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The GT Resonance revealed in β^+-Decay using new experimental techniques

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Abstract. The GT beta decay of ^{150}Ho has been studied with a Total Absorption Spectrometer (TAS), with an array of 6 Euroball CLUSTER Ge detectors (the CLUSTER CUBE), and with an alpha detector. The three techniques complement each other. The results provide the first observation of an extremely sharp resonance in GT beta decay.

Although the problem of the missing strength in Gamow-Teller decay is one of long-standing it remains unresolved. In light nuclei there is a great deal of experimental information, from both beta decay and charge-exchange reactions, which systematically indicates that ~40% of the strength is missing [1]. For heavier nuclei the beta decay information is sparse because of the difficulty of accessing nuclei with allowed decays. In this work we will report studies of Gamow-Teller beta-decay in heavier nuclei. In comparison with charge-exchange reactions they are reaction-model independent and free of background uncertainties. In addition they permit the study of nuclei far from stability. However, due to the selection rules, very few Gamow-Teller decays are allowed above the heaviest N~Z particle stable nuclei. This is because in general the required orbitals for allowed decays lie outside the beta-window. There are only two regions where the $\sigma\tau$ resonance is accessible in β-decay. In both of these regions a proton in a high J orbital decays into its spin-orbit partner neutron orbital with J-1, which is in general less bound than the J proton orbital and therefore empty. The nuclei we refer to lie just below ^{100}Sn and above ^{146}Gd.

The task of making precise β-strength measurements is far from trivial. Traditional high resolution techniques, based on a few Ge detectors to determine the β-feeding, often fail to detect significant but fragmented strength at high excitation energy. To tackle this problem we have performed β-decay measurements at the GSI On-line Mass-separator following two different approaches. First we have used a Total Absorption Spectrometer (TAS) [2] based on a large, cylindrical NaI crystal; see Fig. 1 (left). In order to separate events associated with the EC and β^+ processes we gated on the daughter X-rays or the positrons. This method is sensitive to the level population in the beta decay process rather than to the individual gamma rays. In a second set of experiments we measured the same decays with 6 Euroball CLUSTER detectors arranged to form a cube, see Fig. 1 (right).

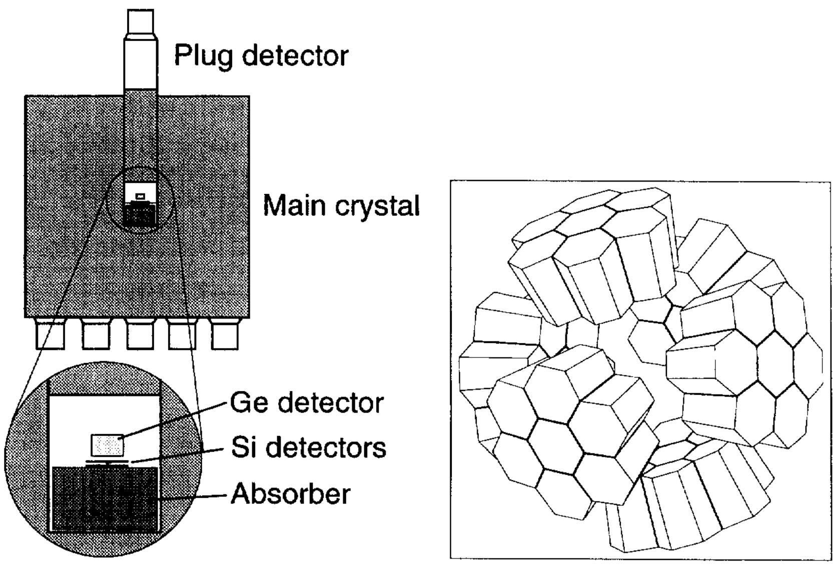

FIGURE 1. The two different experimental set-ups. Left: Total Absorption Spectrometer. Right: array of 6 Euroball CLUSTER Ge detectors (the CLUSTER CUBE)

Here we present the results for ^{150}Ho (2^- isomer) decay, which provides an ideal test of these methods since the strength is expected to be at high excitation energy, but still lie inside the Q_β window. From the TAS experiment we expect to extract the full β-strength distribution accessible in the decay, and from the CLUSTER CUBE experiment the fragmentation of the GT strength in a region of high level density. Moreover, the later experiment should provide the necessary input data to extract the β feeding from the TAS raw data. The comparison of the two independent results should reveal the limitation of the germanium detector techniques when the strength lies at high excitation energy.

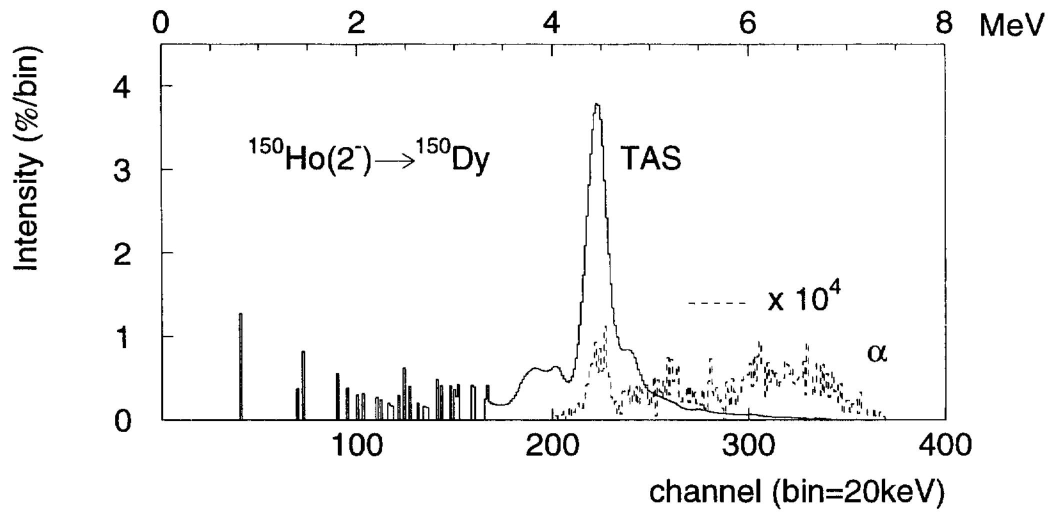

FIGURE 2. The ^{150}Ho (2^-) beta feeding followed by gamma de-excitation, measured with TAS (solid line), and by alpha emission (dashed line).

In the case of ^{150}Ho decay, β delayed alpha emission can compete with gamma de-excitation for sufficiently high excitation energy in the daughter nucleus. In order to check this possibility a third experiment was performed using both a Si ΔE-E particle telescope and a germanium detector at the same time. One limitation in the case of a TAS spectrometer is the impossibility of achieving 100% efficiency for all the gamma rays involved in the decay. The sophisticated procedure required to extract the β-feedings from the TAS raw spectra is explained in a separate contribution to this conference [3]. In Fig.2 we show the combined TAS result from the EC and β^+ decay of ^{150}Ho (solid line). An extremely sharp resonance of ~240 keV width emerges at 4.5 MeV excitation energy. β-delayed alpha emission has been observed for the first time in this nucleus. The result is included in Fig.2 (dashed line). The ratio of alpha to gamma de-excitation is 6×10^{-5}.

The CLUSTER data gave a very rich ^{150}Ho 2^- decay scheme. In a preliminary analysis we have located 900 γ-transitions de-exciting 280 levels. The derived strength is represented by the solid line in Fig.3. In the same figure we show the TAS results. The CLUSTER CUBE data clearly demonstrate the correctness of the analysis method for the TAS experiments: Both experiments give a similar shape, but the CLUSTER CUBE experiment loses sensitivity towards higher energies. The total log ft obtained with the CLUSTER CUBE up to 5.45 MeV (the highest observed level) is 4.18. The log ft obtained with the TAS in the same energy range is 3.94, which represents 74% more strength. The integrated log ft up to the Q_{EC} = 7400 keV limit (from our data) amounts to 3.84.

In a very simple-minded approach, the 2^- isomer in ^{150}Ho can be viewed as $(\pi d_{3/2}\nu f_{7/2})_{2^-}\text{-}(\pi^2)_{0^+}$. Thus, the only allowed decay is when the pair of protons

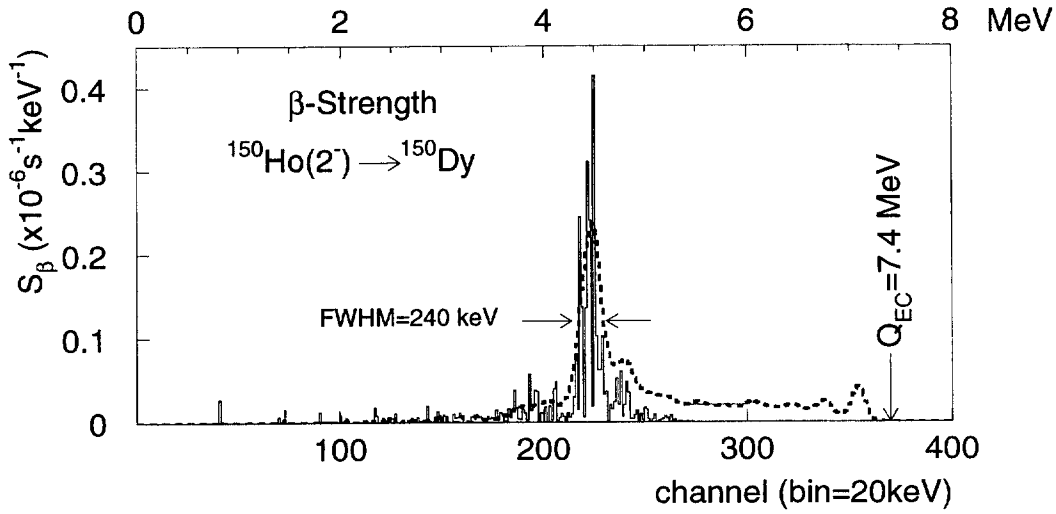

FIGURE 3. The TAS (dashed line) and CLUSTER CUBE (solid line) results for the ^{150}Ho 2^- β strength .

is in the $\pi h_{11/2}$ orbital, and the GT transition $(\pi h_{11/2})_{0^+} \rightarrow (\pi h_{11/2} \nu h_{9/2})_{1^+}$ can occur. The resulting decay will populate 4 qp states at $\approx$4 times the pairing gap energy (4-5 MeV). The very sharp resonance revealed at 4.5 MeV tells us that this picture is substantially correct, and that configuration mixing is very small here. The observed strength is only 0.15 of that derived from the extreme single particle picture where only two protons in the $\pi h_{11/2}$ orbit are considered and the $\nu h_{9/2}$ orbit is empty. Towner [4] has calculated the first order corrections to this simple picture. The predicted strength is still $\sim$30% higher than the observed strength. Now that the GT resonance has been clearly seen for the first time, more elaborated calculations should also aim to reproduce the distribution of the strength.

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