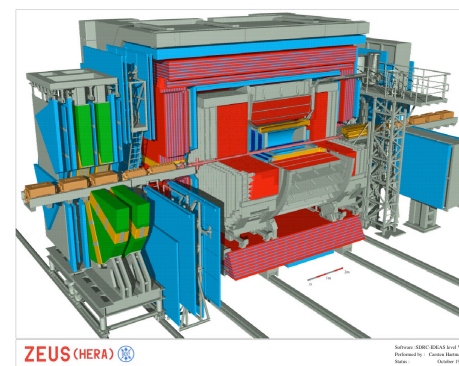
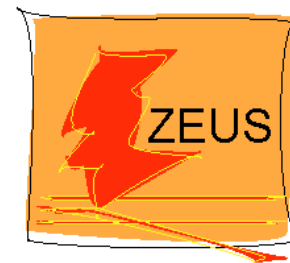
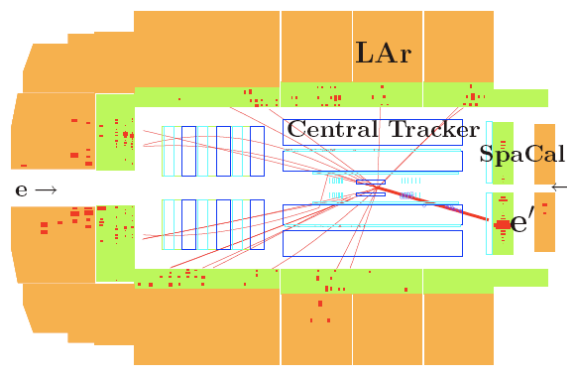
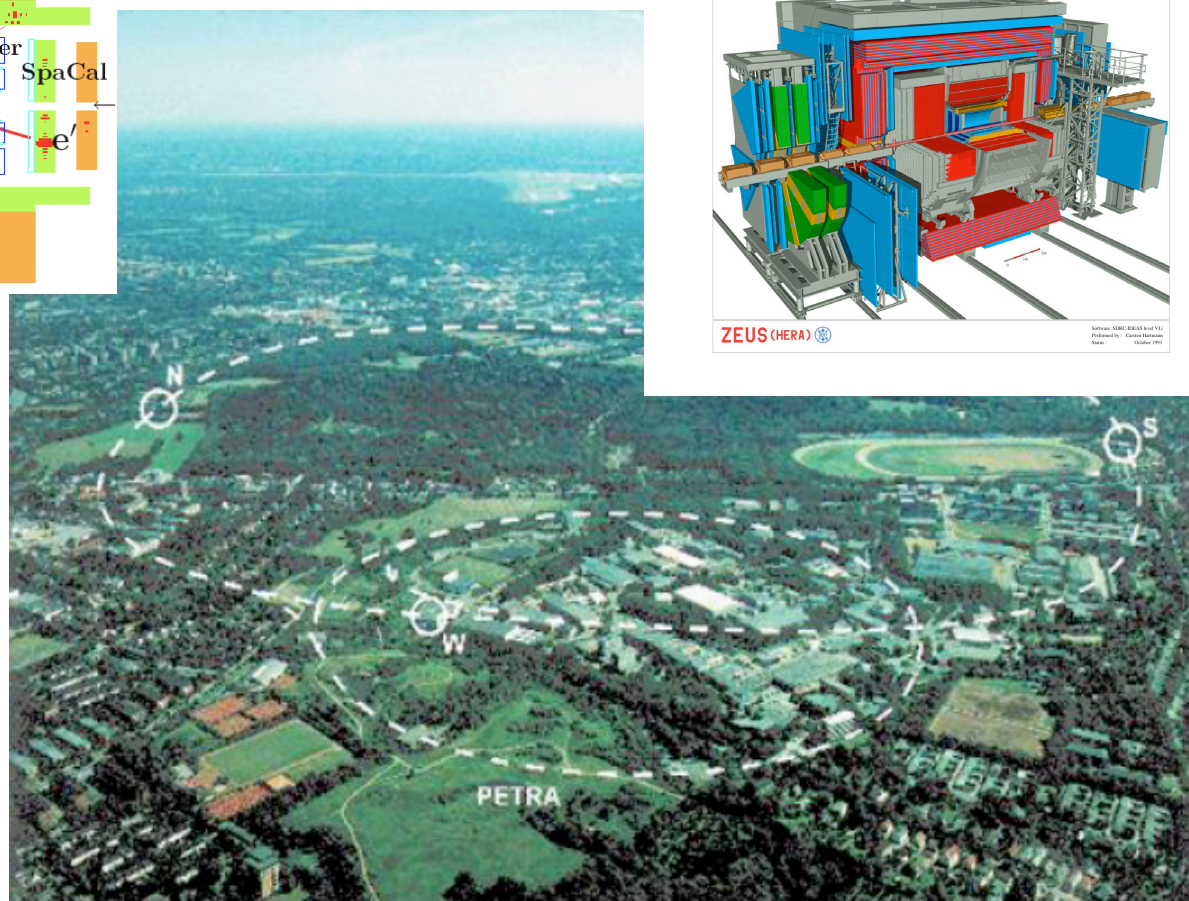


F_L Measurements at HERA

Allen Caldwell, Max Planck Institute for
Physics
Munich, Germany



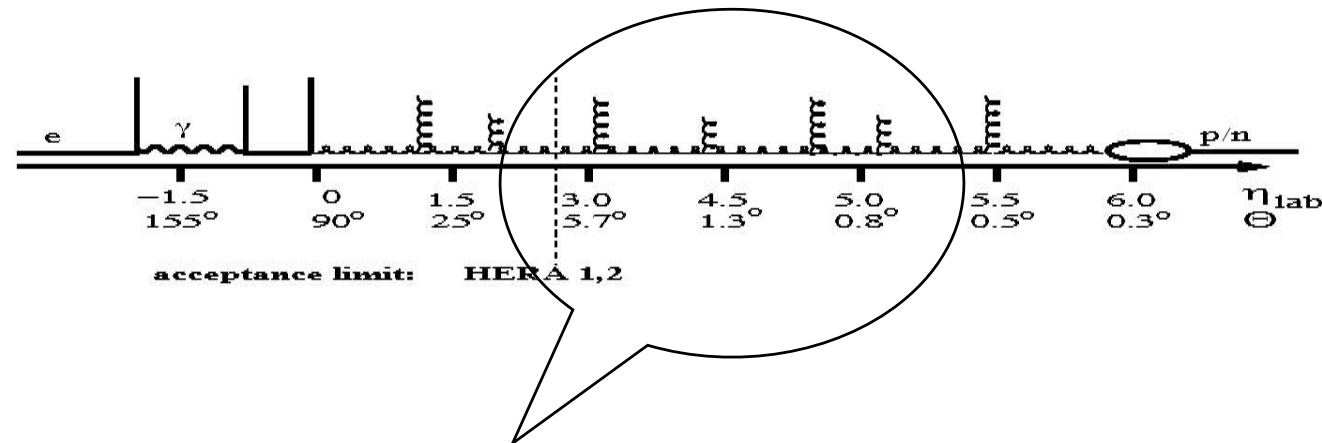
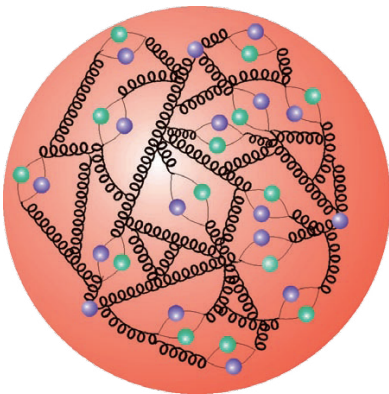
1. Introduction
2. Experimental Issues
3. Results



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, ...

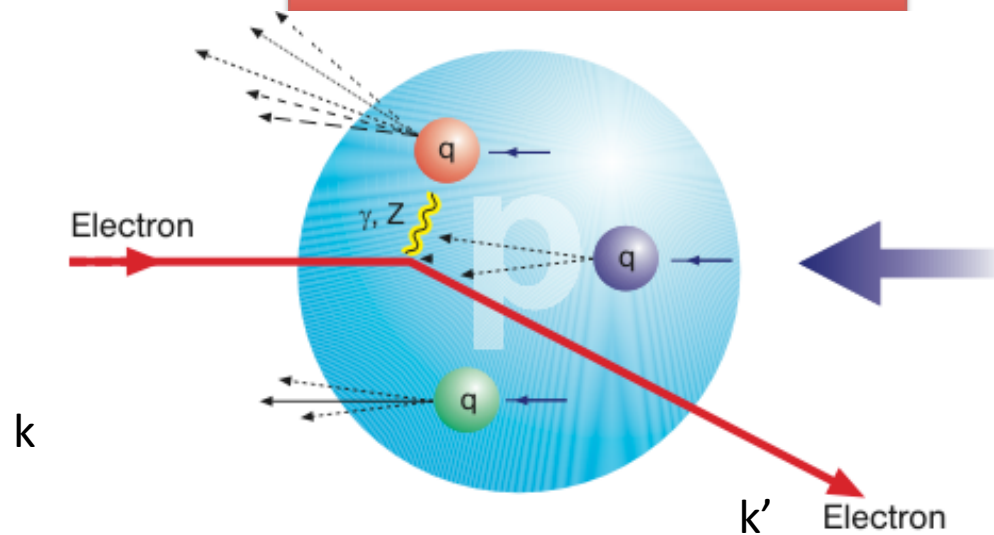


In this region, far from initial conditions: **universal properties?**

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

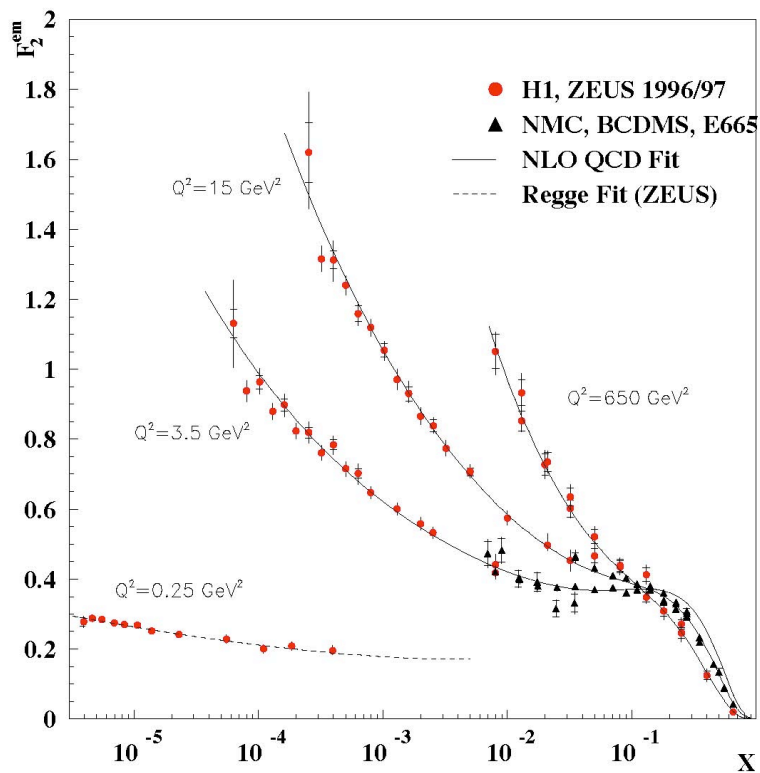
$$\frac{d^2\sigma(e^\mp p)}{dx dQ^2} = \frac{2\pi\alpha^2}{xQ^4} \left[(1 + (1-y)^2) F_2 - y^2 F_L \pm xF_3 \right]$$

First HERA
Measurements
2008

$$Q^2 = -q^2 = -(k - k')^2 \quad \text{Transverse resolution}$$

$$0 \leq x \leq 1 \quad \text{Momentum fraction}$$

$$0 \leq y \leq 1 \quad \text{Inelasticity}$$



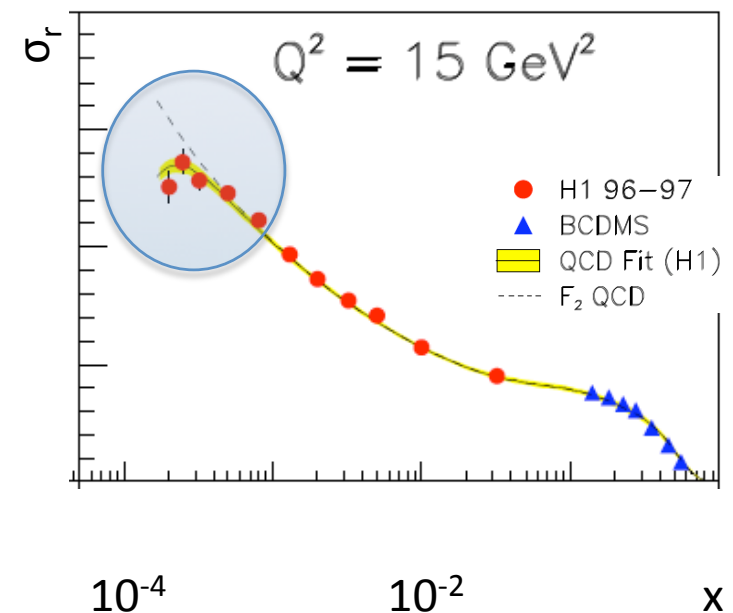
$$\sigma_r = \frac{xQ^4}{2\pi\alpha^2(1+(1-y)^2)} \frac{d^2\sigma(e^\mp p)}{dx dQ^2}$$

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

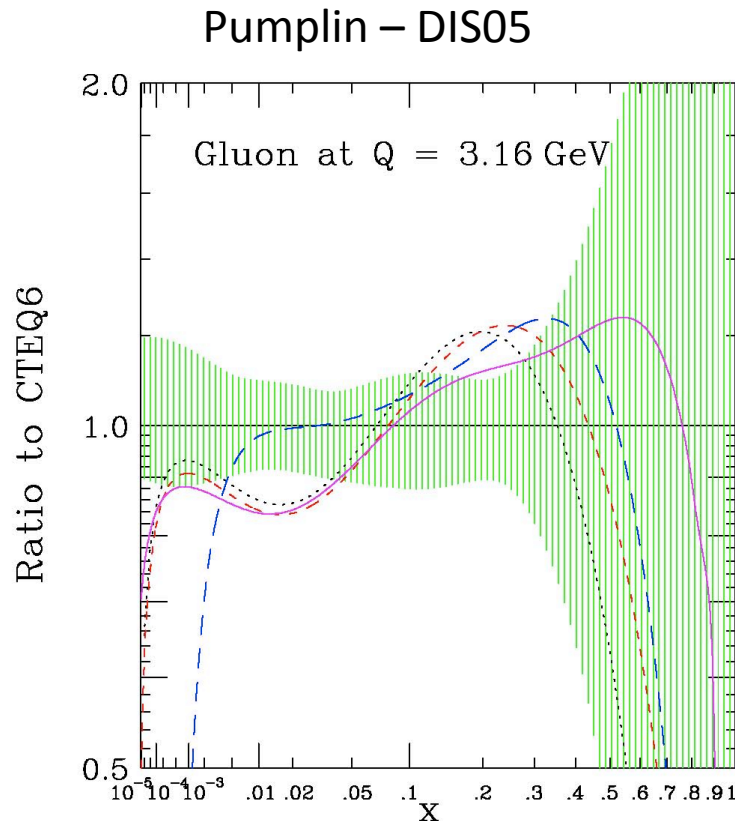
Is turnover due to a saturation of parton densities (F_2) or effect of due to F_L ? Need different beam energies to untangle.

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 !



Small-x physics: the gluon



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 ?

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

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

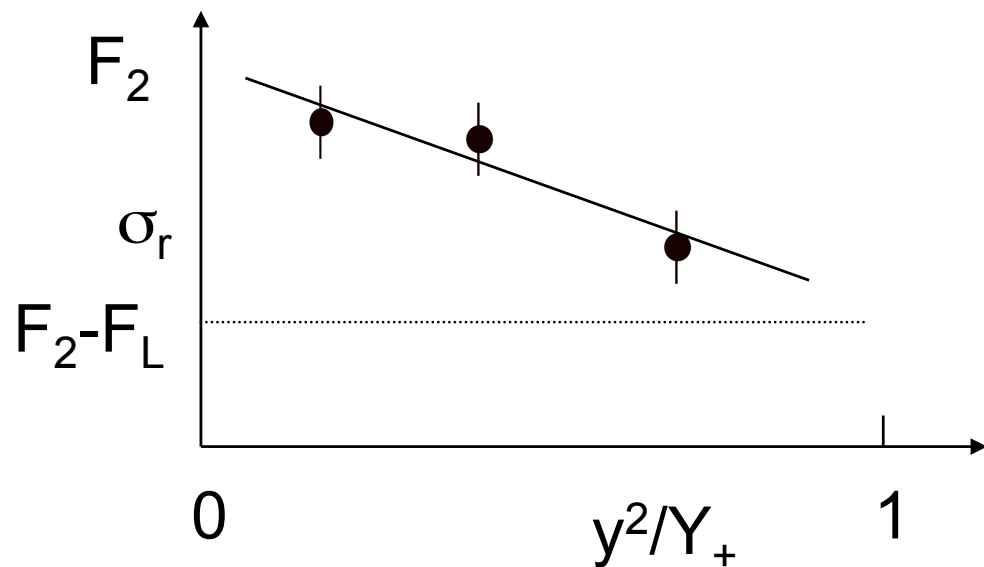
F_L from HERA

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

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

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

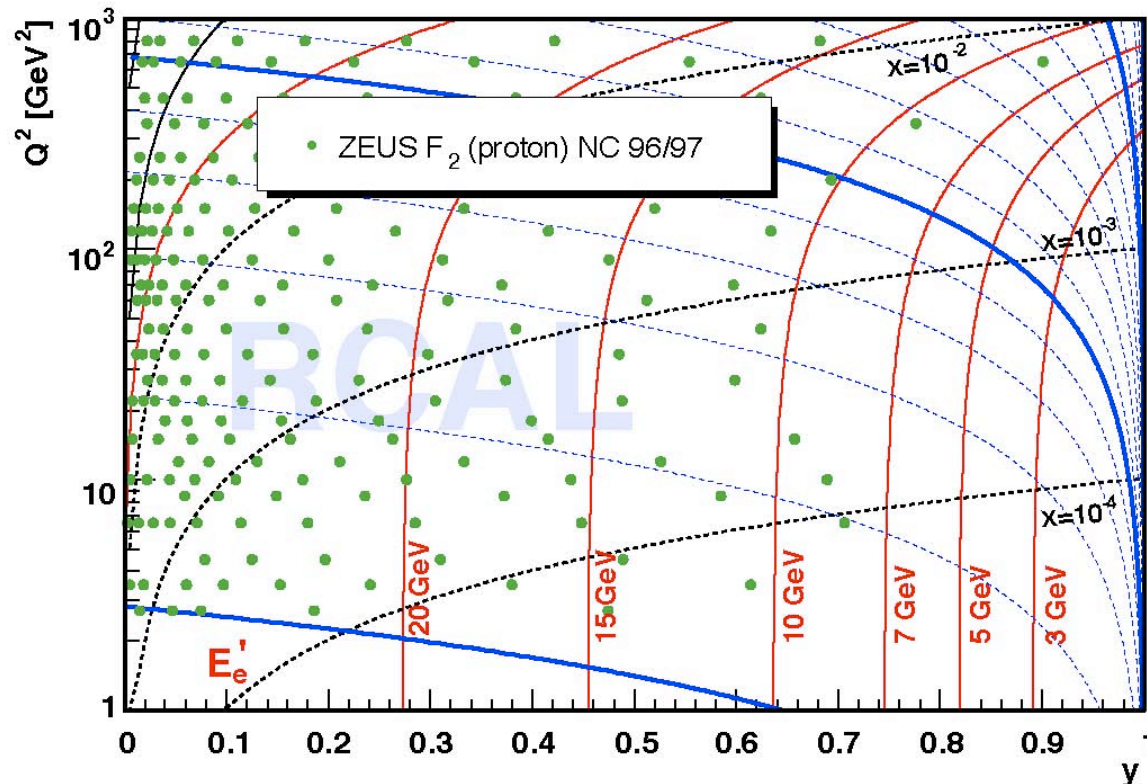
Maximize y difference for fixed x, Q . Implies largest possible difference in s .



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

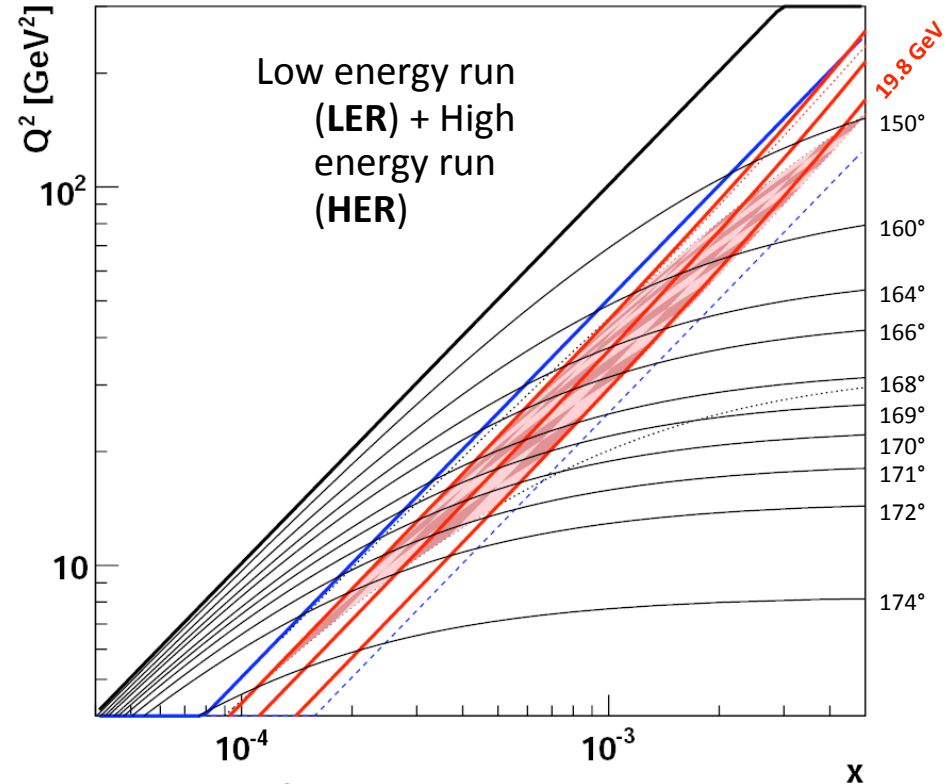
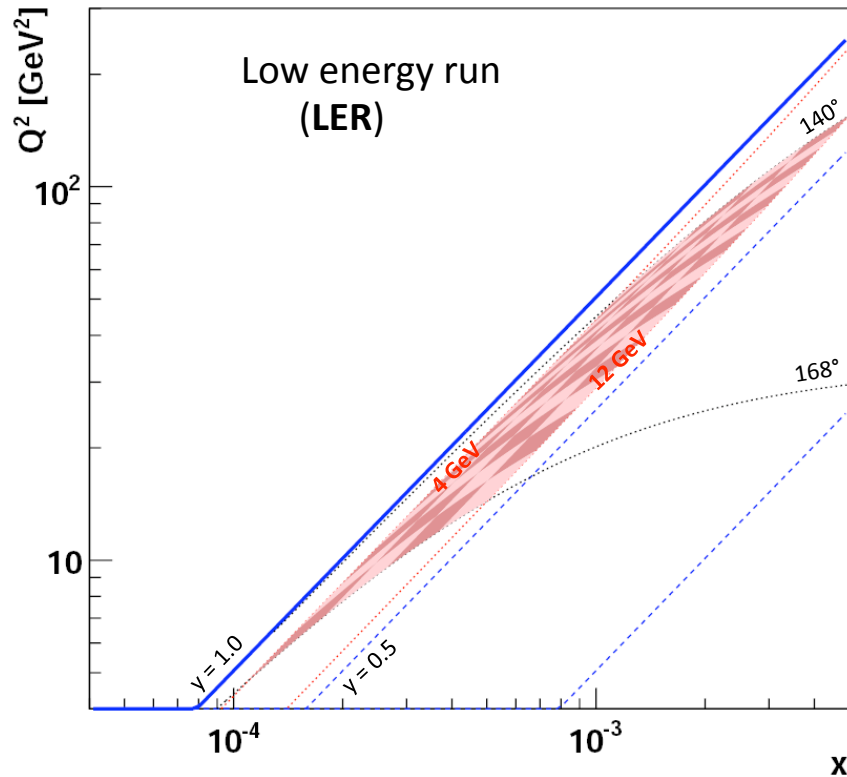
Experimental Issues

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

→ $\Delta E = 2$ GeV

→ $\theta_e = 140^\circ - 168^\circ$

→ $\Delta\theta = 2^\circ$

$E_p = 920$ GeV

→ $E_e = 16 - 20$ GeV

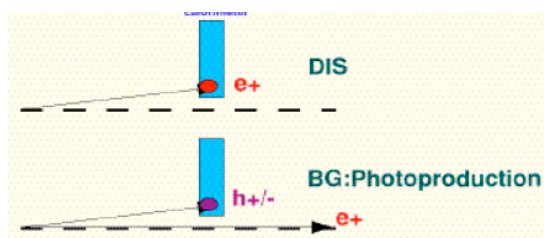
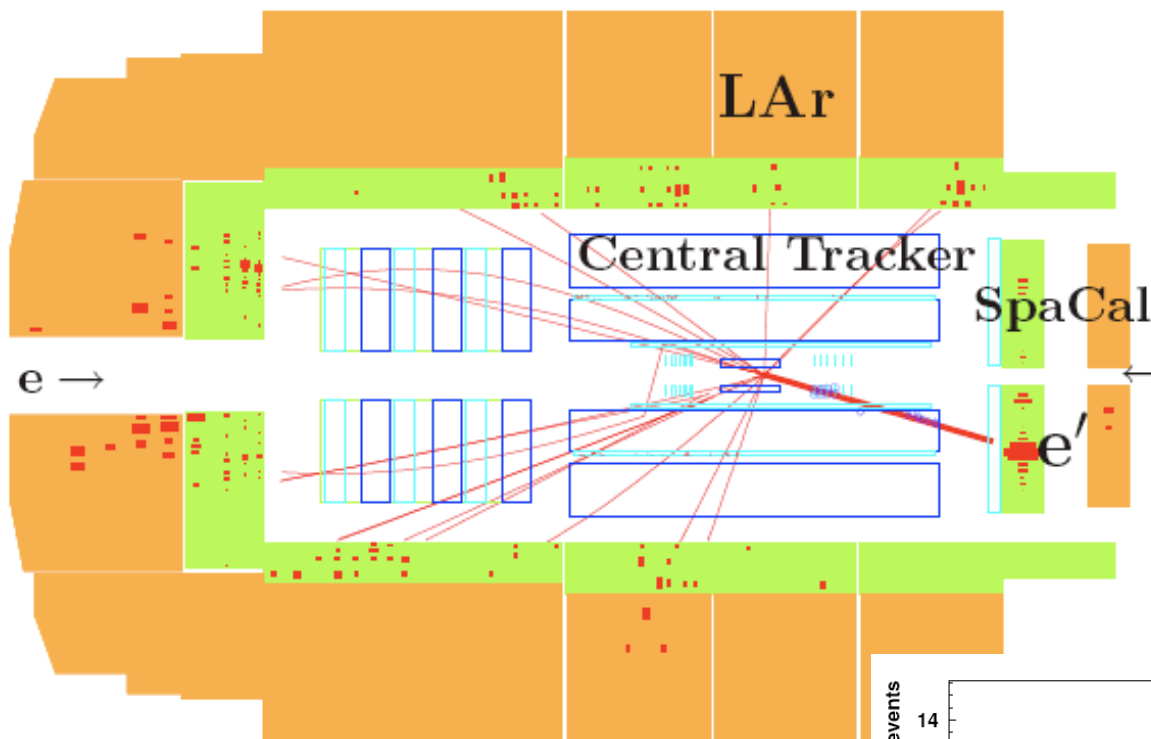
→ $\Delta E = 2$ GeV

→ $\theta_e = 160^\circ - 172^\circ$

→ $\Delta\theta = 1^\circ$

H1 Analysis

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

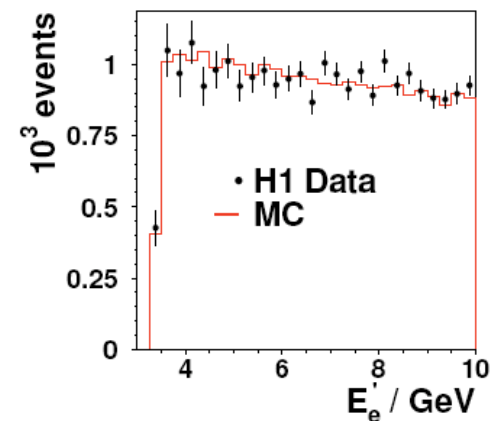
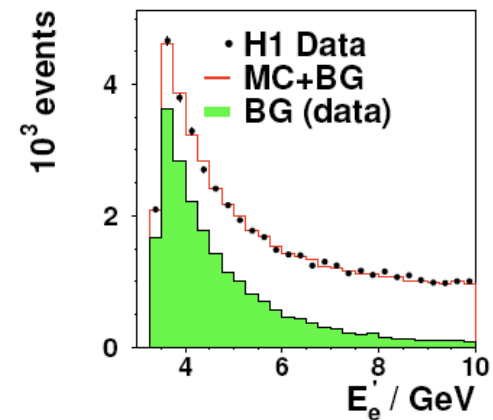
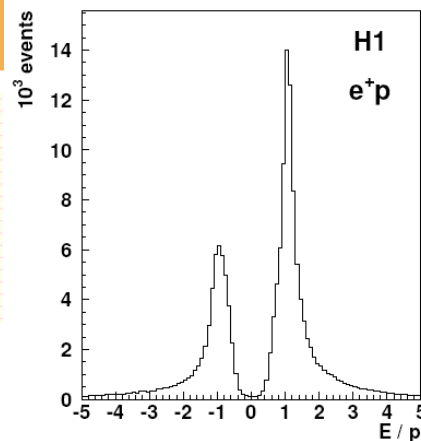


Three Q^2 ranges

3 - 12 GeV^2 : in progress

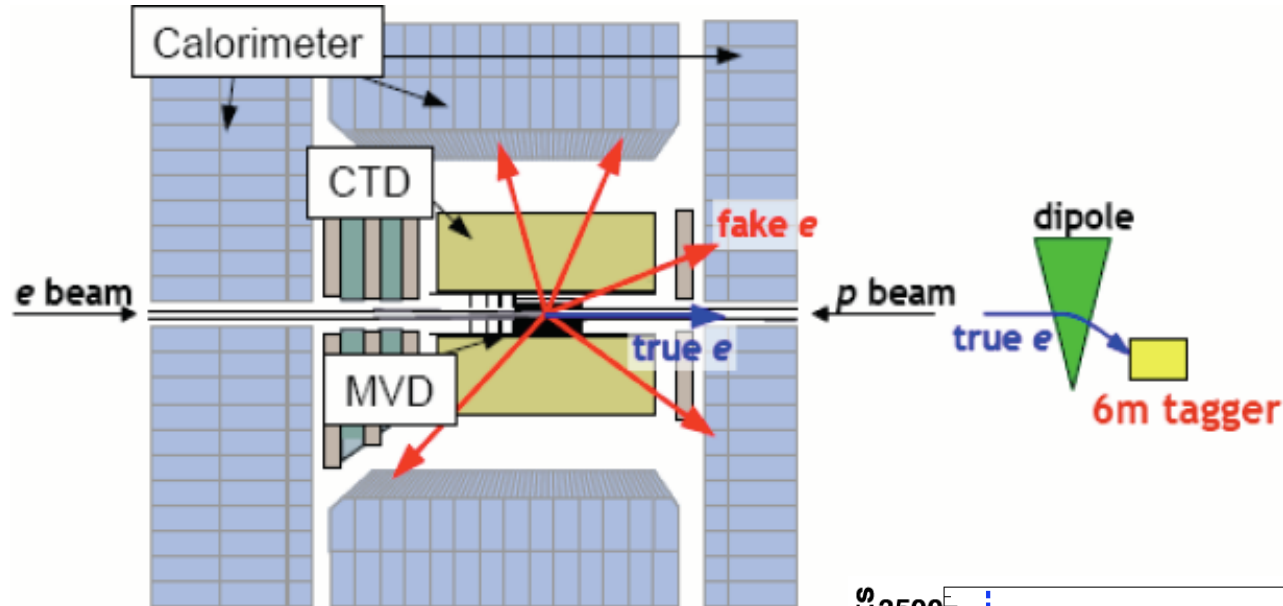
12 - 90 GeV^2 : published 6/08

35 - 800 GeV^2 : preliminary data



ZEUS Analysis

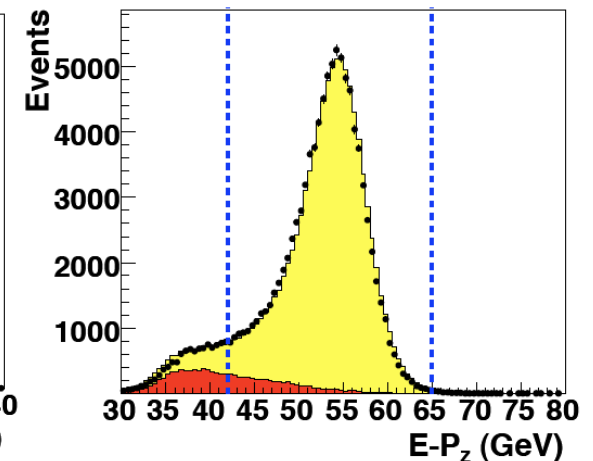
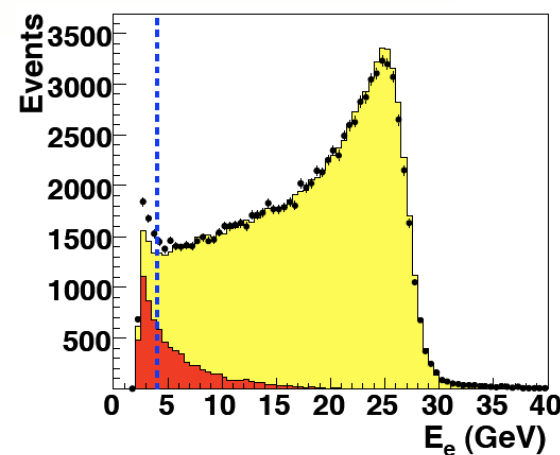
Background example



$E_e > 6$ GeV
Track or hits in CTD+MVD
Interaction vertex
 $42 < E_{p_z} < 65$ GeV

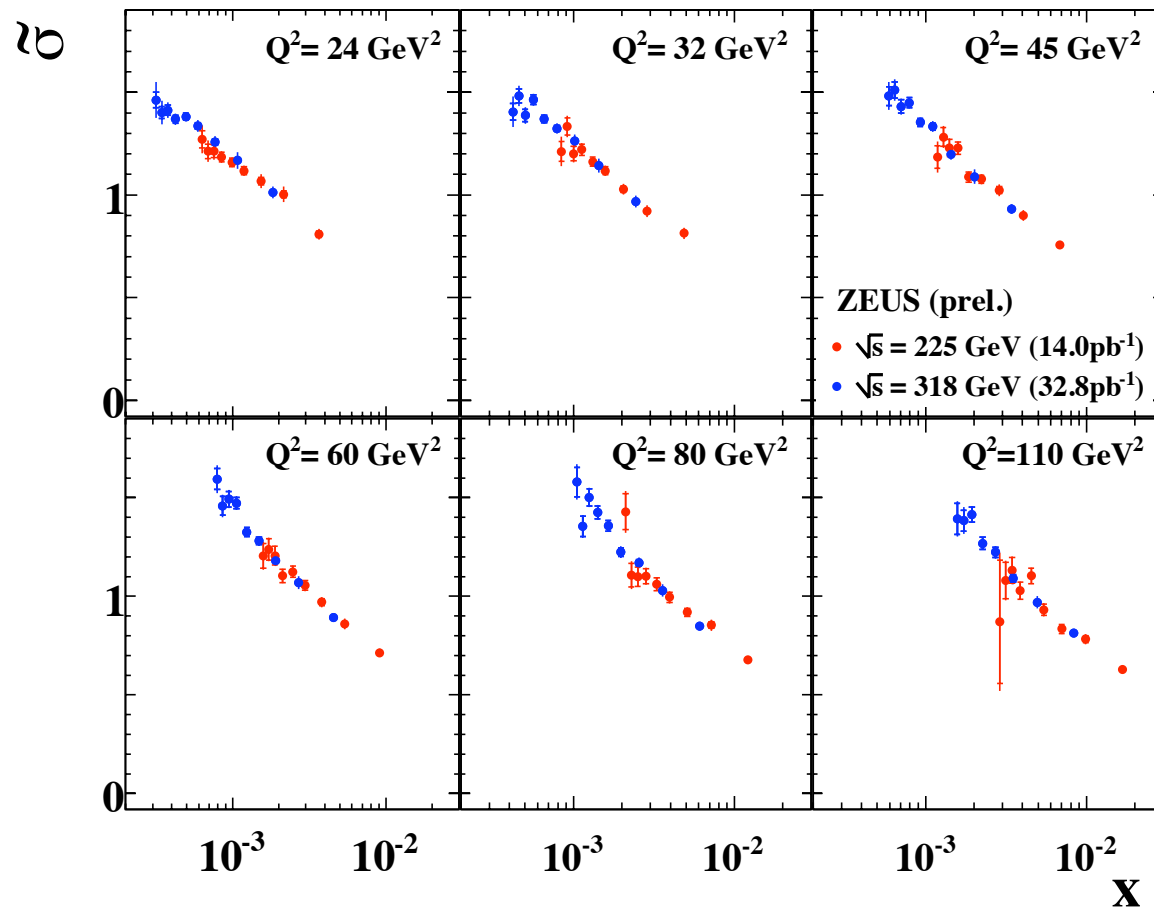
Q^2 range 24-110 GeV^2

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

ZEUS



Status – DIS08. Updated for ICHEP (next slide)

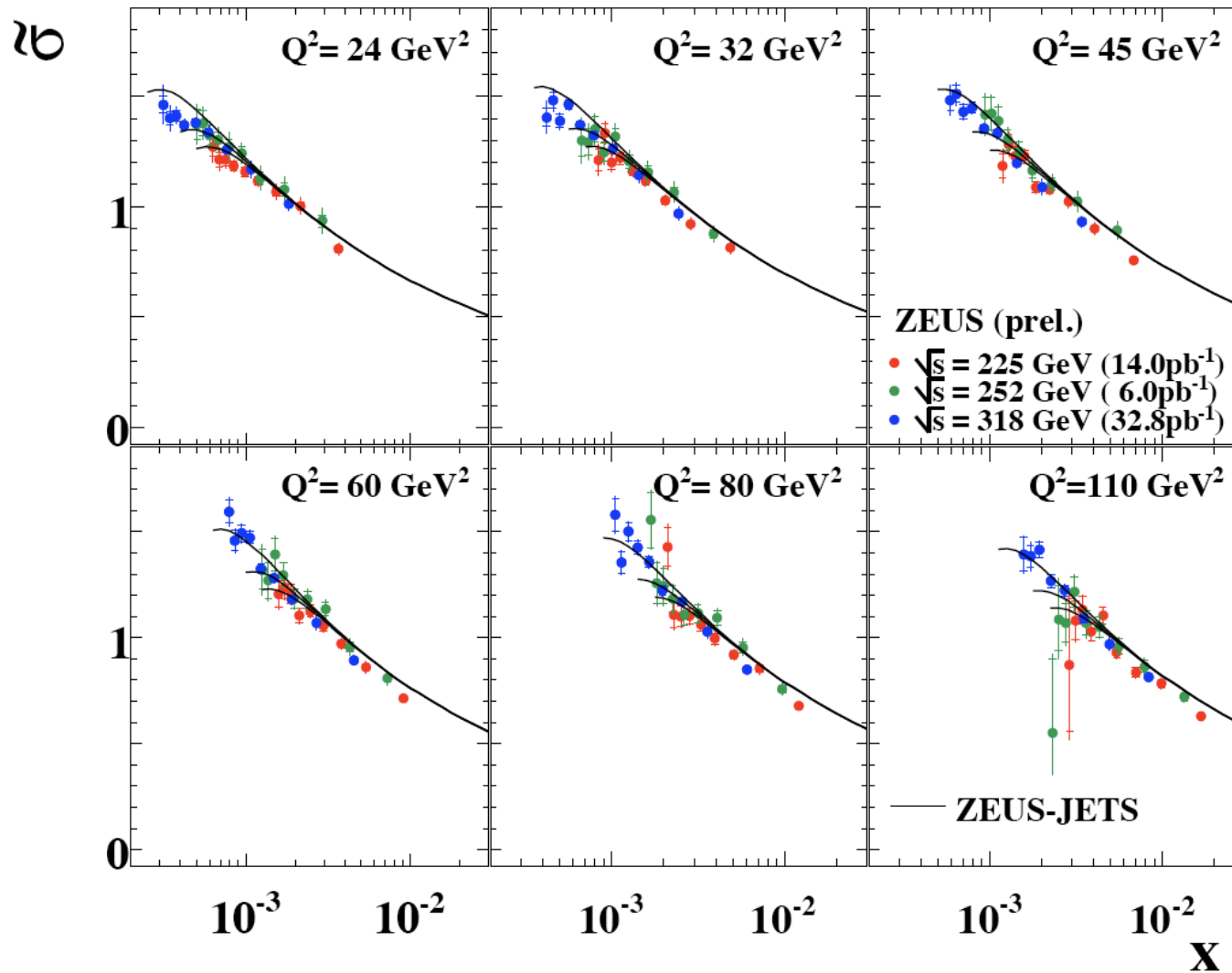
$$\tilde{\sigma} = [Y_+ F_2(x, Q^2) - y^2 F_L(x, Q^2)]$$

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

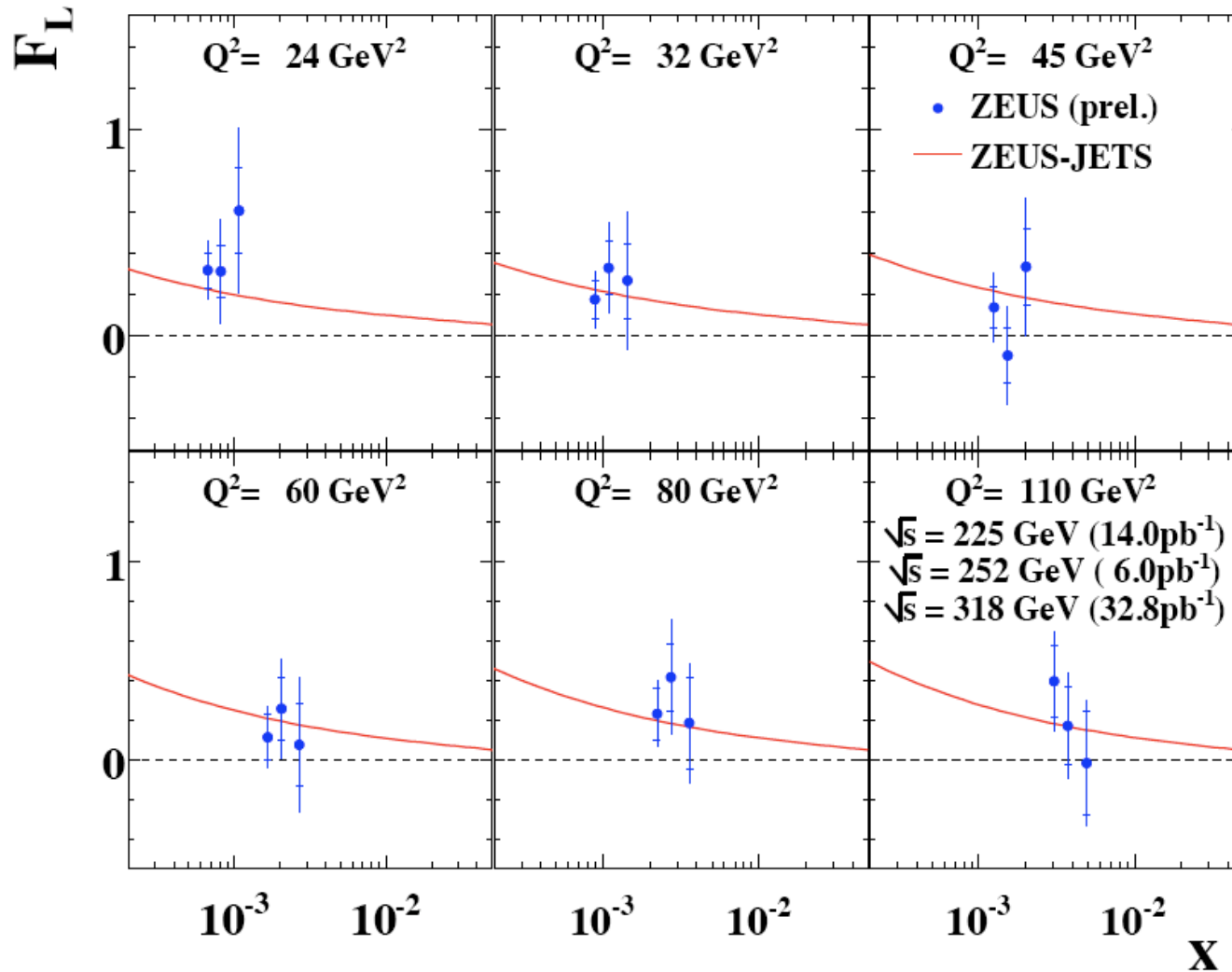
Results



ICHEP update includes the $E_p = 575 \text{ GeV}$ data (green).

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

Results

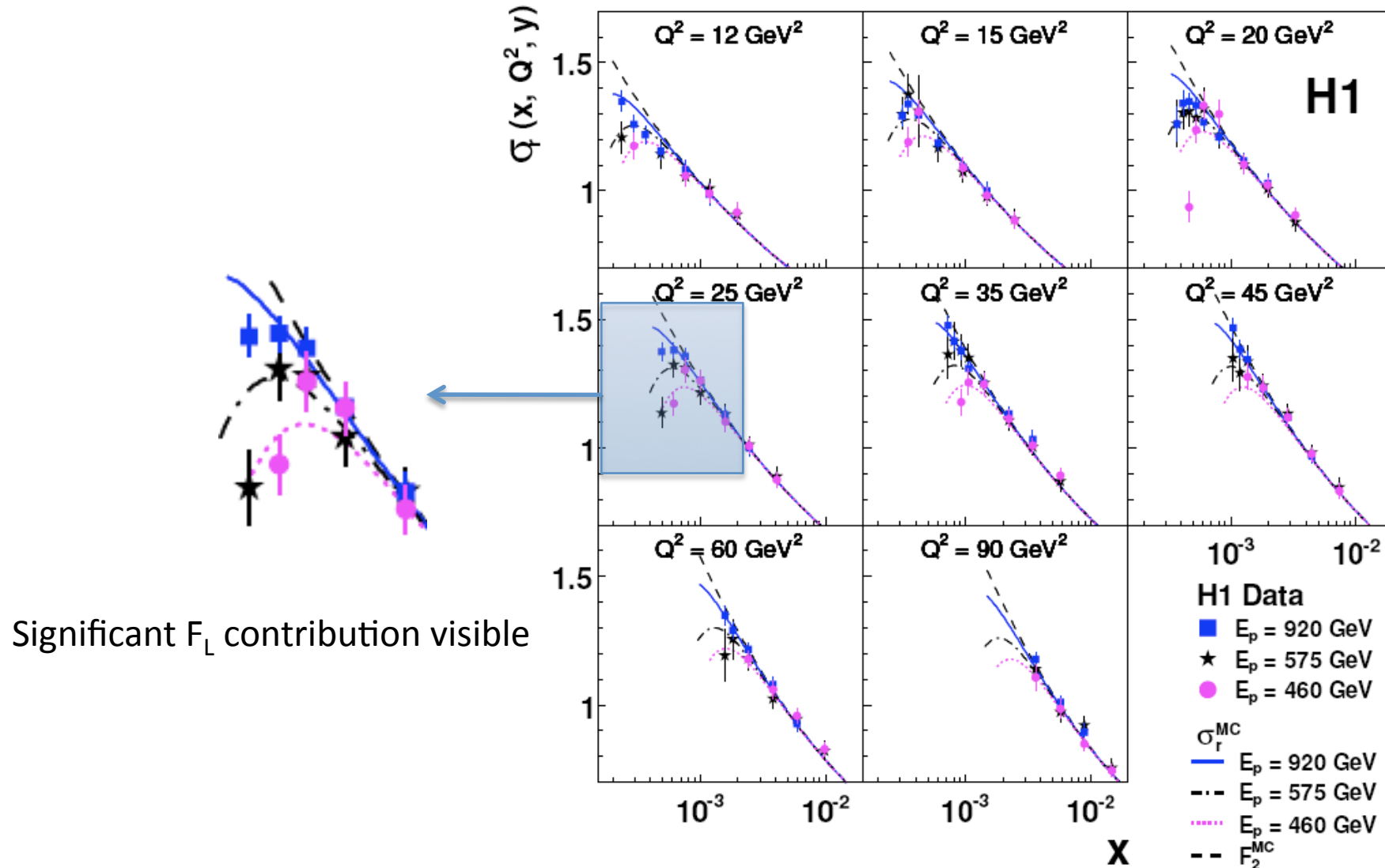


Results consistent with expectations from NLO DGLAP fits to previous data.

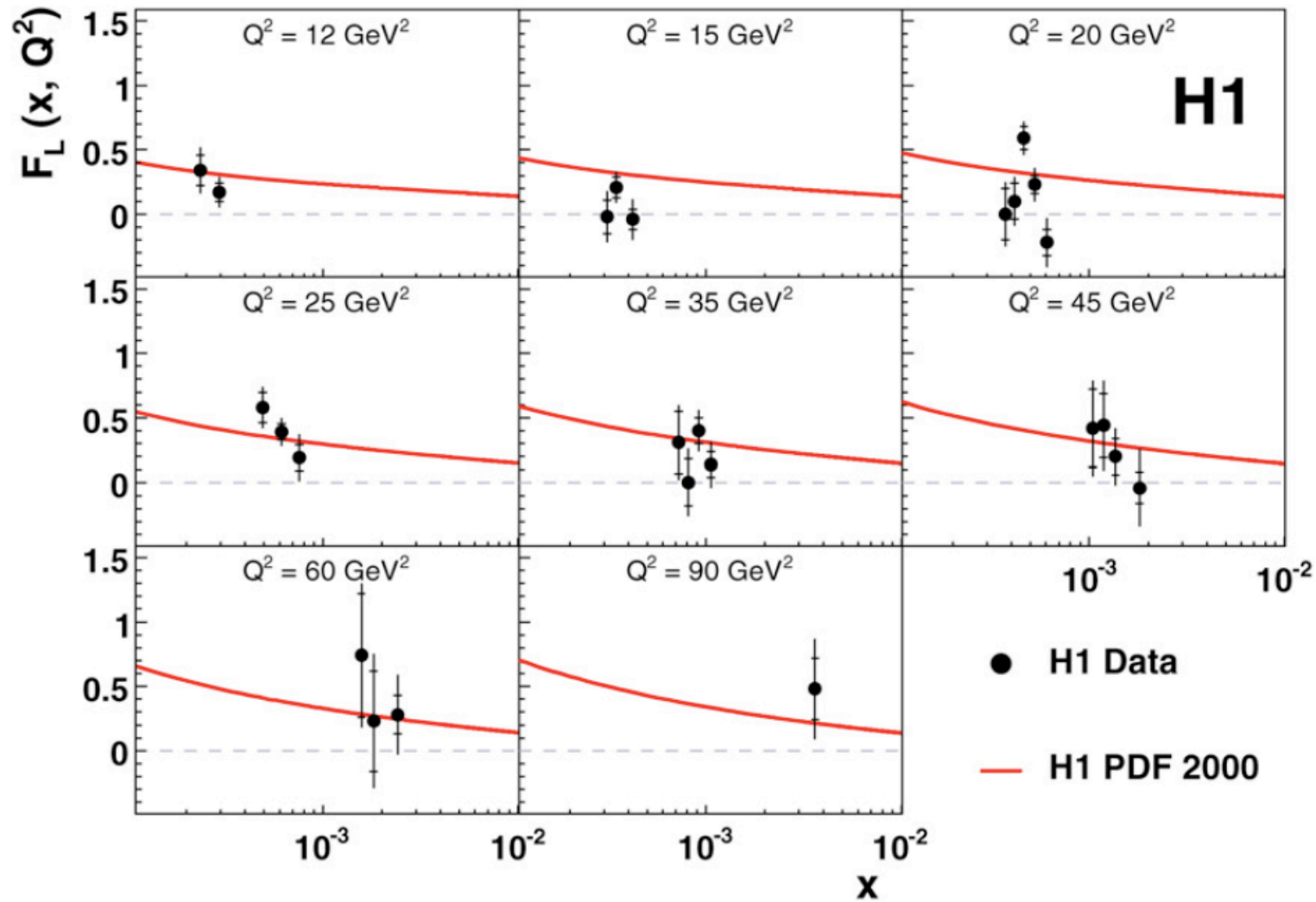
ICHEP update includes the $E_p=575 \text{ GeV}$ data, relative normalization of data sets at low y .

Results

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



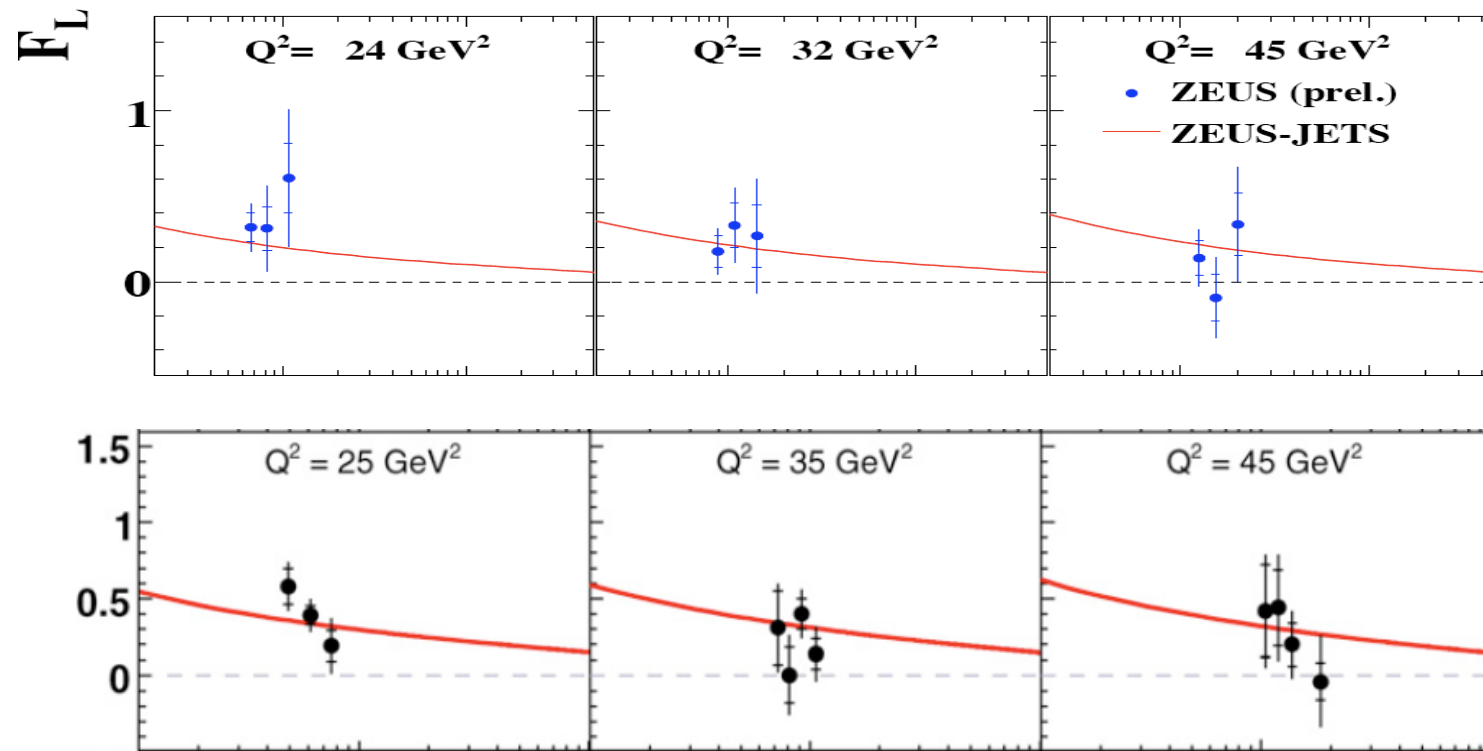
Results



H1 Collaboration Phys.Lett B665(2008)139

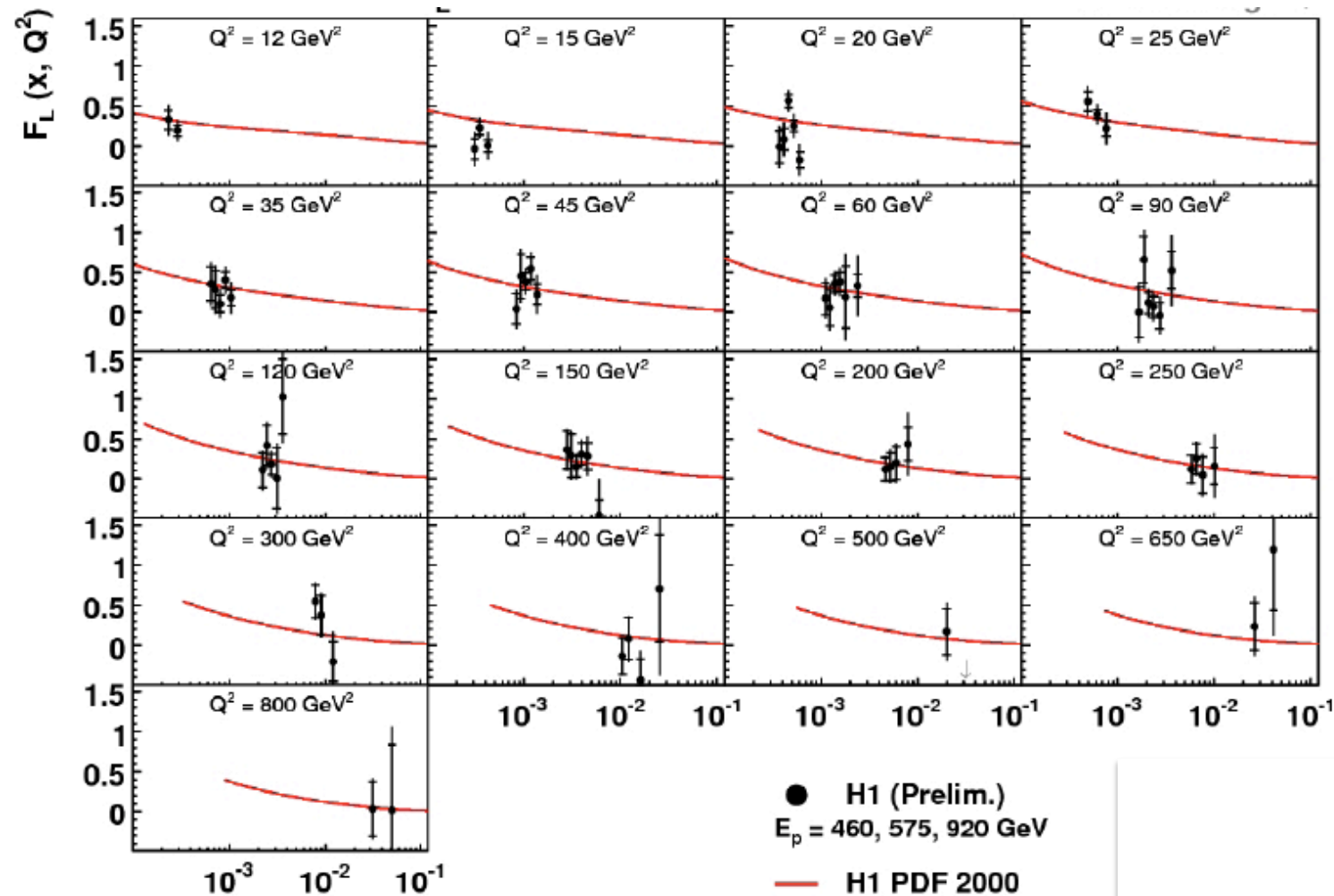
Results

Comparison on F_L Data - ZEUS+H1

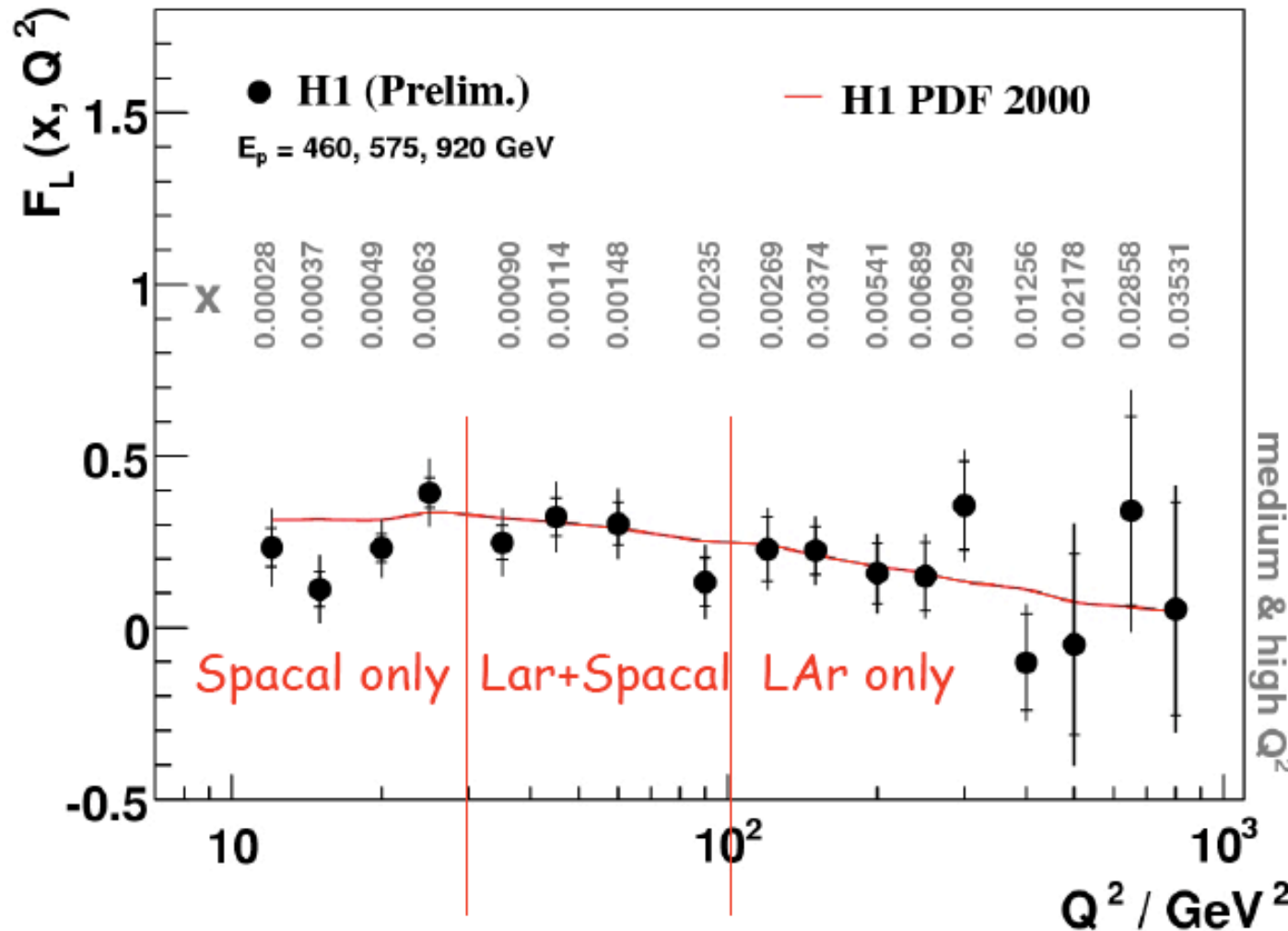


Results

Including LAr data



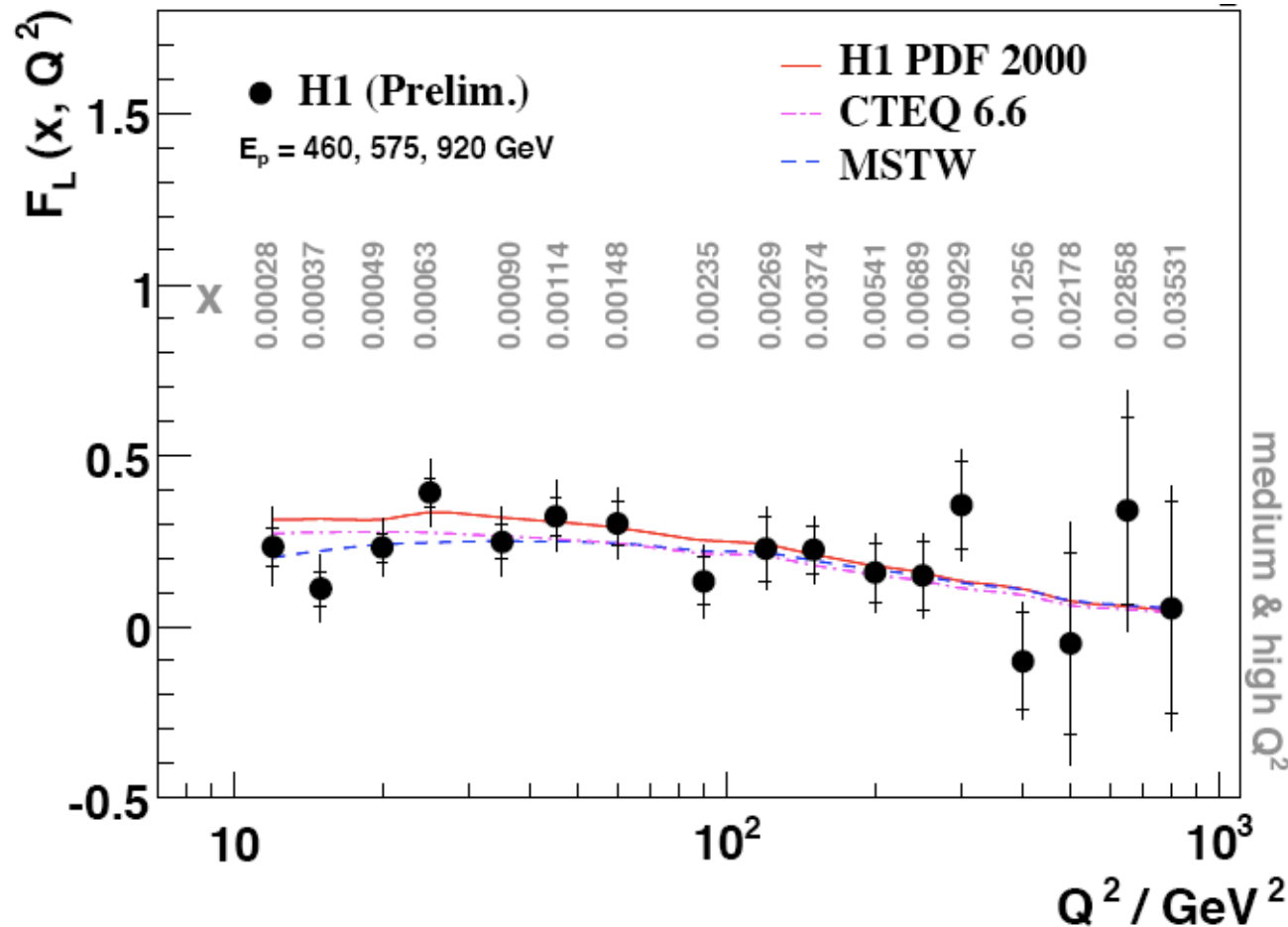
Results



Data at each Q^2 combined and then averaged vs x .
Combination with LAr improves the published SpaCal result for $Q^2 > 30 \text{ GeV}^2$
 Agrees well with NLO QCD fit to previous H1 Data.

Unfortunately, no surprises !

Results

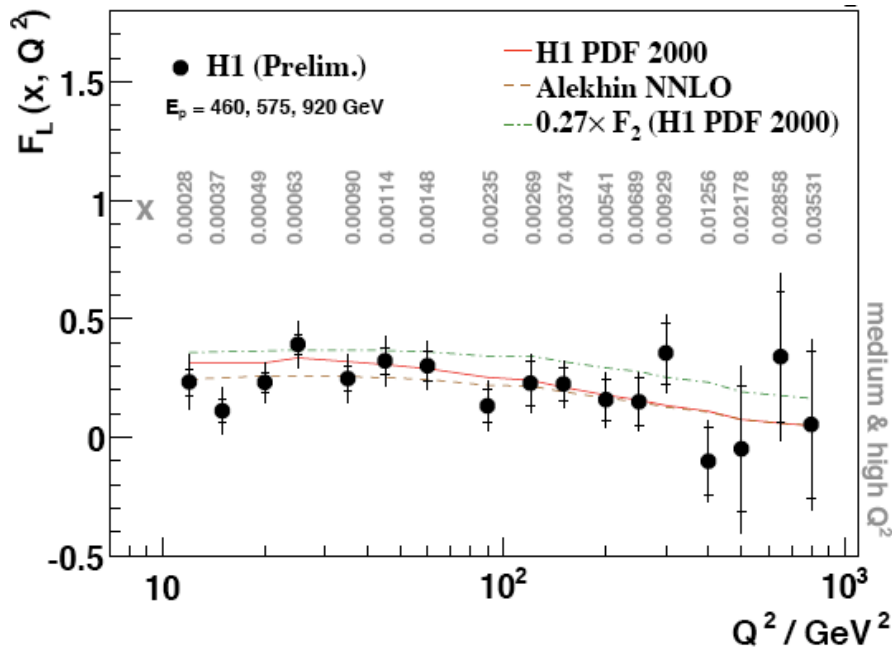


Comparison with popular pdf fits – no big surprises. Also dipole model predictions in good agreement with the data.

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



H1 data also
consistent with
Dipole model
predictions:

$F_L = 3/11 F_2$
arXiv 0806.0202

M.Kuroda, D.Schildknecht

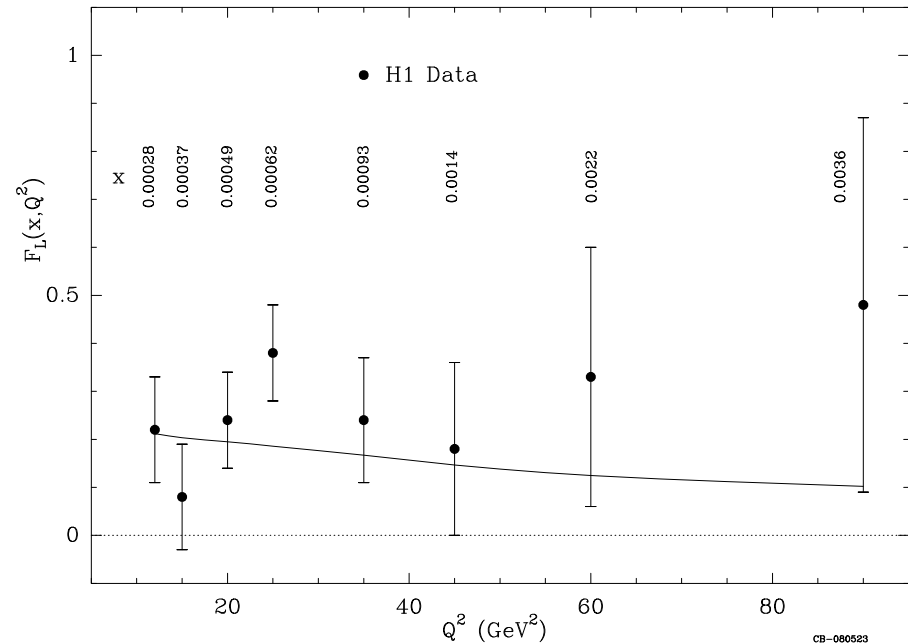
Bound:

$F_L \leq 0.27 F_2$

Ann.Phys. 322(2007)1635

C.Ewerz, O.Nachtmann

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



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