Polarized light-ion physics with EIC

Topical Workshop, Ghent University, 5-9 Feb 2018

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- Welcome
- Context and objectives
- Plan of meeting

Jefferson Lab
Thomas Jefferson National Accelerator Facility

GHENT UNIVERSITY

Nuclear physics with EM probes

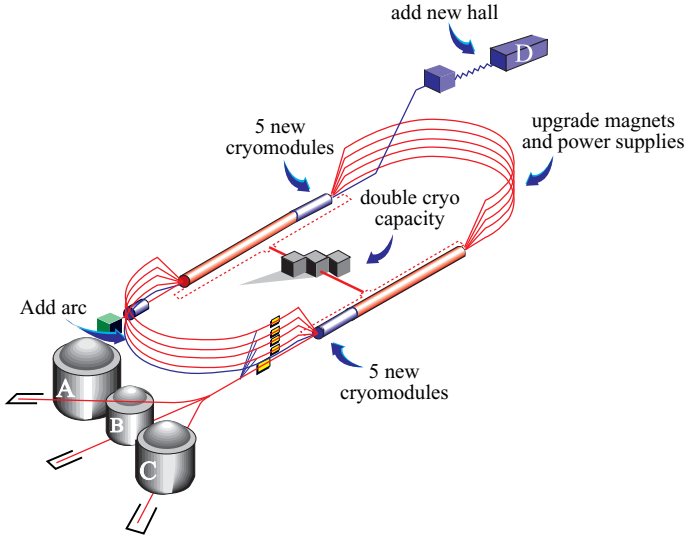
- JLab 12 GeV operations started

  Hall A & D first physics results, Hall C physics running, CLAS12 engineering run

  Four-hall operation demonstrated

  Expect physics results 5-10 years

  Other EM facilities: COMPASS, MAMI, ELSA, MIT Bates



- Electron-Ion Collider as future facility

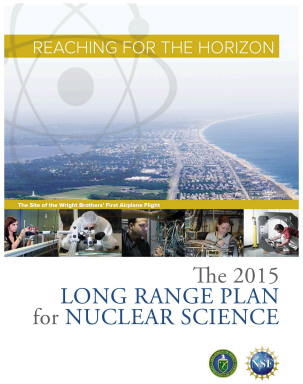
  → Talk A. Deshpande

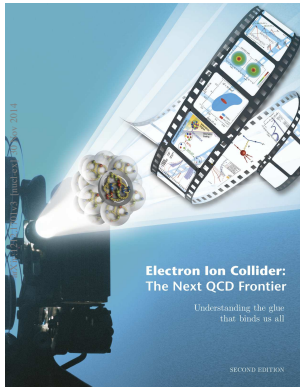
  Recommended in 2015 NSAC Long-Range Plan

  Designs by BNL and JLab

  Vigorous accelerator and detector R&D

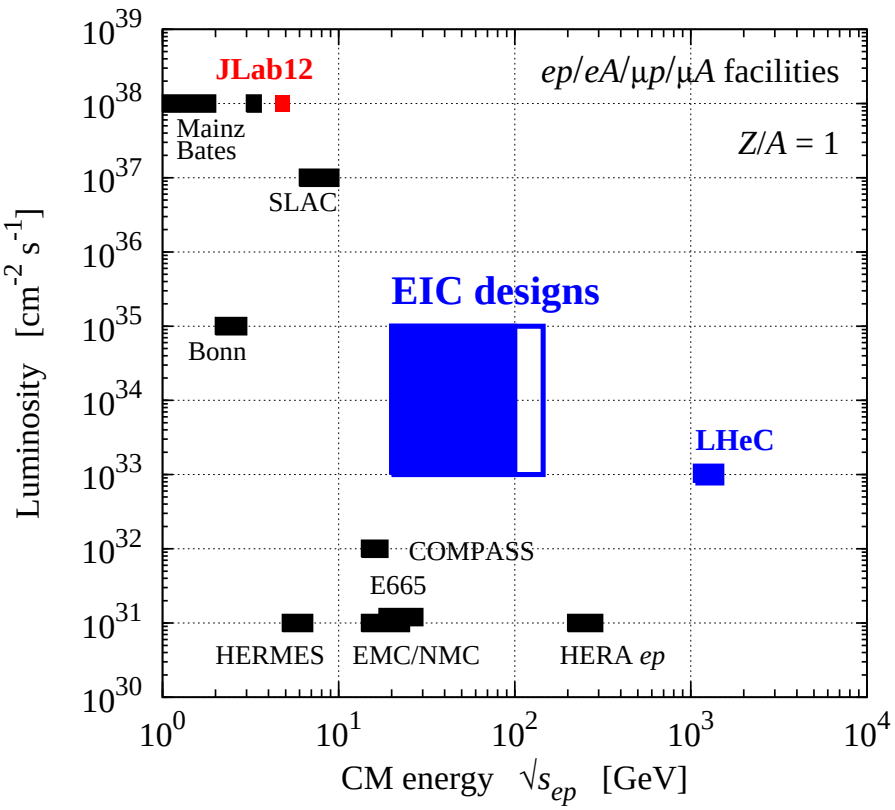
  Driving physics research in exp & thy

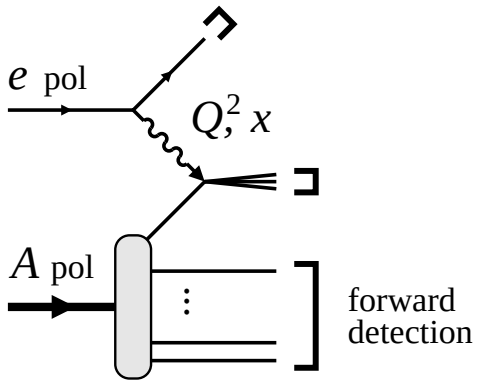




- Hadron probes: LHC, RHIC $pA/AA/\gamma A$, JPARC, GSI FAIR, FRIB

EIC ep/eA capabilities





- CM energy $\sqrt{s_{ep}} \sim$ 20–100 GeV

  Factor $\sqrt{Z/A}$ for nuclei

  Deep-inelastic scattering at
  $x \sim 10^{-1}$–10^{-3}, $Q^2 \lesssim 10^2$ GeV^2

- Luminosity $\sim 10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$

  Exceptional configurations in target
  Multi-variable final states
  Polarization observables

- Polarized protons and light ions

  eRHIC: pol ^{3}He
  JLEIC: pol d and ^{3}He with figure-8

- Forward detection of p, n, A

  Diffractive & exclusive processes
  Nuclear breakup and spectator tagging
  Coherent nuclear scattering

EIC physics topics

I) 3D nucleon structure and spin

Sea quark and gluon polarization, nucleon spin decomposition
Spatial distributions and orbital motion of quarks/gluons
Quark-gluon correlations

II) QCD in nuclei

Nuclear quark/gluon densities, NN interactions in QCD
Color transparency and opacity
Nonlinear effects and gluon saturation at small x

→ Talk A. Deshpande

III) Emergence of hadrons from color charge

Quark/gluon fragmentation and hadronization
Interaction of color charge with matter

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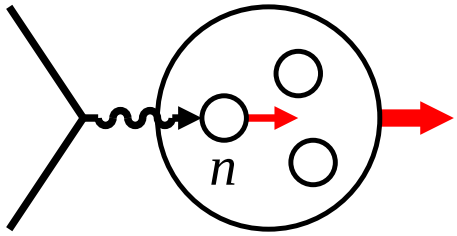
Measurements with $\begin{cases} ep \\ eA(\text{light}) \\ eA(\text{heavy}) \end{cases}$ ← this meeting!

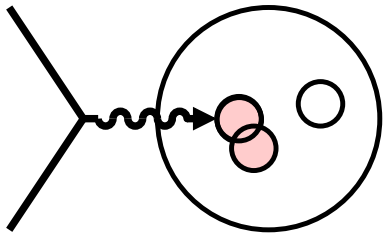
Light ions: Applications



- Neutron structure

  Flavor decomposition of PDFs/GPDs/TMDs,
  singlet vs. non-singlet QCD evolution, polarized gluon

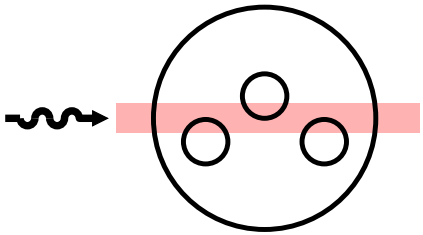
  Eliminate nuclear binding, non-nucleonic DOF!



- Nucleon interactions in QCD

  Nuclear modification of quark/gluon densities
  Short-range correlations, non-nucleonic degrees of freedom
  QCD origin of nuclear forces

  Control nuclear configuration in high-energy process!



- Coherent phenomena in QCD

  Coherent interaction of high–energy probe
  with multiple nucleons, nuclear shadowing

  Identify coherent response!

[Nucleus rest frame view]

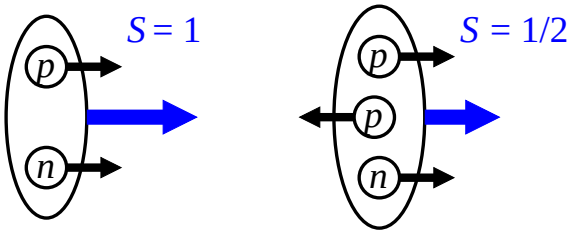
Light ions: Resources

- Polarized ion beams d, ^{3}He, ... ^{7}Li

  Neutron spin structure

  Spin dependence of nuclear modifications

  Tensor-polarized observables $A = 2$

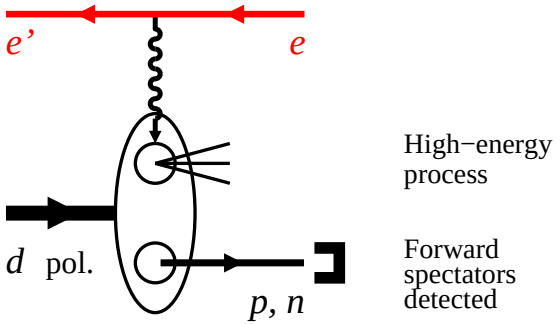


- Spectator tagging and breakup measurements

  Identify active nucleon

  Control nuclear configuration, interactions

  Collider uses forward detectors for $p, n, A-1$,
  many advantages over fixed-target



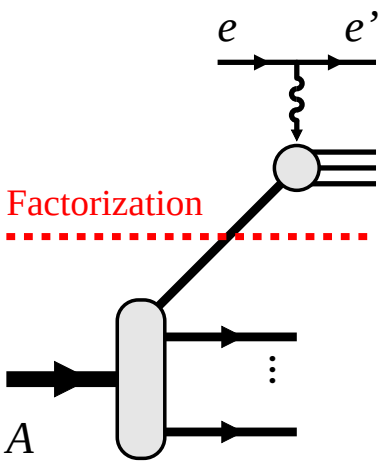
- Nuclear structure from first-principles theoretical calculations

  EFT interactions: Controlled accuracy, 3N forces, matching with QCD

  Few-body bound states: Faddeev-type methods, finite-basis methods, GFMC, Lattice EFT

  Scale dependence: Similarity transforms, RNG

Low-energy structure and high-energy scattering



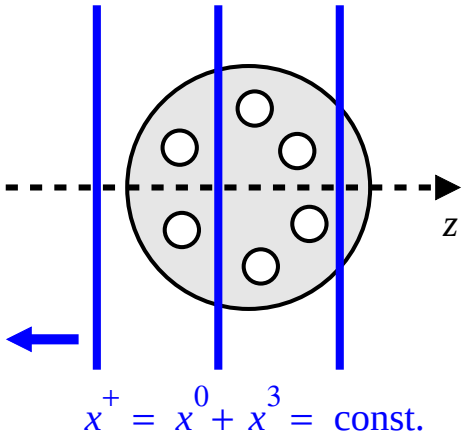
- Factorization of nuclear and nucleonic structure

  Separation of scales, natural in EFT formulation

  High-energy process as operator

  Impulse approxiation, final-state interactions

  Nucleon interactions? Non-nucleonic degrees of freedom?



- Light-front nuclear structure

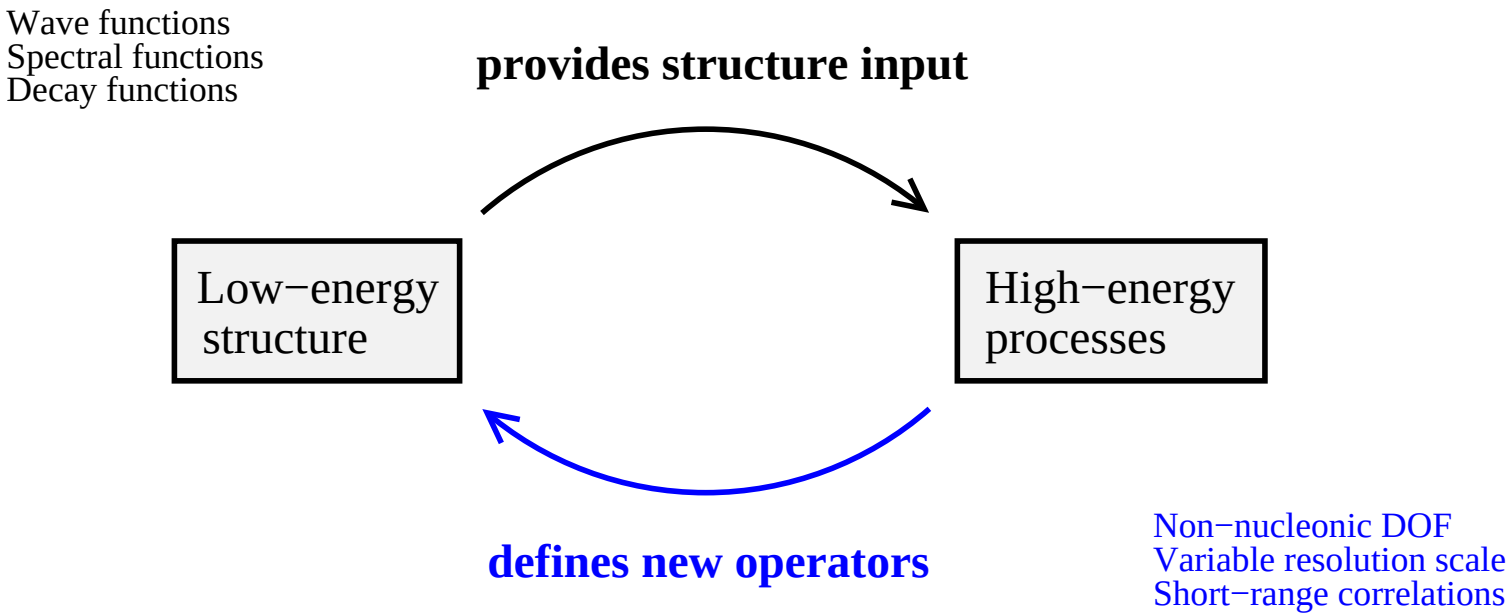
  High-energy scattering probes nucleus at fixed light-front time $x^+ = x^0 + x^3 = \text{const.}$

  Factorization possible if nucleus described by light-front wave function in nucleon degrees of freedom

  Still low-energy structure, just viewed differently! Can be matched with nonrelativistic structure

  Needed for EIC: Light-front momentum densities, spectral functions, decay functions

Low-energy structure and high-energy scattering



- New opportunities for low-energy nuclear structure studies with EIC

  Non-nucleonic degrees of freedom, e.g. Δ isobars

  Short-range NN correlations

  Nuclear breakup induced by by new operators

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Program

- Neutron structure
  - Extraction from nuclear DIS data
  - Impact on PDFs, spin, transverse momentum
  - Theoretical uncertainties

  Martin, Ent, Scopetta, Sato, Schnell, Munoz Camacho

- Theoretical methods for light nuclei
  - Chiral EFT forces and currents
  - Bound states with Faddeev, finite-basis, lattice EFT

  Krebs, Vary, Golak, Elhatisari

- Scale dependence and short-range correlations
  - Dynamical scales in nuclear structure
  - SRC definition and similarity transforms
  - SRCs in $(e, e'N)$ and (e, e') experiments
  - Evidence for 3N correlations

  Strikman, Neff, Hebeler, Ryckebusch, Schmidt, Day, Sargsian

- Nuclear breakup and spectator tagging
  - EMC effect and shadowing in tagged DIS
  - Spectator tagging with EIC
  - IR design and forward detection with EIC

  Dupre, Hyde, Guzey, Lee, Yoshida

- Spin in structure and fragmentation
  - Polarized EMC effect
  - Tensor polarized deuteron observables
  - Polarized nucleon fragmentation and nuclear breakup
  - Polarized ion beams with EIC and polarimetry

  Kohl, Cloet, Lorce, Kumano, Slifer, Kotzinian, Cotogno, Cosyn, Ptitsyn, Morozov