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ON PECULIARITIES OF THE CASCADE γ-DECAY OF HEAVY NUCLEI

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The investigation of two-quanta cascades following the thermal neutron capture in A=163÷183 /1-5/ region reveals that one can distinguish and study a considerable part of the primary γ-intensity, for instance, from 28% in ^{163}Dy to 67% in ^{179}Hf. It has been found that $I^{E}_{\gamma\gamma}$ (the sum of intensity of cascade transitions populated a final state f) in most cases exceeds the calculated intensity $I^{T}_{\gamma\gamma}$. The intensity sum $I^{T}_{\gamma\gamma}$ was calculated according to the modern statistical theory. As a rule, this excess is a few time larger than small statistical fluctuations of $I^{E}_{\gamma\gamma}$ or some calculation inaccuracy of $I^{T}_{\gamma\gamma}$.

The indicated differences between $I^{E}_{\gamma\gamma}$ and $I^{T}_{\gamma\gamma}$ we have tried to connect with some physical properties of investigated rare-earth nuclei. It is necessary to take into account that two-quanta cascade initial states are found in the range of 4 S - maximum of the neutron strength function, i.a. the one-quasiparticle neutron components may have a significant part of a compound-state wave function. The final states for the investigated cascades have simple one-quasiparticle structure too.

It is known from theoretical calculations (see, for instance, /6/) that the reduced neutron width Γ^{o}_{n} of even-even deformed nuclei resonance and matrix element square $M_{\lambda g}$ (E1, $I^{\pi}_{\lambda} \rightarrow K^{\pi}_{g}$) of the primary E1-transition from a resonance to a one-quasiparticle low-lying state are defined by the same value of one-quasiparticle component of the resonance wave function. According to /6/ the mentioned above aspect provides the correlation of Γ^{o}_{n} and partial widths $\Gamma_{\lambda g}$ of primary γ-transitions. As $M_{\lambda g}$ also contents more complex components of the resonance wave function, the Γ^{o}_{n} and $\Gamma_{\lambda g}$ correlation may be observed /6/ for a part of primary γ-transitions only. The direct observation of such a correlation in nuclei of 4 S - maximum neutron strength function is more difficult in comparison with nuclei in 3S or 2P - region because of a nucleus deformation. In deformed nuclei, the one-quasiparticle state strength is fragmented to some levels. As the total intensity of all two-quanta cascades is determined by the sum of primary γ-transitions partial widths, the sufficiently great part of one-quasiparticle state strength must be concentrated in $I^{E}_{\gamma\gamma}$. This concentration provides a decrease of the Porter-Thomas fluctuations of partial widths and ensures a possibility to study a correlation of Γ^{o}_{n} and $\Gamma_{\lambda g}$.

Unfortunately, the cascade intensity of six investigated at present even-odd nuclei is measured for the thermal neutron capture only. There are no experimental data on a resonance capture. Moreover, $I^{E}_{\gamma\gamma}$ is determined not by absolute values of the widths $\Gamma_{\lambda g}$, but by their ratio to a total radiative width.

The Γ^{o}_{n} and $\Gamma_{\lambda g}$ correlation may be revealed taking into account several simple assuptions. So one may refer the ratio $\Gamma^{o}_{n} / \langle \Gamma^{o}_{n} \rangle$, as a criterion of one-quasiparticle mode of a compound state. $\Gamma^{o}_{n} = \sum_i \Gamma^{o}_{ni} \sigma_i / \sum_i \sigma_i$ is obtained by weighing the contribution of these resonance widths i which determined the thermal neutron cross-section σ_i. The $R_{\gamma\gamma} = \sum_f I^{E}_{\gamma\gamma} / \sum_f I^{T}_{\gamma\gamma}$ value can be used as an estimation of non-statistical γ-decay properties. Then it is necessary not only to calculate $I_{\gamma\gamma}$ according to the same number of theoretical assumption, but to consider the individual properties of the low-lying ($E_f \lesssim 1$ MeV) state decay as well.

One may suppose that for the correlated widths the following condition is carried out:

$$\langle M^2_{\lambda g} \rangle = a + b \Gamma^{o}_{n} / \langle \Gamma^{o}_{n} \rangle . \quad (1)$$

Taking into consideration the correlated γ-transitions defining mainly the two-quanta cascade intensity, and non-correlated ones formating all other cascades, one obtains the ratio of the two-quanta cascade intensity with correlation to the intensity without it in the following form:

$$R = \frac{1 + k\alpha \Gamma^{o}_{n} / \langle \Gamma^{o}_{n} \rangle}{1 + k \cdot \Gamma^{o}_{n} / \langle \Gamma^{o}_{n} \rangle} . \quad (2)$$

The comparison between experimentally measured $R_{\gamma\gamma}$ and the expression (2) is shown in fig. 1. The good fitting of experimental data has been obtained by the following value of the parameters K= 0.8 and α= 2. These values do not contradict to the accepted assumptions.

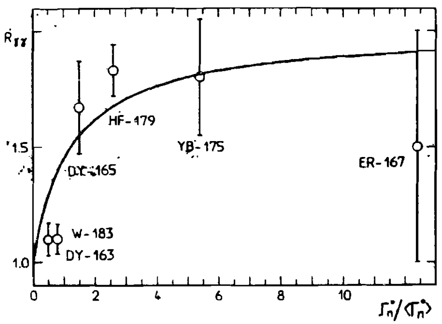

Fig. 1. The dependence of ratio $\sum I^{E}_{\gamma\gamma} / \sum I^{T}_{\gamma\gamma}$ on the $\Gamma^{o}_{n} / \langle \Gamma^{o}_{n} \rangle$ for even-odd nuclei.

Fig.2 presents the sum of absolute intensities of all strong cascades observed in ^{179}Hf /4/ as a function of a primary transition energy. Some deductions of the primary transition energy range where the Γ^{o}_{n}, $\Gamma_{\lambda g}$ correlation is to be expected gives fig.2. Intensified, in comparison with the theoretical predictions, groups of cascades ("sticks" in histogram) have the intermediate level energy values near to the calculated positions of one-quasiparticle states of a deformed Saxon-Woods potential /7/. The same dependence was observed earlier in ^{175}Yb /2/.

The theoretical analysis predicts /6/ the possible Γ^{o}_{n} and $\Gamma_{\lambda g}$ correlation in the case when the primary transition excites the state with a large one-quasiparticle component of the wave function.

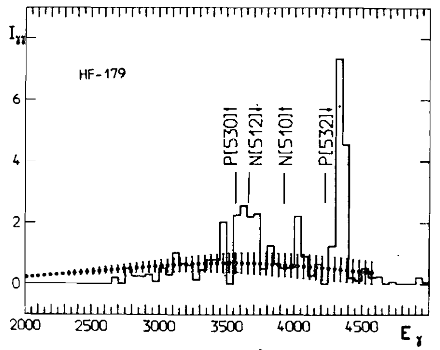

Fig. 2. $I_{\gamma\gamma}$ dependence on the primary transition energy of ^{179}Hf. Histogram - experiment, points - widths calculation with the Porter-Thomas fluctuation. Lines - calculated positions of one-quasiparticle states K/Nn$_z\Lambda$ /.

The presence of strong cascade groups exciting several dozens /4/ of intermediate states points to the existence of the compound state γ-decay channels. This effect characterizes a large number of nuclei in the region of 4S - maximum neutron strength function. The mentioned effect was revealed earlier /8/ while analyzing the low-lying state populated fluctuations at the neutron resonance capture.

Thus it should be noted that the cascade γ-decay of the deformed nuclei is characterized by the existence of strong cascade groups (γ-decay channels). In even-odd compound nuclei this enhancement was observed for resonances with the widths above the mean value. For resonances with low value of Γ^{o}_{n} the two-quanta cascade intensity distribution corresponds to the statistical theory calculation.

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Бонева С.Т. и др. E3-87-537
Особенности каскадного гамма-распада тяжелых ядер

Сопоставление измеренных и рассчитанных по статистической теории сумм интенсивностей двухквантовых каскадов в компаунд-ядрах $163 \le A \le 183$ указывает на зависимость интенсивности каскада от структуры его исходного и промежуточного уровней. Выявлена зависимость сумм интенсивностей двухквантовых каскадов от Γ_n^o компаунд-состояний четно-четных ядер-мишеней редкоземельной области. В ядрах ^{175}Yb и ^{179}Hf найдено значительное увеличение интенсивности двухквантовых каскадов при энергии их промежуточного уровня в районе расчетного положения одноквазичастичных состояний деформированного потенциала Саксона-Вудса.

Работа выполнена в Лаборатории нейтронной физики ОИЯИ.

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Boneva S.T. et al. E3-87-537
On Peculiarities of the Cascade γ-Decay of Heavy Nuclei

A comparison of measured two-quanta cascade intensities of compound state de-excitation and statistical theory calculations have been performed. In the mass number region $163 \le A \le 183$ a dependence of cascade intensity on the level structure of the initial and intermediate cascade state has been indicated.

The investigation has been performed at the Laboratory of Neutron Physics, JINR.

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