RI beam production at BigRIPS in 2019

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 2019 is reported 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, a ^{78}Kr beam campaign was conducted with eight experiments. A ^{67}Se beam was delivered to the SAMURAI spectrometer to study the proton-unbound state of ^{66}Se relevant to the *rp*-process. A PALIS experiment was performed to confirm the practical feasibility using the same settings as for the ^{67}Se beam. A ^{62}Zn beam and, thereafter, a cocktail beam of ^{62}Ga and ^{62}Ge were produced to measure the Coulomb excitation of the $A = 62$ isospin triplets and to extract the $B(E2)$ values as well as proton and isoscalar multipole matrix elements. A ^{56}Zn beam was produced to perform the first γ-ray spectroscopy of the $T_Z = -2$ nucleus ^{56}Zn to investigate the mass dependence of the isospin-breaking effects. ^{48}Cr and ^{64}Ge beams were produced to study Gamow-Teller transitions via the (p, n) reaction on the $N = Z$ unstable nuclei ^{48}Cr and ^{64}Ge. The BigRIPS group measured the production cross sections of the proton-rich nuclei around ^{54}Zn and ^{43}Cr regions, and searched the new isotopes for ^{37,38}Ti and ^{47}Cr.[2]

After the ^{78}Kr beam campaign, a ^{124}Xe beam campaign was conducted with four experiments. A ^{101}Sn beam was produced to measure the energy of the first 2^+ state in ^{100}Sn. A ^{102}Sn beam was produced to study the $E2$ transition strength of ^{102}Sn. An experiment with the DTAS setup was performed to measure the probability of beta decay to excited states populated in the decay of ^{100}Sn using a cocktail beam of nuclei around ^{100}Sn.

In the autumn beam time, a ^{238}U beam campaign was conducted with six experiments. A ^{132}Sn beam was produced to study the ground-state properties of ^{132}Sn using proton elastic scattering with the ESPRI setup. A PALIS experiment was performed to study the extraction efficiency using alpha emitters around the ^{208}Rn region. A cocktail beam of ^{127}Sn and ^{128}Sn was delivered to F8 for the magnetic moment measurement using the time-differential perturbed angular distribution method. Three machine studies[3–5] were performed to develop the production of the neutron-rich nuclei with $N = 126$, the production of a slowed-down RI beam using momentum-compressed optics, and the

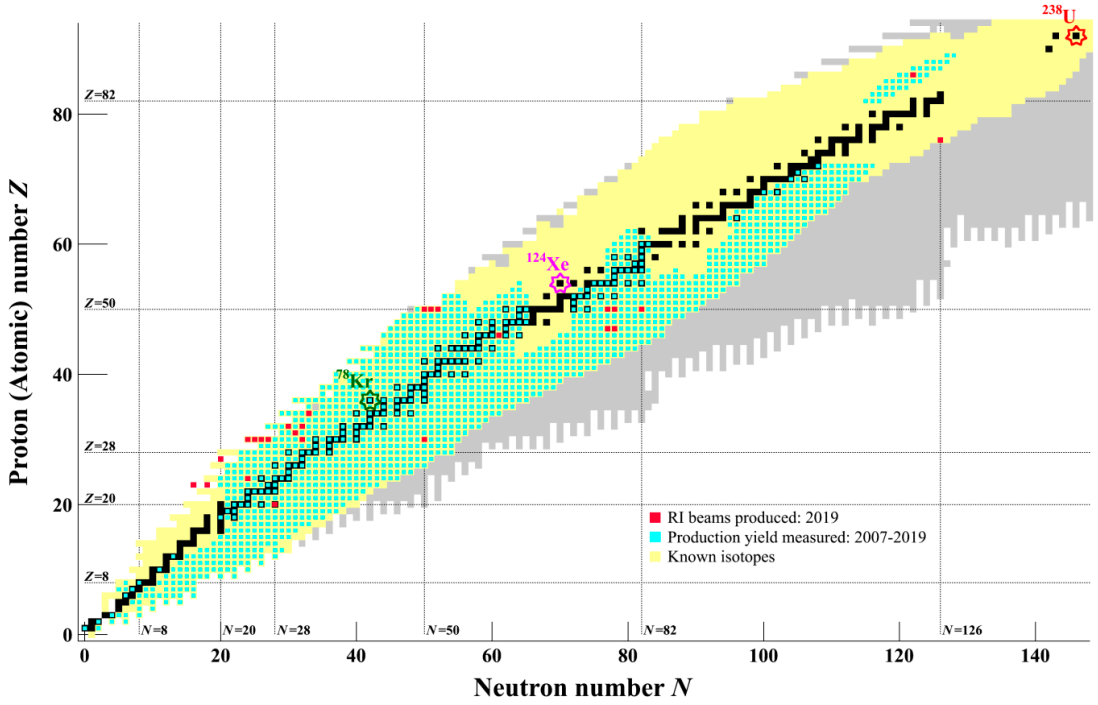

Fig. 1. RI beams produced in 2019 and the production yield measured from March 2007 to December 2019 at the BigRIPS separator.

*1 RIKEN Nishina Center

ion optics of the large-acceptance-dispersive mode for the ZeroDegree spectrometer.

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 191 experiments have been performed so far. Figure 1 shows the RI beams produced in 2019 at the BigRIPS separator on the table of nuclides with red squares. The production yields for 1608 RI beams have been measured from March 2007 to December 2019, and they are indicated with cyan squares.

References
1) T. Kubo, Nucl. Instrum. Methods Phys. Res. B **204**, 97 (2003).
2) H. Suzuki *et al.*, in this report.
3) N. Fukuda *et al.*, in this report.
4) T. Sumikama *et al.*, in this report.
5) H. Takeda *et al.*, in this report.

Table 1. List of experimental programs and RI beams produced at the BigRIPS separator in 2019.

Primary beam (Period)	Proposal No.	Course	RI beams
^{78}Kr 345 MeV/nucleon (Mar. 19 – Apr. 18)	NP1406-SAMURAI24	SAMURAI	^{67}Se, ^{1}H
	NP1712-RIBF166-01	PALIS	^{67}Se
	NP1712-RIBF151R1	ZeroDegree	^{62}Ge/^{62}Ga, ^{62}Zn
	NP1712-RIBF145R1	ZeroDegree	^{56}Zn/^{57}Zn
	MS-EXP19-01	ZeroDegree	^{54}Zn, ^{41}V$^{\#}$
	NP1612-SAMURAI11R1-01/02	SAMURAI	^{48}Cr, ^{64}Ge
	NP1512-RIBF104R1	ZeroDegree	^{54,55,56}Zn
	DA19-01-01	BigRIPS	^{47}Co$^{\#}$, ^{39}V$^{\#}$
^{124}Xe 345 MeV/nucleon (May 29 – Jun. 18)	NP1612-RIBF146	ZeroDegree	^{101}Sn
	NP1612-RIBF153R1	ZeroDegree	^{102}Sn
	NP1612-RIBF147	ZeroDegree	^{100}Sn
	PE19-01	BigRIPS	
^{238}U 345 MeV/nucleon (Nov. 18 – Dec. 6)	NP1512-RIBF79R1	F12	^{132}Sn, ^{48}Ca
	NP1712-RIBF166-02	PALIS	^{208}Rn
	MS-EXP19-06	BigRIPS	^{202}Os
	MS-EXP19-04	ZeroDegree	^{107}Pd
	MS-EXP19-05	ZeroDegree	^{80}Zn
	NP1712-RIBF157	F8	^{124}Ag/^{125}Ag, ^{127}Sn/^{128}Sn

$^{\#}$ assumed RI beam for the BigRIPS spectrometer

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
2019	6	4		8								18
Total	88	12	1	14	6	36	24	1	5	1	3	191