Abstract

Recent and preliminary single-particle data are presented from the AGS Experiment 866 at BNL. Emphasis is put on the transverse mass as well as the rapidity distributions of charged pions, kaons, protons, deuterons and anti-protons measured in the most central Au+Au collisions at an incident kinetic energy of 10.8 AGeV. The data suggest a high degree of stopping power present in these reactions. Applying an expanding fireball scenario to describe the experimental distributions substantial transverse and longitudinal flow velocities result.

1 Introduction

Heavy ion collisions at (ultra-) relativistic energies provide an unique tool to study the properties of nuclear matter far from its groundstate. New and exotic physics is expected to take place in violent collisions of very heavy ions like Au nuclei. These reactions are presently under study covering a huge range of incident energy. Experiment 866, installed at AGS/BNL, was specially designed to investigate Au+Au reactions in the energy regime of 10 AGeV [1]. The E866 spectrometers provide particle identification and momentum measurement for a variety of charged particles. Central reactions can be selected by means of an event characterization. In addition, a program of two-particle correlation measurements is pursued. Having briefly introduced the experimental setup, this contribution emphasizes on the recent and preliminary single-particle data of $\pi^\pm$, $K^\pm$, $p$, $\bar{p}$ and $d$ from the most violent Au+Au reactions at 10.8 AGeV incident kinetic beam energy. These data will be discussed in terms of transverse and longitudinal flow.

2 Experimental Setup

The experiment consists of three parts. First, a combination of several beam counters located before and after the target is used to monitor the beam qual-
ity and to provide the minimum bias and interaction trigger. Second, several global detectors provide the event characterization. Here, the zero-degree calorimeter was used to identify the most central collisions by requiring a minimal energy deposition of projectile nucleons in a cone around the beam axis with an opening angle of 1.5 degrees. The software cut to identify the most central collisions corresponds typically to trigger cross sections below 10% of the interaction cross section. Third, two separate magnetic spectrometers for particle identification and momentum measurement are used: the Henry Higgins (HH) and the Forward Spectrometer (FS) \[2\]. Both are equipped with sophisticated time-of-flight and tracking capabilities. The small solid angle of FS of 5 msr, compared to 25 msr of HH, allows to handle the high multiplicities at emission angles as small as 6 degrees in the laboratory. E866 achieves an optimum and unique phase space coverage by the interplay of both spectrometers. As a consequence rapidity distributions can be computed within \( y = 1.6 \pm 1 \) and even beyond depending on the particle species, taking advantage of the phase space symmetry in mass-symmetric reactions.

3 Preliminary Data from Central Au+Au Reactions

All data presented here are taken from ref. \[1\]. Figure 1, left, shows the kinetic transverse mass spectra at midrapidity for different particle species for the most central Au+Au collisions at 10.8 AGeV incident kinetic energy. The corresponding apparent temperatures (inverse slope parameters) are indicated. They range from 150 (\( \pi \)) to 280 MeV (d) and increase with increasing rest mass of the particle. Note, that the spectra of protons and charged pions significantly deviate from a Boltzmann distribution and a lower fit limit of 0.4 GeV/c\(^2\) in transverse kinetic energy was used. In addition, negative pions are more enhanced at low energies than positive pions. This indicates the influence of Coulomb effects caused by the charged nuclear matter. A quantitative analysis of this effect based on a static Coulomb source located at midrapidity is consistent with an overall ratio \( \pi^-/\pi^+ \approx 1.2 \) and an effective Coulomb boost of about \( \pm 9 \) MeV.

Figure 1, right, shows the rapidity distributions after integrating the spectra over transverse mass. For pions, protons and deuterons fit functions based on the sum of two exponentials have been used. The statistics for anti-protons is not sufficient to compute a rapidity distribution. One observes for central collisions that all distributions exhibit a maximum at midrapidity. The width of the distributions depends on the particle species and it is larger for protons and deuterons than for produced particles. The experimental ratio of negative to positive pions of 1.25±0.06 is almost independent from rapidity. The distinct broad maximum of the proton rapidity distribution suggests a high degree of stopping in central Au+Au collisions at this beam energy regime.
central Au+Au, 10.8 AGeV, E866

Figure 1: Left: Spectra at midrapidity measured in the most central reactions, plotted in a Boltzmann representation. Inverse slope parameters $T_B$ are indicated, resulting from fitting Boltzmann distributions to the spectra (solid lines). $\sigma_{inv} = d^2\sigma/(2\pi m_t dm_t dy)$. Right: Corresponding rapidity distributions, shown in one hemisphere only. Statistical errors only, systematic errors estimated to be $\pm(10-15)\%$. Depending on phase space coverage, data points are combined taking advantage of the symmetry around midrapidity.

This interpretation is supported by two observations: This maximum gradually changes to a pronounced minimum at midrapidity when reducing (i) the violence of the collision, or (ii) the combined mass of the projectile and target, compare to Si+Al [3] and p+p [4] reactions.

4 Transverse and Longitudinal Flow

The left part of fig. 2 summarizes the inverse slope parameters at midrapidity for different particle species, as a result from fitting Boltzmann distributions to the asymptotic high-energy part of the spectra, see fig. 1. The apparent temperatures exhibit a linear dependence on the particle rest mass, as it has been also observed at lower [3] and higher [3] incident energies. One may assume that the apparent temperature is proportional to the sum of the average thermal and radial flow kinetic energy. Based on that the fit shown in fig. 2 gives an estimation of the temperature of about 140 MeV and the flow velocity of about
Figure 2: Left: Apparent inverse slope parameters resulting from fitting Boltzmann distributions to the transverse mass spectra, as a function of the particle rest mass. Right: Proton $\chi^2$/dof surfaces, plotted as a function of the corresponding temperature and flow velocity parameter sets: from transverse mass spectra (upper part) and rapidity distributions (lower part). Arrows indicate the absolute minima.

These results are very similar to what has been analysed for Si+Au data in the same energy regime [7]. In the following a more sophisticated fitting procedure is taken to deduce the common parameter set temperature $T$, average transverse and longitudinal flow velocities $<\beta_t>$, $<\beta_l>$, respectively, from the measured transverse mass spectra and rapidity distributions. This method is described in ref. [8] and has been also used in ref. [6, 7]. These parameters characterize the reaction at freeze-out. The formalism describes an exploding fireball with an cylindrical rather than a spherical expansion profile to account for the possibility of a forward-backward asymmetry. It is assumed that the transverse and longitudinal motion of the thermal source are decoupled.

The procedure is applied to pions, positive kaons, protons and deuterons. The strategy is to explore the parameter space for each particle species in the transverse and the longitudinal degree of freedom, i.e. transverse mass spectra and rapidity distributions, independently, and to compare the final $\chi^2$-surfaces. In contrast to ref. [7] the temperature is not deduced from experimental particle
ratios, but results from the fitting procedure. The transverse velocity profile was chosen to depend linearly on the radius and its average value results from integration over the profile, assuming a freeze-out radius of 6.5 fm. Within the given errors the fit results do not significantly depend on the choice of the freeze-out radius and the velocity profile. A lower fit limit of \( m_t - m_0 = 0.4 \text{ GeV}/c^2 \) was introduced for the pion spectrum to minimize the influence of resonance contributions on the results. The average longitudinal velocity is deduced from the limits of the rapidity interval within which the individual thermal sources are distributed and superimposed.

The right part of fig. 2 shows the corresponding \( \chi^2 \) surfaces for fitting the proton transverse mass spectrum (upper part) and rapidity distribution (lower part). The arrows indicate the absolute minima which are not very pronounced along the valleys. Temperature and transverse flow velocity are anti-correlated, whereas temperature and longitudinal flow are almost decoupled. In order to find a common parameter set, the corresponding projections of the \( \chi^2 \) surfaces of the different particle species are overlayed. An overlapping region for all particles exists for the transverse degrees of freedom, and hence, a common set of temperature and average transverse flow velocity can be deduced. The results for the longitudinal degrees of freedom are not that promising. The maximum of the positive kaon rapidity distribution turns out to be too pronounced in order to agree with a longitudinal flow scenario with substantial flow. On the other hand, the width of the deuteron distribution appears to be too large to deduce a common velocity for deuterons and protons. Besides from that the following common data set represents a fair compromise:

\[
T = (127+10-15)\text{MeV}, \quad <\beta_t> = 0.39\pm0.05, \quad <\beta_l> = 0.50\pm0.10-0.05.
\]

The error bars are deduced from the size of the overlap region of the \( \chi^2 \)-surfaces. Figure 3 summarizes the fit results for the common parameter set (solid lines) and the individual best fits (dashed lines).

5 Summary
Recent and preliminary data from E866 at AGS/BNL are presented. The data from both E866 spectrometers have been successfully combined to cover a huge portion of the phase space for a variety of particle species. Focusing on midrapidity transverse mass spectra and rapidity distributions a flow analysis was performed. The resulting temperature and average flow velocities agree with the trend suggested by the corresponding analysis at different energy regimes.

References
For details on the experimental program and results of E866 see the most recent Quark Matter (Y. Akiba, M. Baker) and HIPAGS (Z. Chen, K. Ashktorab, H. Sako, F. Wang, K. Kurita, L. Ahle) contributions 1996.

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