Partner Institution
Wako Nuclear Science Center, IPNS (Institute of Particle and Nuclear Studies)
KEK (High Energy Accelerator Research Organization)

1. Abstract

The Wako Nuclear Science Center (WNSC) of KEK aims to promote low-energy nuclear physics and nuclear astrophysics research as well as interdisciplinary studies using short-lived radioactive nuclei. WNSC operates the KEK Isotope Separation System (KISS), an electromagnetic isotope separator featuring elemental selectivity from resonance laser ionization in a gas catcher. The KISS facility uniquely provides various neutron-rich isotopes of refractory elements via multinucleon transfer reactions to the users from universities. Its provision of nuclei in the vicinity of the neutron magic number $N = 126$. Optical and β-γ spectroscopy have been applied to these neutron-rich nuclear beams for nuclear structure and nuclear astrophysical studies. Several new developments—a rotating target, a donut-shaped gas cell, and an in-jet laser ionization scheme—have been performed to improve the performance of the KISS facility. The WNSC also leads comprehensive mass measurements of all-available nuclides at RIBF using multi-reflection time of flight mass spectrographs (MRTOF-MS). Three MRTOF setups were placed at the GARIS-II, the beam dump of the ZeroDegree Spectrometer, and the KISS. The masses of more ore than 400 nuclides, including superheavy elements, were measured so far. KISS-II is being considered a future project of WNSC. Combining KISS and MRTOF technologies, 10,000 times more performance than conventional methods are expected. It aims to study the origin of uranium for the first time.

2. Major Research Subjects

(1) Production and manipulation of radioactive isotope beams for nuclear experiments
(2) Explosive nucleosynthesis (r- and rp-process)
(3) Heavy ion reaction mechanism for producing heavy neutron-rich nuclei
(4) Development of MRTOF mass spectrographs for short-lived nuclei
(5) Comprehensive mass measurements of short-lived nuclei including superheavy elements
(6) Development of KISS-II

3. Summary of Research Activity

The Wako Nuclear Science Center (WNSC) provides low-energy short-lived radioactive ion beams of neutron-rich refractory elements to researchers from universities using the KEK isotope separator system (KISS). In FY2021, five experiments with a total of 69 participants from 3 domestic institutes were executed. Due to the restrictions of COVID-19, the participation of foreign collaborators was limited, and no experiment with foreign spokesperson was conducted. A highlight at the KISS facility was the discovery of a new uranium isotope by means of mass spectrometry, described in a different article of this report.

The team of WNSC leads comprehensive mass measurements of all available nuclides at RIKEN RIBF using multiple MRTOF mass spectrographs. KEK announced a press release for the first mass measurement of superheavy elements performed at the GARIS-MRTOF facility. It claims a new method for identifying new elements via a high precision mass measurement. Mass measurement of dubnium isotopes continued with a new sulfide target, allowing the use of much higher primary beam intensity. A newly installed In-MRTOF mass filter eliminates molecular contaminants in a mass spectrum, making possible accurate mass determinations without a need for decay correlation. Mass measurements at the BigRIPS-SLOWRI facility of RIBF continued for more exotic isotopes of nickel. In total, more than 400 nuclides were measured in the campaigns led by WNSC.

The WNSC plans to extend the present KISS facility to investigate the nuclides in the neutron-rich region of uranium using the multi-nucleon transfer reactions of actinide targets to study the origin of uranium. The IPNS organized review committee meetings for the design report of KISS-II and received high marks and helpful suggestions.

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List of Publications & Presentations

Publications

[Original Papers]

M. Mukai, Y. Hirayama, Y. X. Watanabe, H. Watanabe, H. Koura, S. C. Jeong, H. Miyatake, M. Brunet, S. Ishizawa, F. G. Kondev, G. J. Lane, Yu. A. Litvinov, T. Niwase, M. Oyaizu, Zs. Podolyák, M. Rosenbusch, P. Schury, M. Wada, and P. M. Walker, "Ground-state β-decay spectroscopy of ^{187}Ta," Phys. Rev. C **105**, 034331 (2022).

T. Niwase, M. Wada, P. Schury, P. Brionnet, S. D. Chen, T. Hashimoto, H. Haba, Y. Hirayama, D. S. Hou, S. Iimura, H. Ishiyama, S. Ishizawa, Y. Ito, D. Kaji, S. Kimura, J. Liu, H. Miyatake, J. Y. Moon, K. Morimoto, K. Morita, D. Nagae, M. Rosenbusch, A. Takamine, T. Tanaka, Y. X. Watanabe, H. Wollnik, W. Xian, and S. X. Yan, "α-decay-correlated mass measurement of ^{206,207g,m}Ra using an α-TOF detector equipped multireflection time-of-flight mass spectrograph system," Phys. Rev. C **104**, 044617 (2021).

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S. Kimura, D. Kaji, Y. Ito, H. Miyatake, K. Morimoto, P. Schury, and M. Wada, "Reduction of contaminants originating from primary beam by improving the beam stoppers in GARIS-II," Nucl. Instrum. Method Phys. Res. A **992**, 164996 (2021).

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M. Tajima, A. Takamine, M. Wada, and H. Ueno, "Offline ion source for laser spectroscopy of RI at the SLOWRI," Nucl. Instrum. Methods Phys. Res. B **486**, 48–54 (2021).

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[Book]

和田道治, 「重元素の起源と短寿命核原子の質量」, in 「物理科学, この 1 年 2022」, パリティ編集委員会編, 丸善, 2022 年 01 月, pp. 109–113.

[Proceeding]

H. Miyatake, "KISS project," AIP Conf. Proc. **2319**, 080006 (2021).

Presentations

[International Conferences/Workshops]

M. Wada (invited), "KISS to KISS-II—exploring the origins of uranium," JSPS/NRF/NSFC A3 Foresight Program, "Nuclear physics in the 21st century" Joint Annual Meeting, Online, February 18, 2022.

M. Rosenbusch (oral), "The new high-precision MRTOF mass spectrograph at the ZeroDegree spectrometer of BigRIPS," The 16th International Symposium on Nuclei in the Cosmos 2021 (NIC-XVI), Chengdu, Online, September 21–25, 2021.

M. Rosenbusch (oral), "The new MRTOF mass spectrograph at the ZeroDegree spectrometer," RIBF Users Meeting 2021, Online, September 7–9, 2021.

Y. Hirayama (oral), "Nuclear spectroscopy at KISS," RIBF Users Meeting 2021, Online, September 7–9, 2021.

[Domestic Conferences/Workshops]

庭瀬暁隆 (口頭発表), 「MRTOF+α-TOF による ^{257,258}Db の精密質量測定」, 日本物理学会第 77 回年次大会, オンライン, 2022 年 3 月 15–19 日.

平山賀一 (招待講演), 「KISS でのレーザー核分光」, 令和 3 年度専門研究会「短寿命 RI を用いた核分光と核物性研究 (VIII)」, オンライン, 2022 年 1 月 28 日.

庭瀬暁隆 (口頭発表), 「MRTOF と α-TOF 検出器による, α 崩壊に相関した精密質量測定法の開拓」, 日本放射化学会第 65 回討論会（2021）, オンライン, 2021 年 9 月 22–24 日.

庭瀬暁隆 (口頭発表), 「超重核 ^{257}Db の直接質量測定」, 日本物理学会 2021 年秋季大会, オンライン, 2021 年 9 月 14–17 日.

平山賀一 (口頭発表), 「KISS での核分光: MRTOF-MS を用いた不安定核のレーザー共鳴イオン化核分光」, 日本物理学会 2021 年秋季大会, オンライン, 2021 年 9 月 14–17 日.

D. Hou (口頭発表), "Mass measurement in the neutron-rich Mo region using the new ZD-MRTOF system," 日本物理学会 2021 年秋季大会, オンライン, 2021 年 9 月 14–17 日.

W. Xian (口頭発表), "New mass measurements of neutron-rich nuclei of Ge, As, and Se, and an accuracy study of the new ZD-MRTOF system," 日本物理学会 2021 年秋季大会, オンライン, 2021 年 9 月 14–17 日.

飯村俊 (口頭発表), 「新規開発された ZD-MRTOF 装置を用いた中性子過剰 Sc, Ti, V 核の系統的質量測定」, 日本物理学会 2021 年秋季大会, オンライン, 2021 年 9 月 14–17 日.

M. Rosenbusch (口頭発表), "New technologies for multi-reflection time-of-flight mass spectrometry at BigRIPS," 日本物理学会 2021 年秋季大会, オンライン, 2021 年 9 月 14–17 日.

[Seminars]

T. Niwase, "Direct mass measurement of superheavy nuclides via MRTOF mass spectrograph equipped with an α-TOF detector," RIBF Nuclear Physics Seminar, Online, February 12, 2022.

M. Wada, "KISS to KISS-II—An expedition to the origin of uranium—," Nuclear Astrophysics Seminar, Online, November 19, 2021.

Y. Watanabe, "Production of neutron-rich nuclei around $N = 126$ and beyond using multinucleon transfer reactions at KISS project," Virtual SHE seminars, Online, October 12, 2021.

Award

向井もも, 「^{196,197,198}Ir のガスセル内レーザー共鳴イオン化分光」, 2021 年度理化学研究所桜舞賞 (研究奨励賞), 2022 年 3 月.

Press Release

超重元素の初めての精密質量測定に成功〜新元素の新しい原子番号決定法の証明〜, KEK, RIKEN, Kyushu University, 2021 年 8 月 31 日, https://www.kek.jp/ja/press/202109010000/.