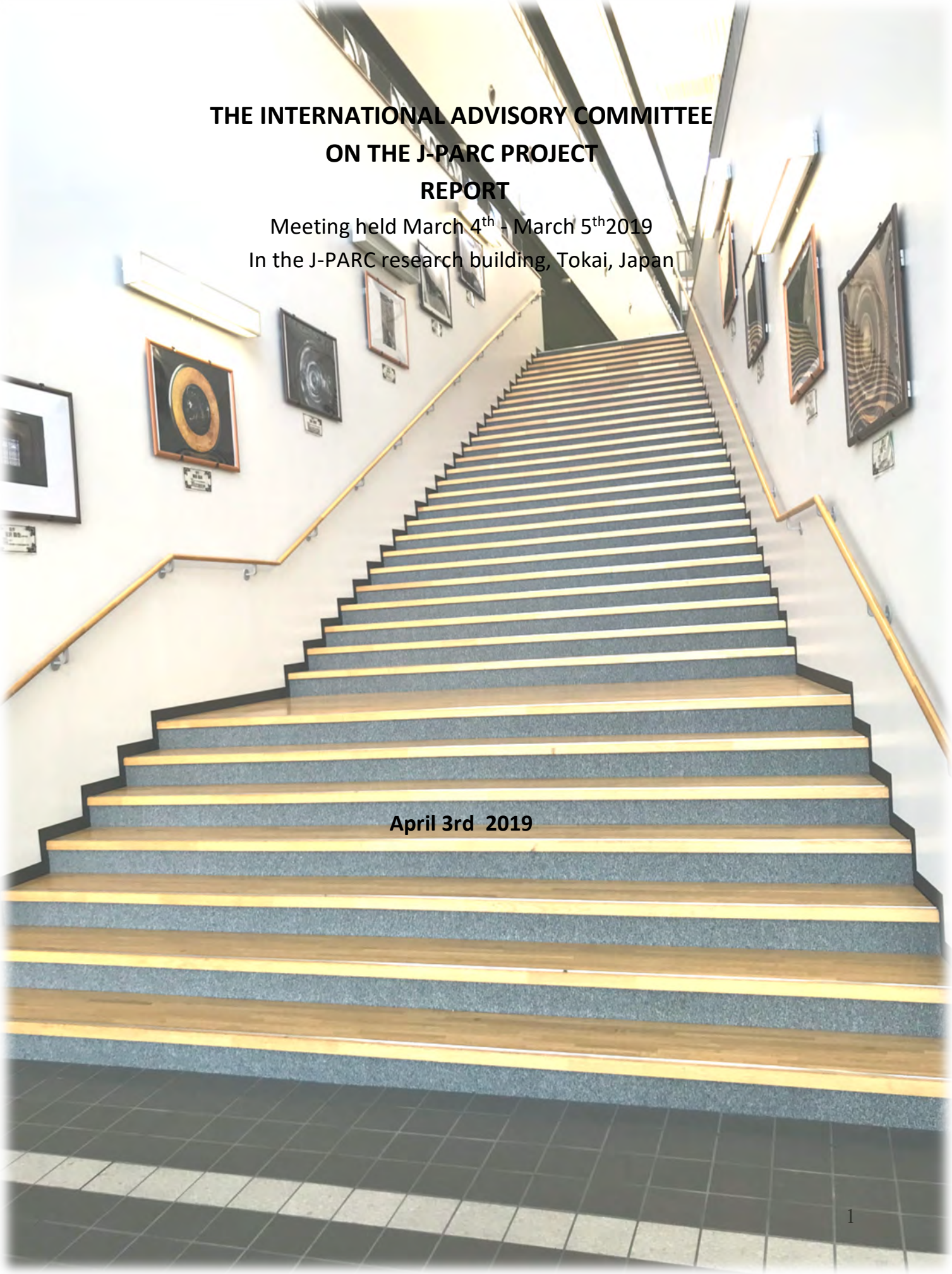

THE INTERNATIONAL ADVISORY COMMITTEE ON THE J-PARC PROJECT REPORT

Meeting held March 4th - March 5th 2019

In the J-PARC research building, Tokai, Japan

April 3rd 2019

Contents

EXECUTIVE SUMMARY:

The International Advisory Committee for J-PARC (IAC) met March 4th and 5th 2019 at J-PARC. The committee heard presentations from the director, the Safety and Accelerator groups, the scientific groups and their respective advisory committee chairs. The committee heard the view of the MEXT funding agency responsible for most of the support for J-PARC during a presentation by Mr. Atsushi Oku, director of the Office of Quantum Science and Technology at MEXT.

Dr. Yukitoshi Miura, Executive Director of JAEA, reported on the situation at JAEA and how J-PARC fits in its renewed mandate. Dr. Junji Haba, Executive Director of KEK, presented the situation at KEK and its support for J-PARC.

The committee was very pleased to see that the shift in priority to favor a safe, reliable delivery of beam at the expense of pushing the frontier of beam power led to an improved production of interesting science in all areas as presented in two parallel sessions.

The accelerators are exhibiting excellent performance and are expected to reach design performance. However, some signs of degradations due to aging are appearing and will require careful risk assessment to optimize the preventive maintenance and refurbishment schedule. Progress is being made in developing more reliable targets with help from J-PARC-wide expertise but the IAC is still advocating a conservative approach in commissioning high-power systems, both from the point of view of reliability and dose management.

The safety culture of J-PARC is improving and is more and more in line with international standards. The implementation of a stop work order policy is still a work in progress. The IAC was shown evidence that the number of safety incidents is decreasing while the reporting of potential problems is increasing indicating that staff is being more aware of safety issues and willing to act to prevent accidents. This is not yet quite the case for external personnel like visitors and contractual workers in particular. A continuing effort to impose the work stop order mechanism across everyone working at J-PARC is still required.

The MLF has generated high quality new results and has instituted new mechanisms for increasing its productivity. The IAC noted the large involvement of industry at the MLF which is very high by international standards. The neutrino program received close to 500 kW of reliable beam on target and was able to show some tantalizing evidence for CP violation in the lepton sector. The IAC notes that good progress is being made to bring new key experiments on the floor (muon g-2/EDM, COMET, JSNS^2 for example) while improvements on the MR slow extraction allowed the hyper-nuclear program to produce new results and lead a world-wide activity in that field. However, the MR program is awaiting anxiously the replacement of the MR magnet power supplies (PS) which will allow a reduction of the beam cycle time and hence improve beam intensity and quality. Supplementary funding for the PS upgrade has been forthcoming this year

but at the expense of running time. This is an urgent matter to be addressed to keep the international appeal of the facility, especially for supporting the Hyper-Kamiokande (HK) program.

J-PARC had a successful review by MEXT last spring and will be celebrating its 10 years of operation in September 2019. Building on its achievements so far, J-PARC has a promising future. The laboratory has been developing long range plans that enhance the current program with exiting new opportunities. The IAC is pleased to be associated with such a dynamic laboratory.

SUMMARY OF THE RECOMMENDATIONS BY SECTIONS IN THE REPORT

Management

The IAC supports the priority given to the upgrade program but also asks for a concerted action in trying to recover more beam delivery to users in the next three years.

Safety

Recommendation:

The IAC supports continued action to promote safety in all aspects of the laboratory activities. The strengthening of the safety group organisation is welcomed. Communications of lessons learned are quite an effective tool to reach the community, and special attention must be paid to external contractor staff members who may not consider J-PARC policies as overriding their internal company ones while on site.

Accelerators

Recommendations:

The IAC recommends to:
- maintain and preferably increase availability by starting to regularly invest in hardware consolidation, with prioritization based on an extensive risk assessment of all elements in accelerators and infrastructure.

-implement a Run permit system as a capacity of the accelerator control system, combined with a robust Machine Protection System to avoid accidents that might lead to long duration beam stops.

-proceed as soon as possible with construction and implementation of improvements required for increasing the MR beam power first at 750 kW and progressively to higher levels. Debugging of the new MR power supplies is likely to require long duration tests.

- plan for additional beam study time to analyse and fix issues with higher beam intensity in the MR.

Particle and Nuclear Physics

Recommendations:

The IAC strongly supports the laboratory decision that the highest priority needs to be given to the Main Ring power supply upgrade for the next three years.

The IAC fully endorses the recommendations made by the IPNS PAC at its last January meeting and "strongly recommends that every effort be made to restore the beam time availability [of the Main Ring] at J-PARC to at least 6 months per year during the period of upgrades towards 1.3MW and to the full 9 months per year afterwards, so that the world-wide scientific community can benefit fully from the unique facilities at J-PARC" and "concludes that even in the case of the proposed severe limitations on operations, the available time should be divided approximately equally between the hadron program (SX) and the neutrino program (FX)" on the beam time allocation in JFY2020.

Materials and Life Science Experimental Facilities:

Recommendations:

The MLF should continue to prioritize stable operations over quickly achieving 1 MW as reliable operation is essential for producing science and securing J-PARCs reputation.

The MLF should concentrate on exploiting the world-leading capabilities provided by its excellent neutron instruments and intense source of neutrons. The current emphasis on producing good science, must be maintained and the current initiatives continued for a period of time to allow them to bear fruit. Now is the time to capitalize on the substantial investment made in the MLF, rather than pursue additional initiatives which could be distractions.

The IAC strongly believes that all users should have a similar scientific experience at the MLF regardless of the instrument "owner". We endorse the idea of "public beamtime" on the instruments owned by JAEA and KEK. We also encourage MLF leadership to ensure

that all instruments are staffed at levels consistent with those of a leading international neutron facility.

The IAC encourages MLF to continue its efforts to develop shared "user services" such as sample environment teams, computing groups *etc*. to efficiently assist users with complex experimental set-ups and to provide support for data acquisition, reduction, visualization and analysis.

MUSE Facility:

Recommendations:

The IAC recommends that the responsibility for the safe delivery of proton beam be shifted away from the MUSE staff to a single dedicated J-PARC-wide group with the expertise and capabilities to deal with these issues in a uniform site-wide manner, ensuring a uniform safety concept. IAC strongly recommends transferring the present MUSE effort responsible for M1/M2 proton beam delivery and muon production target to support MUSE users in order to develop and establish a strong and stable muon user community on the highest international standards. In this way a more uniform operation combining KEK and JAEA resources can be achieved, which is key to the further success of MLF.

The laser for USM generation is of pivotal importance for the experimental program at MUSE. IAC recommends setting up an external advisory team of laser experts to evaluate the present situation, and as a mid-term measure, to establish a "laser development and maintenance team" under the responsibility of J-PARC to ensure long-term stable laser operation for the various experiments requesting USM.

The IAC strongly supports the effort of J-PARC to secure the additional budget for the construction of the H-line to deliver the first beam in 2020, in order to start as soon as possible the exciting science program with the experiments muonium hyperfine structure, muon g-2/EDM, DeeMe and the muon transmission microscope.

TEF (Transmutation Facilities):

Recommendations:

The IAC recommends to start the ADS program with the TEF-T component and on accelerator related activities of interest to both the Accelerator Driven System (ADS) world community and J-PARC.

The IAC recommends to frame the ADS activities and developments of JAEA and J-PARC in the international on-going effort on P&T and ADS development for closing the fuel cycle.

INTRODUCTION:

The International Advisory Committee (IAC) for J-PARC met on March 4th and 5th at the J-PARC research building to review the progress and scientific achievements of J-PARC over the past year. The agenda for the meeting is given in appendix I, the committee's composition in appendix II and the charge to the committee in appendix III. A site visit took place in the afternoon of Tuesday March 5th when the committee toured the MLF experimental areas, the new extension for the COMET experiment and the near detector of the T2K neutrino experiment. The committee heard the view of the MEXT funding agency responsible for most of the support for J-PARC during a presentation by Mr. Atsushi Oku, director of the Office of Quantum Science and Technology at MEXT. Dr. Yukitoshi Miura, Executive Director of JAEA, reported on the situation at JAEA and how J-PARC fits in its renewed mandate. Dr. Junji Haba, Executive Director of KEK presented the situation at KEK and its support for J-PARC.

Safety has been elevated as the overriding priority for all J-PARC activities and the IAC was briefed on the progress made to implement a global safety culture for all permanent staff, contractual workers and users by Dr. T. Ishi.

The committee heard also from the advisory committees monitoring specific areas of the accelerator complex: the Accelerator Technical Advisory Committee (ATAC) represented by its chair Dr. Jie Wei, the Neutron (NAC) and Muon (MAC) Advisory Committees by Dr. K. Kiyanagi and Dr. T. Prokscha while the Transmutation Advisory Committee recommendations were presented by Dr. F. Maekawa. The J-PARC PAC for the particle and nuclear physics held in January 2019 was reported by Dr. K. Tokushuku, director of KEK-IPNS

The IAC attended two parallel sessions on the Materials and Life Science program and on the Particle and Nuclear Physics program. This increased the visibility of the recent scientific achievements and permitted a more direct interaction with key experimenters.

So overall the IAC had a good overview of the past year activities to address its mandate as set by the director.

GENERAL STATUS OF THE PROJECT:

Dr. N. Saito reviewed the major accomplishments of the past year. He placed his remarks in the context of the J-PARC action plan being implemented and showed how he responded to the

recommendations made by the J-PARC IAC last year. The key objective was to provide a safe and stable operation on the way towards high-power operation, with two priority milestones in terms of beam availability to users and science output.

By prioritizing beam availability and delivering more than 90% of the scheduled beam to MLF experiments and 84% to MR users, many groups collected data at a rate which allowed significant progress towards their scientific objectives. All areas produced significant results which were highlighted in the parallel sessions.

The concerted effort to connect with Universities, Industries and Institutes worldwide has continued and is leading to improved support for users. Four Japanese Universities have created branches at J-PARC focusing on support for research and education on site, four Memoranda of understanding have been recently signed with foreign institutes and strong partnership with industries have already led to the funding of special fellowships to support collaborative work (e.g., Sumimoto Fellowship). A notable effort is the creation of the Science Promotion Board at the MLF aiming at facilitating the extraction of results from data collected at the MLF by providing and supporting universal data analysis frameworks. The IAC strongly encourages this effort and values the strong leadership behind it.

The IAC was pleased to see that J-PARC has taken a key role in the RaDIATE organization which allows all major laboratories facing radiation damages issues (e.g. target failures) to share their experience and expertise. J-PARC is studying the radiation hardness of key materials for target and beam windows in very high beam power environment. This is bound to support solutions to the current limitations in power delivery to the various targets or beam windows on J-PARC's beamlines but also at other high-power laboratories.

The major focus of the laboratory is the project to upgrade the capacity of the Main Ring (MR) power supplies to allow a faster cycling rate. This is part of the intensity upgrade required by most experiments using either slow or fast extraction from the MR. Supplementary funding was allocated for the project at the expense of operational funding for the next three years. This is creating a challenging issue as the beam schedule for the MR program will be dictated in part by the progress on the upgrade but mainly by the lack of beam cycles afforded by the budget (3 instead of 7). However, a timely increase in the beam power and beam quality to MR users is crucial for the long-term success of the MR programs. **The IAC supports the priority given to the upgrade but also asks for a concerted action in trying to recover more beam delivery to users in the next three years.**

The laboratory had a successful review by MEXT (this is a mandatory 5-year review). The laboratory was able to demonstrate that it is on the path to and already delivering world class science and given adequate resources could be a world class international attractor for a wider range of scientific researchers. It is now focusing of implementing its five-year action plan to meet these goals.

SAFETY:

Management has made good progress towards implementing all the elements of a safe workplace at J-PARC, which includes: systematic safety reviews, a fully developed and broadly implemented work planning process, a safety culture that allows staff to speak up about unsafe behavior of others and prevent work from being conducted under unsafe conditions. The "Stop Work" policy is implemented locally at J-PARC through the work site manager, who then can also authorize the resumption of work.

The number of incidents at J-PARC continues its downward trend (2) over the last few years while the reported number of "near misses" has been increasing (16) indicating better staff awareness.

However, a serious incident occurred with a contractor worker who lost a finger. The post mortem evaluation indicated that in that case the work was not stopped although it had been perceived that it was done under unsafe condition. This illustrates the difficulty in imposing safety rules and standards to external contractor staff members in particular, and more generally, to non-J-PARC staff members. The safety group is quite aware of that limitation and we encouraged it to continue its effort to promote J-PARC safety culture to all participants. A site wide campaign to publicize the lessons learned from that incident should be considered as part of the extensive safety training being implemented throughout the J-PARC facility.

The IAC recognizes that the dedicated efforts by the safety group are bearing fruits but there is more to be done.

Regarding radiation safety matters, the host institutions have delegated their responsibilities with regards to the Radiation Hazard Prevention Act (RHPA) to the director of J-PARC, instituting a more direct line of reporting and action taking. This is a welcomed management change. The Safety group is addressing the requirements of the radiation hazard protection rules (RHPR) by revising the organization of the safety division adding two new positions in charge of continuous safety promotion and emergency crisis support.

Recommendations:
The IAC supports continued action to promote safety in all aspects of the laboratory activities. The strengthening of the safety group organisation is welcomed. Communications of lessons learned are quite an effective tool to reach the community, and special attention must be paid to external contractor staff members who may not consider J-PARC policies as overriding their internal company one while on site.

STATUS OF THE ACCELERATOR SYSTEMS:

Beam power and availability of the J-PARC accelerators have been steadily raising, reaching reproducibly world-leading performance. The Linac has been operating at an increased beam current of 50 mA peak. The beam power for MLF operation has increased to 500 kW with an availability of 94% and further power increases depend on the neutron target performance. The beam of the Main Ring (MR) for T2K and for slow ejection has reached new record power levels of 500 kW with 86% availability and 51 kW with 83% availability, respectively.

The J-PARC accelerator team is commended for these excellent results which were achieved pursuing machine improvements and system upgrades within the limit of budgetary constraints. Beam studies and R&D efforts have been performed pertaining to J-PARC's upgrade plans which include (i) increasing the peak current and doubling the repetition rate of the Linac for the benefit of the RCS and a future experimental facility for nuclear transmutation, (ii) ramping up beam power of RCS beyond 1 MW to ensure a net 1 MW beam delivery to MLF after MR repetition upgrade as well as feeding future second target station and (iii) staged beam power ramp up of MR to 1.3 MW for meeting demands of neutrino experiments, Hadron Hall extension, COMET-II, and g-2/EDM programs.

Ten years after the J-PARC facility started operating, components show signs of aging and deserve being progressively replaced and/or updated. To preserve and increase the achieved beam power and availability, the regular maintenance work has to be complemented with additional resources subsidizing a healthy consolidation/update programme. A risk-based approach is recommended to properly prioritize these actions.

- Maintain and preferably increase availability by starting to regularly invest in hardware consolidation, with prioritization based on an extensive risk assessment of all elements in accelerators and infrastructure.

Beam power of the J-PARC accelerators can severely damage equipment and cause long duration beam stops. Improper control values can nowadays be entered by human error and the Machine Protection System cannot always interrupt beam in all cases, as revealed by an incident in 2018.

- Implement a Run permit system as a capacity of the accelerator control system, combined with a robust Machine Protection System to avoid accidents that might lead to long duration beam stops.

Contrary to linac and RCS, the MR needs significant hardware changes to reach the nominal beam power of 750 kW.

- Proceed as soon as possible with construction and implementation of improvements required for increasing the MR beam power first at 750 kW and progressively to higher levels. Debugging of the new MR power supplies is likely to require long duration tests.

The number of protons per bunch has to be increased up to $4x10^{13}$ ($3.1x10^{13}$ p/b today) to bring the MR beam power up to 1.3 MW. Longitudinal coupled bunch instabilities observed slightly above today's operational intensity show that extensive beam studies and simulations will be required to reach that goal.

-Plan for additional beam study time to analyse and fix issues with higher beam intensity in the MR.

SCIENTIFIC PROGRAMS:

Particle and Nuclear Physics:

The J-PARC particle physics program includes the neutrino program, the kaon decay physics program in the hadron hall and the muon physics program consisting of the COMET experiment under construction in the hadron hall and the new g-2/EDM experiment in the muon beams of the MLF facility.

During JFY 2018 the Main Ring (MR) delivered about 500 kW beam power with $3.1x10^{13}$ protons per bunch and an availability of 86% for the neutrino program (1053 net hours). The hadron program had 725 net hours of operations with about 50 kW of beam power in MR slow extraction with an availability of 83%. The availability of the MR has improved over previous years and the availability is good. However, the infrastructure is beginning to show its age after ten years of operation and exposure to the rough climate near the sea shore. Deferred maintenance may cause an extended downtime and poses a risk to the science programs.

The laboratory has embarked on a program to upgrade the MR Power Supplies. This high priority upgrade is scheduled to be completed and installed in JFY 2021. The improved beam power will greatly enhance the potential of the neutrino program, particularly if the proposed Hyper-Kamiokande experiment goes ahead as planned. The IAC strongly supports the decision to move quickly on this upgrade but recognizes there will be an impact on the physics program in the short term due to limited running time that results from predicted budget constraints. The MR run schedule in JFY 2019 will be greatly reduced and beam time in JFY 2020 is likely to be significantly impacted as well. The MR will then be shut down in JFY 2021 for installation of the upgrade. Availability and reliability of the complex will be even more critical during this period. The risk to lose researchers to other facilities will certainly grow if this trend of limited beam time

continues. **We recommend a return to a 6 or 9 months running schedule to fully exploit the planned upgrades to 1MW and 1.3MW.**

Neutrino program:

The contribution of J-PARC to understanding neutrino oscillations via the T2K experiment continues to be world leading. The collaboration has grown recently and currently has about 500 members from 12 countries. T2K has accumulated 3.16×10^{21} Protons on Target (POT) which is about 40% of the approved statistics. The high priority upgrade for the MR power supplies will enhance the neutrino program and keep it competitive throughout the next decade. The T2K physics program will certainly benefit from the increased beam power, but the full benefit will be achieved if the Hyper-Kamiokande project goes ahead as planned.

T2K will have a shortened physics run in JFY 2019 due to budget constraints. The target will be replaced. The next run follows the recent Super-Kamiokande (SK) refurbishment in preparation for SK-Gadolinium operations. Gd loading is used to capture thermal neutrons and is used to tag $\bar{\nu}_e$.

T2K published 5 papers in 2018 including the "Search for CP Violation in Neutrino and Antineutrino Oscillations by T2K Experiment with 2.2×10^{21} Protons on Target". This analysis showed a 2σ hint of $\bar{\nu}_e$ appearance and an intriguing hint towards δ_{CP}. In this result, CP conserving values $(0, \pi)$ fall outside of the 2σ CL intervals. T2K sensitivity at 3σ for δ_{CP} is possible following the planned MR power supply upgrades and significant running time through the mid2020s. Competition with the NOvA experiment in the US that is scheduled to run until 2024 is both strong and constructive. Discussions have already begun on how best to combine the results at some time in the future.

The upgrade of the near detector upgrade (ND280) developed in collaboration with CERN is aimed at reducing the systematic errors for the measurement of ν cross sections and the properties of the un-oscillated neutrino beam.

The proposal was recently reviewed by the PAC. ND280 and the neutrino beam line upgrades for 1.3 MW beam power are planned for installation before the end of the shutdown in 2021.

A new experiment, JSNS2, is planned to start operations with a baseline of 24 m at the MLF and will perform as search for Sterile Neutrinos. The experiment is under construction with a projected quick start-up by June 2019.

The neutrino program is a highlight of the J-PARC physics program and will rapidly profit from the planned MR upgrades with more protons on target. The completion of the upgrade is thus identified as the highest priority. The committee notes however that the experiments will subsequently need reliable high-power operations with maximal user time and availability.

Kaon Physics:

The KOTO experiment:

The KOTO experiment has made progress towards reaching the Nir-Grossman limit for the branching ratio $K_L^0 \to \pi^0 \nu\bar{\nu}$. The IAC congratulates the KOTO collaboration on the recent publication of the 2015 results. They set an upper limit of 3.0×10^{-9} for the branching fraction of $K_L^0 \to \pi^0 \nu\bar{\nu}$ at the 90% confidence level (C.L.). This new result shows an improvement of a factor of 10 over the previous best measurement. Improved analysis techniques and an added photon veto system should improve the background rejection in their analysis of the KOTO data collected in the period 2016-2108. The committee looks forward to the publication of the 2016-2018 dataset with factor of 1.4 more statistics. With this data, KOTO should have single event sensitivity (S.E.S) of $8.2\text{x}10^{-10}$, below the current indirect upper limit known as the Nir-Grossman bound.

The collaboration completed a detector upgrade aimed at rejecting hadron cluster background during the autumn of 2018. New charged veto counters were installed inside the vacuum pipe. Data taking with the upgraded detector is underway.

The expected S.E.S for the combined 2015-2018 is $5\text{x}10^{-10}$. Sustained stable running with the current detector could bring KOTO to a result below 10^{-10} within a few years. However, significant and stable running with ideal background conditions and 50-100 kW beam power will be required for KOTO to approach SM sensitivity ($3.0\text{x}10^{-11}$).

Muon Physics:

COMET:

The COMET experiment will search for coherent neutrino-less conversion of a muon to an electron. Progress has been made on the high-momentum/COMET beam line and is scheduled to be completed in JFY 2019. The construction of the first phase of the experiment with the beam line, the Pion Capture Solenoid and the first part of the Muon Transport Solenoid (COMET-I) is scheduled to be completed in JFY 2022. There will be significant competition from the Mu2e experiment at Fermilab which will have greater sensitivity and is currently scheduled to start collecting physics data in 2022.

g-2/EDM:

The g-2/EDM experiment at the MUSE facility in the MLF has made good progress and has received Stage 2 approval. The collaboration is now 102 members from 8 countries. Muon RF

acceleration was demonstrated resulting in publications in 2018 and a PhD thesis at the University of Tokyo. Acceleration up to 1.3 MeV is expected to be achieved soon. However, for the experiment to proceed to physics operations, the ultra-slow muon source (USM) at the MUSE facility is needed. The facility will need to find way to solve the issues with the ionization laser. Although there is significant competition for the measurement of muon anomalous magnetic moment from the FNAL Muon g-2 experiment which has already collected physics quality data, this experiment will remain interesting since it uses an entirely different experimental approach and will hence have different systematic uncertainties.

Nuclear Physics:

The hadron and nuclear physics programs at J-PARC focus on poorly known hadron-hadron interactions and their impact on high density nuclear matter. There are several reasons why this is a particularly advantageous time for this research. First, ab initio quantum chromodynamics calculations have progressed to the point where they are beginning to make more controlled predictions of the hitherto poorly known interactions of many-baryon systems, such as the Σ hyperon-nucleon interaction and multi-hyperon-nucleon forces. Secondly, the multi-messenger observations of neutron star mergers provide a striking new window into high-density baryonic matter where hyperon-nucleon two and three-body forces can play important roles. Finally, there is world-wide interest in recent J-PARC data that shed important new light on these issues.

One of the highlights of the J-PARC program is the publication of the J-PARC data revealing that the K^-pp system has a bound state with a binding energy of 47 +/- 3 MeV. A number of theoretical approaches had suggested such a bound state would exist, but only hints of such a bound system have been observed in previous measurements. The high statistics J-PARC E15 results are definitive.

A second highlight is the success of the J-PARC E07 hybrid emulsion experiment to increase the number of observed double-Λ hyper-nuclei by factors of almost an order of magnitude compared to previous studies. These new hyper-nuclear isotopes give unique information on the ΛΛ interaction that is almost impossible to obtain by any other means. The first analysis of the emulsion data is about half complete and is proceeding rapidly.

Several other experiments casting light on the theme of hyperon-nucleon interactions include studies of the Σ-p interaction (E40) and Ξ-nuclei (E03, E70).

The program with the slow extracted beam is proceeding well. Over the last two years operation has been stable at 50 kW beam power, limited only by the production target, and important improvements continue to be made on the duty factor. A new design of the production target that doubles the cooling power is expected to be able to handle 90 kW of beam power and the plan is to operate at the 70 kW level by the end of 2020 and 80 kW in 2022. This new target will be

installed between June and January JFY 2019. During this shutdown, the new high-p beam line will be completed. With the high-p beam line in place, the number of experiments in the hadron hall that can simultaneous take beam increases from two to three. The first experiment with this new beam line, a search from modifications of the phi-meson mass spectrum in the nuclear medium, is scheduled for beam in 2020.

The primary issue for the science program with the Main Ring has been the limited funding for Main Ring operation that has a strong negative impact on T2K, KOTO, and the nuclear physics program. **The IAC agrees with the laboratory that the highest priority needs to be given to the Main Ring power supply upgrade for the next three years**. At current budget levels this constrains the Main Ring program to perhaps 3 cycles of operation in 2019 and 2020, and a 1-year shutdown in 2021. Once the COMET experiment on μ to e conversion is ready in 2022, operation of the rest of the slow extracted beam program will be limited by the need for COMET to operate at a lower extracted beam energy.

Recommendations

The IAC reiterates that it strongly supports the laboratory decision that the highest priority needs to be given to the Main Ring power supply upgrade for the next three years. The Program Advisory Committee (IPNS PAC) made the following 2 recommendations at its last meeting in January2019 and the IAC endorses them fully:

"The committee strongly recommends that every effort be made to restore the beam time availability [of the Main Ring] at J-PARC to at least 6 months per year during the period of upgrades towards 1.3MW and to the full 9 months per year afterwards, so that the world-wide scientific community can benefit fully from the unique facilities at J-PARC".

On the beam time allocation in JFY2020, "The committee concludes that even in the case of such severe limitations on operations, the available time should be divided approximately equally between the hadron program (SX) and the neutrino program (FX). **There are proposed hadron hall experiments that can conclude in an order of one or two months and deliver important results. The neutrino program can gain valuable experience for operations with the new near detectors (WAGASCI/ baby MIND) as well as with Gd doped SuperK that will be available for JFY 2020."**

Materials and Life Science Experimental Facility (MLF):

MLF - Neutrons

The Materials and Life Science Experimental Facility (MLF) has the potential to be a world leading research institute. The combination of the proton power on the target, the 25 Hz frame rate, the exceptional design of the moderators, and 20 developing instruments provide the scientific community in Japan and around the world an outstanding resource for neutron-based research. In the past, issues with the mercury target including unanticipated failures have limited the productivity of the MLF. Thus, the IAC was pleased to hear that the operation has been stable at 0.5 MW during the current run year. The current target (#9) has performed well allowing the MLF to achieve an impressive availability of 94%. This type of performance is essential for maximizing the scientific return on the considerable investment Japan has made in neutrons at J-PARC. Thus, the IAC applauds this remarkable achievement.

The excellent performance of the current target was fortunate as the MLF has been running without a spare target of equivalent quality to #9 since the summer outage and thus a target failure would have caused an extended shutdown and low power operation of the MLF. The IAC is pleased that three new targets are under construction and that the target procurement plan provides for two spare targets at all times – if there are no more unexpected failures. While the design of the three targets being fabricated is fully informed by the hard-won experience with previous target failures, the IAC notes that this design has not been verified in actual operation. We also note that the MLF does not have any spare targets that could be used in the case that the design of the three new targets has a serious flaw. The new targets therefore represent a single point-of-failure that could cause an extended outage of the MLF. Thus, we believe that the MLF should adopt a conservative approach that prioritizes reliability over power. And we note that the excellent design of the target-moderator assembly along with 25 Hz operation already delivers substantially more cold neutrons per pulse than the SNS delivers at a power of 1.4 MW. In other words, the MLF is already ahead in the "neutron race".

Recommendation

The MLF should continue to prioritize stable operations over quickly achieving 1 MW as reliable operation is essential for producing science and securing J-PARCs reputation.

It also is essential that the MLF learn as much as it can from post irradiation examination (PIE) on each target. This is particularly true for the next target (#10 or #11). To the extent possible, the next target should be operated to maximize the information that can be gained from PIE.

The IAC again congratulates J-PARC on developing an exceptional suite of neutron instruments that the MLF has made available to the scientific community. It is also notable that more than

1,000 scientists used the MLF in the past year. However, scientific success requires more than an excellent source, great instruments, and a lot of users. Thus, it is disappointing that despite the MLF's considerable achievements, the number of publications is still low by international standards. We hasten to note that the large industrial engagement (27%) will significantly reduce the number of publications (probably by 20% or so). But there is still a shortfall. MLF and J-PARC leadership clearly understand this and have taken steps to promote the scientific utilization of the excellent facility they have developed. The IAC applauds these initiatives. In particular, we are impressed by the sensible recommendations made by the Science Promotion Board that should foster better collaboration between MLF scientists and universities. If followed, their recommendations could lead to very effective training of the next generation of scientists well-versed in neutron methods thereby enhancing the neutron community in Japan.

We also note that "solutions" that don't directly address real problems are likely to distract staff from actions that might improve the situation. Moreover, beginning further initiatives to promote science are likely to be distractions. In addition, although the long-term plan for the MLF must include a 2nd target station, the immediate priority should be on realizing the potential of the considerable investment already made in the MLF.

Recommendation

The MLF should concentrate on exploiting the world-leading capabilities provided by its excellent neutron instruments and intense source of neutrons. The current emphasis on producing good science must be maintained and the current initiatives continued for a period of time to allow them to bear fruit. Now is the time to capitalize on the substantial investment made in the MLF, rather than pursue additional initiatives which could be distractions.

While the number of publications may be lower than expected the quality of the publications is easily at the world standard. The IAC members who attended the parallel session on MLF results were quite impressed by quality of science presented. Of note, Toyota considers a new Li ionic conductor ($Li_{9.54}Si_{1.74}P_{1.44}S_{11.7}Cl_{0.3}$) as a candidate for a solid electrolyte of all solid state Li-ion batteries in their 2022 electric vehicles thereby reducing the risk of fire. The development of this material was greatly facilitated by neutron diffraction results from the MLF (Nature Materials (2011) & Nature Energy (2016)). The 2011 paper in Nature Materials is one of the most cited neutron papers of the last decade.

To fully exploit a facility like the MLF and to achieve outstanding results it is important to optimize every single element of the value chain from proposal submission to the publication via the performance review of all aspects of the experiment including data analysis. As outlined above MLF can now count on a reliable operation of its source and features an impressive suite of modern instruments. These are perfect conditions for high scientific output provided the auxiliary services are at the same level of performance. Typical examples for such services are sample environment and data reduction and analysis software. To provide the best possible services, the limited resources available have to be used in the most efficient manner. A good way of enhancing the leveraging power of these resources is standardizing the services over the facility with the added

benefit of a common touch and feel for the users. This overarching approach should be considered in all cases where specific solutions bring no added value for science. The management of this process continues to be challenging as four different organizations operate instruments in the facility. This has led in the past to instruments having very different levels of support for their users. MLF and J-PARC leadership have recognized the need for this efficiency and have taken some important initial steps to try to improve the situation. The IAC considers the use of public beam time particularly promising in this respect. The IAC was impressed with the initiative to engage young staff members to help develop a workable "business model" for 1 MW operation.

Recommendations

The IAC strongly believes that all users should have a similar scientific experience at the MLF regardless of the instrument "owner". We endorse the idea of "public beamtime" on the instruments owned by JAEA and KEK. We also encourage MLF leadership to ensure that all instruments are staffed at levels consistent with those of a leading international neutron facility.

The IAC encourages MLF to continue its efforts to develop shared "user services" such as sample environment teams, computing groups *etc.* to efficiently assist users with complex experimental set-ups and to provide support for data acquisition, reduction, visualization and analysis.

Materials and Life Science (MUSE Facility):

The IAC is pleased to see that the MUSE team is doing outstanding work in all fields of its responsibilities. The previous year has seen a good publication record, reflecting a high standard of productivity, and IAC recognizes that MUSE is attracting an increasing number of proposals. In the ongoing transition from the construction phase to operational mode, user operation in the D1/D2 and S1 areas have been established, while the user program benefited from a world-class proton beam availability of 94%. The negative muon program in D1/D2 is making good progress, and the IAC is very pleased to hear that MUSE provided crucial contributions to the approval of the project "Toward new frontiers: Encounter and synergy of state-of-the-art astronomical detectors and exotic quantum beams" for the Grant-in-Aid for Scientific Research on Innovative Areas in 2018. This will accelerate the further progress in the applications of negative-muon beams and the generation of a focused negative-muon beam, followed by the establishment of a muon-microscope technique. Commissioning of the USM beam line is continuing with improved laser stability, optimized generation of ω_2 light, improved beam transport and μSR spectrometer. However, the absolute counting rate is still about two orders of magnitude too low for a user facility operation, mainly due to the lack of a high-quality laser amplification ceramic rod for the

generation of Lyman-α light. The planning of the H-line construction is well set up with high priority, with beam expected in 2020.

IAC acknowledges that safe operation of MUSE has highest priority. An appropriate plan has been set up to avoid tritium release from the muon production target. The muon target experienced an unexpected failure of a coaxial coupler. A good repair/exchange plan has been developed, and continuous improvements on monitoring of the status of the muon target, including improved interlocking system, will ensure a safe operation of the facility.

Working groups of the J-PARC MLF division and of the Japanese Society of Neutron Science and the Society of Muon and Meso Science of Japan continued their evaluation plans for a future target station 2 in MLF. A conceptual design report (CDR) is currently being prepared, and a letter of intent will be submitted in March 2019 to the Science Council of Japan (SCJ) for the Japanese Master Plan of Large Research Projects.

Recommendations:

The IAC recommends that the responsibility for the safe delivery of proton beam be shifted away from the MUSE staff to a single dedicated J-PARC-wide group with the expertise and capabilities to deal with these issues in a uniform site-wide manner, ensuring a uniform safety concept. IAC strongly recommends transferring the present MUSE people responsible for M1/M2 proton beam delivery and muon production target to support MUSE users in order to develop and establish a strong and stable muon user community on the highest international standards. In this way a more uniform operation combining KEK and JAEA resources can be achieved, which is key to the further success of MLF.

The laser for USM generation is of pivotal importance for the experimental program at MUSE. IAC recommends setting up an external advisory team of laser experts to evaluate the present situation, and as a mid-term measure, to establish a "laser development and maintenance team" under the responsibility of J-PARC to ensure long-term stable laser operation for the various experiments requesting USM.

The IAC strongly supports the effort of J-PARC to secure the additional budget for the construction of the H-line to deliver the first beam in 2020, in order to start as soon as possible the exciting science program with the experiments muonium hyperfine structure, muon g-2/EDM, DeeMe and the muon transmission microscope.

Target Station 2

The IAC welcomes studies of the MLF target station 2 and encourages the continuation on the conceptual design from a long-term viewpoint.

Nuclear Transmutation:

Dr F. Maekawa, the deputy head of the Nuclear Transmutation Division of J-PARC reviewed the progress made in the past year by its team and outlined the conclusions of the recent review by the T-TAC committee. JAEA plans to build the ADS Target Test Facility (TEF-T) to study some of the basic characteristics of an ADS system and evaluate its feasibility. The necessary R&D and design studies for the TEF-T were carried out and resulted in a comprehensive Technical Design Report (TRD) which was submitted and reviewed by the T-TAC committee. In parallel and as reported also by Dr. Y. Miura (see JAEA's section below), JAEA is reorienting its ADS program towards an advanced modeling and simulation effort using state of art computing methods which will rely on existing experimental facilities for validation.

By focusing on the TEF-T part of initial ADS program and leaving out the TEF-P part with its inventory of fissile material, the facility would be easier to integrate into the open access laboratory as intended for J-PARC. Moreover, it is proposed to enlarge the ADS activities towards high power accelerator reliability and stability studies and on high power targetry which could be benefit to both the ADS community and J-PARC or other accelerator spallation facilities. This would be a win-win situation for J-PARC and JAEA. The JAEA expertise in post irradiation evaluation of high-power targets is also of interest for the whole of J-PARC target systems.

JAEA and J-PARC should be revisiting the ADS and waste transmutation program in the light of the NI2050 OECD/NEA on-going roadmap[1] and in particular the one related to the "**Closed fuel cycle and P&T**" and considering the complementarity on the proposed catalogue for TEF-T with the already decided MYRRHA project in Belgium or other facilities of the same type.

Recommendations:

The IAC recommends to start the ADS program with the TEF-T component and on accelerator related activities of interest to both the ADS world community and J-PARC.

The IAC recommends to frame the ADS activities and developments of JAEA and J-PARC in the international on-going effort on P&T and ADS development for closing the fuel cycle.

[1] https://www.oecd-nea.org/ndd/ni2050/

Institutional Support:

MEXT view of J-PARC:

The IAC heard a presentation from Mr. A. Oku, director of the Office of Quantum Science and Technology at MEXT. MEXT supports 4 major projects of national interest: J-PARC, SPring 8, the Kei Super computer facility and the newly approved synchrotron light facility at Sendai.

He reported on the conclusions of the five-year review of J-PARC which evaluated the progress and performance of J-PARC laboratory, its scientific results and its new initiatives. The main recommendations were to work on reaching the design parameters for the accelerator and beam power delivered, to complete the upgrade of the Main Ring to provide high intensity beams to neutrino and hadron users and to develop a business model to augment the research budgets and attract new users.

JAEA's view of J-PARC:

Dr. Y. Miura gave an overview of the JAEA revised mission, which is oriented towards supporting the Japanese nuclear power program and more specifically the efforts of decommissioning nuclear power related facilities. JAEA is fully committed to supporting the pulsed neutron MLF program but is also restarting a related DC neutron source based upon the JRR-3 reactor on site. This combination could provide a very unique resource for neutron users if a symbiotic integration of the two programs is realized and if a strong user program is supported on both.

JAEA is considering reorienting its ADS program towards more development of advanced modeling and simulation, and high-performance computing methods to improve designs of future ADS, reduce uncertainty in facilities development and construction costs. *The new program is named PSi for: Proton accelerator-driven Subcritical virtual system.*

For verification and validation of developed modeling and simulation method, JAEA will make the best use of existing experimental facilities.

KEK's view of J-PARC:

As reported by Dr. J. Haba, KEK manages four major projects funded through MEXT: J-PARC, SuperKEKB, the photon factory and the Japanese contribution to the HL-LHC. The upgrades to the CERN LHC facility (Dipole Magnets, Muon detectors and tracker upgrade) are on a tight schedule dictated by the CERN shutdown schedule. SuperKEKB is now fully commissioned and taking data with a full complement of detectors. Its operating budget needs to ramp up some more. The J-PARC MR upgrades have been given top priority and require supplementary funding which was allocated this past year. With all these constrains, KEK is not likely to fund more than 3 beam cycles from the MR in JFY 2019 and possibly in JFY 2020 and anticipates a year long shutdown in 2021 for the upgrades' installation. Every effort should be made to improve this limited science program in the transition towards the 1 MW operation after the upgrade.

Conclusions:

The IAC had a good overview of all aspects of the J-PARC operation thanks to well prepared presentations. Excellent progress was made last year especially in responding to the recommendations made at the last review to focus on the delivery of science at the expense of pushing the frontiers of the beam intensity. A conservative approach was followed to minimize target failure risks and optimize beam delivery to users. This paid off for MLF users and MR users who produced exciting new results. The laboratory successfully passed its five year review and received strong endorsement from MEXT. Together with a significant improvement in establishing a safety culture at all levels, the IAC finds that J-PARC is operating more and more along international norms.

Challenges remain in particular with the development of reliable high-power targets and with operation funding levels for the MR. The upgrade of the MR power supplies is continuing with high priority with supplementary funding allocated recently. The time scale for this to happen is JFY 2022 and further delay will affect the competitivity of the science program, notably the neutrino effort to nail down the parameters of CP violation in the neutrino sector and the rare Kaon program in the hadron hall. The very limited funding for the running of the MR is a concern for the next three years and every effort should be made to increase the beam time to MR users to not loose their commitment.

Nevertheless, the IAC considers that the future of J-PARC is quite attractive and that a good case can be made to obtain the resources needed to operate the facility reliably and at high power level.

J-PARC management has focused on the near future and urgent requirements (MR power supplies and high-power targets) but is also reviewing the longer term aspirations like a second neutron and muon target, Hadron hall extensions and a heavy ion program.

The J-PARC team is to be congratulated for achieving world class status in many aspects of the scientific program in its first ten years of operation. The IAC is pleased to extend its best wishes for the future.

Appendix I
Agenda for the International Advisory Committee Meeting of J-PARC in 2019

Agenda for the International Advisory Committee Meeting of J-PARC in 2019

Date: March 4 (Mon) and March 5 (Tue), 2019
Place: J-PARC Research Building

March 4 (Mon)

Executive Session				
8:30 –	8:45 (10 + 5)	Charge to the Committee		Naohito SAITO
8:45 –	8:55 (10)	Introduction to JAEA evaluation		Masatoshi FUTAKAWA Kazuhiko SOYAMA
Opening				
8:55 –	9:30 (30 + 5)	Report from the Director		Naohito SAITO
9:30 –	9:55 (20 + 5)	Safety at J-PARC		Tetsuro ISHII
9:55 –	10:05 (10)	Coffee		
Accelerator				
10:05 –	10:30 (20 + 5)	Progress and Prospects		Kazuo HASEGAWA
10:30 –	10:50 (15 + 5)	A-TAC View of Accelerator Activities		Jie WEI
Material and Life Science I				
10:50 –	11:20 (25 + 5)	Overview of Neutron Facility		Toshiji KANAYA
11:20 –	11:50 (25 + 5)	NAC Review		Yoshiaki KIYANAGI
11:50 –	12:40 (50)	Lunch		
Material and Life Science II				
12:40 –	13:00 (15 + 5)	MUSE Status		Yasuhiro MIYAKE
13:00 –	13:20 (15 + 5)	MAC Review		Proksha THOMAS
Particle and Nuclear Physics				
13:20 –	13:40 (10 + 10)	Overview of Particle and Nuclear Physics		Katsuo TOKUSHUKU
13:40 –	14:00 (15 + 5)	Particle physics experiments		Ken SAKASHITA
14:00 –	14:20 (15 + 5)	Nuclear physics experiments		Toshiyuki TAKAHASHI
14:20 –	14:30 (10)	Coffee		
Parallel Sessions				
[Material and Life Science]				
14:30 –	14:45 (10 + 5)	High-Energy Spin-Fluctuations in Iron-Based Superconductors – Using neutron to reveal electron correlation effects –		Naoki MURAI (JAEA)
14:45 –	15:00 (10 + 5)	In-situ observation of change of hydrogen bond of mineral in the Earth's mantle		Asami SANO (JAEA)
15:00 –	15:15 (10 + 5)	Neutron Spin Echo Spectrometers "BL06 VIN ROSE" at MLF		Hitoshi ENDO (KEK)
15:15 –	15:30 (10 + 5)	Dynamics of Rubbery Dead Layers Bound on Carbon Surfaces		Koichiro HORI (KEK)
15:30 –	15:45 (10 + 5)	Local electronic structure of interstitial hydrogen in pyrite		Hirotaka OKABE (KEK)
[Particle and Nuclear Physics]				
14:30 –	14:45 (10 + 5)	KOTO – rare kaon decay		Koji SHIOMI (KEK)
14:45 –	15:00 (10 + 5)	T2K – neutrino oscillation		Megan FRIEND (KEK)
15:00 –	15:15 (10 + 5)	E07 – Λ Λ hypernuclei with emulsion		Junya YOSHIDA (JAEA)
15:15 –	15:30 (10 + 5)	E15 – kaon nuclear bound state		Takumi YAMAGA (RIKEN)
15:30 –	15:45 (10 + 5)	g-2/EDM – muon acceleration		Ryo KITAMURA (JAEA)
Executive Session (closed)				
15:50 –	17:15 (85)	Review and Discussion		IAC Members
17:15 –	17:25 (10)	Group Photo		
Views from Funding Agency and Host Institutes				
17:25 –	17:45 (15 + 5)	Recent Topics of the Quantum Science and Technology Policy in Japan		Atsushi OKU
17:45 –	18:05 (15 + 5)	KEK and J-PARC		Junji HABA
18:05 –	18:25 (15 + 5)	JAEA and J-PARC		Yukitoshi MIURA
Banquet				
19:00 –	21:00 (120)	Banquet		

March 5 (Tue)

Accelerator Driven Transmutation Research				
9:00 –	9:40 (30 + 10)	ADS Project		Fujio MAEKAWA
Executive Session (closed)				
9:40 –	11:30 (110)	Review and Discussion, Drafting Recommendations		IAC Members
Close out				
11:30 –	12:00 (30)	Recommendations		Jean-Michel POUTISSOU
12:00 –	13:30	Lunch		

Appendix II

IAC Committee members for 2019

	Name	Affiliation	Position	Field
1	Jean-Michel Poutissou (chair)	TRIUMF	Associate Director & Nuclear Medicine Division Head emeritus	General
2	Prokscha Thomas	Laboratory for Muon Spin Spectroscopy The Paul Scherrer Institute	LEM Group Head	Muon
3	Jun Sugiyama	Toyota Central R&D Labs., Inc.	Fellow	
4	Jie Wei	Michigan State Univ.	FRIB Accelerator Systems Division Director/Professor	ACC
5	Roland Garoby	European Spallation Source	Technical Director Machine Directorate	
6	Eckhard Elsen	The European Organization for Nuclear Research(CERN)	Director for Research and Computing	Particle
7	Patricia McBride	Fermi National Accelerator Laboratory	CERN Liaison, Office of the CRO	
8	Robert Tribble	Brookhaven National Laboratory	Deputy Director for Science and Technology	Particle/Nucl
9	Donald F. Geesaman	Argonne National Laboratory	Distinguished Argonne Fellow	Nucl
10	Paolo Giubellino	GSI Helmholtzzentrum für Schwerionenforschung	Scientific Managing Director of GSI and FAIR	
11	Hamid Ait Abderrahim	SCK・CEN	Deputy Director-General International Relations of SCK・CEN and Director MYRRHA project	ADS
12	Akira Hasegawa	Department of Quantum Science and Energy Engineering, Graduate School of Engineering, Tohoku University	Professor	
13	Paul Langan	Oak Ridge National Laboratory	Associate Laboratory Director, Neutron Sciences Directorate	Neutron
14	Hidetoshi Fukuyama	Tokyo University of Science	Adviser to the Chair and the President	
15	Dan Alan Neumann	National Institute of Standards and Technology	Group Leader of Neutron Condensed Matter Science Group, NIST Center for Neutron Research	
16	Andrew Dawson Taylor	National Laboratories, Science and Technology Facilities Council	Executive Director	
17	Helmut Schober	Institut Laue-Langevin	Director	

Appendix III

Charges to IAC2019 from J-PARC by N. Saito, director

Charge to IAC 2019

- Evaluate overall performance of J-PARC Center
  - Promotion of science with safety
    - Each facility should have a good balance of user program and facility improvements
    - Future vison of the facility
- Review safety activities at J-PARC
  - Safety culture is well penetrated thru staff and users?
- Any suggestions to improve the total performance are welcome. Our concerns include but not limited to
  - Budget situation
  - Open access for users
  - More uniform operation combining KEK, JAEA, and CROSS efforts is critical to further success of MLF

J-PARC IAC 2019