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SUMMARY OF THE RESEARCH PROGRESS MEETING

of September 8, 1949

H. P. Kramer

October 13, 1949

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SUMMARY OF THE RESEARCH PROGRESS MEETING

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H. P. Kramer

F. M. Cyclotron at Montreal. J. J. Foster.

The newly established Radiation Laboratory of McGill University is housed in a three floor building and employs thirty people of whom twenty five are scientists. The Laboratory is equipped with a cyclotron which is completely underground and is reached from the Laboratory Building through a subterranean passage.

The magnet weighs 300 tons. The pole pieces have a diameter of 82 inches and are separated by a 7.5 in. gap. The maximum magnetic field is 16,500 gauss and tapers 3.8 percent from the 0 to the 36.25 in. radius. The magnet coils consist of extruded aluminum tubing and are cooled by piping water through them. The r.f. system is similar to that which was originally in operation at the Berkeley 184-inch cyclotron. It employs a twenty-four tooth condenser which runs at 600 rpm on a ceramic axle and thus produces 240 cycles per second.

The vacuum chamber consists of stainless steel walls which are welded to the pole pieces. The dee is 3-1/2 in. in height at the center and has a voltage of 10,000 volts.

The magnetic field is remarkably uniform. The azimuthal variation at all radii does not exceed 1/10 percent.

It is possible with this cyclotron to obtain 100 Mev protons with a current strength of 1/10 microampere.

Synchrotron Experiments. R. Hofstadter.

J. McIntyre and the speaker have continued at the synchrotron an investigation into the angular distribution of scattered x-rays which was begun at Princeton

University. In order to present the background of the present experiment, the work that was performed at Princeton University will be briefly described.

The apparatus that was used is shown schematically in Fig. 1. The source of photons was Co^{60} whose γ-ray spectrum consists of two lines at about 1.10 and 1.30 Mev. The scatterer was a stilbene crystal in which a scintillation was produced by the recoil electron. This scintillation was detected by means of a photomultiplier tube. At an angle θ with the direction of the beam of photons, another stilbene crystal was set up to detect the scattered γ-ray. The photomultiplier tubes which viewed the two crystals were connected by a coincidence circuit so that every recorded count indicated the occurence of a scattering event. The number of coincidences were then set down as a function of the angle θ to give the angular distribution for 1.10 and 1.30 Mev photons. It is essential in performing this experiment to know beforehand the energy of the photons which initiate the Compton effect.

However, the x-ray beam of the synchrotron contains photons with a continuous energy distribution over the range from 0 to 327 Mev. Therefore, the experiment had to be redesigned to measure an additional parameter to indicate the energy of the incoming photon. Not only the scatter angle θ, but also the angle ϕ of the trajectory of the recoil electron was measured. These quantities are related to each other and to the energy E of the incoming photon by the equation

$$\cot \phi = (1 + \frac{E}{mc^2}) \tan 1/2 \theta ,$$

where m is the constant rest mass of the recoil electron and c is the velocity of light. By holding the ratio $\cot \phi / \tan 1/2 \theta$ constant it was possible to observe only those photons which carried the same energy E.

The arrangement of the apparatus is shown schematically in Fig. 2. The photon beam is scattered by a thin beryllium foil. The recoil electrons that are produced are detected by a pair of stilbene crystals which subtend an angle of about 12° at the scatterer. Each one of these crystals is viewed by a photomultiplier cell. The scattered γ-rays are detected by means of the scintillations which the electron pairs that they produce in lead foils incite in a series of stilbene crystals sandwiched between the foils. This system of foils and crystals is also viewed by a photomultiplier cell. The three enumerated photomultiplier cells are wired in coincidence. However, a triple coincidence may not only be caused by a scattering event but also by the two members of a pair of electrons produced by the photon in the beryllium target. In order to eliminate the portion of the counts which might be due to pairs, a thin stilbene crystal was placed in front of the sandwich detector and wired in anti-coincidence with the remaining three counters. An electron produces a pulse on this crystal, whereas the probability that a high energy γ-ray excites a scintillation in the first crystal is low, about .03.

The counts are recorded visually by means of an oscilloscope. The pulse from the photon counter Z is used to trigger the electron gun. The pulse from the first β-ray counter X is imposed on the plates which produce deflection along the x-axis of the oscilloscope screen and the vertical deflection is controlled in the positive direction by the pulse from the second β-ray counter Y_1 and in the negative direction by the pulse from the pair detector Y_2. When the pair detector Y_2 produces a pulse it is amplified somewhat more than that from the second β-ray counter so that the image is pulled into a portion of the screen that has been made opaque. A typical oscillogram is pictured in Fig. 3.

The flash from the stilbene crystals decays exponentially with a half-time of 0.01×10^{-6} sec. The amplifiers that are used produce pulses with a Gaussian distribution that vary in half-time between 0.03 and 0.05×10^{-6} sec. These values the resolution of the amplifiers is not sufficiently fast to distinguish between some pairs of successive photo pulses. Even though the presently employed photomultiplier tubes produce pulses of only about 1/10 v. a test showed that the voltage transmitted through a 200 ft. delay line is sufficient to give a 1/4 in. deflection on the oscilloscope screen. This result leads one to think that it may be possible to construct tubes in the laboratory which can be used to activate the oscilloscope directly and that in this way the amplifiers may be eliminated and the resolving time improved.

In the preliminary stages of the experiment some coincidences were lost to the oscilloscope because of the length of time required for electrons to complete the circuit of the large photomultiplier tube 5819 which was used in conjunction with the large β-ray detector. This difficulty was overcome by increasing one delay line by 20 ft. and thus slowing up the other pulses which constitute the triple coincidences.

The number of coincidences which are due to background events was measured by increasing the delay line from the γ-ray detector by 20 ft. When the scatterer is removed one still gets coincidences which originate in the air.

The results which have been obtained at the present time together with the theoretically predicted Klein-Nishina function, the background count and the number of coincidences observed without scatterer are shown in Fig. 4. The graph indicates that at low angles the observed data deviate from the theoretical curve. This is probably due to the fact that the energy imparted to the recoil electron is relatively small when the γ-photon is not scattered appreciably and that low energy electrons are not always detected by the counting apparatus.

In order to make sure that it is the Compton effect which produces the counts, the β-counter was moved out of the plane defined by the γ-ray beam and the γ-counter. The number of coincidences decreased considerably although it did not vanish completely since pair production contributed some counts.

The ideal way to perform this sort of experiment is by analyzing the energy of the recoil electrons with a magnet. The size of the apparatus, in particular, of the γ-ray counter, and the available gap space are the practical factors which constitute the limitations of this plan.

Lifetime of the π^+ Meson. E. Martinelli.

Approximately a year ago J. R. Richardson made a determination of the lifetime of heavy negative mesons produced in the 184-inch cyclotron. (The Lifetime of the Heavy Mesons, J. Reginald Richardson, AECD 2308). In designing the experiment, Richardson took advantage of the fact that, because of the extremely short lifetime of the heavy meson, a substantial number of mesons decay within a small distance from their place of origin. Since the yield of mesons from the deflected beam is not sufficient, the experiment was performed in the vacuum tank of the cyclotron where the magnetic field combined with the vertical momentum of the mesons has the effect of directing the mesons in helical trajectories. By exposing photographic plates at multiples of 180° within a helical channel arranged in a copper block one is able to observe the ratio of the number of heavy mesons that remain after mesons have spiraled through several half-turns to the number of mesons that were produced. With this ratio one can calculate the fraction of mesons that decay in flight between two points on the helical trajectory and thus determine the lifetime. After the conversion of the 184-inch cyclotron to the acceleration of protons, it was decided to elaborate on Richardson's experiment with the mesons of higher energy which are produced by the proton beam.

The apparatus in relation to the cyclotron dee is shown in Fig. 5. Fig. 6 gives a view of the helical channel that was used. Ilford C-2 100 micron plates were placed at 180°, 540°, and 900° from the point of origin of the mesons. From the meson count on these three sets of plates, after subtraction of geometrical losses, the number of mesons that decayed could be computed.

The geometrical losses were determined experimentally by replacing the meson source by a strong alpha emitter and determining the losses which in the case of alpha particles can not be attributed to any but geometrical causes.

Since it is possible for mesons to enter the plates by other paths than those originating at the source it was necessary to count the background by blocking off the channel between the target and the plates.

The optimum position for the meson source with respect to the center of the cyclotron was determined to be 65 in. by calculating the precession of the axis of the helical trajectories which is caused by the gradual decrease in the magnetic field with radius and arriving at a compromise between minimum precession and maximum bombarding energy.

In order to prevent a spurious increase in the meson count from multiple traversals of the source by the alpha beam, a shield was placed at the same radius as the target and 180° removed from it.

The value for the lifetime which was arrived at is

$$\tau = 1.97 \pm \begin{matrix} .14 \\ .17 \end{matrix} \times 10^{-8} \text{ sec.},$$

and the half life is

$$\tau_{1/2} = 1.37 \pm \begin{matrix} .10 \\ .12 \end{matrix} \times 10^{-8} \text{ sec.} \quad .$$

A complete discussion of the work is contained in "The Lifetime of the Positive π^+ Meson", E. Martinelli, Ph.D. Thesis, University of California.

Isotopes of Bismuth. H. Neumann.

In keeping with the program of the Chemistry Division of determining systematic relations which might exist among alpha-particle emitters an investigation of light bismuth isotopes was instituted.

Pb was bombarded and the Bi fraction separated. The following table presents particulars of the four Bi activities which were observed:

Threshold Energy Mev	Half-life	α - emission half-life	α-Energy Mev.	$\frac{\text{Total rate of disintegrations}}{\text{rate of disintegrations with } \alpha\text{-emission}}$
<40 Mev	62 min.	83 yrs.	5.15	7×10^5
40-50	25 min.	2.9 yrs.	5.47	6×10^4
60-50	9 min.	<.42 days	5.83	$< 7 \times 10^3$
	1.7 min.	< 4 days	26.2	$< 3 \times 10^3$

The mass assignments were made in each case by counting the Pb and Tl decay products. The branching ratio was determined by Tl milking and alpha pulse-analysis. The 9 min. isotope was assigned the mass number 198, the 25 min. activity, the mass number 199, and the 62 min. activity the mass number 201. It is believed likely that the 1.7 min. activity corresponds to A = 197.

An interesting alpha-activity was observed for Bi^{210}. This completes an isomeric pair of which one member has an alpha-emission energy of 5.0 Mev and the other an energy of 4.8 Mev. The upper limit of the half-life of the upper energy state is $5 - 10^5$ yrs.

Details of this work are described in the "Quarterly Chemistry Report", UCRL 460.

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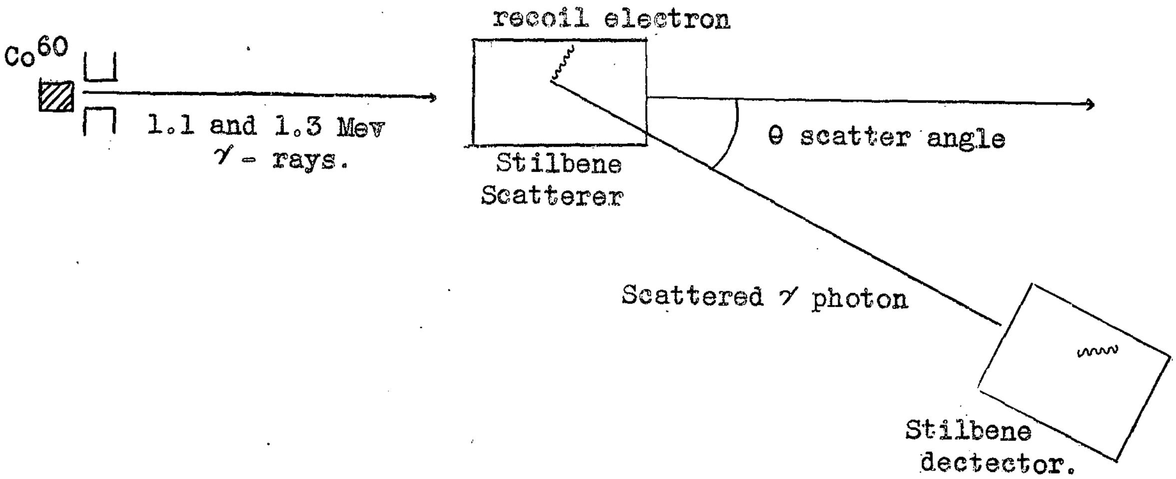


Fig. 1

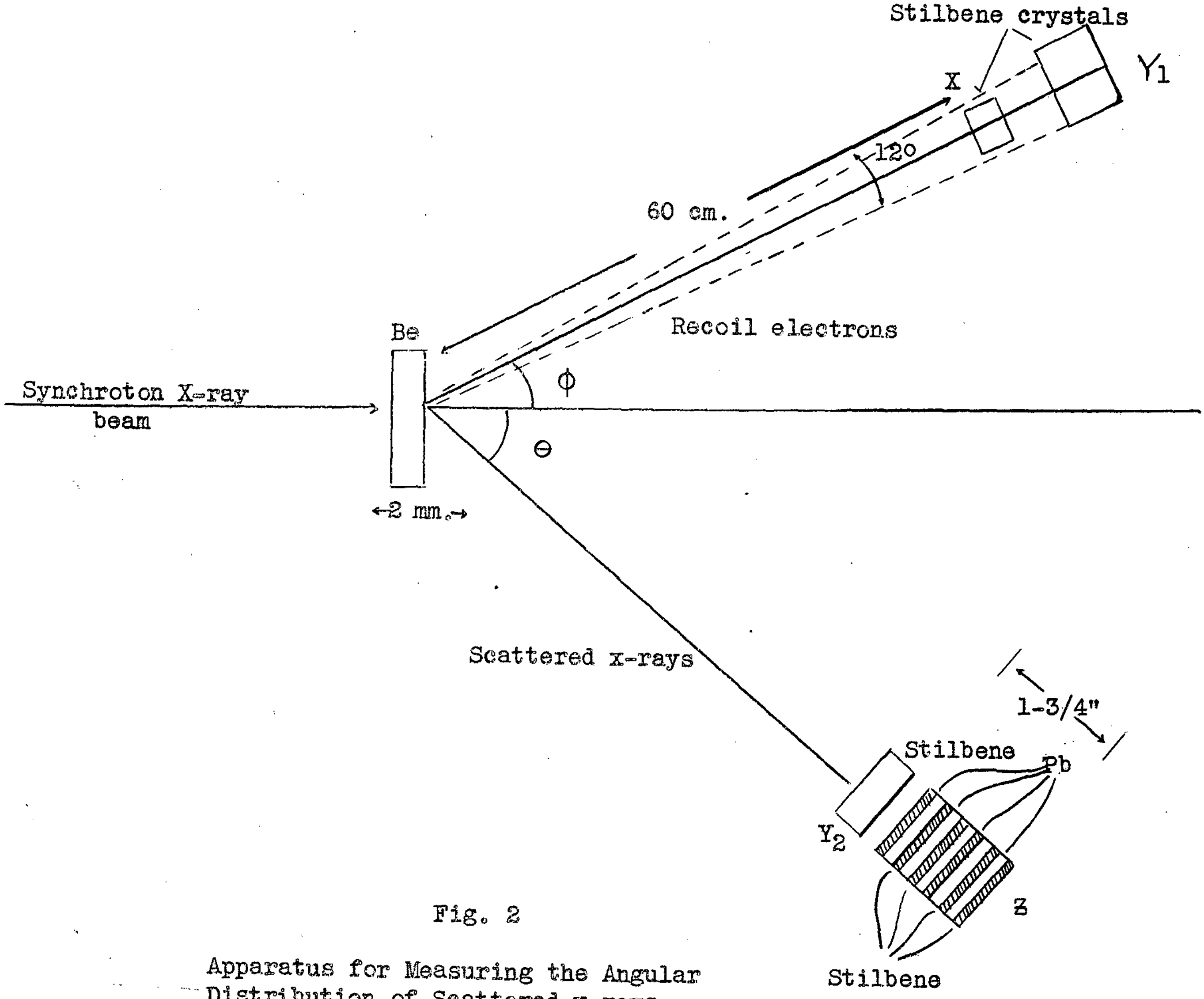
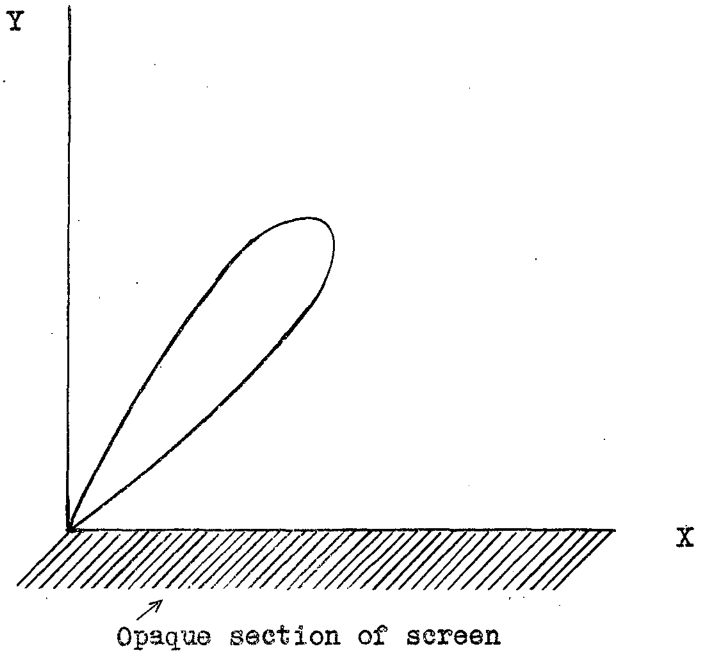


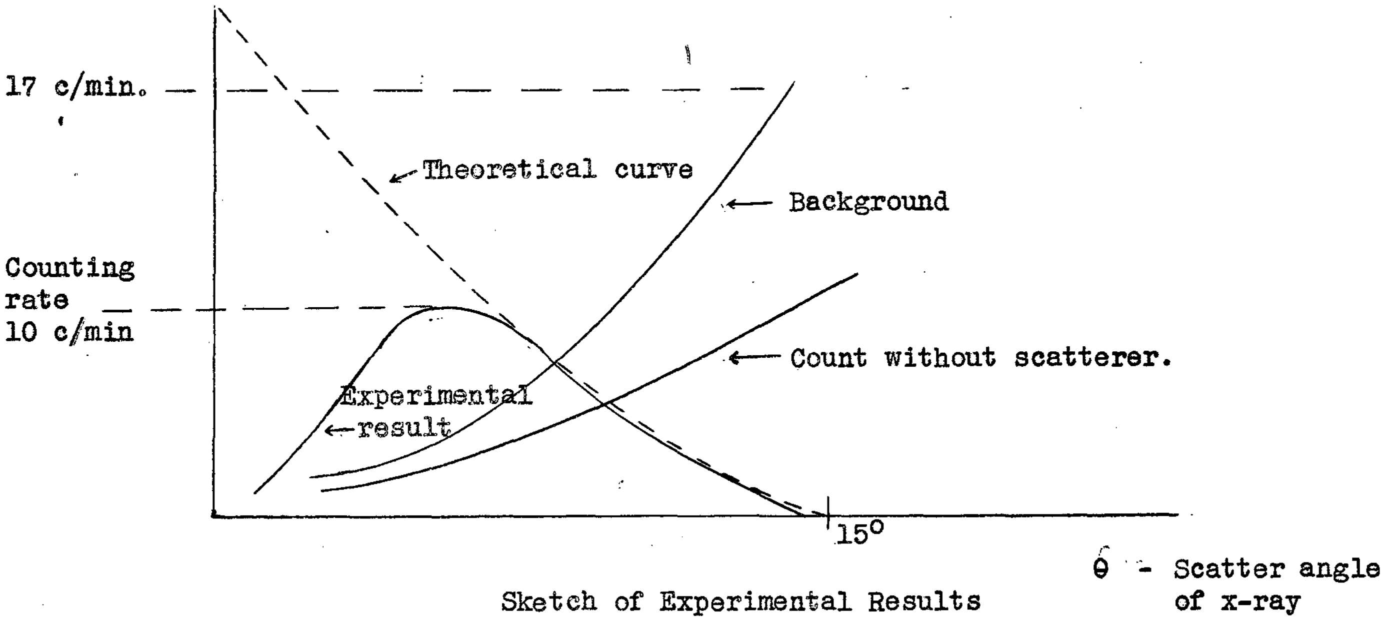
Fig. 2

Apparatus for Measuring the Angular Distribution of Scattered x-rays.



Typical Oscillograph

Fig. 3



Sketch of Experimental Results

Fig. 4

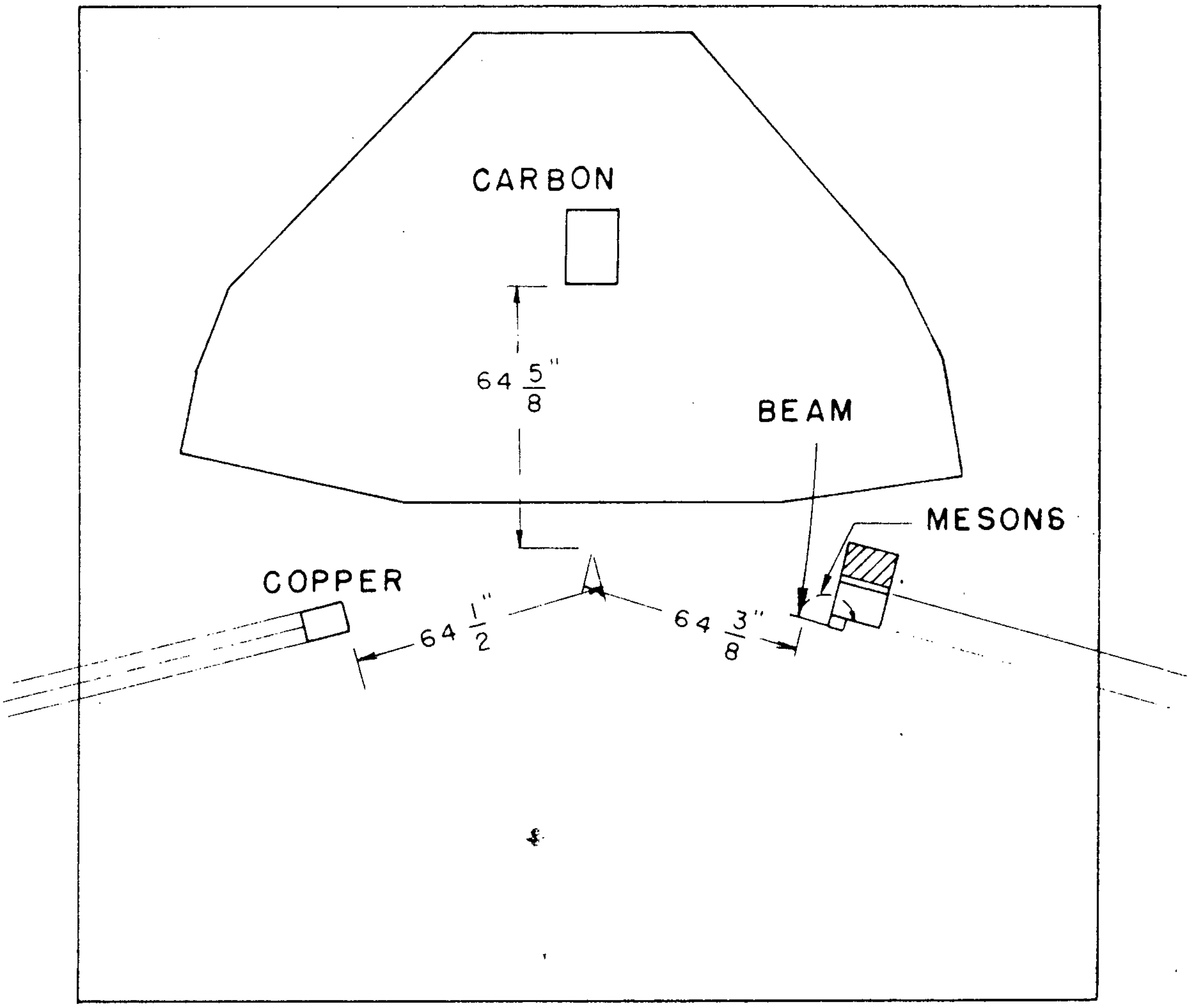


FIG. - 5

LOCATION OF SHIELDING IN THE CYCLOTRON

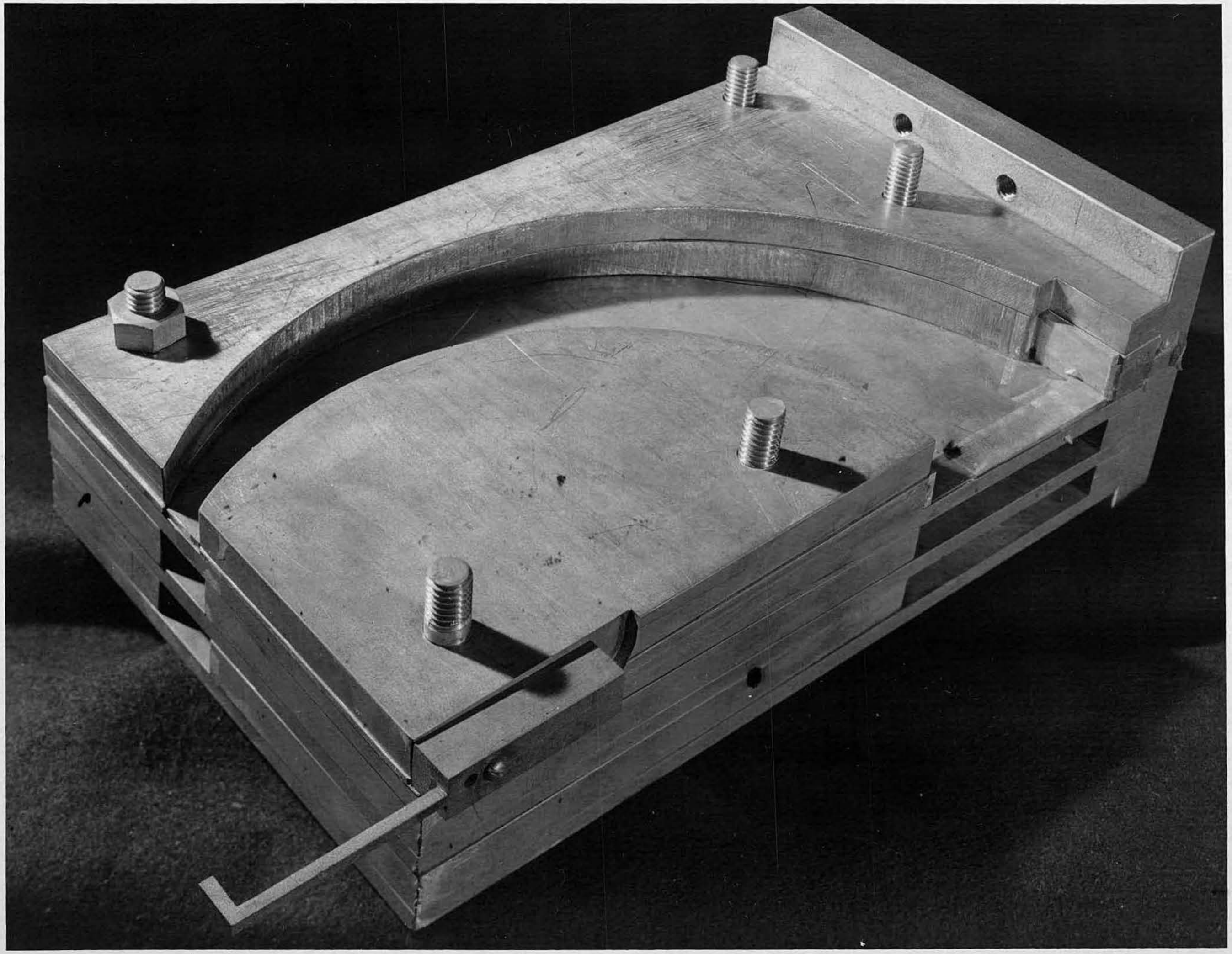


FIG. 6