IS2021
The VI[th] International Conference on the
INITIAL STAGES
OF HIGH-ENERGY NUCLEAR
COLLISIONS

Contribution ID: **196** Type: **bullet talk (poster)**

The geometry of isobaric collisions as a precision probe of the structure of atomic nuclei

Sunday, 10 January 2021 19:45 (1h 30m)

Measurements of elliptic flow in relativistic nuclear collisions are known to be sensitive to the quadrupole deformation of the colliding nuclear species. We explore the possibilities offered by high-precision data collected in Ru+Ru and Zr+Zr collisions at RHIC for studies of nuclear deformation at high energy. By exploiting the fact that isobaric systems share the same hydrodynamic properties, we consider observables that can be predicted from their initial-state geometry, for instance, ratios of cumulants of flow fluctuations of the kind: $\frac{v_2\{2k\}[\mathrm{Ru+Ru}]}{v_2\{2k\}[\mathrm{Zr+Zr}]} = \frac{\varepsilon_2\{2k\}[\mathrm{Ru+Ru}]}{\varepsilon_2\{2k\}[\mathrm{Zr+Zr}]}$, where v_2 is the final-state elliptic flow, while ε_2 is the initial-state ellipticity. In the measurement of such ratios, systematic errors cancel to a large extent thanks to the day-by-day swapping between Ru+Ru and Zr+Zr collisions, so that even deviations of order 1% from unity can be precisely determined, due the large statistics of recorded events.

We perform high-quality predictions for these observables by implementing different prescriptions, motivated by state-of-the-art nuclear structure frameworks, for the deformation of the colliding isobars. Our results demonstrate that the deviations from unity in the above ratios driven by the effect of the deformation of nuclei are in general much larger than the expected experimental errors. This gives the opportunity to make unprecedented tests of the predictions of nuclear structure models with RHIC data. We discuss, thus, the possibilities offered by a potential systematic species scan to be performed at RHIC, aimed at studying the geometric shape of atomic nuclei at high energy.

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Session Classification: Poster

Track Classification: The initial stages of heavy-ion collisions