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Impact of nuclear structure on the chiral magnetic effect in isobaric collisions

Under the assumption of same background but different magnetic fields, isobaric collisions are believed to be an effective way to measure the anomalous chiral effects. The isobaric program at the Relativistic Heavy Ion Collider (RHIC) has been done by colliding $^{96}_{44}Ru + ^{96}_{44}Ru$ and $^{96}_{40}Zr + ^{96}_{40}Zr$, however, it reveals that the chiral magnetic effect (CME) background is different between the two species of isobaric collisions and the predefined CME signatures have not been observed in the blind experimental analysis [1].

We test eighteen cases of Woods-Saxon parameter settings which consider either nuclear deformation or nuclear neutron-skin effect for Ru+Ru and Zr+Zr collisions at 200 GeV, using the AMPT model. Only seven of the eighteen cases (Case 3, Case 4, Case 5, Case 7, Case 9, Case 10, and halo-type case) can reasonably reproduce the experimental ratios of charged-particle multiplicity distribution, average number of charged particles and elliptic flow, which demonstrates that the nuclear deformation and structure information have a non-negligible impact. Isobar collisions can serve for further research of nuclear deformation or nuclear neutron-skin structure, which currently has important implications for both nuclear structure and nuclear astrophysics.

Utilizing the chi-square test χ^2, we choose the halo-type case to study the CME using the AMPT model with different strengths of the CME [2]. The measured $\Delta\delta$, $\Delta\gamma$, $\Delta\delta$ ratio, and $\Delta\gamma$ ratio can be reproduced by the AMPT model without the CME or with a small strength of the CME. On the other hand, they can not be described by the AMPT model with a stronger strength of the CME. This indicates that the initial CME signal in isobar collisions is absent or small in isobar collisions. It could be due to the fact that the final state interactions significantly weaken the initial CME signal, resulting in the non-linear sensitivity of the CME observables. Therefore, more sensitive observables are required for searching for the possible small CME signal in isobar collisions.

[1] M. Abdallah et al. (STAR), Phys. Rev. C 105.014901 (2022).

[2] X. L. Zhao and G. L. Ma, Physical Review C 106, 034909 (2022).

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