Title

Stopping and Two-Pion Bose-Einstein Correlation Results from CERN Experiment NA35

Author

Mitchell, J.T.

Publication Date

1994-08-01

LBL-36104
UC-414

Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

Presented at the the Eighth Meeting of the Division of Particles and Fields of the American Physical Society, Albuquerque, NM, August 2–6, 1994, and to be published in the Proceedings

Stopping and Two-Pion Bose-Einstein Correlation Results from CERN Experiment NA35

J.T. Mitchell and the NA35 Collaboration

June 1994

NUCLEAR SCIENCE DIVISION

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

LBL-36104
UC-414

To be published in the Proceedings of the
Eighth Meeting of the Division of Particles and Fields
of the American Physical Society
Albuquerque, New Mexico, August 2-6, 1994

Stopping and Two-Pion Bose-Einstein Correlation Results from CERN Experiment NA35

Jeffrey T. Mitchell
Lawrence Berkeley Laboratory
University of California, Berkeley, CA 94720

and

the NA35 Collaboration

June 1994

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

STOPPING AND TWO-PION BOSE-EINSTEIN CORRELATION RESULTS FROM CERN EXPERIMENT NA35

JEFFERY T. MITCHELL
Lawrence Berkeley Laboratory
University of California, Berkeley, CA 94720, USA
(and the NA35 Collaboration)

ABSTRACT

Two probes of relativistic heavy ion collisions at 200 GeV/A are discussed. The extent of nuclear stopping via measurement of "proton" rapidity distributions is presented as a function of centrality. The amount of stopping seen is consistent with what is expected from proton-nucleus data at similar energies. Also, two-pion Bose-Einstein correlations are presented as a function of rapidity and relative transverse momentum. These results are discussed in terms of a simple hydrodynamical model.

1. Introduction

The study of relativistic heavy ion collisions has primarily been concerned with searching for signatures of the creation of a quark-gluon plasma. To help achieve this goal, it is important to understand the dynamics of these collisions, which will provide information such as how hot and dense the nuclear matter becomes, or the extent of the space-time region of the particle production. To address these issues, the extent of nuclear stopping will be discussed by examining "proton" rapidity distributions for 200 GeV/A S+Au collisions. Also, the extent of the pion source in nuclear collisions at these energies will be presented by examining two-pion Bose-Einstein correlations.

The NA35 Collaboration at the CERN SPS employs two large acceptance tracking detectors (a 2 m streamer chamber within a 1.5 T analyzing magnet and a Time Projection Chamber (TPC) placed beyond the magnet) to detect charged hadrons. Central collisions covering the upper 6% of the total interaction cross section were selected with the use of calorimeters placed beyond the TPC. Minimum bias events were selected by a set of scintillators placed near the target requiring that an interaction had occurred.

2. Stopping

The extent of nuclear stopping in these collisions can be inferred from the rapidity shift of the incident nucleons. A larger rapidity shift is expected for a larger amount of stopping. “Proton” distributions are obtained using the TPC by subtracting negative hadron distributions from positive hadron distributions. The resulting transverse momentum spectra are divided into rapidity bins 0.2 units wide and corrected for acceptance, two-track resolution, and kaon contamination. The corrected spectra are fitted to the function $f(m_t)=A \exp(-m_t/T)$, where T is the inverse slope parameter. The dN/dy value is then obtained by integrating under the fitted curve over all m_t. Figure 1a shows the “proton” rapidity distribution for central collisions. Extrapolating this curve from y=3 to y=6 and calculating the mean rapidity shift yields a value of $<\Delta y>= -1.97\pm0.07$ for the 15.4±0.6 “protons” in this range. This is consistent with the value measured in 200 GeV p+A collisions [1]. Also shown are string model calculations of positive minus negative hadrons for the VENUS [2] and RQMD [3] models run with an impact parameter less than 2 fm showing good agreement with the data.

In order to study the evolution of the “proton” rapidity shift as a function of centrality, the minumum bias data was divided into three sets using the amount of energy deposited in the veto calorimeter (E_{veto}), which covered less than 0.3 degrees about the beam axis. These sets are labelled according to their relative impact parameter as “Low b” ($400\leq E_{veto}<2600$ GeV), “Mid b” ($2600\leq E_{veto}<4800$ GeV), and “High b” ($E_{veto}\geq4800$ GeV). The central data typically has an E_{veto} value of less than 1000 GeV. The “proton” rapidity distributions for these data sets are shown in Figure 1b. The mean rapidity shift of the data shown is -1.12±0.10 for “Low b”, -0.80±0.10 for “Mid b”, and -0.48±0.09 for “High b”, demonstrating the expected increase in rapidity shift as the centrality of the collision increases.

In order to compare the central data to that taken at other energies, a relative rapidity shift parameter, R(y), is defined as the measured rapidity shift divided by the difference in the beam rapidity and the participant center-of-mass rapidity. R(y) is plotted in Figure 2 for the data presented here, 14.6 GeV/A Si+Pb collisions measured by E814 [4], 100 GeV/A p+A data measured by CRISIS [5], and an extrapolation of p+A data to these energies [6]. When expressed in this manner, there is no significant difference between the relative rapidity shifts at AGS and CERN energies, and these values are consistent with what is expected by examining p+A data.

3. Two-Pion Bose-Einstein Correlations

Information about the physical extent of the source of produced pions can be inferred from the two-pion correlation function, which is the normalized ratio of the two-pion differential cross section to the product of two single-pion cross sections [7]:

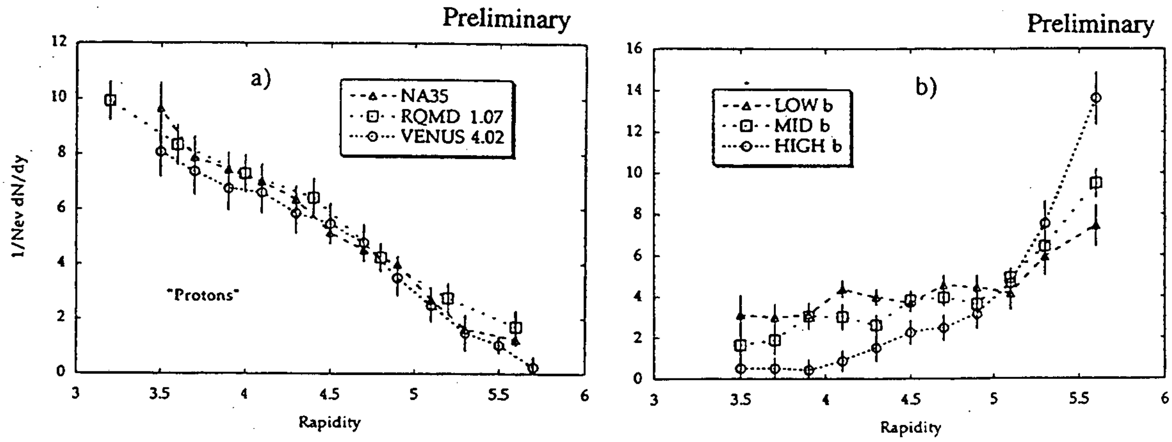

Figure 1. Rapidity distributions for "protons" in a) central and b) minimum bias 200 GeV/A S+Au collisions. Also shown are model calculations compared to the central data.

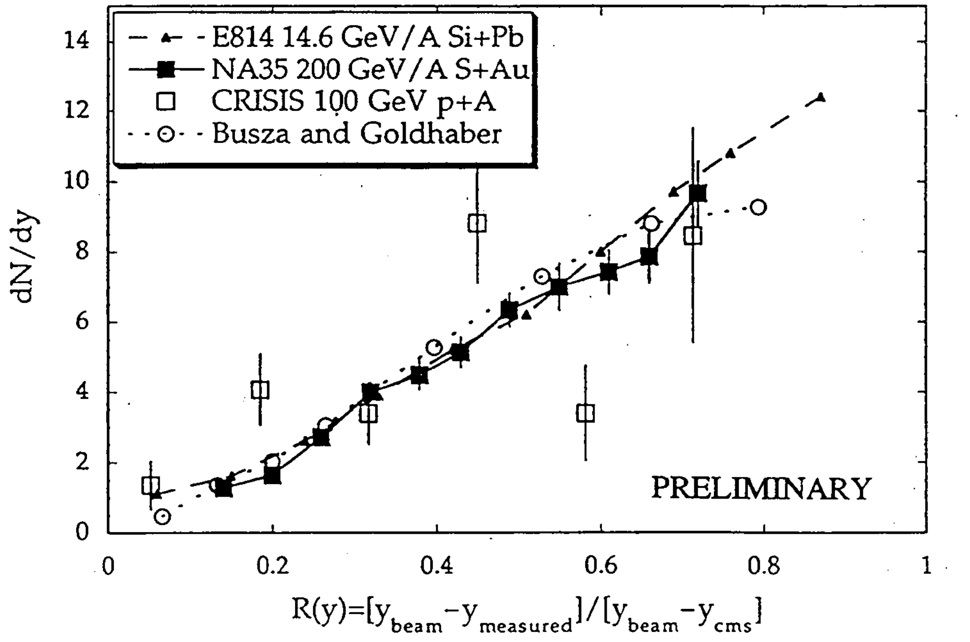

Figure 2. Relative proton rapidity shift from 200 GeV/A S+Au collisions compared to 14.6 GeV/A Si+Pb collisions, 100 GeV p+A collisions, and an extrapolation of p+A data to these energies [6].

$$C_2(p_1,p_2) = N\,[\sigma(p_1,p_2)/\sigma(p_1)\sigma(p_2)] = N^{pairs}(\text{signal})/N^{pairs}(\text{background}) \qquad (1)$$

Here, the numerator is the signal and the denominator is the uncorrelated background, which is determined by taking two pions of a pair from different events. For this discussion, the momentum difference vector of the pion pair is broken up into components that are parallel (Q_{long}) and perpendicular (Q_T) to the beam axis. Q_T can be further decomposed into components Q_{Tout} parallel to the pair transverse momentum vector and Q_{Tside} perpendicular to both the longitudinal and out vectors. These variables are determined as a function of the rapidity of the pair and their average transverse momentum, k_t. All correlation functions are corrected for two-track resolution, particle contamination, and the Coulomb repulsion of the pion pair. The respective radius components, (R_{long}, R_{Tout}, and R_{Tside}) can be determined by performing a three-dimensional Gaussian fit of the correlation function.

The rapidity dependence of the radius components is shown in Figure 3 for 200 GeV/A S+S, S+Cu, S+Ag, and S+Au collisions. R_{Tout} and R_{Tside} are approximately equal and independent of rapidity. R_{long} varies with rapidity in a manner proportional to the longitudinal Lorentz factor of the pair. Therefore, the pion source appears to be approximately boost invariant as expected in the scaling hydrodynamics scenario [8].

The transverse momentum dependence of the radius components are shown in Figure 4. R_{long} decreases with increasing k_t consistent with hydrodynamical model calculations [9] assuming an instantaneous decoupling time of the pions of 4 fm/c with T=150 MeV at the freeze-out time. The k_t behaviour can also be explained by a halo of pions from resonance decays [10]. The small difference in the values of R_{Tside} and R_{Tout} can be interpreted as a short duration of particle emission and evidence against a long-lived mixed phase resulting from a first order quark-gluon plasma phase transition.

R_{Tside} provides the best estimate of the source radius. For the systems shown, R_{Tside} is consistently 60% larger then the root-mean square transverse radius of the interacting nuclear matter.

2. Acknowledgements

This work was supported in part 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.

5. References

1. W. Busza and R. Ledoux, *Ann. Rev. Nucl. Part. Sci.* **38** (1988) 119.
2. A. von Keitz, et. al., *Nucl. Phys.* **A553** (1993) 799c.
3. H. Sorge, et. al., *Phys. Lett.* **B243** (1990) 7.
4. N. Xu, et. al., *Nucl. Phys.* **A553**, (1993) 785c.
5. W. S. Toothacker, et. al., *Phys. Lett.* **B197** (1987) 295.
6. W. Busza and A.S. Goldhaber, *Phys. Lett.* **B139** (1984) 235.

7. M. Gyulassy, et. al., *Phys. Rev.* **C20** (1979) 2267.
8. J. D. Bjorken, *Phys. Rev.* **D27** (1983) 140.
9. Y. M. Sinyukov, *Nucl. Phys.* **A498** (1989) 151c.
10. J. Bolz, et. al., *Phys. Lett.* **B300** (1993) 404.

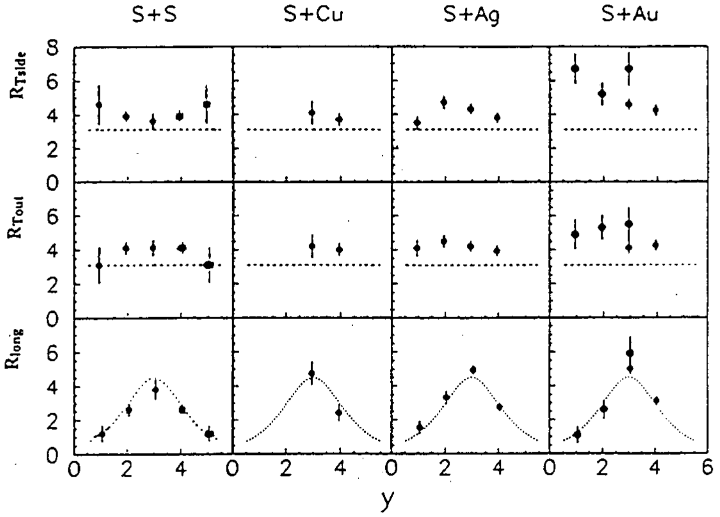

Figure 3. Rapidity dependence of the radius components for several systems. Dashed lines show the value $R_{Tside}=R_{Tout}=3.1$ fm corresponding to the transverse size of the projectile nucleus. The dotted lines are $R_{long}=1/\cosh(y-3)$ [8].

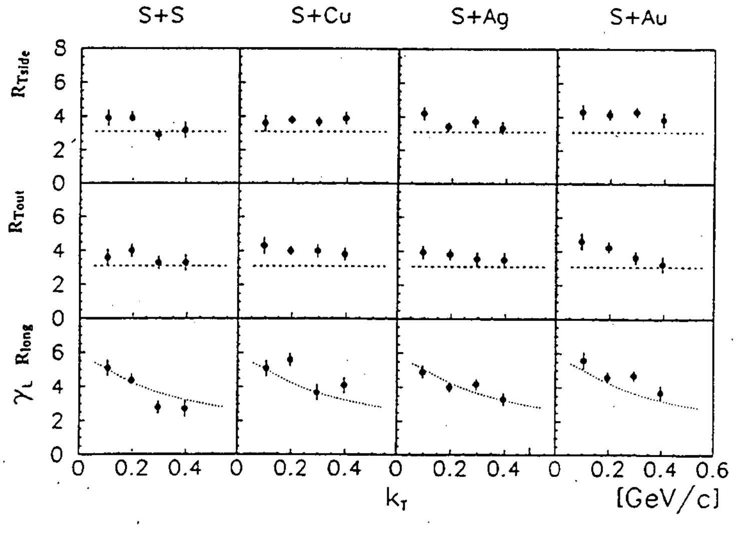

Figure 4. Dependence of the radius components on k_t for several systems over $3.5<y<4.5$. R_{long} is boosted to the reference frame corresponding to y=4.0. Dashed lines show the function $R_{Tside}=R_{Tout}=3.1$ fm. The dotted lines are fits to a simple hydrodynamical model with a freezeout time of 4 fm/c at T=150 MeV.

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