Resonance structure of the strength functions of β^+ decay

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A resonance structure, which contradicts the statistical model, was observed in the measured level population probabilities of the β^+ decay of lutecium and iodine nuclei.

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The β-decay strength function is an important characteristic of nuclei that were removed from the β-stability band. Knowledge of its energy structure is necessary for calculation of the emission probabilities of delayed particles, the probabilities of delayed fission, the yields of different elements (including heavy and superheavy) in astronomical processes and thermonuclear explosions, prediction of the half-life of nuclei that were removed from the stability band, etc.

An analysis of the delayed proton[1] and neutron[2] spectra indicates that a resonance structure of the β-decay strength function can exist, although it must be pointed out that the data for the delayed particles cannot be interpreted unambiguously. On the other hand, the direct measurements performed by the CERN group[3] showed no evidence for the existence of an energy structure of the β^+-decay function; as a results, a statistical population of the levels in the β^+ decay was assumed.

From the microscopic viewpoint, the allowed β decay must yield a certain elementary nuclear excitation mode, a charge-exchange collective state with a moment I^+, an isospin $\tau = 1$, and an isospin projection $\mu_\tau = -1$ for β^- decay and $\mu_\tau = 1$ for β^+ decay. Calculations performed for a wide range of neutron-deficient nuclei[4] showed that this state in the β^+ decay can be below the decay energy.

This raises the basic question of whether the strength of this excitation is spread over a large energy interval or concentrated in a relatively narrow region. In other words, is the β^+ decay strength function a monotonic function or does it have a resonance nature?

We have measured the β^+-decay strength functions for a number of lutecium and iodine isotopes. The sources were obtained from the "IRIS" mass separator[5] that operated on line with the proton beam of the LIYaF synchrocyclotron. The measurements were made using a total-absorption, γ-ray spectrometer,[6] which had much better characteristics than the spectrometer used in Ref. 3. Our spectrometer had a 4π solid angle, an energy resolution of $\sim 9\%$, and an efficiency of 20% at the total-absorption peak for a 4-MeV cascade energy. An important feature of this spectrometer was that the total absorption efficiency of the γ-quantum cascade did not depend on the de-excitation of the excited states. We introduced corrections into the experimental spectra for the total absorption efficiency, for contamination of the other terms of the isobaric chain, and for the continuous distribution due to incomplete absorption

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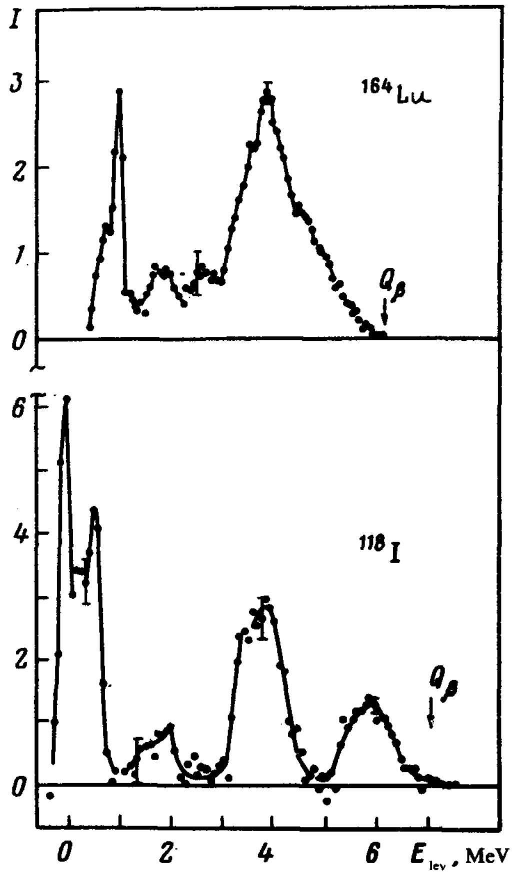

FIG. 1. Level population probabilities of daughter nuclei in the decay of ^{164}Lu and ^{118}I. The population of the ^{118}I ground state was determined from the total absorption peak of the annihilation radiation.

of the γ-quanta in the detectors. The analysis was described in detail in Ref. 6. As a result, the population probability of the levels in the β decay was determined as a function of the excitation energy, from which the β-decay strength functions can be obtained for a known decay energy (Q_β).

The most characteristic feature of the measured distributions is the well-defined maxima in the population probabilites. Figure 1 shows the population probability distributions of the levels for the ^{164}Lu and ^{118}I decay.

The ^{164}Lu nucleus has a half-life of 3.2 min and a decay energy of 6.4 MeV. There are no data for the decay scheme. We can see from our measurements that more than 60% of the decays occur in the levels with an energy of about 4 MeV. A maximum with a structure similar to that of a giant resonance with an average energy of 4.2 MeV and a width of about 1 MeV was observed in the strength function.

Two maxima with energies of 3.8 MeV ($\log ft = 5.3$) and 5.9 MeV ($\log ft = 4.4$) and a width of less than 1 MeV were observed in the ^{118}I decay ($T_{1/2} = 13.7$ min, $Q_\beta = 7.07$ MeV) at excitation energies greater than 3 MeV. We note that this isotope, which was measured in Ref. 3, showed no evidence for the existence of a resonance structure. This is apparently attributable to a deficiency of the spectrometer used in Ref. 3.

Thus, our measurements indicate the existence of maxima in the β^+-decay strength functions, whose widths correspond to the ordinary widths of the intermediate structures. The fact that these strength functions are not statistical in nature must be taken into account in all the calculations of the β decay.

In view of the obtained results, the systematic experimental studies of the resonance structure of the β-decay strength functions and a theoretical description of this structure are of interest.

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