Charged particle production in Pb–Pb collisions at the LHC with the ALICE detector

M. Floris for the ALICE collaboration

CERN, Geneva, Switzerland

Abstract

The ALICE collaboration measured charged particle production in $\sqrt{s_{NN}}$ = 2.76 TeV Pb–Pb collisions at the LHC. We report on results on charged particle multiplicity and transverse momentum spectra. All the results are presented as a function of the centrality of the collision, estimated with a Glauber Monte Carlo fit to multiplicity distributions reconstructed in various detectors. The applicability of the Glauber model at LHC energies, the precision of the centrality determination and the related systematic uncertainties are discussed in detail.

Particles are tracked in the pseudorapidity window $|\eta| \lesssim 0.9$ with the silicon Inner Tracking System (ITS) and the Time Projection Chamber (TPC), over the range $0.15 < p_T \lesssim 50$ GeV/c. The low-p_T cut-off is further reduced in the multiplicity measurement using "tracklets", reconstructed in the 2 innermost layers of the ITS.

The charged particle multiplicity is measured in $|\eta| < 0.5$ to be dN_{ch}/dη = 1601 ± 60 in 5% most central Pb–Pb collisions, indicating an energy density a factor ∼ 3 higher than at RHIC. Its evolution with centrality shows a pattern strikingly similar to the one measured at RHIC. Intermediate ($5 \lesssim p_T \lesssim 15$ GeV/c) transverse momentum particles are found to be most strongly suppressed with respect to pp collisions, consistent with a large energy loss of hard-scattered partons in the hot and dense medium. The results are presented in terms of the nuclear modification factor R_{AA} and compared to theoretical expectations.

Keywords: heavy-ion, charged particles, LHC, Nuclear modification factor

1. Introduction

The ALICE experiment took data at the LHC in pp collisions at $\sqrt{s}$ = 0.9, 2.76 and 7 TeV and in Pb–Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV. Measurements of charged particles are very important early studies which allow for a first characterization of the system produced in such collisions and provide basic constraints to theoretical models. In this paper we present results obtained in Pb–Pb collisions for charged primary particles, defined as all charged particles produced in the collision, including their decay products, but excluding products of weak decays of strange particles.

The ALICE detector is mainly composed of a central barrel and of a forward muon spectrometer [1]. The main tracking elements in the central barrel are a large volume Time Projection Chamber (TPC) and a six-layered silicon detector, the Inner Tracking System (ITS). They are embedded in a 0.5 T solenoidal field and cover the pseudorapidity window $|\eta| \lesssim 0.9$. The material budget for a track going through the TPC is about 10% of a radiation length. The small material budget and moderate field lead to a low p_T cut-off of about 150 MeV/c for full tracks reconstructed

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with the combined information of the ITS and TPC [2]. The p_T resolution in the present analysis is about 10% up to $p_T = 50$ GeV/c. The resolution on the transverse impact parameter relative to the primary vertex is about 200 μm at $p_T = 300$ MeV/c and 35 μm at $p_T = 5$ GeV/c. This allows for a good separation of primary and secondary particles, an important requirement for charged particle measurements at low p_T. The multiplicity measurements employed track segments made of 2 hits in the 2 SPD layers pointing to a common vertex ("tracklets") as the default estimator [3, 4]. As compared to full-fledged tracks, the tracklets have the advantage of a lower p_T cutoff (~ 50 MeV/c) and of an extended η coverage ($|\eta| \lesssim 2$). For triggering purposes, two forward scintillator hodoscopes, the VZERO detectors, covering the pseudorapidity windows $2.8 < \eta < 5.1$ and $-3.7 < \eta < -1.7$ were used. The present analyses use data collected with a minimum bias trigger requiring a combination of hits in the two innermost layers of the ITS (made of silicon pixel detectors, SPD) and in the VZERO.

2. Centrality determination

The determination of the "centrality" of a collision, that is a measurement of the transverse overlap of the two nuclei, is one of the first important steps towards a full characterization of heavy-ion collisions. The data are divided in several centrality bins corresponding to well-defined percentiles of the total hadronic cross-section. The bins are defined using cuts on the multiplicity distributions measured in one of the sub-detectors. Our main estimate is based on the VZERO detector information [5]. Other estimators are used as cross-checks: clusters reconstructed in the SPD, tracks reconstructed in the TPC and energy deposited in the Zero Degree Calorimenters (ZDC, see below). In order to translate a cut in any of the above estimators into a given centrality percentile, the knowledge of the total hadronic cross-section is needed. This can be extracted from the data in two ways: *i)* fitting the experimental distribution with a Glauber model [6, 7], *ii)* correcting the experimental distribution for the trigger efficiency and subtracting any background from non-hadronic interactions. The two approaches yield consistent results, with the former used as the default. The Glauber fit was done using a Monte Carlo calculation, which assumed Woods-Saxon nuclear density profiles (with parameters constrained by low energy electron-nucleus scattering measurements) and a nucleon-nucleon inelastic cross-section of $\sigma_{NN}^{inel} = 64 \pm 5$ mb, as interpolated from cosmic rays and pp data at different energies. This value is also consistent with the measured σ_{pp}^{inel} [8]. From the Glauber model calculation, one can extract the number of participants N_{part} and the number of binary collisions N_{coll}. It is then assumed that the number of particle production centers ("ancestors") is related to the number of participants and binary collisions as $N_{ancestors} = f \cdot N_{part} + (1-f) \cdot N_{coll}$. Each ancestor then produces particles according to a Negative Binomial Distribution (NBD). The NBD parameters and the f parameter are the free parametres in the fit.

The ZDCs are a set of forward hadronic calorimeters, placed on either side of the detector, approximately 114 m away from the interaction point, at zero degree with respect to the beam axis. For the most central events, the energy deposit in the ZDCs is proportional to the number of spectator nucleons. They therefore measure a quantity qualitatively different from the other estimators, providing another implicit confirmation of the applicability of the Glauber model at the LHC.

Comparing the different estimators event-by-event, it is possible to estimate the precision of the centrality measurement. For the VZERO estimator, the centrality resolution is $\sim 0.5\%$ for central events and $\sim 2\%$ for peripheral events. The residual contamination and purity of the events used in the analysis was also studied. This is particularly important for peripheral events. A pure hadronic sample is found after the basic offline selection down to about 90% centrality [5]. The minimum bias trigger efficiency ranges between 97 and 99%, according to the actual trigger settings. More details on the centrality studies can be found in [5].

3. Multiplicity measurements

The charged particle multiplicity was measured in the central rapidity region ($|\eta| < 0.5$) using "tracklets" as the default estimator and crosschecked with tracks. The $dN_{ch}/d\eta$ as a function of N_{part} is compared in Fig. 1 with previous RHIC results at $\sqrt{s_{NN}} = 200$ GeV/c (left) and with theoretical models (right, see [3] and references therein). The dependence on centrality is very similar at the two energies, with an overall scaling factor of ~ 2.14. Models incorporating a moderation of the multiplicity with centrality (i.e. shadowing or saturation) are favored by the data. The measurement has recently been extended to cover a much wider pseudorapidity range ($|\eta| \lesssim 5$) [9], putting