Comment on "Hypersharp Resonant Capture of Neutrinos as a Laboratory Probe of the Planck Length"

In a recent Letter [1] Raghavan claims that the monoenergetic neutrinos emitted from the branch of the radioactive decay of tritium that proceeds by the two-body process of electron capture, could be resonantly reabsorbed by ^{3}He with the natural line width, if both the tritium and the ^{3}He were confined in a suitable Nb metal lattice. The natural width, from the 12.3-year half life, is on the order of 10^{-24} eV. Raghavan then suggests fundamental physics measurements based on this feasibility. Such a line width would be some 13 orders of magnitude smaller than the sharpest line seen in the Mössbauer effect.

The idea that the emission of such monoenergetic neutrinos might conceivably be considered for Mössbauerlike resonant absorption had been suggested by Kells and myself some 25 years ago [2], and we concluded that while tritium was by far the most favorable case, various line-broadening effects made the experiment impractical. Raghavan suggests that line-broadening is absent because of *motional averaging*. There are a number of problems associated with this suggestion. The purpose of this note is to point out a few of them.

(i) *Equivalent sites for* ^{3}H *and* ^{3}He *atoms in a metal lattice.*—For the natural line width to be observed it is essential that the two types of atoms consistently occupy *exactly* the same sites in the metal lattice. Since one is helium, with a closed electron shell, and the other is hydrogen with an odd electron that can interact with the metal atoms, it seems impossible to achieve this, even by the method suggested by Raghavan of producing the absorber from the decay of a tritiated source. The interaction energies of helium and hydrogen with Nb are *very* different. Even if the equilibrium positions were the same, the mean-square excursions from this position will have to be different since the interactions are different. Typical Mössbauer line shifts and broadenings are on the order of 10^{-9}–10^{-8} eV. Even assuming up to 5 orders of magnitude smaller effects, this leaves one with shifts and broadenings 10 to 15 orders of magnitude larger than the natural line width.

(ii) *Random distribution of the* ^{3}H *and* ^{3}He *atoms in the lattice.*—.The presence of a nearby impurity (such as ^{3}H in ^{3}He) in a lattice will cause a perturbation and a slight modification in the electron density, which will cause the energy of the neighboring tritium or helium atoms to be slightly different. A gram-scale Nb sample and a kCi of tritium implies comparable numbers of atoms. Since neither the tritium atoms nor the ^{3}He can be placed in a regular array in the lattice, these modifications will be randomly distributed and not averaged out by motional narrowing. Line broadenings in the Mössbauer effect for alloys are on the order of a few time 10^{-9} eV. Even if one assumes that in the present case these effects are smaller by 10^5, line broadenings of at least 10 orders of magnitude are implied.

(iii) *Mechanical stability.*—To preserve the proposed line width of $\Delta E/E \sim 10^{-29}$ from random Doppler shifts, corresponds to keeping any fluctuation in the distance between the source and absorber to less than 3×10^{-21} m/s ($\sim$0.3 fm/d), several orders of magnitude less than what is achieved even at LIGO.

(iv). *Temperature gradients.*—These can contribute to line broadening because of the relativistic second-order Doppler shift of special relativity [3]. The natural line width would correspond to the temperature throughout the samples being kept constant to better than 0.05 nK. The heating from the 1 kCi of tritium suggested by Raghavan is about 0.1 W. Given the thermal conductivity of niobium it is difficult to see how temperature gradients could be kept below hundreds of mK, causing broadening by some 10 orders of magnitude.

There are other questions, such as whether the averaging implicit in motional narrowing can completely remove the broadening arising from hyperfine interactions between the magnetic moments of Nb nuclei and those of the tritium (or helium) nuclei, or even between pairs of tritium nuclei.

Our estimate 25 years ago was that various sources of line broadening are likely to increase the extremely narrow natural line width by at least 15 orders of magnitude. Unfortunately, it seems unlikely that the improvements suggested by Raghavan would change the situation substantially.

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