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Sub-nucleon geometry and multiparticle cumulants including $c_2\{4\}$ in $p+p$ collisions

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Collective flow-like signals including the ridge structure observed in small collision systems at high energies that are similar to those in large collision systems have led to questions about the onset of collectivity in nuclear collisions. Multiparticle cumulant methods are better in extracting the flow signals as they can suppress nonflow effects that are especially significant in small systems. For example, a negative four-particle cumulant $c_2\{4\}$ is expected when the correlation comes from the collective flow. A previous study from a hydrodynamics-based hybrid model could not produce negative $c_2\{4\}$ for $p+p$ collisions at 13 TeV [1], regardless of the analysis method such as the standard, two-subevent and three-subevent cumulants.

In this study [2], we use the string melting version of a multi-phase transport (AMPT) model without or with the sub-nucleon geometry for the proton to study multiparticle cumulants in $p+p$ collisions at 13 TeV. We have found that both versions of the model can produce $c_2\{4\} < 0$ for high-multiplicity events. The relation between $c_2\{4\}$ and the parton scattering cross section is non-monotonic, where only a finite range of parton cross sections can lead to negative $c_2\{4\}$ for high-multiplicity $p+p$ events. In addition, the AMPT version with the proton sub-nucleon geometry describes the multiplicity dependence of $c_2\{4\}$ much better than the version without. This demonstrates the importance of incorporating the sub-nucleon geometry and the potential of using multiparticle cumulants to probe the detailed sub-nucleon geometry in studies of small collision systems.

[1] W. B. Zhao, Y. Zhou, H. J. Xu, W. T. Deng and H. C. Song, Phys. Lett. B 780, 495-500 (2018).
[2] X. L. Zhao, Z. W. Lin, L. Zheng and G. L Ma, arXiv: 2112.01232.

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