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RESEARCH PROGRESS MEETING

H. P. Kramer

December 9, 1948

Special Review of Declassified Reports
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RESEARCH PROGRESS MEETING

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Absolute Cross Section for Meson Production

V. Peterson

The purpose of this investigation was to test and refine R. Serber's and E. Gardner's preliminary estimate of the cross section for the production by alpha particles of heavy negative mesons $\sigma \sim 10^{-29}$ cm^2. The estimate was essentially correct since it was found that the cross section for carbon is $\sigma = (1.7 \pm .3) \times 10^{-29}$.

The absolute cross section is

$$\sigma = \frac{N_o}{n\phi}$$

where N_o is the total number of mesons emitted by an infinitely thin target during the time of bombardment; n, the number of atoms per cm^2 in the target; and ϕ the number of alpha particles which impinge on the target during bombardment.

Of these quantities n is known with the greatest certainty from the density, the atomic weight, and the physical dimensions of the target. $n = 5.0 \times 10^{22}$ atoms/cm^2.

ϕ was measured by means of polystyrene monitors. The monitors were placed inside the cyclotron in front of the target and in the path of the alpha beam. They were covered with protective foil to prevent the entrance of any particles other than those from the alpha beam. After each run, the two sheets of polystyrene of the same dimensions as the target, 1' x 1' x (1/4')' were placed in a beta counter and the C^{11} activity was measured. The beta radiation which was counted constituted a measure of the alpha flux since in a previous calibration experiment, the activity produced had been related to the time of exposure and the intensity of the alpha beam. This was done by placing polystyrene sheets in the deflected beam outside the cyclotron. (Fig. 1). The beam was collected in a Faraday cup in order to measure the current. Then the beta activity produced in conjunction with the reaction $C^{12}(\alpha,\alpha n)C^{11}$ was counted. In this way the activity produced was known as a function f the alpha flux. At the 81" position inside the cyclotron where the cross section experiment was set up, it was found by this means that the total flux for the standard ten minute run was $\phi = 9 \times 10^{13}$ alphas.

The quantity N_0 is by far the most difficult to determine since the number N of meson tracks which are counted on an exposed photographic plate at a given distance from the target (see Fig. 2) is only a very small fraction of the total number of mesons produced. A number of factors had to be taken into account in deducing the number N_0 from N.

a) Angular Distribution. On the basis of theoretical considerations by R. Serber on the conservation of momentum in the collisions between nucleons producing mesons it was assumed that the emission of the mesons studied was approximately isotropic. Fig. 3 gives the results of a brief experimental check of this assumption. It seems to be justified.

Since the same number of particles are emitted in any one direction as in all others, it was merely necessary to determine how many particles were to be found within a segment of solid angle emanating from the target. Here again the number N of mesotron tracks starting within a short distance from the front edge of the photographic plate and entering with an angle between $\pm 45^\circ$ represented only a fraction of the number of mesotrons appearing in the segment. (In order to utilize just that portion of plate with uniformly thick emulsion, only those tracks starting within a short distance of the front edge and appearing within a central strip, from $d_1 = 13.25$ cm to $d_2 = 15.04$ cm, were counted.) It was decided to deduce first of all the number of mesotrons emitted between $\pm 45^\circ$ at the target with energies in the range from $E_1 = 2.66$ Mev to $E_2 = 7.0$ Mev corresponding to d_1 and d_2. (The mass of the π-mesotron is accurately known from C. Lattes' work. It is 286 m_e.) Figure 4 shows a factor by which the number of tracks of a certain energy in the range had to be divided in order to find the total number of particles emitted within $\pm 45^\circ$ at the given energy. A correction has been applied to account for those mesotrons which might have decayed before striking the photographic plate.

b) Energy Distribution. In order to deduce from the number of mesotrons emitted within a short range of energies the number of mesotrons emitted with all energies from 0 ev to the theoretical limit 45 Mev it was necessary to assume an energy distribution. Here, recourse was taken to the expression developed by W. Horning from consideration of momentum space available in the creation process. The function which was adopted to represent the energy distribution is

$$P(E) = f(E)\ (E_0 - E)^4\ E^{1/2}\ dE,$$

where $f(E) = \frac{2\pi\eta}{1-e^{-2\pi\eta}}$ and $\eta = \frac{Ze^2}{h\ v} \simeq 1/E^{1/2}$. Thus for large η the energy distribution can be approximated by $P(E) \simeq (E_0 - E)^4\ dE$. This approximate distribution, as well as the exact distribution taking into account f(E), the complete coulomb factor, are shown by Fig. 5.

Fig. 6 shows the theoretical energy distribution for a target of finite thickness (1/4" carbon). It also contains a partial check of the theory in the form of two values obtained experimentally by S. White and S. Jones with 1/16" carbon target. In order to fix the ordinates, the curve was fitted through one of these points. It can be seen that the theoretical value is well within the experimental error for the second point.

Finally an integration can be carried out to find the total number of mesotrons emitted, N_0. It was found that $N/N_0 = 6.4 \times 10^{-6}$.

W. Panofsky mentioned the possibility of an error in the flux value in case that some alpha particles pass through the target several times. It was thought, however, that such an effect would be negligible.

In order to improve the experiment somewhat it is contemplated to tilt the photographic plates at a small angle ($10\text{-}1/2^{\circ}$) to the plane of the alpha beam so that one would be absolutely certain of registering all impinging mesotrons and knowing exactly the point of entry into the photographic emulsion. (The thickness of the emulsion was measured accurately with a comparator.)

In the future it is planned to measure the cross sections for Pb and Be with alpha particles, and repeat C, Pb, Be with 350 Mev protons.

Plans for Cloud Chamber Detection of Mesotrons

W. Powell

A chamber with a 16" diameter and a magnetic field of 14,000 gauss will be used. Any difficulty which one might have in detecting mesons would be due to the extremely short half life of π-mesons, .88 x 10^{-8}. The π-mesons which are produced in the target will move out in a decreasing spiral until they deteriorate into a μ-meson which will again spiral towards a point but this time with a different radius of curvature. Eventually the μ-meson will also disintegrate with the emission of an electron. The table shows the calculated radii of curvature for 100 Mev and 30 Mev mesotrons in the direction of the beam, which will be called forward, and in the reverse direction and in the direction at right angles.

Direction	Radius of Curvature for Heavy Mesons		Radius of Curvature for Light Mesons	
	100 Mev	30 Mev	100 Mev	30 Mev
forward	47 cm	28 cm	44 cm	24 cm
lateral	47 cm	28 cm	30 cm	20 cm
backward	47 cm	28 cm	16 cm	12 cm

At 100 Mev it is estimated that 1/13 of all π mesons will disintegrate in passing through the chamber. For 30 Mev this fraction was calculated to be 1/7.

From these data it is expected that a good number of mesons will be seen and that the deterioration of mesons will be seen in all but the forward direction in spite of the large number of electron tracks.

Recent Work in Spectroscopy

J. Conway

Because of the failure of ordinary methods of chemical analysis in measuring hafnium impurity in zirconium, a spectrochemical method was used to good advantage.

One half of the sample which consisted of .1 to .8 gm of material in 0.5 M HF or HCl was placed on each one of the freshly milled copper electrodes. Then the electrodes were dried. A spark was forced to jump the gap by an emf of 2000 v from 3 condensers of

.007 μ fd.

In a calibration experiment the intensity of the light transmitted through exposed film as measured by a photoelectric cell connected to a galvanometer was related to the intensity of the spark. In this way it was possible to judge the intensity of the light producing the characteristic lines from the intensity of the light transmitted by the line on the film. But the intensity of the light which produces the characteristic line on the film is a function of the concentration of the element in the mixture. The calibration was carried out by the sector method whereby a known quantity of light is allowed to hit the photographic plate and the intensity of the light passing through is registered by a photoelectric cell. Fig. 7 shows a schematic plot of the logarithm of the intensity of transmitted light against the logarithm of the intensity of incident light.

Fig. 8 gives a schematic graph of the intensity of the light against the log of the concentration for the two characteristic lines, Zr 2758 A^o and Hf 3072 A^o. The accuracy of the method at present allows one to determine concentrations of Hf to within 4.4% and of Zr to within 7%. With a source of greater power it is expected that Zr concentrations could be measured within an error of only 3%, and that a hafnium impurity of only 1 part in a 1000 of Zr could be detected.

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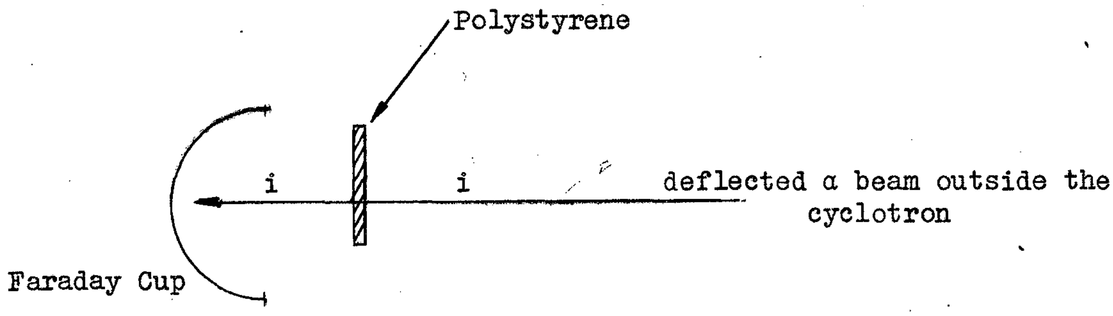
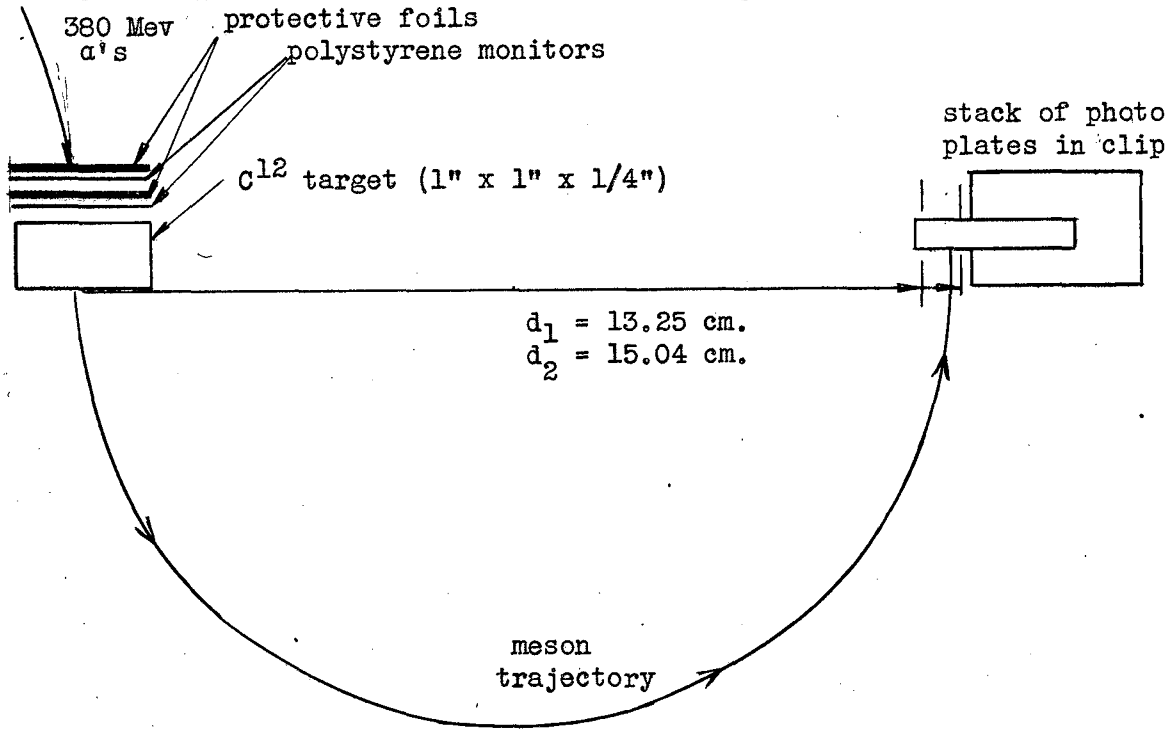


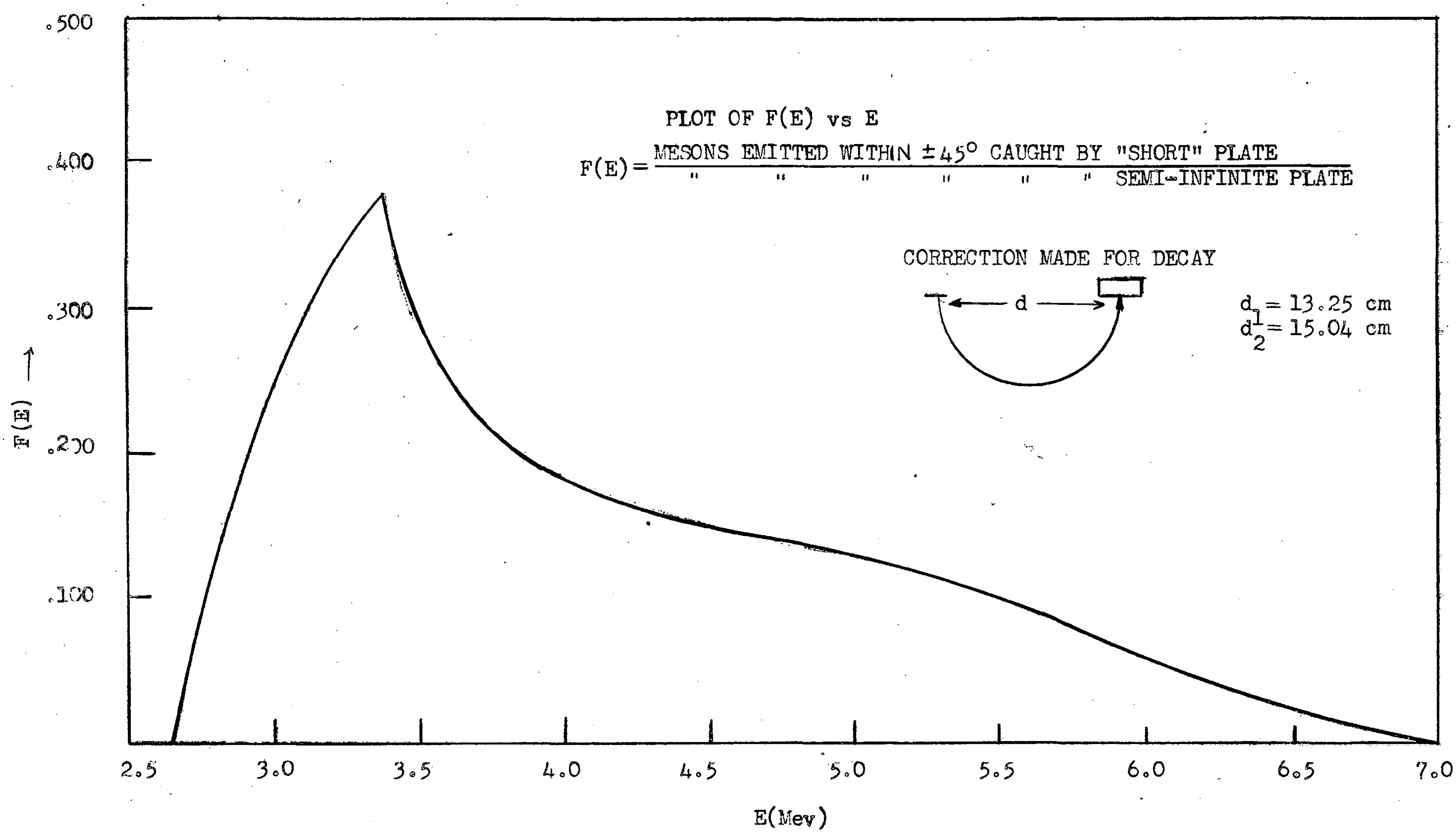
Measurement of C^{11} β-activity induced by deflected α-beam in polystyrene.

Figure 1



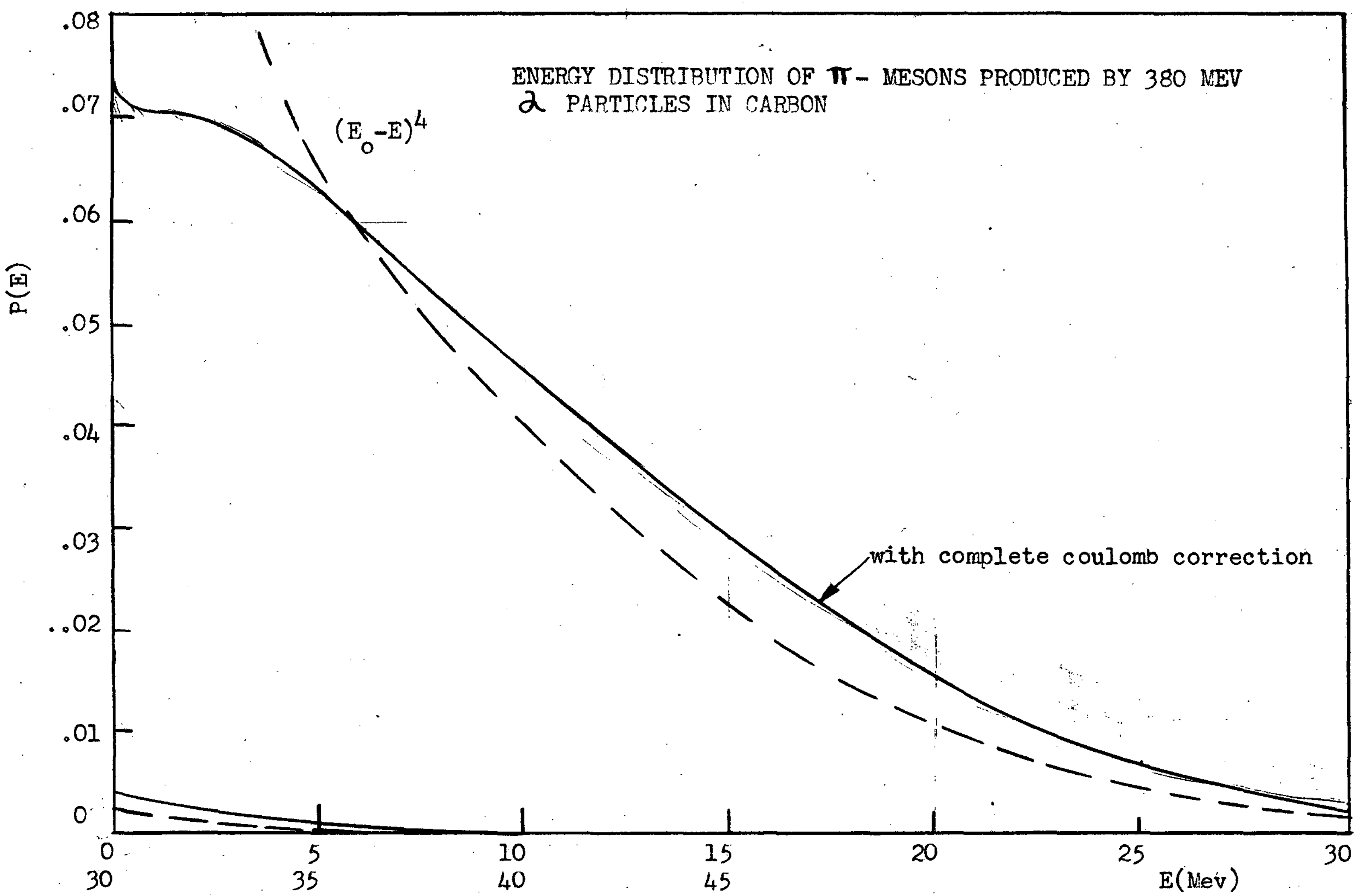
Scheme of the Experimental Arrangement

Figure 2



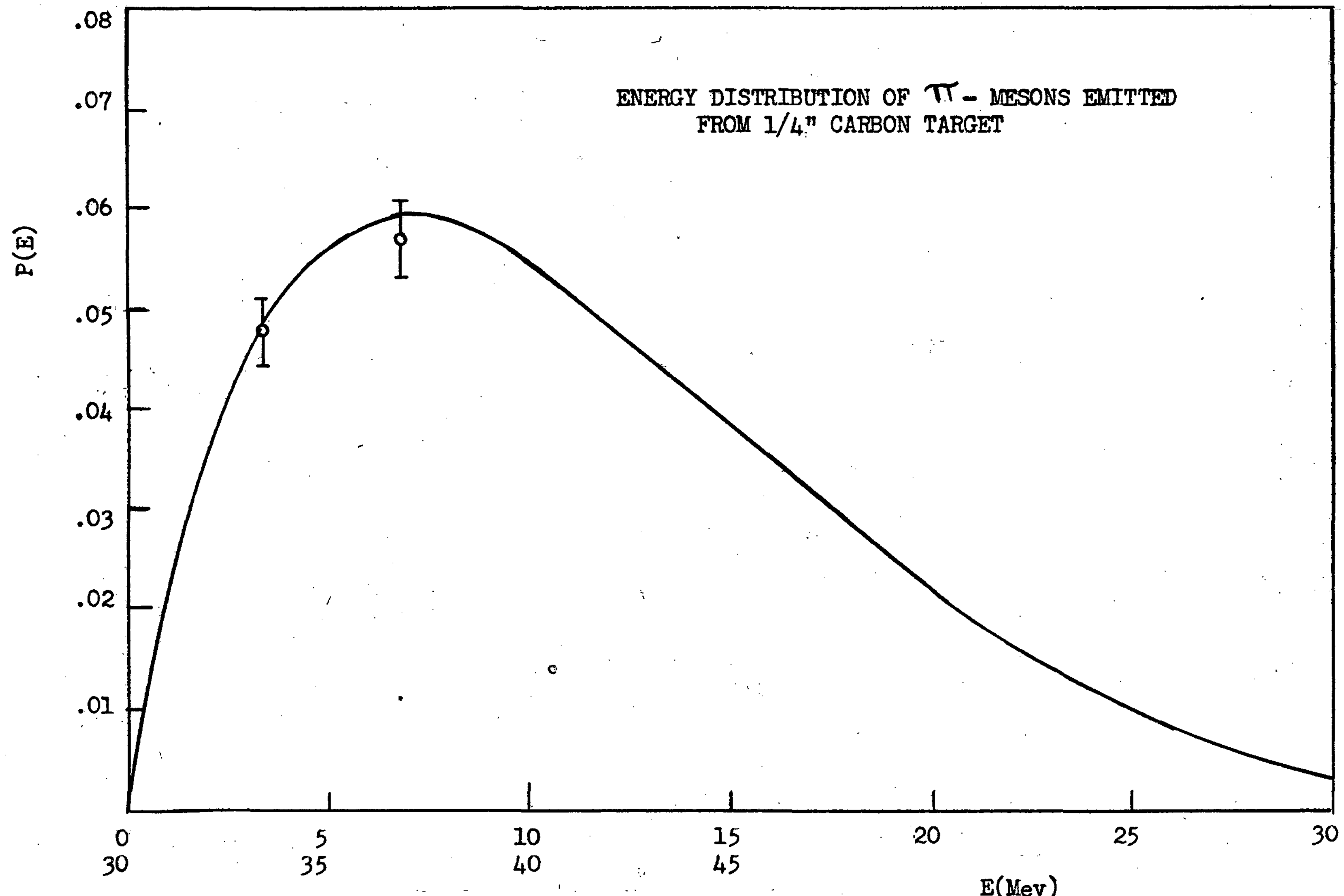
Geometrical Correction

Figure 4



Coulomb Factor

Figure 5



Energy D: stribution with Check Points

Figure 6

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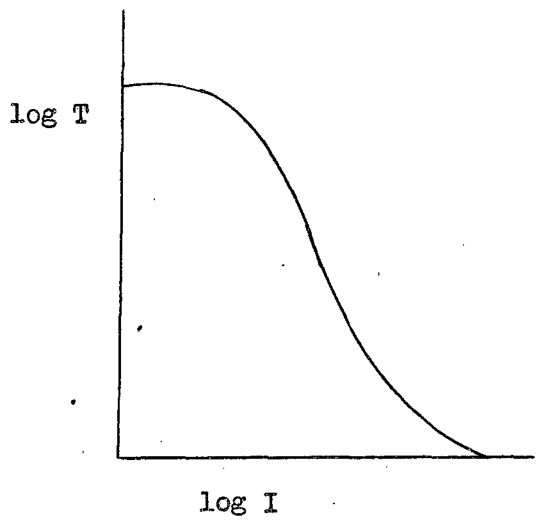

Figure 7

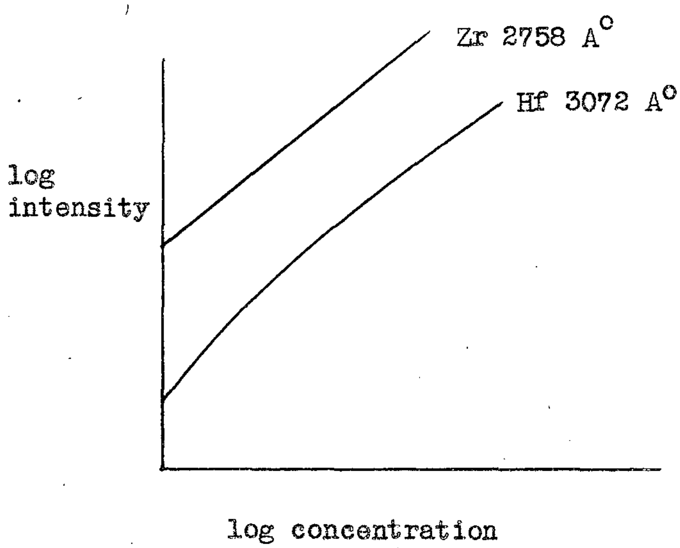

Figure 8

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