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PION AND KAON FREEZEOUT IN NA44

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Abstract

Three dimensional source size parameters measured via two-particle interferometry in experiment NA44 for 200 GeV/nucleon S+Pb show a common $1/\sqrt{mt}$ dependence for all three dimensions. This is consistent with a hydrodynamic model for an expanding source. The single particle spectra are also interpreted within a hydrodymanic model.

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Introduction

The NA44 spectrometer is optimized for the study of single and two-particle particle spectra near mid-rapidity for transverse momenta below $\approx$ 1 GeV/c. A large fraction of all pairs in the spectrometer's acceptance are at low relative momenta, resulting in small statistical uncertainties on the extracted size parameters. In addition, the spectrometer's clean particle identification allows us to measure correlation functions for pions, kaons, and protons. This contribution will concentrate on the source size parameters determined from pion and kaon correlation functions. These size parameters will be compared to calculations from the RQMD event generator[10] and also interpreted in the context of a hydrodynamic model[3]. Finally, the measured single particle spectra will be examined from the viewpoint of hydrodynamics.

Experimental Results

The NA44 Focusing Spectrometer[4, 5, 6] uses two dipole magnets and three quadrupoles, covering a momentum range of $\pm 20\%$ around its central momentum setting. For the data shown here, the central momentum settings are 4 GeV/c (lab) for pions and 6 GeV/c for kaons. The two spectrometer angle settings used for π^+ are referred to as low p_T ($< p_T > \approx$ 150 MeV/c) and high p_T ($< p_T > \approx$ 450 MeV/c). The tracking and time-of-flight uses three scintillator hodoscopes whose time resolution is $\approx$ 100 ps, with a Cherenkov beam counter[7] for the time-of-flight start ($\sigma \approx$ 35 ps).

The NA44 data have been analyzed in terms of three components[8, 9] of the two-particle momentum difference ($\vec{q} = \vec{p_1} - \vec{p_2}$). The data are analyzed in the frame in which the z-component of the pair momentum ($p_{z1} + p_{z2}$) is zero (the longitudinal center of mass system, or "LCMS"). The momentum difference is resolved into a component (q_{beam}) parallel to the beam direction and a component perpendicular to the beam direction. The perpendicular component is further resolved into q_{out} parallel to the sum of the pair momentum and q_{side}, which is perpendicular to the sum and to the beam. Three corresponding source size parameters (R_{beam}, R_{out}, R_{side}) are determined by fitting eq. 1:

$$C(q_{out}, q_{side}, q_{beam}) = A(1 + \lambda \exp(-{q_{out}}^2 R_{out}^2 - q_{side}^2 R_{side}^2 - q_{beam}^2 R_{beam}^2)) \qquad (1)$$

to measured 3D correlation functions from two different spectrometer settings. The "horizontal" focus spectrometer setting optimizes the acceptance for R_{out}, while the "vertical" focus spectrometer setting is for R_{side}. The resolution in q_{out} and q_{beam} is $\approx$15 MeV/c and in q_{side} is $\approx$30 MeV/c.

Discussion

Fig. 1 compares size parameters from NA44[4, 5, 6] to size parameters calculated[10] using the RQMD event generator[1, 2] to generate the single particle emission probability distribution at the point of each particle's last interaction. The two-particle correlation function is calculated from the single particle distribution using a Wigner function formalism[11, 12].

System	$\sqrt{m_T}$	$\sqrt{m_T}R_{to}$	$\sqrt{m_T}R_{ts}$	$\sqrt{m_T}R_l$
High p_T $\pi^+\pi^+$	0.68	2.0 ± 0.1	2.0 ± 0.1	2.1 ± 0.1
Low p_T $\pi^+\pi^+$	0.47	1.9 ± 0.1	2.0 ± 0.1	2.2 ± 0.1
Low p_T K^+K^+	0.74	2.1 ± 0.1	1.9 ± 0.2	2.2 ± 0.2

Table 1: Results of the m_T dependence on radius parameter

In fig. 1, the calculations for low p_T π^+ agree with the NA44 results for two of three size components, but the RQMD result is larger (by 3.4σ) than the NA44 result for R_{beam}. The RQMD result also agrees with the NA44 high p_T result for two of three size parameters, put the RQMD value of R_{out} is significantly larger than the NA44 result. For K^+, the NA44 and RQMD results are in good agreement.

Analytical hydrodynamical calculations show that for collective flow with superimposed thermal motion, the radius parameters in different directions become more equal and scale as $1/\sqrt{m_T}$. [3] In table 1 the radius parameters show a $1/\sqrt{m_T}$ dependence. Such behavior is expected if a hydrodynamical expansion takes place, causing correlations between particle positions and momenta in the transverse as well as longitudinal directions.

In order to accept a hydrodynamic model as a reasonable basis for understanding the two-particle correlation data, we must also try to interpret the single particle spectra in the same framework. One such description[13] suggests that for an expanding source in thermal equilibrium, the inverse exponential slope of the m_T spectrum (dN/dm_T^2dy) can be related

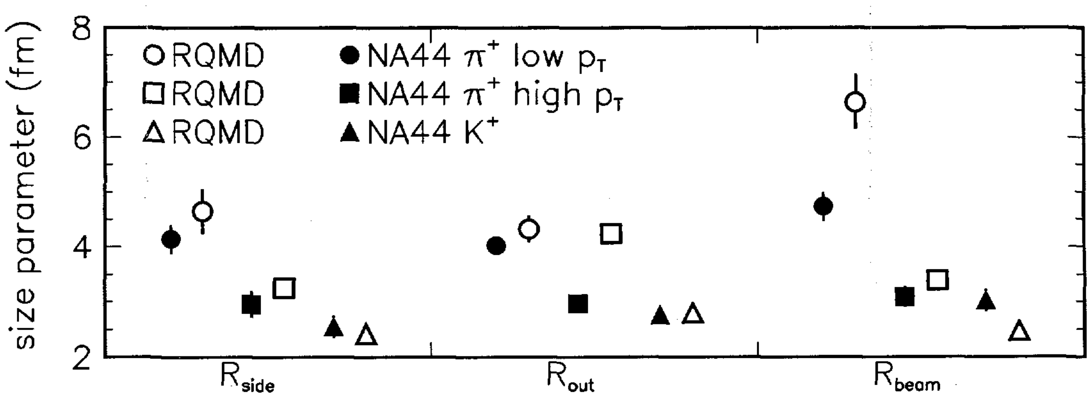

Figure 1: The size parameters, for 200 GeV/nucleon S+Pb, based on fits to 3 dimensional correlation functions, for low p_T π^+ (solid circles), high p_T π^+ (solid squares), and for K^+ pairs (solid triangles) from NA44. The corresponding fit parameters from the correlation functions calculated from RQMD are shown as open symbols.

particle	M_T range fit (GeV)	S (MeV)	T (MeV)
π^+	0 - 0.25	144±16	100±11
K^+	0 - 0.50	206±12	143±8
p^+	0 - 0.90	190±10	132±7
p^-	0 - 0.90	183±10	127±7

Table 2: Preliminary NA44 data: For different particle types, the inverse exponential slope parameters (S) from fits to the m_T spectrum over the specified and the "temperatures" calculated assuming $\beta_T = 0.35$ and equation 2.

to the temperature of the source via the expression:

$$\frac{1}{S} = \frac{1}{T}\sqrt{\frac{1-\beta_T}{1+\beta_T}} \tag{2}$$

where S is the inverse exponential slope from a fit of $\exp(-m_T/S)$ to the m_T spectrum, β_T is the transverse expansion velocity, and T is the true temperature of the source. Using this expression, the measured values of S for π^+, K^+, p^+, p^- can be translated into temperatures. A consistent temperature would reinforce the hydrodynamic interpretation of the data.

An expansion velocity, $\beta_T = 0.35$ has been assumed to translate the measured slope parameters to "temperatures" using eq. 2. The values are roughly consistent for K^+, p^+, p^-, but the "temperature" for pions is lower. However, the pion measurement is mainly at low p_T, where the resonance contribution is significant[10]. These resonances contribute a component with a lower apparent temperature and could explain the differences. To examine this possibility, the RQMD event generator was once again used. In the region of the NA44 data, inverse slope of the (RQMD) pion m_T spectrum is about 12% larger than the inverse slope of the (RQMD) spectrum of pions from which pions from η, η', and $\omega(783)$ decay have been excluded. This factor can explain 1/2 to 1/3 of the difference between the pion "temperature" in table 2 and those for other particles. However, final data and fits over a more consistent m_T range are needed before drawing final conclusions.

Conclusions

We have investigated the m_T dependence of boson correlation functions in S+Pb collisions. The transverse radii for pions and kaons show a common $1/\sqrt{m_T}$ dependence. The data indicates the presence of strong position-momentum correlations in the transverse direction, arising from collective flow. This will be further investigated by careful comparison of hydrodynamical model calculations and single particle data, other (e.g. p-p) two particle correlation data, and d/p ratios.

REFERENCES

1. H. Sorge, H. Stöcker and W. Greiner, Nucl Phys. **A498**, 567c (1989); H. Sorge *et al.* Z. Phys. C**47**, 629 (1990).

2. H. Sorge *et al.* Phys. Lett. B**289**, 6 (1992).

3. T. Csörgo and B. Lorstadt, Lund University preprint LUNFD6/(NFFI-7082), submitted to Phys. Rev. Lett. 1994.

4. H. Becker *et al.*, Phys. Lett. B**302**, 510 (1993).

5. H. Bøggild *et al.*, CERN-PPE/(94-75) (1994), in press, Z. Phys.

6. H. Becker *et al.*, submitted to Phys. Rev. Lett. (1994).

7. N. Maeda *et al*, Nucl. Inst. Meth. **A346**, 132 (1994).

8. S. Pratt, Phys. Rev. D**33**, 1314 (1986).

9. G. Bertsch, M. Gong, M. Tohyama, Phys. Rev. C**37**, 1896 (1988).

10. J. P. Sullivan *et al.*, Phys. Rev. Lett. **70**, 3000 (1993).

11. T. Csörgo *et al.*, Phys. Lett. B**241**, 301 (1990).

12. S. Pratt, T. Csörgo, J Zimányi, Phys.Rev C**42**, 2646 (1990).

13. U. Heinz, this conference.