UPDATED RENORM/MBR PREDICTIONS FOR DIFFRACTION AT THE LHC*

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Updated RENORM/MBR-model predictions of diffractive, total, and total-inelastic cross sections at the LHC are presented and compared with experimental results and predictions from other models. In addition, expectations for diffraction at the upcoming LHC run at $\sqrt{s} = 13$ TeV are discussed.

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1. Introduction

The predictions of the RENORM/MBR (Renormalized, Minimum Bias Rockefeller) model for diffractive, total, and total-inelastic cross sections at the LHC presented at DIS-2015 are in good agreement with measurements [1]. Regarding the precision of the predictions, it was mentioned that the original model uncertainty of $\sim 10\%$ for the total, elastic, and total-inelastic cross sections could be reduced by a factor of about four by determining the energy-squared scale parameter s_0 from measurements of exclusive $\pi^{\pm}$ production with the Axial Field Spectrometer (AFS) at the CERN Intersecting Storage Rings (ISR) (see review in Ref. [2], Section 4.2), with little or no effect on the mean values.

An inquiry [3] into the details of Ref. [2] uncovered a partial wave analysis performed on the AFS data in a Ph.D. Thesis [4], which leads to a more precise determination of s_0 and thereby to an accuracy of better that 2% in the cross sections at LHC energies up to $\sqrt{s} = 13$ TeV. The single, double, and multi-gap diffractive cross sections are not affected. Below, in Sec. 2, we briefly review the main predictions of the version of the RENORM/MBR model presented in DIS-2015, in Sec. 3 we present an update of the model that improves the precision of the predictions, and in Sec. 4 we conclude.

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2. RENORM/MBR predictions presented at DIS-2015

The total, elastic, and total-inelastic cross sections in the RENORM/MBR model depend on the value of the energy-squared scale parameter s_0. Quoting verbatim from Ref. [1]:

"The total cross section ($\sigma_{\rm tot}$) is expressed as [5]

$$\sigma_{\rm tot}^{p^{\pm}p} = 16.79 s^{0.104} + 60.81 s^{-0.32} \mp 31.68 s^{-0.54} \quad \text{for} \quad \sqrt{s} \leq 1.8 \text{ TeV}\,, \quad (1)$$

$$\sigma_{\rm tot}^{p^{\pm}p} = \sigma_{\rm tot}^{\rm CDF} + \frac{\pi}{s_0}\left[\left(\ln\frac{s}{s_F}\right)^2 - \left(\ln\frac{s^{\rm CDF}}{s_F}\right)^2\right] \quad \text{for} \quad \sqrt{s} \geq 1.8 \text{ TeV}\,, \quad (2)$$

where s_0 and s_F are the energy and (Pomeron flux) saturation scales, $s_0 = 3.7 \pm 1.5$ GeV^2 and $\sqrt{s_F} = 22$ GeV, respectively. For $\sqrt{s} \leq 1.8$ TeV, where there are Reggeon contributions, we use the global fit expression [6], while for $\sqrt{s} \geq 1.8$ TeV, where Reggeon contributions are negligible, we employ the Froissart–Martin formula [7–9]. The two expressions are smoothly matched at $\sqrt{s} \approx 1.8$ TeV. The $\sigma_{\rm el}$ for $\sqrt{s} \leq 1.8$ TeV is obtained from the global fit [6], while for $1.8 < \sqrt{s} \leq 50$ TeV, we use an extrapolation of the global-fit ratio of $\sigma_{\rm el}/\sigma_{\rm tot}$, which is slowly varying with $\sqrt{s}$, multiplied by $\sigma_{\rm tot}$. The total non-diffractive cross section is given by $\sigma_{\rm ND} = (\sigma_{\rm tot} - \sigma_{\rm el}) - (2\sigma_{\rm SD} + \sigma_{\rm DD} + \sigma_{\rm CD})$."

Updated results on integrated SD and DD cross sections for proton momentum loss fraction $\xi < 0.05$ are compared in Fig. 1 with MBR predictions based on $\mathbb{P}$-trajectory parameters $\epsilon = 0.08$ and $\alpha' = 0.25$ GeV^{-2} [10]. A downward scaling adjustment implemented on the DD cross section in MBR improves the agreement with the 7 TeV DD data, while preserving compatibility with the CDF DD results within the CDF uncertainties. The adjusted MBR predictions are in good agreement with all the measurements of the SD and DD cross sections in the region of $\sqrt{s} \geq 100$ GeV (see details in [10]).

In DIFFRACTION 2014, the ATLAS Collaboration updated the $\sqrt{s} = 7$ TeV cross sections to $\sigma_{\rm tot} = 95.35 \pm 1.36$ mb, $\sigma_{\rm el} = 24.00 \pm 0.60$ mb, and $\sigma_{\rm inel} = 71.34 \pm 0.90$ mb [11]. These results are in agreement within the errors with the 2013 $\sqrt{s} = 7$ TeV TOTEM results of (a) $\sigma_{\rm tot} = 98.6 \pm 2.2$ mb, $\sigma_{\rm el} = 25.4 \pm 1.1$ mb, and $\sigma_{\rm inel} \equiv \sigma_{\rm tot} - \sigma_{\rm el} = 73.2 \pm 1.6$ mb (Roman pots), (b) $\sigma_{\rm tot} = 98.0 \pm 2.5$ mb and $\sigma_{\rm el} = 25.1 \pm 1.1$ mb (luminosity independent method), and (c) $\sigma_{\rm inel} = 73.7 \pm 3.4$ mb ($\beta^{\star}$ 90 m) [12]. The default RENORM/MBR predictions at $\sqrt{s} = 7$ TeV, $\sigma_{\rm tot} = 98.3 \pm 8.1$ mb, $\sigma_{\rm el} = 27.2 \pm 1.6$ mb, and $\sigma_{\rm inel} = 71.1 \pm 4.8$ mb [5] agree with the ATLAS and TOTEM results.

The TOTEM 2013 measurement at $\sqrt{s} = 8$ TeV, using the luminosity independent method, yielded $\sigma_{\rm tot} = 101.7 \pm 2.9$ mb, $\sigma_{\rm el} = 27.1 \pm 1.4$ mb, and $\sigma_{\rm inel} = 74.7 \pm 1.7$ mb [13]. The default RENORM/MBR predictions for $\sqrt{s} = 8$ TeV are $\sigma_{\rm tot} = 100 \pm 8.3$ mb, $\sigma_{\rm el} = 28.1 \pm 1.8$ mb, and $\sigma_{\rm inel} = 72.3 \pm 4.9$ mb. Again, good agreement between the data and RENORM/MBR predictions is observed.

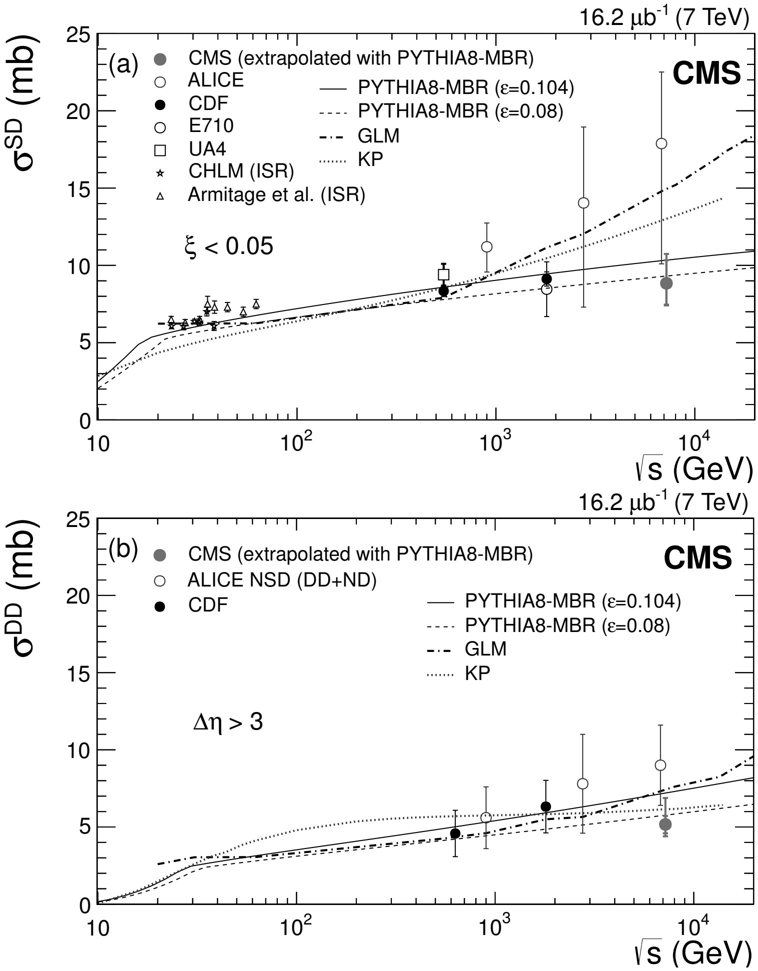

Fig. 1. Measured (a) SD and (b) DD cross sections for forward proton/antiproton momentum loss $\xi < 0.05$ compared with theoretical predictions. The PYTHIA8-MBR model describes well all the measurements (from Ref. [10]).

For $\sqrt{s} = 13$ TeV, the default predictions of RENORM/MBR for $\sigma_{\rm tot}$, $\sigma_{\rm el}$, and $\sigma_{\rm inel}$ are 108, 32, and 77 mb, respectively, with uncertainties of $\sim 11\%$, mainly due to the uncertainty in s_0.

3. Present update

The partial wave analysis of the AFS exclusive $\pi^{\pm}$ data [4], performed in terms of a fit to a model with S-wave and D-wave amplitudes as a function of the di-pion mass up to 2.3 GeV, leads to the results presented in Fig. 2. The D-wave dominates at masses above ~ 2 GeV, and according to the presumed interpretation in [4], it corresponds to a spin-2 tensor glueball of mass $M_{\rm tgb}$. A Gaussian fit to this enhancement yields $M_{\rm tgb} = 2.10 \pm 0.68$ GeV. We identify this bump with the saturated glueball-like enhancement of the MBR model $\sqrt{s_0}$, and obtain $s_0 = 4.42 \pm 0.34$ GeV^2. Using this value in Eq. (2), we predict for $\sigma_{\rm tot}$, $\sigma_{\rm el}$, and $\sigma_{\rm inel}$ the results listed in Table I. The MBR model is compatible with both the TOTEM- and ATLAS-measured cross sections at $\sqrt{s} = 7$ and 8 TeV, and its predictions for $\sqrt{s} = 13$ TeV are $\sigma_{\rm tot} = 103.7 \pm 1.9$ mb, $\sigma_{\rm el} = 10.2 \pm 0.8$ mb, and $\sigma_{\rm inel} = 73.5 \pm 1.3$ mb.

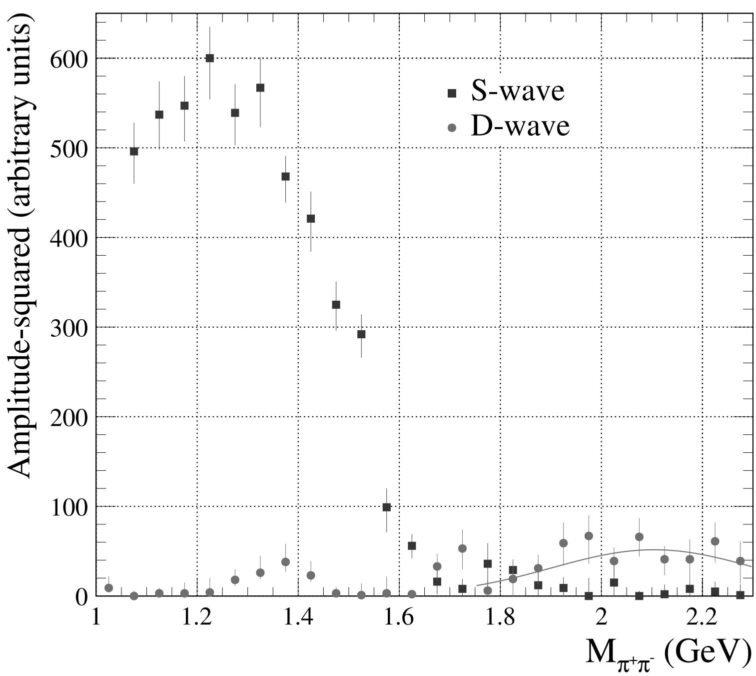

Fig. 2. Extraction of presumed tensor glueball parameters (average mass and width) from ASF data collected at the CERN ISR *pp* Collider (see text).

TABLE I

MBR-predicted total, elastic, and inelastic *pp* cross sections (mb) at the LHC.

$\sqrt{s}$	$\sigma_{\rm tot}$	$\sigma_{\rm el}$	$\sigma_{\rm inel}$	MBR/Experiment
7 TeV	95.4 ± 1.2	26.4 ± 0.3	69.0 ± 1.0	MBR
	98.4 ± 2.2	25.4 ± 1.1	73.7 ± 3.4	TOTEM
	95.35 ± 1.36	24.00 ± 0.60	71.34 ± 0.90	ATLAS
8 TeV	97.1 ± 1.4	27.2 ± 0.4	69.9 ± 1.0	MBR
	101.7 ± 2.9	27.1 ± 1.4	74.7 ± 1.7	TOTEM
13 TeV	103.7 ± 1.9	30.2 ± 0.8	73.5 ± 1.3	MBR

4. Conclusion

We first summarize the pre-LHC predictions of the total, elastic, total-inelastic, as well as the single- and double-diffractive components of the proton–proton cross section at high energies, based on the RENORM/MBR model as presented in DIS-2015 [1]. There, we compared measurements of the SD and DD cross sections from the Tevatron and the LHC with the predictions of the model and found excellent agreement. Good agreement was also observed between the model predictions and the total, elastic, and total inelastic cross sections obtained at the Tevatron at $\sqrt{s} = 1.8$ TeV, and at the LHC at $\sqrt{s} = 7$ and 8 TeV.

Motivated by the success of the RENORM/MBR model in describing well all the measured cross sections at the Tevatron and the LHC up to $\sqrt{s} = 8$ TeV, we used it to extrapolate the cross sections to $\sqrt{s} = 13$ TeV, the nominal foreseen colliding-beam energy at the LHC in Summer 2015. We found for $\sigma_{\rm tot}$, $\sigma_{\rm el}$, and $\sigma_{\rm inel}$ the values of 108, 32, and 77 mb, respectively, with uncertainties of $\sim 11\%$, mainly due to the uncertainty in the energy scale parameter s_0 of the model.

Presented for the first time here, we update the value of s_0 to a more precise based on a tensor glueball interpretation of the Axial Field Spectrometer exclusive charged di-pion data [2, 4]. This change in RENORM/MBR decreases the uncertainties in the predictions of the total, elastic, and total-inelastic cross sections to less than 2% for Tevatron to LHC energies with little or no effect on the mean values, yields cross sections in excellent agreement with measurements by ATLAS at $\sqrt{s} = 7$ TeV and TOTEM at $\sqrt{s} = 7$ and 8 TeV, and predicts $\sigma_{\rm tot} = 103.7 \pm 1.9$ mb, $\sigma_{\rm el} = 20.2 \pm 0.8$ mb, and $\sigma_{\rm inel} = 73.5 \pm 1.3$ mb at 13 TeV.

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