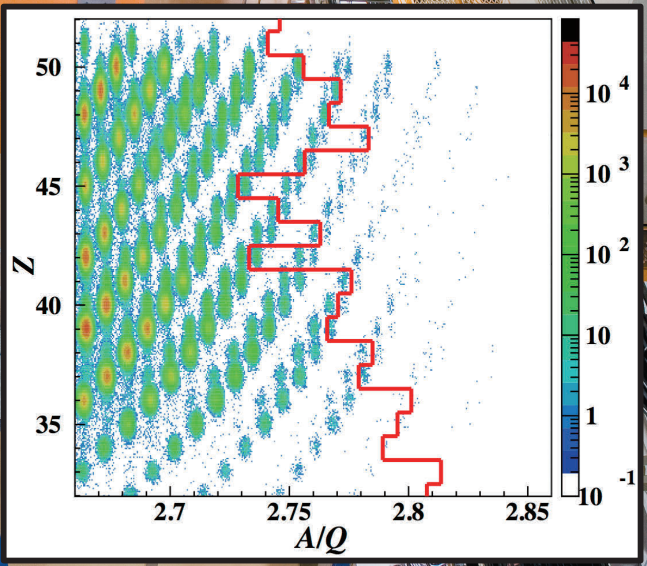
Extending the Nuclear Chart, Expanding our Wisdom

The BigRIPS separator is a new-generation superconducting in-flight fragment separator at the Radioactive Isotope Beam Factory (RIBF). Since 2007, the BigRIPS has produced a wide range of radioactive isotope (RI) beams at unprecedented intensities. It is characterized by large ion-optical acceptances, a two-stage structure, and high resolving power for particle identification (PID).

The large acceptances (±40 and ±50 mrad in the horizontal and vertical directions, respectively, and ±3% in momentum) allow efficient production of RI beams using not only projectile fragmentation, but in-flight fission of a ^{238}U beam with wide kinematical distribution as well.

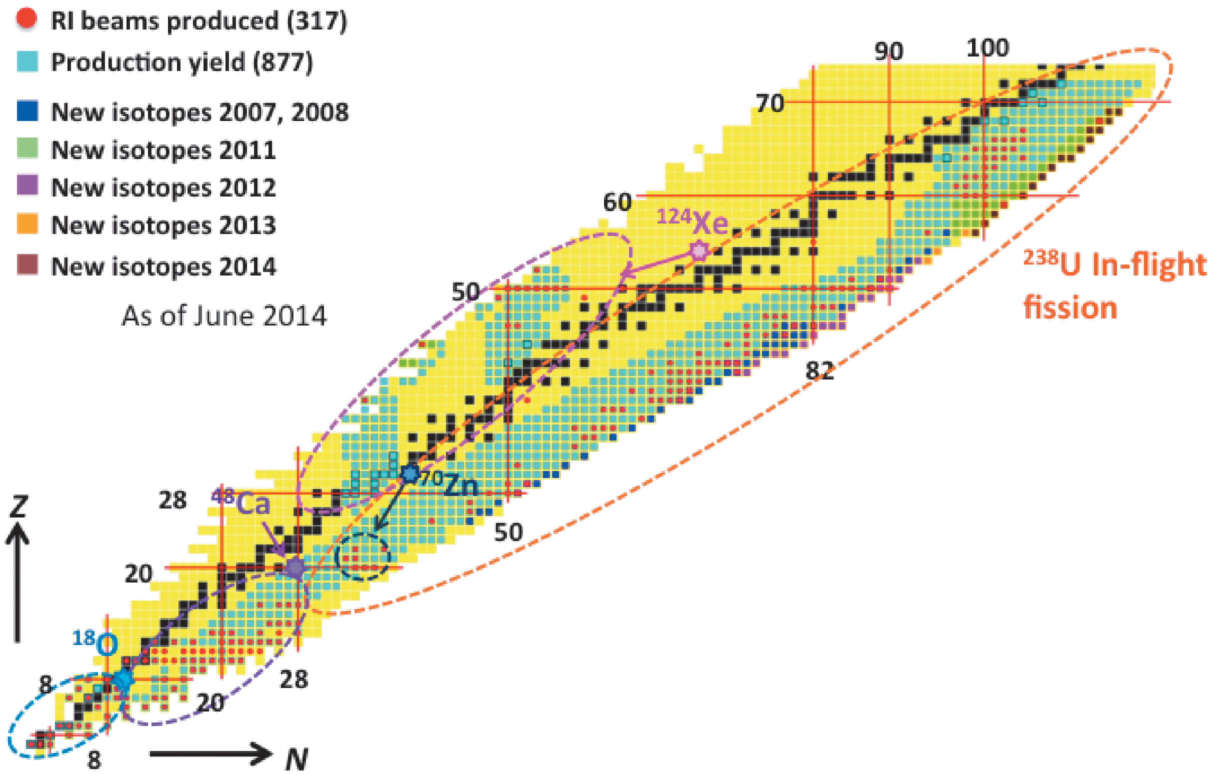
The two-stage structure enables flexible operations, e.g. separator-spectrometer and separator-separator modes, and reduces demands for tagging detectors in the second stage. The latter point results in higher particle identification capability when combined with a high resolving power of the ion-optical system (see page v for details).



RI Beams & New Isotopes for Science

Since 2007, 317 RI beams have been supplied to nuclear physics experiments at the RIBF. The isotopes are produced from primary beams of ^{238}U, ^{124}Xe, ^{70}Zn, ^{48}Ca, and ^{18}O, as shown with red circles in Fig. 1 (see page iv for details).

At the same time, yields and production cross sections have been measured for a total of 877 rare isotopes (light blue squares). Among them 47 (blue squares) and 4 (green squares, proton-rich side) new isotopes produced from the ^{238}U and ^{124}Xe beams are included. The total number of new isotopes produced at RIKEN, since Nishina's discovery of ^{237}U, is 87. This number is still increasing and preliminary results of 69 new isotopes will be reported soon.

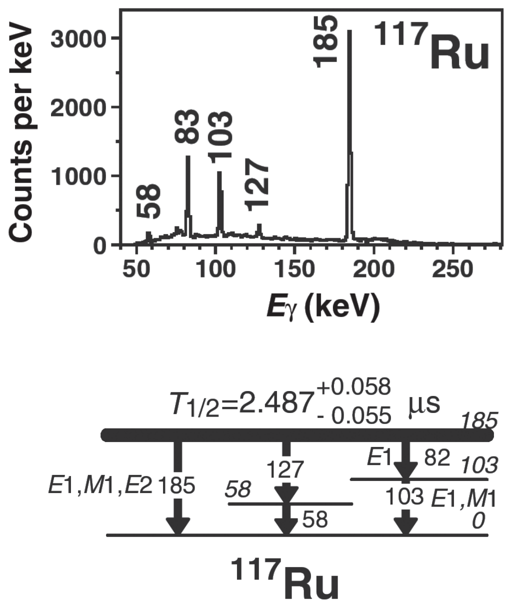


New Isomers

~ Indications of new aspects of nuclear structure ~

We have discovered 18 and 25 new isomers in the new isotope search experiments performed in 2008 and 2011, respectively (see D. Kameda et al., Phys. Rev. C **86**, 054319 (2012) for details). The existence and properties of new isomers provide us with information on the structure of the relevant nuclei that is otherwise unavailable.

The newly discovered isomers are of practical importance too. The characteristic γ-rays from the isomers enable unambiguous particle identification (PID) and can serve as an irreplaceable calibration standard for TOF-Bρ-ΔE PID. A good example is ^{117}Ru shown in the figure on the right. The isomeric states discovered in 2008 have already been used for PID in RI beam production in the EURICA experiments.



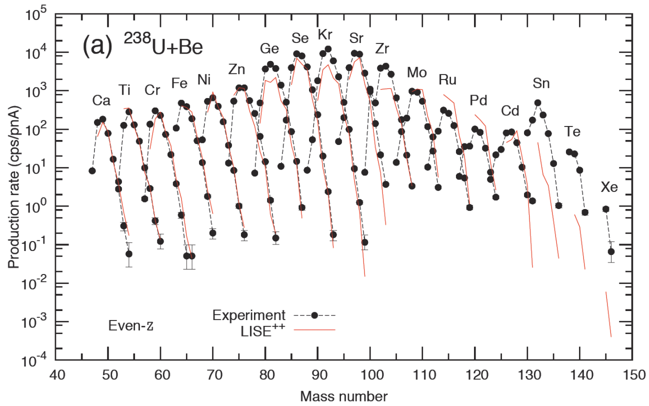
Cross Section and Production Yields of Rare Isotopes

~Baseline of RI-beam science~

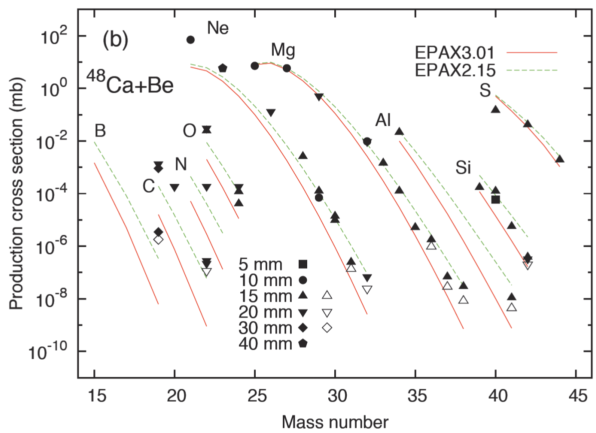
Cross section and production yields of rare isotopes are critical in designing RI-beam experiments. The measured production yields and cross sections are useful to improve our understanding of the reaction mechanism of RI production and refine the theoretical models.
(see pages vi—viii for details)

In figure (a) on the right, the measured production rates from the ^{238}U+Be fission are compared with the LISE++ calculations (version 8.4.1) which employs the abrasion fission (AF) model for the nuclear fission.

The comparison clearly shows a large disagreement in the region of $Z > 50$.



The RI production cross sections by the fragmentation of the ^{124}Xe, ^{70}Zn, ^{48}Ca, and ^{18}O primary beams are compared with predictions of the EPAX3.01 and EPAX2.15 models. EPAX2.15 is found to give better predictions for the ^{48}Ca beam, as shown in the figure (b) on the right, while EPAX3.01 produces successful predictions for the ^{124}Xe primary beam.



These yield and cross section data are available at
http://www.nishina.riken.jp/RIBF/BigRIPS/intensity.html.

Future work

Primary-beam intensities at the RIBF are increasing every year. At the same time, the demand for RI beams with higher Z and/or with higher intensity is increasing.

Recently, several trials were successful in increasing the limits of the counting rate for the detectors and improving A/Q resolution for RI beams with high Z where many charge states are mixed; introduction of Ag electrodes to the parallel plate avalanche counters resulted in better rate duration, i.e. stable operation up to 70 kcps even for RI beams with Z > 60. A new mechanism to shift plastic-scintillator positions, with respect to the beam position, helps us to avoid deterioration of time resolution due to radiation damage by heavy-ion irradiation. New ion-optics is found to be useful in improving the A/Q resolution, where Bρ resolution at the second stage is designed to be doubled compared with the previously used optics.

The BigRIPS team continues to make efforts to provide RI beams with higher intensities and higher qualities.

Hiroshi Suzuki for the BigRIPS team