Phenomenology of single and double diffraction dissociation

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Predictions of the gap-probability renormalization model for single and double diffraction dissociation cross sections in proton-proton collisions at the LHC are presented and compared with recent CMS measurements.

1 Introduction

Measurements at the LHC have shown that there are sizable disagreements among Monte Carlo (MC) implementations of "soft" processes based on cross sections proposed by various physics models, and that it is not possible to reliably predict all such processes, or even all aspects of a given process, using a single model [1, 2, 3]. In the CDF studies of diffraction at the Tevatron, all processes are well modeled by the MBR (Minimum Bias Rockefeller) MC simulation, which is a stand-alone simulation based on a unitarized Regge-theory model, RENORM [4], employing inclusive nucleon parton distribution functions (PDF's) and QCD color factors. The RENORM model was updated in a presentation at EDS-2009 [5] to include a unique unitarization prescription for predicting the total pp cross section at high energies, and that update has been included as an MBR option for simulating diffractive processes in PYTHIA8 since version PYTHIA8.165 [6], to be referred here-forth as PYTHIA8-MBR. In this paper, we briefly review the cross sections [7] implemented in this option of PYTHIA8 and compare the SD and DD predictions with LHC measurements.

2 Cross sections

The following diffraction dissociation processes are considered in PYTHIA8-MBR:

$$\begin{array}{lll} \text{SD} & pp \to Xp & \text{Single Diffraction (or Single Dissociation),} \\ \text{or} & pp \to pY & \text{(the other proton survives)} \end{array} \quad (1)$$

$$\text{DD} \quad pp \to XY \quad \text{Double Diffraction (or Double Dissociation),} \quad (2)$$

$$\text{CD (or DPE)} \quad pp \to pXp \quad \text{Central Diffraction (or Double Pomeron Exchange).} \quad (3)$$

The RENORM predictions are expressed as unitarized Regge-theory formulas, in which the unitarization is achieved by a renormalization scheme where the Pomeron ($I\!P$) flux is interpreted as the probability for forming a diffractive (non-exponentially suppressed) rapidity gap and thereby its integral over all phase space saturates at the energy where it reaches unity. Differential cross sections are expressed in terms of the $I\!P$-trajectory, $\alpha(t) = 1 + \epsilon + \alpha' t =$

$1.104 + 0.25\ (\text{GeV}^{-2}) \cdot t$, the $I\!\!P$-p coupling, $\beta(t)$, and the ratio of the triple-$I\!\!P$ to the $I\!\!P$-p couplings, $\kappa \equiv g(t)/\beta(0)$. For large rapidity gaps, $\Delta y \geq 3$, for which $I\!\!P$-exchange dominates, the cross sections may be written as,

$$\frac{d^2\sigma_{SD}}{dtd\Delta y} = \frac{1}{N_{\rm gap}(s)} \left[\frac{\beta^2(t)}{16\pi} e^{2[\alpha(t)-1]\Delta y}\right] \cdot \left\{\kappa\beta^2(0)\left(\frac{s'}{s_0}\right)^{\epsilon}\right\}, \tag{4}$$

$$\frac{d^3\sigma_{DD}}{dtd\Delta y dy_0} = \frac{1}{N_{\rm gap}(s)} \left[\frac{\kappa\beta^2(0)}{16\pi} e^{2[\alpha(t)-1]\Delta y}\right] \cdot \left\{\kappa\beta^2(0)\left(\frac{s'}{s_0}\right)^{\epsilon}\right\}, \tag{5}$$

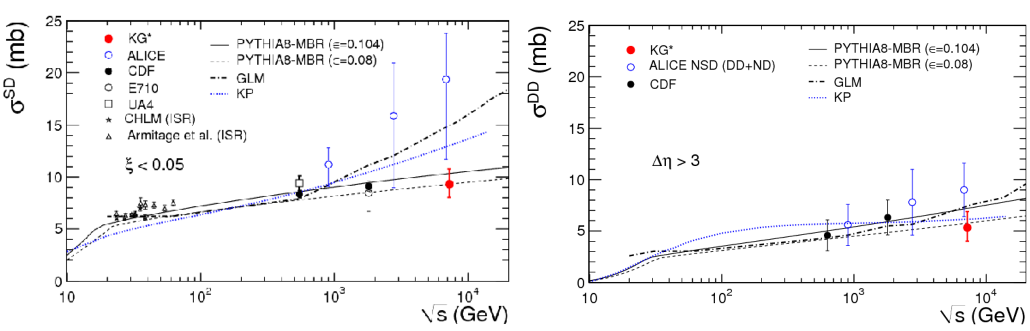
$$\frac{d^4\sigma_{DPE}}{dt_1 dt_2 d\Delta y dy_c} = \frac{1}{N_{\rm gap}(s)} \left[\Pi_i \left[\frac{\beta^2(t_i)}{16\pi} e^{2[\alpha(t_i)-1]\Delta y_i}\right]\right] \cdot \kappa \left\{\kappa\beta^2(0)\left(\frac{s'}{s_0}\right)^{\epsilon}\right\}, \tag{6}$$

where t is the 4-momentum-transfer squared at the proton vertex, Δy the rapidity-gap width, and y_0 the center of the rapidity gap. In Eq. (6), the subscript $i = 1, 2$ enumerates Pomerons in a DPE event, $\Delta y = \Delta y_1 + \Delta y_2$ is the total rapidity gap (sum of two gaps) in the event, and y_c is the center in η of the centrally-produced hadronic system.

3 Results

In this section, we present as examples of the predictive power of the RENORM model some results reported by the TOTEM, CMS, and ALICE collaborations for pp collisions at $\sqrt{s} = 7$ TeV, which can be directly compared with RENORM formulas without using the PYTHIA8-MBR simulation.

Another example of the predictive power of RENORM is shown in Fig. 2, which displays the total SD (left) and total DD (right) cross sections for $\xi < 0.05$, after extrapolation into the low mass region from the measured CMS cross sections at higher mass regions, presented in [8], using RENORM.



KG*: this "data" point was obtained after extrapolation into the unmeasured low mass region(s) from the measured CMS cross sections [8] using the MBR model.

Figure 1: Measured SD (left) and DD (right) cross sections for $\xi < 0.05$ compared with theoretical predictions; the model embedded in PYTHIA8-MBR provides a good description of all data.

4 Summary

Pre-LHC predictions for the SD and DD cross sections at high energies, based on the RENORM special parton-model approach to diffraction, employing inclusive proton parton distribution functions and QCD color factors have been reviewed. The predictions of the model are in good agreement with the CMS results presented at this conference [9].

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