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Neutral meson production in p-Pb collisions with ALICE at the LHC

Tsubasa Okubo[1,a] on behalf of the ALICE collaboration

[1] *Hiroshima University, 1-3-1 Kagamiyama, Higashi-Hiroshima 739-8526, Japan*

Abstract. Strong suppression of high p_T π^0 has been observed in heavy-ion collisions at the Large Hadron Collider (LHC) energies, which can be interpreted by involving various transport properties of the quantum chromodynamics (QCD) medium and initial state effects. Comparing particle production in pp, p-A, A-A reactions has frequently been used to separate initial state effects of colliding nuclei from final state effects in quark matter created by the collisions.

We have measured π^0 and η meson emitted in p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV via complementary methods, using the ALICE electromagnetic calorimeters, PHOS and EMCal, and Photon Conversion Method (PCM), which identifies photons converted to e^+e^- pairs in the material of the ALICE inner detectors, TPC and ITS. In this paper, π^0 and η meson spectra in p-Pb collisions as well as the nuclear modification factor for π^0 ($R^{\pi^0}_{p-Pb}$) will be shown.

1 Introduction

The π^0 and η meson measurement in pp collisions is useful on one hand to understand particle production and provides a test of perturbative quantum chromodynamic (pQCD) predictions. On the other hand, in heavy-ion collisions it is needed to study parton energy loss and particle suppression by the hot and dense medium called the Quark-Gluon Plasma (QGP). Strong suppression of high p_T π^0 has been observed in central Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV [1]. This suppression is stronger than the one measured at RHIC or at SPS [2–4]. The suppression mechanism can be explained by various processes involving transport properties of the QCD medium and initial state effects. Therefore studies in p-Pb collisions which are intermediate between pp collisions and heavy-ion collisions in terms of system size and number of produced particles, are needed to disentangle suppression originating from initial state effects in the colliding nuclei or from final state effects in the Pb-Pb collisions.

2 Neutral meson reconstruction in ALICE

The ALICE experiment [5, 6] measured π^0 and η mesons in p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV with different methods, using the electromagnetic calorimeters PHOS [7] and EMCal [8], and the Photon Conversion Method (PCM). This report is based on minimum bias triggered data with about

[a] e-mail: tsubasa.okubo@cern.ch

10^8 events which corresponds to an integrated luminosity of 50 μb^{-1} collected in the beginning of 2013. The ALICE minimum bias trigger requires a coincidence signal in both scintillator arrays of V0A and V0C. They cover $2.8 < \eta < 5.1$ and $-3.7 < \eta < -1.7$, respectively. The π^0 and η mesons are measured via their photon decay channels $\pi^0 \to 2\gamma$ and $\eta \to 2\gamma$. PHOS and EMCal measure energy and hit coordinates of photons and electrons. The PHOS detector consists of $PbWO_4$ crystals and APD readout at 4.6 m radius from the interaction point. It has high energy resolution ($\sigma_{E(\mathrm{GeV})}/E = 0.01/E \oplus 0.04/\sqrt{E} \oplus 0.01$) and high granularity. Its coverage is $|\,\eta\,| < 0.13$ and $260^\circ < \varphi < 320^\circ$. The EMCal detector is a lead-scintillator sandwich calorimeter with 77 alternating layers of 1.4 mm lead and 1.7 mm scintillator. It is located at 4.4 m from the interaction point and has an energy resolution of $\sigma_{E(\mathrm{GeV})}/E = 0.05/E \oplus 0.11/\sqrt{E} \oplus 0.02$. Its coverage is $|\,\eta\,| < 0.7$ and $80^\circ < \varphi < 180^\circ$. PHOS and EMCal cover the intermediate to high p_T regions (1 GeV/c < p_T < 20 GeV/c). PCM reconstructs and identifies photons converted into e^+e^- pairs in the material of the inner detectors, ITS [9] and TPC [10], via 2γ decay channel and γ-Dalitz decay channel ($\pi^0 \to \gamma^*\gamma \to e^+e^-\gamma$, denoted as PCM-Dalitz). PCM has a wide acceptance with $|\,\eta\,| < 0.9$ and full azimuthal but the photon conversion probability is small (~8.5 %). PCM covers the low to intermediate p_T regions (0.3 GeV/c < p_T < 14 GeV/c).

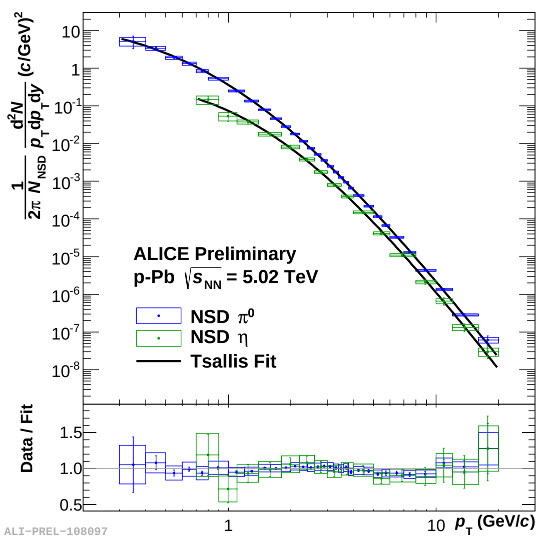

Figure 1. π^0 and η invariant yields in p-Pb collisions with Tsallis fit.

The π^0 and η meson yields are counted from invariant mass distribution of photon candidates pairs with a numerical integral of the number of entries around the reconstructed meson mass. The mass position is determined via a fit after background subtraction. The background is estimated with an event mixing technique. Corrections including acceptance and reconstruction efficiencies are applied to the π^0 and η meson raw yields to obtain the invariant yields.

3 π^0 and η invariant yields in p-Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV

ALICE has measured π^0 and η meson invariant differential yields in p-Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV for the first time (Fig. 1). The π^0 yields are measured by PHOS, EMCal, PCM and PCM-Dalitz within the p_T range 0.3-20 GeV/c and the η meson yields are measured by EMCal and PCM within the p_T range 0.7-20 GeV/c. There is not enough statistics and small acceptance for η meson measurement in PHOS and PCM-Dalitz. Each yield is measured individually with the different methods and they are weighted according to their uncertainties in the combination. The invariant yields are fitted by a Tsallis function and the ratio of measured yield to the corresponding fit is shown in the bottom panel of the Fig. 1.

4 η/π^0 ratio in p-Pb collisions

The η/π^0 ratio in p-Pb collisions has been measured and it is shown in Fig. 2. The ratio is calculated individually with PCM and EMCal and then combined because some systematic uncertainties of the yield measurement cancel this way. The ratio in p-Pb collisions increases in the low p_T region below 4 GeV/c and reaches a plateau of 0.5 in the high p_T region from 4 GeV/c. It is compared to the ALICE pp measurement at $\sqrt{s}$ = 7 TeV [11]. The measurement in both systems indicate similar magnitude and behavior within uncertainties.

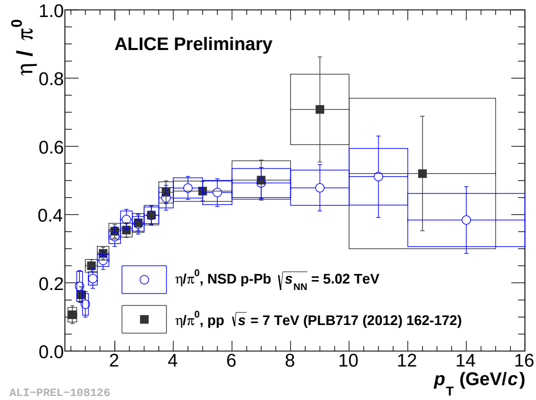

Figure 2. The η/π^0 ratio in p-Pb collisions compared to that in pp collisions at $\sqrt{s}$ = 7 TeV.

5 Nuclear modification factor

ALICE has measured the nuclear modification factor for π^0 in p-Pb collisions, $R^{\pi^0}_{\mathrm{p-Pb}}$ defined as

$$R_{\mathrm{p-Pb}}(p_{\mathrm{T}}) = \frac{\mathrm{d}^2N/\mathrm{d}p_{\mathrm{T}}\mathrm{d}y|_{\mathrm{p-Pb}}}{\langle T_{\mathrm{p-Pb}}\rangle \times \mathrm{d}^2\sigma/\mathrm{d}p_{\mathrm{T}}\mathrm{d}y|_{\mathrm{pp}}} \quad (1)$$

and it is shown in Fig. 3. Here, the nuclear overlap function $\langle T_{\mathrm{p-Pb}}\rangle$ is related to the average number of inelastic proton-nucleon collisions, calculated by a Glauber model [12, 13], which gives $\langle T_{\mathrm{p-Pb}}\rangle = \langle N_{\mathrm{coll}}\rangle/\sigma_{\mathrm{NN}} = 0.0983 \pm 0.0035$ mb^{-1}, with $\langle N_{\mathrm{coll}}\rangle = 6.9 \pm 0.7$ and $\sigma_{\mathrm{NN}} = 70 \pm 5$ mb. The referenced spectrum is estimated with the published π^0 spectrum in pp collisions at $\sqrt{s}$ = 2.76 TeV and 7 TeV for interpolation with a power law fit. $R^{\pi^0}_{\mathrm{p-Pb}}$ is calculated individually for each method due to cancellation of some systematic uncertainties and then combined. It increases at $p_{\mathrm{T}} < 2$ GeV/c and agrees with unity at $p_{\mathrm{T}} > 2$ GeV/c. It is compared to next-to-leading order pQCD (NLO pQCD) calculations which use three different fragmentation functions (FF), KKP, AKK, and fDSS [14], and Color Glass Condensate (CGC) [15]. The model predictions reproduce the data reasonably well.

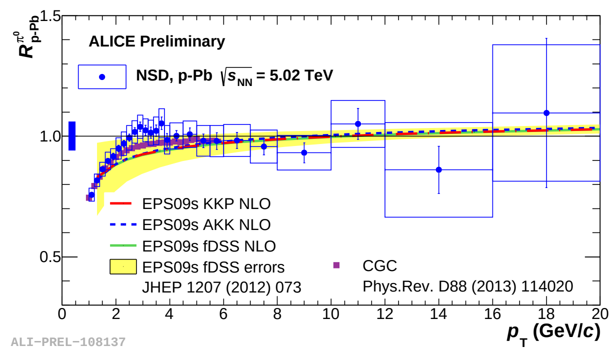

Figure 3. $R^{\pi^0}_{\mathrm{p-Pb}}$ at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV compared to model predictions.

6 Summary

ALICE has measured π^0 and η meson with different methods in p-Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV for the first time. The π^0 invariant yields are measured by PHOS, EMCal, PCM and PCM-Dalitz and the η meson invariant yields are measured by EMCal and PCM. The η/π^0 ratio increases at $p_{\mathrm{T}} <$ 4 GeV/c and arrives a constant value at $p_{\mathrm{T}} >$ 4 GeV/c. The ratio in p-Pb collisions is consistent with that in pp collisions. $R^{\pi^0}_{\mathrm{p-Pb}}$ is calculated with interpolated pp spectrum as reference. It agrees with unity at $p_{\mathrm{T}} > 2$ GeV/c and is well described by NLO pQCD calculations.

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