

Nuclear Science 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

Team Leader

Kouji MORIMOTO

Senior Technical Scientist

Daiya KAJI

Contract Researcher

Pierre BRIONNET

Visiting Scientists

Shin-ichi GOTO (Niigata Univ.)

Eiji IDEGUCHI (Osaka Univ.)

Yuta ITO (JAEA)

Sota KIMURA (KEK)

Katsuhisa NISHIO (JAEA)

Toshitaka NIWASE (Kyushu Univ.)

Fuyuki TOKANAI (Yamagata Univ.)

Student Trainees

Hiroki ASANO (Yamagata Univ.)

Koki IKEDA (Niigata Univ.)

Hatsune SASANUMA (Toho Univ.)

List of Publications & Presentations

Publications

[Original Papers]

- F. Tokanai, T. Moriya, M. Takeyama, K. Kuramoto, K. Morimoto, D. Kaji, K. Nakamura, S. Itoh, and K. Kosugi, "Development of pixelated silicon detector for AMS study," Nucl. Instrum. Methods Phys. Res. B **552**, 165353 (2024).
- K. Kuramoto, K. Morimoto, D. Kaji, P. Brionnet, M. Takeyama, K. Kosugi, and F. Tokanai, Jpn. J. Appl. Phys. **62**, 046001 (2023).
- T. Niwase, M. Wada, P. Schury, M. Rosenbusch, D. Kaji, K. Morimoto, S. Kimura, and W. Xian, "Decay-correlated mass measurement technique via multi-reflection time-of-flight mass spectrograph with the α/β -TOF detector," Nucl. Instrum. Methods Phys. Res. B **541**, 197 (2023).
- M. Tajima, A. Takamine, H. Iimura, M. Wada, S. Kimura, T. Niwase, P. Schury, H. A. Schuessler, J. Lassen, and H. Ueno, "Offline development for collinear laser spectroscopy at the SLOWRI facility," Nucl. Instrum. Methods Phys. Res. B **541**, 272 (2023).
- Y. Cho, Y. H. Kim, S. Choi, J. Park, S. Bae, K. I. Hahn, Y. Son, A. Navin, A. Lemasson, M. Rejmund, D. Ramos, D. Ackermann, A. Utepov, C. Fourgeres, J. C. Thomas, J. Goupil, G. Fremont, G. de France, Y. X. Watanabe, Y. Hirayama, S. Jeong, T. Niwase, H. Miyatake, P. Schury, M. Rosenbusch, K. Chae, C. Kim, S. Kim, G. M. Gu, M. J. Kim, P. John, A. N. Andreyev, W. Korten, F. Recchia, G. de Angelis, R. Perez Vidal, K. Rezykina, J. Ha, F. Didierjean, P. Marini, D. Treasa, I. Tsekhanovich, J. Dudouet, S. Bhattacharyya, G. Mukherjee, R. Banik, S. Bhattacharyya, and M. Mukai, "Particle identification at VAMOS++ with machine learning techniques," Nucl. Instrum. Methods Phys. Res. B **541**, 240 (2023).

- P. Schury, Y. Ito, T. Niwase, and M. Wada, “Multi-reflection time-of-flight mass spectroscopy for superheavy nuclides,” *Atoms* **11**, 134 (2023).
- D. S. Hou, A. Takamine, M. Rosenbusch, W. D. Xian, S. Iimura, S. D. Chen, M. Wada, H. Ishiyama, P. Schury, Z. M. Niu, H. Z. Liang, S. X. Yan, P. Doornenbal, Y. Hirayama, Y. Ito, S. Kimura, T. M. Kojima, W. Korten, J. Lee, J. J. Liu, Z. Liu, S. Michimasa, H. Miyatake, J. Y. Moon, S. Naimi, S. Nishimura, T. Niwase, T. Sonoda, D. Suzuki, Y. X. Watanabe, K. Wimmer, and H. Wollnik, “First direct mass measurement for neutron-rich ^{112}Mo with the new ZD-MRTOF mass spectrograph system,” *Phys. Rev. C* **108**, 054312 (2023).
- Y. Hirayama, M. Mukai, P. Schury, Y. X. Watanabe, S. Iimura, H. Ishiyama, S. C. Jeong, H. Miyatake, T. Niwase, M. Rosenbusch, A. Takamine, A. Taniguchi, and M. Wada, “Helium gas cell with RF wire carpets for KEK Isotope Separation System,” *Nucl. Instrum. Methods Phys. Res. A* **1058**, 168838 (2024).
- J. W. Zhao, D. Amanbayev, T. Dickel, I. Miskun, W. R. Plaß, N. Tortorelli, S. Ayet San Andrés, S. Beck, J. Bergmann, Z. Brencic, P. Constantin, H. Geissel, F. Greiner, L. Gröf, C. Hornung, N. Kuzminchuk, G. Kripkó-Koncz, I. Mardor, I. Pohjalainen, C. Scheidenberger, P. G. Thirolf, S. Bagchi, E. Haettner, E. Kazantseva, D. Kostyleva, A. Oberstedt, S. Pietri, M. P. Reiter, Y. K. Tanaka, M. Wada, D. L. Balabanski, D. Benyamin, M. N. Harakeh, N. Hubbard, N. Kalantar-Nayestanaki, A. Mollaebrahimi, I. Mukha, M. Narang, T. Niwase, Z. Patyk, S. Purushothaman, A. Rotaru, A. Spătaru, G. Stanic, M. Vencelj, H. Weick, and J. Yu, “Increasing the rate capability for the cryogenic stopping cell of the FRS Ion Catcher,” *Nucl. Instrum. Methods Phys. Res. B* **547**, 165175 (2024).
- Y. Hirayama, M. Mukai, Y. Watanabe, P. Schury, T. Niwase, H. Choi, T. Hashimoto, S. Iimura, S. C. Jeong, H. Miyatake, J. Y. Moon, H. Nakada, M. Oyaizu, M. Rosenbusch, A. Takamine, M. Tajima, A. Taniguchi, and M. Wada, “In-gas-cell laser ionization spectroscopy at KISS,” *Interactions* **245**, 41 (2024).
- W. Xian, S. Chen, S. Nikas, M. Rosenbusch, M. Wada, H. Ishiyama, D. Hou, S. Iimura, S. Nishimura, P. Schury, A. Takamine, S. Yan, F. Browne, P. Doornenbal, F. Flavigny, Y. Hirayama, Y. Ito, S. Kimura, T. M. Kojima, J. Lee, J. Liu, H. Miyatake, S. Michimasa, J. Y. Moon, S. Naimi, T. Niwase, T. Sonoda, D. Suzuki, Y. X. Watanabe, V. Werner, K. Wimmer, and H. Wollnik, “Mass measurements of neutron-rich $A \approx 90$ nuclei constrain element abundances,” *Phys. Rev. C* **109**, 035804 (2023).

Presentations

[International Conferences/Workshops]

- K. Morimoto (invited), “Status of new element search at RIKEN,” International Conference on Heavy-Ion Collisions at near-barrier energies, Shizuoka, Japan, November 19–24, 2023.
- K. Morimoto (oral), “Present status and plans of GARIS-II and GARIS-III,” SSRI-PNS Collaboration Meeting 2023, Saitama, Japan 22–August 24, 2023.
- H. Sakai (invited), “SHE research at RIKEN Nishina Center,” International Symposium on Physics of Unstable Nuclei (ISPUN23), Phu Quoc Island, Vietnam, May 4–8, 2023.
- H. Sakai (invited), “New SHE $Z = 119$ search and related experiments at RIKEN,” Mazurian Lakes Conference on Physics, Piecki1, Poland, September 9–13, 2023.
- H. Sakai (invited), “Sigurd’s legacy and pleasant memories—My personal recollection—,” Sigurd Hofmann Memorial Colloquium, GSI, Darmstadt, Germany, October 23, 2023.
- P. Brionnet (invited), “Reaction parameter study of the ^{51}V beam onto deformed target: $^{51}\text{V} + ^{159}\text{Tb}$ reaction,” 20th TASCA 2023 Workshop, GSI Darmstadt, Germany & Hybrid, April 25–27, 2023.
- P. Brionnet (oral), “Superheavy research program at RIKEN: GARIS-III setup latest development and experimental results,” 6th Joint Meeting of the APS Division of Nuclear Physics and the Physical Society of Japan, Hawaii, USA, November 26–December 1, 2023.
- T. Niwase (invited, oral), “Recent progress of superheavy element research,” RIBF Users meeting, Japan, September 6–7, 2023.
- T. Niwase (invited, oral), “High-precision direct mass measurement of (super) heavy nuclides with MRTOF via GARIS-II and KISS setups,” 20th TASCA 2023 Workshop, GSI Darmstadt, Germany & Hybrid, April 25–27, 2023.
- T. Niwase (oral), “High-precision mass measurement of the actinide nuclides via MRTOF-MS of the KEK Isotope Separation System,” 14th International Conference on Stopping and Manipulation of Ions and Related Topics (SMI-2023), Giessen, Germany, May 8–11, 2023.
- T. Niwase (oral), “Direct mass measurement of superheavy nuclides by fusion-evaporation reaction,” International Conference on Heavy-Ion Collisions at near-barrier energies, Shizuoka, Japan, November 19–24, 2023.
- F. Tokanai (oral), K. Kosugi (poster), T. Moriya, M. Takeyama, K. Kuramoto, K. Morimoto, D. Kaji, K. Nakamura, and S. Itoh, “Development of pixelated silicon detector for AMS Study,” IBA&PIXE 2023, Toyama, Japan, October 7–13, 2023.

[Domestic Conferences/Workshops]

- 小杉和正 (口頭発表), 門叶冬樹, 森本幸司, 加治大哉, Pierre Brionnet, 武山美麗, 「超重核実験用大面積ピクセル型半導体検出器の性能評価 II」, 第 84 回応用物理学学会秋季学術講演会, 熊本市 (熊本城ホール), 2023 年 9 月 19–23 日.
- 坂口聡志 (招待講演), 「九大実験核重元素核グループの活動と核融合反応機構の研究」, 研究会「現代核物理の広がり」と展望」, 福岡市 (九州大学), 2023 年 7 月 19–21 日.
- 坂口聡志 (招待講演), “Recent activities and future plan of superheavy element group at Kyushu University,” 第 12 回停止・低速 RI ビームを用いた核分光研究会 (12th SSRI), 豊島区 (立教大学), 2023 年 9 月 4–5 日.
- 坂口聡志 (招待講演), 「融合反応における α 粒子放出過程」, 研究会「低エネルギー重イオン反応と超重元素の科学」, 千代田区 (学士会館), 2024 年 3 月 3 日.
- 坂口聡志 (招待講演), “Recent activities at GARIS and future directions,” The Workshop on Frontier Nuclear Studies with Gamma-ray Spectrometer Arrays (Gamma24), 2024 年 3 月 26–28 日.

庭瀬暁隆 (招待講演), 「MRTOF を用いた質量測定と核反応研究」, 第 12 回停止・低速 RI ビームを用いた核分光研究会 (12th SSRI), 豊島区 (立教大学), 2023 年 9 月 4–5 日.

庭瀬暁隆 (口頭発表), 「高精度質量分析器による蒸発残留核断面積の励起関数測定」, 日本放射化学会第 67 回討論会 (2023), 東広島市 (広島大学), 2023 年 9 月 21–23 日.

nSHE Collaboration (口頭発表), 松浦開, 坂口聡志, 庭瀬暁隆, 「超重元素合成実験における解析手法の開発」, 第 129 回日本物理学会九州支部例会, 長崎市 (長崎大学), 2023 年 12 月 2 日.

nSHE Collaboration (口頭発表), 山ノ内邑希, 坂口聡志, 庭瀬暁隆, 「新元素合成のための最適反応エネルギー推定に向けた $^{51}\text{V} + ^{159}\text{Tb}$ 融合反応の励起関数測定」, 日本物理学会 2024 年春季大会, オンライン, 2024 年 3 月 18–21 日.

nSHE Collaboration (口頭発表), 道本優也, 坂口聡志, 庭瀬暁隆, 「新元素合成のための最適反応エネルギー推定に向けた $^{51}\text{V} + ^{159}\text{Tb}$ 融合反応の障壁分布測定」, 日本物理学会 2024 年春季大会, オンライン, 2024 年 3 月 18–21 日.

森本幸司 (招待講演), 「二ホニウム発見とさらなる新元素発見に向けて」, TFC × TEL 協働プログラム特別講演会, 東北大学片平キャンパス, 2024 年 3 月 9 日.

Award

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, J. Phys. Soc. Jpn. Most Cited Articles in 2023, 2024 年 3 月 29 日.