Report from the 6th J-PARC Muon Science Advisory Committee Meeting Held January 15 - 16th 2008 at J-PARC, Tokai

Presented to J-PARC director by J.-M. Poutissou, Chair

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Executive summary:

The sixth MuSAC meeting took place at Tokai on January 15th and 16th 2008. The committee heard presentations on the construction status of the J-PARC complex, the accelerators, the Life and material science facilities including the MUSE facility. Construction of the phase 1 projects is on time and commissioning with beam will occur in the fall 2008. The committee had a chance to see the Muon target hall as the services (electrical, plumbing and air conditioning) are finalized and the final shielding is being placed. The meticulous execution of the project is truly impressive. The proton beam line has been evacuated and the vacuum achieved is well within specification. Cabling and plumbing is continuing to meet the September deadline for beam-on commissioning. No road blocks are envisaged at this stage. The reconditioned KEK superconducting solenoid was being installed during the visit and could be ready in time for the first beam commissioning. As the committee was meeting, budget discussions were on going to determine the level of operation funding that would be available to the group. It was clear to the committee that the minimum requirement to assure an early muon beam delivery during the planned two month cycle of beam delivery to neutron users was crucial to deliver an early physics output from the lone first muon channel at J-PARC and provide the incentive to the muon user community to seek alternative supplementary funding for core user projects and hence to complete the facility as early as possible. Attracting foreign users and industrial investments is directly linked to having an early minimal initial program available at start up.

The committee strongly pushed to have the decay channel operational during the first beam delivery period planned in FY 2008. The committee would like to have a specific plan to provide ultra slow muons as soon as possible as it is seen as the most innovative and unique opportunity for Muon users.

The committee congratulates the MUSE team for delivering on its promises to have an operational facility September 08.

Introduction:

The sixth meeting of the Muon Science Advisory Committee (MuSAC06) was held at J-PARC, Tokai on January 15th and 16th 2008. This was held at a time when the major construction effort of the first phase of the MUSE facility is coming to a successful conclusion and it was important for the committee to see firsthand the facilities being buttoned up during the tour and to hear about the plans to start the operation of this outstanding complex. The recent success in operating the Rapid Cycling Synchrotron (RCS) at 3 Gev was providing a very positive background for our deliberations. The agenda for the meeting is listed in Appendix A and the composition of the committee in Appendix B.

I. Construction status

1) Status of J-PARC accelerator complex:

Professor S. Nagamiya gave a status report on the J-PARC complex construction which is now entering the final stages of construction and getting ready to accept its first users towards the end of calendar year 2008. Enormous progress is seen on all aspects of the facilities and the first two milestones for the accelerators turn on have been met ahead of schedule. Commissioning of the Linac is progressing very smoothly since its first full energy demonstration and the 3 GeV Rapid Cycling Synchrotron produced its first accelerated beam on Oct 31st. Much more work will be needed to deliver high intensity beams to the users but all the signs are positive.

Enough operation funding have been secured to envisage a two cycles beam production period for a user program towards the end of FY2008. Both neutron and muon users are looking with anticipation for that moment which will mark the end of a long and arduous march by many talented people towards the beginning of the experimental program. The J-PARC staff should be congratulated for their achievements.

2) 3 Gev Rapid Cycling Synchrotron (RCS):

Dr. Y. Yamazaki reviewed the status of the two accelerators relevant for the Material and Life Science program. The injector LINAC is performing very well with stable and reliable operation at low current. The effort is now to increase the beam power level towards 100 Kwatt. The initial operation of the RCS showed that the machine will work as intended. The current commissioning is limited to very low single bunch injection for safety considerations but valuable information is obtained and beam commissioning of the accelerator and beam transport will proceed in the spring and early fall respectively. This is setting the time scale for getting the muon facilities operational.

3) MLF facility status:

The facility is largely complete with 8 neutron beamlines and instruments anticipated at turn on. It is also anticipated that one muon beam will be made available to users at that same time, budget allowing. The building settlement is being monitored and seems to be within acceptable limits. One H2 leak is being dealt with in the neutron moderator and commissioning of the overall systems will continue with on beam commissioning starting in May. Within ten months the first users will take beam. International Scientific Symposia are being organized to prepare for the ramping up of the user program.

4) Proton Beamline and Muon Target station:

Construction of the muon target and of the proton beam transport between it and the neutron target is the responsibility of the muon group. Substantial progress has been accomplished to be ready for the first beam commissioning period later in September. The vacuum has been pulled and very satisfactory leak rate measured. Substantial work is still needed for the cooling water assembly, power cable and air conditioning system inside the tunnel.

The schedule is tight but the team is focused and will catch up with the time table established for beam commissioning.

As soon as beam commissioning will start, radiation handling will become a serious issue and will demand dedicated personnel well trained in procedures. It is important to settle those radiation safety procedures as soon as possible and to build this team in conjunction with the beam transport group and the neutron facility group.

The anticipated floor level changes due to the loading of heavy instruments such as radiation shields were detected but some non uniformity is also observed. Continuous monitoring is needed to assess if and when the realignment of the beam channel components will be required. This has been planned for in the design of the components.

Two static muon production targets are available for initial operation. R&D is continuing on rotating targets needed for the ultimate beam power levels.

5) Construction of secondary beam lines:

For phase 1, the superconducting solenoid channel from MSL/KEK is now being mounted at MLF. It will be commissioned in summer 2008 to be ready for day-one beam and the first two operation cycles of JFY 2008 intended for the start of experiments. The system is a classical backward muon decay channel with a 6 meter long superconducting solenoid as decay channel and conventional pion injection and muon extraction elements. The channel which was in use for 28 years at the MSL of KEK, has been totally overhauled, including new vacuum chambers, heat shields, refurbished quadrupoles, etc.

The channel can produce high quality μ^+ or μ^- beams in a wide momentum range, and also surface muons. A bending magnet near the channel end can direct the muons to separate ports D1 or D2, and an electric kicker allows to generate single pulsed muons. This beam line presents an important and competitive facility for a great variety of muon experiments.

Every effort should be made to have a first muon delivery in the fall commissioning period.

For phase 2, Super-Omega, a special low energy muon beamline is in the design stage. Surface μ^+ or cloud μ^- are captured in a very large solid angle (400 msr) and transported to the experimental area by a special doubly curved solenoid. It will deliver up to 4×10^8/s surface μ^+ (1×10^7/s μ^-) at full production. A special feature of this type of axial focusing channel is that both muon signs are simultaneously accepted and could be separated at the end and delivered to separate experiments. (It may however be difficult to find always two users who have the same beam demands except the opposite muon sign!). The capture solenoid, at the channel's front-end, has already been fabricated and will be installed soon, but for the main part funding still needs to be found. The prospects for physics are bright. By combining muonium production and laser ionization, an ultra low energy muon beam can be generated in sufficient intensity (10^4 -10^6 μ^+/s) to allow μSR studies of surfaces. The only such beam currently running at PSI has a big user demand. This will put J-PARC on the world map with a truly unique facility.

This must be the top priority for the second phase of the project.

II. Science program

The committee heard updates on the scientific program envisaged for MUSE.

1) MuSR in JAEA : μSR study on Spin and Orbital state in f- electron systems

The recent μSR results and proposal of JAEA-ASRC group on rare earth (4*f*) and actinide (5*f*) compounds have been presented by Dr. W. Higemoto.

Rare earth and actinide compounds contain 4*f* or 5*f* electrons with localized and itinerant character. Spin and orbital components of the f-electron wave function are coupled with each other and yield an exotic magnetic or superconducting ground state. The order parameter sometimes has not been unidentified. They pointed out and evidenced that μSR is a powerful probe to clarify the order parameter of such materials, especially magnetic octupole ordering: In NpO_2, $PrPb_3$, $SmRuP_{12}$, the octupole ordering or the octupole component has been revealed by μSR. The contribution of JAEA-ASRC group to this very active field of research is evaluated as excellent and further μSR

studies should be encouraged. The group has proposed to mount a new spectrometer at one of the output from the KEK-MSL decay channel and initiate their program at that location with surface muon beams.

2) Muon Catalyzed Fusion program:

The main goal of the proposals submitted by this group is the detailed study of the Muon Catalyzed Fusion (MCF) phenomenon and measurements of its main characteristics. For many years this group has determined key parameters controlling the recycling rate of muon in D-D and D-T mixtures. The work should be continued, but the milestones of the proposal have to be clarified and detailed, taking into account the previous experiments and their analysis. Particularly, the program on "high temperature-high pressure" and "ortho-para effects" should be specified more precisely and the motivation for extending these measurements should revisited in light of the possible gain in efficiency for reaching a positive balance in energy releases. However it is pointed out that the step of capturing the neutron energy release is far from being well characterized.

The technological MCF-applications (MSF-breeder and MCF- based 14 MeV neutron source) are not the focus of these proposals, nevertheless J-PARC may be in a definite advantageous position compared to the other muon facilities due to the expertise available at the JAEA laboratory (for ex, sub-critical blanket research in the second phase of J-PARC).

The committee is of the opinion that MCF is potentially the most efficient way to produce fast neutrons.

3) Ultra slow muon project:

The ultra slow muon source project proposed at J-PARC is outstanding and unique. Here very high yield of ultra slow muon with up to 10^5 times of present RIKEN-RAL facility can be expected. It also includes five unique features; Variable implantation depth with nm-resolution, high temporal resolution of pico-second, small beam size of 1mm, very low background, synchronization with pulsed perturbation. Those features are very desirable for studies in new materials and in life science applications. The measurements in this project can provide exciting possibilities in wide research fields such as thin film science, surface science and gas-phase science. It will also bring excellent innovation into the other research fields of fundamental physics, $\mu^+-\mu^-$ collider and so on.

The construction of the ultra slow muon source is an urgent issue at J-PARC. This construction plan should be discussed in J-PARC as well as in the Japanese muon science society, and a (possibly international) project team should be formed very quickly.

The committee reaffirms here that this is the highest priority for phase 2 projects for muon users.

4) Industrial applications: Implementation in Phase-I Experiments

As one of the goals of J-PARC, it has been stressed that along with academic sciences opportunities, industrial applications must be promoted from a view point of the social impact of such a large facility, which might develop key technologies for a better life in the future. The muon facility of J-PARC should not be an exception to this guiding principle. In this context, the visible commitment by the Toyota Company has a significant impact on Muon Science promotion, even though at present, it is limited to one direct user from industry. Showing how muons could play an important role on research relevant to the automobile technology is a concrete example. Dr. J. Sugiyama of TOYOTA Central Research Center presented his strategic approach to be a core user of J-PARC's MUSE facility. The scientific program presented is almost the same as that shown last year, but the time schedule has been revisited. To obtain a real support from the company, he felt the need to set first a three years pilot program to have a good enough demonstration of the muon capability before the decision to implement J-PARC core activity can be funded. Considering the power ramp-up schedule of J-PARC, a three years plan seems reasonable because by 2011, the muon intensities will be high enough to carry out state of the art experiments.

J-PARC day-one capability could be competitive to the other facilities in the world if the proton beam power was to be ~50 kW level. Thus, to make a good demonstrative program for the Phase-I experiment, The Toyota group should initiate a program to consolidate existing results in the frame work of free academic beam time allocations.

Also, in the muon user community, more systematic out-reach activity has to be organized to promote industrial usage of the muon probe. As it will take a rather long time to demonstrate visible industrial application, a quick concerted action by the Muon science society is highly desirable.

5) Muonic X-Rays:

Muonic X-ray data provide us with absolute values regarding nuclear charge distributions within a QED accuracy, although they are not the radii themselves. They give us even the values related with the quadrupole components of the charged distributions. Therefore, if we can measure the muonic x-rays of the exotic nuclei, the data will generate the most reliable information on the shape of the exotic nuclei. The high muon intensity makes it possible to extend the life-time reach for these studies, giving us extremely reliable data on the nuclear charge distribution in exotic nuclei, contributing to the understanding of those neutron rich nuclei in particular. For exemple, the quadrupole components reflect the deformation of the exotic nuclei which are very important information for understanding the nuclear physics. From these viewpoints the effort to measure the muonic x-rays of exotic nuclei has very high prospects in future. For these reasons, the Committee strongly endorses the developments in the technique of measuring the muonic x-rays of the exotic nuclei.

The committee heard a proposal for an experimental program at J-PARC to study radioactive muonic atoms using the technique of solid hydrogen films doped with the radioactive isotope to be investigated. This method was developed at RIKEN-RAL and allows to use efficiently small sample quantities (~1 ppm) of ions which have to be implanted, typically 10^{16} ions. With the higher muon luminosities eventually available at J-PARC, the range of possible experiments will be greatly extended. This proposal needs negative muons of high flux, therefore its implementation should wait for higher intensities available at J-PARC.

III. Longer term issues

1) RIKEN-RAL: Pulsed muon and pulsed laser

The committee heard a presentation by Professor M. Iwasaki, outlining the outcome of a recent review of the RIKEN-RAL muon program. In the ramping up period of the J-PARC complex, it is absolutely crucial to maintain the excellent RIKEN-RAL program as an upgrade path towards J-PARC. Several of the key area of science (ultra slow pulsed muon sources, low background set up, Muonic X-rays, for ex) are being developed at RIKEN-RAL but will truly become the flagship facilities of MUSE when the full power of the J-PARC beams will be realized.

2) PRISM:

The committee heard a presentation by Professor Y. Kuno (Osaka University) regarding the PRISM facility envisaged for the Main Ring (MR) accelerator to study very rare decays of the muon. 8 GeV dedicated running of the MR. with a “Lobashev” capture target/solenoid system is considered to reach unprecedented muon intensities with a pulse structure tailored to the muon lifetime. Although not integrated into the present MUSE facility, this unique facility could build on the expertise of the MUSE team.

IV. PAC system and the core user-group formation

The committee was briefed on the policies and organization being developed at J-PARC to deal with research proposals evaluation and core projects:

a) J-PARC will be operated as an international research facility. Beam time will be free of charge for the academic users from any countries, and the review and selection of proposed academic programs shall be made fairly from a view point of scientific quality. The review process will follow world-standards. For example, proposals will be accepted in English only and reviews will be conducted by international referee's teams.

b) In order to foster muon users and to expand the size of the muon sciences community, other criteria will be considered in selecting the experimental program by the PAC system. For example, the educational and training potential of the program shall be taken into account. Apart from according a preferential beamtime treatment for the core user-groups, other financial and logistic supports etc, should be considered to facilitate establishing core-user groups at MUSE. While core users are expected to construct their instruments, promote their excellent science researches and play important roles in the operation of muon facility, the J-PARC laboratory should define clearly and urgently the conditions under which Core groups will operate at J-PARC. It is urgent to trigger core projects proposals and seek funding for those selected to build up the inventory of beams and apparati in the MUSE facility.

Amongst the proposed core-user facility, MuSAC reiterates its strong and unequivocal endorsement for the ultra slow muon facility. The leadership of such group resides at KEK-MSL and RIKEN-RAL and those groups should be allowed to move ahead quickly with a proposal and a campaign for raising internal and external support for it. A detailed work plan should be prepared and put in action.

Conclusions:

After six years of intense effort by a dedicated team, the light is at the end of the tunnel and the prospect of getting muons out of the first channel in the fall is the most exciting news to muons users in Japan. Even with modest initial experimental facilities, it is crucial to initiate experiments by Japanese users as soon as possible to build up the scientific momentum in the community. This will attract users, generate supplementary funding opportunities to quickly position J-PARC at the forefront of this field. The prospect of truly unique facilities like ultra slow pulse muons, the easy access to neutron will make MUSE a key player in material science. The committee recommends that every effort be made to:

1) initiate the muon science program in the fall commissioning period
2) secure funding for the Ultra slow muon source.

The committee presents its congratulations to the accelerator team and to the MUSE facility builders for reaching their milestones on time and on budget.

Appendices

Appendix A : Agenda

January 15th, 2008 (Tuesday) 9:30 – 17:00

0) Closed session

1) Status of J-PARC construction
   - 9:30 Status of J-PARC construction ..... S. Nagamiya
   - 9:55 Status of 3 Gev Synchrotron operation ..... Y. Yamazaki
   - 10:20 Status of MLF construction ..... Y. Ikeda

2) Status of Muon Science Experimental Facility construction
   - 11:00 Overview ..... Y. Miyake
   - 11:25 Status of the M2 Line construction and evaluation of the radiation ..... N. Kawamura
   - 11:35 Muon target and maintenance ..... S. Makimura

3) Construction of secondary beam line
   - 13:00 Superconducting Solenoid and its refrigeration of the Decay Muon Line ..... K. Shimomura
   - 13:20 Fabrication of the Beam Line Components of the Decay Muon Line ..... A. Koda
   - 13:40 Status of the Super Omega Muon Beam Line ..... K. Nakahara

4) Report from JAEA-ASRC
   - 14:00 Status of the JAEA-ASRC Beam Channel ..... W. Higemoto

5) Experimental program at J-PARC
   - 15:00 μSR (JAEA) ..... W. Higemoto
   - 15:20 μCF ..... K. Ishida, T. Matsuzaki, N. Kawamura
   - 15:40 Ultra slow muon beam and application ..... Y. Miyake
   - 16:00 Industrial application ..... J. Sugiyama
   - 16:20 Radioactive muonic atoms study ..... P. Strasser

January 16th, 2008 (Wednesday) 9:00 –

6) Grand design of MUSE

9:00	Proposal from KEK-MSL	K. Nishiyama
9:20	Proposal from JAEA-ASRC	Y. Hatano
9:40	RIKEN-RAL project	M. Iwasaki
10:00	Other project	Y. Kuno
10:10	Discussion	

7) Procedure for evaluating and decision of experimental equipment

10:30		K. Nishiyama

8) Procedure for experimental evaluation

10:40		R. Kadono

9) Closed session
J-PARC tour (MLF-building etc.)

Appendix B :

MuSAC #6 Committee Membership

J. Akimitsu (Aoyama-Gakuin University)

Y. Hatano (JAEA-ASRC)

R. Heffner (JAEA-ASRC)

S. Ikeda (KEK-IMSS)

Y. Ikeda (JAEA- MLF)

M. Iwasaki (RIKEN)

Y. Miyake (KEK-MSL), MuSAC Secretary

N. Nishida (Tokyo Institute of Technology)

K. Nishiyama (KEK-MSL) Chair of Muon Users Group

J.-M. Poutissou (TRIUMF), MuSAC Chairman

C. Petitjean (PSI)

L. Ponomarev (Kurchatov Institute)

Y. Yamazaki (J-PARC, Vice Director)