PROCEEDINGS OF SCIENCE

Inelastic proton cross section at 13 TeV with ATLAS

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The recent measurement of the inelastic cross section at 13 TeV with the ATLAS detector is presented. Method of its calculation is based on the independent measurements of the rate of inelastic collisions and the LHC luminosity. The result of 78.1 $\pm$ 3.0 mb is obtained after extrapolation to the full phase space and is compared with a range of theoretical predictions. In addition, the fraction of diffractive events is estimated using two event selections. The low-luminosity data of total integrated luminosity of 60.1 μb^{-1} recorded in June 2015 is used.

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1. Introduction

The inelastic cross section σ_{inel} for proton-proton collisions is one of the main observables in collider physics. It accommodates all processes, where at least one of the protons breaks up into many particles. All the contributing processes may be divided into two categories according to the color charge flow: diffractive and non-diffractive processes. Since the perturbative QCD calculation diverges at low scale, phenomenological models have to be applied to predict the value of σ_{inel}. Therefore, any precise measurement of σ_{inel} serves as an important constrain for these models. Among other impacts, the estimation of number of soft multiple proton-proton collisions (co called pile-up) at proton colliders and the modeling of atmospheric particle showers initiated by cosmic radiation depend on the precise knowledge of σ_{inel}. Moreover, scaling of total pp corss section with a center-of-mass-system (c.m.s.) energy poses an important question, which started to be explored already at 23 GeV [1,2]. σ_{inel} measurements at the Large Hadron Collider (LHC) were performed at c.m.s. energies of 2.76, 7, 8, and newly 13 TeV, see e.g. [3–7].

In this note, the measurement of the inelastic cross section [8] using pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector [9] at the LHC is shortly presented. The measurement can be viewed as a complementary one to the measurements performed by the ALPHA detector, see e.g. [10] using the Roman Pot detectors more distant from the interaction point and primarily measuring the elastic pp cross section. Presented method relies on the independent measurement of the LHC luminosity. The used data corresponds to the total integrated luminosity of 60.1 $\pm$ 1.1 μb^{-1}. Dataset was recorded in June 2015 during the low-luminosity run, where the contribution from multiple pp collisions is negligible.

2. Event Selection

The events are selected in the so called "minimum bias" regime, where the triggering threshold is as low as possible above the detector noise. For that purpose, Minimum Bias Trigger Scintillators (MBTS) are used for triggering events. These thin polystyrene scintillation counters are located at $\pm$ 3.6 m from the interaction point between inner tracking system and calorimeters. They cover the pseudo-rapidity region 2.07 – 3.86 on both sides of the detector. Each side consists of 12 large segments providing the maximum of 24 hits in the entire MBTS. All events with at least 2 hits (at any side) with a sufficient collected charge in the MBTS are accepted for further selection. Requiring two hits rather than one hit substantially reduces amount of background events. The distribution of events with respect to the number of hits in MBTS (n_{MBTS}) is shown in the left plot in Fig. 2. Data points are already corrected for expected background and compared to different Monte Carlo (MC) simulations: Pythia8 with different pomeron flux models (SS = Schuler-Sjöstrand, DL = Donnachie-Landshoff with tunable parameter ε, Pythia8 using Minimum-Bias Rockefeller (MBR) model, Epos LHC, and QGDJET-II.

A further event selection is based on the analysis of the entire event record. All particles detected are grouped into two particle collections, which are defined through the maximum rapidity distance between any pair of particles. A general situation is sketched in Fig. 1. The total invariant mass for each collection is calculated and the collection with the largest mass (denoted as M_X) is taken for the further event selection. The fiducial region of the final event selection (labeled as

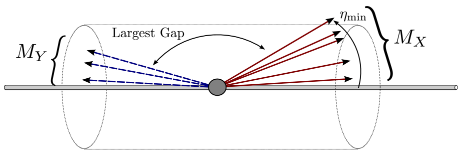

Figure 1: A graphical representation of the M_X definition via the particle collection rapidity separation.

inclusive) requires $M_X > 13$ GeV, which is equivalent to the condition $\xi = M_X^2/s > 10^{-6}$. This choice of the fiducial phase space is motivated by the efficiency of the event selection using MBTS counters. The lowest edge is set to 50% efficiency level which corresponds $\xi \approx 10^{-6}$. The variable ξ is theoretically constrained to be $> 6 \times 10^{-9}$ by the elastic limit of m_p^2/s, where m_p is the mass of the proton. The total number of selected events is 4,159,074.

3. Result

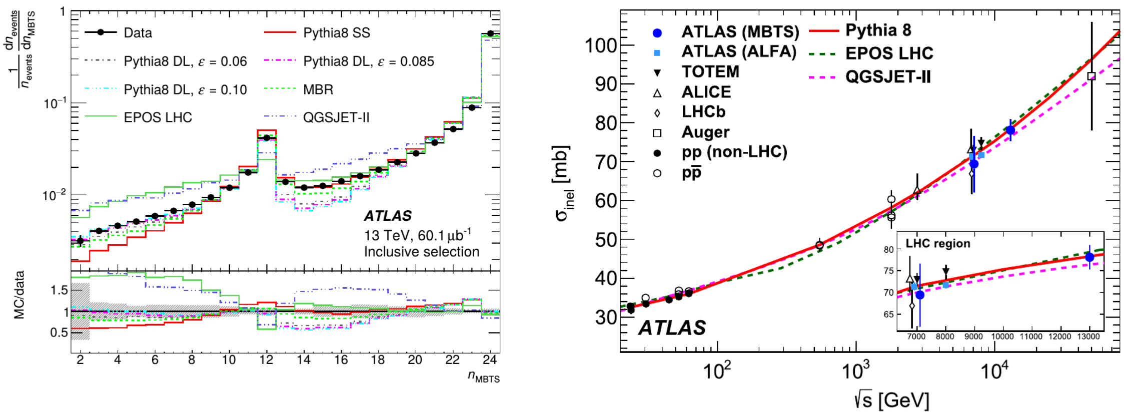

Figure 2: Left: The background-subtracted distribution of the MBTS hits for data and different MC simulations. The distributions are peaked at 12 and 24 hits, which corresond to the maximum number of counters at one and both sides. The ratio of the MC models to the data is also shown. Right: The inelastic cross section for pp collisions as a function of c.m.s. energy. Both figures are taken from [8].

The fiducial cross section is determined by

$$\sigma_{\rm inel}^{\rm fid}(\xi > 10^{-6}) = \frac{N - N_{\rm bkg}}{\varepsilon_{\rm trig} \times \mathscr{L}} \times \frac{1 - f_{\xi < 10^{-6}}}{\varepsilon_{\rm sel}}, \tag{3.1}$$

where N stands for the total number of recorded events and $N_{\rm bkg}$ is estimated number of background events. These may be caused by the interactions of beam with residual gas in the beam pipe, interactions of beam particles with collimators, collision-induced radiation, and activation backgrounds. The magnitude of background effects is estimated from the detector record during the single beam run. 51,187 events are classified as background events with 50% systematic uncertainty. $\varepsilon_{\rm trig}$ and $\varepsilon_{\rm sel}$ are factors accounting for the trigger and event selection efficiencies and are both above 99% with an assigned systematic uncertainty below 0.5%. The factor of $1 - f_{\xi<10^{-6}}$ corrects for the migration of events with $\xi < 10^{-6}$ into the fiducial region and is obtained from MC simulations. $\mathscr{L}$ is the integrated luminosity of the sample. Putting all together, the fiducial cross section is

$$\sigma_{\rm inel}^{\rm fid}(\xi > 10^{-6}) = 68.1 \pm 0.6\ (\text{exp.}) \pm 1.3\ (\text{lum.})\ \text{mb}. \tag{3.2}$$

The first uncertainty refers to all experimental uncertainties apart from the luminosity and the second refers to the luminosity only. The statistical uncertainties are negligible. The measured value of $\sigma_{\text{inel}}^{\text{fid}}$ is in a good agreement with the predictions from Pythia8 DL and Pythia8 MBR models. The Epos LHC and QGSJet-II predictions exceed the data by 2–3σ. The Pythia8 SS model exceeds the measured value by $\sim 4\sigma$.

The extrapolation of the fiducial cross section $\sigma_{\text{inel}}^{\text{fid}}$ to the total phase space inelastic cross section σ_{inel} uses the previous ATLAS measurements [3,10] in order to minimize the model dependence of the component that falls outside the fiducial region:

$$\sigma_{\text{inel}} = \sigma_{\text{inel}}^{\text{fid}} + \sigma_{\text{inel}}^{7\ \text{TeV}}(\xi < 5\times 10^{-6}) \times f_{\text{MC}}. \tag{3.3}$$

Here, the value of the term $\sigma_{\text{inel}}^{7\ \text{TeV}}(\xi < 5\times 10^{-6})$ is obtained by the subtraction of the two previous ATLAS results: total inelastic cross section at 7 TeV measured by the ALPHA detector minus fiducial inelastic cross section at 7 TeV measured using the MBTS counters. The MC-driven factor f_{MC} corrects for the difference between c.m.s. energies between the mixed measurements and the slightly different fiducial space definition. The final result for full inelastic cross section is

$$\sigma_{\text{inel}} = 78.1 \pm 0.6\ (\text{exp.}) \pm 1.3\ (\text{lum.}) \pm 2.6\ (\text{extrap.})\ \text{mb}. \tag{3.4}$$

In summary, the inelastic cross section for pp collisions at 13 TeV is presented. The evaluation method relies on the direct measurement at 13 TeV in the fiducial region $\xi > 10^{-6}$ and than it is extrapolated using previous measurements at 7 TeV. The obtained value for σ_{inel} fits well among the predicted values by different MC models. The comparison is shown in the right plot in Fig. 2 together with a selection of previous measurements including Pierre Auger experiment [11]. An interesting comparison can be made to the recent result from CMS Collaboration [12]. CMS result of 71.5 mb is significantly below the ATLAS result as well as phenomenological predictions despite the fact that the visible cross sections in similar fiducial regions are comparable.

References

[1] S. R. Amendolia *et al.*, Phys. Lett. B **44** (1973) 119.

[2] U. Amaldi *et al.*, Phys. Lett. B **44** (1973) 112.

[3] ATLAS Collaboration, Nature Commun. **2** (2011) 463.

[4] TOTEM Collaboration, Europhys. Lett. **101** (2013) 21004.

[5] LHCb Collaboration, JHEP **1502** (2015) 129.

[6] ALICE Collaboration, Eur. Phys. J. C **73** (2013) no.6, 2456.

[7] CMS Collaboration, Phys. Lett. B **722** (2013) 5.

[8] ATLAS Collaboration, Phys. Rev. Lett. **117** (2016) 182002.

[9] ATLAS Collaboration, JINST **3** (2008) S08003.

[10] ATLAS Collaboration, Nucl. Phys. B **889** (2014) 486.

[11] Pierre Auger Collaboration, Phys. Rev. Lett. **109** (2012) 062002.

[12] CMS Collaboration, CMS-PAS-FSQ-15-005.