Two-particle correlations measured by PHENIX in Au-Au collisions at $\sqrt{s_{NN}} = 200$ GeV.

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In 2001, PHENIX measured particle correlations of identical charged pions and kaons at mid-rapidity in Au-Au collisions at $\sqrt{s_{NN}} = 200$ GeV. Bertsch-Pratt radius parameters of pion pairs are studied for 9 k_T regions from 0.2 to 2.0 GeV/c and for 9 selections of collision centralities. The pion radius parameters are consistent with the result at $\sqrt{s_{NN}} = 130$ GeV, and the ratio R_{out}/R_{side} is below 1 in all $\langle k_T \rangle$ ranges up to 1.2 GeV/c. The radius parameters from charged kaon correlations are compared with those of pions.

1. Introduction

Particle interferometry provides a tool to study the final stage of relativistic heavy ion collisions. Intensity interferometry is based on the Hanbury-Brown Twiss, or HBT, effect. The HBT analysis in relativistic high-energy heavy-ion experiments was originally motivated by theoretical predictions that a large source size and the long duration of particle emission [1] would be observed due to softening of the equation-of-state in a first-order phase transition from a quark-gluon-plasma state. To analyze the HBT data, the Bertsch-Pratt parameterization is employed in a longitudinal co-moving (LCMS) frame, where the three-dimensional Gaussian radii are parameterized to be R_{side}, R_{out} and R_{long} [2]. Assuming a cylindrically symmetric, longitudinally expanding, transversely homogeneous source, R_{side} corresponds to a radial size of the source, while R_{out} is a combination of the radial size and a temporal term of the source duration time. To study the space-time evolution of the source, we introduce two independent external parameters: the transverse momentum of the particle pair and the collision centrality. The transverse momentum, k_T, of the pair is defined by $k_T = (p_{T1} + p_{T2})/2$, where p_{Ti} is the transverse momentum of each particle in the pair. Recently, transport models [4,5] have been used to predict the radius parameters and their k_T dependence. We will compare our results to these predictions.

2. Analysis

The PHENIX detector provides powerful particle identification (PID) capabilities over a wide momentum range [6]. In this analysis, charged pions and kaons are identified by the

*for the full PHENIX Collaboration author list and acknowledgements, see Appendix "Collaborations" of this volume.

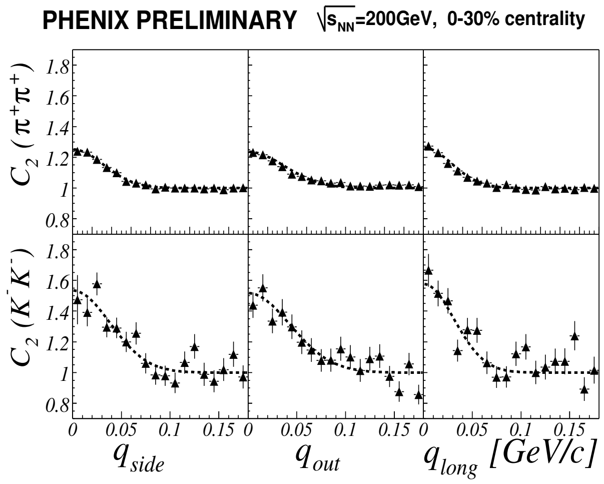

Figure 1. Three-dimensional correlation functions for Bertsch-Pratt radius parameters for π^+ pairs (top) and K^- pairs (bottom). The projection of 3-D correlation functions are averaged over the lowest 40 MeV in the orthogonal directions. The error bars are statistical only. The lines correspond to fits over the entire distribution. k_T range is from 0.2 to 2.0 GeV/c with the $\langle k_T \rangle$ being 0.46 GeV/c for π^+ and 0.76 GeV/c for K^-.

time-of-flight technique using the beam-beam counters and the electromagnetic calorimeter (EMCal), combined with momentum measurement by the drift chamber (DCH). The detector covers the pseudorapidity region $|\eta| < 0.35$ and $\Delta\phi = \pi/2$ in azimuthal angle. The timing resolution is approximately 500 ps. Charged pions and kaons are identified in squared mass versus momentum space using momentum-dependent PID bands which take into account the EMCal timing resolution and DCH momentum resolution. Charged pions and kaons must lie within $1.5\sigma_{m^2}$ of their squared mass peak, but $2.5\sigma_{m^2}$ away from neighboring PID bands. Using 50 million minimum bias events, $\sim$70 million charged pions and $\sim$6 million charged kaons are selected in a momentum range from 0.2 to 2.0 GeV/c. Similar to our previous analyses at $\sqrt{s_{NN}} = 130$ GeV [7], two-track separation cuts were applied using the DCH and EMCal such that pairs within 1 cm in the longitudinal direction and 0.02 radians in the azimuthal direction of each other are removed to eliminate ghost tracks and DCH inefficiency. Pairs that share the same cluster in the EMCal are also removed. The systematic error of the resultant radius parameters from these pair cuts is about 10% in total. The systematic error is evaluated by varying the condition of pair cuts, and the amount of the changes of radius parameters. After the pair cuts, about 160 million charged pion pairs and 1 million charged kaon pairs remain. The statistics are 70 times larger than that obtained in the previous runs [7]. A full Coulomb correction was applied assuming a Gaussian source without pairs coming from resonance decays [3]. The systematic error originating from the Coulomb correction is small compared to the systematic errors for the pair cuts. Figure 1 shows projections of the three-dimensional correlation function onto q_{side}, q_{out} and q_{long} for positive pions (top) and negative kaons (bottom) after the full Coulomb correction.

3. Results

Figure 2 shows the k_T dependence of the chaoticity and the Bertsch-Pratt radius parameters of pions at the most central 30% of the cross section. The radius parameters at $\sqrt{s_{NN}} = 200$ GeV are, within errors, equal to the corresponding results at 130 GeV [7] at the same $\langle k_T \rangle$. While the radius parameters show a strong k_T dependence, the

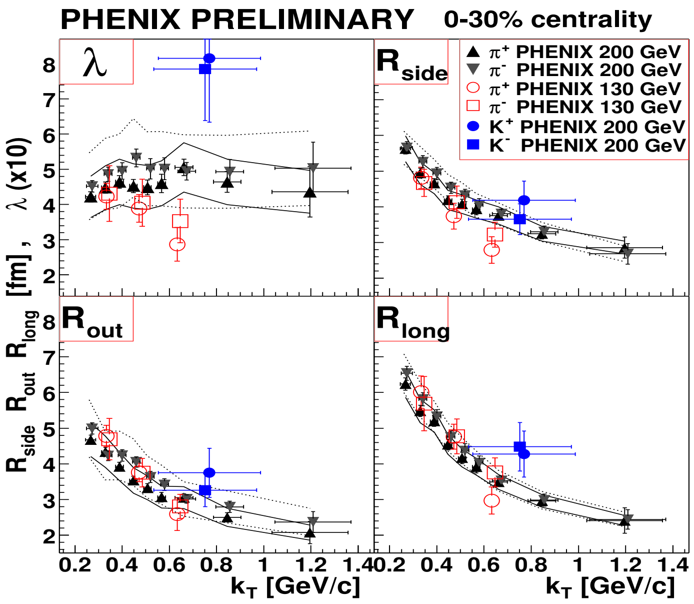

Figure 2. The k_T dependence of Bertsch-Pratt radius parameters and λ for $\pi^{\pm}$ with statistical error bars and systematic error bands. The horizontal error bars indicate the root-mean-square of the k_T distribution. PHENIX results of $\pi^{\pm}$ at 130 GeV and $K^{\pm}$ at 200 GeV are shown with statistical error bars.

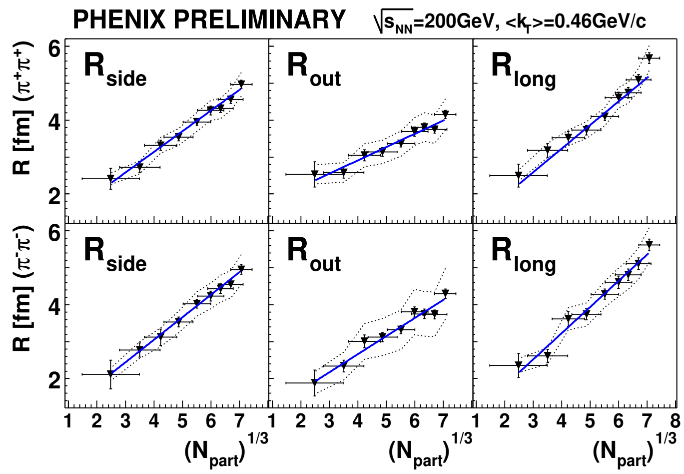

Figure 3. Bertsch-Pratt radius parameters versus the number of participants ($N_{part}^{1/3}$) for $\pi^{\pm}$ with statistical error bars and systematic error bands. k_T range is from 0.2 to 2.0 GeV/c with the $\langle k_T \rangle$ being 0.46 GeV/c. The solid lines show fits with a linear function of $N_{part}^{1/3}$.

chaoticity is constant in all the k_T bins. The kaon radius parameters are slightly larger than those of pions at the same $\langle k_T \rangle$ (the k_T bin for kaons is between 0.2 to 2.0 GeV/c) as shown in Fig. 2; however, the kaon chaoticity is significantly larger than that of pions. Figure 3 shows the collision centrality dependence of the radius parameters. The number of participants (N_{part}) is evaluated from the charged particle multiplicity using a Glauber model calculation [9]. The radius parameters depend linearly on $N_{part}^{1/3}$. In order to study the duration time, we plot R_{out}/R_{side} in Fig. 4 as a function of (a) k_T and (b) centrality. The ratio is independent of centrality and is constant for k_T up to 1.2 GeV/c within error, and is systematically below one.

4. Summary

We have presented HBT results in the Bertsch-Pratt frame for identified charged pions and kaons measured by PHENIX in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV. We have obtained the three-dimensional correlation functions with 160 million charged pion pairs

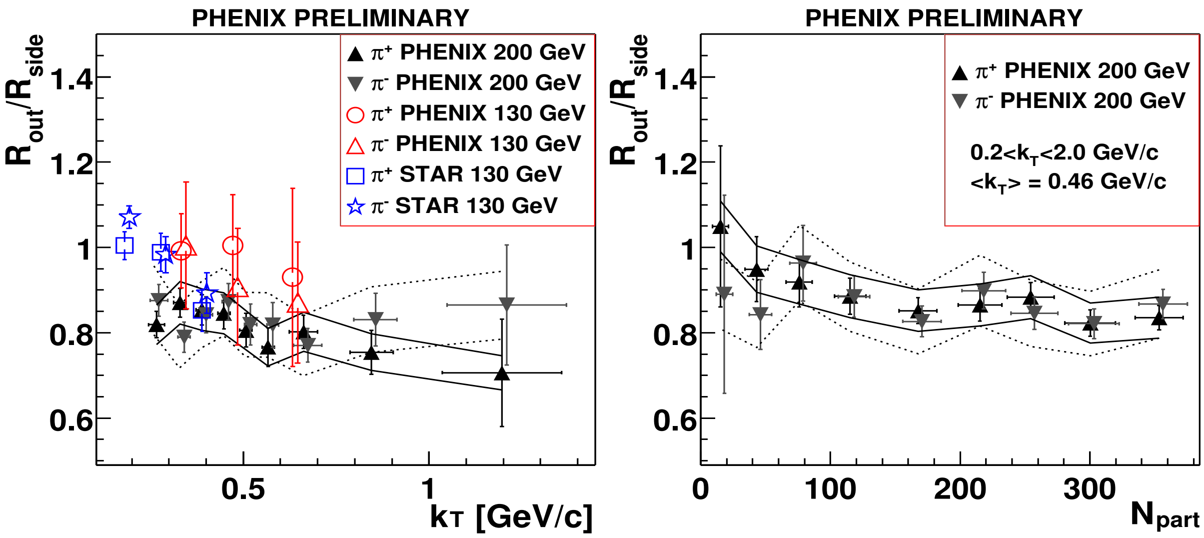

Figure 4. The left (right) figure shows the ratio R_{out}/R_{side} as a function of k_T (N_{part}) with statistical error bars and systematic error bands. In the left figure, results from PHENIX and STAR at 130 GeV [7,8] are shown. The error bars are statistical only.

and 1 million kaon pairs. A clear k_T dependence of the pion radius parameter was found, in agreement with the results at $\sqrt{s_{NN}} = 130$ GeV. The kaon radius parameters are equal to or slightly larger than the pion radius parameters at the same $\langle k_T \rangle$ bin. The pion radius parameters are consistent with a linear parameterization as a function of $N_{part}^{1/3}$. It should be noted that the measured radius parameters in the transverse directions (R_{side} and R_{out}) contradict recent transport model predictions [4,5]. However, the measured longitudinal radius parameter (R_{long}) is well reproduced by those models. The R_{out}/R_{side} ratios are independent of both k_T and centrality, and are systematically smaller than unity albeit with large errors. No evidence is seen for the anomalous increase of R_{out}/R_{side} as predicted from calculations based on the formation of a QGP [10].

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