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Configuration mixing investigation in germanium isotopes through measurement of $E0$ transition strengths

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Summary. — Experimental and theoretical studies of the germanium isotopes on the neutron-rich side of the stability valley point increasingly toward the emergence of triaxiality, configuration mixing, and shape coexistence phenomena. Studies of the $E0$ strengths, which can provide a direct measure of the amount of configuration mixing, are lacking. Thus, determining $E0$ transition strengths is essential for an understanding of the evolution of structures in the Ge isotopes. Beta-decay experiments populating excited states in the ^{72,74,76,78}Ge isotopes were performed at the TRIUMF-ISAC radioactive beam facility. Gamma-ray and electron spectroscopic investigations have been performed, to measure $E0$ strengths between states of $J > 0$, exploiting the GRIFFIN spectrometer combined with the PACES silicon detector array. Preliminary results from this study are presented.

1. – Introduction

The structure of Ge isotopes ($Z = 32$) has been widely investigated both theoretically and experimentally over the years, and indications of shape coexistence, triaxiality and configuration mixing have been found [1-4]. The energy systematics of the first excited 0^+ state of the even-even Ge nuclei around stability varies parabolically and comes to a minimum for ^{72}Ge ($N = 40$), as can be observed in fig. 1. In particular, in ^{72}Ge the 0_2^+ is the very first excited state. Evidence of strong mixing between the ground state and first excited 0^+ state in this nucleus has been drawn from transfer reaction studies, while indications of a weakening of the mixing for the higher mass cases have been found [1]. Moreover, a recent Coulomb excitation study led to the conclusion that the ground state and first excited 0^+ states of ^{72}Ge could be well described via an admixture of two triaxial rotors [3].

Electric monopole ($E0$) transition strengths, $\rho^2(E0)$, can probe the configuration mixing of the initial and final states considered [5]. However, only a few $E0$ strengths have

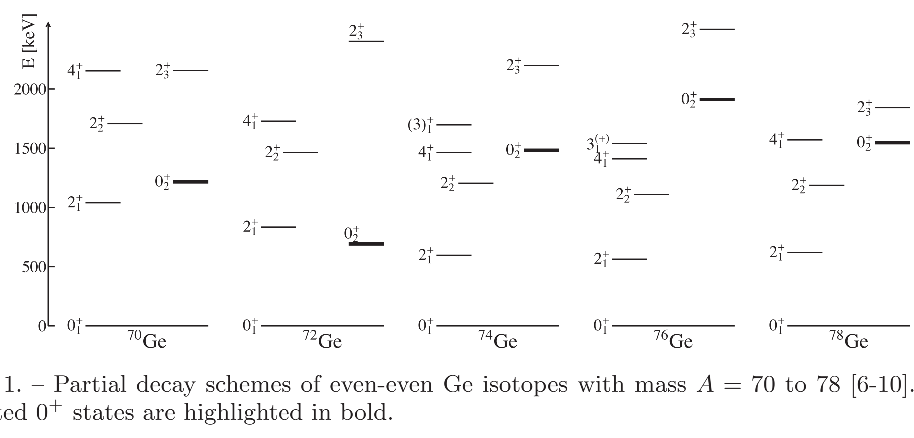

Fig. 1. – Partial decay schemes of even-even Ge isotopes with mass $A = 70$ to 78 [6-10]. The excited 0^+ states are highlighted in bold.

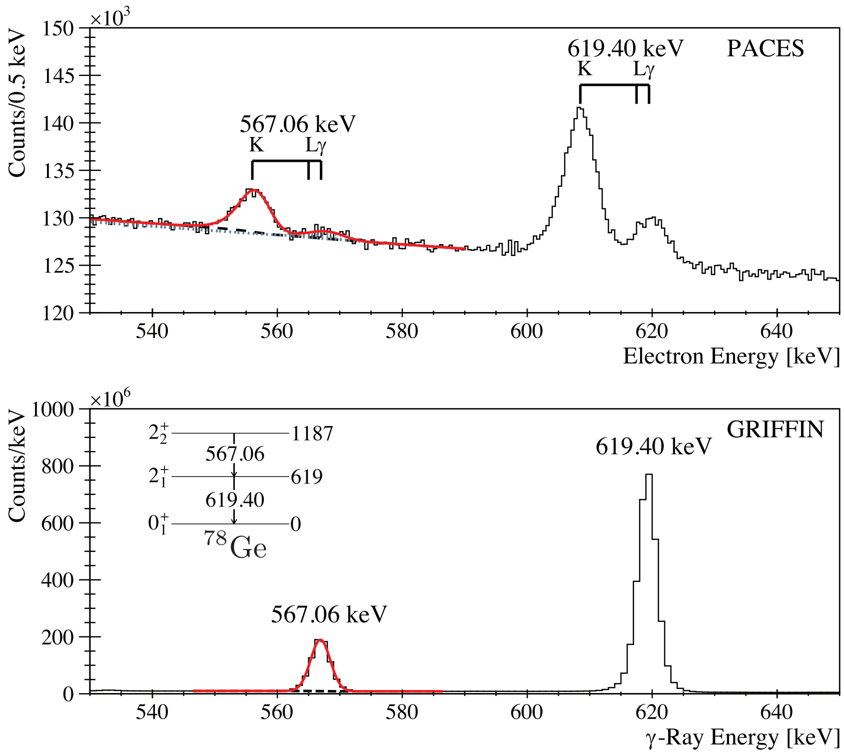

Fig. 2. – Comparison of the spectra recorded with one PACES crystal (top) and the GRIFFIN spectrometer (bottom) for the ^{78}Ge isotope in the 2019 experiment. In the PACES spectrum, a fit of the K-shell, L-shell and photo-peak components of the 567-keV, $2_2^+ \rightarrow 2_1^+$ transition is shown. Note that the background includes contributions from β particles and the Compton continuum of γ rays. The spectrum shown is recorded in singles, hence there is no background subtraction. In the GRIFFIN spectrum, a fit of the photo-peak of the same transition is shown. A partial level scheme of ^{78}Ge indicates the relevant transitions.

been measured in the Ge isotopic chain so far [11]. Therefore, an experimental determination of $E0$ transition strengths is needed for a systematic investigation of configuration mixing along the chain.

This experimental work focused on the even-even Ge isotopes with mass $A = 72$ to 78. Such nuclei were populated through beta-decay experiments. The experimental details are briefly described in the following section. The last section of this paper summarizes the results of the analysis performed.

2. – Experiment and analysis

The experiments were performed at the Isotope Separator and Accelerator (ISAC) facility [12] at the TRIUMF laboratory in Vancouver, Canada, in 2017 and 2019. The four isotopes of interest, ^{72,74,76,78}Ge, were populated through the β^- decay of the corresponding Ga isobars, that were delivered as beams to the center of the GRIFFIN β-decay station [13]. The radioactive Ga beams were produced through the ISOL technique.

The γ-ray and internal conversion decay of the Ge isotopes under investigation were measured by the high-efficiency and high-resolution GRIFFIN γ-ray spectrometer and its ancillary detector PACES. GRIFFIN was composed of 15 high-purity Ge clover detectors, while PACES comprised five lithium-drifted silicon [Si(Li)] crystals.

To determine the $\rho^2(E0)$ value for the $2_2^+ \to 2_1^+$ transition of the nuclei of interest, it is necessary to measure the experimental internal conversion coefficient α and the $E2/M1$ multipole mixing ratio δ of such transition. The coefficient α is a ratio of the intensity of emitted conversion electrons relative to emitted photons for a given transition. To measure the ratio of the intensities, the conversion electron spectra recorded by PACES and the γ-ray spectra recorded by GRIFFIN were used. Figure 2 shows both spectra for the case of ^{78}Ge. Fits of the peaks corresponding to the $2_2^+ \to 2_1^+$ transition are shown in red in the figure. A $\gamma\gamma$ angular correlation analysis is also in progress, to provide a measurement of the $E2/M1$ multipole mixing ratios δ.

3. – Conclusions

Preliminary results from the internal conversion analysis point to the emergence of a finite $E0$ component in the $2_2^+ \to 2_1^+$ transition of ^{72}Ge, and to a near-zero $E0$ strength in the higher mass cases (^{74,76,78}Ge). This result is in agreement with previous transfer reaction studies that indicated a strong configuration mixing in ^{72}Ge, and a weakening of the mixing for the even-even Ge nuclei with $N > 40$. Currently, an effective theoretical description of $E0$ strengths in $J > 0$ transitions is still lacking. Therefore, further efforts on the theoretical side will be needed to provide a comprehensive description of the origin of the $E0$ strength, as well as new experimental measurements of $\rho^2(E0)$ that could benchmark such studies.

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