Brief Reports

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Limits on the emission of heavy neutrinos in ^{3}H decay

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A high-precision β energy spectrum of ^{3}H has been examined for the emission of a heavy neutrino (between 100 eV and 10 keV). No evidence has been found for it, and limits are given as a function of the mixing angle of the heavy neutrino with the usual light neutrino.

There is considerable interest in whether the neutrino (or antineutrino) emitted in weak interactions is a mass eigenstate or a linear superposition of primitive neutrinos of definite mass. If the latter is the case, then energy spectra of β particles will show kinks[1-3] associated with the emission of energetically allowed neutrinos of different mass. An examination of β spectra can therefore be used to look for massive neutrinos and, if observed, to determine the mixing amplitudes.

It is useful to assume that the electron neutrino is predominantly a linear combination of two mass eigenstates ν_1 and ν_2, of masses m_1 and m_2,

$$\nu_e = \nu_1 \cos\theta + \nu_2 \sin\theta \,. \tag{1}$$

Then the β spectrum will be written

$$N_\beta(E, Z) = N_\beta(E, Z, m_1)\cos^2\theta + N_\beta(E, Z, m_2)\sin^2\theta \,, \tag{2}$$

where $N_\beta(E, Z, m)$ is the usual β energy spectrum[4] with the emission of one neutrino of mass m. The neutrino masses must be less than $(m_x - m_y - m_e)c^2$, where m_x, m_y, and m_e are the masses of the parent nucleus, daughter nucleus, and the electron (neglecting differences in atomic binding energies).

This paper presents an analysis of the β energy spectrum of tritium obtained by implantation of the tritium in a Si(Li) x-ray detector. A detailed description of the experiment whose purpose was

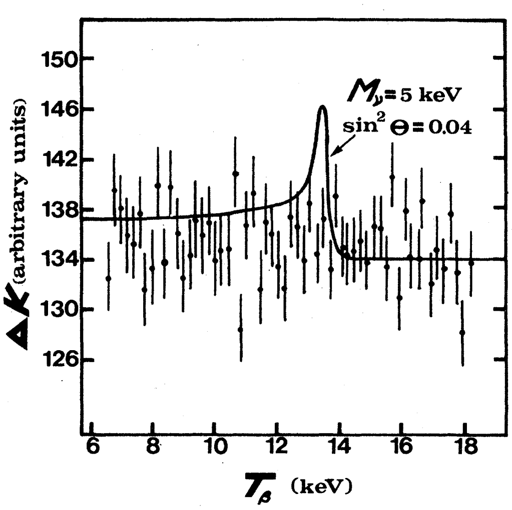

FIG. 1. Magnitude of the difference of adjacent points of the Fermi-Kurie plot for ^{3}H as a function of the kinetic energy of β particles. The smooth curve is theoretically expected for a heavy-neutrino mass of 5 keV and mixing strength $\sin^2\theta = 0.04$.

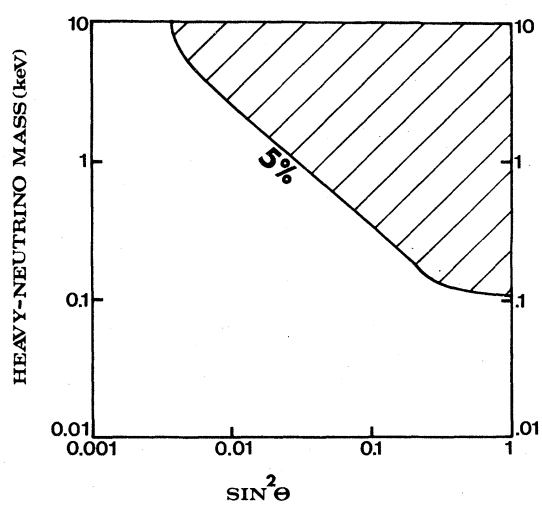

FIG. 2. Limits on the emission of a heavy neutrino from ^{3}H as a function of the coupling strength. The shaded area is excluded at the 95% confidence level.

to measure the neutrino mass has appeared,[5] and only the results of a two-neutrino search are given.

Since β decay of tritium is an allowed decay, the Fermi-Kurie plot is linear,[4] except very near the end in the case of nonzero neutrino mass, and its derivative is a constant. If the β spectrum is as expressed in Eq. (2), then the derivative will have a cusp (smeared by the resolution function) at a β energy m_2c^2 below the extrapolated end-point energy of the β spectrum, and below the energy of the cusp the derivative is larger in magnitude than above. Figure 1 shows the magnitude ΔK of the difference of adjacent points in the Fermi-Kurie plot of the total of the postannealing data of Ref. 5. Also shown is the theoretically expected difference for m_2 of 5 keV and $\sin^2\theta$ of 0.04. There is no firm evidence for cusps in the data. A χ^2 test of expression (2) against the data was then used to determine the limits on the presence of a heavy neutrino m_2 with probability amplitude $\sin^2\theta$ and the shaded area of Fig. 2 shows the region of mass-probability combinations disallowed at the 95% confidence level. In fact only a few masses spanning the energy from about 100 eV to 10 keV were actually tested, and a smooth curve connecting their positions on Fig. 2 produced the 5% contour shown. Note that only masses less than 600 eV can have mixing angles equal to or larger than the Cabibbo angle θ_C, for which $\sin^2\theta_C = 0.05$.

In conclusion, for a restricted range of mass from about 100 eV to 10 keV, the spectrum of tritium puts quite low limits on the strength of mixing of a heavy neutrino with the dominant light one emitted in β decay.

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