

Nuclear structure with an Electron-Ion Collider

C.Weiss (JLab), Joint DNP Town Meetings on Nuclear Structure and Nuclear Astrophysics, Texas A&M University, August 21-23, 2014

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

I) WG Nuclear Structure and Reactions – Experiment

Nuclear structure physics with an Electron-Ion Collider

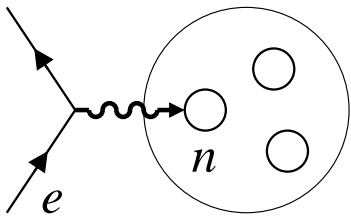
- High-luminosity polarized ep/eA collider (JLab, BNL)

Next-generation facility for QCD and nuclear physics

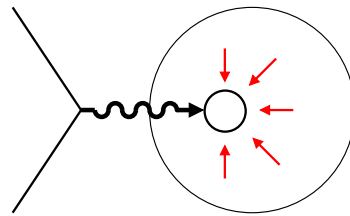
CM energy $\sqrt{s} \sim 10\text{-}40$ GeV/nucleon, luminosity $\sim 10^{34}$ cm⁻²s⁻¹

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

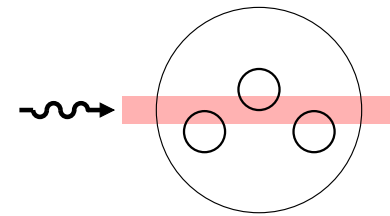
- High-energy eA scattering with light ions



Neutron DIS for
quark spin/ flavor



Bound nucleon in
QCD: $q\bar{q}$ sea, gluons



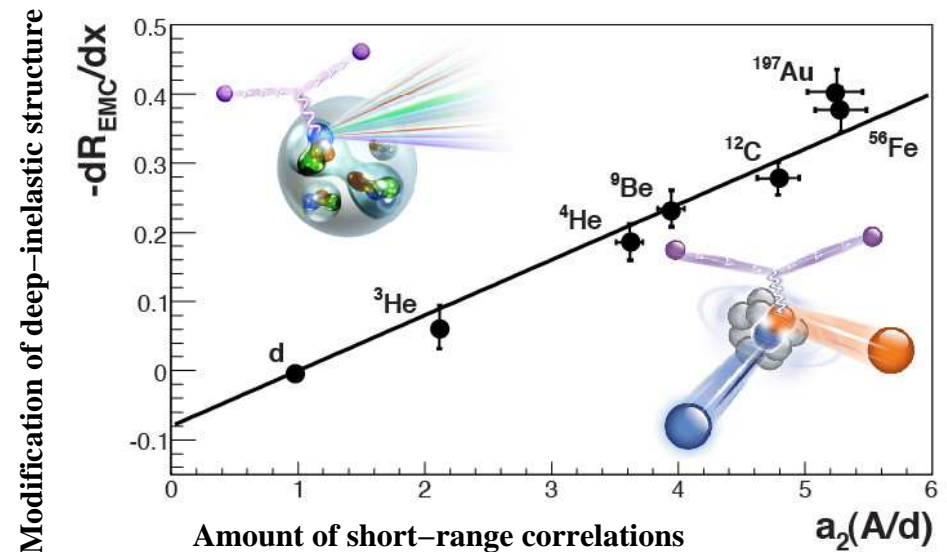
Coherent phenomena,
collective fields

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

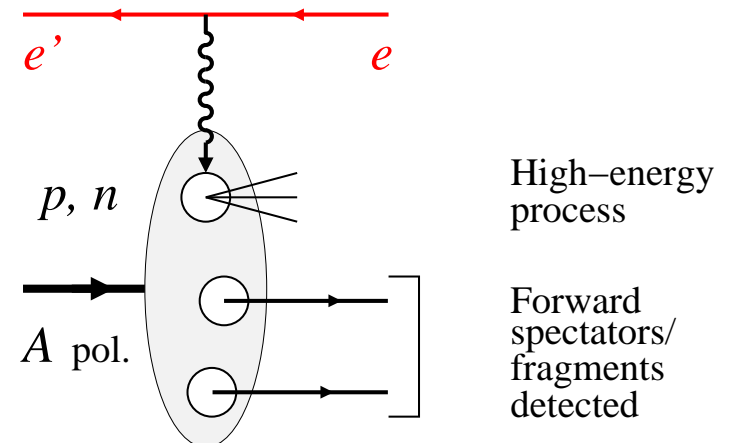
QCD origin of short-range NN interaction?



- 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.

<https://wiki.bnl.gov/eic/> (BNL), <https://eic.jlab.org/wiki/> (JLab).

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

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

- Deep-inelastic scattering from light ions

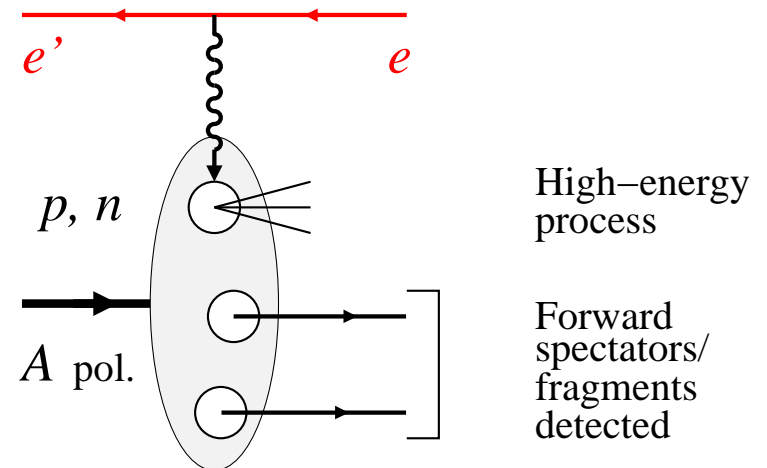
Physics objectives: Neutron partonic structure, bound nucleon in QCD, coherent nuclear phenomena

- Spectator nucleon tagging

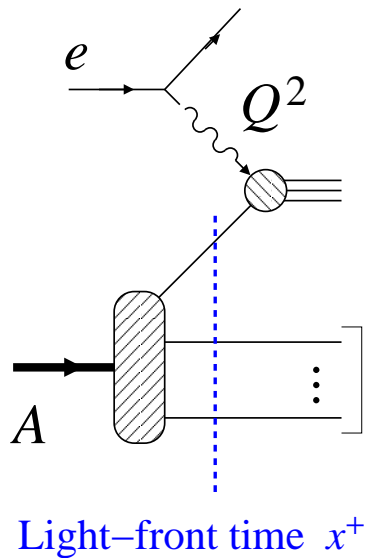
Identify active nucleon,
control its quantum state

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(pol), ${}^3\text{He}(\text{pol})$, ...
in nucleon degrees of freedom $\langle N..N|A \rangle$

Light-front spectral functions $A \rightarrow N(p^+, \mathbf{p}_T) + \text{spectators}$,
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 $p_{\text{Recoil}} \rightarrow 0$. 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

Joint theoretical-experimental R&D for spectator nucleon tagging on-going. Focus on polarized D – simple! Simulations, detector development.

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