THE PRETHERMAL STAGE OF HEAVY-ION COLLISION AND THE PARTICLE PRODUCTION*

Yu.M. Sinyukov[a,b], M.D. Adzhymambetov[a,c], V.Yu. Naboka[a]
V.M. Shapoval[a]

[a]Bogolyubov Institute for Theoretical Physics, 03680 Kiev, Ukraine
[b]Tomsk State University, Department of Physics
Lenin Ave. 36, Tomsk 634050, Russia
[c]Kiev National State University, Department of Physics
60 Volodymyrska Street, Kiev 01033, Ukraine

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The influence of the intensity of matter evolution at the pre-thermal stage of heavy-ion collision on the observed particle spectra is investigated within the integrated hydrokinetic model (iHKM). The simulation results at different values of the thermalization time $\tau_{\rm th}$ and the relaxation time $\tau_{\rm rel}$, characterizing the thermalization rate, at the fixed initial time τ_0 are analyzed for the case of central Pb+Pb collisions at the LHC energy $\sqrt{s_{NN}} = 2.76$ TeV.

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1. Introduction and model description

The early stage of the matter evolution in ultra-relativistic $A + A$ collisions is expected to be very important for the formation of bulk observables. In iHKM, the pre-thermal dynamics of the system's expansion is effectively described within energy-momentum transport approach in relaxation time approximation [1].

At the initial time τ_0, the system's energy-momentum tensor has a form of $T^{\mu\nu}_0(x)$. As the system expands, the tensor evolves and at the thermalization time $\tau_{\rm th}$ acquires the hydrodynamical Israel–Stewart form of $T^{\mu\nu}_{\rm hydro}(x)$. Between τ_0 and $\tau_{\rm th}$ the energy-momentum tensor has the form of

$$T^{\mu\nu}(x) = T^{\mu\nu}_{0,\text{free-evolving}}(x)\mathcal{P}(\tau) + T^{\mu\nu}_{\rm hydro}(x)[1 - \mathcal{P}(\tau)] \qquad (1)$$

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in relaxation time approximation for Boltzmann equation [2]. Here, $\mathcal{P}(\tau) = \left(\frac{\tau_{\rm th}-\tau}{\tau_{\rm th}-\tau_0}\right)^{\frac{\tau_{\rm th}-\tau_0}{\tau_{\rm rel}}}$ is the weight function, such that $\mathcal{P}(\tau_0) = 1$ and $\mathcal{P}(\tau_{\rm th}) = 0$. The initial energy-density profile defining $T_0^{\mu\nu}(x)$ is obtained using the GLISSANDO code for Monte Carlo Glauber simulations [3].

Once the system is thermalized at $\tau = \tau_{\rm th}$, its subsequent locally equilibrated evolution is described in terms of viscous hydrodynamics. Here, for the quark–gluon matter, one uses the equation of state based on the lattice QCD calculations; in this note we use the Laine–Schroeder [4] one.

Gradually, the matter loses the local chemical and thermal equilibrium and decouples into hadrons. At the "particlization" temperature $T_{\rm p}$, the hydrodynamical description is switched to the description in terms of particles. At this stage, treated with UrQMD model [5], the resonance decays and multiple particle scatterings (elastic and inelastic) take place.

Finally, in the output of the model, one obtains the set of particle last collision points and momenta, which are utilized for constructing and analyzing various observables.

2. Results and conclusions

In our previous studies [1], we found that the iHKM results for bulk observables are very sensitive to the initial-state formation time τ_0. In this paper, we analyze the influence of the thermalization rate parameters (relaxation time $\tau_{\rm rel}$ and thermalization time $\tau_{\rm th}$) on the particle momentum spectra, considering the maximal initial energy density in the center of the fireball $\epsilon_0 \equiv \epsilon(\tau_0)$ as a free parameter at fixed $\tau_0 = 0.1$ fm/c.

At first, we perform simulations with two different thermalization times $\tau_{\rm th} = 1.0$ fm/c and $\tau_{\rm th} = 1.5$ fm/c at the same relaxation time $\tau_{\rm rel} = 0.25$ fm/c for both cases. The respective ϵ_0 values are 834 GeV/fm^3 and 681 GeV/fm^3. In Fig. 1, one can see a comparison of the pion, kaon and proton spectra for the central Pb+Pb collisions (c = 0–5%) at the LHC energy $\sqrt{s_{NN}} = 2.76$ TeV, calculated in iHKM, with the experimental data presented by the ALICE Collaboration [6]. The plot demonstrates that varying the maximal initial energy density parameter ϵ_0, one can describe the measured spectra equally well at both thermalization times $\tau_{\rm th}$.

In a similar way, the possibility to compensate the modification of the spectra, associated with the change of relaxation time $\tau_{\rm rel}$, by the variation of the initial energy density ϵ_0 should also be verified. In Fig. 2, we compare with the experimental data the iHKM results on pion, kaon and proton spectra, obtained at fixed thermalization time $\tau_{\rm th} = 1.5$ fm/c and the two different relaxation times, $\tau_{\rm rel} = 0.25$ fm/c and $\tau_{\rm rel} = 0.6$ fm/c. Although the

latter is fairly larger than the former, it still remains smaller than $\tau_{\rm th}$. As one can see, in this case we also obtain similar results for both $\tau_{\rm rel}$ values, tuning our free parameter ϵ_0, which is put to be 630 GeV/fm^3 for $\tau_{\rm rel} = 0.6$ fm/c.

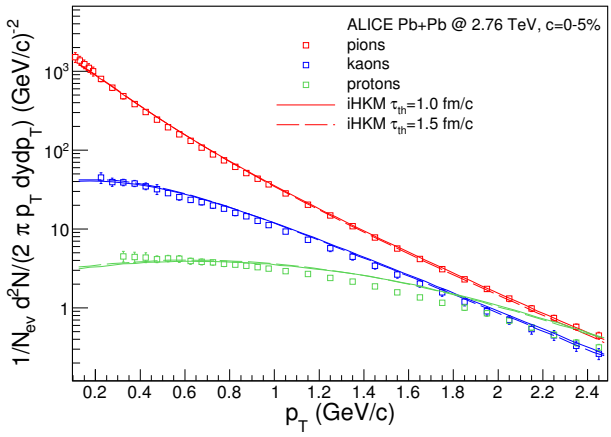

Fig. 1. The pion, kaon and proton spectra in the central ($c = 0$–5%) Pb+Pb collisions at the LHC energy $\sqrt{s_{NN}} = 2.76$ TeV obtained in iHKM at the two different thermalization time values, $\tau_{\rm th} = 1.0$ fm/c (solid lines) and $\tau_{\rm th} = 1.5$ fm/c (dashed lines). The square markers represent the experimental data from the ALICE Collaboration [6].

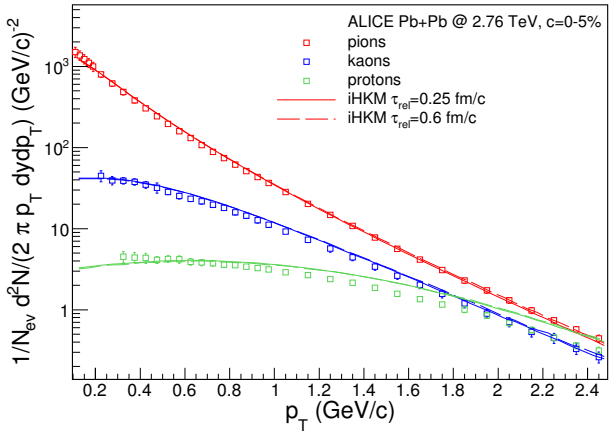

Fig. 2. The comparison of the pion, kaon and proton spectra in the central ($c = 0$–5%) Pb+Pb collisions at the LHC energy $\sqrt{s_{NN}} = 2.76$ TeV obtained in iHKM at the two different relaxation times, $\tau_{\rm rel} = 0.25$ fm/c (solid lines) and $\tau_{\rm rel} = 0.60$ fm/c (dashed lines). The thermalization time in both cases is $\tau_{\rm th} = 1.5$ fm/c. The square markers represent the experimental data measured by the ALICE Collaboration [6].

The obtained results show that the characteristics of the thermalization rate cannot be unambiguously extracted from the experimental data if the initial energy density ϵ_0 is unknown — choosing appropriate ϵ_0 value, one can with equal success describe the observed data at various values of thermalization and relaxation times.

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