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A new Poincare covariant N-body transport approach for interacting wave packets

We formulate an efficient covariant method for interacting N-body systems with correct density-dependent potential and consistent mass-shell constraints. We implement it in the Monte-Carlo event generator JAM2 and calculate anisotropic flows for RHIC Beam Energy Scan (BES) energies.

Microscopic transport approaches such as Boltzmann-Uehling-Uhlenbeck (BUU) and Quantum Molecular Dynamics (QMD) have proven to be effective for simulating the space-time propagation of systems in heavy-ion collisions and for extracting the properties of dense nuclear matter. While BUU is a one-body theory, QMD and its relativistic version, RQMD, approaches evolve an N-body distribution function capable of capturing event-by-event fluctuations and correlations, which are crucial for understanding nuclear cluster formation and fluctuations of conserved charges. However, certain approximations for density-dependent potentials in the conventional QMD and RQMD hinder their accurate reproduction of the equation of state. Explicit three-dimensional integration is needed to obtain the exact density dependence, which is numerically expensive. Furthermore, the traditional RQMD models use mass-shell constraints inconsistent with the underlying theory.

This work addresses these limitations by formulating a covariant approach to interacting Gaussian wave packets that achieves accurate density-dependent potentials under correct mass-shell constraints. Our method introduces a novel approximation scheme for computing the density-dependent potential within the RQMD framework, yielding precise solutions with a reduced computational cost. Starting with an action for interacting wave packets, we derive equations of motion for Gaussian packets consistent with constrained Hamiltonian dynamics.

This new RQMD formulation is implemented in JAM2 together with the covariant collision term [1] and applied to Skyrme-type density-dependent potentials [2], the Walecka model [3], and the parity-doublet model [4]. We present results for anisotropic flows, benchmarked against data from the RHIC-BES energy ranges, and demonstrate the efficacy of this approach in simulating dense nuclear matter.

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Category

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