

QCD FROM THE BOUND STATES' PERSPECTIVE

DATE: August, 2–6

ORGANISERS:

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

NUMBER OF PARTICIPANTS: 22

MAIN TOPICS:

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

SPEAKERS:

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

SCIENTIFIC REPORT:

Aim and Purpose

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

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

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

Results and Highlights

A key goal of modern studies in QCD is to develop an understanding of the spectrum and interactions of light-quark hadrons, whose masses lie in the range 1–2 GeV, and connect this with a description of excited states and putative exotics and hybrids in the charm and bottom sector. Theory, phenomenology, and experimental goals and results in this area were presented. The framework, 45 minute talks followed by a 15-minute question session, nurtured many discussions and comparison between theoretical approaches; the most prolific and widely employed of these are the relativistic quark models, in their various manifestations, Dyson Schwinger equations

and lattice-regularised QCD. The communication between experimentalists and theorists stimulated discussions about how future measurements can most effectively provide additional constraints on theory. In this respect, the talks highlighting recent progress and future programmes at experimental facilities dedicated to hadron physics in Europe, Japan and North America were excellent.

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

Conclusions

The workshop brought together practitioners with expertise in:

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

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

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

Optional If the talks of the workshop are available on a web location, indicate here the corresponding URL. For instance:

The talks can be browsed from the website:
<http://www.ect.it/Meetings/> ?