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Measurement of hadronic resonances with ALICE at the LHC

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Abstract

The ALICE experiment has measured production of hadronic resonances such as $\rho(770)^0$, $K^*(892)^0$, $\phi(1020)$, $\Lambda(1520)$ and $\Xi(1530)^0$ in pp, p-Pb and Pb-Pb collisions at various energies. Due to their short lifetimes, the hadronic resonances are sensitive to the re-scattering and regeneration processes occurring in the time interval between the chemical and the kinetic freeze-outs in heavy-ion collisions. Measurement of resonance yields and their ratios to the long-lived particles are used to study properties and lifetime of the late hadronic phase. In these proceedings, we present the most recent ALICE results on resonance production including the latest results from the LHC Run 2.

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1. Introduction

Over the years, a wide variety of resonances has been measured and studied with ALICE detector at the LHC. Resonances are excited hadronic states with lifetimes comparable to that of the fireball produced in heavy-ion collisions. Many of resonances decay inside the medium before the interacting system breaks up. Among other things, resonances are sensitive to re-scattering and regeneration occurring between the chemical and the kinetic freeze-outs. Hence, resonances can be used to study properties of the late hadronic phase.

2. Particle ratios and properties of the hadronic phase

Processes happening in the hadronic phase depend on lifetime of the hadronic phase, resonance lifetime and scattering cross sections, which depend on daughter particle types and momenta. Table below gives a list of resonances measured at mid-rapidity

Table 1

	$\rho(770)^0$	$K^*(892)^0$	$\Lambda(1520)$	$\Xi(1530)^0$	$\phi(1020)$
$c\tau$ (fm/c)	1.3	4.2	12.7	21.7	46.2
Decay channel	$\pi\pi$	$K\pi$	pK	$\pi\Xi$	KK

with ALICE detector in pp, p-Pb and Pb-Pb collisions at various energies. The resonances are reconstructed in the hadronic decay channels and have very different lifetimes.

Figure 1 shows a ratio of integrated yields, $\rho(770)^0/\pi$, measured as a function of multiplicity in pp and Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV. The $\rho(770)^0$ is a very short-lived resonance, its daughter particles are expected to interact with the surrounding hadrons thus affecting the measured yields. One can see that production of $\rho(770)^0$ meson is suppressed going from pp to peripheral and then to central Pb-Pb collisions. The value of the ratio measured in central collisions is inconsistent with prediction of grand-canonical thermal model with a chemical freeze-out temperature of 156 MeV [1, 2]. However, EPOS3 event generator [3], which includes the UrQMD [4, 5] to simulate the late hadronic cascade describes the observed multiplicity dependence of the ratio well. At this, EPOS3 predict a flat ratio when UrQMD is disabled in the simulation. The measurement is consistent with loss of $\rho(770)^0$ signal due to re-scattering of the daughter pions in the hadronic phase.

Two panels of Figure 2 show $K^*(892)^0/K$ and $\phi(1020)/K$ ratios measured as a function of multiplicity in pp, p-Pb and Pb-Pb collisions at different energies [6-8]. The $K^*(892)^0$ has three times longer lifetime than $\rho(770)^0$ and yet it is only $\sim$ 4.2 fm/c. Hence one can expect similar effects for $K^*(892)^0$ as for $\rho(770)^0$. On the other hand $\phi(1020)$ meson lives ten times longer than $K^*(892)^0$ and one can expect that it behaves as a quasi-stable particle. Indeed one can see that $\phi(1020)/K$ ratio does not change much and it is consistent between pp, p-Pb and different centrality Pb-Pb collisions. At the same time $K^*(892)^0/K$ ratio, similar to $\rho(770)^0/\pi$ ratio, exhibits a suppression from pp to central Pb-Pb collisions. Ratio $K^*(892)^0/K$ in central Pb-Pb collisions is not consistent with thermal model prediction [9]. Measured $K^*(892)^0/K$ ratio is compared to EPOS3 calculation [3] in the figure. One can see that EPOS3 reasonably well reproduces the measured multiplicity dependence. Again this behavior of the ratios is in agreement with expectations from re-scattering of decay products of very short-lived $K^*(892)^0$ in the hadronic phase. At this $\phi(1020)$ meson behaves as a stable particle because of much longer lifetime. It is interesting to note that multiplicity dependent measurements in pp and p-Pb show smooth transition between pp and peripheral Pb-Pb points,

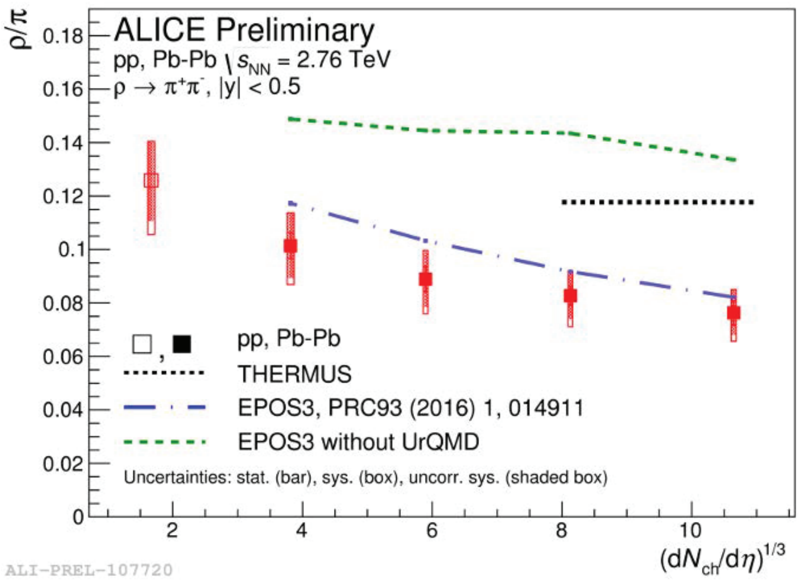

Figure 1: Ratio of integrated yields, $\rho(770)^0/\pi$, in pp and 0–20%, 20–40%, 40–60%, 60–80% central Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV as a function of multiplicity. Statistical uncertainties are shown as bars. The total and uncorrelated systematic uncertainties are shown with open and shaded boxes, respectively. The measurements are compared to EPOS3 calculations [3] and grand canonical thermal model prediction [1, 2].

probably indicating presence of the hadronic medium even in small systems at high multiplicity. Right panel of Figure 2 also compares measurements performed at $\sqrt{s_{NN}}$ = 2.76 TeV and 5.02 TeV. Within uncertainties, there is no energy dependence of the ratios.

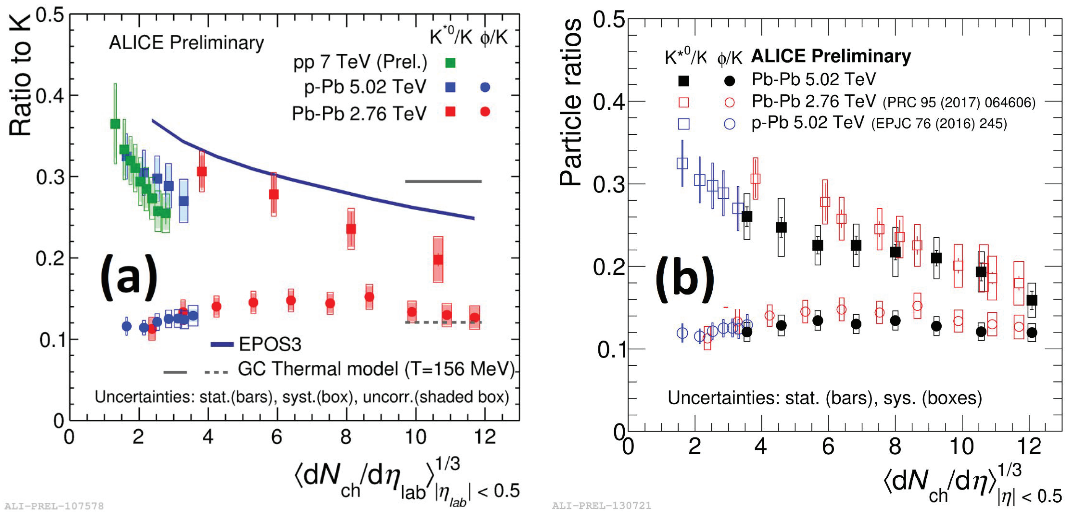

Figure 2: Ratios of integrated yields, K*(892)^0/K and ϕ(1020)/K, in pp, p-Pb and Pb-Pb collisions at different energies as a function of multiplicity [6-8]. Statistical uncertainties are shown as bars. The total and uncorrelated systematic uncertainties are shown with open and shaded boxes, respectively. The measurements are compared to EPOS3 calculations [3] and grand canonical thermal model prediction [9].

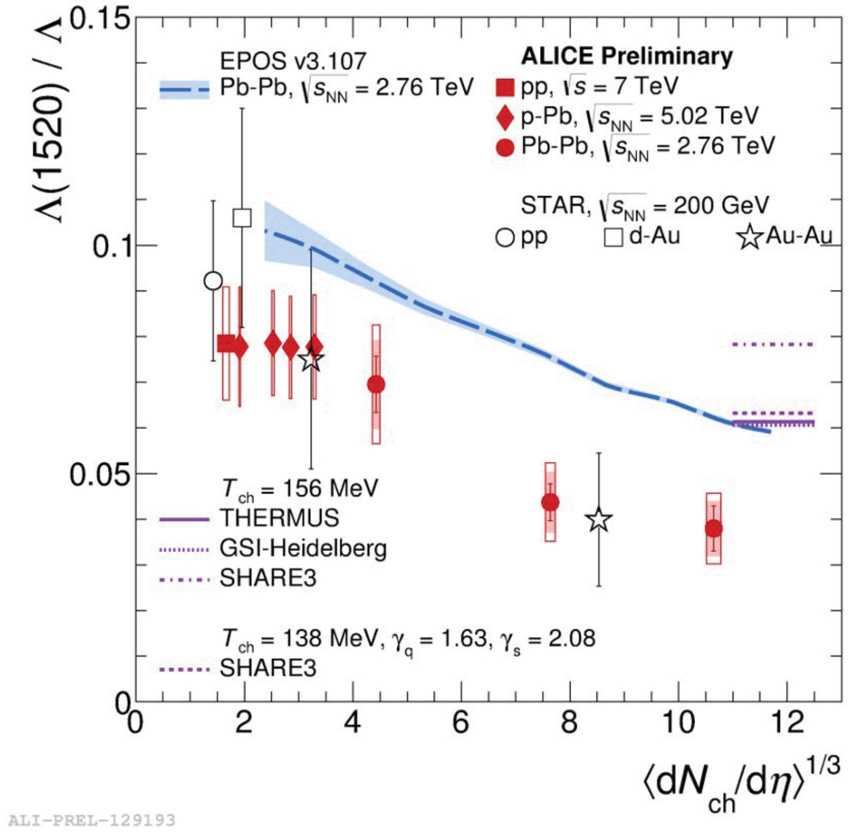

Figure 3: Ratio of integrated yields, $\Lambda(1520)/\Lambda$, in pp, d-Au, p-Pb, Au-Au and Pb-Pb collisions at different energies as a function of multiplicity. Statistical uncertainties are shown as bars. The total and uncorrelated systematic uncertainties are shown with open and shaded boxes, respectively. The measurements in Pb-Pb collisions are compared to EPOS3 calculations [3] and grand canonical thermal model predictions [10-12].

Figure 3 shows results for $\Lambda(1520)/\Lambda$ ratio measured in pp, p-Pb and Pb-Pb collisions at different energies. $\Lambda(1520)$ lives ten times longer than $\rho(770)^0$, $\sim$ 13 fm/c. The ratio stays constant in pp and different multiplicity p-Pb collisions. However, it becomes more and more suppressed going from peripheral to central Pb-Pb interactions. As for other short-lived resonances, ratio in central collisions is not reproduced by thermal model predictions [10-12]. The multiplicity dependence of suppression is qualitatively reproduced by EPOS3 calculations [3] although absolute scaling is not perfect. The LHC points are also consistent with previous measurements by STAR at $\sqrt{s_{NN}}$ = 200 GeV.

Figure 4 shows the multiplicity dependence of $\Xi(1530)^0/\Xi$ ratio in pp, p-Pb and Pb-Pb collisions at different energies. The $\Xi(1530)^0$ lives two times longer than $\Lambda(1520)$ for which we observed the suppression. However, it lives two times shorter than $\phi(1020)$ for which we observed no multiplicity dependent effects. The ratio was measured with high precision in pp and p-Pb collisions and at these multiplicities the ratio stays constant. There is a hint of suppression observed in Pb-Pb collisions although within large systematic uncertainties. Thermal models [1,2,10-12] overestimate the ratio in Pb-Pb, while Pythia8 [13] and DPMJET [14] underestimate it in pp and p-Pb, respectively. The EPOS3 [3], which was very successful for other resonances does not predict significant multiplicity dependence of the ratio in Pb-Pb collisions. Experimental uncertainties of the measurements in Pb-Pb should be reduced in order to be conclusive.

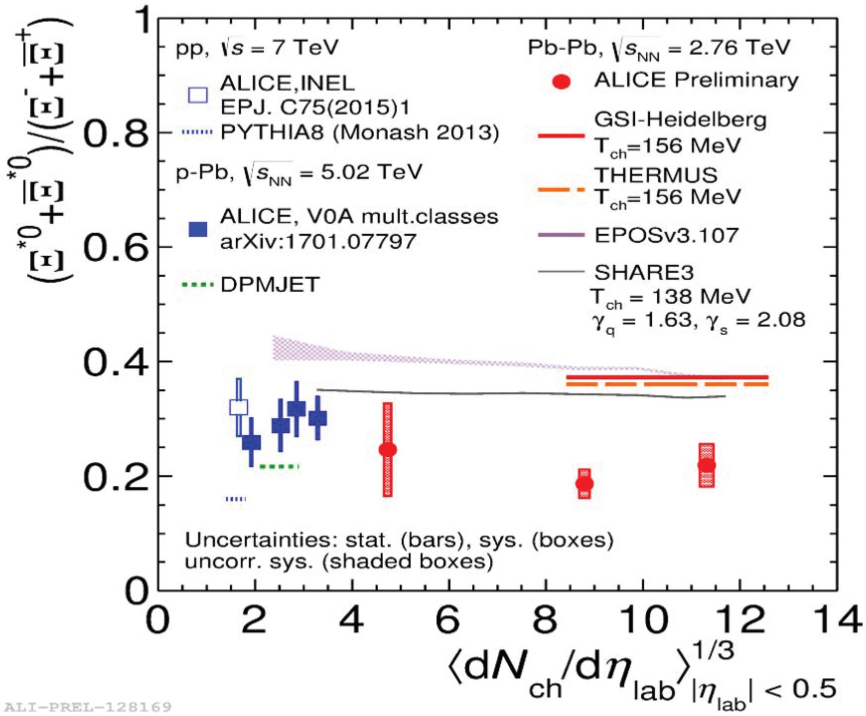

Figure 4: atio of integrated yields, $\Xi(1530)^0/\Xi$, in pp, p-Pb and Pb-Pb collisions at different energies as a function of multiplicity. Statistical uncertainties are shown as bars. The total and uncorrelated systematic uncertainties are shown with open and shaded boxes, respectively. The measurements in Pb-Pb collisions are compared to EPOS3 calculations [3] and grand canonical thermal model predictions [1,2,10-12]. Measurements in pp and p-Pb are compared to predictions of Pythia 8 [13] and DPMJET [14] event generators.

3. Conclusion

From the $\rho(770)^0/\pi$, $K^*(892)^0/K$, $\Lambda(1520)/\Lambda$, $\Xi(1530)^0/\Xi$ and $\phi(1020)/K$ ratios shown in these proceedings one can see that as the resonance lifetimes becomes larger the suppression of the yields becomes less prominent or absent as for the case of $\phi(1020)$. Ratios are reasonable well reproduced by EPOS3 event generator [3] that models hadronic cascade with UrQMD [4, 5]. Obtained results support the existence of the hadronic phase, which lasts long enough to cause a significant reduction of the reconstructed yields of short-lived resonances. The measured ratios coupled to model predictions can be used to estimate the hadronic phase lifetime. Current lower limit for the hadronic phase lifetime is 2 fm/c [15, 16].

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