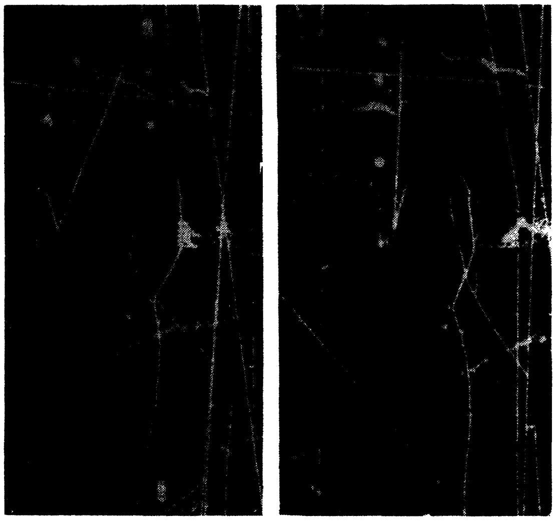

FIG. 2. Photograph of $\pi^- - p$ scattering. Event could be electron-proton scattering, but electron intensity is relatively small and Coulomb scattering through a large angle is extremely improbable.

for negative pions of 85 Mev.[3] The difference may be due to the difference in energy, or possibly to "charge exchange" scattering which would be missed in our experiment, or simply to our poor statistics. Our result agrees with a value of 2 to 4 mb calculated by Bethe and Wilson.[4]

We are indebted to the Nevis cyclotron staff for the opportunity to operate there and for the generous cooperation of members of the staff and operating crew. Many members at this laboratory contributed to this work, especially H. Marshak, R. Walker, and V. P. Kenney who have scanned many of the pictures.

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* Work performed at the Brookhaven National Laboratory, Upton, New York, under the auspices of the AEC.

[1] Miller, Fowler, and Shutt, Rev. Sci. Instr. 22, 280 (1951).

† Supported jointly by the ONR and AEC

[2] Lederman, Booth, Byfield, and Kessler, Phys. Rev. 83, 685 (1951).

[3] Chedester, Isaacs, Sachs, and Steinberger, Phys. Rev. 82, 958 (1951).

[4] H. A. Bethe and R. R. Wilson, Phys. Rev. 83, 690 (1951).

Satellite Pulses from Photomultipliers*

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(Received October 22, 1951)

IN the course of an experiment on μ-meson decay,[1] it was observed that the pulse from a scintillation counter was frequently followed within about one microsecond by one or more pulses, usually smaller than the first pulse, and that the frequency of these secondary pulses greatly exceeded the known rate of random noise pulses. Let us call the pulse which triggers the counting device the main pulse, and the secondary ones satellite pulses. The object of the investigation reported here was to find information which might be useful in devising methods of preventing satellite pulses from interfering with scintillation counting experiments. Three specific items of information were sought: the source of the satellites, their distribution in time after the main pulse, and how their frequency of occurrence depends on the voltage applied to the photomultiplier.

TABLE I. Comparison of noise and scintillation satellites.

Type of main pulse	Scintillation	Noise
Number of main pulses	140	129
Gross number of satellites	154	144
Estimated number of satellites due to random noise	30	10
Net number of satellites	124	134
Number of satellites per main pulse	0.89±0.08	1.04±0.09

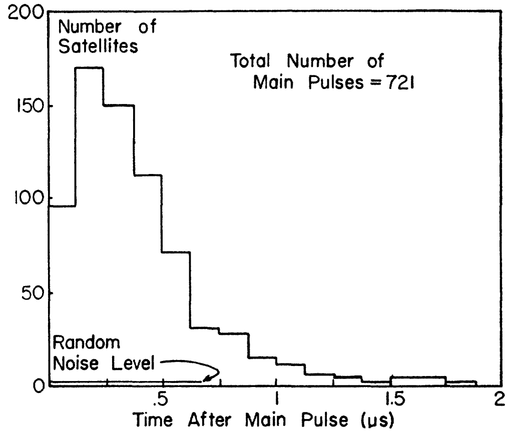

FIG. 1. Time distribution of satellites following scintillation pulses. The number of pulses shown in the first ¼-μsec channel is unreliable because there the presence of the main pulse made the search for small pulses difficult.

In order to determine whether the satellites originate in the scintillator or in the photomultiplier, we took first a group of oscilloscope pictures in which the main pulse was known to be a scintillation pulse, and secondly, a group of pictures in which the main pulse was a noise pulse. The pulses from a 1P21 photomultiplier looking into a cell with a terphenyltoluene solution were sent through distributed amplifiers, and displayed on an oscilloscope trace. Scintillations in the solution were detected by using coincidences with an auxiliary photomultiplier to trigger the oscilloscope. When noise pulses were being studied, the cell was removed, and the oscilloscope was triggered directly by the photomultiplier pulses. The traces were photographed, and then searched for satellites, the smallest pulse accepted being 1/30 of the minimum main pulse size. To make sure that the effect studied did not arise in the amplifier or oscilloscope, we verified that fast artificial pulses did not give satellites. In addition, satellites were observed with setups involving several different amplifiers and oscilloscopes. Twelve photomultipliers, including both 1P21's and 5819's, were examined, and all showed satellites.

Table I gives the results of the analysis of the two groups of pictures taken to determine the source of the sattelites. The photomultiplier was run at 1100 volts. The errors quoted are statistical. The distributions in time of the satellites after the main pulses were similar in the two cases. After 1.5 μsec the curves were essentially flat; so the random noise rate in Table I was computed by counting the number of pulses on the last 4 μsec of the trace.

The fact that there are the same number of satellites per main pulse, within the statistical error, whether the main pulse comes

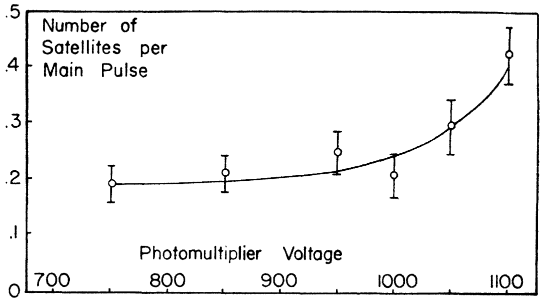

FIG. 2. Variation of satellite rate with photomultiplier voltage. The ordinate gives the number of satellites per trace greater than 1/15 of the minimum main pulse size.

from a scintillation or from photomultiplier noise, indicates that the satellites originate in the photomultiplier rather than in the counter solution.

The time distribution of the satellites was measured in another group of pictures of scintillation pulses. The results are given in Fig. 1. The variation of the rate of occurrence of satellites with photomultiplier voltage is shown in Fig. 2.

The time delays of the satellites are consistent with their being due to single positive ions, produced by the electrons of the main pulse, drifting back and striking an electrode.

In an experiment in which one records more than one pulse from the same scintillation counter—for instance, in the measurement of the π^+ meson lifetime—it will be necessary to take into account the multiple pulses due to satellites, which will give a background much greater than that calculated from the random noise rate.

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* Supported by the joint program of the ONR and AEC.

[1] Harrison, Keuffel, and Reynolds, Phys. Rev. **83**, 680 (1951).

An Energy Level in Li^6

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(Received October 30, 1951)

PRIOR to the work reported herein and the concomitant investigation of Gove and Harvey,[1] there had been no conclusive evidence for the position of an energy level in Li^6.[2] Bjerge and Broström proposed a level at 3.7 Mev from the beta-decay of He^6,[3] and Pollard and Margenau deduced a level at 2.4 Mev from the resonance yield in the recoil deuterons when 2.6-Mev alpha-particles were scattered in deuterium.[4,5]

A level has been determined at 2.12±0.05 Mev (Fig. 1) by using a single-focusing 180° magnetic spectrograph in conjunction with the 7-Mev proton beam of the Rochester 26″ cyclotron to measure the energy spectrum of protons scattered from an enriched target. The target was prepared from a sample of LiF, enriched in Li^6,[6] by evaporating the LiF onto a thin film of polystyrene. By bombarding through such a target (i.e., so that the spectrograph slit accepts scattered particles which have emerged from the "back" face of the target), the angles between the target plane, incident beam, and emergent beam can be so chosen as to permit a first-order correction for energy loss in the target.

The low mass of the Li^6 target nucleus created a difficult problem: In a given scattering experiment the energy carried away by the recoiling target nucleus is a function of the scattering angle, and the variation of the scattering angle over the aperture of the spectrograph introduces, for light nuclei, so large a change in the recoil energy as to interfere seriously with the conditions of 180° focusing. It was found, however, that the position of a line on which focus is restored can be computed in terms of the parameters of the experiment.

Eastman NTA plates were used for detection. Background was materially reduced by having the microscopist accept only those tracks whose orientation in the emulsion satisfied stringent criteria.

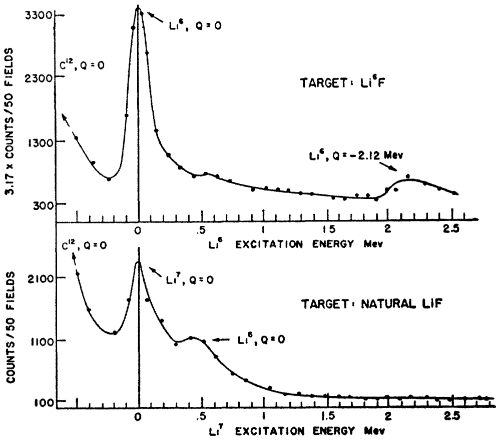

FIG. 1. Comparison of excitation curves obtained by proton scattering in which the targets were lithium fluoride enriched in Li^6, and natural lithium fluoride. The intensities have been normalized to correspond to the same bombarding flux per atom of lithium.

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* Assisted in part by a grant from the Research Corporation of America. Now at Brookhaven National Laboratory, Upton, New York.

[1] H. E. Gove and J. A. Harvey, Phys. Rev. **82**, 658 (1951).

[2] Browne, *et al.* [Phys. Rev. **83**, 179 (1951)] announce a level at 2.19 Mev from the reaction $Be^9(p, \alpha)Li^{6*}$.

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[5] E. Pollard and H. Margenau, Phys. Rev. **47**, 833 (1935).

[6] Obtained from the Stable Isotopes Division of Oak Ridge.

Shot Noise in Germanium Single Crystals*

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THE excess noise of thin single-crystal Germanium filaments has been measured over the frequency range 1–1600 kc by connecting the filaments to the input of a sensitive selective amplifier and measuring the noise ratio n of the filament.[1] The filaments were of the type used by Montgomery and Shockley in their noise measurements at lower frequencies.[2] They consisted of N-type material, but the excess noise was found to be caused by the generation of holes at the surface of the filament. The lifetime of the holes was of the order of 10^{-6} sec. At lower frequencies the noise ratio could be represented by a formula:[2]

$$n = 1 + AI^2/f, \tag{1}$$

where I is the dc current and A a constant.

The noise of one of the filaments measured by us showed important deviations from (1) at higher frequencies; we found that the experimental values of n could be very well represented over a wide frequency range by a formula of the type (Fig. 1):

$$n = 1 + AI^2/f + BI^2/[1 + (f/f_0)^2]. \tag{2}$$

At a filament current of 3 ma we found

$$AI^2 = 9.3 \times 10^5; \quad BI^2 = 54 \quad \text{and} \quad f_0 = 1.5 \times 10^5 \text{ cycles/sec};$$

f_0 was practically independent of the dc current.

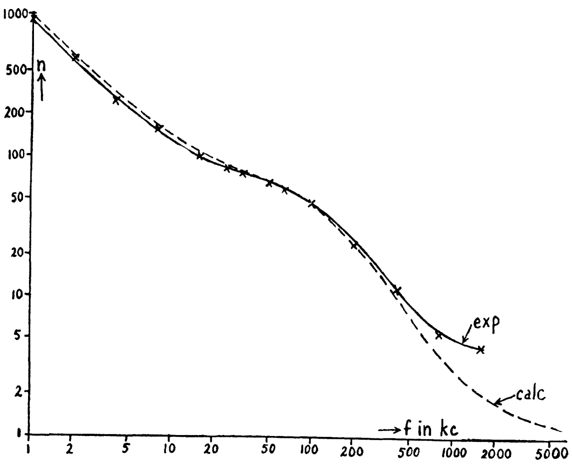

FIG. 1. Noise ratio n as a function of frequency for a current I of 3 ma. Crosses and full-drawn line: experimental results; dotted line: formula (2) with $AI^2 = 9.3 \times 10^5$; $BI^2 = 54$; $f_0 = 1.5 \times 10^5$ cycles/sec.