THE BETA STRENGTH FUNCTION STRUCTURE IN β^+ DECAY OF LUTECIUM, THULIUM AND CESIUM ISOTOPES

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Abstract

The spectra of total γ-absorption in the decays of some Lutecium, Thulium and Cesium isotopes have been measured. The probabilities for level population in the decay of the isotopes have been determined. The deduced beta strength functions reveal pronounced structure. Calculations of the strength functions using the Saxon-Woods potential and the residual Gamow-Teller interaction are presented. It is shown that in β^+decay of light Thulium and Cesium isotopes the strength function comprises more than 70% of the Gamow-Teller excitations with $\mu_\tau = +1$. This result is the first direct observation of the Gamov-Teller resonance in β^+ decay of nuclei with $T_z > 0$.

1. Introduction

Beta decay of atomic nuclei is a charge-exchange process where the states with large components of charge-exchange excitations are populated most intensively. For the Gamow-Teller type of beta decay these states are the following: a proton particle - a neutron hole (in β^- decay) and a proton hole - a neutron particle (in β^+ decay) coupled into 1^+ moment. The Gamow-Teller residual interaction causes collectivization of these states, which may be considered as elementary excitations with isospin $\tau = 1$ and isospin projection $\mu_\tau = +1$ (in β^+ decay) or $\mu_\tau = -1$ (in β^- decay) 1). These states reveal in the beta strength function as maxima which energies, intensities and widths can be calculated in terms of different microscopic models.

Not long ago there dominated an alternative point of view which stated that the strength function is a smooth function of E, β -decay is not sensitive to the nature of the final states and its probability is mainly determined by the density of the final states 2). Within this approach the strength functions for β^- decay do not differ qualitatively from that for β^+ decay (except for the Gamow-Teller resonance in β^- strength function which was introduced in one version of the model) and they do not vary significantly for different nuclei.

Within the microscopic approach there is a qualitative difference between the two functions. For transitions with $\mu_\tau = -1$ two strong collective states should be observed. They are the Gamow-Teller resonance and the states of core-polarization type 3). However, in this case the Gamow-Teller resonance is above the analogue state and may not be populated in β^- decay. The situation is completely different for β^+ decay. As show calculations 4) it is typical for many nuclei that for the Gamow-Teller transitions with $\mu_\tau = +1$, the main strength is below the β^+ decay energy Q_β and so these collective states may be populated in β^+ decay. Detection of such resonant states and evaluation of the quota from the total strength of the Gamow-Teller transitions inclosed in the energy interval from zero to Q_β would be of principal interest.

Nonstatistical behaviour of the β^- strength function was shown in a number of papers. Thus, the energy structure of the β^- decay strength function was observed in the high-resolution investigations of delayed neutron spectra 5). The states of the core-polarization type were observed in the M1 γ decay of analogue states 6,7). The Gamow-Teller resonance with $\mu_\tau = -1$ was recently disco-

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vered in the (p,n) reaction on heavy nuclei 8).

Experimental data on the β^+ decay strength function are more poor. No pronounced energy structure was observed for certain nuclei in the direct measurements which were performed using the total γ ray absorption method 9). The data on the strength functions derived from delayed proton spectra are discrepant. Energy structure was not observed in the majority of cases, though a pronounced maximum is seen for some nuclei 10).

It should be noted that the available data refer to the spherical nuclei. As for the strength functions for the strongly deformed nuclei, there were no investigations on the point.

However, the knowledge of the energy structure of beta strength functions for β-decaying nuclei is important in different areas of nuclear physics. Predictions of the halflives of nuclei far from stability and calculations of the intensities and spectra of delayed particles require definite assumptions on the structure of the beta strength functions. Such information is also necessary to deduce the parameters of fission barriers for nuclei far from stability 11). In ref.12) it is pointed out that the energy structure of the strength functions of beta transitions affects strongly the results of calculations of yields of elements in astrophysical processes, in thermonuclear reactions, etc.

These are the reasons why the experimental study of beta strength functions for various nuclei (here, in the first place, are far-from-stability nuclei) is an important problem of today.

Reported in this paper are the measurements of the β^+ decay strength functions for a number of Lu, Tm and Cs isotopes. It has been found that more than 50% of the total strength of Gamow-Teller transitions falls into the measured energy interval for some of these nuclei.

2. Experimental method

The radioactive sources were produced with the help of the IRIS - facility 13), a mass-separator on-line with the 1 GeV synchrocyclotron proton beam. Tantalum targets were used to get Lutecium and Thulium isotopes, and molted Lanthanum targets for Cesium isotopes. The measurements were carried out using a γ-ray total absorption spectrometer (Fig.1).

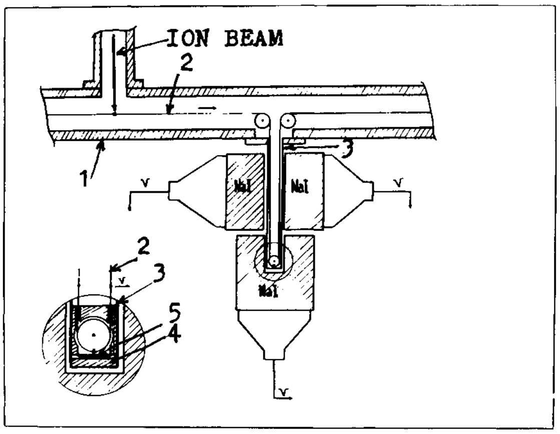

Fig.1 Schematic diagram of the γ-ray total absorption spectrometer. 1 - casing of the tape-transport mechanism, 2 - magnetic tape, 3 - casing of the vacuum inlet, 4 - plexiglass absorber, 5 - positron detector.

It consists of three NaI crystals of the following dimensions: the main one - ⌀200 mm x 200 mm (with a pit of ⌀ 40 mm x x 100 mm) and two minor crystals - ⌀200mm x x 100 mm. The signals from the crystals are summed up. A beam of mass-separator ions is transplanted on a magnetic tape and transported into the pit of the main detector. The transportation time is about 2 sec which allows to measure isotopes with the halflife down to some seconds. The plexiglass shielding of the source was used to protect the detectors from the positrons. To take into account the annihilation radiation a thin Si(Li) detector was set up in front of the source. Its efficiency depends weakly on the positron energy and makes up 20-25% of the total positron number. Simultaneous measurements of the spectra of total absorption of γ rays and the spectra of coincidences with positrons make it possible to tell between the processes of ε-capture and β^+-emission. The biggest error to the correction on β^+-emission takes place in a narrow interval of energies where the probabilities for β^+-emission and for ε-capture are of close value. In the analysis, the sum of the two processes is determined.

The spectrometer is described in detail in Ref. [14]. The main characteristics of the spectrometer are as follows.

1. The solid angle of 4π-steradian is practically available, the efficiency in the peak of the total absorption depends exponentially on the excitation energy and practically is independent on the scheme of de-excitation. The efficiency is determined experimentally with the error less than 5% and at 4 MeV it comprises ~17%.

2. The probability for 1-3 MeV γ-quanta registration is 80-90% and the registration probability for a cascade of two or more quanta is near 100%. That allows to determine the absolute intensity of the measured sources.

3. The level of the background is rather low, especially in the high-energy region which is of the greatest interest. At energies above 3.5 MeV the background is less than a pulse per 1 MeV in a second that makes it possible to measure the activities beginning from 100 decays in a second.

In handling the absorption spectra corrections are introduced for the spectrometer background, for the dead time of the measuring system, for random coincidences of the pulses from decay of different nuclei and for the admixture of some other members of isobaric chains. The contribution of continuous distribution is taken into account by simulation using several methods. This correction gives the largest uncertainty at the energies below the main maximum. Within the 10% range the probabilities for population of the main maximum and of the high-energy levels do not depend on the method the continuous distribution is taken into consideration.

Handling of the experimental spectra gives the density of the level population I(E) in the daughter nuclei. Beta strength function $S_\beta(E)$ is defined by the expression

$$S_\beta(E)=\frac{I(E)}{T_{1/2}\cdot f(Q_\beta-E)} \qquad (1)$$

where $Q_\beta-E$ is the transition energy, $T_{1/2}$ is the halflife and f is the Fermi function. Note, that when $E\rightarrow Q_\beta$, the function $f(Q_\beta-E)$ goes to zero, and expression (1) leads to overestimation of $S_\beta(E)$ in the region of energy close to Q_β because of the limited resolution of the spectrometer. Estimations show that expression (1) is valid up to the energy $E = 0.9Q_\beta$.

3. Experimental data

Lutecium isotopes. The level population probabilities in beta decay of 11 Lutecium isotopes with A = 173-163 have been measured. The decays of the A = 172-169 long lived isotopes are studied carefully and it is stated that our data are in good agreement with the results derived from the balance of the decay schemes [15], which is one more evidence in favour of the accepted method. Complete data on the level population in beta decay of other isotopes under investigation are obtained for the first time. There can be distiguished several maxima in the spectra as a rule. Presented in Table 1 are the energies, population percentage and corresponding values of the log ft for some resonances. Figure 2 presents an example of the probability curve for level population in the decay of the ^{166}Lu isotope (the upper curve).

From previous decay studies it could be derived only that the 2234 keV level is populated intensively (log ft = 4.9). Our results confirm these data. The main maximum in the population probability is at 2.2 MeV, the intensity of population is 70% per a decay and log ft = 4.6. However, it is actually only 50% of the whole strength in the excitation energy region up to 5 MeV. A number of other peaks with halfwidths slightly wider than the instrumental one are rather clearly seen in the spectrum. The experimental strength function is shown in the middle of Fig.1. Similar spectra are observed for the rest of Lutecium isotopes $^{16)}$, though for some of them peaks are resolved worse.

Table 1
Intensities of the level population in the beta decay of Lu isotopes

A	E, MeV	I,%	logft	A	E, MeV	I,%	logft
172	1.2	8	8.3	166	0.7	2	6.2
	1.6	10	8.0		1.6	6	5.6
	1.8	8	7.8		2.2	70	4.6
	2.05	64	6.7		2.9	16	5.1
	2.2	9	7.3		3.6	3.3	5.4
	2.5	0.4	7.8		4.1	3.7	5.0
171	0.84	92	6.5		4.7	1.0	5.1
	1.35	0.3	7.5		5.1	0.2	5.4
170	1.45	7	8.3	165	<1	~6	-
	2.15	41	7.6		1.3	9	5.8
	2.4				1.7	22	5.4
	3.0	45	5.9		2.06	48	4.9
169	0.6	6.5	8.0		2.8	12	5.0
	0.94	28	7.2		3.2	3	5.3
	1.4	32	6.7		3.6	0.6	5.4
	1.65	22	6.7	164	1.6	20	5.9
	1.9	9	6.7		2.2	6	6.2
	2.1	2	6.9		3.1	12	5.5
	2.3	0.3	7.0		3.8	45	4.7
168m	1.3	40	5.2		4.5	7	5.1
	2.3	54	4.7		5.0	7	4.9
	2.9	2	6.0		5.5	2.4	5.0
	3.7	4	5.0		6.0	0.7	4.8
167	0.15	31	6.2	163	<1.8	25	-
	1.25	5	6.5		2.3	52	4.4
	1.9	47	5.1		3.1	16	4.7
	2.2	13	5.5		3.6	5	4.9
	2.4	4	5.6		4.1	1.5	4.9
	2.8	0.2	5.0				

<u>Thulium isotopes</u>. The probabilities for level population in beta decay of A = = 163-157 Thulium isotopes have been determined. On the whole the picture is similar to that of Lutecium. In all cases there emerge pronounced maxima in the population probabilities, often with an unresolved structure which can be conventionally decomposed. The results of such decomposition

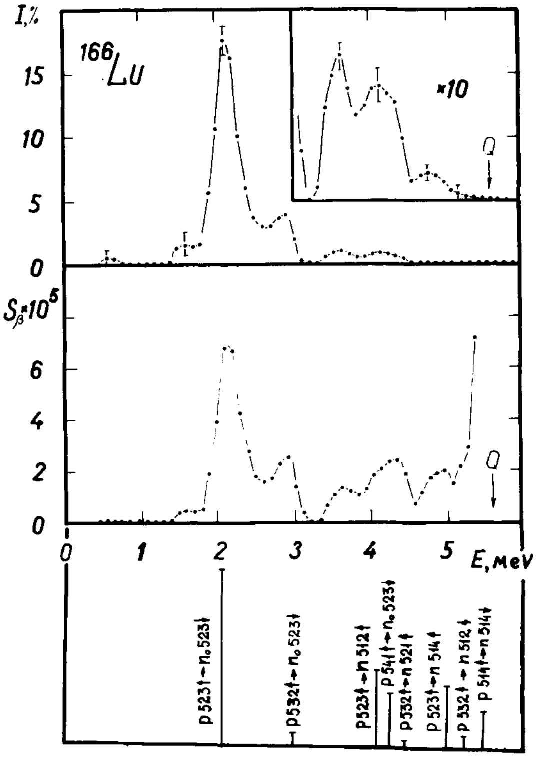

Fig.2 Probabilities of the level population and the strength function for ^{166}Lu.

are presented in Table 2. Quite natural that these results are only estimations for the level population in the region of corresponding energies.

Figure 3 presents the level population probabilities and the strength function for ^{159}Tm, beta decay of which was studied rather poorly before. The halflife of ^{159}Tm is found to be 9.15 (17) min. and the decay energy Q_β = 3.85 MeV is determined as the boundary of the total absorption spectrum. The main maximum of the strength function corresponds to the energy of approximately 2.5 MeV and it is fed nearly in 60% of decays.

It should be noted that in the region of the main maximum and at higher energies the uncertainty of the strength function, connected with an uncertainty of the Q-value, in many cases exceeds considerably the proper experimental errors which are present in the population data. Thus the change of Q_β-value for ^{159}Tm by 0.2 MeV brings about distortions of the strength function (in the region of the main maximum) by 20%, whereas the pure experimental errors do not exceed 10%.

Table 2
Intensities of the level population in the beta decay of Tm isotopes

A	E, MeV	I, %	log ft
157	0.1	12	6.0
	0.7	12	5.7
	1.5	4	5.8
	2.2	24	4.7
	2.6	34	4.5
	3.0	7	4.9
	3.4	5	4.7
	4.0	2	4.2
158	0.1	20	6.6
	0.5	5	7.0
	0.9	4	7.0
	1.4	12	6.3
	2.3	2	6.8
	3.1	10	5.7
	3.7	7	5.6
	4.1	2	6.0
	4.5	16	4.9
	5.0	16	4.6
	5.8	4	4.5
	6.1	2	4.3
159	0.3	31	5.6
	0.8	7	6.1
	1.1-1.8	6	-
	2.1	11	5.2
	2.5	30	4.6
	2.8	12	4.7
	3.3	3	4.8
160	1.6	18	6.2
	2.2	12	6.1
	3.0	18	5.6
	3.8	20	5.2
	4.1	17	5.1
	4.7	7	5.2
	5.0	8	4.8
161	0.3	22	6.0
	0.5	5	6.6
	0.9	6	6.2
	1.7	24	5.9
	2.0	31	4.9
	2.6	12	4.7
162	0.1	4	7.4
	1.6	10	6.4
	2.0-3.0	32	-
	3.5	50	4.8
	4.3	4	5.1
163	0.4	15	6.3
	0.6	11	6.3
	0.8-1.1	6	
	1.3	12	5.8
	1.6	24	5.3
	1.8	21	5.0
	2.1	2	5.4

Even when the decay schemes are constructed, from their balance one often determines essentially incorrect level population and beta decay strength function. For example, in the decay scheme of ^{158}Tm $^{15)}$ all 100% of decays go to the levels lower than 3 MeV, meanwhile it is seen from Table 2 that more than 50% of decays populate the levels of higher energies, and that these decays contribute to the strength function most substantially. The level population in beta decay of ^{160}Tm and ^{162}Tm given by $^{15)}$ do not correspond to our experimental data either. Detailed information on the strength functions of beta decay of Thulium isotopes is presented in Ref. $^{17)}$.

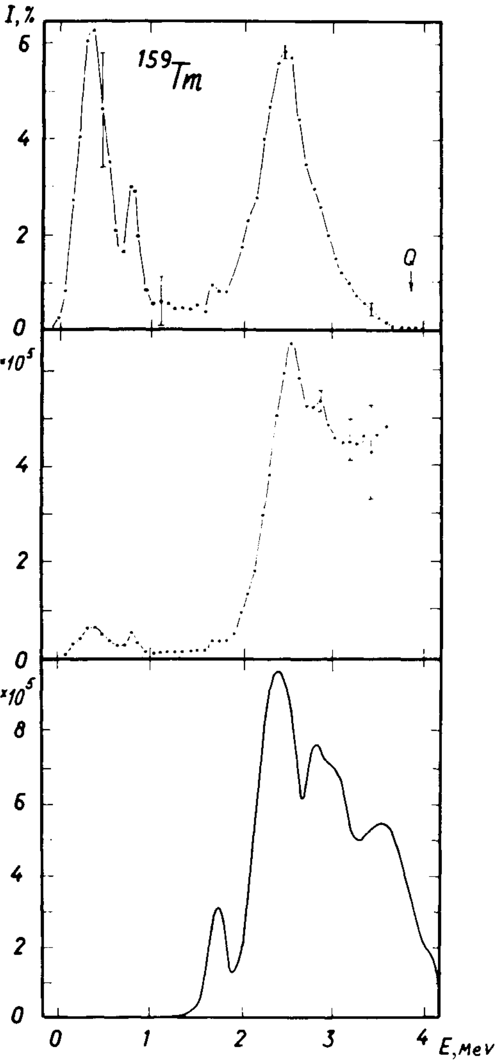

Fig.3 Probabilities of the level population and the strength function for ^{159}Tm.

Cesium isotopes. The total absorption spectra for the A = 128-119 Cesium isotopes have been measured. These nuclei are treated sometimes in terms of spherical and sometimes in terms of deformed nuclear models, so there is a possibility to compare the experimental values of the strength functions with different predictions. Ground states of even Cesium isotopes have $I^\pi = 1^+$ and the decay proceeds mainly to the ground and first excited levels of the daughter xenon isotopes. However, when the decay energy is over 5 MeV (A = 122, 124), a considerable population of the 3-5 MeV levels takes place contributing substantially to the beta strength function. The main maximum is observed at E = 4-5 MeV. For odd Cesium isotopes strong transitions are also observed onto the ground and the neighbouring states, however the maximum of the strength function is at E = 3-4 MeV.

Figure 4 presents the population probabilities and the strength function of the ^{123}Cs beta decay. In spite of 56% of transitions to the ground or near-to-ground states of ^{123}Xe (E< 50 keV) with log =5.3, the main contribution of the strength function is due to the transitions onto the 3-3.5 MeV levels. The maximum with the mean energy of 3.3 MeV, the halfwidth of 0.5 MeV and the log ft value of 4.0 is observed in the strength function in this case.

The analysis of the data for the other measured Cesium isotopes is on progress.

4. Calculations and discussion

Evidently seen in the figures are the pronounced peaks both in the population probabilities and in the beta decay strength functions. Similar pictures are observed for nearly all the isotopes we have investigated, though the shape and positions of maxima are different even for the neighbour isotopes. The strength functions are of the resonant character. Clear, that the statistical theory of beta decay based on the structureless assumptions concerning the strength function is not able to describe beta strength function behaviour properly.

In this work we have performed calculations of the beta strength functions on the basis of the microscopic description of the Gamow-Teller excitations using the Saxon-Woods potential and the residual interaction $H_{GT}=G_{GT}(\tau_1\tau_2)(\sigma_1\sigma_2)$. For the Lutecium isotopes the calculations in the Tamm-Dankov approximation are carried out. The comparison of the calculations with the experiment shows that the method describes the behaviour of the strength function fairly well.

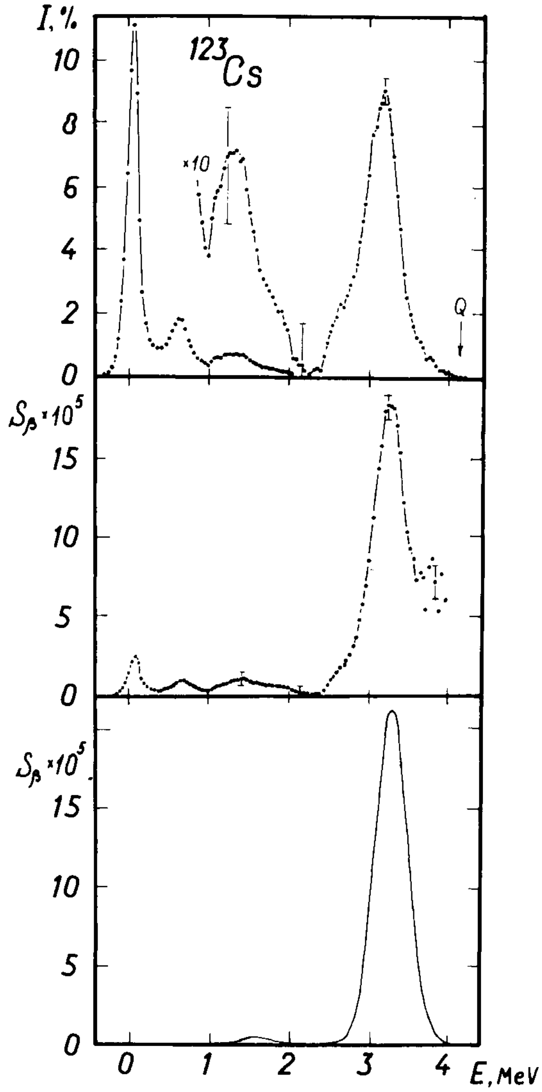

Fig.4 Probabilities of the level population and the strength function for ^{123}Cs.

In the bottom of Fig.2 the results of the calculations for the ^{166}Lu strength function are presented. It is obvious that the calculations make it possible to interpret the structure of the strength functions linking the maxima of the strength functions with the excitations of neutron particle-proton hole type. The main maximum corresponds to the $p[523]\uparrow \rightarrow n[523]\downarrow$ transition onto the two-quasuparticle state $p[404]\downarrow + p[523]\uparrow$, but not to the $p[514]\uparrow \rightarrow n[514]\downarrow$ as given by $^{18)}$. The calculations in this approximation, however, do not describe the transition probabilities properly, since the interlinking of the

$\mu_\tau = +1$ and $\mu_\tau = -1$ charge exchange modes of excitations is not taken into account.

To include this effect, the random phase approximation (RPA) has been used in the calculations of the strength functions for beta decay of Thulium isotopes. The energies and the wave functions of the single particle states are treated in the calculations as the solutions of the Schrödinger equation for the deformed Saxon-Woods potential. The parameters for the one-particle potential and for the deformation parameters are chosen from the data of Refs. 19) and 20), respectively. The constant of the Gamow-Teller interaction is assumed to be $G_{GT} = 50/A$ MeV. The derivation of the equations is given in Ref. 17). Solutions of the secular equations describe two branches of excitations with $\mu_\tau = +1$ and $\mu_\tau = -1$. The reduced probabilities of the Gamow-Teller transitions (B_{GT}) are related 1) with the ft-values as

$$ft \cdot B'_{GT} = \frac{2\pi^3 \hbar^7 \ln 2}{g_V^2 m_e^5 c^4} = 6250\,\mathrm{sec}. \qquad (2)$$

For $k_{i,f} \neq 1/2$

$$B'_{GT} = B_{GT}/(g_V^2/4\pi) = \frac{G_A^2}{g_V^2} \langle I_i k_i 1\, k_f - k_i | I_f k \rangle^2 |M|^2 \qquad (3)$$

where

$M = \langle k_f | \beta | k_i \rangle$ is the matrix element of the beta decay, $G_A = \gamma g_A$. The factor γ is responsible for the renormalization of the nuclear spin current 21).

According to the calculations, the main strength of excitations with $\mu_\tau = -1$ for rare earth elements is to be found in the 17-20 MeV energy region, the sum $\Sigma |M|^2$ being equal to 30-40. As for $\mu_\tau = +1$ excitations, the main strength is to be located in the interval of energies 2-5 MeV, the sum $\Sigma |M|^2$ being equal to 1-5. The β^+ strength function is of a giant resonance character with the width of 1-1.5 MeV.

In the bottom, Fig.3 presents the strength function calculated according to the formula

$$S_\beta(E) = \frac{\sum_n B'_n \, \eta(E_n)}{6250\,\mathrm{sec}}, \qquad (4)$$

where $\eta(E_n)$ is the Gaussian distribution with the maximum at E_n and the halfwidth of $0.15E_n$ which somewhat exceeds the experimental resolution. It is seen that the calculation describes the shape of the experimental strength function for ^{159}Tm beta decay good enough. The same quality of description of experimental strength functions is typical for the rest of Thulium isotopes.

Comparison of the experiment with the theory allows to estimate the value of the coefficient for renormalization of the nuclear spin current. The results for Thulium isotopes are presented in Table 3. In the second column of the Table is the sum of the reduced probabilities (B'_{GT}) deduced from the data of Table 2. The third column is the sum of the squares of the transition matrix elements taken from the theory within the same energy interval. The ratio of G_A/g_V obtained using the second and the third columns is given in the fourth column. The average value of the G_A/g_V ratio equals to 0.63 which is in excellent agreement with the 0.69 given by 21). The fifth column of the Table presents the theoretical estimate of the quota of the total strength of the Gamow-Teller transitions which belongs to the excitation energy interval from zero to Q_β.

Table 3

A comparison of the experimental strength of Gamow-Teller transitions with the experiment for Tm isotopes

A	$\Sigma B'_{exp}$	$S = \Sigma \|M\|^2_{th}$	G_A/g_V	$\frac{S(E<Q)}{S_{tot}}$,%
163	0.13	0.22	0.77	21
162	0.15	0.60	0.50	49
161	0.22	0.53	0.64	25
159	0.43	1.24	0.59	82
158	0.80	2.37	0.58	96
157	0.94	2.03	0.68	91

It is evident that the main strength of transitions for $A \leq 159$ Tm isotopes is found in the energy interval below the Q_β value. For example, experimental strength function for ^{157}Tm beta decay should conquer 70-90% of the total strength of the Gamow-Teller transitions. The structure in the strength functions may be interpreted, therefore, as a direct experimental observation of the Gamow-Teller resonance in β^+ decay (μ_τ = +1) of $T_z > 0$ nuclei.

Experimental data on Cesium confirm the predictions of 4) concerning the existence of low-energy maximum in beta decay strength function for $A \geqslant 119$ isotopes. RPA calculations supposing Cs nuclei to be deformed describe the form of the beta strength functions quite well. The lower part of Fig.4 presents the strength function calculated for ^{123}Cs beta decay. Deformation parameters $\beta_{20} = 0.25$, $\beta_{40} = 0.02$ and $p[420]\uparrow$ ground state configuration for ^{123}Cs nuclei are assumed. A very good agreement of the theory with the experiment is seen in this case too. The main maximum in the beta strength function with the width of about 0.5 MeV is due to $p[404]\uparrow \rightarrow n[404]\downarrow$ transition. The strength function in the zero to Q_β energy interval comprises about 80% of the total sum of the Gamow-Teller excitations. So this is one more experimental observation of the Gamow-Teller resonance in β^+ decay of $T_z > 0$ nuclei.

References

1) A.Bohr, B.R.Mottelson, Nuclear Structure, v.II, edited W.A.Benjamin, Inc. New York, Amsterdam (1974).

2) K.Takahashi, M.Yamada, Progr.Theor. Phys., 41 (1969) 1470.

3) Yu.V.Naumov, Izv.Akad.Nauk SSSR, Ser. Fiz., 39 (1975) 1645.

4) A.A.Bykov and Yu.V.Naumov, Izv.Akad. Nauk SSSR, Ser.Fiz., 42 (1978) 1911.

5) K.L.Kratz et al., Nucl.Phys., A317 (1979) 335.

6) C.Gaarde et al., Nucl.Phys., A143 (1970) 487.

7) Yu.V.Naumov et al., Elem.Chast.Atom. Yad. (USSR), 9 (1978) 1282.

8) D.J.Horen et al., Phys.Lett., 95B (1980) 27.

9) P.G.Hansen, Adv.Nucl.Phys., 7 (1973) 159.

10) E.Roeckl et al., Z.Phys., A294 (1980) 221.

11) I.N.Izossimov, Yu.V.Naumov, Izv.Akad. Nauk SSSR, Ser.Fiz., 42 (1978) 2248.

12) H.V.Klapdor, Phys.Lett., 65B (1976) 35.

13) E.Ye.Berlovich et al., Izv.Akad.Nauk SSSR, Ser.Fiz., 40 (1979) 2036.

14) A.A.Bykov et al., Izv.Akad.Nauk SSSR, Ser.Fiz., 44 (1980) 918.

15) C.M.Lederer and V.S.Shirley, Table of Isotopes, 7th ed. (1978) New York.

16) A.A.Bykov et al., Izv.Akad.Nauk SSSR, Ser.Fiz., 45 (1981) N5.

17) A.A.Bykov et al., Preprint LNPI-647, Leningrad (1981).

18) E.P.Grigoryev, V.G.Solovyov, "Structure of even deformed nuclei", ed.Nauka (1974) Moscow.

19) V.A.Gareev et al., Elem.Chast.Atom. Yad. (USSR), 4 (1973) 357.

20) I.Ragnarsson et al., Nucl.Phys., A233 (1974) 329.

21) W.Knupper et al., Phys.Lett., 95B (1980) 349.

DISCUSSION

P.G. Hansen: Maybe a few words can clarify the situation. The so-called "resonances" discussed here are not collective; they are states of two-particle nature and have as far as I could see from your numbers something like 1/6'th of the single-particle strength. This agrees well with the usual spin-isospin reduction of 1/8'th for the GT matrix elements (see Żylicz et al., Lysekil Conf. 1966). The onset of the strength at 2 MeV corresponds simply to the pairing gap 2Δ.

C.-O. Wene: Let me first congratulate you for those beautiful spectra. I do not think that the systematically occurring resonant-like structures in your S_β can be explained by fluctuations, especially as they seem to be well correlated with calculated states. Have you been able to make direct comparisons with the earlier CERN data for individual nuclei?

G. Alkhazov: We have performed a conparison of our measurements for ^{118}I (G.D. Alkhazov et al., Pis'ma Zh.Eksp.Teor.Fiz. No. 1, 68-70 (1980)) with the old CERN measurements. In our data a very pronounced structure is seen. In the CERN data this structure is also seen; however, it seems to be much less developed. We suppose that this difference in the experimental results is due to better characteristics of our spectrometer.

J.C. Hardy: It is perhaps worth noting that there is no essential disagreement between the results and the delayed proton data, for example. Here you observe most structure at low energies, either below the pairing gap where "statistical" behaviour is not expected, or just above it, where the level density is still low. Beyond that, there is little difference in the appearance of S_β between your results and the "strength function" I showed for ^{69}As. Where we differ is in our analysis. You choose to investigate the detailed anatomy of S_β; I am content with its average behaviour. Actually the "Gross theory" would, I think, do very well in explaining the trends of your data just as it did.

C. Gaarde: Is the measurement giving on an absolute scale the g_A/g_V? Is it not only a model dependent quantity you are quoting?

G. Alkhazov: The ratio of g_A/g_V is obtained from a comparison of the calculated β-strength function with the absolute values of the strength function measured in the experiment. Of course, the deduced value of g_A/g_V is subject to some influence of the approximations involved in the calculations.

K.K. Seth: I am somewhat confused about your claim that you see 80% of the GT strength expected theoretically. As you probably know, in recent (p,n) experiments at Indiana at medium energies it has been clearly demonstrated that only $\sim$ 30% of the GT sum rule strength is observed below say 10 MeV. Bohr and Mottelson, among others have recently written papers on how the missing strength is most likely sapped by the (3,3) resonance 300 MeV away. Considering all this how can you claim seeing 80% in your experiments? It is 80% of what?

G. Alkhazov: Our results are in good agreement with the GT strength function reduction at low energies you said about. This reduction is taken into account in the calculations of the present work by the factor γ. When we claim that we observe about 80% of the GT strength in β^+ decay we mean that we see 80% from the low energy part of the GT strength function (below say 30 MeV). This conclusion is drawn on the basis of the calculated beta strength function and from the good agreement of the calculated strength function with the experimental one at $E < Q$.