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LAWRENCE RADIATION LABORATORY
UNIVERSITY of CALIFORNIA BERKELEY

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A METHOD FOR MAPPING THE SPATIAL DISTRIBUTION OF STOPPING π^- MESONS IN TISSUE *

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Stopping π^- beams have been proposed[1,2,3] for radiotherapeutic applications in view of the fact that the 'star' formation in the capture reaction produces a highly localized dense ionization region. This is of interest as a possible method for the treatment of deep-seated tumors containing anoxic cells.

Due to inhomogeneities in the average density of bone and tissue layers in each patient, it may be difficult to locate the exact position of the capture star formation region in the patient's tumor. This difficulty also exists in other methods of radiation treatment using Bragg peak ionization effects. Pi minus mesons have an advantage in this respect in view of the fact that γ-rays are emitted in the capture process. In this paper we describe the use of the capture γ-rays for the purpose of mapping the stopping region.

In addition to the emission of charged particles from star events, about 2% of stopping pions produce high energy γ's, peaking in the energy region of 100 MeV.[4] Calculations of the capture of negative pions by Guthrie et al.,[5] indicate an average excitation energy of about 5 MeV, that will be emitted as γ-rays. In addition to these pi-mesic X-rays will also be emitted.

In the present investigation γ-rays of energy greater than $\sim$ 15 MeV were detected using the appartus shown in Figure 1. A Pb collimator is used in order to specify the direction from which the γ's are coming. The collimator consists of 3 mm sheets of Pb separated by 3 mm gaps, and has a

thickness of 25 cm. After passing through the collimator the γ-rays are converted into electrons by a 3 mm thick lead converter. These electrons traverse the chamber and are detected by a pair of scintillators separated by a 2.5 cm aluminum absorber which requires that the electrons have an energy of at least 15 MeV to traverse the full distance. The coincidence signal from these two scintillators and from a beam monitor scintillator triggers the wire spark chamber. The position of the spark is determined by the magnetostrictive readout technique. The chamber consists of two grids of wires with a wire separation 1 mm and a grid separation of 1 cm which gives a spatial resolution for particles normal to the chamber of about .25 mm. In the present application, the spatial resolution of the system is $\approx$ 6 mm and is determined by the spacing of the lead plates in the collimator.

The measured distributions are shown below in Figure 2. The three peaks are those produced by the successive addition of 6 mm slabs of lucite absorber which displace the stopping region by the same amount. The γ-ray distributions shown on the upstream side of the stopped meson peaks are presumably due to captures in flight.

The overall sensitivity of the system can be gauged from the measured ratio S of detected γ-rays to stopping pions. In our experimental arrangement $S = 5 \times 10^{-6}$. Hence, it would be possible to locate the stopping pion region in a patient with a dose much smaller than the treatment dose.

In addition to the capture γ-rays that we have used in this measurement, it is also possible to use the pi-mesic X-rays emitted in the cascade process prior to nuclear capture. For this purpose we propose to use Silicon detectors. A further intriguing possibility is also available; a small fraction of the π^- ($\sim$ 1%) will produce π^o mesons by charge exchange

on protons. The two 65 MeV γ-rays emitted at 180° to each other can be used--without collimators--to locate the stopping region by using two spark chambers in a similar fashion to that used for positron annihilation γ-rays.

Footnote and References

* This work was done under the auspices of the U. S. Atomic Energy Commission.

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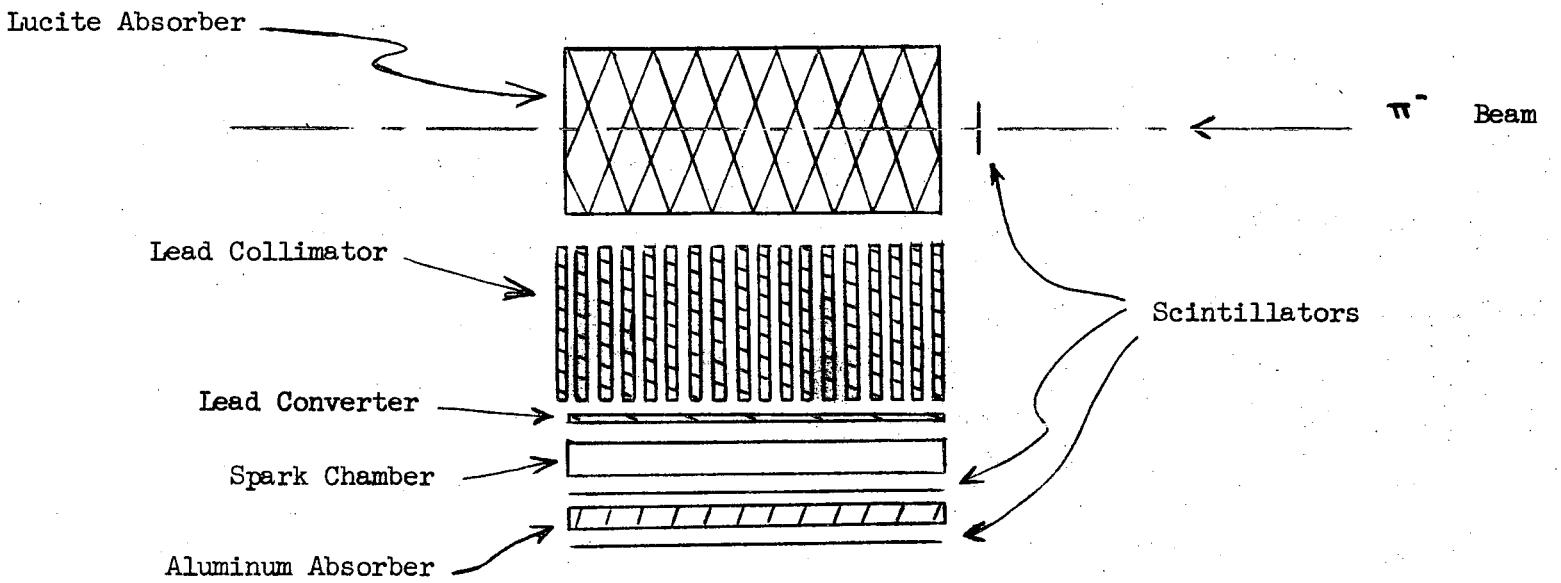

Figure 1. Experimental Set-up.

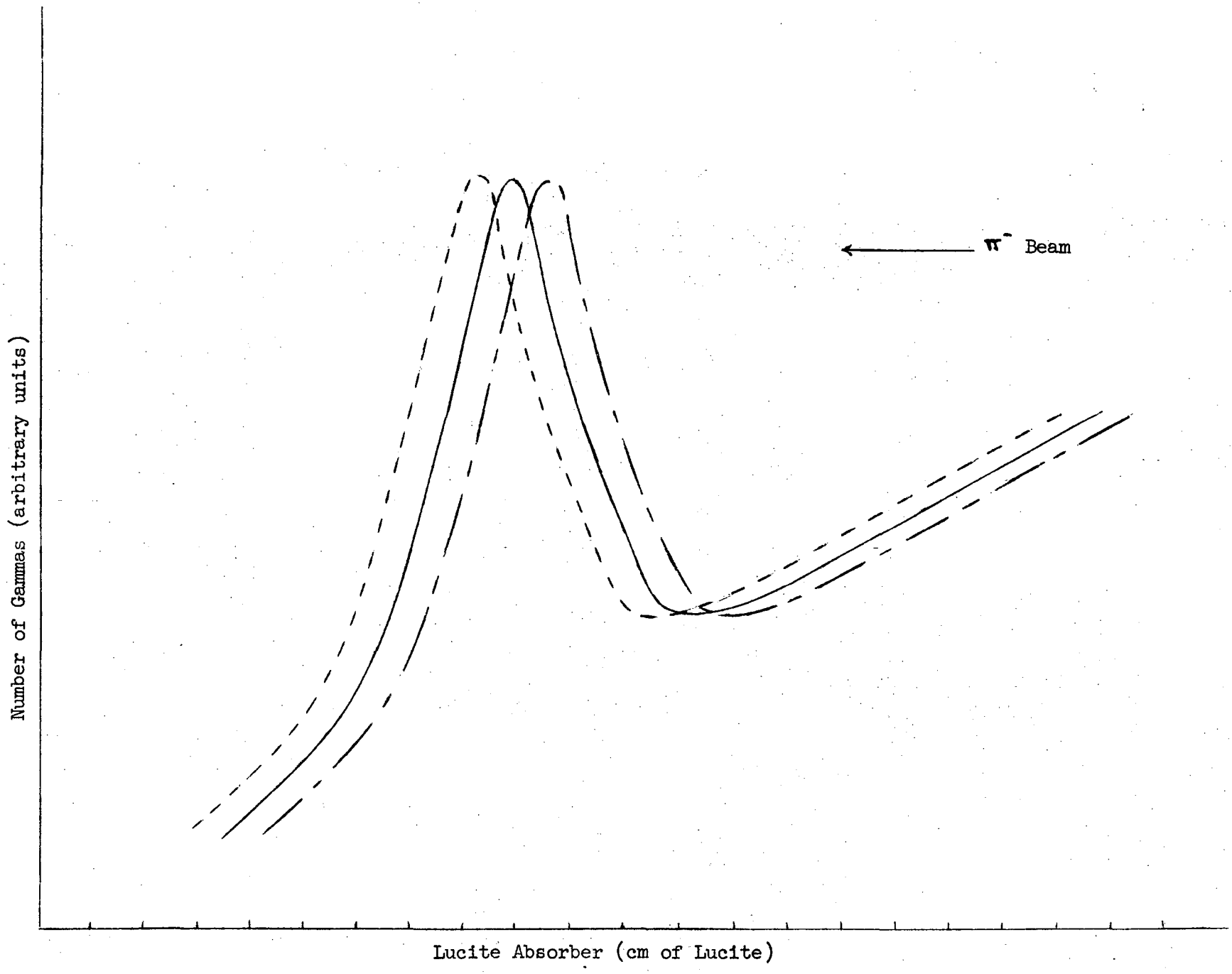

Figure 2. Number of gammas detected as a function of lucite absorber. The dashed curves are obtained by alternately adding or removing 6 mm of lucite.

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