begindocument/before

Exploring system size dependence of bulk properties of medium at LHC energies through hadronic resonances

Prottay Das (for the ALICE Collaboration)*
National Institute of Science Education and Research, Jatni 752050, India,
Homi Bhabha National Institute, Training School Complex,
Anushaktinagar, Mumbai 400094, India

Introduction

During the hadronization phase in heavy-ion collisions, short-lived particles known as hadronic resonances, which decay through strong interactions, play a substantial role. Within this phase, resonances with lifetimes akin to the phase's duration engage in processes like regeneration and rescattering. Rescattering modifies decay daughter particles momenta, preventing the resonance reconstruction via invariant-mass analysis. Pseudo-elastic scattering could also regenerate resonances, elevating their yields. By investigating ratios of resonance-to-stable particle yields and considering system size and theoretical models, we gain insights into these processes and the nature of hadronic interactions.

Recent measurements of light-flavored hadron production in high-multiplicity pp and p–Pb collisions unveil traits traditionally associated with the medium formed in heavy-ion collisions [1]. These collisions can be categorized based on the midrapidity charged-particle pseudorapidity density ($\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta\rangle_{|\eta|<0.5}$). Recent ALICE studies reveal a smooth evolution of hadron species yields with respect to $\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta\rangle_{|\eta|<0.5}$ across different systems and collision energies. The mean transverse momentum ($\langle p_{\mathrm{T}}\rangle$), influenced by radial flow, increases more rapidly in smaller systems. Earlier ALICE observations demonstrated K^{*0} meson production suppression in such collisions, aligning with $\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta\rangle_{|\eta|<0.5}$ trends across collision energies [2]. Measuring K^{*0} meson production in medium-sized nucleus collisions, like Xe–Xe, allows to further test the continuous evolution of yield ratios by providing multiplicities bridging between p–Pb and Pb–Pb collisions. ALICE's data from pp, p–Pb, Xe–Xe, and Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ around 5 TeV enables systematic investigation of hadronic rescattering's system-size dependence. Comparing K^{*0} yield and $\mathrm{K}^{*0}/\mathrm{K}$ ratio across these collisions, along with p–Pb and Pb–Pb results, provides insights into K^{*0} production's system-size tendencies and the impact of hadronic rescattering [3]. The $\mathrm{K}^{*0}/\mathrm{K}$ ratio constrains the hadronic phase lifetime, while comparing $\langle p_{\mathrm{T}}\rangle$ of K^{*0} across collisions helps to understand radial flow evolution from small to heavy-ion systems.

*Electronic address: prottay.das@niser.ac.in

Analysis details

The analysis is performed on ALICE data collected during pp, p–Pb, Xe–Xe, and Pb–Pb runs using the ALICE detectors. All events considered in this analysis are recorded using a minimum bias trigger. The V0 signal is used in classifying Pb−Pb, Xe−Xe events into different centrality classes and pp, p−Pb events into different multiplicty classes. Resonance yields are extracted from the invariant-mass distribution of their hadronic decay products. The event mixing technique is used to describe the combinatorial background. The signal yields for the resonances in different centrality (multiplicity) classes and various p_{T} intervals are obtained after subtracting the combinatorial background from the same event invariant mass distributions.

Results

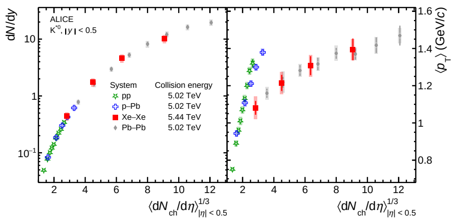

FIG. 1: The $\mathrm{d}N/\mathrm{d}y$ (left panel) and $\langle p_{\mathrm{T}}\rangle$ (right panel) of K^{*0} as a function of $\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta\rangle^{1/3}_{|\eta|<0.5}$ for different collisions systems.

Figure 1 presents K^{*0} $\mathrm{d}N/\mathrm{d}y$ (left) and $\langle p_{\mathrm{T}}\rangle$ (right) plotted against $\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta\rangle^{1/3}_{|\eta|<0.5}$ in various collision systems, which is proportional to the size of the medium. A consistent trend in $\mathrm{d}N/\mathrm{d}y$ across collision systems suggests K^{*0} production correlates with charged-particle multiplicity, acting as a system size proxy. Conversely, $\langle p_{\mathrm{T}}\rangle$ of K^{*0} rises with $\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta\rangle^{1/3}_{|\eta|<0.5}$ for all collisions, implying radial flow velocity increases from low- to high-multiplicity events. Notably, unlike $\mathrm{d}N/\mathrm{d}y$, $\langle p_{\mathrm{T}}\rangle$ displays strong system-dependence and doesn't scale uniformly with particle multiplicity, with steeper increases observed in smaller systems compared to heavy-ion collisions. This observation is in accordance with the hydrodynamical expansion modeled by the blast wave, where small collision systems exhibit a larger pressure gradient and faster expansion of produced matter compared to heavy-ion collisions with similar charged-particle multiplicity. Moreover, the $\langle p_{\mathrm{T}}\rangle$ of K^{*0} in Xe−Xe and Pb−Pb collisions is similar at comparable $\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta\rangle^{1/3}_{|\eta|<0.5}$, indicating similar evolution of the produced system in collisions involving large and medium-sized nuclei at LHC energy.

The left panel of Fig. 2 shows the p_{T}-integrated $\mathrm{K}^{*0}/\mathrm{K}$ yield ratio as a function of $\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta\rangle^{1/3}_{|\eta|<0.5}$. Measurements in Xe–Xe collisions are compared with the yield ratios obtained in pp, p–Pb and Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV. The $\mathrm{K}^{*0}/\mathrm{K}$ yield ratio in different collision systems shows a smooth evolution with $\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta\rangle^{1/3}_{|\eta|<0.5}$, and is independent of the collision system at similar final-state charged-particle multiplicity. This further confirms the smooth evolution of hadron chemistry, observed for other light flavour hadrons. The $\mathrm{K}^{*0}/\mathrm{K}$ yield ratio decreases with increasing event multiplicity. This decrease in the $\mathrm{K}^{*0}/\mathrm{K}$ yield ratio can be understood as the rescattering of K^{*0} meson's decay daughters inside the hadronic phase and qualitatively well explained by the HRG-PCE calculations [4] compared to EPOS3+UrQMD predictions. The $\mathrm{K}^{*0}/\mathrm{K}$ yield ratio is also used to get an estimate of the lower bound of the hadronic phase lifetime τ and it is found to evolve smoothly with multiplicity.

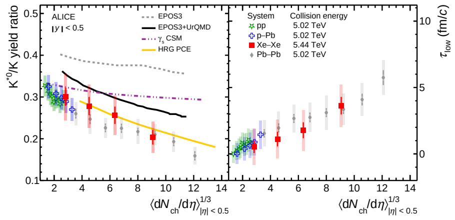

FIG. 2: The left panel shows the measured $\mathrm{K}^{*0}/\mathrm{K}$ yield ratio along with model calculations. The right panel shows the lower limit of hadronic phase lifetime as a function of $\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta\rangle^{1/3}_{|\eta|<0.5}$ in different collision systems.

Acknowledgments

The author acknowledges financial support from DAE-DST projects.

References

[1] ALICE Collaboration, Nature Phys. 13 (2017) 535-539

[2] ALICE Collaboration, Phys. Lett. B 807 (2020) 135501

[3] ALICE Collaboration, arXiv:2308.16115

[4] A. Motornenko, V. Vovchenko, C. Greiner, and H. Stoecker, Phys. Rev. C 102 (2020) 024909