Measuring F_2^n (F_2^d) at the EIC: Some preliminary thoughts

EIC Collider Workshop:

Electron-Nucleon Exclusive Reactions

Rutgers University

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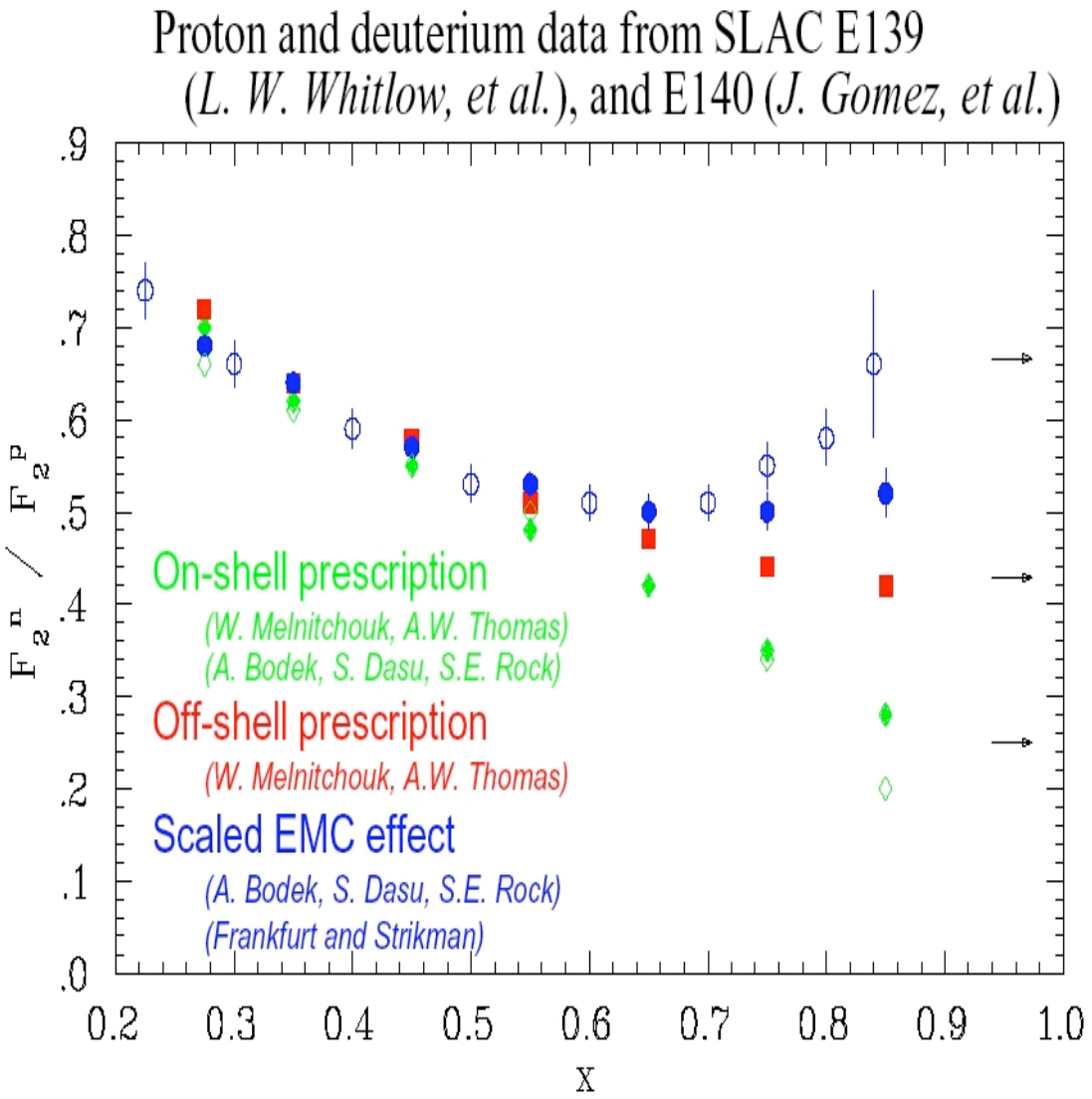
F_2^n/F_2^p and d/u data are from proton and *deuteron* scattering



Neutron structure typically derived from deuterium target by subtracting proton

Large uncertainty in unfolding nuclear effects (Fermi motion, off-shell effects, deuteron wave function, coherent scattering, final state interactions, nucleon structure modification ("EMC"effect)……

F_2^n/F_2^p (and, hence, d/u) is essentially unknown at large x:

- Conflicting fundamental theory pictures
- Data hindered by lack of free neutron target

Review Articles :

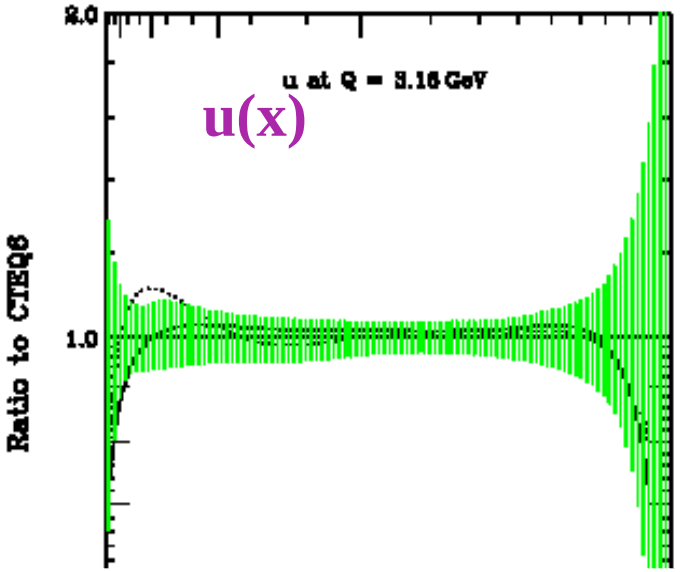
Isgur, Phys. Rev. D59, 34013 (1999)

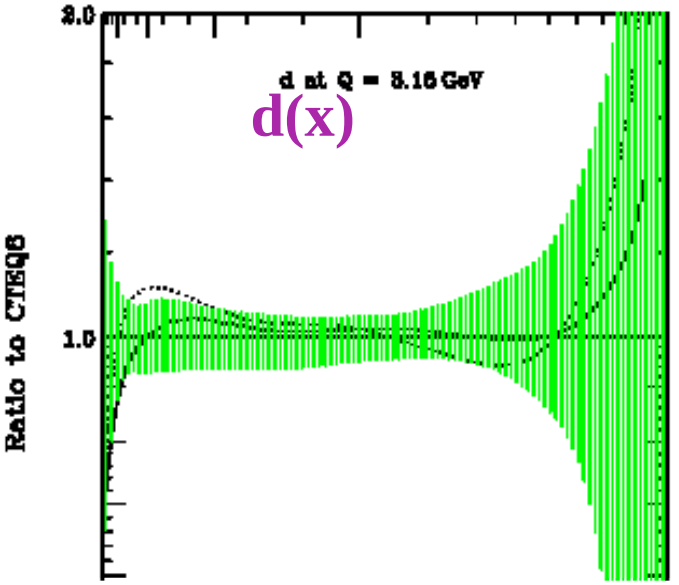
Brodsky et al., Nucl. Phys. B441, 197 (1995)

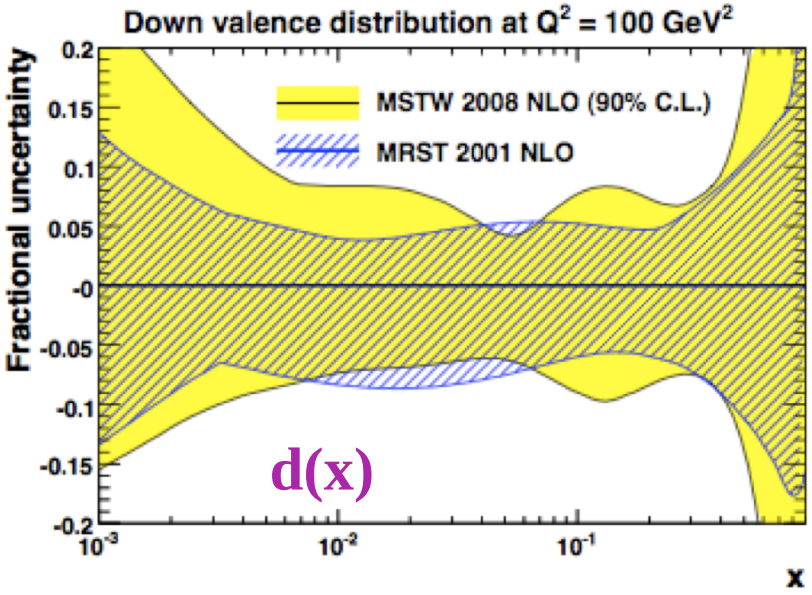
Melnitchouk and Thomas, Phys. Lett. B377, 11 (1996)

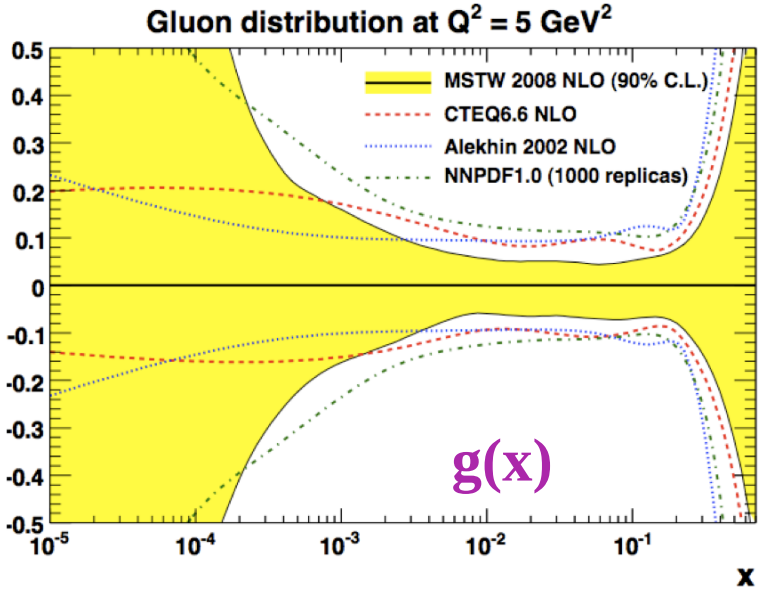
No help available from (or for) global fits, either....

Large x (x > 0.1) -> Large PDF Uncertainties

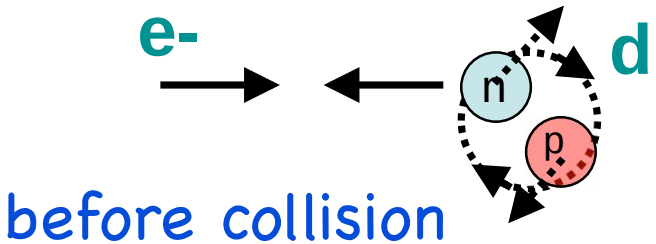






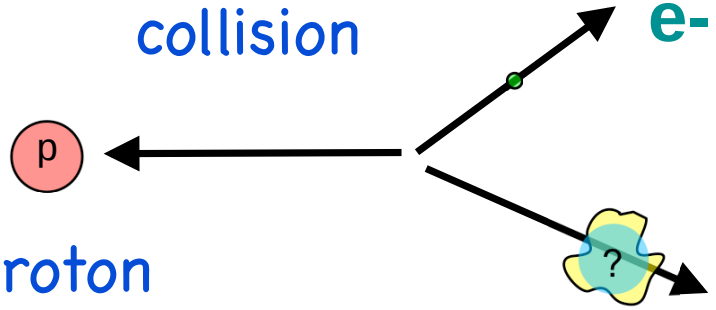


The Spectator Tagging Approach: An Effective Free Neutron Target from Deuterium….



before collision

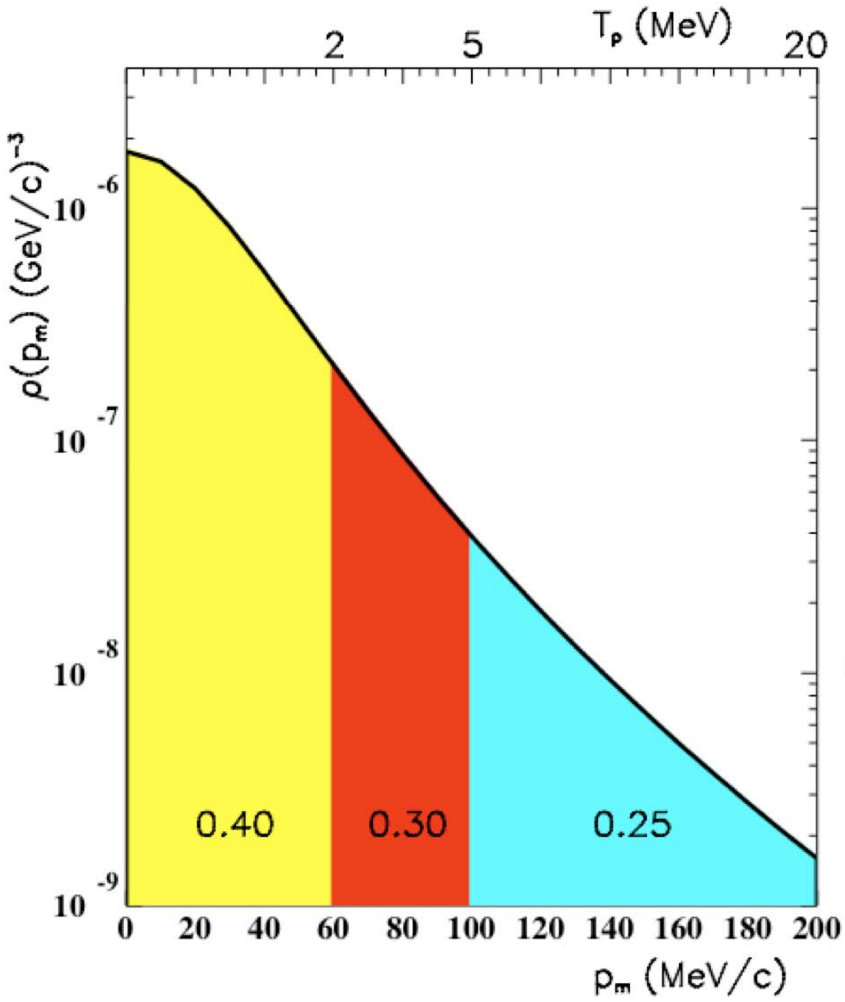
after e-n collision



"spectator" proton

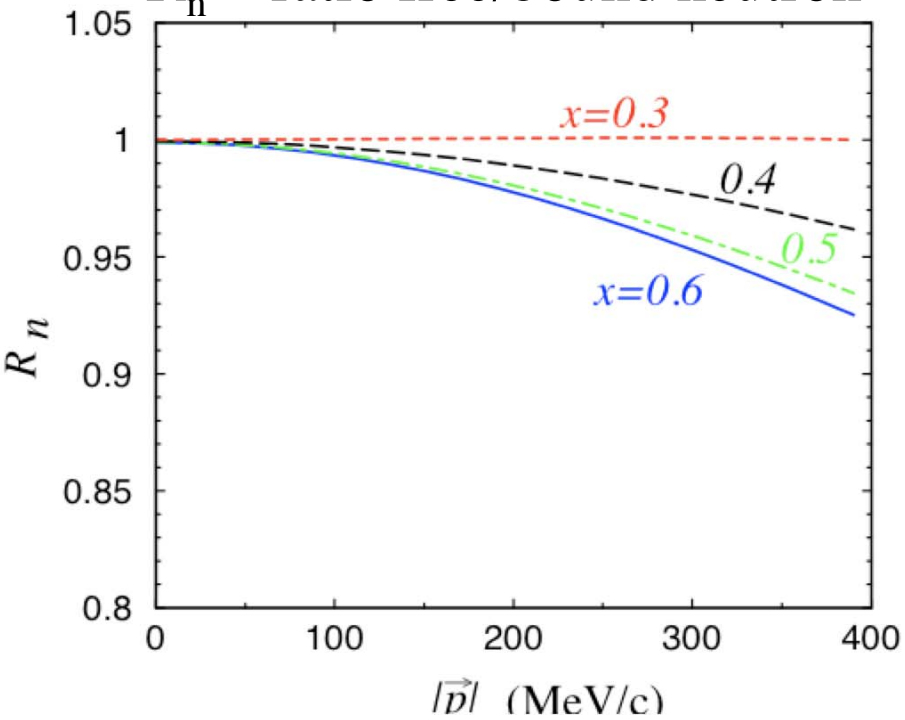
standard DIS event - *from a neutron target!*

Need "VIPs" (Very Important Protons)



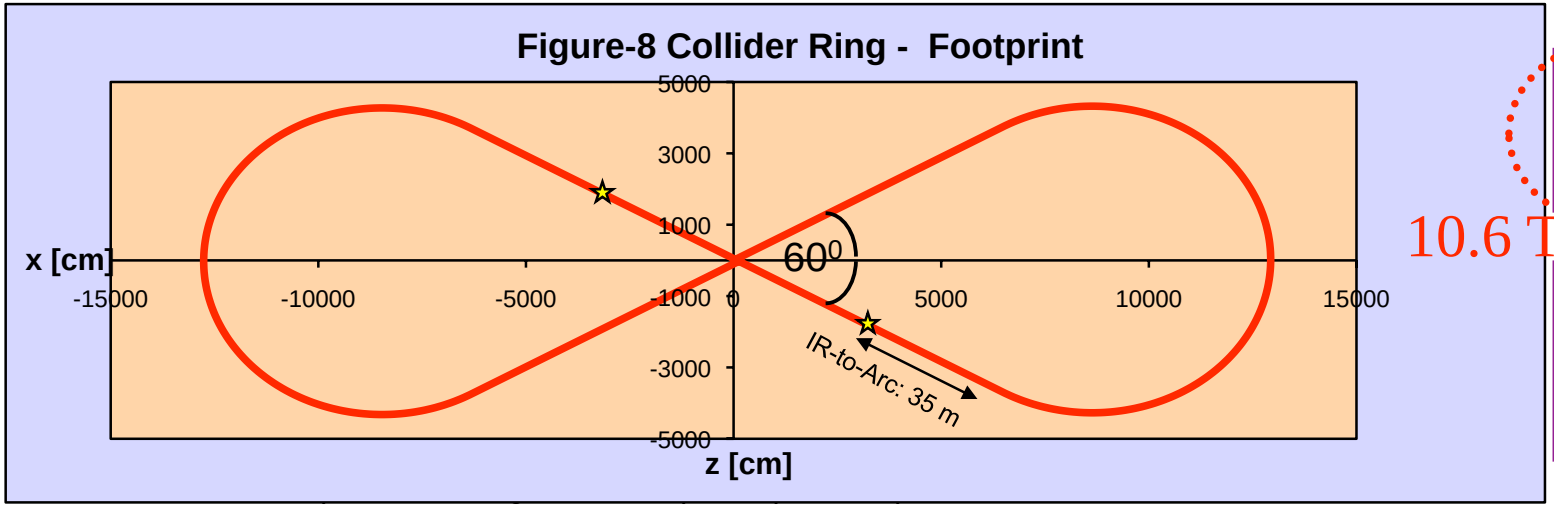
Deuteron ~ free proton + free neutron *only at small nucleon momenta*

R_n = ratio free/bound neutron



plot from W. Melnitchouk

ELIC Figure-8 Ion Ring – Arc Optics 60 GeV



Arc dipoles

$Lb=200 cm

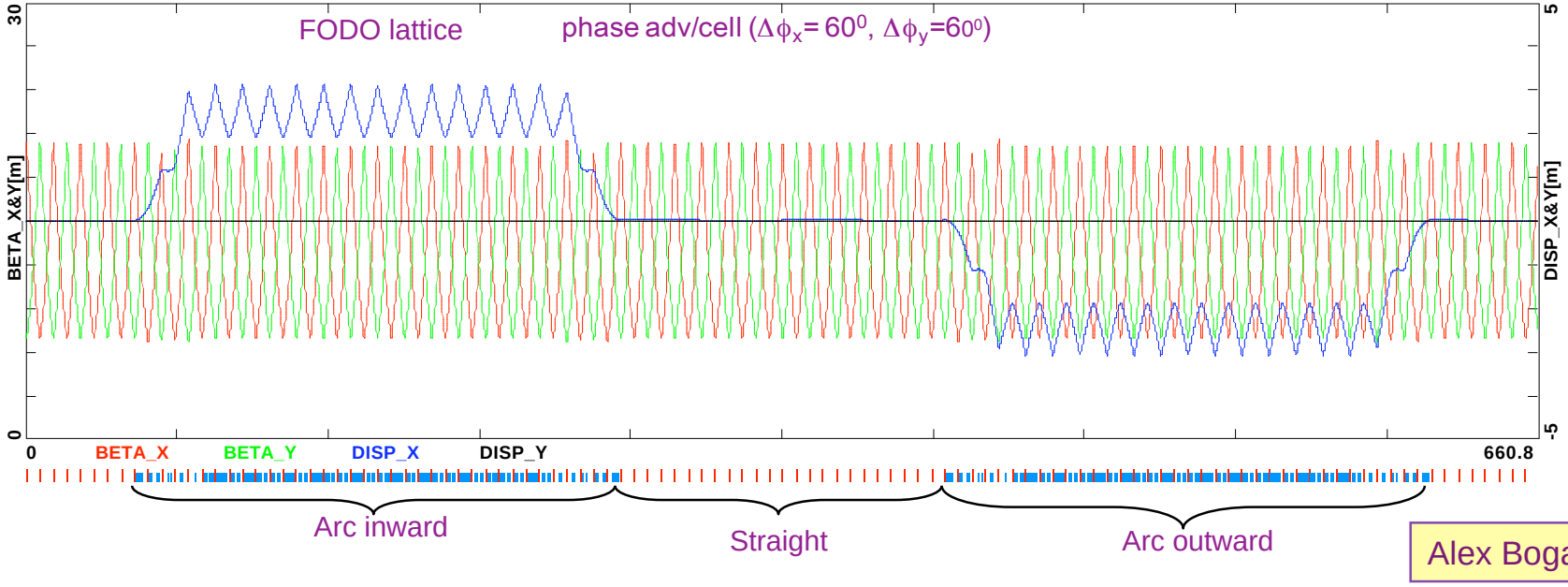
$B=53 kG

10.6 Tm

Arc quads

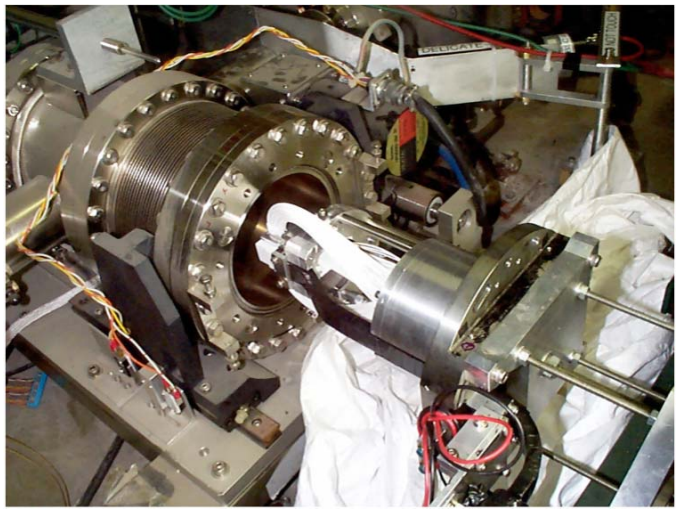
$Lb=40 cm

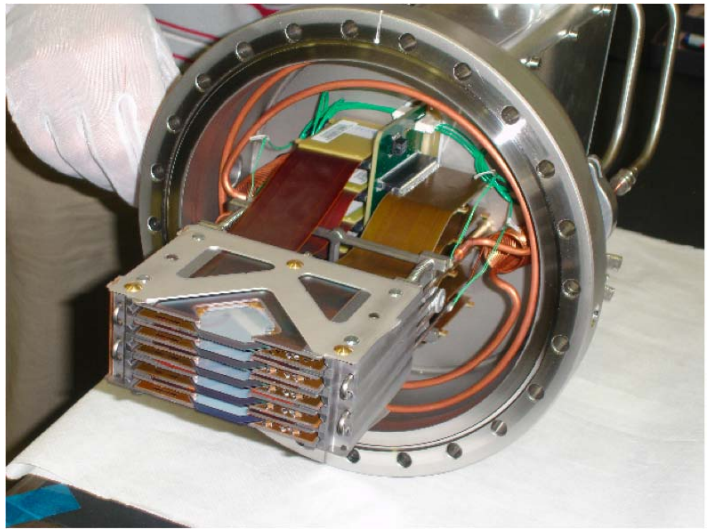
$G= ±**8.5** kG/cm



Alex Bogacz

Proton Tagging





- 10.6 Tm: 30 GeV/nucleon beam bends 106.0 mr

- corresponds to a primary beam bend of 21.2 cm at 1 m after the dipole exit

-1.0% (300 MeV/c) bends 107.07 mr, or 21.4 cm, (too) close to 21.2 cm!

- Try after 4 dipoles, 2 m long with 1 m between, now a separation of (11 + 8 + 5 + 2) * 0.2 cm = 5.2 cm (or 1.7 cm for 0.33%, 100 MeV/c, and 3.4 cm for 0.67%, 200 MeV/c)

- Could go further (halfway) into the arc

- Roman pots (photos at CDF (top), LHC (bottom),……) ~1mm from beam achieve proton detection with < 100μ resolution

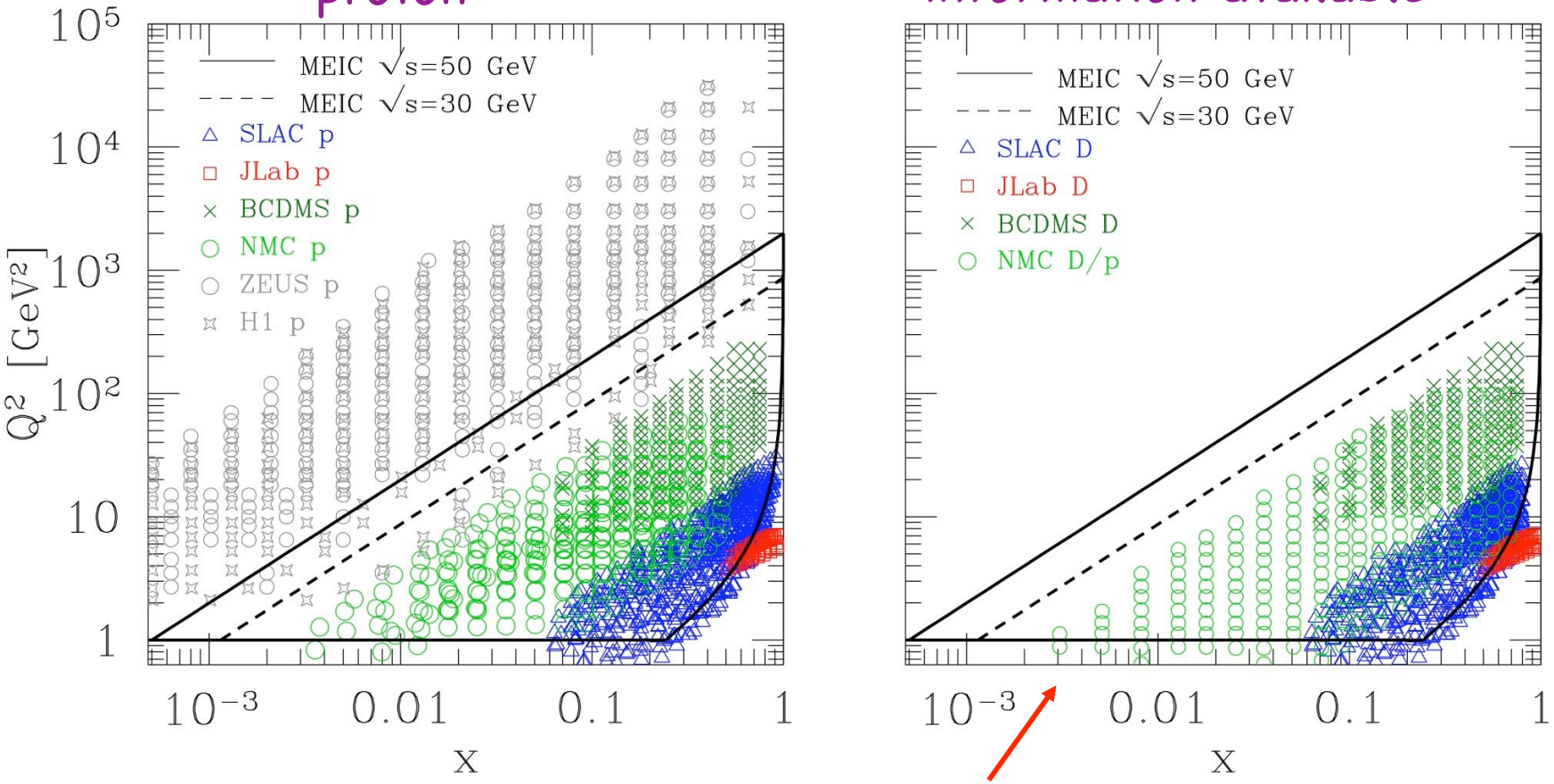
- *Proton tagging concept needs work, but looks doable!*

- Neutrons more difficult - needs some thought

Projected Results I - F_2 Structure Function Phase Space
(plots from A. Accardi, kinematics from R. Ent)

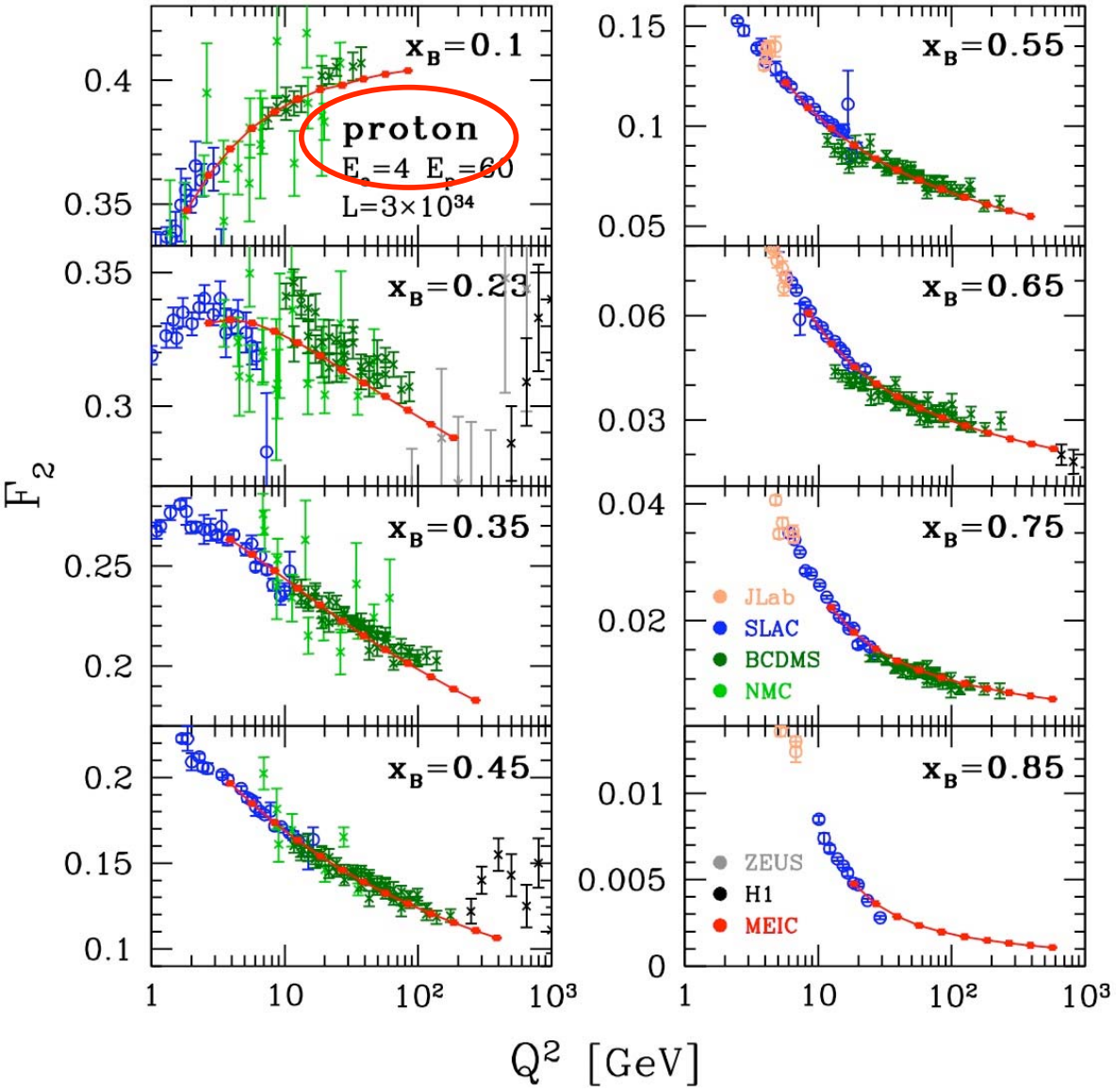
proton

deuteron - *much less information available*



MEIC will probe lower x in the shadowing region, and higher Q^2 at large x.

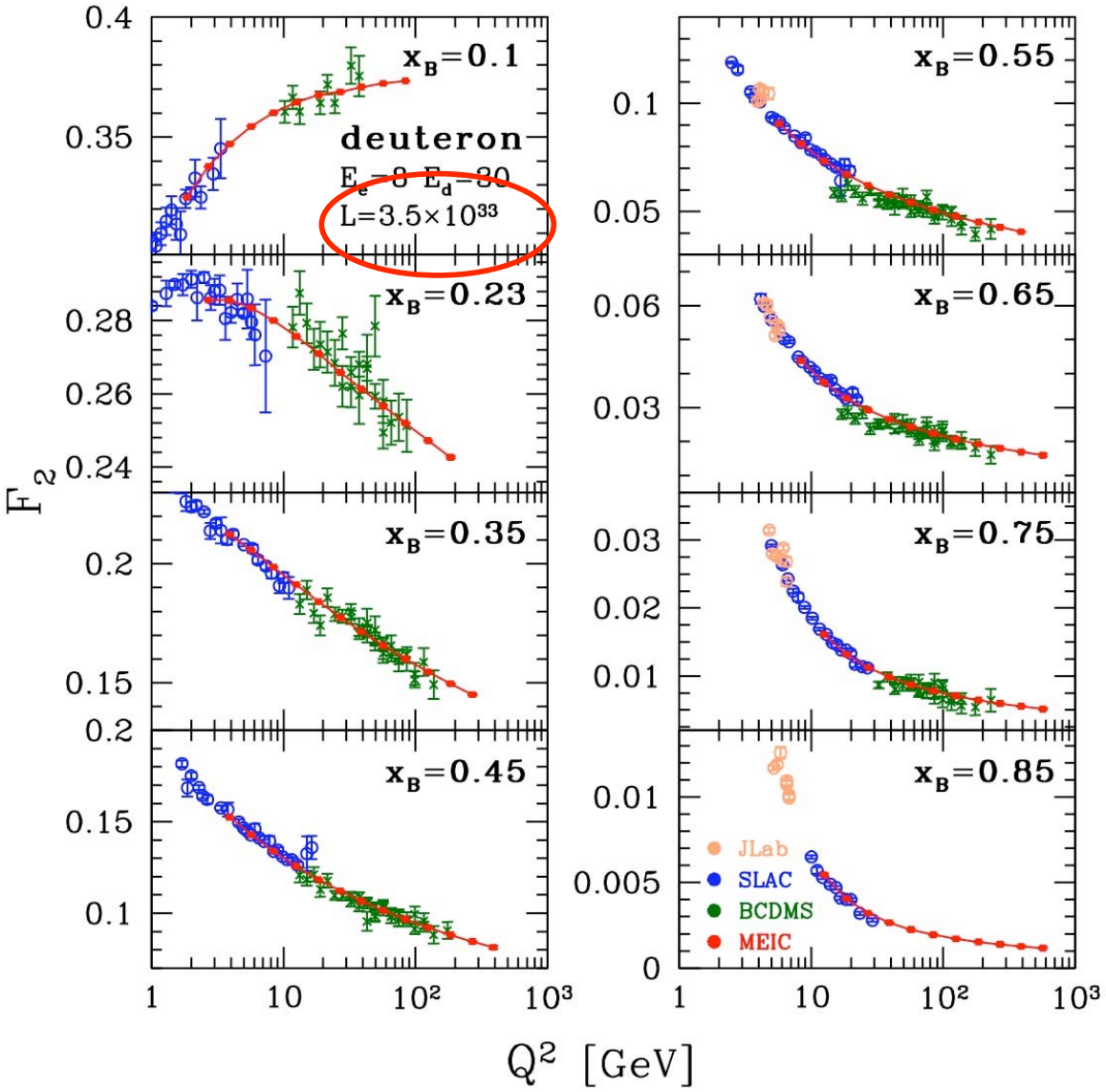
Projected Results IIa - F_2^p Structure Function (from CTEQ6X pdfs)



statistical errors only on projected results

- E_e = 4 GeV, E_p = 60 GeV (s = 1000)
  - larger s (~4000 MeRHIC, or ~2500 MEIC) would cost luminosity
- Somewhat smaller Q^2 reach and large luminosity is better choice at large x, $\sigma \sim (1\text{-}x)^3$
- Luminosity ~ 3 x 10^{34} for MEIC (possible 10^{33} for MeRHIC)
- $0.004 < y < 0.8$
- One year of running (26 weeks) at 50% efficiency, or 230 fb^{-1}

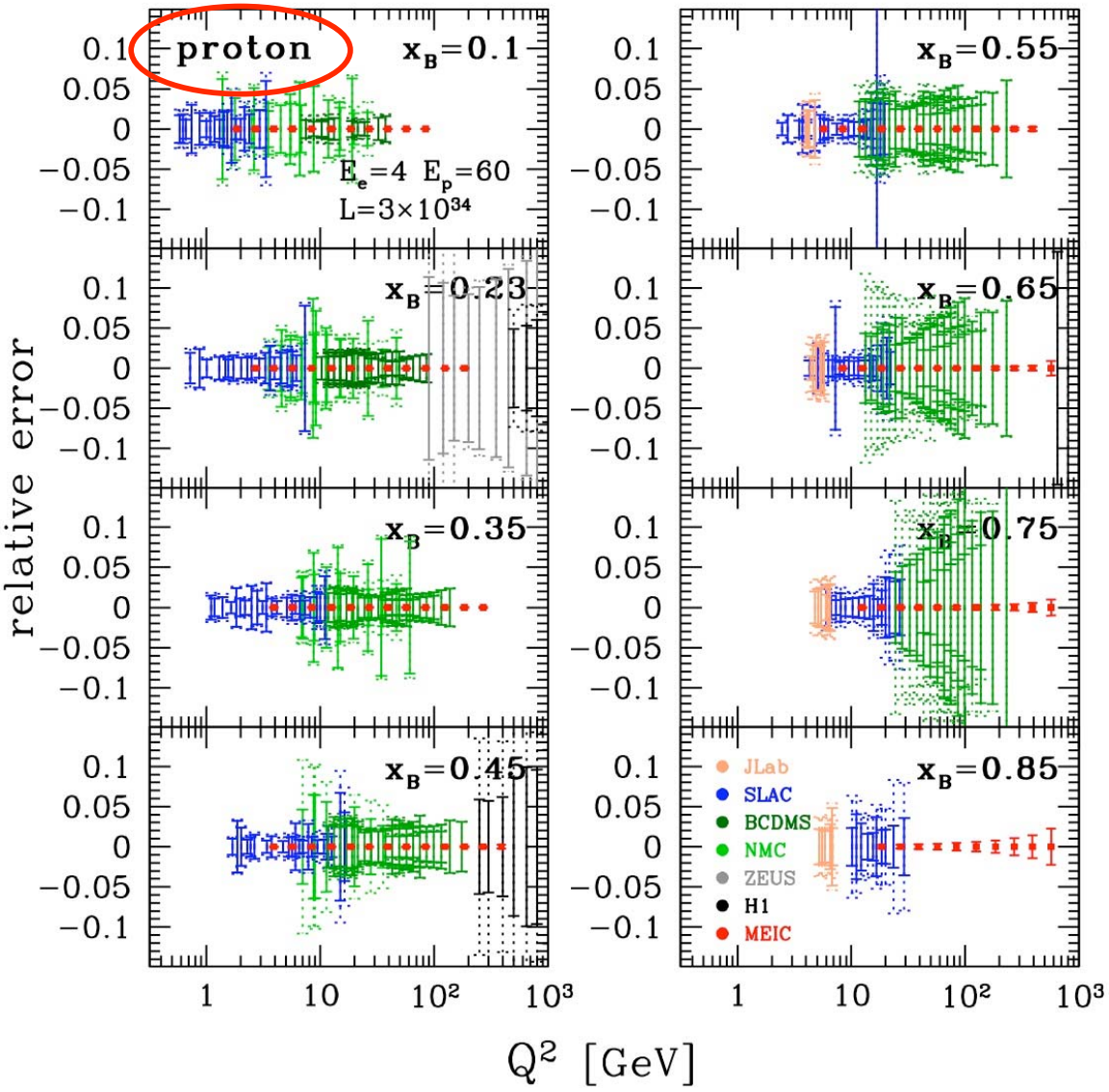
Projected Results IIb - F_2^d Structure Function



- E_e = 8 GeV, E_N = 30 GeV (s = 1000) luminosity ~ 3.5 x 10^{33} for MEIC (scales with synchrotron limit)
- Smaller neutron structure function, reduced luminosity, lose about a factor of 10 loss in rate.
- One year of running (26 weeks) at 50% efficiency, or 35 fb^{-1}
- *Can tag spectator proton, measure neutron, concurrently*

statistical errors only on projected results

Projected Results IIIa - F_2^p Structure Function Relative Uncertainty



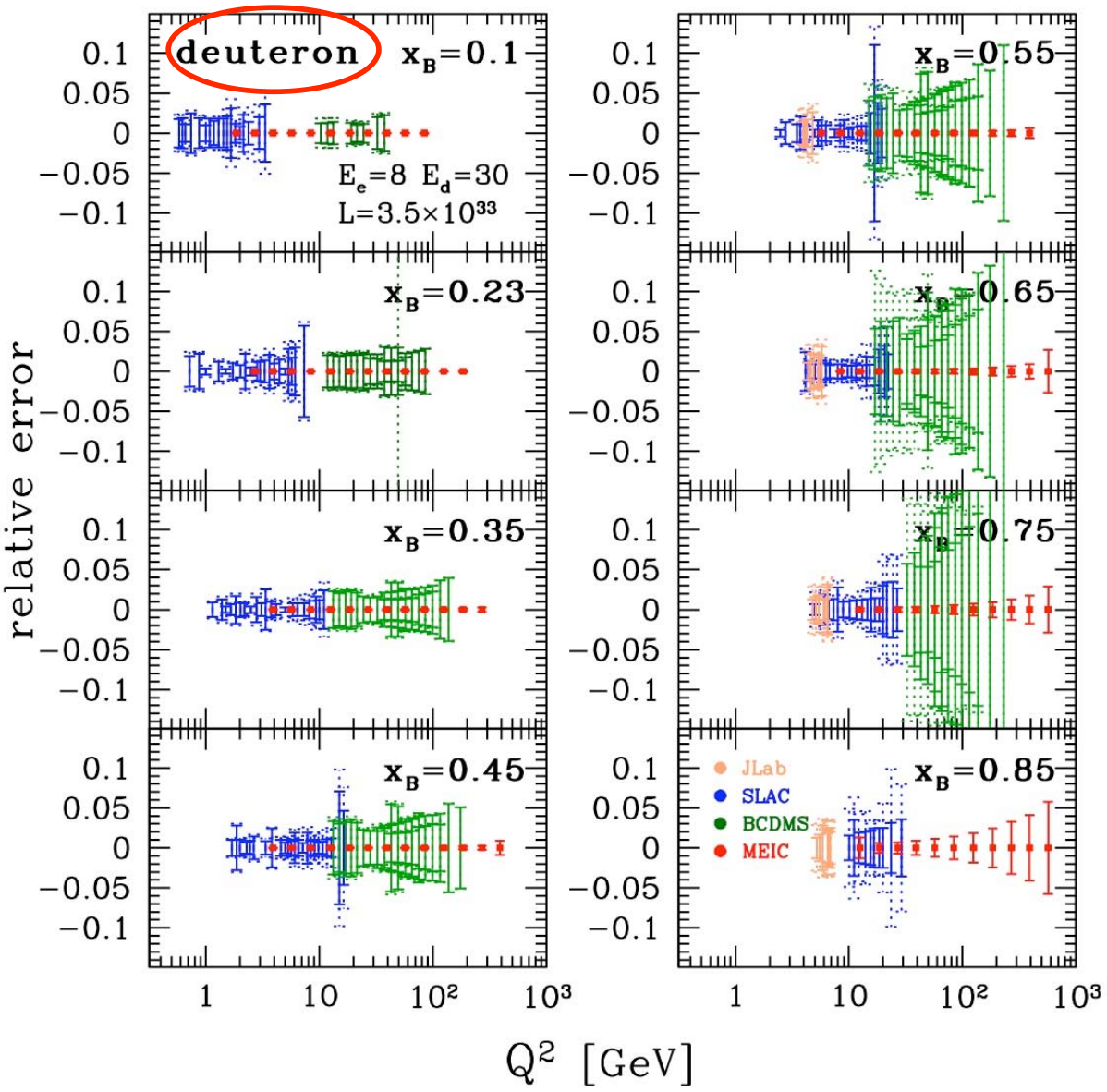
Solid lines are statistical errors, dotted lines are stat+syst in quadrature

For MeRHIC the luminosity is probably down by a factor of ~10, so these error bars will go up ~50%

Huge improvement in Q^2 coverage and uncertainty

Will, for instance, greatly aid global pdf fitting efforts

Projected Results IIIb - F_2^d Structure Function Relative Uncertainty



Even with a factor 10 less statistics for the deuteron the improvement compared to NMC is impressive

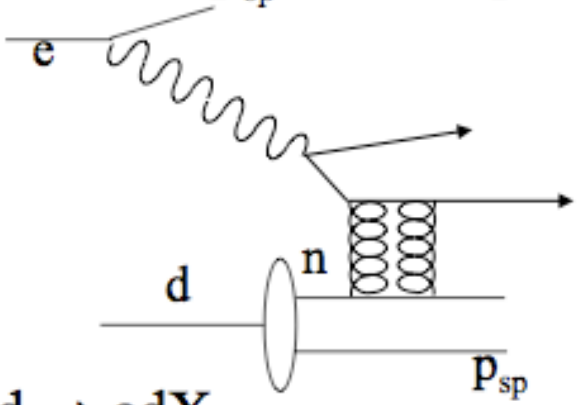
EIC will have excellent kinematics to measure n /p at large x!

And, there's more physics to do as well……

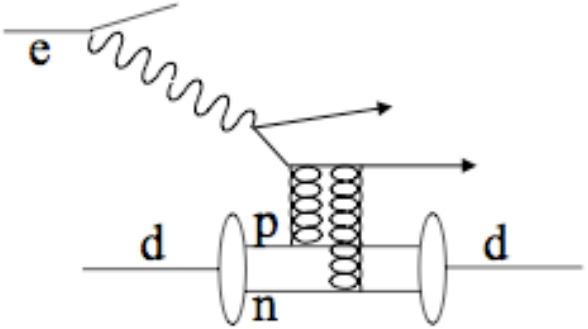
Other physics to do….

For example, diffraction

- Running with ed, plus tagging, allows study of:
  - $ed \rightarrow enXp_{sp}$ $(ed \rightarrow epXn_{sp})$



  - $ed \rightarrow edX$



- Is structure of diffractive exchange same in electron neutron and electron proton scattering?
- Is diffractive exchange produced coherently off deuteron same as that from proton?

And that's not all! Pion structure function, improved α_s determination, singlet/non-singlet separation, nuclear shadowing in deuterium, charged-current cross sections, higher Z targets……!!!!!! ……

Conclusions

- *Much* work to do
  - tagger detector design considerations
  - more detailed analysis
  - FSI, other nuclear effects
  - impact in global fits
  - improvements in radiative corrections
  - etc. etc. etc…….

- Spectator tagging should open up an exciting physics program for the EIC