Inclusive and Exclusive Diffraction at HERA

MORIOND QCD 2007

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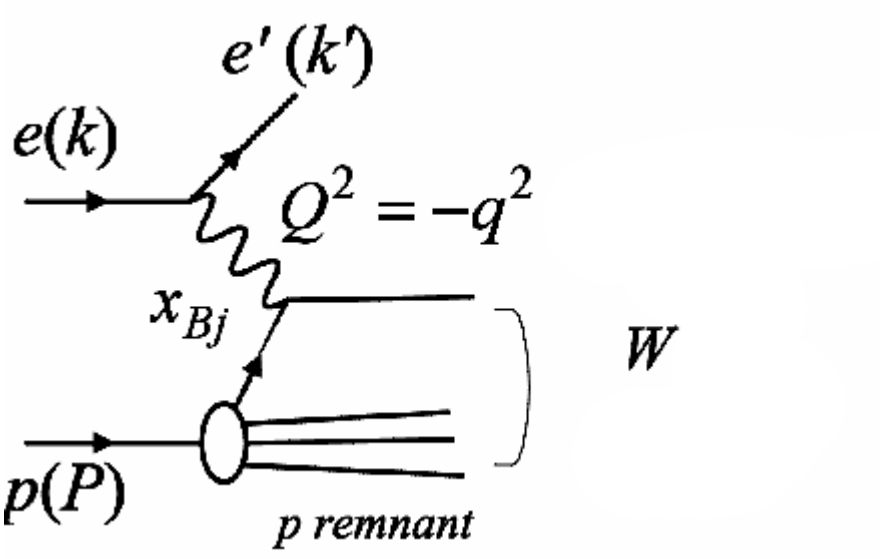
on behalf of
H1 and ZEUS collaborations

Inclusive Diffraction
Diffractive Parton Densities
Factorisation Tests
Exclusive Final States

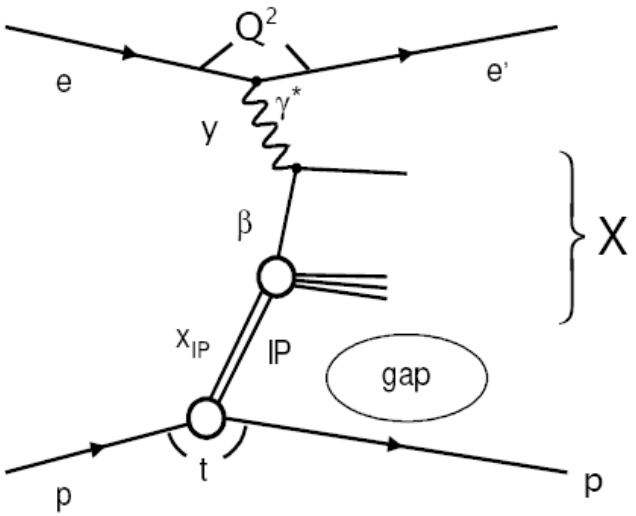
Diffractive Scattering at HERA

Deep inelastic scattering



- proton breaks
- p remnant and struck q connected by colour fields
- γ* probes internal structure of proton

Diffractive DIS



- proton stays intact
- no colour flow between p and γ* (t-channel of exchange of the vacuum quantum numbers)

→ gap in rapidity between X and p

~ 10% of low x events at HERA are diffractive

Diffractive Scattering at HERA

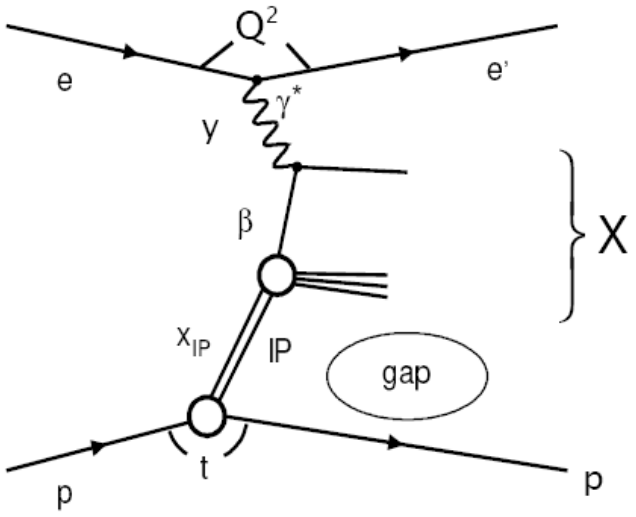
-in addition to DIS:

β = momentum fraction of IP taken by parton in hard subprocess

x_{IP} = proton momentum loss ($x_{BJ} = \beta x_{IP}$)

t = momentum transfer squared at p vertex

Diffractive DIS



- with high energy at HERA → hard diffraction with pQCD approach (hard scale by Q^2, q mass, E_T …)

→ **probe partonic structure of diffractive exchange**

Main observable - reduced cross-section

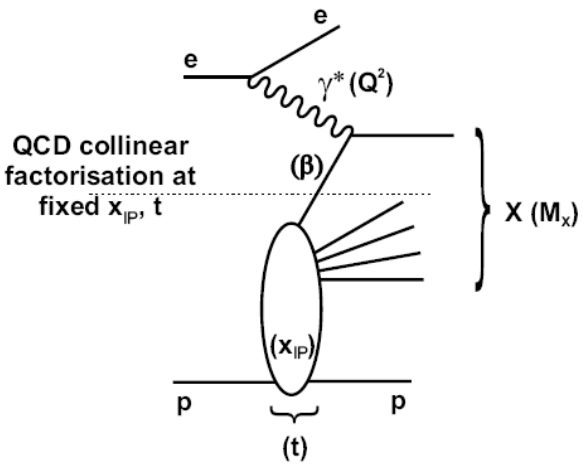
$$\frac{\mathrm{d}^3\sigma^{ep\to eXY}}{\mathrm{d}x_{I\!P}\,\mathrm{d}x\,\mathrm{d}Q^2} = \frac{2\pi\alpha^2}{xQ^4}\cdot Y_+ \cdot \sigma_r^{D(3)}(x_{I\!P}, x, Q^2)$$

$$\sigma_r^{D(3)} = F_2^{D(3)} - \frac{y^2}{Y_+}F_L^{D(3)}$$

F_2^D defined in similar way as inclusive F_2

F_L^D important at high y

Factorisation in Hard Diffraction

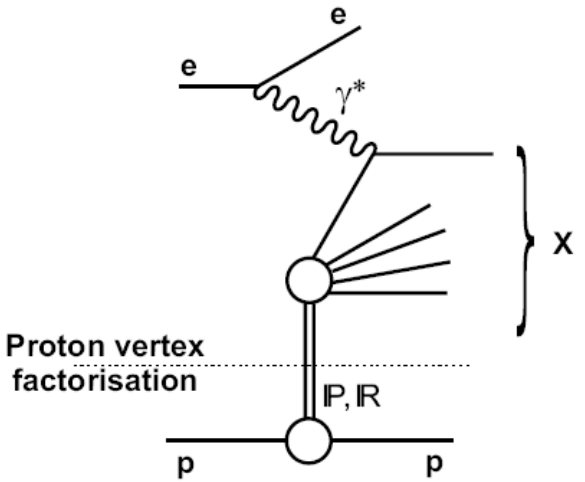


QCD factorisation proven by Collins:

$$\mathrm{d}\sigma^{ep\to eXY}(x, Q^2, x_{I\!P}, t) = \sum_i f_i^D(x, Q^2, x_{I\!P}, t) \otimes \mathrm{d}\hat{\sigma}^{ei}(x, Q^2)$$

→ **allows DPDFs to be introduced:**

f_i^D = the parton distribution function for a parton i under the constraint that the **proton survives the diffractive scattering**; universal for all hard processes



Assumption of proton vertex factorisation:

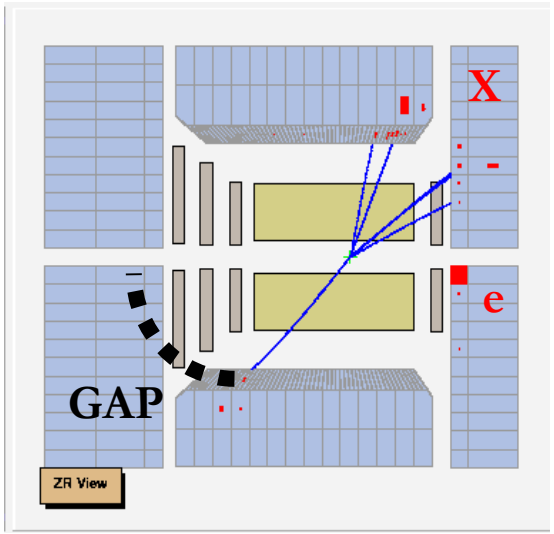
$$f_i^D(x, Q^2, x_{I\!P}, t) = f_{I\!P/p}(x_{I\!P}, t) \cdot f_i(\beta = x/x_{I\!P}, Q^2)$$

- supported by data within present precision
- no firm basis in QCD

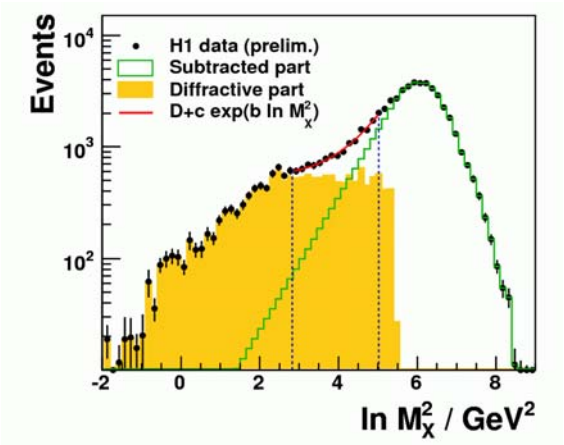
Selection Methods at HERA

$$e\,p \rightarrow e\,X\,p$$

indirect



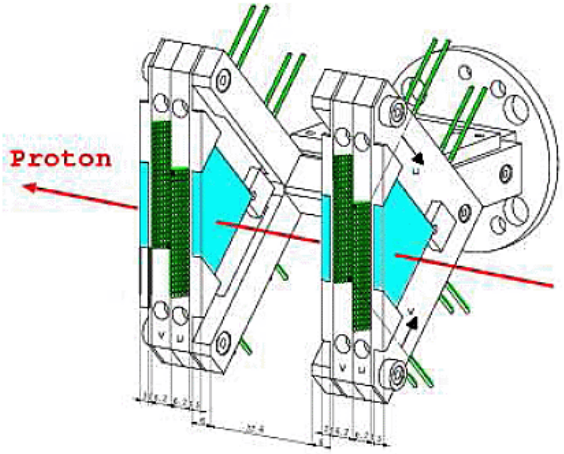
Look for large rapidity gap between outgoing p and X system



M_X method, different mass spectrum in diffr. vs non-diffr:

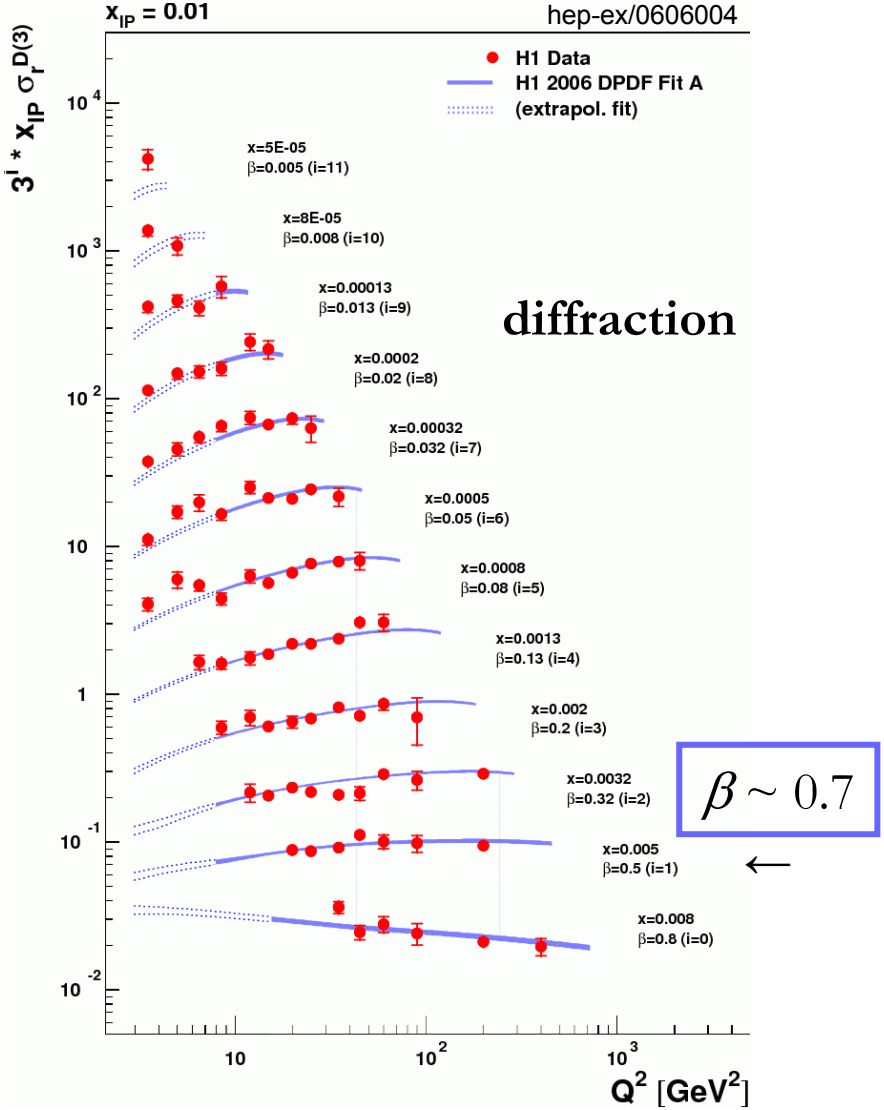
$$\frac{dN}{d\ln M_X^2} = D + c \cdot \exp(b\ \ln M_X^2)$$

direct



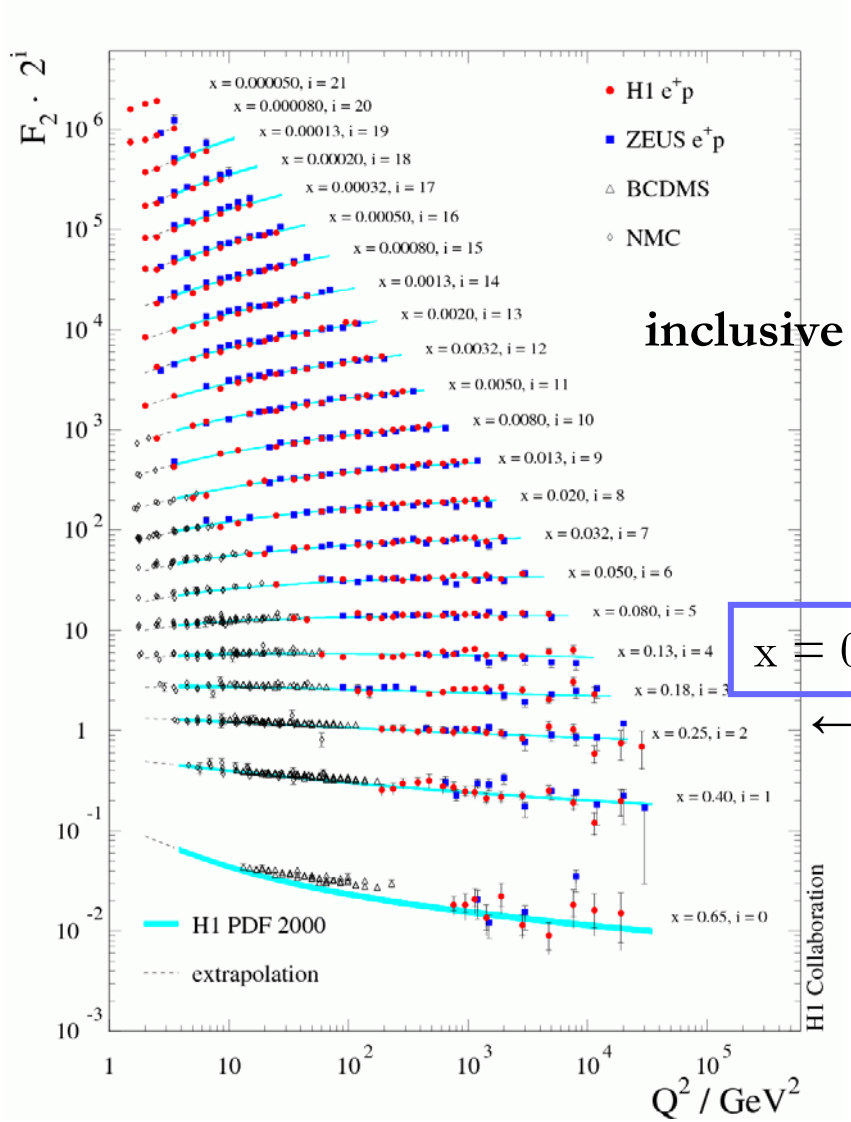
use proton spectrometers (FPS, LPS) to measure p, direct access to t

Diffractive Structure Function F_2^D



diffraction

$\beta \sim 0.7$ ←



inclusive

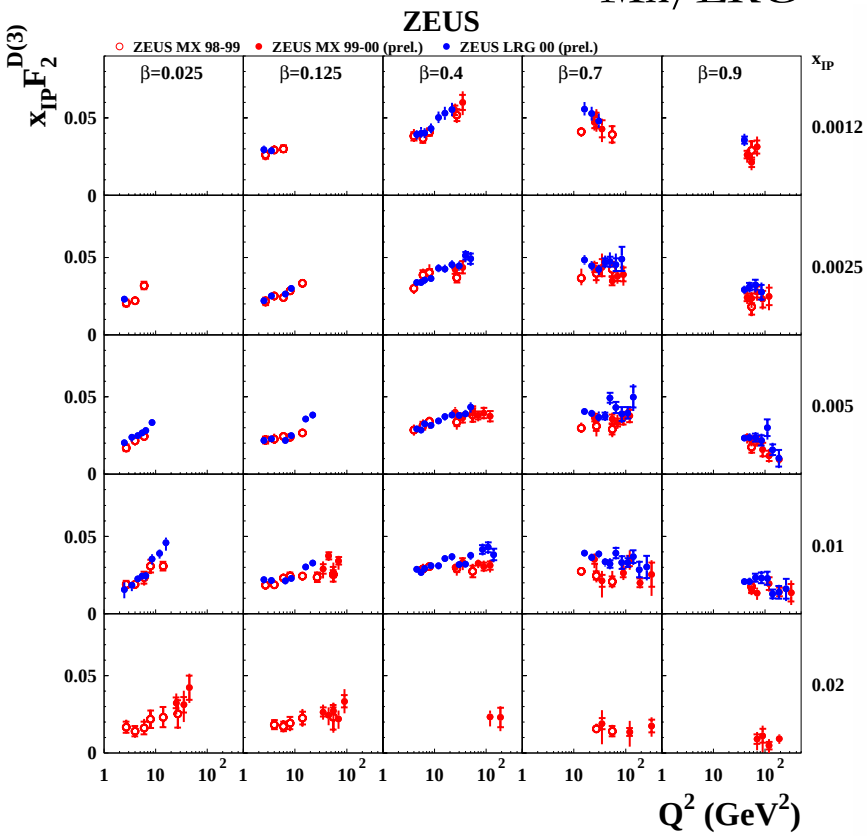
$x = 0.2$ ←

- large positive scaling violations up to $\beta \sim 0.7$ → **suggests large gluon content**

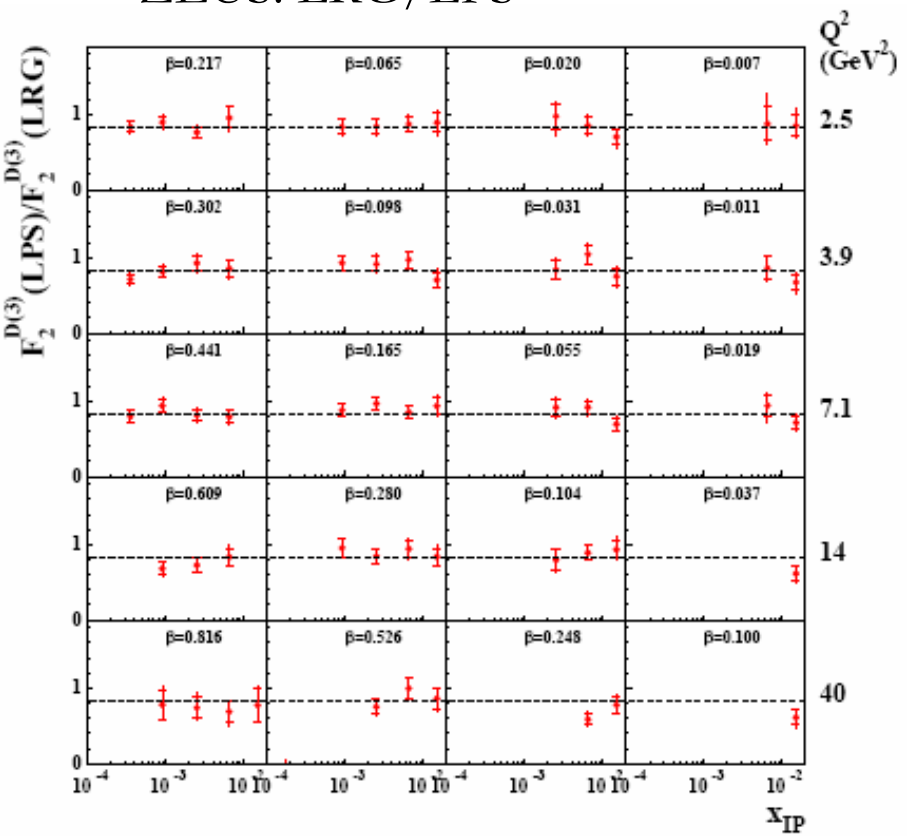
F_2^D : Different Methods Agreement

Combined analysis of the same dataset using different methods to test their agreement

Mx/LRG



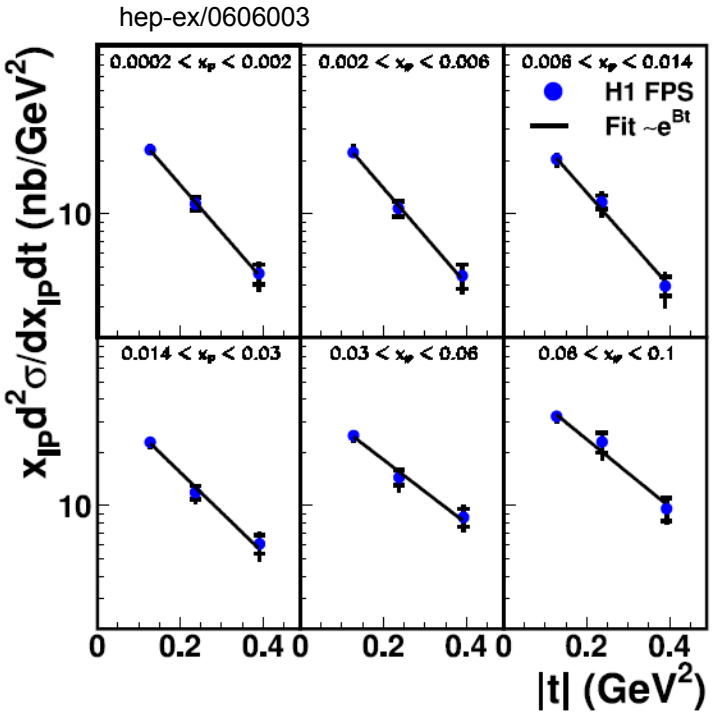
ZEUS: LRG/LPS

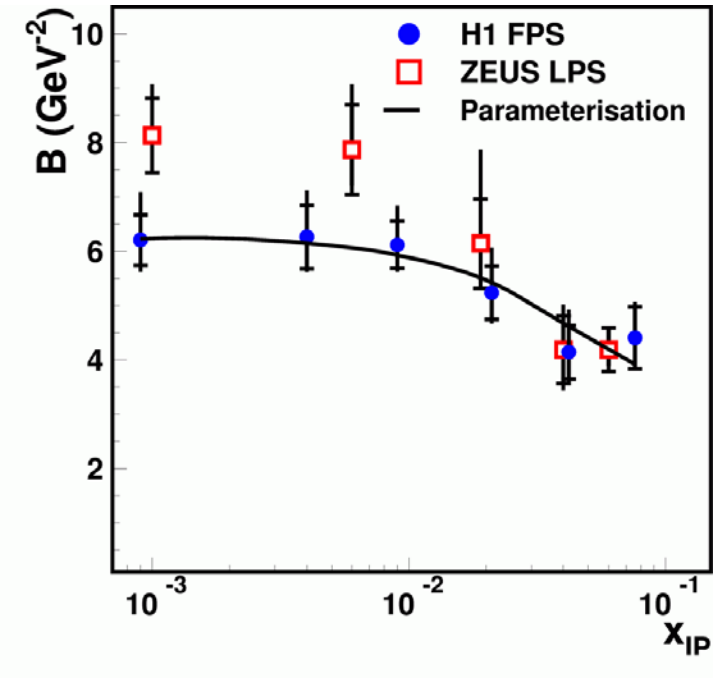


reasonable agreement found; work still ongoing to understand possible differences

Diffraction with Proton Spectrometers

Access to t measurement = study of $d\sigma^D/dt \sim e^{-B|t|}$



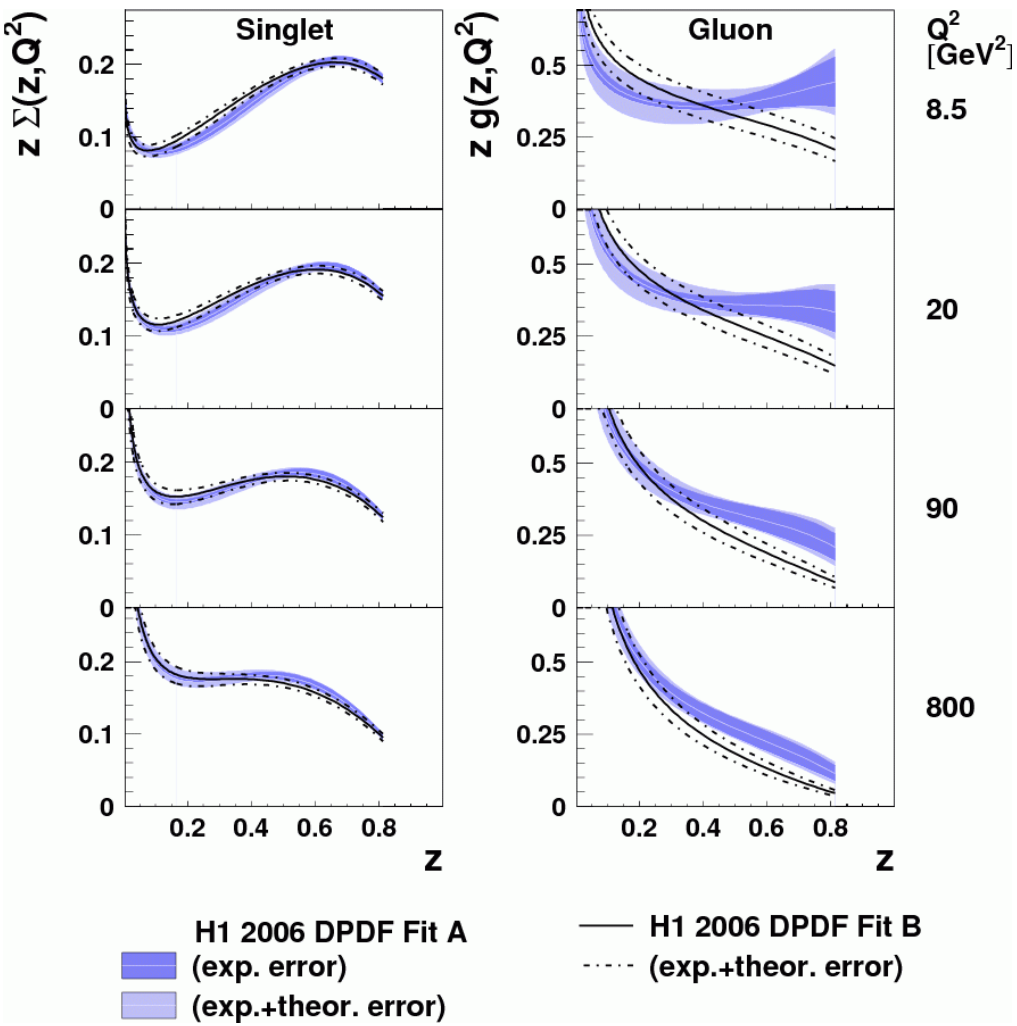


- low x_{IP} region fitted with
$B = B_{IP} - 2\alpha'_{IP} \ln x_{IP} \approx 6$ GeV^{-2}

- decrease of slope observed at high x_{IP} region ($x_{IP} > 0.03$)

Diffractive Parton Distribution Functions

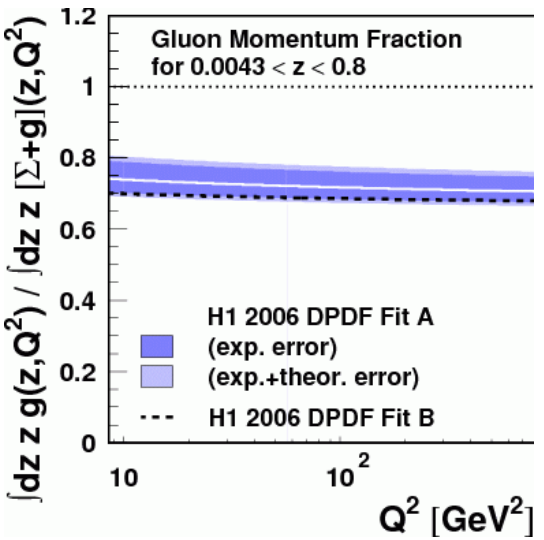
hep-ex/0606004



New set of DPDFs obtained from NLO DGLAP QCD Fit to Q^2 and β dependences of F_2^D (data: 97, 99-00)

- singlet is well constrained

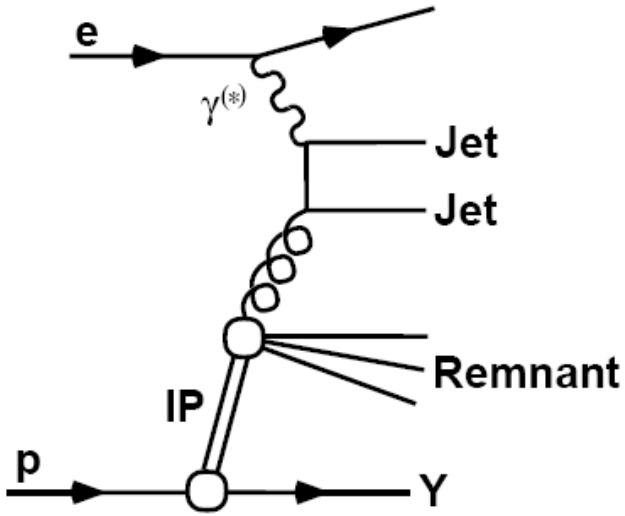
- DPDFs dominated by gluons extracted indirectly from scaling violations
→ large uncertainties in gluon contr.

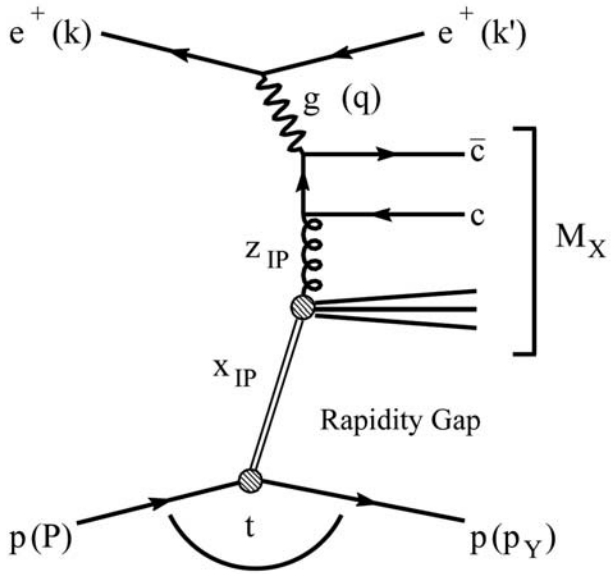


70% of momentum carried by gluons

QCD Factorisation Tests

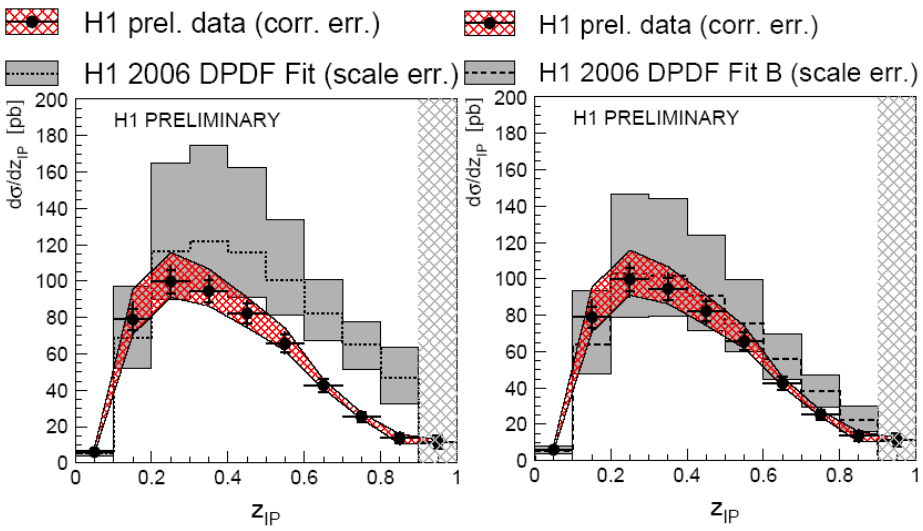
- take diffractive PDFs from inclusive cross-section measurement and predict NLO cross-section in other hard diffractive processes:





Would the QCD factorisation hold?

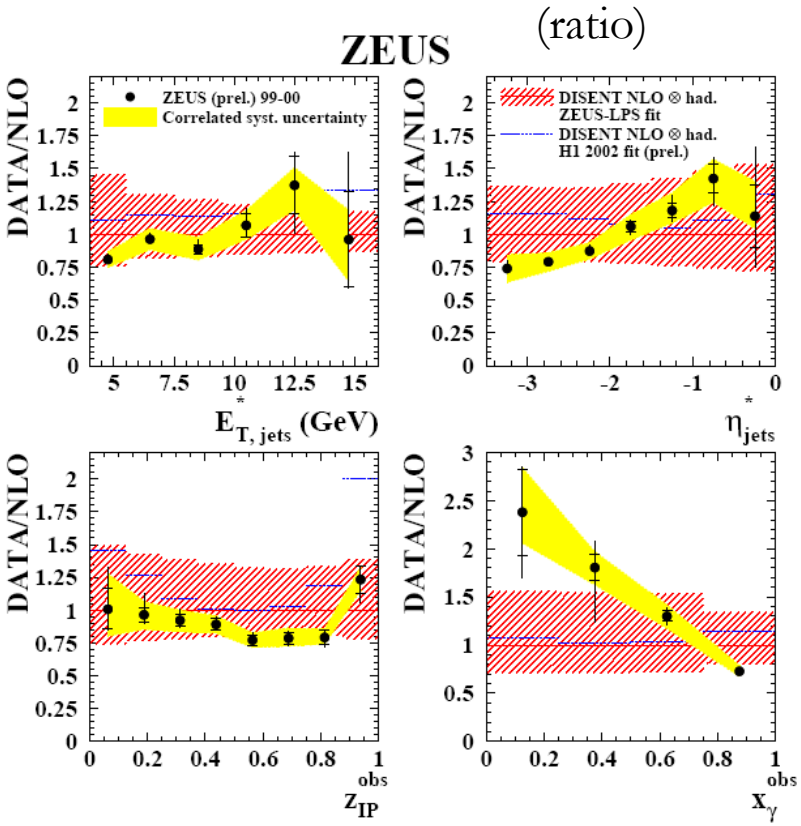
Dijets in DIS



QCD Fit A from inclusive DDIS doesn't describe high z_{IP} (most sensitive to gluon)

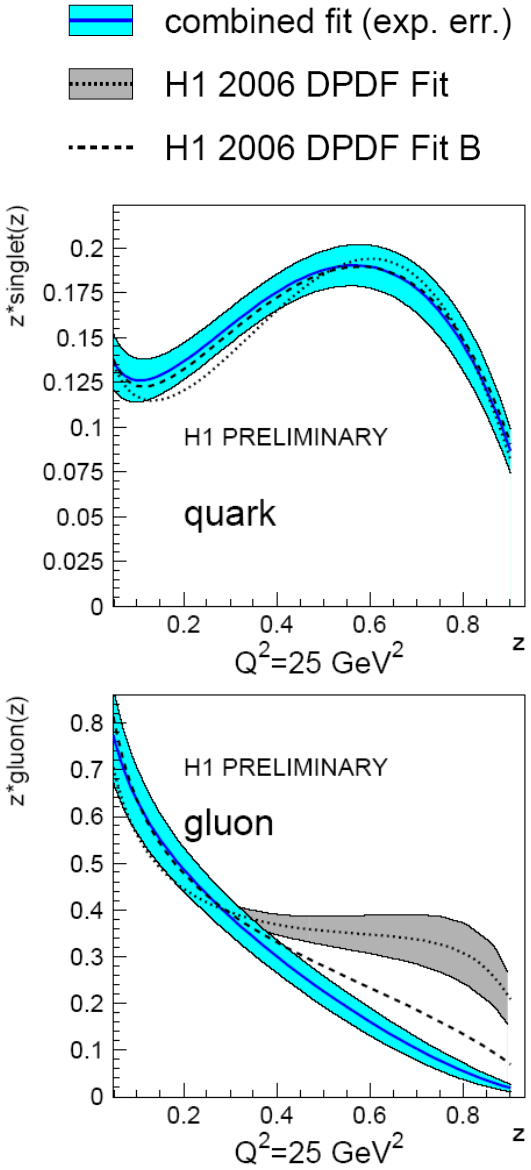
→ use dijets to constrain gluon in fits (as jets arise dominantly due to boson-gluon fusion process) and extract new set of DPDFs…

(ratio)



QCD factorisation confirmed for diffractive dijets in DIS regime

Combined QCD Fit



- combined NLO QCD Fit to inclusive diffraction + dijets

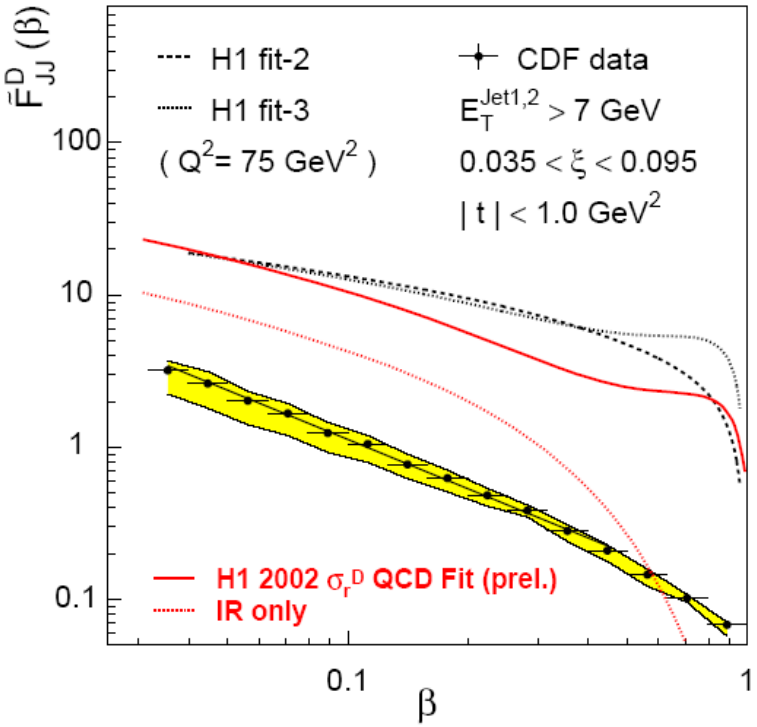
- new fit constrains quark and gluon densities over a wide range ($0.05 < z < 0.9$)

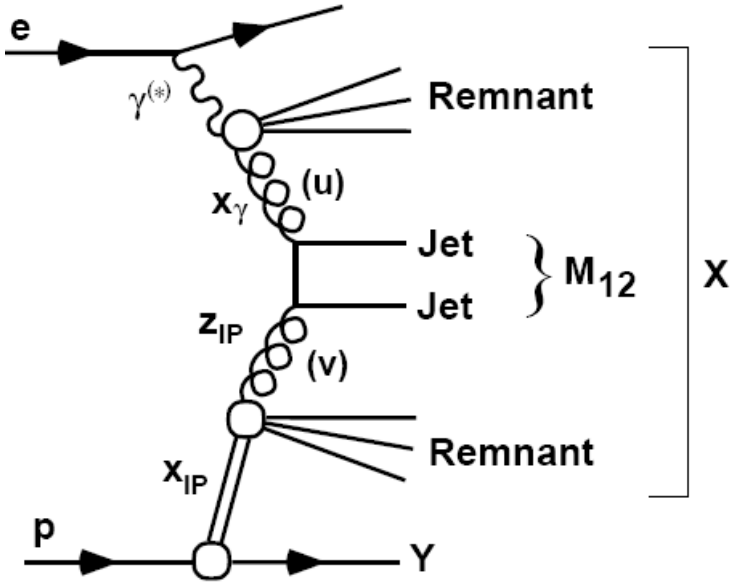
- precision on gluon component is better and shows smaller contribution than fits from inclusive data alone

- close to H1 2006 Fit B

QCD Factorisation Tests in Photoproduction

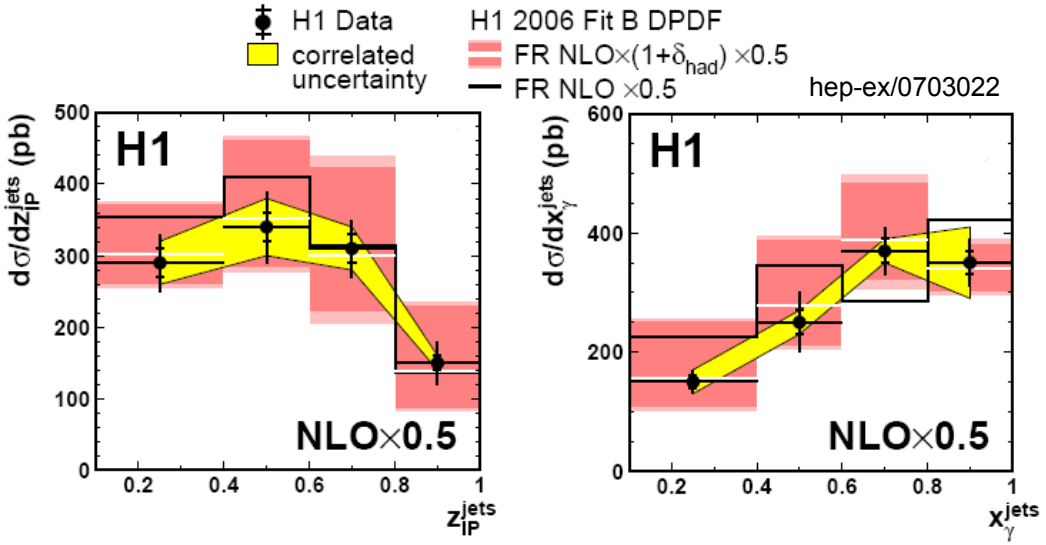
- **factorisation is not proven for h-h interactions**: broken at Tevatron, by factor of ~ 10 in normalisation, when using extrapolated HERA DPDFs



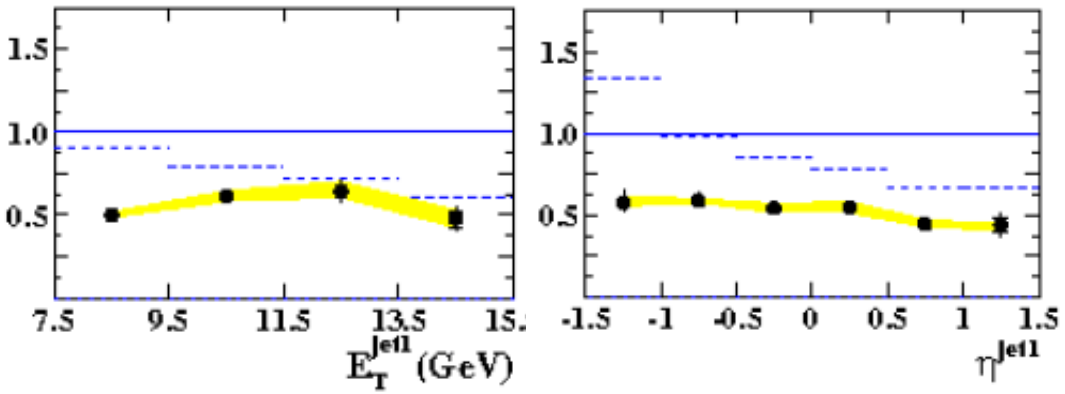


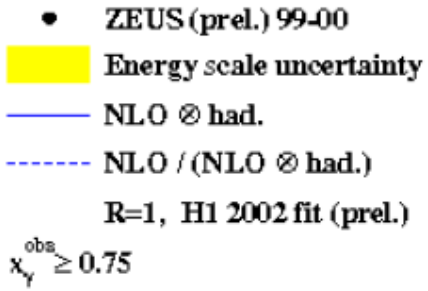
- **test at HERA in photoproduction through resolved photon component**

Dijets in Photoproduction / QCD Factorisation Breaking



(ratio)



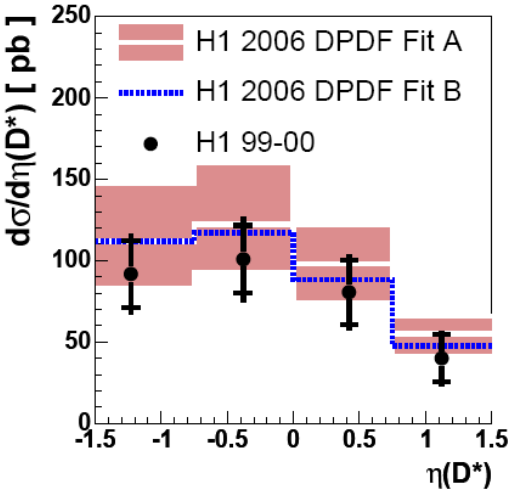


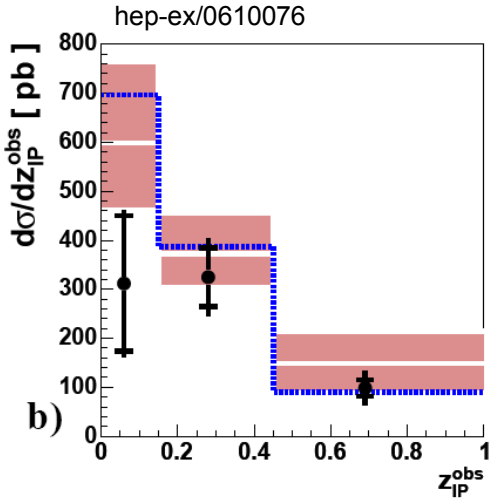
- NLO predictions describe shape but scaled by 0.5 to resolved *and* direct photon

QCD factorisation broken uniformly over x_γ

Diffractive D* Measurement

D* in DIS

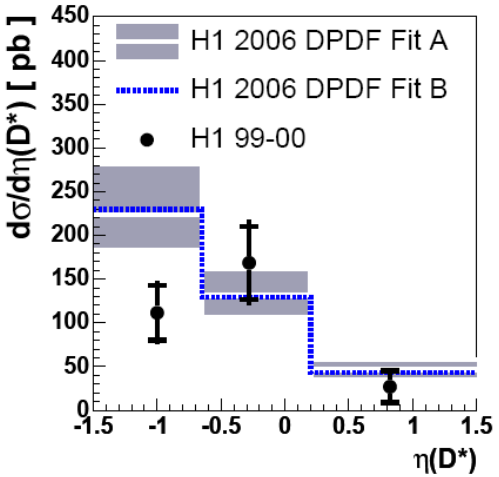


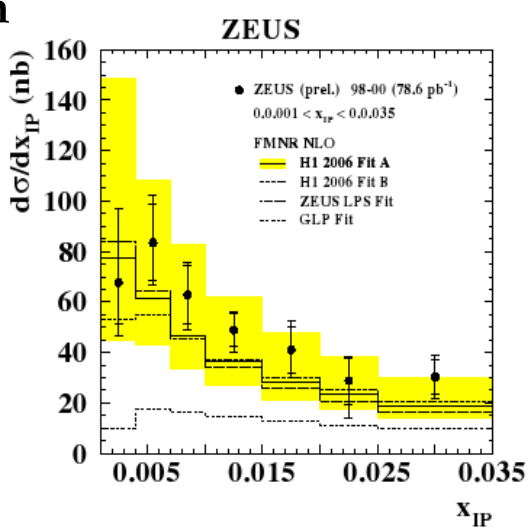


- another way to test universality of DPDFs

through $D^* \rightarrow K \pi \pi_s$

D* in photoproduction

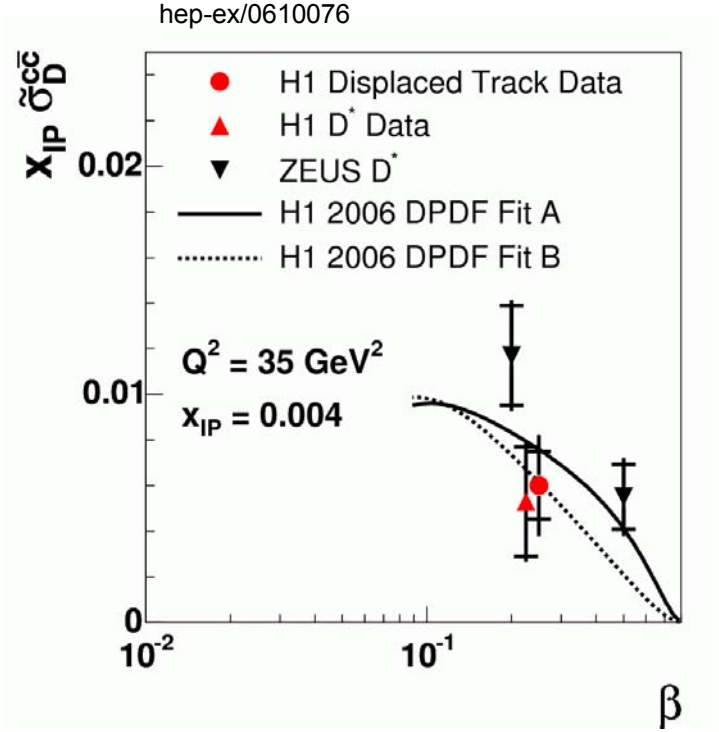


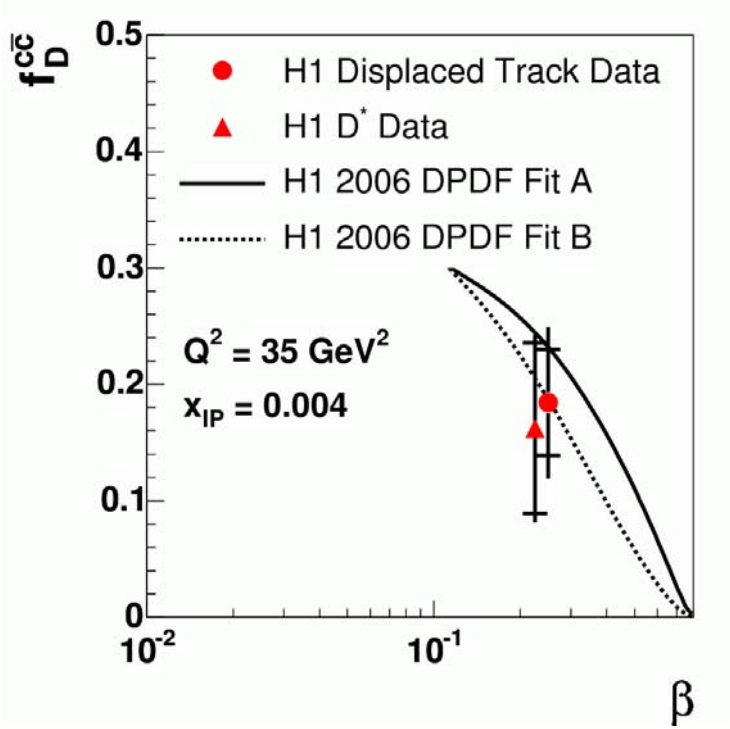


In agreement with NLO QCD predictions in both regimes, but within large errors (supports QCD factorisation)

F_2^{Dcc}

hep-ex/0610076





- use of displaced tracks from primary vertex to distinguish (statistically) between events containing heavy charm quark from those containing only light quarks

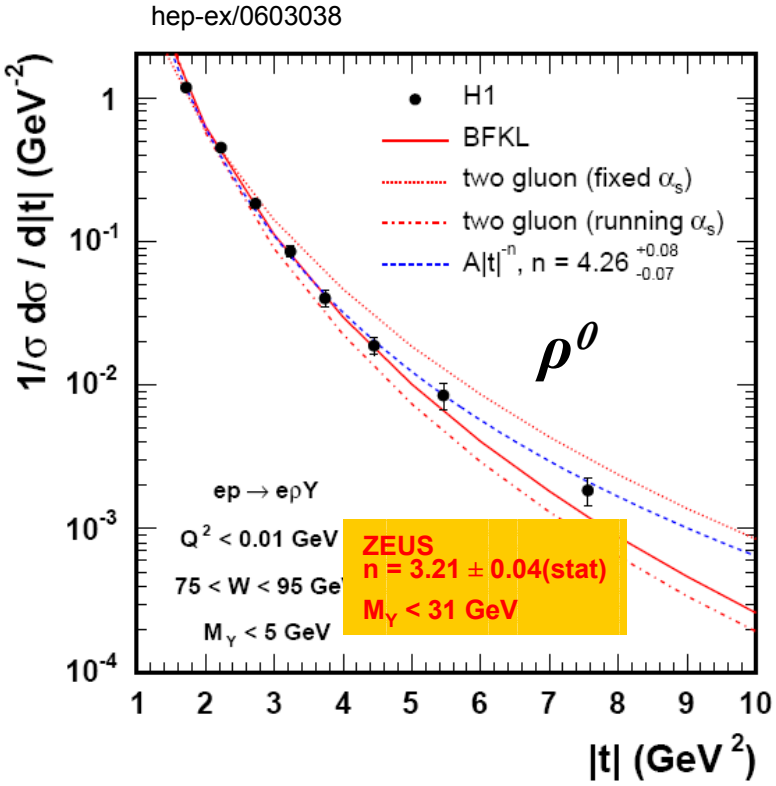
- good agreement between experiments, but statistically limited
- predictions from H1 2006 QCD Fits describe data well
- **charm contribution to $F_2^D \sim 20\%$** (similar as for inclusive DIS)

Exclusive Final States

- ρ^0 and J/Ψ at large t in photopr. $\quad ep \rightarrow eVMY$

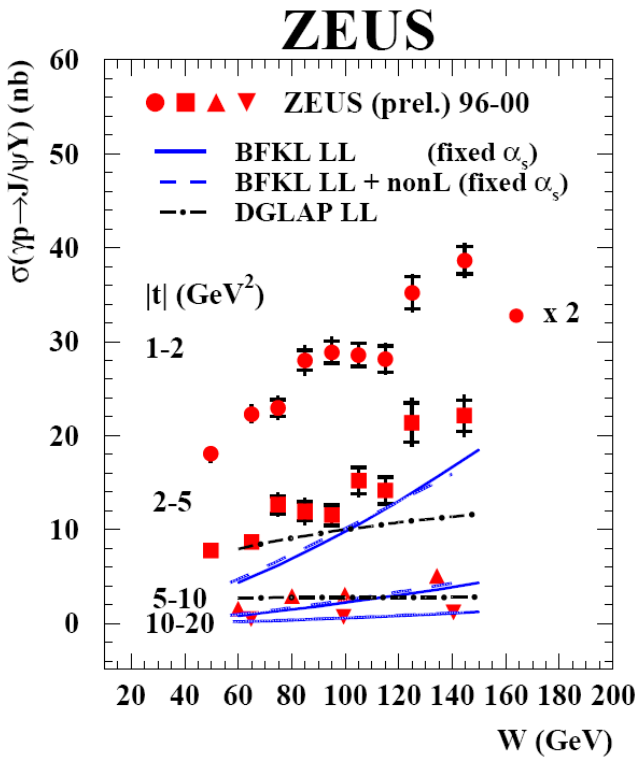
- ρ^0 at small t in photoproduction $\quad ep \rightarrow e\rho p$

ρ^0 and J/Ψ Meson in PHP at High *t*



BFKL gives reasonable description for the shape of *t* distribution

s-channel helicity conservation violation observed



J/Ψ

- observed strong rise with W

Fit in W motivated by Regge formalism

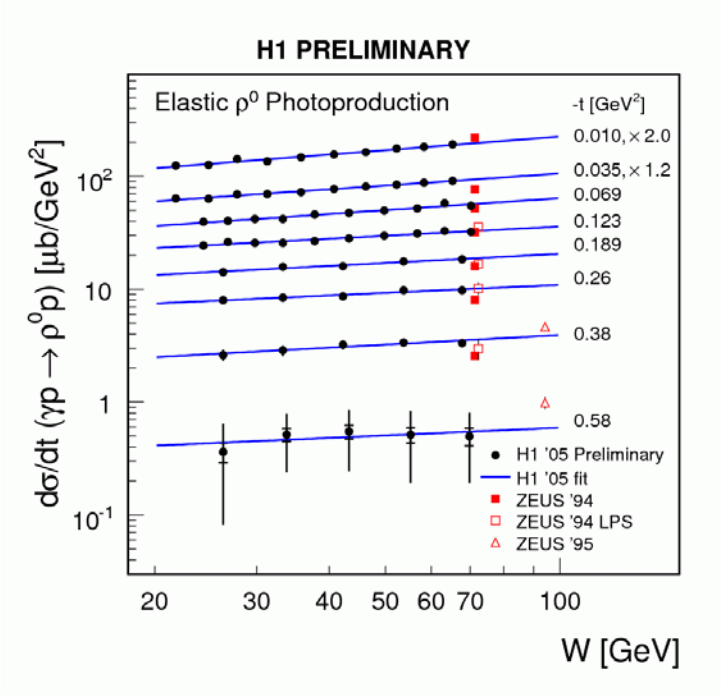
$\alpha_{IP}(0) = 1.153 \pm 0.048_{stat} \pm 0.039_{syst}$

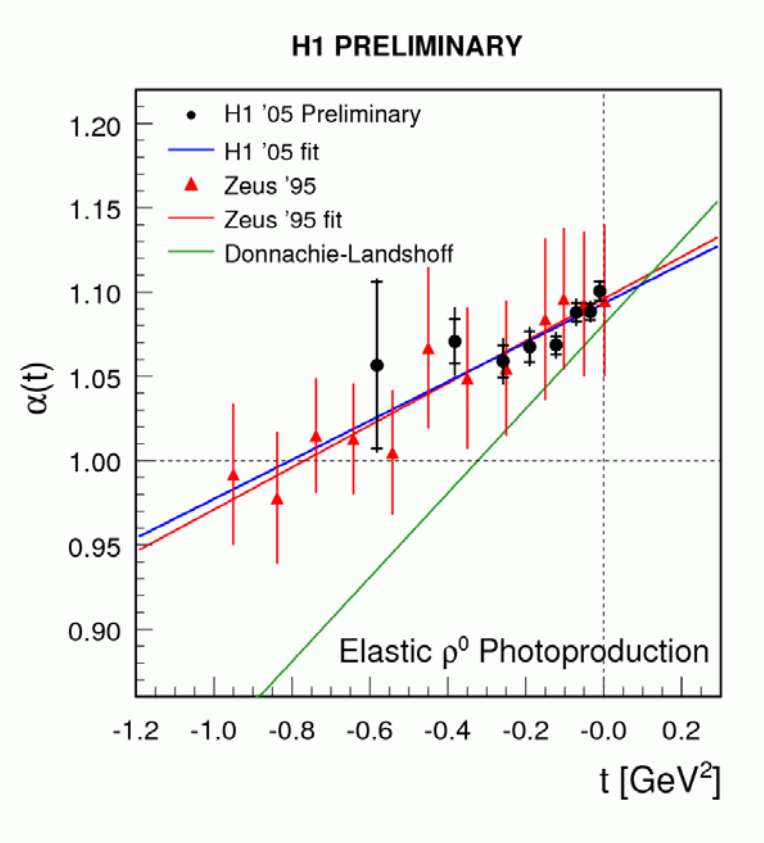
$\alpha'_{IP} = -0.020 \pm 0.014_{stat} \pm 0.010_{syst}$

- similar to H1 values
- consistent with BFKL prediction

ρ^0 Meson in Photoproduction

- first measurement of $\alpha_{IP}(t)$ from a single experiment (~ 240k events)





Fit: $$\frac{\mathrm{d}\sigma^{\gamma\mathrm{P}}(W)}{\mathrm{d}t} = \frac{\mathrm{d}\sigma^{\gamma\mathrm{P}}(W_0)}{\mathrm{d}t}\left(\frac{W}{W_0}\right)^{4(\alpha-1)}$$

$$\alpha_{\mathbb{P}}(t) = 1.093 \pm 0.003(stat.)^{+0.008}_{-0.007}(syst.) + (0.116 \pm 0.027(stat.)^{+0.036}_{-0.046}(syst.))\ \mathrm{GeV}^{-2} \cdot t$$

α'_{IP} not compatible with 0.25 GeV^{-2} (Donnachie, Landshoff)

- confirms indirect ZEUS measurement

Summary

- new H1 QCD Fits from inclusive diffractive DIS are available and can be used to test QCD hard scattering factorisation

- combined QCD fit result with dijets gives better constrain on gluons at high z

- QCD factorisation is observed in DIS for dijets and charm and is broken in dijets in photoproduction by a factor of 2 (holds in charm, but within large uncertainties)

- ρ^0 and J/Ψ mesons at high t in photoproduction confirm predictions based on BFKL evolution of parton densities

- ρ^0 meson photoproduction shows disagreement with the soft pomeron trajectory slope

Backup slides

H1 2006 QCD Fit

at low β strong sensitivity to gluon (g → qq)
at high β sensitivity to g weakens (q → qg)

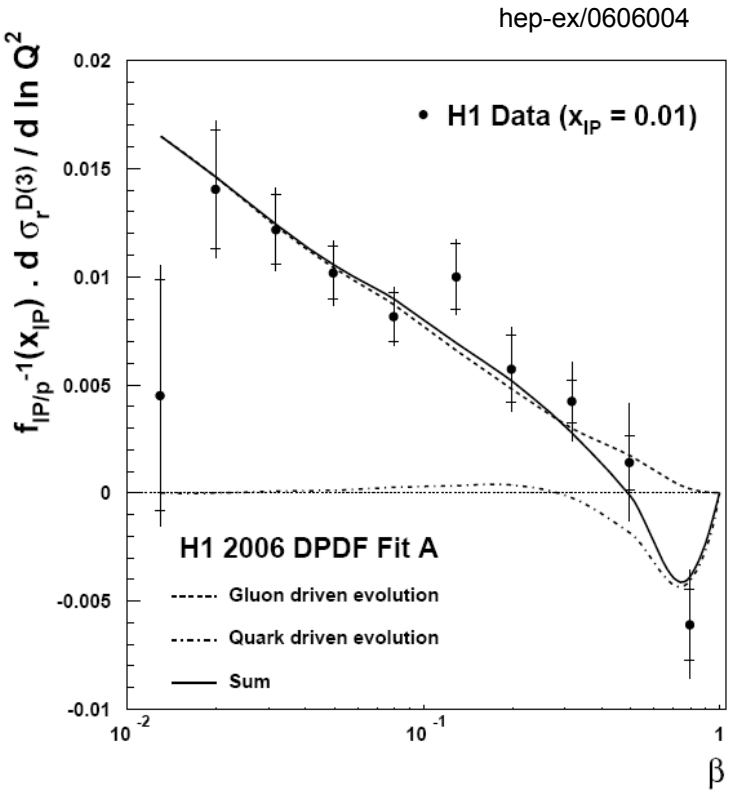
- kinematic region: $\beta < 0.8$, $Q^2 > 8.5$ GeV^2

Parton density parameterisation:

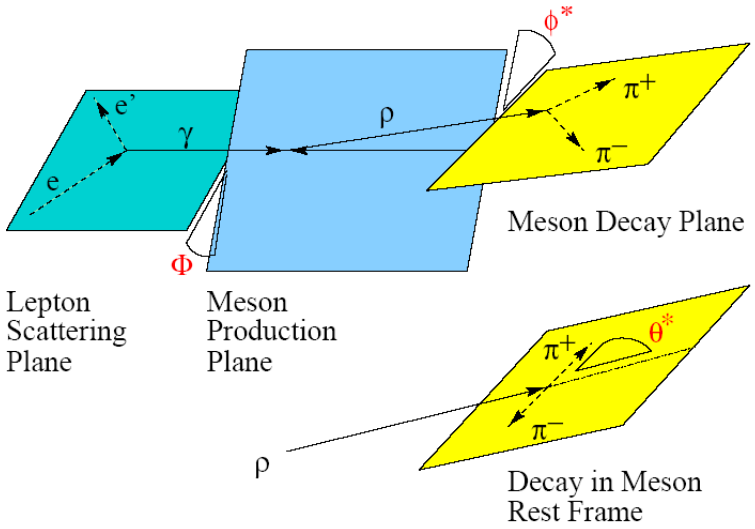
$$z\Sigma(z,Q_0^2) = A_q\, z^{B_q}\, (1-z)^{C_q}$$

$$zg(z,Q_0^2) = A_g\, (1-z)^{C_g}$$

$\partial F_2^D \,/\, \partial \ln Q^2$



ρ^0 Meson s-channel helicity conservation violation



- in photoproduction access only to Φ*, θ*