Measurement of charged-particle pseudorapidity density with ALICE at LHC

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Abstract. The ALICE experiment, designed primarily for studying heavy-ion collisions at the Large Hadron Collider, has several features in its apparatus that allow it to contribute significantly to the first proton–proton physics. ALICE started proton–proton data taking at the end of 2009: data collected at a centre-of-mass energy of 0.9, 2.36 and 7 TeV allowed several first physics studies to be carried out. In this contribution, the first measurements of the charged-particle pseudorapidity density at the three energies will be presented. These measurements have been obtained using mainly the two innermost layers of the inner tracking system. The reconstruction algorithm and the analysis procedure are described and the results are compared to other measurements and model predictions.

1. Introduction
The ALICE experiment [1] has been taking data since November 2009 when LHC started colliding proton beams. With the data collected at the three energies explored so far, several studies have been carried out. The first measurement is the multiplicity of primary charged particles and its pseudorapidity density distribution. ALICE results have been compared with those from CMS experiment [2] and, at the lowest energy, also with the existing results for p-p obtained at SPS [3]. At high energies the multiplicity measurement will constrain the hadroproduction models allowing the Monte Carlo generators to be correctly tuned and the energy dependence of the charged-particle density to be determined.

2. The pixel detector and the tracklet algorithm
The ALICE Silicon Pixel Detector (SPD) consists of two cylindrical layers equipped with hybrid pixels and placed at 3.9 and 7.6 cm from the beam line. The pseudorapidity coverage is $|\eta| < 2$ for the inner layer and $|\eta| < 1.4$ for the outer layer.

Using the reconstructed hits in the two layers and exploiting their spatial correlations, the position of the primary interaction vertex can be calculated. Then, charged tracks crossing the detector can be reconstructed using the vertex as the origin and looking for pairs of reconstructed points, aligned with the vertex within predefined tolerances, so called “tracklets”. The algorithm consists of an iterative procedure that associates the pairs with the minimum distance in the $\varphi$-$\theta$ plane as described in [4]. The multiplicity is estimated counting tracklets and the pseudorapidity is calculated using the $\theta$ angle given by the point in the inner layer and the primary vertex. There are several advantages in using the SPD to reconstruct tracks compared to the measurement based on tracks reconstructed in the full tracking system: the SPD has a larger acceptance...
coverage both in pseudorapidity and transverse momentum than the rest of the central tracking system and relies on faster alignment and calibration procedures.

3. Data taking conditions and data samples
The first proton–proton collisions at $\sqrt{s} = 0.9$ TeV took place on the 23rd of November 2009. The first physics publication of the LHC is based on 284 events collected that day with the ALICE detector [5]. Subsequently, in the data taking of December 2009 and March-April 2010, higher statistics samples have been collected at $\sqrt{s} = 0.9$, 2.36 and 7 TeV with magnetic field $B = 0.5$ T. At $\sqrt{s} = 0.9$ and 7 TeV the trigger used for data acquisition was based on the SPD and the V0 detector: essentially this trigger selects events with at least one charged particle in $|\eta| < 8$. The SPD can contribute to the Level 0 (L0) trigger of the experiment with its digital Fast-Or signal [1]. The V0 detector consists of arrays of scintillators placed at either side of the nominal interaction point around the beam-pipe and allows collisions and beam–gas interactions to be distinguished using its timing signals with respect to beam crossing time. The trigger requirement was at least one SPD Fast-Or or at least one hit in either one of the two V0 arrays. The signals were required to be in coincidence with passing bunches. Control triggers to remove beam-induced and accidental background were used during data taking as described in [6]. At $\sqrt{s} = 2.36$ TeV the V0 detector was switched off, so the trigger condition was looser and based on SPD signals only, in coincidence with passing bunches. This results in a higher systematic error.

4. Data analysis
The event classes chosen for the analysis are the following: inelastic (INEL), non-single-diffractive (NSD) and events with at least one charged particle, i.e. at least one tracklet, reconstructed in $|\eta| < 1$ (INEL $>$0) [7]. The latter has been chosen for the 7 TeV data analysis, where no information about the cross section of diffractive processes is available yet, to reduce the dependency of the measurements on the models used to calculate the corrections and hence the systematic uncertainty.

Offline selections were applied to reject beam-induced background. In addition, at 0.9 TeV a subset of the triggered sample has been extracted for the NSD analysis: in order to reduce the fraction of single-diffractive events, signals in both V0 counters have been required. The vertex range of events accepted in the analysis has been limited to $|z_{vtx}| < 10$ cm since for larger values the efficiency in reconstructing the vertex decreases due to the SPD acceptance in z. For the INEL $>$0 class the range has been further restricted to $|z_{vtx}| < 5.5$ cm to have the pseudorapidity range used to define the event class fully within the SPD acceptance.

Primary particles are defined as prompt particles produced in the collision and all decay products, except products from weak decays of strange particles. To obtain the number of primaries, the number of reconstructed tracklets has been corrected for the following effects: contaminations from secondary interactions, long-lived particle decay products and gamma conversions, transverse momentum cut-off (approximately 50 MeV/c), detector acceptance and efficiency, reconstruction efficiency and combinatorial background. The corrections are calculated as a function of $\eta$ and the longitudinal position of the primary vertex. The number of events has also been corrected for the trigger and selection efficiencies.

Monte Carlo samples have been generated to calculate the corrections and to study the systematic uncertainties. The combinatorial background has been assessed from data by rotating the SPD inner layer by 180$^\circ$, thereby destroying real correlations of hits. The event generators used are PhoJet [8] and several tunes of PYTHIA (D6T [9], ATLAS-CSC [10] and Perugia-0 [11]).
Table 1. Measured dN_{ch}/d\eta at central pseudorapidity in |\eta|<0.5 for INEL and NSD classes at √s=0.9 and 2.36 TeV [6] and in |\eta|<1 for INEL>0 class at the three centre-of-mass energies [7]. PYTHIA has been used to calculate the corrections. The first uncertainty is statistical and the second is systematic. The asymmetric systematic uncertainties indicate that there are differences when calculating corrections with PhoJet.

|       | 0.9 TeV   | 2.36 TeV  | 7 TeV    |
|-------|-----------|-----------|----------|
| INEL  | 3.02±0.01+0.08−0.05 | 3.77±0.01+0.25−0.12 | 3.81±0.01+0.07−0.05 |
| NSD   | 3.58±0.01±0.12      | 4.43±0.01+0.17−0.12 | 4.70±0.01+0.11−0.08 |
| INEL>0| 3.81±0.01±0.07      | 4.70±0.01+0.11−0.08 | 6.01±0.01+0.20−0.12 |

5. Results

In Tab. 1 the values of the pseudorapidity density at central pseudorapidity at the three energies and for different event classes are quoted.

In Fig. 1 the dN_{ch}/d\eta as a function of pseudorapidity measured at √s=0.9 TeV (left panel) and 2.36 TeV (right panel) are shown for the INEL and NSD events. ALICE results at 0.9 TeV are compared to UA5 p-p results for both event classes and to CMS distribution for NSD events. At 2.36 TeV the NSD results are compared with the CMS measurement and with PYTHIA tune D6T and PhoJet predictions (which are the lowest and the highest values for INEL events respectively). As for the systematic uncertainty shown as shaded areas in the figures, it can be observed that at 2.36 TeV the errors are higher (at 0.9 TeV 2.5% and 3.3% for INEL and NSD respectively and at 2.36 TeV 6.7% and 3.7% for INEL and NSD events). The systematic uncertainties are dominated by the uncertainty in the cross sections of diffractive processes and their kinematics. CMS did not include charged leptons in its definition of primary charged particles so the measured values are expected to be 1.5% lower than the ALICE ones.

In Fig. 2 the energy dependence of pseudorapidity density at central pseudorapidity is shown for ALICE and CMS data, as well as for existing measurements of ISR, SPS, RHIC and Tevatron experiments. In Fig. 3 the relative increase of the dN_{ch}/d\eta predicted by PhoJet and the three tunes of PYTHIA considered is shown for the INEL>0 class. These predictions are compared

Figure 1. dN_{ch}/d\eta distribution measured by ALICE and compared with other measurements and model predictions. The statistical error is not visible and the systematic uncertainty is represented by the shaded areas. The error bars for CMS data points are the sum in quadrature of systematic and statistical uncertainties. Figures reproduced from [6].
Figure 2. \(dN_{ch}/d\eta\) at central pseudorapidity (\(|\eta| < 0.5\)) as a function of the centre-of-mass energy. For the INEL>0 class the pseudorapidity range considered is |\(\eta| < 1\). The data for the three event classes have been fitted using a power law (curves). Figure reproduced from [7].

Figure 3. Predictions of various models for the relative increase of the \(dN_{ch}/d\eta\) in the (INEL>0) event class at central pseudorapidity from 0.9 to 2.36 TeV (open symbols) and from 0.9 to 7 TeV (full symbols). The increase measured by ALICE in both cases is represented by the two lines where the width of the grey regions is the sum in quadrature of the statistical and systematic uncertainties. Figure reproduced from [7].

to the increase measured by ALICE that is 57.6% ± 0.4%\(^\pm\)3.6% between the 0.9 and 7 TeV data.

6. Conclusions

ALICE has measured the pseudorapidity density distribution using data provided mainly by the SPD and collected in December 2009 and March-April 2010. The values are consistent with previous UA1 measurements and the new CMS experiment results. Model predictions at the highest energy significantly underestimate the value of \(dN_{ch}/d\eta\) at central pseudorapidity, except for the PYTHIA tune ATLAS-CSC. Studying the dependence of the \(dN_{ch}/d\eta\) on the centre-of-mass energy, it is observed that it increases much faster than predicted by the models considered.

References

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