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Authors
Diaz, Justo
Kaplan, Selig N.
MacDonald, Burns
et al.

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It has been pointed out by Wheeler[1] that there are two ways in which a μ^- meson stopped in uranium may induce nuclear fission. The energy released in the nonradiative transition of the mesonic atom to its 1s state as well as that liberated in the nuclear-capture process, $\mu^- + U^{238} \rightarrow Pa^{238} + \nu$, should be sufficient sometimes to induce fission. These two possible fission-inducing mechanisms can be distinguished experimentally, since the fissions induced by atomic transition would be observed to occur promptly ($\tau \ll 10^{-9}$ sec), whereas those due to nuclear capture would occur with the characteristic mean lifetime of a μ^- meson stopped in uranium.[2]

Galbraith and Whitehouse failed to observe fission by cosmic-ray mesons in an ionization chamber and set an upper limit of 0.25 on the fission-to-stopping ratio.[3] John and Fry, using uranium-loaded nuclear emulsions, observed 7 μ^- fissions, from which they estimated that fission occurs about 15% of the time when a meson stopes in uranium.[4] Considering only the nonradiative atomic transitions, Zaretsky[5] has recently calculated a fission probability that is consistent with the results of John and Fry.

The preliminary results of an experiment performed to obtain the relative probabilities of the two-meson-induced fission mechanisms are presented in this Letter. A gas scintillation counter containing nine stainless steel disks 3-1/4-in. in diam by 0.015-in. thick, coated on both sides with 0.85 mg/cm^2 UF_4 (natural isotopic mixture), was filled to 45 psi above

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atmospheric pressure with a mixture of 80% A and 20% N_2. The μ^- beam, obtained at the 184-inch cyclotron for studies of the neutron multiplicities from μ^- capture in various elements,[6] was estimated to contain not more than one π^- per 1000 μ^- mesons.

An oscilloscope was triggered by a three-fold coincidence between the two photomultiplier tubes looking at the gas scintillator, and a 3.7×10^{-7}-second gate triggered by the coincidence-anticoincidence pulse. This pulse was formed by simultaneous pulses in the plastic scintillators S_2, S_3, and S_4, together with the absence of a pulse in the water Čerenkov counter C (Fig. 1). The absence of a prompt pulse in the last plastic scintillator, A, was not required for triggering the oscilloscope because of our concern about accidental pulses in A induced by mesonic x-rays or products of a prompt fission. Pulses from S_3, S_4, and A, as well as a sum pulse from the two gas-scintillator phototubes were displayed on the oscilloscope and photographed. A precision, 50-Mc/sec oscillator was used to calibrate the sweep speed of the oscilloscope, and a weak Cf^{252} spontaneous-fission source was included in the chamber to permit frequent calibrations of the fission-fragment detection efficiency.

The zero-time calibration was obtained by photographing the pulses when a piece of plastic scintillator was placed in the fission chamber and also by photographing π^--induced fissions. In both cases the uncertainty in the zero time was about 3×10^{-9} sec. The background counting rate when plates that were not uranium-coated were bombarded was completely negligible. The random fission background with uranium in the chamber was 2.4 ± 0.8% fissions per coincidence-anticoincidence trigger, presumably caused by the neutron flux from the accelerator. Pulses from A (usually quite small) were observed about 10% of the time. In nearly all of these cases they were in coincidence with the fission pulse and not with the other counter-telescope pulses. The few observed cases of an S_2 S_3 A coincidence were not associated with prompt fissions. They are included in the data.

The number of fissions per 1 x 10^{-8}-sec interval is shown in Fig. 2 as a function of the time elapsed after the stopping of the meson. The background has not been subtracted in the figure. It was considered possible that a $\tau = 20 \times 10^{-8}$-sec component [2, 7] might be created by fissions produced by neutrons from the nuclear capture of mesons in the stainless steel plates. In this case, Be plates might be necessary, but the counting rate for delays greater than a few mean lifetimes is consistent with that expected from the random background. Accordingly, the data, excluding the first time interval, were analyzed by the method of Peierls,[8] and a total mean life of $(7.54 \pm 0.55) \times 10^{-8}$ sec was obtained. This value is slightly smaller than, but consistent with, the $(8.8 \pm 0.4) \times 10^{-8}$-sec mean life of μ^- mesons in U as measured by Sens.[2] It is also in agreement with the theoretical value of 7.4×10^{-8} sec calculated by Primakoff.[9]

The fissions associated with this lifetime must be due to nuclear capture. By extrapolating these results to the first time interval, we may say that 44.7 ± 3.0 fissions were to be expected. The number actually observed was 62. We therefore conclude that the fraction of the fissions that occurred promptly, due to the nonradiative transition of μ^- mesons to the lowest mesonic Bohr orbit, was 5.6 ± 2.7% (at most only a small fraction of the total). An absolute fission probability cannot be given at this time, because of the uncertainty of the relative stopping power of the U at the end of the μ^- range.

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experiment, H. Bowman for advice on the filling of the gas scintillation counter, and S. Thompson and T. Sikkeland for providing the Cf^{252} source.

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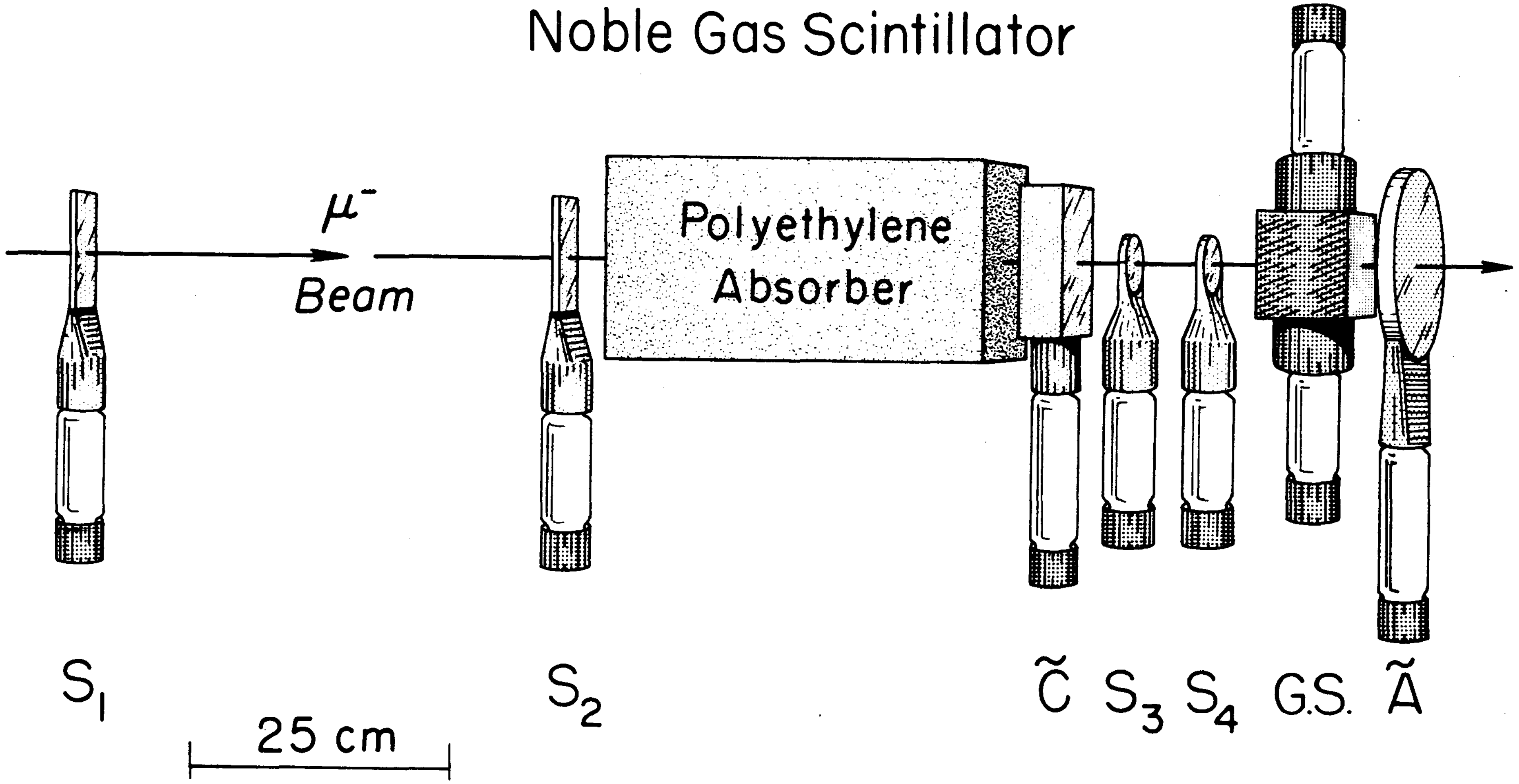
Figure Legends

Fig. 1. Counter-telescope arrangement. Here S_1, S_2, S_3, S_4, and A are plastic phosphors, C is a water Čerenkov counter in anticoincidence to eliminate the small electron contamination in the beam, and G. S. is the gas scintillator containing the uranium-covered plates.

Fig. 2. Histogram of μ^--induced fission events before subtraction of 2.4% background.

Detection of μ^- Meson Induced Fission in Uranium with a Noble Gas Scintillator



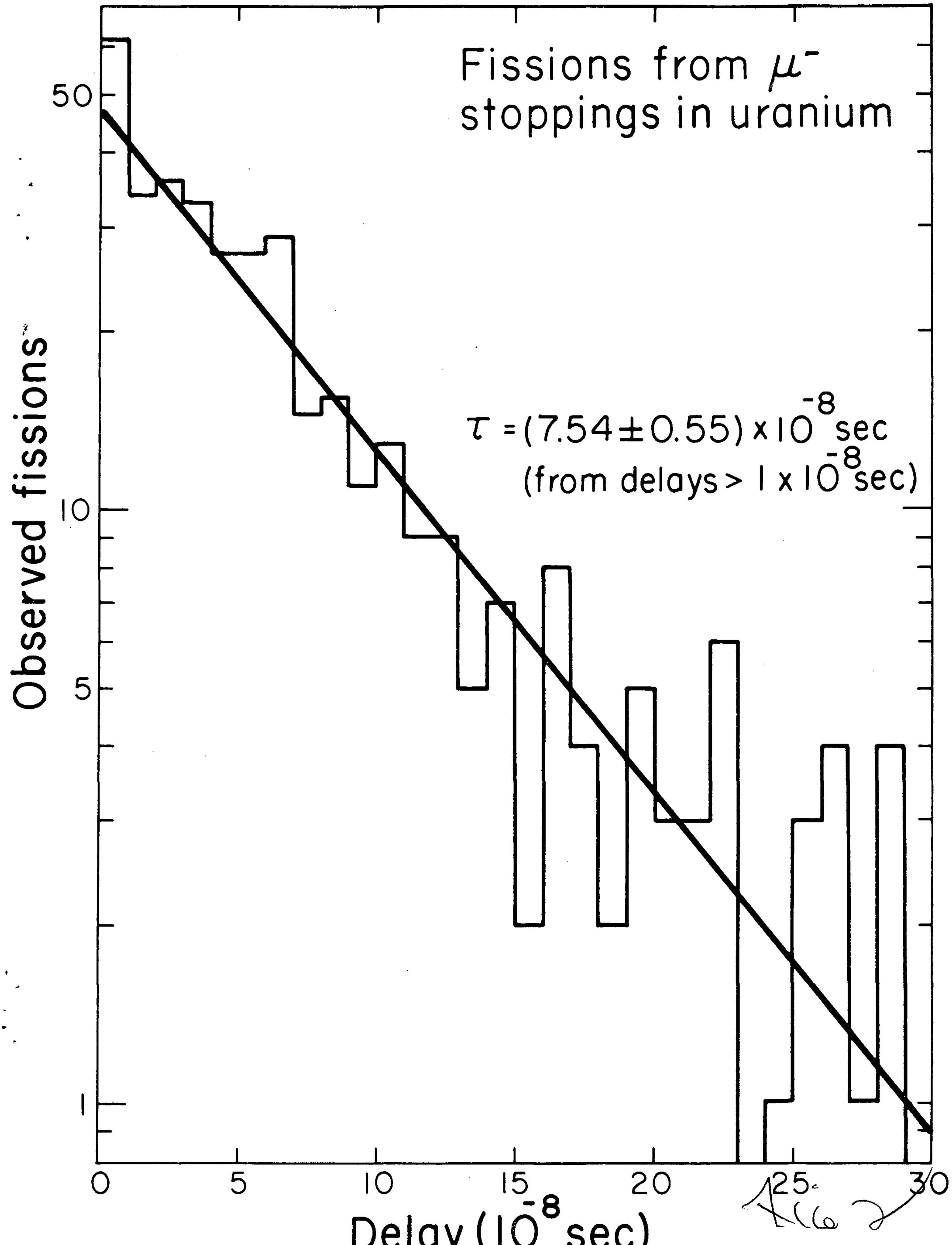

Fissions from μ^- stoppings in uranium
$\tau = (7.54 \pm 0.55) \times 10^{-8}$ sec
(from delays > 1×10^{-8} sec)
Observed fissions
50
10
5
1
0
5
10
15
20
25
30
Delay (10^{-8} sec)

Fig 2