Luminosity upgrade:
RHIC-II science by-passing RHIC-II project
Opportunity for upgrade or 1st EIC stage
EIC = Electron-Ion Collider;
eRHIC = BNL realization by adding e beam to RHIC
LHC HI starts
Long-Term (>2020) Future of QCD Physics at RHIC: EIC → eRHIC

Add ERL injector with polarized e\(^{-}\) source to enable \(\bar{e}p, ^{3}\text{He}\) and e+A (up to Uranium) to study matter in gluon-dominated regime

- 10 GeV electron design energy. Possible upgrade to 20 GeV by doubling main linac length.
- 5 recirculation passes (4 in RHIC tunnel)
- Multiple electron-hadron interaction points (IPs) permit multiple detectors;
- Full polarization transparency at all energies for the electron beam;
- Ability to take full advantage of transverse cooling of the hadron beams;
- Possible options to include polarized positrons at lower luminosity: compact storage ring or ILC-type \(e^{\pm}\) source
- R&D already under way on various accelerator issues; more to come.

Subsequent stages/alternative layouts could increase e-beam & ion-beam energies and \(\mathcal{L}\) from nominal 10 × 250 GeV, \(~3 \times 10^{33}\) \(\text{cm}^{-2}\text{s}^{-1}\) \(\bar{e}p\)
Intermediate-Term Possibilities: 1st (Medium Energy) Stage of EIC?

- Stage I e-RHIC with ERL inside RHIC tunnel @ IP2: 4 GeV e with RT magnets
- 3 recirculating passes: 0.74, 2.05, 3.35 GeV
- Minor civil construct’n required
- 3 recirculating passes: 1.39 and 2.70 GeV plus 4 GeV through detector

Would enable 4 GeV $e^-$ on 100 GeV/N heavy ions and 250 GeV $p^+$

- First look at saturation surface for nuclei in e+A DIS, confirmation of nuclear “oomph” factor; e+A diffraction tests of high gluon occupancy
- $e^-p^+$ program extending DIS, adding: transverse-spin SIDIS over broad $Q^2$-range ⇒ TMD evolution; detection of boosted target fragments to probe spin-dependent correlations, intrinsic heavy flavor in nucleon.

- Developing science case, detector design, cost estimate.
- Most equipment would be reused later in full EIC

Main ERLs:
- 6 cryostats x 6 cavities x 18.1 MeV/cav − 0.652 GeV
Backup Slides
What are the unique quantum many-body manifestations of a non-Abelian gauge theory and self-interacting force carriers? Are there lessons for other fundamental theories, that are more difficult to subject to laboratory investigation? How do we pump/probe fleeting partonic matter in $10^{-23}$ s?

Apply to

new matter: quantify properties of "near-perfect liquid" seen @ RHIC
old matter: determine partonic decomposition of p spin @ RHIC & eRHIC
hot matter: search for critical point in QCD phase diagram in RHIC E-scan, symmetry-violating vacuum fluctuations at high temperature
cold matter: expose & map intense force field (Color Glass Condensate) at heart of all ordinary matter, using eRHIC
EIC Science: Study of Force (Gluon)-Dominated Matter

Search for supersymmetry @ LHC, ILC (?): seeking to unify matter and forces

Electron-Ion Collider: reveal that Nature blurs the distinction

Deep inelastic scattering @ HERA ⇒

Gluons dominate the soft constituents of hadrons! But density must saturate...

EIC probes weak coupling regime of very high gluon density, where gauge boson occupancy >> 1. All ordinary matter has at its heart an intense, semi-classical force field -- can we demonstrate its universal behavior?
Polarized e⁻ + N at EIC

- Polarized DIS, γ-gluon fusion to determine gluon polarization down to \( x \sim \text{few} \times 10^{-4} \)
- Bjorken sum rule test to ≤ 2% precision
- SIDIS for low-x sea-quark polarization and transverse spin studies

More luminosity-hungry:
- Polarized DVCS, exclusive reactions + LQCD ⇒ GPD’s ⇒ map low-x transverse position-dep. PDF’s; \( J_q \) from Ji sum rule
- Parity violation in e⁻+p,d at high \( Q^2 \) to study running of weak coupling below Z-pole

Note INT workshops on EIC science, Fall ’09 and ’10.
Suggested Framing Questions for EIC Science Case

1) **Is main goal of EIC “discovery” or “characterization”?** If latter, what is transformational (as opposed to incremental)? How are we likely to fundamentally alter understanding of QCD and/or QCD matter? Are there likely to be implications beyond QCD? What facility features not available at HERA ($\bar{N}$, A-beams, higher $L$) enable transformational measurements? Not doable in p-A?

2) **Why should scientists not directly involved in QCD studies care about dense gluonic matter?** If we find, or don’t find, clear evidence that gluon field strength saturates, what do we conclude about QCD or nuclei? Are there general implications of transition from dilute parton gas to high gauge boson occupancy?

3) **Are gluon degrees of freedom important for understanding nuclear structure?** Should soft gluon distributions in nuclei exhibit evidence of confinement, or should saturated gluonic matter look identical in nucleons and nuclei? Can we measure gluon spatial distributions in nuclei with sufficient resolution to see nucleon-scale “clumps”?
Suggested Framing Questions, continued...

4) If we can’t solve the nucleon spin puzzle without EIC, can we solve the puzzle with EIC? Do we have a clear strategy for completing a full measurement of the spin sum rule in either target rest frame (Ji sum rule) or on light front (ΔG sum rule)?

5) What features do we hope to unravel with 3D maps from GPDs at low x (more than x-dependence of overall transverse size)? Do we have the transverse spatial resolution to see “fine” structure? Is there a viable strategy to J_q by combining DES with LQCD constraints on moments of GPD’s?

6) Will the running of $\sin^2 \theta_W$ below the Z-pole, at sensitivity levels accessible with PVES @ EIC still be a significant question on the timescale of EIC measurements? Are there other unique EW symmetry opportunities with EIC?

7) What fraction of above science goals could be accomplished, or at least started, with 1st lower-energy stage of EIC? In what ways can experience gained at 1st stage inform accelerator / detector design and cost-effectiveness for a full EIC?