STAR Note 384

RQMD predictions for $\pi\pi$ and K^+K^+ correlations at RHIC

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Abstract

Correlation functions have been calculated using the RQMD model (v2.4) for central Au+Au collisions at C.M. energy of 200 GeV/nucleon. The correlation functions are calculated as a function of transverse momentum (p_T) for both the $\pi\pi$ and K^+K^+ systems. The effect of the two-particle Coulomb interaction is studied by comparing the "ideal" correlation functions with the Gamow corrected correlation functions.

1 Introduction

RQMD has been very successful in describing two-particle correlation data at AGS and SPS energies [1, 2]. Recently, a new version of RQMD (v2.4) has become available that can deal with RHIC energies and multiplicities. Based on the model's previous successes, the predictions of the RQMD model should be considered as reasonable baseline estimates for the two-particle correlation functions at RHIC.

2 Calculational Method

Events were generated using RQMD (version 2.4). For this study, 530 central ($b < 3$fm) RQMD events are used in the calculations. The freeze-out positions and momenta are fed into a correlation after-burner written by Scott Pratt [3]. This program takes the space-time and momentum information from a model, calculates the correlation weights for mixed pairs from the input model, and bins the resulting weighted pairs as a function of relative momentum. The correlation weight can be calculated incorporating the effects of both Coulomb and strong interactions between the outgoing pairs. For these calculations, strong interactions are ignored. Coulomb interactions are calculated using the exact Coulomb wave function. The Coulomb correction to the correlation function is done using the Gamow factor.

For these calculations, particles arising from weak decays are not included. Without the SVT, it probably will not be possible to distinguish these particles from those coming from the primary vertex if the secondary vertex is within 2cm of the primary vertex.

The correlation functions are fit using ROOT. A χ^2 fit is used. The three-dimensional fit function used to parameterize the correlation function is,

$$C_2(Q_{TO}, Q_{TS}, Q_L) = A(1 + \lambda e^{-Q_{TO}^2 R_{TO}^2 - Q_{TS}^2 R_{TS}^2 - Q_L^2 R_L^2}), \tag{1}$$

where A is the normalization, Q_L is the momentum difference along the beam axis, Q_{TO} is the momentum difference transverse to the beam axis and parallel to the total transverse momentum of the pair, and Q_{TS} is the direction transverse to the beam axis and perpendicular to the total transverse momentum of the pair.

The correlation function is calculated as a function of single-particle transverse momentum p_T. Cuts on average pair momentum ($k_T = (p_T(1) + p_T(2))/2$) were also used, and the results were nearly identical. Using a k_T cut rather than a p_T cut only increases the statistics at high $\vec{Q}$ and does not affect the interesting part of the correlation function. In addition, since all events are mixed in these model calculations, the p_T cuts reduces the computational time by helping to ensure that the randomly selected pairs are not at high momentum difference.

3 Results

All of the results presented will be for Au+Au collisions at $\sqrt{s} = 200$ GeV/nucleon. Figure 1 shows the projections of a typical correlation function along with the projections of the Gaussian fit functions. This particular correlation function is for low-p_T, mid-rapidity pions ($0 < p_T < 200$ MeV/c, $-0.5 < y < 0.5$). The RQMD correlation functions are usually well described by a Gaussian. This particular kinematic region is where one would expect the radius parameters to be largest. Indeed, the R_L radius parameter is over 12 fm. This is much larger than the 7 fm R_L radius parameter predicted by RQMD at SPS energies and measured by experiments NA44 and NA49. The two transverse radii are similar to those measured at SPS energies.

Figure 2 shows the p_T dependence of the fitted HBT radius parameters. The transverse radius parameters depend weakly on transverse momentum, while the longitudinal radius parameter decreases dramatically with increasing transverse momentum. The intercept parameter λ increases slightly with increasing transverse momentum, but never reaches a value of unity. Since the pions from weak decays are not included in these calculations, the predicted λ parameter is probably an over-estimate of what will be seen at RHIC.

Correlation functions were also calculated as a function of rapidity ($-1.5 < y < -0.5$, $-0.5 < y < 0.5$, and $0.5 < y < 1.5$). Within the STAR acceptance, the HBT radius parameters show very little dependence on rapidity.

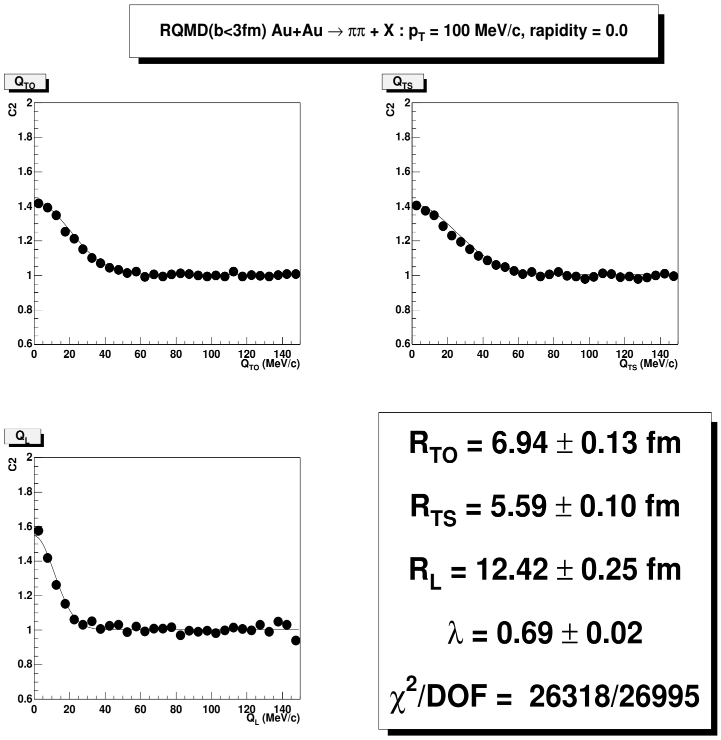

Figure 1: Projections of the three-dimensional RQMD correlation function. The projections are over 20 MeV/c in the other directions of the momentum difference. Also shown are the projections of the Gaussian fit function.

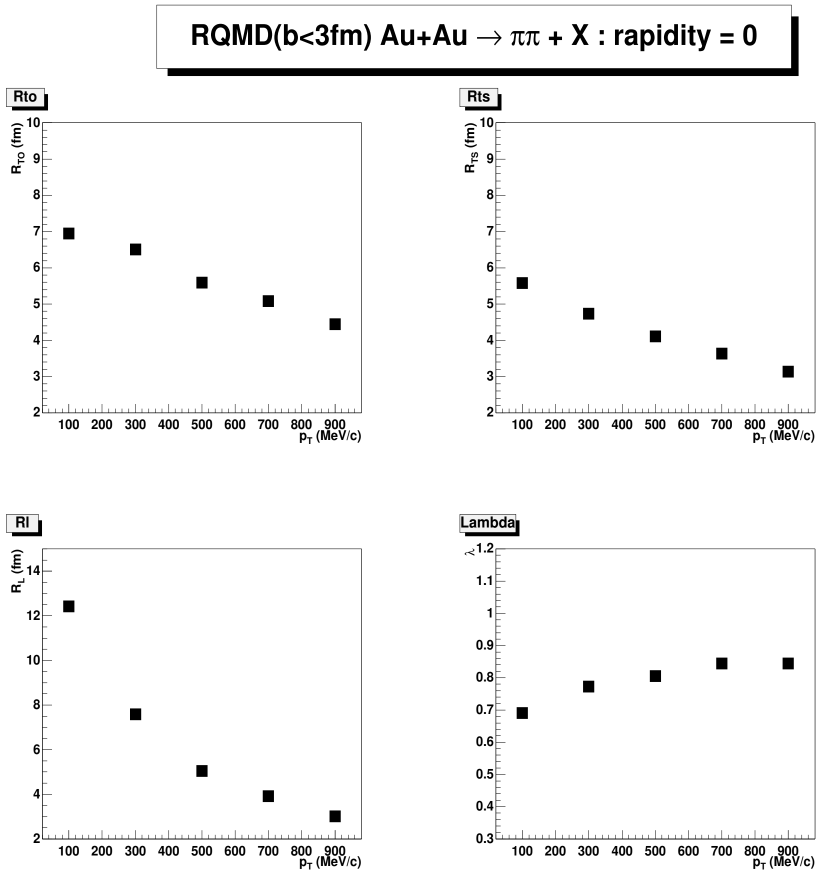

Figure 2: Fitted three-dimensional radii and λ parameters for mid-rapidity ($|y| < 0.5$) pions as a function of single particle transverse momentum p_T.

An important experimental question is how much the two-particle Coulomb interaction distorts the measured correlation function. The calculations presented to this point have ignored these Coulomb interactions. In order to estimate the distortions caused by the Coulomb interactions, the correlation functions are calculated using symmeterized Coulomb waves as the outgoing two-particle wave function. The resulting correlation function is then Coulomb corrected using the standard Gamow factor. For extended sources, the Gamow factor is known to be an over-correction. With the large source sizes predicted by RQMD for RHIC it is interesting to estimate the magnitude of the error caused by using the Gamow factor. Figure 3 compares the projections of the correlation function using the Gamow factor to the ideal correlation function. The projections clearly show that the Gamow factor is an over-correction. The intercept is slightly higher for the Gamow corrected correlation function. In addition, the correlation function seems to have a slope at intermediate $\vec{Q}$.

Figure 4 compares the fitted radius and λ parameters for the "ideal" correlation function (no Coulomb interactions) and the Gamow corrected correlation function as a function of p_T. In all cases, the "error" caused by the Gamow correction is less than 20% even for the large radius parameters expected at RHIC. Although it is desirable to use the most accurate Coulomb correction possible when analyzing data, it is even more important to use the same Coulomb correction when making model comparisons. By doing this, the experimental data and model can be compared in spite of the fact that both use an incorrect Coulomb correction.

K^+K^+ correlations were also calculated. The K^+ tends to have a lower interaction cross-section than a pion. This may lead to the earlier decoupling of the K^+, and a consequently smaller source. In addition, fewer resonances contribute to the kaon sample. Figure 5 shows the low-p_T mid-rapidity K^+K^+ correlation function predicted by RQMD. The width of the correlation function is larger than pions in a similar kinematic range. In addition, the intercept is indeed close to unity as one would expect for an incoherent particle sample relatively free of resonance decay contributions.

Figure 6 compares the fitted three-dimensional radius and λ parameters for pions and kaons. At low p_T, the kaons have smaller radius parameters than pions. As the p_T is increased, however, the radius parameters for the pions and kaons seem to converge.

4 Conclusions

This note presents the first calculations of RQMD $\pi\pi$ and K^+K^+ correlation functions at RHIC energies. RQMD predicts that the longitudinal radius parameter R_L will be more than 12 fm at low p_T and will scale strongly with p_T. The transverse radius parameters (R_{TO} and R_{TS}) are predicted to be roughly the same size as measured in central Pb+Pb collisions at the SPS and scale only weakly with p_T. The use of the Gamow factor is shown to lead to at most a 20% reduction in the extracted radius parameters. The radius parameters extracted

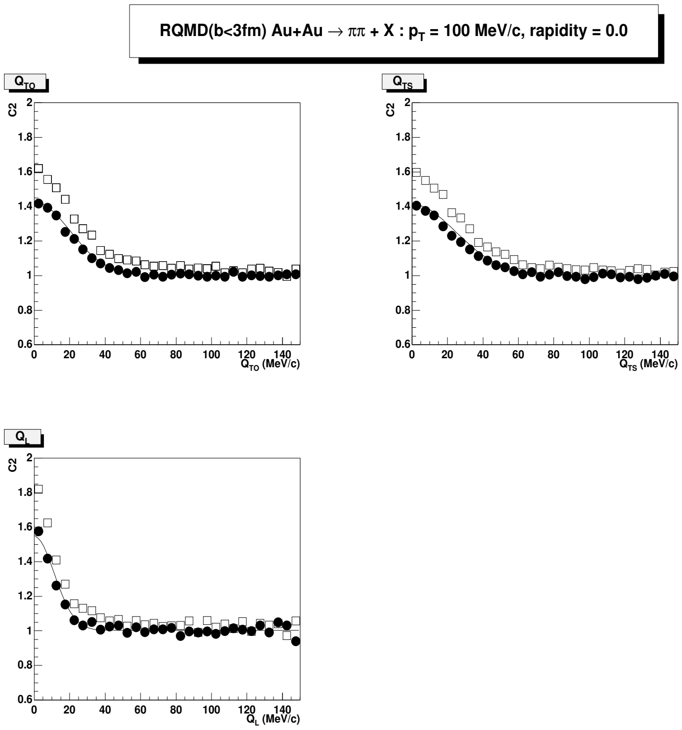

Figure 3: Projections of the "ideal" three-dimensional RQMD correlation function (solid circles) and the Gamow corrected RQMD correlation function (open squares). The projections are over 20 MeV/c in the other directions of the momentum difference.

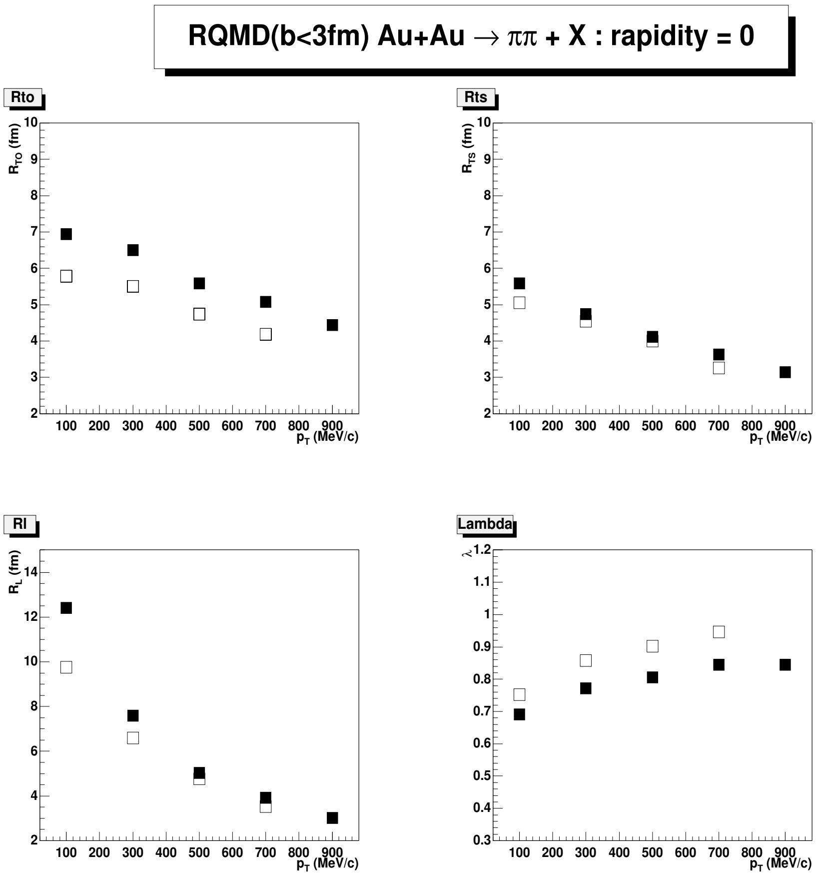

Figure 4: Comparison of the fitted three-dimensional radii and λ parameters for mid-rapidity ($|y| < 0.5$) pions as a function of single particle transverse momentum p_T for the ideal correlation function (solid squares) and the Gamow corrected correlation function (open squares).

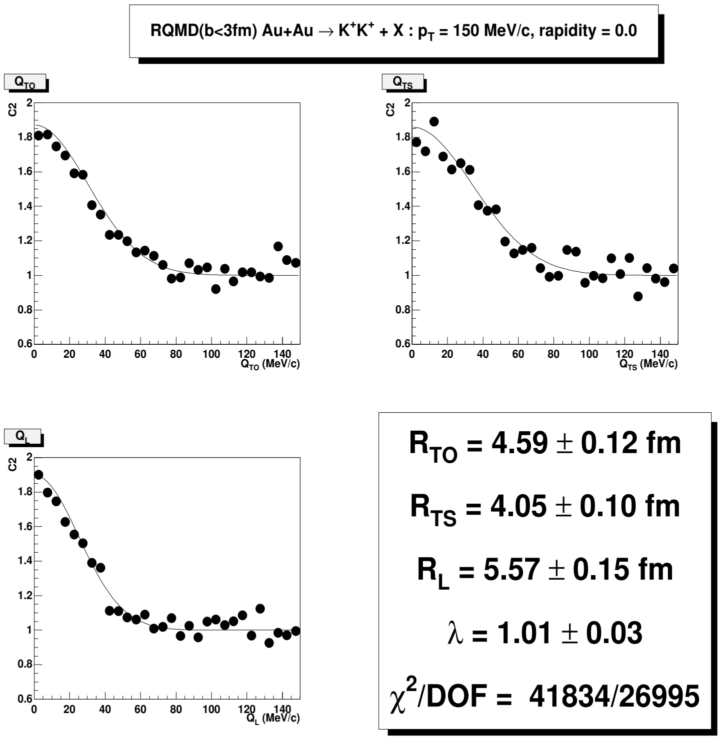

Figure 5: Projections of the three-dimensional RQMD K^+K^+ correlation function. The projections are over 20 MeV/c in the other directions of the momentum difference. Also shown are the projections of the Gaussian fit function.

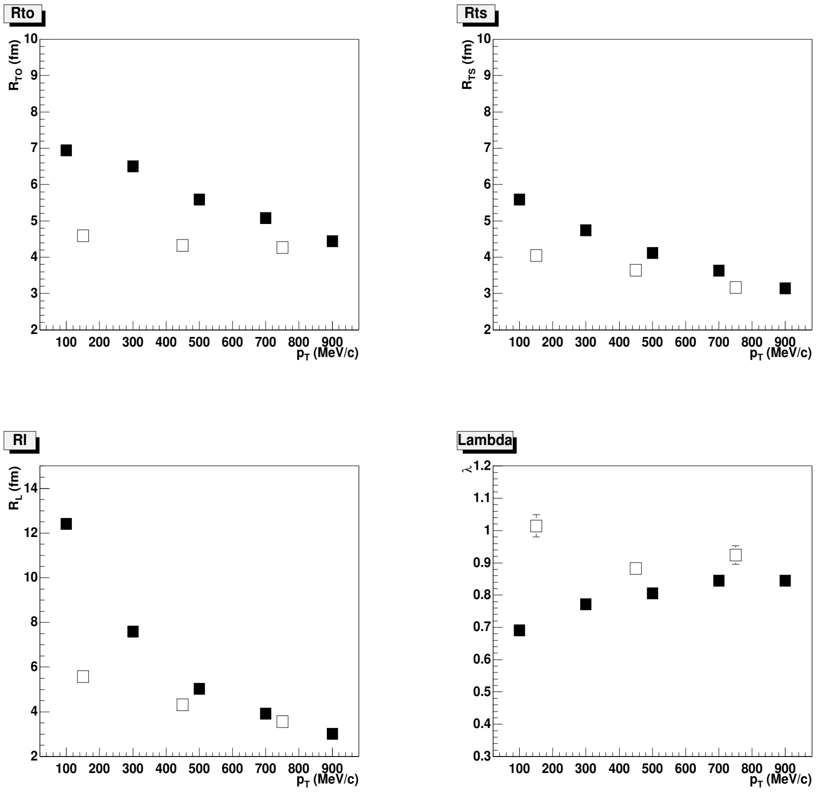

Figure 6: Comparison of the fitted three-dimensional radius and λ parameters for mid-rapidity ($|y| < 0.5$) pions (solid squares) and kaons (open squares) as a function of single particle transverse momentum p_T.

from K^+K^+ correlations are smaller than those extracted from $\pi\pi$ correlations at the same p_T.

5 Acknowledgements

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