Nuclear modification factor in O-O collisions at LHC: A transport model study

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Introduction

In the upcoming year, LHC plans for short runs of oxygen-oxygen (O-O) and proton-oxygen (p-O) collisions. The possibility of QGP formation in small systems has been revealed by recent findings at the LHC [1]. O-O and p-O collisions are being studied to understand the origin of collectivity and test hydrodynamics in small systems. This research offers a key opportunity to explore effects seen in high-multiplicity pp, p-Pb, and peripheral Pb-Pb collisions with similar charged-particle multiplicities. Analyzing the initial-state effects on the final-state observables in ^{16}O–^{16}O collisions is also an interesting way to look for possible signatures of a α–clustered nuclear geometry [1–3]. Here, we report the nuclear modification factor (R_{AA}) for all charged hadrons and identified particles in the O-O collisions at $\sqrt{s_{NN}}$ = 7 TeV using a multi-phase transport model (string melting mode of version 2.26t9b). Additionally, we have also compared the behavior of R_{AA} with the same multiplicity environment between O-O and Pb-Pb collisions.

Results and Discussion

Fig. 1 shows the p_T dependence of R_{AA} for both charged hadrons and identified particles in O−O collisions at $\sqrt{s_{NN}} = 7$ TeV. To investigate the effect of the nuclear density profile on the charged particle production, we considered both α−clustered (Fig. 1 (top)) and Woods-Saxon (Fig. 1 (bottom)) density profiles. Results are shown for the most central (0-5)%, mid-central (30-40)%, and peripheral (60-70)% collisions. It is interesting to note that, despite changes in density profiles and/or centralities, a mass ordering between $\pi^{\pm}$, $K^{\pm}$, and protons are conserved toward $p_T < 2$ GeV (Fig. 1). However, this pattern seems to break down for both density profiles above $p_T > 2$ GeV. In Fig. 2 (left), the effects of density profiles for O−O collisions are further investigated. Here, considering α−clustered and Woods-Saxon (WS) density profiles, the ratio of R_{AA} of all charged hadrons is examined with transverse momentum in different centralities. WS and α-clustered density profiles yield similar results in the most central (0-5%) collisions. However, in mid-central (30-40%) to peripheral (60-70%) collisions, α-clustered profiles have a greater effect on particle production than Woods-Saxon.

The charged-particle multiplicity in O-O (0-5%) aligns with Pb-Pb (50-60%) collisions, showing similar multiplicities environment [3]. The nuclear modification factor of charged hadrons and identified particles in Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV for (50-60)% is depicted in Fig. 2 (right), taking into account the Pb-Pb yield from AMPT simulation and the *pp* yield from experimental data (ALICE). Fig. 2 (middle) shows the ratio of R_{AA} value in Pb-Pb collisions to O-O collisions. It is observed that R_{AA} value is smaller in Pb-Pb collisions than in O-O collisions. Thus, within a similar multiplicity range, the suppression effect is more in Pb-Pb collisions than in O-O collisions. Pb-Pb collisions exhibit a 60% larger radius than O-O at similar multiplicity [3], indicating partons in Pb-Pb traverse a longer path, leading to greater energy loss.

Summary

The study utilizes a multi-phase transport model to explore the effects of nuclear density

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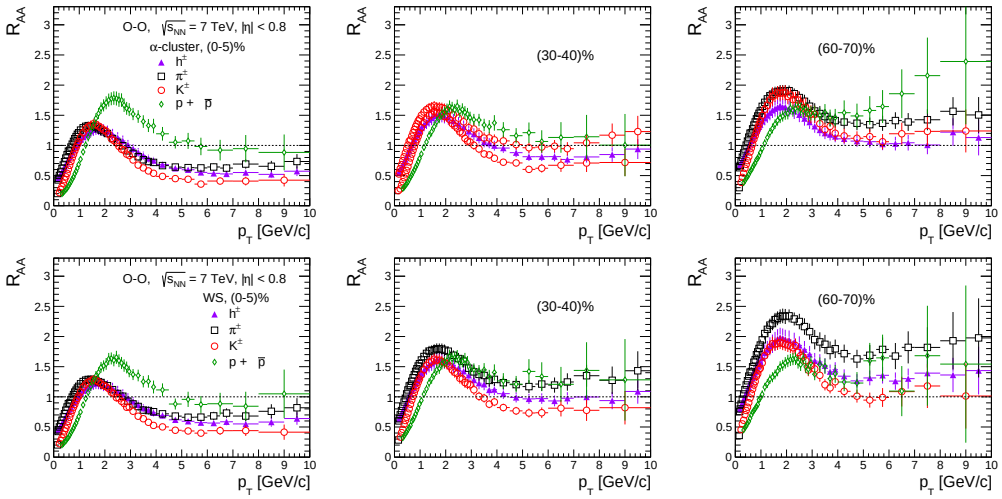

FIG. 1: R_{AA} of all charged hadrons ($h^{\pm}$) and identified particles ($\pi^{\pm}$, $K^{\pm}$ and $p+\bar{p}$ in O-O collisions at $\sqrt{s_{NN}} = 7$ TeV for (0-5)% [Left], (30-40)% [Middle] and (60-70)% [Right], with α-clustered (top) and Woods-Saxon (bottom) density profiles, taking p_T-spectra of pp from ALICE for estimating R_{AA} [3]

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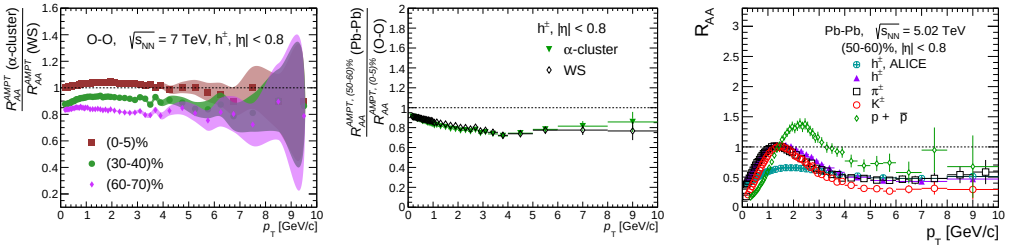

FIG. 2: Ratio between R_{AA} of $\alpha-$clustered to Woods-Saxon density potential (left), ratio between R_{AA} in Pb-Pb collisions of (50-60)% at $\sqrt{s_{NN}} = 5.02$ TeV to O-O collisions of (0-5)% at $\sqrt{s_{NN}} = 7$ TeV of charged hadrons ($h^{\pm}$) (middle) and R_{AA} of charged hadrons and identified particles in Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV for (50-60)% (right) [3]

profiles (α-clustered and WS) on particle production. It compares the results between O-O and Pb-Pb collisions, revealing that particle suppression is stronger in Pb-Pb collisions at similar multiplicity environment.

Acknowledgments

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References

[1] D. Behera, N. Mallick, S. Tripathy, S. Prasad, A. N. Mishra and R. Sahoo, Eur. Phys. J. A **58**, 175 (2022).

[2] D. Behera, S. Prasad, N. Mallick and R. Sahoo, Phys. Rev. D **108**, 054022 (2023).

[3] D. Behera, S. Deb, C. R. Singh and R. Sahoo, Phys. Rev. C **109**, 014902 (2024).