CERN-PPE/92-117

10 July 1992

THE 17 keV NEUTRINO DOES NOT EXIST

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Abstract

This work is based on a recent paper that analyses the ability of an experiment to see a massive neutrino in a Kurie plot, as well as part of the latest high quality results. It is shown that the negative experiments have convincingly answered criticism, and that very likely the kinks seen are not attributable to β decay.

Contributed to Neutrino 92, Granada, Spain, June 1992

The question whether or not a 17 keV neutrino exists has been around for some seven years now [1]. Whilst several experiments (all using solid state detectors) have seen an effect at a neutrino mass of 17 keV and a branching $\sin^2 \theta$ of 0.9%, many others have not. If the 17 keV neutrino does not exist, then the kink seen is probably due to some effect not yet understood in the interaction between matter and radiation.

If the 17 keV neutrino does exist, then the most likely explanation is a faulty data analysis by all of the negative experiments, which use arbitrary functions to fit out unknown systematic effects. Each and everyone of the negative experiments uses one or two parameter polynomials on top of the four physical parameters in the fit to extract an acceptable χ^2 from the data.

I have recently written a paper in which the problem of arbitrary fitting is studied in detail [2]. As it turns out, misfitting the unknown shape factor in the low-energy region does produce large and unpredictable systematic errors. An example is shown in Fig. 1. The experiment had two corrections (F_B and T) changing by $\approx 10\%$ across the scan and strongly non-linear. A missing distortion of the order of 2.5% was assumed to be linear (α in Fig. 1). If the distortion had a shape similar to the corrections already in use, then the fit would have tried to make up for the misfit by moving all of the other parameters, most notably $\sin^2 \theta$. The combined effect of most statistics and highest non-linearity in the low-energy region amplifies this source of systematic error on $\sin^2 \theta$.

Using a simulation program, I was able to routinely produce ‘fits’ as in Fig. 2, where a plot with statistical errors, 10^8 events, a non-linear distortion, and a kink of 0.8% was fitted with a negative (-0.1%) kink, a linear distortion, and a reduced χ^2 of less than 1. I thus concluded that most experiments (amongst them some positive) had potentially fatal flaws. I proposed some statistical checks and quality cuts for the experiments with statistics of $\approx 10^8$ events, and suggested that very good and conclusive experiments would indeed be useful.

Since then, some high-quality results, reported by Boehm at this Conference, have appeared and they answer this criticism convincingly. Two of them were statistically analysed and the Tokyo experiment [4] in particular is an impressive result. Firstly, they performed a spectrometric scan whilst weighing unequally three different regions above, around, and below the kink. Every point had roughly the same statistics ($\approx 10^6/\text{bin}$). Thus the more densely populated low-energy region is statistically not dominating over the kink region. Secondly, their shape factor was small, changing by no more than 1% from the minimum to the maximum of the scan. This improves by a factor of three the previous lowest shape factor. Thirdly, they collected a huge number of events (2.4×10^9), up by a factor of 20 with respect to most other experiments. Each of these improvements greatly reduces the chance of an accidental misfit.

A simulation of the statistical power of the Tokyo experiment shows that there is no possibility that the kink could have been missed and the χ^2 be around 1 at the same time. Figure 3 shows two groups of fits using non-linear distortions (see Ref. [2] for details), and they are well separated and within 0.1% of their input value. The systematic error due to a misfit was estimated to be roughly 0.1%, much larger than the error quoted in the experiment. It is very likely that the 22σ significance quoted by the paper is an overestimation. However, this does not change the main conclusion that the result is totally incompatible with a massive neutrino. I suggest that the analysis be re-done with arbitrary shape factors to estimate the true systematic error. It is not a perfect method, but it is the best one can do.

A result by the Caltech group [5] also showed an excellent shape factor of the order of 1% change. Their most significant result was obtained with a narrow scan, 7 keV wide around the kink. Most of these narrow scans are of limited or no statistical significance, because the global correlation coefficients are often very close to 1. However, the Caltech group managed to obtain a good result by minimizing the number of free parameters (two) whilst conveniently fixing other parameters to the value obtained with another, wider, scan. Again they saw no kink. Furthermore, they used a synthetic kink generated by degrading part of the source to prove that there is no smearing of the spectrum features in their experiment. This is a nice check, somewhat complementary to the Tokyo result.

The above results seem by all standards conclusive evidence that the kink observed in some experiments is not specific to β decay: the possibility of misfits is excluded, and there is excellent control over the detector response. Of the positive experiments produced so far, two would not pass the quality cuts of Ref. [2]. One is the ^{63}Ni result by Hime and Jelley which has low statistics, the other, the ^{14}C by the Berkeley group, because of a large and potentially treacherous shape factor (6%, although it is not clear how much is due to theory and how much to experimental effects).

One experiment, the ^{35}S result by Hime and Jelley was proven to be statistically sound [6], whereas another, by Simpson and Hime, has not to my knowledge been reanalysed. The sharp transition observed in these experiments is most probably of instrumental origin and remains to be explained.

I would like to thank F. Boehm for providing me with several recent results.

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Figure 1: Plot of the two major corrections (window transmission T and backscattering fraction F_B) to the Kurie plot and of the linear shape factor from Ref. [3].

Figure 2: Fake experiment, from Ref. [2]. The input Kurie plot had a 0.8% kink and a non-linear shape factor. The output (fitted) Kurie plot had a linear shape factor, a -0.1% kink, and a reduced χ^2 of 0.99.

Figure 3: Fake fits from Ref. [2], using statistics similar to those of Ref. [4]. One group of fits was distorted according to one group of distortions and had no kink in input. Another was distorted according to another group of distortions and had a 0.8% kink in output. The two groups are cleanly separated, with systematics errors (the average deviation with respect to the input value) no larger than 0.1%.