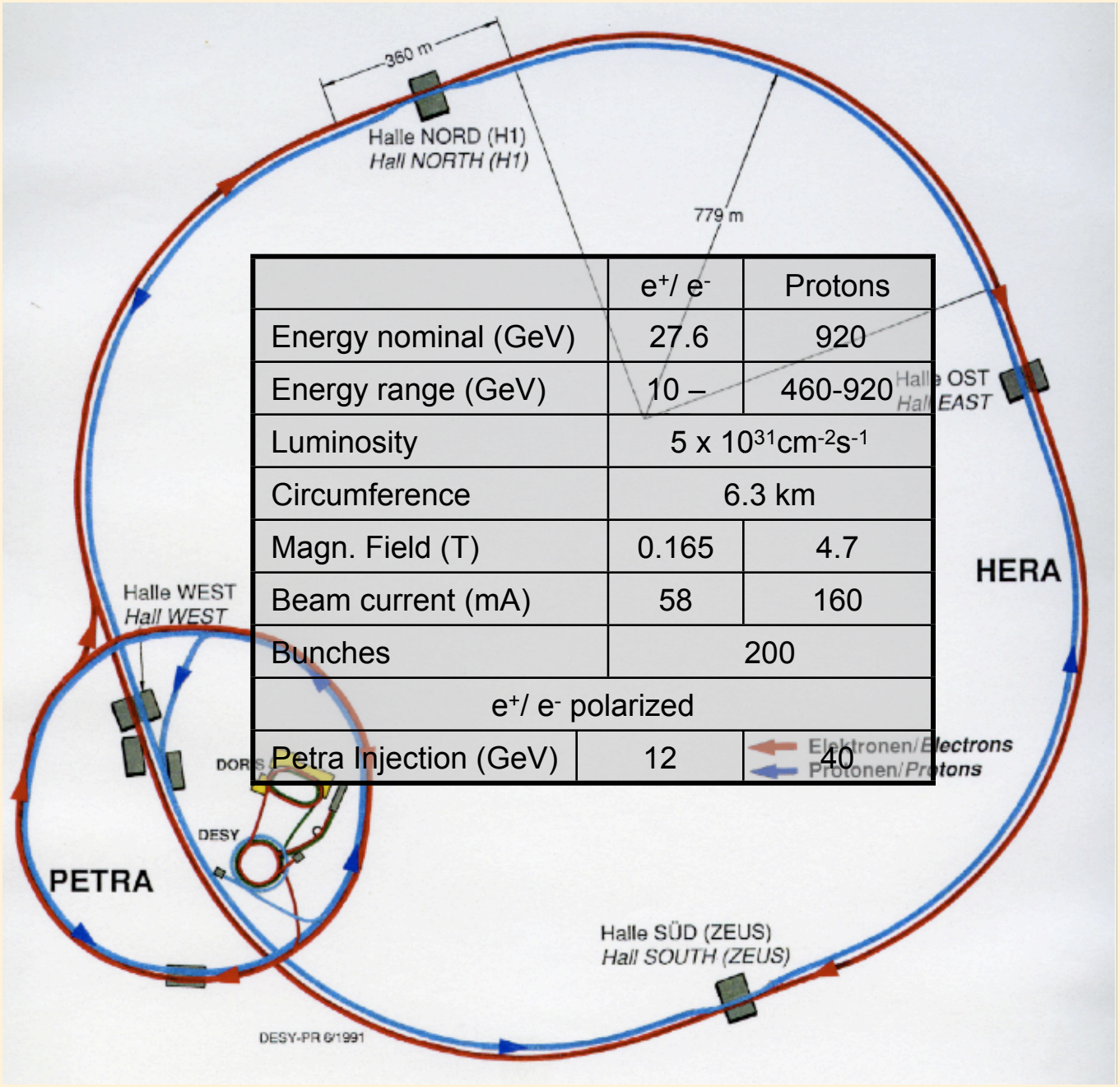
Recent results from HERA

QNP09

Tobias Haas/DESY

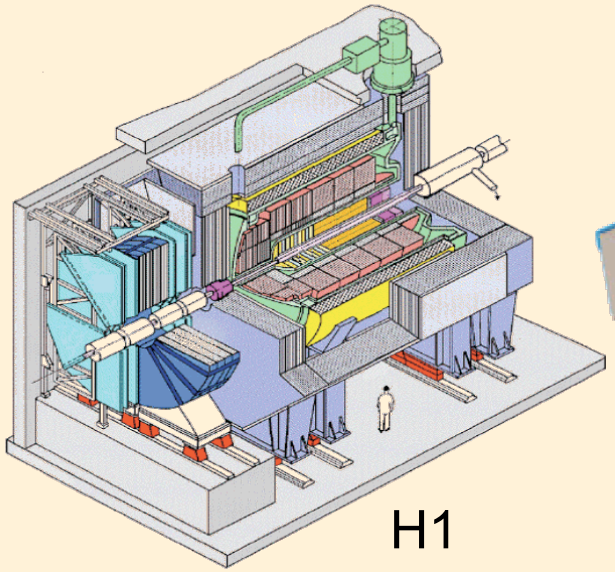

HERA
PETRA



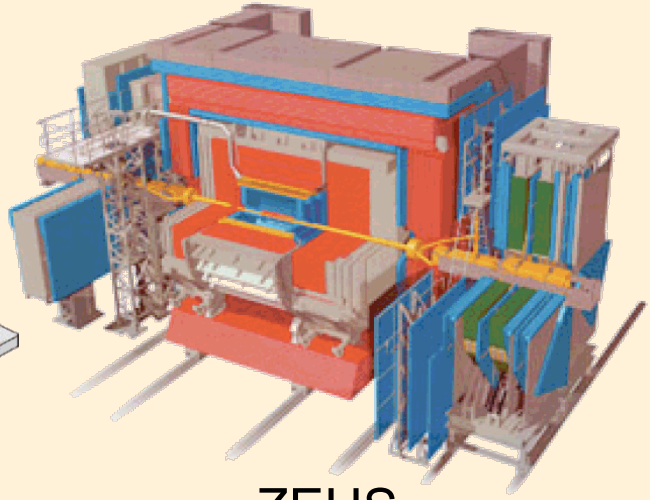
	e^+/ e^-	Protons
Energy nominal (GeV)	27.6	920
Energy range (GeV)	10 –	460-920
Luminosity	$5 \times 10^{31} cm^{-2} s^{-1}$	
Circumference	6.3 km	
Magn. Field (T)	0.165	4.7
Beam current (mA)	58	160
Bunches	200	
e^+/ e^- polarized		
Petra Injection (GeV)	12	40

HERA Detectors

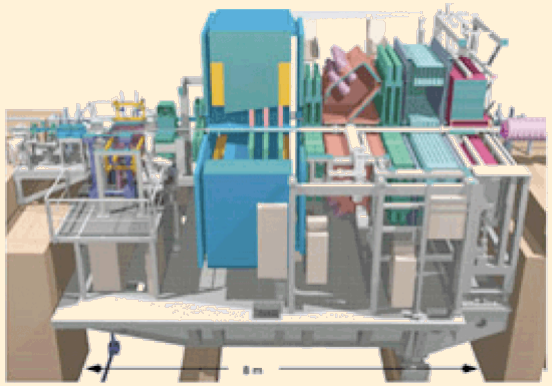
(~800 physicists)



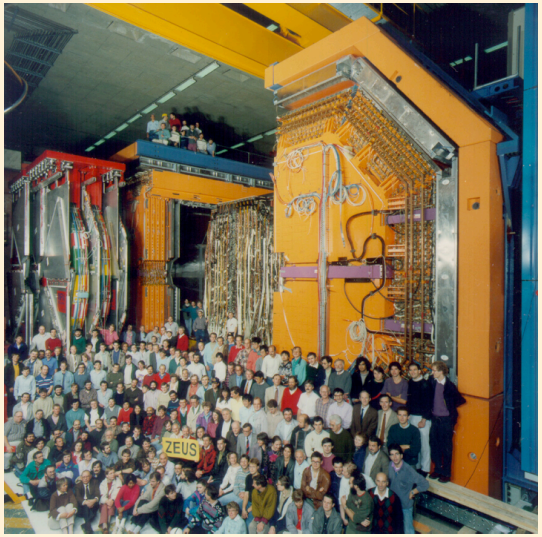
H1



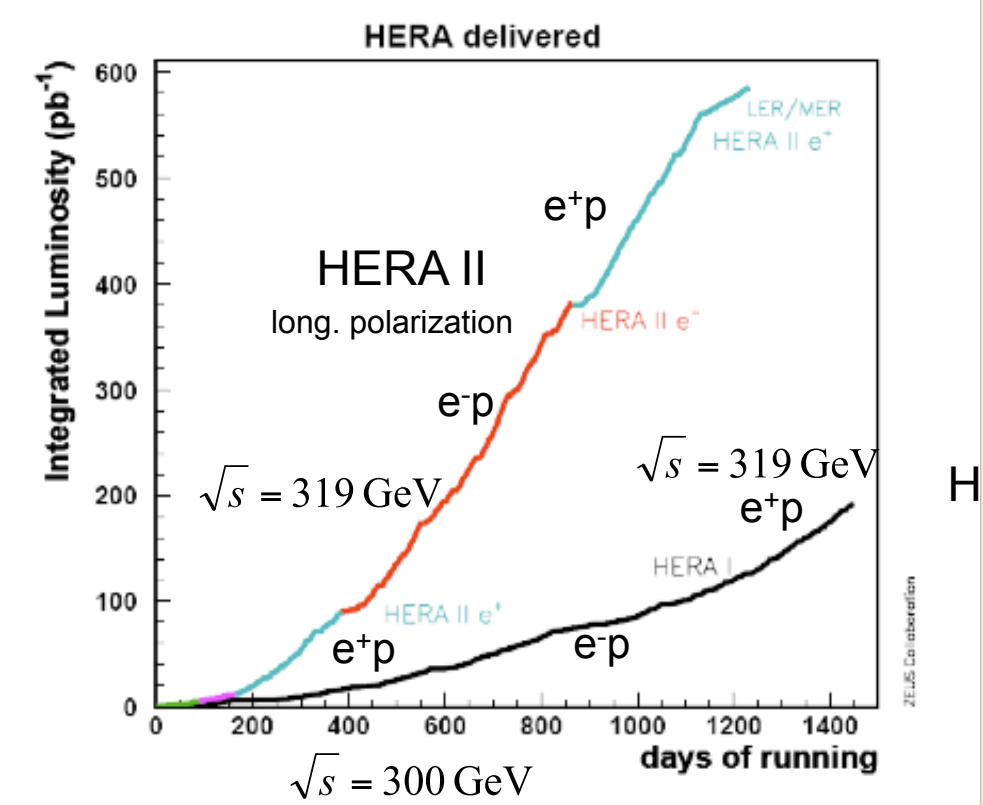
ZEUS



HERMES



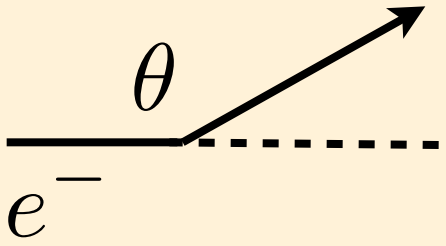
HERA Running: 1992 - 2007

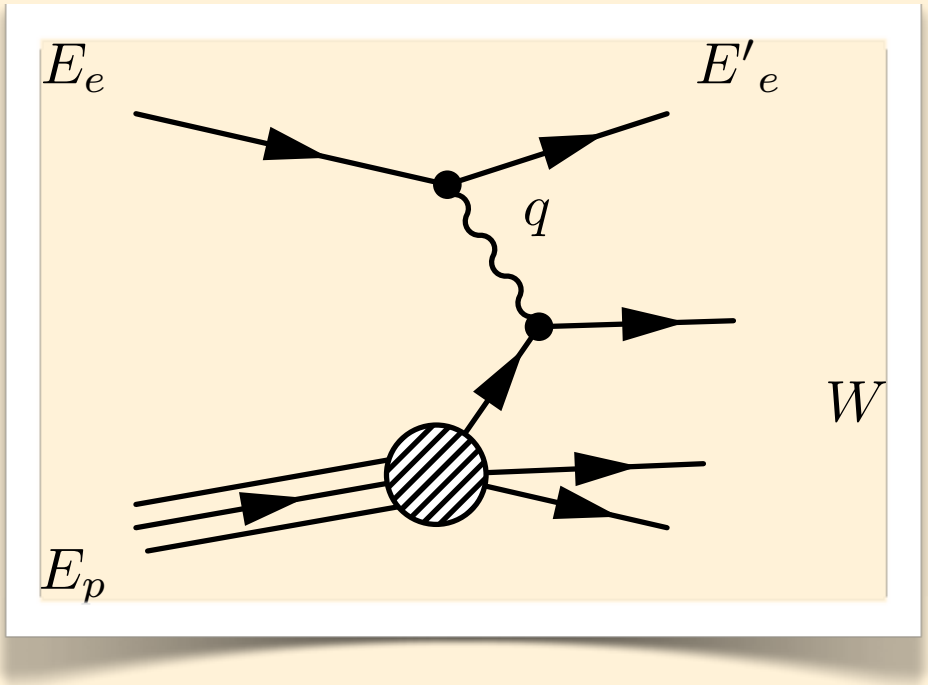


HERA I

- Luminosity: 0.8 fb^{-1} delivered/ 0.5 fb^{-1} gated
- ~ equal amounts of left and right-handed polarizations (30-40%)

DIS Basics





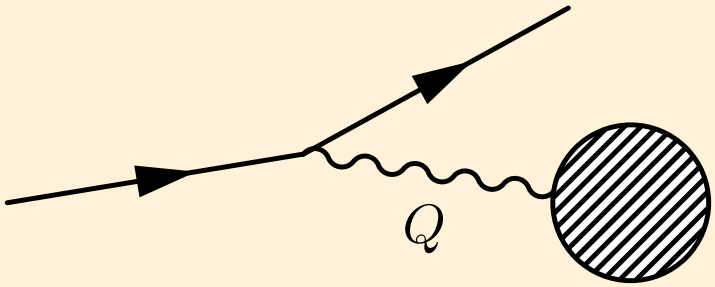
$$y = 1 - E'_e/E_e \sin^2(\theta/2) \quad \text{Inelasticity}$$

$$Q^2 = 2E_e E'_e \cos^2(\theta/2) \quad \text{Momentum transfer}$$

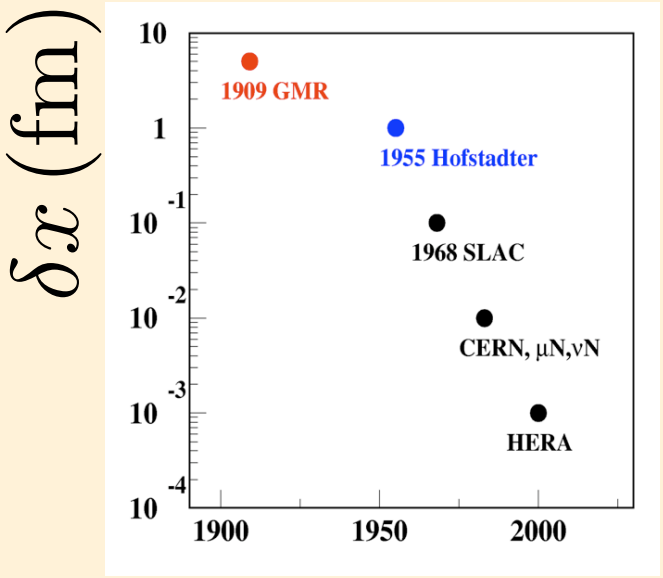
$$s = 4E_e E_p \quad \text{CMS energy}$$

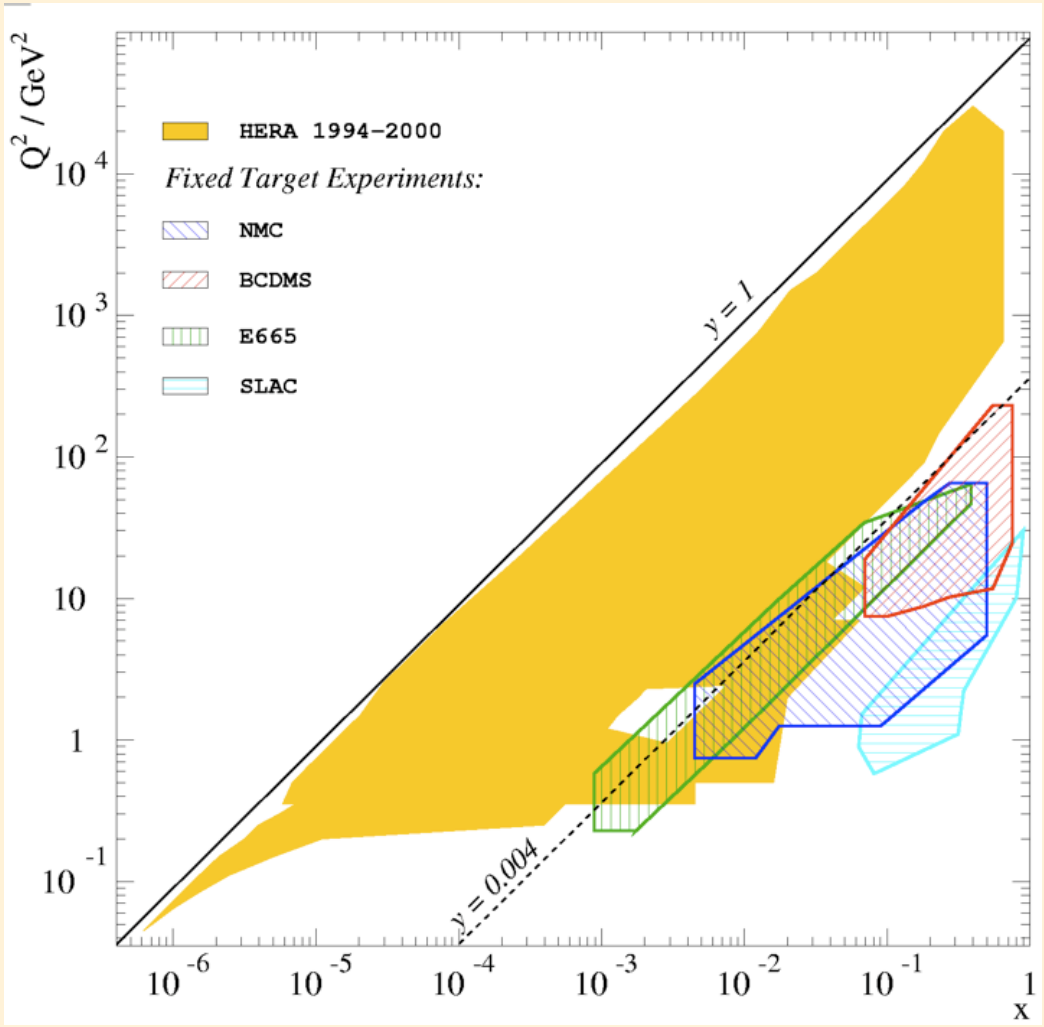
$$x_{Bj} = Q^2/sy \quad \text{Bjorken scaling var.}$$

HERA kinematic reach



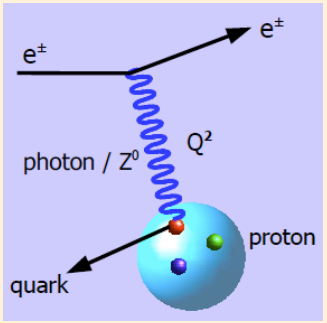
$$\delta x \approx \frac{200\mathrm{MeV}}{Q}$$



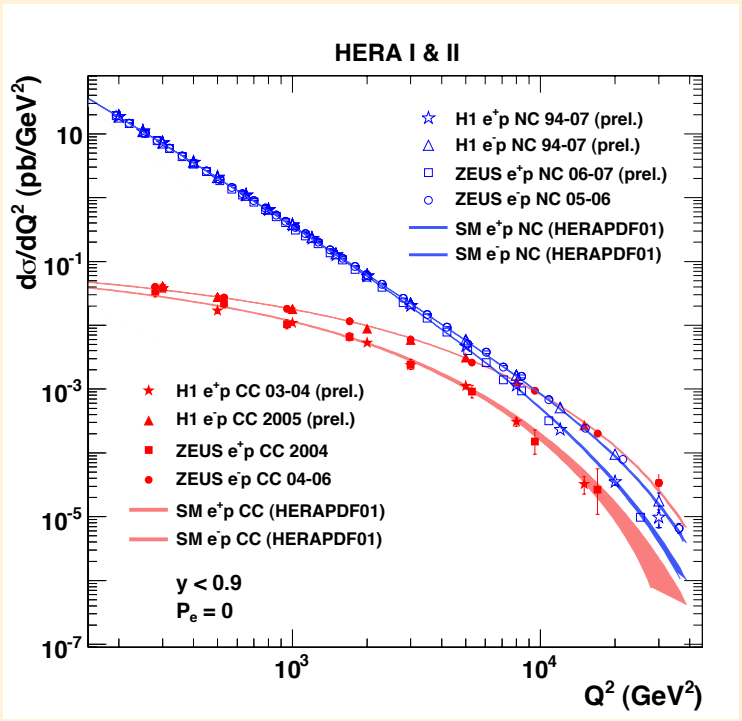


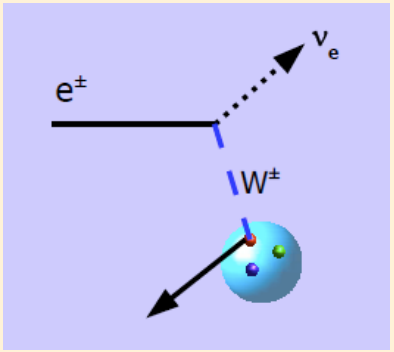
DIS at HERA

$$\frac{d^2\sigma(e^{\pm}p)}{dQ^2dx} = \frac{2\pi\alpha^2}{Q^4x}Y_+\left(F_2 - \frac{y^2}{Y_+}F_L \mp \frac{Y_-}{Y_+}xF_3\right)$$



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





$$\frac{d^2\sigma^{CC}(e^+p)}{dQ^2dx} = \frac{G_F^2}{2\pi}\left(\frac{M_W^2}{M_W^2+Q^2}\right)\left[\overline{u}+\overline{c}+(1-y)^2(d+s)\right]$$

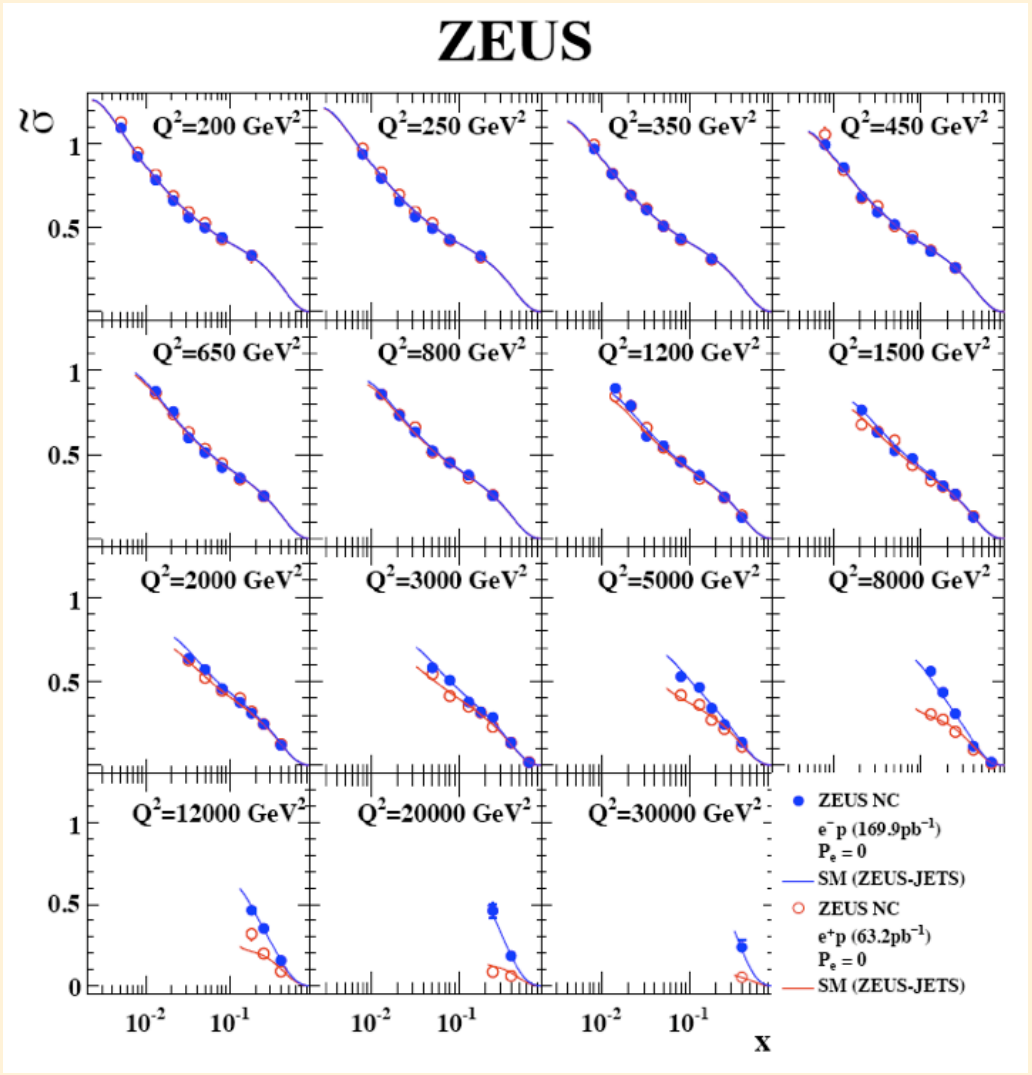
$$\frac{d^2\sigma^{CC}(e^-p)}{dQ^2dx} = \frac{G_F^2}{2\pi}\left(\frac{M_W^2}{M_W^2+Q^2}\right)\left[u+c+(1-y)^2(\overline{d}+\overline{s})\right]$$

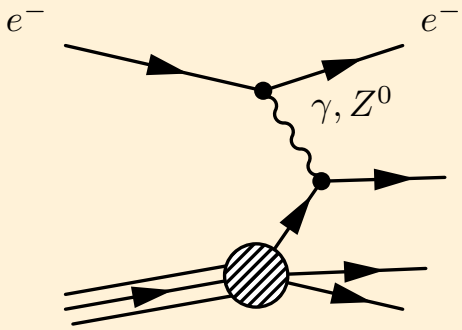
Recent results

- Polarized NC and CC cross sections
- Combined cross section and HERA PDFs
- Longitudinal structure function F_L
- Charm and Beauty production
- Glueball candidates

High Q^2 neutral currents

$$\tilde{\sigma} = F_2 - \frac{y^2}{Y_+} F_L \mp \frac{Y_-}{Y_+} xF_3$$

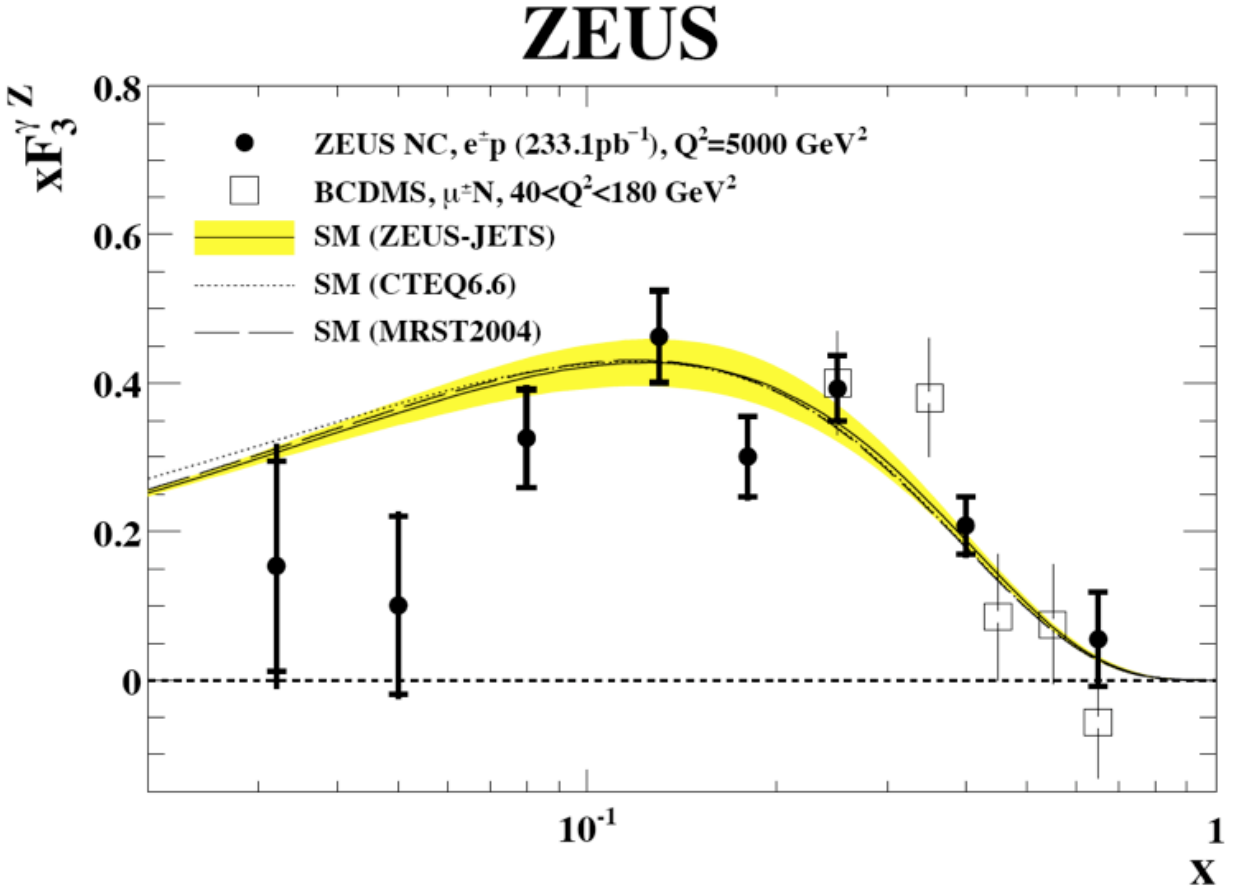




- e^- final results
- γ/Z^0 interference
- e^+ vs e^- $\Rightarrow$ xF_3

DESY-08-202

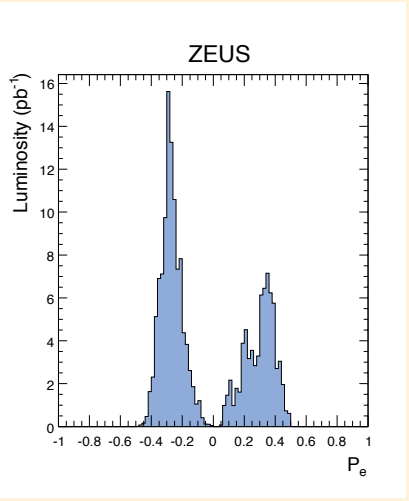
xF_3

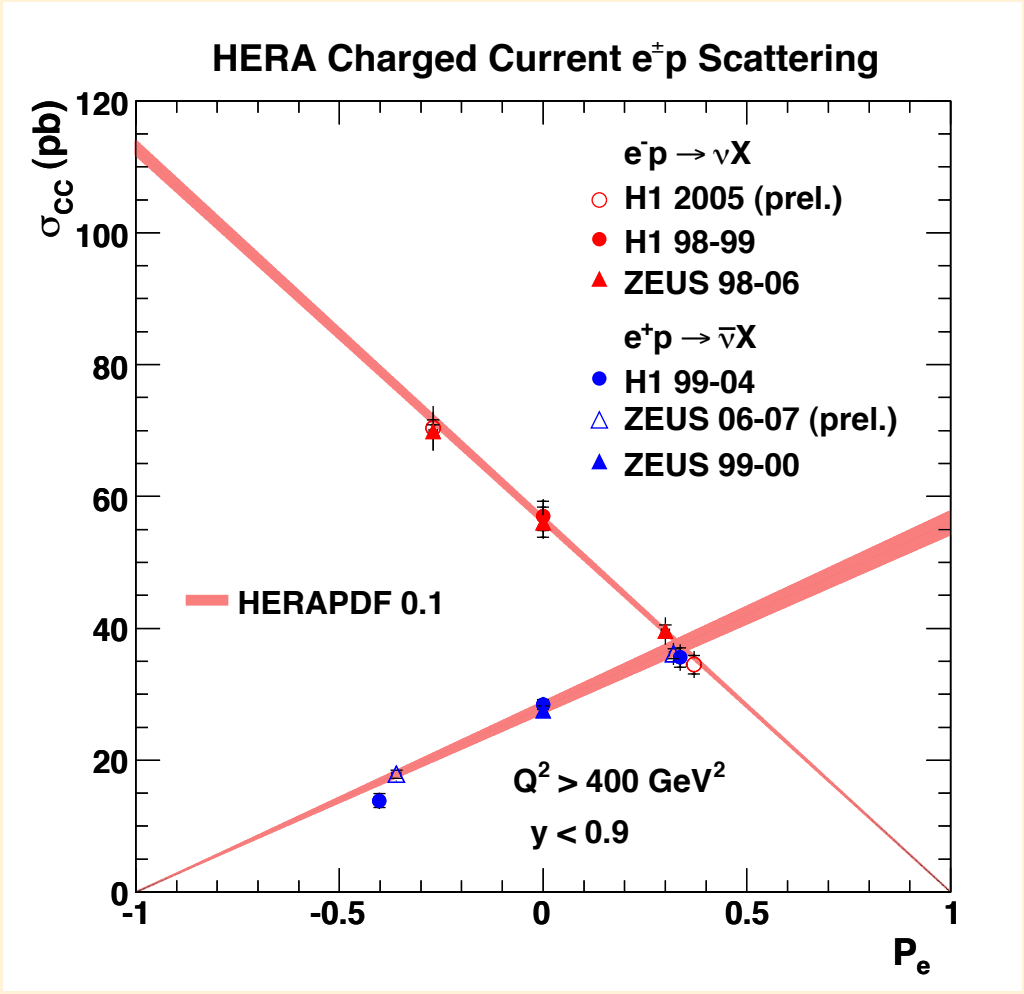


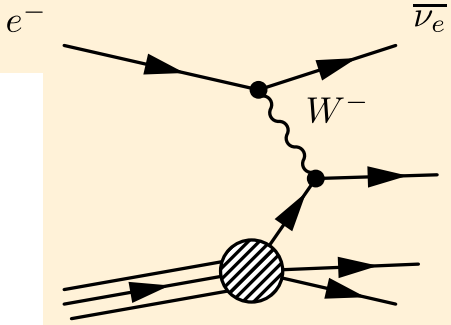
$$xF_3 \propto \sum_{i=u,d,\ldots} (q_i - \overline{q_i})$$

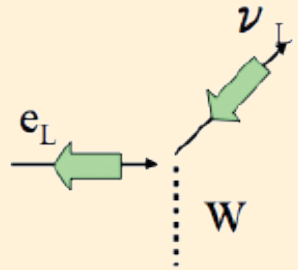
Valence quarks

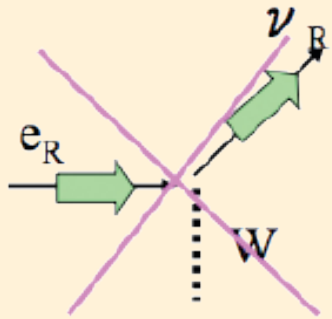
High Q^2 charged currents



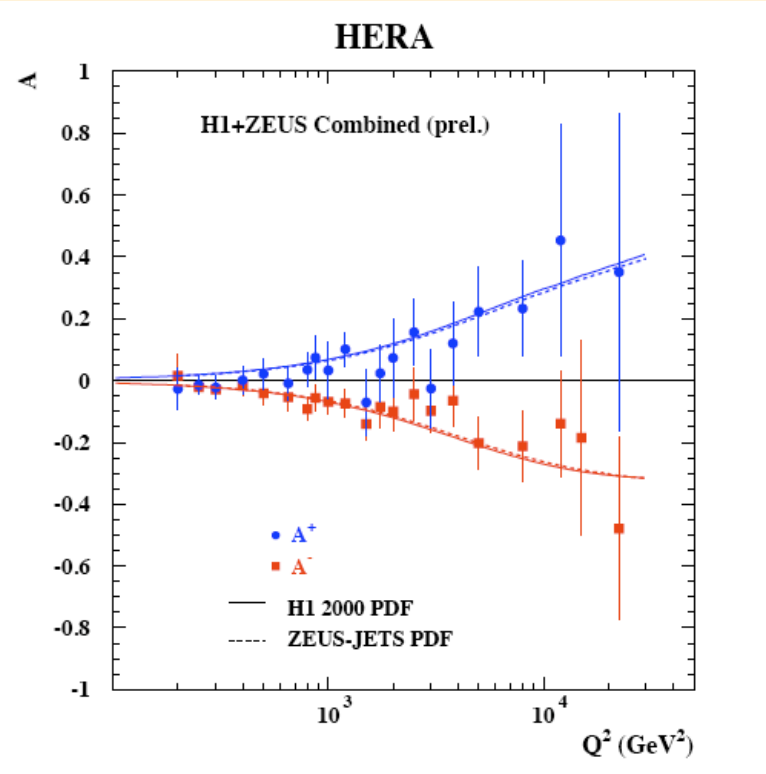






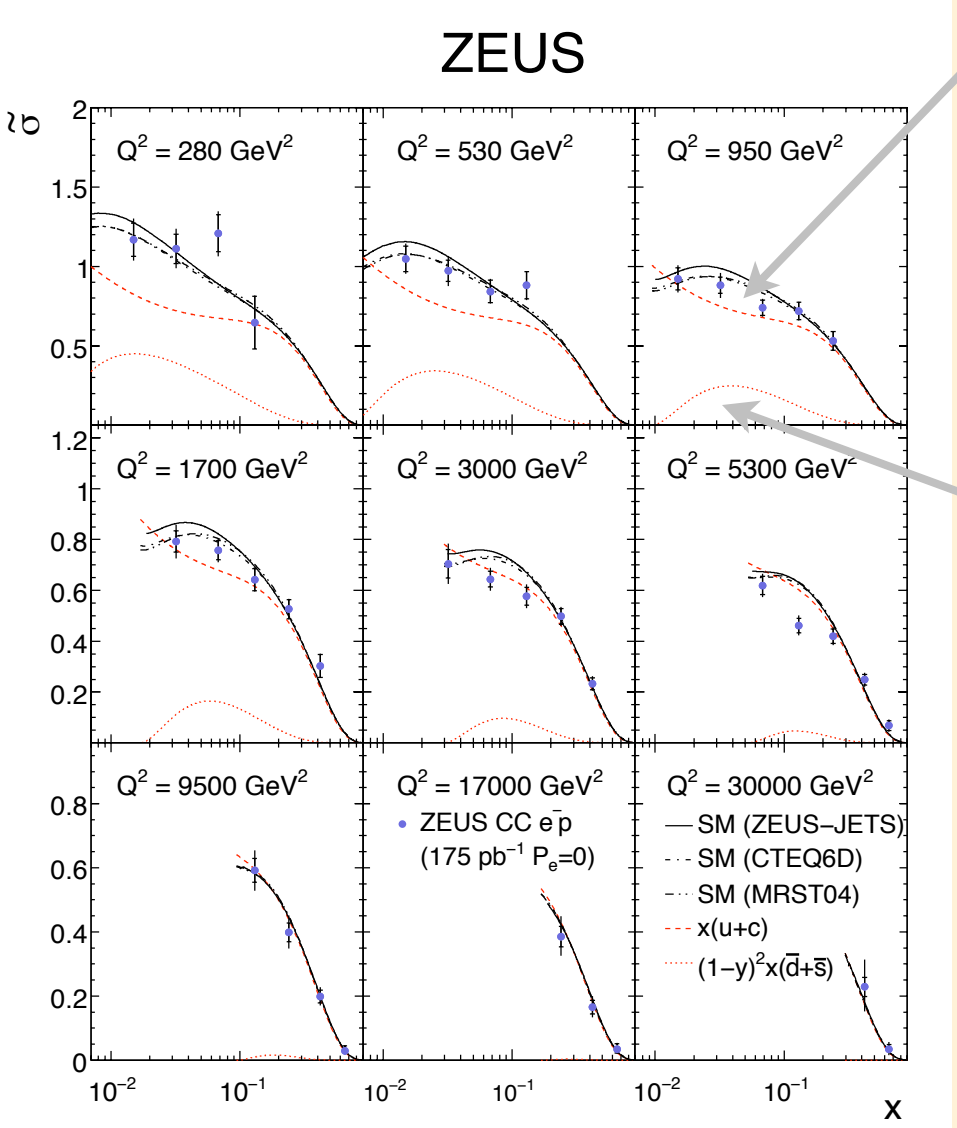


Parity violation in neutral currents



$$A^{\pm} = \frac{2}{P_R - P_L} \cdot \frac{\sigma^{\pm}(P_R) - \sigma^{\pm}(P_L)}{\sigma^{\pm}(P_R) + \sigma^{\pm}(P_L)} \simeq \mp k a_e \frac{F_2^{\gamma Z}}{F_2}$$

High Q^2 charged currents

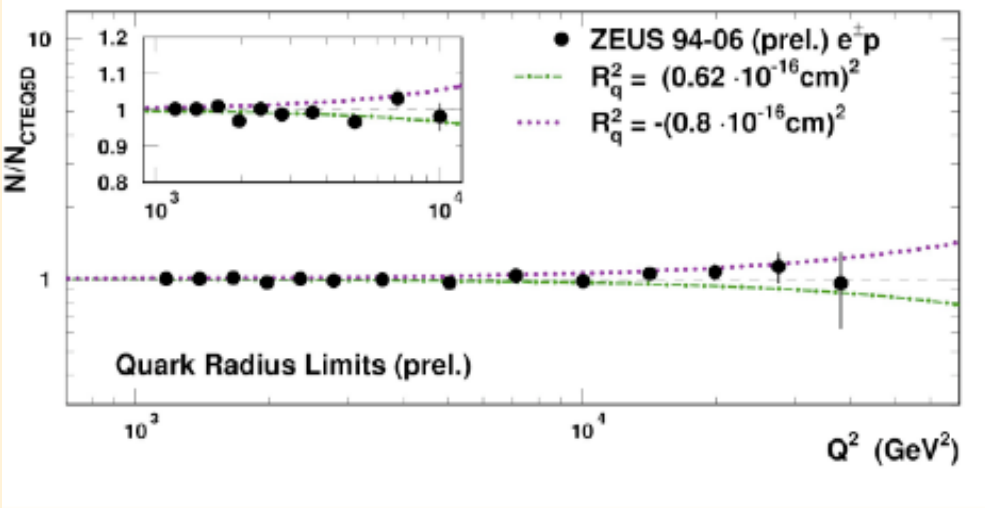


$u_v(x)$

$d_v(x)$

- flavor separation!

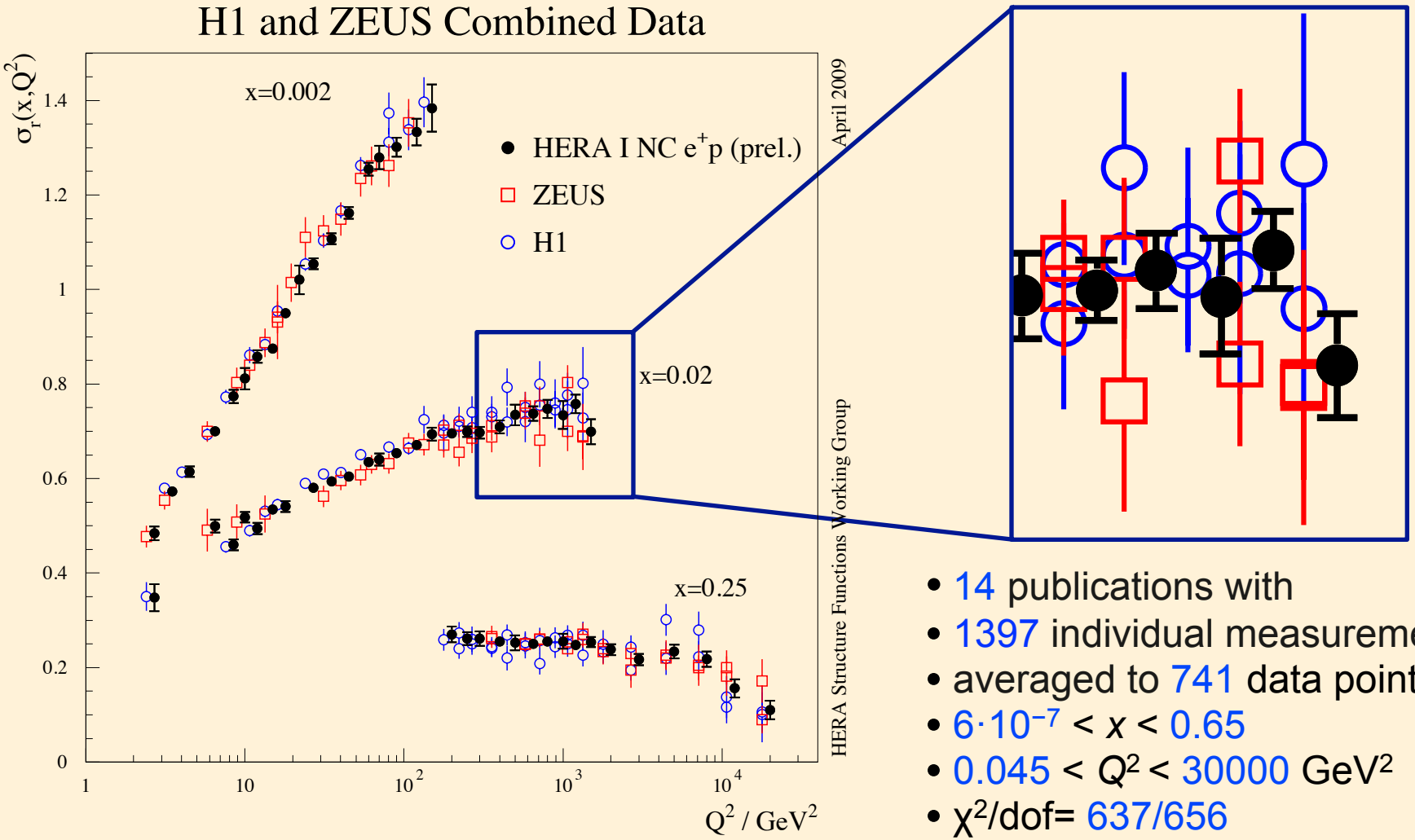
Deviations: quark radius



$$\frac{d\sigma}{dQ^2} = \frac{d\sigma^{SM}}{dQ^2} \cdot \left(1 - \frac{R_q^2}{6} Q^2\right)$$

$R_Q < 0.6 \times 10^{-18}$ m (1/1000 of the proton radius)

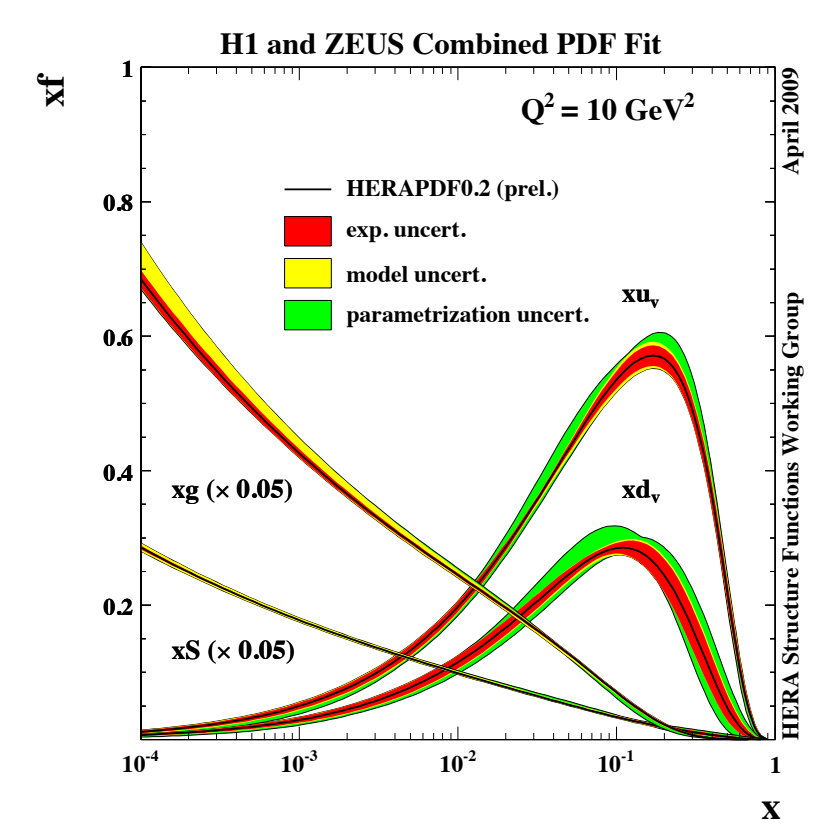
F_2 and parton densities



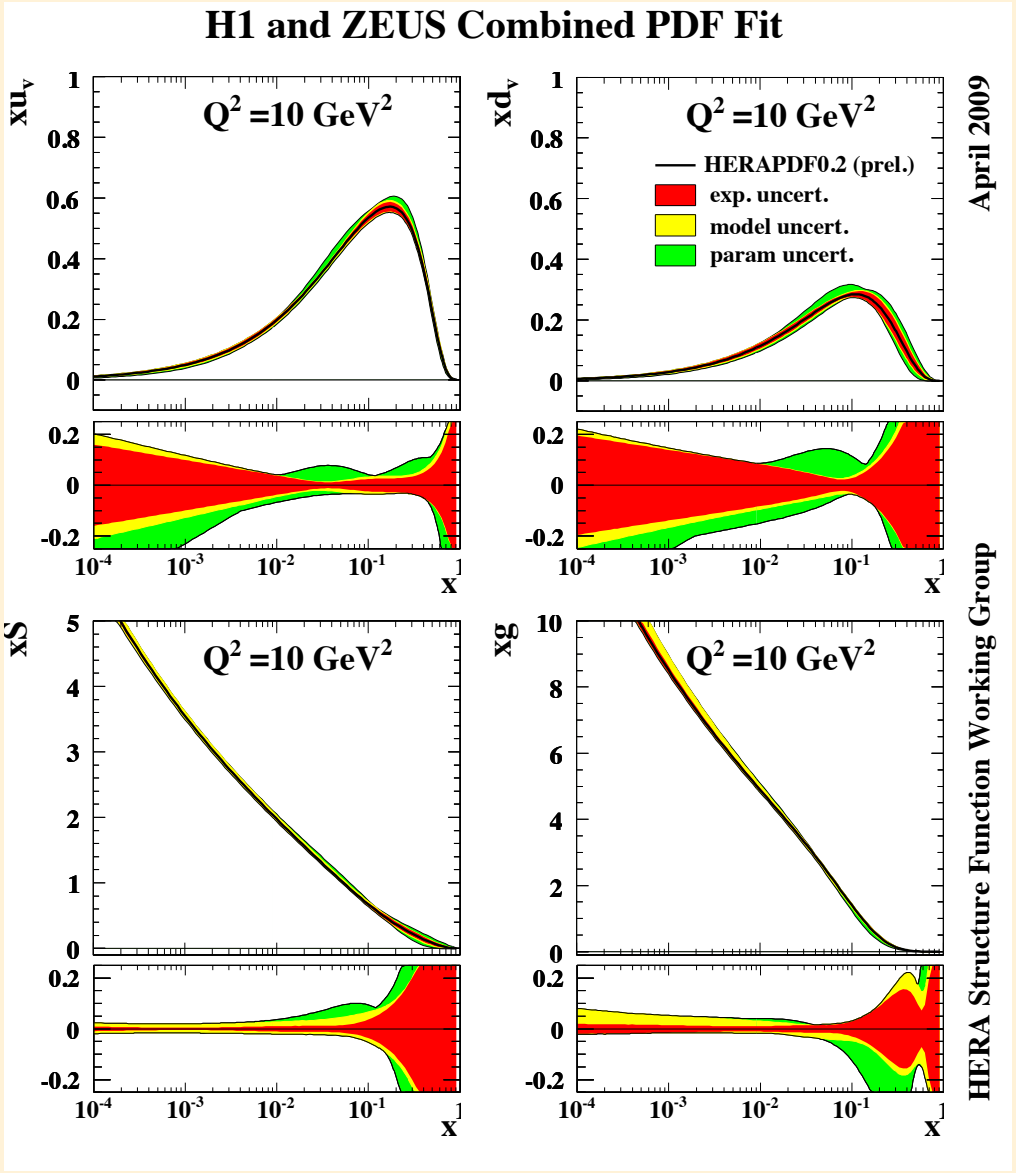
- 14 publications with
- 1397 individual measurements
- averaged to 741 data points
- $6 \cdot 10^{-7} < x < 0.65$
- $0.045 < Q^2 < 30000$ GeV^2
- χ^2/dof= 637/656

Unprecedented precision due to cross calibration of detectors

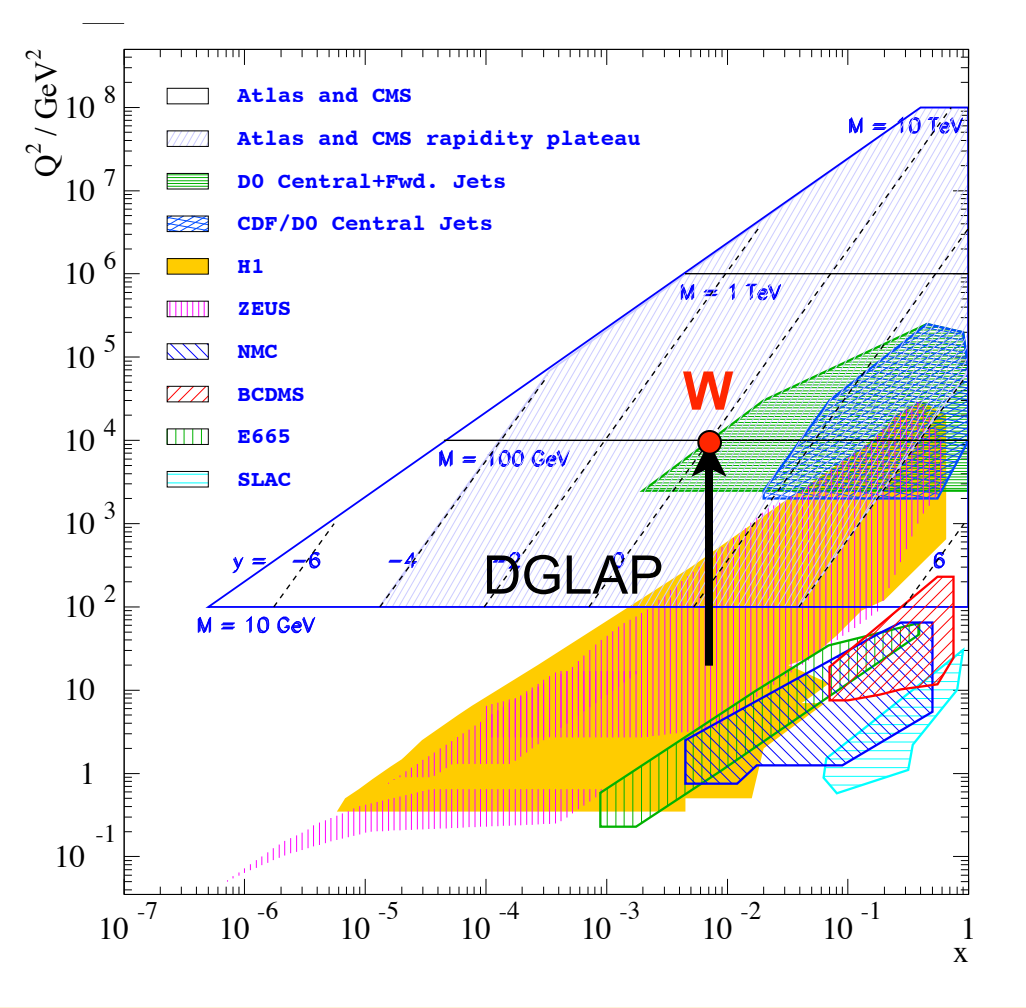
HERA PDFs

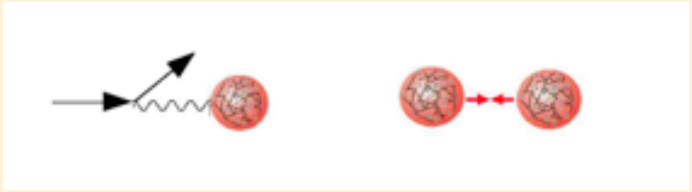


Excellent precision!



HERA and the LHC



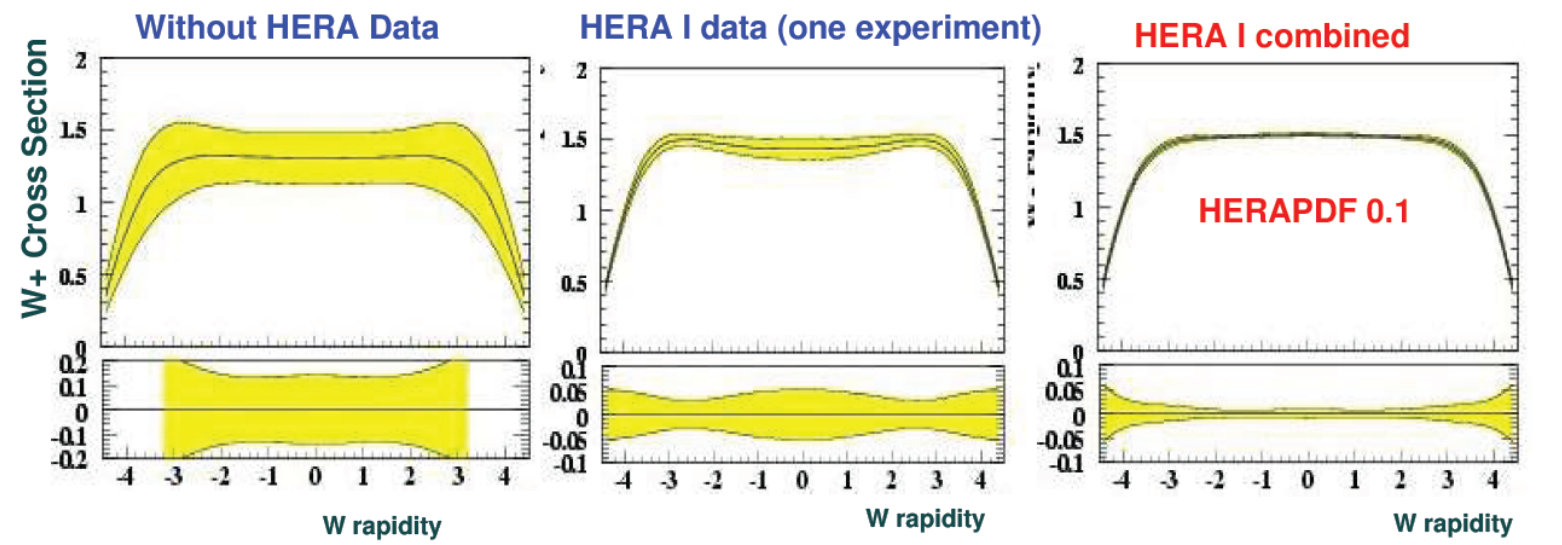


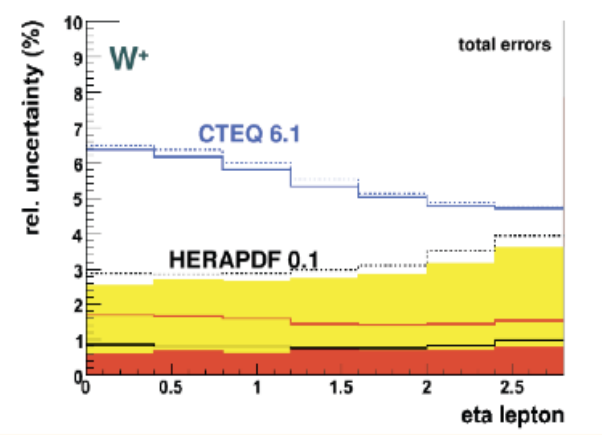
Centrally produced 100 GeV object

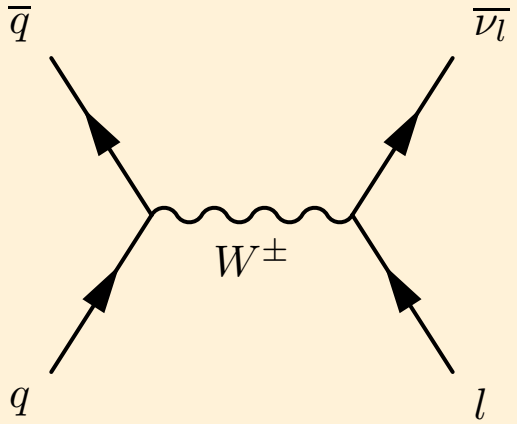
⇔

$x \sim 10^{-2}$, $Q^2 \sim 10000$ GeV^2

Single W Production at LHC



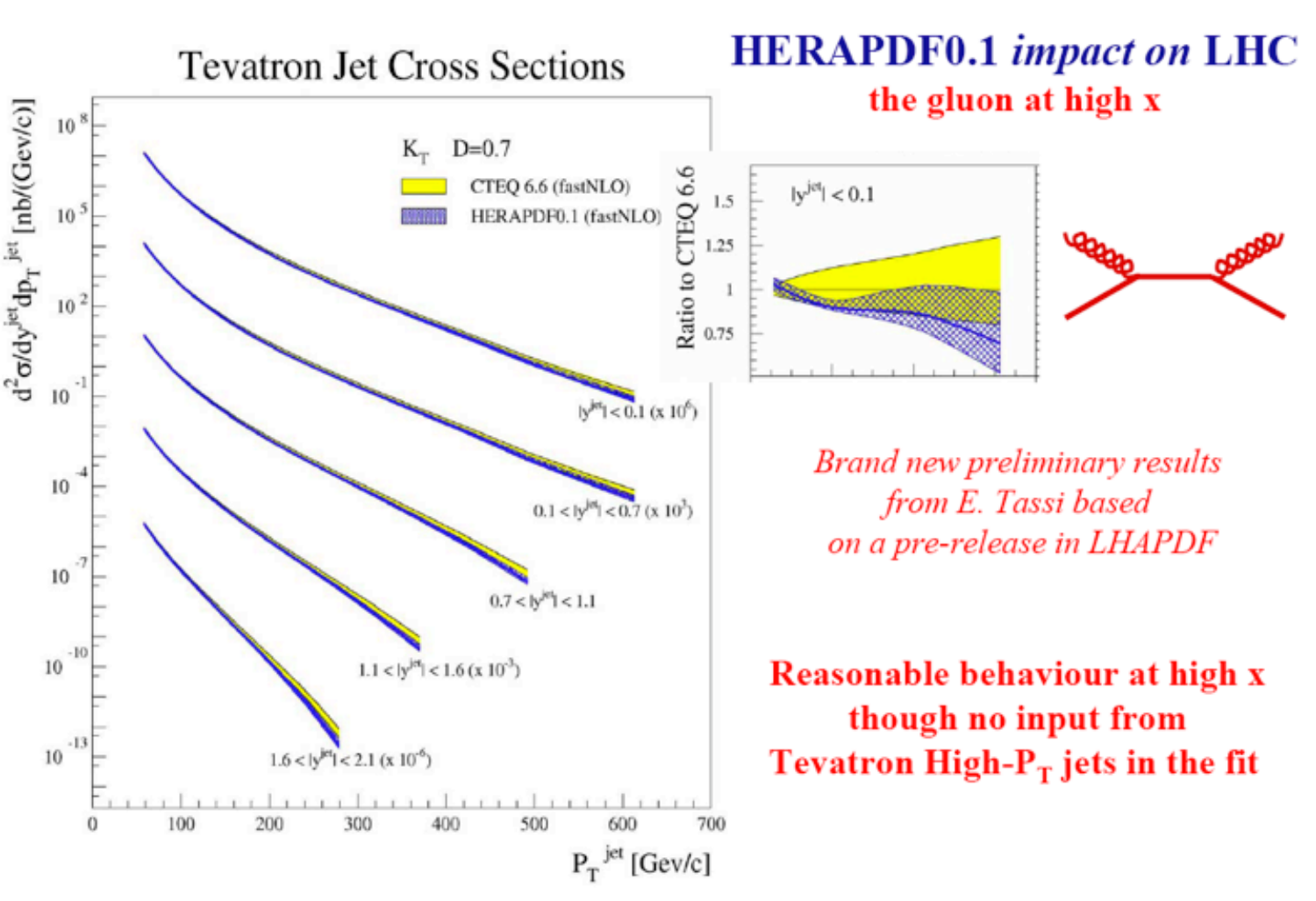




A. Cooper-Sarkar
E. Perez
Presented at HERA and the LHC
26 – 28 May 2008

Uncertainties $\sim$ 3%

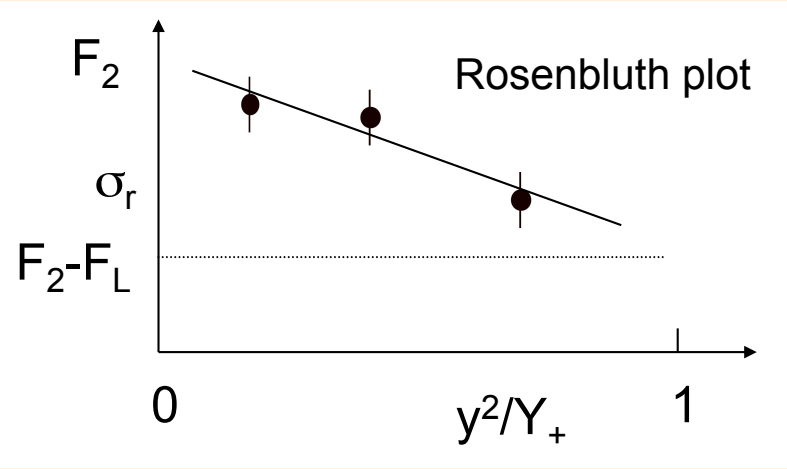
Cross check Tevatron



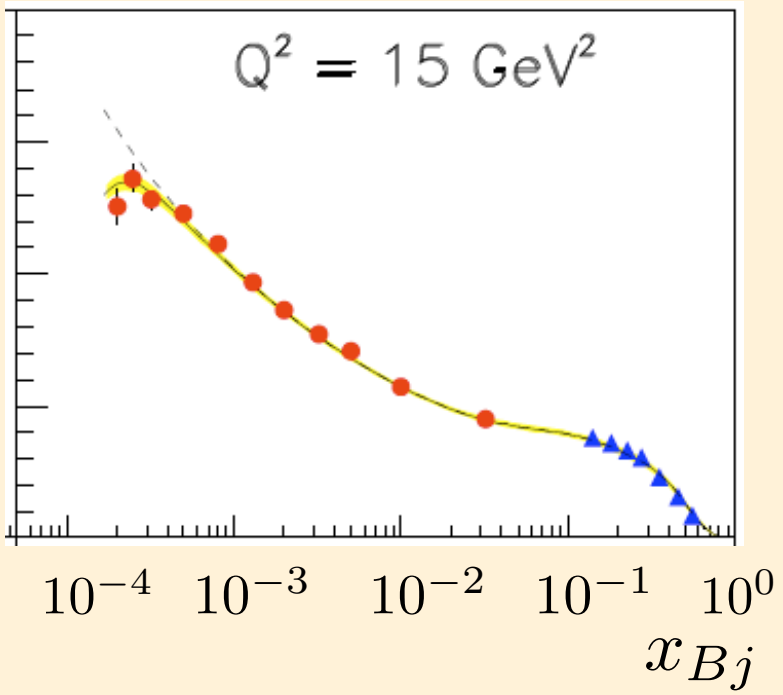
F_L

DIS reduced cross section (low x): $\tilde{\sigma} = F_2(x,Q^2) - \frac{y^2}{Y_+} F_L(x,Q^2)$

$Q^2 = sxy$



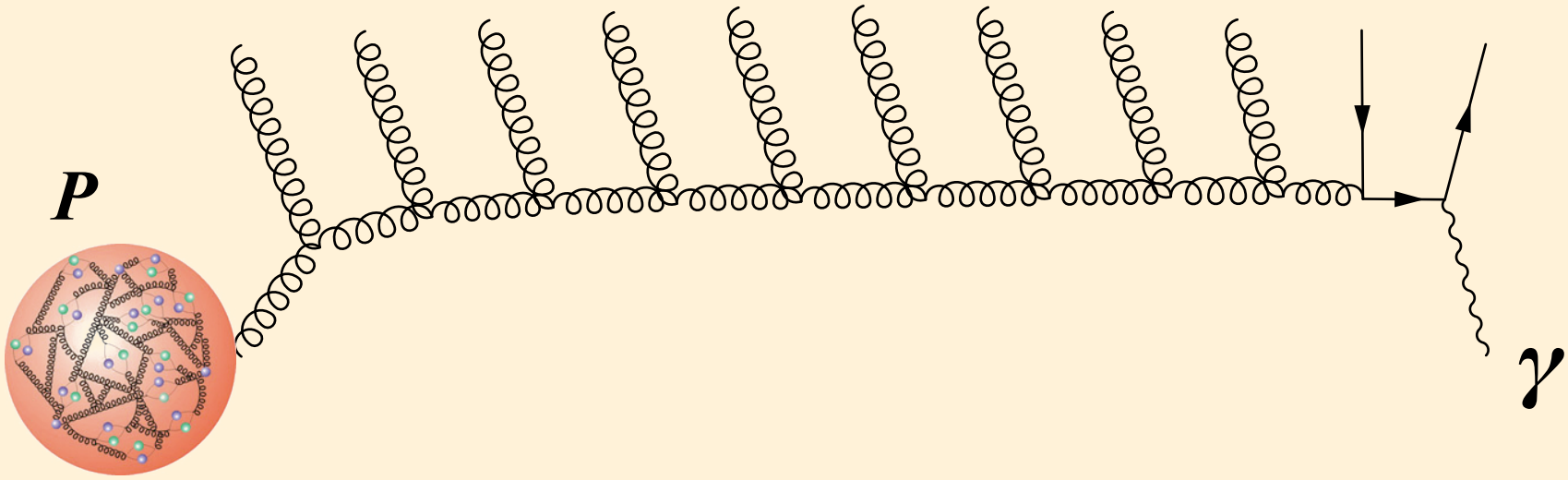
$\tilde{\sigma}$



3 months of running with E_P=460, 575 GeV

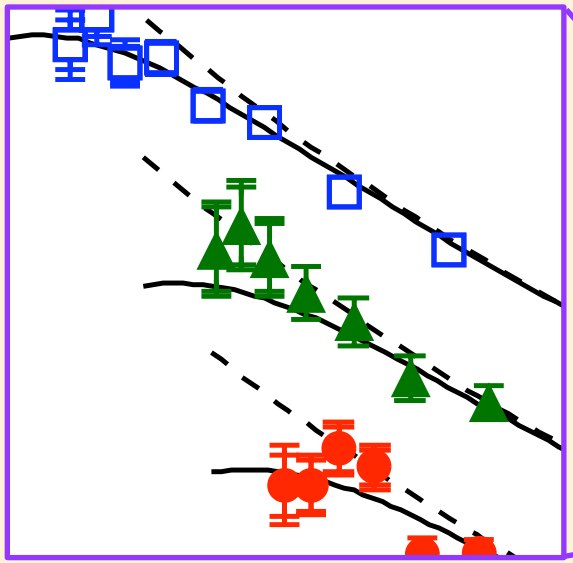
What about F_L?

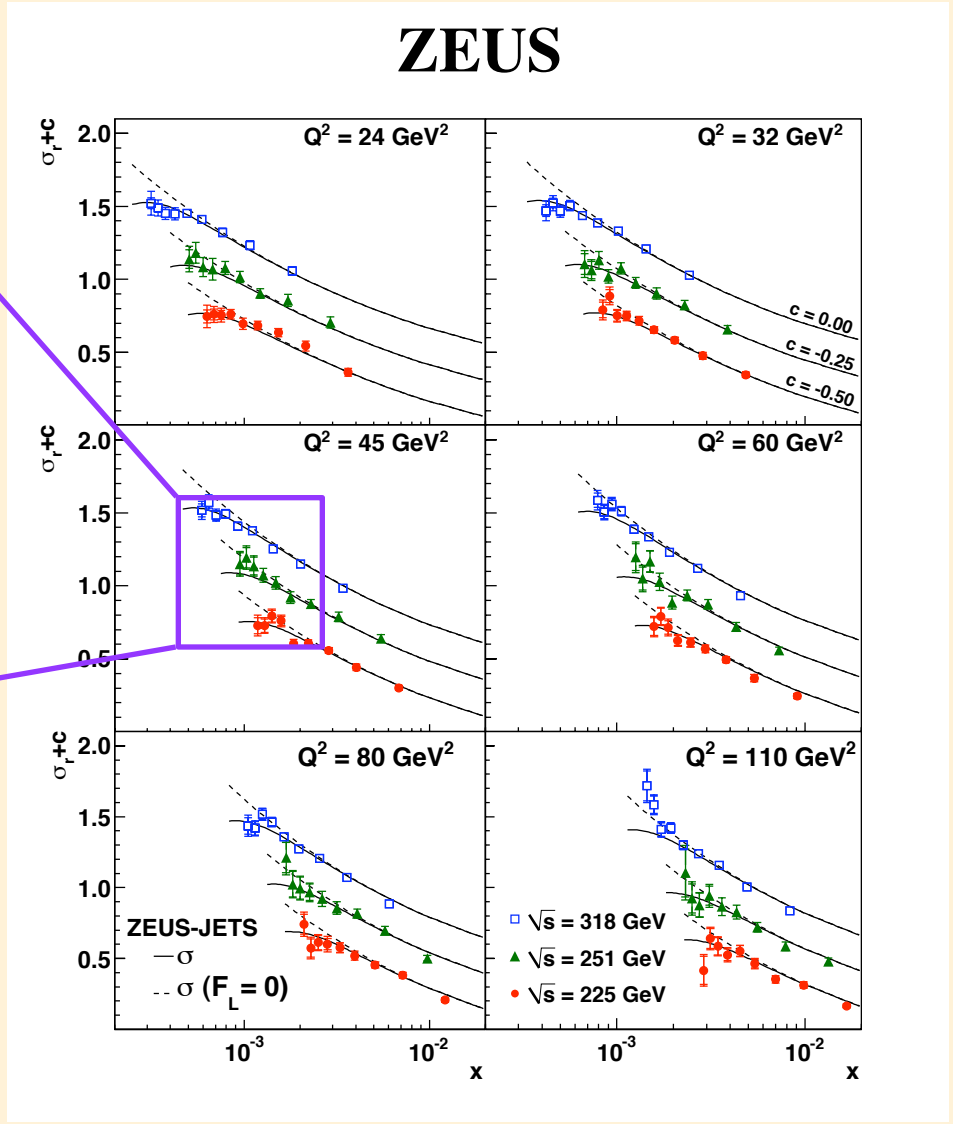
- F_L is an independent structure function
- F_L is directly related to the gluon density



- The behavior of this gluon cloud is a very fundamental property of nature!

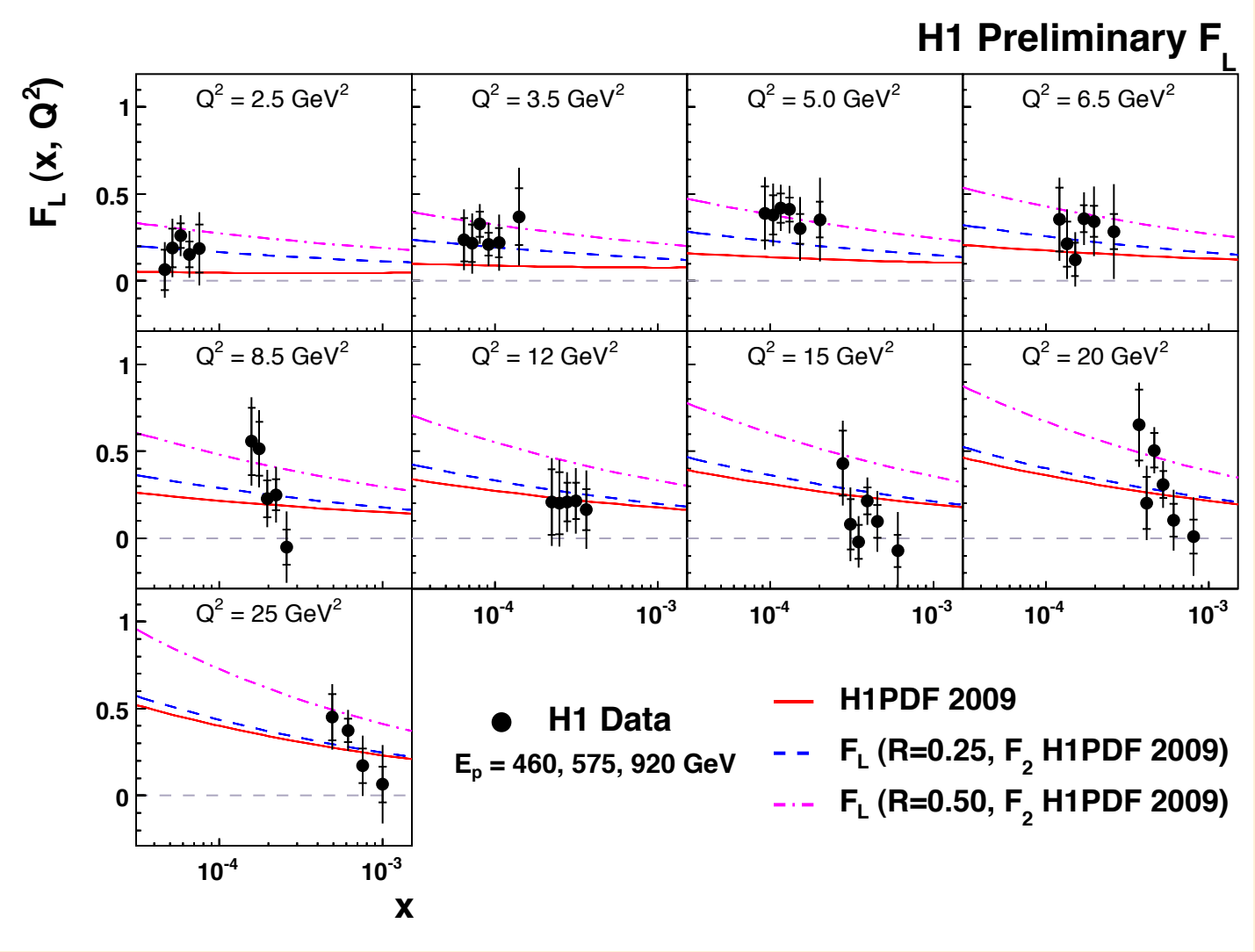
A challenging measurement



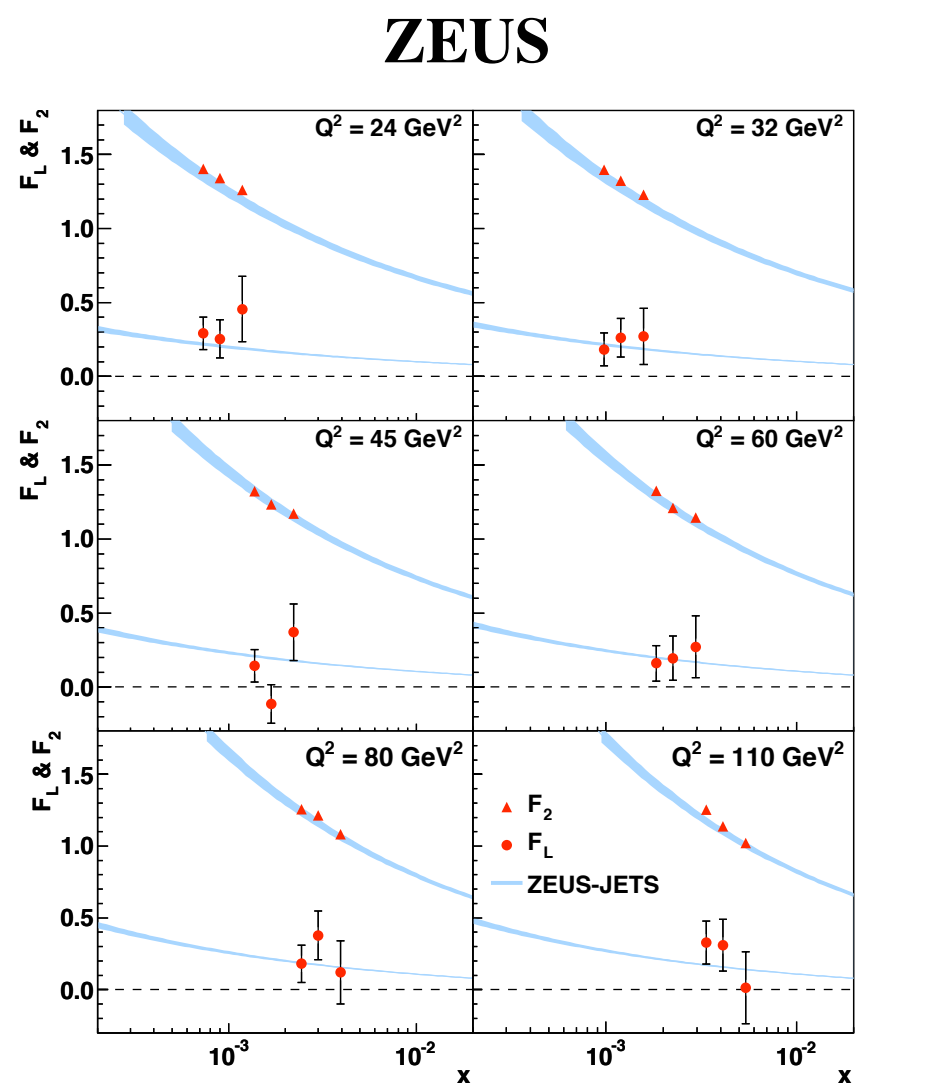


- Identify electrons at small energies
- measure at the edge of the acceptance
- control systematics
- absolute normalization

F_L

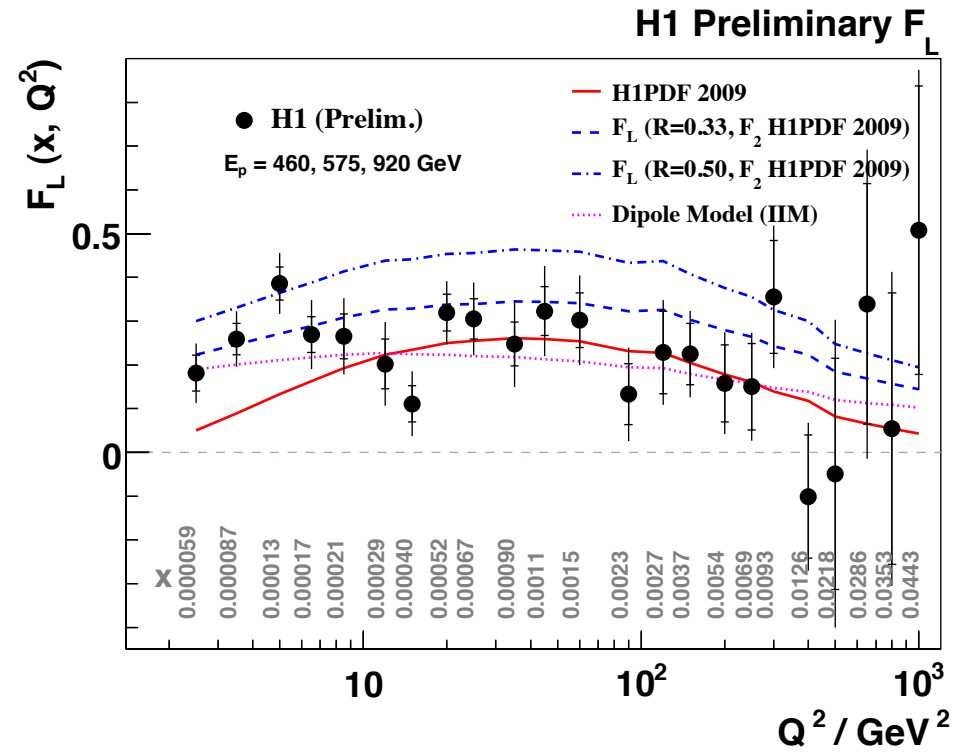

H1 Preliminary F_L
F_L (x, Q^2)
Q^2 = 2.5 GeV^2
Q^2 = 3.5 GeV^2
Q^2 = 5.0 GeV^2
Q^2 = 6.5 GeV^2
Q^2 = 8.5 GeV^2
Q^2 = 12 GeV^2
Q^2 = 15 GeV^2
Q^2 = 20 GeV^2
Q^2 = 25 GeV^2
H1 Data
E_p = 460, 575, 920 GeV
H1PDF 2009
F_L (R=0.25, F_2 H1PDF 2009)
F_L (R=0.50, F_2 H1PDF 2009)
x

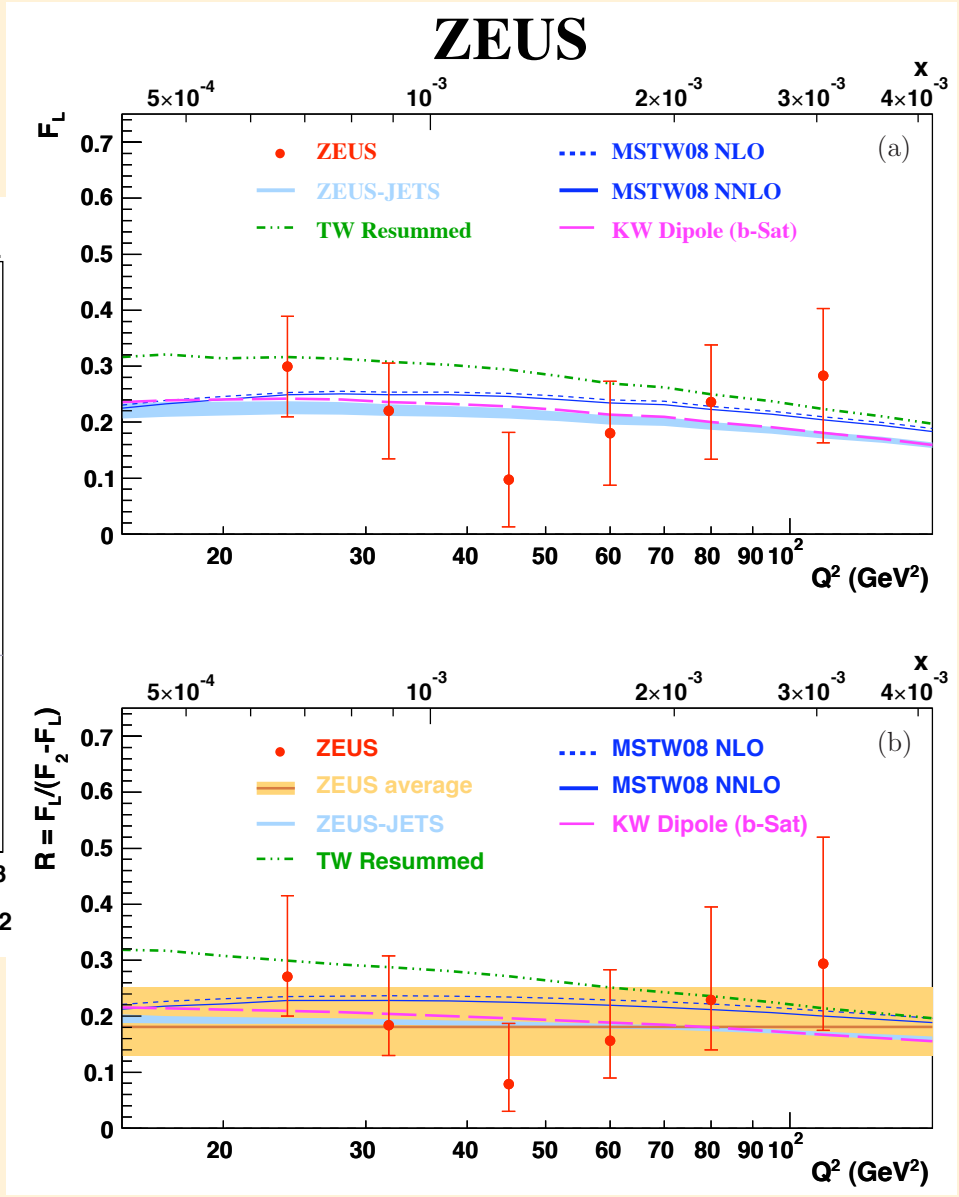
F_L



Also the most precise F_2 points

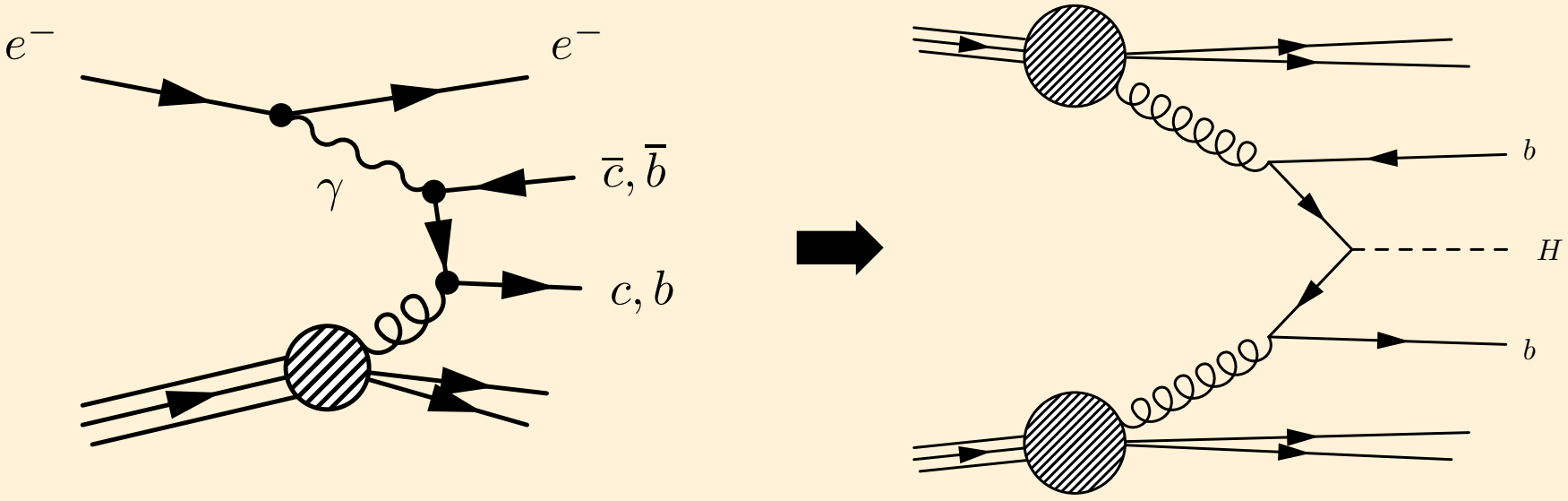
F_L vs. Q^2


H1 Preliminary F_L
H1 (Prelim.)
E_p = 460, 575, 920 GeV
H1PDF 2009
F_L (R=0.33, F_2 H1PDF 2009)
F_L (R=0.50, F_2 H1PDF 2009)
Dipole Model (IIM)
F_L (x, Q^2)
0.5
0
x
0.000059
0.000087
0.00013
0.00017
0.00021
0.00029
0.00040
0.00052
0.00067
0.00090
0.0011
0.0015
0.0023
0.0027
0.0037
0.0054
0.0069
0.0093
0.0126
0.0218
0.0286
0.0353
0.0443
10
10^2
10^3
Q^2 / GeV^2

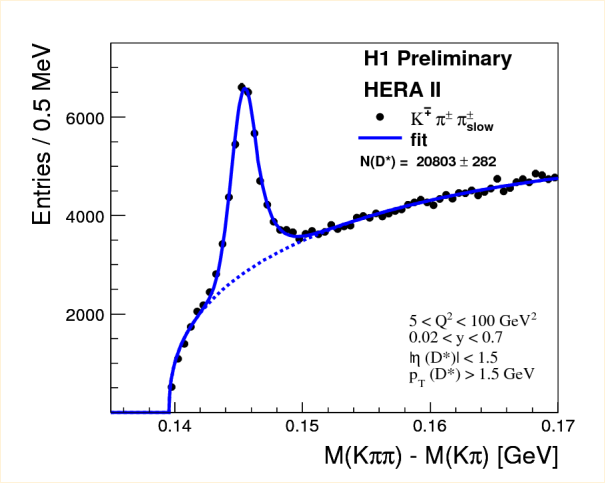

ZEUS
x
5×10^-4
10^-3
2×10^-3
3×10^-3
4×10^-3
F_L
ZEUS
ZEUS-JETS
TW Resummed
MSTW08 NLO
MSTW08 NNLO
KW Dipole (b-Sat)
(a)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
20
30
40
50
60
70
80
90
10^2
Q^2 (GeV^2)
R = F_L/(F_2-F_L)
ZEUS
ZEUS average
ZEUS-JETS
TW Resummed
MSTW08 NLO
MSTW08 NNLO
KW Dipole (b-Sat)
(b)

Heavy Quarks

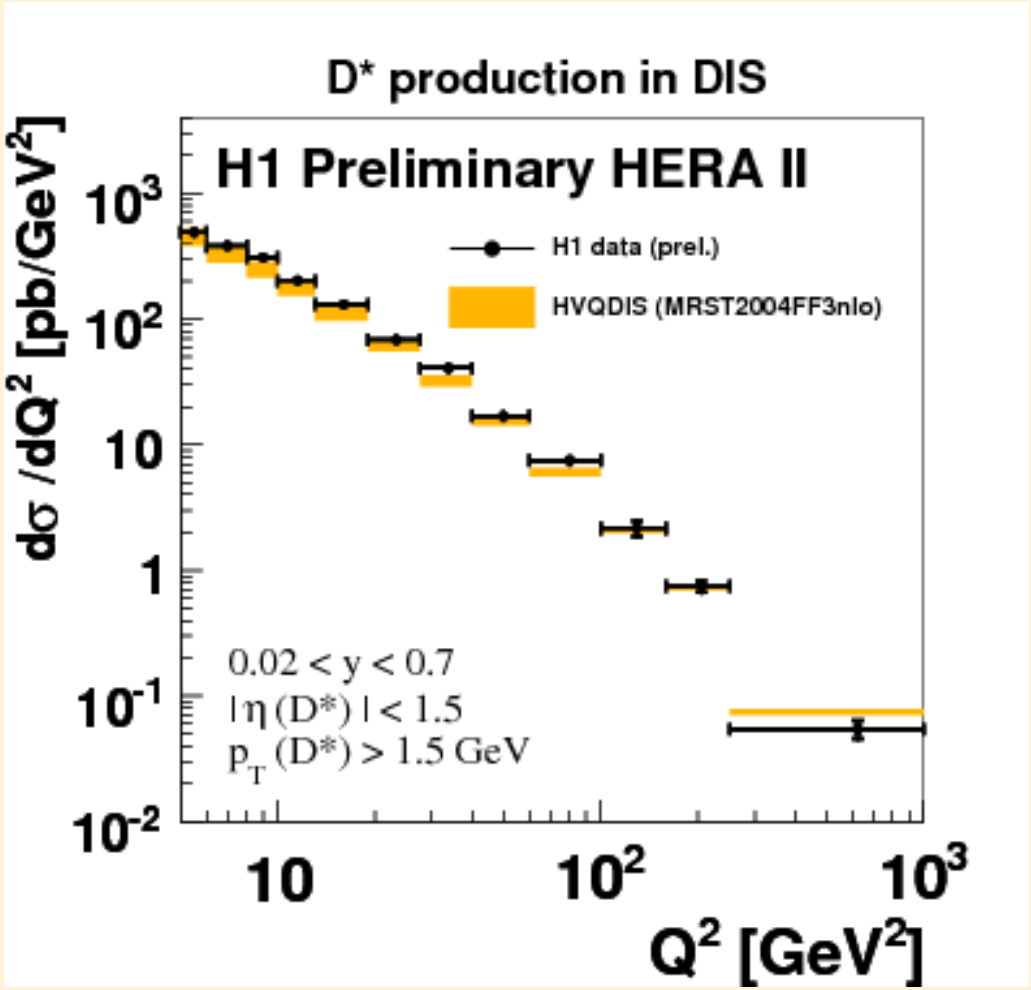
- Charm: 20 - 30%, Beauty: few percent
- Important check of QCD
- HERA results at high Q^2 ➡ bb → H at LHC



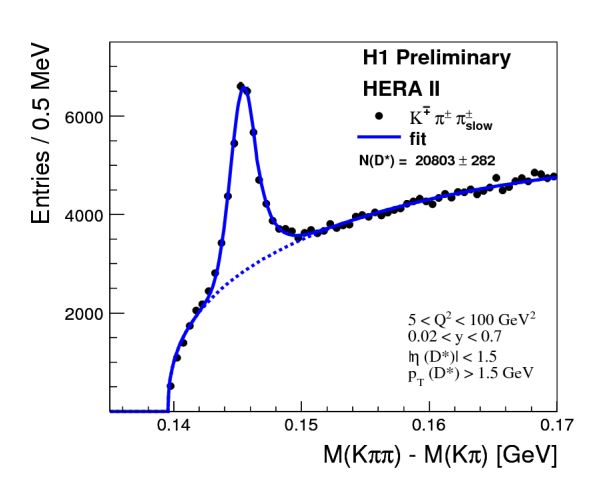
D^* production in DIS

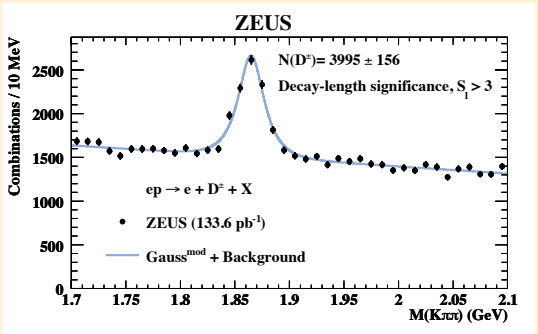


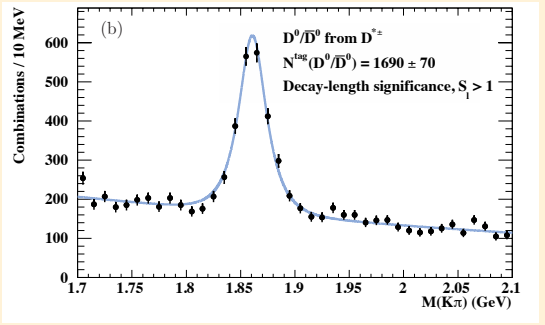
- Full HERA II statistics
- NLO calculation gives a reasonable description

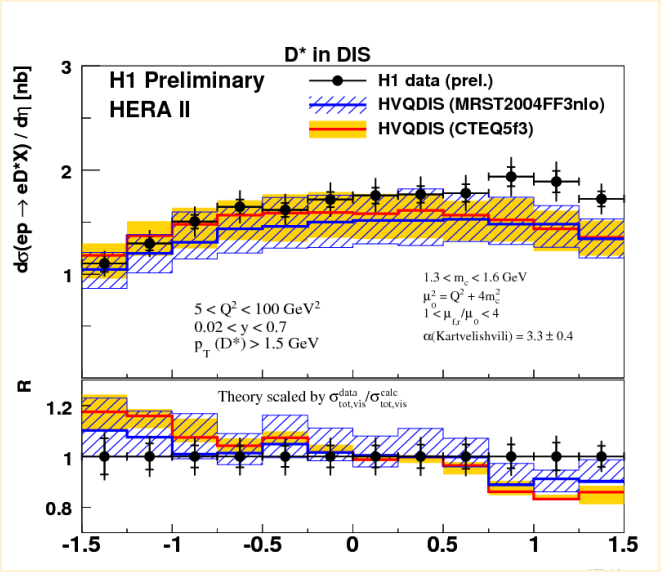


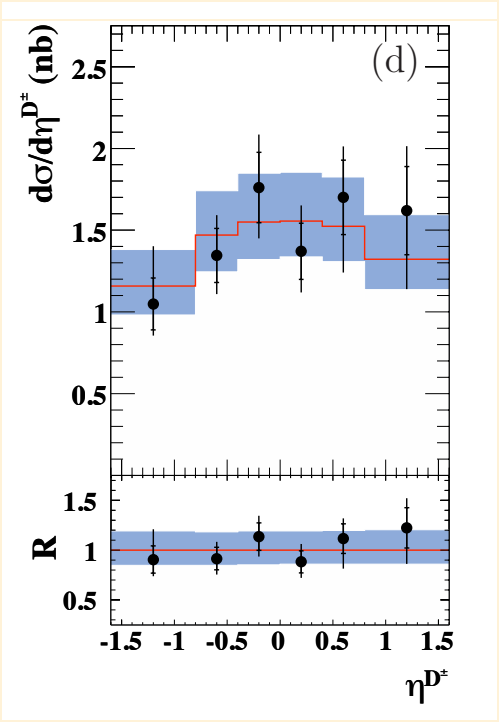
D Meson cross sections

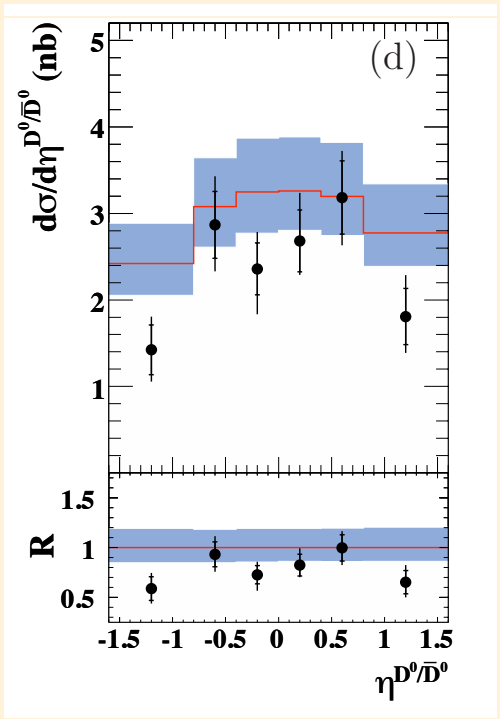






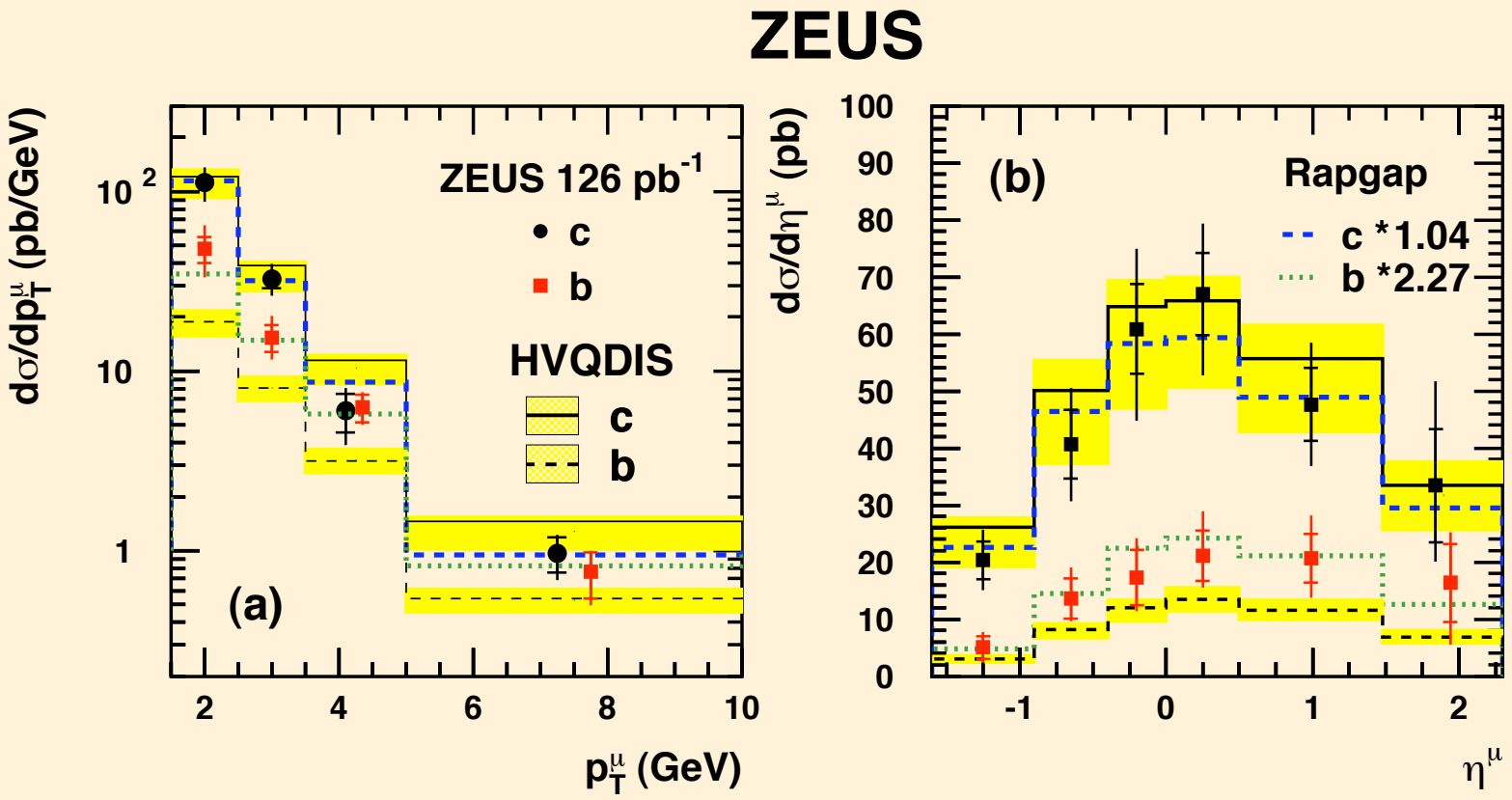






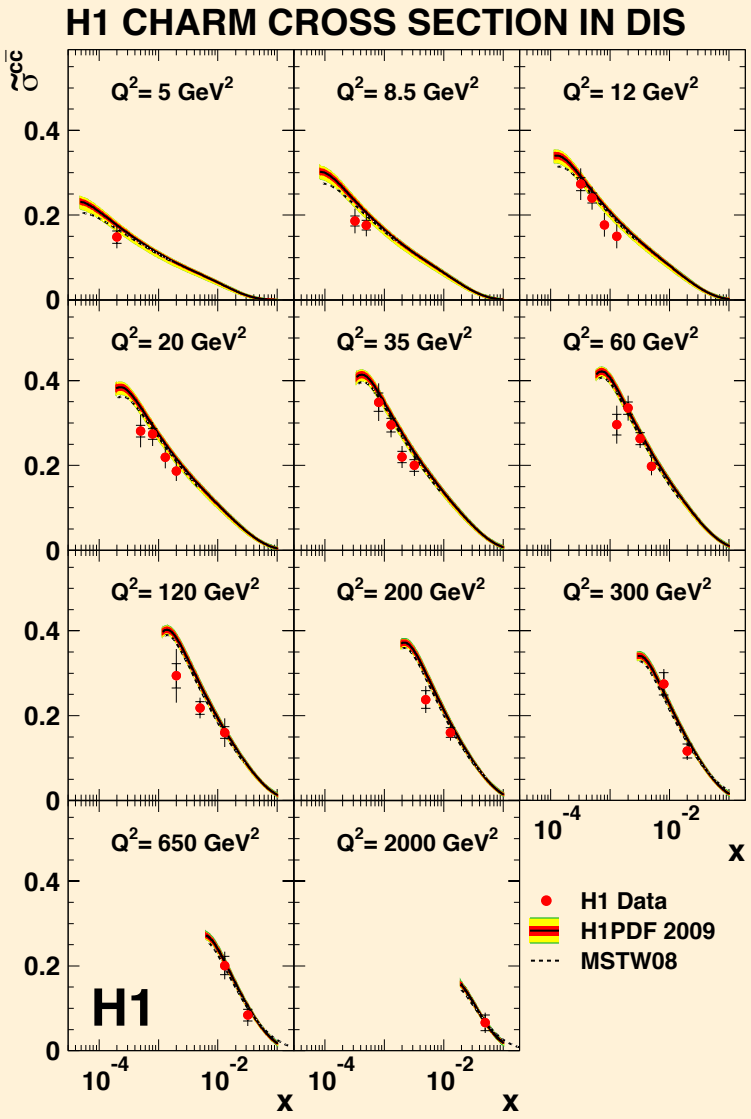
Beauty in DIS

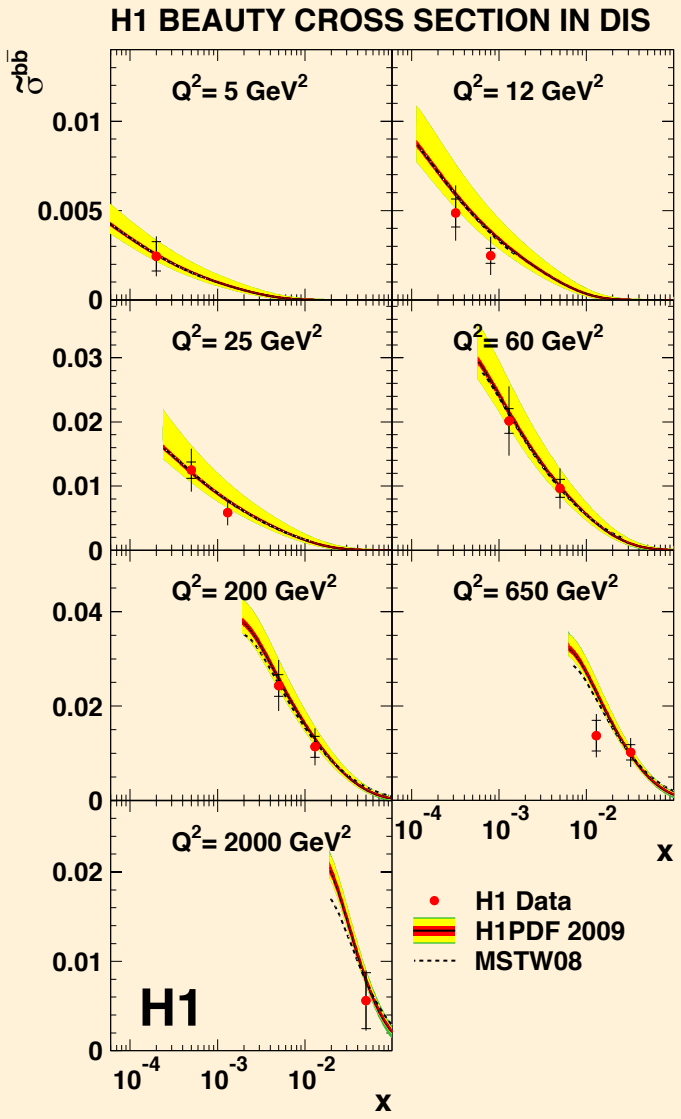
$$B \rightarrow \mu + \text{jets}$$



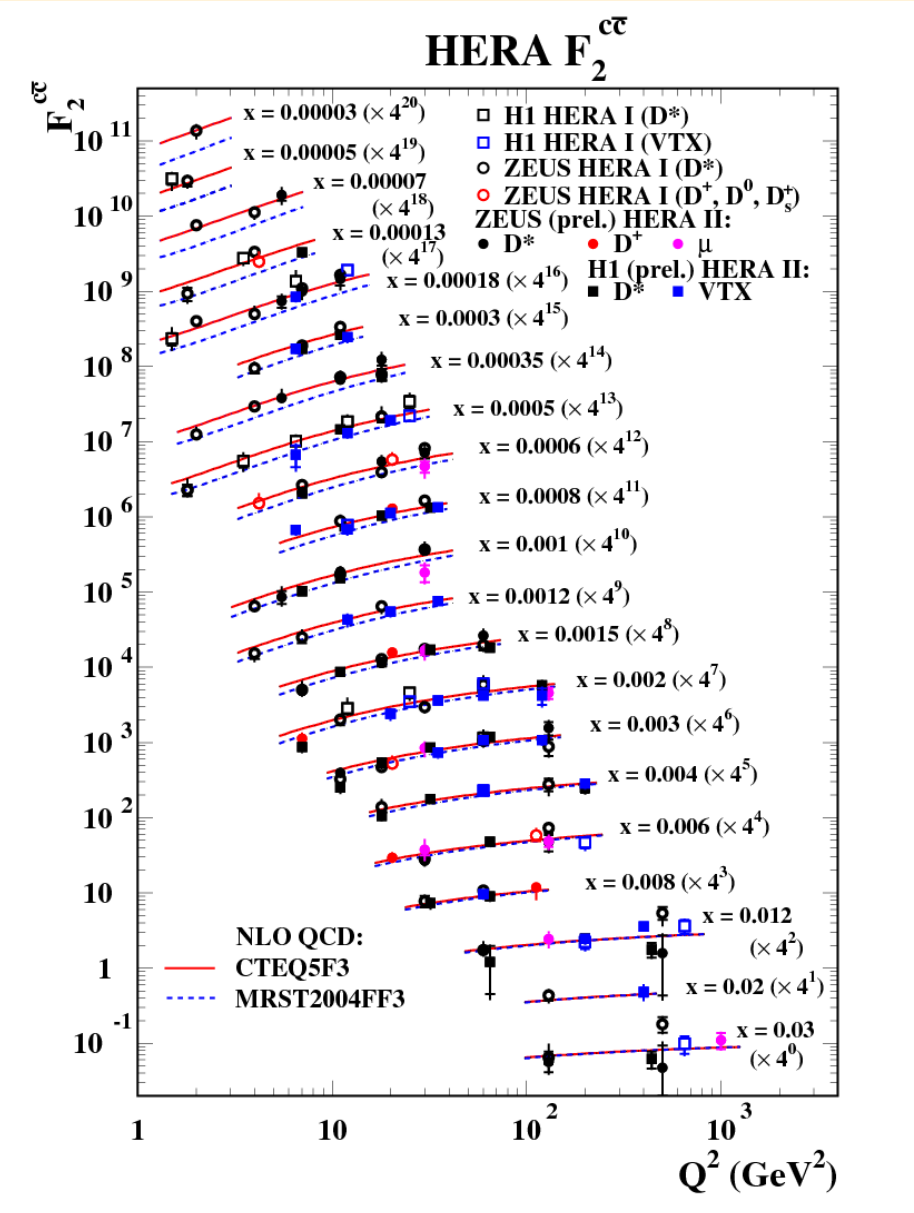
- $Q^2 > 20\ \text{GeV}^2$, $0.01 < y < 0.7$,
$P_T\mu > 1.5$ GeV, $-1.6 < \eta_\mu < 2.3$

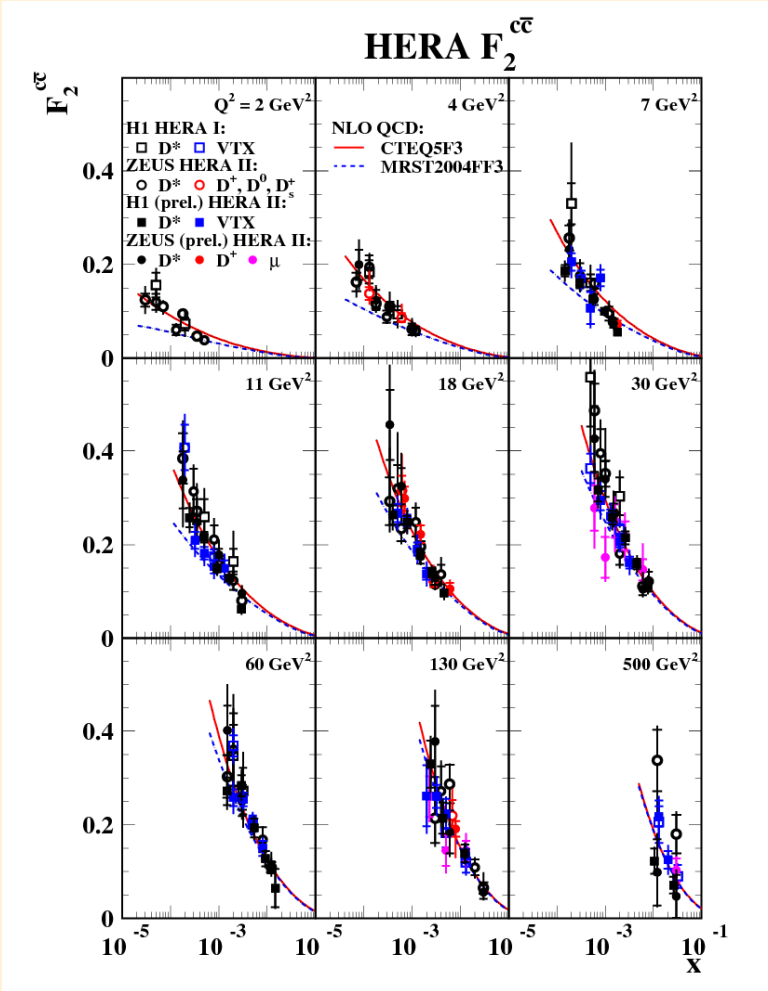
$F_2^{c\bar{c}}$ (lifetime tagging)





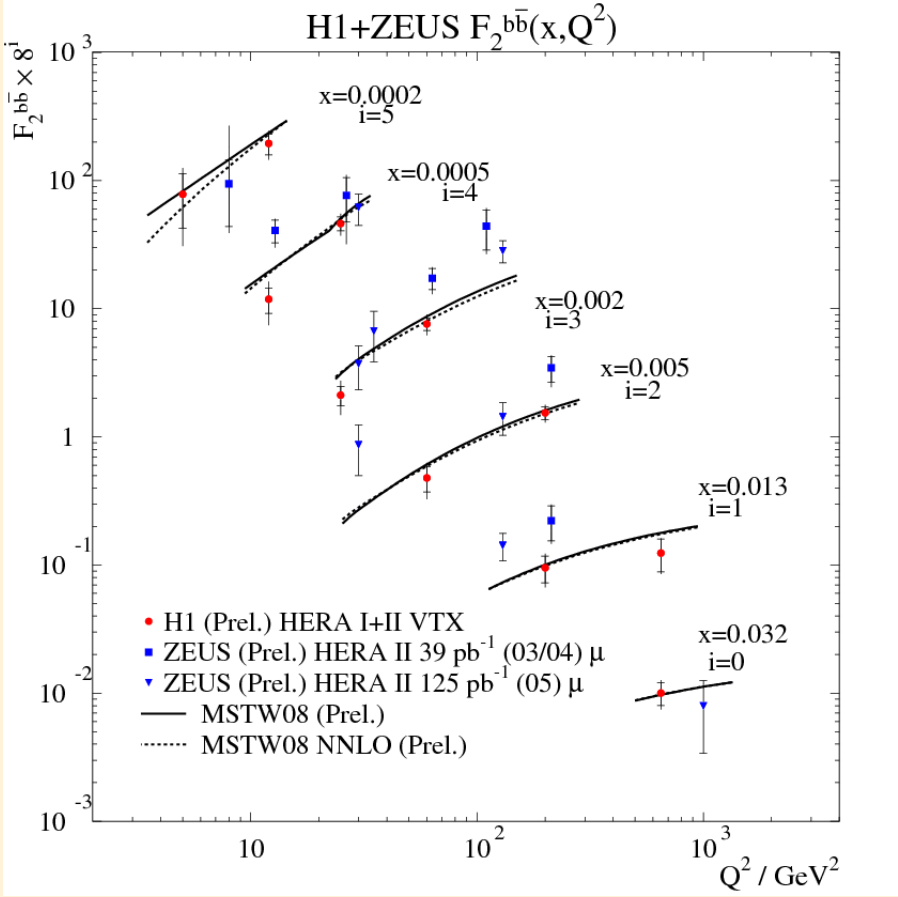
$F_2^{c\bar{c}}$

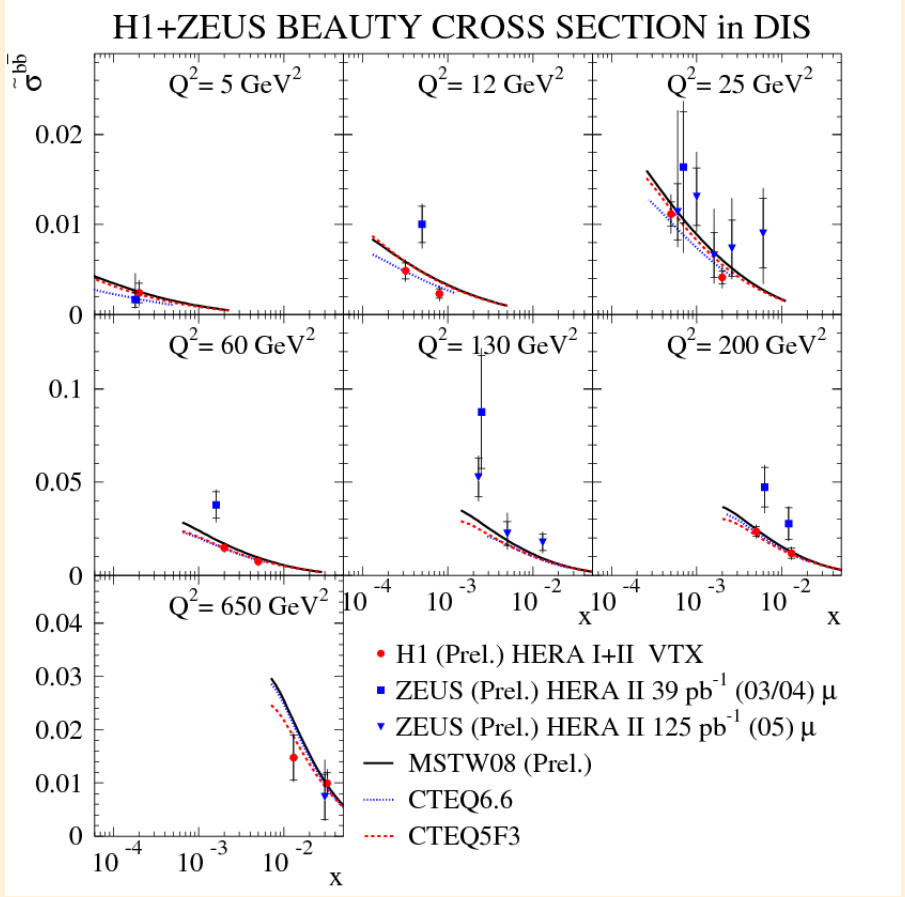




- Current precision ~ 10%
- Inclusive analyses have great potential
- Will reach 3 - 5 % eventually

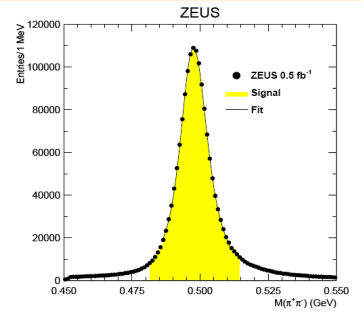
$F_2^{b\bar{b}}$

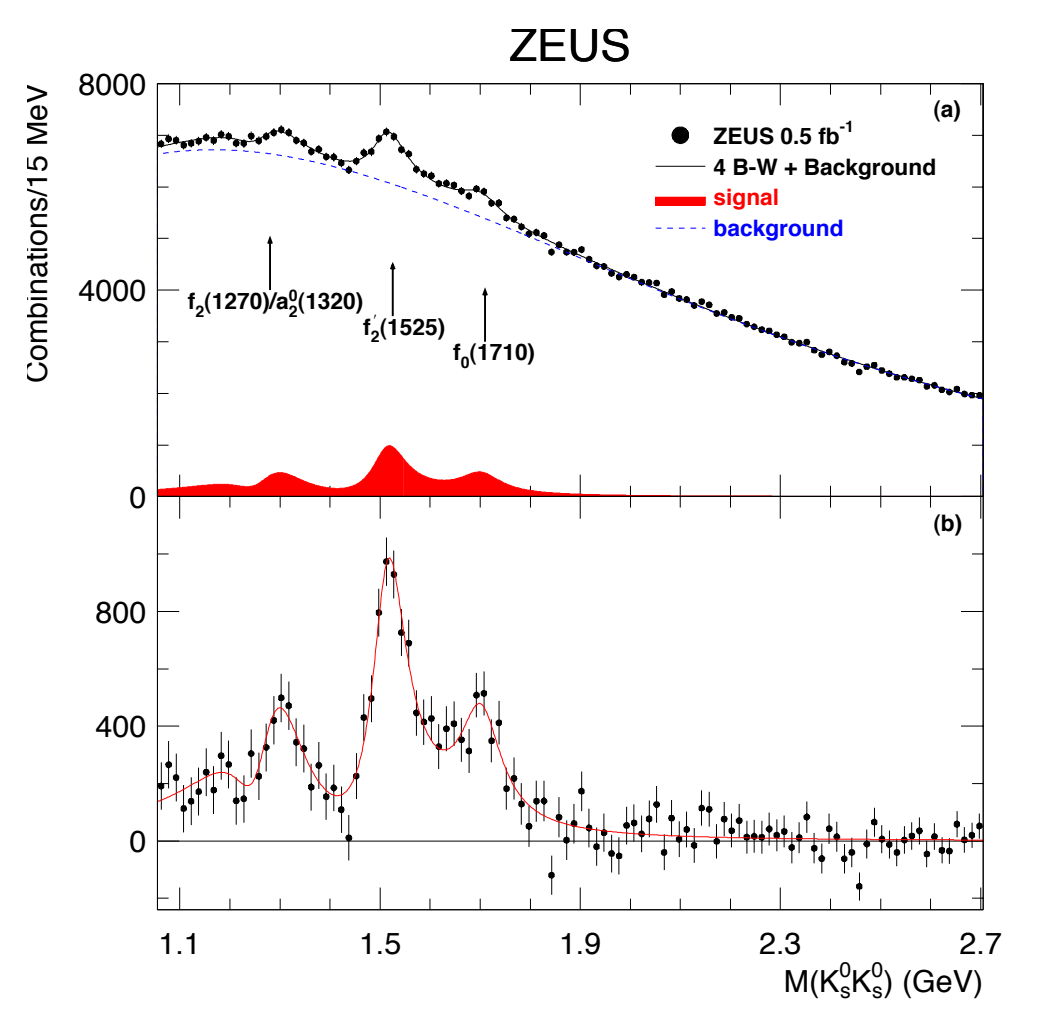




- Current precision ~ 25 %
- Will reach 10 % eventually

A possible glueball candidate





- Most significant (5σ) observation of $f_0(1710)$

Conclusions

- HERA still provides a wealth of data on a wide spectrum of topics
  - High Q^2/EW/searches are coming to an end
  - Precision on PDF fits is still improving
  - Low Q^2/Flavour physics/spectroscopy still in full swing
  - We prepare to maintain analysis activities for 5 more years
  - There is a wealth of data and maybe still some surprise hidden in them...