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

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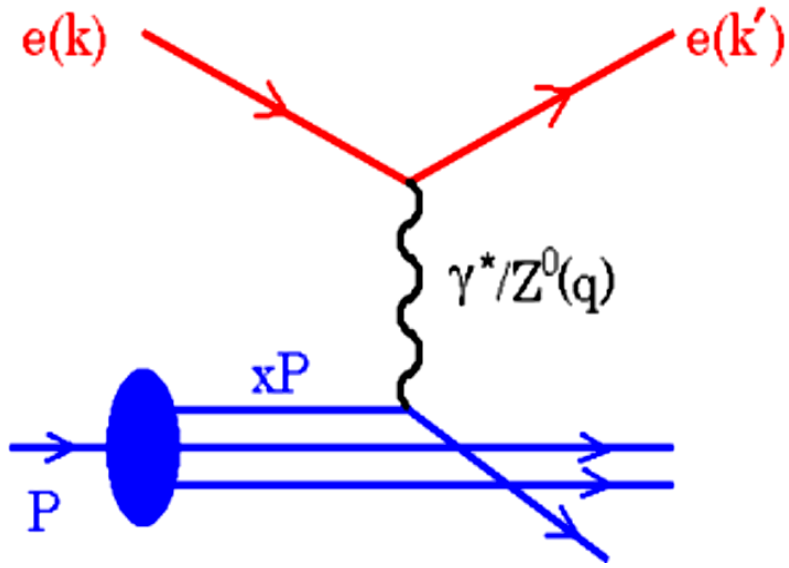
Introduction

- 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 $Q^2 = xys$

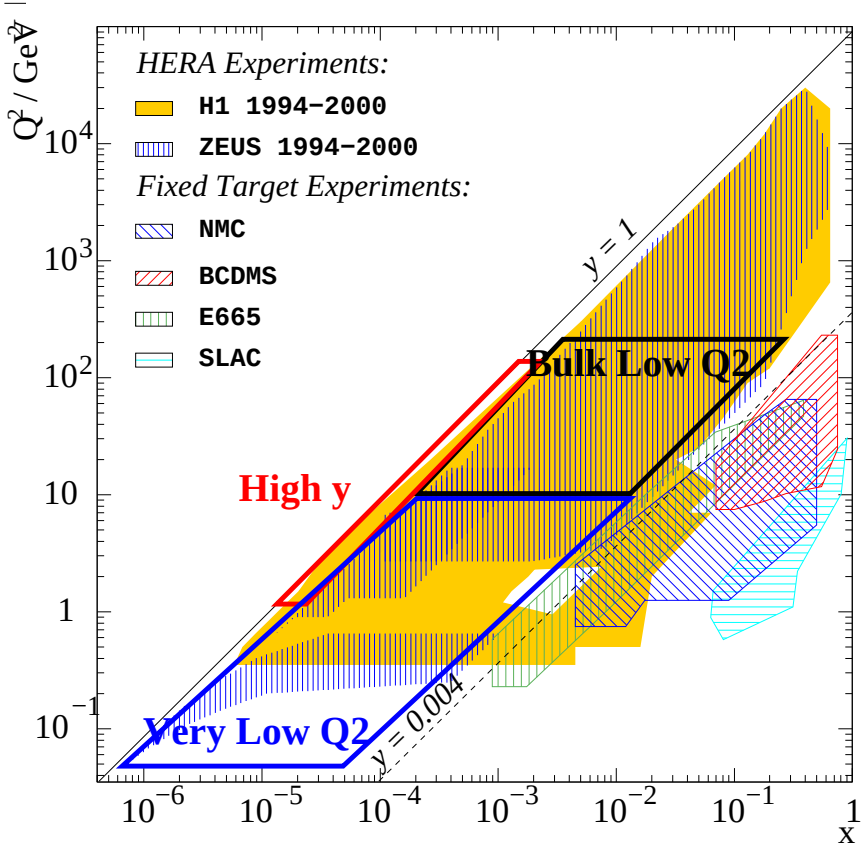


Inclusive DIS Cross Section

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

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

- Bulk Low Q^2 Domain ($10\mathrm{GeV}^2 \leq Q^2 \leq 150\mathrm{GeV}^2$): DGLAP evolution, PDFs, highest precision
- Lowest Q^2 Domain ($Q^2 \leq 10\mathrm{GeV}^2$): 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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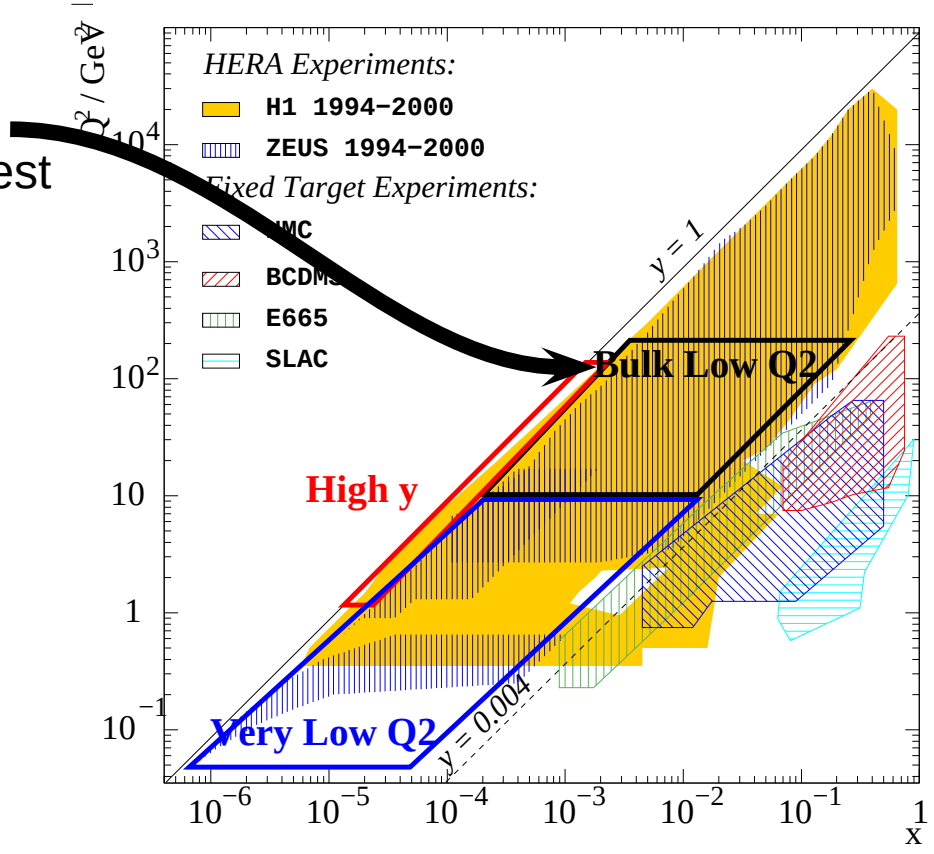

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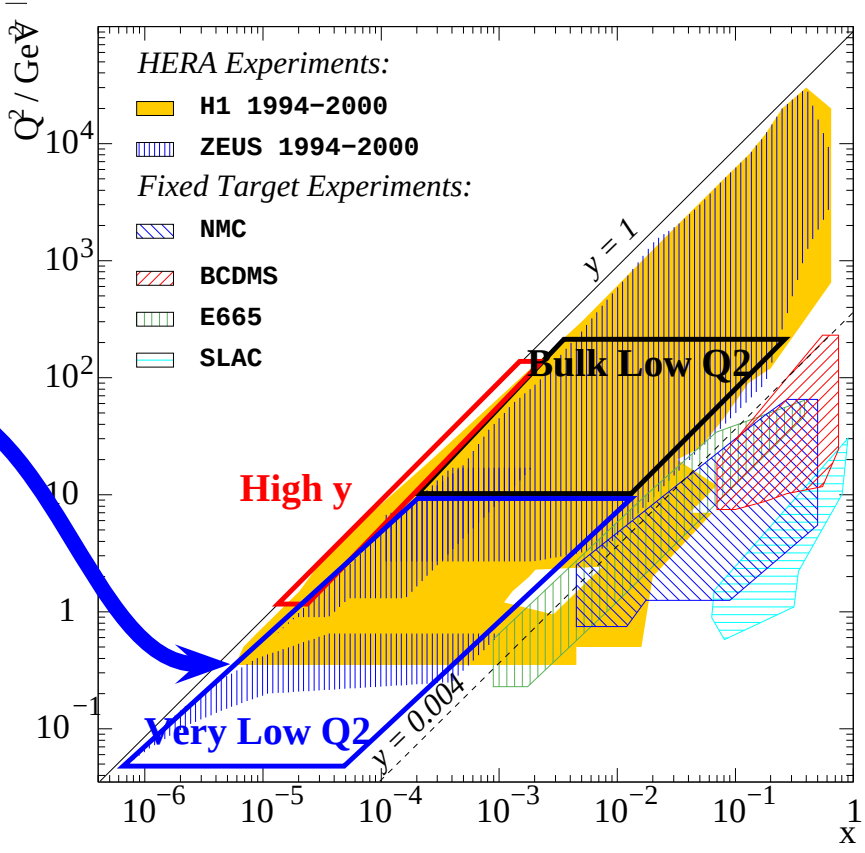

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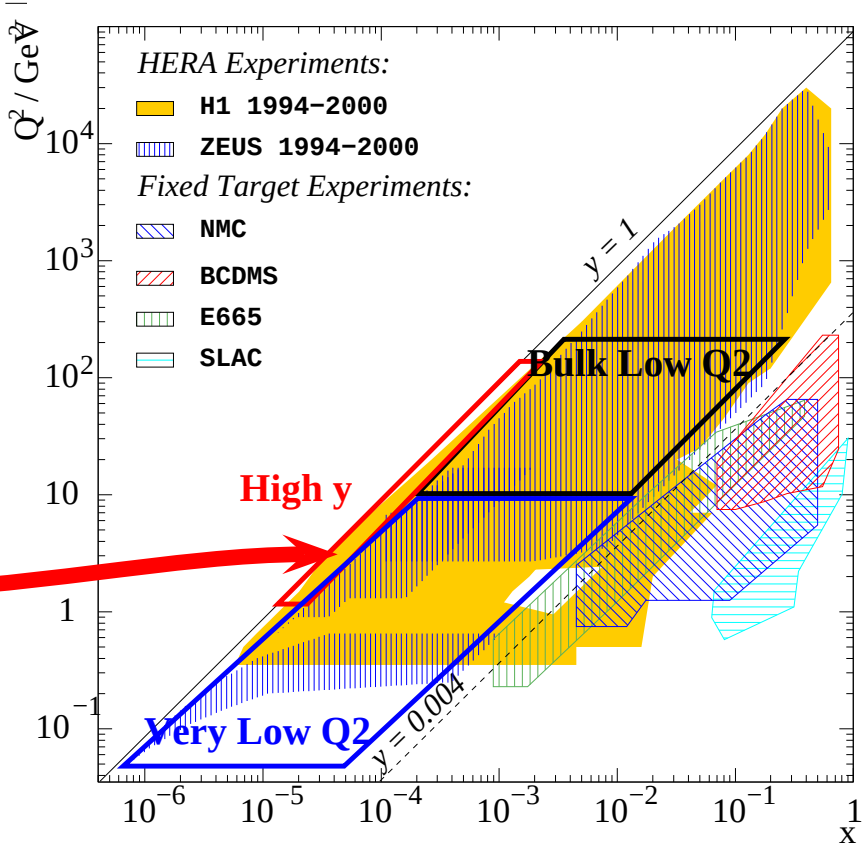
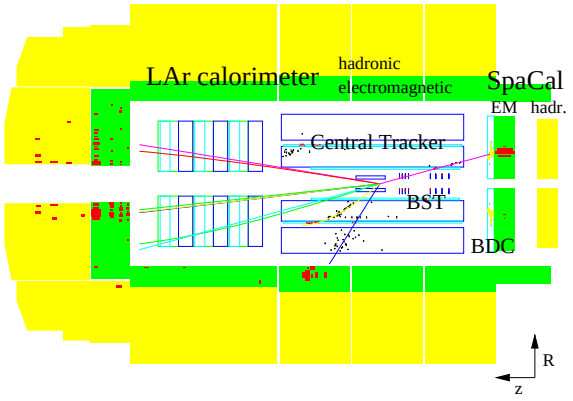
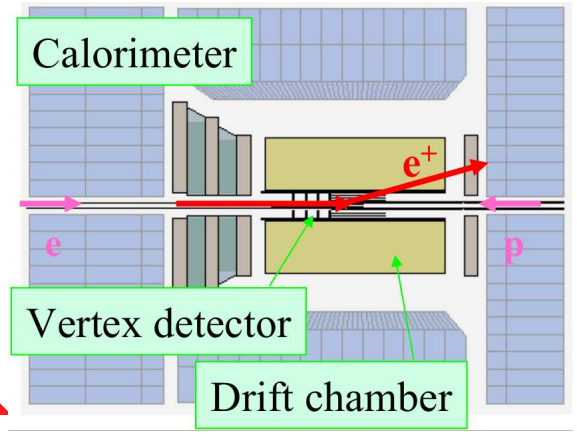


The HERA Collider

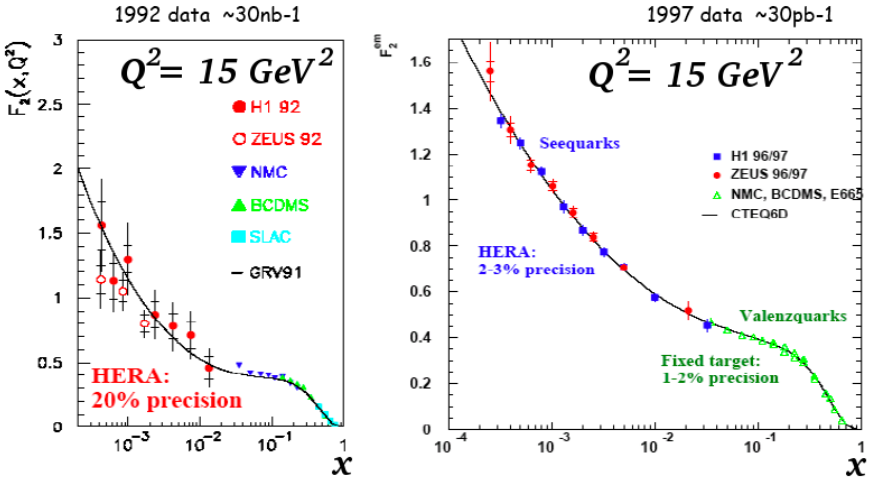
- HERA accelerator: 920 GeV p + 27.6 GeV $e^{\pm} \Rightarrow \sqrt{s} = 320$ GeV
- H1 and ZEUS: general purpose detectors, Measurement of the Proton Structure in full kinematic range one of the prime objectives

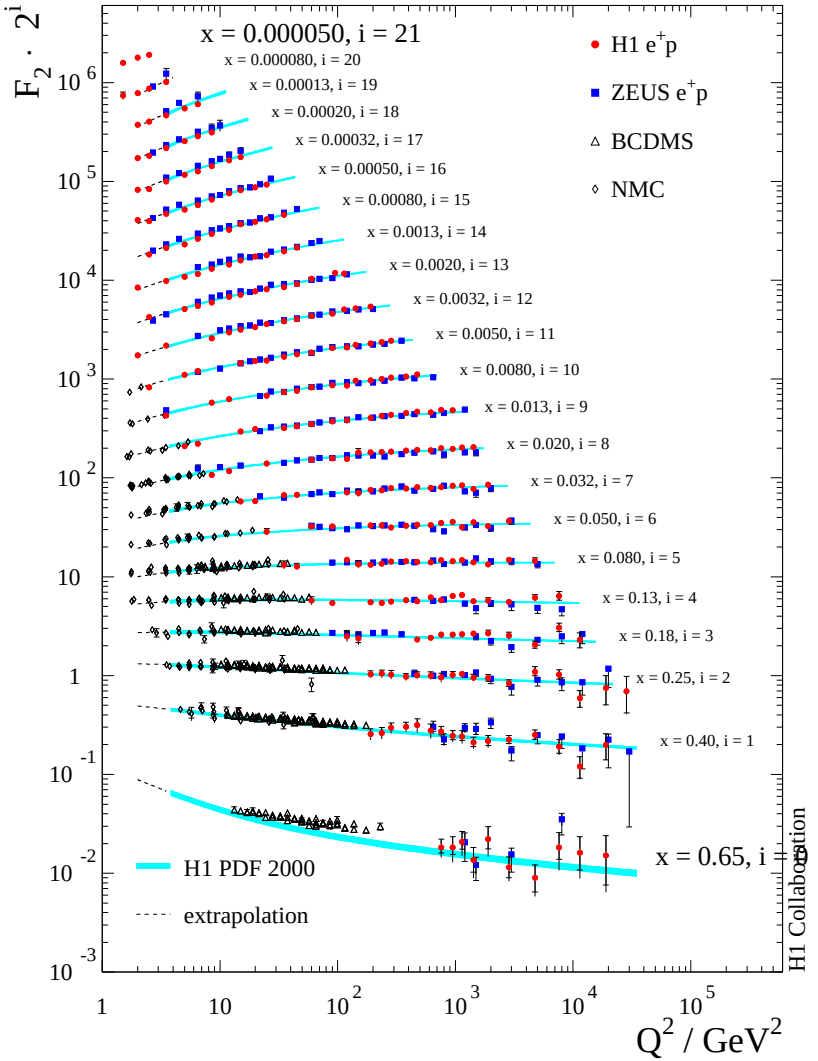




Low Q^2 Bulk Results

- F_2 has been measured with up to $2-3\%$ precision in the "HERA Bulk Region" $10 \leq Q^2/\mathrm{GeV}^2 \leq 150$ 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

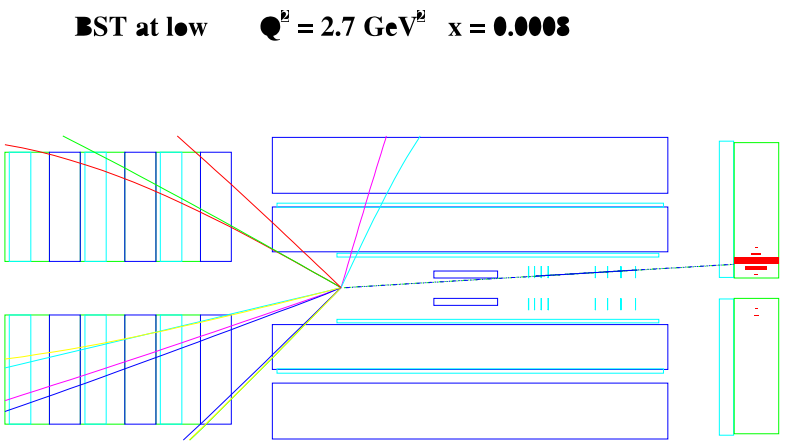




Lowest Q^2 Region

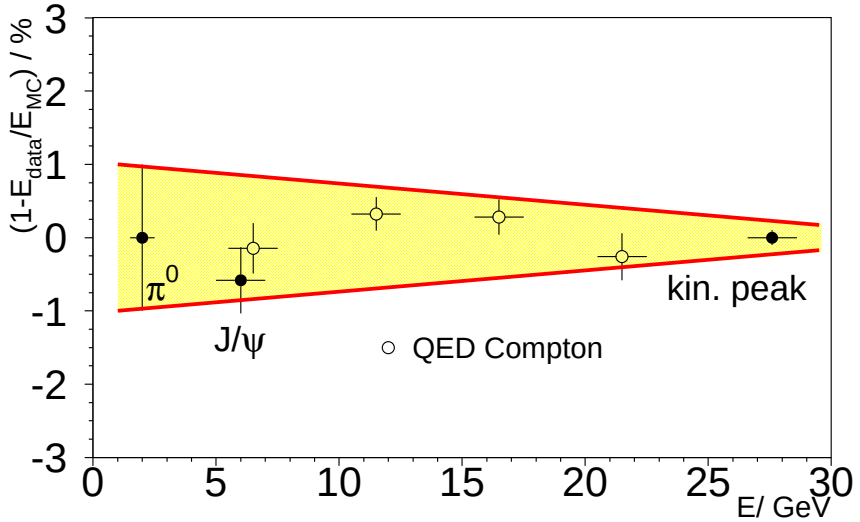
- Transition to non-perturbative region $Q^2 \to 0$ is of theoretical interest
- The lowest $Q^2 < 10\mathrm{GeV}^2$ region is accessed using specialised techniques to detect scattered leptons at very small angles:
  - Data taken with shifted event vertex (H1)
  - Events with tagged (ZEUS) or untagged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

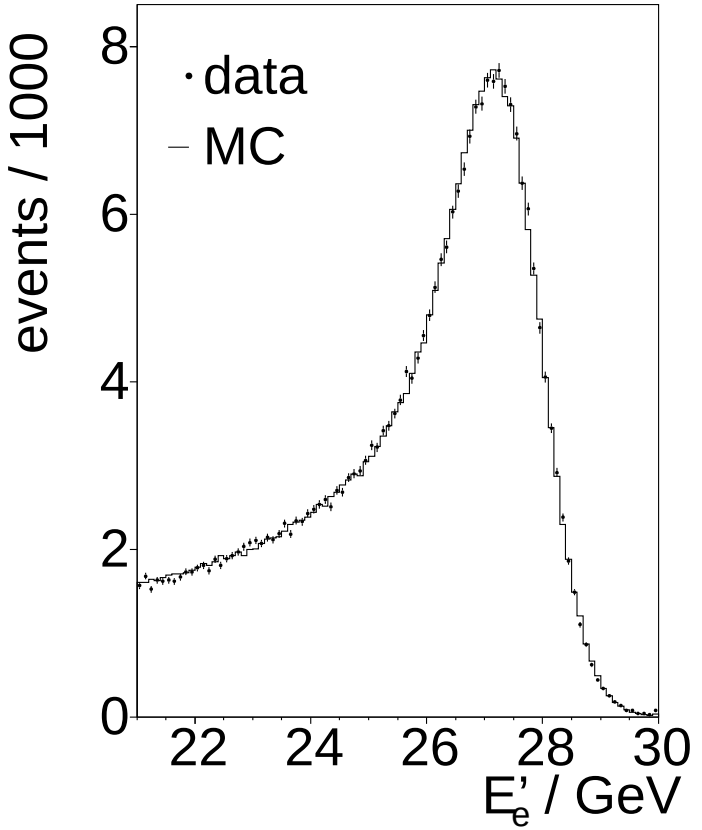
- New preliminary results of H1 for DIS 2007: HERA results complete for this region!



Lowest Q^2 Analysis

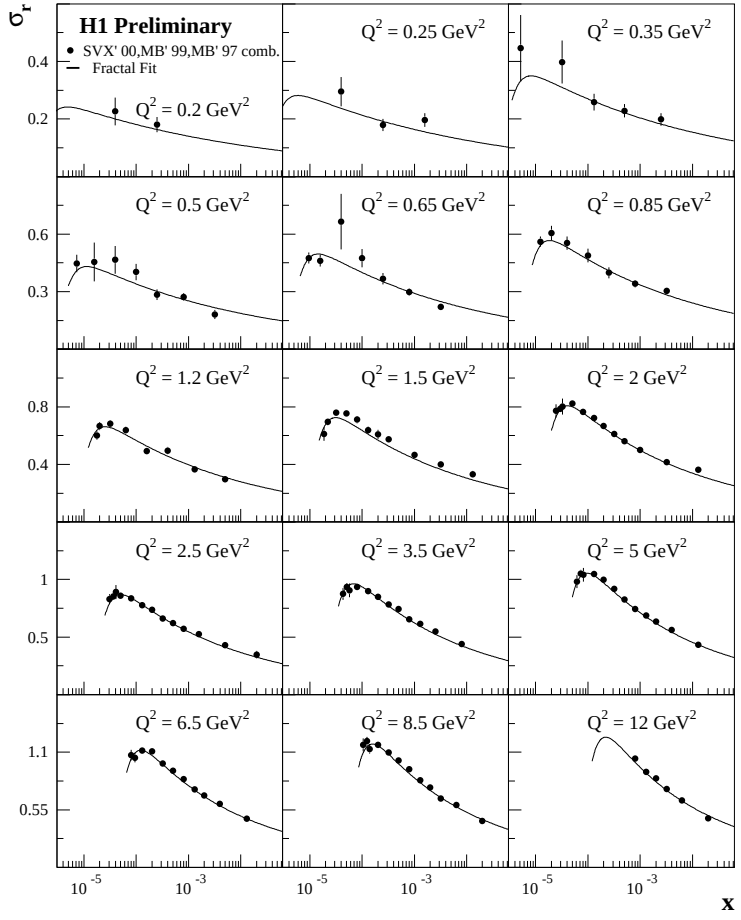
- Main features of the preliminary new H1 analysis:
  - Control of the Lepton Energy Scale to $0.2 - 1.0\%$
  - Kinematic reconstruction mainly independent of the hadronic final state using the BST
  - Further improvements due to combination of 3 H1 data sets taking into account systematic errors

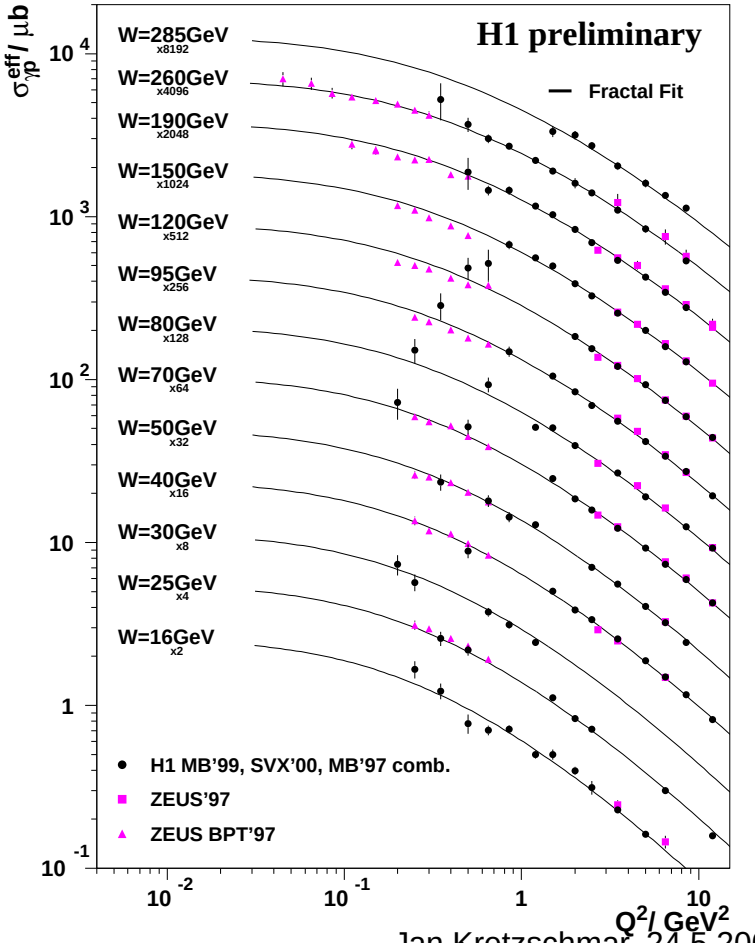




Lowest Q^2 Results

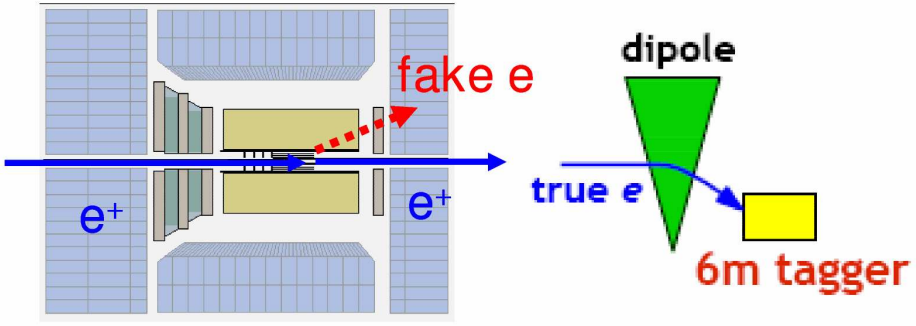
- Reduced cross section σ_r and effective $\gamma^* p$ cross section:
- Typical precision: ZEUS BPT data $< 4\%$, combined H1 data: $1.5 - 10\%$

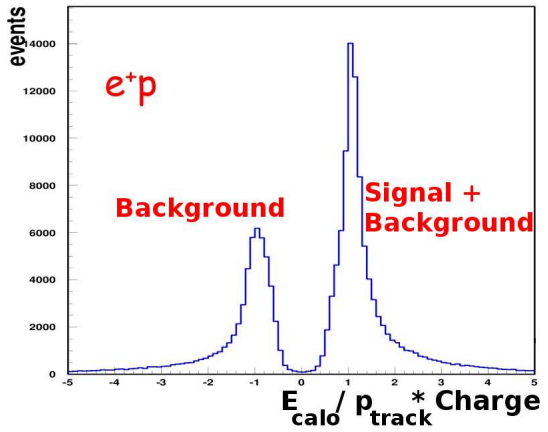




The High y Region

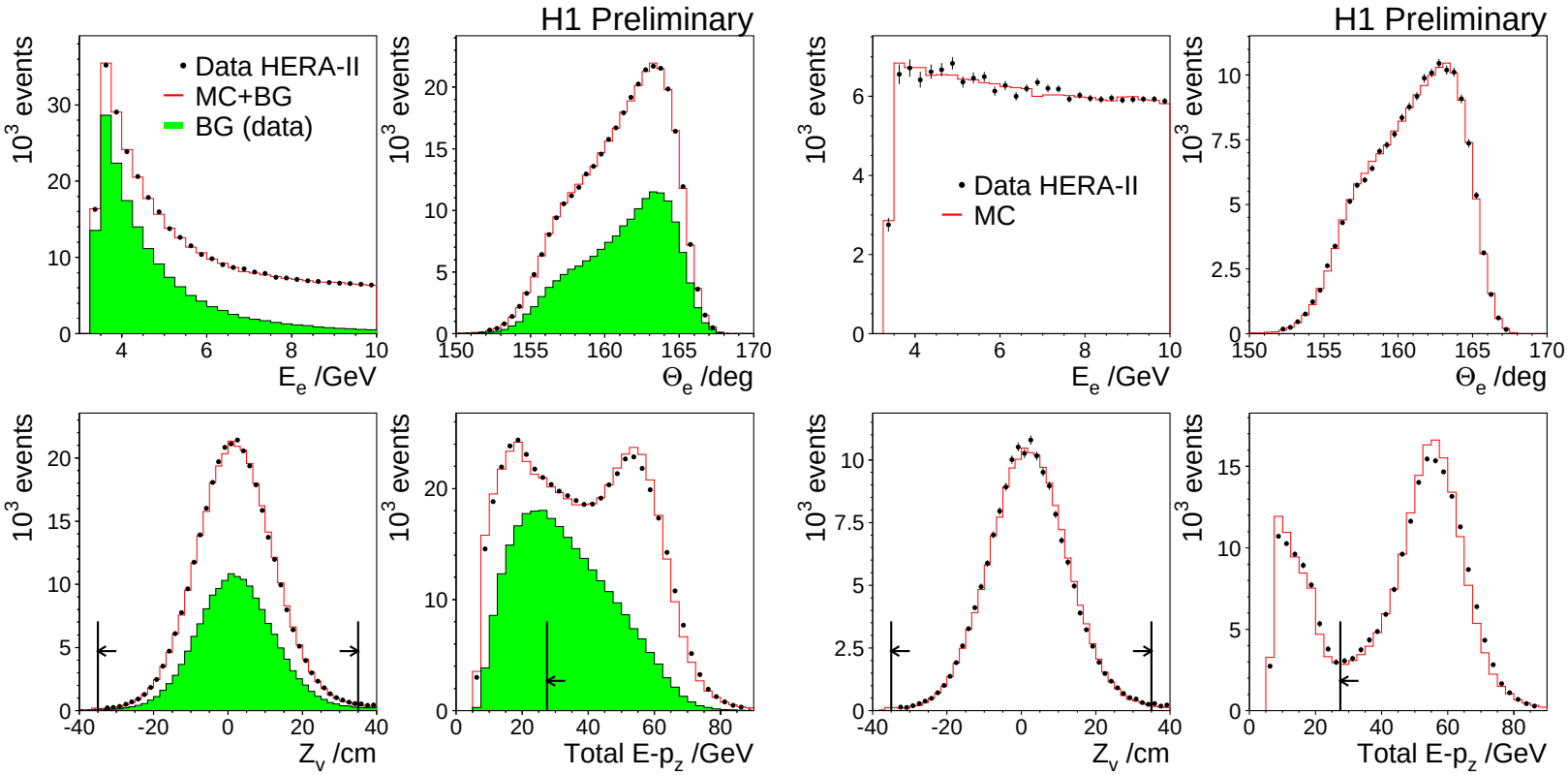
- Analysis in the high $y > 0.6$ region especially challenging — difficult to identify the scattered lepton with low E'_e and high γp background
- Results interesting because of sensitivity to F_L
- Experimental problems similar to direct F_L measurement, both H1 and ZEUS have released preliminary improved 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 $y = 0.9$





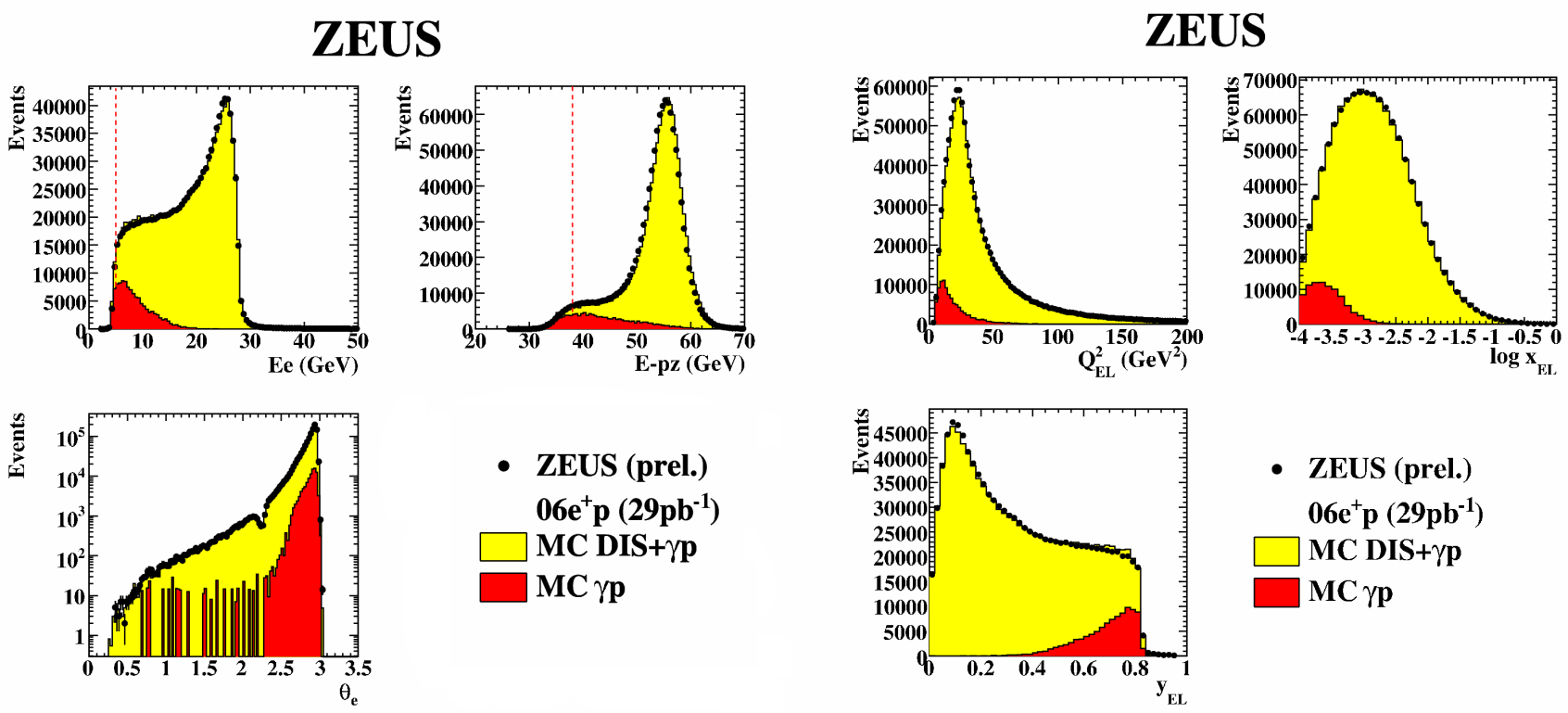
H1 High y Analysis

- Large HERA II data set with $\mathcal{L} = 96\mathrm{pb}^{-1}$, 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



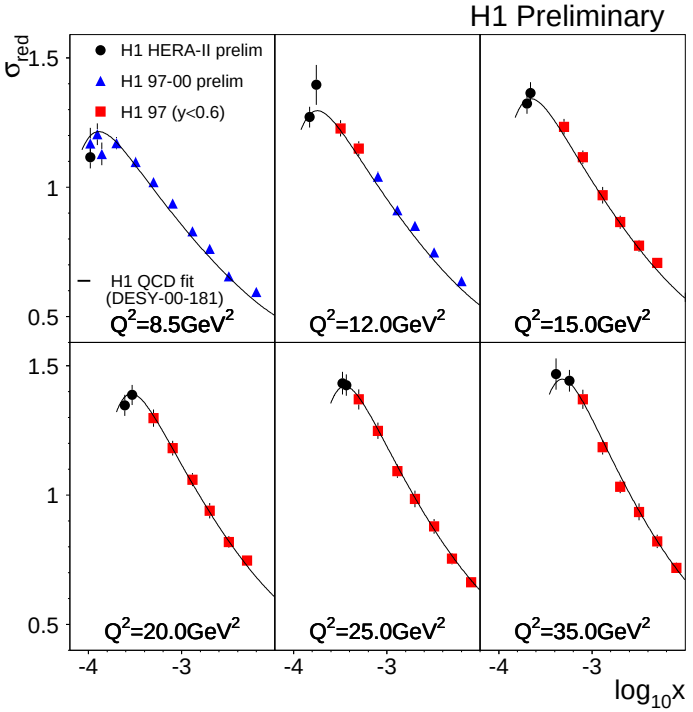
ZEUS High y Analysis

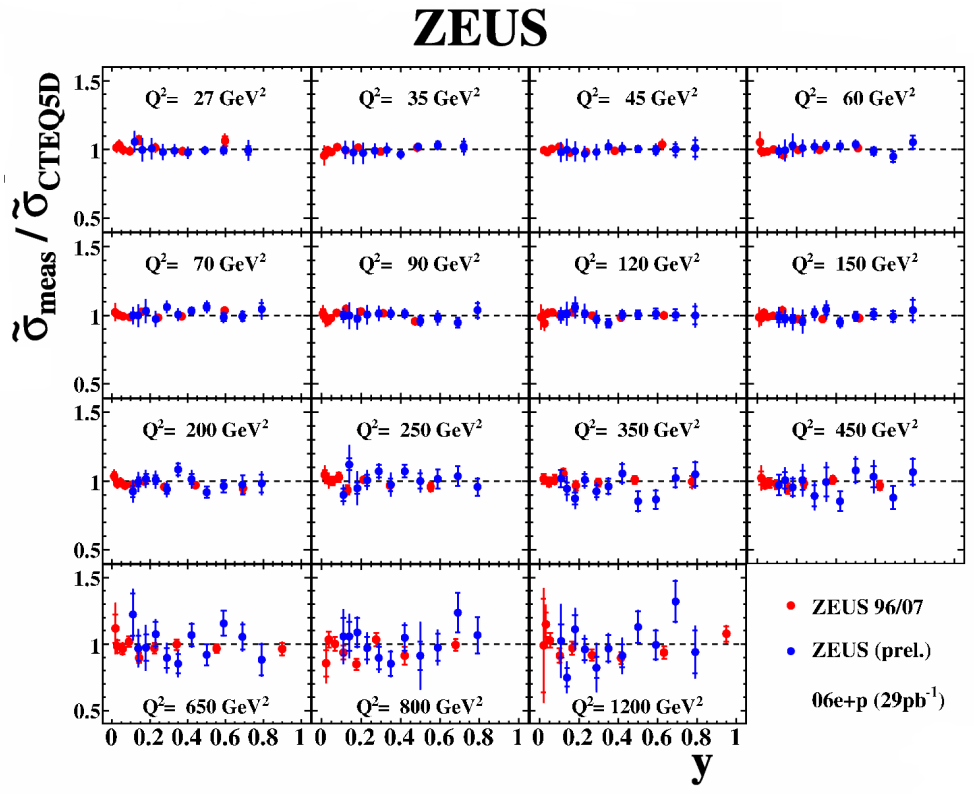
- Good MC description of DIS signal and γp background
- Assigned systematic uncertainty on γp MC normalisation is 10%



High y Results

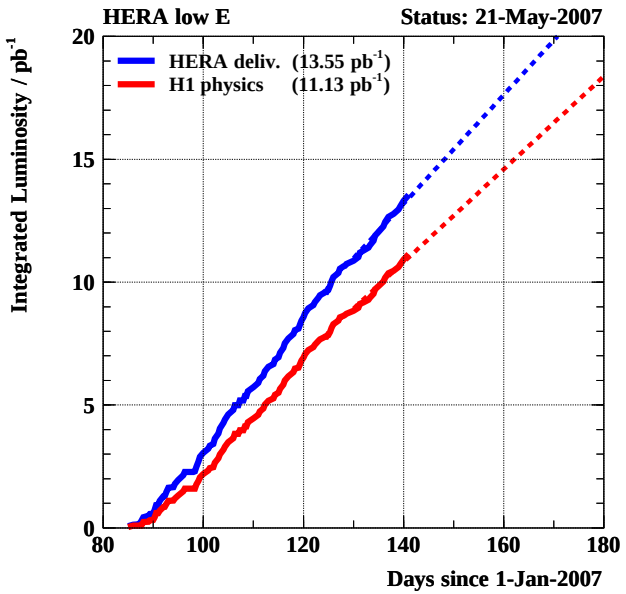
- H1 uncertainties improved by a factor 2 over former publication, total errors $2-3\%$; to be extended to lower and higher Q^2 (BST and LAr calorimeter)
- First measurement at high y by ZEUS, covers the whole kinematic range, at higher Q^2 statistics limited

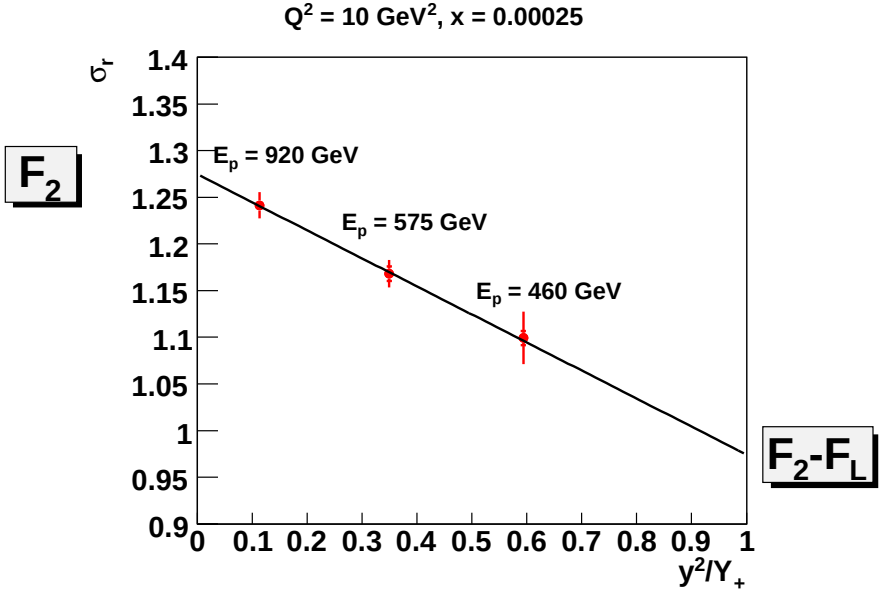




Direct F_L Measurement

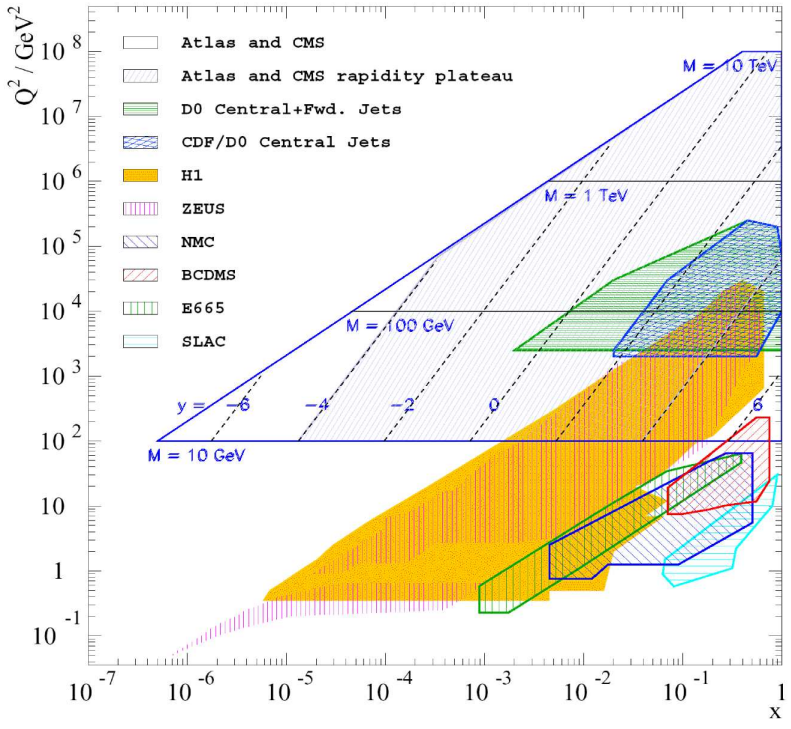
- HERA structure function measurement program is not complete without measuring $F_L \Rightarrow$ Needs cross section measurements at different $\sqrt{s}$
- Since end of March 2007 HERA is running at reduced proton beam energy $E_p = 460$ GeV and H1 and ZEUS are taking data efficiently
- Thanks to the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

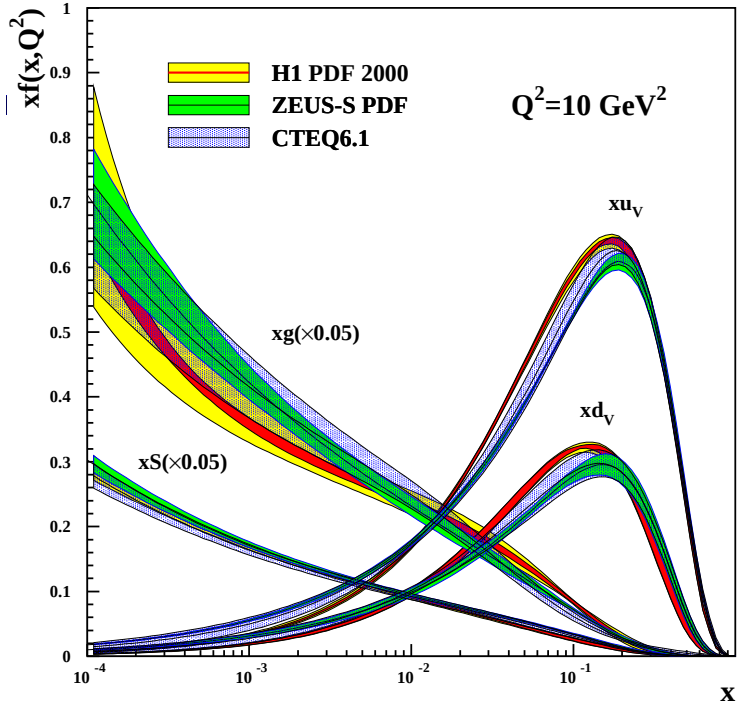




Outlook

- 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