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# Transverse Momentum Dependence of Bose-Einstein Correlations in S+Nucleus Collisions at 200 GeV/Nucleon

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**Abstract**

The NA35 experiment has collected a high statistics set of momentum analyzed negative hadrons near and forward of mid-rapidity for central collisions of 200 GeV/Nucleon $^{32}$S projectiles incident on S, Ag and Au targets. Using two pion momentum space correlations in order to study the size of the source of particle production, small dependences upon transverse momentum are found for the transverse source dimensions; however for the heaviest system, $R_{long}$ decreases by about 40% as transverse momentum is increased over the interval $50 < p_T < 600$ MeV/c. Preliminary model calculations using a microscopic phase space approach (RQMD) appear to reproduce the observed characteristics of the data.

## INTRODUCTION

The motivation for studies of particle production in relativistic heavy ion collisions is the expectation of finding novel collective phenomena not directly attributable to a superposition of independent nucleon-nucleon collisions. Under ideal conditions the two particle correlation function, experimentally defined as the ratio of the actual measured relative momentum distribution A(q) to a so-called background distribution B(q) modeling two particle phase space in the absence of the Bose symmetrization,

$$C_2(q) \equiv A(q)/B(q) = 1 + \lambda \mid \tilde{\rho}(q) \mid^2, \tag{1}$$

is used in order to infer the source extent subject to the assumption of a plausible static pion spatial source distribution, $\rho(r)$, with Fourier transform $\tilde{\rho}(q)$. It has been shown that this simple picture breaks down whenever there exist strong correlations between particle emission points and their momenta. Under these circumstances, the correlation function becomes a function of the pair momenta, and it has been suggested that this dependence is a sensitive probe of the dynamical processes governing the expansion of the primordial high energy density reaction volume [2]. The dynamical evolution of a central relativistic heavy ion collision is expected to lead to a situation in which there are strong correlations between particle production points and momenta. Thus, the evolution in pion pair momentum space of the correlation function becomes a diagnostic of source evolution scenarios including collective transverse or longitudinal expansion [2], Bjorken-scaling [3], and string excitation and decay [4]. Additionally, through the Wigner function formalism [4,5], it is now possible to make direct comparisons between the predictions of microscopic phase space models and experimental data [6]. As a consequence of this theoretical work, the primary interest in studies of Bose-Einstein correlations in relativistic heavy ion collisions is in this elucidation of the dynamical features of the particle production process inaccessible to single particle inclusive spectra. In this measurement, we concentrate on the evolution of the transverse projections of the correlation function with the transverse momenta of the pion pair constituents, $p_T$, in order to assess the degree of transverse expansion during the hadron production process.

## DATA

The NA35 experimental setup at the CERN SPS, which has been described previously [1], consists of a streamer chamber in a large volume dipole magnet, and a time projection chamber (TPC) [8], installed in the field-free region between the streamer chamber and the veto calorimeter. A beam of 200 GeV/Nucleon $^{32}S$ ions from the CERN SPS was normally incident upon Au, Ag, and S targets, 8 cm upstream of the streamer chamber, of thickness 940, 750, and 1165 mg/cm$^2$ respectively (corresponding to 1.1, 1.2, and 3.8% of an interaction length). A hardware trigger selected events corresponding to the lowermost 6, 3, and 3% respectively of the energy spectrum detected by a veto calorimeter covering the beam fragmentation region; the result is to geometrically constrain the collisions to *dive-in* centrality. There were approximately 26, 18, and 24 K TPC triggers recorded for each of the systems. In addition, 15 K streamer chamber events for S+Ag were analyzed. The acceptances of the streamer chamber and the TPC for negative hadrons overlap at $y \approx 3.5$ and, together, achieve a wide and uniform coverage of the longitudinal phase space, $0.5 < y < 4.6$. For this analysis, we restrict the transverse momentum acceptance to $0.05 < p_T < 0.6$ GeV/c. The correlation functions are constructed as the ratio of the observed, or *actual*, and the so-called *background* two particle phase space distributions, $C_2 \equiv A(q_{Tside}, q_{Tout}, q_{long}) / B(q_{Tside}, q_{Tout}, q_{long})$[9]. The background is constructed according to the event-mixing prescription and the actual distribution is corrected on a pair-wise basis for the dipion Coulomb interaction using the Gamow penetration factor[10]. No attempt is made to correct the data for the absence of track-wise negative particle identification, resulting in a systematic underestimate of the extracted intercept parameter. Under the assumption of a source density distribution which is Gaussian in all spatial dimensions and uncorrelated with momentum, the three dimensional correlation functions are fit to the functional form

$$C_2(q_{Tside}, q_{Tout}, q_{long}) = N\left[1 + \lambda e^{(-q_{Tside}^2 R_{Tside}^2 - q_{Tout}^2 R_{Tout}^2 - q_{long}^2 R_{long}^2)/2}\right], \qquad (2)$$

using the principle of maximum likelihood. Note that the overall center of mass rapidity (the position of the observer) has been fixed at y=3.0.

## RESULTS

The results of this procedure, for each of the systems studied, are shown in Fig. 1. Concerning the evolution of the longitudinal component of the correlation function with transverse momentum, for all systems we see a distinct and significant trend in which

$R_{long}$ decreases with $p_T$. This trend is well-reproduced by calculations employing the microscopic RQMD model [7]. The evolution of $R_{long}$ with $p_T$ is also consistent with predictions of a scaling hydrodynamic expansion description of the particle production process [3, 4]. In Fig. 1 the (arbitrarily normalized) $1/\sqrt{m_t}$ behaviour dictated by hydrodynamic expansion is represented by the solid lines. Fig. 1 also shows the radii $R_{Tside}$ resulting from fits of the sideward source parameters of the correlation functions, employing eq. 2. The dependence on transverse momentum can be analyzed either in successive windows of the transverse momentum, $p_T$, of pions contributing to the correlation functions, or in bins of the average momentum, $k_T = \frac{1}{2} \mid \vec{p}_T^1 + \vec{p}_T^2 \mid$, of the constituent pairs; we have shown the dependence on $p_T$ for the TPC and $k_T$ for the streamer chamber. For both representations we observe similar radii, that exhibit only a very slight decrease with increasing transverse momentum, all data gathering in the narrow interval $5 < R < 4$ fm. This also holds for the adjacent bins in rapidity, $0.5 < y < 1.5$ and $2.5 < y < 3.5$ (not illustrated here). Fig. 1 thus suggests that the transverse momentum dependence of the source parameters is very weak. The $p_T$ dependence is statistically flat except for the high statistics S+Au and S+Ag (SC) data which show a slight (25%) decrease toward higher transverse momentum, both in the $R_{Tside}$ and $R_{Tout}$ parameters. The RQMD results [7] fit our data for S+Au quite well as is also shown in Fig. 1.

The purpose of this investigation was to search for a systematic widening of two pion correlation function with pion transverse momentum, leading to a decrease in the extracted "source radii" for higher $p_T$ or $k_T$. This effect was demonstrated by theoretical investigations [2] to present a sensitive test of collective expansion. What we observe is consistent with earlier predictions for both string-motivated and Bjorken/thermal descriptions of the reaction dynamics [2,4], physical pictures with no strong collective transverse expansion. On the other hand, our data for the longitudinal direction are indeed perfectly compatible with a collective, isentropic longitudinal "scaling" expansion, showing effects that are as strong as expected [2, 3].

Our current interpretation is that qualitatively different mechanisms must drive the longitudinal and the transverse expansions of the initial reaction volume. The observed good agreement of the microscopic RQMD model with both the longitudinal and transverse source parameters may suggest a tentative explanation. The longitudinal correlation between momentum and position may result, not from a pressure driven hydrodynamic expansion, but simply from the relativistic kinematics of particle production from decaying strings which are oriented along the beam direction at the high SPS energy. The net outcome may well resemble that of a Bjorken-Sinyukov collective model. The transverse expansion, however, may indeed be *thermal*, as is assumed in the RQMD model. Our present data then suggest that the degree of collectivity in this expansion is weak.

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## TABLES AND FIGURES

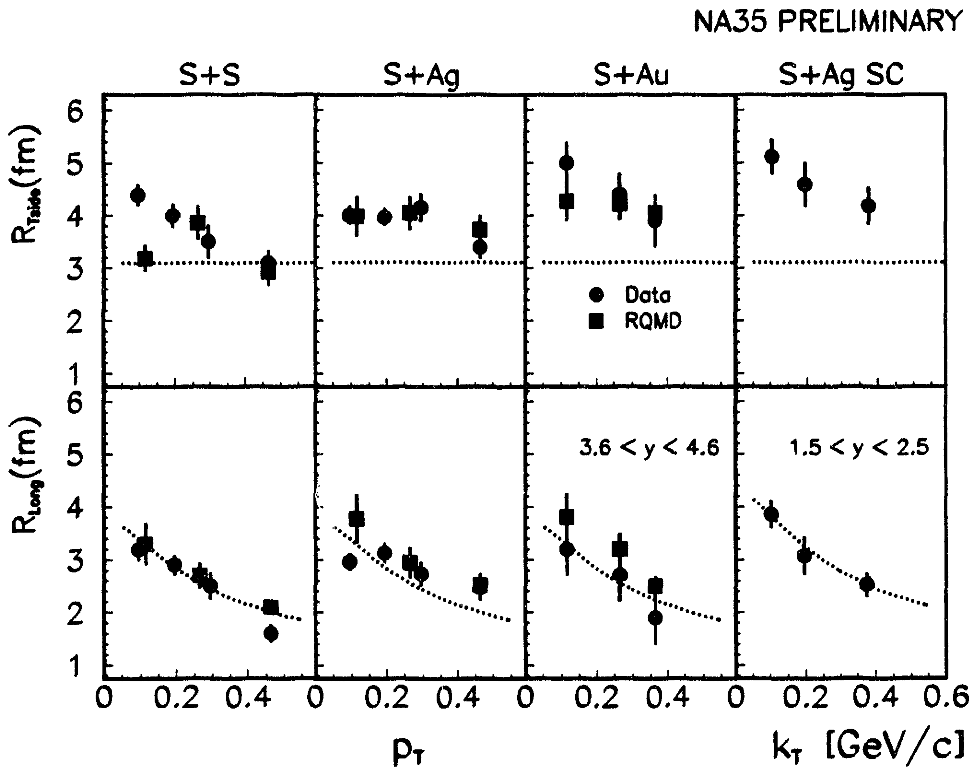


Fig. 1: Evolution of source parameters $R_{Tside}$ and $R_{long}$ with $p_T$ and $k_T$ at 200 GeV/Nucleon. The left-most six panels are from the TPC, subtending the rapidity interval 3.6<y<4.6, and are analyzed in $p_T$; the right-most two panels are from the streamer chamber, subtending the rapidity interval 1.5<y<2.5, and are analyzed in $k_T$. The data are represented as filled circles while the RQMD calculations are filled squares. Note the suppressed zero on the vertical scale.

## REFERENCES

1. A. Sandoval et al., Nucl. Phys. A461, 465c (1987)
2. S. Pratt, Phys. Rev. Lett. 53, 1219 (1984), and Phys. Rev. D33, 1314 (1986)
   G. Bertsch, M. Gong, and M. Tohyama, Phys. Rev. C37, 1896 (1988)
3. K. Kohlemainen and M. Gyulassy, Phys. Letters B180, 203 (1986),
   A. N. Maklin and Y. M. Sinyukov, Z. Phys. C39, 69 (1988),
   Y. M. Sinyukov, Nucl. Phys. A498, 151c (1989)
4. S. Pratt, T. Csörgö, and J. Zimanyi, Phys. Rev. C42, 2646 (1990)
5. S. Padula, M. Gyulassy, and S. Gavin, Nucl. Phys. B329, 357 (1990)
6. J. Sullivan et al., Phys. Rev. Lett. 70, 3000 (1993)
7. H. Sorge, H. Stöcker, and W. Greiner, Nucl. Phys. A498, 567c (1989)
8. J. W. Harris et al., Nucl. Instr. Meth. A306, 446 (1991)
9. cf. [2] for the definitions of $q_{Tside}$, $q_{Tout}$, and $q_{long}$.
10. M. Gyulassy and S. K. Kaufmann, Nucl. Phys. A362, 503 (1981)

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