Study of the scattering of fission antineutrinos by electrons with an organofluoric-scintillator detector

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Preliminary results of an experimental study of the elastic scattering of fission antineutrinos by electrons with the help of a detector based on an organofluoric scintillator are reported. Over the energy range 3150–5175 keV of the recoil electrons, the cross section $\sigma_{\text{exp}} = (6.8 \pm 4.5) \times 10^{-46}\ \text{cm}^2/\text{div}$ was found, with a value $\sin^2\theta_w = 0.29 \pm 0.10$ for the adjustable parameter of the theory of electroweak interactions.

The scattering of an antineutrino by an electron is one of the most interesting processes accessible to experimental study in the flux of fission antineutrinos. Research on this purely leptonic process, which goes by channels of neutral and charged weak currents simultaneously, provides the most direct information on the structure of the weak current and makes it possible to determine the adjustable parameter of the theory of electroweak interactions: $\sin^2\theta_w$.

To study this process experimentally, however, is an exceedingly complicated matter, primarily because of the small cross section ($\sim 10^{-45}$ cm^2) and also because only a single particle is detected: the recoil electron. The effect is to significantly limit the possibilities for reducing the background by electronic methods. Note also that hydrogen in the detector creates a background which is correlated with the operation of the reactor, because of the inverse beta decay at the proton, whose cross section is larger than that for the scattering of fission antineutrinos by an electron by a factor ~ 100.

Only two such experiments have been carried out so far.[1-3] Some serious difficulties involving the suppression of the correlated background from inverse beta decay at the proton were overcome in Refs. 1 and 2, since the target was a plastic scintillator containing hydrogen. Derbin *et al.*[3] regard their results as only qualitative, since the background in their detector exceeded the expected effect by a factor of more than 50.

In the present study, we used a liquid organofluoric scintillation detector to detect the $\tilde{\nu}_e e$ scattering. The detector materials were selected for a high radiation purity and the absence of hydrogen. These requirements are satisfied quite well by fluoroplastic-4 (CF_4) and hexafluorobenzene (C_6F_6).

The detector is an array of seven identical scintillation chambers, each monitored by two FÉU-49 photomultipliers. The chambers are made of fluoroplastic-4 in the form of three-section hexahedral prisms separated by quartz glass windows (Fig. 1). The central section (the target) is filled with scintillating hexafluorobenzene[4]; the outer sections (filled with pure hexafluorobenzene) double as lightguides and additional passive shielding against external γ radiation. With the internal configuration of the chamber selected, and after the appropriate position for the mirror reflector [aluminized Lavsan (a polyester)] was chosen by trial and error, the light collection of the chamber was uniform within $\pm 8\%$, and the energy resolution at $E = 3$ MeV was 14%.

The total weight of the scintillator in the detector is 103 kg (3.0×10^{28} electrons). The weight of the scintillating admixtures (BPO) is 520 g (1.6×10^{25} hydrogen atoms).

The apparatus is in an underground room at a depth of a few tens of meters water equivalent. The detector itself is inside a magnetic shield of Armco iron and is surrounded by passive shielding of steel, copper, and lead (~ 100 g/cm^2 on a side) and borated polyethylene (~ 24 cm on a side). Two layers of polymethyl methacrylate scintillation plates are used as active shielding against cosmic-ray muons (Fig. 2).[5] In the course of the measurements, the entire apparatus is in a continuous flow of pure air from cylinders.

An electronic system provides an additional suppression of background. This system selects events which are detected simultaneously by the two photomultipliers which are monitoring one and only one of the scintillation sections (coincidences). In

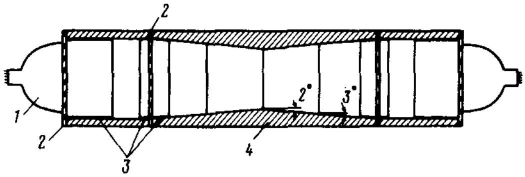

FIG. 1. One scintillation chamber. *1*—FÉU-49 photomultiplier; *2*—quartz glass; *3*—aluminized Lavsan; *4*—fluoroplastic-4.

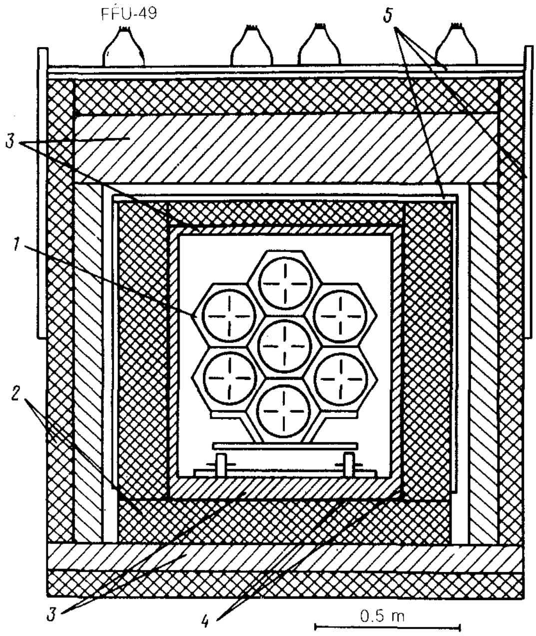

FIG. 2. Overall appearance of the apparatus. *1*—Detector; *2*—borated polyethylene; *3*—steel, copper, lead; *4*—Armco iron; *5*—anticoincidence plates.

addition, this coincidence must not be accompanied within 170 μs by signals of any other type (from either a photomultiplier or the active shielding). A special electronic system works from the ratio of the heights of the signals from the different photomultipliers at one chamber to distinguish the working volume and to forbid events occurring outside it.

The detector was calibrated with the help of γ sources, PuBe (the edge of the Compton spectrum is $T^M = 4.19$ MeV) and ^{60}Co ($T^M = 1.12$ MeV), and also with the help of a ^{207}Bi point source (conversion electrons with $T_e = 976$ keV).

The measurements were carried out over 25 days while the reactor was shut down and 55 days while the reactor was in operation (in an antineutrino flux of 3.4×10^{12} cm$^{-2}\cdot$s^{-1}). In the energy interval 3150–5175 keV, the following results were obtained in one series of measurements:

Reactor in operation	Reactor shut down	Difference
8.37 ± 0.39	7.21 ± 0.54	1.16 ± 0.66

The calculated effect from inverse beta decay at the hydrogen of the scintillation admixtures was 0.10 over the same time interval.

After corrections for the energy resolution and the edge effect, we find the following results for the spectrum of fission antineutrinos[6]:

$$\sigma_{\exp} = (6.8 \pm 4.5) \cdot 10^{-46} \text{ cm}^2/\text{fiss},$$

and

$$\sin^2 \theta_w = (0.29 \pm 0.10).$$

This experiment is still under way.

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