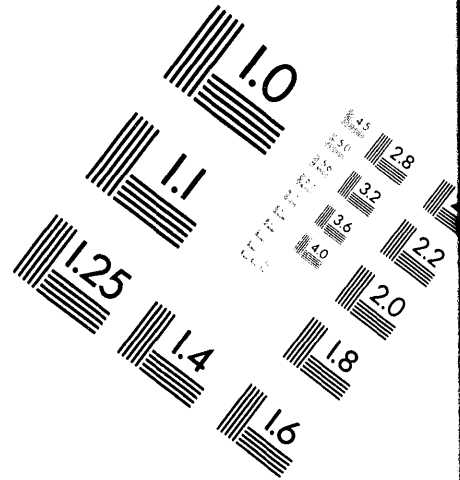
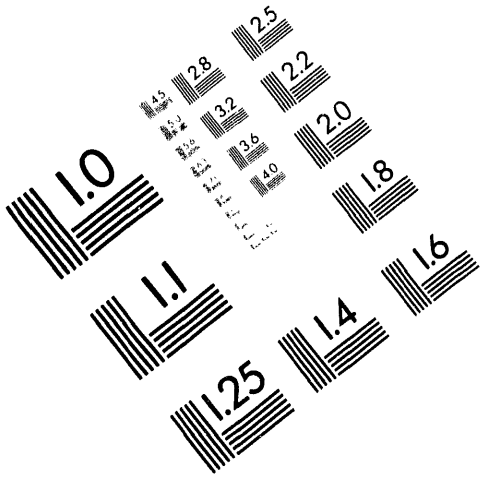




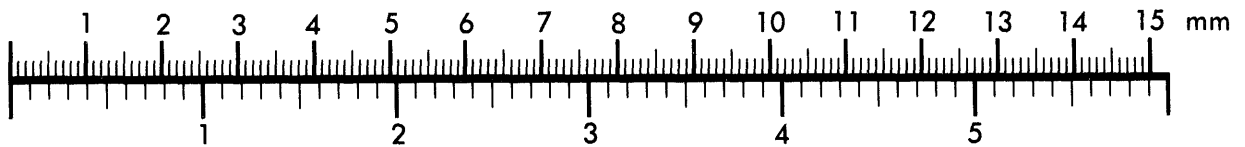
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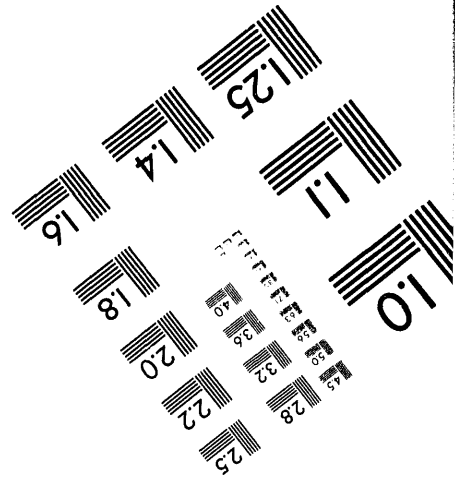
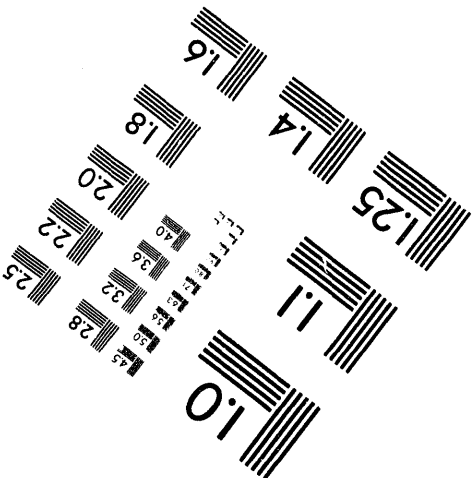
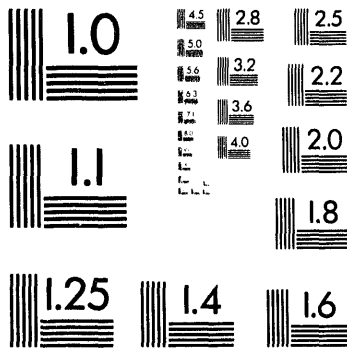
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Low p_t Pion Enhancement in $^{28}\text{Si} + \text{Pb}$ Collisions at 14.6 A GeV/c

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1. INTRODUCTION

The pion is produced copiously in nucleus-nucleus collisions at AGS energies and is expected to be easily thermalized due to its large cross section for interaction in dense nuclear matter. Pion enhancement at low transverse momentum has been predicted as the result of a variety of processes. For example, the decay of the $\Delta(1232)$ resonance is expected to be a major source of such enhancement and has been proposed as an alternative measure of the system temperature.¹ The nucleons and pions produced as the daughters of the Δ share their parent's energy and thereby produce a "cold component" in the pion spectrum. The delta resonance is believed to be a major contributor to the imaginary part of the scattering amplitude of the pion in dense baryon rich matter. The real part of the scattering amplitude of the pion in medium can be related to an attractive mean field potential.² Upon exit from the collision zone, a pion must climb out of this potential and will thereby be "cooled". At sufficient density, many low energy pions could become trapped in the mean field leading briefly to a pion liquid state which would also populate the low $m_t = \sqrt{p_t^2 + m_\pi^2}$ region.² Additionally, a diminishing of the quark condensate as one approaches chiral restoration³ would be expected to produce an enhancement as "light" mesons dress themselves to their free masses upon exit from the medium. Non-equilibrium effects leading to a finite pion chemical potential have also been shown to create low p_t enhancement.⁴ For all these reasons, the study of pion (and other hadron) spectra at or near zero transverse momentum provides a sensitive tool for understanding the dynamics of the hot collision zone. First indications for low p_t enhancements have been observed for negatively charged particles⁵ at the AGS and for negatively charged particles,⁶ negative hadrons,⁷ and neutral pions⁸ at CERN. For a review, see the contribution of J. Simon to these proceedings. Here we present first results on identified pion spectra from AGS experiment E814.

2. PION SPECTRA

Figure 1 shows a summary of the π^- spectra resulting from 14.6 GeV/c per nucleon $^{28}\text{Si} + \text{Pb}$ central (upper 2%) collisions. The data shown are $m_t - m_\pi$ spectra for different bins in rapidity, successively multiplied by factors of 10. The vertical axis is $1/m_t \times \sigma_{inv}$, the representation in which a Boltzmann distribution is a pure exponential. Our acceptance in m_t is broadest for rapidities $3.0 < y < 4.0$. The measurable range in m_t is limited by geometry at low y and particle identification at high y . The solid curves

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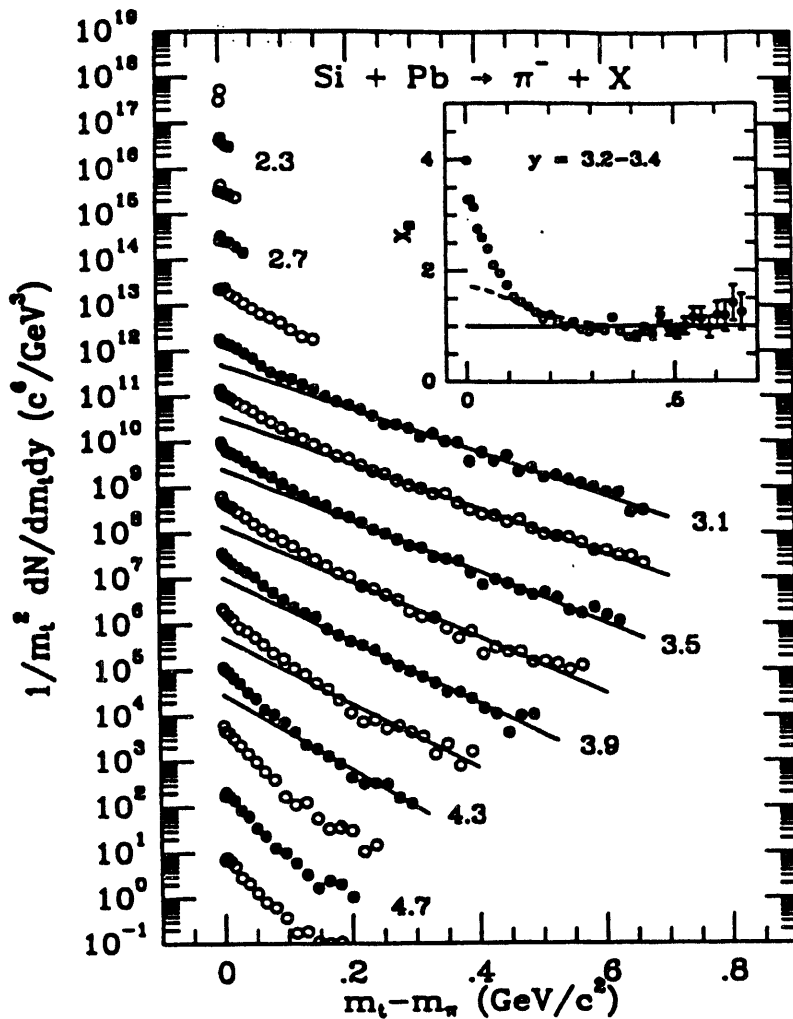


Fig. 1: π^- Pion spectra for central ($\sigma/\sigma_{geo} = 2\%$) Si + Pb collisions in different rapidity intervals. Starting with $y=4.7$, the data in each successively lower y bin has been multiplied by increasing powers of 10. Shown in the inset are the ratios: Data/Boltzmann (points) and m_t exponential/Boltzmann (dashed line).

not shown in Fig. 2 and the π^+ spectra). ARC also accounts for the data well, although it underpredicts the data at the lowest m_t and overpredicts at high m_t . The main source of the rise at low m_t in both of the cascade models is the decay of the $\Delta(1232)$ resonance.

3. Δ^{++} PRODUCTION

The excellent agreement between the data and the cascade model calculations implies that the majority of the enhancement could be attributed to the decay of the $\Delta(1232)$ resonance. To further test this hypothesis we have reconstructed the Δ^{++} via its decay to $p\pi^+$. This is the most easily measured of all Δ decays since (i) its branching ratio is nearly 100%, (ii) all particles in the final state are charged, and (iii) there is no interference from the nearby Λ decay (which could disturb Δ^0 measurements). Additionally, the charge asymmetry of the E814 spectrometer acceptance makes it best suited for like-sign measurements.

show Boltzmann fits to the interval $m_t - m_\pi > 200$ MeV/c. The data exhibit a significant enhancement over this functional form at low m_t . This can be seen most clearly in the small inset which shows the ratio of the data to the thermal fit on a linear scale. The dashed line demonstrates that the data rise even faster than $\sigma \sim e^{m_t/T}$. Results for π^+ (not shown) show enhancements of the same strength as π^- . The strength of the enhancement does not vary with centrality in the range $0.1 \times \sigma_{geo} - 0.02 \times \sigma_{geo}$.

Figure 2 shows a comparison of the RQMD⁹ and ARC¹⁰ models to the data. Neither the data nor the models are scaled in any way. These models include contributions from the $\Delta(1232)$ and other resonances. To compare model predictions to the data, the experimental trigger condition was applied to the former. RQMD reproduces all our pion data quantitatively (including the rapidity bins

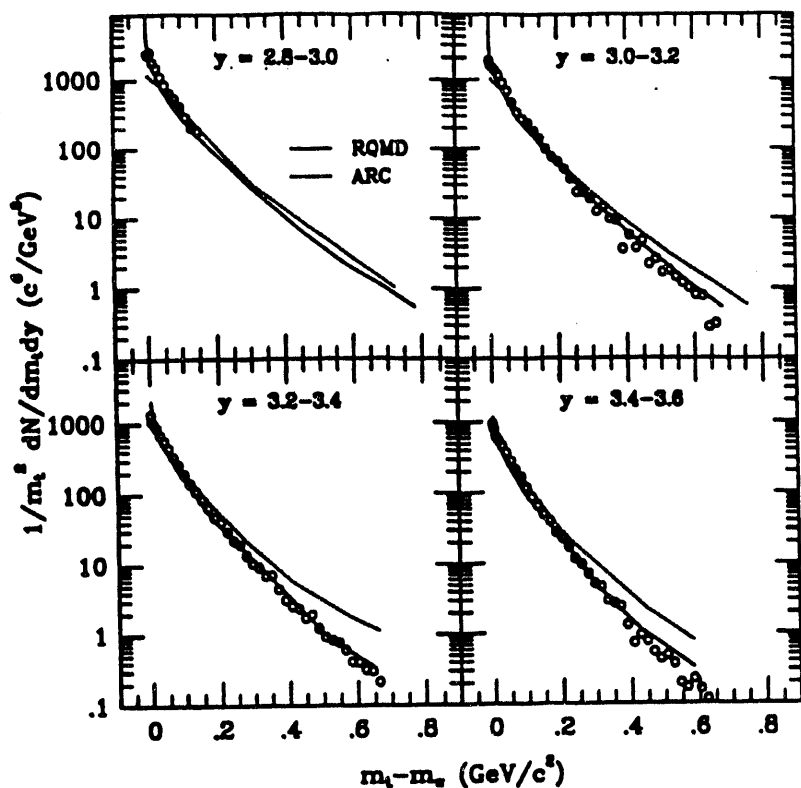


Fig. 2: Pion spectra for central ($\sigma/\sigma_{geo} = 2\%$) Si + Pb collisions together with calculations from the RQMD and ARC models.

shape of the combinatorial background by constructing an invariant mass spectrum using protons and pions from different events. The resulting distribution is normalized to the true pair spectrum and subtracted away. The solid and dashed curves in the figure show our results for the true pair invariant mass (M_{inv}) distribution and the normalized background distribution respectively.

To normalize, we treat the combinatorial spectrum as an analytic function of a single free parameter, the normalization constant. This function is fitted to the high mass end ($M_{inv} > M_1$) of the true pair spectrum, choosing that normalization constant which minimizes χ^2 . The net Δ^{++} yield was shown to not differ beyond statistics using M_1 values in the range $1.4 < M_1 < 1.8 \text{ GeV}/c^2$. Lower values of M_1 result in over-subtraction and higher values suffer from statistical uncertainties.

The robustness of the analysis procedure was tested via Monte Carlo analysis. A "negative test" data sample of uncorrelated proton-pion pairs was generated using the measured single particle distributions. Analysis of these data show no Δ signal. Additionally, a "positive test" was performed on RQMD-generated events to verify that the Δ resonance is observed correctly there.

The subtraction procedure described above is quite delicate. Small changes in the background normalization constant produce large changes in the overall measured yield. The results shown in this manuscript represent the state of a continuing analysis at the time of the writing. Although the results appear to be robust against all our tests we consider them to be very preliminary.

The M_{inv} spectrum of $p\pi^+$ pairs after background subtraction is shown in the top

The invariant mass for $p\pi^+$ pairs was reconstructed for central (top 2 %) collisions. Protons near beam rapidity ($y \geq 3.1$) were rejected from the sample since they are in part projectile fragments. Pions below rapidity 3.0 were rejected since the Δ decay kinematics do not permit such pions into the 814 acceptance using the above proton cut.

Figure 3 shows a summary of our measurement of the Δ^{++} using $p\pi^+$ pairs. The analysis follows the standard "mixed events" technique. This method allows one to separate a small signal from the large background formed by combinatorics of uncorrelated pairs. In this method one determines the

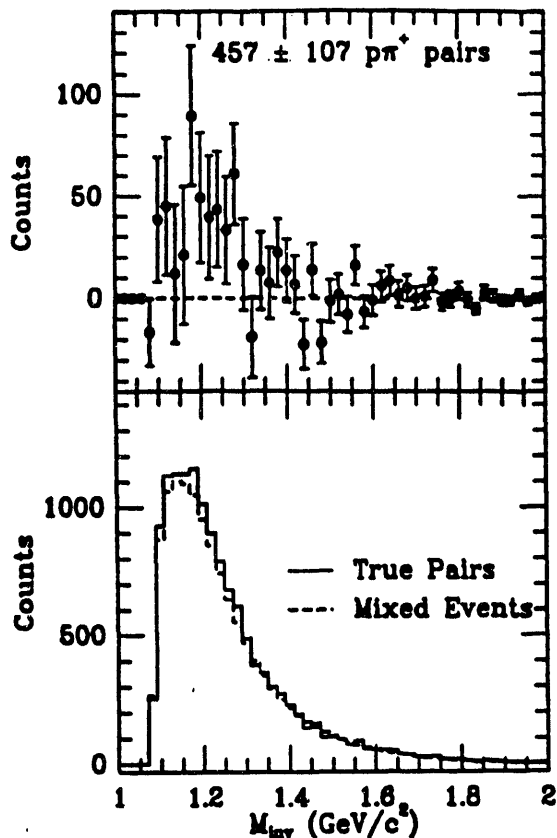


Fig. 3: π^- spectra for central ($\sigma/\sigma_{geo} = 2\%$) Si + Pb collisions together with calculations from the RQMD and ARC models.

panel of Figure 3. The total yield into the E814 acceptance for $\sim 2.52 \times 10^5$ central collisions is $457 \pm 107 \Delta^{++}$.

For a central Si + Au collision RQMD predicts¹¹ 17.2 Δ^{++} , 20.2 Δ^+ , 22.2 Δ^0 , and 23.2 Δ^- at freezeout. We have simulated the E814 acceptance for Δ^{++} by sampling a rapidity distribution as in RQMD and a p_t spectrum which follows that of the nucleon. Under these conditions, 1.61×10^{-4} of all produced Δ^{++} fall into the experimental acceptance. Using this and an overall reconstruction efficiency of $(0.75)^2$ our measurement implies $20.0 \pm 4.7 \Delta^{++}$ per central Si+Pb collision in close agreement with the RQMD prediction. The pion spectrum can also be described well by a model which includes thermal excitation of nucleon resonances using a temperature close to 150 MeV. (see J. Stachel, these proceedings).

The same concentration of freezeout Δ 's simultaneously explains our pion enhancement and the measured yield of Δ^{++} . Calculations of the resonance population inside the hot collision zone in the RQMD model¹¹ show that the density of resonances can exceed the density of nucleons and that for significant periods of time in the compressed zone the density of resonances alone exceeds nuclear matter density. Such a state has been referred to by some as "Delta-Resonance Matter" or simply "Resonance Matter" (see H. Stöcker, these proceedings). The predicted density for Au+Au collisions at AGS energies exceeds $8 \times$ normal nuclear matter density over finite sizes and times.

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