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PARTICLE PRODUCTION AT HIGH $p_\perp$ IN ^{28}Si+A COLLISIONS AT 14.6 A·GeV/c

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ABSTRACT

Single particle inclusive spectra are presented for particle production in Si+Al and Si+Au reactions at the nucleon-nucleon center-of-mass rapidity for projectiles incident at 14.6 A·GeV/c. The invariant cross sections are all well described by an exponential dependence in the transverse mass $m_\perp$. An analysis in terms of different components in $p_\perp^2$ shows the importance of resonance production and decay as a reaction mechanism at AGS energies.

1. Introduction

The goal of experiment E802 at the Brookhaven AGS is to measure semi-inclusive particle spectra at mid-rapidity. Data have now been analyzed that extend the range in transverse momentum out to values near the kinematic cut-off for nucleon-nucleon scattering. These data shed important insights into the mechanism for particle production at these energies and help address the question whether new reaction mechanisms emerge in relativistic heavy-ion collisions. The work discussed here is largely the result of the Ph.D. thesis work of Brian Cole.[1] These data reported here are just a part of the overall E802 program; some of the data at lower $p_\perp$ are presented in Ref. 2. A second-level trigger has now been implemented (E859) in order to provide event selection of rarer type events, such as K^- production and K^+K^+ correlations. We hope for some running with Au projectiles (E866) already in Spring, 1992.

There are several reasons why the study of particle production at high $p_\perp$ ($= p\sin\theta$) is interesting. Hard scattering processes are more important at high $p_\perp$. Thus, in this region, we may be studying different dynamical features of the reaction. Multiple collisions are needed to reach beyond the kinematical limits for particle production from single N-N collisions. It has been proposed[3] that such multiple collisions are an important mechanism for producing strange mesons (kaons). A measurement of the production strength in this region could experimentally determine if such multiple

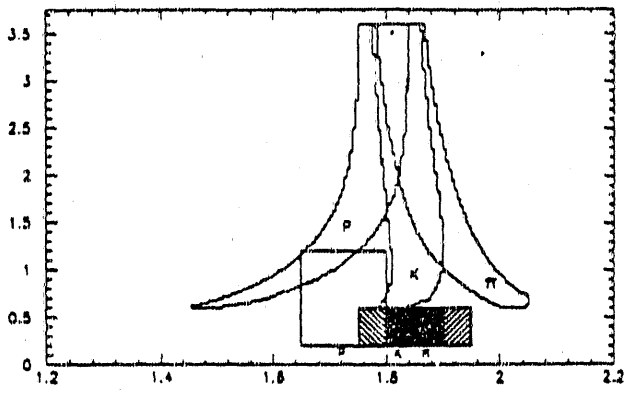

Fig. 1: The acceptance in $p_\perp$ (ordinate) and rapidity (abscissa) for the ČC. The boxes indicate the acceptance for the low $p_\perp$ points included in the figures.

collisions are indeed an important contribution to the cross section. Finally, there may be new processes apparent in A+A collisions that are not seen in p-p collisions, and the high $p_\perp$ part of the spectra may be the best place to see them. For example, the intrinsic momentum distribution of the the nucleons in nuclei gives rise to a smearing of the baryon momentum spectra out to higher $p_\perp$.

2. The Experiment

The data were obtained using a small solid-angle spectrometer arm, the Čerenkov complex (ČC) of three tanks,[4] each with pressurized Freon, in conjunction with the main E802 Spectrometer.[5] This apparatus was built and assembled at Brookhaven by the Institute for Nuclear Study at Tokyo University and an analysis of some early data has already been performed.[6] The acceptance for pions, kaons and protons with the ČC is shown in Fig. 1. Note that the rapidity acceptance is centered near the nucleon-nucleon center-of-mass rapidity y_{NN} of 1.7. Extensive Monte-Carlo calculations have been performed to determine the spectrometer acceptance and efficiency. The cross sections have been corrected for the geometrical acceptance and for losses due to particle decays, multiple Coulomb scattering, and hadronic absorption. Fig. 2 shows the invariant cross sections as a function of $p_\perp$, near mid-rapidity, for Si collisions with Al and Au targets. The pion cross-section values are the average of the π^+ and π^- values, which agree within experimental errors. The kinematic limits for production of various particles are indicated. Only for protons do the data extend well beyond the limit. However, there is no apparent change in the exponential decrease in the cross sections even near the kinematic limits, as one would expect if phase space restrictions were coming into play. Note that the data for pions are well fit by an exponential distribution over 5 orders-of-magnitude in cross section.

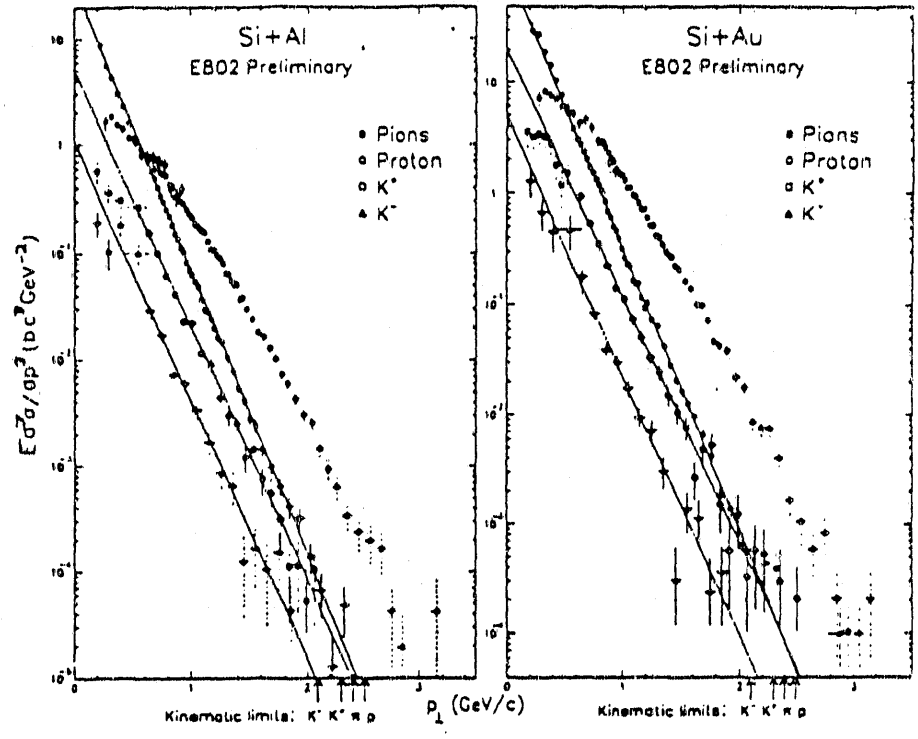

Fig. 2: The inclusive invariant cross-sections for emitted particles near y_{NN} from Si+Al and Si+Au reactions, shown as functions of $p_\perp$. The lines are only intended to guide the eye.

3. Interpretation

The roll-off in the cross-sections at low $p_\perp$ indicates that the data may be better described by an exponential in transverse mass, where

$$m_\perp = \sqrt{p_\perp^2 + m^2}. \tag{1}$$

The same data as in Fig. 2 are now shown plotted as a function of transverse kinetic energy, $m_\perp - m$, in Fig. 3. We see that all the data are well described by this simple exponential dependence, except for some enhancement at low $m_\perp$ for pion production with the Au target. This observed exponential dependence with $m_\perp$ is similar to what is observed in p-p collisions, albeit that the observed slopes with Si beams are different for the different produced particles, whereas the slopes are all similar in p-p reactions ($T \approx$ 150-160 MeV). Note also that an exponential dependence in $m_\perp$ does not imply a thermal (Boltzmann) fit. A thermal description of the spectra would yield a form of the invariant cross-section with a leading $m_\perp$ factor, namely

$$E \cdot d^3\sigma/dp^3 = A\, m_\perp \exp(-m_\perp/T). \tag{2}$$

Alternatively, at AGS energies it is known that excitation and decay of baryonic and mesonic resonant states is a major channel for p-p reactions. It has been observed

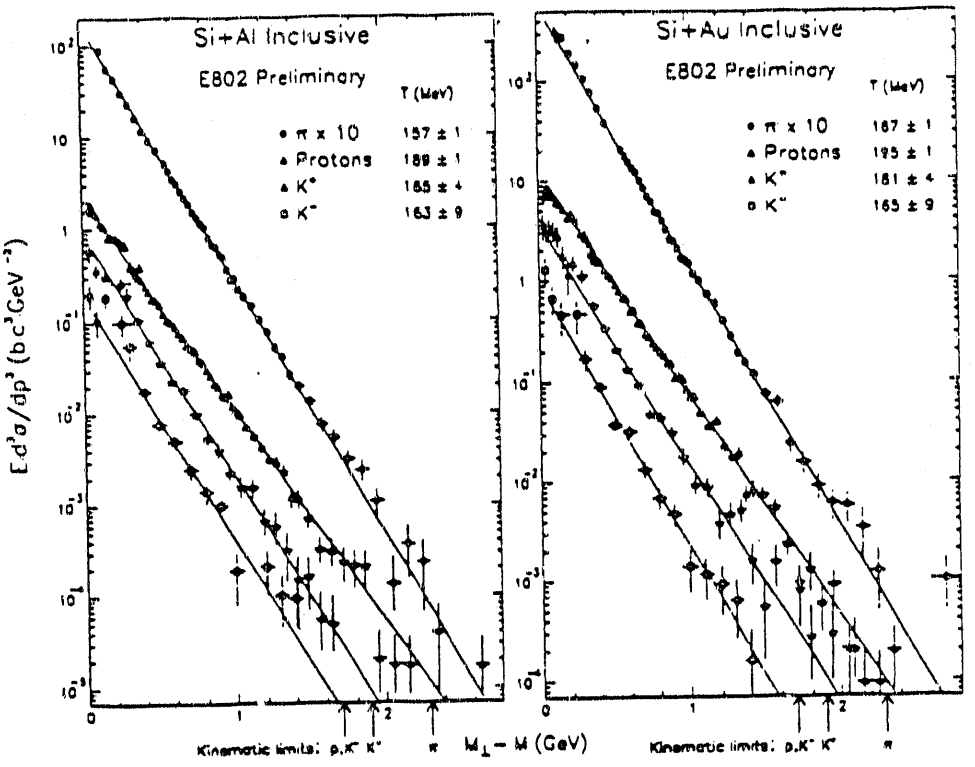

Fig. 3: The same data shown in Fig. 2 now shown as functions of transverse kinetic energy. The lines show exponential fits in $m_\perp$. Note that the pion data are shown multiplied X10 for clarity.

that the pion decay of these resonant states can be described by an exponential dependence of the invariant cross section in $p_\perp^2$. That the spectrum contained different components was already seen in the early work (1969) of Day *et al.*[7] Fig. 4 shows the more recent work of Bakken *et al.*[8] for p-n reactions at 19 GeV/c incident energy, comparing inclusive pion production to pions observed from the specific decay of the baryonic resonance $\Delta^{++}(1232)$ and the mesonic resonance ρ^0. The inclusive spectrum breaks up nicely into the two resonant components. The authors suggest that these resonances may not be the only ones which contribute, but that in general the decay of the baryonic resonances will be similar to the $\Delta^{++}(1232)$ and the decay of the mesonic resonances will be similar to the ρ^0. There is also a third component with flatter slope that sets in above ≈ 1.2 (GeV/c)^2.

In a similar spirit we have looked at pion production in very peripheral Si+Al reactions, where the event selection was made by selecting on the forward energy in the range 300-400 GeV, as observed in the forward calorimeter. This calorimeter subtends an 0.8 degree cone about the beam axis. Fig. 5 shows these data and fits to them, for the three components observed in p-p reactions. The fitted slopes are similar to those observed in the p-p data, as seen in Table 1. Now taking these three components, keeping the same slopes, and only adjusting the relative strengths

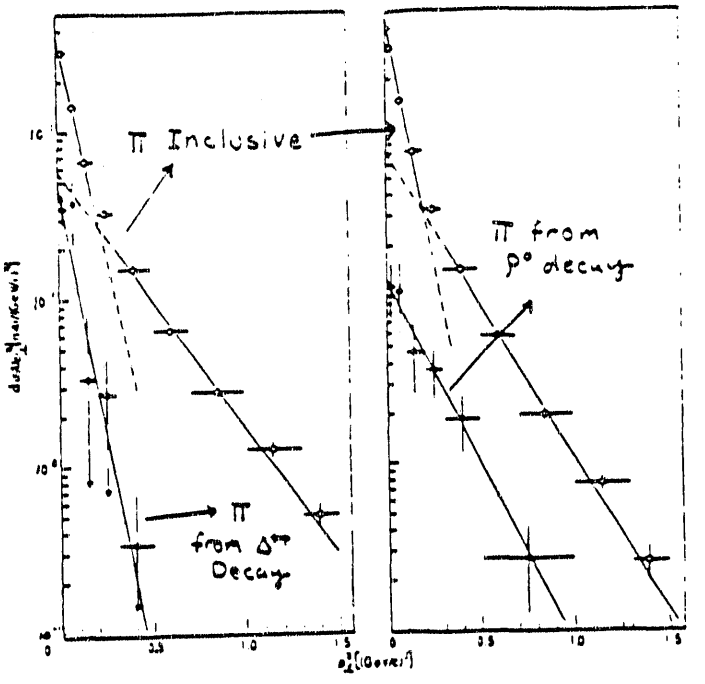

Fig. 4: Inclusive pion cross-sections and cross-sections for the decay of Δ^{++} and ρ^0 resonances into pions for p-n collisions at 19 GeV/c.

$p_\perp^2$ component	$p-p$	Si + Al
Low	11.5 ± 0.3	9.5 ± 0.9
Middle	4.3 ± 0.1	4.0 ± 0.1
High	$2.7 \pm$?	2.3 ± 0.6

Table 1: The slopes (in GeV^{-1}) of the three components in the p-p and very peripheral Si–Al reactions.

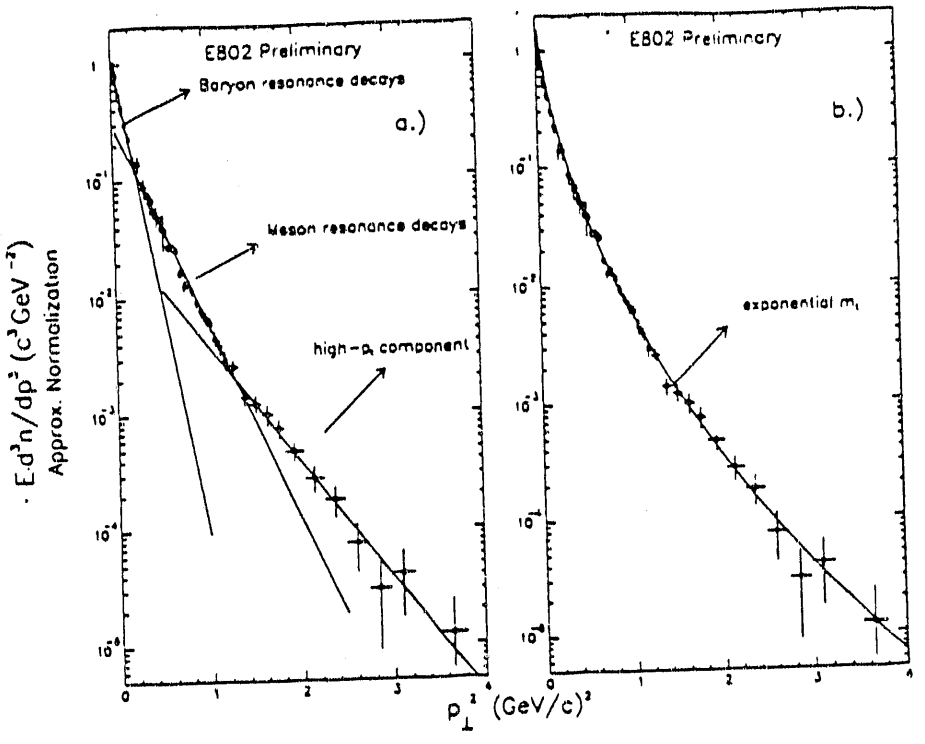

Fig. 5: Invariant cross-section for pion production from very peripheral Si+Al collisions, shown as a function of $p_\perp^2$. In a) are shown the fits to the three $p_\perp^2$ components, and in b) is shown an exponential $m_\perp$ fit to all data points.

we see how well these components can describe the data for the inclusive Si+Al and Si+Au collisions in Fig. 6. The data for the Al target are reasonably well described by the three components, although there is a significant deviation for high $p_\perp$. For the Au target, the low $p_\perp$ part of the spectrum, dominated by the baryon resonance contribution, has a flatter slope as well. Nevertheless, there seems to be remarkable similarity between the production with Si beams and p beams. It would be an interesting study to compare kaon production for Si and p projectiles in a similar way.

In conclusion we observe that the invariant cross-sections for inclusive particle production near mid-rapidity can be well described by an exponential dependence in transverse mass. No attenuation of the cross section near the nucleon-nucleon kinematic limit is seen. Alternatively, by studying the dependence as a function of $p_\perp^2$, the spectrum can be described as consisting of 3 or 4 components, similar to what is observed in p-p reactions, with most of the cross section dominated by decay of baryonic and mesonic resonant states. The origin of higher lying components is still unknown, and provides an interesting challenge to theorists to provide possible mechanisms.

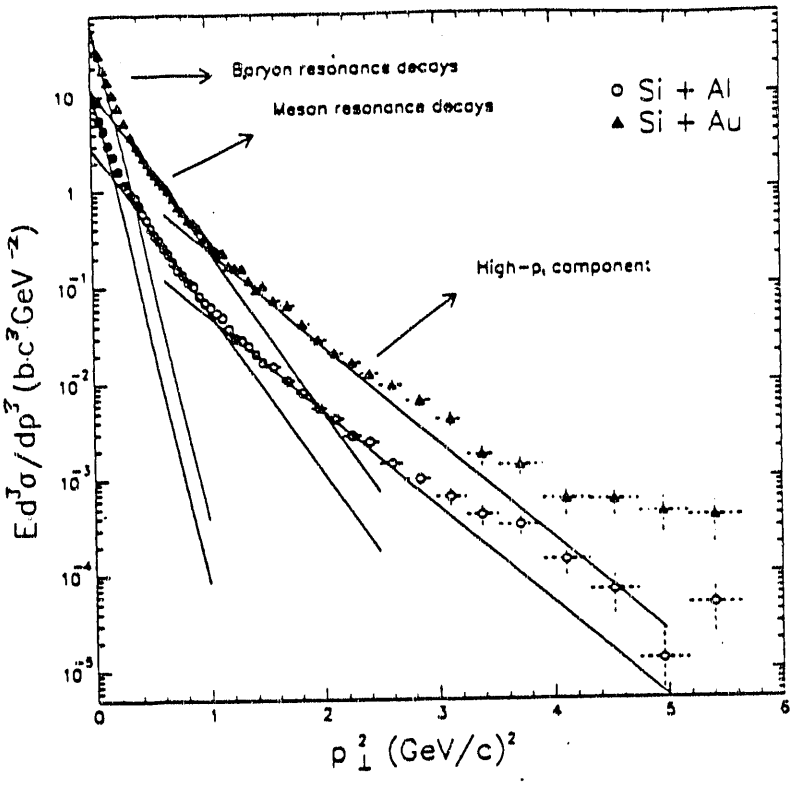

Fig. 6: Inclusive cross-sections for pion production in Si+Al and Si+Au collisions, shown as a function of $p_\perp^2$. The lines have the slopes of the very peripheral Si+Al components shown in Fig. 5.

4. Acknowledgements

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