Selection of ZEUS results

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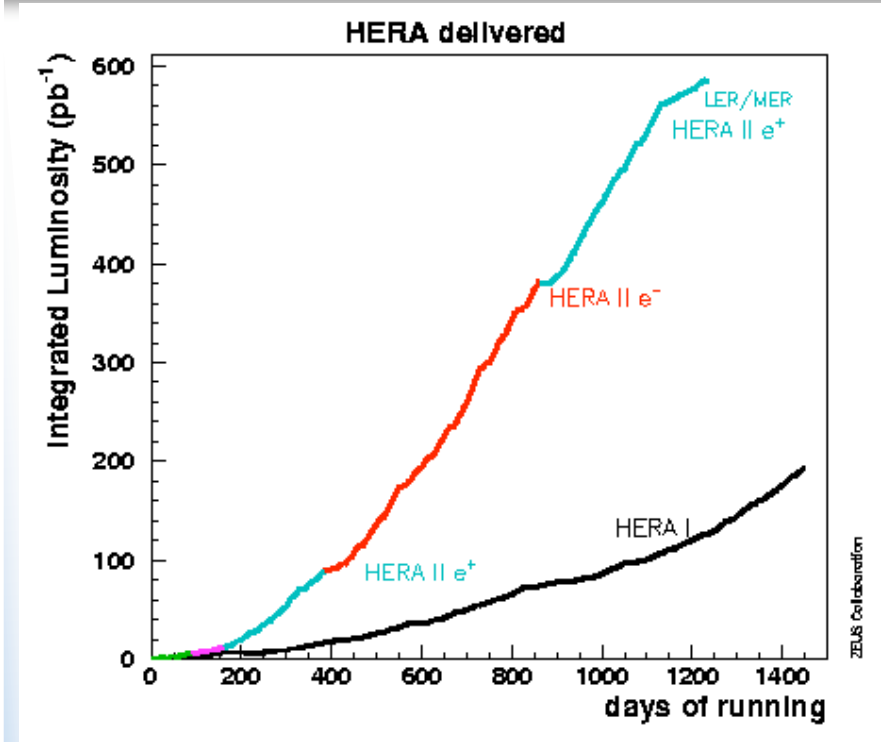
- hadronic final states
- heavy flavors
- energy dependence of $\sigma_{tot}(\gamma^* p)$
- diffraction
- inclusive DIS measurement (H1/ZEUS F_2 and PDFs)
- F_L determination

HERA Luminosity



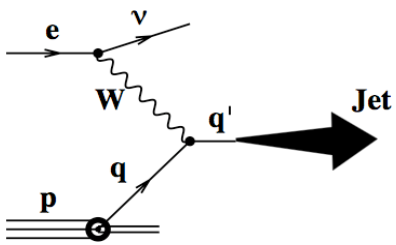
Available luminosity		HI	HII
		(pb^{-1})	
HER E_p=920 GeV	e^+p	125	190
	e^-p	19	210
MER E_p=575 GeV	e^+p	8	
LER E_p=460 GeV	e^+p	14	

Polarised e^+, e^- ($P \approx \pm 0.30$)

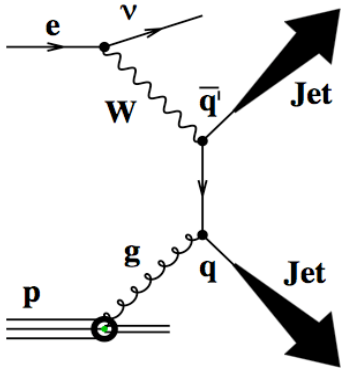
HERA stopped operation on June 30, 2007

Hadronic final states - Jets

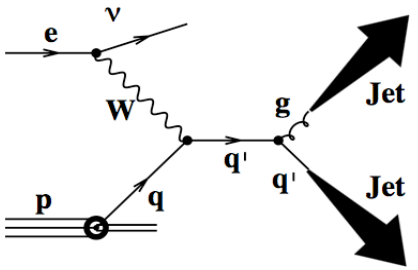
Usually source of information about α_S
In CC also sensitivity to quark flavors



QPM



BGF - low x

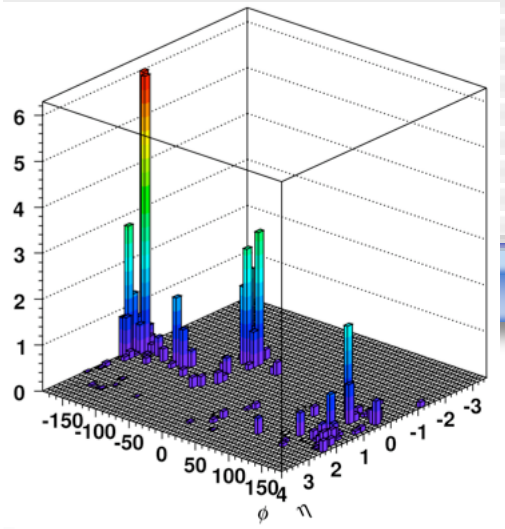


QCDC - large x

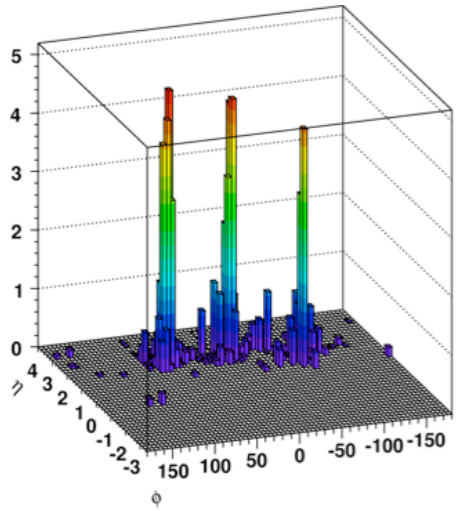
CC DIS cross section in QPM:

$$\frac{d^2\sigma^{e^- p}_{CC}}{dx\,dQ^2} = \frac{G_F^2}{2\pi}\,\frac{M_W^4}{(M_W^2+Q^2)^2}\sum_{i=1}^{2}\left[u_i(x,Q^2)+(1-y)^2\bar{d}_i(x,Q^2)\right]\times(1-P_{e^-})$$

$$\frac{d^2\sigma^{e^+ p}_{CC}}{dx\,dQ^2} = \frac{G_F^2}{2\pi}\,\frac{M_W^4}{(M_W^2+Q^2)^2}\sum_{i=1}^{2}\left[\bar{u}_i(x,Q^2)+(1-y)^2 d_i(x,Q^2)\right]\times(1+P_{e^+})$$

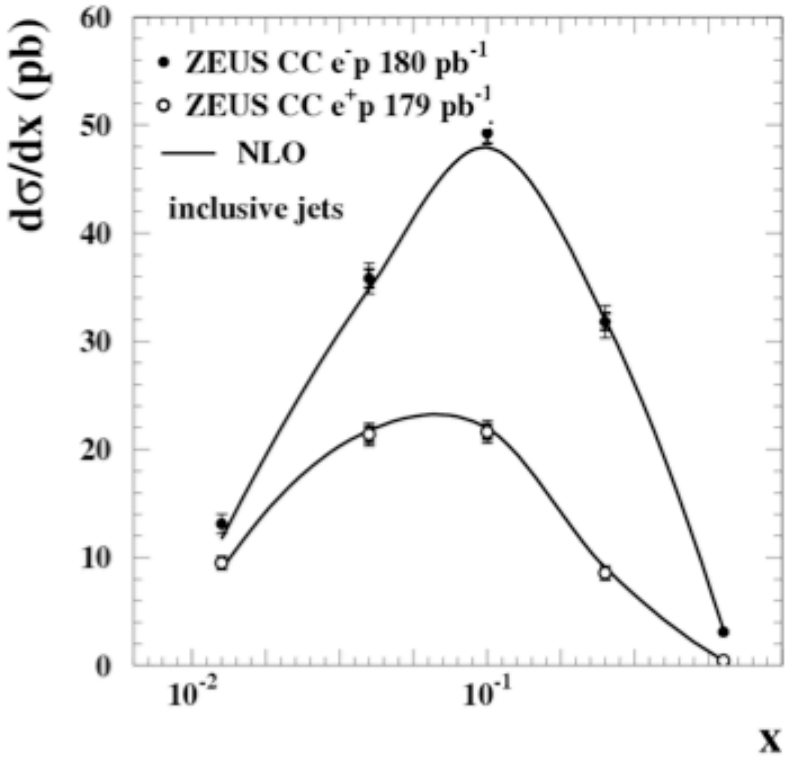


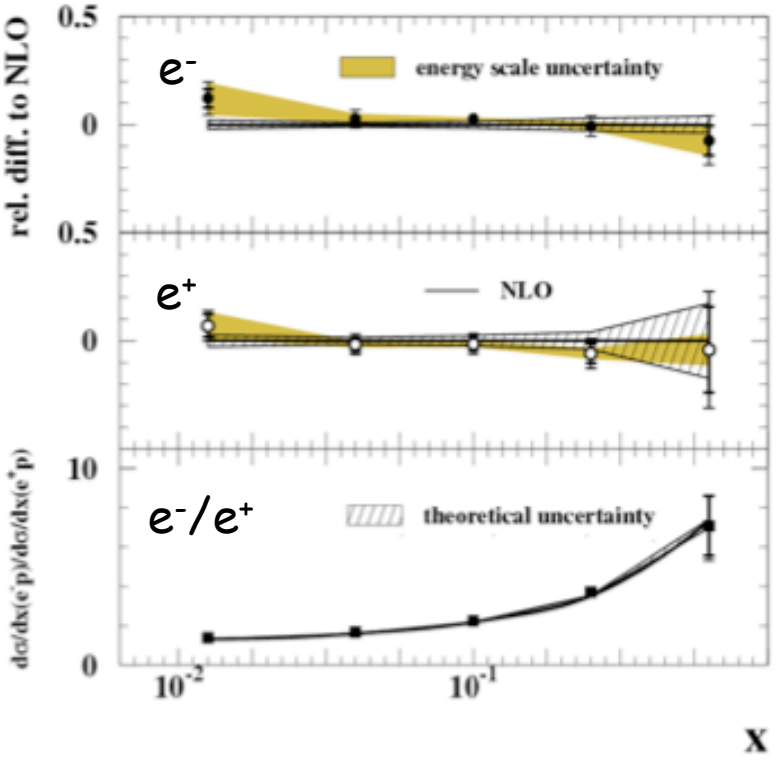
Inclusive jets in CC $e^{\pm}p$



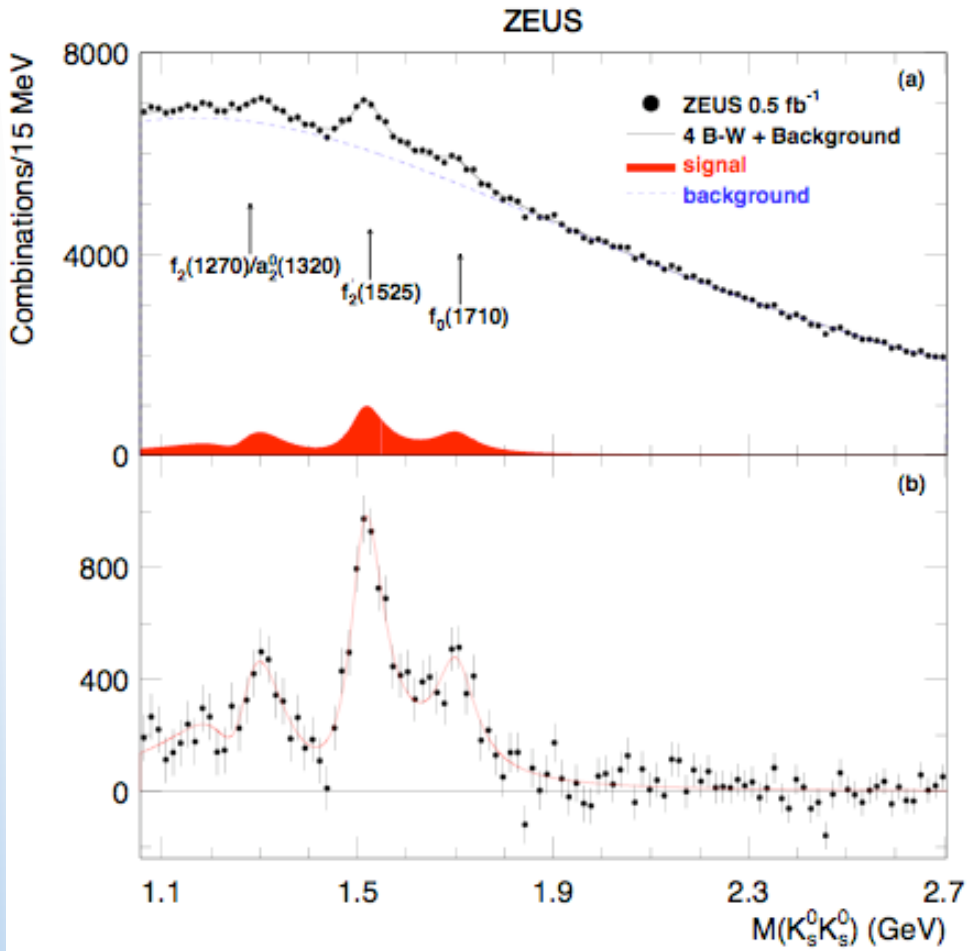
NLO - MEPJET with ZEUS-S PDFs

PDF uncertainties included





Hadronic final states - $K_S^0\ K_S^0$



Hunt for glueballs

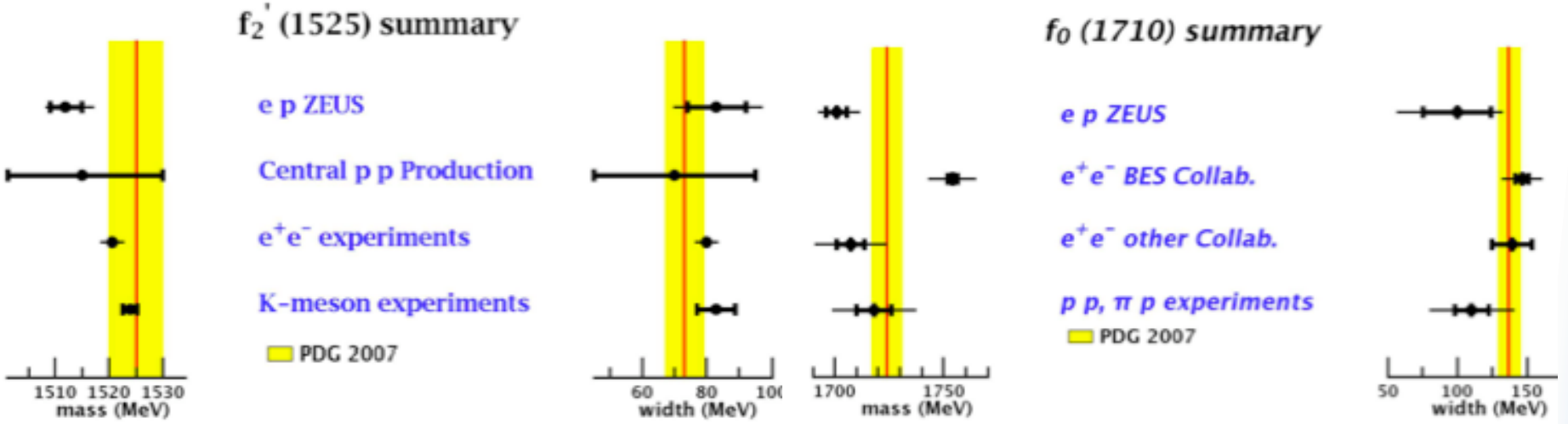
All Q^2 data mostly $Q^2<1$ GeV^2

- Fit M and Γ of 4 resonances
- Include interference for 2^+ states (SU(3) symmetry)

- χ^2/ndf=86/97
  $N_{f0(1710)}$=4058±820 (5σ)
  candidate for glueball (0^+)

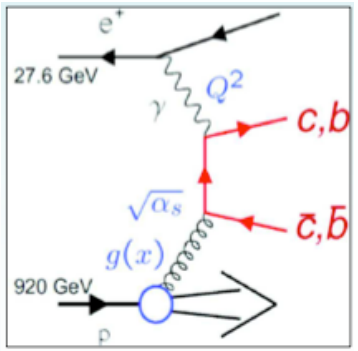
- fit without f_0 χ2/ndf=162/97

Hadonic final states - $K_S^0\ K_S^0$



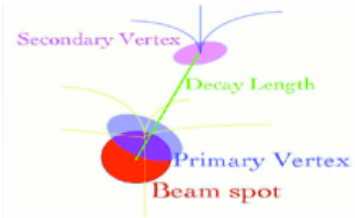
- f_0 also seen in TASSO/L3 - cannot be pure glue state
- masses lower than PDG (includes other measurements)
- widths agrees with PDG

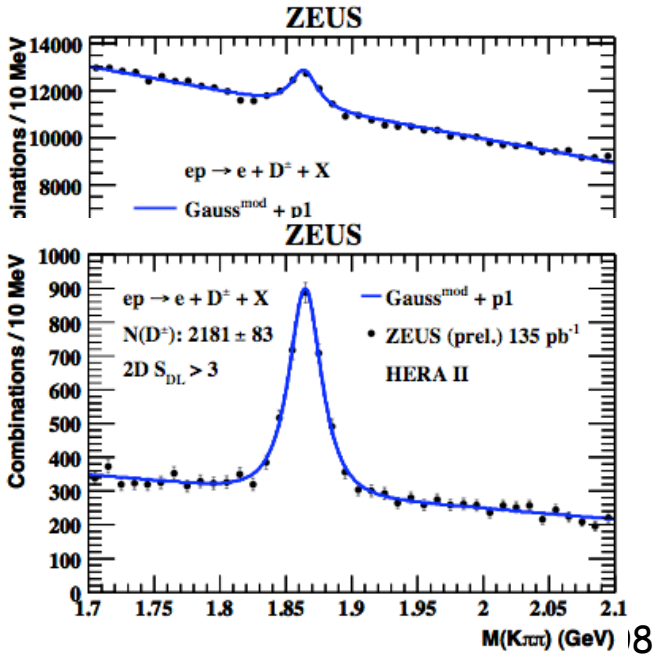
Heavy flavor production

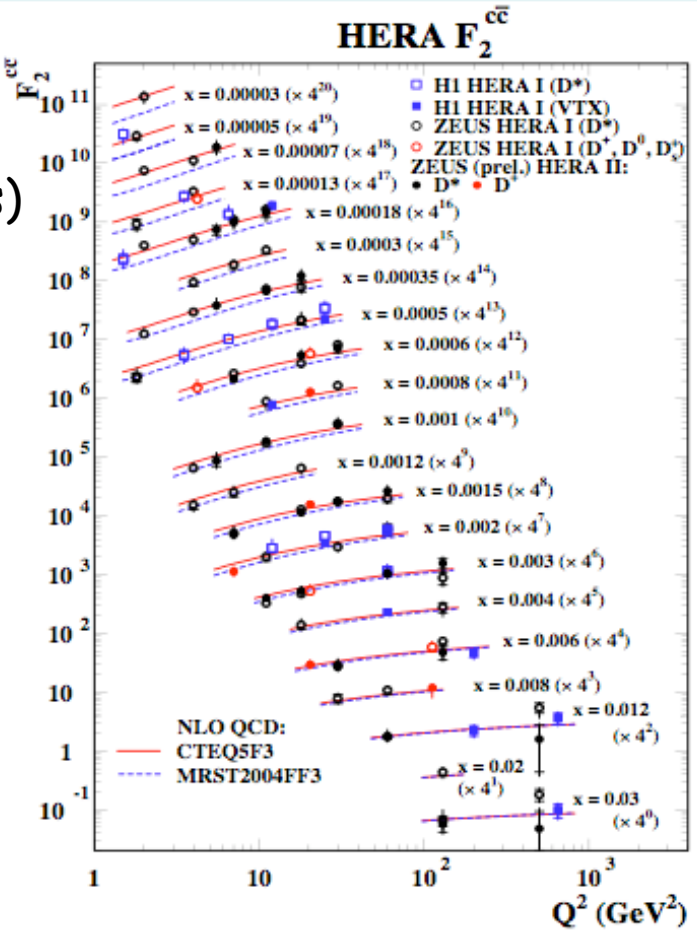


Charm, beauty production with sensitivity to

- gluons
- pQCD (various mass schemes)
- not included in PDFs

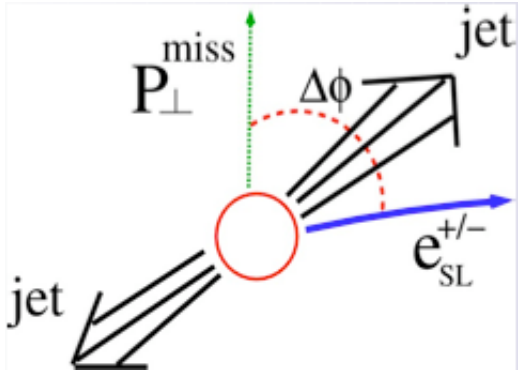




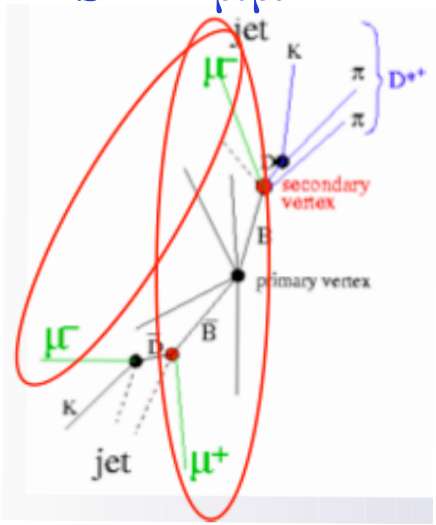


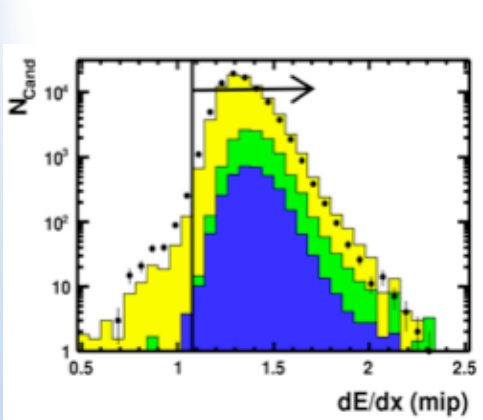
Heavy flavors production

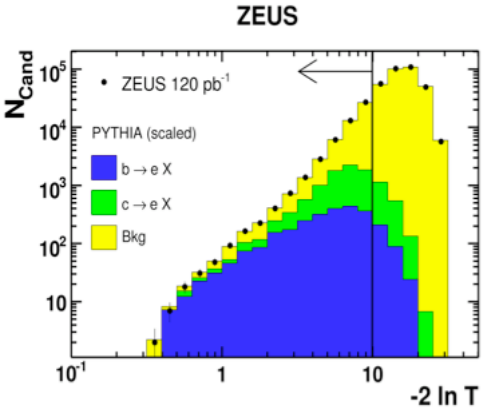
b → e+jet

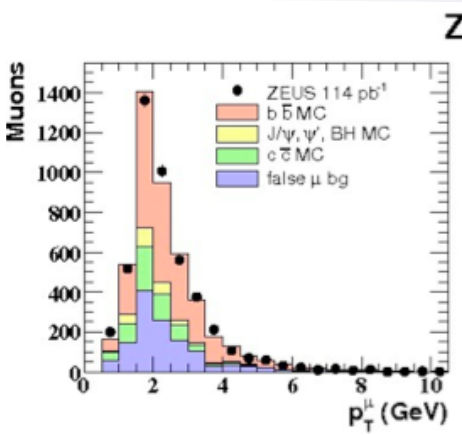


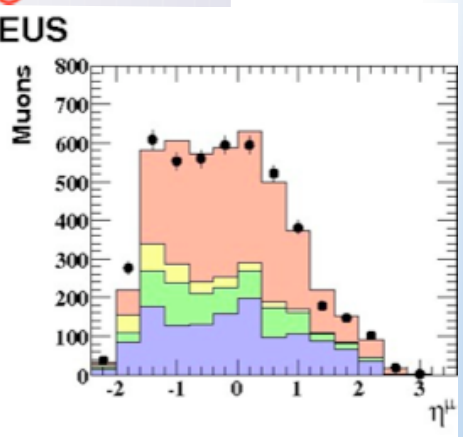
b → μμ











Beauty production

NLO QCD by FMNR

$\mu = \mu_0 = \sqrt{(p_T^b)^2 + (m_b)^2/2}$

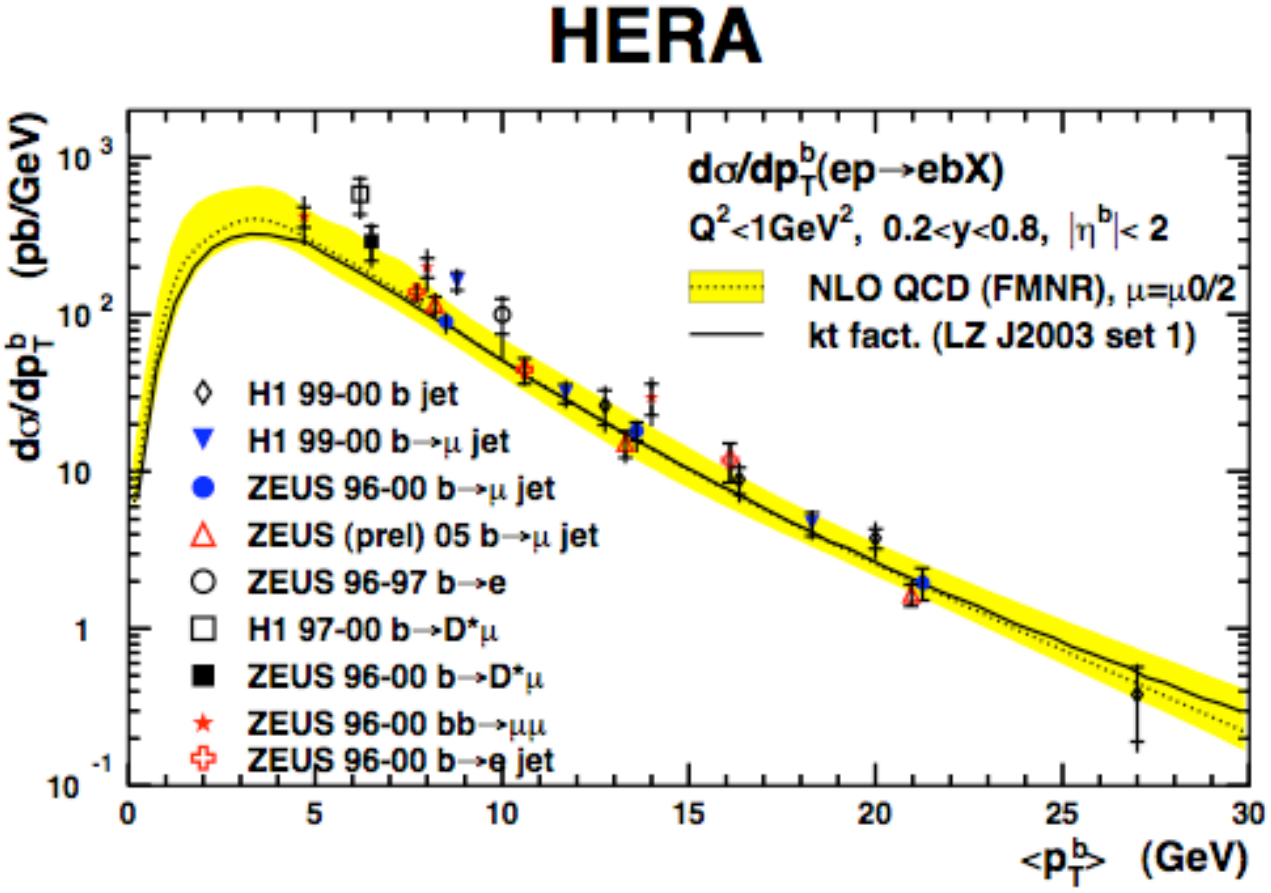
$0.5\mu_0 < \mu < 2\mu_0$

$m_b = 4.75\,\mathrm{GeV}$

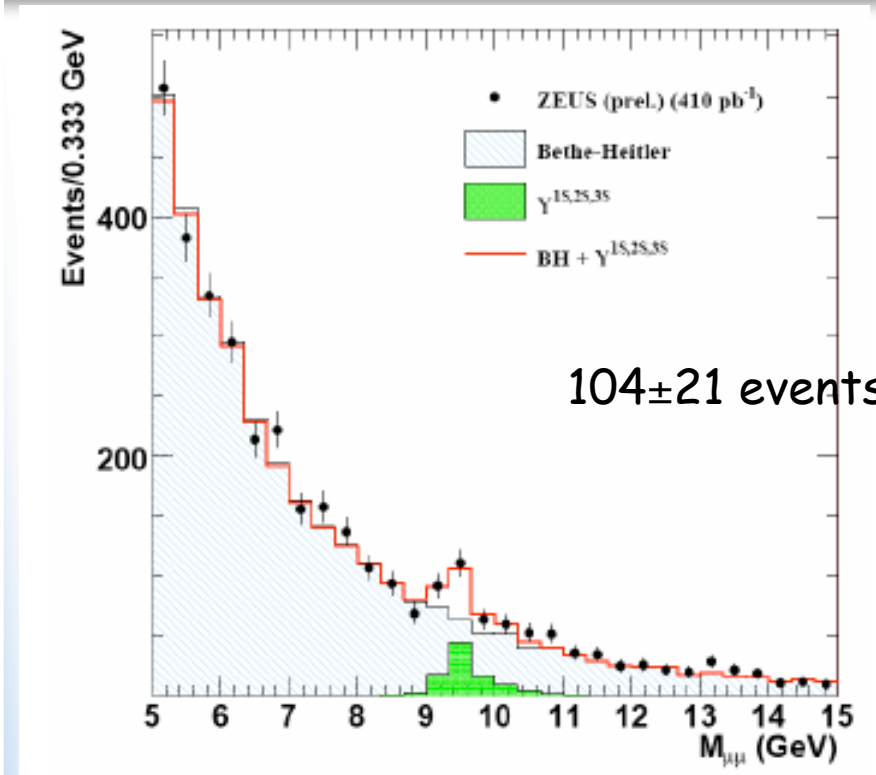
$4.5\,\mathrm{GeV} < m_b < 5\,\mathrm{GeV}$

CTEQ5M, GRV – G HO

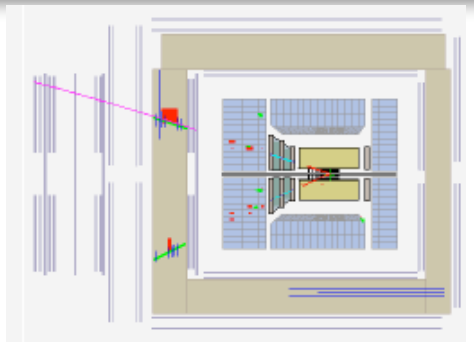
Latest summary

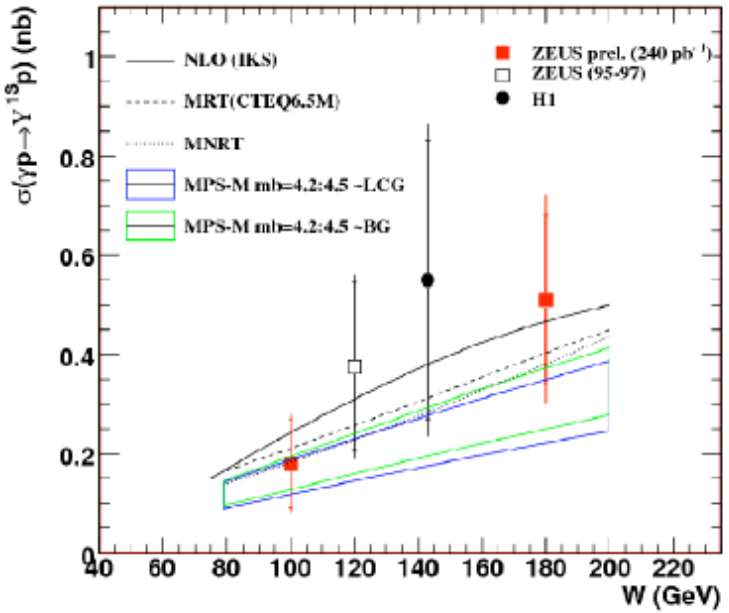


Exclusive beauty production



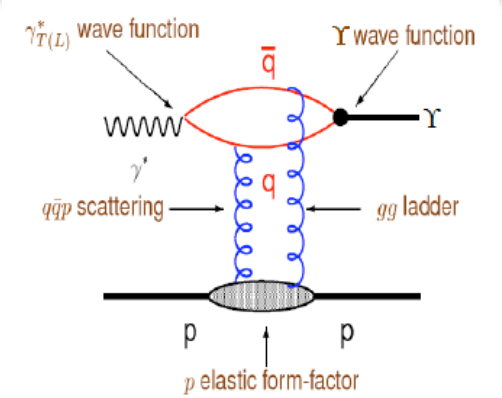
104±21 events





1998-2007 ZEUS data with Ep=920GeV
integrated luminosity 410pb-1
5σ signal from Υ(1S), Υ(2S), Υ(3S)

Exclusive processes

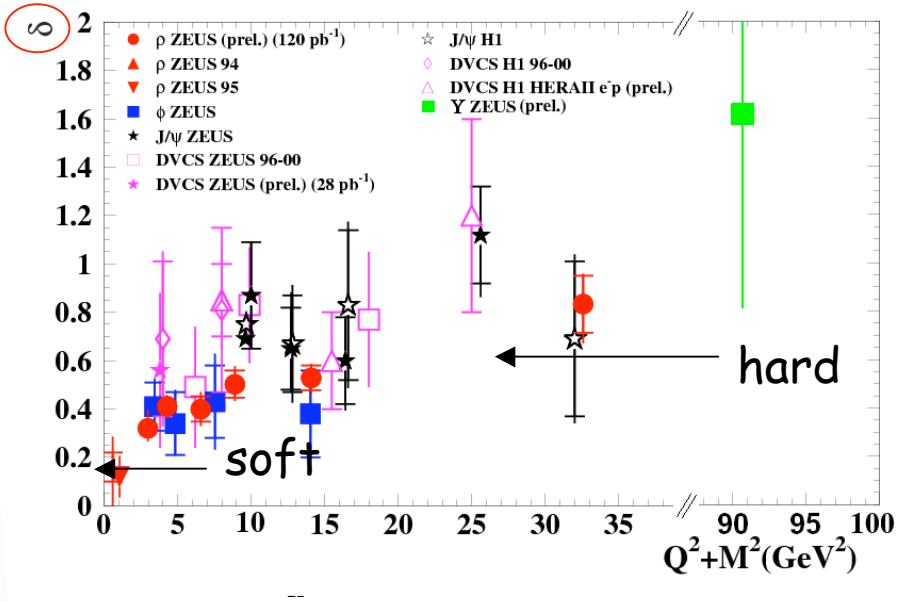


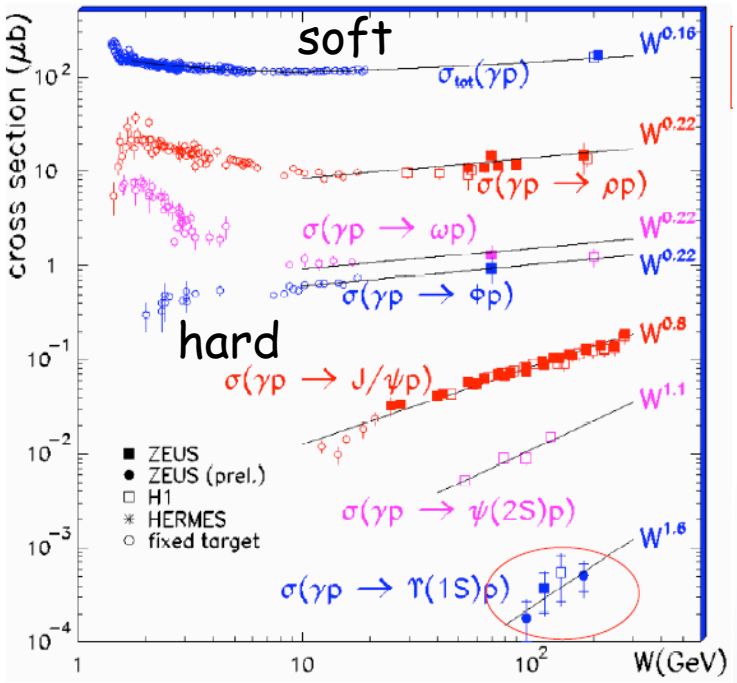
$$\sigma(W) \Rightarrow \delta \ (\propto W^{\delta})$$

$$\sigma(Q^2) \Rightarrow n \ \ (\propto (Q^2 + M^2)^{-n})$$

$$\frac{d\sigma}{dt} \Rightarrow b(Q^2) \ (\propto e^{-b|t|}) \ , \ \alpha_{IP}(t) \ (\propto W^{4(\alpha_{IP}-1)}) \ , \ n \ (\propto |t|^{-n} \text{ at large } |t|)$$

$$r^k_{ij} \Rightarrow R(W) \ , \ R(Q^2)$$



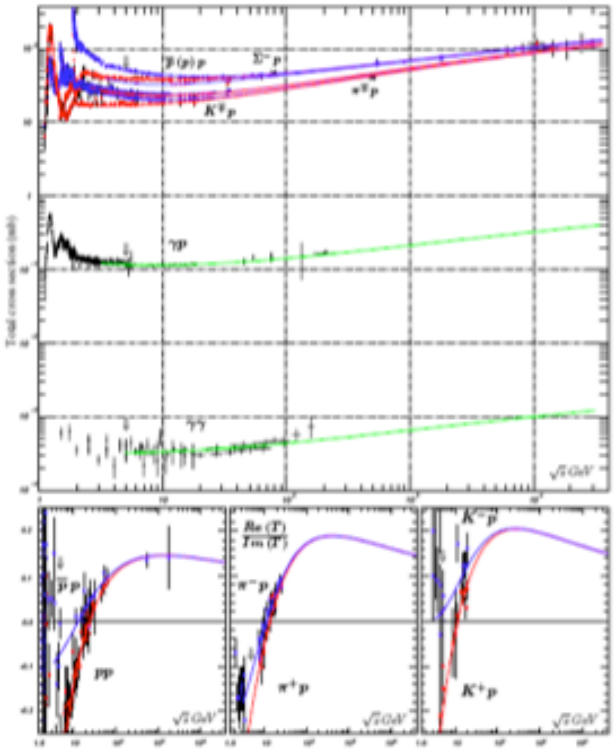


W dependence of $\sigma_{tot}(\gamma p)$

What does it mean soft?

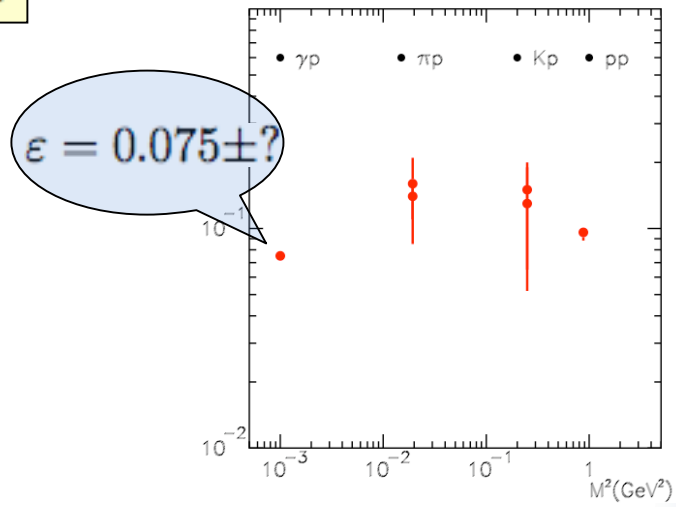
Donnachie Landshoff

$$\sigma_{tot}(h-h) = As^{\alpha_{IP}(0)-1} + Bs^{\alpha_{IR}(0)-1}$$
$$= As^{0.0808} + Bs^{-0.4525}$$

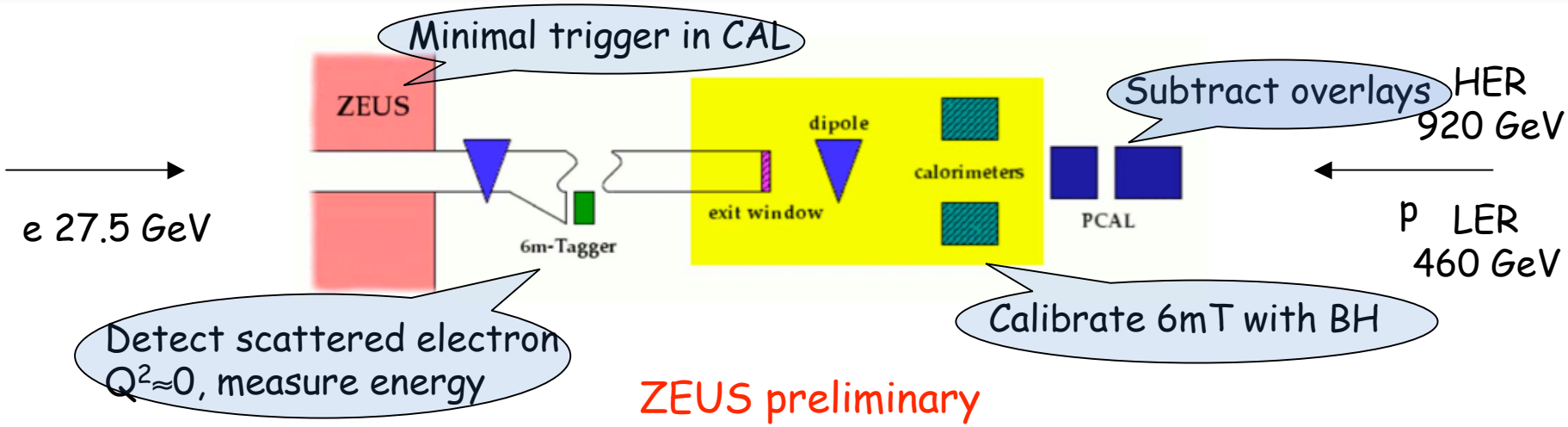


Cudell et al. (after rejecting some data)

$$\varepsilon = 0.096^{+0.012}_{-0.009}$$



W dependence of $\sigma_{tot}(\gamma p)$



ZEUS preliminary

$$R = \frac{\sigma^{\gamma p}_{HER}}{\sigma^{\gamma p}_{LER}} = \frac{N^{HER}_{evt}}{N^{LER}_{evt}} \cdot \frac{\mathcal{L}_{LER}}{\mathcal{L}_{HER}} \cdot \frac{f_{LER}}{f_{HER}}$$

Uncertainties:

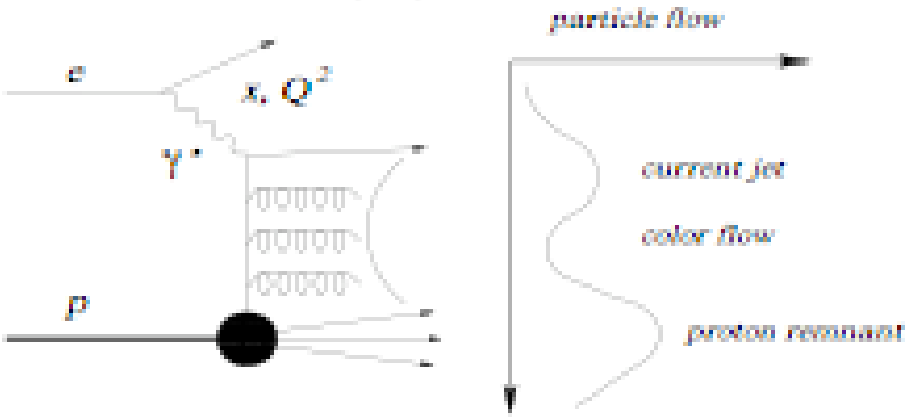
	±0.52% (stat.) ±1.05%(sys.)	±1%	±3.5%
from:	signal measurement	LUMI	tag6 (much room to improve!)

$$\varepsilon = 0.070 \pm 0.007(\text{stat.}) \pm 0.021(\text{syst.}) \pm 0.050(6\text{mT})$$

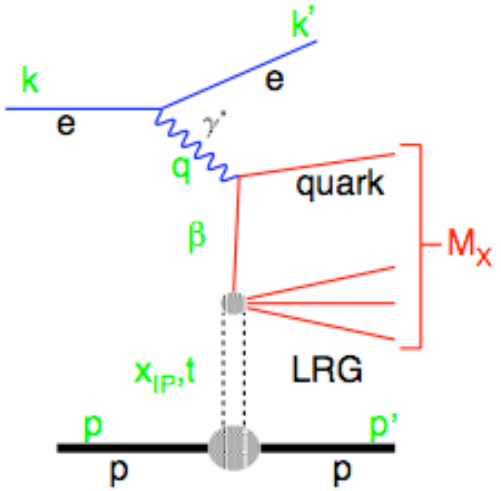
Inclusive diffraction

- Large fraction of DIS events have LRG (visible 10%)

DGLAP



$$Q^2 = -q^2 = -(k-k')^2$$
$$x = \frac{Q^2}{2P\cdot q}$$
$$y = \frac{q\cdot P}{k\cdot P}$$
$$W^2 = (q+P)^2$$

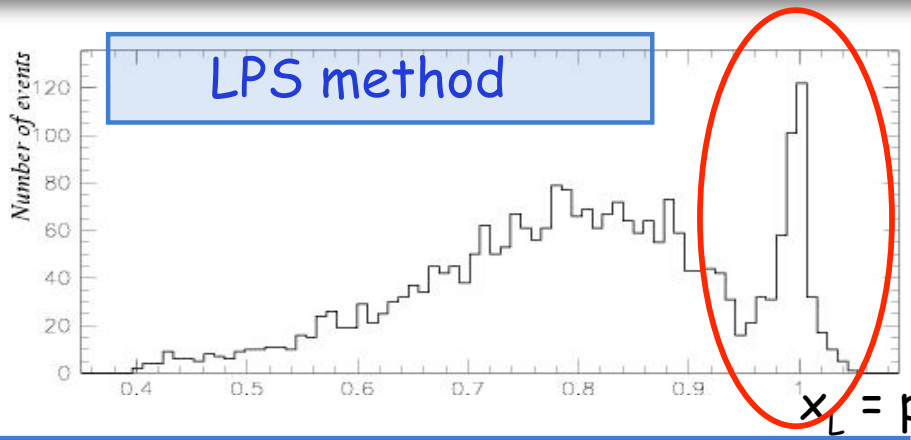


$$t = (p-p')^2$$
$$x_{I\!P} = \frac{q\cdot(p-p')}{q\cdot p} \simeq \frac{Q^2+M_X^2}{Q^2+W^2}$$
$$\beta = \frac{Q^2}{2q\cdot(p-p')} \simeq \frac{Q^2}{Q^2+M_X^2}$$

LRG cannot be generated by DGLAP.
Maybe it is there in the initial condition?

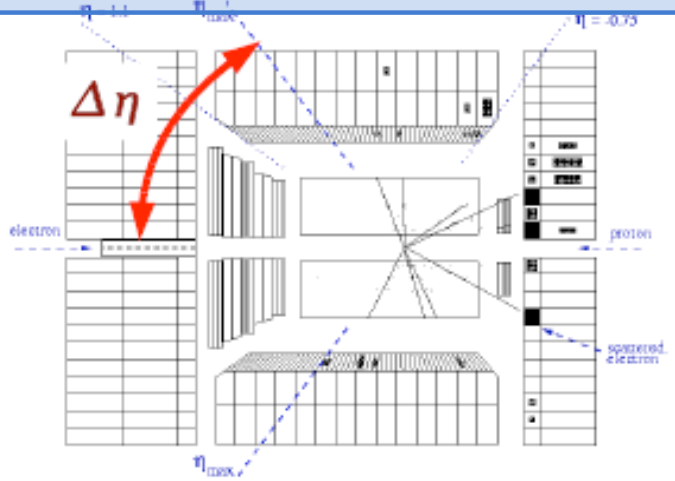
Inclusive diffraction - selection

LPS method



$x_L = p_z'/p_z$

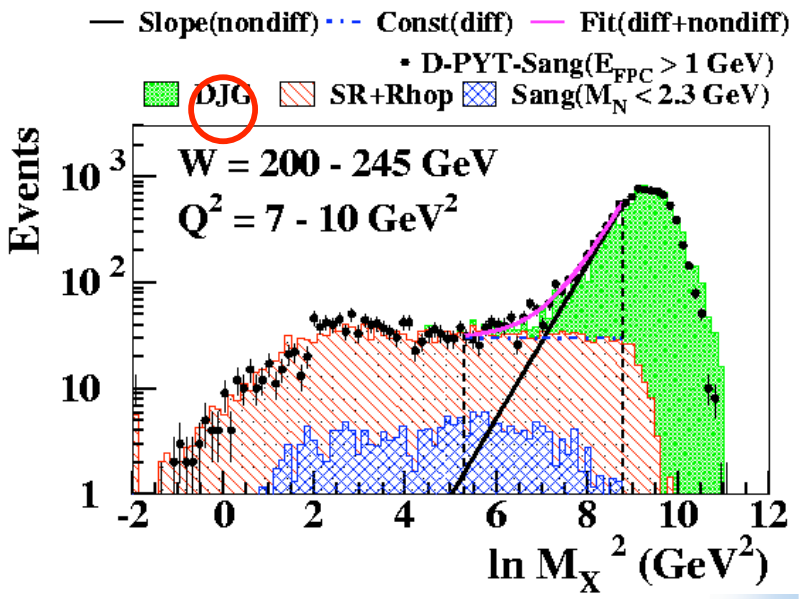
Large Rapidity Gap (LRG) method



Selection methods

Difference in proton dissociation and statistics

M_x method

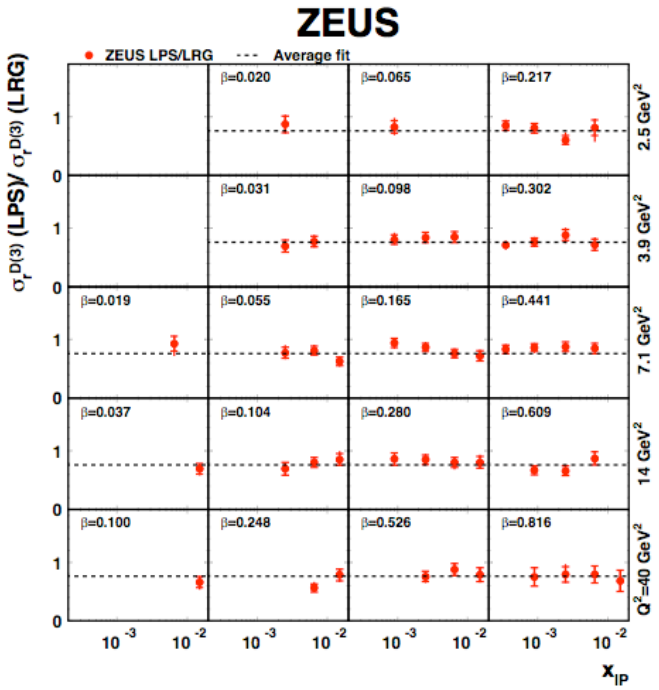


Inclusive diffraction - normalisation

LPS/LRG = 0.76 +-0.01(stat)
+0.03-0.02(sys) +0.08-0.05 (norm)

→ p-diss. background in LRG data:

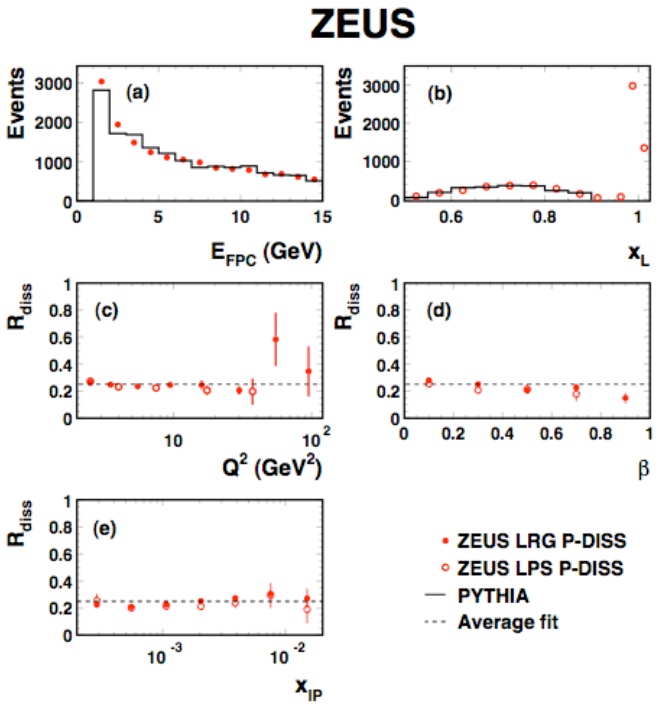
[24 +-1(stat) +2-3(sys) +5-8(norm)]%



Pythia tuned to FPC and LPS (x_L<0.90)

→ p-diss background in LRG data:

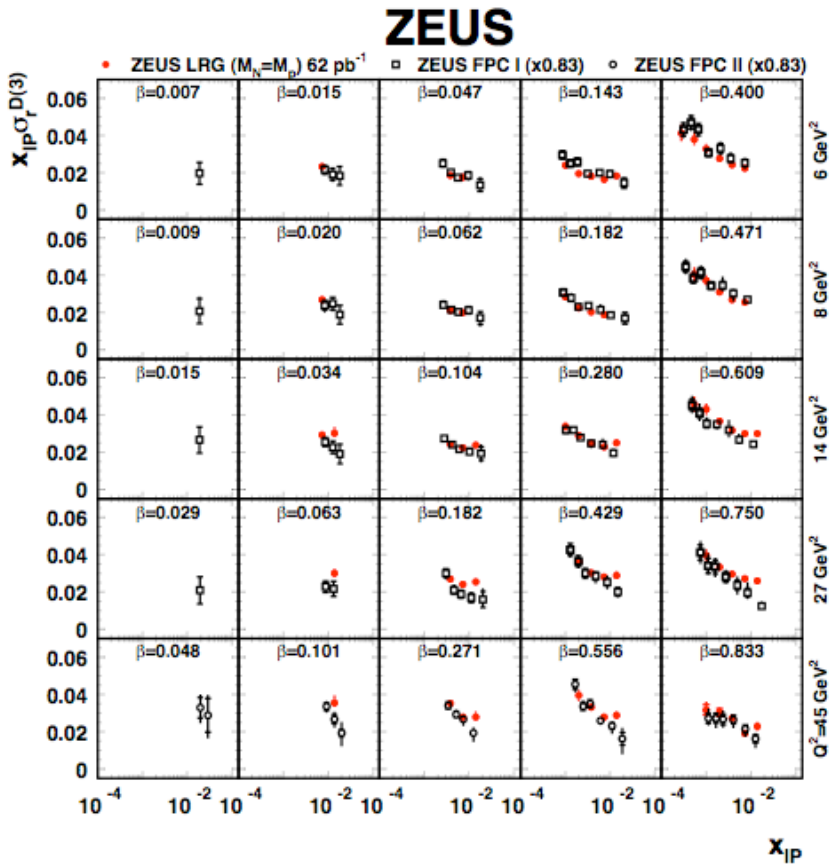
[25 +-1(stat) +-3(sys)]%

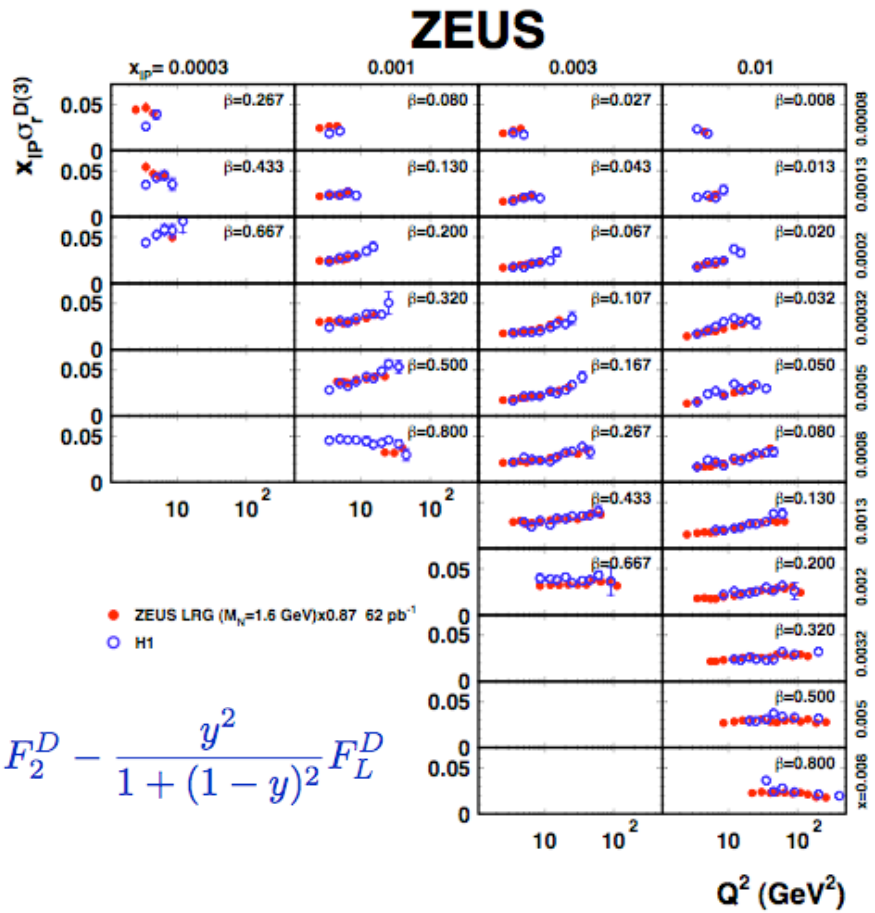


Inclusive diffraction - comparison

LRG(M_N=M_p)=M_X(M_N<2.3 GeV)· 0.83

H1=LRG (M_Y<1.6 GeV) · 0.87



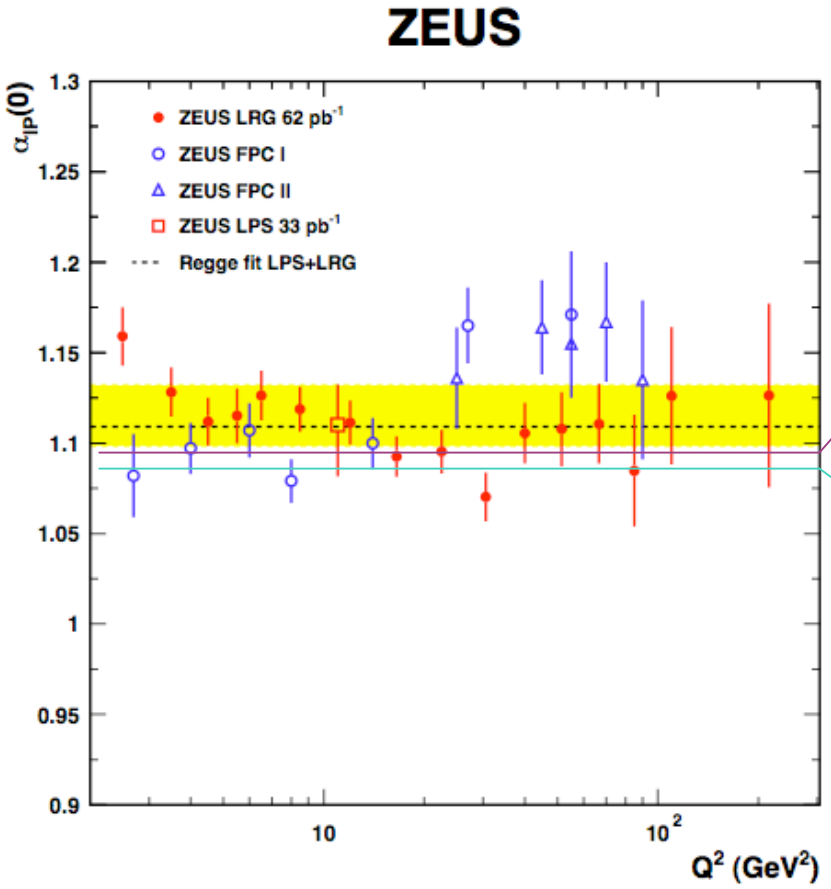


$$\tilde{\sigma} = F_2^D - \frac{y^2}{1+(1-y)^2} F_L^D$$

Inclusive diffraction in DIS soft vs hard

Inclusive diffraction in DIS comes out to be a soft phenomenon, even at large Q^2

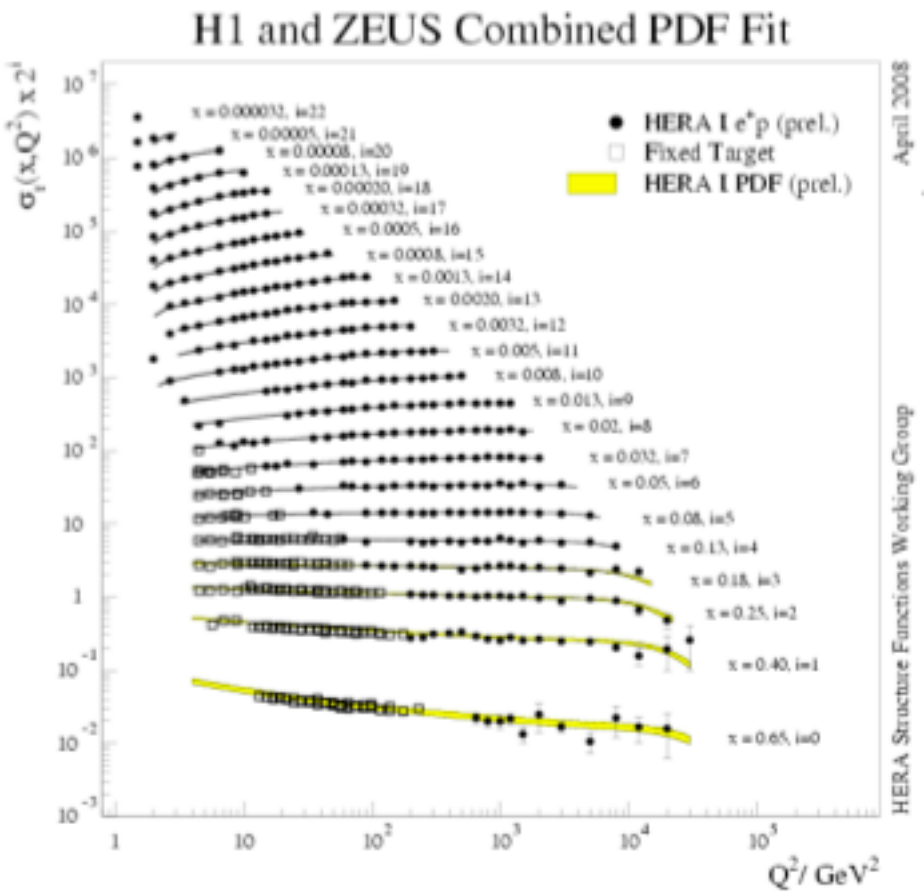
- LPS/LRG Regge fit
- W-dep. of σ^D

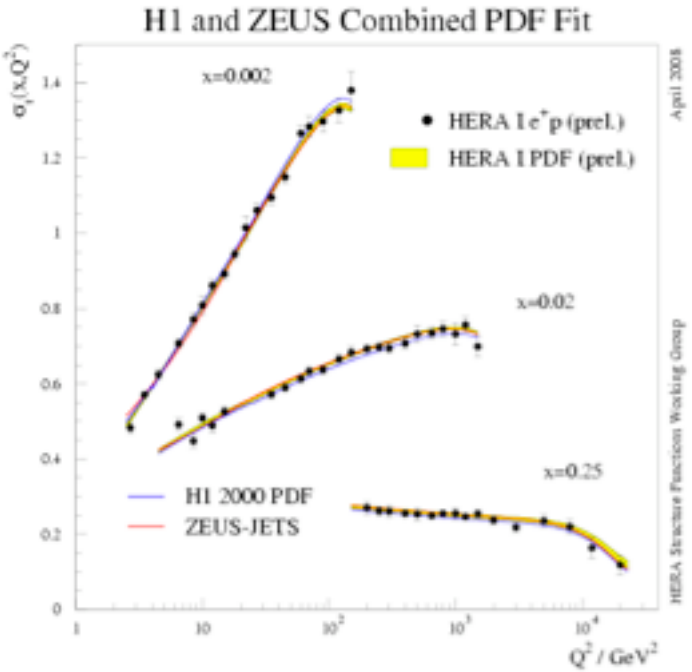


Cudell et al.

ZEUS(prel.)

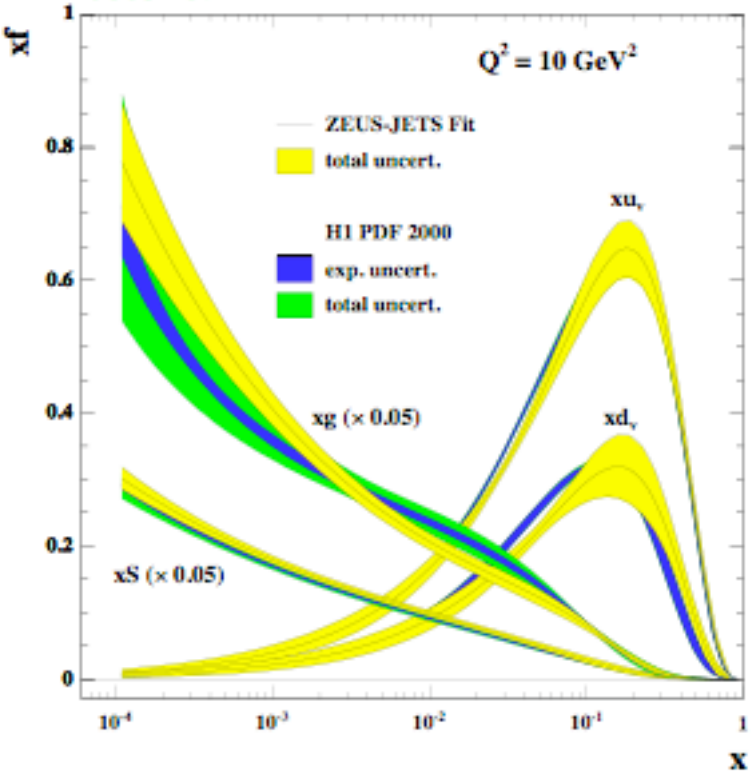
F_2 and PDFs - HERA I H1/ZEUS combined



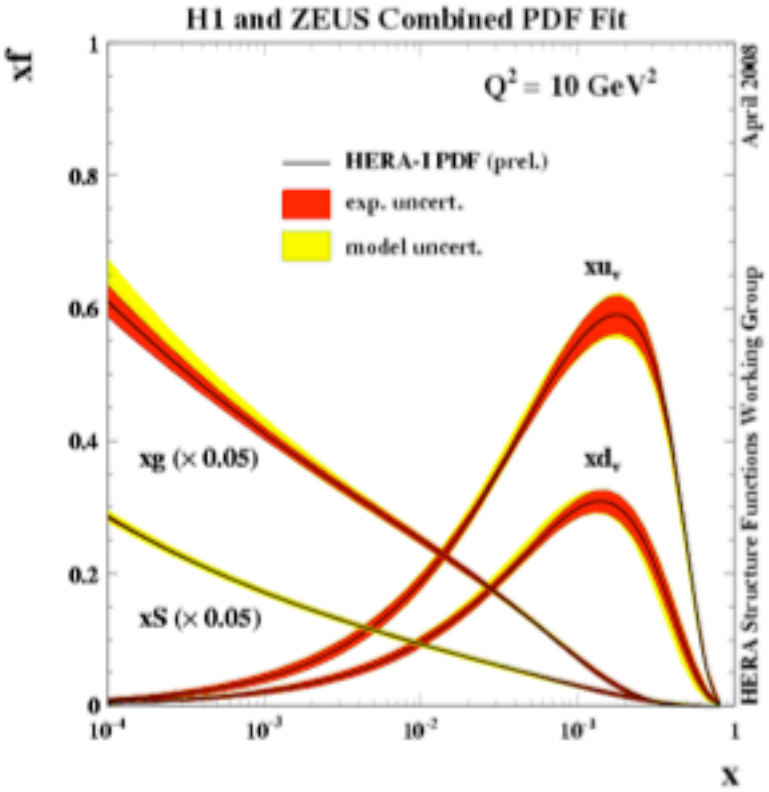


F_2 and PDFs - HERA I H1/ZEUS combined

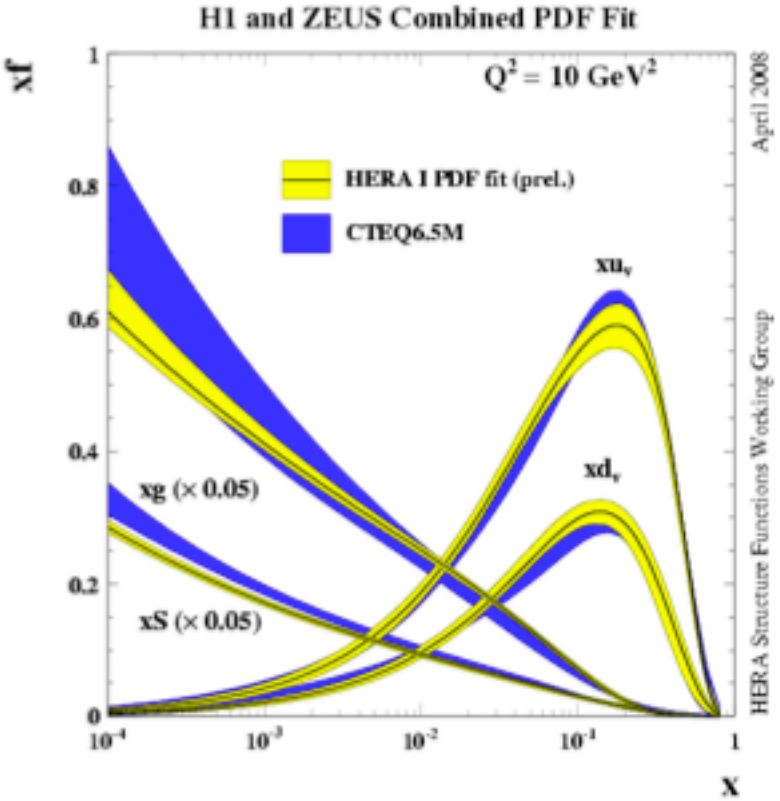
Note in published PDFs H1 has alphas variation included in model error, ZEUS does not.

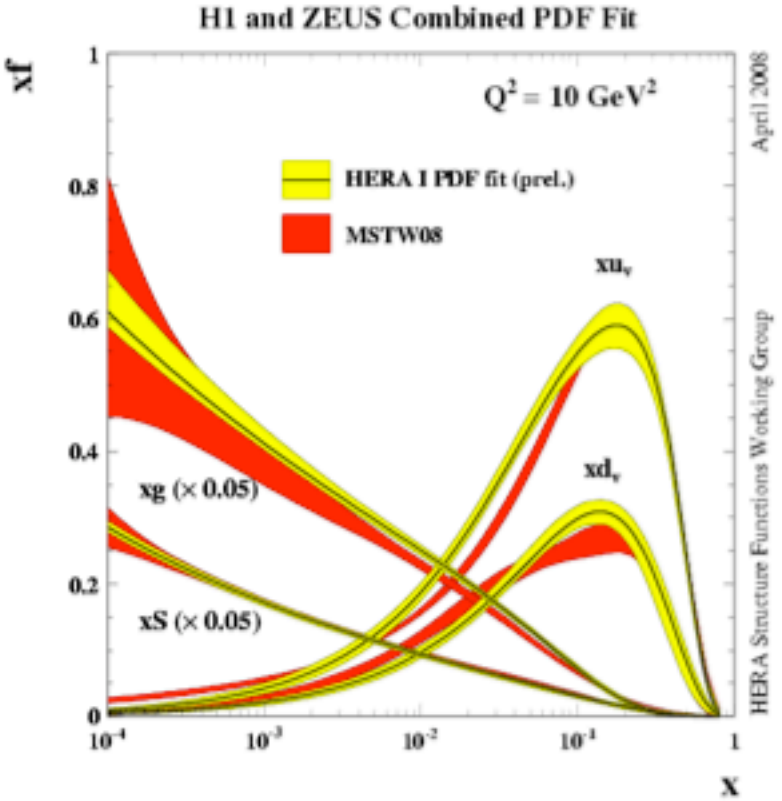


Systematic uncertainty greatly reduced when data combined



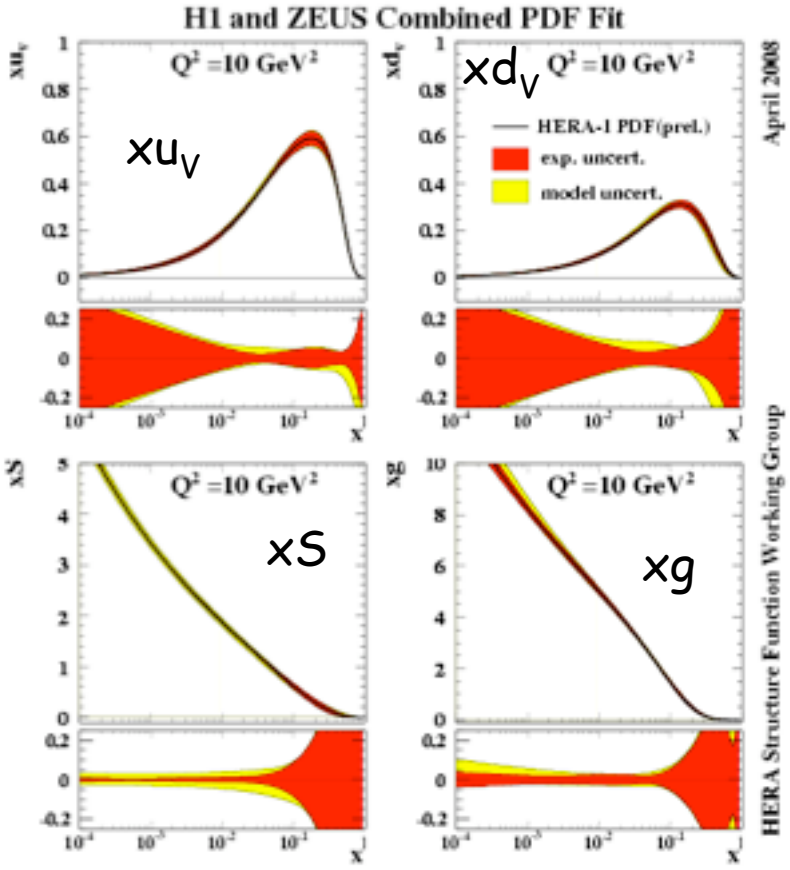
F_2 and PDFs - HERA I H1/ZEUS combined

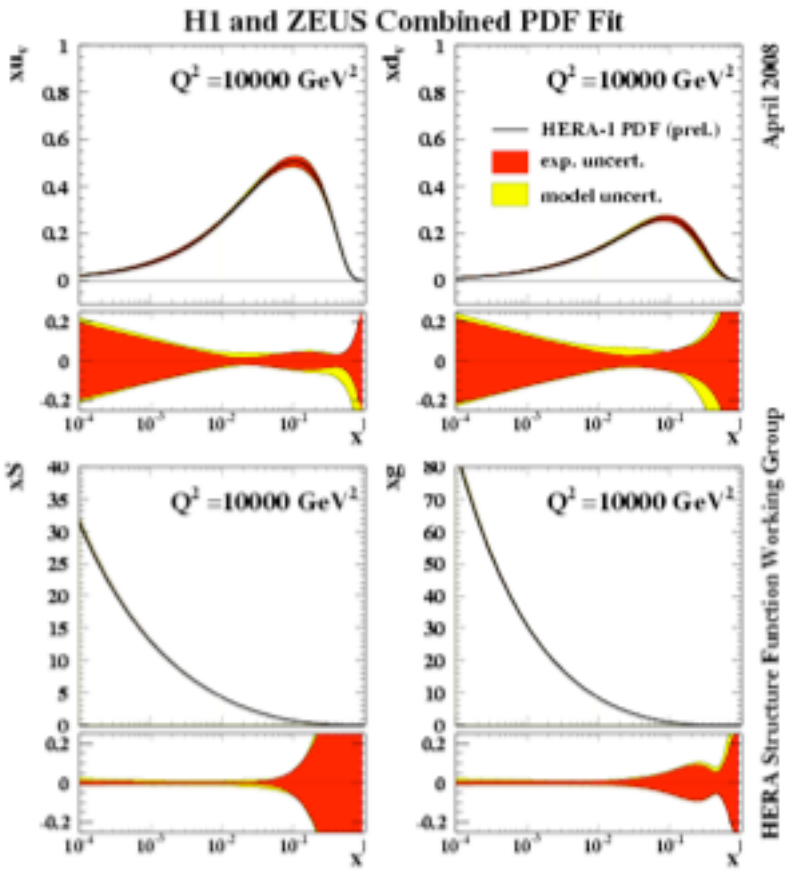




Note MSTW08 is as yet unpublished - a prerelease

F_2 and PDFs - HERA I H1/ZEUS combined

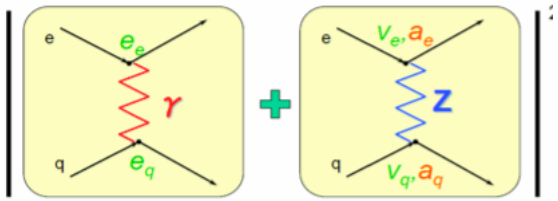




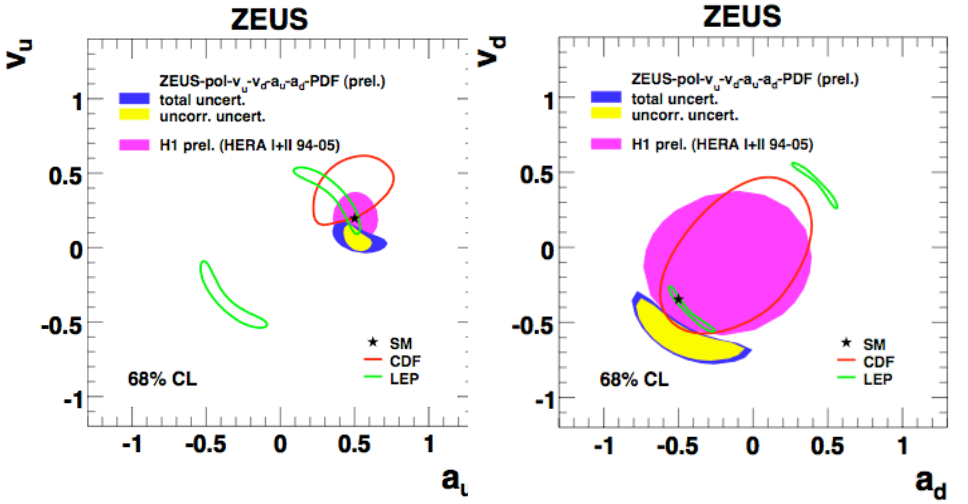
High Q^2 - a taste of future

Electroweak couplings of light quarks (using $e^-_{L,R}$)

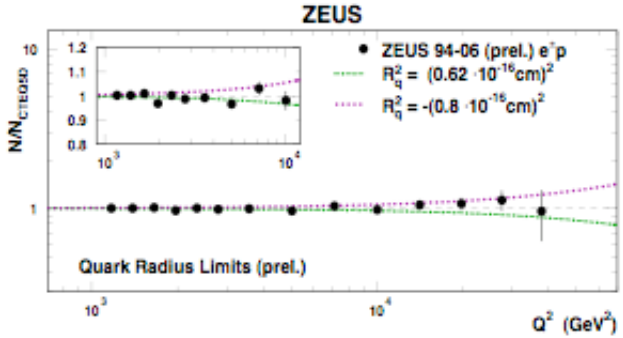
Light quark couplings to Z



Global QCD fit



ZEUS 1994-2006: e^-

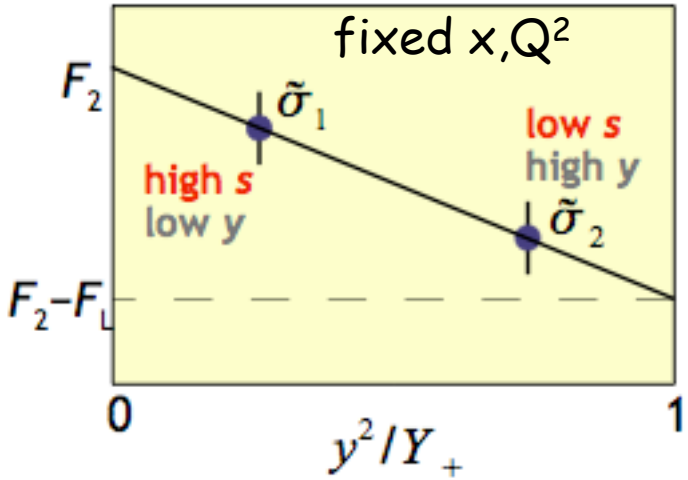


$R_q < 0.62 \cdot 10^{-16}$ cm

ZEUS limit on quark R_q<0.62 10^{-16} cm

LEP limit on electron R_e<0.28 10^{-16} cm

F_L - measurement principle



$$Y_+ = 1 + (1 - y^2)$$

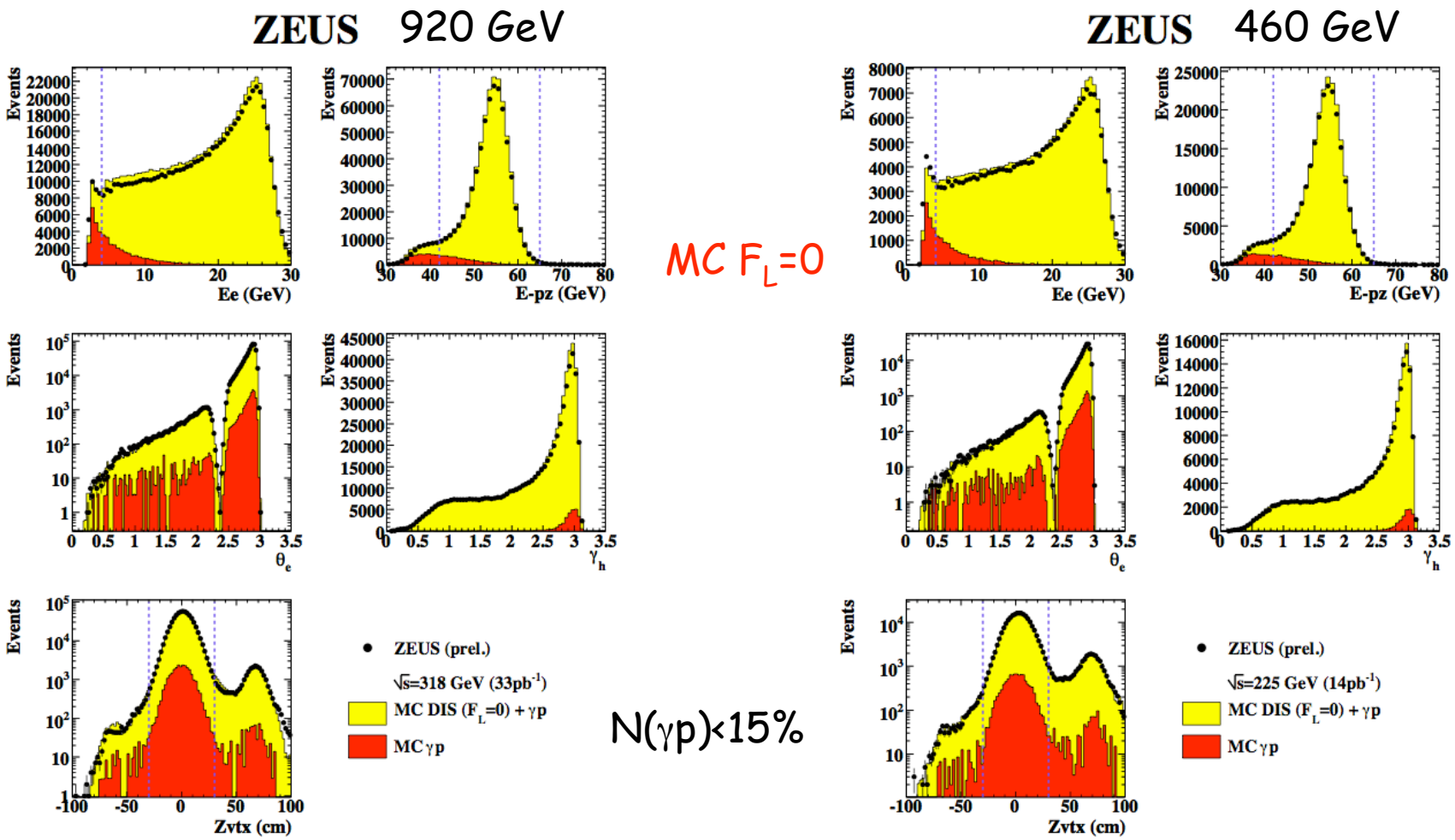
$$\tilde{\sigma}(x, Q^2) = F_2(x, Q^2) - \frac{y^2}{Y_+} F_L(x, Q^2)$$

$$F_L(x, Q^2) = \frac{\tilde{\sigma}_1(x, Q^2, y_1) - \tilde{\sigma}_2(x, Q^2, y_2)}{y_2^2/Y_{2+} - y_1^2/Y_{1+}}$$

High s - E_p=920 GeV
Low s - E_p=460 GeV
Medium s - E_p=575 GeV , not reported here

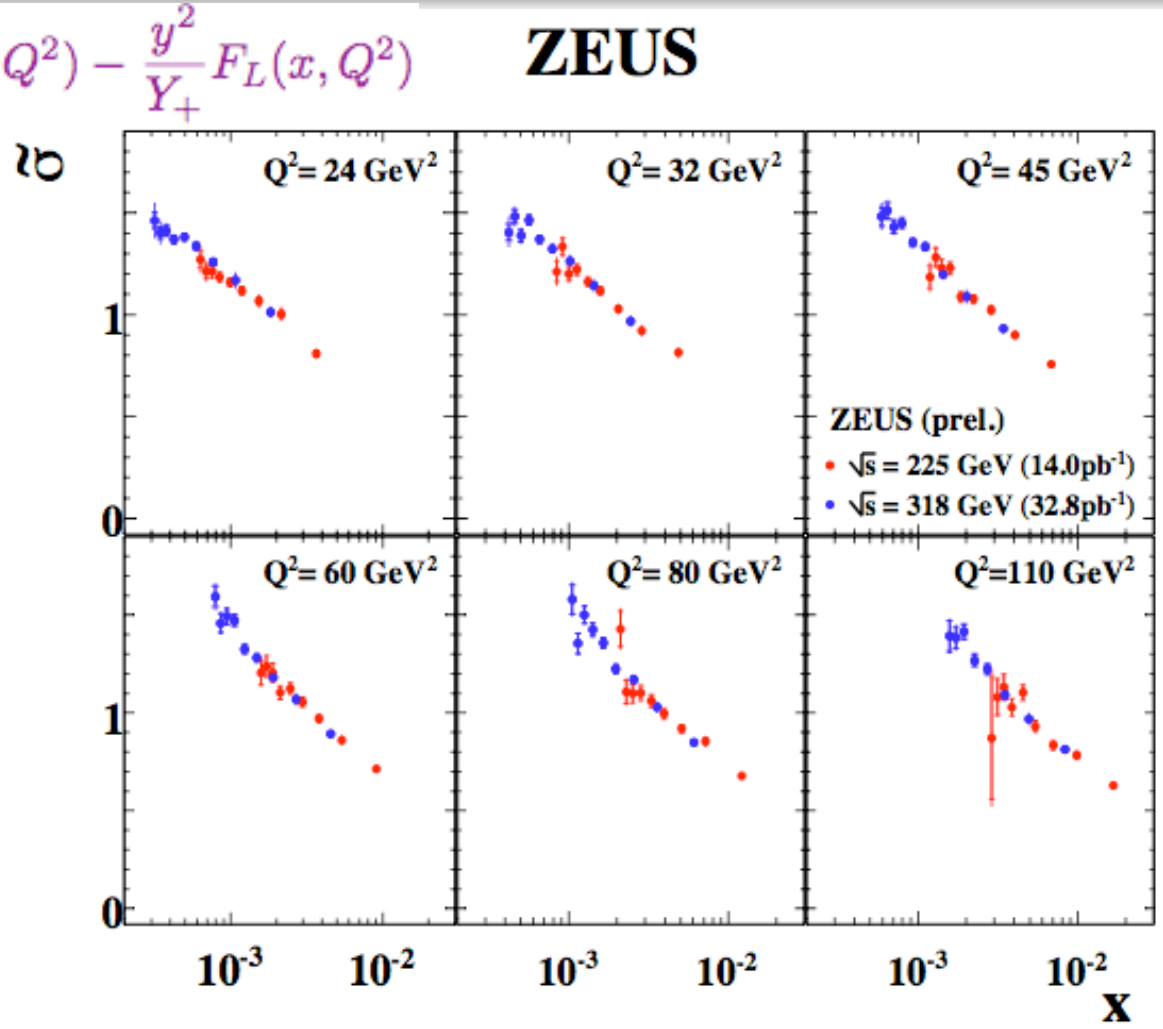
- Sensitivity to F_L requires high y
- Challenge - high y means low electron energy and large background from γp
- Need additional tools
  - use CTD/MVD hit information
  - use 6mT to normalise γp

F_L - control plots



Reduced cross section as a function of x, Q^2

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



Reduced cross section as a function of x,Q^2

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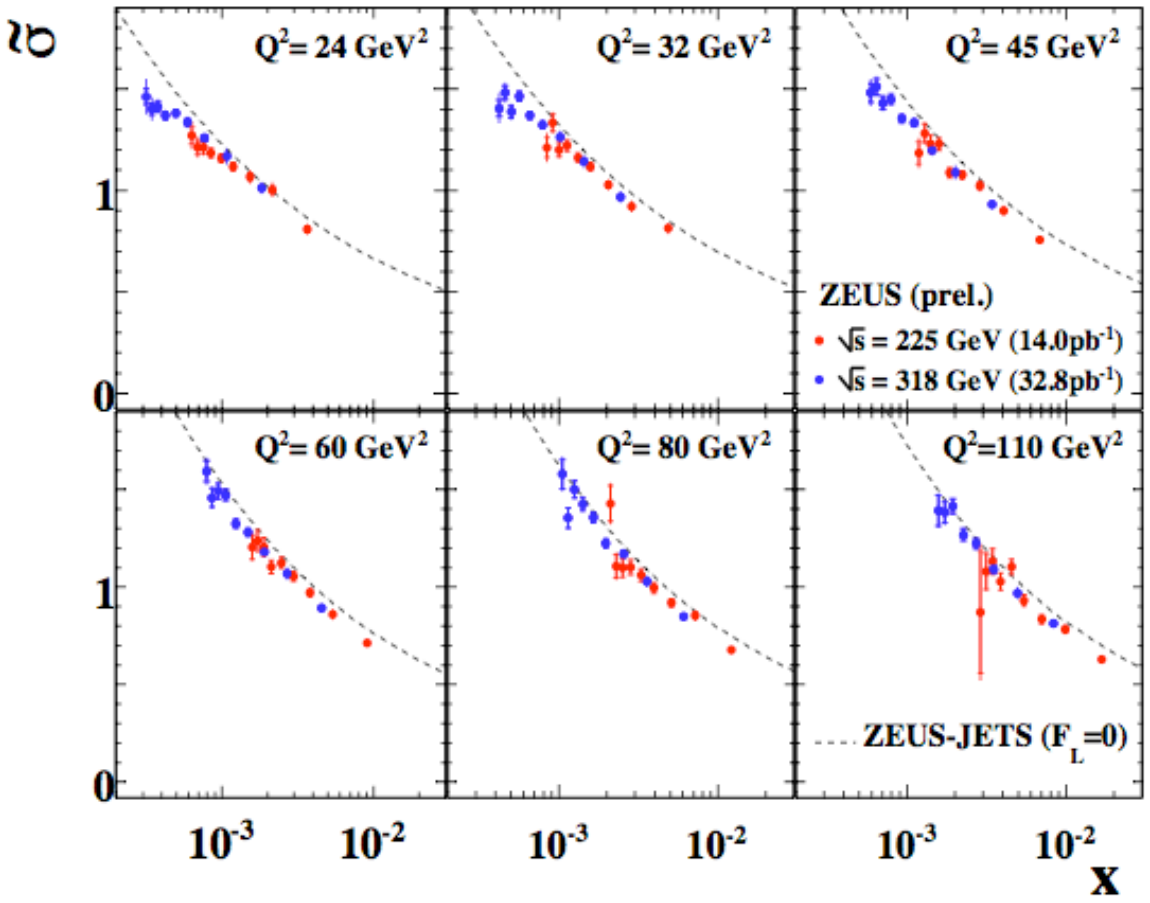
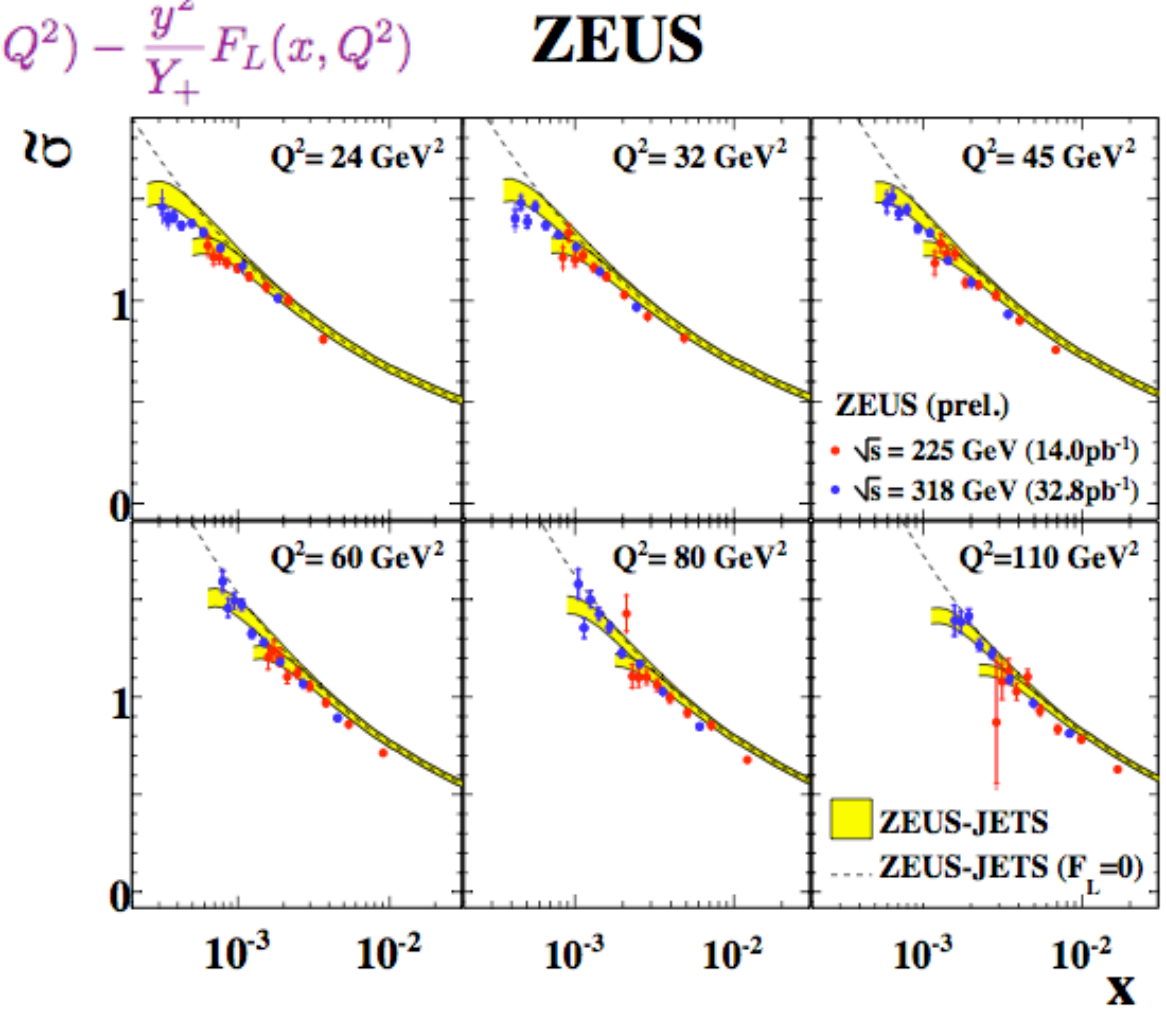
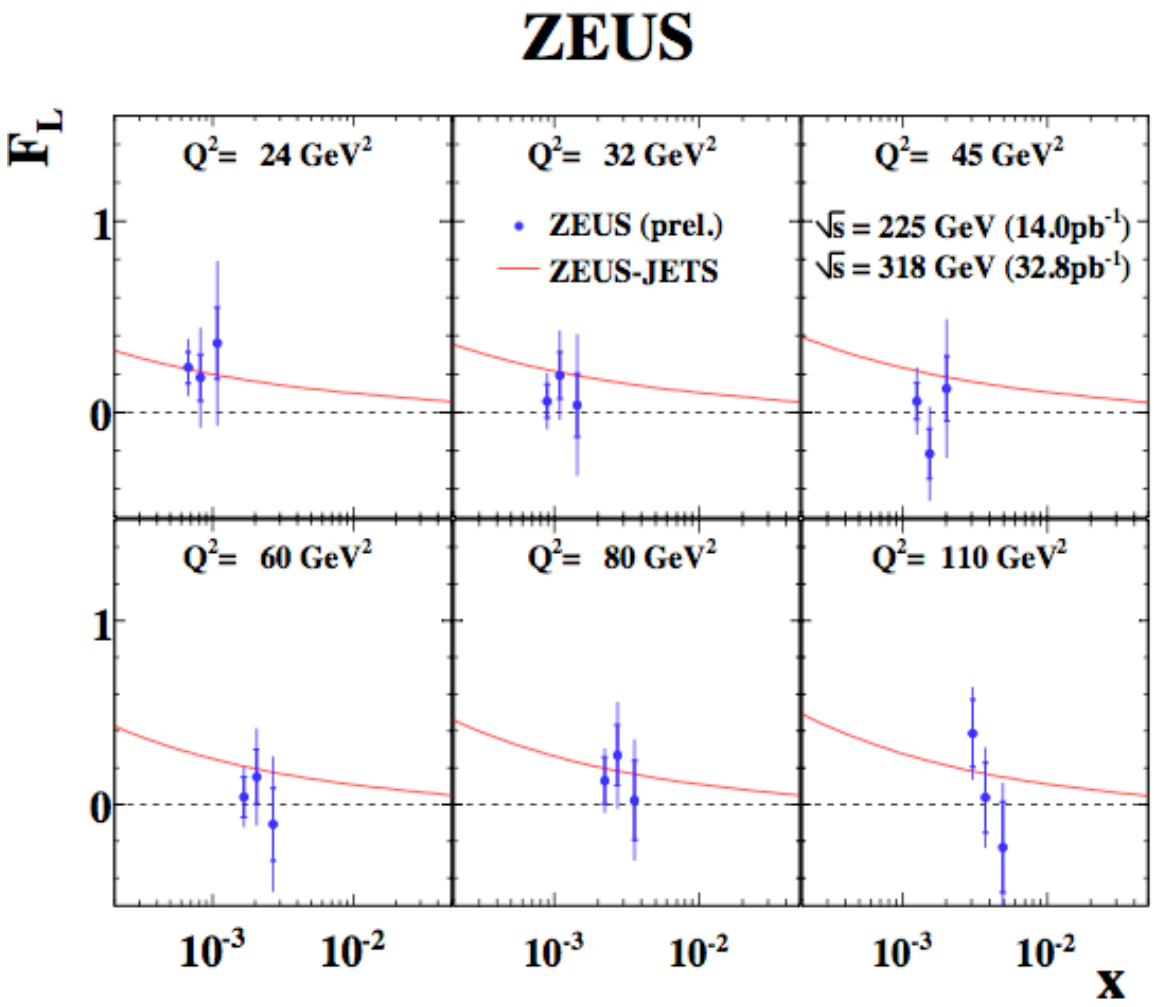


Reduced cross section as a function of x,Q^2

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



F_L


ZEUS
F_L
Q^2= 24 GeV^2
Q^2= 32 GeV^2
Q^2= 45 GeV^2
ZEUS (prel.)
ZEUS-JETS
$\sqrt{s}$ = 225 GeV (14.0pb^{-1})
$\sqrt{s}$ = 318 GeV (32.8pb^{-1})
Q^2= 60 GeV^2
Q^2= 80 GeV^2
Q^2= 110 GeV^2
1
0
1
0
10^{-3}
10^{-2}
10^{-3}
10^{-2}
10^{-3}
10^{-2}
x

Summary

Those are exciting times

Many more results and many more details
will be presented in the parallel sessions