BEYOND THE CONVENTIONAL POMERON

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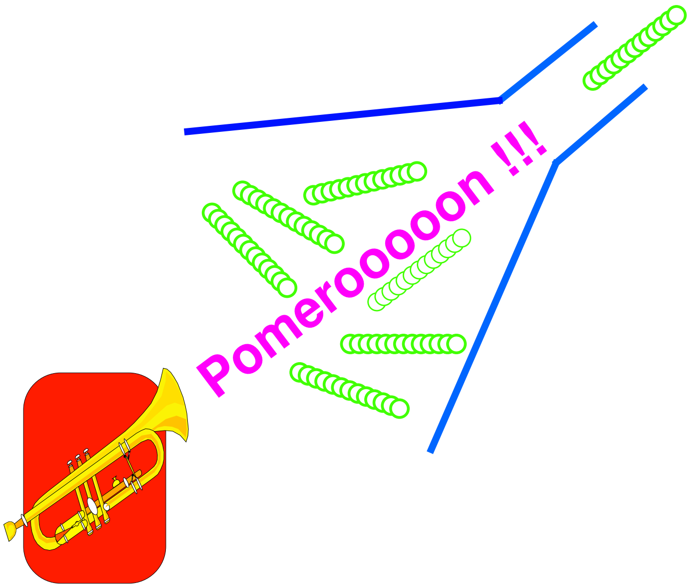
ABSTRACT

Diffractive processes at hadron colliders and at HERA exhibit similar but not identical behaviour to that expected for conventional Pomeron exchange. We present the experimental evidence for beyond the standard Pomeron properties of diffraction and review a phenomenological model in which a Pomeron-like behaviour emerges from the quark-gluon sea of the nucleon. Experimental data on soft and hard diffraction are compared with predictions based on this model.

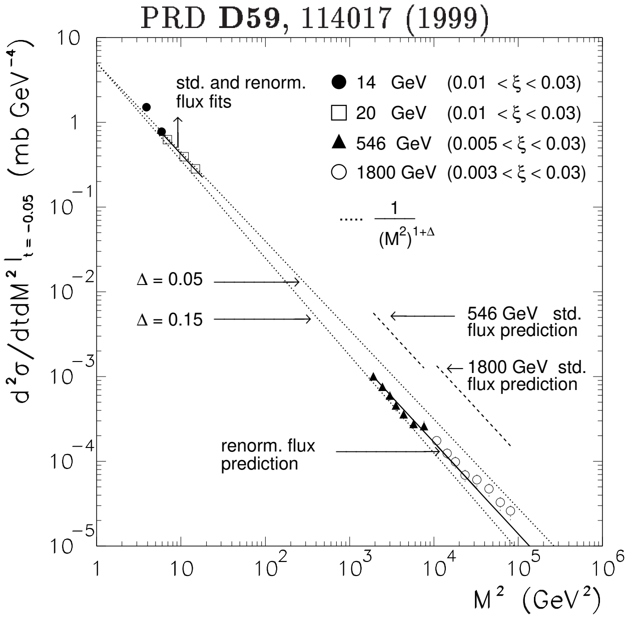


- Introduction
- Elastic and total cross sections
  - Regge approach
  - Parton model approach
- Soft diffraction and multi-gap cross sections
- Hard diffraction

M^2-scaling in diffraction

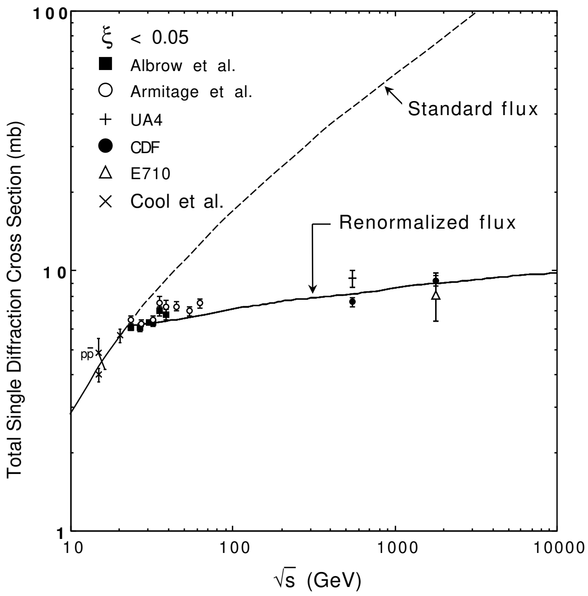
Single Diffraction

K. Goulianos and J. Montanha
PRD **D59**, 114017 (1999)



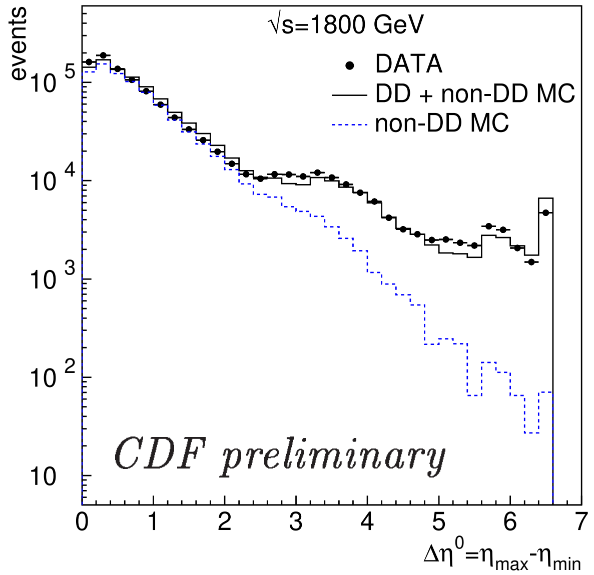
The M^2 dependence of the $\bar{p}p$ single diffraction differential cross section at $t = -0.05$ GeV^2 does not depend on the s-value (M^2-scaling). This is contrary to the Regge theory triple-pomeron prediction of an $s^{2\epsilon}$ dependence.

K. Goulianos, PLB **358**, 379 (1995)

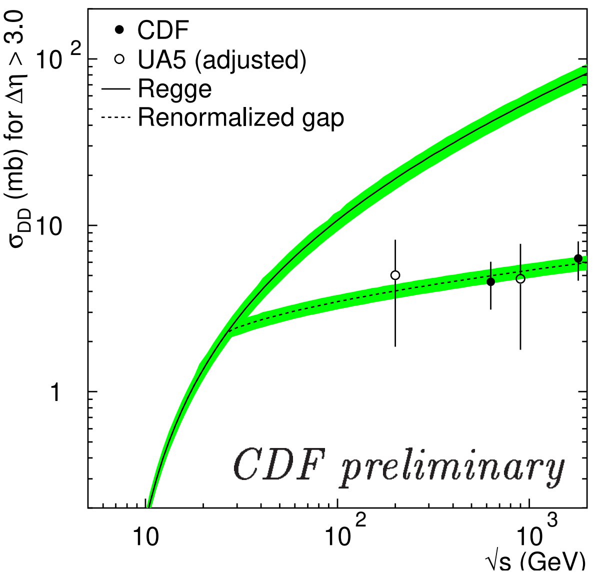


The $\bar{p}p$ total single diffraction cross section has an s-dependence consistent with M^2-scaling, contrary to the Regge theory $s^{2\epsilon}$ behaviour and in agreement with the Pomeron flux renormalization prediction of the above reference.

Double diffraction

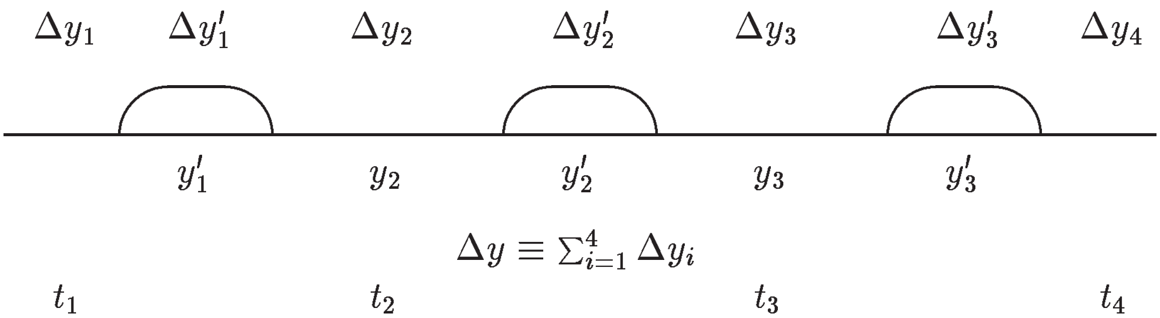


The CDF central rapidity gap data agree in shape with the Monte Carlo prediction for double diffraction dissociation based on Regge theory and factorization.



The σ^T_{DD} agrees with the prediction of the *renormalized rapidity gap* model based on M^2-scaling (KG, hep-ph/9806384), contrary to the $s^{2\epsilon}$ expectation from Regge theory.

Multi-gap cross sections



Rules for calculating multi-gap cross-sections

The high energy cross section for a multi-gap process can be calculated from the parton-model scattering amplitude

$$\mathrm{Im}\, f(t, \Delta y) \sim e^{(\epsilon + \alpha' t)\Delta y}$$

- For the rapidity regions $\Delta y' = \sum_i \Delta y_i'$ where there is particle production, the $t = 0$ parton model amplidude is used and the *sub-energy cross section* is given by $C \cdot e^{\epsilon \Delta y'}$.
- For rapidity gaps, Δy, which can be considered as resulting from elastic scattering between clusters of particles, the square of the full parton-model amplidude is used, $e^{2(\epsilon + \alpha' t_i)\Delta y_i}$, and the form factor $\beta^2(t)$ is included for a surviving (anti)proton.
- The *gap probability* (product of all rapidity gap terms) is normalized to unity.
- A *color factor* κ is included for each gap.

Calculation of the 4-gap differential cross section of the above figure:

- There are 10 independent variables, V_i, shown below the figure.
- $\frac{d^{10}\sigma}{\Pi_{i=1}^{10} dV_i} = P_{gap} \times \sigma(\mathrm{sub-energy})$
- $\sigma(\mathrm{sub-energy}) = \kappa^4 \left[\beta^2(0) \cdot e^{\epsilon \Delta y'}\right]$ $\qquad (\Delta y' = \Sigma_{i=1}^3 \Delta y_i')$
- $P_{gap} = N_{gap} \times \Pi_{i=1}^4 \left[e^{(\epsilon+\alpha' t_i)\Delta y_i}\right]^2 \times [\beta(t_1)\beta(t_4)]^2$

$$P_{gap} = N_{gap} \cdot e^{2\epsilon \Delta y} \cdot f(V_i)|_{i=1}^{10} \qquad (\Delta y = \Sigma_{i=1}^4 \Delta y_i)$$

- N_{gap} : factor that normalizes P_{gap} over all phase space to unity.

Diffractive DIS

Inclusive DIS $\frac{d^2\sigma}{dx\, dQ^2} \sim \frac{1}{x} \cdot F_2(x, Q^2)$

Diffractive DIS $\frac{d^4\sigma}{dt\, d\xi\, d\beta\, dQ^2} \sim \frac{1}{\beta} \cdot F_2^D(t,\, \xi,\, \beta,\, Q^2)$

$$\boxed{x = \beta\xi}$$

$$F_2^D(t,\, \xi,\, \beta\,,Q^2) = f_c \cdot F_2^{\text{sub-energy}}(\beta,\, Q^2) \cdot P_{gap}(t,\, \xi,\, Q^2)$$

$$\boxed{\Delta y = \ln\frac{1}{\xi} \quad \Rightarrow \quad \frac{d\Delta y}{d\xi} = \frac{1}{\xi}}$$

$$P_{gap} = N_{gap} \cdot \frac{1}{\xi} \cdot \left[e^{[(\epsilon + \alpha' t) + \lambda(Q^2)] \ln\frac{1}{\xi}} \right] \cdot \beta^2(t)$$

$$N_{gap}^{-1}(Q^2,\, \xi_{min}) = \int_{\xi_{min}}^{1} \xi^{-[1+\,\epsilon + \lambda + \alpha' t]}\, \beta^2(t)\; dt\, d\xi$$

$$\boxed{\xi_{min} = \frac{x_{min}}{\beta} = \frac{Q^2/s}{\beta} \quad \Rightarrow N_{gap} = f\left(Q^2,\, \frac{Q^2}{s\beta}\right)}$$

Ignoring $t \Rightarrow$ $\qquad N_{gap} = (\epsilon + \lambda) \cdot (Q^2/s\beta)^{\epsilon + \lambda}$

To guarantee factorization at large Q^2:

$(n = \epsilon + \lambda, \quad C = N_{\text{fact}})$

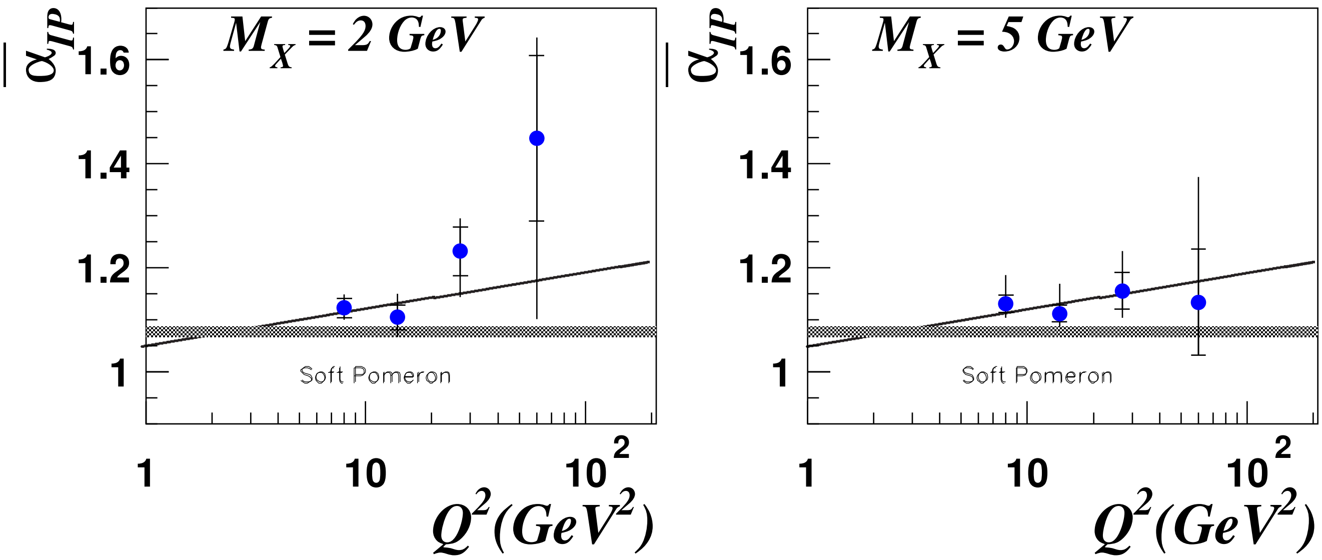
$$\boxed{F_2^D(\xi,\, \beta,\, Q^2) = C \cdot \frac{n}{\xi^{1+n}} \cdot \left[1 - e^{-\frac{1}{C}(Q^2/s\beta)^n}\right] \cdot \left[f_c \cdot \frac{A_\lambda}{\beta^\lambda}\right]}$$

Comparison with HERA data

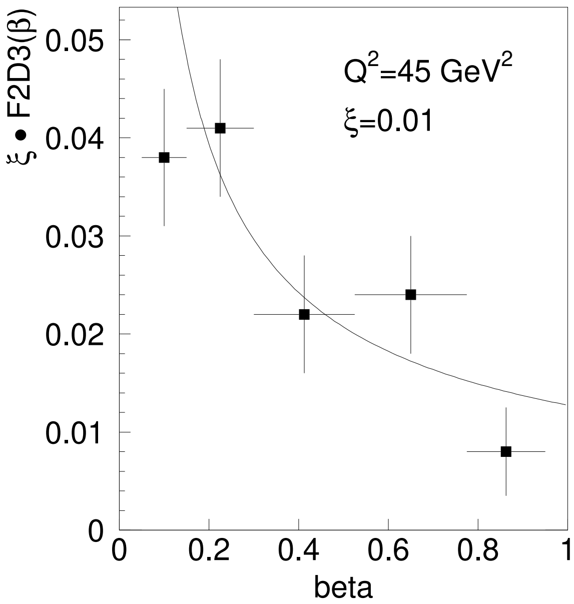
Dependence of $\alpha^{I\!P}(0)$ on Q^2:

$\boxed{\alpha^{I\!P}(0) = 1 + \frac{1}{2}\left[\epsilon + \lambda(Q^2)\right]}$ (use $\epsilon = 0.1$ and $\lambda = 0.1 + 0.053 \ln Q^2$)

ZEUS 1994



Diffractive structure function prediction (hep-ph/0001092)



H1 DATA:
$Q^2 = 45$ BeV^2
$F_2(Q^2 = 50,\ x = 0.00133) = 1.46$
$\Rightarrow F_2(x) = 0.2/x^{0.3}$
$\xi \approx 0.01$

$\epsilon = 0.1$
$\lambda = 0.3$

The solid curve in the figure is predicted using the above data/parameters and $f_c = 0.5$.

CONCLUSIONS

- Soft diffraction
  - A parton-model approach to diffraction was presented based on the observed M^2-scaling (s-independence) in single and double diffraction $\bar{p}p$ differential cross sections, $d\sigma/dM^2$.
  - This approach leads to unitarized cross sections without the need to introduce multi-Pomeron exchanges to account for saturation effects (screening, survival-probability ...).
  - Multi-gap differential cross sections are predicted.

- Hard diffraction
  - Diffractive structure function in DIS:

$$F_2^D(\xi, \beta, Q^2) \sim \frac{1}{\beta^\lambda} \cdot \frac{1}{\xi^{1+\epsilon+\lambda}} \times N_{gap}(Q^2, \beta)$$

  - Dependence of Pomeron intercept on Q^2:

$$\alpha(0) = 1 + \frac{1}{2}[\epsilon + \lambda(Q^2)]$$

  - Ratio of diff/non-diff structure functions at the Tevatron:

$$R \sim 1/x^{\epsilon+\lambda}$$