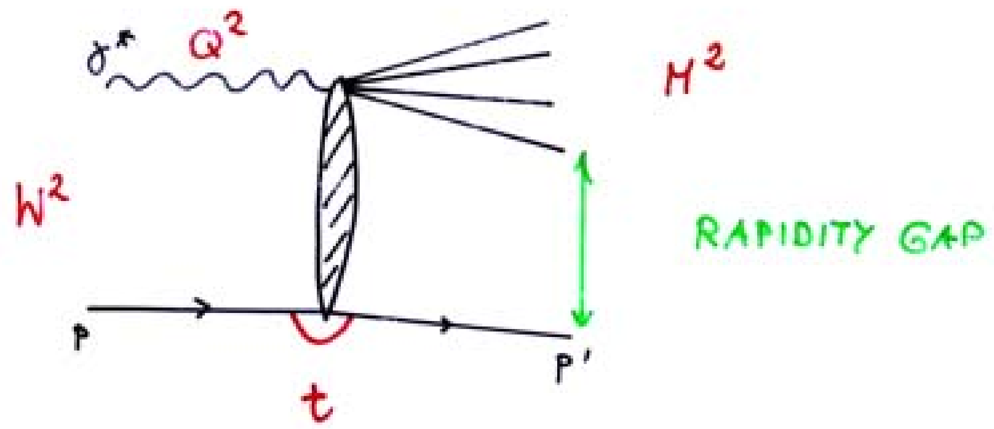
SATURATION AND DIFFRACTIVE DIS

K. GOLEC-BIERNAT
INP KRAKOW

XXXIII ISMD

KRAKÓW, 10.09.2003

DIFFRACTIVE DIS



– 4 DIMENSIONFUL SCALES

$$W^2 \gg Q^2, \quad M^2, \quad |t|$$

HARD SCALE (Q^2)

$\hookrightarrow$ SOFT SCALE ($|t|$)

REGGE LIMIT

– DIMENSIONLESS RATIOS

$x = \dfrac{Q^2}{W^2}$ Bj variable $\ll 1$

$x_{I\!P} = \dfrac{Q^2+M^2}{W^2}$ proton mom. fraction transferred into diffr. system $\ll 1$

$\beta = \dfrac{x}{x_{I\!P}} = \dfrac{Q^2}{Q^2+M^2}$ Bj variable for diffractive system

DIFFRACTIVE STRUCTURE FUNCTION

$$\frac{d^3\sigma}{dx_{I\!P}\, dx\, dQ^2} = \frac{4\pi\alpha^2}{x\, Q^4}\left(1-y+\frac{y^2}{2}\right)\cdot F_2^D(x, x_{I\!P}, Q^2, t)$$

HERA: F_2^D DEPENDS LOGARITHMICALLY ON Q^2

FOR FIXED $\beta = x/x_{I\!P}$

DIFFRACTIVE PARTON DISTRIBUTIONS

$$F_2^D = \sum_f e_f^2\, \beta \left\{ q_f^D(\beta, Q^2, x_{I\!P}, t) + \bar{q}_f^D(\ldots) \right\}$$

β - Bj variable

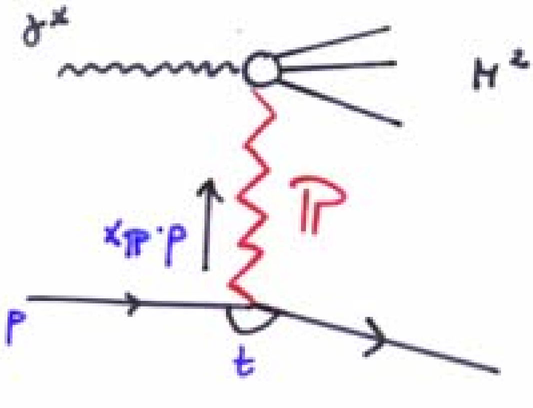
Q^2 - evolution variable (DGLAP = ev. eqs)

t, $x_{I\!P}$ - parameters for evolution

PROBLEM: TO MODEL $t, x_{I\!P}$ DEPENDENCE

β - FORM FROM QCD FITS TO DATA

INGELMAN - SCHLEIN MODEL



POMERON

$$F_2^D = \underbrace{f(x_{\mathbb{P}}, t)}_{\text{POMERON FLUX}} \cdot 2 \cdot \sum_f e_f^2 \, \beta \left\{ \underbrace{q^{\mathbb{P}}(\beta, Q^2)}_{\text{POMERON PD}} \right\}$$

POMERON FLUX

$$= B^2(t) \, x_{\mathbb{P}}^{1 - 2\alpha_{\mathbb{P}}(t)}$$

POMERON PD

$$\alpha_{\mathbb{P}}(t) = \alpha_{\mathbb{P}}(0) + \alpha' \cdot t$$

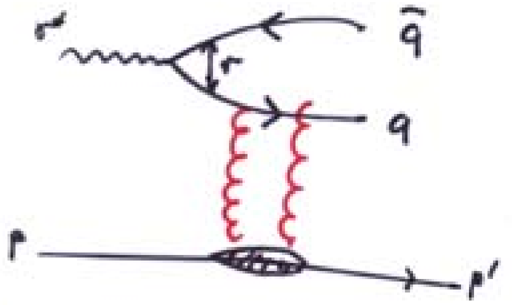
Regge trajectory

IN THIS MODEL : REGGE FACTORIZATION OF DIFFRACTIVE PD

$$q^D(\beta, Q^2, x_{\mathbb{P}}, t) = f(x_{\mathbb{P}}, t) \cdot q^{\mathbb{P}}(\beta, Q^2)$$

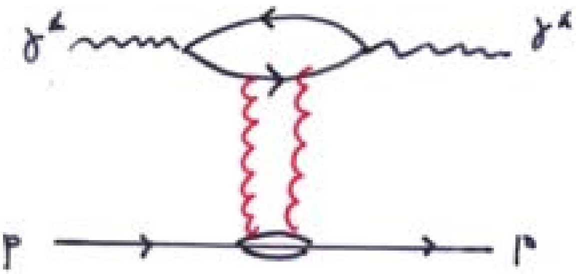
WHAT IS $\mathbb{P}$ IN QCD?

- TWO GLUON EXCHANGE - NO ENERGY DEPENDENCE
- BFKL LADDER
- MANY GLUON EXCHANGES ....



DIFFRACTIVE

$$\frac{d\sigma^D}{dt}\bigg|_{t=0} = \int d^2r\, dz\; |\Psi(r,z,Q)|^2 \;\hat{\sigma}^2(r,x)$$



INCLUSIVE

$$\sigma^{inc} = \int d^2r\, dz\; |\Psi(r,z,Q)|^2 \;\hat{\sigma}(r,x)$$

$\hat{\sigma}(r,x)$ - dipole cross section

$F_2 \sim Q^2\, \sigma^{inc,D}$

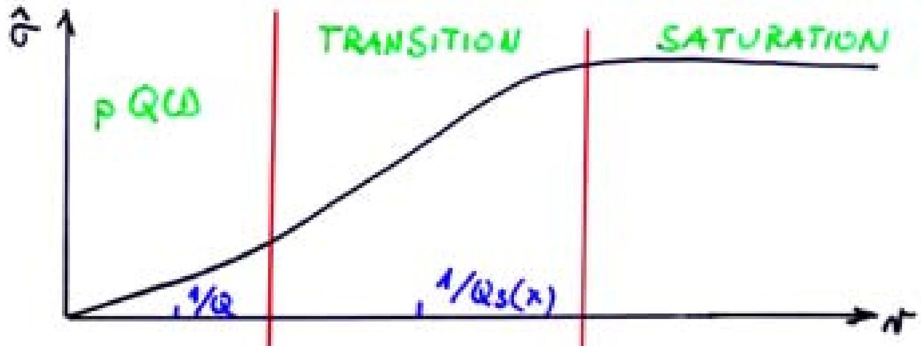
SATURATION AND DIFFRACTION

MODEL OF DIPOLE CROSS SECTION:

$$\hat{\sigma}(r,x) = \sigma_0 \left(1 - e^{-r^2 Q_s^2(x)}\right)$$

$$Q_s(x) \sim x^{-\lambda} \quad , \; \lambda \approx 0.15$$

SATURATION SCALE



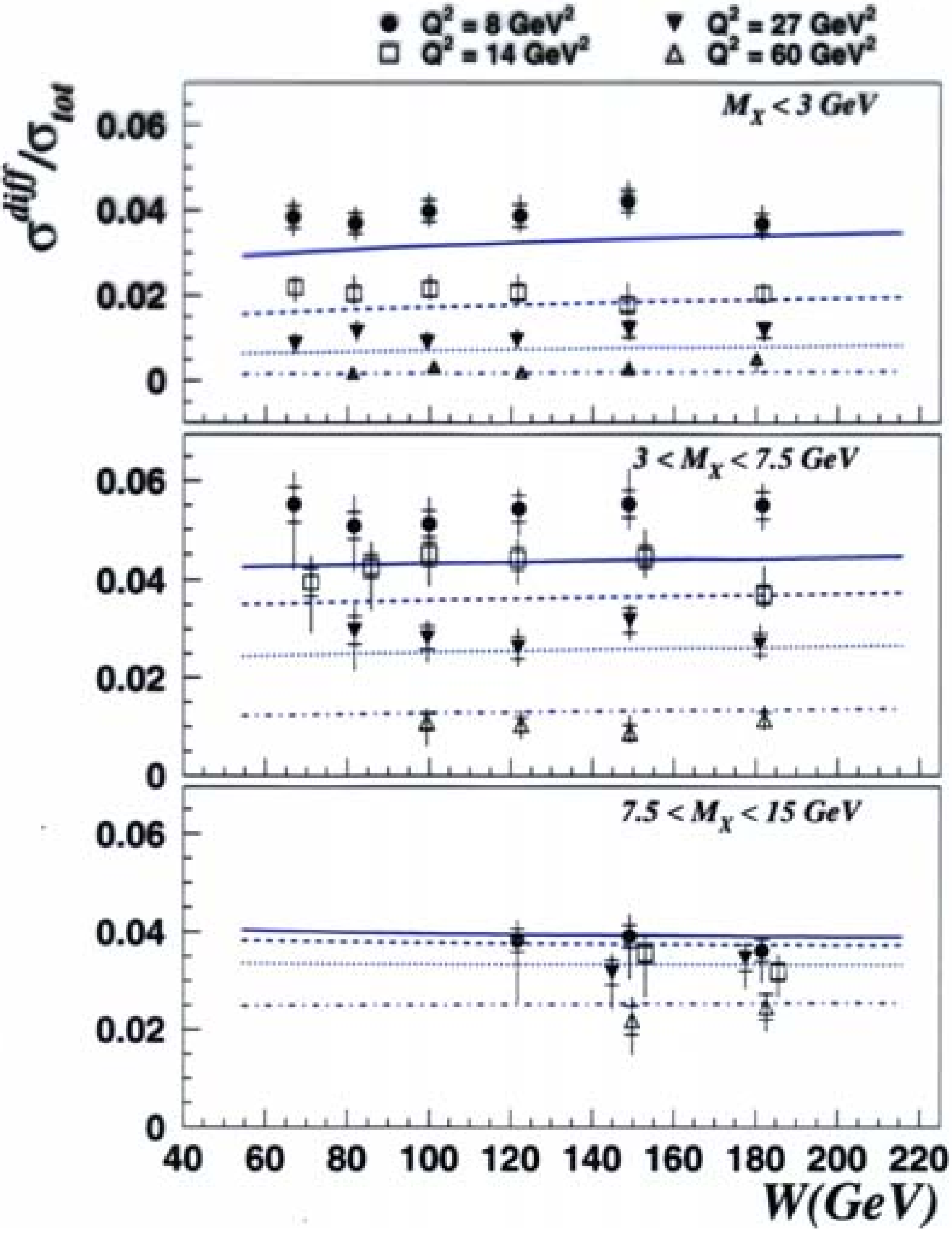
	pQCD	TRANSITION	SATURATION
$\sigma^{incl} \sim$	$\frac{Q_s^2}{Q^2}$	$\frac{Q_s^2}{Q^2} \ln\left(\frac{Q_s^2}{Q^2}\right)$	$\frac{Q_s^2}{Q^2}$
$\sigma^{D} \sim$	$\left(\frac{Q_s^2}{Q^2}\right)^2$	$\frac{Q_s^2}{Q^2}$	$\frac{Q_s^2}{Q^2}$

- DIFFRACTION PROBES DIRECTLY SATURATION REGION !
- RATIO:

$$\frac{\sigma^{D}}{\sigma^{inc}} \sim \frac{1}{\ln \frac{Q_s^2(x)}{Q^2}}$$

DEPENDS LOGARITHMICALY ON x (ENERGY) !

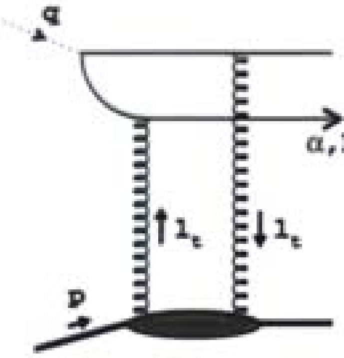
$\sigma^{diff}/\sigma^{tot}$ ratio and ZEUS 94 data

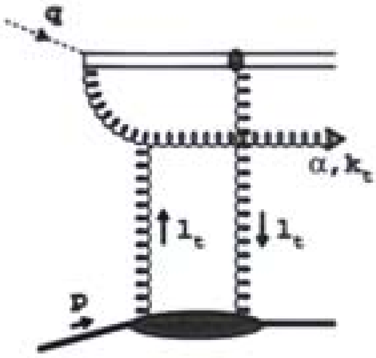


Saturation model in diffraction

Diffractive state is formed by $q\bar{q}$ and $q\bar{q}g = gg$ dipoles.

Interaction with the proton given by the found dipole cross section $\hat{\sigma}(r/R_0(x))$. $(R_0 = 1/Q_s)$





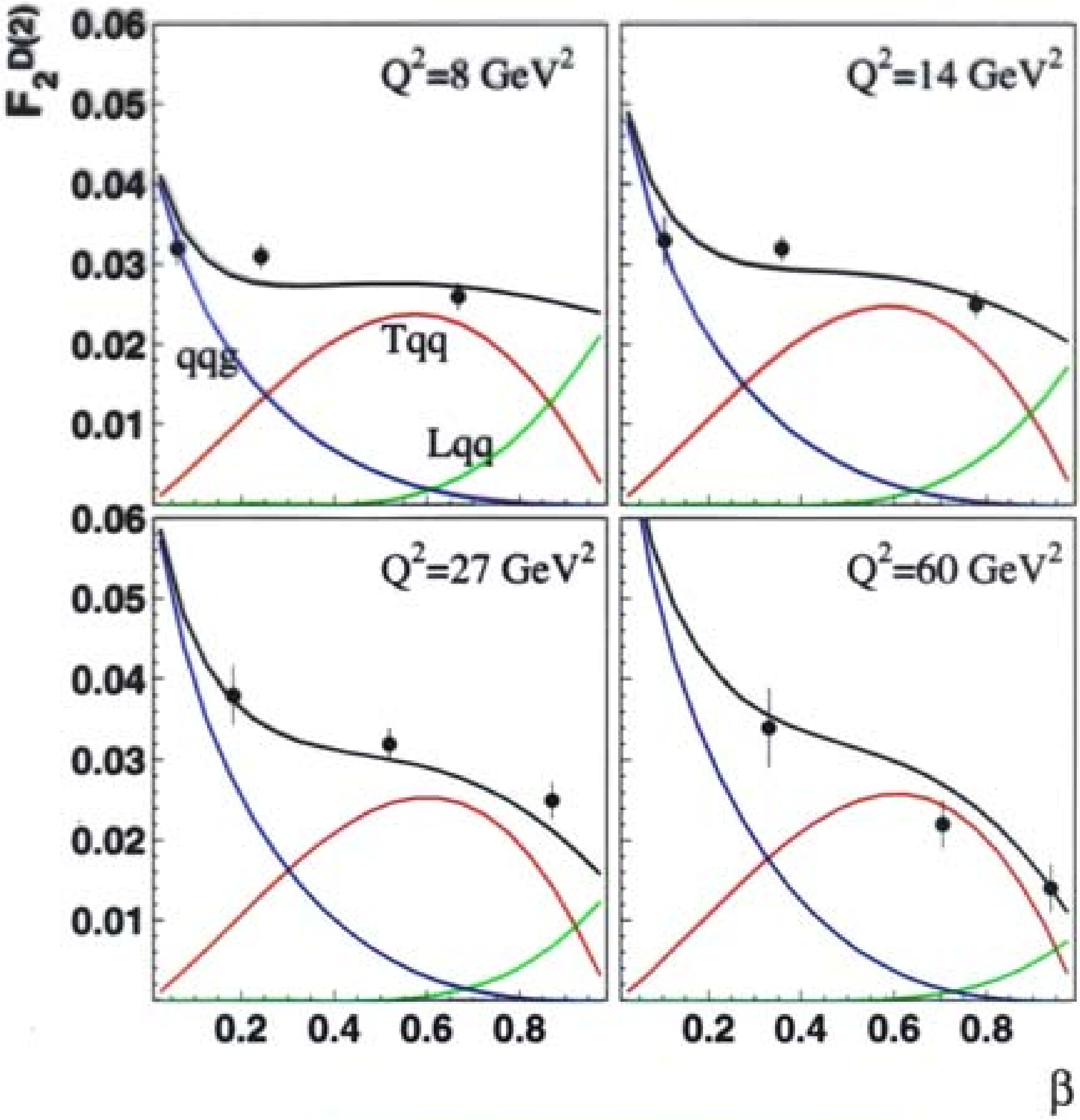
$\} M^2$

The diffractive structure function

$$F_2^{D(3)}(\beta, Q^2, x_{I\!P}) = F_{q\bar{q}}^T + F_{q\bar{q}}^L + F_{q\bar{q}g}^T$$

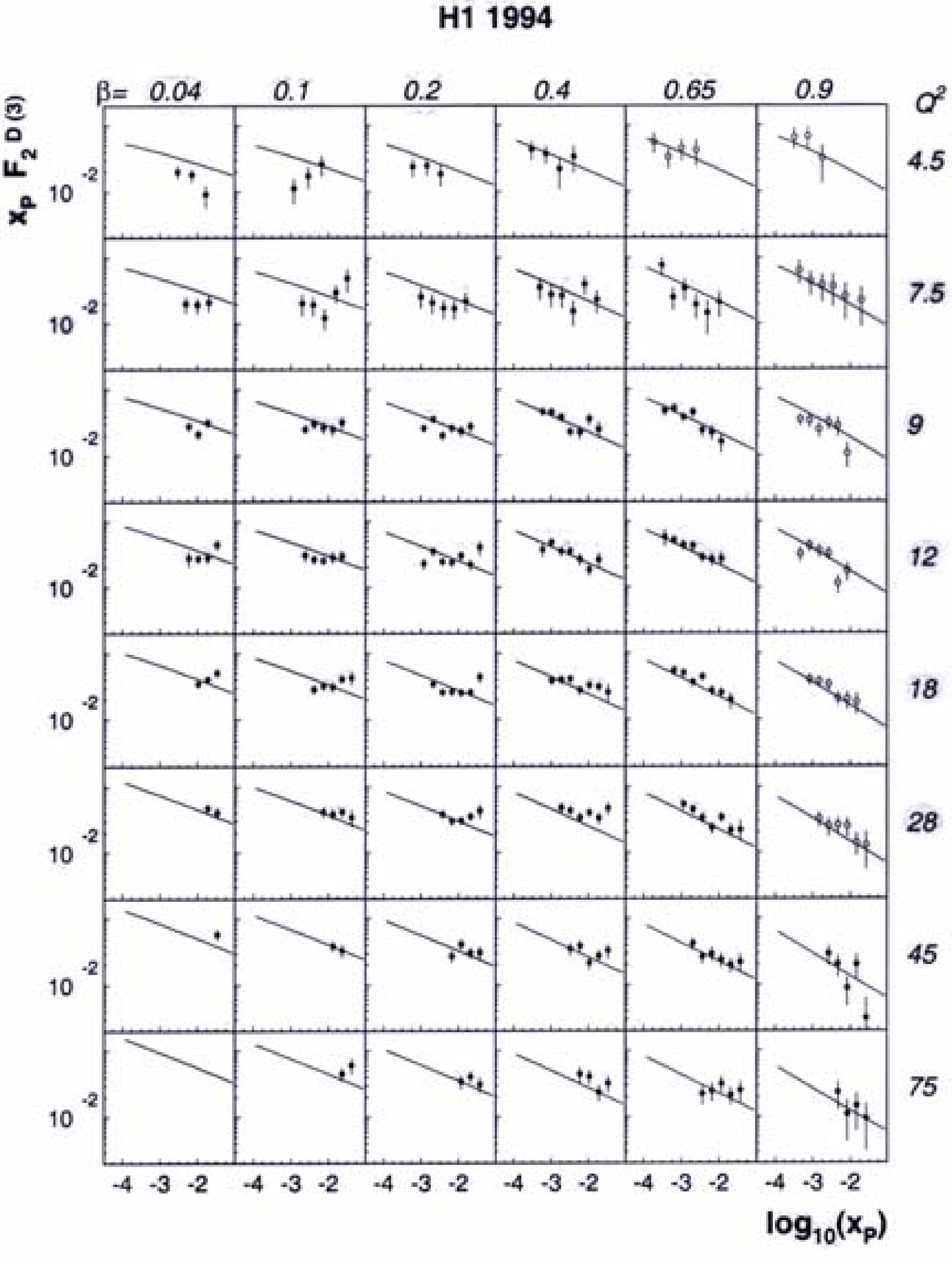
$$F^D \sim \frac{Q^4}{x} \frac{d\sigma^D}{dM^2}$$

ZEUS 94 data at $x_{I\!P} = 0.0042$

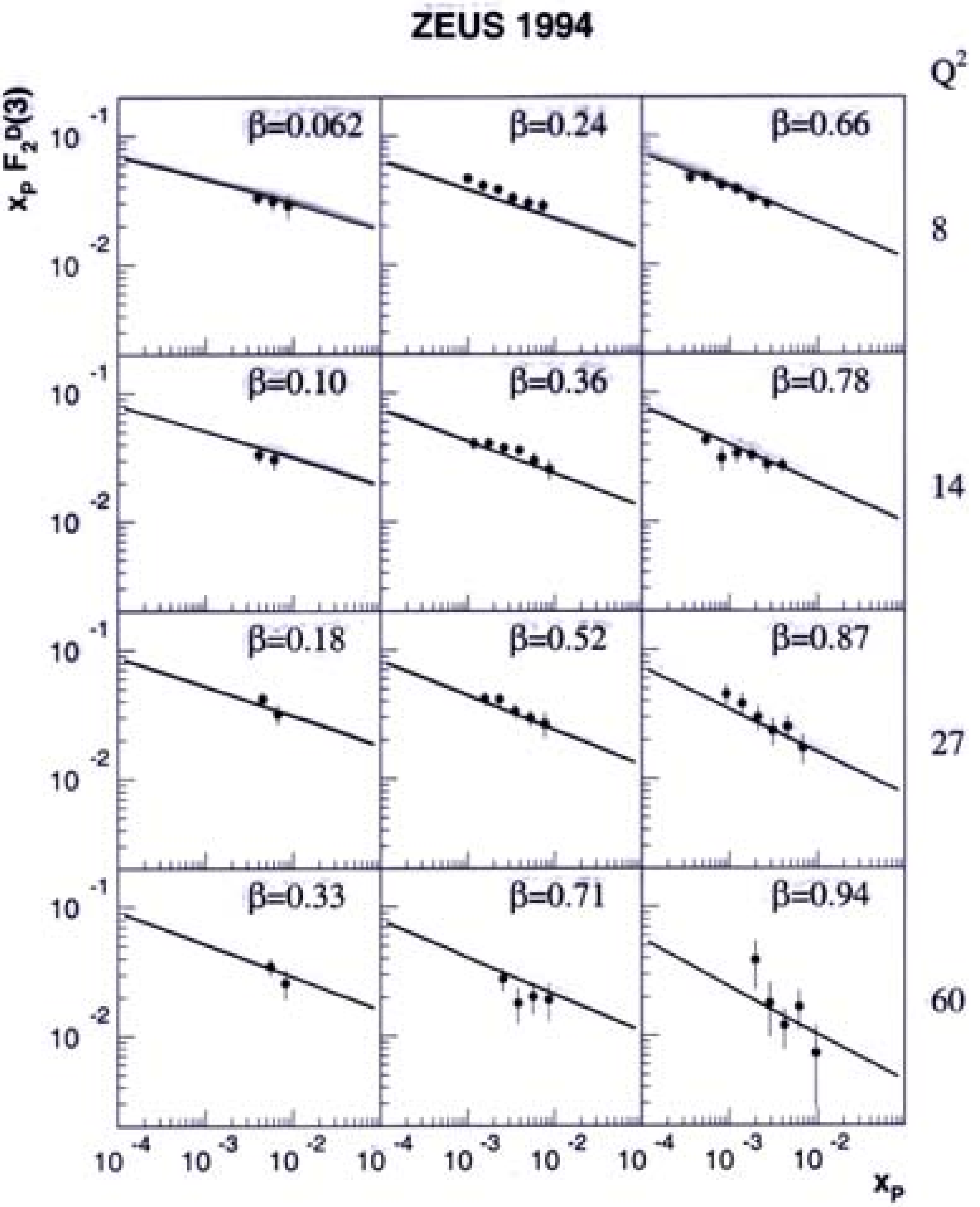


$F^L_{q\bar{q}}$ is higher twist $\sim 1/Q^2$.

$$\beta = \frac{Q^2}{Q^2 + M^2}$$



$x_{I\!P}$-dependence - comparison with H1 data



$x_{I\!P}$-dependence - comparison with ZEUS data

$$x_{I\!P} \cdot F_2^{D(3)}\left(\underbrace{\beta, Q^2}_{\text{fixed}}, x_{I\!P}\right) \sim x_{I\!P}^{-\lambda}$$

DIFFRACTIVE PD FROM SATURATION MODEL

$$\boxed{F_2^D = F^T_{q\bar{q}} + F^L_{q\bar{q}} + F^T_{q\bar{q}g}}$$

1. From $F^T_{q\bar{q}}$ quark DPD $\longrightarrow$ $q^D(\beta, x_{I\!P})$

2. From $F^T_{q\bar{q}g}$ gluon DPD $\longrightarrow$ $g^D(\beta, x_{I\!P})$

3. $F^L_{q\bar{q}}$ higher twist $\sim 1/Q^2$

RESULT:

q^D, g^D HAVE REGGE FACTORIZATION PROPERTY

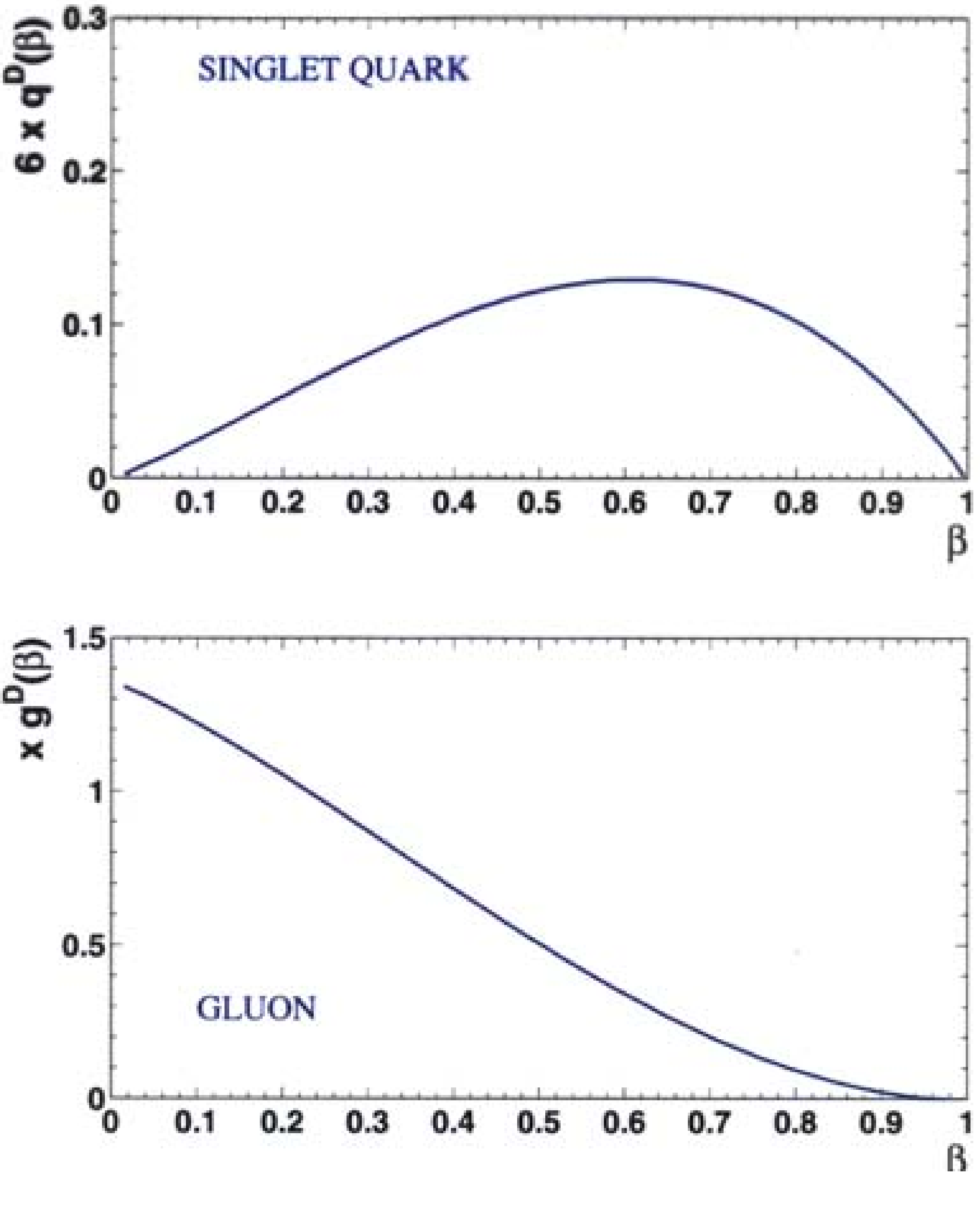
$$\begin{cases} x\,q^D(\beta, x_{I\!P}) \sim Q_s^2(x_{I\!P}) \cdot h_q(\beta) \sim x_{I\!P}^{-0.29} \\ x\,g^D(\beta, x_{I\!P}) \sim Q_s^2(x_{I\!P}) \cdot h_g(\beta) \sim x_{I\!P}^{-0.29} \end{cases}$$

WHICH LEADS TO MEASURED EFFECTIVE $I\!P$ INTERCEPT

$$F_2^D \sim x_{I\!P}^{1-2\alpha_{I\!P}^{eff}} \Rightarrow \boxed{\alpha_{I\!P}^{eff} = 1.15\,!}$$

DGLAP evolution DOES NOT AFFECT $\alpha_{I\!P}^{eff}$.

Diffractive pd at $Q_0^2 = 1.5\ \mathrm{GeV}^2$
and $x_{I\!P} = 0.003$

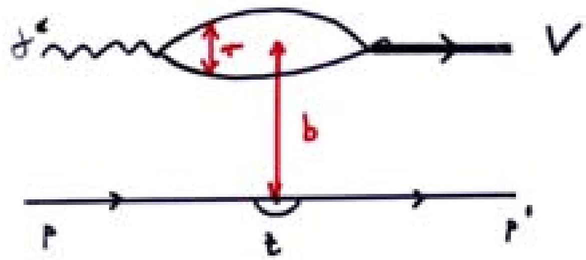


DIFFRACTIVE VECTOR MESON PRODUCTION

①. DIPOLE CROSS SECTION:

$$\hat{\sigma}(r,x) = 2 \int d^2b \, N(r,b,x)$$

dipole scattering amplitude



② IN VM PRODUCTION $\gamma^* \to q\bar{q} \to V$

$$\frac{d\sigma^{\gamma^* p \to Vp}}{dt} = \left| \psi^V \otimes \int d^2b \, e^{i\vec{b}\cdot\vec{\Delta}} N(r,b,x) \otimes \psi^{\gamma^*} \right|^2$$

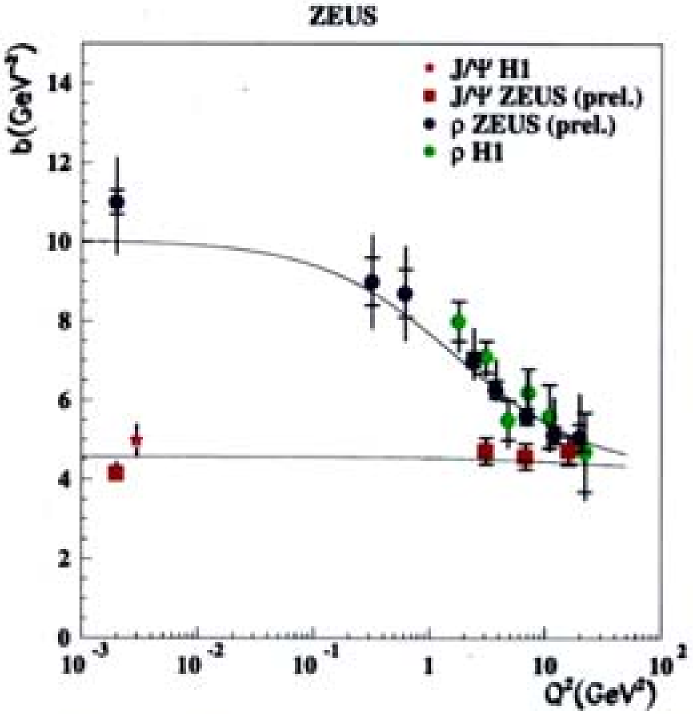
WHERE

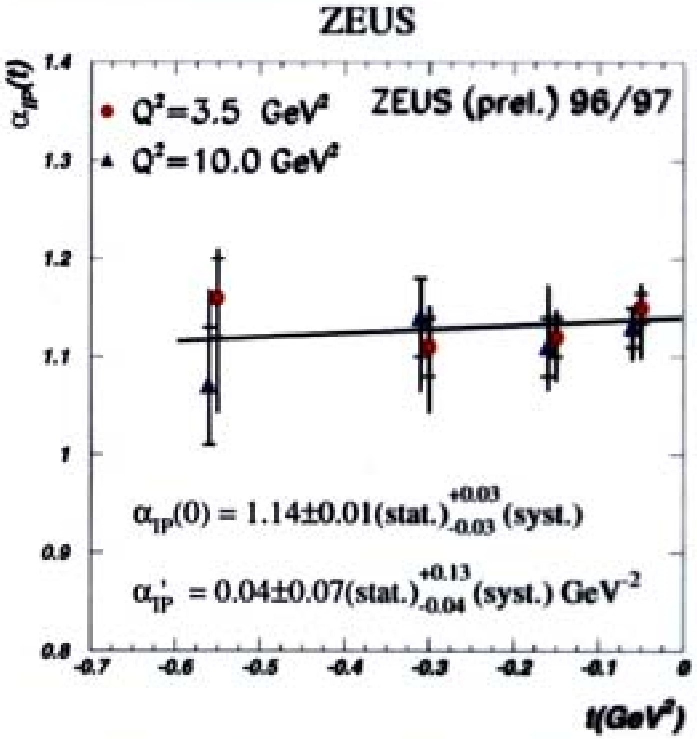
$$t = -\vec{\Delta}^2$$

FROM t-dependence of $\frac{d\sigma^{VM}}{dt}$ TO b-dependence of scattering amplitude.

EXCLUSIVE ρ^0 MESON IN $\gamma^* p$

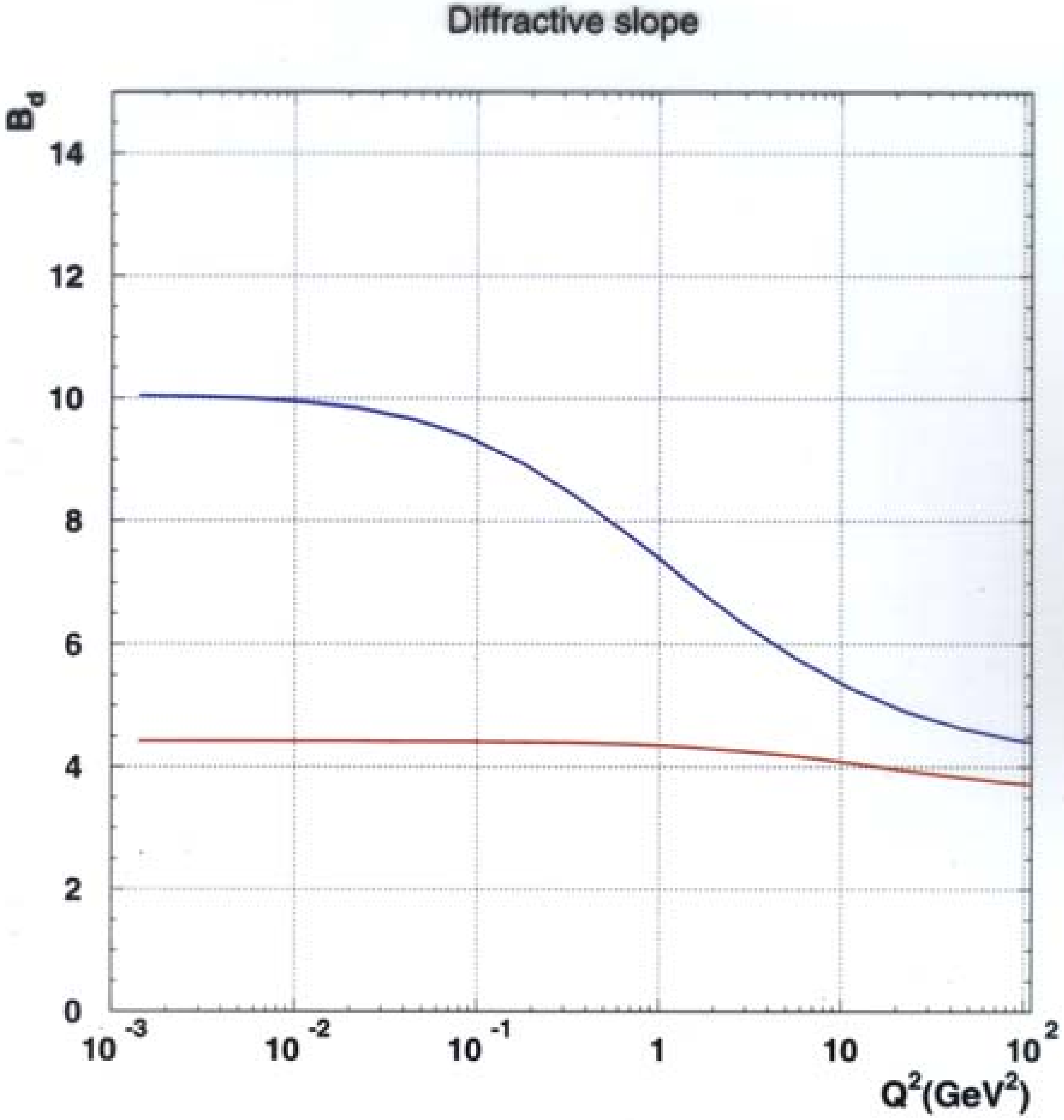
t dependence of $\sigma(\gamma^* p \to \rho^0 p$ and $\alpha_{I\!P}(t)$





$\Rightarrow$ For ρ^0 b decreases with Q^2

$\Rightarrow$ Possibly small shrinkage


Diffractive slope
B_d
14
12
10
8
6
4
2
0
10 -3
10 -2
10 -1
1
10
10 2
Q^2(GeV^2)

SUMMARY

1. DIPOLE CROSS SECTION WITH SATURATION APPLIED TO INCLUSIVE DIFFRACTION IN DIS DESCRIBES:

   - ENERGY DEPENDENCE ($x_{\mathbb{P}}$)
   - CONSTANT RATIO σ^D/σ^{inc}

2. IN LEADING TWIST DESCRIPTION, DIFFR. PARTON DISTR. HAVE REGGE FACTORIZATION ⇒ MOTIVATION FOR INGELMAN SCHLEIN MODEL

3. DIFFRACTIVE VM PRODUCTION PROVIDES ACCESS TO STUDY OF b-dependence of DIPOLE SCATTERING AMPLITUDE

HOPE: CONSISTANT PICTURE OF INCLUSIVE AND DIFFRACTIVE PROCESSES IN DIS EMERGES.