Status and Plans for Structure Functions Analysis at Low x at HERA.

Ewelina Maria Lobodzinska
on behalf of ZEUS and H1

F_2 and F_L structure functions

- NC DIS reduced ep cross-section at low Q2:

$$\sigma_r = \frac{Q^2 x}{2\pi\alpha^2 Y_+} \frac{d^2\sigma}{dxdQ^2} = F_2(x,Q^2) - f(y) F_L(x,Q^2)$$

$$Y_+ = 1 + (1-y)^2$$

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

dominant

sizable only at high y

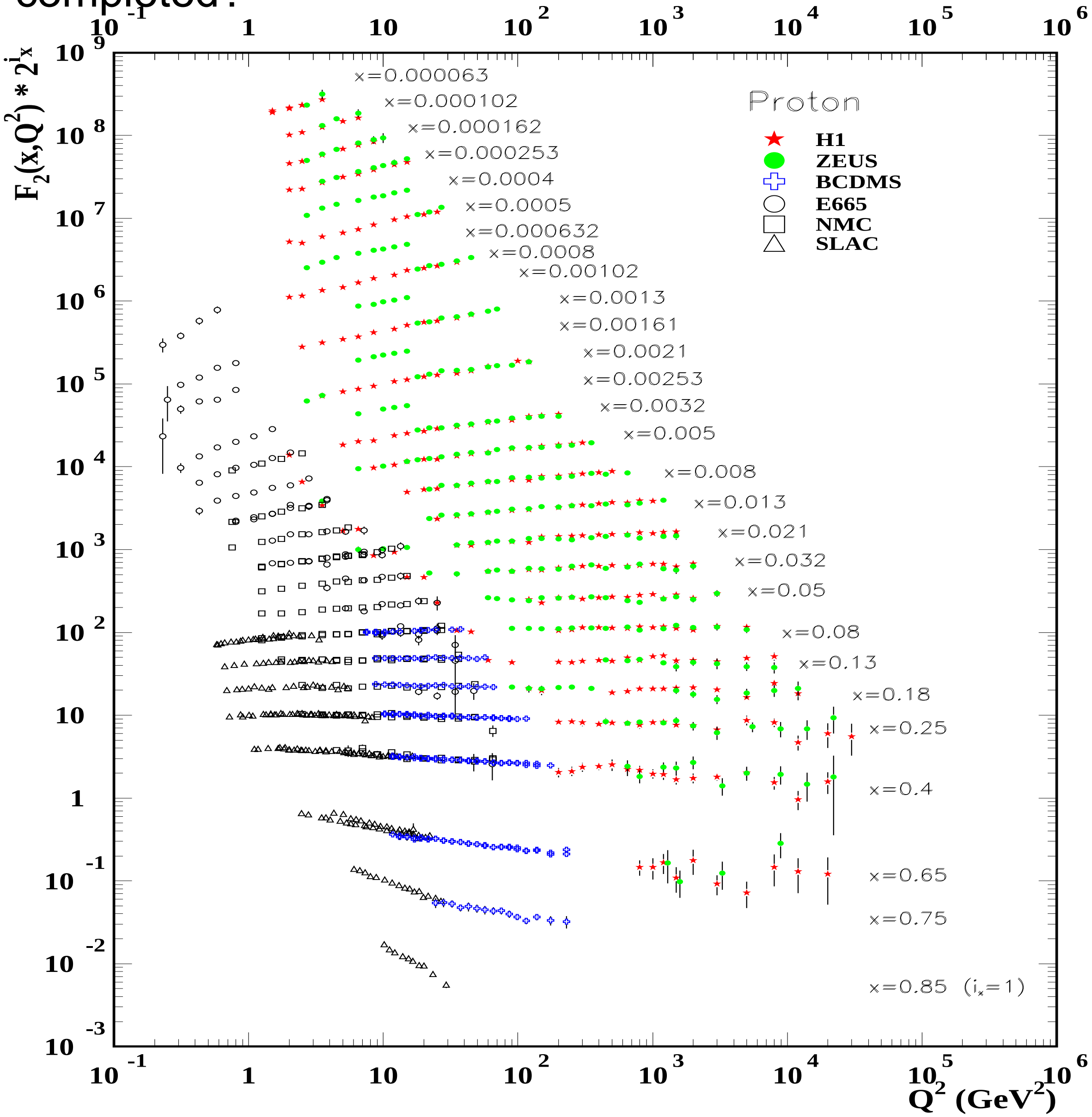
At high y gluon density dominates over see quarks density => FL determines rather directly the gluon distribution (Altarelli-Martinelli relation):

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

HERA closes down in 3 months …
have we learned all we could about the proton structure function?

Proton structure function - HERA’s main measurement, main achievement.

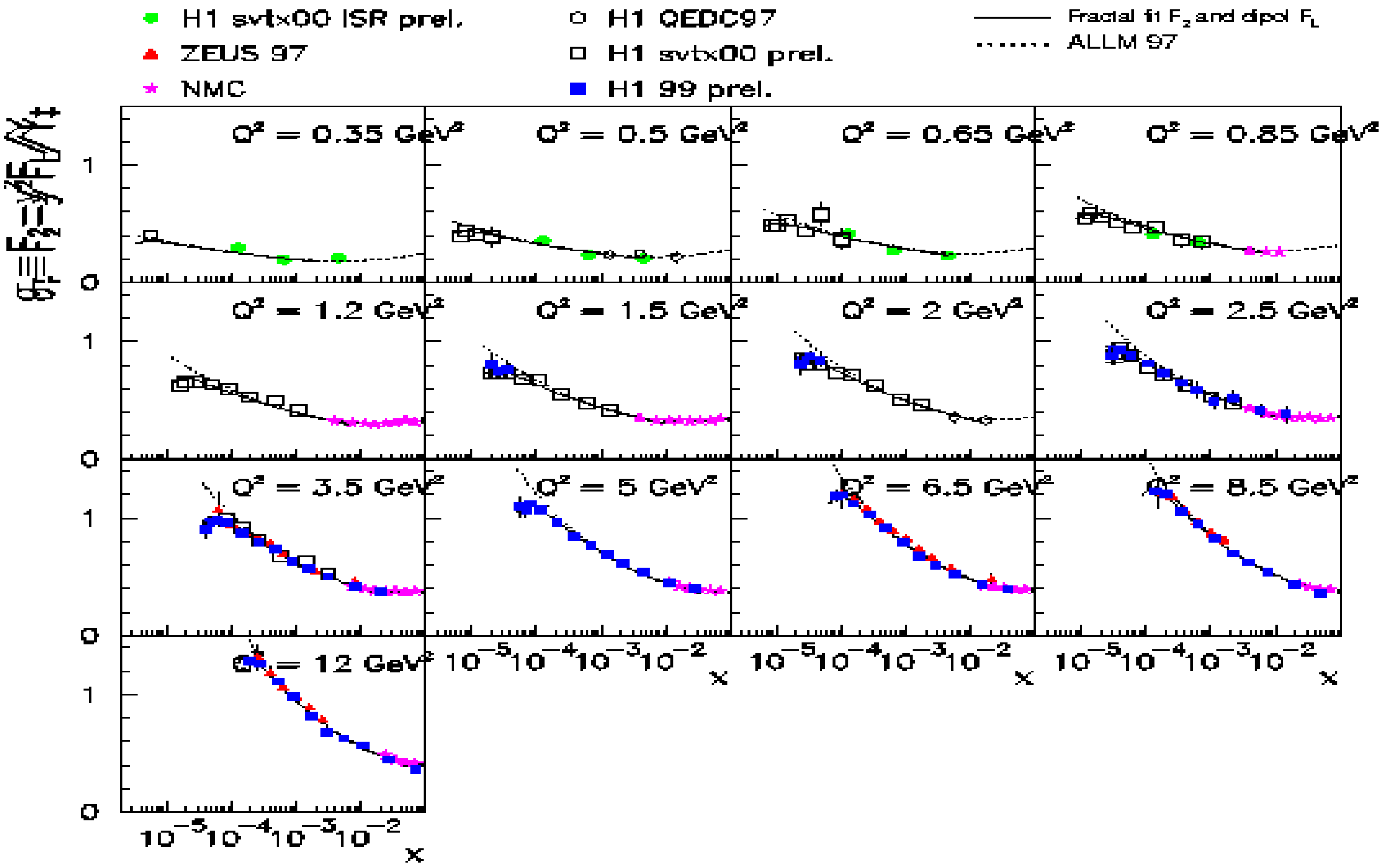
Is it already completed?



Ongoing structure function analyses in H1 and ZEUS:

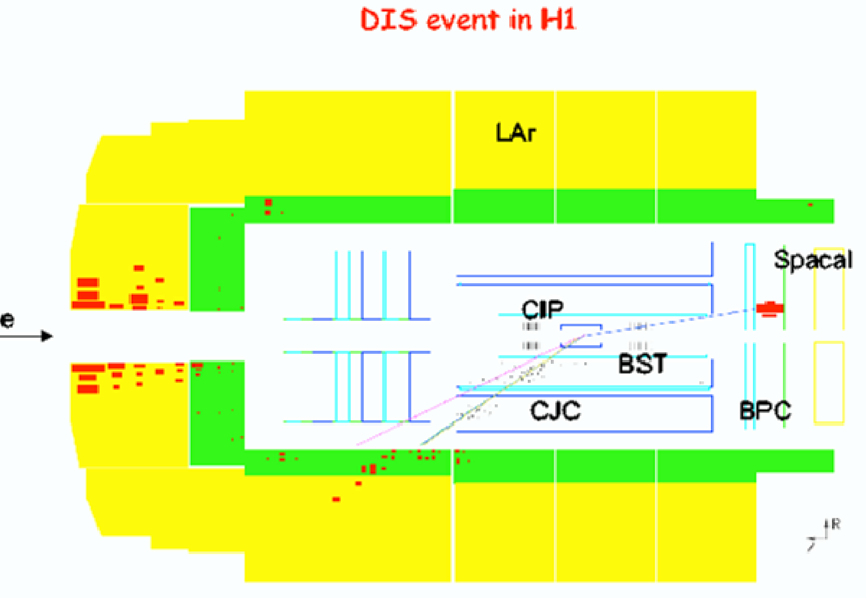
- High precision measurement of F_2 in H1.
- F_2 at high y in ZEUS and H1.
- F_L measurement in ZEUS and H1.

F_2 measurement



Accuracy of F_2 measurement is ~1.7% (H1 99 minimum bias). In the ongoing analysis of 2000 bulk data H1 aims for even higher precision.

Accuracy of the F_2 measurement



Main sources of uncertainty:

1. Electron energy scale in backward calo.

– 0.15% at E’=27GeV

- 1% at 7GeV

2. Polar angle of scattered electron 0.3 mrad

3. Hadronic energy scale calibration – 2% in forward and central calo.

-3% in fraction carried by tracks

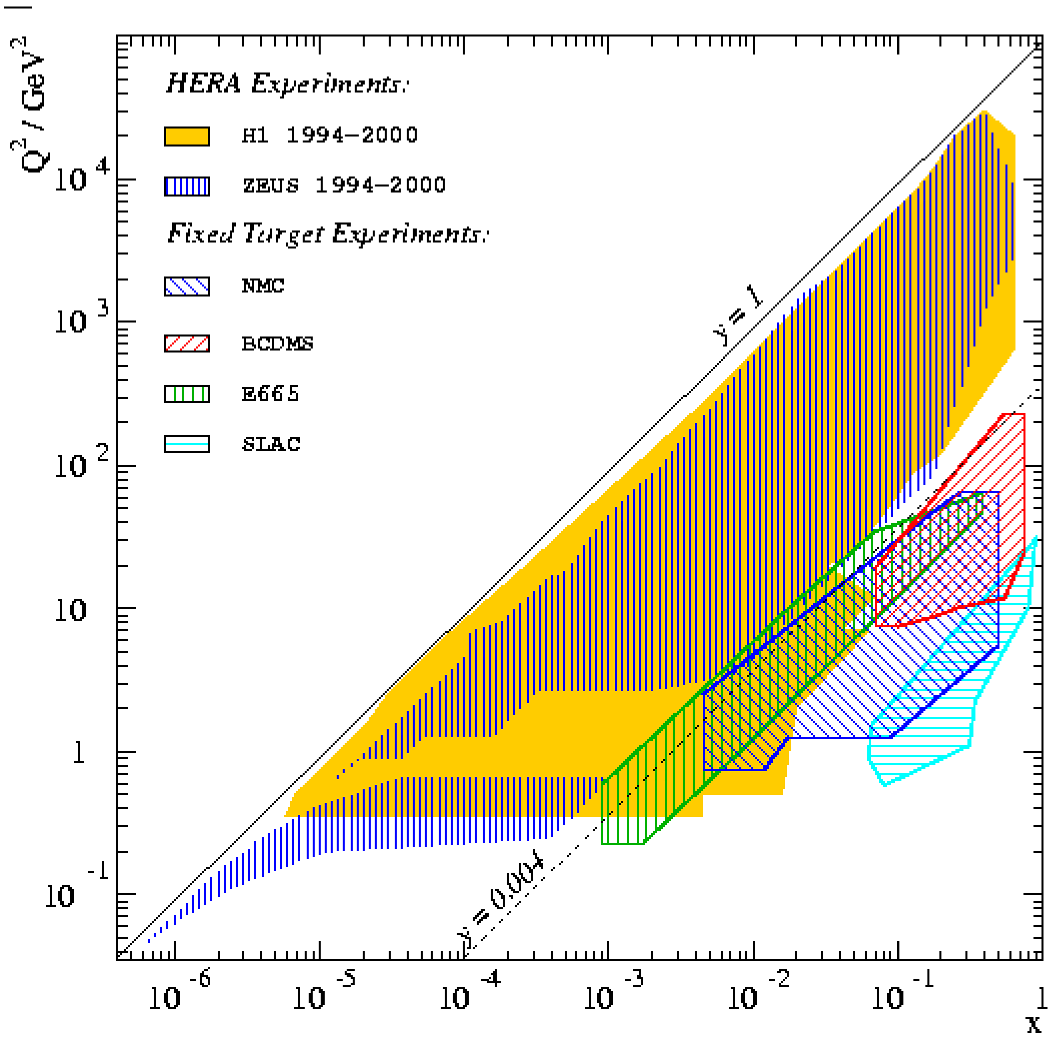
4. Noise description – up to 10%

5.Photoproduction background estimation – 10% at high y, negligible at low y.

Due to improved electron energy measurement, high MC statistics, understanding of noise the precision of 1% may be reached for low x bins.

(G.Medin, A.Glazov, T.Lastovicka proceedings from“HERA-LHC workshop”)

Kinematics plane coverage



Not too many analyses trying to reach high y region …

Can we measure F_2 at high y?

Which precision can we achieve?

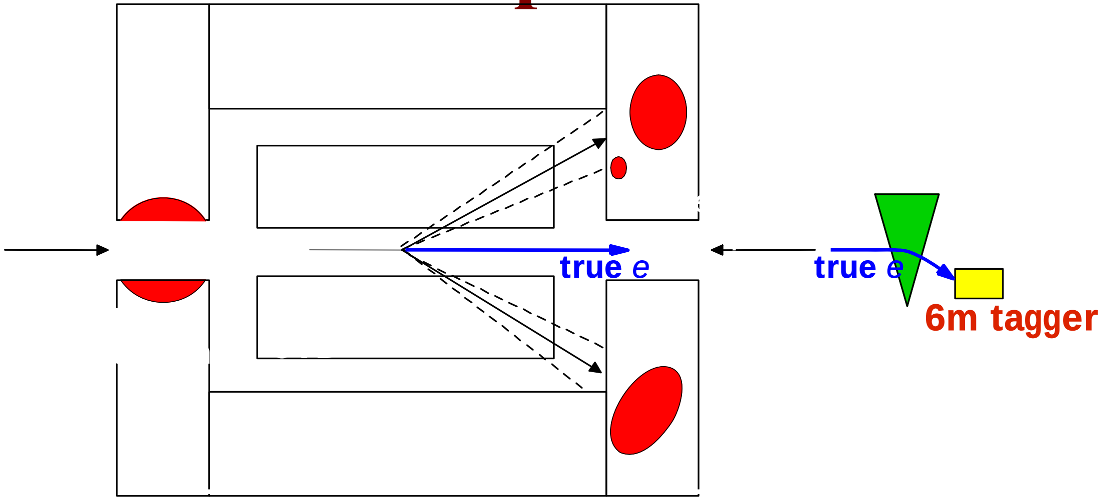
What are the main problems for this measurement?

F2 at high y - main challenges

- At low Q^2 y=1-E'/E (E' energy of the scattered electron) => at high y low energy electron needs to be identified in a large background of hadrons from photoproduction and also from DIS (high y = low x i.e. HFS are scattered backwards)
- Two main challenges

1. Electron finding – needed electron finder that efficiently recognizes low energy electron (for high y electron energy is smaller than the energy of the hadronic jet) with relatively small scattering angle
2. Photoproduction background – electron escapes down the beam pipe, some other particle fakes electron in the calorimeter – needed a tool to remove this background and to estimate its remaining contribution

Photoproduction handling at ZEUS



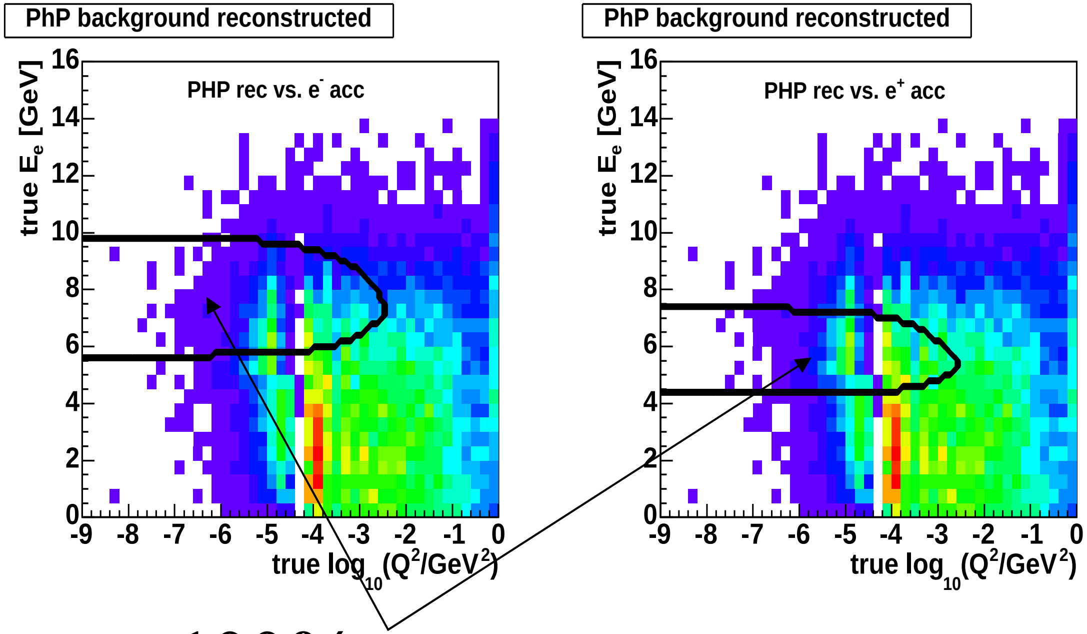
6m tagger :

-> 2% agreement with lumi measurement ;

-> fully simulated and reconstructed;

-> for e+ running 25% of php events can be directly rejected by tagger ;

-> php MC can be normalized with use of tagger and used for stat. subtraction of php background

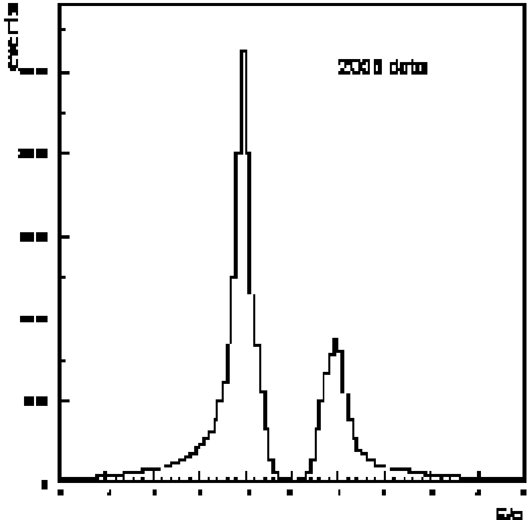


~100% acceptance

Photoproduction handling by H1

-> analysis based only on data, no php MC
-> requirement of track linked to electron cluster removes neutral php background
-> charge asymmetry factor determined from tagged php events and from “wrong sign” background in e+p and e-p runs
-> “wrong sign” php background subtracted directly, “right sign” background statistically using charge asymmetry factor

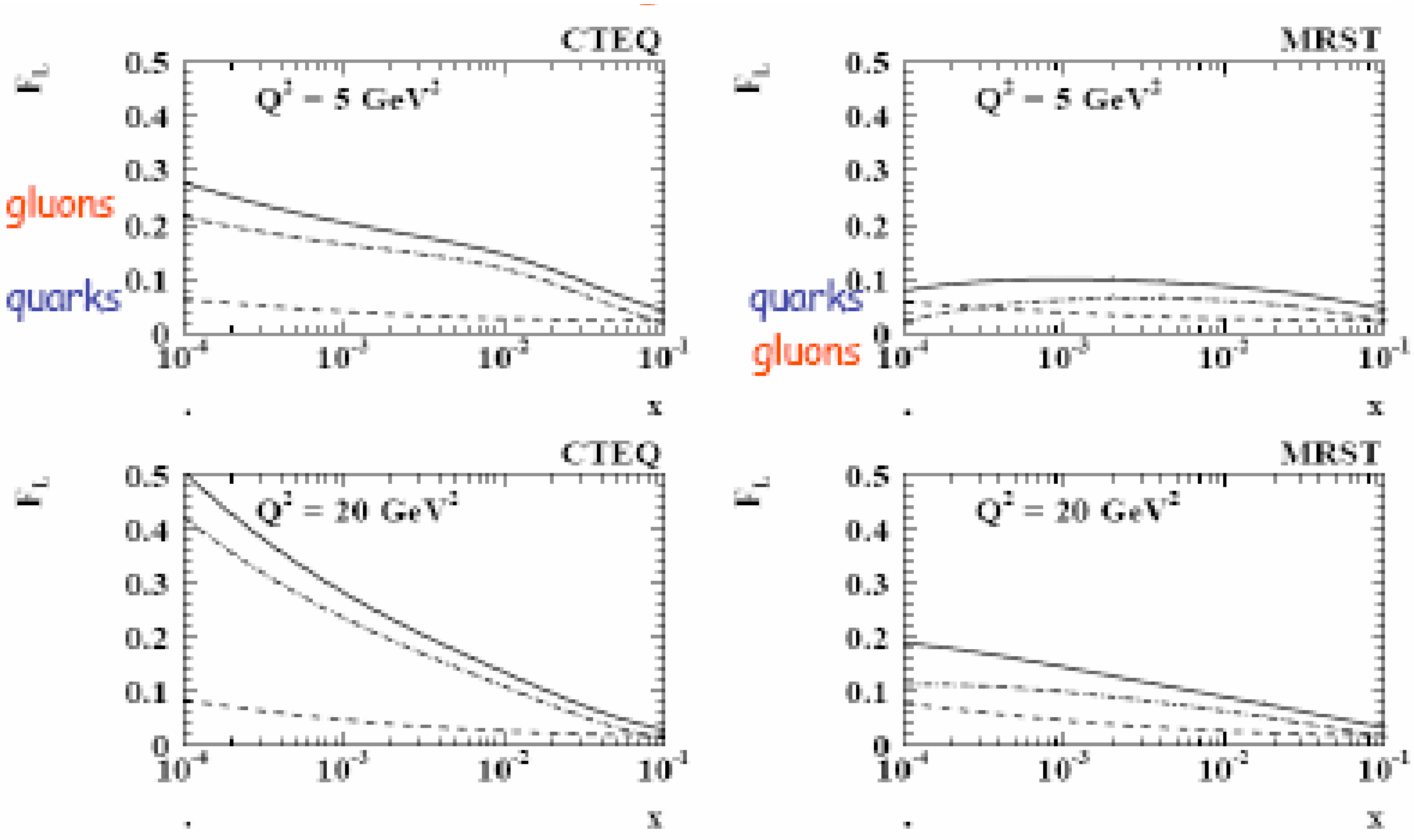
E/p ratio for clusters linked to track



F_2 at high y

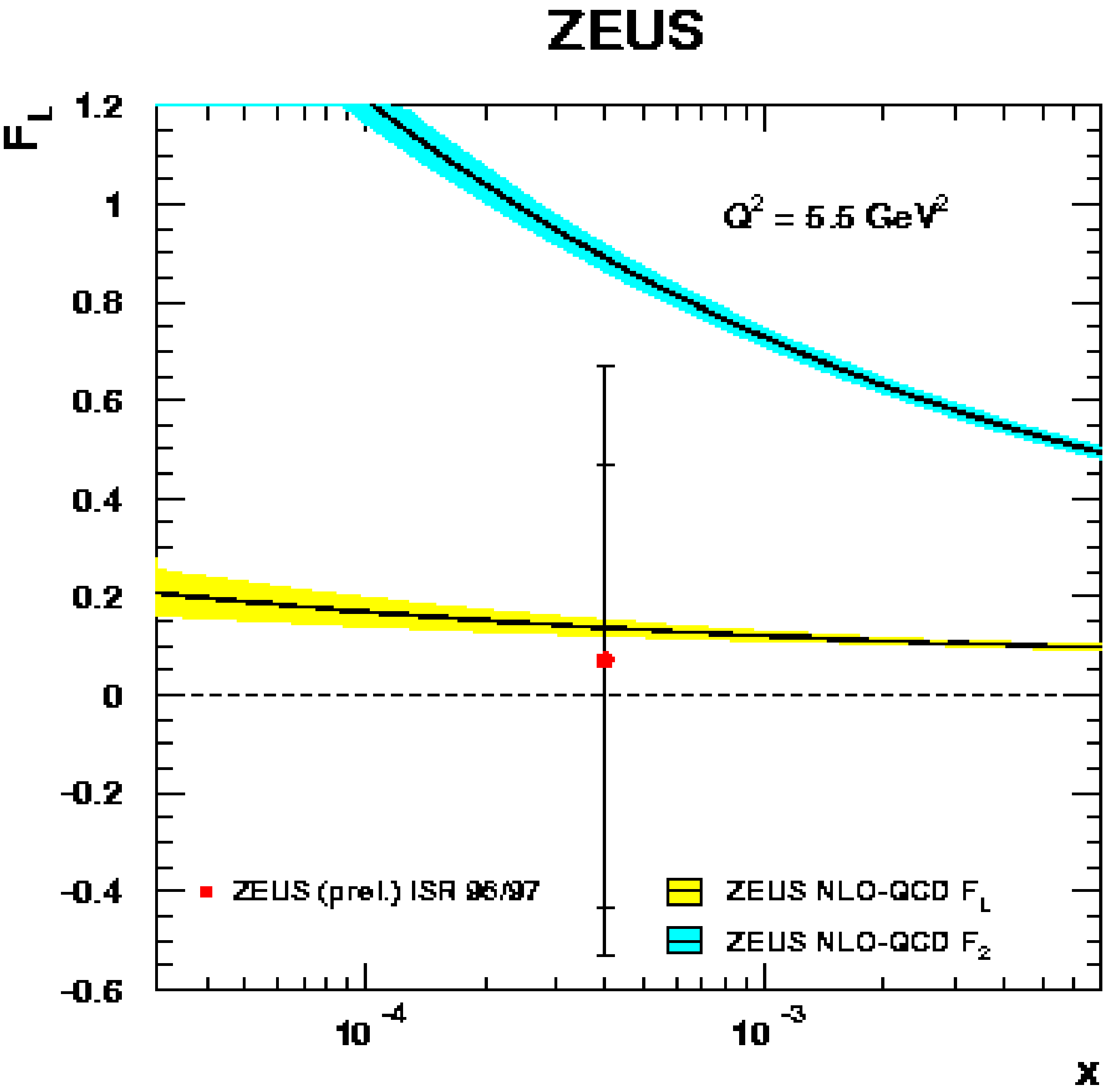
- **Preliminary results of F_2 at high y from ZEUS and H1 expected for DIS 2007**
- **F_2 at high y measurement – a good "training" for F_L measurement, as for LER high y region has to be reached**

Predictions for the longitudinal structure function F_L



F_L and the gluon density at low x poorly constrained by present data.

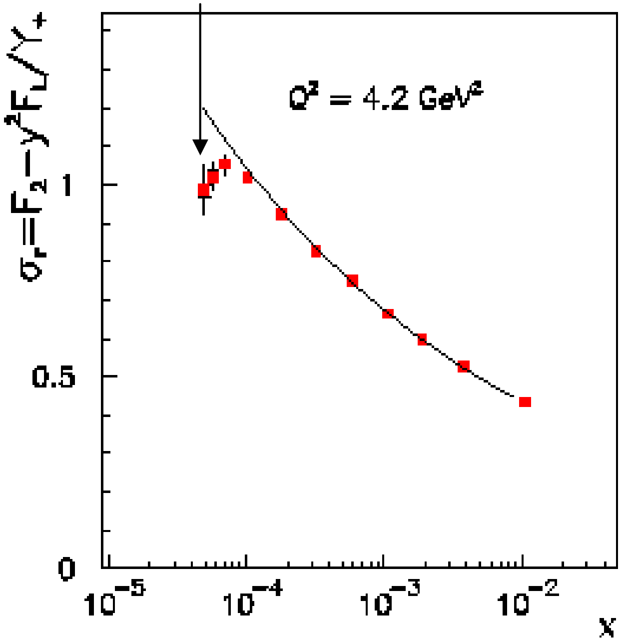
F_L measurement by ZEUS using ISR events



Is it possible to measure the FL structure function with higher precision?

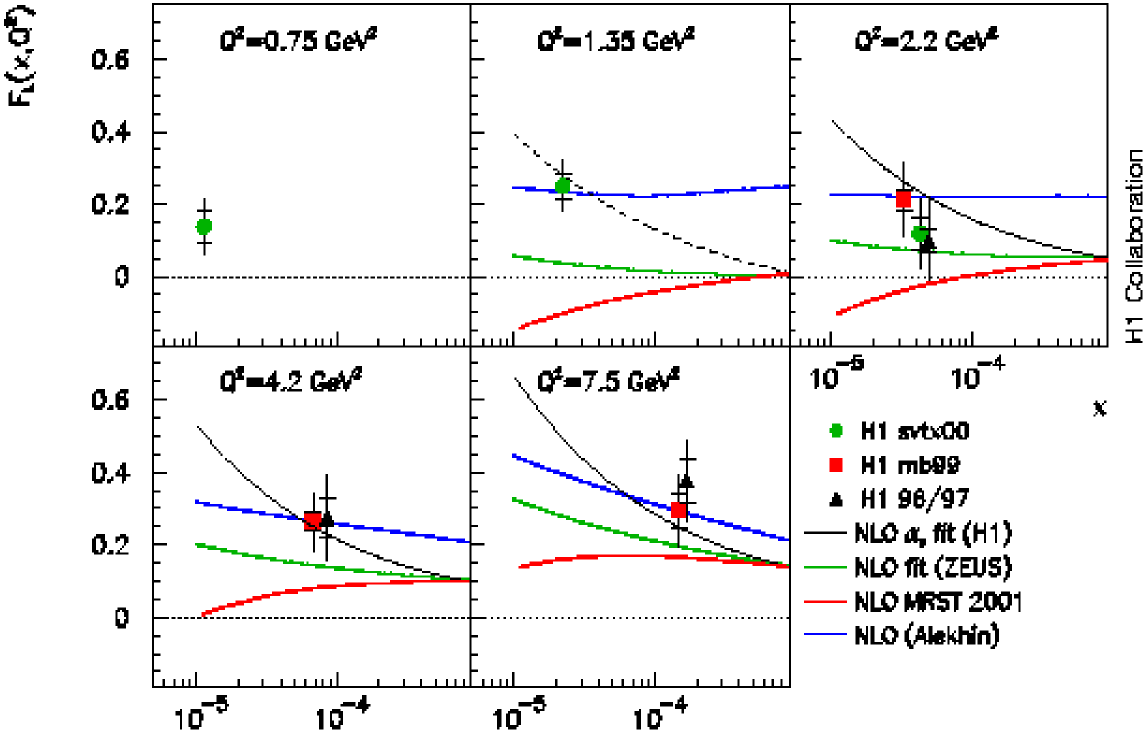
Extraction of the F_L structure function by H1.

Bend of cross-section attributed to F_L



Cross-section fitted with:

$$\sigma_r = c\, \underset{\downarrow\ F_2}{x^{-\lambda}} - f(y)\, F_L$$



F_L extracted from fit to the cross section

Can we measure F_L without assumptions about F_2?

Can we measure x dependence of F_L for fixed Q^2?

FL measurement at HERA

Alan Martin at DIS04:

"It is inconceivable that HERA will not measure F_L with sufficient precision to determine the gluon. Low energy runs should be done."

At March 21st HERA lowered the proton beam energy.

Low energy running will take about 3 months.

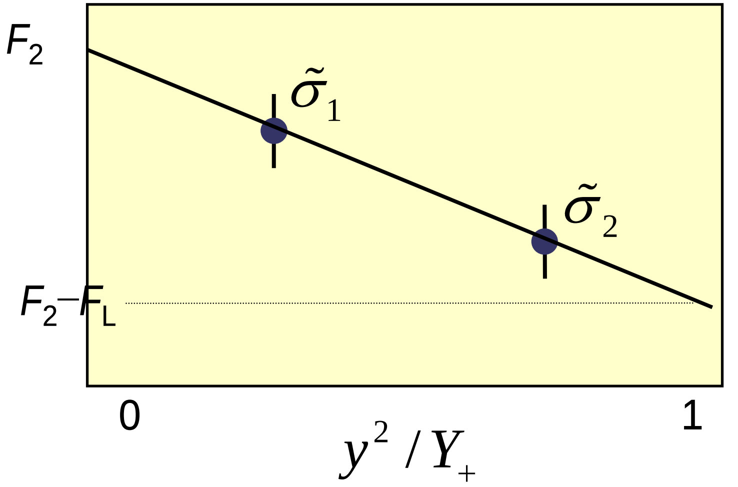
10 pb^{-1} should be collected at 460 GeV proton beam energy

Both ZEUS and H1 prepare for the F_L structure function analysis.

Idea of the measurement

Reduced cross-section $\sigma = F_2 - f(y) F_L$

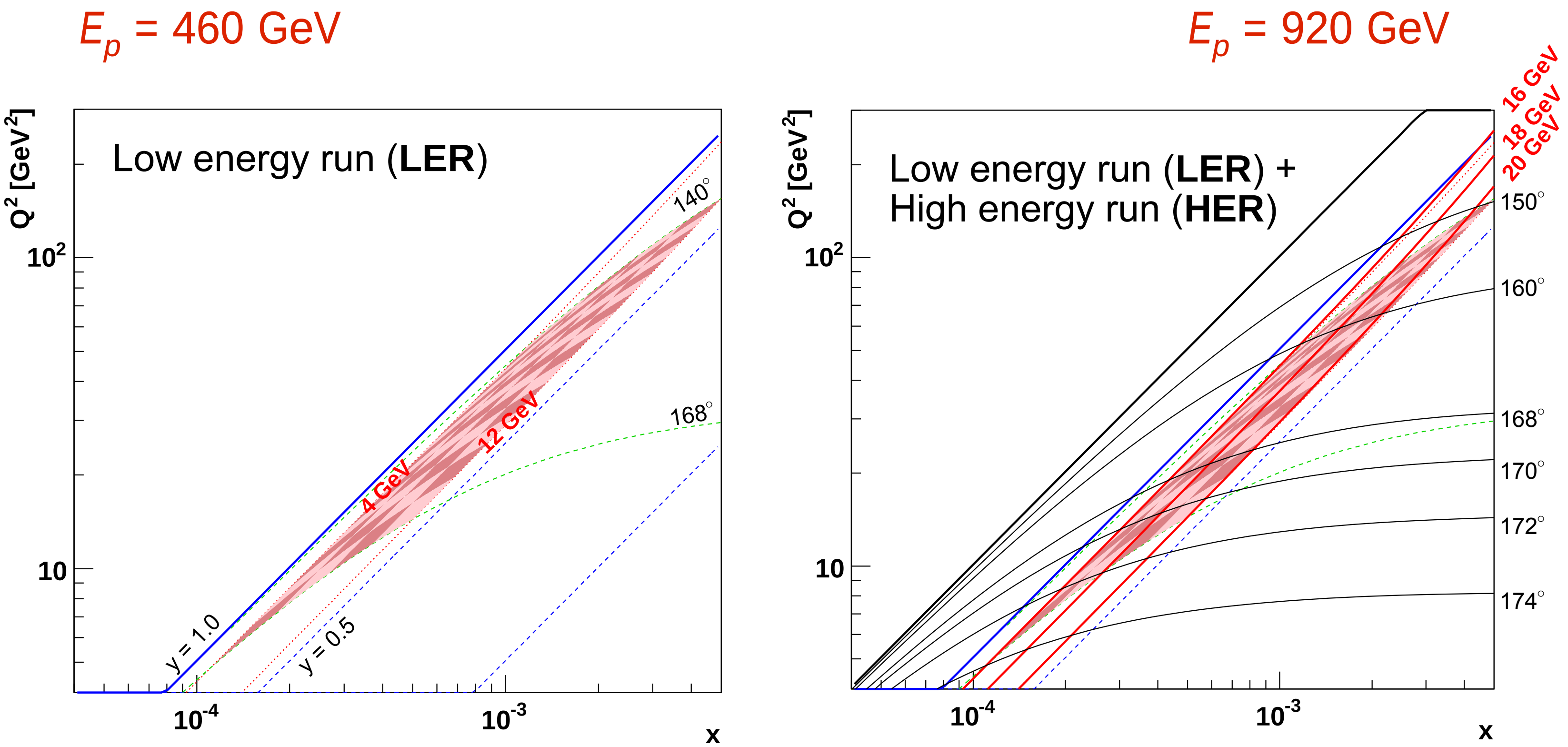
In order to separate F_2 and F_L cross section measurement at the same x and Q^2, but different y (i.e. different s, different beam energies) is needed.



$$F_L(x,Q^2) = \frac{\sigma_1(x,Q^2,y_1) - \sigma_2(x,Q^2,y_2)}{f(y_2) - f(y_1)}$$

Larger y difference ⇔ higher accuracy of F_L .

Kinematics plane coverage for F_L measurement



E_p = 460 GeV

E_p = 920 GeV

Low Q^2 acceptance region given by high E_p

Large Q^2 acceptance region given by low E_p

Need to reach highest y (lowest E') for LER

Main systematic uncertainties in F_L measurement by ZEUS

- Event selection:

• HER:	LER:
◦ 16 < E’ < 20GeV	◦ 4 < E’ < 12 GeV
◦ 160 < Θ < 172 deg	◦ 150 < Θ < 168 deg
	◦ track for E’>10 GeV

- PhP subtracted directly or statistically with help of 6m tagger and the php MC

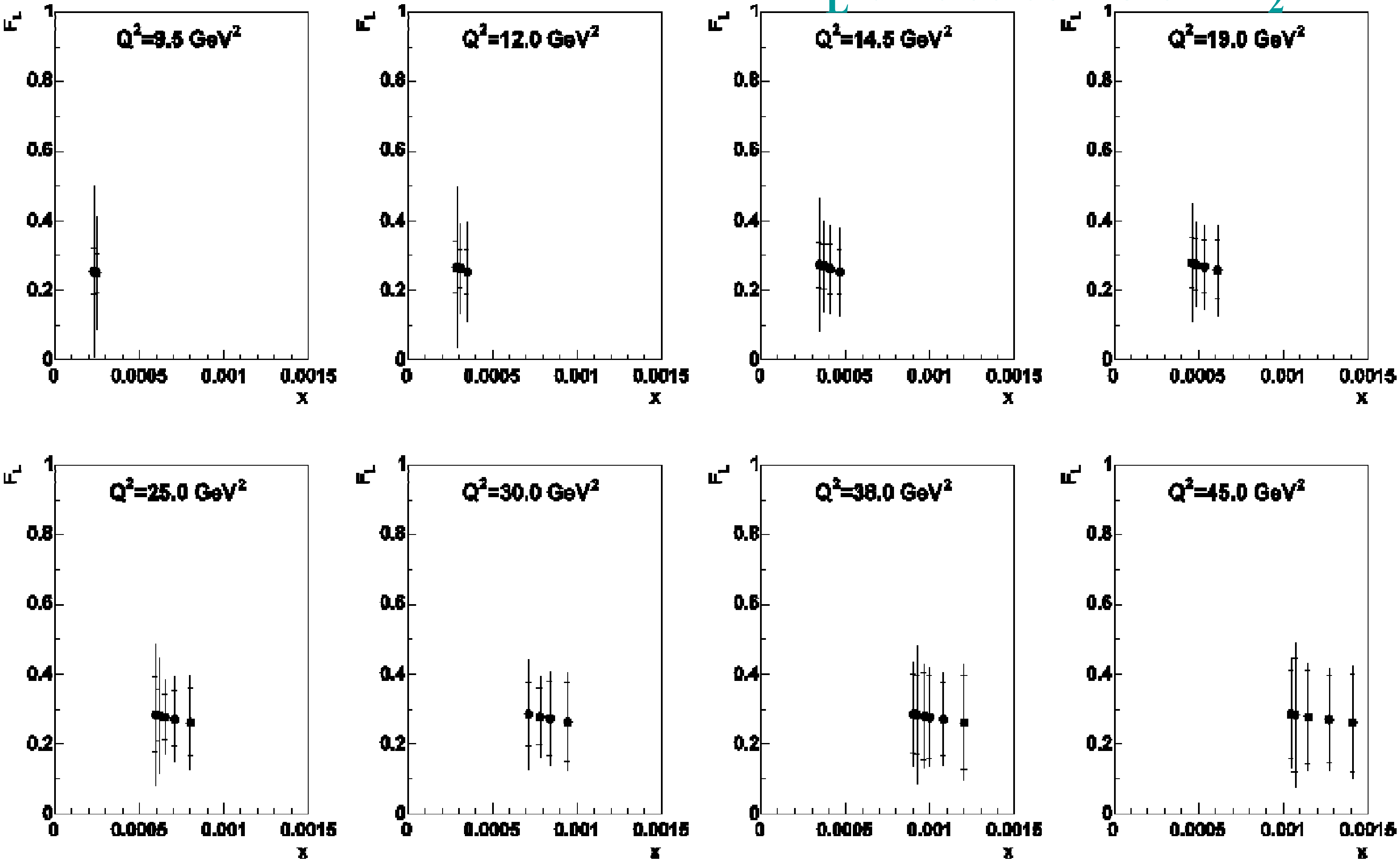
Systematic uncertainties:

- Photoproduction background subtraction → 10%
- Electron finder + trigger → 1%(high E’) – 4%(low E’)
- Energy scale → 1%(E’=27.5GeV) - 2%(E’=4GeV)
- Luminosity uncorrelated → 1%
- Luminosity correlated → 2%

Uncertainties of F_L measurement by ZEUS

Low Q^2 : small stat., big syst.

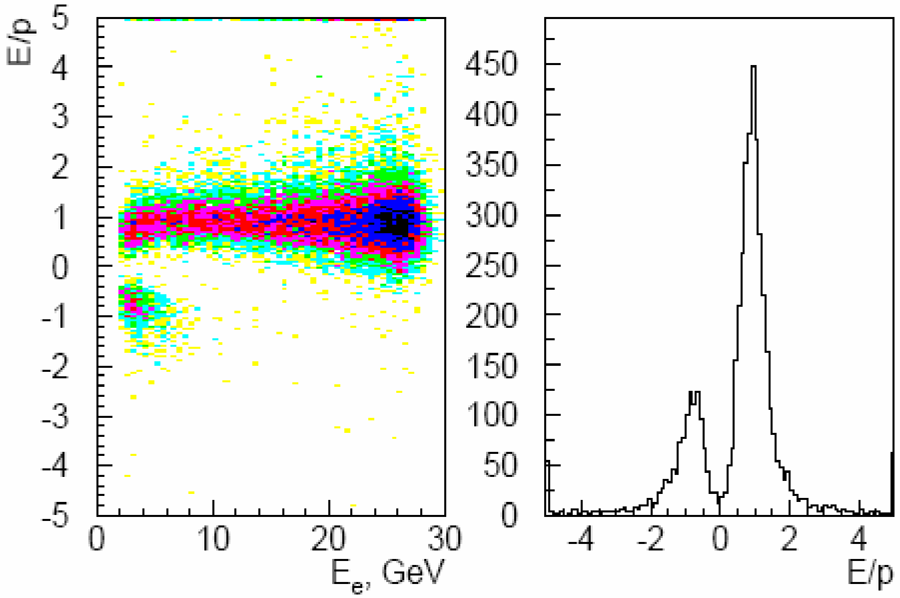
F_L values set to 0.2 F_2



High Q^2 : big stat., low sys.

Main systematic uncertainties in F_2 measurement by H1

Backward Silicon Tracker – 2006 data

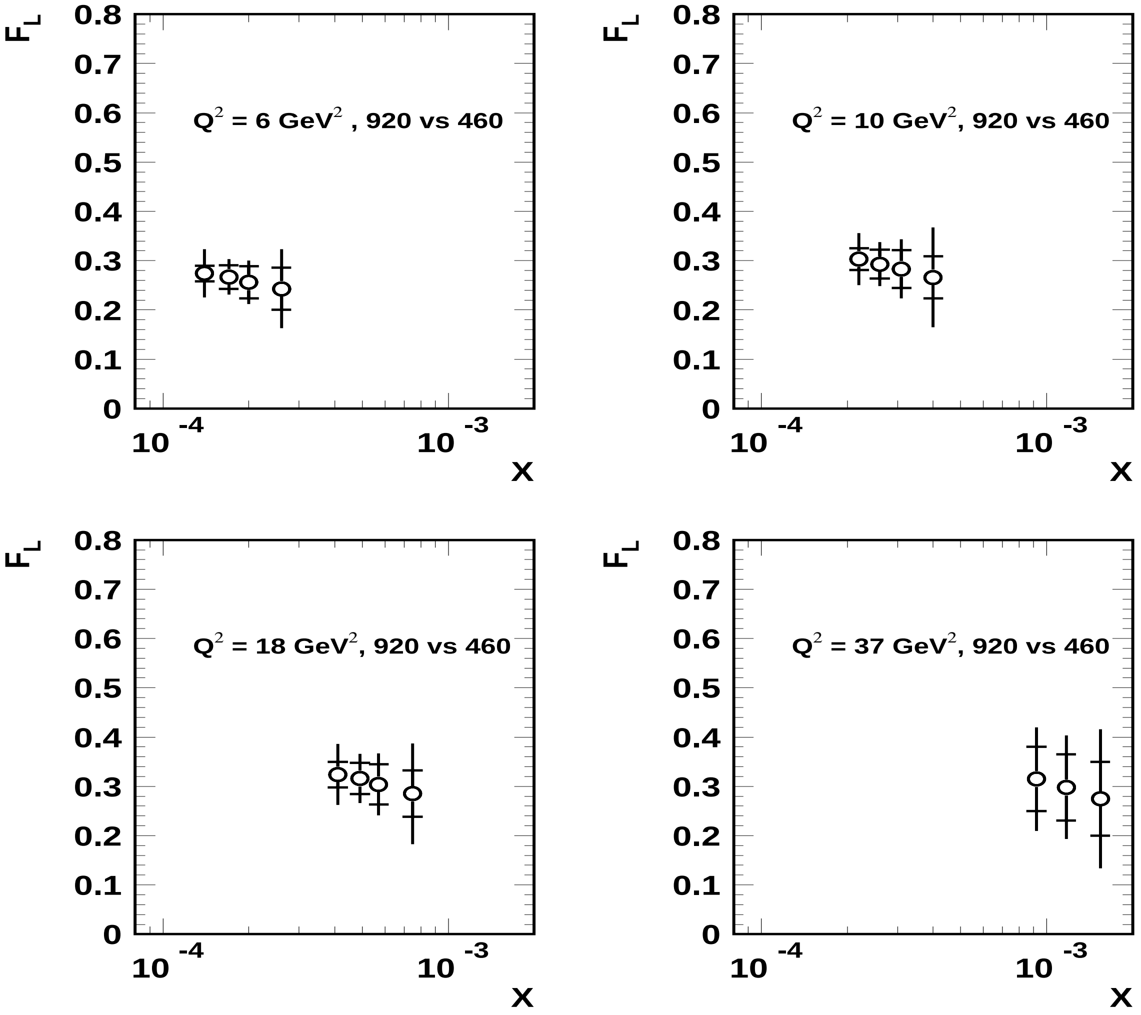


Electron energy measurement down to 3 GeV.

Php background rejected using the tracks and the charge analysis.

- Php background → 4% (at y=0.9)
- Energy of scattered electron → 0.2% (3GeV) – 2%(27.5 GeV)
- Angle of scattered electron → 0.2mrad (BST) – 1 mrad
- Uncorrelated eff. (electron ident., trigger, vtx, rad. corr.) →1%

Simulation of FL measurement by H1



920GeV → 30 pb-1

460GeV → 10 pb-1

Error 0.05 – 0.1

F_L measured to 5-6 standard deviations.

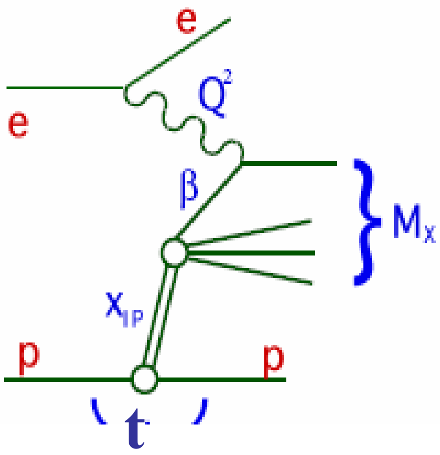
The Diffractive Longitudinal Structure Function F_L^D

By analogy with inclusive case,

$$\frac{d^3\sigma^{ep\to eXY}}{\mathrm{d}x_{I\!P}\,\mathrm{d}\beta\,\mathrm{d}Q^2} = \frac{2\pi\alpha^2}{\beta Q^4}\cdot Y_+\cdot\sigma_r^D(x_{I\!P},x,Q^2)$$

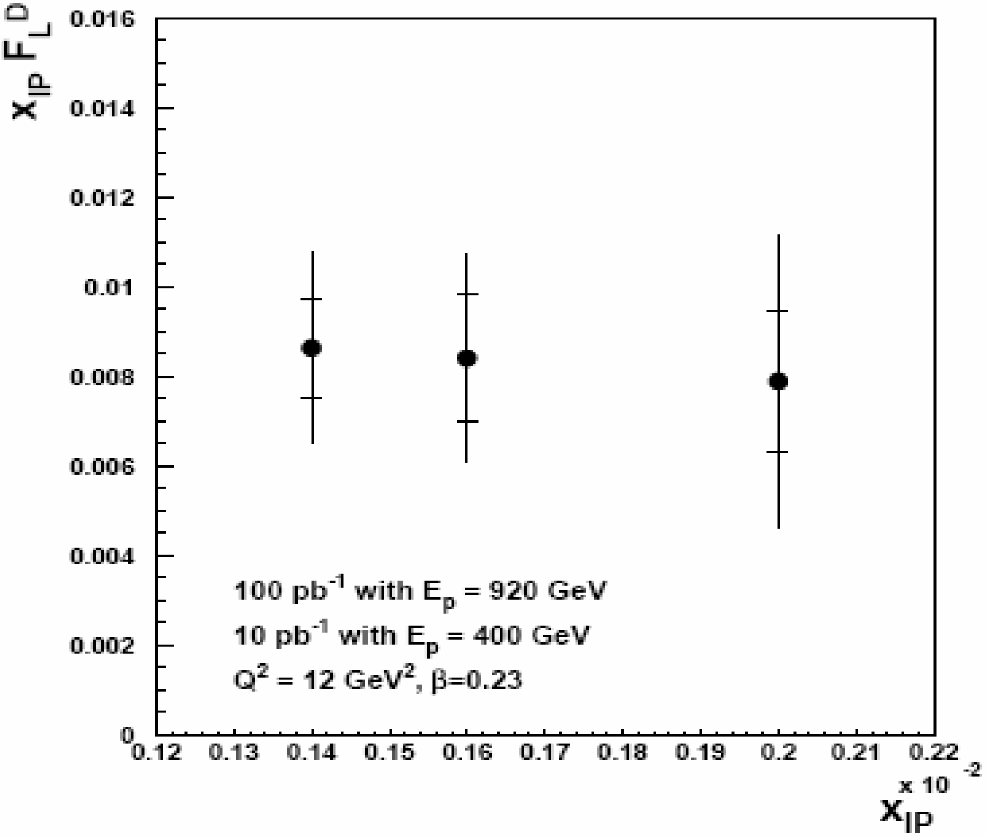
where $\sigma_r^D = F_2^D - \frac{y^2}{Y_+}F_L^D$ and $Y_+ = 1+(1-y)^2$

$x_P=Q^2/(sy\,\beta)$



→vary y at fixed Q^2, β, x by changing s (i.e. proton beam energy)

Simulation of the measurement of diffractive F_L structure function by H1



Diffractive events determined via the rapidity gap.

Many systematic effects cancel, so diffractive F_L determined to 3 sigma accuracy.

Diffractive F_L has never been measured so far. Important for understanding inclusive diffraction.

Summary

- Analyses of the proton structure functions are ongoing.
- The precision of the F_2 measurement is still being improved
- F_2 at high y is being measured by H1 and ZEUS
- Huge amount of php background and low energy electron identification – main problems for high y analyses.
- Low energy run at HERA already started.
- Both ZEUS and H1 prepared to measure F_L.
- Simulations show reasonably good accuracy of F_L measurement.
- Diffractive F_L can also be measured with good accuracy.

- Full precision structure function analysis still to come from HERA.