Direct F_L measurement at HERA

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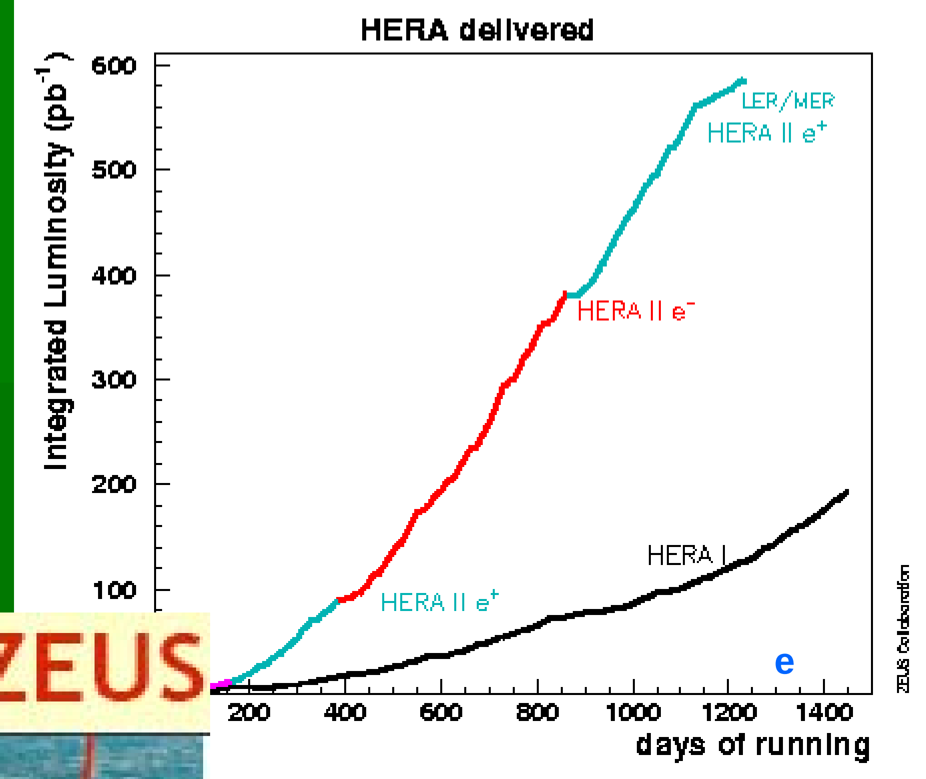
On behalf of ZEUS and H1 Collaborations

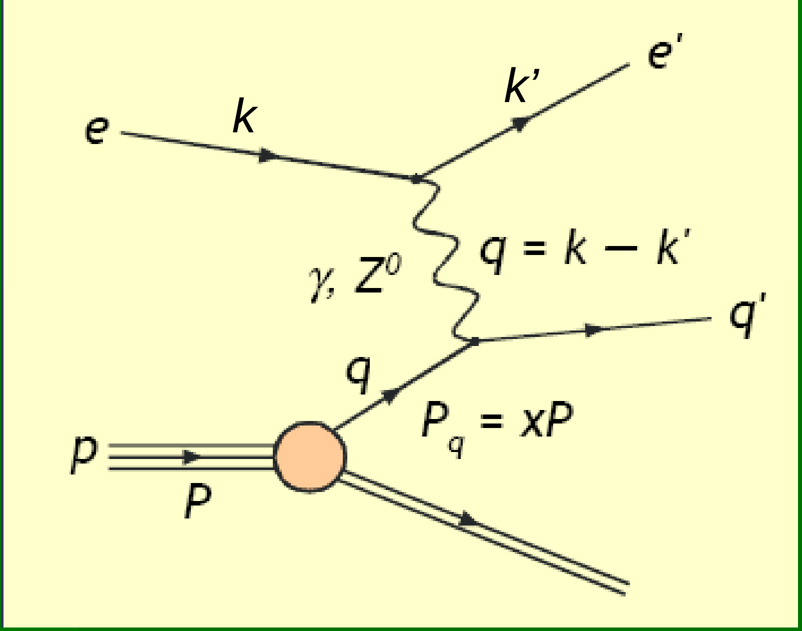
Experiments at HERA (1992-2007)

p^+ 920 GeV (HER),
575 GeV (MER),
460 GeV (LER)
$e^{+/-}$ 27.5 GeV



Neutral current Deep Inelastic Scattering (DIS)

Deep inelastic scattering at HERA:
• provides a unique tool to study the structure of proton
• helps in QCD tests



Kinematics of the NC DIS:

➢ central mass energy (CME) of the ep system: $s=(p+k)^2$

➢ four momentum transfer (virtuality of the intermediate boson): $Q^2 = -q^2 = -(k-k')^2$

➢ Bjorken scaling variable (fraction of the proton momentum carried by the struck quark): $x = Q^2/2Pq$

➢ inelasticity of interaction $y = qP/kP$

➢ $Q^2 = xys$

FL structure function

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

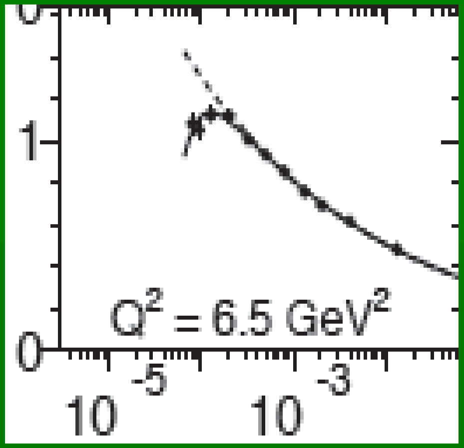
$$\sigma_r = \frac{Q^2 x}{2\pi\alpha^2 Y_+}\frac{d^2\sigma}{dxdQ^2} = F_2(x,Q^2) - f(y)F_L(x,Q^2)$$

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

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

dominant

sizable only at high y

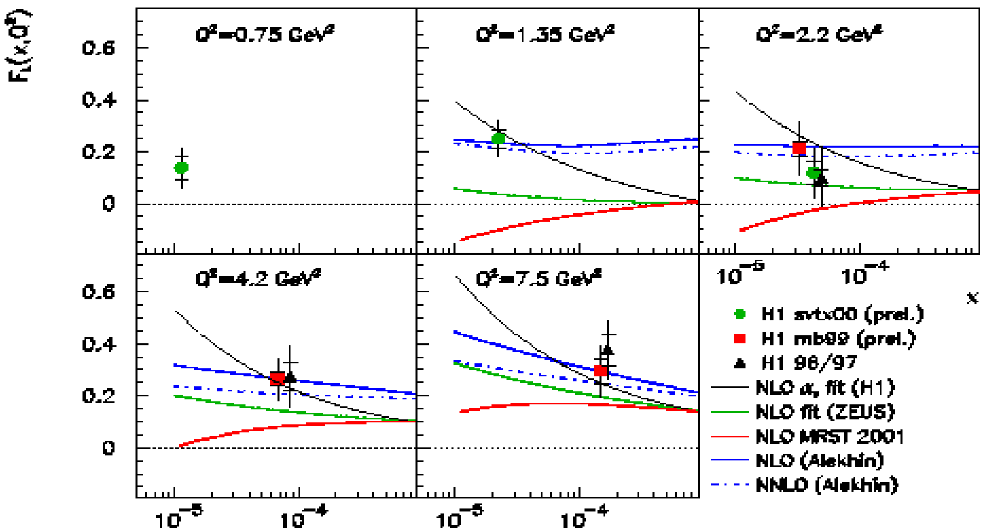


At high y (low x) the F_L contribution becomes sizable. Visible as bending of the x-section.

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

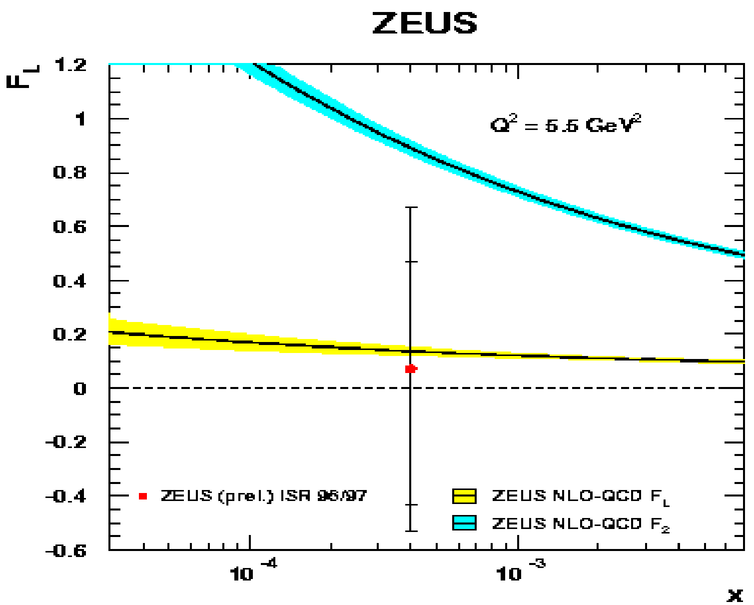
$$F_L = \frac{\alpha_s}{4\pi} x^2 \int_x^1 \frac{dz}{z^3}\left[\frac{16}{3}F_2 + 8\sum e_q^2 \left(1-\frac{x}{z}\right) zg\right]$$

Attempts to determine F_L at HERA



F_L determination by the H1 Collaboration based on the fit to the reduced x-section. An assumption about F_2 needed. One F_L point per Q^2 bin => no possibility to determine the x evolution of F_L.

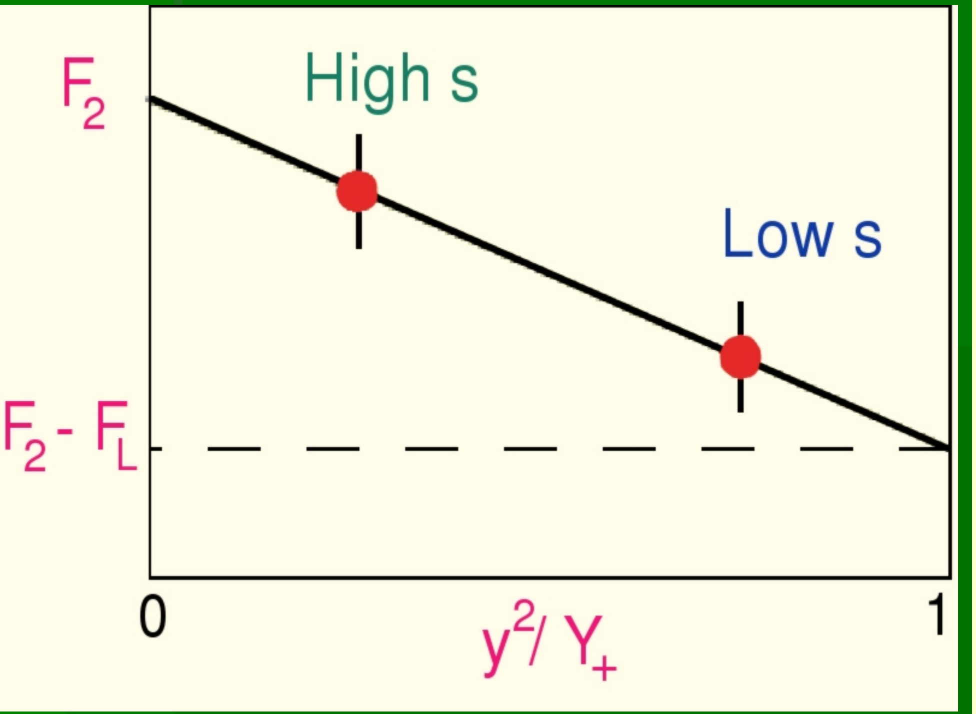
F_L measurement by the ZEUS Collaboration based on ISR events i.e. events with lower electron energy due to emission of gamma. Very difficult and imprecise measurement.



F_L measurement at HERA

- Alan Martin (DIS 2004): "It would be inconceivable that HERA will not measure F_L with sufficient precision to determine the gluon. Low energy runs should be done".

Principle of the measurement:



- reduced x-section measured for the same (x,Q^2) but different y (CME)
- a straight line fit to extract F_2 and F_L
- $\sigma_r = F_2 - y^2/Y_+ F_L$
- F_L the slope of the fit
- F_2 the intercept with y axis
- the bigger distance between the measured points the higher precision of the F_L measurement i.e.
- large difference in beam energy required
- highest y at low beam energies required

Analysis strategy

High energy run (HER) p beam 920 GeV, L_{ZEUS} =32.8 [pb^{-1}], L_{H1} =21.9 [pb^{-1}]

Middle energy run (MER) p beam 575 GeV, L_{H1} = 6.2 [pb^{-1}]

Low energy run (LER) p beam 460 GeV, L_{ZEUS} = 14. [pb^{-1}], L_{H1} =12.4 [pb^{-1}]

Electron method used for kinematics reconstruction:

$$y = 1 - \frac{E_e'}{E_e} \sin^2(\theta_e / 2)$$

$$Q^2 = \frac{E_e'^2 \sin^2 \theta_e}{1 - y}$$

In order to access the same (x,Q^2) region but for different CME -> different regions of measurement of electron variables.

Low y analysis ⇔ high s (HER)

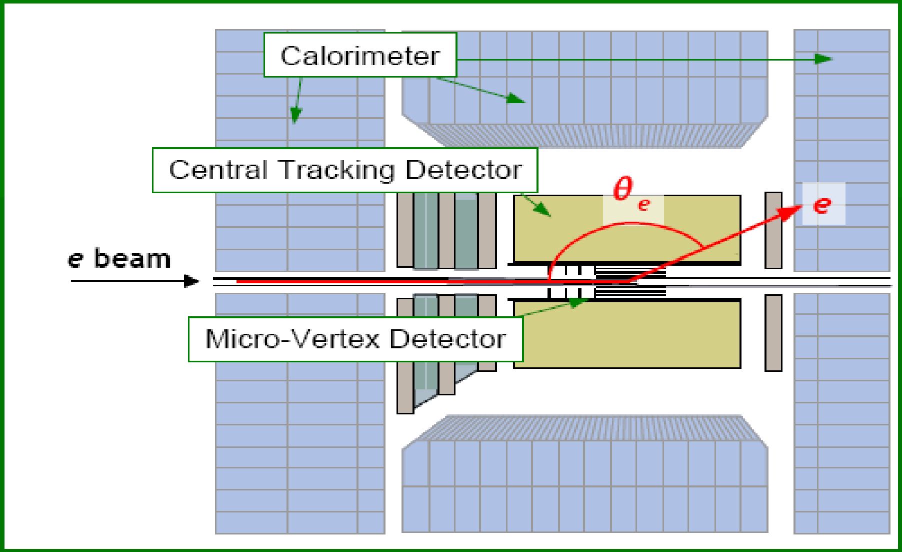
- **high energy electron, well separated electron cluster => easy electron identification**
- **very little background**
- **no F_L sensitivity**

High y analysis ⇔ low s (LER)

- **low energy electron, intensive hadronic activity => difficult electron identification**
- **huge γp background => needs to be taken care of**

ZEUS: background rejection at high y

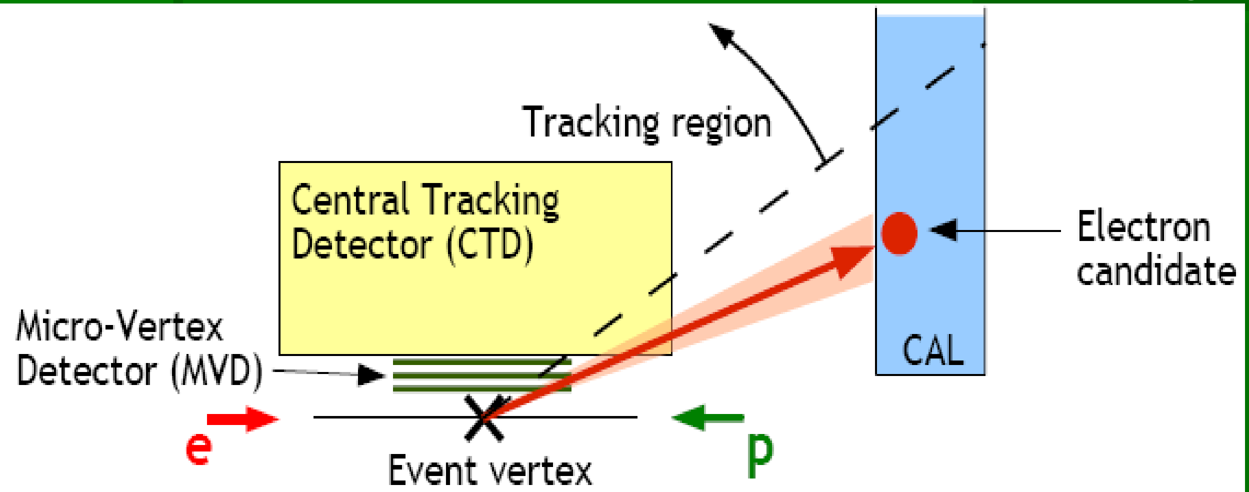
Significant part of the photoproduction background consists of neutral particles (γ,π^0) faking electron in the backward calorimeter, close to the beam-pipe



ZEUS tracking system very limited in the backward region i.e. for $\theta > 154^o$

New technique using single hits allowed to extend “tracking” to the edges of detector acceptance.

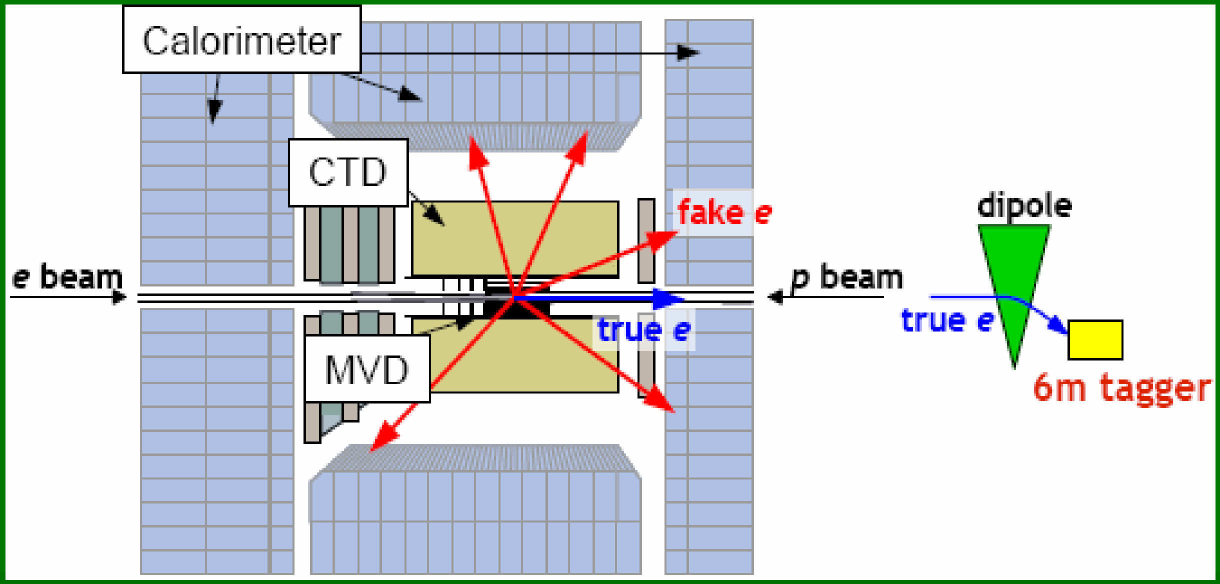
A road created between vertex and cluster. Electron candidate rejected if not enough hits around the road.



High efficiency of the “single hit approach” - comparable to tracking.

ZEUS – background rejection at high y

For further reduction of photoproduction background 6m tagger used. It allows to tag electrons (in a limited kinematical region) escaping down the beam pipe.

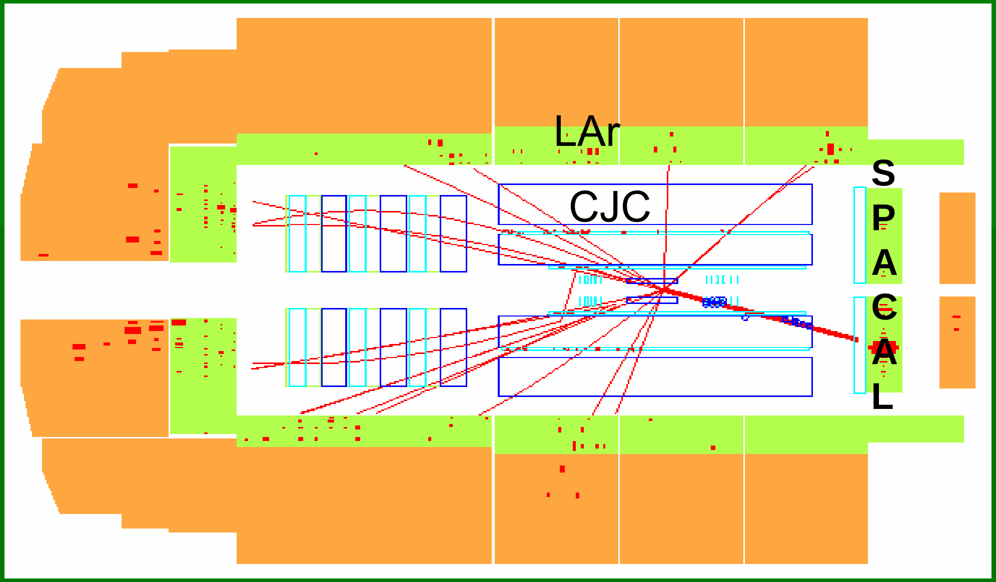


Tagged events may be used to normalize the photoproduction Monte Carlo, which is later used for statistical subtraction of remaining photoproduction background.

The statistical subtraction is verified by use of an independent sample “γp enriched” sample.

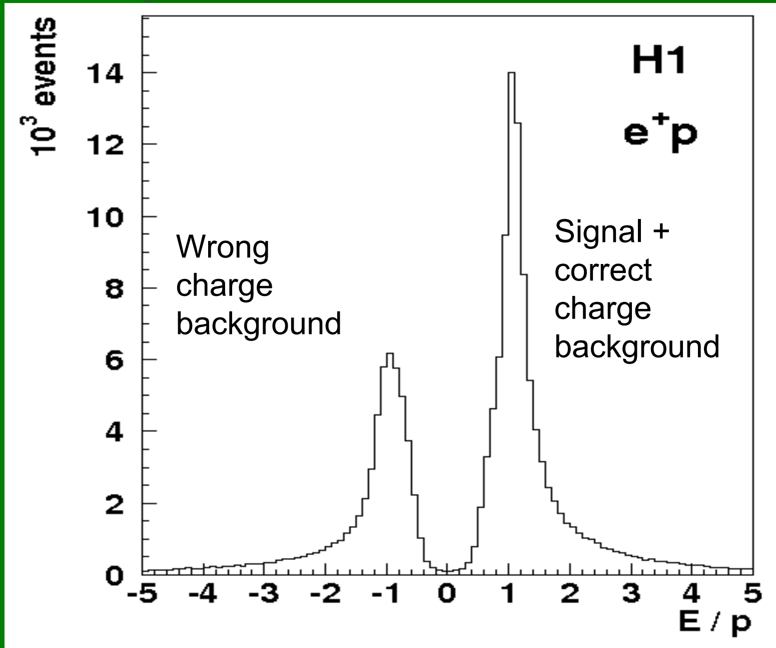
H1: background rejection at high y

Neutral background removed with high efficiency thanks to well equipped backward tracking det.



Charged background rejection based on data analysis only i.e. on the charge measurement in CJC.

Good separation between different charges.

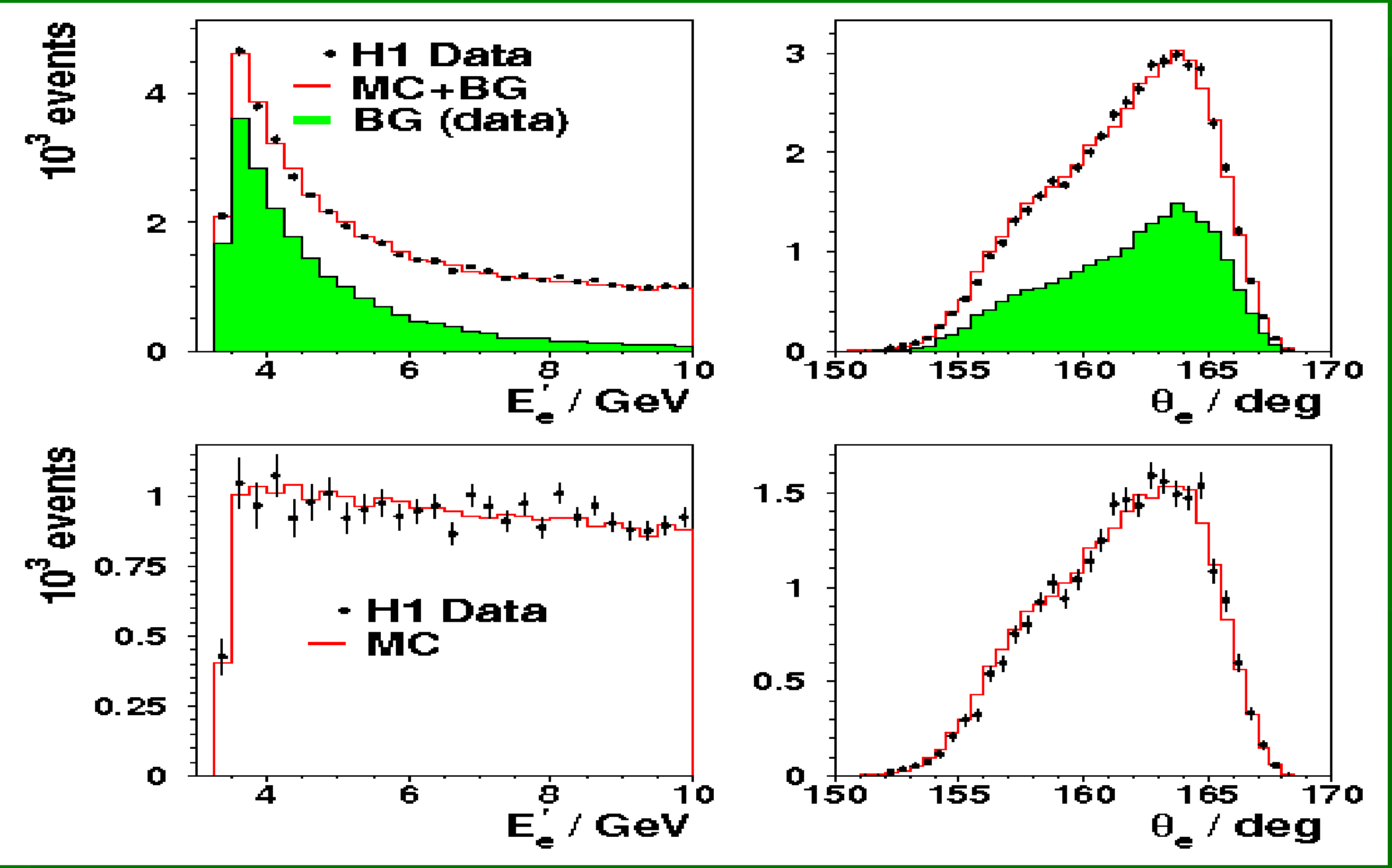


"Correct charge" – the same charge as the incoming lepton. "Wrong charge" – opposite charge to the charge of the incoming lepton.

Wrong charge background rejected directly.

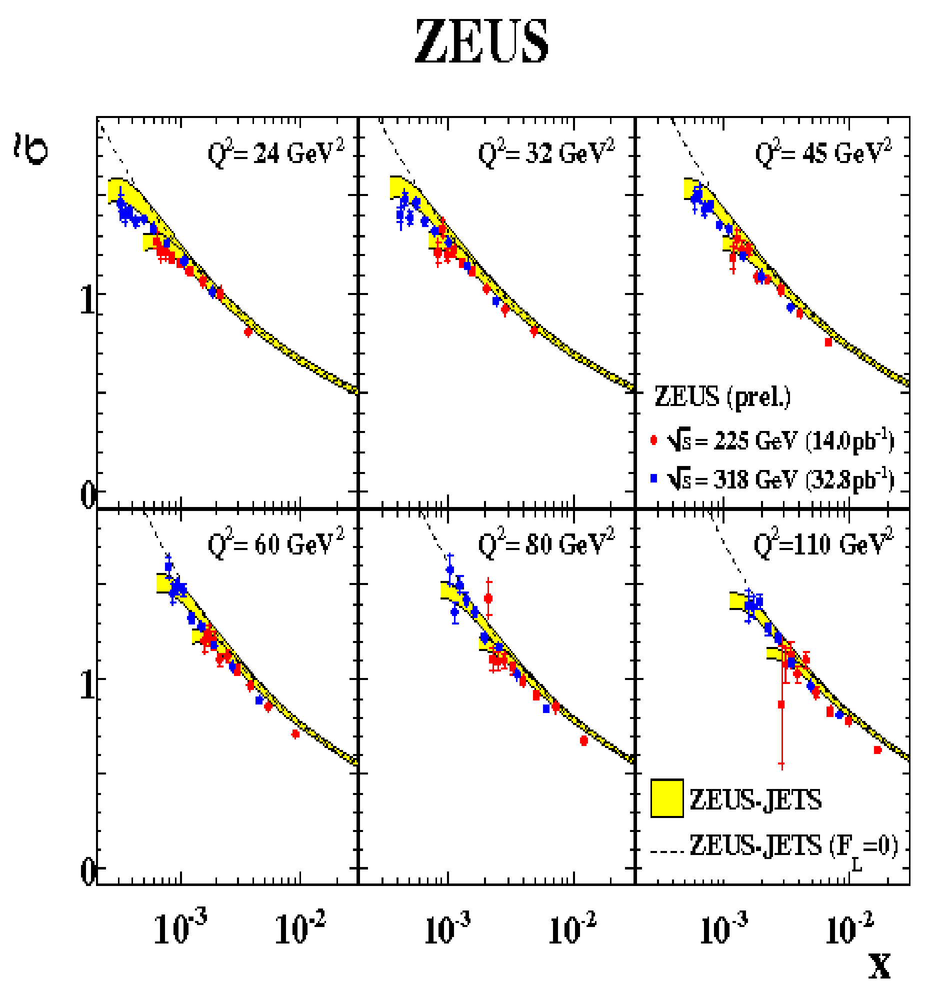
Correct charge background rejected statistically taking into account the amount of the wrong charge background and a charge asymmetry factor (determined in a separate analysis).

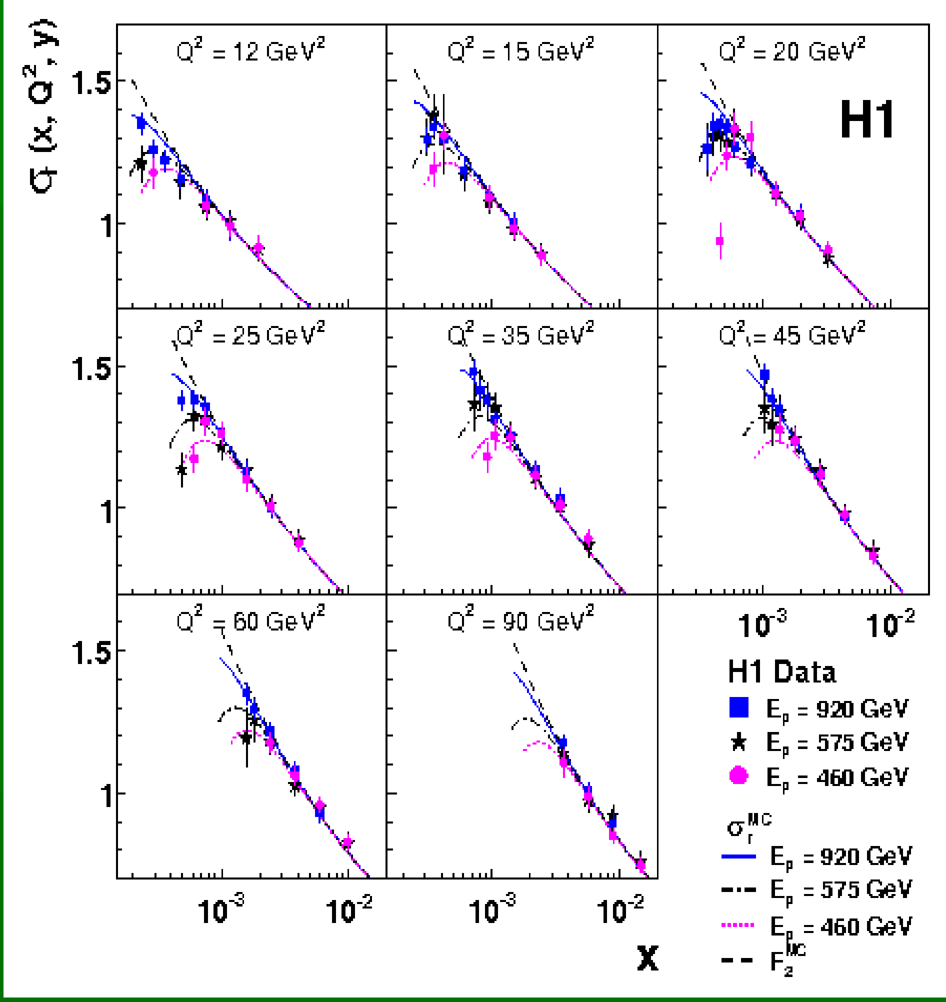
Control plots before and after background subtraction.



Significant photoproduction background estimated and subtracted with high precision.

Reduced x-section for different beam energies

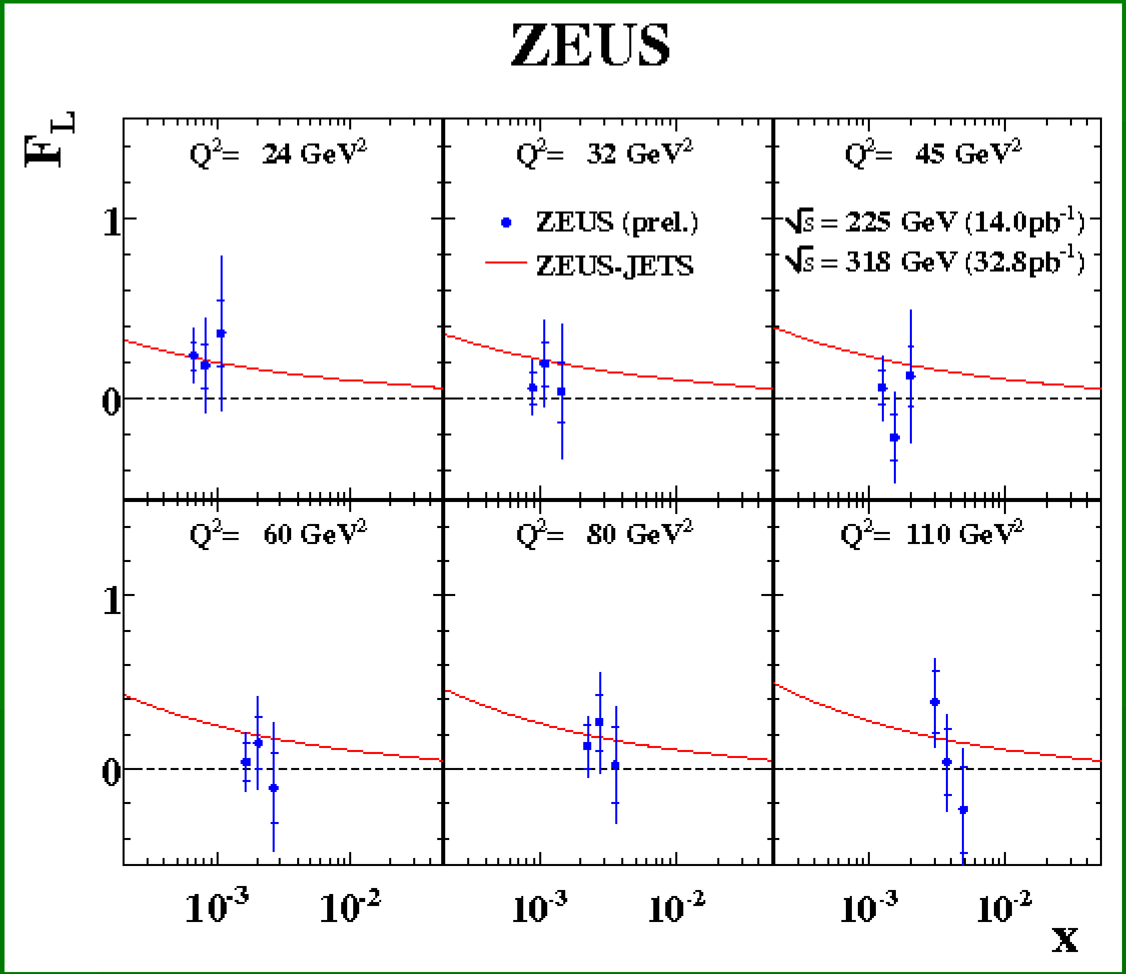




At high y (low x) visible differences between x-sections for HER ,LER (and MER).
At low y (high x) both x-sections agree.

At high y (i.e. where the contribution of F_L expected) the x-sections turn over.

F_L measurement at ZEUS



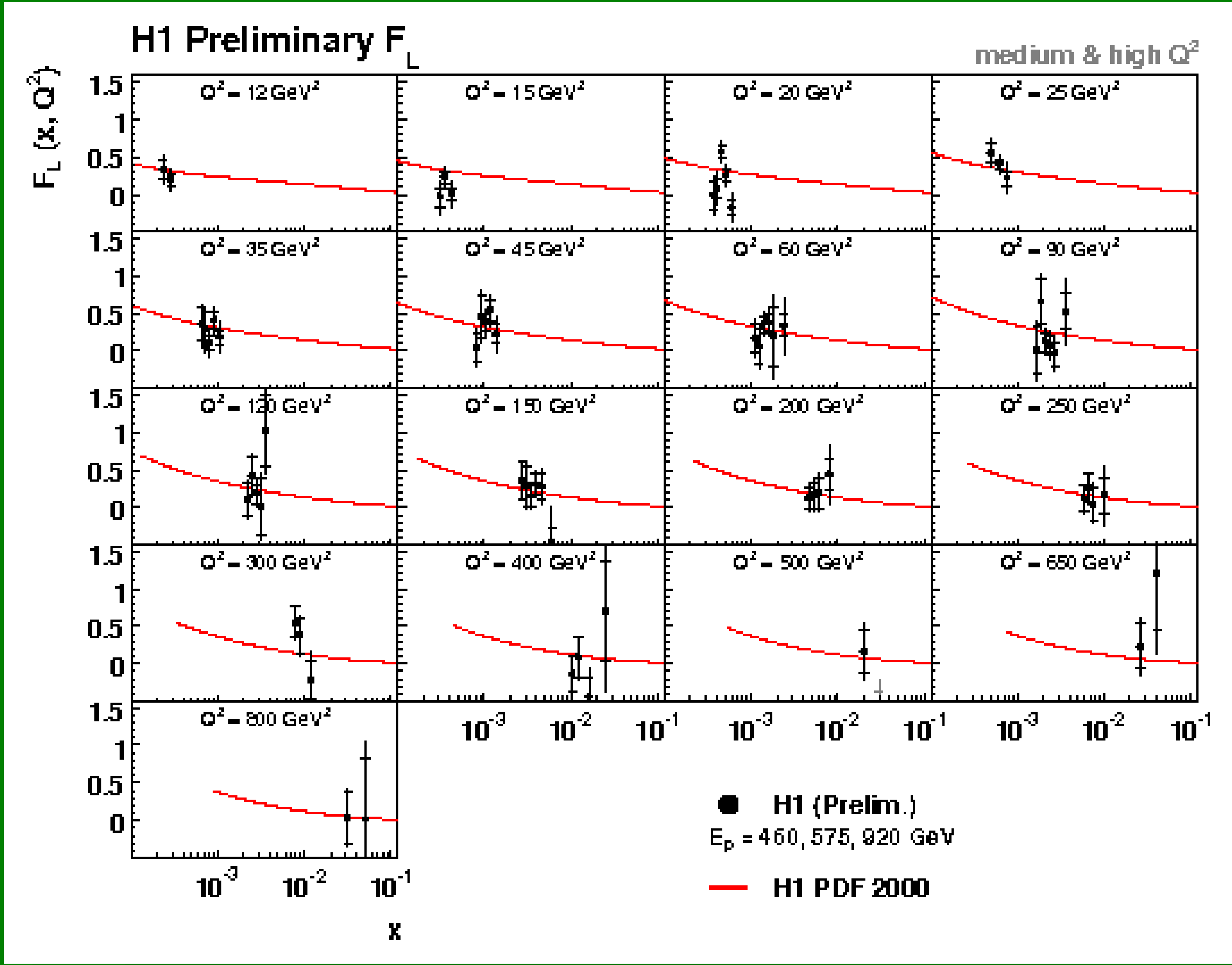
First measurement of the F_L at ZEUS using the lowered proton beam energy.

Uncertainties still very high.

Measurement consistent with both:
ZEUS pdf fit (ZEUS-JETS) and with zero.

Improved measurement accessing higher y region expected.

F_L measurement at H1 (medium and high Q^2)



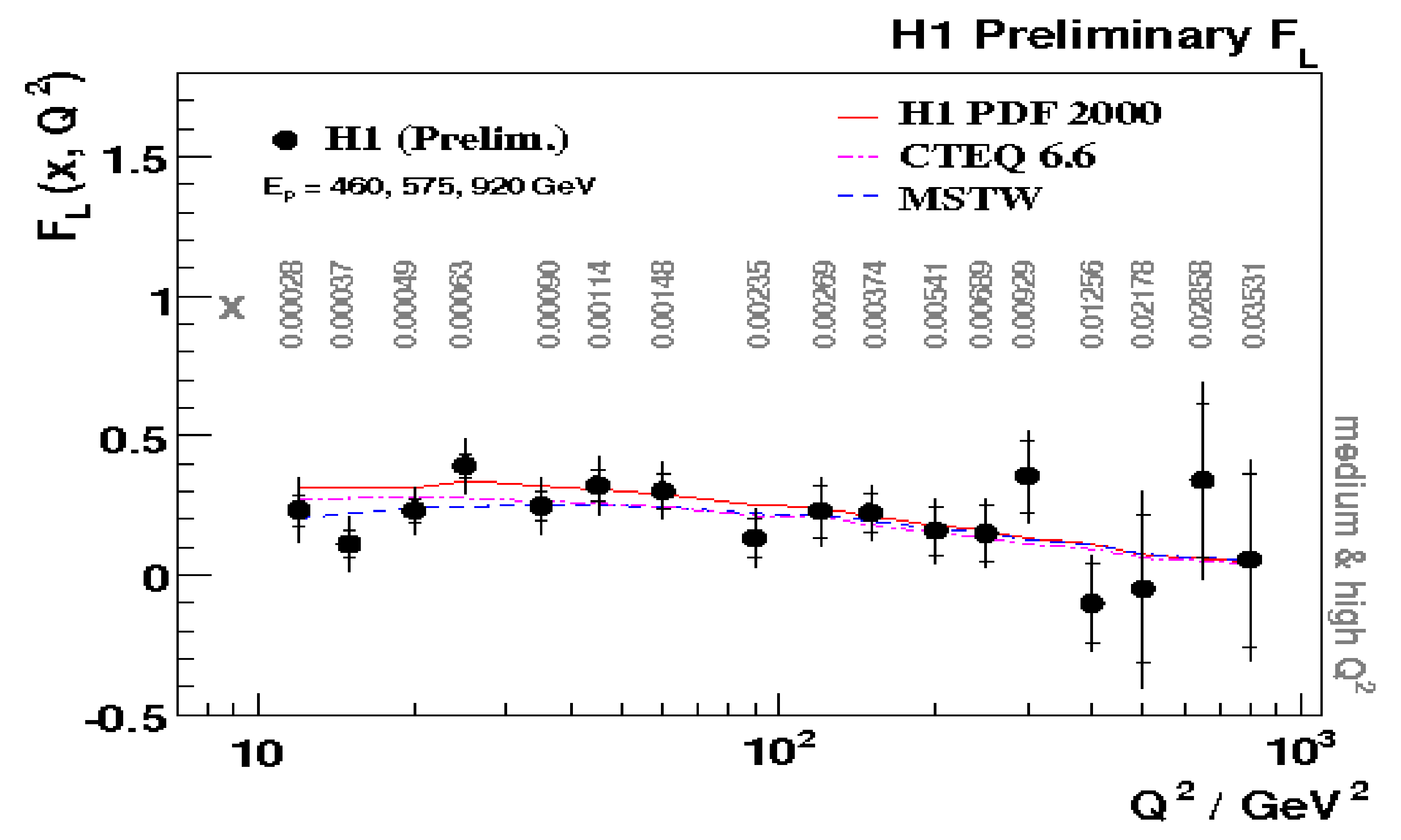
First measurement of the F_L at H1 using the lowered proton beam energy.

F_L measured in the full range of medium and high Q^2 (using electron detected in backward and central calorimeters),

Results consistent with the predictions of H1 PDF fit (obtained using only the H1 high energy x-section data) and with earlier determinations of F_L by H1 (slide 5).

Averaged (in x bins) F_L vs. Q^2 in the full medium and high Q^2 range

x values of F_L (Q^2) measurement listed on the picture



Results consistent with H1 fit and with expectations from global parton distributions fits at higher order perturbation theory => DGLAP describes low x region at HERA.

Summary

- First direct measurement of F_L at HERA done by both Zeus and H1
- H1 results for medium Q2 published in Phys. Lett. B
- Results cover Q^2 region 24-100 GeV^2 Zeus
  12-800 GeV^2 H1
- Results consistent with DGLAP QCD predictions for $F_L(x,Q^2)$ determined from the previous HERA data (dominated by a large gluon density at low x)
- Some improvements still to be expected:
  - ZEUS - improved precision of measurement by accessing higher y region and by using the MER data
  - H1 - measurement at low Q^2 (using Backward Silicon Tracking detector)