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MID-RAPIDITY PION CROSS SECTIONS: NEW DATA CONFRONT THEORIES

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Pion production by collisions of relativistic heavy ions has been studied recently by Wolf et al.[1] For the reaction 1.05 GeV/A $^{40}Ar + Ca \rightarrow \pi^+$, they discovered a peak in the invariant cross section at mid-rapidity at $p_\perp \sim 0.5\ m_\pi c$. This peak is not apparent in the 730 MeV p+p data of Cochran et al[2] and was attributed to possible 'hydrodynamic flow effects'. Several authors have suggested that the π^+ peak is a Coulomb effect[3,4,5] - the π^+ at $p_\perp = 0$, $p_{\parallel cm} = 0$ would be depleted if there is a charged fireball in the center-of-mass, leaving a π^+ peak at larger $p_\perp$. These models predict the π^- would be drawn in towards the fireball, leaving an essentially flat distribution in the mid-rapidity region.

We have measured mid-rapidity π^+ and π^- cross sections using a 1.05 GeV/A argon beam with calcium, uranium, and carbon targets. The pions were measured with a magnetic spectrometer set at 15° to the beam and were stopped in a scintillator range telescope. A description of the spectrometer and detection techniques can be found in a recently submitted publication.[6]

In the region that we studied, our $^{40}Ar + 2\ gm/cm^2\ Ca \rightarrow \pi^+$ data are essentially flat. The π^-/π^+ ratio we measure of 1.5:1 is much less than those predicted by the models[3,4,5]. Our data overlap the data of Wolf et al. only at a laboratory angle of 30°. As shown in Fig. 1, there is excellent agreement between the two sets data. There is no renormalization correction. When the data of Wolf et al. are reflected across the center-of-mass, some of their points lie within our acceptance, and some of these points differ from ours by $\sim$25%. The cause of this discrepancy could possibly be explained by noting that it is not strictly legitimate to reflect about the C.M. as we are not studying a symmetric system.

We further compare our data with that of Wolf et al. with the aid of computer drawn contour plots of the invariant cross section. Figure 2 shows these plots. The bottom half uses only the data of Wolf et al. and is quite similar to their published plot. Our data combined with that of Wolf et al. are shown in the top half of the figure. The dashed line is our spectrometer acceptance. With the addition of our data the peak appears to extend all the way to $p_\perp = 0$.

We next investigate the possibility that our spectrometer was incapable of observing the mid-rapidity peak.

The first possible problem is that the $\pi\mu$ correction may be large due to our flight path. The decay correction is approximately 20% and was obtained by Monte Carlo calculation. This correction can be almost correctly estimated by using the survival probabilities for flight through a magnetic field plus a short flight path ($\sim$50 cm) outside the magnetic field, averaged over the spectrometer's acceptance. We note that the survival probability in a magnetic field is momentum independent. The $\pi\mu$ decay correction in our spectrometer has only a slight momentum dependence due to the path traveled outside of the spectrometer, and we believe we have made this correction properly.

A second possible problem is the resolution of our spectrometer. We used a 2 gm/cm^2 thick target while Wolf et al. used a target that was 200 mg/cm^2, which is 1/10 the thickness of ours. The dominant term in the formula for the scattering angle in multiple Coulomb scattering is proportional to the square root of the length traversed.[7] Our angular resolution is dominated by multiple scattering in the target; however this is only $\sim$3x the multiple scattering in the target of Wolf et al. As they measure points every 20°, the peak must be at least 20 wide, while we have data every 4°. Our resolution calculation includes corrections for $\pi\mu$ decay, multiple scattering in the target, and scattering in the scintillator range stack. Our resolution in the region of our acceptance is given approximately by $<\Delta p^2>^{\frac{1}{2}} \sim 5$ MeV/c, $<\Delta\theta^2>^{\frac{1}{2}} \sim 3.5^\circ$, or alternatively by $<\Delta y^2>^{\frac{1}{2}} \sim .02 - .03$ and $<\Delta p_\perp^2>^{\frac{1}{2}} \sim 0.05\text{–}0.06\ m_\pi c$. We estimate the effect of our resolution on the mid-rapidity peak. As a 'worst case' let us assume that the data of Wolf et al. represent the true spectrum and can be represented by a gaussian in $p_\perp$ and y with full widths at half maximum of 0.3 $m_\pi c$ in $p_\perp$ and 0.4 in y. These numbers are estimated from their contour plot in the region of our acceptance assuming a peak at 9 and a smooth background at 6 units of cross section. In this case the width in y would increase from 0.4 to 0.41 and the width in $p_\perp$ would increase from 0.3 to 0.33. The height of the peak above background would be reduced from 9-6=3 to 2.7, or to a height of 8.7. If our resolution is twice as poor as we claim, the height of the peak above background would still be 2.1, or a total height of 8.1. Thus even in our worst case estimates, we should be able to see the peak.

The discrepancies between the two sets of data could be resolved by a high statistics experiment with good resolution, with data on both sides of the center of mass. More interesting information could be obtained with the use of symmetric systems such as Ca + Ca, or higher mass systems such as Pb + Pb.

The mid-rapidity π^-/π^+ ratios that we measured appeared to be consistent with Coulomb calculations that required the projectile and target to be transparent to one another. As this seems unlikely, we decided to perform Coulomb trajectory calculations with boundary conditions in which the pion originates on the nuclear surface and never travels within the nuclei. Preliminary calculations show that for pion velocities corresponding to the center of mass velocity, the Coulomb effects on the π^-/π^+ ratio are less than 5%. The π^-/π^+ ratio we measure may be nearly the primitive ratio at "freeze-out" or loss of chemical equilibrium with nuclear matter. The π^-/π^+ ratio in excess of unity may be primarily due to the neutron excess of ^{40}Ar spoiling isobaric symmetry.

REFERENCES

1. K.L. Wolf, H.H Gutbrod, W.G. Meyer, A.M. Poskanzer, A. Sandoval, R. Stock, J. Gosset, C.H. King, Nguyen Van Sen, and G.D. Westfall, Phys. Rev. Lett. 42, 1948 (1979).

2. D.R.F. Cochran, P.N. Dean, P.A.M. Gram, E.A. Knapp E.R. Martin, D.E. Nagle, P.B. Perkins, W.J. Shlaer, H.A. Thiessen, and E.O. Theriot, Phys. Rev. D6, 3085 (1972).

3. K.G. Libbrecht and S.E. Koonin, Phys. Rev. lett. 43, 1581 (1979).

4. J. Cugnon and S.E. Koonin, Nucl. Phys. A355, 477 (1981).

5. M. Gyulassy and S.K. Kauffmann, Nucl. Phys. A362, 503 (1981).

6. J.P. Sullivan, J.A. Bistirlich, H.R. Bowman, R. Bossingham, T. Butke, K.M. Crowe, K.A. Frankel, C.J. Martoff, J. Miller, D.L. Murphy, J.O. Rasmussen, W.A. Zajc, O. Hashimoto, M. Koike, J. Péter, W. Benenson, G.M. Crawley, E. Kashy, J.A. Nolen, Jr., LBL-11971 (1981), and to be published.

7. Particle Data Booklet or Rev. Mod. Phys. 52(2), ptII(1980)S44.

FIGURE CAPTIONS

Fig. 1. Data at 30 degrees for this experiment (open circles) and for the experiment of Wolf et al. (closed circles).

Fig. 2. Computer drawn contour plots of Lorentz- invariant cross sections of the ^{40}Ar + Ca system at E/A = 1.05 GeV/n. Dots show the locations of data points of Wolf et al, and the dashed line encircles the region of our data. The open circles show reflected data points. The plot in the lower half was made with the data of ref. 1 alone, and the plot in the upper half with data from both experiments. The abscissa is the rapidity variable and ordinate is perpendicular momentum in units of $m_\pi c$. Contours are at invervals of 1 $\mu b\, sr^{-1}\, MeV^{-2}$.

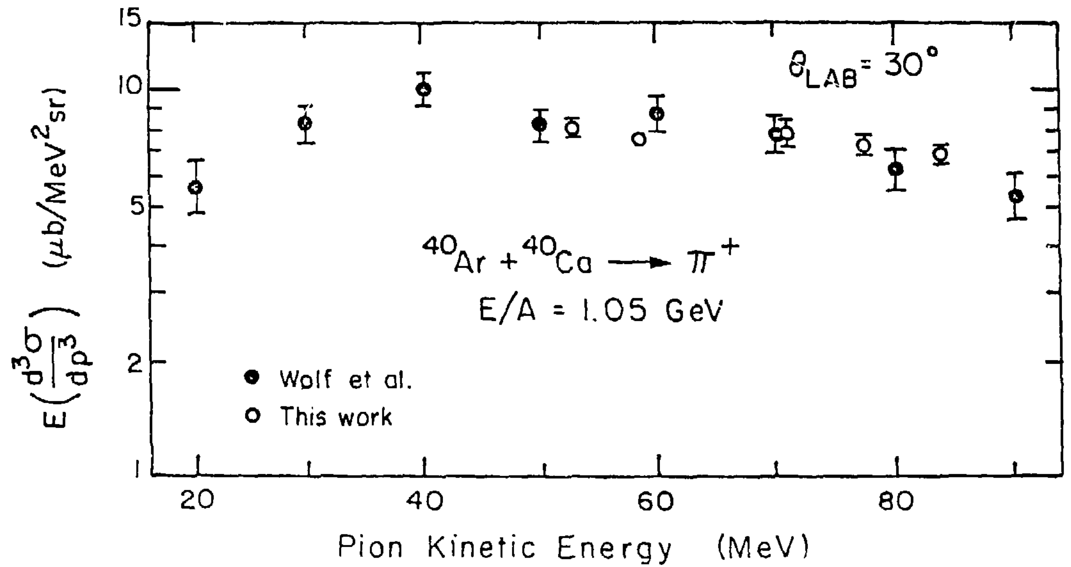

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Fig. 1

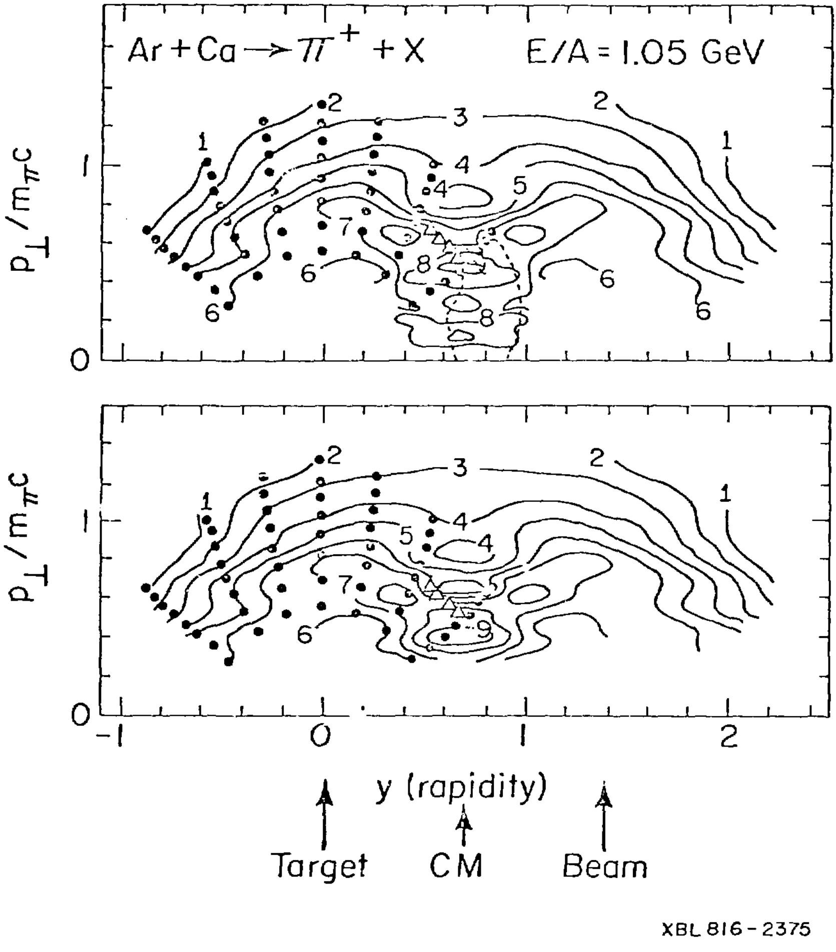

Fig. 2