1. Introduction

The four-day workshop: “The Nature of Hadron Mass and Quark-Gluon Confinement from JLab Experiments in the 12-GeV Era”, gathered a select group of hadron-physics world experts and early-career researchers in order to accelerate progress toward a solution of the two greatest problems in the Standard Model; namely, the origin of hadron masses and gluon and quark confinement, from the experimental results on the ground and excited hadron structure with
electromagnetic probes. The Workshop is aimed to facilitate synergistic efforts between experimentalists, phenomenologists and theorists in the analyses of the available and future data on exclusive meson photo-/electroproduction off nucleons which will be acquired at JLab in the 12 GeV era at still almost unexplored ranges of highest photon virtualities ever achieved in exclusive electroproduction $Q^2 < 12-15 GeV^2$. The expected results will allow, for the first time, an exploration of QCD’s running coupling and masses at those length-scales that seem to be associated with more than 98% of the measured mass of hadrons. These studies pave a way for further insight to the confinement regime from the data of experiments foreseen with Electron-Ion Collider getting access to unexplored phenomena at extremely small values of $x$-Bjorken variables, e.g. quark and gluon saturation. A remarkable synergy currently exists between the capacities and interests of experiment and theory; and the purpose of this workshop, therefore, is to capitalize on existing successes and foster new collaborative efforts that will lead JLab through the 12-GeV era, and also explore novel avenues for physics at a future electron ion collider (EIC) with nuclear femtography.

2. Organization

The workshop took place at Asian Pacific Center for Theoretical Physics, Pohang, Korea from July 1 to July 4, 2018.

The organizing committee consisted of:

Volker Burkert (JLab)
Daniel S. Carman (JLab)
Latifa Elouadrhiri (JLab)
Ralf W. Gothe (Univ. of South Carolina)
Chueng Ryong Ji (North Carolina State Univ.)
Hyon-Suk Jo (Kyungpook National Univ.)
Kyungseon Joo (Univ. of Connecticut)
Viktor Mokeev (JLab)
Herve Moutarde (Saclay)
Carlos Munoz (Orsay)
Yongseok Oh (Kyungpook National Univ./APCTP)
David G. Richards (JLab)
Craig D. Roberts (Argonne National Lab.)

Full information on the Workshop can be found in:
https://www.apctp.org/plan.php/JLab-12GeV
3 Budget

The Workshop was supported by:

Jefferson Lab (USA): $2,500
University of Connecticut (USA): $2,000
Irfu/SPhN, CEA, Saclay (France): $1,000
CNRS/IN2P3, Orsay (France): $1,000
Asia Pacific Center for Theoretical Physics (Korea): $15,000.

JSA awarded $2,500 that was used to cover travel expenses to Korea for young researchers Andrey Kim, University of Connecticut (USA), experimentalist with research activity focused on the GPD studies from the data of deeply virtual meson production experiments and Cerdic Mezrag INFN (Italy), theorist with research activity focused on the development of continuum QCD methods for description of the ground and excited hadron structure.

4 Workshop Summary

The workshop consisted of 37 invited talks. A detailed list of the talks and participants can be found on the workshop web page in Section 2. The workshop canvass a wide range of experiment and theory, e.g.

(a) nuclear femtography with computation and measurement of the momentum and spatial distributions of partons inside a hadron using new opportunities from semi-inclusive DIS, DVCS and DVMP experiments in the 12 GeV era, and diverse array of methods in order to expose emergent phenomena via quasiparticle formation, shedding light on the emergence of hadron mass and quark-gluon confinement,
(b) new opportunities in exploration of the nucleon structure with electron and positron beams, combined,
(c) exploring the dynamics and impacts of hadron mass generation with hadron elastic, transition \( N \rightarrow N^* \), and meson form factors,
(d) prospects to gain the insight to the hadron mass generation and to map the QCD’s running coupling in the transition from confinement to pQCD regimes from the data of Hall A/C on nucleon elastic form factors at \( Q^2 < 15 \text{ GeV}^2 \) and the data of Hall B on electroexcitation amplitudes of all prominent nucleon resonances at \( Q^2 < 12 \text{ GeV}^2 \),
(d) nucleon resonance contribution to DIS processes from the experimental results on \( N \rightarrow N^* \) transition form factors,
(e) search for the new states of hadron matter, hybrid mesons and baryons with glue as active structural component in Halls B and D at JLab,
(f) nuclear matter as laboratory for the studies of quark hadronization and modifications of hadron properties in nuclear media.

The workshop initiated the development of QCD-rooted multi-prong theoretical framework aimed for relating the experimental results on the structure of the ground and excited hadrons to strong QCD dynamics underlying the hadron mass generation and quark-gluon confinement emergence. In particular, the results on 3D ground nucleon state structure determined from DVCS and DVMP data can be calculated using continuum methods in QCD and related therewith to the same running masses and couplings that were used to describe the pion, nucleon elastic, and N→N* transition form factors. Consistency between the experimental results on all GPDs and the theoretical expectations from the strong QCD approaches that reproduce the hadron elastic and transition form factors will deliver an understanding of the strong QCD dynamics behind hadron mass generation. This will provide further insights into the emergence of confinement encoded in the strong momentum dependence of QCD’s effective charge and its saturation at infrared momenta.

Joint activity between the experts in N* and DIS physics was initiated with a goal to explore the nucleon resonance contributions to inclusive electron scattering from the experimental data on N→N* transition form factors. The expected results are of interest in the studies of quark-hadron duality. They will also offer an insight to the parton distributions in the ground nucleons from the new inclusive electron scattering data foreseen in 12 GeV era at JLab including the resonance region of large x-Bjorken. New ideas in LQCD afford the prospect of the direct calculation of the x-dependence of PDFs encapsulated in the study of quasi- and pseudo-distributions, making access to the PDF from the inclusive electron scattering data in full range of x- Bjorken the hot topic in hadron physics.

Understanding of the origin of hadron mass and the emergence of quark-gluon confinement represent a key science goal in contemporary hadron physics. Participants of the workshop unanimously strongly encourage fostering joint efforts between experimentalists, phenomenologists and theorists in this key area by organizing the future topical workshops focused on this last unexplored chapter of the Standard Model.