Kaon femtoscopy in Au+Au collisions at $\sqrt{s_{\mathrm{NN}}}$ = 200 GeV at the STAR experiment

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Abstract. In this proceedings, the STAR preliminary results on femtoscopic correlations of identical kaons from Au+Au collisions at $\sqrt{s_{\mathrm{NN}}}$=200 GeV are presented. The measured kaon source radii are studied as a function of collision energy as well as centrality and transverse pair mass m_{T}. In addition, extracted kaon blast-wave freeze-out parameters are presented.

1 Introduction

Quantum Chromodynamics calculations predict that under sufficiently high temperature or energy density nuclear matter undergoes a phase transition from hadrons to a state of deconfined quarks and gluons, the Quark-Gluon Plasma. The properties of this novel state of matter have been extensively studied in high-energy nuclear collisions at RHIC. Two-particle interferometry measurement, known as femtoscopy or HBT, is a standard method of studying space-time characteristics of the created system during the heavy-ion collisions [1]. It has been most common to perform the femtoscopic analyses with pions [2, 3] as they are the most abundantly produced particles in heavy-ion collisions. Recently collected high-statistic datasets allow measurements with the heavier but less abundant particles. In this proceedings, we report on the latest results from kaon femtoscopy at the STAR experiment. In comparison with pions, the kaons are less affected by the long-lived resonance decays, contain strange quarks and have a smaller cross-section with the hadronic matter. Hence the kaon femtoscopy can be sensitive to the earlier stage of the collisions evolution and can provide additional information about the created system in the heavy-ion collisions.

2 Two-particle correlation function

Experimental correlation function is defined as a ratio of two-particle spectrum from the same events, $N(\vec{q})$, and two-particle spectrum from the mixed events, $D(\vec{q})$,:

$$C(\vec{q}) = \frac{N(\vec{q})}{D(\vec{q})}, \tag{1}$$

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where $\vec{q}$ is the pair 4-momentum difference of the first and the second particle decomposed in the Bertsch-Pratt coordinate system [4, 5] to q_{out}, q_{side}, and q_{long} components. The source radii are extracted from the correlation functions by the standard Bowler-Sinyukov [6, 7] method, which is based on the separation of the Coulomb interaction, $K(q_{\text{inv}}, R_{\text{inv}})$, from the pure Bose-Einstein correlation function. In this analysis, the experimental correlation functions were fitted assuming Gaussian shape of the correlation function

$$C(\vec{q}) = N\left[1 - \lambda + \lambda K(q_{\text{inv}}, R_{\text{inv}})\left(1 + \exp\left(-R_{\text{out}}^2 q_{\text{out}}^2 - R_{\text{side}}^2 q_{\text{side}}^2 - R_{\text{long}}^2 q_{\text{long}}^2\right)\right)\right], \tag{2}$$

where λ is the correlation strength, N is the normalization and R_{out}, R_{side} and R_{long} are the Gaussian source radii.

3 Results

3.1 Kaon source radii

Figure 1 shows the STAR preliminary results on kaon femtoscopic radii from Au+Au collisions at $\sqrt{s_{\text{NN}}} = 200$ GeV as a function of the centrality and the average transverse pair momentum $k_{\text{T}} = \left|\vec{p_1} + \vec{p_2}\right|_{\text{T}}/2$, where $\vec{p_1}$ and $\vec{p_2}$ is the 3-momentum of the first and second particle, respectively. The presented analysis was performed for 4 centralities, namely 0-10%, 10-30%, 30-50% and 50-80% most central Au+Au collisions and for 6 k_{T} bins. The correlation functions were constructed separately for positive and negative kaon pairs. Within errors, no difference between source radii for positive and negative kaons has been found. The extracted kaon source radii follow typical centrality and transverse pair momentum dependence. The expansion of the system and the transverse flow causes the decrease of the R_{out} and R_{side} with the increasing k_{T}. The longitudinal expansion is encoded in the falling of R_{long} with the increasing k_{T}.

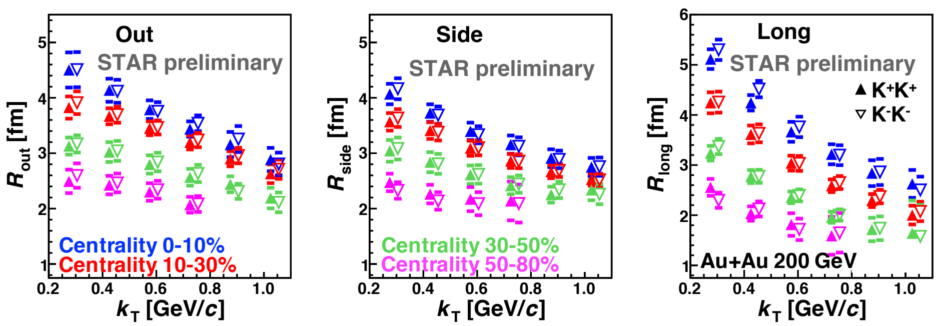

Figure 1. The R_{out}, R_{side} and R_{long} as a function of the transverse pair momenta k_{T} for 4 centrality (0-10%, 10-30%, 30-50% and 50-80%) for positive kaon pairs (solid triangles) and negative kaon pairs (open triangles) from Au+Au collisions at $\sqrt{s_{\text{NN}}} = 200$ GeV. The points are horizontally offsetted for better clarity.

Figure 2 shows a comparison of kaon and pion source radii for the most 0-5% and 30-40% central Au+Au collisions. This analysis extended the previous pion femtoscopy results [3] to higher m_{T} using the ToF detector, which allows pion identification up to momenta $p \sim 1.55$ GeV/c. The R_{out} values for kaons are systematically larger than those of pions, while the R_{side} values for kaons and pions are comparable, and the m_{T}-dependence of R_{long} is different between kaons and pions. Similar behaviors have been recently reported by the ALICE collaboration from Pb+Pb collisions at $\sqrt{s_{\text{NN}}}$=2.76 TeV [8].

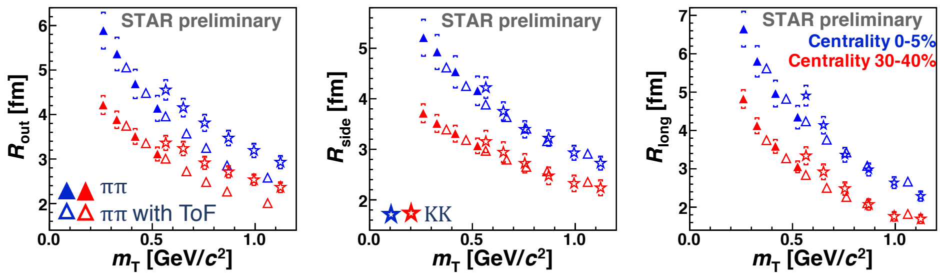

Figure 2. The comparison of the kaon and pion source radii from Au+Au collisions at $\sqrt{s_{NN}}$=200 GeV in STAR. The solid triangles represents the pion source radii taken from [3] .

These behaviors indicate different space-time configuration at the kinetic freeze-out for the pions and kaons. However, deeper understanding of the observed behavior needs a comparison with the full three-dimensional hydrodynamic calculations with rescattering in the hadronic phase.

3.2 Kinetic freeze-out parameters

One of the most commonly used source models in femtoscopy is the blast-wave parametrization, such as in [9], which aims to describe the system at the kinetic freeze-out with a minimal set of parameters. The extracted kaon source radii from Figure 1 and transverse particle spectra ($\pi^{\pm}$, $K^{\pm}$, p, $\bar{p}$) [10] were simultaneously fitted in order to obtain the following 5 parameters of the kinetic freeze-out: temperature T, radius of the system R, maximum transverse rapidity ρ_0, emission duration $\Delta\tau$ and the system proper lifetime τ. Figure 3 shows the extracted kinetic freeze-out parameters of the kaon source as a function of the collision centrality.

While the temperature, T, decreases, the system size, R, and the maximum transverse rapidity, ρ_0, increase with increasing centrality of the collisions. The expansion of the larger system takes longer as shown by the decreasing system evolution time τ and the emission duration last also longer $\Delta\tau$ for more central collisions. Figure 3 also shows that within systematic errors the STAR preliminary results on the blast-wave model kinetic freeze-out parameters for kaons are consistent with the published PHENIX results [12]. At the same time the comparison with STAR pion results from [2] reveals that while the extracted temperature is systematically larger for kaons than for pions, the radius of the system and the system proper time is smaller for kaons. Such behavior can indicate different kinetic freeze-out configuration for pions and kaons.

4 Conclusions

In this proceedings, preliminary results from the STAR experiment on identical kaon femtoscopy from Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV have been presented. The kaon source radii R_{out}, R_{side} and R_{long} are extracted from the three-dimensional analysis for different collision centralities and transverse pair momenta. The extracted source radii show centrality and transverse pair momenta dependence typical for collectively expanding source. Parameters of blast-wave model describing the kaon source at freeze-out are extracted by a simultaneous fit of the kaon source radii and particle spectra. The parameters of the kinetic freeze-out configuration are different for kaons and pions within the blast-wave parametrization. Further comparisons to hydrodynamic models are required to reach a quantitative physics conclusion.

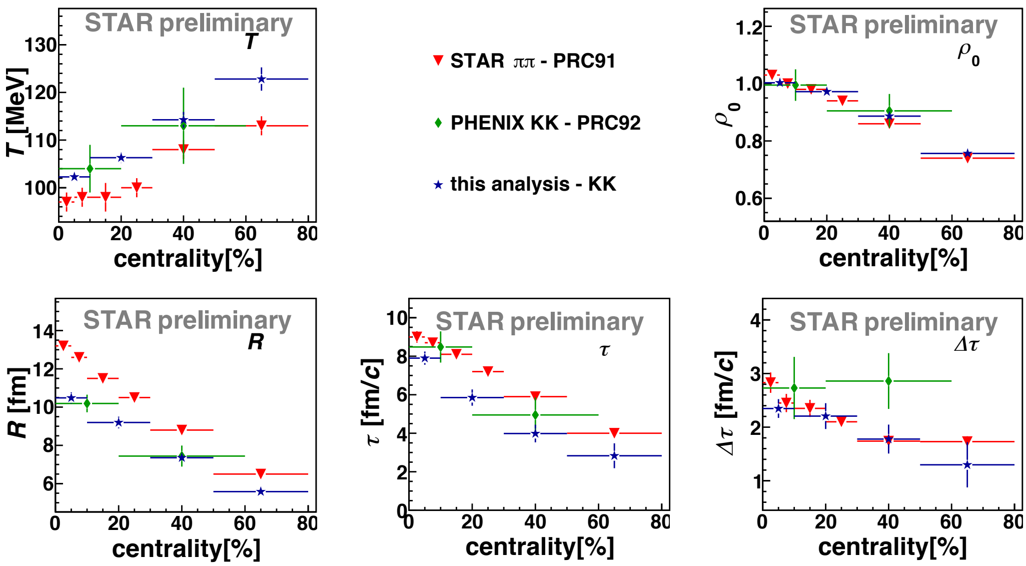

Figure 3. Fit results from kaon source radii: kinetic freeze-out temperature T, radius of the system R, maximum transverse rapidity ρ_0, emission duration $\Delta\tau$ and the system proper time τ as a function of centrality for Au+Au collisions at $\sqrt{s_{\mathrm{NN}}}$ = 200 GeV. The results from pion femtoscopy are taken from [11] and the PHENIX results are taken from [12].

Acknowledgments

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