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Strangeness and hadronic resonance production in pp, p-Pb and Pb-Pb collisions measured by ALICE at the LHC

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The measurement of strangeness production is one of the powerful tools to study the thermal properties of the QGP and while strangeness enhancement is a well established experimental observation in heavy ion collisions, its interpretation is still debated. In particular the study of (multi-)strangeness particle production as a function of the event multiplicity in different collision systems, reported by ALICE, has shown a smooth increase of strange particle yields with respect to yields of non-strange particles. In this proceedings, we present the latest results on multiplicity-dependent strangeness production in different colliding systems at LHC energies.

Furthermore, recent measurements of mesonic and baryonic resonances will be presented to investigate how hadronic scattering processes affect measured resonance yields. The experimental results obtained in pp, p–Pb and Pb–Pb collisions will also be compared with the theoretical predictions.

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1. Introduction

Studies of strangeness production play an important role in understanding the matter produced in heavy-ion collisions. Measurements of strange and non-strange particle yields can be described by grand-canonical thermal models in heavy-ion collisions, while canonical suppression is expected in small systems. Enhancement of strangeness production has been observed in high energy nucleus–nucleus (A–A) collisions with respect to pp collisions at RHIC (Relativistic Heavy-Ion Collider) and LHC (Large Hadron Collider) energies [1]. The study of strangeness production as a function of the charged particle multiplicity produced in the collision systems from pp to AA, therefore, allows one to investigate the origin of the enhancement.

Particles with open strangeness may be subject to canonical suppression in small collision systems with respect to large systems, whereas the ϕ, a particle with hidden strangeness, is not expected to be canonically suppressed. Comparisons of particles with open and hidden strangeness can help to understand strangeness production.

Hadronic resonances with various lifetimes are valuable probes to study the properties of the hadronic medium formed in ultra-relativistic heavy-ion collisions, since the yield ratios of resonances to stable hadrons provide information about the re-scattering and regeneration effects in the hadronic medium. If loss of resonances due to elastic or pseudo-elastic scattering of their decay products (re-scattering) is dominant over regeneration, the resonance yield after kinetic freeze-out will be smaller than the one originally produced at the chemical freeze out. Considering the expected lifetime of the hadronic phase ($\sim$ 10 fm/c), the measurement of the production of a comprehensive set of particles with different lifetimes comparable to that of the hadronic phase can be used to study the interplay of particle re-scattering and regeneration.

2. Experiment and Results

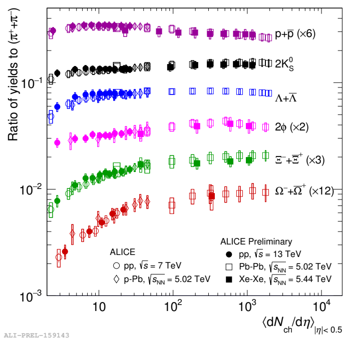

Figure 1: p/π, K^0_s/π, Λ/π, Ξ/π, Ω/π and ϕ/π ratios as a function of $\langle dN_{ch}/d\eta \rangle_{|\eta|<0.5}$ in different collision systems, pp at $\sqrt{s}$ = 7 [2] and 13 TeV, p–Pb at $\sqrt{s_{NN}}$ = 5.02 TeV [3, 4], Pb–Pb at $\sqrt{s_{NN}}$ = 5 TeV and Xe-Xe at $\sqrt{s_{NN}}$ = 5.44 TeV.

Strange and resonance particle yields are measured in pp, p–Pb and Pb–Pb collisions at different energies (pp: 900 GeV-13 TeV, p–Pb: 5.02 and 8.16 TeV, Pb–Pb: 2.76 and 5.02 TeV) and recently in Xe–Xe collisions at $\sqrt{s_{NN}}$ = 5.44 TeV. Figure 1 shows yield-ratios of various strange and non-strange hadrons to pions as a function of the mean charged-particle multiplicity $\langle dN_{ch}/d\eta \rangle_{|\eta|<0.5}$ for different collision systems and different energies. The ratios of all strange particle yields to pions increase with $\langle dN_{ch}/d\eta \rangle_{|\eta|<0.5}$ and saturate near the thermal model value in larger collision systems such as Pb–Pb and Xe–Xe collisions. The magnitude of the increase depends on strangeness content. It is observed that the ratios are consistent at similar multiplicities in all collision systems at all LHC energies.

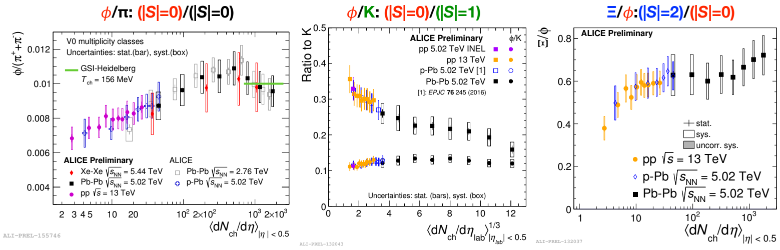

Figure 2: Multiplicity dependence of p_T-integrated $\phi/(\pi^- + \pi^+)$ (left), ϕ/K and K^{*0}/K^- (middle) and Ξ/ϕ (right) yield ratios across different collision systems. Statistical (bars) and systematic (boxes) uncertainties are indicated.

In order to investigate the behavior of hidden strangeness, p_T-integrated yield ratios of ϕ ($|S|$=0) to the other particles having different strangeness are compared as shown in Figure 2. Figure 2 (left) presents the yield ratio of ϕ to π. As already shown in Figure 1 in a logarithmic scale and in Figure 2 in linear scale, the ratio of $\phi(|S|=0)/\pi(|S|=0)$ increases with multiplicity in small collision systems and converges on the thermally predicted value at high multiplicity in large collision systems, similar to the other yield-ratios of strange particle as shown in Figure 1. This is in contrast to the approximately constant behavior of $\phi(|S|=0)/K(|S|=1)$ ratios across the different collision systems as shown in Figure 2 (middle). It has been observed that the Ξ/ϕ ratio is also consistent with a constant within 1 sigma except for the first point as shown in Figure 2 (right).

To study the re-scattering and regeneration effects in the hadronic medium, the yield ratios of resonances to stable hadrons are measured as a function of $\langle dN_{ch}/d\eta_{lab} \rangle_{|\eta_{lab}|<0.5}$ and presented in Figure 3. The K^{*0}/K^- ratio exhibits a decreasing trend from pp to peripheral and central Pb-Pb collisions, while the ϕ to K^- ratio is nearly constant as a function of multiplicity. The ρ^0/π, K^{*0}/K^- and Λ^*/Λ ratios decrease from peripheral to central Pb–Pb collisions and are eventually suppressed with respect to the thermal model predictions in central Pb–Pb collisions. This behavior of short-lived resonances can be explained by the dominance of (pseudo-)elastic re-scattering of decay daughters over regeneration in the hadronic phase, which has a lifetime comparable to the lifetimes of ρ^0(1.3 fm/c), K^{*0} (4.2 fm/c) and Λ^*(12.6 fm/c). Also in the case of K^{*0}/K^-, ϕ/K^- and Λ^*/Λ, the ratios are consistent for different collision systems at different energies. The Ξ^{*0}/Ξ ratio in central Pb–Pb collisions is suppressed with respect to pp and p–Pb collisions and thermal model predictions despite the relatively longer lifetime of Ξ^{*0}(22 fm/c) compared to that of the hadronic phase [7]. The measurements of ρ^0/π, Λ^*/Λ, and Ξ^{*0}/Ξ are compared with EPOSv3 [8] calculations with UrQMD. We have observed that the EPOSv3 prediction, which includes a modeling of re-scattering and regeneration in the hadronic phase, qualitatively well describes the trend from peripheral to central Pb–Pb collisions, even though all thermal model calculations [12] seriously overestimate the results.

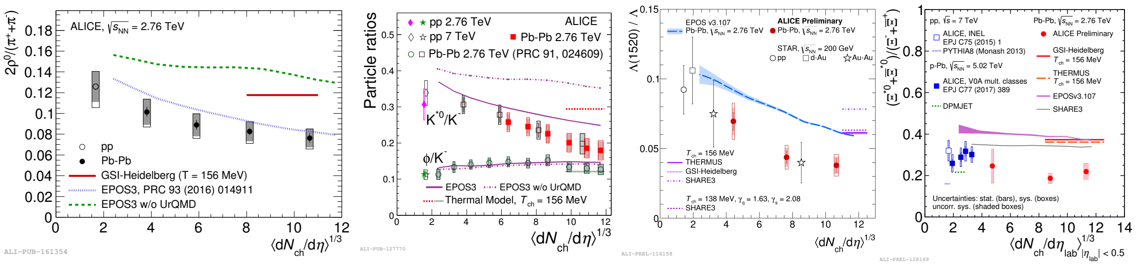

Figure 3: (Left top) K^{*0}/K^- and ϕ/K^- ratios as a function of $\langle dN_{ch}/d\eta_{lab}\rangle^{1/3}_{|\eta_{lab}|<0.5}$ measured at mid-rapidity in pp collisions at $\sqrt{s}$ = 5.02 and 13 TeV, p-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV [6] and Pb–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV. Ratios of ρ^0/π (right top), Λ^*/Λ (left bottom) and Ξ^{*0}/Ξ (right bottom) for different collision systems. Bars represent the statistical uncertainties, empty boxes represent the total systematic uncertainties, and shaded boxes represent multiplicity-uncorrelated systematic uncertainties. The EPOS3 predictions are also shown as curves [8]. A few model predictions [9, 10, 11] are also shown as lines at the appropriate abscissa. Note that on the x-axis $\langle dN_{ch}/d\eta_{lab}\rangle_{|\eta_{lab}|<0.5}$ is equivalent to $\langle dN_{ch}/d\eta\rangle$.

3. Summary

The latest results on multiplicity-dependent strangeness and resonance production in all the available collision systems are presented. We observed a smooth increase of strangeness production across a wide range of multiplicity and the enhancement increases with strangeness content of the hadron under study. The ϕ-meson with hidden strangeness shows, however, similar behavior to particles with open strangeness and seems to have an effective strangeness between 1 and 2. The ratios of ρ^0/π, K^{*0}/K and Λ^*/Λ exhibit a decrease from pp and peripheral Pb–Pb to central Pb–Pb collisions as well as suppression with respect to thermal models in central Pb–Pb collisions. This behavior can be explained by the dominance of (pseudo-)elastic re-scattering of decay daughters over regeneration in the hadronic phase and reproduced qualitatively with the EPOS3 model.

References

[1] S. Acharya *et al.* (ALICE Collaboration), *Nucl. Phys. A* **971** (2018) 1-20

[2] J. Adam *et al.* (ALICE Collaboration) *Nat. Phys.* **13** 535-539 (2017).

[3] J. Adam *et al.* (ALICE Collaboration) *Phys. Lett. B* **728** (2014) 25-38.

[4] J. Adam *et al.* (ALICE Collaboration) *Phys. Lett. B* **758** (2016) 389-401.

[5] B. Abelev *et al.* (ALICE Collaboration) *Phys. Rev. Lett.* **111** (2013) 222301.

[6] J. Adam *et al.* (ALICE Collaboration) *Eur. Phys. J. C* **76** (2016) 245.

[7] G. Torrieri and J. Rafelski 2002 *J. Phys.* G **28** 1911.

[8] A.G. Knospe, C. Markert, K. Werner, J. Steinheimer and M. Bleicher 2016 *Phys. Rev.* C **93** 014911.

[9] A. Andronic and P. Braun-Munzinger and and J. Stachel 2009 *Phys. Lett.* B **673** 142-145.

[10] S. Roesler, R. Engel, and J. Ranft 2000, Conference Proceedings, MC2000, Lisbon, Portugal, October 23-26

[11] M. Petran, J. Letessier, J. Rafelski, and G. Torrieri 2014 *Comput. Phys. Commun* **185** 2056-2079

[12] S. Wheaton, J. Cleymans, and M. Hauer 2009 *Comp. Phys. Comm.* **180** 84-106.