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Radiation Laboratory

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SUMMARY OF THE RESEARCH PROGRESS MEETING OF APRIL 10, 1952

S. Shewchuck

May 5, 1952

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Berkeley, California

SUMMARY OF THE RESEARCH PROGRESS MEETING OF APRIL 10, 1952

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I. Cross Sections for Attenuation of 50 Mev π^+ Mesons in Various Nuclei.

D. Stork

Preliminary results have been obtained on the two π^+ beams studied, 62 Mev and 85 Mev. In the experiment the beams were taken out of the cave in a manner similar to that used by the cloud chamber group. The targets used were 1 in. polyethylene and 1 in. carbon respectively. The proton beam striking the target gave a π^+ meson beam bent magnetically through $\sim 90^\circ$ and with the momentum selected. The beam then was directed through the cave wall to a counter telescope. In the front there were placed two stilbene crystal counters and in the back an 8 in. diameter liquid scintillation counter. The three pulses from the counters, after being separated by delay lines, appeared on a scope which was triggered by a double coincidence. The scope was photographed and the pulse heights were measured later by re-projection. For the 62 Mev beam a plot of the counting rate vs. the magnetic field located the production peak of the meson beam from polyethylene, the field being set at the peak counting rate $2\pi^+/in^2/sec$. For the 85 Mev beam the field was set at maximum, yielding $1.5\pi^+/in^2/sec$. from the carbon target. A check of the range for both beams gave a width of $\pm$ 3 Mev for the 62 Mev beam and $\pm$ 8 for the 85 Mev, the range resolution being not too good in the latter case.

Contamination was studied by a combination of differential range curves, the pulse height, the momentum, etc. The μ meson contamination is due to π decay in flight and is given off within a 16° cone. Conse-

quently, two energy groups appear: ~83 Mev from forward center of mass decay direction and ~23 Mev from the backward. A pulse height analysis of the 62 Mev beam gives the following percentages after a production target in, target out subtraction:

93%	π^+ (<5% in 83 Mev μ group)
2%	23 Mev μ's
1%	minimum ionization particles
4%	large pulse particles

High energy μ's cannot be distinguished from the π's by pulse height but should be of the order of ~4 percent. Although the work is not finished with the 85 Mev beam, the percentage picture is about the same except that there is far more background in the large pulse group.

There is quite a problem with multiple coulomb scattering in doing attenuation experiments. A large back counter is required in spite of bad coulomb geometry. At present the data obtained on pulse height distribution (counting rate vs. P.H.) from the back counter gave a good fit with a Poisson distribution curve and showed adequate separation of true zero pulses from statistical fluctuations in the pulse height, and, the data from the two front counters for the 62 Mev π^+ beam gave a Gaussian fit. Figure 1 gives the anticoincidence pulse height distribution. The π^+ beam Gaussian distribution fits the π^+ peak well. Here the second group is significant since it represents 100 percent stoppage in the absorber. It is identified as being μ's in the 23 to 25 Mev group. This low group fits in with the idea of π-μ decay. Corrections in cross section due to overlap of μ group are essentially negligible.

Due to the geometry designed to overcome multiple coulomb scattering the angle of acceptance of the back counter is large and, therefore,

some particles from stars and from elastic and inelastic scattering produced in the absorber will record in the back counter and will not show up as anticoincidences. This effect will be small for the geometry used with the lighter elements but rather large for the heavier elements. The following table gives the cross section values obtained for various elements used as absorbers. Because of the different angles used between the elements it is difficult to make a valid comparison of the cross sections until more complete results are obtained.

	Absorber	Back counter angle	Total cross section (mb)	Ratio of σ to nuclear area
50 ± 8 Mev	Be	30°	149 ± 16	0.56 ± 0.06
	C	30°	212 ± 19	0.65 ± 0.06
	Al	45°	397 ± 40	0.70 ± 0.07
	Cu	80°	391 ± 90	0.40 ± 0.09
	Pb	80°	1330 ± 200	0.62 ± 0.09
75 ± 10 Mev	C	20°	264 ± 31	0.81 ± 0.09

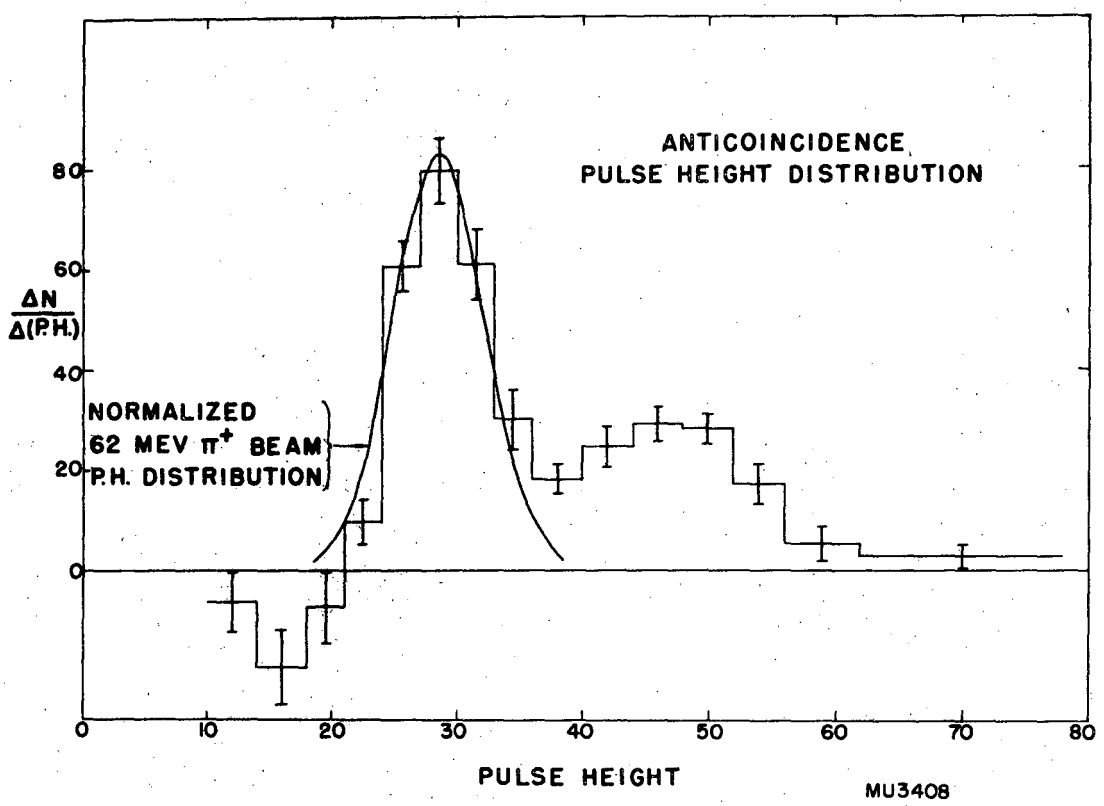
ANTICOINCIDENCE
PULSE HEIGHT DISTRIBUTION
NORMALIZED
62 MEV π+ BEAM
P.H. DISTRIBUTION
ΔN
Δ(P.H.)
80
60
40
20
0
0
10
20
30
40
50
60
70
80
PULSE HEIGHT
MU3408

Fig. 1

II. Meson Carbon Interaction. R. LeLevier

Lederman's experimental results on π^+- carbon interaction when first reported at Rochester created considerable comment. In 12 percent of the cases with π^+ he got two protons, 60 Mev, going in opposite directions. This would be compatible with the reaction

$$\pi^+ + d \longrightarrow p + p \, .$$

According to Levinger theory of the photoelectric effect there are 1.6 A deuterons "floating" in a heavy nucleus. Lederman estimates the number to be of the order of 5 Z or ~2.5 A.

Lederman gets the following data and curves:

	Elastic 20° - 180°	Total abs.	Total cross section
π^-	165 ± 15	194 ± 28	359 mb
π^+	88 ± 11	168 ± 30	257 mb

Elastic $\Delta E < 15$ Mev

Inelastic $\Delta E > 15$ Mev

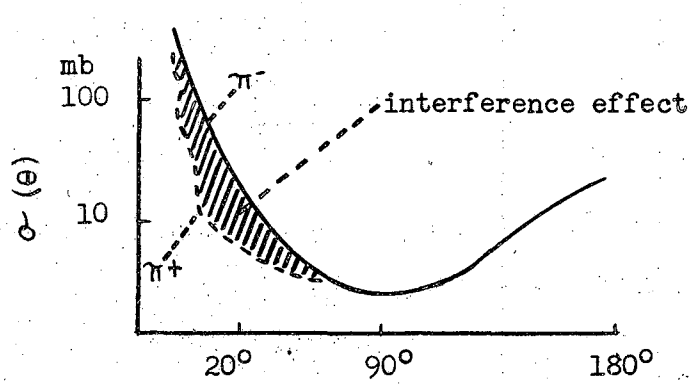

Figure 2

The total cross section is of the order of πR^2 and not $2 \pi R^2$. For carbon there apparently is a large transparency effect. In heavier nuclei σ_t is close to geometric and does not depend too strongly on energy. Bethe has analyzed the transparency effect and on the basis of the optical model gets an attractive potential,

$$V_0 = 10 \text{ Mev} \pm 10 \text{ Mev} .$$

Because of the apparently small index of refraction Bethe infers that the amplitude for scattering of mesons by a free porton should be of opposite sign to that for scattering by neutrons.

Peaslee has investigated the interference effect (Fig. 2) at small angles near 20°.

$$\text{For } \pi^-,\ f_{coulomb}(\theta) > 0 \text{ at small angles}$$
$$\pi^+,\ f_{coulomb}(\theta) < 0 \text{ at small angles}$$

Interference between Coulomb and a shallow attractive nuclear potential would explain the difference in the π^+ and π^- curves in Figure 2.

On this basis one might conclude that the deductions from Schiff's non-linear theory are untenable since the prediction is that the scattering of mesons from nuclei should be like the scattering from repulsive spheres. However, one notes that a potential which is all repulsive or all attractive cannot lead to a fit with the data over the entire angular range. A potential which is repulsive over the central region of the nucleus and attractive near the surface leads to the correct interference effects at small angles and still gives a peak in the backward directions.

Recent experimental results by Fermi in meson - nucleon angular distributions indicate the interaction to be perhaps too complicated for simple models to comprehend. The angular distributions according

to him are fitted by a formula $a + b \cos \theta + c \cos \theta^2$; where a, b and c are coefficients determined experimentally. Fermi gives the following values for a, b and c for 135 Mev mesons:

	a	b	c
π^+	3.8 ± 2.2	-6.8 ± 2.7	17.5 ± 6.6
π^- charge exchange	1.21 ± 0.22	-2.5 ± 0.32	6.0 ± 1.89
π^- elactic	1.11 ± 0.61	-0.03 ± 0.32	0.45 ± 0.68

Peter Wolff calculated the angular distribution on the basis of gradient coupling with damping.

π^+	$\sim 1 + a \cos^2 \theta$
π^- charge exchange	$\sim \cos^2 \theta$
π^- elastic	$\sim$ flat

The isobar picture predicts the ratio for π^+: π^- charge exchange: π^- elastic to be 9 : 2 : 1. Integration of Fermi's experimental data above gives 9 : 3 : 1.

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