

# **RIKEN Nishina Center Advisory Committee Report**



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## **NCAC Meeting July 21-23, 2016**

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

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## Foreword: Element 113

- A Joint IUPAC/IUPAP Working Party (JWP) has confirmed the discovery of element 113 by Dr. Morita's group on New Year's Eve, 2015.
- Dr. Morita's Group proposed the name "nihonium" and symbol "Nh" for the new element to the Inorganic Chemistry Division of IUPAC.
- Following careful deliberations, the Inorganic Chemistry Division recommended these proposals for acceptance, and these were then adopted by IUPAC. IUPAC began the five-months public review of the name and symbol on June 8<sup>th</sup>, 2016.

**The Nishina Center Advisory Council (NCAC) would like to enthusiastically congratulate Dr. K. Morita and his team, as well as the management of the RIKEN Nishina Center (RNC), the RNC researchers and staff, for this memorable achievement.**

### Foreword

NCAC is also very pleased to emphasize here that research on "exotic nuclei" developed at the RNC has resulted in the awarding of the **2015 Nishina Memorial Prize for Studies on "Anomalous Magicity" to Dr. T. Motobayashi and Prof. H. Sakurai. This is a well-deserved recognition for these two outstanding leaders in this area of nuclear physics.**

Last, but not least, NCAC has been most impressed by a key development in **accelerator technology achieved by the RNC accelerator team** under Dr. O. Kamigaito, whereby the use of new "graphene" carbon foils has enabled the Rare Ion Beam Factory (RIBF) to reach an **unprecedented, worldwide record in the intensity of 50 pA for a <sup>238</sup>U beam**. This accomplishment bolsters the present status of RIBF as the premier facility for rare isotope research in the world.

## I. Introduction

The NCAC wishes to thank RIKEN President Hiroshi Matsumoto, Drs. Y. Matsumoto and S. 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 efforts made to present the view and the scope of the activities of the RNC carried out by the research divisions, both locally and overseas, as well as to outline the mid-term management and scientific strategy for future projects. NCAC would like to thank the RNC team for the excellent preparations for this meeting. Specifically, the quality of the supporting documents and the clarity of the presentations were instrumental in greatly facilitating this NCAC review.

NCAC is aware that this review of the RNC came at a particular time with RIKEN management having recently undergone a complete change. This situation did result in a detailed 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 ongoing projects and the 10-year strategic plan for the Center guided by these terms of reference provided by the president of RIKEN, Prof. H. Matsumoto.**

## II. Organization, Management, Personnel and Budget

## **Findings:**

NCAC finds that the current management structure works well to effectively promote science at RNC. This science sometimes requires long-term efforts extending beyond a generation. NCAC also finds that the Program Advisory Committee system works well to maintain the high quality of projects through external review.

NCAC finds that the current RNC management structure and organization successfully fosters scientific excellence, as evidenced by: the successes of the Super-Heavy Element (SHE) and RIBF programs, the RHIC spin physics program, the RAL MuSR program, theoretical research, as well as applications such as the ImPACT program.

NCAC finds that the RNC is recognized as a world-wide hub for science and technology innovation — based on its unique accelerator complex and its state-of-the-art particle detector technologies.

NCAC finds that the cutting edge science and unique facilities at RNC attract many researchers and collaborators from overseas resulting in a high fraction of RNC users being international. Also, the unique RIKEN branches overseas at BNL and RAL accelerate intellectual mobility within RNC.

NCAC finds that RNC researchers are recognized as leaders in their field, as evidenced by the Nishina Memorial Prize being granted to Drs. Sakurai and Motobayashi, by Dr. Akiba being appointed PHENIX spokesperson, as well as through a number of other recognitions for RNC researchers.

## **Recommendations:**

**NCAC urges RIKEN to implement its human resource reform in a way that preserves the strength of the special organizational structure of the RNC in order to ensure continuity of the current world-class research programs.**

**NCAC reiterates that 8 months of operations are necessary to exploit the full discovery potential and capabilities of the unique world-class RIBF facility, hereby optimizing the return on the substantial investment into the infrastructure and preserving its world-leading position.**

**NCAC encourages tighter connections between sub-groups within RNC; e.g., theory and experimental groups or domestic and overseas groups in order to maximize scientific outcomes.**

## **III. Science Highlights from RIBF**

### **Finding 1: Facility in general**

RIBF is a world-class facility due to the combination of (a) the capabilities of the accelerator facility to produce the most exotic nuclei with world-leading intensities; (b) the availability of cutting edge experimental equipment; and (c) the dedication of first-rate teams of local and international scientists carrying out research at the very frontiers of the field.

### **Finding 2: Heavy elements research**

As demonstrated recently by the naming of element  $Z = 113$  (Nh), this research program is world class and makes major contributions to the general understanding of the science associated with the heaviest elements. To do so, the group has used successfully the GARIS separator and has now brought online

the GARIS-II separator; i.e., the group has the instrumentation necessary to continue to be a major contributor in this field.

First experiments using the “hot fusion” approach have focused on the production of Lv (Z=116), confirmed the magnitude of the cross sections reported in the literature, confirmed the known decay chains, and found new ones.

The chemistry of Sg (Z=106) has confirmed its assignment to group 6 of the periodic table and the research team is gearing up for the study of the chemistry of elements with Z = 107, 108, 109, and 112 — with the promise to evaluate the role of relativistic effects on their chemistry.

GARIS-II was successfully commissioned with the production of element 112, and the group is now aggressively preparing for searches of elements Z = 118 and 119 with  $^{248}\text{Cm}$  targets and intense Ti and V beams, and element Z = 120 with  $^{248}\text{Cm}$  targets and a Cr beam, or  $^{249}\text{Cf}$  targets and a Ti beam. If successful, these experiments will keep this program at the forefront of SHE research.

### **Finding 3: Nuclear Structure and Nuclear Astrophysics research**

- The existing instrumentation has matured in the last few years and is an outstanding match to the scientific program. In this context:

- Experiments with SAMURAI allow for kinematically-complete nuclear reaction studies of exotic nuclei, in particular weakly-bound systems, and have started to demonstrate the capabilities of the instrument in combination with the liquid hydrogen target MINOS, the gamma-ray detector DALI2 and the FAIR/GSI neutron detector NEULAND.
- The EURICA campaign has completed its extensive program in decay spectroscopy studies across the nuclear chart and continued to produce outstanding results.
- The SEASTAR international collaboration, combining the MINOS liquid hydrogen target and the DALI2 gamma-ray array with the zero degree spectrometer, has proven to be a powerful tool for the study of the first excited states of very exotic nuclei.

- Tantalizing evidence for a low-energy resonance in the tetra-neutron system has been reported. Stringent check on this intriguing result is expected to come from a recently completed higher-statistics experiment.

- High-precision spectroscopy of unbound  $^{26}\text{O}$  has not only provided a firm confirmation of the unbound ground-state threshold resonance, but also resulted in the determination of the excitation energy of the first  $2^+$  level.

- The structure of weakly-bound nuclei at the limits of the island of inversion beyond  $^{32}\text{Mg}$  have been explored with first spectroscopy of odd-even  $^{37}\text{Mg}$  and  $^{39}\text{Mg}$  and even-even  $^{40}\text{Mg}$ . These systems are not only weakly bound, but also very deformed, perhaps the best examples thus far of deformed open quantum systems.

- The measurement of the first excited states in  $^{78}\text{Ni}$  not only demonstrates the doubly-magic character of this nucleus, but also provides new challenges for theory to describe.

- First signatures for the anticipated oblate-to-prolate-to-oblate shape change with neutron number has been found in the N = 52 - 60 neutron-rich Se isotopic chain.

- Shell structure beyond doubly-magic  $^{132}\text{Sn}$  has been explored with the delineation of excited states in  $^{136}\text{Sn}$  and  $^{138}\text{Sn}$ , for example.
- Two experimental campaigns have provided lifetime data for 110 isotopes in the  $Z = 37 - 50$  region and for an additional 97 ones in the  $Z = 51 - 62$  region. The half-lives of about 100 of these neutron-rich nuclei were determined for the first time. These data represent crucial input for the r-process nucleosynthesis network calculations.

**Finding 4: Noteworthy future developments of the experimental capabilities:**

Among the many ongoing developments at RIBF, NCAC wishes to highlight the followings which offer great promise for future scientific progress:

- Mass measurements with the Rare RI Ring, which have started very recently, will allow for important studies related to the evolution of nuclear shells and the elucidation of the astrophysical r-process.
- The possible development of an Asian gamma-ray tracking array (a collaborative effort with China and South Korea) which would represent an essential component and a welcome enhancement of the capability to carry out world-class in-beam high-resolution gamma-ray spectroscopy at RIBF.
- The SLOWRI facility that extracts RI beams from gas-stoppers connected to the BigRIPS facility which will enable world-leading programs in mass spectrometry (with a MR-TOF device) as well as in atomic beam resonance spectroscopy for moment measurements of exotic nuclei.
- The BRIKEN neutron-counter array, for which an international collaboration has brought a large number of He-3 counters to RIKEN. This device will enable a program measuring beta-delayed neutron branching ratios relevant for the astrophysical r-process.

## IV. Theory

**Findings:**

The Theoretical Research Division of the RNC, under the leadership of Dr. T. Hatsuda, has the highest national and international visibility. Its two research directions "From QCD to Cosmos" and "Exploring new frontiers" are currently built around the research efforts of Drs. T. Hatsuda and E. Hiyama. Two of the associate chief scientists, Drs. T. Nakatsukasa and K. Hashimoto have left the theory group since the last NCAC review of 2014 to take on full professorships at the University of Tsukuba and Osaka University, respectively. Dr. T. Nakatsukasa's area of expertise is in Nuclear Density Functional Theory while Dr. K. Hashimoto works in string theory based on the Gauge/Gravity Duality.

Dr. T. Hatsuda's group conducts frontline research in Lattice Gauge Theory, including studies of two-baryon systems from QCD first principles. It has performed pioneering computations of the baryon-baryon interaction including strangeness, moving systematically towards realistic quark masses and larger volumes. These activities and related projects in quantum field theory pave the way toward 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. Dr. E. Hiyama is an expert on ab-

initio few-body theory and conducts highly visible research in the few-neutron systems, light hypernuclei, Fermi gases in the unitary limit, and also pursues systematic studies of many-fermion systems.

The Theoretical Research Division is one of the strongest with an impressive research record. Through state-of-the art research at the forefront of theoretical nuclear physics, it provides excellent career opportunities for a large number of junior scientists (postdocs and PhD students). The group collaborates with leading theory and experimental efforts in Japan and abroad. NCAC is also impressed by the strong interdisciplinary initiatives under Dr. Hatsuda's leadership in the Interdisciplinary Theoretical Science Research Group (iTHES) project. This project connects to other areas of physics, biology, chemistry and computational science. It incorporates the HPCI (High Performance Computing Infrastructure) program with access to the powerful computing facility (K-Computer) at RIKEN Kobe. The groups involved use a wide range of tools, including analytic theory, advanced algorithms, and high-performance computer facilities.

While appreciating the uniqueness of the theory effort at the RNC, NCAC is extremely concerned about the future of the theory group. As mentioned, Drs. T. Nakatsukasa and K. Hashimoto have recently left the group. In addition, Dr. T. Hatsuda is planning to retire in 2018 from the RNC. These developments run the risk of jeopardizing the entire theory effort at the RNC. Timely measures should be taken to secure the future of a broad and internationally highly competitive nuclear theory program at the RNC, especially strengthening modern nuclear structure theory. This initiative would benefit the RIBF experimental program as well as low-energy experimental and theoretical nuclear science worldwide.

**Recommendation:**

**To secure the future of the current broad and internationally highly competitive nuclear theory program, Dr. Hatsuda's Chief Scientist position should be filled as soon as possible. Reaffirming its earlier recommendation, NCAC urges to create permanent positions in modern nuclear structure theory to provide support and intellectual guidance for experimental radioactive ion beam programs at the RNC and elsewhere.**

## **V. Hadronic Physics at the RNC**

**Findings:**

Hadronic physics research at the RNC involves experiments at a number of laboratories including RIBF, BNL-RHIC, GSI, LEPS, and J-PARC. The main focus of these studies is the creation and study of mesonic atoms and mesons in nuclei. One of the recent highlights is the high-resolution experimental study at RIBF of the pionic atom for Sn isotopes. The new data will yield more accurate information on chiral symmetry in nuclear matter. Preliminary data from the first measurement of  $\eta'$  nuclei at GSI were also presented.

At J-PARC, several hadron physics experiments are underway led by members of the RNC group. Recent preliminary data on kaonic nuclei show a structure resulting from a possible K-pp state. If this preliminary result is confirmed, this would represent a significant new observation. The R&D and preparation for measurements of kaonic atom X-rays and of the mass shift of the  $\phi$  meson in nuclei are underway, including R&D for a novel X-ray detector (TES).



**Recommendation:**

**NCAC recommends that, building on its past achievements, the RNC hadron physics group strive to maintain its leadership position in the field via future activities at J-PARC.**

## **VI. Accelerator & Applications**

### **VI.1 Accelerator**

**Findings:**

The RNC has been remarkably successful in maximizing the performance of the RIBF accelerator complex for a large variety of ion beams ranging from  $H_2^+$  to U. Impressive improvements in beam stripping technology and in beam power/performance have been achieved reaching, for example, ~700 pA for  $^{48}Ca$  and 50 pA for  $^{238}U$ . The beam availability (reliability) has reached a noteworthy level of ~90%.

The RIBF accelerator complex with GARIS is also providing reliable, independent operational modes for both SHE research and Radio-Isotope (RI) production, the latter using the AVF cyclotron. It should be noted that the operation with RILAC (3 MeV/u) and its booster (2 MeV/u) was essential for the discovery of the Z = 113 SHE which was assigned the symbol Nh.

NCAC stresses the outstanding progress and performance achieved with the world-leading RIBF accelerator complex including the Superconducting Ring Cyclotron (SRC).

NCAC recognizes the necessity for a replacement program for ageing components. Furthermore, it points out that the level of manpower available for maintaining the outstanding ongoing activities is minimal and this situation needs to be improved.

**Recommendation:**

**NCAC recognizes the outstanding performance of the RNC accelerator complex and recommends that adequate expertise and resources be maintained in order to be able to further improve the acceleration efficiency as this is a key to the long-term future of the program.**

### **VI.2 Applications**

#### ***VI.2.1 Ion beam breeding***

**Findings:**

The Ion beam breeding activities remain a very visible and productive application of the RNC. As a part of the SIP program "Technologies for creating next-generation agriculture, forestry and fisheries", these activities are an effective contributor to the development of important technologies that address societal challenges related to health, food, environment and biofuel.

The mutation rate dependence on LET was studied and has shown that a best LET value exists and depends on the specific species examined. Also, the LET effect on the deletion size in mutated genes

was investigated. These studies are useful for the design of irradiation treatments tailored to user's requests.

The high-energy heavy ion breeding team has produced excellent results which owe a lot to the leadership of the team by Dr. Abe. To maintain the vitality and quality of this area of research, it is very important to consider carefully the development of potential successors.

**Recommendation:**

**NCAC recognizes the importance of the ion beam breeding program, and strongly recommends that further efforts be considered to optimize its benefits for further applications.**

***VI.2.2 Radio-Isotopes (RI) production***

**Findings:**

The most notable activities in this area concern the development of production techniques for the diagnostic/therapeutic medical isotopes Cu-67 and At-211. Commercial activities include the delivery of RI's as well as the irradiation of semiconductors for use in space.

The development of radiopharmaceuticals is poorly established in Japan, although several accelerators suitable for RI production are currently in operation. This is due to the fact that there is no platform where researchers from these accelerator facilities can communicate and discuss systematic strategies for radiopharmaceutical production and delivery.

A noteworthy and beneficial innovation is the development of an instrument for gamma-ray imaging of industrial components that allows studying the wear of mechanical components. A patent application has been filed.

**Recommendation:**

**NCAC recommends that the RNC play an active role in helping establish a platform for radiopharmaceutical research, for example by cooperating with the Japan Radioisotope Association.**

***VI.2.3 Nuclear transmutation experiments at RIBF***

**Findings:**

Cross section measurements of reactions related to the transmutation of long-lived fission fragments (LLFP) using BigRIPS and the Zero Degree Spectrometer represent an important contribution to the ImPACT program aiming to develop a concept for the "separation and recovery of LLFP from high-level radioactive wastes".

Using inverse kinematics, the cross section measurements for nuclear reactions induced by proton and neutron bombardment on radioactive target nuclide are possible and unique to RIBF.

**Recommendation:**

**NCAC encourages and supports RNC initiatives in the ImPACT program. More specifically, the measurements related to transmutation of LLFP are taking advantage of the unique capabilities of RIBF.**

## **VII. RIKEN-BNL**

### **Findings:**

RBRC is a world-leading center for studies of QCD. It has contributed significantly to the availability of unique facilities at BNL; i.e., to the development of the world's first and only polarized proton collider. This facility has been used to achieve an outstanding scientific result, namely the determination of a significant contribution of the gluons to the spin of the proton as measured by both the PHENIX and STAR experiments. This noteworthy accomplishment has been made possible only through the substantial financial investments by RIKEN and the sustained scientific contributions from RBRC over the past two decades.

NCAC notes that Dr. Y. Akiba is now the spokesperson for the PHENIX experiment.

RBRC continues to be a unique, highly successful model for international scientific collaboration. The growing, worldwide network of RBRC faculty at research universities and laboratories is very impressive and demonstrates the scientific vitality of RBRC.

The RBRC theory group continues to make a major scientific impact. For example, chiral matter, which originated in heavy ion theory, is now an exciting experimental activity at the interface of condensed matter and nuclear physics. This is a fine example of the power of cross-disciplinary research. In the area of lattice QCD, the All-Mode Averaging technique developed by RBRC physicists has now become the standard used by the lattice community worldwide.

### **Recommendations:**

**The proposed extension of RBRC for the years 2018-23 offers a plan to complete the RHIC-era scientific program and to seize on new opportunities. It will enable the analysis of a significant quantity of data already taken; allow RBRC participation in the construction and operation of the new detector sPHENIX; make possible potential RBRC contributions to the EIC and develop a new cross-disciplinary initiative on chiral matter.**

**NCAC strongly endorses the proposed extension of RBRC for the years 2018-23. This will maintain the Center's outstanding scientific productivity in the areas of experiment, theory, and lattice QCD at the RHIC facility.**

## **VIII. RIKEN-RAL**

### **Findings:**

Muon science research at the RIKEN-RAL facility is characterized by a very diverse range of fundamental and applied science with a strong focus area in condensed matter physics and a very good publication record in the past 2 years. The diversity in research has been continuously developed and NCAC appreciates the introduction of new projects such as chip irradiation and elemental analysis making use of negative muons. The recent observation of neutral muonium in the high-pressure SiO<sub>2</sub> mineral Stishovite (N. Funamori et al., Scientific Reports 5 (2015) 8347) suggesting that hydrogen may be able to

exist in neutral atomic form deep in the Earth's mantle is a highlight displaying an innovative and interdisciplinary use of the facility.

The RIKEN-RAL facility is expected to close with the start of the full-scale operation of the muon facility at J-PARC. A plan has been presented for collaboration for a further 5 years, until 2023, with RAL mainly responsible for operations costs of the facility, RIKEN mainly responsible for refurbishment costs and with the ownership of the facility to move to RAL in 2023. During these years, a user program for Japanese researchers would continue on the instruments used for muSR studies of materials and the ultra-slow muon development would continue on Port 3. RIKEN may wish to continue to use Port 1 for fundamental physics studies.

**Recommendation:**

**NCAC endorses the joint program to sustain the RIKEN-RAL facility into the future as proposed. NCAC would like to see the user program within a broader collaborative effort with J-PARC with the goal to expand the muon user community. NCAC recommends the development of the slow muon technique to be coordinated with the similar development at J-PARC so that it can effectively contribute to the timely completion of the ultra-slow muon beam for the condensed matter and g-2 programs.**

## **IX. Cross-Disciplinary Research**

**Findings:**

A number of excellent cross-disciplinary projects are running at the RNC, including astrophysics, climate science and solar-terrestrial physics, irradiation of electronics components, interdisciplinary theoretical science, and condensed matter science. Explicitly, cooperation was highlighted between the RNC and the Condensed Molecular Materials Laboratory, the RIKEN Center for Advanced Photonics, and the RIKEN Quantitative Biology Center. However, despite all these excellent projects, there seems to be room for more.

iTHES (Interdisciplinary Theoretical Science Research Group) offers excellent examples of interdisciplinary research.

Strengthening the links with condensed matter science was emphasized as a future plan for cross-disciplinary research, in particular the increased collaboration between RIKEN-RAL and RIKEN Center for Emergent Matter Science (CEMS), and the application of  $\beta$ -NMR and DNP (dynamic nuclear polarization) techniques to hard and soft condensed matter are proposed.

**Recommendation:**

**Ongoing and excellent cross-disciplinary research should be strongly encouraged as it creates outstanding science and spreads the word about the relevance of nuclear science and technology. Following the successful model of iTHES, the exchange of scientists with other RIKEN centers should be promoted. By exploring interfaces across domains, opportunities are also created to answer important questions pertaining to the field of nuclear physics.**

## X. Strategic Plan and Future Projects

*This section addresses the presentations on the specific subject matters but, for completeness, also reiterates some of the findings and recommendations presented earlier in this report.*

### 1. Findings on scientific direction and initiative:

The RNC proposes to integrate research in nuclear physics, hadron physics and astrophysics that is currently carried out in its three divisions under the thrust of "Cosmo Nuclear Physics". NCAC considers the strategy to develop a coherent effort in Cosmo Nuclear Physics to be promising.

The RIBF Research Division will exploit both the extensive production and experimental capabilities of the facility to investigate nuclear structure at the extremes of isospin and produce new isotopes, with a particular focus on elucidating the astrophysical r-process. This will be complemented by laboratory studies of the isospin dependence of the Equation of State (EOS) of nuclear matter and astrophysical studies of neutron stars.

The cutting edge program on SHE will focus on efforts to produce new SHE beyond  $Z = 118$  and study the chemistry and structure of elements  $Z = 106 - 112$ .

The long-term future of the research program will rely heavily on the accelerator upgrades described below.

In the context of the increasing international competition by upcoming RI beam facilities, it is important that the RNC focus its long-term efforts on the unique capabilities of RIBF to carry out the most impactful experiments that cannot be done elsewhere. While a first comparison of such capabilities was presented for the proposed upgrades, further work is needed to spell out the unique scientific advantages that the combination of future RIBF production and experimental capabilities will have when compared to other facilities, in particular to FRIB and FAIR.

With the Rare RI Ring, SLOWRI and SCRIT, new experimental devices are starting operation in the mid-term at RIBF and they will contribute to the efforts to maintain unique capabilities for the research programs. However, SCRIT will have to undergo an upgrade in order to achieve the luminosities required to make meaningful measurements for  $^{132}\text{Sn}$ , one of its key targets.

Plans for low-energy RI beams are being developed, and unique programs should be proposed to be complementary to the capabilities for post-accelerated RI beams at ISOL facilities as well as at the FRIB re-accelerator.

### Recommendations:

**While NCAC strongly endorses the overall scientific strategy for the RIBF Research Division, the RNC should carry out a more detailed study to identify scientific programs and technical capabilities where RIBF will have unique advantages in the mid- and long-term.**

**The development of new experimental capabilities should be evaluated with the view of strengthening unique capabilities.**

### 2. Finding on the Cosmo-Nuclear Physics Strategy:

Under the Cosmo-Nuclear Physics strategy, the plan for the Sub-Nuclear System Research Division with a continuing strong coraboration with BNL is to focus on advancing the understanding of how hadrons and nuclei are created in or from a quark-gluon plasma, on the spin content of the nucleon with continuous involvement at RHIC, focusing on sPHENIX, and on the hadron physics program at J-PARC.

**Recommendation:**

**The plans for the future direction of the Sub-Nuclear System Research Division should be refined further, with strong involvement of the new Chief Scientist who will lead this division, and the connection of the experimental hadron physics program with state-of-the-art theoretical efforts should be strengthened.**

**NCAC then strongly endorses the proposed extension of RBRC for the years 2018-23. This will maintain the Center's outstanding scientific productivity in the areas of experiment, theory, and lattice QCD at the RHIC facility.**

**3. Finding on the Theory Research Division:**

While the Theoretical Research Division is considered to be an important pillar of the Cosmo-Nuclear Physics strategy, its future is uncertain since Dr. Hatsuda is expected to transition to iTHES in the mid-term and several of the Associate Chief Scientists have moved to university professorships.

**Recommendation:**

**To secure the future of the current broad and internationally highly competitive nuclear theory program, Dr. Hatsuda's Chief Scientist position should be filled as soon as possible. Reaffirming its earlier recommendation, NCAC urges to create permanent positions in modern nuclear structure theory to provide support and intellectual guidance for experimental radioactive ion beam programs at the RNC and elsewhere.**

**4. Finding on Applications:**

The multifaceted application program will be continued with a particular focus on the programs related to nuclear waste transmutation, heavy-ion beam breeding, as well as production and dissemination of radioactive isotope tracers.

**Recommendation:**

**NCAC recommends to further strengthen the pursuit of applications of societal benefit, building on the strengths of the current programs. It is important to ensure that a timely succession plan is in place for the excellent breeding program.**

**5. Finding on RIKEN-RAL:**

It is proposed that the RIKEN-RAL Muon Facility will undergo a major refurbishment carried out by RIKEN, after which the ownership of the facility will be transferred to RAL.

**Recommendation:**

**NCAC endorses the joint program to sustain the RIKEN-RAL facility into the future as proposed. NCAC would like to see the user program within a broader collaborative effort with J-PARC with the goal to**

**expand the muon user community. NCAC recommends the development of the slow muon technique to be coordinated with the similar development at J-PARC so that it can effectively contribute to the timely completion of the ultra-slow muon beam for the condensed matter and g-2 programs.**

#### **6. Finding on Accelerators – Technical aspects:**

A strategic future plan for the RNC accelerator complex is being proposed that consists of two major initiatives: (1) a beam intensity improvement of the cyclotron complex by a factor 30 and (2) an energy increase of the booster linac for the SHE program.

#### **Recommendation:**

**NCAC recommends to optimize further the detailed plan for the upgrade. R&D efforts in Superconducting RF cavity technology should proceed in cooperation with experienced laboratories such as KEK. The strategic plan for the accelerator complex should cover a time range of more than 10 years and the expected performance has to be competitive with that of upcoming international facilities.**

#### **7. Findings on Scientific Management:**

While the consequences of the RIKEN human resource reform for the RNC are not entirely clear yet, NCAC wants to emphasize that the current mixture of permanent and temporary staff within the RNC has served the laboratory well and it is essential that continuity of expertise be maintained.

The current portfolio of research activities of the RNC represents a healthy balance with focus on areas of strength while maintaining a diversity that allows to make contributions to interdisciplinary activities.

Synergies between different sub-fields are beneficial and should be encouraged further.

#### **Recommendation:**

**In developing the optimal strategy for the RNC structure, management should consider the impacts of different funding scenarios.**

## **XI. Response to the NCAC 2014 recommendations**

The committee congratulates the RNC management and staff for the efforts made to respond with a number of actions to the previous recommendations.

NCAC understands that the request for additional operation hours at RIBF requires an increase in funds and external new sources could be considered. However, for collaborations around instruments, the successful policy of in-kind contributions should be continued. The facility should continue to adhere to the open access rules for academic research.

The project for the RIBF upgrade is sound with the two identified directions consisting in increases in the production of both neutron-rich nuclei and SHE. The uniqueness of the science program as compared to other facilities should be considered further and addressed appropriately.

Several initiatives on applications have been taken: the “Abrasion-inspection test using RI beams” which is bringing money to RIKEN; the R&D in nuclear medicine using <sup>211</sup>At; the “dynamic nuclear polarization (DNP) and  $\beta$ -NMR spectroscopy for material sciences and life sciences”; the development of a new type

of gel dosimeter which has been taken over by the RIKEN Cluster for Industry Partnership to promote its commercialization.

Ion beam breeding continues to run as a RNC mission. The connections with industry have been expanded and strengthened. It is still challenging to have sufficient incentives for growing commercial accelerator applications, although work has been done and more is in the pipeline.

NCAC endorses the future plan of the Sub-nuclear System Division to cooperate in the continuation of RBRC and RIKEN-RAL.

As state above, the proposed extension of RBRC for the years 2018-23 offers a plan to complete the RHIC-era scientific program and to seize on new opportunities. It would enable the analysis of a significant quantity of data already taken; allow RBRC participation in the construction and operation of the new detector sPHENIX; make possible potential RBRC contributions to the EIC and develop a new cross-disciplinary initiative on chiral matter. Thus, NCAC strongly endorses the proposed extension of RBRC for the years 2018-23. This will maintain the Center's outstanding scientific productivity in the areas of experiment, theory, and lattice QCD at the RHIC facility.

For RIKEN-RAL, the plan was to move to J-PARC by 2018. A smooth turnover is now in place through a joined program with ISIS. The collaboration of RIKEN-RAL with CEMS has started and it is expected to provide a plan for future strategic cooperation. With CEMS, the nuclear theorists at RBRC are working on chiral magnetic effects and a joint workshop will take place at RIKEN later in 2016.

It is unfortunate that the recruitment of personnel at the RNC was suspended. In spite of the work done so far, the recruitment of personnel remains a critical issue in order to retain essential expertise and ensure effective succession planning.

NCAC remains extremely concerned about the future of the theory effort at the RNC. The present situation is worse than in 2014. Reaffirming its earlier recommendation, NCAC urges to create permanent positions in modern nuclear structure theory to provide support for the local and international experimental programs with radioactive ion beams.

**For the Nishina Center Advisory Council**

**Sydney Gales**



**Chair of NCAC**





## XII. Recommendations from the NCAC to President Hiroshi Matsumoto

TOR 1	<p><i>RI Beam Facility, Super-Heavy Element research, n-rich RIB, RHIC physics, Lattice QCD, Ion Breeding.</i></p>	<p>Insufficient RIBF beam time. Lack of manpower for facility operations. Human resource policy is still unclear in RIKEN. Lack of theory support for RIBF.</p>
<p><i>RNC mission objectives were successfully accomplished. It is essential to fully exploit RIBF's research potential; RNC must proceed with RIBF upgrade; invest in sPHENIX @RHIC; strengthen RIBF theory; and strengthen applications &amp; cross disciplinary R&amp;D.</i></p>		
TOR 2	<p><i>RIBF is at full bloom so that there is no need to restructure this center now. RNC should enhance collaborations with iTHES, RAP, CEMS, QBIC, AICS, CLST. Many germinating new initiatives show promise.</i></p>	
<p><i>The main focus must be on mainstream nuclear physics; i.e., Cosmo Nuclear Physics based on world-leading accelerator- and detector-based technologies.</i></p>		
TOR 3	<p><i>RNC excels in the 5 initiatives. Especially, RIBF is the world-leading hub for nuclear science. With RIBF, BNL and RAL, RNC serves as a place for top level brain circulation, fostering world-class scientists. ImPact/SIP programs are opening new research fronts.</i></p>	
<p><i>NCAC reiterates that 8-month operations are needed to make further advances. Implement human resource strategy that preserves the world-class research programs. Enhance theory to support and guide RIBF research programs.</i></p>		
TOR 4	<p><i>The proposed name "nihonium" (Nh) for element 113 has become a symbol of RIKEN's world leadership in research and technology. RIBF with unprecedented uranium beam intensities together with the highly effective scientific hubs at RIBF, BNL &amp; RAL have contributed largely to the achievements and reputation of RIKEN.</i></p>	

**XIII. Annexes**

**Annex I : Agenda of the NCAC meeting July 21-23 2016**

July 21 2016

**Nishina Center Advisory Council (NCAC)  
July 21-23, 2016  
Agenda**

**July 21<sup>st</sup> (Thu.) @ RIKEN Wako Branch (Conference Room / RIBF Bldg.)**

**16:00-17:30** Welcome address, Overview of RIKEN, explanation of Terms of Reference  
Yoichiro Matsumoto  
Executive Director, RIKEN  
Introduction of members, overview of the Nishina Center  
Hideto En'yo  
Director, RNC

**17:30-18:30** NCAC Closed Session

**18:30-20:00** *Buffet Supper at Hirosawa Club*

**July 22<sup>nd</sup> (Fri.) @ RIKEN Wako Branch (Conference Room / RIBF Bldg.)**

**Morning session (9:00-12:45)** Chair: Sydney Galès  
Session secretary: Osamu Kamigaito

**9:00-10:40** Report on research activities  
(1)RIBF Division overview and highlights  
Hiroyoshi Sakurai/Hideaki Ostu/Tomoko Abe/Atsushi Yoshida

**10:40-10:55** *Coffee Break*

**10:55-12:00** (2)Sub Nuclear System Research Division overview and highlights  
Masahiko Iwasaki/Yasuyuki Akiba

**12:00-12:45** (3)Theoretical Research Division overview and highlights  
Tetsuo Hatsuda / Takumi Doi

**12:45-14:45** *Working Lunch at Hirosawa Club (closed)*

**Afternoon session (14:45-18:30)** Chair: Sydney Galès  
Session secretary: Hiroyoshi Sakurai

**14:45-15:30** *Report on accelerator research activities*

(1) Accelerator research overview

Osamu Kamigaito

**15:30-16:15** (2) Experimental facility overview

Masanori Wakasugi

**16:15-16:40** *Coffee Break*

**16:40-17:20** RBRC research activity & future prospect

Samuel Aronson

**17:20-18:00** RAL research activity & future prospect

Philip King

**18:00-18:30** NCAC Closed Session

**18:30-20:00** *Dinner at Hirosawa Club (Closed)*

**July 23<sup>th</sup> (Sat.) @ RIKEN Wako Branch (Conference Room / RIBF Bldg.)**

**Morning session (9:00-11:05)** Chair: Sydney Galès

Session secretary: Osamu Kamigaito

**9:00-10:00** The RNC Committee on Scientific Strategy and Management Policy Report by  
the Committee Chair

Hideki Ueno

**10:00-11:05** Response to the last NCAC recommendations by the RNC director

Hideto En'yo

**11:05-12:30** NCAC Closed Session

**12:30-13:30** *Working Lunch at RIBF 203 (Closed)*

**13:30-17:30** NCAC Closed Session

**17:30-18:30** Summary and Closeout

Sydney Galès

**18:30** End of the meeting, Back to hotel

**19:30** *Dinner (Japanese Restaurant "Hanamusashi Shunka" at Hotel Metropolitan Tokyo)*

**Annex II : List of the members of Nishina Center Advisory Committee (NCAC 2016)**

members' name	institute	job title	contact
Sydney Galès (Chair)	CNRS-IN2P3(Fr) and ELI-NP(Ro) Extreme Light Infrastructure – Nuclear Physics (ELI- NP)	Professor Dr. Director of Research IPN Orsay CNRS Scientific Director ELI-NP	TEL +33 607654243 gales@in2p3.fr
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