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SUMMARY OF THE RESEARCH PROGRESS MEETING

June 23, 1949

H. P. Kramer

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SUMMARY OF THE RESEARCH PROGRESS MEETING

June 23, 1949

H. P. Kramer

Light Pu Isotopes. Don Orth.

Regularities that are observed in nature constitute one of the aspects of the aim of scientific effort since they systematize and "explain" natural phenomena. At the same time they are tools that facilitate, guide and spur further work by making prediction possible and giving direction to research. Thus, the observation by G. Seaborg that a plot of the logarithms of half-lives of even-even alpha emitters against the energy of the α-rays emitted consists of a family of lines whose slopes are almost constant with A and Z, has served to motivate and orient the present attempt to find accurate values for the half-lives of decay by α emission of Pu^{232} and Pu^{234}.

The determination of these half-lives is complicated by the fact that Pu^{232} and Pu^{234} decay both by α-emission and by nuclear capture of orbital electrons. If one denotes by T_t the total half-life, by T_α the half-life of α-decay and by T_o the half-life of decay by orbital electron capture, these quantities are related by the equation

$$\frac{1}{T_t} = \frac{1}{T_\alpha} + \frac{1}{T_o} \quad .$$

If one furthermore specifies F_α to be the fraction of substance that decays by α emission and F_o the fraction that decays by orbital electron capture, and if one makes use of the fact that

$$\frac{T_\alpha}{T_o} = \frac{F_o}{F_\alpha} \quad ,$$

one obtains an equation that is convenient for the evaluation of the half-life of

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α-emission T_α,

$$T_\alpha = T_t \left(1 + F_o/F_\alpha\right) .$$

Thus, the determination of the half-life of α-emission reduces to the measurement of the ratio F_o/F_α.

The measurement of the quantity F_α is a relatively simple matter since every decay by α-emission would fire the counting tube if it were not for geometrical limitations. Therefore, in order to calculate the total number of decays by α-emission from the number of ionizing events, it is merely necessary to multiply the count by a geometrical correction factor.

However the measurement of F_o is much more complex than this. A Pu nucleus may decay by orbital electron capture with finite probability either by capturing an electron from the K shell or by capturing an electron from the L shell. When a vacancy is left in one of these shells it is filled by an electron from one of the shells that are farther removed from the nucleus. When an electron jumps from a level of higher energy to one of lower energy, the difference between the energies of the two levels is usually emitted from the atom in the form of an x-ray quantum. Such an x-ray is called a K x-ray if it is emitted in the process of completion of the K shell and an L x-ray if it is emitted when the L shell is filled. Among K x-rays one generally distinguishes three different types, each one of which is characterized by its energy. One denotes by K_α an x-ray that is produced when an electron falls from the L shell into the depleted K shell. A K_β x-ray is sent forth when the K shell is filled by an electron from the M level. And finally one lumps all x-rays that are produced by electrons that come from the N or higher levels and calls them K_γ. L x-rays are classified similarly. An L_α ray for example is one that is produced by the removal of an electron from the M shell into the L shell.

Since L x-rays produce more ionization than K x-rays and therefore are more

easily detected with a counting tube it was found best to bias the counting equipment for the counting of L x-rays. It was found that the efficiency of an argon filled tube for counting K x-rays was only .1 percent whereas it was .6 percent for the detection of L x-rays. With a xenon filled tube it is possible to achieve an efficiency of 3 percent in the counting of L x-rays.

In deducing the total number of disintegrations by orbital electron capture from the L x-ray count it is necessary to itemize the factors that operate to produce this count and to relate these to the total number of disintegrations:

a) Every capture of an electron from the L shell is accompanied by the emission of one L quantum.

b) Of all the disintegrations that proceed by the capture of an electron from the K shell only those in which the K shell is replenished by an electron from the L shell contribute to the L x-ray count, for when the K shell is completed by an electron from a higher level, the L shell is left intact so that no L x-rays are sent forth. Since the number of L x-rays observed from this source is equal to the K_α count, a determination of the ratio K_α/K will be necessary for an evaluation of the total number of disintegrations.

c) Every orbital electron capture is accompanied by the emission of a γ-ray from the nucleus. There is a finite probability that such a γ-ray may expel an electron from the K or L shell by internal conversion. The vacancy that is left in the shell will then be filled by an outer electron and in this process K and L x-rays are produced. The number of such x-rays must be determined and subtracted from the count since the inclusion of this number would give a weight of two to the disintegrations that are accompanied by the emission of an internal conversion electron. The ratio of internal conversion electrons to the total L count was measured and found to be about .1 . Eventually it is hoped that it will be possible to subtract this contribution to the total count by installing a coincidence system that

eliminates from the total count those L x-rays that appear simultaneously with an internal conversion electron.

d) The daughters that are produced in the decay of Pu^{232} and Pu^{234} again disintegrate by orbital electron capture and add their L x-rays to the total count. This quantity must be subtracted. In the case of Pu^{234} both the α and K capture daughter are sufficiently long-lived, that is, the number of disintegrations in unit time is so small in comparison to the decay rate of the parent, that the effect can be neglected. This is not, however, the case for Pu^{232}.

e) Not all of the disintegrations by orbital electron capture are announced to the world by the emission of an x-ray quantum. It may happen that the available energy is employed in the emission of one of the electrons of an outer orbit. It is estimated that half of all of the disintegrations that occur result in the expulsion of an Auger electron from the atom instead of an x-ray.

f) It was mentioned during discussion that there exists one additional source of spurious L x-rays. The atoms that decay by α-emission contribute to the L x-ray count whenever an α-particle knocks an electron from the K or the L shell. The probability of this event is however so small that it can be neglected in relation to the other contributions.

Work is in progress at present to perfect the measurement of the quantities discussed under b) and c) by means of coincidence arrangements. In order to arrive at a preliminary result however it is necessary to assume that the opposite effects b) and c) tend to cancel each other and that after appropriate corrections for counting efficiency and geometry have been made, the total number of disintegrations equals twice the number of L x-rays emitted.

The counting rates that were observed for Pu^{234} are 120 counts/min. of L x-rays and 475 counts/min. of α-particles. After the above-mentioned assumptions and corrections are applied one arrives at the provisional value $F_{\sigma}/F_{\alpha} = 25$.

This number together with the accepted value for the total half-life T_t yields an approximate value of the α decay half-life $T_\alpha \cong 9$ d.

Some work has been started on the determination of T_α for Pu^{232}. However, the measurements for this isotope are complicated by the fact that the daughters are relatively short lived and therefore their contribution to the total L x-ray count must be taken into account. A very crude value of F_0/F_α has been arrived at, $F_\alpha/F_0 \cong 50$. To this number there corresponds an α decay half-life of 30 hr. These values are subject to the additional uncertainty introduced by the possibility of Np contamination of the sample.

The X-ray Spectrum from the Synchrotron. W. Powell.

A sequence of measurements has been initiated to determine the energy distribution of x-ray quanta produced by 335 Mev synchrotron accelerated electrons in a platinum target. The determination is made on the basis of the pair production in a lead sheet placed in the cloud chamber. From $H\rho$ and the mass and charge of an electron, the energy of the pair and therefore the energy of the quantum that produced the pair can be calculated. From a knowledge of the cross section for pair production in lead, one can then compute the energy spectrum of the x-ray beam. Two hundred and forty pairs have been analyzed thus far. It is planned to examine a total of 1500 pairs.

Fig. 1 shows a plot of the product of the cross section for production of quanta of energy k by bremsstrahlung and the energy k versus the energy. It is apparent from the graph that this product can be fairly well approximated by a constant and that therefore, the cross section varies inversely with the energy. The total number of quanta with energy in excess of k and less than k_0, the maximum possible energy, is a linear function of log k. k_0, the maximum possible energy, corresponds to the energy of the electron beam, 335 Mev, and a quantum carrying this energy is one that was produced by a complete transfer of energy without loss.

$$N(k) = E/E_0 \ (\log k_0 - \log k) \ .$$

The graph of Fig. 2 shows the number of observed electron pairs whose total energy was less than the maximum energy and greater than k, for the range of values k = 0-335 Mev. The graph of Fig. 3 has the same ordinate but a logarithmic scale for the abscissa. Since the graph is almost linear it corresponds to what is expected for the energy distribution of quanta in the x-ray beam. It will be noticed that the curve intercepts the axis of energies at 320 Mev which is fairly close to the expected value of 335 Mev. Taking into account the variation of the cross section for pair production to obtain a more nearly accurate picture of the x-ray energy distribution would have the effect of making the graph even more linear.

Photographs of tracks in the cloud chamber are shown in Figs. 4 and 5. Electron pairs can be observed emanating from the thin plate of lead and from the gas filling of the chamber.

Mesons. L. Alvarez.

The apparatus that is shown in Fig. 6 has been set up in the shielded cave outside the evacuated chamber of the 184-inch cyclotron in the path of the electrostatically deflected proton beam. Two ionization chambers are located immediately outside the exit window. One of these performs the function of keeping the cyclotron crew informed about the proton current so that necessary adjustments can be made by them to maintain the proton current at a constant value. The other one monitors the beam in conjunction with the experiment. A beryllium target in the path of the beam is used for a radiator and an anthracene crystal taped to a photomultiplier tube serves for a detector. Provisions have been made for the insertion in the proton beam of copper attenuators for beam energy control. Lead foils placed between the radiator and detector slow down radiation that is produced in the beryllium target.

The purpose of the experiment is to measure the half-life of the decay of π^+ mesons into μ^+ mesons and thence to electrons. Since the cyclotron is pulsed,

the protons that are accelerated arrive at the beryllium target in closely packed groups. A burst of protons releases a great variety of radiation in the target. Since the experiment is concerned only with the π mesons that are produced it is necessary to select a property of π mesons that distinguishes them from other radiation and thus makes possible discrimination by the counting mechanism. The characteristic of π mesons that is used to differentiate them from the other types of radiation produced is the short range of π and μ mesons and the delayed emission of electrons. All other radiation is produced and dissipated almost instantaneously. π mesons however decay into μ mesons and then into electrons with an approximate half-life of 2.5 microseconds.

In order to avoid the counting of radiation other than that consisting of electrons from mesons, the signals from the counter are passed through an electronic gate that prevents the counting of pulses for 3 microseconds after the production of radiation by a parcel of accelerated protons, then allows the transmission of pulses for 3 microseconds, and finally is shut down again until the next production of a shower of radiation occurs.

Fig. 7 shows a graph of counting rate versus thickness of lead interposed between the radiator and the detector. Counts were observed at a thickness of lead of 4 in. This thickness corresponds roughly to a meson energy of 150 Mev. The range of electrons in Pb is however neglected and the value is therefore too high. However, it is felt that this number is a strong indication that the energy of mesons exceeds the theoretical maximum of about 90 Mev.

A preliminary value for the cross section for meson production is .2 μbarns per Be nucleus.

It is planned to mount a G.M. tube on a turntable in order to measure angular variations in the production of mesons.

Absorption of γ-rays Producing γ-n and γ-2n Reactions. Karl Strauch.

A number of materials have been exposed to the x-ray beam of the synchrotron. The following reactions were observed and identified by the half-lives of the products.

	Reaction	Product Half-life
1)	$Cu^{63}(\gamma,n)Cu^{62}$	10 min.
2)	$Cu^{63}(\gamma,2n)Cu^{61}$	3.4 hr.
3)	$Cu^{65}(\gamma,n)Cu^{64}$	12 hr.
4)	$Cu^{63}(\gamma,2p)Co^{61}$	1.5 hr. (?)
5)	$Zn^{64}(\gamma,n)Zn^{63}$	38 min.
6)	$Zn^{64}(\gamma,2n)Zn^{62}$	9.4 hr.
7)	$Zn^{64}(\gamma,d)Cu^{62}$	10 min.
8)	$C^{12}(\gamma,n)C^{11}$	20 min.
9)	$Al^{27}(\gamma;2p,n)Na^{24}$	14.8 hr.

The hypothesis that the yield of Cu^{62} in reaction (7) was produced by a (γ,n) reaction from Cu instead of by the indicated one implies a 10 percent Cu impurity in the Zn target and must therefore be ruled out.

The target for reaction (9) consisted of a 60 mil aluminum disk and the initial observed counting rate was 100 counts/min.

In order to investigate yield as a function of x-ray energy a sandwich consisting of alternating layers of lead and copper foil was prepared and exposed to the x-ray beam. The intensity I of β^- emission by the reaction products was then measured for the various foils and the data compiled in graphs like that of Fig. 8. Here, I_o represents the intensity of the β^- emission from a foil in the full intensity beam and the abscissa is marked in shower units. 1 s.u. equals about .5 cm of lead and has the effect of decreasing the energy of a highly energetic particle to about half its initial value.

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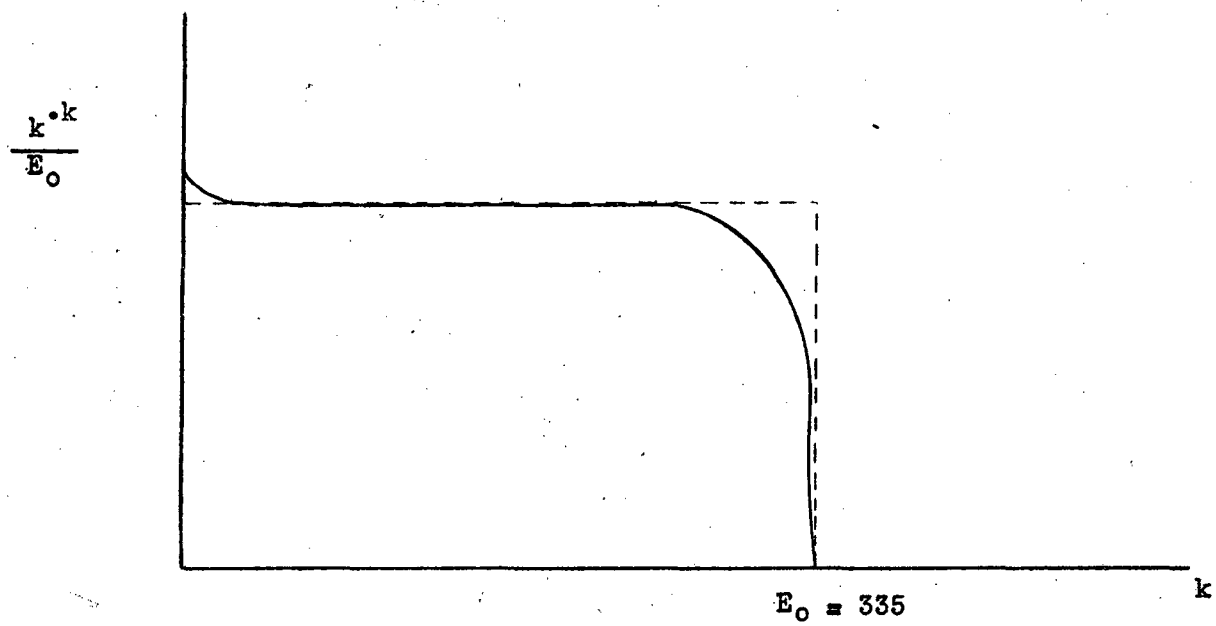

Production of Bremsstrahlung Quanta

Fig. 1

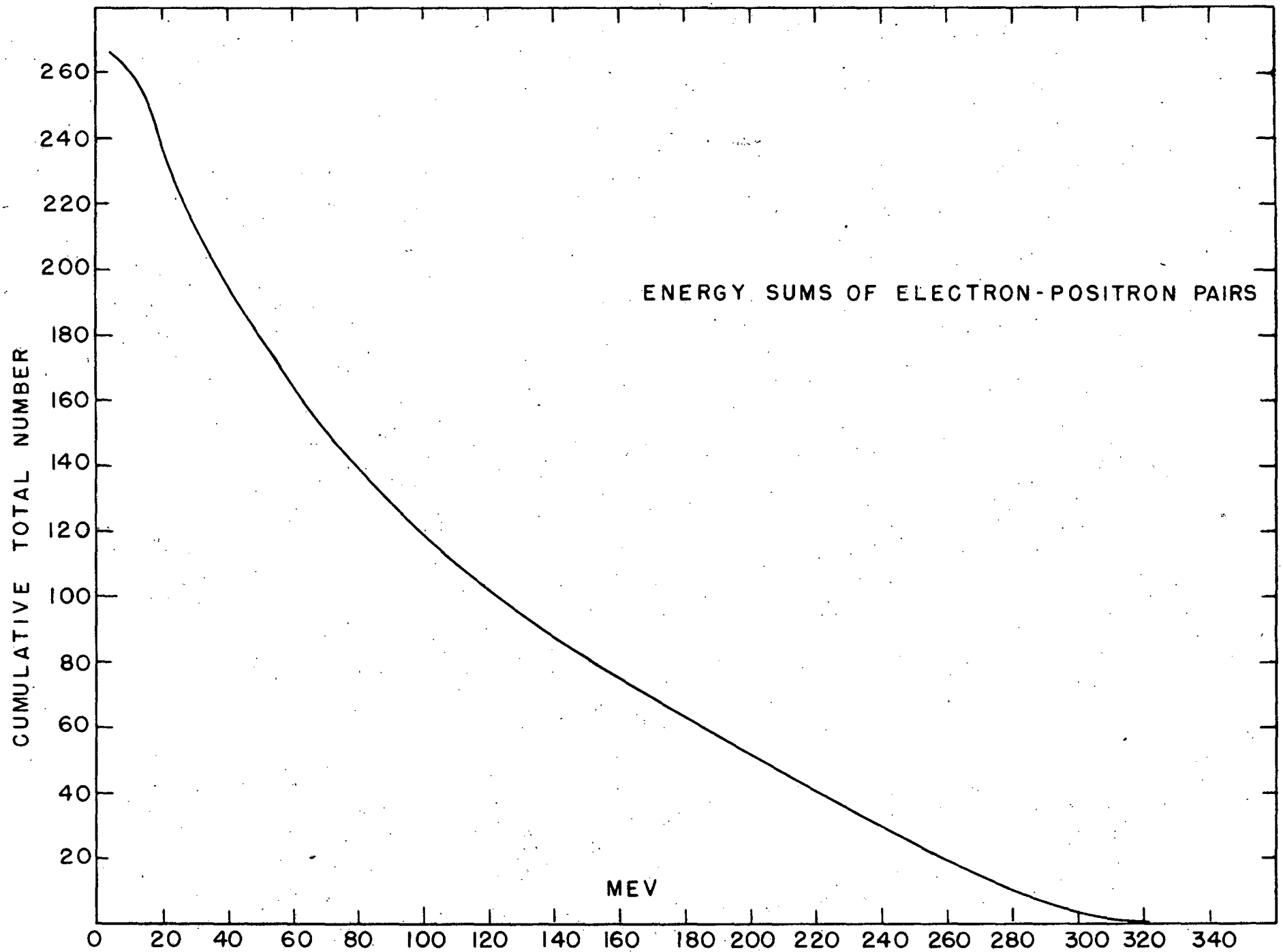
ENERGY SUMS OF ELECTRON-POSITRON PAIRS
CUMULATIVE TOTAL NUMBER
260
240
220
200
180
160
140
120
100
80
60
40
20
MEV
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340

FIG. 2

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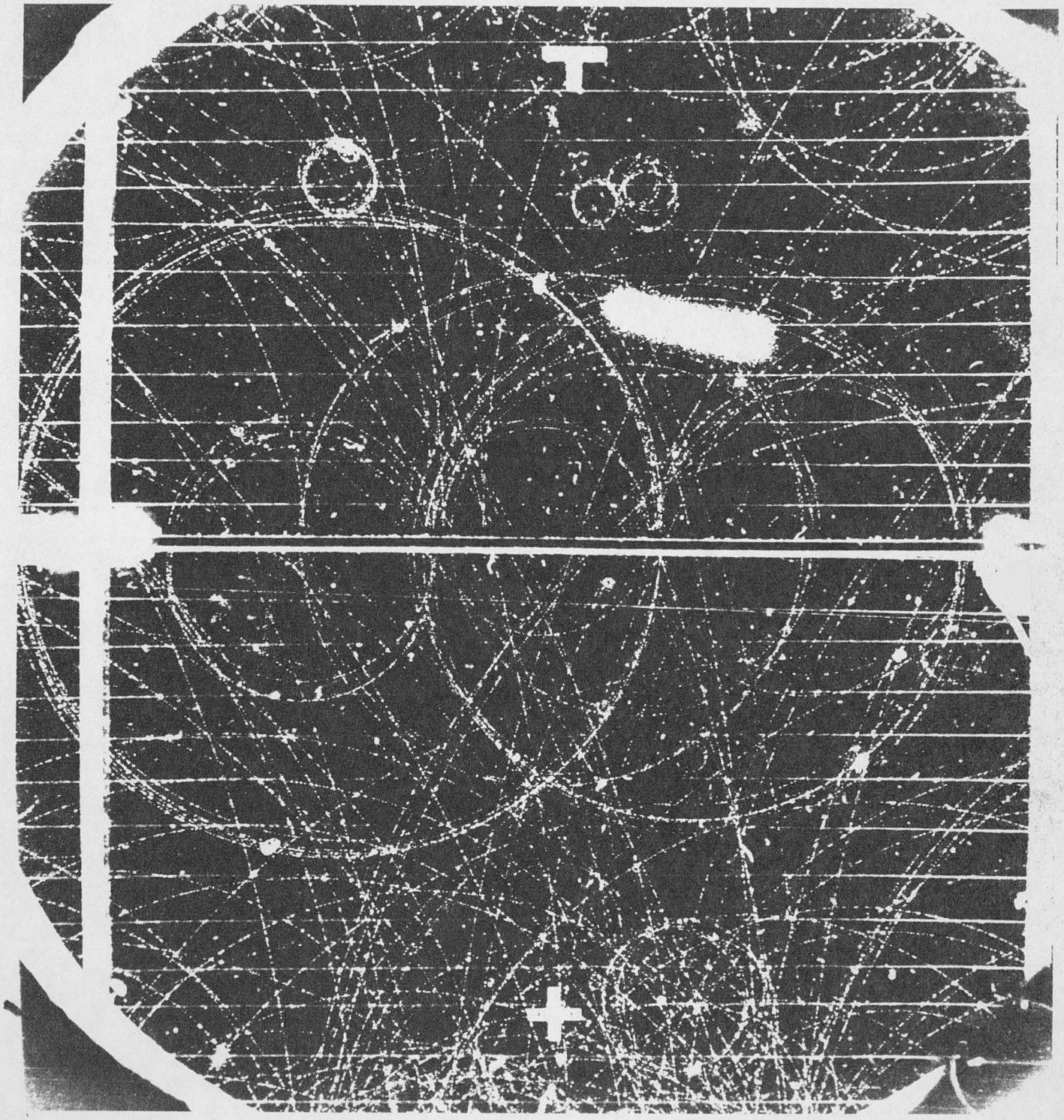

FIG. 4

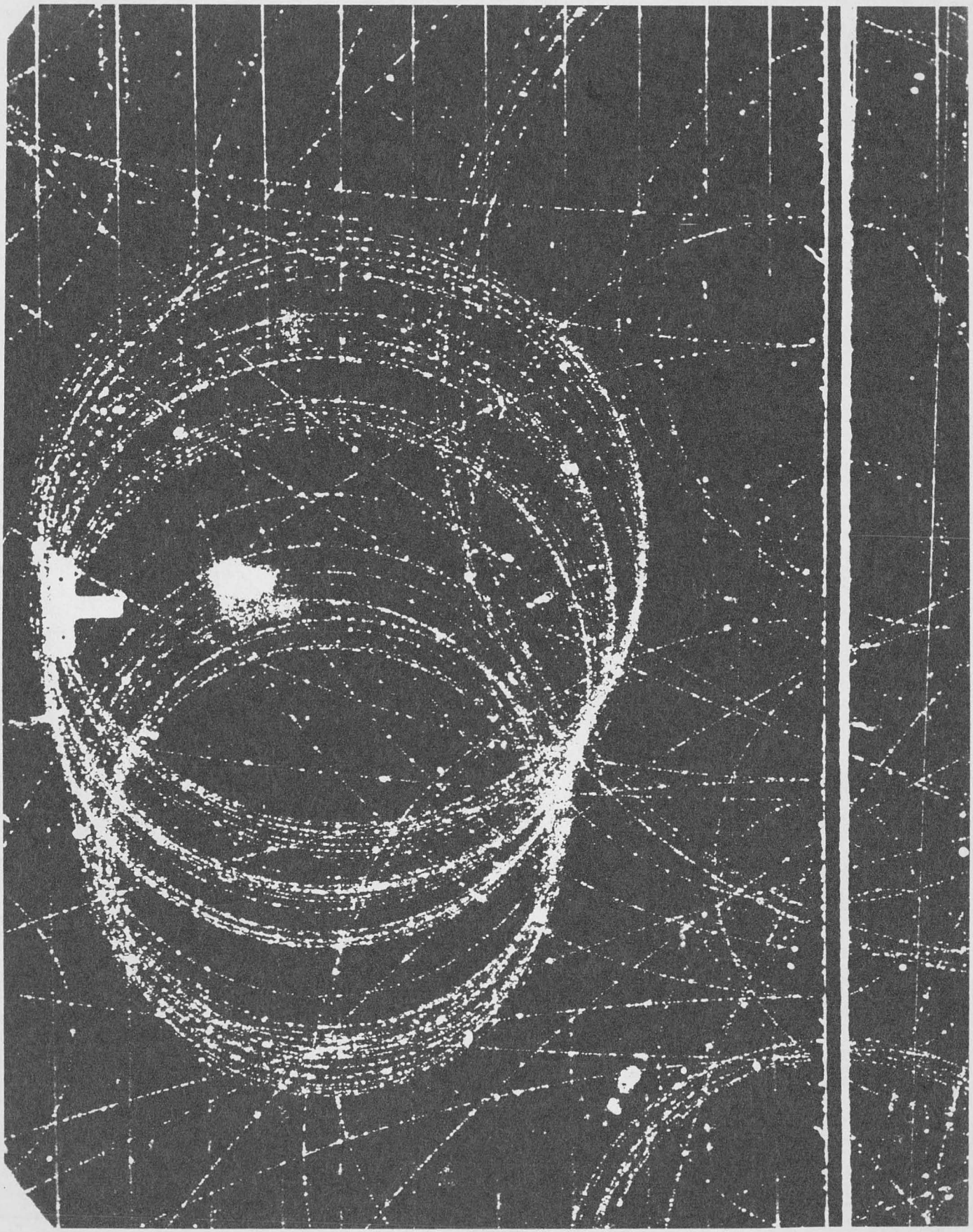

FIG. 5

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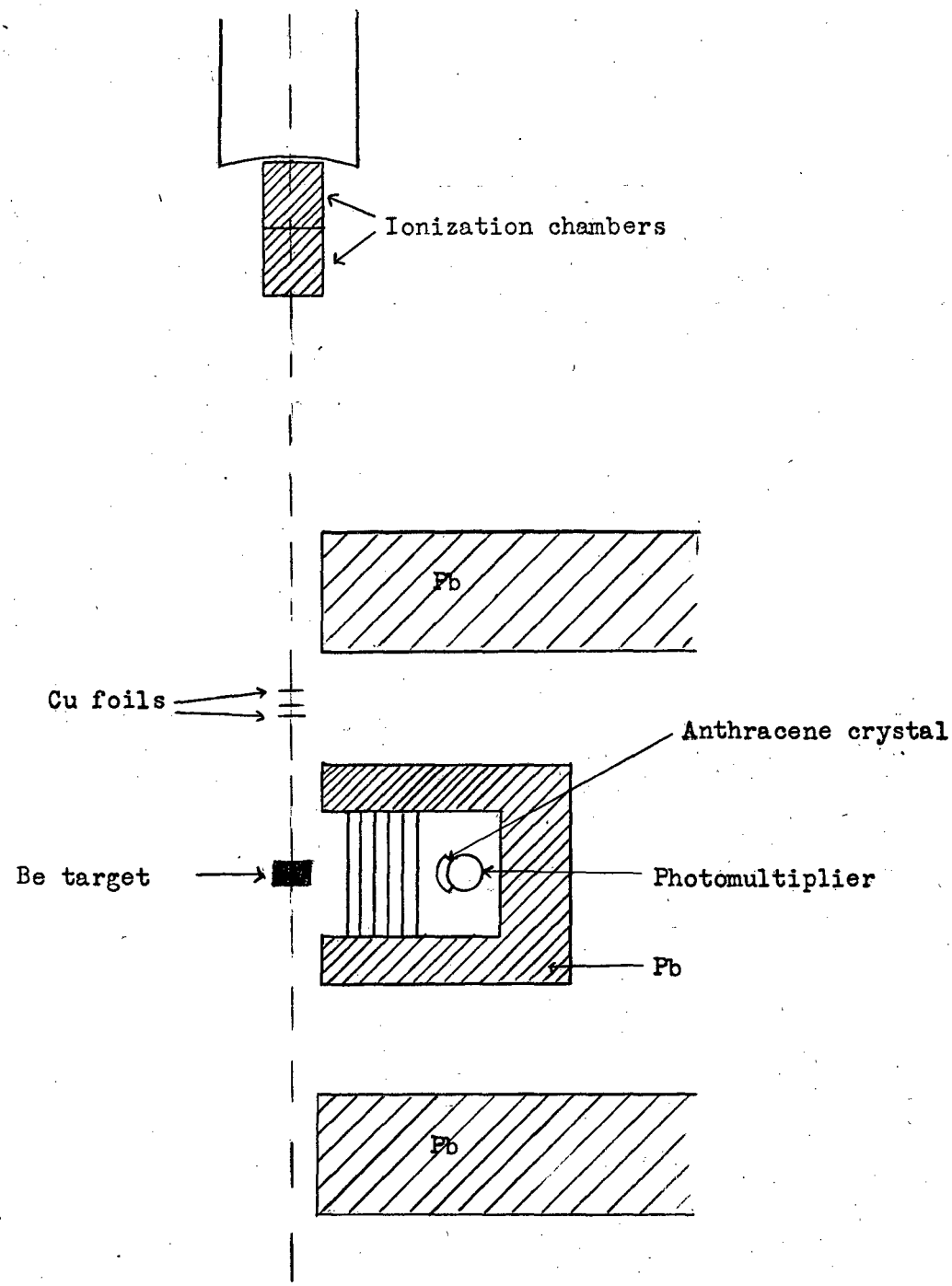
Ionization chambers
Pb
Cu foils
Anthracene crystal
Be target
Photomultiplier
Pb
Pb

Fig. 6

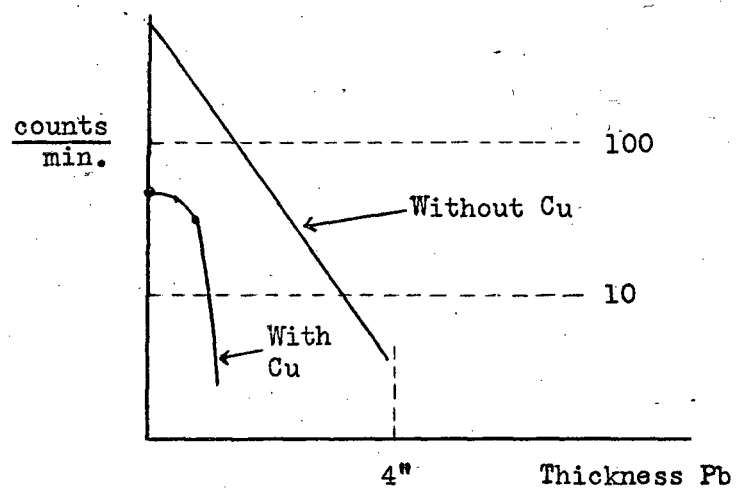
counts
min.
100
10
Without Cu
With
Cu
4"
Thickness Pb

Fig. 7

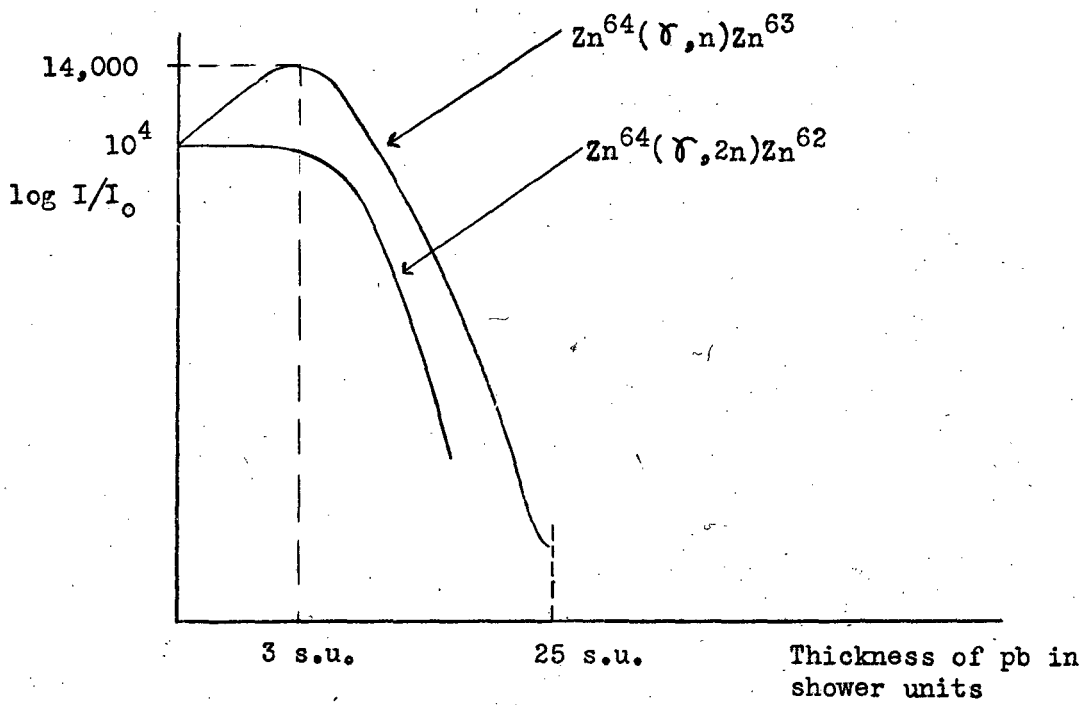
14,000
10^4
log I/I_o
$Zn^{64}(\gamma,n)Zn^{63}$
$Zn^{64}(\gamma,2n)Zn^{62}$
3 s.u.
25 s.u.
Thickness of pb in
shower units

Fig. 8.

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