PROCEEDINGS OF SCIENCE

Overview of neutral-meson production in pp, p–A and A–A collisions at the LHC measured by ALICE

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Neutral pion and η-meson production in pp, p–A and A–A collisions at LHC energies measured with the ALICE experiment is reviewed. In pp collisions the measured invariant production cross-section both of π^0 and η-mesons is reproduced by Pythia 8 Monash tune while NLO pQCD calculations predict significantly higher yield. The multiplicity dependence of neutral meson production in p–Pb collisions strongly depends on the rapidity gap between the measured particles and the multiplicity estimator. Nuclear modification factors Q_{pA} of neutral mesons and D-mesons in these collisions are close in all centralities. Neutral meson production in Pb–Pb collisions shows close nuclear modification factors for two energies, $\sqrt{s_{\mathrm{NN}}} = 2.76$ and 5.02 TeV. Suppression of neutral pions and D-mesons is similar at high $p_{\mathrm{T}} > 10$ GeV/c, while at lower p_{T} D-mesons show smaller suppression.

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1. Introduction

Neutral mesons can be reconstructed and identified through their two-photon decays in a wide range of transverse momenta (p_T), providing the possibility to test strong interactions over a wide kinematic range. Meson production in pp collisions is described with perturbative QCD as a convolution of parton distribution functions (PDF), elementary parton cross-sections and fragmentation functions (FF) [1]. The neutral meson yield can be used either as a constraint or as an input in the global fit in PDF and FF parameterizations. The neutral meson spectra measured in p–A collisions are in addition sensitive to the modification of PDF in nuclei and to cold nuclear effects, while at low p_T they reflect possible collective flow effects. In Pb–Pb collisions one can look at the modification of meson yield at high p_T compared to the baseline provided by pp and p–A collisions, and scaled with the number of binary nucleon-nucleon collisions, reflecting parton energy loss in hot quark-gluon matter. At low p_T spectra are sensitive to the presence of collective effects.

2. ALICE experiment

Neutral mesons can be reconstructed in ALICE via their two-photon decay channels. Photons can be measured either in the electromagnetic calorimeters EMCal [2] and PHOS [3] or reconstructed as a e^+e^- pair created in the photon conversion on material of inner detectors (Photon Conversion Method [4]). The EMCal, which is built using shashlyk design, has large acceptance but modest energy resolution. The PHOS uses $PbWO_4$ crystals and has small acceptance but good energy resolution. In these analyses the advantages of each technology are used: the large acceptance and good momentum resolution of the tracking system at low p_T, so that with PCM the π^0 spectrum can be measured down to very low p_T. Energy resolution of calorimeters improves with p_T and together with trigger abilities one can extend the p_T range up to few tens of GeV/c. In addition, a hybrid method is used, where one photon is reconstructed in the calorimeter and the second with the PCM method. Thus the effect of merging of photon clusters from high-p_T π^0 is mitigated. Here we present results of analysis of pp, p-Pb and Pb–Pb data collected in 2010-2013 corresponding to the Run 1 LHC period.

3. Meson production in pp and p–Pb collisions

ALICE measured π^0 production cross-sections in pp collisions at several collision energies $\sqrt{s} = 0.9$, 2.76, 7 and 8 TeV [4, 5, 6], see Fig. 1, left plot. For comparison, predictions of the Pythia 8 Monash tune [7] and NLO pQCD calculations [8] are shown. To make a quantitative comparison, the data were fit with Two Component Model [9] functions and both data and theoretical calculations were divided by the fit, see Fig. 1, middle plot. Pythia 8 approximately reproduces data, while NLO pQCD calculations predict 20-30% higher yield at all colliding energies. Spectra of the η-meson were also measured in these collision systems [4, 5, 6]. The ratio of the measured spectra of η-meson and of theoretical prediction to the fit to data with TCM function are shown in Fig. 1, right plot. Similar to the π^0 case, Pythia 8 approximately reproduces the yield, while NLO pQCD calculations [8] predict approximately twice higher yield. It is interesting that the η/π^0 ratio is universal for all collision energies and is approximately reproduced both by Pythia 8 and NLO pQCD calculations [4, 5, 6].

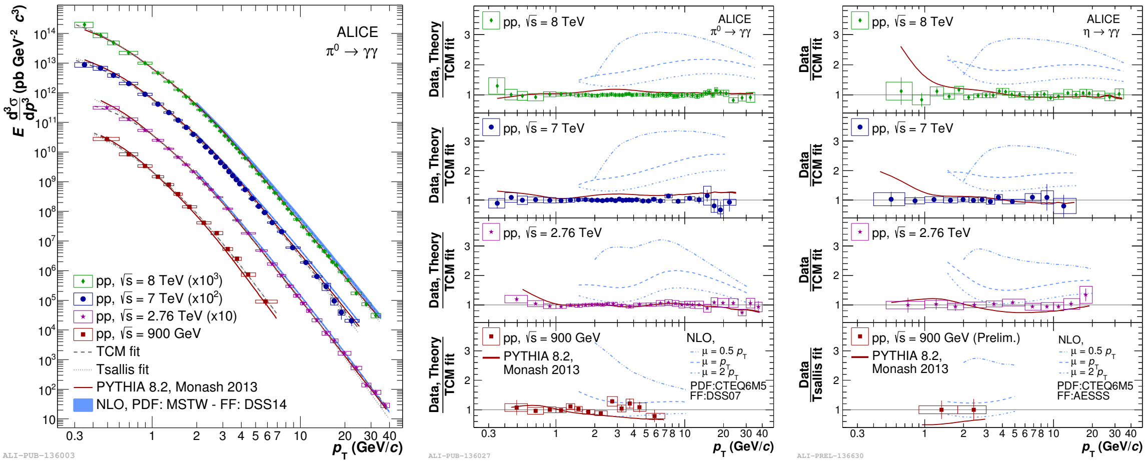

Figure 1: Left: Invariant cross-section of π^0 production at midrapidity in pp collisions at different LHC energies, compared to Pythia 8 [7] and NLO pQCD predictions [8]. Error bars represent statistical and boxes systematic uncertainties. Middle: Ratio of measured π^0 production cross-sections and theoretical calculations to the fit to data. Right: Ratio of measured η-meson production cross-sections and theoretical calculations to the fit to data.

Previously ALICE has measured the π^0 and η production yields in non single-diffractive (NSD) p-Pb collisions [10]. Presently these measurements are extended to several multiplicity classes in these collisions. Because of large fluctuations and possible correlations between the multiplicity estimator and the measured spectrum, three multiplicity estimators were used [11]: the ZNA, based on the response of neutral zero degree calorimeter, covering pseudorapidity $|\eta| > 8.7$, the V0A scintillator covering $2 < \eta < 5.1$ in Pb direction, and the CL1 estimated using the two inner layers of the ITS detector, covering $|\eta| < 1.4$. Note that, thanks to the neutrality of π^0 and η-mesons there are no trivial auto correlations even in the case of CL1 estimator. The nuclear modification factors

$$Q_{\rm pA} = \frac{1/N_{\rm ev}{\rm d}N^{\rm pPb}/{\rm d}\eta {\rm d}p_{\rm T}}{\langle N_{\rm coll}\rangle 1/N_{\rm ev}{\rm d}N^{\rm pp}/{\rm d}\eta {\rm d}p_{\rm T}}$$

calculated in four multiplicity classes for each multiplicity estimator are shown in Fig. 2. The $Q_{\rm pA}$ notation is used here to stress dependence of calculation of $\langle N_{\rm coll}\rangle$ on multiplicity estimator in p–A

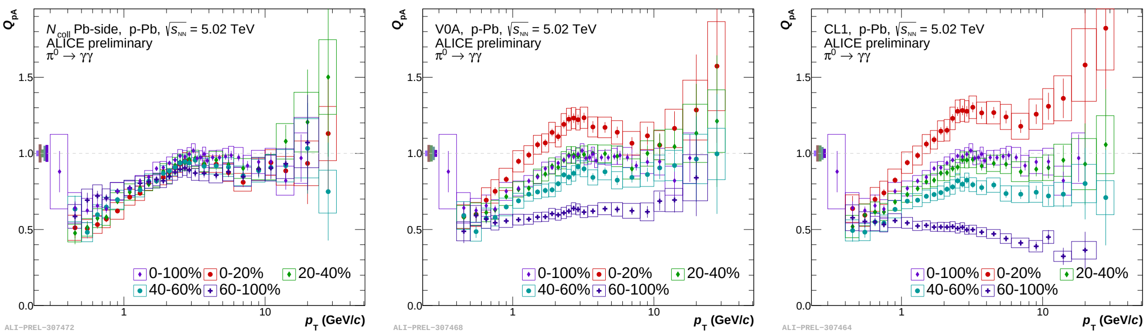

Figure 2: Nuclear modification factors $Q_{\rm pA}$ measured in four multiplicity classes of p-Pb collisions using ZNA ($|\eta| > 8.7$) (left), V0A ($2 < \eta < 5.1$) (middle) and CL1 ($|\eta| < 1.4$) (right) multiplicity estimators.

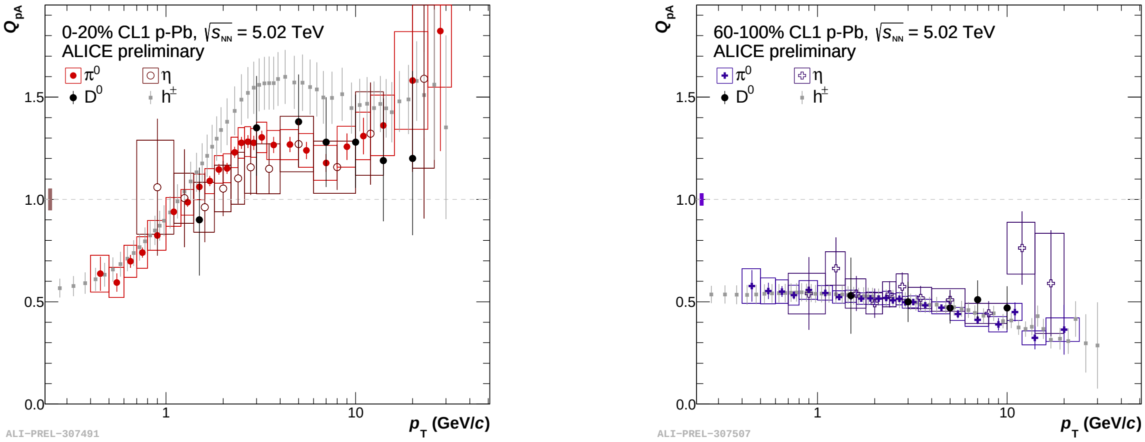

Figure 3: Neutral pion nuclear modification factor Q_{pA} for π^0 and η-mesons compared to Q_{pA} for unidentified charged particles [11] and D-mesons [12] in two extreme CL1 ($|\eta| < 1.4$) centralities of p-Pb collisions.

collisions. For the ZNA estimator with the largest $\Delta\eta$ gap no significant multiplicity dependence is observed. For the V0A and CL1 estimators, a clear multiplicity dependence is seen, stronger in case of smaller $\Delta\eta$ gap.

The dependence of Q_{pA} on particle species is illustrated in Fig. 3. The Q_{pA} for neutral pions, η-mesons, charged hadrons and D-mesons for two extreme centralities, calculated with the CL1 estimator, are compared. Nuclear modification factors for π^0, η-mesons and D-meson are consistent with each other over the whole p_{T} range, while charged particles show some bump around $p_{\mathrm{T}} \sim 3$ GeV/c, probably related to the proton contribution. Similar to the pp case, the η/π^0 ratio follow the same universal trend and shows no multiplicity dependence in any multiplicity estimator.

4. Meson production in Pb–Pb collisions

Neutral meson spectra and nuclear modification factors R_{AA} were measured earlier in Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV [13, 14]. A corresponding measurement at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV shows close values [15]. One can compare the energy loss of heavy and light quarks, by comparing the nuclear modification factors for light and heavy flavored hadrons, shown in Fig. 4. In peripheral collisions nuclear modification factors R_{AA} for all species are consistent with each other within uncertainties. In central collisions R_{AA} for all three species show the same suppression at high transverse momenta, while at low p_{T} D-mesons show considerably smaller suppression compared to neutral pions and unidentified charged particles.

5. Conclusions

Neutral meson production was measured in pp, p-Pb and Pb–Pb collisions at LHC energies. In pp collisions, state-of-the-art NLO pQCD calculations predict considerably higher yield both for π^0 and η mesons while Pythia 8 Monash tune approximately reproduces the data. Neutral pion production in p-Pb collisions shows no multiplicity dependence with the ZNA multiplicity estimator, across a large rapidity gap, and shows a considerable multiplicity dependence with the

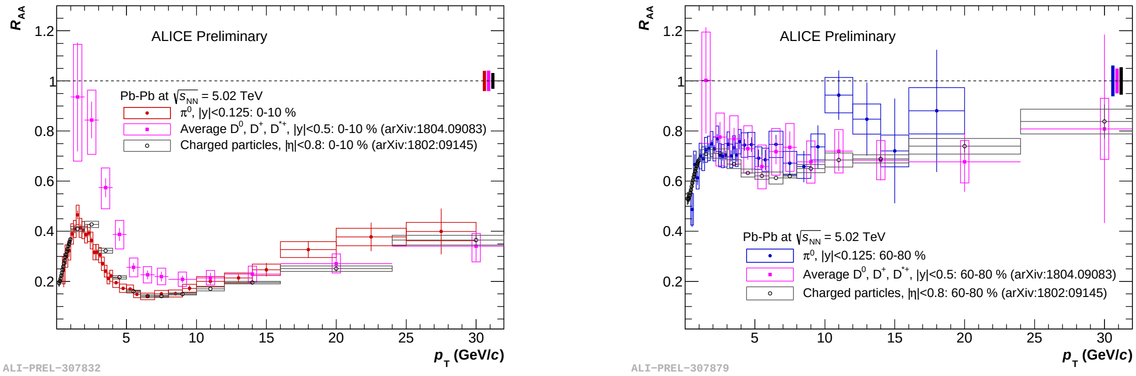

Figure 4: Nuclear modification factors R_{PbPb} of neutral pions, D-mesons [16] and unidentified charged particles [17] measured in central (left) and peripheral (right) Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV.

V0A and CL1 multiplicity estimators, having small or no rapidity gap with measured mesons. Nuclear modification factors for neutral mesons and D-mesons are consistent with each other within uncertainties in all centralities in p-Pb collisions. Nuclear modification factors of π^0 measured in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ and 5.02 TeV are close to each other. The R_{AA} of π^0 and D-mesons are consistent at $p_T > 10$ GeV/c, while at $p_T < 10$ GeV/c D-mesons show a smaller suppression.

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