# NCAC Meeting
# Jan 15-17, 2009

***Recommendations and Conclusions***
***From the NISHINA Center Advisory Council***

## Executive Summary - Recommendations and Terms of Reference

The Nishina Center Advisory Council (NCAC) met on January 15-17, 2009 at RIKEN, Wako-Shi, to review recent developments and status of the Center and to advice on its ongoing and future plans. In addition to the accepted aspects of peer review, NCAC was tasked by Prof. R. Noyori, President of RIKEN, to evaluate the performance of the Center along specific *Terms of Reference* that he has established for RIKEN.

This Executive Summary summarizes the core recommendations and conclusions of NCAC, and then discusses them briefly in the context provided by the before-mentioned *Terms of Reference*. More detailed justification leading up to NCAC's recommendations is provided in the main body of this Report.

The most striking recent advance at the Nishina Center has been the successful commissioning of the new Radioactive Isotope Beam Factory (RIBF) and the first experimental results. The NCAC congratulates the Center on reaching this major milestone which has propelled it to the forefront of rare-isotope science world-wide with tremendous potential for scientific discovery. Given the scientific potential, we commend the high priority assigned by the Center to move toward more operational hours for experiments, more reliable operation, and reduced beam development time.

- **To help achieve these goals NCAC recommends that a set of indicators be developed to monitor progress.**

Possible indicators are suggested in the main text of this report.

We applaud the plans of the Center to increase the primary beam intensity. A new 28 GHz ECR is nearing completion, and significant effort is underway to improve stripper lifetimes. We also heard initial ideas for a new compact cyclotron that could solve the current limitations of stripper technology and achieve the design intensity goals for uranium.

- **We recommend that the Center continue the effort to increase beam intensity, since the discovery potential of the facility is directly related to the intensity of the radioactive beams that can be produced.**

While it is important for the Center to achieve its intensity goals, the facility is currently capable of achieving groundbreaking results.

- **We recommend that careful consideration be given to maximize the time available for experiments with the new facility, while progress on increasing intensity is made.**

Given the increase in scientific output it will make possible, the construction and early commissioning of the newly approved and funded injector is highly recommended. The new injection is necessary to allow simultaneous beam to be delivered to the radioactive beam and superheavy element programs, both of which are presently unique worldwide.

The Nishina Center has strong collaboration with accelerator laboratories at the universities such as the RCNP, Osaka University and the ICR, Kyoto University. These collaborations are very important for the development of the accelerator science and education of the next generation of accelerator physicists.

- **Given the importance of accelerators to science and industry, NCAC recommends that these collaborations be enhanced.**

Given the large capital investment in RIBF and the great scientific potential demonstrated by its recent achievements, the council considers that current operational level of 5 months to be woefully inadequate. NCAC is well aware of the budget difficulties in the current financial climate to expand usage of any science infrastructure. But we would be remiss of the unique opportunities that RIBF currently presents if we would not emphasize its unique position to enable discoveries in nuclear science.

- **NCAC suggests that eight months operation is necessary to exploit fully the potential of the facility, fulfilling the responsibility of RIKEN to the nuclear physics community and to society**

The success of the initial research program has immediately propelled the research facility to a forefront and world leadership position. This success is based on: i) the outstanding advances made in 2008 in the technical performance and operations characteristics of the new accelerator facility; ii) the planning and structured processes that have been implemented by the Center's management to define the best, appropriate, and scientifically most promising research program (included the establishment of the international Program Advisory Committee (PAC) and steps to increase international participation); and iii) the first-rate devices that constitute the initial baseline instrumentation for experiments.

Major new spectrometers are currently under development and construction. Others that will be needed for more detailed studies and further advances in the science are at an initial stage of consideration. Some of these are quite sophisticated and expensive (such as a high-resolution, position-sensitive germanium ball gamma-ray detector). They most likely need to be realized in international collaboration, to assemble the specialized expertise needed. For longer-term support and involvement from the international community it will be important to get the latter involved at an early stage.

- **NCAC recommends to establish a structured process for future developments of instrumentation and for involvement of the international community at an early stage**

A formal structure that could be used to guide this process is the current, PAC, possibly supplemented on a case-by-case basis with specific technical experts.

Now that RIBF is operational, international collaboration will increase at all levels. However, the Center staff should continue to encourage international scientific collaborations though specific programs. For example, targeted information transfer, which goes beyond general public relations efforts, are one action the Center could take.

- **NCAC recommends that the Center implement and/or enhance specific programs to further international participation, such as workshops in major countries, student exchange programs, and fostering international interest through enhanced information transfer.**

The council welcomes and supports the proposal to organize the structure of the Nishina Center into three functionally related divisions, namely i) Theory; ii) Subnuclear Systems; and iii) RIBF Research. We suggest that three deputy or associate directors be appointed corresponding to each Division.

- **The NCAC notes that considering the importance and size of the RIBF Research Division, RIKEN might consider a broader, possibly international, approach to identify its leadership.**

The new organizational structure will also strengthen the visibility of theory within the Nishina Center. Following a suggestion from the last Advisory Council Report, the Nishina Center has added a theory group working on nuclear structure and reactions, which matches the focus of the experimental program. This move of introducing an active theoretical group on nuclei far from stability line is highly appreciated by the Advisory Council. The Council sees an additional opportunity for leadership in nuclear astrophysics

- **NCAC recommends adding theory positions in nuclear astrophysics to the Theoretical Research Division.**

RIKEN has a long tradition of promoting applications of nuclear physics and instrumentation for science and for the betterment of society. This tradition continues to remain a constant theme in the current research facilities locally at Nishina Center and also in RIKEN activities elsewhere in Japan and in the world (RIKEN-RAL).

We note that the Accelerator Application Research Division and Industrial Cooperation Team have unique capabilities for RI production and delivery, heavy-ion induced plant mutation, and biological irradiation. There are other accelerators for such applications in Japan (e.g. the AVF cyclotron at the JAEA-Takasaki laboratory and the HIMAC at the NIRS for heavy ions).

- **NCAC suggest that the Nishina Center management explore whether it would be desirable to make a network connecting the accelerator institutes for coordination of users' demands.**

The International Advisory Committee (IAC) for the RIKEN-RAL Facility concluded that it provides unique instruments which serve a dynamic user community and produce excellent science. The superb technical skills used to develop state of art equipment are matched by the competence and dedication of a strong physics team. RIKEN can take pride in such achievements.

The NCAC also supports the principle (expressed by the RIKEN RAL IAC in their report) that to deliver a balanced future programme, which builds on recognized strengths and maximizes world-class science, future investments should go to the most exciting and ambitious projects. This will be the best way to foster increasing engagement with Japanese and international research communities and the host facility.

- **NCAC endorses the recommendation of the RIKEN-RAL IAC that *Condensed Matter and Molecular Science* and *Ultra-Slow Muon Source Development* be prioritized as the first of two central pillars of the future RIKEN-RAL facility programme, and given sufficient resources to enable its continued development. The NCAC further supports the IAC recommendation for an extension of the RIKEN-RAL agreement beyond 2010 by at least another 7½ years to 2018.**

The RIKEN-BNL Research Center (RBRC) is a role model for successful international collaboration. The physics issues addressed by the RBRC are among the most important in subnuclear physics, the results obtained to date are highly significant and of long term value. A major strength of the RBRC research program is its focus on one broad topic, QCD. Its experimental program and theory program including the lattice computation program are all aimed at understanding the structure and properties of QCD matter. There is good reason to believe that prospects are there for the RBRC to continue being a highly successful scientific enterprise with potential for major scientific discoveries. In the longer term, the focus of RHIC will be on realizing eRHIC. This will be a powerful, unique tool of the study of QCD. Its capabilities will dramatically extend the limits of existing machines to probe the spin structure of the nucleon and the role of partons in nuclei.

- **NCAC concurs with the view of the RBRC Advisory Committee that RBRC has been highly successful and cost effective, that it is doing fore front science and that its strong support should be continued.**

The ISIS muon facility is now delivering science in a mature way and is entering an exciting stage with the development of an ultra-slow muon scientific program. At the same time, the RIKEN-BNL activities are also very productive and addressing issues of great current interest.

- **NCAC sees future similar opportunities at J-PARC and suggests that the interested parties explore the establishment of a RIKEN J-PARC Center.**

In conclusion, the Nishina Center research program is of highest quality, multi-faceted, and internationally leading in many respects. With the new facilities now operational it has a bright future for international leadership at the very forefront. In the **Terms of Reference** established by the President of RIKEN, we make the following summary assessment:

**Summary Assessment in Terms of Reference**:

NCAC's detailed review of the Nishina Center, as described in the main body of the Report, and its suggestions and recommendations, as summarized in this Executive Summary, need to be seen before the background of the Terms of Reference, as provided by the President of RIKEN. The following provides NCAC's summary assessment in those Terms of Reference:

**1- Are there achievements with major scientific significance or achievements with significant social impacts? Are there achievements which will be notable in the history of science?**

Development, construction and successful operation of the RIBF will be regarded as a major milestone in the history of nuclear physics accelerators. The facility is at the beginning of its scientific production but has already discovered new isotopes. These and future results will likely be standard components in text books. The discovery of the new chemical element 113 at RIKEN is a major scientific achievement as well as an advance in understanding that will add to basic human knowledge and social relevance.

With these technical developments at the Nishina Center the potential now exists for major breakthroughs in nuclear physics including a more predictive model of the nucleus and an understanding of the chemical history of the Universe.

RIKEN's participation in the relativistic polarized-proton and heavy-ion programme at RHIC/Brookhaven has given the Center with comparatively modest investment a disproportionate involvement and, to a certain extent, leadership role in the study of QCD and partonic matter. The exploration of the new regimes and resulting science discoveries will be absolutely notable in the history of science.

**2- How does the Center compare with similar research institutions abroad? Make recommendations for possible improvement based on this investigation. Where does the RNC rank in the worldwide research community?**

The RIBF is the world-leading rare isotope beam facility. It can provide radioactive beams of more than an order of magnitude higher than other facilities. To achieve the full potential of this facility, it is important the Center take steps to increase the number of hours of beam time available to experiments. This can only be achieved by increasing the number of hours of funded operation and reduction of the beam development and delivery time. A critical aspect of achieving the scientific potential is that the funded operation increase from five to eight months.

RNC ranks now as the leader in rare-isotope research; forefront and leadership roles are also played by the Japanese groups in the RIKEN-RAL muon programme and the RIKEN-BNL relativistic beam program in QCD and quark-gluon matter.

RIKEN should be considered in the top group of research institutions worldwide in the physical sciences.

**3- Evaluate the Center's collaborations within RIKEN and with outside institutions, and evaluate the Center's effort to promote international collaborations. Are the RNC's collaborations resulting in better research achievements and more contributions to society?**

RIKEN has demonstrated its deep-rooted intent for international collaboration with the RIKEN-RAL and the RIKEN-BNL Centers. Also the RIBF facility at the RIKEN Nishina Center has already significant international collaborations. Additional opportunities exist for expanding on such collaborations with the completion of RIBF. A major advance could come from earlier and more involvement of the international community in the development of major instrumentation at RIBF which will determine future research programmes. Added international scope is expected to generate increased opportunities for scientific achievements and societal contributions.

# Full Report

## Introduction

Following the invitation of the President of RIKEN the Nishina Center Advisory Council has reviewed the organization, resources, operation, development, science programs and ongoing projects of the Center guided by the terms of reference given to us by the president of RIKEN Prof R. Noyori.

1- Are there achievements with major scientific significance or achievements with significant social impacts? Are there achievements which will be notable in the history of science?

2- How does the Center compare with similar research institutions abroad? Make recommendations for possible improvement based on this investigation? Where does the RNC rank in the worldwide research community?

3- Evaluate the Center's collaborations within RIKEN and with outside institutions, and evaluate the Center's effort to promote international collaborations. Are the RNC's collaborations resulting in better research achievements and more contributions to society?

The members of the NCAC want to express their thanks to Dr. Yano, to Dr Motobayashi, and to the RIKEN teams for their hospitality during our visit. We have appreciated the quality and detail of the presentations and the written materials provided during and in advance of the meeting. Open discussions on all the subjects discussed below were also highly appreciated.

***The NCAC wants to congratulate the accelerator team and all the members of the center for the first extracted beam from SRC, the world's largest cyclotron. This event is a significant mile stone in the history of accelerator science.***

***Soon after, the first physics experiment was performed, coupling the accelerator to the BIGRIPS spectrometer. The production of new isotopes already in this first experiment demonstrated the rich potential for discoveries that RIBF brings to science.***

***These early achievements clearly indicate that RIBF is now a leading center worldwide for nuclear science and the physics of "exotic nuclei".***

## 1. Organization

The RIKEN Nishina Center consists of five Divisions (Accelerator, Nuclear Physics Research, User Liaison and Support, Sub Nuclear System Research and Accelerator Application Research), one Group (Safety Management) and two international facilities (RIKEN-BNL Research Center and RIKEN Facility Office at RAL). The number of staff (permanent researchers, contract researchers, technical staff, special PD and junior RA) is 182 and the number of external researchers (collaborators, etc.) amounts to 662. It is essential to have an effective and efficient organization system to run the Nishina Center considering the diversity of the research areas and the numbers of personnel and external researchers.

We had considerable discussion regarding optimization of the center organization. The committee welcomes and supports the proposal to organize the structure of the Nishina Center into three functionally related divisions, namely

- Theory
- Subnuclear Systems
- RIBF Research

and suggests that three deputy or associate directors be appointed corresponding to each Division. This level of supervision is justified given the number and diversity of research groups involved.

**NCAC notes that considering the importance and size of the RIBF Research Division, RIKEN might consider a broader, possibly international, approach to identify the associate director for this division**

## 2. Resources and Communication

Budget

Given the large capital investment in RIBF and the great scientific potential demonstrated by its recent achievements, the committee considers that current operational level of 5 months to be woefully inadequate. There is a backlog of 188 days of the PAC-approved experiments at RIBF which corresponds to about 1.5 years' beam time. NCAC suggests **that eight months operational is necessary to reduce the backlogs as well as to exploit fully the potential of the facility fulfilling the responsibility of RIKEN to the nuclear physics community and to society**. RIBF is currently in a unique position to enable discoveries in nuclear science

Information transfer to the community

The information transfer to the communities regarding progress made at RIBF and the capabilities at the facility has room for improvement. For example, the RIBF Quarterly is only distributed to the registered researchers, and not to potentially interested parties.

We strongly urge the RIBF to make an effort to transfer information as widely as possible to the international community. Among other activities to this end, it may be appropriate to organize workshops in target countries.

## 3. RIBF Facility accelerator operation and projects

The first beam of $^{27}Al^{10+}$ at energy of 345MeV/u was extracted from the SRC at 4 pm on December 28, 2006.This event and the production of the first radioactive beams shortly thereafter is a remarkable accomplishment. The completion of the RIBF facility on this timescale was viewed as very ambitions by the previous IAC in 2006, and its achievement is a testament to the dedication and considerable ability of the Center staff.

Since first beam extraction, the staff has made significant progress in increasing the intensity of the beams for radioactive beam production. The intensity of the uranium beams has increased by more than an order of magnitude and a $^{48}Ca$ beam has been run at near the facility design goals. This progress has been completed in spite of a significant interruption of operations due to oil contamination in the liquid helium refrigerator system of the SRC and BigRIPS. Repair of this problem caused a 200-day shut down from February to November 2008. The staff should be commended for their careful analysis and solution to this problem.

The RIBF facility is now moving from a period of development to a state of operations. This transition is proceeding well.

The accelerator staff has continued fast progress in the implementation of new equipment to enhance the performance of the facility. A new 28GHz superconducting ECR ion source is under construction and will be mounted on a 100kV voltage platform. In addition to promising increases in beam intensity, it will allow Super Heavy Elements research with the RILAC to be conducted independently of the RIBF research. A new injector consisting of a new 4-rod injector RFQ and drift-tube linac cavities for the RRC will be placed in the AVF cyclotron vault.

It is a significant and positive development that this new injector has been funded. This will allow three simultaneous users, including simultaneous operation of the superheavy element program and the RIBF facility. This has the potential to double the groundbreaking scientific output of the Center.

A 300MeV electron storage ring KSR at the ICR, Kyoto University has been used for the development of the SCRIT device and the used SR-ring AURORA-2S at Sumitomo Heavy Industry were already transferred to RIKEN as an electron accelerator for the future SCRIT project at RIKEN. The accumulation of electron beam at 300MeV has been tested and confirmed at HiSOR, Hiroshima University for the modification of the AURORA-2S to an AURORA-2D type ring. The collaborations with accelerator groups of the Kyoto University and the Hiroshima University were very effective for the development of the SCRIT.

During the commissioning and development phase of the RIBF facility successful and significant scientific programs have continued using the RIKEN Ring Cyclotron, the RILAC linac, and AVF cyclotron. These include the world-leading programs in the creation of new superheavy elements, condensed matter studies, applications of heavy ions beams, radioactive beams with CRIB, and the radioactive beam program with RIPS.

With operation of the world's most powerful radioactive beam facility, there is tremendous potential for scientific discovery. Indeed, already, each of the first experiments performed with the pilot beams from the facility have yielded significant and surprising results. Given the scientific potential, we commend the high priority assigned by the Center to move toward more operational hours for experiments, more reliable operation, and reduced beam development time. **To help achieve the goal, we recommend that a set of indicators be developed to monitor progress.** This could include among other things tracking of machine development time, radioactive beam development time, time used for experiments, and the ratio of scheduled to actual beam time used for experiments.

We note and applaud the plans of the Center to increase the primary beam intensity. A new 28 GHz ECR is nearing completion, and significant effort is underway to improve stripper lifetimes, including implementation of a gas stripper. We also heard initial ideas for how addition of a new compact cyclotron could solve the current limitations of stripper technology and achieve the design intensity goals for uranium. **We recommend that the Center continue the effort to increase intensity, since the discovery potential of the facility is directly related to the intensity of the radioactive beams that can be produced.**

It will be necessary for the Center to achieve a proper balance of beam delivery and beam development. While it is important for the Center to achieve its intensity goals, the facility is currently capable of achieving groundbreaking results. **We recommend that careful consideration be given to maximize the time available for experiments with the new facility, while progress on increasing intensity is made.**

As the facility moves into its operations phase, the effort required for development activities and operation for users will change. In order to ensure that the needs of the users are met, **we recommend that the Center management carefully consider the workforce needed to achieve sustainable operations in the areas of cyclotron operation, radioactive beam production, and system optimization.**

The accelerator development program for the future is well planned both in connection with technical aspects and for the realization of the physics program. Given the increase in scientific output it makes possible, the construction and commissioning of the new injector is highly recommended. The new injection is important to have more beams dedicated to the radioactive beam and superheavy element programs, both of which are presently unique worldwide.

The Nishina Center has strong collaboration with accelerator laboratories at the universities such as the RCNP, Osaka University and the ICR, Kyoto University. These collaborations are very important for the development of the accelerator science and education of the next generation of accelerator physicists. **Given the importance of accelerators to science and industry, we recommend that these collaborations be enhanced.**

# 4. Physics Results and Instrumentation

The research program at the new RIKEN RIBF was started in FY07. Very soon after start-up and in particular in the second half of 2008, outstanding first physics results have been obtained that have immediately propelled the research facility to a forefront and world leadership position. The success of these experiments is based on: i) the outstanding advances made in 2008 in the technical performance and operations characteristics of the new accelerator facility; ii) the planning and structured processes for the experimental program that have been implemented by the Center's management to define the best, appropriate, and scientifically most promising research program. This included establishing an international Program Advisory Committee (PAC) and steps to increase international participation and collaboration; and iii) the first-rate devices that constitute the initial baseline instrumentation for experiments.

The advances in accelerator performance are described in detail elsewhere in this Report. In the context of the science discussion it is worth repeating that the accelerator staff did an outstanding job not only in establishing design performance characteristics but, in a systematic and focused way, implemented a painstaking multitude of specific measures at this first-of-a kind facility, that now provide the stability and reliability in performance that must underlie a successful research program.

The initial research program had been established by a structured process implemented by the Center's management. It involved, in addition to the long-term development and construction of the first experimental instrumentation, a general and public call for research proposals and a subsequent evaluation process by the facility's international Program Advisory Committee (PAC). Special emphasis was placed by management on important day-1 experiments which were of considerable scientific importance but also allowed for fast extraction of initial results. This strategy has been very successful with, in particular, the discovery of initially 2 but by now more than 20 new isotopes that were previously unknown and that are important steps in our understanding of the nuclear chart away from stability and towards the neutron-rich limits of nuclear binding. The success of the round of experiments performed at the end of calendar year 2008 is based on substantially improved and world leading intensities for two important beam species, uranium and the neutron-rich calcium isotope $^{48}$Ca. In addition to delivering record primary-beam intensities, the increased beam energies of about 350 MeV per nucleon that the new facility provides led to an unexpected increase in secondary reaction yield and thus rare isotope beam intensity. This in turn already allowed for first successful spectroscopic studies on nuclei previously not even known.

These first series of successful experiments constitute a major success for the facility. It will trigger worldwide attention and attract additional scientists and collaborations. The Center's management is encouraged to promote such developments with specific steps that we indicate in section 6 of this Report.

A major component of the successful experiments was the first-rate baseline instrumentation that had been developed and installed at RIBF: the two-stage, high-acceptance, and high-resolution super-conducting fragment separator and the zero-degree spectrometer with an appropriate complement of particle identification and detection devices. Further major spectrometers are under development and construction: (i) the high-resolution focusing SHARAQ spectrometer, scheduled for first commissioning in March this year, (ii) the SCRIT facility that aims for the worldwide unique capability to perform experiments of electron scattering from radioactive nuclei; this looks especially promising in view of the planned linkage with the future SLOWRI facility for slow radioactive ions, (iii) and the non-focusing, large-acceptance window frame SAMURAI set-up that provides for multi-particle detection, including a neutron time-of-flight wall, and which is scheduled for completion in 2011.

While major baseline instrumentation is, or will be, constructed and available for experiments, there is a wide complement of sophisticated detector systems, such as a full sphere of position-sensitive high-resolution gamma-ray detectors for precision spectroscopy that are needed for more detailed studies and further advances in the science. Some of these systems, e.g. the "germanium-ball"- type device just mentioned, are very expensive and most likely will only be realized in international collaborations. It will be a major task for the near-term research planning to find appropriate solutions (and participating groups).

Secondly, the NCAC heard about status and plans for a major complement of additional experimental facilities for RIBF which are very exciting, often quite novel and seminal. These need to be pursued; good science arguments exist for all of them. However, the limits in funding and available technical and scientific effort will require a process of evaluation and priority setting that the management needs to implement in a broader sense. It is obvious that this has been already done to some level within the facility and/or the Japanese research community. For longer-term support and involvement from the international community though it will be important to get the latter involved at an early stage. **NCAC recommends to establish a structured process for future developments of instrumentation and for involvement of the international community at an early stage.**

The formal structure to help organize this process and help with advice in close connection with the ongoing scientific program could be the by now well-established PAC, possibly supplemented on a case-by-case basis with specific technical experts.

We have focused on the important recent developments and results in connection with the start-up of the new RIBF. We need to mention that parallel to the work with RIBF, the research programs at the other accelerators, and in particular the superheavy-element work with the discovery of element 113 and production of isotopes for elements 110 and 111, has had major successes and a major impact on the field of nuclear structure physics. It has placed RIKEN in the forefront institutes of this research and drawn worldwide attention to the excellence of the RIKEN program.

## 5. Applications of Nuclear Physics and Instrumentation

RIKEN has a long tradition of promoting applications of nuclear physics and instrumentation for science and for the betterment of society. This tradition continues to remain a constant theme in the current research facilities locally at Nishina Center and also in RIKEN activities elsewhere in the world.

In particular, there is a broad range of applications that span many areas of science including condensed matter physics, radio isotope production for pharmaceutical purposes, space radiation effects, and the influence of radiation on biological systems. Of particular practical importance is the ongoing work on mutation of plants, which could have a profound beneficial effect on society. There is also a growing program to provide specialized radio-pharmaceuticals for medial purposes and to study the influence of heavy ions on biological systems. The fundamental work on the single atom chemistry of super heavy elements is of broad international interest. In this regard the new RIB factory is already competitive with comparable facilities in the world even though it has not yet reached its full potential.

There is also a highly successful and productive research program at the RIKEN-RAL facility that uses muons as a probe of condensed matter and physical chemistry. The facility attracts many users from within Japan and also an international group of collaborators. The RIKEN-RAL is unique in the world in the use of lasers used in conjunction with the pulsed beam at RAL. The efforts to produce a low energy muon beam are particularly important to the world wide community. Provided the ionization laser developments proceed as expected, the beam at RIKEN-RAL will exceed the only other beam of this type now operating at PSI. That is the most heavily subscribed muon beam line in the world. The committee notes that the developments at RIKEN-RAL in the area of low energy muon beams, detectors and lasers are all essential for the successful evolution of the anticipated world leading muon spin rotation program at JPARC.

We note that the Accelerator Application Research Division and Industrial Cooperation Team have unique capabilities for RI production and delivering, heavy-ion induced plant mutation and biological irradiation. Since there are other accelerators for such applications in Japan (e.g. the AVF cyclotron at the JAEA-Takasaki laboratory and the HIMAC at the NIRS for heavy ions), **NCAC suggests that the Nishina Center explore whether it would be desirable to make a network connecting the accelerator institutes for coordination of users' demands.**

## 6. Theory

The new structure of the Nishina Center proposes the establishment of a Theoretical Research Division, consisting of independent groups working in particle physics, nuclear structure and strangeness nuclear physics, all of them working on a highly international level. This new organizational structure strengthens the position and visibility of theory within the Nishina Center. The Theoretical Research Division now covers the super-string theory, the hadron physics, hypernuclear physics and nuclear physics.

Following a suggestion of the last Advisory Council report, the Nishina Center has added a theory group working on nuclear structure and reactions, which matches the focus of the experimental program. This move of introducing an active theoretical group on nuclei far from stability line is highly appreciated by the Advisory council. Together with the group at the University of Tokyo led by Professor Otsuka, the theory activities in nuclear structure and reaction physics are now on a world-leading level.

The council welcomes the activities to strengthen the theory support for the Nishina Center experimental program by initiating collaborations inside Japan and with institutions abroad. This goal is achieved by the RIBF theory forum combining young researchers from various institutions inside Japan as well as by international collaborations like JUSTIPEN with the nuclear theory community of the USA and by bilateral arrangements with various countries in Europe like France and Germany. The theory collaboration between the Nishina Center and the Center for Nuclear Study of the University of Tokyo is a good example for a fruitful collaboration, like the one in the experimental programs. Training of the next generation of researchers is achieved by a strong theory participation in international schools for students and graduates.

We feel, however, the theory capacity associated with the power of the RIBF experiments is not enough to fully utilize the output of the RIBF facility. To strengthen the support of the RIBF experimental program even further **the NCAC recommends adding theory positions in nuclear astrophysics to the Theoretical Research Division**. A close collaboration with theorists working in fields like astrophysical nucleosynthesis will help to define the crucial astrophysics experiments to the benefit of the Nishina Center, which will be the leading nuclear astrophysics laboratory in the coming years. The contact to other Japanese institutions like the NAO might also be strengthened by enlargening the theory component in nuclear astrophysics.

## 7. International Collaborations

Because the facility is now in the operation stage, the international collaboration is growingly important. In particular, because the facility is world class and unique, a proper advertisement to potential users would be vital and useful.

We learned that the collaboration with Chinese institutions is growing. Also, collaboration with other institutions is gradually growing. However, as compared to the anticipated goal, we find that several efforts can still be done to enhance the international collaboration.

We would like to list several examples to accelerate the international collaboration.

1 Organizing workshops in major countries would be a key element for accelerating international cooperation. By doing this, the facility can be exposed more vividly among people who participate in these workshops.

2 RI beam science is a priority worldwide with regional facilities in operation or underdevelopment in most areas. Considering the fact that Europe and the Americas have RI beam facilities, a focus on close collaborations with Asian countries (regional effort) is especially encouraged

3 Major review for new instrumentations by an international committee, such as a proposal of gamma balls among many countries involved, will help. Such a proposal is often discussed among many nations but in personal base. No systematic and coherent effort toward one experiment has been proposed in so far, primarily because the detector is large scale and major commitments by different institutions are needed. By designing this type of detector, therefore, the effort will accelerate both domestic and international collaboration. The review committee of this can be, for example, the existing PAC.

4 Collaboration under the RIKEN - University of Tokyo Agreement is very successful. Expanding such collaboration scheme to other domestic universities is an important element not only to increase the number of active collaborating institutions but also to strengthen the research capabilities for both institutions. The arrangement of such must be extended to domestic and international regime.

5 Student exchange program, such as the agreement with Peking University, is an excellent initiation for education. New agreement with Shanghai Jia Dong University was also signed. Holding a school and initiating an exchange of Ph.D students were started in 2008. Maintaining and enhancing this type of effort is very important, in both educational and research purposes.

**NCAC recommends that the Centre implement and/or enhance specific programs to further international participation, such as workshops in major countries, student exchange programs, and fostering international interest through enhanced information transfer.**

# 8. RIKEN_BNL RESEARCH CENTER

The Council overall assessment is that the physics issues addressed by the RBRC are among the most important in particle and nuclear physics, that the results obtained to date are highly significant and of long term value. The contribution of the RBRC scientists to the collaborative efforts have exceeded their relative numbers and that RBRC has in a very significant and positive manner fostered international collaboration and the development of young leaders in the field. Furthermore, there is good reason to believe that prospects are there for the RBRC to continue being a highly successful scientific enterprise with potential for major scientific discoveries.

A major strength of the RBRC research program is its focus on one broad topic, QCD. Its experimental program and theory program including the lattice computation program all are aimed at understanding the structure and properties of QCD matter. In the proton spin program the focus is on the study of the contribution of the spin and angular momentum of the quarks and gluons to the one half spin of the proton, in order to get an understanding of "the proton spin crisis" (the observation that the spin of the quarks contribute only about 25% to the total proton spin). The heavy ion program focuses on the properties of the hot, high energy density, extremely low viscosity state created in the collision of ultra relativistic heavy ions. The aim is to study the phase diagram of QCD, i.e. see if and what new forms of hot QCD matter exist and what are their properties. The theory program focuses on laying the framework for the understanding of the experimental results and on solving the QCD equations on the lattice.

Since its inception in 1997, RBRC has not only been a major contributor to and participant in the important scientific achievements at BNL, it has been instrumental in the training of a new generation of extremely talented physicists and fostering strong international collaboration between physicists in the US and Japan.

It has to be said that the RBRC, in mode of operation, is quite unique. It is a relatively small research institute in a major laboratory setting. Its contribution to the overall research output is disproportionate to its size. For example, PHENIX, a collaboration of some 500 scientists last year published 13 papers. Of these, in 4, RBRC with 17 scientists played the leadership role. Furthermore currently 2 of the 3 deputy spokespersons of PHENIX are from RBRC.

The computing group at RBRC has a very successful collaboration outside RIKEN, i.e., with the Theory Department of BNL, Columbia University, the UKQCD Collaboration in the United Kingdom, in particular Edinburgh University and Southampton University, and also with Bielefeld University in Germany. The research activity is strengthened through these collaborations as it enhances both computing resources and researchers focus on a common target. As a result it is undoubtedly one of the leading collaborations in lattice QCD computing worldwide.

RBRC is a powerful example of the important benefits of international collaboration. It has enhanced the scientific output of RHIC and produced new knowledge for mankind, in the process training a cohort of excellent physicists and fostering a new generation of young leaders in the field of QCD worldwide. The RBRC record here is truly impressive when compared against comparable programs at other laboratories. It is widely admired as a model in international scientific collaboration. RBRC brings great credit to Japan for originating and generously supporting this important international enterprise.

Looking to the future, there are major scientific opportunities at RHIC for RBRC. With increased collision luminosity, uranium beams and low energy scan capabilities plus the upgraded PHENIX, hot dense matter at RHIC energies will be studied in a comprehensive and precise way. The goal will be to reach a deeper understanding. This will require careful attention to systematic uncertainties, an emphasis on measurement of rare processes and close collaboration with theorists and lattice QCD computing. The RHIC-spin program will focus on achieving by about 2015 the most definitive determination of the gluon contribution to the proton's spin and measurement of the sea quark polarizations.

**The Committee concurs with the view of the RBRC Scientific Review Committee that RBRC has been highly successful and cost effective. That it is doing forefront science and that it's strong support should be continued.**

In the longer term, the focus of RHIC will be on realizing eRHIC, an electron-ion collider. Its capabilities will dramatically extend the limits of existing machines to probe the structure of the nucleon and the role of partons in nuclei. As in 1997, RIKEN and Japan will have the opportunity of a major involvement in the development of the world's leading hadronic physics facility.

## 9. RIKEN – RAL International Advisory Committee

The Council is of the opinion that the RIKEN-RAL Facility provides unique instruments which serve a dynamic user community and produce excellent science. The superb technical skills used to develop state of art equipment are matched by the competence and dedication of a strong physics team. RIKEN can take pride in such achievements.

**The Council concurs with the recommendations of the RIKEN-RAL International Advisory Committee (IAC) where two key programme pillars were identified, namely *condensed matter and molecular science* and *ultra-slow muon source development***

***Condensed matter and molecular science.***

The Council considered that this area is highly productive and successful for the RIKEN-RAL Muon Facility, and is going from strength to strength. It is generating significant (in number and quality) publications, and is a key example of the relevance of RIKEN-RAL science to societal benefit. It is an area which attracts researchers from throughout Japan, and has opportunities for significant community expansion in other Asian countries. This activity also maps strongly on to the primary research area of the ISIS facility as a whole, and so is a key area for development of further collaboration.

*The IAC recommends that this area be prioritized as the first of two central pillars of the future RIKEN-RAL facility programme, and strongly recommends that it be given sufficient resources in terms of finances, manpower and leadership to enable its continued development.*

***Ultra-slow Muon source development.***

The Council recognized the unique nature of the low energy muon source that has been developed at the RIKEN-RAL Facility, and considered it to be one of the most promising areas in muon science with high potential for a wide range of applications. These applications include a variety of condensed matter and molecular physics areas. In addition, the recent development of ideas to use the low energy muon source for future g-2 measurements further strengthens the case for its development.

*The IAC recommends that this area be prioritized as the second of two central pillars for the future RIKEN-RAL programme, and recommends that the strong and well focused R&D effort is continued to develop the world's best pulsed low energy muon source.*

The IAC is convinced that these two areas form a basis of core activity that will ensure a healthy balance between fostering *outstanding science now* and investing in *future science for tomorrow*. The IAC considers that it is necessary for RIKEN to focus current resources (manpower and financial commitment) to both of these areas to ensure continuing success.

To ensure development of RIKEN world-class science focusing on these two pillars, **the IAC recommends an extension of the RIKEN-RAL agreement beyond 2010 by at least another 7½ years to 2018.**

This will deliver a balanced future programme which builds on recognized strengths, maximizes world-class science, strongly invests in only the most exciting and ambitious future plans and fosters increasing engagement with Japanese and international research communities together with the host facility.

## Towards a RIKEN J-PARC Center

The ISIS muon facility is now delivering science in a mature way and is entering an exciting stage for science with ultra-slow muon techniques. At the same time, the RIKEN-BNL activities are also very productive and addressing issues of great current interest.

**The Council sees future opportunities at J-PARC and suggests that the interested parties explore the establishment of a RIKEN J-PARC Center.**

Creation of this Center is logical, and it will benefit from the increased Japanese involvement in muon and hadron science stimulated by ongoing activities at RAL and BNL.

For the Nishina Center Advisory Council

S.Gales
Chair of NCAC