

Nuclear Science and Transmutation Research Division
 Superheavy Element Research Group
 Superheavy Element Device Development Team

1. Abstract

A gas-filled recoil ion separator has been used as a main experimental device for the study of superheavy elements. This team is in charge of maintaining, improving, developing, and operating the separators and related devices. In the RIBF facility, three gas-filled recoil ion separators are installed at RILAC and RRC facility. One is GARIS that is designed for a symmetric reaction such as coldfusion reaction, and the other two are developed for an asymmetric reaction such as hot-fusion reaction, GARIS-II and GARIS-III. New elements $^{278}113$ were produced by $^{70}\text{Zn} + ^{209}\text{Bi}$ reaction using GARIS. Further the new element search is currently in progress by using GARIS-II and GARIS-III.

2. Major Research Subjects

- (1) Maintenance of GARIS, GARIS-II and development of new separator GARIS-III
- (2) Maintenance and development of detector and DAQ system for superheavy element research
- (3) Maintenance and development of target system for GARIS, GARIS-II and GARIS-III

3. Summary of Research Activity

The GARIS-II and III are newly developed which has an acceptance twice as large as existing GARIS, in order to realize higher transmission. A new element search program aiming to element 119 was started using GARIS-II. And new separator GARIS-III was developed and installed into the RILAC experimental hall. After the some commissioning works of GARIS-III, new 119th element search has been started. We will also offer user-support if a researcher wishes to use the devices for his/her own research program.

Members

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List of Publications & Presentations

Publications

[Original Papers]

- P. Brionnet, R. K. Grzywacz, D. Kaji, T. T. King, T. Niwase, K. Morimoto, K. P. Rykaczewski, and H. Sakai, "Development of digital electronics for the search of SHE nuclei using GARIS-II/III at RIKEN," *Nucl. Instrum. Methods Phys. Res. A* **1049**, 168068 (2023).
- H. Sakai, H. Haba, K. Morimoto, and N. Sakamoto, "Facility upgrade for superheavy-element research at RIKEN," *Eur. Phys. J. A* **58**, 238 (2022).
- M. Tanaka, P. Brionnet, M. Du, J. Ezold, K. Felker, B. J. P. Gall, S. Go, R. K. Grzywacz, H. Haba, K. Hagino, S. Hogle, S. Ishizawa, D. Kaji, S. Kimura, T. T. King, Y. Komori, R. K. Lemon, M. G. Leonard, K. Morimoto, K. Morita, D. Nagae, N. Naito, T. Niwase, B. C. Rasco, J. B. Roberto, K. P. Rykaczewski, S. Sakaguchi, H. Sakai, Y. Shigekawa, D. W. Stracener, S. VanCleve, Y. Wang, K. Washiyama, and T. Yokokita, "Probing optimal reaction energy for synthesis of element 119 from $^{51}\text{V} + ^{248}\text{Cm}$ reaction with quasielastic barrier distribution measurement," *J. Phys. Soc. Jpn.* **91**, 084201 (2022).
- T. Niwase, Y. X. Watanabe, Y. Hirayama, M. Mukai, P. Schury, A. N. Andreyev, T. Hashimoto, S. Iimura, H. Ishiyama, Y. Ito, S. C. Jeong, D. Kaji, S. Kimura, H. Miyatake, K. Morimoto, J. -Y. Moon, M. Oyaizu, M. Rosenbusch, A. Taniguchi, and M. Wada, "Discovery of new isotope ^{241}U and systematic high-precision atomic mass measurements of neutron-rich Pa-Pu nuclei produced via multinucleon transfer reactions," *Phys. Rev. Lett.* **130**, 132502 (2023).
- T. Niwase, W. Xian, M. Wada, M. Rosenbusch, S. Chen, A. Takamine, J. Liu, S. Iimura, D. Hou, S. Yan, H. Ishiyama, H. Miyatake, S. Nishimura, D. Kaji, K. Morimoto, Y. Hirayama, Y. X. Watanabe, S. Kimura, P. Schury, and H. Wollnik, "Development of a β -TOF detector: An enhancement of the α -TOF detector for use with β -decaying nuclides," *Prog. Theor. Exp. Phys.* **2023**, 031H01 (2023).

- M. Rosenbusch, M. Wada, S. Chen, A. Takamine, S. Iimura, D. Hou, W. Xian, S. Yan, P. Schury, Y. Hirayama, Y. Ito, H. Ishiyama, S. Kimura, T. Kojima, J. Lee, J. Liu, S. Michimasa, H. Miyatake, M. Mukai, J. Y. Moon, S. Nishimura, S. Naimi, T. Niwase, T. Sonoda, Y. X. Watanabe, and H. Wollnik, “The new MRTOF mass spectrograph following the ZeroDegree spectrometer at RIKEN’s RIBF facility,” *Nucl. Instrum. Methods Phys. Res. A* **1047**, 167824 (2023).
- S. Iimura, M. Rosenbusch, A. Takamine, Y. Tsunoda, M. Wada, S. Chen, D. S. Hou, W. Xian, H. Ishiyama, S. Yan, P. Schury, H. Crawford, P. Doornenbal, Y. Hirayama, Y. Ito, S. Kimura, T. Koiwai, T. M. Kojima, H. Koura, J. Lee, J. Liu, S. Michimasa, H. Miyatake, J. Y. Moon, S. Naimi, S. Nishimura, T. Niwase, A. Odahara, T. Otsuka, S. Paschalis, M. Petri, N. Shimizu, T. Sonoda, D. Suzuki, Y. X. Watanabe, K. Wimmer, and H. Wollnik, “Study of the $N = 32$ and $N = 34$ shell gap for Ti and V by the first high-precision multireflection time-of-flight mass measurements at BigRIPS-SLOWRI,” *Phys. Rev. Lett.* **130**, 012501 (2023).

[Proceeding]

- H. Sakai, H. Haba, K. Morimoto, and N. Sakamoto, “Facility upgrade for SHE research at RIKEN Nishina Center,” *Acta Phys. Pol. B Proc. Suppl.* **16**, 4-A10-1–12 (2023).

Presentations**[International Conferences/Workshops]**

- H. Sakai (invited), “Facility upgrade for SHE research at RIKEN Nishina Center,” 57th Zakopane Conference on Nuclear Physics, Zakopane, Poland, August 28–September 4, 2022.
- K. Morimoto (oral), “Present status and plans of GARIS-II and GARIS-III,” SSRI-PNS Collaboration Meeting 2022, Wako, Saitama & Online, September 1, 2022.
- S. Kimura (oral), “Study of the neutron-rich ^{252}Cf -fission-fragments with MRTOF-MS,” The 16th International Symposium on Origin of Matter and Evolution of Galaxies (OMEG16), Hanoi, Vietnam, October 24–28, 2022.
- M. Tanaka (poster) and S. Sakaguchi for nSHE Collaboration, “Probing optimal energy for synthesis of element 119 from $^{51}\text{V} + ^{248}\text{Cm}$ reaction,” The 28th International Nuclear Physics Conference (INPC 2022), South Africa, September 11–16, 2022.
- P. Brionnet (invited), “Upgrade of the detection setup of the gas-filled recoil separator GARIS-III,” 19th TASCA22 Workshop, GSI Darmstadt, Germany & Online, May 10–12, 2022.
- P. Brionnet (poster), “Development and optimization of the digital electronic for the search of new super heavy element at RIKEN on GARIS-III,” 19th International Conference on Electromagnetic Isotope Separators and Related Topics, EMIS 2022, Daejeon, South Korea, October 3–7, 2022.

[Seminar]

- H. Sakai, “Facility upgrade for SHE research at RIKEN Nishina Center,” C2R2 Seminar, IBS CENS, September 29, 2022.

[Domestic Conferences/Workshops]

- 倉本幸作 (ポスター発表), 森本幸司, 加治大哉, 武山美麗, 門叶冬樹, 「超重核実験用ピクセル型大面積半導体検出器の性能評価」, 第 37 回 研究会「放射線検出器とその応用」, 茨城県つくば市 (高エネルギー加速器研究機構放射線科学センター), 2023 年 1 月 25–27 日.
- 倉本幸作 (ポスター発表), 森本幸司, 加治大哉, 武山美麗, 門叶冬樹, 「超重核実験用ピクセル型大面積半導体検出器の性能評価」, 第 83 回応用物理学会秋季学術講演会, 東北大学川内北キャンパス & オンライン, 2022 年 9 月 20–23 日.
- 倉本幸作 (口頭発表), 森本幸司, 加治大哉, 武山美麗, 門叶冬樹, 「超重核実験用ピクセル型半導体検出器の不感層評価」, 第 59 回 アイソトープ・放射線研究発表会, オンライン, 2022 年 7 月 6–8 日.