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A comparative study between UrQMD and SMASH: Numerical implementations associated with hadronic transport in the context of heavy ion collisions

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The quark-gluon plasma is a state of matter where quarks and gluons, the fundamental components of protons and neutrons, are free and constantly interacting due to the properties of quantum chromodynamics, such as confinement and asymptotic freedom. This state can only be produced under extreme energy conditions, such as those that existed in the early universe after the Big Bang or in the core of neutron stars. To
study the QGP, these extreme conditions are recreated in laboratories by colliding heavy ions accelerated to relativistic speeds.
The QGP resulting from these collisions has a dimension on the order of 10^{-4} meters and survives for approximately 10^{-23} seconds. Due to its small scale and brevity, direct observation is not feasible, requiring indirect measurements such as the final particle spectrum detected. Thus, studying the QGP requires a series of simulations describing each stage of the collision, connecting theories with experimental data to refine our understanding of the fundamental forces governing subatomic particles.
A crucial stage in this process is hadronic transport, which occurs after the QGP expands and cools, when quarks and gluons reconfine into hadrons. At this stage, the system is described as a gas whose temporal evolution is governed by the Boltzmann equation, considering collisions and decays of hadrons. Several computational models describe this stage. A comparative study of different implementations is essential to identify discrepancies and improve the models'approximation to experimental data.
UrQMD (Ultra-relativistic Quantum Molecular Dynamics) is a numerical implementation that solves the Boltzmann equation for all hadrons, simplifying by considering binary collisions, elastic, and inelastic, as well as decays. It is available as open-source code in Fortran. Similarly, SMASH (Simulating Many Accelerated Strongly-interacting
Hadrons) is a solution for the non-equilibrium dynamics of hadrons, considering inelastic collisions as resonance excitations that decay with vacuum properties. It is also available as open-source code, in C++.
This work compares the UrQMD and SMASH programs, evaluating the considerations made in the construction of each model and the relationship between their final results, using the same input data.

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