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SURVEY OF RESULTS FROM BROOKHAVEN EXPERIMENT 802 AT THE AGS

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Abstract

Brookhaven Experiment 802 (E–802) is a magnetic spectrometer experiment which is directed towards the measurement of particle momentum spectra and particle–particle correlations following reactions with 14.5 GeV/u O and Si ions. In addition to the spectrometer there are detectors to measure the transverse energy flow, longitudinal energy flow, and the multiplicity. These detectors can be used to characterize the particle spectra or correlated between themselves. Particle spectra have been obtained for protons, pions, and kaons using targets of gold, copper, and aluminum although the data are not entirely analyzed as yet. A first result that is of interest is the K^+/π^+ ratio for Si + Au reactions which is larger than expected on the basis of the known p+p data.

Introduction

Experiment 802 uses the 14.5 GeV/c heavy–ion beams at the Brookhaven AGS. The long term goal of the experiment is to find evidence for quark–gluon plasma formation in heavy–ion reactions. The immediate effort however is directed to understanding general aspects of heavy–ion reactions at this energy. Towards this end E–802 has implemented counters for characterizing the global reaction features such as the multiplicity, the transverse energy, and the longitudinal energy distributions as well as a magnetic spectrometer arm with particle identification for measuring the yields and momentum distributions of the emitted particles. Relationships between the different event characterization detectors as well as their correlation with the spectrometer arm can be determined. The experimental arrangement has been essentially completed for about a year and has taken data with proton, oxygen, and silicon beams. E–802 is a large collaboration of about 40 scientists, 15 students, and 11 institutions.

A plan of the experiment is given in Fig. 1. As one looks in the direction of the beam (to the right in the figure) the spectrometer with its tracking and particle identification detectors is on the left side. The target is placed within a multiplicity counter (TMA) which has about 3300 pads; there is a lead–glass array (PbGl) of 265 blocks on the right which subtends the central rapidity region and a calorimeter (Z–Cal) in the forward direction which is also the beam stop. The details of the apparatus are described elsewhere.[1]

Event Characterization

When the experiment was first being assembled there was an opportunity to implement a small array of the lead-glass blocks and measure the spectrum in the glass (largely proportional to the total neutral energy). The counter subtended a 2π azimuthal angle and 1 unit of rapidity about the nucleon–nucleon central rapidity. Several targets were used with a primary oxygen and secondary proton beam. The spectra observed (Fig. 2) in this simple experiment are so revealing that they are still worth repeating here.[2] The first and most obvious thing about the distributions is that the Cu and Au spectra appear to end at an energy that is independent of target. The simplest interpretation is that the oxygen beam is "stopped" in targets of intermediate or large mass: that is, there is no increase in the production of pions in the central rapidity region with increasing size of the target. This very striking and important conjecture is made more convincing in Fig. 3. Here the distribution in the lead glass that arises in the p+Au reaction is used to generate the spectrum from O+Au. The method used is to express the O+Au spectrum as a sum of terms representing the contributions of individual projectile nucleon collisions with the target. The likelihood, g_n, that n projectile nucleons will interact with the target is obtained from a purely geometric Monte Carlo calculation using realistic nuclear mass distributions. The spectral distribution which is associated with n collisions is given by the n^{th} convolution integral of the p+Au distribution and its intensity is given by the weight, g_n. The sum of these weighted convolutions for all n makes up the final spectrum. Both the individual weighted convolutions and the sum is shown in Fig. 3. The remarkable fit, *summed over the projectile nucleons only*, confirms the "complete stopping" picture of the reaction. Surprisingly the p+Au spectrum can also be convoluted to obtain the p+Cu spectrum with appropriate weighting factors for copper but with no other changes.

Fig. 1: A plan view of the E-802 experiment. The beam comes from the left UDEW and BTOT are beam defining counters. BTOF is a timing counter (see text for further description).

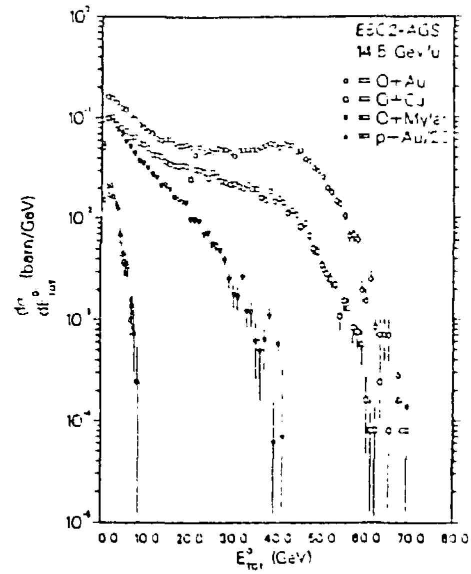


Fig. 2: Spectra from the provisional lead–glass array in its preliminary position (see text). The horizontal scale, E°_{tot}, shows total neutral energy after corrections for charged hadrons.

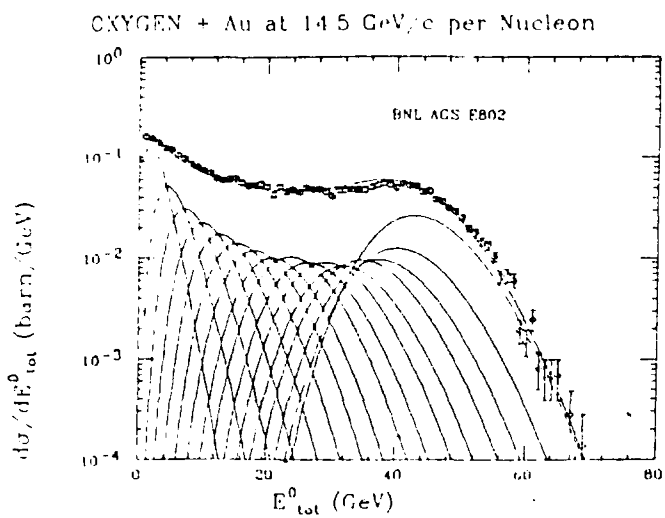


Fig. 3: E°_{tot} spectrum, 16 individual weighted convolutions, and weighted sum of convolutions. First convolution spectrum is a fit to p+Au data.

After this brief but revealing effort with the small lead-glass array and the oxygen beam, the experiment was configured in its present arrangement with the lead glass now subtending only half of the azimuthal angle but still the central unit of rapidity. Figure 4 shows the spectra obtained in this new position but now with a silicon beam and targets of Au, Ag, Cu and Al. As before the distributions are seen to come together at the highest energy, the signature of "nuclear stopping", with the exception of the Al target. Although it is likely that the silicon projectile is not "stopping" in the aluminum case, it cannot be ruled out by these data. Very rare events may still dissipate the whole energy. On purely geometric arguments it must be a rare event indeed when the silicon projectile and the aluminum target nucleus (of close to the same diameter) manage to line up (impact parameter ~0) so that all the nucleons can interact.

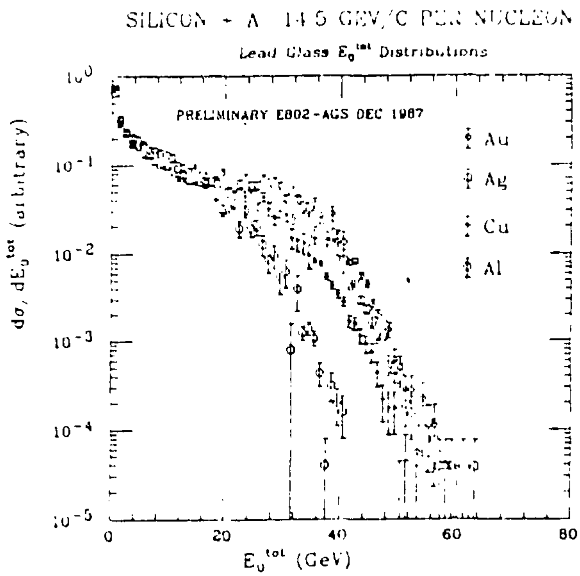


Fig. 4: E_o^{tot} spectra from lead-glass detector in its final position.

Data have also been taken using the multiplicity array, a barrel, and wall arrangement surrounding the target with a polar angle coverage $6° < \theta < 149°$. The data shown in Fig. 5 are for the silicon beam on targets of Al, Cu and Au. These data have not been corrected for missing detector panels or multiple hits on a single pad, corrections of ~20%. A major difference between this spectra and the lead-glass spectra is that the distributions do not come together at the upper end although the spectra have the same general shape. The explanation probably lies in the fact that the multiplicity array subtends the target fragmentation region and is sensitive to low energy protons. The lead glass, on the other hand, is a Čerenkov counter primarily sensitive to the gamma rays (which convert in the glass) from pi-zero decay and, to a lesser extent, the charged pions. The multiplicity measurements result also in pseudo-rapidity plots because the great number of pads provide good angular definition. Figure 6 shows the rapidity distributions for the silicon beam with targets of Al, Cu, Ag, and Au. The targets are increasingly separated at the small pseudo-rapidity end which is also a manifestation of the slow target protons. On the large rapidity end all targets look alike but presumably a difference would be seen for different projectiles. A clear shift can be seen in the position of the peak of the distributions for the different targets with the Au target behind and the aluminum target ahead in pseudo-rapidity. For nucleon–nucleon collisions the central rapidity is at $\eta \cong 1.7$. Whether this shift is a sign of "fireball" kinematics, a consequence of the target nucleons being counted, or some other kinematic effect is not as yet understood. The shift is, however unlikely as it may seem, consistent with a "fireball", which for the gold target consists of 28 projectile nucleons and about 80 target nucleons.

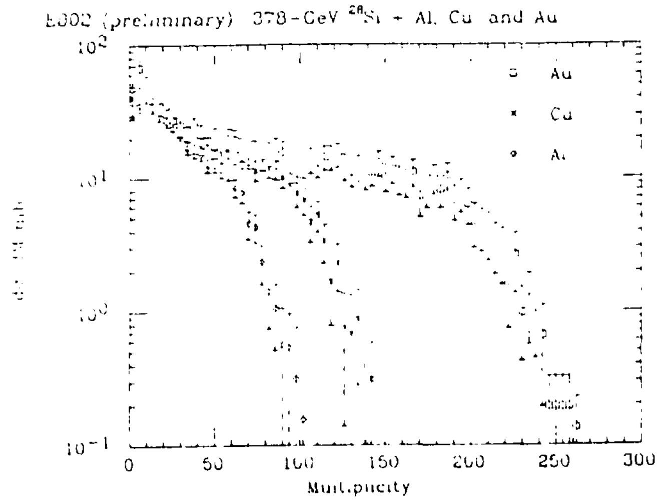


Fig. 5: Multiplicity spectra from the TMA detector.

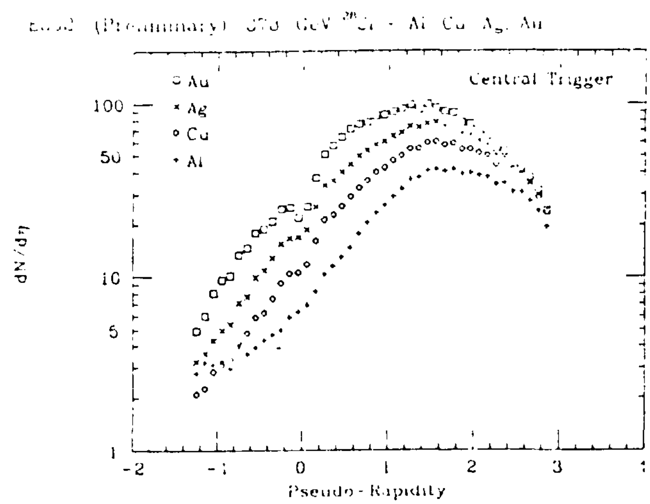


Fig. 6: Pseudo-rapidity spectra from the TMA detector.

Spectrometer Arm

The spectrometer arm of E-802 consists of a 25 msr magnet, 4 drift chambers for tracking (T1-T4), an aerogel Čerenkov counter (AEROČ) of 90 segments, a time-of-flight (TOF) array with 160 pickets, a gas Čerenkov counter (GASČ) with 40 segments, and a pad readout back counter (BC). There is also a very long small solid angle detector, the Čerenkov Complex (ČC), which is used for high momentum particles in the forward direction. The time-of-flight wall has unusually good time resolution ($\sigma \cong 80$ psec) and can provide excellent particle identification up to about 2.3 GeV/c for separating π's, K's, and protons as is shown in Fig. 7.

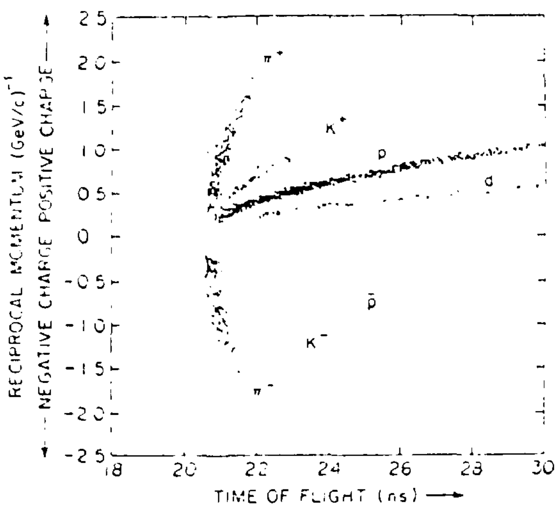
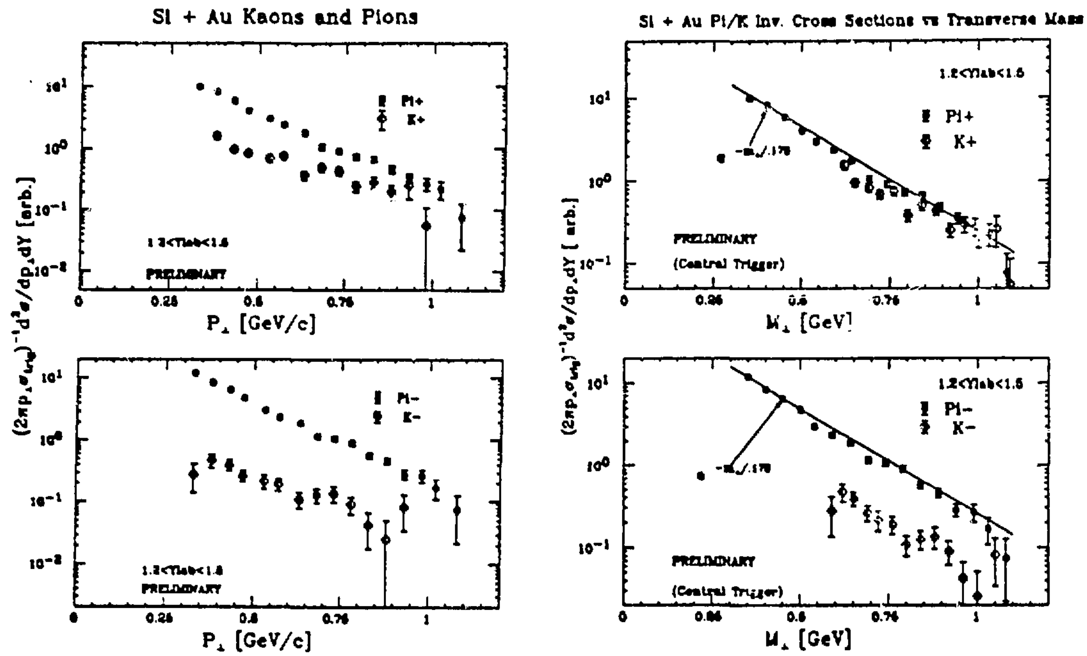


Fig. 7: The reciprocal of particle momenta measured in the spectrometer plotted against time of flight.

Particle spectra for π's and K's are shown in Fig. 8 where the invariant cross section is plotted against the transverse momentum for a small rapidity interval. The π^+ and π^- yields are close to equal and of similar shape. K^- yields are smaller than K^+ and also of similar shape but the slope of the π's and K's is different. If one believes that these spectra are really thermal (Boltzman) distributions then it is more appropriate to plot the data against $m_\perp$ $[m_\perp = (p_t^2 + m^2)^{1/2}]$ than the transverse momentum. The use of $m_\perp$ as a variable is also common in particle physics. Figure 9 shows the same data as in Fig. 8 replotted as a function of $m_\perp$. It is now clear that the slopes of the π^+ and π^- spectra are closely the same with an effective slope parameter ("temperature") of ~170 MeV/c, considerably above the values achieved at the Bevalac. The K^+ and K^- spectra now appear to have slopes which are also closely 170 MeV/c giving some credence to believing that there is a common source for all these particle species.



Figs. 8–9: The invariant cross section vs. transverse momentum and transverse mass for pions and kaons.

Proton and deuteron spectra have also been obtained. In Figure 10 the proton and deuteron invariant cross sections are shown plotted against $m_\perp$ as above. The proton spectra are in the same rapidity range as the π spectra, considerably in front of the target region; the deuterons are from further back. Nonetheless if it is assumed that the deuterons were made from a simple "accidental" coalescence of protons and neutrons (both with the slope parameter of the protons) then the deuterons would have this same slope parameter. In fact a reasonable fit to the deuteron spectra can be made with the proton slope parameter of 230 MeV/c, but there appears also to be a higher $m_\perp$ tail to the measured distribution. The statistics are not sufficiently good to establish this with any certainty.

It has been suggested[3)] that a signal of the quark–gluon plasma (or perhaps a high density hadron gas) might be an unusually large K^+/π^+ ratio. Figure 11 shows this ratio as measured in E–802 with comparisons compiled from the literature for the p+p and p+Pb reactions. Not all of the comparison ratios are taken at the same energy nor in the same rapidity range as the E–802 data. Clearly there is a more pronounce transverse momentum dependence to the E–802 data as well as an enhancement even at the lowest p_t points. Before drawing any definite conclusions from this data it must be remembered that the data are compiled from differing kinematic regions and energies and that no effort has been made to take account of possible rescattering in the heavy ion case.

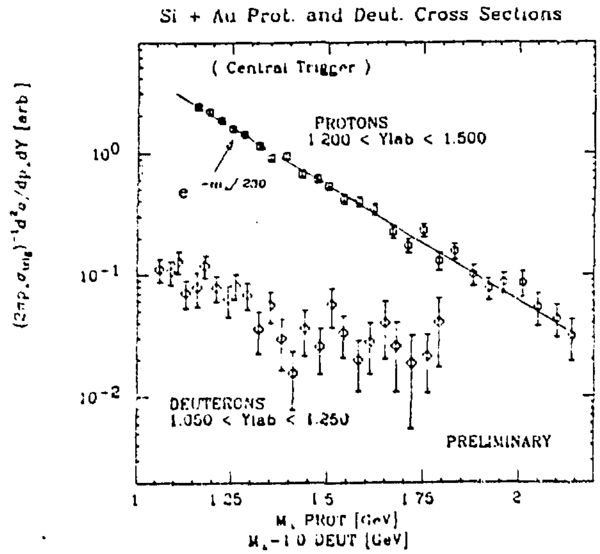


Fig. 10: Proton and deuteron invariant cross sections. The rapidity interval is different for the two spectra.

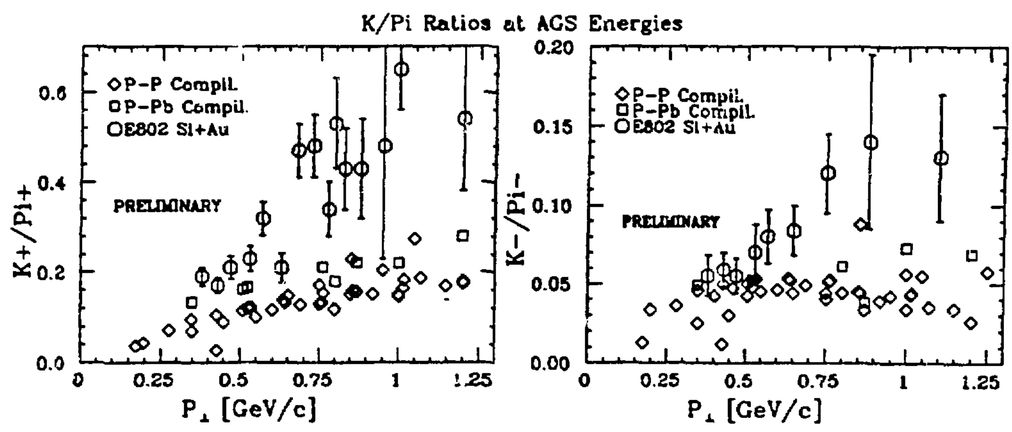


Fig. 11: K^+/π^+ and K^-/π^- measured by E-802 with comparisons from the literature for p+Pb and p+p (see Ref. 4).

The future plans for the E–802 collaboration are to extend the range and scope of the spectrometer measurements. This June we will measure the source dimensions by means of the two particle pion correlation and extend the momentum range of the transverse momentum spectra to higher $p_{\perp}$. After this we hope to obtain improved spectra for kaons and anti–protons and try to do two particle K correlations. In the fall of 1991 it is expected that the Booster Synchrotron for the AGS will be completed and a Au beam will be available. We have already started planning experiments for this very challenging and exciting facility.

Acknowledgements

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