New experiment on elastic scattering of reactor neutrinos by electrons

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A low-background apparatus with a 25-kg semiconductor silicon detector is described. The cross section for ν_e, e scattering in the energy range 0.8–4.0 MeV of recoil electrons is measured.

1. Experimental study of the processes such as the interaction of low-energy neutrinos with matter, neutrino-free double β decay, electron and neutrino stability, and other processes is restricted by the background level of the detectors at energies

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below 5 MeV, where the background is caused by the natural radioactivity of ^{238}U, ^{232}Th, and ^{40}K. This problem can be solved directly by using as the detector material very pure materials such as semiconductor germanium and silicon. The use of silicon has the added advantage of suppressing the γ-ray background because of partitioning. Derbin *et al.*[1] have proposed the construction of a silicon detector 1 m^3 in volume, with a background that would allow quantitative measurements of $\tilde{\nu}e$ scattering to be carried out in a neutrino flux of 10^{12} $cm^{-2} \cdot s^{-1}$. A detector 25 kg in mass, consisting of 305 coaxial Si(Li) modules 50 mm high and 30 mm in diameter has now been constructed. The energy resolution of the module is 3–6 keV. The number of electrons in the detector, with the exception of the surface layer, is $(4.4 \pm 0.2) \times 10^{27}$. Structurally, the detector consists of five matrices, each containing 61 modules. The matrices are inserted into a lead container held at a temperature of 100 K under a vacuum (Fig. 1). The external passive shield consists of copper, lead, and cadmium. This assembly is placed into the cavity of a liquid scintillation detector and polyethylene shield.

The matrix arrangement for measuring and recording of data from 80 spectrometric channels enables the energy spectrum to be measured with the identification of events that occur in one of the moduli.

2. Figure 2 shows the background spectra which were measured under different detector shielding conditions. To calibrate in terms of energy, we measured the spectrum of the ring-shaped ^{24}Na source (histogram 1). The energy resolution of the whole detector is 45 keV.

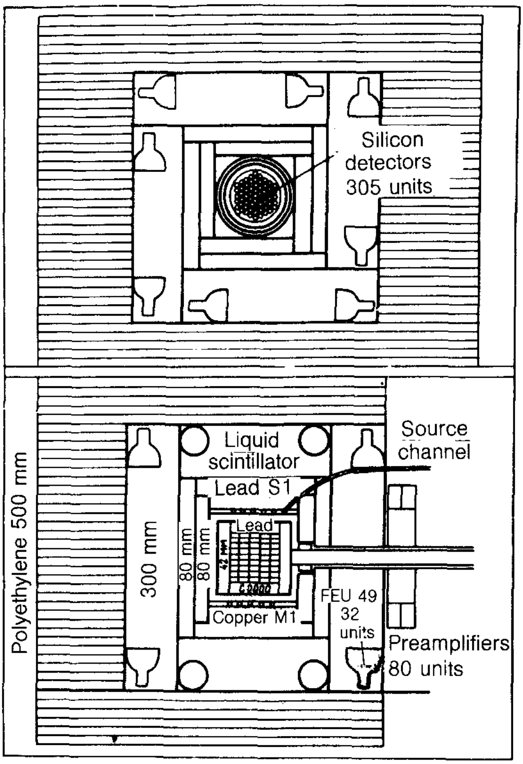

FIG. 1. Schematic of the apparatus with a silicon detector.

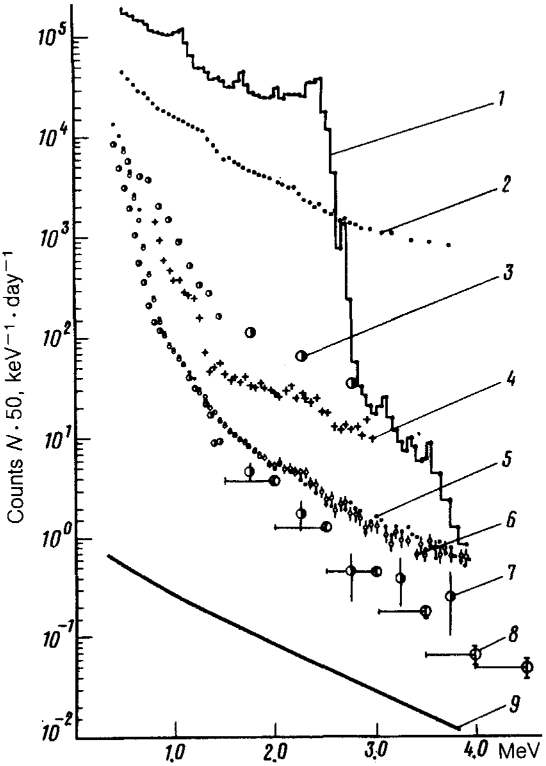

FIG. 2. Spectra of single events from the silicon detector. 1—Calibration according to Refs. 2 and 4; 2—background at the earth's surface; 3—central module at the earth's surface; 4—at the neutrino laboratory of the Rovno nuclear power plant (30 meters water equivalent) with preamplifiers situated at the surface of the cryostat; 5,6—after removing the electronic components from the cryostat and installing an active shield; 7—the same for the central module; 8—background from Rainis' experiment; 9—predicted spectrum of recoil electrons from the $\tilde{\nu}e$ scattering.

The factor for the suppression of 2.75-MeV γ rays due to multiple scattering in the detector under these conditions is 3.3 for a surface module and 6.25 for a central module. The background of the central module, scaled to the whole detector, is $N_b = 50 \pm 10$ day^{-1} for the energy range 1.5–4.0 MeV.

3. This detector was installed in the neutrino laboratory[3] of the Rovno nuclear power plant at a distance of 18.1 m from the core center of the 1375-MW reactor in a neutrino flux of 6×10^{12} cm$^{-2} \cdot$ s^{-1}. The spectra of single events recorded in the detector were measured when the reactor was running (44 days), after the reactor was shut down (22.34 days), and when it was started again (20 days). The difference in the spectra for a running reactor and for a shutdown reactor is shown in Fig. 3.

The upper values show the integral effect in the range from E to 4.0 MeV and the lower values are the corresponding values of the standard theory for an antineutrino spectrum taken from Ref. 4 and $\sin^2 \theta_w = 0.23$. This restriction on the cross section $\sigma(\tilde{\nu},e) = (5.3 \pm 7.1) \times 10^{-45}$ cm^2/fission for $1.5E_e$ to 4.0 MeV is consistent with the measurement result of Ref. 2.

Interest in the study of the scattering of electronic (anti) neutrinos by an electron stems primarily from the fact that the interference between a neutral and a charged current can be observed. Our measurement is consistent with the negative sign on the interference for > 1.0-MeV recoil electrons.

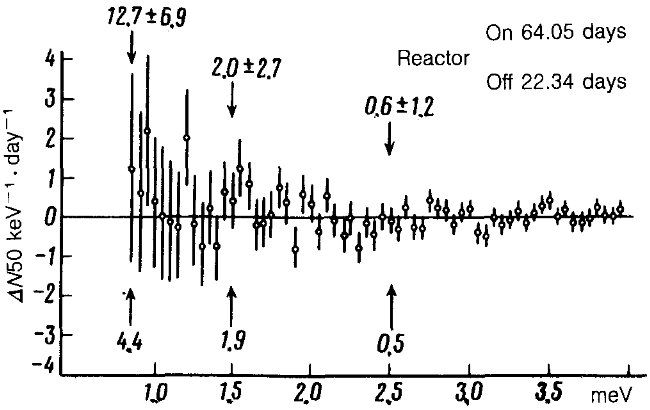

FIG. 3. Difference spectrum from the silicon detector during reactor operation and after shutdown.

Because of the relatively high efficiency at which the γ rays are detected (4%), the restriction we can impose (based on our data) on the neutrino lifetime relative to the decay,[5] $\tau_{\text{c.m.}}/m_\nu$, is 50 s · eV^{-1}.

4. We wish to emphasize that because of the small volume of the detector, the detector background, which is 50 times higher than the effect due to νe scattering, is determined by the small suppression of the γ rays. The rated background for the 250-kg detector, which will operate in 1986, will exceed the effect only severalfold in the same neutrino flux, thus permitting quantitative measurements to be carried out.

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