Institute Laboratory Assessment Interim Review

Advanced Meson Science Laboratory

Laboratory Head: Masahiko IWASAKI (D. Sci)

Date: February 26, 2010

Place: Nishina Hall, Nishina Center, Wako, RIKEN

Reviewer:

Tadafumi Kishimoto: Director, Research Center for Nuclear Physics, Osaka University, Japan

Tomofumi Nagae: Professor, Graduate School of Science, Kyoto University, Japan

Kusuo Nishiyama: Honorary Professor, KEK, Japan

Robert F. Kiefl: Professor, Department of Physics and Astronomy, University of British Columbia, Canada

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Review of Professor Iwasaki, chief scientist.

RIKEN-Nishina Centre, Wako campus February 26th, 2010

The director of the RIKEN-Nishina centre asked a committee of experts from Japan and foreign institutions to perform an interim review of the Advance Meson Science Laboratory under the leadership of Professor Masahiko Iwasaki.

The committee (the composition is given in appendix A) met over a full day and heard presentations from the Nishina Centre director, Dr. En'yo and RIKEN 's executive director, Dr.Y. Doi, about the objectives of the review and from Dr. Iwasaki on past and future research programs of his group. The committee also interviewed individually each of the scientists in Dr. Iwasaki's group. (See appendix C for the program).

After consulting each other and comparing our own observations, the committee decided to try and produce a consensus report which would address the points in the charge presented to us by the director of the Nishina Centre. (see appendix B)

Prof. R. Kiefl

Prof. T. Kishimoto

Prof. T. Nagae

Prof. K. Nishiyama

Dr. J.-M. Poutissou

Report

1) Research accomplishments and research expertise:

Under Iwasaki's leadership, the group's effort has evolved from being the purely muon based program of the previous chief scientist to a two pronged program with the inclusion of a strong hadronic component.

The achievements of the group are very significant indeed:

1) *Condensed matter science:*

The RIKEN-RAL program in muon science is ranked one the best in the world in terms of publications science achievements and instrumentation development. The high Tc superconductor program is world class.

In instrumentation, they are credited with developing laser ionization of muonium to produce low energy muons, low background (pass-through muon) MuSR spectrometers, one of the most powerful system of studying Muon catalyzed fusion in a variety of environment (solid, gaseous deuterium and tritium over a range of temperatures and pressures) etc.

The productivity of the Riken-RAL group in terms of publications, invitation at international conferences, and theses is very good and on par with the best groups in the world.

2) *Hadron Physics:*

a) K-mesic X-ray:

The hadronic component of the program focused initially on exotic X-rays searches at KEK with a successful determination of the shifts and width of K-X-rays to determine the basic properties of the K-nucleon and K-nucleus interactions. This has been put on solid basis experimentally thanks to the dedicated and state of art experimental techniques developed for the KEK PS. After the successful measurement of the X-ray from Kaonic hydrogen, the group has achieved an unprecedented precision on Kaonic ^{4}He atom X-ray measurement by observing the 3d to 2p transition in KEK E570. The result finally resolved the Kaonic helium puzzle, and a large energy shift of -43±8 eV which had been reported in the literature, was found to be almost negligible, 2±2±2 eV. The group is credited with resolving many conflicting publications on shifts and width of K-p, K-^{4}He and establishing the attractive nature of the K-Nucleus interaction. The group has good theoretical connections which allows them to interpret their measurements in the global context of hadronic interactions at intermediate energies

b) Hadron masses:

Hadrons are made up of quarks. Although isolated quarks have little mass, quarks confined in hadrons acquire significant masses. Properties of hadrons are thus affected when hadrons are in nuclear media.

The program included a search for deeply bound states of pions and later of antiprotons and kaons at foreign facilities (TRIUMF, GSI, CERN and DAFNE) in a strong partnership with the University of Tokyo group (Yamazaki-san and Hayano-san). Establishing the existence of such deeply bound nuclear states for strongly interacting mesons is a world class result which opens up the possibility to explore systematically the restoration of chiral symmetry in a dense medium. Having realized that X-ray techniques were not suited for populating such states due to the strong absorption in the nucleus, the group is credited for developing the technique of soft momentum transfer reactions to probe such states.

-Deeply bound Pionic nuclear states:

Iwasaki and his colleagues have been studying properties of mesons in a nuclear media by a novel method. The experiment was carried out in GSI, Darmstadt, utilizing (d, ^{3}He) pion transfer reaction to realize zero-momentum transfer effectively. A pionic 2p state in the ^{207}Pb was first discovered. There were series of experiments to measure a pionic 1s state in the ^{205}Pb and tin isotopes. Observation of X-rays is practically impossible for such deeply bound states thus the direct production is the unique and only way. They successfully observed deeply bound pionic states and clarified the change of properties in a nuclear media. This work, started before Iwasaki was appointed the group leader, continues under his leadership as chief scientist and is an excellent achievement.

Deeply-bound Kaonic nuclear states:

The existence of deeply-bound Kaonic nuclear states is a big issue in this research field at present. A candidate signal of strange tri-baryon state was reported by Iwasaki's group of KEK E471, which had triggered extensive discussions among theorists. The original signal was not confirmed in a following measurement in KEK E549 with much improved statistics, unfortunately. On the other hand there exist several experimental observations suggesting the existence of Kaonic bound states: K^-pp signals in FINUDA and DISTO experiments, and in-flight (K^-,n) spectra reported by Osaka group in KEK E548. It is of vital importance to get an experimental confirmation of such a state unambiguously.

These accomplishments are now being followed by a refocusing of the program towards J-PARC and its future opportunities for intense muon and meson beams.

2) Future programs:

The future research program has three main components: condensed matter research using MuSR techniques, the new g-2 experiment proposed at J-PARC and the search for the origin of hadron masses as revealed through deeply bound exotic mesonic atoms.

The first program is very mature, having been the main focus of the RIKEN-RAL program and serves a large community of users with pulsed muon beams. It is run through an agreement with ISIS which is going to be renewed for 7 more years. This is a world class program which is producing the bulk of the publications of the group and which has strong ties to the university community in Japan.

a) *Condensed matter program:*

The cold muon source which Iwasaki proposes to develop for the g-2 experiment is of considerable interest for other purposes, in particular condensed matter physics (CMP). The group has extensive experience in this area since it has been developing a low energy polarized muon beam at RIKEN-RAL based on laser ionization of muonium evaporating from hot tungsten foil. The main purpose of the existing low energy muon beam is for condensed matter studies in nano-structures using the technique of muon spin rotation. However, until now, the muon production rates and polarization are too low to be competitive with a similar CW muon beamline at PSI using a solid noble gas moderator technique. It should be noted that the latter is the most heavily subscribed MuSR beamline in the world and significant new results appear regularly in Nature and PRL. The proposed new RIKEN slow muon source based upon laser ionization of muonium should greatly exceed the capabilities of the PSI beamline for the purposes of condensed matter research. In particular the pulsed nature of the beam and much smaller beam spot will open up many new experiments and represent a significant advance in the field. Eventually the technology could be transferred to J-PARC. The first step should ~~to~~ be to improve the laser ionization efficiency using existing technology and to apply a magnetic field at the source to fully polarize the low energy muons. An enhancement factor of 100 in beam intensity coupled with full polarization will already make the RIKEN-RAL beam competitive with PSI for the purposes of condensed matter research. We expect that making the beam much colder than 300K (e.g. 10K) is a far more difficult step, considering the significant binding energy of muonium on most surfaces other than He. Although this may be necessary for the g-2 experiment it is not so important for CMP applications.

Iwasaki has successfully led the RIKEN-RAL muon project for the past 8 years. The group is internationally recognized and has produced many significant results in condensed matter physics and chemistry. The group has also pioneered to use lasers in the area of MuSR. This is a remarkable achievement since Iwasaki 's main interests are in Hadron physics which now consumes most of the manpower of the group. Unfortunately this has led to a critical shortage of resources devoted to CMP at RIKEN-RAL. In our view it will not survive much longer without significant influx of resources and manpower. This is especially tragic given the anticipated scientific impact of an intense cold muon source in the area of CMP. On the other hand, we also note that user support is a subtle issue at RIKEN which is not a user facility.

A smaller component of the program is based upon the Mossbauer technique with isotopes provided by the RIBF facility. The program is focused on the study of Fe ions localization (with important technological implication for example in Si semiconductors) and their role in di-state organic materials. Ru and Ni ions are also available for in-beam Mossbauer studies and have been exploited to study a variety of compounds from catalyst material, shape retention materials, battery materials, etc. This program has been integrated in the Meson science laboratory recently.

For the condensed matter part of the program, the group is well positioned to play the leading role in the research as well as in beam and instrumentation development. However the size of the effort will have to be ramped up and strong collaborations with university community will have to be nurtured.

The other two research programs are long term experimental programs that will have substantial scientific impact in the area of particle and nuclear physics when J-PARC will be in a position to deliver the required beams.

b) G-2 program:

The goal of this new proposal to J-PARC is to determine the anomalous magnetic moment of the muon to a precision level of 10^{-10}, sufficient to establish with confidence whether or not there is a discrepancy with the Standard model prediction as hinted by the recent measurement of E821 at BNL (where a 3.7 sigma difference was reported). If proven to be true, this would be a benchmark constraint on possible extensions of the standard model of particle physics, of which they are many although by itself it will not identify which model is most promising.

The J-PARC experiment will be based upon an entirely new method which will use low energy muons (300MeV) as compared to 3GeV muons for the BNL experiment, thus avoiding some of the most challenging corrections and the dominant systematic errors associated with them. However, the requirements for the muon beam emittance are pushing the present state of the art in several directions. Hence the proposal is risky even though no show stoppers have been identified yet.

The proposal is original, and will produce a result with entirely different systematic uncertainties than those of the BNL experiment, while its successor at Fermilab will reuse the BNL technique with an improved 3GeV beam intensity.

The RIKEN group is committing to develop the new ultra cold muon source necessary for producing a muon beam that can be stored for many lifetimes without the need of any electric fields. The slow muon source is based upon a development which was carried over the last five years at the RIKEN-RAL facility using muonium laser ionization, which has produced 30 ultra cold muons per sec at ISIS. The expertise of the RIKEN laboratory in powerful pulsed UV laser is critical and Iwasaki has established a solid collaboration with the expert group of Wada-san. A factor 100 improvement in ionization efficiency is required. If achieved, this can be tested and implemented at the RIKEN-RAL facility and would readily provide a very interesting pulsed ultra slow muon beam for condensed matter studies which will be competitive and complementary to the PSI DC source as mentioned above.

The other requirement of low transverse and longitudinal emittance can be realized if sufficient muonium can be produced from a cold surface (rather that the hot foil used at RIKEN-RAL). This development is the responsibility of Iwasaki group and again here he is making use of the expertise in muon beams in his group, in nano-material technologies available at RIKEN and in several other Japanese material science groups.

The responsibilities of the group are well matched to their abilities and they have engaged multi institutions collaborations to foster the development. The group is well organized and has refocused several of their other programs to support the demanding R/D effort. The leadership of Iwasaki in pushing the g-2 experiment is well recognized in the international collaboration which is growing around the g-2 program at J-PARC.

This is a long term effort that will only bear fruits in a distant future and will required considerable investments.

These muon source developments are of great interest to the material science community using MuSR techniques and should be implemented at J-PARC to make a unique source of ultra slow muon. Hence to long term goal of the g-2 program will have important and more immediate applications in condensed matter at ISIS and J-PARC. The synergy between the two programs is very compelling.

c) *Hadron mass investigations:*

X-Ray program:

In relation to the existence of deeply-bound Kaonic nuclear states (see below), the group is now preparing a new measurement, E17, at J-PARC aiming to observe the Kaonic ^{3}He atom X-ray. This experiment is one of five Day 1 experiments at the J-PARC Hadron experimental hall. A large difference of energy shifts between Kaonic ^{4}He and ^{3}He is expected assuming the existence of a Kaonic nuclear bound state. New silicon drift detectors and preamplifiers are in preparation under collaboration with Stefan Meyer Institute. The experiment is approved for first data taking as soon as the slow extracted beam is made available to the Hadron hall at J-PARC.

Hadron masses program:

Iwasaki's group is preparing the J-PARC E15 experiment for the ^{3}He(K^{-},n) reaction at 1 GeV/c. This experiment is also a Day 1 experiment. One of the goals of the experiment is to search for a theoretically predicted K^{-}pp bound state. The K^{-}pp state would be identified both in the missing-mass of the (K^{-},n) reaction and in the invariant mass of a Λ-p pair in a good energy resolution. A cylindrical detector system (CDS) has been constructed for this experiment, and it is in the commissioning phase at the K1.8BR beam line. A new inner tracker system based upon a Time projection Chamber read out by Thick Gas Electron Multiplier chambers is being developed to identify secondary vertex from Λ and ∑ decays. Finally a super fluid liquid ^{3}He target based upon the design of the E471 ^{4}He target used at KEK, is being commissioned. The whole detector system should be available for the new K^{-} beam at K1.8BR beam line, expected for the fall 2010.

The program envisages a systematic search of various mesons mass shifts (ρ, Λ, Ω, ϕ,..) and is well connected to theorists who are guiding the interpretation of the observations. There is also an interesting idea to search for multi-Kaonic nucleus in anti-proton nucleus reactions submitted by the group as a Letter of Intent for a future program.

The group has learned the lessons from the KEK PS effort and is building a state of the art high acceptance spectrometer to carry out these searches at the new J-PARC Kaon beamlines.

The committee views this program as unique in Japan and around the world with the possibility to attract more visibility in the future. There is strong interest in the theory community for experimental evidence of Chiral symmetry restoration in dense media.

3) Laboratory management:

The group seems to be well run with monthly meetings bringing all the components together. Most of the communications rely on one to one conversations with the chief scientist. There is a need to be a bit more formal in establishing a work plan that the whole group buys into and follows.

The permanent staff members speak highly of the capacity of the chief scientist to listen to their concerns, to be making key decisions in a fair way and to defend the group's aspirations. The structure of the group is essentially horizontal below Iwasaki and he should try and aim at structuring the group around the key pillars of its research program: Hadron program, muon program at RIKEN-RAL and g-2 effort with senior group leader assigned and being delegated some power and responsibilities.

Over the last 8 years, the chief scientist has developed a meson science program which is now encompassing a major nuclear physics component, a strong condensed matter program and a flagship particle physics experiment.

Several long term issues are on the table: Future participation in the J-PARC activities in Nuclear Physics, Role of the RIKEN–RAL program and possibility of transferring such a program at the MUSE facility at J-PARC, commitment to a long term particle physics experiment.

On the first issue, the group will have to play a leadership role in fostering a national and international nuclear physics program at J-PARC that could be user oriented in a sense of supporting as well non RIKEN partnerships. It is proposed to consider establishing a major facility as part of the J-PARC Hadron hall. That could be accomplished in establishing a RIKEN-J-PARC centre dedicated to such nuclear physics activities. This is a worthy goal which will require negotiation with the J-PARC partners and the nuclear physics community in Japan. To get there, the group should engage more fully in some national and international activities such as organizing workshops and conferences for increasing its visibility, and identify the key role it could play.

On the second issue, establishing a strong condensed matter program with ultra slow muon beams at RIKEN-RAL is a prerequisite for eventually transferring the facility at J-PARC and capturing the interest of a large community of material scientists.

For the RIKEN-RAL and for MuSR program at J-PARC, one should consider splitting the group and hiring a dedicated scientist to build up this area with the above mentioned low energy muon MuSR as a center piece. One then could also consider integrating the small component of condensed matter research presently based upon the Mossbauer technique into such a material science group and further develop new activities based upon other RIBF opportunities.

The new scientist would be responsible for developing the method and transferring the technology to J-PARC where it would be fully realized. Iwasaki would then be free to pursue his main interests in g-2 and hadron experiments.   This kind of arrangement requires support of the management of the Nishina Center.

Conclusions:

The committee was very impressed by the accomplishment of the group and liked the vision offered for its future. It is ambitious yet very focused on interesting issues. The challenge for the group will be to deliver on all three fronts simultaneously. The committee feels that the group needs to increase its manpower and restructure its organization more vertically as indicated in the text. Another key issue will be to engage more directly the large communities from Japanese Universities and from abroad that could participate and collaborate on these important topics by taking the initiative to lead national and international networking activities.

Within the constraints of the resources available, the group is performing very well indeed and the leadership of Professor Iwasaki is commendable.