Transverse momentum spectra and nuclear modification factors of charged particles at $\sqrt{s_{NN}} = 5.02$ TeV measured by ALICE at the LHC

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Abstract. The ALICE experiment at the LHC is designed to study the properties of the Quark-Gluon Plasma (QGP) based on high energy pp, p-Pb and Pb–Pb collisions. Certain properties of these collisions can be studied by measuring the production of charged particles. A suppression of the yield of charged particles was observed at high $p_T$ by comparing central Pb-Pb events scaled by the number of binary collisions to pp collisions, in terms of the nuclear modification factor $R_{AA}$. This suppression can be an effect of the energy loss of partons as they propagate in a hot and dense QCD medium (QGP).

In the end of 2015, pp and Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV were measured by ALICE. Here, transverse momentum distributions of inclusive charged particles in pp and Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV as well as the nuclear modification factor in six centrality classes are presented and compared with model predictions.

1. Introduction

Transverse momentum ($p_T$) spectra of charged particles in heavy-ion collisions were measured by PHENIX and STAR at RHIC at collision energies of up to $\sqrt{s_{NN}} = 200$ GeV [1][2]. The particle yield in heavy-ion collisions was observed to be suppressed compared to nucleon-nucleon collisions scaled by the number of binary collisions. In 1982 Bjorken suggested that this could be caused by the energy loss of partons in hot and dense QCD matter, i.e. the Quark-Gluon Plasma (QGP), which is created in heavy-ion collisions [3]. This energy loss leads to a modification of the $p_T$ of the final particles and in consequence to a suppression of the particle yield at a given $p_T$.

Typically, the parton energy loss is studied by means of the nuclear modification factor $R_{AA}$:

$$R_{AA} = \frac{1}{\langle T_{AA} \rangle} \frac{dN_{AA}/dp_T}{d\sigma_{pp}/dp_T}$$  (1)

It compares the particle yield in nucleus-nucleus collisions ($dN_{AA}/dp_T$) to the particle cross section in nucleon-nucleon collisions ($d\sigma_{pp}/dp_T$) scaled by the average nuclear overlap function $\langle T_{AA} \rangle$ which can be obtained by Glauber Monte Carlo calculations. The latter relates to the average number of binary collisions $\langle N_{coll} \rangle$ via $\langle T_{AA} \rangle = \langle N_{coll} \rangle / \sigma_{inel}^{NN}$ with the inelastic cross section $\sigma_{inel}^{NN}$ of proton-proton collisions and depends strongly on the centrality of the collision. While $R_{AA} = 1$ indicates that a heavy-ion collision is a superposition of nucleon-nucleon
collisions, an observation of $R_{AA} < 1$ manifests a suppression of charged-particle yields in AA collisions.

In the LHC-Run 1 ALICE measured the nuclear modification factor of inclusive charged particles at $\sqrt{s_{NN}} = 2.76$ TeV \[4\]. The observed suppression was larger compared to RHIC and it was stronger for most central collisions than in peripheral collisions. In order to distinguish between initial-state and final-state effects and to show that binary scaling is a valid assumption at the LHC energies, ALICE measured the nuclear modification factor $R_{pPb}$ of inclusive charged particles for p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV \[5\], where no hot and dense QCD matter is expected. At high $p_T$ the $R_{pPb}$ of inclusive charged particles is consistent with unity and indicates that binary scaling works at this collision energy.

In heavy-ion collisions at $\sqrt{s_{NN}} = 5.02$ TeV ALICE measured 20% more charged particles compared to the production at $\sqrt{s_{NN}} = 2.76$ TeV \[6\], indicating a larger, hotter or longer living medium.

2. Analysis
In this work, the scintillator detectors V0A ($0 \leq \phi < 2\pi$, $2.8 > \eta > 5.1$) and V0C ($0 \leq \phi < 2\pi$, $-3.7 > \eta > -1.7$) are used for estimating the centrality \[7\] of the event and for triggering. With the Inner Tracking System (ITS), the Time Projection Chamber (TPC) and the Transition Radiation Detector (TRD) the tracks of charged particles are reconstructed. A detailed description of the ALICE detectors and of the reconstruction procedure can be found in \[8\].

The transverse-momentum spectrum of primary charged particles is measured in the full azimuthal acceptance and within $|\eta| < 0.8$. Primary particles are defined as all prompt particles including products of short lived strong and electromagnetic decays, but excluding products of
3. Results

The invariant yield of charged particles as a function of the transverse momentum has been measured in pp at $\sqrt{s} = 5.02$ TeV and in Pb–Pb at $\sqrt{s_{\text{NN}}} = 2.76$ TeV in different centrality classes. In figure (left) the $p_T$ distribution in pp is shown for $0.15$ GeV/$c < p_T < 40$ GeV/$c$ for $|\eta| < 0.8$ and compared with model predictions from the EPOS LHC event generator and from PYTHIA 8 (Monash-2013-tune). A discrepancy between models and measurement up to $\sim 20\%$ can be observed.

The transverse momentum distribution in Pb–Pb is shown in six different centrality classes...
The nuclear modification factor $R_{AA}$ is compared to three different models at high $\sqrt{s_{NN}}$.

Figure 3 shows $R_{AA}$ for 0–5% central Pb–Pb collisions and compares the measurement with predictions from Djordjevic et al. [13] and Majumder et al. [14]. Figure 3 (right) shows $R_{AA}$ for 0–10% central Pb–Pb collisions in a comparison to a prediction from Vitev et al. [15]. The measurement is in good agreement with all three model predictions within their uncertainties.

4. Summary and Outlook

Measurements of charged-particle $p_T$-distributions in pp collisions and Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV by the ALICE collaboration are presented. The nuclear modification factor $R_{AA}$ at $\sqrt{s_{NN}} = 5.02$ TeV is found to be consistent with the measurement at $\sqrt{s_{NN}} = 2.76$ TeV.

The strongest suppression is observed at central collisions (0–5%) at $p_T \approx 6 – 7$ GeV/$c$ and it increases significantly for high $p_T$. In peripheral collisions $R_{AA}$ is about 0.6–0.7 in the minimum at $p_T \approx 6 – 7$ GeV/$c$. Towards higher center of mass energy the energy density increases as more charged particles are produced [6]. The agreement between the two measurements of $R_{AA}$ of inclusive charged particles at different center of mass energies could hint to a larger parton energy loss in the hotter and denser medium. The systematic uncertainty is reduced in this analysis compared to the previous measurement of $R_{AA}$ at $\sqrt{s_{NN}} = 2.76$ TeV.

In this analysis 25% of the pp statistics and 3% of the Pb–Pb statistics were considered. The analysis of the full statistics is on the way. Additionally the improved analysis method will be used for the measurement at $\sqrt{s_{NN}} = 2.76$ TeV to reduce systematic uncertainties and for more...
precise comparison of results.

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