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Observation and detailed measurements of nuclear deformations at STAR

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Nuclear deformation is an ubiquitous phenomenon for most atomic nuclei, reflecting collective motion induced by interaction between valance nucleons and shell structure. In most cases, the deformation has a quadrupole shape that is characterized by overall strength β_2 and triaxiality γ, and/or a octuple shape β_3. Nuclear deformation enhances the fluctuations of harmonic flow and radial flow, and therefore, can be probed by v_2, v_3, and mean transverse momentum $[p_{\rm T}]$ fluctuations. Furthermore, deformation parameters can be constrained very precisely from ratios of flow measurements in two systems of isobar collisions. We present two sets of results:

i) The measurement of v_2, cumulants of $[p_{\rm T}]$, and Pearson correlation coefficient $\rho(v_2^2, [p_{\rm T}])$ in ^{197}Au+^{197}Au and ^{238}U+^{238}U collisions. Significant differences for variance and skewness of $[p_{\rm T}]$ fluctuations are observed between the two systems. The $\rho(v_2^2, [p_{\rm T}])$ values are positive over the full centrality in Au+Au collisions, while they change sign in 0-5\% central U+U collisions. The enhancement of $[p_{\rm T}]$-skewness and the suppression of $\rho(v_2^2, [p_{\rm T}])$ is consistent with large prolate deformation for Uranium.

ii) The measurement of v_2, v_3, and cumulants of $[p_{\rm T}]$ in ^{96}Ru+^{96}Ru and ^{96}Zr+^{96}Zr isobar collisions at 200 GeV. The ratios of these observables between the isobars show significant deviations from unity as a function of centrality. A comparison with hydrodynamic model simulations implies a large quadrupole deformation in Ru nucleus ($\beta_{2,\rm Ru} \sim 0.16$) and a large octuple deformation in Zr nucleus ($\beta_{3,\rm Zr} \sim 0.2$). The non-monotonic centrality dependence of ratios of v_2 and $[p_{\rm T}]$ fluctuations, especially for mid-central collisions also requires a difference in the surface diffuseness between Ru and Zr. Our results provide the first observation and quantitative extraction of the quadrupole and octuple deformation in Ru and Zr nuclei using heavy-ion collisions.

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