UC-414
LBL-29552

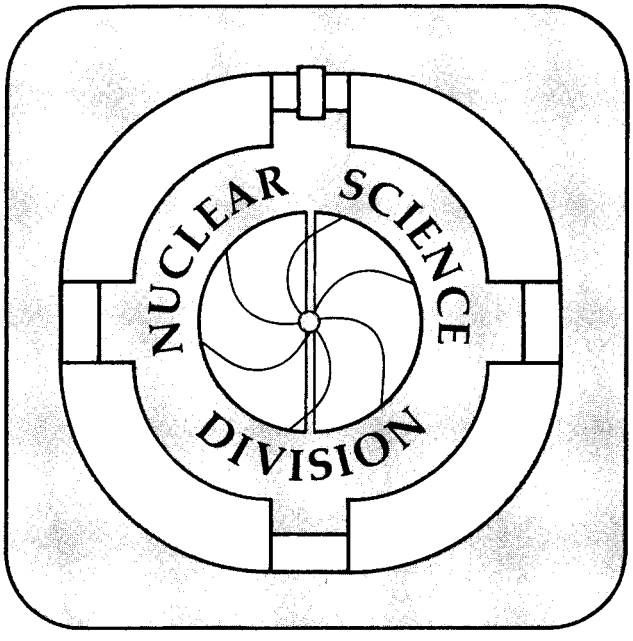
Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

Presented at the PANIC XII
Cambridge, MA, June 24–29, 1990, and
to be published in the Proceedings

New Results from AGS Heavy-Ion Experiments

M.A. Bloomer, W. Love, and L. Waters

August 1990



For Reference

Not to be taken from this room

LBL-29552
Copy 1
Bldg. 50 Library.

Prepared for the U.S. Department of Energy under Contract Number DE-AC03-76SF00098.

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

LBL - 29552

New Results from AGS Heavy-Ion Experiments

Matthew A. Bloomer[a]
E802 Collaboration - ANL, BNL, UC Berkeley, UC Riverside, Columbia, Hiroshima, INS, Kyushu, LLNL, MIT, Tokyo

William Love[b]
E810 Collaboration - BNL, CCNY, John Hopkins, Rice

Laurie Waters[c]
E814 Collaboration - BNL, Los Alamos, McGill, New Mexico, Pittsburgh, Stony Brook, Tel Aviv, Texas A&M, Yale

(a) Lawrence Berkeley Laboratory, Berkeley, CA 94720
(b) Brookhaven National Laboratory, Upton, NY 11973
(c) State University of New York, Stony Brook, NY 11794

August 1990

This work was supported by the Director, Office of Energy Research, Division of Nuclear Physics of the Office of High Energy and Nuclear Physics of the U.S. Department of Energy under Contract DE-AC03-76SF00098

NEW RESULTS FROM AGS HEAVY-ION EXPERIMENTS

Matthew A. BLOOMER[a]
E802 Collaboration — ANL, BNL, UCBerkeley, UCRiverside, Columbia, Hiroshima, INS, Kyushu, LLNL, MIT, Tokyo

William LOVE[b]
E810 Collaboration — BNL, CCNY, John Hopkins, Rice

Laurie WATERS[c]
E814 Collaboration — BNL, Los Alamos, McGill, New Mexico, Pittsburgh, Stony Brook, Tel Aviv, Texas A&M, Yale

[a] Lawrence Berkeley Laboratory, Berkeley, CA, 94720
[b] Brookhaven National Laboratory, Upton, NY, 11973
[c] State University of New York, Stony Brook, NY 11794

We review the most recent data from Experiments 802, 810 and 814 of the heavy-ion program at the Brookhaven Alternating Gradient Synchrotron (AGS).

1. E802

Experiment 802[1] has recently completed, among its many goals, a survey of semi-inclusive particle production over a broad range of projectiles (p, ^{16}O and ^{28}Si) and targets (Be, Al, Cu and Au) at p_{beam} = 14.6 A·GeV/c. With such measurements it is easier to identify directly from the data interesting nuclear effects on particle production.

Measurements of inclusive cross sections for pA collisions have confirmed what had already been observed in central ^{28}Si + Au collisions[2]; namely, the invariant cross sections of $\pi^{\pm}$, K$^{\pm}$ and protons, within the available statistics and $p_{\perp}$ range of the spectrometer ($p_{\perp} > 0.3$ GeV/c) are well described by exponential curves in transverse mass:

$$E\frac{d^3\sigma}{dp^3} = Ae^{-(m_{\perp}-m_o)/T_0},$$

where $m_{\perp} = \sqrt{m_o^2 + p_{\perp}^2}$, m_o is the particle rest mass, and $p_{\perp}$ is its transverse momentum. A and T_0 are parameters, where the inverse slope parameter T_0 (at a given rapidity) uniquely characterizes the shape of the spectral distributions.

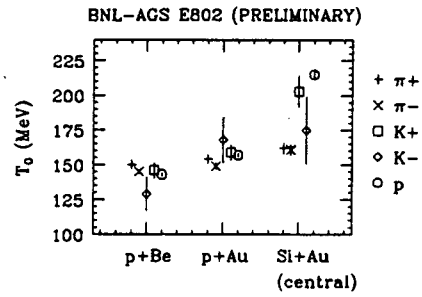


Fig. 1 Inverse slope parameters T_0 for $\pi^{\pm}$, K$^{\pm}$ and p, as obtained from the inclusive spectra between $1.2 \leq y \leq 1.4$ of pBe, pAu and central ^{28}Si + Au collisions. Preliminary data from E802 AGS collaboration.

Fig. 1 displays T_0 for $\pi^{\pm}$, K$^{\pm}$ and protons from pBe, pAu and central (i.e., high multiplicity) ^{28}Si + Au collisions, obtained from spectra measured within the rapidity range $1.2 \leq y \leq 1.4$.

The inverse slope parameters for K^+ and protons increase dramatically as one goes from light systems (pBe and pAu) to heavier systems (central ^{28}Si + Au), in stark contrast to the slope parameters of $\pi^{\pm}$.

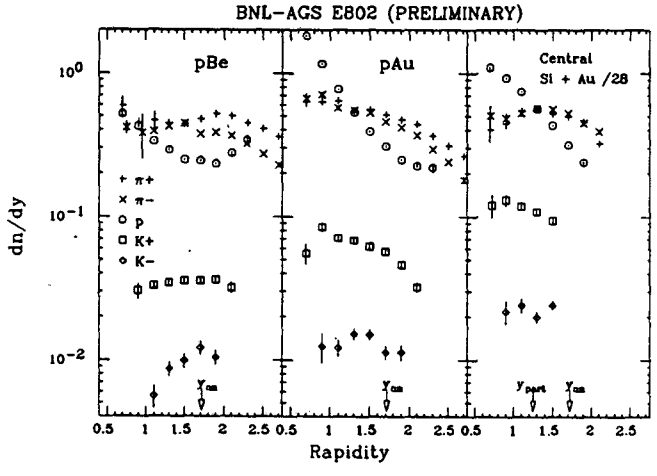


Fig. 2 dN/dy for $\pi^{\pm}$, $K^{\pm}$ and protons for pBe, pAu and central ^{28}Si + Au collisions. Note that dN/dy for central ^{28}Si + Au has been divided by the number of ^{28}Si projectile nucleons (= 28). Preliminary data from E802 AGS collaboration.

The invariant cross sections for the same systems were integrated to yield the rapidity densities dN/dy as a function of rapidity. Fig. 2 is a plot of dN/dy for $\pi^{\pm}$, $K^{\pm}$ and protons for pBe, pAu and central ^{28}Si + Au collisions. Note that for ^{28}Si + Au, the rapidity distributions for all particles have been divided by the number of ^{28}Si projectile nucleons (= 28). The rapidity distribution of K^+ differs significantly in shape and peak position from that of $\pi^{\pm}$ for central ^{28}Si + Au, even though they have similar shapes for pBe and pAu. In addition, dN/dy for $K^{\pm}$ increases more quickly than dN/dy for $\pi^{\pm}$ at all measured rapidities as one goes from pBe to central ^{28}Si + Au collisions. These facts strongly suggest that for heavy-ion collisions, $K^{\pm}$ and $\pi^{\pm}$ are produced via different mechanisms, presumably due to the presence of a large amount of nuclear matter.

2. E814

Brookhaven AGS Experiment 814 combines nearly complete 4π calorimetry with a high-resolution forward spectrometer. Details of the experimental setup may be found in reference 3. Data have been taken with a 14.6 A·GeV/c ^{28}Si beam on targets of Al, Cu and Pb in a program to investigate global energy flow as well as the simultaneous measurement of forward-going nucleon spectra ($\theta_{lab} < 1°$) in central relativistic heavy-ion collisions.

Energy flow is studied in a 992 element NaI(Tl) calorimeter surrounding the target and covering the pseudorapidity interval $-.5 < \eta < .8$. Distributions of transverse energy (E_T)

for the three targets are shown in Fig. 3. These data[3] have not been corrected for energy leakage due to the finite depth of the NaI(Tl) crystals. Superimposed on the data are spectra from the event generator HIJET[4] after tracking with the detector simulation program GEANT to properly include detector response and acceptance. Two separate HIJET predictions are shown for each target, representing the model with and without rescattering of the secondary particles within the target and projectile nuclei. The Pb target presents more opportunities for rescattering in spectator matter; HIJET can only reproduce these data if this process is included. The effect lessens, as expected, as the mass of the target decreases.

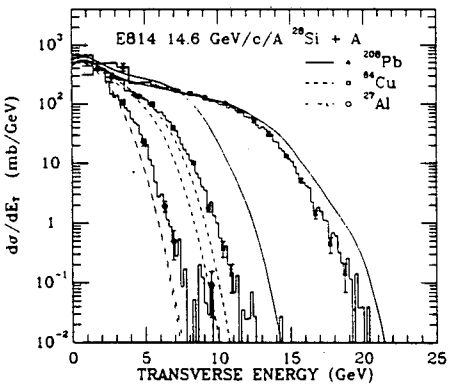


Fig. 3 Transverse energy (E_T) distributions[3] in the target calorimeter of E814 for ^{28}Si on Al, Cu and Pb. HIJET results are shown for each target with (upper curve) and without (lower curve) rescattering.

A more detailed picture of the collision may be obtained by studying the simultaneous distributions of forward-going nucleons. Reference 3 presents neutron rapidity distributions; the corresponding p_T spectra are shown here. E814 is unique in its ability to measure these distributions down to $p_T = 0$. Neutron kinetic energies and positions are measured in a series of six uranium-copper calorimeters.

Shown in Fig. 4 are $(1/p_T)(d\sigma/dp_T)$ distributions of neutrons[5] in three rapidity regions for ^{28}Si on Pb. The distributions include all events with $E_T > 6$ GeV in the NaI(Tl) calorimeter, approximately 20% of the geometric cross section. The data are corrected for the acceptance of the forward spectrometer which, due to the constant cone angle, varies as a function of rapidity. The top curve corresponds to projectile fragmentation and is consistent in shape with the corresponding rapidity distribution[5]. Both are accounted for by the Fermi momentum dis-

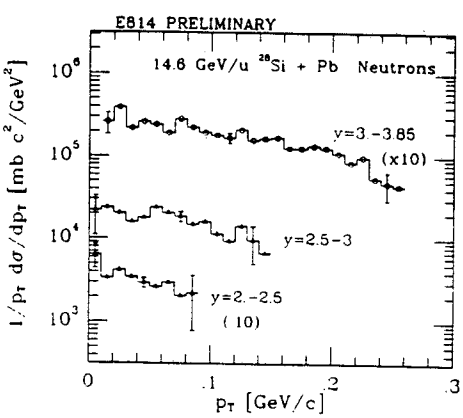


Fig. 4 Transverse momentum spectra of neutrons for ^{28}Si + Pb measured by E814[5] with E_T in the target calorimeter greater than 6 GeV, for various rapidity regions.

tribution of nucleons in the fragmenting ^{28}Si nucleus. The two lower distributions, corresponding to nucleons that have interacted strongly, show the flat behavior expected for thermal distributions as $p_T \rightarrow 0$. Plans are now underway to increase the spectrometer acceptance, thereby extending these spectra to higher values of p_T, where their shape is more sensitive to the detailed emission mechanism.

3. E810

AGS Experiment 810 uses a Time Projection Chamber[6] (TPC) to measure all charged tracks forward of $\theta_{lab} \simeq 20°$. The TPC contains 36 rows of short anode wires which give 3-D space points but no dE/dx information. The data presented here are from a short run with a ^{28}Si beam in June 1989 using thin (< 0.01 radiation lengths) Au and Cu targets to reduce contamination of the events by electrons from converted π^0 photons. A multiplicity cut of 50 or more TPC tracks was used to select central collisions, yielding 2291 Au events and 2170 Cu events, corresponding to cross sections of 0.59 and 0.20 barns, respectively. These were the "central" samples for the charged particle distributions presented here.

Assuming the pion mass for all negative tracks, we obtain the acceptance-corrected π^- rapidity distribution shown in Fig. 5. The Cu and Au π^- distributions are very similar. By computing the rapidity of all tracks using the proton mass and subtracting the negatives from the positives, we obtain an approximation to the proton rapidity distribution. This "difference" distribution is also shown in Fig. 5, plotted one decade lower for clarity. The "protons" emerging from Cu are substantially more forward than those from Au.

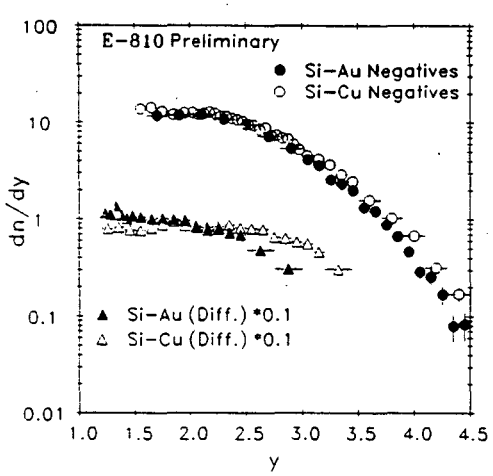


Fig. 5 Rapidity distribution of negatives (circles) and "difference" (scaled × 0.1), for ^{28}Si + Cu and Au.

In Fig. 6 the transverse momentum distribution $(1/p_\perp)(dn^2/dp_\perp dy)$ is plotted versus $m_\perp - m_o$. The pion mass is used for the negative spectra, the proton mass for the spectra obtained by subtracting the negatives from the positives. The negative spectra show substantial deviation from an exponential, unlike pion production in pp collisions in this energy region[7]. Since the electrons contribute less than 1% and the K^-/π^- ratio was measured by E802 to be about 4%[2], this effect represents an excess production of low $p_\perp$ pions in nuclear collisions.

The large aperture of the TPC detector yields a good acceptance for detecting Λ, $\bar{\Lambda}$ and K^0_s by the characteristic V^0 decay. We have reconstructed approximately 750 (850)

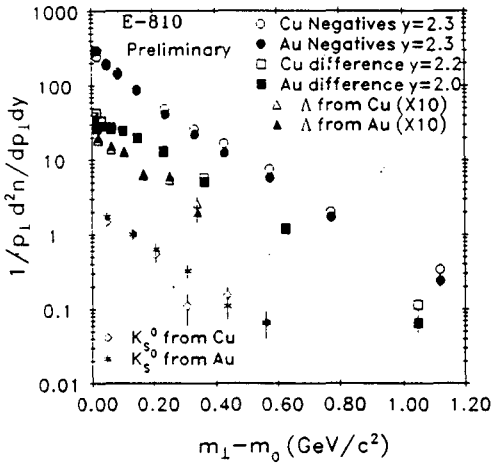


Fig. 6 Transverse momentum spectra of pions, protons, K_s^0 and Λ ($\times 10$), for ^{28}Si + Cu and Au.

Λ and 300 (400) K_s^0 from the Au (Cu) events[8]. The $m_\perp$ distributions for Λ's in the region $1.2 < y(\Lambda) < 3.0$ and K_s^0's in the region $2.2 < y(K_s^0) < 3.0$ are also plotted in Fig. 6. The Λ points are plotted one decade high for clarity. The V^0 data correspond to "central" events with no multiply-charged projectile fragments, as determined by a veto counter behind the TPC. Using a negative particle multiplicity cut to select events of yet greater centrality we measure a small sample with a net Λ yield of 1.9 ± 0.2 per ^{28}Si + Au event in our rapidity region. When we remove the Λ and the K_s^0 tracks, and plot the effective mass for the $\pi^+\bar{p}$ hypothesis, no detectable $\bar{\Lambda}$ signal is observed. With a 95% confidence upper limit, $n(\bar{\Lambda})/n(\Lambda) < 0.07$.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the support of the US Department of Energy, NASA, the US-Japan High Energy Physics Collaboration Treaty, and the National Science Foundation for this work.

REFERENCES

1) E802 Collaboration, T. Abbott et al. Nucl. Inst. and Meth. **290A** (1990) 41.

2) E802 Collaboration, T. Abbott et al. Phys. Rev. Lett. **64** (1990) 849.

3) E814 Collaboration, J. Barrette et al. Phys. Rev. Lett. **64** (1990) 1219.

4) T. Ludlam, A. Pfoh and A. Shor, RHIC Workshop, Experiments for a Heavy Ion Collider, Brookhaven National Laboratory Report 51921 (1985) 373; A. Shor and R. Longacre, Phys. Lett. **218B** (1989) 100.

5) R. Bellwied for the E814 Collaboration, "Baryon Spectra in the Low Pt-Region," *Proceedings of the Workshop for Heavy Ion Physics at the AGS*, ed. Ole Hansen, Brookhaven National Laboratory, March 1990, in print.

6) A. Etkin et al., Nucl. Instr. Meth. **283A** (1989) 557.

7) V. Blobel et al., Nucl. Phys. **69B** (1974) 454.

8) E810 Collaboration, Eiseman et al. Phys. Lett. **B**, in press.

LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
INFORMATION RESOURCES DEPARTMENT
BERKELEY, CALIFORNIA 94720