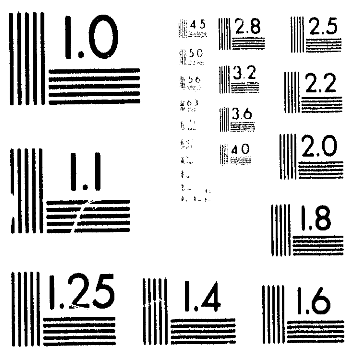
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TITLE: CALCULATIONS OF BOSE-EINSTEIN CORRELATIONS FROM RELATIVISTIC QUANTUM MOLECULAR DYNAMICS

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Calculations of Bose-Einstein Correlations from Relativistic Quantum Molecular Dynamics

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1. INTRODUCTION

Bose-Einstein correlation functions which are in good agreement with pion data [1, 2] can be calculated from an event generator [3]. Here pion and (preliminary) kaon data from CERN experiment NA44 [2, 4, 5] are compared to the calculations. The dynamics of 200 GeV/nucleon ^{32}S + Pb collisions are calculated, without correlations due to interference patterns of a many-body wavefunction for identical particles, using the Relativistic Quantum Molecular Dynamics model (RQMD) [6]. The model is used to generate the phase-space coordinates of the emitted hadrons at the time they suffer their last strong interaction (freeze-out). Using the freezeout position and momentum of pairs of randomly selected identical particles, a two-particle symmetrized wave-function is calculated and used to add two-body correlations. Details of the technique have been described previously [3]. The method is similar to that used in the Spacer program [7].

2. RESULTS AND DISCUSSION

Fig. 1a compares the calculated correlation function for π^+ pairs to the NA44 [8] data. The correlation functions vs. the magnitude of the four-momentum difference ($q_{inv} = \sqrt{-q \cdot q}$) are shown. In fig. 1 and in the figures which follow, the calculated correlation functions use only particles within a model of the NA44 acceptance [2, 8] in the low transverse momentum (p_T) spectrometer setting. For pions, this requires $p_T < 0.4$GeV and $3.1 < y < 4.1$, where y is the laboratory rapidity. For kaons, the acceptance is in the range $p_T < 0.6$GeV and $y \approx 3$. The good agreement gives us some confidence is the technique and in the details of the model which influence the shape of the correlation function.

When using an event generator to calculate correlation functions, we can examine not only the correlation functions, but the position distributions of the particles which give rise to the correlation function. The rms value of the transverse position (R_T) for pions (4.92±.02 fm) in the NA44 acceptance is significantly larger than the corresponding value

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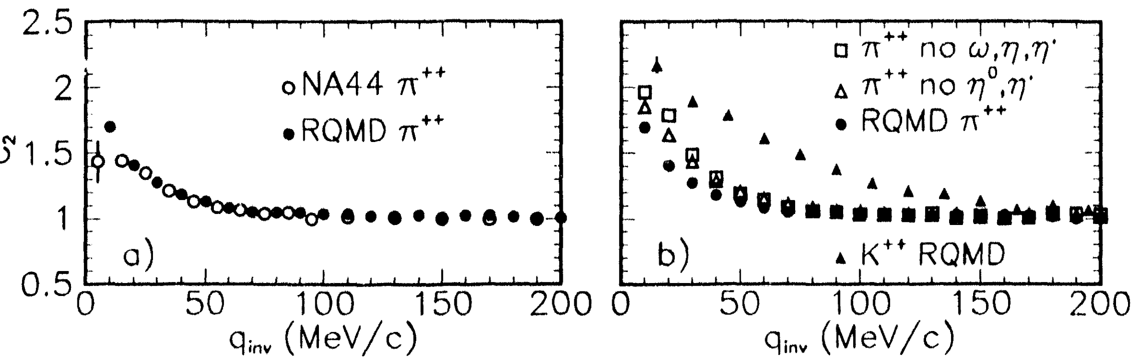

Figure 1. a) Comparison of pion correlation functions calculated from RQMD with the NA44 data for 200 GeV/u S+Pb collisions. b) Comparison of pion correlation functions calculated with all pions (from RQMD) and correlation functions omitting pions from 1) η^0, η' and 2) η^0, η', ω decay. A calculated K^+ correlation function is also shown.

for K^+ (4.06±.06 fm), where the uncertainties are statistical and the rms values use only particles with $R_T < 20$ fm; such a difference is also seen in the data [4].

Resonances influence the R_T distributions and have important effects on correlation functions, especially for pions [9]. A resonance important for the shape of the pion correlation function is the $\omega(783)$, which produces about 14% of all charged pions with $2 < y < 4$ in RQMD. With a long lifetime ($\Gamma = 8.43$ MeV) compared to the lifetime of the particle source, it contributes to a narrower and sharper peak in the correlation function. About 13% of the pions in RQMD with $2 < y < 4$ come from η^0 and η' decay, whose widths (1.19 keV and 0.2 MeV, respectively) produce components of the correlation function too narrow to measure. The result is a reduction in the intercept (λ) of the measured correlation function. For π^+ in the NA44 acceptance (low p_T) the contribution from the $\omega(783)$ increases to 20% and the $\eta^0 + \eta'$ contribution increases to 21%. For kaons, the most important long-lived resonance is the $K^*(892)$, however its width ($\Gamma = 50$ MeV) is more closely matched to the widths of the kaon correlation functions. In addition, about 3% of K^+ in RQMD with $2 < y < 4$ come from the $\phi(1020)$ ($\Gamma = 4.4$ MeV) decay — increasing to 4% in the NA44 acceptance. Fig. 2 shows the resonance contributions to the correlation functions as a function of p_T. The fraction of pions from

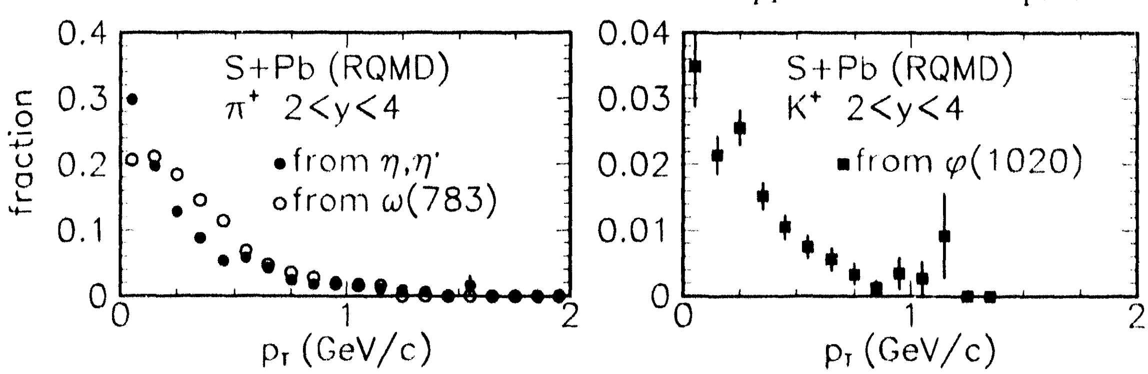

Figure 2. From 200 GeV/u S+Pb collisions in RQMD: The fraction of π^+ in the region $2 < y < 4$ from $\omega(783)$ and the fraction from $\eta^0 + \eta'$ decay as a function of p_T (left). On the right, the fraction of K^+ from $\phi(1020)$ decay.

resonance decays drops rapidly with increasing p_T. The resonance contribution is much less for K^+ – pointing out one advantage of kaon correlation functions [9].

Figure 1b shows the influence of these resonances on the calculated correlation functions. When the contributions from resonance decays are removed (open squares), the intercept approaches the ideal value of 2. Adding the pions from $\omega(783)$ decay (open triangles) reduces the intercept and decreases the width of the correlation function – corresponding to a larger apparent source. Including pions from η and η' decay (solid circles) further reduces the intercept of the correlation function. This case, with all resonance decays included, is compared to the data in figure 1a. For comparison, the calculated K^+ correlation function (solid triangles) is also shown. It has an intercept near 2 and is significantly wider (smaller source) than any of the pion correlation functions. This is expected since the K+ source is smaller than the pion source.

Fig. 3 compares correlation functions calculated from RQMD for K^- and K^+ in the NA44 acceptance to the preliminary NA44 data [4, 5]. The agreement is not as good as for pions. The calculated correlation functions are significantly wider than the data, therefore the apparent size of the kaon source is larger in the data than in the calculations. The disagreement is similar for both kaon charges. If the size differences (between π and K^+) were entirely due to differences in rescattering cross sections, then K^+ would reflect a smaller size than pions — as is observed. For K^- the expectations are not so straightforward. Like K^+, their rescattering cross sections with other mesons are smaller than for pions. However, their rescattering cross sections on nucleons are larger than the πN cross sections. Differences in the measured K^+ and K^- source sizes are expected if a significant fraction of the rescattering is from nucleons rather than mesons. In both the calculation and in the data the K^+ and K^- correlation functions are similar to one another — suggesting that collisions with nucleons do not dominate the dynamics.

Fig. 4 compares the measured and calculated K^+ correlation function [4, 5] in more detail. In this case the correlation function is broken into three components [10, 11], defined relative to the direction of the average momentum of a pair of particles with momenta $\vec{p_1}$ and $\vec{p_2}$, ($\vec{P} = (\vec{p_1} + \vec{p_2})/2$) in a reference frame where the average longitudinal momentum of the pair is zero ($P_Z = 0$). In this frame $\vec{P}$ is in the transverse direction. The component of the momentum difference ($\vec{q} = \vec{p_1} - \vec{p_2}$) along $\vec{P}$ is q_{Tout}; the component along the beam axis is q_{beam}; the third component (q_{Tside}) is perpendicular to the first

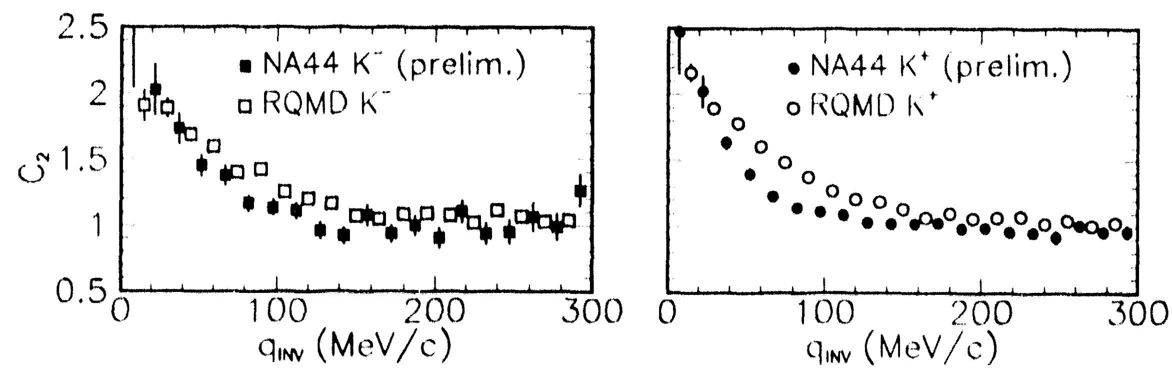

Figure 3. K^- (left) and K^+ (right) correlation functions calculated from RQMD compared to preliminary NA44 data for 200 GeV/u S+Pb collisions.

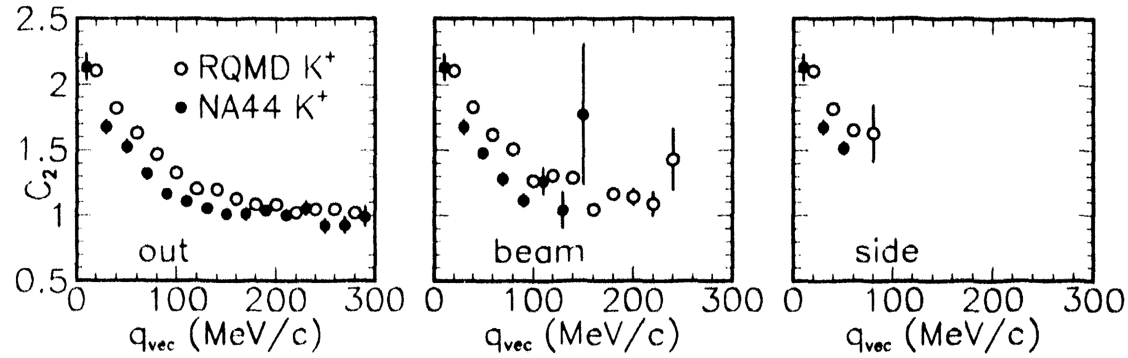

Figure 4. For 200 GeV/u S+Pb, three components of K^+ (right) correlation functions calculated from RQMD compared to preliminary NA44 data.

two. In fig. 4, each component of the correlation function is defined by plotting $\vec{q}$ while requiring the magnitude of the other two components to be less than 40 MeV/c. The disagreement between the calculated and measured correlation functions is about the same in all directions.

3. CONCLUSIONS

The predicted correlation functions for pion pairs are remarkably consistent with experiment. For kaon pairs, the agreement with the data is not as good. However, both the calculations and the data show kaon source sizes which are smaller than those for pions and the K^+ correlation functions are similar to the K^- correlation functions. The disagreement between the calculated and measured K^+ correlation function is not confined to any directional component. Resonances have an important influence on the pion correlation functions. As shown in fig. 2, the influence of resonances on the pion correlation functions could be minimized by measuring at higher p_T [12].

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