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THE EVIDENCE FOR A 17 KEV NEUTRINO REVISITED†

DAVID B. CLINE and WOOPYO HONG

Departments of Physics & Astronomy, University of California at Los Angeles
405 Hilgard Avenue, Los Angeles, California 90024

ABSTRACT

We review the evidence for a 17 KeV neutrino obtained in some recent experiments from a distortion of the β decay spectrum near the end point for various nuclei. We also indicate the experiments that have failed to observe this signal and contrast the two results. A number of questions are posed for both types of experiments and we show that the presence of unexpected non-gaussian errors could simulate a signal in some experiments.

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1. INTRODUCTION AND CURRENT RESULTS

For sometime now there have been very strong claims for the existence of a 17 KeV neutrino derived from the study of the end point spectrum of several nuclear β decay processes[1,2]. There have been stronger claims from groups using magnetic spectrometry and other techniques that fail to find any evidence for a 17 KeV neutrino signal[1]. In addition, there have been suggestions for the possibility of an instrumental effect that explains either set of results.

In this brief review we summarize the available results up to February 1992, including the results of a workshop held at UC Berkeley in December 1991[2].

In Table 1 we list all the experiments known to us as reported in open meetings or in the literature up to February 15, 1992 and the salient result. While no results from magnetic spectrometers supports the claim of a 17 KeV neutrino hypothesis at the level of $\sim 0.8\,\%$ emission probability, it is important to note that there are null results from non-magnetic spectrometer experiments, as well.

There positive results, while very impressive at face value, also exhibit some new problems. For example, the two experiments on ^{71}Ge obtained different masses for the "17"KeV neutrino (13.5 KeV and $\sim$ 17 KeV)[2]. The experiment obtaining a low mass claims to have ten times better statistics[2]. The Tokyo experiment of Ohi, et al., used a Si detector but failed to report a signal to the 0.3 % level (90 % C.L.)[7]. Present results from ^{55}Fe seem inconclusive but a previous report indicated a "17"KeV mass of 22 KeV[15]. The Oxford ^{63}Ni results are not many standard deviations and may suffer from back-scattering effects (although, the authors have attempted to correct for this as best possible)[2].

Therefore, the major claims for the existence of a 17 KeV neutrino arise from the results of Simpson and Hime and Jelly[8,9] and the ^{14}C data of the LBL group[2,16]. Because of the pivotal nature of these results, we discuss some of the criteria of the results here (see also Appendix A).

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2 MAGNETIC SPECTROMETER SYSTEMS ISSUES

Obviously any experiment with the difficulty of finding a very small effect on a rapidly falling electron spectrum will have some type of problems to overcome. Some of the problems possible with magnetic spectrum experiments (hypothetically) that have been suggested are

1) Stability of magnetic field – compensation for Earth's field
2) Variation of efficiency with field
3) Shape function and long tail in the response function
4) Fitting of parameters arbitrary function

While some criticism of the magnetic spectrometer technique may be valid, we note that several experiments have shown, by Monte Carlo techniques, that evidence for the 17 KeV signal should be apparent in the corrected data. Interestingly, it is not.

Further, we note that the Caltech group has shown their sensitivity to a neutrino-like signal by placing a thin foil in the electron "beam". The effect of the foil was clearly observed in the uncorrected data and lends some credibility to their claims of sensitivity[14].

3. SOLID STATE DETECTOR SYSTEMS ISSUES

It is extremely difficult to identify the source of any problems in the solid state detector experiments since the authors of the reports either claim no problems exist or believe they have taken into account any other problems (i.e. such as electron back-scattering). Nevertheless, it is a rare experiment in Physics that does not end up with some unexplained effects or does not encounter sources of non-Gaussian errors in the resolution function. In addition, it is up to the experimenter who claims a signal to identify any such problems; it is difficult for outsiders to do the same! We therefore list a set of hypothetical problems that have been reported at various discussion. We do not claim these effects exits but simply provide a list of possibilities[14].

1) Response function as a function of energy (atomic scattering, radiative effects)
2) Pile up effects due to rate in source or width of time window to carry out calorimetry
3) Source thickness effects
4) Collimator effects
5) Incorrect deconvolution of line profile (see Appendix A)
6) χ^2 fits to data with large number of parameters

4. CONCLUSIONS

We plot, in Fig. 1, all the current limits and mixing fractions for the search for a 17 KeV neutrino, classifying the experiments by technique. While no magnetic spectrometer experiments have observed a signal, it is important to note that there are solid state experiments that also do not observe a signal, as well. A possible reason for the difference in the various solid state experiments could be due to the different geometry of the experiments. We note that the null experiment of Ohi, et al.[7], used a nearly 4π geometry, whereas the experiments of the Guelph and Oxford groups use a small angle geometry and a collimeter. We have also shown (Appendix A) how small non-Gaussian effects in the tails of the resolution functions can mimic a 17 KeV-like signal. We believe that the null effects displayed by most experiments will be clarified during 1992 and continue to express reservations about the existence of a 17 KeV neutrino.

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TABLE 1.

Experiments Searching for a 17 KeV Neutrino Signal (up to Feb. 1992)					
SOURCE	SIGNAL	MIXING LEVEL OR LIMIT	GROUP	REF.	TECHNQ.
^{35}S	Null	< 0.25% (90%)	Caltech (85)	3	MS
^{35}S	Null	< 0.4% (99%)	Princeton (85)	4	MS
^{35}S	Null	< 0.17% (90%)	ITEP (85)	5	MS
^{35}S	Null	< 0.6% (90%)	BARC/TIRF (85)	6	MS
^{35}S	Null	< 0.3% (90%)	Tokyo (86)	7	SS
^{35}S	Signal 0.84 ± 0.08		Guelph (89)	8	SS
^{35}S	Signal	0.73 ± 0.1	Oxford (91)	9	SS
^{35}S	Null	< 0.3% (90%) (17 KeV excluded at 90% C.L.)	Caltech (91)	2,14	MS
^{35}S	Null	? ?	Oxford (91)	(2)	MS
^{63}Ni	Null	< 0.3% (90%)	Chalk River (86)	10	MS
^{63}Ni	Null	< 0.25% (90%)	Caltech (86)	11	MS
^{63}Ni	Signal	$0.99 \pm 0.22\%$	Oxford (91)	12	SS
^{63}Ni	Null	<0.2% (90%) Experiment in Progress	Tokyo (91)		MS
^{177}Lu	Null	<0.4% (68%) <1% (90%)	Grenoble (91)	2	MS
^{71}Ge	Signal	$1.6 \pm 0.8\%$	Zagreb (90)	2	SS
^{71}Ge	Null	Rule Out 17KeV (85% C.L.)	TANDAR (91)	2	SS
^{14}C	Signal	$1.2 \pm 0.3\%$	LBL (91)	2,16	SS
^{55}Fe	Signal ?*		LBL (91)		SS
^{3}H	Signal	$0.6 - 1.6\%$	Guelph (89)	13	SS
^{3}H	Null	< 0.4% (90%)	Oklahoma St. (91)	2	P

MS = Magnetic Spectrometer Technique
SS = Solid State Detector Technique (Si or Ge)
P = Proportional Counter Technique

* Signal reported at 1991 APS Mtng. at $M \sim 22$KeV by the LBL group; no other references are known to us.

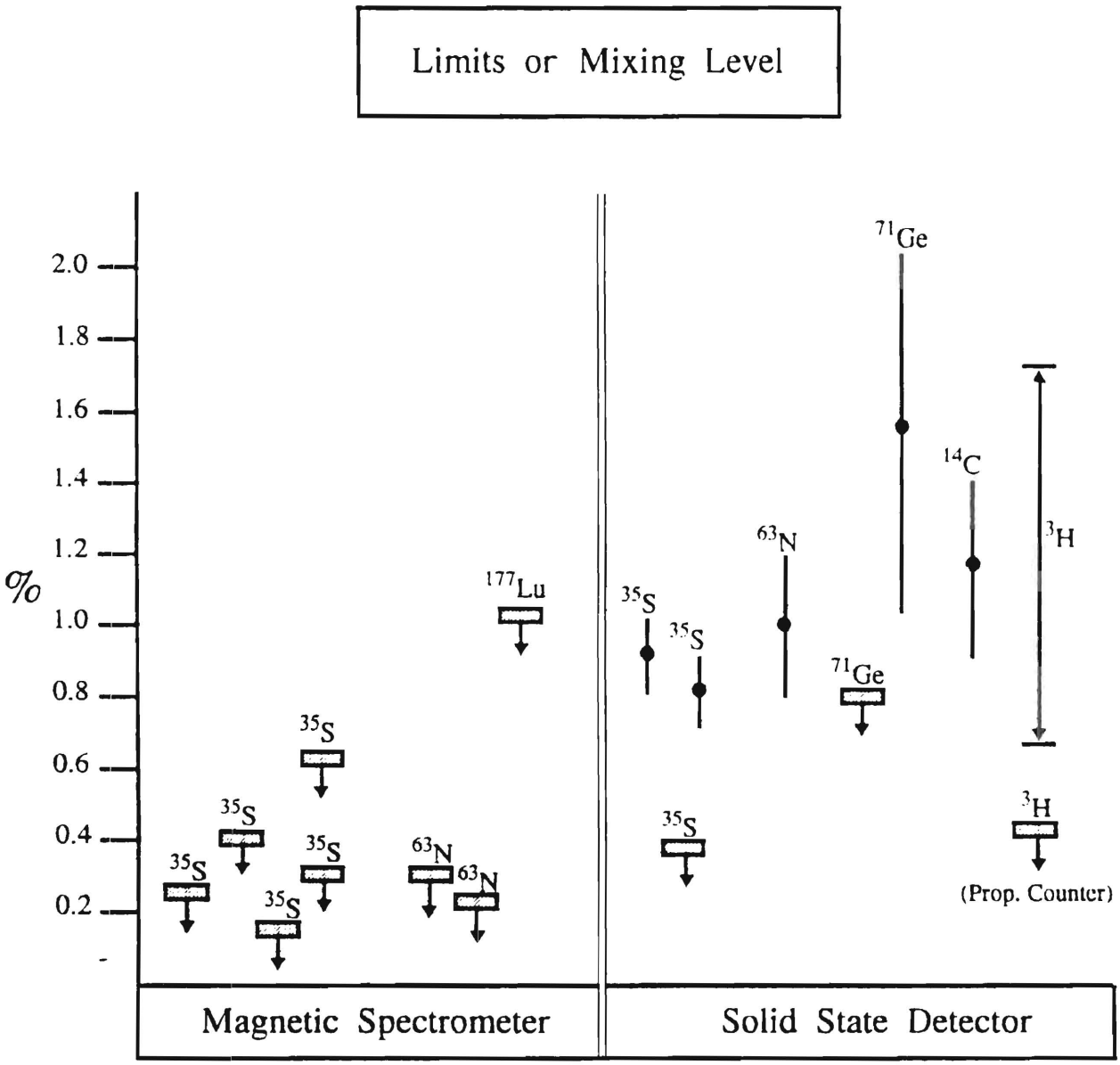

Fig. 1 Limits on mixing level for the 17KeV hypothesis by detector type (see Table 1).

A 17KEV NEUTRINO SIGNAL PRODUCED BY THE NON-GAUSSIAN TAIL OF THE ELECTRON RESOLUTION FUNCTION

It is our intention to show that a high energy side non-gaussian tail of the electron resolution function may produce a 17KeV neutrino signal of the ^{35}S, ^{14}C and ^{55}Fe spectrum near the end point energy. We conjecture the existence of the non-gaussian tail, believing that it originates from unknown sources (i.e. electron pile-ups in a solid target detector or amplifier non-linear responses). We show below that the end point spectrum of various β decay spectrum are very sensitive to a small non-gaussian tail of the resolution function.

To simulate the 17KeV signal as shown in solid target detector experiments, we define the shape function, $S(E_\beta)$, as

$$S(E_\beta) = \frac{\int^E R^{NG}(E_\beta - \tau)\, N_\beta(\tau)\, d\tau}{\int^E R^G(E_\beta - \tau)\, N_\beta(\tau)\, d\tau}$$

where R^{NG} is the non-gaussian resolution function (see Fig. 2) and N_β is the theoretical β spectrum of various nuclei with a zero neutrino mass[17]. The non-gaussian tail is parameterized as $\exp(a_0 + a_1 \times E + a_2 \times E^2) \times 10^4$ where $a_0 = 52411.5$, $a_1 = -923.913$ and $a_2 = 4.07169$. The FWHM of the R^G is 0.3KeV (we use the same normalization as Hime and Jelly's resolution function[9]).

The result of the shape function convolution is shown in Fig. 3 for cases ^{35}S and ^{14}C. Note that our assumed non-gaussian resolution function provides a similar structure to the experimental data[8,16]. The distortion identified as the signal for the 17KeV neutrino arises from the higher side of the resolution function.

It should be pointed out that the recent positive evidence for a 17KeV neutrino has utilized β spectra with a high end point value. Our calculations show that the distortion is not expected to change much for different nuclei. The energies at which the maximum distortion occurs, E_d, for the different nuclei are

$$0.89Q \quad \text{for} \quad {}^{14}\text{C}$$
$$0.9Q \quad \text{for} \quad {}^{35}\text{S}$$

Since these E_d are in between we expect that the maximum distortion energy for ^{55}Fe should occur at $\sim$ 22KeV, below the end point energy at which

$$\sim 0.9Q \quad \text{for} \quad {}^{55}\text{Fe}$$

where $Q \sim 231$KeV.

Looking at Fig. 3, we can clearly see that the distortion in the shape function occurs near 22KeV. This is below the end point energy of ^{55}Fe. This result is in agreement with a report given by E. Norman et al., at the Washington APS Spring meeting in which their data was presented[15].

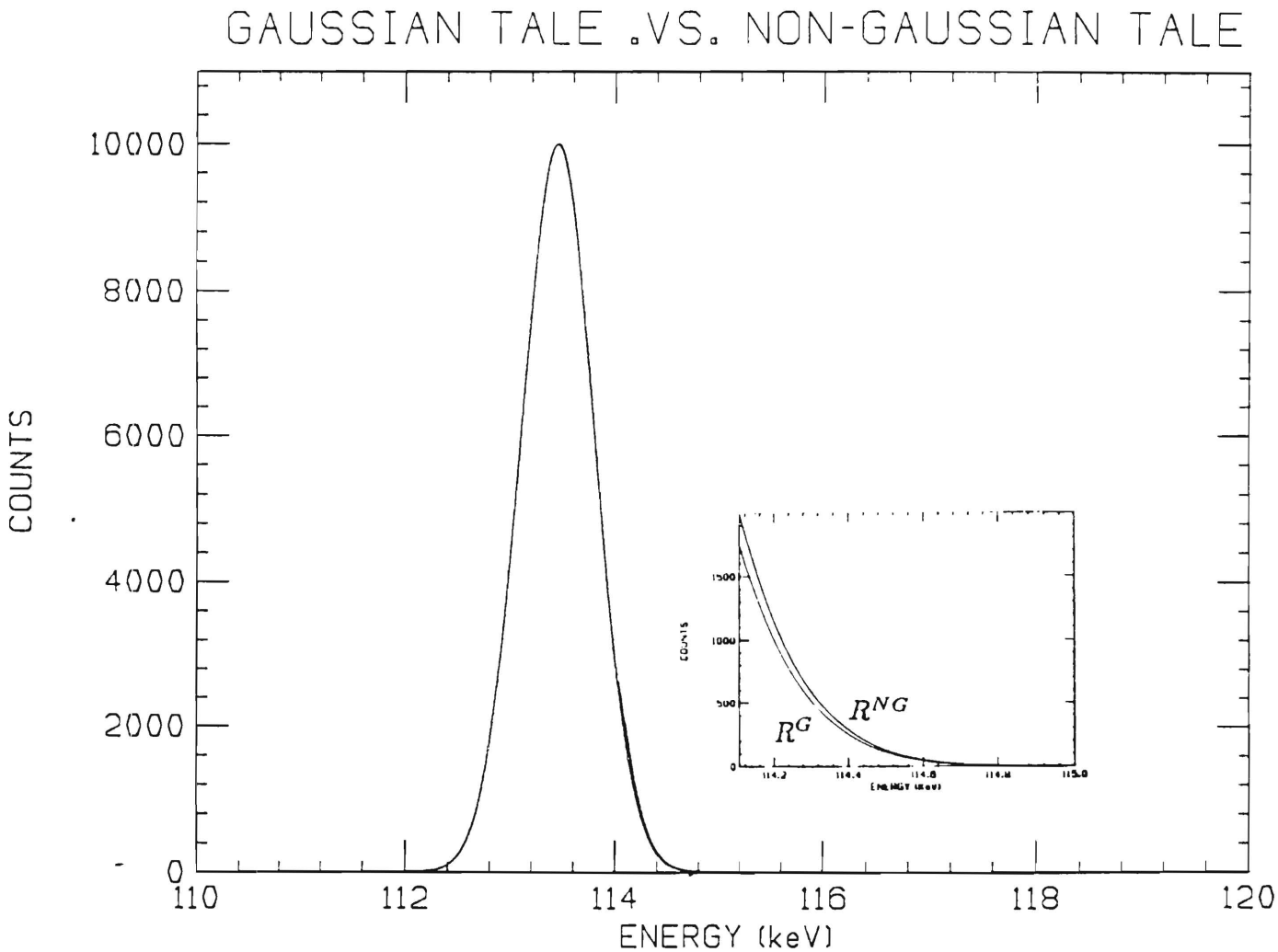

Fig. 2 The box inside the figure shows the magnified non-gaussian correction function, R^{NG}, and the gaussian correction function, R^G, used for the convolution of ^{35}S, ^{14}C and ^{55}Fe. The non-gaussian tail is fitted by function $\exp(a_0 + a_1 \times E + a_2 \times E^2) \times 10^4$ where $a_0 = 52411.5$, $a_1 = 923.913$ and $a_2 = 407169$.

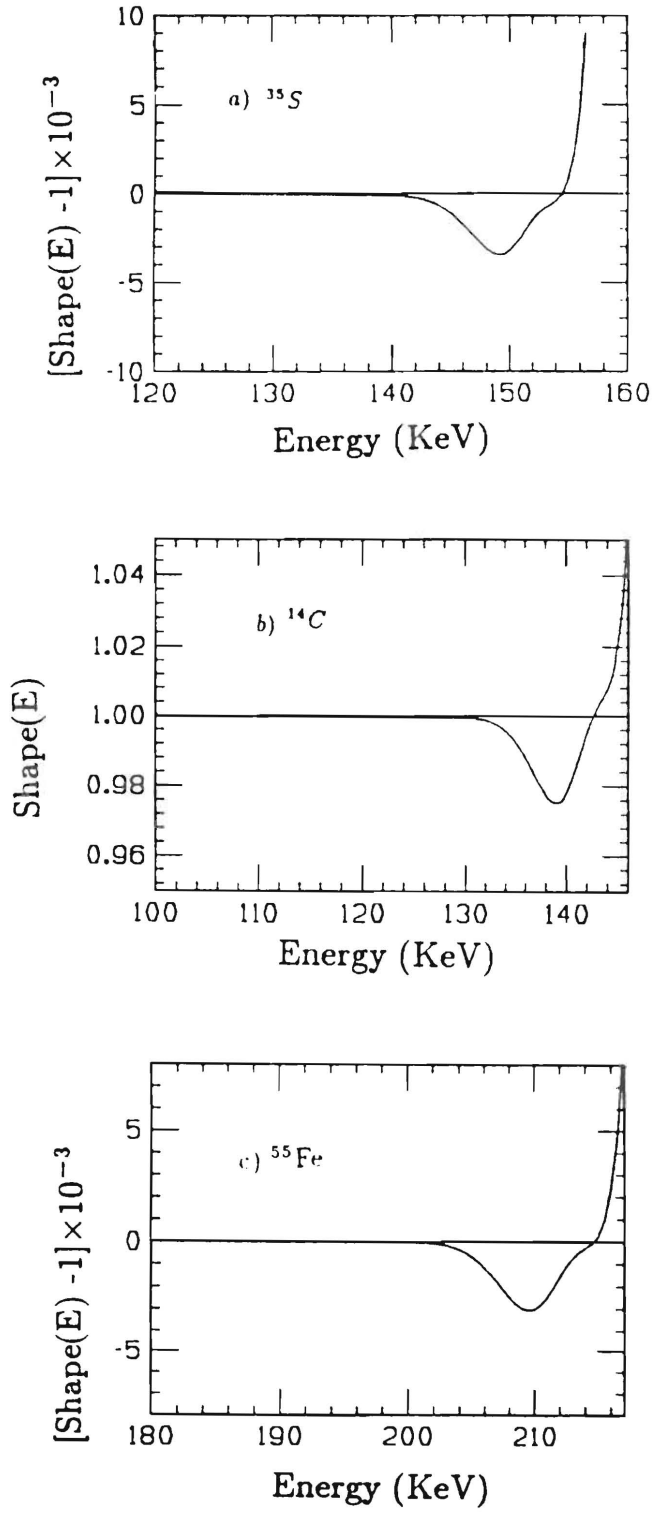

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Fig. 3 The shape function, defined as the ratio of the non-gaussian convolution to the gaussian convolution, is given for ^{35}S in **a**) and for ^{14}C in **b**). The predicted non-gaussian convolution shape function for ^{55}Fe β decay is given in **c**).