Global properties in O+O collisions at $\sqrt{s_{\rm NN}} = 7$ TeV using a multi-phase transport model

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Introduction

The primary goal of ultra-relativistic heavy-ion collision experiments is to study the nuclear matter and the phase transition of hadronic matter to quark-gluon plasma (QGP) under extreme conditions of high temperature and energy density. Results from small collision systems act as baseline for those results. Recent LHC studies show QGP-like behavior in high-multiplicity pp collisions [1, 2]. Since the system size of O+O collisions has overlap between p+Pb and pp collisions, studying global properties may give a deeper insight into the heavy-ion-like behaviour observed in small collision systems. Oxygen has very compact structure and it is assumed to be stable against decay because of doubly magic nucleus. Here, we report the Bjorken energy density, speed of sound and kinetic freeze-out parameters as a function of collision centrality in O+O collisions at $\sqrt{s_{\rm NN}} = 7$ TeV for both harmonic oscillator and Woods-Saxon nuclear density profile incorporated in oxygen nucleus using AMPT.

Results and Discussion

The initial energy density can be estimated via the Bjorken boost-invariant hydrodynamics model [3]. The Bjorken energy density ($\epsilon_{\rm Bj}$) is given as [4],

$$\epsilon_{\rm Bj} \approx \frac{1}{\tau\pi R_0^2\left(\frac{N_{\rm part}}{2}\right)^{2/3}}\left[\frac{3}{2}\times\left(\langle m_{\rm T}\rangle\frac{dN}{dy}\right)_{\pi^\pm} + 2\times\left(\langle m_{\rm T}\rangle\frac{dN}{dy}\right)_{K^\pm,p,\bar{p}}\right], \quad (1)$$

where, dN/dy is the integrated yield in mid-rapidity region ($|\eta| < 0.8$), $\langle m_{\rm T}\rangle$ is the mean transverse mass, $N_{\rm part}$ is the number of participants. The multiplicative factor in each term accounts for the neutral particles.

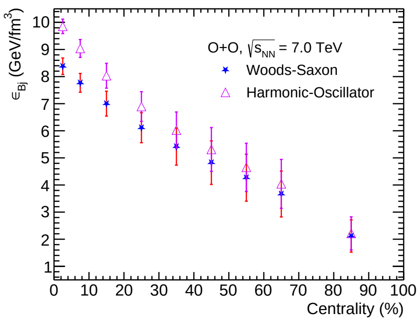

FIG. 1: Bjorken energy density as a function of centrality classes in O+O collisions at $\sqrt{s_{\rm NN}} = 7$ TeV [6].

Figure 1 shows $\epsilon_{\rm Bj}$ as a function of centrality classes in O+O collisions. $\epsilon_{\rm Bj}$ is found to be higher for most central collisions and linearly decreases from central to peripheral collisions. $\epsilon_{\rm Bj}$ for harmonic oscillator density profile is found to be higher as compared to Woods-Saxon density profile. For all centralities, the estimated initial energy density is higher than

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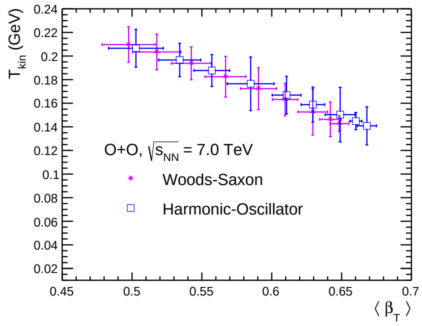

FIG. 2: Kinetic freeze-out temperature versus average transverse radial flow from simultaneous fit of identified particles using Boltzmann-Gibbs blastwave distribution in O+O collisions at $\sqrt{s_{\rm NN}}$ = 7 TeV [6].

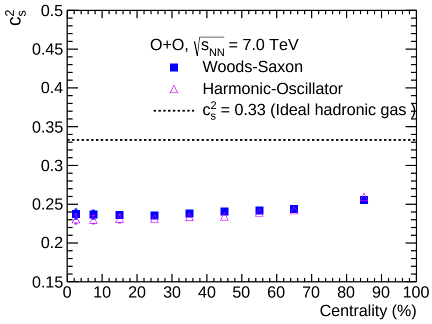

FIG. 3: Squared speed of sound as a function of centrality classes in O+O collisions at $\sqrt{s_{\rm NN}}$ = 7 TeV obtained using AMPT model [6].

the lattice QCD predicted 1 GeV/fm^3, required for a quark-hadron phase transition.

Figure 2 shows the transverse radial flow versus kinetic freeze-out temperature ($T_{\rm kin}$) obtained from simultaneous fit of identified particles' $p_{\rm T}$-spectra with Boltzmann-Gibbs blastwave distribution in O+O collisions at $\sqrt{s_{\rm NN}}$ = 7 TeV. $T_{\rm kin}$ and transverse flow is found to be lower, and higher for most central collisions, respectively. This behavior is expected due to the fact that the central collisions have larger system size and hadronic phase lasts longer, which makes the $T_{\rm kin}$ lower. Due to larger system size, the transverse flow is found to be higher for central collisions. Within uncertainties the kinetic freezeout parameters are found to be independent of density profiles.

Figure 3 shows the squared speed of sound (c_s^2) as a function of centrality classes for pions, kaons, and protons in O+O collisions at $\sqrt{s_{\rm NN}}$ = 7 TeV for both Woods-Saxon and harmonic-oscillator density profiles. To obtain c_s^2, a double Gaussian distribution [5] is used to fit the pseudorapidity distributions and width of the distribution is obtained. c_s^2 is found to be similar as a function of centrality within the uncertainties (Fig. 3). The black dotted line in Fig. 3 shows the limit of ideal gas, and the c_s^2 from O+O collisions is about 25% lesser than the ideal gas limit.

Summary

Using AMPT, we have predicted the global properties in O+O collisions at $\sqrt{s_{\rm NN}}$ = 7 TeV. We report the mid-rapidity charged-particle multiplicity, Bjorken energy density as a function of collision centrality, kinetic freeze-out temperature versus transverse radial flow, and squared speed of sound as a function centrality classes. The results are shown for both harmonic oscillator and Woods-Saxon nuclear density profile incorporated for oxygen nucleus. As Bjorken energy density is found to be dependent on density profile of oxygen nucleus. An extensive study including elliptic flow could be useful for future experimental results, which will be reported.

References

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