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Preliminary Spectrometer Results from E-802

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1. Introduction

This report presents preliminary spectrometer results from the E-802 experiment at the Tandem-AGS accelerator complex at Brookhaven National Laboratory. The data presented were taken in late April of 1987 using a $14.5 \text{ GeV}/c$ per nucleon ^{28}Si beam from the AGS. Data were obtained for a variety of targets and spectrometer settings, but we present here the analysis of data for one target-angle combination: a Au target with the spectrometer spanning $14^\circ - 28^\circ$ in the lab. At this energy the laboratory mid-rapidity angle in N-N collisions is $\approx 21^\circ$.

The primary goal for the E-802 experiment is to measure inclusive particle spectra with good particle identification (PID) over a wide range of rapidity and transverse momentum, and to correlate these spectra with observables that characterize the event topology such as total charged particle multiplicity and neutral transverse energy. The acceptance of the spectrometer is large enough to span roughly one unit of rapidity in a single setting and is adequate for studies of particle-particle correlations. The spectrometer is also sufficiently compact (6.5 m in length) to allow a reasonable fraction of low momentum pions and kaons to traverse the entire particle identification system. Segmentation for the tracking and PID counters was designed to handle particle multiplicities up to 15 through the spectrometer and 20 in front of the magnet.

2. The E-802 spectrometer

The experimental setup is shown in Fig. 1. Devices used to define the event topology and provide central triggers include the target multiplicity array (TMA), lead-glass array (PBGL), zero-degree hadronic calorimeter (CAL), and beam counter system (not shown in the figure). One of the beam counter gives start timing for the time-of-flight measurement.

The tracking component of the spectrometer consists of four drift chambers, two in front of and two behind a magnet. Although the magnet can operate at $\leq 1.5 \text{ Tm}$, the data presented here were taken with an integrated field of 0.9 Tm . PID is now provided by a time-of-flight scintillator array (TOF) and an Aerogel Čerenkov detector (AEROČ). The TOF wall consists of 160 plastic scintillator (BC404) slats, most of which are 1.6 cm square by 78 cm long with a photomultiplier tube (Hamamatsu R2083) on each end with a timing resolution that allows π -K separation to above $2 \text{ GeV}/c$ momentum. The Aerogel (index of refraction of 1.02) is a threshold Čerenkov detector with 96 elements, which complements and extends the PID range provided by the TOF wall. In the future, the addition of a segmented gas Čerenkov detector will provide complete separation of π 's,

K 's, and protons up to $5 \text{ GeV}/c$.

The acceptance of the spectrometer is illustrated in Fig. 2, in which transverse momentum is plotted as a function of nucleon-nucleon center of mass rapidity (the laboratory rapidity of the N-N center of mass is 1.74). The heavy solid lines correspond to the momenta and angles over which the spectrometer can accept and identify particles. In the present configuration, the angular range available is $5^\circ - 55^\circ$ in the lab with the low momentum cut-off at $0.5 \text{ GeV}/c$ as shown in the figure. The upper momentum cut-off represents the present limit on PID using only the TOF wall and the Aerogel detectors. An extension of the PID will be provided shortly by the gas Čerenkov detector and is shown by the heavy dashed line. The region for which data is presented in this article is shown by the cross-hatched area. Fig. 3 illustrates the momentum range over which each of the counters provide particle identification.

The four tracking chambers are all projective drift chambers with multi-hit capability on each wire. They are located at 1.0, 1.5, 4.0, and 4.5 m from the target. Drift lengths vary from 4 mm in the smallest chamber to 17 mm in the largest. Each chamber contains 10 independent planes of sense wires arranged in 4 or 5 modules, with each module containing wires at a different angle. This large redundancy in determining the position of a given particle trajectory is essential for handling high-multiplicity events. The chambers in front of the magnet resolve the left-right ambiguity by having two planes of wires in which the field wire of one plane is aligned with the sense wire of the adjacent plane, while the two chambers after the magnet use three sense wires with a 0.7 mm staggering to resolve the left-right ambiguity. Single particle position resolution on individual wires is roughly $\sigma_x \approx 125 \mu m$ and pulse pair resolution is $\approx 2 \text{ mm}$.

3. Particle spectra

Several hardware triggers were implemented for the April run in conjunction with a beam trigger, which selected $Z = 14$ projectiles in the correct geometry, used for normalization. A minimum bias interaction trigger was derived from the the beam trigger by demanding that the charge of the projectile remnant leaving the target satisfied the requirement $Z \lesssim 12$. A central trigger was derived from the interaction trigger by requiring a high charged-particle multiplicity in the TMA counter (upper $\approx 7\%$ of the distribution). The beam and interaction triggers were scaled down to allow enrichment of the data sample in central events.

Fig. 4a shows the timing resolution (including the resolution of the start counter) of

each TOF wall slat. The measurement was made with a $15 \text{ GeV}/c \ \pi^-$ beam passing through the counter. Time slewing due to pulse height variation was corrected in software. Most of the slats show $\approx 75 \text{ ps}$ resolution (1σ), which allows a π - K separation up to $2.5 \text{ GeV}/c$, with the assumption of a K/π ratio of 5% and 5σ separation between π and K peaks (see Fig. 4b). With no software correction, 100 ps resolution was achieved.

The tracking algorithm used here first reconstructs tracks in the two chambers behind the magnet, T3 and T4. These tracks are then projected onto the TOF wall and the TOF is used to correct the T3/T4 drift time measurement for transit time effects. By assuming the target position, these tracks are projected backwards through the magnet. T1 and T2 can then be used to verify that each track did in fact come from the target (in the data shown, only T1 was used).

Particles are identified by combining the TOF information and the momentum analysis from the tracking system. Fig. 5 shows a scatter plot between the TOF and the inverse of momentum for both positive and negative particles observed in Si + Au collisions with all trigger conditions added. Note that the acceptance for positives and for negatives is not symmetric. The tracks which do not originate from the target are rejected by the track reconstruction algorithm. Since the pulse height correction for the TOF has not yet been performed for the Si run, π - K separation is achieved only up to $2.2 \text{ GeV}/c$. For positive particles π^+ , K^+ , p , and d , and for negative particles π^- , K^- , and $\bar{p}$ are clearly observed.

4. Discussion

There is a remarkable difference between the production rates of K^+ and K^- in the plot: more K^+ than K^- are observed. Because of the difference in acceptance between positive and negative particles, we compare the K^+/π^+ ratio to the K^-/π^- ratio as listed in Table 1. The decay-in-flight corrections have been made using the measured momentum spectra. Note that the K/π ratios are compared for slightly different kinematic regions for positives and for negatives. Nonetheless, the K^+/π^+ ratio from Si + Au is evidently much higher than the K^-/π^- ratio. Also, with central triggers selected, the K^+/π^+ ratio tends to increase while the K^-/π^- ratio tends to decrease, although the ratios remain the same within errors. As listed in Table 2, the K/π ratios from p-p and p-nucleus collisions are strongly dependent on the kinematic region and also on the beam momentum, and the K^+/π^+ ratio is systematically larger than the K^-/π^- ratio. Detailed comparison with proton-nucleus collisions will be performed in a future run.

Qualitative explanations of the K/π ratios have been proposed based on the different

properties of K^+ and K^- in nuclear matter. Since the cross section for K^- -nucleon scattering is larger than that for K^+ -nucleon, the K^- has a shorter mean free path in nuclear matter. Therefore, more K^- 's than K^+ 's may be absorbed on the way out of the interaction region. Another important difference is that K^+ can be produced more easily in a hot hadron gas than K^- (for example, via $\pi^+ + N \rightarrow K^+ + \Lambda$). These aspects must be considered before drawing conclusions about an anomalous K/π ratio. It must also be stressed that the above results are preliminary and there may be experimental biases. For example, the tracking efficiency for this analysis may be as low as 50% for high multiplicity events and may be dependent on the multiplicity. The momentum spectra obtained are, however, qualitatively similar to those obtained in p-p collisions.

5. Summary

We have made the first measurement with the E-802 spectrometer in April, 1987, using a 14.5 GeV/c per nucleon ^{28}Si beam. We have demonstrated good particle identification capability to at least 2.2 GeV/c. From the measurement of Si+Au collisions, with an angular coverage of $14^\circ - 28^\circ$ (mid-rapidity), we observe a higher K^+/π^+ ratio than K^-/π^- ratio.

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Table 1. K/π ratios measured in 14.5 GeV/c per nucleon Si + Au collisions at $14^\circ - 28^\circ$, $p_{lab} < 2.0$ GeV/c. (preliminary)

	Min.bias trigger	Central trigger
$(K^+/\pi^+)_{present}$	$19 \pm 5 \%$	$24 \pm 5 \%$
$(K^-/\pi^-)_{present}$	$6 \pm 5 \%$	$4 \pm 4 \%$

Table 2. K/π ratios in p-p and p-nucleus collisions.

	p_{inc} (GeV/c)	Reaction	Angle	Momentum (GeV/c)	Ratio (%)	Reference
K^+/π^+	19.0	p+p	6.6°	1.7	4.5 ± 2.0	1
K^-/π^-					3.4 ± 2.0	1
K^+/π^+				2.4	7.1 ± 2.0	1
K^-/π^-					3.6 ± 2.0	1
K^+/π^+	12.3	p+Be	10°	1.0	3.7 ± 0.3	2
K^-/π^-					1.3 ± 0.2	2
K^+/π^+		p+Cu	10°	1.0	5.7 ± 0.5	2
K^-/π^-					1.7 ± 0.2	2
K^+/π^+	30.0	p+Be	20°	1.25	2.7 ± 1.2	3
K^-/π^-					1.2 ± 0.5	3
K^+/π^+				2.5	23.0 ± 1.2	3
K^-/π^-					8.8 ± 0.9	3

Figure captions:

- Fig. 1 Schematic view of E-802 experiment.
- Fig. 2 Acceptance of E-802 spectrometer shown in a $p_{\perp}$ vs rapidity plot. The hatched area shows the kinematic region for the present data, ignoring the acceptance difference of positive and negative particles.
- Fig. 3 The momentum range over which each of the counters provide particle identification. The wide bars indicate where particle separation is possible. For example, since π 's with a momentum of $> 1.0 \text{ GeV}/c$ and K 's with $> 2.8 \text{ GeV}/c$ emit Čerenkov light in AEROČ, π - K separation is given by AEROČ at the momentum range of $1.0 - 2.8 \text{ GeV}/c$.
- Fig. 4a Timing resolution of TOF wall slats measured with a $15 \text{ GeV}/c \pi^-$ beam passing through the counter. Most of the slats with $\sim 100 \text{ ps}$ resolution have 3.2 cm wide scintillator.
- Fig. 4b Expected TOF distribution with the separation of 5σ between π and K when the K/π ratio is 5%.
- Fig. 5 Scatter plot between the TOF and the inverse of momentum for positive and negative particles obtained in Si + Au collisions ($\theta_{lab} = 14^\circ - 28^\circ$) at a beam momentum of $14.5 \text{ GeV}/c$ per nucleon.

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Fig 1

MOMENTUM ACCEPTANCE

Fig 2

	Performance	Segmentation	Particle Separation		
			$\pi - K$	$K - p$	$p - d$
TOF	$\sigma_{TOF} \approx 80ps$	160	0.5 2.5 GeV/c	0.5 4.1 GeV/c	0.5 >5 GeV/c
Gas $\check{C}$	$n=1.004$ $P_{th}^{\pi}=1.5 \text{ GeV/c}$	40	2.0 5.5 GeV/c	GeV/c	GeV/c
Aerogel $\check{C}$	$n=1.02$ $P_{th}^{\pi}=0.7 \text{ GeV/c}$	96	1.0 2.8 GeV/c	2.8 5.0 GeV/c	GeV/c

Fig 3

Fig 42

Fig 4 b

Fig 5