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TITLE: SINGLE PARTICLE MEASUREMENTS AND TWO PARTICLE INTERFEROMETRY RESULTS FROM CERN EXPERIMENT NA44

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SINGLE PARTICLE MEASUREMENTS AND TWO PARTICLE INTERFEROMETRY RESULTS FROM CERN EXPERIMENT NA44

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1. Introduction

CERN experiment NA44 is optimized for the study of identified single and multiple particle distributions to $p_T = 0$ near mid-rapidity. We measure $\pi^{\pm}$, $K^{\pm}$, p, pbar, d and dbar, in p+A and A+A collisions at 450 and 200GeV/u, respectively. Two-particle intensity interferometry results from $\pi^+\pi^+$, K^+K^+, and K^-K^- measurements and single particle distributions are presented.

2. NA44 Experimental Setup

The NA44 spectrometer is a focussing spectrometer, including three quadrupoles and three dipole magnets. The momentum range selected by the spectrometer covers a band of ± 20% around its nominal momentum setting. Only one charge state is detected at a time.

Two threshold Cherenkov counters discriminate π from $K + p$ or $\pi + K$ from p, and identify electrons. These allow trigger level particle identification and elimination of conversion electron contamination. A scintillator just beyond the target is used to trigger on "minimum bias" events (at least one minimum ionizing particle) or "central" events (large particle multiplicity). A silicon pad detector measures the charged-particle multiplicity with 2π acceptance and $1.5 < \eta < 3.3$. A uranium-scintillator calorimeter separates e, π, and μ.

Tracks are reconstructed from hit positions on three hodoscopes, constrained by the target position and straight-line trajectories after the magnets. The particle identification from both time-of-flight and the Cherenkov counters is used. The p_T distributions are corrected for geometrical acceptance, reconstruction inefficiencies, multiple scattering effects, and decay in flight.[1–3]

3. Two-Particle Interferometry

$\pi^+\pi^+$ correlations from S+Pb collisions at 200 GeV/c per nucleon have been measured from a data sample containing 227 000 reconstructed pion pairs.[1] Our high statistics allow a study of the shape of the correlation function. We fit the data with both a gaussian and an exponential parametrization and the results are shown in Table 1. The radius parameter in Table 1 is much larger than that obtained in experiments on hadron collisions, consistent with the picture that we are measuring a geometrical effect related to the large dimensions of the nuclear system. Pions arising from the decay of resonances add a pion source with an effectively longer lifetime and populate the correlation function at small Q_{inv}, modifying the shape so that it appears more exponential.[4] Although the fit to the exponential function yields a better χ^2, it is possible that the actual shape of the correlation is neither exponential nor gaussian.

Table 1. Fitted results of gaussian and exponential parametrizations.

Parametrization	Normalization	λ	R_{inv} (fm)	χ^2/N_{dof}
gaussian	0.800±0.002	0.46±0.04	4.50±0.31	18.1/16
exponential	0.794±0.004	0.77±0.08	3.54±0.33	12.0/16

Our statistics permit multi-dimensional fits which are more sensitive to interesting dynamics, less influenced by relativistic effects, and more plausibly related to emission volumes than correlations analyzed in the four-momentum difference (Q_{inv}) of the two particles which average all directions over the acceptance of the experiment.[5,6] When fitting in 2 dimensions, Q_t is perpendicular to the beam, and Q_l is parallel to the beam. The direction perpendicular to the beam may be further resolved into a direction along the momentum sum of the particles, Q_{t_o} and perpendicular to this, Q_{t_s}.

Charged kaons are less affected by resonance decay than pions and could provide a cleaner signal of the source.[7,8] Furthermore the different total cross sections of K^+, K^-, and π^+ with nuclear matter may allow one to investigate the source at different decoupling times.[9] The two-dimensional correlation functions we measure in S+Pb collisions for K^+ and K^- are similar, indicating that the different interaction cross section with nucleons are not important in the central region at SPS energies.[2] $K-\pi$ scattering dominates, which is similar for K^+ and K^-. We conclude that the central region of the S+Pb collisions is almost nucleon-free.

Results from 3-dimensional fits to $\pi^+\pi^+$ and K^+K^+ data are shown in Table 2.[2,3] High p_T pions have smaller R parameters than low p_T pions. The R parameters for low p_T kaons and high p_T pions are comparable. Higher p_T pions may decouple from the system earlier in time[10] , include fewer pions from resonance decays,[11] and consequently show a smaller radius parameter. Using RQMD[12] we can investigate how resonances can change the extracted radius parameters from correlations by turning off all resonances in the code. We find that the kaon R_{ts} parameter decreases by about 10% and the pion radius by about 20%. This does not fully account for the difference between the measured radius parameters for kaons and pions.

In p-Pb it is natural to expect in the central region little rescattering, thermalization, or collective motion, so the transverse motion should be very different from that along the beam. Indeed we see that the R_l is quite different from R_{to} and R_{ts}. In S-Pb collisions the three R-parameters are nearly equal, suggesting significant influence from thermalization and collective motion.[2] The R parameters for pions and kaons show a $1/\sqrt{m_T}$ dependence. This dependence can be explained by the presence of strong position-momentum correlations, arising from collective flow.[3]

Table 2. Summary of Radius Parameters

System	Particle	λ	R_{to} (fm)	$R_{ts}(fm)$	R_l (fm)
p+Pb	$\pi^+\pi^+$	0.43(0.01)	1.8(0.1)	1.4(0.1)	2.5(0.1)
	K^+K^+	0.70(0.07)	1.53(0.17)	1.22(0.76)	2.40(0.30)
S+Pb	$\pi^+\pi^+$ (150p_T)	0.56(0.02)	4.02(0.14)	4.15(0.27)	4.73(0.26)
	$\pi^+\pi^+$ (450p_T)	0.55(0.02)	2.97(0.16)	2.95(0.24)	3.09(0.19)
	K^+K^+(240p_T)	0.82(0.04)	2.77(0.12)	2.55(0.20)	3.02(0.20)

4. Single Particle Distributions

Inverse slopes for $\pi^\pm$, $K^\pm$, p and pbar M_T spectra for various projectile-target combinations have been compared with predictions from RQMD (with rescattering) and FRITIOF[13] event generators (no rescattering). The inverse slopes of $\pi^\pm$ are equal within errors and nearly independent of the system. The pions do not appear to be a sensitive probe of the initial system or the time evolution of the hadronic matter. The inverse slopes of $K^\pm$ are also equal within errors but increase for larger systems. RQMD follows this trend while FRITIOF does not. This may indicate that rescattering affects the kaons independently of their charge, which would be expected if the rescattering is with primarily pionic, rather than baryonic, matter. Finally, the inverse slopes of protons and antiprotons increase markedly from p+A to S+A collisions; this trend is reproduced by RQMD but not FRITIOF. This again underscores the importance of rescattering for the hadron spectra.[14]

We measure p+Be (as an approximation to p-p) and p-nucleus collisions at 450GeV, and nucleus-nucleus collisions at 200GeV/A in the same experiment to characterize any low p_T enhancement and distinguish among the proposed explanations.[15] The data are in the range $0 \leq p_T \leq 320$MeV/c. Results are presented as ratios of p_T distributions of heavier systems to those of lighter systems. The p_T acceptance for this data set extends to 320MeV/c and we normalize to the last two bins at p_T of 260 and 300MeV/c.

Figure 1 shows the ratios of π^- production as a function of p_T for different projectile-target combinations. The shaded area in Figure 1 represents the statistical uncertainty in the normalization to $260 < p_T < 320$MeV/c and dominates the error associated with the calculated difference. The measured pions span a unit of rapidity. The results have been corrected for variations in dN/dy with y in our acceptance using the RQMD model. A small enhancement is visible at low p_T in the A+A/p+Be results; p+Pb shows an enhancement over p+Be, similar in magnitude to S+Pb/p+Be. Kaon production does not exhibit any enhancement at low p_T.[16]

The NA44 results extend the rapidity range at CERN energies to $y = 4$, so we may study the rapidity dependence. The pion low p_T enhancement in NA44 is smaller than that reported by HELIOS and NA35, which both measure backwards of

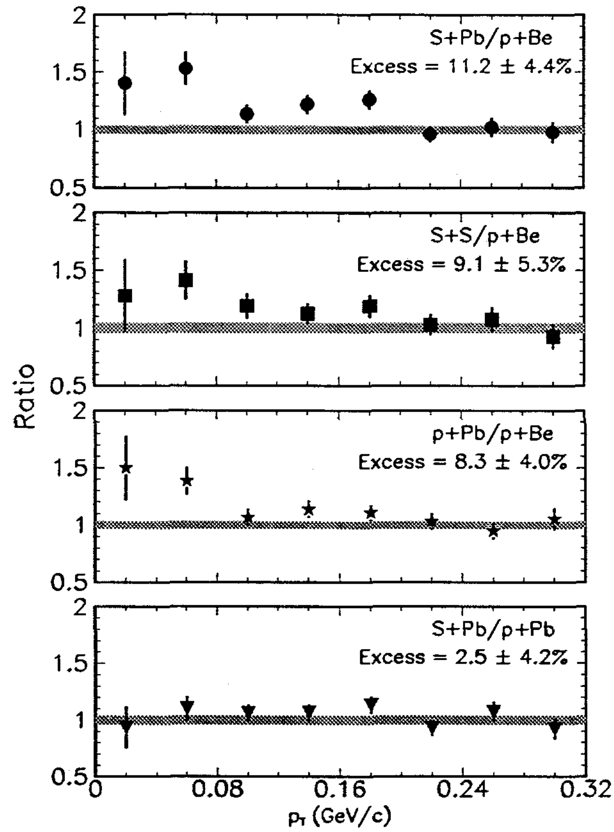

Fig. 1. Ratios of π^- p_T distributions for different projectile-target combinations, normalized at $240 < p_T < 320$MeV/c.

mid-rapidity. NA35 has demonstrated that the low p_T enhancement increases at more backward rapidities.[15,17] The similarity of enhancement in p+A and A+A collisions and lack of target dependence was also reported by HELIOS and NA35.[18,19] It is well known that resonances strongly influence the p_T distribution of hadrons.[20] The RQMD event generator which includes hadronic rescattering and the excitation of strings and resonances, also predicts a rapidity dependence of the low p_T enhancement. RQMD results indicate that the stronger low p_T enhancement observed near target rapidity is due to baryonic resonances, which decreases as the nucleon-free central region is approached.[16]

5. Conclusions

We have investigated K^+ and K^- correlation functions at mid-rapidity and found them to be similar, indicating a nucleon-free central region in our collisions. Extracted radius parameters for kaons are smaller than those for pions. Resonance decays to pions can in part account for this difference. The radii we measure for $S + Pb$ and $p + Pb$ collisions are both larger than the projectile signaling the presence of collective expansion. The R parameters for pions and kaons show a $1/\sqrt{m_T}$ dependence, consistent with the scenario of exisiting position-momentum correlations, arising from collective flow.[3]

Ratios of p_T distributions have been used to search for enhanced π and K production at $0 < p_T < 240$MeV/c. A small low p_T enhancement is observed for mid-rapidity pions in p+A and A+A collisions. The excess is similar in p+Pb and A+A and shows no target dependence. Excess soft pion production is largest at target rapidities and decreases with increasing y; RQMD simulations show that these pions arise from baryonic resonance decay. There is no low p_T excess evident in K^- p_T data.

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