GSI-Preprint-98-44
Aug. 1998

Beta–decay of ^{103}In studied by using a total absorption spectrometer

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Abstract. The β decay of the neutron–deficient isotope ^{103}In was investigated by using total absorption γ–ray spectrometry on mass–separated sources. The measurement reveals a high–lying resonance of the β–decay strength in striking disagreement with high–resolution γ–ray data. The result is discussed in comparison with shell–model predictions.

Within the last few years, the region of nuclei near the ^{100}Sn has been subject of intense experimental and theoretical investigations ([1–3] and references therein). Although ^{100}Sn was observed by using high–energy fragmentation reactions, its detailed spectroscopy appears to be still out of experimental range. For nuclei *near* ^{100}Sn, however, both in–beam and decay spectroscopy is already feasible today.

One of the particularly interesting features of decay studies in the ^{100}Sn region is the occurrence of fast β transitions related to the Gamow–Teller (GT) transformation of a $\pi g_{9/2}$ proton into a $\nu g_{7/2}$ neutron. A measurable quantity suited for comparison with theoretical predictions is the β strength defined as:

$$B_{GT}(E) = \frac{D \cdot I(E)}{f(Q_{EC} - E) \cdot T_{1/2}}, \qquad (1)$$

where $D = 3860(18)$ s is a constant corresponding to the value of the axial vector weak interaction coupling constant g_A for the decay of the free neutron, I the β intensity, E the excitation energy in the daughter nucleus, f the statistical rate function, Q_{EC} the total energy released in electron–capture (EC) decay, and $T_{1/2}$ the β–decay half–life. The $B_{GT}(E)$ distributions, deduced from measurements of $I(E)$, Q_{EC} and $T_{1/2}$, can be compared to the calculated square of the GT transition matrix element. The quenching of the experimental GT transition rates with reference to model predictions has been a puzzle for many years. A renormalization of g_A (or of the GT operator) has been applied [2,3] in order to account for the missing GT strength in the ^{100}Sn region. This led to a consistent picture for the decays of even–even nuclei, but the dramatic reduction of the shell–model GT strength remained to be explained for the decays of non even–even nuclei (see [4] for a recent example).

We report on a re–investigation of the β decay of ^{103}In, a five–quasiparticle configuration with respect to the ^{100}Sn core. In order to deduce B_{GT} we performed a measurement of $I(E)$ by means of total absorption spectrometer (TAS), and took the values of Q_{EC} (6.05(2) MeV and $T_{1/2}$ (60(1) s) from the literature. In order to estimate the systematic uncertainties involved in the evaluation of TAS data, we performed two independent evaluations. They differ in the applied Monte–Carlo simulation codes, and in the assumptions made for the de–excitation pattern of high–lying ^{103}Cd levels. Details of this work are presented in [6].

The TAS [7], installed at the on-line mass separator at GSI, consists of a large NaI crystal (ϕ 356 $mm\times$ 356 mm) surrounding the radioactive source, two small Si detectors (ϕ 16 $mm\times$ 450 μm) above ("top") and below ("bottom") the source, and one Ge detector (ϕ 16 $mm\times$ 10 mm) placed close in the center of the NaI crystal just above the "top" detector. By demanding coincidence with signals from the Si detectors, the β^+ decay component for the nucleus of interest is selected, whereas coincidences with characteristic $K_{\alpha,\beta}$ X–rays recorded by the Ge detector can be used to select the EC mode. The total γ–ray efficiency of TAS for monoenergetic photons between 0.2 and 4.0 MeV is above 88%, and its photopeak efficiency is above 56%.

The ^{103}In isotope was produced by means of ^{50}Cr(^{58}Ni,3p2n)^{103}In fusion–evaporation reactions. The energy and intensity of the ^{58}Ni beam on the ^{50}Cr (3.6 mg/cm^2) target amounted to 285 MeV and 40–50 particle nA, respectively. After ionization in a FEBIAD–B2–C ion source [8], and mass separation the ^{103}In beam was implanted into a transport tape and moved to the center of the TAS.

In order to deduce the β–intensity $I(E)$ as a function of the excitation energy E in the daughter nucleus from an experimental TAS spectrum $S(x)$, one has to solve the equation

$$S(x) = \sum_i R_i(x) \cdot I_i, \qquad (2)$$

where I_i is the β–feeding to level i. Any column $R_i(x)$ of the response matrix, transformed from energy into experimental spectrum channels (x), represents the "level response function" of TAS to the cascade of γ rays deexciting the level i. In the case of TAS measurements of exotic nuclei one usually faces the problem that, even though some β–delayed γ rays are known from high–resolution measurements, many of them have escaped from observation in these experiments. Correspondingly, the decay schemes obtained from high–resolution data are incomplete, and hence assumptions have to be made in deducing I_i. Such assumptions may introduce ***unpredictable*** systematical uncertainties. Therefore, we decided to carry out two independent data analyses (recursive folding (RF) and peel-off (PO) methods) and to confront their results in order to estimate the systematical uncertainties (for details see [6]). The B_{GT} distributions for ^{103}In, obtained from the RF and PO methods (see Fig. 1), agree in the *gross* features, i.e. the dominant resonance around E = 3.8 MeV with a full width at half maximum of the order of 2 MeV. A closer inspection shows, however, that the B_{GT} resonance is split into two components, and that a long tail extends towards high excitation energies. Furthermore, distinct differences occur between the results obtained by the two unfolding procedures. These differences, which are interpreted as representing the systematical uncertainties involved in these procedures, concern more the shape

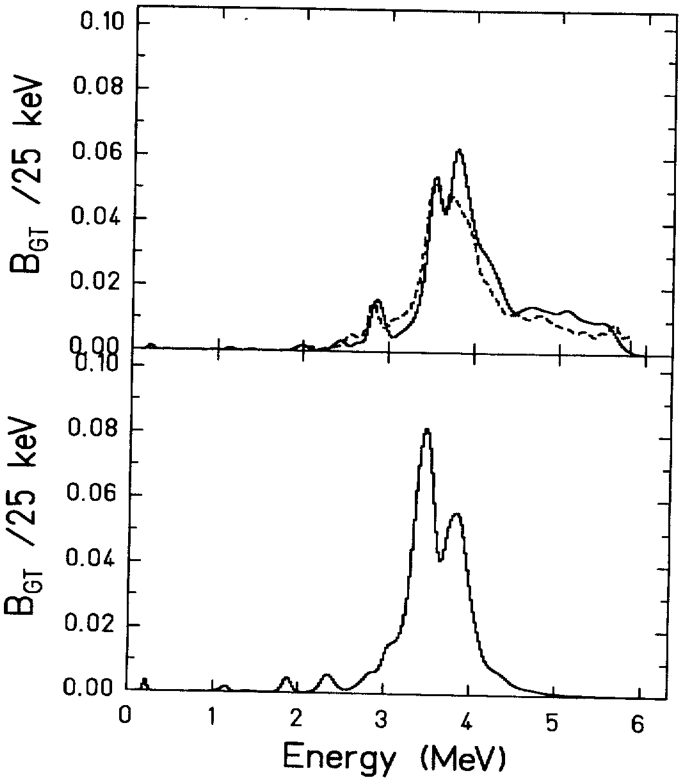

FIGURE 1. B_{GT} values for the ^{103}In decay as a function of the ^{103}Cd excitation energy. Upper panel: TAS data derived by the recursive–folding (RF) method (solid line) and the peel–off (PO) approximation (broken line); lower panel: results obtained by the shell–model calculations The shell–model B_{GT} values were divided by a factor of 5.1

than the summed B_{GT} values $\Sigma B_{GT}^{(exp)}$ of 2.54(25) and 2.40(25).

The model space and interaction we have used for the analysis of the ^{103}In GT β–decay is that denoted by SNB in [2], where it was introduced to calculate β–decay properties for nuclei near ^{100}Sn. A $^{103}\text{In} \rightarrow {}^{103}\text{Cd}$ GT-decay is calculated as $(\pi p_{1/2},g_{9/2})^{11};(\nu g_{7/2},d_{5/2})^{4} \rightarrow (\pi p_{1/2},g_{9/2})^{10};(\nu g_{7/2},d_{5/2})^{5}$. The calculated B_{GT} distribution is shown in Fig. 1 in comparison with experiment. The centroid and width of the theoretical distribution is very close to that of the experiment. The main difference in the *shape* of the distributions is that the experiment yields a high–energy tail which is not present in our calculation.

The total experimental GT strength for ^{103}In, obtained from the average of the two analysis methods is 2.47±0.25, and the total theoretical strength from the SNB calculation is 12.7. Thus, h_{exp} is 5.1±0.5. This is the first time that one has been able to extract this factor for an odd-even nucleus close to ^{100}Sn with the confidence that most of the expected strength has been detected experimentally.

These results represent an important step in the understanding of the hindrance factors for β^{+}/EC decays near ^{100}Sn. It is the first time that the *complete* GT strength has been measured for a "non even-even" nucleus so close to ^{100}Sn that a comparison with full–space shell–model calculations becomes possible. Thus, the quality of the data obtained in this work goes beyond that reached in previous experiments for ^{100}In [9], ^{103}In [4], and ^{100}Ag [5].

Acknowledgements

This work was supported in part by the Polish Committee of Scientific Research under grant KBN 2 P03B 039 13, by the European Community under Contract No. ERBFMGECT950083, by the U. S. National Science Foundation under grant 9605207, and by the Russian Fund for Basic Research and Deutsche Forschungsgemeinschaft under contract No. 436 RUS 113/201/0(R), by C.I.C.Y.T. (Spain) under project AEN96-1662, by U.S. DOE under DE–AC05–96OR22464. M.K. would like to acknowledge financial support from the Foundation for Polish Science. B.A.B. wishes to thank the Alexander von Humboldt–Foundation for support. ORNL is managed by Lockheed Martin Energy Research Corporation.

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