


Low Q^2 and High y Inclusive Cross Section Measurements from the HERA Experiments ZEUS and H1

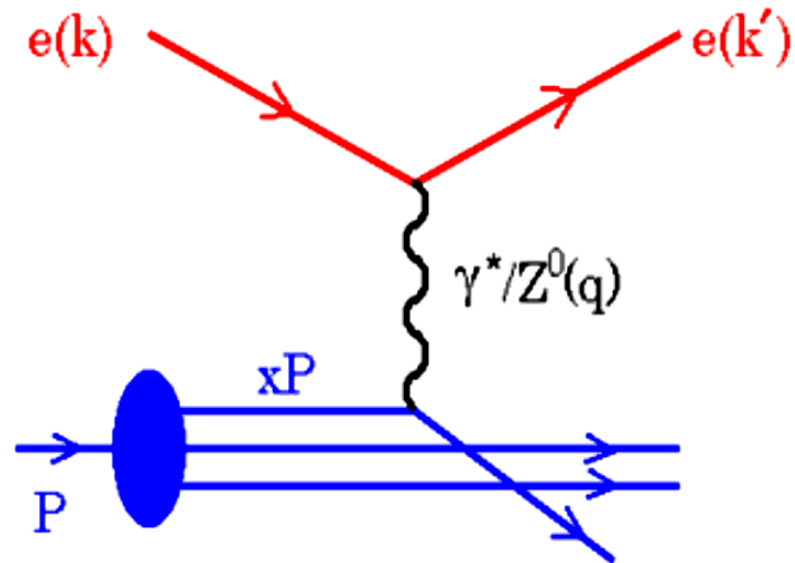
**Jan Kretzschmar
DESY Zeuthen**

**12th International Conference on Elastic and Diffractive Scattering,
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Introduction

- Deep Inelastic Scattering (DIS) is one of the best tools for
 - Testing QCD dynamics: validity of DGLAP evolution equations at low Q^2 and low x
 - Measurement of the substructure of the proton: quark and gluon content (PDFs)
- Kinematics described by Lorentz invariant quantities:
 - $Q^2 = -q^2 = -(k - k')^2$
virtuality/resolving power
 - $x = \frac{Q^2}{2P \cdot q}$ Bjorken scaling variable, momentum fraction of the scattered parton
 - $y = \frac{q \cdot P}{k \cdot P}$ inelasticity
- Related by $Q^2 = xys$

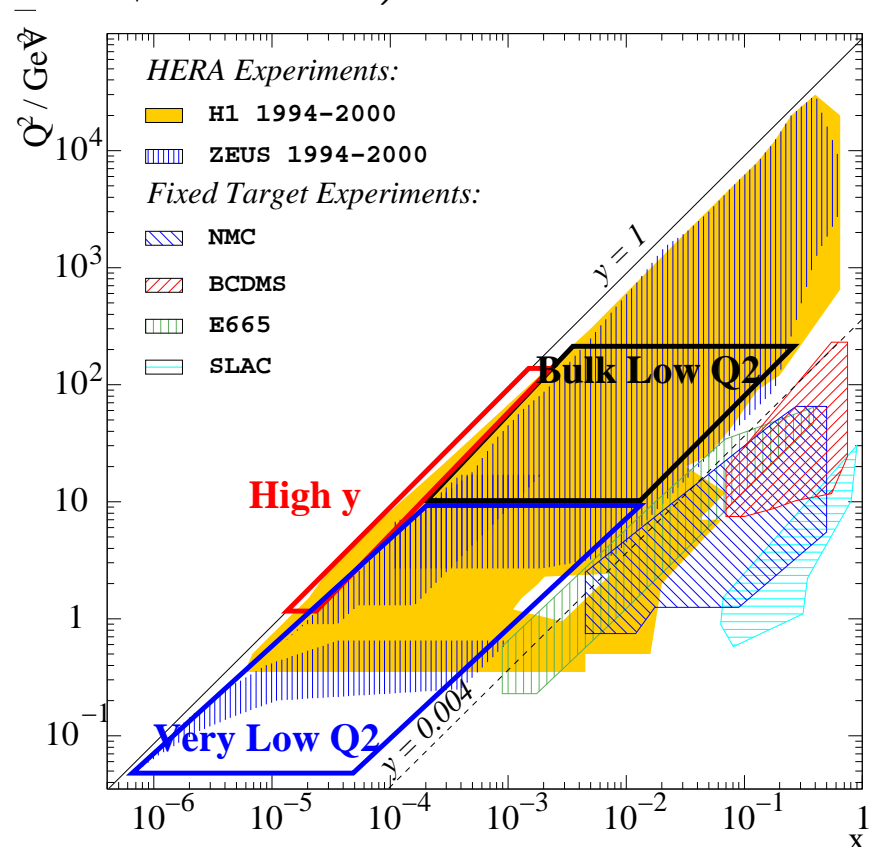


Inclusive DIS Cross Section

- Two structure functions $F_2(x, Q^2)$, $F_L(x, Q^2)$ parametrise the inclusive NC cross section for $ep \rightarrow e'X$:

$$\frac{d^2\sigma_{NC}^{ep}}{dx dQ^2} = \frac{2\pi\alpha^2 Y_+}{xQ^4} \left(F_2(x, Q^2) - \frac{y^2}{Y_+} F_L(x, Q^2) \right), \quad Y_+ = 1 + (1-y)^2$$

- Bulk Low Q^2 Domain**
($10\text{GeV}^2 \leq Q^2 \leq 150\text{GeV}^2$):
DGLAP evolution, PDFs, highest precision
- Lowest Q^2 Domain**
($Q^2 \leq 10\text{GeV}^2$):
Transition to non-perturbative regime
- High y Domain ($y > 0.6$):**
Sensitivity to F_L
- Low E_p running and direct F_L Measurement:**



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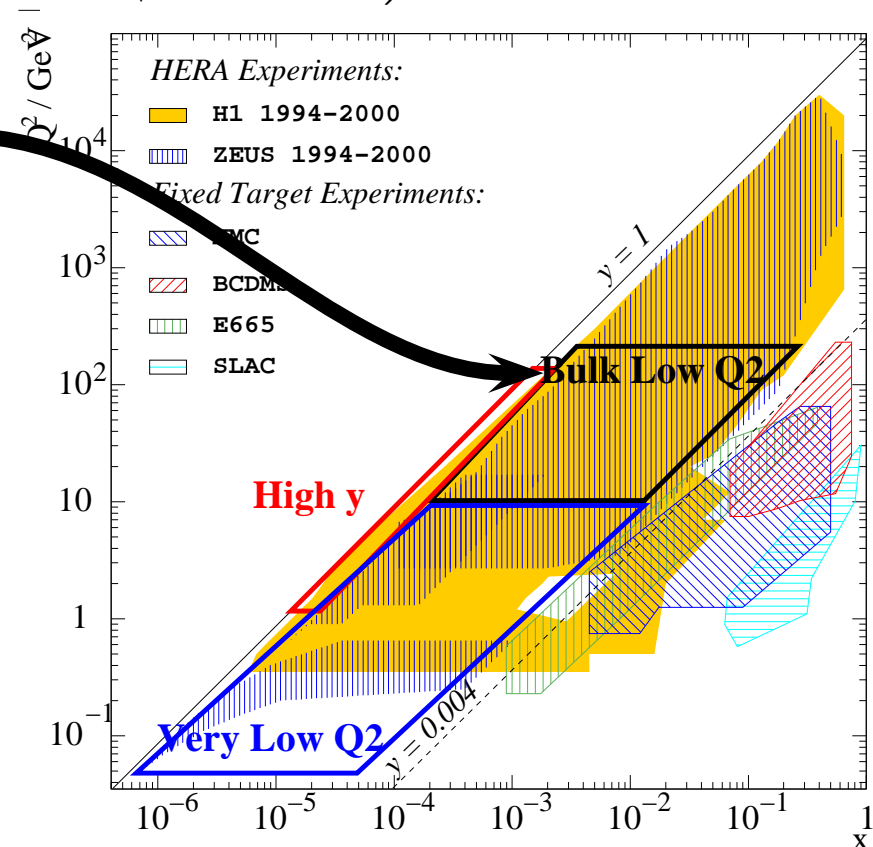
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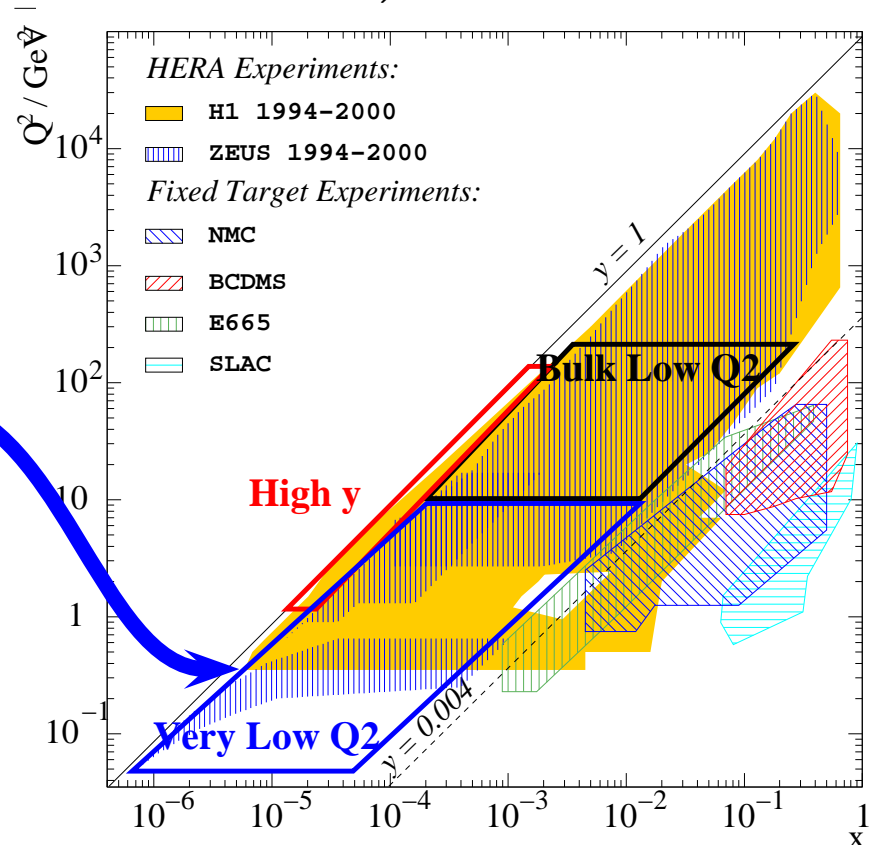


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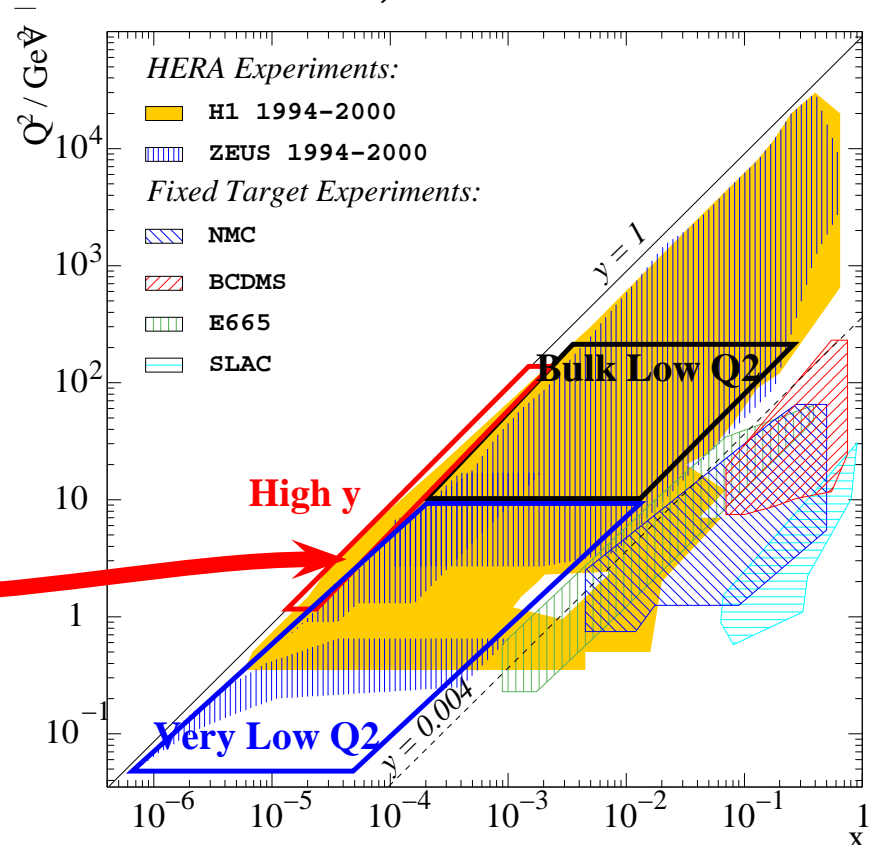


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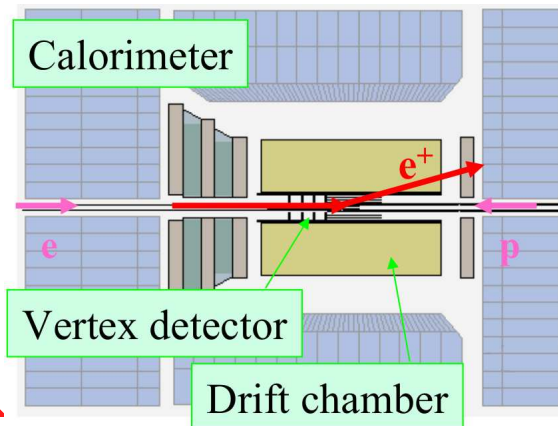
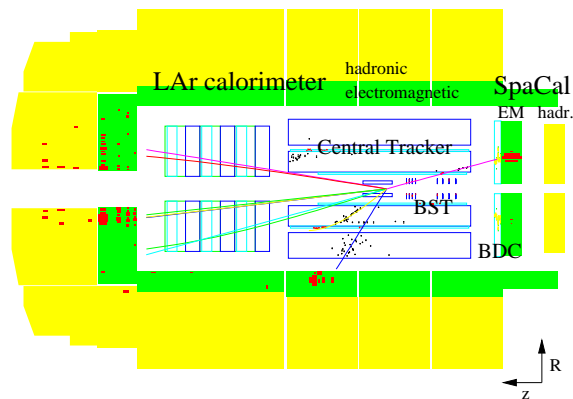
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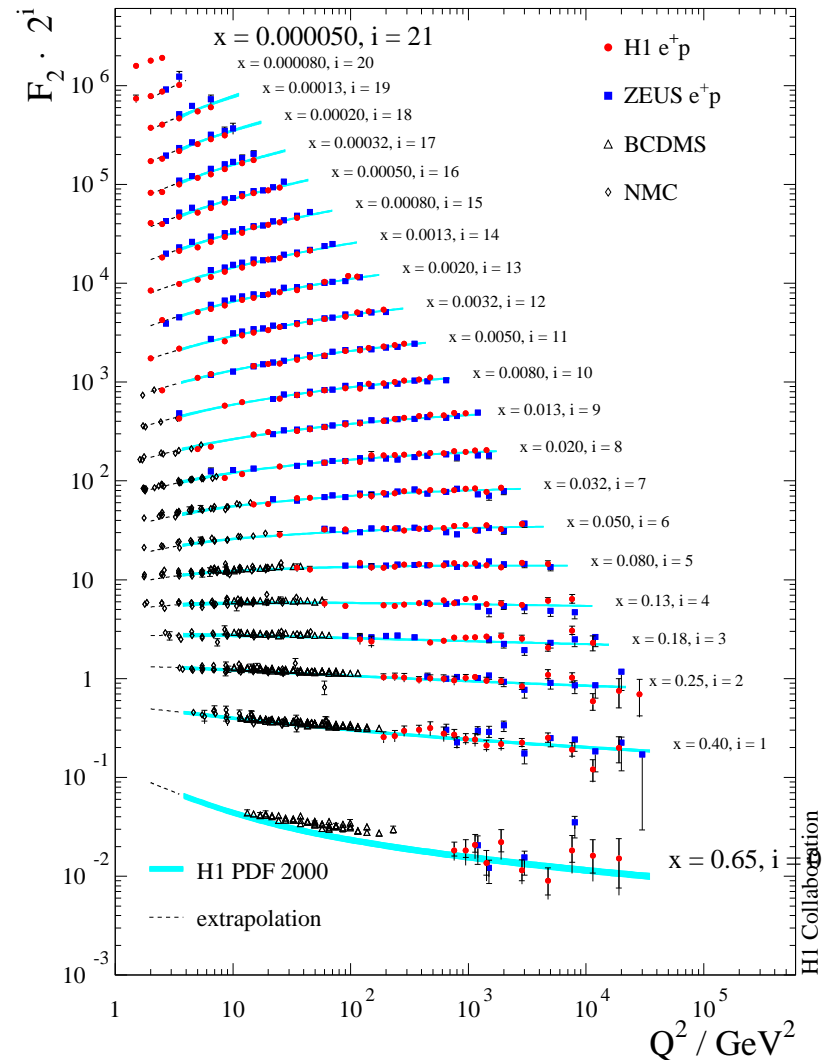
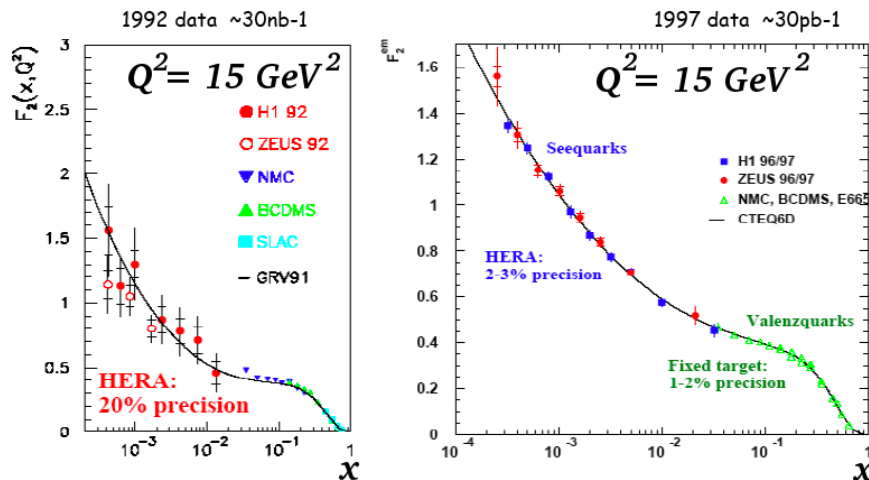
The HERA Collider

- HERA accelerator: $920 \text{ GeV } p + 27.6 \text{ GeV } e^{\pm} \Rightarrow \sqrt{s} = 320 \text{ GeV}$
- H1 and ZEUS: general purpose detectors, Measurement of the Proton Structure in full kinematic range one of the prime objectives



Low Q^2 Bulk Results

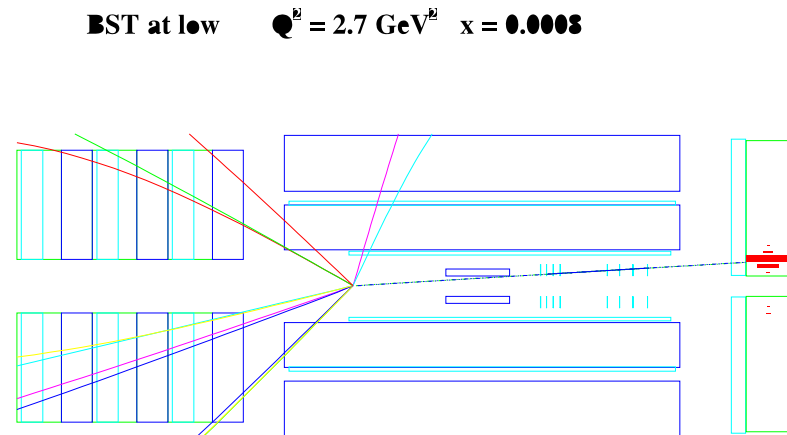
- F_2 has been measured with up to 2 – 3% precision in the “HERA Bulk Region” $10 \leq Q^2/\text{GeV}^2 \leq 150$ by both H1 and ZEUS
- A new H1 measurement with reduced systematic errors expected
- Further Improvements may be possible by combining ZEUS and H1 data



Lowest Q^2 Region

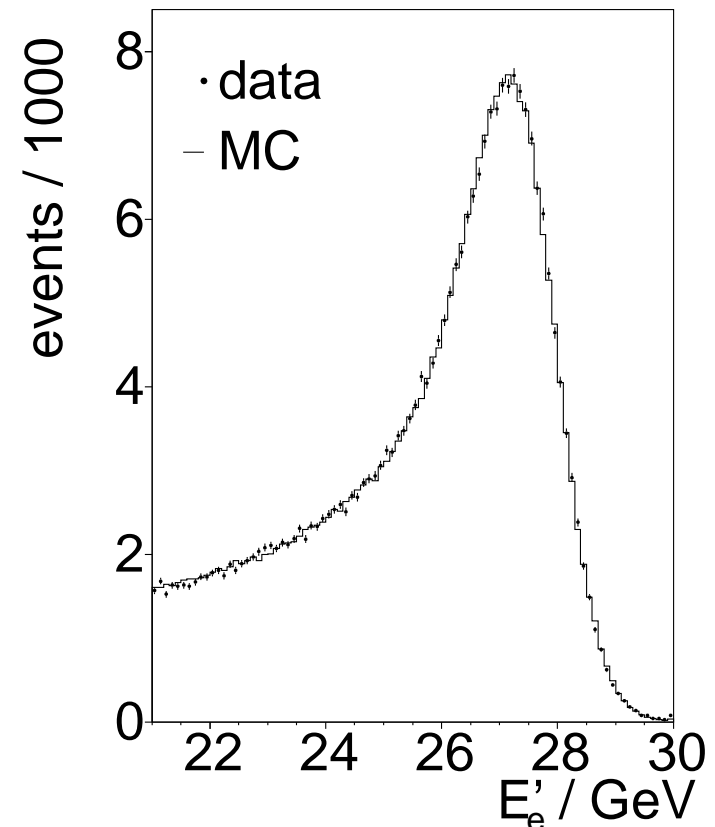
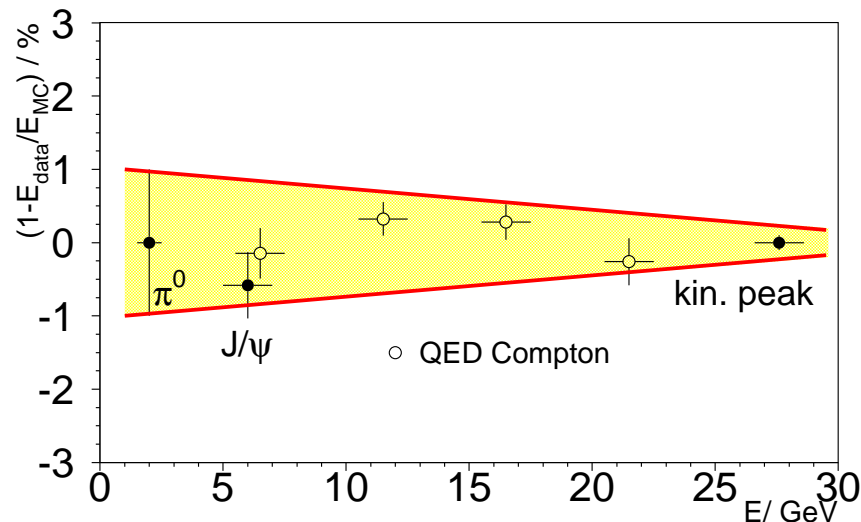
- Transition to non-perturbative region $Q^2 \rightarrow 0$ is of theoretical interest
- The lowest $Q^2 < 10\text{GeV}^2$ region is accessed using specialised techniques to detect scattered leptons at very small angles:
 - Data taken with shifted event vertex (H1)
 - Events with tagged (ZEUS) or untagged (H1) Initial State Radiation
 - Special low angle calorimeter + tracker (BPT, ZEUS)
 - Minimum Bias Trigger data + Backward Silicon Tracker (H1)

- New preliminary results of H1 for DIS 2007: HERA results complete for this region!



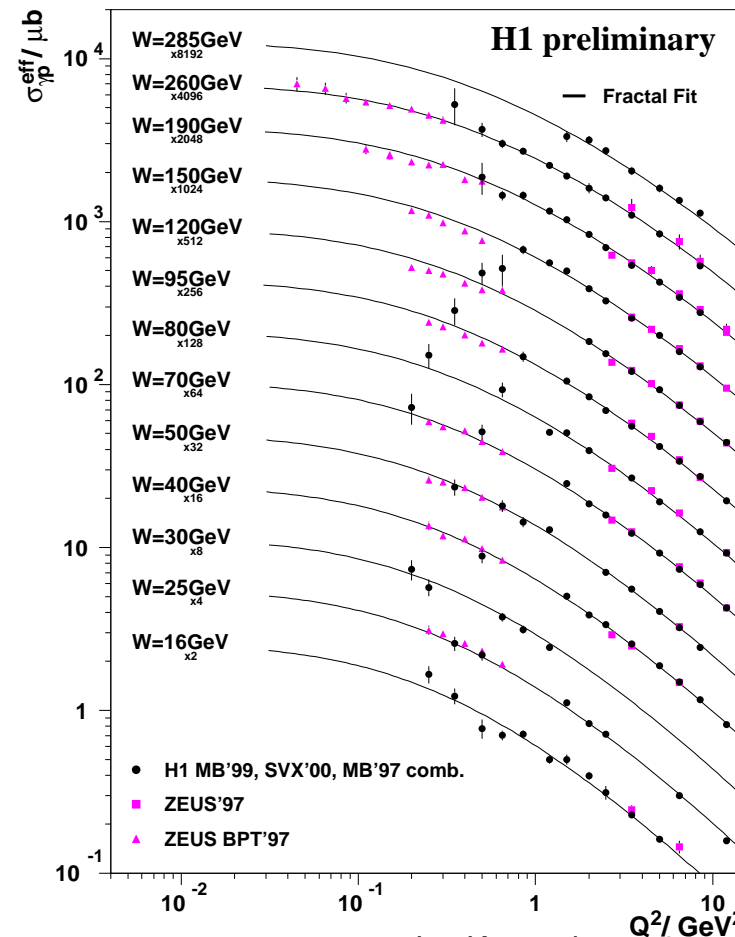
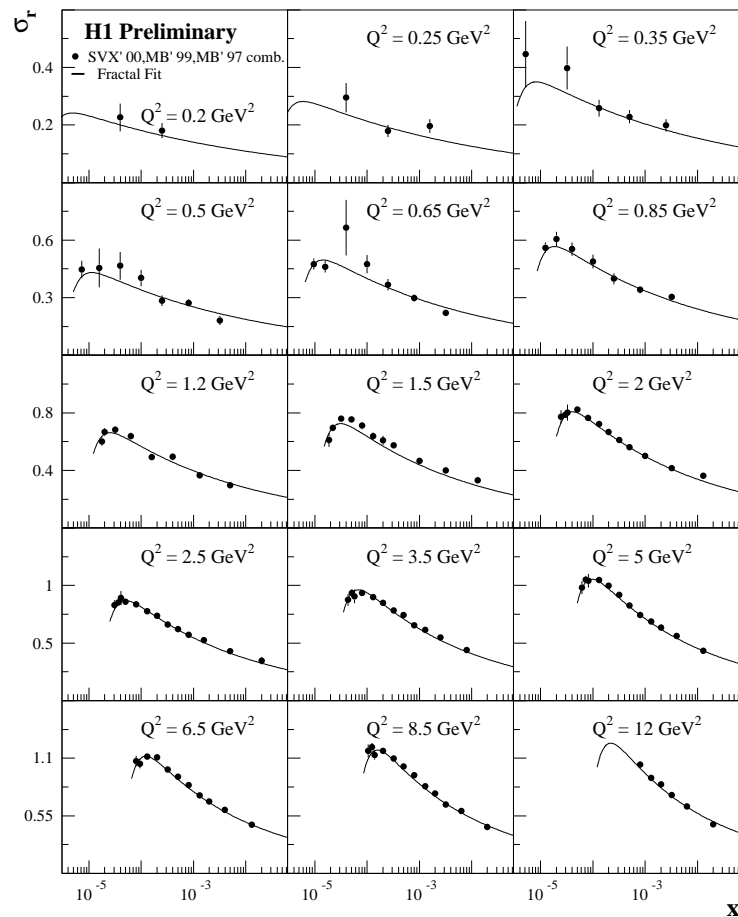
Lowest Q^2 Analysis

- Main features of the preliminary new H1 analysis:
 - Control of the Lepton Energy Scale to 0.2 – 1.0%
 - Kinematic reconstruction mainly independent of the hadronic final state using the BST
 - Further improvements due to combination of 3 H1 data sets taking into account systematic errors



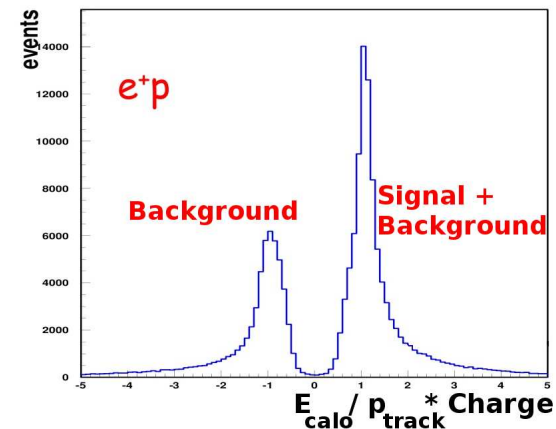
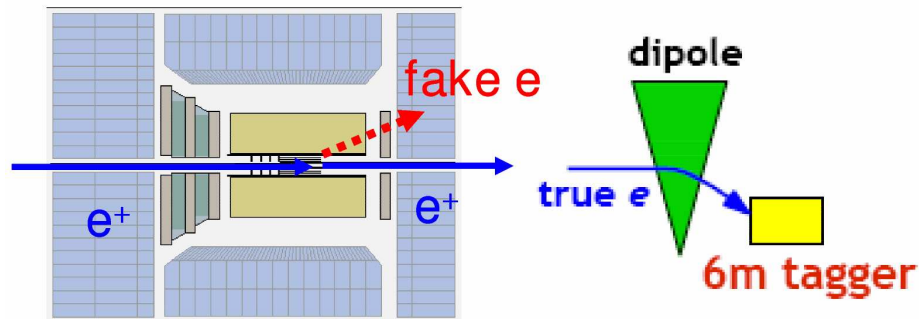
Lowest Q^2 Results

- Reduced cross section σ_r and effective γ^*p cross section:
- Typical precision: ZEUS BPT data $< 4\%$, combined H1 data: 1.5 – 10%



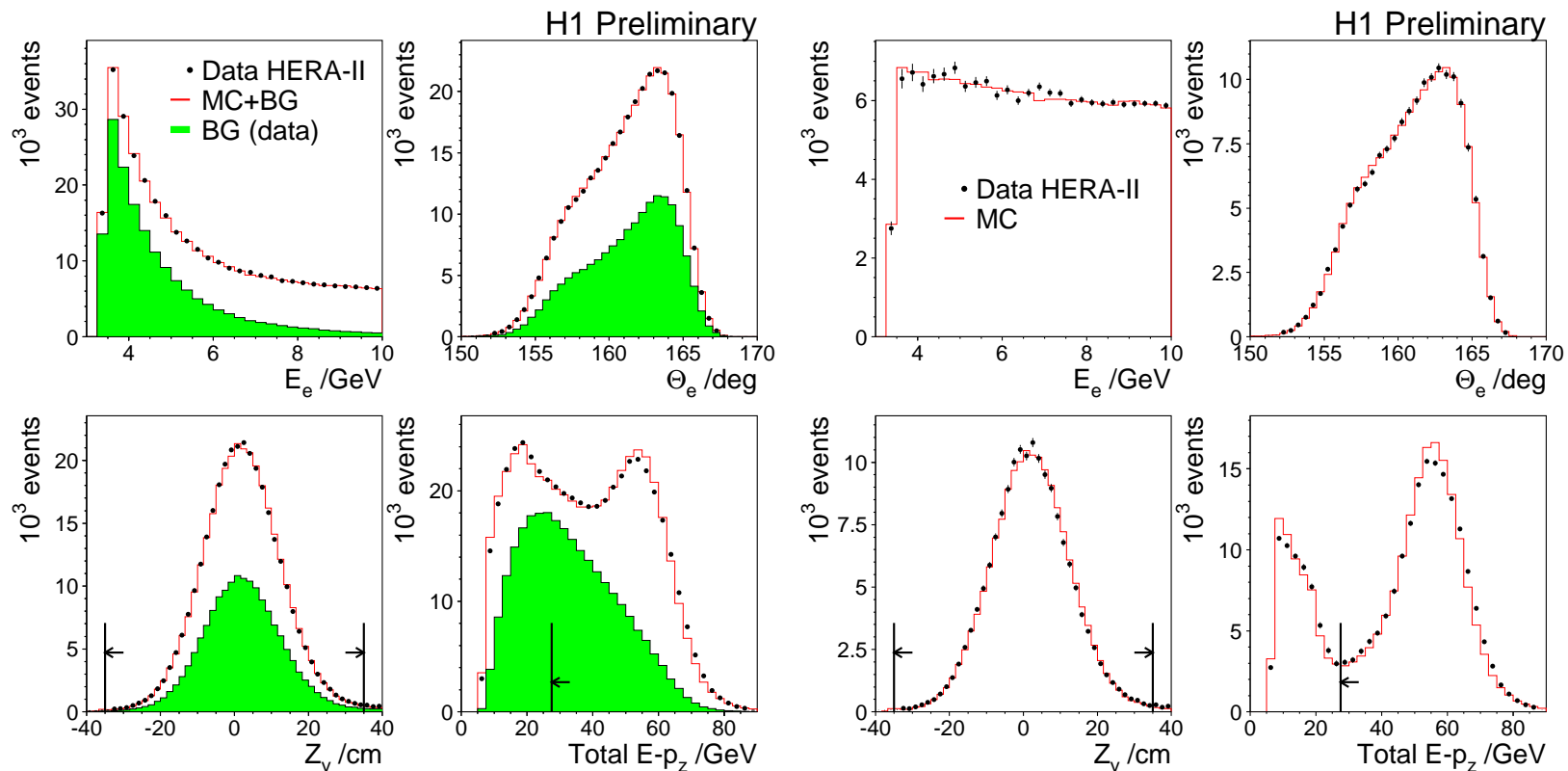
The High y Region

- Analysis in the high $y > 0.6$ region especially challenging — difficult to identify the scattered lepton with low E'_e and high γp background
- Results interesting because of sensitivity to F_L
- Experimental problems similar to direct F_L measurement, both H1 and ZEUS have released preliminary improved y cross section measurements
 - ZEUS: Measurement uses γp MC for BG subtraction, can be studied using tagged events; Analysis down to $E'_e = 5$ GeV and up to $y = 0.8$
 - H1: Background determined directly from data using the track charge; Analysis down to $E'_e = 3.3$ GeV and up to $y = 0.9$



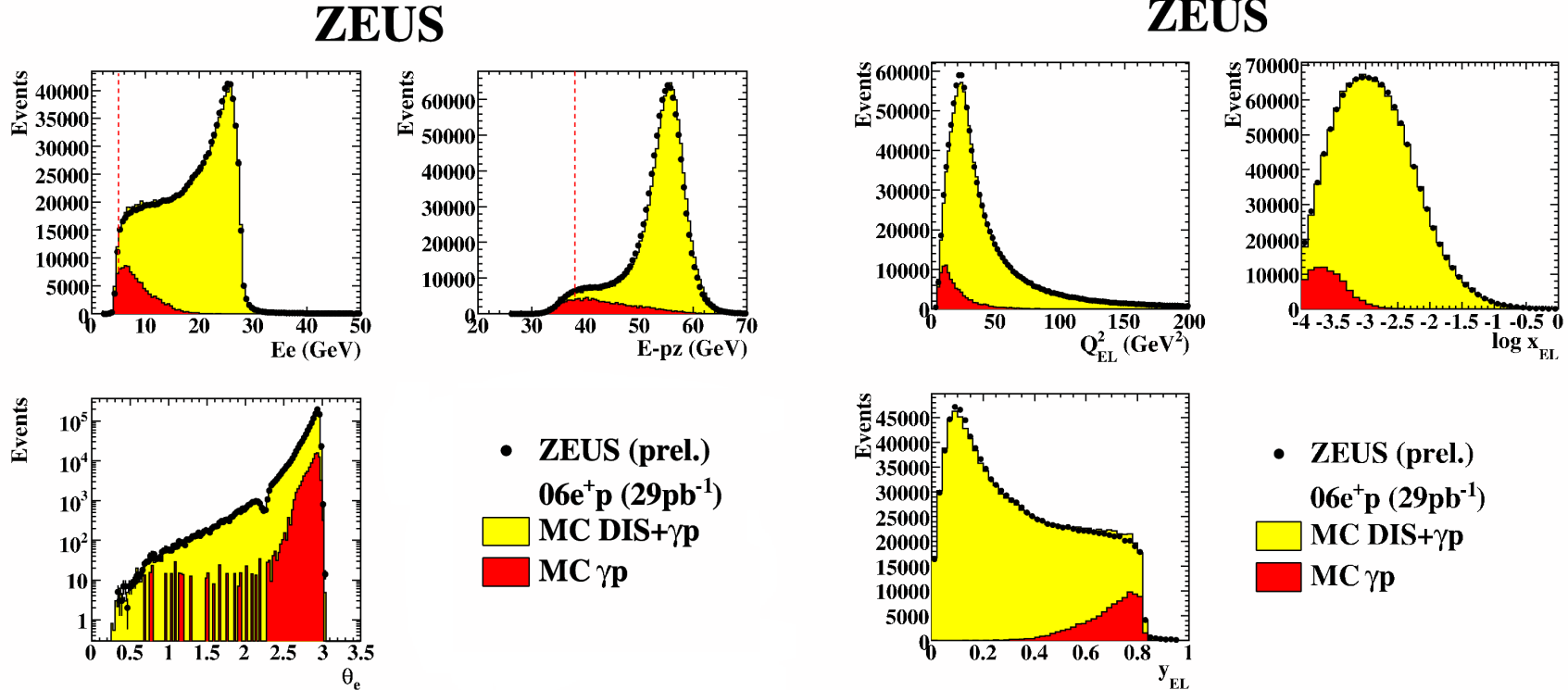
H1 High γ Analysis

- Large HERA II data set with $\mathcal{L} = 96\text{pb}^{-1}$, Subtraction of large backgrounds at low scattered lepton energy works very well
- Lepton identification cuts tuned for high efficiency, not background rejection; good sample for systematic cross checks



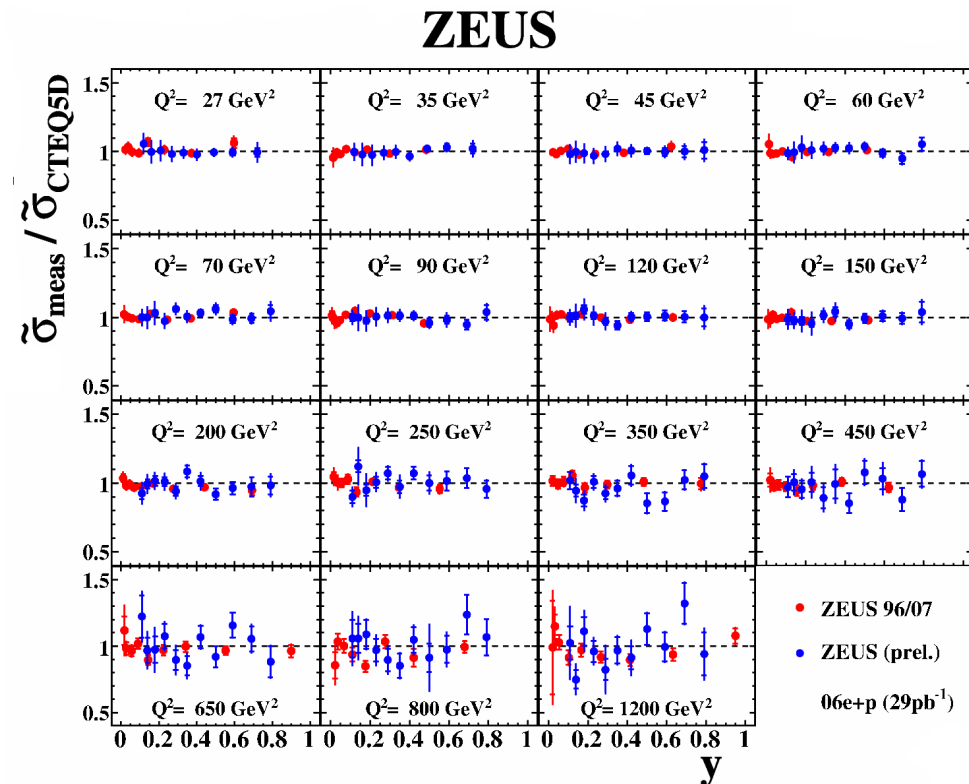
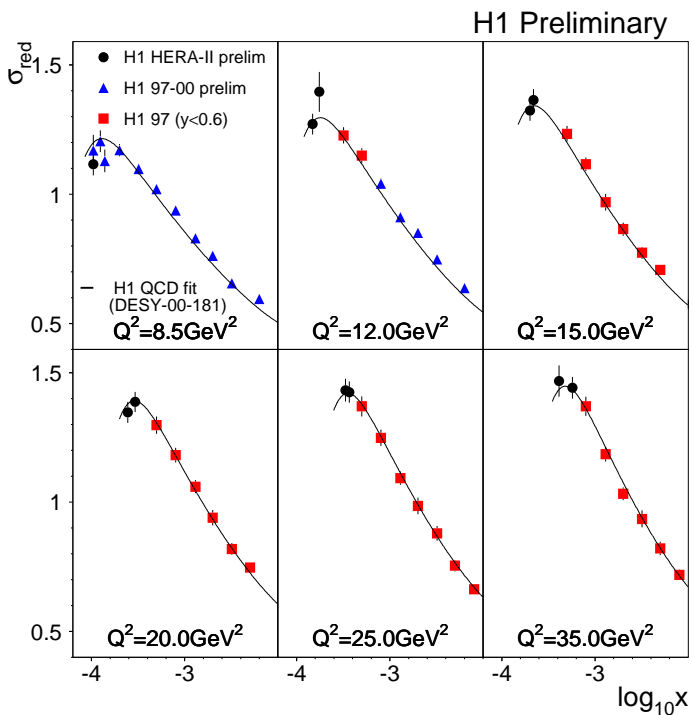
ZEUS High γ Analysis

- Good MC description of DIS signal and γp background
- Assigned systematic uncertainty on γp MC normalisation is 10%



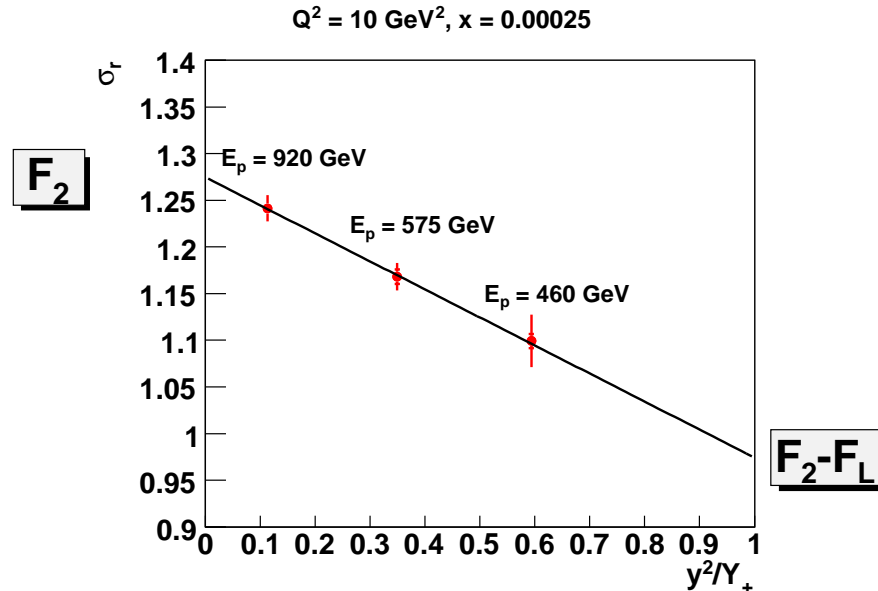
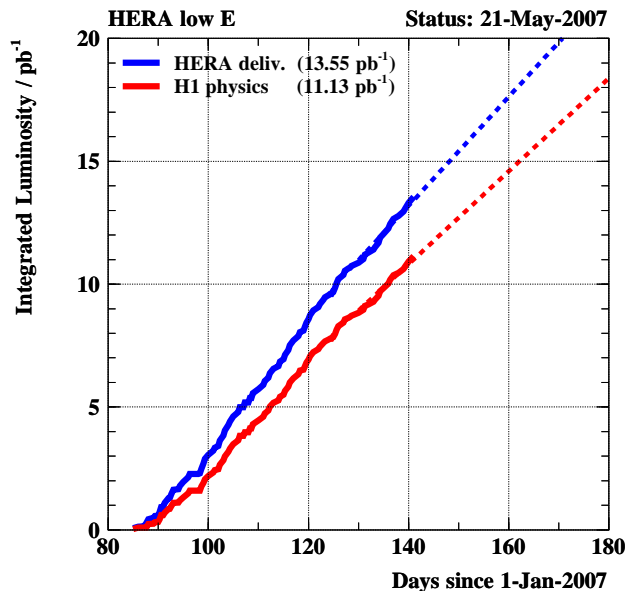
High y Results

- H1 uncertainties improved by a factor 2 over former publication, total errors 2 – 3%; to be extended to lower and higher Q^2 (BST and LAr calorimeter)
- First measurement at high y by ZEUS, covers the whole kinematic range, at higher Q^2 statistics limited



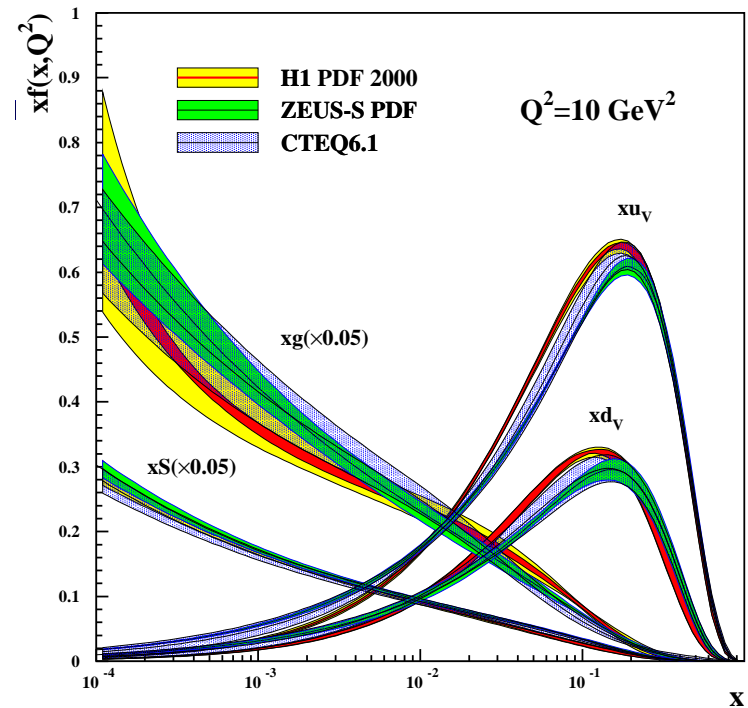
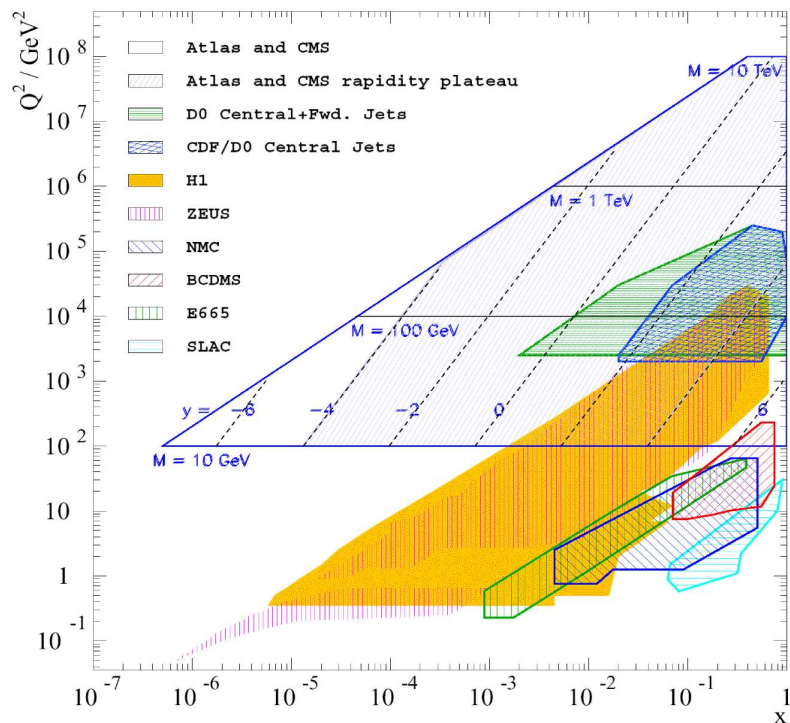
Direct F_L Measurement

- HERA structure function measurement program is not complete without measuring $F_L \Rightarrow$ Needs cross section measurements at different \sqrt{s}
- Since end of March 2007 HERA is running at reduced proton beam energy $E_p = 460$ GeV and H1 and ZEUS are taking data efficiently
- Thanks to the good HERA performance: collect $\mathcal{L} = 13\text{pb}^{-1}$ at lowest $E_p = 460$ GeV and additional $\mathcal{L} \approx 9\text{pb}^{-1}$ at an intermediate energy of $E_p = 575$ GeV



Outlook

- DGLAP QCD fits to inclusive cross section measurements determine the parton densities of the proton and test the theory
- Precise knowledge of proton structure essential for other experiments, e.g. W^\pm, Z^0 production by gluon fusion at the LHC



Conclusions



- The HERA experiments still have potential at low Q^2
- Recently new and improved results presented at DIS 2007 for lowest Q^2 and in the high y domain
- Currently HERA is running successfully at lowered E_p , F_L will be measured directly using this data
- Not to forget: Low and High Q^2 bulk results will be updated soon
- Improved experimental input and combined HERA combined will eventually lead to a reduction of the PDF uncertainties, valuable input for the LHC, and test QCD