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Using Multivariate Cumulants to Constrain the Initial State in XeXe and PbPb Collisions at the CMS Experiment

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Xenon (Xe) nuclei are deformed and have a nonzero quadrupole moment, whereas lead (Pb) nuclei are considered spherical in shape. The study of XeXe collisions at a center-of-mass energy per nucleon pair of $\sqrt{s_{\mathrm{NN}}} = 5.44$ TeV opens up a window to study nuclear deformation using the CMS experiment. When compared to the Run 3 PbPb data at a center-of-mass energy per nucleon pair of $\sqrt{s_{\mathrm{NN}}} = 5.36$ TeV, which is very close to that of XeXe, one can explore the dependence of the Fourier flow coefficients on the size and initial-state geometry of the colliding system. For the first time, correlations between higher order moments of two as well as three flow harmonics (v_2 to v_6, up to orders 8 or 10) are measured in XeXe and PbPb collisions as a function of collision centrality. These new measurements have been calculated with multiparticle mixed harmonic cumulants using charged particles in the pseudorapidity region $|\eta| < 2.4$ and the transverse momentum range $0.5 < p_{\mathrm{T}} < 3.0$ GeV /c. The results have also been compared to theoretical model predictions provided by the IP-Glasma+MUSIC+UrQMD model, which helps us to constrain the initial-state deformation parameters of Xenon nuclei. Furthermore, it has been shown that both hydrodynamic probes $\frac{\mathrm{v}_2\{6\}-\mathrm{v}_2\{8\}}{\mathrm{v}_2\{4\}-\mathrm{v}_2\{6\}}$ and $\frac{\mathrm{v}_2\{8\}-\mathrm{v}_2\{10\}}{\mathrm{v}_2\{6\}-\mathrm{v}_2\{8\}}$ are centrality dependent, explained by introducing newly measured higher order moments in the Taylor expansion of the corresponding generating function of the cumulants. The higher order moments, skewness, kurtosis, and the superskewness (5th moment) are expressed through the $v_2\{2k\}$ (k = 1, ..., 5) harmonics and are shown as a function of collision centrality. Overall, these studies will significantly constrain initial-state model parameters and give us a better understanding of the transport properties of the quark-gluon plasma created in heavy ion collisions at the LHC.

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