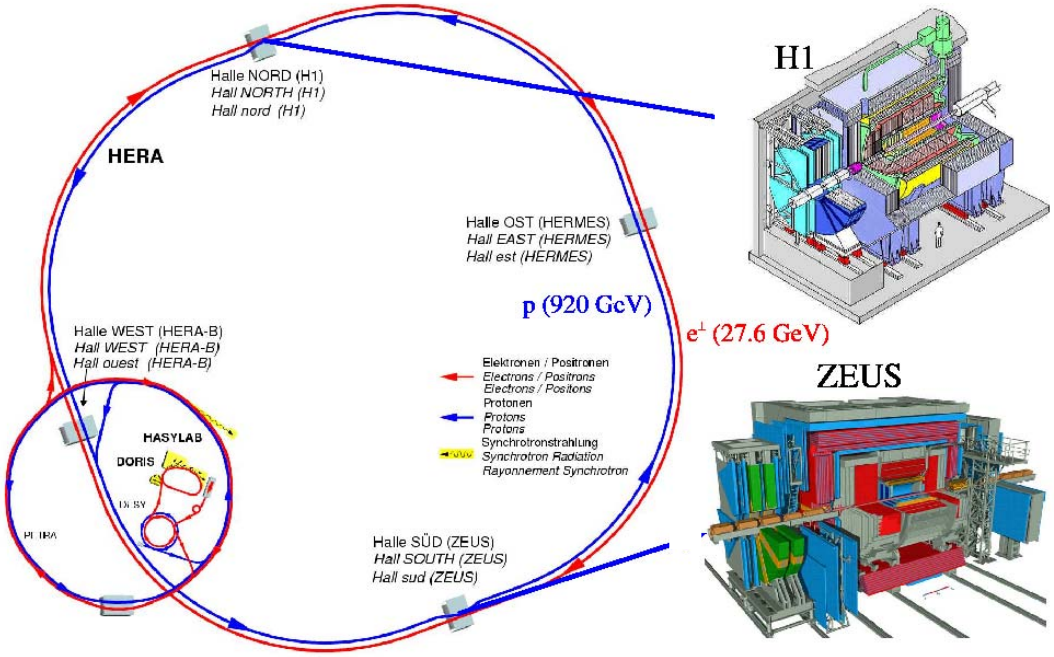
Measurement of Inclusive Diffraction using LRG method

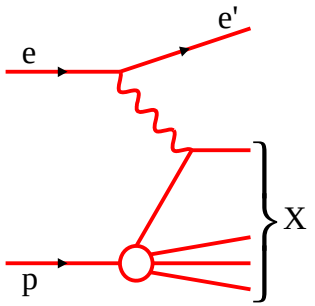
Alice Valkárová,
Charles University, Prague

on behalf of H1 and ZEUS collaborations

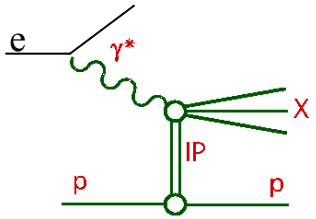
HERA collider experiments

- 27.5 GeV electrons/positrons on 920 GeV protons →√s=318 GeV
- two experiments on colliding beams: H1 and ZEUS
- HERA I,II: ~ 500 pb^{-1}
- closed July 2007, still excellent data to analyse……





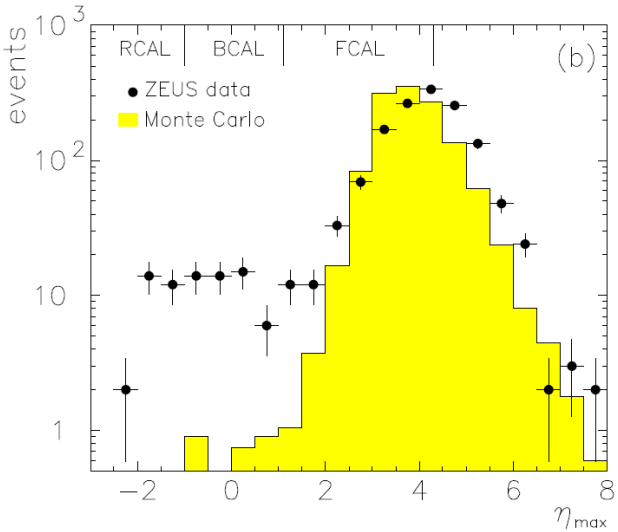
DIS: Probe structure of proton → F_2



Diffractive DIS: Probe structure of difraction → F_2^D

Historical reminder

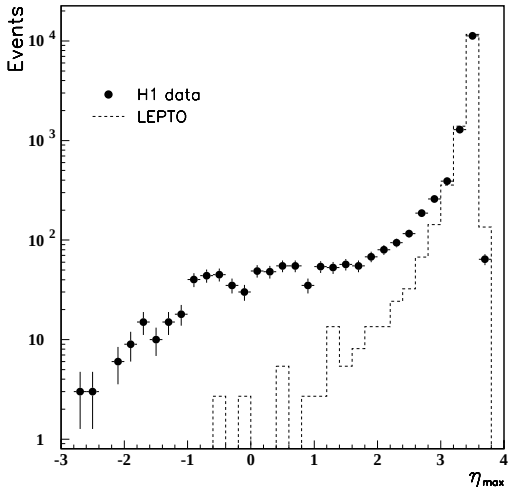
- 20 years after first DIS data, 19 years after the observation of diffractive DIS events at HERA!



ZEUS Collab.,Physics Letters B 315 (1993) 481-493

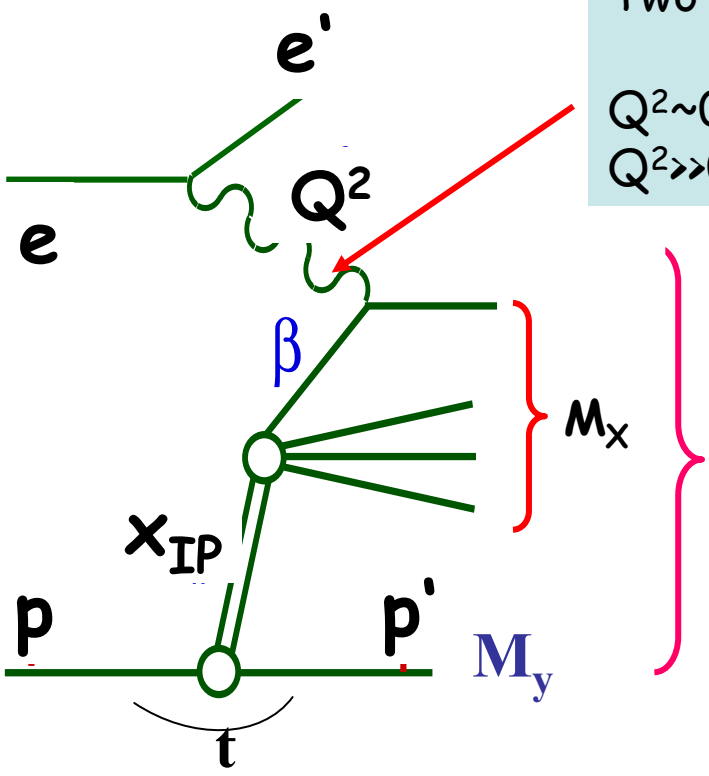
1993-1994

HISTORY



H1 Collab., Nucl. Phys. B429 (1994) 477

Diffraction and diffraction kinematics



Two kinematic regions of diffractive events:

$Q^2 \sim 0\ GeV^2 \rightarrow$ photoproduction

$Q^2 \gg 0\ GeV^2 \rightarrow$ deep inelastic scattering (DIS)

HERA: ~10% of events diffractive

W

$$x_{IP} = \frac{q \cdot (p - p')}{q \cdot p} \approx \frac{Q^2 + M_X^2}{Q^2 + W^2} \longrightarrow$$

momentum fraction of color singlet exchange

$$\beta = \frac{x}{x_{IP}} \approx \frac{Q^2}{Q^2 + M_X^2} \longrightarrow$$

fraction of exchange momentum, coupling to γ

$$t = (p - p')^2 \longrightarrow$$ 4-momentum transfer squared

$M_y = m_p$ proton stays intact, needs detector setup to detect protons

$M_y > m_p$ proton dissociates, $\longrightarrow$ contribution should be understood

Diffractive reduced cross section

y – inelasticity → $1-(E'_e/E_e)$

$$\frac{d^4\sigma(ep \to eXp)}{d\beta\, dQ^2 dx_P dt} = \frac{4\pi\alpha_{em}^2}{\beta Q^4}\left(1 - y + \frac{y^2}{2}\right)\sigma_R^{D(4)}(\beta, Q^2, x_P, t)$$

$\sigma_R^{D(4)}$ → diffractive reduced cross section

$\sigma_R^{D(4)} \approx F_2^{D(4)}$ at low and medium y

$$\sigma_R^{D(4)} = F_2^{D(4)} - \frac{y^2}{2\left(1 - y - \frac{y^2}{2}\right)} F_L^{D(4)}$$

$\sigma_R^{D(4)} = F_2^{D(4)}$ if

$F_L^{D(4)} = 0$

Integrate over *t* when proton is not tagged

→ $\sigma_R^{D(3)}(\beta, Q^2, x_P)$

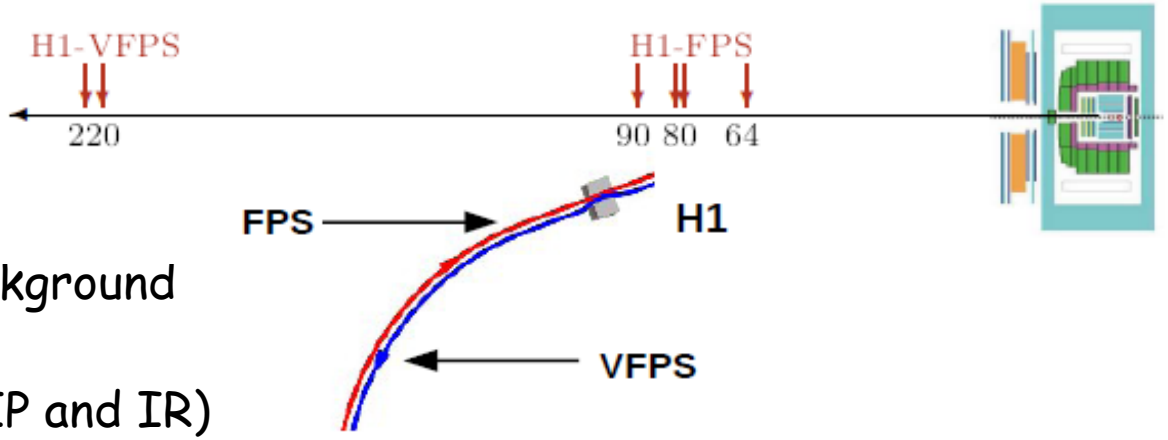
Methods of diffraction selection

Proton spectrometers

ZEUS: LPS (1993-2000)

H1: VFPS (2005-2007)

FPS (1997-2007)



☺ free of p-dissociation background

☺ x_{IP} and t measurements

☺ access to high x_{IP} range (IP and IR)

☹ small acceptance

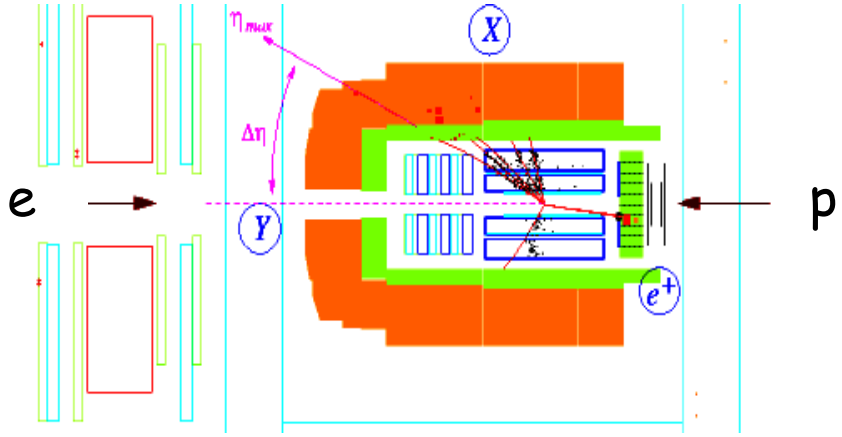
Large Rapidity Gap, H1, ZEUS:

require no activity beyond η_{max}

☹ t not measured,integrated over $|t|<1GeV^2$

☺ very good acceptance at low x_{IP}

☹ p-diss background about 20% ☠

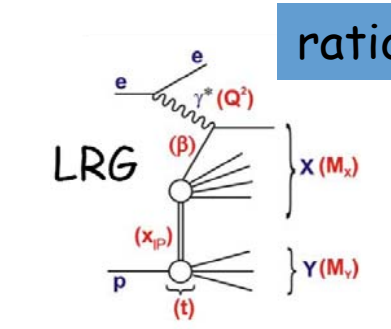


Different phase space and systematics – non-trivial to compare!

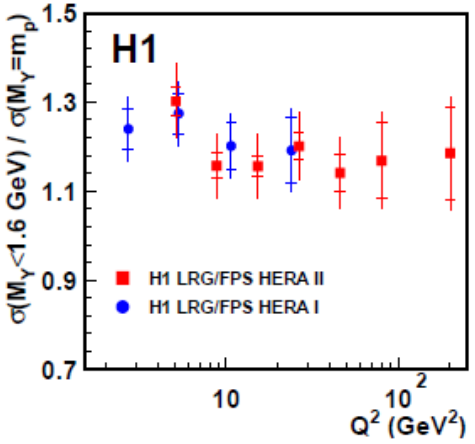
Comparison between methods – H1

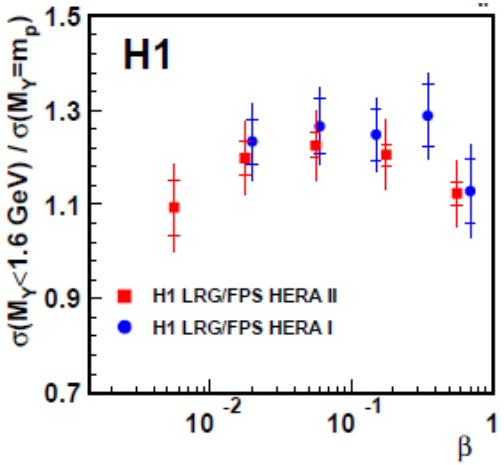
Are „rapidity gap" and „forward proton" methods compatible?

ratio

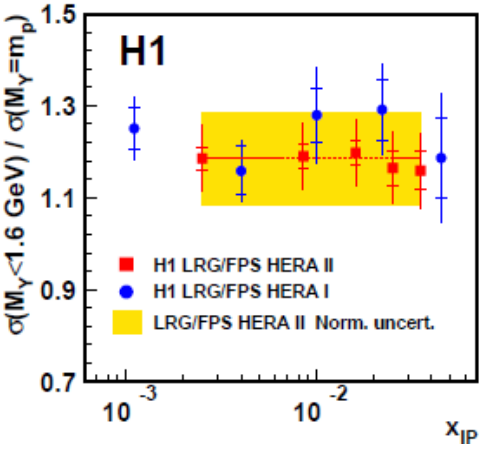


H1, LRG/FPS = 1.18 ± 0.03 (stat) ± 0.06(uncor.syst.) ± 0.10(norm)





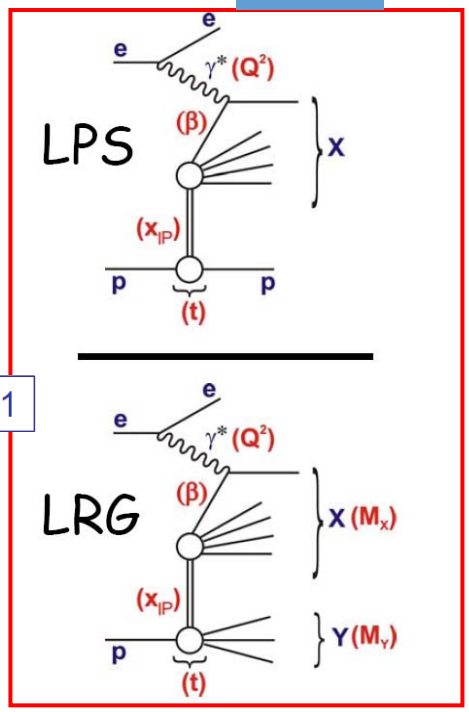
EPJ C71 (2011) 1578



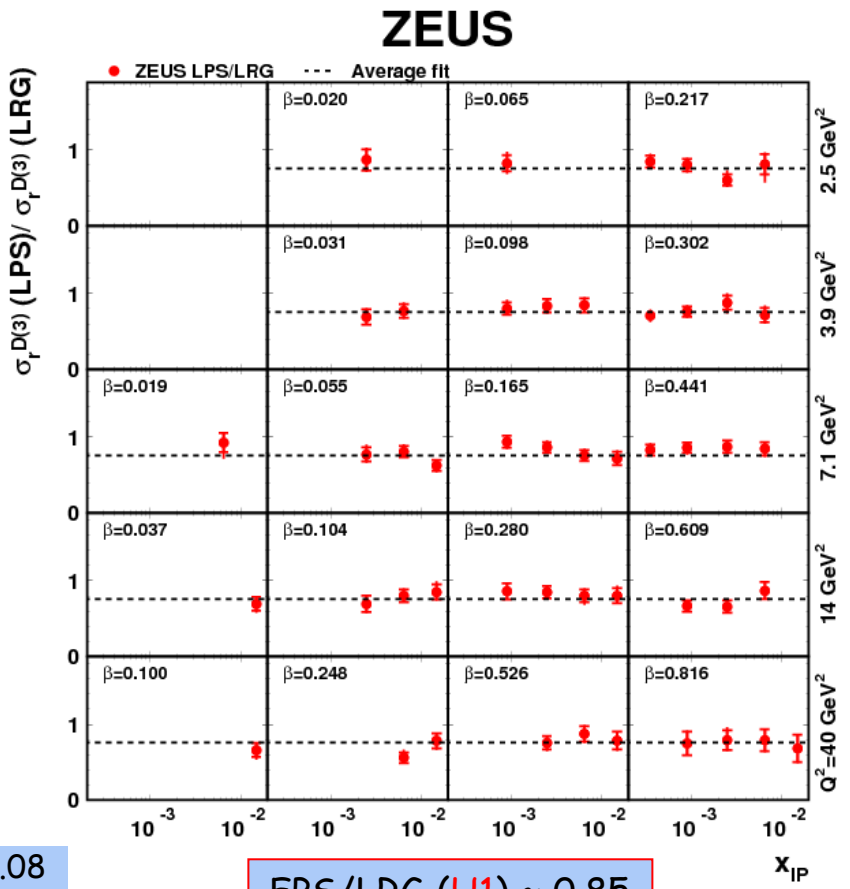
Precise knowledge and corrections for proton dissociation background-
key point in H1- ZEUS data comparison

Comparison between methods - ZEUS

ratio



NP B816 (2009) 1

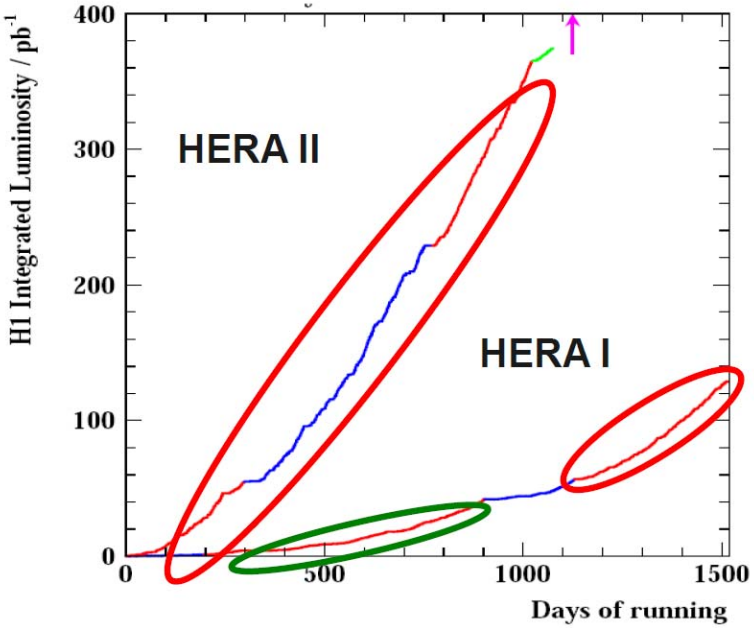


ZEUS, LPS/LRG = $0.76 \pm 0.01 \pm^{0.03}_{0.02} \pm^{0.08}_{0.05}$

FPS/LRG (H1) ~ 0.85

- LRG selection contains about 20% events of proton diss.
- no significant dependence on any variable
- well controlled, precise measurements

Full H1 LRG data sample



DESY - 12 - 041

Data Set	Q^2 range (GeV^2)	Proton Energy E_p (GeV)	Luminosity (pb^{-1})
New data samples			
1999 MB	$3 < Q^2 < 25$	920	3.5
1999-2000	$10 < Q^2 < 105$	920	34.3
2004-2007	$10 < Q^2 < 105$	920	336.6
Previously published data samples			
1997 MB	$3 < Q^2 < 13.5$	820	2.0
1997	$13.5 < Q^2 < 105$	820	10.6
1999-2000	$133 < Q^2 < 1600$	920	61.6

[H1 Coll. EPJC28 (2006) 715]

All results combined to one single LRG cross section set

Kinematic region →

$3.5 < Q^2 < 1600$ GeV^2

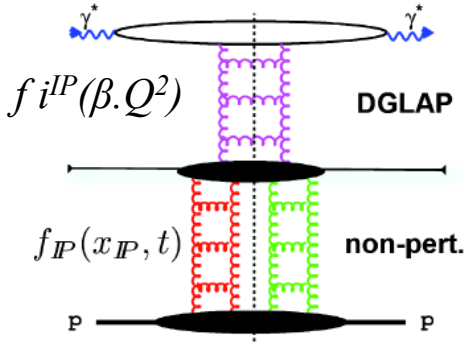
$0.0017 < \beta < 0.8$

$0.0003 < x_{IP} < 0.03$

Increase in statistics by factor 3 - 30

Modelling of diffraction

QCD collinear factorisation theorem



Infinite momentum frame - partons

[H1 Coll. EPJC28 (2006) 715]

$$\sigma^D(\gamma^* p \to Xp) = \sum_{parton\_i} f_i^D(x,Q^2,x_{IP},t)\cdot\sigma^{\gamma^* i}(x,Q^2)$$

$$f_i^D(x,Q^2,x_{IP},t) = f_{IP/p}(x_{IP},t)\cdot f_i^{IP}(\beta = x/x_{IP},Q^2)$$

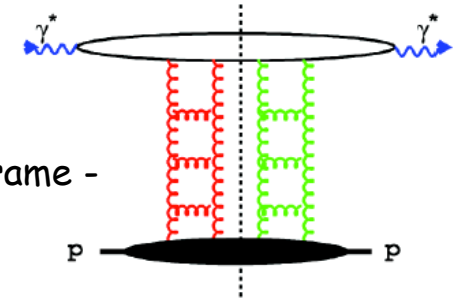
$$f_{IP/p}(x_{IP},t) = \frac{e^{Bt}}{x_{IP}^{2\alpha(t)-1}}$$

Pomeron flux factor
Regge factorisation

diffractive DPDF

DPDFs extracted from DIS data

Dipole model



Proton rest frame - dipoles

[C. Marquet PRD76 (2007) 094017]

$$d\sigma_{diff}^{\gamma^* p}/dt \propto \int dz dr^2 \Psi^* \sigma_{qq}^2(x,r^2,t)\Psi$$

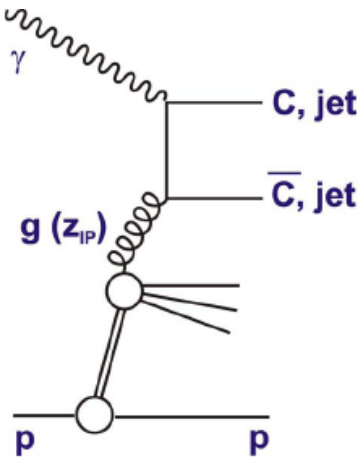
Long living quark pairs interact with gluons of the proton

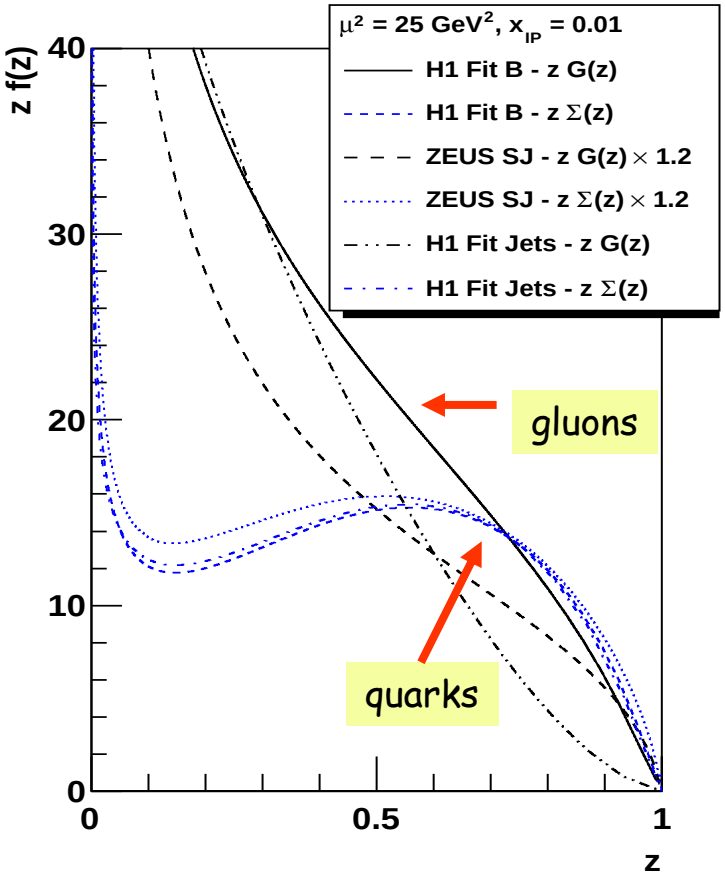
No extra parameters needed for DDIS

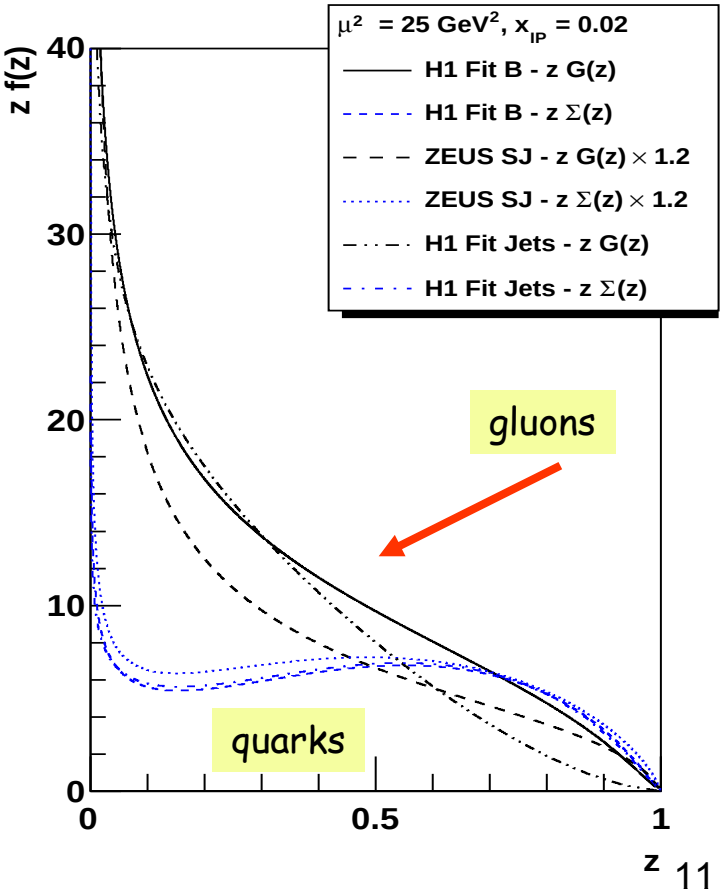
DPDFs in DIS

DPDFs obtained by H1 and ZEUS from inclusive, dijet (and D* measurements….)
DPDFs used in HERA analyses – **H1 fit B, H1 fit Jets, ZEUS fit SJ**
Main differences are in gluonic part.

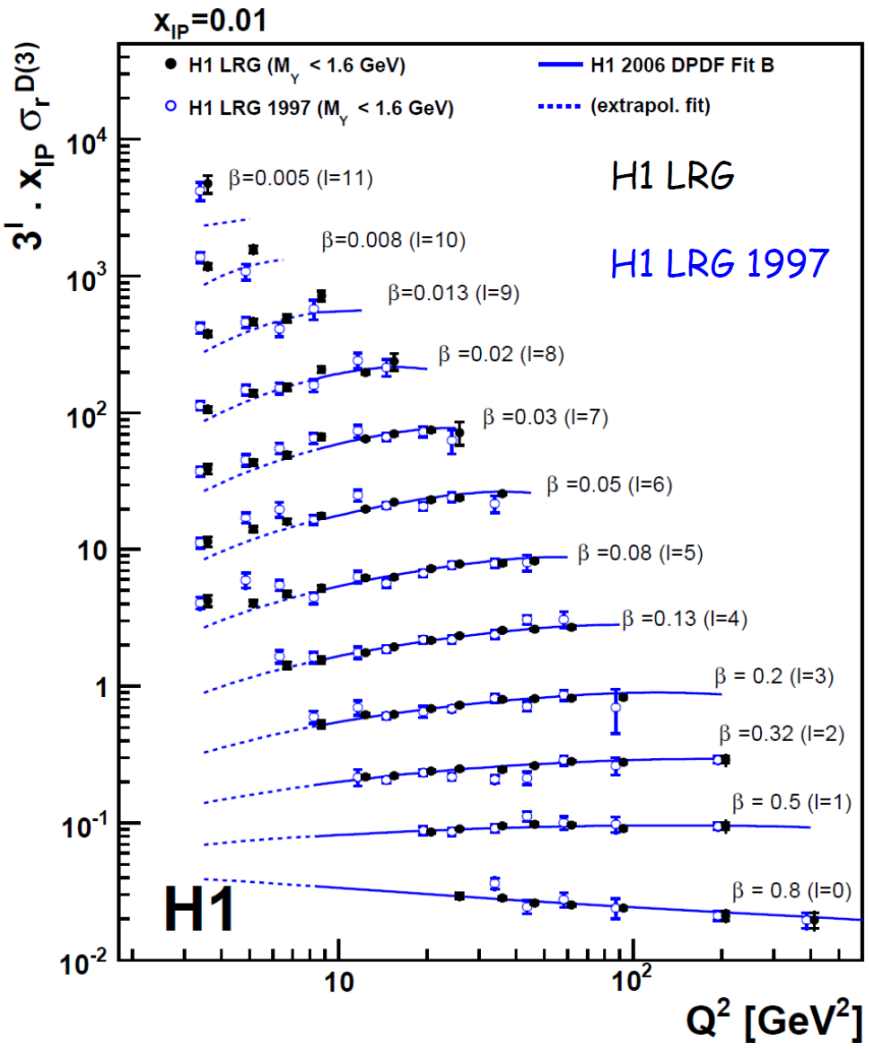
$$z_{IP} = \frac{Q^2 + M_{12}^2}{Q^2 + M_X^2}$$







Combined H1 LRG cross section



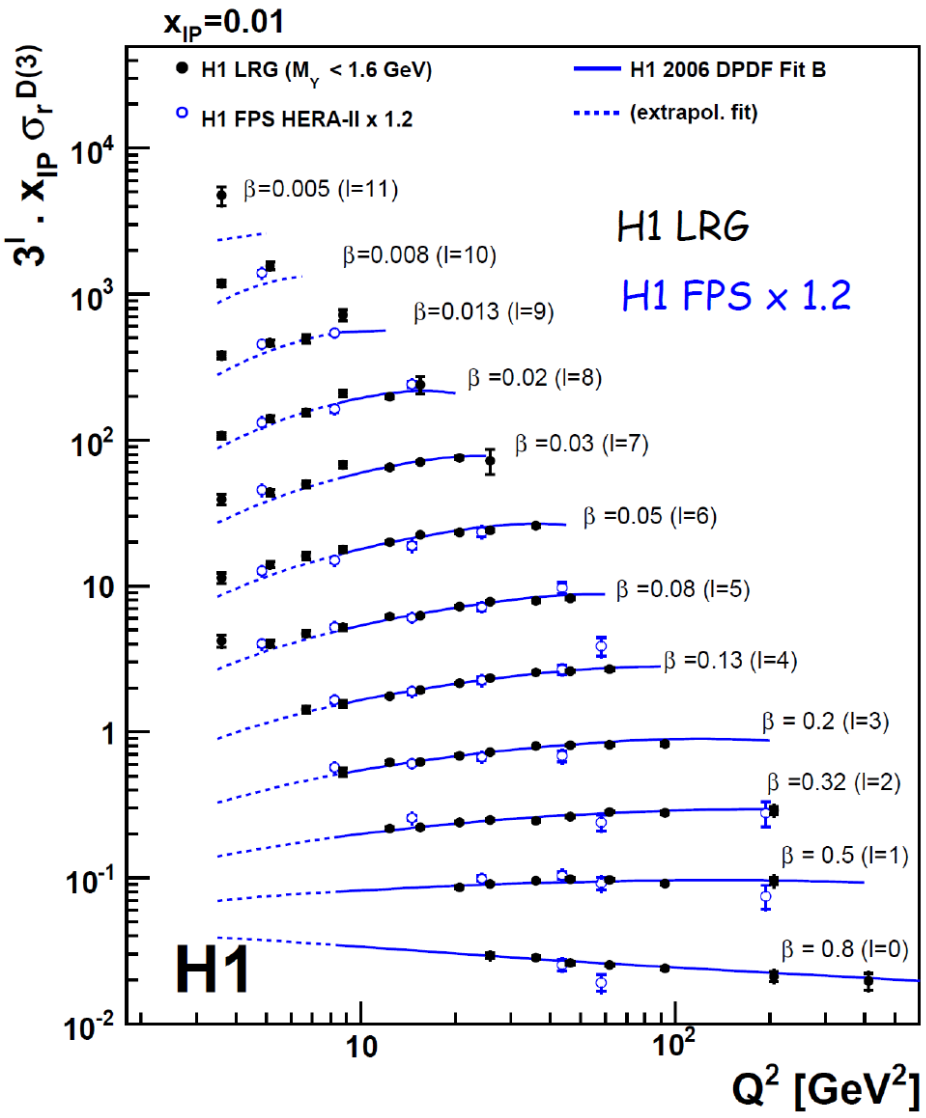
Published in 1997 and new cross sections agree well

Large reduction of statistical errors

Typical precisions for $Q^2 > 12$ GeV^2

1% (stat.)
5% (sys.)
4% (norm.)

LRG & FPS method



The ratio LRG/FPS :

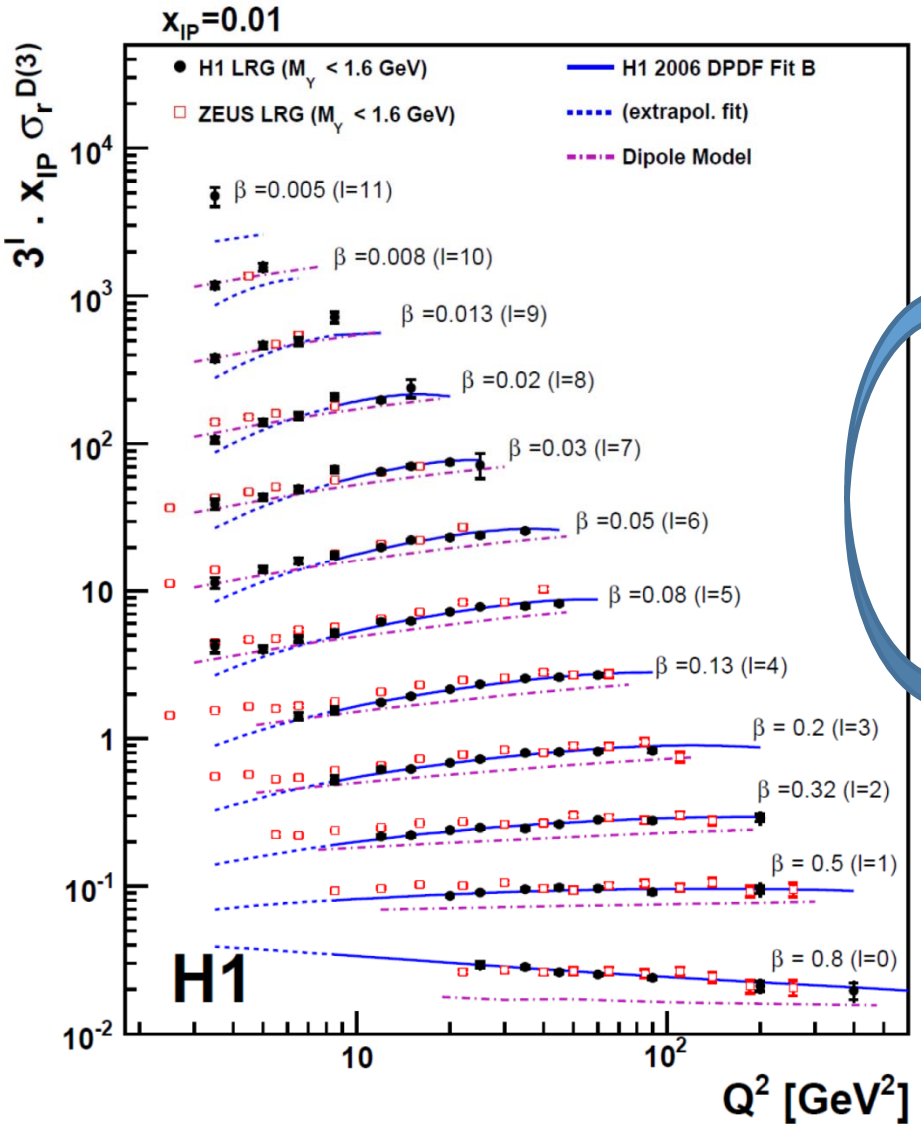
$$\frac{\sigma\,(M_Y < 1.6\,\mathrm{GeV})}{\sigma\,(Y = p)} = 1.203 \pm 0.019(\mathrm{exp.}) \pm 0.087(\mathrm{norm.})$$

(1.6%) (7.2%)

FPS cross sections are multiplied by factor 1.2 to take into account the dissociation admixture in LRG sample

Agreement with previous results, no Q^2 or β dependence of differences observed !

H1 & ZEUS & models (LRG data)



H1 data $M_Y < 1.6$ GeV^2

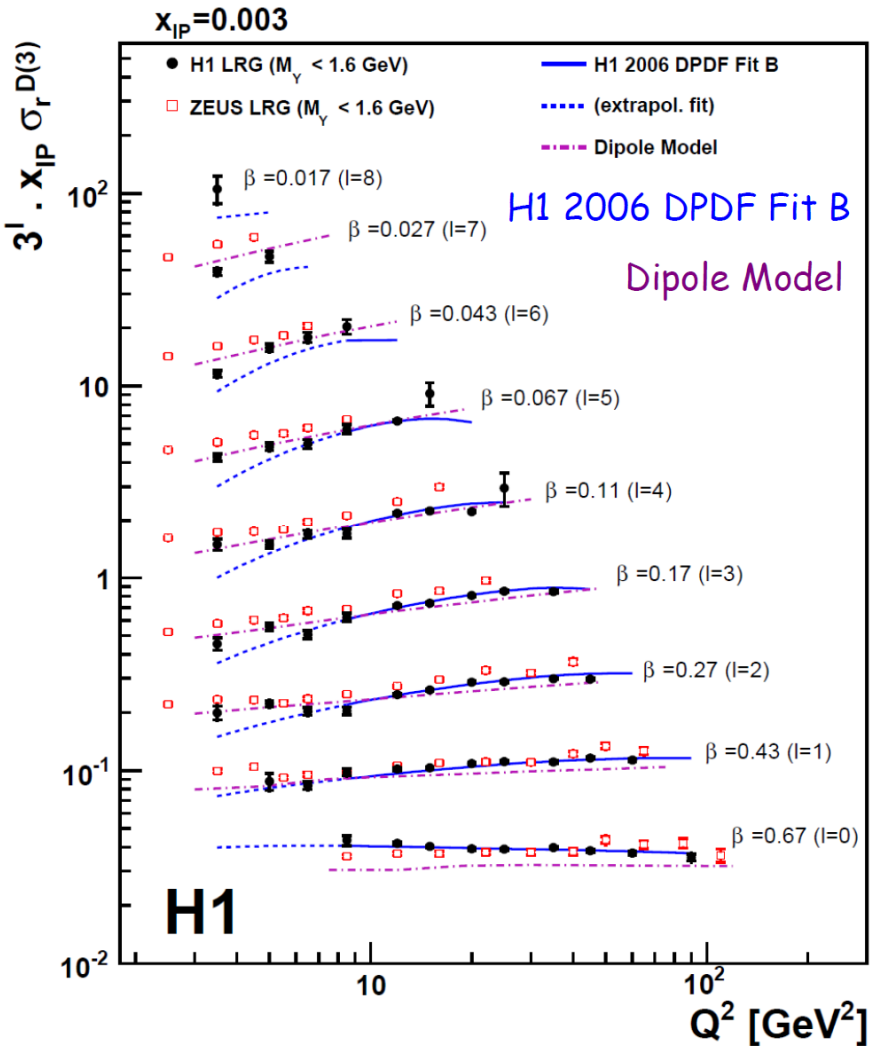
ZEUS data rescaled to $M_Y < 1.6$ GeV^2 (by factor 0.91).

[ZEUS Coll. NPB816 (2009) 1]

ZEUS data tend to be higher than H1, normalisation difference ~ 10% (within normalisation uncertainties of each measurement – 4% H1 and 2.25% ZEUS and uncertainty of the proton-dissociation factor) Similar to normalisation difference of ZEUS LPS and H1 FPS cross section results (15%)

Comparison is sensitive to systematic effects

Comparison with models



- low Q^2 – better description by dipole model, higher twist contributions?
- high Q^2 – better description by H1 fit B DPDF

Data available for comparison with models

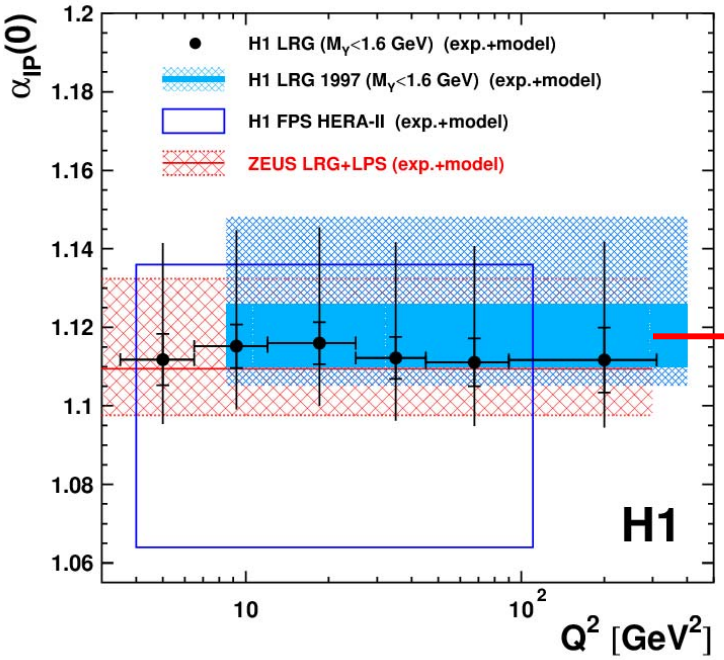
HERA LRG data combination……

Extraction of the pomeron trajectory

Regge fit to LRG cross sections:

$$F_2^{D(3)}(Q^2,\beta,x_{I\!P}) = f_{I\!P/p}(x_{I\!P})\; F_2^{I\!P}(Q^2,\beta) + n_{I\!R}\; f_{I\!R/p}(x_{I\!P})\; F_2^{I\!R}(Q^2,\beta)$$

$$f_{I\!P/p,I\!R/p}(x_{I\!P}) = \int_{t_{cut}}^{t_{min}} \frac{e^{B_{I\!P,I\!R}t}}{x_{I\!P}^{2\alpha_{I\!P,I\!R}(t)-1}}\mathrm{d}t \qquad \alpha_{I\!P,I\!R}(t) = \alpha_{I\!P,I\!R}(0) + \alpha'_{I\!P,I\!R}t$$



The mean value of pomeron intercept

$$\alpha_{I\!P}(0) = 1.113 \;\pm 0.002\;(\mathrm{exp.})\; {}^{+0.029}_{-0.015}\;(\mathrm{model})$$

No Q^2 dependence ->it supports the hypothesis of the proton vertex factorization

Conclusions

- H1 final results of LRG cross section measurement ➔ DESY –12 -041

  ZEUS results published in 2009 ➔ Nucl. Phys. B 816, (2009) 1

- Proton vertex factorisation confirmed once more…
- Combination of H1 and ZEUS LRG data should come
- Data available for comparison with models