

Understanding Baryon Stopping and Baryon Diffusion from Baryon-AntiBaryon Elliptic Flow Splitting

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The Beam Energy Scan (BES) program at the Relativistic Heavy Ion Collider (RHIC) provides a unique opportunity to explore QCD matter at finite baryon chemical potential, where the medium created in heavy-ion collisions becomes baryon-rich at lower collision energies. A characteristic feature of this regime is baryon stopping. Experimentally, this enhanced baryon stopping is reflected not only in the increasing baryon-to-antibaryon yield asymmetry, but also in a pronounced splitting between the anisotropic flow coefficients of baryons and antibaryons, particularly in the directed flow v_1 and elliptic flow v_2 [1]. Understanding the origin of this baryon–antibaryon flow splitting is therefore essential for developing realistic initial conditions for finite-density QCD matter.

Despite significant advances in relativistic hydrodynamic modeling [2], existing frameworks have encountered difficulties in simultaneously reproducing the correct ordering or sign of the observed baryon–antibaryon flow splitting. Conventional initial-state prescriptions often employ a factorized ansatz in which the transverse and longitudinal structures of baryon deposition are treated independently.

In this work, we introduce a novel density-dependent baryon deposition ansatz in which the longitudinal rapidity distribution of the deposited baryon number is dynamically correlated with its transverse position. Specifically, the rapidity loss of each participant nucleon is determined by the local density of participants from the opposing nucleus. Regions experiencing a larger opposing participant density therefore undergo stronger baryon stopping, while regions with lower density experience a smaller rapidity loss.

We combine this density-dependent baryon deposition with a tilted initial energy-density profile and evolve the resulting matter using a relativistic hydrodynamic framework [3] that consistently incorporates finite net-baryon density and baryon diffusion. We demonstrate that the resulting framework provides a simultaneous description of the baryon–antibaryon splitting in both v_1 and v_2 . Our study establishes a physically motivated initial-state framework for baryon-rich matter at RHIC BES energies and provides a unified baseline for investigating observables sensitive to finite baryon density. In particular, the framework can serve as a foundation for future studies of fluctuations and transport phenomena relevant to the search for the QCD critical point.

References

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