

Study of the neutral mesons in Pb-Pb collisions at $\sqrt{s_{NN}}=2.76$ TeV in the ALICE experiment at LHC

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Abstract. The π^0 and η meson production in Pb-Pb collisions at $\sqrt{s_{NN}}=2.76$ TeV is studied with the ALICE experiment at the LHC. The π^0 meson invariant yields and nuclear modification factor R_{AA} are presented here in six centrality classes. The results are obtained using the Photon Conversion Method (PCM) and utilizing the PHOS detector, for the transverse momentum range $0.4 < p_T < 12$ GeV/c. The π^0 meson R_{AA} is studied in different centrality classes and compared with results from experiments at lower energies, as a function of transverse momentum. The η meson production is studied using the PCM and utilizing the EMCal detector. The combination of these two independent methods will make possible the measurement of the η differential invariant cross section as a function of transverse momentum from 1 to 22 GeV/c in different centrality classes.

1. Introduction

The ALICE experiment's [1][2] scientific program is focused on the analysis of heavy-ion collisions and on the study of the Quark-Gluon Plasma, a state of the matter with high temperature and large energy density, where gluon and quarks are deconfined, as predicted by QCD. As this medium has high color charge density, partons produced in the earlier stage of the collision lose energy through radiative gluon emission and multiple scattering while traversing it. The parton energy loss affects the hadron yields in the high p_T region, a modification that can be observed comparing results on particle production in Pb-Pb collisions with those from pp collisions. In order to study this effect, the nuclear modification factor R_{AA} is used:

$$R_{AA}(p_T) = \frac{d^2N/dp_T dy|_{AA}}{\langle T_{AA} \rangle d^2\sigma/dp_T dy|_{pp}} \quad (1)$$

where $\langle T_{AA} \rangle = \langle N_{coll} \rangle / \sigma_{inel}^{pp}$ is used to scale the pp yield to the Pb-Pb yield. Here, $\langle N_{coll} \rangle$ is the average number of binary nucleon-nucleon collisions obtained from the Glauber model [3] and σ_{inel}^{pp} is the pp inelastic cross section [4]. The π^0 meson R_{AA} has been studied through its two photon decay channel with the ALICE experiment [5][6]. The detectors involved in the measurement of photons are a lead-scintillator electromagnetic calorimeter (EMCal) and the photon spectrometer (PHOS), made of lead tungstate crystals. The EMCal covers $|\eta| < 0.7$ and $\Delta\phi = 100^\circ$ while PHOS covers $|\eta| < 0.25$ and $\Delta\phi = 60^\circ$. It is also possible to measure photons through their conversion into electrons and positrons in the detector material. This method is called Photon Conversion Method (PCM) and relies on the Inner Tracking System (ITS) and on the Time Projection Chamber (TPC), which have full azimuthal coverage. The material thickness, up to the middle of the TPC, is $X/X_0 = 11.4 \pm 0.5_{sys}\%$.



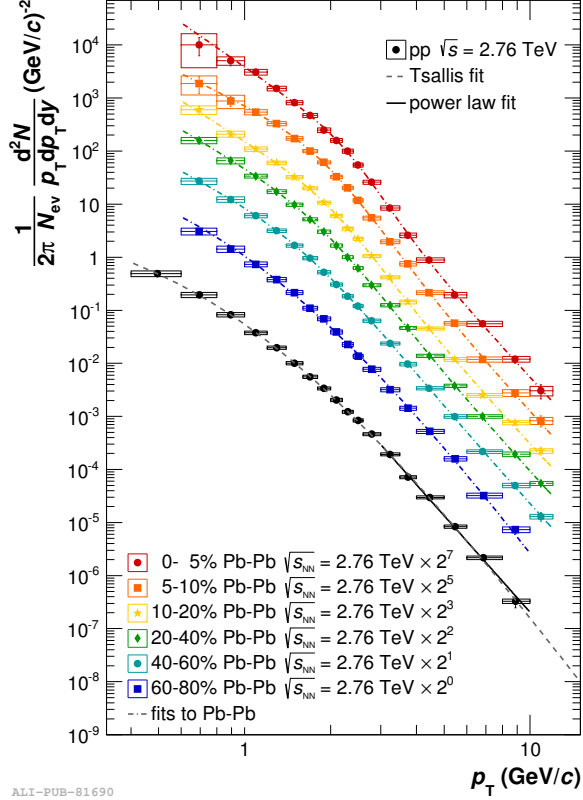


Figure 1. (Color online) Invariant differential yields of neutral pions produced in PbPb and inelastic pp collisions. The spectra are the weighted average of PHOS and PCM results. Vertical lines represent statistical uncertainties, boxes systematic uncertainties and horizontal lines indicate bin width.

2. Results

The π^0 meson invariant yields presented here have been measured independently by PHOS and PCM and were then combined into a weighted average. In Fig. 1, the combined PHOS-PCM π^0 meson yields are shown for pp collisions and Pb-Pb collisions in 6 centrality classes. For PHOS, the data sample consists of 16.1×10^6 events collected in the 2010 Pb-Pb run and of 34.7×10^6 events from the 2011 pp run at $\sqrt{s_{NN}} = 2.76$ TeV, while for PCM it is 13.2×10^6 and 58×10^6 events, respectively [6]. The transverse momentum range is 0.6 to 12 GeV/c. For the pp spectrum, a Tsallis function [7] for the full p_T region and a power law $Ed^3N/d^3p \propto 1/p_T^n$, only for the high p_T region ($p_T > 3$ GeV/c), are shown. The power law fit extrapolation above 8 GeV/c is used as reference in the R_{AA} calculation. The Pb-Pb spectra parametrization is described in the appendix of [6].

The neutral pion nuclear modification factor is calculated with Eq. 1. The nuclear overlap

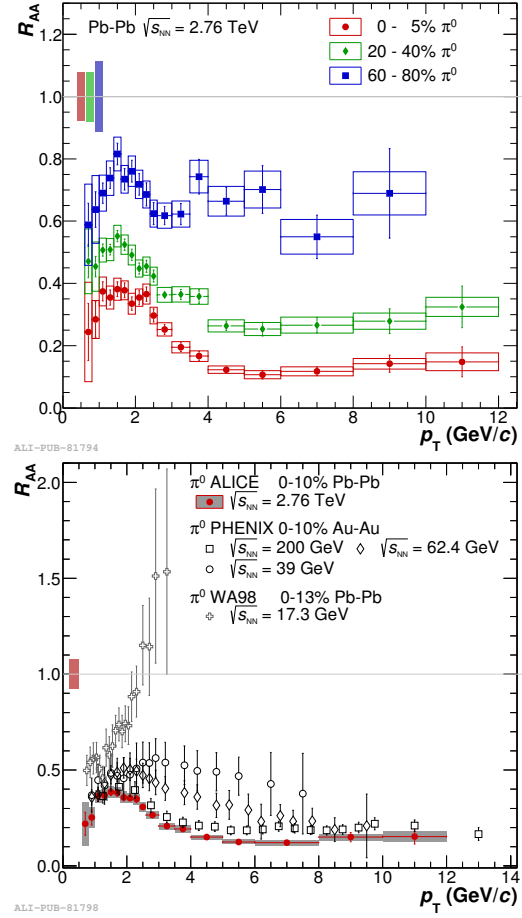


Figure 2. (Color online) Top: Neutral pion modification factor in Pb-Pb collisions. Bottom: Neutral pion modification factor in Pb-Pb for centrality class 0-10% measured by ALICE [6] is compared with the results from Au-Au collisions measured by PHENIX [10][11] and from Pb-Pb collisions at the CERN SPS [12].

function $\langle T_{AA} \rangle$ was obtained with a Monte Carlo calculation [3][8][9] and the values including their uncertainties for each centrality class can be found in [6]. In Fig. 2, top panel, the combined PCM-PHOS result for the π^0 R_{AA} is shown. The R_{AA} decreases going from peripheral to central collisions, due to different energy loss in the medium. For all the centrality classes, the R_{AA} has a maximum for $p_T < 2$ GeV/c, decreases until $p_T < 6$ GeV/c and stays flat after $p_T > 6$ GeV/c. In this last region, particle production is expected to be dominated by fragmentation of hard-scattered partons.

The dependence of R_{AA} on the system energy has also been studied. In the bottom panel of Fig. 2 the π^0 meson R_{AA} for Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV measured with ALICE is compared to previous results at lower energies. ALICE data points are below the lower energies points and their suppression is more evident for $p_T > 2$ GeV/c. Models attribute this behavior to the higher initial energy densities created at larger $\sqrt{s_{NN}}$. This dominates over the expected increase of R_{AA} due to the harder initial p_T spectra [13]. Also, no increase at high p_T is observed. It is also noted that the position of the maximum seems to be shifting towards lower transverse momentum with increasing collision energy. The neutral pion R_{AA} has been compared with different theoretical models. These comparison plots can be found in [6]. The GLV calculation [14][15] and WHDG [16] prediction describe the interaction of hard-scattered parton with the medium using perturbative QCD. EPOS [17] and Nemchik et al. [18][19] calculations use a hydrodynamic description at low p_T and absorption of color dipoles at high p_T .

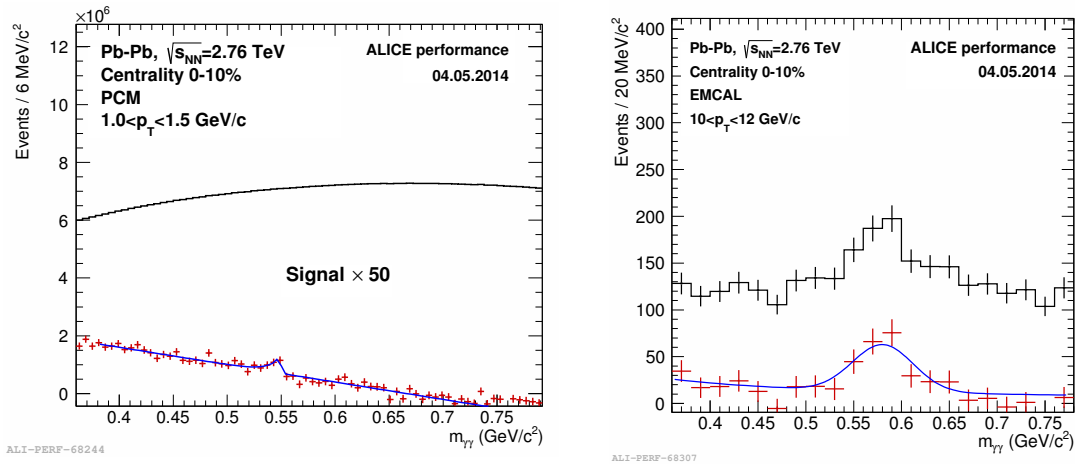


Figure 3. (color online) Photon pair invariant mass distribution in the η meson mass region in selected p_T slices for PCM (left) and EMCal (right) for 0-10% Pb-Pb collisions. The black histogram and the red points show the data before and after background subtraction, respectively. For PCM, the invariant mass spectra after background subtraction is scaled by a factor 50. The blue line shows the fit to the invariant mass spectra after the background subtraction.

The η meson can be measured in ALICE in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV with the 2011 data sample. It has an integrated luminosity one order of magnitude larger than the corresponding one for 2010, making a reliable reconstruction of the η meson spectrum possible. We show here the first steps towards a combined PCM-EMCal η meson measurement. The data sample consists of about 17 million events in the central class 0-10% for both PCM and EMCal. The transverse momentum range for this combined measurement can go from 1 to 22 GeV/c with an overlap between the two approaches in the intermediate transverse momentum region

($4 < p_T < 10$ GeV/c).

In Fig. 3, the photon pair invariant mass distribution is shown for two sample transverse momentum bins. The η meson peak is clearly visible. For PCM (left panel), the lowest p_T bin is shown. The general fit function used by PCM for all p_T is a Gaussian function combined with an exponential tail on left side of the peak (to account for the electron bremsstrahlung) and with a linear fit to describe the remaining combinatorial background under the peak after the combinatorial background subtraction. The fit is used only to extract the η meson peak position and width. The η meson yields are then extracted by integrating the peak area and subtracting the integral of the linear fit. In the right panel of Fig. 3, a bin in the intermediate range of the EMCal p_T reach is shown. The fit function used here is a Crystal-Ball function while a linear fit or a parabola, depending on the p_T and centrality, is adopted for the residual background hypothesis.

3. Conclusions

Measurements of the neutral pion production in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV have been shown combining two independent methods, the measurement of the photons with the PHOS detector and the reconstruction of the converted photons with the tracking system. These two independent measurements are consistent and were combined in a weighted average for the π^0 spectra. The neutral pion nuclear suppression factor was calculated from the measured neutral pion spectra separately for the two methods and then combined, in order to reduce the systematic errors. The π^0 meson R_{AA} was studied for different centrality classes and compared to low-energy results. The suppression is stronger for higher collision energy when comparing Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV to results from RHIC and CERN SPS.

The η meson invariant mass distributions for two transverse momentum bins from the 2011 Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV are shown. Also here two independent methods are used, the photon measurement with the EMCal detector and the photon conversion. The transverse momentum range for this combined measurement will go from 1 to 22 GeV/c with an overlap in the intermediate transverse momentum region ($4 < p_T < 10$ GeV/c). This analysis will allow to study the η meson suppression in Pb-Pb collisions.

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