Recent diffractive results from HERA

Jo Cole
University of Bristol

On behalf of the H1 and ZEUS Collaborations

21st February 2004

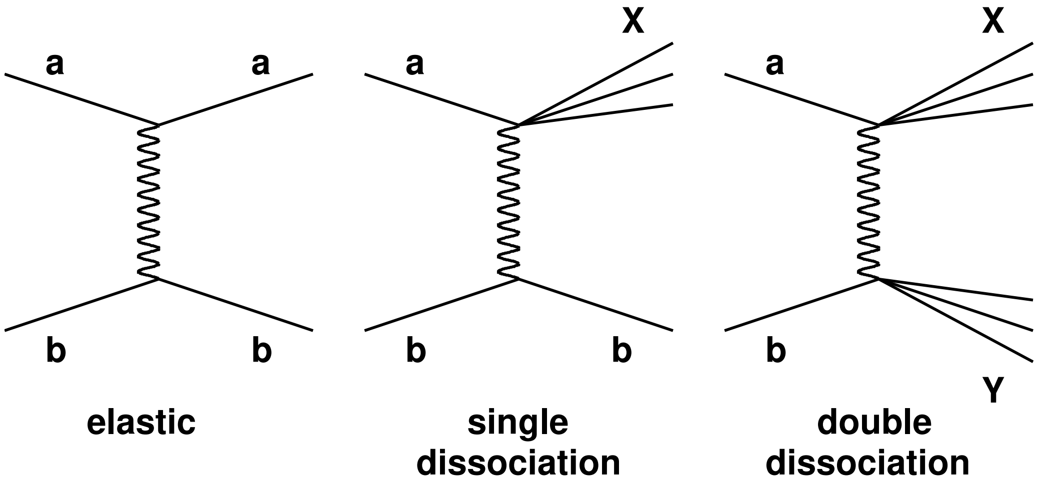
- ▷ What is diffraction ?
- ▷ Diffraction at HERA: Theory and experimental techniques
- ▷ The diffractive structure function of the proton
- ▷ Next-to-leading order QCD fits of diffractive data
- ▷ Tests of QCD factorisation
- ▷ Charm production in diffraction

What is diffraction ?

- In hadron-hadron and lepton-hadron scattering
- Large fraction of events from:
  - elastic scattering
  - single dissociation
  - double dissociation
- In all cases, t-channel exchange of colourless object → Pomeron $\mathbb{P}$
- Final states, X and Y hadronise independently

  ⇒ rapidity gap in the final state

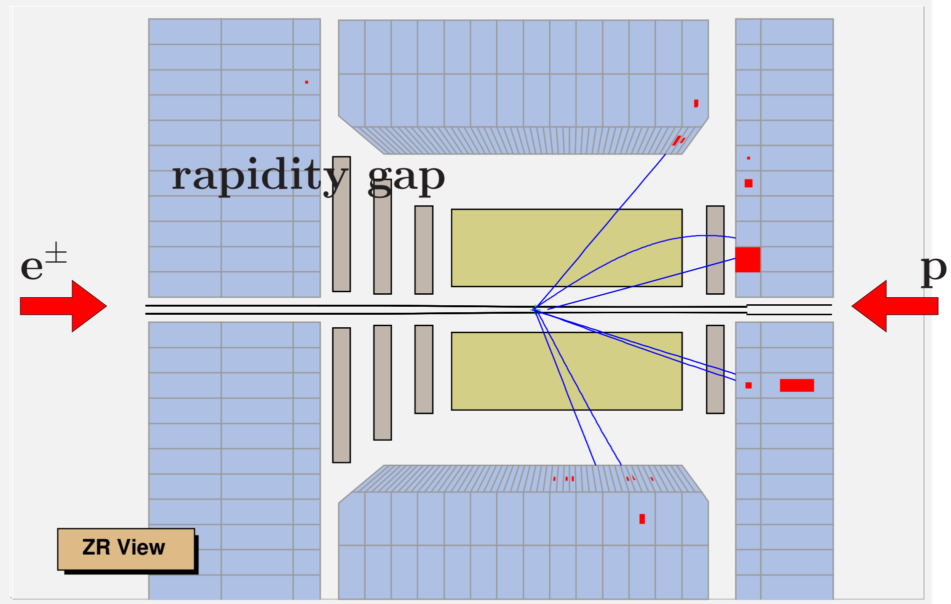
  if s large enough

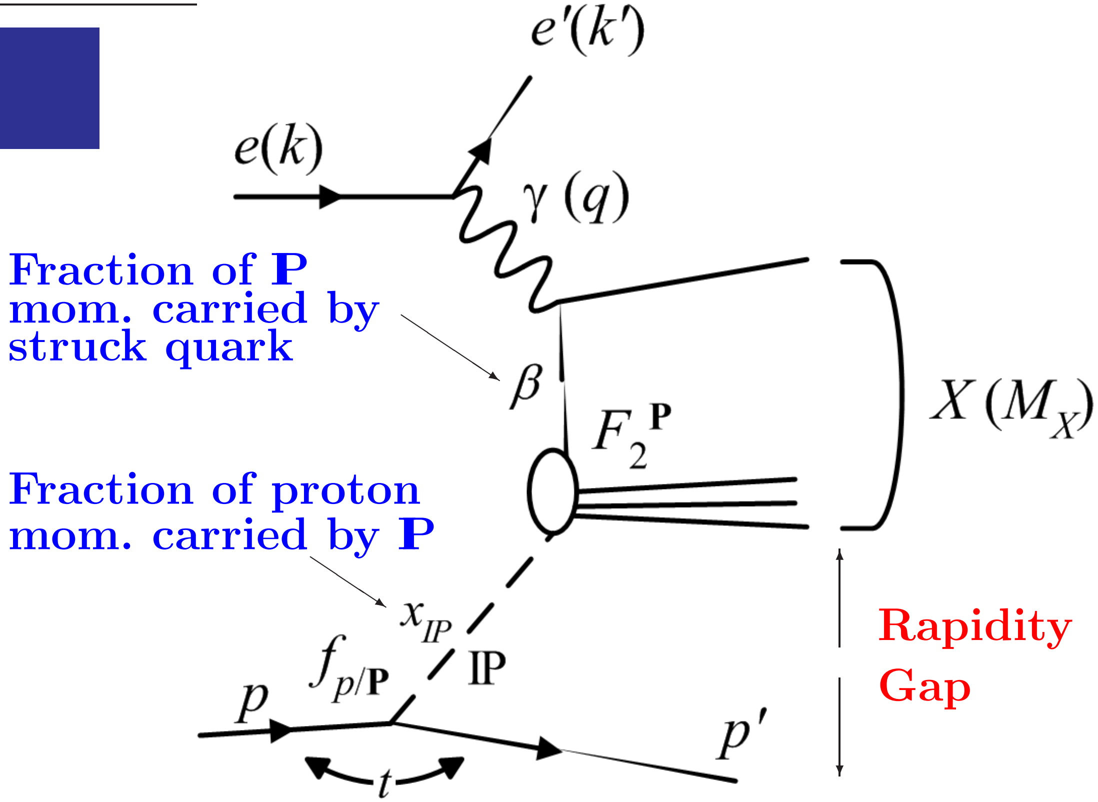


In ep scattering, interested in these processes

$(a = \gamma^*, \; b = p)$

Diffraction at HERA





▷ Define diffractive structure function:

$$\frac{d^4\sigma}{d\beta dQ^2 dx_P dt} = \frac{4\pi\alpha^2}{\beta Q^4}(1 - y + y^2/2)\sigma_r^{D(4)}(\beta, Q^2, x_P, t)$$

$$F_2^{D(4)} - \frac{y^2}{1+(1-y)^2}F_L^{D(4)}$$

▷ Number of ways to identify events:

- identify rapidity gap (η_{MAX} method)
- tag final state proton (LPS/FPS)
- Use M_X distribution

▷ Usually integrate over t: $F_2^{D(3)}(\beta, Q^2, x_P)$

Diffractive structure function of the proton (ZEUS-LPS)

Assume $F_L^D = 0$

▷ Scaling violations observed

- QCD evolution — large gluon contribution

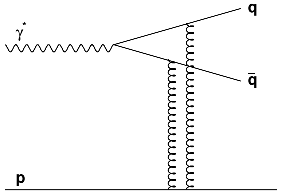
▷ Behaviour similar in all x_P regions

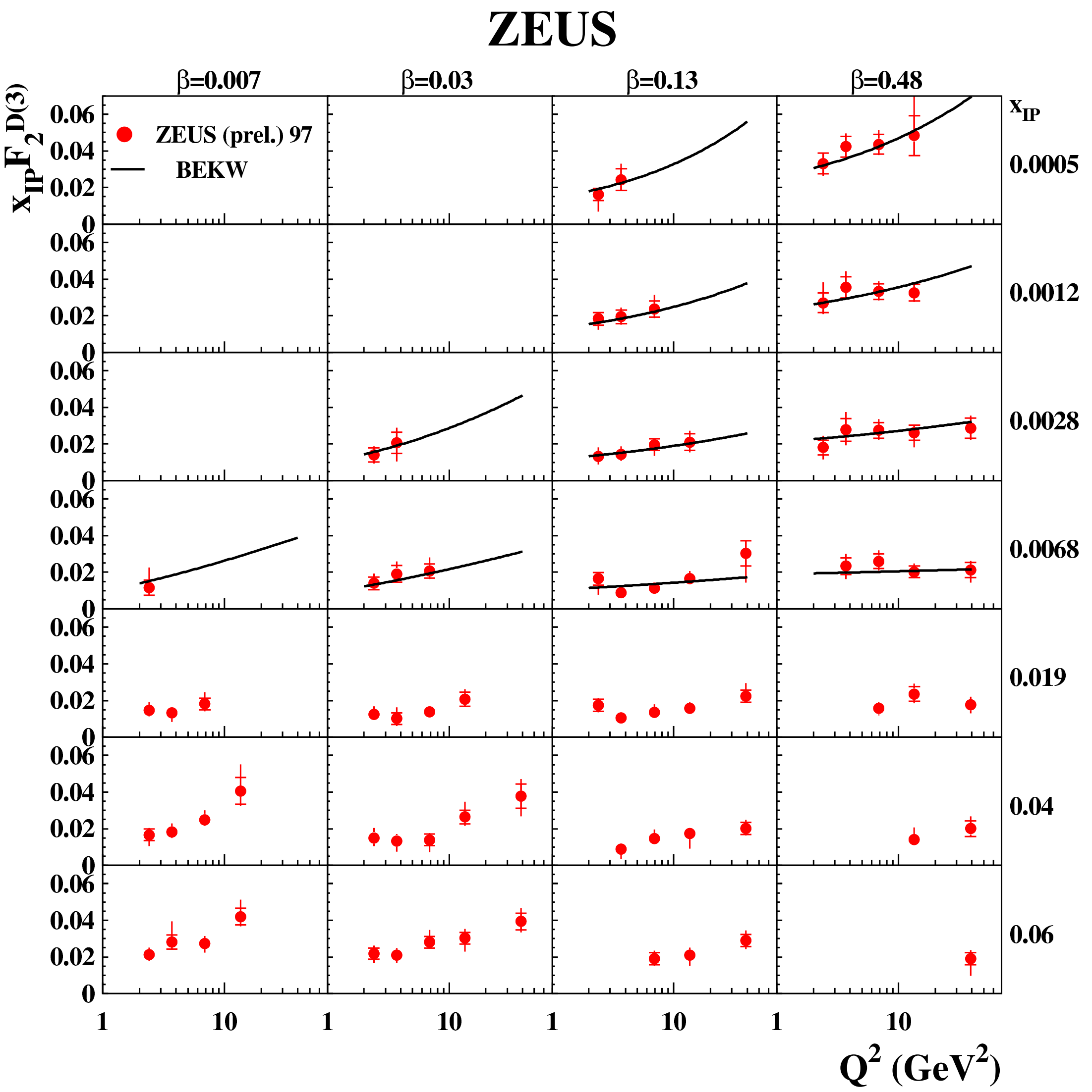
- Regge factorisation:

$$F_2^{D(3)} = f_P(x_P) \cdot F_2^{D(2)}(\beta, Q^2)$$

▷ Results compared to model of Bartels et al. (Dipole model)

- $\gamma^* \to q\bar{q}, q\bar{q}g$ downstream of proton
- $q\bar{q}$ interacts with proton via exchange of gluon ladder





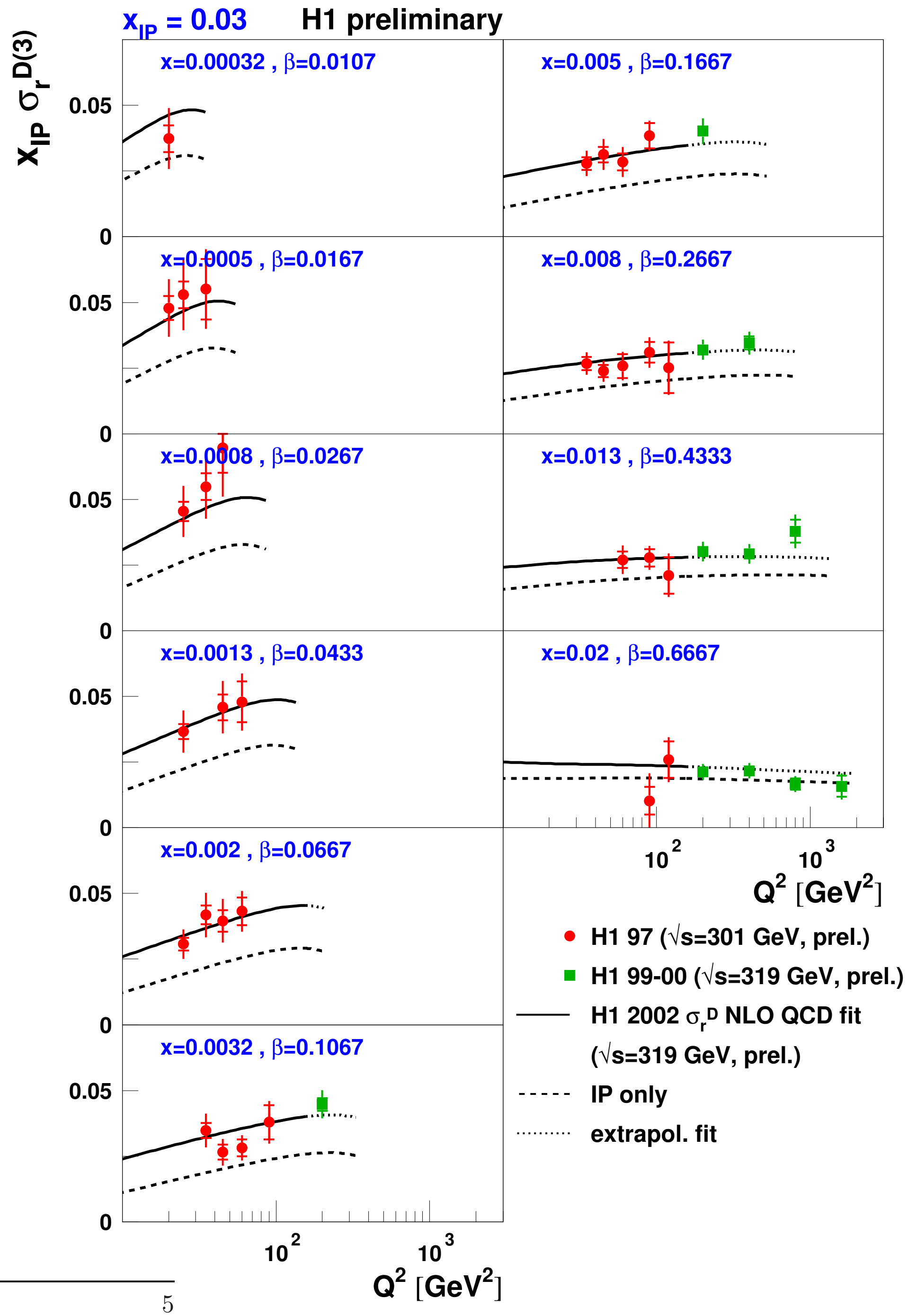
▷ Good agreement with data

High Q^2 Measurements (H1)

- ▷ $\sigma_r^{D(3)}$ measured at high Q^2 (green points)
- ▷ Observations from low Q^2 persist at higher Q^2
- ▷ Tendency to decrease as β increases

  $\Rightarrow$ QCD evolution & increase of subleading exchange contribution

- ▷ Results compared to NLO DGLAP QCD fit
  - Based on exchange of partonic **P** (Ingelman & Schlein)
  - Assume Regge factorisation holds
- ▷ Fit generally describes new high Q^2 data



The structure function of the Pomeron (ZEUS)

▷ Assume:

▷ $F_2^{D(3)}(x_P, \beta, Q^2) = f_P(x_P, Q^2) \cdot F_2^{D(2)}(\beta, Q^2)$

▷ $f_P(x_P, Q^2) = (1/x_P) \cdot (x_0/x_P)^{n(Q^2)}$

▷ This means that for $x_P = x_0$

$$F_2^{D(2)}(\beta, Q^2) = x_0 \cdot F_2^{D(3)}(x_0, \beta, Q^2)$$

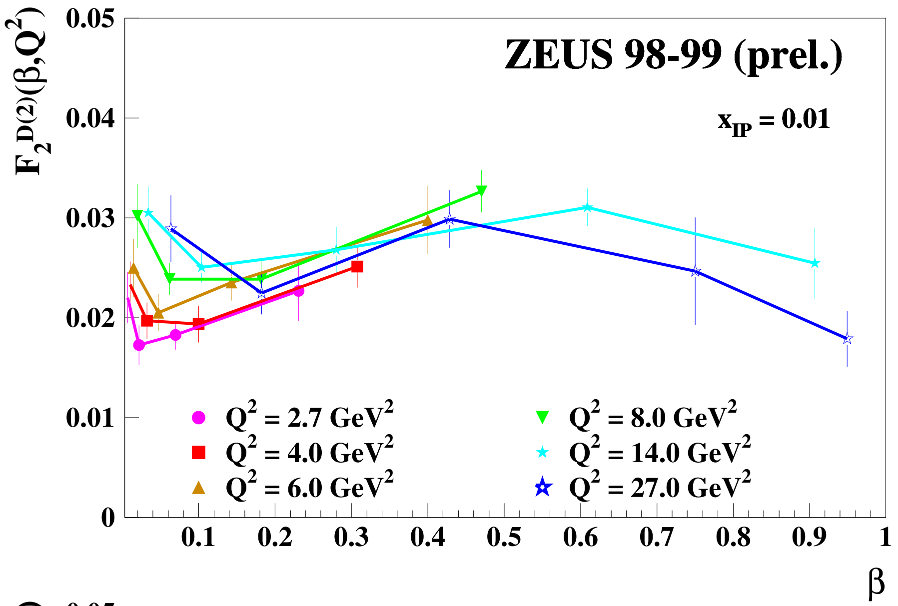
▷ Take $x_0 = 0.01$ and extract $F_2^{D(2)}(\beta, Q^2)$

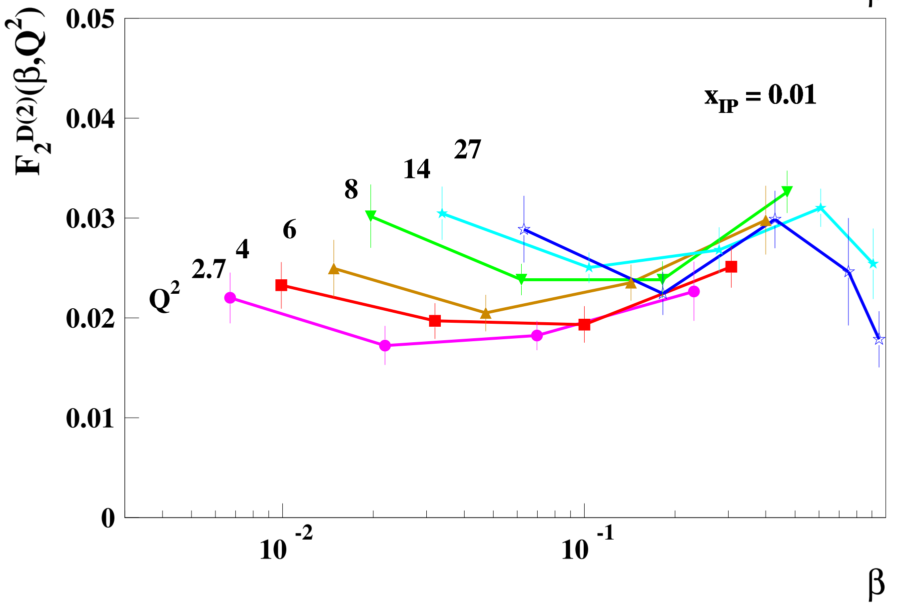
▷ High β, $F_2^{D(2)}$ decreases with increasing Q^2

▷ As $\beta \to 0$, $F_2^{D(2)}$ increases

▷ Behaviour reminiscent of proton structure function, F_2

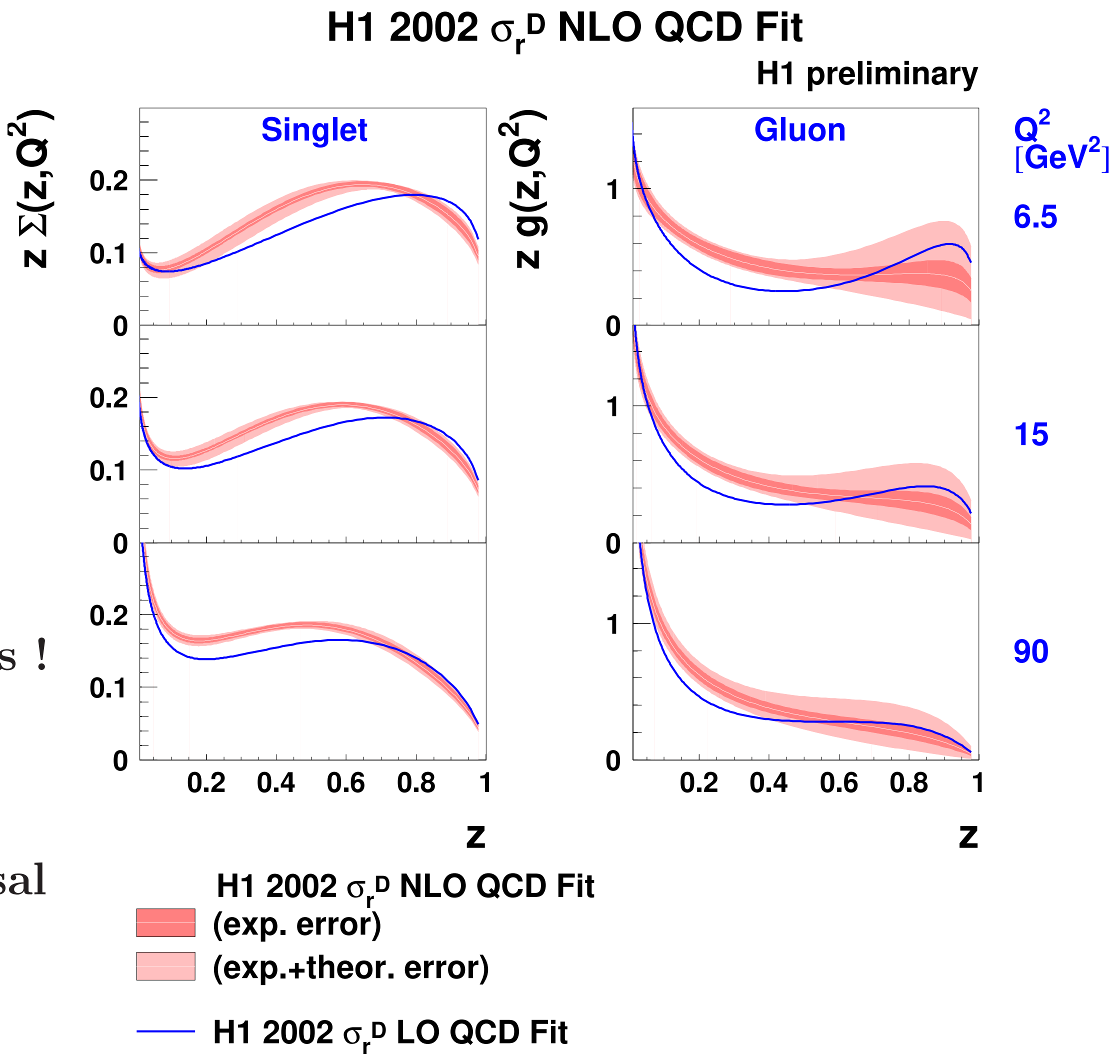
⇒ Evidence for QCD evolution





NLO QCD fits of diffractive data (H1)

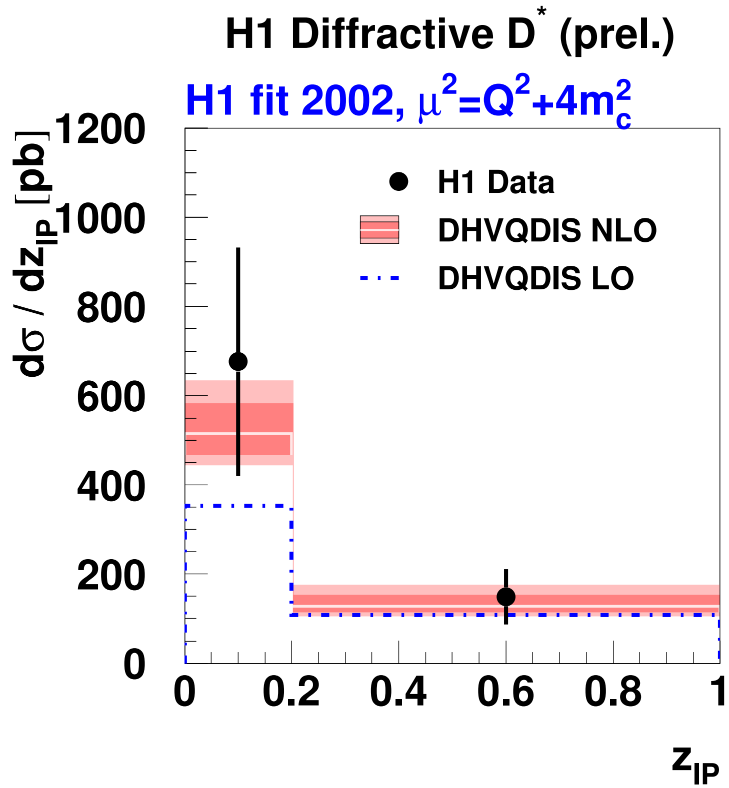
- ▷ Diffractive data can be fitted in similar way to proton F_2 data
  - ▷ Assume partonic Pomeron & Regge factorisation
- ▷ Quark sea and gluon distributions determined
  - ▷ z = momentum fraction of q/g entering hard interaction
- ▷ Gluons dominate diffractive interactions !
- ▷ If QCD factorisation holds:
  - – diffractive parton densities = universal
  - – Test: predict other processes eg. charm or dijet production

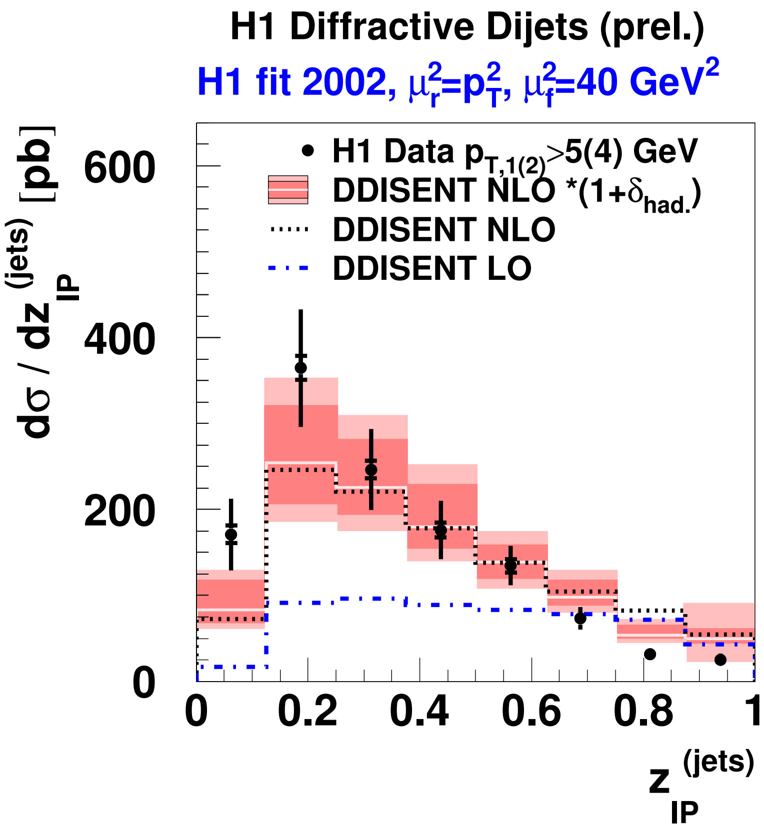


Testing QCD factorisation in diffraction

▷ Compare results of NLO QCD fit to other diffractive processes

- ▷ DIS dijets production
- ▷ DIS $D^{*\pm}(2010)$ production

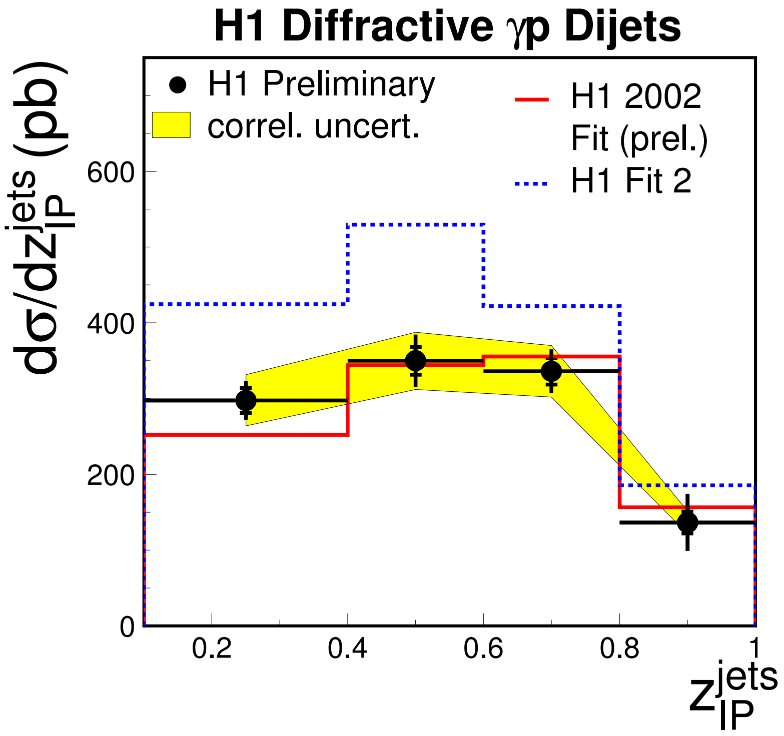




▷ Good description of data

▷ QCD factorisation holds in diffractive DIS

Testing QCD factorisation in diffraction (II)



▷ QCD factorisation holds in diffractive DIS
 → broken in hadron-hadron scattering

▷ Study transition at HERA: diffractive photoproduction

- direct: point-like γ → similar to DIS
- resolved: γ = source of partons
 → similar to hadron-hadron scattering

▷ "H1 fit 2" — old LO QCD fit

→ Describes DIS dijet production well

→ Overestimates γp dijet production by factor ≈ 1.4

▷ "H1 2002 fit" — new LO QCD fit

→ Describes γp dijet production well

▷ New LO fit describes data surprisingly well

▷ Quantify: take ratio of data to MC for DIS and γp

- "ratio of ratios" $= 1.3 \pm 0.3$

▷ No clear evidence for QCD factorisation breaking

The charm contribution to $F_2^{D(3)}$ (ZEUS)

▷ Use events containing $D^{*\pm}(2010)$ mesons to determine $F_2^{D(3),c\bar{c}}$

▷ Charm production expected to be sensitive to gluon content of $\mathbb{P}$

▷ Consistent inclusive diffractive measurements:

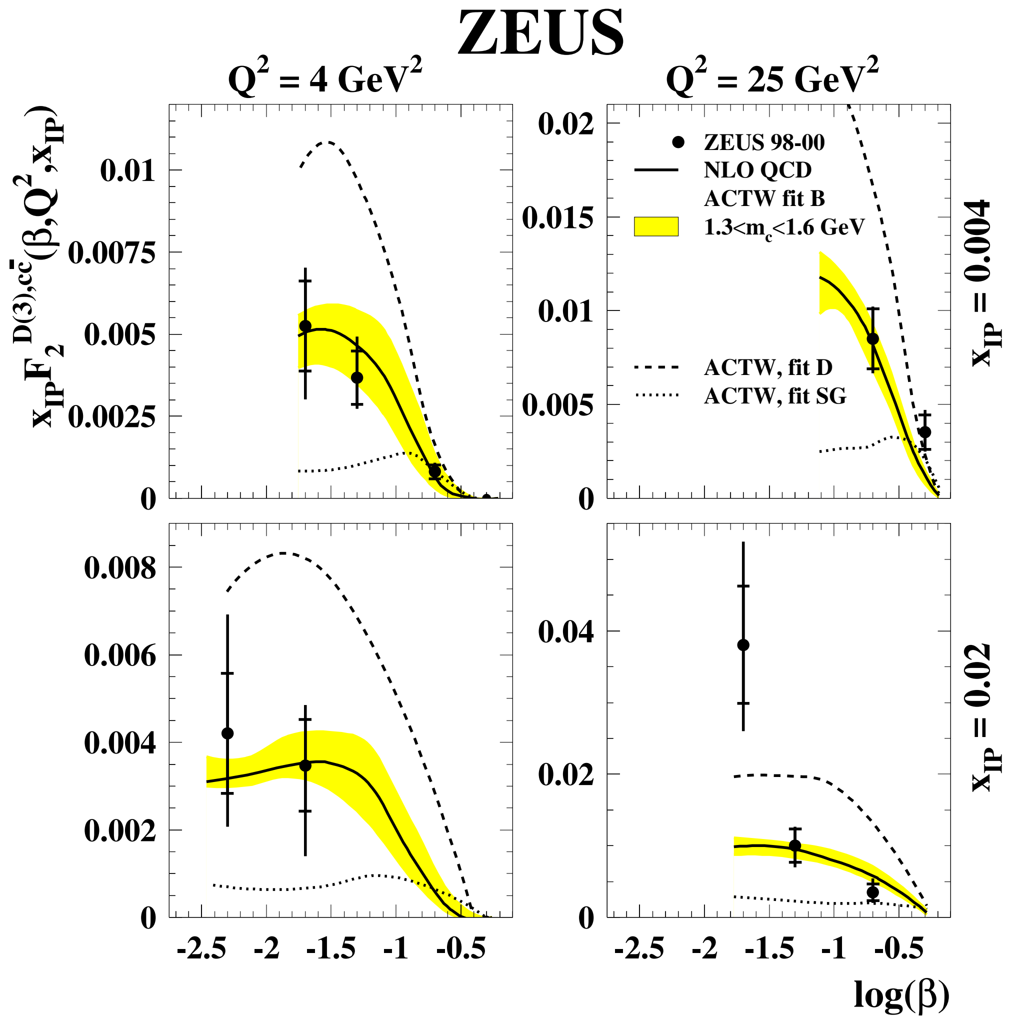
  ▷ Decreases at high β

  ▷ Significant fraction of $F_2^{D(3)}$

▷ Results compared to Alvero et al. NLO QCD fit (similar to H1 fit)

  – Different predictions → different pdfs

  – Charm has clear discriminatory power !



Conclusions

- ▷ **Our understanding of diffraction at HERA has improved in recent years**
- ▷ **Diffractive exchange dominated by gluons**
- ▷ **QCD factorisation holds in diffractive deep inelastic scattering**
- ▷ **No significant evidence of expected QCD factorisation breaking in photoproduction**
- ▷ **Charm production is powerful tool in study of diffraction**
- ▷ **Looking forward to first results on diffraction from HERA II data !**