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Letter of Intent to the INTC committee

Coulomb excitation of ^{84}Se

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Abstract
The properties of nuclei with 28<Z<40 on the N=50 line are of interest as they are benchmarks for shell model calculations in the region around ^{78}Ni. Since N=50 is a magic neutron number, the structure of the low spin states in these nuclei can be assumed to be predominantly proton excitations in the $\pi p_{3/2}$-$f_{5/2}$-$p_{1/2}$ valence space. Experimental input is necessary to test the residual interaction and to fix the effective charges in the chosen valence space.

Physics case

The neutron rich $_{34}$Se isotopes are located near the proton shell closure Z=28 and neutron shell closure N=50. The excitation spectrum of the stable even-even $_{34}$Se isotopes (A=74 up to 82) show features typical for spherical harmonic quadrupole vibration or rotational nuclei. Several Coulomb excitation studies have been performed on these stable even-even Se isotopes (A=74 up to 82) [1-3], indicating the complex collective nuclear structure of these isotopes.

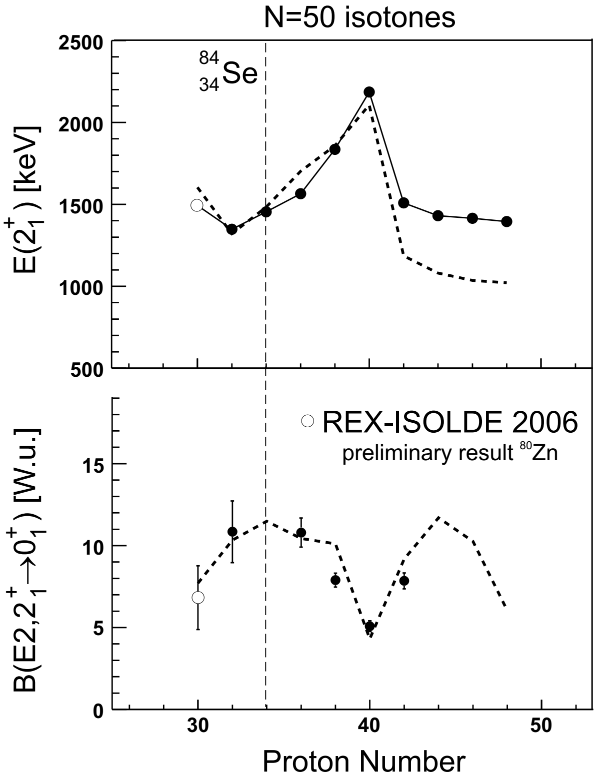

Fig. 1 : $E(2^+{}_1)$ and $B(E2,2^+{}_1\rightarrow0^+{}_1)$ systematics of N=50 isotopes, compared to recent shell model calculations by A. Lisetskiy (dashed line) [18]. The open circles represent the preliminary results from the Coulomb excitation experiment on ^{80}Zn performed at REX-ISOLDE in 2006 [20]. Experimental values are taken from [21] (Z>34) and [12] (Z=32).

The first radioactive neutron rich even-even Se isotope is ^{84}Se ($T_{1/2}$=3.1 min) and is located on the N=50 line. This nucleus has been investigated by β-decay [4] and (t,p) reactions [5,6] and more recently the medium-spin states have been explored up to $J^\pi=7^+$ in a deep-inelastic reaction using the GASP gamma ray spectrometer [7], by a fusion-fission reaction utilizing the Euroball IV gamma spectrometer [8] and by spontaneous fission of ^{252}Cf utilizing Gammasphere [9]. In comparison with shell model calculations it was shown that at least 1p-1h excitations across the N=50 shell gap have to be included in the configuration space to get a reasonable description of the positive parity states above spin 4^+ in ^{84}Se [7]. In these calculations, the shell gap at N=50 was fixed to 4 MeV. The good shell model description of other N=50 isotopes leads to the conclusion that this N=50 shell-gap persists down to Z=32. In [8] the decrease in energy of all medium spin states when going from Z=40 down to Z=34 leads to the suggestion that neutron core excitations across N=50 need to be taken into account in shell model calculation of lighter N=50 isotopes. Shell model results compared to high spin states observed in ^{83}Se indicate as well the existence of 1p-1h excitation across N=50 [10]. In conclusion, shell model calculations have indicated that N=50 core breaking is needed to describe medium and high spin states, but remains a good shell closure for low spin states.

The knowledge of $B(E2,0^+{}_1\rightarrow2^+{}_1)$ [=B(E2)↑] strengths on the N=50 line was, up to 2005, rather scarce [11]. Recent experimental work at ORNL has provided the B(E2)↑ strength in $^{82}Ge_{50}$ [12]. During the last running period at REX-ISOLDE, the $2^+{}_1$ state in ^{80}Zn and the B(E2)↑ value have been measured for the first time. The only experimental B(E2)↑ values lacking on the N=50 line and within the $\pi p_{3/2}$-$f_{5/2}$-$p_{1/2}$ configuration space are those in ^{84}Se and ^{78}Ni (see Fig. 1, bottom). From the discussion above, it can be assumed that the 2^+_1 states in N=50 isotones are predominantly proton excitations in the $\pi p_{3/2}$-$f_{5/2}$-$p_{1/2}$ shell with possible contributions from Z=28 core breaking and the B(E2)↑ are crucial in fixing the proton residual interaction in this valence space. In Fig. 1, recent shell model calculations of $E(2^+_1)$ and $B(E2,2^+_1 \rightarrow 0^+_1)$ by A. Lisetskiy [18] are compared to the available experimental data on N=50 isotopes.

The intermediate energy Coulomb excitation of ^{84}Se has been performed at RIKEN in 2001, but no B(E2)↑ results have been published so far [13].

Feasibility of the experiment

Beam production

At ISOLDE isobaric pure post-accelerated ^{70}Se beams have been produced and used for a Coulomb excitation experiment [14]. The isobaric contamination level was proven to be below 1% [14]. This ^{70}Se beam was produced with a ZrO_2 target and a proton beam of 1.4 GeV (PSB). The radioactive ions were extracted in a molecular form : ^{70}Se^{12}C^{16}O (A=98). The yield of this molecular beam was 3.0E5 ions/μC. The molecule was subsequently broken up in the EBIS by the intense electron beam [15]. Utilizing a Ta target and a proton beam energy of 600 MeV (SC), the yield of ^{87}Se was measured at the SC-ISOLDE to be 4.5E4 ions/μC [16]. The yield of ^{84}Se was never measured for either target (PSB+ZrO_2 nor SC+Ta target).

Even if the produced beam intensity were very low (region of 1E4 ions/μC), the experiment would still be possible if the post accelerated beam is isobarically pure. Then, only a limited uncertainty on the normalization enters through the beam contamination and the major concern becomes the statistical uncertainty.
At the radioactive ion beam facility of ORNL, an experiment is planned on ^{84}Se [17], with a beam intensity of 8×10^3 ions/sec. If this number were higher at ISOLDE, the B(E2)↑ measurement could be performed with lower statistical uncertainty.

The different options for producing a ^{84}Se beam at ISOLDE are [19] :

- Ta foils as primary target
- UC_x primary target + hot plasma ion source + additional CO_2 leak + ^{84}Se^{12}C^{16}O extraction (A=112)
- ZrO_2 or ThO_2 primary target + hot plasma ion source + additional CO_2 leak + ^{84}Se^{12}C^{16}O extraction (A=112)
- Possible A=112 contamination from ^{112}In could be reduced by the use of the convertor.

Counting rates (comparison to ^{80}Zn)

In order to show the feasibility of this experiment, a comparison is made here with the N=50 ^{80}Zn beam, post accelerated in 2006. The following parameters were used :

1- Assuming an extrapolated B(E2)↑ value of 0.15 e^2b^2 for ^{84}Se;
2- The existing MINIBALL setup, consisting of a Silicon strip detector covering 16-50 degrees in the laboratory system and eight triple cluster Germanium detectors.

3- A tentative 1E4 ions/μC yield for ^{84}Se
4- 1% REX transmission efficiency and 7% gamma detection efficiency for the $2^+_1 \rightarrow 0^+_1$ transition energy in ^{84}Se (1455 keV)
5- A 2.0 mg/cm^2 ^{108}Pd secondary target.

Isotope	σ [mbarn]	$I_{Primary\ Target}$ [ions/μC]	I_{PROTON} [μA]	Counts/day	Shifts
$^{80}Zn_{50}$	55$^{(*)}$	3E4	4	12$^{(**)}$	13
$^{84}Se_{50}$	76$^{(***)}$	1E4	4	2	15

$^{(*)}$ Preliminary cross section (depends on preliminary B(E2) value)
$^{(**)}$ This is the experimental count rate, from which a higher REX transmission efficiency can be deduced (~3% instead of the conservative value of 1%).
$^{(***)}$ Cross section based on the extrapolated B(E2)↑ value of 0.15 e^{2}b^2 for ^{84}Se

Request

The yield of ^{84}Se was never measured before and different target options exist as well as different molecular beams can be investigated. Therefore we request the investigation of the different options for producing a ^{84}Se beam during the online running period with different target options in order to investigate the feasibility of this experiment. If the tests are successful, the collaboration will prepare a proposal to measure the B(E2)↑ values for ^{84}Se and some of the heavier even-even Se isotopes.

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