Physics with a low–energy ep/eA collider

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$s_{ep} \sim 100\,\text{GeV}^2$

$\mathcal{L} \approx 10^{33}\,\text{cm}^{-2}\,\text{s}^{-1}$

e.g. $E_p/E_e = 4/4 - 9\,\text{GeV}$

→ Presentation by Yuhong Zhang

- Sea quarks and gluons in nucleon

  Semi-inclusive/exclusive DIS
  J/ψ and charm production

  x, Q^2 coverage
  luminosity

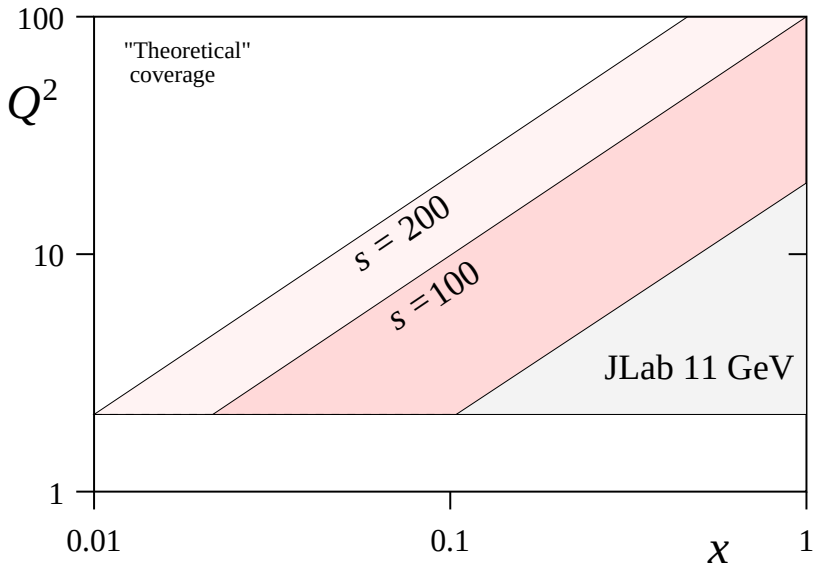
- QCD in nuclei — novel probes and effects

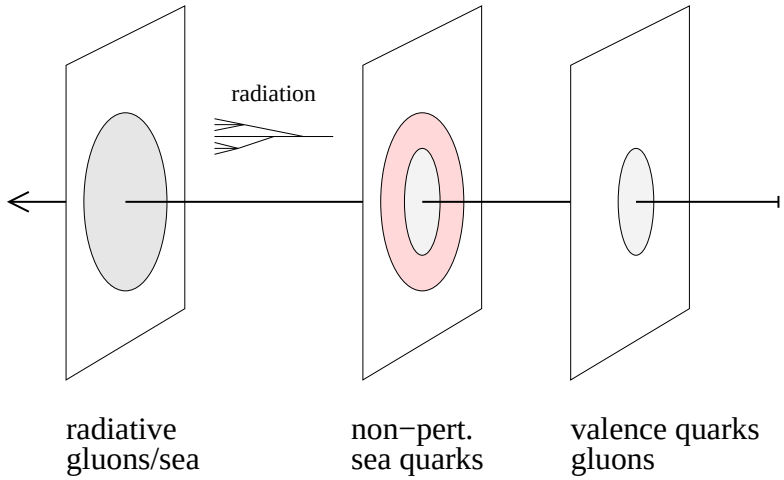
  Coherent nuclear processes
  Spectator tagging

  forward detection
  resolution

- Electroweak physics? Spectroscopy?

Nucleon structure in QCD: Landscape





- JLab 11 GeV: Valence quarks spin/flavor/spatial distributions

  . . . essential pieces missing!

- Non-perturbative sea quarks
  - QCD vacuum ("meson cloud")
  - Flavor non-singlets: Lattice, models
  - Nuclear binding in QCD

- Gluons at $x > 0.1$
  - Spatial distribution: Input for small x
  - Quark spin-orbit interactions
  - Polarization?

- HERMES, COMPASS: Most relevant observables at $x \sim 10^{-1}$, not 10^{-2} !

Low–energy collider: ep

- Inclusive DIS: ΔG and $\Delta q + \Delta\bar{q}$ from global fits [+ JLab 12GeV, COMPASS]

- Charm as direct probe of gluons
  - Spatial distribution of gluons from exclusive J/ψ ←
  - $D\Lambda_c$, open charm?

- Semi–inclusive DIS
  - Flavor decomposition $q \leftrightarrow \bar{q}$, $u \leftrightarrow d$, strangeness s, $\bar{s}$ ←
  - Spin–orbit interactions from azimuthal asymmetries, p_T dependence (TMDs)
  - Target fragmentation and fracture functions

- Exclusive processes and GPDs
  - Spin/flavor/spatial quark structure from meson production ($Q^2 \sim 10\,\text{GeV}^2$) ←
  - Helicity GPDs, spatial quark imaging from DVCS in wide kinematic range
  - Resonance structure from $N \to N^*$ transition GPDs

Low–energy collider: eA

- Spectator tagging in $D(e, e'p)X$
  - Neutron structure (lower p_{spec}, significant improvement over BONUS, CLAS12)
  - EMC effect

- Coherent nuclear processes
  - Coherent J/ψ: Gluonic radius of nucleus
  - Coherent DVCS: Matter vs. charge radius
  - ^{4}He: Spin–0 nucleus, "simplest" target!
  - Coherent meson production: Color transparency, QCD dynamics

  . . . much easier than in fixed–target: $|t_{\text{min}}| < R_A^{-2}$

- Quark propoagation / hadronization in medium?

Energy and luminosity considerations

- High–energy collider ($s \sim$ few 10^3 GeV^2) required for
  - σ_L at $x < 10^{-2}$ and low–x gluon density
  - Gluon shadowing in nuclei from $(d/dQ^2)\, F_{2A}(x, Q^2)$
  - Semi–inclusive production at high p_T
  - "Definitive" determination of ΔG? Not so simple. . .
    Requires detailed study of precision vs. Q^2 reach in global fits, systematics, etc.

- Limited by luminosity 10^{33}
  - Meson production at $Q^2 \sim 10$ GeV^2
  - Semi-inclusive DIS at $p_T \sim$ few GeV $\leftrightarrow$ pQCD
  - Exclusive J/ψ production
  - L/T separation in pseudoscalar meson production

Luminosity upgrade may be feasible:
Second–generation physics program!

Summary

- Rich physics program in nucleon/nuclear structure,
  several potentially unique applications

- Takes full advantage of present/expected progress in theory:
  QCD factorization, lattice

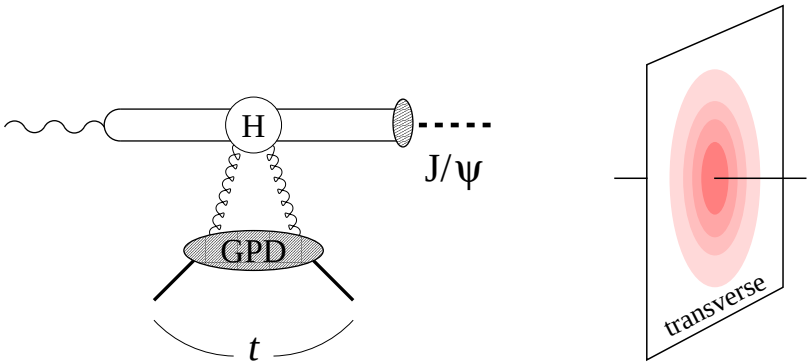
- Natural extension of JLab 12 GeV fixed–target program;
  could get large part of present user community on board

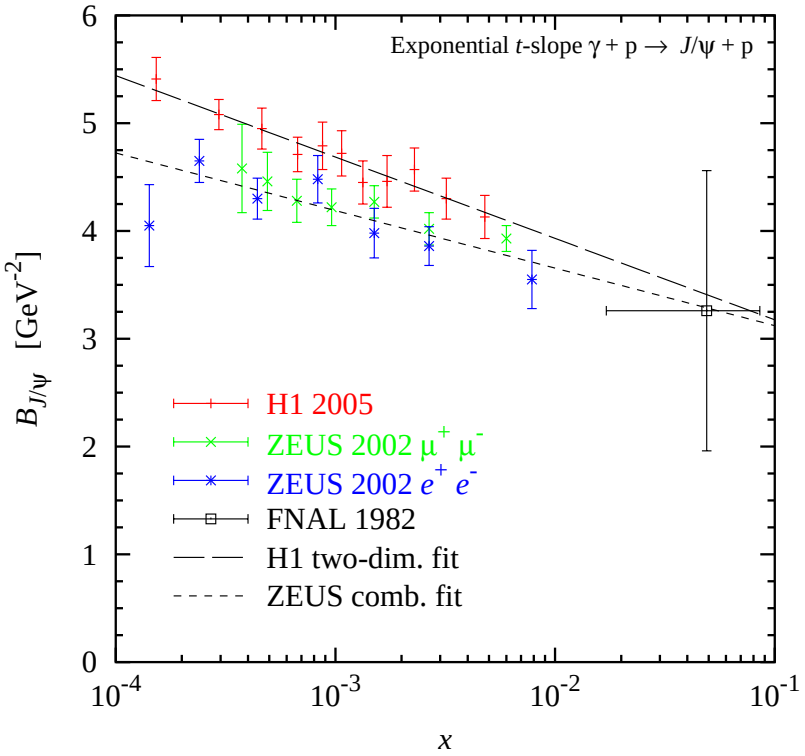
- Detailed simulations needed!
  - Adapt ELIC simulations
  - Use HERMES, COMPASS results; parametrizations

We ask JLab to support further exploration of this concept

Additional material

Exclusive J/ψ: Spatial distribution of gluons

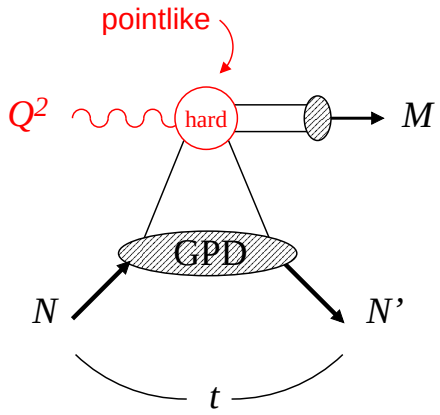




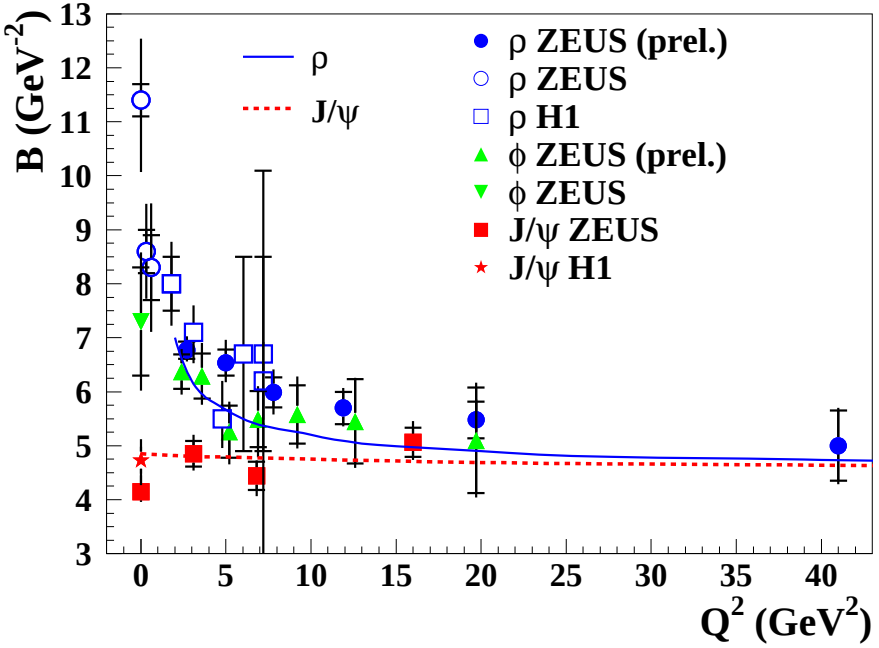
- J/ψ probes gluon GPD: Transverse distribution of gluons
  - Fundamental characteristic of nucleon
  - Input to high–energy pp collisions [LHC]
  - Initial condition for saturation
- Interesting data at small x [HERA, FNAL]
  . . . How to relate to large–x nucleon structure?
- Limited data at large x [SLAC, Cornell]: Exclusivity? t–range?
- Feasible with collider at $L = 10^{33}$!

"Gluon imaging" in valence region

Exclusive meson production: GPDs



Exclusive vector meson t–slope



- QCD factorization: Meson produced in pointlike configuration $r_T \sim 1/Q$

  . . . requires $Q^2 \sim 10\,\mathrm{GeV}^2$! [cf. HERA]

- Vectors ρ^0, ϕ: Unpolarized quarks
  - Large cross section (diffractive)
  - L/T separation through decay

- Pseudoscalars π, η, K: Polarized quarks
  - $\Delta u, \Delta d, \Delta s$ without target polarization
  - L/T separation through Rosenbluth
  - Charged pion formfactor?

Quark spin/flavor/spatial distributions through GPDs