Contribution ID: **82** Contribution code: **POS-BLK-06** Type: **Poster**

Scaling approach to nuclear structure in nuclear collisions

Tuesday 14 June 2022 17:23 (1 minute)

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 AMPT simulations as a proxy for hydrodynamics, we find a general scaling relation between these parameters and a large class of experimental observables such as anisotropic flow v_n, particle multiplicity distribution $p(N_{\rm ch})$ and mean transverse momentum $[p_T]$ fluctuations. 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_n, $p(N_{\rm ch})$ and mean $[p_T]$ fluctuations 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 and extend this study to include the systems with similar mass numbers. This scaling approach towards heavy-ion observables demonstrates that isobar collision is a precision tool to probe the shape and radial structures, including the neutron skin, of the atomic nuclei across energy scales.

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Present via

Online

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Session Classification: Poster

Track Classification: Bulk matter phenomena, QCD phase diagram, and Critical point