NuPECC Long Range Plan
Working Group 1 – “Hadron Physics”

Diego Bettoni and Hartmut Wittig

Conveners

NuPECC Meeting
ECT* Trento
11–12 March 2016

Working Group “Hadron Physics”

Conveners: Diego Bettoni (Ferrara), Hartmut Wittig (Mainz)

Reinhard Alkofer (Graz)
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Ulrike Thoma (Bonn)
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NuPECC Liaison: Bernd Krusche, Eberhard Widmann, Tord Johansson

First Meeting: 18/19 February, Mainz

Tentative Structure

* **Introduction**

* **Theoretical framework** (Nora Brambilla)

* **Hadron Spectroscopy** (Dave Ireland)

* **Hadron Structure** (Nicole D'Hose)

* **Hadronic Interactions** (Andrzej Kupcs)

* **Recommendations**

Subsection: Theoretical Framework

Topics:

- Tools: QCD, effective field theories, models, S-matrix theory, functional methods
- Interplay between lattice QCD and EFTs
- Rôle of symmetries
- Confinement mechanism — exp. studies of hadronisation, QGP
- Hadronic matrix elements: QCD factorisation, lattice QCD
- Hadron resonances: theoretical interpretation; “ab initio” studies
- Quantify hadronic uncertainties in precision observables — work towards “precision era” of hadron physics
- Strongly interacting systems and multi-scale problems
- Anomalies, axions

Subsection: Hadron Spectroscopy

Topics

- Charm and bottom spectroscopy: X, Y, Z states, pentaquarks (Experiments: BES-III, PANDA, LHC-b, ATLAS, CMS, Belle)
- Light quark spectroscopy, including exotics and glueballs (Experiments: COMPASS, JLab, PANDA)
- Interpretation: PWA, statistical analysis methods (MEM, inference methods,…); reduce model dependence in interpreting experimental data
- Isospin breaking
- …

Subsection: Hadron Structure

Recent achievements / current status

- *Proton radius puzzle:* ep scattering, atomic physics & laser spectroscopy
- *Electromagnetic form factors:* role of two-photon processes
- *GPDs, PDFs, TMDs:* Data analysis, theoretical interpretation, role of hadron beams; relevance of PDFs for LHC
- *Polarisabilities*: experimental determinations and tests of theoretical formalisms

Future directions

- *GPDs, PDFs, TMDs:* continuation of current program
- *Form factors:* timelike regime; strangeness form factors
- …

Subsection: Hadronic Interactions

Topics

- Multi-hadron systems; hadronic molecules; hypernuclei
- Study $\pi\pi$, πN, NN, πH, NH interactions; van der Waals interactions
- Tools: PWA, NN potentials from EFT perspective (2- and 3-body forces,…)
- …

(clarify overlap with WG3 – Nuclear Structure)

Issues to be discussed…

Lattice QCD and computing

- Also relevant for WG2 (Phases of Strongly Interacting Matter), WG3 (Nuclear Structure and Dynamics), WG5 (Fundamental Interactions)
- World-wide effort towards exascale computing; corresponding recommendations in the US LRP
- Calls for a more general discussion / presentation within the LRP; could add appropriate “boxes”

Searches for new light particles; “New Physics”

- What is the appropriate section for new light particles searches (“dark photons”, axions,…)
- More general issue: experimental techniques originate from hadron physics

Issues to be discussed…

Facilities (in Europe and elsewhere)

- FAIR: PANDA, HESR (status — implications from “Heuer Report”)
- Prospects for IKP@FZ Jülich — implications for HESR, pEDM
- CERN: COMPASS, ALiCE
- Lepton beams: DAPHNE, ELSA, MAMI, MESA, S-DALINAC
- Electron-Nucleon / Electron-Ion Collider
- Polarised proton–antiproton beams; LHeC

Recommendations

Priorities in “Hadron Physics” from LRP 2010

I. Speedy construction of PANDA@FAIR

II. Complete and exploit current facilities to ensure attractive research opportunities prior to completion of FAIR

III. Continued support for theory

IV. Upgrade of HESR into proton–antiproton collider