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FEMTOSCOPY WITH UNLIKE-SIGN KAONS AT STAR IN 200 GeV Au+Au COLLISIONS* **

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In this paper, a status report of a STAR analysis of unlike-sign kaon femtoscopic correlations in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV is presented. The experimental results are compared to theoretical predictions that include the treatment of $\phi(1020)$ resonance due to final-state interaction.

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1. Introduction

Femtoscopy, measurements of two particle correlations at small relative momenta, is a standard tool to measure the space-time characteristics of the particle emitting source. Nowadays, femtoscopic studies span many different particle species and include even non-identical strongly interacting particles [1–3].

The approach proposed by Lednicky in [4] extends the femtoscopic formalisms to higher relative momenta between the two emitted particles in a system where the final-state interaction (FSI) contains a narrow, near-threshold resonance. It is predicted that the correlation function will exhibit high sensitivity in the region of the resonance, where the strength of the correlation should scale with the source, r as inverse volume $\sim r^{-3}$. In addition, such measurements are statistically advantageous, since the two-particle spectra fall rapidly at low relative momenta.

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The non-identical kaons are a good example of such a system, since they contain a narrow $\phi(1020)$ resonance in the FSI. The $\phi(1020)$ resonance is characterized by the decay width $\mathit{\Gamma} = 4.3$ MeV and the decay momentum in the rest frame $k^* = 126$ MeV/c.

In this paper, there are first presented results on correlation functions of like-sign kaons, which provide information about the source size $R_{\rm inv}$ and the λ parameter. Consequently, with these parameters of kaon emission source, the theoretical correlation functions of unlike-sign kaons are calculated by Lednicky model [4] and compared with the experimentally measured ones.

2. Data analysis

The data used for this analysis were collected in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV by the Solenoidal Tracker at RHIC (STAR) [5] in 2011. The most important STAR subdetectors for this analysis are the Time Projection Chamber (TPC) [6] and the Time of Flight (ToF) [7]. The kaons were required to fullfill two main selection criteria. The tracks were required to have $|n\sigma_K| < 3$, where $n\sigma_K$ is a distance from the expected mean $\langle {\rm d}E/{\rm d}x \rangle$ in TPC expressed in terms of standard deviation units σ_K. They were also required to have a signal from the ToF and satisfy a cut on the mass: $0.21 < m^2 < 0.28$ GeV$^2/c^4$.

3. Like-sign 1D correlation function

In this analysis, the correlation functions were constructed for 5 centralities and 4 different bins of transverse pair momentum $k_{\rm T} = (\vec{p_1} + \vec{p_2})_{\rm T}/2$. The experimentally measured like-sign correlation functions were corrected for misidentification and effects of momentum resolution. The source radii $R_{\rm inv}$ and the λ parameters were obtained from fitting experimental correlation functions with a standard Bowler–Sinyukov form of one-dimensional correlation function [8]

$$\mathrm{CF}(q_{\rm inv}) = \left[(1-\lambda) + \lambda K\left(q_{\rm inv}\right)\left(1 + e^{-R_{\rm inv}^2 q_{\rm inv}^2}\right)\right] N\,, \tag{1}$$

where N is a normalization and $K\left(q_{\rm inv}\right)$ is the Coulomb function integrated over source of size $R_{\rm inv}$. The correlation function depends on $q_{\rm inv}$ defined as $q_{\rm inv}^2 = -(p_1^\mu - p_2^\mu)^2$, where $p_1{}^\mu$ and $p_2{}^\mu$ are the four-momenta of the first particle and the second particle, respectively. In the pair rest frame, $q_{\rm inv} = 2k^*$.

The extracted parameters are shown in figure 1. As can be seen, the source radii $R_{\rm inv}$ increase with the centrality and decrease with the pair transverse momentum $k_{\rm T}$. The errors of fit results are dominated by systematic uncertainties which were estimated by varying the fit ranges. Further study of other systematic uncertainties, such as pair selection cuts, is underway.

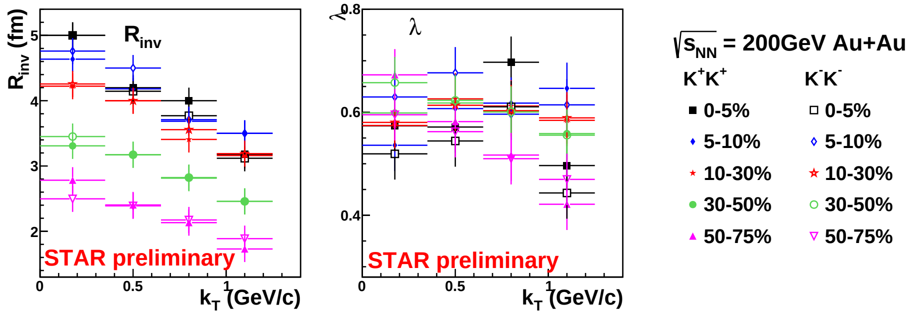

Fig. 1. Fit results of one-dimensional K^+K^+ and K^-K^- correlation functions.

4. Unlike-sign 1D correlation function

Figure 2 shows the STAR preliminary results of K^+K^- correlation functions from Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. While at the low $q_{\rm inv}$, the attractive Coulomb interaction and strong interaction in s-wave can be observed, in the region of $q_{\rm inv} \sim 0.25$ GeV$/c$, the strong interaction in p-wave via $\phi(1020)$ resonance is present. As can be seen, the correlation function is sensitive to the source size. In particular, a strong dependence on the collision centrality and on the pair $k_{\rm T}$ was observed in the resonance region.

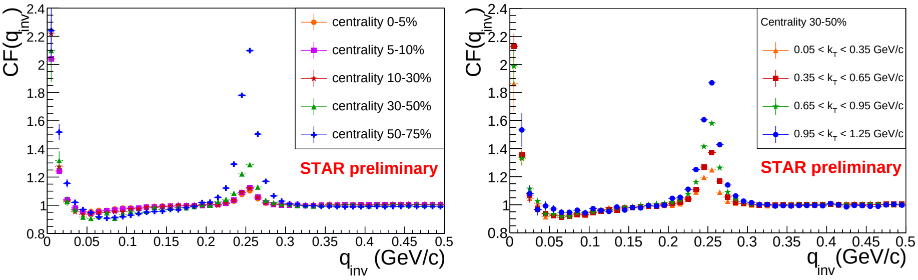

Fig. 2. Left: Centrality dependence of one-dimensional unlike-sign correlation function from Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. Right: $k_{\rm T}$ dependence of one-dimensional unlike-sign correlation function for centrality 30–50% from Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV.

The experimental results of the unlike-sign one-dimensional correlation function were compared to the theoretical prediction from the Lednicky model [4] using a relation

$$\mathrm{CF}\left(q_{\mathrm{inv}}\right)=\int \mathrm{d}^3 r S\left(r, k^*\right)\left|\psi_{1,2}\left(r, k^*\right)\right|^2 , \qquad (2)$$

where $S(r, k^*)$ is the source function describing emission of two particles at relative distance r with the relative momentum k^* in the pair rest frame (PRF). The interaction between the two emitted particles is characterized by their wave function $\psi_{1,2}(r, k^*)$. The source was parametrized by one-dimensional Gaussian in the pair rest frame with a parameter R_{inv} extracted from fitting like-sign correlation function (figure 1). The used FSI model of

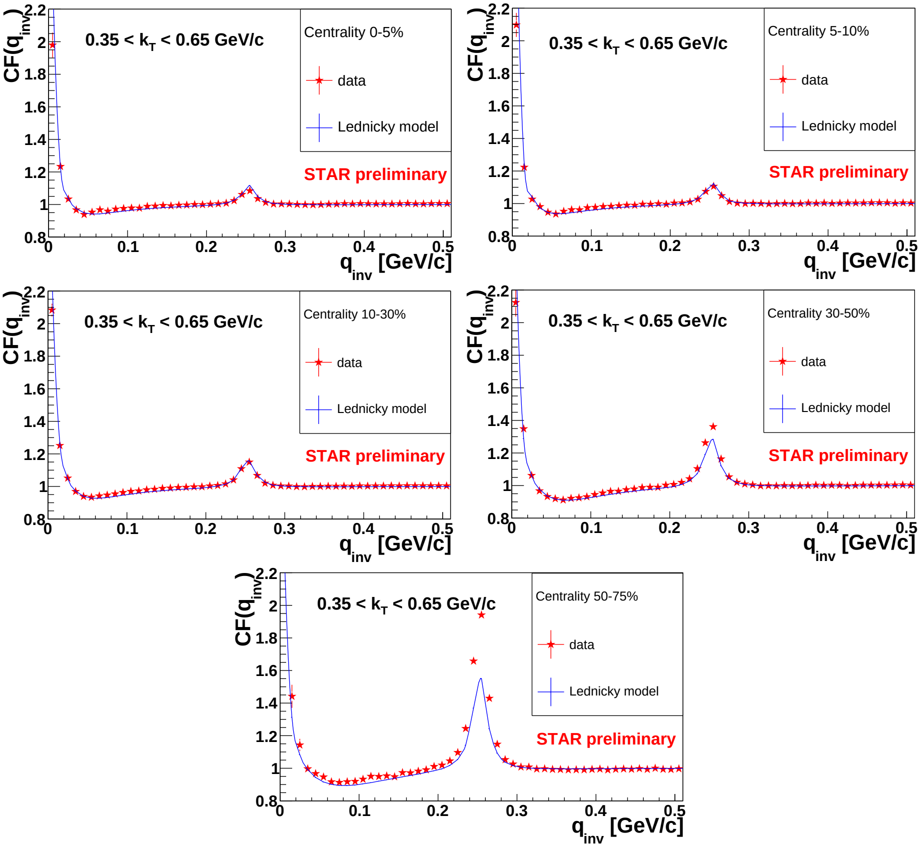

Fig. 3. Comparison of experimental K^+K^- correlation functions from Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV to theoretical calculations for 5 different centralities for $0.35 < k_{\mathrm{T}} < 0.65$ GeV$/c$.

Lednicky [4] includes the treatment of the $\phi(1020)$ resonance in the final state. The model also introduces a generalized form of the smoothness approximation which is needed for correct description of the correlation function in the region of the resonance. Since the theoretical function did not include effects contained in the experimental λ parameter, it was scaled for the comparison according to $\mathrm{CF} = \left(\mathrm{CF}^{\mathrm{theor}} - 1\right)\lambda + 1$, where λ parameter was also obtained from the fit to the like-sign correlation function. The comparison of the experimental and theoretical calculation is shown in figure 3.

As can be seen, the model reproduces the overall structure of the observed correlation functions, both at low q_{inv} where the Coulomb and strong interaction in s-wave are present, as well as in the region of $\phi(1020)$ resonance. The agreement in the ϕ region is very good for central collisions, however, with decreasing source size, the height of the resonance peak is underestimated.

5. Summary

In this paper, preliminary results of STAR analysis of unlike-sign kaon femtoscopic correlations in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV have been presented. The measured K^+K^- correlation function exhibits strong centrality and k_{T} dependence in the region of $\phi(1020)$ resonance. The obtained correlation function has been compared to a theoretical FSI model with parameters R_{inv}, λ obtained from like-sign correlation functions. The Lednicky FSI model reproduces the correlation function in central collisions, but underpredicts the strength of correlation in the $\phi(1020)$ region for peripheral collisions.

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