Nuclear physics at the energy-luminosity frontier: From JLab 12 GeV to an Electron-Ion Collider

L. Elouadrhiri, C. Weiss (Organizers), APS DNP Session 1WA, 23–Oct–13

This workshop
Physics at “energy–luminosity frontier”
Complementarity JLab 12 GeV – EIC
Status and prospects of EIC

- Scattering energy
  Resolution scale $1/Q$
  Target configurations, types of constituents

- Luminosity
  Rare processes, exceptional configurations
  Multi-variable final states
  Polarization effects
Physics topics

I) Three–dimensional structure of nucleon in QCD

- Quark/gluon number densities
- Spin and orbital motion
- Spatial distributions
- Multiparticle correlations

Xiangdong Ji

II) QCD in nuclei – short distances, high energies

- Short–range structure and $NN$ interaction in QCD
- Modification of nucleon’s quark/gluon structure
- Collective effects: Shadowing, diffraction
- High gluon densities and saturation

M. Sargsian

III) Emergence of hadrons from color charge

- Parton fragmentation, color neutralization, hadron formation
- Interaction of color charge with matter

W. Brooks

Natural complementarity/evolution JLab 12 GeV $\rightarrow$ EIC

Other topics: Electroweak physics, hadron spectroscopy, in DNP sessions!

Other contexts for EIC physics: RHIC Spin, HERA $ep$, RHIC/LHC heavy–ion, not excluded!
Physics: 3D nucleon structure in QCD

- Relativistic many-body system
  
  Particle number changes with energy and resolution scale!

  JLab 12 GeV: Valence quark component, incl. $x \to 1$

  EIC: Sea quarks, gluons, scale dependence

- Physical characteristics
  
  Quark/gluon number densities, incl. spin and flavor dependence  PDFs

  Transverse spatial distributions  GPDs

  Orbital motion  TMDs

  Multiparticle correlations  GPDs

  Reveal structure in unprecedented detail!
Physics: QCD in nuclei

- Small–size probe of color fields
  Color fields change with energy and probe size!

- JLab 12: Coherence length short
  Short–range correlations, QCD origin of $NN$ interaction
  Quark structure of bound nucleon

- EIC: Wide range of probe size and coherence length
  Collective color fields in nuclei: Shadowing, diffraction, transparency
  Nuclear sea quarks and gluons
  High gluon densities, saturation

Explore region of new QCD phenomena!
Facilities: JLab 12 GeV

- CEBAF “race track” accelerator with linacs + arcs
  
  Uses unique superconducting RF technology
  
  Extensible to max. 24 GeV

- Experimental halls
  
  A, C  Magnetic spectrometers
  
  B  Large–acceptance detector CLAS

- JLab 12 GeV Upgrade
  
  Double beam energy $6 \rightarrow 12$ GeV
  
  Largely complete, accelerator to be commissioned

  Add Hall D: $\gamma$ beam, GlueX detector
  
  Hall construction finished, detector assembly on-going

  New/upgraded detectors in existing halls:
  
  CLAS12 in Hall B, SHMS in Hall C
  
  Assembly on-going

  DOE project (CD0 2004, CD3 2008)
  
  Total cost $\sim 300M$

CW beam $\sim 100 \mu A$

Energy before upgrade 6 GeV

Accelerator operating since 1994
Facilities: Electron–Ion Collider

- **BNL linac–ring design eRHIC**
  RHIC proton/ion beam up to 325 GeV
  5–20 (30) GeV electrons from linac in tunnel staged
  Luminosity $\sim 10^{34}(10^{33})$ cm$^{-2}$s$^{-1}$ over wide range
  Re-use RHIC detectors? PHENIX, STAR

- **JLab ring–ring design MEIC/ELIC**
  11 GeV CEBAF as injector continued fixed-target op
  Medium–energy: 1 km ring, 3–11 on 60/96 GeV
  High–energy: 2.5 km ring, 3–11 on 250 GeV
  Luminosity $\sim 10^{34}$ over wide range
  Figure–8 for polarization transport, up to four IP’s
  Polarized deuteron beam possible

- **Related proposals**
  CERN LHeC: 20–150 GeV on 7 TeV ep unpol
  Ring–ring and linac–ring discussed, $L \sim 10^{33}$

EIC@China project in Lanzhou
Design targets similar to JLab MEIC

GSI ENC: 3.3 GeV on 15 GeV ring–ring
using FAIR HESR, $L \sim 10^{32}$ PANDA detector

Convergence in design parameters, "staging."
Different technological challenges!

First $eA$ collider, first polarized!