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Understanding medium anisotropy in p–O and p–C collisions at the LHC with exotic α-clustered nuclear density profiles

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One of the major motivations for the planned p–O and O–O collisions at the LHC is to explore the possibilities of small system collectivity. Such transverse collective expansion results in the appearance of long-range azimuthal correlation and is quantified via the coefficients, $v_{\rm n}$, of Fourier expansion of the azimuthal momentum distribution of the final-state particles. These flow coefficients serve as the medium response to the initial spatial anisotropy and are sensitive to the density profile of the colliding nuclei. Light nuclei such as ^{12}C and ^{16}O are theorized to possess extra stability due to the presence of an α-clustered arrangement of its nucleons. In this context, studies on ultra-relativistic p–A collisions involving ^{12}C or ^{16}O nuclei can serve a dual purpose: exploring small system collectivity along with investigating the effects of a clustered nuclear geometry on the medium anisotropy. With this motivation, for the first time, we study p–O and p–C collisions at $\sqrt{s_{\rm NN}}$ = 9.9 TeV through a multi phase transport model (AMPT) simulations. We attempt to explore how an initial α-clustered nuclear structure of ^{16}O and ^{12}C influences the production yield, initial eccentricities and flow coefficients in the final state, in comparison to an unclustered density profile, Sum-Of-Gaussians (SOG). The flow coefficients are estimated via a two-particle Q-cumulant method.

The results show that $\langle\epsilon_2\rangle$ varies with centrality in a unique manner for α-clustered p–O and p–C collisions, similar to O–O collisions. However, the centrality dependence of $\langle\epsilon_2\rangle$ and $\langle\epsilon_3\rangle$ is not effectively carried forward to the final state v_2 and v_3, owing to lesser participants. We also see that the dependence of v_2 on centrality is much less in comparison to v_3, which is reflected in the v_3/v_2, $v_2/\langle\epsilon_2\rangle$ and $v_3/\langle\epsilon_3\rangle$ ratios studied in our work. We notice that the α-clustered case shows almost a flatter trend of v_3 with centrality than the corresponding collisions with a SOG profile, possibly indicating the discretized internal structure of an α-clustered nucleus. Thus, by probing the effects of the nuclear structure employing ultra-relativistic collisions, this work serves as a transport-model-based prediction for the upcoming p–O collisions in the LHC Run 3.

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