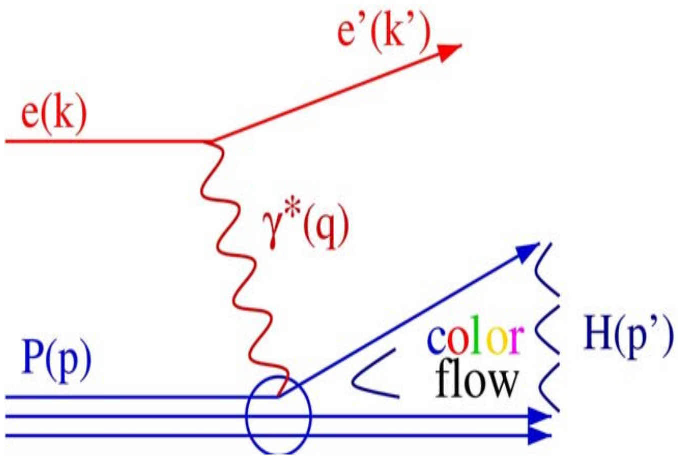
Results on Inclusive Diffraction From The ZEUS Experiment by the M_X-Method

Presented by B.Löhr on behalf of ZEUS

1. DIS and diffractive DIS kinematics
2. The M_X-Method
3. $d\sigma^{diff}/dM_X$
4. Diffractive structure function $x_{IP}F_2^{D(3)}$
5. The BEKW-fit
6. The Q^2-dependence of $x_{IP}F_2^{D(3)}$
7. Summary

(Data are from the running period 1999-2000 (prelim.) and 1998-1999 (publ.)

Inclusive DIS events :



$$s = (k+p)^2$$ center of mass energy squared

$$Q^2 = -q^2 = -(k-k')^2$$ virtuality, size of the probe

$$W^2 = M_H^2 = (p+q)^2$$ γ^* - proton cms energy squared

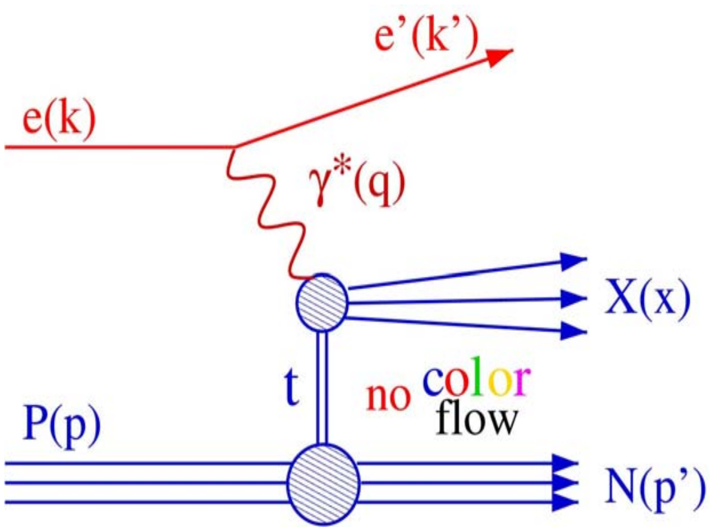
$$x = \frac{Q^2}{2p \cdot q} \qquad y = \frac{p \cdot q}{p \cdot k}$$

x: fraction of the proton carried by the struck parton

y: inelasticity, fraction of the electron momentum carried by the virtual photon

$$Q^2 = x \cdot y \cdot s$$

Diffractive DIS events :



For diffractive events in addition 2 variables

$$M_x$$ mass of the diffractive system X

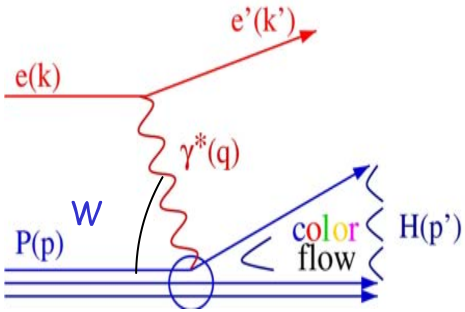
$$t = (p-p')^2$$ four-momentum transfer squared at the proton vertex

$$x_{IP} = \frac{(p-p')\cdot q}{p \cdot q} = \frac{M_X^2+Q^2}{W^2+Q^2}$$ momentum fraction of the proton carried by the Pomeron

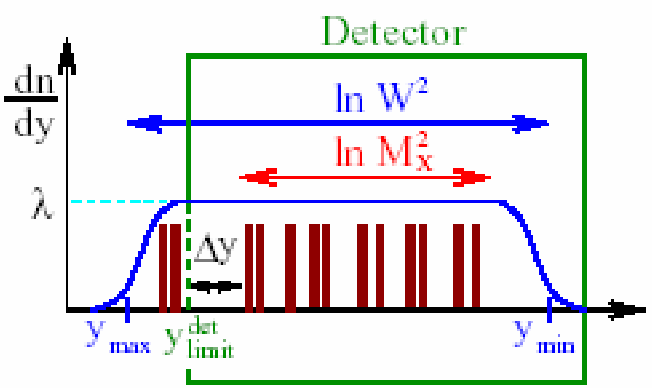
$$\beta = \frac{Q^2}{2(p-p')\cdot q} = \frac{x}{x_{IP}} = \frac{Q^2}{M_X^2+Q^2}$$ fraction of the Pomeron momentum which enters the hard scattering

The M_X-Method (I)

Non diffractive events



Uncorrelated particle emission between incoming p-direction and scattered quark.



$$y = \frac{1}{2}\ln\frac{E+p_z}{E-p_z}$$

Rapidity , property of a produced particle

$$\frac{dN_{part}}{dy} = \lambda = \text{const.}$$

$$W^2 = c_0 e^{y_{max} - y_{min}}$$

$$M_X^2 = c_0 e^{y_{limit} - y_{min}}$$

Poisson distr. for Δy in nondiffractive events

$$P(0) = e^{-\lambda \Delta y} \Rightarrow \frac{dN_{nondiff}}{d \ln M_X^2} = c \cdot e^{b \cdot \ln M_X^2}$$

Diffractive events :

$$\frac{dN_{diff}}{dM_X^2} \propto \frac{1}{(M_X^2)^n}$$

At high energies and not too low M_X

$n \approx 1$

$$\Rightarrow \frac{dN_{diff}}{d \ln M_X^2} \approx \text{const.}$$

The M_X-Method (II)

Nondiffractive + diffractive contributions

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

D is the diffractive contribution

Two approaches for fit to the data

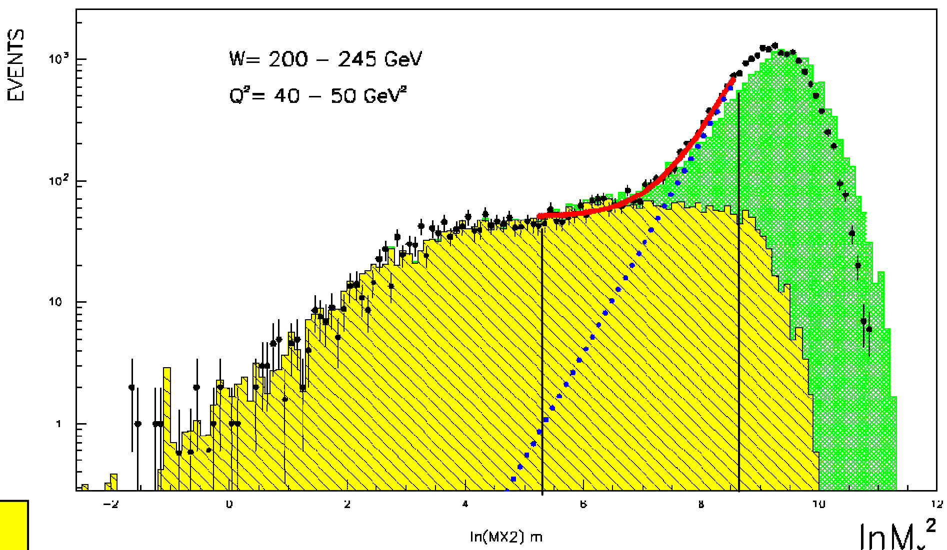
1.) take D=const. for a limited range in $\ln M^2_X$

2.) take D from a BEKW-model (*see later*) parametrization which describes our measured data. This is an iterative procedure.

Fit slope b, c and D

for $\ln M_X^2 \leq \ln W^2 - \eta_0$

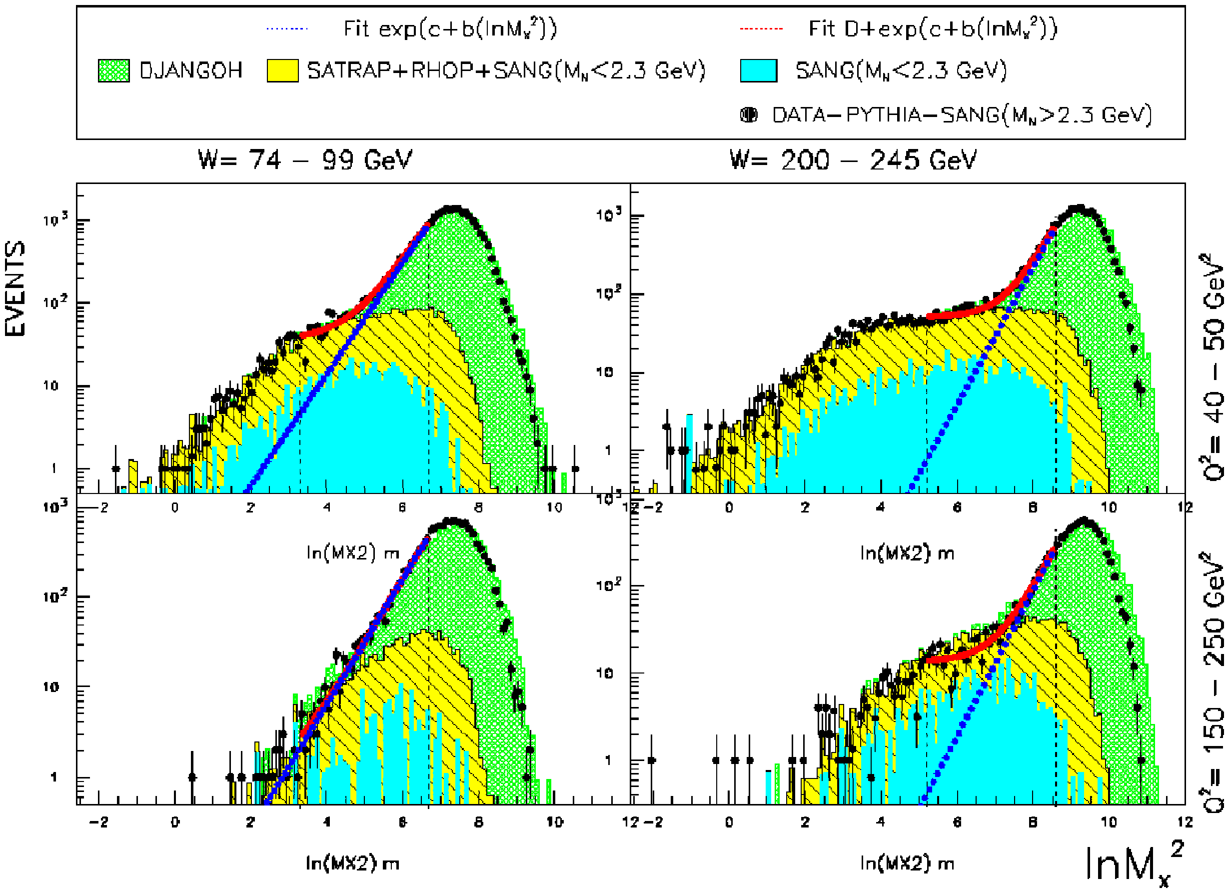
Determine diffractive events by subtracting nondiffractive events from measured data bin by bin as calculated from fitted values b and c.



Both approaches give the same results

The M_X-Method (III)

Diffractive data selected by the M_X-method do not contain contribution from Regge exchanges.
They contain, however, contributions from proton dissociative diffractive events.



fit to data in the fit region

fitted slope of of nondiffractive events

MC-simulation

nondiffractive : DJANGOH

diffractive : SATRAP

proton diss.: SANG

SANG adjusted to fit specially selected data which are dominated by proton dissociation

Proton dissociation can be reliably calculated for M_N > 2.3 GeV and has been subtracted from data

The ZEUS M_X-results contain contributions from proton dissociation for masses M_N < 2.3 GeV.

ZEUS M_X - data from 1998 - 2000 (II)

Mx 98-99, Mx 99-00 (prel.)

Mx 98-99 :

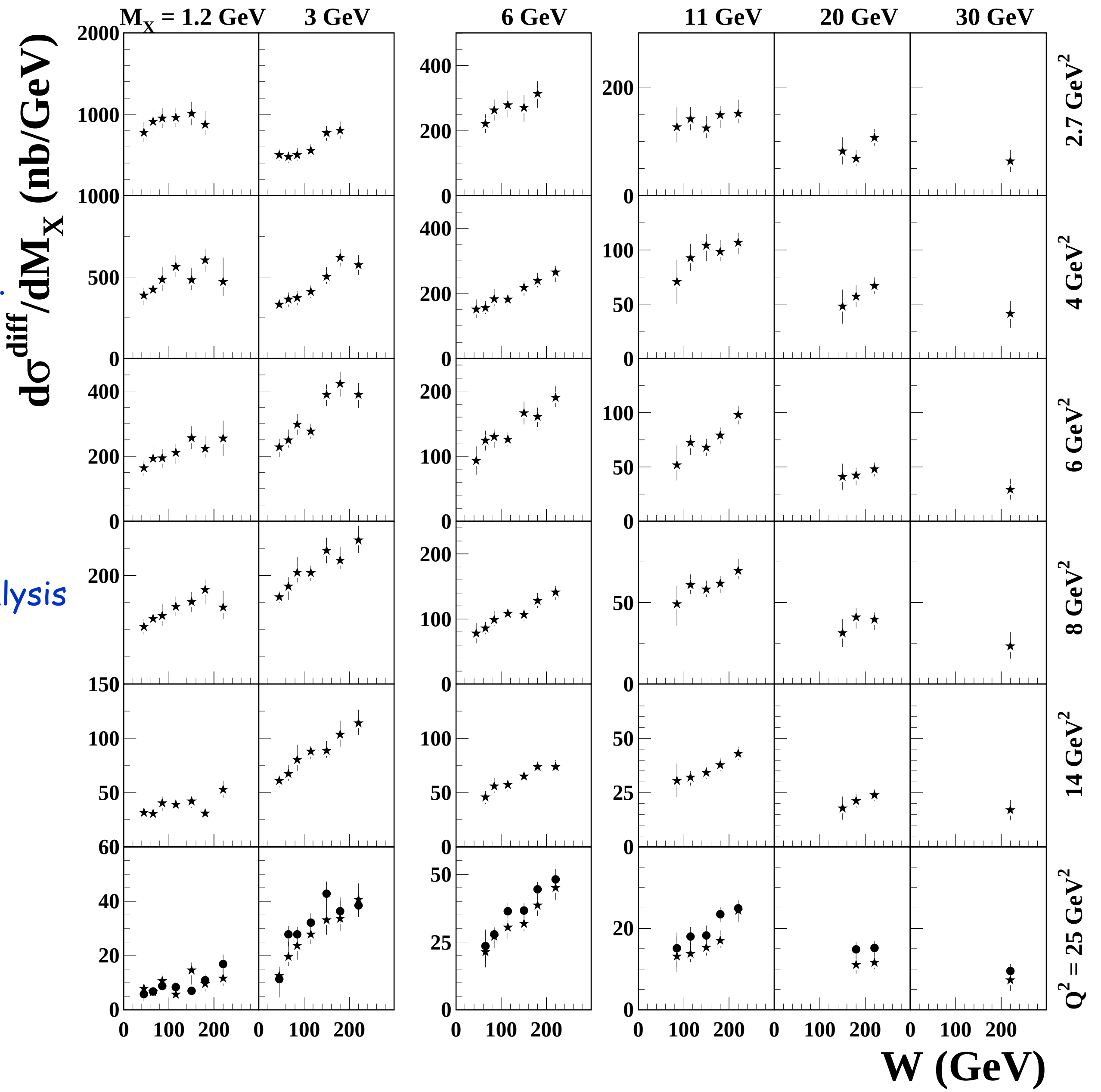
Published data from 1998-1999 period

(ZEUS Coll., S.Chekanov et al. Nucl. Phys B 713, 3 (2005))

Prel. Mx 99-00:

Preliminary results from 1999-2000 period.
Extension of Mx 98-99 analysis to higher Q^2.

Mx 98-99 and Mx 99-00 analyses have common bin at Q^2 = 25 GeV^2



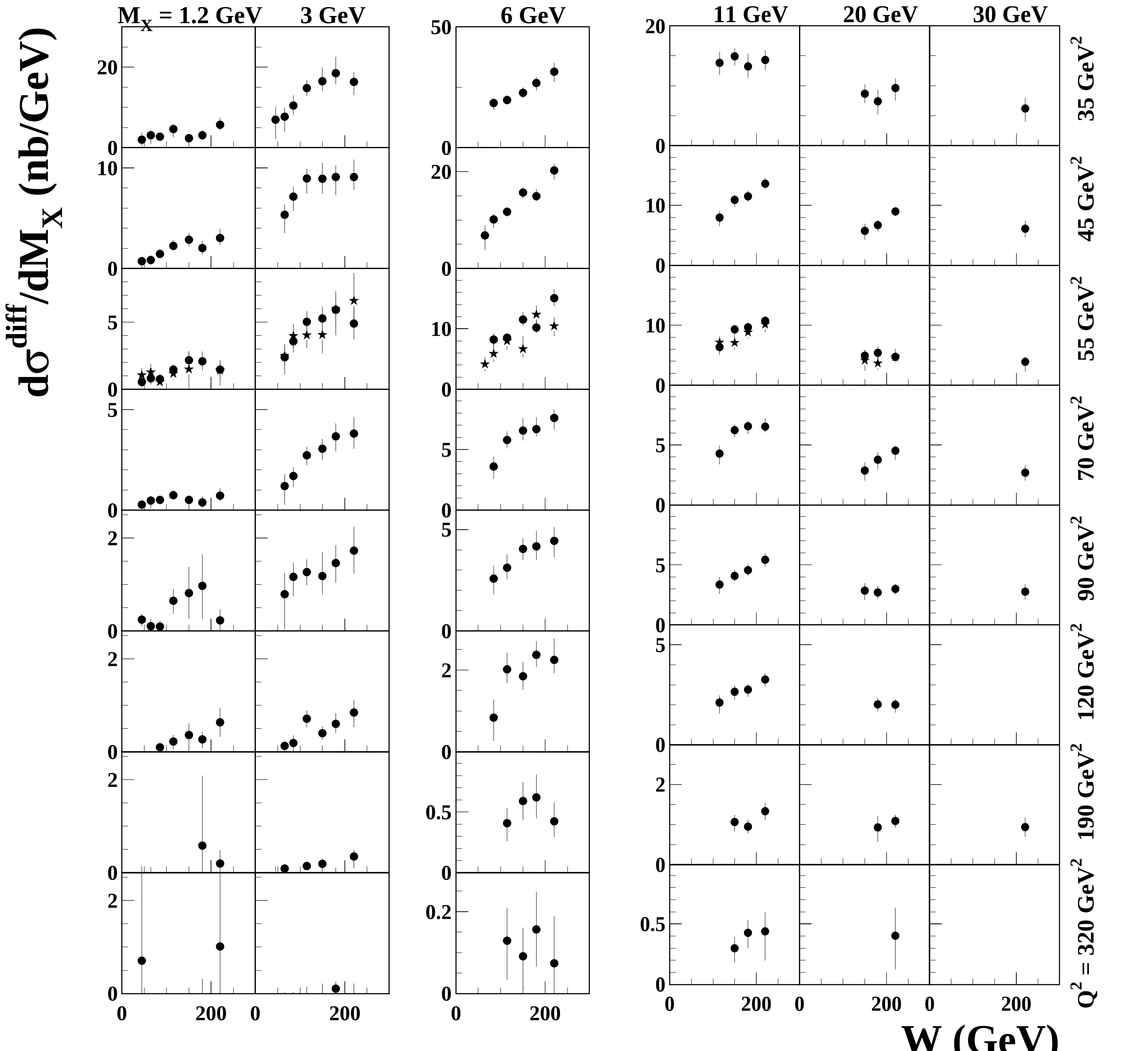
ZEUS M_X- data from 1998 - 2000 (III)

Mx 98-99:

Prel.
Mx 99-00:

Mx 98-99 and Mx 99-00 analyses have common bin at Q^2 = 55 GeV^2

Within syst. errors good agreement between Mx 98-99 and Mx 99-00 results



Inclusive DIS:

For small x, F_2 rises rapidly as x-> 0

$$F_2 = c \cdot x^{-\lambda} \qquad W \propto \frac{1}{x}$$

$$\lambda = \alpha_{IP}(0) - 1$$

Inclusive diffractive DIS:

$$\frac{d\sigma_{\gamma^* p \to XN}}{dM_X} = h \cdot \left(\frac{W}{W_0}\right)^{a^{diff}}$$

$$\overline{\alpha}_{IP} = 1 + \frac{a^{diff}}{4} \quad \text{averaged over t}$$

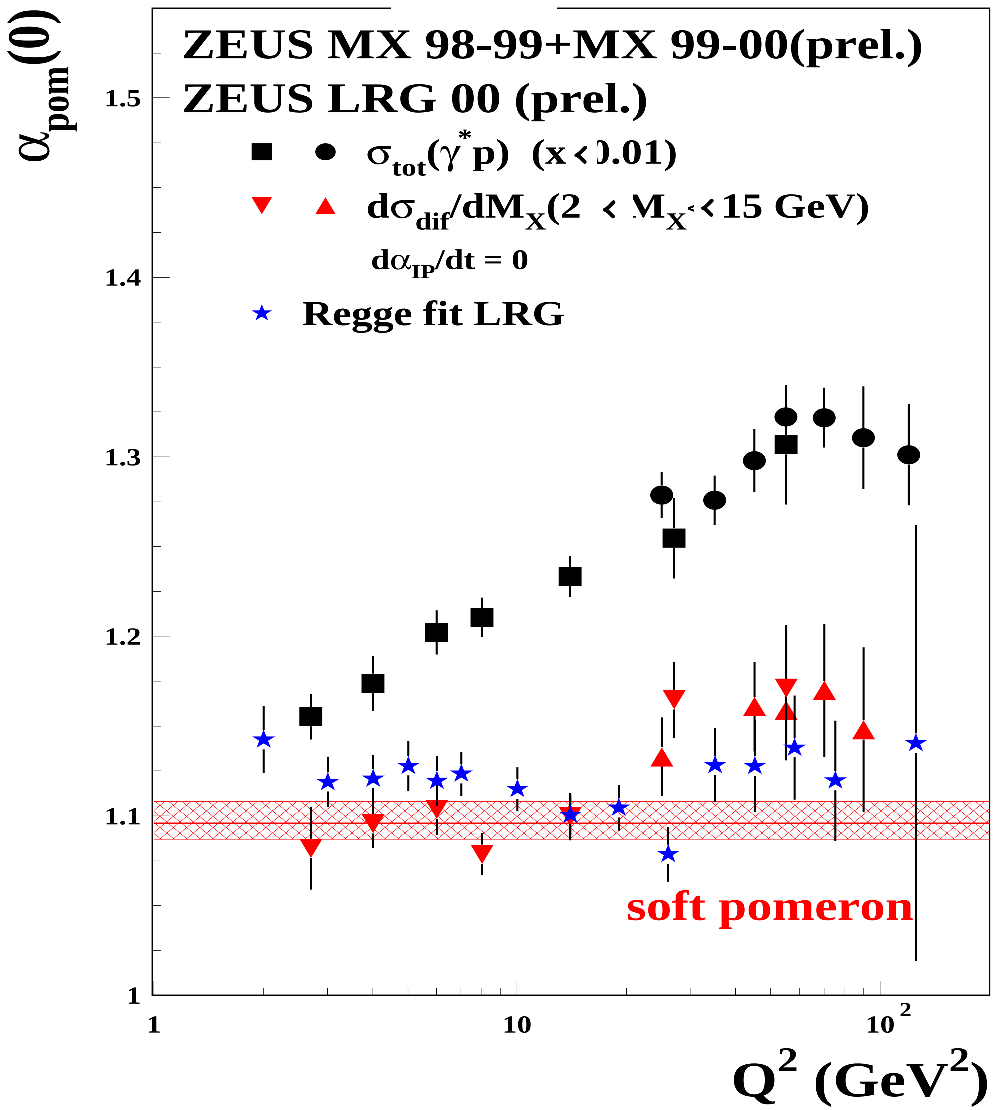
$$\alpha_{IP}(t) = \alpha_{IP}(0) + \alpha'_{IP} \cdot t$$

$$\frac{d\sigma}{dt} = f(t) \cdot e^{2(\alpha_{IP}(t)-1)\cdot \ln\left(\frac{W}{W_0}\right)^2}$$

$$\frac{d\sigma}{dt} \propto e^{A \cdot t} \quad \text{for small t.}$$

take $A = 7.9 \pm 0.5(\text{stat.})\,^{+0.9}_{-0.5}(\text{syst.})\,\text{GeV}^2$

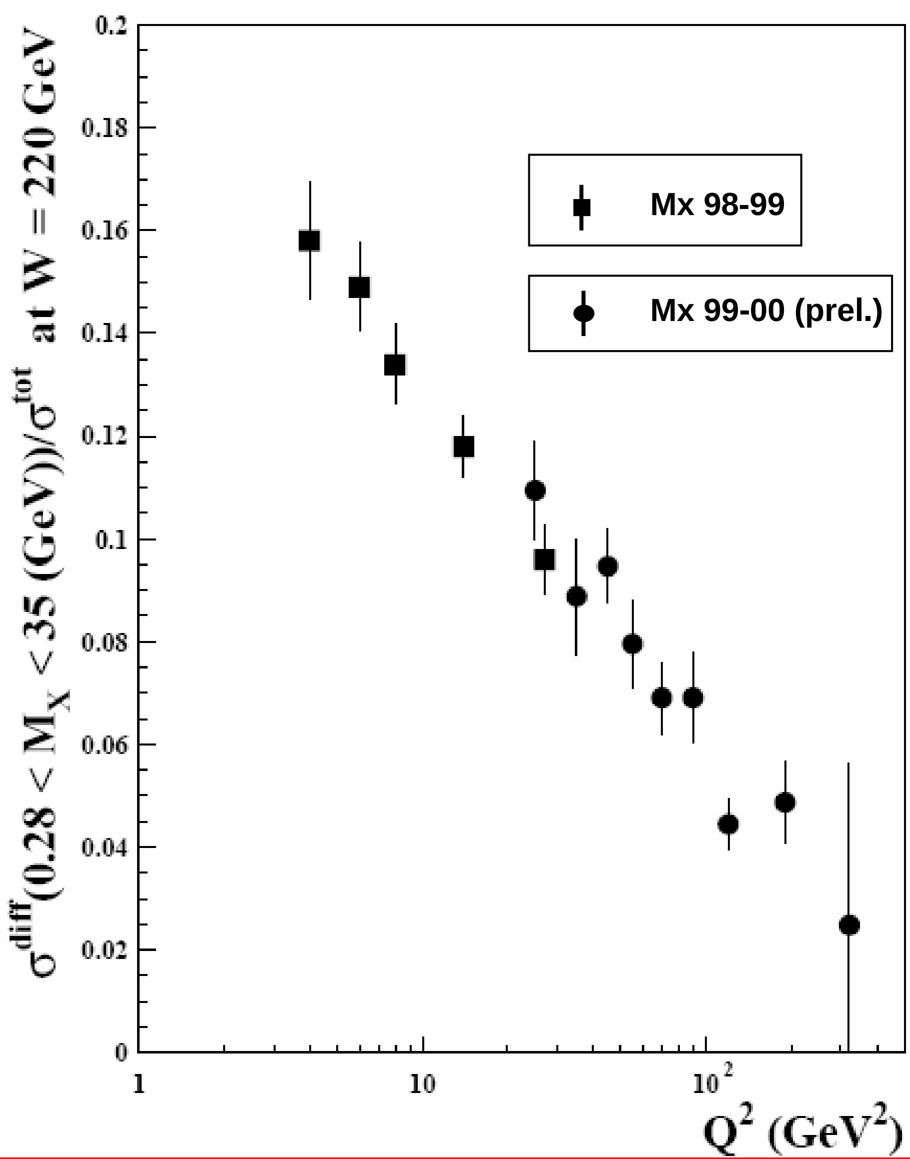
as measured by ZEUS LPS



Inclusive DIS and inclusive diffractive DIS are not described by the same 'Pomeron'.

Ratio of total diffractive cross-section to total DIS cross-section

Ratio plotted at W=220 GeV because only there the full M_X range is covered by measurments



$r = \sigma^{diff}(0.28 < M_X < 35\ GeV)/\sigma^{tot}$

Within the errors of the measurements r is independent of W.

At W=220 GeV, r can be fitted by

$$r = 0.22 - 0.034 \cdot \ln(1+Q^2)$$

This logarithmic dependence of the ratio of total diffractive cross-section to the total DIS cross section indicates that diffraction is a leading twist process for not too low Q^2.

Diffractive Cross-Section and Diffractive Structure Functions

$$\frac{d^4\sigma}{dQ^2 dt dx_{IP} d\beta} = \frac{2\pi\alpha_{em}}{\beta Q^2}[1-(1-y)^2]\cdot F_2^{D(4)}(Q^2,t,x_{IP},\beta)$$

ZEUS neglects the contribution from longitudinal structure function

H1 defines : sizable only at high y

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

If t is not measured :

$$\frac{d^3\sigma^{diff}_{\gamma^* p\to XN}}{dQ^2 d\beta dx_{IP}} = \frac{2\pi\alpha^2}{\beta Q^4}\left[1+(1-y)^2\right]\cdot F_2^{D(3)}\left(\beta, x_{IP}, Q^2\right)$$

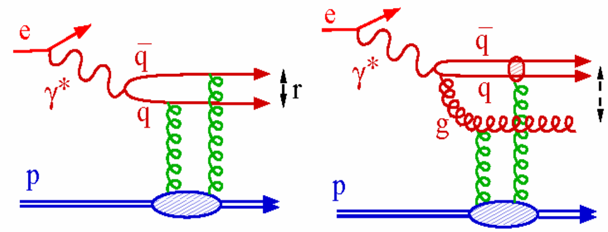
$$\frac{1}{2M_X}\frac{d\sigma^{diff}_{\gamma^* p\to XN}\left(M_X, W, Q^2\right)}{dM_X} = \frac{4\pi^2\alpha}{Q^2\left(Q^2+M_X^2\right)} x_{IP} F_2^{D(3)}\left(\beta, x_{IP}, Q^2\right)$$

If $F_2^{D(3)}\left(\beta, x_{IP}, Q^2\right)$ is interpreted in terms of quark densities, it specifies the probability to find in a proton which undergoes a diffractive interaction a quark carrying a fraction $x = \beta x_{IP}$ of the proton momentum.

ZEUS modified BEKW Fit

Fit with BEKW model

(Bartels, Ellis, Kowalski and Wüsthoff, 1998)



- $$x_{I\!P} F_2^{D(3)} = c_T \cdot F^T_{q\bar{q}} + c_L \cdot F^L_{q\bar{q}} + c_g \cdot F^T_{q\bar{q}g}$$

$$F^T_{q\bar{q}} = \left(\frac{x_0}{x_{I\!P}}\right)^{n_T(Q^2)} \cdot \beta(1-\beta)\,,$$

$$F^L_{q\bar{q}} = \left(\frac{x_0}{x_{I\!P}}\right)^{n_L(Q^2)} \cdot \frac{Q_0^2}{Q^2+Q_0^2} \cdot \left[\ln\left(\frac{7}{4} + \frac{Q^2}{4\beta Q_0^2}\right)\right]^2 \cdot \beta^3(1-2\beta)^2\,,$$

$$F^T_{q\bar{q}g} = \left(\frac{x_0}{x_{I\!P}}\right)^{n_g(Q^2)} \cdot \ln\left(1+\frac{Q^2}{Q_0^2}\right) \cdot (1-\beta)^\gamma$$

assume $n_T(Q^2) = c_4 + c_7 \ln\left(1+\frac{Q^2}{Q_0^2}\right)$, $n_L(Q^2) = c_5 + c_8 \ln\left(1+\frac{Q^2}{Q_0^2}\right)$,

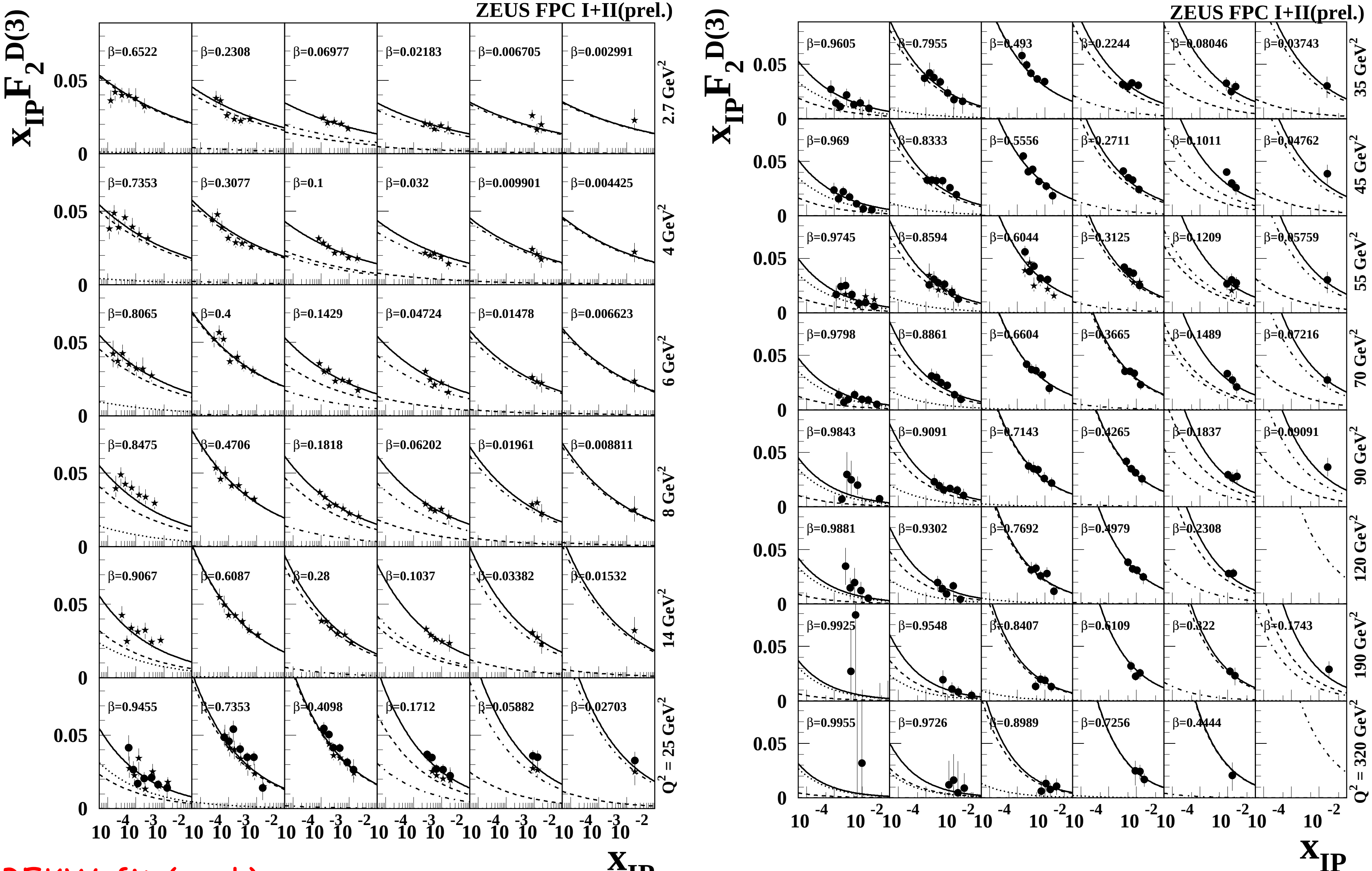
$$n_g(Q^2) = c_6 + c_9 \ln\left(1+\frac{Q^2}{Q_0^2}\right)$$

The ZEUS data support taking $n_T(Q^2) = n_g(Q^2) = n_1 \cdot \ln(1+Q^2/Q^2_0)$ and $n_L = 0$

Taking $x_0 = 0.01$ and $Q^2_0 = 0.4$ GeV^2 results in the modified BEKW model (BEKW(mod)) with the 5 free papameters :

c_T , c_L , c_g , $n_1^{T,g}$, γ

$x_{IP}F_2D(3)$ Results from the Mx 98-99 and Mx 99-00 Analyses with BEKW(mod) Fit (I)

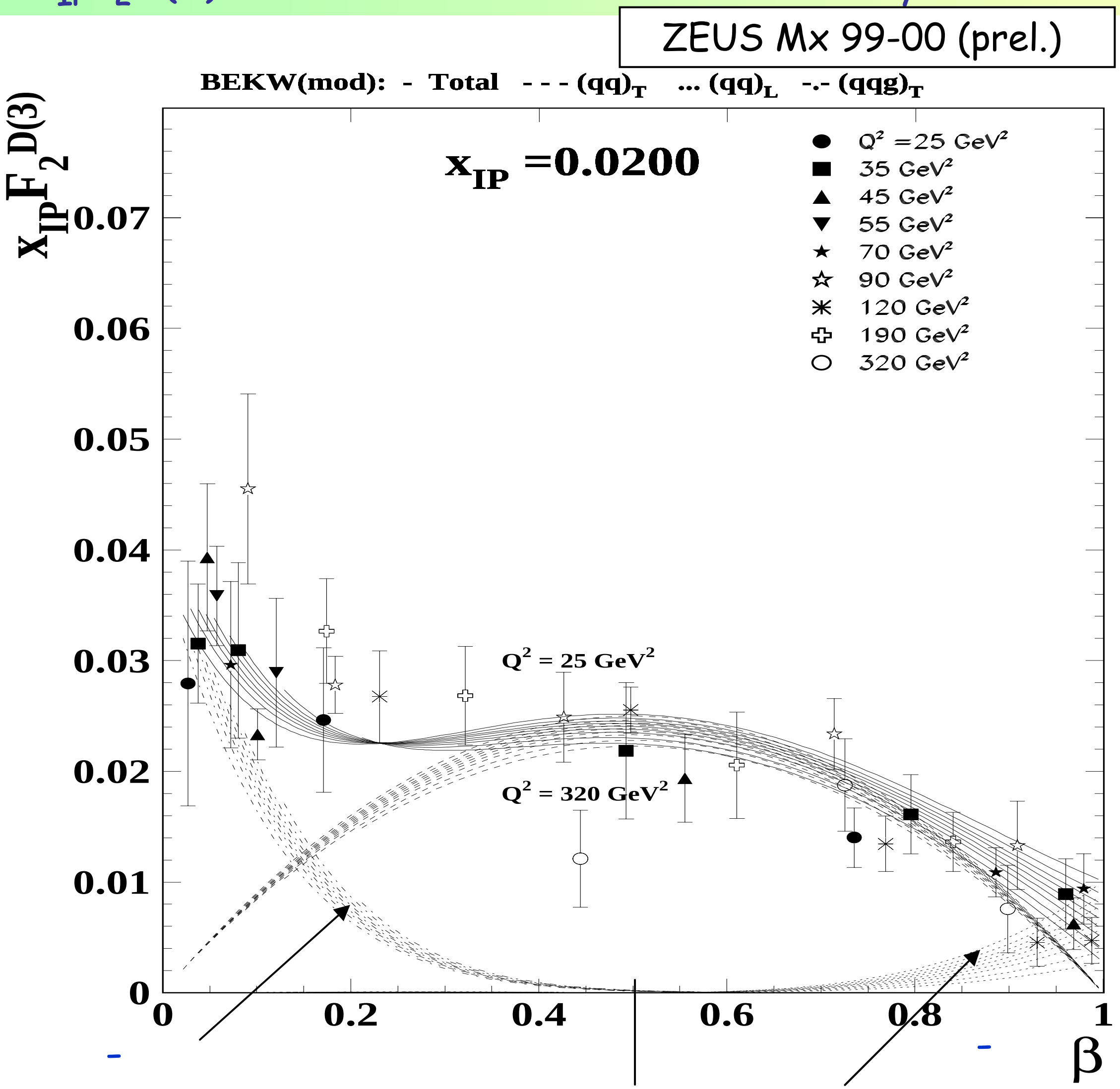


BEKW-fit (prel.):

> 400 points, 5 parameters
χ^2/n_D = 0.71 , total errors

- solid line: sum of all contributions
- dotted line: longitudinal qq contribution
- dashed line: transverse qq contribution
- dash-dotted line: transverse qqg contribution

$x_{IP}F_2D(3)$ Results from the Mx 99-00 Analysis with BEKW(mod) Fit (II)



Fixed x_{IP} = 0.02

$25 < Q^2 < 320$ GeV^2 in one plot

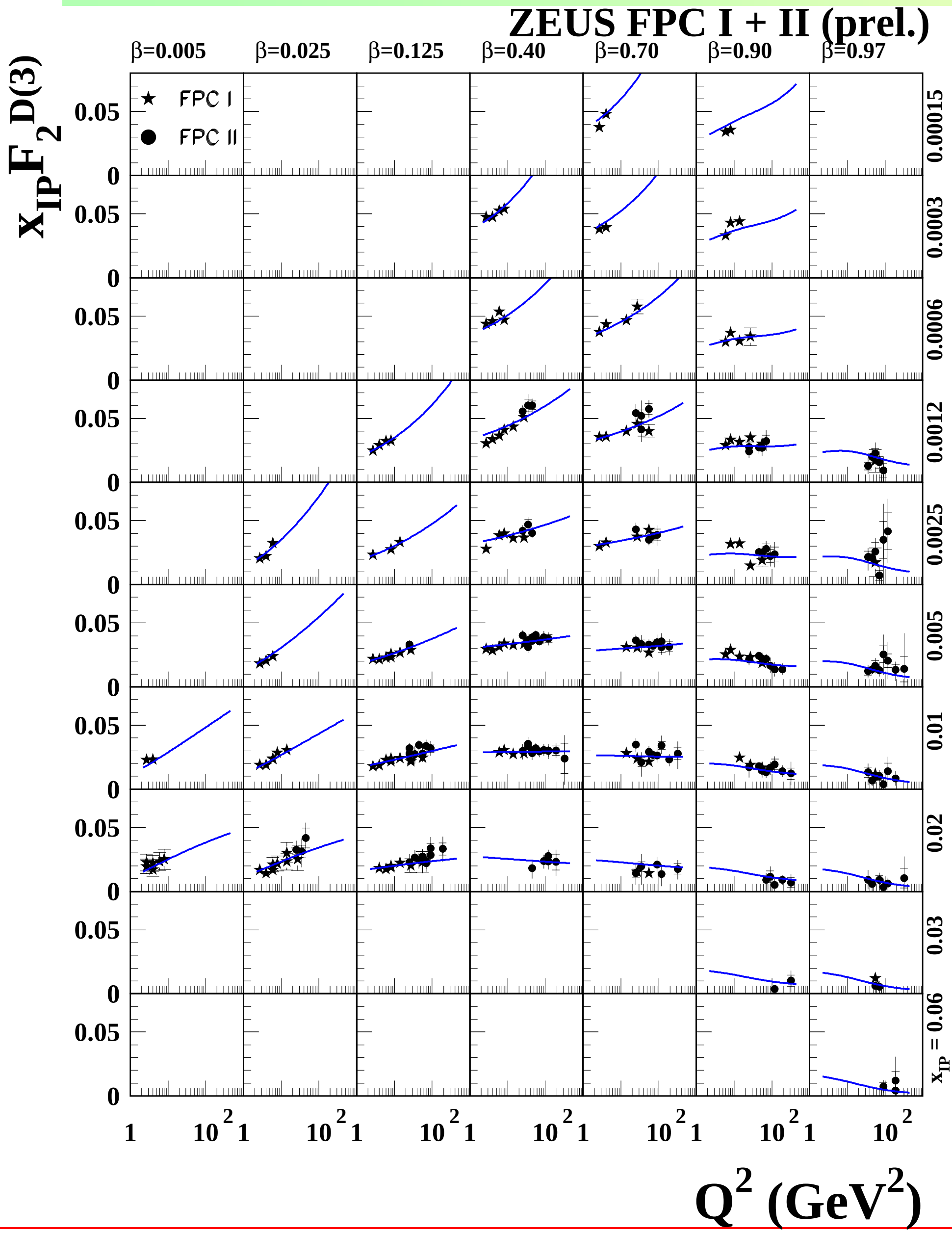
The 3 contributions from BEKW(mod) fit for the above Q^2 values plotted

qqg-contributions

longitudinal qq-contributions

The BEKW model has an effective QCD-type Q^2-evolution incorporated.

$x_{IP}F_2D(3)$ Results from the Mx 98-99 and Mx 99-00 Analyses with BEKW(mod) Fit (III)



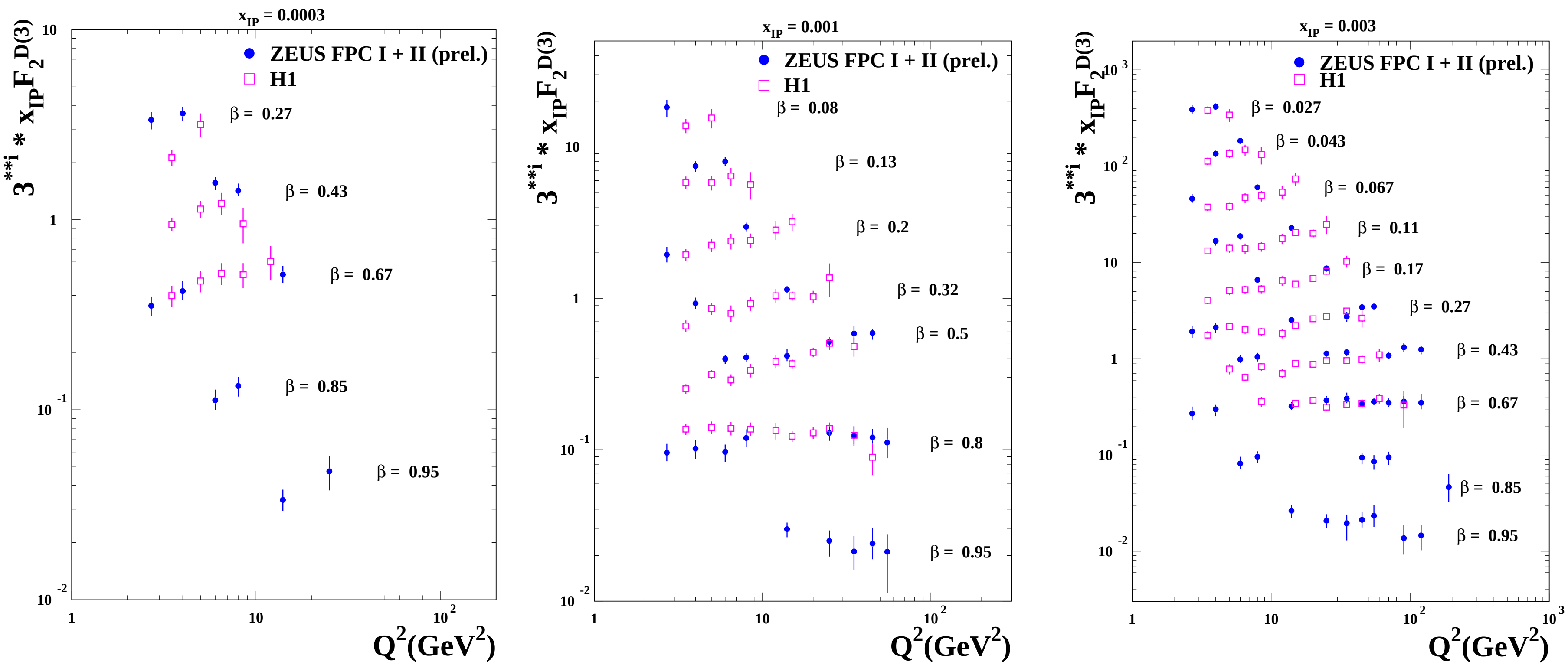
Events in fixed (x_{IP},β)–bins

Result of the BEKW(mod) fit

$x_{IP}F_2D(3)$ shows considerable scaling violations:

from positive scaling violations over near constancy to negative scaling violations.

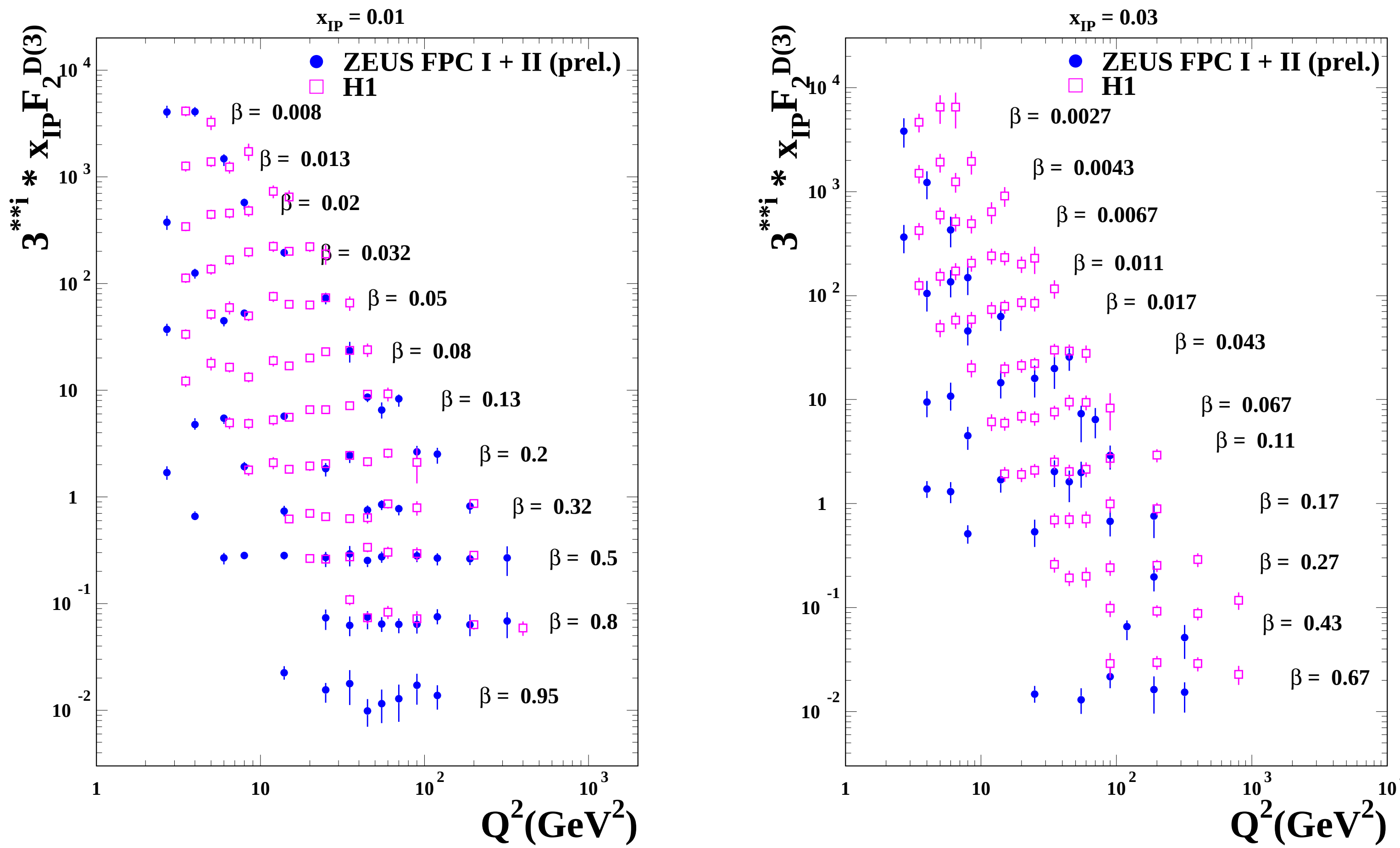
$x_{IP}F_2^{D(3)}$ Results from the Mx 98-99 and Mx 99-00 Analyses
Comparison with H1 Results in H1-binning (I)



Note: ZEUS results contain contributions from p-dissociation with masses $M_{p\text{-}diss}$< 2.3 GeV , H1 results contain contributions with masses $M_{p\text{-}diss}$< 1.6 GeV.

ZEUS results do not contain contributions from Reggeon-exchanges, H1 results may contain such contributions for higher x_{IP}.

$x_{IP}F_2D(3)$ Results from the Mx 98-99 and Mx 99-00 Analysis
Comparison with H1 Results in H1-binning (II)



Comparison to H1 data

Fair agreement,
except maybe for a few (x_{IP}, β) bins

Note: ZEUS points are shifted to H1 bins using BEKW parametrization. Only those ZEUS point are shown for which the shift was <30%.

Summary

- ZEUS presented preliminary results on inclusive diffraction from the M_X-Method for the extraction of inclusive diffractive events from the 1999-200 data and from published data taken during 1998-1999.
- The results span a wide range of the kinematic region from low to high Q^2.
- There is good agreement between the published data from 1998-1999 and the preliminary results from 1999-2000.
- The ratio of the total diffractive cross section to the total DIS cross section indicates that diffraction is a leading twist process.
- DIS and diffractive DIS cannot be describe by a single unique pomeron.
- The combined data from 1998-2000 are well described by the BEKW(mod) model.
- The diffractive structure function $x_{IP}F_2^{D(3)}$ exhibits logarithmic scaling violations.
- There is good agreement compared to results from H1.