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# DRoplet and hAdron generator for nuclear collisions: An update

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ABSTRACT

The Monte Carlo generator DRAGON simulates hadron production in ultrarelativistic nuclear collisions. The underlying theoretical description is provided by the blast-wave model. DRAGON includes second-order angular anisotropy in transverse shape and the amplitude of the transverse expansion velocity. It also allows to simulate hadron production from a fragmented fireball, e.g. as resulting from spinodal decomposition happening at the first-order phase transition.

**New version program summary**

*Program Title:* DRAGON

*Program Files doi:* 10.17632/pcx8rk4wj5.1

*Licensing provisions:* GNU General Public License 3

*Programming language:* C++

*Journal reference of previous version:* Computer Physics Communication 180 (2009) 1642

*Does the new version supersede the previous version?:* Yes in the used algorithms, not in physics.

*Nature of problem:* Deconfined matter produced in ultrarelativistic nuclear collisions expands and cools down and eventually returns into the confined phase. If the expansion is fast, the fireball could fragment either due to spinodal decomposition [1] or due to suddenly arising bulk viscous force [2]. Particle abundances are reasonably well described with just a few parameters within the statistical approach. Momentum spectra integrated over many events can be interpreted as produced from an expanding and locally thermalised fireball. The present Monte Carlo model unifies these approaches: fireball decays into fragments of some characteristic size. The fragments recede from each other as given by the pre-existing expansion of the fireball. They subsequently emit stable and unstable hadrons with momenta generated according to thermal distribution. Resonances then decay and their daughters acquire momenta as dictated by decay kinematics. If the fireball does not fragment, all hadrons are produced from the bulk as described by the blast-wave model [3].

*Solution method:* The Monte Carlo generator repeats a loop in which it generates individual events. First, sizes of fragments are generated. Then the fragments are placed within the decaying fireball and their velocities are determined from the one-to-one correspondence between the position and the expansion velocity in the blast wave model. Since hadrons may be emitted from fragments as well as from the remaining bulk fireball, first those from the bulk are generated according to the blast wave model. Then, hadron production from the fragments is treated. Each hadron is generated in the rest frame of the fragment and then boosted to the global frame. Finally, after all directly produced hadrons are generated, resonance decay channels are chosen and the momenta and positions of final state hadrons are determined.

*Reasons for the new version:** The main reason for the new version is the slow performance and precision errors in the procedure for the determination of particle types. We also fixed some bugs which had small effect on the determination of the momenta.

*Summary of revisions:** The calculation of the probabilities of different types of hadrons and resonance species has been completely rewritten. Before, this calculation was a major time consumer at the beginning of the running and also was less precise. The new routines use the method for calculation of density integrals proposed in [4].

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A new procedure for the determination of momenta has been introduced. Previous version included deviations from the proper quantum-statistical distributions; this was investigated and documented in the original paper. In the new version we solved the problem how to efficiently generate momenta [5]. The generated values are drawn now exactly from the Fermi–Dirac or Bose–Einstein distribution, and practically any allowed value of the chemical potential is feasible. The algorithm uses rejection method with acceptance probability better than 90%.

Some bugs connected with incorrect use of the Cooper–Frye formula [6] have been fixed. The output has been checked against calculable spectra where they can be determined.

Finally, we introduced a new long int variable `grandma` into the class `Particle`. For every hadron which comes from a resonance decay, it stores the ID of the original resonance at the beginning of the decay chain. It assumes the value 0 for directly produced hadrons. This allows to trace the origin of the hadrons and judge about the importance of higher resonances.

*Restrictions:* none

*Unusual features:* none

*Additional comments:* none

*Running time:* Depends on the required number of events to be generated and on the values of the parameters. The test run with the default setting which generates 500 events corresponding to 2 units of rapidity in Au+Au collisions at top RHIC energy with no drops takes about 1 minute on MacBook Pro with 2.9 GHz Intel Core i7 with OSX 10.11.5 (El Capitan).

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