QCD Theory: Hadron Physics, Quark Matter & Heavy-Ion Physics

Hadron structure and spectroscopy, QCD phase diagram, real-time dynamics of QCD plasma, etc.

Reinhard Alkofer

Institute of Physics, University of Graz, NAWI Graz, Universitätsplatz 5, 8010 Graz, Austria

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Research Agenda

Low-energy QCD in the strongly-interacting domain

An introductory remark

Hadronisation: Relation to Collider Phenomenology

Hadronic “uncertainties”: Relation to Flavour Physics

Hadronic γ-γ scattering: Relation to $(g-2)_\mu$

⚠ An understanding of hadron structure is mandatory for an interpretation of results obtained in high-energy experiments.

Non-perturbative QCD and its phenomena (confinement, dynamical chiral symmetry breaking, axial anomaly, phases of strongly-interacting matter, . . .) are a highly interesting research topic on its own, and in addition their understanding is an indispensable ingredient to all high-energy physics.

Research Agenda

Low-energy QCD in the strongly-interacting domain

- Further developments of theoretical methods
  - lattice QCD
  - functional methods
  - effective field theory
  - holographic framework
  - QCD kinetic theory
  - . . .
- Understanding the experimental results
  - hadron spectroscopy (incl. exotic hadrons)
  - hadron structure
  - hadronic reactions and decays
  - phases of QCD
  - real-time dynamics in heavy-ion collisions & the early universe
  - . . .

Facilities

- Further developments of theoretical methods:

  Sustained access to High-Performance Computing

  incl. Quantum Computers

Facilities

Experiments

- FAIR
  - CBM for the study of dense matter, critical end point, phases, . . .
  - PANDA for precision hadron physics, access to otherwise unexplored kinematical regions, . . .
- Belle II for hadron flavour physics
- EIC for hadron structure (incl. spin,) role of quarks & glue in nuclei, . . .
- Hadron physics experiments at CERN including
  - ALICE
  - LHCb
  - COMPASS / AMBER

Facilities

Experiments

- Use of HL-LHC for hadron physics!
- Use of polarised beams and targets!

  Example: Fixed-target experiment at FCC-ee (“Super-HERMES”)

Exploit also in future CERN’s existing infrastructure for hadron physics.

Overlap to Nuclear Physics

New NuPECC long range plan is currently formulated:

Renewed statement of the importance of FAIR

Overlap to Astrophysics

Multi-messenger astrophysics will enable novel insights!

Example:

Learn about inner core of neutron stars (NS) by observing

- electromagnetic radiation,
- gravitational waves, and
- neutrinos

from NS – NS merger.

Summary

The Austrian QCD theory community would / will profit from

- FAIR (CBM <u>and</u> PANDA)
- EIC
- BELLE II (and potential successor)
- Hadron physics at CERN including
  - ALICE
  - LHCb
  - COMPASS / AMBER
  - other future experiments (Super-HERMES, . . .)
- multi-messenger astronomical / astrophysical observations (e.m., grav.waves & ν's)