MEASUREMENTS OF GAMOW-TELLER STRENGTH FOR DOUBLE-BETA DECAYING NUCLEI VIA THE (p,n) REACTION AT 134 MeV

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Double β decay (denoted ββ decay)[1] can occur in two modes:

$$(Z,A) \rightarrow (Z+2,A) + e_1^- + e_2^- + \nu_1 + \nu_2 \qquad (2\nu)$$

$$(Z,A) \rightarrow (Z+2,A) + e_1^- + e_2^- \qquad (0\nu)$$

The first of these modes can be thought of as a second order process, a sequence of two normal β decays passing through (virtual) intermediate states of the nucleus (Z+1,A). The second is of great fundamental interest since it does not conserve lepton number.

Recently there has been a renewed interest in these decays because limits on the (0ν) branch for ^{82}Se and ^{76}Ge decay have been used to place limits on the masses of Majorana neutrinos[2] and because the first direct electron counting experiment[3] has been performed for $^{82}Se \rightarrow {}^{82}K + 2e^- + 2\nu$, yielding a lifetime of $1.0 \pm 0.4 \times 10^{19}$ years. This is about a factor of thirty shorter than the life-time obtained by geochemical methods. A detailed model calculation of the (2ν) lifetime has been performed by Haxton, Stephenson and Strottman (HSS)[2] and is in good agreement with the direct counting result but not with the geochemical results for ^{82}Se or ^{76}Ge. Other analyses based on the experimental ratio of the lifetimes for ^{128}Te and ^{130}Te indicate that the non-lepton conserving 0ν process may have been observed. This argument involves only the assumption[4] that the ββ matrix elements for ^{128}Te and ^{130}Te are the same. Theoretical shell model calculations[5] bear out this assumption but also greatly overestimate the strength of the transition, weakening the conclusion about the ratio.

In an attempt to provide constraints on the calculations we have used the neutron time-of-flight system at the Indiana University Cyclotron Facility to obtain (p,n) spectra at 0°, 4° and 8° for ^{76}Ge, ^{82}Se and ^{128,130}Te. The flight path was 85 m and overall time resolution was 750 psec, corresponding to an energy resolution of 360 keV. The L=0 strength at 0° (low q) is closely proportional to the Gamow-Teller (GT) strength to the (virtual) intermediate states of the ββ process. Strength is observed to the giant GT resonance region and to narrow low-lying structures populated with $\sim 10^{-2}$ the strength of the giant resonance. The spectrum for ^{82}Se is shown in Fig. 1.

The results for ^{128,130}Te are simplest to interpret, since the ββ decay analysis assumes only that the matrix elements are the same. Since the Fermi-like (L=0,S=0) transition to the isobaric analog state (IAS) is proportional to (N-Z) for the target, an estimate of the difference in the GT strengths, independent of many systematic errors, can be obtained by normalizing the spectra so the IAS yield is proportional to N-Z. This has been done for the spectrum shown in Fig. 2 where we plot the quantity

$$\frac{Y(^{130}Te) - Y(^{128}Te)}{Y(^{130}Te)}$$

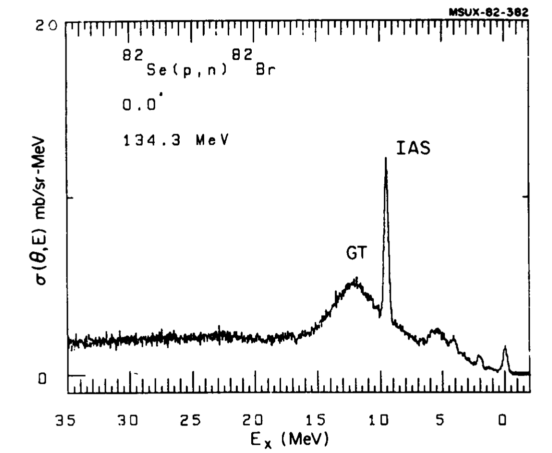

Figure 1. Spectrum for the $^{82}Se(p,n)^{82}Br$ reaction measured 0° and E_p = 134 MeV.

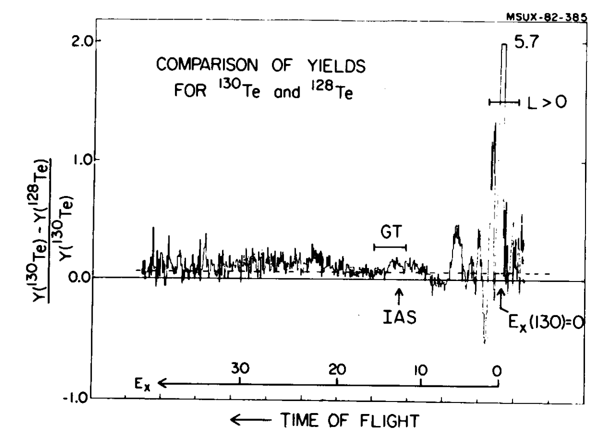

Figure 2. Normalized fractional difference in yields for ^{128}Te and ^{130}Te at E_p = 134 MeV. The positions of the IAS and GT giant resonances are indicated.

Here the Y's are the yields for the noted nucleus, normalized as dicussed above. To the extent that only L=0 GT strength is observed at 0°, a good approximation in the neighborhood of the giant Gamow-Teller resonance, the plotted ratio is also the fractional difference of the allowed (L=0) GT strength for ^{128}Te and ^{130}Te. We see that this difference is less than 15% in the neighborhood of the giant GT resonance. (Since summed Gamow-Teller strength is also proportional to N-Z we might expect a ratio of 13/12). At low excitation the GT strengths differ markedly but a rather small portion of the total strength is involved and moreover, this strength is mostly L>0 and does not contribute to the ββ process.

1) D. Bryman and C. Picciotto, Rev. Mod. Phys. 50, 11 (1978).

2) W.C. Haxton, G.J. Stephenson and D. Strottman, Phys. Rev. Lett. 47, 153 (1981).

3) M.K. and D.D. Lowenthal, Phys. Rev. C 22, 2186 (1980).

4) B. Pontecorvo, Phys. Lett. 26B, 630 (1968).

5) W.C. Haxton, et al., preprint.