Highlights from Parallel Session B: Diffraction (Experimental Part)

Frank-Peter Schilling / DESY
(with Alessia Bruni, Markus Diehl)

12th Workshop on
Deep-Inelastic Scattering (DIS 2004)
Strbske Pleso, Slovakia, April 2004

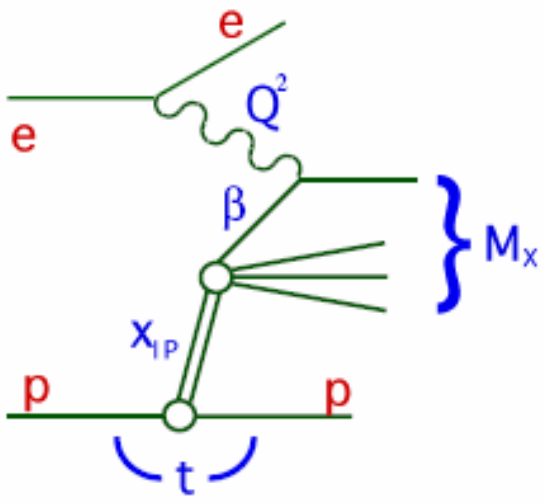
21 experimental talks ...

- Diffraction at HERA
  - Inclusive Diffraction / Leading Baryons
  - Diffractive final states (jets, charm)
- Vector Meson Production and DVCS
  - Vector Meson Production (HERA and RHIC)
  - DVCS
- Diffraction at the TEVATRON
  - Results from CDF and D0
- The near and not-so-near Future of Diffraction
  - The new H1 Very Forward Proton Spectrometer
  - Forward Physics at the LHC (ATLAS, CMS, TOTEM)

Diffraction at HERA

- Inclusive Diffraction
  - Diffractive Structure Function at low, medium and high Q2 (Kapishin, H1 and Ruspa, ZEUS)
  - Observation of Diffractive Charged Current Events (Klimek, ZEUS)
  - Leading Baryons: Pion Trajectory and DIS with leading protons (Sacchi, ZEUS)
- Diffractive Final States: Jets, Charm
  - Jets in Diffractive DIS and Photoproduction (Schaetzel, H1 and Kagawa, ZEUS)
  - D* production in diffraction and with leading neutron (Vlasov, ZEUS)
  - Light-cone wave function of the photon (Ukleja, ZEUS)

Inclusive Diffractive DIS



$x_{I\!P} = \xi = \frac{Q^2+M_X^2}{Q^2+W^2} = x_{I\!P/p}$
(momentum fraction of colour singlet exchange)

$\beta = \frac{Q^2}{Q^2+M_X^2} = x_{q/I\!P}$
(fraction of exchange momentum of q coupling to γ^*, $x = x_{I\!P}\beta$)

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

Diffractive reduced cross section σ_r^D:

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

Structure functions F_2^D and F_L^D:

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

Integrated over t: $F_2^{D(3)} = \int dt\ F_2^{D(4)}$

– Longitudinal F_L^D: affects σ_r^D at high y
– If $F_L^D = 0$: $\sigma_r^D = F_2^D$

[γ inelasticity $y = Q^2/sx$]

Factorization in Diffraction

Proof of QCD Factorization for diffractive DIS:

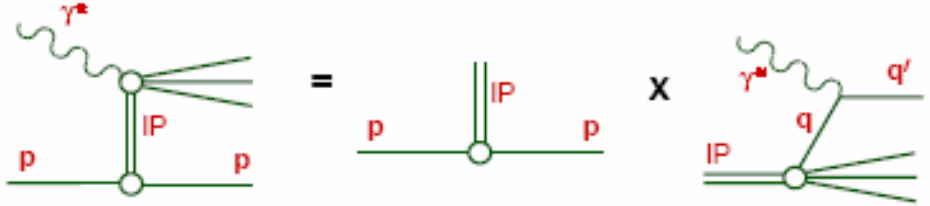
- Diffractive parton distributions (Trentadue, Veneziano, Berera, Soper, Collins, ...):

$$\frac{d^2\sigma(x,Q^2,x_{I\!P},t)^{\gamma^* p\to p' X}}{dx_{I\!P}\ dt} = \sum_i \int_x^{x_{I\!P}} d\xi \hat{\sigma}^{\gamma^* i}(x,Q^2,\xi)\ p_i^D(\xi,Q^2,x_{I\!P},t)$$

- $\hat{\sigma}^{\gamma^* i}$ hard scattering part, as in incl. DIS
- p_i^D diffractive PDF's in proton, conditional probabilities, valid at fixed $x_{I\!P}, t$, obey (NLO) DGLAP

Regge Factorization / 'Resolved Pomeron' model:

$x_{I\!P}, t$ dependence factorizes out (Donnachie, Landshoff, Ingelman, Schlein, ...):

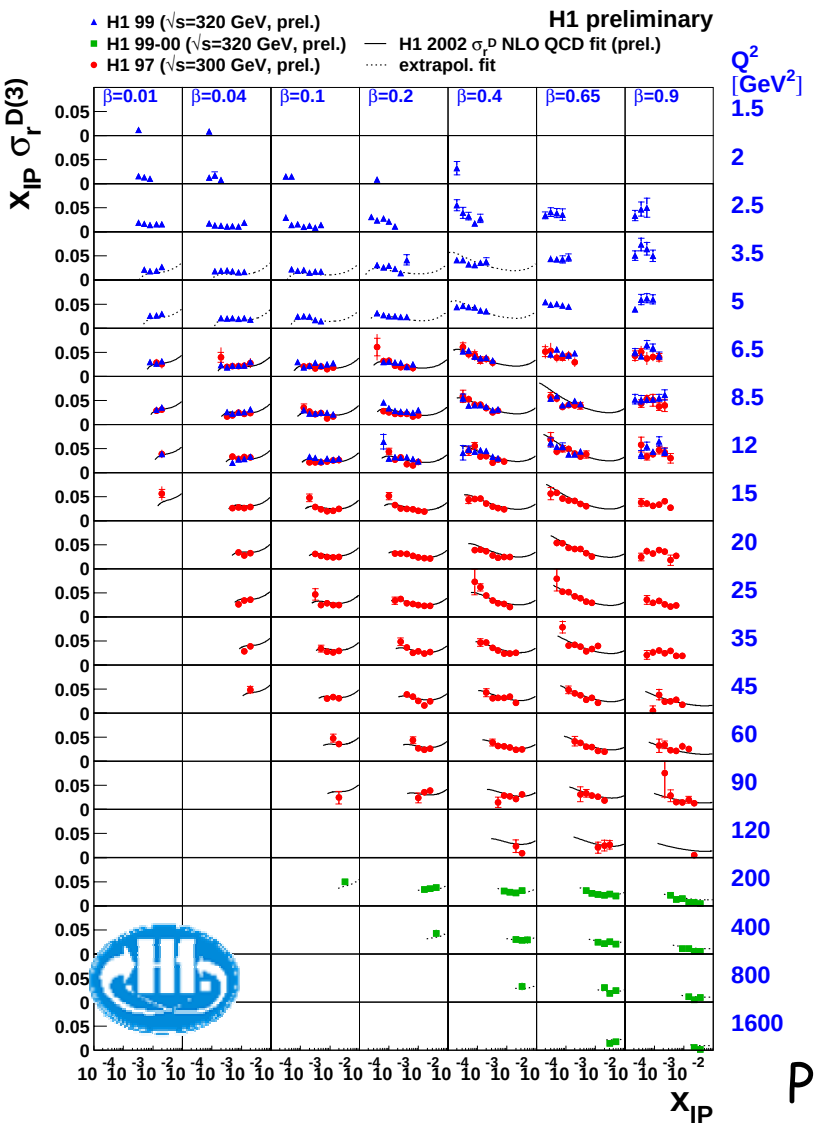


$$F_2^D(x_{I\!P},t,\beta,Q^2) = f_{I\!P/p}(x_{I\!P},t)\ F_2^{I\!P}(\beta,Q^2)$$

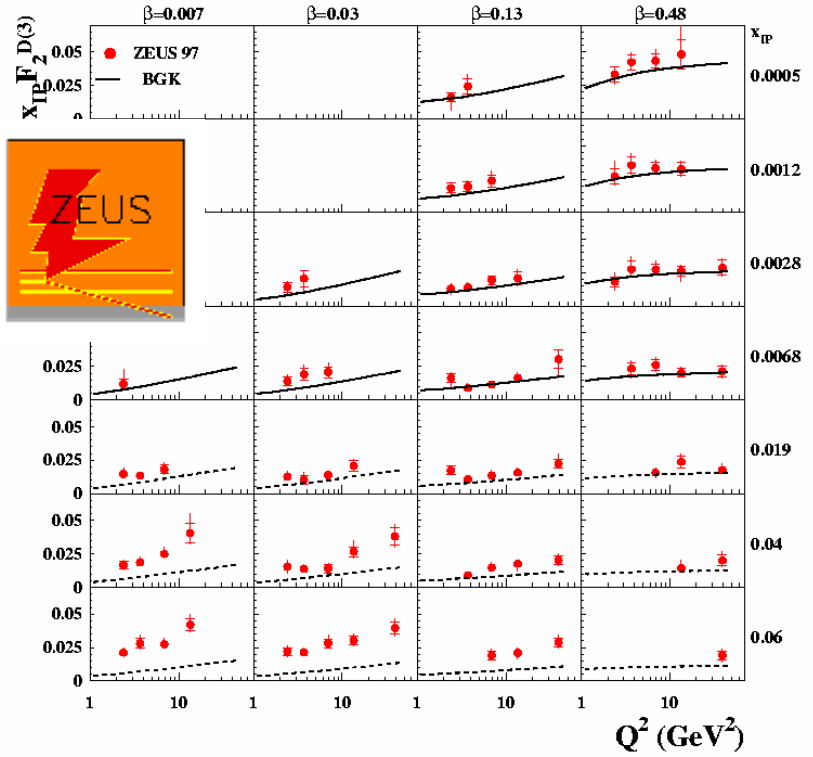
- additional assumption, no proof !
- consistent with present data if sub-leading $I\!R$ included

Shape of diffr. PDF's indep. of $x_{I\!P}, t$, normalization controlled by Regge flux $f_{I\!P/p}$

Inclusive Diffractive DIS Data



Precision HERA-I data …



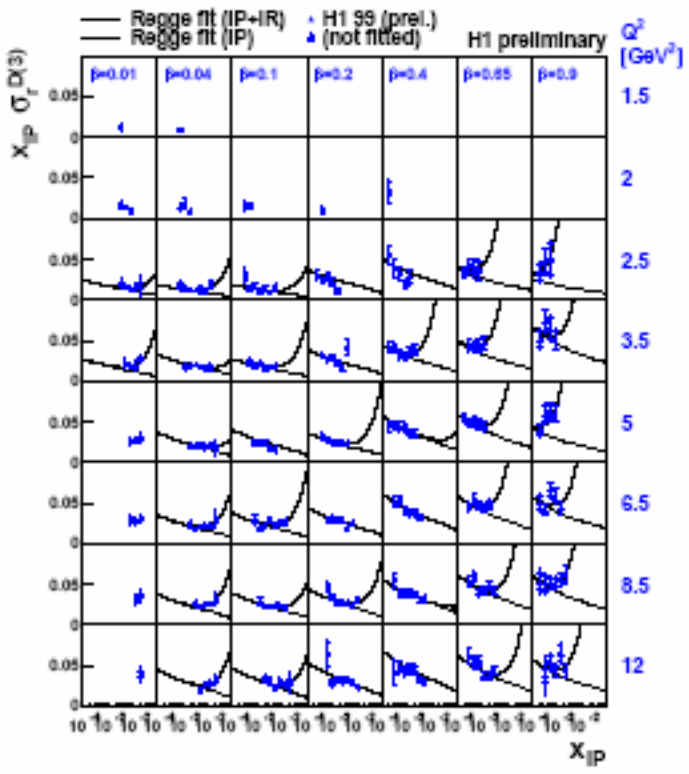
Leading Proton Spectrometer (Roman Pot) data

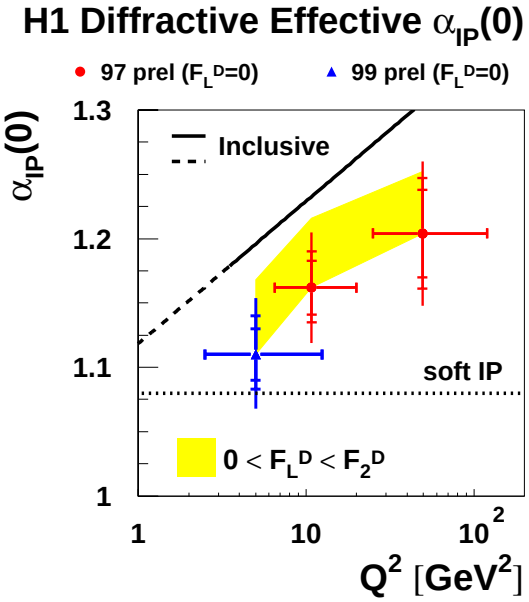
Precise data using Rapidity Gap method

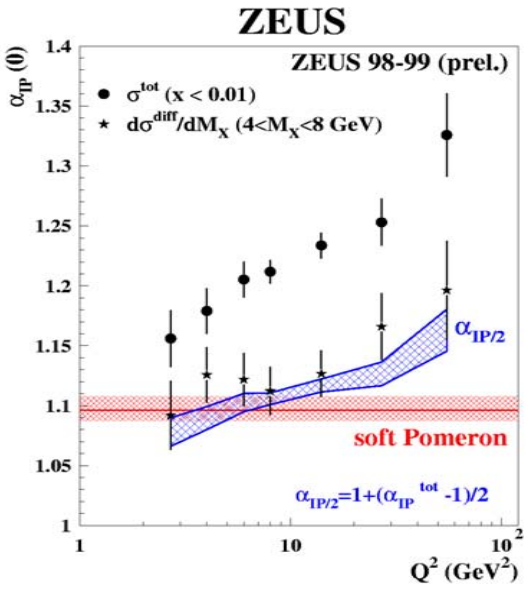
Pomeron Intercept vs Q^2

From fits to xpom or W dependence …

$x_{IP}F_2^D \sim A(\beta,Q^2)\, x_{IP}^{2-2\alpha(t)}$ $\qquad$ $F_2 \sim B\, x^{1-\alpha(Q^2)}$



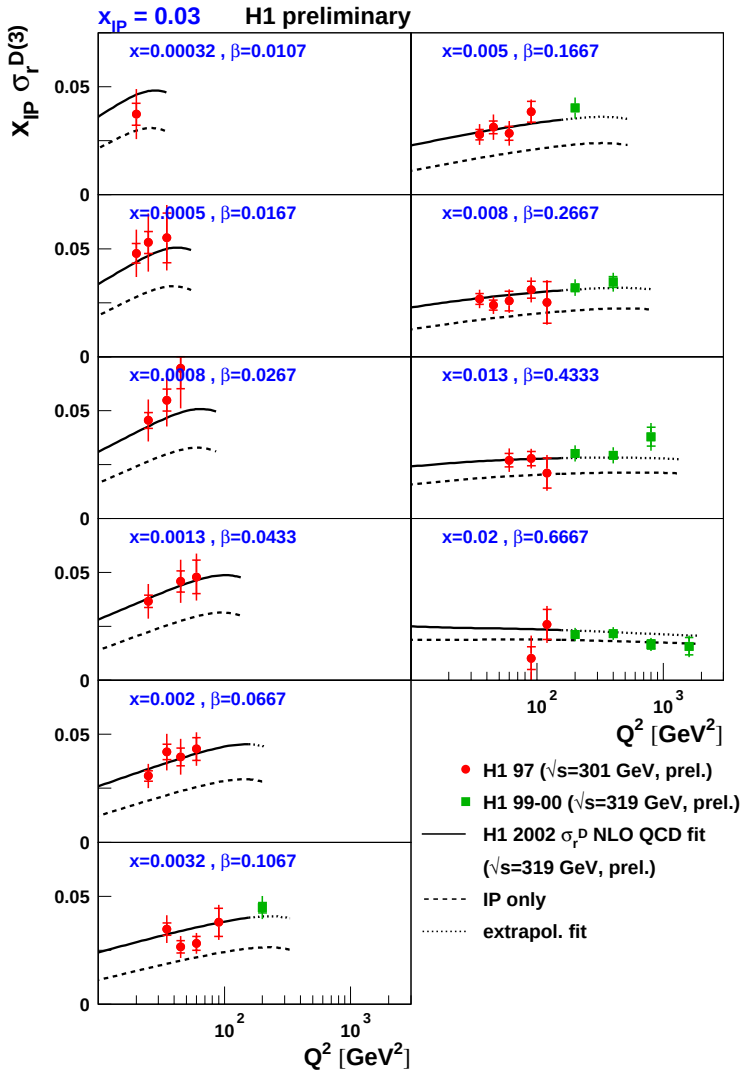




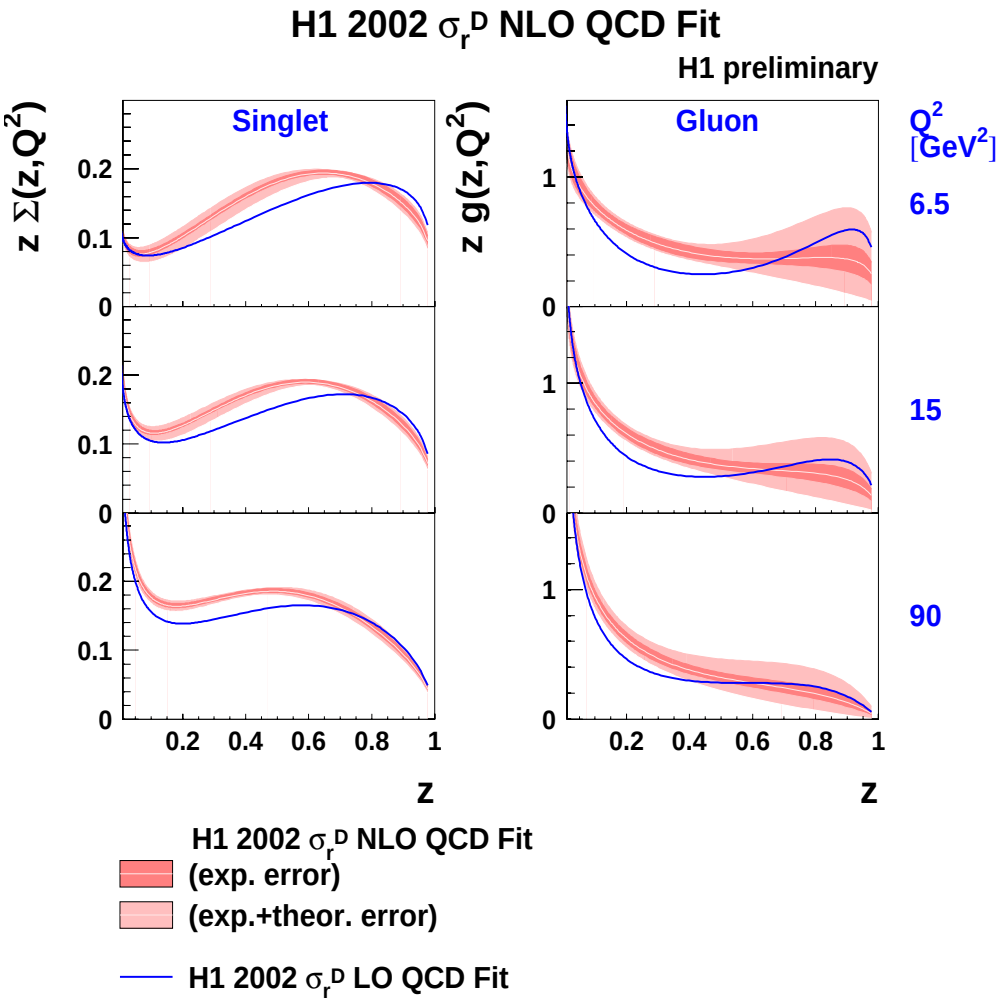
Indications for rise with Q^2?
.. large systematics, in particular due to F_L ignorance

Need to get better handle on F_L^D!

H1 NLO QCD interpretation of data



Postive scaling violations to highest β …



Diffractive NLO pdf's with errors!

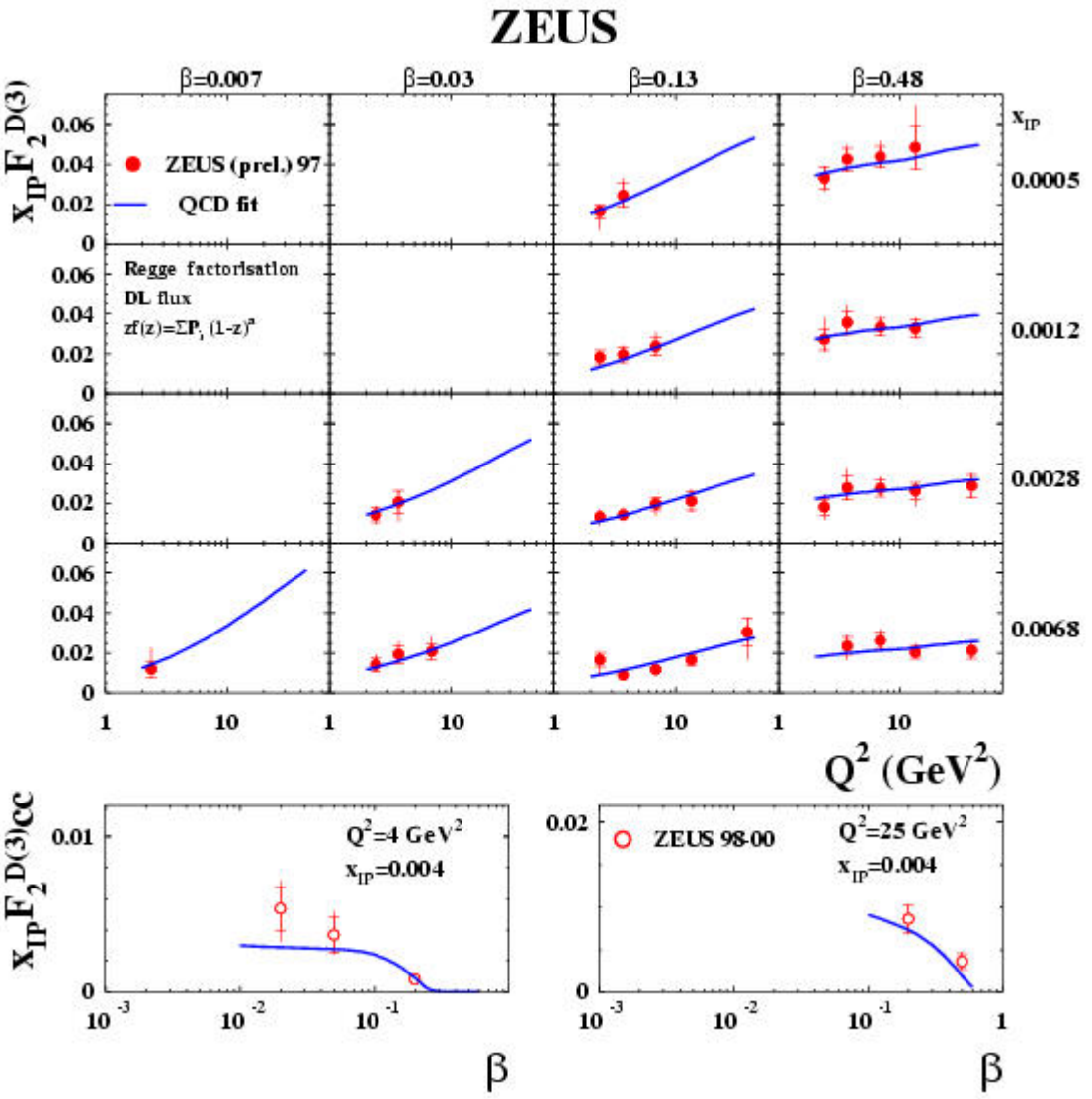
ZEUS NLO QCD fit to F_2^D and charm

Combined fit to LPS F_2^D
And diffr. charm data …

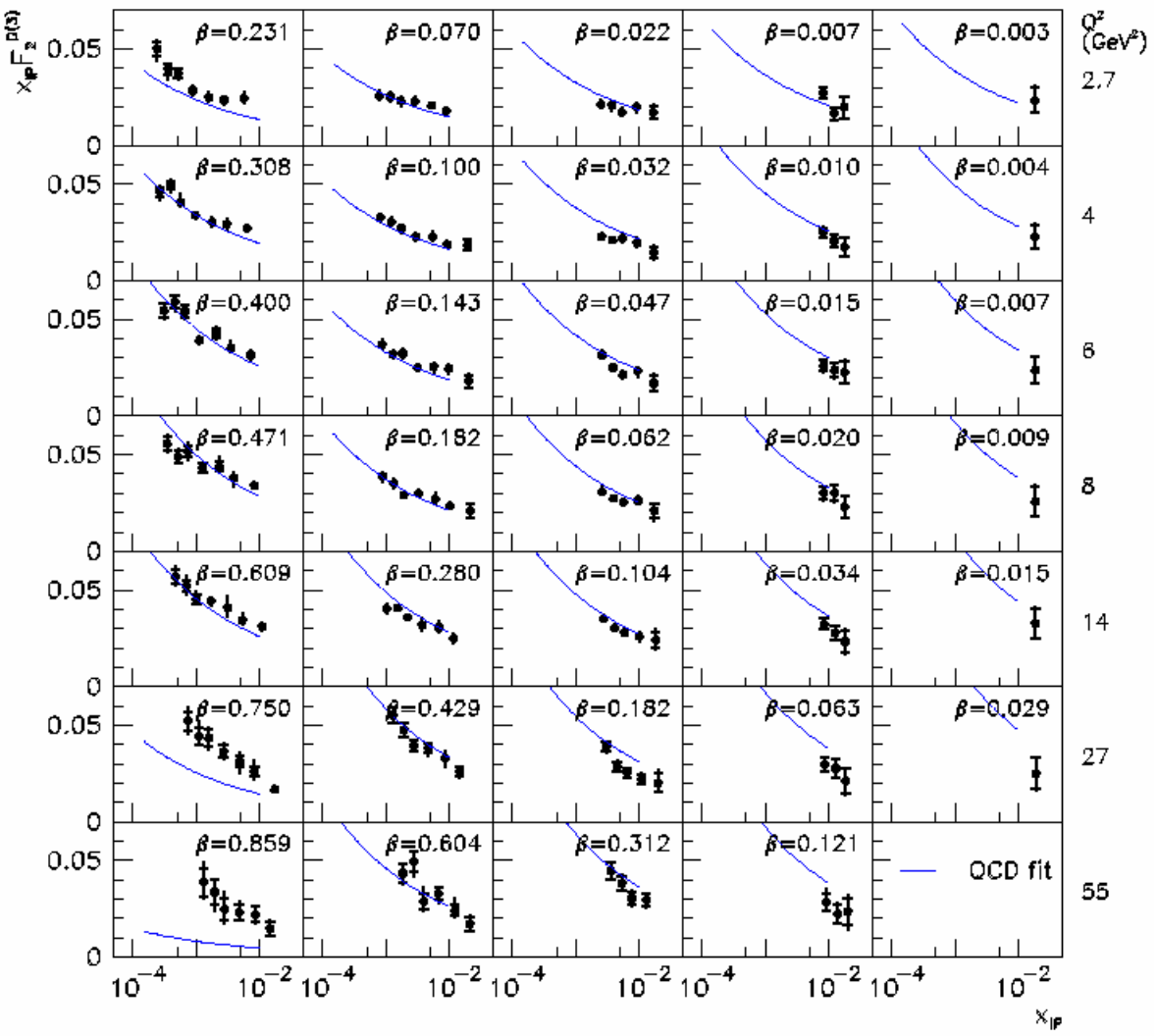
- x_{IP} <0.01, β<0.5
- QCDNUM
- Regge factorisation assumption possible for this small data set
- DL flux
- initial scale Q^2=2 GeV^2
- $zf(z)=(a_1+a_2z+a_3z^2)(1-x)^{a4}$
- Thorne-Robert variable-flavour-number-scheme

Shape of pdf's not well constrained

Gluon fraction ~82%



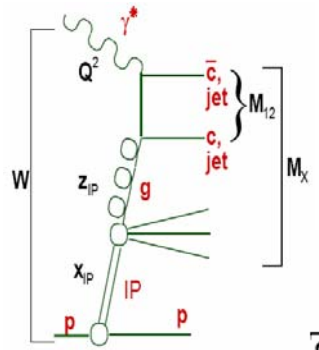
Comparison with Mx data



Agreement within kinematic Range of LPS data

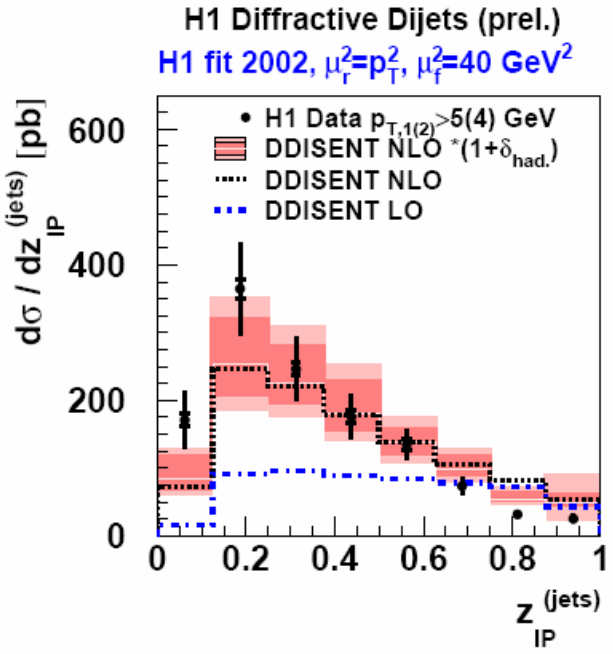
N.B. p dissociation Correction 30%

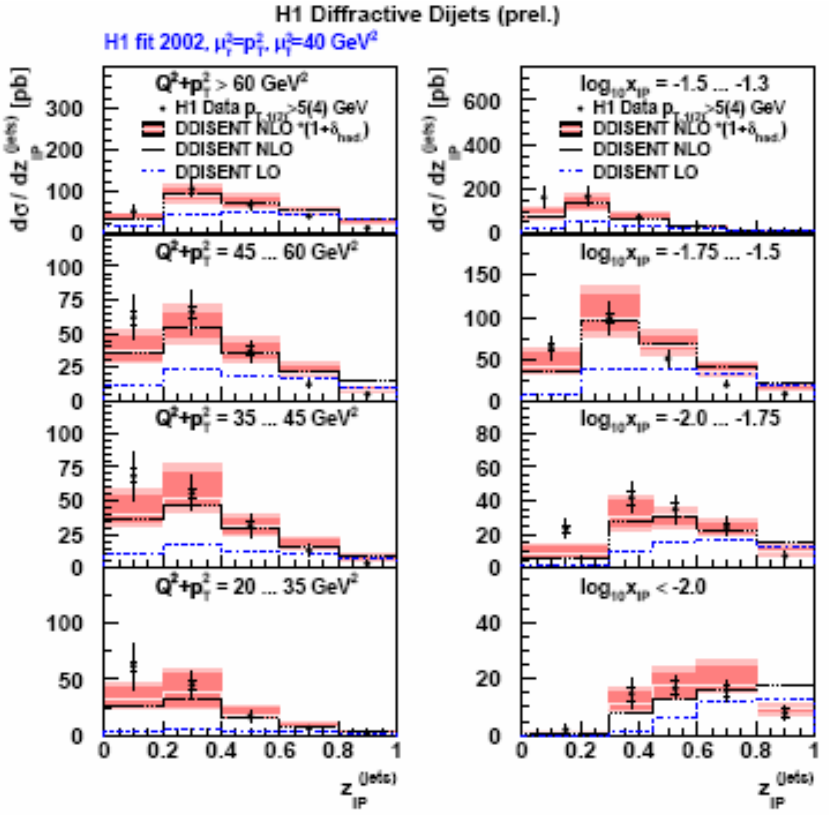
Test QCD factorization in diffr. DIS: Jets



New: **NLO** Calculations for dijets, charm in DIS using diffractive Pdf's obtained from incl. data

Diffractive DIS jets
P_T>5(4) GeV

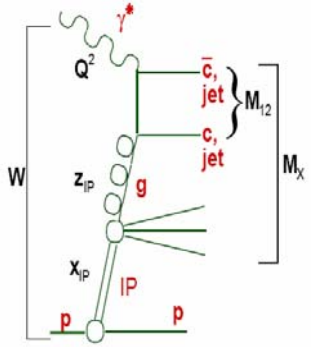


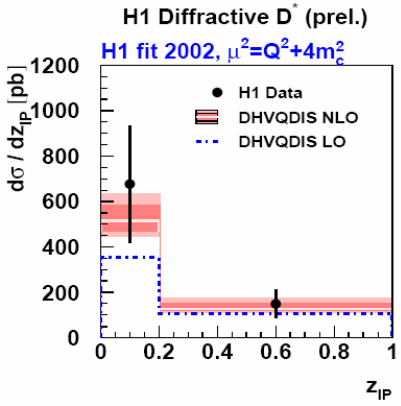


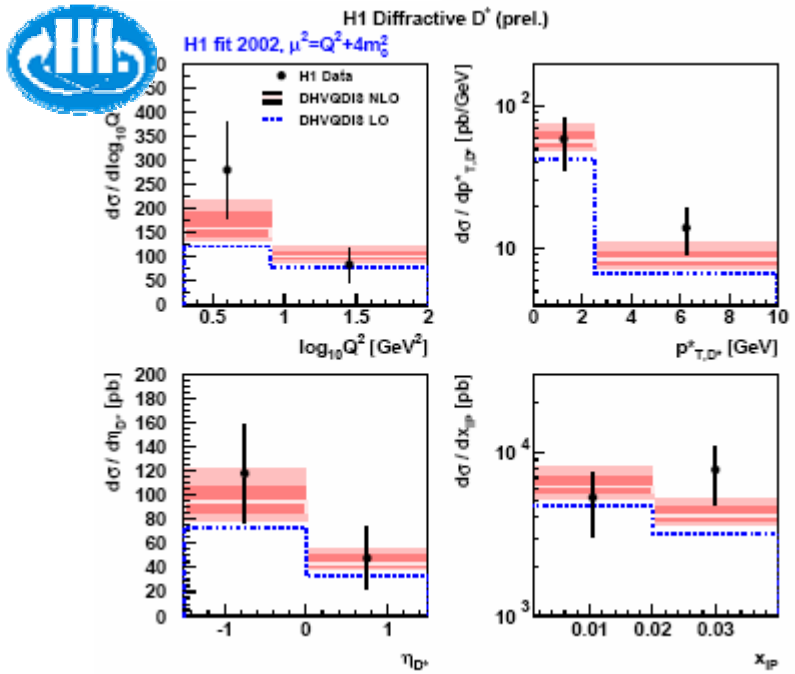
Calculations based on DISENT

Good agreement with NLO calc. based on H1 pdf's!

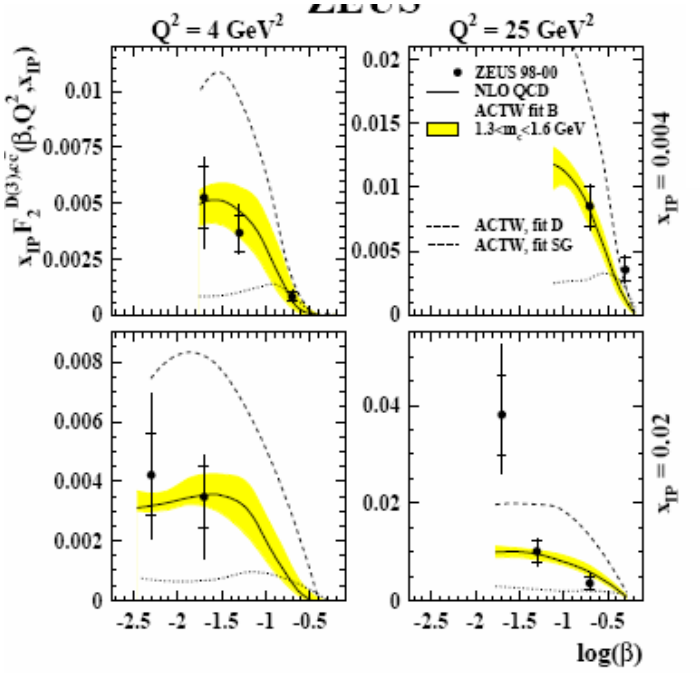
Test QCD Factorization in DIS: Charm







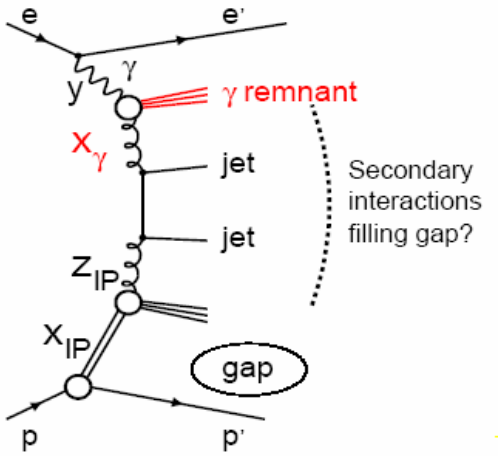
Diffractive D* production, Calculations based on HVQDIS



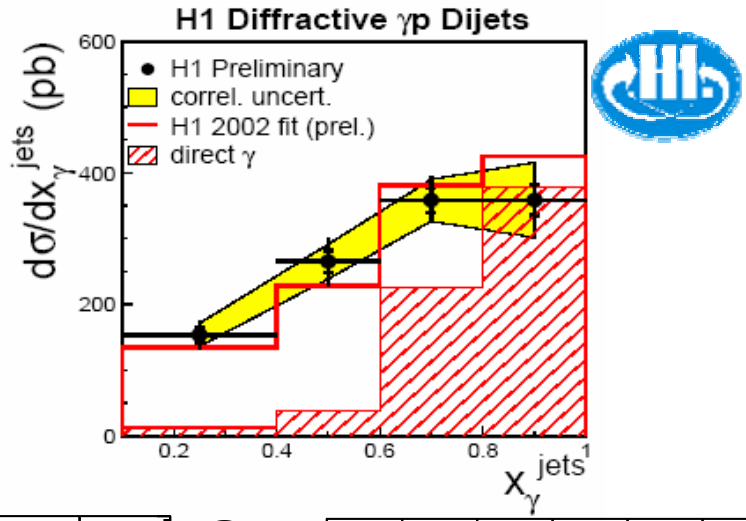
Diffr. DIS jets and charm: Consistent picture of diffractive DIS to NLO QCD!

Dijets in Diffractive Photoproduction

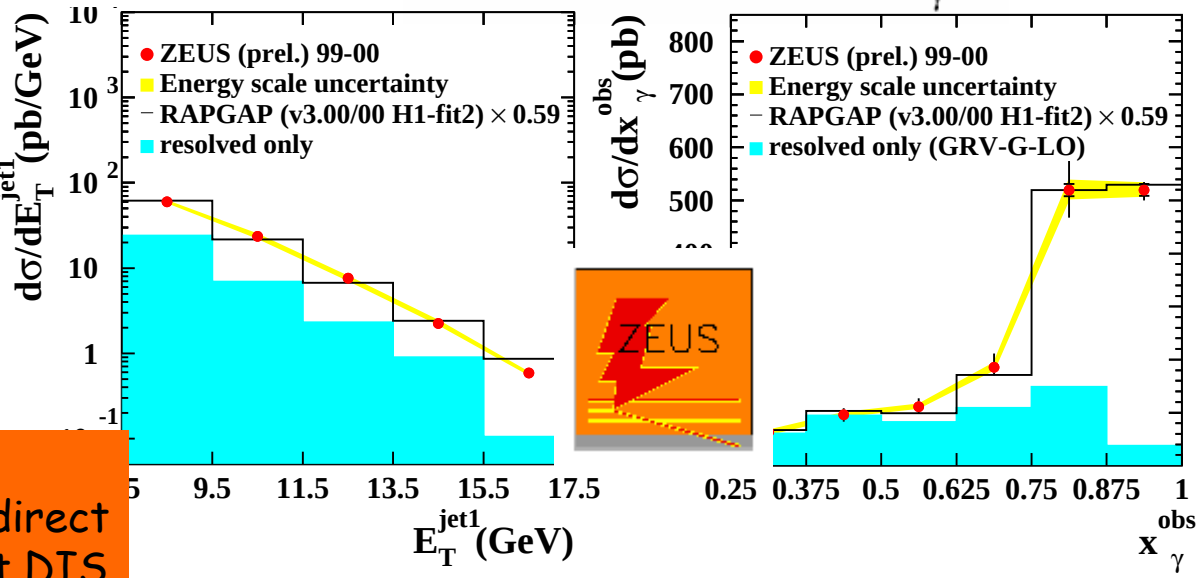
Real photon (Q^2~0) can develop hadronic structure …



- x_γ =1: direct photon coupling, DIS−like
- x_γ <1: resolved photon, hadron−like



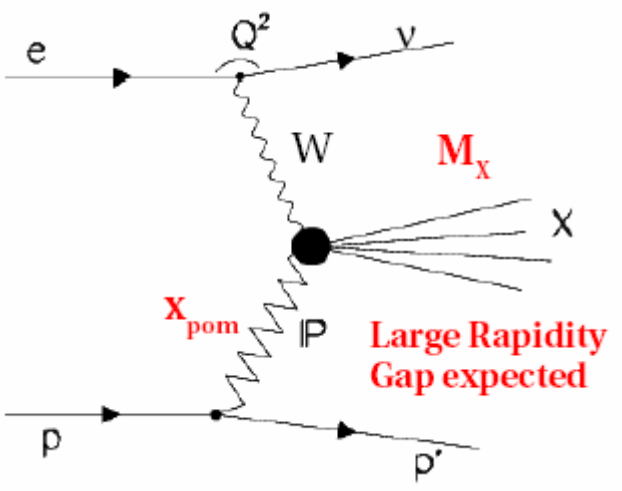
Does factorization break down?
(c.f. TEVATRON data)



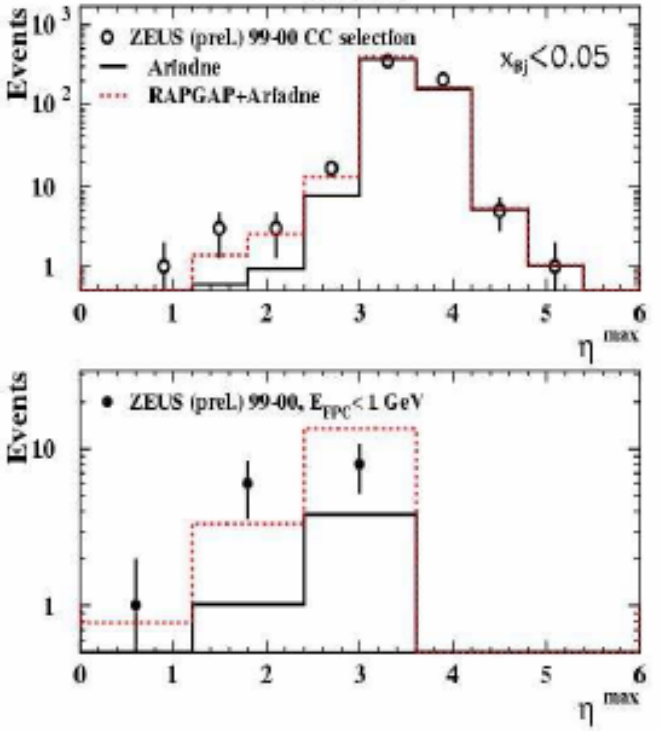
Data show:
No suppression of resolved w.r.t direct
No suppression of photoprod w.r.t DIS

N.B. LO+PS comparisons, need NLO …

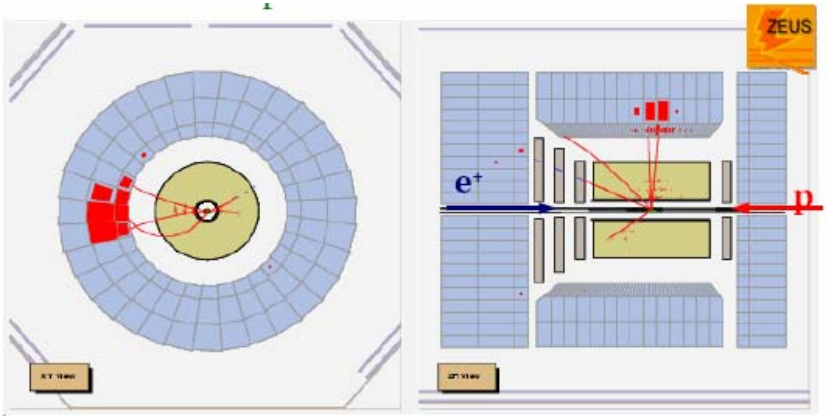
Observation of diffractive Charged Currrent events



after diffractive selection, 9 events remain …



Q^2>200 GeV^2, x_{IP}<0.05



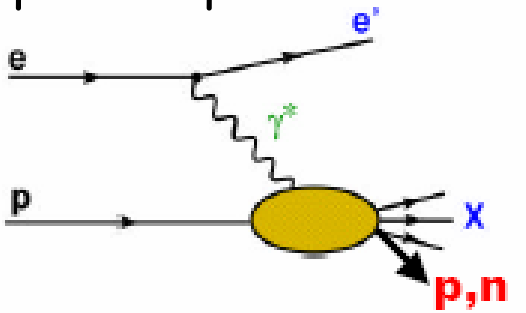
$\sigma^{\text{CC DIFF}}_{(Q^2>200\ \text{GeV}^2,\ x_{pom}<0.05)} =$

$= 0.49 \pm 0.20\ (\text{stat}) \pm 0.13\ (\text{syst})$ pb

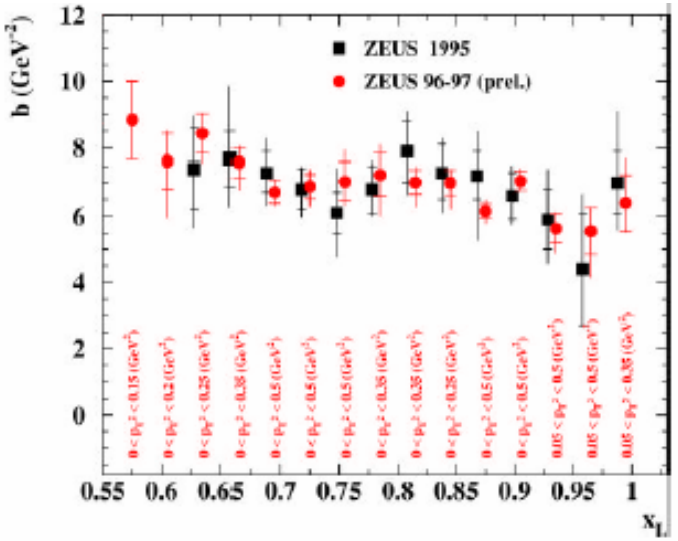
Consistent with expectation …

Leading Baryon Production

e+p->e+X+p/n

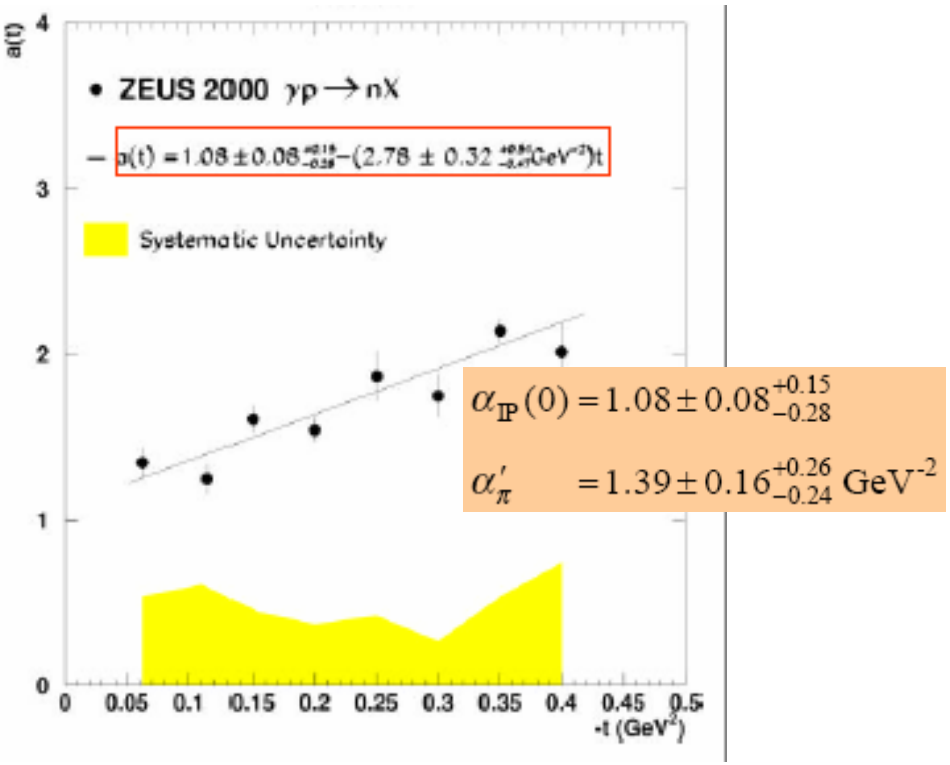


Important tool to understand
P fragmentation / vertex factorization



Leading p: t dependence vs x_L=Ep'/Ep

Leading n:
Triple Regge analysis
to extract π trajectory



Q^2 dependence wanted …

Vector Mesons and DVCS

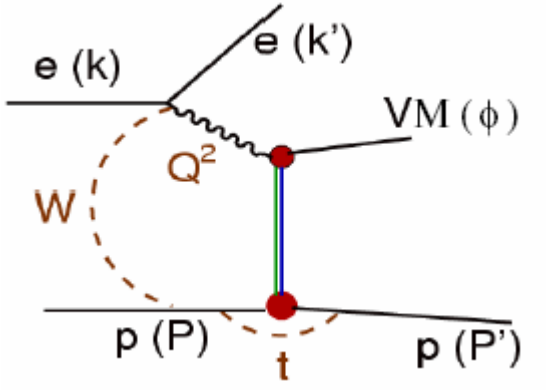
- Vector Meson Production
  - Phi production in DIS
    (Helbich, ZEUS)
  - J/Psi production in DIS (low |t|)
    (Bruni, ZEUS)
  - J/psi or photon production at high |t|, high W
    (Olsson, H1+ZEUS)

  Vector Meson Electroproduction at HERMES
    (Borissov, HERMES, see WG F summary)
  - Vector Meson Photoproduction in Heavy Ion Collisions
    (Ogawa, STAR)

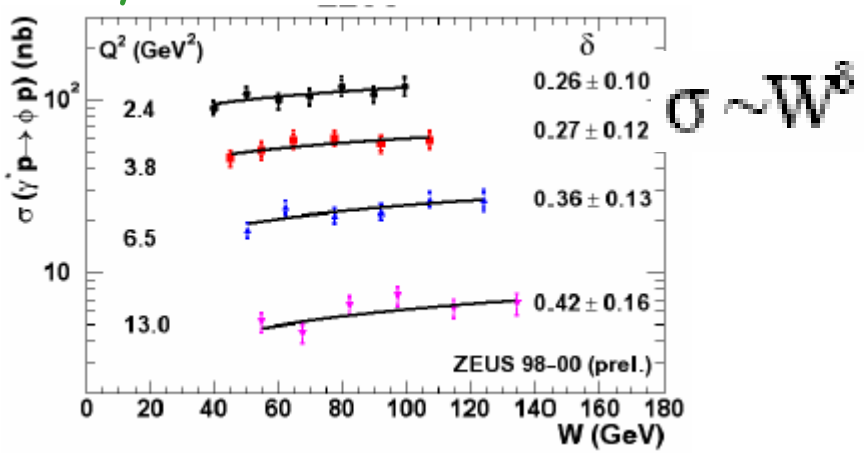
- DVCS
  - New DVCS cross sections from HERA (Favart, H1)
  - HERMES DVCS roadmap (Ellinghaus, HERMES, see WG F summary)

Exclusive Φ Production in DIS

VM production as clean laboratory to study soft-hard transition …

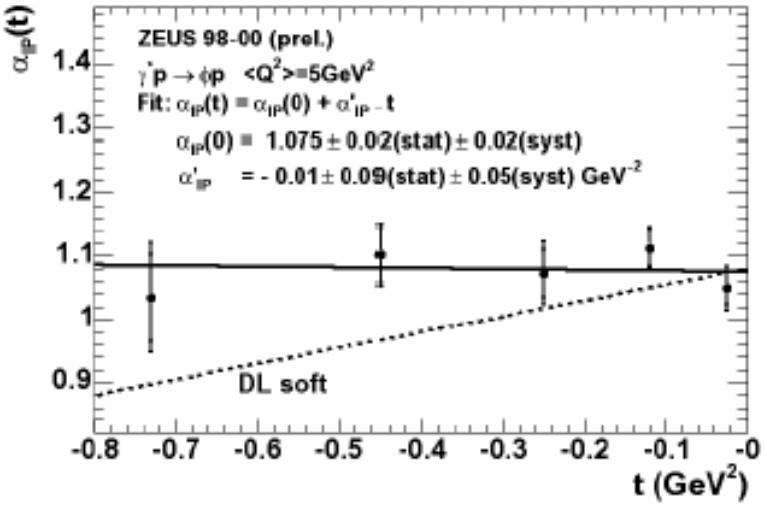


New Φ data:
L=66 pb^{-1}
4000 events



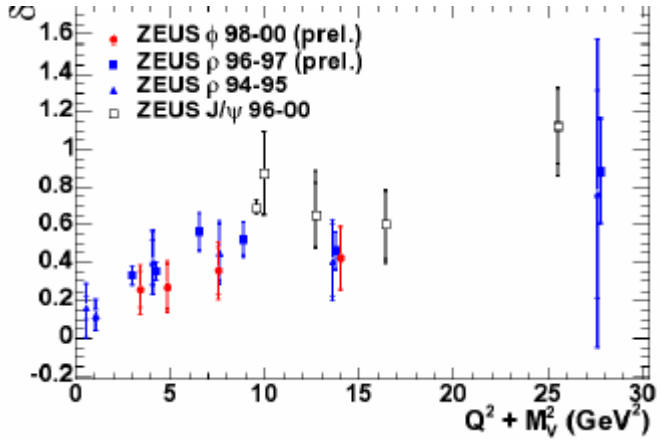
$\sigma \sim W^{\delta}$

W dependence vs. t:



α' consistent with 0: pQCD?

W dependence getting steeper with Q^2?

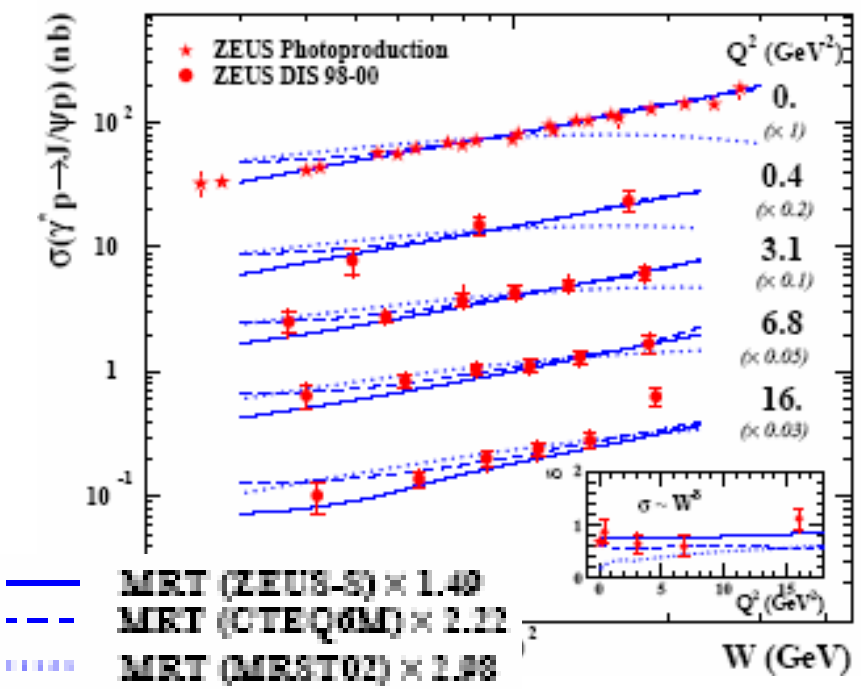


δ vs Q^2+M^2 for ρ, Φ, J/Ψ

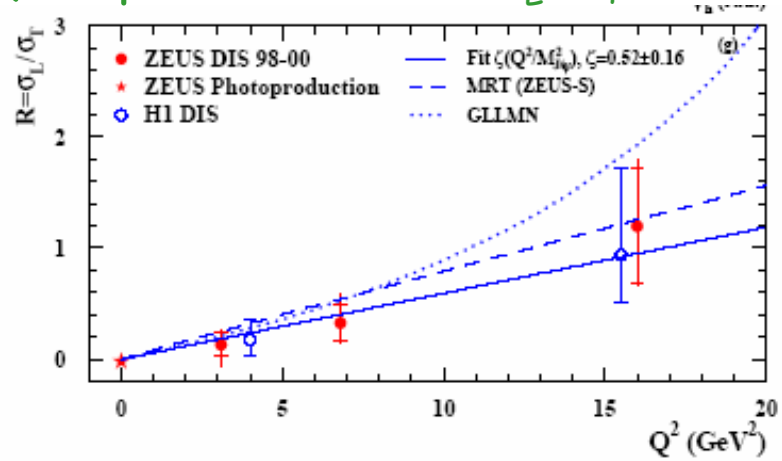
J/Ψ Production in DIS

$0 < Q^2 < 100\ \mathrm{GeV}^2 \quad 30 < W < 220\ \mathrm{GeV}$

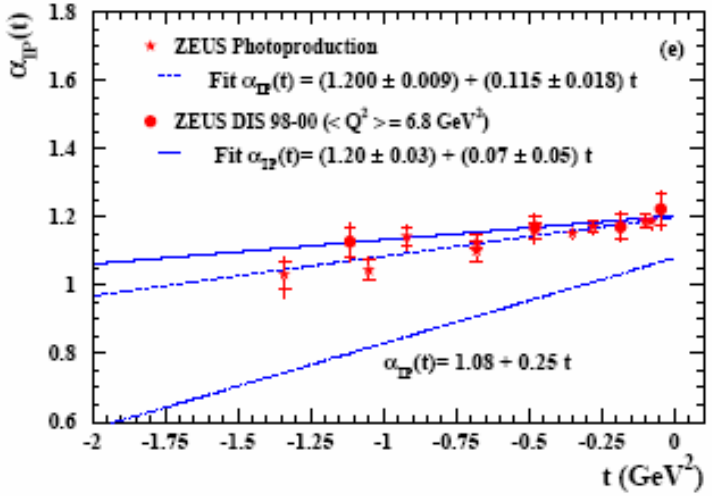
W dependence vs Q^2



Q^2 dependence of $R=\sigma_L/\sigma_T$:



IP trajectory <> soft IP



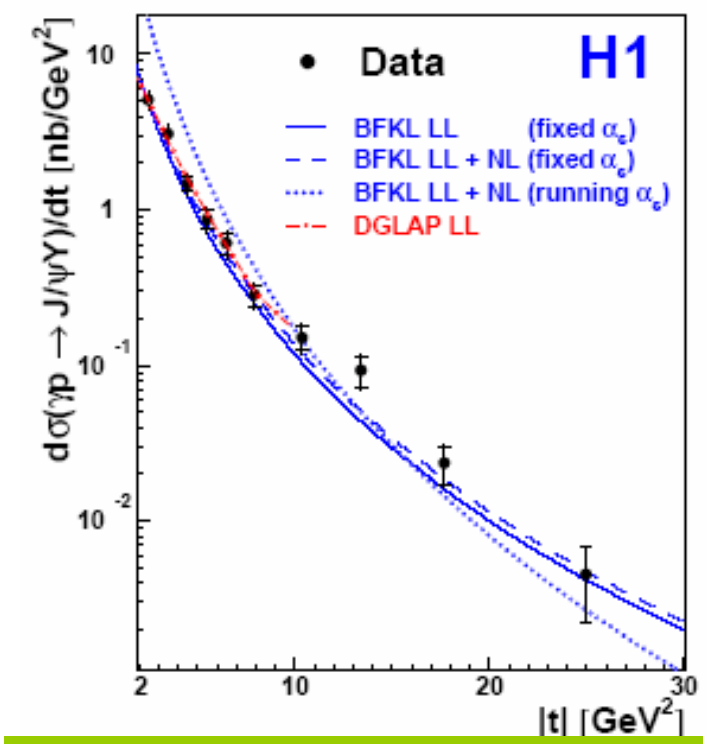
- Sensitive to (generalised) gluon
- Need NLO before inclusion into global fits

α' smaller in DIS than photoprod.!

J/Ψ and Photon production at high |t|

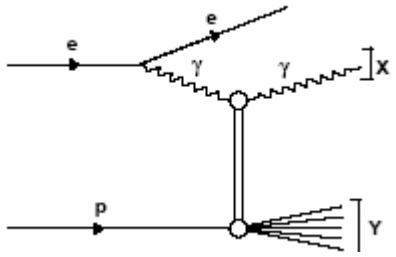
Looking for BFKL …

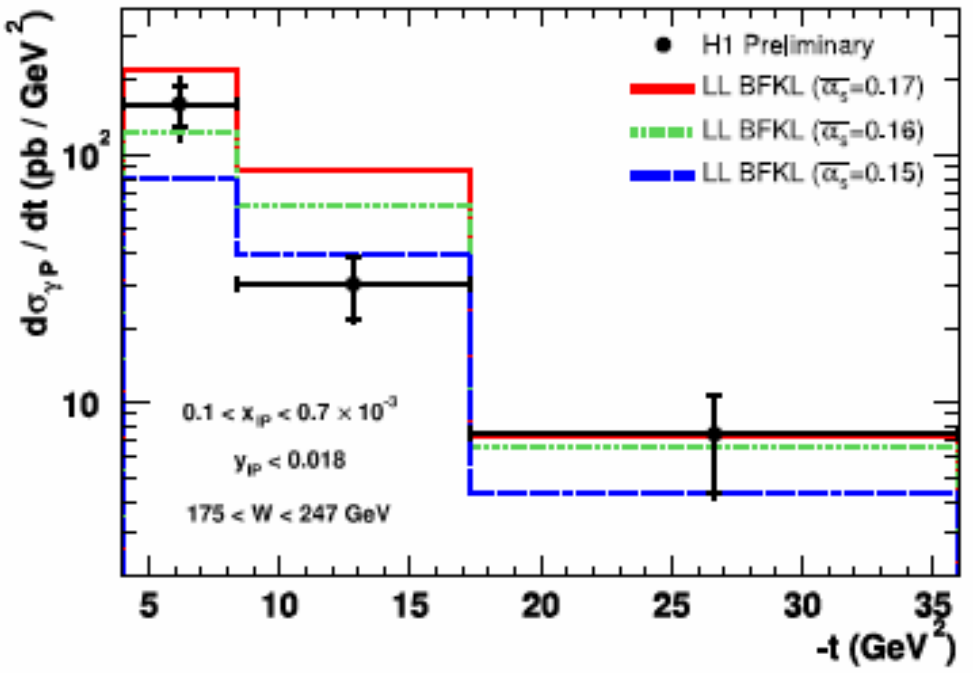
a) J/ΨPsi at high |t|<30 GeV²



BFKL LL+NL does good job (also W dep. vs t)

b) Photon production at |t|<35 GeV

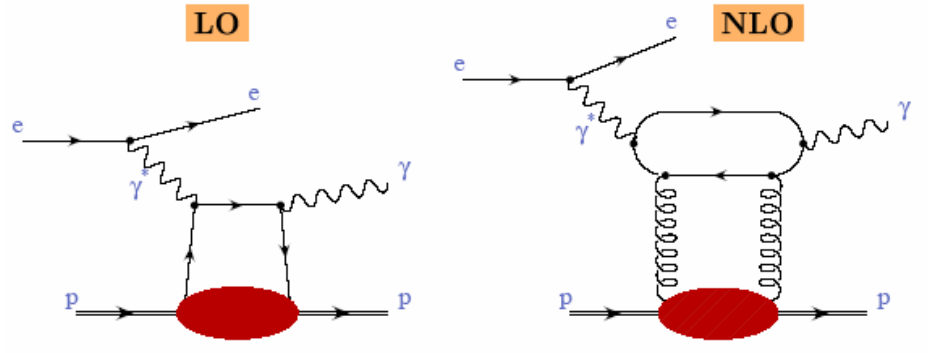




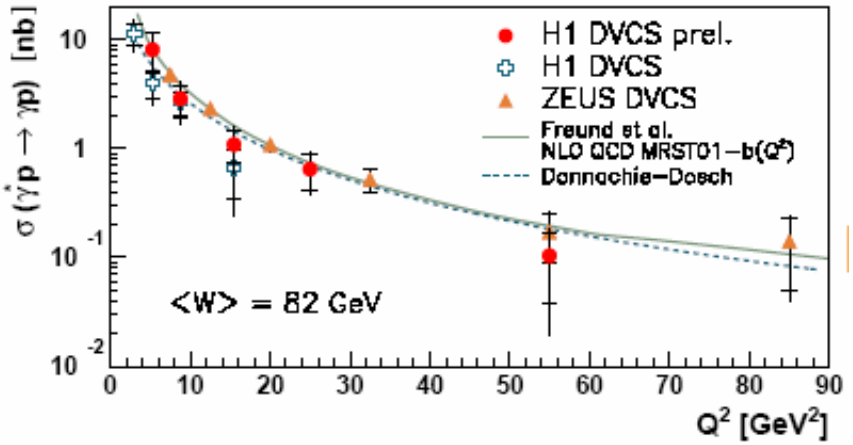
LL BFKL reasonable (but only LL)

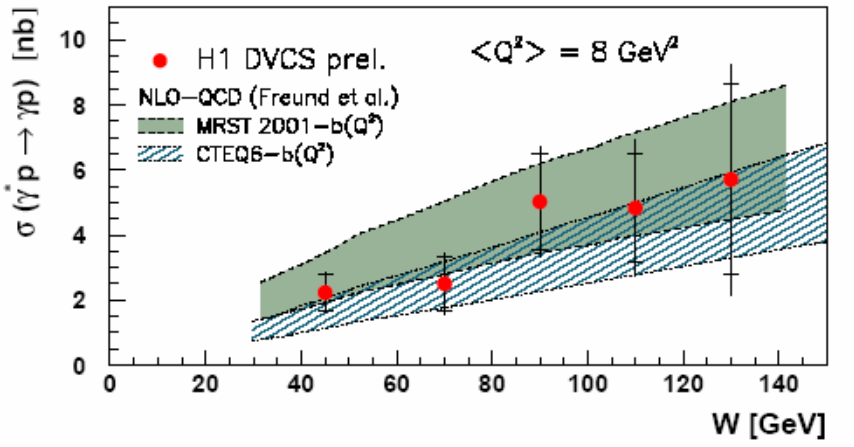
(N.B. Similar conclusions from ZEUS J/Ψ for |t|<7)

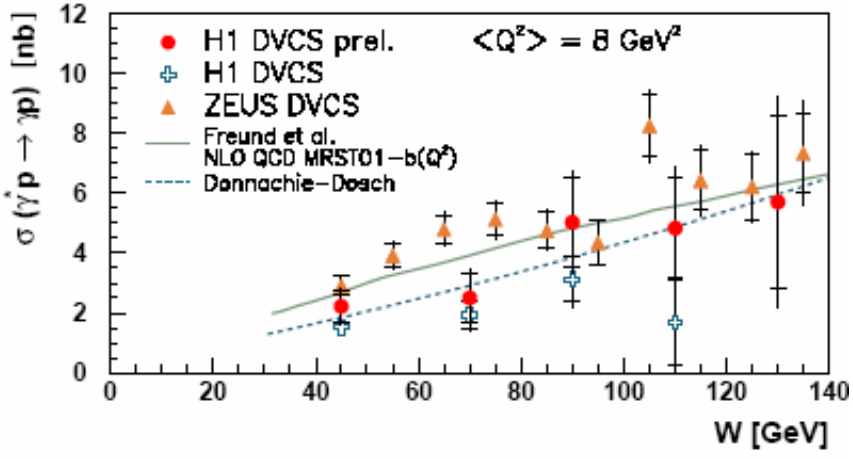
Deeply Virtual Compton Scattering (DVCS)



- Very clean process (no VM WF!)
- Fully calculable in QCD
- Sensitivity to GPD's







Dominant theor. Uncertainty: t-dep.!
Need to measure (e.g. H1 VFPS)

Major topic for HERA-II

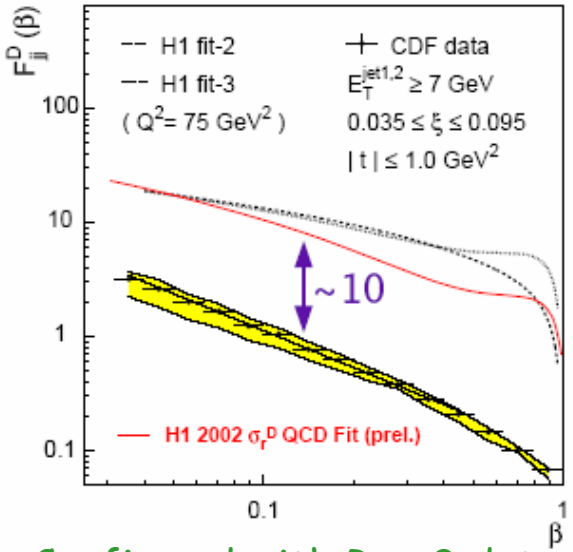
Diffraction at the TEVATRON

- Diffraction at CDF
  (Terashi, CDF)

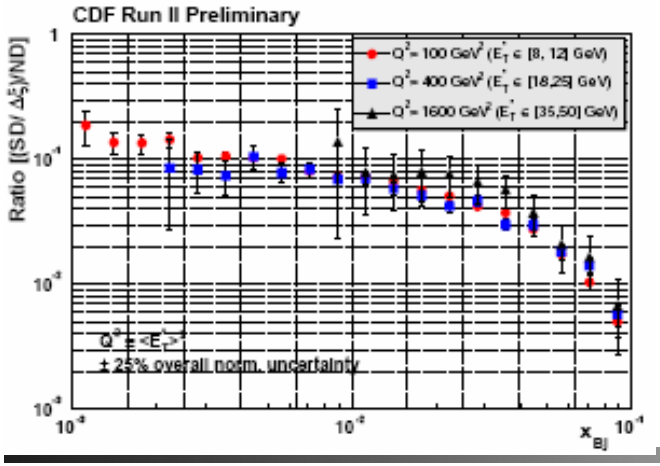
- Diffraction at D0
  (Edwards, D0)

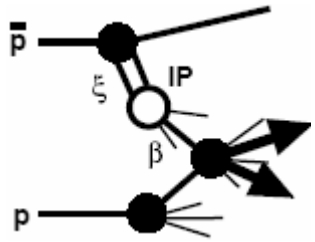
CDF Diffractive Structure Function

a) From single to non diffractive ratio:



Confirmed with Run 2 data:

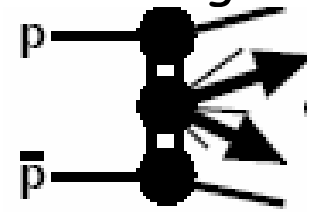


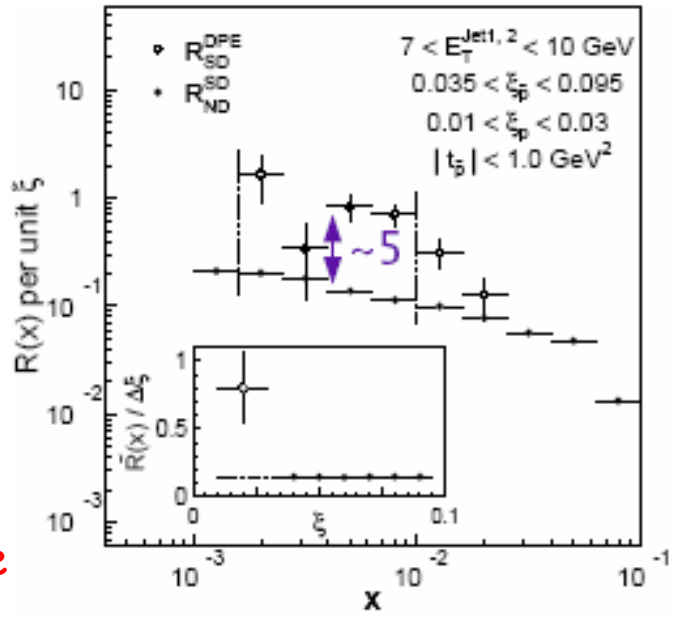


Breakdown of factorization: Predictions based on HERA factor 10 too high!

New:
No P_T dependence observed!

b) From double/single diffr. Ratio:

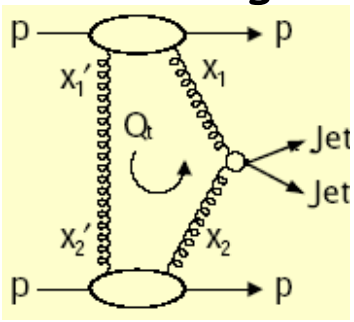




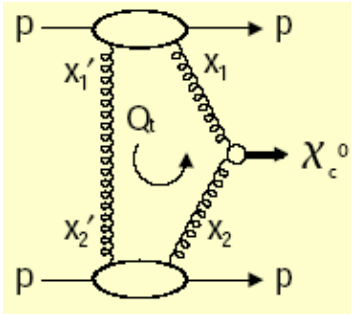
Only small exta suppression going from 1 to 2 gaps!

Run-II exclusive dijets/X_c

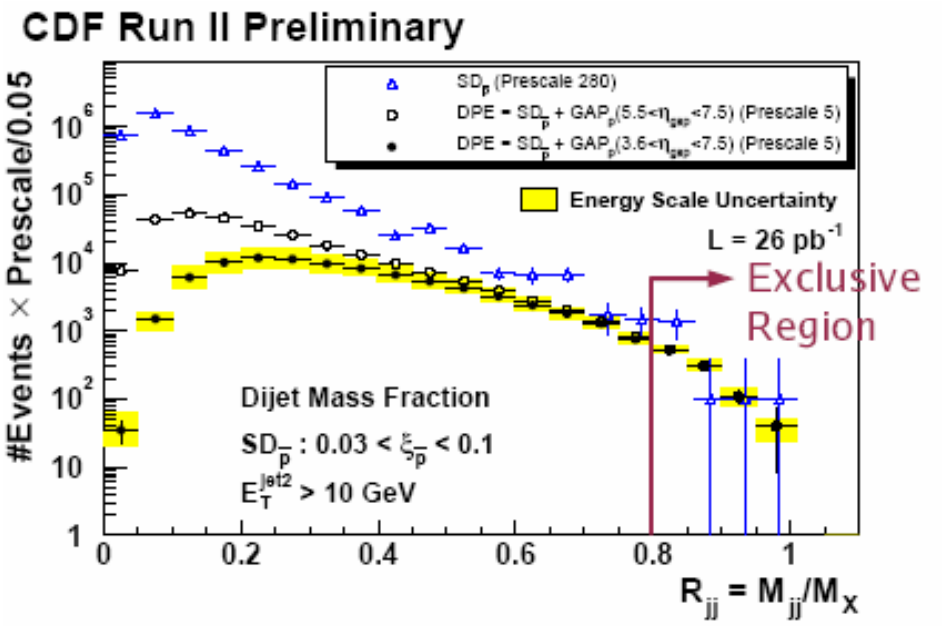
Calibrating diffractive Higgs models for the LHC …

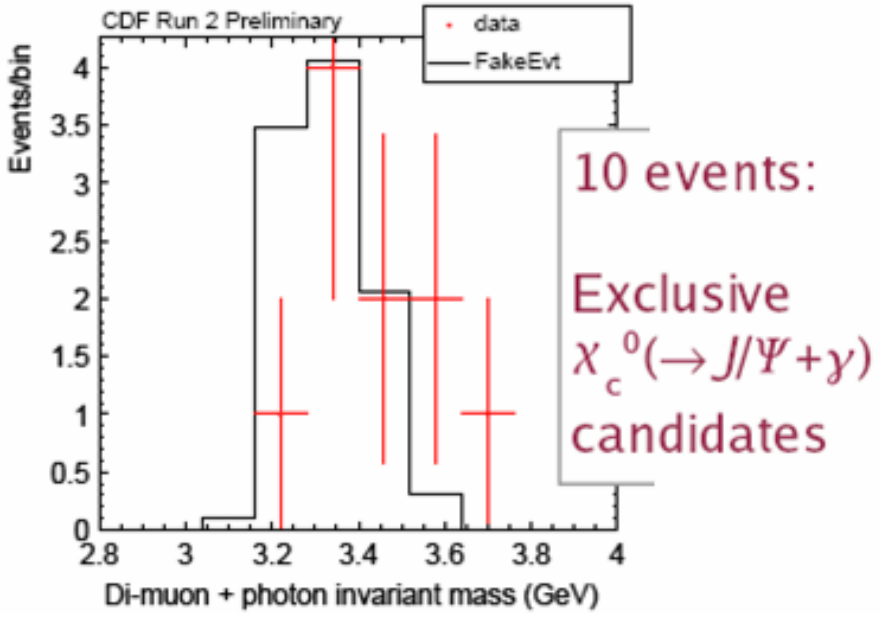


Exclusive DPE
Dijet production



First look at
X_c production

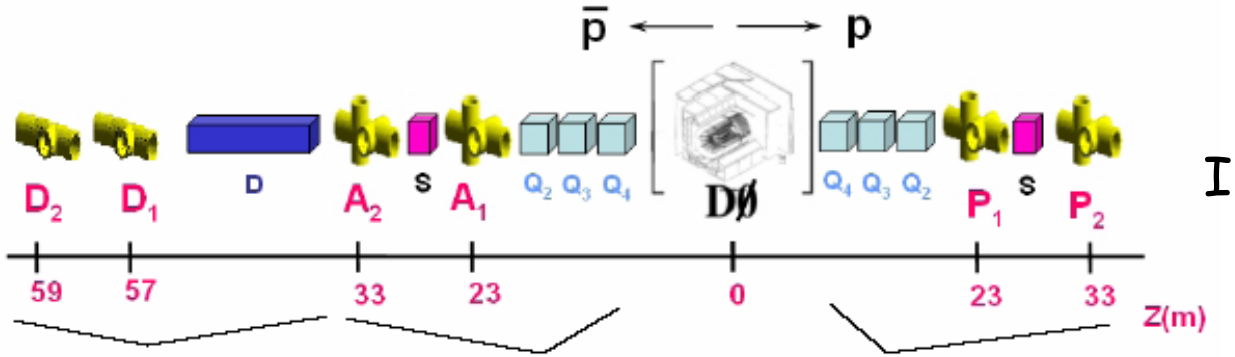




Consistent with Khoze, Martin, Ryskin model

Need more data …

New Forward Proton Detector

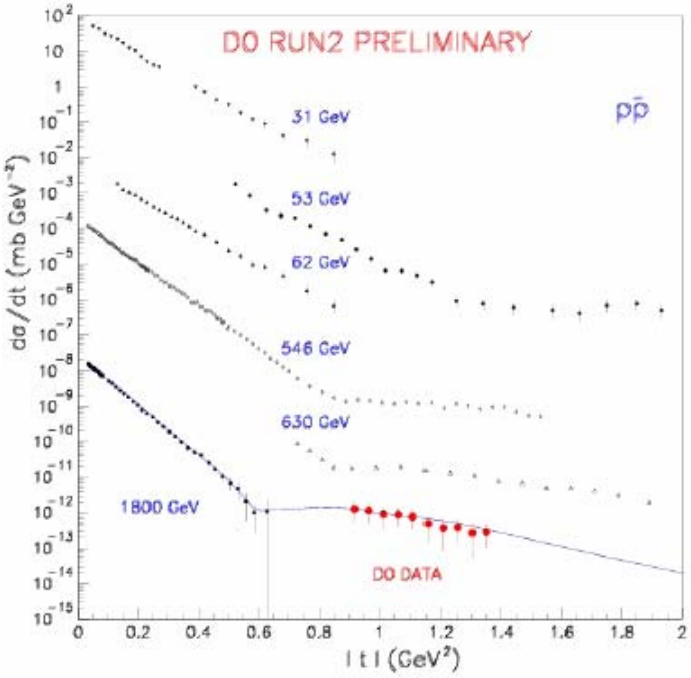


- **Dipole Spectrometer**
- inside the beam ring in the horizontal plane
- use **dipole magnet** (bends beam)

- **Quadrupole Spectrometers**
- surround the beam: up, down, in, out
- use **quadrupole magnets** (focus beam)
- also shown here: **separators** (bring beams together for collisions)

A total of 9 spectrometers composed of 18 Roman Pots

Initial measurement of Elastic t slope:



Now both CDF and D0 have roman pots and are actively pursuing broad diffractive physics program

Many D0 Run-I diffractive results already using rapidity gap selection

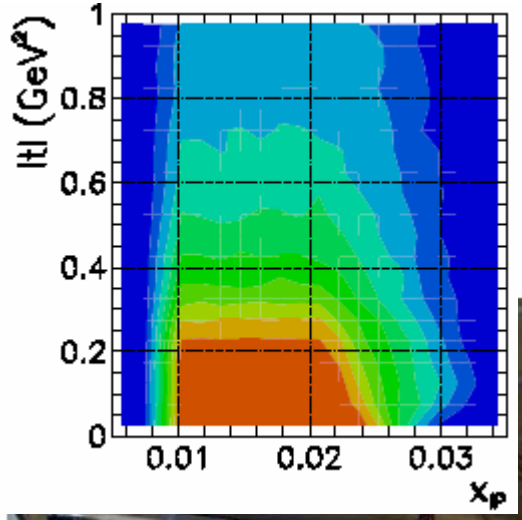
Future Opportunities

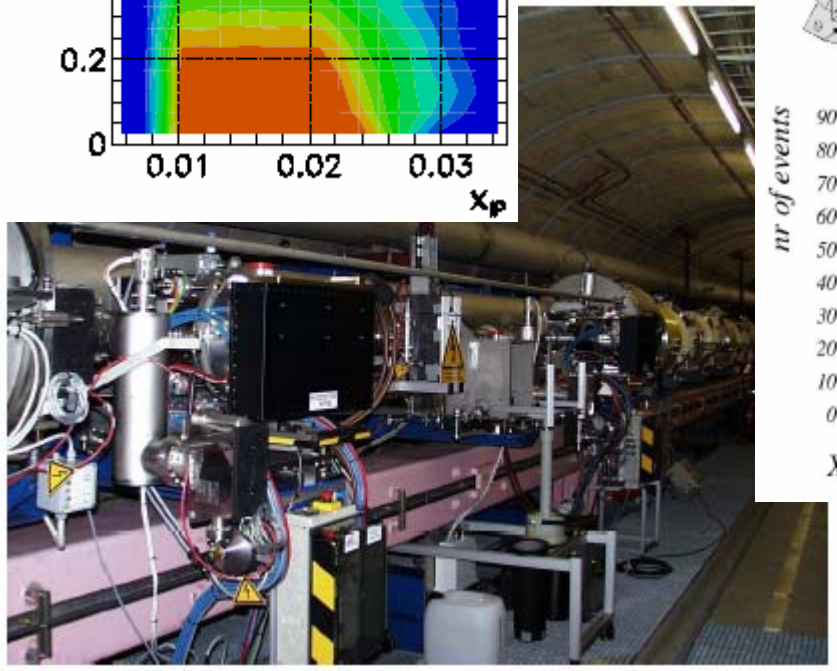
- The new H1 Very Forward Proton Spectrometer
  (Janssen, H1)

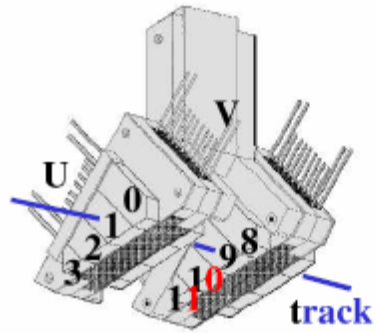
- Forward and Diffractive Physics at the LHC
  (Boonekamp, ATLAS;
  Tasevsky, CMS;
  Deile, TOTEM)

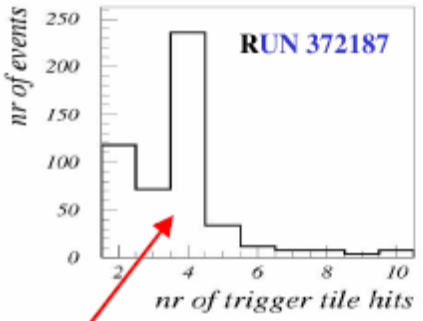
New H1 Very Forward Proton Spectrometer

New Roman Pots at 220m with large acceptance in diffractive regime:



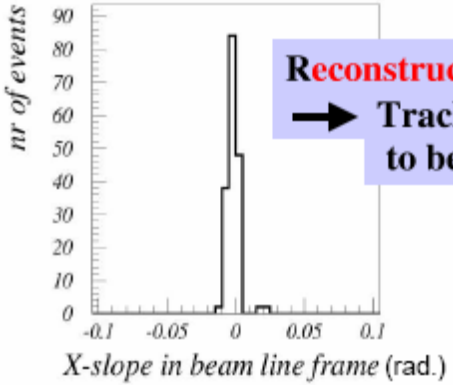


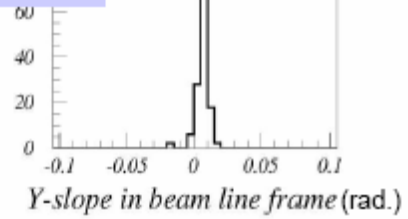




Coincidence of 4 triggered planes

Reconstructed slope is close to zero
→ Tracks are nearly parallel to beam line





First reconstructed tracks from elastic protons seen!

Installed in 2003 HERA shutdown

Conclusions

- Precise HERA and TEVATRON data available
- Consistent picture of inclusive diffractive DIS and DIS final states in terms of NLO diffr. Pdf's
- HERA photoproduction vs TEVATRON?
- VM and DVCS to constrain gpd's and map out soft-hard transition

- Future: Significant more HERA Run-2 (incl. H1 VFPS) and TEVATRON data
- Challenging forward detector+physics programs at LHC (ATLAS, CMS+TOTEM)