Jean-Philippe Lansberg	University of Liége,
Vadim Lensky	Institut fr Kernphysik,
Cédric Serge Corinne Lorcé	University of Liége,
Nicolas Matagne	University of Liége,
Vicent Mateu Barreda*	University of Valencia - IFIC,
Stefan Michalski*	University Dortmund,
Yusuke Nishida	University of Tokyo,
Felix Riek	GSI,
Matthias Ralf Schindler*	University of Mainz,
Adam Smetana*	Institute of Particle and Nuclear Physics, Prague,
Federica Sozzi	University of Trieste,
Christian Türk	University of Torino,
Annelies Van Dyck	University of Gent,
José Maria Verde Velasco	University of Salamanca,
Zhenyu Ye	DESY-HERMES

[1] According to EC rules, Italian participants are non-eligible for Marie Curie Fellowships at ECT* as the Centre is based in Italy.

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

Cyril ADAMUSCIN : 15th of June, 2005, "The puzzle of big disagreement between SLAC and JLab experimental data".

Deborah Nancy AGUILERA : 12th July, 2005, "Color superconducting quark matter in a two flavor non-local chiral model under compact star constraints".

Petr BENES: 14th June, 2005, "Dynamical fermion mass generation by a strong Yukawa interaction".

Adam BZDAK: 31st May, 2005, "The square root of the Dirac equation".

Adam BZDAK: 19th July, 2005, "Double diffractive Higgs, two jets, charm(bottom)onium, two photon production".

Marco CRISTOFORETTI: 26th July, 2005, "Quark-quark correlations in non perturbative QCD".

Sara DELLA MONACA: 25th July, 2005, "Electromagnetic responses in few body nuclear systems".

Magali ESTIENNE: 13th July, 2005, "An overview of heavy ion collision experiments".

Vicent MATEU BARREDA: 29th June, 2005, "V_{us} Determination from Hyperon Semileptonic Decays".

Stefan MICHALSKI: 23rd May, 2005, Tutorial on Lattice QCD "Local gauge invariance, Wilson loops and why those might help you on the lattice".

Stefan MICHALSKI: 22nd June, 2005,"Resummation as a non-perturbative method in quantum field theory. Comparing and testing two different resummation schemes".

Yusuke NISHIDA: 19th May, 2005, "BCS-BEC crossover in relativistic superfluid and its possible realization in QCD".

Felix RIEK: 1st June, 2005, "Selfconsistent rho and omega mesons in hot and dense matter".

Matthias Ralf SCHINDLER: 23rd May, 2005, "Lorentz-invariant formulations of Baryon ChPT" (talk given in the workshop on Two-Photon Physics).

Matthias Ralf SCHINDLER: 15th June, 2005, Discussion: "Vector Mesons in Baryon Chiral Perturbation Theory: Power Counting and Consistency Conditions".

Adam SMETANA: 7th June, 2005, "Two-colour QCD and Goldstone bosons with a quadratic dispersion law".

Christian TÜRK: 25th May, 2005, "Spin and the proton in high-energy physics".

José Maria VERDE VELASCO: 5th July, 2005, "Study of leptonic decays of pseudoscalar B,D and vector B*,D* mesons and the semileptonic $B \to D$ and $B \to D^*$ decays".

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. Some of these researchers belong to the "Quantum Information Processing Group" which is briefly described in the next section.

3.1 The Quantum Information Processing Group at ECT*

ECT*, owing to its institutional goals, is interested in research on computing technologies for the simulation of complex quantum many-body systems. On a normal computer this requires exponential computational resources; this would not be the case, should the computer itself obey the laws of quantum mechanics. These basic considerations have started in recent years the new research field of Quantum Information Processing (QIP). Despite rapid progress, no experimental method has yet led to a scalable realization of a quantum computer. An urgent need therefore remains for the development of new technologies to enable this. In this context, ECT* has been coordinating since 2000 the theoretical research of the Research and Technology Development Network ACQUIRE (Atom Chips for QUantum Information REsearch), aiming at the implementation of an elementary quantum processor on an atom chip, based on a proposal developed by Dr. Tommaso Calarco and Prof. Zoller within a collaboration with the University of Innsbruck. The project was funded under the Future and Emerging Technologies Proactive Initiative (FET-QIPC) of the Information Society Technologies Fifth Framework Programme with a grant administrated at ECT* under the responsibility of Dr. Calarco. The project has continued under the name ACQP (Atom Chip Quantum Processor) until the end of 2005.

This gave ECT* the opportunity to strengthen the local research group in QIPC, comprised of a few undergraduate and graduate students and a few post-docs, while always keeping collaboration with Innsbruck. Based on this, ECT* became a node of the European QIPC Network of Excellence QUIPROCONE.

The activities are going to be carried on also under the EC Sixth Framework Program, as ECT* is going to be partner (with the same budget level as in ACQP) of the recently approved FET Integrated Project SCALA, started in November 2005.

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

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

Furthermore, Dr. Calarco has been appointed also as the responsible of the European QIP Roadmap for FP7, in the framework of ERA-Pilot QIST Project, in a joint effort between INFM and the Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences. Dr. Daniele Binosi, a former ECT* postdoc, has been hired to actually carry on this job. ECT* is also involved as a workpackage leader in the recently submitted coordination action QUROPE, due to continue the ERA-Pilot work, which received very high marks in the recent evaluation by EC experts and is expected to enter negotiations soon.

3.2 Projects of ECT* Researchers

• Daniele Binosi

This year has been my second year as a post-doc at ECT*, and was characterized by a shifting in my interests towards the area of Quantum Computation. Early in 2005 (February), I in fact quitted my post-doc position at ECT* for being hired as a post-doc at the Institute for Quantum Optics and Quantum Information (IQOQI) in Innsbruck (my worksite being however the ECT*). This new job has (in principle) no research involved, and it is managerial in nature, being its primary scope the one of helping Dr. Tommaso Calarco in co-ordinating the work of the European project ERA-Pilot QIST (Quantum Information Sciences and Technologies). In particular, the main task I had to work on has been the realization of the first stable version of the "Quantum Information Processing and Communication: strategic report on current status, visions and goals for research in Europe". This is a roadmap-type document which has the goals of promoting QIPC research in Europe, strengthening its image and expressing it in a coherent way, unifying the research community, elaborating a common European strategy and goals, providing input to the European Commission for the preparation of the Seventh Framework Programme and reaching in an appropriate way decision makers, and finally, expanding and strengthening activities on European level. Besides being a document addressed to policy makers and funding agencies (both at the European and national level), the report contains also a detailed scientific assessment of the state-of-the-art, main research goals, challenges, strengths, weaknesses, visions and perspectives of all the most relevant QIPC sub-fields, that has been published in [1].

On the other hand, I have continued to develop my research in elementary particle physics. In particular in [2] we have described a new method for determining the renormalization of Green functions to all orders in perturbation theory, which we call the "displacement operator formalism", or the D-formalism, in short. This formalism exploits the fact that the renormalized Green functions may be calculated by displacing by an infinite amount the renormalized fields and parameters of the theory with respect to the unrenormalized ones.

With the help of it, we were able to obtain the precise form of the deformations induced to the Nielsen identities after renormalization, and thus derive the exact dependence of the renormalized Green functions on the renormalized gauge-fixing parameter to all orders. As a particular non-trivial example of its use, we have also calculated the gauge-dependence of $\tan\beta$ at two loops in the framework of an Abelian Higgs model, using a gauge-fixing scheme that preserves the Higgs-boson low-energy theorem for off-shell Green functions. This formalism was presented in July as a contribution in the "Non perturbative physics" session of the International Europhysics Conference on High energy Physics held in Lisboa [3]. Finally, we have just finished a work [4] in which we study the impact of CP violation through particle mixing on the lineshape of the CP-even and CP-odd neutral scalars which appear in the spectrum of models with two Higgs-doublets, such as the supersymmetric extensions of the standard model. In the absence of mixing, the mass-difference between these two particles tends to be relatively small. It turned out that CP-violating effects increase this mass-splitting significantly, but in a way, which, in most cases, can be clearly distinguished from the alternative possibility where CP is conserved, and the two masses happened to be far apart due to the rather large value of the $\tan\beta$. This analysis suggests that the lineshape of this Higgs system may provide valuable information on the CP nature of the underlying theory, allowing a direct experimental distinction between CP-conserving and CP-violating models.

Last but not least, in September I was awarded the "Premio Extraordinario de Doctorado", a prize that is given once per year by the University of Valencia to the best doctoral thesis of the previous two years. The prize has been given during a formal ceremony held in the ancient (1599) University buildings.

References

[1] P. Zoller *et al.*, Eur. Phys. J. D **36**, 203, (2005).

[2] D. Binosi, J. Papavassiliou and A. Pilaftsis, Phys. Rev. D **71**, 085007 (2005) [arXiv:hep-ph/0501259].

[3] J. Papavassiliou, D. Binosi and A. Pilaftsis, arXiv:hep-ph/0512030.

[4] J. Bernabeu, D. Binosi and J. Papavassiliou, "*CP violation through particle mixing and the H-A line-shape*," in preparation.

• Jean-Paul Blaizot

I have continued several lines of research:

- **thermodynamics of hot QCD.** In collaboration with A. Ipp at ECT*, and A. Rebhan and U. Reinosa in Vienna, we have tested techniques that we had developed to calculate the entropy of the quark-gluon plasma, in the case of QCD with a large number of flavors. We found that these techniques work surprisingly well even for large values of the coupling constant. (ECT*-05-07, ECT*-05-08, ECT*-05-11)

- **phenomenology of heavy ion reactions.** We have argued that, contrary to many claims in the recent literature, hydrodynamics does not provide a perfect account of the data on elliptic flow. We suggest instead that these data indicate that matter produced at RHIC is not fully thermalized and gave predictions that can easily be tested. (ECT*-05-30)
- **high energy QCD.** We have constructed an effective theory describing the dynamics of "pomerons" and which exploits a duality property of high density QCD recently discovered. (Phys. Lett. B 615 (2005) 221)
- **Bose-Einstein condensation.** We have extended our work on the transition temperature of the weakly interacting Bose gas to the case of two dimensions and analyzed the relation between Bose-Einstein condensation and the Kosterlitz-Thouless-Berezinski transition. (ECT*-05-23)
- **non perturbative renormalization group.** We have extended on previous work on the development of new methods to solve the non perturbative renormalization group equations and obtain the momentum dependance of n-point function. (ECT*-05-02, ECT*-05-24, ECT*-05-25, ECT*-05-26)
- **investigation of the Landau-Pomeranchuck-Migdal effect on the production of photons in a quark-gluon plasma:** we have established that the formalism recently developed by Arnold Moore and Yaffe is equivalent to solving a usual Boltzmann equation. (ECT*-05-22)

• Tommaso Calarco

My research has developed along two main lines:

Relaxing constraints on neutral-atom QIPC

Neutral atoms lend themselves in a very natural way to a scalable implementation of QIPC. Besides the capability of handling a big number of qubits at once, the high degree of parallelism of operations achievable in periodic potentials would allow in a straightforward way for the nested redundant encoding needed for fault-tolerant quantum computation. Anyway, design of a quantum processor has to meet the conflicting requirements of control of a large quantum system and avoiding decoherence. Here, what becomes critical is the fidelity of the elementary single- and two- qubit operations, defined basically as the projection of the desired quantum logical state onto the one which is actually obtainable via the physical interaction under consideration. Besides the well-known general criteria formulated by D. DiVincenzo, the fulfilment of various practical desiderata, specific to atomic implementations, basically can make the difference on the road to experimental realization. For instance:

- laser addressing of single qubits, though being theoretically trivial, is limited by diffraction, imposing a lower bound on the actual spacing between qubits;
- performing gate operations in state-dependent potentials creates entanglement between internal and external degrees of freedom, which in turn is prone to decoherence, as random fields typically affect differently the two logical states;

- the gate fidelity usually decreases with temperature, as the evolution cannot be controlled to yield the same outcome regardless of the motional state of the system;
- the same is true for internal-state entanglement, if the qubit states are chosen with different Land factor and unless the latter vanishes for both states, they will be sensitive to magnetic-field fluctuations;
- extensive use of swap operations to exchange information between different quantum memory locations can be significantly less efficient than physically transporting atoms between lattice sites;
- parallel as well as site-selective operations are possible; last but not least;
- quantum gates need of course to be performed in the shortest possible time.

Improving gate performance via quantum optimal control

An essential feature for a quantum gate to be scalable up to a general-purpose fault-tolerant architecture is its fidelity, to be smaller than a certain threshold. The precise value of the latter is still debated, as it has been shown to depend to a certain extent from the specific error model suitable to describe a specific physical implementation. In particular, different physical scenarios will be affected most significantly by a few decoherence mechanisms, while many other types of gate errors will be negligible if not absent at all.

Therefore a very important objective of my research has been to understand and to model the effects of decoherence on the performance of quantum gates between neutral atoms, and to develop efficient coherent control strategies to minimize its impact. Quantum optimal control techniques, as developed in the context of laser controlled molecular reactions, allow for a general and automatic numerical search for pulse sequences tailored to attain with very high fidelities the desired evolution up to a pre-defined goal state.

We applied a systematic development of coherent control ideas to multiple quantum gates scenarios. Several previous quantum gate proposals ranging from cold atoms in optical lattices to artificial ions (doped quantum dots) have been reconsidered with the account of the coherent control ideas.

• Markus Antonio Cirone

My scientific activity at ECT* concerns the development of new schemes and implementations of quantum logic gates with neutral atoms in atom chips and other devices. This work is done together with Tommaso Calarco and Antonio Negretti. The activity has focused on the elaboration of realistic schemes for the implementation of quantum logic gates on atom chips. In our investigations we take into account the real experimental conditions that limit the performance of many ideal schemes present in the literature and require thus further developments and improvements before being implemented.

It has been recently shown by experimental partners of ACQP that two hyperfine states of Rubidium (those with F=2, mF=1 and F=1, mF=-1, henceforth denoted as 0 and 1, respectively) trapped by magnetic fields above an atom chip surface can be kept in a coherent state for a few seconds (a long time for neutral atoms). Since preservation of coherence is a

fundamental issue in quantum information processing, these states are very good candidates for implementing a logic gate.

In collaboration with the experimental group of J. Schmiedmayer in Heidelberg we have elaborated a new scheme that makes use of the states 0 and 1 only to store information and transfers it to the external degree of freedom when it must be processed. In this way we combine the potentiality of the internal hyperfine states with the flexibility of the external states, that have been already considered in a few other schemes. The gate operation occurs with the vibrational states of two atoms trapped in a double well potential (one atom in each well). The double–well configuration allows an interaction between excited vibrational states in the classically forbidden region under the barrier that separates the two wells, while the vibrational ground states are well separated and do not interact with each other. The experimental conditions to realize such a gate operation with static magnetic traps on atom chips have been found.The performance of the phase gate has been estimated. The operation time is about 16 ms with a fidelity above 99

We have then established a collaboration with Eric Charron in Paris, who had elaborated a scheme for a phase gate with atoms in a double well potential with a time–dependent barrier. We have studied the feasibility of such scheme on atom chips. We have found how to create a double-well potential with a time-dependent barrier by varying currents on the atom chip and studied the performance of the phase gate. An operation time on the order of 20 ms with a fidelity above 99.9% has been found.

Finally, we also started a collaboration with the experimental group of T. Hänsch–J. Reichel in Munich in order to study the implementation of a phase gate with state–dependent potentials. For this purpose, the following scheme has been elaborated: dc currents and static homogeneous bias fields create a static magnetic double-well potential; a microwave ac current is then switched on. The electromagnetic field created by the microwave current has opposite effects on the two hyperfine states 0 and 1. For one state, it gives rise to a potential that increases the height of the barrier that separates the wells, whereas for the other state the potential cancels the barrier, thus allowing collisions between the two atoms only for those states. The details for an implementation of this scheme are under investigations.

• Marco Cristoforetti

Instantons and Chiral Extrapolation

in collaboration with P. Faccioli (Trento Univ. and ECT), J. W. Negele (MIT) and M. Traini (Trento Univ. and ECT*)*

We have completed the development of a mathematical and numerical framework to calculate hadronic observables at different values of the quark masses, in the Interacting Instanton Liquid Model. 5 set of unquenched configurations of the instanton ensemble, with different masses in the range $10 - 100\ MeV$ have been generated using the ECT* supercomputing facility. We have used such ensembles to calculate non-perturbatively momentum-projected two-point correlation functions of the lowest-lying mesons and baryons. We found that nucleon, pion and delta-isobar are bound by instanton forces in the whole range of values of the quark mass considered. The comparison with the predictions of chiral-perturbation

theory is in progress.

• Sara Della Monaca

My research activity during the last year has been focusing mainly on calculations of a two body current operator describing a virtual photoexcitation of a $\Delta - Isobar$ and its subsequent decay by means of one pion exchange between nucleons.

As a first step, calculations have been performed by using the so called Static Approximation, i.e. by neglecting every kinetic energy terms in Δ propagator. I created subroutines for numerical calculation of the operator and I implemented these subroutines in the main program. It calculates transverse response functions of electron scattering inclusive reactions on three body nuclear systems. In particular, electromagnetic response functions are calculated by using Lorentz Integral Transform (LIT) method.

I also collaborated in analytic calculations and numerical implementation of meson exchange nuclear current operators, such as Seagull and pion-in-flight currents.

As a next step I plan to work on a different approach of treating Δ excitation and deexcitation contribution in transverse response, by avoiding use of Static Approximation. It consists in considering $\Delta - Isobar$ as an explicit degree of freedom, as nucleons, and in considering two different components of nuclear wave functions.

• Carlo Ewerz

Since I arrived at ECT* in October I have worked on different aspects of Quantum Chromodynamics.

In collaboration with Otto Nachtmann (Univ. Heidelberg) I have studied the nonperturbative foundations of the dipole picture of high energy scattering. We were able to identify all approximations and assumptions necessary to obtain the dipole picture from a general nonperturbative starting point.

In collaboration with Thomas Bittig (Max-Planck-Institut für Physik komplexer Systeme, Dresden), Gregory Korchemsky and Samuel Wallon (both at LPT, Univ. de Paris XI, Orsay) I have investigated the conformal properties of Pomeron vertices in high energy QCD. We find that the four-Pomeron vertex can be expressed in terms of the three-Pomeron vertex via a conformal bootstrap relation. This result indicates that the whole set of Pomeron diagrams in high energy scattering can be formulated in terms of a conformal field theory or even a string theory.

I have also worked on a numerical study of the Gribov-Dyson-Schwinger equation for the light quark's Green function in Feynman gauge. This study includes in particular the back-reaction of pions on the quark. This framework allows one to see how chiral symmetry breaking occurs, and also permits to establish a relation with Gribov's confinement scenario according to which chiral symmetry breaking and confinement are caused by supercritical color charges.

Furthermore, I have studied various properties of the Odderon which is the leading exchange in high energy scattering processes that carries negative chargy parity quantum

numbers.

• Pietro Faccioli

Strong CP Breaking and the Topological Structure of the QCD Vacuum

Collaborators: O. Leitner (ECT) and T. Schäfer (NCSU)*

The most general QCD Lagrangian introduces strong CP violations for any finite value of the parameter $\overline{\theta}$. Although measurements of the neutron electric dipole moment have shown that $\overline{\theta} \leq 10^{-9}$, it has recently been suggested that local spontaneous violations may occur at finite temperature, in the proximity of the QCD phase transition. At present, such a conjecture is subject of experimental investigation at RHIC.

From a theoretical point of view, strong CP violations are very difficult to study, because they are due to purely non-perturbative topological effects. No attempt to study the possibility of spontaneous CP violation near T_c using a microscopic approach has been made so far. We have developed a formalism to perform such an analysis using the Instanton Liquid Model, i.e. assuming that the topology of the vacuum is saturated by semi-classical vacuum gauge field fluctuations. We have identified the Green's functions encoding information about local CP violations and developed the mathematical and numerical codes to perform numerical grand-canonical averages in the Instanton ensemble. Simulations at different temperatures are presently running.

Instantons and Chiral Extrapolation

Collaborators: J.W. Negele (MIT) M. Cristoforetti (Trento Univ. and ECT) and M. Traini (Trento Univ. and ECT*)*

We have completed the development of a mathematical and numerical framework to calculate hadronic observables at different values of the quark masses, in the Interacting Instanton Liquid Model. 5 set of unquenched configurations of the instanton ensemble, with different masses in the range $10-100\ MeV$ have been generated using the E.C.T.* supercomputing facility. We have used such ensembles to calculate non-perturbatively momentum-projected two-point correlation functions of the lowest-lying mesons and baryons. We found that nucleon, pion and delta-isobar are bound by instanton forces in the whole range of values of the quark mass considered. The comparison with the predictions of chiral-perturbation theory is in progress.

Theoretical Biophysics

Collaborators: F. Fogolari (Udine Univ.), F. Pederiva (Trento Univ.), L. Pieri (Udine Univ.), H. Orland (CEA) and M. Sega (Trento Univ.)

We have set-up a 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 study protein folding,

unfolding and bio-molecules aggregation.

We have established contacts and collaborations with experts in theoretical and experimental aspects of protein dynamics. We have organized a collaboration meeting on "Theoretical Modeling of Protein Dynamics", which was held in ECT on May 2005 19-21. We identified two main projects based on parallel-computing, which have been developed using the E.C.T.* tera-flop supercomputing facility:

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

   Developers: Esposito, Fogolari, Pieri

   Amyloidoses are diseases caused by tissue deposition of protein aggregates. Human β-2 microglobulin ($\beta - 2m$) is one of the 17 proteins associated with such diseases. It is known that a mutation resulting in proteolysis of the N-terminal region of $\beta - 2m$ leads to the truncation of the six N-terminal residues ($\Delta N6\beta 2 - m$). This truncated species has a higher tendency to self-aggregate than the full-length protein and does not form a fully folded native state at the end of the refolding procedure. A set of structures obtained through NMR is now available, due to the experimental work of Esposito and collaborators.

   In direct collaboration with the Udine Group lead by Esposito and Fogolari, several Molecular Dynamics simulations of the first $10-20\ ns$ of the aggregation process of this protein, not completely folded have been performed. Results have shown indications about the initial processes that end in the formation of fibrils. The results are about to be submitted for publications.

2. **Determination of the Dominant Folding Pathways by Means of Path Integral Methods**

   Developers: Faccioli, Orland, Pederiva, Sega

   We have developed a novel approach 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 have derived a Hamilton-Jacobi variational principle from which we were able to compute the most probable pathway of folding. This approach is completely general and does not require the prior knowledge of any reaction coordinate. The method was 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 all computed paths display strong similarities. We are now developing the parallelization/optimization of the code which is required to perform realistic all-atom simulations. In this context we have established a connection with the Chemical Physics Laboratory of NIH, in which experiments on folding kinetics are being performed.

• Luca Girlanda

In 2005 I have been working at ECT* from January to April.

In the field of the nuclear few-body problem, with the aim of unambiguously identifying all relativistic effects, I have formulated, in collaboration with Michele Viviani (INFN, Pisa), a relativistic quantum mechanics (with fixed number of degrees of freedom) of the Bakamjian-Thomas type, along the lines of a recent proposal by W. Klink. The conceptual ingredient that we have added is the consideration of an effective field theory inspired approach, in which, at sufficiently low energy, only the lightest degrees of freedom are active: in the case at hand, only the valence nucleons and the pions. This statement can be made precise in the framework of a systematic expansion in powers of small momenta and pion mass, divided by the intrinsic hadronic scale, as in ordinary chiral perturbation theory. We have explicitly verified that, at least for the two-nucleon system, our approach is consistent up to the first order in the chiral expansion. With our framework we have worked out the physical observables of the two-nucleon system related to the bound and the scattering states. The description which, analogously to what happens in ordinary chiral perturbation theory, takes into account 1 pion exchange and leading nucleon-nucleon contact interactions, is in reasonable agreement with the phenomenology. To finalize our work, we want to consider on the same footing the pion-nucleon scattering, in order to fully exploit the constraints coming from chiral symmetry.

I have also continued the collaboration with the Orsay group (Jan Stern and collaborators), concerning the rearrangement of the chiral perturbation theory series, in the Goldstone boson sector, in order to take into account the presence of large fluctuations of strange quark-antiquark pairs, as indicated by phenomenology. We have used our method of resummation of the fluctuations to study the pion and kaon scalar form factors. The aim is to determine the impact of a new dispersive analysis of the above form factors (of the Mushkelishvili-Omnès type) on chiral symmetry breaking order parameters in the three-flavour case. At the present time we are investigating how to properly take into account the experimental correlations in the dispersive determination of the form factors, in the framework of a Bayesian analysis, already experimented in our analysis of pion-pion scattering.

• Andreas Hiroichi Ipp

In 2005 we could successfully finish the entropy calculation in the large flavor number limit using the ECT* Teraflop cluster (see below). During this year, I have further suggested the installation of the internal ECT* wiki. Also, during the 2005 ECT* doctoral training programme, I have been mentor of the students Magali Estienne, Stefan Michalski, Yusuke Nishida, and Felix Riek. In October, I helped to organize the Joint Theory Meeting between the ECT*, the Bose-Einstein Condensation Group, and the Theory Group of the University of Trento.

Quantum field theory at finite temperature and density

in collaboration with J.-P. Blaizot (ECT), A. Rebhan (TU Vienna), and U. Reinosa (Univ. Heidelberg)*

The understanding of the thermodynamics of hot QCD poses a theoretical as well as experimental challenge. The proper interpretation of data acquired from heavy ion collision experiments at CERN-SPS, RHIC, and soon also the LHC requires a good understanding of the equation of state. A successful scheme to overcome the poor convergence properties of strict perturbation theory in the temperature regime close to the QCD phase transition is the Φ-derivable two-loop approximation by Blaizot, Iancu, and Rebhan, which gives remarkable agreement with lattice simulations down to $T \geq 3T_C$. Together with Jean-Paul Blaizot, Anton Rebhan, and Urko Reinosa, we demonstrated recently that this scheme has the potential for further remarkable improvement when going to full next-to-leading order HTL resummation (NLO-HTL). This result has so far been obtained in the large N_f limit. Since the NLO-HTL calculation turned out to be numerically quite involved, I had to port programs to C++ with MPI to run in parallel on the ECT* Teraflop Cluster.

Large N_f QCD dispersion relations

in collaboration with J.-P. Blaizot (ECT), A. Rebhan (TU Vienna)*

At large number of flavors (N_f), thermodynamic quantities like the pressure or entropy can be calculated exactly for weak and strong couplings at next-to-leading order in a $1/N_f$ expansion. It is therefore an ideal testbed for various resummation techniques (e.g. Borel resummation, 2PI, HTLpt) that try to overcome the poor convergence properties of strict perturbation theory. We have calculated the dispersion relations in the large N_f limit and described the qualitative changes beyond hard thermal loops (HTL).

Non-perturbative renormalization group equation

in collaboration with J.-P. Blaizot (ECT), R. Mendez Galain (Republica U. Montevideo), and N. Wschebor (Republica U. Montevideo)*

In a new project we want to study the renormalization group flow of the effective potential at finite temperature. As the vacuum pressure is very sensitive to the implementation of the cutoff Λ, the initial conditions of the flow have to be chosen carefully in accordance with the regulator. The study of the flow should shed light on the question why some perturbative approaches at finite temperature work well even if the expansion parameter is not small.

• Olivier Leitner

Strong CP breaking and the topological structure of the QCD vacuum

in collaboration with P. Faccioli (University of Trento and ECT) and T. Schäfer (NCSU)*

The most general QCD Lagrangian introduces strong CP violations for any finite value of the parameter $\overline{\theta}$. Although measurements of the neutron electric dipole moment have shown that $\overline{\theta} \leq 10^{-9}$, it has recently been suggested that local spontaneous violations may occur at finite temperature, in the proximity of the QCD phase transition. At present, such a conjecture is subject of experimental investigation at RHIC.

From a theoretical point of view, strong CP violations are very difficult to study, because they are due to purely non-perturbative topological effects. At present no attempt to study the possibility of spontaneous CP violation near T_c using a microscopic approach has been made so far. We have developed a formalism to perform such an analysis using the Instanton Liquid Model, i.e. assuming that the topology of the vacuum is saturated by semi-classical vacuum gauge field fluctuations. We have identified the Green's functions encoding information about local CP violations and developed the mathematical and numerical codes to perform numerical grand-canonical averages in the Instanton ensemble. Simulations at different temperatures are presently running.

Baryon decays into two vectors

in collaboration with Z. J. Ajaltouni (LPC-LHCb, Clermont-Ferrand)

Calculations of the angular distributions, which represent *real physical observables*, as well as branching ratios of the process $\Lambda_b \to \Lambda V$ with $\Lambda \to P\pi^-$ and $V \to \ell^+\ell^-$ or $V \to h^+h^-$ have been performed by using the helicity formalism and stressing on the correlations which arise among the final decay products. Thanks to the so-called Jacob-Wick-Jackson helicity formal in, both the mathematical aspect and the dynamics of the processes are well separated and appear very clearly in our analysis. Moreover, the polarizations of the intermediate states, Λ and $V(-1)$, arise automatically in our approach and the derivation of angular distributions in the intermediate helicity frames are straightforward. In all these calculations, particular role of the Λ_b polarization has been put into evidence. The initial polarization, $\mathcal{P}_{\Lambda_b}$, appears explicitly in the polar angle distribution of the Λ hyperon in the Λ_b rest-frame. Similarly, the azimuthal angle distributions of both proton and ℓ^- in the Λ and V frames, respectively, depend directly on the Λ_b polarization. Furthermore, a first computation of the asymmetry parameter, α_{As}, in Λ_b decays into $\Lambda V(1^-)$ has been performed as well as the longitudinal polarization of the vector meson, ρ^V_{00}, which is shown to be dominant ($\geq 56\%$).

Form factors in HQET

in collaboration with Z. J. Ajaltouni (LPC-LHCb, Clermont-Ferrand)

The Heavy Quark Effective Theory (HQET) formalism has been used to evaluate the hadronic form factors involved in Λ_b-decay. Weak transitions including heavy quarks can be safely described when the mass of a heavy quark is large enough compared to the QCD scale, Λ_{QCD}. Properties such as flavour and spin symmetries can be exploited in such a way that corrections of the order of $1/m_Q$ are systematically calculated within an effective field theory.

QCD factorization applied to baryon decays

in collaboration with X. H. Guo (Beijing Normal University, Beijing)

This project has been started with the aim of developing an accurate formulation of QCD factorization which holds for baryon decays. The heavy-to-light quark transition in baryon decays yields to the inclusion of Feynman diagrams where the baryon light quark spectators play a crucial role. The work is still in progress.

• Antonio Negretti

For the most part of the year 2005 I was in Trento (Italy). During the course of 2005 the research activity was focused on the following subjects:

Quantum computation with neutral atoms

With the collaboration of my Italian supervisor Dr. Tommaso Calarco, the Post-Doc Dr. Markus Cirone, and with Prof. Dr. Jörg Schmiedmayer and Dr. Peter Krüger (Physikalisches Institut-Heidelberg-Germany), we investigated new simple schemes for implementing a phase gate on an atom chip. We discussed the feasibility of realizing these schemes with cold ^{87}Rb atoms magnetically trapped on atom chips, where the internal states are used to store and the external states to process information, respectively. We also investigated the performance of such schemes in atom chip traps with realistic parameter values and high fidelity gate operations are obtainable. In the last part of the year we studied the implementation of a collisional quantum phase gate with the collaboration of Prof. Dr. Jakob Reichel (ENS-Paris-France) and the PhD student Philipp Treutlein (LMU-Munich-Germany). The phase gate employs cold trapped neutral atoms and the gate operation is obtained with internal state-selective trapping potentials that allow collisional interaction between the atoms. We studied in some detail how this idea can be applied in order to realize a realistic quantum phase gate on atom chip. We considered several sources of imperfections: one and two-photon transitions, losses due to the vicinity of the microtraps at the chip surface, dephasing mechanisms, and electric fields created by the microwave.

Atom interferometry with Bose-Einstein condensate

With the collaboration of my German supervisor Dr. Carsten Henkel (Institut für Physik-Potsdam-Germany) we have improved our understanding of integrated atom interferometry with Bose degenerate gases. Our atomic interferometer consists of a quasi one-dimensional BEC adiabatically split in two halves and then recombined. When the two Bose gases are well separated from each other, we imprint a relative phase shift on the interferometer arms. We studied the situation when thermal modes are populated in the initial sample. We used a classical field approach, known as "Truncated Wigner method", to the dynamics of the interferometer. We have seen that the temperature also plays an important role on the output signal of the system. The dipole mode oscillations survive and their amplitude is even larger than for a pure condensate. On the other hand, the sensitivity to a phase shift is significantly reduced.

• Andrea Nobile

I have been working at ECT* since November as the supercomputer administrator.

My scientific activity is deeply connected with supercomputers and numerical calculations. My field of interests are stochastic simulations of biopolymers, Edward-Anderson spin-glasses and, in general, hard optimization problems.

My previous research activity focused on effective simplified models for protein folding and on efficient algorithms for simulations. I have submitted a paper to Journal of physics: Condensed matter.

Now my interest are more directed into the creation of general algorithms inspired by statistical mechanics that can be used to solve a wide range of physical or non-physical stochastic and optimization problems. My current work consists in the simulation of Edward-Anderson spin-glasses to study the feasibility of a hybrid quantum/classical simulation algorithm to get fast thermalization and better glass-phase (low temperature) sampling. I started planning a collaboration with Daniele Binosi in order to implement a distributed computing network in the style of seti@home.

• Claudia Ratti

My postdoctoral activity at the ECT* started in August 2005, and it has been mostly devoted to the development of a phenomenological model to describe QCD-based thermodynamics at zero and finite quark chemical potential. Most of this work has been done in collaboration with Prof. Wolfram Weise of the Technical University of Munich. In this generalized Nambu Jona-Lasinio model, quarks couple simultaneously to the chiral condensate and to a background temporal gauge field representing Polyakov loop dynamics. This so-called PNJL model thus includes features of both deconfinement and chiral symmetry restoration.

We have fixed the parameters of the Polyakov loop effective potential in the pure gauge sector of QCD, while the parameters of the standard NJL part of the Lagrangian have been fixed to reproduce some known physical quantities in the hadronic sector. The chiral condensate and the Polyakov loop as functions of temperature and quark chemical potential have been calculated by minimizing the thermodynamic potential of the system. We found that the chiral and deconfinement phase transitions take place at the same critical temperature, in agreement with lattice QCD results. Predictions concerning the resulting equation of state at zero quark chemical potential, the (scaled) pressure difference and quark number density at finite quark chemical potential have been obtained in the model, and a perfect agreement has been found with the corresponding Lattice QCD data.

One of the extensions of the model is the incorporation of strange quarks, with a bare quark mass much bigger than those of up and down quarks. Lattice data exist for the pressure difference and quark number density of a system of 2+1 quark flavours, but with a vanishing chemical potential for strange quarks. In our model, we are able to reproduce the available lattice data extremely well and, moreover, we can also make predictions, for the same quantities, in the case of non-vanishing strange-quark chemical potential, which has not yet been studied on the lattice.

At present we are investigating the phase diagram of the model in the temperature-chemical potential plane, and exploring its dependence on the bare quark mass: the corresponding lattice data exist only for rather large values of the quark masses, so that in our model we are able to make predictions for the phase diagram, corresponding to physical values of the bare quark masses. We are also investigating the position of the tricritical point, separating first order phase transition from crossover, and its quark mass dependence.

• Alessio Recati

This year my research activity has concerned:

- the behaviour of a one-dimensional (1D) Fermi gases in presence of impurity, in particular, we analyse the bath induced interaction between static impurities. We find different regimes, themost relevant being the Casimir one, where the impurities interact via a Casimir-like force, the fluctuating field being the phonon-like mode of the bosonized theory of the 1D Fermi gas.
- photonic crystal structures, for which we propose a time-dependent structure, in which the carrier frequency of an optical pulse is shifted, without changing its shape. The effciency of the device takes advantage of slow group velocities of light attainable in periodic photonic structures. The frequency shifting effect isquantitatively studied by means of Finite Difference Time Domain simulations for realistic systems with optical parameters of conventional silicon technology.
- Quantum Computation with Cold Atoms, where we propose a scheme for controlling interactions between Rydberg-excited neutral atoms in order to perform a fast high-delity quantum gate. Unlike dipole-blockade mechanisms already found in the literature, we drive resonantly the atoms with a state-dependent excitation to Rydberg levels,and we exploit the resulting dipole-dipole interaction to induce a controlled atomic motion in the trap, in a similar way as discussed in recent ion-trap quantum computing proposals. This leads atoms to gain the required gate phase, which turns out to be a combination of a dynamic and ageometrical contribution. The fidelity of this scheme is studied including small anharmonicity and temperature effects, with promising results for reasonably achievable experimental parameters.

• Marco Traini

in collaboration with the Pavia group (B. Pasquini and S. Boffi)

Generalized parton distributions (GPDs) have been studied at the hadronic (nonperturbative) scale within different assumptions based on a relativistic constituent quark model. In particular, by means of a meson-cloud model we have investigated the role of nonperturbative antiquark degrees of freedom and the valence quark contribution. A QCD evolution of the obtained GPDs has been used to add perturbative effects and to investigate the GPDs' sensitivity to the nonperturbative ingredients of the calculation at larger (experimental) scale.

• Christian Trefzger

I came at ECT* on the 1st of July 2003 and since then have been working on my diploma thesis with the supervision of Tommaso Calarco on problems in Quantum Information Processing. In particular, we have been investigating the role of fermionic atoms in building a two-qubit Quantum Phase Gate in optical lattices and it turns out that fermionic

atoms have several advantages over bosonic atoms. The Pauli exclusion principle avoids certain states to be occupied such that the system evolves in a reduced and more simple Hilbert space.

We are currently studying the addition to the system of a Feshbach resonance which has the effect of coupling antisymmetric internal atomic states to molecular bound states altering the scattering length property of the two colliding atoms. This results in a change of phase.

We propose a scheme where a state dependent Hamiltonian for the two qubits is obtaind by shining two counterpropagating lasers on the trapped atoms. By combining the Pauli blocking effect with the Feshbach resonance we propose to obtain a phase difference between parallel and anti-parallel internal spin states neded to obtain a Quantum phase gate.

• Dionysis Triantafyllopoulos

QCD at High Energy

One of the main active fields of research within QCD has been the study of its behavior in the high energy limit. In general and due to the QCD triple-gluon coupling, one expects the wavefunction of a hadron to be dominated by a high density system of gluons. When the energy of the hadron becomes sufficiently high, one expects this density of gluons to reach the asymptotic limit $1/\alpha_s$ and the wavefunction to exhibit saturation. In particular, but not necessarily, the phenomenon of saturation is enhanced in the case of a large nucleus due to the large number of valence quarks which naturally "emit" a large number of gluons. As the energy increases, more and more gluonic modes saturate and therefore the intrinsic dynamically generated "saturation scale" is an increasing monotonic function of the energy. The QCD coupling constant becomes small and therefore the problem can be approached by analytical methods. Indeed, 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. Improvements over the current effective theory, deeper understanding of its structure and its solutions, and more precise applications to the experimental data of deep inelastic lepton-hadron scattering (HERA) and heavy-ion collisions (RHIC, LHC) are and should be expected in the near future.

Since my arrival at Trento ECT* in October, and together with my collaborators at Saclay, we have been able to analyze the advantages and drawbacks of the color dipole representation of high energy scattering. An elementary introduction/mini-review, based on a set of lectures I gave last June, has been written and published. At the moment my research is concentrated on the study of diffractive deep inelastic scattering and on the search for (asymptotic) analytical solutions to the effective theory.

3.3 Publications of ECT* Researchers

D. Binosi, J. Papavassiliou and A. Pilaftsis
Displacement operator formalism for renormalization and gauge dependence to all orders
Phys. Rev. D **71**, *085007 (2005) [arXiv:hep-ph/0501259]*

J. Papavassiliou, D. Binosi and A. Pilaftsis
Displacement operator formalism
[arXiv:hep-ph/0512030]

J.-P. Blaizot, A. Ipp, A. Rebhan and U. Reinosa
The entropy of hot QCD at large N(F): succesfully testing weak coupling techniques
Contributed to 18th International Conference on Ultrarelativistic Nucleus-Nucleus Collisions: Quark Matter 2005 (QM 2005), Budapest, Hungary, 4-9 Aug 2005 Submitted to Rom. Rep. Phys. [hep-ph/0510115]

J.-P. Blaizot, A. Ipp, A. Rebhan and U. Reinosa
Asymptotic thermal quark masses and the entropy of QCD in the large-N(F) limit
ECT-05-08, TUW-05-12, Sep 2005. 31pp. [hep-ph/0509052]*

J.-P. Blaizot, A. Ipp and A. Rebhan
Study of the gluon propagator in the large-N(f) limit at finite temperature and chemical potential for weak and strong couplings
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ECT-05-10*

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Phenomenological Meson Wave Functions in Covariant Light Front Dynamics
ECT-05-14*

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Testing Fundamental Symmetries with $Lambda_b \to \Lambda$-Vector decays
ECT-05-15*

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Transition Form Factors in Covariant Light Front Dynamics
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A. Negretti, T. Calarco , M. A. Cirone and A. Recati
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Impact of finite temperature on a quasi one-dimensional BEC interferometer
submitted to J. Phys. Conf. Series [*proceedings of the Conference on Atoms and Molecules near Surfaces (CAMS), Heidelberg April 2005*]

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Contribution to the International Conference "Quark Matter 2005", Budapest, Hungary, 4-9 August 2005. To be published in the Conference Proceedings

C. Ratti, M. A. Thaler and W. Weise
Phases of QCD: lattice thermodynamics and a field theoretical model
Contribution to the International Conference "PANIC 05", Santa Fe, New Mexico, 22-28 October 2005. To be published in the Conference Proceedings by the AIP.

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Generalized parton distributions of the nucleon in constituent quark models
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E. Iancu, G. Soyez and D. N. Triantafyllopoulos
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hep-ph/0510094 To appear in Nucl. Phys. **A**, *ECT*-05-12*

D. N. Triantafyllopoulos
Pomeron Loops in High Energy QCD
Acta Phys. Pol. **B 36** *(2005) 3593 hep-ph/0511226, ECT*-05-18* [*lectures given at "Cracow School of Theoretical Physics, XLV Course, 2005", Zakopane, Poland*]

3.4 Seminars and Presentations at International Conferences by ECT* researchers

• Jean-Paul Blaizot

Hot and dense QCD matter
Colloquium, University of Bochum
17 January 2005, Bochum, Germany

Ultrarelativistic heavy ion collisions. Theoretical overview
Opening talk at the International Conference on the Physics and Astrophysics of the Quark-Gluon Plasma
8 February 2005, Kolkata, India

Hot and dense QCD matter
Talk given at Technisches Universität München
2 May 2005, Munich, Germany

The transition temperature of the weakly repulsive Bose gas
Talk given at Technisches Universität München
4 May 2005, Munich, Germany

Thermodynamics of hot QCD - Weak coupling calculations
Talk given at the workshop on the study of the Quark-Gluon Plasma
8 June 2005, Frascati (Rome), Italy

The search for the Quark-Gluon Plasma - Theoretical and experimental status
Invited talk at the inaugural symposium of the Galileo Galilei Institute of Theoretical Physics
20 September 2005, Firenze, Italy

Thermodynamics of the High Temperature Quark-Gluon Plasma
Seminar at the Yukawa Institute of Theoretical Physics
28 November 2005, Kyoto, Japan

Lectures on the thermodynamics of the Quark-Gluon Plasma
Lectures given at the University of Tokyo
25 November 2005, Komaba (Tokyo), Japan

- **Tommaso Calarco**

  Quantum computation with neutral atoms
  Laboratoire de Physique Théorique et Modèles Statistiques
  13 April 2005, Orsay, France

  Quantum optimal control theory for quantum information processing
  Abteilung Quanteninformationsverarbeitung
  21 April 2005, Ulm, Germany

  The ERA-Pilot QIST project
  6^th European QIPC Workshop
  25-26 May 2005, Vienna, Austria

  Quantum information processing with cold bosons and fermions
  Dipartimento di Fisica "A. Volta"
  30 May 2005, Pavia, Italy

  Quantum computation from controlling neutral atoms to artificial ions
  Centro INFM-S3
  30 June 2005, Modena, Italy

  Statistics and control in quantum gates: bosonic, fermionic and artificial atoms
  Workshop Topological Quantum Information Processing
  20-23 July 2005, Torino, Italy

  Statistics and control in quantum gates: bosonic, fermionic and artificial atoms
  University of Connecticut Quantum Information Seminar
  1 November 2005, Storrs, CT, USA

- **Markus Antonio Cirone**

  Towards realistic schemes for quantum gates on atom chips
  TQMFA 2005 (New Trends in Quantum Mechanics: Fundamental Aspects and Applications)
  11-13 November 2005, Palermo, Italy

  Towards realistic schemes for quantum gates on atom chips
  Laboratoire Aime' Cotton, Universite' Paris Sud
  30 November 2005, Orsay, France

- **Sara Della Monaca**

  Risposte elettromagnetiche in sistemi nucleari a tre corpi
  Seminar given at Dep. of Physics, Università degli Studi di Lecce
  26 May 2005, Lecce, Italy

  Inclusive electron scattering responses of trinucleon systems
  22th Students' Workshop on Electromagnetic Interaction
  4-9 September 2005, Bosen (Saar), Germany

- **Carlo Ewerz**

  QCD at High Energy
  Joint Theory Meeting of ECT* and Univ. Trento
  25 October, Trento, Italy

- **Pietro Faccioli**

  Correlations in Hadrons
  seminar given at the Physics Department of the Genoa University
  February 2005, Genoa, Italy

  Path Integral Approach to Protein Folding
  Collaboration Meeting on "Theoretical Physics Methods in Protein Dynamics"
  9-14 May 2005, Trento, Italy

  Strong CP Breaking and Quark-Antiquark Repulsion
  contribution to the conference "QCD@work 2005"
  16-20 June 2005, Conversano (Bari), Italy

  Instantons and the Structure of the Nucleon at 0 and Finite θ
  contribution to the workshop on "Effective Theories in Nuclear Physics and Lattice QCD"
  18-23 July 2005, Trento, Italy

  Studying Diquark Correlations in Lattice QCD
  contribution to the conference "Lattice 2005"
  25-30 July 2005, Dublin, Ireland

  Instanton-Induced Contribution to Hadron Form Factors
  contribution to the workshop "Nucleon05"
  12-14 October 2005, Frascati (Rome), Italy

- **Andreas Hiroichi Ipp**

  The entropy of hot QCD: Successfully testing weak coupling techniques
  Poster contribution at Quark Matter 2005
  21 July 2005, Budapest, Hungary

  The entropy of hot QCD: Successfully testing weak coupling techniques
  Poster contribution at the Workshop on Quark-Gluon Plasma Thermalization
  28 July 2005, Vienna, Austria

  Thermodynamics of large N_f QCD at finite chemical potential for weak and strong couplings
  Seminar given at University of Illinois at Chicago
  14 November 2005, Chicago, USA

  Thermodynamics of large N_f QCD at finite chemical potential for weak and strong couplings
  Seminar given at University of Minnesota
  15 November 2005, Minneapolis, USA

  Thermodynamics of large N_f QCD at finite chemical potential for weak and strong couplings
  Seminar given at Stony Brook University
  17 November 2005, Stony Brook, USA

  Thermodynamics of large N_f QCD at finite chemical potential for weak and strong couplings
  Seminar given at Brookhaven National Laboratory
  18 November 2005, Brookhaven, USA

  Thermodynamics of large N_f QCD at finite chemical potential for weak and strong couplings
  Seminar given at Lawrence Berkeley National Laboratory
  21 November 2005, Berkeley, USA

  Thermodynamics of large N_f QCD at finite chemical potential for weak and strong couplings
  Seminar given at University of Washington
  22 November 2005, Seattle, USA

Thermodynamics of large N_f QCD at finite chemical potential for weak and strong couplings
Seminar given at McGill University
25 November 2005, Montreal, Canada

- **Olivier Leitner**

Direct CP violation B decays and $\rho - \omega$ mixing
Seminar given at Lal
9 May 2005, Orsay (Paris), France

Light Front Dynamics, an overview
Seminar given at SUBATECH
17 May 2005, Nantes, France

Direct CP violation in $B \to \rho 0(\omega)\pi$ and $B \to \rho 0(omega)K$
HEP2005 International Europhysics Conference on High Energy Physics
21-27 July 2005, Lisboa, Portugal

QCD factorization in B decays, branching ratios and CP violation
Seminar given at LPNHE
18 October 2005, Jussieu (Paris), France

- **Antonio Negretti**

Quantum Computers, Algorithms and Chaos International School of Physics "Enrico Fermi"
5-15 July 2005, Varenna, Italy

Quasi one-dimensional BEC interferometer beyond mean-field and quantum computation on atom chip
Conference on Atoms and Molecules near Surfaces - Internationales Wissenschaftsforum
4-8 April 2005, Heidelberg, Germany

Enhanced phase sensitivity and soliton formation in an integrated BEC interferometer
11th Young Atom Opticians Conference - Advanced School on Field Atom Surface Interactions
8-12 February 2005, Hannover, Germany

- **Claudia Ratti**

  Thermodynamics of three colour QCD
  Talk presented at the Technische Universität of Munich
  28 April 2005, Munich, Germany

  Thermodynamics of three colour QCD
  Talk presented at the International School "Quark gluon plasma and relativistic heavy ions: past, present and future"
  11-17 May 2005, Torino, Italy

  Phases of QCD: lattice thermodynamics and a field theoretical model
  Invited seminar at the Laboratori Nazionali di Frascati
  9 June 2005, Frascati (Rome), Italy

  Phases of QCD: lattice thermodynamics and a field theoretical model
  Poster presented at the International Conference "Quark Matter 2005"
  4-9 August 2005, Budapest, Hungary

  Phases of QCD: a field theoretical model
  Invited seminar at the II Workshop of the Virtual Institute "Dense Hadronic Matter and QCD phase transition"
  6-8 October 2005, Prerow, Germany

  Phases of QCD
  Talk presented at the Technische Universität of Munich
  17 October 2005, Munich, Germany

  Phases of QCD: lattice thermodynamics and a field theoretical model
  PANIC05 Particles and Nuclei International Conference
  24-28 October 2005, Santa Fe, New Mexico, USA

  Phases of QCD: lattice thermodynamics and a field theoretical model
  Invited seminar at the Lawrence-Berkeley National Laboratory
  31 October 2005, Berkeley, California, USA

  Phases of QCD: lattice thermodynamics and a field theoretical model
  Collaboration Meeting on "Many-body techniques at high energies: electro-weak scattering on nuclei versus the physics of the QGP"
  7-11 November 2005, Villazzano (Trento), Italy

3.5 Lectures and Seminars at ECT*

3.5.1 Lectures

- Chiral perturbation theory
  (May 9 - 14)
  Lecturer: Stefan Scherer (University of Mainz, Germany)
- Charm physics on the lattice
  (May 16 - 21)
  Lecturer: Christine T. H. Davies (University of Glasgow, UK)
- Large-N_c QCD
  (May 23 - 28)
  Lecturer: Aneesh Vasant Manohar (University of California, San Diego, USA)
- Photon-hadron interactions and parton distributions
  (May 30 - June 4)
  Lecturer: John Collins (Penn State University, USA)
- Parton distributions in exclusive processes
  (June 6 - 11)
  Lecturer: Mark Vanderhaeghen (TJNAF, College of William and Mary, USA)
- Quark model and exotics
  (June 27 - July 1)
  Lecturer: Francis Close (Oxford University, UK)
- Spin structure functions
  (July 4 - 9)
  Lecturer: Piet J. Mulders (Vrije University, the Netherlands)
- Hadron-hadron interactions
  (July 18 - 23)
  Lecturer: Evgueni Kolomeitsev (University of Minnesota, USA)
- Small-x (high energy) QCD
  (October 27 - November 2, 8, 11)
  Lecturer: Dionysis Triantafyllopoulos (ECT*)

3.5.2 Seminars

13.01
Non-Fermi liquid effects in dense matter and compact star cooling
K. Schwenzer (*North Carolina State University*)

26.01
Color Glass Condensate: From statistical physics to high energy QCD
E. Iancu (*Service de Physique Theorique, Saclay*)

17.03
Non-perturbative short-range correlations
P. Faccioli (*University of Trento*)

07.04
Skyrmions as models of nuclei
N. S. Manton (*Cambridge University*)

14.04
An approximation scheme for non-perturbative situations
N. Wschebor (*Instituto de Fisica, Facultad de Ingenieria, Montevideo*)

21.04
Time Reversal in Subnucluear Physics: Phenomenology and Experiment
Z. J. Ajaltouni (*LPC Universite Blaise Pascal-Clermont II*)

19.05
BCS-BEC crossover in relativistic superfluid and its possible realization in QCD
Y. Nishida (*University of Tokyo*)

25.05
Spin and the proton in high-energy physics
C. Türk (*University of Turin and INFN*)

31.05
The square root of the Dirac equation
A. Bzdak (*Jagiellonian University, Krakow*)

01.06
Selfconsistent rho and omega mesons in hot and dense matter
F. Riek (*Theory Division, GSIN*)

14.06
Dynamical fermion mass generation by a strong Yukawa interaction
P. Benes (*Nuclear Physics Institute, Rez near Prage*)

15.06
The puzzle of big disagreement between SLAC and JLab experimental data
C. Adamuscin (*Institute of Physics, Slovak Academy of Sciences, Bratislava*)

22.06
Resummation as a non-perturbative method in quantum field theory. Comparing and testing two different resummation schemes
S. Michalski (*University Dortmund*)

29.06
V_{us} determination from hyperon semileptonic decays
V. Mateu Barreda (*University of Valencia, IFIC*)

05.07
Study of leptonic decays of pseudoscalar B, D and vector B^*, D^* mesons and the semileptonic $B \to D$ and $B \to d^*$ decays
J. M. Verde Velasco (*University of Salamanca*)

06.07
Subtleties in pion reactions on few nucleon systems. Precision calculation of the reaction $\gamma d \to \pi^+ nn$ within ChPT.
V. Lensky (*Forchungscentrum, Jülich*)

12.07
Color superconducting quark matter in a two flavor non-local chiral model under compact star constraints
D. N. Aguilera (*University of Rostock*)

13.07
An overview of heavy ion collision experiments
M. Estienne (*Laboratoire SUBATECH*)

19.07
Double diffractive Higgs, two jets, charm(bottom)onium, two photon production
A. Bzdak (*Jagiellonian University, Krakow*)

21.07
Phases of QCD: Lattice Thermodynamical and Field Theoretical Models
C. Ratti (*TU Munich*)

25.07
Electromagnetic responses in few body nuclear systems
S. Della Monaca (*University of Trento*)

26.07
Quark-quark correlations in non perturbative QCD
M. Cristoforetti (*University of Trento*)

03.11
Geometric Scaling in High-Energy QCD
G. Soyez (*Service de Physique Theorique, Saclay*)

10.11
Constraining freeze-out with yields and fluctuations
D. G. Torrieri (*McGill University*)

16.11
QCD Vacuum Topology and Glueballs
H. I. Forkel (*IFT - UNESP, San Paolo*)

4 ECT* Computing Facilities

4.1 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

4.2 BEN, the ECT* teraflop cluster

(Pierfrancesco Zuccato)

The joint initiative for Scientific Supercomputing and Grid-enabled Technologies between ECT*, ITC, Exadron (the HPC division of Eurotech spa) and INFN, has led to a number of accomplishments and has set the foundations for further results.

This scientific report covers the activities performed at ECT* until the end of my collaboration with the Centre (May '05). After this, I have supported the transition of the facility to the new System Administrator. This process has been completed recently and now the system is under the full control of Dr. Andrea Nobile.

The major activities can be summarized as follows:

- The entire cluster has been completely reconfigured in its software infrastructure. This action has made it possible to achieve two significant results:
  - Much better stability of the system. The new software configuration does not relay on the local hard disks. Since this is the only mechanical part of the cluster, it is also the most probable source of downtime.
  - Improved manageability of the system. In the perspective of a change of the system administrator, I have reworked the entire management system in order to streamline most tasks.
  - Updated and more complete software tools. New tools have been introduced on request by the users, such as the GNU Fortran 90/95 compiler.

- The ApeNet boards have been installed, cabled and validated with internal tests. One formal test and validation will be performed at the presence of the parties involved in a short time. The preliminary test has demonstrated the capabilities of the boards in terms of connectivity and speed, when compared to a standard connection. Of course, the software layer an higher functions are two of the research topics of the project and, therefore, will change with time.

- A number of major and minor projects have been allocated on the cluster. Some of these projects have ended and some scientific deliverable is expected in a short time (papers, posters, etc), while others have reached their first milestones.

- A questionnaire has been sent to the users: the information collected will help improving the facility and provides an external opinion of the usefulness of the facility and of the quality of service.

- The total uptime of the system has been good, since the machine has been always been available to the users, with the exception of a few occasions. It is quite difficult to provide precise data about the uptime of the cluster. In fact, this number relies heavily on the metrics that define it. A fair picture of the stability of the system is the following: in the course of this year, there have been some failures that have

reduced the availability of the facility. The downtime sources can be distinguished in two categories:

  - Systemic: that make the system totally unavailable
  - Local: that only affect a node, while the rest of the machine is working fine
  - Management related: not due to problems, but necessary to perform upgrades and improvements

  Only few *systemic failures* have been experienced, most of which due to external conditions (not related to the cluster). During these conditions the machine was stopped and running jobs crashed; in order to recover from this state, a couple of days were necessary.
  Local problems have been relatively more frequent, due to some local disk failure. In this case, only one job could experience a crash, while the rest of the users would not perceive the issue and would run flawlessly their tasks. This kind of problem should not appear again, thanks to the new configuration of the machine.
  Management related downtime is not due to a problem, but it is a necessary action when some configuration tasks have to be performed. Since this is an experimental facility and there have been some changes (such as the installation of the ApeNet boards), from time to time it has been necessary to make parts of the cluster unavailable.

- The overall load of the cluster has been very good: as soon as a resource is made available, it is immediately put in use. More precise data will be available in the next months, when the statistics on the new configuration are available.

- One third of the system has been reserved and is not available for generic computation. These resources are necessary for the training of the new system administrator and for further developing the ApeNet software.

- One Collaboration Meeting has been organised in order to foster the activities around the computing facility.

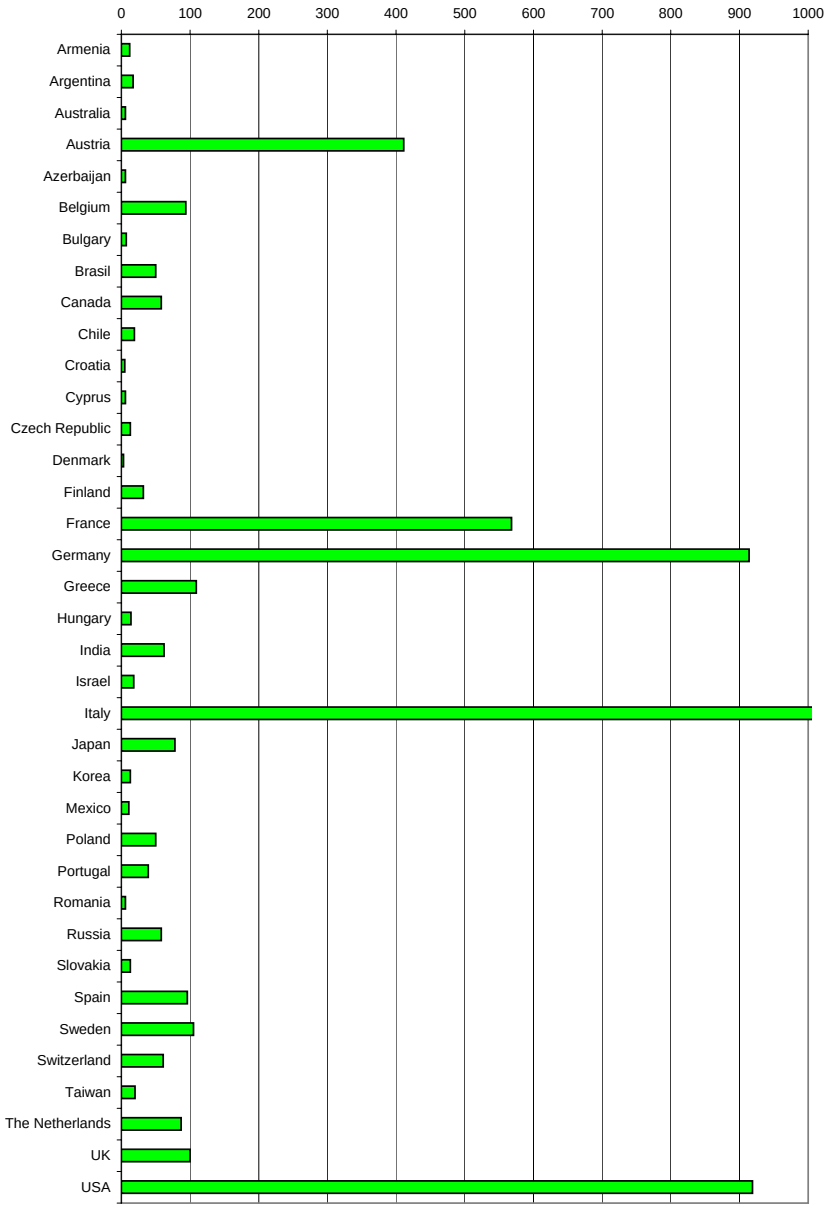
5 ECT* Guest House in S. Donà

ECT* has been renting a Guest House since the first of October 2005. The guest house is located in S. Donà N. 96, on the hillside near Povo. It is a large apartment comprising 6 bedrooms (3 single and 3 double rooms), 3 bathrooms, a kitchen and a large living room with a TV set and a balcony. The rooms and the common area are cleaned once per week; fresh towels and linen are supplied once a week.

The guest house has no private parking, but a free parking lot is available on the opposite side of the street, three minutes walking distance from the apartment, next to the junction. The guest house can be reached by common transportation.

6 Statistics

Visitor Days Spent at ECT*
(total number of visitors in 2005: 552)



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