

RI beam production at BigRIPS in 2015

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The radioactive isotope (RI) beam production at the BigRIPS fragment separator¹⁾ in 2015 is presented. Table 1 summarizes the experimental programs that involved the use of the BigRIPS separator in this period and the RI beams produced for each experiment.

The first uranium beam time started in March with the ImPACT program at the ZeroDegree spectrometer. To study the nuclear-transmutation reaction for the long-lived fission products, ¹³⁵Cs, ^{108,107}Pd, ^{94,93}Zr, and ⁹⁰Sr were produced by the in-flight fission of the ²³⁸U beam. The SEASTAR campaign were performed to measure $E(2_1^+)$ energies of

¹¹⁰Zr, ¹⁰⁰Kr, ⁹⁴Se, ⁸⁸Ge, and ⁸⁴Zn. The polarized ²H beam experiment was performed to investigate the three nucleon force. The ⁷⁸Kr primary beam was provided for the first time. We have measured the production yields and the production cross sections for a variety of RI beams produced by projectile fragmentation of the ⁷⁸Kr beam²⁾. Highly proton-rich isotopes, such as ⁶⁷Kr, ⁶³Se, and ⁵⁹Ge, from the ⁷⁸Kr beam were delivered to the EURICA experiments. Search for new proton-rich isotopes was performed. The spring beam time ended with the Rare RI Ring commissioning using the ⁷⁸Kr primary beam.

Table 1. List of experimental programs together with RI beams produced at the BigRIPS separator in 2015.

Primary beam (Period)	Proposal No.	Course	RI beams
²³⁸ U 345 MeV/nucleon (Mar. 26 – May 8)	IMPACT14-01	ZeroDegree	¹³⁵ Cs, ^{108,107} Pd, ^{94,93} Zr, ⁹⁰ Sr
	NP1406-RIBF126	ZeroDegree	^{77,73} Cu
	NP1306-RIBF98R1	ZeroDegree	¹³⁶ Te
	MS-EXP15-03	BigRIPS	¹³² Sn
	MS-EXP15-02	BigRIPS	¹³² Sn
	NP1312-RIBF18R1 (SEASTAR) PE15-01	ZeroDegree ZeroDegree	¹¹¹ Nb, ¹⁰¹ Rb, ⁹⁵ Br, ⁸⁹ As, ⁸⁵ Ga
² H 190 MeV/nucleon (May 12 – May 16)	NP1112-RIBF65-02	BigRIPS	² H (primary beam)
⁷⁸ Kr 345 MeV/nucleon (May 24 – Jun. 22)	NP1112-RIBF94-02	ZeroDegree	^{72,70} Kr
	NP0702-RIBF4R1	EURICA	⁶⁷ Kr, ⁶³ Se, ⁵⁹ Ge, ⁵¹ Ni
	NP1112-RIBF82	EURICA	^{66,64} Se, ⁶⁰ Ge
	NP1112-RIBF93	EURICA	^{71,70} Kr
	DA14-02-04	BigRIPS	⁵⁹ Ge
	MS-EXP15-04	Rare RI Ring	⁷⁸ Kr (primary beam)
²³⁸ U 345 MeV/nucleon (Oct. 20 – Nov. 14)	MS-EXP15-01	ZeroDegree	²¹² Ra, ¹³⁶ Sn
	IMPACT15-01	SAMURAI	
	MS-EXP15-06	SAMURAI	^{94,93} Zr, ^{80,79} Se
	MS-EXP15-07	SAMURAI	
	MS-EXP15-08	BigRIPS	¹³² Sn
	MS-EXP15-09	BigRIPS	¹³² Sn
	NP1412-RIBF124R1	F8	⁷⁶ Zn
	NP1306-RIBF99	F8	⁹⁹ Zr
⁴⁸ Ca 345 MeV/nucleon (Nov. 19 – Dec. 4)	MS-EXP15-10	BigRIPS	⁴⁸ Ca (primary beam)
	MS-EXP15-11	SAMURAI	¹ H
	NP1312-SAMURAI21	SAMURAI	²⁹ Ne, ²⁹ F, ²⁴ O, ²⁰ F
	MS-EXP15-12	Rare RI Ring	³⁸ K

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The second uranium beam time started in October with the ImPACT program at the SAMURAI spectrometer. A machine study was conducted to investigate particle identification and isotope separation in the region around atomic number $Z = 88$ ³⁾. ^{29}Ne and ^{29}F were produced by projectile fragmentation of a ^{48}Ca beam to study resonance states of the neutron-rich oxygen isotopes $^{27,28}\text{O}$ using the SAMURAI spectrometer. The autumn beam time ended with the Rare RI Ring experiment using the ^{38}K RI beam.

The number of the experiments using the RI beams at the BigRIPS separator is tallied in Table 2, for various primary beams in each year. A total of 115 experiments have been

performed so far. Figure 1 shows the RI beams produced at the BigRIPS separator from March 2007 to December 2015 on the table of the nuclides. The number of RI beams produced at the BigRIPS separator amounted to about 400. The number of new isotopes reached about 140. Production yields for more than 1400 RI beams have been measured.

References

- 1) T. Kubo: Nucl. Instr. Meth. B **204**, 97 (2003).
- 2) H. Suzuki et al.: In this report.
- 3) T. Sumikama et al.: In this report

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	^4He	^2H	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
Total	49	7	1	6	2	28	12	1	5	1	3	115

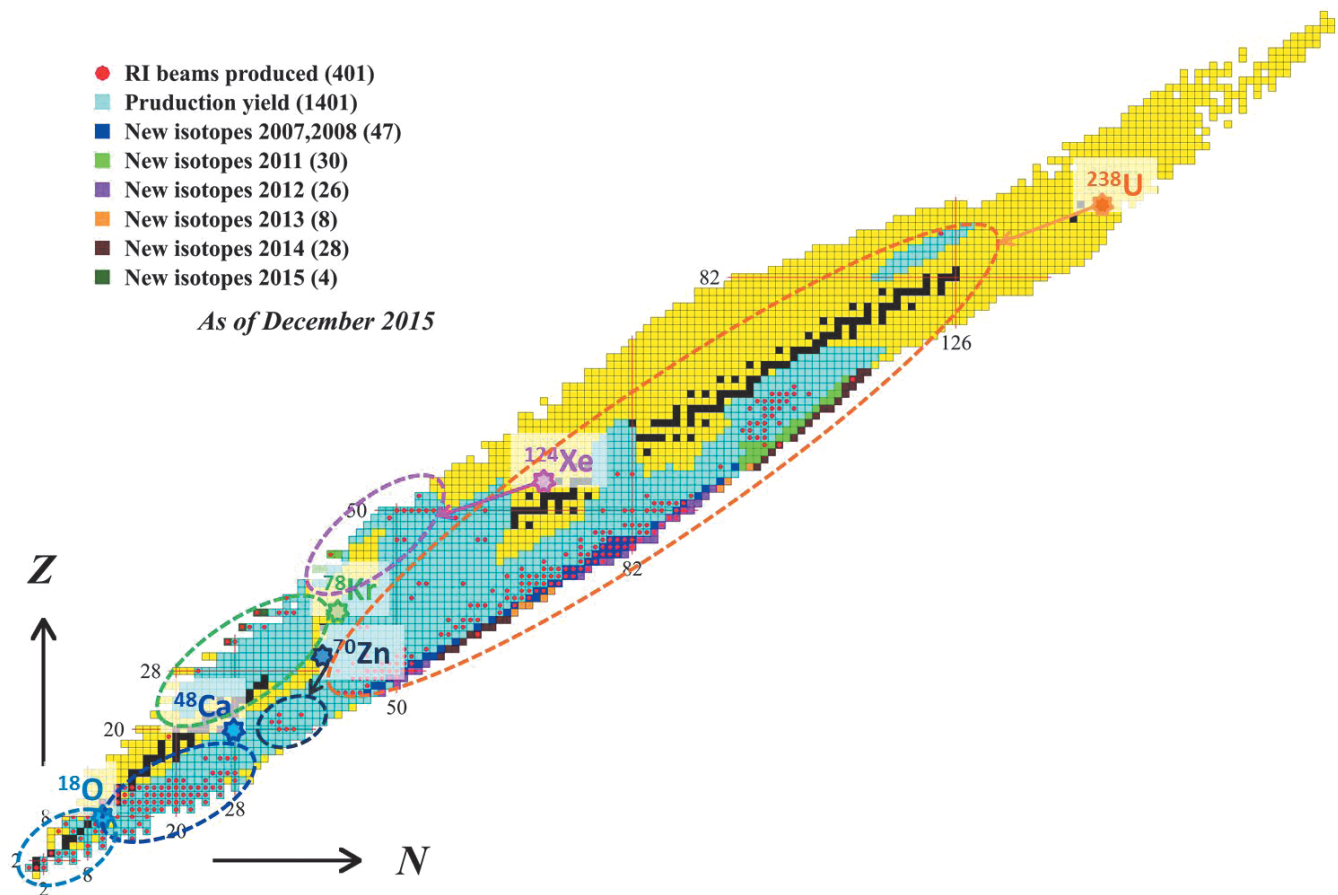


Fig. 1. RI beams produced at the BigRIPS separator from March 2007 to December 2015.