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COULOMB EFFECTS IN CHARGED PARTICLE SPECTRA FROM HEAVY ION COLLISIONS AT AGS AND SIS *

C. Müntz

for the E802/E866 and KaoS Collaborations

University of Frankfurt
69 I Darmstadt, Germany

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Data from the AGS experiment E866 on charged particles emitted in central Au+Au collisions at 10.8 *A*GeV incident energy is reviewed. The study of spectral shapes indicates the presence of collective transverse flow and — in particular for charged pions — of Coulomb final state interaction between emitted particles and the nuclear charge distribution. The comparison to SIS pion data measured with KaoS elucidates the role of charged pions to probe nuclear reaction dynamics at lower incident energies.

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1. Experimental results at 10.8 *A*GeV incident energy

Experiment 866, installed at AGS/BNL, was designed to investigate Au+Au reactions in the energy regime of 10 *A*GeV [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. Figure 1 summarizes recent, partly preliminary results studying central Au+Au collision at 10.8 *A*GeV bombarding energy [2]. The rapidity distributions depicted on the right panel demonstrate the large phase space around midrapidity covered by the experiment. The distributions of protons and charged mesons are peaked at midrapidity, deuterons exhibit a rather flat distribution. The protons pile up at midrapidity confirms the expectation of a large amount of stopping and the concomitant expectation of high baryon density in central Au+Au collisions.

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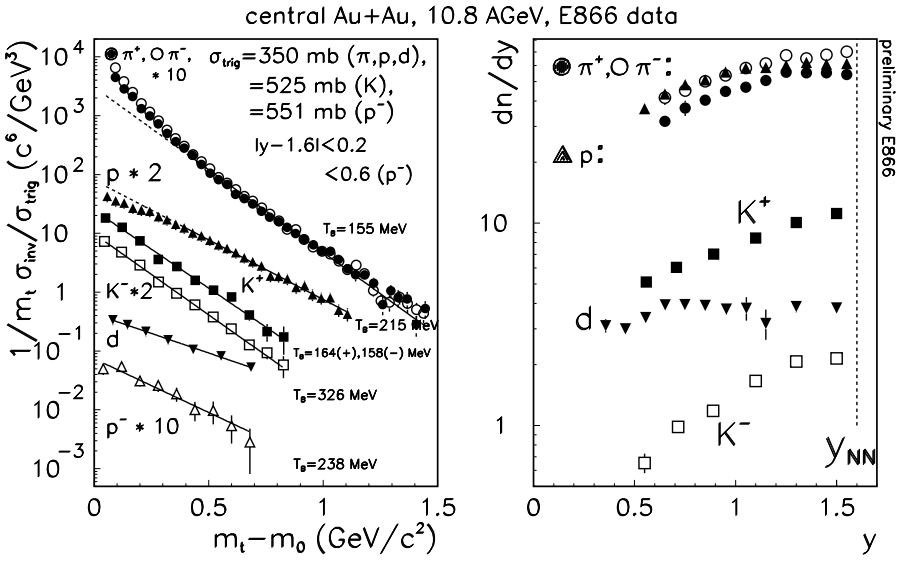


Fig. 1. Data from E866. Left: Boltzmann representation of spectra measured around midrapidity in central Au+Au collisions. T_B denotes the inverse slope parameter. Right: rapidity distributions, shown in one hemisphere. Besides pion and proton distributions data is preliminary. Statistical errors only, systematic errors estimated to be $\pm(10-15)\%$.

Corresponding m_t spectra of particles emitted at midrapidity are plotted on the left panel in a way that thermal spectra would appear as a straight line. Studying the inverse slope parameters T_B of the spectral distributions an almost linear increase of T_B with the particle mass results. The inverse slope parameters of the heavier particles can hardly be described within a thermal picture alone. Similar observations have been made at SPS energies [3].

The mass dependence of T_B suggests taking into account flow effects. Accordingly, the data presented here have been analyzed in transverse direction assuming an exploding fireball scenario [4]. A common freeze-out temperature of 127^{+10}_{-15} MeV and an average transverse flow velocity $\langle\beta_t\rangle = 0.39\pm0.05$ results which fits to a trend given by similar analysis in the SIS/BEVALAC and SPS energy regimes.

Most recently, preliminary data on charged particle production measured by E866 and E917 in the energy range between 1 and 10 AGeV has become available [5]. Their analysis will systematically complete the gap in incident energy between SIS/BEVALAC and AGS.

2. Charged particle ratios and Coulomb effects

Positively and negatively charged pions exhibit a significant difference at low m_t, already visible in the compressed scale of Fig. 1, left panel, in addition to their common low-m_t enhancement. Figure 2 studies this difference in detail, and for different reactions, including all available data

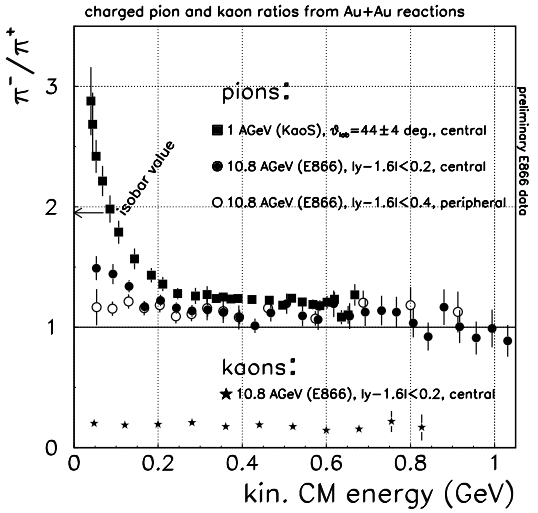


Fig. 2. Energy differential ratios of spectral distribution of positively and negatively charged pions and kaons at 1 and 10.8 AGeV incident energy [6, 2]. Preliminary data, besides the pion data at central reactions. Statistical errors only.

[2, 6] at 1 and 10.8 AGeV incident energy. The following observations can be made:

(i) The π^-/π^+ ratio rises at low pion CM energies for central Au+Au collisions both at 1 and 10.8 AGeV [1].

(ii) The high-energy asymptotic value of this ratio, beyond 400 MeV, levels off close to one.

(iii) The ratio of pions from peripheral reactions at 10.8 AGeV does not depend on the pion energy. It agrees with the integrated negative to positive pion ratio of 1.20±0.15 measured at central collisions.

(iv) The ratio of charged kaons does not depend on the kaon CM energy. And most important,

(v) the low-energy rise of the pion ratio is most pronounced at 1 AGeV, exceeding the isobar value of 1.95 which reflects the N/Z asymmetry

[1] Hyperon decays can be excluded causing this effect at 10.8 AGeV.

of the colliding system. It is intriguing to note that the measured integrated negative to positive pion ratio is 1.9 ± 0.1 at this incident energy.

These observations point to the presence of significant Coulomb final state interactions between emitted charged pions and the remaining nuclear charge distribution. Hence, data are analyzed in the framework of a static Coulomb source resting at midrapidity [7], giving rise to a distortion of spectral distributions due to both a momentum shift and a change of the momentum phase-space density. The assumption of a static scenario is motivated by considering pions with kinetic CM energies above 60 MeV only. The corresponding CM velocities ($\beta_{\mathrm{CM}} > 0.7$) are significantly larger than the expansion velocity of the nuclear fireball ($\beta_t < 0.45$ [4]).

At AGS energies the pion spectra and the corresponding ratio can be well described within this static scenario, yielding a rather moderate Coulomb energy of 9 ± 3 MeV. The corresponding Coulomb potential does not affect the charged kaons within the experimental acceptance. Similar results consistent with a moderate effective Coulomb potential have been reported for SPS data [8]. In contrast, using the same static approach to describe the SIS data fails. An detailed analysis [6] including pion energy dependent Coulomb energies suggests, that low-energy pions feel rather moderate Coulomb forces at freeze-out, while high-energy pions, which are produced well below nucleon–nucleon threshold at 1 AGeV incident energy, are exposed to a rather high Coulomb potential above 20 MeV when freezing-out.

In Ref. [6] the variation of the Coulomb energy with the pion CM energy is interpreted as an experimental evidence for different freeze-out radii of high- and low-energy pions emitted in central Au+Au collisions at 1 AGeV: low-energy pions are emitted predominantly from a more dilute nuclear charge distribution with consequently larger effective freeze-out radii compared to high-energy pions, emitted from a more compact source.

Refined model calculations [9] support this interpretation and suggest that charged pion spectra probe the dynamics of nuclear expansion in relativistic heavy ion collisions. In particular at low incident energies, different freeze-out radii can be linked to pion emission during different stages of the reaction. Whereas low-energy pions are emitted later during expansion, high-energy pions freeze-out early [10], still at a time where the nuclear density is enhanced and multiple baryon-baryon collisions preferentially trigger the production of energetic subthreshold pions and kaons. In contrast, the comparably weak signal of charged pion ratios at higher bombarding energies indicates, that the Coulomb source disintegrates fast compared to the time scale of pion emission. Consequently, the extracted Coulomb energy represents an averaging over reaction dynamics.

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