# RIKEN Nishina Center Advisory Committee Report


**Submitted on August 5th, 2019**

**NCAC Meeting July 24-26, 2019**

***Report: Findings/Comments and Recommendations* from *the NISHINA Center Advisory Council (NCAC)***

**Contents:**

**Foreword:**

**Following the discovery of element 113, named Nihonium (Nh), the celebration of the 150th anniversary of the Periodic Table of Chemical Elements and completion of its 7th row under UNESCO, the official closing ceremony will take place in TOKYO, 5th December., 2019.**

**The Nishina Center Advisory Committee (NCAC) would like to enthusiastically congratulate, Dr K. Morita and his team, RNC management, and the RNC researchers and staff for this superb achievement.**

**NCAC is also very pleased to emphasize here that research on Transmutation of Long-lived Fission Products within the ImPACT program, developed at Riken Nishina Center (RNC), has resulted in the awarding of the 21th Century Prize Invention Award (2018).**

**The Riken Nishina Center should be congratulated to the recent publication in the journal Nature of the pioneering spectroscopy of 78Ni, indicating that this neutron-rich nucleus is doubly magic and possibly displays shape coexistence.**

## I. Introduction

Firstly, the NCAC wishes to thank RIKEN President Hiroshi Matsumoto, Executive Director Shigeo Koyasu, Nishina Center Director Hideto En'yo, as well as all the members of the RIKEN Nishina Center (RNC) for their hospitality. It also acknowledges the considerable efforts made in presenting the perspective and scope of the activities of the RNC carried out by the research divisions, both locally and overseas, as well as the mid-term management and scientific strategy for future projects. NCAC was impressed by the excellent preparation for this committee meeting. In particular, the quality of the preparatory documents and the clarity of the presentations during the review were instrumental in facilitating this NCAC review. The committee congratulates the RNC Director, management and staff for the efforts made to respond with quite a number of actions to our previous recommendations. NCAC has appreciated the transparent and direct interaction with RNC Management and presenters during this three-day meeting.

NCAC is aware that this review of the NRC came at a rather special time due to the significant recent organizational changes: the transition from the Research Infrastructure Center to the Strategic Research Center, and the consolidation of the Chief Scientist Laboratories to the Cluster for Pioneering Research – CPR. This conversion of RNC into a strategic research center and associated reorganization with four Divisions is successfully providing more visibility for the infrastructure component of the lab as well as for the transmutation and other applied research.
This situation did result in rather precise guidance for the review process formulated as "terms of reference" to be addressed by NCAC. Thus, NCAC has reviewed the organization, the resources, the personnel

operations and development, the science programs, the important upgrade projects and the 7-year strategic plan for the RNC guided by these terms of references provided by the president of RIKEN, Prof H. Matsumoto, and by the Director of the RNC, H. En'yo.

## II. Organization, Management, Personnel and Budget

**Findings/ Comments:**

### Organization

As a result of RIKEN's overall organizational change and personnel system reform in JFY2018, the RNC organization underwent significant changes. These included the transition from the research infrastructure center to the strategic research center, and the consolidation of the Chief Scientist Laboratories to the Cluster for Pioneering Research (CPR).
The conversion of RNC into a strategic research center and associated reorganization with four Divisions is successfully providing more visibility for the infrastructure component of the lab as well as for the transmutation and other applied research.

### Management

The RNC Director presented a realistic high-level SWOT analysis for the RNC.
A survey of the PIs on the RNC director's management indicate that approval for 5 of the 6 questions was around 70 %. However, the initiatives to promote diversity were viewed as weakest (~50%).

### Personnel

NCAC acknowledges that the personnel system reform in JFY2018 has enabled the indefinite-term employment of 17 staff supporting the facility operation, providing more stability.
RNC management considers the number of staff supporting the facility as insufficient and sees challenges with succession.
Overall, NCAC is happy to see the stabilization of the employment situation for key research and technical staff for RIBF. It will be important for RNC to carefully plan for succession of key personnel in leadership positions as the center undergoes a generational change.
The limited diversity of the staff, in particular with respect to women among the PIs and among research staff, remains a problematic issue and no active program seems to be in place to improve gender diversity.
RNC is attracting many domestic and international users, demonstrating the demand for and excellence of the facility.

### Budget

Building on the success of the ImPACT transmutation projects, which temporarily increased the funding, RNC plans to continue to pursue national scale projects that are aligned with the national scientific policies. NCAC endorses this strategy to contribute to the global challenges and secure extra funding.
The implementation of user fees was considered but not carried out. The in-kind contributions by external groups are considered more valuable than the level of experimental running cost that could be offloaded onto the experiment collaborations.

**Recommendations**:

- **NCAC would like to see RNC establishing key performance indicators to define and measure RNC's success in delivering on its strategic plan objectives.**

- **NCAC recommends the urgent implementation of an effective strategy to increase gender diversity among the PIs as well as research and technical staff.**

- **NCAC recommends that RNC, together with RIKEN broadly, develop a strategy for its medical isotope production capabilities, in particular alpha emitters like At-211, focusing on supporting R&D with radioisotopes.**

- **NCAC encourages RNC to develop effective strategies to further strengthen links to universities and international partners.**

## III. Nuclear Science Division and Transmutation Division

**Findings/ Comments:**

### Facility in general

RIBF is a world-class facility due to

(i) the presently unrivaled intensities and variety of rare-isotope beams across the nuclear chart;
(ii) the availability of state-of-the-art experimental equipment – provided locally as well as contributed from abroad – for cutting-edge experiments;
(iii) the dedication and enthusiasm of teams of local and international research groups carrying out first-rate nuclear science research at the frontier of the field.

### Superheavy elements research

- The superheavy element program is world-class. Since the last NCAC meeting, the naming of element Z=113 (Nh) was approved by IUPAC and this exciting discovery has garnered the attention of society, as evidenced in many public lectures given about this topic.

- The group has developed a strategy for the production of the new elements with Z=119 and Z=120 in hot fusion reactions induced by intense V and Cr beams on Cm targets, employing – in the long-term – the upgraded GARIS separator at the new RILAC facility. This will keep RNC's SHE research program at the cutting edge in the field.

- More than 80 masses were measured with a Multi-Reflection Time-Of-Flight (MR-TOF) setup, including 6 first-time mass measurements of isotopes of the transuranium elements Es and Md. This is an exciting new research avenue within the SHE research portfolio.

## Nuclear structure physics

- The RIBF has continued to maintain and attract new world-class instrumentation to capitalize on nuclear science opportunities, often within big international collaborations. The instrumentation includes the Zero Degree, SAMURAI and SHARAQ spectrometers, the MINOS liquid hydrogen target, the gamma-ray detector DALI2, the NEBULA neutron detector together with the FAIR/GSI neutron detector NEULAND, the SπRIT TPC, a beam-line system to spin-polarize projectile fragments for precision moment measurements, and involves international collaborations such as EURICA, BRIKEN, and SEASTAR.
- Important highlights, at this point only achievable at RIKEN, include:
    - The publication (in the journal Nature) of the pioneering spectroscopy of the first excited states in the doubly-magic nucleus $^{78}$Ni and resulting evidence for shape coexistence;
    - The first measurement of the low-lying excited states of $^{40}$Mg, posing a puzzle for state-of-the-art configuration-interaction shell-model approaches;
    - The discovery of the very neutron-rich key isotopes $^{60}$Ca (N=40) and $^{39}$Na (N=28), providing critical information on the location of the neutron dripline and providing stringent benchmarks for nuclear theory on the quest to model nuclear binding across the nuclear chart;
    - The first observation of a Gamow-Teller giant resonance in a radioactive nucleus accomplished using a charge-exchange reaction on doubly magic $^{132}$Sn, at a quality comparable to stable-beam experiments, culminating in the extraction of the Landau-Migdal coupling constant;
    - The first magnetic-moment measurement for the $3/2^-$ isomer of $^{75}$Cu, reported in the journal Nature Physics;
    - The proof of an extended neutron wave function for the very neutron-rich nucleus $^{22}$C and first tantalizing hints for interesting di-neutron correlations in $^{11}$Li;
    - The half-life measurements with EURICA that have an impact on our understanding of the formation of the rare-earth peak in the r process.

**Additional observation: Nuclear structure physics**

- Noteworthy future developments of the experimental capabilities that should be strongly supported include
    - Mass measurements with the Rare RI Ring;
    - The HiCARI high-resolution in-beam gamma-ray spectroscopy campaign;
    - The SLOWRI program with low-energy RI-beams;
    - First SCRIT experiments enabling electron scattering on rare isotopes;

## ImPACT:

**Finding/Comments:**

ImPACT (ImPACT-1 and beyond ImPACT-1) is a new strategic program at RIKEN/RNC, aiming at the "Reduction and recycling of high-level radioactive wastes through nuclear transmutation". RNC focuses on:

(i) nuclear data accumulation at RIBF (ImPACT-1) with direct cross-section measurement of Long Life Fission Product (LLFP) and direct detection of reaction residues (at ZD or SHARAQ spectrometers), taking significant advantages of RNC accelerator/beam-line facilities

(ii) and accelerator and target development (post ImPACT-1) with a one ampere-class deuteron linac for nuclear transmutation and demonstration of the effectiveness.

The ImPACT-1 program was a unique effort to start connecting basic science with the need of society. It was prioritized under the RIKEN/NRC initiative and provided fundamental prospects from the deep understanding of transmutation process to the technology to reduce nuclear waste drastically.

The one ampere-class deuteron single-cell linac proposed for nuclear transmutation (as the post ImPACT-1) is very innovative and challenging. It aims at realizing single-cell RF cavities with magnetic focusing elements to accelerate deuterons up to 200 MeV/u. To realize it, RNC should prepare for the next development program. First, RNC will need to lead the basic research to demonstrate technical feasibility. As the new development program will become inherently large-scale, the collaboration with appropriate partners will be inevitably required. Considering its scale and the impact on RIKEN, the preparation of new development program needs strong lead and support with the RIKEN headquarter.

**Recommendations:**

- **Complete the conceptual design of the linac and then have a technical review on the design, which are essential to conduct the prototyping program as the next step and to attract major funding support beyond the ImPACT-1 program.**

- **Establish strong collaborations with appropriate partners for key technologies for the accelerator and target systems.**

## Nuclear Astrophysics

**Findings/Comments:**

Astronomy projects with space instruments on the Hitomi and Maxi missions are a successful complement of the RNC towards astrophysics.
The High-Energy Astrophysics Laboratory had been involved in establishing the Hitomi and Maxi space experiments for astronomy in X rays. Cosmic plasma can be heated to highest temperatures that emit X-ray continuum and line radiation. This typically occurs near supernova explosions and in intergalactic space; recombination lines signify the presence of heavy elements such as Nitrogen, Sulfur, or Iron, and thus allow to obtain a cosmic census of the production of those heavy elements by cosmic nuclear fusion reactions and supernova explosions ejecting products thereof.

The Maxi mission on the space station has the group as the PI institution. It has been successful monitoring transient events in the X-ray sky, which often are related to bursts releasing nuclear-fusion energy on the

surface of compact stars. The instrumental activities linked closely to the space agency JAXA and to space experiments and its high-energy radiation detectors is essential towards any future project in high-energy astronomy.
NCAC compliments the team on the successful first Hitomi data, and strongly supports the replacement mission efforts, as well as the presented future hardware plans. NCAC encourages continued collaborations with experiment, theory and observations and recommends to maintain focus on the nuclear-astrophysics questions.

The Astro-Glaciology Research Group has established and exploited access to unique samples of ice from Antarctica, which includes a record of cosmic events and extraterrestrial variations such as imparted by nearby supernova explosions.

The group showed impressive detail recorded from solar-activity cycles, as well as tantalizing signal spikes that may be related to supernova explosions in our Galaxy in the past thousands of years. This archeological research put the group into a world-leading role. Challenges in chemistry and geophysical processes are addressed through collaborations with several other institutions. The exploitation of ice-core data record will be expanded to nearly the past million years of history in the next ten years. The new laser-aided ice melting device will further strengthen this position and the new instrumentation based on this project is strongly supported.

**Recommendations:**

- **RNC should strongly support these unique astrophysics programs and strengthen the links to nuclear astrophysics experiment, theory, and modeling.**

- **The Focus of the Laboratory's work towards nuclear physics in the universe and its nuclear-structure connections will maintain and extend the Laboratory's role both within RIKEN and representing RIKEN in the scientific community of nuclear physics and of astrophysics.**

# IV. Subnuclear System Research Division

## Theory

**Findings/ Comments:**

The RNC theory division is playing a leading role in guiding new developments and in the fundamental connections of nuclear and particle theory, with outstanding scientific accomplishments broadly in the area of QCD and few-body physics, and has led to the establishment of the interdisciplinary iTHEMS program. Highlights of the theory division include pioneering studies in lattice QCD of few hadron systems, QCD-based descriptions of dense matter in neutron stars, and investigations of strongly interacting few-body systems including their universal aspects. At the same time, the world-leading RIBF is opening up new, high-impact directions in theory, which are key to maximize the science return and future planning at RIBF.

The NCAC is very concerned about the future of the RNC theory effort. The two present group leaders have recently moved to iTHEMS program director and to Kyushu University and the group has so far not been rebuilt. In addition, 3 of the 6 permanent scientists will move to iTHEMS, which will further decrease theoretical activities connected to the RIBF discoveries. The NCAC therefore strongly supports the RNC's

initiative to recruit a tenured Group Director as a successor to Hatsuda as quickly as possible, in order to secure a broad and internationally highly competitive nuclear theory program.

Considering the strong competition among international rare isotope beam facilities, strong leadership in nuclear theory at RIBF is critical. Otherwise the intellectual leadership at RIBF is facing serious threats once the international competing facilities start to become operational in 2022. Recruiting an outstanding nuclear theorist to lead and develop the RNC theory division located at RIBF is therefore urgently needed.

**Recommendations:**

- **In addition to a tenured Group Director, the NCAC strongly recommends to urgently rebuild the theory group with permanent positions in modern low-energy nuclear theory, located at the RIBF building, to provide support and intellectual guidance for RIBF.**

- **In order to develop a long-term and broad theory effort, the NCAC recommends to consider emulating the highly successful RIKEN-BNL theory fellow program to seed new faculty positions in theory at universities.**

## Hadron Physics at RIKEN Subnuclear System Division

**Findings/Comments:**

Hadron Physics research activities are conducted by several groups in the RNC such as Meson Science Lab., Radiation Lab. etc. at variety of research facilities over the world, RIBF, GSI, LEPS, BNL-RHIC and J-PARC, based on the competitive funds independent from the RNC budget. These research activities are important to keep the diversity of basic sciences in broader range of hadron physics in RNC. Nowadays, a close relationship is rapidly growing between high-density hadronic matter physics and nuclear astrophysics in the r-process nucleosyntheses in connection with the gravitational wave observations from neutron star binary merger.

Recent highlights of the groups include:

(i) the discovery of an exotic nucleus containing two protons and a kaon "$K^-pp$" at J-PARC.
(ii) nearly start of data taking on the mass modification of φ vector-meson in nuclei at J-PARC.
(iii) new data on deeply-bound π mesonic atom in Sn isotopes with spectroscopic accuracy at RIBF.
(iv) an experimental search for the η′ meson bound state at GSI.

Recently, a new Chief Scientist laboratory has been launched in RIKEN in the field of hadron physics. Hypernuclear physics with heavy ions at FAIR in Germany and at HIAF in China is planned to be a new research field. By applying new production mechanisms of hyper fragments, a new type of hypernucleus so far impossible to access would become within experimental reach. This is a totally new research direction similar to the hypernuclear spectroscopy in J-PARC. By strengthening the domestic and international cooperation, the RNC hadron physics groups could maintain their leads in hadron physics at J-PARC. It would be also nice to observe timely alternation of generations in the leadership of hadron physics in the RNC in the coming several years.

**Recommendation:**

- **NCAC recommends to organize research collaborations between CPR and RNC in hadron physics as complementary partners.**

**RIKEN-BNL Research Center**

**Findings/Comments:**

RBRC is a world-leading center for the high-energy study of QCD and has made possible the world's first and only polarized proton collider at RHIC. Substantial financial investments from RIKEN and the sustained scientific contributions from RBRC over two decades were essential. A new MOU for JFY 2018-23 has been signed and RBRC continues to be a unique, highly successful model for international scientific collaboration in experiment, theory and computation.

Recent scientific highlights include: the surprisingly strong nuclear dependence of the single spin asymmetry associated with forward neutrons in p-A collisions; the impressive progress in the study of chiral matter, which is a growing enterprise in condensed matter physics with broad potential applications, e.g. quantum computing; and precision lattice QCD calculations of the anomalous magnetic moment of the muon, whose measurement is in tension with the Standard Model prediction and where new, high precision data are expected in the near future.

RBRC is playing a leading role in the construction of the sPHENIX detector that will be used to carry out a study of jet structure in heavy ion collisions. sPHENIX will study jets and associated phenomena at RHIC energies that are complementary to the LHC, and where backgrounds are lower. At present, it is anticipated that sPHENIX will take data in the years 2023-25.

Beyond sPHENIX, if the EIC design based on RHIC is selected and proceeds to construction, Japan will be presented with a significant opportunity to participate in the next frontier collider built on the RBRC investments. It is anticipated that the U.S. Department of Energy will formally launch the EIC project in the near future.

**Recommendation:**

- **NCAC recommends that RBRC should remain an active, international center for high-energy QCD until the full scientific output of sPHENIX is realized.**

**RIKEN-RAL**

**Findings/Comments:**

Muon science research at the muon facility at RAL covers a diverse range of topics, from fundamental to applied, with emphasis on condensed matter science. Research highlights include: the discovery of unusual spin dynamics in High-Tc superconductors, the characterization of intrinsic ion diffusion in ionic

conductors, the development of depth dependent elemental analysis and the measurement of the proton Zemach radius.

NCAC endorses the decision of RIKEN to close the operation of RIKEN-RAL facility. NCAC acknowledges the effort of RIKEN-RAL over 30 years to promote Muon science research and to bridge nuclear science and condensed matter science.

Based on the new contract between RIKEN and RAL, the joint program on muon science will be maintained until 2023, while the ownership and the responsibility of operation of the facility were already transferred to RAL. The financial commitment of RIKEN to the facility at RAL will be terminated in 2023. However, the muon facility at RAL will be open for users under the initiative of RAL even after 2023. In parallel, an increase in the performance of the muon facility at J-PARC is expected in the next few years. The opportunity of conducting muon science for users will not decrease or may even increase in at least the next five years. The effort of RIKEN to not influence the on-going and future activities of muon science at RAL is highly appreciated.

**Recommendation:**

- **RIKEN may consider implementing its excellent expertise in muon science to the condensed matter science community through RIKEN-CEMS. NCAC recommends further strengthening this effort in completing the development of the ultra-slow muon technique.**

# V. Accelerator Applications Research Division

## Beam Mutagenesis Group

**Findings/Comments:**

Beam Mutagenesis group has developed high mutation rates and various mutant with very short irradiation of heavy ion beams, which is a unique tool for the discovery of novel functions of genome, compared to the genome editing. The Ion Beam Breeding activities remain a very visible and productive application of RNC, which includes both application such as breeding of plants and microbes and basic science such as genome evolution by heavy-ion beam radiation.

NCAC recognizes the importance of ion beam breeding, as evidenced by the launch of an IAEA Coordinated Research Project in 2019, which will lead to an increasing number of international users in the near future

## Recommendation:

- **NCAC recommends the group to become a "Hub" of activity of mutagenomics for society.**

## Radio Isotopes Application Research Group

**Findings/Comments:**

Most notable activities are the development of production techniques for the theragnostic medical isotopes $^{67}$Cu and $^{211}$At; distribution of $^{67}$Cu has started in 2018, large-scale production of $^{211}$At was achieved, and R&D for producing $^{225}$Ac and $^{212}$Pb is arranged. Alpha-particle therapy, has potential for significant societal

impact. The activity has been carried out through collaboration with other institutions that also provide precious radio isotopes, which is highly beneficial to society.

**Recommendation:**

- **NCAC recommends that RNC (or RIKEN) should develop the optimal strategy to maximize the benefit of accelerator applications to society. Specifically, medical use of short-lived radio isotopes is expected to increase significantly in the near future, and RNC (or RIKEN) should strengthen collaboration with related organizations to the maintenance of a platform for the stable supply of short-lived radio isotopes and development of the network.**

# VI. Research Facility Development Division

## Accelerator development

**Findings/Comments:**

NCAC congratulates RNC on the excellent operation of the accelerator complex and with steadily improving performance. Developments such as the 28 GHz ECRIS, the high-pressure windowless charge state stripper and the modification of the RRC cavity have improved the performance of RIBF accelerators significantly since NCAC2016. U-beam intensity was increased from 49 to 71 pnA and Xe-beam increased from 102 to 173 pnA boosting the beam power beyond the ten-kilowatt regime.

An increase of the beam intensity provided to the SHE program will be achieved by the RILAC upgrade using superconducting QWR and a new 28GHz ECRIS. This SRILAC will be in operation by the end of the year 2019. NCAC congratulates the Accelerator Group to the successful collaboration with KEK on the SRF development, which has become the foundation of the RILAC upgrade program.

The beam power is reaching the 5-15 kW level depending on the element, which is destructive for equipment so that the Machine Protection System (MPS) needs to be reviewed and eventually upgraded.

The availability of the machine complex is decreasing because of ageing equipment and deferred maintenance as a result of lack of funds and limited staff. In the period of the mid-to-long term plan, the Accelerator Group will lose a significant number of people due to retirement. NCAC realizes that a refurbishment program and adequate staffing is required.

An intensity increase by a factor of 10 has been proposed and will need development of the accelerators (fRC, SRC), of the MPS and of the scientific instrumentation. The key development for the increase of intensity, the charge stripper ring, is a unique and challenging device.

The high-intensity frontier is and will be the driving force in the field of RI-beam science. However, the intensity increase will cause serious problems because of heat load, increased radiation and high electricity costs. The development of beam recycling technology with a storage ring will become critically important to pursue the efficiency frontier. RNC needs to proceed with this R&D effort as a mid- and long-term scope.

**Recommendations:**

- **NCAC recommends to establish the accelerator intensity upgrade plan and to organize an intense technical review of the beam optics, technical feasibility, and required funding, to realize this plan with the highest priority as the RNC near future project.**

- **NCAC advises to start the R&D effort on the energy efficiency improvement.**

- **NCAC recommends to strengthen connections to university groups in accelerator science and to attract students to work on the unique intensity upgrade projects.**

### Experimental Facilities in RIBF

**Findings/Comments:**
Experimental facilities have been well developed in the period reviewed. Great efforts have been put into the improvement of BigRIPS reliability and efficiency.

The SAMURAI experiments have started, which opens further opportunities for reaction research with RI beams. The unique facility of SCRIT is ready for electron scattering experiments. A test experiment has been successfully run for rare RI-ring with a mass resolution of $\delta m/m \sim 10^{-5}$. MRTOF with RF carpet technology measured mass values about 100 nuclides.
NCAC congratulates the dedicated RIBF staff on successful operation of these unique research facilities.

Evaluations of high-power thermal and stress tolerance of target and primary beam dump have been conducted with ANSYS in view of the successful intensity increase. However, NCAC points out that the significant beam power upgrade requires a major development of the target to cope with the significantly large power deposition.

**Recommendation:**

- **NCAC recommends the establishment of the upgrade plan for the accelerators and scientific instrumentation including target development and to conduct technical reviews to realize the intensity increase program as soon as possible.**

## VII. Safety Management Group and User group

### Radiation safety

**Findings/Comments:**

The RIBF has a dedicated radiation safety group that (i) is in charge of the radiation monitoring equipment, ensures the safety of (ii) researchers and (iii) experiments, and that (iv) manages all regulatory and legal matters related to radiation safety.

- Important achievements include:
    - The group provides online radiation-safety training for about 500 users per year
    - The team manages the radiation safety infrastructure and procedures for the RILAC upgrade
    - An upgrade of the radiation control system of RIBF
    - Securing the license for the linac construction and the use of unsealed radionuclides in the framework of radioisotope production

With the newly established program to produce research quantities of radioisotopes, the facility must continue to adjust the procedures and implement additional safety measures to cope with the increasing potential for radiation exposure of nuclear chemistry workers.

### User program

**Findings/Comments**

RIBF continues to attract large number users, domestic as well as from abroad (e.g. ~100 domestic and 200 users from abroad in 2018). Some of the user groups have contributed significant, cutting–edge experimental instrumentation that enabled new research avenues, e.g. EURICA (high-resolution Ge detectors for decay spectroscopy), NeuLAND (neutron detectors), and BRIKEN ($^{3}$He neutron detectors).

- Important achievements in the support of users include:
    - RIBF has a Program Advisory Committee with world-class researchers that recommends proposed experiments for machine time, keeping the program at the cutting edge.
    - Development of a comprehensive data base that provides rare-isotope yields, cross sections, and data on isomers for secondary beams produced at RIBF. This empowers the users to plan their experiments more independently.
    - An online radiation safety training is offered for all users to introduce them to local regulations and interlocks.

## VIII. Scientific strategy and Management

This section addresses the presentation by the chair of the RNC Committee on Scientific Strategy and Management Policy, a committee formed in 2018.

### Findings and comments of the scientific direction

With major international competition expected to come into operation in the next 3-5 years, such as FRIB in the U.S., and FAIR in Europe, it is essential that RIBF positions itself in terms of cutting-edge, scientific capabilities, leveraging its considerable, existing unique capabilities and upgrading RIBF to stay at the global forefront of rare isotope science. The NCAC considers that particularly promising opportunities exist

with the Rare RI-ring for mass measurements and reaction studies, the SCRIT RIB-electron scattering facility, as well as utilization of multiple primary and rare isotope beams in parallel.

NCAC congratulates RNC on their plan to bring to a successful completion the missions of the multi-decade long, highly productive, international centers at BNL and RAL. RBRC's legacy is a worldwide high-energy QCD community that drives the twenty-first century study of the fundamental structure of matter. The RIKEN-RAL muon facility has established muon technique as one of the most useful tools in modern condensed matter science.

**Recommendation:**

- **NCAC strongly advises RNC to regularly evaluate scientific opportunities which build on these RIKEN investments or leverage these unique mechanisms for international collaboration and investment.**

The overall strategy for future RNC research will maintain a priority on the theme of Nuclear Science in the Cosmos while extending research in nuclear and hadron dynamics with reaction studies related to nuclear transmutation, production of SHE and new isotopes, as well as opening a new research area within the RNC on strangeness physics and cold dense matter, while pursuing plans for facility upgrades and a new accelerator initiative for nuclear transmutation.

A new chief scientist recently hired at the CPR will focus on hypernuclear physics with experiments planned at FAIR and HIAF, charting a new direction in hadronic physics. At the same time, the current hadronic physics program within RNC is focusing its efforts on J-PARC.

**Recommendation:**

- **NCAC strongly encourages the development of a coherent collaborative program between CPR and RNC in hadronic physics, with an appropriate balance in pursuing scientific opportunities at FAIR, HIAF, and J-PARC.**

A new RIBF theory group in modern low-energy nuclear theory, located at the RIBF building, will be established, which will provide leadership and support for the world-class experimental RIBF program**.**

**Recommendation:**

- **The NCAC strongly recommends to rapidly move forward with the RNC's initiative to recruit a prominent nuclear theorist to build an RIBF theory group, in order to secure a broad and internationally highly competitive nuclear theory program that provides support and intellectual guidance for RIBF**.

The RNC rightly focuses its scientific strategy and goals on "Nuclear Science in the Cosmos". The NCAC recognizes that the various astrophysical topics (e.g. r-process, SN Ia, kilonovae, etc.) are best addressed

through a different mix of approaches. This includes experiments with RIBs at RNC and various theoretical studies from nuclear physics to astrophysical modelling, while linking these RNC activities to various efforts of the larger astrophysics community, such as various astronomical observation and astrophysical modelling.

**Recommendation:**

- **NCAC recommends that RNC optimize the coordination and organization of the activities of its astrophysics related efforts in order to maximize scientific impact on specific topics related to the Nuclear Science in the Cosmos.**

## Findings and comments on the management and organizational structure

RNC has transitioned within the RIKEN structure from a Research Infrastructure Center to a Strategic Research Center. As such, the RNC should address global and societal needs and RNC's mission and research program already addresses select topics in energy, health, climate and sustainability. The transmutation research activities and the establishment of the Accelerator Application Research Division indicate an increased focus on societal needs, which NCAC strongly endorses.

RNC is facing a generational change over the next years. NCAC strongly emphasizes the timely appointment of successors in leadership positions. It is essential that the necessary expertise for research as well as the accelerator and facility operations be maintained.

NCAC considers the RIBF upgrade as the highest priority for the future of RNC, while at the same time encouraging RIKEN to provide support for a significant increase in the annual RIBF operation time so that RNC can remain competitive globally.

## Findings and comments on the RIBF upgrade and the post ImPACT activities

NCAC acknowledges that the scientific strategy to choose superconducting technology for the SRC and RI beamlines has been successful in delivering very stable and reliable beams for various experiments, leading to outstanding scientific results. NCAC strongly supports the plans that the RIBF program remains the main/core program at RNC for the foreseeable future.

The RIBF upgrade program is proposed for the accelerator complex, cyclotrons, RI beam lines and experimental facilities as a near future program at RNC, based on the current excellent performance developed over the past twelve years of operation for nuclear science and its applications.

RNC should prioritize the realization of the intensity upgrade as a near future program, targeting an increase of factor 10 in Uranium beam intensity, with charge stripper rings to be added.

The energy efficiency for accelerator operation needs to be continuously improved in parallel with the beam intensity increase. In the longer time scale, the beam recycling technology development should be important as a unique concept as proposed.

The ImPACT program is recognized as an important science program, with a mid- and long-term scope, to connect fundamental research to society with maximizing the RNC RIBF capability to provide fundamental data key to the understanding of the transmutation mechanism and guidelines for its further development.

NCAC acknowledges the importance of basic R&D for advanced accelerator technology to drastically reduce nuclear waste as an important output.

NCAC highly appreciates the progress made by RNC on accelerator applications and knowledge transfer and encourages the continuation of these efforts.

**Recommendations:**

- **Establish/realize the RIBF upgrade program with the highest priority and continue efforts to improve the energy efficiency in the facility operation.**
- **Proceed with the transmutation program as an important R&D effort and extend scientific leadership to connect basic research to the needs of society, as a long-term future program, in cooperation with appropriate other partners.**

# Recommendations from NCAC to President Hiroshi Matsumoto

**TOR 1**

[*Research*] RIKEN Nishina Center has fully achieved its ambitious goals and is regarded as a world class research center, thank to its RIBF facility, with the presently unrivaled intensities worldwide and variety of rare-isotope beams across the nuclear char combined with state-of-the-art experimental equipment – provided locally as well as contributed from abroad.

The super heavy element program is in full bloom and RBRC continues to be a world-leading center for the high-energy study o QCD.

[*Contributions to society*] NCAC strongly supports the ImPACT program which is recognized as an important science program, with a mid- and long-term scope, to connect fundamental research to society with maximizing the RNC RIBF capability to provide fundamental data key to the understanding of the transmutation mechanism.

NCAC acknowledges the importance of basic R&D for advanced accelerator technology to drastically reduce nuclear waste as a important output.

NCAC highly appreciates the progress made by RNC on accelerator applications (Mutation genesis, Radio-Isotopes) and knowledge transfer and encourages the continuation of these efforts.

[*Consistency with 7-year plan*] RNC has successfully accomplished its core mission and aligned its strategy with the current 7-year plan goals. RNC has improved its research base, make widely available its world-class facility to the international scientific community. This statement is illustrated by the following results and projects.

-World class research on SHE, towards element 119 and Nuclear astrophysics,

-ImPACT program and beyond to contribute to important societal issues in environment and energy, via transmutation research and resources through practical application.

-Developments of applications of heavy ion beams in the areas of agriculture, industry and RI medicine.

**TOR2**

| *[Strengths (internal/positive)]* | *[Weaknesses (internal/negative)]* |
|---|---|
| - World leading high-power accelerator RIBF and new RILAC for Super Heavy Element associated to state of the art experimental equipment.<br>- The personnel system reform in JFY2018 has enabled the indefinite-term employment of staff supporting the facility operation, providing more stability.<br>- Strong user communities ( Universities and domestic /overseas institutions) and brain circulation. | - Operating budget of RIBF insufficient, needs to cover a minima of 6 months (up to now 3-5 months' operation/year).<br>- Mobility of human resources due to change in personnel system and aging of some key leaders in Accelerators and Research Staff.<br>- Aging deterioration of RIBF's core equipment.<br>-New Chief Scientist recruitment in Hadron Physics at RIKEN(CPR) and RNC Subnuclear system division strategy goals should to be aligned |
| [*Opportunities (external/positive)]* | [*Threats (external/negative)]* |
| - Discovery of new elements/ isotopes and nuclear transmutation research at RIBF.<br>- Unique astrophysics programs and strengthen the links to nuclear astrophysics experiment, theory, and modeling.<br>- Strong opportunities for RNC (or RIKEN) to define its strategy in order to maximize the benefit of accelerator applications to society (Nuclear Transmutation, medical use of short-lived radio isotopes, Ion beam Breeding). | - With major international competition expected to come into operation in the next 3-5 years, such as FRIB in the U.S., and FAIR in Europe, RIBF leadership may be challenged in cutting-edge scientific capabilities.<br>- Investment budget not at the level needed to ensure competitive upgrade plan and operation of new experimental instruments at RIBF.<br>- Considering the strong competition among international rare isotope beam facilities, building an RIBF theory group and ensuring strong leadership in nuclear theory at RIBF is critical. |

TOR3

[Collaborations/S&T Hub]

- NCAC recommends that RNC optimize the coordination and organization of the activities in astrophysics in order to maximize scientific impact on specific topics related to the Nuclear Science in the Cosmos.
- NCAC recommends to strengthen connections to university groups in accelerator science and to attract students to work on the unique RIBF intensity upgrade projects.
- Establish strong collaborations with appropriate partners for key technologies for the accelerator and target systems.
-RIKEN may consider implementing their excellent expertise in muon science to condensed matter science community through RIKEN-CEMS.
- RNC (or RIKEN) should strengthen collaboration with related organizations to the maintenance of a platform for stable supply of short-lived radio isotopes and development of the network.
- The Ion Beam Breeding, a very visible and productive application of RNC. The group may become a "Hub" of activity of mutagenomics for society.

[Internationalization]

- NCAC strongly encourages the development of a coherent collaborative program between CPR and RNC in hadronic physics, with an appropriate balance in pursuing scientific opportunities at FAIR, HIAF, and J-PARC.
- NCAC recommends that RBRC should remain an active, international center for high-energy QCD until the full scientific output of sPHENIX is realized**.**

- RNC is encouraged to regularly evaluate scientific opportunities which build on RIKEN investments overseas or leverage these unique mechanisms for international collaboration and investment.

TOR4

**Results of PI Evaluations-Overview**

- NCAC has discussed this matter at length and concluded that it is not in a position to carry out an informed evaluation of individual PIs. We are unfamiliar with the process of internal evaluation and are not comfortable with making global statements that could be open to misinterpretation in individual cases.

**For the Nishina Center Advisory Council**

**Sydney Gales**

**Chair of NCAC**

## X. Annexes

### Annex I: Agenda of the NCAC meeting June 24-26 2019

**June 24(Monday)**

**15:00(90)** **Welcome address, Explanation of Terms of Reference,**

**Introduction of members,**

**Overview of the Nishina Center Koyasu En'yo**

**16:30(30)** **Response to the last NCAC recommendations by the RNC director En'yo**

**17:00(80)** **Closed session**

**18:20 Reception**

**20:00 Back to hotel**

**June 25(Tuesday)**

**9:00** **Report on research activities (overview and highlights)**

**Nuclear Science and Transmutation Research Division**

**9:00(50)** **RIBF Sakurai**

**9:50(30)** **ImPACT Otsu / Okuno**

**10:20(15)** **Superheavy Elements Morimoto**

**10:35(30)** **Nuclear Astrophysics Tamagawa / Motizuki**

**11:05(15)** **Coffee break**

**Sub-nuclear System Research Division**

**11:20(40)** **Theory Hatsuda**

**12:00(30)** **Accelerator Applications Research Division Abe / Haba**

**12:30(60)** **Lunch (reviewers only)**

**13:30(90)** **Research Facility Development Division Kamigaito / Wakasugi**

**15:00(15)** **Coffee break**

**Sub-nuclear System Research Division**

**15:15(50) Subnuclear System Research Iwasaki**

**16:05(20) RBRC SRC Report Milner**

**16:25(15) RAL Iwasaki**

**16:40(80) Closed Session**

**18:30 Back to hotel**

**19:30 Dinner**

**June 26(Wednesday)**

**9：00(20) Safety Management Group Tanaka**

**9：20(60) The RNC Committee on Scientific Strategy and Management Policy**
**Report by the Chair Uesaka**

**10:20(120) Closed Session**

**12:20(60) Lunch**

**13:20(30) Facility Tour (Those who are interested only)**

**13:50(240) Closed Session**

**17:50(60) Summary and closeout Gales**

**18:50 End of the meeting, Back to hotel**

**19:50 Dinner**

**June 27 (Thursday) Checkout-Departure**

## Annex II: List of the members of Nishina Center Advisory Committee (NCAC 2019)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | 5th Center for Nishina Center Advisory Council | | | | |
| | | | Date: 2019/06/24～2019/06/26 | | | | |
| | | | | | | | |
| | | | **Chair/ Vice-Chair/ Member** | **Name** | **Title** | **Affiliation** | **Scientific background** | **Email** |
| 1 | | | Chair | Sydney Galès | Scientific Director Director of Research | The Academy of Europe PHYSICS & ENGINEERING SCIENCES | Nuclear Reaction Exp. | gales@ipno.in2p3.fr |
| 2 | | | member | Richard G. Milner | Professor / Director | Department of Physics / Laboratory for Nuclear Science, Massachusetts Institute of Technology | Cold QCD | milner@mit.edu |
| 3 | | | member | Reiner Krücken | Deputy Director | TRIUMF | Nuclear Exp. | reinerk@triumf.ca |
| 4 | | | member | Akira Yamamoto | emeritus professor | High Energy Accelerator Research Organization \| KEK | Accelerator | akira.yamamoto@cern.ch |
| 5 | | | member | Hidenori Takagi | Director / Professor Dr. | Department of Quantum Materials, Max-Planck Institute for Solid State Research | Interdisciplinary | h.takagi@fkf.mpg.de |
| 6 | | | member | Alexandra Gade | Professor and Chief Scientist | Michigan State University | Nuclear Structure Exp. | gade@nscl.msu.edu |

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|---|---|---|---|---|---|---|---|---|
| 7 | | | member | Tomofumi Nagae | Professor | Division of Physics and Astronomy, Graduate School of Science, Kyoto University | Hadron, Hyperon, Hypernuclei Exp. | nagae@scphys.kyoto-u.ac.jp |
| 8 | | | member | Hushan Xu | Director | Institute of Modern Physics, Chinese Academy of Sciences (IMP) | Nuclear Mutation | hushan@impcas.ac.cn |
| 9 | | | member | Oliver Kester | Associate Lab Director | Accelerator Division, TRIUMF | Accelerator | okester@triumf.ca |
| 10 | | | member | Achim Schwenk | Professor | Technische Universität Darmstadt | Theory | schwenk@physik.tu-darmstadt.de |
| 11 | | | member | Atsushi Tanaka | Vice Director | Quantum Beam Science Research Directorete Kansai Photon Science Institute National Institutes for Quantum and Radiological Science and Technology | Interdisciplinary | tanaka.atsushi@qst.go.jp |
| 12 | | | member | Roland Diehl | Professor. Dr. | Max Planck Institute for Extraterrestrial Physics | Nuclear Astrophysics | rod@mpe.mpg.de |
| 13 | | | member | Alinka Lépine-Szily | Professor | Departamento de Física Nuclear Universidade de Sao Paulo | Nuclear Exp. | alinka@if.usp.br |

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|---|---|---|---|---|---|---|---|---|
| 14 | | | member | Hiroko Nagahara | Fellow | Earth-Life Science Institute (ELSI)<br>Tokyo Institute of Technology | Cosmochemistry, Astromineralogy | nagahara@elsi.jp |
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