# MAC-2017 Meeting

## Held on February 28th and March 1st 2018
## at J-PARC Center, Tokai

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# I. Facility Overview

## Introduction and J-PARC Overview:

Prof. K. Yamada, Director of KEK-IMSS, welcomed the committee and introduced the facility and then J-PARC Director Professor N. Saito gave an overview of J-PARC status and activities, highlighting the improving operational efficiency of > 90 % in combination with the establishment of 500 kW operation and the continuing progress towards 1 MW operation. Within MUSE the S1 user program is now ramping up, U-line commissioning is in progress and the construction of the H-line power substation is under way. Finally, a set of charges was given to MAC to evaluate the facility operation and make suggestions for improvements.

## MLF Facility Overview:

Prof. T. Kanaya the Director of the MLF gave an overview of operations in FY2017. The key development has been the installation of the newly designed #8 neutron target allowing 400 kW operation from January 2018 and 500 kW operation from April. A test of 1 MW operation of the #8 target is scheduled for June. Future plans involve progressing to #10 target, which has a constraint-free design. The benefits of the switch to more stable operation in FY2017, even at limited operation power, are revealed in a return to the trend of increasing numbers of MLF users after the previous fall due to the serious target trouble.

Overall MLF shows a good publication record with the fully operational muon instruments showing a particularly strong rate of publication per experiment.

## MUSE Facility Overview:

An overview of the current status of the MUSE facility was presented by Prof. R. Kadono. Work has progressed on each of the D, U, S, and H-lines as well as on the muon production target. His summary demonstrated the steady progress of each case. Detailed comments in each area will be given in subsequent sections of this report.

## Inter-University Research Program:

After a healthy number of proposals for beam time in 2017, early indications show a significant reduction in 2018. It is too early to tell whether this is a statistical fluctuation or represents a worrying trend. However, if it indicates the latter, then causes and remedies should be addressed vigorously as soon as possible. One suggested possibility is a loss of interest by users, due for example, to accumulated frustration with the difficulty of getting experiments approved and getting beam time scheduled. It should be considered carefully if the current proposal system presents a barrier to inexperienced users, or whether it makes sense to change the policy of the proposal review committee, for example by dedicating some time for new users (similar to P type proposals). Outreach to the user base is also crucial, because many of the factors that have frustrated new users in the recent past have been addressed, and, looking forward, users can now expect a higher availability of beams. Initiating a mentoring program for new users and including training on proposal writing in future summer schools are other avenues worth considering.

Although the overall publication record is good, the number of publications produced in 2017 was relatively low. This is likely to be a lagging response to the low availability of beam over the previous years. Despite this, the highlights of recent progress from the IURP were encouraging for their breadth and novelty, including new applications of muonic X-rays to industrial problems like Li batteries, and the role of cosmic ray muons in electronics failures.

It was very encouraging to see that a number of hires were made at MUSE in the past year and more are planned. This is important in view of retirements expected in the near future, as well as the ending of fixed term positions. Even after these hires, there remains a substantial ongoing staff shortage at MUSE, the total staff number having decreased by 3 between 2017 and 2018, which is around 10 % of the total. It might be helpful to have a clear statement of a realistic target number of personnel per beamline that is in line with other facilities like neutrons and synchrotron X-rays, to make the case for more staff positions as clear as possible.

## II. MUSE Facility Activity

### Muon Production Target:

The current rotating muon target has operated for 40 months without trouble, making 10 M revolutions out of its full design life of 50 M. Work continues on improving the target diagnostics and developing next generation muon targets using materials such as SiC coated graphite and SiC composites. Participation in the RaDIATE international collaboration covering radiation damage in accelerator target environments is a new and welcome development.

### Muon Source Facility: M1/M2 Area;

Stable operation and maintenance of the primary beam transport section from the muon target to the neutron target and the front-end elements of the four muon beam lines is the responsibility of the muon section. The airflow at the M2 tunnel is closed and slowly and continuously exhausted by a turbo molecular pump (TMP) through the MLF stack. The primary proton beam produces tritium in the graphite production target, but there is no real time monitoring system for the tritium concentration in the exhaust air due to the difficulty of the detection of its low energy beta ray. A 2 kBq/cm$^2$ tritium contamination was detected around the TMP and this contamination is believed to be due to the adsorption of water containing tritium formed by isotope exchange with the tritium produced in the remaining air in the tunnel.

The risk of an abrupt tritium emission from the graphite muon production target is recognized, and a task force has been created to work on this issue. Diffusion of tritium in graphite is not supposed to be fast at the operation temperature of the target, but there is currently no reliable data for the graphite material used for the muon target. To get some data on this issue, a test sample will be irradiated with a proton beam at RCNP of Osaka University, and the tritium produced in the sample will be examined by a radiochemical method.

For the M2 tunnel area an upgrade to a new exhaust monitoring system with two buffer tanks is proposed to guard against abrupt emission of tritium.

MAC recognizes the effort being made to identify and assess potential risks associated with the tritium production in the beam tunnel.

### D1/S1 Sample Environment:

μSR sample conditions have been upgraded steadily at the D1 and S1 ports. Experiments at temperatures from 20 mK to 500 K can now be conducted. Temperatures lower than 1.5 K are only achievable with the dilution refrigerator at the D1 port. High demand for measurements below 1.5 K leads to congestion at the D1 port where various experiments other than μSR are conducted. A $^3$He refrigerator is in preparation and will soon be available at the S1 port providing temperatures down to 0.3 K that will help to alleviate the tight beam demand at the D1 line from low temperature experiments.

New micro transverse field coils installable inside the μSR detector system were introduced that can apply fields up to 400 G. A new airtight sample holder has been made and a holder for very small samples has been made, which is very effective for μSR measurements of such samples with the aid of a fly-past setup. A new cryo-furnace enabling seamless wide range temperature control from 1.5 K to 500 K has been installed and is expected to reach 800 K.

The unified user-interface for temperature and magnetic field control independent of the cryostat shows good usability features and provides for easy maintenance by the support staff.

MAC evaluates highly the continuing efforts to supply stable and user-friendly measurement control systems and to extend the range of available sample conditions in terms of temperature and magnetic field.

**D1/S1 μSR Spectrometer/DAQ Upgrade:**

Kojima-san reported the development of the new solid-state positron detector system, Kalliope, for which he was awarded the Koshiba-prize in 2018. Although the initial version yielded a distorted spectrum at early times, these problems have now been solved. Now, Kalliope has become a very reliable system, which also has enough capacity for the 1 MW operation in the near future. A potential future issue of noise events related to high proton beam power has been noted and will require careful testing.

By using the auto-run software, IROHA2, μSR experiments are now more comfortable and reliable than in the past. Furthermore, users can now check the current experimental situation and download their measured data files through the internet. Such progress has made MUSE an excellent world-class facility in terms of user interface to the experiments.

One great area of progress is in using the combination of small TF coils and a rotating sample rod controlled by IROHA2 to provide the detailed angle dependence of the muonic hyperfine constant for a single crystal sample within an auto-run mode.

A 5T muon spectrometer, CYCLOPS, will soon be tested in the S1 area. For the future operation of CYCLOPS that may be installed in the S2 or S3 area, stray fields should be reduced down to a negligible level at the other S areas.

In order to further develop the D1/S1 μSR Spectrometer and DAQ system, particularly for the near future 1 MW operation the committee recommends to increase the number of staff in this area to continue the current progress and activities.

**Negative Muons at D2:**

Creative advances in beam diagnostics enabled a substantial improvement in beam transport of negative muons at D2. This enabled implementation of a new collimator system and measurement chamber and resulted in demonstration experiments with these new capabilities.

This progress, complementary to standard μSR, is excellent, and it should soon move beyond demonstration experiments and begin to have impact in other fields. We look forward to high profile uses of muonic X-ray elemental analysis, positive and negative muon-induced single event upsets diagnosis of operating electronics, and negative muon spin rotation and relaxation ($\mu^-$SR) in the coming year.

**U-line/Ultra Slow Muons: Beam Line;**

The MAC is pleased to see the good progress made in beam tuning and beam transport simulations, which now provide a good understanding of the electro-magnetic transport system of the ultra-slow muon (USM) beam line. As a result of these efforts, the first USM muon spin precession signals were presented in applied fields of 20 and 200 G for muons with 30 keV energy stopping in Ag. MAC expresses its congratulations to MUSE on this important milestone.

Compared to the rate reported to MAC last year, the USM rate was doubled, which can be attributed to both increased proton beam intensity and improved focusing of the surface muon beam after insertion of an additional axial focusing superconducting solenoid in the U-line.

Problems in the USM extraction after photo-ionization due to both the bent hot tungsten foil (which distorts the accelerating field) and the stray magnetic field of the additional axial focusing solenoid have been investigated. The bending of the tungsten foil has been reduced by a different method of installation of the cold foil, and the vertical beam offset due to the stray magnetic field has been compensated by asymmetric operation of the beam focusing electric quadrupoles, as suggested by beam transport simulations. Further countermeasures against the stray fields using new magnetic shields are in progress.

Open issues at the moment are:

i) the detection efficiency of the MCP detectors used for measuring the USM beam spot and intensity at various positions of the USM beam line

ii) the detection efficiency of the positron detectors of the spectrometer and the low positron event rate

iii) the low observed decay asymmetry of 0.06.

A proper detector efficiency calibration is essential in order to calculate the rate of ionized Mu atoms at the tungsten source, using the known transmission from the beam transport simulations. This rate is of fundamental importance, since it allows estimating the overall USM generation efficiency. This is key information for understanding and optimization of the laser ionization process – which is in addition crucial for the planned muon g–2/EDM experiment and the Transmission Muon Microscope at the H-line.

The low positron event rate reflects a small solid angle of < 20 % covered by the positron detectors. MAC suggests increasing the solid angle of the positron detectors in order to significantly reduce the time needed to record a μSR spectrum with the current low USM rate. The low measured asymmetry of 0.06 can be only partly explained by the 50 % loss of polarization due to Mu formation at the tungsten foil. The origin of this low asymmetry should be investigated and action should be taken, if possible, to increase the observable decay asymmetry.

### U-line/Ultra Slow Muons: Laser System;

The development and operation of a long-term stable laser system to generate Lyman-alpha light for the photo-ionization of thermal muonium is pivotal for the progress of the U-line research programme. At the same time, it is crucial for the production of a high quality bright positive muon beam at the H-line for use in the muon g−2/EDM experiment at the J-PARC H-line.

MAC acknowledges, in particular, the progress that has been made in the past year concerning the operation and the further development of the laser system for muonium ionization at the U-line.

The laser system at the U-line has benefited from well-prepared upgrades concerning the noble gas optical mixing cell, as well as refinements of the optical beam path, and a 20-year-old pump laser will be replaced by a more modern system. The laser system appears to be working more reliably now, yet still there are remaining issues concerning the time stability of the produced laser light, on the scale of hours.

MAC is confident that the measures taken will provide a remedy, and the continuous programme for the upgrade of components promises further steady improvements. MAC also looks forward to hearing about results from the new way of producing Nd:YGAG with, in particular, improved optical quality, and the developments around a new material Nd:YSAG.

MAC appreciates the structured activities that have been started in order to develop a backup solution concerning the important ceramic frequency mixing material. We appreciate in particular the professional approach in an area where pioneering technological solutions are being developed by the J-PARC team and their partners. The past hiring of dedicated staff and the attention of J-PARC management appears to be paying off. New pump laser and new crystal making procedures promise higher stability and the short-term drop in intensity due to gas impurities should disappear. The expected overall improvement in Lyman-alpha-light intensity by a factor of 2 to 3 due to various system improvements appears to be well justified.

MAC realizes that besides further development of the system, stable operation is also being given high priority, as many experiments depend on the reliable operation of the system. In particular, the remaining issues concerning the obtaining of crystals or optical ceramics of sufficient optical quality needs further attention and continued full support. The measures taken in this respect reflect a well-designed development programme. We are convinced that this is the right approach, and it will provide the desired stability for the operation of ultra-cold muon production using muonium laser ionization at the heart of the new facilities. Being at the core of several activities, strengthening of the laser expertise by additional staff is strongly advised.

**H-line:**

The H-line will be the spinal cord of a broad new research programme at J-PARC. Its speedy completion is strongly needed and MAC recommends to J-PARC/ KEK management that all possible means should be taken to prioritize and realize the H-line and its promising scientific programme. We are pleased to learn that the necessary steps were already taken to provide an additional 4 MW of electric power to the experimental hall. We assume that this development, that has now started, will be completed within the next couple of years. MAC recommends that the necessary funds be secured for a speedy completion of a fully functional H-line.

The timely completion of the H-line will be important for the scientific success and impact of experiments such as the muonium hyperfine structure, muon g–2/EDM, DeeMe and the muon microscope. All of these projects are timely now and have tremendous scientific discovery potential. The exciting science programme planned for the H-line can only be enabled with a functioning H-line, which we recommend to be completed with high priority.

**MLF Second Target** :

Working groups of J-PARC MLF division and of the Japanese Science Societies for neutron and muon research were organized to discuss the plans for a future target station 2 in MLF. This plan includes an upgrade of the proton beam power to 1.5 MW, a splitting of the proton beam in front of the existing MLF hall by a fast magnetic kicker, and the building of a new experimental hall with a combined muon/neutron spallation target. The extraction of the muons from the entrance window of the spallation target will be achieved by a large acceptance (1 sr) solenoid, and a surface muon beam intensity increase by a factor of 50 compared to the existing muon beams at target station 1 are expected.

This is a project for the time horizon beyond 2030 and MAC welcomes and encourages the further development of these initial ideas for future large-scale muon projects at J-PARC.

## III. General Comments and Recommendations

MAC appreciates the recent hiring of new staff. This both compensates for the retirement of experienced personnel in the near future and provides new opportunities. In particular, we appreciate the opening of a new full professorship for muon science and the potential for future research areas that it offers.

As part of the move from construction to operational mode, the user support requirement from staff will naturally increase. We strongly recommend to consider hiring additional staff with part of their duties assigned to the 'instrument scientist' role that includes assisting new users in preparing proposals and learning to run their experiments. Developing a strong and stable muon user community relies on such support from the facility.

MAC acknowledges the achievement of stable running of the facility over the last year and we are looking forward to the scheduled intensity upgrades, working towards 1 MW beam power. These activities can build reliably on the experience gained from operation in recent years. We appreciate in particular that safe operation of the facility is visibly given highest attention.

MAC applauds the initiative to set up a new 4 MW power station for supporting in particular the installation of the H-line in the experimental hall. We recommend a top level of priority for the provision of sufficient resources for speedy completion of this infrastructure task in order to take advantage of this unique scientific window of opportunity.

MAC appreciates the visible progress in further building up the facilities and the high level of engagement of the mostly young scientists actively working on the instruments in the experimental hall. With the highest priorities given to the U- and H-lines, we emphasize that the completion of the remaining S-lines will be very important for the long-term operation of the overall muon facilities at J-PARC with a broad science portfolio. Establishing and operating a second S-line spectrometer will soon be needed in order to make efficient use of the available beam intensity as the accelerator returns from single pulse to double pulse operation following the planned increases in beam power.

**Charges Given to MAC:**

- Evaluate the appropriateness of the facility operation and its upgrades with respect to the following points ;
  - safe, stable and efficient operation towards the production of science in a timely manner
  - timely construction of beam lines and their preparation to maintain the uniqueness of the facility, attracting not only domestic users, but also international users

- Any suggestions for improvements are appreciated. Our particular concerns include, but are not limited to, the following;
  - Limited manpower to operate and maintain the beam lines
  - Urgency of commissioning of the U-line, preparation for H-line construction and the remaining S beam lines