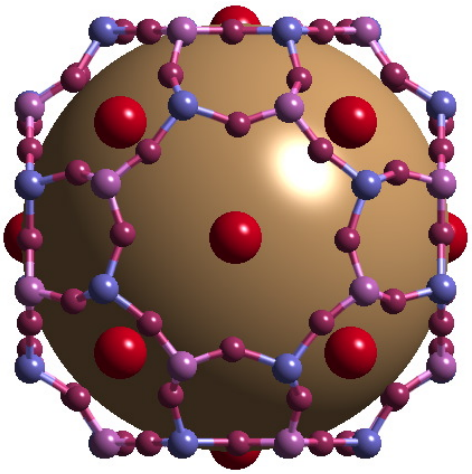
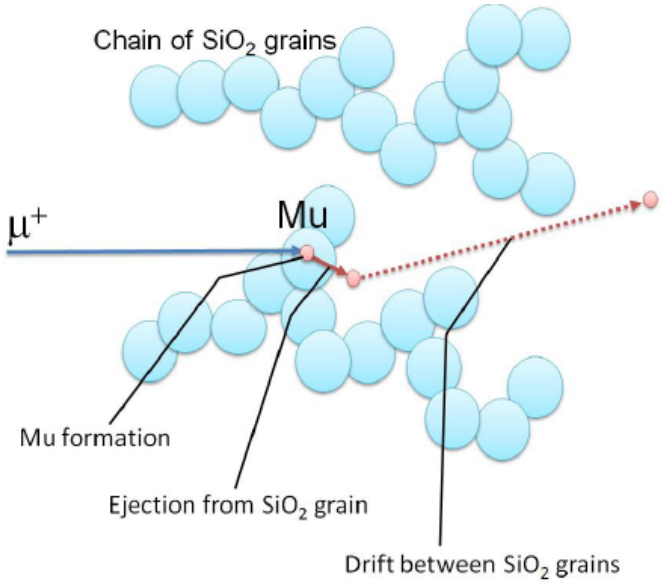
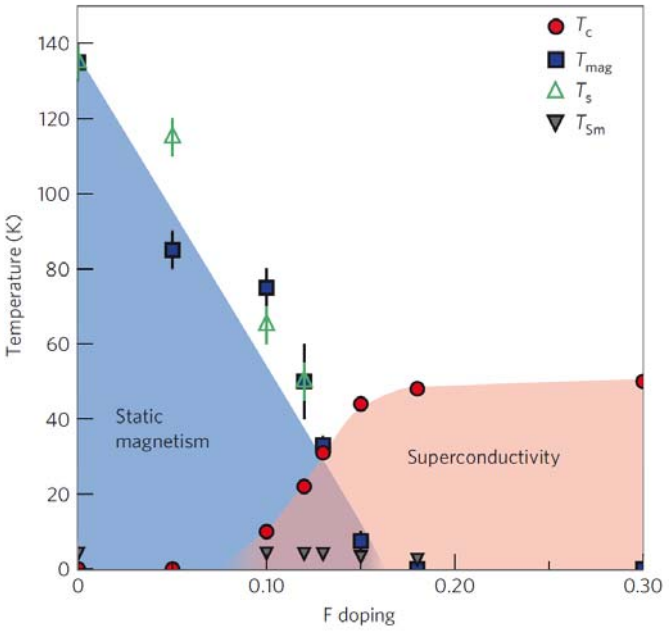
RIKEN-RAL MUON FACILITY

# THIRD INTERNATIONAL ADVISORY COMMITTEE REVIEW REPORT

24-25 February 2011





**Contents**

## 1. Executive Summary

This third meeting of the RIKEN-RAL International Advisory Committee took place during 24-25 February 2011 at the RIKEN Nishina Centre, Wako, Japan. The aim of the third meeting, building on the findings of the first and second IAC reports, was to evaluate the scientific activities of the RIKEN-RAL facility since the last report, to comment on implementation of previous IAC recommendations, and to answer specific questions provided by RIKEN President Noyori. The Committee consisted of both international and Japanese experts – Committee members are listed in Appendix 1.

The Committee heard a variety of reports on the activities of the Facility, together with documentary evidence relating to Facility work, including publications and annual reports. The Committee's agenda is given in Appendix 2. The following sections of this report give more detailed findings and recommendations for each of the various science areas covered by Facility activities. The broad findings and recommendations are summarised below.

### 1.1. Findings and Recommendations of the Third IAC Meeting

**The IAC continues to endorse its conclusions and recommendations from previous reports. Specifically, the IAC was pleased to see the renewal of the RIKEN-RAL contract to 2018, together with developments in both programme pillars identified in the last IAC report: condensed matter and molecular science; and ultra slow muon development.**

***Condensed matter and molecular science:*** **the IAC continues to find that this is a successful, diverse and productive programme, with many collaborating groups from Japan and overseas. It welcomes the provision of a new spectrometer (Chronus) for μSR studies.**

**However, the Committee was concerned about the staffing level, the temporary nature of personnel associated with this part of the programme and the rapid staff turnover. There will soon be two spectrometers available for the condensed matter and molecular science user programme once Chronus is fully commissioned. Based on the ISIS model for providing support for instruments within its neutron and muon user programme, the Committee would expect to see four scientific staff available to support the science on the RIKEN-RAL spectrometers, in addition to technical support. The Committee therefore urges RIKEN to provide staff to support the programme at a level appropriate to ensure its ongoing success.**

***Ultra slow muon development:*** **the IAC notes the continued activity in this area, for development of a low energy muon source for materials studies and g-2 measurements. The activity at RIKEN-RAL provides a necessary stepping-stone to enable future implementation at J-PARC. The IAC recommends putting in place an action plan, with milestones and resource allocation, to ensure continued future development. Staffing levels for the development activities seem adequate; however, the committee recommends identification of a science leader for the future materials programme.**

***Muon catalysed fusion:*** **the IAC notes ongoing work to develop μCF measurements under pressure. However, the Committee felt that, at present, there are not sufficient resources available for the considerable technical and theoretical challenge that this aspect of the programme will require, and recommends continuing to focus on the two programme pillars discussed above.**

***Other science:*** **the IAC recommends that nuclear transmutation activities with muons are not taken forward.**

***Project planning:*** **the IAC notes that the extension of the RIKEN-RAL agreement to 2018 provides a good timescale for a planned and timely transition to J-PARC of muon activities, as facilities at J-PARC allow.**

***Collaborative activity:*** **the IAC continues to note that the RIKEN-RAL muon facility is an extremely successful international collaboration in its own right. In addition, a wide variety of collaborations within RIKEN, within Japan, internationally, and at ISIS and TRIUMF, were noted. It recommends further publicising of RIKEN-RAL activities widely within RIKEN to develop further collaborations with other RIKEN centres.**

## 2. Introduction

### 2.1. Aims of the Review

The IAC was charged by Dr. En'yo, Director of the RIKEN Nishina Centre, to evaluate the scientific activities of the RIKEN-RAL Muon Facility for the past four years and to consider the IAC's reaction to how its previous recommendations had been carried out.

Further terms of reference were provided by RIKEN President Noyori:

*President Noyori's suggested topics for deliberation by the Advisory Councils for RIKEN's Centers and Institutes:*

1. *Does the Center/Institute have achievements of major scientific significance and/or social impact?*
    - *Evaluate RIKEN-RAL scientific impacts of 'Condensed matter and molecular science', 'Ultra-slow muon beam development', and 'Instrumentation for muon science'.*

2. *Does the Center/Institute have a functioning Plan-Do-Check-Action (PDCA) cycle? In particular, are the mechanisms for reorganizing, improving or closing laboratories working effectively?*
    - *Evaluate planning and achievements of scientific projects at the RIKEN-RAL Muon Facility*

3. *Are the personnel management practices (hiring and employment conditions) of the Center/Institute appropriate to its world-class standing? Are the quality and the diversity of researchers being maintained at a sufficiently high level?*
    - *Evaluate personnel management of the RIKEN-RAL Muon Facility.*

4. *Evaluate the Center/Institute's collaborative activities within and outside RIKEN, as well as its efforts to promote international collaborations.*
    - *Evaluate the RIKEN-RAL muon project in its internationality and domestic collaboration.*

The structure of this report is based on the topics for deliberation given by President Noyori.

This report is presented to the President of RIKEN through the RIKEN Nishina Centre Advisory Committee.

### 2.2. Summary of Previous IAC Reports and Evaluation of Responses to Recommendations

The International Advisory Committee continues to endorse its summary conclusion from its previous report, namely that

> *'The RIKEN-RAL Facility provides unique instruments which serve a dynamic user community and produce excellent science at a competitive cost. The superb technical skills used to develop state of art equipment are matched by the competence and dedication of a strong physics team. RIKEN should be proud of such an achievement.'*

In its report of January 2009, the RIKEN Nishina Centre Advisory Committee (NCAC) stated that:

> *NCAC endorses the recommendation of the RIKEN-RAL IAC that Condensed Matter and Molecular Science and Ultra-Slow Muon Source Development be prioritized as 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 7.5 years to 2018.*

This followed from the previous RIKEN-RAL IAC recommendations (November 2008):

> *'In order to deliver a balanced future programme which builds on recognised 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, two key programme pillars were identified:*
>
> *1. Condensed matter and molecular physics*
> *2. Ultra-slow muon development*
>
> *The committee are 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 Committee considers that it is necessary for RIKEN to focus 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 Committee recommends an extension of the RIKEN-RAL agreement beyond 2010 by at least another 7½ years to 2018.'*

**The RIKEN-RAL IAC was pleased to find that, at a ceremony at RAL in July 2010, RIKEN President Prof Noyori and STFC Chief Executive Prof Mason signed a renewal of the RIKEN-RAL agreement, continuing it until at least 2018.**

**The IAC continues to endorse its previous recommendation for the prioritisation of the two programme pillars. The IAC was pleased to see that developments had taken place in the areas of these two key programme areas. Significant results continue to be produced by the RIKEN-RAL facility in the area of condensed matter and molecular science, and this is also the area where the facility has strong and diverse collaborative activity across Japan and more widely. The construction of a new spectrometer for condensed matter and molecular science is further evidence of RIKEN's work within this programme pillar. Development of an ultra-slow muon facility also continues, with plans to produce significant low energy muon flux increases through laser system developments.**

**The Committee continues to endorse its recommendation that sufficient resources, particularly manpower, be given to these two pillars to ensure their ongoing success.**

## 3. Findings in Detail: Scientific Impacts

### 3.1. Condensed Matter and Molecular Science

The RIKEN-RAL muon facility has continued to provide a *highly successful, diverse and productive* condensed matter and molecular science programme. There was strong evidence that the programme was having real scientific impact across a number of areas and was producing work that was of extremely high quality. These science results reflect extremely well on RIKEN and its staff. The research has been obtained by a deepening partnership between RIKEN and a growing number of very strong research groups based in Japan and also internationally. Recent developments include the construction of a second spectrometer (Chronus) for μSR studies.

The IAC noted that the publication output from the RIKEN-RAL facility has grown considerably in both depth and impact. Highlights of the condensed matter programme include:

- Determination of the phase diagram in iron arsenide superconductors
- Discovery of s-electron magnetism in zeolite nano-cages
- Magnetism in single-chain magnets and single molecule magnets
- Spin liquid state in triangular lattices using organic molecules
- Charge carrier transport in molecular semiconductors and polymers

One measure of impact is from citations of research papers (though of course this does not capture all aspects of impact, something which is not fully apparent for many years). Analysing the impact from RIKEN-RAL output in terms of citations shows the following scientific highlights:

- Highest cited work - studies of new iron arsenide superconductors: Nature Materials **8**, 310 (2009) - 84 citations to date; Phys. Rev. Lett. 101, 097010 (2008) - 59 citations to date *[Fribourg, London, Oxford, PSI, Hefei, RIKEN]*
- Highly cited work – cuprate superconductors: Phys. Rev. B **67**, 014514 (2003) - 55 citations to date *[Kyoto, Riken]*, Phys. Rev. B **69**, 184507 (2004) 40 citations to date *[Sendai, Riken, Tsukuba]*
- Highly cited work – excitations in polymers: Phys. Rev. Lett. **79**, 2855 (1997) – 42 citations to date *[Riken, Oxford, Tsukuba, Durham]*

These very highly-cited publications, together with many other highly cited papers produced by RIKEN-RAL, demonstrate the unique capability of μSR at RIKEN-RAL to study magnetism, superconductivity and dynamics in molecular systems.

The IAC noted that there has been significant effort by RIKEN-RAL staff to engage university researchers and attract them to RIKEN-RAL for condensed matter and molecular studies. The IAC was very pleased to have presentations from several university groups describing their research work at RIKEN-RAL. It was particularly notable that all the university groups emphasised that support of RIKEN-RAL team was essential to the success of their work. This underlines the importance of a healthy RIKEN-RAL team to support the growth in user experiments, since this partnership between university researchers and RIKEN scientists is vital for the continued success of the science programme. As will be discussed further in section 5 on page 11, the IAC had strong concerns about the staffing level of the RIKEN-RAL facility, particularly for μSR. A key recommendation is that adequate staffing be given to the RIKEN-RAL instrument scientist team in order to underpin the successful scientific programme.

The IAC noted that through key technical developments by the RIKEN-RAL staff, it has been possible to take advantage of the pulsed structure of the ISIS beam for the following scientific opportunities:

- Lasers together with muons are now providing a new method for probing photoexcitation of carriers in semiconductors to study spin currents
- High pressure and high magnetic field are allowing μSR to access new regions of phase diagrams
- The wide temperature range obtained using the dilution refrigerator is allowing studies of fundamental behaviour of condensed matter
- Electric field excitation techniques are being developed for new experiments
- The Chronus spectrometer commissioning has gone well and this new capability will provide high data rate and field compensation, as well as very low background, allowing new experiments to be performed

The IAC welcome these new technical developments that will allow the RIKEN-RAL condensed matter programme to reach into new areas of science and broaden their impact. The next step will be to deliver a vibrant and healthy science programme to fully exploit this investment that has been made by RIKEN. ***To achieve this, it will be vital to address the staffing issues of the condensed matter μSR group so that these exciting new developments can deliver for Japanese and international science (see Section 5).***

### 3.2. Low Energy Muon Development

The IAC recognised that the development of an intense ultra slow muon (USM) beam will provide unique capabilities for condensed matter and materials science, and ultimately for fundamental particle physics. Access to a low energy muon facility would broaden and enhance the already strong μSR programme in Japan.

The low-energy muon facility at PSI has already demonstrated that these techniques can have a transformative impact in a wide range of science areas. The unique capability of a RIKEN-RAL low energy muon facility would derive from the combination of pulsed beam and laser techniques, allowing an unparalleled ability to study small samples and achieve a high timing resolution, facilitating some world-first experiments at RIKEN-RAL.

The development of a USM facility is widely supported by the Japanese community. A group of almost 50 researchers and 20 collaborators have submitted a proposal to the government for an USM based materials science programme at J-PARC. The instrument and programme have been approved by PAC at KEK/J-PARC and supported by RIKEN.

The RIKEN contribution to the USM source at RIKEN-RAL is very strong and significant recent progress has been achieved in target release experiments and laser development. With the currently planned upgrades to the laser facilities, providing an expected two orders of magnitude improvement in low energy muon flux (several hundred ultra slow muons per second), a viable materials science programme could be started.

Starting a first class materials science programme based on ultraslow muons at RIKEN-RAL will allow for a rapid start-up of a programme at J-PARC, once the J-PARC beamline becomes available. There is therefore a very strong driver for the RIKEN-RAL group to (a) develop the technique, (b) grow the expertise in the technique, and (c) promote the potential of the new technique.

The g-2 experiment is very ambitious and will require and additional 2-3 orders of magnitude higher intensity of low energy muons beyond that required for materials studies. The experience of exploiting a USM source at RIKEN-RAL will be invaluable to the g-2 team.

The USM activities at RIKEN-RAL thus fit well into the current plans to start activities in this area at J-PARC in a few years, and will provide the necessary experience for the J-PARC work to happen. The USM work also fits well with the extension of the RIKEN-RAL contract until 2018. There is therefore a significant opportunity to progress the science at ISIS in order to maximise the subsequent benefit at J-PARC.

***The IAC recommend that the project establishes a coordinated action plan with milestones, timelines and deliverables – and introduces metrics to monitor progress.***

### 3.3. Muon Catalysed Fusion

The IAC commented in its last reports on the past achievements of this group which have been substantial, and which have included development of state-of-the art facility at RAL for μCF studies. However, with the limited resources available for RIKEN-RAL at present, this programme is no longer part of the two science pillars of the RIKEN-RAL programme.

The IAC notes that, due to other commitments, there was no new data taking since the last review. The group is preparing a new high pressure solid $D_2$ target to study density dependant effects as this seems to be the dominant factor in improving the fusion probability. However, it is clear that the group's ability to pursue this activity depends strongly on their other commitments.

***The committee reiterates that the next step in this programme will involve challenging technological developments and would require considerable resources and theoretical support, none of which are foreseen at the moment.***

### 3.4. Other science

*Nuclear transmutation by muon beam*
As an additional activity outside of the two main programme pillars, the possibility of nuclear transmutation of actinide nuclei by induced fission after stopping muons was presented. The committee recognized the importance of the nuclear waste problem, and the significance of research into the application of particle beams for this purpose, as noted its previous report. However, the committee suggested that there should be further evaluation of the potential and technical practicality of this proposed method.

The IAC noted that discussions had taken place with experimental and theoretical nuclear physicists regarding nuclear transmutation using muons. A proposal for a large scaled grant-in-aid for 'Nuclear transmutation by various kinds of beams' including the muon beam had been submitted but was not successful. Details of the advantage of using muons over other particles were not presented to the IAC in a quantitative manner.

***The Committee has severe concerns on the practicality of the method and recommends that this activity should not continue.***

*Moessbauer gamma rays in $\mu^-$ capture reactions*
An interesting idea was presented to study unusual (exotic) chemical (or atomic) species around an implanted single impurity metal by using the 14.4keV Moessbauer state in $^{57}$Fe in the muon

capture reaction of $^{59}Co(\mu^-, 2n)^{57}*Fe$. As an example case where such spectroscopy had been applied and effects observed, the $^{56}Fe(n,\gamma)$ process was shown.

It was, however, not explained (or shown) which kinds of atomic states can be studied in this method in addition to the site rearrangement effects considering rather long half life of the 14.4-keV state. Also seeing the small population yield of the state, more exact theoretical prospects for those chemical (atomic) states should be obtained before proceeding further with the muon beam experiments.

The Committee noted that the apparatus for $\mu^-$ capture experiments had been transported to J-PARC, and future experiments in this area are not planned at RIKEN-RAL.

## 4. Findings in Detail: Planning of scientific projects

The IAC were asked to comment upon the planning of scientific projects at the RIKEN-RAL muon facility.

The IAC noted the overall renewal of the RIKEN-RAL agreement until 2018, and welcomed this. This further 7.5 year agreement allows scope for the planning of RIKEN-RAL activities well into the future.

The two programme pillars previously endorsed by the IAC have been prioritised. The area of condensed matter and molecular studies has seen development of the Chronus spectrometer. The area of ultra slow muon generation is seeing developments in laser intensity which would support a materials science programme in the near future and provide a basis for g-2 measurements.

In December 2010, the RIKEN Ion Beam Facility PAC meeting ranked proposals using the scale given in the box on the right. The RIKEN-RAL IAC also chose to use this scale to indicate its view with regard to the planning of RIKEN-RAL muon facility projects.

***RIKEN Ion Beam Facility Programme Advisory Committee: Proposal ranking scale***

**S**: Star proposal, must be done, earliest possible
**A**: Experiment is approved and must be done soon
**B**: Experiment is approved and can be done if and when sufficient beam time is available
**C**: Experiment is not approved and must not be done
**D**: Experiment is deferred.

***Using this scale, the IAC considers the two programme pillars of condensed matter and molecular science, and ultra slow muon development, to be 'Star' proposals which should be prioritised. As noted previously, the IAC recommends an action plan with timescales should be developed to enable the ultra slow muon project to be taken forward.***

Regarding muon catalysed fusion, the development of pressure experiments is noted. ***However, using the RIKEN RIBF scale, the IAC considers this to be a 'B' experiment, i.e. could be taken forward only if there are sufficient resources available following prioritisation of the two key programme pillars.***

***The muon induced transmutation programme was felt to be a 'C' experiment, i.e. the committee recommend that it is not taken forward.***

The IAC noted that the muonic x-ray programme had been transferred to J-PARC, in order to make way for the new μSR spectrometer Chronus. The Committee felt that this was an appropriate example of good programme planning and prioritisation. The Committee consider the muonic x-ray programme to be a 'D' experiment, i.e. it is deferred.

### *4.1 Transition to J-PARC*

The IAC recognises the need for a transition of muon activity to J-PARC in due course. The Committee recognises that the RIKEN-RAL facility has considerable value for the J-PARC muon activities, and will continue to provide this value as the J-PARC muon facilities continue to develop. Specifically, RIKEN-RAL will continue to enable:

- growth and development of the Japanese and Asian muon communities in μSR
- development of key technologies for low energy muons – both for condensed matter studies and g-2 development
- maintaining and developing key Japanese expertise in muon instrumentation development and muon science.

Therefore, there needs to be a planned and timely transition to J-PARC of muon activities, which is responsive to progress in developing the muon facilities at J-PARC.

## 5. Findings in Detail: Personnel Management

As noted in the previous IAC reports, RIKEN-RAL staff are very able both scientifically and technically, and are very committed to the work of the RIKEN-RAL muon facility and its development.

The IAC comments that a core group of critical size is essential to fulfil the mission of RIKEN in supporting a growing community of users and in training the next generation of researchers.

The committee had concerns regarding manpower support for the μSR programme. This programme has huge potential, and here is a large and growing community of researchers using the facility. The new Chronus spectrometer is about to come online, and there is a high potential for low energy muon applications. However, there is only one permanent staff member in this area, with other support provided by temporary researchers leading to a rapid turnover of team. Several of these temporary researchers (Y Ishii, P Bakule, T Suzuki, K Ohishi, Risdiana) are leaving the RIKEN-RAL team in a relatively short space of time during 2010/11. There is therefore a sudden loss of expertise and support for the RIKEN-RAL experiment programme, particularly in the μSR area. The IAC felt that this was not a sustainable position for the ongoing operations of the RIKEN-RAL Facility.

With the introduction of Chronus, the Facility will have two μSR spectrometers scheduled for user experiments. Using normal ISIS operations as an example, running a user programme on two instruments would be expected to require four scientific staff, in addition to technical and other support staff. At the time of the IAC meeting, the μSR programme appeared significantly under-staffed for the planned programme, having only one permanent staff member and one or two temporary staff.

***The IAC therefore recommends that sufficient manpower resource be allocated to the μSR programme pillar to put this into a sustainable state.***

The personnel effort for the development of the pulsed ultra slow muon (USM) source at RIKEN-RAL includes groups from RIKEN and KEK in Japan plus international collaborators. The RIKEN component is very strong and significant progress has been achieved in target release experiments, while the laser group from RIKEN ASI has produced a credible laser development plan. Although manpower for the R/D phase is rather constrained, it should be sufficient provided the personnel does not get diverted to other activities. The leadership and responsibilities are well identified for the development part. However, it is imperative that a strong leadership be established to nurture a competitive science programme using ultra slow muons at RIKEN-RAL. This will be crucial for kick-starting the USM programme at RIKEN-RAL and for transferring it to J-PARC when the MUSE source becomes available. We anticipate a strong demand for this facility and a need for a strong, dedicated scientific manager who will make this a success story.

***The IAC therefore recommends that RIKEN identify a suitable condensed matter or molecular scientist to establish the scientific leadership for this aspect of the low energy muon project.***

The experience of exploiting a USM source at RIKEN-RAL will also be invaluable to g-2 team. For that effort, a schedule which includes the project's resource (funding and manpower) requirements would be useful to monitor the progress of this project which will extend for many years into the future.

## 6. Findings in Detail: International and Domestic Collaborations

Collaborative activity is at the heart of the RIKEN-RAL muon facility. Fundamentally, the whole RIKEN-RAL project is a significant international collaboration for both RIKEN and for RAL.

In addition to this, there are a wide variety of collaborative activities ongoing as part of the RIKEN-RAL science programme:

- Within RIKEN: The Kato group is involved in studies of molecular systems. The Wada group is leading developments of the laser systems for ultra slow muon generation.

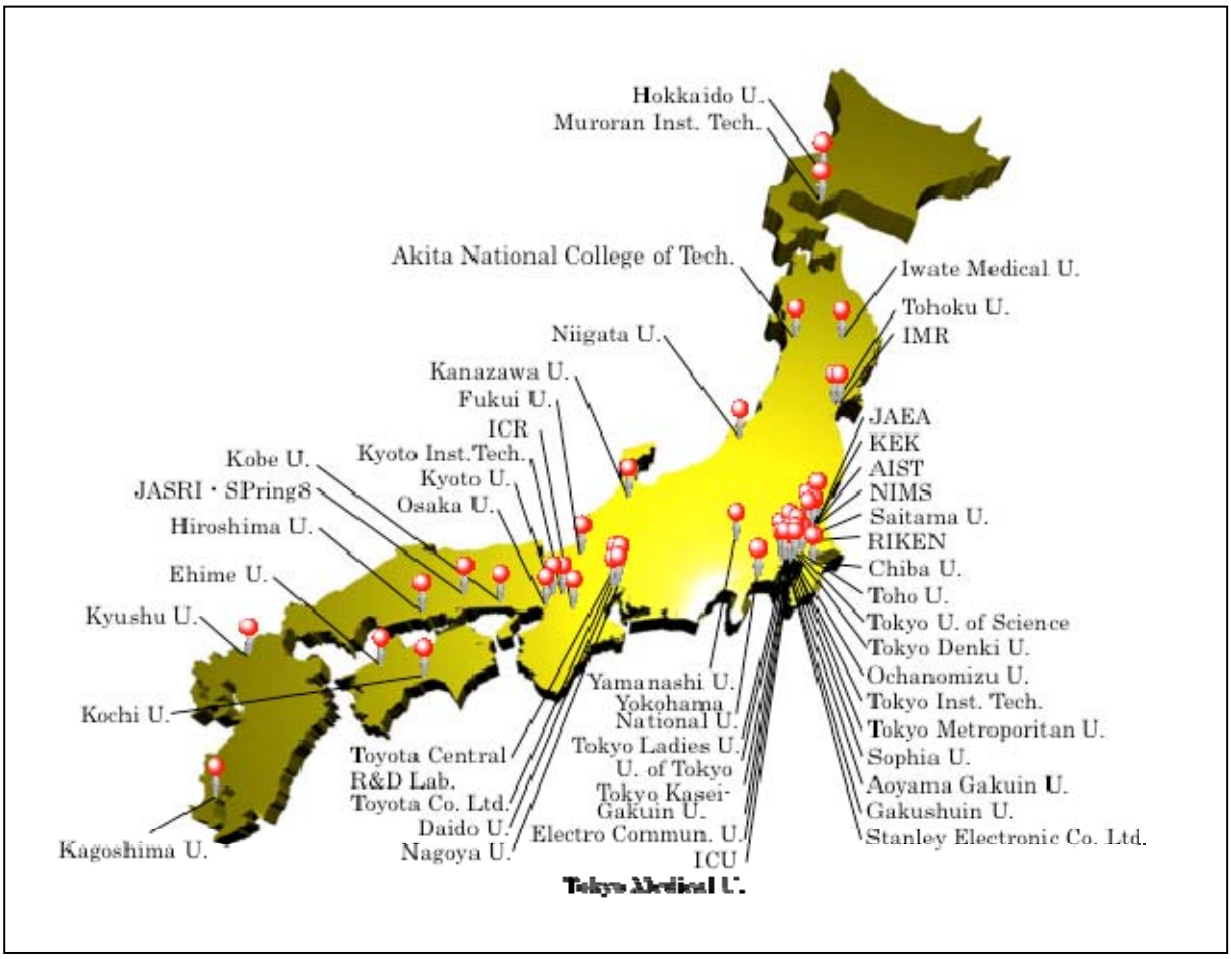
- Within Japan: Many Japanese university groups are using RIKEN-RAL. RIKEN-RAL also has the office for the Japanese meson users group (150 members).

- Within the wider world: new users from China, Indonesia and elsewhere in Asia are coming to use the RIKEN-RAL facility. There is regular use of ARGUS by UK and European groups through ISIS Muon Facility Access Panel.

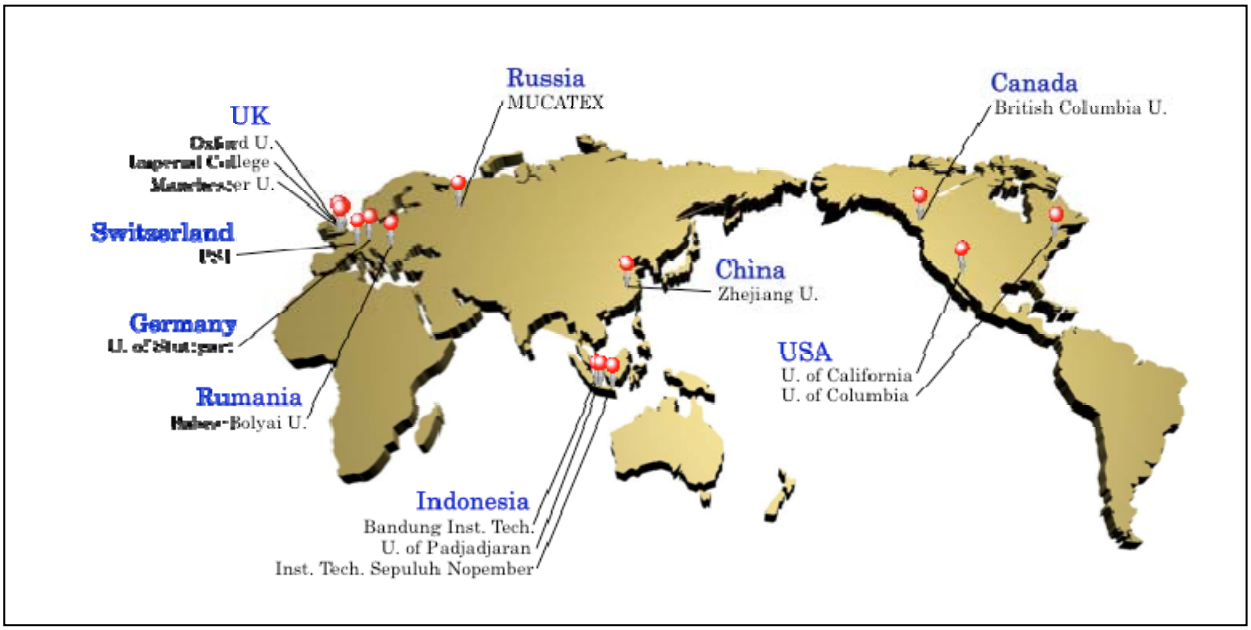
- Experimental collaboration with TRIUMF: This includes scintillators for detectors on Chronus and development of targets for low energy muons.

- Science and Technical collaboration within ISIS: This includes collaboration with ISIS technical groups for development of pressure cells for materials studies; use of the ISIS high field instrument; and joint colloquia with ISIS muon group.

***The Committee recommends that opportunities are taken to publicise the activities of the RIKEN-RAL muon facility within RIKEN beyond the Nishina centre, in order to make contacts with other parts of RIKEN involved in relevant science.***




*Map of Japan showing locations of groups using the RIKEN-RAL muon facility.*




*Map showing locations of international collaborations with RIKEN-RAL.*

## Appendix 1: List of International Advisory Committee Members

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## Appendix 2: Agenda for the 3rd RIKEN-RAL International Advisory Committee

*Thursday 24 February 2011*

| | |
|---|---|
| ***Opening address*** | H En'yo |
| ***Present status and highlights*** | |
| Present status of the RIKEN-RAL muon facility | T Matsuzaki |
| Present status of ultra-slow muon beam projects | K Ishida |
| Recent mSR highlights of RIKEN group | I Watanabe |
| Recent mSR highlights of UK group | P King |
| ***Research activity*** | |
| Commissioning of new mSR spectrometer at Port 4 | D Tomono |
| Focusing effect of muon beam with capillary method | D Tomono |
| High pressure solid D2 target for mCF | T Matsuzaki |
| Upgrades of the current Lyman-alpha laser system at Port 3 | K Yokoyama |
| Muon probes of the electron spin in semiconductors | K Yokoyama |
| Reaction rate of muonium with stimulated-Raman-pumped H2* | P Bakule |
| Measurement of Mossbauer γ-rays from exotic Fe atoms | Y Kobayashi |
| Upgrades of the facility for condensed matter science | I Watanabe |
| Magnetic correations between s electrons in nano-cages of Zeolite | T Nakano (Osaka U) |
| Order and motion of magnetic domain wall in quasi 1-D polymer | T Ishida (Electro Comm U) |
| Soft-mode motion in bond-disordered quantum spin system | T Goto (Sophia U) |

*Friday 25 February 2011*

| | |
|---|---|
| ***Future plan*** | |
| RIKEN Nishina Centre | H En'yo |
| RIKEN J-PARC Centre Project | H En'yo |
| ISIS Muon Facility at RAL | P King |
| The RIKEN-RAL Muon Facility | T Matsuzaki |
| Strategy for collaborations with Asian countries | I Watanabe |
| Future plans and strategies for material sciences | I Watanabe |
| Ultra slow muon beam and g-2 project | K Ishida |
| Development of high intensity laser system | S Wada |

***Closed discussion***

***Summary talk by IAC Chairman***