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THE FEMTOSCOPY SCALES IN Au+Au COLLISIONS AT THE TOP RHIC ENERGY*

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The pion and kaon femtoscopy radii depending on transverse momentum are studied for Au+Au collisions at the RHIC energy $\sqrt{s_{NN}} = 200$ GeV within the integrated hydrokinetic model (iHKM). The time of the maximal emission $\tau_{\rm max}$ for both particle species is extracted from the analytical fit to the $R_{\rm long}$ dependence on mean transverse momentum of $k_{\rm T}$ of the particle pair.

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1. Introduction and model description

In this work, we present the results for the interferometry radii in ultrarelativistic Pb+Pb collisions at the RHIC with the energy $\sqrt{s_{NN}} = 200$ GeV obtained from the simulations in the integrated hydrokinetic model (iHKM) [1].

The iHKM simulates the full process of relativistic nuclear collision. The simulation starts with the description of the pre-thermal stage of matter evolution, at which the system gradually transforms from its initial non-thermalized state to a one close to local thermal and chemical equilibrium. Then the stage of continuous medium evolution, described by the viscous hydrodynamics approximation in Israel–Stewart formalism, follows. At $T_p = 165$ MeV, one switches from the hydrodynamical description of matter expansion to the description in terms of particles (we call this switching "particlization"). During the final "afterburner" stage of the hadron gas evolution, the resonances decay and numerous particle scatterings occur. These processes are described in iHKM using the UrQMD model [2].

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The initial transverse energy density profile for the pre-thermal stage is generated using the GLISSANDO Glauber Monte Carlo code [3]. The obtained profile is scaled by the factor ϵ_0, defining the maximal initial-energy density at starting proper time τ_0, in the most central collisions. Another parameter, α, regulates the proportion between the contributions from the "binary collisions" and the "wounded nucleon" models in GLISSANDO. The values of $\epsilon_0(\tau_0)$ and α are fixed based on experimental charged particle multiplicity *vs.* centrality and the slope of pion $p_{\rm T}$ spectrum in the most central collisions, and they set up the whole simulation regime. In this paper, we use the values $\epsilon_0 = 235$ GeV/fm^3 at $\tau_0 = 0.1$ fm/c and $\alpha = 0.18$.

We also utilize the Laine–Schroeder equation of state [4], corrected for the non-zero baryon and strange chemical potentials according to the method described in [5].

2. Results and conclusions

Figures 1–4 demonstrate the iHKM results on the interferometry radii $R_{\rm long}$, $R_{\rm out}$, $R_{\rm side}$ for $\pi^-\pi^-$ (grey/red) and K^-K^- (black/blue) pairs for the centrality classes $c = 0$–10%, $c = 10$–20%, $c = 30$–40%, $c = 60$–70%. For the construction of the correlation function, the particles in the $p_{\rm T}$-range $0.15 < p_{\rm T} < 1.55$ GeV/c and $|\eta| < 1$ were selected. We compare our results for the centrality classes $c = 0$–10% and $c = 10$–20% with the PHENIX data for pions and kaons [6], and with the STAR results for pions [7], as well as with the STAR preliminary data for kaons [8].

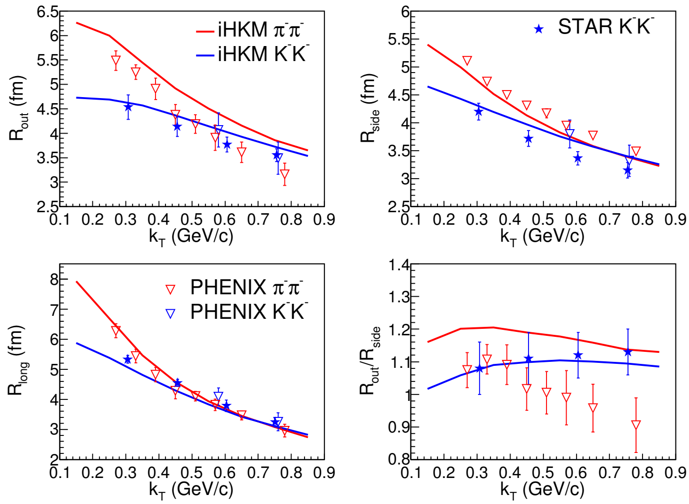

Fig. 1. (Colour on-line) Interferometry radii of negatively charged pion and kaon pairs for the centrality $c = 0$–10%. Black/blue colour corresponds to kaons, grey/red — to pions. Lines show the iHKM results, triangles — the PHENIX results [6] , stars — the STAR results [7, 8].

For the centrality $c = 0$–10%, we also extract the time of the maximal emission of pions and kaons, according to the procedure described in [9]. Firstly, from the simultaneous fit of the pion and kaon spectra in the $p_{\rm T}$ range, $0.45 < p_{\rm T} < 1.0$ GeV/c, we extract using the formula [9]

$$p_0 \frac{{\rm d}^3N}{{\rm d}^3p} \propto \exp\left[-\left(m_{\rm T}/T + \alpha\right)\left(1 - \bar{v}_{\rm T}^2\right)^{1/2}\right] \tag{1}$$

the effective temperature parameter value $T = 141$ MeV and the flow strength parameters $\alpha_\pi = 7.86 \pm 2.11$, $\alpha_K = 5.54 \pm 2.61$ for pions and kaons. Then we made a fit of $R_{\rm long}$ dependence on $m_{\rm T}$, extracted from the correlation function in the range of $|q| < 0.3$ GeV/c, which was constructed from the particles with $p_{\rm T} < 1.55$ GeV/c and $|\eta| < 1$, using the analytical formula [9]

$$R^2_{\rm long}\left(k_{\rm T}\right) = \tau^2\lambda^2\left(1 + \frac{3}{2}\lambda^2\right) , \tag{2}$$

where

$$\lambda^2 = \frac{T}{m_{\rm T}}\left(1 - \bar{v}_{\rm T}^2\right)^{1/2} , \tag{3}$$

the transverse velocity in the saddle point $\bar{v}_{\rm T} = k_{\rm T}/(m_{\rm T} + \alpha T)$. Here, $T = T_{\rm me}$ is the temperature at the hypersurface of maximal emission, proper time of the maximal emission $\tau = \tau_{\rm me}$.

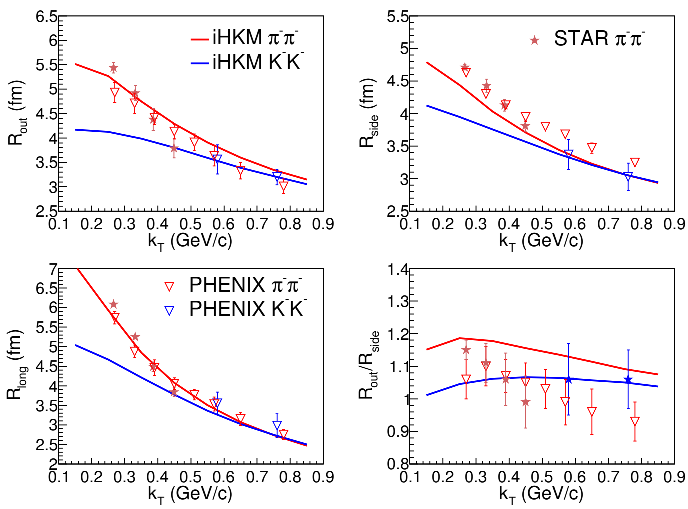

Fig. 2. (Colour on-line) The same as in Fig. 1 for the centrality $c = 10$–20%.

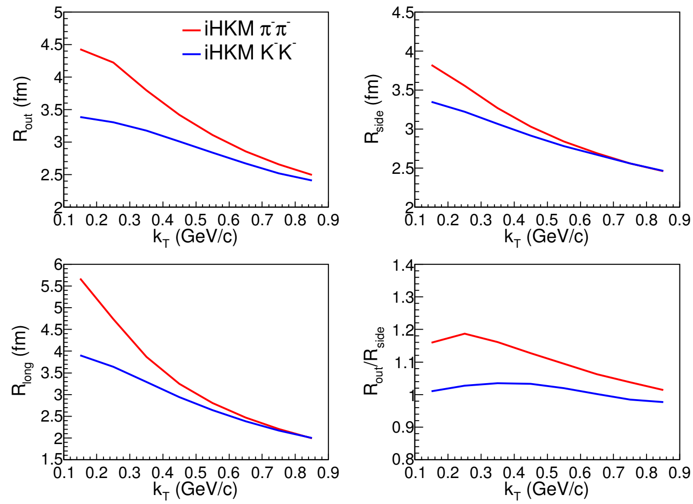

Fig. 3. (Colour on-line) The same as in Fig. 1 for the centrality $c = 30$–40%.

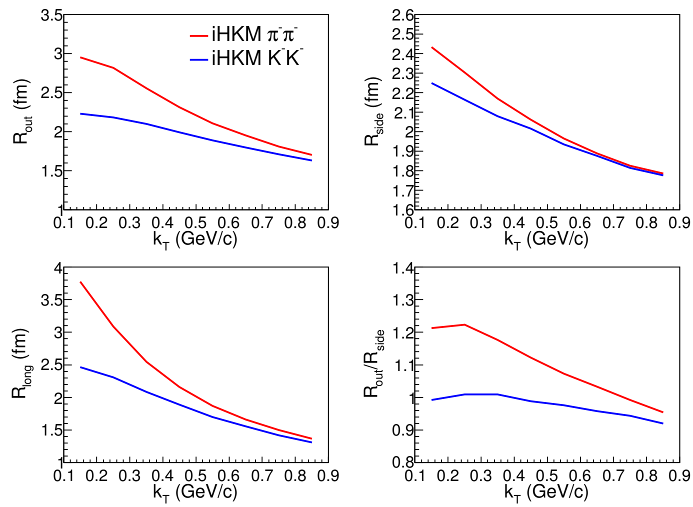

Fig. 4. (Colour on-line) The same as in Fig. 1 for the centrality $c = 60$–70%.

As a result, we have obtained the time of maximal emission $\tau_{\max} = 7.12 \pm 0.01$ with $\alpha_\pi = 7.05 \pm 0.17$ for pions, and $\tau_{\max} = 9.71 \pm 0.02$ for kaons. The corresponding $R_{\rm long}$ fits are demonstrated in Figs. 5 and 6. Figure 7 shows a spatiotemporal picture of the emission of pions and kaons obtained in iHKM, which confirms our results for the times of maximal emission, obtained from the $R_{\rm long}$ fit.

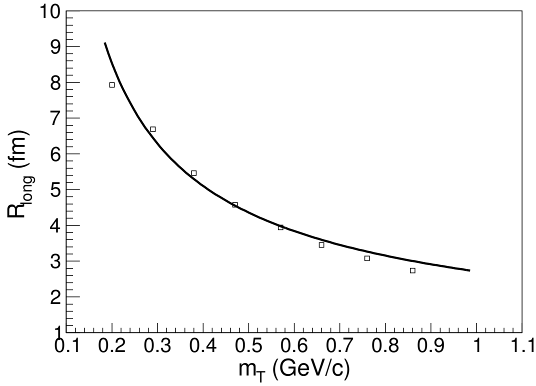

Fig. 5. Dependence of $R_{\rm long}$ on $m_{\rm T}$ for the $\pi^-\pi^-$ pairs and its fit.

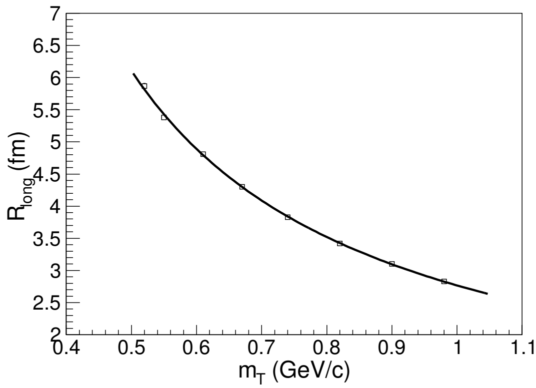

Fig. 6. Dependence $R_{\rm long}$ on $m_{\rm T}$ for the K^-K^- pairs and its fit.

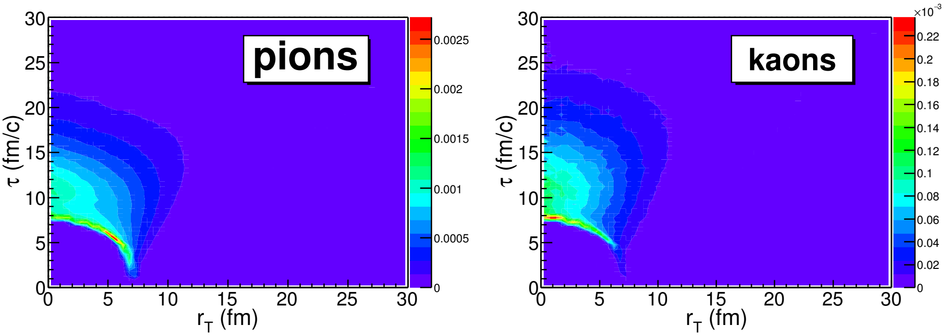

Fig. 7. The space-time picture of pion and kaon emission in iHKM.

As one can see from Figs. 1 and 2, the iHKM reproduces well the experimental R_{long} behaviour for both kaon and pion pairs. As for R_{out}, the description of its dependence on k_{T} for the $\pi\pi$ case looks satisfactory for $c = 10$–20%, but for $c = 0$–10%, the model overestimates the data, especially at large momenta. At the same time, R_{out} for KK pairs are described well at both centralities. The R_{side} radii again are reproduced in iHKM well for the kaon case, and the pion radii are underestimated, especially for large k_{T}. Accordingly, the $R_{\mathrm{out}}/R_{\mathrm{side}}$ ratio is well described for kaon pairs and overestimated for pion pairs.

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