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Imaging event-by-event nuclear shapes in relativistic nuclear collisions

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The event-by-event shapes of colliding nuclei are imprinted on flow patterns measured in relativistic heavy-ion collisions because of the strong hydrodynamic response to collision geometry. In this work, we perform high-statistics simulations to study the impacts of nuclear structure on the ratios of anisotropic flow observables between different collision systems. We study ^{208}Pb+^{208}Pb and ^{129}Xe+^{129}Xe collisions at the Large Hadron Collider, and find the ratios of anisotropic flow in the same centrality class between the two collision systems to be strongly affected by the nuclear structure inputs in the initial state, providing a novel opportunity to probe the deformed nuclear geometry at very high energies [1]. The ratios of $v_2\{4\}/v_2\{2\}$ in these collisions are sensitive to the nuclear skin thickness of the colliding nuclei, providing indirect constraints on the nuclei's neutron skin. We will also highlight the unique opportunities at the upcoming fixed-target SMOG2 experiments at the LHCb. With input from ab initio calculations of the structure of ^{16}O and ^{20}Ne, we compute 3+1D hydrodynamic predictions for the anisotropic flow of Pb+Ne and Pb+O collisions to be tested with upcoming LHCb data. Elliptic flow in Pb+Ne collisions is significantly enhanced compared to the Pb+O baseline due to the shape of ^{20}Ne, which is deformed in a bowling pin geometry [2]. These studies open a new and emerging avenue for synergy between the nuclear structure and heavy-ion communities, advancing the precision era of relativistic nuclear collisions.

[1] H. Mäntysaari, B. Schenke, C. Shen and W. Zhao, "Probing Nuclear Structure of Heavy Ions at the Large Hadron Collider," arXiv:2409.19064 [nucl-th]

[2] G. Giacalone, W. Zhao, et al. "The unexpected uses of a bowling pin: anisotropic flow in fixed-target ^{208}Pb+^{20}Ne collisions as a probe of quark-gluon plasma," arXiv:2405.20210 [nucl-th]

Category

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Authors: SCHENKE, Bjoern (Brookhaven National Lab); SHEN, Chun (Wayne State University); Dr MÄNTYSAARI, Heikki (University of Jyväskylä); ZHAO, Wenbin (Wayne State University)

Presenter: SHEN, Chun (Wayne State University)

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