Diffractive Dissociation at LHC

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- see recent Khoze, Martin, Ryskin results (Durham/St. Petersburg group)

In special:

- KMR: multi-ch eikonal + multi-Regge + ∼BFKL q_t diffusion [hep-ph/0710.2494]
- Shuvaev+KMR: $pp \to p + A + p$, e.g. $A = H \to bb \Rightarrow$ irreducible $gg \to bb$ QCD background suppressed at NLO [hep-ph/0806.1447]
- Luna+KMR: 2-ch eikonal + triple-Pomeron analysis $\Rightarrow$ screening corrections systematically included $\Rightarrow g_{3I\!P}$ coupling consistent with the reasonable extrapolation of the perturbative BFKL Pomeron vertex to the low scale region [hep-ph/0807.4115]

THE MODEL

- In our model the Born level amplitude is written as

$$\mathcal{A}_{Born}(s,t) = \mathcal{A}_{I\!P}(s,t) + \mathcal{A}_{a/f}(s,t) + \tau\mathcal{A}_{\omega/\rho}(s,t)$$

and the opacity (or eikonal) $\Omega(s,b)$ is given by

$$\Omega(s,b) = \frac{2}{s}\int_0^\infty q\,dq\,J_0(bq)\,\mathcal{A}_{Born}(s,t).$$

- The Pomeron contribution is given by

$$\mathcal{A}_{I\!P}(s,t) = i\beta_{I\!P}^2(t)\left(\frac{s}{s_0}\right)^{\alpha_{I\!P}(t)},$$

$$\alpha_{I\!P}(t) = \alpha(0) + \alpha' t + \frac{\beta_\pi^2 m_\pi^2}{32\pi^3}\, h\left(\frac{4m_\pi^2}{|t|}\right) \qquad (1)$$

$\Rightarrow$ last term of expression (1) generated by t-channel unitarity $\Rightarrow$ pion-loop insertions

- thus the eikonalized amplitude is given by:

$$\mathcal{A}(s,t)=is\int_0^\infty b\,db\,J_0(bq)\left[1-\frac{e^{-\frac{\Omega}{2}(1+\gamma)^2}}{4}-\frac{e^{-\frac{\Omega}{2}(1-\gamma^2)}}{2}-\frac{e^{-\frac{\Omega}{2}(1-\gamma)^2}}{4}\right],$$

  where $\gamma = 0.55 \Rightarrow s$-channel unitarity with elastic and a low mass M^2 intermediate state via a 2-ch eikonal approach (using a representative effective low mass proton excitation N^*)

- the elastic ant total cross section are given by

$$\frac{d\sigma_{el}}{dt}(s,t) = \frac{\pi}{s^2}\,|\mathcal{A}(s,t)|^2,$$

$$\sigma_{tot}(s) = \frac{4\pi}{s}\,\mathrm{Im}\,\mathcal{A}(s,t=0).$$

- in the triple-Regge description (see Figure I) of high mass diffractive dissociation we have

$$M^2 \frac{d\sigma}{dtdM^2} = \beta_j(0)\beta_i^2(t)g_{iij}(t)\left(\frac{s}{M^2}\right)^{2\alpha_i(t)-2}\left(\frac{M^2}{s_0}\right)^{2\alpha_j(0)-1}$$

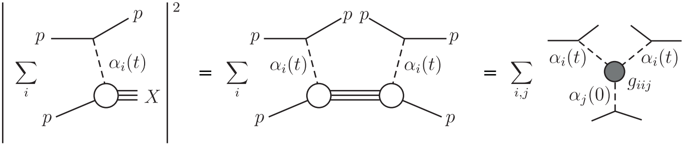

Figure I: *The triple-Regge description of high-mass diffractive dissociation* $pp \to pX$

- screening effects are best included by working in impact parameter space and using suppression factors of the form $\exp(-\Omega(b))$

$\Rightarrow$ to determine the t dependence we take the Fourier transforms with respect to the impact parameter:

$$M^2 \frac{d\sigma}{dtdM^2} = A \int \frac{d^2 b_2}{2\pi} e^{i\vec{q}_t \cdot \vec{b}_2} F_i(b_2) \int \frac{d^2 b_3}{2\pi} e^{i\vec{q}_t \cdot \vec{b}_3} F_i(b_3) \int \frac{d^2 b_1}{2\pi} F_j(b_1) \quad (2)$$

where

$$F_i(b_2) = \frac{1}{2\pi\beta_i} \int d^2 q_t \beta_i(q_t) \left(\frac{s}{M^2}\right)^{-\alpha_i' q_t^2} e^{-b_{iij}' q_t^2} e^{i\vec{q}_t \cdot \vec{b}_2},$$

$$F_j(b_1) = \frac{1}{2\pi\beta_j} \int d^2 k_t \beta_j(k_t) \left(\frac{M^2}{s_0}\right)^{-\alpha_j' k_t^2} e^{-b_{iij}' k_t^2},$$

$$A = \beta_j(0)\beta_i^2(0) g_{iij}(0) \left(\frac{s}{M^2}\right)^{2\alpha_i(0)-2} \left(\frac{M^2}{s_0}\right)^{\alpha_j(0)-1}.$$

- to calculate screening corrections we must include in the integrands on the right-hand side of (2) the factors

$$\exp(-\frac{\Omega(\vec{b}_2+\vec{b}_1)}{2})\exp(-\frac{\Omega(\vec{b}_3+\vec{b}_1)}{2}) \equiv S(\vec{b}_2+\vec{b}_1)S(\vec{b}_3+\vec{b}_1)$$

$\Rightarrow$ that is, we need to compute

$$M^2\,\frac{d\sigma}{dtdM^2}\bigg|_{iij} = A\int\frac{d^2b_1}{2\pi}F_j(b_1)|I_d(b_1)|^2$$

where

$$I_d(b_1) \equiv \int\frac{d^2b_2}{2\pi}\,e^{i\vec{q}_t\cdot\vec{b}_2}\,F_i(b_2)\,S_i(\vec{b}_2+\vec{b}_1).$$

- the generalization to a two-channel eikonal takes into account the Pomeron couplings to each diffractive eigen component k to be $\beta_{I\!P,k}(t) = (1\pm\gamma)\beta_{I\!P}(t)$

DETERMINATION OF THE TRIPLE-POMERON VERTEX

- first step: global fit to total and differential cross sections $\Rightarrow$ model including low mass diffraction, pion loop insertions in the Pomeron trajectory, and rescattering effects via a two-channel eikonal
- second step: generalization of screening calculations to a two-channel eikonal $\Rightarrow$ large expressions $\Rightarrow$ hard computational task
- third step: triple-Regge analysis of $pp \to pX$ data $\Rightarrow$ all the screened effects included $\Rightarrow$ determination of the triple-Pomeron coupling $g_{3I\!P}(0)$

$\Rightarrow$ it is important to distinguish between the *weak* and *strong* triple-Pomeron coupling behaviours

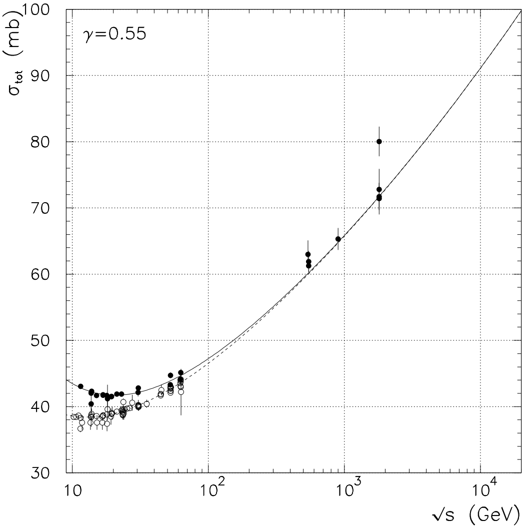

Figure II: *Two-channel model description of total cross section data*

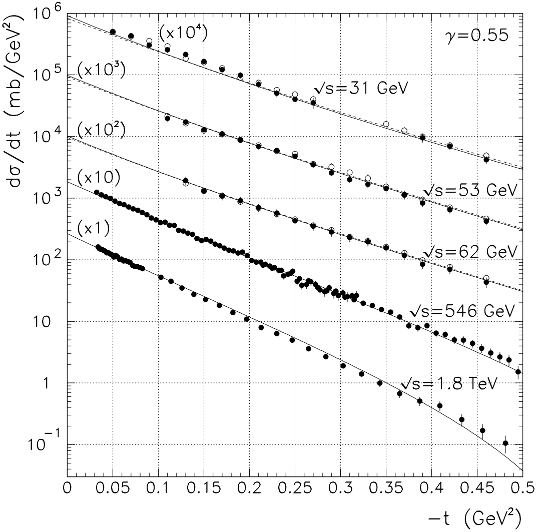

Figure III: *Two-channel model description of differential cross section data*

- the energy behaviour of the scattering amplitude may be consistently described by two different scenarios for the asymptotic regime $\Rightarrow$ *weak* $\times$ *strong* $I\!P$-couplings
- in the weak coupling scenario σ_{tot} tends to the universal constant value: $\sigma_{tot} \to$ constant as $s \to \infty$
  $\Rightarrow$ in order to not violate unitarity $g_{3I\!P} \propto q_t^2$ as $q_t^2 \to 0$
- in the strong coupling scenario the cross section grows as $\sigma_{tot} \propto (\ln s)^\eta$ with $q_t \to 0$
  $\Rightarrow$ in this case the bare vertex $g_{3I\!P}|_{q_t \to 0} \to$ constant

$\Rightarrow$ we see from a χ^2 analysis that the data clearly prefer the *strong* triple-Pomeron coupling

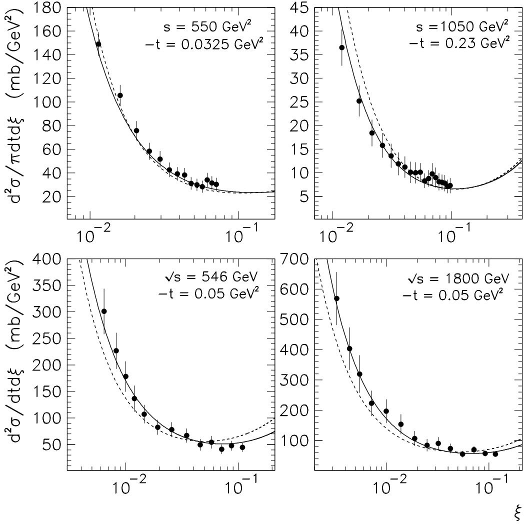

Figure IV: *The description of a sample of the $d^2\sigma/dtd\xi$ cross section data that are fitted using the strong (continuous curves) and weak (dashed curves) triple-Pomeron coupling ansatzes ($\xi \simeq M^2/s$).*

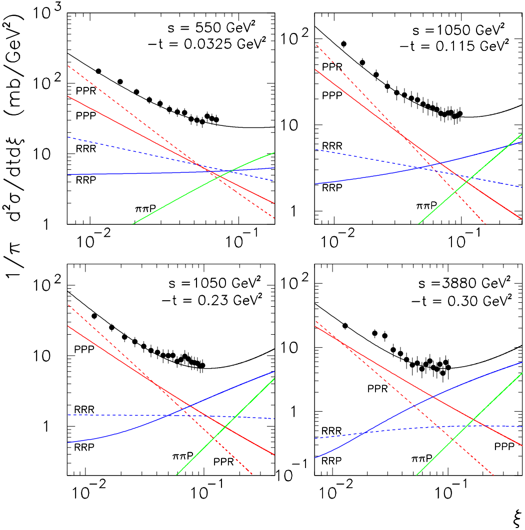

Figure V: *The description of the CERN-ISR* $pp \rightarrow pX$ *cross section data obtained in the strong triple-Pomeron coupling scenario*.

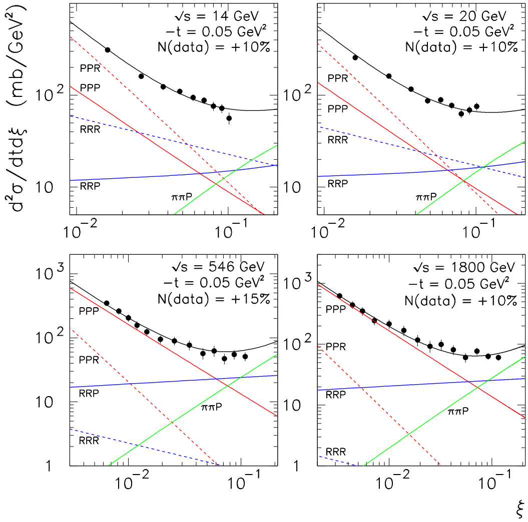

Figure VI: *The description of the* $d^2\sigma/dtd\xi$*, measured in fixed-target and collider experiments at FNAL (strong triple-Pomeron coupling scenario)*.

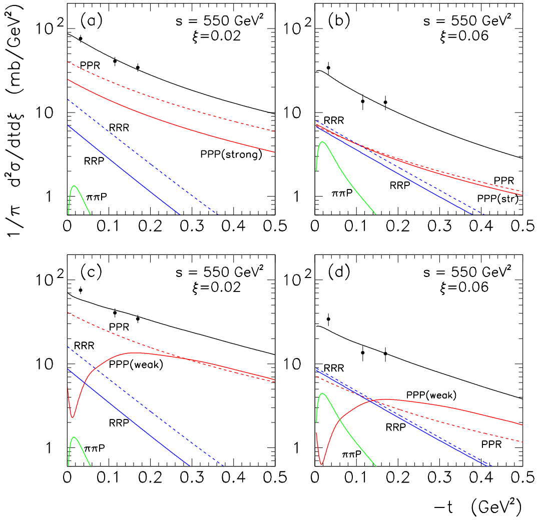

Figure VII: *The t-dependence of the* $d^2\sigma/dtd\xi$ *at* $\xi = 0.02, 0.06$ *and* $s = 550$ *GeV²* *obtained in the strong and weak triple-Pomeron fits.*

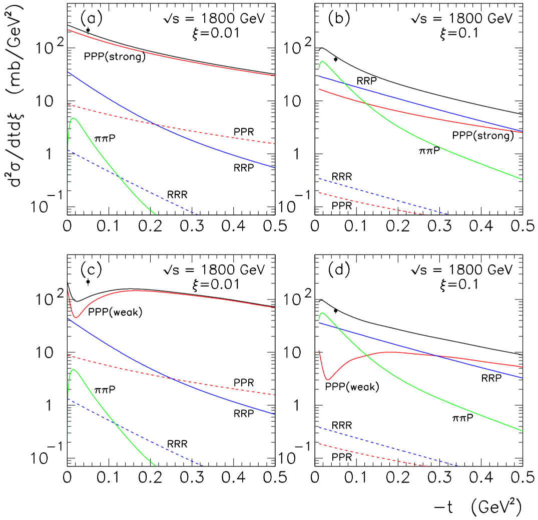

Figure VIII: *The t-dependence of the* $d^2\sigma/dtd\xi$ *at* $\xi = 0.01, 0.1$ *and* $\sqrt{s} = 1800$ *GeV obtained in the strong and weak triple-Pomeron fits.*

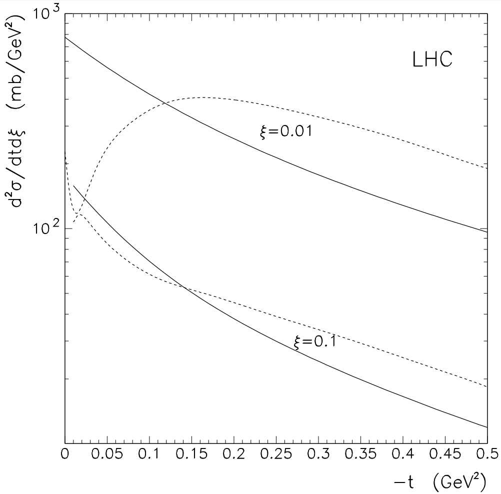

Figure IX: *The continuous curves are the predictions for the t-dependence of the $d^2\sigma/dtd\xi$ at $\xi = 0.01$, 0.1 and $\sqrt{s} = 14$ TeV in the strong triple-Pomeron fit. The disfavoured weak coupling predictions are shown by dashed curves.*

- the process $\gamma p \to J/\psi + Y$ at large values of M_Y offers, in principle, an opportunity to determine the triple-Pomeron coupling where the screening corrections are smaller than in the pure hadronic reactions

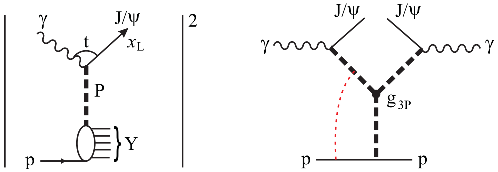

Figure X: *The process of proton dissociation in diffractive J/ψ photoproduction, $\gamma p \to J/\psi + Y$, which is described by a diagram with a triple-Pomeron vertex in which the rescattering effects are small. The dotted line would mean the diagram became an enhanced diagram*.

$\Rightarrow$ unfortunately the M_Y^2 distribution has not measured yet...

- however there exists a comparison of the HERA data for the "elastic" photoproduction process, $\gamma p \to J/\psi + p$ with the proton dissociation data
$\Rightarrow$ the ratio, at the photon-proton centre-of-mass energy $W = 200$ GeV and $t = 0$ is (ZEUS, H1):

$$r \equiv \frac{d\sigma(\gamma p \to J/\psi + Y)/dt}{d\sigma(\gamma p \to J/\psi + p)/dt} \simeq 0.2, \qquad (3)$$

where the "inelastic" cross section has been integrated over the mass region $M_Y < 30 GeV$.

- our analysis gives $r = r_{3I\!P} + r_{I\!PI\!PI\!R} = 0.12 + 0.06$
$\Rightarrow$ this result is consistent with HERA data, within the uncertainties.

- in our formalism

$$r_{3I\!P} = \frac{g_{3I\!P}}{\pi \beta_{I\!P}} \int \frac{dM^2}{M^2} \left(\frac{W^2}{M^2}\right)^{2\hat{\alpha}_{I\!P}-2} \left(\frac{M^2}{s_0}\right)^{2\alpha_{I\!P}(0)-1} \tag{4}$$

$$r_{I\!PI\!PI\!R} = \frac{g_{I\!PI\!PI\!R}}{\pi \beta_{I\!P}} \int \frac{dM^2}{M^2} \left(\frac{W^2}{M^2}\right)^{2\hat{\alpha}_{I\!P}-2} \left(\frac{M^2}{s_0}\right)^{2\alpha_{I\!R}(0)-1} \tag{5}$$

$\Rightarrow$ here $\alpha_P(0)$ is the usual “soft” Pomeron
$\Rightarrow$ $\hat{\alpha}_P$ include DGLAP evolution from a low initial scale $\mu = \mu_0$ up to a rather large scale $\mu = M_{J/\psi}$ at the J/ψ production vertex
$\Rightarrow$ the summation of the double logarithms $(\alpha_s \ln(1/x) \ln(\mu^2/\mu_0^2))^n$ leads to a steeper x-dependence and hence to a larger effective intercept $\longrightarrow$ we adopt $\hat{\alpha}_P = 1.18$, which corresponds to the W dependence observed in the HERA data

CONCLUSIONS

- we have described a global analysis of available pp and $p\bar{p}$ in CERN-ISR to Tevatron energy range
- first triple-Pomeron analysis including screening corrections $\Rightarrow$ screening corrections vital $\Rightarrow$ we can use this analysis to predict the diffractive effects at the LHC
- we have obtained $g_{3I\!P}(0) = 0.44 \pm 0.06$ GeV^{-1} $\Rightarrow$ this coupling is supported by an analysis of J/ψ photoproduction data measured at HERA $\Rightarrow$ $g_{3I\!P}(0)$ value consistent with the reasonable extrapolation of the perturbative BFKL Pomeron vertex to the low scale region
- model predict $\sigma_{tot} \sim 94.8$ mb at LHC, due to screening
- soft-hard transition emerges:
  $\Rightarrow$ "soft" compt. $\longrightarrow$ heavily screened $\longrightarrow$ little growth with s
  $\Rightarrow$ "intermediate" compt. $\longrightarrow$ some screening
  $\Rightarrow$ "hard" compt. $\longrightarrow$ little screening $\longrightarrow$ large growth with s ($\sim$ pQCD)