Abstract. In November 2010 the ALICE experiment at CERN has collected the first Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV produced by the LHC. A first characterization of the hot and dense state of matter produced in this new energy domain became available shortly after the run. In this paper we present the results on charged-particle multiplicity, Bose-Einstein correlations, elliptic flow and their dependence on the collision centrality. Results from first measurements of strange and identified particle production and suppression of high-momentum hadrons with respect to $pp$ collisions are also reported.

Keywords: Relativistic heavy-ion collisions, ALICE experiment, LHC

INTRODUCTION

ALICE (A Large Ion Collider Experiment) has been specifically designed to study the properties of the strongly interacting matter created in heavy-ion collisions at the LHC energies\cite{1, 2}. The experimental apparatus is optimized to measure a large variety of observables in the very high multiplicity environment of the heavy-ion collisions. The detector is also recording $pp$ collisions as required primarily to have comparison data for the heavy-ion programme\cite{1}. It consists of a central part ($|\eta| < 0.9$) to detect hadrons, electrons and photons, a forward spectrometer to measure muons and additional smaller forward detectors for event characterization and triggering: a detailed description of the eighteen subsystems can be found in\cite{3}. The detector is fully installed, commissioned and operational, with the exception of the Transition Radiation Detector (TRD) and the ElectroMagnetic CALorimeter (EMCAL): both systems had a 40% of their active area installed in 2010, the EMCAL has been fully installed in the winter shutdown 2010/11 and the TRD will be completed for the 2012 data taking.

After collecting data from $pp$ collisions at $\sqrt{s_{NN}} = 0.9, 2.36$ and 7 TeV, the first Pb–Pb collisions were recorded in November 2010 at a center-of-mass energy per nucleon pair of 2.76 TeV, more than a factor 10 higher compared to the previous heavy-ion experiments. In the following, after a brief description of the data taking conditions, the very first results with Pb–Pb collisions published by ALICE will be presented and discussed.

DATA ANALYSIS AND RESULTS

During the first heavy-ion data taking period at LHC, from 4 to 114 bunches of about $7 \times 10^7$ ions of $^{208}$Pb were brought into collision at $\sqrt{s_{NN}} = 2.76$ TeV in the ALICE interaction region. The maximum rate of hadronic events was about 100 Hz, corresponding to an estimated luminosity of about $2 \times 10^{25}$ cm$^{-2}$ s$^{-1}$ reached at the end of the run. Signals from the outermost pixel layer (SPD, Silicon Pixel Detector, $|\eta| < 1.5$) and from two forward scintillator hodoscopes (VZERO-A and VZERO-C, $2.8 < |\eta| < 5.1$ and $-3.7 < |\eta| < -1.7$) were used to implement a minimum-bias interaction trigger: a total of about 30 M minimum-bias Pb–Pb interactions to tape were finally recorded. The sum of the amplitudes of the signals in the VZERO counters is also used as a measure of the event centrality.

The first measurement concerned the charged-particle multiplicity density in central collisions. It was based on the counting of the SPD tracklets, i.e. combinations of pairs of hits on the two pixel layers aligned to the main interaction vertex within predefined tolerances. The value $dN_{ch}/d\eta = 1584 \pm 4(stat) \pm 76(syst)$ measured in the 5% most central Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV corresponds to a value of $8.3 \pm 0.4(syst)$, with negligible statistical error, when normalized to the number of participant pairs. In the left panel of Fig.1 the ALICE result in Pb–Pb collisions is compared with other measurements in nucleus-nucleus and non-single diffractive $pp (p\bar{p})$ collisions in a wide range of energies\cite{4}. The pseudorapidity density increases significantly, by a factor 2.2, when going from RHIC highest energy Au–Au collisions to the Pb–Pb collisions at 2.76 TeV. An estimate of the Pb–Pb energy density $\varepsilon$ at LHC indicates approximately a factor 2.5 increase with respect to that at RHIC, assuming identical equilibration time at both energies.
The average multiplicity per participant pair is also found to be a factor 1.9 higher than in $pp$ and $p\overline{p}$ collisions at similar energies. The measurement of $dN_{ch}/d\eta$ per participant pair as a function of centrality in Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV, illustrated in the right panel of Fig.1, shows a steady increase by about a factor 2 between peripheral and central collisions, with a behaviour similar to that observed in Au–Au collisions at $\sqrt{s_{NN}} = 0.2$ TeV [5].

### FIGURE 1.
Left panel: Charged-particle pseudorapidity density per participant pair for central nucleus-nucleus and non-single diffractive $pp$ ($p\overline{p}$) collisions as a function of $\sqrt{s_{NN}}$. Right panel: Centrality dependence of charged-particle pseudorapidity density per participant pair for Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV and Au–Au collisions at $\sqrt{s_{NN}} = 0.2$ TeV. The scale for for lower-energy data is shown on the right-hand side and differs from that at higher energy by a factor 2.1.

Results concerning the freeze-out volume and the total lifetime of the system created in Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV have been obtained by measurement of identical particle interferometry (HBT) [6]. The product of the three radii, presented in the left panel of Fig.2, is connected to the volume of the homogeneity region by a factor of $(2\pi)^{3/2}$. The volume exhibits a linear dependence on the charged-particle pseudorapidity density and reaches a value of about 4600 fm$^3$ for central Pb–Pb collisions, nearly 5 times the volume of a Pb nucleus. In the right panel of Fig.2 the same trend can be observed for the extracted decoupling times: here the ALICE estimate is about 30% higher compared to RHIC.

### FIGURE 2.
Product of the three pion HBT radii (left panel) and decoupling time (right panel): the ALICE points (red filled dots) are compared to the results obtained by other experiments at lower energies.

Elliptic flow ($v_2$) measurements indicate the creation of a strongly-interacting medium of low viscosity in nucleus-nucleus collisions at RHIC energies. The $v_2$ integrated over $p_T$ as measured by ALICE in Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV has been compared with results at lower energies [7]. An increase of about 30% with respect to the top RHIC energy is observed: this confirms that the medium created in Pb–Pb collisions at LHC behaves very much as at RHIC and should constrain the temperature dependence of the ratio $\eta/s$ between shear viscosity and entropy density. The left panel of Fig.3 shows the $p_T$-differential flow for various centralities, obtained with different methods and compared with the corresponding results in Au–Au collisions at $\sqrt{s_{NN}} = 0.2$ TeV: the value of $v_2(p_T)$ does not change within the uncertainties from RHIC to LHC and the transverse momentum dependence is qualitatively similar for all centralities. In particular, the result that the differential elliptic flow stays the same over almost two order
of magnitudes in energy was not anticipated: the increase in the integrated $v_2(p_T)$ between RHIC and LHC is due to an increase in the average transverse momentum, which can be partly attributed to an increased radial flow [8].

The nuclear modification factor $R_{AA}(p_T)$ for central Pb–Pb collisions has been also measured by ALICE with the first heavy-ion data [9]. The measured charged-particle spectra in $|\eta| < 0.8$ and $0.3 < p_T < 20 \text{ GeV}/c$, when compared to the expectation in $pp$ at the same $\sqrt{s_{NN}}$ scaled by the number of underlying nucleon-nucleon collisions, shows a pronounced minimum around 6-7 GeV/$c$ and then increases significantly at larger $p_T$. As shown in the right panel of Fig.3, the high-$p_T$ suppression measured by ALICE is significantly larger than that observed at lower energy, indicating a stronger parton energy loss in the very dense medium formed in central Pb–Pb collisions at LHC.

Measurements of transverse momentum spectra of identified pions, kaons and protons for both charged states have been carried out as well: a stronger power law dependence than observed at RHIC suggests a stronger radial flow at LHC. The “baryon anomaly” (enhanced baryon to meson ratios) observed at RHIC has been found also at LHC. The $\Lambda/K^0_s$ ratio measured by ALICE is slightly larger than that at RHIC, with a very little shift of its maximum in $p_T$ [8].

CONCLUSIONS

The first ALICE measurements with Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV have been presented. In general a smooth evolution from RHIC to LHC has been observed, with qualitatively similar but quantitatively different results on most of the measurements. While a lot of physics analyses are currently ongoing on this first data, ALICE looks forward to the next (higher luminosity) heavy-ion run to continue the exciting travel into the “hot and dense matter” Wonderland.

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