Measurement of neutral current (e^+p) cross sections at high-x using HERA-II data

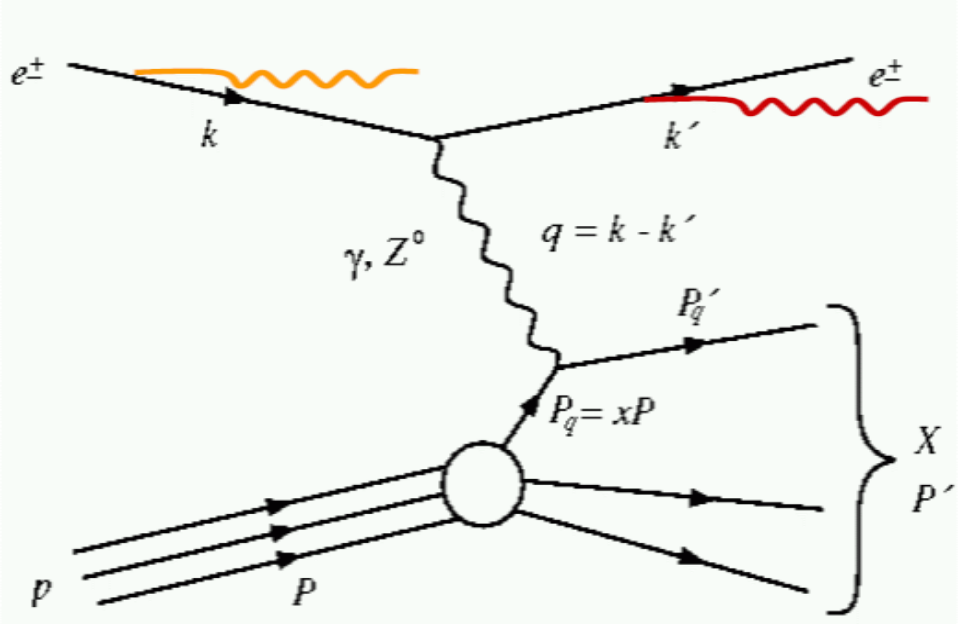
DIS 2011, Newport News, VA USA

Inderpal Singh
Panjab Univ./ MPI, Munich

On behalf of ZEUS collaboration

MAX-PLANCK-GESELLSCHAFT

NC Deep inelastic scattering at HERA



DIS cross-section can be described by :-

Q^2 : Four momentum transfer (probing power)

x : Bjorken Scaling variable (momentum fraction of struck quark)

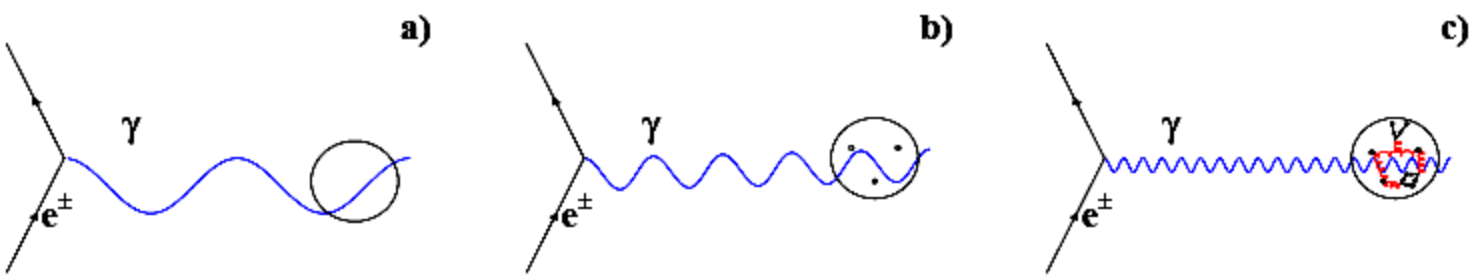
y : inelasticity

$Q^2 = -q^2 = -(k - k')^2$, $\quad x = \dfrac{Q^2}{2p.q}$

$y = q.k/p.k$ $\quad Q^2 = sxy$

s = center of mass energy square

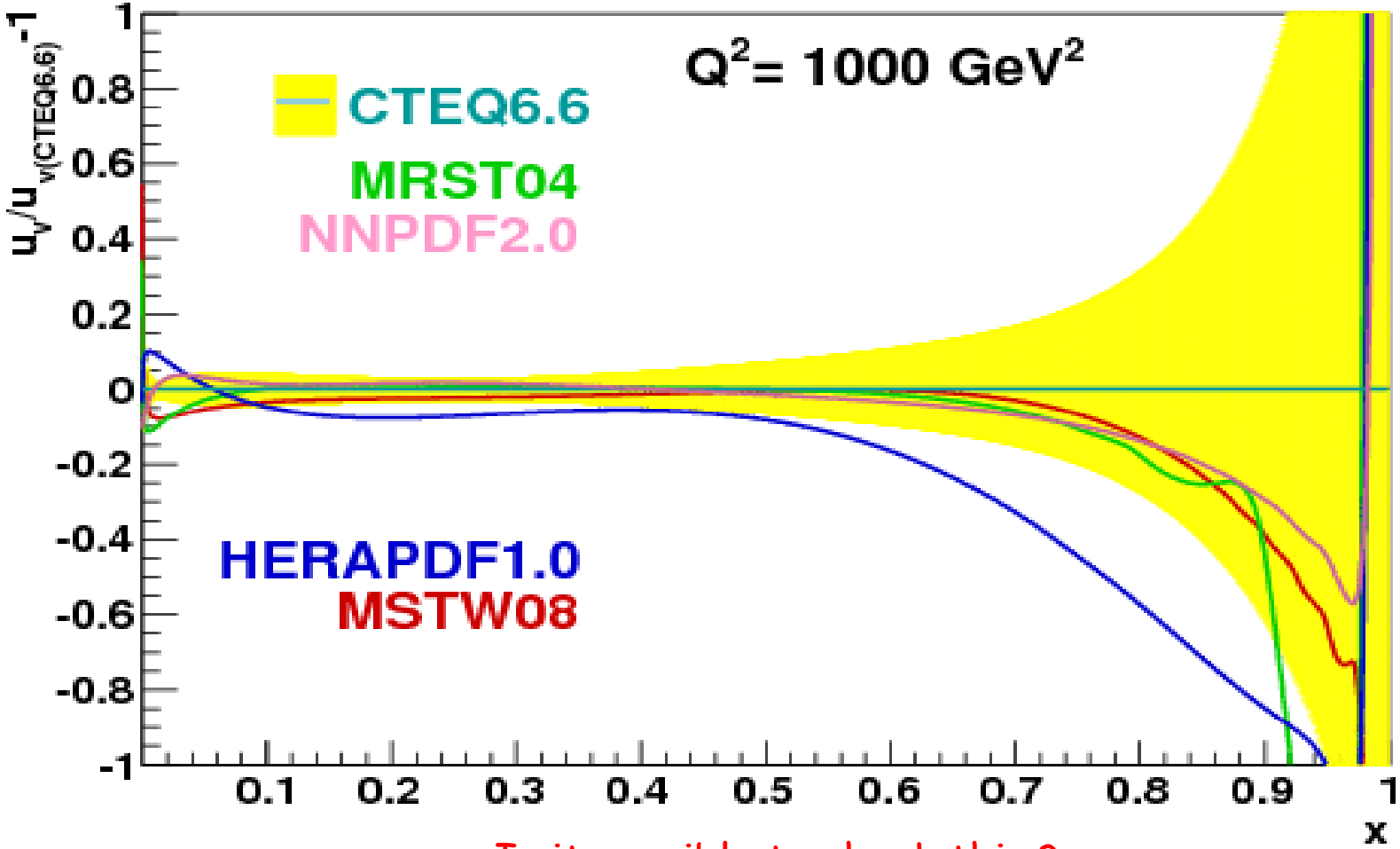
$$\Delta p.\Delta x \approx \hbar \Leftrightarrow \sqrt{Q^2} \approx \frac{\hbar}{\lambda}$$



Motivation

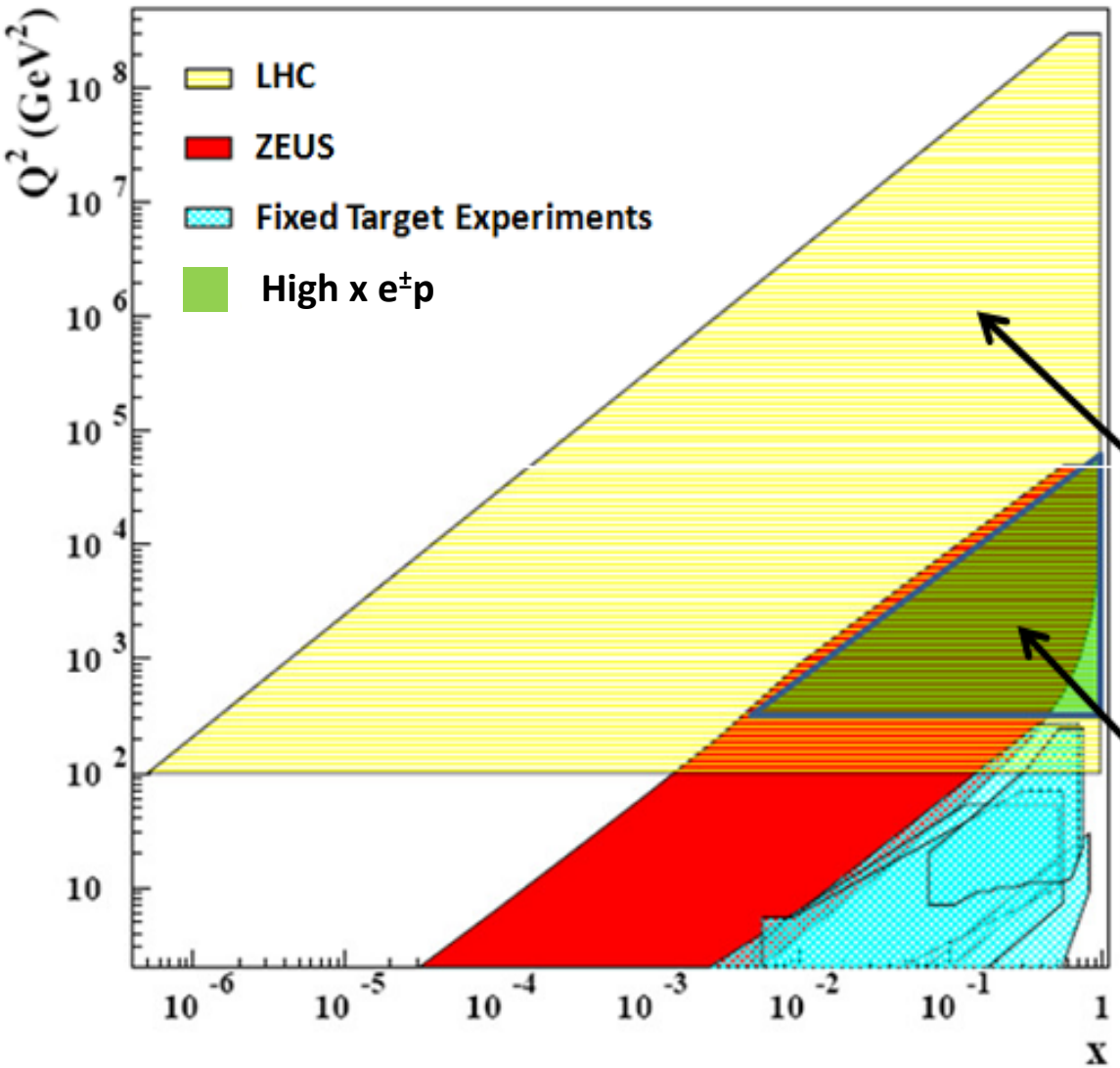
The proton PDF's are poorly determined at high-x.

Relative difference of different valance u quark pdf's



Is it possible to check this ?

HERA and LHC



Large x is relevant to understand Physics at LHC

DGLAP evolution sensitive to values of x upto 1

Measurements from HERA upto x =1

NC cross sections and structure functions

At Born level (Lowest order in QED)

$$\frac{d^2\sigma_{NC}(e^{\pm}p)}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4}\left[Y_+ F_2^{NC}(x,Q^2) \mp Y_- xF_3^{NC}(x,Q^2) - y^2 F_L^{NC}(x,Q^2)\right]$$

Longitudinal structure function

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

$$\tilde{\sigma}_{NC}(e^{\pm}p) = \frac{xQ^4}{2\pi\alpha^2}\frac{1}{Y_+}\frac{d^2\sigma_{NC}(e^{\pm}p)}{dxdQ^2} = [F_2^{NC}(x,Q^2) \mp \frac{Y_-}{Y_+} xF_3^{NC}(x,Q^2) - \frac{y^2}{Y_+} F_L^{NC}(x,Q^2)]$$

Reduced cross section

$$F_2(x,Q^2) = x\sum_f A_f(Q^2)(q_f(x,Q^2) + \bar{q}_f(x,Q^2))$$

$\propto$ includes cross-section of both longitudinal and transversely polarized exchanged boson

$$xF_3(x,Q^2) = x\sum_f B_f(Q^2)(q_f(x,Q^2) - \bar{q}_f(x,Q^2))$$

$\propto$ contains parity violating part of cross-section which is negligible at low Q^2

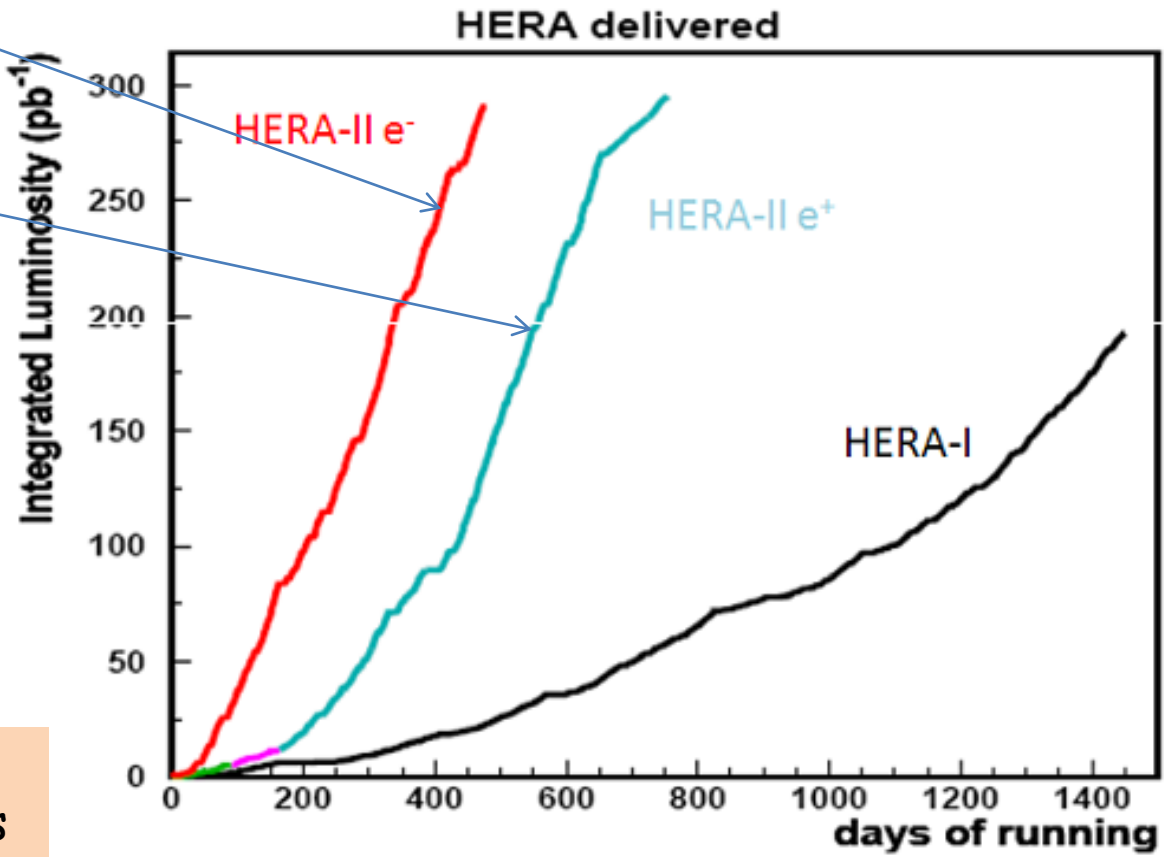
Parton density function(PDF)

probability density of finding parton q or $\bar{q}$ carrying the momentum fraction x at given Q^2

HERA luminosity

ZEUS Prel. 2010

ZEUS Prel. 2011



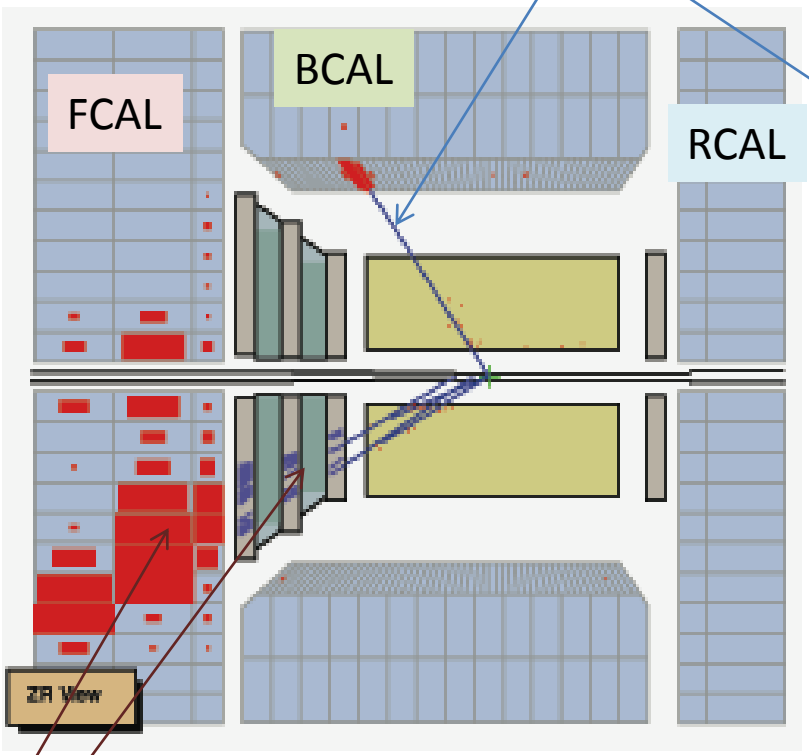
HERA-I : 1992-2000
HERA-II :2001-2007

In HERA-II the luminosity collected was at least 3 times of HERA-I

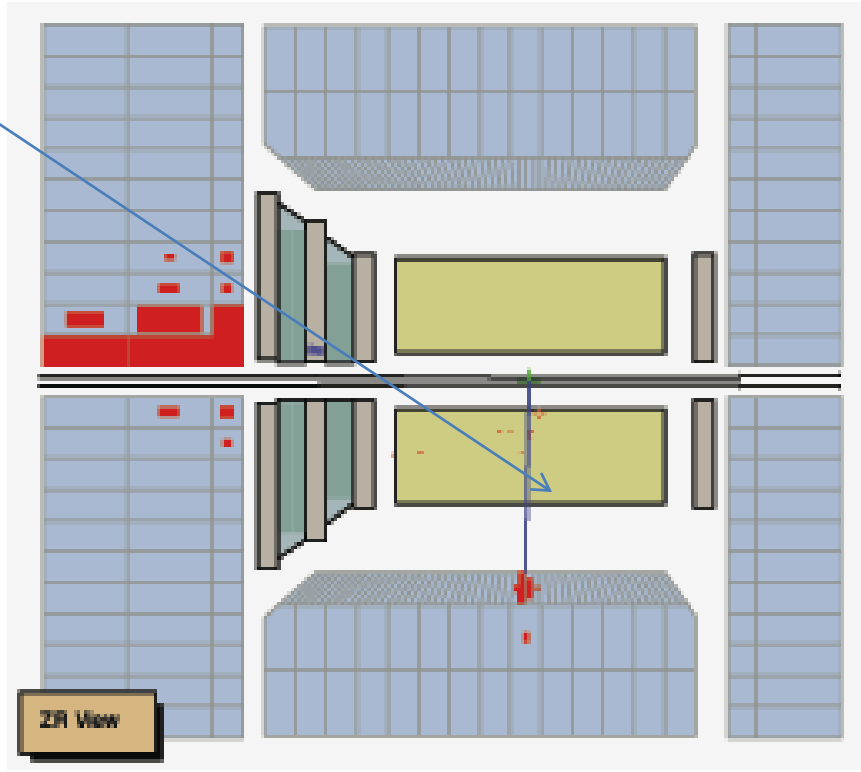
Event topology at high-x

Good Jet

Electron



Θ_{jet}<0.11, No jet found

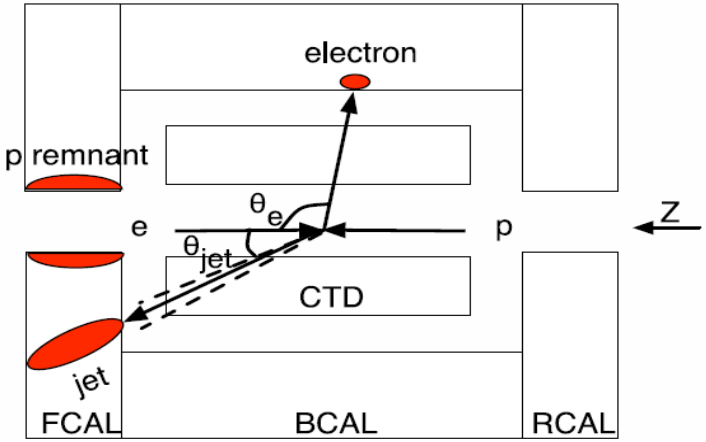


Jet defination: E_T > 10. GeV , θ_{jet}>0.11

No jet information: x > x_{edge}

x : reconstructed from jet information, x<x_{edge}

Q^2 and x reconstruction



Electron + jets information used

Electron is well reconstructed for the Q^2 range of this analysis

Define Q^2 bins from E_e and θ_e:

$$Q^2 = 2E_e E_e^{'}(1+\cos\theta_e)$$

In each Q^2 bin, define x bins:

If jets are not close to the beam pipe ($\theta_{jet} > 0.11$) :

- For one jet events Pt balance between jet and electron is used and $E_{T,jet}$ is replaced by Pt_{el}

$$x = \frac{E_{T,jet}/\sin\theta_{jet}(1+\cos\theta_{jet})}{2E_p\left(1-\frac{E_{T,jet}/\sin\theta_{jet}(1-\cos\theta_{jet})}{2E_e}\right)}$$

- For multijet events jet variables are calculated as:

$$E_{T,jet} = \sum_i E_{T,i}\ ,\ \theta_{jet} = 2\tan^{-1}(e^{-\eta_{jet}})\ ,\ \eta_{jet} = \frac{\sum_i E_{T,i}\eta_i}{E_{T,jet}}$$

If there is no well reconstructed jet

→ count events as zero jet

→ $x_{edge} < x < 1$ → integral of cross section

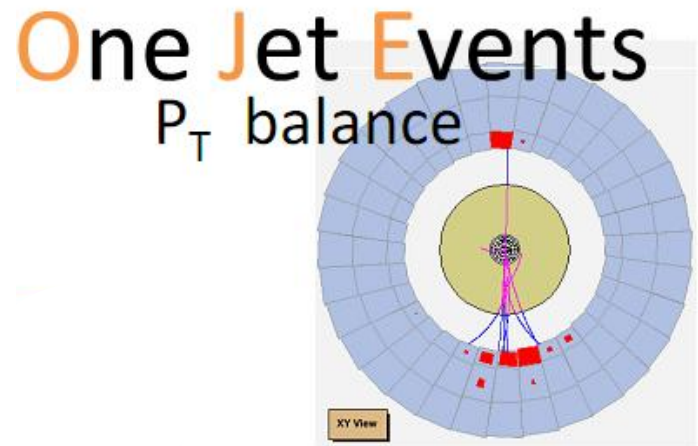
Calibration scheme

BCAL
Electron
Calibration

Measured energy compared to expected energy to find the energy scale which is better than 1%

BCAL electron calibration is key to whole detector calibration

BCAL +
FCAL
jet energy
scale



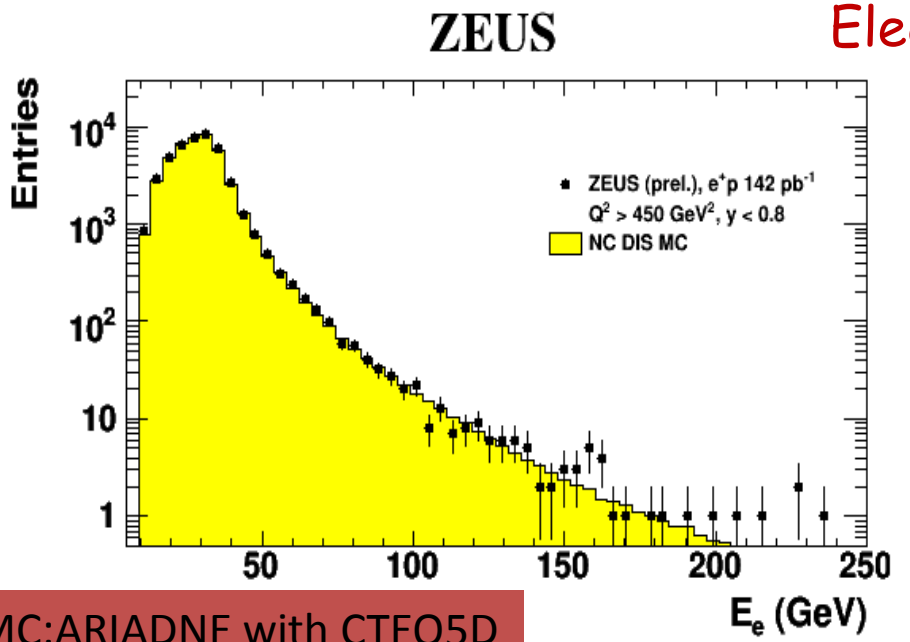
Jet energy scale depends upon BCAL electron
Jet energy scale better than 2%

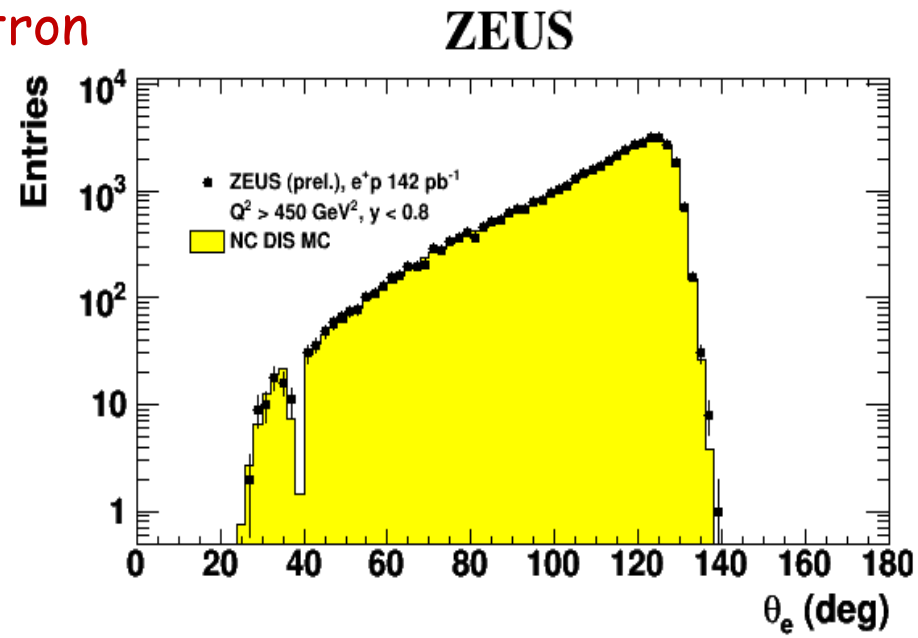
FCAL
electron
energy
scale

FCAL electron energy scale relies on jet energy scale

Event properties

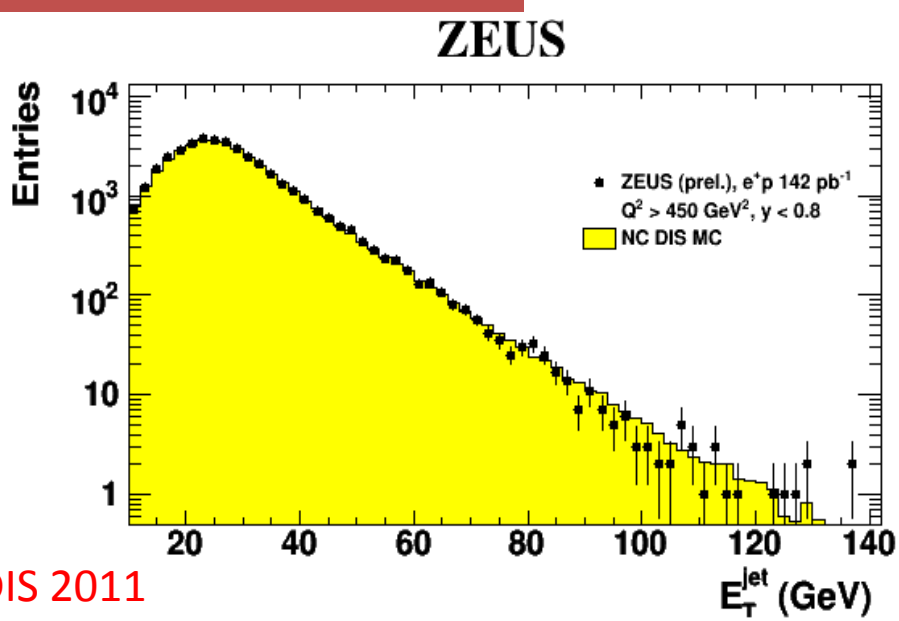
Electron

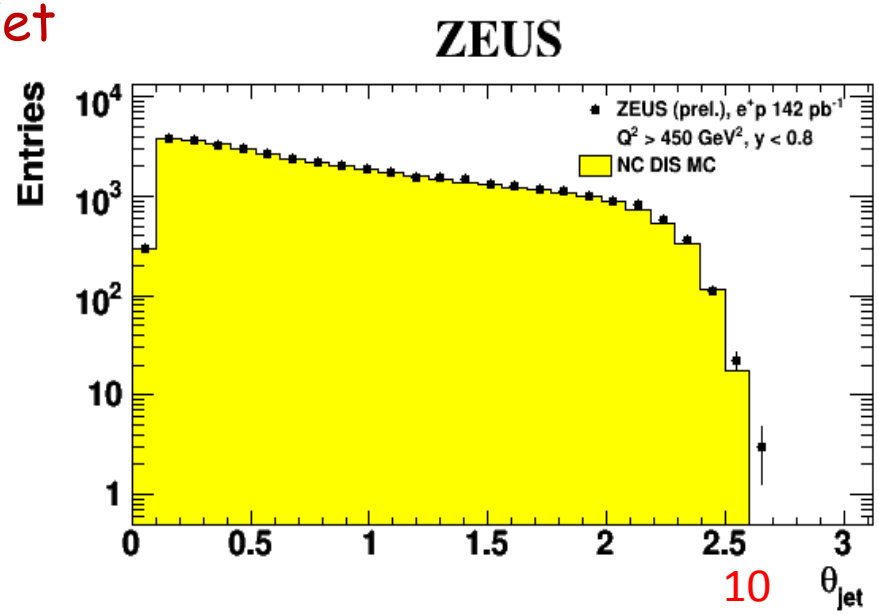




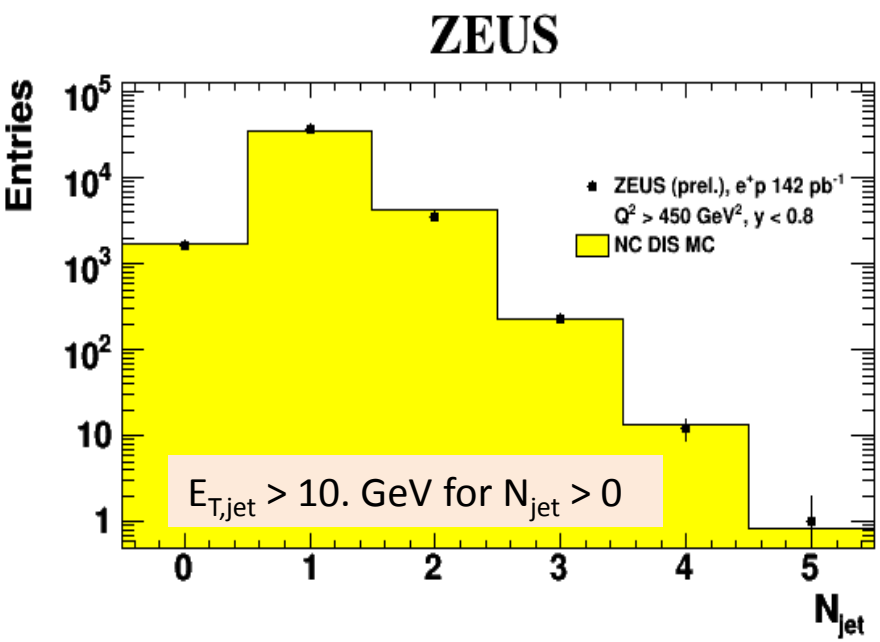
MC:ARIADNE with CTEQ5D

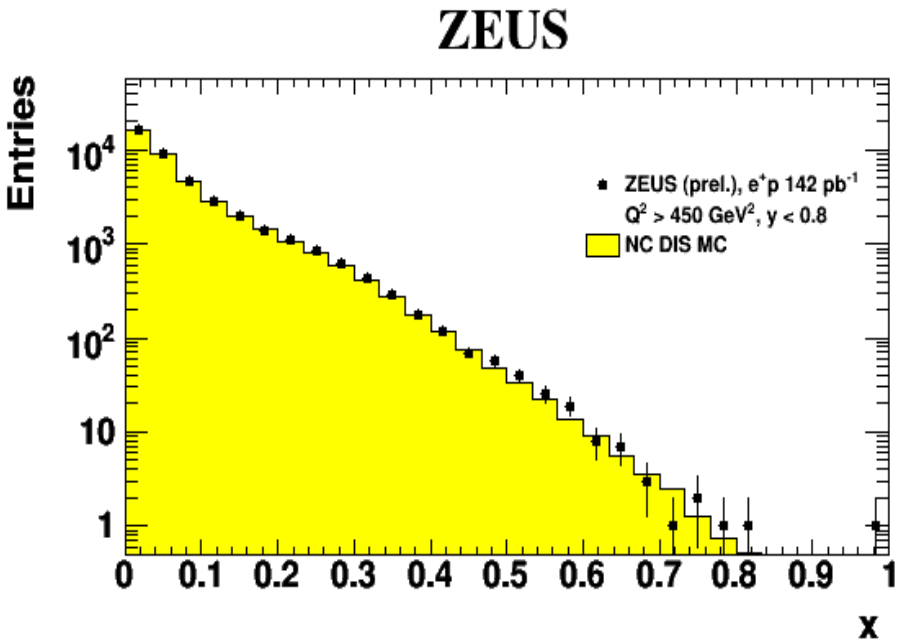
Jet

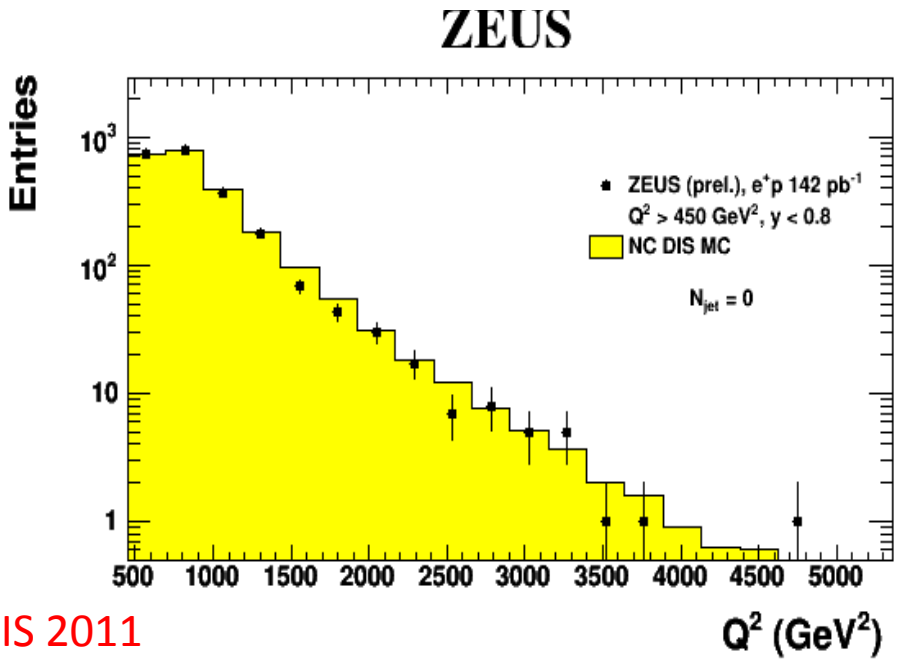


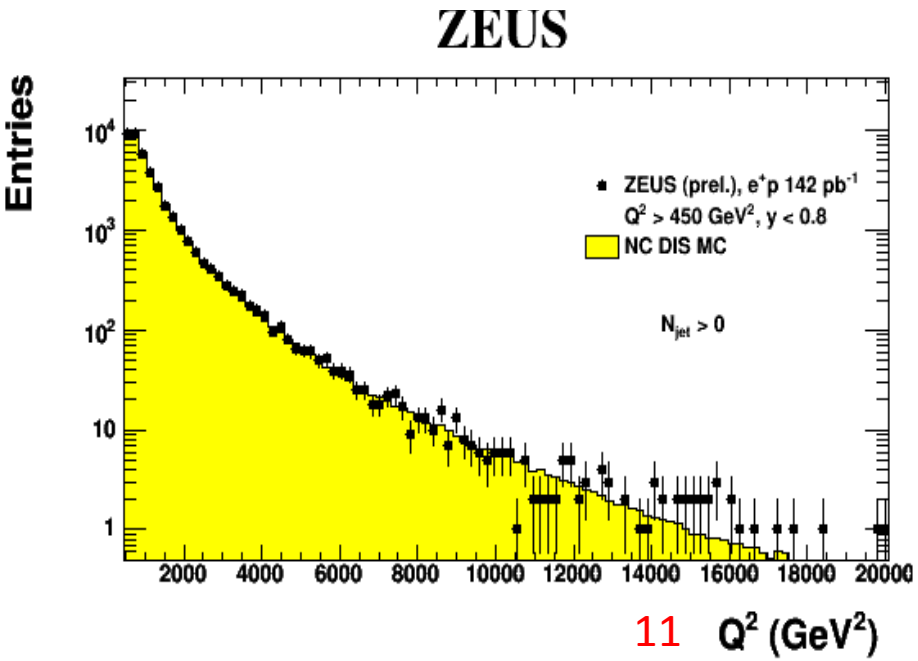


Event properties

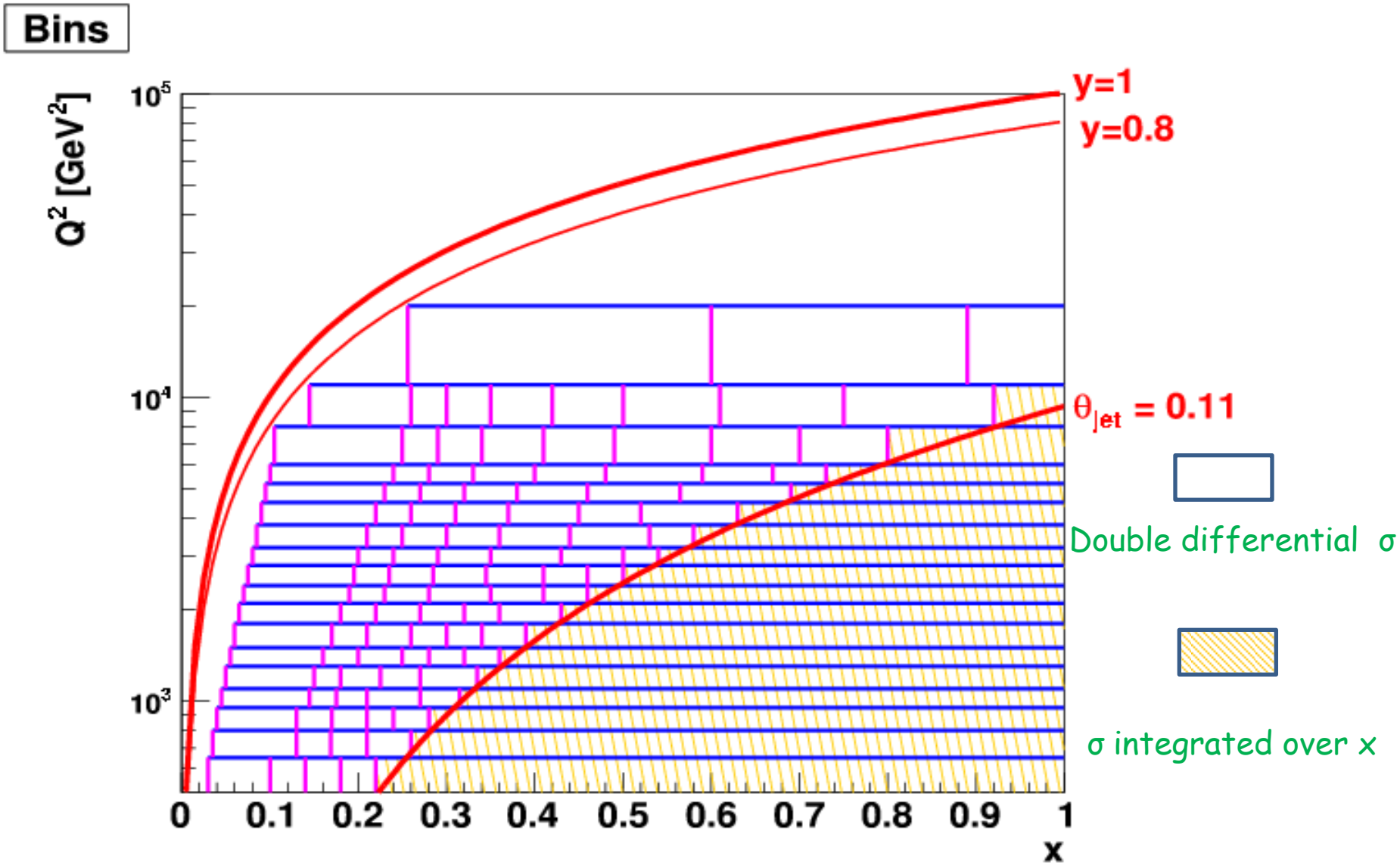




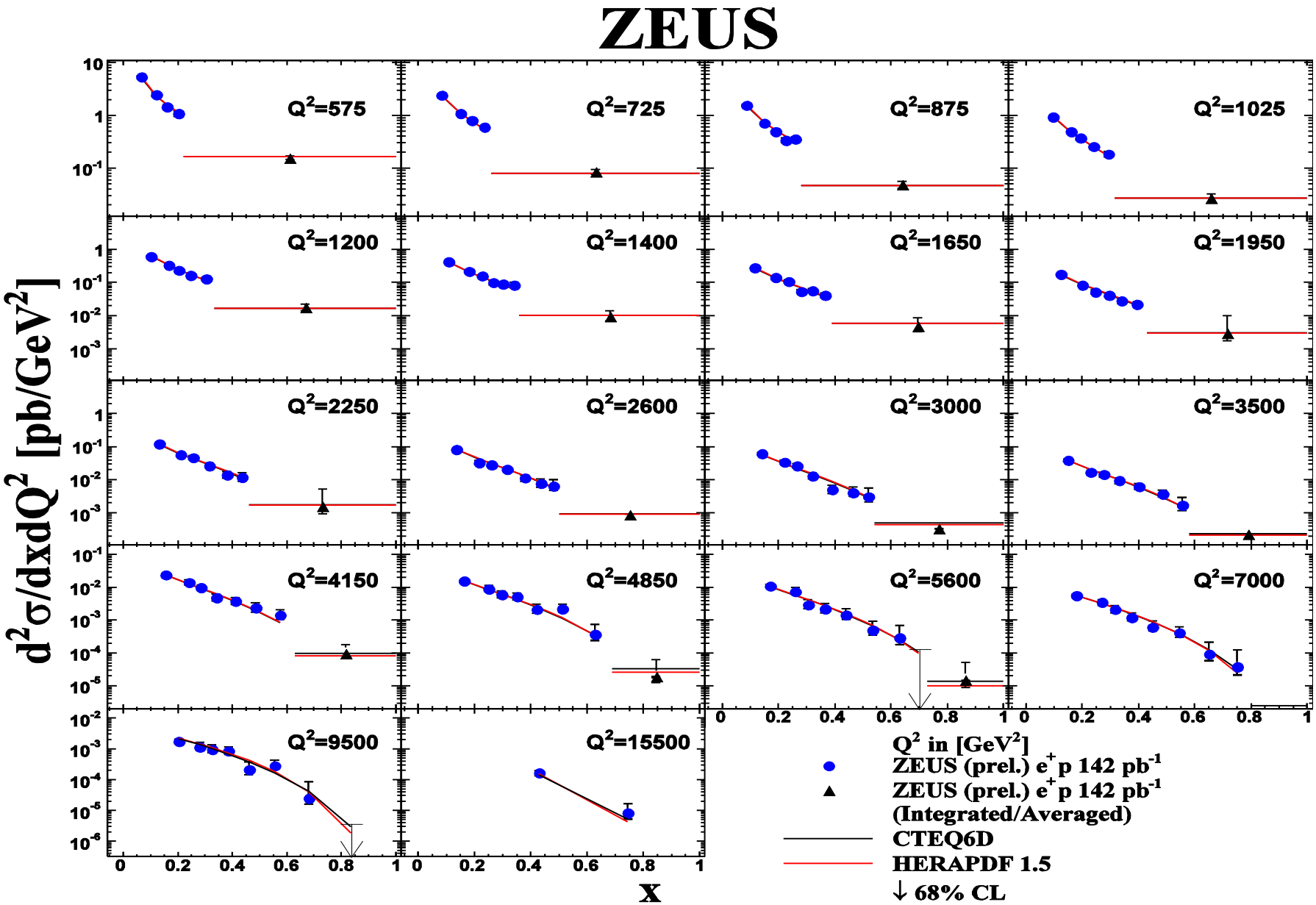




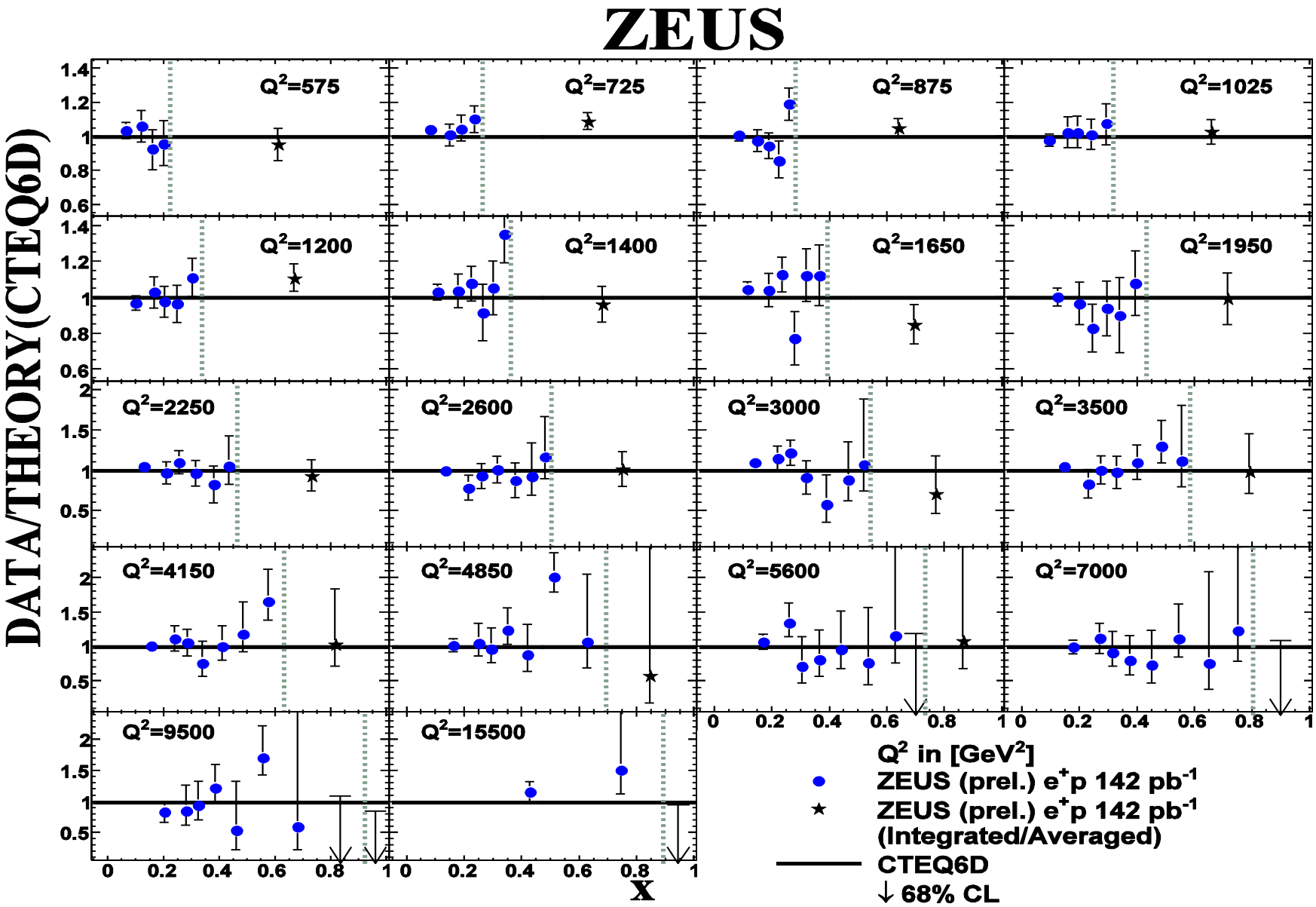
Binning


Bins
Q^2 [GeV^2]
10^5
10^4
10^3
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
x
y=1
y=0.8
θ_{jet} = 0.11
Double differential σ
σ integrated over x

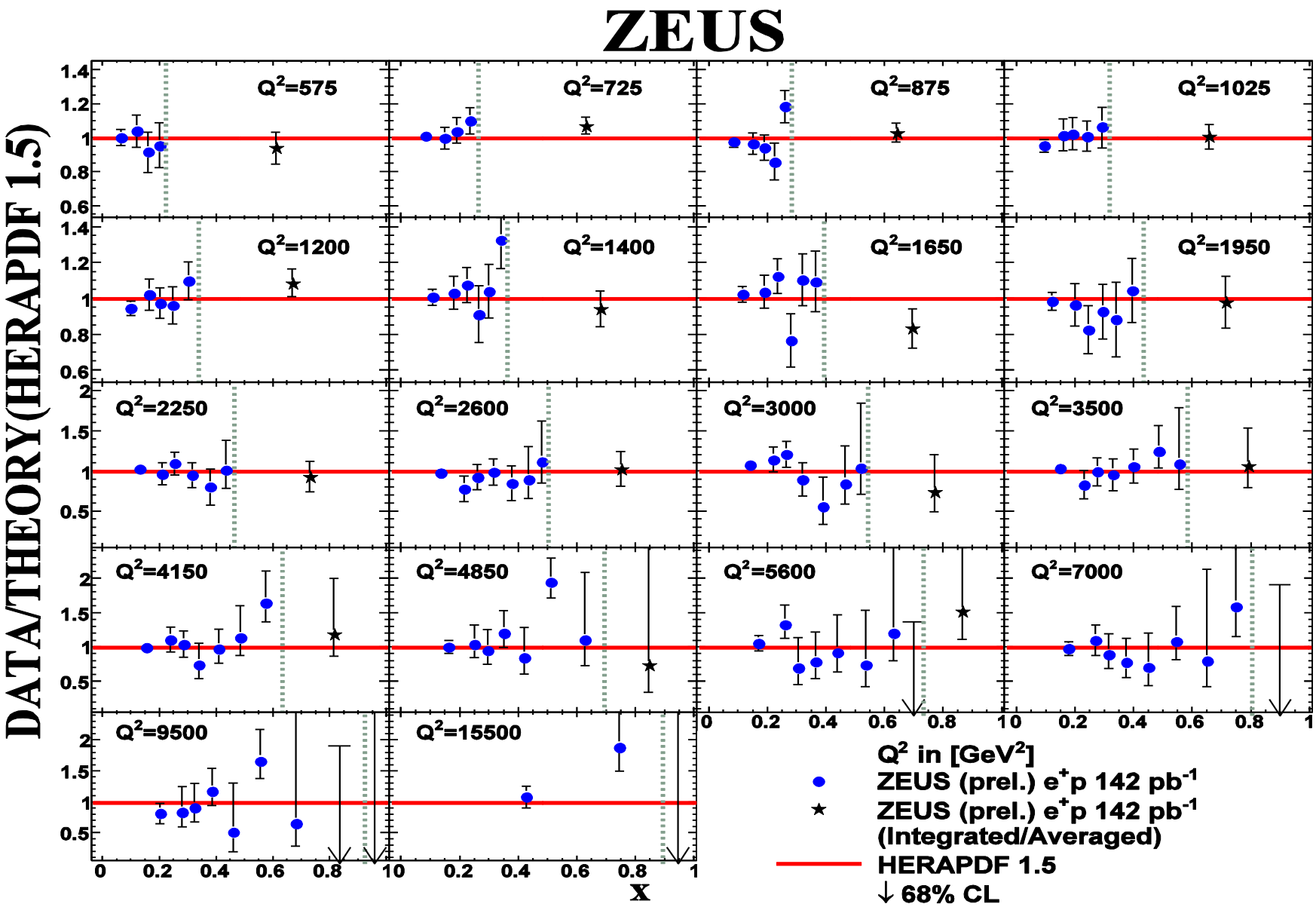
Results: NC($e^{\pm}p$) cross sections



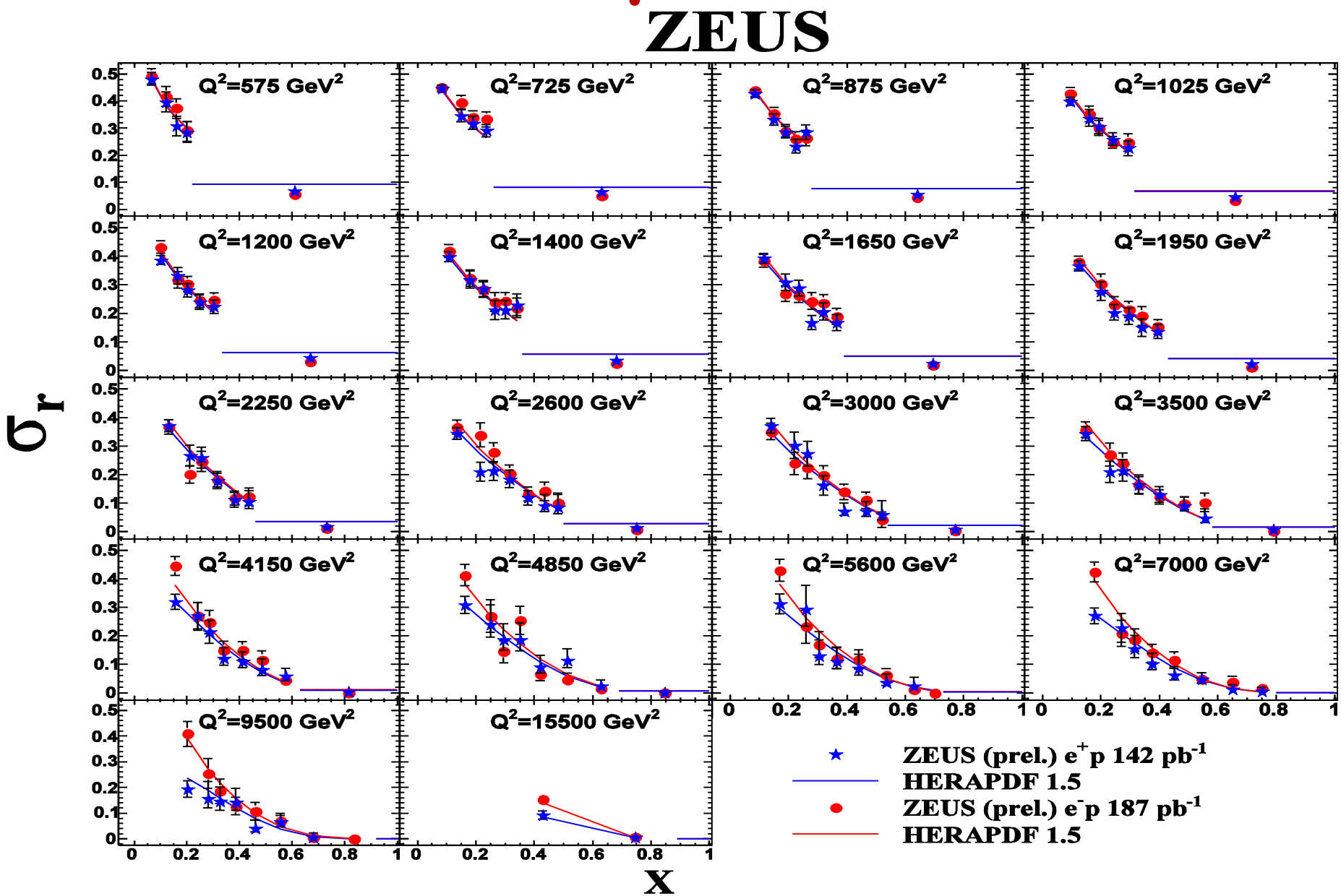
Comparison to theory: CTEQ6D



Comparison to theory: HERAPDF1.5



Comparison


ZEUS
σ_r
Q^2=575 GeV^2
Q^2=725 GeV^2
Q^2=875 GeV^2
Q^2=1025 GeV^2
Q^2=1200 GeV^2
Q^2=1400 GeV^2
Q^2=1650 GeV^2
Q^2=1950 GeV^2
Q^2=2250 GeV^2
Q^2=2600 GeV^2
Q^2=3000 GeV^2
Q^2=3500 GeV^2
Q^2=4150 GeV^2
Q^2=4850 GeV^2
Q^2=5600 GeV^2
Q^2=7000 GeV^2
Q^2=9500 GeV^2
Q^2=15500 GeV^2
ZEUS (prel.) e^+p 142 pb^{-1}
HERAPDF 1.5
ZEUS (prel.) e^-p 187 pb^{-1}
HERAPDF 1.5
x

Summary

1. Latest HERA-II e^+p data (142 pb^{-1})
2. New x-reconstruction method leading to better resolution
3. More x bins compared to HERA-I high x analysis.
4. Completes HERA-II high-x analysis, cross sections for e^-p were presented at DIS2010.

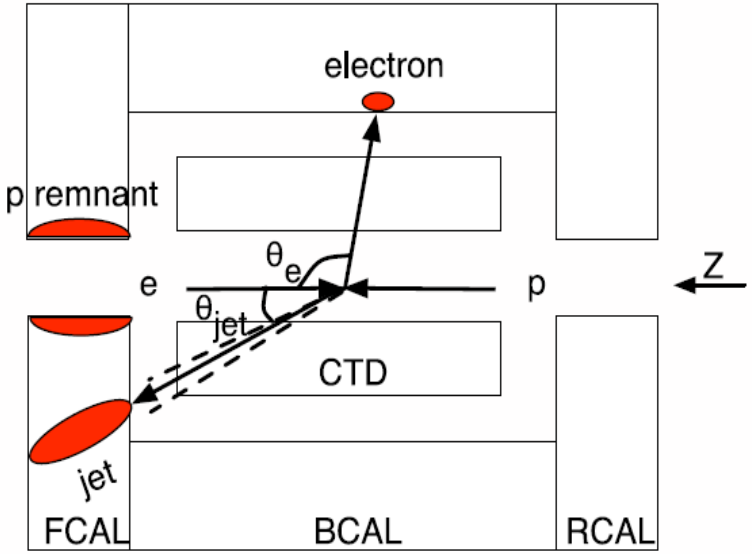
Expected outcome:

- F2 and xF3 can be calculated using e^+p & e^-p HERA-II data.
- PDF uncertainty at high x may reduce.

Thanks

Back Up

Q^2 and x reconstruction



$$Q^2 = 2E_e E_e^{'}(1+\cos\theta_e)$$

$$x = \frac{Q^2}{sy}$$

$$Q^2 = \frac{p_{T_{jet}}^2}{1-y}$$

$$y = \frac{(E-P_z)_{jet}}{2E_0}$$

$$p_{T_{el}} = p_{T_{jet}}$$

$$x = \frac{E_{jet}(1+\cos\theta_{jet})}{2E_p\left(1-\frac{E_{jet}(1-\cos\theta_{jet})}{2E_e}\right)}$$

$$x = \frac{(p_{t_e}/\sin\theta_{jet})(1+\cos\theta_{jet})}{2E_p(1-\frac{(p_{t_e}/\sin\theta_{jet})(1-\cos\theta_{jet})}{2E_e})}$$

Reconstruction of x

Best resolution achieved

Multi jet events

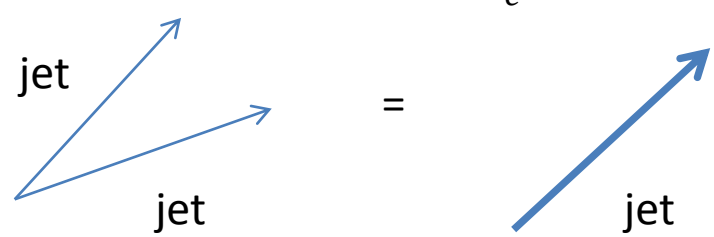
$$x = \frac{p^2{}_{t_{jets}}}{s y_{jb}(1 - y_{jb})}$$

$$p^2{}_{t_{jets}} = (\sum_i p_{x_{jet}})^2 + (\sum_i p_{y_{jet}})^2$$

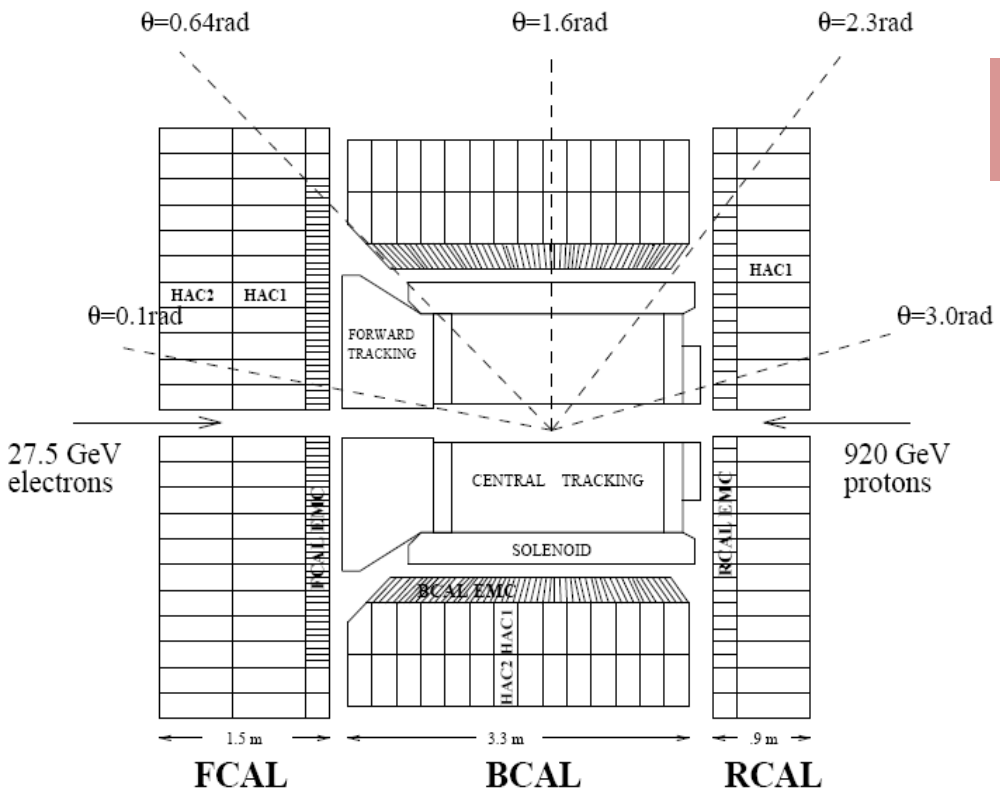
$$y_{jb} = \frac{\sum_i [E_{jet_i}(1 - \cos\theta_{jet_i})]}{2E_e}$$

One jet events

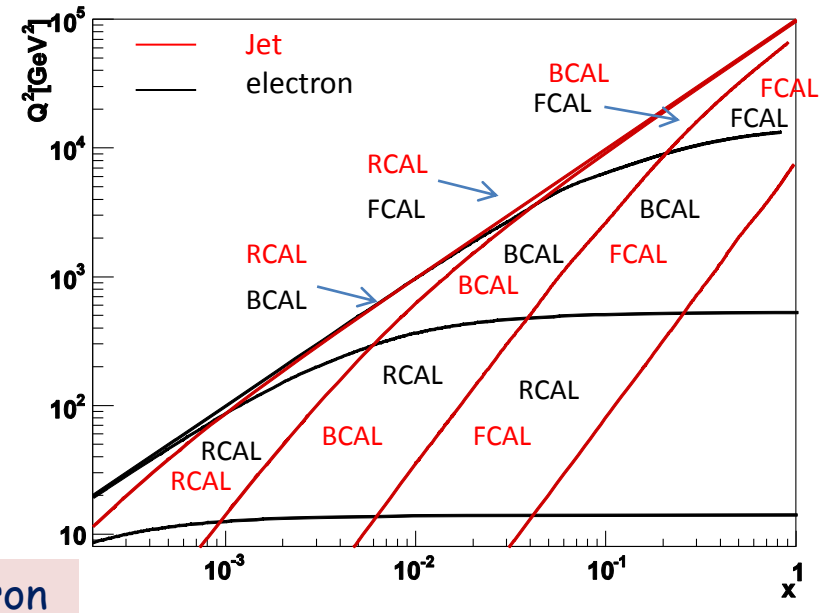
$$x = \frac{(p_{t_e} / \sin\theta_{jet})(1 + \cos\theta_{jet})}{2E_p\left(1 - \frac{(p_{t_e} / \sin\theta_{jet})(1 - \cos\theta_{jet})}{2E_e}\right)}$$



Projection of ZEUS detector on x and Q^2 plane



At high x and high Q2 events the jets and the electron can be found in BCAL and FCAL



Important to understand BCAL and FCAL electron and hadron energy scales