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# EXAMINATION OF HEAVY-ION COLLISIONS USING EPOS MODEL IN THE FRAME OF BES PROGRAM*

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Recent studies of QCD phase diagram force physicists to investigate creation of quark matter with nuclear collisions at lower energies. At the Relativistic Heavy Ion Collider, there is a program called Beam Energy Scan, where gold ions are collided with various energies ($\sqrt{s_{NN}} = 7.7$, 11.5, 19.6, 27, 39, 62.4 GeV). The lower temperatures or velocities and higher baryon chemical potential vitally change the scenario of matter production. Such behavior is now studied using EPOS3117 approach. Yields, ratio and transverse momentum spectra are examined and compared with results obtained by the STAR experiment in order to adapt the theory and validate it.

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## 1. Introduction

A variety of examined systems in high-energy physics should provide an understanding of the processes of quark matter creation. There are numerous theories trying to explain the complexity of possible scenarios, although there is none universal one for all energies of nuclear collisions. A sophisticated approach needs to be implemented in the theoretical model in order to achieve the agreement with experimental predictions. One of such attempts is now strongly developed with the EPOS model, successfully used in studies at the LHC. The hybrid model consists of a lot of well-known features, however unique is the connection of all of them into one single approach. The process of the evolution of the system in the model will be described in the following.

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## 2. EPOS model

### *2.1. Initial conditions*

The process of the collision of the two nuclei consists in reality in hundreds parallel collisions of partons. The exchange of the gluon can be illustrated with a "ladder" where the rungs are constituent by newly created gluons. Such a structure can be considered as a quasi-longitudinal color field, "flux tube", which is treated as a relativistic string. In the central part of the string, a so-called "kink" moves in the transverse direction. One can distinguish segments of the string characterized by the constant value of velocity of each piece, which then fragment into $q$–$\bar{q}$ or $qq$–$\bar{q}\bar{q}$ [1].

### *2.2. Core–corona approach*

One can divide the obtained medium into areas with high (core) and low (corona) density of string segments (with some critical density $\rho_0$ per unit volume). The corona particles have high momenta and position close to the kink, they constitute jets of hadrons. The particles located far from the surface, with low velocity, compose fluid (core) and are hyrodynamically evolved. More detailed discussion in [1].

### *2.3. Viscous hydrodynamic expansion*

With a given proper time $\tau_0$, the relativistic viscous hydrodynamic expansion of the core begins. It is described with a compatible with lattice QCD, "smoother" cross-over equation-of-state [1].

### *2.4. Statistical hadronization*

The matter starts to be treated as individual particles when the system reaches the hadronization hyper-surface (described with given temperature $T_{\mathrm{H}}$). The Cooper–Frye procedure is applied.

### *2.5. Hadronic cascade*

Particles from the hadronization surface are implied into the hadronic cascade model UrQMD. The hadronic interactions are performed until the system is dense enough.

## 3. Results

The results of $p_{\mathrm{T}}$ spectra and yields calculation of collisions of Au+Au ions simulated with EPOS model are compared with those published by the STAR experiment [2].

EPOS 3117 yields are consistent with the experimental data, see Fig. 1. Small discrepancies are visible for the heavier particles. Ratios are correctly reproduced in most of the cases. For $\sqrt{s_{NN}} = 7.7$ GeV, the ratio of particle pairs ($\pi$, $K$, $p$, $\Lambda$, $\Sigma$) forming core and corona is closer to unity. Hadronic cascades (UrQMD) have a relevant impact on preserving the numbers of net-particles especially for lower collision energies.

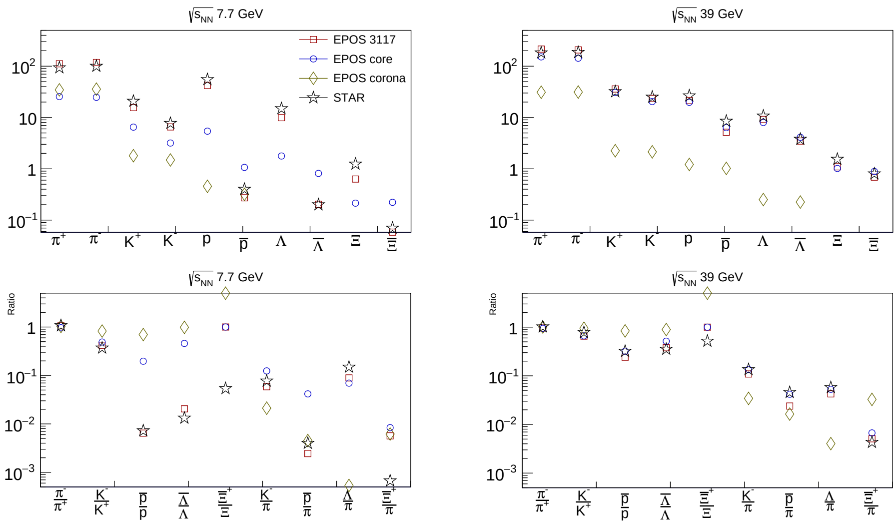


Fig. 1. In the top row yields, in the lower, ratios for $\sqrt{s_{NN}} = 7.7$ and 39 GeV. Centrality 0–5%, $|y| < 0.1$ [2].

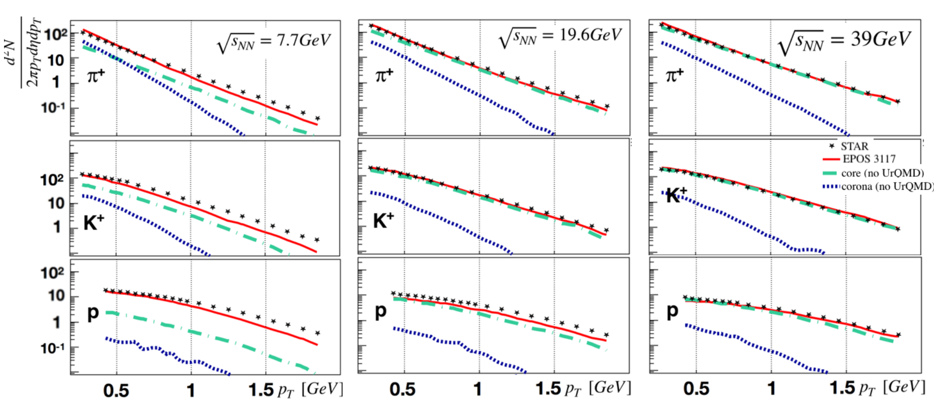


Fig. 2. The transverse momentum spectra of $\pi^+$, $K^+$, $p$ for three collision energies. Centrality 0–5%, $|y| < 0.1$ [2].

The selected plots of $p_{\mathrm{T}}$ spectra are presented in Fig. 2. The strong agreement between simulated and experimental data is visible for $\sqrt{s_{NN}} = 39$ GeV. With the decrease of energy, the fraction of fluid is less dominating, which can cause the small discrepancies in slopes of examined data sets.

## 4. Summary

The multiplicity and transverse momentum spectra of newly-created hadrons give the general information about the studies which need to be done in order to develop the theory included in the EPOS model. The fractions of core and corona need to be investigated as well as the process of hydrodynamic evolution of obtained fluid.

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## REFERENCES

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