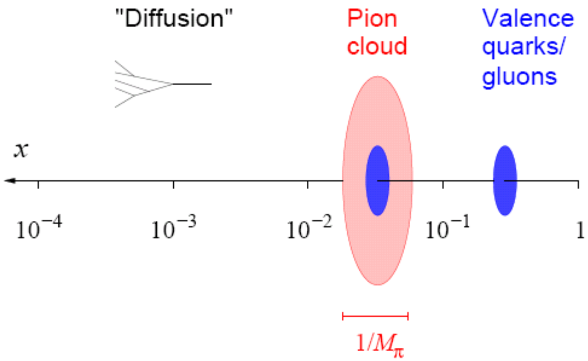
Physics goals of a staged EIC

Tanja Horn (JLab)

EIC collaboration meeting, 13 December 2008



EIC Physics Objectives

NSAC Long Range Plan 2007

QCD at high gluon densities

- High energy (~ HERA), nuclear targets
- Mostly inclusive / diffractive
- Related to *p-p* and ultraperipheral *p-A* / *A-A* programs at LHC and RHIC

AND

Nucleon structure: spin / flavor / spatial

- High luminosity at lower energy, detector resolution, acceptance, PID
- Exclusive / semi-inclusive / inclusive
- Builds on JLab 12 GeV and RHIC spin

How do we get there?

Top-down staging: start by building a high-energy e-A machine

- Staged upgrades will improve luminosity
- Will we be able to carry out the complete *e-p* program?

OR

Bottom-up staging: adopt a physics driven staging scheme

- Machine will evolve to higher ion energies over time
- Performance can be optimized for various physics challenges
- Different parts of the physics program will be completed at each stage

Starting big: eRHIC stage 1

List of topics was discussed at ECT Trento, July 14-18, 2008:

[→ A. Deshpande]

- Inclusive and semi-inclusive DIS: *e-p*
- Systematic study of target fragmentation
- DIS with unpolarized electrons and nuclei from H to U

Details being discussed in working groups (e.g., e-A, e-p)

Starting small: medium-energy collider

Unique opportunity for nucleon structure physics

- Substantial part of the EIC spin / GPD / TMD program can be completed in a smaller collider at an early stage
- High luminosity at medium energies (10^{33} cm^{-2}s^{-1})
- Symmetric kinematics improve resolution, acceptance, and PID
- Difficult or impossible to do with a high-energy collider

Growing interest in nuclear physics community

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

Cost-effective staging path for ELIC

[→ G. Krafft]

- Required booster rings will serve as colliders

e-p at medium energies: overview

- Exclusive processes and GPDs
  - DVMP: spin/flavor/spatial quark structure (Q^2 ~ 10 GeV^2)
  - DVCS: helicity GPDs, spatial quark and gluon imaging
  - Resonance structure from N $\leftrightarrow$ N^* transition GPDs
- Charm as direct probe of gluons
  - J/ψ, exclusive: spatial distribution of gluons
  - D Λ_c, open charm (including quasi-real D^0 photoproduction for ΔG)
- Semi-inclusive DIS
  - Flavor decomposition: $q \leftrightarrow \bar{q}$, $u \leftrightarrow d$, strangeness $s, \bar{s}$
  - TMDs: spin-orbit interactions from azimuthal asymmetries, p_T dependence
  - Target fragmentation and fracture functions
- Inclusive DIS
  - ΔG and $\Delta q+\Delta\bar{q}$ from global fits (+JLab 12 GeV, COMPASS)

e-A at medium energies: overview

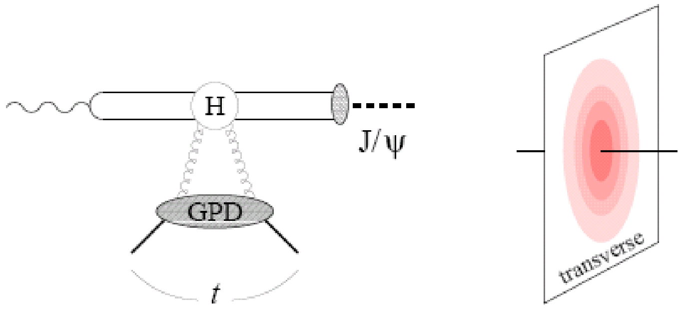
- Inclusive reactions
  - Neutron structure: spectator tagging in *d(e,e'p)X*
  - EMC effect

- 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

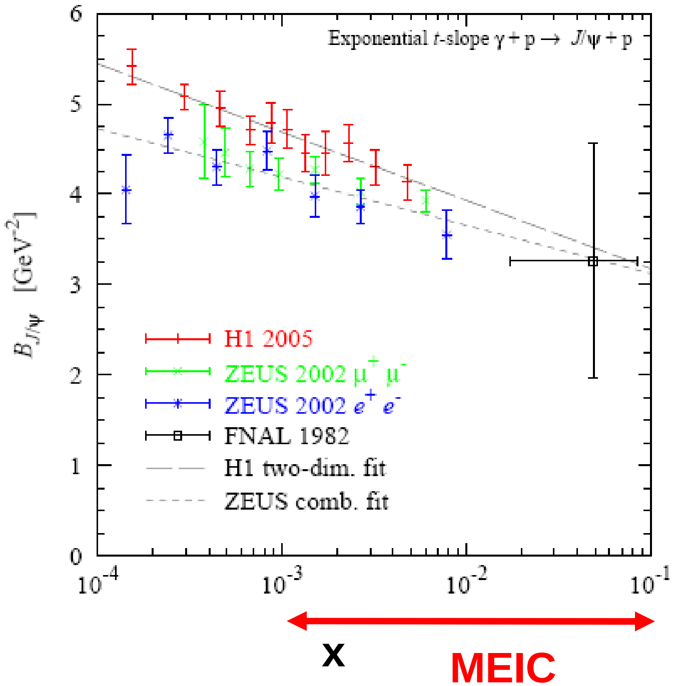
    … much easier than in fixed-target: $|t_{min}| < R_A^{-2}$

- Quark propagation and hadronization in medium

Exclusive J/Ψ: spatial distribution of gluons

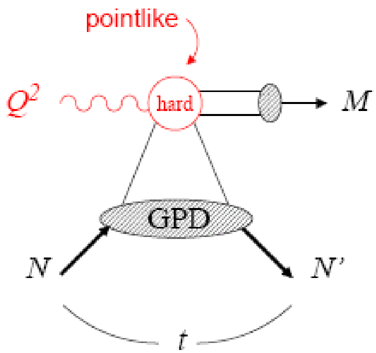


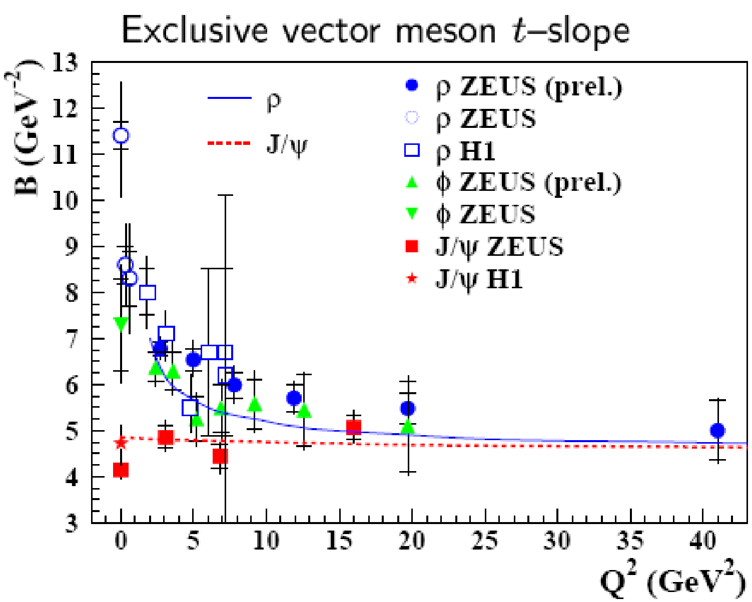
- J/Ψ probes gluon GPDs:
  transverse distribution of gluons
  - Fundamental characteristic of nucleon
  - Input to high-energy p-p collisions (LHC)
  - Initial condition for saturation



- 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
- Gluon imaging in the valence region
- Feasible with a luminosity of 10^{33}

Exclusive meson production: GPDs

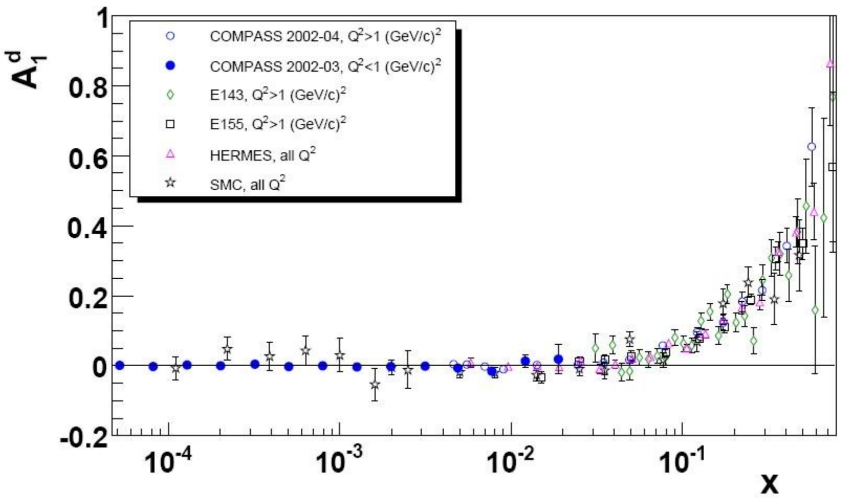


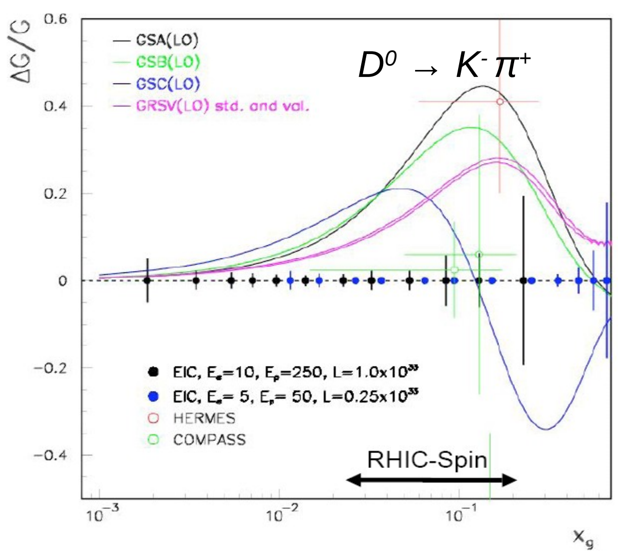


- QCD factorization: meson cloud produced in pointlike configuration $r_T \sim 1/Q$
  - Requires $Q^2 \sim 10$ GeV^2! (cf. HERA)
- Vectors ρ°, φ: unpolarized quarks
  - Large cross section (diffractive)
  - σ_L / σ_T separation through decay
- Pseudoscalars π, η, K: polarized quarks
  - Δu, Δd, Δs without target polarization
  - σ_L / σ_T separation through Rosenbluth
  - Charged pion form factor?
- Quark spin/flavor/spatial distributions through GPDs

These measurements are practically impossible with a high-energy collider

Spin structure: ΔG





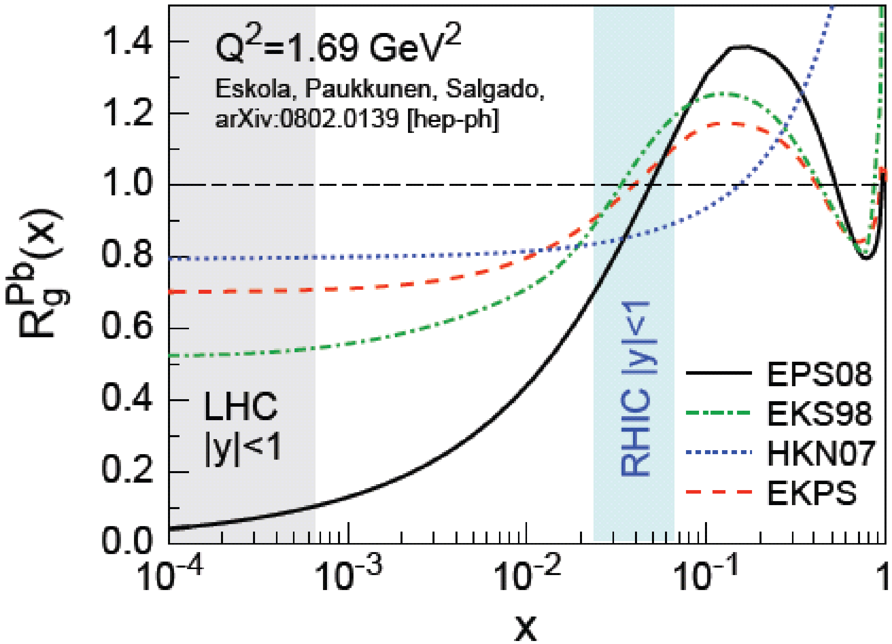
- COMPASS data show that A_1 mostly located at x > 0.01
- No benefit in measuring at small x
- A good determination of ΔG can be made from global fits at moderate values of *s* (<400 GeV^2)
- Detailed studies: Sidorov *et al.*

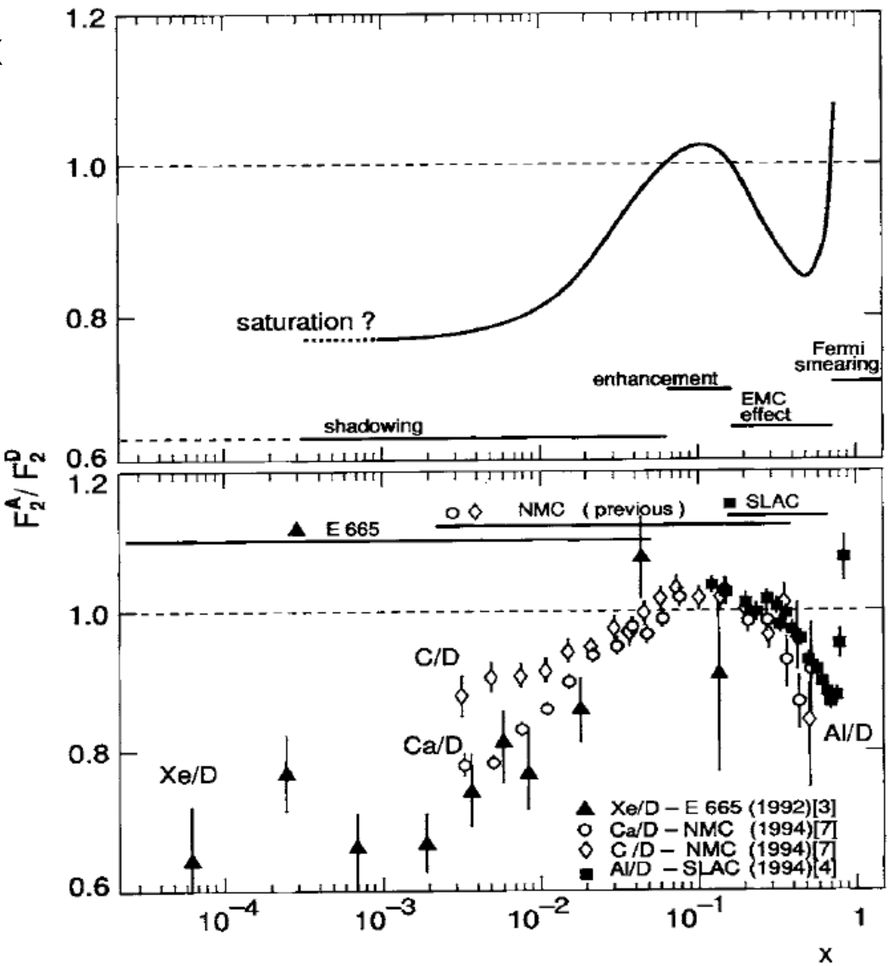
  [→ EIC Hampton meeting talk]

Nuclear modifications: EMC effect

- The MEIC covers a sensitive range in x
  - check for NMC and E665 data
  - better precision than SLAC
- Overlap with LHC at full EIC

Shadowing|Antishadowing|EMC

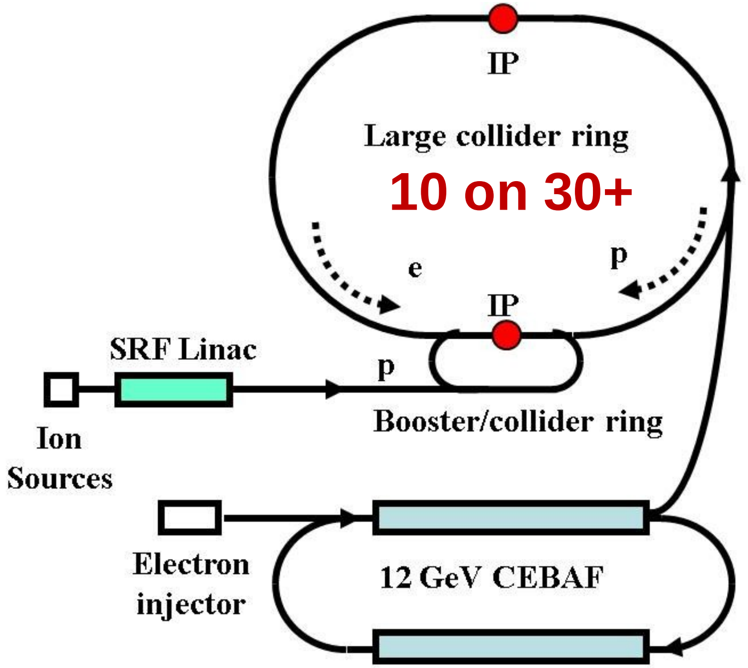




Full EIC ? MEIC

How high does medium energy go?

$$s \approx 4 p_e p_{ion}$$



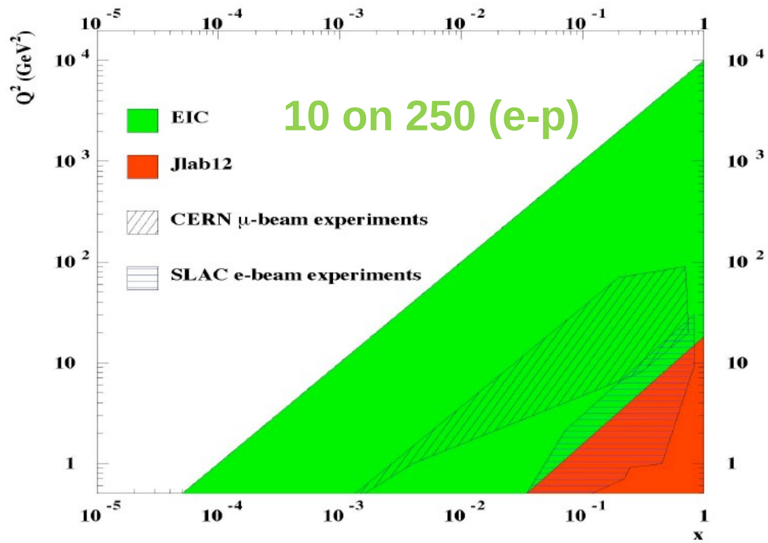
- A few examples (electron on ion):
  - 4 on 250 is like 10 on 100
  - 2 on 250 is like 10 on 50
  - 2 on 150 is like 10 on 30

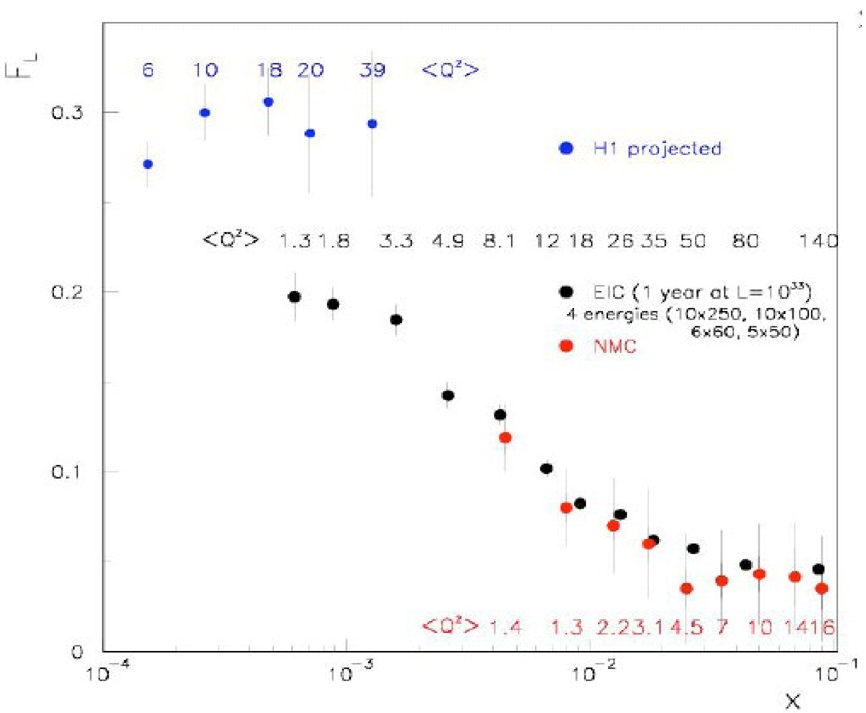
- Stage 2 of a medium energy collider (based on 30+ GeV ELIC booster) would already have a considerable coverage in x and Q^2.
  - with SC magnets, ion energy can be increased to 200+ GeV in the same tunnel

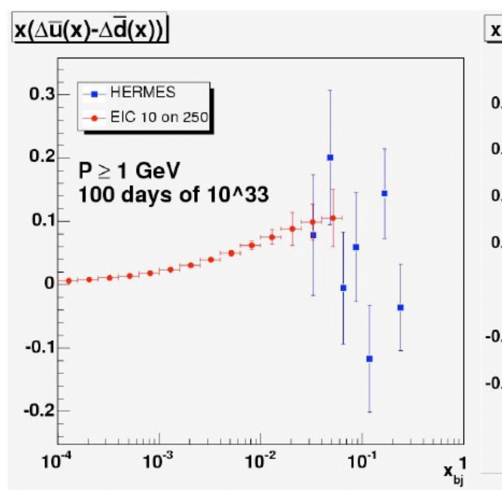
Inclusive reactions at eRHIC or ELIC

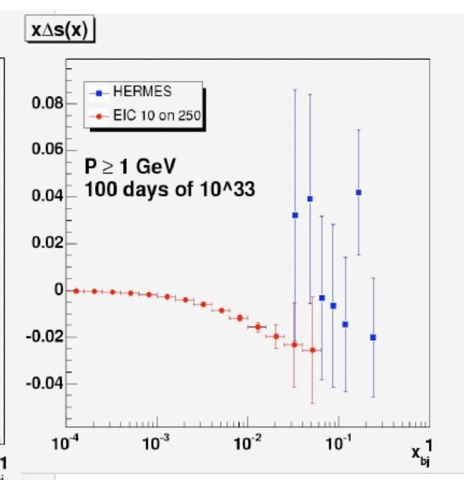
- The low-*x* tails require full EIC
- Low energy may be advantageous for F_L measurements for control of systematic uncertainty

[→ J. Dunlop]







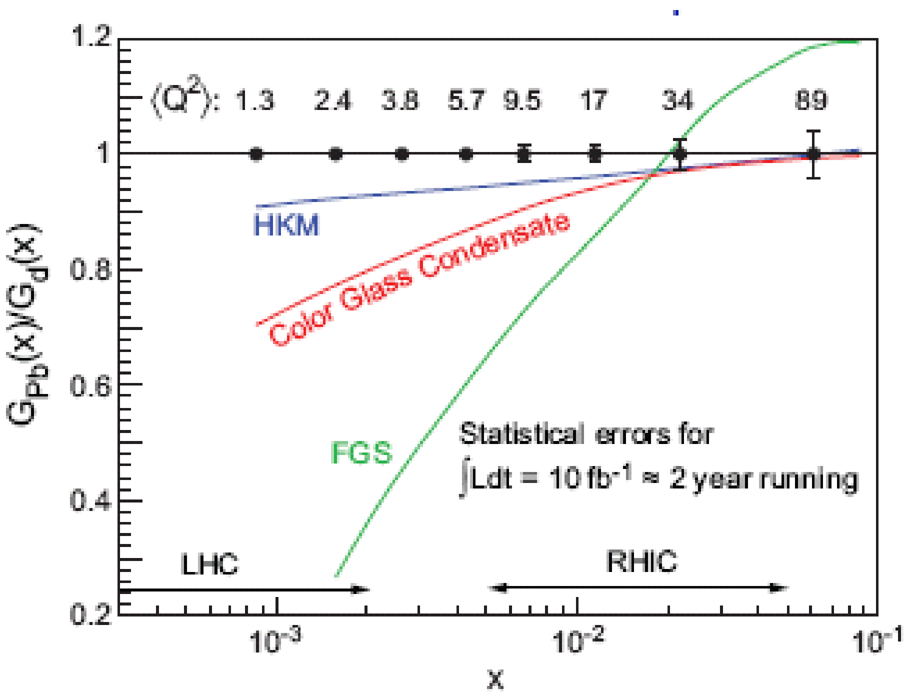


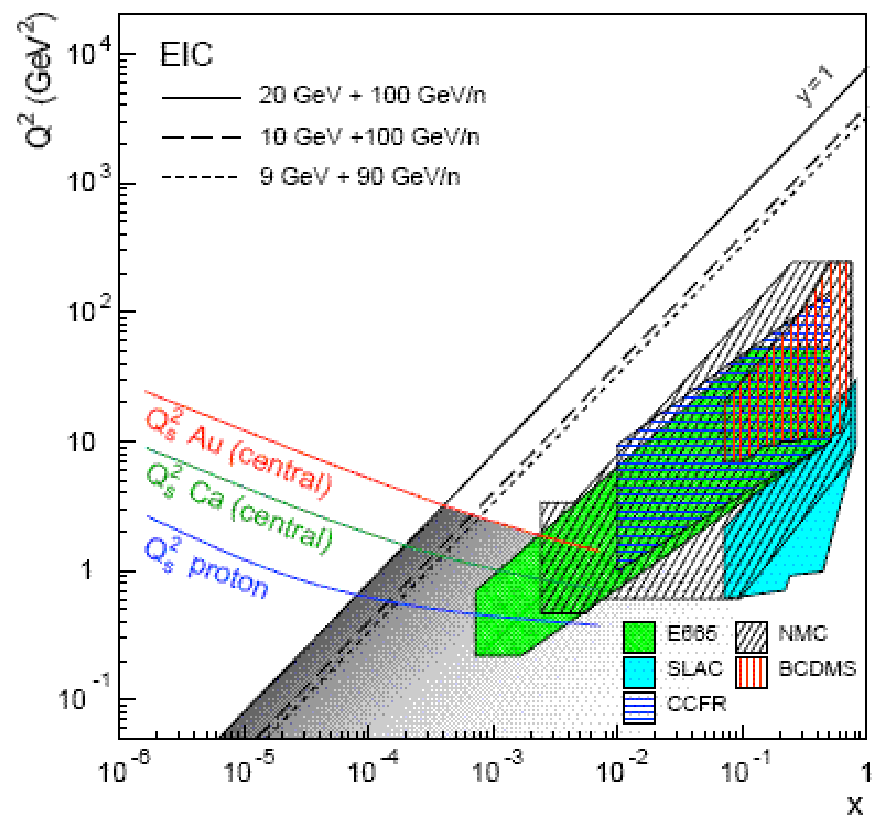
MEIC MEIC

[→ J. Seele]

Gluon Saturation

- Large enhancement of Q_s^A over Q_s^p ?
- New physics?
- Need to need overlap with UPC programs at LHC and RHIC





Theoretical motivation for crossing the saturation scale? [→ J. Dunlop]

Summary

A staged eRHIC would focus on

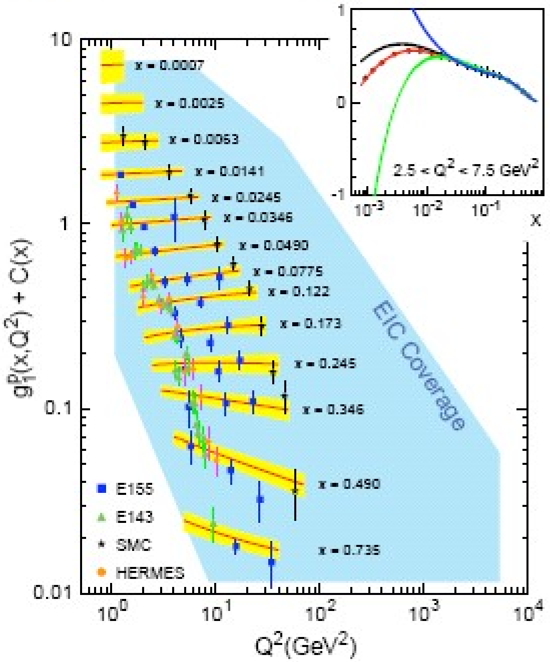
- Inclusive and semi-inclusive (polarized) DIS
- e-A physics with unpolarized electrons and ions ranging from H to U

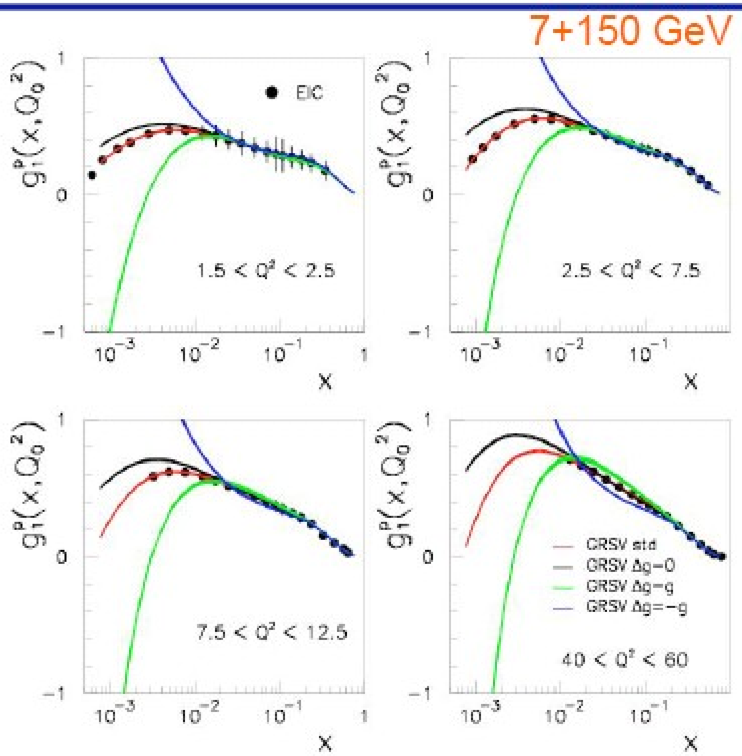
A medium-energy collider as staging for ELIC would allow

- Completing a major part of the EIC nucleon structure program:
  - spin structure + GPDs and TMDs from polarized DVCS, DVMP, SIDIS, J/Ψ
- Polarized e-A for: coherent nuclear processes, neutron structure

Inclusive reactions at high energy

g_1: Energy = x,Q^2 reach





- EIC studies used old GRSV – need to be updated

  [→ W. Vogelsang]