Recent Results in Diffractive ep Scattering at HERA

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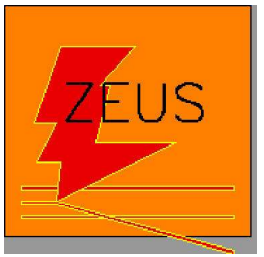
(DESY)

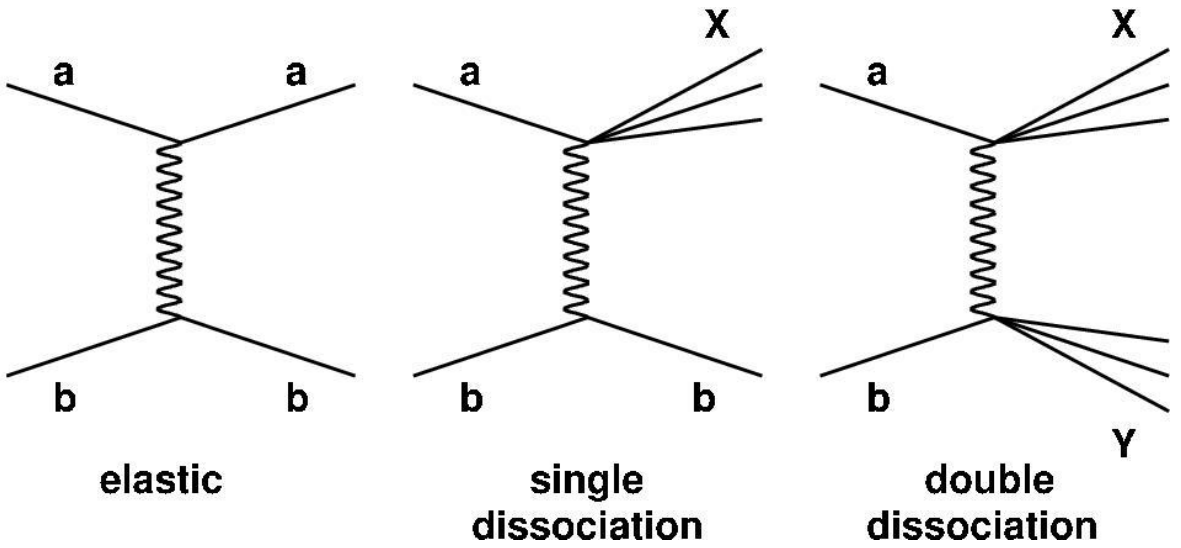


On behalf of the H1 and ZEUS collaborations

Lake Louise Winter Institute 17th-23rd Febuary 2006

- Introduction to diffraction in ep
- Exclusive final state measurements
- Diffractive vector meson production
- DVCS

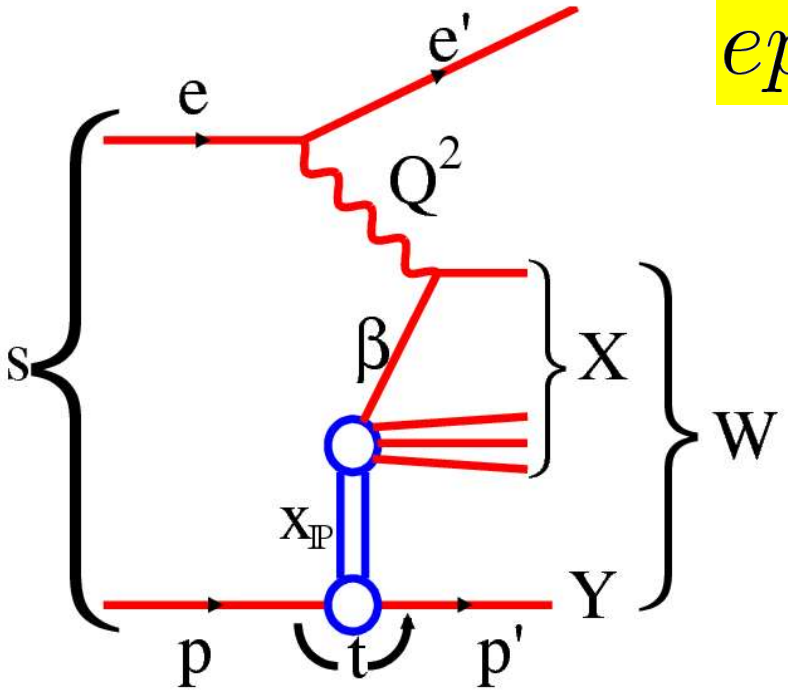
Diffraction



- Lepton-hadron (γ-p) or hadron-hadron (p-p) scattering with large gap in rapidity between final states
- Particles stay intact or dissociate to low mass states X, Y (M_X, $M_Y << s$)
  - X = jet, vector meson, photon
- Independent hadronisation between X and Y systems
- Interpret as *t*-channel exchange of colourless object:
  diffractive exchange or Pomeron (*IP*)

How to interpret in (p)QCD?

Diffraction at HERA



$$ep \to eXY$$

$Q^2=-q^2$	Virtuality of photon
W	photon-proton centre of mass energy
t	four-mom. transfer of diff exchange
x_{IP}	fraction of p mom. carried by IP
β	fraction of IP mom. carried by struck parton $(x=x_{IP}\beta)$

- Define diffractive structure functions (in analogy to DIS)

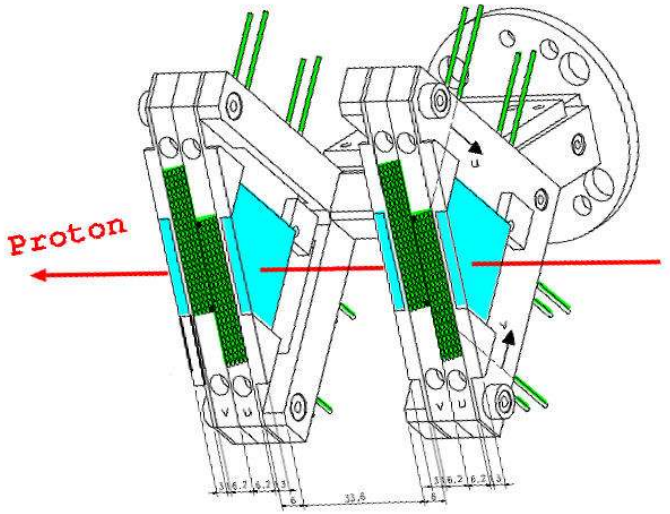
$$\frac{d^4\sigma}{d\beta dQ^2 dx_{I\!P} dt} = \frac{4\pi\alpha^2}{\beta Q^4}(1-y+y^2/2)\sigma_r^{D(4)}(\beta, Q^2, x_{I\!P}, t)$$

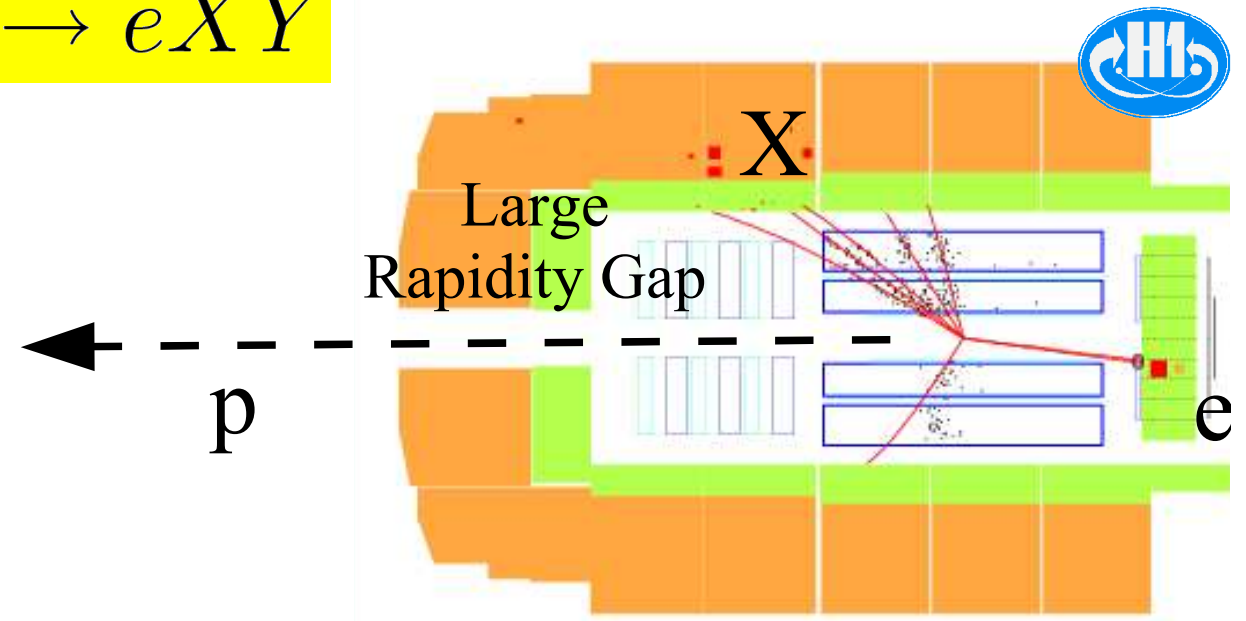
where $\sigma_r^{D(4)} = F_2^{D(4)} - \frac{y^2}{1+(1-y)^2} F_L^{D(4)}$

- Usually integrate over t ($|t|< 1$ GeV^2) $\rightarrow F_2^{D(3)}(\beta, Q^2, x_{I\!P})$

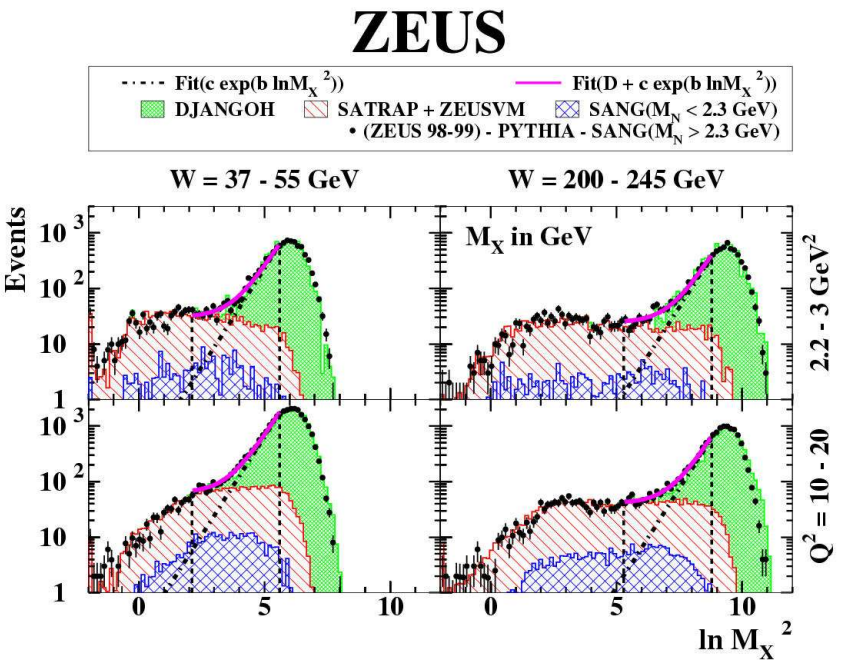
Measuring Diffraction at HERA

$$ep \to eXY$$

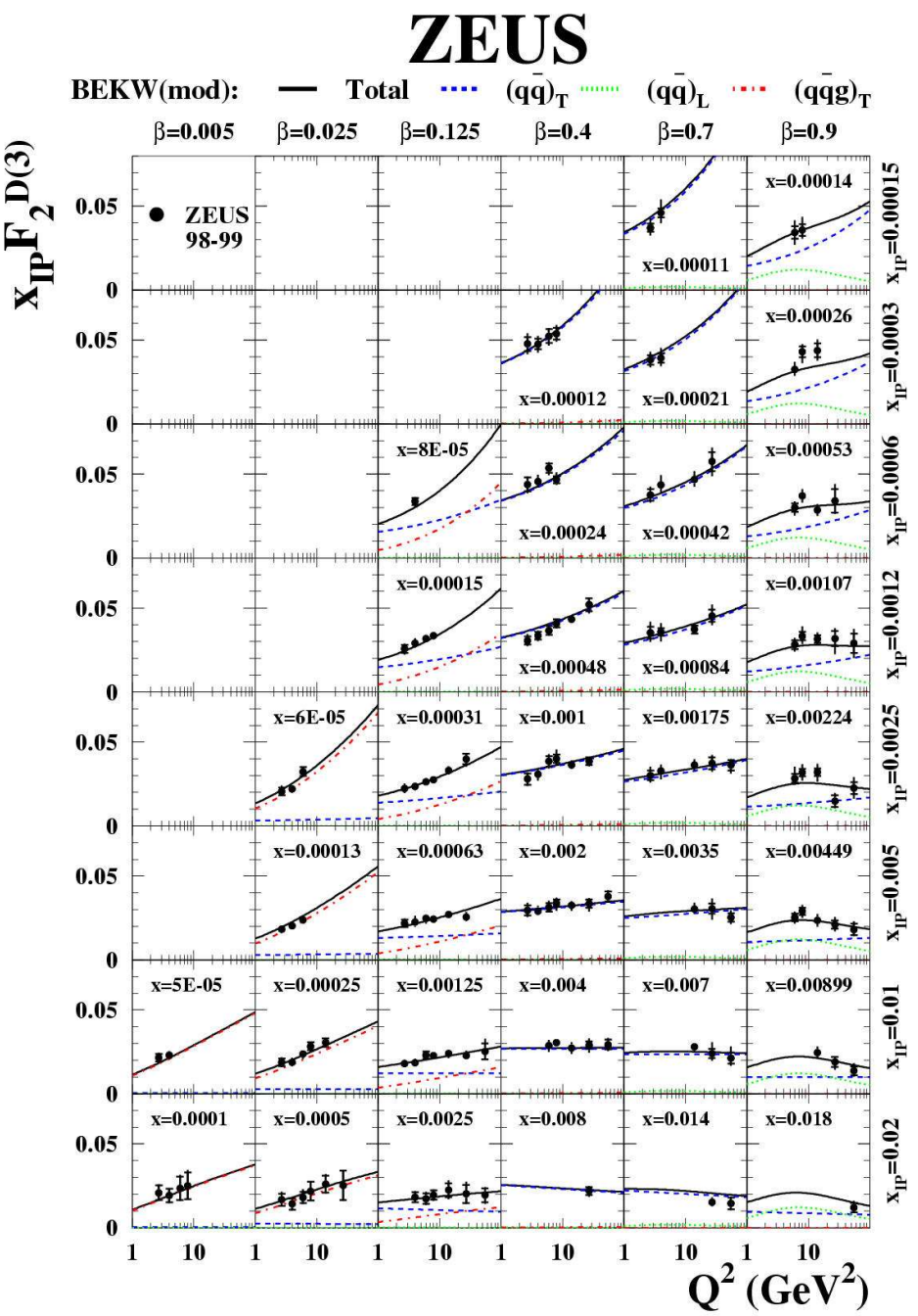


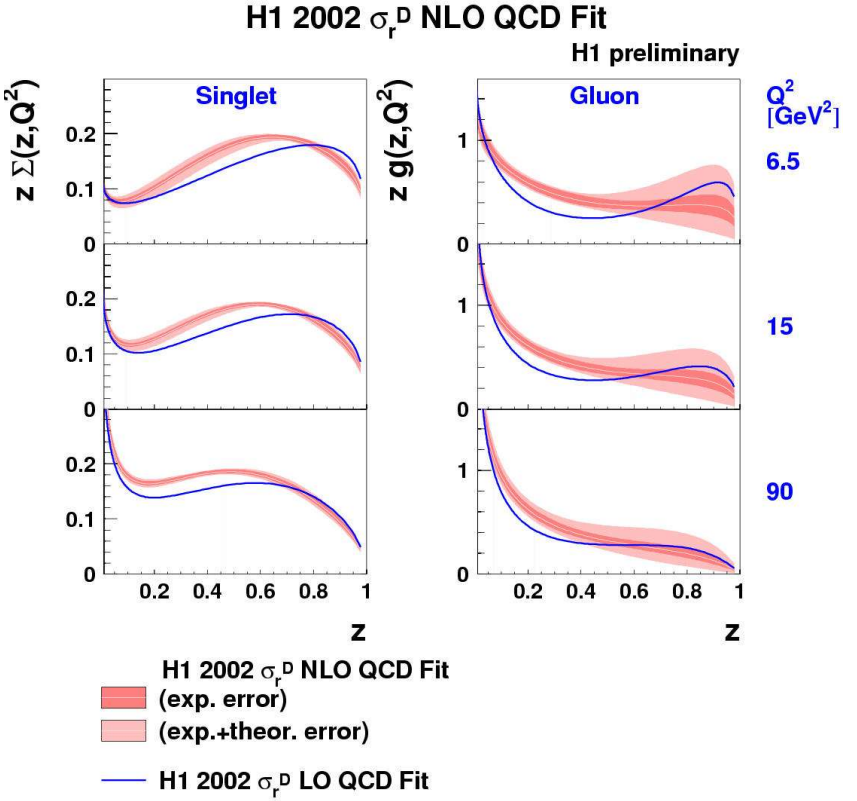


- Identify diffraction by:
  - rapidity gap between X and Y systems in detector
  - tagging final state proton in tunnel systems (eg. (V)FPS at H1, LPS at ZEUS)
  - M_x distribution



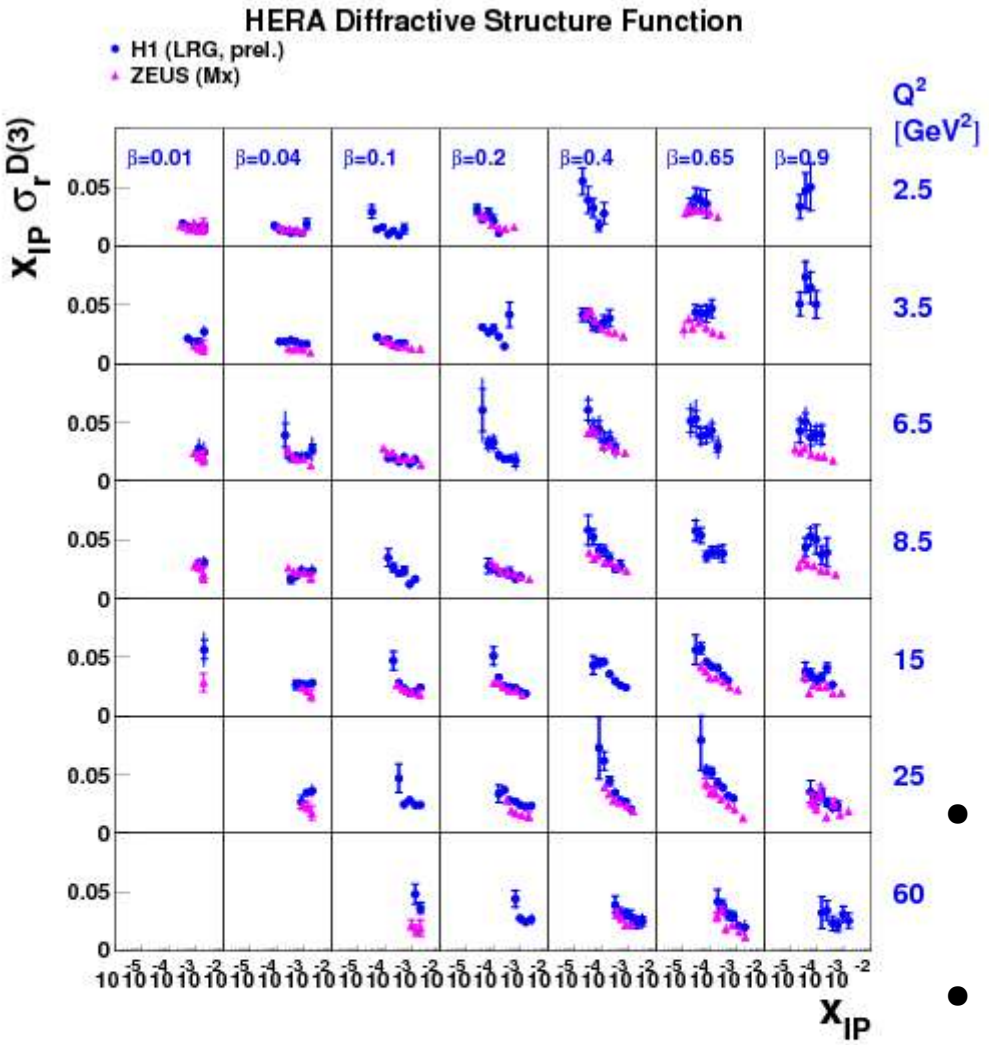
Diffractive Structure Functions

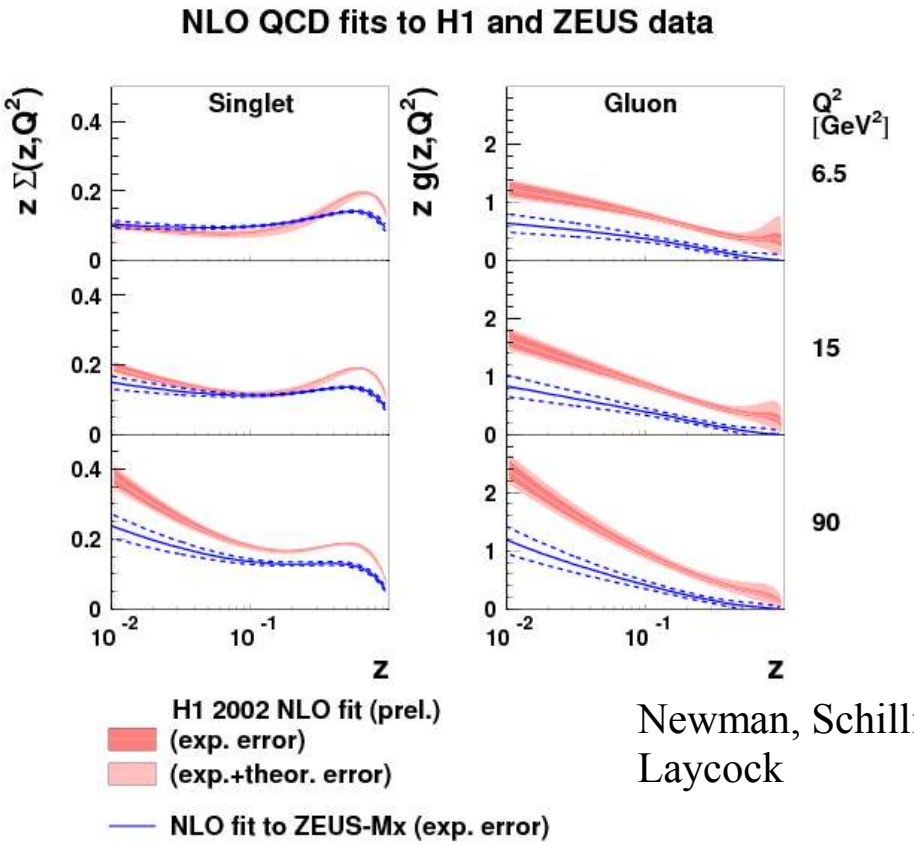




- Scaling violations - even at high β
- Important gluon contribution, especially at low x
- Extract diffractive PDFs (NLO QCD)
- Large gluon contribution in DPDFs

Diffractive Structure Functions II

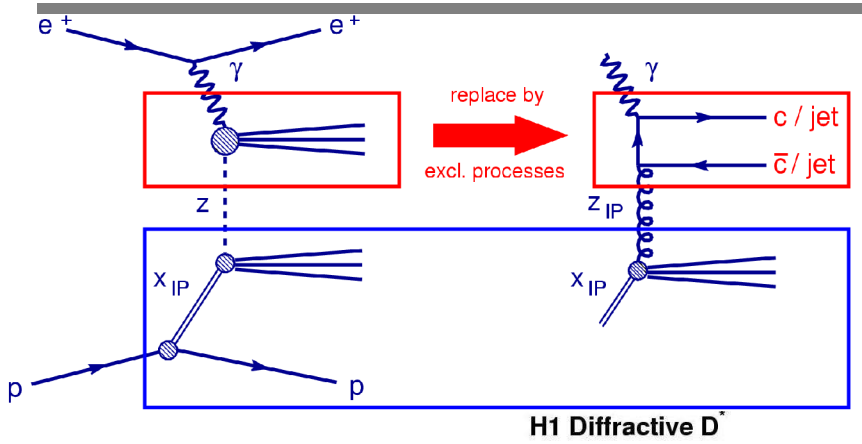




Newman, Schilling, Laycock

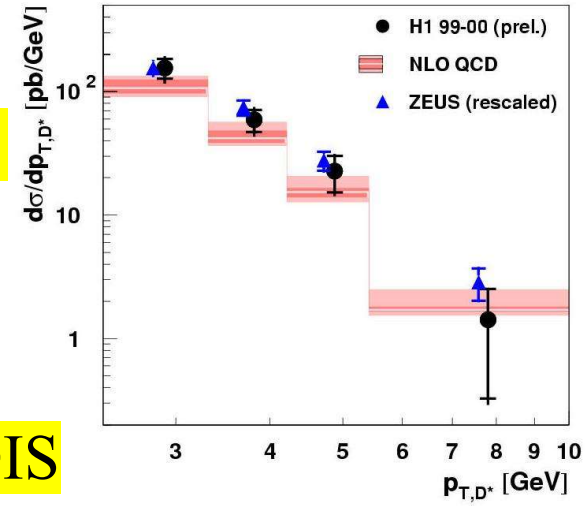
- Fit ZEUS data in very similar way to H1FIT2002 (HERA-LHC workshop)
- Factor ~2 difference in gluon dist.
- Due to different Q^2 distributions in H1 and ZEUS data sets

Diffractive D^* and Dijets (DIS)

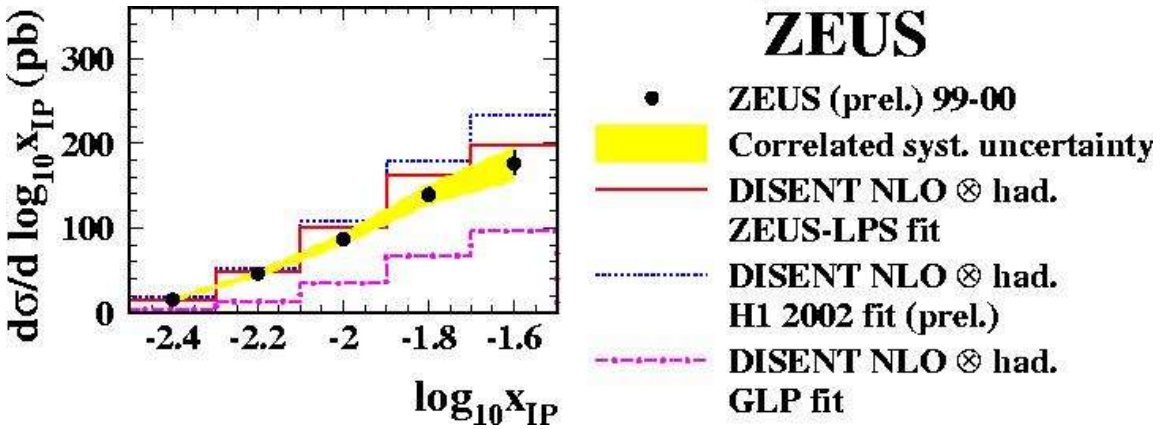


H1 Diffractive D*

D^* in DIS



Dijets in DIS

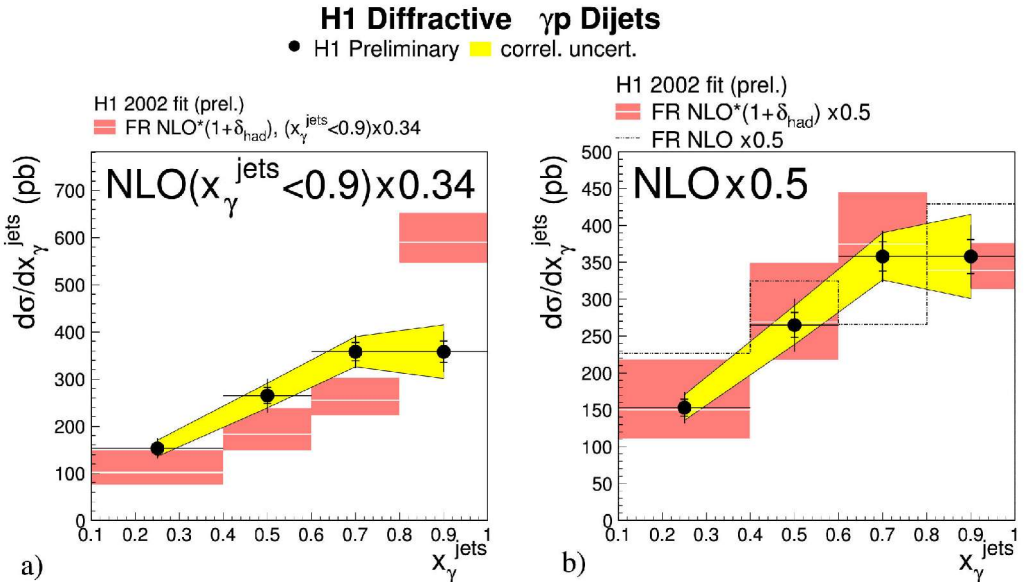


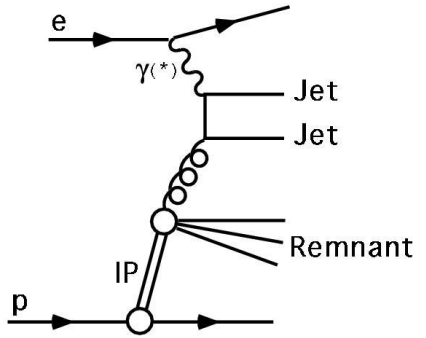
- QCD factorisation: $F_2^D \sim f_i^D \otimes \hat{\sigma}_i$
  - are diffractive PDFs universal?
- Test DPDFs with charm and dijet prod.
  - Good description of diff. D^* in DIS from H1 2002 NLO fit
  - Good agreement between diff. dijet and NLO predictions from ZEUS-LPS and H1 2002 NLO fits
  - ZEUS-GLP (M_x) fit lower than data

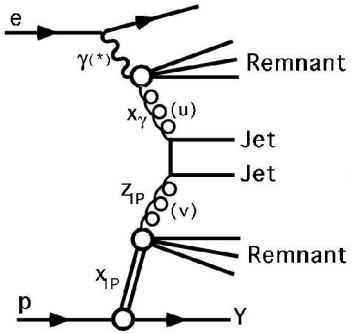
- Factorisation possibly holds in DIS?
- Need more work on DPDFs to make conclusion

Diffractive D^* and Dijets (γp)

Dijets in γp

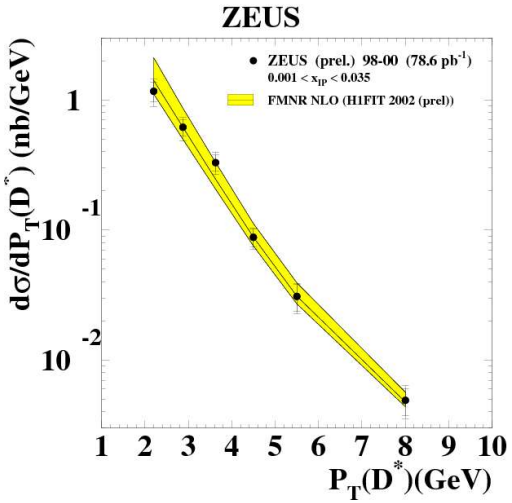


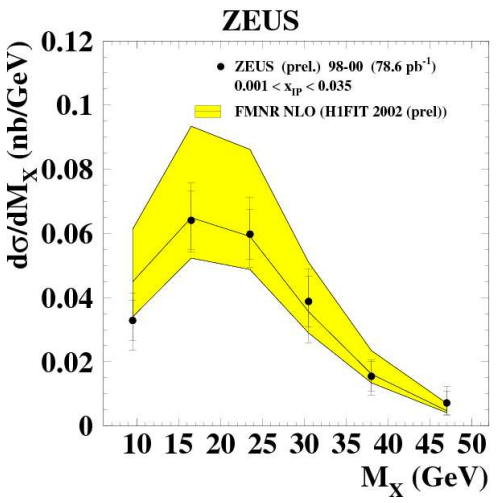




- Dijet data described by NLO × 0.5
- Expected suppression of 'hadron-like' photon interaction (x_γ<0.9) unable to describe data

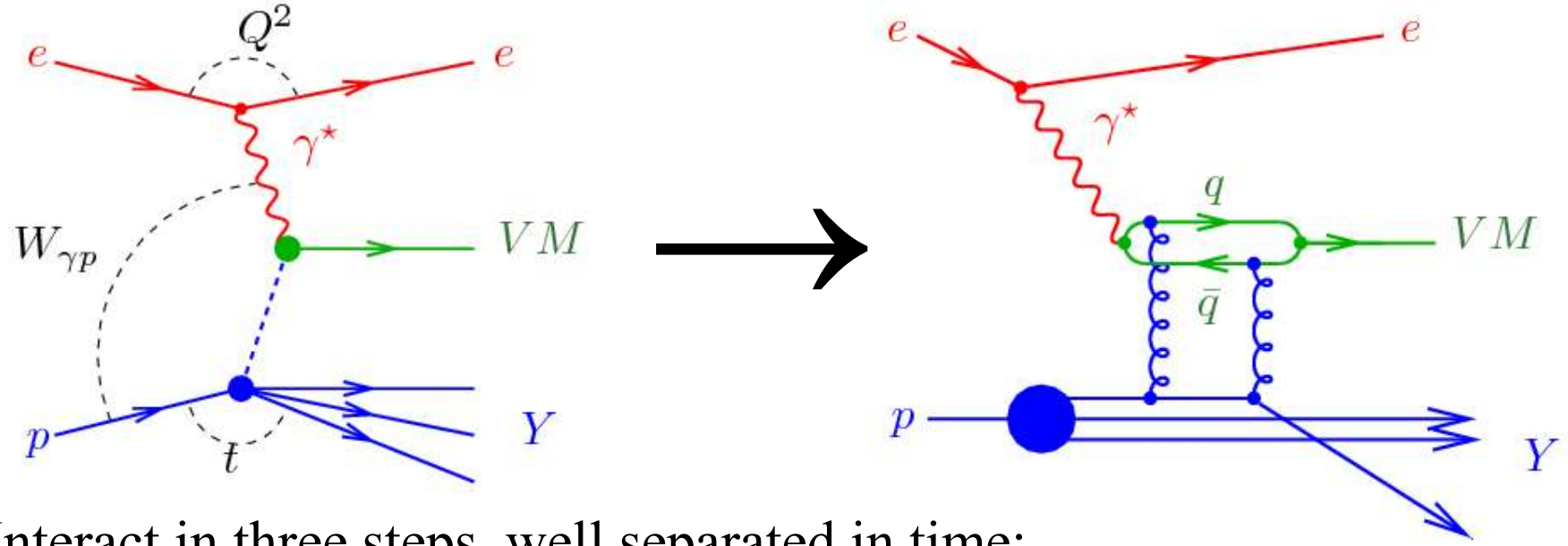
D^* in γp



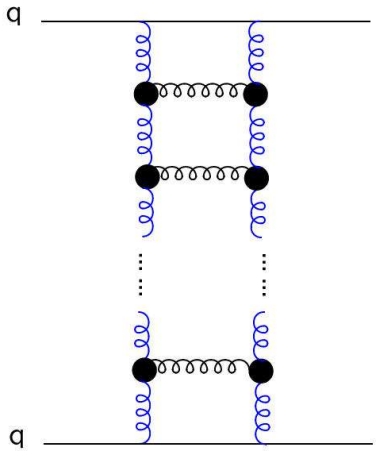


- Dijet data described by NLO × 0.5
- Expected suppression of 'hadron-like' photon interaction (x_γ<0.9) unable to describe data
- NLO consistent with D^* within large errors
- Is factorisation broken in γp?
- Need better understanding of DPDFs and uncertainties to make conclusions
- Use dijets, D^* in DPDF fits?

Diffractive VM Production



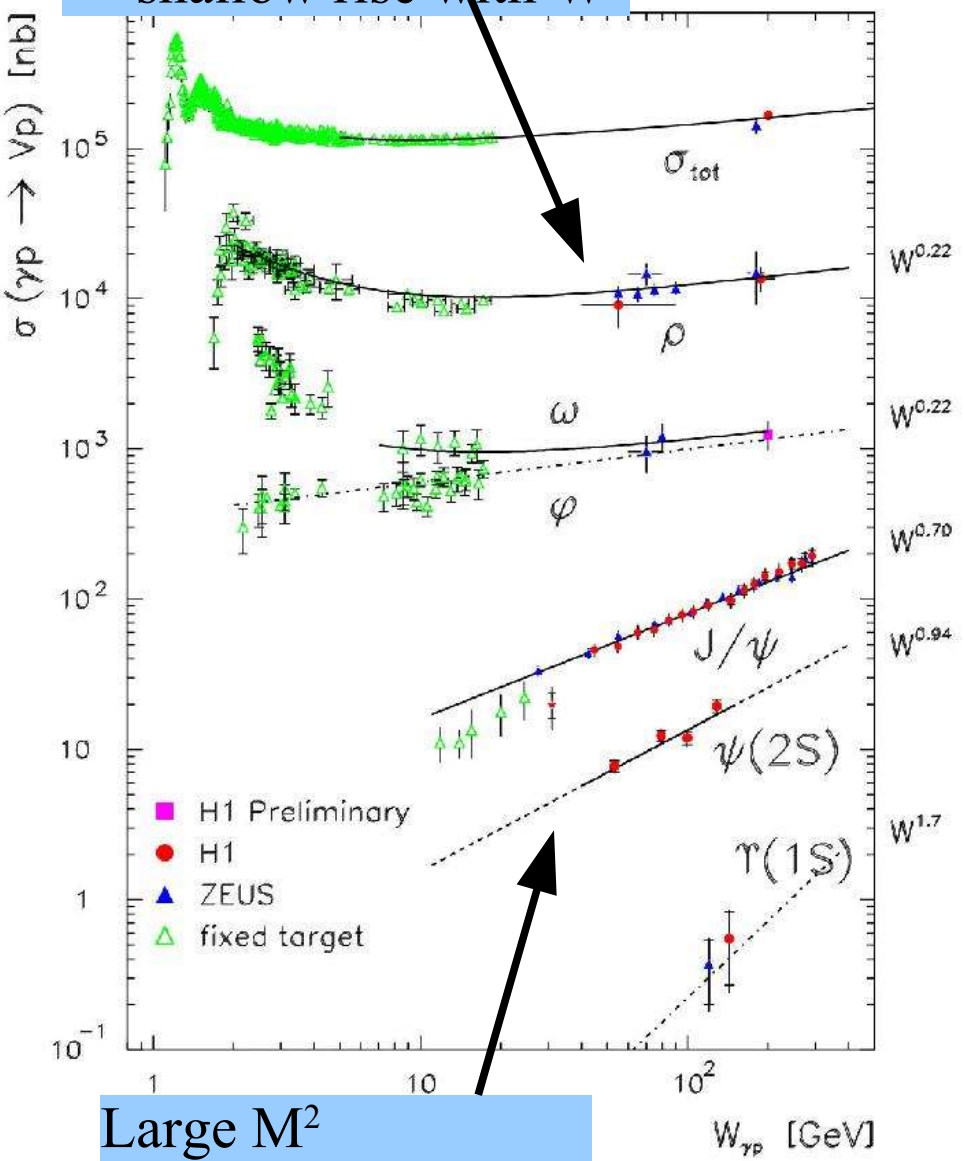
- Interact in three steps, well separated in time:
  - photon fluctuates into $q\bar{q}$ pair
  - exchange 2 gluons (LO) or gluon ladder (higher order)
  - form vector meson
- exchange modelled by BFKL or DGLAP evolution eqns
- Provides information on gluon in p: $\sigma \propto [xg(x,Q^2)]^2$



Hard scale (large M^2, Q^2 and/or $|t|$)
= small $q\bar{q}$ dipole size → pQCD calculation

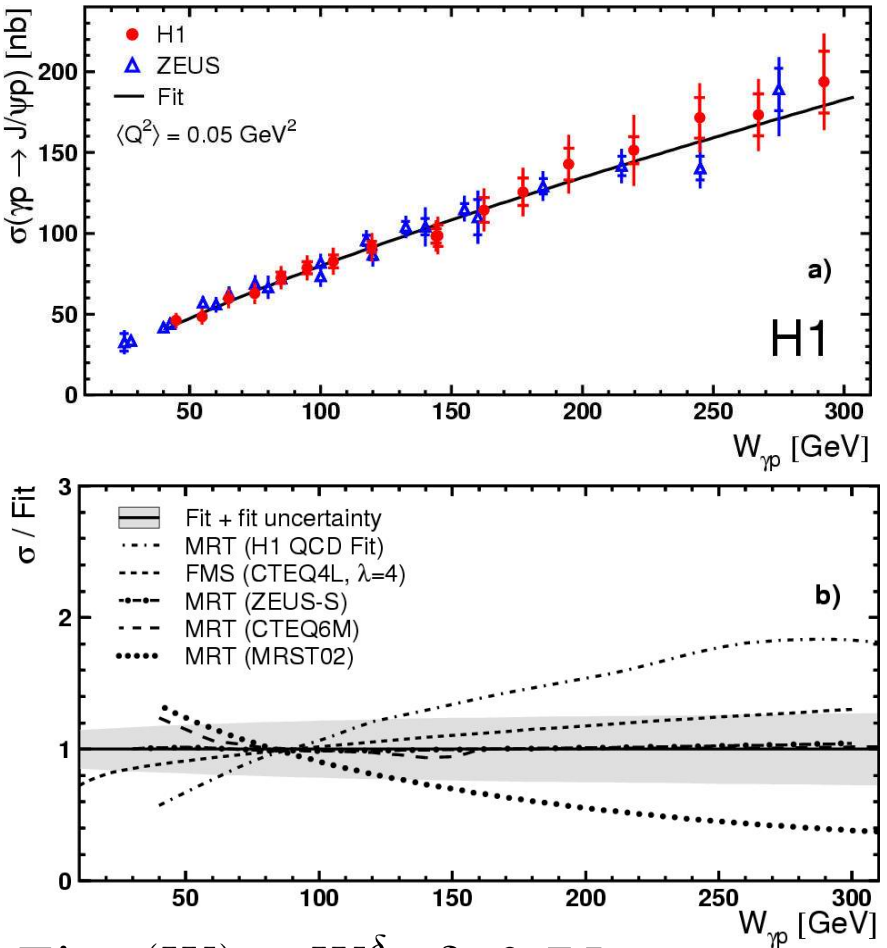
Diffractive Elastic J/ψ

Small M^2
→ shallow rise with W



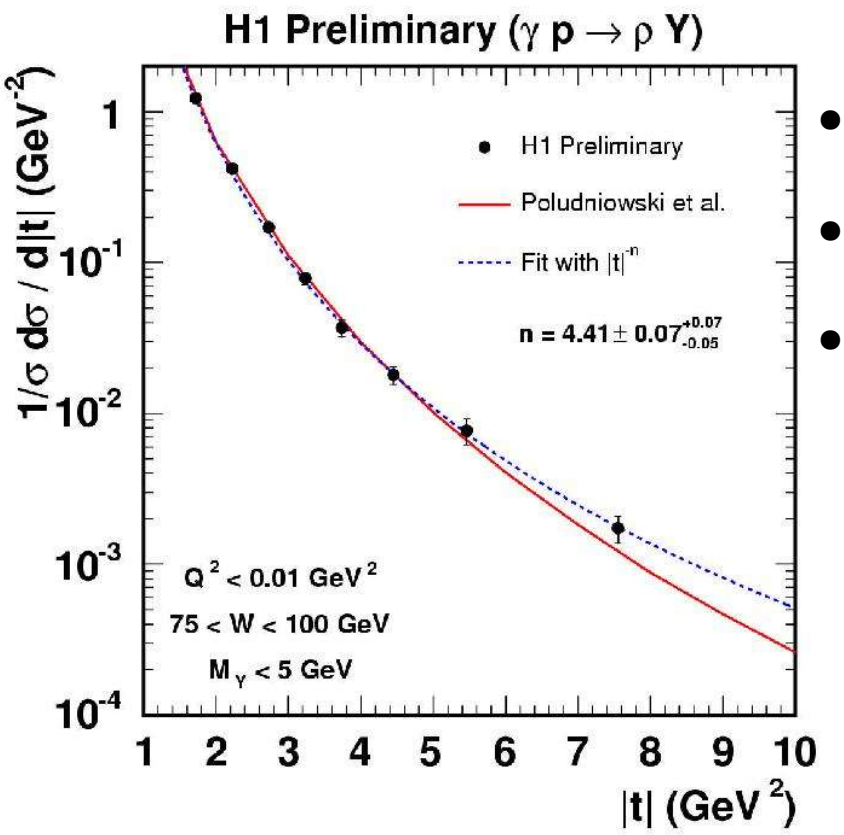
Large M^2
→ steep rise with W

$\gamma p \rightarrow J/\psi\ p$



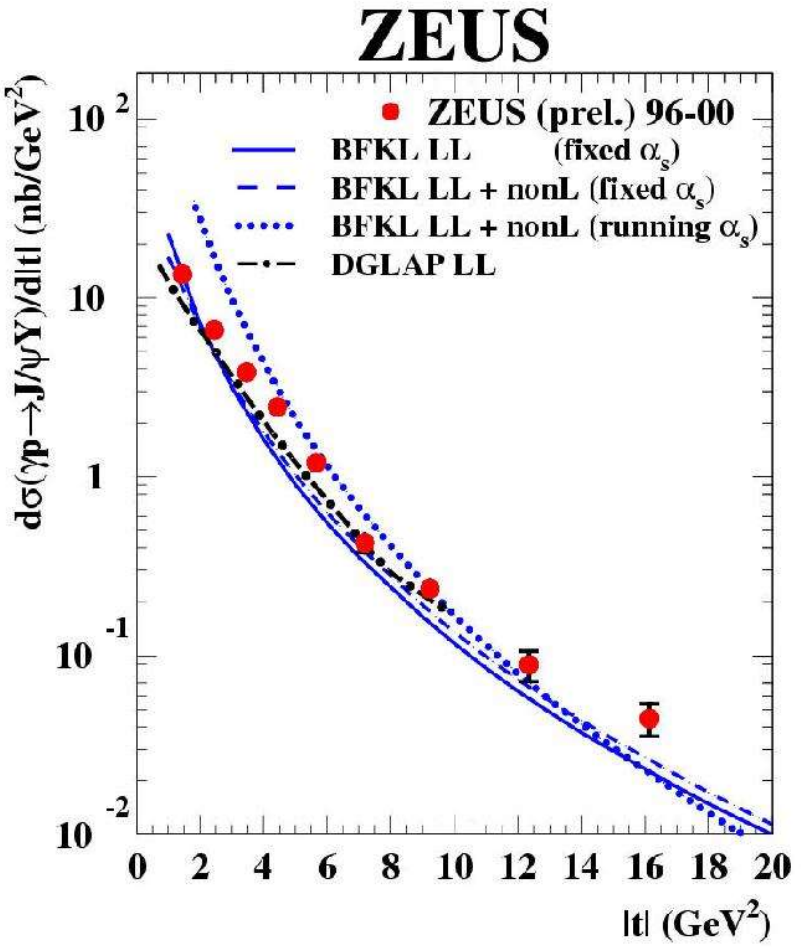
- Fit $\sigma(W) \sim W^{\delta}$:δ=0.75
  → hard scale from M
  (cf. δ~0.22 for soft interaction)
- Data sensitive to gluon distribution

Diffractive High t VMs



$\gamma p \rightarrow \rho\, Y$

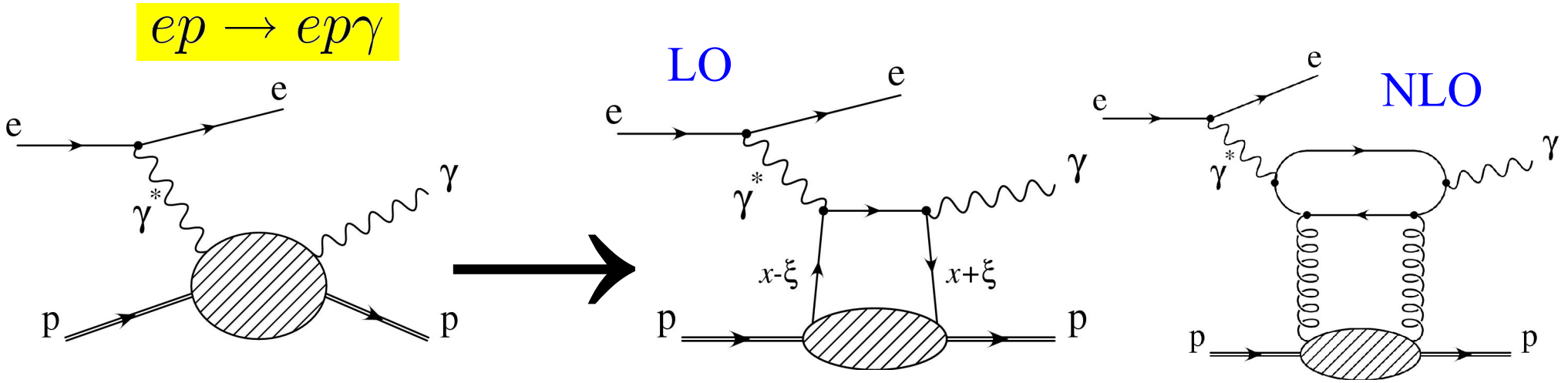
- high t → hard scale → probe diff. exchange
- fit power law $|t|^{-n}$ with n=4.41
- t dep. well described by BFKL model



$\gamma p \rightarrow J/\psi\, Y$

- QCD models (BFKL and DGLAP) able to describe data

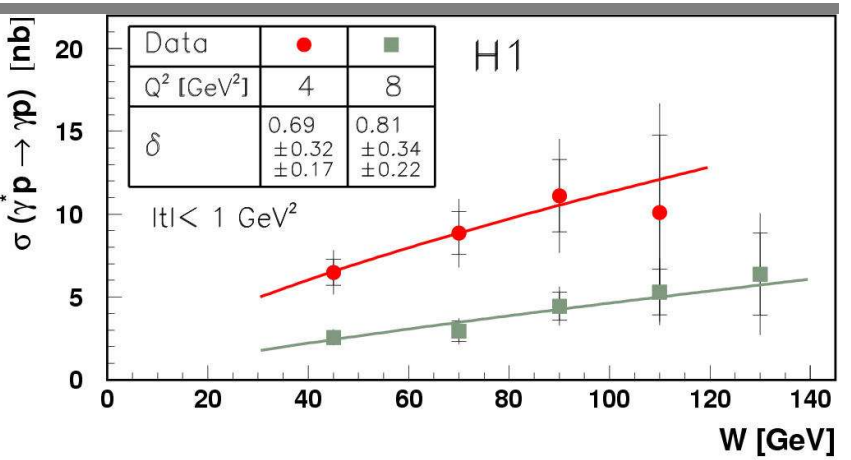
Deeply Virtual Compton Scattering

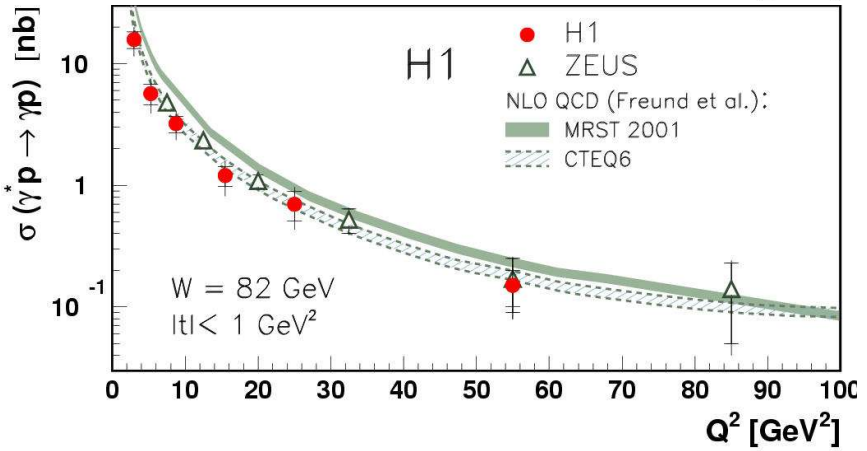


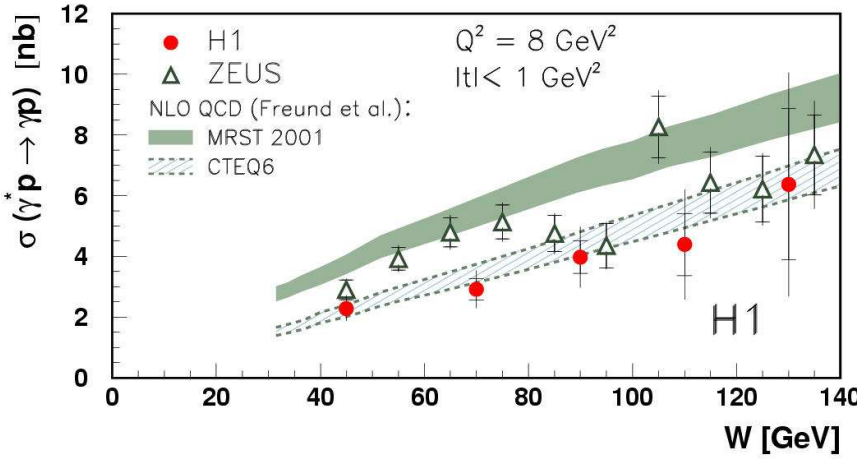
- $ep \to ep\gamma$ at high Q^2, low $|t|$
- Factorisation: hard process (calculable in QCD) + parton density
- Skewedness ξ = non-zero
  → sensitive to generalised parton distributions (GPDs)
- GPDs generalise PDFs → info on parton correlations + transverse motion
  - equal to DIS PDFs as $\xi \to 0, t \to 0$

DVCS

- Steep rise with W (δ=0.77) sim. to J/ψ
  - indicates hard scattering
- NLO with two different GPDs (from MRST or CTEQ6 PDFs)
- Reasonable description by theory
- Differences due to relative sizes of singlet and gluon in PDFs







Summary

- *ep* scattering at HERA important tool to study diffractive exchange
- Extract diffractive structure functions + DPDFs in analogy proton PDFs
  - large gluon content of diffractive exchange
- Some DPDFs able to describe diffractive D^* and dijet production in DIS, but some problems in photoproduction
  - more work on DPDFs needed for firm conclusions on factorisation
- New measurements on diffractive vector mesons
  - sensitivity to gluon distribution of *p*
  - good description from pQCD models
- New DVCS measurement
  - potential sensitivity to GPDs
  - good description by NLO QCD