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LIKE-SIGN KAON FEMTOSCOPY FOR THE BEAM ENERGY SCAN AT STAR*

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In this paper, a status report of a STAR analysis of like-sign kaon one-dimensional femtoscopy for the Beam Energy Scan program is presented. It includes results from Au+Au collisions at six energies from $\sqrt{s_{NN}} =$ 7.7 GeV to $\sqrt{s_{NN}} = 39$ GeV. The centrality and energy dependences are studied.

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1. Introduction

The Beam Energy Scan (BES) program was launched in 2010 at the Relativistic Heavy Ion Collider (RHIC) to study the Quantum Chromodynamics (QCD) phase diagram [1]. The first phase of the program ended in 2014 after collecting data in Au+Au collisions at $\sqrt{s_{NN}} = 7.7$, 11.5, 14.5, 19.6, 27 and 39 GeV.

Data collected by the Solenoidal Tracker at RHIC (STAR) during the BES program were used for the femtoscopic analysis presented in this paper. Femtoscopy uses correlations between two particles at final state with small relative momenta to get information on the space-time characteristics of the particle emitting source. Those correlations are sensitive to the source size and to the final state interactions (FSI) at small relative momenta. The FSI for identical charged bosons usually consists of the Bose–Einstein symmetrization, the strong and the Coulomb interactions. For two identical charged kaons, we assumed the strong interaction to be negligible [2].

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2. Data analysis

The data used for this analysis were collected by the STAR experiment in Au+Au collisions at $\sqrt{s_{NN}}$ = 7.7, 11.5, 14.5, 19.6, 27 and 39 GeV. All events were selected according to the cuts listed in Table I, where $z_{\rm vert}$ is the vertex z coordinate, $R_{\rm vert}$ the distance to the beam axis and $N_{\rm ev}$ the number of events for minimum bias. The analysis was done for minimum bias, for central collisions (0–30%) and for peripheral collisions (30–80%). The centralities were defined with a Monte Carlo simulation based on the Glauber model [3].

TABLE I

Event cuts.

$\sqrt{s_{NN}}$ [GeV]	$z_{\rm vert}$ [cm]	$R_{\rm vert}$ [cm]	$N_{\rm ev}$
7.7	$[-70, 70]$	$[0, 2]$	4.7 M
11.5	$[-50, 50]$	$[0, 2]$	12.1 M
14.5	$[-50, 50]$	$[0, 1]$	8.7 M
19.6	$[-30, 30]$	$[0, 2]$	17.2 M
27	$[-30, 30]$	$[0, 2]$	68.7 M
39	$[-30, 30]$	$[0, 2]$	75.1 M

Particles were selected with a momentum range of $p \in [0.2, 1.6]$ GeV/c and a pseudorapidity range of $\eta \in [-0.5, 0.5]$. The particle identification was done with two subdetectors, the Time Projection Chamber (TPC) [4] and the Time of Flight (ToF) [5]. The deviations N_{σ_π}, N_{σ_K}, N_{σ_p} of the $\mathrm{d}E/\mathrm{d}x$ provided by the TPC to the theoretical values given by the Bethe–Bloch formula for pions, kaons and protons were calculated and the squared mass m_β^2 was calculated from β provided by the ToF, and the momentum provided by the TPC.

For particles with momentum $p > 0.4$ GeV/c, the ToF signal was always required. In this case, we required $\left|N_{\sigma_K}\right| < 2$ and $m_\beta^2 \in [0.18, 0.35]$ (GeV/c)^2. For particles with momentum $p < 0.4$ GeV/c, the ToF signal was used if there but not required. If the ToF signal was there, the same cuts were used, but if the ToF signal was missing, we used only the TPC information with the following cuts: $\left|N_{\sigma_K}\right| < 2$, $|N_{\sigma_\pi}| > 2$ and $\left|N_{\sigma_p}\right| > 2$.

3. Results

3.1. Correlation functions

The correlation functions (CF) were built for pairs with transverse pair momentum $k_{\rm T} \in [0.2, 0.4]$ GeV/c, where $k_{\rm T} = (\vec{p}_{{\rm T},1} + \vec{p}_{{\rm T},2})/2$. We used the mixing event procedure (Eq. (1)) to calculate the CF, dividing the relative momentum distributions for pairs of particles coming from the same event ($A(q_{\rm inv})$) by pairs of particles coming from different events with similar $z_{\rm vert}$ and centrality ($B(q_{\rm inv})$), where $q_{\rm inv}$ is the pair invariant relative momentum. The uncertainties in the results are statistical only

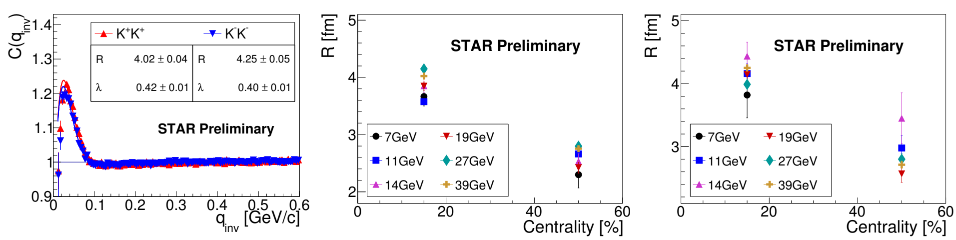
$$C(q_{\rm inv}) = \frac{A(q_{\rm inv})}{B(q_{\rm inv})} \,. \tag{1}$$

The fit was done with the Bowler–Sinyukov procedure [6] with Gaussian approximation (Eq. (2)). Figure 1 (a) shows the CF at $\sqrt{s_{NN}} = 39$ GeV for the 0–30% centrality

$$C(q_{\rm inv}) = 1 - \lambda + \lambda K(q_{\rm inv}) e^{-q^2_{\rm inv} R^2} \,. \tag{2}$$

3.2. Centrality dependence

There is a clear centrality dependence of the radii at all energies for both K^+K^+ and K^-K^- shown in Fig. 1 (b) and (c). The radii increase for more central collisions.

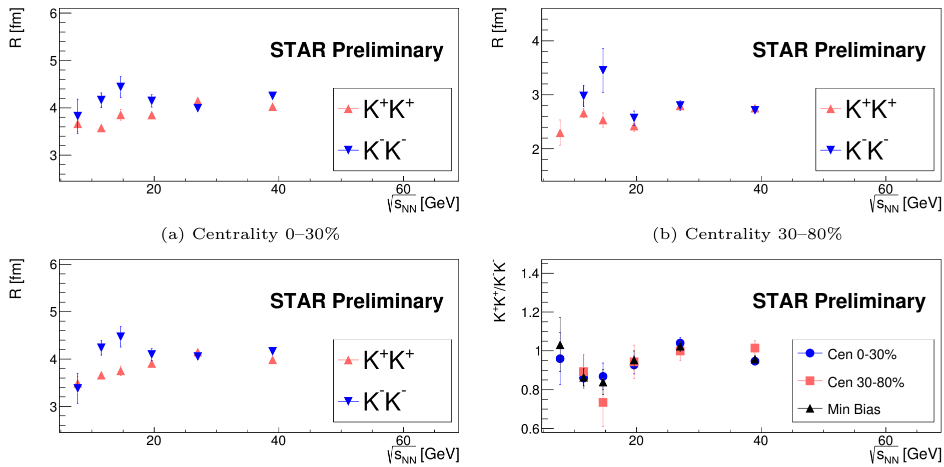


(a) CF at $\sqrt{s_{NN}} = 39$ GeV (b) K^+K^+ (c) K^-K^-

Fig. 1. Centrality dependence for centrality 0–30%.

3.3. Energy dependence

Figure 2 (a), (b) and (c) shows the beam energy dependence of radii for K^+K^+ and K^-K^- in the central, peripheral, and minimum bias events. Figure 2 (d) shows the ratio of radii for K^+K^+ and K^-K^- for the three centralities. For the higher energies ($\sqrt{s_{NN}} = 19.6$, 27 and 39 GeV), the results show no energy dependence and no differences between K^+K^+ and K^-K^- radii. For the lower energies, especially at $\sqrt{s_{NN}} = 11.5$ and 14.5 GeV, there might be some difference between K^+K^+ and K^-K^-, with a small dip visible in the ratio, but the statistics are low and the systematic uncertainties are still to be calculated.



(a) Centrality 0–30%

(b) Centrality 30–80%

(c) Min Bias

(d) K^+K^+/K^-K^-

Fig. 2. Energy dependence for K^+K^+ and K^-K^-.

4. Summary

Preliminary results of like-sign kaon one-dimensional femtoscopy for the BES program at STAR were presented. Correlation functions were calculated for six energies between $\sqrt{s_{NN}} = 7.7$ and 39 GeV in central (0–30%), peripheral (30–80%) and minimum bias events.

The results show the expected increase of the radii for more central collisions for K^+K^+ and K^-K^- at all energies. No clear energy dependence or differences between K^+K^+ and $K-K^-$ were observed for the radii at the energies above $\sqrt{s_{NN}} = 19.6$ GeV. The low statistics for the lowest energies prevent the claim of any energy dependence of the radii or differences between K^+K^+ and K^-K^-.

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