F_L Measurements at HERA

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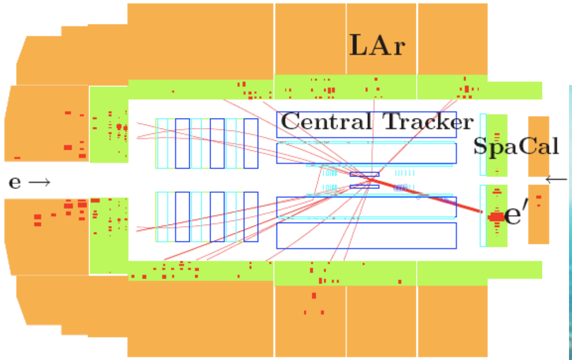
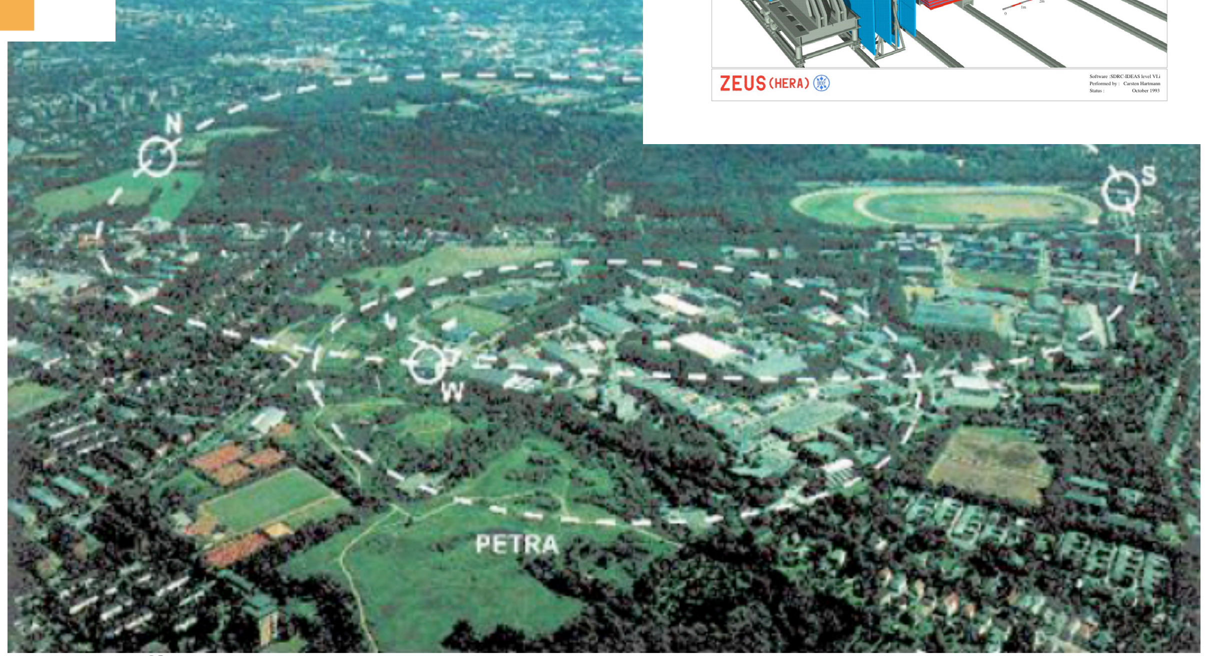
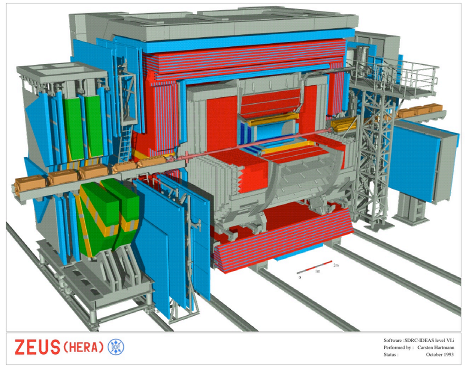




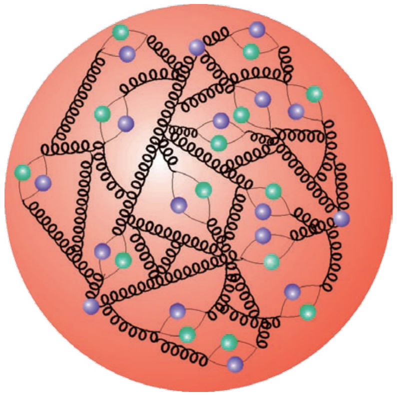


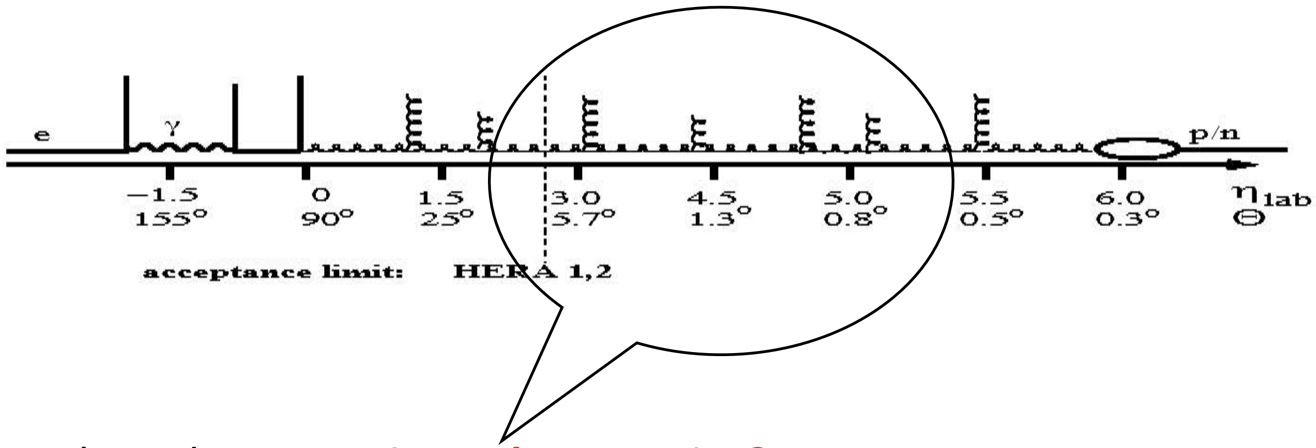
1. **Introduction**
2. **Experimental Issues**
3. **Results**

Small-x physics: the universal fuzz

HERA has opened the new field of small-x, or wee-parton, physics. These partons are a universal aspect of nature (not just proton structure).

Mostly gluons fluctuate in/out of existence. Sources can be hadrons, photons, vacuum, …



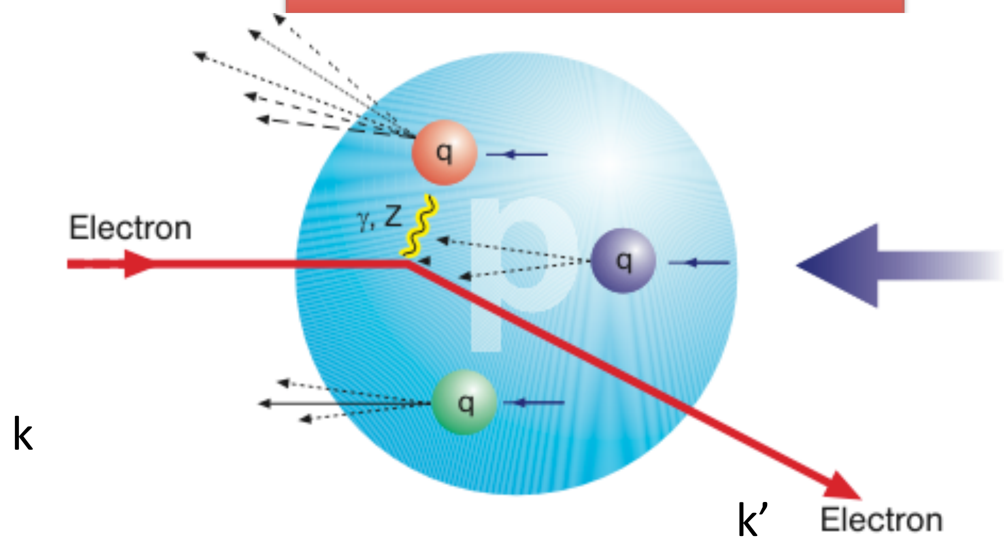


In this region, far from initial conditions: **universal properties?**

How well do we understand the small-x physics ??

F_L could be an important ingredient to making progress in the theoretical understanding.

Structure Functions



Extensive results available

Not relevant at small x

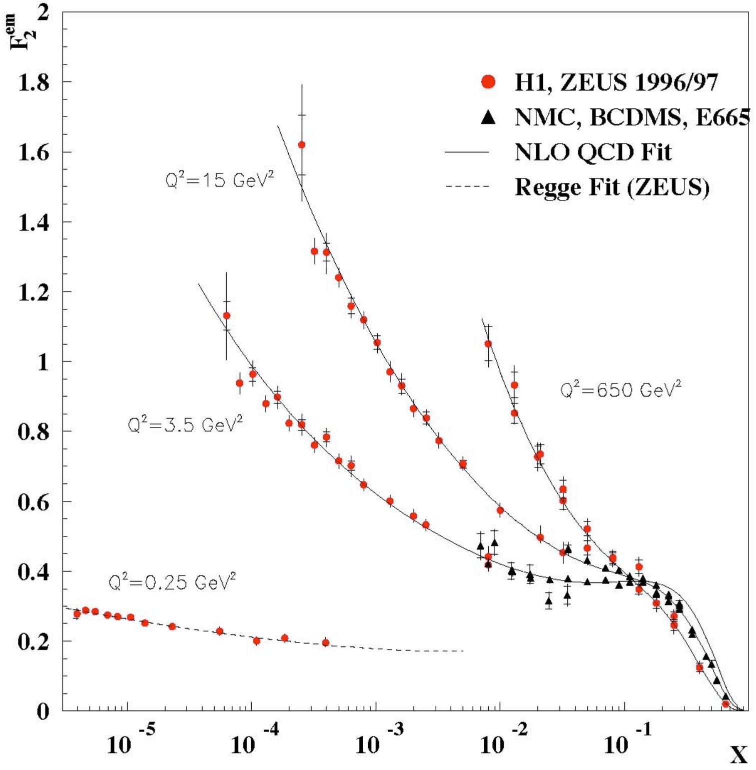
$$\frac{d^2\sigma(e^{\mp}p)}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4}\left[(1+(1-y)^2)F_2 - y^2F_L \pm xF_3\right]$$

First HERA Measurements 2008

$Q^2 = -q^2 = -(k-k')^2$ Transverse resolution

$0 \leq x \leq 1$ Momentum fraction

$0 \leq y \leq 1$ Inelasticity

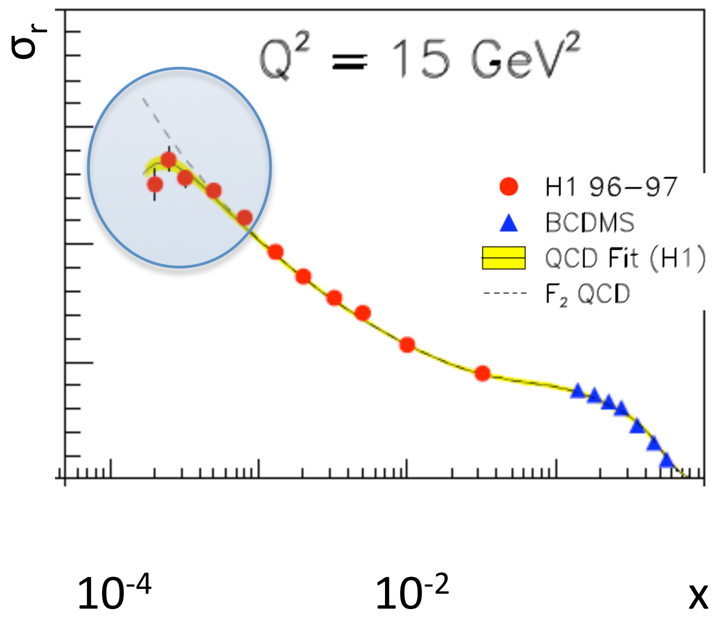


HERA Discovery!

The rise of the parton densities (and of F_2) with decreasing x is strongly dependent on Q^2. Implies very large density of partons in the proton when probe at high energies !

$$\sigma_r = \frac{xQ^4}{2\pi\alpha^2(1+(1-y)^2)} \frac{d^2\sigma(e^\mp p)}{dxdQ^2}$$

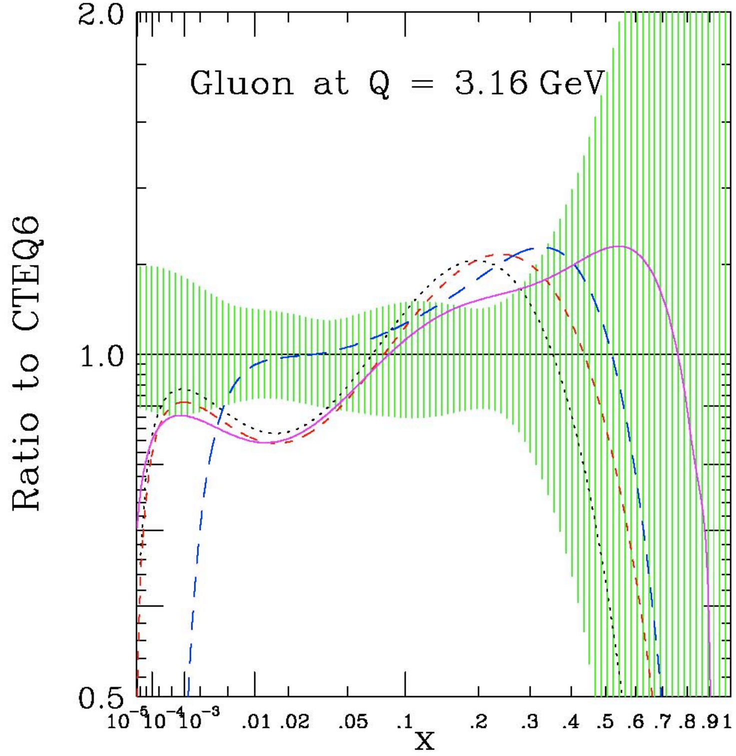
$$\approx \left[F_2 - \frac{y^2}{(1+(1-y)^2)} F_L \right]$$



Is turnover due to a saturation of parton densities (F_2) or effect of due to F_L ? Need different beam energies to untangle.

Small-x physics: the gluon

Pumplin – DIS05



mrst2001, mrst2002, mrst2003, mrst2004

The uncertainties in the gluon density are large at small-x. Long running discussion on $xg(x,Q^2)<0$ at NLO. Differences in gluon densities much larger than claimed uncertainties !!

What other information do we have ?

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

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

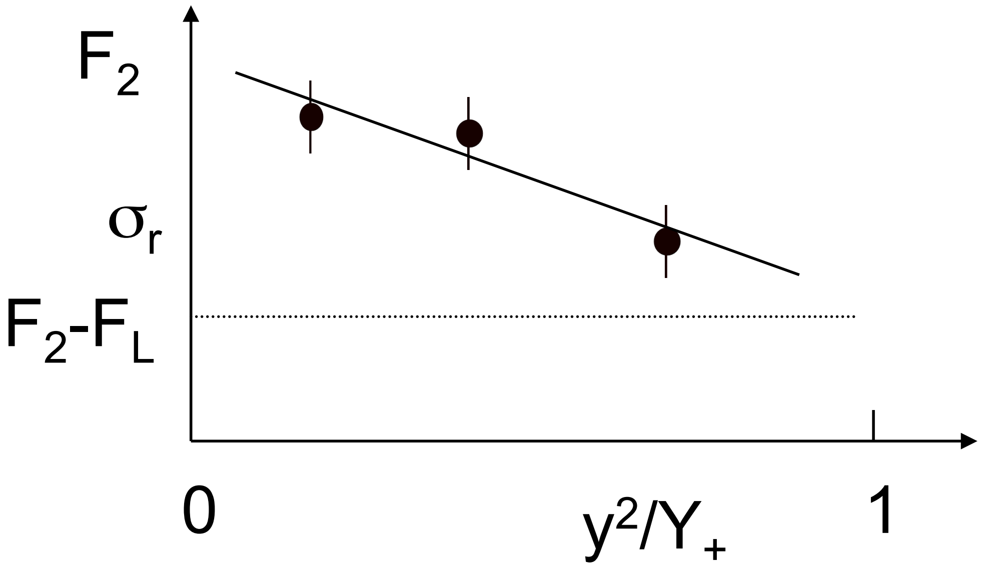
F_L from HERA

$$\sigma_r = \frac{xQ^4}{2\pi\alpha^2(1+(1-y)^2)}\frac{d^2\sigma(e^{\mp}p)}{dxdQ^2}$$

$$\approx \left[F_2 - \frac{y^2}{(1+(1-y)^2)}F_L\right]$$

Need to measure differential cross section at two beam energies (at least).

Maximize y difference for fixed x,Q. Implies largest possible difference in s.

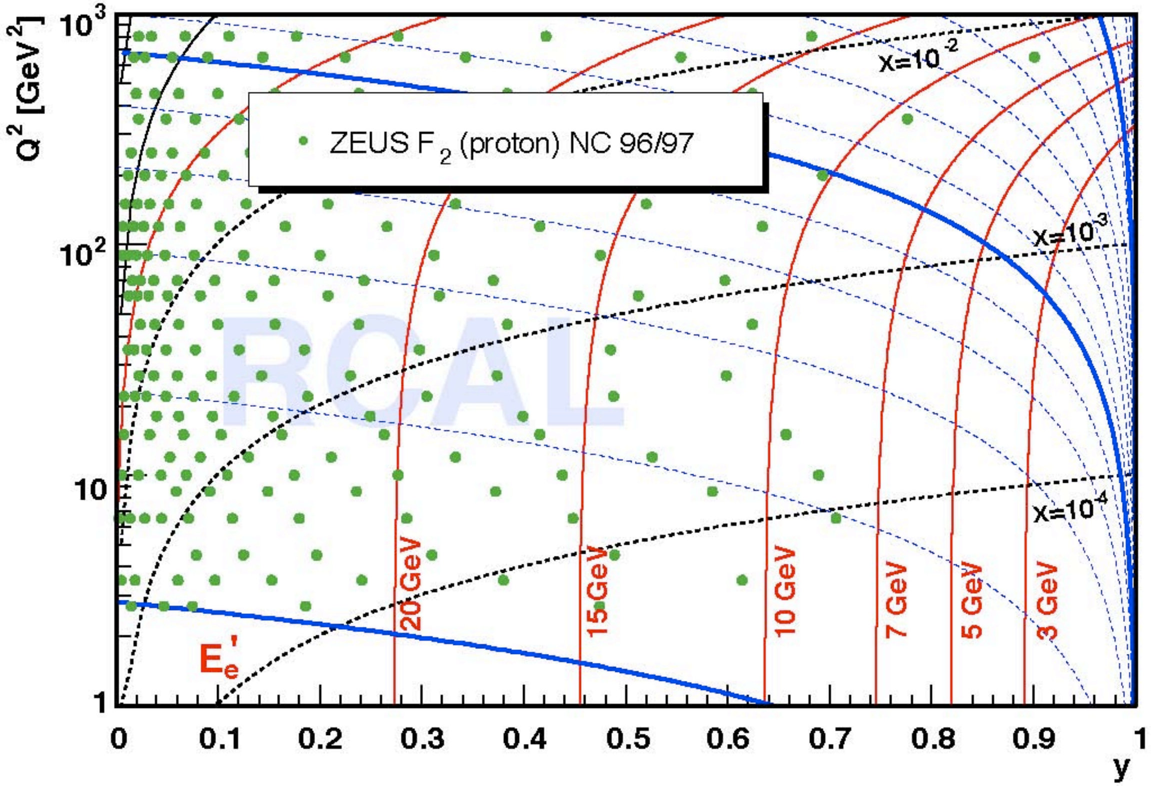


Available luminosity (pb^{-1})

HER	E_p=920 GeV	e^+p	>300
		e^-p	>200
MER	E_p=575 GeV	e^+p	8
LER	E_p=460 GeV	e^+p	14

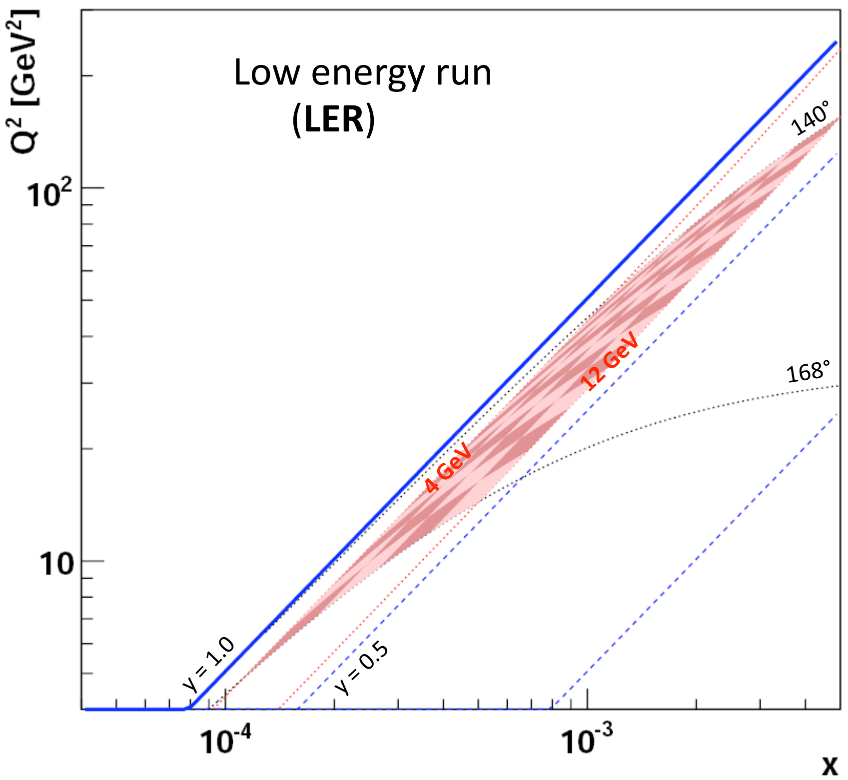
Experimental Issues

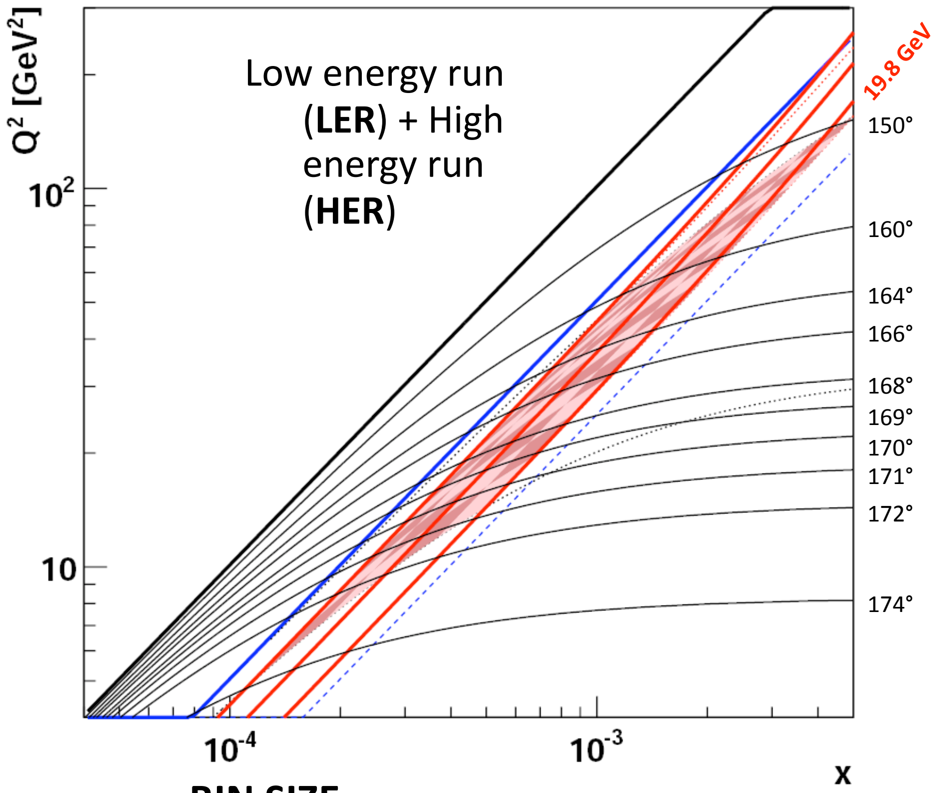
For best sensitivity, need to reach highest possible y



- High y means low electron energies
- Low electron energies ➔ triggering issue
- Low electron energies ➔ lower efficiency for finding electron
- Low electron energies ➔ large fake rate from photoproduction events

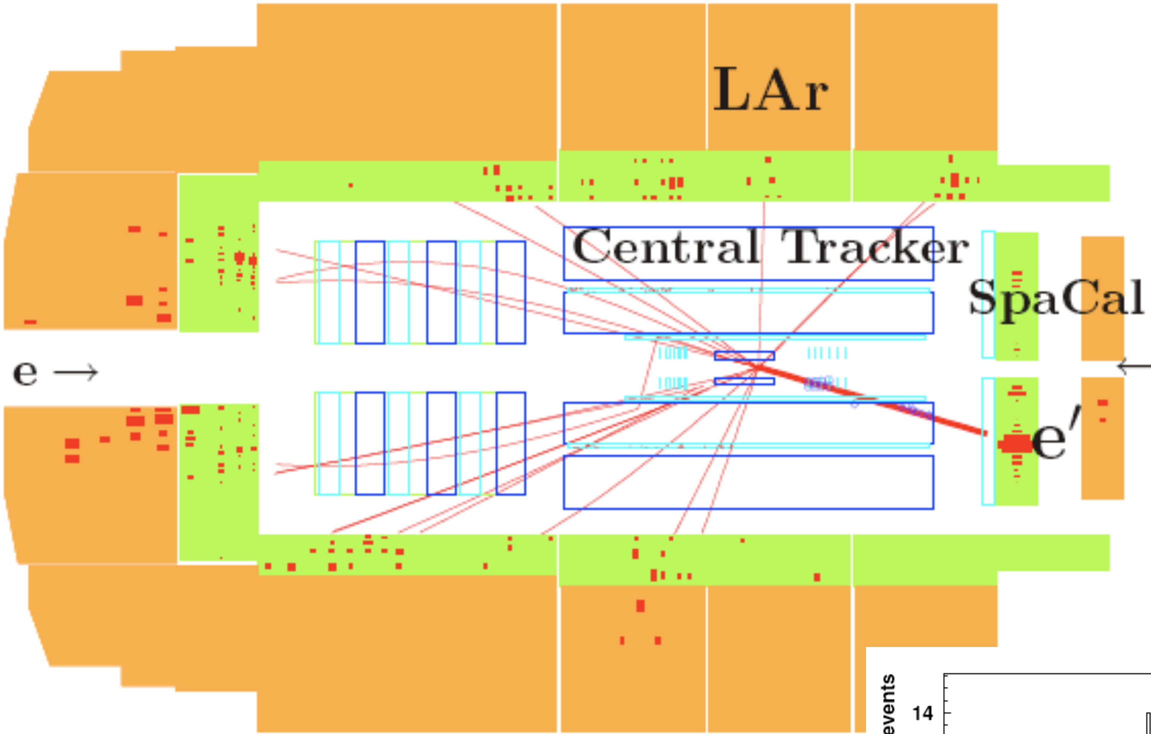
Example binning



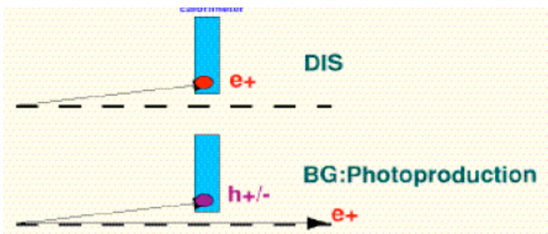


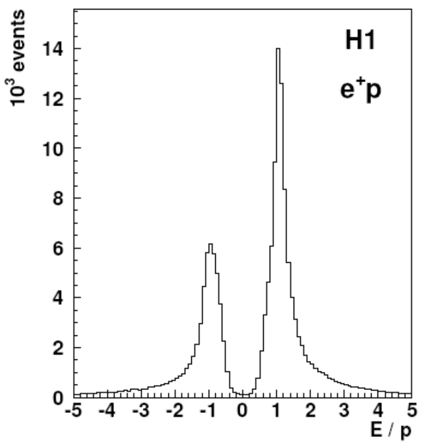
		BIN SIZE:
E_p = 460 GeV	→ E_e = 4 – 12 GeV	→ ΔE = 2 GeV
	→ θ_e = 140° – 168°	→ $\Delta\theta$ = 2°
E_p = 920 GeV	→ E_e = 16 – 20 GeV	→ ΔE = 2 GeV
	→ θ_e = 160° – 172°	→ $\Delta\theta$ = 1°

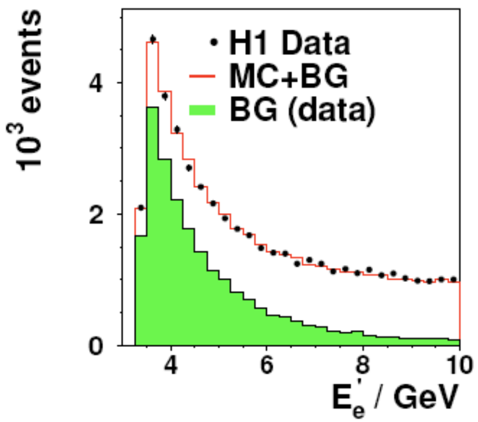
H1 Analysis

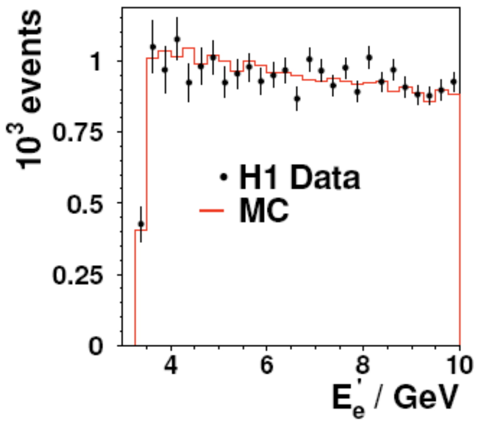


E_e > 3 GeV
Track (reject neutrals, E/p)
Interaction vertex
E-P_z > 35 GeV (reduces radiative corrections and photoproduction background)





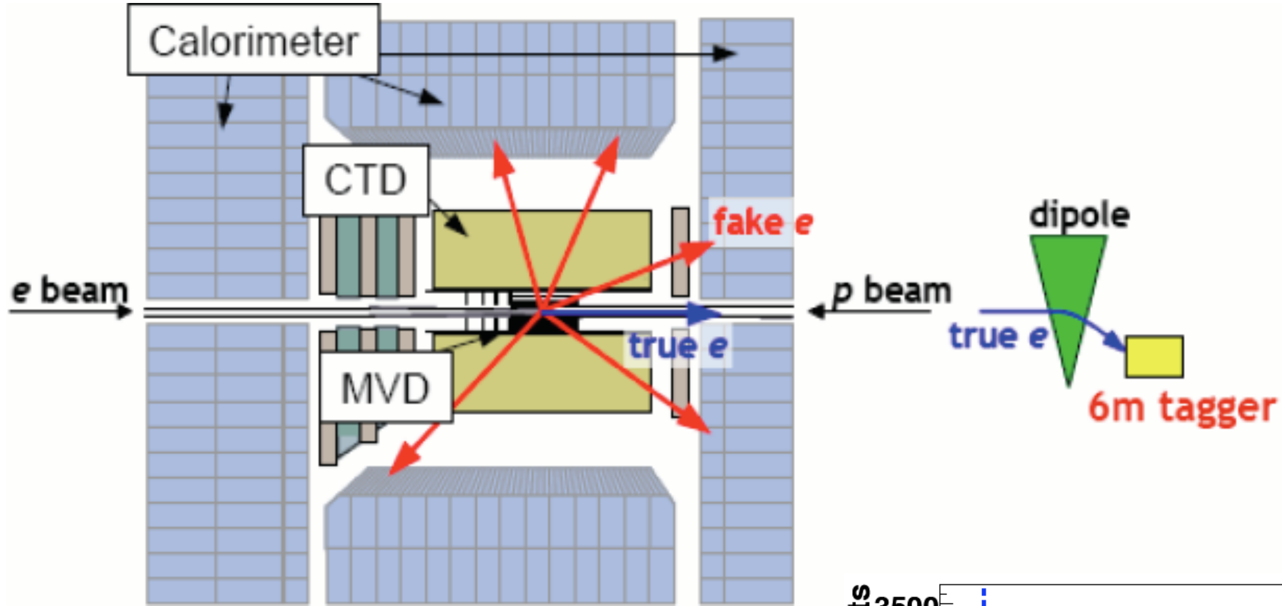




Three Q^2 **ranges**
3 - 12 GeV^2 : in progress
12 - 90 GeV^2 **: published 6/08**
35 - 800 GeV^2 **: preliminary data**

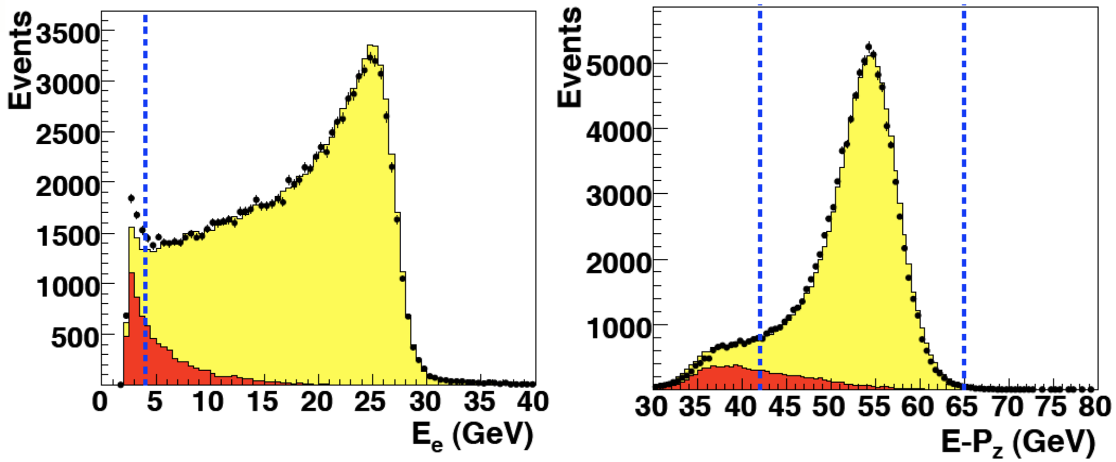
ZEUS Analysis

Background example



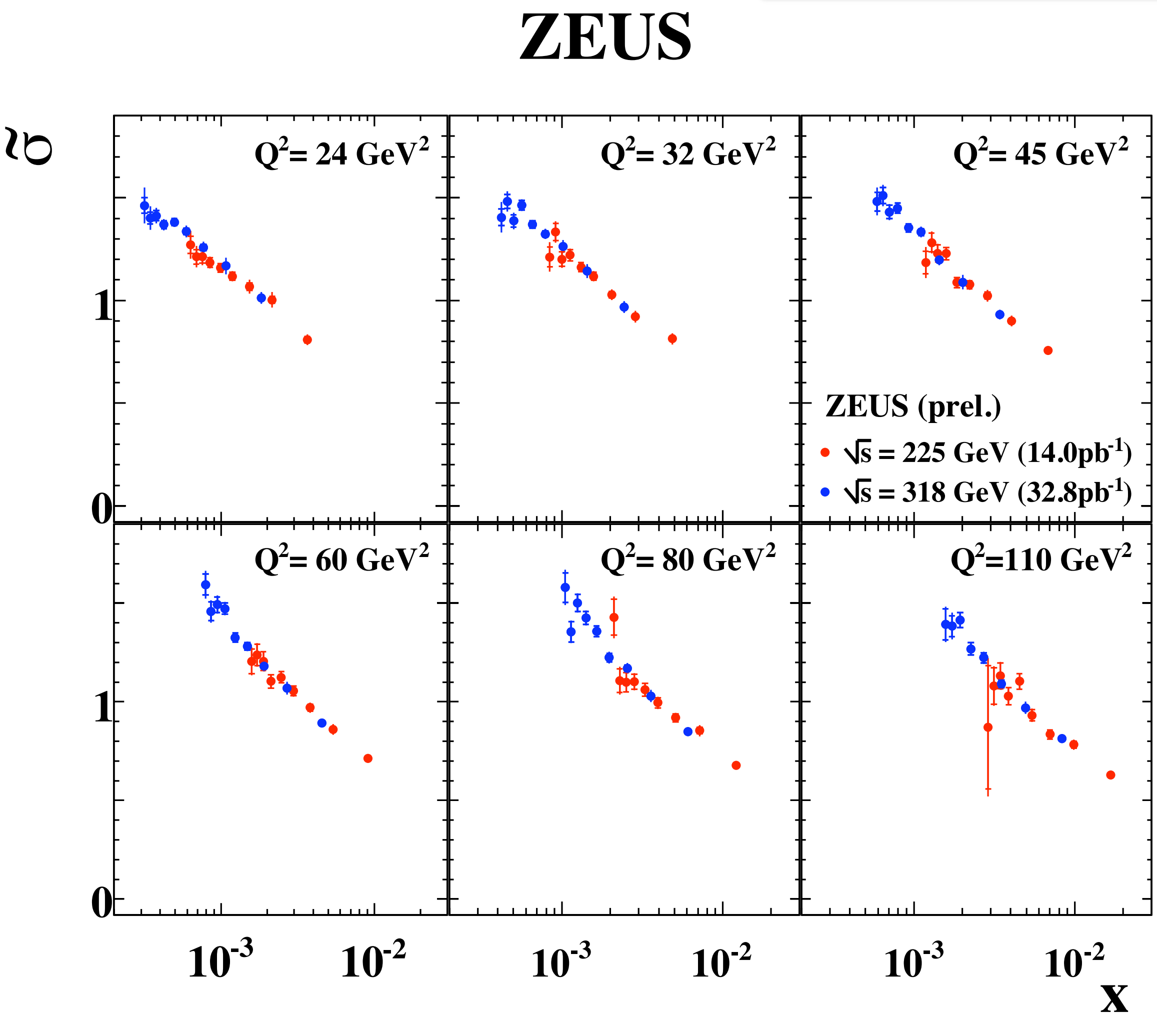
$E_e > 6$ GeV
Track or hits in CTD+MVD
Interaction vertex
$42 < \text{E-pz} < 65$ GeV

Q^2 range 24-110 GeV^2



Photoproduction background subtracted using PYTHIA MC with subprocess weights readjusted to cross section data. MC normalized with 6m electron tagger data (sees about 1/5 of photoproduction background).

Results



Status – DIS08. Updated for ICHEP (next slide)

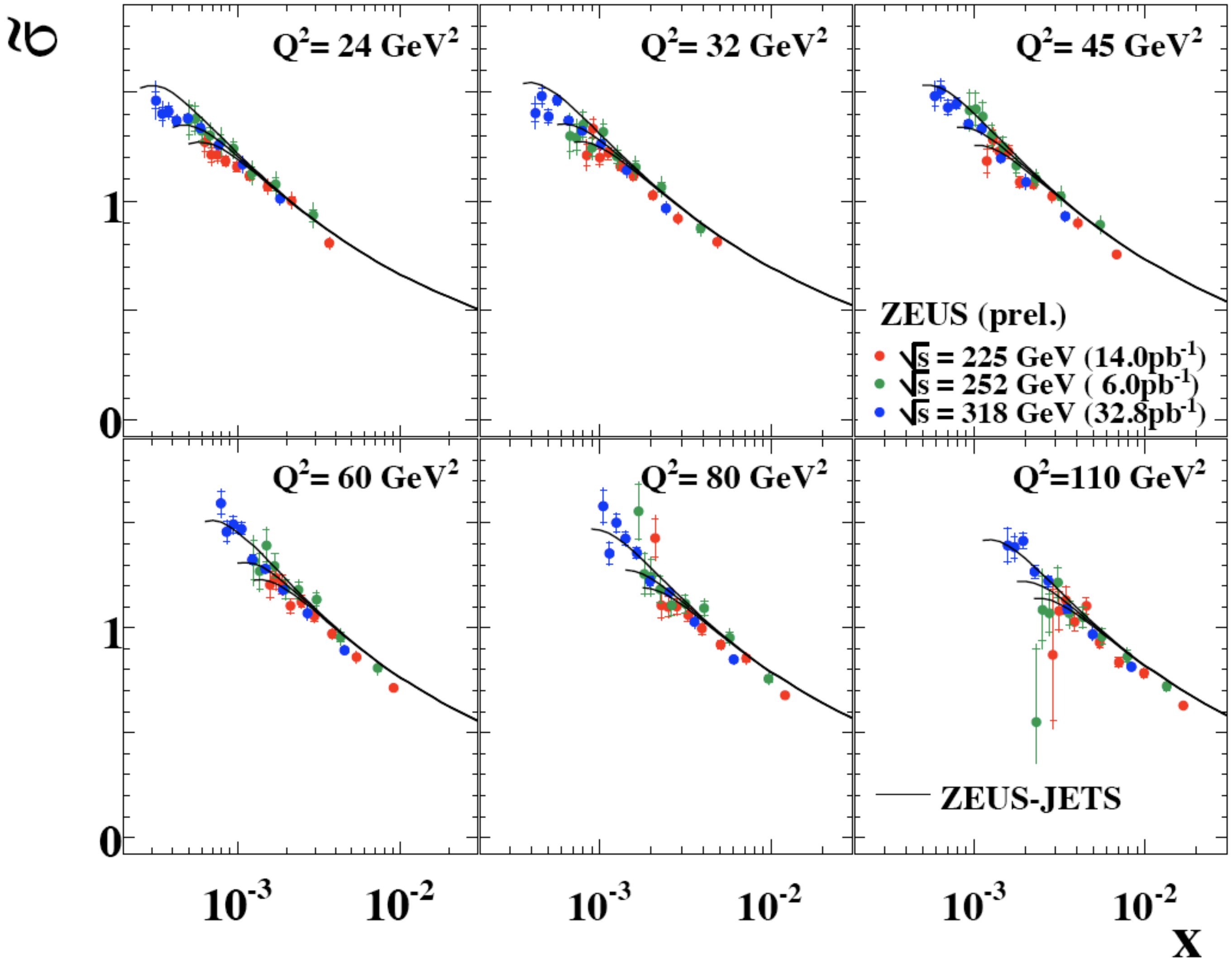
$$\tilde{\sigma} = \left[Y_+ F_2(x,Q^2) - y^2 F_L(x,Q^2) \right]$$

F_L expected to produce turnover at small-x (assuming F_2 continues as $x^{-\lambda}$)

F_L from difference in cross sections (blue – red).

Note: $\sigma_r = \tilde{\sigma}$

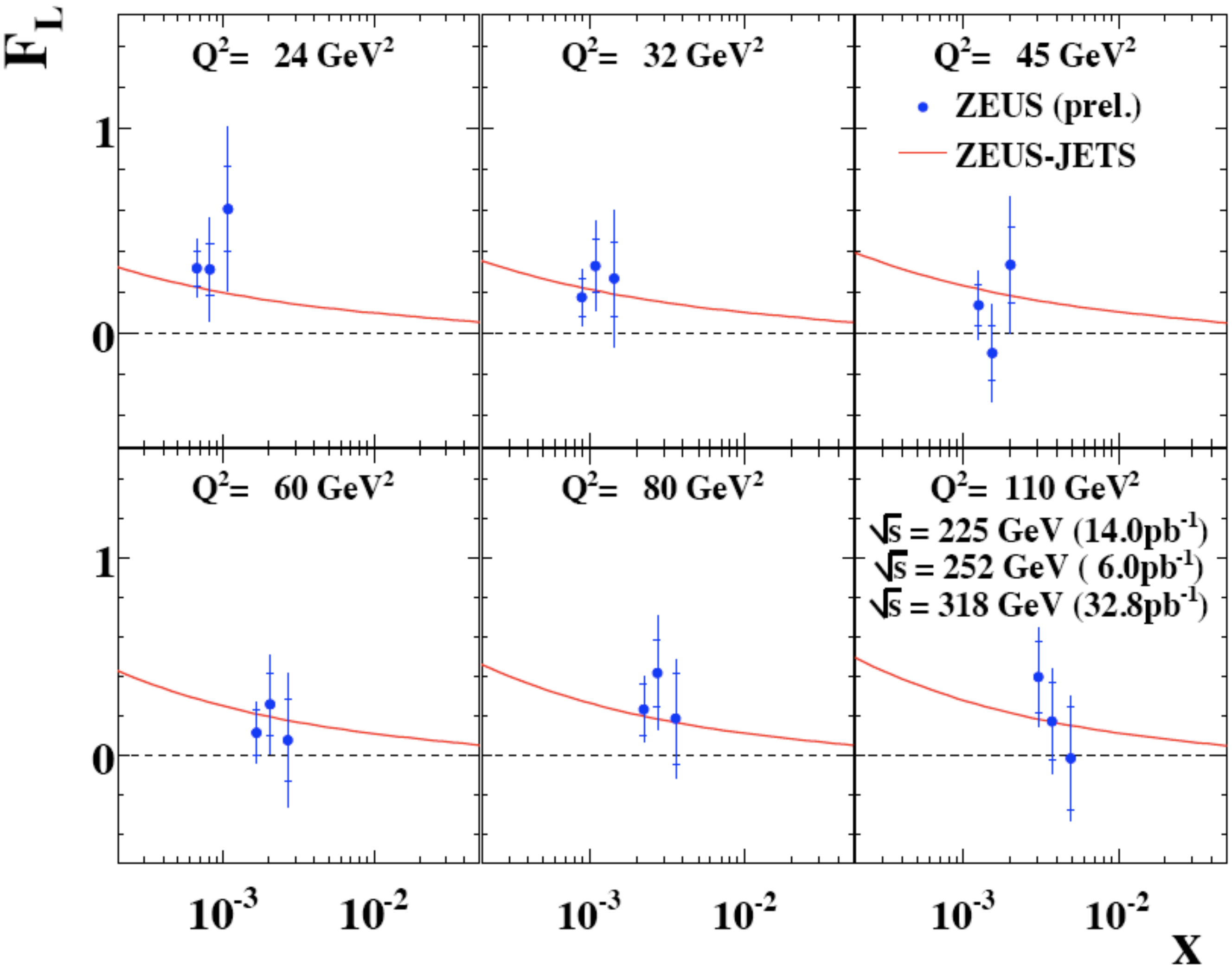
Results



ICHEP update includes the E_p=575 GeV data (green).

Curves are from fits by ZEUS to previous data assuming forms for parton densities continue to small x, NLO DGLAP

Results



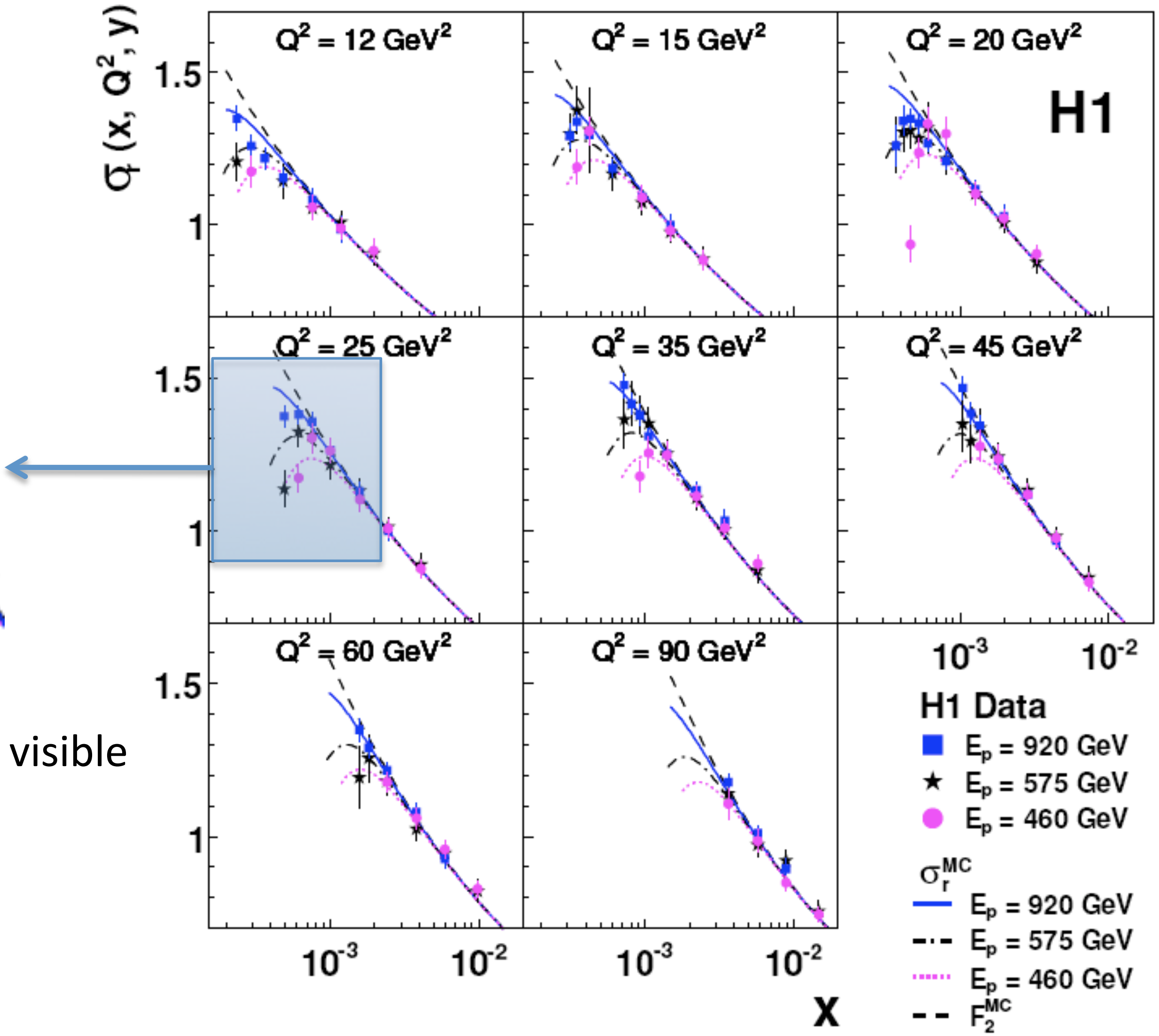
Results consistent with expectations from NLO DGLAP fits to previous data.

ICHEP update includes the E_p=575 GeV data, relative normalization of data sets at low y.

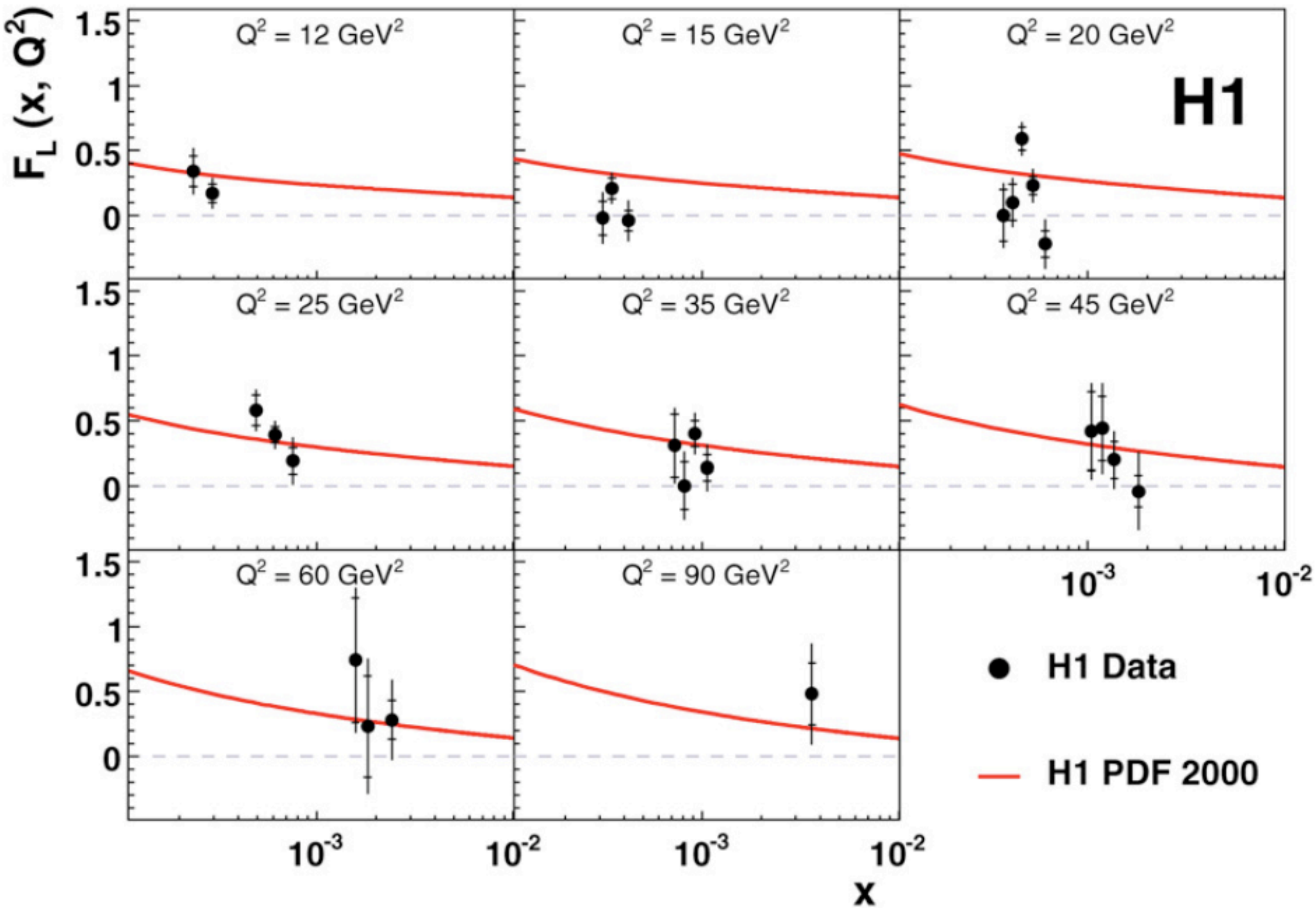
Results

Cross Section Results - H1 - SpaCal Data - Medium Q^2

Significant F_L contribution visible



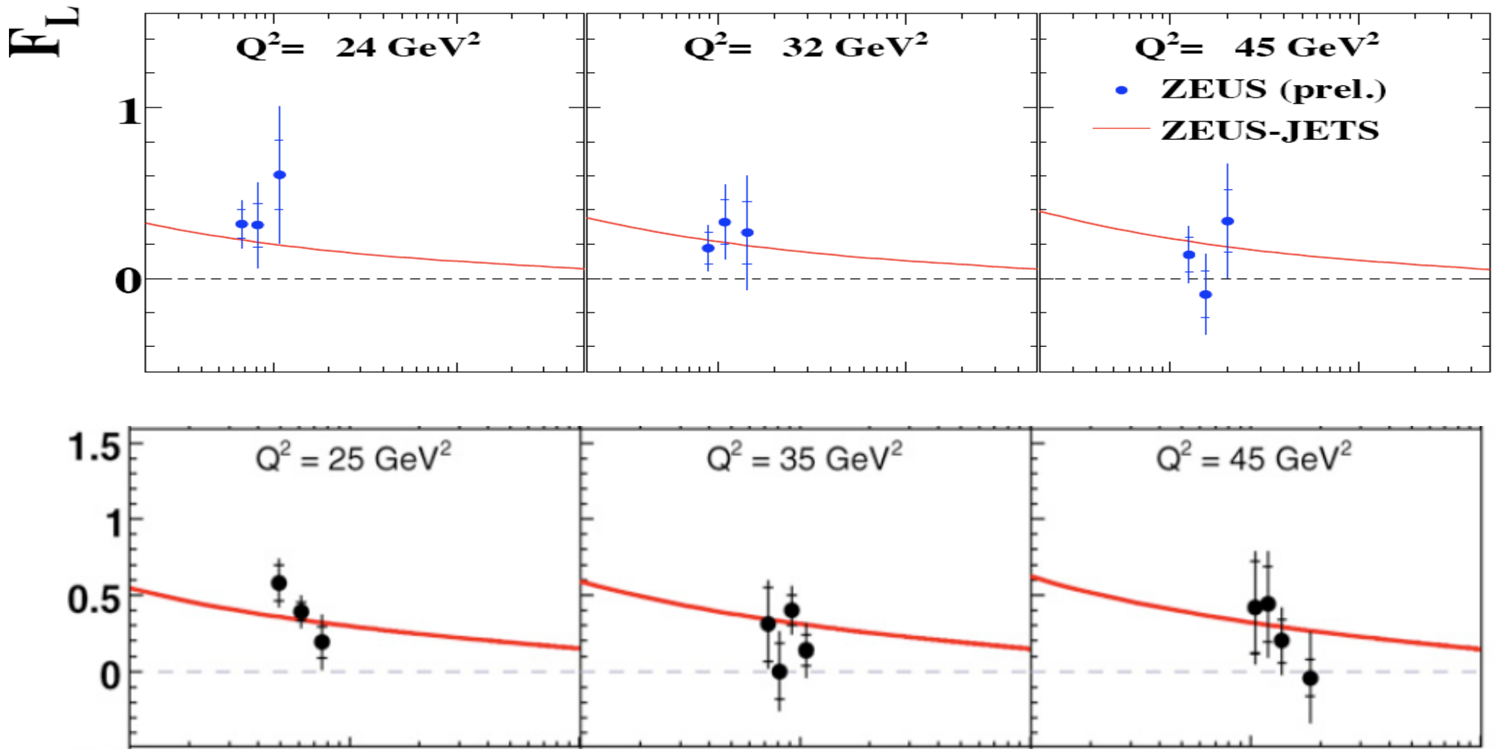
Results



H1 Collaboration Phys.Lett B665(2008)139

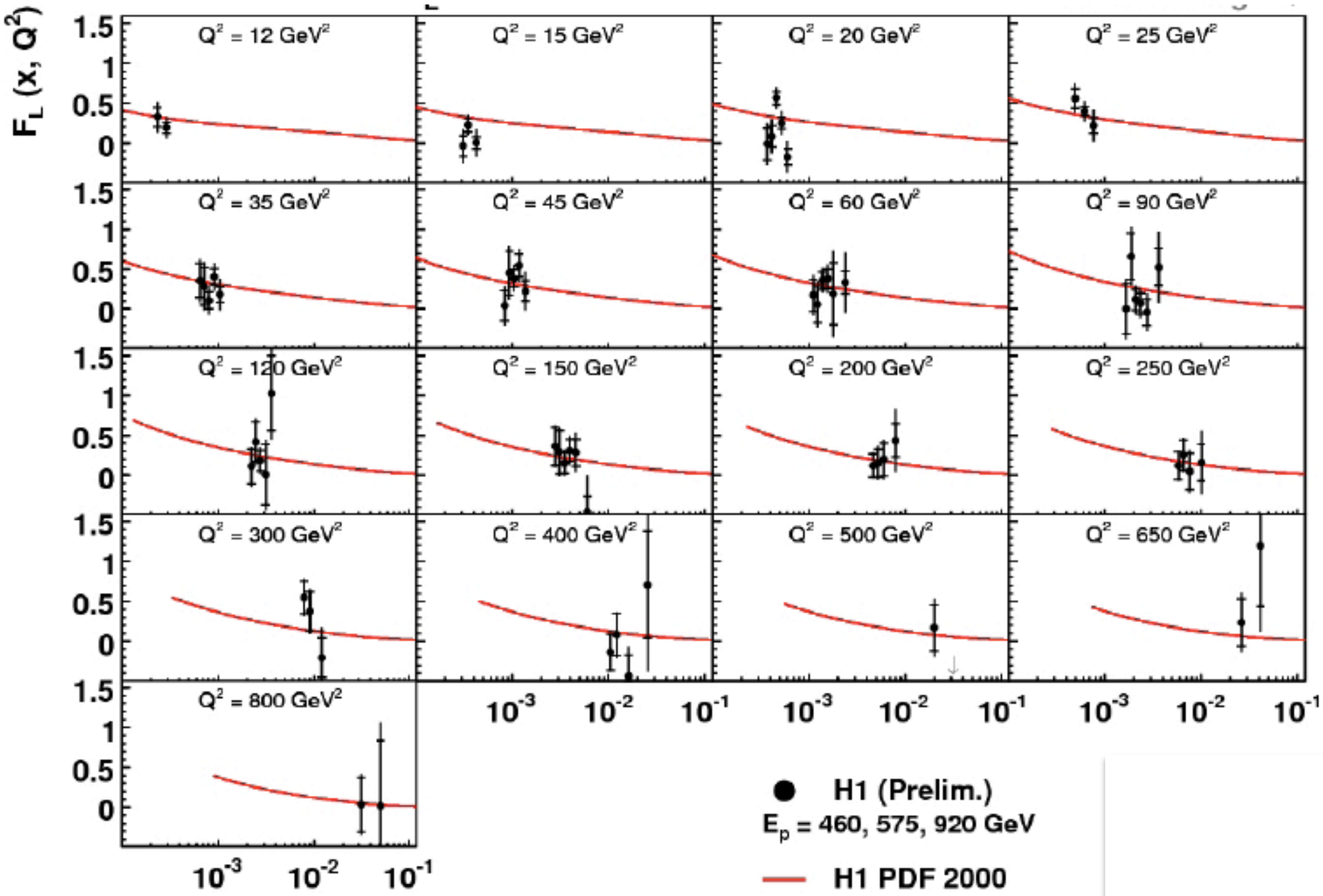
Results

Comparison on F_L Data - ZEUS+H1

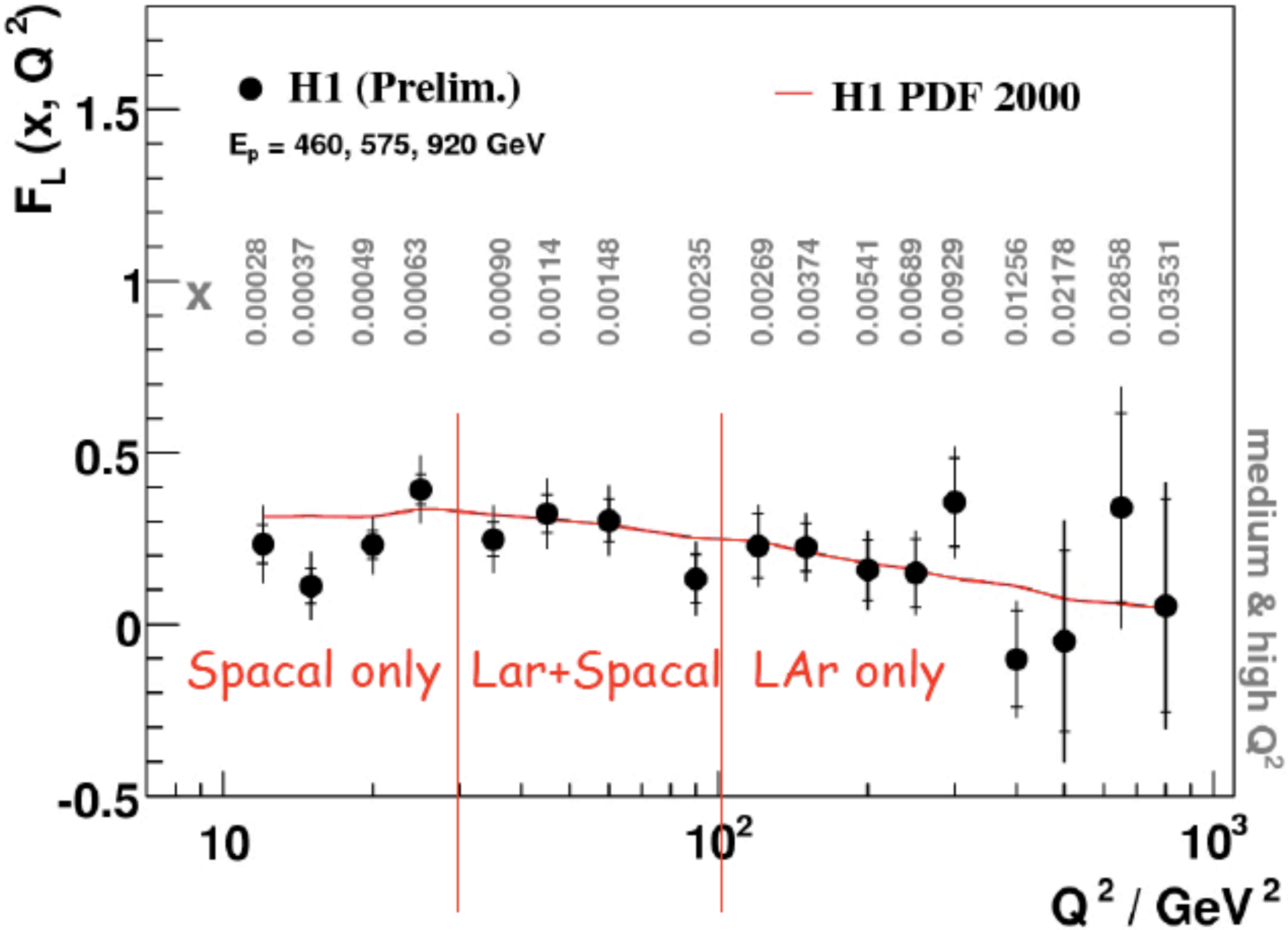


Results

Including LAr data



Results



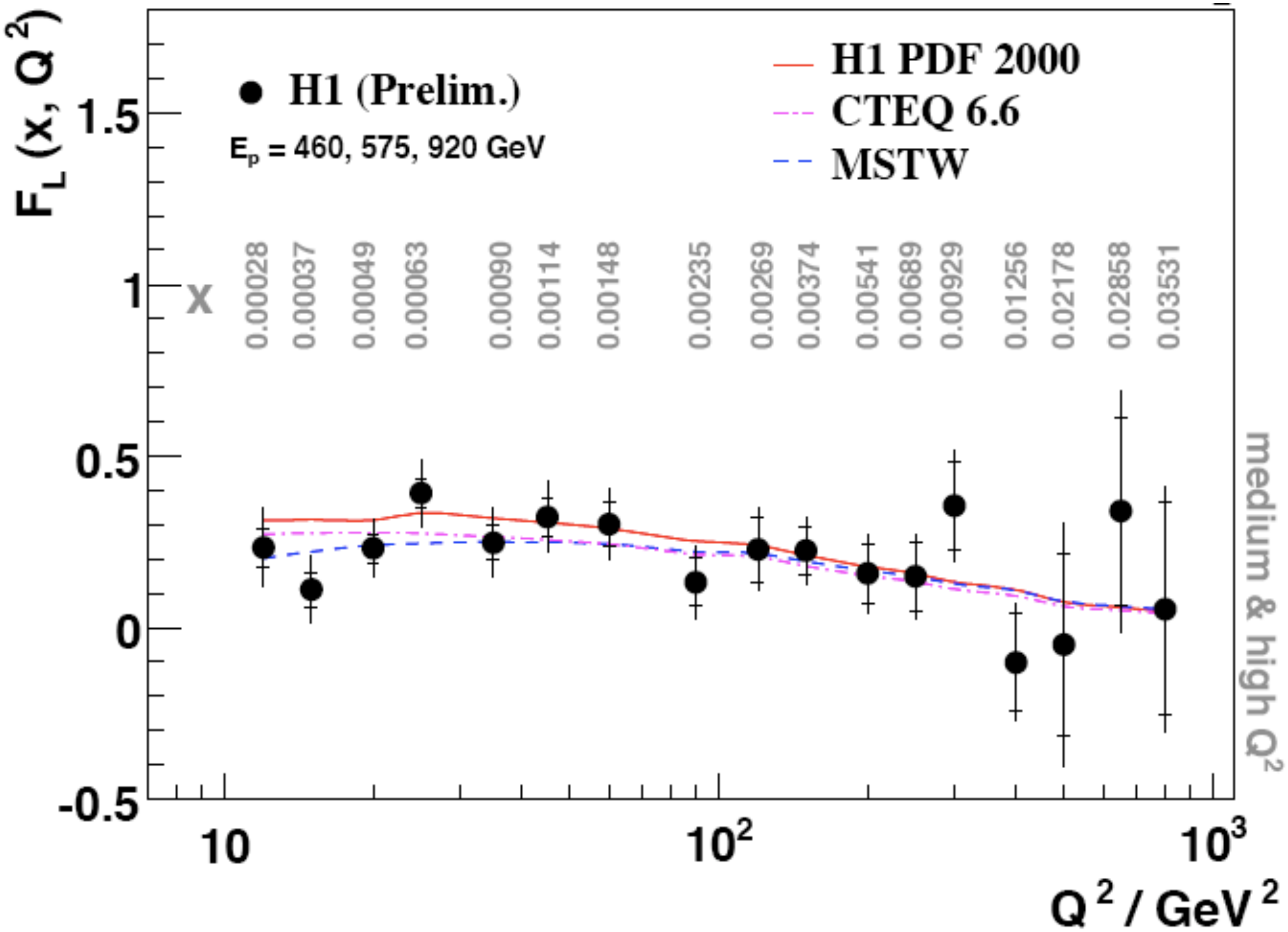
Data at each Q^2 combined and then averaged vs x.

Combination with LAr improves the published SpaCal result for Q^2 **> 30** GeV^2

Agrees well with NLO QCD fit to previous H1 Data.

Unfortunately, no surprises !

Results

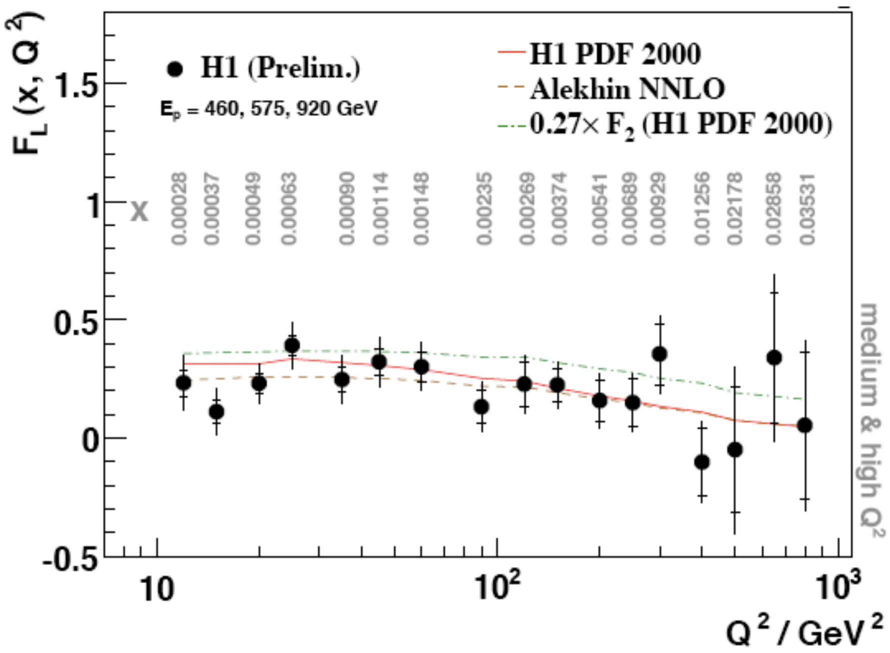


Comparison with popular pdf fits – no big surprises. Also dipole model predictions in good agreement with the data.

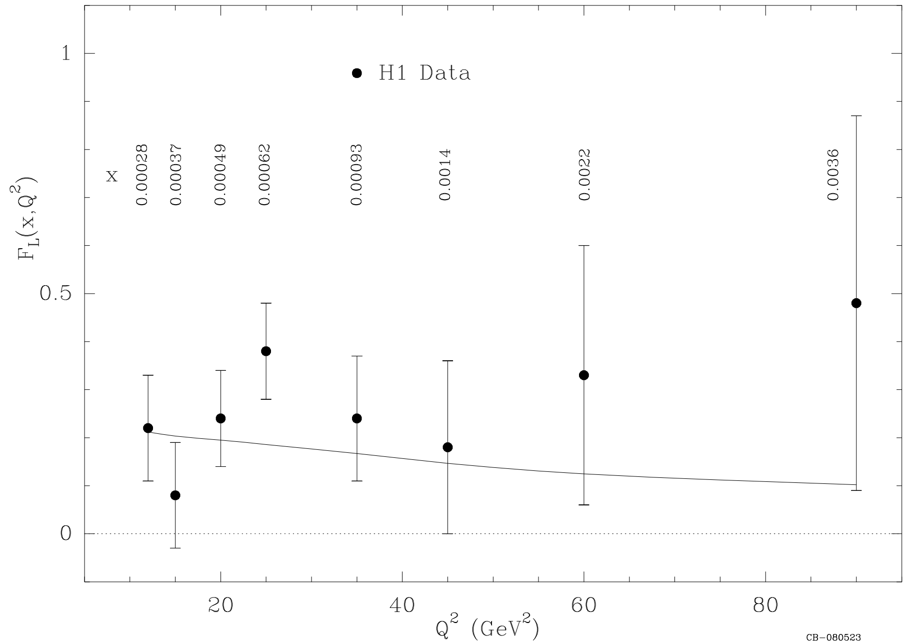
Differences increase at small Q^2. Important to push F_L analysis to as low in Q^2 as possible.

Results

Comparison of FL Data with Dipole Model



Comparison of prelimary H1 data with statistical pdf of Bourelly, Soffer



H1 data also consistent with Dipole model predictions:
$F_L = 3/11\ F_2$
arXiv 0806.0202
M.Kuroda, D.Schildknecht

Bound:
$F_L \leq 0.27\ F_2$
Ann.Phys. 322(2007)1635
C.Ewerz, O.Nachtmann

Summary

• HERA experiments have finally measured F_L ! Thanks to HERA team for very successful effort.

• Results are consistent with expectations from NLO DGLAP fits to previous data sets where specific assumptions were made for the behavior of the pdfs.

• Extension of kinematic range expected. Predictions diverge at smaller Q^2.

• Cross section data needed for pdf fitters