



# Neutral and Charged Current Cross Sections and Extraction of Structure Functions and Parton Distributions

**Shiraz Habib**

**Lake Louise 2008**

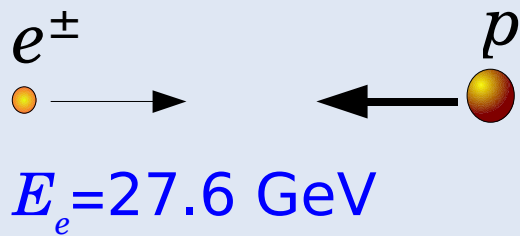
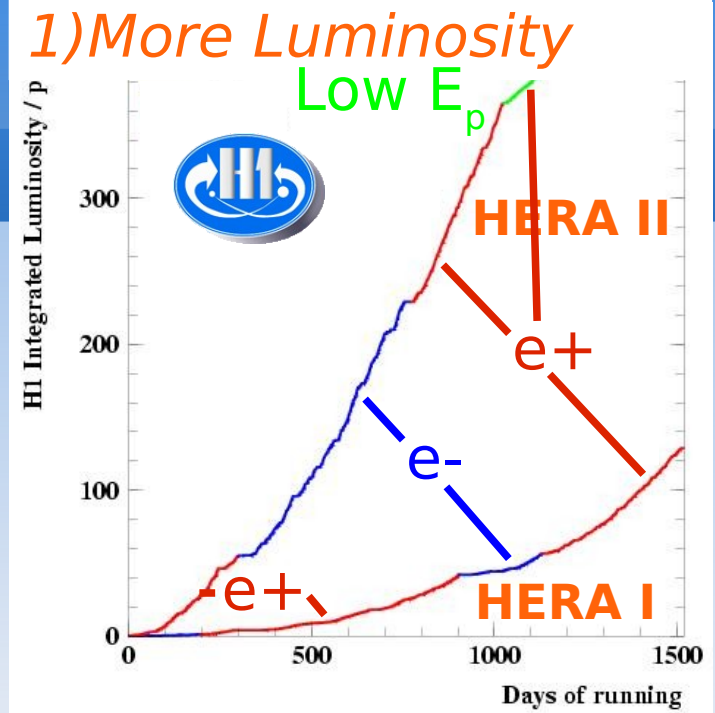
# Outline:

- HERA Collider and the H1 and ZEUS Detectors
- Inclusive Physics at HERA
- Recent Results:
  - H1 and ZEUS Combined Reduced Cross Sections
  - High  $y$  Cross Section Measurements
  - Parity Violation
- Summary and Outlook

# HERA Collider and the H1 and ZEUS Detectors



2000 Lumi Upgrade



$E_p$	$\sqrt{s}$
820	301 GeV
920	319 GeV
460	225 GeV
575	252 GeV

Average Specific Lumi increased by **x4** from HERAI- $\rightarrow$ HERAII

Luminosity Summary  
(per Detector)

Total : 0.5 fb<sup>-1</sup>  
e+/e- : 1.6

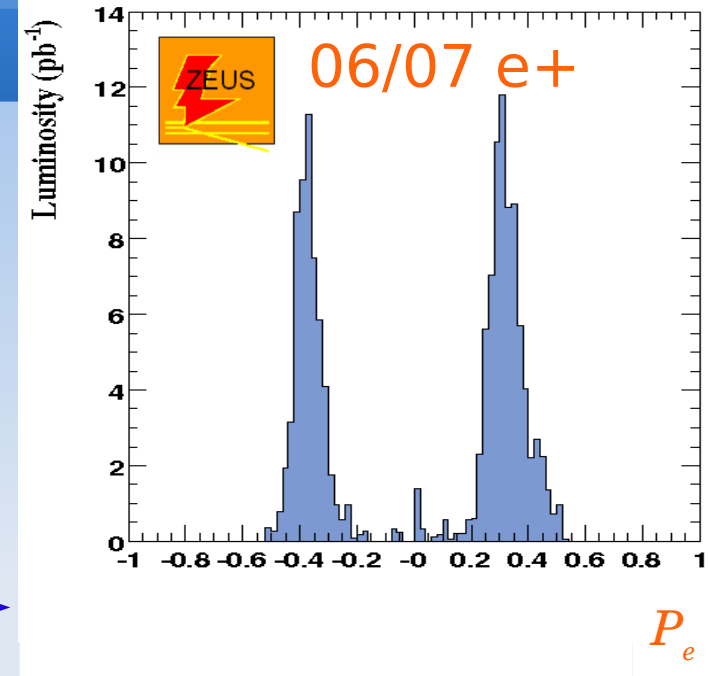
Different  $\sqrt{s}$  allows *direct measurement* of the different structure functions contributions at a given point in phase space.

# HERA Collider and the H1 and ZEUS Detectors



2000 Lumi  
Upgrade

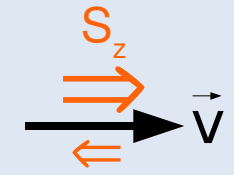
## 2) Longitudinal Pol. $e^\pm$



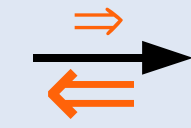
$E_p$	$\sqrt{s}$
820	301 GeV
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$$P_e = \frac{N_R - N_L}{N_R + N_L}$$

$P_e > 0$ :



$P_e < 0$ :



Different  $\sqrt{s}$  allows *direct measurement* of the different structure functions contributions at a given point in phase space.

# HERA Collider and the H1 and ZEUS Detectors

Some Figures:

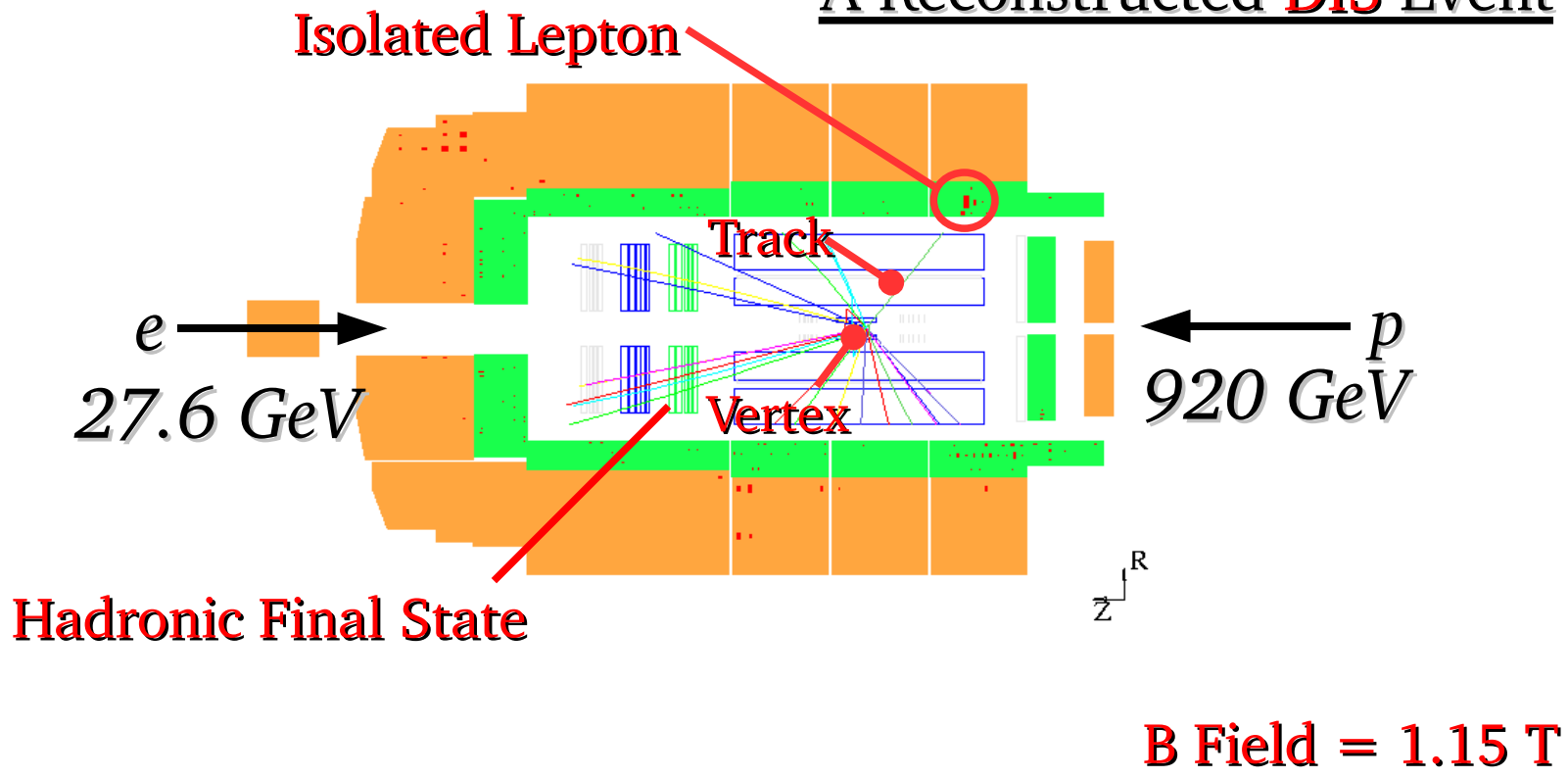


Volume [m<sup>3</sup>](x x y x z) : 12 x 15 x 10  
 Mass [tonnes] : 2800

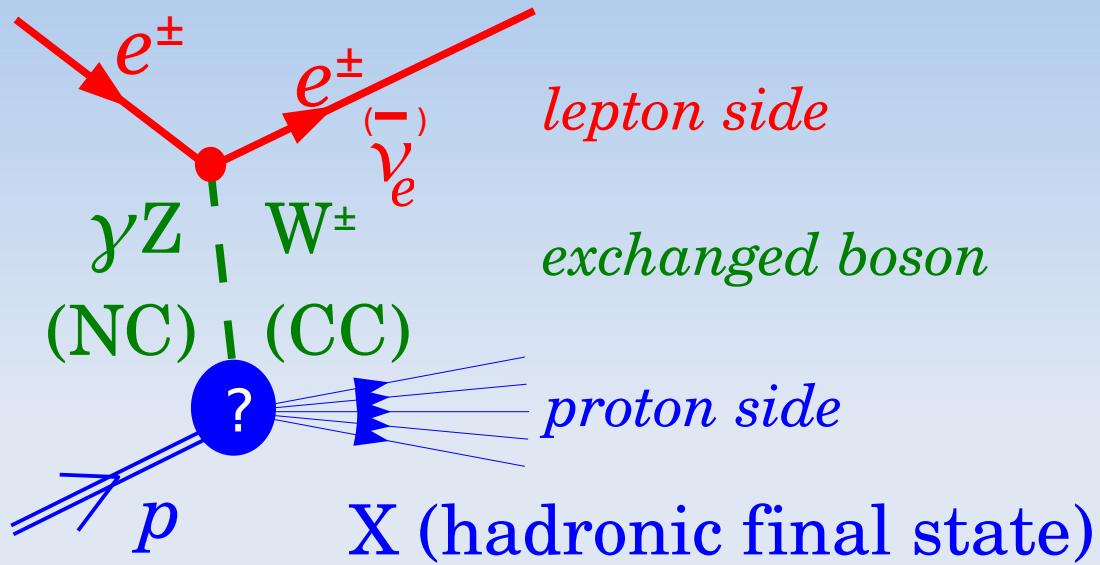
ATLAS

25 x 25 x 46  
 7000

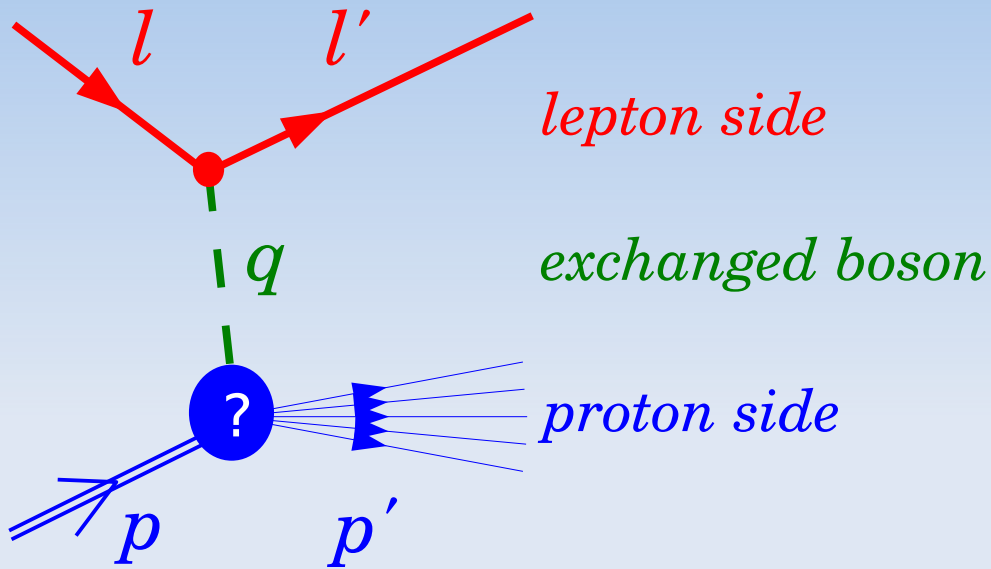
## A Reconstructed DIS Event



# Inclusive Physics at HERA



# Inclusive Physics at HERA



Kinematics uniquely specified by 2 of 3 variables:

- $Q^2 = -q^2$
  - $x = Q^2 / 2q \cdot p$
  - $y = q \cdot p / l \cdot p$
- $Q^2 = sxy$

*Unpolarized Reduced Cross Section:*

$$\sigma_r^\pm \equiv \frac{d^2\sigma}{dx dQ^2} \frac{Q^4 x}{2\pi\alpha^2 Y_\pm} = \underbrace{F_2}_{\text{Dominant Contribution}} \mp \frac{Y_-}{Y_+} \underbrace{x F_3}_{\text{Contributes at high } y} - \frac{y^2}{Y_+} \underbrace{F_L}_{\text{Contributes at high } y}$$

$$Y_\pm \equiv 1 \pm (1 - y)^2$$

*From Weak Interaction  $\Rightarrow$  contributes at high  $Q^2$*

# Recent Results:

## ◆ H1 and ZEUS Combined Reduced Cross Sections

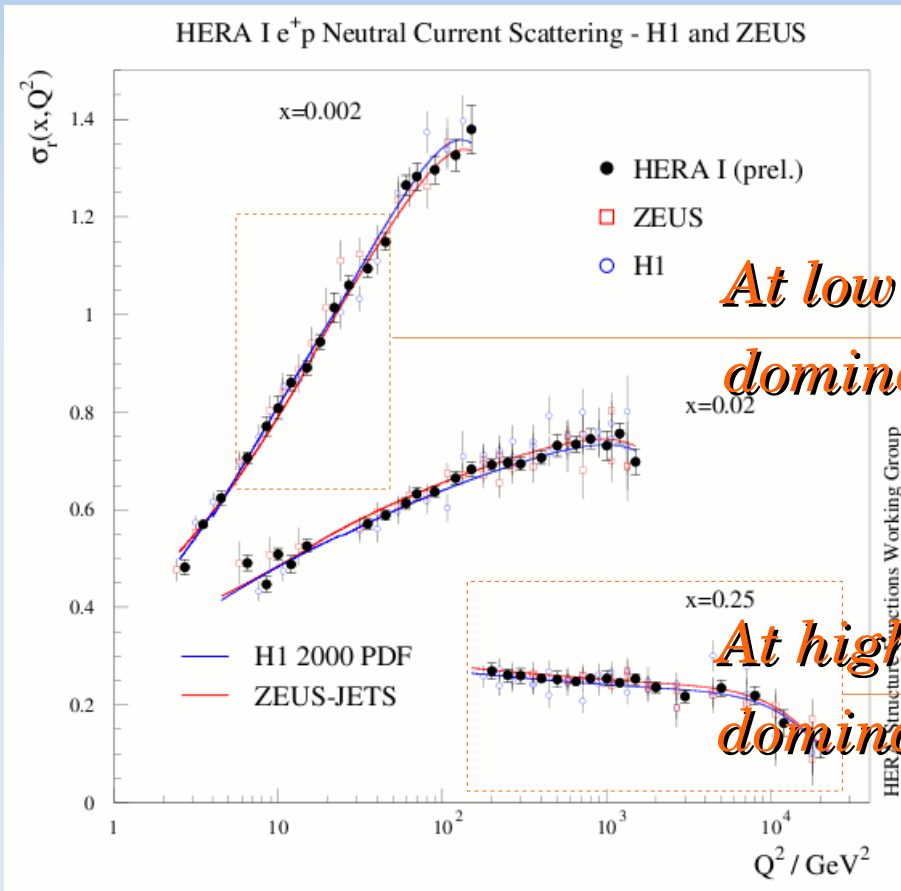
- The **NC and CC Reduced Cross Sections** are the main input used to determine **Parton Distributions (PDFs)** by performing **QCD Fits**.
- H1 and ZEUS have combined their **published HERA I Cross Sections** with the aim of reducing both the **statistic** and **systematic** uncertainty.
- The **Method** used [*See: S.Glazov XIII International Workshop on Deep Inelastic Scattering*] uses a novel approach in taking **correlations** between the measurements of the 2 experiments into account.



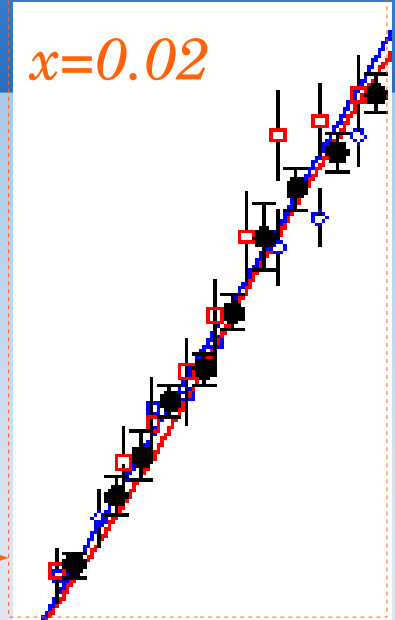
# Recent Results

## ◆ H1 and ZEUS Combined Reduced Cross Sections

### HERA $e^+p$ NC Reduced Cross Sections



*At low  $Q^2$  where systematics dominate, error improves*



*At high  $Q^2$  where stats dominate, fluctuations reduce*

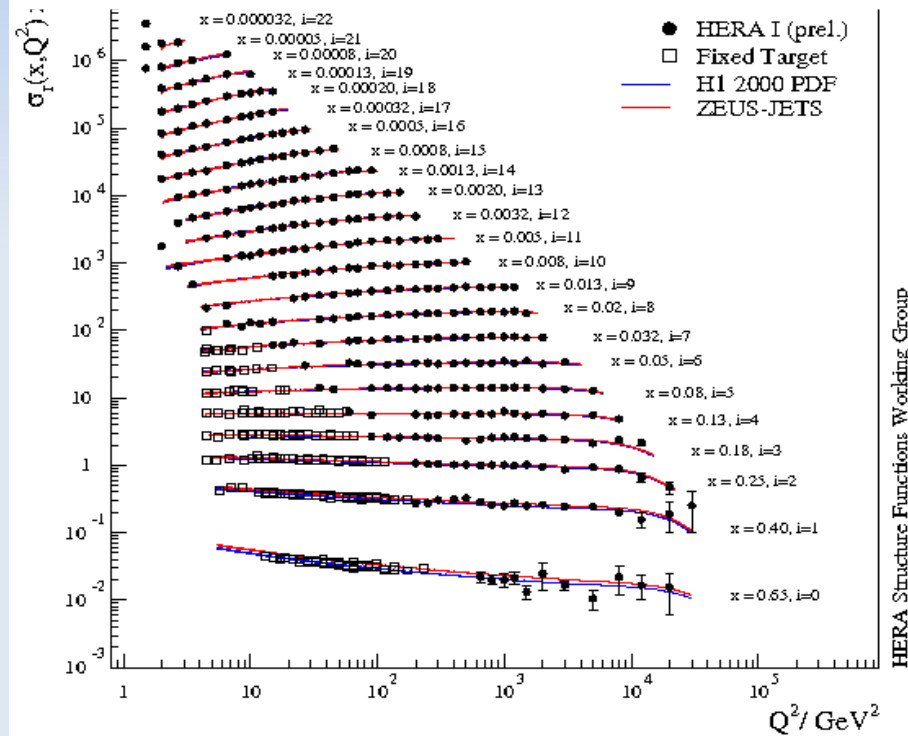


Combined points agree well with both the H1 2000 PDF and ZEUS-JETS QCD Fits

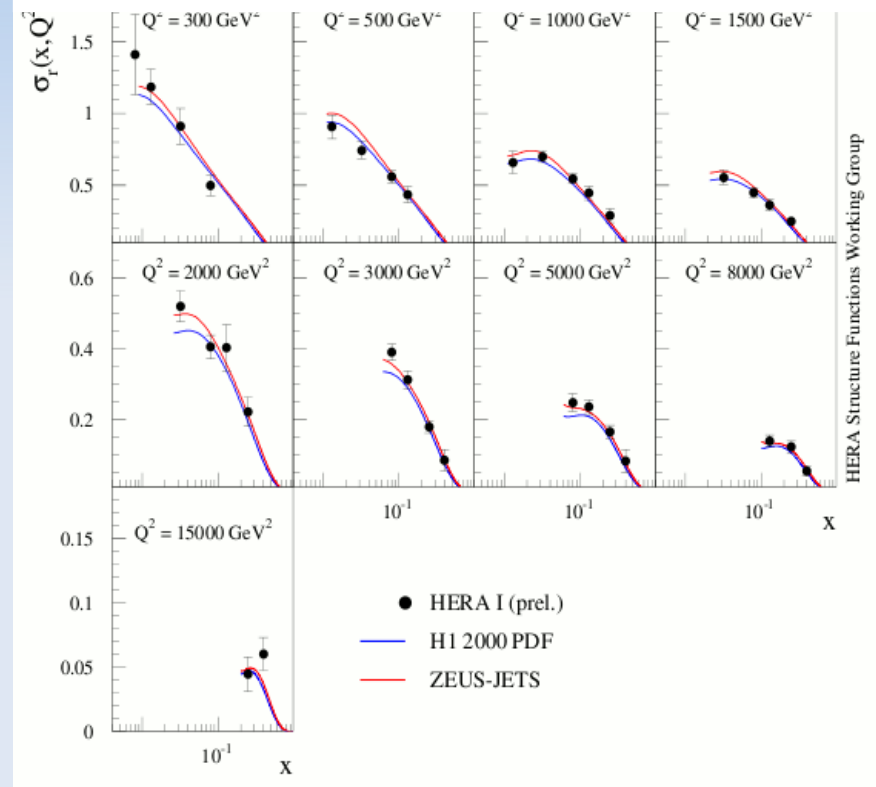
# Recent Results

## ◆ H1 and ZEUS Combined Reduced Cross Sections

### HERA I $e^+p$ NC Reduced Cross Sections relative to fixed target experiments



### HERA I $e^+p$ CC Scattering



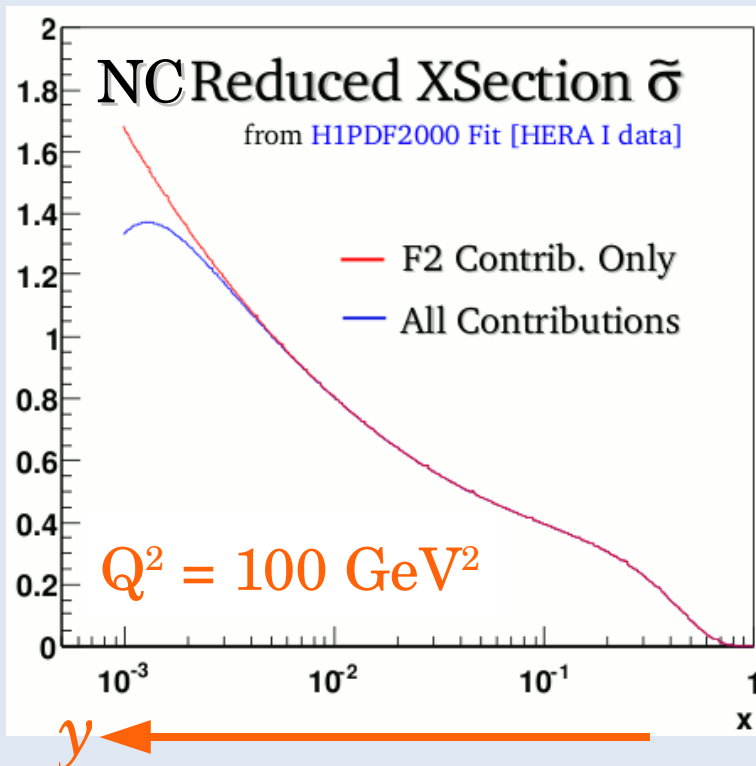
**Next: Combine All HERA I / HERA II Cross Sections of the 2 Experiments**

*H1 and ZEUS Combined Reduced Cross Sections should play a significant role in establishing final PDFs at HERA*

# Recent Results

## ◆ High $y$ Cross Section Measurements

- $F_L$  Structure Function is one of the basic measurements of Proton Structure
- $F_L$  is also sensitive to the gluon density which is important for many LHC processes e.g. SM Higgs, W and Z Production
- $F_L$  contributes to the Cross Section only at high  $y$  ( $\sigma_r^\pm = \dots -y^2 F_L / Y_+$ )



- High  $y \Rightarrow$  **low energies** of the scattered electron.

e.g.  $Q^2 = 100 \text{ GeV}^2$  :

$$E'(y) \simeq 1 + 27.6 (1 - y)$$
$$E'(0.1) \simeq 26 \text{ GeV}$$
$$E'(0.75) \simeq 8 \text{ GeV}$$

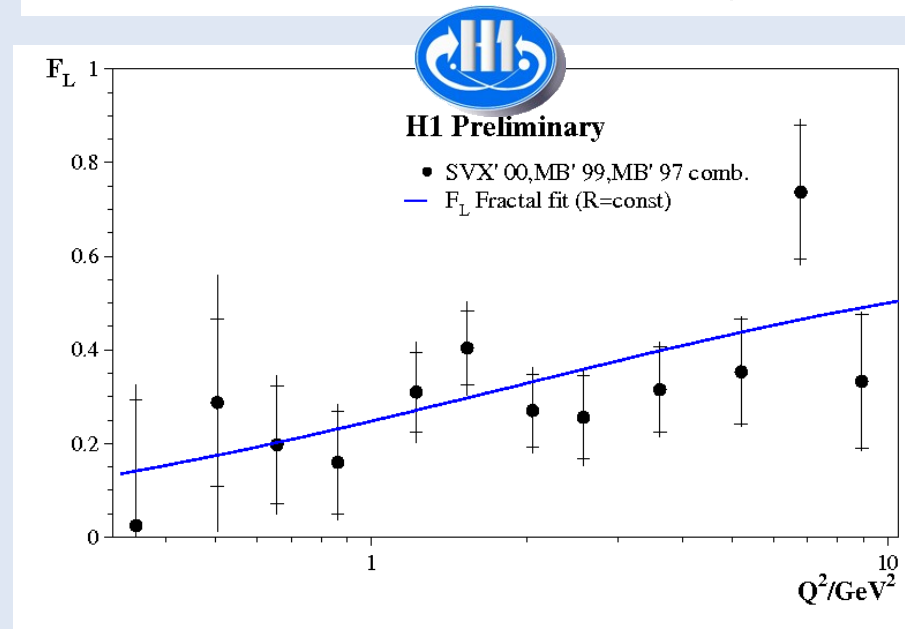
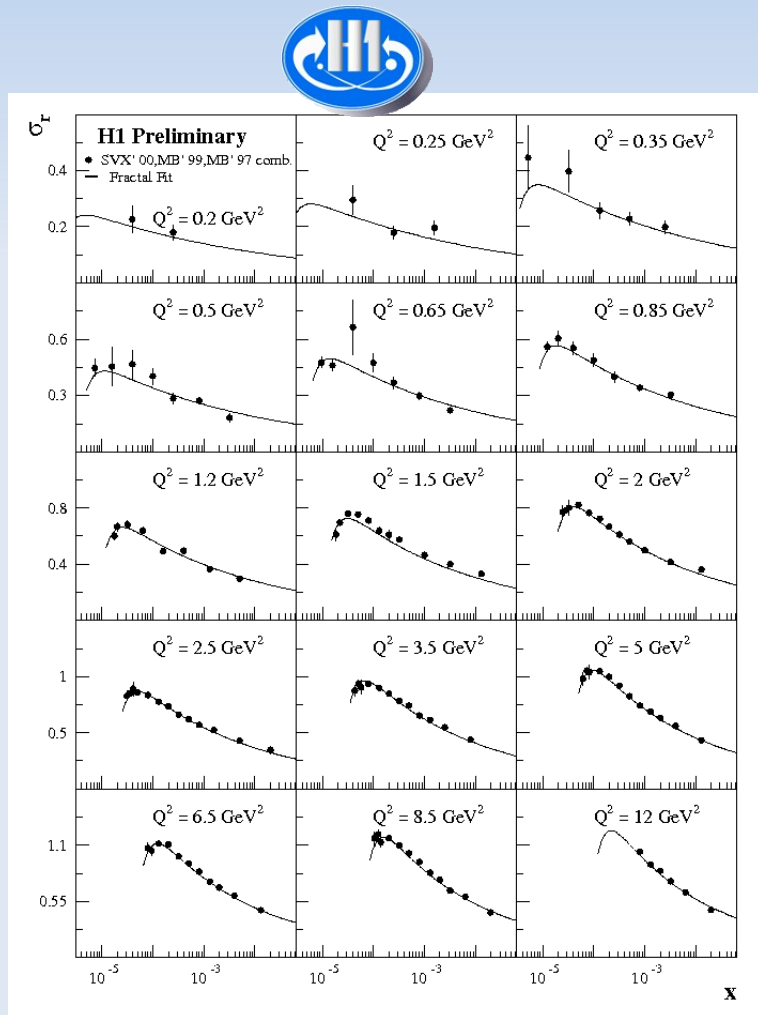
- At **Low energies** detector imperfections (cracks) and inefficiencies begin to take hold. Signal also becomes easier to fake.  
 $\Rightarrow$  Require Dedicated *High  $y$  Analysis!*

# Recent Results

- ◆ High  $y$  Cross Section Measurements : **Photoproduction-DIS Transition**
- **Low  $Q^2$  [0.2 to 12 GeV<sup>2</sup>]** Cross Sections measured using  $e^+p$  HERA I Data [SVX`00, MB`99, MB`97] and then combined

- Outside pQCD validity  
 ⇒ **Phenomenological Models**
- Cross Sections fitted to a **Model** where  $F_L$  is a fit parameter.

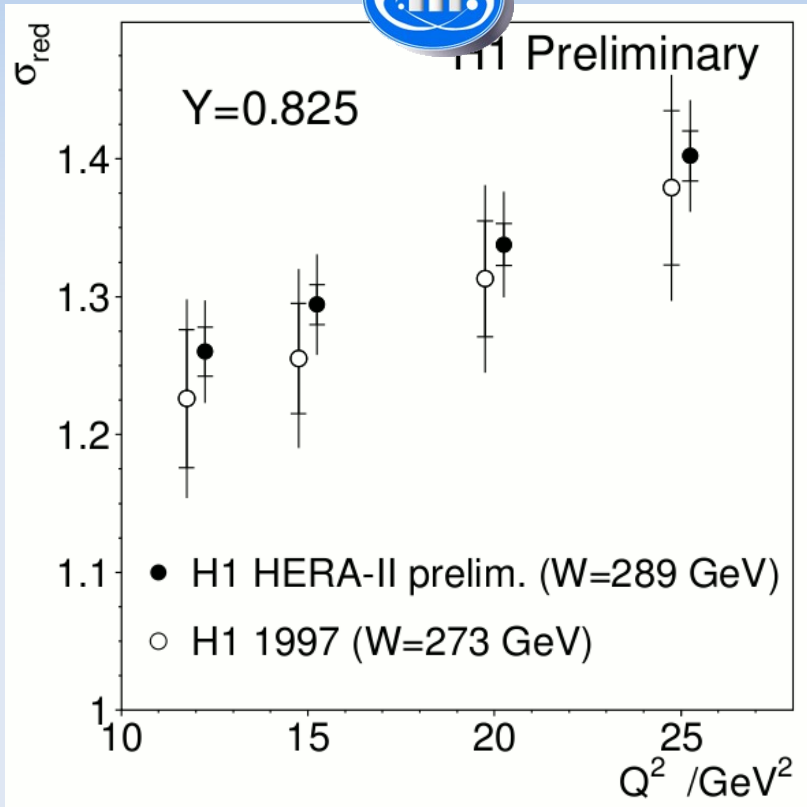
$$\sigma_r(x, Q^2) = c(Q^2)x^{-\lambda(Q^2)} - \frac{y^2}{Y_+} F_L(Q^2)$$



# Recent Results

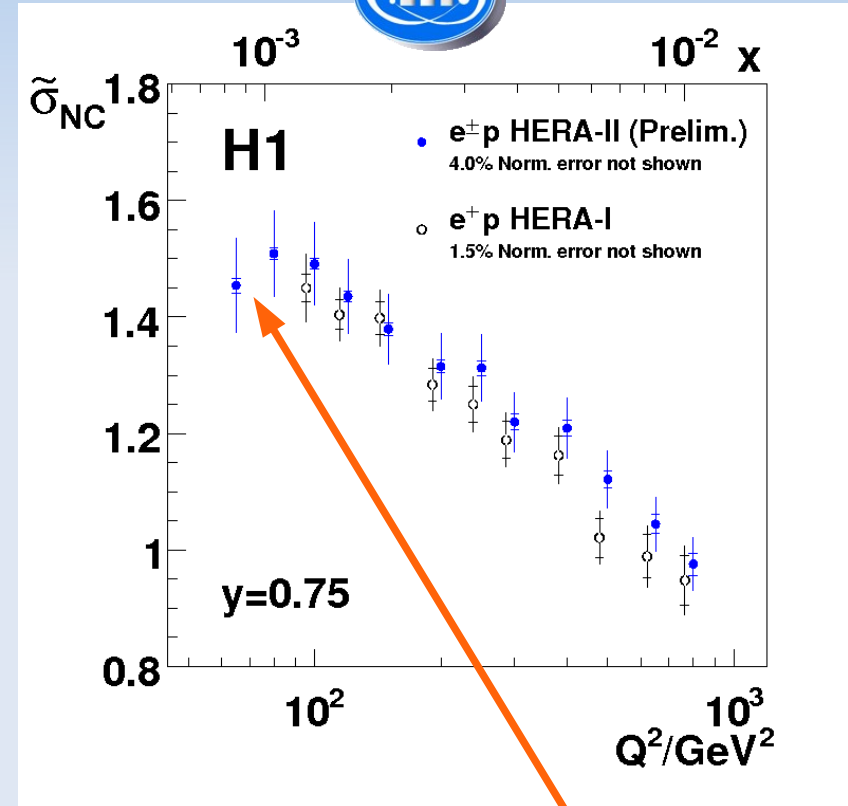
## High $y$ Cross Section Measurements : $Q^2 > 10 \text{ GeV}^2$

96 pb<sup>-1</sup> of  $e^\pm p$



- Factor 2 better error

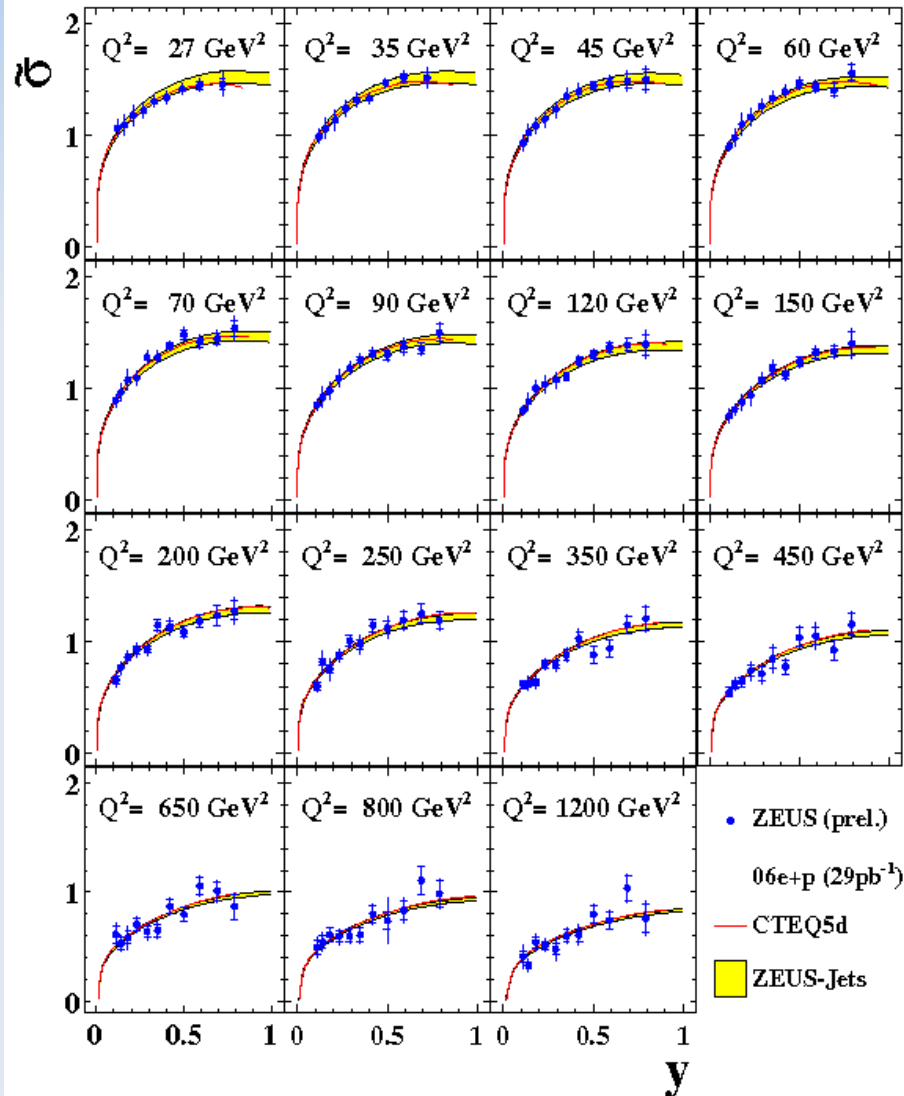
All HERA II 315 pb<sup>-1</sup> of  $e^\pm p$



- New measurements at lower  $Q^2$
- Errors systematically dominated but should improve.

# Recent Results

## ◆ High $y$ Cross Section Measurements : $Q^2 > 25 \text{ GeV}^2$



- Extension of phase space to high  $y$  at low  $Q^2$ .
- Data well described by QCD Prediction

**Next: Extract FL from the High  $y$  Cross Sections using F2 prediction from QCD Fits.**

*Low energy data ( $E_p=460,575\text{GeV}$ ) of approx  $20 \text{ pb}^{-1}$  are being analysed to **measure**  $F_L$  directly.*

# Recent Results

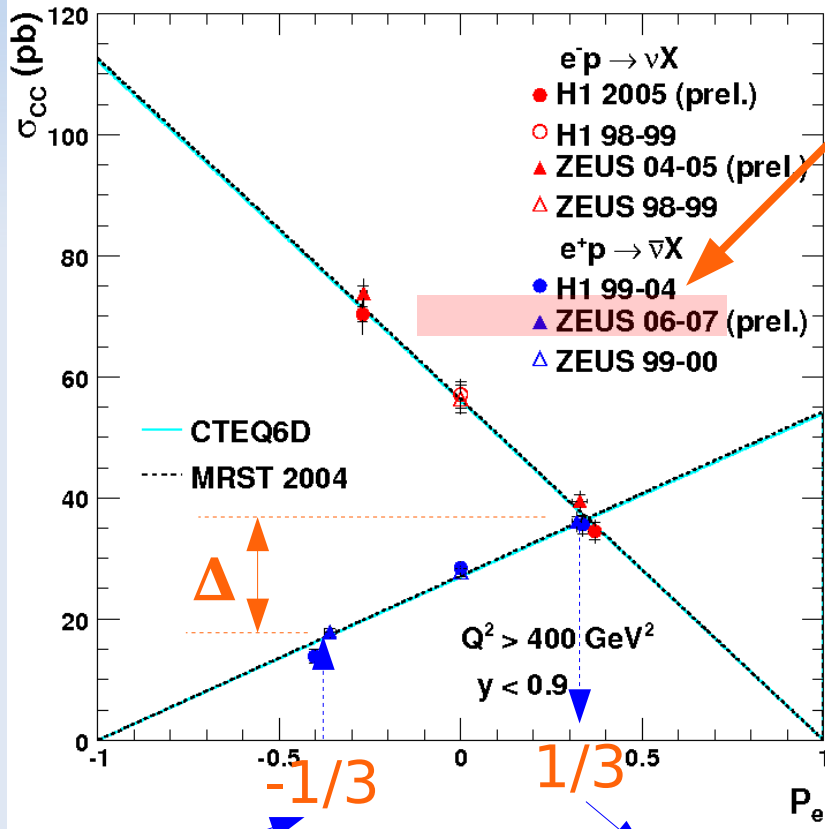
## ◆ Parity Violation



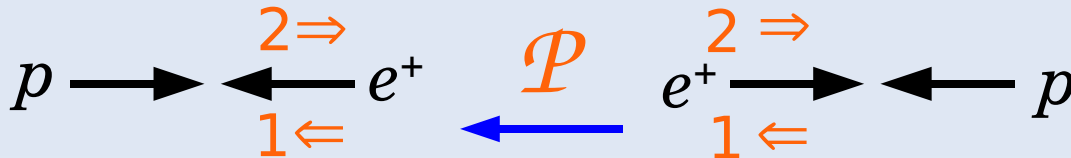
$$\sigma_{CC}^{\pm}(P_e)$$



ZEUS's 0607 Prel. (138pb<sup>-1</sup> ep)

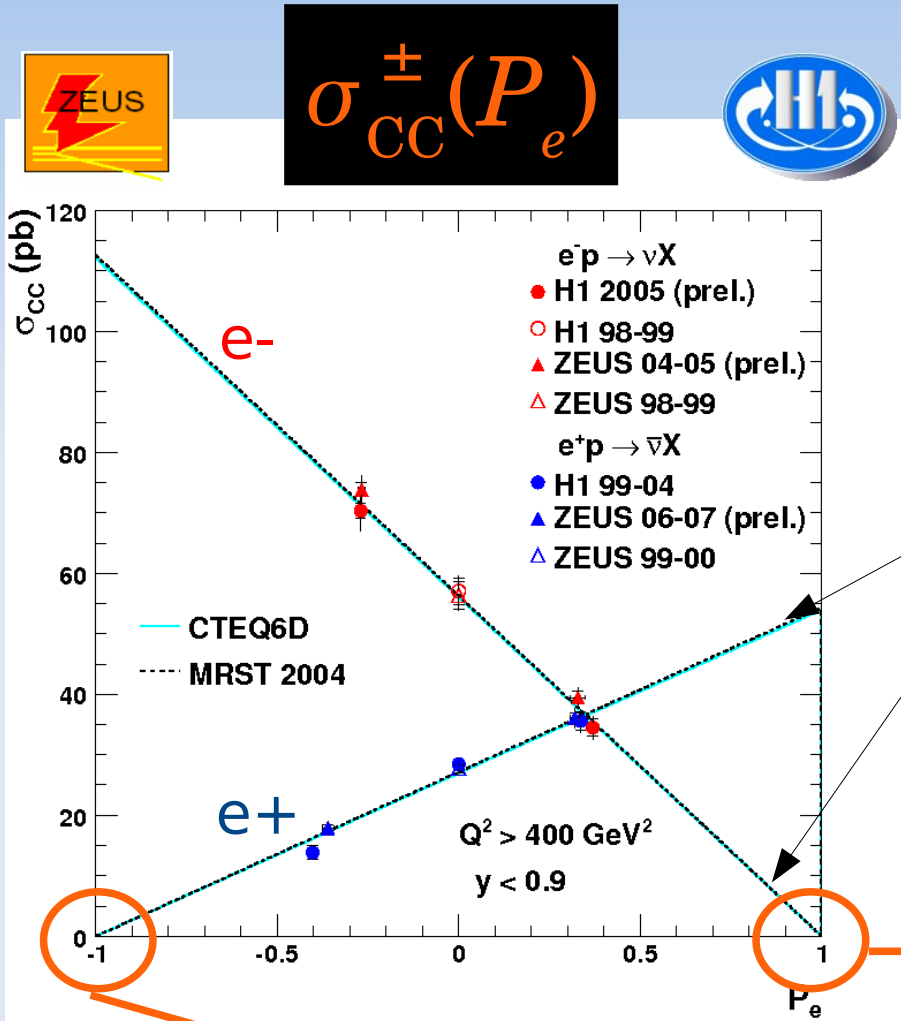


$\Delta \neq 0 \Rightarrow$  PARITY VIOLATION  
*which is the case!*



# Recent Results

## ◆ Parity Violation



Matter of Fact , From SM:

$$\sigma_{CC}^{\pm}(P_e) = (1 \pm P_e) \underbrace{\sigma_{CC}^{\pm}(0)}_{\text{HERAI}}$$

SM Expectation based on CTEQ6D and MRST2004 Parameterisations.

Data agrees with SM prediction supporting that  $W$ 's do not couple to

*right-handed*  $e^-$  (particle) and

*left-handed*  $e^+$  (anti-particle)



# Summary & Outlook

- H1 and ZEUS are well on the way to combining their Inclusive Cross Sections for all of HERA Data ( $1 \text{ fb}^{-1}$ ) to provide the most accurate knowledge we have of Proton Structure.
- High  $y$  Cross Sections have been measured using HERA II data by both experiments in new regions of phase space. This will help to provide precise knowledge of  $F_L$  and Gluon densities and thus predict various Cross Sections at the LHC.

Thanks

(in memory of Prof. Beate Naroska)