Conceptual physics study of UrQMD Model

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Introduction

The field of high energy physics is very challenging in carrying out theories and experiments to unlock the secrets of heavy ion collisions. To understand the phenomena there is variety of theories developed and implied in the form of Monte-Carlo codes for modeling the nuclear collisions. Few codes are based on principles like lattice QCD calculations and perturbative QCD models [2]. Some emphasize on collective phenomena, for example the thermal and hydro [3] models, models which treat microscopic phenomena like the parton scattering, jet quenching, string fragmentation, etc [4]. The models can also be classified, based on the stage of evolution like initial state models (Glauber [5], CGC [6], partonic interactions and cascades [7], hydrodynamic expansion models [8], hadronization models [9] and hadron cascade models [10]. In addition to this some hybrid models are also there. In this paper the Ultra relativistic quantum molecular dynamics model is described in brief.

Ultra Relativistic Quantum-Molecular Dynamics (UrQMD)

The UrQMD [1] comes in the category of microscopic models and the basis of this model is the phase space description of the reaction. The model is able to implement the phenomena into wide range and includes many unknown parameters which are to be fixed by the results of experimental data or by the assumptions of the model. The model deals with both hadronic and partonic interactions through string formation and fragmentation and here, it is not priory assumed about the existence of a stage with deconfined partons.

The study under UrQMD collision means that it includes 55 baryon mass states (up to 2.25 GeV/c^2) and 32 meson mass states in addition to that considers their corresponding anti-particle and all isospin-projected states too. All the above mentioned states may be created whether in string decays, s-channel collisions between hadrons or resonance decays. At lower energy in the range of beam energies of 8-10 GeV/nucleon, meson- or baryon-resonance decays dominate the particle production process. On the other hand for higher energy range the mechanisms which are very important like, string excitation and fragmentation dominate the region. The elementary cross sections are used to fit to the available proton-proton, proton- neutron or pion-proton data and the isospin symmetry is used whenever possible. In the cases when experimental data on cross sections do not exists like hyperon-baryon resonance scattering few assumptions can be made. One of those is the additive quark model assumption, where the dependence of cross sections is only on the number of quarks which the colliding hadrons are containing.[18] according to the given empirical formula:

$$\sigma_{tot} = 40(2/3)^{n_M}(1 - 0.4x_1^s)(1 - 0.4x_2^s)[\text{mb}] \quad (1)$$

$$\sigma_{el} = 0.039\, \sigma_{tot}^{2/3}) \quad (2)$$

Here n_M = 0, 1, 2 represents the number of colliding mesons and x_i^s is the ratio of strange to non-strange quarks in the i-th hadron. These cross sections do not depend on energy and momentum and they match very well with experimentally known hadron-hadron cross sections even at high energies. The other assumption made is the detailed balance and it is based on the time-reversal invariance of the matrix element of the reaction:

$$\sigma_{f\to i} = \frac{p_i^2}{p_f^2}\frac{g_i}{g_f}\,\sigma_{i\to f} \quad (3)$$

Here the g factors are defining the spin-isospin degeneracy factors for the initial, i, and final, f state.
The string excitation-fragmentation method is used for the modeling of inelastic hadron-hadron interactions at high energies. Strings are formed between the quark and diquark (antiquark) from the same hadron in baryon-baryon (meson-meson) interactions. These strings are further stretched and the constituent quarks are assigned with the longitudinal momenta as according to the structure functions of hadrons. The Lund JET-SET routine [11], used in the UrQMD, where it is supposed that the string always breaks into a sub-string and a particle on a mass shell.

A number of empirical suppression factors are used in UrQMD to control and curb the creation of certain meson or baryon species. The s-quark suppression factor is very much sensitive regarding to the production of kaon whereas the diquark suppression factor is very useful and plays an important role for the anti-nucleon production. The model considers the standard values as:

$$u : d : s : qq = 1 : 1 : 0.35 : 0.1 \qquad (4)$$

These values can be tuned by using the model parameters or in some work the default values can be used.

Conclusions

The UrQMD transport model described here basically stands on the similar principles as QMD and RQMD. The model provide acceptance of a consistent calculation of excitation functions from the intermediate energy region to the ultra-relativistic energies. Microscopic transport model UrQMD is an important key to provide deep insight in understanding the dynamics of heavy ion collisions and interactions in very different energy ranges whether it is the Coulomb barrier (several MeV per nucleon) region or the highest energies currently available or expected to achieve in the future. Moreover the thing above all is that it can be used to provide a basic framework which can be able to introduce new transport theoretical concepts and physical ideas, and the ultra-relativistic heavy ion reactions may be explored further.

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