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Kinetic versus potential mechanism for deuteron production in heavy-ion collisions from SIS to RHIC energies

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The understanding of the mechanisms for the production of weakly bound clusters, such as a deuteron d, in heavy-ion reactions at midrapidity is presently one of the challenging problems which is also known as the "ice in a fire" puzzle.
In this study we investigate and compare two main mechanisms for the deuteron production based on the Parton-Hadron-Quantum-Molecular Dynamics (PHQMD) [1] microscopic transport approach: the so-called "kinetic mechanism" for the deuteron production (and disintegration) by hadronic reactions via pion or nucleon catalysis as well as the formation of deuterons by a potential interactions between nucleons.
The "kinetic mechanism" is realized by the implementation of the dominant inelastic reactions for deuteron production in the PHQMD, i.e. $\pi NN \leftrightarrow \pi d$, $NNN \leftrightarrow Nd$ and $NN \leftrightarrow d\pi$, based on the covariant rate formalism [3] for $3 \leftrightarrow 2$ reactions obeying the detailed balance.
Differently to other studies [4], we accounted for the quantum origin of the deuteron as elongated object with a radius of $r_d \sim 1.8$ fm, while in semi-classical transport approaches, realized within a test particle method, the deuteron is treated as a point like particle. The final size effect has been modelled by the "excluded-volume" (defined to the physical radius of the deuteron), which forbids the formation of deuteron in the presence of any hadrons within the deuteron radius r_d. The latter reduces substantially the deuteron production by the "kinetic mechanism" in the dense medium. Moreover, we take into account the full isospin decomposition of the various $\pi NN \leftrightarrow \pi d$, $NNN \leftrightarrow Nd$ and $NN \leftrightarrow d\pi$ channels which is important due to the isospin asymmetry of Au+Au reactions.
The "potential" deuterons are identified in the PHQMD via Minimum Spanning Tree (MST) algorithm [2] which is used to recognize the formation of clusters due to the potential interaction of baryons during the dynamical evolution of the fireball.
The final results including deuterons, produced by the both mechanisms, provide a good description of the available measurements for deuterons at mid-rapidity from SIS to the RHIC energies and provide useful predictions for the upcoming CBM FAIR experiment.

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