Model calculations of a two-step reaction scheme for the production of the neutron-rich secondary beams

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Actually, the design of more powerful next-generation secondary-beam facilities is being intensively discussed. The main challenge is the production of neutron-rich isotopes, because the neutron-drip line has only been reached for the lightest elements. The traditional way for producing neutron-rich nuclei is fission of actinides. Another approach introduced recently, based on cold fragmentation [1], has successfully been used to produce a number of new neutron-rich isotopes. A new idea is to combine these two methods in a two-step reaction scheme. Medium-mass neutron-rich isotopes are produced with high intensities as fission fragments. They are used as projectiles in a second step to produce even more neutron-rich nuclei by cold fragmentation. This idea might be realised in an-flight facility by consecutive reactions in a thick target, while the application in an ISOL-based facility needs post acceleration to sufficiently high energies to allow for fragmentation in a second target.

In our recent work [2], we studied the feasibility of this two-step reaction scheme by calculating the relevant cross sections and the beam intensities to be obtained. We concentrated our studies on the second step of this approach, cold fragmentation of projectiles far from stability, since there are no experimental data available for the fragmentation of exotic, very neutron-rich projectiles. Two types of codes were used, EPAX [3], the semi-empirical parameterisation of fragmentation cross sections and COFRA [4,1], a modern analytical version of the abrasion-ablation nuclear reaction model. In figure 1, the cross sections from fragmentation of ^{132}Sn as predicted by the two codes are compared. While the EPAX code extrapolates the production cross sections, measured in fragmentation of the available stable projectiles, the nuclear-reaction code takes into account the variation of the nuclear properties as a function of neutron excess. Most important is an enhanced neutron evaporation caused by the low neutron-separation energies of the extremely neutron-rich fragments. This leads to considerably lower cross sections if compared to EPAX.

According to the COFRA calculations, the direct production by fission of ^{238}U prevail in most cases. The two-step scenario might only become advantageous in the production of extremely neutron-rich isotopes. The situation changes appreciably if we consider the available secondary-beam intensities including extraction, ionisation and re-acceleration in an ISOL-type facility. Here, the two-step reaction scenario can be useful by profiting from very high secondary-beam intensities to be obtained for specific neutron-rich nuclides. Extracting an abundant and long-lived neutron-rich nuclide like ^{132}Sn from the ISOL source and fragmenting it, one can reach those isotopes that have low ISOL efficiencies due to their short half lives or difficulties in the extraction from the source [5].

We conclude that the predictions of EPAX for the production of very neutron-rich nuclides by fragmentation of non-stable neutron-rich projectiles seem to be far too optimistic. The two-step reaction scheme studied might be advantageous in specific cases.

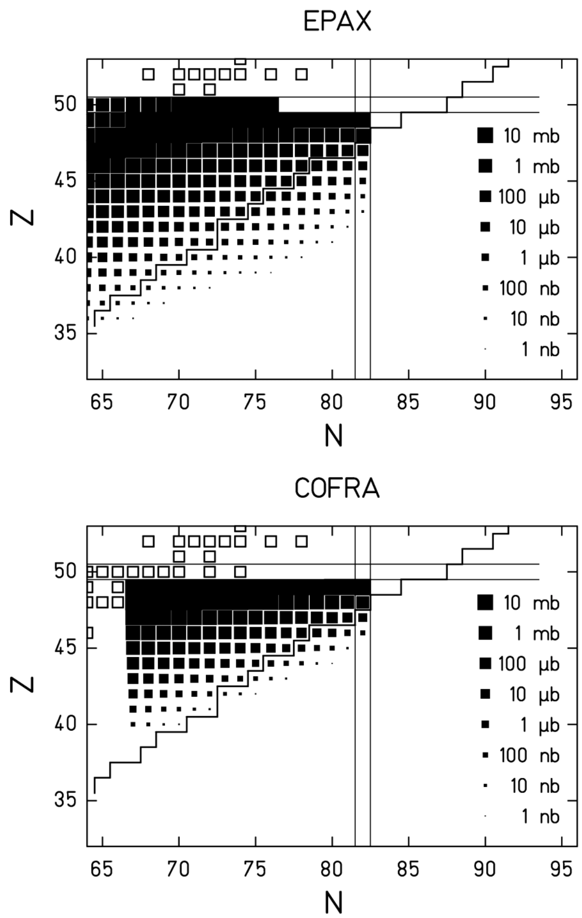

Figure 1. Predicted cross sections for the cold-fragmentation of ^{132}Sn in beryllium target from the empirical systematics EPAX and the nuclear-reaction code COFRA on a chart of the nuclides.

References

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