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EXPERIMENTS ON THE COMPETITIVE DOUBLE-GAMMA DECAY

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Double-gamma (gg) decay of an excited quantum state is an electromagnetic decay process of second order in the coupling constant. It represents the emission of two photons in a single quantum transition instead of one. Their total energy corresponds to the transition energy and their energy distributions are dictated by the available phase space. The process of gg-decay is equivalent to the double-beta decay of weak interaction and represents its electromagnetic analogon. Both second-order processes of the electroweak interaction have first been discussed by Maria Goeppert-Mayer [1] some 90 years ago. In particular the neutrino-less double-beta (0nbb) decay has lately received a great deal of attention because of its sensitivity to the possible Majorana character of the neutrino and to the neutrino mass, both, representing two of the most outstanding contemporary problems of particle physics. Given a future measurement of the 0nbb-decay transition rate, the determination of the neutrino mass requires a reliable prediction of the corresponding nuclear matrix element. Nuclear models that claim predictive power for electroweak second-order decay processes must be expected to correctly predict gg-decay reactions and should be tested against corresponding data.

Double-gamma-decay processes in nuclei [2] have been observed previously in peculiar situations, only, where the first-order process, i.e., decay by a single-gamma ray transition, is forbidden. This is the case for J^p = 0+ to 0+ transitions due to the strict conservation of the finite helicity of the photon. For more than 30 years, nuclear spectroscopists have searched for signals of gg-decay processes in the general situation where the gg-decay competes with an allowed single-gamma decay, up to recently without success.

We will report on our discovery [3] of the Competitive Double-Gamma (gg/g) Decay process of an excited nuclear state and on our measurements of its decay rate and its multipole contributions from the measured decay branching ratio and its angular distribution. We have studied the electromagnetic decay of the T1/2 = 2.5 min., 11/2- isomer of the nuclide 137Ba at 662 keV excitation energy to its 3/2+ ground state. The 662 keV gg/g-decay branch amounts to 2 x 10-6 resulting in a partial halflife of more than 2 years and it is dominated by M2-E2 cascades with substantial E3-M1 contributions. The data will be presented. This observation was facilitated by the combination of excellent time resolution and considerable energy resolution of recently emerging LaBr3:Ce gamma-ray detectors that we have used for our measurements. The possible development of this kind of experiments will be discussed.

[1] M. Göppert, Naturwissenschaften 17, 932(1929); M. Göppert-Mayer, Ann. Phys. (Leipzig) 9, 273 (1931).
[2] J. Kramp et al., Nucl. Phys. A 474, 412 (1987).
[3] C. Walz, H. Scheit, N. Pietralla, T. Aumann, R. Lefol, V.Yu. Ponomarev, Nature 526, 406 (2015).

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