QCD dipole predictions for DIS and diffractive structure functions

DIS 97
Chicago

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PLAN

- Dipole model – Application to DIS
  → F_2, 3 parameter fit to the 94 H1 data
- Prediction for σ_G, R
- Prediction for the 3 dimensional structure function $F_2^{D(3)}$
  Comparison with H1 data

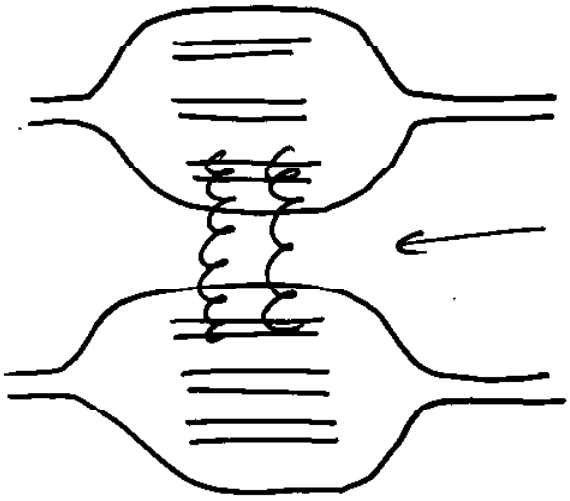
Work done in collaboration with

A. Bialas (Krakow), R Peschanski (Saclay)
→ diffraction

H. Navelet, R. Peschanski, S. Wallon → F_2, R
(Saclay) (DESY)

Dipole model: alternative approach

(Mueller)
(Mueller Patel)



x_{01} transverse size

soft gluon exchange

x'_{01}

In the regime of soft gluons emission (LL $1/x$), when $N_c \to \infty$:

onium - onium scattering ≡ expressed as a cascade of dipole

For $x_{01} \sim x'_{01}$:

$$\sigma_{tot} \propto e^{(\alpha_P - 1)\ln\frac{1}{x}}$$

BFKL pomeron

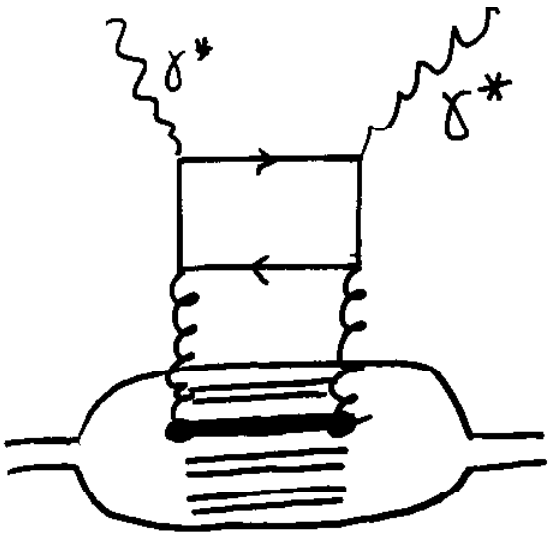
$$\alpha_P - 1 = \frac{12\alpha_s \ln 2}{\pi}$$

(no DGLAP evolution)

dipole model + k_T factorisation $\Big\}$ $\Longrightarrow$ "BFKL F_2"

(H. Navelet, R. Peschanski, C. R. [illegible])

Application to DIS



1st k_T factorisation

2nd k_T factorisation.
dipoles (onium)

how to get F_2 =
H. Navelet, R. Peschanski, C-R., PLB 366 (1996) 329.
+ S. Wallon, PLB (1996) 357.

- DIPOLE MODEL (Mueller et al.)
- $\oplus$
- k_T Factorisation. (Catani et al.)

DIS cross section of a γ on an onium state:

$$Q^2 \sigma = \int_{Q^2} d^2\vec{k} \int_0^1 \frac{dz}{z}\, \sigma^{\gamma}\left(\frac{x}{z}, \frac{\vec{k}^2}{Q^2}\right) F\left(z, (k\cdot r)^2\right)$$

$\gamma g \to q\bar{q}$ cross section

unintegrated gluon distribution of a dipole state (radius r)

1st k_T Factorisation

$$\hat{F}(\omega,\gamma) = \frac{1}{\gamma}\frac{\alpha N_c}{\pi}\frac{\nu_\gamma}{\omega - \frac{\alpha N_c}{\pi}\chi(\gamma)}$$ (Mueller et al

Lipatov anom dimension

Mellin transform of the gluon dipole coupling

$\nu_\gamma \equiv$ calculated using the onium onium scattering amplitude $\oplus$ k_T Factorisat.
$\equiv$ gluon dipole coupling.

$$Q^2\sigma = \frac{\alpha N_c}{\pi}\int\frac{d\gamma}{2i\pi}\, h(\gamma)\, \nu(\gamma)\left(\frac{Q^2}{M^2}\right)^{\gamma} e^{\frac{\alpha N_c}{\pi}\chi(\gamma)\ln\frac{1}{x}}\, \omega(\gamma, \frac{r}{a})$$

$h(\gamma)$: $\gamma g \to q\bar{q}$ cross section

$\nu(\gamma)$: onium

M^2: arbitrary factorisation scale

$$\omega\left(\gamma, \frac{M^2}{Q_0^2}\right) = \left(\frac{M^2}{Q_0^2}\right)^{\gamma}\omega(\gamma)$$

$\omega \equiv$ Factorised non perturbative hadron-onium structure function (target $\equiv$ proton, ~~onium~~ ---)

[$Q_0 \equiv$ scale parameter introduced to describe the non perturbative coupling to proton]
(possible interpretation: onium wave function of the proton)

saddle point approximation: $\gamma_c = \frac{1}{2} - a \ln \frac{Q}{Q_0}$

$$F_2 = \mathcal{N} a^{1/2} e^{\frac{1}{Ka} + \ln \frac{Q}{Q_0}\left(1 - \frac{a}{2} \ln \frac{Q}{Q_0}\right)}$$

$$a^{-1} = K(\alpha_p - 1) \ln 1/x \quad \left(K \equiv \frac{7}{4 \ln 2} \zeta(3)\right)$$

$\Rightarrow$ 3 parameter fit of F_2
$(\mathcal{N}, Q_0, \alpha_p)$

Data used $\equiv$ H1 data (DESY 96-039)

$\rightsquigarrow$ Figures.

$Q^2 \leq 150$ GeV^2 (x small)

$\alpha_p = 1.282$ ($\rightarrow \alpha_s = 0.11$)

$Q_0 = 0.627$ GeV

$\mathcal{N} = 0.077$ ($\sim \alpha_s$ of the order of the dipole-gluon coupling)

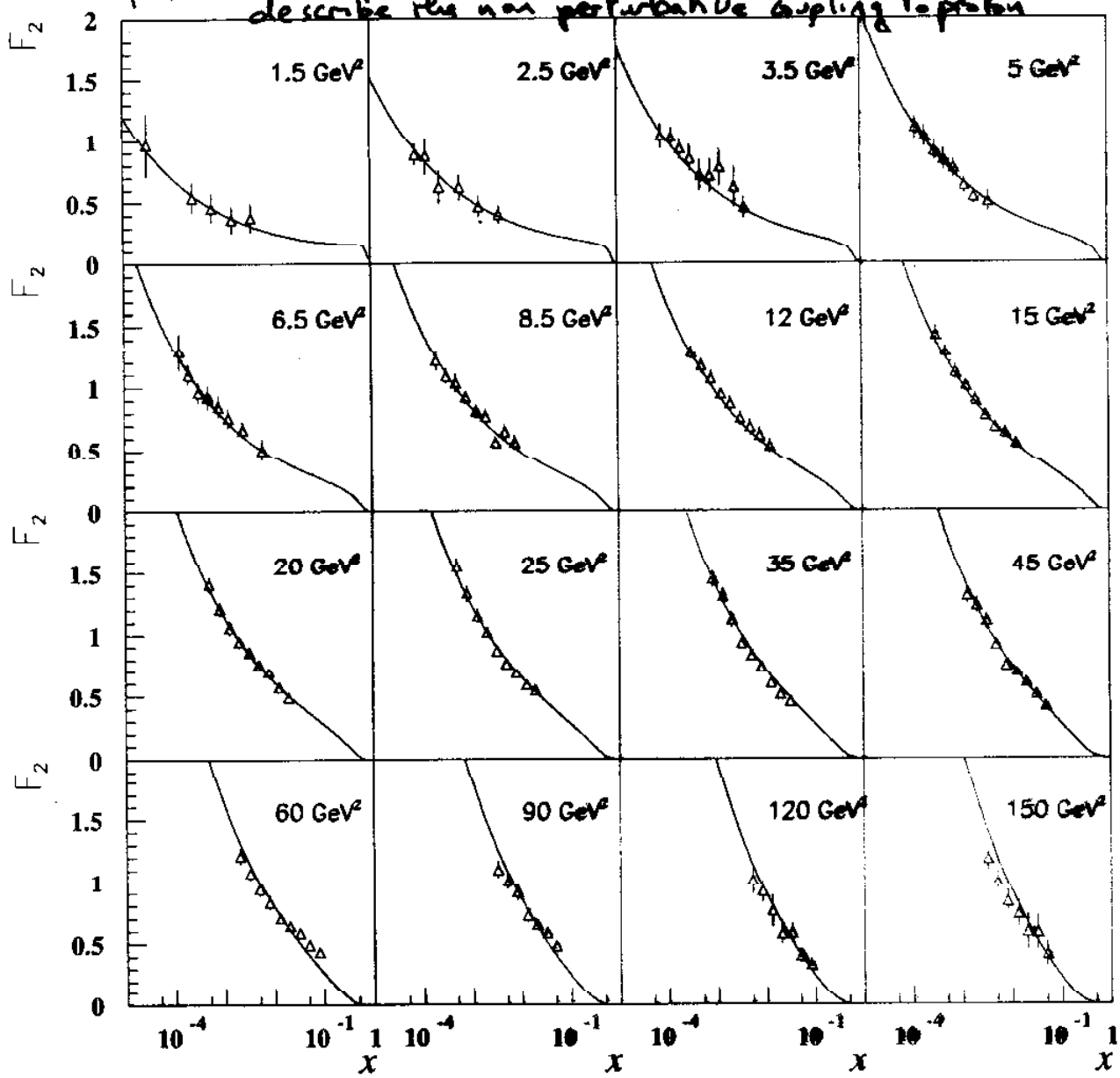
$\chi^2 = 101$ for 130 points

$\rightsquigarrow$ higher Q^2 : valence?
higher x : higher orders?

3 parameter F_2 fit

$\mathcal{N}$: normalisation
α_P : "Lipatov" exponent
Q_0 : scale parameter introduced to describe the non perturbative coupling to proton

H1 data (94)
DESY 96-039

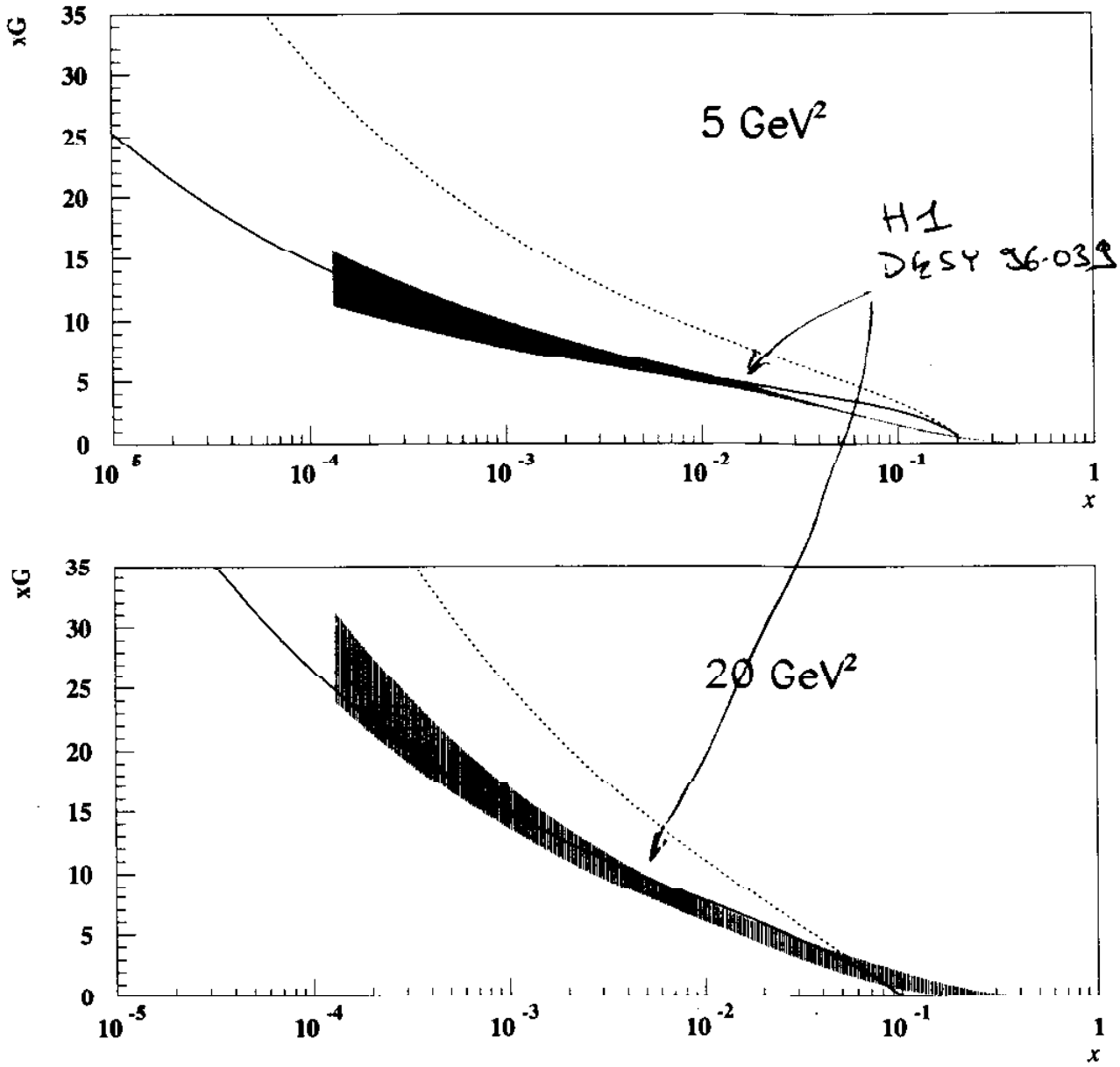


$$F_2 = \mathcal{N}\, a^{1/2}\, e^{\frac{1}{k a} + \ln\frac{Q}{Q_0}\left(1 - \frac{a}{2}\ln\frac{Q}{Q_0}\right)}$$

$$a^{-1} = K(\alpha_P - 1)\ln 1/x$$

$Q^2 \leq 150\ \mathrm{GeV}^2$

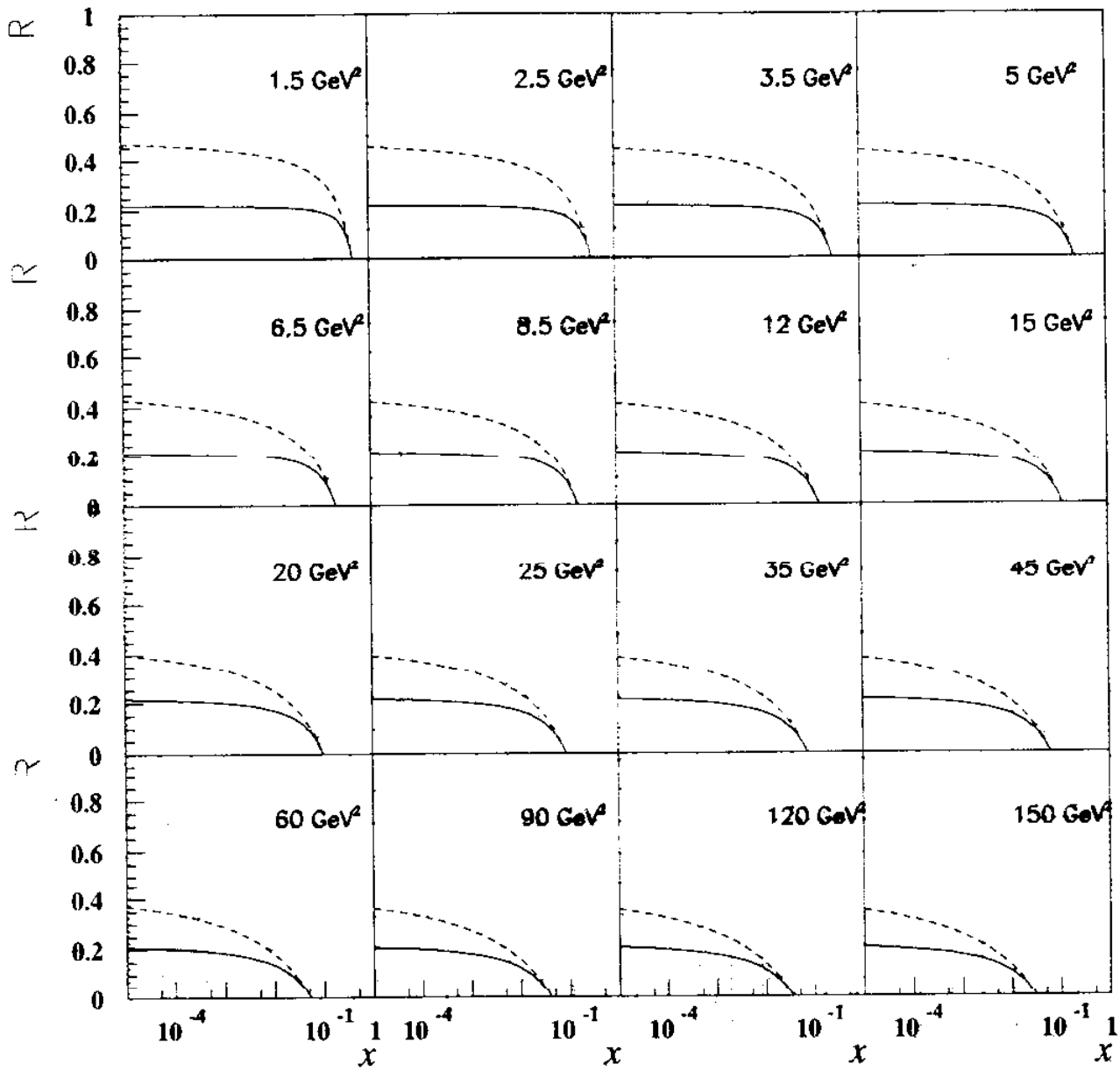
— prediction
····· 1st order } ≠ effects of the ln 1/x resummation



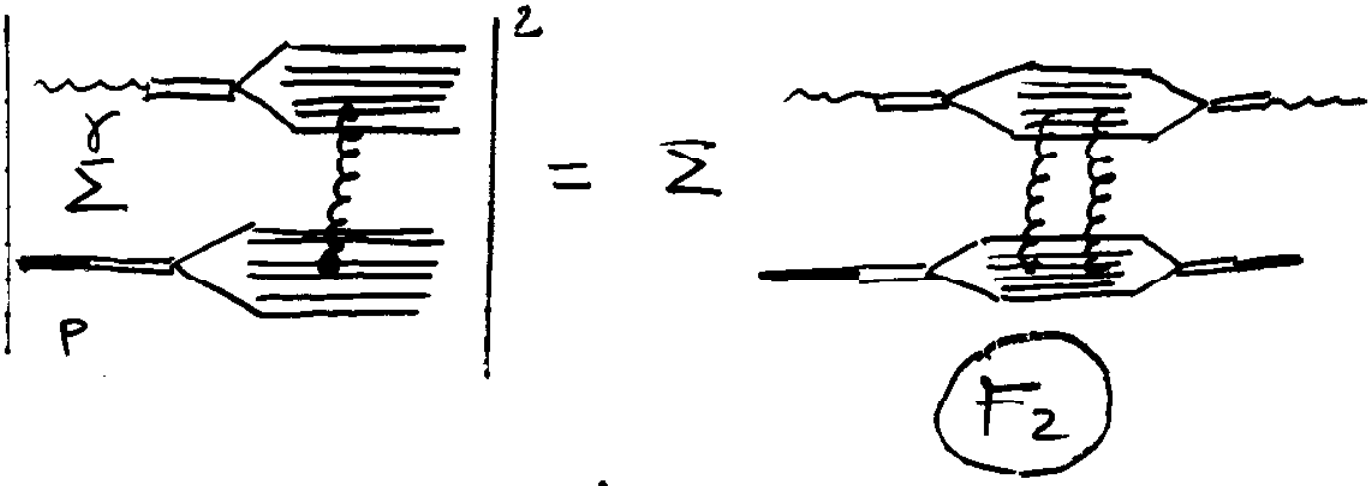
Dipole model

—— prediction
- - - - 1st order (DGLAP fixed α_s)

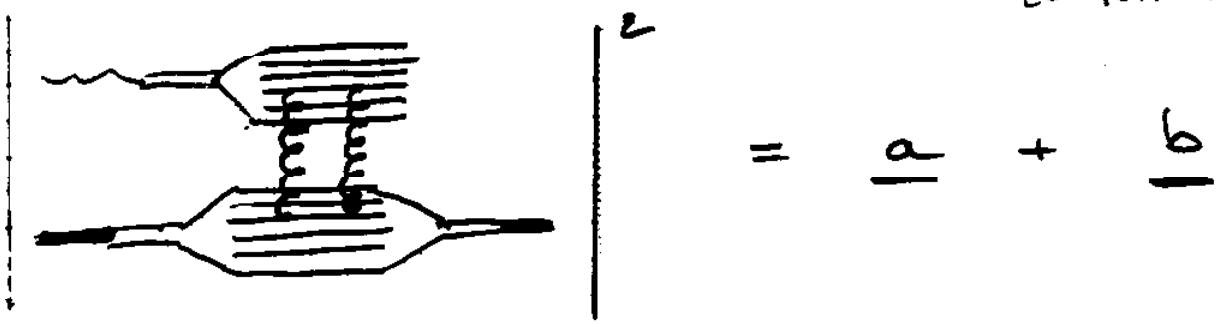
) → effects of $\alpha \ln 1/x$ resummation

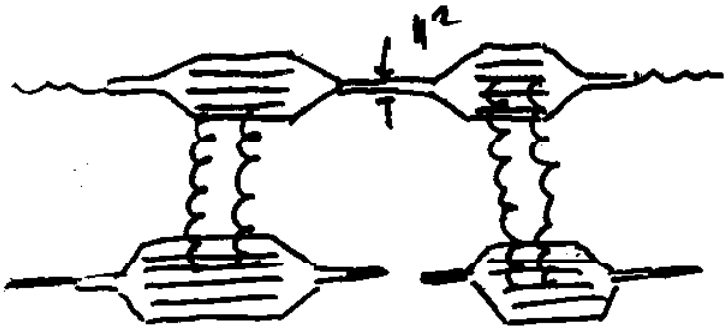


Hard diffraction in the QCD dipole model



Diffraction: 2 components (cf Nikolaev-Zakhar



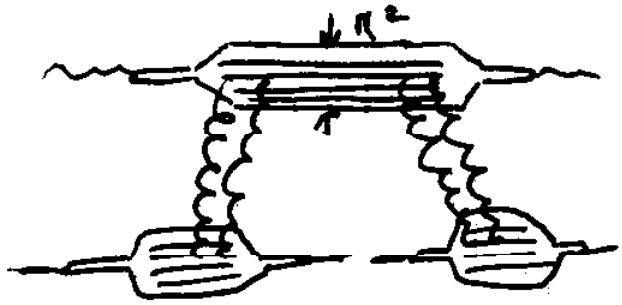


(a)

ELASTIC DIPOLE

elastic scattering of the onium on the target proton

(Bialas, Peschanski,



(b)

INELASTIC

triple pomeron term (dominant at large masses)

(Mueller, Patel, Bialas, Peschanski

INELASTIC COMPONENT (b)

- dominates at low β
- Factorisation:

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

"pomeron" flux factor — "pomeron" structure function

- Effective intercept:

$$\Phi_P = x_{IP}^{+1-2\alpha_P} \left(\frac{2a(x_{IP})}{\pi}\right)^3 \propto \frac{1}{\ln 1/x_{IP}}$$

The effective exponent $\left(n \propto \frac{d \log F_2^D}{d \log 1/x_{IP}}\right)$ depends on x_{IP} - ($\rightsquigarrow$ plot)

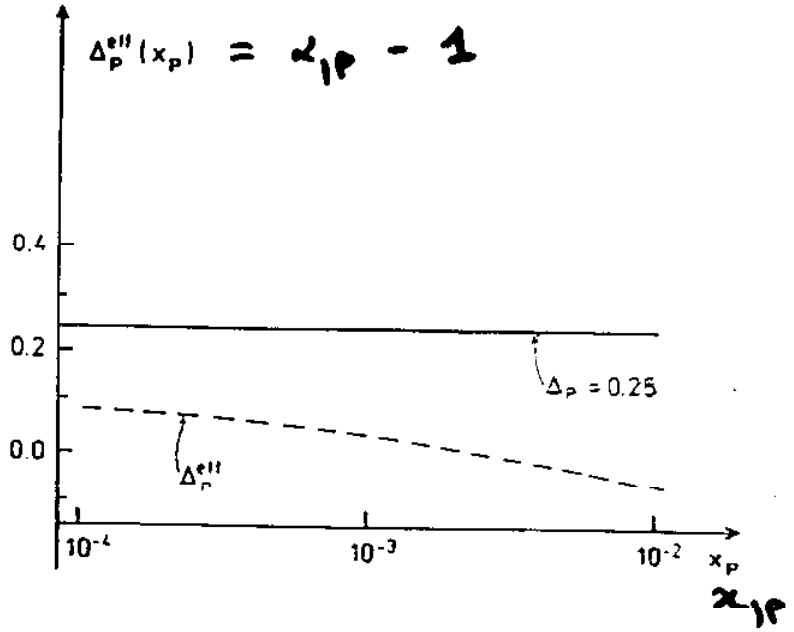
- Equivalence $F_{IP} \sim F_{proton}$ at small β

$$F_{IP}(Q^2, \beta) \sim C_3\, F_{proton}(Q^2, \beta = x_{BJ})$$

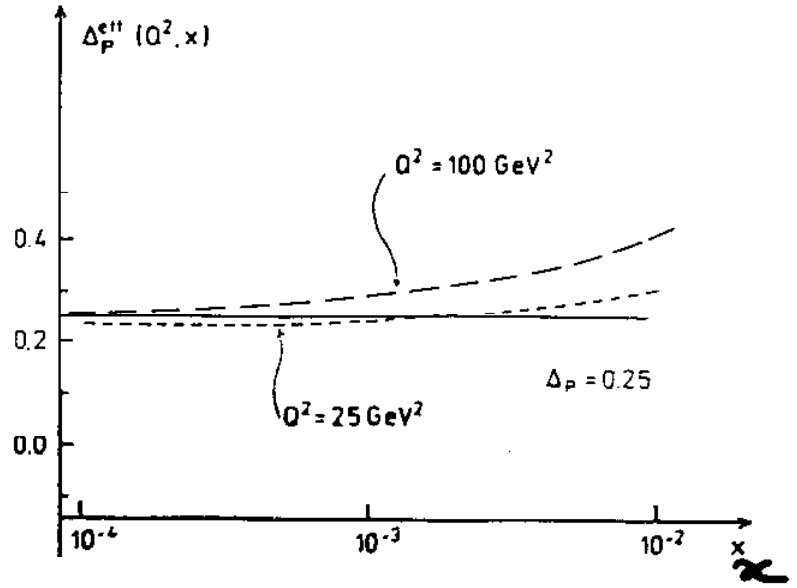
C_3: triple pomeron coupling.

Inelastic component:

EFFECTIVE POMERON INTERCEPT FROM DIFFRACTIVE STRUCTURE FUNCTION



EFFECTIVE POMERON INTERCEPT FROM F_2



A. Białas, 2nd Cracow Epiphany Conference, 1996.

ELASTIC COMPONENT (a)

- dominates at high β
- Factorisation

  ~ Factorisable (small Factorisation breaking)

  but: different flux factor compared to inelastic
- β dependance

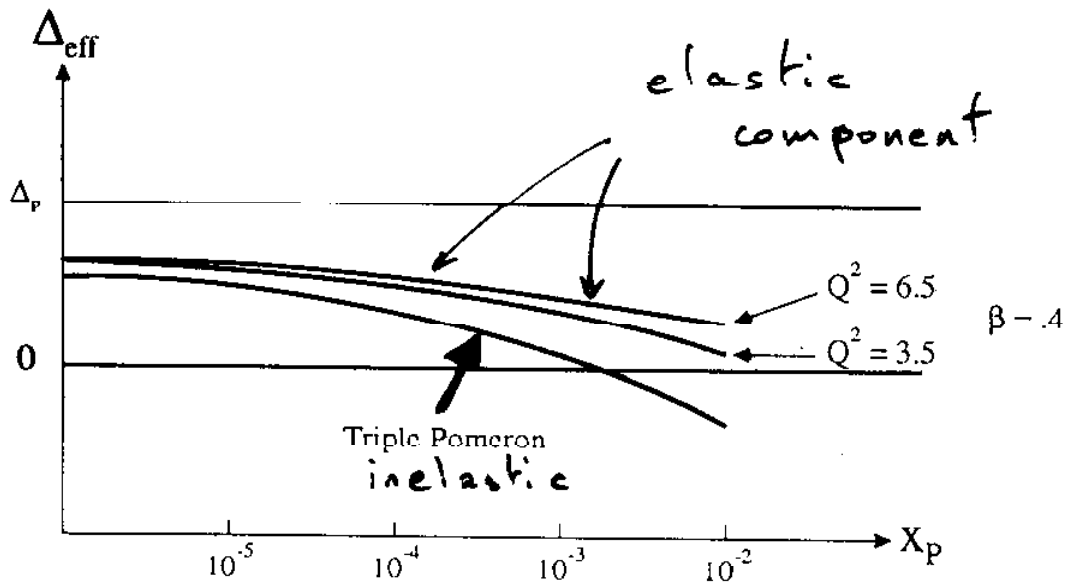
  ~ Flat at high β ($\beta > 0.5$)

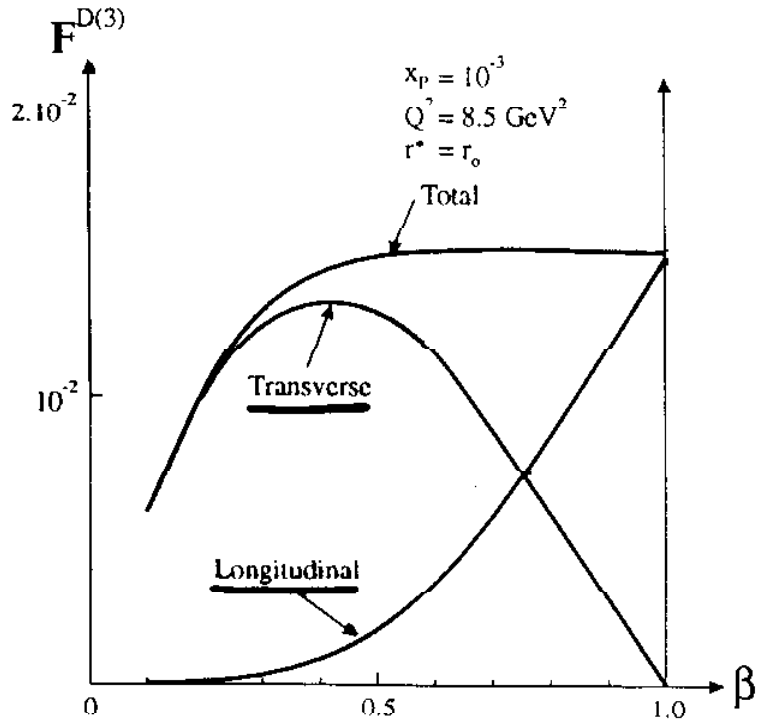
  $$R = \frac{\sigma_L}{\sigma_T} > 1 \quad \text{when } \beta > 0.7$$

  "interplay" between F_L, F_T. so that $F_L + F_T \sim$ cte
- Q^2 dependance

  increasing for all β

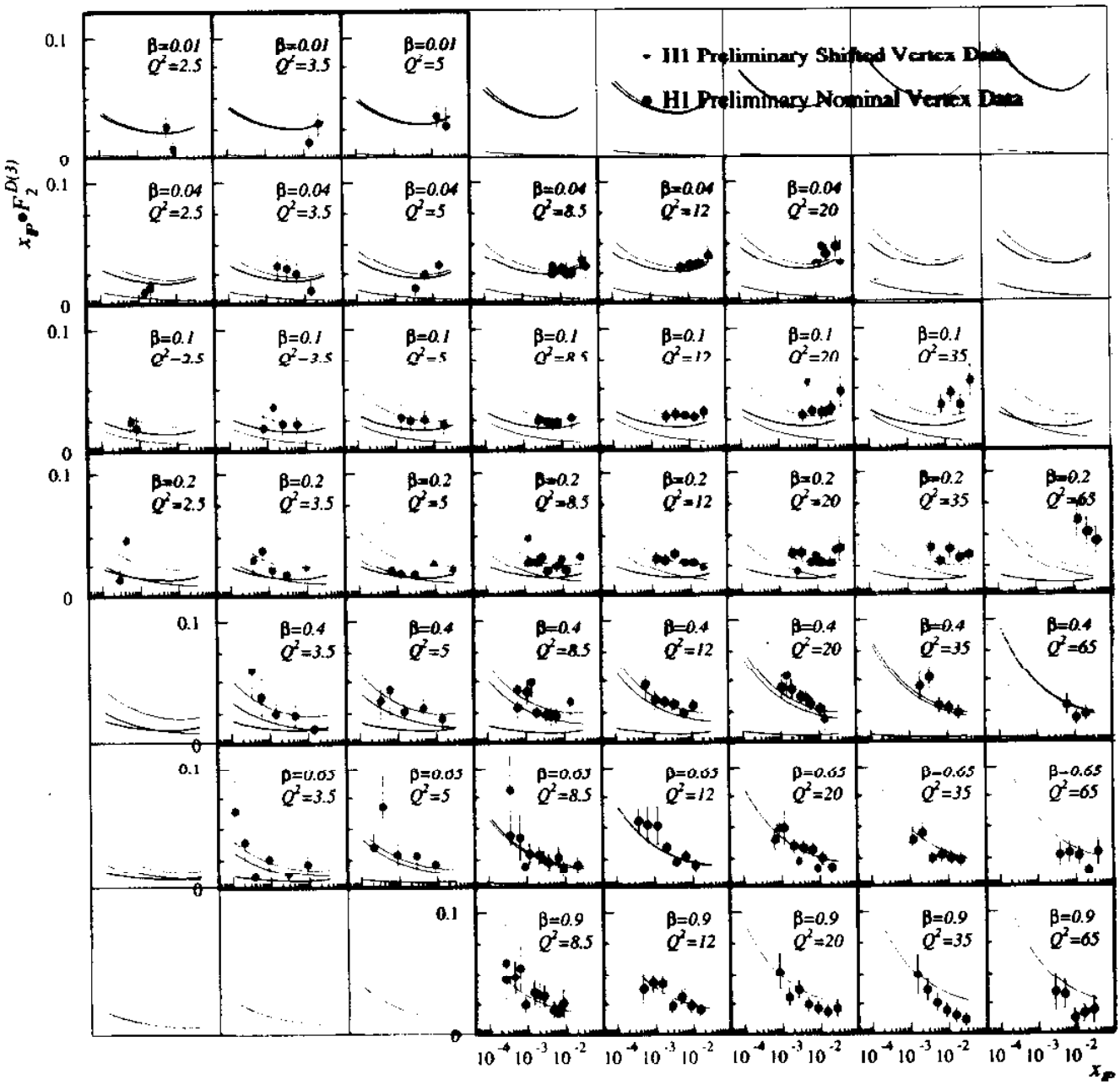
elastic component:





— inelastic component
— elastic component
— sum of both components

Comparison of $F_2^{D(3)}$ Shifted and Nominal Vertex Data



C. Royon, ICHEP 96 Warsaw.
(to be published in '01 ...

Conclusion

The dipole model seems to be relevant for HERA data (moderate Q^2 - small x)

- good description of F_2, xG
- prediction for R
  ($\rightarrow$ possible sizeable difference between DGLAP / BFKL)
- 1st attempt to describe $F_2^{D(3)}$
  $\rightarrow$ prediction
  relatively good agreement with the data.