Heavy-Neutrino Emission

Simpson's "17-keV neutrino," an effect at the level of 2×10^{-3}, can easily be an artifact of systematic effects in his experiment.[1] His statistical precision is better than 10^{-3}, while systematic corrections are large. While he qualitatively discusses some of the systematic effects, he does not fold in any systematic errors. We comment on some of the systematics.[2]

The noise spectrum, not shown, should have a width less than the 220 eV quoted for the resolution function at 6 keV. The data of Fig. 1 require a Gaussian width greater than 250 eV or a non-Gaussian tail; otherwise the total noise counting rate would exceed the inverse of the amplifiers shaping time by more than an order of magnitude. A tail on the noise spectrum would contribute excess counts at low energy.

However, the dominant effect in Simpson's present analysis appears to be his piecewise treatment of the spectrum: 0.7 to 3.2 keV,[1] 6.5 to 18 keV,[3] and 9.5 to 17 keV.[4] He avoids facing systematic discrepancies in the data by changing the end point of the spectrum by a large amount compared to the usual 20 to 65 eV.[4] Simpson[1] adjusts the Q value from Q_0 to $Q_0+\Delta$, so that the Kurie plot $K\sim Q_0+\Delta-T$ instead of $K_0\sim Q_0-T$. To "undo" this effect, we must apply a correction $\delta K/K=\Delta/(Q_0-T)-\Delta/(Q_0-2.5\text{ keV})$ normalized to zero at 2.5 keV. The values of $\delta K/K$ are -2.7, -2.1, -1.5×10^{-3} at 0.5, 1, and 1.5 keV and -0.7, 0, 0.8×10^{-3} at 2, 2.5, and 3 keV using Simpson's (average) $\Delta=+0.4$ keV.[5] These corrections tend to wipe out any excess below 1.5 keV when added to the data shown in Fig. 3. We note that the other published full tritium spectrum,[6] taken at 3% statistics, showed a deficit at low energy.

We suggest that Simpson should present his data using overall spectrum fits, and quote upper limits on heavy neutrinos (extending Ref. 3 results). Or he could divide his experimental data by phase space and obtain an "experimental Fermi function," including systematic errors, to be compared with theory. We believe that Simpson's data are inadequate to claim new physics in the face of substantial systematic effects.

Finally, we point out that the existence[1] of a 17-keV neutrino with significant ($\sin^2\theta=0.03$) mixing with the electron neutrino could result in a substantial discrepancy between theory and experiment for the triton lifetime. Using[7] $Q=18.59\pm0.02$ keV and a half-life[8] of $t=12.330\pm0.013$ yr, we find $ft=1123\pm5$ s based upon a standard Fermi function[4] (which makes a 45% increase in f). We can translate this into a statement about the axial-vector matrix element by writing

$$(ft)^{-1}=(G^2m^5/2\pi^3\ln2)[1+3(G_A/G_V)^2(1-\epsilon)^2].$$

With[9] $G_A/G_V=-1.254\pm0.006$ we find $1-\epsilon=0.957\pm0.008$, where the largest sources of errors are the uncertainties in G_A/G_V, Q, and t, in decreasing order of importance. This result is consistent with that of Bargholtz.[10] However, Budick[11] has pointed out that atomic effects may change $1-\epsilon$ significantly, raising $1-\epsilon$ to 0.970 ± 0.008, which includes revised values of t and Q. This may already present a conflict with theory: Bargholtz's calculation[10] gives $1-\epsilon=0.950\pm0.009$, where we use his values from point-coupling and monopole-form-factor computations to give upper and lower limits, respectively. [Note added: Ciechanowicz and Truhlik[12] obtain $1-\epsilon=0.967$. If we include two of Bargholtz's corrections, which they acknowledge but do not use, $\delta(\text{rel})$ and $\delta(\text{rec}+\text{norm})$, we find $1-\epsilon=0.953\pm0.007$, in agreement with the above number.]

If Simpson's interpretation of his experiment is correct, it would reduce the theoretically predicted $(ft)^{-1}$ value by the factor $[1-\sin^2\theta(1-f_2/f_1)]$, where f_1 (f_2) is the phase-space factor for a massless (massive) neutrino. With $m_2=17$ keV, $f_2/f_1=0.037$, so that the absence of any significant phase space for the heavy neutrino results in a 3% decrease in the rate. This would increase the discrepancy between Budick's "experimental" number and Bargholtz's central theoretical value from 0.020 to 0.038, a 4 standard deviation difference.

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