CONF-8403112--9

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DE86 008989

OVERLAPPING β DECAY AND RESONANCE NEUTRON SPECTROSCOPY

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Invited paper presented at the
International Symposium on
Nuclear Spectroscopy and Nuclear Interactions
Osaka University, Japan
March 21-24, 1984

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Abstract

By carrying out a detailed study of ^{87}Kr levels, we have shown that delayed neutron spectroscopy can be a viable method for studying individual levels and that a broad resonance-like structure is present in the β-strength distribution.

We have recently studied the energy levels in ^{87}Kr using two different methods.[1] The first method comprises neutron capture and transmission measurements on an enriched gas target of ^{86}Kr using neutron time-of-flight techniques. In this way 39 resonances were identified below a neutron energy of 400 keV. The second method is a decay study of 56-s ^{87}Br in which a level scheme of ^{87}Kr was established with 138 levels.

Why did we carry out such a detailed study? The first reason has to do with a debate concerning the interpretation of peaks in delayed neutron spectra. Some authors have interpreted these peaks as representing individual transitions.[2-4] Others have suggested that because of the expected high density of levels populated in β decay, these peaks are not in general representative of individual transitions but result from the summation within the detector resolution of many randomly spaced lines.[5,6]

In the case of ^{87}Kr, we made a detailed comparison of the low-energy part of the delayed neutron spectrum with our p-wave resonance data. The agreement was good, suggesting that delayed neutron spectroscopy can indeed be used to study the decay of individual levels in a relatively heavy nucleus such as ^{87}Kr. At the same time, we observed no marked selectivity in the β decay to individual levels in the unbound region of ^{87}Kr.

The second reason for studying ^{87}Kr has to do with the nature of the β-strength function, which has many applications.[7] Pronounced bumps have been reported in the β-strength functions of several nuclei.[8,9] Are they real? The Gamow-Teller matrix elements in ^{87}Kr are shown in Fig. 1. It is our conclusion that the bump at 5.3 MeV is genuine. Our conclusion is based partly on the following arguments. Those who argue against bumps in the β-strength function (ascribing them instead to inadequacies in the measurements) do so by invoking the well-known Porter-Thomas fluctuations. The current data on ^{87}Kr have been subjected to a fluctuation-type of analysis by Stefanon.[10] The method is described in Ref. [11] Stefanon finds that the 170 matrix elements in the 0-5910 keV region by themselves yield $\nu \approx 0.9$. When these matrix elements are viewed as fluctuations about the Lorentzian fits [i.e., analyzing the ME(data)/~~matrix~~ ME(fit)], he obtains $\nu \approx 1.8$. Because ν is expected to be unity, the above results at first sight seem to argue against the need for a bump. However, many weak β branches have been undoubtedly missed in our measurements. If they are taken into account, the ν value gets lowered. Therefore, the best chances of reaching $\nu = 1$, if that is indeed the aim, rests with having a bump and not otherwise.

The more than 200 matrix elements included in Fig. 1 render ^{87}Br decay one of the best studied decays throughout the periodic table. The sum of the matrix elements (=0.353) represents 0.7% of the (nearly) model independent G-T sum rule strength [given by[12] $\approx 3(N-Z)$] of 51.

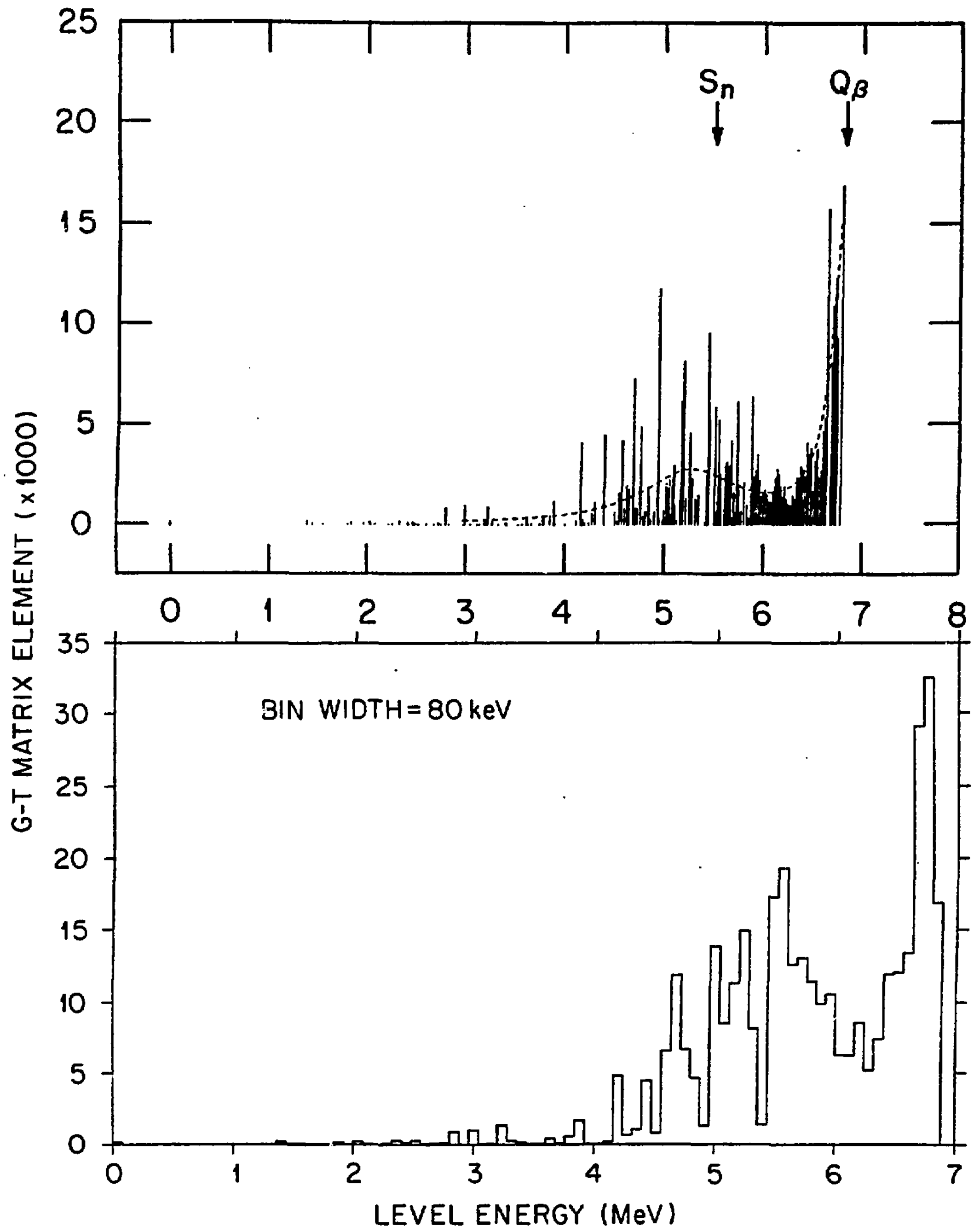

Fig. 1. Gamow-Teller matrix elements for β^- decay of ^{87}Br to levels in ^{87}Kr deduced from γ-ray and delayed neutron measurements. The Lorentzian fits (dashed line) are both to guide the eye and to argue in favor of a bump at 5.3 MeV.

Because ^{87}Kr is a very special case, it is doubtful whether we have put to rest all debates concerning either the significance of the delayed neutron spectra or the nature of the β-strength function. In general, nuclei emitting delayed neutrons cannot be reached through neutron resonance reactions because the corresponding targets are unstable. Only two other cases in the periodic table (^{137}Xe and ^{49}Ca) bear similarity to ^{87}Kr. Because the neutron-emitting levels in ^{137}Xe have relatively high spins ($5/2^+$, $7/2^+$, $9/2^+$), the overlap between β decay and resonance neutron spectroscopy (which favors low spins) in ^{137}Xe is not a priori expected to be as clean as in ^{87}Kr. In the case of ^{49}Ca, in addition to sample preparation problems, one is required to identify d-wave resonances (which are weak and more difficult to observe) over a wide (≈ 2.3 MeV) neutron-energy window. For these reasons, ^{87}Kr is unique indeed.

We thank our coauthors listed in Ref.[1] and M. Stefanon. This work was sponsored by the Division of Basic Energy Sciences, U. S. Department of Energy, and by the Swedish National Science Research Council.

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