



ZEUS Results

E. Tassi - Calabria Univ. and INFN

DIS 2009 Workshop - Madrid



Outline

- Inclusive Measurements and Proton Structure



- ❖ HERA-I H1-ZEUS combined cross sections and HERAPDF0.2
- ❖ HERA-II Low Q^2 NC e^+p Cross sections, F_2 and F_L
- ❖ HERA-II High- Q^2 NC/CC e^-p and CC e^+p cross sections
- ❖ ZEUS 2009 Proton's PDFs
- ❖ Inclusive diffraction and dPDFs

- Exclusive processes and pQCD

- ❖ Jet production in NC DIS and α_s
- ❖ Subjets in NC DIS
- ❖ Semileptonic Charm and Beauty in DIS
- ❖ Beauty in γp
- ❖ Prompt-photon production

ZEUS Results for DIS09

Electroweak:

- | | |
|-------------------------|-------------------|
| ▪ Single Top production | Stefano Antonelli |
| ▪ Isolated Leptons | Gerhard Brandt |
| ▪ Multi-leptons | Monica Turcato |

Inclusive:

- | | |
|-----------------------------|----------------------|
| ▪ FL | Julia Grebeniuk |
| ▪ High-Q ² NC/CC | Amanda Cooper-Sarkar |
| ▪ H1/ZEUS Combination | Enrico Tassi |
| ▪ HERAPDF0.2 | Voica Radescu |

Hadronic Final States:

- | | |
|------------------------------------|-----------------|
| ▪ Jet Substructure | Elias Ron |
| ▪ K ₀ S ₀ s | David Saxon |
| ▪ Scaled momentum distributions | John Morris |
| ▪ Angular Correlations in 3-jets | Steve Magill |
| ▪ Jet Cross Sections in DIS and gp | Claire Gwenlan |
| ▪ Prompt-photon production | Matthew Forrest |

Diffraction:

- Inclusive Diffraction
- Factorization Tests
- Leading Barions
- Vector Meson Production

Marta Ruspa
Wojtek Slominski
Graziano Bruni
Aharon Levy

Heavy Flavours:

- Charm production in DIS
- Beauty Production in DIS
- J/psi helicity distributions
- Charm Fragmentation

Philipp Roloff
Silvia Miglioranza
Alessandro Bertolin
Leonid Gladilin

H1-ZEUS combined HERA I cross sections

New combination based on the
full HERA-I incl. data $L=240\text{pb}^{-1}$

Added since DIS08:

- ❖ Zeus 95-97 “low Q^2 ”
- ❖ H1 95-00 “low Q^2 ”
- ❖ H1 96-00 “Bulk”

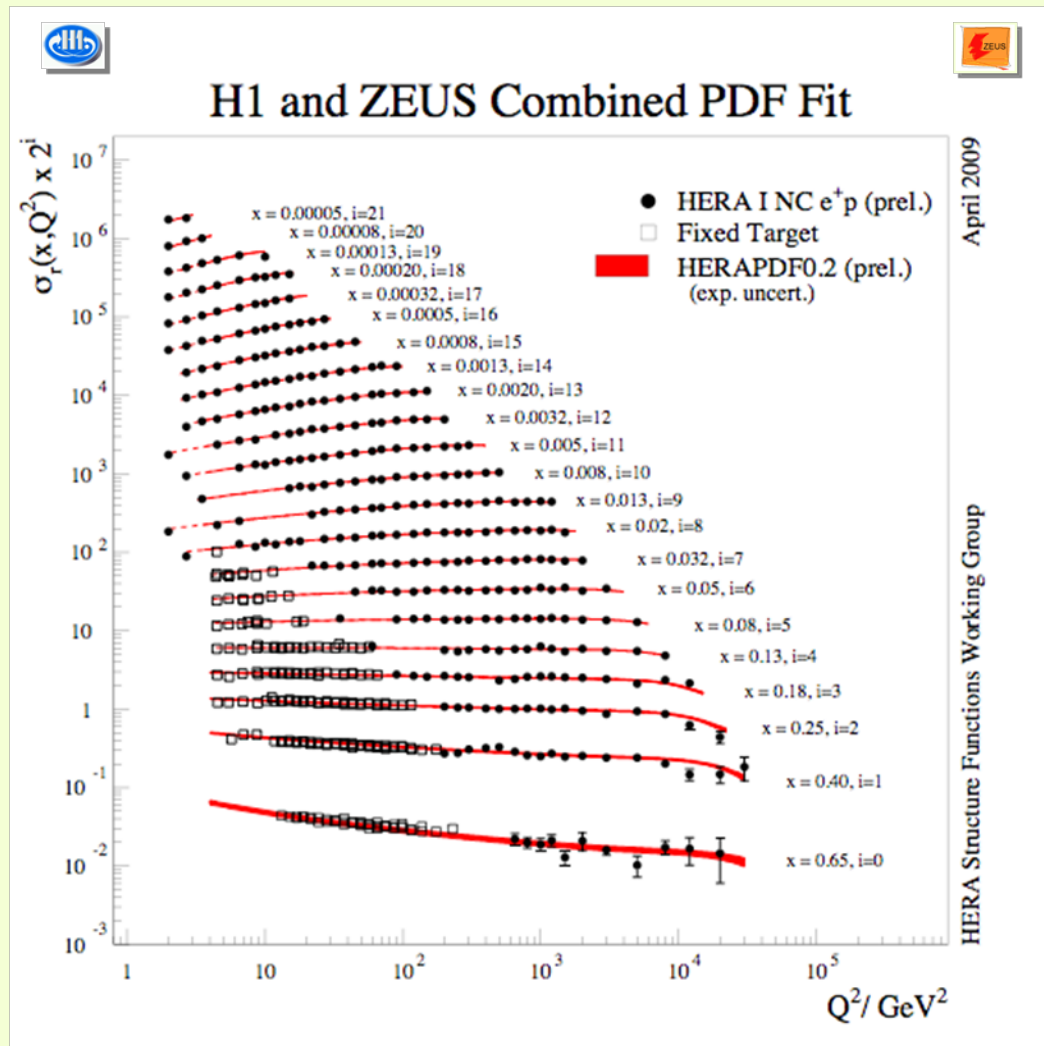
Reduced systematic uncert.
and O(1%) precision for:

$$10 < Q^2 < 100 \text{ GeV}^2$$

Used as single input to a new
QCD analysis:

⇒ **HERAPDF0.2**

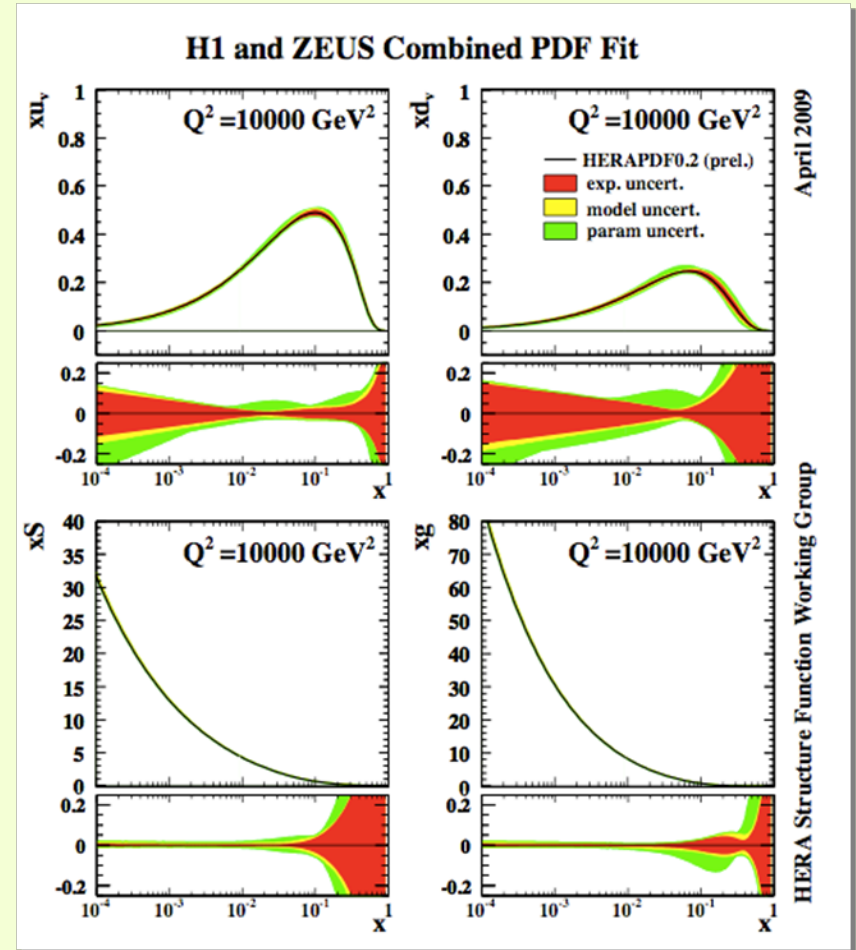
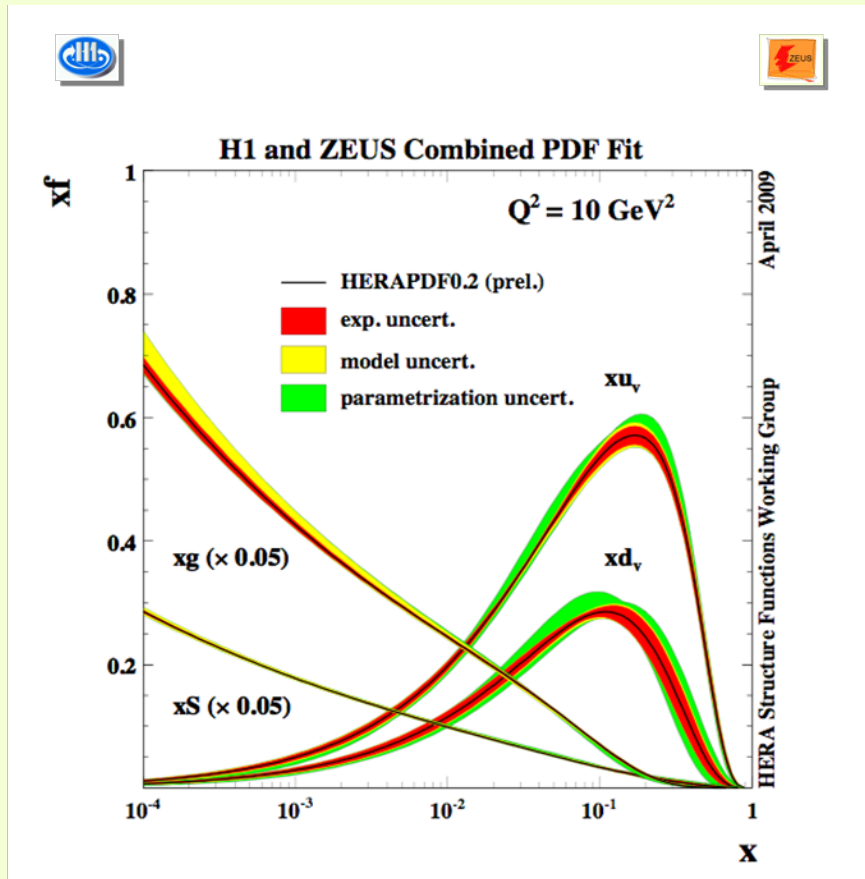
see E.T.[63]



New PDF Fit to the combined HERA-I data

HERAPDF0.2:

- ❖ Very detailed study of PDFs uncert.
- ❖ Heavy Flavours (Roberts-Thorne)



xS, xg high precision at low- x

see V. Radescu[86]

2006/07 NC e^+p at low- mid- Q^2 : “ F_L runs”

Three data sets collected with dedicated triggers at the center of mass energies:

- 318 GeV (HER) 44.5 pb⁻¹
- 251 GeV (MER) 7.1 pb⁻¹
- 225 GeV (LER) 13.9 pb⁻¹

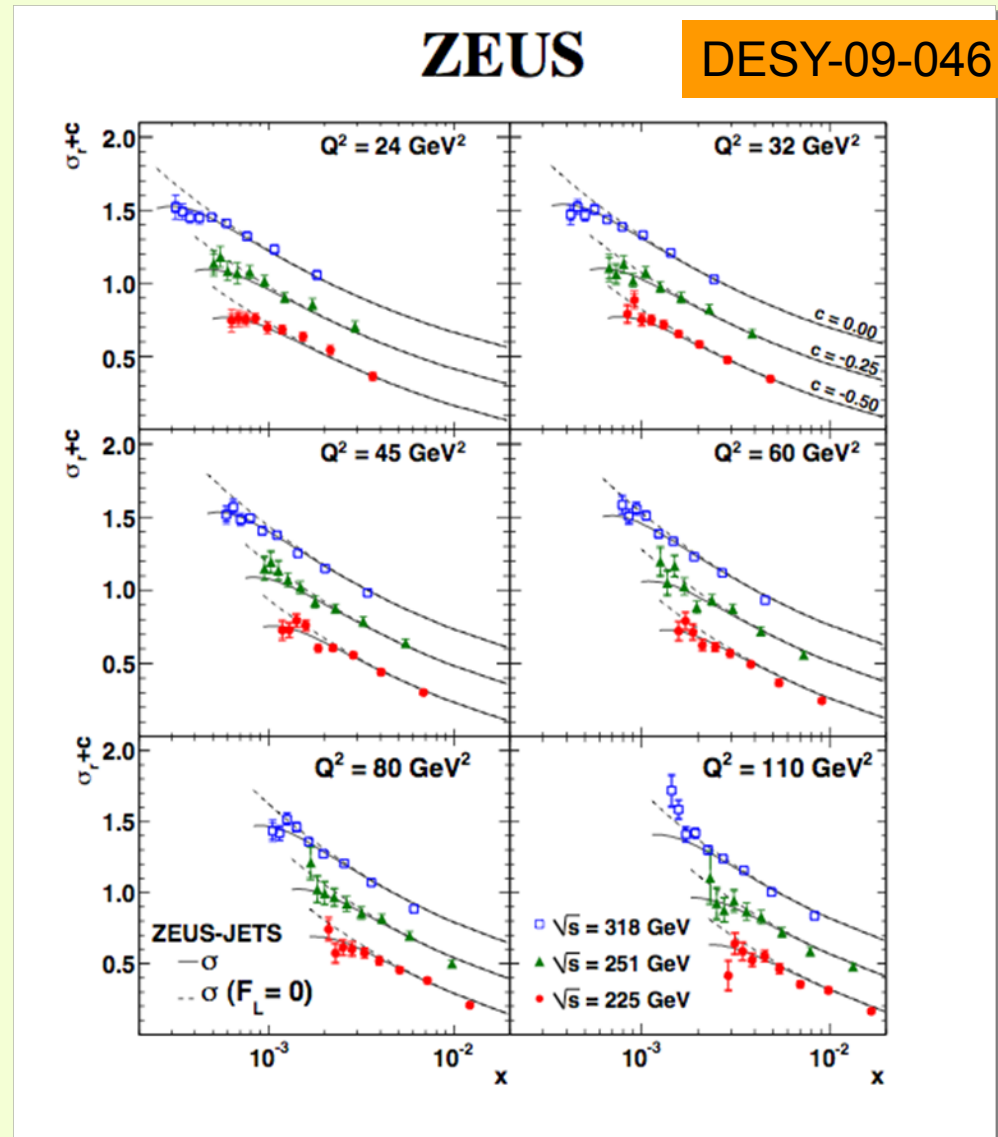
Reduced cross sections measured in the kinematic region:

$$20 < Q^2 < 130 \text{ GeV}^2$$

$$5 \times 10^{-4} < x < 0.007$$

A precise measurement and an important input to QCD analyses

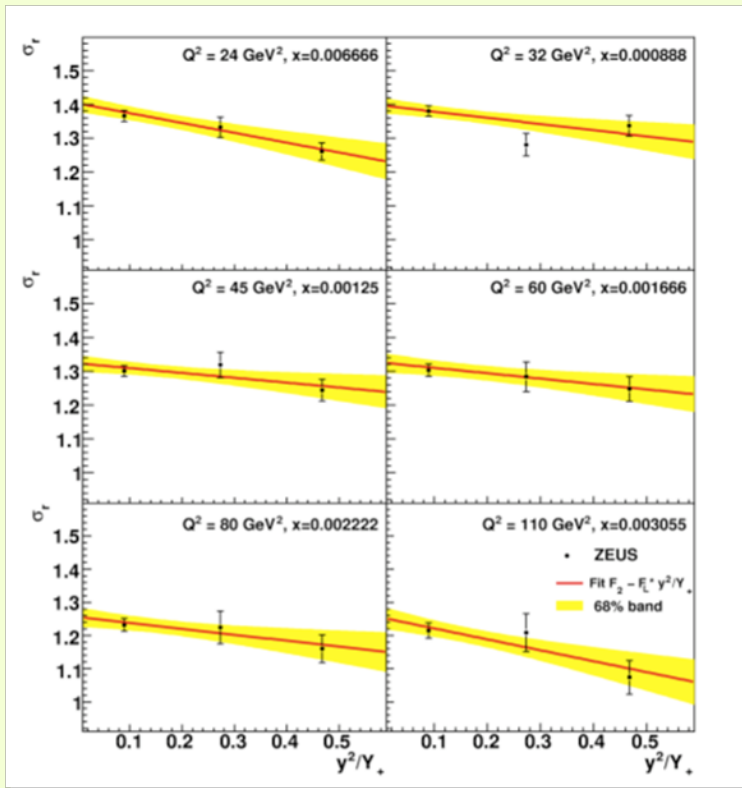
see J. Grebenyuk[44]



$$\sigma_r(x, Q^2, y) = F_2(x, Q^2) - \frac{y^2}{Y_+} \cdot F_L(x, Q^2)$$

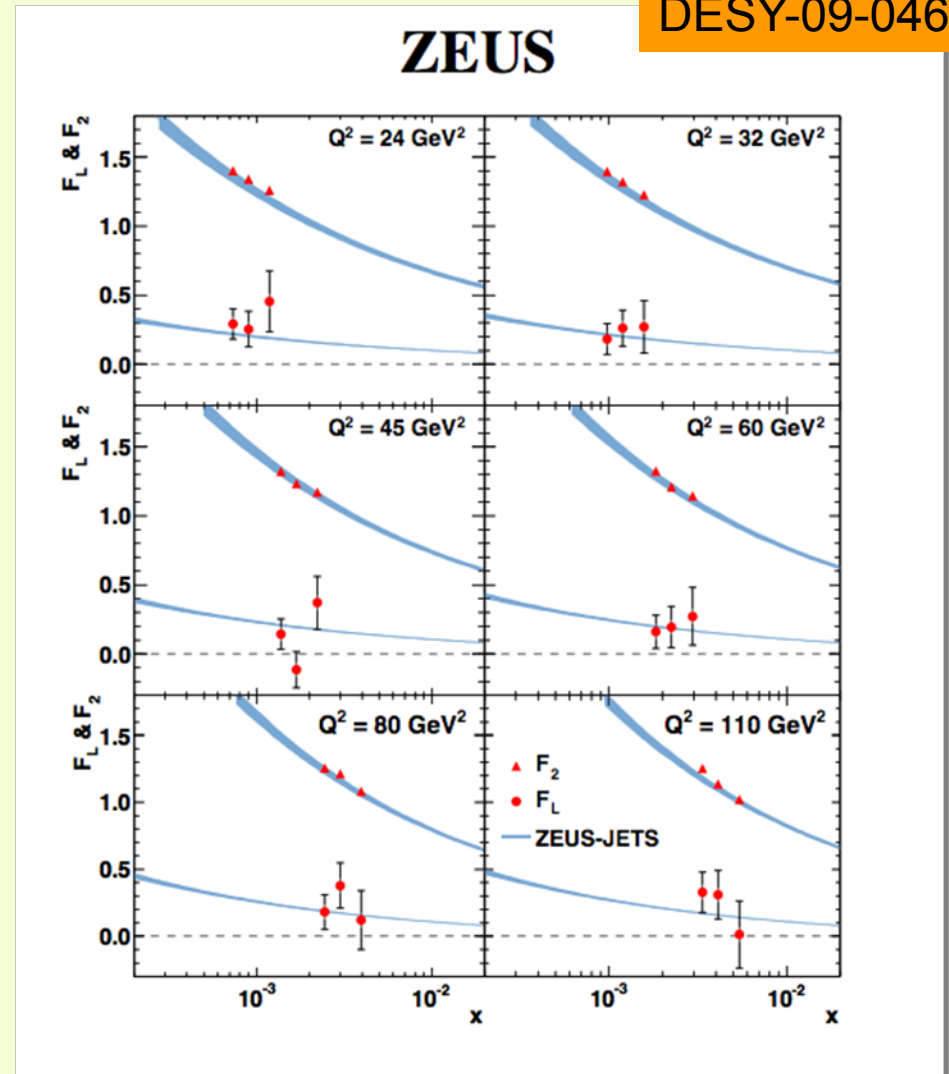
F₂ and F_L

DESY-09-046

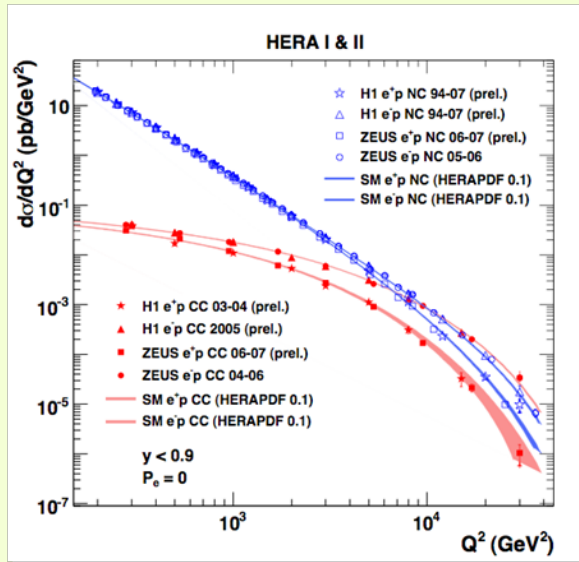


❖ Most precise F₂ from ZEUS in
□□□ this kinematic
region

❖ Data support non-zero F_L



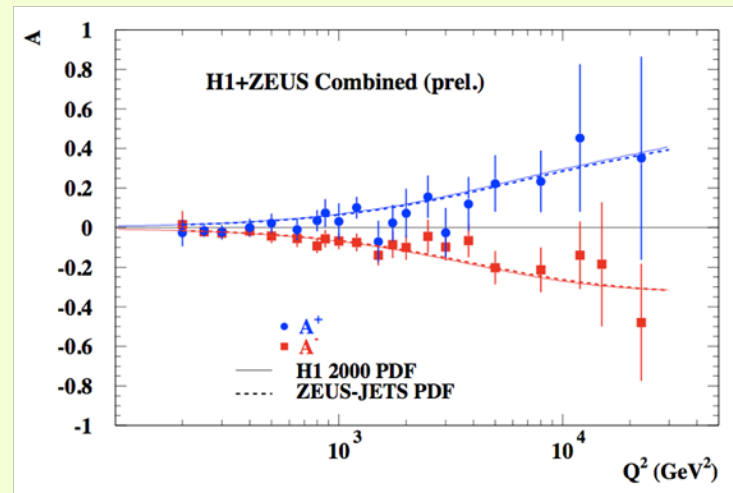
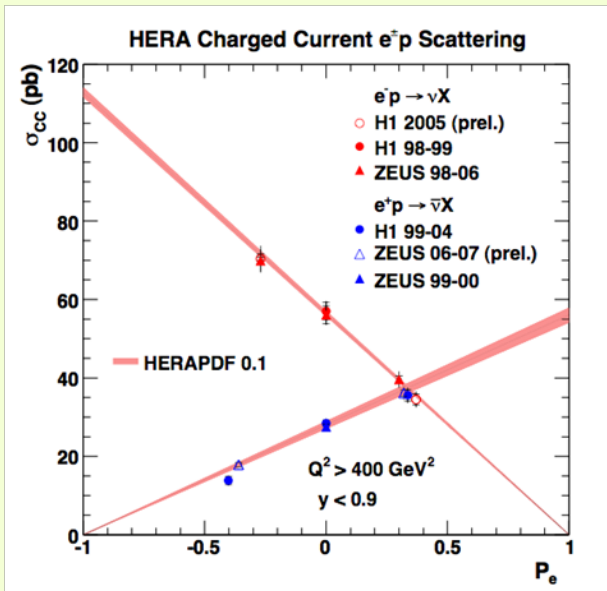
NC/CC High- Q^2 Cross sections at HERA



Important **Electroweak Physics** program:

- ❖ Electroweak unification
- ❖ Chiral nature of the SM
- ❖ Determination of light-quarks couplings
- ❖ Parity violation in DIS at high- Q^2 (10^{-18}m)

Here will concentrate on their impact on the proton structure



High Q^2 NC e^-p cross sections

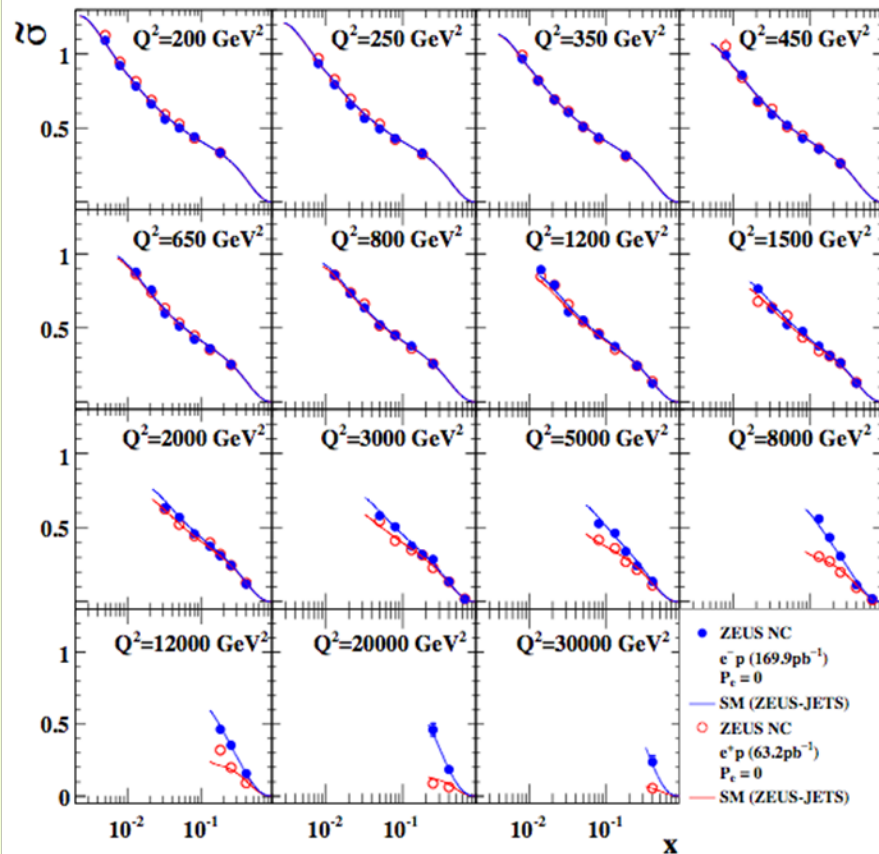
$$\tilde{\sigma}^{e^\pm p} = \frac{xQ^4}{2\pi\alpha^2} \frac{1}{Y_+} \frac{d^2\sigma(e^\pm p)}{dx dQ^2} = \tilde{F}_2(x, Q^2) \mp \frac{Y_-}{Y_+} x\tilde{F}_3(x, Q^2)$$

$$x\tilde{F}_3 = \frac{Y_+}{2Y_-} (\tilde{\sigma}^{e^-p} - \tilde{\sigma}^{e^+p})$$

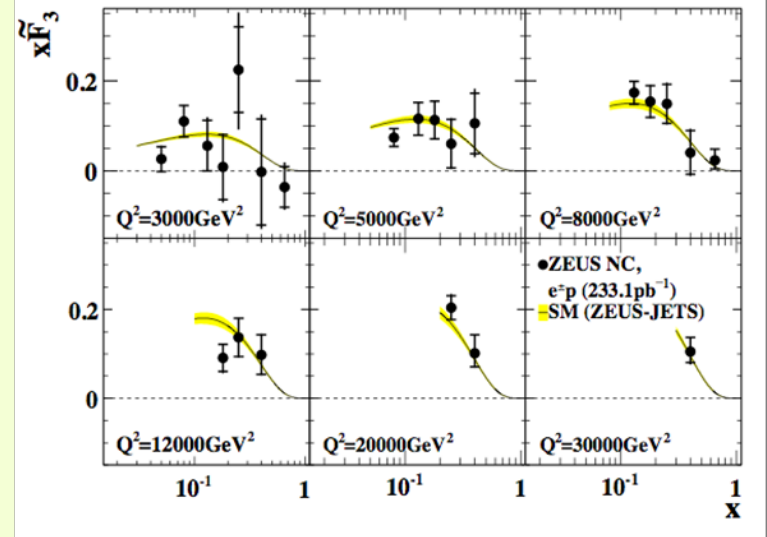
$L=170 \text{ pb}^{-1}$ (HERA-I 16 pb^{-1})

DESY-08-202

ZEUS



ZEUS



$$xF_3^{\gamma Z} = 2x[e_u a_u u_v + e_d a_d d_v] = \frac{x}{3}(2u_v + d_v)$$

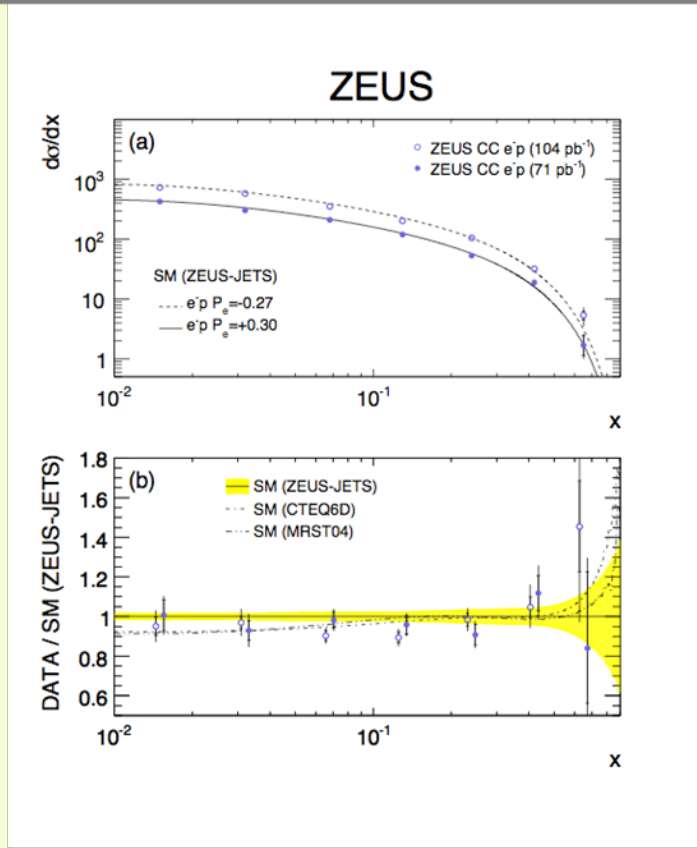
\Rightarrow Improve xu_v at high- x

see A. Cooper-Sarkar[59]

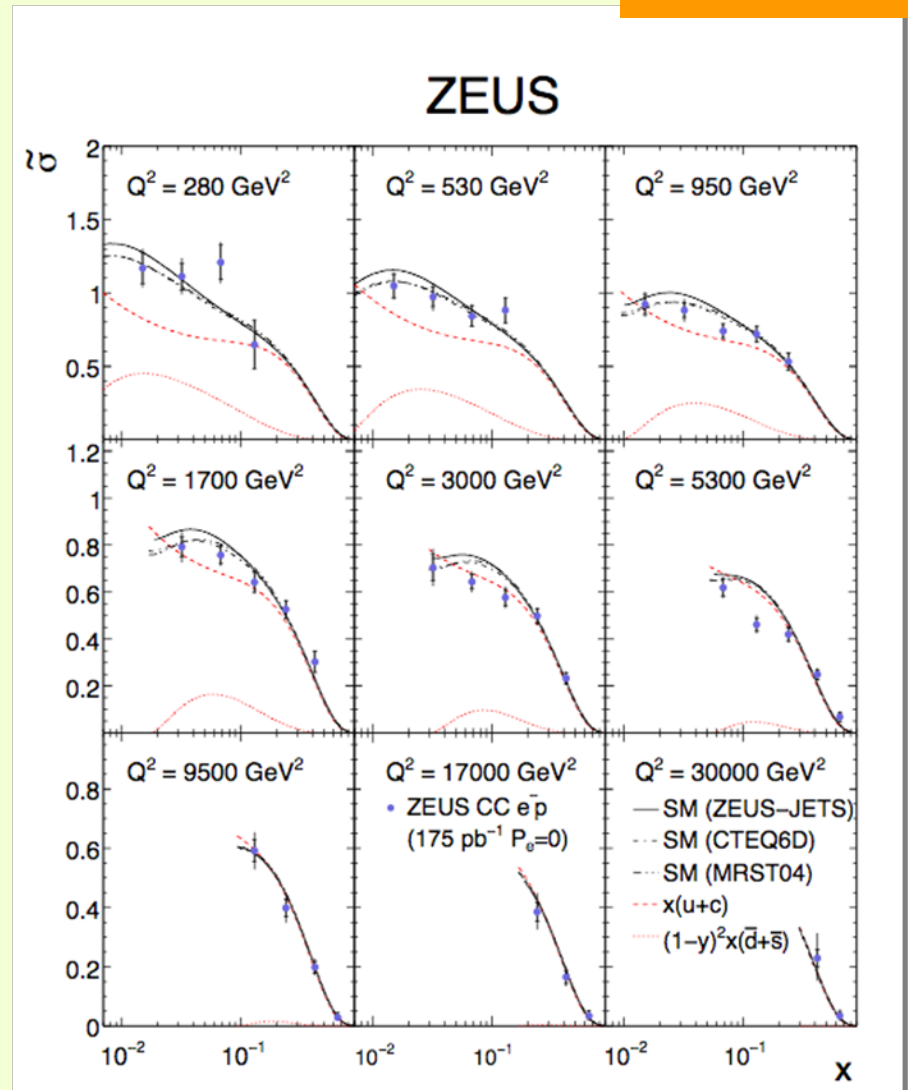
High Q^2 CC e^-p cross sections

DESY-08-177

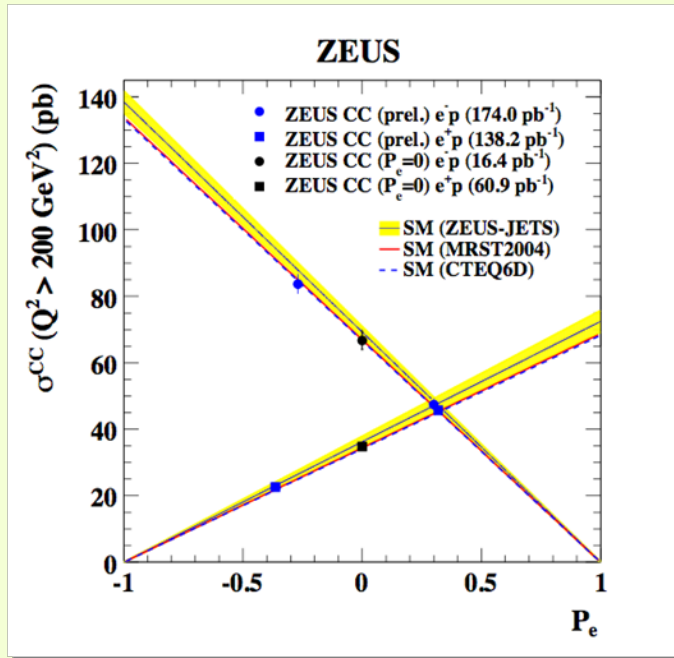
$$\tilde{\sigma}(e^-p \rightarrow \nu_e X) = x [u + c + (1-y)^2(\bar{d} + \bar{s})]$$



\Rightarrow Improve xu_v at high- x



High Q^2 CC e^+p cross sections

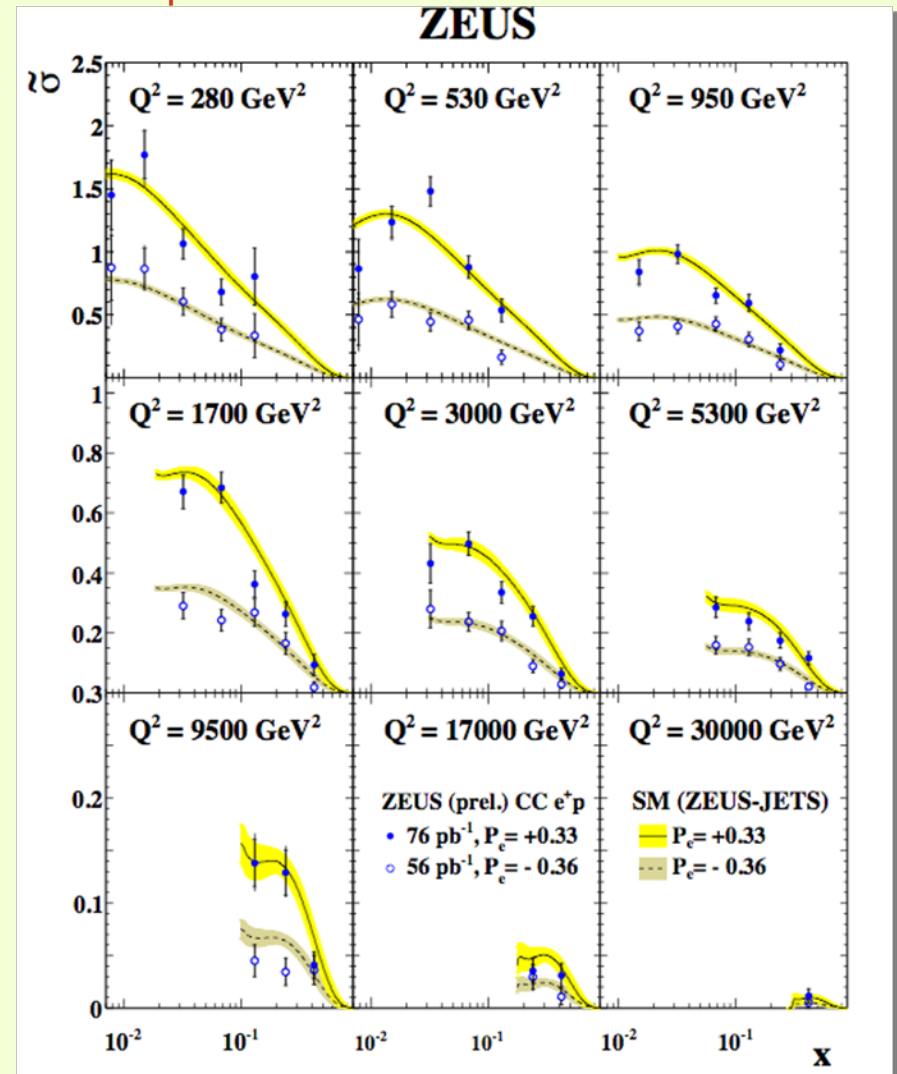


$$\tilde{\sigma}(e^-p \rightarrow \nu_e X) = x [(\bar{u} + \bar{c} + (1-y)^2(d+s))]$$

d-flavour sector less well-known

⇒ Important input to improve $x d_\nu$

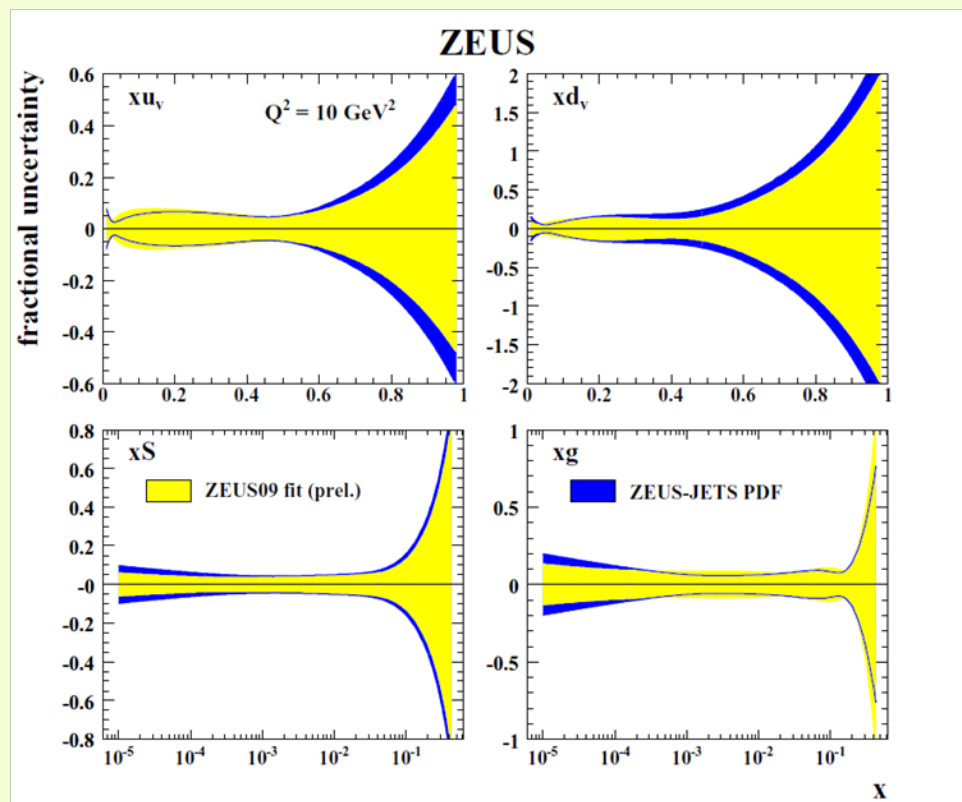
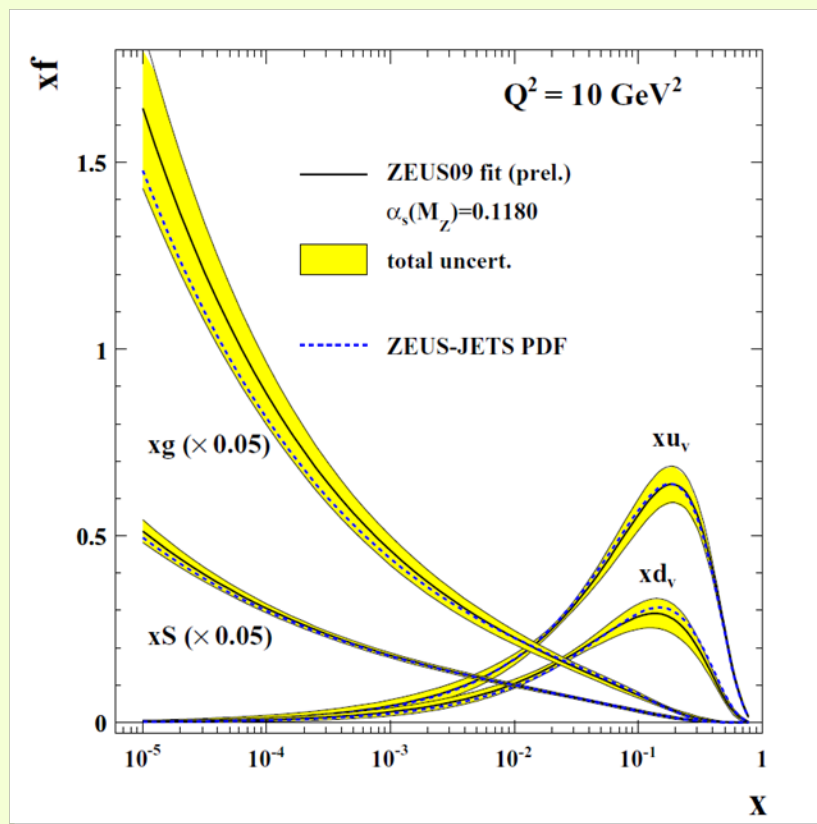
$L=136 \text{ pb}^{-1}$



Zeus 2009 Fit

Use same approach as for the published ZEUS-JETS Fit to assess the impact of the new data:

CC e^+p , NC e^-p and NC e^+p H/M/LER



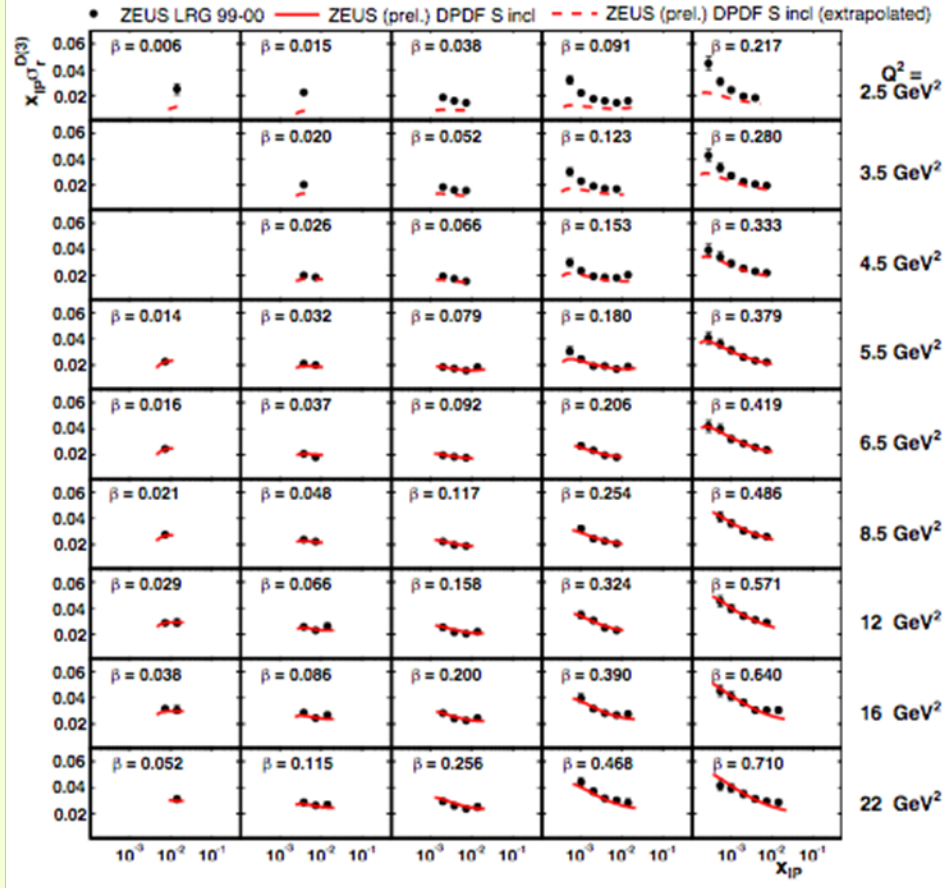
- ❖ improve unc. on xu_v , xd_v
- ❖ slightly steeper gluon

see A. Cooper-Sarkar[59]

Diffraction fit and dPDFs

LRG

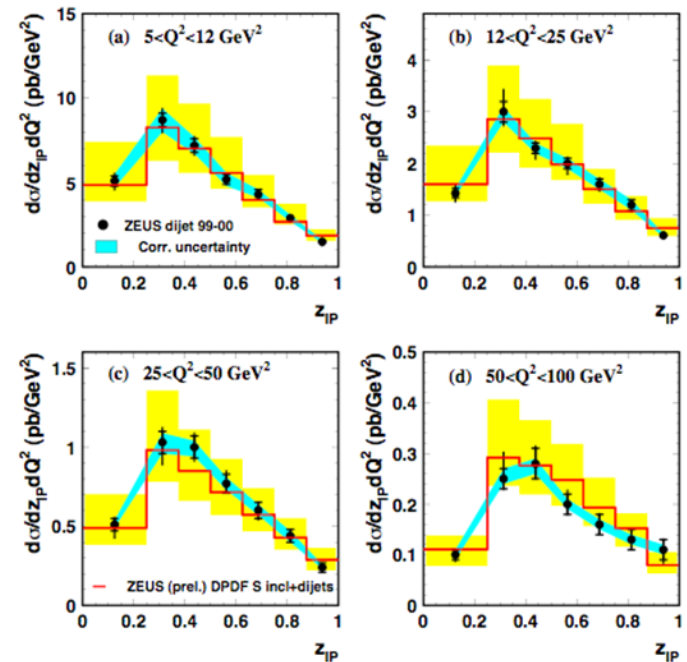
ZEUS



- ❖ NLO QCD fit to incl. DIS data
- ❖ Comparison and fit to dijet in DIS
- ❖ Comparison to dijet in PHP
- ❖ Heavy Flavours (Roberts-Thorne)

ZEUS

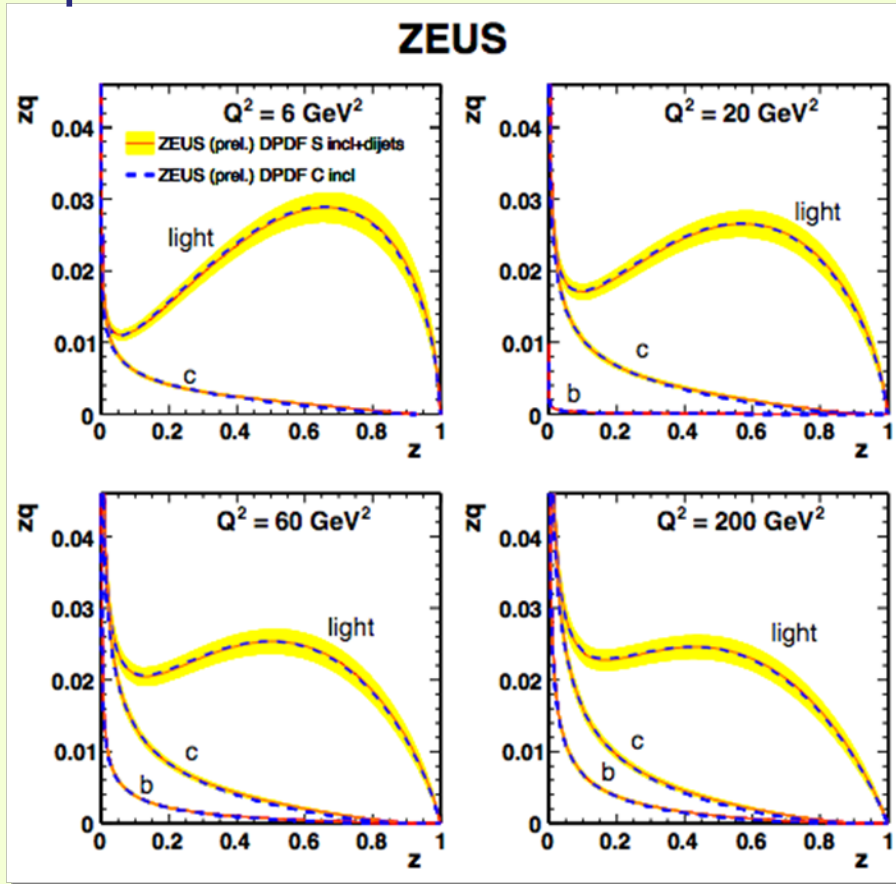
Dijet



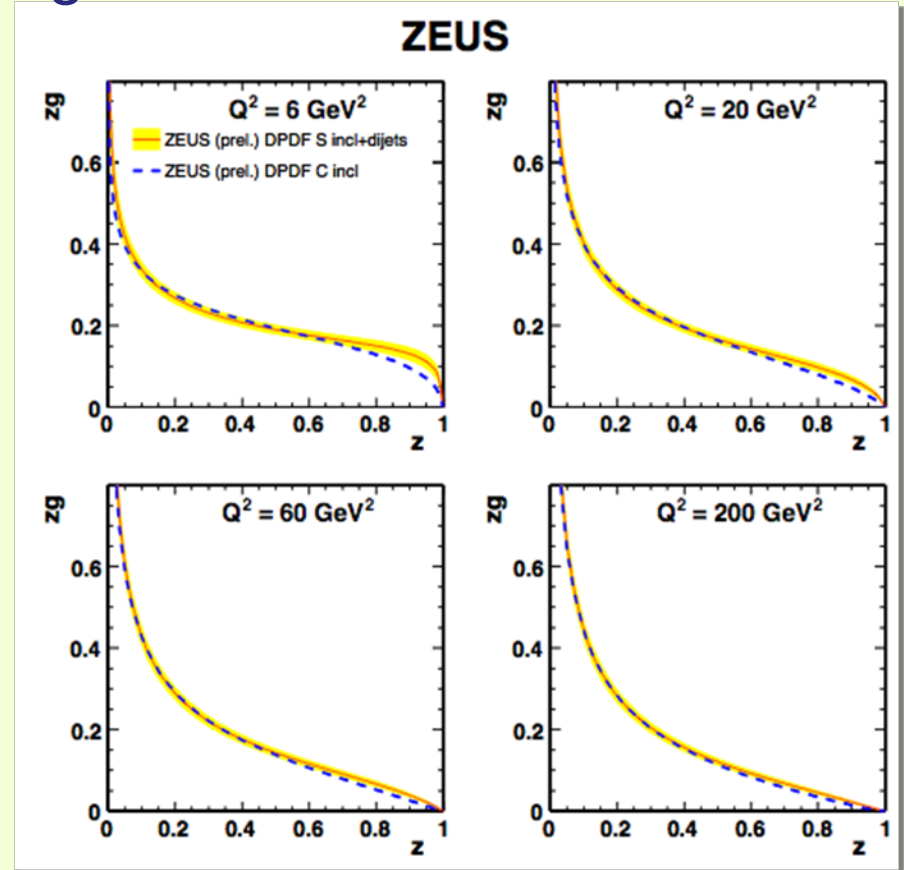
see W. Slominski[121]

Diffractive fit and dPDFs

zq

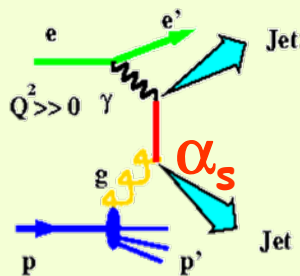


xg

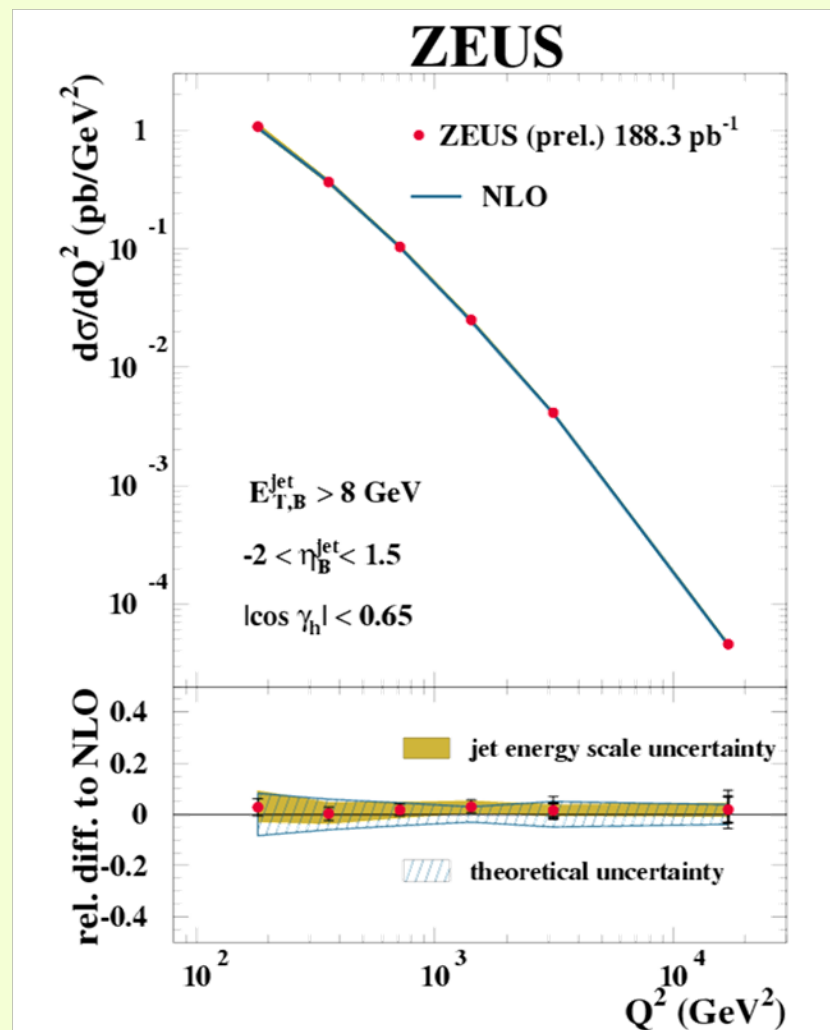
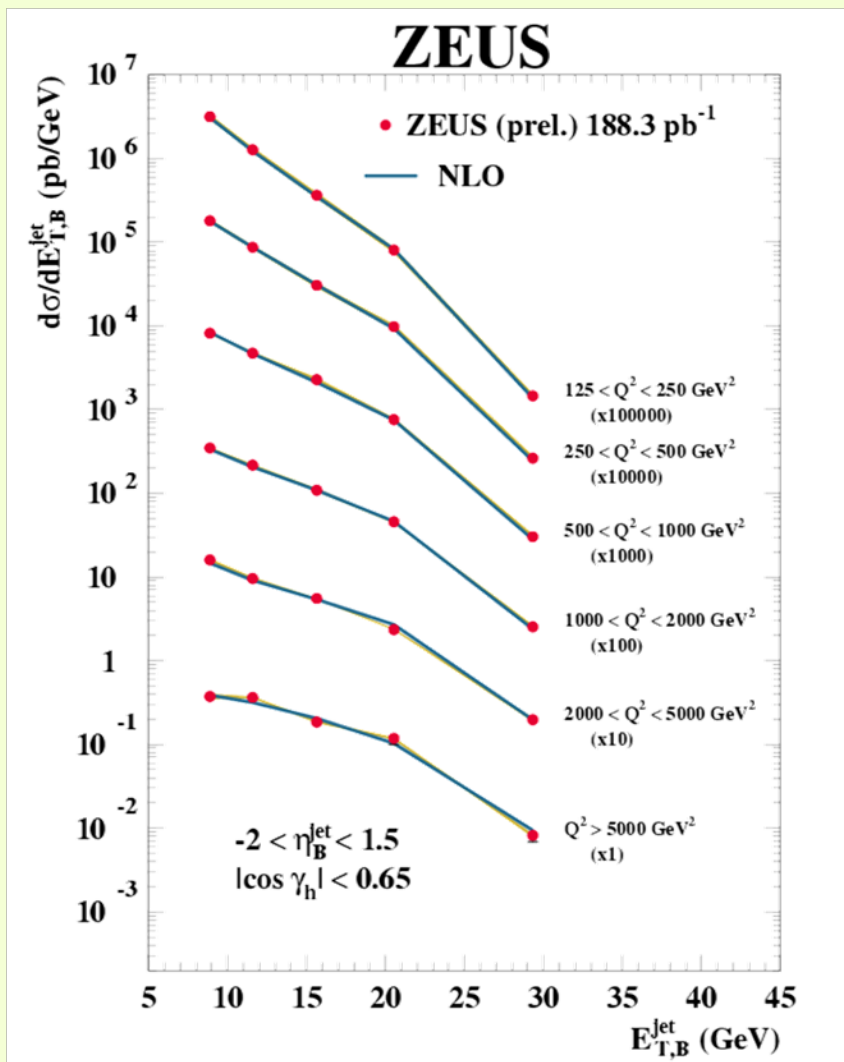


see W. Slominski[121]

Jet production in NC DIS



HERA-II e-p



$\Rightarrow \alpha_s$ determination \square

Strong coupling

HERA-II NC DIS inclusive jets

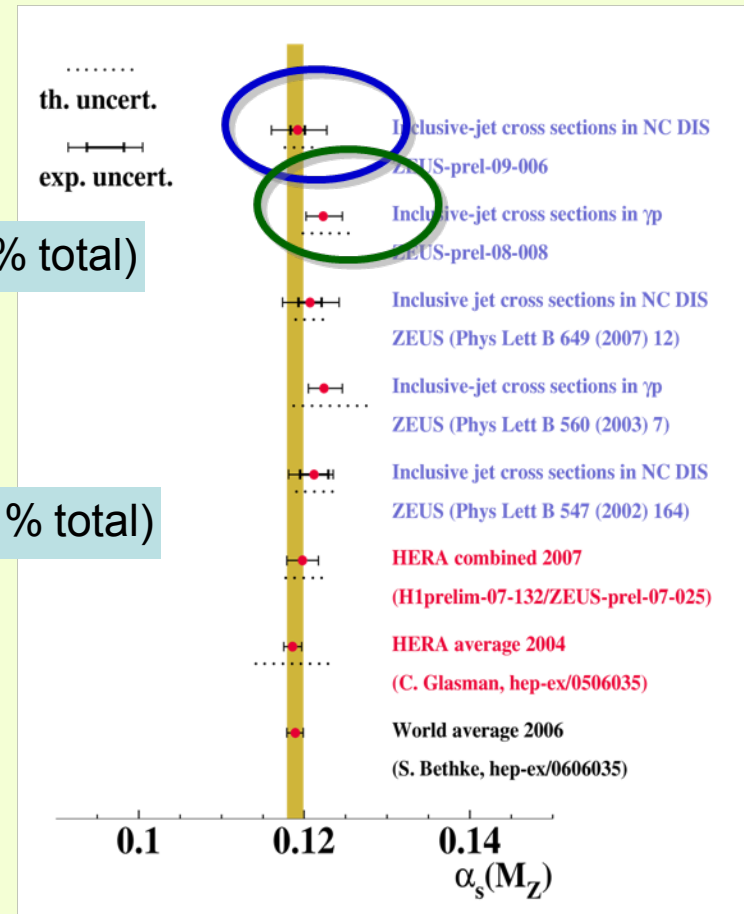
(first determination from ZEUS with HERA-II data):

$$\alpha_s(M_Z) = 0.1192 \pm 0.0009 \text{ (stat.)}_{-0.0032}^{+0.0035} \text{ (exp.)}_{-0.0021}^{+0.0020} \text{ (th.) (3.5\% total)}$$

Re-analysis of HERA-I γp incl. jets:

$$\alpha_s(M_Z) = 0.1223 \pm 0.0001 \text{ (stat.)}_{-0.0021}^{+0.0023} \text{ (exp.)}_{-0.0030}^{+0.0029} \text{ (th.) (3.1\% total)}$$

- ❖ Improved exp. unc. from full HERA data
- ❖ Need NNLO



see C. Gwenlan[238]

Subjets

DESY-08-178

Study transition $\text{parton} \Rightarrow \text{hadrons}$

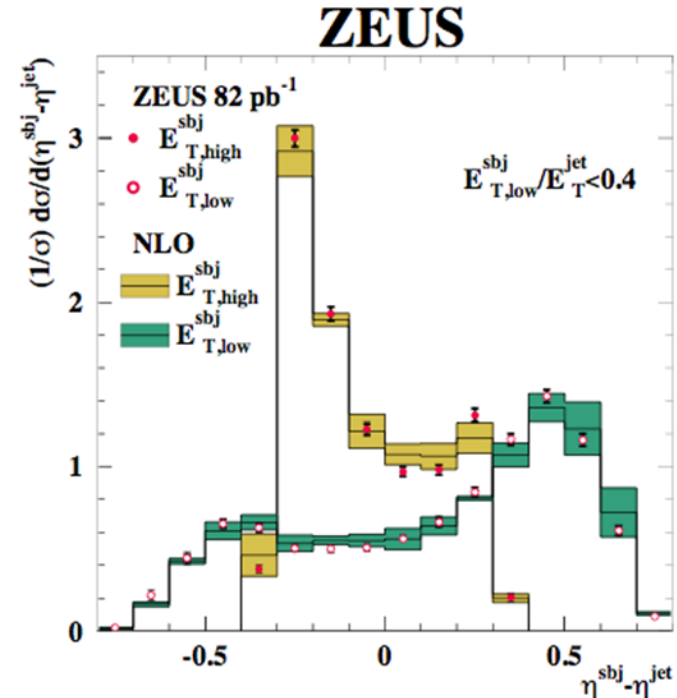
Two resolved subjets ($y_{\text{cut}}=0.05$):

- ❖ Highest E_T jet closer to the jet axis
- ❖ Lowest E_T jet towards p-beam direction

New for DIS2009:

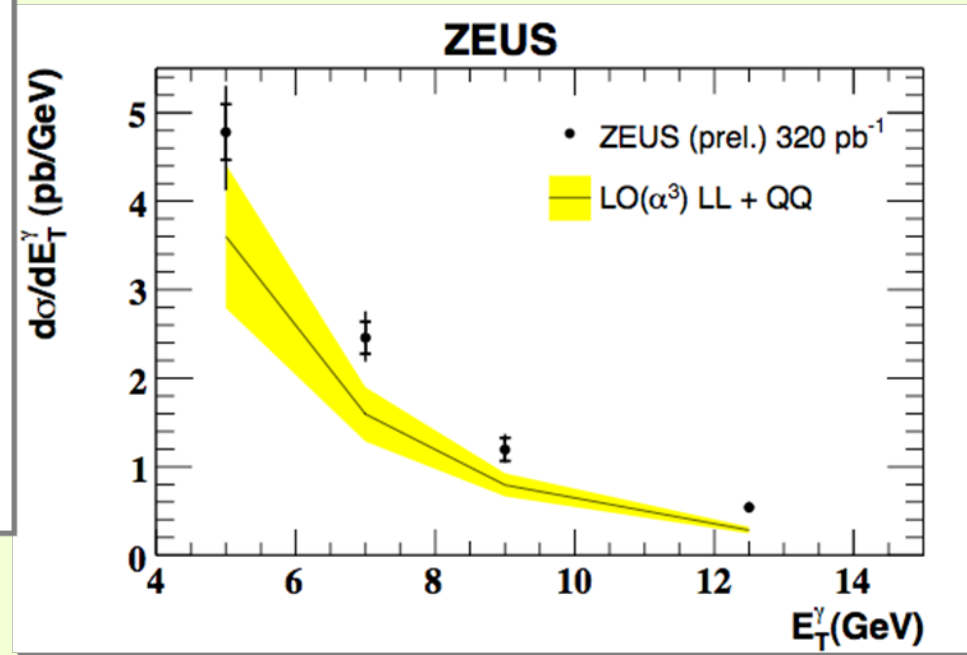
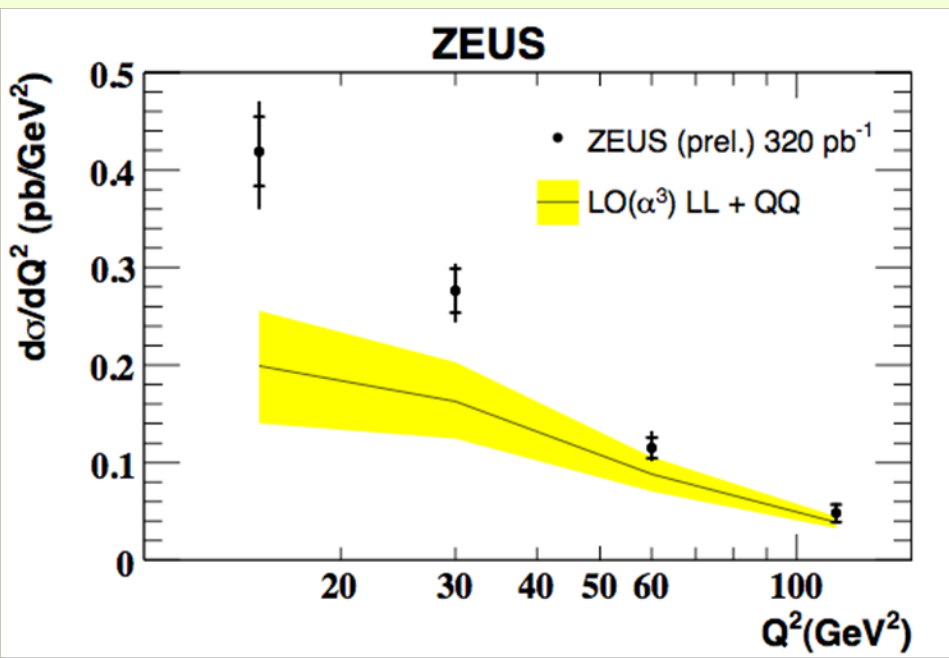
Three resolved subjets ($y_{\text{cut}}=0.03$)

($L=334 \text{ pb}^{-1}$)



see E. Ron[240]

Prompt-photon production

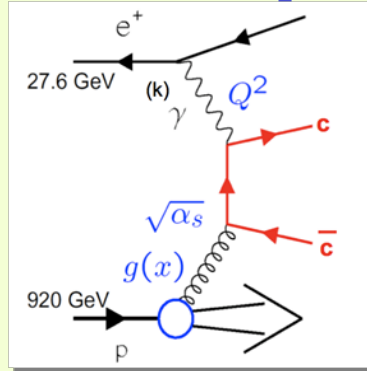
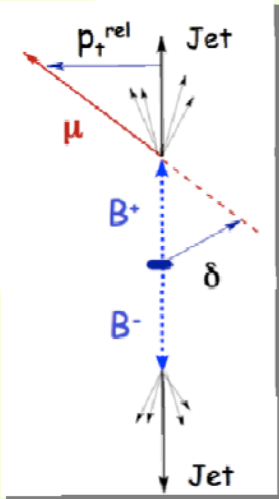


- ❖ Large statistics
- ❖ Only LO predictions available

see M. Forrest[282]

Semileptonic Charm and Beauty

DESY-09-056



HERAII e-p (2004/05) 126 pb⁻¹

$Q^2 > 20 \text{ GeV}^2$

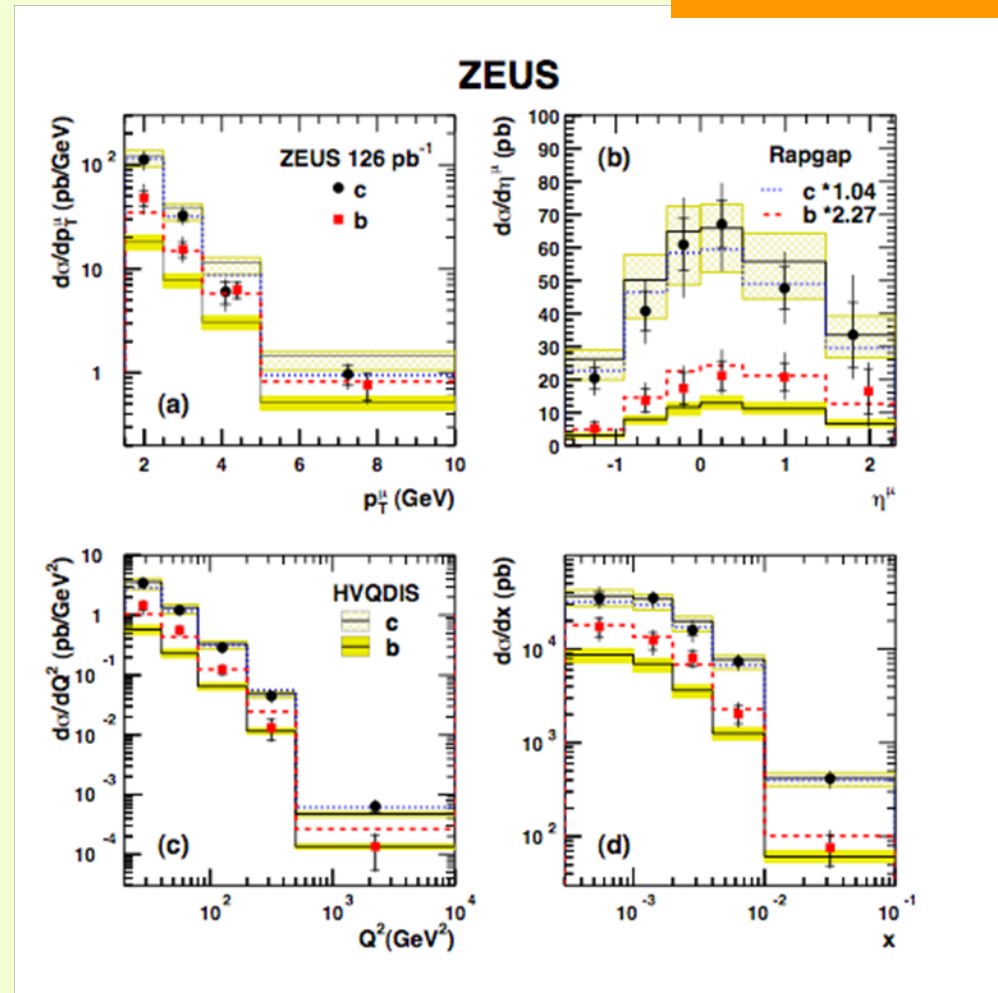
c, b and lf fractions extracted from a simultaneous fit of 3 discriminating variables:

P_T^{rel} , δ , $p_T^{\text{miss}||\mu}$

Theory : FFNS NLO (HVQDIS)

Charm : Good description

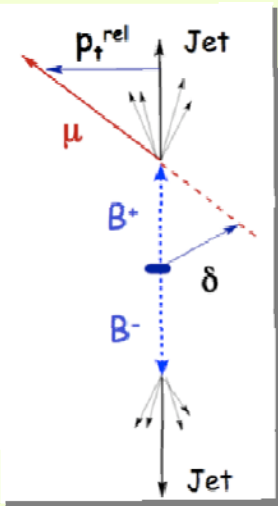
Beauty: Excess at low Q^2 ($\sim 2 \sigma$)



see P. Roloff[168], M. Bindi[179]

Beauty in Photoproduction

DESY-08-210



HERA II data (05 e⁺p) 125 pb⁻¹

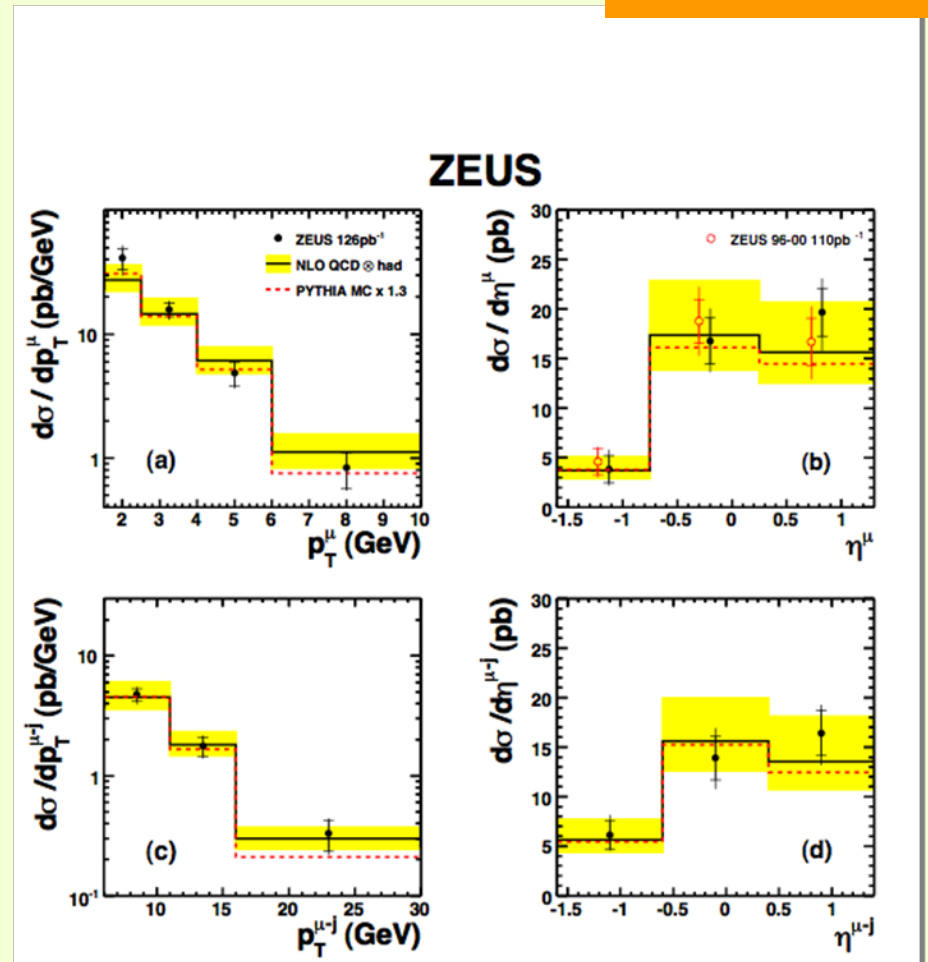
Look for **b** in two jets events with high-pt lepton

Kt clust:

$N_{\text{jet}} \geq 2$, $P_t > 7(6)$ GeV, $|\eta| < 2.5$

Theory: FMNR

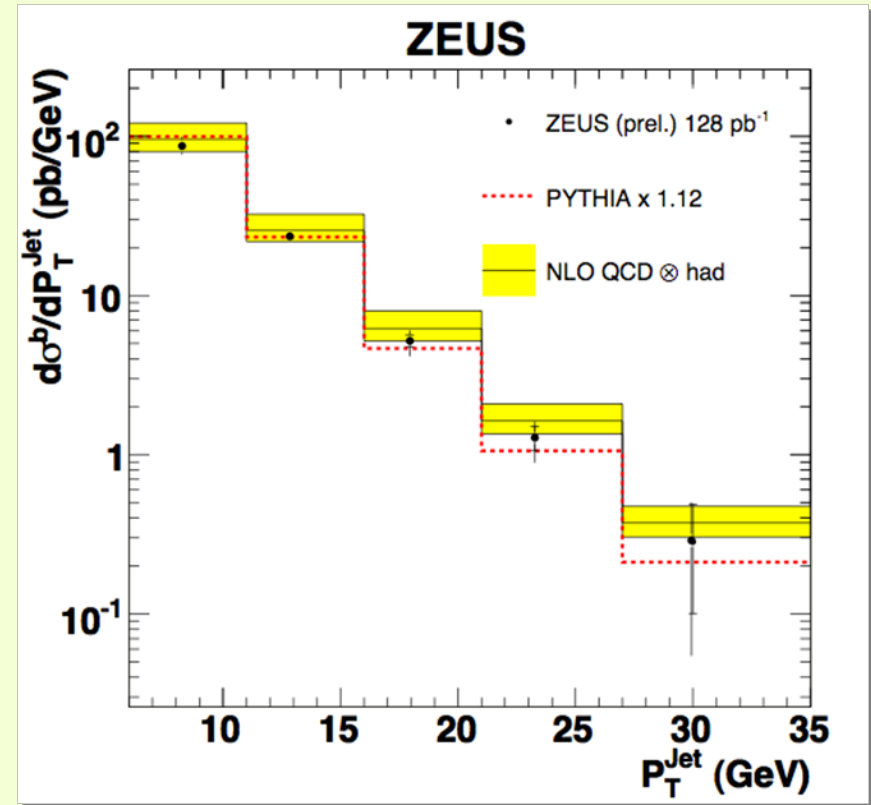
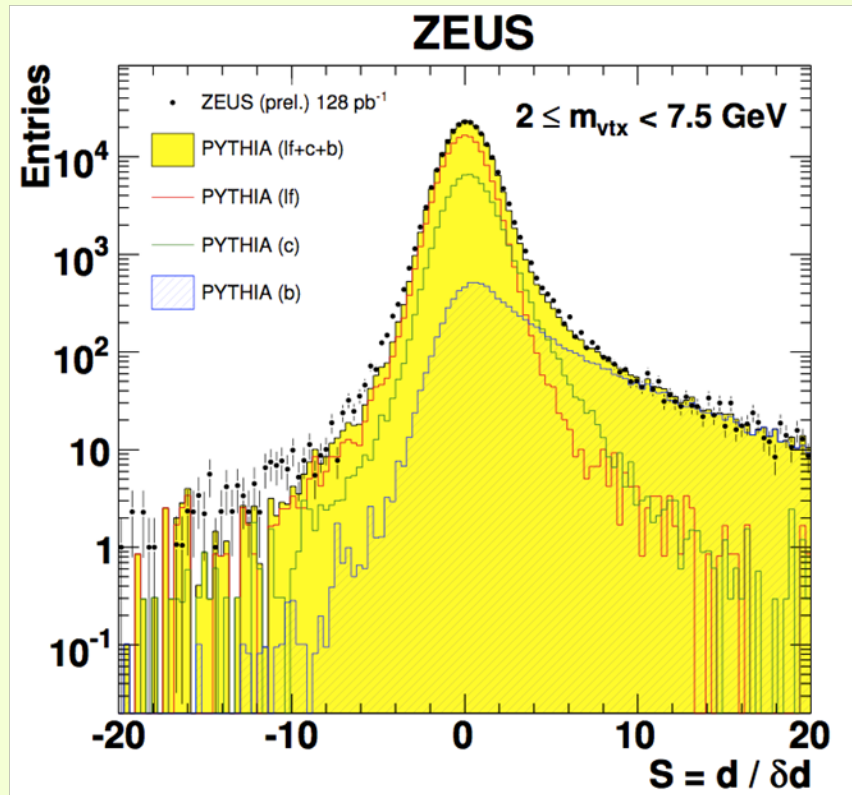
Good agreement with NLO QCD



Beauty in Photoproduction

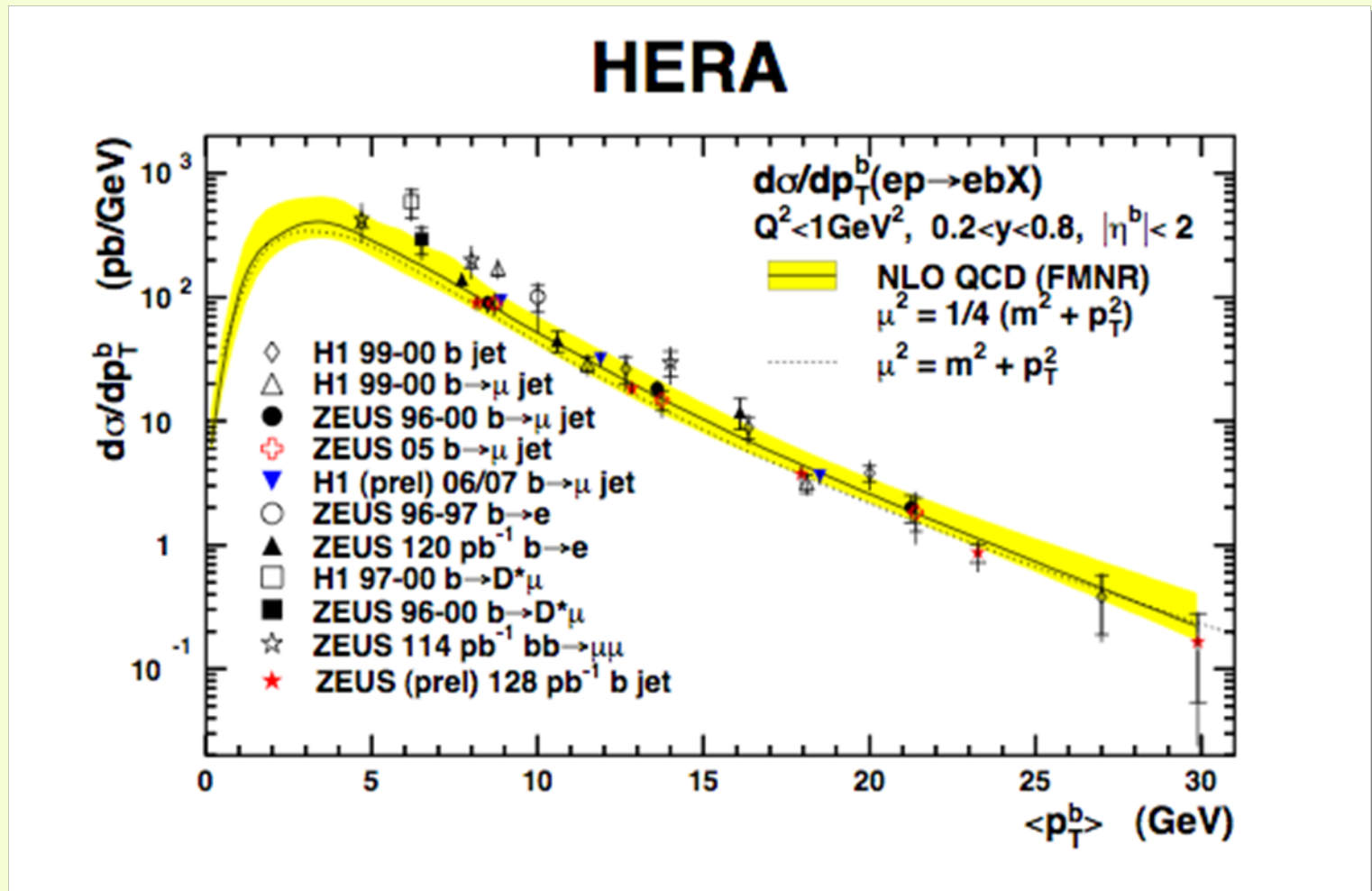
Lifetime tagging: Fraction of b from decay length significance

Good agreement with NLO QCD



see S. Miglioranzi[120]

Beauty: Summary plot



Summary

- Inclusive Measurements and Proton Structure
 - ❖ Steady progress in the H1/ZEUS combination
 - ❖ First F_L measurement from ZEUS completed
 - ❖ Huge effort to complete high- Q^2 cross sections
=> impact on the new ZEUS PDFs
- Exclusive processes and pQCD
 - ❖ New precise results on Jet and heavy quarks production
 - ❖ We need better theory here

It has been a productive year for ZEUS
(18(6) papers 2008(9), 20 presentations to this Workshop)
But a lot of work (and fun!) analysing HERA II data is still waiting us...