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THE K NUCLEON INTERACTION

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Talk given by L. T. Kerth at the December, 1960  
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## I. INTRODUCTION

The purpose of this paper is to summarize the broad details of the K nucleon interaction and in addition to present data from three new experiments carried out at the Lawrence Radiation Laboratory. These new experiments are: I. The Total Cross Section for  $K^-$  Mesons on Protons and Neutrons in the Momentum Region 1-4 Bev/c<sup>1</sup>; II. Total Cross Section for  $K^-$  Mesons on Protons and Neutrons in the Momentum Region .6 - 1.1 Bev/c<sup>2</sup>; and III. Total Cross Section for  $K^+$  Mesons on Protons and Neutrons in the Momentum Region .8 - 2.9 Bev/c<sup>3</sup>. In the final section of the report we shall speculate on some possible interpretations of the data as they appear at the present time. Since the analysis and correction of the data from Experiments II and III have not been completed yet, the corresponding results are presented below with rather large errors.

## II. $K^-$ NUCLEON TOTAL CROSS SECTION

There are many accurate total cross section measurements now available for  $K^-$  mesons on protons up to a momentum of 10 Bev/c. These data are shown in Figures 1 and 2. Figure 1 shows the total cross section as a function of laboratory momentum between 1 Bev/c and 9 Bev/c. The data from Experiment I and the data from von Dardel<sup>4</sup> are consistent and indicate that the cross section above 3 Bev/c is essentially flat with momentum at a value of approximately 25 millibarns. Figure 2 shows the  $K^-$  total cross section from 0 to 3 Bev/c. The data from Experiment II shows a considerable structure (which we will tentatively refer to below as a "resonance") in the  $K^-$  proton

cross section in the region of 1 Bev/c. The resonance, however, does not appear — at least to anything like the same degree — in the  $K^-$  neutron cross section, also shown in Figure 2. Since the  $K^-$ -neutron system is a pure  $T = 1$  state and the  $K^-$ -proton system is a mixture of the  $T = 1$  and  $T = 0$  states, the resonance in the  $K^-$ -proton cross section is in the  $T = 0$  state. The structure evident in the  $K^-$ -proton cross section in the region 1.5 Bev/c in Figures 1 and 2 is of smaller magnitude and needs to be investigated more thoroughly. A better idea as to the position and the shape of the resonance at 1 Bev/c can be obtained by guessing at the smooth non-resonant background and subtracting it from the data of Figure 2. The data in Figure 3 are plotted as a function of the center-of-mass kinetic energy. The curve is a single level resonance formula drawn for comparison only. No attempt has been made statistically to fit the data. However, it shows that the resonance represents an excess energy in the  $K^-$  nucleon system of about 380 Mev and a width of approximately 120 Mev. It has been pointed out<sup>5</sup> that from global symmetry one would expect the same isobaric states that appear in the  $\pi$ -nucleon system to appear in the  $\pi$ -hyperon system. It is interesting to conjecture what such an assumption would predict as far as resonances in the  $K^-$  nucleon interaction is concerned. It has been pointed out by Alston, et al.<sup>6</sup> that the  $(3\ 3)$  resonance in the  $\pi$ -nucleon system under the above assumption predicts a resonance in the  $\pi$ -hyperon system which corresponds remarkably well to the mass of the  $Y^*$ . The  $Y^*$  is below threshold in the  $K^-+p$  system. However, the other two isobaric states in the  $\pi$ -nucleon system predict isobaric states in the  $\pi$ -hyperon system above the threshold of the  $K^-$ +nucleon system. The third  $\pi$ -nucleon isobar would give a resonance in the  $K^-$ -nucleon system at approximately 275 Mev from an isobar in the  $\Lambda\pi$  system, and at about 70 Mev less from the  $\Sigma\pi$  isobar. Therefore we would expect two resonances in the  $K^-$ -nucleon

system in the region of 300 Mev in the center of mass. The resonance observed in the  $K^-p$  scattering is at slightly higher energy and somewhat wider than would be expected from the  $\pi$ -nucleon resonance. However, it is impossible to determine from the present data if this is a single resonance or two resonances separated by 70 Mev. The assumption of two overlapping resonances can account for the observed width. Of course there are many difficulties with such an interpretation as this. The fact that the width of the  $Y^*$  resonance is now thought to be narrower than the  $(3\ 3)$  resonance in the  $\pi$ -nucleon system is disturbing. In addition, the idea of global symmetry would predict that the  $Y^*$  would have the same spin as the pion-nucleon isobar, i.e.,  $J = 3/2$ . At present writing, it is not clear what the spin of the  $Y^*$  is from the experimental data.

The  $K^-$ -neutron total cross sections from Experiments I and II shown in Figure 2 represent all of the data that is now available. To arrive at  $K^-$ -neutron cross sections from  $K^-$ -deuteron scattering is very difficult at low energies. The corrections arising from the spectator proton become unreliable when the proton cross section becomes large — as it does below about 0.6 Bev/c.

### III. $K^+$ -NUCLEON TOTAL CROSS SECTION

Figure 4 shows the  $K^+$  proton total cross section as a function of laboratory momentum. In the region between 2 and 3 Bev/c there was some difficulty in drawing a smooth curve through the points of Burrowes et al.<sup>7</sup>, at 2.3 Bev/c, and those of von Dardel<sup>4</sup> et al., which start at 3 Bev/c. The new data from Experiment III indicates general agreement with all but the highest energy points of Burrowes et al. The best description of the  $K^+$ -proton total

cross section that can be given at the moment is that at zero momentum it starts at about 12 mb (nuclear part only), increases to about 17 mb at about 1.5 Bev/c, and then slowly rises to about 18 - 19 mb at higher energies. It has been known for some time that at low momenta (below 500 Mev/c) the angular distributions of the  $K^+$ -proton scattering indicated that the simplest explanation for the scattering is that of S-wave scattering only. Angular distributions have been taken at as high as 800 Mev/c in a collaborative experiment between the Lawrence Radiation Laboratory and UCLA using the 15" hydrogen bubble chamber<sup>8</sup>. They find that at 800 Mev/c the angular distribution is still predominantly S-wave and that the total cross section includes about 1 mb of inelastic scattering. Apart from total cross sections, the angular distributions for elastic scattering at 1.0, 1.2, and 2.0 Bev/c were measured in Experiment III. As yet the results are not available; however, it would appear from a preliminary look at the distribution that they are not isotropic and certainly there is a fair amount of inelastic scattering contributing to the total cross section in this momentum region.

To date there is little data on the  $K^+$ -neutron interaction except at lower energies. The  $K^+$  neutron total cross section from emulsion work starts out at a very low value at low momenta and in the region of 500 Mev/c becomes equal to the  $K^+$  proton total cross section and apparently remains equal to it from there to approximately 2 Bev/c. However, the angular distributions indicate that higher angular momentum states play an important role in the elastic scattering. The data from the 15" bubble chamber<sup>8</sup> indicates that even at as low as 500 Mev/c it requires D-wave phase shifts to fit the data. Since the  $K^+$ -p system is a pure  $T = 1$  state and the  $K^+$ -n system is a mixture of the  $T = 1$  and  $T = 0$ , these states indicate that the  $T = 0$  state is much more complicated than the  $T = 1$ . The final important point to notice as far



as the high energy behavior of both the  $K^+$  and the  $K^-$  proton total cross sections is that each has become flat as a function of energy. However, even as high as 10 Bev/c they have not become equal. It would seem that for K mesons 10 Bev/c is not a high enough momentum for the Pomeranchuk theorem to obtain.

#### IV. DISPERSION RELATIONS

At present, the only technique for correlating and parameterising the strong interaction data which shows any promise at all is that of dispersion relations. Dispersion relations for K nucleon scattering have been written by analogy to the  $\pi$ -nucleon system<sup>9</sup>. A number of calculations have been carried out in the past using dispersion relations to try and relate the various aspects of the K-proton scattering data<sup>10</sup>. The first thing that one could hope to derive from dispersion relations is the value and sign of the average pole term,  $\overline{pX}$ , representing the parity and the coupling constant of the K-nucleon-hyperon system. Calculations have been hampered in the past by the lack of low energy  $K^-$  proton data. Furthermore, the existence of the resonance around 1 Bev/c (Figure 2), which was heretofore unsuspected, certainly has not been accounted for properly in any of the calculations. The momentum dependence of the total cross section which has been used in the past has usually varied roughly as  $1/v$  and consequently the cross sections in the region below 1 Bev/c were overestimated by a large factor. In addition to the lack of total cross section data, there have not been available statistically accurate numbers for the real part of the forward scattering amplitude at various energies. With the new angular distributions which have been measured for both  $K^+$  and  $K^-$  proton interactions at various energies and the measurements of the total cross sections at various momenta, it is possible to consider

a more reliable use of dispersion relations. In this vein we have calculated the average value of the pole term,  $\overline{pX}$ , using the doubly-subtracted form of the dispersion relation

$$\omega_0 D^+(\omega) - \frac{1}{2}(\omega_0 + \omega) D^+(\omega_0) - \frac{1}{2}(\omega_0 - \omega) D^-(\omega)$$

after the technique of Karplus, Kerth, and Kycia<sup>11</sup>. Using all of the data presently available, we find a value of the average pole term which varies depending upon the data used, between approximately  $-.1$  and  $-.4$ , but small positive values cannot be excluded.

It is believed with the angular distributions that will be obtained in Experiment III, a much better value of the average pole term will be obtained. At the moment it seems premature to report further results on dispersion calculations.

#### V. SUMMARY

To summarize the present data as far as the K nucleon interaction is concerned, one may characterize the  $K^-$  proton data by a very high cross section at low momentum, varying apparently as approximately  $1/v$ , with a resonance appearing at about 1 Bev/c, and a final asymptotic value at high energy of about 25 mb.  $K^-$  neutron data do not exist at low energies, so the very low energy behavior of the  $K^-$  neutron total cross section is not known; however, at higher energies it seems to be approaching the same value as the  $K^-$  proton data. Therefore we say that at high energy the  $T = 1$  and  $T = 0$  states are approximately equally effective. The resonance appears only in the  $T = 0$  state and not in the  $T = 1$  state. In the  $K^+$  interaction, the  $T = 1$

state has a rather simple total cross section behavior rising very slowly at low energies to an asymptotic value of approximately 20 mb at high energies. The  $T = 0$  total cross section, however, starts at a rather low value at zero momentum, increases to be about the same value as in the  $T = 1$  state in the region of 500 Mev/c, and then remains equal to the  $T = 1$  state at high energies. On the angular distributions measured in the lower energy  $K^+$  nucleon experiments one can say that the  $T = 1$  scattering appears to be predominantly S-wave below 800 Mev/c, whereas the  $T = 0$  state is very much more complicated, requiring up to D-waves to fit the data.

## FIGURE CAPTIONS

- Figure 1. The  $K^-p$  total cross section in the momentum range 1 - 4 Bev/c. For the data of Experiment I where no error bars are shown, the errors are smaller than the symbols used.
- Figure 2. The  $K^-p$  and  $K^-n$  total cross sections in the momentum range 0 - 3 Bev/c. The momentum resolution of Experiment II was approximately 1%.
- Figure 3. The  $K^-p$  total cross section with the non-resonant background subtracted. The curve is a single resonance form drawn for comparison.
- Figure 4. The  $K^+p$  total cross sections in the momentum region 0 - 8 Bev/c. The data of Experiment III is preliminary and is plotted with an error equal to twice the statistical errors.

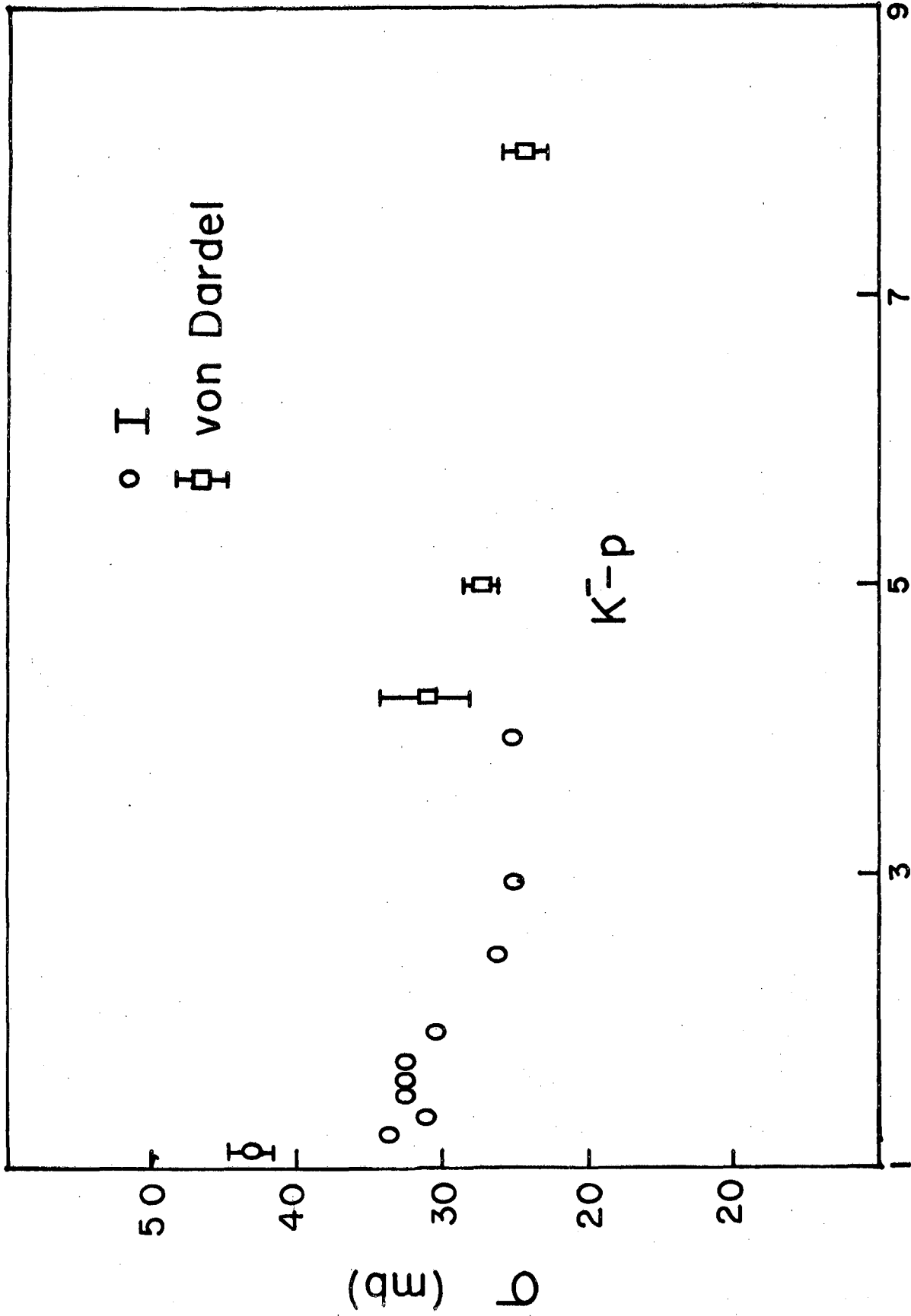


Fig 1

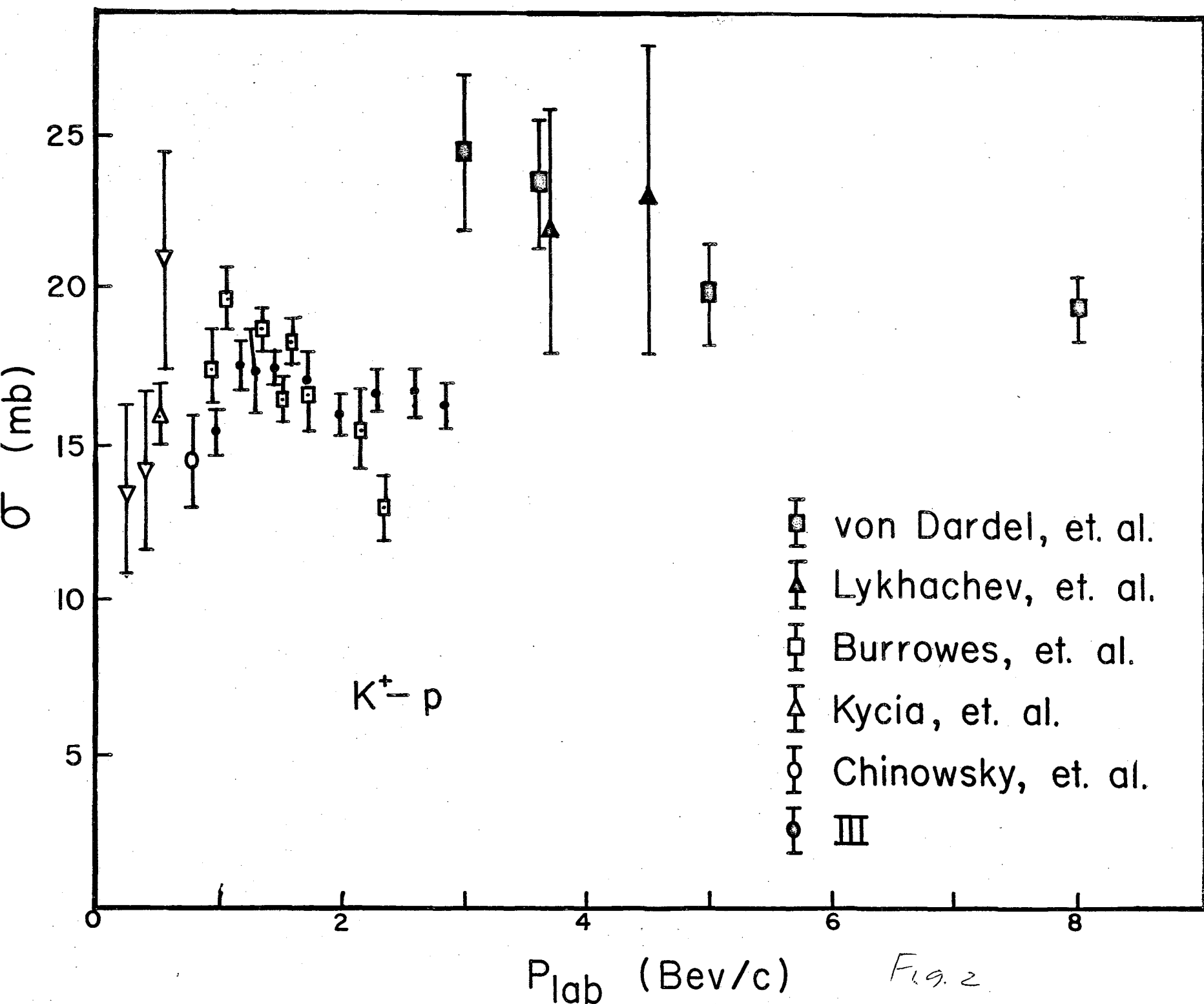


Fig. 2

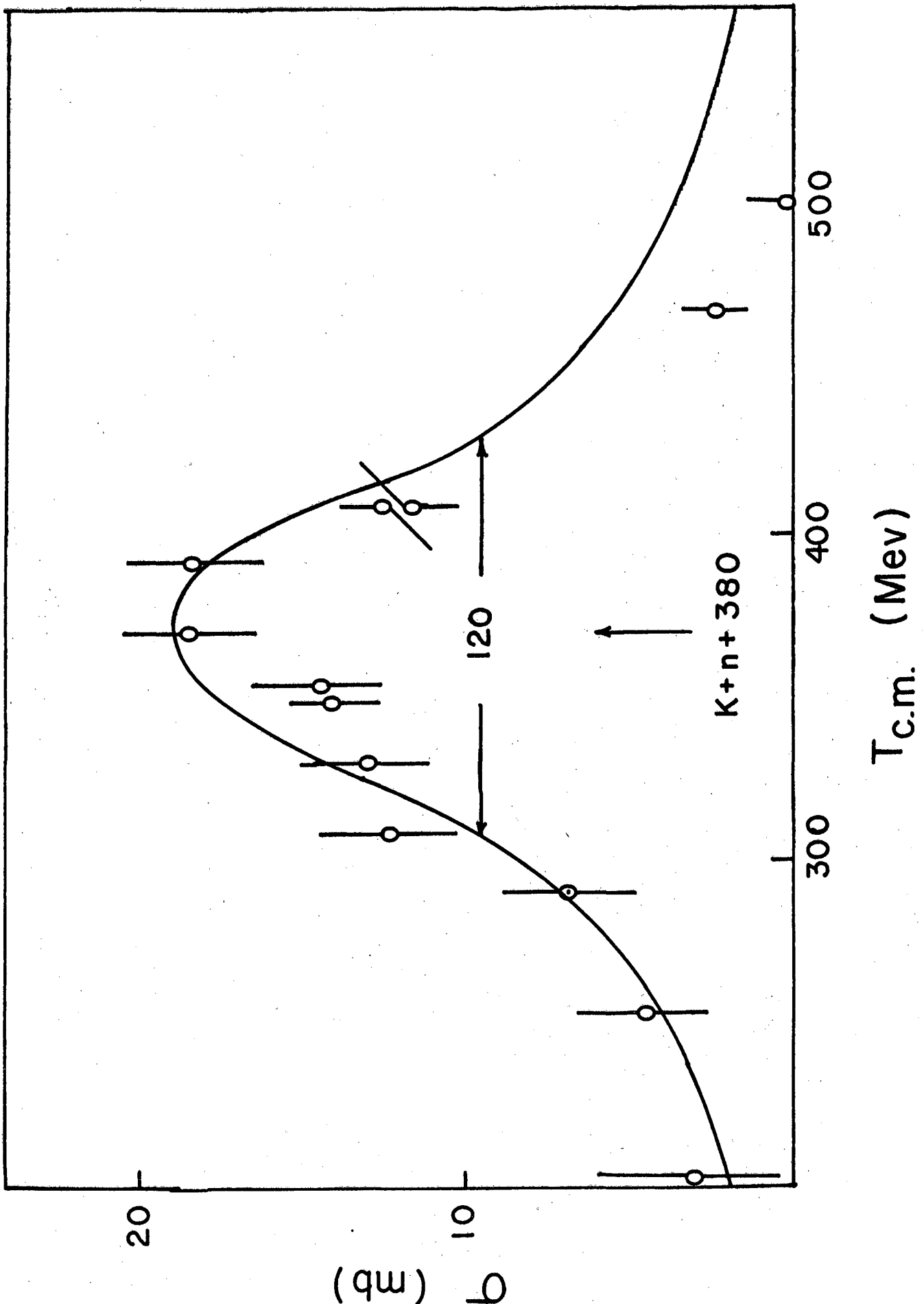


Fig. 3

I  
 II  
 Bastien, et. al.  
 ( $K^-p$ )

○

●

△

$\sigma$  (mb)

$K^-p$

$K^-n$

$P_{lab}$  (Bev/c)

Fig 4

60

40

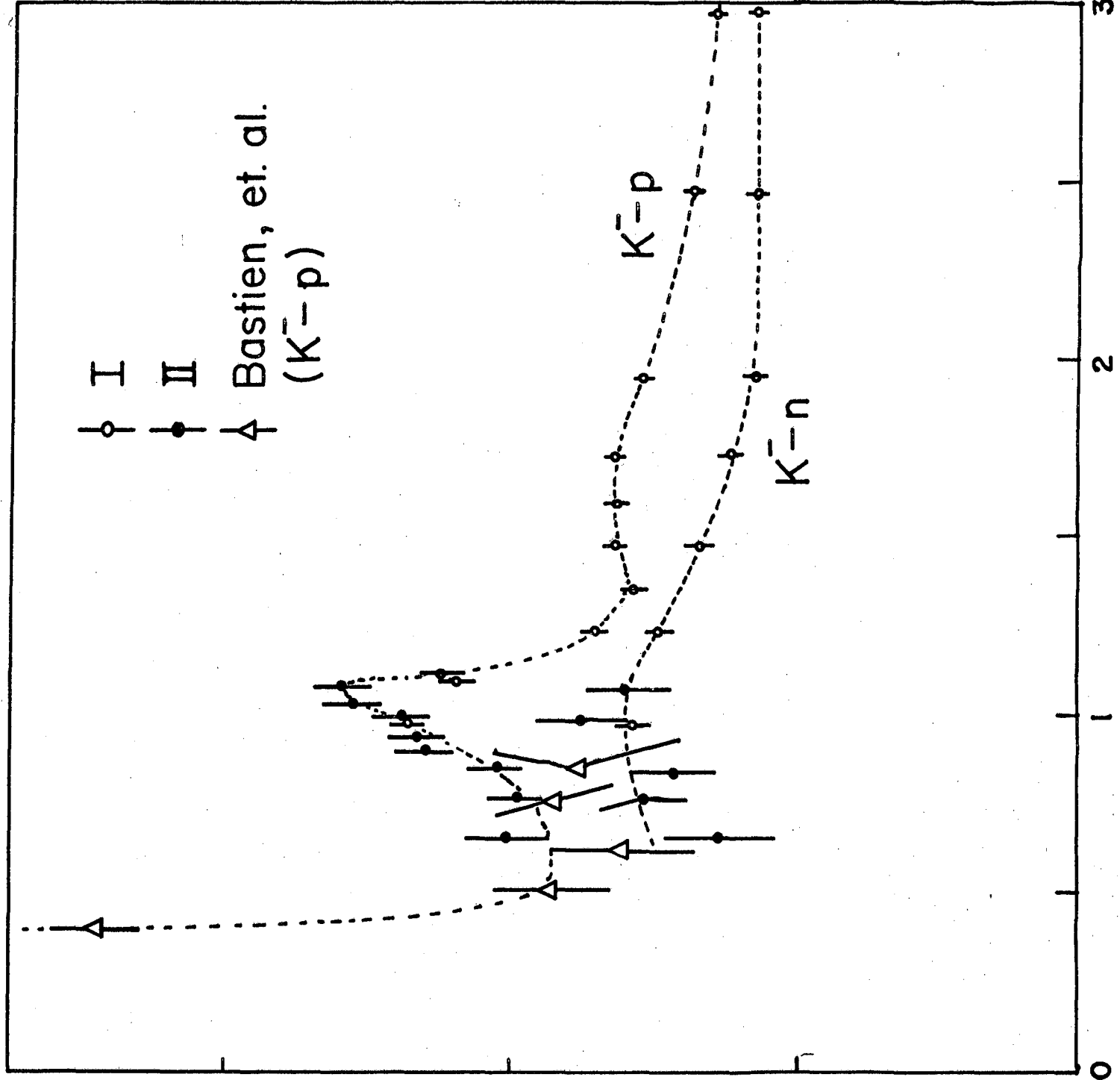
20

0

1

2

3





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