LIFETIME MEASUREMENT OF 2_1^+ STATE IN ^{74}Zn WITH DIFFERENTIAL PLUNGER TECHNIQUE*

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We have measured the lifetime of the 2_1^+ state in ^{74}Zn by the recoil distance Doppler-shift method at GANIL. It resulted to be of 27.6(43) ps and is consistent with previously measured values of transition rates from Coulomb excitation measurements.

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1. Introduction

One of the most critical ingredients in determining the disappearance or appearance of magicity in nuclei far from stability is the evolution of single-particle energies with increasing neutron or proton numbers when moving away from the valley of stability. The three known cases of disappearance of shell gaps at $N = 8$, 20 and 28 in neutron-rich nuclei [1, 2, 3, 4, 5] are understood as due to the tensor part of the nucleon–nucleon interaction [6]. The tensor force is held responsible for the strong attraction between protons and neutrons in spin-flip partner orbits. A recent generalization of such mechanism foresees a similar behavior also for orbitals with non-identical orbital angular momenta. It is expected that orbitals with anti-parallel angular momenta attract each other and orbitals with parallel angular momenta repulse each other.

In this context neutron-rich nuclei in the vicinity of ^{78}Ni are particularly interesting. It is predicted, for example, that the $Z = 28$ gap for protons in the pf-shell becomes smaller when moving from $N = 40$ to 50 as a consequence of the attraction between the proton $f_{5/2}$ and neutron $g_{9/2}$ orbits and the repulsion between the proton $f_{7/2}$ and the neutron $g_{9/2}$. The same argument would also predict a weakening of the $N = 50$ shell gap when depleting the proton $f_{7/2}$ state upon approaching the ^{78}Ni nucleus, due to the diminished attraction between the neutron $g_{9/2}$ and the proton $f_{5/2}$ orbits and the reduced repulsion between the neutron $g_{9/2}$ and the proton $f_{7/2}$ states.

2. Experiment and analysis

In order to investigate the shell evolution in the vicinity of ^{78}Ni, we have performed a lifetime measurement for the 2_1^+ state in ^{74}Zn by the differential plunger technique. A primary beam of ^{76}Ge at an incident beam energy of 60 MeV/nucleon was used to produce a cocktail beam of ^{73,74}Zn by the projectile-fragmentation reaction on a ^{9}Be target. The cocktail beam was separated by the first half of the LISE spectrometer at GANIL. The secondary beam with an energy of 34 MeV/nucleon was used to bombard a secondary CD_2 target to induce inelastic and transfer reactions, and the outgoing particles were selected and identified by the second half of LISE [7, 8]. Gamma rays emitted from the reaction products were detected by 8 EXOGAM detectors [9], which were surrounding the secondary target at angles of 45 and 135 degrees relative to the beam direction. The Köln plunger system [10] consisting of 270 μm thick target of CD_2 and 300 μm thick degrader of ^{9}Be was placed in the center of the EXOGAM detectors to measure lifetimes of excited states with the recoil distance Doppler-shift (RDDS) method. Plunger target-degrader distances were set to 0.0, 0.75, 1.75, 2.5, 3.5, 5.0, 8.0, 15.0 and 20.0 mm. An example of a Doppler-corrected gamma-ray spectrum after background subtraction with the plunger distance of 1.75 mm is shown in Fig. 1.

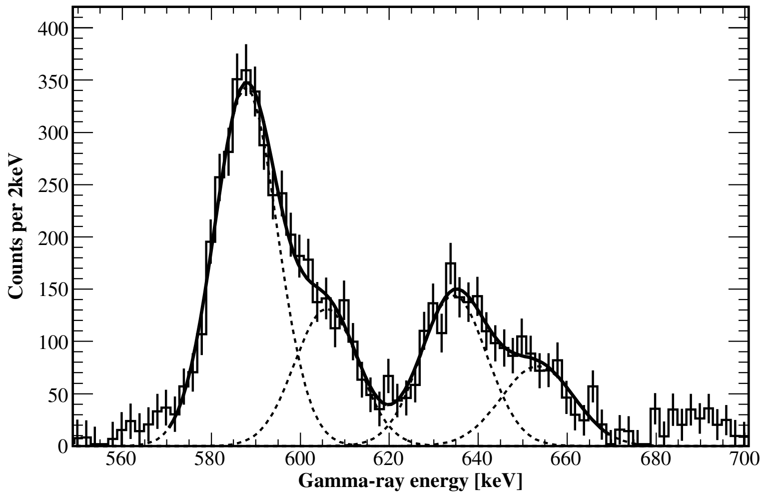

Fig. 1. Example of a gamma-ray spectrum taken with a plunger distance of 1.75 mm. Dotted lines represent four gamma peaks corresponding to gamma rays emitted before and after the degrader for ^{72,74}Zn, respectively, and solid line is a result of the fitting.

The evolution of the gamma-ray yields of the $2_1^+ \rightarrow 0_1^+$ transition in ^{74}Zn emitted after the degrader as a function of the plunger target-degrader distance is shown in Fig. 2. After fitting with an exponential line, we obtain the lifetime of 27.6(43) ps for the 2_1^+ state in ^{74}Zn. This lifetime corresponds to $B(E2 : 2^+ \rightarrow 0^+)$ of 19.9(35) W.u. and is consistent within the error bar with prior measured values of transition rates from Coulomb excitation measurements at GANIL (22.1(16) W.u.) [11] and ISOLDE (21.7(9) W.u.) [12]. Together with a Coulex experiment, the lifetime measurement allows for the determination of a quadrupole moment, giving new and additional insight into the nuclear structure of the isotopes being studied. Such analysis depends on the precision of both measurements when combining them. Therefore it is particularly important to control all sources of systematic errors during the experiment and a careful error analysis is to be carried out afterwards. This error analysis is currently in process.

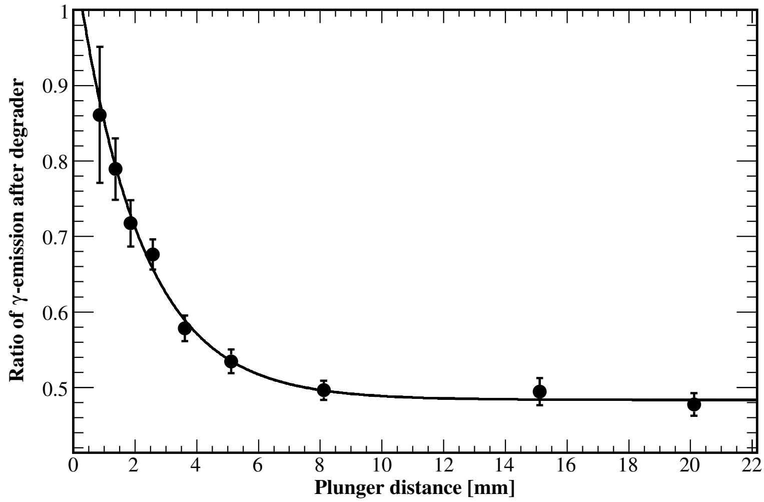

Fig. 2. Evolution of gamma-ray yields of the $2_1^+ \to 0_1^+$ transition in ^{74}Zn emitted after the degrader as a function of the plunger target-degrader distance.

3. Summary

We have measured the lifetime of the 2_1^+ state in ^{74}Zn by the RDDS method at GANIL. The lifetime value resulted to be of 27.6(43) ps, with consistent with previously measured values of transition rates from Coulomb excitation measurements. This work was partly supported by the Polish Ministry of Science and Higher Education (Grant No. N N202 309135).

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