Report from
the Muon Advisory Committee
(J-PARC Center)

April, 2015

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Held on February 11 - 12th 2015
at J-PARC, Tokai

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I. Facility Overview Session

Prof. Y. Ikeda, Director of J-PARC Center, gave the welcome address and an overview before presenting the charges to the MAC committee. Progress on various fronts was achieved in 2014. A central point was the recovery from the Hadron facility accident. This prompted also a reconsideration of the safety situation and led to the implementation of improved safety measures such as the installation of a new air-tight system around the muon production target and of an air-confinement system of the primary beam line. He stressed the importance of all the safety/risk assessment aspects. A reinforced safety management system with the goal of promoting a comprehensive safety culture was introduced under a new organization, which makes use of internal and external review and control schemes. The committee fully supports these efforts.

Stable operation at 300 kW (and at a later stage at 400 kW) could be achieved in FY2014. Remarkably, on October 15, the Linac accelerated a beam of 50 mA and high power tests demonstrated that RCS is able to operate at the envisaged 1 MW level. Progress was reported in the neutrino program, which restarted in May 2014 and in the particle physics program regarding the COMET as well as the g−2 collaboration. On the materials science side new beam lines and instruments at the neutron and muon source were put in operation. This progress has been shadowed by the struggles because of the fire incident at MUSE on 16th of January 2015. In agreement with the expectation of the local authorities of a serious and prompt response, the operation was immediately stopped and did not resume yet at the moment of the MAC meeting. Dr. Ikeda gave a detailed report of the technical reasons of the accident and of its consequences. The committee was also pleased to hear about the various activities to improve the attractiveness of the facilities as well as about the internalization efforts on one side and the numerous information and exchange opportunities offered to the Tokai residents. For FY 2015 Dr. Ikeda summarized the goals under the guiding line of the key words Priority, Coherence and Reality.

Prof. H. Seto, on behalf of Dr. M. Arai, gave an overview of the activities in FY2014 of the Materials and Life Science Experimental Facility (MLF). The mercury target was replaced and the proton beam of ~ 300 kW was stably delivered to the MLF users. A rotating muon graphite target was also successfully installed on Sep. 2014 and has been in stable operation since then. At the moment there are 21 out of 23 neutron beam lines (including 7 of public use) and 1 of 4 muon beam lines available for user operations. The other beam lines are under commissioning or construction and most of them are expected to be soon operational. The MAC appreciates the intense effort made to restore and upgrade the facility, overcoming the Hadron Hall radiation accident in the preceding year.

The committee is also pleased to note that vigorous effort has been made to expand the user community by targeting users not only domestically but also abroad. Regarding the outcome of the research activities, 9 press releases issued during the course of the year were well-received. The fact that 4 of them were based on the contribution of the single D line in MUSE is noteworthy.

The MAC agrees with the self-analysis that there is still room for improvement in an optimized exploitation of MLF, e.g. by developing more efficient and high-performance software for DAQ and data analysis. Lastly, Dr. Seto gave a comprehensive explanation about merits and demerits of changing the radiation control classification of the experimental halls from the second to the first level. The MAC supports a careful analysis of all related issues.

Prof. Y. Miyake summarized the activities of the MUSE facility. He expressed his deep regret for the fire accident at MUSE, which caused the stop of J-PARC. The fire was immediately extinguished and no leakage of radioactive material, not only in the control area, but also in the surrounding environment was detected. Nobody was exposed to radiation or injured as a consequence of the fire. Dr. Miyake gave a detailed outline of the accident and its causes, which turned out to originate from a design error in a circuit modification of a power supply transformer of the D line septum magnet. He also mentioned the different steps implemented to identify sources of accidents and measures to cultivate a safety culture at MUSE.

In spite of this serious accident, progress could be reported on key elements and on the beam lines of the muon facility. The new rotating graphite target was successfully installed and put in operation without any trouble. For μSR experiments at the D1 station the new Kalliope spectrometer which is able to collect up to 200 M events/h as well as a dilution refrigerator are now available. At the U line for ultraslow muon science, various test measurements with laser ionized H^+ and Li ions were performed. The S line was completed up to the S1 area. The plan for the H-line is to complete the H1 areas for the DeeMe and Muonium Hyperfine experiments in 2015. More details about the various beam lines are reported below in the dedicated subchapters.

Prof. R. Kadono reported about the Inter-University Research Program. Since the MAC-2014 meeting 51 Inter-University Research Program proposals have been approved, 22 have been put on reserve, and 6 have been rejected. The committee sees this as a testament to the abundant and diverse experimental research that can eventually take place at J-PARC MUSE. Unfortunately, there is currently insufficient beam time available at MUSE to accommodate all of the approved experiments, and those on reserve will likely never materialize. Moreover, there has been insufficient beam time to carry out complete experimental studies, and researchers have relied on supplementing measurements at J-PARC MUSE with data collected at other muon facilities outside of Japan. While these are temporary issues, they underscore the urgency to establish other functional muon beam lines, apart from the D-line.

The number of publications from the past year containing muon measurements performed on the D-line at J-PARC MUSE is comparable to previous years; with the exception of 2011 and 2013, when beam time was limited by the earthquake and the Hadron Hall incident. Highlights include the discovery of novel spin-glass magnetism in an iridium spinel compound, published in Physical Review Letters, and chosen as an Editors' Choice highlight in Science. Another is the demonstration of the use of muonic X-ray spectroscopy to provide information on the light-element content inside a meteorite, published in Scientific Reports. Hence despite the current severe limitations on available beam time, there continues to be prominent scientific achievements.

II. MUSE Activity

Muon Production Target:

The progress with the development, installation and commissioning of a new rotating muon target were reported in a presentation by Mr. S. Makimura.

For stable long term operation of the target under the high level proton irradiation at 1 MW operation level of the accelerator, the installation of a rotating muon target is mandatory before working at these levels. A new rotating target has now been designed and manufactured. The expected lifetime, essentially determined by the bearings, is 10 years. Radiation resistance tests using an electron beam were completed in 2014 and the final version of the rotating target was installed in September 2014. Stable operation has been observed between November 2014 and January 2015 with proton beam power ranging between 300 kW and 470 kW and the target shaft temperature was found to be stable at 78 C.

A project for the design of a SiC target for the DeeMe experiment has proceeded with the testing and modelling of a 1/3 scale target and further work is planned in 2015.

Another project investigates by measurement and modelling the performance of Scraper No. 1 in terms of beam loss, the effect of thermal radiation and its suitability for 1 MW operation. The management of the disposal of the radioactive parts is an important task for this group. MAC is pleased to learn that additional staff resources have now become available with a further member joining the group in April and a plan now in place for the training of company staff to assist the group with all aspects of the remote handling procedures.

MAC was again impressed overall by the high level of engineering of the still small team involved in this important project.

D-line:

The recovery work of the D-line was reported by Drs Shimomura and Fujimori. The work allowed an increase in the flux of low energy muons, by a factor of order 100 at 4MeV/c. The new elements consist of a new warm-bore solenoid coupled to an on-line He refrigerator, a new triplet of quadrupole magnets, new power supplies and the modification of the septum bending magnet power supply to give an enlarged range of stability. The new warm-bore solenoid will have a larger bore than the one it replaces and eliminates the need for foil windows so that low energy muons could be better transported through the beam line. It is currently under construction, to be finished in March 2015. The compressor in the refrigeration system has already been upgraded to give an increase of cooling power from 65 W to 160 W. The new quadrupole triplet is delivered and ready to install, as are the power supplies for the new quadrupoles and for the DB2 and SY magnets. All upgrades are planned to be completed in the summer of 2015.

The final element of the planned reconstruction concerns the septum magnet power supply, which requires modification to operate with stability at the low output needed to work at low momentum. Unfortunately this did not go as well as the other upgrades and a problem with the electrical design of the modifications led to an electrical fire while the supply was being tested in situ in the experimental hall. The fire was extinguished immediately by the personnel in the hall who were testing the supply and the damage was localized to internal components of the power supply. However the need to carefully assess safety implications of such an incident brought the entire J-PARC center to a complete stop. The J-PARC management reacted immediately, very cautiously and responsibly in view of the background of the recent radiation incident at the hadron section and we understand the reasons and concern beyond this decision. However, the committee thinks that, for the future, measures should be taken so that the impact of similar events should be more localized.

A multipurpose user facility such as J-PARC would benefit from a risk inventory and detailed classification scheme of hazards. Potential hazards could be clearly associated with the relevant parts of the facility without interfering with those that are not directly affected. We suggest modeling such a risk assessment considering examples at similar research centers worldwide.

D1 μSR spectrometer / DAQ upgrade:

MAC was provided by Prof. K. Kojima with the current status of the D1 μSR spectrometer upgrade, which has resulted in marked improvements of experimental capabilities on the D1 beam line. The new JAEA magnet-based spectrometer, which has replaced the old DΩ-1 spectrometer from KEK, increases the maximum static magnetic field for experiments from 1.5 to 4 kG, and enhances data acquisition rates via an increase in the solid angle subtended by the positron detectors and the replacement of the photomultiplier-tube-based detectors with multi-pixel photon counters (MPPC). Since the new spectrometer was installed just prior to the MAC-2014 meeting, extensive commissioning had not yet taken place.

Usage since has revealed a few problems with the new spectrometer that need to be resolved. At present the amplitude of the μSR signal drifts with time after the magnet is turned on. The problem has been traced to temperature stability and the need for thermal shielding between the magnet and detectors, and a temperature feedback system for the high-voltage power supplies. The new spectrometer also suffers from a long "dead time" after detection of a positron, which significantly affects the early times of the μSR signal. The solution to this problem is being worked on, and upgrades to the existing MPPCs and/or circuits are being considered. MAC was pleased to hear that some consultation with experienced staff at the ISIS pulsed-muon source in the U.K. is taking place. It is imperative that the problems with the new D1 μSR spectrometer be resolved early in this next year, since these place limitations on experiments that use the D1 beam line. Furthermore, a clone of this spectrometer has already been built for the S1 beam line.

In addition to the spectrometer, MAC learned of recent developments of a user interface for creating auto-run sequences with improved data acquisition efficiency, and of a remote web-based tool for accessing and viewing data. The committee fully supports such sustained efforts for improving accessibility and convenience to users.

U-line / USM: Laser system:

The purpose of the U-line is to produce ultra-slow muons in with high intensity by laser ionization of Muonium atoms. The working of the principle has been demonstrated in the past years. The realization of the world's highest intensity ultra-slow muon beam for use in experiments is underway. In order to reach the goal a state-of-the-art laser system has been developed. The committee appreciates the very good progress that has been made over the past year in developing the new and stable laser system for Muonium ionization.

The team concentrates on refining the system and on achieving high UV output power. The principle of the facility bases on resonant excitation of the 1S-2P transition in Muonium by 122 nm (Lyman-α) pulsed laser light which is followed by ionization of the 2p state with 355 nm light. Generation of light at 122 nm is a most challenging task which is excellently addressed by sum-difference frequency mixing of light at wavelength 212 nm and at wavelength 821 nm. For this a laser setup has been moved from RIKEN to J-PARC in February 2014 and is now employed. Constantly refinements are in progress and the system is continuously improved to achieve higher output power and high long term stability. The way of progressing is fully adequate and the team performs very well in view of the enormous complexity of the laser system. The observation of Lyman-α radiation with sodium salicylate in May 2014 must be appreciated as a major step forward.

The laser beam guiding and transport system to the muon beam has been set up. This includes sophisticated laser beam and power diagnostics. MAC is very pleased with the goal oriented progress made in the past year and is impressed by the highly structured work and the very professional setup that has been realized in the experimental hall. In particular, generation of 1 μJ of Lyman-a radiation is considered a major step forward. The team expects 100 μJ this spring. For this a new amplifying ceramic crystal needs to be made. MAC recommends to consider using the already available radiation for numerous test and further developments, wherever highest intensity is not indispensable. Already at this rather low power many important steps can be taken such that the waiting time for the new ceramic crystal can be beneficially used. We also encourage in particular detailed and structured testing of the beam guiding system to the experimental setups using H^+ and Li^+ ions. With those particles several specific problems can be addressed such as, e.g., stability problems which are related to the wavelength mixing in Kr gas. Such work could also be performed in particular during the accelerator shut down.

MAC expects that the sophisticated equipment that has been set up at the U-line will provide for generating low-energy muons within the coming year. It would be important to start producing slow muons even if the new ceramic crystal will be delayed. In this case an initial rate well below design specifications would nevertheless be an important success and major step forward. Much of the indispensable optimization work for the experimental stations can benefit from the availability even of low intensity slow muons. MAC considers this a high priority the development of MUSE in order to provide for competitive muon science in a most efficient way.

U-line / Beam line and equipment:

Dr. Ikedo first explained the reason and the solution of the problems in the cooling system of the curved solenoid in U-line, which delayed the beam delivery by more than 12 months. The problem was detected in January of 2014, repaired in July, and the performance of the cooling system could be confirmed in August. It was caused by an undefined status in the valve control system, which occurred under particular circumstances. In the last MAC meeting, the committee pointed out that, "the trouble of the cooling system for the superconducting transport solenoid is likely a serious problem, since there are no clear reasons for explaining the trouble". The committee therefore is glad to hear that the problem could be identified and solved and acknowledges the hard effort for repairing and solving the trouble. It is confident that the similar problems will no longer occur in the U-line.

Dr. Adachi then reported about the beam transport tests in the ultraslow-muon microscope (USM) using the laser resonant ionized hydrogen (H^+). Although the statistics of the measurements is very low, the results are consistent to those obtained in 2014 using Li ions, which are present in the tungsten target as impurity. Considering the mass difference between muon and Li, the present investigations are very important to understand and optimize the transport of ultraslow muons. At present, the committee thinks that the production of the ultra-slow muons is already possible, if a reasonable number of muons are delivered to U-line. Considering that the problems with the curved solenoid mentioned above have been solved and the progress of the proton beam intensity at J-PARC, the committee expects a first ultra-slow muon beam in 2015.

U-line / USM: USM transport & tuning:

Dr. T Adachi presented results from detailed studies of the ultraslow muon beam transport using thermally emitted (from the 2000K W foil) and ionized Li ions and laser ionized H^+.

The field of the einzel lenses has been calculated using the Opera 2D software and the particle transport using the musrsim package from PSI. Measurement of the beam profiles were performed using Microchannel plate detectors, which can be inserted at various positions of the USM beam line. Close to the target position a width (rms) in x direction of 2.9 mm and in y-direction of 6.4 mm could be achieved. The tunings using Laser Resonant Ionized H^+ at a rate of about 1 count/sec allowed to test also the overall timing resolution, which is presently 30 ns. The committee appreciates the progress that has been made over the past year in developing the laser system for Muonium ionization and in the beam testing with ions. There is now the expectation that the U-line generates low-energy muons within the next year. A first attempt in FY2014 was not conclusive because of voltage problems of the transport system.

S-line / S1 area construction

Dr. Koda reported about the progress of the S-line, which is designed to deliver a high intense muon beam to measure small samples and perform high statistics experiments in short time. In the final stage it will include four areas. The installation of the beam line equipment is completed, so that the line is ready to provide muons to the S1 area and beam commissioning will start soon.

The MAC committee appreciated that the S1-line, for which a new spectrometer is now available, has been completed on a time line as scheduled and fully compatible with the planned layout of 3 additional legs and experimental areas. However, we recognized that the novel spectrometer for the S1 area has the drift problems as the one in the D1-line. Solutions to the current problems inevitably have to be found urgently. Operation of the S1-line within the next FY will be crucial for enhancing the scientific output of MUSE and to satisfy some of the user community demands for the muon beam time.

H-line R&D

The H-line will be crucial for the planned experiments in the area of fundamental physics. The design of the beam line aims for a high muon intensity as well as tunability of the muon momentum and the possibility to accommodate a kicker and a Wien filter. This can be achieved with large aperture axial focusing magnets. For this the new beam line concept includes two opposite field solenoids between which a Wien filter and kicker can be installed and it provides for extending the beam line at low losses with a further pair of solenoids.

MAC acknowledges the good progress that has been made by installing the frontend magnets in the M2 tunnels during the accelerator shutdown periods in the summer of 2012 and (continued) in the summer of 2014. It is important that the cabling work is completed before significant activation of elements such as HB1 in the tunnel. Because of expected high temperatures aluminum bus bars are being used between the tunnel and the experimental hall. The installation of all devices in the M2 tunnel could be successfully completed in fall 2014 such that now all frontend devices are in place. We recognize that devices further downstream are now being prepared. MAC is pleased that the importance of shielding is recognized, in particular that attention is given to the areas for the precision experiments.

The H-line is in need of further funding at high priority; the delay in funding is regrettable. The committee appreciates the steps the management is taking to realize the H-line by means that are possible and that it takes the best suited steps given the overall bounding conditions to achieve speedy full realization of the project. This includes in particular the funding that is available through the Grant-in–Aids of JSPS and which enables completing the H1 area for the DeeMee and Muonium HFS experiments in 2015. We applaud the proposal for MEXT to obtain further funding to build the H-line. A detailed planning and scheduling of the further steps and work in the construction of the H-line will now be needed to reach the goal of completing the beam line by the end of 2017.

The scientific urgency of the planned scientific projects justifies that all reasonable efforts are made to get the H-line operational soon. The crucial importance of the H-beam line for the planned important experiments suggests strongly that the scientists connected with the anticipated experiments to have stronger involvement both in designing and constructing this beam line. We feel that with this additional manpower the design can be further optimized and the process can be speeded up.