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Scaling approach to nuclear structure in high-energy heavy-ion collisions

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In high-energy heavy-ion collisions, the energy density profile of the produced quark-gluon plasma and its space-time dynamics are sensitive to the shape and radial profiles of the nuclei, described by the collective nuclear structure parameters including quadrupole deformation β_2, octupole deformation β_3, radius R_0 and surface diffuseness a [1-3]. Using a transport model simulation as a proxy for hydrodynamics, we find a general scaling relation between these parameters and a large class of experimental observables such as elliptic flow v_2, triangular flow v_3 and particle multiplicity distribution $p(N_{\rm ch})$ In particular, we show that the ratio of these observables between two isobar collision systems depends only on the differences of these parameters. Using this scaling relation, we show how the nuclear structure parameters of ^{96}Ru and ^{96}Zr conspire to produce the non-monotonic centrality dependence of ratios of v_2, v_3 and $p(N_{\rm ch})$ between ^{96}Ru+^{96}Ru and ^{96}Zr+^{96}Zr collisions, in agreement with measurements by the STAR Collaboration. We investigate how these scaling relations depend on the transport properties such as η/s and found they are insensitive to these final-state effects. Furthermore, we extend this study to include the systems with similar mass number, and rather robust corrections to these scaling relations are found. This scaling approach towards heavy-ion observables demonstrates that isobar collisions is a precision tool to probe the shape and radial structures, including the neutron skin, of the atomic nuclei across energy scales.

[1] arXiv:2111.15559 [nucl-th].
[2] arXiv:2109.01631 [nucl-th].
[3] arXiv:2105.05713 [nucl-th].

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