SEARCH FOR 17-keV NEUTRINOS IN ^{63}Ni BETA DECAY

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Whether the mass and current states of neutrinos are identical is one of the most interesting present problems in elementary particle physics. Search for neutrino oscillations at reactors and accelerators, on the one hand, and analysis of the kinematics of two- and three-particle decays accompanied by neutrino emission, on the other, have so far yielded no more than limitations on values of the masses and mixing angles. Exceptional cases are the analysis of the beta spectra of the nuclei ^{3}He, ^{35}S, ^{14}C, and ^{63}Ni and of the bremsstrahlung spectra of ^{55}Fe and ^{71}Ge from which it can be concluded that a neutrino with a mass of 17 keV and a mixing angle 0.1 exists.These results stand in clear contradiction with the data of corresponding experiments which have used magnetic spectrometers to measure the energies of the electrons.

In the present study [1] a thin layer of ^{63}Ni ($T_{1/2} \cong 100$ yr, $E_0 \cong 67$ keV) was deposited directly on the gold coating of a $Si(Li)$ detector. This detector was pressed tightly (without any gap) against a second, identical detector, and a bias voltage was applied to the common *p*-type contact being formed. In this geometry, with the detectors connected in anticoincidence, the contribution of backscattered electrons to the low-energy part of the response function of the detectors was effectively suppressed. For normal incidence of the beta particles on the surface of the detector, the relative number of such electrons is about 15%. With the detectors butted together and connected in anticoincidence, the low-energy part of the resolution function is determined primarily by electrons which are emitted at small angles relative to the surface and which lose some of their energy in the dead layer of the detector. The magnitude and shape of the tail of the resolution function in our case thus differ from works with normal incidence. The way in which this tail is actually taken into account may be the reason for discrepancies.

Fig.1 shows the energy spectrum of noncoincident beta-particles from ^{63}Ni for one series of measurements, the spectrum of electrons detected by the two detectors in the same series (multiplied by a factor of 3 for the sake of comparison) and the overall energy spectrum of electrons for all 20 series (in logarithmic scale). For energies about 30 keV the spectra of independent and double events have a similar shape. The backscattering probability determined for the electrons is 23%.

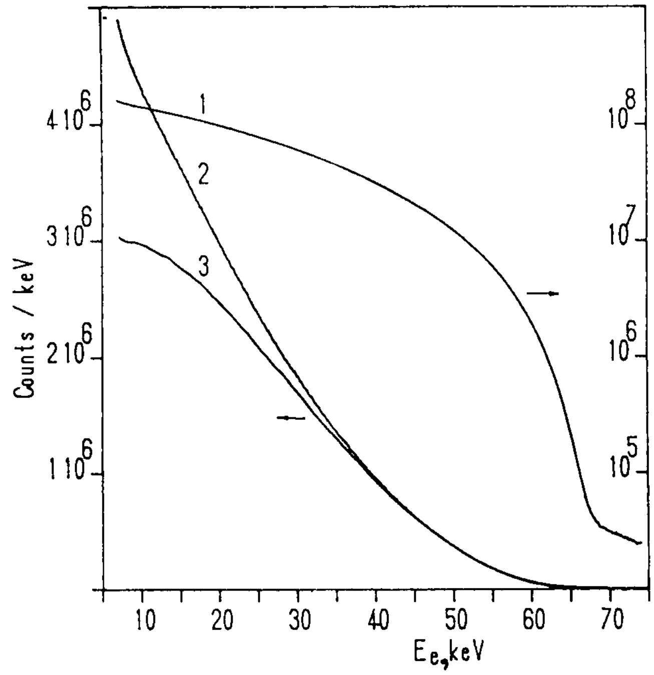

Fig.1. 1 — Total energy spectrum adopted for the analysis;
2 — spectrum of noncoincidence events for one series of measurements;
3 — spectrum of events detected by the two detectors (multiplied by 3) for one series of measurements

The obtained experimental spectrum of ^{63}Ni beta particles was compared with the theoretical spectrum by searching for a minimum of the functional χ^2. First, two parameters of the linear approximation of the background were found for the interval 69–75 keV. These parameters were used for the entire spectrum and were not varied. These two parameters actually described the background due to the natural radioactivity and the background from superimposed pulses which were not eliminated by the rejection circuit. The remainder of the spectrum was compared with the expression

$$N(E_i) = A\Sigma F(E_k, Z)S(E_k, E_0, U_{eH}, M_\nu)R(\sigma, E_i, E_k)(1 + \alpha(E_0 - E_k)),$$

where A is a normalization constant, $F(E_k, Z)$ is the Fermi function with a correction for screening, R is a Gaussian resolution function with a standard deviation σ, and $S = (1 - U_{eH}^2)S(M_\nu = 0 \text{ keV}) + U_{eH}^2 S(M_\nu = 17 \text{ keV})$ is the sum of the two beta spectra, with an end-point energy E_0 and a neutrino mass M_ν. The parameter α has been introduced to offset the low-energy tail in the resolution function. When searching for a minimum of the functional χ^2, we thus varied four parameters: A, E_0, σ, and α. This fitting procedure leads to an acceptable value of χ^2 in the interval 30–75 keV. The distribution of values of χ_i with the parameters from the optimum fit at a fixed value $U_{eH} = 0$ is shown in the upper part of Fig.1 ($\chi^2_n = 1.39$). For the fixed value $M_\nu = 17$ keV, the minimum value of χ^2 is found at $U^2_{eH} = 0.0002$. The model chosen for the theoretical function thus agrees with experimental results under the assumption $U_{eH} = 0$. The solid curve shows the additional contribution to the spectrum (not normalized) in the case in which a 17-keV neutrino is emitted with a probability $U^2_{eH} = 0.001$.

The results of the optimum fit for the values $U^2_{eH} = 0.01$ and $M_\nu = 17$ keV are shown in the lower part of Fig.2. The value $\chi^2 = 12.3$ found here contradicts with the results which support the existence of a heavy neutrino; for 40 degrees of freedom, it corresponds to 50 standard deviations. If we use a $\chi^2(U_{eH})$ dependence to determine a limitation on the possible value of U_{eH}, we find $U^2_{eH} < 0.0015$ at the 90% confidence level. This value is close to the upper limits found in previous works with magnetic spectrometers (≤ 0.003 for ^{63}Ni and ≤ 0.0017 for ^{35}S) and is in substantial contradiction with the mean value (0.0085 ± 0.001) obtained in experiments confirming existence of 17 keV neutrino.

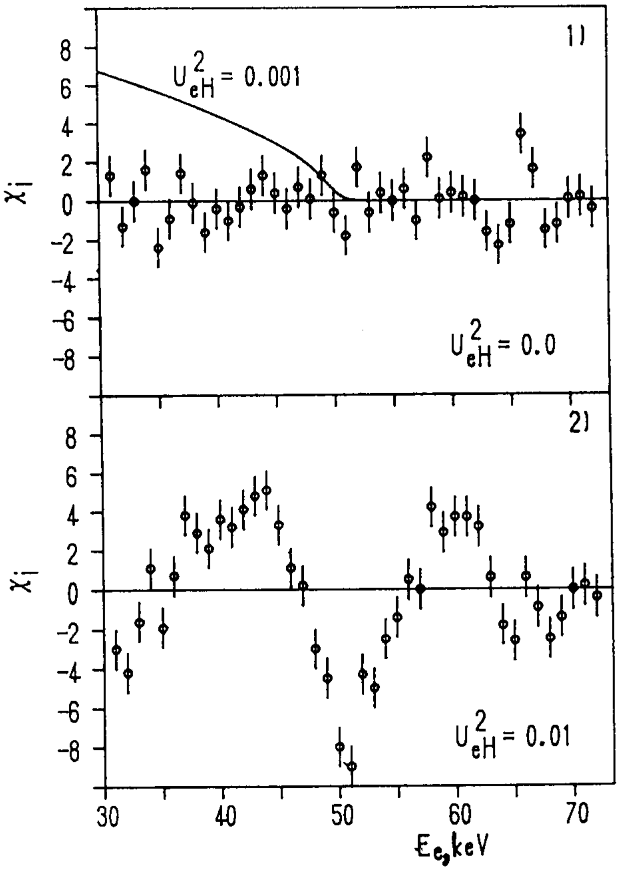

Fig.2. Results of optimum fit for $M_\nu = 0$ and $|U_{eH}|^2 = 0$ (top) and $M_\nu = 17$ keV and $|U_{eH}|^2 = 0.01$ (bottom). The solid curve shows the additional contribution to the spectrum (not normalized) for $M_\nu = 17$ keV and $|U_{eH}|^2 = 0.0001$

REFERENCES

1. *Derbin A.V., Egorov A.I., Muratova V.N., Popeko L.A., Bakhlanov S.V., Cherny A.V.* //JETP Lett., 1993. V.58. P.1.