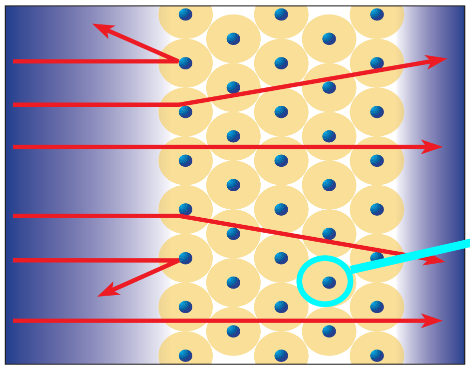
F_L and the Gluon Density

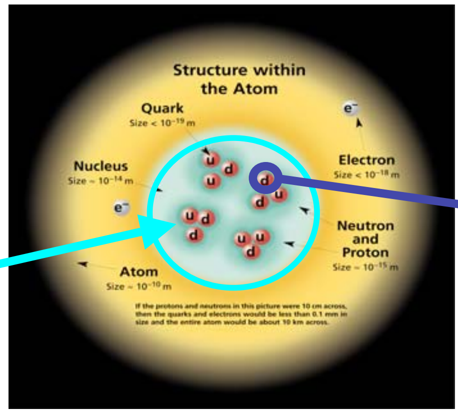
EIC meeting, April 6,7, MIT

A. Caldwell

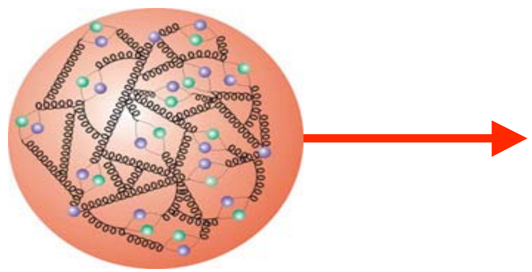
Rutherford



SLAC-MIT,…



HERA

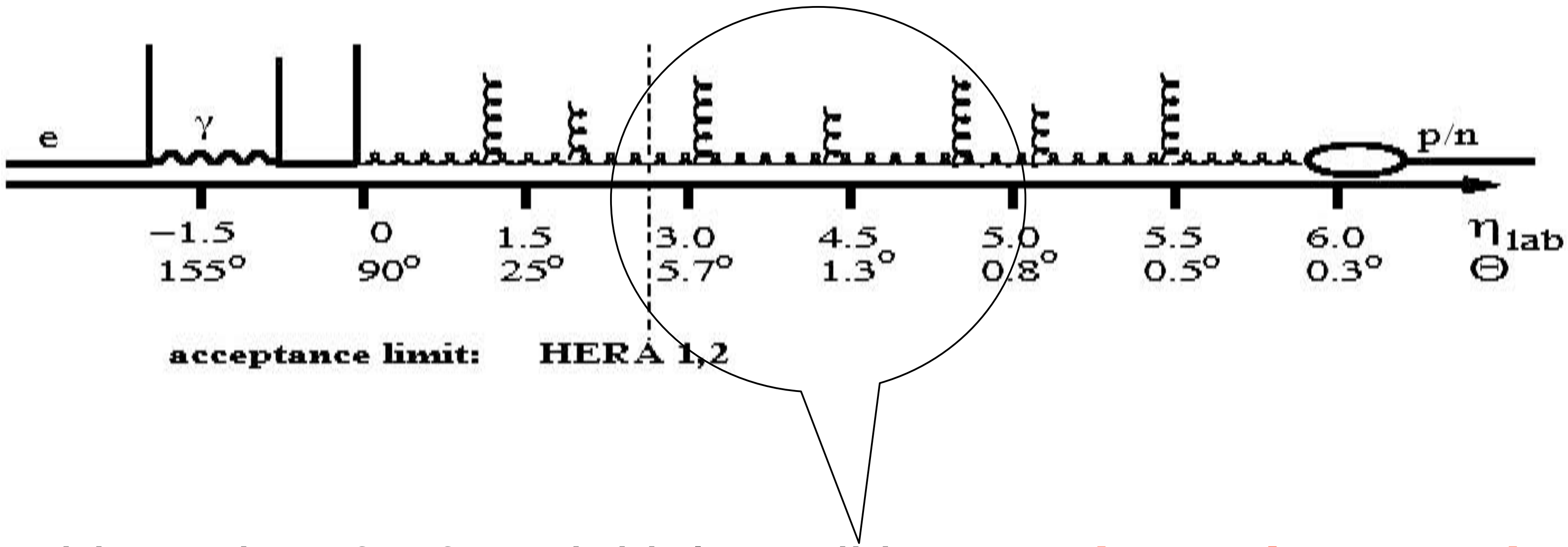


EIC

?

Motivation

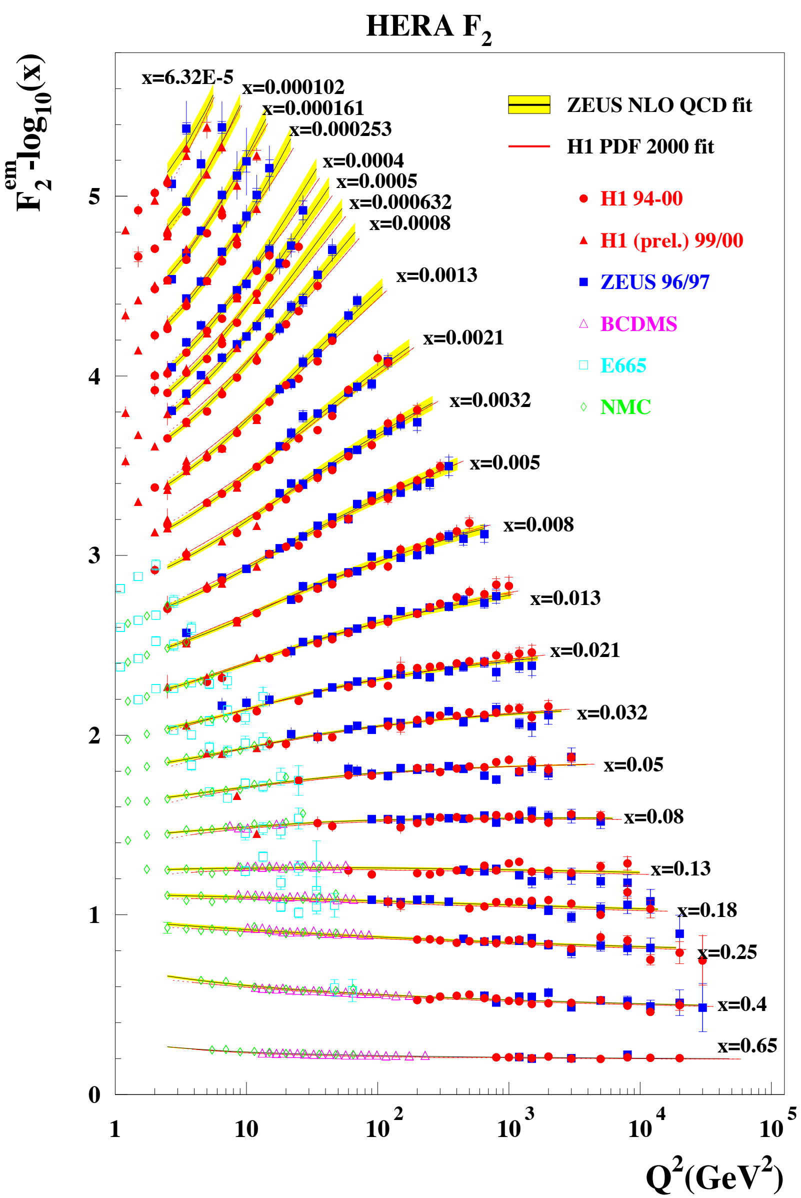
At small x, gluons physics dominates



In this region, far from initial conditions: **universal properties?**

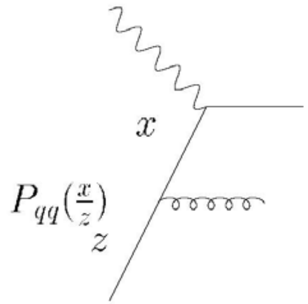
Fundamental aspect of QCD. F_L good probe of this physics.

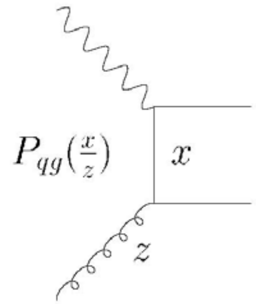
Proton Structure



Q^2 dependence in agreement with the expectations of perturbative QCD (famous **Dokshitzer, Gribov, Lipatov, Altarelli, Parisi** evolution equations).

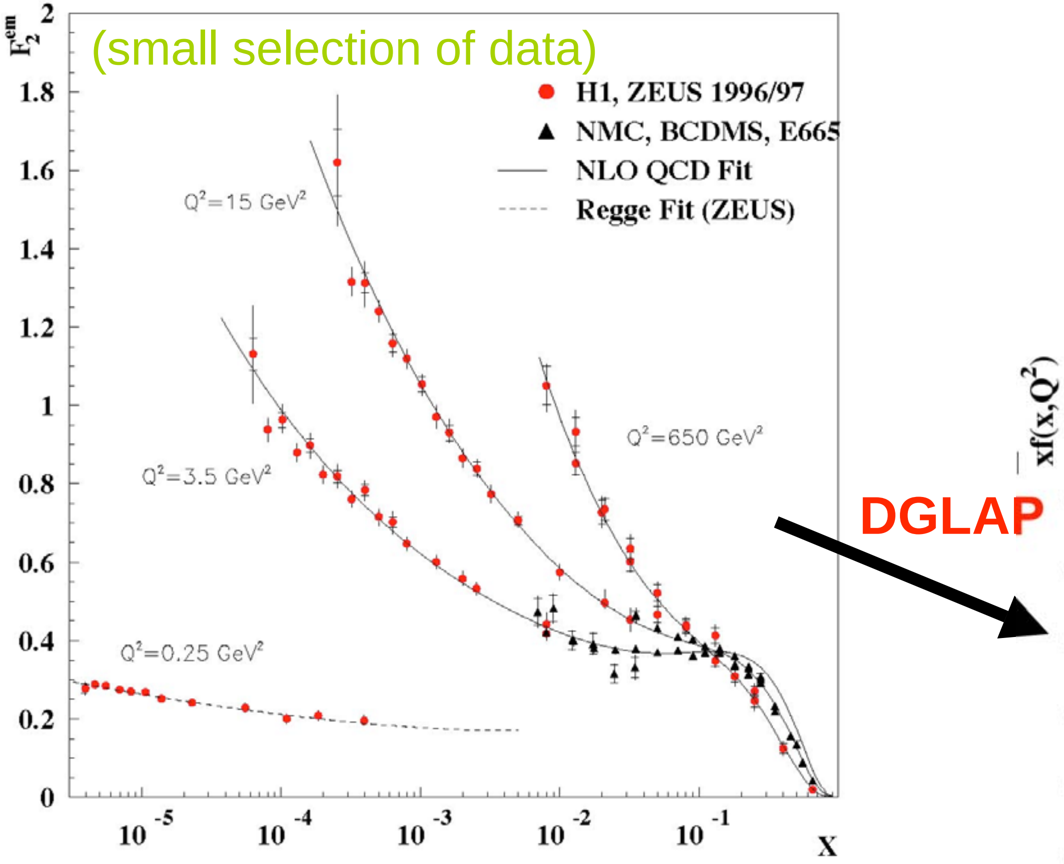
DGLAP



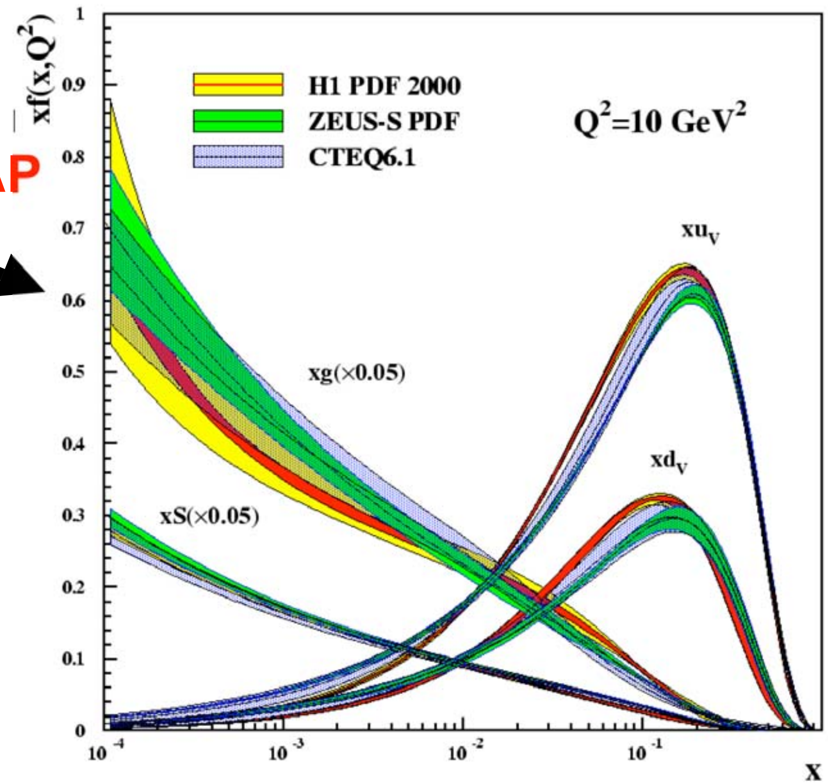


$$\left.\frac{\partial F_2}{\partial \ln Q^2}\right|_x = \frac{\alpha_S(Q^2)}{2\pi}\left[\int_x^1 \frac{dz}{z}\left(\frac{x}{z}\right)P_{qq}\left(\frac{x}{z}\right)F_2(z,Q^2) + \int_x^1 2\sum_q e_q^2 \frac{dz}{z}\left(\frac{x}{z}\right)P_{qg}\left(\frac{x}{z}\right)zg(z,Q^2)\right]$$

Proton Structure



QCD based fits can follow the data accurately, yield parton densities.



Proton Structure

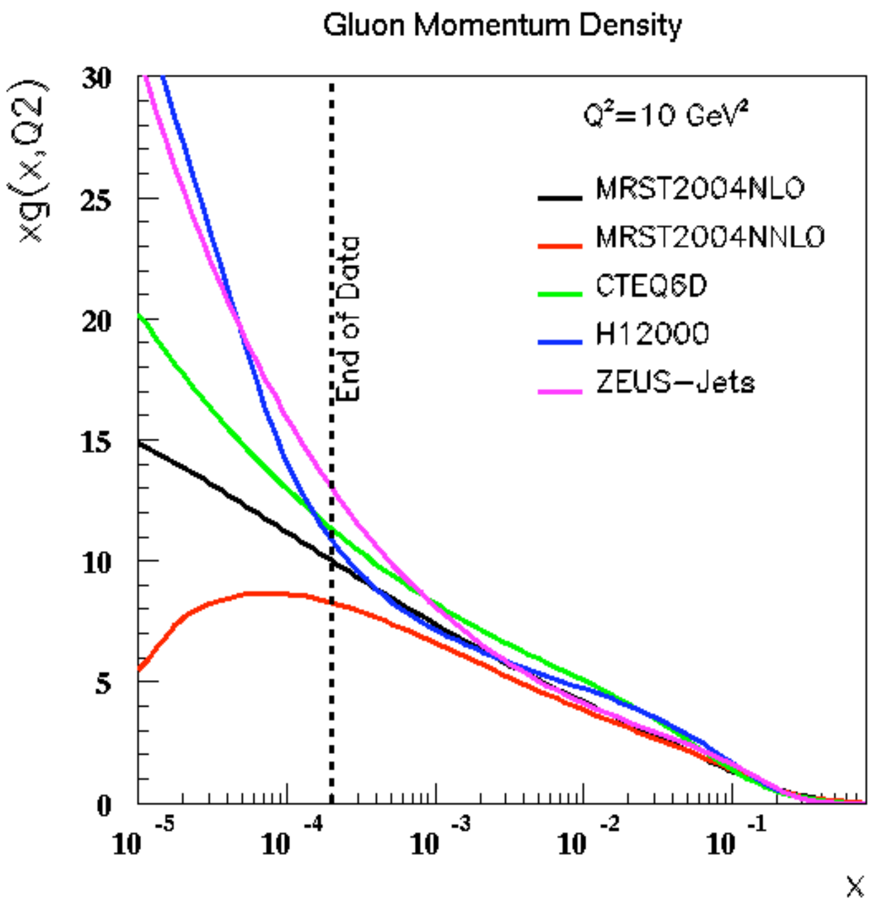
BUT:

- many free parameters (18-30) (DGLAP only knows how parton densities evolve in Q^2)

- form of parametrization fixed by hand (not given by theory)

- Fits don't agree at small-x ! In particular, large uncertainty in gluons

- parametrizations should not be extended beyond measurement range in x



(divergence at fixed small-x larger at low Q^2, smaller at high Q^2)

F_L

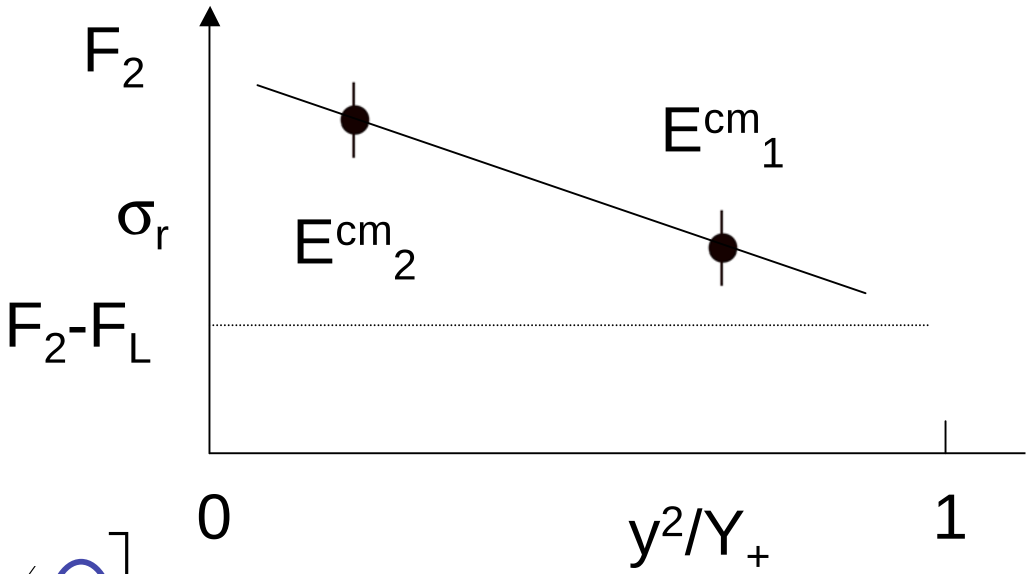
Need better data to test whether our parton densities are reasonable. The structure function F_L will provide an important test.

negligible at small Q^2

$$\frac{d^2\sigma(e^{\mp}p)}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4}\left[Y_+F_2(x,Q^2) - y^2F_L(x,Q^2) \pm Y_-xF_3(x,Q^2)\right]$$

$$Y_\pm = \left(1 \pm (1-y)^2\right)$$

Need two beam energies to measure F_L



$$F_L = \left(\frac{Q^2}{4\pi^2\alpha}\right)\sigma_L$$

$$F_L = \frac{\alpha_S}{4\pi}x^2\int_x^1\frac{dz}{z^3}\left[\frac{16}{3}F_2 + 8\sum e_q^2(1-x/z)zg\right]$$

Directly sensitive to xg at small-x

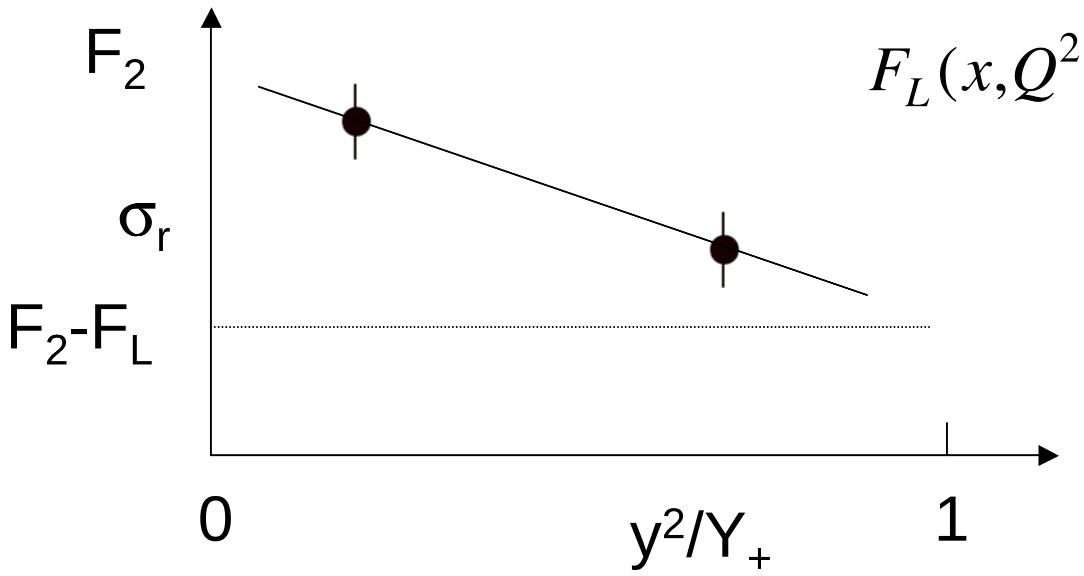
Measuring F_L

$$\frac{d^2\sigma}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4}\left[Y_+ F_2(x,Q^2) - y^2 F_L(x,Q^2)\right]$$

Small Q^2, ignore F_3

$$Y_+ = \left(1 + (1-y)^2\right)$$

$$\sigma_r = \left(\frac{2\pi\alpha^2 Y_+}{xQ^4}\right)^{-1} \frac{d^2\sigma}{dxdQ^2} = \left[F_2(x,Q^2) - \frac{y^2}{Y_+} F_L(x,Q^2)\right]$$



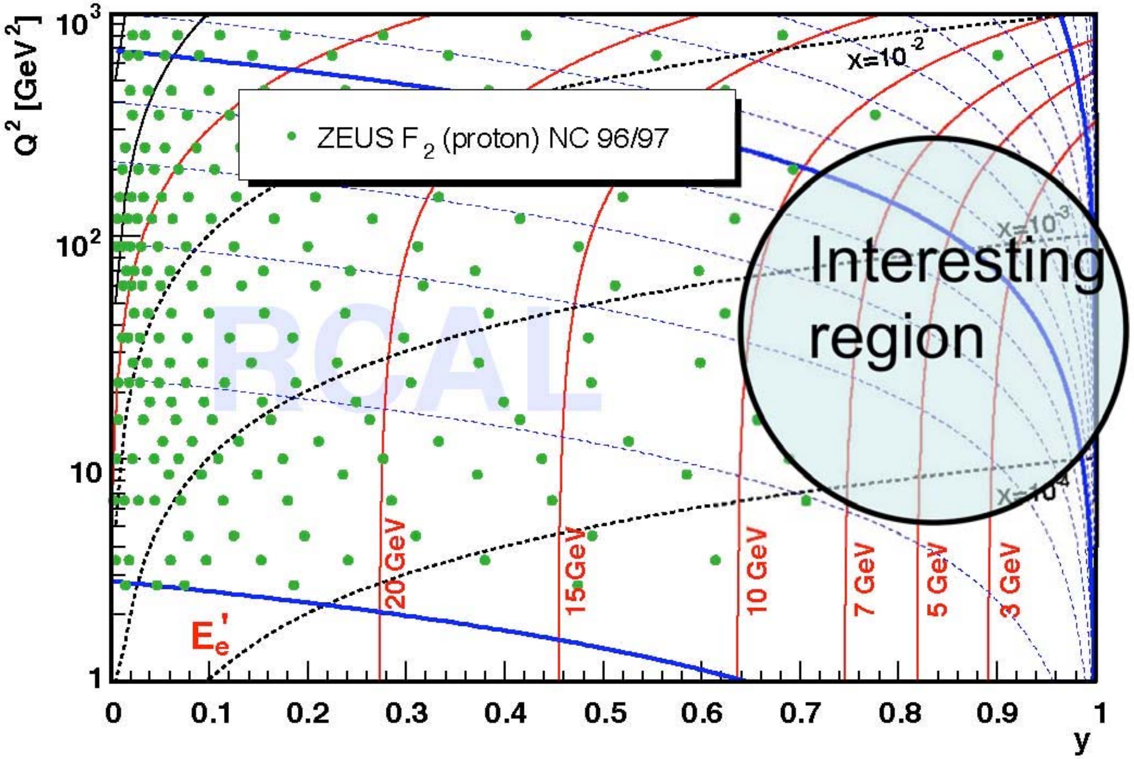
$$F_L(x,Q^2) = \frac{\sigma_r(x,Q^2,y_1) - \sigma_r(x,Q^2,y_2)}{f(y_2) - f(y_1)}$$

$$f(y) = {y^2}/{Y_+}$$

For best sensitivity, maximize lever arm (y-range)

Measuring F_L

HERA Kinematics

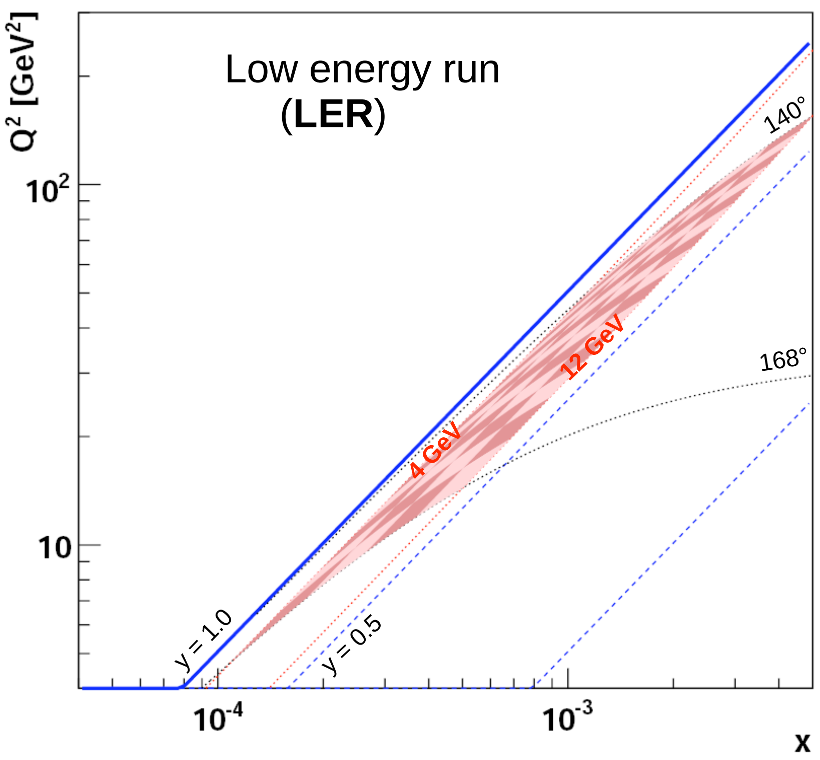


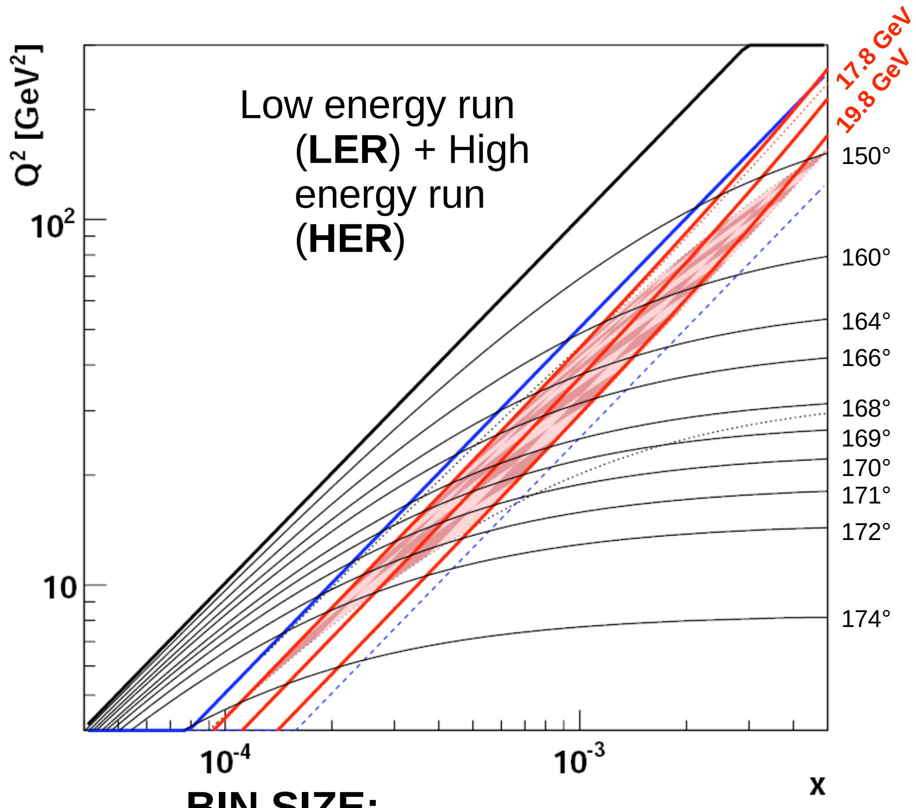
Need to go to lowest possible scattered electron energy:

- lower E_P rather than E_e
- trigger efficiency
- electron finder efficiency
- electron finder purity (photoproduction background, wrong candidate)

Measuring F_L

HERA Kinematics



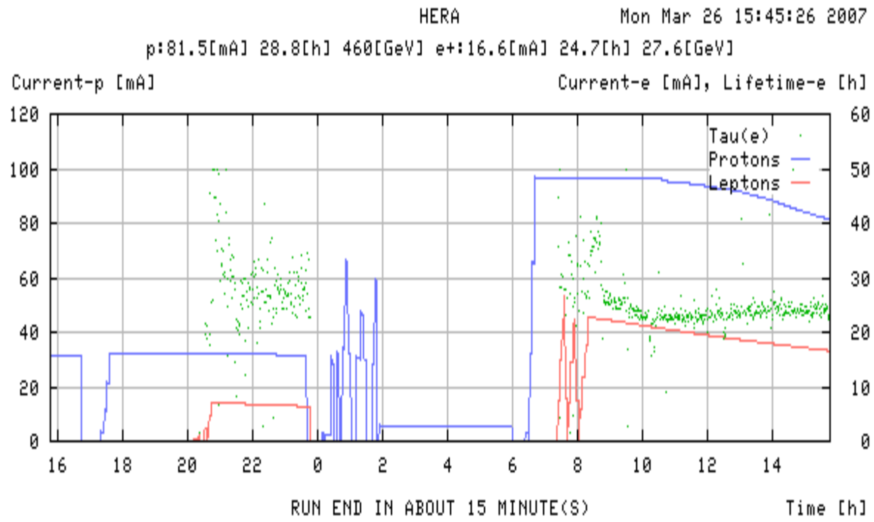


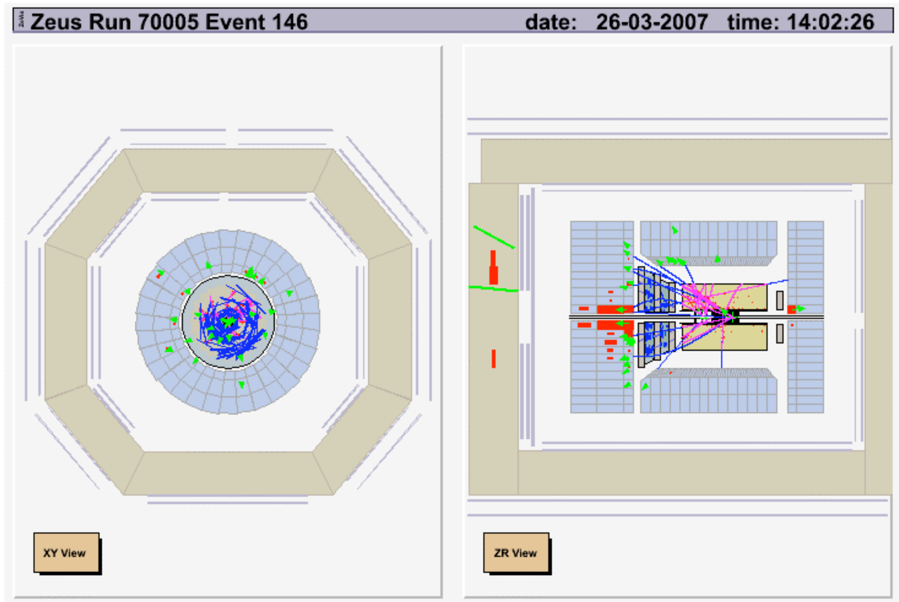
		BIN SIZE:
E_p = 460 GeV	→ E_e = 4 – 12 GeV	→ ΔE = 2 GeV
	→ θ_e = 140° – 168°	→ $\Delta\theta$ = 2°
E_p = 920 GeV	→ E_e = 16 – 20 GeV	→ ΔE = 2 GeV
	→ θ_e = 160° – 172°	→ $\Delta\theta$ = 1°

Bins have square shape in E_e and θ_e

Low Energy Run

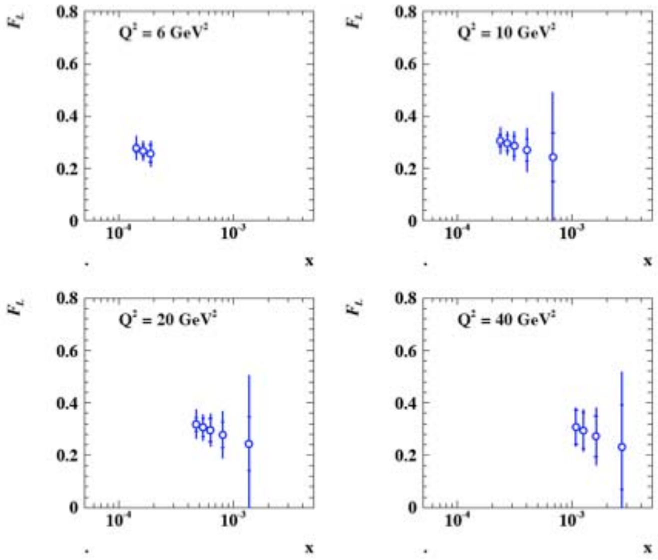
The HERA low energy has started and is planned to continue until 2 July, 2007 at 10:00AM. Expect ≈10 pb^{-1} of data.





F_L

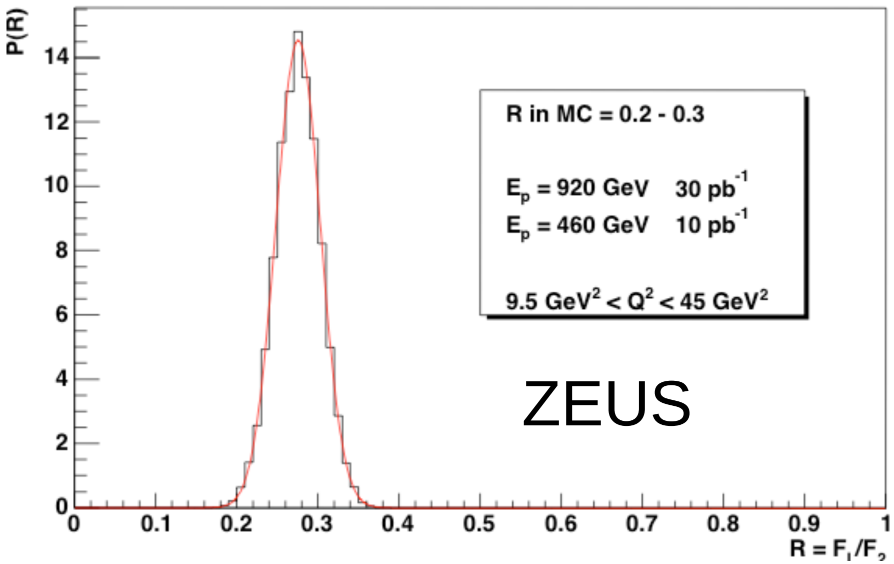
The F_L measurement at HERA will serve primarily as a check of the gluon distributions extracted using the DGLAP fits



H1

920 GeV
30 pb⁻¹

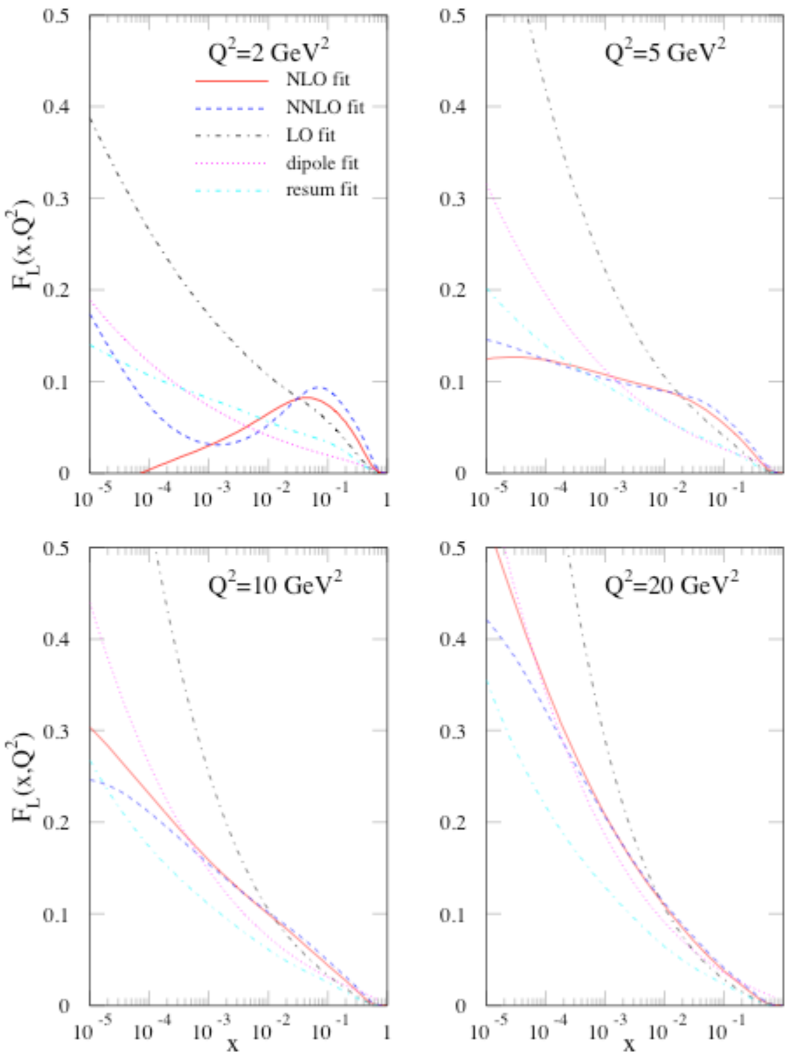
460 GeV
10 pb⁻¹



ZEUS

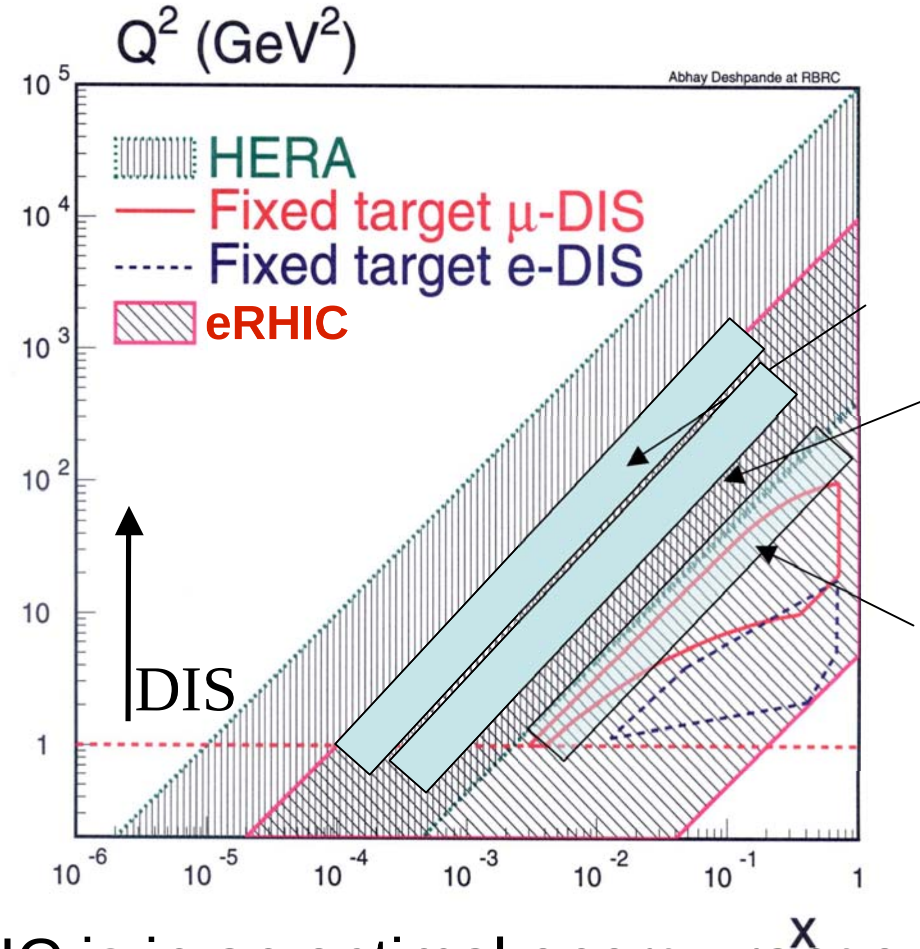
CTEQ5D	R=0.25
MRST2002(LO)	0.30
MRST2004(NLO)	0.18
MRST2004(NNLO)	0.18

Predictions for F_L



F_L predictions from MRST group at different orders in DGLAP, a fit which resums the leading ln(1/x) and β_0 terms, and a dipole type model. Very large differences at small Q^2 where gluon uncertainty large.

F_L: EIC & other Measurements



F_L measurement from EIC+HERA

EIC standalone

F_L measurement from EIC+fixed target

EIC is in an optimal energy range to extract F_L via cross section comparisons to previous experiments.

F_L from EIC, HERA comparison

$$F_L(x,Q^2) = \frac{\sigma_r(x,Q^2,y_1) - \sigma_r(x,Q^2,y_2)}{f(y_2) - f(y_1)} \qquad f(y) = {y^2}/{Y_+}$$

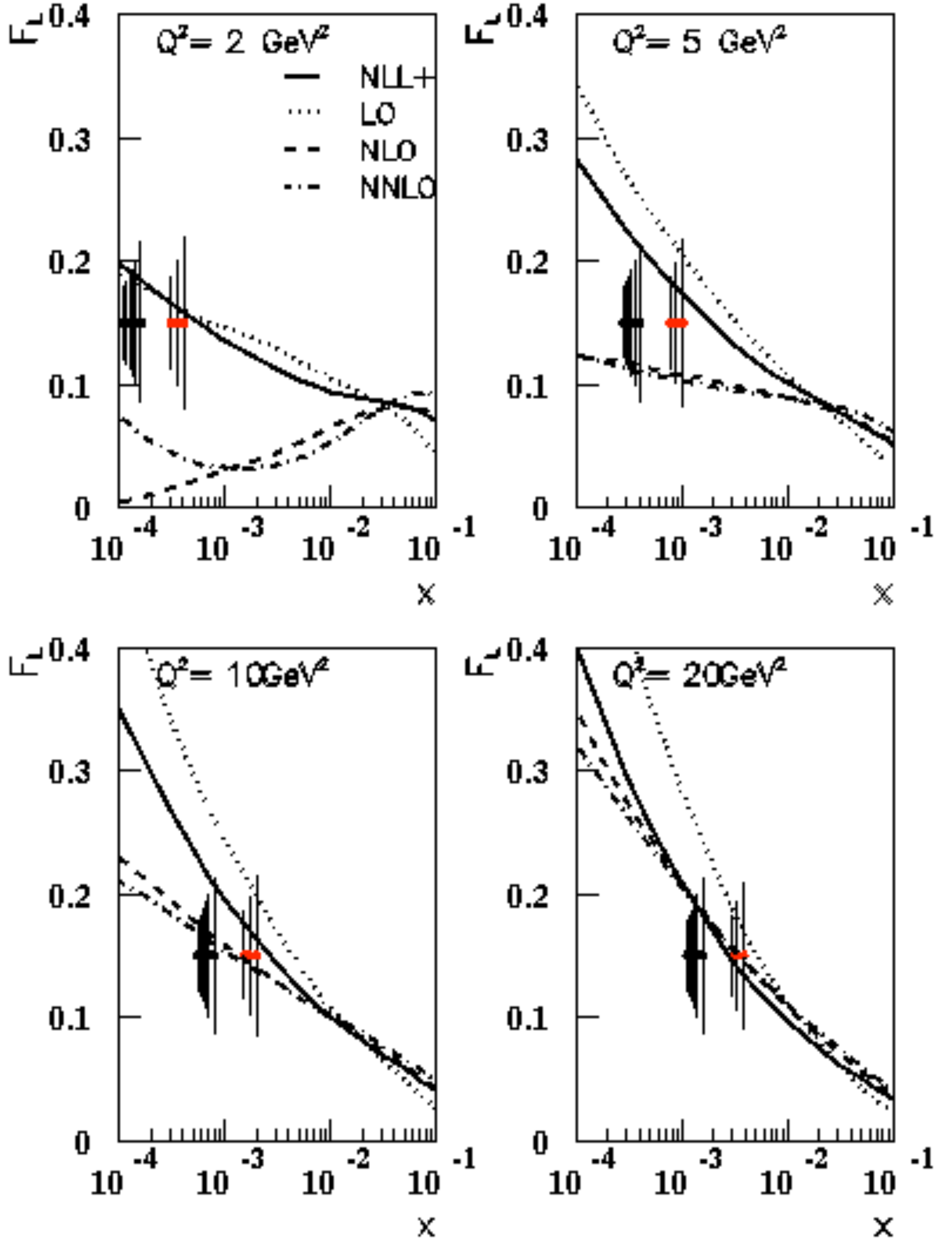
$$\delta F_L \approx [\delta\sigma_r(y_1) \oplus \delta\sigma_r(y_2)] \cdot F_L \cdot \left[\frac{1+R}{Ry_1^2}\right] \quad \text{where } y_1 \text{ is the larger } y$$

$$R = \frac{F_L}{F_2 - F_L}$$

Assumptions:
E_e=20, 10 GeV E_p=250,200 GeV

2% cross section measurement precision
R=0.2
E'=2,3,4,5,6,7.5,9,11

F_L from EIC, HERA comparison



Summary

• F_L is important in really understanding the parton densities at small-x

• The EIC is in a great kinematic position to give F_L measurements over a wide kinematic range

• Measurements will be possible with EIC alone, and from comparisons of cross sections EIC with existing measurements