Search for a two-neutrino mode of double beta decay of the isotope ^{150}Nd

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Measurements of the isotope ^{150}Nd with the SYSTEMA-II detector over an exposure time of 650 h are reported.

We recently began an experimental search for $\beta\beta$ decay of the isotope ^{150}Nd with a new version of our SYSTEMA-II detector (Fig. 1). This detector was developed and put into operation in the laboratory for low-background studies of the Baksan Neutrino Observatory of the Institute of Nuclear Physics, Russian Academy of Sciences. The laboratory is at a depth of 660 meters water equivalent.[1] The SYSTEMA-II consists of four plastic scintillators and two proportional chambers, separated by a cassette holding thin powdered samples (~ 100 mg/cm^2). Each scintillator is monitored by four photomultipliers. The energy resolution of each scintillator is 17% at an energy of 1 Mev. The inner scintillator plates are used to measure the energy of the electrons which leave the sample. The two outer scintillation plates are used as active shielding. The proportional chambers are intended for distinguishing two-electron events which occur in the sample, with a detection efficiency on the order of 90%. The test sample (enriched) and a control sample (generally not enriched) were studied simultaneously in order to avoid systematic errors due to fluctuations in the detector background. For this purpose, each proportional chamber was partitioned into two sections, with independent signal outputs. The cassette holding the samples was made in two halves: one for the enriched sample and one for the unenriched sample. To avoid systematic errors associated with a possible instability of the operation of the photomultipliers, the halves of the cassette were interchanged after each 100 h of measurements.

Layers of a material equivalent to Mylar, 20 μm thick, were used to prepare a thin sample. These layers were attached to a titanium frame. The powdered sample was distributed uniformly between the Mylar layers; the volume was then evacuated, and the cassette sealed off.

The system used to detect electrons is capable of recording events in an $E_1 \times E_2 \times N_{ev}$ event-correlation matrix, which is formed from the signals received from the upper and lower inner scintillators upon simultaneous operation of two proportional chambers corresponding to a given sample, in the absence of signals from the outer scintillators and the other pair of proportional chambers. The energy threshold for each scintillator was set at 125 keV, and that for the proportional chambers at ~ 1 keV.

These measurements were carried out in an underground laboratory fitted with

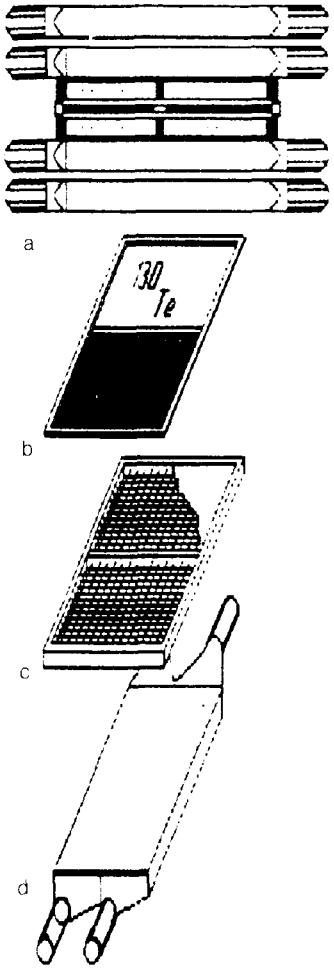

FIG. 1. Schematic diagram of the SISTEMA-II apparatus. a—Overall view; b— cassette with ^{150}Nd and ^{130}Te samples; c—two-section proportional chamber; d—plastic scintillator monitored by four photomultipliers through optical fibers.

special passive shielding against γ rays from the surrounding rock. This shielding consisted of 0.5 m of low-radioactivity concrete and 0.5 m of dunite. Some additional passive shielding was used: 5 cm of tungsten, 10 cm of plastic, and 20 cm of OFHC copper.[2]

The relatively high energy of the $\beta\beta$ transition of ^{150}Nd (E=3.37 MeV) makes this isotope the most promising among various isotopes which might be used in a search for $\beta\beta$ decay.[3] Before the measurements were begun at the SYSTEMA-II detector, the sample of the ^{150}Nd isotope (enriched to 92%) was purified at Ames Laboratory (Ames, Iowa).

The γ-ray spectrometry and the mass spectroscopy of the purified ^{150}Nd sample were carried out at Pacific Northwest Laboratory (Richland, Washington). These measurements showed that the sample contained impurities of the isotopes ^{152}Eu and

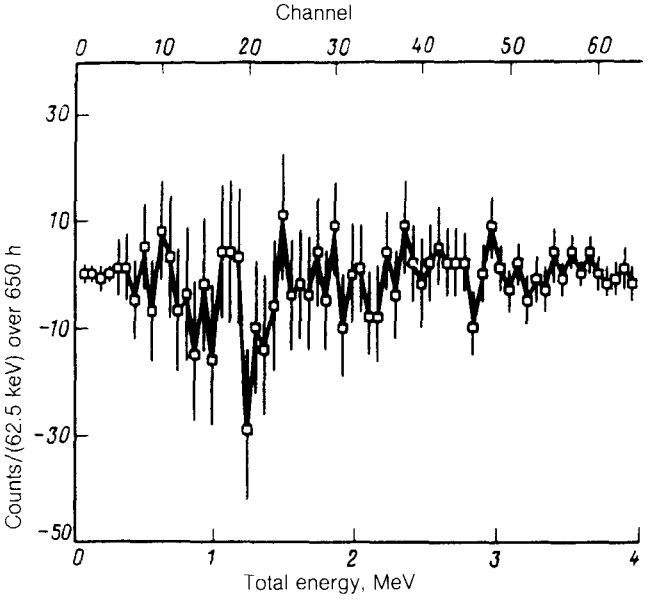

FIG. 2. Spectrum of the total energy E of two-electron events, found by subtracting the spectrum of the ^{130}Te sample from that of the ^{150}Nd sample. The acquisition time was 650 h. .

^{154}Eu. The purification of the sample reduced the concentration of these isotopes by a factor of 400.

The test sample contained 48.5 g of $^{150}Nd_2O_3$; as a control sample we used 48 g of ^{130}Te. Figure 2 shows the difference spectrum of the total energy of two-electron events, accumulated over 650 h. This spectrum was found by subtracting the spectrum of the ^{130}Te sample from that of the ^{150}Nd sample. In the energy region corresponding to the two-neutrino mode of $\beta\beta$ decay of ^{150}Nd, no statistically significant excess of events is observed. The efficiency of the detector in detecting two-electron events from two-neutrino $\beta\beta$ decay of the isotope ^{150}Nd is 12%. Working from the measured count rates for the samples, we find a limit on the decay half-life of ^{150}Nd:

$$T_{1/2}(\beta\beta,\ 2\nu) > 1.1\times 10^{19}\ \text{yr},\ 90\%\ \text{C.L.}$$

[1] S. I. Vasil'ev, A. A. Klimenko, S. B. Osetrov *et al.*, JETP Lett. **51**, 622 (1990).
[2] A. A. Klimenko *et al.*, Nucl. Instrum. Methods B **17**, 445 (1986).
[3] H. V. Klapdor and K. Grotz, Phys. Lett. B **142**, 323 (1984).

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