Charged hadron distributions in pA and AA collisions at the CERN SPS

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Single particle distributions of $\pi^{\pm}, K^{\pm}, p, \bar{p}$ and d near mid-rapidity from 450 GeV/c pA and 200 GeV/c per nucleon SA collisions are presented. Inverse slope parameters are extracted from the transverse mass spectra, and examined for indications of collective phenomena. Proton and antiproton yields are determined for different projectile-target combinations. First results from 160 GeV/c per nucleon PbPb collisions are presented.

1. The NA44 experiment

The NA44 detector is described in [1]. The spectrometer is optimised to measure single- and two-particle distributions of charged hadrons produced near mid-rapidity over a wide p_T range: $0.0 \leq p_T \leq 1.5$ GeV/c. This coverage is provided by operating the spectrometer in two angular settings, at 44 and 131 mrad with respect to the incident beam. Scintillator hodoscopes are used for tracking, and also provide time-of-flight information with $\sigma_{\mathrm{TOF}} <$ 100 ps. The momentum resolution $\delta p/p$ is approximately 0.2%. Two threshold Cherenkov detectors in conjunction with the time-of-flight information provide particle identification. In all cases, particle contamination is less than 5%, and for most of the data presented here, it is less than 1%. An interaction (and centrality) trigger is provided by 2 rectangular scintillator paddles sitting downstream of the target and covering approximately $1.3 < \eta <$ 3.5. Offline, a silicon pad multiplicity detector with 2π azimuthal coverage over the range $1.5 < \eta < 3.3$ is used for event characterisation.

2. Results from 450 GeV/c pA and 200·A GeV/c SA collisions

NA44 has measured single particle distributions for a variety of collision systems, ranging from pBe to SPb. For the pA data, events are triggered by requiring a track candidate

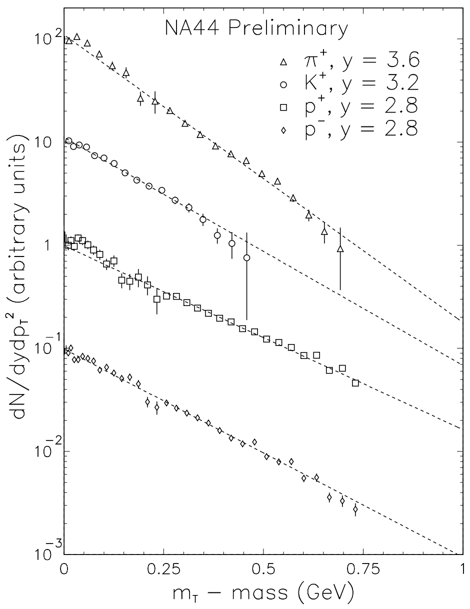


Figure 1. Invariant cross-section (arbitrary units) as a function of m_T - m for π^+, K^+, p and $\bar{p}$ in central SPb collisions. Errors are statistical only.

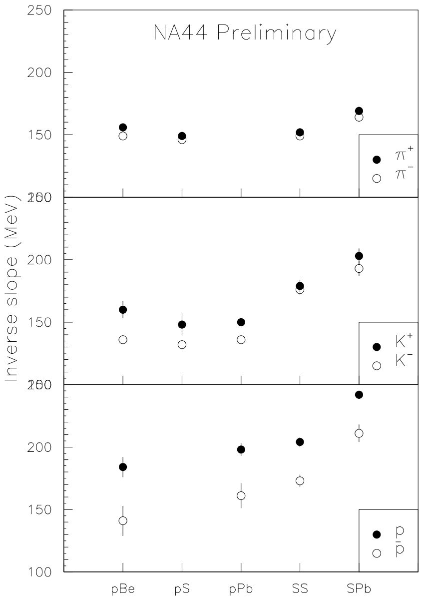


Figure 2. Inverse slopes as a function of collision system. Slopes are fit over the range $p_T < 800$ MeV/c. Systematic errors on the absolute values are $\pm$ 15%, relative errors within one particle type are smaller.

in the spectrometer arm and at least one charged particle in the downstream scintillator. In the case of the SA data, an additional centrality (large pulseheight) requirement is made on the downstream scintillator: for the SS and SPb data presented here, this corresponds to approximately the 10% most-central interactions.

Figure 1 shows the invariant cross-section for π^+, K^+, p and $\bar{p}$ as a function of $m_T - m$ ($m_T = \sqrt{p_T^2 + m^2}$) in central SPb collisions. In each case, the data are close to mid-rapidity ($y_{NN} \sim 3$). The distributions have been corrected for geometrical acceptance, momentum resolution, reconstruction efficiency and decays in flight (pions and kaons). Also shown are the results of fits to a single exponential of the form $Ce^{-\frac{m_T}{T}}$. Extracting the inverse slope parameters from these fits yields values of 156$\pm$8 MeV for π^+, 206$\pm$6 MeV for K^+, 242$\pm$3 MeV for protons, and 215$\pm$6 MeV for antiprotons. The errors are statistical only. Systematic errors are under study and currently estimated to be <15%.

The data can be reasonably well described by exponentials in m_T. There is a clear increase of the inverse slope with particle mass. Detailed study [2] of the spectral shapes below $p_T = 240$ MeV/c shows that there is a small ($< 10\%$) low-p_T enhancement of both π^+ and π^- in central SPb collisions with respect to peripheral SPb or pBe collisions. No enhancement is seen in the kaon spectra. Both the spectral shapes and inverse slopes are in good agreement with those predicted by the RQMD(1.08) event generator (with ropes) [3], for which events are generated with approximately the same impact parameter distribution as the data.

Figure 2 shows the inverse slopes as a function of collision system. The inverse slopes

Table 1
Preliminary yields for p and $\bar{p}$ at mid-rapidity in central SS and SPb collisions.

	SS		SPb	
	p	$\bar{p}$	p	$\bar{p}$
NA44	3.6±0.5	0.4±0.1	13.8±2.1	1.4±0.2
RQMD	4.8±1.2	1.2±0.3	13.3±1.3	2.3±0.2

for SA collisions increase with particle mass and system size, illustrating the importance of rescattering in the heavy systems. It is interesting to note the similarity between K^- and K^+ inverse slopes in the SA data, suggesting that the rescattering is largely meson-dominated at mid-rapidity. This result is confirmed by NA44 two-particle correlation measurements, which show the same source size for K^- and K^+ [4], and by preliminary $\frac{dN}{dy}$ measurements indicating a relative yield for p:π^+ of $\sim$ 1:4.

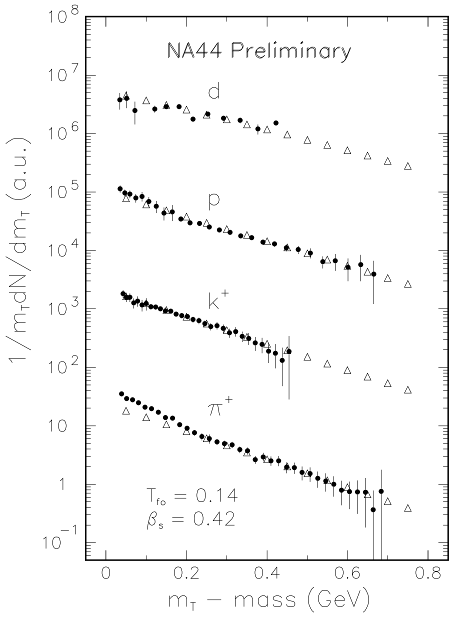
Antiprotons are of particular interest in AA collisions since enhanced production of antibaryons may signal the formation of quark matter [5]. The measured yield, however, is a combination of (possibly enhanced) $\bar{p}$ production and subsequent $\bar{p}$ annihilation in the surrounding hadronic medium. Proton and antiproton yields have been extracted from the normalised transverse mass spectra, extrapolating the exponential fits over the full m_T range. Table 1 shows p and $\bar{p}$ yields at $y \sim 2.8$ in SS and SPb collisions. Systematic errors in the normalisation are under study. Clearly there are a significant number of protons at mid-rapidity, indicating partial stopping even at CERN energies. Also shown are the corresponding RQMD predictions for events with the same centrality selection. The agreement is reasonable, although the $\bar{p}$ yields fall somewhat below the model for both SS and SPb.

Recent results on deuteron and antideuteron production [6] allow us to extend the study of transverse mass spectra to heavier particles. Figure 3 shows the deuteron spectrum measured in central SPb collisions, alongside those for π^+, K^+, and protons. The deuterons have been measured at $y \sim 2.2$. A single exponential fit to the data yields an inverse slope of 349±47 MeV (statistical error only). The increase of the inverse slope with particle mass noted above is clearly confirmed in the deuteron spectrum.

Given this trend, it is natural to study the data in the context of a thermal model. Schnedermann et al. have developed such a model [7] incorporating longitudinal and transverse flow. The computed transverse mass spectrum has the form:

$$\frac{dN}{m_T dm_T} \propto \int_0^R r dr m_T I_0 \left(\frac{p_T \sinh(\rho)}{T_{fo}}\right) K_1 \left(\frac{m_T \cosh(\rho)}{T_{fo}}\right) \tag{1}$$

where $\rho = \tanh^{-1}\beta_r$, $\beta_r(r) = \beta_s \left(\frac{r}{R}\right)^n$ with $n = 1$, and I_0, K_1 are modified Bessel functions. This then determines the shape of the m_T spectra in terms of two parameters: the freezeout temperature T_{fo} and the surface velocity β_s. Figure 3 shows the result of fitting the NA44 data to (1), yielding T_{fo} = 140 MeV and $\beta_s = 0.42c$. The data are consistent with the existence of transverse flow, however it must be noted that there are many different pairs (T_{fo}, β_s) which fit the data: measurement of β_s from NA44 two-particle correlation data [8] should allow us to determine a unique solution.



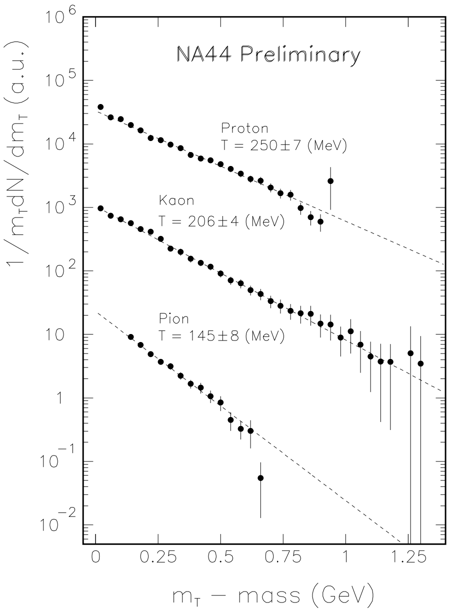


Figure 3. Invariant cross-section (arbitrary units) for π^+, K^+, p and d in central SPb collisions (shaded circles). Also shown (open triangles) are the results of fitting to (1).

Figure 4. Invariant cross-section (arbitrary units) for π^+, K^+, and p in central PbPb collisions. Errors are statistical only.

3. First results from 160·A GeV/c PbPb collisions

The NA44 detector successfully took data during the first Pb beam run at CERN in November 1994. The detector itself had been upgraded to provide improved tracking (new pad and strip chambers) and improved particle identification (two new Cherenkov counters). Figure 4 shows preliminary m_T spectra for π^+, K^+ and p in central PbPb collisions. The spectra are well described by exponentials in m_T: the inverse slopes are 145±8 MeV for π^+, 206±4 MeV for K^+, and 250±7 MeV for p (statistical errors only). The trend of increasing inverse slope with particle mass seen in the SPb data is again seen here, and the values themselves are in agreement with those measured in SPb. The K^+ spectrum shows no indication of deviation from the exponential fit at low-p_T.

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