

Imaging the shape of atomic nuclei in high-energy nuclear collisions from STAR

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1 The collective properties of nuclear structure, such as radii and deformations, leave distinct sig-
2 natures in the initial and consequently final stages of relativistic heavy-ion collisions. Collisions
3 of deformed nuclear enhance the fluctuations of harmonic flow coefficients v_n and event-wise
4 mean transverse momentum $[p_T]$, therefore offering a viable approach to establish clear corre-
5 spondences between the structure of colliding nuclei and the final state observables.

6 We present measurements of v_n , $[p_T]$ fluctuations as well as v_n - $[p_T]$ correlations from the
7 STAR experiment. Significant differences are observed for $[p_T]$ fluctuations and v_n - $[p_T]$ correla-
8 tions between $^{197}\text{Au}+^{197}\text{Au}$ and $^{238}\text{U}+^{238}\text{U}$ collisions, which can be quantitatively explained by
9 the large prolate deformation of ^{238}U with $\beta_{2,\text{U}} \sim 0.28$ and $\gamma_{\text{U}} \sim 0$. Striking differences are also
10 observed in isobar collisions of $^{96}\text{Ru}+^{96}\text{Ru}$ and $^{96}\text{Zr}+^{96}\text{Zr}$, where ratios of many observables
11 show significant deviations from unity and exhibit rich patterns as a function of centrality. A
12 comparison with hydrodynamic model simulations suggests a large quadrupole deformation in
13 Ru nucleus with $\beta_{2,\text{Ru}} \sim 0.16$ and a large octupole deformation in ^{96}Zr nucleus with $\beta_{3,\text{Zr}} \sim 0.2$.
14 The non-monotonic dependence of ratios of multiplicity distribution, v_2 , and $[p_T]$ fluctuations
15 in the mid-central collisions also requires a difference in the surface diffuseness between ^{96}Ru
16 and ^{96}Zr in the model calculations. Combining all these observables, we can precisely constrain
17 the parameters associated with various nuclear deformations in isobar nuclei. Building on our
18 pioneering demonstration of nuclear structure effects, we present a more precise quantitative ex-
19 traction of the quadrupole and octupole deformation parameters in ^{96}Ru and ^{96}Zr nuclei using
20 heavy-ion collisions.