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Bose-Einstein Correlation of Positive Kaon Pairs in E859 — Extended Results and Model Comparisons

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Results are presented for multidimensional BEC analyses of π^+ and K^+ mid-rapidity pairs collected by BNL-AGS experiment E859 in 14.6 A-GeV/c Si + Au central collisions. Comparisons are made to the cascade codes ARC (v. 1.9.5) and RQMD (v. 1.08).

1. Introduction

Bose-Einstein correlations (BEC, Hanbury-Brown/Twiss, HBT) are an important tool in the study of heavy ion collisions [1, and references therein]. Recently we have become aware of the relevance of dynamical correlations to the interpretation of the source parameters in terms of a naive geometrical picture. One can turn to models to see if predicted and measured BEC parameters agree, irrespective of their geometrical meaning [2,3]. To gain model-independent insight, one must examine the dependence of extracted parameters on kinematic quantities [4,5]. This analysis uses both approaches.

The investigation of K^+ BEC was motivated by several factors [6, and references therein]:

- It had never been done in a statistically meaningful way.
- The K^+ -baryon cross-section is relatively small, therefore the K^+ 's should freeze-out at an early, hot, dense time in the collision. The small cross-section also led to theoretical interest since K^+ BEC will presumably be more sensitive to the primordial production points.
- A kaon source is much less contaminated by long-lived resonance contributors than a pion source. The $K^*(892)$ is the only significant contributor to K^+ production at AGS energies.

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The E859 apparatus is described in [7]. A $3\text{-}\sigma$ π/K separation below $1.8\text{ GeV}/c$ was obtained in a 25 msr rotating magnetic spectrometer. The TMA is a 2988-element pad chamber that almost completely surrounds the target and is sensitive to the total charged multiplicity in the event. This detector served as our first-level centrality trigger; we cut on the upper 20% of the charged multiplicity distribution. A second-level trigger, with $40\text{ }\mu\text{s}$ online PID capability, was added to the E802 experimental apparatus [8]. This trigger enhanced the collection rate for K^+ -pairs by a factor of 12.

We examined experimental data sets consisting of ≈ 50000 K^+ pairs and ≈ 110000 π^+ pairs, with rarely more than one pair in an event. Data were corrected with the standard Gamow factor. A two-particle efficiency correction, parameterized from the data in terms of the spatial separation of the tracks [9], was also applied. All correlation functions were fit in the center of mass frame of the participants ($Y = 1.25$). Careful study of parameter dependence on the various correction factors leads us to estimate a systematic error for all parameters of $\approx 5\text{-}10\%$ [6].

300,000 ARC [10] events and 30,000 RQMD [11] events were generated with geometrically distributed impact parameter and cut on the experimental acceptance and centrality trigger. Remaining phase-space points were binned by impact parameter (0.2 fm bins for the pions, 0.5 fm bins for the kaons). We imposed BEC on the models using Pratt's Wigner-density formalism [12]. Pairs were created by mixing the single-particle phase-space points in each impact parameter bin. Weights were calculated for each pair by symmetrizing the Coulomb wavefunction. Results presented here suffer from overuse of single-particle phase-space points in generating the model pairs. This caused super-Poisson fluctuations in the models' relative-momentum distributions, which in turn led to large values of χ^2/dof and unrealistically small error bars.

In order to examine the kinematic dependence of extracted source parameters, the pion data samples were split in two by applying a cut at $350\text{ MeV}/c$ in the single-particle p_T distribution.

2. Results

We present results for three correlation functional forms derived from different Gaussian source parameterizations:

$$R_T : C_2 = 1 + \lambda \exp(-(QR)^2 - (q_0\tau)^2) \quad (1)$$

$$R_L R_T : C_2 = 1 + \lambda \exp(-(Q_L R_L)^2 - (Q_T R_T)^2) \quad (2)$$

$$R_L R_T, R_{T_0} : C_2 = 1 + \lambda \exp(-(Q_L R_L)^2 - (Q_T, R_{T_0})^2 - (Q_{T_0} R_{T_0})^2) \quad (3)$$

Results from 1D [13] and 2D [14] parameterizations have been presented previously. Correlation functions for both 2D parameterizations were fit to all data sets. Confidence contours for these parameterizations are presented in figure 1. The 3D parameterization was only tested on the full data sets; results are presented in figure 2. All fit results are summarized tables 1-3.

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Table 1

Summary of results for the $R_L R_T R_o$ parameterization for all data sets examined.

Data Set			R_L	R_T	R_o	λ	χ^2/dof
E859	π^+	All	2.75 ± 0.15	2.95 ± 0.19	3.77 ± 0.13	0.65 ± 0.02	2605/2711
ARC	π^+	All	1.59 ± 0.18	2.56 ± 0.23	2.98 ± 0.11	0.69 ± 0.03	3905/2514
RQMD	π^+	All	2.83 ± 0.23	1.16 ± 0.54	4.09 ± 0.22	0.68 ± 0.05	3948/2382
E859	K^+	All	1.71 ± 0.14	2.09 ± 0.20	2.07 ± 0.16	0.83 ± 0.08	2374/2402
ARC	K^+	All	1.16 ± 0.10	2.12 ± 0.25	2.25 ± 0.13	1.20 ± 0.10	3258/1977
RQMD	K^+	All	1.50 ± 0.07	1.13 ± 0.20	1.93 ± 0.10	0.96 ± 0.04	3330/1995

Table 2

Summary of results for the $R_L R_T$ parameterization for all data sets examined.

Data Set			R_L	R_T	λ	χ^2/dof
E859	π^+	All	2.52 ± 0.18	3.56 ± 0.13	0.64 ± 0.04	729/759
ARC	π^+	All	1.48 ± 0.17	2.98 ± 0.12	0.63 ± 0.03	1354/777
RQMD	π^+	All	2.64 ± 0.19	3.30 ± 0.14	0.66 ± 0.04	1284/750
E859	π^+	$p_T^<$	3.21 ± 0.31	3.76 ± 0.21	0.70 ± 0.05	75/76
ARC	π^+	$p_T^<$	2.78 ± 0.29	3.71 ± 0.20	0.74 ± 0.05	568/332
RQMD	π^+	$p_T^<$	3.08 ± 0.30	3.65 ± 0.20	0.70 ± 0.05	561/331
E859	π^+	$p_T^>$	2.30 ± 0.22	3.37 ± 0.23	0.77 ± 0.07	225/195
ARC	π^+	$p_T^>$	1.52 ± 0.18	2.48 ± 0.17	0.72 ± 0.06	1233/759
RQMD	π^+	$p_T^>$	2.94 ± 0.26	2.60 ± 0.19	0.88 ± 0.09	1316/733
E859	K^+	All	1.63 ± 0.12	2.10 ± 0.12	0.84 ± 0.07	874/854
ARC	K^+	All	1.29 ± 0.09	2.41 ± 0.11	1.29 ± 0.09	1562/838
RQMD	K^+	All	1.52 ± 0.11	1.60 ± 0.10	0.88 ± 0.06	1584/831

Table 3

Summary of results for the $R\tau$ parameterization for all data sets examined.

Data Set			R	τ	λ	χ^2/dof
E859	π^+	All	2.84 ± 0.09	2.94 ± 0.30	0.67 ± 0.04	468/434
ARC	π^+	All	2.06 ± 0.13	2.72 ± 0.18	0.66 ± 0.04	720/439
RQMD	π^+	All	2.54 ± 0.16	3.27 ± 0.31	0.66 ± 0.05	797/424
E859	π^+	$p_T^<$	3.22 ± 0.24	2.65 ± 0.51	0.69 ± 0.05	44/45
ARC	π^+	$p_T^<$	2.92 ± 0.18	2.49 ± 0.39	0.71 ± 0.05	260/151
RQMD	π^+	$p_T^<$	3.37 ± 0.21	2.57 ± 0.60	0.69 ± 0.05	247/154
E859	π^+	$p_T^>$	2.69 ± 0.18	1.91 ± 0.50	0.74 ± 0.07	102/114
ARC	π^+	$p_T^>$	2.23 ± 0.17	2.05 ± 0.37	0.86 ± 0.09	728/439
RQMD	π^+	$p_T^>$	2.66 ± 0.17	2.29 ± 0.92	0.93 ± 0.15	736/424
E859	K^+	All	1.83 ± 0.07	0.01 ± 0.94	0.78 ± 0.07	457/393
ARC	K^+	All	1.69 ± 0.08	2.11 ± 0.39	1.14 ± 0.09	925/406
RQMD	K^+	All	1.58 ± 0.24	0.88 ± 2.46	0.94 ± 0.29	929/396

Figure 2. Data quality for the $R_L R_T R_{T0}$ parameterization shown for π^+ 's (top) and K^+ 's (bottom). The slices along the different relative-momentum axes are cut along each of the two axes orthogonal to the slice axis (q_{perp}). For π^+ 's this cut is $5 < q_{\text{perp}}(\text{MeV}/c) < 35$; for K^+ 's the cut is $5 < q_{\text{perp}}(\text{MeV}/c) < 65$. Note that the correlation function is obtained through a PML minimization technique in the full 3D phase-space.

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3. Conclusions

Bose-Einstein correlation analyses have been performed on high statistics K^+ and π^+ pair data sets collected at mid-rapidity in 14.6 A-GeV/c Si + Au central collisions. The measured pion source is observed to be $\approx 50\%$ larger than the measured kaon source in every size-parameter tested. For pions, all source parameters are observed (at the $2\text{-}\sigma$ level) to vary inversely with $\langle p_T \rangle$.

Both ARC and RQMD qualitatively reproduce these trends. ARC's consistent underprediction of the pion size parameters and overprediction of the kaon λ -parameter are at least partially explained by the lack of the ω and K^* mesons in the code's tested version. Further failure by both models to quantitatively reproduce measured source parameters, especially the variance with $\langle p_T \rangle$, may hint at the power of Bose-Einstein correlations to elucidate information about source dynamics.

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