First measurement of the forward rapidity gap distribution in pPb collisions at 8 TeV

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Abstract

We present the forward rapidity gap spectra from proton-lead collisions for both $\mathbb{P}$-Pb and $\mathbb{P}$-p topologies measured at the CMS at a center-of-mass energy of 8.16 TeV. For the $\mathbb{P}$-Pb topology, the cross-section predicted by EPOS-LHC is a factor of two lower than the data while has reasonable description of the spectrum shape. For the $\mathbb{P}$-p topology, the EPOS-LHC, QGSJET II and HIJING predictions are significantly lower than the data, what can be explained by a contribution of ultra-peripheral photoproduction events. The obtained data may be of significant input for understanding the high energy limit of QCD and modeling cosmic ray air showers.

1 Introduction

The t-channel exchange object with the quantum numbers of the vacuum – pomerons ($\mathbb{P}$) [1,2] – are responsible for the majority of collisions at the Large Hadron Collider – for the diffractive events [3–7]. They are connected to the very fundamental parts of QCD [8–13].

Pomerons can take part in elastic, non-diffractive and diffractive processes. In the diffractive dissociation the large gaps in the rapidity distribution are produced, which are usually measured from the most forward region of detectors. For the hadron-nuclear diffraction cross section the special Gribov inelastic shadowing [14] can be involved. Also, such diffraction is relevant to modeling cosmic ray showers [15].

The first measurement of diffractive proton-nucleus cross sections at the LHC is presented in this talk. The analysis [16] was done with the forward rapidity gap studies at $\sqrt{s_{\mathrm{NN}}} = 8.16$ TeV with the CMS detector. The previous measurements of the forward rapidity gap cross section were done in proton-proton collisions by the ATLAS [3] and CMS [4] collaborations at the LHC at center-of-mass energy of 7 TeV, while the previous proton-nuclear diffraction cross section studies was made by HELIOS [17] collaboration at proton-nucleon center-of-mass energy of 29.1 GeV.

2 Data analysis

The measurement of diffractive pPb collisions was performed with the CMS detector [18] at $\sqrt{s_{\mathrm{NN}}} = 8.16$ TeV with 6.4 $\mu\mathrm{b}^{-1}$ of pPb collision data collected in 2016 [16]. The analysis is based on the detection of a rapidity gap started from the forward detector region (FRG, $\Delta\eta^{\mathrm{F}}$), based on the tracker, the electromagnetic and hadron calorimeters. The flux of a coherent quasi-real photons from the lead ion adds an additional contribution of ultra-peripheral electromagnetic photoproduction processes to the sample with the rapidity gap on the nucleon side [19–23]. Figure 1 shows Feynman diagrams and schematic topologies of single diffractive pomeron-lead (IPPb) and pomeron-proton (IPp) processes for pPb collisions.

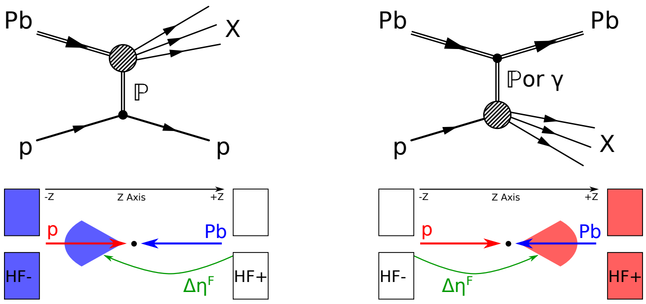

Figure 1: Top: Feynman diagrams of pPb events with large rapidity gaps for IPPb (left) and IPp or γp (right). Bottom: topologies of such events. The blue (red) cones indicate the products of diffractive dissociation for the lead ion (proton). The rapidity gaps are marked with green arrows.

For this analysis, FRG is calculated from $|\eta| = 3.0$ and the phase space within $|\eta| = 3.0$ is divided in 12 bins.

To increase the sensitivity to diffractive events the extending of the rapidity gap size to the region $3.15 < |\eta| < 5.2$ adjacent to the rapidity gap the reweighting was performed. The every bin of the FRG cross section distribution for the $|\eta| < 3.0$ was reweighted to the probability to have no signal in $3.15 < |\eta| < 5.2$. After that, the obtained distributions (tagged as 'diffraction enhanced distributions") was unfolded to hadron level using EPOS-LHC response matrices.

The statistical and systematic uncertainties for the data are added in quadrature. In Fig. 2 the full uncertainty is shown as yellow band, and the full uncertainty excluding the error introduced with the correction for the undetectable energy in the region $3.15 < |\eta| < 5.2$ is shown as gray band.

3 Results

The obtained hadron level cross section shown on the Fig. 2 was compared with the EPOS-LHC [24], QGSJET II-04 [25] and HIJING v2.1 [26] event generators.

For the IPPb topology the predictions of the FRG distribution for the EPOS-LHC and QGSJET II event generators have a shape similar to the CMS results, but the predicted cross sections by EPOS-LHC generator are two times less then CMS result, while the QGSJET II prediction found to be four times lower then CMS data. The shape of the HIJING predictions differs from the CMS results, and the predicted cross sections are lower than data. For the IPp topology the large γp contribution, not included in the used generators, leads to the huge difference between the generator predictions and the data.

In Fig. 3 the hadron level prediction from EPOS-LHC shown on Fig. 2 was splitted down to non-diffractive and single, central and double diffractive events. The prediction shows that the $\frac{d\sigma}{d\Delta\eta^{\mathrm{F}}}$ for the events with no energy deposition in the $3.15 < |\eta| < 5.2$ region adjacent to FRG the contribution of the diffractive events become dominant after $\Delta\eta^{\mathrm{F}} = 1.0$.

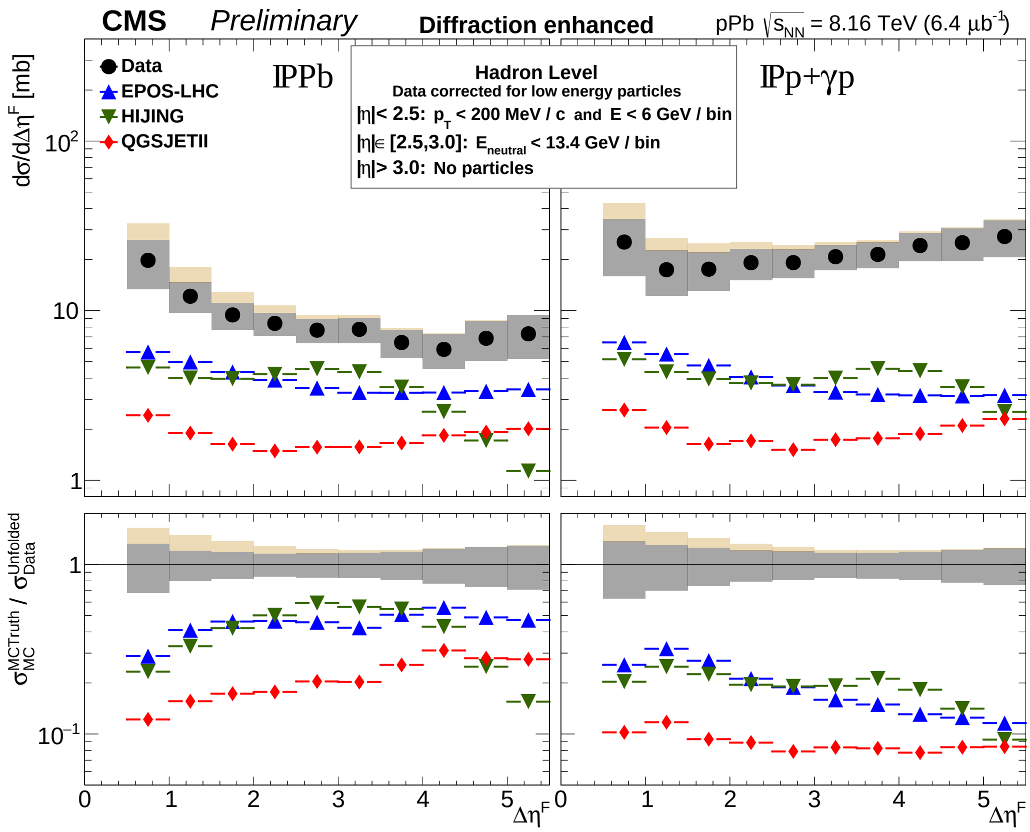

Figure 2: Top: the hadron level $\frac{d\sigma}{d\Delta\eta^F}$ distribution with no energy deposition in the $3.15 < |\eta| < 5.2$ region adjacent to FRG for the CMS data [16] (black), and the predictions of the EPOS-LHC [24] (blue), QGSJET II [25] (red) and HIJING [26] (green) event generators. The distributions are shown for the IPPb (left) and IPp topologies. Bottom: ratios between generator predictions and CMS data.

4 Conclusion

The forward rapidity gap cross section $\frac{d\sigma}{d\Delta\eta^F}$ distribution for the proton-lead collisions at the LHC were measured for the first time with the CMS detector at the energy $\sqrt{s_{NN}} = 8.16$ TeV for both, IPPb and IPp topologies. For the IPp topology cross section the large difference between CMS results and the generator prediction was found. It suggests to a large contribution of ultra-peripheral photoproduction events. For the IPPb the shape of the EPOS-LHC and QGSJET II was found to be similar to CMS data, but the cross section magnitude is two and four times lower then CMS result for the EPOS-LHC and QGSJET II generators, respectively. The HIJING generator predictions falls for large FRG sizes contrary to the data

The obtained rapidity gap cross section distributions provide important information for diffractive processes on nuclei and for modeling cosmic ray collisions.

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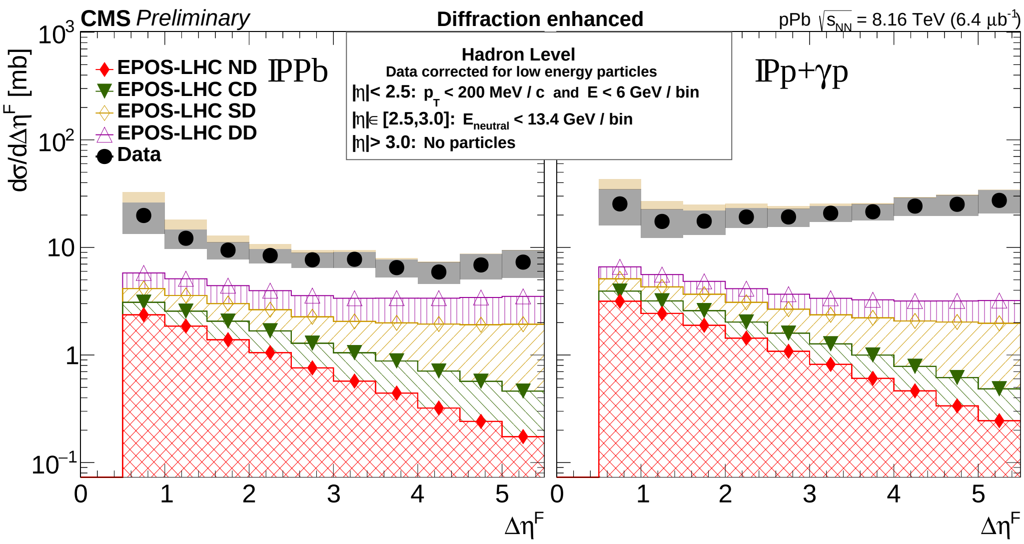

Figure 3: The hadron-level $\frac{d\sigma}{d\Delta\eta^F}$ distribution for the events with no energy deposition in the $3.15 < |\eta| < 5.2$ region adjacent to FRG for the EPOS-LHC [24] generator, broken down to non-diffractive (red), single (magenta), central (green) and double (yellow) diffractive events compared to CMS results [16] (black)

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