Nuclear structure with an Electron-Ion Collider

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http://www.lecmeeting.org/home.html

I) WG Nuclear Structure and Reactions – Experiment
Nuclear structure physics with an Electron-Ion Collider

- High-luminosity polarized $ep/eA$ collider ($J_{Lab}$, BNL)
  Next-generation facility for QCD and nuclear physics
  CM energy $\sqrt{s} \sim 10-40$ GeV/nucleon, luminosity $\sim 10^{34}$ cm$^{-2}$s$^{-1}$
  Polarized light ions: Deuterium D(pol), $^3$He(pol), $^4$He, Li, Be, . . .

- High-energy $eA$ scattering with light ions

Neutron DIS for quark spin/flavor
Bound nucleon in QCD: $q\bar{q}$ sea, gluons
Coherent phenomena, collective fields

Probes nuclear structure as much as short-range QCD dynamics!
Opportunities for novel nuclear structure studies!
• Example: Deep-inelastic structure and short-range $NN$ correlations

Modification of nuclear DIS structure at $x > 0.2$ proportional to amount of short-range $NN$ correlations

“EMC effect,” JLab 6/12 GeV

QCD origin of short-range $NN$ interaction?

• Spectator nucleon tagging

Identify active nucleon, control its quantum state

Uniquely suited for collider: Dedicated forward detectors, full coverage for nucleons/fragments, momentum resolution $\delta p/p \sim 10^{-4}$

JLab MEIC interaction region & forward detector design
Next-generation nuclear structure studies with EIC

Nuclear modification of single–nucleon properties:
QCD structure of bound nucleon ($q\bar{q}$ sea, gluons),
non-nucleonic degrees of freedom, role of color

*Tagging with $p \sim p_{\text{Fermi}}$*

QCD origin of short-range $NN$ correlations:
Effect on deep-inelastic structure, spin-isospin dependence, universality.
→ Superdense matter in astrophysical systems

*Tagging with $p \gg p_{\text{Fermi}}$*

Low–energy nuclear breakup induced by high-energy processes:
New operators, new probes of low-energy structure.
Light–front wave functions, spectral functions.

*Tagging with $A > 2$, multiple spectators, cluster breakup*

R&D efforts and resources

EIC accelerator and detector R&D at BNL and JLab.
Physics simulations available. Great interest in user community.

Joint theoretical–experimental R&D for spectator nucleon tagging.
JLab 2014 LDRD project “Physics potential of polarized light ions with EIC@JLab”
II) WG Theory for Low-Energy Nuclear Science
Nuclear structure theory for an Electron–Ion Collider

- High-luminosity polarized $ep/eA$ collider (JLab, BNL)

  CM energy $\sqrt{s} \sim 10-40$ GeV/nucleon, luminosity $\sim 10^{34}$ cm$^{-2}$s$^{-1}$

  Polarized light ions: Deuterium D(pol), $^3$He(pol), $^4$He, Li, Be, . . .

- Deep-inelastic scattering from light ions

  Physics objectives: Neutron partonic structure, bound nucleon in QCD, coherent nuclear phenomena

- Spectator nucleon tagging

  Identify active nucleon, control its quantum state

  Next-generation measurements: Precision, theoretical control

  Uniquely suited for collider: Forward detectors, spectator momenta measured, no target material
• Nuclear structure in high–energy scattering

Factorize deep-inelastic process — nuclear structure. Impulse approximation, final–state interactions

Nucleus probed at fixed light–front time \( x^+ = t + z \). Low-energy structure, just viewed differently!

• Theory input for spectator tagging

Light–front wave functions of light nuclei \( D(\text{pol}), {^3}\text{He}(\text{pol}), ... \) in nucleon degrees of freedom \( \langle N...N|A \rangle \)

Light–front spectral functions \( A \rightarrow N(p^+, p_T) + \) spectators, including components with \( p \gg p_F \) from correlations

Estimates of final–state interactions using phenomenological models, identification of configurations minimizing FSI
• Applications of spectator tagging

Free neutron structure from $D$ with proton tagging and on-shell extrapolation $p_{\text{Recoil}} \to 0$. Eliminate Fermi motion and binding effects

Quark/gluon structure of short-range $NN$ correlations from tagging deep–inelastic processes with $p_{\text{Recoil}} \gg p_F$

• R&D status and needs

JLab 2014 LDRD project “Physics potential of polarized light ions with EIC@JLab”

$A > 2$ nuclei need dedicated theoretical effort. Expert groups, several years

• Intellectual challenges

Light–front nuclear structure from NMBT – new formulation! Use of EFT–constrained interactions for light–front structure?

Nuclear theory input needed to realize full potential of next–generation experiments at EIC with spectator tagging