FIRST RESULTS OF ALICE IN Pb–Pb COLLISIONS AT $\sqrt{s_{NN}} = 2.76$ TeV*

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In this paper, we report on the results from ALICE during the first Pb–Pb data taking period at the CERN LHC. We present the centrality dependence of the multiplicity density at mid-rapidity, the first results on Bose–Einstein correlations, the first elliptic flow measurements as well as the studies related to the suppression of high p_{T} particles in central collisions (R_{AA}).

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1. Introduction

In November 2010, ALICE (A Large Ion Collider Experiment) collected data during the first Pb–Pb collisions at a center-of-mass energy per nucleon pair $\sqrt{s_{NN}} = 2.76$ TeV delivered by the LHC (Large Hadron Collider) at CERN. The luminosity varied within 5×10^{23}–1.3×10^{25} cm^{-2}s^{-1}. A detailed description of the experiment can be found in [1]. The data readout was triggered by the LHC bunch-crossing signal and a minimum-bias interaction trigger based on trigger signals from two forward scintillator hodoscopes (VZERO-A and VZERO-C) and two innermost layers of a Silicon Pixel Detectors (SPD). Fig. 1 shows the distribution of the summed amplitudes in the VZERO scintillator tiles together with the distribution obtained with a model of particle production based on a Glauber description for the nuclear collision geometry [2]. Central Pb–Pb collisions, with small impact parameter, generate large multiplicity in VZERO. Centrality classes are determined by integrating the measured distribution. From the Glauber model

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fit, the mean number of participating nucleons, $\langle N_{\rm part}\rangle$, and the mean number of binary collisions, $\langle N_{\rm coll}\rangle$, are extracted for each centrality classes. An alternative way to define the centrality bins based on the uncorrected multiplicity distribution of charged particles in the Time Projection Chamber (TPC, $|\eta| < 0.8$) was also used in the elliptic flow analysis [3].

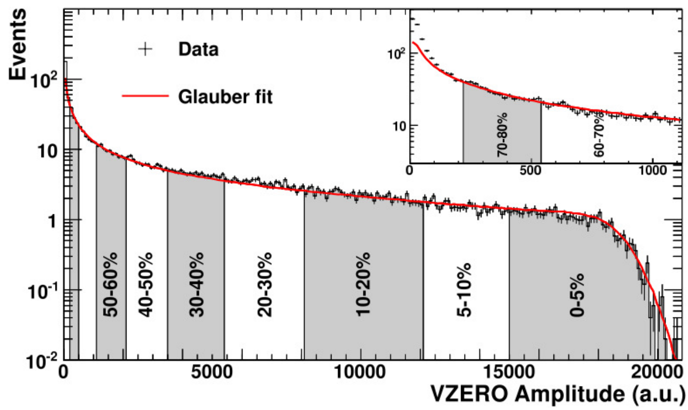

Fig. 1. Distribution of the summed amplitudes in the VZERO scintillator tiles (histogram) together with the Glauber Model fit (curve); insert shows the low amplitude part of the distribution. In order to avoid the region contaminated by electromagnetic processes, the fit is restricted to the VZERO amplitude above 150.

2. Charged-particle multiplicity density at mid-rapidity

The primary charged-particle pseudo-rapidity density, $dN_{\rm ch}/dp_{\rm T}$, was measured at mid-rapidity with the SPD [4]. In the most central 5% Pb–Pb collisions, $dN_{\rm ch}/dp_{\rm T}$ was found to be $1584 \pm 4\,({\rm stat.}) \pm 76\,({\rm sys.})$, which leads to a charged-particle pseudo-rapidity density per participating nucleon pair of $8.3 \pm 0.4\,({\rm sys.})$. Fig. 2 shows $(dN_{\rm ch}/dp_{\rm T})/(0.5N_{\rm part})$ as function of $\sqrt{s_{NN}}$ for central nucleus–nucleus and non-single diffractive $pp/p\bar{p}$ collisions. In 0–5% central Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV, an increase of about a factor 1.9 relative to pp collisions at similar collision energies, and about a factor 2.2 to central Au–Au collisions at $\sqrt{s_{NN}} = 0.2$ TeV is observed.

The centrality dependence of the charged-particle multiplicity was presented in [2]. From peripheral (70–80%) to central (0–5%) Pb–Pb collisions, $(dN_{\rm ch}/dp_{\rm T})/(0.5N_{\rm part})$ increases by about a factor 2. The centrality dependence is found to be very similar to that observed in Au–Au collisions at $\sqrt{s_{NN}} = 0.2$ TeV. The data were compared with models based on different mechanisms for particle production in nuclear collisions. The centrality dependence is well reproduced by a saturation model [5].

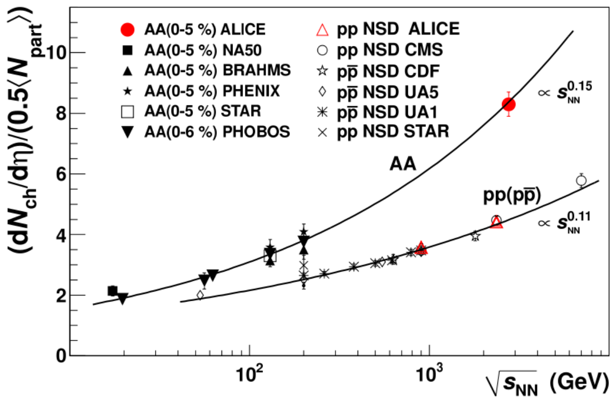

Fig. 2. Charged particle pseudo-rapidity density per participant pair for central nucleus–nucleus and non-single diffractive $pp/p\bar{p}$ collisions, as function of $\sqrt{s_{NN}}$. To lead the eyes, a $s_{NN}^{0.15}$ for nucleus−nucleus, and $s_{NN}^{0.11}$ for $pp/p\bar{p}$ collisions energy dependence lines are also plotted.

3. Bose–Einstein correlations

From the momentum-space two particle correlations of identical bosons, the size of the homogeneity volume and the decoupling time in the collisions can be estimated. The measurement of two-pion Bose–Einstein correlations in 0–5% most central Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV was performed with the Inner-Tracking-System (ITS) and the TPC [6]. The correlation functions were studied in bins of transverse momentum, defined as half of the modulus of the vector sum of the two pion transverse momenta, $k_{\rm T} = |\boldsymbol{p}_{\mathbf{T},1} + \boldsymbol{p}_{\mathbf{T},2}|/2$. Fig. 3 shows the homogeneity volume at

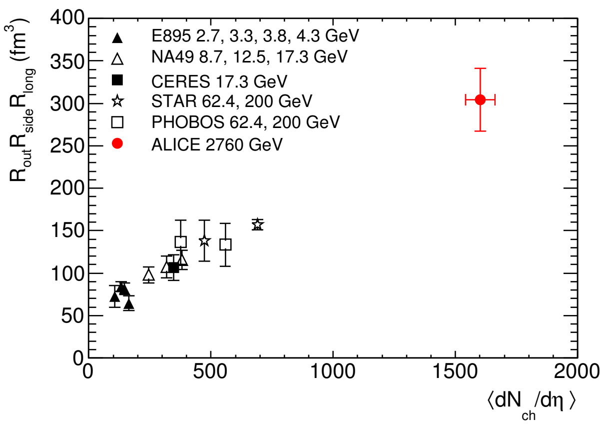

Fig. 3. Homogeneity volume at $k_{\rm T} = 0.3$ GeV$/c$. The ALICE result is compared to results for central gold and lead collisions at lower energies (see text).

$k_T = 0.3$ GeV$/c$ as function of dN_{ch}/dp_T. The ALICE result for Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV is compared to central gold and lead collisions at lower energies [7]. A linear dependence on the charged-particle pseudorapidity density is observed. The homogeneity volume is a factor two larger at the LHC than at RHIC. Under certain assumptions the decoupling time for hadrons at midrapidity, τ_f, can be extracted from the longitudinal pion homogeneity radius. It was found to exceed 10 fm$/c$, which is 40% larger than at RHIC.

4. Elliptic flow v_2 vs. centrality and p_T

When nuclei collide at finite impact parameter, the geometrical overlap region is anisotropic. The almond shape of the initial matter distribution produces a pressure gradient, which elvolves into momentum space via multiple collisions. The second moment of the final state hadron azimuthal distribution is called elliptic flow, v_2. The charged particle elliptic flow in Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV was measured at midrapidity ($|\eta| < 0.8$) in the transverse momentum range $0.2 < p_T < 5.0$ GeV$/c$ with the ITS and the TPC [3]. In the 40–50% centrality class, v_2 averaged over transverse momentum and pseudo-rapidity was found to be $0.087 \pm 0.002\,(\text{stat.}) \pm 0.004\,(\text{syst.})$. Compared to RHIC Au–Au collisions at $\sqrt{s_{NN}} = 0.2$ TeV, an increase of about 30% is observed. The differential elliptic flow $v_2(p_T)$ is presented in Fig. 4 for various centralities and compared to STAR measurements. The results are very similar at RHIC and the LHC. The p_T-integrated flow increase at the LHC compared to RHIC is due to a rise in average p_T, which points to a stronger radial flow.

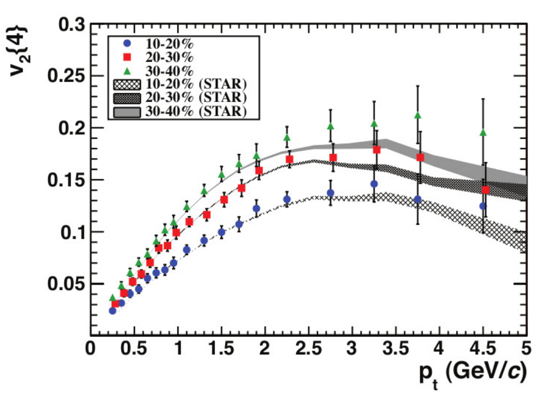

Fig. 4. Elliptic flow for various centralities compared in Pb–Pb at $\sqrt{s_{NN}} = 2.76$ TeV to STAR measurements in Au–Au at $\sqrt{s_{NN}} = 0.2$ TeV.

5. High p_{T} charged particle suppression

Medium effects can be quantified in heavy ion collisions by comparing the inclusive transverse momentum spectra of primary charged particles scaled by the number of binary collisions with that in *pp* collisions at the same center-of-mass energy per nucleon pair. The ratio is called nuclear modification factor R_{AA}. The charged particle spectra in Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV were measured at midrapidity ($|\eta| < 0.8$) in the transverse momentum range $0.3 < p_{\mathrm{T}} < 20.0$ GeV/c with the ITS and the TPC for two centrality bins, 0–5% and 70–80% [8]. Since at that time no *pp* reference was measured at $\sqrt{s_{NN}} = 2.76$ TeV, the inclusive charged particle p_{T} spectrum was interpolated between $\sqrt{s_{NN}} = 0.9$ TeV and 7 TeV. In peripheral Pb–Pb collision, only weak medium effects are observed ($R_{AA} \approx 0.7$). Fig. 5 shows the nuclear modification factor R_{AA} as function of p_{T} in central Pb–Pb collisions at the LHC together with measurements at $\sqrt{s_{NN}} = 0.2$ TeV by the PHENIX [9] and STAR [9] experiments at RHIC. The vertical bars around $R_{AA} = 1$ correspond to the p_{T} independent scaling errors on R_{AA}. At the LHC, R_{AA} reaches a minimum of about 0.14 at $p_{\mathrm{T}} = 6$–7 GeV/c, smaller than at RHIC, and increases at larger p_{T}. Despite the much flatter p_{T} spectrum at the LHC compared to RHIC, the R_{AA} is smaller.

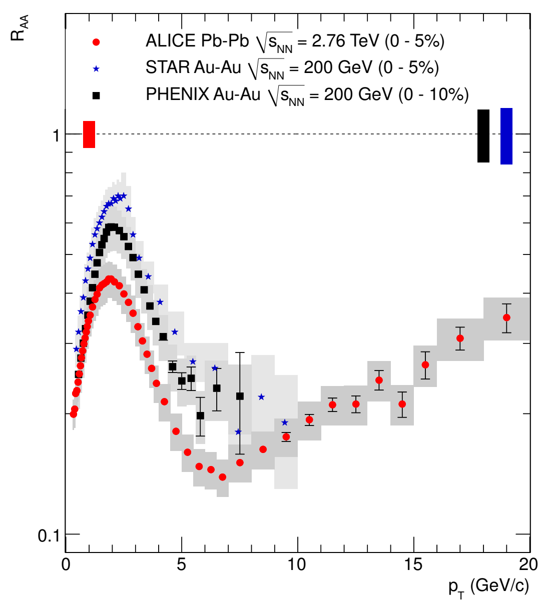

Fig. 5. Comparison of R_{AA} in central Pb–Pb collisions at the LHC to measurements at $\sqrt{s_{NN}} = 0.2$ TeV by the PHENIX and STAR experiments at RHIC.

6. Conclusion

First results in Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV were presented: the charged-particle multiplicity density at mid-rapidity, Bose–Einstein correlations, elliptic flow v_2 and high p_{T} charged-particle suppression. They provide evidence for a large medium density, strong collective effects and strong parton energy loss at the LHC.

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