Production of ^{237}Np from ^{238}U beam at BigRIPS

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A variety of unstable nuclear beams with atomic numbers (Z) up to 92 can be produced by the projectile fragmentation and in-flight fission from high-intensity U beams at RIBF. Recently, it was found that $^{234-238}$Np can be created by a proton pickup reaction on 1 GeV/nucleon ^{238}U beam.[1)] Owing to the recent developments of the high-Z beams at BigRIPS,[2,3)] energy dependence of the proton pickup reaction on ^{238}U can be obtained at RIBF. Thus, we conducted an experiment to determine the energy dependence of the production cross section of ^{237}Np. A test of the production of Np isotopes was performed by using the BigRIPS spectrometer at RIBF in March 2022.

Secondary beams around $Z = 90$ were produced by a ^{238}U beam with energies of 345 and 250 MeV/nucleon[4)] impinging on a 1-mm-thick ^{9}Be production target at F0 in BigRIPS. To reduce ambiguity of production cross section, no degraders for separation were inserted in the F1/F5 dispersive focal planes. The particle identification (PID) of the secondary beam was performed using the TOF-$B\rho$-ΔE method.[5)] Plastic scintillators at F3 and F7, and parallel-plate avalanche counters (PPACs) at F3, F5, and F7 were installed, respectively. As no materials were installed at F1, charge states of ions were unchanged between F0 and F3. The configuration of the BigRIPS was optimized for the production of a ^{237}Np beam, with magnetic rigidity $B\rho$ values at D1, D2, D3-D4, and D5-D6 set to optimized for fully-stripped, fully-stripped, H-like, and He-like ^{237}Np ions, respectively. Further, newly developed ionization chamber (IC) with xenon-based gas was utilized at F7 for better separation of Z at high-Z region.[6)]

Figure 1 shows a PID plot of Z vs. A/Q, with typical relative A/Q and Z resolutions of 0.057% and 0.43% in 1σ, respectively. Calibrations of A/Q and Z were conducted using primary beams of $^{238}U^{90+,91+}$ that had passed through the 1-mm-thick Be target. Even with the new IC, the blobs, corresponding to nuclides of incoming beam, are not clearly separated. To validate the production of the $^{237}Np^{91+}$, a two-dimensional (2D) Gaussian fitting approach was conducted in accordance with the distribution patterns of neighboring ions of $^{234}U^{90+}$,$^{235}U^{90+}$, and $^{232}Pa^{89+}$. Figure 2(a) shows the experimental data and the fitted distribution by the 2D Gaussian function in color lego and red mesh, respectively. By subtracting the fitted distribution from the experimental data, the residuals were deduced and are presented in Fig. 2(b). As evident the blob of $^{237}Np^{91+}$ at $Z = 93$ and $A/Q = 2.604$. As shown in Fig. 2(b), it was found that $^{237}Np^{91+}$ can be counted up with contaminated U/Pa isotopes using the 2D Gaussian fitting technique. In the future, we plan to determine the production cross section by examining the beam amount and transport efficiency. We are also planning to analyze the data of 250 MeV/nucleon to discuss the energy dependence of the production cross section.

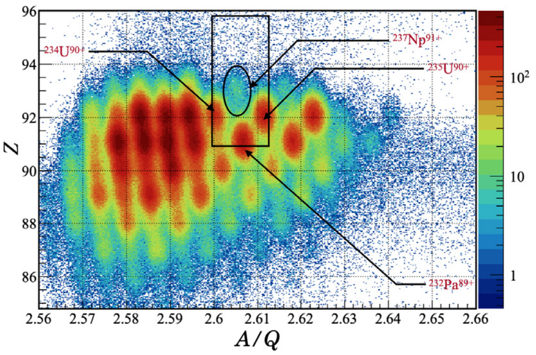

Fig. 1. Particle identification plot of Z vs. A/Q for fragments produced in the 345-MeV/nucleon ^{238}U. The box region around $^{237}Np^{91+}$ was used for the two-dimensional fitting approach (see Fig. 2).

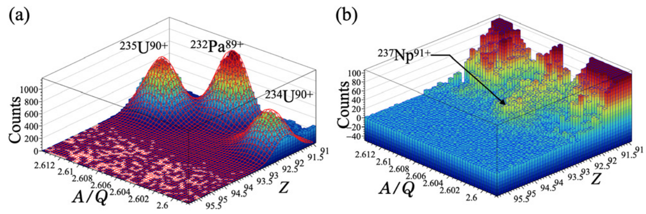

Fig. 2. (a) 3D-lego plots of PID around $^{237}Np^{91+}$ in the box region of Fig. 1. (b) Residual by subtracting the fitted distribution from the experimental data.

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