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TITLE: ANTINEUTRINO DETECTOR FOR $\bar{\nu}$ OSCILLATION STUDIES AT FISSION WEAPON TESTS AND AT LAMPF

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Antineutrino Detector for $\bar{\nu}$ Oscillation Studies at Fission Weapon Tests and at LAMPF, H.W. KRUSE, R. LONCOSKI, and J. MACK,* Los Alamos Scientific Laboratory--Two $\bar{\nu}$ oscillation experiments are planned, incorporating large volume (4200 ℓ) liquid scintillation detectors 1) at large distances (450-800 m) from fission weapon tests and 2) at 12-50 m from LAMPF beam dump where significant $\bar{\nu}_e$ events are detected only if some oscillation operates, such as $\bar{\nu}_\mu \to \bar{\nu}_e$. Design criteria, detector characteristics, and experimental considerations are given.

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ANTINEUTRINO DETECTOR FOR $\bar{\nu}$ OSCILLATION STUDIES AT FISSION WEAPON TESTS AND AT LAMPF

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I. Purpose of Experiment

Interest in neutrino oscillation experiments has heightened recently, following announcement[1-2] that oscillations may have been observed. We are planning two types of experiments, utilizing the same detector, to study $\bar{\nu}$ oscillations in rather unique ways.

At the Nevada Test Site we plan to observe $\bar{\nu}_e$ events at large distances (450-800 m) from a weapon test. Oscillations may be observed by inspecting departures of signal rates from $1/r^2$ in this range or, if the oscillation length is small, a reduction in the signal rates (in comparison to computed values) would be apparent.

At LAMPF, $\bar{\nu}_e$ interactions will be sought in the range of 12-50 m from the beam dump. In this case, a significant number of such signals are expected only if oscillations are present, such as $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$.

II. Experiment Design

The inverse beta decay reaction

$$\bar{\nu} + p \rightarrow \beta^+ + n$$

can best be used to study oscillations, because of its relatively high cross sections. The original detection scheme, employed by Reines and Cowan in the original identification experiment,[3] still appears to be a proper choice since it incorporates a powerful method for background reduction.

Figure 1 illustrates features of the detectors. An inner volume (1390 ℓ) contains a liquid scintillator in which $\bar{\nu}$ interact with protons. Resultant β^+ deposits kinetic and annihilation energy in the scintillator giving a prompt pulse from photomultipliers (50 each 20-cm dia). The neutron moderates in a few μs and is captured by Gd, loaded into the inner scintillator volume. Capture gammas (8 MeV total) give rise to a second pulse. This delayed coincidence of two events provides excellent background discrimination.

A lead shield surrounds the sensitive volume to reduce gammas from the soil and a 4π anticosmic blanket surrounds the entire detector. A recording system is under construction which digitizes and stores quantities of interest. For the weapon-test experiment, ground shock mitigation is incorporated into the design.

Figure 2 illustrates the n capture efficiency for various Gd percentages, obtained with Monte Carlo computations. Similarly, the β^+ detection efficiency will also be computed. Figure 3 depicts the detection efficiency for 2-MeV gammas, resulting from neutron capture.

III. Signal/Noise

For a typical weapon test, we expect about ten $\bar{\nu}$ events to be recorded (with no $\bar{\nu}$ oscillation) within a time interval of ~ 30 s, with good signal/noise, ~ 10. In order to improve the statistical uncertainty in such a result, recording on several weapon tests is planned; we also hope to construct several additional detector units.

For the LAMPF experiments where the β^+ energy is much higher, it appears desirable to eliminate the inner tank and simply load Gd into the larger volume (4200 ℓ). The loss in detection efficiency in this case has been computed, approximately, as in Fig. 4. The resulting signal rates at LAMPF are low but acceptable (one per day at 25 m) at distances of 12 to 35 m, assuming $\bar{\nu}$ oscillations exist and create the signal. Construction of additional detector units would permit larger distances.

This operational mode (4200 ℓ containing Gd) may also be employed on weapon tests to increase the total count by a factor of three with some loss of detection efficiency and signal/noise. However, following some tests with the small volume containing Gd, which provides greater confidence in the reaction identification, additional tests with the larger sensitive volume may be prudent.

REFERENCES

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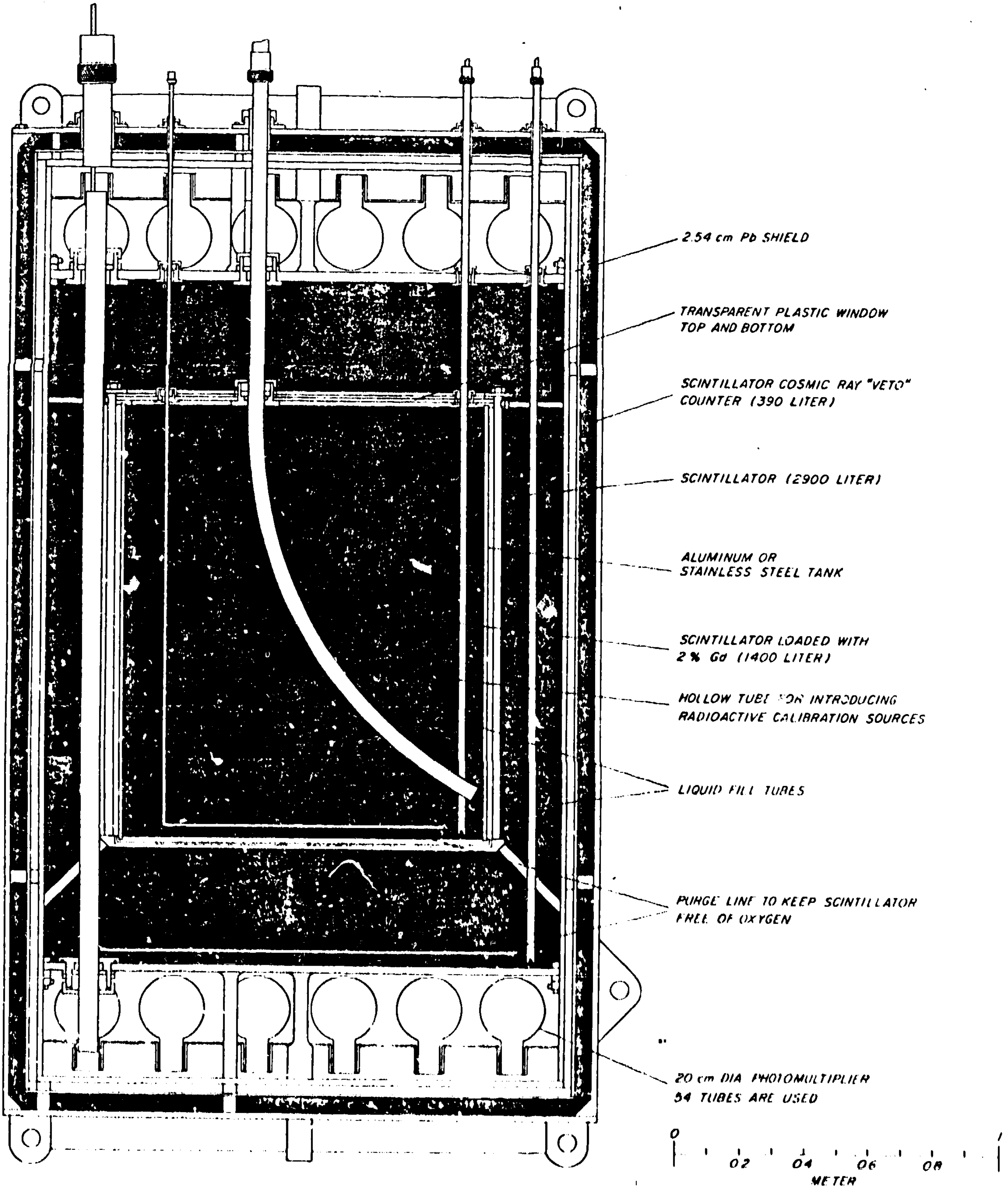

Fig. 1 Neutrino detector assembly. The detector contains about 5 tons of liquid scintillator and the total weight is about 20 tons.

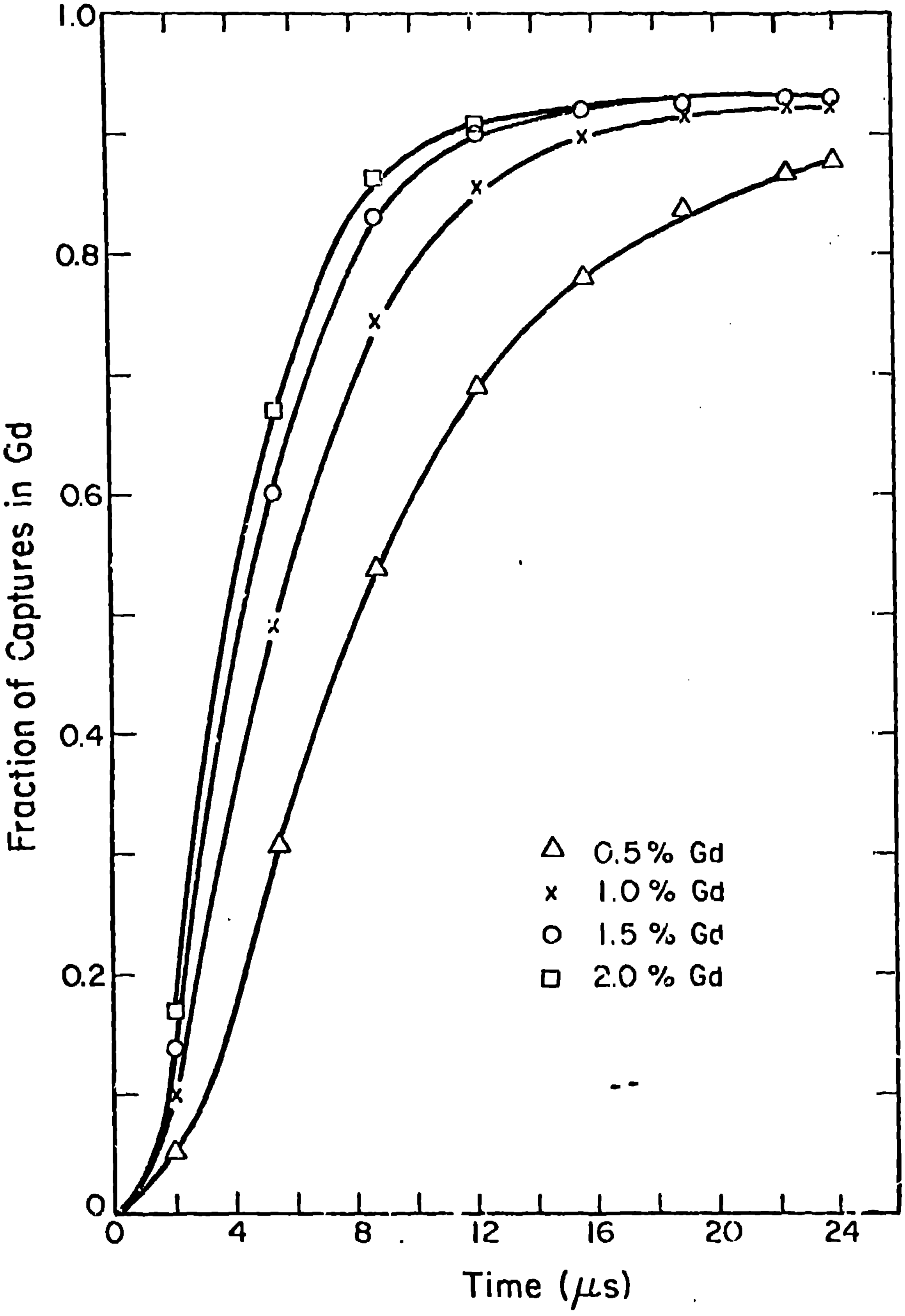

Fig. 2 Capture probability for 20 keV neutrons uniformly distributed in 1500 liter liquid scintillator

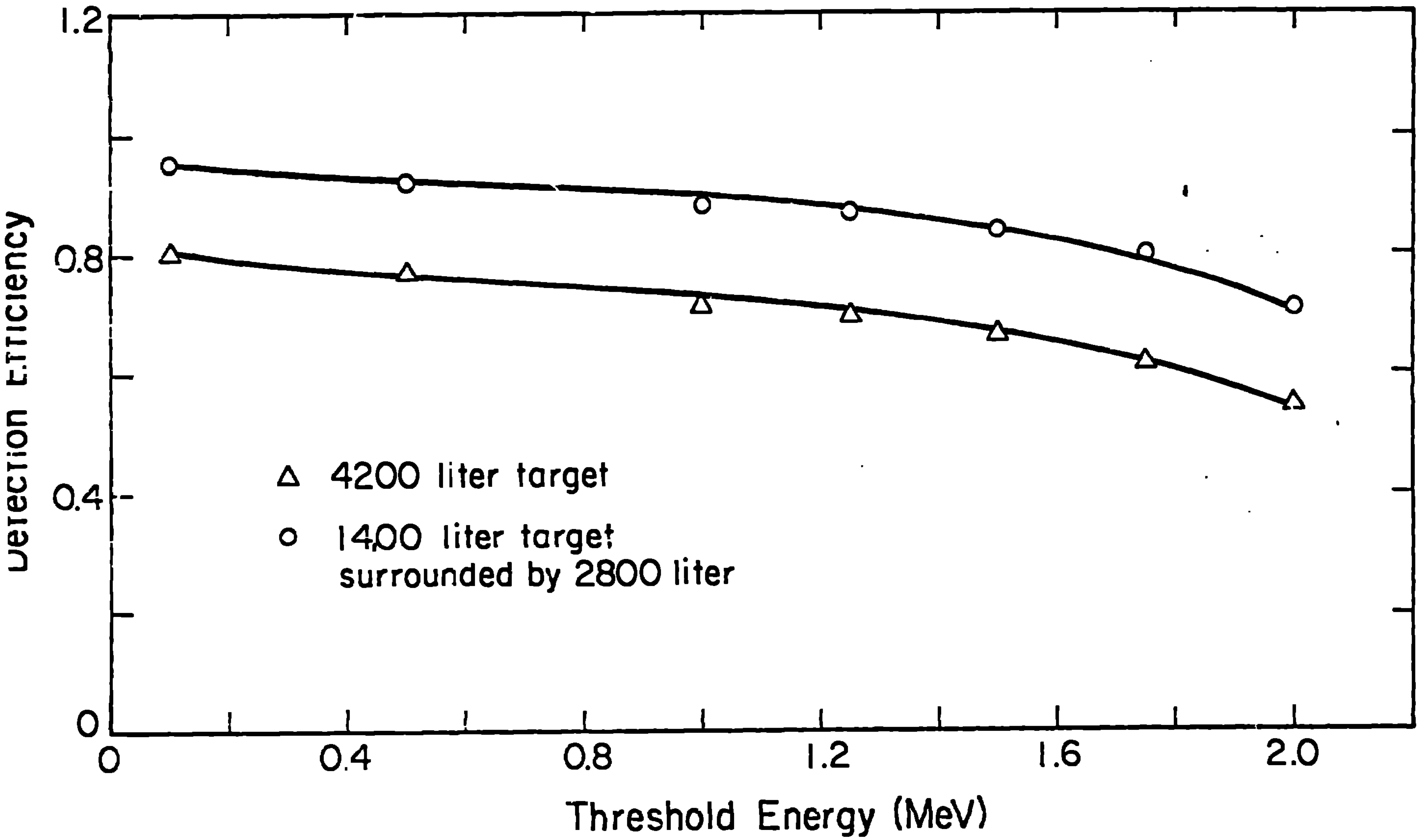

Fig. 3 Detector Efficiency for 2 MeV gamma rays

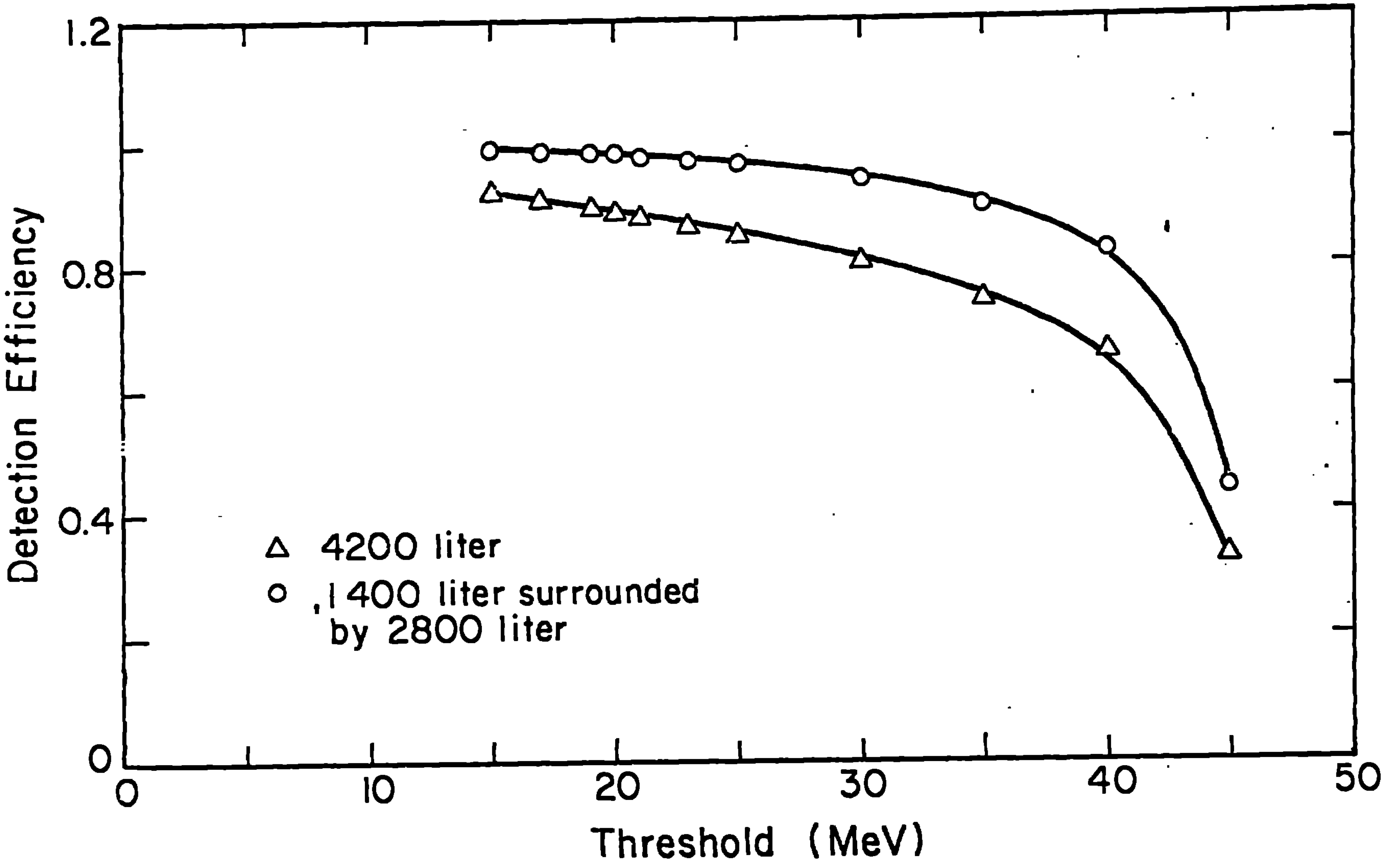

Fig. 4 Detection efficiency of 45 MeV electrons uniformly generated in liquid scintillator volumes.