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Strange behavior of rapidity dependent strangeness enhancement of particles containing and not containing leading quarks

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Abstract

Rapidity dependent strangeness enhancement factors for the identified particles have been studied with the help of a string based hadronic transport model UrQMD-3.3 (Ultra-relativistic Quantum Molecular Dynamics) at FAIR energies. A strong rapidity dependent strangeness enhancement could be observed with our generated data for $Au + Au$ collisions at the beam energy of 30A GeV. The strangeness enhancement is found to be maximum at mid-rapidity for the particles containing leading quarks while for particles consisting of produced quarks only, the situation is seen to be otherwise. Such rapidity dependent strangeness enhancement could be traced back to the dependence of rapidity width on centrality or otherwise on the distribution of net-baryon density.

Keywords: Rapidity; Strangeness enhancement; Net-baryon density; UrQMD

1. Introduction

In heavy-ion collisions, the pattern of variation of net-baryon density (μ_B) in rapidity space is found to vary with beam energy. For example, at SIS18/AGS energies, the variation of net-

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baryon density with rapidity is found to be of Gaussian shape with its peak at mid-rapidity [1], whereas at top SPS and RHIC energies, such variation of μ_B shows bimodality with a minimum at mid-rapidity [2–7]. At LHC energies, the net-baryon density is found to be close to zero at mid-rapidity [8]. It is therefore easily comprehensible that the rapidity distribution of a particle, the production of which is sensitive to net-baryon density, or otherwise, the particles containing leading quarks (such as k^+, Λ, Ξ^-), might tend to follow the net-baryon density distribution. The rapidity dependence of other particles whose none of the constituents is u or d quark might not exhibit any such dependencies on net-baryon density. Our earlier work [9] on the variation of rapidity width of various produced particles on beam rapidity, with special reference to Λ and $\overline{\Lambda}$, has vindicated such prediction. It may, therefore, be not completely out of context to believe that a number of other kinematic and dynamical properties of heavy-ion collision might get coupled with this net-baryon density distribution effect.

Strange particles are produced only at the time of collisions and thus expected to carry important information of collision dynamics. Strangeness enhancement is considered to be one of the traditional signatures [10,11] of formation of Quark Gluon Plasma (QGP). Due to the limitation of the detector acceptance, the past and ongoing heavy-ion experiments could measure the strangeness enhancement at mid-rapidity only. All such measurements assume a global conservation of strangeness. However, Steinheimer et al. [12] from UrQMD calculation predicted that strangeness is not uniformly distributed over rapidity space leading to a local violation of strangeness conservation. Thus, the study of rapidity dependent strangeness enhancement is of considerable significance.

Considering the fact that with the large acceptance detectors of the upcoming FAIR-CBM experiment [13–16], measurement of the rapidity dependent strangeness enhancement factor could be a possibility, strangeness enhancement factor at different rapidity bin has been estimated for various identified particles produced in $Au + Au$ collisions at 30A GeV using a string based hadronic transport model UrQMD-3.3 (Ultra-relativistic Quantum Molecular Dynamics).

2. The UrQMD model

Ultra-relativistic Quantum Molecular Dynamics (UrQMD) [17,18] is a microscopic transport model based on a phase space description of $p+p$, $p+A$ and $A+A$ collisions that remains successful in describing the observables of heavy-ion collisions over a wide range of beam energies, that is, from $E_{lab} = 100A$ MeV to $\sqrt{s} = 200$ GeV [19–22]. At low and intermediate energies ($\sqrt{s} < 5$ GeV), it describes the phenomenology of heavy-ion collisions in terms of interactions between known hadrons and their resonances. Fifty-five baryon species up to an invariant mass of 2.25 GeV and 32 meson species up to 2 GeV have been included in this model. At higher energies ($\sqrt{s} > 5$ GeV), the excitation of color strings and their subsequent fragmentation into hadrons are taken into account [17,18,23]. The string models [24] are found to be very successful in describing various dynamical features of high-energy heavy-ion collisions. One of the main ingredients of the string models is the *string fragmentation function*. The fragmentation function in string models generally determines the kinematics of the produced particles. The fragmentation function f(x) represents the probability distribution for hadrons to acquire the longitudinal momentum fraction x from the fragmenting string [18]. Over the year, different types of fragmentation functions were proposed e.g. Lund-fragmentation [24], Field-Feynman fragmentation functions [25] etc. In the default setting of the UrQMD model, Field-Feynman [25] fragmentation scheme is used for the produced particles (see Eqn. (1)) whereas for the leading nucleons, a different kind of fragmentation scheme is implemented (see Eqn. (2)). The values of the free pa-