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EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Letter of Intent to the ISOLDE and Neutron Time-of-Flight Committee

Laser spectroscopy measurements on neutron-rich $^{77-83}$Ge isotopes across $N = 50$ and establishing shape coexistence in ^{81}Ge via laser spectroscopy (COLLAPS)

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Abstract

Following the proposal for laser spectroscopy measurements on Ge isotopes, this letter of intent mainly aims to motivate beam development for measurement of the ground- and isomeric state properties of the very neutron-rich $^{77-83}$Ge isotopes, across the $N = 50$ major shell closure. This will enable the study of shell structure evolution around $N = 50$, and provide new information on the Z-dependence of the proton orbit inversion found in this region. Additionally, the existence of a long-lived ($1/2^+$) isomer in ^{81}Ge makes it an ideal candidate to study the shape coexistence in this region, which has recently been reported from different experiments (^{79}Zn,^{80}Ge) and has been identified in a theoretical (^{78}Ni) study. In addition, the measurement will provide a prominent test of recently developed shell-model interactions in an extended model space including the orbits above $N = 50$.

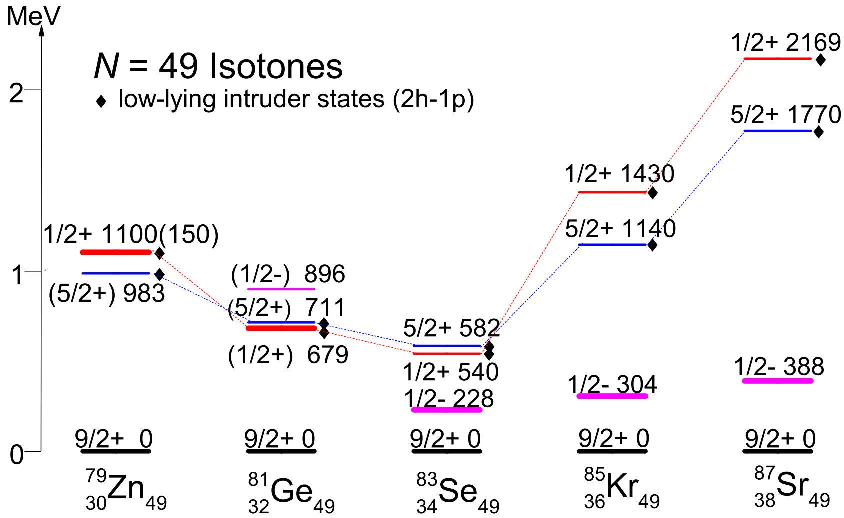

Figure 1: Odd-mass $N = 49$ level systematics [6]. The levels with a thick solid line are the long-lived isomeric states, and the diamonds mark the $1/2^+$ and $5/2^+$ intruder states.

1 Introduction and physics motivation

The persistence (or not) of double-magicity in ^{78}Ni has attracted significant experimental and theoretical attention [1, 2]. Besides that, the monopole migration of proton single particle levels has been a major avenue of research in recent years. Here we have provided substantial new information from the laser spectroscopy studies on neutron-rich isotopes around $Z = 28$ (Cu, Ga, Zn)[3, 4, 5] between the $N = 40$ subshell gap and the $N = 50$ shell gap. Very recently, an unexpected shape coexistence in ^{79}Zn has been observed by a laser spectroscopy measurements at COLLAPS-ISOLDE [6]. Nearly simultaneously, the evidence of shape coexistence has been reported by another experimental team, through observing a low-lying 0_2^+ state in ^{80}Ge [7], as well as in a recent theoretical study of ^{78}Ni [8].

In order to obtain a systematic understanding of various nuclear properties observed in this region, and as a continuation of our earlier work in the neutron-rich $Z = 28$ region [3, 4, 5], we propose the measurement of the ground- and isomeric state nuclear spins, moments and charge radii of Ge isotopes up to ^{83}Ge, beyond $N = 50$. The general physics motivation for this study has been well described in the proposal [9]. Following the summary of known information in Ge isotopes in Table 1 of Ref.[9], the information for $^{77-83}$Ge isotopes is listed in Table 1. Basically, ground state properties (magnetic and quadrupole moments, charge radii) have not been measured for these isotopes except the tentative spin assignment, and therefore are proposed to be studied here. However, due to questions on the production of very neutron-rich Ge isotopes at ISOLDE using UC$_x$, the study of the very neutron-rich $^{77-83}$Ge is suggested by the ISOLDE target group as a separated letter of intent, which is motivated by specific key physics cases, as described below.

The inversion of the proton $\pi p_{3/2}$ and $\pi f_{5/2}$ effective single particle orbits as neutrons fill the $\nu g_{9/2}$ orbit has been predicted by theoretical studies and confirmed by the spin assignment and magnetic moments measurements of neutron-rich Cu and Ga [3, 4]. Recently, from nuclear moments measurement of the neutron-rich Zn isotopes ($Z = 30$), this proton level inversion has also been confirmed in Zn [5]. The magnetic and quadrupole moments measurement of neutron-rich Ge isotopes, together with the shell-model calculations, will allow the Z-dependence of the proton level inversion to be established.

The nuclear charge radii of isotopes in this region have been summarized in Fig.1 of Ref. [9]. Near $Z = 28$, only the measurement of Ga has extended beyond the $N = 50$ major shell closure. The "kink" (increase of charge radius) at $N = 50$ seems stronger than in the case of the high-Z isotopic chains Kr, Rb, Sr. However a substantial uncertainly on the charge radius of ^{82}Ga remains since the nuclear spin could not be uniquely determined. Therefore, it is needed to perform precision isotope shift measurements in this region beyond $N = 50$, in order to confirm this finding.

As previously noted, the signature of shape coexistence has been observed in ^{79}Zn, by the measurement of the spin and magnetic moment of a newly discovered long-lived isomer, in combination with the observation of a large isomer shift [6]. The intruder states in the $N = 49$ isotones have been discussed more than 30 years ago, as shown in Figure 1. As a member of this $N = 49$ isotone series, ^{81}Ge will be an ideal candidate to study the shape coexistence, since a long-lived ($1/2^+$) isomer is known to exist in this isotope. In addition, evidence of shape coexistence has also been suggested in the neighbouring isotope ^{80}Ge. The laser spectroscopy measurement of ^{81}Ge will give direct measurement of the spin, the magnetic moment and isomer shift. This will provide further information on the shape coexistence near $N = 50$, and enhance our understanding of the intruder isomers. To be able to explain the intruder isomer in ^{79}Zn and the measured quadrupole moments of the neutron-rich Zn isotopes [5], new shell model interactions with an extended model space, including the neutron-orbits beyond $N = 50$ have been developed [8, 10]. The ground state quadrupole moment of neutron-rich ^{79,81,83}Ge and the magnetic moment of $1/2^+$ isomer in ^{81}Ge will provide a compelling test to these new interactions.

2 Experiment and requested development

The proposed experimental setup, as well as the laser transition used for the hyperfine spectra measurement will be the same as in Ref. [9]. The ISOLDE online yield database provides very promising production yield for neutron-rich Ge up to ^{82}Ge ($N = 50$), as shown in Table 1. However since only one single yield measurment has been performed at the PSB for ^{84}Ge [11], it is unclear if these numbers would accurately indicate the yield we could expect at the PSB. In addition only 1 mass scan is available for a UCx target with a sulfur leak and this indicates stable molecular contamination at levels beyond the space-charge limit of ISCOOL for a number of the isotopes of interest. It is not clear that this is representative and therefore we would request that both the yield and contamination for these masses is fully investigated prior to submission of a full proposal. In the event that the large mollecular contaminations on these masses are found to persist, we would request that the release characteristics and associated yields of Ge are investigated without the sulfur leak, but with the recently developed RILIS ionization scheme [12]. Additionally the

Table 1: Known information for neutron-rich $^{77m,78-83}$Ge, as well as the production yield from UC_x target listed in the ISOLDE database. The yield for ^{83}Ge isotope is a simple extrapolation from other isotopes.

Isotopes	Spin	Half-life	μ (μ_N)	$Q_s(b)$	Yield (ISOLDE online database)
^{77}Ge	$(7/2^+)$	11.21h			
^{77m}Ge	$(1/2^-)$	53.7s			
^{79}Ge	$(1/2^-)$	18.9s			1.2×10^7
^{79m}Ge	$(7/2^+)$	39s			
^{81}Ge	$(9/2^+)$	7.6s			1.3×10^6
^{81m}Ge	$(1/2^+)$	(7.6s)			
^{83}Ge	$(5/2^+)$	1.85s			$\sim10^4$
$^{78-82}$Ge	0^+				

target team have suggested that a better method for production of Ge at PSB-ISOLDE may be the use of a ThO target with an atomic sulfur leak, in an analogous way to the production of the neutron deficient isotopes addressed in the proposal. We additionally request that this alternative is fully investigated.

References

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Appendix

DESCRIPTION OF THE PROPOSED EXPERIMENT
The experimental setup comprises: COLLAPS

Part of the	Availability	Design and manufacturing
(COLLAPS)	☒ Existing	☒ To be used without any modification

HAZARDS GENERATED BY THE EXPERIMENT
Hazards named in the document relevant for the fixed CRIS installation.

Additional hazards: None