Study of initial state in O+O collisions at 7 TeV

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Introduction

The study of relativistic heavy-ion collisions has provided strong evidence for the formation of a hot and dense Quark-Gluon Plasma (QGP) state of matter [1]. The initial spatial anisotropy in the collision zone, characterized by initial eccentricity (ϵ_2), triangularity (ϵ_3), and higher-order harmonics, arises from the collision geometry and fluctuations in energy and entropy density. This anisotropy results in momentum anisotropies in the final-state particles via collective expansion of the QGP.

The presence of a clustered structure in light nuclei such as ^{7,9}Be, ^{12}C, and ^{16}O leads to nuclear deformities [2, 3], which in turn result in significant spatial anisotropies in the overlap region compared to collisions of uniform nuclei at relativistic energies. The possibility of clustered states in light nuclei was first proposed by Gamow [4]. Recently, proposals for dedicated ^{16}O-^{16}O collision runs at LHC have emerged. Given that the system size of ^{16}O-^{16}O is comparable to high-multiplicity pp and peripheral Pb-Pb collisions, this offers a unique opportunity to investigate the origin of collective behavior in small collision systems and to explore the effects of initial-state α-clustered structures (such as the presence of ^{4}He nuclei) on final-state observables.

In this work, we examine the initial eccentricities as a function of centrality and initial nucleon density profiles for α-clustered ^{16}O-^{16}O collisions with tetrahedral structures at 7 TeV using GLISSANDO initial conditions. Our study compares these results with those from unclustered ^{16}O-^{16}O collisions. Furthermore, we aim to extend this analysis to investigate the impact of cluster structure on the flow observables of final-state particles.

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GLISSANDO

GLISSANDO-3 [5] is a Monte Carlo event generator designed to implement various Glauber-like models that characterize the initial stages of relativistic heavy-ion collisions. It models the spatial distribution of transverse energy deposited by the interaction of nucleons and includes several approaches such as the wounded nucleon model, the wounded quark model, the binary collision model, and a mixed model. GLISSANDO-3 also accounts for nucleon substructure fluctuation effects and incorporates studies of light nuclei collisions (e.g., ^{3}He and ^{3}H) as well as α-clustered nuclei (e.g., ^{7,9}Be, ^{12}C, ^{16}O). The generator has been demonstrated to successfully reproduce particle multiplicities observed at both RHIC and LHC.

Results

Figure 1 shows the nucleon density distribution in the transverse plane for the orientation angles $\theta = 0^\circ$ in the most central collisions of α-clustered and unclustered oxygen nuclei. The orientation angle θ is defined as the angle between the beam axis (z-axis) and the symmetry axis of the tetrahedral configuration of the oxygen nucleus. The nucleon density at the center of each hot spot region in the α-clustered case is significantly higher

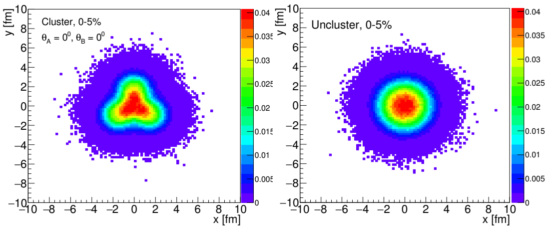

FIG. 1: Nucleon density distribution per event corresponding to the collisions of clustered O+O and unclustered O+O respectively for 0-5% centrality. $\theta = 0^0$ implies the symmetry axes of both the tetrahedrons are aligned with beam axis. Mixed model has been considered here.

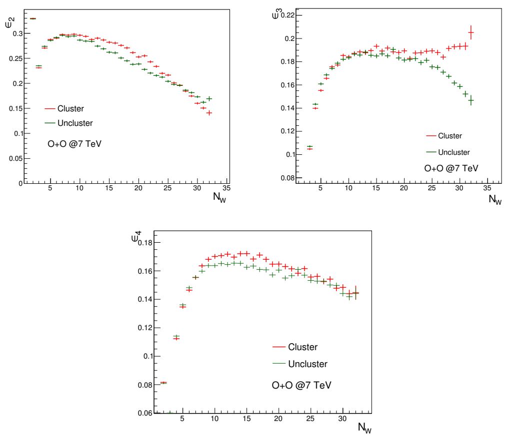

FIG. 2: Initial eccentricity (ϵ_2), triangularity (ϵ_3), and higher-order harmonics as a function of wounded nucleons

compared to the density observed at the center of the unclustered case.

Figure 2 presents the initial spatial anisotropy ϵ_n of the overlapping zone in α-clustered O+O collisions as a function of the number of wounded nucleons, alongside a comparison with results from collisions of unclustered or uniform oxygen nuclei. In the most central collisions involving α-clustered oxygen, a notably large triangular eccentricity ϵ_3 is observed, which exceeds the elliptic eccentricity ϵ_2. This enhanced ϵ_3 leads to a correspondingly larger triangular flow in oxygen nuclei. The ϵ_n values are averaged over a substantial number of events, and these anisotropy measurements are expected to be reflected in the flow observables, influencing the momentum anisotropy of the final-state particles which will be studied in our future work.

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