Diffraction at Tevatron and LHC in the Miettinen-Pumplin model

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OUTLINE

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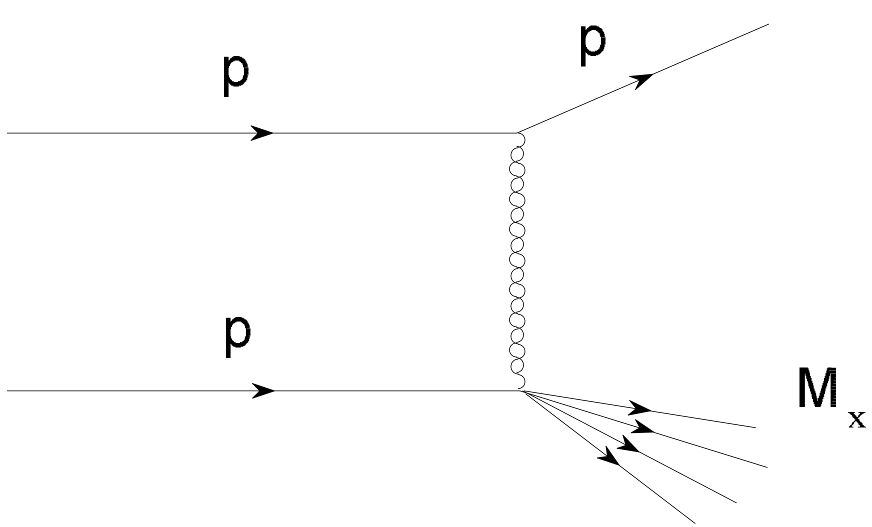
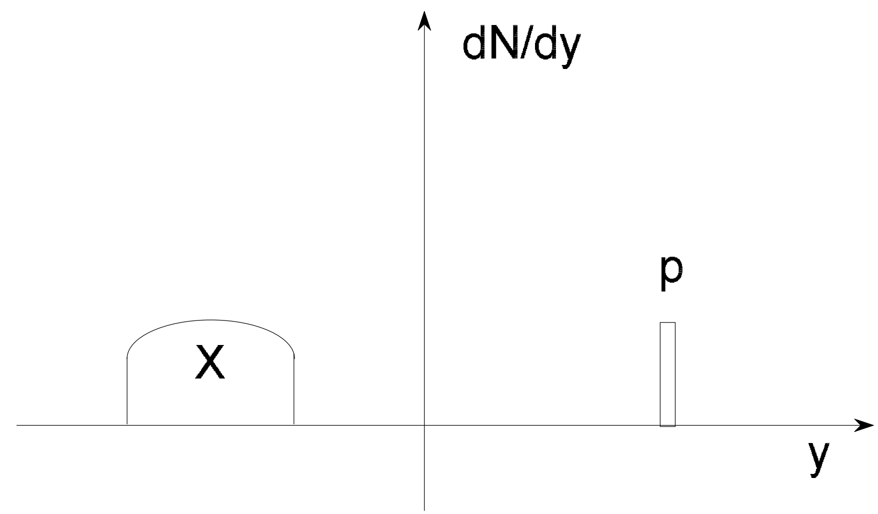
DIFFRACTION

INELASTIC, SINGLE, SOFT



Generic signature of diffraction: RAPIDITY GAP



THE GOOD - WALKER MECHANISM

Proton:

$$| B\rangle = \sum_k C_k \mid \psi_k\rangle$$

Different eigenstates are absorbed by the target with different intensity - inelastic production of particles takes place

Basis $\rightarrow$ EIGENSTATES OF DIFFRACTION

$$ImT \mid \psi_k\rangle = t_k \mid \psi_k\rangle$$

where

$$\langle\psi_i \mid \psi_j\rangle = \delta_{ij} \qquad \langle B \mid B\rangle = \sum_k |C_k|^2 = 1$$

The elastic amplitude - the AVERAGE over absorption coefficients

$$\langle B \mid ImT \mid B \rangle = \sum_k \mid C_k \mid^2 t_k = \langle t \rangle$$

The total and the elastic cross section

$$\frac{d\sigma_{tot}}{d^2\vec{b}} = 2\langle t \rangle \qquad \frac{d\sigma_{el}}{d^2\vec{b}} = \langle t \rangle^2$$

The cross section for diffractive production - the DISPERSION of absorption coefficients

$$\begin{aligned} \frac{d\sigma_{diff}}{d^2\vec{b}} &= \sum_k \mid \langle \psi_k \mid ImT \mid B \rangle \mid^2 - \frac{d\sigma_{el}}{d^2\vec{b}} \\ &= \sum_k \mid C_k \mid^2 t_k^2 - (\sum_k \mid C_k \mid^2 t_k)^2 = \langle t^2 \rangle - \langle t \rangle^2 \end{aligned}$$

THE MIETTINEN - PUMPLIN MODEL

Diffractive states $\rightarrow$ WEE PARTON STATES

$$| \psi_k \rangle \equiv | \vec{b_1}, ..., \vec{b_N}, y_1, ..., y_N \rangle$$

hence

$$| B \rangle \quad = \quad \sum_{N=0}^{\infty} \int \prod_{i=1}^{N} d^2 \vec{b_i} dy_i C_N(\vec{b_1}, ..., \vec{b_N}, y_1, ..., y_N) \mid \vec{b_1}, ..., \vec{b_N} \; y_1, ..., y_N \rangle$$

N $\rightarrow$ given by Poisson distribution with mean number G^2

$$| C_N(\vec{b_1}, ..., \vec{b_N}, y_1, ..., y_N) |^2 = e^{-G^2} \frac{G^{2N}}{N!} \prod_{i=1}^{N} | C(\vec{b_i}, y_i) |^2$$

Partons in the projectile are uncorrelated

THE MIETTINEN - PUMPLIN MODEL

The probability of the parton state to interact

$$t_N(\vec{b_1}, ..., \vec{b_N}, y_1, ..., y_N) = 1 - \prod_{i=1}^{N}(1 - \tau_i(\vec{b}_i, y_i))$$

Partons interact independently with the target

THE MIETTINEN - PUMPLIN MODEL

Single wee parton probability distribution

$$| C(b,y) |^2 = \frac{1}{2\pi\beta\lambda} \exp\left(-\frac{| y |}{\lambda} - \frac{b^2}{\beta} \right)$$

Interaction probability of a single wee parton

$$\tau(b,y) = A \exp\left(-\frac{| y |}{\alpha} - \frac{b^2}{\gamma} \right)$$

The parameters

$\lambda \quad \beta \quad \alpha \quad \gamma \quad A \quad G^2$

Miettinen and Pumplin set:

$A = 1 \quad \alpha/\lambda = 2.0 \quad \gamma/\beta = 2.0$

THE MIETTINEN - PUMPLIN MODEL

Three equations

$$\frac{d\sigma_{tot}}{d^2\vec{b}} = 2\left[1 - \exp\left(-G^2\frac{4}{9}e^{-b^2/(3\beta)}\right)\right]$$

$$\frac{d\sigma_{el}}{d^2\vec{b}} = \left[1 - \exp\left(-G^2\frac{4}{9}e^{-b^2/(3\beta)}\right)\right]^2$$

$$\frac{d\sigma_{diff}}{d^2\vec{b}} = \exp\left(-2G^2\frac{4}{9}e^{-b^2/(3\beta)}\right) \cdot \left[\exp\left(G^2\frac{1}{4}e^{-b^2/(2\beta)}\right) - 1\right]$$

Two parameters: $\beta \quad G^2$

$\sigma_{tot}, \sigma_{el}$ (experiment)

$$\downarrow$$

$$\beta \quad G^2$$

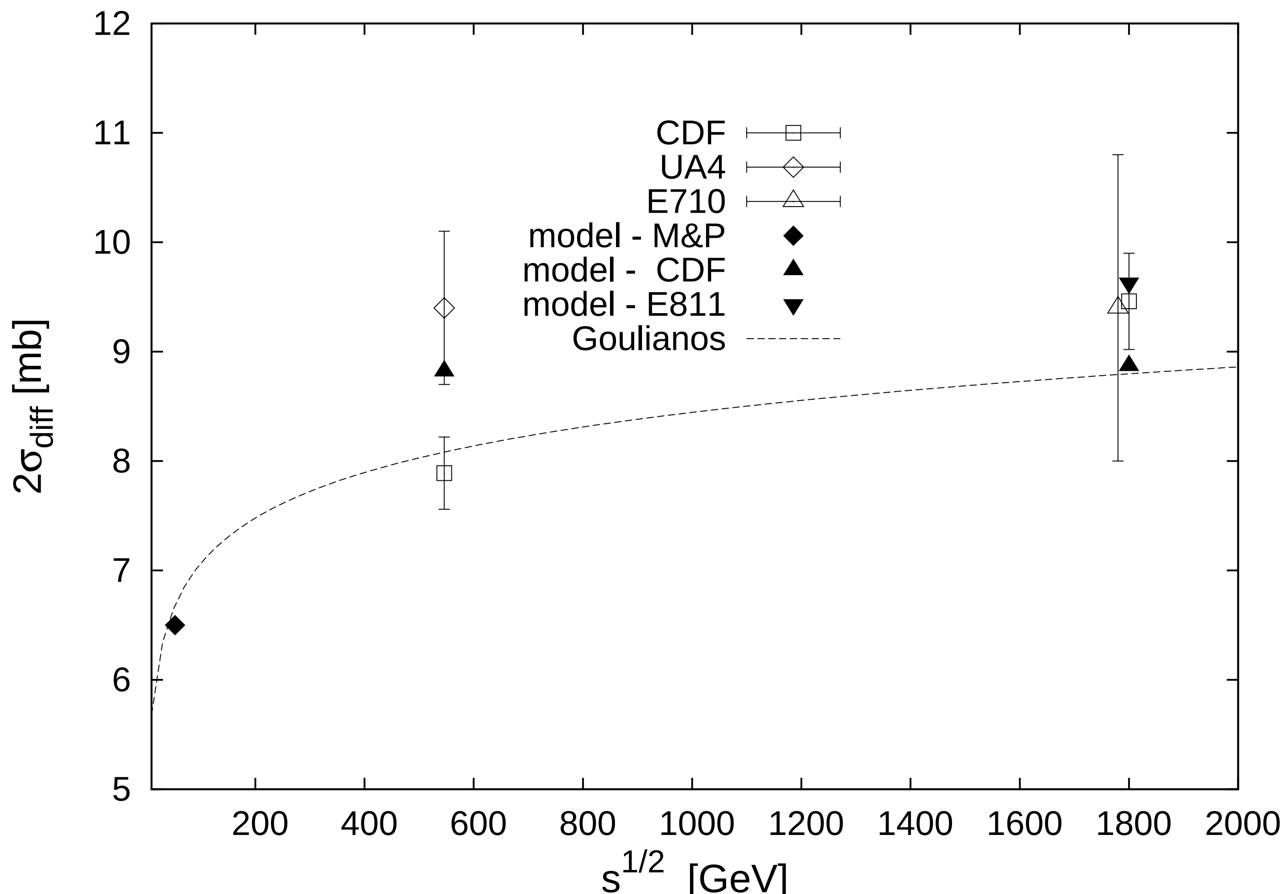
$$\downarrow$$

$$\frac{d\sigma_{diff}}{d^2\vec{b}}, \sigma_{diff}, \frac{d\sigma_{diff}}{dt}$$

In 1978 Miettinen and Pumplin performed calculations within their model for two colliding protons at $\sqrt{s} = 53\,\mathrm{GeV}$. The results were in very good agreement with experimental data.

THE MIETTINEN - PUMPLIN MODEL AT TEVATRON ENERGIES

Data	$\sqrt{s}\ [GeV]$	$\sigma_{tot}\ [mb]$	$\sigma_{el}\ [mb]$	G^2	$\beta\ [GeV^{-2}]$	$2\sigma_{diff}\ [mb]$
ISR	53	43	8.7	2.91	6.0	6.51
CDF	546	61.26	12.87	3.12	8.2	8.82
E811	1800	71.71	15.79	3.38	9.0	9.63
CDF	1800	80.03	19.70	4.20	8.6	8.87



ELASTIC AND DIFFRACTIVE SLOPES

Momentum transfer $|t|$ dependent cross sections obtained by Fourier transform.

Parametrization for $|t| < 0.2\ \mathrm{GeV}^2$

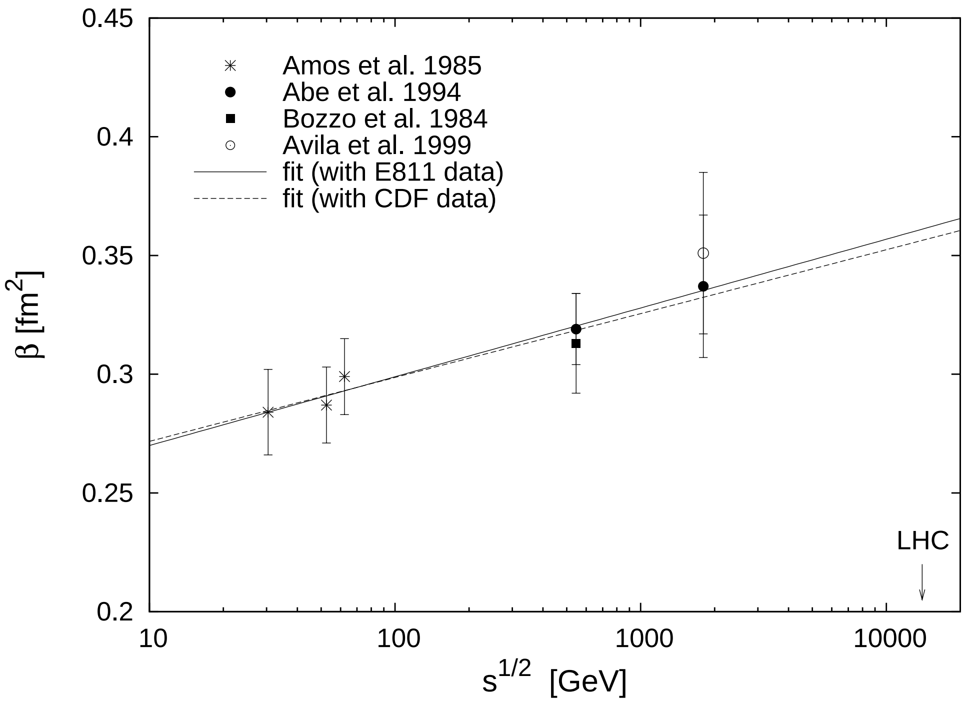
$$\frac{d\sigma}{dt} = \left.\frac{d\sigma}{dt}\right|_{t=0} e^{-B|t|}$$

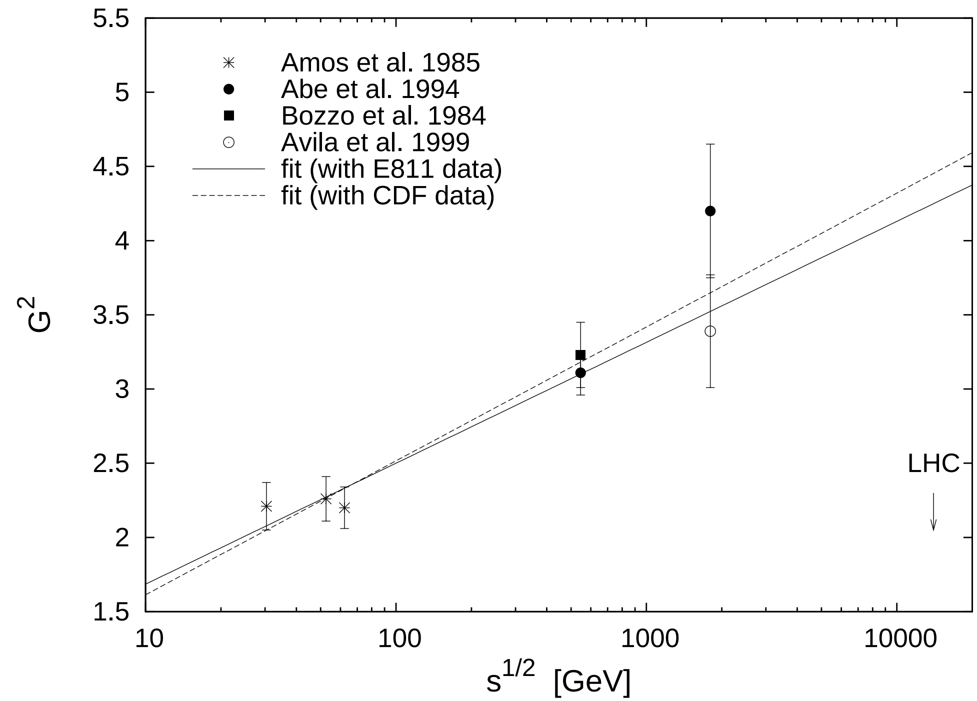
Data sets	$\sqrt{s}$	B_{el}	Experiment
ISR	30.4	12.4	12.70 ± 0.50
ISR	52.6	12.6	13.03 ± 0.52
ISR	62.3	13.1	13.47 ± 0.52
CDF	546	14.8	15.28 ± 0.58
UA4	546	14.7	15.20 ± 0.20
E811	1800	16.9	16.98 ± 0.25
CDF	1800	17.1	16.99 ± 0.47

Data sets	$\sqrt{s}$	B_{diff}	Experiment
E710	1800	10.4	10.5 ± 1.8

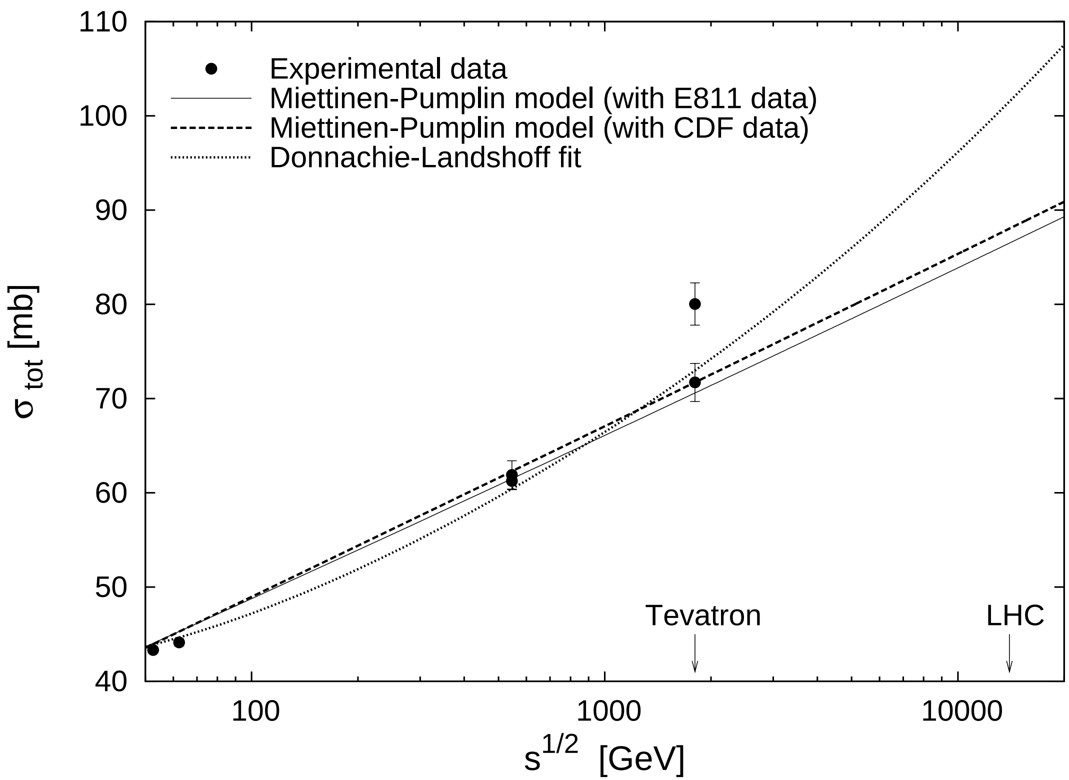
($\sqrt{s}$ in GeV and $\mathrm{B_{el}}$, $\mathrm{B_{diff}}$ in GeV^{-2})

EXTRAPOLATION OF THE PARAMETERS OF THE MODEL





PREDICTIONS FOR LHC - TOTAL AND ELASTIC CROSS SECTION



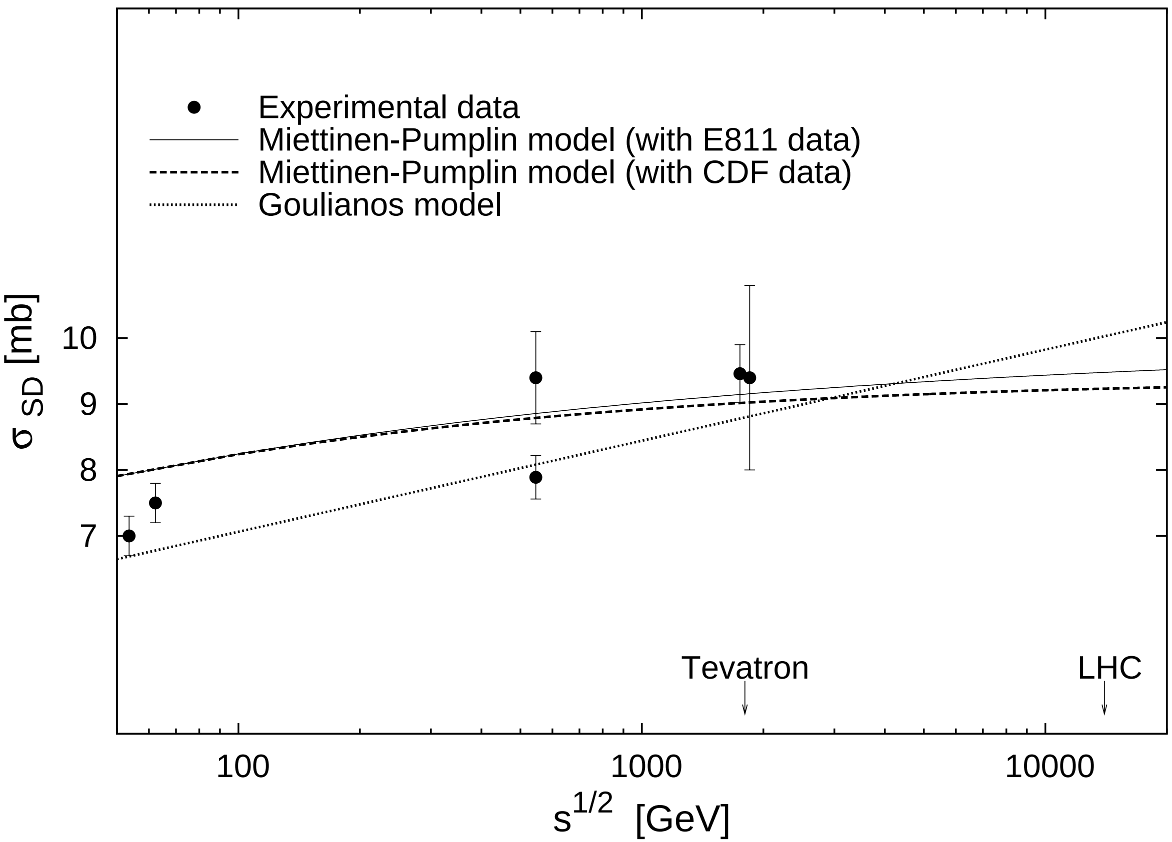
Scenarios	σ_{tot} [mb]	σ_{el} [mb]
with E811 data	86 ± 4	21 ± 1
with CDF data	88 ± 4	22 ± 2

The total cross section 15% smaller than determined by Donnachie and Landshoff

At high $\sqrt{s}$

$$\sigma_{tot} \propto \ln(s)\, \ln(\ln s)$$

PREDICTIONS FOR LHC - DIFFRACTIVE CROSS SECTION



Scenarios	σ_{diff} [mb]
with E811 data	9.5 ± 0.4
with CDF data	9.2 ± 0.5

The diffractive cross section almost constant at Tevatron-LHC energy range

The behaviour of the diffractive cross section at the Miettinen-Pumplin and the Goulianos models is qualitatively different

SUMMARY

- The Miettinen – Pumplin despite its simplicity and *ad hoc* assumptions correctly describes diffractive production at Tevatron energies
- Good agreement of the calculated values of the slope parameters with experimental data makes the model trustworthy
- Extrapolation of the parameters of the model to the LHC energy results in the prediction for the total cross section 15% smaller than determined by Donnachie and Landshoff
- The Miettinen – Pumplin model predicts almost constant diffractive cross section in the Tevatron–LHC energy range