Cross section measurement for the spallation reaction of long-lived fission products

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Long-lived fission products (LLFPs) are one of the major components in the nuclear waste from nuclear reactor systems. LLFP nuclei are highly radioactive and have long half lives. In order to reduce the quantity of high-level radioactive waste, partitioning and transmutation technology has been introduced in recent years[1]. For LLFP transmutation, the possibility of proton-induced spallation reaction has been discussed[2]; however, experimental data are insufficient. For a systematic study on LLFP transmutation, we report on the spallation reactions for ^{90}Sr, ^{93}Zr, ^{107}Pd, and ^{135}Cs with protons and deuterons at different reaction energies, following the study for ^{90}Sr and ^{137}Cs in 2014[3].

Secondary beams were produced by the in-flight fission of a ^{238}U primary beam at 345 MeV/nucleon on a beryllium target with a thickness of 1 mm. The momentum acceptance of BigRIPS was set as 0.1%. Several secondary beam settings were applied in BigRIPS and optimized for ^{90}Sr, ^{93}Zr, ^{107}Pd, and ^{135}Cs. Note that the secondary ^{90}Sr and ^{93}Zr beams were produced with the same BigRIPS setting. The beam energies for ^{90}Sr, ^{93}Zr, ^{107}Pd, and ^{135}Cs were approximately 115 MeV/nucleon in front of the secondary targets. In addition, another setting was used for ^{107}Pd to study the reaction at a high reaction energy of 220 MeV/nucleon. Secondary cocktail beams were identified event-by-event via the TOF $- B\rho - \Delta E$ method by using standard BigRIPS diagnosis detectors[4].

To induce the secondary reactions, CH_2, CD_2[5], and ^{12}C targets were used. Their thicknesses were 179.2, 217.8, and 226.0 mg/cm^2, respectively. In order to obtain the background contribution, data were accumulated using the target holder with no target inserted.

Reaction residues were identified by measuring TOF, $B\rho$, ΔE, and the total kinetic energy in the ZeroDegree spectrometer[6] with the large acceptance mode. In order to cover a broad range of spallation products, several different $B\rho$ settings were applied in the ZeroDegree spectrometer. An example of the particle identification (PID) for the reaction residues detected by the ZeroDegree spectrometer is shown in Fig. 1. The PID plot was obtained in the ^{107}Pd setting at 220 MeV/nucleon with the CD_2 target.

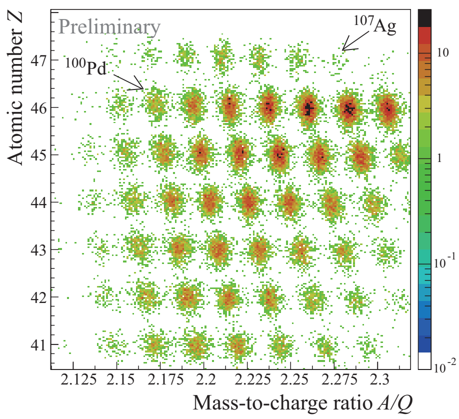

Fig. 1. Particle identification plot of Z versus A/Q in the ZeroDegree spectrometer for the reaction residues produced from the ^{107}Pd beam at 220 MeV/nucleon.

The analysis of the proton- and deuteron-induced cross sections for the LLFP nuclei is currently in progress. This work was supported by ImPACT program of Council for Science, Technology and Innovation (Cabinet Office, Government of Japan).

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