PRODUCTION OF NEUTRON-RICH NUCLEI WITH $A < 80$ IN SUPERASYMMETRIC FISSION AT IGISOL*

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Ion guide-based isotope separator has been used in order to study the superasymmetric fission mode at intermediate proton energies. These results, together with the fission fragment mass distributions obtained with HENDES array, indicate that fission at intermediate proton energies is a potential tool in producing nuclei near doubly magic ^{78}Ni. Furthermore, the beta-decay of ^{69}Co has been identified for the first time and its half-life has been measured.

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The experimental study of exotic neutron-rich nuclei far from the valley of stability is one of the powerful means for testing and stimulating the development of theoretical nuclear models to describe properties of nuclei around doubly-magic ^{78}Ni. Neutron-rich beta-unstable nuclei near $Z = 28$ have recently gained increased interest for at least two reasons. First, new phenomena connected with large neutron excess (large isospin) and decrease of binding energy when approaching the drip lines have been predicted [1]. One crucial prediction is the weakening of the conventional shell closures. This seems possible according to the experimental studies of very neutron-rich isotopes carried out at Louvain-La-Neuve [2]. The second reason for the study of this region is that some of the neutron-rich nuclei currently within experimental reach are touching the r-process path for element synthesis [3].

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Questions such as the strength of shell effects near ^{78}Ni are of upmost importance for the reliability of the input nuclear parameters in the modelling of the astrophysical processes. This region has been an active field of research recently.

Most of the neutron-rich isotopes have been produced either by thermal fission or by projectile fragmentation. In several isotope separator facilities, such as IGISOL in Jyväskylä, new neutron rich nuclei and their decay modes are being discovered in fission at intermediate energies. As we go further away from stability, however, the production of these neutron-rich nuclides becomes more and more difficult due to decreasing fission cross sections. In studying charge and mass distributions for neutron-rich nuclei we learn about the experimental possibilities to reach further away from stability using more reliable extrapolations of refined models. Direct mass distributions in fission are being studied with HENDES detector array. The HENDES array measures the masses of fission fragments with time-of-flight technique together with neutrons and light charged particles emitted at different stages of fission.

In addition to providing input data for tuning the models for fission, the experiments on mass and charge distributions add new spectroscopic information on nuclei at the limit of the presently known region. In this way, such experiments could possibly show first hints for the predicted phenomena at larger isospin. At JYFL one has been measuring the yields of $Z = 28$ nuclei in proton induced fission of ^{238}U using the ion guide isotope separation technique IGISOL [5]. It is based on thermalisation of fission products in helium, which are then guided by electric field, accelerated and separated by mass. The advantage of IGISOL is its capability to deliver the fission products in a very short time, enabling us to study radioactive nuclei with considerably short lifetimes (τ>1 ms) which is the case for very exotic neutron-rich isotopes. The fission measurements with IGISOL indicate that the superasymmetric mass division of a fissioning nucleus in comparison with thermal neutron induced fission is enhanced. This division is enhanced at intermediate excitation energy [6]. The heaviest observed nickel isotope was ^{71}Ni with a production rate of 5.7(17) atoms/s but heavier and more exotic isotopes are expected to be reachable at JYFL following the deveplopment around the facility.

Recently a 24 hour measurement of proton ($E = 50$ MeV) induced fission of ^{238}U was performed at IGISOL. The main motivation was to find preliminary evidence for the ^{69}Co beta-decay and to measure the production yields for the $A = 69$ isobaric chain. We were able to detect for the first time the beta-decay of ^{69}Co, based on beta-gamma coincidence measurements with fast beam pulsing. The analysis of peak intensity versus cycle time (TDC), with a 0.6 s beam on and 0.8 s beam off period, clearly shows one gamma-transition, 594 keV, which belongs to a short-lived isotope. Part of the gamma spectrum is shown in figure 1. The fit for the 594 keV gated TDC projected spectrum gives a half-life of $t = 0.27(10)$ s, which is in excellent agreement with the previous lifetime measurement of ^{69}Co using a recoil spectrometer, $t = 0.27(5)$s [7]. The 594 keV transition has also been detected in in-beam studies [8] and has been placed in the level scheme of ^{69}Ni. We measured the production yield of ^{69}Co both in continous and pulsed beam mode as 1.1(5) atoms/s and 0.4(2) atoms/s respectively.

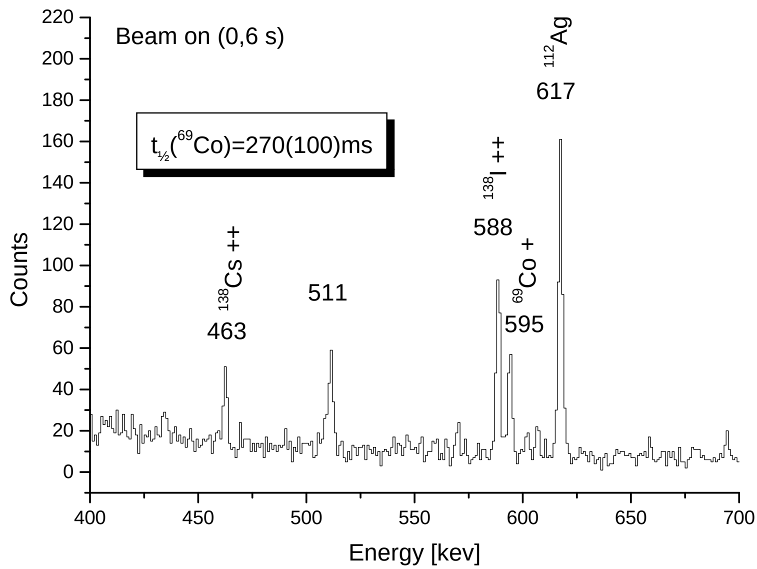

Fig. 1. A gamma spectrum recorded at $A = 69$ for 15 hours of measurement. The 595 keV gamma from ^{69}Co beta-decay can be clearly seen, and rest of the peaks can be identified either as doubly charged ions or contamination next to the collection tape (^{112}Ag).

If we wish to fill the boundaries of the nuclide chart we are forced to extend our knowledge of the production as well as efficient detection of nuclei lying on these extreme limits. The present status at IGISOL concerning the continuation of the study of superasymmmetric fission is concentrating on the development of the ion guide and the mass separator system, including a cooling device and an ion trap. One also expects that fast neutron induced fission could provide a method for production of extremely neutron-rich isotopes, and this has recently been studied with the HENDES array.

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