RIKEN Nishina Center
Advisory Committee Report

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Contents

Nishina Center Advisory Committee 2014 Report

I. Introduction

The Nishina Center Advisory Committee (NCAC) met at RIKEN from July 1, through July 3, 2014. A full list of the committee members is given in the appendix to this report. Presentations were made to the Committee on actions taken following the NCAC 2011 (NCAC2011) report, as well as updates on on-going RIKEN Nishina Center (RNC) programs and proposed plans for future activities.

The Committee was extremely impressed with the overall program at the RNC. Highlights enumerated below include the discovery of many new isotopes, evidence for the modification of shell structure far from stability, great strides in mapping out the rapid neutron capture process line, and the definitive determination of element 113. The advances made in beam intensities and species at RIBF, coupled with the recent additions of major equipment, have propelled the facility into being the best one in the world for fast radioactive ion beams. In its present configuration, RIBF can be the world-leading facility for radioactive beam research for at least the next five years. With the proposed upgrades to the facility, it can maintain a world leadership position for at least the next decade. But this will require that the facility provides radioactive beams to experimenters for substantially more hours in the future than it has been able to do in the past few years. This point has been made by past review committees and more recently by the Program Advisory Committee in a letter to President Noyori and Professor En'yo, which is attached at the end of this report. If RIKEN is not able to provide resources to operate RIBF close to eight months a year, it will become known as the best equipped facility for radioactive beam experiments but one where beam time is nearly impossible to obtain. This will quickly erode user interest and support, especially international users.

Other RNC activities also have advanced over the past three years. Examples include: major advances in nuclear theory and in lattice QCD in particular; continued success in external programs outside of Japan at the Rutherford Appleton Lab and at Brookhaven National Lab; advances in preparations for experiments in hadron physics at J-PARC and SPring-8. Below, we provide more detailed highlights of these and other efforts along with recommendations for future consideration. The five principal recommendations in the report are summarized below. They are also repeated in appropriate sections of the report.

Principal Recommendations

- **As the highest-priority recommendation, NCAC reiterates the need to ensure the additional budget for eight-month operation of RIBF. Only this will allow RIBF to fully exploit the unique time window open for the upcoming years to establish and maintain its world leading position in this research area.**
- **NCAC recommends that the RNC vigorously pursue accelerator upgrades to the present RIBF to keep it competitive with new facilities being built in other parts of the world. The upgrade path should strive to keep capabilities world leading through at least 2025.**
- **NCAC most strongly recommends continuing all efforts to increase the permanent staff for RIBF by at least 10 tenured positions in the coming 5 years. The RNC and RIKEN must work together to develop a plan for this staffing increase, which is critical for the research program, the targeted eight-month operation of RIBF and for the full design of a future major upgrade of the**

facility. The plan also needs to address the problem of replacing scientists who are retiring or moving to other prestigious positions. Consideration of research efforts that span over many decades must be included in developing new approaches to solve this problem.

- **NCAC recommends establishing a second Chief Scientist position in the Theoretical Research Division, preferentially in the field of theoretical nuclear and astrophysics, in addition to the existing Chief Scientist position (Hatsuda) that is devoted primarily to QCD theory and applications.**
- **The present framework at RIKEN does not provide sufficient incentives for growing commercial accelerator applications. NCAC recommends that RNC together with RIKEN explore ways to encourage growth in this area.**

This report is structured according to the elements in the charge to the Committee. The report provides feedback on the progress made toward implementing the recommendations from the NCAC2011 report and observations that either indicate that the Committee sees no need for changes or finds areas where changes are recommended.

II. Organization, Management, and Budget

Evaluate RNC's response to the recommendations made by NCAC2011

(*recommendations from NCAC2011 are in italics*)

** To further increase experimental running time at RIBF, the amount of time spent on beam development has been reduced. It is important for a new facility to devote time to developing new beams and to increasing the intensity of existing beams that are now limited in beam current. In the future, management must continue carefully weighing the need for beam development versus running experiments. Finding the optimum mix to the two can be very difficult.*

The primary high-energy beam intensity of RIBF has continuously increased since 2011. Impressive, world record (particle beam) intensities of up to 415 particle nano-Amperes (note all beam currents listed as nA are particle nano-Amperes unless otherwise indicated) for ^{48}Ca, 38 nA for ^{136}Xe, and 25 nA for ^{238}U have been reached. At the same time the availability of the beam during the time that the facility was operating increased from about 67% in 2011 to 90% in 2013. Thus the primary beam intensity, its availability and a development of a new primary beam of ^{70}Zn at 100 nA meet the recommendation of NCAC2011.

**The lack of technical staff to provide support for outside users to mount experiments on the equipment can slow progress and result in less efficient overall operation. Furthermore, it adds an undue burden on the professional staff members who are responsible for the equipment. An increase in permanent staff by about 20% would provide a significant boost to the overall efficiency of the operation.*

and From 3.3

** The permanent accelerator science staff appears too minimal to operate the facilities, to make intensity improvements, to improve reliability, and to develop the plans for facility upgrades. We strongly support an increase in the permanent accelerator and research support staff as the facility moves to eight-month operation. This higher level will also be necessary to allow sufficient free time to allow the staff to define its future program.*

Actions towards increasing the staff by 20% were undertaken by RNC management. Newly hired staff and personnel transferred from other institutes led to an increase of the permanent staff by 3 persons between 2011 and 2013. With the amendment of the Labor Contract Law, it became possible for fixed-term employees to convert their employment contract to a contract without a definite period.

This action is expected to increase the permanent staff by 10 positions in 5 years. However, according to the present planning the size of the accelerator group will increase (through FY2014) by only 2 persons. At the same time the overall technical staff for accelerators at RNC stayed constant (45) from FY2011 to FY 2013 (17 permanent, 10 contract, 18 operators). The currently available personnel will not be sufficient to carry out the targeted eight-month operation with needed improvements to performance and stability, and simultaneously move forward with the ambitious plans for an upgrade of RIBF.

** If RIKEN were to add a second 10MW generator to the facility, it would have the power that is required to operate RIBF without using power from the grid. The NCAC supports investigating the feasibility of adding this second 10 MW generator.*

The RIKEN HQ decided to construct a new gas-engine generator of 3 MW in order to keep the research activity ongoing even at times when the Wako campus is fulfilling the request by the government for electric-power saving by 15%. Presumably, this request for power reductions will be terminated soon easing the situation significantly. Although the 3 MW generator is too small to supply the full power for the RIBF operation, it is helpful to reduce the peak electric-power of the Wako campus in times of peak energy-consumption.

Observations

The current management structure, which is organized around three divisions and laboratories and groups, is adequate to reach the goals of RNC and responds to the recommendations of NCAC2011. In particular, a coherent action of the Director, Deputy Directors, and Chief Scientists strongly contributed to the top-level research program and the efficient operation of the Center.

Actions towards an increase of staff by 20% were undertaken by management. Newly hired staff and personnel transferred from other institutes allowed the RNC to increase the permanent staff by 2-3 persons between 2011 and 2013. However, the overall number of positions stayed constant. The establishment of the User Liaison Office with its one-stop policy has been a great success and most useful for all users.

Two areas related to budgets are noted here. One is an on-going problem of obtaining sufficient support to maintain operations for about eight months a year and the other is a potential future problem with changes in the funding structure that are being made by the Japanese government. Both need careful consideration in the future.

Recommendations

- **As the highest-priority recommendation, the Committee reiterates the necessity to ensure the additional budget for the eight-month operation of RIBF. Only this will allow the RIBF to fully exploit the unique time window open for the upcoming years to establish and maintain its world-leading position in this research area.**
- **NCAC most strongly recommends continuing all efforts to increase the permanent staff by at least 10 tenured positions in the coming 5 years. The RNC and RIKEN must work together to develop a plan for this staffing increase, which is critical for the research program, the targeted eight-month operation of RIBF and for the full design of a future major upgrade of the facility. The plan**

also needs to address the problem of replacing scientists who are retiring or moving to other prestigious positions. Consideration of research efforts that span over many decades must be included in developing new approaches to solve this problem.

- **The Committee strongly encourages more joint appointments as a way to engage university groups in the programs.**
- **The Committee strongly encourages the RNC management to fully explore additional funding schemes related to the National Research & Development Institutions.**

III. Highlights, Operation, and New Proposals

Observations

NCAC would like to congratulate Director En'yo and the scientific and accelerator staff for the outstanding progress made on many aspects of the facility operation:

i) higher beam efficiency for RIBF;
ii) higher RIBF beam availability for users;
iii) increase in beam intensity of ^{238}U beam to 25 nA in good progress towards the final goal of 100 nA;
iv) development of other beams for users.

While NCAC applauds the efforts noted above, it encourages the accelerator staff to optimize further the operation of the facility.

NCAC would like to congratulate the scientific staff for the great discoveries of new isotopes far from the valley of stability and also for elucidating the structure of many of these isotopes involving shell and shape evolution as function of N/Z ratio. Spectacular examples include spectroscopy of ^{42}Si, ^{54}Ca ^{136}Sn, quadrupole moment measurement of ^{43m}S, spectroscopic factor determination of ^{37}Mg, and beta-decay half-life measurements of $^{79,80}Ni$.

The Committee is very pleased to see the great progress made with the forging of the large international collaborations to pursue research at the RIBF facility. This has led, in particular, to the successful campaign of EURICA and to the recent SEASTAR collaboration which was established around a new collaboration concept for RNC, i.e. PSP (Proposal for Scientific Program).

NCAC appreciates the firm establishment of element 113 as a possible RIKEN discovery, and the confirmation of the production of two isotopes of element 116 (^{293}Lv and ^{292}Lv) in the ^{248}Cm + ^{48}Ca reaction. It strongly supports the group in its efforts to unambiguously observe element 118 in a ^{238}Cm + ^{50}Ti experiment with GARIS and discover elements beyond 118. Indeed the Committee would like to see a strong program in super-heavy chemistry being developed and maintained.

The RNC through RIBF has a unique window of opportunity for the coming 5 to 7 years in which it will be the worldwide leading center for research with radioactive beams. This should be used to the fullest to map the nuclear chart far beyond the valley of stability and make important discoveries in nuclear structure and nuclear astrophysics, in particular helping delineating the path for the r-process. For this reason, the Committee is disappointed to see that the goal of eight-month operation of the RIBF facility has not been realized in spite of the great efforts of the accelerator staff. The operation time has indeed decreased after the earthquake-tsunami disaster of March, 2011. While this is understandable, it nevertheless has created concern in the community, both in Japan and outside of Japan, that the facility will continue to be underutilized. The Committee strongly advises the RIKEN Directorate to help make the necessary budget available for an eight-month operation of the RIBF facility.

In this context, it is important that RNC should judiciously think about undertaking upgrades or new technical projects, taking into consideration not only the scientific opportunities that they may bring but also the financial consequences they may have on running the facility efficiently and for a longer period of operation per year.

The unique RIBF data, especially on neutron-rich nuclei are crucial for constraining and validating nuclear structure and reaction models. The Committee suggests that the impact of experimental program at RIBF on theory developments worldwide is better articulated by RIBF leadership.

Below, we provide some highlights of activities over the past three years. One danger of making such a list is that important parts of the program may not be represented. This list was put together by the Committee and thus reflects the bias that comes from the membership of the group.

RIBF Highlights

The highlights of the RIBF facility since the NCAC2011 meeting can be divided into three categories: i) highlights regarding facility improvement and operation, ii) highlights regarding initiating international collaborations, and iii) scientific highlights.

Facility improvement and operation

Several milestones have been reached during the period since the last NCAC meeting complying with the recommendation of NCAC2011.

- Following NCAC2011, the new injector RILAC2 was fully and successfully commissioned with uranium beam.
- High-intensity uranium beams could be achieved through several improvements including joint operation of the 18 GHz and superconducting 28 GHz ECR sources and modification of RRC electric deflection channel.
- fRC was successfully upgraded in 2012.
- Windowless gas strippers were developed and replaced the carbon-foil stripper between RRC and fRC thus solving the long-standing problem of the limited lifetime of the stripping system. The higher-intensity beams exiting fRC necessitated using a beryllium-foil stripper for uranium and air stripper for xenon between fRC and IRC.
- The above improvements led to a high efficiency of operation and a routine availability of beam to users of greater than 90%. They allowed the delivery of uranium and xenon beams of around 25 nA and 38 nA, respectively, and much higher ^{70}Zn (123 nA) and ^{48}Ca (415 nA) beam intensities, well on the way to the stated goals of 1,000 nA for most ions and 100 nA for uranium or xenon.

Programs, projects and international collaborations

International collaborations result in high international visibility and high impact of research performed at RNC.

- The initiative to bring the RISING Ge-array to RIKEN under the international collaboration EURICA, which had a very successful campaign in the last two years with outstanding results.

- The recent SEASTAR international collaboration which was established around a new collaboration concept for RNC, i.e. PSP, and which was based on the initiative to operate the MINOS target and detection system in conjunction with DALI2. The collaboration had its first successful experimental campaign this year.
- The new program for studies in the framework of nuclear-waste transmutation. This is a funded project within the ImPACT program for Reduction and Resource Recycle of High-Level Nuclear Waste with Nuclear Transmutation. It aims at collecting data through characterization of long-lived fission products with reactions in inverse kinematics. It has a high visibility and is of great societal need in Japan and the world.

Scientific highlights

The research performed with the RNC/RIBF facilities has been in the last years at the forefront of what is pursued worldwide in this field. It has led to high quality publications that appear in high impact journals. Some of the outstanding and exciting results that will pave the way for further interesting research in the future are:

- RIBF continues at present to be the most important facility worldwide for the production and identification of new isotopes and isomers. About 70 new isotopes were successfully produced and identified at RIBF since NCAC2011 and 18 new isomers were found.
- A facility for mass measurements of slow-RI based on a multi-reflection TOF (MRTOF) mass spectrograph demonstrated 50 parts per billion mass precision with a few ms flight time.
- Evidence for disappearance of magic numbers 20 and 28 for neutron-rich nuclei has been obtained through observation of large deformation of ^{36,38}Mg and of ^{42}Si. In particular, the low excitation energy of the 2^+ level observed in γ-ray spectroscopy of ^{42}Si indicates strong deformation and signals disappearance of N=28 magicity, thus resolving a controversy over earlier results from NSCL and GANIL.
- In the region of large deformation, evidence for a new type of p-wave neutron-halo nucleus has been found where a valence neutron forms a halo around a well-deformed core, e.g. ^{31}Ne and ^{37}Mg.
- Evidence was found for a new magic number in the isotope ^{54}Ca. The study showing that N = 34 is a subshell closure in ^{54}Ca was published in the journal Nature.
- Isomer spectroscopy with the EURICA array provided data to establish the low-lying structure of neutron-rich N=82 nuclei. This new data indicate that the N=82 magic gap is present all the way down to palladium.
- Mapping of Gamow-Teller strength was performed with the (p,n) reaction in inverse kinematics using beams of ^{12}Be and ^{132}Sn. This was done with the purpose of testing and improving theoretical models.
- The half-lives of 20 neutron-rich nuclei with Z=27–30 have been measured at the RIBF, including five new half-lives of ^{79,80}Ni.
- The first 2^+ excited state in the neutron-rich tin isotope ^{136}Sn has been identified. This result confirms the trend of lower 2^+ excitation energies of even–even tin isotopes beyond N=82.
- Projectile fragmentation (PF) is known to produce spin-aligned RI beams. At RIBF a new method for high-spin alignment was developed using the two-step process of PF + dispersion matching, which was published in Nature Physics journal.
- A mapping study of γ-rays in Cassiopeia A from decay of radioactive ^{44}Ti, a direct tracer of a supernova blast, was made with the focusing telescope. The ^{44}Ti map

displayed some asymmetry, supporting a mildly asymmetric explosion model with low-mode convection. The result was published in Nature.

- Conclusive identification of element 113 through a new event that was observed on August 12, 2012, in the cold-fusion reaction $^{209}Bi + ^{70}Zn$. The decay through a chain of six consecutive alpha decays connecting to well-known daughter nuclides provided a conclusive evidence for formation of $^{278}113$.
- Ion-beam breeding remains an important application activity of RNC. In the period since NCAC2011, two cherry blossom cultivars were newly created: "Nishina Haruka" and "Nishina Komachi". In the meantime, RNC is collaborating to breed i) commercial rice varieties, "Hitomebore" and "Manamusume", that will grow normally in saline paddy fields affected by the recent tsunami and ii) new wakame cultivars of high yield and high environmental adaptability.

Theory Highlights

- Determination of baryon-baryon interactions from Lattice QCD.
- Derivation of the nuclear matter equation-of-state using the Lattice QCD NN force.
- Reaching physical pion mass in LQCD computations on the K-computer.
- World's most accurate calculation of the few-body bound state of ^4He atoms.
- Description of ^{12}C structure (including the Hoyle state) using statistically generated Slater determinants.
- Time-dependent simulations of heavy-ion fusion and predictions of fusion hindrance effects due to pairing.
- Predictions that shape fluctuations can strongly impact shell evolution.
- Prediction of a new type of collective decoupled pygmy modes in neutron-rich nuclei.
- Formulation of particle production with real-time Stochastic Quantization.
- First r-process nucleosynthesis study based on 3D, general-relativistic neutrino-transport simulations of neutron-star mergers.
- Computation of 10^{th}-order contribution to electron and muon g-2.
- Launching the Interdisciplinary Theoretical Science (iTHES) Research Project that facilitates new interdisciplinary frontiers.

RBRC Highlights

- The RHIC-spin program has achieved 630 pb^{-1} of integrated luminosity, which provides the first quantitative determination of the contribution of gluons to proton spin.
- The VTX detector in PHENIX was completed, commissioned, and is smoothly taking data. The upgrade provides over two orders of magnitude improvement in sensitivity for charged hadron detection at high p_T.
- The PHENIX trigger upgrade for the muon arms enabled the measurement of flavor decomposition of anti-quark spin through a $W^{\pm}$ asymmetry measurement.
- Major accomplishments in Lattice QCD that are noted above in the **Theory Highlights** are partially related to RBRC activities.
- Over 600 Tflops computing performance realized (Ken Wilson Lattice Award 2012).
- Yasayuki Akiba, Experimental Group Leader at RBRC, won the 2011 Nishina Memorial Prize for heavy-ion physics.
- Many young scientists trained through RBRC now have tenured positions at leading institutions in Japan.

RAL Highlights

- Continuing success of the condensed matter program which is world-leading in its field with over 24 high quality journal papers published during this period and over 250 publications in total.
- Science highlights of this area include:
  - detailed investigation of model magnetic systems including a quantum spin; system (published in Nature), molecular superconductors and magnetic semiconductors;
  - studies using RIKEN-RAL's pressure capabilities in organic and inorganic magnetic systems;
  - investigation of Li-ion diffusion in battery materials, including work by Toyota;
  - charge- and spin-dynamics studies in molecular semiconductors;
  - studies of nanoscale defects in metal alloys;
  - pump-probe laser experiments investigating electron polarization in semiconductors and vibrationally-excited hydrogen.
- Commissioning of the advanced Chronus spectrometer, now playing an important role in maintaining a strong μSR program at the facility.
- Breakthroughs in the ultra-slow muon project, with developments of laser and target technologies in collaboration with other RIKEN groups.
- Development of chip irradiation experiments investigating single event upsets generated by muons.
- Promotion of condensed matter μSR across Asian countries, developing a vibrant user community and involving MOUs between RIKEN and Malaysian universities, international symposia in Bali and Penang, and visits to RIKEN-RAL by Korean, Indonesian and Malaysian scientists.
- Development of density functional theory calculations of muon site occupancy, a new area of work that is of importance.

IV. Theory

Evaluate RNC's response to the recommendations made by NCAC2011

**The theory efforts as well as the connection to experimental activities at RNC should be further enhanced by strengthening the collaboration with nuclear theory groups at Japanese universities working on RIBF physics. This can be enhanced by establishing a domestic theory forum, where such efforts can be coordinated.*

The Committee notes below the significant progress that has been made in the theory program over the past three years. The part of the theory program related to nuclear physics has been improved by excellent additions to the staff. Some of these key staff members are now on the verge of leaving to fill academic positions at Japanese universities. This is an excellent testament to the success of the effort but it foretells a drop in productivity if replacement staff members are not appointed. The theory program leaders have also reached out to develop cross-cutting research at RIKEN that involves groups in physics, chemistry, biology and computational science.

**NCAC recommends adding an expert in nuclear astrophysics doing large-scale nucleosynthesis simulations in order to make the theory as well as the experimental efforts of RNC coherent.*
and
**It would be advantageous if he [Hatsuda] could keep ties with the University of Tokyo to optimize the attraction of talented theory students. RIKEN should explore the possibility of a joint appointment.*

The Committee notes that the first of these two recommendations has been done with the recent addition of an expert theorist in nucleosynthesis simulations. The Committee further notes that Prof. Hatsuda has a continuing role as a visiting professor at the University of Tokyo through 2016.

**We [NCAC] would like to see the theory activities to tie the nuclear–particle physics with astrophysics.*

Activities concerning topics in astrophysics conducted by the RNC theory division have indeed been expanded considerably in recent years. The group led by Hatsuda pursues several projects related to astrophysical aspects of dense hadronic matter as it is realized in the center of neutron stars. The nuclear theory program led by Nakatsukasa has strong ties to low-energy nuclear astrophysics. There is an ongoing attempt to establish a coherent theoretical framework under a common theme “From QCD to Cosmos” within the RNC Theory group. The group is a strong component of “Field 5: The Origin of Matter and the Universe” of the computational MEXT HPCI Program (Hatsuda and Nakatsukasa are members of the steering committee) that involves the broad particle-nuclear-astro community in Japan. The NCAC applauds the establishment of a Joint HPCI-iTHES RIKEN effort in nuclear astrophysics.

Observations

The Theoretical Research Division of the Nishina Center under the leadership of Tetsuo Hatsuda represents an effort that is unique worldwide. Its big picture "From QCD to Cosmos”, presented to the Committee, spans a broad and coherent spectrum including frontline research activities in Lattice Gauge Theory (the Quantum Hadron Physics group of Hatsuda), Theoretical Nuclear Physics and Density Functional Theory (the group of Nakatsukasa), Strangeness Nuclear Physics with a focus on exact Few-Body Methods (the group of Hiyama) and physics based on the Gauge-Gravity Duality (the Mathematical Physics group of Hashimoto). This excellent compound of four theory groups, the strongest one of its kind in Japan, provides an optimal framework for bridge-building between various tasks: it aims at a comprehensive understanding of low- and high-energy nuclear and particle physics phenomena, and it elucidates the role played by hadrons and nuclei in the Cosmos. NCAC is impressed by the strong interdisciplinary initiatives under Hatsuda’s leadership: the iTHES project with connections to other areas of physics, biology, chemistry and computational science, and the HPCI (High Performance Computing Infrastructure) program with access to the powerful computing facility (K-Computer) at the Kobe Center. The groups use the whole range of tools, including analytic theory, advanced algorithms, and high-performance computer facilities (in particular the Kobe Center). Last but not least, the group collaborates with leading theory and experimental groups in Japan and abroad.

The goal of the lattice QCD task, led by Hatsuda, is to provide foundations for nuclear physics in terms of the fundamental degrees of freedom of the strong interaction: quarks and gluons. This group has made pioneering computations of the nucleon-nucleon interaction, moving systematically towards realistic quark masses corresponding to the physical pion mass. These activities and associated projects are on the way to making unique predictions relevant for experimental programs studying properties of cold and hot QCD matter, the nuclear equation of state and the physics of neutron stars. The nuclear many-body task, led by Nakatsukasa, employs time-dependent Density Functional Theory and its extensions. Predictions for weakly bound, neutron-rich nuclei support the experimental program at RIBF and provide intellectual foundations for future programs. Other components of the theory effort (those led by Hashimoto and Hiyama) are also very visible. It is refreshing to see a large community of young people (postdocs and PhD students) attracted to, and stimulated by, the current theory program.

While appreciating and admiring the uniqueness of this theory effort, NCAC is concerned about its future. Nakatsukasa and Hashimoto have recently accepted professorships at universities, and they will be leaving shortly. This implies that the activities of their groups within the Nishina Center will be terminated in 2014/15. There is no mechanism for replacing their positions promptly with the motivation of maintaining, in particular, the vital interaction between theory and experimental programs around RIBF. There is a risk that this will destabilize the theory effort at RNC. To avoid such a scenario, which the Committee considers unacceptable, it is recommended to establish a second Chief Scientist position in the Theoretical Research Division, preferentially in the field of theoretical nuclear and astrophysics, in addition to the existing Chief Scientist position (Hatsuda) that is devoted primarily to QCD theory and applications. Since a RIKEN Chief Scientist can hire at least two permanent researchers, which would make the number of permanent theory staff at least six, thus providing a critical mass with an opportunity for expansion. Such a structure will guarantee the coherence of the overall theory program, enable wider collaborations inside and outside of the Nishina Center, and provide support and intellectual underpinning for associated experimental programs.

After listening to various opinions about the value of theory in a place such as RNC, the Committee believes that some general comments about the interaction between experiment and theory may be useful. To optimize the scientific progress, it is important to enhance the positive feedback in the "experiment-theory-experiment" loop of the scientific method. The role of theory should not be limited to data interpretation “after the fact”. Theory should lay foundations for future experimental avenues by identifying critical measurements and assessing the scientific impact of planned experiments. A RIBF theory initiative, working closely with the experimentalists associated with RIBF, should serve as a focal point for facilitating active exchange aimed at enhancing the experiment-theory cycle.

Recommendation

- **NCAC recommends establishing a second Chief Scientist position in the Theoretical Research Division, preferentially in the field of theoretical nuclear and astrophysics, in addition to the existing Chief Scientist position (Hatsuda) that is devoted primarily to QCD theory and applications.**

V. Hadron Physics at RNC

Evaluate RNC's response to the recommendations made by NCAC2011

**NCAC would like to see scientists in various universities in Japan participating in the experimental activities through these [experimental programs of RNC at J-PARC and SPring-8] collaborations.*

The Committee notes that this is one area where a major shift of focus has occurred since the last review, following the decision not to pursue the Hadron Hall extension funding for J-PARC. KEK is now leading this quest. The RIKEN Nishina Center group is focusing its efforts on the approved experiments in the existing hall either as a lead organization or as a major collaborator. This is well received by the participating university groups who praised the contributions made by the RIKEN group, as reported by the chair of the J-PARC Hadron hall users group.

Observations

The overall physics objective of the hadron physics program is to study the in-medium modification of hadron properties in nuclei. This includes measurements of the η' at SPring-8, K and φ mesons at J-PARC, π's at RIBF and eventually η' at FAIR.

With the problems that have been encountered at J-PARC, the program of planned experiments and the expansion of the Hadron hall that was to be supported by RIKEN has yet to begin. Indeed since the last review, the scope of the RNC program at J-PARC has been changed to a participation in targeted experiments, leaving KEK to secure the funding for an expansion of the Hadron hall.

The J-PARC effort from the RNC involves collaboration in experiments which are now being developed (E16) or about to take data (E15). Both of these experiments have high priority from the KEK IPNS PAC and involve large collaborations. The physics case for them is strong and the experiments are unique. RIKEN is providing leadership in developing and carrying out the experiments and key instruments being used in them.

Delays at J-PARC have been hampering the program but recovery there is under way. J-PARC has developed beams from slow extraction with good beam quality that will be used for experiment E15. A pilot run of the E15 setup showed that it is working as planned. The high momentum beam required for E16 will be available after an approved reconfiguration of the existing hall for the COMET rare muon decay program is complete.

At SPring-8, an experiment that is searching for the photo-production and propagation of η' mesons in nuclei is starting to take data with the new spectrometer LEPS2. A joint appointment between Osaka University and RIKEN provides strong leadership to the experiment.

These programs, which were initiated in the RNC during the third five-year term, should soon start producing interesting data. The scope of the program is very diverse and a focus on key components of the program is needed to provide timely results.

Key leaders of these programs are soon expected to retire from RNC. If they are not replaced, this area of research would lack the significant leadership at RNC that has made them possible.

Recommendation

- **NCAC recommends that RIKEN actively continues the successful participation and leadership of RNC researchers in the present and future Hadron Physics programs at J-PARC and SPring-8.**

VI. Accelerator Applications

Evaluate RNC's response to the recommendations made by NCAC2011

**Within the RIKEN Wako campus, more synergetic collaborations should be developed by linking directly to the newly formed Research Cluster for innovation. For example, short-lived isotopes could be promoted making unique use of the RNC production capabilities within the Wako campus.*

A collaboration with the Imaging Team of the RIKEN Center for Life Science Technology has been active for the production of multi-tracer isotopes from the AVF cyclotron. A new collaboration with RIKEN Quantitative Biology Center is being formed in order to improve MRI sensitivity using the dynamic nuclear polarization technique. In addition, ^{89}Zr, ^{124}I were produced and distributed for medical and industrial applications, and more recently purified ^{28}Mg and $^{86,87}Y$ are being developed for medical and biological research. NCAC encourages RNC to continue developing synergistic collaborations within the Wako campus by linking directly to the Research Cluster for innovation. This effort is very closely connected to the cross-disciplinary research in the Designated National Research Institute. The Committee provides more details on this in a different section below.

**If this [industrial applications] program becomes very successful, a strategy for accommodating a larger industrial user demand should be established to maintain a good balance with the main fundamental research activities.*

At this time the demand for industrial applications does not interfere with the research program. Nevertheless, a strategy to accommodate growth has been implemented by increasingly using the AVF cyclotron (rather than the RRC cyclotron) for the production of radioactive isotopes for medical and industrial applications. This has the double benefit of minimally interfering with the research program and lowering the cost to the users.

**The visibility of this expertise [as a major resource center in Nuclear Science] should be increased by RIKEN management. NCAC strongly supports the efforts by RNC management to increase the visibility of the Accelerator Applications Group.*

Impressive progress has been made on the public relations front, and several new initiatives have been launched to enhance the visibility of the Accelerator Applications Group to multiple stakeholders, including the scientific and industrial user community, government, and the general public. Initiatives include articles featured on the RNC website, and in the new public relations magazine, RIKEN, newspaper articles, TV programs, and press-releases through MEXT. A reorganized Public Relations Committee has been formed at the intersections of research and administration with specific focus on promoting strategic public relations.

Observations

Accelerator applications with radioactive ion beams span a wide range, from very basic research of super-heavy element (SHE) chemistry and the production of targets and special materials for ion sources for the RIKEN RIBF program, to applied research for societal applications, such as radioactive ion production for medical use, gamma-ray inspection, and as a tracer to diagnose wear of industrial material in real-time. The latter application was developed in close partnership with industry and led to a patent application.

Other noteworthy applications include support for testing and understanding the consequences of the 2011 Fukushima Dai-ichi nuclear power plant accident and irradiation activities for food, e.g. radiation biology (sake), plant breeding for wakame (seaweed), salt-resistant rice. These activities could serve as a role model for encouraging accelerator applications tailored to specific needs of a region. The group has a new program called ImPACT, which will measure nuclear reaction cross sections for long-lived isotopes. The goal is to reduce and recycle high level nuclear waste with nuclear transmutation. The program was approved in June just before the meeting of NCAC and is a step toward accelerator-driven transmutation of waste in Japan.

As applied activities increase, care must be exercised to ensure a proper balance between the basic and applied areas of accelerator applications. The Committee recognizes the importance of supporting both of these areas and encourages management to set priorities to make that happen. In particular management should work with the Accelerator Applications Group to articulate RNC's vision for industrial, social & economic accelerator applications, and set goals and milestones.

Recommendations

- **Strengthen and expand connections with industry. To overcome the person-power limitations, consider a model in which routine RI production for fee-based distribution is supported by sub-contractors, the cost of which is borne by the customer/user [is included in the fee for full-cost recovery].**
- **Pursue R&D for accelerator applications in collaboration with industry. A possible funding model may involve industry providing: a) personnel directly involved in the developments, b) cash, and/or c) in-kind contributions, e.g. experimental instrumentation, which can be used for the research program. A system for such cooperative R&D work with industry should be much more encouraged and boosted.**
- **Explore component irradiation as a possible application and a source of revenue for RNC. This is a promising area that would benefit both RIKEN and Japanese industry.**
- **RNC management is encouraged to actively pursue opportunities for closer partnership among the various RIKEN centers (e.g. RNC and Brain Centre) and other organizations, for the production of novel medical isotopes for research and development and eventually commercialization.**
- **The present framework at RIKEN does not provide sufficient incentives for growing commercial accelerator applications. NCAC recommends that RNC work with RIKEN to explore ways to encourage growth in this area.**

VII. RIKEN-BNL Research Center

Evaluate RNC's response to the recommendations made by NCAC2011

**Future development of high energy QCD physics at RHIC represents a great opportunity for RBRC for the present (R&D in accelerators and detectors) and the future science.*

RBRC continues to be a very successful, international scientific collaboration focused on understanding high-energy QCD matter at the RHIC collider, at Brookhaven National Laboratory in Upton, NY, using a broad range of theoretical, computational, and experimental tools. RBRC has provided unique spin capabilities at RHIC and these continue to provide new insight into the origin of nucleon spin. Further, these collider spin capabilities are a cornerstone of the planned eRHIC accelerator, whose science focus is the precision understanding of QCD. RBRC is optimally positioned to exploit the outstanding scientific opportunities at eRHIC, if this evolution of RHIC is realized.

Observations

RBRC continues to play a leadership role in studying the origin of proton spin. In 2013, the integrated luminosity for RHIC-spin reached an impressive 630 pb^{-1} with 50% polarization of the colliding proton beams. The emerging conclusion from the pioneering RHIC-spin experiments is that gluons make a significant contribution to the proton's spin. This can now be quantified once the data in hand are analyzed.

RBRC played a major role in the trigger upgrade of muon arms for the PHENIX collaboration which enabled the measurement of flavor decomposition of anti-quark spin through $W^{\pm}$ asymmetry measurements. RBRC also played an important role in the heavy-ion collision experiments for the study of QGP. Y. Akiba received the Nishina Memorial Prize in 2011 for his contribution for the study of the QGP, specifically the successful determination of the initial temperature of the hot, dense matter.

RBRC physicists led the development of the new vertex detector for PHENIX and this is now in routine operation. It enables the clean measurement of charged hadrons out to high p_T and heavy quark productions. This has been employed in the 2014 Au-Au running at RHIC where the RHIC II luminosity goal has been reached.

Since NCAC2011, the computing performance available to RBRC has exceeded 600 TFlops. This is being employed to carry out a number of important calculations of fundamental observables in hadron physics. We note that in 2012 the RBRC group was awarded the Ken Wilson Award for the calculation of the $K \rightarrow \pi\pi$ decay amplitude.

Looking to the future, RBRC scientists are working on an upgrade detector, known as sPHENIX whose scientific focus is the precision study of jet quenching and quarkonium suppression in ultra-relativistic heavy-ion collisions that produce the sQGP. In the plan for the future presented by BNL, sPHENIX would take data in 2021/22.

In the long term, the BNL plan is to convert RHIC to an electron-ion collider, eRHIC, whose scientific focus is to understand high-energy QCD matter using the lepton probe. The U.S. QCD community (both BNL and Jefferson Lab) has embraced and Electron Ion Collider as a machine for the future and will seek the endorsement of the full nuclear physics community to establish such a machine as a priority for new construction in the U.S. 2015 Long Range Planning exercise. If such a priority is established, and eRHIC is the preferred design, sPHENIX could be straightforwardly converted into an eRHIC detector. The conversion is called ePHENIX, and a letter-of-intent, prepared with significant RBRC leadership, was favorably reviewed in January, 2014.

Recommendation

- **Overall, RBRC is positioning itself well to maximize scientific output from the remaining years of RHIC operation as well as to take advantage of eRHIC, if this new scientific opportunity opens up in the U.S. NCAC recommends continued effort on this program. NCAC also notes that finding a successor to Dr. En'yo as the leader of the effort will be crucial to its future.**

VIII. RIKEN – RAL

Evaluate RNC's response to the recommendations made by NCAC2011

**The Committee recommends continuing to build on the success of RIKEN-RAL by focusing on the two prioritized pillars:*

- Condensed matter: exploiting the unique CHRONUS spectrometer

- Low-energy muons: development of new laser systems

**Establishing the core group of RIKEN-RAL staff needed for the ongoing success of RIKEN-RAL. This work [sufficient manpower resource to be allocated to the CHRONUS spectrometer], together with the USM development, will act as a springboard for subsequent exploitation of J-PARC.*

**Creating of an action plan for the USM project.*

**Post the Earthquake disaster, using RIKEN-RAL to support the Japanese Muon User Program.*

**Building a successful condensed matter program for the Japanese and International community and transitioning the activity to J-PARC at the end of the Third Midterm Plan.*
Exploring opportunities for further collaboration within RIKEN, particularly within the area of condensed matter and molecular science, at other RIKEN sites and centers.

The Committee endorses the activities of the two key pillars of RIKEN-RAL facility, highlighting its successes in the condensed matter and molecular science program where the facility is clearly world-leading, and noting the exciting developments in laser and target technologies that promise a viable ultra-slow muon source at the facility.

The Committee applauds the collaboration between RIKEN-RAL and J-PARC that enabled a number of J-PARC experiments to be carried out at the UK facility following the 2011 Earthquake of East Japan.

Observations

The condensed-matter and molecular-science program continues to be a very strong area for RIKEN-RAL and a central pillar of its activity. A diverse science program has continued, studying a broad range of topics including magnetism, superconductivity, ionic diffusion, and spin and charge dynamics. The unique capabilities of the facility**,** providing high pressure and laser stimulation in combination with a pulsed beam, enhance this program. The facility is very productive**,** and there is strong evidence from the portfolio of highly cited work presented to the committee for scientific excellence in the output of a facility that is clearly world-leading in this field**.**

New areas being developed include the study of diffusion in battery materials and in the life sciences. A second high data rate spectrometer, Chronus, is now commissioned using a data acquisition system developed in collaboration with ISIS. Further technical and scientific collaborations with ISIS – the development of density functional theory calculations of muons site occupancy being a highlight – are flourishing.

Chip irradiation experiments represent an important new opportunity for the facility since the previous NCAC meeting. There is clearly significant potential to grow this activity in the future, the Committee suggesting links with industry are explored and the complementarity with the existing neutron program at ISIS in this area exploited.

The ultra-slow muon project has progressed significantly with the development of a high intensity Lyman-α laser system coupled with the discovery of enhanced muonium production from fine-drilled laser-fabricated room-temperature silica aerogel targets at TRIUMF. Together, these improvements can realistically be expected to provide almost an order of magnitude increase in slow muon flux, and it is possible to envisage a science program based upon this source. Collaborative work with other RIKEN groups has been key to the development of the high-power laser system. This research is expected to make a key contribution to future ultra-slow muon production at J-PARC and the g-2 experiment, while also providing a new facility at RIKEN-RAL for surface and interface studies. The Committee noted that this provides a great opportunity for new condensed matter physicists to come into the field, both in Japan and in Europe. The facility promises higher timing resolution and a smaller spot size compared to PSI in Switzerland.

The Committee applauds the success of the promotional activities by RIKEN–RAL staff in engaging with the developing condensed matter community in Asia, but notes that a

commitment of effective and dedicated user support personnel will be necessary for success in this area.
The Committee recognizes the dual role played by RIKEN-RAL staff, leading the science and providing an effective user support role for Japanese and foreign researchers. The success of the condensed matter pillar is predicated by the dedication of RIKEN-RAL staff.

A proposed new initiative for the measurement of the hyperfine-splitting in muonic hydrogen promises to become a high profile project. The determination of the proton radius has become an increasingly interesting topic in science: recent laser spectroscopy of the Lamb-shift in muonic hydrogen at PSI suggests that the proton size measured with muons is significantly smaller than that obtained with laser spectroscopy of electronic hydrogen or deduced from electron scattering. The approach of measuring the hyperfine-structure in muonic hydrogen appears a very promising method for developing this area.

In view of its scientific importance and anticipated impact of the proton radius experiment, the Committee strongly encourages the development of a full proposal with high priority. The proposal may then be scrutinized by the responsible PAC, enabling the impact of this experiment on the other two program pillars of condensed matter and molecular science, and low energy muon production, to be evaluated.

The Committee recognizes the need to plan <u>**now**</u> for the ***Transition to J-PARC*** assuming that the current RIKEN-RAL agreement will not be extended in its present form. One needs to take into account RIKEN-RAL's potential to act as springboard for developing J-PARC activities; the need to transition people; to addressing decommissioning costs; and to developing a new agreement with ISIS.

Recommendations

- **The Committee recommends continuing to build on the success of RIKEN-RAL by focusing on and supporting its two pillars.**
- **The Committee recommends continued support of RIKEN-RAL until 2018 to exploit high level output in condensed matter science and development of ultra-slow muons.**
- **The Committee recommends developing new strategies for staffing in the run up to the transition from RIKEN-RAL to J-PARC, and notes that RIKEN-RAL operation should provide an excellent training ground for new and young scientists in the field of muon physics. Staff trained at RIKEN-RAL will provide immediate expertise for future activities at J-PARC. The Committee recognizes the need for detailed planning for the future of the RIKEN-RAL facility beyond 2018, and encourages discussions with ISIS as soon as possible. The UK interest in continuing a condensed-matter program at the facility post 2018 should be explored in tandem with a detailed assessment of the decommissioning liability for the facility in case decommissioning should be necessary.**
- **The Committee noted the possibilities afforded by linking with RIKEN's recently established Center for Emergent Matter Science and encouraged RIKEN to explore ways of developing this area.**

IX. Strategic Plan

Evaluate RNC's response to the recommendations made by NCAC2011

**For the RI production at the AVF cyclotron, improvements to increase the beam energy and intensity will be needed to carry out the expanded program and work in this direction is recommended.*

**We [NCAC] recommend that both options [two different options for long-term upgrades to RIBF] be pursued as potential upgrade paths for the facility in the future. A choice based on the potential physics program that will be enabled by an upgrade may need to be made in the future if both options are found to be feasible but resources dictate that only one can be carried out.*

NCAC heard about an effort that was made to upgrade the AVF cyclotron. No changes were made due to operating concerns. Rather an effort to obtain funds to support the construction of a new cyclotron has been started.

The Committee was updated on the plans for future upgrades. A proposal to the Science Council of Japan for a new superconducting linac injector and a new fRC accelerator that would reduce the number of times that beam stripping was required and thus significantly boost beam intensity was not among the top projects submitted but RNC has been encouraged to continue developing this project.

Observations

The RNC through RIBF has a world-class accelerator system with high quality RIBs, and user-oriented experimental setups. An effective user liaison team has organized an active user community for fundamental research and initiated prospective industrial collaboration users, which should extend to international industrial users in the future. Successful improvements at RIBF have been realized over the past three years, with excellent accelerator-based applications such as the development of RIB production technology for specific isotopes (^{65}Zn, ^{88}Y, ^{124}I, ^{89}Zr, ^{109}Cd), chemistry technology for superheavy element research, studies of radiation effects in electronics and soil survey from the Fukushima event, trace technology for wear-loss analysis of rotating objects, mutation breeding for agriculture, imaging for medicine, and other applications have been achieved. Recent new programs in nuclear data and related research for nuclear transmutation of nuclear waste from nuclear power stations are good choices for solving existing societal problems, which may obtain government support. To fulfill society needs, applications for life and medical science, biology, materials, and the chip industry should be enhanced.

With the completion of the major ancillary equipment, the RIBF facility is poised to carry out a world-leading program harvesting new discoveries and developing new perspectives for scientific achievements in the coming 5-7 years. This program should be pursued and supported by sufficient government funding for beam time to achieve eight months of running time over the next five years and to sustain the scientific staff required to keep RIKEN in the forefront of research in this area.

Income from industrial users, especially international users, should be allowed as a complementary budget to support facility operation and to develop new capabilities. In the long term, new electricity-saving facilities like superconducting machines and devices should be encouraged and developed.

For the Cosmo-nuclear science, NCAC encourages exploring the production mechanism leading to heavy elements and identifying the synthesis site associated with explosive astrophysical phenomena. NCAC also encourages investigating the structure of hadrons and its relation to the structure of matter under extreme conditions in compact stars in collaboration with other institutes.

For RIBF initiatives, up to now many new isotopes have been discovered since RIBF started operation in 2007. In the next decade, an additional one hundred new isotopes could be expected to be found. A number of important improvements presented to the Committee should be made, such as a uranium oven for the 28GHz ECRIS, modifications to the fRC and SRC, improved transmission efficiency of gas strippers, Be disk target for uranium acceleration, gas stripper for RILAC injector, and upgrade of RF power for RRC and SRC. Industrial applications of radioactive isotopes, polarized RI for material science, application of triplet DNP to MRI, basic data for nuclear transmutation are being developed for social and economic benefits. The upgrade plan aiming at completion in 2020 has been submitted to the Science Council of Japan in 2013. Although it was not listed in the top 27 proposals, NCAC recommends that the proposal should be resubmitted after improving the accelerator design and physics case. R&D for production, separation of heavy and n-rich nuclei and particle identification techniques are key issues for the intensity upgrade and science at RIBF.

Active programs carried out by RNC scientists at other facilities such as RBRC/RHIC-PHENIX and RIKEN_RAL Muon Facility/RAL have been very productive and should be continued as described by RNC management. In the near future, efforts in hadron physics at J-PARC and SPring-8 will start to provide new results. The Committee encourages further consideration of future work at new facilities such as FAIR.

It is important for the RNC to collaborate with new projects under construction around the world and in Japan. In addition, the R&D for new accelerator technology development for the future upgrade project should start as soon as possible. This should include work toward new facilities to fulfill society needs like reducing energy resources and recycling based on in-house technologies and next generation facilities that will incorporate new challenging technologies (superconducting linac and storage ring) and initiatives connected to existing research.

NCAC highly appreciates and fully supports the directions proposed for the future SHE program including the SHE chemistry behind GARIS. It should continue to play a key role in the RNC research. Concerning the primary task to search for elements beyond element 118, the envisaged path based on actinide target and projectiles slightly heavier than ^{48}Ca is fully endorsed. Securing the availability, perhaps through collaborations, and permission to handle sufficient actinide target material, presumably up to ^{249}Cf, if needed, is of importance as well as the development of a stable, high-intensity ^{50}Ti beam, which is one of the most essential ingredients for a successful future program. The proposed next step in this research, to probe the difference between the doubly-magic projectile ^{48}Ca and the, presumably, next best projectile ^{50}Ti in synthesis reactions of element 118 will be of key importance to show the path into the future. This should be pursued with highest priority and an appropriate amount of beam time while leaving sufficient time for shorter but also very exciting SHE chemistry experiments at GARIS.

In addition, carrying out basic studies to exploit the possibilities of deep-inelastic transfer reactions to synthesize presently not accessible neutron-rich isotopes of superheavy elements is highly encouraged. With such a program, and sufficient beam time, RNC can play a world-leading role in SHE research for the upcoming years and can significantly contribute to the question of the limits of existence of nuclear matter and chemical elements at the farthest reach of the Periodic Table.

The "accelerator application" program has developed very well and has great perspectives. Presently, it is still lacking (a) personnel to fully exploit the possibilities of the RNC to serve the needs of a wide community and the society and (b) a strong contribution from outside user-like industry, private companies, universities, and research laboratories. Both aspects, the personnel and the contribution from outside users, should be taken care of to further widen and deepen this program in good balance with the main fundamental research activities.

Recommendations (note that the second recommendation is the same as one given earlier – it applies to several sections of the report)

- **NCAC recommends that the RNC vigorously pursue accelerator upgrades to the present RIBF to keep it competitive with new facilities being built in other parts of the world. The upgrade path should strive to keep capabilities world leading through at least 2025.**
- **NCAC most strongly recommends continuing all efforts to increase the permanent staff by at least 10 tenured positions in the coming 5 years. The RNC and RIKEN must work together to develop a plan for this staffing increase, which is critical for the research program, the targeted eight-month operation of the RIBF and for the full design of a future major upgrade of the facility. The plan also needs to address the problem of replacing scientists who are retiring or moving to other prestigious positions. Consideration of research efforts that span over many decades must be included in developing new approaches to solve this problem.**
- **NCAC recommends that RNC continues to vigorously pursue applications of accelerator technology that serve Japanese society.**

X. Cross-disciplinary research between RNC and other centers at RIKEN

Observations

The Committee is pleased with the continuous and increasing efforts to develop cross-disciplinary research between RNC and other research centers at RIKEN. In particular, synergistic collaborations on accelerator based applications were and are being developed linking directly to the research cluster for innovation.

The results obtained for biological experiments with ion beams at RIBF are excellent and unique. The corresponding publications are cross-disciplinary.

A successful interdisciplinary initiative conducted by the Theoretical Research Division of RNC is the iTHES project in conjunction with the High Performance Computing Infrastructure (HPCI) and with access to the powerful computing facility (K-Computer) at the Kobe Center. This is a major joint activity involving RNC scientists together with RIKEN researchers in other areas of physics, biology, chemistry and computational science. The iTHES initiative within RIKEN integrates and enhances the scientific outcomes of RIBF and the researchers in various different fields that are socially linked through iTHES under the unified theme of cosmo-nuclear physics and represents the power and diversity of RIKEN institutes and interdisciplinary research.

The new projects on MRI for moving organs, on sensitivity improvement for imaging and the application opportunities connected with the new developments for β-NMR will enhance the collaboration of RNC with other RIKEN centers and should be supported together with other new initiatives in the same direction.

Efforts to develop a production capability for short-lived isotopes are now underway, particularly for non-conventional isotopes.

Recommendations

- **RNC should continue to support the activities of the Ion Beam Breeding Team by securing beam time and providing a dedicated beam line.**
- **There is an opportunity for RNC to further develop RIKEN-RAL for life-science related proposals.**
- **Hiring an experienced liaison person to connect accelerator sciences and life sciences would be highly effective. NCAC recommends that this be explored.**

XI. Concluding Remarks

The RIKEN Nishina Center has a long tradition of carrying out forefront research in accelerator based nuclear science. This continues today with a robust science program that includes world class efforts in several major fields. The RIBF is the best facility in the world for producing and studying a broad range of nuclei far from stability. With the complement of ancillary equipment now in place, it is poised to dominate research in nuclear structure, reactions, and nuclear astrophysics with rare isotope beams. With upgrades, it can maintain this position for at least the next decade. The RNC makes effective use of its accelerator facilities for other efforts such the super-heavy element program and accelerator-based applications, which reach out to a broad segment of programs at RIKEN. The theory effort at the RNC is first-rate, but some care will be needed to maintain this position as universities in Japan entice strong researchers to their institutions. The experiments being carried out at J-PARC and SPring-8, the work at the Rutherford Appleton Lab, and the collaboration with Brookhaven National Lab through the RIKEN-BNL Research Center are all excellent programs that deliver cutting edge science and international visibility to RIKEN.

Looking to the future, the RNC has a strategic plan that will keep it at the forefront for many years. The plan is focused on the accelerator complex at RIKEN but it also maintains a strong international component. By moving forward with this plan, the RNC will maintain the prestigious international recognition in nuclear science that it now has. The Committee strongly endorses this plan as a path forward.

Respectfully submitted,

Robert E. Tribble

APPENDIX

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2 January 2014

Dear Prof. Noyori and Prof. En'yo,

I am writing to you both in my capacity as chair of the Nuclear Physics Program Advisory Committee (NP-PAC) of the RIKEN Nishina Center for Accelerator-Based Science and as a concerned scientist. I want to express my concerns, also on behalf of NP-PAC, regarding beam-time availability for research at the accelerator facilities of RIKEN Nishina Center. I explain these concerns hereunder.

Before I discuss the issues of concern to our nuclear physics community, I would like to stress the obvious facts. Nishina Center RIBF is at present unique worldwide and will remain so for the next five to seven years to come. Internationally, it serves a very important and crucial role for nuclear science, which explains the scientific attractiveness of the facility not only for Japanese nuclear scientists but also for scientists from all over the world. This has led to a very vibrant scientific atmosphere at Nishina Center through the cross-fertilization of ideas and the synergies among the different Japanese and international groups which elevated the scientific endeavor at the Center to a very high level.

At the start of the Radioactive Ion Beam Facility at Nishina Center, hope was raised that the facility will reach a steady state of running after a few years with the projected aim of delivering 120 days of beam on target for the users. This corresponds to 8 months of operation. The trend was clearly in this direction in the first years of operation, with increasing intensity and availability of beams delivered, thanks to the great efforts of the accelerator and technical staff of RIKEN Nishina Center. The scientists at Nishina Center also developed the different state-of-the-art experimental facilities and ancillary equipment, often in collaboration with international colleagues, creating a truly worldwide unique facility. Unfortunately, this increasing trend was dealt a severe blow by the disastrous earthquake and tsunami in March 2011. Fortunately, however, the accelerator and experimental facilities sustained little damage and the operation of the Nishina Center facilities could be resumed quickly. Nevertheless, there was a strong dip in the number of days of beam delivered in 2011. Although the directorate and accelerator staff tried to increase the number of beam days delivered, the total number in 2012 and 2013 was only slightly higher than 60 days per year. I understand that the reason for this is the huge increase in the electricity bill in addition to other fiscal

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measures. The consequences of this on the research program of RIKEN Nishina Center are drastic.

There is now a huge backlog of not executed experimental proposals which have been evaluated excellent to outstanding by previous NP-PACs. The most severe is the backlog for the RIBF where of all the beam-days approved since its start only about half of them has been used. However, the pressure on beam time requests has not reduced as a consequence of this. RIBF being unique still attracts a large number of excellent groups from all over the world. During the last NP-PAC meeting, the NP-PAC members were faced with tough choices to make. To quote the NP-PAC minutes of this last meeting: "The decision about beam-time allocation was quite difficult this time due to two reasons: i) there were many excellent proposals and ii) there was little beam time to distribute.". Of the 194.5 days requested in the proposals for the RIBF, we had because of the huge backlog the freedom to approve only about 45 days, i.e. less than 25% of the total requested. As you can imagine, this will lead to frustrations of outstanding scientists who see the opportunities to perform experiments at the unique RIBF diminish, if not disappear. Furthermore, this will impact the research of many PhD students and other young scientists whose future careers depend critically on the research proposed. This can have adverse effects on the image of the RIKEN Nishina Center as a host laboratory with unique facilities indeed that cannot be used effectively. Colleagues worldwide have difficulties to understand how such a unique and excellent facility that has cost so much in human and financial resources to build cannot be given sufficient resources to run for more than half a year per year.

Therefore, I would like to ask you kindly to provide sufficient funds to help mitigate the financial effects of the earthquake/tsunami disaster. The goal should be to provide a minimum of 8 months of beam time using the accelerator and experimental facilities. This should allow RIKEN Nishina Center to fulfill the promise, in terms of beam time and support to RIBF users, projected at the start of its operations. This would also keep the strong positive image of RIKEN Nishina Center worldwide as a center where cutting-edge research could be performed without a strong competition for the coming 5 to 7 years.

Looking forward to your response, I remain,

On behalf of NP-PAC,
Sincerely yours,

Muhsin N. Harakeh
NP-PAC Chair
Professor Emeritus, University of Groningen, the Netherlands