Report from the Muon Advisory Committee (J-PARC Center) following a meeting held on February 14th and 15th 2016 at J-PARC Center, Tokai

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I. Facility Overview

Introduction:

The welcome address was given by Prof. K. Yamada, Director of the Institute of Materials Structure Science (IMSS) within KEK, who described how muons form one of four probes provided for material and life sciences within KEK-IMSS, with synchrotron radiation and slow positron facilities available at the Tsukuba campus and neutron and muon facilities available at the Tokai campus. He pointed out that muons can learn much from the 33 year history of the KEK photon factory in providing continuous and timely facility upgrades, developing new types of experiment, nurturing good in-house scientists, keeping power users and building up a base of new users in various fields of science and technology. A J-PARC overview and charge to MAC was next presented by the new Director of the J-PARC Center, Prof. N. Saito, who took over from Prof. Y. Ikeda in 2015.

MLF Overview:

Prof. T. Kanaya, the new Director of the Materials and Life Science Experimental Facility (MLF), taking over from Dr. M. Arai, gave an overview of operations in FY2015. A great improvement of beam size for small samples was achieved by the replacement of superconducting solenoid in D-line. The first beam was obtained at the S1 area of S-line. Unfortunately, several troubles have been encountered over the year. These were the problems with the mercury neutron target system under high power operation, the fire accident in the muon area and problems with the heat exchanger for the neutron system. Some of them are beyond expectations. As a result of this the available beam time became extremely short. An investigation of the causes of the trouble has been carried out and tentative measures were taken for some issues. MAC will be waiting patiently for successful improvements of the system.

MUSE Facility Overview:

An overview of the status of the MUSE facility was presented by Prof. R. Kadono. Although the beam time was very limited due to the multiple troubles, several improvements were successfully made to the facility. The solenoid at the D-line was replaced with a new windowless solenoid and the staff succeeded in obtaining a good quality beam after recovery of the septum magnet power supply. They also finally obtained the surface muon beam at the S-line. The intensity might be still smaller than expected, but the optimization during the coming commissioning period is scheduled. We learned that the U-line is ready, apart from the laser operation. As for the muon production section, it is surely highly evaluated that the new rotation target operates well.

Inter-University Research Program:

Prof. Y. Miyake next reported on the status of the Inter-University Research Program (IURP). Progress with the IURP was very limited in FY2015 due to the lack of beam time. It is certainly a challenge to maintain and build a user community without more beam time and more predictability in the beam schedule. Every effort should be made in the coming year to provide users with the beam necessary to make progress in their projects. Plans are in place for this and it appears that the experimental program at the S1 line is ready to begin. Safety must remain a key aspect of facility operation. While safety training has focused within the muon section, it is also crucial to train users in the importance of safety.

In terms of proposed research, interest remains strong but appears to be diversifying away from traditional topics. This may place additional demands on the facility for non-traditional sample environments. The IMSS is encouraging multiprobe proposals to increase synergy. It will be interesting to see what examples come from this.

Changes have been made to the S-type proposals to distinguish between long-term project proposals that compete with general use proposals. This seems like a reasonable plan to balance the demands and keep the facility scientific productivity high in the immediate future, while still allowing for large-scale projects that often develop some new capabilities for future general use.

Long term plans are being formulated now for the 2017 JPARC Master Plan. The current plan includes a transmission muon microscope and a new neutron/muon target. While the total intensity of muons from a neutron target may be higher, it is not clear that the usable flux will be much higher than with a dedicated muon source. Ideas for the Master Plan are essential for the long-term future of the facility, but it is hard to imagine with the current manpower shortage how the ambitious plans being proposed could be carried out.

Unpredictability in the schedule presents a significant risk to the Inter-University Research Programme. On this basis, a compromise in beam power may be a wise choice, rather than aiming for the full design power as a goal on its own. The real goal is scientific productivity, whether the design power is reached or not. While the overall scientific productivity of the programme has suffered from interruptions in beam delivery in 2015, we saw several recent highlights that indicate a healthy, diversified underlying programme, and look forward to a substantial increase in productivity in the coming year.

II. MUSE Activity

Muon Production Target/Scraper:

We appreciate the steady effort made in the maintenance of muon targets and the work towards future development. Good news is the stable operation of the new rotating target adopting WS2 lubricant that replaced the previous fixed graphite target. This was followed by a proper replacement of the scraper whose thermal diagnostics were not functioning correctly.

It is clearly anticipated that the increase of residual radiation activity will be serious under current and future operating conditions. We learned that the facility is steadily preparing for this case with the commissioning of the hot cell and the planning of extensive monitoring systems. Provision of long term storage facilities for waste material is also an issue that needs review.

One concern is surely the lack of manpower. We support the request to increase the number of staff members involved in the target section.

D-line Modifications:

The replacement of the thirty year old superconducting solenoid coil with a new one with a wider bore has been successful, yielding a beam that can be tuned to a smaller spot and a better S/N ratio that will be especially effective for smaller samples.

The warm bore design of the new solenoid has made the heat shield foils obsolete and more low energy muons will be available at the D-line than before.

The unfortunate fire incident of the septum magnet power supply last year provided an opportunity to reform and improve J-PARC wide safety awareness.

D1 μSR spectrometer/DAQ upgrade:

MAC is pleased to learn that an automatic beamline tuning program was installed and this program is working well. In fact, the spot size of the muon beam became very sharp. The staff of J-PARC also plan to install an advanced autorun system including an active zero field mode. Such a system is very important for measuring small internal magnetic fields in a sample on the beam line, which is close to several magnets of the neighboring beam lines. A further useful development is that muon users are now able to see the data from outside of J-PARC.

By these activities, J-PARC/MLF/MUSE looks to approach a facility with an international standard of service to users. Such user-focused activities should be particularly accelerated to make the facility attractive for international users.

One possible remaining problem is a large temperature dependent response of the new counter MPPC system. To control this problem a thermal shield and temperature control system using water has been installed. However it is noted that such a shield may reduce the spatial freedom for the setup of counters. Also, it might be difficult to perform experiments using an oven.

Therefore, we recommend developing a more thermally stable detector system that retains compatibility with experiments at high temperatures.

U-line/USM: Laser system:

The development of a state-of-the-art unique laser system for photo ionization of muonium atoms is steadily progressing. Significant improvements of laser output power and long term stability have been achieved. The group managed to solve problems with optical components. The use of Nd:YGAG ceramic for obtaining the necessary optical irradiation level is a development that has high potential. This development should be further pursued as this piece of optics is a central and crucial element in the whole optical setup and deserves full attention. MAC appreciates in particular the muon group's contacts with commercial suppliers.

The hiring of a laser expert is an important step forward and it is expected to assure smooth laser performance for the facility. The number of ionized and transported atoms is expected to be some two orders of magnitude higher as compared to earlier work. The indispensable tests with muon beam unfortunately have been significantly delayed by the septum power supply shut down during the past year. With the beams back it will be necessary to demonstrate the production and the delivery of low energy muons to the experimental ports.

MAC applauds very much the structured approach towards improving key elements in the sophisticated whole U-line system and the tests of the low energy particle beam with low mass ions such as H^+ and Li^+. In particular we acknowledge careful diagnostics with sophisticated tools along the beam line. We are looking forward to first slow muon experiments at MUSE in the near future.

U-line/USM: Beamline and Equipment:

The preparations for the generation of the first ultra-slow muons at J-PARC are progressing well. For selecting the proper thickness of the tungsten foil used for the generation of thermal muonium in vacuum, SRIM simulations of muon stopping profiles in the tungsten foil and measurements with beam have been carried out. In the experiment the number of muons stopping in the tungsten foil and the number of transmitted muons at the position F1 of the USM beam line have been measured as a function of beam momentum of the U-line. For this purpose, the coincidence rates of two positron telescopes outside of the vacuum vessel at the target and F1 position were recorded. As a result of both simulation and measurements the thickness of the tungsten degrader/target system has been changed from 100 μm (50 μm degrader and 50 μm target) to 75 μm (25 μm degrader and 50 μm target). With this change the number of muons stopping at the downstream side of the target foil is maximized, which should translate into a maximum yield of thermal muonium in vacuum, and therefore into a maximum yield of ultra-slow muons after laser ionization of thermal muonium.

The USM beam line has been tested offline by thermally generated protons and $^{7}Li^{+}$ ions and by laser ionization of H in a small volume downstream of the tungsten foil. The beam rate and spot of these ions were measured by single anode and position sensitive delay-line anode MCP detectors at several positions in the USM beam transport system. Problems due to a non-uniform detection efficiency of one of the MCP detectors have been solved by replacing the single MCPs of this detector. The amplitude of the anode signal of this detector in the H laser ionization experiments in 2015 indicate, that about one thousand protons are generated per laser pulse, which is at least two orders of magnitude larger compared to a previous test in 2014. This enhancement is attributed to a larger laser power and an improved tuning of the laser. The timing of the laser with respect to the muon beam still has to be tested and optimized.

U-line/USM: Transport and Tuning:

The long periods without beam in 2015 due to the fire incident and due to the problems with the spallation target have been well used to prepare the USM beam transport system for operation with muon beam. The transport and tuning of thermally ionized $^{1}H^{+}$ and $^{7}Li^{+}$ ions as well as of laser ionized $^{1}H^{+}$ have been studied in detail and cross-checked by simulations using the musrSim package from PSI, which is based on Geant4. The effect of slits and various electrostatic elements on beam shape and rate at positions F1 and F3 has been investigated at different acceleration voltages of 20 kV, 25 kV, and 30 kV. There is a fairly good qualitative agreement between measured and simulated beam profiles, which indicates that the USM beam transport system is well understood. Some of the presented beam profile plots show a scatter of data points which are

significantly larger than the given errors. The origin of this large variation of data points is not clear at the moment, but it could explain some of the quantitative discrepancies between measured and simulated beam profiles.

Overall, the committee has the impression that the USM beam transport system is being well prepared for the first tests of generating ultra-slow muons at J-PARC. The committee is looking forward to the results of the first muon beam experiments with a fully operational laser system.

S-line: S1 Area Construction:

Dr. A. Koda presented a report on the construction and the start of beam commissioning to the S1 area, the first of four experimental areas planned for the S line. The commissioning was unfortunately cut short by the problems with the neutron target and moderator in 2015, however the successful start of beam commissioning to the S1 port is very good news.

The long-awaited surface muon beam line will more than double the μSR beam time at MUSE when a new μSR spectrometer is installed in 2016.

H-line: Research and Development:

Dr. N. Kawamura presented a report on the current status of the H-line. The H-line setup in the tunnel up to the wall to the hall is basically completed. Scientifically well-motivated experiments are waiting for further beam line elements being installed. Important radiation studies have been carried out. Their results show that for the DeeMe experiment extra radiation shielding against neutrons and photons will be essential.

It appears that the electrical power installation in the experimental hall is not sufficient for operating the H-line with its experiments that demand high energy muons. However, there is already sufficient electricity supply for operating an early version of the muonium hyperfine structure experiment.

We are looking forward to the installation of the next beam line elements and the H-line muon beam appearing in the experimental hall within this fiscal year.

We recognize that the muonium hyperfine structure experiment in zero magnetic field is in preparation at the D-line. For this a multilayer μ-metal shield has been designed around the radiofrequency cavity and noble gas target. Data taking can take place towards the end of the year.

We recommend that the muon group and J-PARC management jointly work on resolving the power and shielding issues concerning prospective experiments at the H-line. At the same time the experiments requiring rather little additional electrical power, such as the muonium hyperfine structure experiment, can be installed, started and continued, respectively.

M1 & M2: Maintenance and Future Development:

Dr. Kawamura also reported some new issues in the M1 & M2 tunnel. Most of the magnets are working well, but some problems were reported. The actual radiation damage in some areas is greater than expected based on the original estimates and trouble with some beam line elements is expected in the future.

For the Q magnet, a standby replacement magnet is already prepared, but a replacement is not yet available for the XY magnet, which is expensive and takes a long time for production. A task force will be launched covering these magnet issues.

This issue has been the responsibility of the muon side for historical reasons, but in the present circumstances a close cooperation with the neutron group is recommended by MAC to forge a path towards a unified strategy for maintenance of the proton beamline.

Muon Regeneration Task Force: Reuniting and revising activities on muon facility operations:

We agree with the notion “Safety is our first priority” and the activity explained by Koda-san, “Risk prediction training”, that is noted to be very popular for universities and private companies in Japan. Thus, it is preferable to continue such a training program at J-PARC, particularly for non-experts and freshmen.

Although we understand the sensitive situation that applies at J-PARC, we recommend making a clear boundary of responsibility for staff in this training. Otherwise, the individual staff of J-PARC have an unreasonable expectation to become expert across the whole range of activities and types of equipment, even if they are purchased from outside.