Inclusive production of π^0 in pp collisions at 0.9 and 7 TeV and perspectives for heavy-ion measurements with the ALICE calorimeters

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Abstract

The inclusive spectrum of π^0 production has been measured in pp collisions at $\sqrt{s} = 900$ GeV and 7 TeV with the ALICE experiment. The preliminary results of these measurements are presented, and perspectives for π^0 measurements with heavy ions are discussed.

Key words: Hadron production, differential cross section, experimental data analysis
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1. Introduction

Hadron production measurements in proton-proton collisions at the LHC energies opens up a new kinematic regime for testing and validating the predictive power of quantum chromodynamics, and to impose new constraints on models and their parameters. Quantitative description of hard processes is provided by perturbative QCD (pQCD). However, a significant fraction of hadrons are produced in pp collisions at high energies via soft parton interactions, and thus they cannot be well described within the framework of pQCD. Many advanced event generators have to appeal to phemonenological models, along with the pQCD calculations, in order to describe hadron production adequately. Evidently, such phenomenological models are tuned to available experimental data, and have been validated using data delivered by lower-energy colliders, like RHIC, SPS and Tevatron. Extrapolation of these models to LHC energies cannot be valid *a priory*, because the increase in the collision energy is very large. Even the validity of the pQCD predictions cannot be guaranteed at the LHC, since the parton density functions (PDF) are not well determined at such a high energy.

Hadron spectra measured in heavy ion collisions shed light onto the parton energy loss in hot quark-gluon matter, via comparison with the spectra measured in pp collisions.

Suppression of the hadron yield, defined as the ratio of the hadron production spectra in central heavy ion and pp collisions, normalized per nucleon-nucleon collision, is referred to as the nuclear modification factor R_{AA}. It was measured in Au-Au collisions at $\sqrt{s_{NN}} = 200$ GeV by PHENIX [1] and STAR [2] at RHIC. The LHC brings the Pb-Pb collisions to almost 10 times higher energy, $\sqrt{s_{NN}} = 2.76$ TeV, and thus the measurements of R_{AA} becomes important for understanding the properties of the quark matter produced in these high-energy nuclear collisions. Suppression of charged particle production at large p_T in central Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV has been already observed by ALICE [3].

The ALICE experiment [4] performs measurements of the neutral pion production in pp collisions at the collision energies $\sqrt{s} = 7$ TeV and 900 GeV, and in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV at mid-rapidity in a wide range of the tranvserse momenta p_T. Conventionally, the π^0 meson is detected via its two-photon decay in the electromagnetic calorimeters, PHOS and EMCAL. The PHOS detector [5] covers the acceptance of $260° < \varphi < 320°$ in azimuth angle and $|\eta| < 0.13$ in pseudorapidity. The EMCAL [6] acceptance is $80° < \varphi < 120°$ and $|\eta| < 0.7$. The decay $\pi^0 \to \gamma\gamma$ was also measured by ALICE via identifying the conversion photons produced in the material of the ALICE inner tracking system, $\gamma \to e^+e^-$, described elsewhere [7,8].

2. Analysis

The proton-proton collision data used for the measurements of the π^0 spectrum were collected by the ALICE detector in 2010 with the minimum bias trigger [9]. This trigger required a hit in the Silicon Pixel Detector (SPD) or in either one of the two scintillator hodoscopes V0A and V0C surrounding the interaction point at large rapidities. The integrated luminosities of the event samples are $\int \mathcal{L}dT = 5.5$ nb^{-1} at $\sqrt{s} = 7$ TeV and $\int \mathcal{L}dT = 0.14$ nb^{-1} at $\sqrt{s} = 900$ GeV.

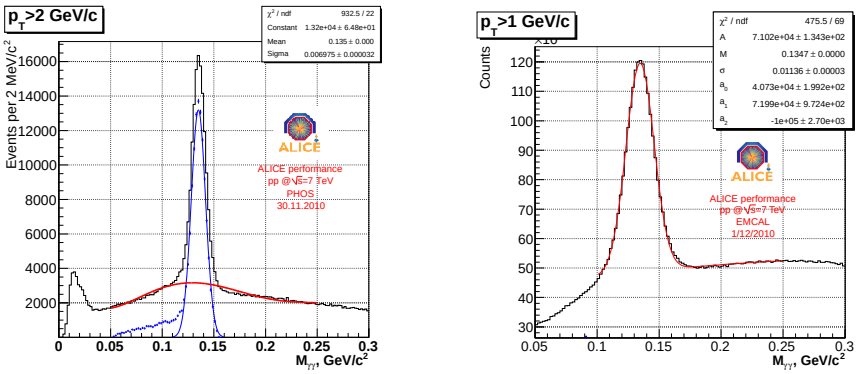

Fig. 1. Invariant mass spectra of cluster pairs measured in PHOS and EMCAL.

Reconstruction of the π^0 mesons in the ALICE calorimeters, PHOS and EMCAL, was performed by invariant mass analysis. To minimize a possible bias by the photon identification, rather loose cuts on the photon candidates were imposed. To suppress a major part of hadronic background, the lower cut on the cluster energy was set to a value just above the minimum ionizing energy, $E > 0.3$ GeV. An additional cut on the number of cells in a cluster was set in PHOS — all clusters containing at least 3 cells were

considered as candidates for photons. Due to the low occupancy of both calorimeters by the secondary particles in pp collisions, the background under the π^0 peak is not very large and allows easily to extract the number of π^0's. Examples of the invariant mass distributions in PHOS and EMCAL are shown in Fig.1. The number of reconstructed π^0's was found in each p_T bin from the invariant mass distributions by fitting and extracting the number of events under the π^0 peak. The raw spectrum obtained was corrected for the reconstruction efficiency calculated in Monte Carlo simulations tuned to reproduce the real-data characteristics.

3. Results and discussion

Data collected with the PHOS detector in the pp run allowed to measure the π^0 spectra in the p_T range from 0.6 to 25 GeV/c at the center-mass energy $\sqrt{s}$ = 7 TeV and in the p_T range from 0.6 to 7 GeV/c at $\sqrt{s}$ = 900 GeV. The invariant π^0 production yields normalized per pp minimum bias collision are shown for both collision energies in Fig.2. Besides the PHOS measurements, these plots show the results of the measurements in

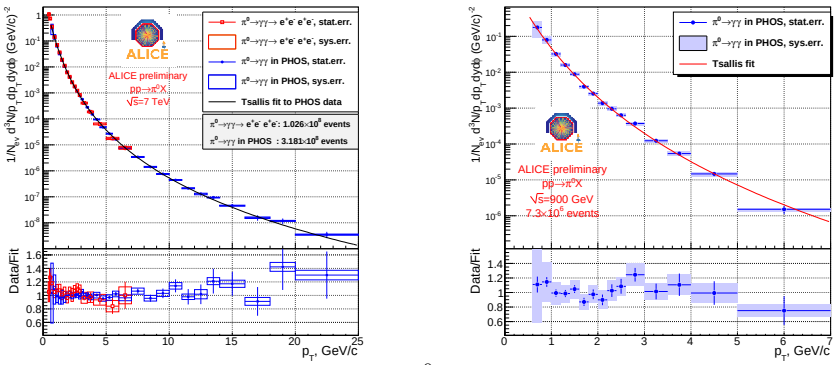

Fig. 2. Normalized invariant production yield of π^0 mesons in pp collisions at $\sqrt{s}$ = 7 TeV (left) and 900 GeV (right).

the central tracking system via photon conversion. The PHOS points were fitted by the Tsallis function $d^3N/p_t dp_t dy d\phi = C[1+(m_T-m)/nT]^{-n}$ and the ratio of the data points to the fitting function, shown at the bottom of the spectra, illustrates the stability of the measured points. These normalized spectra were converted to the invariant differential cross section of the π^0 production $Ed^3\sigma/dp^3|_{y=0}$ with the assumption of the absolute cross section of pp collisions. Within conservative uncertainty estimation, the pp cross section was taken as $\sigma_{pp} = 67 \pm 10$ mb at $\sqrt{s} = 7$ TeV and $\sigma_{pp} = 50 \pm 10$ mb at $\sqrt{s} =$ 900 GeV. The production cross sections obtained are shown in Fig.3. Next-to-Leading Order pQCD calculations with the parton density function CTEQ5M, fragmentation function KKP and different QCD scales μ [10] have been compared with the data. The ratio of the measured cross section to the NLO prediction is shown in the bottom panels. The uncertainty in the pp cross section $\pm$10 mb is represented by the pink box. At the collision energy of 900 GeV the NLO calculations at $\mu = p_T$ describe well the measured data, while at $\sqrt{s} = 7$ TeV the higher QCD scale ($\mu > 2p_T$) is required to reproduce better the data, although the discrepancy is still significant.

Data collected by the ALICE calorimeters in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV are sufficient to measure the π^0 spectrum at $1 < p_T < 15$ GeV/c. More sophisticated analysis

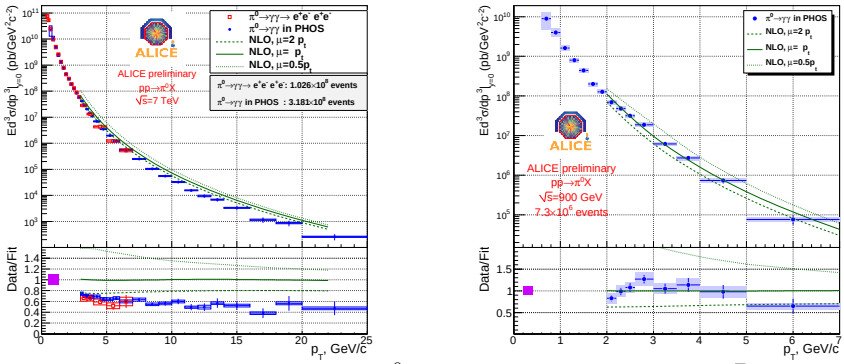

Fig. 3. Differential invariant cross section of π^0 production in pp collisions at $\sqrt{s} = 7$ TeV (left) and 900 GeV (right).

is ongoing now involving advanced methods of background subtraction and of reconstruction efficiency evaluation in a high-multiplicity environment. The nuclear modification factor R_{AA} of the π^0 spectrum will be a complimentary measurement to the charged particle suppression [3] which will lead to better understanding of transport propereties of hot QCD matter.

Conclusion

The ALICE experiment at the LHC has measured the production spectrum of neutral pions in proton-proton collisions at the energies $\sqrt{s} = 7$ TeV and 900 GeV, using two independent methods. The photons from the π^0 were detected by the calorimeters, as well as via photon conversion identified in the central tracking system. Deploying these techniques provided a cross check and allowed to reduce systematic uncertainties in the overlapping p_T region and to extend the joint spectrum to a wide p_T range. The production yield was measured at mid-rapidity at $0.4 < p_T < 25$ GeV/c at $\sqrt{s} = 7$ TeV and at $0.6 < p_T < 7$ GeV/c at $\sqrt{s} = 900$ GeV. These measurements allow a test of pQCD-based calculations and provide reference data to measure the nuclear modification factor R_{AA} of the π^0 production in heavy ion collisions at the LHC.

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