Cross section measurement of residues in proton- and deuteron-induced spallation reactions of ^{93}Zr and ^{93}Nb

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The long-lived fission products (LLFPs), which are produced in nuclear reactors have been an important issue because of the difficulty of their disposal owing to their remarkably long lifetimes. Therefore, a treatment method to transform the LLFPs into short-lived and/or low-toxic materials is strongly desired, and nuclear transmutation technology is one of the promising candidates for this. However, the reaction data of LLFPs required for the design of optimum pathways of the transmutation process are currently quite scarce.

We performed an experiment to measure isotopic production cross section of ^{93}Zr, which is an LLFP nuclide with a half-life of 1.61×10^6 years, using proton- and deuteron-induced spallation reactions at the RIKEN RI Beam Factory (RIBF). For the experimental setup, see Ref.[1]

Figure 1 shows one of the plots, which was used for particle identification using the ZeroDegree spectrometer (ZDS). Each reaction residue was successfully identified with a 10σ separation of mass number A. The isotopic production cross section was obtained from the production yield for each nuclide and the number of beam particles. The transmission ratio in the ZDS was estimated from the position distribution at a dispersive focal plane F9. Then the cross sections were compared with the calculations using PHITS[2] with the Intra-Nuclear Cascade model of Liège (INCL)[3] and the Generalized Evaporation Model (GEM)[4]. Figure 2 shows the preliminary results for Nb, Zr, Sr, and Kr isotopes corresponding to proton- and deuteron-injection. The calculations reproduced the experimental cross section to some extent, but they underestimate the number of evaporated neutrons and hence the resulting cross sections are distributed in an A region slightly larger than the experimental ones. Further examination of the calculation models is needed.

The analysis for the spallation reaction on ^{93}Nb, which was included in the ^{93}Zr beam setting, is underway. The cross sections of ^{93}Nb will be compared with the experimental data obtained using the activation method[5] in order to verify the effectiveness of the method used in this experimental series.
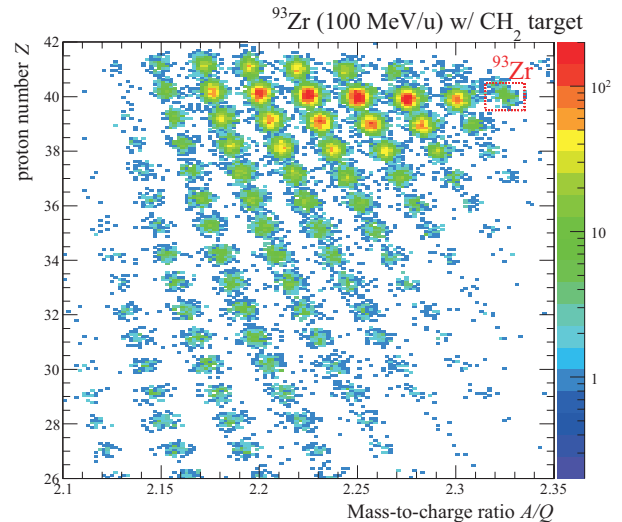
Fig. 1. Correlation of proton number Z and mass-to-charge ratio A/Q of reaction residues produced from ^{93}Zr beam at 100 MeV/u and CH$_2$ target.
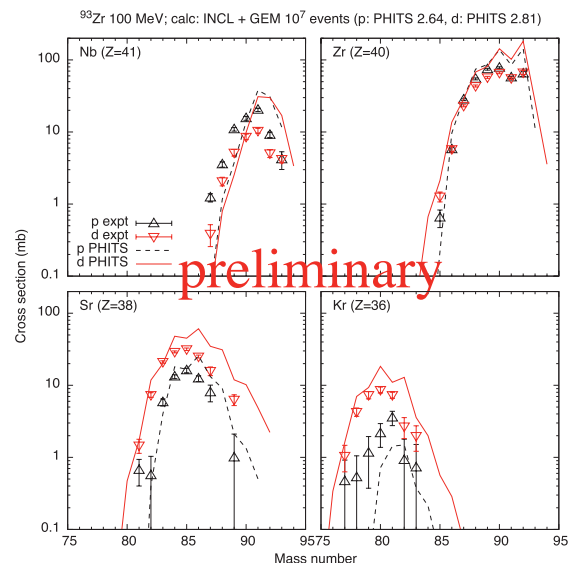

Fig. 2. Experimental and calculated cross sections for spallation reactions of ^{93}Zr at 100 MeV/u with protons and deuterons.

References
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