

LIFETIME MEASUREMENTS
OF SHORT LIVED STATES IN $^{66}\text{Ge}^*$

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Lifetimes of high-spin states in ^{66}Ge have been measured using Doppler shift attenuation technique with the GASP and RFD setup. The ^{66}Ge nucleus was populated in the $^{40}\text{Ca}(^{32}\text{S}, \alpha 2p)$ reaction at beam energy of 95 MeV. The transition quadrupole moment, Q_t , of the negative parity band in this nucleus has been determined to be approx. 0.9 ± 0.1 eb.

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1. Introduction

The ^{66}Ge nucleus lies close to the $N = Z$ line, between doubly magic ^{56}Ni and strongly deformed ^{76}Sr isotopes. The coexistence of the prolate and oblate shapes is a typical phenomenon in the nuclei with mass $A \approx 70$. Here, the number of active nucleons is large enough to create a coherent motion but, on the other hand, this collectivity can still be tracked to the single particle degrees of freedom. Excited states lifetime measurements provide information on the nuclear deformation and the properties of collective structures, variety of which occurs in this region of the nuclear chart. The measurements, however, are quite difficult to perform and relevant data on electromagnetic properties of such bands at high spin are still unavailable.

2. Experimental setup

In the present experiment, ^{66}Ge nucleus was populated via the $2p1\alpha$ reaction channel. A 95-MeV ^{32}S pulsed beam was delivered by the Tandem XTU accelerator at LNL INFN and impinged on a self-supporting ^{40}Ca target which was 0.8 mg/cm^2 thick. Evaporation residues were detected by the segmented Recoil Filter Detector (RFD) in coincidence with γ rays measured with the GASP germanium detector array. The trigger condition for collecting events in the various evaporation channels required at least two γ rays and recoiling nucleus in prompt coincidence.

The RFD [1] detector is a set of heavy ion detectors. Each segment provides the time of flight with respect to the beam pulse reference signal and the direction of each detected evaporation residuum. In these way, the recoil velocity vector could be determined and used for the event-by-event Doppler correction of coincident γ rays. A unique feature of the RFD detector is the possibility to determine the lifetime τ of an excited state if it is comparable to, or shorter than the transit time of the recoil through target material (typically of the order of femtoseconds). Gamma lines corresponding to very fast transitions emitted inside the target are broadened and exhibit an angle-dependent tail due to a difference between the measured velocity of the recoil and its velocity at the time of γ ray emission. This difference is caused by the straggling of the recoil in the target. The line shape analysis allows to deduce the ratio of the number of γ rays emitted outside the target (which are properly Doppler corrected) to the total number of decays. This ratio is analytically related to the excited state lifetime τ .

3. Experimental results

In Fig. 1, the γ - γ -recoil coincidence spectra, gated by selected ^{66}Ge transitions, are presented for the rings of detectors at different angles. Event-by-event Doppler correction has been applied to the data under the assumption

that the γ rays were emitted after the nucleus left the target. As seen in the picture, the 1638 keV, 1413 keV and 1969 keV lines, corresponding to the consecutive γ -transitions in the cascade (known from previous study [2]), exhibit angle-dependent tails. Apparently, these lines are not properly Doppler corrected what indicates that the corresponding γ rays were emitted while nucleus was still travelling inside the target. For comparison, the 1510 keV transition is seen as a narrow, symmetric γ line at all angles, what indicates that a longer lifetime is associated with its emission.

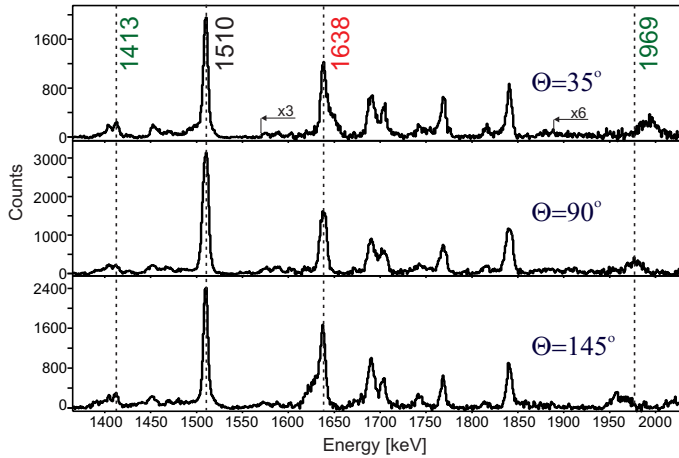


Fig. 1. The summed spectrum of γ rays gated on the 521, 1288 and 1510 keV transitions of the negative parity rotational band in ^{66}Ge . The upper panel shows γ rays registered at forward angle, the middle panel corresponds to 90 degrees and the lowest shows those detected at backward angle with respect to the beam axis. The 1638 keV, 1413 keV and 1969 keV lines, corresponding to the consecutive γ -transitions, exhibit angle-dependent tails due to the femtoseconds range level lifetimes. In contrast, the γ line at 1510 keV resulting from the level with longer lifetime is sharp.

Figure 2 displays line shape of the 1638 keV transition originating from the $I^\pi = 11^-$ state at 7130 keV, in the spectrum measured at 145 degrees with respect to the beam direction. Also, simulated line shape is shown assuming the 250 fs excited state lifetime. More detailed analysis yielded the cumulative lifetime of 250 ± 50 fs for the 1638 keV transition.

The measured states lifetimes can be used to extract transition quadrupole moments, Q_t , which, in turn, can be related to nuclear deformation. The transition probability T [s^{-1}] for a band member of a spin I is described by the expression [3]

$$T(E2, I \rightarrow I - 2) = 1.22 \times 10^9 E_\gamma^5 [\text{MeV}] B(E2) [e^2 \text{fm}^4] , \quad (1)$$

where the reduced transition probability $B(E2)$ is given by

$$B(E2, I \rightarrow I-2) = \frac{15}{32\pi} e^2 Q_t^2 \frac{(I-1-K)(I-1+K)(I-K)(I+K)}{(I-1)(2I-1)I(2I+1)}. \quad (2)$$

The K value is the projection of the total spin I onto the symmetry-axis of the deformed nucleus.

For the 1638 keV transition, taking the excited state lifetime of 250 ± 50 fs, the reduced transition probability, according to the formula (1), is $B(E2, 11^- \rightarrow 9^-) = 277 \pm 55 e^2 \text{fm}^4$ and resulting transition quadrupole moment $Q_t(K=0) = 0.9 \pm 0.1$ eb.

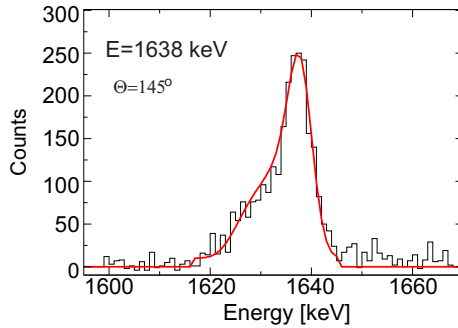


Fig. 2. Comparison between experimental and simulated line shape, assuming the 250 fs excited state lifetime, for the 1638 keV transition deexciting the $I^\pi = 11^-$ state at 7130 keV.

4. Conclusions

In summary, excited states lifetimes in the femtosecond range were assessed by measuring γ -recoil coincidences with the GASP germanium array and the Recoil Filter Detector. Analysis of the 1638 keV γ -line shape allowed to extract the lifetime of 250(50) fs for the $I^\pi = 11^-$ state at 7130 keV in ^{66}Ge , from which the transition quadrupole moment of the negative parity band built on the 5^- state at 3683 keV could be deduced.

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