Modern Physics Letters A,

COMMENT ON "EVIDENCE FOR NEUTRINOLESS DOUBLE BETA DECAY"

C. E. Aalseth[1], F. T. Avignone III[2], A. Barabash[3], F. Boehm[4], R. L. Brodzinski[1], J. I. Collar[5],
P. J. Doe[6], H. Ejiri[7], S. R. Elliott[6]*, E. Fiorini[8], R.J. Gaitskell[9], G. Gratta[10],
R. Hazama[6], K. Kazkaz[6], G. S. King III[2], R. T. Kouzes[1], H. S. Miley[1], M. K. Moe[11], A. Morales[12],
J. Morales[12], A. Piepke[13], R. G. H. Robertson[6], W. Tornow[14], P. Vogel[4], R. A. Warner[1], J. F. Wilkerson[6]
[1] *Pacific Northwest National Laboratory, Richland, WA, 99352, USA*
[2] *Department of Physics and Astronomy, University of South Carolina, Columbia, SC 29208, USA*
[3] *Institute for Theoretical and Experimental Physics, Moscow 117259, Russia*
[4] *Department of Physics, California Institute of Technology, Pasadena, CA 91125, USA*
[5] *Enrico Fermi Institute, University of Chicago, Chicago, IL 60637, USA*
[6] *Center for Experimental Nuclear Physics and Astrophysics, University of Washington, Seattle, WA 98195, USA*
[7] *International Institute for Advanced Studies, Kizu-cho, Kyoto, 619-0025 and JASRI, SPring-8, Hyogo 679-5198, Japan*
[7] *Emeritus, Research Center for Nuclear Physics, Osaka University, Ibaraki, Osaka 567, Japan*
[8] *Dipartimento di Fisica dell' Universita' di Milano-Bicocca and Istituto Nazionale di Fisica Nucleare, Sezione di Milano, Italy*
[9] *Department of Physics, Brown University, Providence, RI 02912, USA*
[10] *Physics Department, Stanford University, Stanford, CA 94305, USA*
[11] *Emeritus, Department of Physics and Astronomy, University of California, Irvine, CA 92697, USA*
[12] *Laboratory of Nuclear and High Energy Physics, University of Zaragoza, 50009 Zaragoza, Spain*
[13] *Department of Physics and Astronomy, University of Alabama, Tuscaloosa, AL 35487, USA*
[14] *Department of Physics, Duke University, Durham, NC 27708, USA*

Received (received date)
Revised (revised date)

We comment on the recent claim for the experimental observation of neutrinoless double-beta decay. We discuss several limitations in the analysis provided in that paper and conclude that there is no basis for the presented claim.

1. Introduction

In a paper by Klapdor-Kleingrothaus, Dietz, Harney, and Krivosheina[1] (Hereafter referred to as KDHK) evidence is claimed for zero-neutrino double-beta decay in ^{76}Ge. The high quality data, upon which this claim is based, was compiled by the careful efforts of the Heidelberg-Moscow collaboration, and is well documented[2].

---

*Corresponding author

However, the analysis in KDHK makes an extraordinary claim, and therefore requires very solid substantiation. In this letter, we outline our concerns for the claim of evidence.

Unfortunately, a large number of issues were not addressed in KDHK. Some of these are:

1. There is no null hypothesis analysis demonstrating that the data require a peak. Furthermore, no simulation has been presented to demonstrate that the analysis correctly finds true peaks or that it would find no peaks if none existed. Monte Carlo simulations of spectra containing different numbers of peaks are needed to confirm the significance of any found peaks.
2. There are three unidentified peaks in the region of analysis that have greater significance than the 2039-keV peak. There is no discussion of the origin of these peaks.
3. There is no discussion of how sensitive the conclusions are to different mathematical models. There is a previous Heidelberg-Moscow publication[2] that gives a lower limit of 1.9×10^{25} y (90% confidence level). This is in conflict with the "best value" of the new KDHK paper of 1.5×10^{25} y. This indicates a dependence of the results on the analysis model and the background evaluation.

A number of other cross checks of the result should also be performed. For example, there is no discussion of how a variation of the size of the chosen analysis window affects the significance of the hypothetical peak. There is no relative peak strength analysis of all the ^{214}Bi peaks. Quantitative evaluations should be made on the four ^{214}Bi peaks in the region of interest. There is no statement of the net count rate of the peaks other than the 2039-keV peak. There is no presentation of the entire spectrum. As a result, it is difficult to compare relative strengths of peaks. There is no discussion of the relative peak strengths before and after the single-site-event cut. This is needed to elucidate the model for the origin of the peaks.

Our investigations of several of these issues create doubt as to the validity of the paper's conclusions. Below, we demonstrate this by briefly discussing two items. Our analyses suggest that, at best, KDHK failed in presenting a strong case for their extraordinary claim, and at worst, that their analyses or assumptions have led to an incorrect claim.

2. The Choice of Window and Background

In Fig. 2 of KDHK, the count rate in the region of 2000-2080 keV is 0.168 c/(keV·kg·yr), and in the 2034-2045 keV region it is 0.167 c/(keV·kg·yr). These numbers indicate a flat background and very little signal. However, KDHK found numerous peaks in the 2000-2080 keV region in their search for a peak. Next, they constrained their double-beta decay ($\beta\beta$) analysis to a small region that excluded these peaks. An analysis only within that limited region is used to claim a 2039-keV peak at the 2-3 σ level. The conclusion in KDHK must depend on the choice of window and on the number of peaks in the region near the window. In particular, it requires that the other peaks found are real so that the background level can be diminished.

3. The Relative Strength of the ^{214}Bi Peaks

The KDHK paper provides data only in the 2000-2080 keV region. However a recent paper by the Heidelberg-Moscow collaboration[2] (hereafter referred to as HM) shows the entire spectrum[a] from 100-2700 keV, which permits a relative-intensity peak-analysis. Although the two data sets are not entirely congruent, they are very similar, having 47.4 kg-y of data (HM) and 46.5 kg-y of data (KDHK). They both quote comparable backgrounds in the 2000-2080 keV region.

The table below summarizes an analysis of the ^{214}Bi peak intensities, as given in HM and in KDHK. The first column gives the peak energy of seven of the ^{214}Bi lines: three major lines spanning the region of interest and the four weak lines that can appear in the region of interest. KDHK claims to have observed lines at the positions of the 4 weak ^{214}Bi lines.

Table 1. A comparison of the intensities of the ^{214}Bi lines. The count rates for the peaks labeled as *Ref. Peak* come from Ref.[2]. The relative efficiency for the peaks in the 2000-2080 keV region is an interpolated value based on the 3 reference peaks.

Peak (keV)	Rate (c/(kg·yr))	Branching Ratio[4]	Relative Efficiency	Expected Rate (c/(kg·yr))
609.3	44	44.8%	1	Ref. Peak
1764.5	16	15.36%	1.08	Ref. Peak
2010.7	-	0.05%	1.11	0.05
2016.7	-	0.0058%	1.11	0.006
2021.8	-	0.02%	1.11	0.02
2052.9	-	0.078%	1.11	0.08
2204.2	5.2	4.86%	1.13	Ref. Peak

The rates for the 3 major peaks given in Column 2 were calculated by integrating the spectrum in HM. For those 3 peaks, the fourth column is the relative peak count rate divided by the branching fraction. If the efficiency were the same for all peak energies, these should all have the same value. In fact, peak efficiency is rarely independent of energy, and here it actually increases slightly with increasing energy.

Since the relative counting efficiency is virtually flat as a function of energy, all peaks in the 2000-2080 keV region are assigned the same interpolated number. The last column uses the measured ^{214}Bi disintegration rate from the three major

---

[a] Fig. 1 in HM has an incorrect caption and the Figure is actually for only 1 detector. Therefore we multiplied the net peak counts from that detector by 4 so it would correspond to a spectrum composed of 4 detectors and could be compared to Fig. 2 in KDHK. A similar analysis using a 49.03 kg-y, 5-detector spectrum from Ref. [3] leads to the same qualitative conclusions.

(and prominent) peaks and calculates the expected count rate for the four minor ^{214}Bi peaks in KDHK. These rates are all ≤ 0.08 c/(kg·yr). For a peak width of ≈4 keV, this corresponds to 0.02 c/(keV·kg·yr) and therefore too low to be observed as peaks superimposed upon a background of 0.17 c/(keV·kg·yr) as shown in Fig. 2 of KDHK. The strongest of these peaks would produce only about 4 counts in 46.5 kg-y over an expected background of ≈32 counts. One is led to conclude that there are no observable ^{214}Bi peaks in the 2000-2080 keV region. That is, the ^{214}Bi peaks found by KDHK in the region of interest appear to be spurious.

4. Conclusions

A simple analysis of the ^{214}Bi peaks suggests that the peak finding procedure used by KDHK can produce spurious peaks near the $\beta\beta(0\nu)$ endpoint. However, the existence of these claimed peaks is crucial to the KDHK claim of a peak at 2039 keV, which is interpreted as zero-neutrino double-beta decay. Hence, all the peaks claimed in the 2000-2080 keV region may be spurious, and the entire count rate therefore attributable to a flat uniform background. Alternatively, if all the peaks are real but unidentified, the putative 2039-keV feature may be simply another of those unidentified lines.

These two examples emphasize the importance of addressing all the items listed in the Introduction. By failing to address these issues, the KDHK paper does not provide sufficient support for its claim of evidence for $\beta\beta(0\nu)$.

5. Acknowledgements

We would like to acknowledge supportive discussions with Dale Anderson, Laura Baudis, Theodore Bowyer, David Jordan, Bela Majorovits, William Pitts, Eric Smith, Bob Thompson, Albert Young, and Igor Kirpichnikov.

The preprint by Feruglio, Strumia, and Vissani[5] with independent criticisms of the KDHK result became available during the final preparation of this manuscript.

6. References

1. Klapdor-Kleingrothaus HV, Dietz A, Harney HL, and Krivosheina IV, *Mod. Phys. Lett.* **16** 2409 (2001).
2. Klapdor-Kleingrothaus HV, *et al.*, *Eur. Phys. J.* **A12** 147 (2001).
3. Baudis, L. Dissertation, University of Heidelberg, (1999).
4. *Table of Isotopes*, edited by V.S. Shirley (John Wiley and Sons, New York, 1996), 8th ed.
5. F. Feruglio, A. Strumia, and F. Vissani, hep-ph/0201291.