

Partner Institution
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1. Abstract

The Center for Nuclear Study (CNS) aims to elucidate the nature of nuclear system by producing the characteristic states where the Isospin, Spin and Quark degrees of freedom play central roles. These researches in CNS lead to the understanding of the matter based on common natures of many-body systems in various phases. We also aim at elucidating the explosion phenomena and the evolution of the universe by the direct measurements simulating nuclear reactions in the universe. In order to advance the nuclear science with heavy-ion reactions, we develop AVF upgrade, CRIB and SHARAQ facilities in the large-scale accelerators laboratories RIBF. The OEDO facility has been developed as an upgrade of the SHARAQ, where a RF deflector system has been introduced to obtain a good quality of low-energy beam. A new project for fundamental symmetry using heavy RIs has been starting to install new experimental devices in the RIBF. We promote collaboration programs at RIBF as well as RHIC-PHENIX and ALICE-LHC with scientists in the world, and host international meetings and conferences. We also provide educational opportunities to young scientists in the heavy-ion science through the graduate course as a member of the department of physics in the University of Tokyo and through hosting the international summer school.

2. Major Research Subjects

- (1) Accelerator Physics
- (2) Nuclear Astrophysics
- (3) DONUTS/NUSPEQ
- (4) Quark physics
- (5) Nuclear Theory
- (6) OEDO/SHARAQ project
- (7) Exotic Nuclear Reaction
- (8) Fundamental Physics

3. Summary of Research Activity

(1) Accelerator Physics

One of the major tasks of the accelerator group is the development of ion sources and the optimization of the beam transport system for the experimental devices installed in the E7 experiment room. In 2022, HyperECR ion source was operated for 2,151 hours. A new method for sustainable magnesium beam production was put into practical use for CRIB. The $^{24}\text{Mg}^{8+}$ beam was successfully produced for 18 days with four breaks to refill the sample crucible. In a university-industry collaboration, a magnetic design for a new ECR ion source was proposed for industrial applications. For the development of the pepper-pot emittance monitor to diagnose the beam extracted from AVF cyclotron, an optical system with a digital camera was completed. Then, the required angular accuracy was estimated to be less than 0.3 mrad. The beam test for the prototype was planned and the preparation was started.

(2) Nuclear astrophysics

The main activity of the nuclear astrophysics group is to study astrophysical reactions and special nuclear structure, such as clusters, using the low-energy RI beam separator CRIB. In October 2022, a ^6He radioactive beam was produced for the second time at CRIB, with improved beam intensity and purity by introducing wire chambers (MWDC) and a degrader. In Mar 2023, we performed a direct measurement of astrophysical $^{14}\text{O}(\alpha, p)$ reaction in an international collaboration with the groups in IBS (Korea), Texas A&M University (US) and others. An active-target system developed in Texas (TexAT) was brought to Japan to perform this measurement with the thick-target method using the ^{14}O radioactive beam at CRIB. This was the first experiment at CRIB with participants from foreign countries after the pandemic.

(3) DONUTS/NUSPEQ

The Low Energy Nuclear Reaction group studies exotic structures in high-isospin and/or high-spin states in nuclei. In the spring of 2022, two nuclear reactions, $^{130}\text{Sn}(d, p)$ and $^{56}\text{Ni}(d, p)$, SHARAQ18 and 19, respectively, were performed at the OEDO-SHARAQ system in inverse kinematics by employing the surrogate technique, where the decay channels of the unbound states were identified directly from the measurement of reaction residues. Prior to the SHARAQ18, MS22-01 was carried out to establish a new optics for transporting the ion beam with better transmission. In winter 2022, another OEDO experiment, SHARAQ12, for the single particle structure in ^{51}Ca was partially performed. The analyses of the experiments, ImPACT17-02-01, -02, and SHARAQ11, $^4\text{He}(^8\text{He}, ^8\text{Be})4n$ reaction, are in progress. The analysis of the groundbreaking experiment on the inelastic decay from the isobaric analog resonances is almost finished. The CNS GRAPE (Gamma-Ray detector Array with Position and Energy sensitivity) is a major instrument for high-resolution in-beam gamma-ray spectroscopy. The digital signal processing equipment for the GRAPE is under development.

(4) Quark physics

Main goal of the quark physics group is to understand the properties of hot and dense nuclear matter created by colliding heavy nuclei at relativistic energies. The group has been involved in the PHENIX experiment at Relativistic Heavy Ion Collider (RHIC) at

Brookhaven National Laboratory, and the ALICE experiment at Large Hadron Collider (LHC) at CERN. As for ALICE, the group has involved in the data analyses, which include the measurement of low-mass lepton pairs in Pb-Pb collisions, the measurement of long range two particle correlations in p -Pb collisions, searches for thermal photons in high multiplicity pp collisions. The group has involved in the ALICE-TPC upgrade using a Gas Electron Multiplier (GEM), where the group is very active in the development and benchmarking of the online space-charge distortion corrections using machine learning techniques running on the Graphical Processing Unit (GPU). The group has started simulation studies for the ALICE 3 future upgrade.

(5) Nuclear Theory

The nuclear theory group is conducting large-scale shell-model calculations, having a strong relationship to the project “Program for Promoting Researches on the Supercomputer Fugaku.” One of the key achievements in FY2022 is finding the mechanism of the strongly hindered $E0$ transition from the superdeformed 0^+ state to the ground state in ^{40}Ca . We are also performing shell-model calculations for the structure of neutron-rich nuclei in collaboration with experiments carried out in RIBF, RIKEN, focusing on the region around ^{54}Ca . Another important direction of our activity is application to the fundamental physics. In this year, we have found that the nuclear Schiff moment is strongly correlated to nuclear magnetic moments, which enables providing reliable Schiff moments in comparison to existing data.

(6) OEDO/SHARAQ project

The OEDO/SHARAQ group pursues experimental studies with RI beams by using the high-resolution beamline and the SHARAQ spectrometer, and the OEDO for the decelerated RI beams. The uniqueness of the OEDO-SHARAQ system is its versatile performance in low-energy RI production and high-resolution spectroscopy. In FY2022, taking advantage of this feature, two low-energy RI experiments for (d, p)-type surrogate reactions and a high-resolution direct mass measurement for two-proton radioactivity were performed. Through the measurements, we were able to demonstrate a smooth re-arrangement of the beamline and experimental detector setups. In addition, we installed an active stopper detector and γ -ray detectors for the in-flight isomeric tagging of exotic nuclei in the mass measurement program. Data analysis of performed experiments is ongoing. The experimental study of 0^- strength in nuclei using the parity-transfer charge exchange ($^{16}\text{O}, ^{16}\text{F}$) is in the final stage. The results of the first and second experiments with the OEDO system for LLFPs will be completed and reported soon.

(7) Exotic Nuclear Reaction

The Exotic Nuclear Reaction group studies various exotic reactions induced by heavy-ion beams. We proceeded with the data reduction of the double charge exchange ($^{12}\text{C}, ^{12}\text{Be}$) reaction taken in the previous year for a search of double Gamow-Teller resonance.

(8) Fundamental Physics

The development of the quantum sensor to search for a permanent electric dipole moment (EDM) with an optical lattice interferometer is in progress at RIKEN. The RF filter was newly developed and installed to the beam transport system to obtain the secondary beam of the Fr ion with a high purity, which was used to improve the trapping efficiency of the magneto-optical trap. The parameter tuning to get high intensity cold Fr atoms in the MOT is continued. Furthermore, a homemade Yb-doped fiber amplifier (YDFA) is developed, required to generate a deep optical lattice potential that would enable a long interrogation time for the EDM measurement.

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- H. Murakami for the ALICE Collaboration, “Thermal radiation and direct photon production measurements with dielectrons in Pb–Pb and pp collisions,” *Strangeness in Quark Matter (SQM 2022)*, June 13–17, 2022, Busan, Korea, *EPJ Web Conf.* **276**, 06011 (2023).
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- Shutaro Hanai, Shinsuke Ota, Reiko Kojima, Masanori Dozono, Nobuaki Imai, Shin’ichiro Michimasa, Susumu Shimoura, Juzo Zenihiro, Kento Inaba, and Yuto Hijikata “Development of fast-response tracking detector for high-intensity ion beams,” *Radiation Detectors and Their Uses Proceedings of the 36th Workshop on Radiation Detectors and Their Uses in KEK*, 2023, pp. 24–34.
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Presentations

[International Conferences/Workshops]

- H. Yamaguchi (invited), “RIB induced reactions: Studying astrophysical reactions with low-energy RI beam at CRIB,” The 11th European Summer School on Experimental Nuclear Astrophysics (Santa Tecla School, ESSENA 2022), INFN-LNS, Catania, Italy, June 12–19, 2022.
- H. Yamaguchi (invited), “New evaluation of $^{22}\text{Mg}(\alpha, p)$ reaction rate and X-ray burst light curve,” UKAKUREN-RCNP Conference on AstroNuclear Physics (ANP2022), Osaka University, Toyonaka, Osaka, Japan, July 20–21, 2022.
- H. Yamaguchi (invited), “Big-Bang Li problem and nuclear reactions,” International Workshop “Origin of Elements and Cosmic Evolution: From Big-Bang to Supernovae and Mergers” (OECE2022), Beihang University, Beijing, China, July 20–22, 2022.
- S. Hayakawa (invited), “New measurement of the $^7\text{Be} + n$ reactions and its impact on the primordial ^7Li abundance,” The 16th International Symposium on Origin of Matter and Evolution of Galaxies (OMEG16), Hanoi, Vietnam, October 24–28, 2022.
- H. Yamaguchi (invited), “Studies on RI-involving astrophysical reactions at CRIB,” ECT* Workshop “Key Reactions in Nuclear Astrophysics,” ECT*, Trento, Italy, December 12–16, 2022.
- H. Yamaguchi (oral), 「X線バーストにおける重要不安定核反応の実験的検証/Experimental investigation of relevant unstable-nucleus reactions in X-ray bursts」, RIBF ULIC Mini Workshop-39 星の進化と爆発天体における核反応の物理 (Physics of nuclear reactions in stellar evolution and explosive stellar objects), Wako, Saitama, Japan (RIKEN), February 20–21, 2023.
- K. Okawa (poster), “Direct measurement of the $^{26}\text{Si}(\alpha, p)^{29}\text{P}$ reaction for the nucleosynthesis in the X-ray bursts,” FoPM International Symposium, Hongo Campus (Ito International Research Center), February 6–8, 2023.
- S. Hayakawa (oral), “Nuclear astrophysics at the low-energy RI beam separator CRIB,” RIBF Users Meeting 2022, Web meeting hosted by RIKEN, Wako, Saitama, Japan, September 7–9, 2022.
- T. Gunji (invited) for the ALICE Collaboration, “Recent results from the ALICE experiment at the LHC and its future prospects,” The 15th Asia Pacific Physics Conference (APPC15), Online, August 21–26, 2022.

- T. Gunji (invited), “Hunting for dark photons,” GSI EMMI RRTF, Real and Virtual photon production at ultra-low transverse momentum and low mass at LHC, GSI, August 1–8, 2022.
- T. Gunji (invited), “High-energy nuclear physics in Japan and view on EIC,” EIC Asia Workshop, RIKEN, March 16–18, 2023.
- H. Murakami for the ALICE Collaboration, “Thermal radiation and direct photon production in Pb–Pb and pp collisions with dielectrons,” Strangeness in Quark Matter (SQM 2022), Busan, Korea & Online, June 13–17, 2022.
- D. Sekihata for the ALICE Collaboration, “Thermal radiation and direct photon production in Pb–Pb and pp collisions with dielectrons in ALICE,” International Conference on High Energy Physics, Bologna, Italy, July 6–13, 2022.
- Y. Utsuno (invited), “Recent findings about shell evolution in the neutron-rich Ca region,” RIKEN Workshop on Physics of RI: Recent Progress and Perspectives, Wako, Japan, May 30–June 1, 2022.
- Y. Utsuno (invited), “Large-scale shell-model calculations: from low-lying spectra to compound states,” A3F-CNS Summer School 2022, Kumagaya, Japan, August 20–24, 2022.
- Y. Utsuno (invited), “Overview of shell-model results for the 3rd SEASTAR campaign,” REIMEI Workshop on Unveiling nuclear shells and correlations in exotic nuclei through knockout reactions, Darmstadt, Germany, October 10–12, 2022.
- K. Yanase (oral), “Theoretical uncertainty on the nuclear Schiff moments of ^{129}Xe and ^{199}Hg ,” The 14th International Workshop on Fundamental Physics Using Atoms (FPUA2022), Fukuoka, Japan, November 24–25, 2022.
- Y. Utsuno (invited), N. Shimizu, and Y. Tsunoda, “Large-scale shell-model approach to nuclear collective motion,” 66th DAE Symposium on Nuclear Physics, Guwahati, India, December 1–5, 2022.
- K. Yanase (invited), “Shell-model study for the Nuclear Schiff moments of ^{129}Xe and ^{199}Hg ,” KMI workshop: Searches for Electric Dipole Moments: From Theory to Experiment, Nagoya, Japan, March 2–4, 2023.
- Y. Utsuno (invited), “The nuclear shell model,” INTPART School 2023, Onna, Japan, February 20–March 7, 2023.
- S. Michimasa (invited) “Direct mass measurements around neutron-rich Ca region at SHARAQ,” Physics of RI: Recent progress and perspectives RIKEN Nishina Center, Saitama, Japan, May 30–June 1, 2022.
- S. Michimasa (invited) “Present Status of OEDO/FY2020–2022” OEDO/SHARAQ collaboration meeting 2022, Web meeting hosted by CNS, Wako, Saitama, Japan, August 30, 2022.
- N. Imai (invited) “SHARAQ18” OEDO/SHARAQ collaboration meeting 2022, Web meeting hosted by CNS, Wako, Saitama, Japan, August 30, 2022.
- S. Hanai (invited) “SHARAQ13” OEDO/SHARAQ collaboration meeting 2022, Web meeting hosted by CNS, Wako, Saitama, Japan, August 30, 2022.
- S. Michimasa (invited) “OEDO-SHARAQ system: multifaceted performances in low-energy RI production and high-resolution spectroscopy,” The 19th International Conference on Electromagnetic Isotope Separators and Related Topics (EMIS XIX), RISP/IBS, Daejeon, Korea, October 3–7, 2022.
- S. Michimasa (invited) “Mass measurements of exotic nuclei at OEDO-SHARAQ,” The International Symposium on Nuclear Spectroscopy for Extreme Quantum Systems (NUSPEQ2023), Numazu, Sizuoka, Japan, March 7–9, 2023.
- T. Chillery (poster) “Treating Radioactive Waste: Measurement of $^{93}\text{Zr} + d$ Reactions at 30 MeV/nucleon,” The International Symposium on Nuclear Spectroscopy for Extreme Quantum Systems (NUSPEQ2023), Numazu, Sizuoka, Japan, March 7–9, 2023.
- N. Kitamura (poster) “In-beam γ -ray spectroscopy of ^{32}Mg ” The International Symposium on Nuclear Spectroscopy for Extreme Quantum Systems (NUSPEQ2023), Numazu, Sizuoka, Japan, March 7–9, 2023.
- R. Yokoyama (poster) “New implantation detectors for decay spectroscopy at fragmentation facilities” The International Symposium on Nuclear Spectroscopy for Extreme Quantum Systems (NUSPEQ2023), Numazu, Sizuoka, Japan, March 7–9, 2023.
- S. Hanai (poster) “Direct mass measurement of neutron-deficient Fe isotopes” The International Symposium on Nuclear Spectroscopy for Extreme Quantum Systems (NUSPEQ2023), Numazu, Sizuoka, Japan, March 7–9, 2023.
- J. Li (poster) “Study of heavy-ion fusion reactions in inverse kinematic systems using low-energy ^{136}Xe beam,” The International Symposium on Nuclear Spectroscopy for Extreme Quantum Systems, Numazu, Sizuoka, Japan, March 7–9, 2023.
- S. Hanai (invited) “Direct measurement of the masses of Fe isotopes around the proton dripline,” RIBF users meeting, Web meeting hosted by RIKEN Nishina Center, Wako, Saitama, Japan, September 22, 2022.
- T. Chillery (invited) “Recent Studies on Heavy-Isotope Nucleosynthesis Using (d,p) Transfer Reactions at OEDO-SHARAQ,” RIBF users meeting, Web meeting hosted by RIKEN Nishina Center, Wako, Saitama, Japan, September 22, 2022.
- J. T. Li (oral), “Study of the fusion reaction in inverse kinematics with the low-energy ^{136}Xe beams,” UT-Tsinghua University Joint mini workshop, Tsinghua University, Beijing, China, March 13, 2023.
- S. Hanai (poster), “Development of a fast response PPAC for high-intensity heavy-ion beams,” The 19th International Conference on Electromagnetic Isotope Separators and Related Topics (EMIS XIX), Daejeon, Korea (RISP/IBS), October 3–7, 2022.
- K. Yako (oral), “Double and single charge exchange reactions on ^{48}Ca by ^{12}C beam at 250 A MeV,” YKIS2022b, Kyoto, May 23–27, 2022.
- A. Sakaue (poster), “The Search for double Gamow-Teller giant resonance at RIBF BigRIPS,” Annual meeting of A3 Foresight Program, Nuclear Physics in the 21st century, Osaka, February 13–15, 2023.
- A. Sakaue (poster), “The search for double Gamow-Teller giant resonance with the ($^{12}\text{C}, ^{12}\text{Be}(0_2^+)$) reaction,” NUSPEQ2023, Numazu, March 7–9, 2023.
- K. Kawata (poster), “The production of high-spin isomers around ^{52}Fe in fragmentation reaction of ^{58}Ni and ^{59}Co beams at 350 MeV/nucleon,” NUSPEQ2023, Numazu, March 7–9, 2023.
- K. Nakamura (oral), “400-m-Long Polarization-Maintaining Fibers for Magneto-Optical Trapping of francium Atoms,” The 15th Pacific

Rim Conference on Lasers and Electro-Optics (CLEO-PR 2022), Online, August 2, 2022.

H. Nagahama (invited), “Searching for the permanent electric dipole moment using laser cooled francium atoms,” 6th Workshop on the Physics of fundamental Symmetries and Interactions at low energies and the precision frontier (PSI2022), Switzerland (Paul Scherrer Institute), October 19, 2022.

M. Fukase (invited), “Search for permanent EDM by using Fr atoms,” 14th International Workshop on Fundamental Physics Using Atoms (FPUA2022), Fukuoka, Japan (Kyushu University), November 24, 2022.

[Domestic Conferences/Workshops]

鎌倉恵太 (ポスター発表), 「14 GHz Hyper ECR イオン源を用いた ECR プラズマの研究」, 第 19 回日本加速器学会年会, オンライン, 2022 年 10 月 18–21 日.

大川皓大 (口頭発表), 「X 線バースト中の元素合成における $^{26}\text{Si}(\alpha, p)^{29}\text{P}$ 反応の直接測定」, 日本物理学会 2022 年秋季大会, 岡山理科大学, 2022 年 9 月 6–8 日.

S. Hayakawa (oral), “Activity report of CRIB,” RIBF Users Meeting 2022, Session 3, オンライン, 2022 年 9 月.

早川勢也 (口頭発表), “Measurement of the $^7\text{Be} + n$ reactions by Trojan Horse method updating primordial ^7Li abundance,” 宇宙核物理の展開 UKAKUREN-RCNP Conference on AstroNuclear Physics (ANP2022), 大阪大学 & オンライン, 2022 年 7 月.

山口英斉 (口頭発表), 「軽い原子核の直鎖クラスター状態の実験的検証」, シンポジウム「原子核クラスター物理の新たな進展と展望」, 日本物理学会 2023 年春季大会, オンライン, 2023 年 3 月 25 日.

H. Murakami for the ALICE Collaboration, “Direct photon production in proton-proton collisions at $\sqrt{s} = 13$ TeV via interanl conversion technique with ALICE,” 日本物理学会 2022 年秋季大会, 岡山理科大学, 2022 年 9 月 6–8 日.

関畑大貴, 「電磁・ソフトプローブを通じた QGP 物理の結果と展望」, 日本物理学会 2023 年春季大会, 実験核物理・理論核物理領域合同シンポジウム: 次世代の高エネルギー原子核衝突: 何が理解され, 何を理解すべきか?, オンライン, 2023 年 3 月 22 日.

馬場仁志 for the ALICE Collaboration, 「機械学習を用いた, ALICE-TPC 検出器における空間電荷効果の補正」, 日本物理学会 2022 年秋季大会, 岡山理科大学, 2022 年 9 月 6–8 日.

T. Gunji (招待講演), “Future Prospects of Quark Cluster Physics using ultra-relativistic heavy-ions,” 第 8 回クラスター階層領域研究会, 大阪大学吹田キャンパス接合科学研究所, 2023 年 2 月 9–11 日.

T. Gunji (招待講演), 「LHC-ALICE 実験の新しいデータ収集系」, RCNP 研究会「原子核実験の次世代データ収集システム基盤開発にむけて」, 大阪大学吹田キャンパス, 2022 年 5 月 16–17 日.

T. Gunji (invited), 「WG4 (オンラインフィルタリング・演算加速器) 報告と展望」, 原子核実験の先端データ収集システム—標準化と将来—, 2023 年 3 月 17 日.

T. Gunji (invited), 「ALICE 実験における Vertex Trackers」, シリコンプラットフォーム研究会, KEK, 2022 年 8 月 9 日.

宇都野穰 (招待講演), 「大規模殻模型計算—現実的な原子核構造を得るには」, 研究会「宇宙核物理の展開」, 豊中市 (大阪大学), 2022 年 7 月 19–21 日.

宇都野穰 (口頭発表), 清水則孝, 井手口栄治, 青井考, 「大規模殻模型計算と 3 準位模型による ^{40}Ca の超変形状態からの E0 遷移の理解」, 日本物理学会 2022 年秋季大会, 岡山市 (岡山理科大学), 2022 年 9 月 6–8 日.

柳瀬宏太 (招待講演), 「原子核殻模型によるキセノン原子核の核行列要素の理論計算」, 二重ベータ崩壊核行列要素実験理論合同研究会, 吹田市 (大阪大学核物理研究センター), 2022 年 10 月 3–4 日.

柳瀬宏太 (口頭発表), 清水則孝, 角田佑介, 宇都野穰, 「モンテカルロ殻模型による $N = 82$ 付近のベータ崩壊半減期の理論計算」, 日本物理学会 2023 年春季大会, オンライン, 2023 年 3 月 22–25 日.

N. Kitamura (招待講演), 「高性能波形ディジタイザの需要調査と今後の開発方針」, 原子核実験の先端データ収集システム—標準化と将来—, 大阪大学核物理研究センター, 2023 年 3 月 17 日.

R. Yokoyama (招待講演), 「原子核の複数粒子放出過程」, 第四回若手放談会, エキゾチック核物理の未来, 理研神戸・融合連携イノベーション推進棟, 2023 年 3 月 15–17 日.

R. Yokoyama (招待講演), 「核破碎・分裂反応式不安定核生成施設における β 核分光のためのシンチレーション検出器」, Scintillator for Medical, Astroparticle and Environmental Radiation Technologies, Tokushima University, December 17–19, 2022.

N. Imai (invited), “Study of the neutron capture rate on the unstable nuclei via the surrogate reactions,” Workshop for the nucleosynthesis in the universe from the neutron capture, Tokyo, Japan (University of Tokyo), February 9–10, 2023.

T. Chillery (oral), “Measurement of $^{130}\text{Sn}(d,p)$ Reaction for Neutron-Capture Rate in r -process Nucleosynthesis,” JPS Autumn 2022 meeting, Okayama, September 6–8, 2022.

阪上朱音 (口頭発表), 「 $(^{12}\text{C}, ^{12}\text{Be}(0_2^+))$ 反応を用いた二重ガモフ・テラー巨大共鳴状態の探索」, 日本物理学会 2022 年秋季大会, 岡山理科大学, 2022 年 9 月 6–8 日.

[Seminars]

S. Hayakawa, C2R2 Seminar “Direct and indirect methods at CRIB for nuclear astrophysical reactions,” Online, Organized by CENS, IBS, June 2022.

Y. Utsuno, “Unveiling exotic nuclear structure far from stability,” Colloquium at Saha Institute of Nuclear Physics, Kolkata, India, December 7, 2022.

N. Imai, “OEDO beam line at RIBF and Its physics program,” Beijing China (Tsinghua University), March 13, 2023.

N. Imai, “The decelerating and focusing device OEDO in RIBF and the nuclear astrophysics program with the surrogate nuclear reaction,” Beijing, China (Chinese Institute of Atomic Energy), March 13, 2023.

N. Imai, “OEDO, the deceleration and focusing element at RIBF, and the physics program using OEDO,” Lanzhou, China (Institute of Modern Physics), March 16, 2023.

Awards

- S. Hanai, ANPha Award in The International Symposium on Nuclear Spectroscopy for Extreme Quantum Systems (NUSPEQ2023), Numazu, Sizuoka, Japan, March 7–9, 2023.
- A. Sakaue, Poster award for young scientists, Annual meeting of A3 Foresight Program, Nuclear Physics in the 21st century, Osaka, February 13–15, 2023.

Outreach Activity

- N. Imai “Beyond the nano scale: a femto world consisting of protons and neutrons,” Open campus of the School of Science, the University of Tokyo, Tokyo, Japan, August 4, 2022.