ECT*

Annual Report 2004

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

Preface

Workshops and collaboration meetings continue to represent a highly visible and successful part of ECT* activities. Altogether, 14 projects were run in 2004, involving more than 500 participants. As usual, the projects spanned a large variety of activities in nuclear physics and related areas, covering topics in low energy nuclear physics, astrophysics and high energy physics. The Marie Curie Doctoral Training Programme, which started three years ago, has become an important part of ECT* scientific activities. It is attracting an increasing number of students who recognize the unique opportunity they are offered to spend time in the international environment of ECT* and to benefit from advanced lectures in their field. This year, the program was devoted to Neutrino Physics. It has allowed for an interesting joint venture with the "Indian Summer School" organized by our colleagues in Prague. Aside from its regular postdoctoral fellows carrying out research on nuclear physics in a board sense, ECT* hosts since the year 2000 and together with the nearby Institute on Bose Einstein Condensation (BEC), a small research group on quantum computing. Joint activities have been organized in the fall, and efforts will continue to strengthen the relations between ECT* and the BEC Institute and, more generally, between ECT* and the Physics Department of the University of Trento.

At the meeting of the EJFRC committee (Finance Committee) which took place in January, the general agreement with the major funding agencies of France, Italy and Germany was renewed. The President of the Istituto Trentino di Cultura also assured us of the continuing support of ITC. The ITC provides about half of the present budget of ECT*, the rest coming from national funding agencies and the EU. One cannot overstate the importance for ECT* of this regular support from various European countries, including that from the many small contributors. It is this regular support that allows the Center to engage in long term actions.

Some concern arose toward the end of 2003 from the uncertainty of European funding. This has now largely vanished and, in particular, ECT* can count on the support of EURONS for the coming years. Nonetheless, the splitting of the nuclear physics community into the two Integrated Infrastructure Initiatives, EURONS and HADRON PHYSICS, conflicts with ECT* missions, and the Center will continue its efforts to maintain the unity of the field in its various facets. In this perspective, discussions have been undertaken with the managers of the I3 HP in order to find ways to develop collaborations reflecting the wide use of the ECT* by the hadronic physics community.

The successful installation of the Teraflop computer represents a major addition to the ECT* computing facilities and opens the way to new scientific activities. Let us recall that this is the fruit of a joint venture initiated by R. Leonardi, the ECT* Scientific Secretary, which involves the Province of Trentino, the ITC, the INFN and the Exadron division of Eurotech. The computer is now running, and it will soon be available to external users.

Several improvements of the ECT* infrastructure took place in 2004. The local staff in charge of the computing system has been reinforced in order to face the increasing demand. The network has been significantly upgraded, and it reaches now high security standards. The library has been moved to a new location and its catalog is being thoroughly rebuilt.

In closing, I would like to pay tribute to Wolfram Weise for his successful directorship, and thank Georges Ripka for having accepted to take the interim before my arrival in early September. Such transition periods are undoubtably sources of stress for the members of the staff: I would like to gratefully acknowledge their continuous dedication, unique at ECT*. Finally, special thanks are due to Stefania Campregher for her assistance in the preparation of this report.

Jean Paul Blaizot   Director, ECT*

Contents

1 ECT* Board of Directors, Staff and Researchers

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

Marcello Baldo (from June 2002)	INFN, Catania, Italy
Gordon Baym (from October 2000 until October 2003)	University of Illinois, Urbana-Champaign, USA
Michael Birse (from February 2003)	University of Manchester, UK
Peter Braun-Munzinger (from October 2002 - chairman)	GSI, Darmstadt, Germany
Jacek Dobaczewski (until June 2004)	University of Warsaw, Poland
Muhsin Harakeh (from Februry 2003)	NuPECC
Paul Hoyer (from October 2004)	University of Helsinki, Finland
Frithjof Karsch (from October 2004)	Bielefeld University, Germany
Karlheinz Langanke (until June 2004)	University of Aarhus, Denmark
Elvira Moya de Guerra (from June 2002)	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

Honorary Member of the Board:

Professor Ben Mottelson — NORDITA, Copenhagen, Denmark

ECT* Director:

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

Professor Georges Ripka (April-August 2004) — ECT* and CEA Saclay

Professor Wolfram Weise (until March 2004) — ECT* and TU Munich

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

1.3 Resident Postdoctoral Researchers and supported Students

- **ECT* postdocs:**

François Arleo (France) (until January 2004)

Daniele Binosi (Spain) (from January 2004)

Pietro Faccioli (Italy)

Paolo Finelli (Italy)(until October 2004)

Luca Girlanda (Italy) (until September 2004)

Andreas Hiroichi Ipp (Austria)(from September 2004)

Daisuke Jido (Japan) (until June 2004)

Olivier Leitner (France) (from October 2003)

Massimiliano Procura (Spain) (until January 2004)

Dolores Sousa (Spain) (until January 2004)

- **Quantum Computing Group:**

Tommaso Calarco (Italy) (from June 2003)

Markus Antonio Cirone (Italy) (from October 2004)

Antonio Negretti (Italy) (from September 2004)

Uffe Vestergaard Poulsen (Denmark) (until October 2004)

Christian Trefzger (Italy) (from July 2004)

Alessio Recati (Italy) (from October 2004)

- **ECT* supported students:**

Marco Cristoforetti (Italy) (from July 2004)

Sara Della Monaca (Italy) (from January 2004)

- **Teraflop Cluster:**

Pierfrancesco Zuccato (Italy) (from May 2003)

1.4 Marie Curie Fellows

Anatael Enrique Cabrera Serra (Spain/UK)	University of Oxford
Doron Gazit (Israel)	University of Jerusalem
Diego Rubiera Garcia (Spain)	Autonomous University of Madrid - Oviedo
Ivo Rolf Seitenzahl (Germany/USA)	University of Chicago
Krzysztof Turzynski (Poland)	University of Warsaw
Nikolaj Thomas Zinner (Denmark)	University of Aarhus

1.5 Visitors in 2004

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

Everton Alvarenga Zanella	University of San Paolo, Brazil (TP)
Jeremy Argyriades	CEA Saclay, France (TP)
Samoil Bilenky	JINR, Dubna - SISSA, Trieste, Italy (TP)
Nicolas Borghini	CEA Saclay, France (VS)
Matthias Burkardt	New Mexico State University, USA (VS)
Mark Anthony Caprio	Yale University, USA (VS)
Thomas William Donnelly	MIT, Boston, USA (TP)
Gianluigi Fogli	University of Bari, Italy (TP)
Hilmar Forkel	IFT-UNESP, Brasil (VS)
Nicolao Fornengo	University of Torino, Italy (TP)
Alex Giacomini	University of Trento, Italy (TP)
Steen Hannestad	University of Southern Denmark, Denmark (TP)
Francesco Iachello	Yale University, USA (VS)
Hans Thomas Janka	Max Planck Institute Garching, Germany (TP)
Jeremy Jones	University of Arizona, USA (TP)
Ramutis Kazys Kalinauskas	Institute of Physics, Lithuania (VS)
Anastasiya Malikh	JINR, Dubna, Russian Federation (VS)
Ramon Mendez Galain	University Montevideo, Uruguay (VS)
Fred Myhrer	University of South Carolina, USA (VS)
Barbara Pasquini	University of Pavia, Italy (VS)
Oleg Pavloski	Moscow University Russian Federation (VS)
Francisco Perez Bernal	Huelva University , Spain (VS)
Amanda Porta	University of Trento, Italy (TP)
Sofia Quaglioni	University of Torino, Italy (TP)
Guenter Sigl	GReCO, Paris, France (TP)
Klaas Vantournhout	Gent University , Belgium (TP)
Petr Vogel	Kellogg Radiation Lab, Pasadena, USA (TP)
Metag Volker	University of Giessen, Germany (VS)
Wolfram Weise	TU Munich, Germany (VS)
Wschebor Pellegrino Nicolas	University Montevideo, Uruguay (VS)

2 Scientific Activities in 2004

2.1 Summary

As in the previous years, scientific activities at ECT* in 2004 covered a wide range of research in nuclear physics and related areas.

Altogether 14 projects where accepted with a total of more than 500 participants. All projects were performed by selected groups of experts from Europe and other parts of the world. Particular efforts were made to support young postdoctoral researchers and PhD students, in particular through the Advanced ECT* Doctoral Training Programme.

This chapter contains the scientific reports prepared by the organizers of each project.

2.2 Workshops and Collaboration Meetings in 2004

10–12 Feb. **Pentaquark states: structure and properties collaboration meeting**
Organisers: K. Goeke (Co-ordinator) (*Ruhr-Univ. Bochum*),
V. Guzey (*Ruhr-Univ. Bochum*)
M. V. Polyakov (*Univ. Liege*) [p. 9]

2–12 Mar. **Spectroscopic factors**
Organisers: A. Bonaccorso (Co-ordinator) (*INFN Pisa*),
A. Fabrocini (*Univ. Pisa*),
S. Gales (*IPN Orsay*),
P. G. Hansen (*MSU*),
L. Lapikas (*NIHKEF*) [p. 11]

25–26 Mar. **CDF - Italia Collaboration Meeting (Collider - Detector Fermi Lab.)**
Organisers: I. Lazzizzera (Co-ordinator) (*Univ. Trento*) [p. 16]

20–29 Apr. **Tracing the Onset of Deconfinement in Nucleus-Nucleus Collisions**
Organisers: M. Gazdzicki (Co-ordinator) (*Univ. Frankfurt, Swietokrzyska Academy*),
E. Shuryak (*Stony Brook*),
P. Seyboth (*MPI Munich*) [p. 17]

3–7 May **Creation and Flow of Baryons in Hadronic and Nuclear Collisions**
Organisers: A. Polleri (Co-ordinator) (*TU Munich*),
G. Garvey (*LANL*),
H. Oeschler (*GSI Darmstadt*),
B. Kopeliovich (*MPI Heidelberg*) [p. 19]

24–28 May **Advances and Challenges in Nuclear Astrophysics**
Organisers: C. Angulo (Co-ordinator) (*Univ. Catholique de Louvain*),
P. Descouvemont (*Univ. Libre de Bruxelles*),
M. Wiescher (*Notre Dame*) [p. 22]

14–18 Jun. **Transversity: New Developments in Nucleon Spin Structure**
Organisers: G. van der Steenhoven (Co-ordinator) (*Washington Univ., St. Louis*),
E. Desanctis (*INFN Frascati*),
M. Baldo (*INFN Catania*),
W-D. Nowak (*DESY Zeuthen*),
M. Radici (*INFN Pavia*) [p. 24]

21–25 Jun. **Fundamental Interactions**
Organisers: K. Jungmann (Co-ordinator) (*Univ. Groningen*),
R. G. E. Timmermans (*Univ. Groningen*),
Ch. Weinheimer (*Helmholtz Institut fr Strahlen und Kernphysik*) [p. 29]

5–9 Jul. **Large N QCD**
Organisers: N. Scoccola (Co-ordinator) (*TANDAR*),
J. L. Goity (*Hampton Univ. and Jefferson Lab*),
R. F. Lebed (*Arizona State Univ.*),
A. Pich (*Univ. Valencia*),
C. L. Schat (*Duke Univ.*) [p. 31]

12–17 Jul. **Hadrons and Strings**
Organisers: M. Stephanov (Co-ordinator) (*Univ. of Illinois-Chicago*),
N. Evans (*Univ. of Southampton*),
C. Korthals-Atles (*CPT, Marseille*),
D. T. Son (*Univ. of Washington*) [p. 34]

6–17 Sept. **Novel Approaches to the Nuclear Many-Body Problem: From Nuclei to Stellar Matter**
Organisers: C-H. Lee (Co-ordinator) (*Pusan National Univ.*),
N. Kaiser (*TU Munich*),
A. Schwenk (*Ohio State Univ.*) [p. 36]

20–25 Sept. **Neutron Stars: Structure and Cooling**
Organisers: P. Haensel (Co-ordinator) (*N. Copernicus Astr. Cent., Poland*),
G. Pavlov (*Penn State Univ.*),
D. Yakovlev (*St. Petersburg*) [p. 38]

4–8 Oct. **Neutrinos and the Early Universe**
Organisers: M. Lindner (Co-ordinator) (*TU Munich*),
M. Turatto (*Padova Observatory*),
G. Raffelt (*MPI Munich*) [p. 40]

18–22 Oct. **Exploring the Impact of New Neutrino Beams**
Organisers: C. Volpe (Co-ordinator) (*IPN Orsay*),
J. Bouchez (*CEA Saclay*),
M. Lindroos (*CERN*),
M. Mezzetto (*Univ. of Padova*),
T. Nilsson (*CERN*) [p. 42]

2.3 Reports on Projects and Collaboration Meetings

1. PENTAQUARK STATES: STRUCTURE AND PROPERTIES

(Collaboration Meeting)

DATE: 10–12 Feb

ORGANISERS:
K. Goeke (Co-ordinator) (*Ruhr-Universit*), V. Guzey (*Ruhr-Universit*), M. Polyakov (*Université de Liège au Sart Tilman*)

NUMBER OF PARTICIPANTS: 20

MAIN TOPICS:

- recent and planned experiments
- large N_c and chiral quark soliton pictures of pentaquark states
- quark model approaches to pentaquarks
- lattice QCD studies of pentaquarks

SPEAKERS:

M. Battaglieri (*Genova*),
T. Bauer (*NIKHEF*),
T. Cohen (*Maryland*),
H. Eyrich (*Erlangen*),
L. Glozman (*Graz*),
V. Guzey (*Ruhr-Universität*),
K. Hicks (*Ohio*),
V. Kouznetsov (*INR, Moskow*),
P. Pobylitsa (*Ruhr-Universität*),
M. Polyakov (*Liege*),
A. Raval (*ZEUS*),
P. E. Reimer (*HERMES*),
A. Sbrizzi (*NIKHEF*),
Fl. Stancu (*Liege*)

SCIENTIFIC REPORT:

Aim and Purpose: The aim and purpose of the workshop was to discuss the status of pentaquark studies from both the experimental and theoretical point of view, with an emphasis on future directions in this field. There was an even balance between experimental, phenomenological and theoretical presentations at the workshop.

Main points discussed at the workshop. The workshop addressed the following broad questions:

- Does Θ^+ really exist?
- If Θ^+ does exist, what are its properties?
- Are there excited states of Θ^+?
- What should be done next and expected in the field of exotic baryon spectroscopy?

Does Θ^+ really exist? At this stage, it is premature to claim the existence of Θ^+. While many experiments observe Θ^+, the statistical significance of the signals is mostly only at the 4-6 σ level. Most of the analyses used the existing data (in contrast to forthcoming dedicated experiments) and imposed rather severe cuts on the data leaving approximately 30-50 events. The new ZEUS result presented at the workshop is the only experiment with combined about 500 events of Θ^+. In all the experiments, the background is very large and the conclusion about the existence of Θ^+ crucially depends on not understood but rather phenomenologically parameterized background.

At the workshop, new experimental results indicating the existence of Θ^+ were presented by SPring-8, CLAS, ZEUS and COSY-TOF experiments.

The question of the existence of Θ^+ should soon be answered when new high-statistics CLAS data will be taken and analyzed.

However, one should also mention a negative result of the Θ^+ search by the HERA-B experiment presented at the workshop.

If Θ^+ does exist, what are its properties? Assuming that Θ^+ exists, what are its properties? We list the properties of Θ^+ in order of the increasing difficulty of their experimental determination: isospin, mass, width, spin and parity.

The world average mass of Θ^+ seems to converge to 1.53 GeV, the originally predicted value. This suggests that the CLAS peak at 1.555 GeV and a peak at 1.573 GeV of the recent analysis of CLAS data presented at the workshop by the Genova group are most likely to be from a possible excited state, if it exists.

The question of width of Θ^+ is the most important and challenging. The new results from HERMES and ZEUS, both presented at the workshop, seem to suggest that the total width of Θ^+, Γ^{tot}, could be as large as 10 MeV. This appears to contradict other CLAS data and other experiments as well as the partial wave analysis (PWA) of kaon-nucleon scattering.

While the exact value of Γ^{tot} is probably not very important, the fact that Θ^+ is so narrow is puzzling and striking. Neither large-N_c QCD nor chiral quark soliton and quark models give an explanation of how such a heavy baryon could be so narrow. Which mechanism is responsible for this? Is there a hidden parameter or quantum number that almost prohibits the decay of Θ^+? More theoretical work is needed to clarify this issue.

The question of parity of Θ^+ is the most difficult one. Determination of parity requires polarized experiments. At the moment, the best candidate to determine parity of Θ^+ is polarized protons on polarized protons near threshold scattering. Unfortunately, this experiment can be performed at COSY-TOF only after year 2007. Other methods to determine parity of Θ^+, for instance by measuring the photon asymmetry in photoproduction of Θ^+ on unpolarized hydrogen or deuterium, are model-dependent and, again, require presently unavailable high statistics. It is likely that parity of Θ^+ might go undetermined for about 5 years and that the answer will come from hadronic reactions such as measured at COSY or suggested in the letter of intent submitted to KEK.

Are there excited states of Θ^+? If Θ^+ has positive parity, then it might have a spin-orbit partner with spin-3/2 close by, within 100 MeV of the ground state, as discussed by Glozman at the workshop. The original prediction of Θ^+ said nothing about spin-orbit partners (which is intrinsically a quark model prediction). Hence, an experimental search for excited states of Θ^+ should significantly contribute to the discrimination between different pictures of exotic baryons.

Presently, there might be two indications of excited Θ^+. First, the CLAS data on the proton in the reaction $\gamma p \to \Theta^+ \pi^+ K^-$ indicate a peak with mass 1555 ± 10 MeV. Second, the Genova group analysis of CLAS data in the reaction $\gamma p \to \Theta^+ K^0$ reports two peaks, one of them with mass 15773 ± 5 MeV. It is of paramount importance that these results are confirmed or refuted by other experiments.

What should be done next and expected in the field of exotic baryon spectroscopy? Clearly, the way to proceed in studies of Θ^+, its excited states and other members of the antidecuplet is to perform dedicated high-statistics experiments which will establish unambiguously the existence and masses of these states. Whenever possible, along with the desired signals, the experiments should see the already known resonances listed in the Particle Data Group. In relevant cases, it might be useful to compare yields of the exotic Θ^+ to those of $\Lambda(1520)$.

The most direct way to study Θ^+ is by resonant kaon-nucleon scattering. This option might be realized in future kaon beam KEK and BNL experiments.

A new PWA analysis of kaon-proton and kaon-deuteron data is desired.

Conclusions of the workshop. The most important conclusions of the workshop are:

- The fate of Θ^+ will soon be decided when dedicated CLAS data is taken and analyzed.
- Large-N_c QCD by itself does not allow to determine mass and width of Θ^+.
- Recent experimental data indicate that the total width of Θ^+ is of the order 10 MeV.
- There are experimental indications that the spectrum of the antidecuplet might contain spin-orbit partners of Θ^+.

2. SPECTROSCOPIC FACTORS

DATE: 2–12 March

ORGANISERS:
Angela Bonaccorso (Co-ordinator) (*INFN, Sez. di Pisa*), Adelchi Fabrocini (*Università di Pisa*), Sydney Galès (*IPN Orsay*), P. Gregers Hansen (*Michigan State University*), Louk Lapikás (*NIKHEF*)

NUMBER OF PARTICIPANTS: 62: 30 experimentalists, 32 theoreticians

MAIN TOPICS:

- Shell model and spectroscopic factors
- Short and long range correlations
- Spectral functions
- Nucleon knockout with electromagnetic and nuclear probes
- Transfer and breakup reactions with normal and exotic nuclei
- Nuclear reaction theories, DWBA, eikonal and semiclassical models

SPEAKERS:

T. Aumann (*GSI*),
F. Azaiez (*IPN Orsay*),
C. Barbieri (*TRIUMF, Vancouver*),
G. Baur (*Inst. für Kernphysik*),
O. Benhar (*Univ. 'La Sapienza', Roma*),
A. Bonaccorso (*INFN, Pisa*),
D. M. Brink (*Oxford Univ.*),
F. Carstoiu (*NIPNE, Bucharest*),
W. H. Dickhoff (*Washington Univ.*),
A. Dieperink (*KVI, Groningen*),
H. Emling (*GSI*),
M. Freer (*Univ. Birmingham*),
S. Galès (*IPN Orsay*),
C. Giusti (*Univ. Pavia*),
T. Glasmacher (*Michigan State Univ.*),
P. G. Hansen (*NSCL, East Lansing*),
M. Ishihara (*RIKEN*),
E. Jans (*NIKHEF*),
J. J. Kelly (*Univ. Maryland*),
J. Kolata (*Univ. Notre Dame*),
A. A. Korsheninnikov (*RIKEN*),
L. Lapikás (*NIKHEF*),
E. Moya de Guerra (*CSIC*),
T. Nakamura (*Tokyo Inst. of Technology*),
G. Orlandini (*Univ. Trento*),
T. Otsuka (*Univ. Tokyo*),
P. Roussel Chomaz (*GANIL*),
J. Ryckebusch (*Univ. Gent*),
H. Scheit (*MPI, Munich*),
J. P. Schiffer (*Argonne National Lab*),
P. Schuck (*Inst. de Physique Nucleaire*),
S. Shimoura (*Univ. Tokyo*),
I. Sick (*Univ. Basel*),
R. Siemssen (*Kernfysisch Versneller Inst.*),
M. Strikman (*Penn State Univ.*),
J. Tostevin (*Univ. Surrey*),
L. Trache (*Texas A&M Univ.*),
S. Typel (*GSI*),
J. S. Vaagen (*Univ. Bergen*),
E. Vigezzi (*INFN, Milan*),
N. Vinh Mau (*Univ. Paris Sud*),
J. W. Watson (*Kent State Univ.*)

SCIENTIFIC REPORT:

Aim and Purpose: The purpose of the workshop was to discuss the short and long range aspects of nuclear correlations under the joint heading of "Spectroscopic Factors". The motivation for bringing the communities that study lepton-induced and hadron-induced reactions together lay in recent progress in the theory of both areas but also in the appearance of new experimental techniques in the areas of high-energy electron scattering and reactions of radioactive beams ("knockout reactions") that may lead to new and accurate information on long- and short-range correlation effects.

Final report: Looking at the topics and goals to be covered by the workshop and to the talk's schedule, it appears that this meeting, attended by more than 60 physicists worldwide from both the electromagnetic and hadronic communities was a real success. The workshop run for ten days with a constant, very high attendance. There was a perfect mixture of theoreticians and experimentalists (50% each). Furthermore it was characterized by a remarkable presence of young physicists (20%) who presented also their work.

The original goal of the workshop was fully attained. The two different communities exchanged knowledge, comments and suggestions in a very relaxed and constructive atmosphere. It was agreed that the information on the single particle degrees of freedom in nuclei, obtained with the traditional and well established lepton-induced reactions and those from more recent hadron-induced reactions, in particular those using rare isotopes beams, are consistent and in many ways complementary. Foresights on future developments and possible collaborations were also given.

The presentations and discussions, centered around the long and short range aspects of nuclear correlations under the joint heading of "Spectroscopic Factors", have led to real and in-depth understanding of the theoretical issues related to short range correlations in the shell model sector and in the non-nucleonic sector. Consequently the subject of determining spectroscopic factors (absolute values) via electron induced reactions, transfer with energetic light ion and unstable exotic beams reactions, were intensively discussed with quite a few solid conclusions.

The structure of the spectral functions for one-proton knock out reactions, as deduced from (e, e' p) reactions is fairly well understood and agrees rather well with advanced nuclear structure calculations, provided that a relativistic framework be used to describe the reaction process. For valence protons the spectroscopic factors are quenched to about 60-70% of the shell model values. Between 10 to 20% of the one particle strength function is shifted to very high excitation energies (above 80 MeV), beyond the shell model space, due to short range correlations. Coupling to low and high lying collectives modes leads to strength fragmentation and reduces further the spectroscopic strength found in the valence single particle-states by 10 to 15%. The spectroscopic factors from transfer reactions, found generally to amount to 80-100% of the shell model expectations, can be reconciled with those extracted from (e, e' p), provided that full microscopic finite range DWBA codes are employed and proper values of the radius of the transferred nucleon wave function (from e, e' p) are used. The transfer reaction approach remains unique to locate deep-neutron hole states and single-particle strengths above the Fermi sea.

The subject of determining spectroscopic strength via electron-induced reactions was discussed intensively, with contributions presenting (new) experimental data, detailed descriptions of the reaction mechanism, and nuclear-structure calculations based on realistic interactions. These discussions build upon the observations made in the eighties and nineties that spectroscopic factors of valence protons are quenched to about 60-70% of the Independent-Particle-Shell Model value.

New experimental (e, e' p) data nowadays result mainly from experiments at either high momentum transfer Q^2 or high missing momentum and energy. The availability of the high Q^2 data makes it possible to verify the validity of the usual description of electron-induced nucleon knockout in Impulse Approximation (IA). By going to higher Q^2 and energy transfer ω, two aspects, which are less important at low energies, start to play an important role : i) the reaction receives contributions from non-IA processes e.g. intermediate delta-excitation and/or meson-exchange currents; ii) relativistic effects need to be included in the description of both the bound state and the scattering state of the struck nucleon.

New TJNAF data for the reaction ^{16}O(e, e' p) at higher Q^2 than previous NIKHEF data were presented and discussed extensively. A consistent analysis of these data within one (relativistic) framework showed that the low- and high-Q^2 data for the ground-state transition agree within about 5%. In ensuing discussions the earlier observed larger discrepancies for data at low- and high-Q^2 in ^{12}C(e, e' p) were attributed to the possible presence of unresolved strength in the missing-energy spectrum, non-negligible channel couplings, and relativistic effects in the treatment of the Final-State Interaction.

A comparison of data and theory for proton knockout at large missing momentum from few-body nuclei now unambiguously shows the need to include short-range and tensor correlations in order to describe the size and shape of the momentum distributions correctly.

An interesting and promising development is the study of the spectral function in the region of two-nucleon knockout (with or without detection of the second nucleon). In this region direct sensitivity to e.g. short-range correlations exists, provided that the kinematical regime is suitably chosen. Predictions for the 2N spectral function, based on realistic interactions, are becoming available, but a reliable interpretation of the data depends on our thorough understanding of all contributing processes to the reaction yield (e.g. two-body currents, final-state interaction, rescattering). In this respect it is important that more 2N knockout experiments like the ones in NIKHEF, Mainz and TJNAF become available.

In summary it can be concluded that the structure of the spectral function for one-proton knockout, as deduced from (e, e' p) reactions, is fairly well understood. Both experimental occupations and spectroscopic factors agree rather well with advanced nuclear-structure calculations, provided that the description and analysis of the reaction is done in a relativistic framework. The study of the spectral function for two-nucleon knockout is beginning to yield results that help to unravel the intertwined contributions of nuclear structure (e.g. correlations) and reaction mechanism (e.g. one-, two-body currents) to the experimental data.

Many experiments using energetic light and heavy ions have extended the study of single-particle response in the continuum part of the spectrum and new theoretical work were presented at the workshop to account for the unbound nature of the transferred nucleon.

A number of contributions to the Workshop dealt with measurements of spectroscopic factors in hadron-induced reactions. It is now clear that the transfer reactions that most often gave spectroscopic factors closer to unity (a number of 90±10% was quoted for the (d,3He) reaction) can be reconciled with the (e, e' p) experiments. Many experiments using heavy-ion probes have extended the studies to single-particle states in the continuum, and new theoretical work presented at the workshop has developed a theoretical treatment of these reactions in a way that accounts for both energy and momentum conservation.

Many presentations dealt with experimental and theoretical studies of far-unstable nuclei, now accessible in experiments at rare-isotope accelerators. There is strong evidence that the nucleon numbers corresponding to the major shell closures are modified in many places. New theoretical work presented at the meeting pointed to the components of the interaction that in particular cases (mainly for neutron-rich nuclei) are responsible for shifting the neutron gaps from 8 to 6, from 20 to 16, and from 40 to 34. The spin-orbit splitting is also modified by neutron excess, and new measurements of transfer reactions leading to the antimony isotopes have found a consistent pattern of shifts in the binding of the h11/2 and g7/2 states under conditions where the spectroscopic factors remain approximately constant. The conclusion is that the spin-orbit splitting is largest at the stability line and decreases with neutron excess.

There were extensive discussions of measurements of spectroscopic factors in radioactive-beam experiments. With high-energy beams produced in fragmentation reactions, nucleon knockout can be studied in inverse kinematics. A consequence of this approach is a very high sensitivity, linked to the strong forward focusing, the use of thick targets, and benefiting from large hadronic cross sections. A second asset has been the development of the appropriate theoretical tools. The accurate spectroscopic factors obtained with this method are rooted in the development of reaction-theoretical methods in the high-energy limit and based on the eikonal approximation. Fully quantum mechanical models also exist and have been used to test the accuracy of the more approximate approaches. These offer formal, practical and quantitative advantages over conventional transfer-reaction approaches. A special advantage is that since the reactions are surface-dominated, the analysis avoids having to specify the motion of nucleons in the interior of the nucleus. The technique applies equally well to protons and neutrons and it is applicable to rare radioactive isotopes, something that, at least for now, is not possible with electron beams. It should however be remarked that the spectroscopic factors are deduced using shell model wave functions and therefore they are dependent on the nuclear structure models used to analyse the data.

The results on quenching agree with the (e, e' p) results for stable nuclei but for nuclei close to the drip lines, where the neutron- and proton-Fermi surfaces are very asymmetric, they can be close to unity or very small. The spectroscopic factors clearly reflect a strong influence of the nucleon separation energy. Since the binding energy is related to the nuclear symmetry energy, this raises the question of what the spectroscopic factors are in very asymmetric nuclear matter. This issue was also discussed theoretically in another context at the workshop.

Many other subjects came up during the workshop, especially during the second week. Groups at RIKEN and the GSI are studying spectroscopic factors in Coulomb-dissociation experiments with fast radioactive ions from fragmentation beams and heavy nuclear targets. Early experiments with slow post-accelerated beams from ISOLDE have observed Coulomb excitation and transfer reactions and obtained promising results. The subject of asymptotic normalization coefficients (ANC) and their use in studies of reactions of astrophysical interest was also discussed in several contributions, both experimental and theoretical.

A number of talks dealt with the problem of studying exotic nuclei unstable against neutron emission and the problem of determining the energy and strength of their single particle unbound states in the continuum. These nuclei are very important to determine the position of the driplines and the structure of the three body borromean nuclei. A related subject, discussed also extensively at the workshop, was the clusterization phenomena occurring for light nuclei and their dependence on the Z/N ratio.

3. CDF - ITALIA COLLABORATION MEETING (COLLIDER - DETECTOR FERMI LAB.)

(Collaboration Meeting)

DATE: 25–26 March

ORGANISERS:
I. Lazzizzera (Co-ordinator) (*INFN and Univ. Trento*),
F. Bedeschi (*INFN and Univ. Pisa*)

NUMBER OF PARTICIPANTS: 40

MAIN TOPICS:

- Italian contributions to detector and computing
- Charm and Beauty physics: status and perspectives of mixing measurements
- Charm and Beauty physics: CP violation

SPEAKERS:

S. Amerio (*Univ. Trento, INFN Padova*),
P. Azzi (*INFN Padova*),
G. Bellettini (*INFN Pisa*),
S. De Cecco (*INFN Roma*),
A. Cerri (*LBNL*),
G. Corcella (*CERN*),
G. Cortiana (*Univ. Padova, INFN*),
F. Curbis (*'La Sapienza', Roma, INFN*),
CS. Da Ronco (*Univ. Padova, INFN*),
S. Donati (*INFN Pisa*),
M. Donega' (*Univ. Geneva*),
J. Donini (*INFN Padova*),
A. Fabbri (*INFN Roma*),
A. Gresele (*INFN Bologna*),
F. Happacher (*INFN Frascati*),
M. Iori (*INFN Roma*),
D. Jeans (*INFN Roma*),
I. Lazzizzera (*Univ. Trento, INFN Padova*),
G. Pauletta (*Univ. Udine, INFN*),
F. Piccinini (*INFN Pavia*),
M. Rossi (*Univ. Udine, INFN*),
G. Salamanna (*'La Sapienza', Roma, INFN*),
P. Squillacioti (*INFN Pisa*),
A. Sidoti (*INFN Pisa*),
D. Tonelli (*INFN Pisa*),
S. Torre (*INFN Pisa*),
E. Vataga (*INFN Pisa, Univ. Athens*),
S. Vallecorsa (*Univ. Geneva*)

SCIENTIFIC REPORT:

This meeting was focused on Italian contributions to CDF experiment. Italians are spanning a wide range of relevant physics topics, including both high pt and low pt physics. Many good results have already been achieved and as a consequence italians cover key positions in the CDF data analysis hierarchy. The meeting was an opportunity to have an overall view on the analysis of Italian groups but also on their needs (computing, manpower,...) and on their plans for the future.

4. TRACING THE ONSET OF DECONFINEMENT IN NUCLEUS–NUCLEUS COLLISIONS

DATE: 20–29 April

ORGANISERS:
M. Gaździcki (Co-ordinator) (*University of Frankfurt*), E. Shuryak (*State University of New York*), P. Seyboth (*MPI Munich*)

NUMBER OF PARTICIPANTS: 54

MAIN TOPICS:

- review of the most recent experimental data on energy dependence of particle production in nuclear collisions (SIS, AGS, SPS, RHIC)
- discussion of the experimental status of observation of theoretically proposed signals of deconfinement in the energy dependence of pion and strangeness inclusive production and fluctuations
- presentation and discussion of new ideas related to the observation of the onset of deconfinement in nucleus–nucleus collisions and to effects of the high baryonic density reachable in experiments
- presentation and discussion of directions of future experimental studies, in particular: heavy ion program at the GSI SIS200, a possible energy scan program with intermediate and light ions at the CERN SPS and a possible extension of the BNL RHIC program to lighter ions and lower energies

SPEAKERS:

Speakers of the NA49 Collaboration Meeting

C. Alt (*IKF, Frankfurt*),
D. Barna (*Budapest*),
L. Betev (*Cern*),
H. Bialkowska (*IPJ, Warsaw*),
C. Blume (*IKF, Frankfurt*),
M. Botje (*NIKHEF, Amsterdam*),
P. Christakoglou (*Univ. of Athens*),
F. Diakonos (*Univ. of Athens*),
P. Dinkelaker (*IKF, Frankfurt*),
D. Flierl (*IKF, Frankfurt*),
V. Friese (*GSI, Darmstadt*),
Z. Fodor (*Budapest*),
M. Gazdzicki (*IKF, Frankfurt*),
C. Hoehne (*GSI, Darmstadt*),
A. Hungs (*FZK, Karlsruhe*),
M. Kliemant (*IKF, Frankfurt*),
S. Kniege (*IKF, Frankfurt*),
V. Kolesnikov (*JINR, Dubna*),
R. Korus (*AS, Kielce*),
I. Kraus (*GSI, Darmstadt*),
P. Levai (*Budapest*),
B. Lungwitz (*IKF, Frankfurt*),
G. Melkumov (*JINR, Dubna*),
M. Meurer (*FZK, Karlsruhe*),
M. Mitrovski (*IKF, Frankfurt*),
R. Renfordt (*IKF, Frankfurt*),
A. Richard (*IKF, Frankfurt*),
D. Röhrich (*Bergen, NA57, Brahms*),

M. Rybczynski (*IKF, Frankfurt*),
P. Seiboth (*MPI, Munich*),
F. Sikler (*Budapest*),
G. Stefanek (*AS, Kielce*),
M. van Leeuwen (*LBNL, Berkeley*),
G. Vesztergombi (*IKF, Frankfurt*),
I-K. Yoo (*Univ. of Pusan, Korea*)

Speakers of the workshop

F. Antinori (*Padova, NA57*),
N. Antoniou (*Athens*),
H. Appelshäuser (*GSI, CERES*),
F. Becattini (*Florence*),
C. Blume (*IKF, Frankfurt*),
E. Bratkowskaya (*Frankfurt*),
P. Braun-Munzinger (*GSI, CERES*),
K. Bugaev (*LBNL*),
P. Dinkelaker (*IKF, Frankfurt*),
P. Fachini (*BNL*),
V. Friese (*GSI, Darmstadt*),
A. Forster (*GSI, Kaos*),
M. Gorenstein (*Kiev*),
T. Hatsuda (*Tokyo*),
T. Hemmick (*Stony Brook, Phenix*),
D. Hofman (*Chicago, Phobos*),
A. Keranen (*Florence*),
E. Laermann (*Bielefeld*),
R. Lacey (*Stony Brook, Phenix*),
M. Lisa (*OSU, Star*),
A. Marin (*GSI, CERES*),
C. Nonaka (*Duke*),
S. Pratt (*MSU*),
R. Rapp (*Texas AM*),
D. Röhrich (*Bergen, NA57, Brahms*),
E. Shuryak (*Stony Brook*),
R. Snellings (*NIKHEF, Star*),
J. Stachel (*Heidelberg, CERES*),
A. Starinets (*INT Seattle*),
M. Stephanov (*Chicago*),
D. Teaney (*BNL*),
M. van Leeuwen (*LBNL, Berkeley*),
O. S. Zozulya (*Kiev*)

SCIENTIFIC REPORT:

The Workshop consisted of two parts: the NA49 Collaboration Meeting and the Workshop on Tracing the Onset of Deconfinement in Nucleus-Nucleus Collisions.

During the NA49 Collaboration Meeting the most recent results of the analysis of the NA49 data on hadron production in nucleus-nucleus, proton-nucleus and proton-proton collisions at the CERN SPS energies were presented and critically discussed. In particular data on inclusive particle spectra, two particle correlations and fluctuations in the energy region of the hypothetical onset of deconfinement were reviewed. Numerous publication drafts were presented and discussed. Further analysis steps were planned. The meeting was closed by the discussion of a new project of measurements of hadron production in collisions of light ions and protons in the energy range 10-200 GeV/nucleon by use of the upgraded NA49 detector.

The Workshop on Tracing the Onset of Deconfinement in Nucleus-Nucleus Collisions followed directly the NA49 Collaboration Meeting. It was focused on the key issues addressed by the recent NA49 measurements, i.e. whether the onset of deconfinement is observed in central Pb+Pb collisions at low SPS energies. In the first part of the Workshop the most recent results from SIS, AGS, SPS and RHIC were reviewed. It continued with the presentation of the experimental and theoretical status of the main signals of deconfinement: the anomalies in energy dependence of pion and kaon production as well as in the shape of

the transverse mass spectra of hadrons. Moreover, new theoretical results and ideas were presented and discussed, in particular:
- the role of fluctuations in study of the onset of deconfinement and the search for the critical point in the phase diagram of hadronic matter,
- the hypothesis of strongly coupled QGP and its relation to the results from the strongly coupled super-symmetric YM theories,
- the effect of baryon density on the properties of strongly interacting matter,
- the adiabatic paths on the phase diagram close to the QCD critical point,
- phase transitions in small systems.

The Workshop was closed by the presentation and discussion of new ideas on experimental studies in the region of the onset of deconfinement:
- the new GSI project and the CBM experiment,
- the light ion program at the CERN SPS and
- the fixed target program at RHIC.

There is rapidly growing interest in the subjects covered by the Workshop: the experimental and theoretical study of nucleus-nucleus collisions in the energy range 10-200 GeV/nucleon. It was therefore suggested to establish a series of annual meetings.

5. CREATION AND FLOW OF BARYONS IN HADRONIC AND NUCLEAR COLLISIONS

DATE: 3–7 May

ORGANISERS:
A. Polleri (Co-ordinator) (*TU Munich*), G. Garvey (*LANL*), B. Kopeliovich (*MPI Heidelberg*)

NUMBER OF PARTICIPANTS: 22

MAIN TOPICS:

- Baryon Production and $p\bar{p}$ annihilation, energy dependent hierarchy of mechanisms
- Baryon Number stopping in DIS and pp collisions
- Baryon Number in heavy-ion reactions: rapidity, $p_\perp$ and centrality dependence
- Finite baryon density and lattice QCD thermodynamics at finite baryochemical potential

SPEAKERS:

W. Alberico (*Torino*),
A. Andronic (*GSI*),
L. Csernai (*Bergen*),
D. Grünewald (*Heidelberg*),
Y. Ivanov (*Kurchatov, GSI*),
S. Kahana (*BNL*),
B. Kopeliovich (*Heidelberg*),
V. Magas (*Valencia*),
D. Molnar (*Ohio State*),
J. Nemchik (*Kosice*),
D. Ozerov (*DESY*),
O. Piskounova (*Lebedev*),
J. Ranft (*Siegen and CERN*),
A. Rybicki (*CERN*),
K. Safarik (*CERN*),
K. Schweda (*LBNL*),
H. Stöcker (*Frankfurt*),
D. Varga (*CERN*),
J. Velkovska (*Vanderbilt*),
F. Videbæk (*BNL*)

SCIENTIFIC REPORT:

Aim and realization of the workshop: The intent of the organizers was to have a meeting in which both theorists and experimentalists could be confronted with each other. This resulted in very interesting and lively discussions, both on present and future issues. More than 25 % were young researchers under 35 years of age. These provided plenty of fresh ideas and established useful contacts with the senior participants.

As it can be seen on the attached schedule, each day addressed specific issues and talks were grouped according to the day's topic. Ample time was allocated for each speaker as well as for discussion, allowing the audience to ask detailed questions and receive thorough answers.

Focus of the workshop: As it is for most of the studies within heavy ion physics, the two main areas of interest concern initial state effects and final state interactions with the medium. The first aspect of the problem concerns the understanding of the so-called nuclear effects which appear already in proton-nucleus (pA) collisions but can be studied also with the photon-nucleus (γA) system. These are parton energy loss, transverse momentum broadening, coherence, shadowing, etc. The second aspect is directly related to the issue of quark gluon plasma production in nucleus-nucleus (AB) collisions, since it concerns the effects of a medium with high energy density on the probe under consideration. A summary of what was presented and discussed at the workshop follows:

The notion that the baryon number (BN) is carried by valence quarks has caused in the past misleading conclusions, most notably that BN must reside at large Bjorken x and the stopping of BN in relativistic nucleus-nucleus collisions is achieved with poor efficiency. While the valence quarks reflect the BN distribution of a hadron, they are not the fundamental origin of that BN. Data from Hera were presented in support of this idea.

The interesting and challenging question of the nature and dynamics of BN goes back nearly 30 years, when studies of $p\bar{p}$ annihilation were fashionable. How baryon annihilation is related to the difference between $\bar{p}p$ and pp cross sections, how it depends on energy, and many other issues have been debated during the workshop, although some are still controversial issues. Many of these problems have been addressed in connection with new opportunities for experimental studies at the future antiproton facility at GSI.

Those ideas are now of particular interest because of the importance of BN dynamics in relativistic heavy-ion collisions. BN stopping at central rapidity has implications for the value of the baryochemical potential in modern lattice QCD thermodynamic studies. In order to set the ground for theoretical discussions, all the data for pA and AB collisions collected by experiment NA49 at CERN were reviewed. Successively, the newest results from experiments at the BNL-RHIC were presented, most notably the rapidity dependence of net protons as measured by the BRAHMS experiment.

Issues involving BN arise in all high-energy collisions ranging from e^+e^- to nuclear collisions. The experience gained in each of these areas has been brought together in the attempt to unify the approach to the dynamics of BN. Various notions of what constitutes BN have been discussed and we addressed questions such as: Where does BN reside in the nucleon? How should one interpret it in terms of the parton model? What is the dynamics of BN flow and creation in energetic collisions? What is the role of parton energy loss in BN stopping in heavy ion collisions? Moreover, the current status of models for baryon pair production and BN transport has been reviewed by several participants. Most of the models are based on a string description of high-energy soft interactions and were discussed in the framework of the Dual Parton Model. Many treatments related BN to a specific topological structure of gluonic fields (some models identify the structure as a string junction). This description has surprising consequences for BN dynamics and allows for the ready production of strange baryons. This latter feature has been shown to have important implications for the interpretation of strangeness enhancement in heavy ion-collisions as a signature of Quark-Gluon Plasma formation.

Having together theorists and experimentalists we succeeded with the goal of consolidating our understanding of the dynamics of BN and see what one might expect in future experiments. We also attempted to delineate an experimental program that could directly test the reality of the string junction paradigm.

Summary: It was a very exciting and fruitful meeting, in which participants discussed openly different physics ideas with the intent to find a common ground. It also was evident that a high degree of sophistication is beginning to be employed to address various problems. This is an important and necessary step for further advances in this field.

6. ADVANCES AND CHALLENGES IN NUCLEAR ASTROPHYSICS

DATE: 24–28 May

ORGANISERS:
C. Angulo (Co-ordinator) (*Univ. Catholique de Louvain*), P. Descouvemon (*Univ. Libre de Bruxelles*), M. Wiescher (*Univ. Notre Dame, South Bend (IN) ,JINA*)

NUMBER OF PARTICIPANTS: 41

MAIN TOPICS:

- reaction models in nuclear astrophysics
- solar neutrino physics
- standard Big-Bang nucleosynthesis
- nucleosynthesis in novae, supernova and X-ray burst (experiments and models)
- photon induced reactions
- experimental studies of reactions involved in explosive events
- experimental questions and challenges for the s-, r- and p-process
- nucleosynthesis in AGB stars
- gamma-ray astronomy

SPEAKERS:

D. Baye (*PNTPM, ULB*),
J. Blackmon (*ORNL, Oak Ridge*),
C. Brune (*Ohio Univ.*),
M. Busso (*Univ. of Perugia*),
A. Chieffi (*IASF, Frascati*),
A. Coc (*CSNSM, Orsay*),
B. Davids (*TRIUMF*),
R. Diehl (*MPI Garching*),
G. Fiorentini (*INFN, Ferrara*),
Z. Fülöp (*ATOMKI, Debrecen*),
S. Goriely (*IAA, ULB*),
M. Hass (*Weizmann Inst., Rehovot*),
M. Heil (*FZ Karlsruhe*),
C. Iliadis (*TUNL/North Carolina*),
T. Itahashi (*Osaka*),
J. José (*IEEC, Barcelona*),
A. Junghans (*Rossendorf*),
F. Käppeler (*FZ Karlsruhe*),
A. Laird (*York*),
G. MacLaughlin (*NCS Univ.*),
G. Martinez Pinedo (*IEEC, Barcelona*),
T. Motobayashi (*RIKEN*),
A. S. Murphy (*Edinburgh*),
H. Schatz (*NSCL/MSU*),
O. Sorlin (*IPN, Orsay*),
C. Spitaleri (*Catania*),
K. Sümmerer (*GSI*),
F. Thielemann (*Basel*),
N. Timofeyuk (*Surrey*),
H. P. Trautvetter (*Bochum*),
S. Typel (*GSI*),
H. Utsunomiya (*Konan Univ.*),
H. Weller (*TUNL*),
F. Weber (*San Diego State Univ.*)

SCIENTIFIC REPORT:

Aim and Purpose: Nuclear astrophysics has become in the last years one of the most exciting areas of interdisciplinary research, in the crossroads of nuclear physics, astrophysics and astronomy. The goal of the workshop was to bring together specialists to discuss the most recent advances and highlights in nuclear astrophysics.

The interest of the workshop was motivated by the most recent results, mainly in stellar evolution models and in nuclear reaction studies. Indeed, recent observations from the Hubble satellite and from earth-based telescopes have yielded results that provide an innovative insight into the history of element nucleosynthesis, star formation, and novae and supernova explosions. These observations challenge our models of nucleosynthesis and energy production in explosive scenarios. Observations of gamma-ray lines from the Compton Gamma-Ray Observatory and expected results from the INTEGRAL mission, recently launched with success, will provide a wealth of data guiding our understanding of novae and supernovae events.

Simultaneously with the progress in astronomical observations, a new era for the measurements of nuclear reactions relevant for the understanding of stellar evolution has opened with the development of radioactive nuclear beams (RNB), on one side, and with the location of underground facilities, on the other side. The traditional studies of nuclear reactions using low-energy stable-beams have been followed in the last ten years by the measurements of reaction cross sections involving short-live nuclides. Several RNB facilities in Europe, North America and Japan have undertaken this task with many remarkable examples of studied reactions, mainly concerning the hot CNO cycle and the rp-process. On the other hand, underground facilities (as the LUNA facility at the Gran Sasso) made possible the direct measurement of nuclear reactions at the Gamow energies.

Many of the reactions of interest in astrophysics cannot yet be fully studied in the laboratory due to several experimental difficulties (small cross sections, important background from open channels, radioactive beams, etc). Nuclear reaction models are then used for obtaining cross section values or for extrapolating cross sections measured at higher energies to the stellar energy range. Theoretical approaches such as cluster models have the major advantage of providing a consistent description of bound, resonant and scattering states and have been successfully applied to determine cross sections for astrophysical important reactions. Other procedures, such as the R-matrix model, are often used to fit the data (cross sections, phase shifts) and to extrapolate the cross sections down to stellar energies. Moreover, the dedicated effort of astrophysicists, devoted to stellar modelisation, is a driving force for experimental investigations.

Results and Highlights: The workshop developed very much in the way it has been foreseen and its goal was successfully achieved. We had 8 to 9 speaker per day. The formula of 25 minutes of oral presentation plus 20 minutes of discussion was very adequate. During the presentations, there was a very active participation of the audience from the very beginning. In special, there was an intense exchange of point of views between the nuclear physicists and the astrophysicist as well as between experimentalist, theoreticians and observers. On the other hand, there was an active collaborative work going on among the participants. Several collaborations have also been set during the workshop.

The scientific highlights presented included new experimental data on several astrophysical important reactions, observations and theoretical models. Because the broad character of the field, it seemed to us an impossible task to cover all the relevant aspects of the field. We concentrated in more detail on several fundamental features of nuclear astrophysics by bringing together dedicated researchers on the area : (i) recent advances in reaction models in nuclear astrophysics, (ii) neutrinos in astrophysics, (iii) standard big bang nucleosynthesis, (iii) nucleosynthesis in novae, (iv) photon induced reactions and nucleosynthesis, (v) experimental studies of reactions involved in explosive events, (vi) indirect methods in experimental nuclear astrophysics, (vii) neutron sources for the s-process, (viii) experimental questions and challenges for the s-, r- and p-process, (ix) latest results from the underground facilities, (x) gamma-ray line astronomy and cosmic nucleosynthesis; (xi) cold dark matter.

The talks can be browsed from the website: http://pntpm3.ulb.ac.be/Trento

7. TRANSVERSITY: NEW DEVELOPMENTS IN NUCLEON SPIN STRUCTURE

DATE: 13–18 June

ORGANISERS:
G. van der Steenhoven (Co-ordinator) (*NIKHEF*), E. De Sanctis (*INFN, Frascati*), W. D. Nowak (*DESY, Zeuthen*), M. Radici (*INFN, Pavia*)

NUMBER OF PARTICIPANTS: 37

MAIN TOPICS:

- First measurements of transversity
- Properties of transverse spin distributions
- Chirally-odd distribution and fragmentation functions
- Single-spin asymmetries
- Alternative approaches to transversity
- Theoretical and experimental perspectives

SPEAKERS:
Chr. Aidala (*Columbia*),
M. Anselmino (*Torino*),
H. Avagian (*Newport News*),
A. Bacchetta (*Regensburg*),
D. Boer (*Amsterdam*),
M. Burkardt (*NMSU*),
J. Collins (*Penn State*),
M. Diehl (*DESY*),
U. D'Alesio (*Cagliari*),
E. Di Salvo (*Genova*),
L. Gamberg (*Penn State*),
G. Goldstein (*Boston*),
M. Grosse-Perdekamp (*Urbana-Champaign*),
Ph. Hägler (*Amsterdam*),

D. Hasch (*Frascati*),
D.S. Hwang (*SLAC*),
X. Jiang (*Rutgers*),
R. Joosten (*Bonn*),
A. Kotzinian (*Torino*),
N. Makins (*Urbana-Champaign*),
A. Metz (*Bochum*),
A. Miller (*TRIUMF*),
P.J. Mulders (*Amsterdam*),
F. Pijlman (*Amsterdam*),
F. Rathmann (*Juelich*),
M. Schlegel (*Bochum*),
P. Schweitzer (*Bochum*),
D. Sivers (*Portland*),
H. Tanaka (*Tokyo*),
P.B. van der Nat (*NIKHEF*)

SCIENTIFIC REPORT:

Aim and Purpose: The ECT* workshop on "Transversity: New Developments in Nucleon Spin Structure" brought together leading experimental and theoretical physicists in the field of hadron spin structure. Apart from many nice presentations, which also included a number of talks given by PhD students and postdocs, the workshop was characterized by many lively discussions. These discussions were essential in order to bridge the emerging gap between new experimental data (which in some cases were first ever presented at this workshop) and new theoretical concepts and models.

Key Result: In fact, the new field of transverse spin physics is developing so rapidly that part of the discussions at the workshop were devoted to setting up a document in which the various sign and angular conventions were defined for future reference. This documents (known as the 'Trento Convention') will soon be submitted to the eprint archives, and is considered to be essential for the further development of the subject. A well documented convention will form a lasting service to the community as it enables an unambiguous comparison of data and model calculations. The Trento Convention is probably the most visible and an unusually important result of the workshop held at the ECT* in June 2004.

Physics Highlights: In order to be able to summarize the physics highlights of the workshop, the initial paragraphs of the document in which the present workshop was first proposed are repeated below. These paragraphs describe the relevance of transverse spin phenomena for developing our understanding of the angular momentum carriers of the nucleon in the framework of the theory of the strong interaction, i.e. Quantum-Chromodynamics (QCD).

"The determination and interpretation of the nucleon transverse spin structure and its related observables has become a key issue in studies of the leading quark structure of the nucleon. Measurements of transverse spin distributions, or transversity distributions, provide new information on the dynamics of quarks inside hadrons and enable the study of the validity of as yet untested Quantum Chromodynamics (QCD) predictions:

- *The tensor charge (the lowest moment of the transversity distribution) is predicted to be much larger than the axial charge (the lowest moment of the helicity distribution).*
- *The Q^2 evolution of the transversity distribution is much weaker than the Q^2 evolution of the helicity distribution.*

Both predictions are counter-intuitive, and the confirmation of the first prediction would provide one of the first successful tests of QCD in the non-perturbative domain.

Until recently transversity was not accessible experimentally owing to its peculiar spin structure. Its chirally-odd nature requires the occurrence of a second chirally-odd hadronic object in a given physical observable. This happens, for instance, in the polarized Drell-Yan process, which involves a second transversity distribution. However, the probability that the anti- quark transversity distribution (which enters the description of the Drell- Yan process) is sizable in the proton is expected to be small. Therefore, no such results are available at present. Alternatively, one can require the observation of a hadron in polarized deep-inelastic lepton scattering experiments. In fact, recently such semi-inclusive spin-dependent deep- inelastic scattering processes have become accessible experimentally. By carrying out such experiments with transversely polarized targets, and detecting hadrons over a sufficiently large azimuthal range, it is possible to obtain information on transversity. In this process, the fragmentation of quarks into hadrons is described by an unknown spin-dependent fragmentation function, which has to be measured as well. These new (chirally-odd) fragmentation functions are not only indispensable tools for the extraction of transversity from semi-inclusive deep-inelastic scattering experiments, but are also of great interest themselves, since they bear witness of the process of hadronisation, or, in other words, of the way quark confinement arises."

During the workshop the first generation of data on transverse (single) spin asymmetries were presented and new theoretical work was presented that is needed to arrive - in due time - at a solid interpretation of the various new data sets. In her summary talk Prof. Naomi Makins selected the following four highlights of the workshop:

1. New experimental data:

    - The HERMES collaboration (talk A. Miller) presented data on the single-target spin asymmetry A_{UT} corresponding to the so-called Sivers effect. The non-zero asymmetries give evidence of the existence of orbital angular motion of the quarks in the nucleon.
    - The HERMES (A. Miller) and COMPASS (R. Joosten) presented data on asymmetries corresponding to the Collins effect. The consistency of these two data sets can be demonstrated by assuming u-quark dominance and the surprising equivalence of leading and sub-leading Collins fragmentation functions (Artru model).
    - New asymmetries measured in p-p collisions by STAR and PHENIX (Chr. Aidala) improved and confirmed earlier single-spin asymmetries reported by the E704 collaboration. Various competing effects can be invoked to explain these data.
    - The CLAS collaboration (H. Avagian) reported new beam-spin asymmetries that are sensitive to the previously unmeasured twist-3 distribution function $e(x)$.
    - The HERMES collaboration (P. van der Nat) reported first data on alternative approach to transversity by presenting single spin asymmetries for semi-inclusive two-pion production. The effects turn out to be small but hold considerable promise for future high-luminosity data.

2. Are the new distribution and fragmentation functions universal, i.e. process independent?

    - Not only the k_T dependent moments but also the k_T dependence itself of the new T-odd distribution function $f_{1T}^{\perp}$ are found to be universal up to a sign that is opposite in deep-inelastic scattering and Drell-Yan (J. Collins, D. Sivers).
    - A. Metz reported that k_T dependent fragmentation functions are also found to be universal, which is very important in view of the efforts of the Belle collaboration to extract the Collins function from pp data such that it can be applied in the extraction of the transversity distribution from deep-inelastic scattering data.
    - The issue as to whether universality also applies to other process such as the $pp \to \pi^0 X$ reaction explored by E704 could not be answered definitively, but it is probable (J. Collins, A. Metz, P.J. Mulders).

3. Modeling of new distribution and fragmentation functions.

    - Several new model calculations were presented or discussed at the workshop. A few examples: (i) Gamberg and Goldstein calculated the Sivers function via 1-gluon exchange in a quark-diquark spectator model. Unfortunately, the unclear sign (and orientation) conventions prevented a direct comparison to the new data (see introduction); (ii) D'Alesio succeeded in reproducing the asymmetries reported by E704 and STAR, finding an apparenly small Collins and larger Sivers contributions; (iii) Kotzinian showed how the Sivers effect alone is able to account for the existing A_{UL} data from HERMES, while previously these data were used as evidence for the existence of the Collins effect. It was concluded that a new global analysis based on all now existing data is now essential in order to be able to reach consistent conclusions. For this reason the aforementioned development of the Trento Convention is very timely.
    - While Sivers presented a more intuitive picture of the T-odd distribution function $f_{1T}^{\perp}$ (Sivers function) based on a shadowing argument and intrinsic orbital motion of the quarks, other speakers (Hwang, Collins, Boer) discussed the same distribution function in terms of gauge links and the interference between L=0 and L=1 states. The representations are not inconsistent.
    - Burkhardt presented a rigorous derivation of the phenomenological picture of the Sivers function and its connection to the quark orbital angular momentum. Using this picture it could be deduced that the sign of the orbital angular momentum of u quarks is most likely positive.

4. New avenues:

    - Apart from transversity the recently re-introduced generalized parton distributions (GPDs) are considered to be one of the most important developments in the field of hadron structure. Diehl showed that apart from the well-known GPDs which can be probed in exclusive reactions with or without a longitudinally polarized target, four more GPDs exist with can be accessed with transversely polarized targets. The transverse quark GPDs give complementary information and in the forward limit one of them reduces to the transversity distribution.

- First lattice gauge calculations (lQCD) for these transverse GPDs were presented by Haegler. Sofar these simulations are limited to $u - d$ differences in order to get rid of the so-called disconnected pieces of the calculation.
- Hasch showed how future experiments will provide a true wealth of data on the issues discussed at the workshop.
- Rathmann presented a very recent idea to use transversely polarized antiprotons at the HESR ring at GSI to measure transversity directly in low-energy Drell Yan.

Although only a first small sample of data on transversity is now available, the field is already confronted with rapid (theoretical) developments giving new insights in hadronic structure in general and the role of orbital angular momentum and transverse spin more in particular. The many discussions at the workshop reflected the enormous activity in this relatively new field of QCD physics. This was further emphasized by the announcement of a follow-up workshop in the not-too-distant future (QCD N'06).

Suggestions and comments:

- The present workshop at the ECT* also served as the first workshop of the recently approved transversity network of the Hadron Physics I3 project, which is funded by the 6th Framework programme of the European Commission.
- Apart from the EU support, additional financial support was received from DESY (Germany) and NIKHEF (The Netherlands).
- The organisation and scientific program of the ECT* workshop was very well received by the participants. Afterwards emails were sent to the organisers that included statements such as:
  - *"I would like to thank you one more time for the great workshop (the best one I ever attended). It was a kind of workshop, which shape the future of proton structure studies. I was delighted to be invited and enjoyed very interesting and informative discussions with nice people." [H. Avagyan]*
  - *"I really enjoyed this inspiring workshop very much. Is there a web address where I can access the slides from all the talks?" [M. Burkardt]*
  - *"I wanted to commend you for a job well done on the workshop. The organization, science and venue were excellent. Again thanks for the invitation to present." [L. Gamberg]*
- The editors of the CERN COURIER have agreed to publish a short report written by two of the organizers (Radici and van der Steenhoven) on the workshop, which appeared in the October issue of 2004.

8. INTERNATIONAL WORKSHOP ON FUNDAMENTAL INTERACTIONS

DATE: 21–25 June

ORGANISERS:
K. Jungmann (Co-ordinator) (*Groningen Univ.*), R. G. E. Timmermans (*Groningen Univ.*), Ch. Weinheimer (*Bonn Univ.*)

NUMBER OF PARTICIPANTS: 32

SPEAKERS:
H. Abele (*Univ. Heidelberg*),
W. Bernreuther (*RWTH Aachen*),
M. Beyer (*Univ. Rostock*),
L. Corradi (*INFN, Legnaro*),
D. Eversheim (*Univ. Bonn*),
A. Giuliani (*Univ. Insubria*),
F. Glück (*Univ. Mainz*),
P. Herczeg (*LANL*),
K. Jungmann (*KVI, Groningen*),
S. Karshenboim (*Mendeleev Inst.*),
Y. Khriplovich (*BINP, Novosibirsk*),
N. Severijns (*Katholieke Univ. Leuven*),
L. Simons (*PSI*),
R. Timmermans (*KVI, Groningen*),
F. Vissani (*LNGS*),
K. Kirch (*PSI*),
H. Klapdor-Kleingrothaus (*MPI, Heidelberg*),
M. Lindner (*TU Munich*),
Ch.-P. Liu (*KVI, Groningen*),
M. Murphy (*MIT*),
O. Naviliat-Cuncic (*LPC-Caen, Univ. Cae*),
G. Onderwater (*KVI, Groningen*),
K. Pachucki (*Warsaw Univ.*),
A. Pilaftsis (*The Schuster Laboratory*),
J. Sapirstein (*Univ. of Notre Dame*),
Y. Semertzidis (*BNL*),
C. Weinheimer (*Univ. Bonn*),
L. Willmann (*KVI, Groningen*),
H. Wilschut (*KVI, Groningen*)

SCIENTIFIC REPORT:

In modern physics most astounding success has been achieved with the so-called Standard Model. It is most succesful in describing the strong and the electroweak forces. Excluding some recent observations in the neutrino sector, the Standard Model describes all experimental observations in (particle) physics. However, the existence of new fundamental interactions is expected, for several compelling theoretical reasons and especially because of the recently observed evidence for neutrino oscillations. More experimental clues are urgently needed to distinguish among the many proposed speculative extensions of the Standard Model and to guide new model building. The big accelerator centers of particle physics are not the only arena in which the search for new interactions is being conducted. In fact, nuclear physics facilities, at low and intermediate energy, offer unique opportunities to contribute to this quest. NuPECC recognized this in connection with its 2004 long range plan. Some of the most central and intriguing questions that face the field in the near future, and that are within the realm of nuclear physics:

- In order to learn about the nature of the neutrinos the mixing parameters must be determined and precise measurements of the absolute masses are needed. Double b-decay experiments should be pursued to settle the question of neutrinos being Dirac or Majorana particles.

- Searches for electric dipole moments in different systems (neutron, nuclei, atoms, molecules) have a very high potential to discover new sources of CP violation which are required by baryo/leptogenesis models.
- Processes that violate baryon or lepton number or lepton flavor are extremely well suited to constrain speculative extensions of the Standard Model.
- Correlation measurements in b-decay can reveal non-V-A contributions to weak processes.
- Parity nonconservation in atoms and in electron-nucleon scattering.
- Speculations about violation of CPT and Lorentz invariance.
- Possible time dependence of fundamental "constants", such as the fine-structure constant.

At the workshop, ongoing efforts to answer these questions, both theoretically and experimentally, were highlighted and discussed in depth. The workshop was concluded in a final discussion where urgent future work was identified, complementary to the productive abovementioned ongoing activities.

Several experiments that need well-founded input from theory were identified. (1) The new-physics potential of atomic parity violation experiments needs to be establised and the reliability of the necessary atomic theory must be improved. (2) The calculation of the Schiff moment of deformed nuclei must be put on a firmer microscopic basis. (3) The relation between forward nuclear scattering and fundamental issues needs to be firmed up. (4) New microscopic approaches to the nuclear matrix elements for 0n2b experiments are urgently needed. (5) The inconsistency in the hadronic contribution for the muon g-2 from e+e and t-decay data needs to be resolved and the hadronic light-by-light evaluation must be improved. (6) What are the relevant quantities to compare in testing CPT invariance?

Similarly, theoretical activities that needs experimental confirmation or input were found. (1) First and foremost, there is the question whether neutrinos are Dirac or Majorana particles. (2) The Heidelberg/Moscow 0n2b experiment points at Majorana neutrinos, but needs independent confirmation. The Cuoricino experiment is under way and its succesor Cuore is in an advanced plannning stage. (3) Direct mass measurements are imperative to fully understand neutrinos. (4) The nature of neutrinos is intimately related to leptonic CP violation, which should be looked for. More precise neutrino oscillation experiments are needed. This research could benefit from a multi- MW proton accelerator, like many others, such as searches for rare decays. (5) Experiments to measure the EDM in Radon and Radium are under way. (6) A new technique to measure the EDMs of charged particles in a magnetic storage ring has been proposed. The deuteron and the muon are the first candidates to be studied with this technique. (7) There are hints from cosmological observations for a time variation of the fine structure constant a, which needs independent confirmation. (8) The implications of the time variation a for other fundamental constants needs to be studied. (9) Additional experimental input to the hadronic contribution of the muon g-2 is expected from experiments such as Belle, BaBar and KLOE.

We expect that the guidance provided through these results will contribute to a more effective way of progress towards a better understanding of the fundamental forces and symmetries governing nature.

9. REPORT OF THE "LARGE N_C QCD 2004"

DATE: 5–9 July

ORGANISERS:
N. Scoccola (Co-ordinator) (*TANDAR, Argentina*), J. Goity (*Hampton Univ. and Jefferson Lab, USA*), R. Lebed (*Arizona State Univ., USA*), A. Pich (*Univ. of Valencia, Spain*) C. Schat (*TANDAR, Argentina*)

NUMBER OF PARTICIPANTS: 30

MAIN TOPICS:

- Large N_c gauge theories
- Large N_c QCD: mesons, ChPT
- Large N_c QCD: baryons
- Large N_c QCD: lattice
- Large N_c gauge theory-string theory duality
- Instantons and monopoles in large N_c gauge theory

SPEAKERS:
T. Cohen (*Univ. of Maryland*),
G. F. de Teramond (*Univ. de Costa Rica*),
P. Faccioli (*ECT**),
R. Flores-Mendieta (*UASLP, Mexico*),
J. Goity (*JLab and Hampton Univ.*),
R. Kaiser (*Univ. of Vienna*),
R. F. Lebed (*Arizona State Univ.*),
A. Manohar (*California Univ., San Diego*),
N. Matagne (*Univ. of Liege*),
M. Shifman (*Univ. of Minnesotta*),
N. N. Scoccola (*TANDAR, Argentina*),
M. Teper (*Oxford Univ.*),
D. Mateos (*Perimeter Inst., Ontario*),
R. Narayanan (*Florida International Univ.*),
H. Neuberger (*Rutgers Univ., USA*),
S. Peris (*Univ. Autonoma de Barcelona*),
P. Pobylitsa (*Univ. Bochum*),
J. Prades (*Univ. de Granada*),
D. Richards (*JLab, USA*),
J. Russo (*Univ. de Barcelona*),
T. Schaefer (*North Carolina State Univ.*),
G.'t Hooft (*Utrecht Univ.*),
A. Zhitnitsky (*Univ. of British Columbia*)

SCIENTIFIC REPORT:

Aim and purpose: The Large N_c QCD workshop had as the main purpose the bringing together of theorists who are actively working in the different aspects of the $1/N_c$ expansion. The idea was that through presentations and discussions of all the aspects of current interest, new ideas and directions would result.

The $1/N_c$ expansion has reached the mature age of 30 years old. However, there are many open problems yet to be satisfactorily understood at the qualitative as well as quantitative levels. For instance, we do not have analytic methods that would allow us to describe QCD in the infinite N_c limit. Although this is strictly true, there have been a number of important developments in that direction thanks to the advent of the concepts of string/gauge theory dualities, which are truly useful in supersymmetric cases, and still under development for the non-supersymmetric case. Other aspects, such as the role of instantons and monopoles in large N_c are examples where solid progress in conceptual and analytic understanding has been achieved. The numerical study of QCD in large N_c with the lattice is another direction where great insight is being gained, and where there is great promise to study difficult aspects where quantitative results are needed. Last but not least is the phenomenological side of the $1/N_c$ expansion, where the expansion provides a framework to formulate the phenomenology in the spirit of effective theory. This has been shown very poignantly in the meson sector where ChPT and the $1/N_c$ expansion have been brought together in a consistent framework, and in the baryon sector where a flurry of activity has taken place over the past ten years leading to very enlightening results. Having all these and other aspects discussed in a single forum was expected to be inspiring and constructive for further developments.

Results: As the founder of the topic of $1/N_c$ QCD, G. 'tHooft focused on the problem of confinement and the possible role of the $1/N_c$ expansion in helping elucidate its mechanism. He presented in lucid detail the scheme in which the dual color superconductor mechanism results from the condensation of monopoles. The issue of pseudoparticles, in particular instantons in the large N_c limit is not a closed chapter. Th. Schaefer discussed the issues for instantons giving an up to date overview of where the problem stands. He also discussed the issue in an environment of large baryon number density. In relation to the latter, A. Zhitnitsky discussed topological excitations in dense baryonic matter (color superconductor) and in large N_c limit, showing the common feature that the existence of a Goldstone mode in those limits, the η', serves to give rise to non-trivial topological excitations, namely domain walls and vortices. This kind of topic was also addressed by P. Faccioli. From the discussions and questions ensuing during and after these talks it is apparent that the issues concerning the role of topological excitations in QCD will be illuminated by further studying them using the $1/N_c$ expansion. T. Cohen presented a discussion of questions surrounding the problem of implementing the $1/N_c$ in dense baryonic matter. This a new direction in which the $1/N_c$ expansion has started to be considered.

The very modern approach, in which the large N_c limit plays a central role, to non-perturbative dynamics by means of the AdS/CFT correspondence was presented in several talks. J. Russo gave an overview on this correspondence, and presented details on the extraction of a glueball spectrum by means of it. He discussed issues associated with supersymmetry breaking (at the basic level supersymmetry is necessary in order to have the correspondence) and their role in the calculations he presented. He also addressed briefly the inclusion of quarks. In the same vein, D. Mateos presented the program of the AdS/CFT correspondence including flavor (leading eventually to full QCD). M. Shifman discussed the planar equivalence between N=1 gluodynamics (super-Yang-Mills theory) and a non-supersymmetric orientifold field theory. An application of the correspondence techniques to baryons was given by G. de Teramond, where he discussed possible scenarios with particular quark contents (quarks not necessarily in the fundamental representation) where the correspondence can be implemented. The topics discussed by these speakers are very exciting and there is great potential for these methods to become effective tools for understanding the non-perturbative regime of QCD.

Lattice QCD represents the most developed mean to study non-perturbative QCD. It therefore serves as a powerful tool to also study QCD in the large N_c limit. M. Teper gave an overview of the current lattice simulation in pure gluodynamics, where the large N_c limit happens to be reached more rapidly given that the expansion is in $1/N_c^2$ rather than $1/N_c$. H. Neuberger discussed planar QCD on the lattice, and the issues of reduction to finite volume a la Eguchi-Kawai. He showed how the reduction can be done down to a critical volume. He also discussed the inclusion of quarks. The issues discussed in Neuberger's talk were further developed in a talk by R. Narayanan, where he discussed among other things the issue of spontaneous chiral symmetry breaking and its interplay with reduction. Finally, D. Richards presented a talk on baryon spectroscopy from lattice QCD, on which comments are given below.

The use of the $1/N_c$ expansion in hadronic phenomenology is not new, but in recent years there has been consistent advance thanks to the combination of the $1/N_c$ expansion with effective theory techniques. The application to mesons has been developed rather extensively for the Goldstone Boson sector where the combination of ChPT and the $1/N_c$ expansion is proving to be very potent. R. Kaiser gave a detailed overview of this development, showing how the $1/N_c$ expansion can, among other things, clarify various aspects of ChPT, in particular those in which the η' meson plays a role. S. Peris gave an overview on the applications of the $1/N_c$ expansion to K-meson decays, and showed how the method helps implement sum-rule methods in a more rigorous way. In a similar vein, J. Prades presented a calculation of the important B_K parameter that characterizes the magnitude of the $\Delta s = 2$ matrix elements that are required for indirect CP-violation. He showed how the $1/N_c$ expansion is very useful for this purpose.

There were a number of talks on the $1/N_c$ expansion in baryons. An overview was presented by A. Manohar emphasizing the role of $1/N_c$ and the ensuing spin-flavor dynamical symmetry that leads to powerful predictions in the sector of ground state baryons. He also presented the new extension to exotic baryons, in particular to the so called penta-quark (for $N_c = 3$) type of states. There were several talks on excited baryons. R. Lebed presented the large N_c excited baryons from the point of view of the Skyrme picture. J. Goity discussed several issues on countings for excited baryons in particular for decays and configuration mixings. N. Matagne presented an analysis of higher excited even parity baryons. N. Scoccola talked about the analysis of strong decays of the negative parity baryons carried out in a complete fashion to order $1/N_c$. In the same vein, an overview talk on excited baryons in lattice QCD was given by D. Richards. Combining these advances in lattice baryon spectroscopy with an analysis of the results by means of the $1/N_c$ expansion was assessed as a very promising future area of activity. R. Flores-Mendieta presented a very detailed analysis of hyperon semileptonic decays carried out in the combined framework of ChPT and the $1/N_c$ expansion; he was able to show the superiority of this framework in calculations such as the ones needed to extract V_{us} from these decays. P. Pobylitsa discussed the issue of T-odd parton distributions from the large N_c perspective. There were in general very useful discussions among the people working in baryons from which several interesting issues as food for thought emerged.

The schedule left plenty of time for discussion in the afternoons, and these opportunities were profitably used by the participants.

Another important aspect of the workshop was that some students and young postdocs attended and gave talks.

The organizers are satisfied with the results of the workshop. It was attended by a good number of the most active people in the topic, gave a good cross section of the current work and provided through the lively discussions, during and after the talks, with many questions and ideas that we hope will serve well to the further progress of the field of non-perturbative QCD through the $1/N_c$ expansion.

10. HADRONS AND STRINGS

DATE: 11–17 July

ORGANISERS:
M. Stephanov (Co-ordinator) (*Univ. of Illinois*), N. Evans (*Univ. of Southampton*), C. Korthals-Altes (*Centre de Physique Théorique au CNRS*), D. T. Son (*Univ. of Washington*)

NUMBER OF PARTICIPANTS: 36

MAIN TOPICS:

- String theory descriptions of QCD
- Open problems in QCD Phenomenology
- Hidden Local Symmetries in QCD
- Holographic description of chiral symmetry breaking
- Lattice studies of large N QCD and SUSY QCD
- Spin model description of SUSY QCD

SPEAKERS:

J. Barbon (*CERN*),
A. Belitsky (*Univ. Maryland*),
A. Buchel (*Univ. Western Ontario*),
Ph. De Forcrand (*ETH and CERN*),
L. Del Debbio (*CERN*),
P. Di Vecchia (*Niels Bohr Institut*),
J. Erdmenger (*Humboldt Univ.*),
N. Evans (*Univ. Southampton*),
A. Feo (*Univ. Parma*),
Z. Guralnik (*Humboldt Univ.*),
C. Herzog (*Univ. California, St. Barbara*),
E. Iancu (*SPhT, CEA Saclay*),
R. Jaffe (*M.I.T.*),
G. Korchemsky (*Univ. Paris Sud*),
B. Lucini (*ETH, Zurich*),
D. Mateos (*Perimeter Inst., Canada*),
D. Nogradi (*Leiden Univ.*),
L. Pando-Zayas (*Univ. Michigan*),
F. Sannino (*NORDITA*),
M. Shifman (*Univ. Minnesotta*),
A. Starinets (*Univ. Washington*),
M. Stephanov (*Univ. Illinois*),
G. 't Hooft (*Utrecht Univ.*),
M. Teper (*Oxford Univ.*),
K. Yamawaki (*Nagoya Univ.*),
K. Zarembo (*Univ. Uppsala*)

SCIENTIFIC REPORT:

Aim and Purpose: The purpose of the workshop was to discuss recent developments in our understanding of the relationship between field theory and string theory, with a focus on the physics of strong interactions and QCD. QCD has traditionally provided an excellent description of strong interaction physics particularly in the high energy perturbative regime. The nature of confinement and of the rich hadron spectrum are questions to which QCD is believed to possess the answers, but it has long become apparent that such answers are not easy to get from QCD. The Maldacena conjecture, put forward in 1997, established an explicit link between such gauge theories and string theories. Although Maldacena's original example does not exhibit confinement, very soon the gauge-string correspondence was extended to confining theories somewhat similar to Yang-Mills or QCD. This workshop was intended to bring experts together from both areas of study to further our understanding of the links and work towards a string description of true QCD.

We believe that the workshop was extremely successful and the organizers were particularly pleased by the rich variety of participants. In particular members of the perturbative QCD, QCD exotics, lattice QCD, string theory, AdS/CFT Correspondence and spin model communities all attended. The discussions were therefore very rich and multi-disciplinary and the workshop enabled new academic links that might otherwise not have occurred.

Particular highlights include: The attendance and presentation by Nobel laureate Gerard 'tHooft who was one of the first people to make the connection between QCD and strings. Misha Shifman also has a wealth of experience in QCD physics and contributed greatly to the discussions throughout the workshop. Bob Jaffe likewise was enthusiastic in forcing the string community to face real QCD phenomenology. Much of tuesday was taken up with the very recent holographic descriptions of chiral symmetry breaking including a chance for many experts in the field to discuss new results such as those of Pando Zayas. Wednesday was devoted to lattice presentations in which both of the groups worldwide investigating large N QCD were represented - there was a great deal of discussion on the merits of various models of QCD strings. On thursday much of the discussion centred on the very recent understanding of the AdS/CFT Correspondence in terms of spin chains. There were many other good discussions including reports on the impressive use of the AdS/CFT Correspondence to predict properties of strongly coupled plasmas such as that created in heavy ion collisions.

We would also like to mention the success of the facilities and social events put on by the ECT* staff. Trento is a super place for such workshops and it was clear that all participants greatly enjoyed themselves. The pizza evenings and banquet were all very well attended - many thanks to Ines for the organization.

We believe the workshop provided an important contribution to the evolution of the on going endeavour to understand the links between QCD and Strings. Many outstanding problems were highlighted - can we understand vector meson dominance, the glueball and QCD string spectrum, for example. Many of the participants were enthusiastic about the new understandings and links they had made and we expect fruitful collaborations to have been borne. We are pleased to be able to report of future workshops planned on the same topic in Seoul and Santa Babara before the end of this year. We are seriously considering requesting to run a follow up meeting to this one at the ECT* in 2006.

11. NOVEL APPROACHES TO THE NUCLEAR MANY-BODY PROBLEM: FROM NUCLEI TO STELLAR MATTER

DATE: 6–17 September

ORGANISERS:
C.-H. Lee (Co-ordinator) (*Pusan National Univ.*), N. Kaiser (*TU Munich*), A. Schwenk (*Ohio State Univ.*)

NUMBER OF PARTICIPANTS: 40

MAIN TOPICS:

- Renormalization Group Approach to Nuclear Forces and Interacting Many-Body Systems
- Low-Momentum Interaction in Nuclei
- Effective Theories for Shell Model Interactions
- Many-Body Correlations, Coupled Cluster Method, Density Matrix Renormalization Group
- Density Functional Theory and Effective Action
- Effective Field Theories at Finite Density
- Finite Density Lattice Simulations
- Microscopic Physics for Neutron Stars and Supernovae
- QCD Phase Diagram, Correlations in High-Density QCD, Non-Fermi Liquid Effects

SPEAKERS:

B. Binz (*Univ. Fribourg*),
M. Birse (*Univ. Manchester*),
J.-P. Blaizot (*CEA, Saclay*),
S. Bogner (*Univ. Washington*),
J. Bowers (*Univ. Washington*),
J. Braun (*IKP, Heidelberg*),
L. Coraggio (*INFN, Napoli*),
D. Dean (*Oak Ridge National Lab*),
B. Friman (*GSI*),
R. Furnstahl (*Ohio State Univ.*),
H.-W. Hammer (*Univ. Washington*),
S. Hands (*Univ. Wales Swansea*),
M. Harada (*Nagoya Univ.*),
K. Hebeler (*GSI*),
C. Honerkamp (*MPI, Stuttgart*),
C. Horowitz (*Indiana Univ.*),
C.-H. Lee (*Pusan National Univ.*),
D. Lee (*North Carolina State Univ.*),
D. Litim (*Univ. Southampton*),
T. Luu (*LANL*),
D.-P. Min (*Seoul National Univ.*),
E. Olsson (*Uppsala Univ., NORDITA*),
P. Papakonstantinou (*TU Darmstadt*),
T. Papenbrock (*Oak Ridge National Lab*),
T.-S. Park (*KIAS, Seoul*),
J. Polonyi (*Louis Pasteur Univ.*),
A. Rebhan (*TU Wien*),
M. Rho (*CEA Saclay, Hanyang Univ.*),
C. Sasaki (*Nagoya Univ.*),
B.-J. Schaefer (*IKP, Darmstadt*),
T. Schaefer (*North Carolina State Univ.*),
A. Schwenk (*Indiana/Ohio State Univ.*),
R. Shankar (*Yale Univ.*),
E. van Dalen (*Univ. Tübingen*),
J. Wambach (*TU, Darmstadt*),
W. Weise (*TU, Munich*)

SCIENTIFIC REPORT:

Over the past decade, there has been considerable success in applying effective theory and renormalization group methods to nuclear forces and the nuclear many-body problem. Both methods offer a variety of ways to approach strongly interacting many-body systems in a controlled manner. These methods are also being applied to powerful conventional techniques, such as effective shell-model interactions, Fermi-liquid theory or density functional theory. Effective approaches are especially important for matter under extreme conditions, i.e., high density or large proton or neutron excess, where reliable extrapolations away from the standard nuclear many-body program are necessary.

This workshop brought together scientists from nuclear physics and related fields working on the renormalization group and effective theories. In addition, we invited experts on powerful conventional methods. The interdisciplinary character and the participation of experts from condensed matter and high-energy physics has lead to a unique and stimulating meeting for the advancement of renormalization group and effective theory ideas in nuclear physics. Among the main topics of the workshop were the renormalization group, effective field theory, effective nuclear interactions, density functional theory, finite-density lattice simulations, microscopic physics for neutron stars, correlations in high-density QCD and non-Fermi liquid effects. The workshop covered applications ranging from finite nuclei to stellar matter, as insights from one region, e.g., few-body systems, lead to improvements of the methods in another, e.g., the derivation of effective interactions in heavy nuclei and neutron stars. Another highlight were very fruitful exchanges with participants working on the renormalization group in condensed matter systems with competing instabilities (Shankar, Polonyi, Binz and Honerkamp).

During this meeting, several important future problems were outlined and a number of collaborations on improvements and extensions of current applications in nuclear physics have been formed. These include a detailed comparison of low-momentum interactions, when applied in nuclear matter, to the chiral dynamics approach; the application of low-momentum interactions in the coupled cluster and Bloch-Horowitz approach; a direct derivation of $V_{\mathrm{low}\,k}$ from NN phase shifts; a detailed comparison of the exact RG approach with the renormalization group method of Shankar, in particular regarding error estimates and the treatment of momentum dependences; scientific exchanges on lattice techniques for nuclear matter; an understanding of induced interactions in high-density QCD; and the impact of non-central correlations on the physics of neutron stars and supernovae.

This workshop was partially supported by APCTP (Asia-Pacific Center for Theoretical Physics). It provided a unique international meeting in this research area, which will continue and start important international collaborations on these topics. We are thankful to APCTP for the support.

Finally, it is a pleasure to thank the ECT* staff for the excellent support and the great flexibility in the organization.

12. NEUTRON STARS: STRUCTURE AND COOLING

DATE: 20–25 September

ORGANISERS:
P. Haensel (Co-ordinator) (*N. Copernicus Astronomical Center, Poland*), G. G. Pavlov (*Penn State Univ.*), D. G. Yakovlev (*Ioffe Physical Technical InstituteSt. Petersburg*)

NUMBER OF PARTICIPANTS: 41

MAIN TOPICS:

- Neutron-star interiors: neutrino emission mechanisms, superfluidity, and strong magnetic fields
- Formation of neutron-star emission spectra
- Cooling of isolated neutron stars
- Thermal state and evolution of accreting neutron stars
- Observations of neutron stars in X-ray and optical regions
- Observational evaluations of neutron-star masses, radii, and surface magnetic fields

SPEAKERS:

L. Bildstein (*UCSB, Santa Barbara*),
D. Blaschke (*Univ. Bielefeld*),
E. Brown (*Michigan State Univ.*),
N. Chamel (*Paris Observatory*),
Ph. Chang (*UCSB, Santa Barbara*),
M. Colpi (*INFN Milano*),
F. Haberl (*MPI, Garching*),
S. Kaminker (*Ioffe Inst., St. Petersburg*),
D. Kaplan (*Caltech, Pasadena*),
S. Kubis (*IFJ, Krakow*),
J. Lattimer (*SUNY, Stony Brook*),
B. Link (*Montana State Univ.*),
J. Margueron (*Tuebingen Univ.*),
L. Mornas (*Univ. Oviedo*),
D. Page (*UNAM, Mexico*),
S. Park (*Penn State Univ.*),
G. Pavlov (*Penn State Univ.*),
C. Pethick (*NORDITA*),
J. Pons (*Univ. Alicante*),
S. Popov (*SAI, Moscow*),
A. Possenti (*INAF, Cagliari*),
S. Reddy (*LANL*),
B. Rutledge (*McGill Univ., Montreal*),
H.-J. Schulze (*INFN Catania*),
A. Schwenk (*Ohio State Univ.*),
A. Sedrakian (*Tuebingen Univ.*),
S. Shibata (*Yamagata Univ.*),
T. Strohmayer (*NASA, Huntsville*),
T. Tatsumi (*Kyoto Univ.*),
C. Thompson (*CITA, Toronto*),
J. Truemper (*MPI, Garching*),
R. Turolla (*Univ. Padova*)

SCIENTIFIC REPORT:

Aim and Purpose: The aim of the workshop was to bring together theorists and observers, and discuss the current status of the problem of neutron star cooling and its relation to neutron star structure. Such a gathering was particularly timely in view of an important increase of the quality and quantity of observations of neutron stars performed in the recent years by X-ray and optical space observatories such as AXAF-Chandra, XMM-Newton, and Hubble Space Telescope. We did our best to have a fair balance between the theoretical and observational talks. Some theoretical problems of neutron-star physics that were discussed are: physics of matter in neutron star interiors, including neutrino emission mechanisms, baryon superfluidity, effects of strong magnetic fields. Moreover, recent progress in physics of exotic phases of dense matter (quark matter, kaon condensate) was reviewed in several talks. Critical review of the theory of formation of neutron star emission spectra was given by several speakers. Various aspects of cooling of isolated neutron stars were reviewed. The issue of the thermal state and evolution of accreting neutron stars has been critically reviewed. The theory was confronted with observational data on neutron stars of various types, in different spectral bands, with emphasis on recent X-ray and optical observations.

Scientific Highlights: Several talks presented recent slow progress in the difficult field of the equation of state of neutron star matter (Schulze, Tatsumi, Kubis, Reddy). A number of talks dealt with present status of theoretical description of strong (nuclear) interactions in dense neutron star matter and their impact on neutrino processes and superfluidity (Schwenk, Pethick, Tatsumi, Sedrakian, Chamel, Margueron, Mornas). New realistic simulations of cooling of isolated neutron stars were presented, dependence on dense matter models were delineated, and cooling curves confronted with measured surface temperature of a few available isolated close-by neutron stars (Page, Kaminker, Pons, Blaschke, Lattimer, Popov).

Leaders of teams observing neutron stars in the X-ray and optical domains presented critical reviews of existing observations and measurements (Truemper, Pavlov, Kaplan, Shibanov, Turolla). Rapid proper motions of black holes and neutron stars from their birth places were discussed by Colpi. Very recent results on dynamics, evolution, and internal structure of accreting neutron stars, which manifest themselves as the X-ray transients and X-ray bursters and superbursters, were reviewed by a group of North American speakers (Bildsten, Chang, Brown, Rutledge). Important new methods and discoveries enabling measurement of neutron stars masses and radii were presented, together with observational basis, in several talks during last two days of the workshop (Lattimer, Strohmayer, Rutledge, Possenti).

13. NEUTRINOS AND THE EARLY UNIVERSE

DATE: 4–8 October

ORGANISERS:
M. Lindner (Co-ordinator) (*TU Munich*), G. Raffelt (*MPI, Munich*)

NUMBER OF PARTICIPANTS: 40

MAIN TOPICS:

- Leptogenesis and related topics
- Phenomenology of Neutrino Oscillations
- Theory of Masses and Mixing Matrix
- Beyond "Standard Neutrino Mixing", BBN
- Neutrinos and Cosmic Structures, Mass Limits, High-Energy Sources

SPEAKERS:
K. Abazajian (*LANL*),
E. Akhmedov (*Univ. Valencia*),
S. Antusch (*Univ. Southampton*),
K. R. S. Balaji (*McGill Univ., Montreal*),
G. Branco (*TU Munich*),
W. Buchmueller (*DESY*),
P. Di Bari (*MPI, Munich*),
M.-T. Eisele (*TU Munich*),
Y. Farzan (*ICTP, Trieste*),
G. Fuller (*Univ. California*),
K. Hamaguchi (*DESY*),
S. Hannestad (*Univ. Southern Denmark*),
M. Kaplinghat (*Univ. California*),
D. Kirilova (*Bulgarian Acad. of Sciences*),
R. Mohapatra (*Univ. Maryland*),
M. Mueller (*MPI, TU Munich*),
T. Ohlsson (*KTH, Stockholm*),
E. Paschos (*Univ. Dortmund*),
S. Pascoli (*UCLA*),
P. Olbratowski (*Univ. Warsaw*),
S. Pastor (*IFIC, CSIC, Univ. Valencia*),
M. Pluemacher (*CERN*),
M. Ratz (*Bonn Univ.*),
A. Ringwald (*DESY*),
J. Sato (*TU Munich*),
M. Schmidt (*TU Munich*),
P. D. Serpico (*MPI, Munich*),
A. Smirnov (*ICTP, Trieste*),
J. Valle (*IFIC, Valencia*),
R. Volkas (*Univ. Melbourne*),
T. Weiler (*Vanderbilt Univ.*)

SCIENTIFIC REPORT:

Neutrino physics has seen tremendous progress over the past few years in that the phenomenon of flavor oscillations has been unambiguously identified in the solar and atmospheric neutrino fluxes as well as in laboratory experiments. It is now established that the three families of neutrinos mix with each other and that neutrinos have masses. The small sub-eV mass differences are now well measured and two of the three mixing angles have been measured to be large while the third one is known to be small while its exact value is not yet determined. Against this backdrop of recent experimental progress, the workshop "Neutrinos in the early universe" focused on evaluating the role of neutrinos in cosmology and to identify further lines of progress in this quickly developing field.

One key topic that was broadly debated by the workshop attendants is the connection between neutrino masses and the creation of the cosmic matter-antimatter-asymmetry that is crucial for our own very existence. The current status of this "leptogenesis" scenario was reviewed and unsettled aspects were discussed such as the relevant non-equilibrium quantum field-theoretical formulation of the lepton-number generation. New and non-standard leptogenesis scenarios were proposed and the connection to dark energy and neutrino mass models was discussed. The current experimental evidence, the expected future progress, and the theoretical interpretation of neutrino oscillations were also reviewed and discussed.

Another crucial topic of neutrino cosmology is the role of massive neutrinos as a cosmic dark-matter component. While neutrinos are only a small fraction of the overall dark matter density, they act as "hot dark matter" and as such leave a fingerprint in cosmological precision data of the cosmic microwave background radiation and the large-scale galaxy redshift surveys. The most restrictive limit on the overall neutrino mass scale derives from these cosmological observations. Therefore, the status of these results and their systematic uncertainties were hotly debated at the workshop. Further progress seems inevitable, but will depend on our improved understanding of these systematics. New results were presented on the clustering properties of low-mass neutrinos in the background structures of cold dark matter. Galaxies such as our own seem to host a surprisingly large over-density of cosmic background neutrinos.

Cosmological and astrophysical observations not only constrain the neutrino mass, but also provide very restrictive limits on the existence of additional neutrino states beyond the usual three standard families and on exotic neutrino interactions such as Majoron couplings. New results were presented on the compatibility of the hotly-debated "sterile neutrinos" with big-bang nucleosynthesis, based on a paper that was actually finished at the workshop. Given the current observational uncertainties of the primordial light-element abundances, the sterile-neutrino hypothesis can not be conclusively ruled out.

The high standards of the scientific talks and the intensity of the discussions at the workshop proved that neutrino cosmology is a vibrant field with a broad variety of fascinating activities. The participants went away with a sense of stimulation and direction for future work in one of the most active areas of astroparticle physics.

14. EXPLORING THE IMPACT OF NEW NEUTRINO BEAMS

DATE: 18–22 October

ORGANISERS:
M. C. Volpe (Co-ordinator) (*Institut de Physique Nucléaire Orsay*), J. BOUCHEZ (*CEA Saclay*), M. LINDROOS (*CERN*), M. MEZZETTO (*Padova University*), T. NILSOON (*CERN*)

NUMBER OF PARTICIPANTS: 32

MAIN TOPICS:

- beta-beams
- low energy beta-beams
- super-beams
- neutrino factories
- neutrino properties
- physics with exotic ion beams
- CP violation
- leptogenesis and baryogenesis
- hadron physics
- neutrino-nucleus interactions
- nucleosynthesis and supernova physics

SPEAKERS:

J. Bernabeu (*Univ. Valencia*),
J. Bouchez (*CEA Saclay*),
J. B. Castell (*Univ. Valencia*),
P. Butler (*CERN*),
F. Cei (*Pisa Univ.*),
J. Charles (*CPT, Marseille*),
M. Chartier (*Univ. Liverpool*),
P. Delahaye (*CERN*),
R. Edgecock (*Rutherford Appleton Lab*),
S. Forte (*Milano Univ.*),
S. Gilardoni (*CERN*),
A. Guglielmi, (*INFN, Padova Univ.*),
S. Hancock (*CERN*),
P. Huber (*TU Munich*),
N. Jachowicz (*Ghent Univ.*),
M. Lindroos (*CERN*),
D. Meloni (*Granada Univ.*),
M. Mezzetto (*INFN Padova*),
P. Migliozzi (*INFN Naploli*),
A. Mirizzi (*Bari Univ.*),
G. McLaughlin (*Univ. North Carolina*),
L. Mosca (*CEA Saclay*),
F. Myhrer (*South Carolina Univ.*),
T. Nilsson (*TU Darmstadt*),
J. Orloff (*Clermont-Ferrand Univ.*),
V. Palladino (*Napoli Univ.*),
J. Papavassiliou (*Valencia Univ.*),
M. Rolinec (*TU Munich*),
A. Rubbia (*Zurich*),
S. K. Singh (*Aligarh Muslim Univ.*),
E. Truhlik (*Inst. of Nuclear Physics Rez*),
C. Volpe (*IPN, Orsay*)

SCIENTIFIC REPORT:

The experimental and theoretical discoveries in weak interactions of mesons and nuclei have been milestones for the developments of the $SU(3) \times SU(2) \times U(1)$ Standard Model. The Standard Model is now confirmed with a high precision. Nevertheless, it still contains conceptual problems like the hierarchy problem and requires a number of input parameters. From the theoretical point of view it is expected to be a low energy effective model of a more fundamental theory. However, until recently, no experimental evidence for physics beyond the Standard Model had been found, with one exception: The discovery of neutrino oscillations. The fact that neutrinos are massive particles has considerable impact on different domains of physics: in particle physics, where the description of non-zero masses and mixing requires the extension of the Standard Model of fundamental interactions; in astrophysics, for the comprehension of various phenomena such as nucleosynthesis; in cosmology with, for instance, the search for dark matter.

In the last few years positive oscillation signals have been found in a series of experiments using neutrinos produced with various sources. In view of the importance of this discovery and its implications, a number of projects are running, planned in the near future, or under study in order to address many still open questions about neutrinos. Among them are those concerning their Majorana or Dirac nature, the mass hierarchy and absolute mass scale, the knowledge of the mixing angle θ_{13}, the possible existence of sterile neutrinos and of CP violation in the leptonic sector.

As far as CP violation is concerned, three options are at present under very active investigation : superbeams, neutrino factories and beta-beams. While superbeams are conventional neutrino beams pushed to their ultimate intensities, neutrino factories and beta-beams are novel concepts. Neutrino factories are based on the production, collection, acceleration and storage of muons to obtain muon and electron neutrino beams of opposite helicities. The energy of these beams would be of several tens of GeV and the needed baseline of the order of 3000 Km. These beams could address in one step the leptonic CP studies, the measure of the hierarchy of the neutrino masses and the precision measurement of the θ_{23}, δm^2_{23} and θ_{13} parameters. Beta-beams consist in accelerating and storing radioactive ions decaying through beta decay. Very pure (anti)electron neutrino beams of energies up to 1 GeV can be produced. In the beta-beam baseline studied so far, neutrinos from a beta-beam and a superbeam are sent to a gigantic Cherenkov detector to an upgraded underground Frejus laboratory. The superbeam would be produced by the same beta-beam proton driver. A large physics program can be performed, going from CP (and CPT violation) in the leptonic sector to proton decay and the detection of supernova neutrinos.

Recently it has been proposed to use the beta-beam concept to have intense neutrino beams at low energies (typically a few tens of MeV up to about a hundred MeV). Very intense exotic beams will be avalaible in the future at various facilities like at GANIL and GSI or the EURISOL project, offering different possible sites for a low-energy beta beam facility. This could offer a unique opportunity to study intrinsic neutrino properties like the neutrino magnetic moment or to perform systematic studies on neutrino-nucleus interactions in an energy range of interest for nuclear, particle physics and astrophysics. In fact, these reactions are extremely important for the interpretation of some current neutrino experiments, like oscillation measurements, as well as for the study of the feasibility of new projects, such as new observatories to detect neutrinos emitted in a supernova explosion, a phenomenon not yet fully understood. Finally, the role of neutrino-nucleus interactions in nucleosynthesis is at present under active investigation.

More information on the facilities can be found on the web-sites :
http://muonstoragerings.web.cern.ch/muonstoragerings/Welcome.html
http://beta-beam.web.cern.ch/beta-beam/

The workshop has aimed at bringing together worldwide experts, experimentalists and theoreticians, working on the feasibility and physics potential of the above-mentioned facilities, as well as on the implications in other fields, such as astrophysics and cosmology. Having this in mind, we have devoted much time to informal discussions.

A number of excellent talks have been given that have : - presented the present status and future projects in neutrino physics and nuclear physics with exotic ion beams;
- discussed the feasibility and physics potential of neutrino factories, beta beams and low-energy beta-beams;
- addressed the impact in other fields, among which hadron physics, muon physics, baryogenesis and nucleosynthesis.

During all sessions we have had lively discussions in particular on the high energy beta-beams scenarios, on the competition/complementarity between beta-beams and neutrino factories, on the physics program of megaton detectors, on the impact on leptogenesis/baryogenesis, on open issues in neutrino-nucleus interactions and on the physics potential of low energy beta-beams. This particular option has arosen a lot of interest and now seems ready for a letter of intent. A prototype might be studied which would exploit one of the storage rings already existing at CERN.

2.4 ECT* Doctoral Training Programme

The 2004 Marie-Curie Doctoral Training Programme was devoted to "Neutrino Physics". It was held at ECT* during the five month period June-October 2004.

The Programme was prepared by Alessandro Bottino (Torino) who was the co-ordinator, together with Marcello Baldo (Catania) and Karlheinz Langanke (Aarhus) who acted as co-organizers. The student applications were examined in ECT* by Georges Ripka (ECT and Saclay) who was the Acting Director of ECT*.

2.4.1 Lecture Series

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

- **Neutrinos in particle physics**
  Lecturer: Samoil Bilenky (JINR, Dubna, Russia and SISSA, Trieste, Italy)
- **Neutrino mixings and oscillations**
  Lecturer: Gianluigi Fogli (Bari University, Italy)
- **Neutrino-nucleus interaction**
  Lecturer: Thomas William Donnelly (MIT, Boston, USA)
- **Neutrino-related processes in nuclei**
  Lecturer: Petr Vogel (Kellogg Radiation Laboratory, Pasadena, USA)
- **Neutrino Cosmology**
  Lecturer: Steen Hannestad (University of South Denmark, Denmark)
- **Physics at neutrino telscopes I**
  Lecturer: Nicolao Fornengo (Torino University, Italy)
- **Physics at neutrino telscopes II**
  Lecturer: Guenter Sigl (GReCO/IAP and APC, Paris, France)
- **Supernova physics and neutrino**
  Lecturer: Hans Thomas Janka (Max Planck Institute, Garching, Germany)

The following workshop projects were also open to the participants of the Training Programme:

- **Fundamental Interaction**
- **Neutron Stars: Structure and Cooling**
- **Neutrinos and the Early Universe**
- **Exploring the Impact of New Neutrino Beams**

2.4.2 Participants

On the basis of their academic and scientific profiles and achievements, 14 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 (3-6 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 *):

Everton Alvarenga Zanella	(Univ. of San Paolo),
Jeremy Argyriades	(CEA Saclay),
Anatael Enrique Cabrera Serra*	(Univ. of Oxford),
Sara Della Monaca	(Univ. of Trento),
Doron Gazit*	(Univ. of Jerusalem),
Alex Giacomini	(Univ. of Trento),
Jeremy Jones	(Univ. of Arizona),
Amanda Porta	(Univ. of Trento),
Sofia Quaglioni	(Univ. of Torino),
Diego Rubiera García*	(Autonomous Univ. of Madrid - Oviedo),
Ivo Rolf Seitenzahl*	(Univ. of Chicago),
Krzysztof Turzynski*	(Univ. of Warsaw),
Klaas Vantournhout	(Gent Univ.),
Nikolaj Thomas Zinner*	(Univ. of Aarhus)

2.4.3 Further scientific activities of the Marie-Curie Programme

In addition to the lectures and workshops listed above, further scientific activities consisted of seminars and lectures given at ECT* by the participants, and the participation of 6 students to the Indian Summer School on "Understanding Neutrinos", which was held in Prague September 8-13, 2004.

Seminars given at ECT* by the students

Anatasia MALYKH : 17th of June, 2004 "Low-energy universal properties of three-body systems in two dimensions".

Krzystof TURZYNSKI: 7th of October, 2004, "On leptogenesis with degenerate minimal seesaw."

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

Lecture series given at ECT*

One participant, Alex Giacomini (University of Trento), gave and extended series of 10 tutorial lectures on "Graviation and the General Theory of Relativity".

Participation to the Indian Summer School on Neutrino Physics in Prague

As an implementation of the Cooperation Agreement between the Nuclear Physics Institute (Academy of Sciences of the Czech Republic) in Rez near Prague and ECT*, it was agreed that some of the Marie-Curie students would attend the Indian Summer School on "Understanding Neutrinos", which was held in Prague September 8-13, 2004, a period during which no Marie-Curie lectures were given at ECT*. Six students from ECT* attended the Indian Summer School: Cabrera, Giacomini, Jones, Seitenzahl, Turzynski, and Zinner. The Nuclear Physics Institute in Rez generously covered the food and board expenses for the six students. In addition, Ripka was invited to attend on a research grant of Hosek. The travel was provided for by ECT*: the participants were driven by Mauro in the ECT minibus.

Three of the students from ECT* gave a talk at the Indian Summer School: Anatael Cabrera, Ivo Seitenzahl and Krzystof Turzynski.

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).

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, due to start by the end of 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 a one-day workshop held at ECT* in December 2004. Along this line, Dr. Calarco has recently been appointed first as an INFM Researcher (since November 1st, 2004) and later as a Senior Researcher (due to start in 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 planned whose cost is being equally shared among the ECT* general budget and the ACQP project.

Furthermore, very recently Dr. Calarco has been appointed also as the responsible of the European QIP Roadmap for FP7, in the framework of the newly started (on February 1st) 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.

3.2 Projects of ECT* Researchers

• François Arleo

Photon tagged correlations in heavy ion collisions

in collaboration with P. Aurenche, Z. Belghobsi, J.-P. Guillet (LAPTH, Annecy)

Energy loss of hard partons propagating through a dense QCD medium (say a pion gas or quark-gluon plasma) is expected to be large. Consequently, this mechanism may serve to signal deconfinement in high energy nuclear reactions. In order to probe how this produced medium affects the fragmentation process, we suggest to study the correlations of two photons, experimentally accessible and calculable in QCD perturbation theory. Tagging on the photon directly produced in the hard collision allows us to map out the medium-modified fragmentation function of the less energetic photon. Furthermore, such correlations are experimentally accessible and calculable in QCD perturbation theory. First results indicate that this observable proves a promising tool to characterize dense media produced at the LHC.

Hints for the non-universality of transverse momentum broadening

in collaboration with J. Aichelin, P.-B. Gossiaux, T. Gousset (SUBATECH) and S. Peigné (LAPTH)

Within the scalar QED model of Brodsky we compare the leading-twist $K_\perp$-dependent quark distributions $f_q(x, K_\perp)$ probed in deep inelastic scattering and Drell-Yan production. We extend the Drell-Yan production model to the case of a neutral composite projectile and study the role of spectator Coulomb rescatterings. The model is consistent with $K_\perp$-factorization and the universality of $f_q(x, K_\perp)$. We then show that at higher-twist, Coulomb rescatterings are responsible for non-universal transverse momentum exchange. In Drell-Yan production the typical transfer is of the order of an infrared cut-off, possibly explaining the surprising smallness of nuclear transverse momentum broadening in Drell-Yan production.

• Daniele Binosi

I have arrived at ECT* in January 2004, and since then I have been involved in a variety of research topics. My interests range from gauge fixing parameter dependence of Green's functions in non-Abelian gauge theories, to laser pulse propagation in photonic crystal fibres. I am also interested in programming languages (Java, HTML, and so on), and in September 2004, I started to build up from scratch the new ECT* web site, which will provide electronic submission of project proposals and job applications. The site is expected to be up and running around February of 2005.

Gauge fixing parameter dependence of Green's functions

In non-Abelian gauge theories (off-shell) Green's functions (*e.g.,* the gluon propagator) will in general delvelop non trivial gauge fixing parameter dependence. These dependences render problematic the generalization of useful concepts such as effective charges or form factors, familiar from Abelian gauge theories.

The pinch technique (PT) is a diagrammatic technique, which systematically exploits the symmetries built into physical observables, such as S-matrix elements, in order to construct off-shell sub-amplitudes that are kinematically akin to conventional Green's functions, but, unlike the latter, are also endowed with the desirable properties (being gauge fixing parameter independence one of these). In its original one- and two-loop application, the PT boiled down to the study of the kinematic rearrangements produced into *individual* Feynman diagrams when elementary tree-level Ward identities are triggered.

During my Ph.D. I have shown that the PT can be successfully generalized to all orders in the QCD case, by abandoning the algebraic operations inside individual Feynman graphs approach, for resorting to a more formal procedure, which allowed the collective treatment of entire sets of diagrams through the judicious use of the Slavnov-Taylor identity satisfied by a special Green's function, which serves as a common kernel to all higher order self-energy and vertex diagrams.

Early the past year I have applied the method above to the highly non trivial case of the electroweak sector of the standard model, where, with respect to the QCD case, one has to face two main difficulties: the proliferation of Feynman diagrams due to the richer particle spectrum of such theories, and the complications arising from the presence of Goldtone's bosons, which implies that the BRST symmetry (and therefore the Slavnov Taylor identities) are realized through them. Nevertheless, I have been able to successfully generalize the PT also to this case.

The latter result pave the way to the resolution of yet another problem: the all orders definition of the neutrino charge radius. It is well-known that, even though within the Standard Model the photon does not interact with the neutrino at tree-level, an effective photon-neutrino vertex is generated through one-loop radiative corrections, giving rise to a non-zero neutrino charge radius. Traditionally (and, of course, rather heuristically) the latter has been interpreted as a measure of the "size" of the neutrino when probed electromagnetically, owing to its classical definition (in the static limit) as the second moment of the spatial neutrino charge density. However, the direct calculation of this quantity has been faced with serious complications, which, in turn, can be (once again) traced back to the fact that in non-Abelian gauge theories off-shell Green's functions depend in general explicitly on the gauge-fixing parameter.

Using the PT, we have then shown that it is possible to have an all order consistent definition of the neutrino charge radius.

Non linear propagation of light pulses in dielectric media

Nonlinear propagation of light pulses in dielectric media such as optical fibers has been traditionally modeled using the Nonlinear Schrödinger Equation (NLSE). However, it is well known that NLSE needs modifications to describe a number of higher-order nonlinear effects which become important at increasing powers and short pulses. Recently, the access to new optical systems in which nonlinearities can be considerably enhanced together with the experimental availability of ultrashort pulses, push the description based on the NLSE and its modified versions to a limit. A typical example of this new scenario is provided by the phenomenon of supercontinuum generation in photonic crystal fibers, which requires a specific modeling that goes beyond approaches based on conventional versions of the NLSE. These new approaches are expressed in new evolution equations that differ from the NLSE in the amount of approximations needed to achieve them [generalized NLSE, nonlinear envelope equation (NEE), forward Maxwell equation (FME), unidirectional pulse propagation equation (UPPE)]. Briefly, the aim of these equations is to describe pulse propagation in the regime where the frequency width of the pulse is comparable to the carrier frequency, which, in turn, translates into the fact that usual approaches, such as the slowly varying approximation, no longer hold. The specific form of these equations is, on the one hand the result of applying some other different approximations *e.g.*, assuming propagation in a homogeneous medium (NEE and UPPE), or single-mode propagation in fibers (generalized NLSE and FME). On the other hand, two common features of all of them are the neglecting of the backward components of the electromagnetic field and their first-order character.

In a recent paper we have explicitly unveil the role of backward components in the case of an axially-invariant inhomogeneous nonlinear medium, by explicitly finding the coupled first-order equations that drive the forward and backward components of the electromagnetic field in an axially-invariant nonlinear system. These first order forward-backward equations (FBEs) are equivalent to the original second-order equations for the electric components of the electromagnetic field. The FBEs provide a common framework that can encompass different nonlinear phenomena: In fact, since these equations explicitly manifest the couplings between spatial and time-frequency degrees of freedom typical of spatial-temporal phenomena, they can be easily particularized to describe either purely temporal or purely spatial effects within the same framework, revealing the total generality of this formalism.

• Jean-Paul Blaizot

My research focuses on quantum field theory at finite temperature, quantum chromodynamics at high density, the non perturbative renormalization group, Bose-Einstein condensation, the phenomenology of ultra-relativistic heavy ion collisions.

Together with Andreas Ipp at ECT* and colleagues in Vienna, I am working on approximation schemes which allow a semi-analytic calculation of the entropy of the quark-gluon plasma. The results one gets are in good agreement with those obtained from lattice gauge calculations for temperatures 2 to 3 times above the deconfinement temperature.

Together with R. Mendez Galain and N. Wschebor who visited ECT* in December, I continue the development of a new method to solve the non perturbative renormalization group. This method has been applied to the calculation of the shift of the temperature of Bose-Einstein Condensation due to small repulsive interactions.

• Tommaso Calarco

High-fidelity quantum register initialization with fermions

In [1], we showed that fermionic atoms have crucial advantages over bosonic atoms in terms of loading in optical lattices for use as a possible quantum computation de-vice. After analyzing the change in the level structure of a non-uniform confining potential as a periodic potential is superimposed to it, we showed how this structure combined with the Pauli principle and fermion degenera-cy can be exploited to create unit occupancy of the lattice sites with very high efficiency (Fig. 1).

Figure 1: Fermions in an optical lattice: level structure (top) and density profile (bottom) for two different lattice dephts [1].

Marker qubits and molecular interactions for quantum computing with atoms in optical lattices

In [2], we developed a scheme for quantum computation with neutral atoms, based on the concept of "marker" atoms, i.e., auxiliary atoms that can be efficiently transported in state-independent periodic external traps to operate quantum gates between physically distant qubits. This allows for relaxing a number of experimental constraints for quantum computation with neutral atoms in microscopic potential, including single-atom laser addressability. We discussed the advantages of this approach in a concrete physical scenario, namely in two-component optical lattices, whereby atom transport is achieved via adiabatic transfer between motional states in neighboring lattice wells (Fig. 2), and the mechanism used to mark atoms is the molecular interaction responsible for Feshbach resonances, which are currently a subject of intense experimental research in the field of cold atoms. In other words, our proposal relies on techniques that are presently being developed, and represents therefore a feasible candidate for the implementation of quantum information processing with neutral atoms in optical lattices.

Figure 2: Adiabatic transfer between neighboring wells in a lattice potential for gate operation [2].

Two-atom collisions in tightly confined anisotropic geometries

In [3], we solve the problem of two atoms interacting through regularized delta potential and confined in a harmonic trap. We derive exact analytical results for the energy spectra, in the case when the ratio of axial to radial trap frequency is an integer (cigar-shape traps), or the inverse of an integer (pancake-shape traps). We demonstrate that in very elongated traps the lowest excited states of the system can be calculated from the one-dimensional theory with renormalized scattering length. On the other hand, the properties of the ground-state in elongated traps depend solely on the frequency of the tight confinement, and must be calculated from the full three-dimensional theory. The same is true in the opposite regime, when the ratio of axial to radial frequency is very small. We derive analytical expressions for the wave functions of the system, valid for arbitrary ratio of axial to radial trap frequency. Finally, we analyze the energy spectrum of two interacting atoms in the vicinity of a Feshbach resonance, utilizing a model with an energy-dependent scattering length.

[1] L. Viverit, C. Menotti, T. Calarco, A. Smerzi, "Efficient and robust initialization of a qubit register with fermionic atoms", cond-mat/0403178 (accepted on Phys. Rev. Lett.)

[2] T. Calarco, U. Dorner, P. Julienne, C. Williams, P. Zoller, "Quantum computations with atoms in optical lattices: marker qubits and molecular interactions", quant-ph/0403197 (in

print on Phys. Rev. A).

[3] Z. Idziaszek, T. Calarco, "Exact analytic solution for two atoms colliding in a tight anisotropic trap" (to be submitted).

• Markus Antonio Cirone

My scientific activity at ECT* has started on October 1st this year within the IST project ACQP and 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. At present the activity focuses on the elaboration of a new scheme for implementing logic quantum gates that uses both the internal and the external degrees of freedom.

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. The same mechanism that preserves coherence, however, also make a two-qubit operation on 0 and 1 very hard to realize. The new scheme we are elaborating uses 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. We are studying the conditions to realize this scheme in atom chips or in other environments, like e.g. optical microtraps, that might result better suited for this purpose.

We also study the actual realization in atom chips of schemes that are already present in the literature. The implementation of theoretical schemes on real devices usually requires refinements and improvements of both the devices and the schemes that may lead to new significant progress in the field of quantum information.

I have also completed a work on entanglement measures and their connection with correlations and Bell inequalities that I started before coming to ECT*.

• Marco Cristoforetti

Instantons and nonleptonic weak decays

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

We have studied nonleptonic hyperon weak decays with strangeness variation equal to one. These processes are characterized by the so called $\Delta I = 1/2$ rule. What we tried was to find some explanation of this rule with the explicit introduction of instantons in the amplitudes calculation. Using ILM we have obtained good agreement with experimental data.

Lattice QCD and diquark content of the nucleon

in collaboration with P. Faccioli (ECT), G. Ripka (ECT*, CEA Saclay) and M. Traini (Univ. Trento, ECT*)*

We have defined and analyzed some lattice-calculable matrix elements, which encode information about the non-perturbative forces, in different color anti-triplet diquark channels. We have suggested a lattice calculation to check the quark-diquark picture and clarify the role of instanton-mediated interactions. We have also studied in detail the physical properties of the 0^+ diquark, using the Instanton Liquid Model. We have found that instanton forces are sufficiently strong to form a diquark bound-state, with a mass of $\sim$ 450 MeV, in agreement with earlier estimates and a charge radius of $\sim$ 0.7 fm.

Instantons and chiral extrapolation

in collaboration with P. Faccioli (ECT) and J. W. Negele (MIT)*

We have progressed in our study of the behaviour of hadronic observables as a function of the quark masses. The idea is to use the ILM to generate the gauge configurations in boxes which are larger than those of currenlty feasible lattice simulations. We have been studied in details volume artifacts and other related sources of systematic errors.

• Sara Della Monaca

My research activity during last year has been focusing mainly on the detection of a Δ isobar current operator in coordinate space.
This operator has to be inserted into electron scattering reactions analysis concerning three body nuclei, by using a realistic potential as NN interaction.
The idea is that of computing, by means of the Lorentz Integral Transform (LIT) method, a transverse response function which has to be inserted into the electron scattering cross section.

• Pietro Faccioli

Strong CP breaking and the topological structure of the QCD vacuum

in collaboration with D. Guadagnoli (Univ. Rome "La Sapienza") and S. Simula (Univ. "Roma3")

In the context of a calculation of the CP-breaking neutron electric moment in lattice QCD, we have studied some quenching artifacts which can be generated by the topological structure of the QCD vacuum. This work triggered the interest in investigating how QCD works, at finite θ angle. Our main result in this context is the discovery that, in the presence of strong CP breaking, quantum tunneling phenomena in the QCD vacuum generate an effective repulsion between matter and antimatter, leading to a local separation of positive and negative baryon number density.

Lattice QCD and diquark content of the nucleon

in collaboration with M. Cristoforetti (ECT), G. Ripka (ECT*, CEA Saclay) and M. Traini (Univ. Trento, ECT*)*

We have defined and analyzed some lattice-calculable matrix elements, which encode information about the non-perturbative forces, in different color anti-triplet diquark channels. We have suggested a lattice calculation to check the quark-diquark picture and clarify the role of instanton-mediated interactions. We have also studied in detail the physical properties of the 0^+ diquark, using the Instanton Liquid Model. We have found that instanton forces are sufficiently strong to form a diquark bound-state, with a mass of $\sim$ 450 MeV, in agreement with earlier estimates and a charge radius of $\sim$ 0.7 fm.

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We have progressed in our study of the behaviour of hadronic observables as a function of the quark masses. The idea is to use the ILM to generate the gauge configurations in boxes which are larger than those of currenlty feasible lattice simulations. We have been studied in details volume artifacts and other related sources of systematic errors.

• Paolo Finelli

During the last year my reserch activity has been focused on different subjects:

1. Application of DFT (Density Functional Theory) methods to low-energy nuclear physics, in particular to finite nuclei structure. Within this framework I proposed a relativistic density-dependent point coupling model in which the functional form of the interaction is constrained by QCD and chiral symmetry. This approach is completely new and it represents a first step towards estabilishing connections between the structure of finite nuclei and underlying principles of low-energy QCD. It has been successfully tested in the analysis of symmetric and asymmetric nuclear matter and in bulk properties of finite nuclei. Predictions agree with experimental data at a quantitative level comparable with the best phenomenological mean field models. Many different numerical codes have been produced, to perform calculations along drip-line nuclei (Relativistic Hartree-Bogoliubov scheme) and for deformed systems. Work along this line is still in progress.

2. I have started to study collective excitations of the model previously described. In particular I began writing a numerical code for RPA calculations.

3. Study of parity violating electron scattering at low-energies, and its relation with neutron density distributions.

• Luca Girlanda

Relativistic quantum mechanics for the few-body nuclear problem

During 2004 I have started a collaboration with Michele Viviani (INFN of Pisa), to obtain a relativistic description of few-nucleon systems valid at low energy. In the last decade a proposal made by Weinberg has allowed to obtain the nuclear forces starting from the underlying QCD dynamics, or better from its effective realization at low energy, Chiral Perturbation Theory (ChPT). Among the achievements of this approach are the explanation of the hierarchy of these forces (2-body forces are larger than 3-body forces, and so on) and the possibility to control the theoretical error of calculations and systematically improve on it. Nevertheless this framework uses the old-fashioned (non relativistic) perturbation theory. In our approach we construct a Bakamjian-Thomas mass operator starting from an interacting Lagrangian, which we take to be the ChPT Lagrangian, which satisfies the good Poincare commutation relations. This mass operator is restricted to act on a truncated Fock space containing only a fixed number of particles (nucleons and pions). This truncation can be justified because the creation of more pions is suppressed at low energy. We succeed in establishing a chiral power counting similar to the one which applies in ChPT, and perform a complete leading order calculation in the two-nucleon sector. The resulting NN scattering and bound state observables are in reasonable agreement with the experiments below 100 MeV and show a satisfactory improvement with respect to the non-relativistic limit. Our work is in its final stage and we expect to publish our results soon.

Effect of $\bar{q}q$ vacuum fluctuations on scalar form factors of pions and kaons

I am continuing a long-lasting collaboration with the Orsay group (Jan Stern, Sebastien Descotes-Genon and Juan Jose Sanz-Cillero) to investigate the effect of fluctuations of virtual (strange) quark-antiquark pairs on SU(3)×SU(3) chiral symmetry breaking. Our proposal to reformulate the ChPT expansion in order to account for the possibility that these fluctuations be large is already published for the case of $\pi\pi$ scattering observables. We are extending this framework to the analysis of the scalar form factors of Goldstone bosons, expected to be more sensitive to chiral fluctuations. This analysis requires the solution of the so called Mushkelishvili-Omnès problem, which allows to determine the scalar radii from the experimental phaseshifts in the $\pi\pi$ and πK system. The work is still in progress.

• Andreas Hiroichi Ipp

I started working at ECT* in September 2004, directly continuing research based on an earlier collaboration with J.-P. Blaizot. My work is concentrated on thermodynamics of very hot or dense QCD in the deconfined phase where it forms a so-called quark-gluon plasma. This new state of matter has been produced at the particle colliders SPS/CERN and RHIC and will be studied at the new LHC/CERN starting presumably 2007. In particular, I have calculated the numerical solution to pressure and entropy in the large-flavour-number limit, which serves as a theoretical test bed for real QCD. Together with A. Rebhan and U. Reinosa from TU Vienna, we hope for new insights into the entropy formula as formulated in the 2PI framework in the large-flavour-number limit. We started to systematically analyze the bosonic and fermionic dispersion relation functions which turn out to be numerically demanding. It is work in progress to rewrite existing Mathematica routines to C++ to make full use of the calculation capabilities of ECT*.

• Daisuke Jido

In 2004, I have been working at ECT* (Trento) from 1.1.2004 to 30.6.2004, and I have moved to Technische Universität Muünchen (Munich) on 1.7.2004. During this year, my research is concentrated on the following topics.

Spectral functions of the nucleon electromagnetic form factors
in collaboration with W. Weise (TU München and ECT)*

In this project, we investigate the nucleon electromagnetic form factors in a dispersion relation approach, in which we evaluate the imaginary parts of the form factors in the time-like region first, and transform them to the form factors using dispersion relation techniques. We have considered contributions from K^+K^- and decuplet baryons together with an empirical spectral function up to 1 GeV^2, which is obtained by a sophisticated analysis of the pion nucleon scattering amplitude. We have found that the K^+K^- contribution is very small due to a cancellation between the Λ and Σ baryons, and that it does not improve discrepancy seen above $Q \simeq 0.7$ GeV in the form factors calculated by only the empirical spectral functions. We develop also a method to obtain the spectral functions directly from data of the form factors as a deconvolution problem of integral equation. This work is still in progress.

Formation of mesic nuclei by (γ, p) reactions
in collaboration with H. Nagahiro and S. Hirenzaki (Nara Women's Univ.)

In this project, we have made a theoretical evaluation of the formation rates of the η and ω meson in nuclei induced by the (γ, p) reaction at an ideal recoilless kinematics. We have found that the (γ, p) reactions are good practical tool to investigate the properties of the mesons created deeply inside the nucleus due to the small distortion effects. This good advantage provides the distinct difference in the formation spectra of the η-nucleus system obtained by the two chiral models which are based on the different physical pictures of the $N(1535)$ resonance. For the ω-nucleus system, we have compared three types of the ω optical potentials in the (γ, p) spectra, showing the definitely different shapes of the spectra. We have also investigate the (γ, p) spectra at the recoilless condition for the two pion production in order to study an impact of the creation of the deeply bound states of the sigma meson associated with the partial restoration of chiral symmetry in heavy nuclei. We have found that a prominent enhancement around the two pion threshold in the missing mass spectra in case of a sufficient strength of the partial restoration in medium.

- **Olivier Leitner**

Form factors $B \to \pi$ and $B \to K$

in collaboration with X. H. Guo (Beijing Normal University, Beijing) and A. W. Thomas (Jefferson Lab, Newport News)

The $B \to \pi$ and $B \to K$ transition form factors involved in hadronic B decays have been extensively investigated in a phenomenological way through the framework of QCD factorization. By comparing our results with experimental branching ratios from the BELLE, BABAR and CLEO collaborations for all the B decays including either a pion or a kaon, we have proposed boundaries for the transition form factors $B \to \pi$ and $B \to K$ depending on the Cabibbo-Kobayashi-Maskawa (CKM) matrix element parameters ρ and η. From this analysis, the form factors required to reproduce the experimental data for branching ratios are $F^{B\to\pi} = 0.31 \pm 0.12$ and $F^{B\to K} = 0.37 \pm 0.13$. We have also calculated the direct CP violating asymmetry parameter, a_{CP}, for $B \to \pi\pi\pi$ and $B \to \pi\pi K$ decays, in the case where rho-omega mixing effects are taken into account. Based on these results, we have found that the direct CP asymmetry reaches its maximum when the invariant mass $\pi\pi$ is in the vicinity of the omega meson mass. The inclusion of rho-omega mixing provides an opportunity to erase, without any ambiguity, the phase uncertainty mod(pi) in the determination of the CKM angles α in case of $b \to u$ and γ in case of $b \to s$.

Wave functions for pseudo-scalar and vector mesons

in collaboration with J. F. Mathiot (LPC, Clermont-Ferrand)

In the framework of the explicitly covariant formulation of light front dynamics, we made a phenomenological determination of various meson wave functions. We focused on the pseudo-scalar particles B, D, π and K, as well as on the vector mesons ρ and ω. All these relativistic wave functions are defined on an arbitrary light front plane in four dimensional space. Their relativistic structure is fully determined. The parameters are well constrained by several experimental data sets: decay constant, transition form factor, electromagnetic form factor and charge radius.

Baryon decays into two vectors

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

A complete study of the angular distributions of the process $\Lambda_b \to \Lambda V$ with $V \to P\pi$ and $V \to l^+l^-$ or $\pi^+\pi^-$, K^+K^- has been performed. Emphasis was put on the initial Λ_b polarization in the proton proton collisions. The polarization density matrices of the vector mesons V are derived to construct T odd observables which allow us to perform Time reversal and CP violation tests violation.

QCD factorization applied to baryon decays

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

This project has started in 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 2004 I was in Potsdam (Germany) in connection with my joint PhD between the University of Trento (Italy) and the University of Potsdam (Germany). During the course of 2004 the research activity was focussed on the following subjects:

Quantum computation with neutral atoms

With the collaboration of my Italian supervisor Dr. Tommaso Calarco, Dr. Markus Cirone and Dr. Alessio Recati, we have finished an investigation on the performance of a phase gate operating with two neutral atoms in anharmonic potentials. We have found a threshold of anharmonicity of 0.001, beyond that the gate fidelity decreases below the limits necessary considering quantum error correction codes. We have also begun the study of the same problem in a situation where the potential depends on the time exploiting optimal control techniques, in order to have the most suitable potential. In the same spirit we have also begun to consider different geometry of wires on a surface (the so called "atom chip"), whose configurations create a trapping potential for the neutral atoms. Finally with such realistic potential we are trying to consider other possible schemes for quantum gates.

Atom interferometry with Bose-Einstein condensate

With the collaboration of my German supervisor Dr. Carsten Henkel we have improved our understanding of integrated atom interferometry with Bose degenerate gases. Recent experiments on atom interferometers with Bose-Einstein condensates have led to the impression that atom-atom interactions may seriously perturb their stable operation. This is related to density-dependent phase shifts and to relative phase diffusion while the interferometer arms are split. On the contrary we have been able to show that, interactions can improve the sensitivity of an interferometer to an external phase, under specific conditions. This enhancement is related to the interactions amplifying a phase difference between the interferometer arms by a mechanism akin to the Josephson effect. It happens during the recombination stage and is related to an instability in the split condensate excitation spectrum. As a consequence, there exists an operation mode around a controlled π phase shift where small deviations lead to a large change in the output ports. We could show that two ways exist to detect the output signal: either observe the condensate "dipole mode" whose amplitude depends on the phase deviation from π, or determine the oscillation amplitude of a moving "dark soliton" that is formed in the recombined condensate.

• Uffe Vestergaard Poulsen

In 2004 we continued the investigations regarding quantum computation in atomic systems. The main effort was directed towards analysis of sources of errors in the socalled pushing-gate. This gate proposal utilizes internal states in ions in individual traps as qubits. The single-bit gates are implemented via lasers coupling these internal levels while two-bit gates relying on the Coulomb interaction between the ions and state-dependent pushing. Imperfections in the pushing forces leads to non-optimal performance of the gate, especially if the motional state of the ions is not strongly cooled. We have worked on identifying the most important sources of errors in different regimes. Our most important result is the realization that non-linear push-potentials couple the center-of-mass and relative motions and that this is potentially very damaging for the gate performance. We are now trying to apply optimal control theory to minimize these errors.

• Massimiliano Procura

I worked for my Ph.D. thesis with Prof. Wolfram Weise (Technische Universität München and ECT*) and Dr. Thomas R. Hemmert (Technische Universität München) on chiral extrapolation of nucleon properties from lattice QCD.

Lattice QCD on one side and chiral effective field theory on the other are progressively developing as important tools to deal with the nonperturbative nature of low-energy QCD and the structure of hadrons. At present, however, there is a gap between the relatively large quark masses accessible in fully dynamical lattice QCD simulations and the small quark masses relevant for comparison with physical observables. In our work we study a way to merge Baryon Chiral Perturbation Theory which predicts the quark mass dependence of a nucleon observable and lattice simulations where the quark mass is a tunable parameter.

We analyze the quark mass dependence of the nucleon mass M_N[**?**] and the nucleon axial-vector coupling constant g_A[**?**], comparing two different formulations of $SU(2)$ Baryon Chiral Effective Field Theory, with and without explicit $\Delta(1232)$ degrees of freedom. We perform an interpolation of these nucleon properties between their physical values and sets of fully dynamical two-flavor lattice QCD data. We obtain good interpolation functions already at the one-loop level. The inclusion of $\Delta(1232)$ as an explicit degree of freedom turns out to be not essential for the nucleon mass, but crucial for g_A. Our study represents a first step towards a systematic approach for chiral extrapolation of lattice results for nucleon observables.

• Alessio Recati

I started my collaboration with the ECT* last October. My research interest is two-fold, on one side many-body physics of cold trapped atoms and other mesoscopic systems and on the other side implementation of quantum information processing. They were developed during my PhD at the Institut für Theoretische Physik in Innsbruck.

In the last months in collaboration with Jean-Noel Fuchs, who is now at the Laboratoire de Physique des Solides in Orsay (Paris) and Wilhelm Zwerger from the Technische Universität in Garching (Munich), we have studied two models for a BCS-BEC-like crossover in quasi one-dimensional trapped fermionic atoms. In the first one (single channel model) we explored the role of the confinement induced resonance, while the second one is based on the boson-fermion resonance model. We have found that aside from a small region of parameters the two model can be mapped into an exactly solvable that we called "modified Yang-Gaudin model", so that all the quantities can be in principle calculated. The main feature is that the system, depending on the interaction strength, evolves from a BCS-like state to a Tonks-gas of dimers to a BEC-like state. Moreover both the models can be physically realized within current technology. It is interesting to mention that the requirement for our two models to be equivalent is the same as the one for the three dimensional single channel model and the three dimensional resonance model to be equivalent.

We are considering the mediated interaction of two impurities in a fermionic or bosonic one-dimensional bath. It turns out the in certain regimes the physics is the same as in the Casimir effect. Such a system can be implemented using ultra-cold gases. The problem is also relevant for a general understanding of the physics of a quantum wire/Luttinger liquid (e.g., finite-size blockade and resonances in the trasmission) and could provide a new way to realize entanglement and more generally quantum gates using neutral atoms.

With the group of Tommaso Calarco (ECT* and CRS BEC-INFM Povo) we are working out the feasibility of the so-called quantum gates in the context of atom chips. Moreover in collaboration with the memebers of the CRS BEC-INFM at the faculty of physics, we are workig on possible realizations of quantum gates using neutral atoms in optical lattice or tight confinement potentials.

• Marco Traini

Generalized parton distributions

in collaboration with B. Pasquini (ECT and Univ. Pavia) and S. Boffi (Univ. Pavia)*

The core of the present research program is the investigation of those interesting energy and momentum transfer regions where transition between the degrees of freedom of low-energy nuclear physics (baryons and mesons) and the description in terms of quarks and gluons takes place and perturbative nonperturbative QCD descriptions are interrelated. In particular:

i) Deep inelastic scattering of leptons off nucleons: the classical perturbative region of QCD where a large amount of data have been accumulated, becomes an interesting area for testing nonperturbative models when a radiative quark-parton approach is formulated for both polarized and unpolarized nucleon structure functions. Non perturbative effects such as the meson cloud and the internal structure of the constituent quarks, can be included and a consistent light-front picture formulated.

The next generation of polarized observables (transversity distributions, gluon polarization, angular momentum contribution to the nucleon spin etc.) can be studied in details within our covariant quark models. A specific attention is devoted to the new class of universal distributions, the Generalized Parton Distributions (GPDs), in both polarized and unpolarized sectors, including nonperturbative effects like the meson cloud and higher order Fock components. In addition QCD evolution of GPDs are studied and a new approach formulated. The new scheme includes all the genuine Next-to-leading order effects and extends the radiative parton model (formulated for tradional parton ditribution functions) to their generalization (GPDs).

Non-Perturbatibe aspects of QCD

in collaboration with M. Cristoforetti (ECT) and P. Faccioli (ECT*)*

We analyze some lattice-calculable matrix elements, which encode information about the non-perturbative forces, in different color anti-triplet diquark channels. We suggest a lattice calculation to check the quark-diquark picture and clarify the role of instanton-mediated interactions. We study in detail the physical properties of the 0^+ diquark, using the Random Instanton Liquid Model. We find that instanton forces are sufficiently strong to form a diquark bound-state, with a mass of about 450 MeV, in agreement with earlier estimates. We also compute its electric charge distribution and find that it is a broad object, with a size comparable with that of the proton.

We performe a study of the non-perturbative contributions in non-leptonic hyperon decays. We show that the instanton-induced 't Hooft interaction can naturally explain the $\Delta I = 1/2$ rule by generating quark-diquark clustering inside octet baryons. The P-wave and S-wave amplitudes in the Instanton Liquid Model (ILM), are in good agreement with experiment. We propose a model-independent procedure to test on the lattice if the leading quark-quark attraction in the 0^+ anti-triplet channel responsible for diquark structures in hadrons is originated by the interaction generated by quasi-classical fields or it is predominantly due to other perturbative and/or confining forces.

• 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.

- **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.

In particular, the following steps have been completed:

- Validation of the functional aspects of the Supercomputer
- Implementation of a front end node as a borderline between the Supercomputer and the World (with managing, accounting and security duties)
- Implementation of users' polices, such as the capability of accessing or using different resources of the Supercomputer
- Installation of a number of scientific applications (including the a possible customisation or optimization of the codes)
- Successful testing of the first production samples of the APE3D technology on a subsection of the Supercomputer
- Benchmarking of the system against the most recent supercomputers
- Production phase of the Supercomputer (end December)

Some other activities are at an advanced stage and will be completed in a short time, including:

- Installation of the APE3D technology on the Supercomputer
- Assistence to the initial users' base
- Further customisation of the software architecture according to the users' needs
- Dissemination of the results among the supercomputing community

3.3 Publications of ECT* Researchers

A. Ferrando, M. Zacares, P. Fernandez de Cordoba, D. Binosi, A. Montero
Forward-backward equations for nonlinear propagation in axially-invariant optical systems
Phys. Rev. A (in press) [arXiv:physics/0407029]

J. Bernabéu, J. Papavassiliou and D. Binosi
The neutrino charge radius in the presence of fermion masses
arXiv:hep-ph/0405288, (Nucl. Phys. B submitted)

D. Binosi
Electroweak pinch technique to all orders
J. Phys. G **30***, 1021 (2004) [arXiv:hep-ph/0401182]*

J.-P. Blaizot, R. Mendez Galain, N. Wschebor
Non perturbative renormalization group, momentum dependence of N-point functions and the transition temperature of the weakly interaction Bose gas.
SPHT-T04-105, ECT-04-26, (Dec 2004) 4pp [cond-mat/041281]*

E. Pazy, T. Calarco, P. Zoller
Spin State Readout by Quantum Jump Technique: For the Purpose of Quantum Computing
IEEE Transactions on Nanotechnology 3, 10 (2004)

L. Viverit, C. Menotti, T. Calarco, A. Smerzi
Efficient and robust initialization of a qubit register with fermionic atoms
Phys.l Rev. Lett. 93, 110401 (2004)

T. Calarco, U. Dorner, P. Julienne, C. Williams, P. Zoller
Quantum computations with atoms in optical lattices: Marker qubits and molecular interactions
Phys. Rev. A 70, 12306 (2004)

A. Negretti, T. Calarco, M. Cirone e A. Recati
Performance of quantum phase gates with cold trapped atoms
To be published in the European Physical Journal D

Z. Idziaszek, T Calarco
Two atoms in an anisotropic harmonic trap
preprint quant-ph/0410163 (2004)

M. Cristoforetti, P. Faccioli, M. Traini and E.V. Shuryak
Instantons, Diquarks, and nonleptonic weak decays of hyperons
hep-ph/0402180, Phys. Rev. **D70** *(2004) 054016* [*Preprint No.: ECT-04-13*]

M. Cristoforetti, **P. Faccioli**, G. Ripka and M. Traini
Are There Diquarks in the Nucleon?
hep-ph/0410304, Submitted to Phys. Rev. **D** [*Preprint No.: ECT-04-14*]

P. Faccioli, D. Guadagnoli and S. Simula
The Neutron Electric Dipole Moment in the Instanton Vacuum: Quenched Versus Unquenched Simulations
hep-ph/0406336, Rev. **D70** *(2004) 074017* [*[Preprint No.: ECT-04-12]*]

P. Faccioli
Strong CP Breaking and Quark-Antiquark Repulsion in QCD, at Finite θ
Phys. Rev. Lett. hep-ph/0404137 [*[Preprint No.: ECT-04-05]*]

M. Cristoforetti, **P. Faccioli**, G. Ripka and M. Traini
Are There Diquarks in the Nucleon?
Phys. Rev. **D** *hep-ph/0410304* [*[Preprint No.: ECT-04-14]*]

P. Faccioli
Instanton Contribution to the Electro-magnetic Structure of Hadrons
To be published in the proceeding of the "X Convengno su Problemi di Fisica Nucleare Teorica", Cortona, October 6-9 2004

P. Faccioli
Non-Perturbative Short-Range Correlations and the Electro-Magnetic Structure of Hadrons at Large Q^2
To be published in the proceeding of the "26th International School in Nuclear Physics", Erice, September 15-24 2004

P. Faccioli
Non-perturbative Correlations in Hadrons
To be published in the proceedings of the "VIII Workshop on Non-Perturbative Quantum Chromodynamics", Institut Astrophysique de Paris, Paris, June 7-11, 2004 [*[hep-ph/0411088, Preprint No.: ECT-04-17]*]

P. Finelli, N. Kaiser, D. Vretenar and W. Weise
Relativistic nuclear point-coupling model constrained by QCD and chiral symmetry
*Nucl. Phys. A***735***, 449-481 (2004)*

P. Finelli, N. Kaiser, D. Vretenar and W. Weise
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Proceedings of the conference "IX Convegno su Problemi di Fisica Nucleare Teorica", Cortona, Arezzo, (Italy), 6-9 October 2004. Edited by S. Boffi, A. Covello, M. Di Toro, A. Fab-

rocini, G. Pisent and S. Rosati. In press, World Scientific 2005 [[arXiv:nucl-th/0411122]]

L. Girlanda, A. Rusetsky and W. Weise
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Nucl.Phys. B649 (2004) 243-262

3.4 Presentations at International Conferences and Symposia

- **François Arleo**

Quenching of hadron spectra in DIS on nuclear targets
Tenth International Conference BARYONS04
25-29 October 2004, Palaiseau, France

- **Jean-Paul Blaizot**

From SPS to RHIC: Pursuing new states of matter
APS meeting, Division of Nuclear Physics 2004
26-29 October, Chicago, USA

Dilepton and photon production: perturbative vs. lattice QCD
Hard Probes 2004
4-10 November 2004, Lisbon, Portugal

- **Tommaso Calarco**

The basics of optical spin quantum computing
317 Heraeus Seminar Spintronics
11-14 January 2004, Bad Honnef, Germany

All-optical spin quantum computing
Symposium Cryptography and Quantum Information
14-17 January 2004, Karpacz

Quantum computation with molecular interactions between neutral atoms
International Conference Quantum information with atoms, ions and photons
6-12 March 2004, La Thuile, Italy

2nd Workshop Semiconductor Quantum Optics
14-17 April 2004, Rügen, Germany

2nd Workshop Quantum Information with atoms and photons
26-27 April 2004, Torino, Italy

Exploiting quantum control for quantum computation in optical lattices: marker atoms and molecular interactions
Quantum Information and Quantum Control Conference
19-23 July 2004, Toronto, Canada

Quantum computations with atoms in optical lattices: marker atoms and molecular interactions
Fifth European QIPC Workshop
20-22 September 2004, Roma, Italy

Quantum information processing with quantum optical systems
XC Congresso Nazionale Societ Italiana di Fisica
22-24 September 2004, Brescia, Italy

Quantum control of atomic systems for quantum information processing
2nd Workshop Fault tolerance, control and stability in QIP
11-12 November 2004, Torino, Italy

- **Pietro Faccioli**

Are there Diquarks in the Nucleon?
Seminar given at the Center for Theoretical Physics of the Massachussets Institute of Technology, Cambridge
December 2003, Cambridge, USA

Theory and Applications of Instantons in QCD
Set of lectures given at the Departement for Theoretical Physics of the Turin University
May 2004, Torino, Italy

Non-Perturbative Correlations in Hadrons
8th Workshop on Non-Perturbative Quantum Chromodynamics
June 2004, Paris, France

Instantons, Diquarks and Large N_c
contribution to the workshop on "Large N_c QCD 2004"
July 2004, Trento, Italy

Non-Perturbative Structures in Hadrons
26th International School in Nuclear Physics
September 2004, Erice

Non-perturbative Correlations and Hadronic Form Factors
Seminar given at the Physics Department of the Stockholm University
October 2004, Stockholm, Sweden

Instanton Contribution to the Electro-Magnetic Structure of Hadrons
X Conference on Theoretical Problems in Nuclear Physics
6-9 October 2004, Cortona, Italy

Non-Perturbative Correlations in Hadrons
Seminar given at the State University of New York at Stony Brook
November 2004, Stony Brook, USA

Strong CP Breaking and Matter-Antimatter Repulsion in QCD
Seminar given at the Brookhaven National Laboratories
November 2004, Long Island, Upton, USA

- **Paolo Finelli**

DPG Nuclear Physics Spring meeting
8-12 March 2004, Cologne, Germany

Lectures (6 hours) about relativistic mean field theories
May 2004, Bologna, Italy

Seminar zur Physik der starken Wechselwirkung
10 May 2004, München, Germany

Nuclear Structure Constained by QCD and Chiral Symmetry
Workshop on Relativistic Density Functional Theory for Nuclear Structure
20-24 September 2004, Seattle, USA

A microscopic relativistic point-coupling model of nuclear many-body dynamics constrained by in-medium QCD sum rules and chiral symmetry
X Convegno su Problemi di Fisica Nucleare Teorica
6-9 October 2004, Cortona, Italy

- **Luca Girlanda**

  Introduction to Nuclear Chiral Perturbation Theory
  Seminar given at University of Pisa
  2 April 2004, Pisa, Italy

  Introduction to Nuclear Chiral Perturbation Theory
  Seminar given at University of Padova
  29 June 2004, Padova, Italy

  The π-nucleus optical potential to $O(p^5)$ in Chiral Perturbation Theory
  Tenth International Conference BARYONS04
  25-29 October 2004, Palaiseau, France

  Chiral perturbation theory for heavy nuclei
  Effective Field Theories in Nuclear, Particle and Atomic Physics
  13-17 December 2004, Bad Honnef, Germany

- **Daisuke Jido**

  Chiral dynamics of the two Lambda(1405) states
  10th International Conference on the Structure of Baryons, Baryons04
  25-29 October 2004, Ecole Polytechnique, Palaiseau, France

  Chiral dynamics of the two Lambda(1405) states
  Workshop on the Physics of Excited Nucleons, NSTAR2004
  24-27 March 2004, LPSC, Grenoble, France

  Chiral dynamics of the two Lambda(1405) states
  KEK Workshop on Nuclear Chiral Dynamics
  18-20 March 2004, KEK, Tsukuba, Japan

- **Olivier Leitner**

  Direct CP violation in B decays
  Seminar given at the Laboratoire de Physique Thorique d'Orsay, Universit Paris-Sud
  February 2004, Orsay (Paris), France

  Direct CP violation in B decays
  Seminar given at Subatech
  February 2004, Nantes, France

$Lambda_b$ baryon decays and CP violation
Tenth International Conference BARYONS04
25-29 October 2004, Palaiseau, France

- **Antonio Negretti**

  Phase gate with neutral atoms: an optimal control approach
  School on Quantum Logic & Communication
  16-27 August 2003, Cargese (Corsica), Italy and France

  Dynamics of a quasi one-dimensional BEC interferometer
  13th International Workshop in Laser Physics
  12-16 July 2004, Trieste, Italy

  How nonlinearity makes condensate interferometers work
  Advanced School on Field Atom Surface Interactions
  03-06 May 2004, Les Houches, France

  How nonlinearity makes condensate interferometers work
  DPG Tagung (Deutsche Physikalische Gesellschaft)
  22-26 March 2004, München, Germany

  How nonlinearity makes condensate interferometers work
  Interactions in ultracold atomic and molecular gases
  16-18 March 2004, Potsdam, Germany

- **Massimiliano Procura**

  Nucleon mass, sigma term and lattice QCD
  DPG Tagungen
  08-12 March 2004, Köln, Germany

  Chiral extrapolation of nucleon mass and axial-vector coupling constant
  Matching light quarks to hadrons
  25 July - 13 August 2004, Benasque, Spain

  Chiral extrapolation of nucleon mass and axial-vector coupling constant g_A
  Tenth International Conference BARYONS04
  25-29 October 2004, Paris, France

- **Marco Traini**

  Exclusive reactions and generalized parton distributions
  HiX2004 Workshop - Structure of the Nucleon at Large Bjorken x
  26-28 July 2004, Marseille, France

- **Pierfrancesco Zuccato**

  Multiscale computing: mapping computer resources on your problems
  Theoretical Methods in Quantitative Biology
  23-25 September 2004, Milano, Italy

3.5 Lectures and Seminars at ECT*

3.5.1 Lectures

- Neutrinos in particle physics
  (June 1 - 5)
  Lecturer: Samoil Bilenky (JINR, Dubna, Russia and SISSA, Trieste, Italy)
- Neutrino mixings and oscillations
  (June 8-11)
  Lecturer: Gianluigi Fogli (Bari University, Italy)
- Neutrino-nucleus interaction
  (June 28 - July 2)
  Lecturer: Thomas William Donnelly (MIT, Boston, USA)
- Neutrino-related processes in nuclei
  (July 19-23)
  Lecturer: Petr Vogel (Kellogg Radiation Laboratory, Pasadena, USA)
- Neutrino Cosmology
  (July 26-30)
  Lecturer: Steen Hannestad (University of South Denmark, Denmark
- Physics at neutrino telscopes I
  (September 1-3)
  Lecturer: Nicolao Fornengo (Torino University, Italy)
- Physics at neutrino telscopes II
  (September 6-7)
  Lecturer: Guenter Sigl (GReCO/IAP and APC, Paris, France)
- Supernova physics and neutrino
  (September 28-October 1)
  Lecturer: Hans Thomas Janka (Max Planck Institute, Garching, Germany)

3.5.2 Seminars

22.01
New building blocks of the perturbative expansion
D. Binosi (*ECT**)

29.01
Thermodynamics of two-colour and the Nambu Jona-Lasinio model
C. Ratti (*TU Munich and ECT**)

05.02
Instantons, diquarks and the Delta I =1/2 rule for non-leptonic hyperon decays
P. Faccioli (*ECT**)

12.02
Diamagnetism of the nucleon
B. Pasquini (*Pavia*)

26.02
Nucleon mass, sigma term and lattice QCD
M. Procura (*TU Munich and ECT**)

01.03
Intoductory QCD
W. Weise (*ECT**)

18.03
Are fundamental constants time-dependent?
H. Fritzsch (*University of Munich*)

23.03
The Nucleon in a Box
T. R. Hemmert (*TU Munich*)

24.03
Nuclear many-body dynamics (a QCD constrained model)
P. Finelli (*ECT**)

25.03
In-medium properties of hadrons recent experimental results
V. Metag (*University of Giessen*)

01.04
Probing matter with antimatter - New perspectives for hadron physics with antiprotons at the future International Accelerator Facility at GSI
V. Metag (*University of Giessen*)

29.04
Introduction to Nuclear Chiral Perturbation Theory
L. Girlanda (*ECT**)

05.05
Quantum information processing: understanding and using entanglement
T. Calarco (*ECT**)

06.05
Are there sterile neutrinos or is CPT violated?
G. Garvey (*Los Alamos NL*)

27.05
Point form mass operator from vertex interactions: an effective theory point of view
L. Girlanda (*ECT**)

10.06
Quantum information theory
U. Poulsen (*ECT* and University of Trento*)

16.06
Low-energy universal properties of three-body systems in two dimensions
A. V. Malykh (*Dubna, Russia*)

23.06
Superalgebras and applications
F. Iachello (*Yale University*)

29.06
Tutorials on gravitation
A. Giacomini (*University of Trento*)

29.06
Nuclear physics and Paintings Invited talk at INPC2004 (Gotheborg)
R. Leonardi (*ECT* and University of Trento*)

30.06
Two photon exchange in elastic electron-nucleon scattering
B. Pasquini (*Pavia*)

06.07
Tutorials on gravitation
A. Giacomini (*University of Trento*)

07.07
Superalgebras and Applications
F. Iachello (*Yale University*)

08.07
Random Lattice QCD and chiral effective theories
O. Pavlovsky (*Moscow State University*)

09.07
Tutorials on gravitation
A. Giacomini (*University of Trento*)

15.07
Tutorials on gravitation
A. Giacomini (*University of Trento*)

03.09
Tutorials on gravitation
A. Giacomini (*University of Trento*)

07.10
On leptogenesis with degenerate minimal supersymmetric seesaw
K. Turzynski (*Warsaw University*)

12.10
Atomic interferometry with condensates and quantum computation in microtraps
A. Negretti (*University of Trento and ECT**)

28.10
What can quantum information theory tell us about physical processes?
M. Cirone (*ECT**)

02.11
Effective field theory and weak hadronik currents
F. Myhrer (*University of South Carolina*)

19.11
Coherence and superfluidity of Bose-Einstein condensed gases in optical lattices
L. P. Pitaevskii (*INFM-BEC*)

19.11
A quantum register with fermions
C. Menotti (*University of Trento*)

19.11
BEC under rotations
B. Jackson (*INFM-BEC*)

19.11
Casimir Effect with cold atoms
M. Antezza (*INFM-BEC*)

16.12
Gluonic infrared degrees of freedom in QCD
H. Forkel (*IFT-UNESP San Paolo*)

4 ECT* Computing Facilities and Library

The computing facilities available to researchers at ECT* have been improved significantly in 2004.

For handling the numerous tasks associated with the development and maintenance of a computing network which is being used both by local researchers and by numerous visitors, the staff has been reinforced by the arrival of G. Fattore and D. Gonzo who are now working part time at ECT*. They collaborate with Barbara Curró Dossi, who is full time system manager. A major development in 2004 concerns the security of the network which has been considerably enhanced.

The installation of the Teraflop computer has been successfully completed. P. Zuccato has been deeply involved in the various steps of the implementation.

Finally, the library constitutes an essential tool for researchers in theoretical physics. Significant improvements have been realized at the end of 2004.

4.1 Available computing resources

2 license servers:	2 PC (MATHEMATICA) [10 concurrent users] 1 PC (MATLAB) [2 concurrent users]
computation servers:	1 Alpha Bi-Processor 533 MHz (NAG libraries)
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 The Parallel Computing Lab @ECT*

(Pierfrancesco Zuccato)

The Parallel Computing Lab @ECT* is an ongoing project that has reached a full production production status, with the first users running actual scientific project on it.

It consists of a cluster of 96 nodes devoted to calculation, 3 nodes that act as resource servers (file servers) and one node that performs authentication and monitoring tasks (the front-end).

As a part of the joint initiative that involves ECT*, INFN and Exadron, the cluster will make use of a novel network technology that allows the physical implementation of a physical 3D communication mesh. The boards that provide the new networking technology have been manufactured and are currently undergoing the testing phase. Moreover, the software that is necessary to drive the boards is sufficiently complete and stable to allow some pilot projects.

Overall, the Parallel Computing Lab @ECT* is a facility that has begun to provide its service with good reports from initial users. In the near future, the inter-node network upgrade will make it even more efficient at running selected scientific codes that would not scale well on conventional clusters.

4.3 The library

The ECT* library has undergone a significant change in the course of 2004. The collection of monographs has been moved to the inner room in the ground floor of the Villa (previously used as a seminar room) an put on open shelves, whereby the room has been access-controlled via a badge reader. A connection with the central database of the Catalogo Bibliografico Trentino has been established, with a terminal equipped with a barcode reader that allows for borrowing and returning books with a normal user card of the Trentino Library System. Borrowing privilege has been retained only for ECT* members and selected members of the Physics Department and of the BEC Centre. Users will be able to borrow books by just filling a standard borrowing form for ITC libraries. At the same time, a design for an adequate furnishing of the new library room (to be occasionally used also as meeting and/or seminar room) has been laid out, and a grant proposal has been put forward towards the Trento Province, in order to get support for covering its costs.

5 Statistics

Visitor Days Spent at ECT*

(total number of visitors in 2004: 559)

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