PRODUCTION CROSS SECTIONS FROM THE FRAGMENTATION OF A VERY NEUTRON RICH PROJECTILE ^{132}Sn

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1. Introduction

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.

In our recent work [2] we studied the feasibility of the two-step reaction scheme by calculating the cross sections for the reaction products from this kind of reactions. Two types of codes were used, EPAX [3], the semi-empirical parameterisation for fragmentation cross sections and ABRABLA/COFRA[4,1], the modern versions of the abrasion-ablation nuclear reaction model. The predictions of EPAX and the nuclear reaction codes for the cross sections for the nuclei produced by the fragmentation of a very neutron rich projectile differ considerably. This difference can be clearly seen in the comparisons of figure 1 and table 1. We might assume that the nuclear-reaction models ABRABLA and COFRA, which consider the variations of nuclear properties as a function of neutron excess, are better suited for extrapolating in the far neutron-rich region than the EPAX empirical systematics. Nevertheless, it would be desirable to obtain a clear answer from a dedicated experiment.

We propose an experiment where a secondary beam of ^{132}Sn would be produced by the electromagnetic induced fission of ^{238}U in a ^{208}Pb target. Then the ^{132}Sn beam would be further fragmented in a secondary target of ^{9}Be, and cross sections of selected fragments would be measured. The obtained results are of a great importance for the EURISOL project, developing the next generation ISOL-type radioactive beam facility.

Table 1. Cross sections of different Pa isotopes predicted by EPAX and COFRA codes.

	^{121}Pd	^{122}Pd	^{123}Pd	^{124}Pd
EPAX	0.421 mb	0.285 mb	0.182 mb	0.109 mb
COFRA	0.174 mb	0.106 mb	0.045 mb	0.024 mb

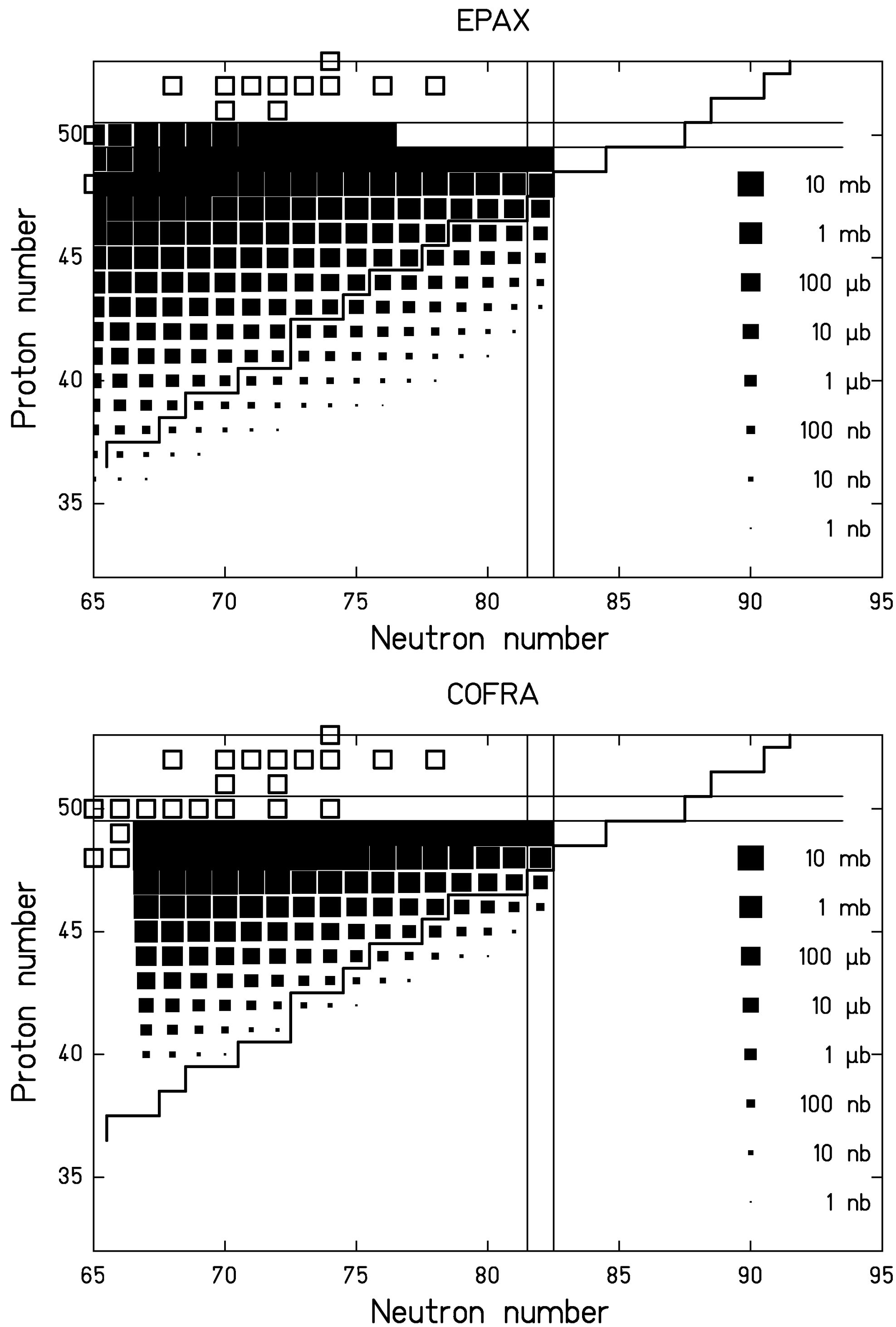


Figure 1. The cross sections for fragments resulting from reaction $^{132}Sn + {}^{9}Be$ calculated with two different models EPAX and COFRA.

2. Experimental details

The experiment would be carried out at the FRS. Primary beam of 1 A GeV ^{238}U is shot to the ^{208}Pb target with a thickness of 258 mg/cm^2. The secondary beam of ^{132}Sn is created in the electromagnetic-induced fission of ^{238}U. The forward emitted part of the fission fragments is utilised. The production cross section for this reaction is well known from our previous studies [5]. The identification and selection of the wanted secondary beam would base on the following principles:

- the angular acceptance of the FRS is limited to 10 mrad in order to increase the resolution at S2 by limiting the longitudinal velocity spread of the transmitted fission fragments
- the charge of the produced fragment is identified with a small MUSIC ionisation chamber positioned at S2
- the mass of the secondary beam is selected by setting the slits at S1.

The calculated separation of the different isotopes of tin at S2 is shown in figure 2. From the figure it can be observed that by setting the slits at positions that limit the S2 fragment distribution in between –2 cm and 4 cm the purity of 92.0 % for the selected ^{132}Sn beam can be obtained.

After the selection, the secondary beam hits the secondary target which is 2.397 g/cm^2 of ^9Be. The produced fragments are identified using the standard FRS detectors (scintillators at S2 and S4, multiwire and MUSIC detectors at S4). A schematic drawing of the setup is shown in figure 3.

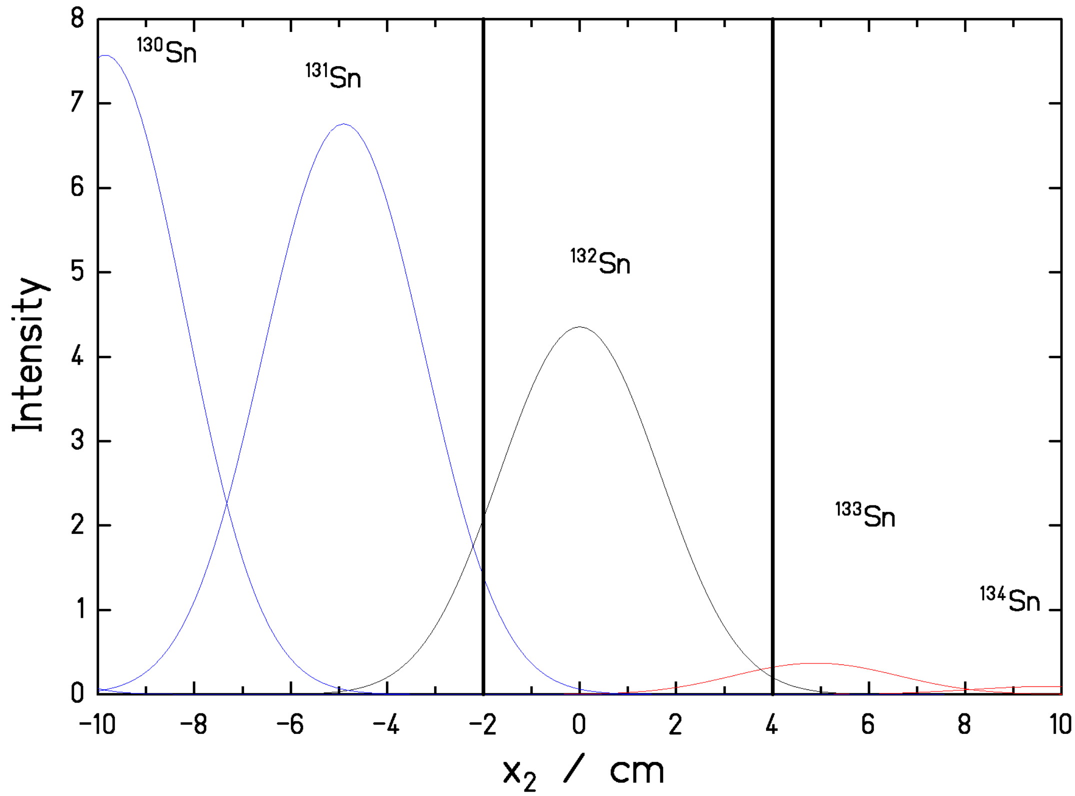
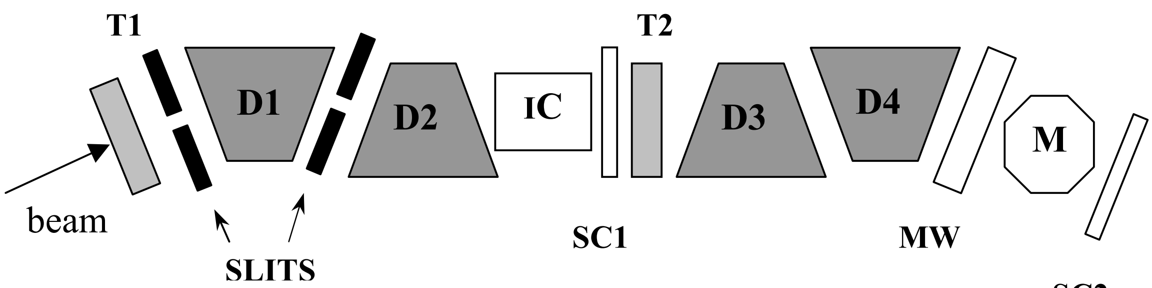


Figure 2. Position distribution of tin isotopes at S2 with proposed settings.



<u>LEGEND:</u>
D1…D4 – FRS dipole magnets
T1, T2 – 1st and 2nd targets
SC1, SC2 – scintillator detectors
MW – multiwire detector
M – MUSIC ionisation chamber
IC – ionisation chamber

Figure 3. A schematic drawing on the proposed setup.

3. Rate considerations and beam time request

From figure 1, one can deduce that a level of 0.1 mb in cross section would be needed to make the difference in between the predictions of the two models. The estimated rates occurring in the experiment aiming to this precision are presented in table 2. The cross sections of neutron-rich secondary fragments with Z ≈ 46 can be obtained with 3 magnetic settings of the second part of FRS. If a spill cycle of 5 s is used, the production rate for the fragments with cross sections of about 0.1 mb will be about 10 cts/day. Considering the amount of settings and the rates of table 1 we need 3.5 days of beam time for defining the needed cross sections with error bars on the order of 20%.

For the confirmation of the right selection of the secondary beam, half a day of beam time with scanning with different magnetic fields would be needed. The preparations and the actual production run could be combined in a common block with the beam time of experiment S227.

Table 2. The estimated rates.

Beam: ^{238}U, E = 1 A GeV
Beam intensity: 10^9 particles / spill
Total rate at S2 IC ≈ 5000 / spill
The percentage of cross section of ^{132}Sn to the total cross section at S2 ≈ 3.5 %
The purity of ^{132}Sn ≈ 92.0 % (when slits at –2 cm and +4 cm)
Intensity of ^{132}Sn ≈ 590 / spill
Cross section level studied with the second target = 0.1 mb
The rate of the secondary fragments (Z=46) at 0.1 mb cross section ≈ $4.8 \cdot 10^{-4}$ / spill
≈ 10 / day with spill cycle of 5 s

As a conclusion, a total of 4 days of beam time with ^{238}U beam at the energy of 1 A GeV is requested.

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