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Diffraction at HERA

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On behalf of the H1 and ZEUS collaborations

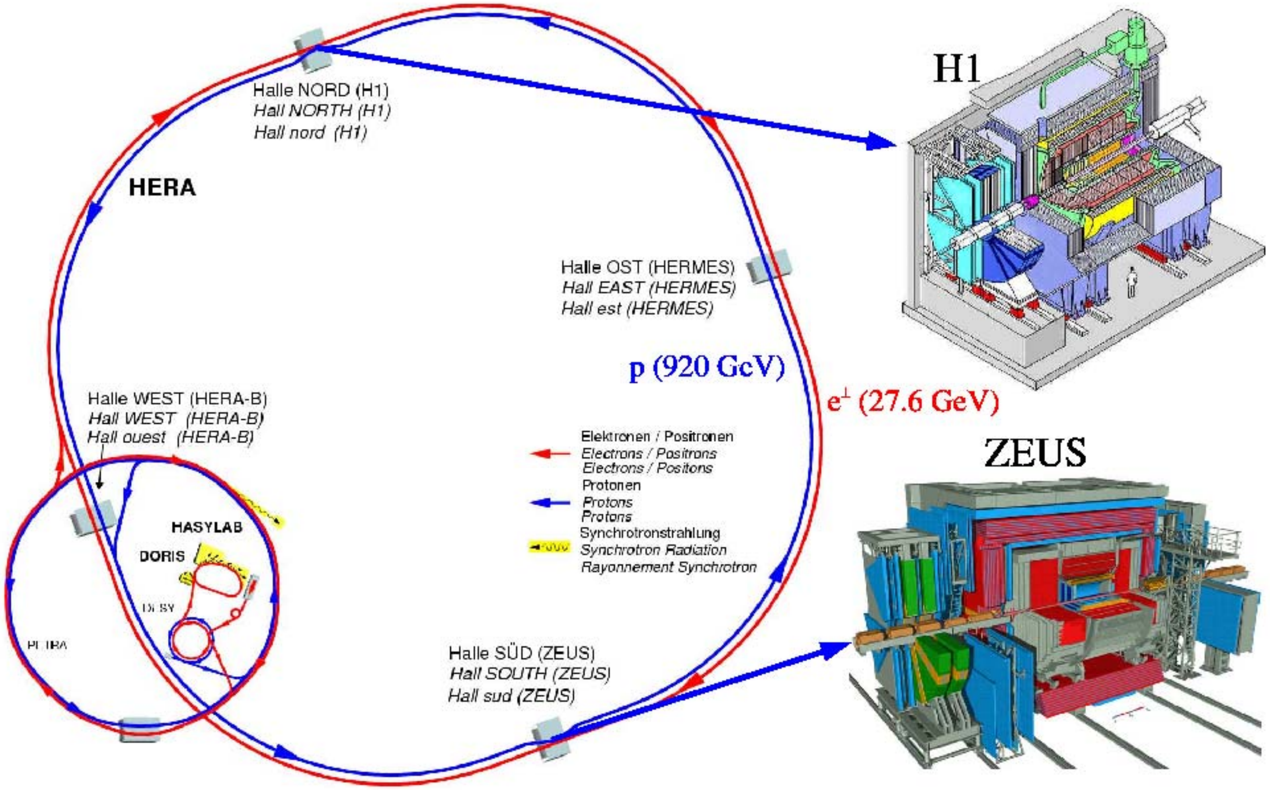
Outline

- Introduction
- Measurements of F_2^D and QCD fits
- Test of QCD factorization with jets and charm
- Summary

➢ *DVCS and Vector Meson topics are presented by Niklaus Berger*

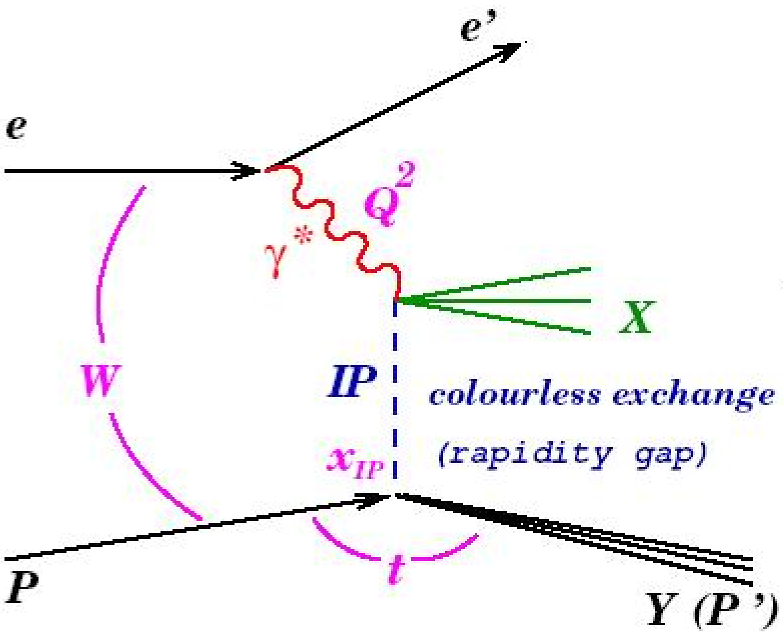
HERA

Electron/positron-proton collider. E_e = 27.6 GeV E_p = 920 GeV
Two colliding experiments: H1 and ZEUS ($\sqrt{s}$ = 319 GeV)
Fixed target experiment: HERMES



The results presented in this talk are based on HERA-I data

Kinematic variables definition



Colorless exchange, vacuum quantum numbers

- proton survives the collision intact or dissociates to low mass state
- large region in pseudorapidity is left empty
- small momentum transfer t

$Q^2 = -q^2$	photon virtuality
$x = \frac{Q^2}{2q\cdot p}$	Bjorken scaling variable
$W^2 = (p+q)^2$	$\gamma^* p$ CM energy squared
$t = (p - p_Y)^2$	4-momentum transfer squared
$x_{\mathbb{P}} = \frac{q\cdot(p-Y)}{q\cdot p}$	fraction of p momentum transferred to $\mathbb{P}$ ($x_{\mathbb{P}} \simeq 1 - E_Y/E_p$)
$\beta = \frac{Q^2}{2q\cdot(p-Y)}$	fraction of $\mathbb{P}$ momentum carried by struck quark ($x_{\mathbb{P}}\beta = x$)
M_X	Inv. mass of system X

~10% of DIS events at HERA are diffractive

Cross section of inclusive diffraction

Cross Section

$$\frac{d\sigma}{d\beta\, dQ^2 dx_{IP} dt} = \frac{2\pi\alpha}{\beta\, Q4}\left(1 - y - y^2/2\right)\cdot \sigma_r^{D(4)}\left(\beta, Q^2, x_{IP}, t\right)$$

$$\sigma_r^{D(4)} = F_2^{D(4)} - \frac{y^2}{1+\left(1-y\right)^2} F_L^{D(4)}$$ - reduced diffractive cross section

QCD factorization – proven in diffractive DIS (Collins 1997)

$$\sigma^D\left(\gamma^* p \to Xp\right) \propto \sum_i f_{i,p}^D(x_{IP}, t, x, Q^2) \otimes \sigma^{\gamma^*,i}\left(x, Q^2\right)$$

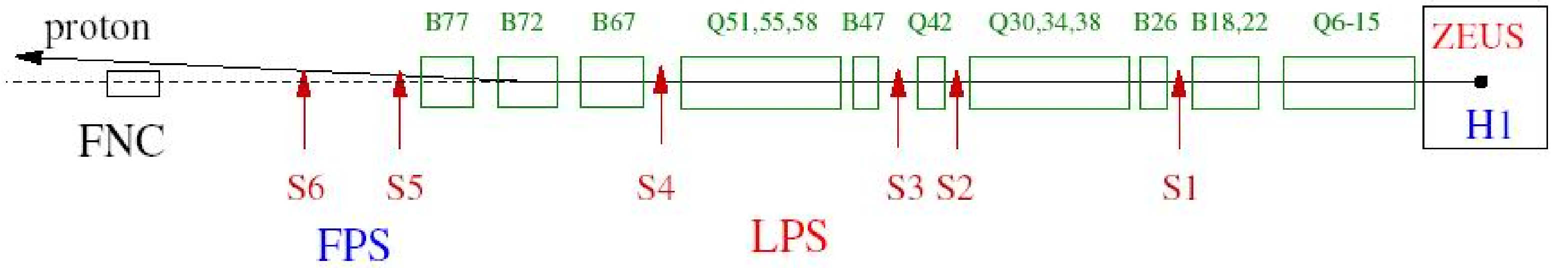
$f_{i,IP}^D$ -- diffractive parton distribution function

$\sigma^{\gamma^*,i}$ -- universal hard scattering cross section

At HERA we usually measure cross section integrated over t

Leading proton method (scattered proton detected in "Roman Pots")

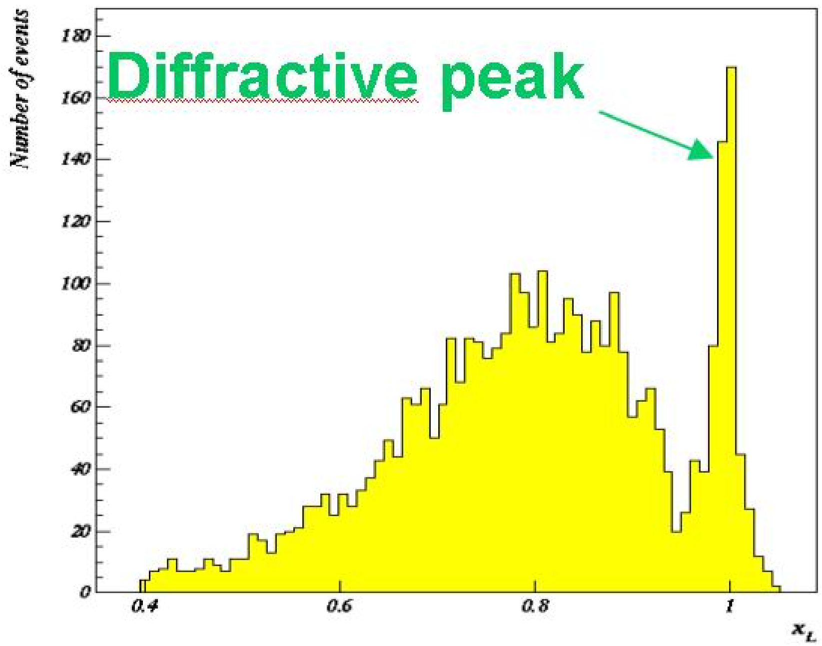
Using Forward/Leading Proton Spectrometers at H1 and ZEUS



Direct measurement of

- $t = (P - P')$
- $x_{IP} = 1 - E'_p/E_p$

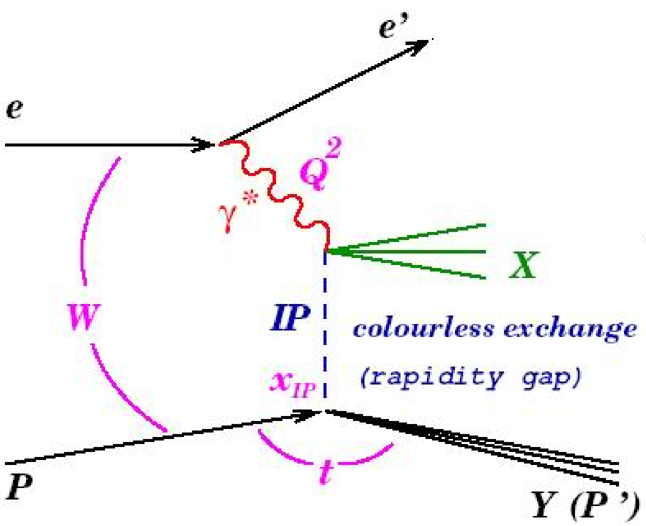
Reject proton dissociation background

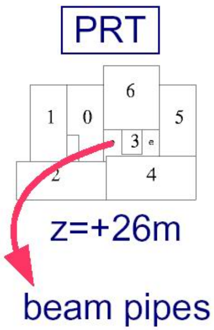


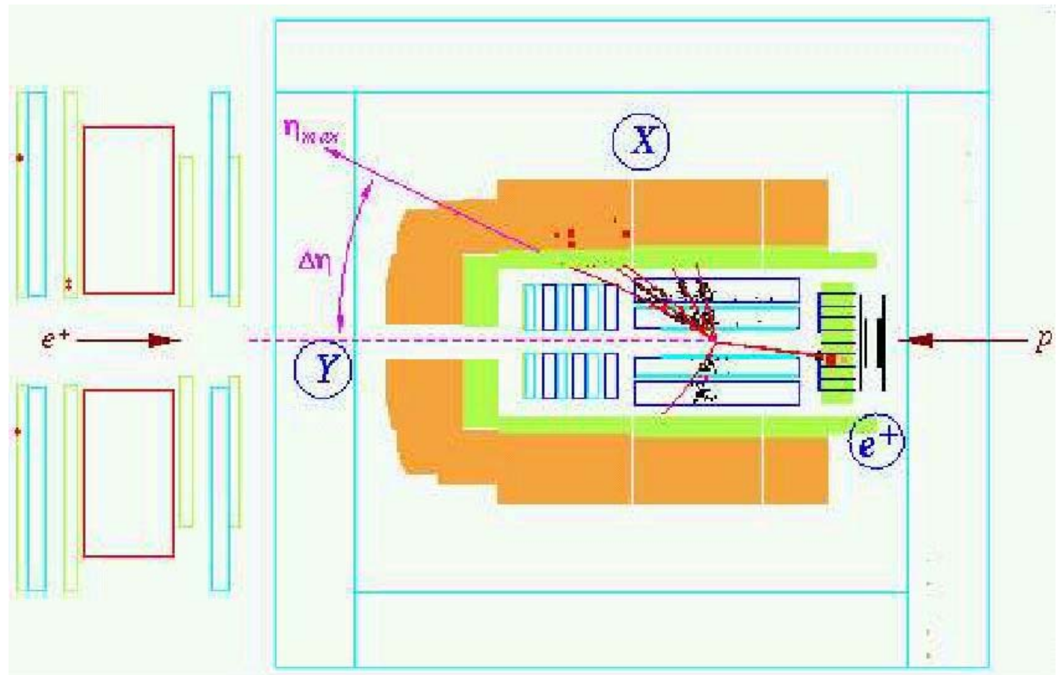
Large rapidity gap method

No activity in the forward region of the H1 detector: $\eta_{max} < 3.2$

No hits in proton remnant tagger.

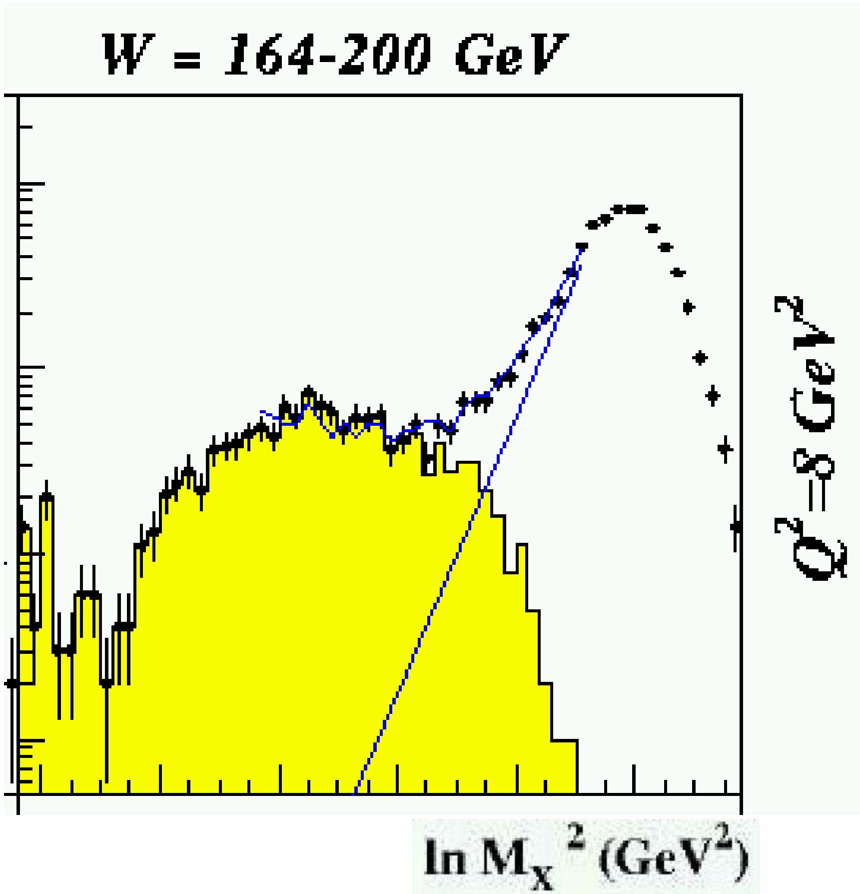






$M_y < 1.6$ GeV

ZEUS M_x method



ln M_X^2 distribution

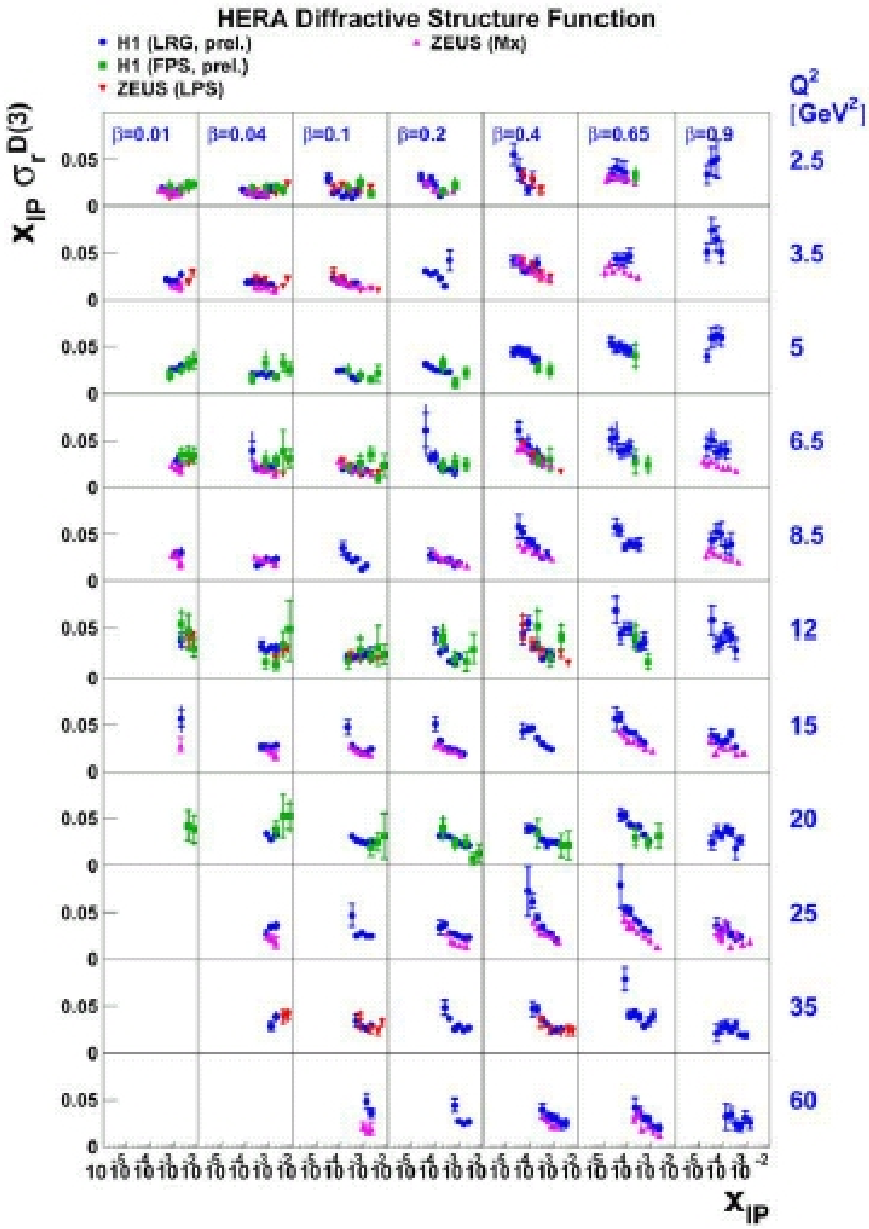
$$\frac{dN}{d\,lnM_X^2} = D + c \cdot exp(b \cdot lnM_X^2)$$

- exponential rise with M_X for non-diffractive events
- different shape for diffractive events

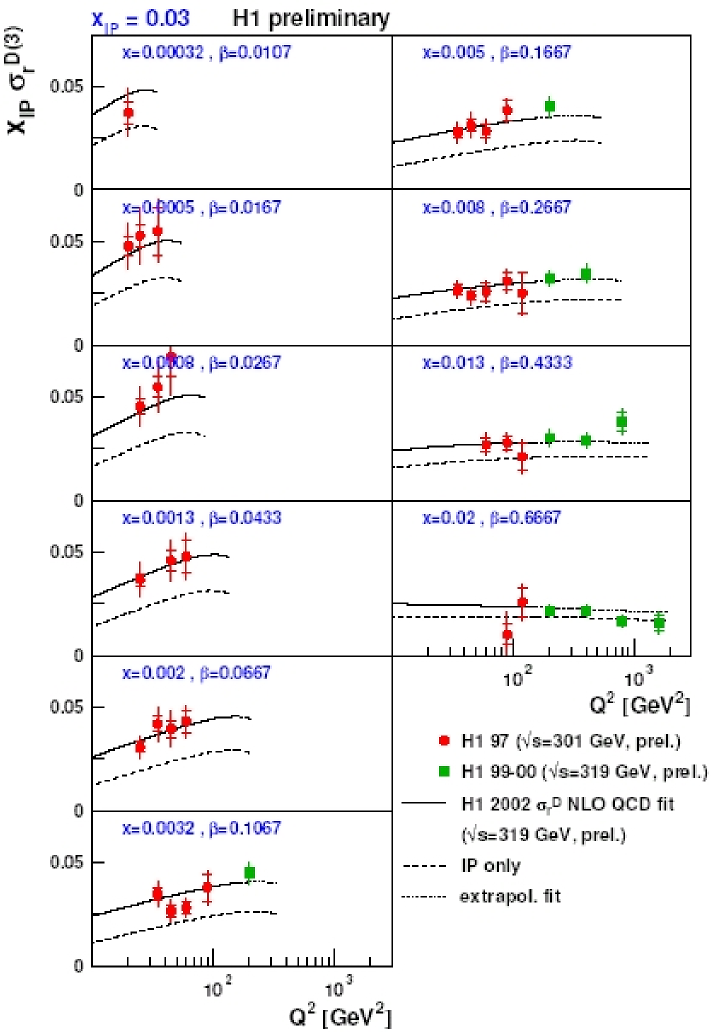
Fit subtracts non-diffractive events

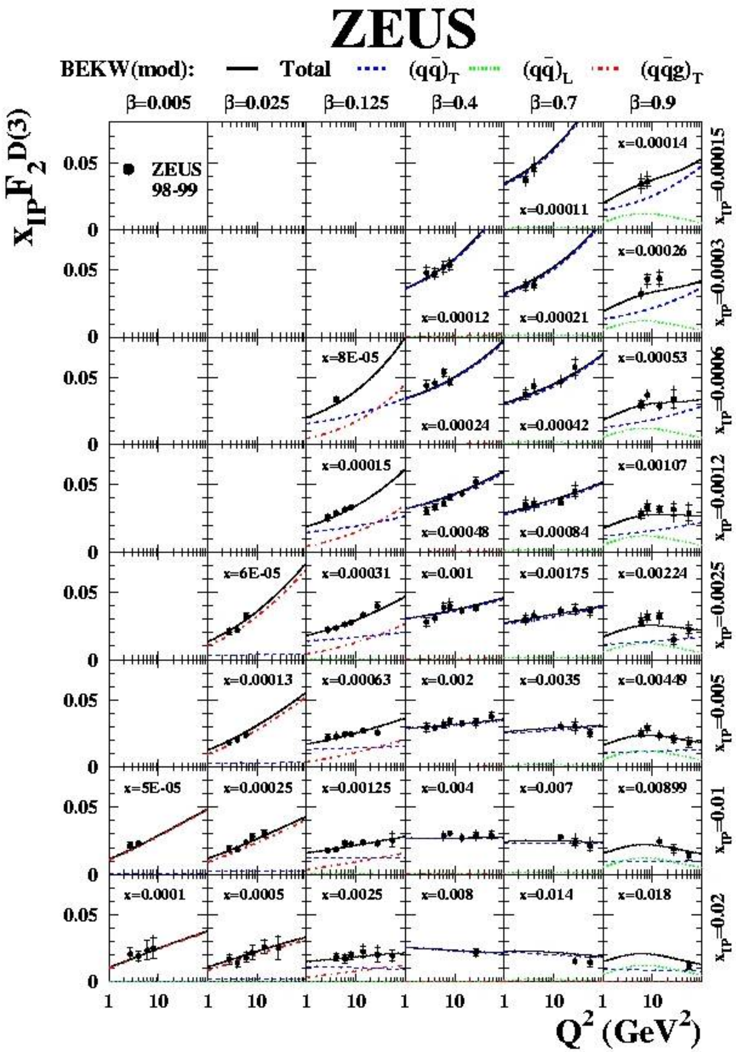
Comparison of F_2^D measurements

Good agreement between three methods and two experiments



Q^2 dependence





x·F_2 increases with Q^2 → positive scaling violation up to large β

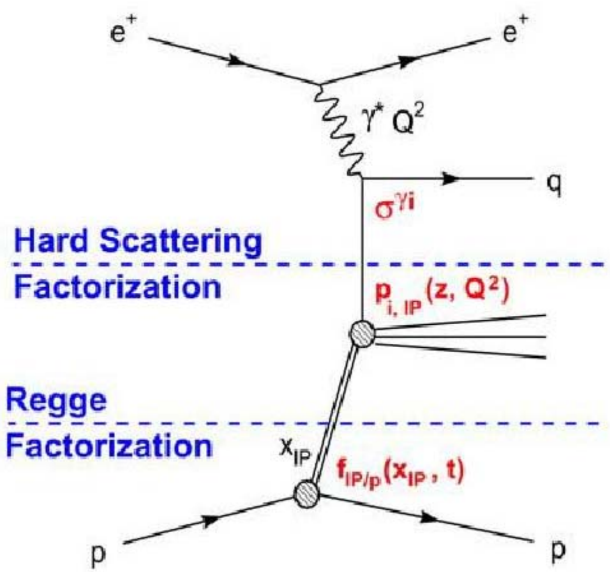
Suggests large gluon contribution to diffractive PDF

QCD Fit to $F_2^{D(3)}$

Apply same NLO QCD DGLAP technique to Q^2 and β dependencies as for inclusive DIS

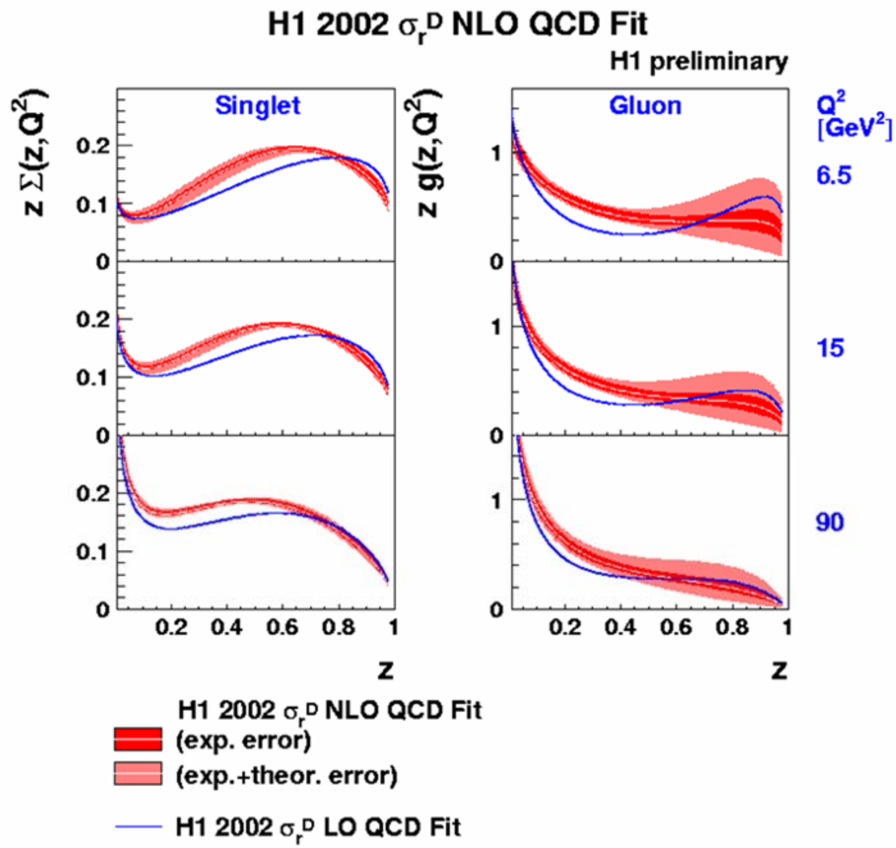
- quark density directly from F_2^D
- gluon density from scaling violation

Assume Regge factorization: PDF = Pomeron-flux x Pomeron-parton-density



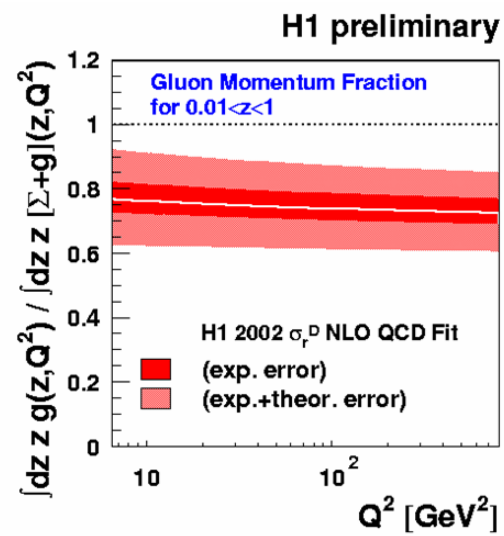
$$F_2^{D(4)}\left(x_{IP}, t, Q^2, \beta\right) = f_{IP/p}(x_{IP}, t) F_2^{IP}(Q^2, \beta)$$

H1 NLO QCD fit - diffractive PDFs



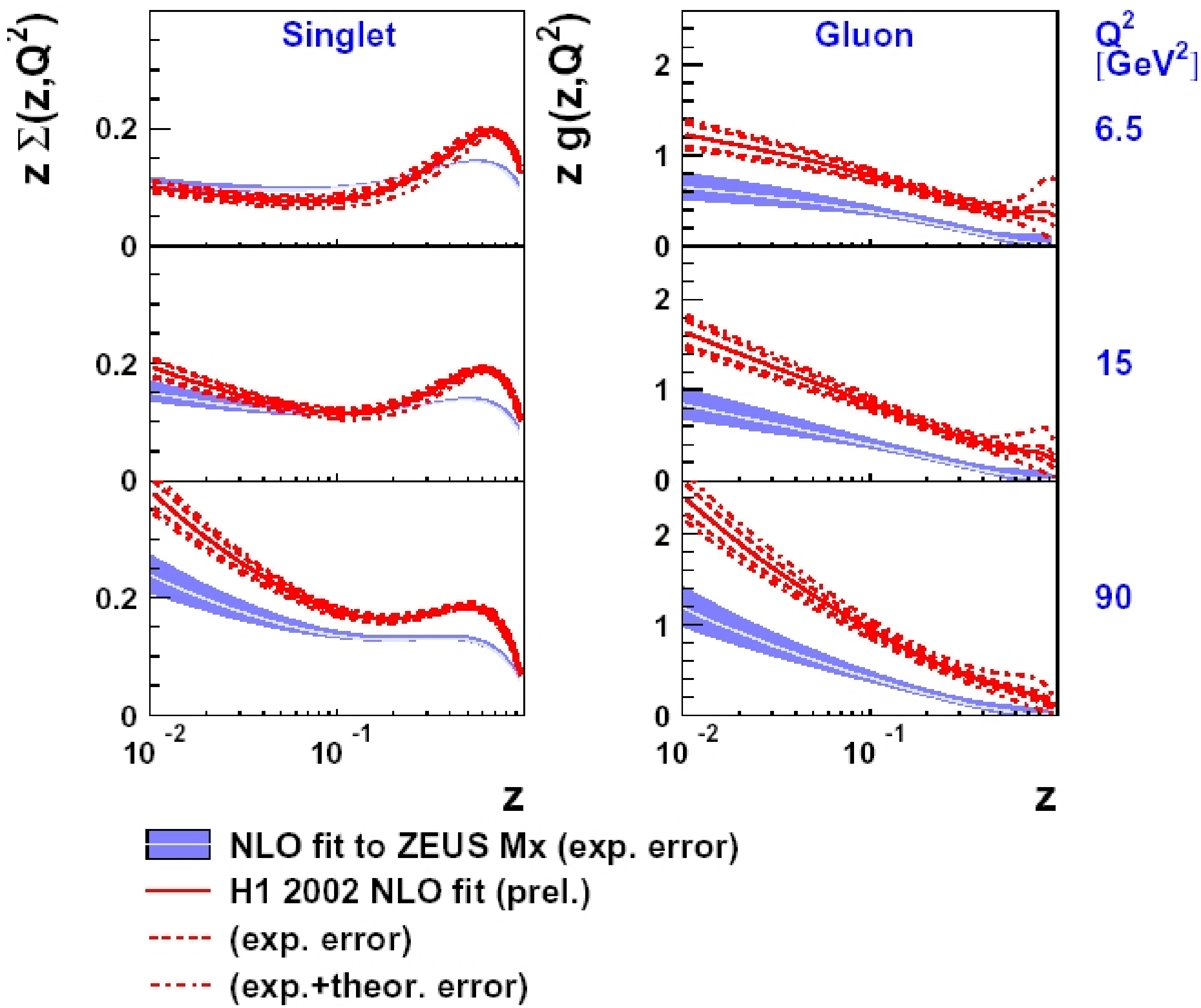
- assume Regge factorization
- determined from NLO QCD analysis of diffractive structure function
- large uncertainty at large z_P
- gluon carries 75%±15% of pomeron momentum

Fraction of the overall diffractive exchange momentum carried by gluons in NLO fit



This fit to preliminary H1 data is used in following for comparison with exclusive processes

NLO QCD fits to H1 and ZEUS data



Fit to H1 and ZEUS data by
Paul Laycock,
Paul Newman,
Frank-Peter Schilling

This differ from H1 2002 fit, so could be larger uncerntanty in PDFs

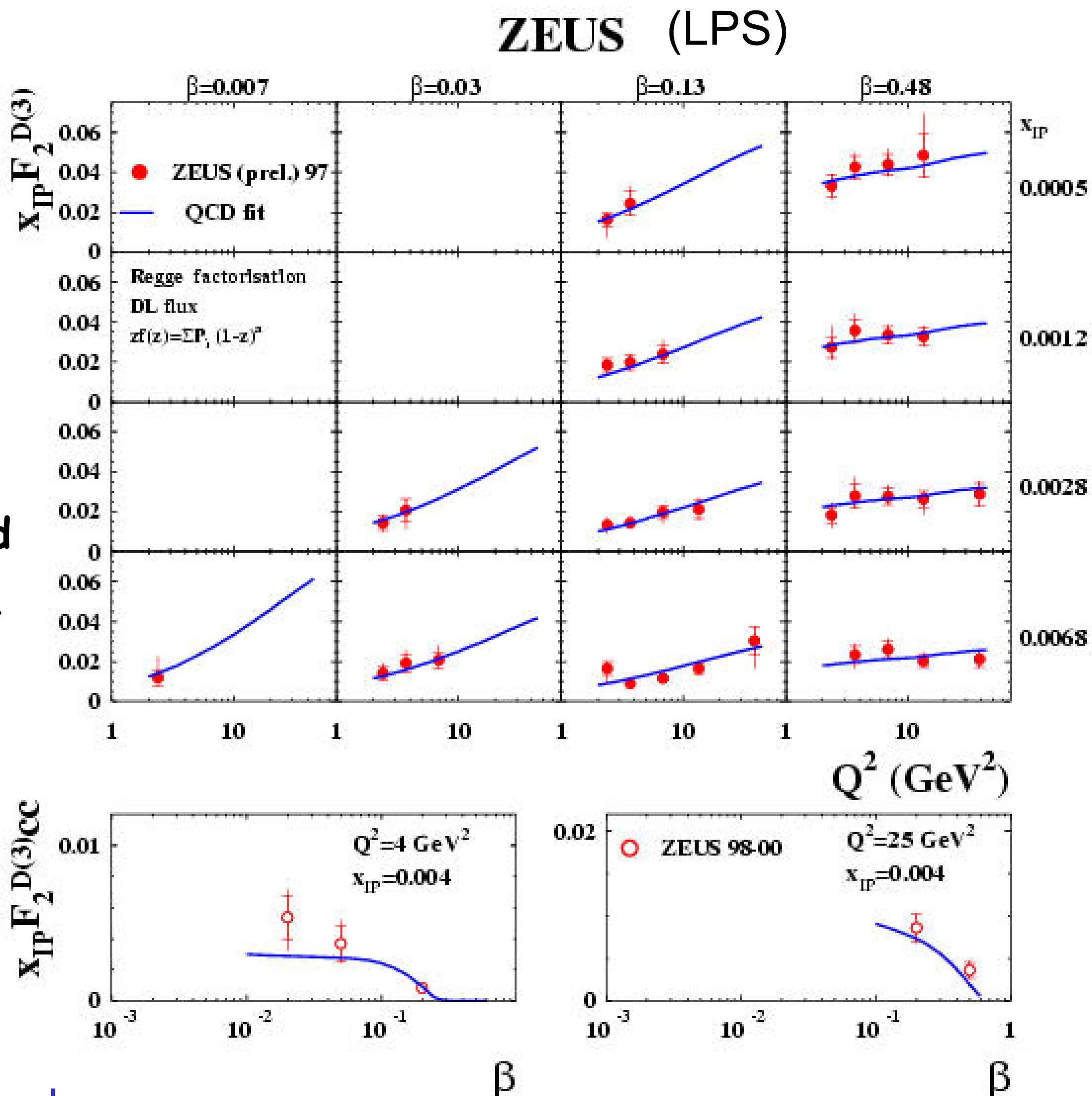
ZEUS NLO QCD fit to F_2^D and charm

- x_{IP} <0.01
- QCDNUM
- Regge factorisation assumption possible for this small data set
- DL flux
- initial scale Q^2=2 GeV^2
- $zf(z)=(a_1+a_2z+a_3z^2)(1-x)^{a4}$
- other PDFs parametrisation tried
- Thorne-Robert variable-flavour-number-scheme

- QCD fit describes data

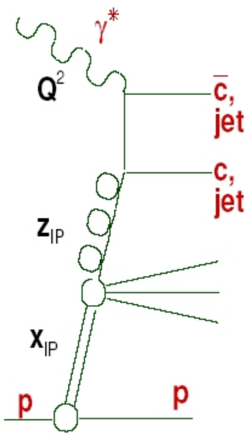
  $(\chi^2/ndf = 37.9/36)$
- fractional gluon momentum

  $(82 \pm 8(stat) \pm 9(sys))\%$
- shape of pdfs not well constrained



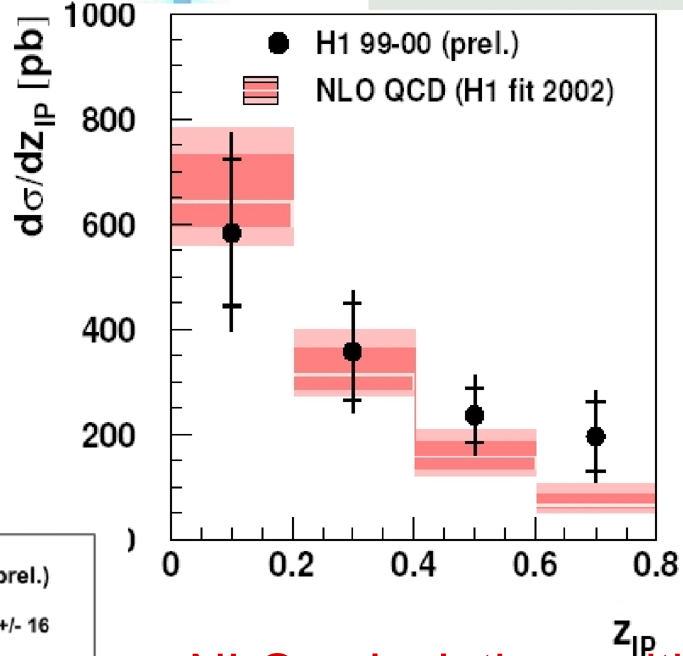
[$F_2^{D(3)cc}$ from DESY-03-094]

Diffractive D* in DIS

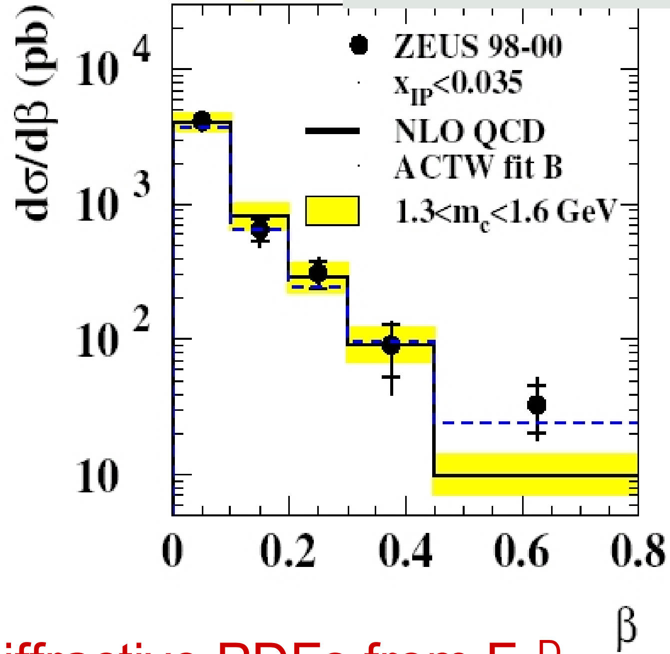


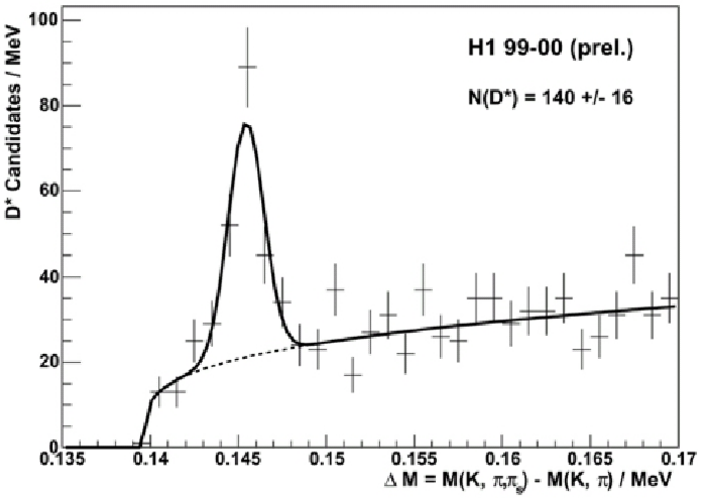
$\gamma g \rightarrow c\bar{c}$

$Q^2>2$ GeV^2
$x_{IP}<0.04$
$p_T^{D^*}>2$ GeV/c



$Q^2>1.5$ GeV^2
$x_{IP}<0.035$
$p_T^{D^*}>1.5$ GeV/c



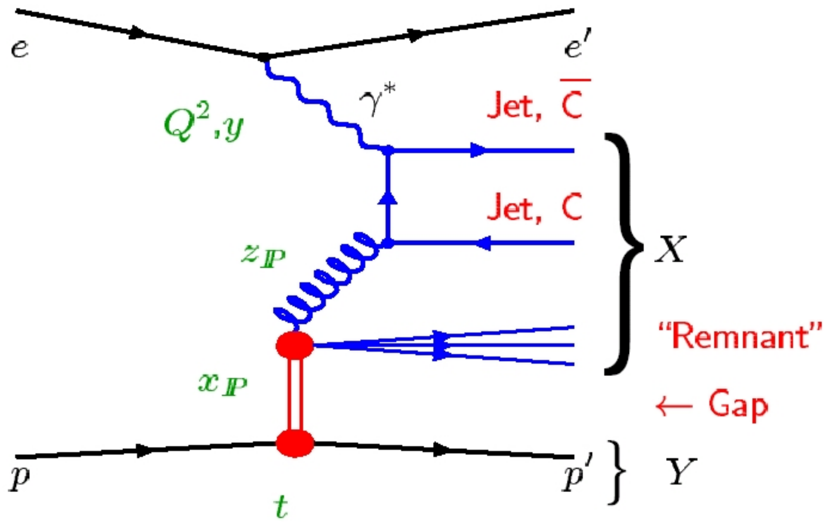


NLO calculations with diffractive PDFs from F_2^D

Good description. Factorization holds.

Extract D* from fit to $\Delta M = M_{K\pi\pi} - M_{K\pi}$

Jet Production in DIS

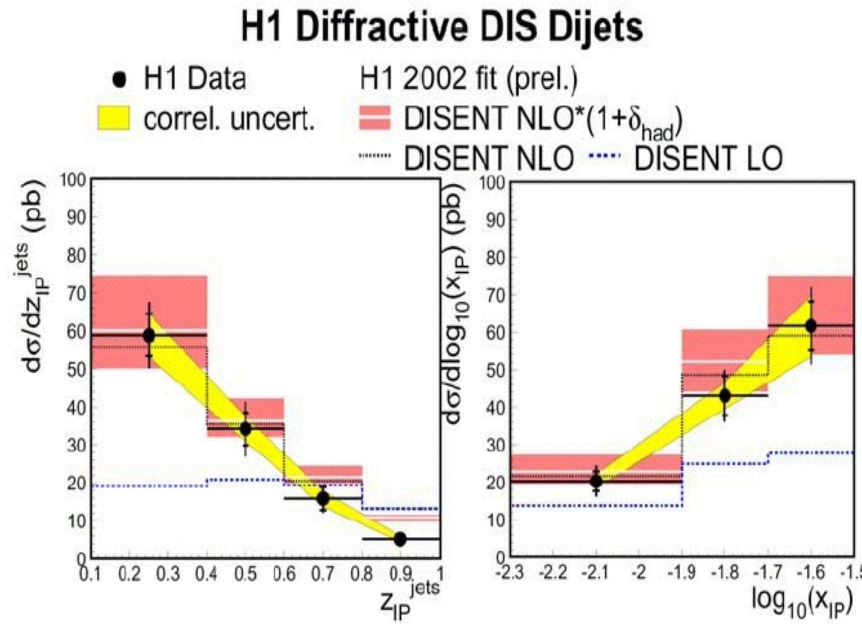


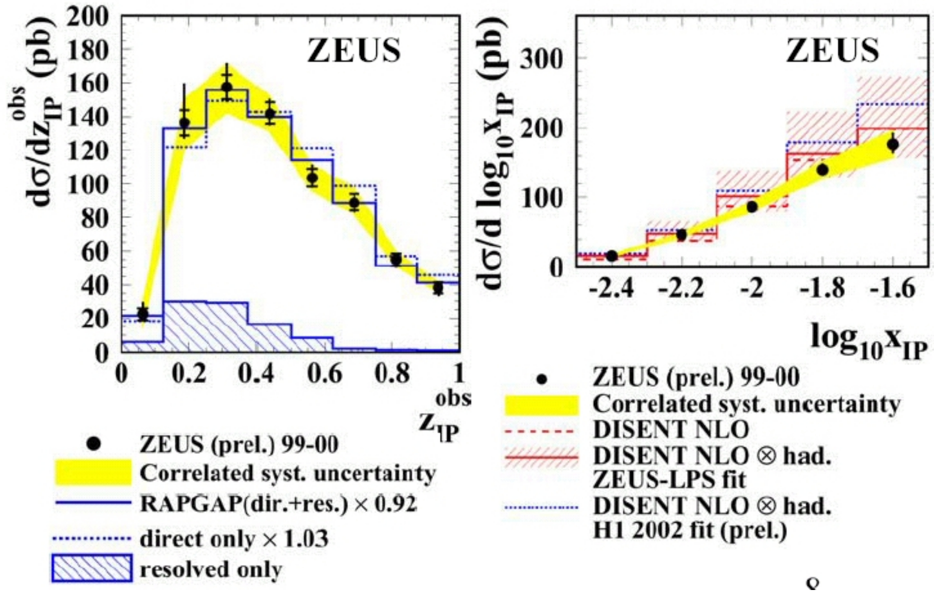
$$x_{I\!P} = \frac{Q^2 + M_X^2}{Q^2 + W^2}$$

$$z_{I\!P} = \frac{Q^2 + M_{J1\,J2}^2}{Q^2 + M_X^2}$$

NLO calculations: DISENT with diffractive PDFs

good description. factorization holds

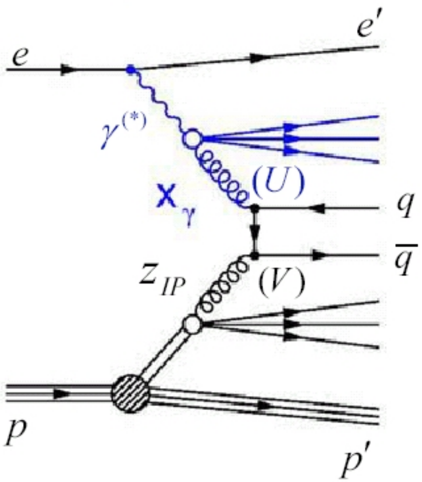




Jets in photoproduction

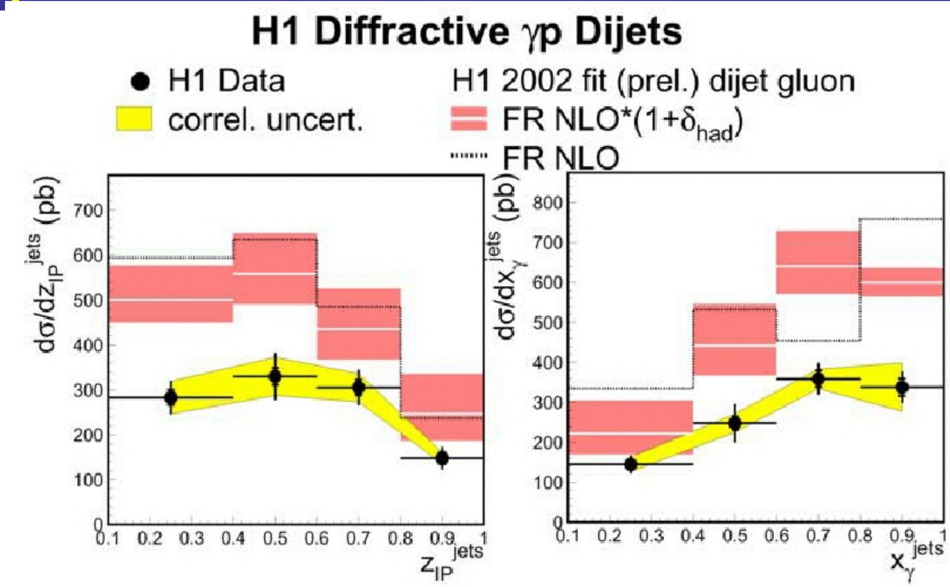
Direct and resolved γ interaction:

- *γ involved point-like into γp:* $x_\gamma \sim 1$
- *γ fluctuate into hadronic system:* $x_\gamma < 1$



$$x_\gamma = \sum_{jets} (E - p_z) / (2yE_e)$$

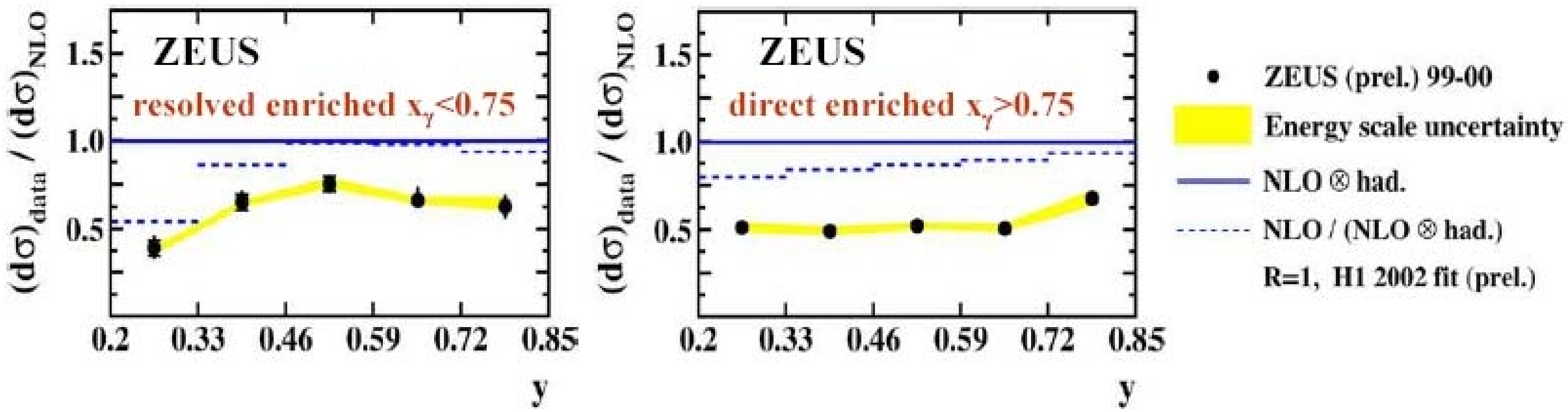
Momentum fraction of
γ carried by γ-parton



$y = Q^2/sx$

inelasticity

Ratio data/NLO for dijets in photoproduction



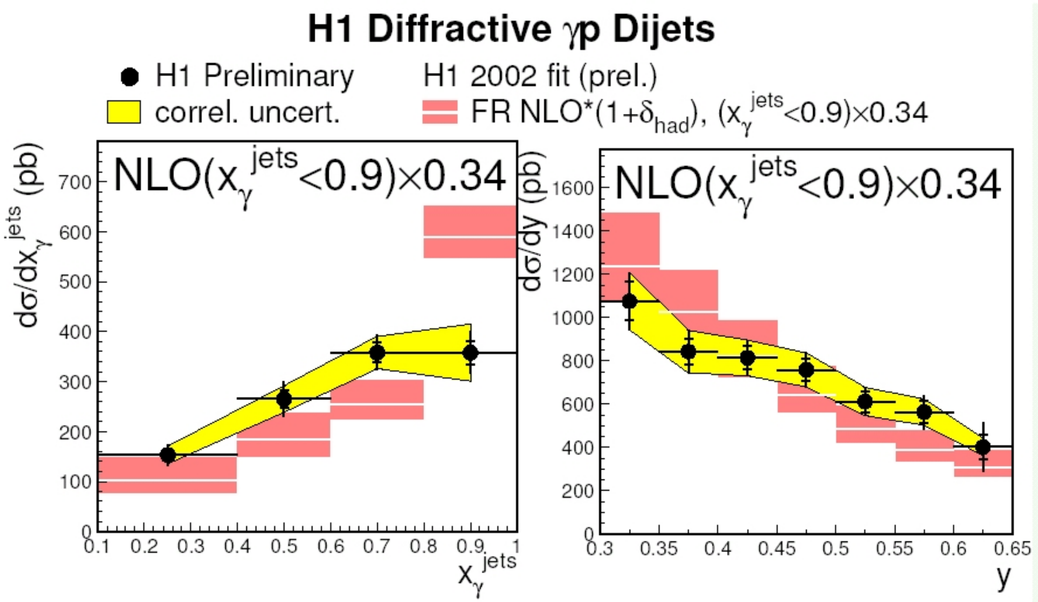
NLO overestimates dijet in photoproduction data by factor 2 for both direct and resolved photon

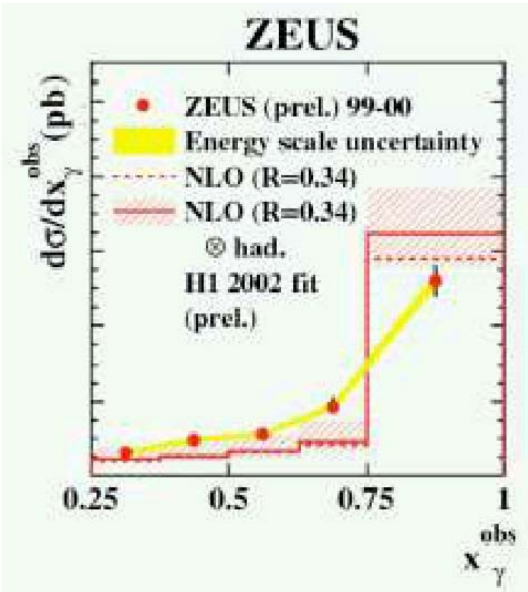
Factorization fails

Factorization failed in diff. γp, continued

Kaidalov, Khoze,Martin and Ryskin: In real photoproduction the resolved contribution is suppressed by 0.34. (Phys.Lett.B567 (2003) 61)

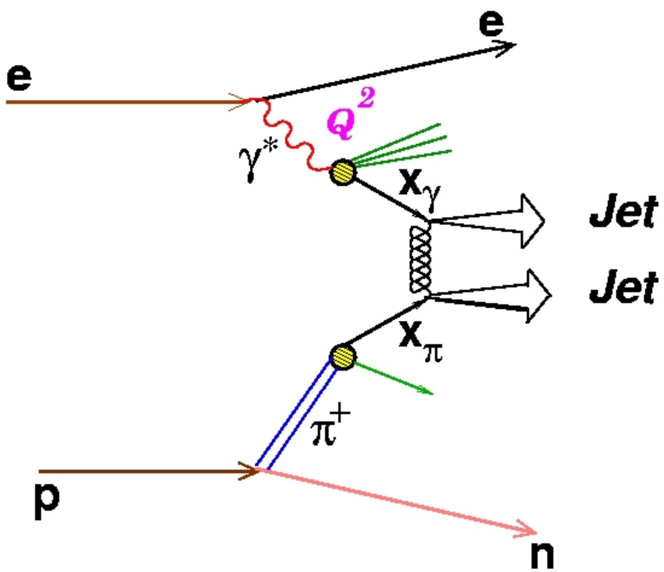
But suppression of only resolved component by factor 0.34 is not favored by these measurements:





Good prediction with NLO when using diffractive PDFs globally suppressed by factor ~0.5.

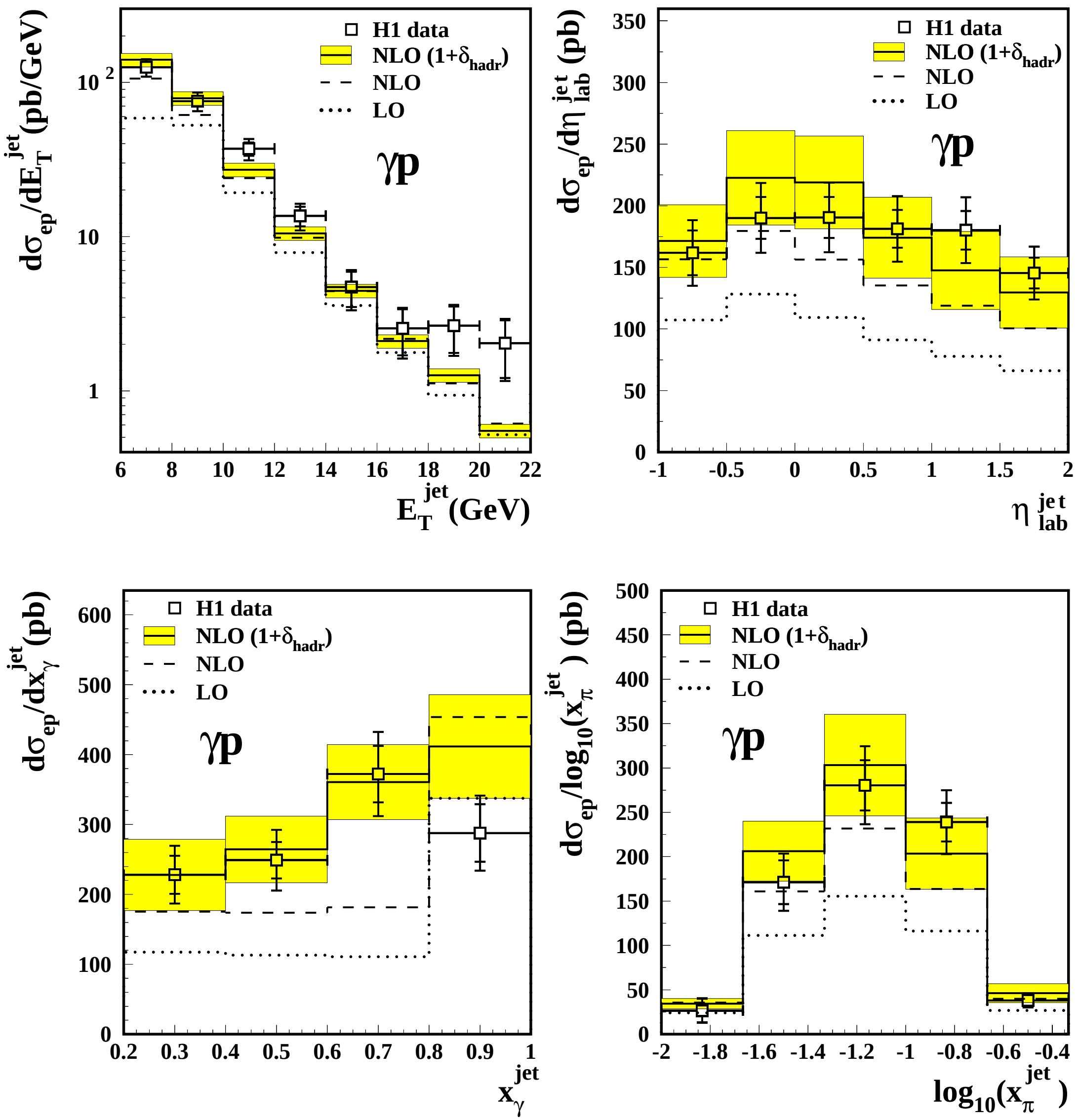
Jets in γp with leading neutron production



$$e + p \rightarrow e' + n + jet + jet + X$$

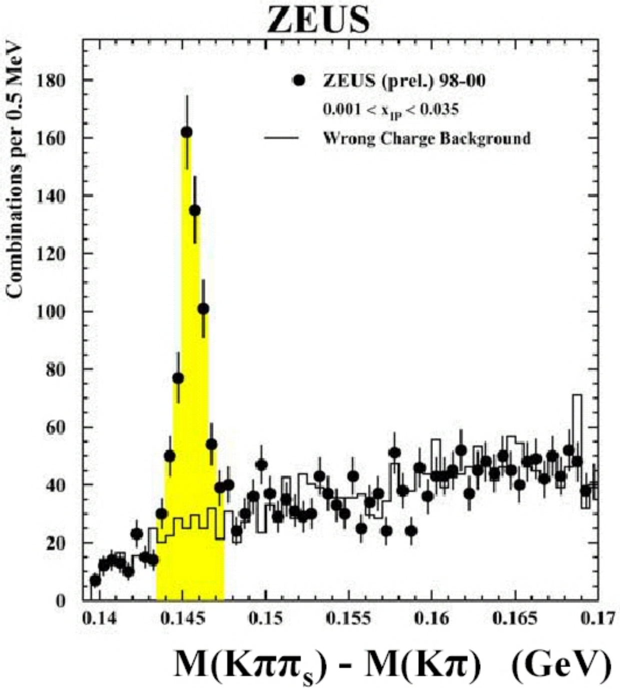
- Photoproduction ($Q^2 < 10^{-2}$ GeV^2)
- pQCD is applicable (Monte Carlo models, theory calculations)

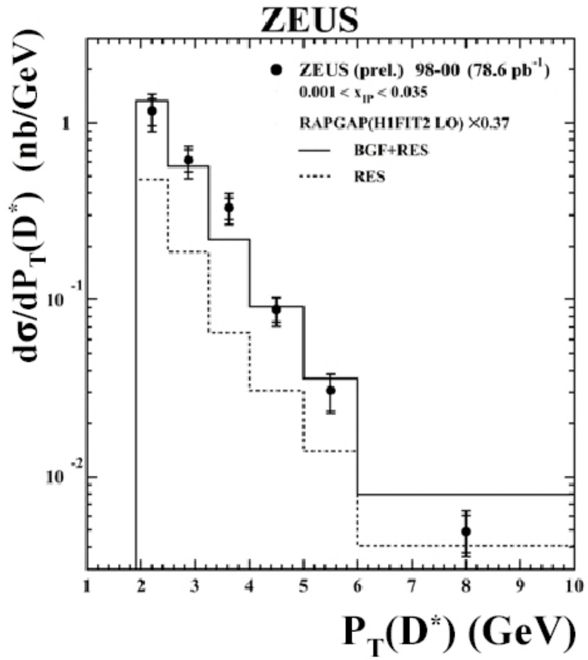
NLO calculation describes the jet cross sections both in shape and normalization

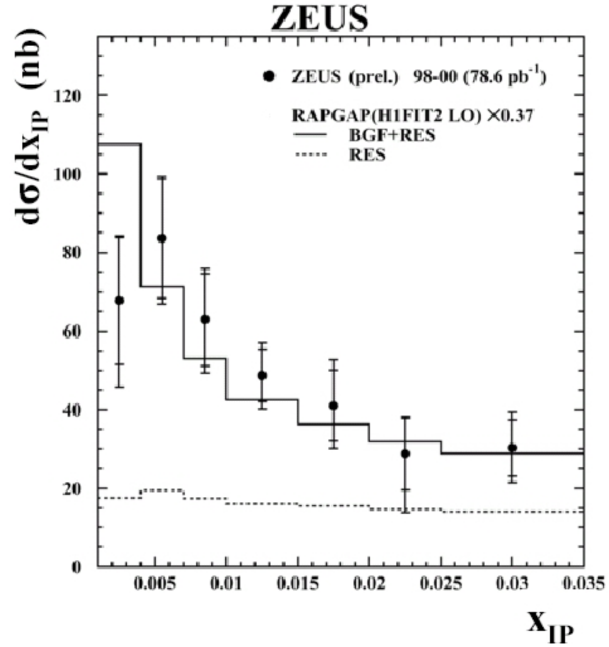


D* in diffractive photoproduction

First D* measurement in diffractive phoroproduction at HERA!







Statistics:
450 candidates

shape of data is well described by LO MC

NLO calculations are in progress:

- test whether the factorization is hold or broken in diffractive D* PhP

Summary

- **High precision HERA data with wide range in Q^2 (1.5 – 1600 GeV^2) have improved our understanding of diffraction**

- **QCD factorization in dijets and charm:**

- **holds in DIS**
- **fails in photoproduction for dijets in both direct and resolved regions**

- **ZEUS: first measurement of D^* in diffractive photoproduction**

- **HERA-II: more data to come…**

template