# RI beam production at BigRIPS in 2018

Y. Shimizu,[*1] N. Fukuda,[*1] H. Takeda,[*1] H. Suzuki,[*1] D. S. Ahn,[*1] N. Inabe,[*1] K. Kusaka,[*1] M. Ohtake,[*1] Y. Yanagisawa,[*1] T. Komatsubara,[*1] H. Sato,[*1] K. Yoshida,[*1] and T. Uesaka[*1]

The radioactive isotope (RI) beam production at the BigRIPS fragment separator[1] in 2018 is presented here. Table 1 summarizes the experimental programs that involved the use of the BigRIPS separator during this period and the RI beams produced for each experiment.

In the spring beam time, the $^{18}$O beam campaign was performed with seven experiments. The $^{10,12,14}$Be beams were delivered to the SAMURAI spectrometer to study the cluster structure of neutron-rich Beryllium isotopes. The $^{14}$O beam was produced to investigate the single-particle structure and nucleon correlation in exotic nuclei using knockout reactions. Cocktail beams of $^{14}$Be, $^{11}$Li, and $^{8}$He were produced to measure the spin-isospin responses of the neutron dripline nuclei. $^{9}$C beam was produced to study the single-particle structure of $^{8}$B relevant to nuclear astrophysics. Two machine studies were performed to develop the dispersion-matched ion-optical system of the SRC and BigRIPS.[2,3] The BigRIPS group has measured the production cross-sections of the proton-rich nuclei for the Li–F region and the momentum distribution of $^{10}$C beam in the machine study.[4]

In the autumn beam time, the $^{238}$U beam campaign was conducted with seven experiments. $^{134,136}$Sn beams were produced to study the unbound $\gamma$-decaying states in $^{133,135}$Sn. The first physics experiments using the Rare-RI Ring were performed to measure the precise masses of $^{74,76}$Ni, $^{122}$Rh, and $^{124}$Pd isotopes. The BRIKEN experiment was performed to measure the beta-delayed multi-neutron emission probabilities in the rare-earth region using the cocktail beam around $^{165}$Pm. The first experiment with the VANDLE array setup was performed to study the beta-delayed neutron emission in the vicinity of $^{78}$Ni using the cocktail beam around $^{82}$Cu. The $^{132}$Sn beam was used to produce the tertiary $^{130}$Sn beam using a two-step scheme with a momentum-dispersion matching technique[5] at F5. The tertiary $^{130}$Sn beam was delivered to F12 for the magnetic moment measurement using the time-differential perturbed angular distribution method.

The number of experiments using RI beams at the BigRIPS separator is tallied in Table 2 for various primary beams in each year. A total of 174 experiments have been performed so far. Figure 1 shows the RI beams produced in 2018 at the BigRIPS separator on

Table 1. List of experimental programs and RI beams produced at the BigRIPS separator in 2018.

| Primary beam (Period) | Proposal No. | Course | RI beams |
|---|---|---|---|
| $^{18}$O 230 MeV/nucleon (May 15 – Jun. 8) | NP1612-SAMURAI12R1 | SAMURAI | $^{10,12,14}$Be, $^{4}$He |
| | NP1512-SAMURAI31 | SAMURAI | $^{14}$O |
| | MS-EXP18-03 | BigRIPS | $^{9}$C |
| | NP1412-SAMURAI30 | SAMURAI | $^{14}$Be/$^{11}$Li/$^{8}$He |
| | MS-EXP18-04 | BigRIPS | $^{17,18}$F, $^{13,14,15}$O, $^{12,13,17,18}$N, $^{9,10,11,14}$C, $^{8,13,14}$B, $^{7,10,11}$Be, $^{6}$Li |
| | NP1412-SAMURAI29R1 | SAMURAI | $^{9}$C |
| | MS-EXP18-02 | BigRIPS | $^{9}$C |
| $^{238}$U 345 MeV/nucleon (Oct. 16 – Dec. 10) | NP1712-RIBF162 | ZeroDegree | $^{134,136}$Sn |
| | NP1612-RIBF149 | | |
| | NP1612-RIRING2 | Rare-RI Ring | $^{74,76}$Ni |
| | NP1612-RIBF148-03 | ZeroDegree | $^{165}$Pm |
| | NP1712-RIRING1R1 | Rare-RI Ring | $^{124}$Pd, $^{122}$Rh |
| | NP1512-RIBF136 | ZeroDegree | $^{82}$Cu |
| | INSPECTION18 | BigRIPS | |
| | NP1712-RIBF143R1 | F12 | $^{132}$Sn |

*1 RIKEN Nishina Center

Table 2. Number of experiments performed using RI beams in each year.

| Year | $^{238}$U | $^{124}$Xe | $^{86}$Kr | $^{78}$Kr | $^{70}$Zn | $^{48}$Ca | $^{18}$O | $^{16}$O | $^{14}$N | $^{4}$He | $^{2}$H | Yearly total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2007 | 4 | | 1 | | | | | | | | | 5 |
| 2008 | 2 | | | | | 4 | | | | | | 6 |
| 2009 | 3 | | | | | 3 | | | 3 | 1 | | 10 |
| 2010 | | | | | | 10 | 1 | | 2 | | 1 | 14 |
| 2011 | 4 | 2 | | | | | 2 | | | | | 8 |
| 2012 | 6 | 3 | | | 1 | 4 | 6 | | | | | 20 |
| 2013 | 4 | 2 | | | | | 3 | | | | | 9 |
| 2014 | 11 | | | | 1 | 3 | | 1 | | | 1 | 17 |
| 2015 | 15 | | | 6 | | 4 | | | | | 1 | 26 |
| 2016 | 13 | 1 | | | | 6 | 2 | | | | | 22 |
| 2017 | 13 | | | | 4 | 2 | 3 | | | | | 22 |
| 2018 | 7 | | | | | | 7 | | | | | 14 |
| Total | 82 | 8 | 1 | 6 | 6 | 36 | 24 | 1 | 5 | 1 | 3 | 173 |

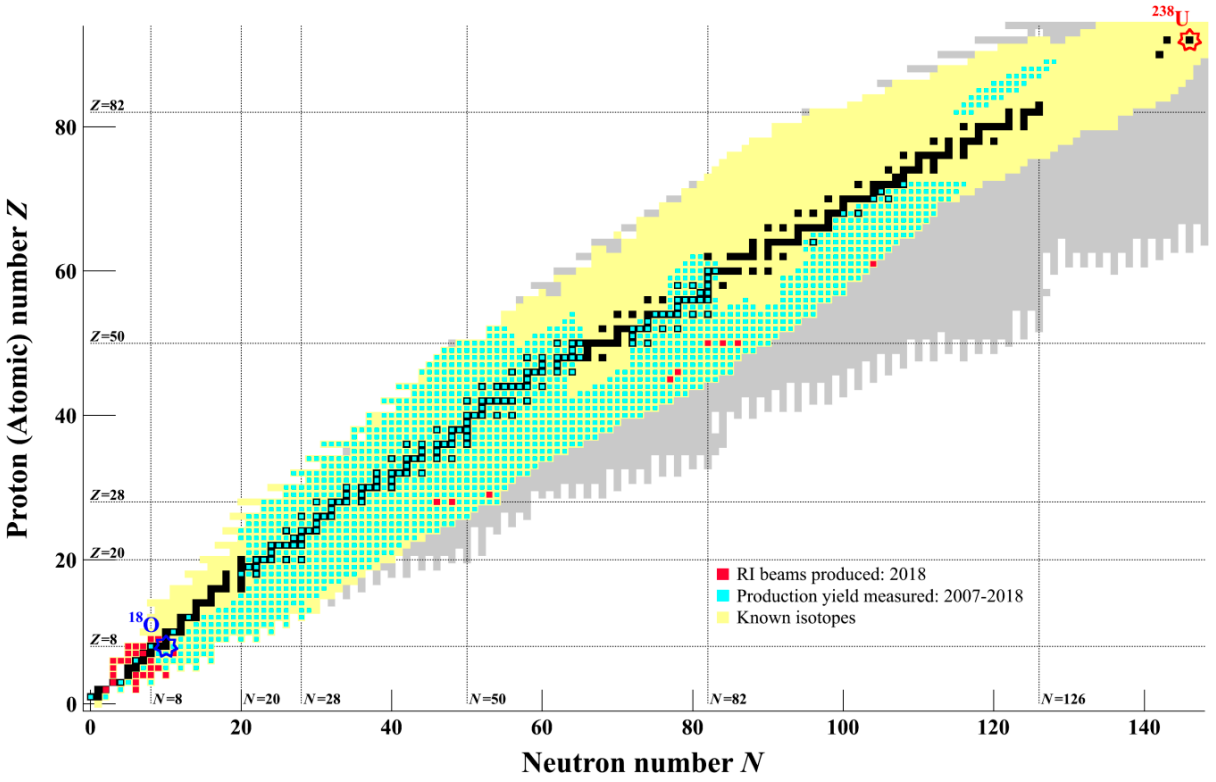


Fig. 1. RI beams produced in 2018 and the production yield measured from March 2007 to December 2018 at the BigRIPS separator.

the table of nuclides with red squares. The number of RI beams produced in 2018 is 40. The production yields for 1608 RI beams have been measured from March 2007 to December 2018 and they are indicated using cyan. The yellow color indicates the known isotopes. The number of new isotopes is approximately 140.

References
1) T. Kubo, Nucl. Instrum. Methods Phys. Res. B **204**, 97 (2003).
2) S. Y. Matsumoto *et al.*, in this report.
3) T. Nishi *et al.*, in this report.
4) H. Takeda *et al.*, in this report.
5) Y. Ichikawa *et al.*, Nature Phys. **8**, 918 (2012).