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The kinematic interpretation of the two-particle angular correlation

In high-energy heavy-ion collision experiments, a pseudo-rapidity, η, independent behavior emerges in a two-particle angular correlation in the forward direction over a relatively wide range of η. This behavior is designated the "Ridge." The Ridge behavior observed during high-energy nucleus-nucleus (AA) collisions, which was adequately explained by elliptic and higher-order flows based on hydrodynamics. After that, the Ridge behavior has been observed in small systems, such as high-multiplicity proton-proton (pp) collisions. This phenomenon has been a subject of considerable debate due to the insufficiency of such small systems in generating a hot and dense medium, namely the Quark-Gluon Plasma (QGP), which is necessary to explain the Ridge behavior through hydrodynamic flows. Consequently, there has been extensive discourse surrounding the comprehension of this Ridge behavior in high-multiplicity small systems, which includes this study.

Our study aims to develop a pure kinematic model of the interaction between jet particles and medium partons, to gain insight into the Ridge behavior. Concerning kinematics, the jet particles lose energy during their passage through the medium partons in high-energy heavy-ion collisions. The energy lost by the jet particles is partially transferred to the medium partons as momenta. At the same time, the rest is emitted as photon and gluon radiation, along with thermal energies produced in the collisions. This process causes the medium partons to align with the jet particles' motion direction, thereby generating a collective motion of the medium partons. This collective motion may contribute to the observed Ridge behavior in small system collisions. Accordingly, we attempt to explain the Ridge phenomenon through the lens of the energy loss mechanisms associated with these jet particles. The present study will concentrate on radiational processes, known as Bremsstrahlung, which represent the primary source of energy loss in jet particles.

In practical calculation, our model requires information on the initial states to calculate the cross-section, hence we employ the Parton Distribution from the hard scattering model (PDh) as a distribution function for the initial medium partons' momentum. The PDh has three free parameters: the fallout parameter, α associated with the shape of the rapidity distribution; the non-extensive parameter, β related to the fine shape of the rapidity and transverse momentum distribution; and the temperature of the system, T connected with the scales of the rapidity and transverse momentum distributions. We choose values for these free parameters by comparing PYTHIA8-string shoving simulation for proton-proton collisions at $\sqrt{s} = 13\,\text{TeV}$ with high-multiplicity events.

Also, we set up the initial conditions for jet particles with 10 GeV entering at 0°. Then, calculate the cross-section for various jet particles' energy losses and outgoing angles, respectively. In this study, we consider two aspects of the cross-section and the correlation: between jet particles and radiations, and between jet particles and medium partons. For the case between jet particles and radiations, the scales of these cross-sections and interaction rate are inversely proportional to both the energy losses and outgoing angles. This phenomenon signifies that the interaction between the jet particles and the final medium partons is more pronounced when both decrease energy losses and outgoing angles. And the cross-sections are aligned in the direction of the final jet particles and final medium partons, thereby causing the correlation to concentrate on a specific region. This phenomenon can be regarded as a type of collective motion. For the case between jet particles and medium partons, the scales of these cross-sections are inversely proportional to both the energy losses and outgoing angles, and these results significantly affect the shapes of correlations. This is expected from the results of the case between jet particles and radiation. In practical scenarios, the cross-section must be integrated for various energy losses and outgoing angles of jet particles, employing the adopted weighting functions for each, based on the experimental results. The results show the Ridge behavior, manifested as a shoulder on the near side and a flat structure on the away side. Furthermore, the values of v_2 are obtained from the results of this study, ranging from 0.013 to 0.038. This indicates the potential for elliptic flows, as evidenced by a comparison of the experimental results in range from 0.01 to 0.04.

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