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ABSTRACT: The spatial asymmetry of internal bremsstrahlung from ^{119}Sb polarized in Fe at low temperature has been observed. The data fit the theoretical correlation function well although some dependence of the asymmetry coefficient A on photon energy was found. At energies near the end-point, complete parity violation was observed, in agreement with theoretical predictions.

We wish to report the first observation of the forward-backward asymmetry of inner bremsstrahlung (IB) photons accompanying the electron-capture decay of polarized nuclei. This result provides a direct test of the IB mechanism. It also extends directional-distribution studies of beta decay to electron-capture cases.

Nuclear decays occurring through the weak interactions are accompanied by a weak, continuous IB photon spectrum associated with the acceleration or deceleration of leptonic charges during the decay.[1a,b,c] The process may be represented by diagrams of the type shown in Fig. 1. Because of the nonconservation of parity in weak interactions, the IB photons are predicted to show circular polarization[2a] and an asymmetric directional correlation with the nuclear quantization axis.[2b,c] The latter effect has been treated by several authors.[1b,c;3a,b] The asymmetry may be detected by observing the IB from polarized source nuclei, although the observation is made difficult by the weak intensity of the IB.[4a,b] In the case of IB accompanying negatron or positron decays, the gamma spectrum is overlapped by the external bremsstrahlung produced when the electrons are stopped, necessitating a large background correction. A more promising case is a pure electron capture decay that populates only the ground state or a low-lying level of the daughter nucleus, thus avoiding interfering radiation. A suitable example is the decay of ^{119}Sb(5/2+) to the 23.8 keV level of ^{119}Sn(3/2+). This decay is 100% EC with an IB endpoint of 526 keV[5] and a (radiative s capture/total electron capture) ratio of about 10^{-4}.[2b,5] The only interfering radiations are the 23.8 keV gamma ray from the Sn daughter and the Sn x rays. The magnetic moment of ^{119}Sb is +3.45 ± 0.03 nm[6] and the hyperfine field for Sb in dilute Sb<u>Fe</u> alloys is +230 kOe[7]; thus nuclear polarization by the low-temperature thermal equilibrium method is feasible.

Antimony-119 was prepared in nearly carrier-free form by a method similar to that of Ref. 5., and was placed in an iron lattice by melting Fe foils plated with the Sb activity. The ingots were hammered to a thickness of ca.0.005" and annealed. Four such foils were prepared having Sb concentrations in the range from 0.1-0.5 at. %. The foils were cooled to about 20 mdeg. K and polarized by application of a field H_0 = 2.3 kOe in an apparatus similar to one previously described.[8] Temperatures were measured by using a combination of internal ^{60}Co thermometry and magnetic susceptibility measurements on the chromium potassium alum cooling salt. The results of all runs with four different samples agree within statistical accuracy. This supports the validity of the temperature scale and the reliability of alloy preparation.

The IB spectrum from 125-500 keV was observed by two 3 × 3" NaI detectors placed at 0° and 180° relative to H_0; typical counting rates were 2000/min, with a signal-to-background ratio of about 10. The resulting asymmetry is shown in Fig. 2. The solid curves represent the best fit to the correlation function

$$W(\theta) = 1 + AQ_1P\cos(\theta) \qquad (1)$$

where θ is the angle between the detector axis and H_0, P is the polarization $\langle I_z \rangle / I$ and contains the temperature dependence, Q_1 is a correction for the finite solid angle of the detector, and A is the asymmetry coefficient, which for a V-A weak interaction in a decay of the type $I \rightarrow I-1$ is predicted to have the value +1.[3a,b] The mean value of A_{obs}, integrated over the energy range shown, is found from the fit in Fig. 2 to be +0.506 ± 0.027, 50% below the predicted value.

A more detailed examination of the asymmetry data reveals an energy dependence in A_{obs} as shown in Fig. 3. This apparent dependence on photon energy may arise from several factors: first, although the asymmetry of the IB accompanying capture of s-state electrons is expected to show only slight energy dependence,[2b;3a,b;4a,b] the s-capture spectrum is overlapped at low energies by IB from p-state electron capture, which should be isotropic.[2b] At the lowest energies observed, the latter is expected to contribute more than 50% of the total IB intensity[2b,5] and thus adds an isotropic background which attenuates A_{obs}. Secondly, photons emerging at right angles to H_0 may be scattered into the detectors by the Nb polarizing magnet or the walls of the cryostat, further increasing the isotropic background. Finally, the importance of relativistic and Coulomb corrections in the calculation of A may have been underestimated in Refs. 3a, b, so that in fact A is not energy independent.

However, a calculation of the probable scattered intensity gives a value for the second effect which is too small to explain all the observed attenuation at low energies (see Fig. 3). This conclusion is supported by a comparison of our experimental IB spectrum with that reported in Ref. 5, corrected to our detector response curve; there is no evidence of large deviations in the observed spectrum owing to scattering at low energies. At the highest energies, in any case, all of the above effects should be negligible. Using the high energy values obtained from plots like those of Fig. 3, which has been corrected for a weak gamma impurity peak which was present at ~425 keV, we find

$$A = +1.001 \pm 0.093$$

in agreement with the theoretical predictions of Ref. 3a,b.

It is instructive to interpret the sign of A in terms of the diagram in Fig. 1. For negatron decay, the symmetry of the weak interaction requires the electron to be emitted antiparallel to the nuclear spin in an allowed $I \rightarrow I-1$ sequence, i.e., at $\theta = \pi$. Thus $A < 0$ for this case. For positron emission or electron-capture IB decay, processes that are inverse to negatron decay, the positron or photon is expected to be emitted parallel to the nuclear spin direction. Since both μ and H_{hf} are positive for ^{119}Sb$\underline{\text{Fe}}$, we therefore expect $W(0) > W(\pi)$, or $A > 0$.

FOOTNOTES AND REFERENCES

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[**] National Science Foundation Graduate Fellow, 1967-68.

1a. P. Morrison and L. I. Schiff, Phys. Rev. 58, 24 (1940).

b. J. K. Knipp and G. E. Uhlenbeck, Physica 3, 425 (1936).

c. F. Bloch, Phys. Rev. 50, 472 (1936).

2a. R. E. Cutkosky, Phys. Rev. 107, 3301 (1957).

b. P. C. Martin and R. J. Glauber, Phys. Rev. 109, 1307 (1958).

c. T. D. Lee and C. N. Yang, Phys. Rev. 105, 1671 (1957).

3a. Y. Koh, O. Miyatake, and Y. Watanabe, Nucl. Phys. 32, 246 (1962).

b. S. F. Timashev and V. A. Kaminskii, JETP 38, 284 (1960).

4a. S. R. De Groot, H. A. Tolhoek, and W. J. Huiskamp in Alpha, Beta, and Gamma Ray Spectroscopy, K. Siegbahn, ed. (North-Holland Publ. Co., Amsterdam, 1965) p. 1258.

b. M. Vinduska and F. Janouch, Proc. 3rd. Regional Conf. on Physics and Techniques of Low Temperatures (Prague, 1963) p. 243.

5. J. L. Olsen, L. G. Mann, and M. Lindner, Phys. Rev. 106, 985 (1957).

6. G. J. Garrett, A. D. Jackson, Jr., and E. H. Rogers, BAPS II 12, 509 (1967).

7. M. Kontani and J. Itoh, J. Phys. Soc. Japan 22, 345 (1967).

8. G. A. Westenbarger and D. A. Shirley, Phys. Rev. 138, A161 (1965).

FIGURE CAPTIONS

Fig. 1. Diagram for radiative electron capture.

Fig. 2. Integral asymmetry data for ^{119}Sb. The best (integrated) value of A_{obs} from 0° curve is 0.527 ± 0.025; the 180° fit gives 0.485 ± 0.028.

Fig. 3. Variation of asymmetry with photon energy. The upper dashed curve is the expected $W(0)$ assuming Eq. (1) with $A = +1$ for s-capture radiation and $A = 0$ for p-capture IB. Lower dashed curve is an approximate lower limit to $W(0)$ attenuated by scattering.

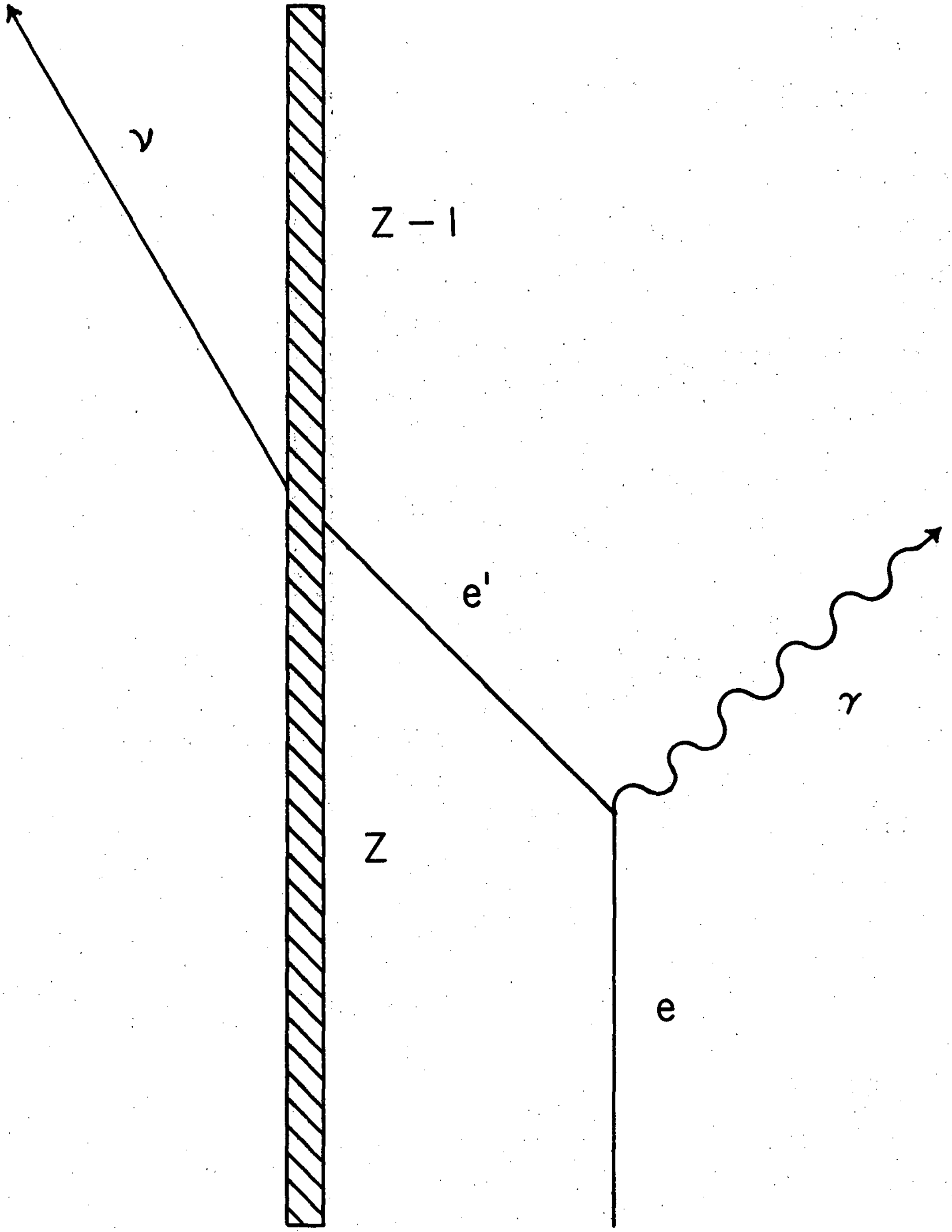

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Fig. 1

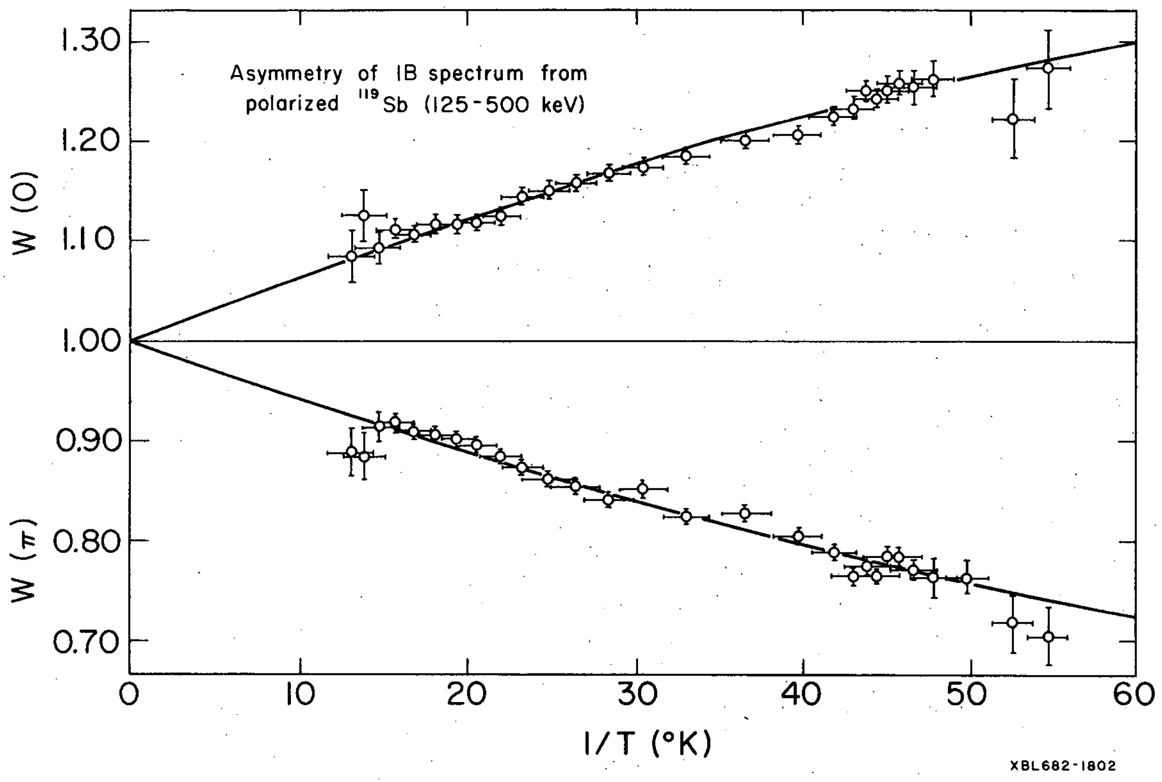
Asymmetry of IB spectrum from polarized ^{119}Sb (125-500 keV)
W (0)
W (π)
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0
10
20
30
40
50
60
1/T (°K)
XBL682-1802

Fig. 2

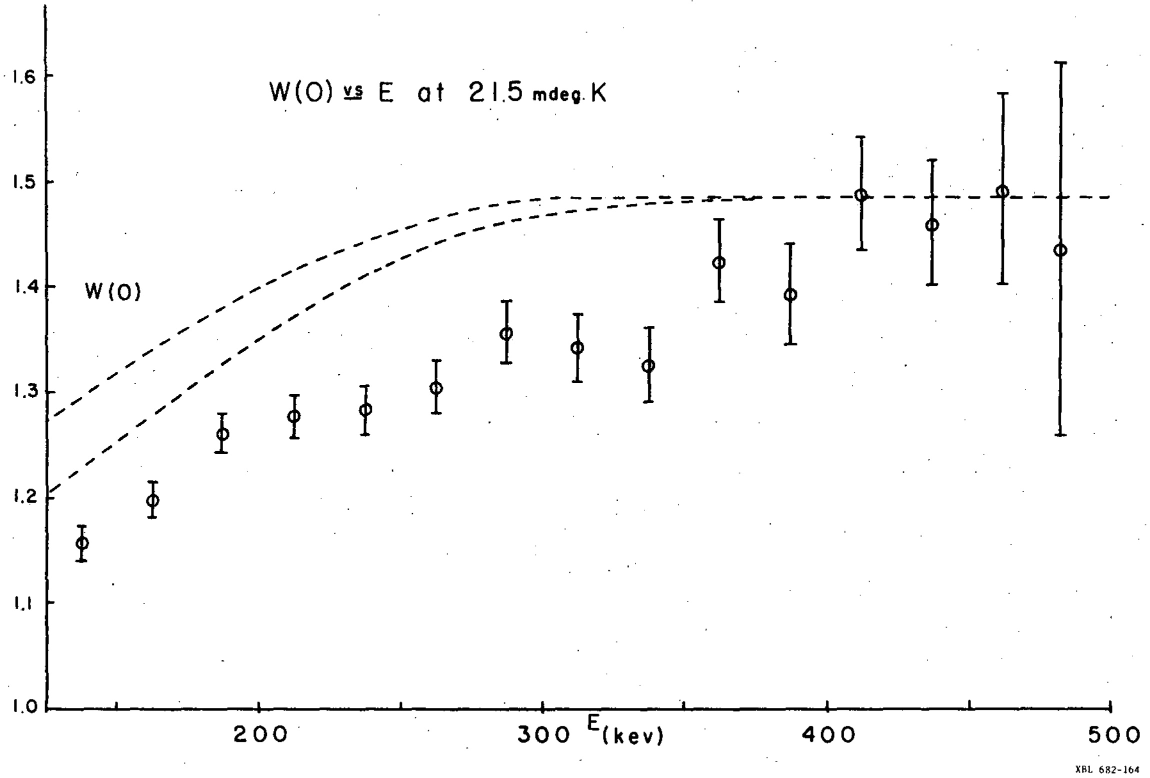
W(O) vs E at 21.5 mdeg. K
W(O)
1.6
1.5
1.4
1.3
1.2
1.1
1.0
200
300
E(kev)
400
500
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Fig. 3