Results on inclusive diffraction from ZEUS

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on behalf of

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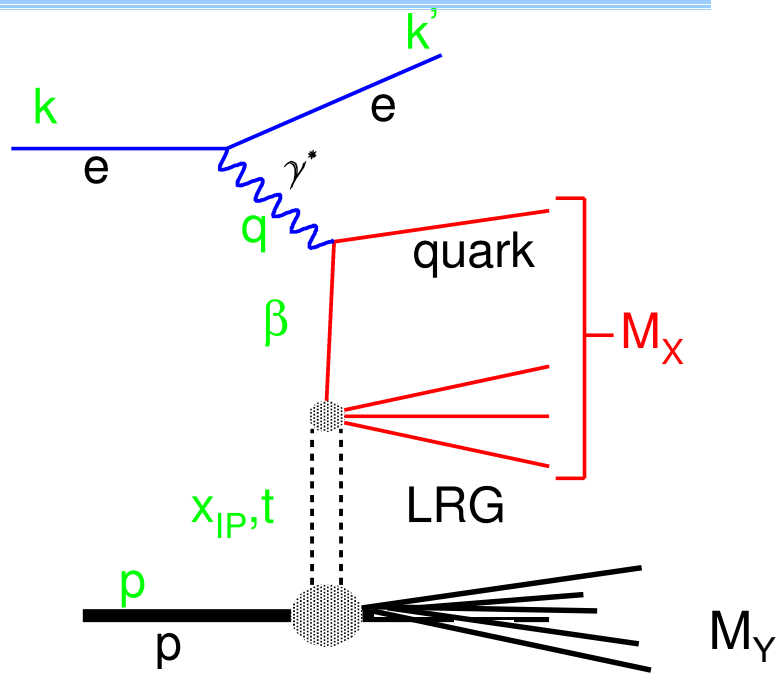
- **Diffractive kinematics**
- **Experimental method**
- **F_2^D at high Q^2 (EPS 01)**
- **$\frac{d\sigma^D_{\gamma^* p}}{dM_X}$ vs W,Q^2 (DESY 02-029)**
- **$\frac{d\sigma^D_{\gamma^* p}}{dM_X}$ vs Q^2 (NEW!)**

Kinematics of inclusive diffraction $\gamma^* p \to Xp$

Diffractive γ^*p interactions at HERA exploiting the hadronic properties of the photon



$Q^2 = - q^2$

$x = Q^2/2p\cdot q$

$W^2 = (q + p)^2$

$M_X{}^2 = (q+P-P')^2$

$$t = (p - p')^2 \approx -\frac{p_t^2}{x_L}$$

$$x_L = \frac{p'_z}{p_z} \approx 1 - x_{IP}$$

$$x_{IP} = \frac{q\cdot(p-p')}{q\cdot p} \approx \frac{Q^2 + M_X^2}{Q^2 + W^2}$$

$$\beta = \frac{Q^2}{2q\cdot(p-p')} \approx \frac{Q^2}{Q^2 + M_X^2}$$

NB: if proton not detected, background from proton dissociative events

Measurement of inclusive diffraction

✓ $\gamma^* p$ cross section

$$\frac{d\sigma^{D}_{\gamma^* p}}{dM_X} = \frac{\pi \quad Q^2 W}{\alpha\,(1+(1-y)^2)} \cdot \frac{d^3\sigma_{ep\to e'Xp'}}{dQ^2 dM_X dW}$$

✓ **4-fold differential diffr. structure function** (t measured)

$$F_2^{D(4)}(\beta, Q^2, x_{IP}, t) = \frac{\beta Q^4}{4\pi\alpha^2(1-y+y^2/2)} \cdot \frac{d\sigma_{ep\to e'Xp'}}{d\beta dQ^2 dx_{IP} dt}$$

✓ **3-fold differential diffr. structure function** (t integrated)

$$F_2^{D(3)}(\beta, Q^2, x_{IP}, t) = \frac{\beta Q^4}{4\pi\alpha^2(1-y+y^2/2)} \cdot \frac{d\sigma_{ep\to e'Xp'}}{d\beta dQ^2 dx_{IP}}$$

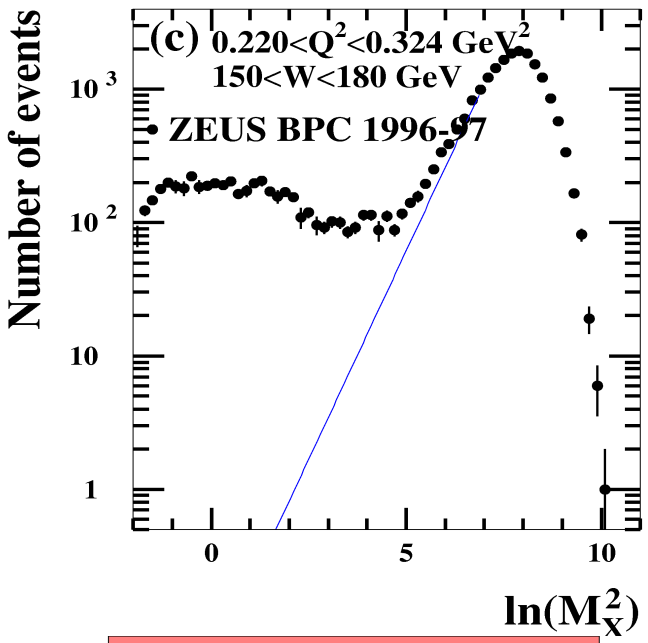
(assumes $F_L = 0$)

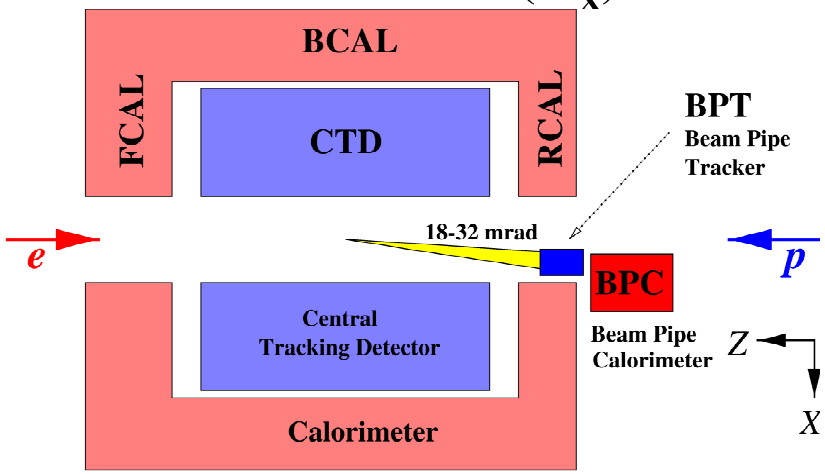
✓ **Energy dependence in Regge theory**

$$d\sigma^{D}_{\gamma^* p}/dM_X \propto (W^2)^{2\bar{\alpha}_{IP}-2}$$

Selection of inclusive diffractive events

M_X method





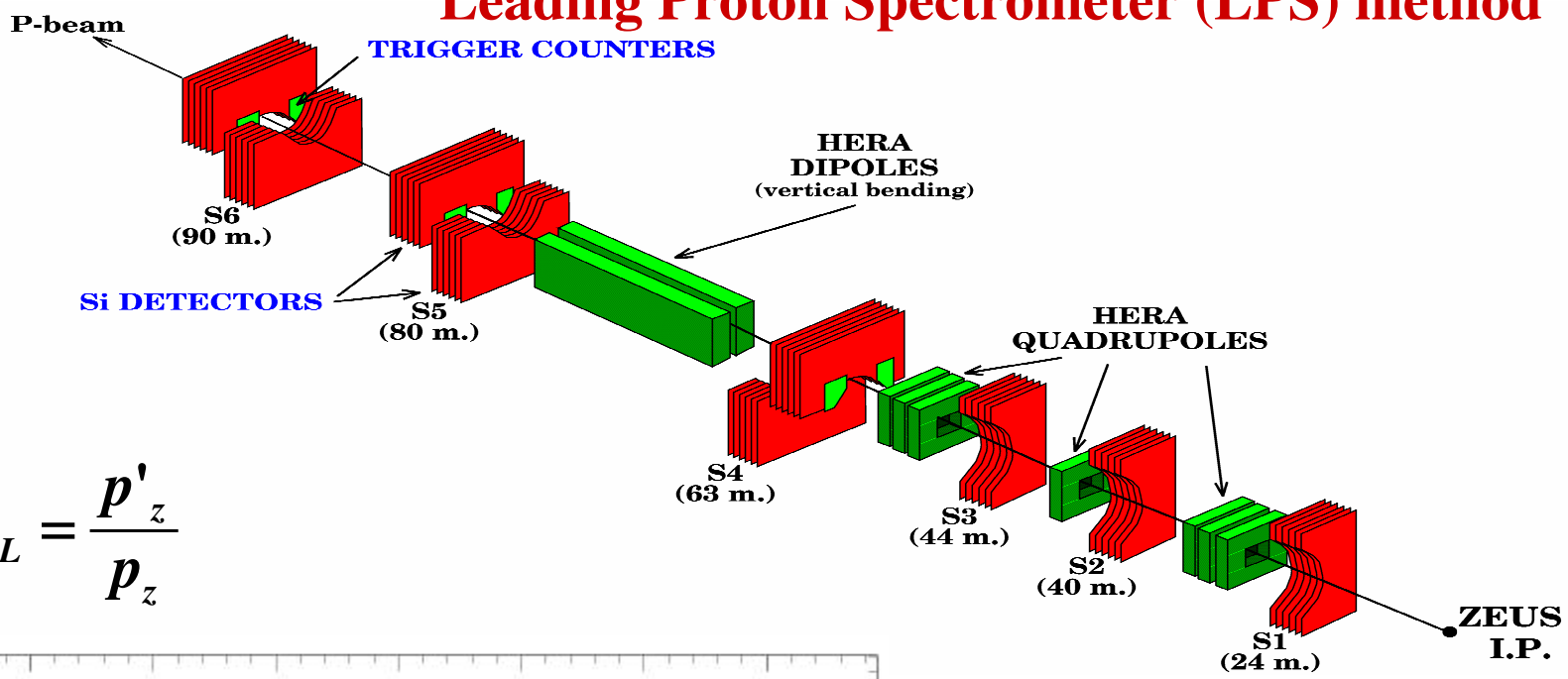
Exploit properties of M_X distribution:

- **Flat vs $\ln M_X^2$ for diffractive events**
- **Exponentially falling for decreasing M_X for non-diffractive events**

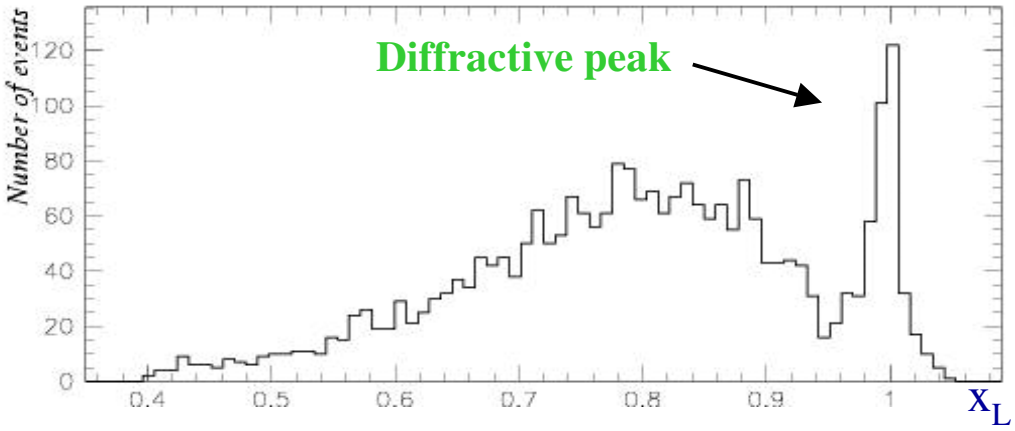
- Good statistics!
- t measurement not possible
- Large systematics from p-diss

Selection of inclusive diffractive events

Leading Proton Spectrometer (LPS) method



$$x_L = \frac{p'_z}{p_z}$$



- Measurement of t distribution
- Free of p-diss background
- Lower acceptance

Data samples

97 high Q^2 sample

$4 < Q^2 < 100$ GeV^2

$0.0001 < x_{IP} < 0.04$

$0.01 < \beta < 0.6$

$M_X > 2$ GeV

$0.075 < t < 0.35$ GeV^2

$x_L > 0.95$

LPS method

95-97 from low to high Q^2

$0.14 < Q^2 < 50$ GeV^2

$80 < W < 250$ GeV

$M_X > 3$ GeV

$0.073 < t < 0.4$ GeV^2

$x_L > 0.97$

LPS method

M_x method

97 low Q^2

$0.03 < Q^2 < 0.6$ GeV^2

$65 < W < 285$ GeV

$M_X > 1.5$ GeV

$0.075 < t < 0.35$ GeV^2

$x_L > 0.96$

LPS method

EPS 01 (paper n.566):

$F_2^{D(4)}(\beta, Q^2, x_{IP}, t) \rightarrow \alpha_{IP}(0)$

$F_2^{D(3)}(\beta, Q^2, x_{IP})$

DESY 02-029:

$d\sigma^{Diff}/dM_X$ (and $\alpha_{IP}(0)$)

$d\sigma^{Diff}/dM_X$ and σ^{tot} ratio

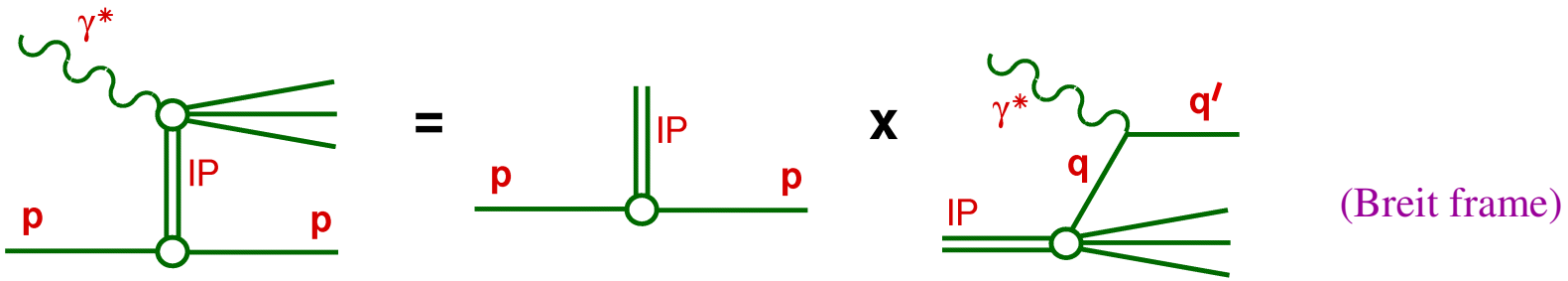
BEKW fit

Preliminary:

$d\sigma^{Diff}/dM_X$ vs Q^2

Factorization

- **Regge factorization - "resolved IP model" (IP with partonic structure):**



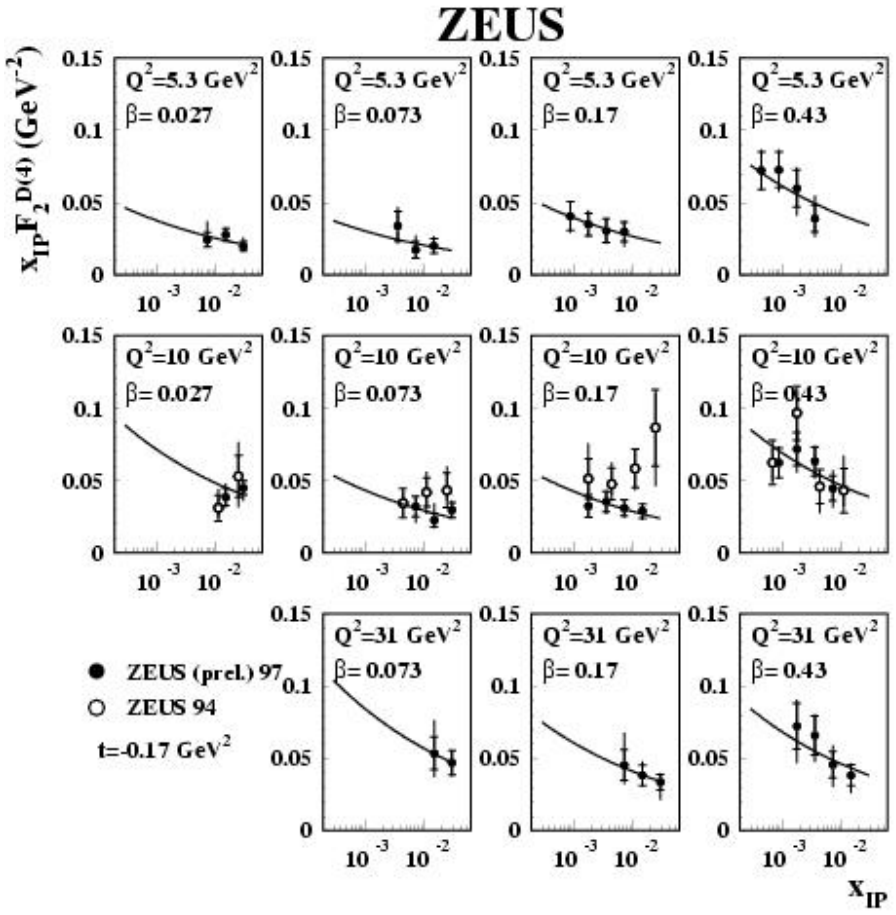
(Breit frame)

$$\sigma(\gamma^* p \to X p) \quad \sim \quad f_{\mathbb{P}/\mathrm{p}}(x_{I\!P}, t) \quad \otimes \quad F_2^{\mathbb{P}}(\beta, Q^2)$$

Regge motivated pomeron flux $$f_{IP/p}(x_{IP}, t) = \frac{e^{Bt}}{x_{IP}^{2\alpha(t)-1}}$$

Structure functions evolve according to DGLAP

$F_2^{D(4)}(\beta, Q^2, x_{IP}, t)$



Common x_{IP} dependence in all bins consistent with the assumption of factorization of the structure function

from Regge factorization:

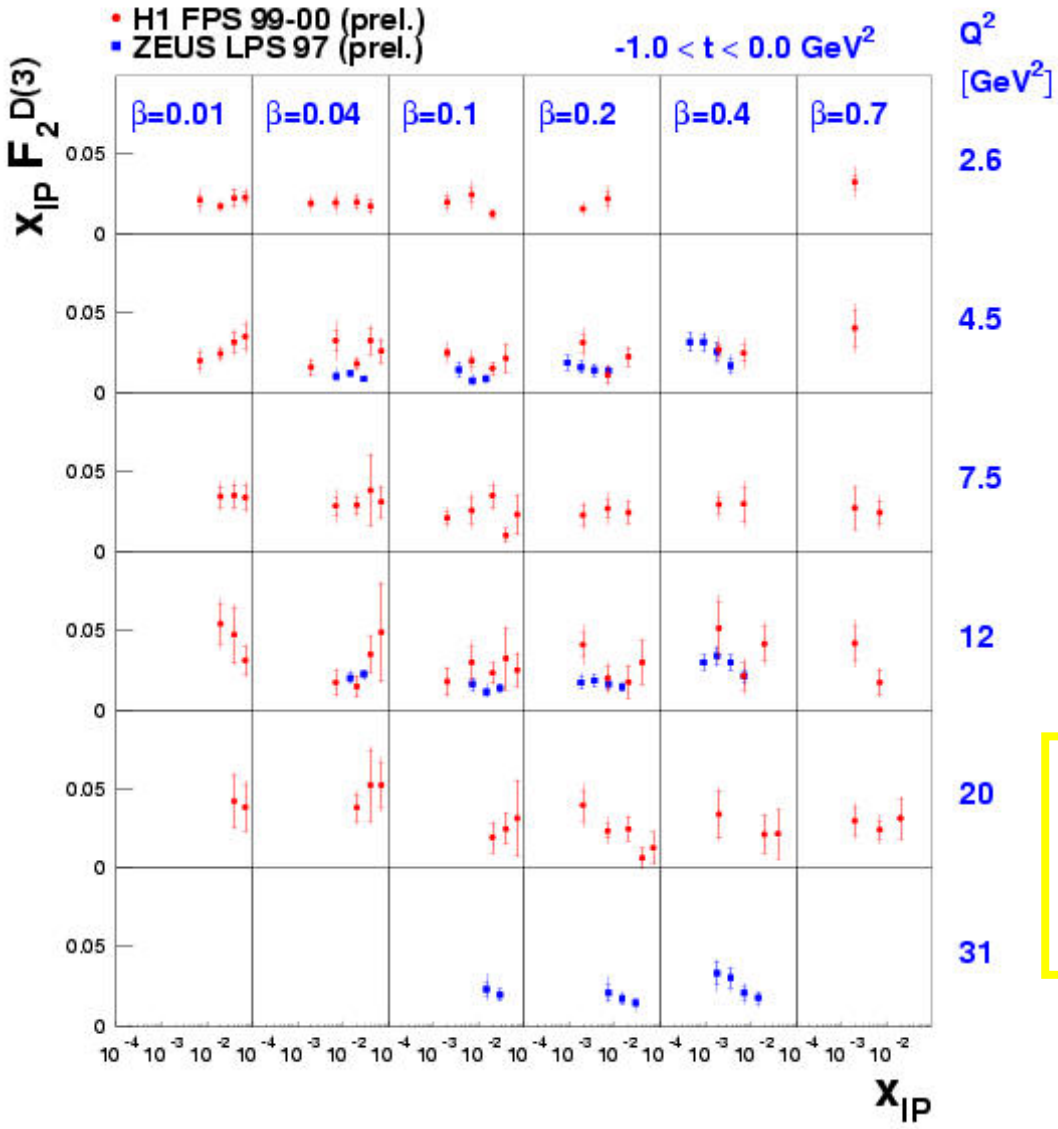
$$F_2^{D(4)} = f_{IP/p}(x_{IP}, t) \cdot F_2^{IP}(\beta, Q^2)$$

with $$f_{IP}(x_{IP}, t) \propto \left(\frac{1}{x_{IP}}\right)^{2\alpha_{IP}(t)-1}$$

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

Extract $\alpha_{IP}(0)$ by fitting x_{IP} dep. at fixed β, Q^2: $\alpha_{IP}(0) = 1.13 \pm 0.03(stat.)^{+0.03}_{-0.01}(syst.)$

$F_2^{D(3)}(\beta, Q^2, x_{IP})$



Use measured t-slope to extrapolate in t:

$$F_2^{D(3)} = \int F_2^{D(4)} dt$$

$F_2^{D(3)}$ results from H1(FPS method) and ZEUS (LPS method) similar

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W dep. of the diffractive cross section

Fit to the data a constant power of W:

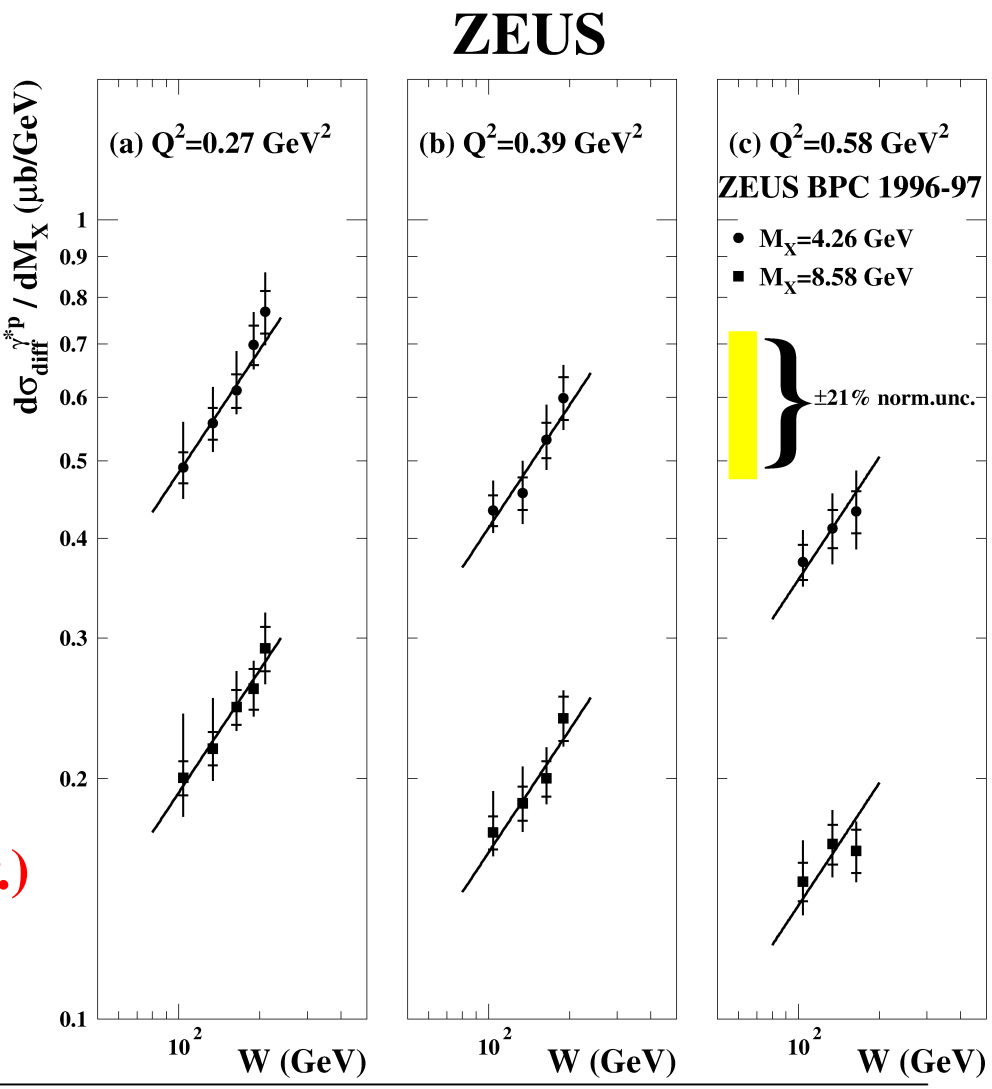
$$\frac{d\sigma^{\gamma^* p}_{Diff}}{dM_X} = A_i \cdot (W)^{a_{diff}}$$

$$a_{diff} = 4\bar{\alpha}_{IP} - 4$$

$$\bar{\alpha}_{IP} = \alpha_{IP}(0) - \alpha'_{IP} \cdot |\bar{t}|$$

A_i free to vary on Q^2, M_X bins

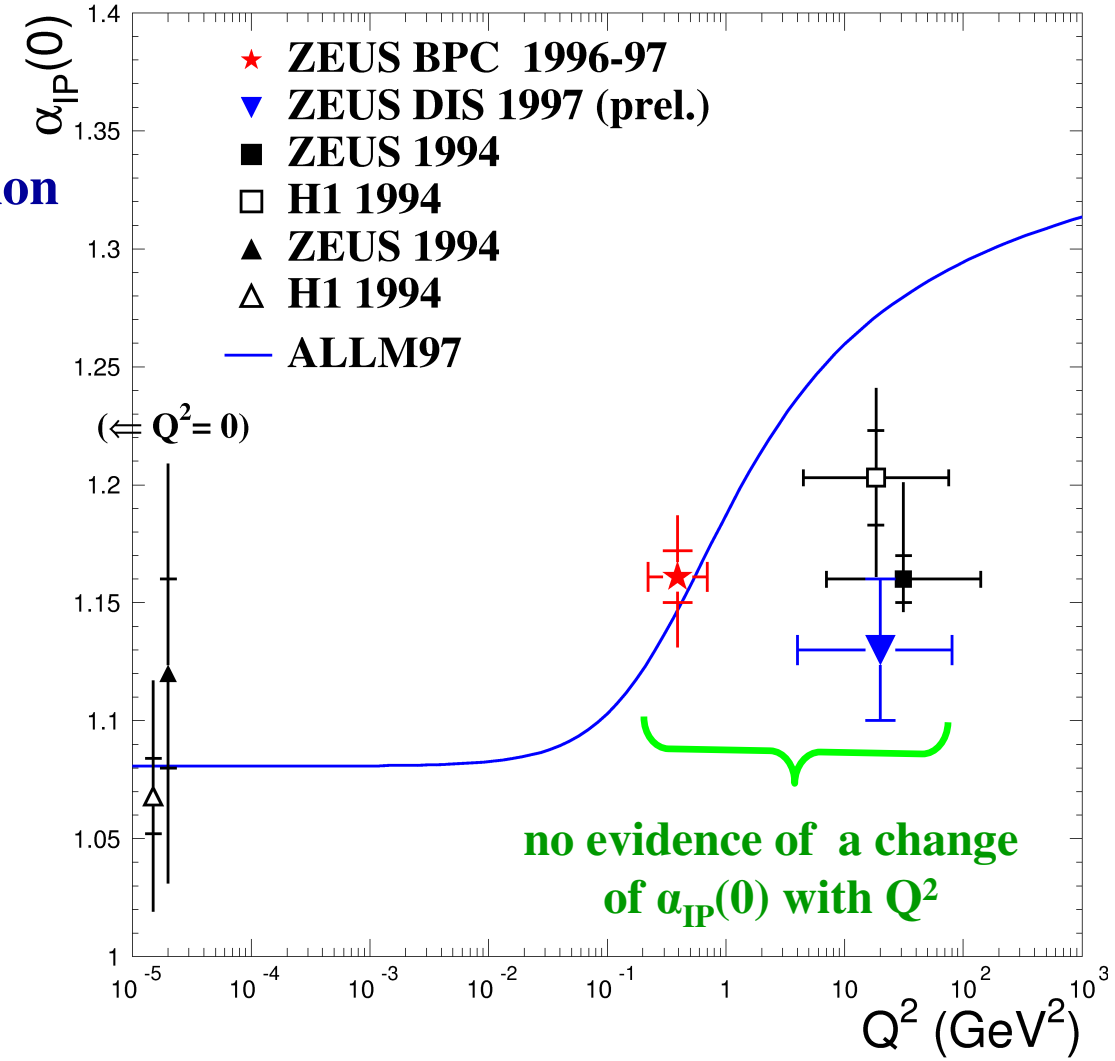
$$\alpha_P(0) = 1.161 \pm 0.011\ (stat.)\ ^{+0.026}_{-0.030}(syst.)$$



How universal is the IP?

$\alpha_{IP}(0)$ measured in diffraction at different Q^2

➡ Within the uncertainties there is no evidence of a change of $\alpha_{IP}(0)$ with Q^2

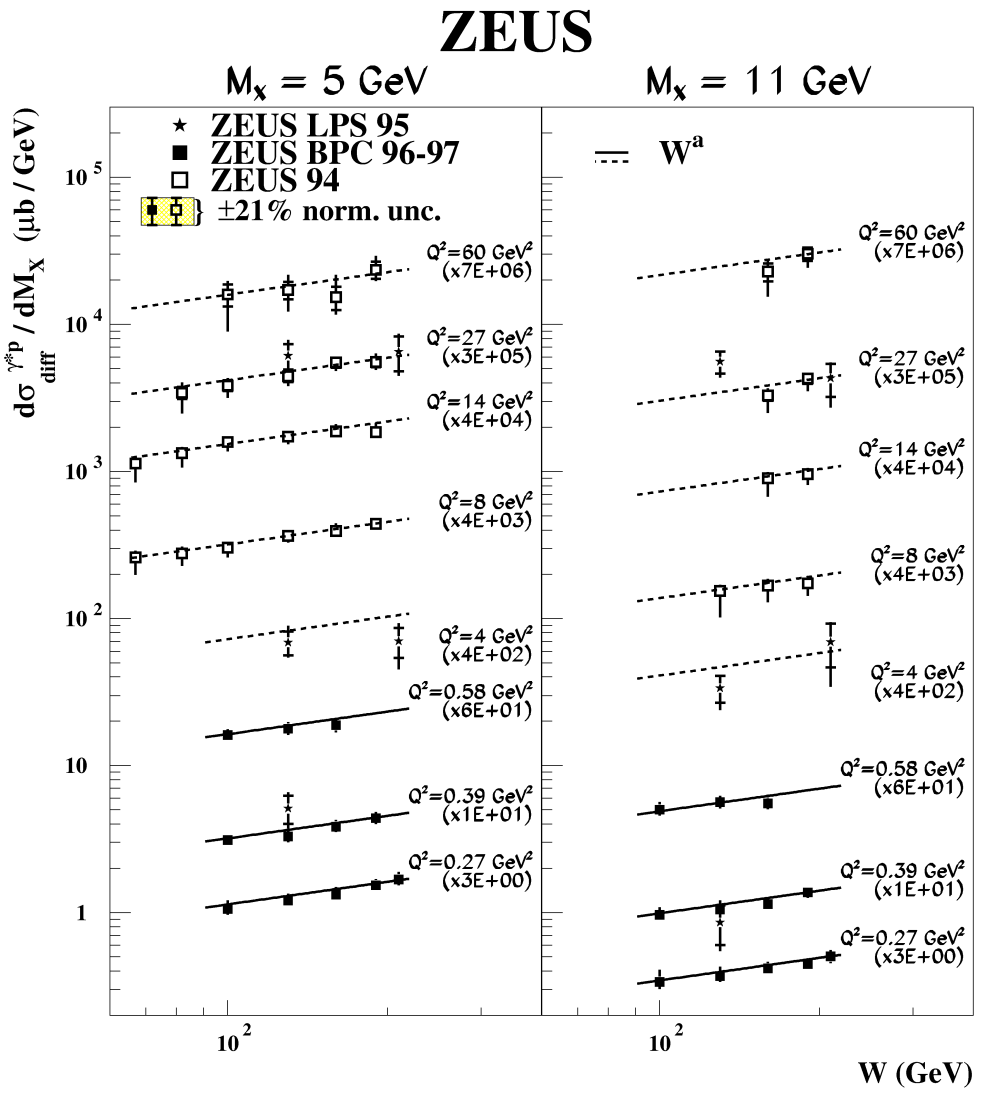


Energy dep. of the diffractive cross section

Regge theory:

$$\frac{d\sigma}{dM_X} \propto (W^2)^{2\bar{\alpha}_{IP}-2}$$

No statistically significant change from the low Q^2 to the DIS regime



Energy dep. of diffractive to inclusive ratio

Regge theory:

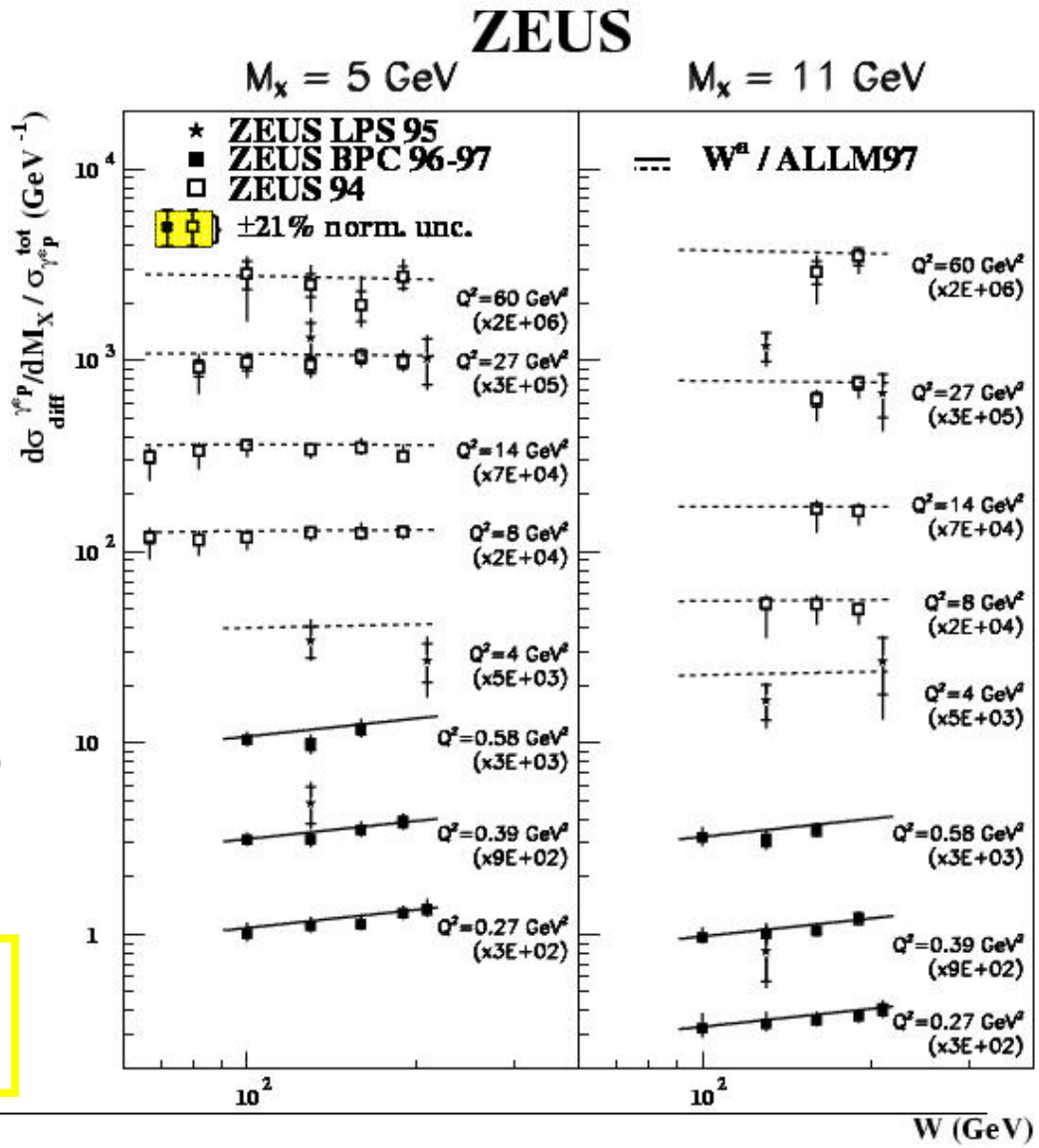
$$\frac{d\sigma^{D}_{\gamma^* p}/dM_X}{\sigma^{tot}_{\gamma^* p}} \propto \frac{(W^2)^{2\bar{\alpha}_{IP}-2}}{(W^2)^{\alpha_{IP}(0)-1}} = W^{0.19}$$

Fit: $$\frac{\int dt d\sigma^{D}_{\gamma^* p\to Xp}/dM_X dt}{\sigma^{tot}_{\gamma^* p\to X}} \propto W^{\rho}$$

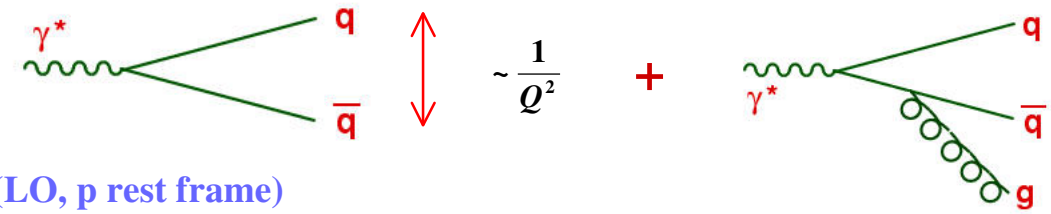
→ **at high Q^2:** $\rho = 0.00 \pm 0.03(stat.)$
not Regge-like

→ **at low Q^2:** $\rho = 0.24 \pm 0.07(stat.)$
Regge-like

Regge prediction is not fulfilled in the DIS regime



Color dipole models



(LO, p rest frame)

Color dipole scatters elastically off the proton

IP described as 2-gluon color singlet exchange

Provide a good description of the DIS diffractive data

e.g. Saturation Model (Golec-Biernat and M. Wusthoff) (cf. DIS00, DIS01)

e.g. BEKW model (Bartels et al.,Eur. Phys. J. C7,443 (1999))

$F^T_{qq} \sim \beta(1-\beta)$, no Q^2 dep.

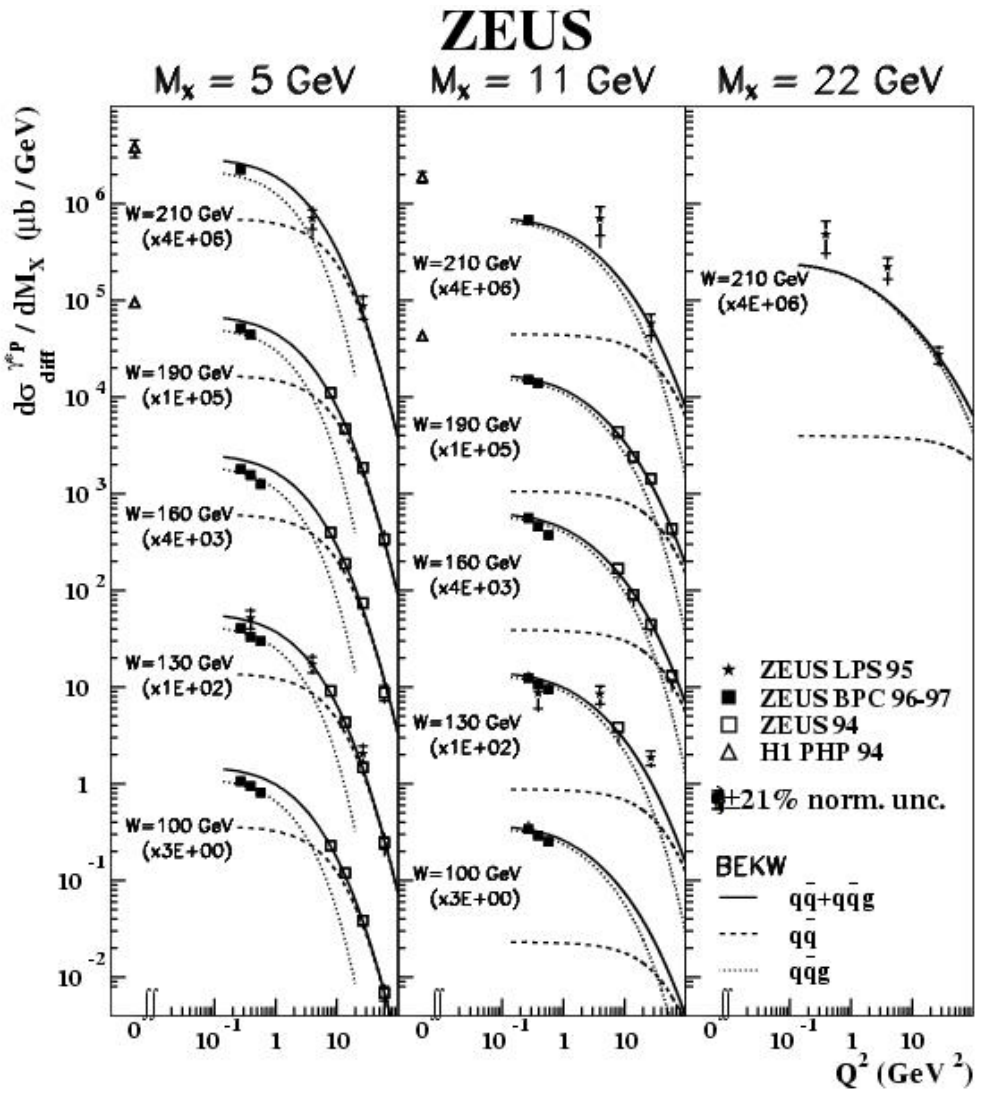
$F^T_{qqg} \sim (1-\beta)^\gamma$, $\ln(1+Q^2/Q^2_0)$, $Q^2_0 = 1\,GeV^2$

F^L_{qq} only at high β

energy dep. for both : $x_{IP}^{-n_{diff}(Q^2)}$

from fits to the data

Q2 dep. of the diffractive cross section



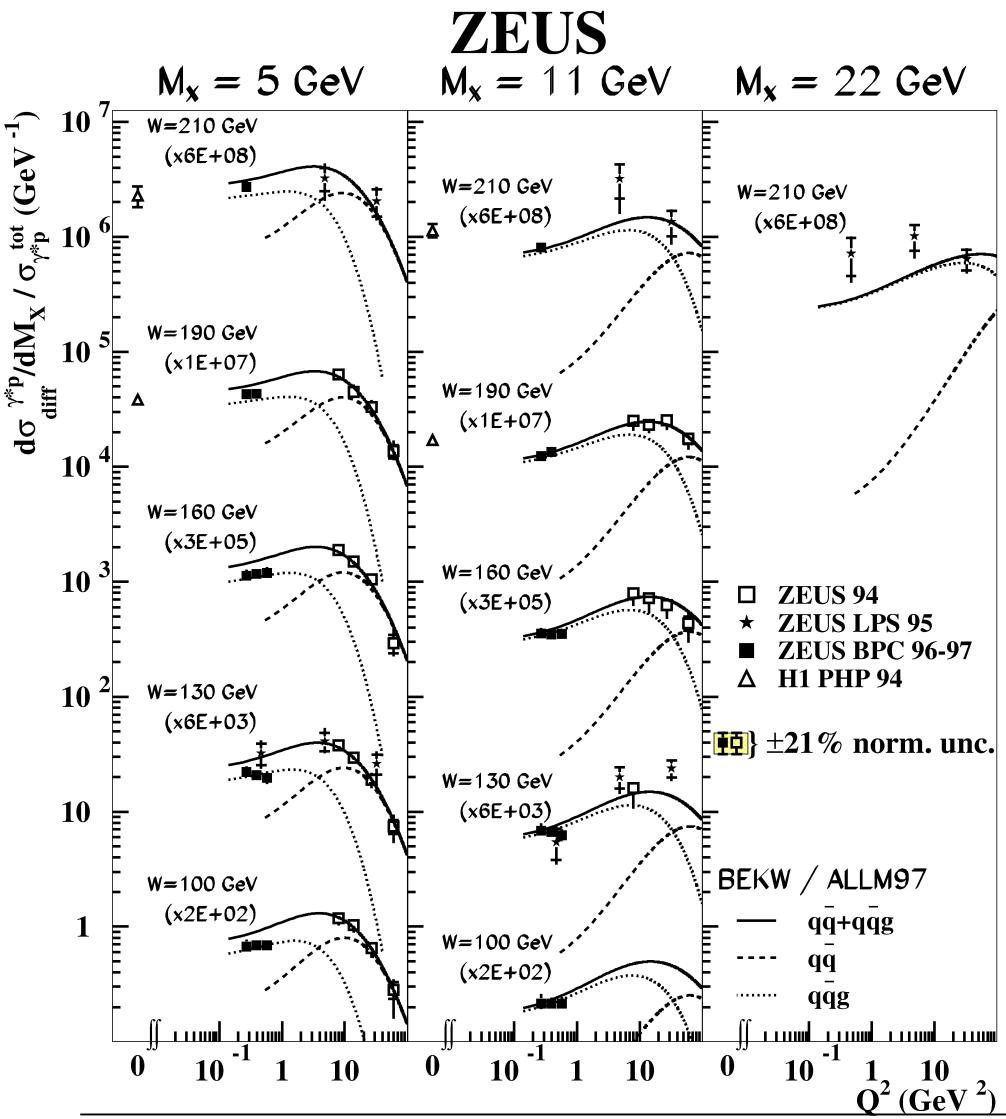
Going from the DIS regime to the low Q^2 we observe a change in the Q^2 dependence of the diffractive cross section

This is similar to what observed for the total cross section $\sigma_{\gamma^* p}$ at $Q^2 \sim 1$ GeV^2

Main features of the data described by BEKW parametrization

- $q\bar{q}g$ γ fluctuations dominant
- for large M_X
- for low Q^2

Q2 dep. of diffractive to inclusive ratio



At low Q^2 the ratio shows little dependence on Q^2

At high Q^2 the diff cross section decreases more rapidly than σ_{tot}

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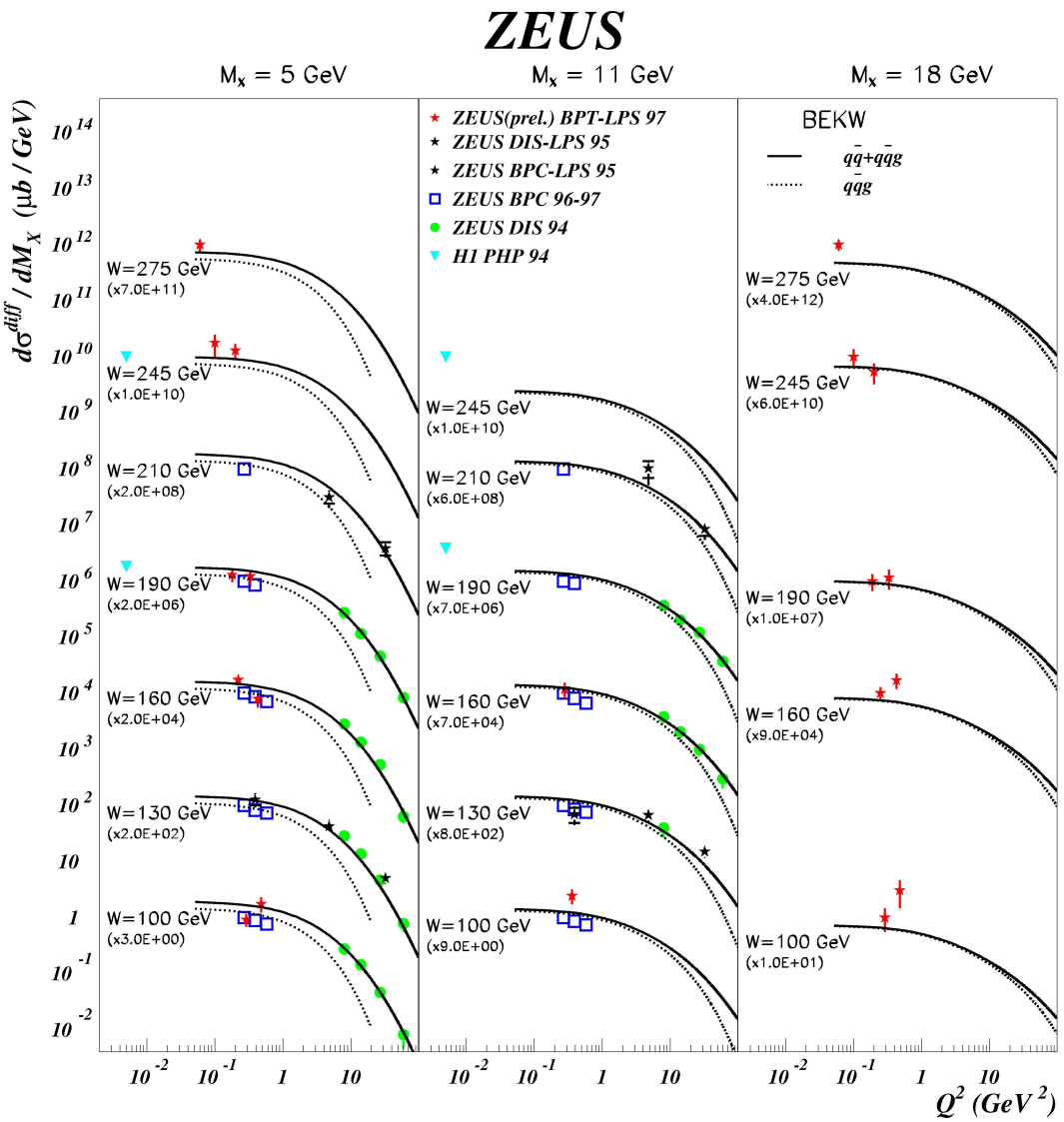

New preliminary: 97 LPS data!

Higher W,

lower Q^2 and more data at high M_X

Same behaviour in the new region

Summary

- New ZEUS F_2^D and $d\sigma^{Diff}/dM_X$ results covering a wide kinematical range
- W dependence of diffractive and total cross section becomes similar at large Q^2 contrary to what happens at low Q^2
- Q^2 dependence of the diffractive softens considerably for $Q^2 \rightarrow 0$
- Features of the data consistent with models assuming $q\bar{q}$ and $q\bar{q}g$ fluctuations of the photon