Report of the 22nd Meeting of the Accelerator Technical Advisory Committee for the Japan Proton Accelerator Research Complex (J-PARC)

January 26 – 28, 2023
Hybrid Meeting

The Accelerator Technical Advisory Committee (A-TAC) for the J-PARC Project held its twenty-second meeting from January 26 to 28, 2023, at the J-PARC Research Building in Tokai, Japan. Zoom connections were provided for committee members who were unable to attend in person. The A-TAC members participating were: Alexander Aleksandrov (ORNL), Wolfram Fischer (BNL), Simone Gilardoni (CERN), Mats Lindroos (ESS), Toshiyuki Shirai (QST), John Thomason (STFC), Sheng Wang (IHEP), Robert Zwaska (FNAL) and Jie Wei (MSU, chair) (Appendix 1).

The A-TAC thanks the J-PARC management and staff for their thoughtful arrangement of this in-person / remote hybrid meeting under the COVID-19 circumstances, and all the presenters for their excellent and comprehensive talks. In addition, the accelerator team responded appropriately, arranging specific talks to the requests made at the last A-TAC Review and to the questions and homework requests from the committee at this review.

Executive Summary

Since the last A-TAC review held in February 2022, the J-PARC accelerator complex has continued to maintain high beam power with an impressively high machine availability for a scientific user facility for both discovery and applications. The beam power for MLF operation is steadily in the range between 730 kW and 830 kW with availability above 96%. The beam power capability for MR-FX to the neutrino experimental facility and MR-SX to the hadron experimental facility have been maintained at 510 kW and 64 kW, respectively. This past year has been dominated by the extensive upgrades of the Main Ring including installations, commissioning, and beam tests for higher beam powers. A-TAC commends the J-PARC accelerator teams for their diligent efforts and congratulates J-PARC on retaining the status of world's highest intensity of neutron pulsed beam.

A-TAC was presented with J-PARC Accelerator Division's near-term plan until year 2028 of attaining high-availability operation at 1 MW beam power level to be realized by steadily increasing beam power annually by 100 kW, and to complete MR power upgrade project meeting design goals. The KEK Project Implementation Plan (PIP) until 2028 did not include priorities pertaining to extending J-PARC's accelerator capabilities. The proposed plan for KEK-side of J-PARC for the next 10 years includes raising accelerator beam power to 1.3 MW, hadron/muon

experiments in the HD hall and HD hall extension, T2K and upgrade for HK, neutron/muon in MLF, and muon g-2/EDM in MLF. Responding to the call by the Science Council of Japan for "medium- to long-term academic research strategy", submitted J-PARC related projects include those extending the accelerator capability with high-intensity heavy-ion beams at J-PARC for study of super high-density matter, MLF second target station for innovative developments in neutron and muon science, and ADS test facility and user facility for nuclear engineering.

During the past year, the J-PARC accelerator complex operated smoothly with no reportable incidents on personnel safety or machine protection.

Commissioning of the new MR power supplies has been challenging. Several events of device or system failures delayed the progress of testing and beam commissioning. While acceleration, extraction, and optics tuning at 8 GeV have been successful, the planned 30 GeV acceleration, extraction, and tunings for user operation have been delayed. Device failures further exposed vulnerability to a shortage of spare components with long lead time. As the root causes of failure events are not all clear, contingency plans are needed to prevent further delays to user operations.

The cost of electricity in Japan has fluctuated in recent years, nearly doubling within the last two years. This unanticipated cost threatened to reduce MLF operation in JFY2022 by 51 days. J-PARC worked to secure additional funds and reduced that impact to 16 days. Nevertheless, the high present costs would reduce the anticipated beam time in JFY2023 by more than half to 60 days for both RCS/MLF and the Main Ring. J-PARC continues to seek additional funding to increase operations hours after the summer shutdown.

The J-PARC accelerator team has addressed most of the ten A-TAC 2022 recommendations. Presentations were given at this review covering the six topics requested by A-TAC at the 2022 Review. Responses to the three homework assignments at the 2023 Review were timely and comprehensive. The committee commends the J-PARC team on their dedication and vigor addressing pressing issues.

In the following, we summarize the main recommendations of the A-TAC 2023. Each of the recommendations (**R01 – R13**) will be elaborated multiple times across the main body of this report following committee findings and comments. The order of the main body of this report follows the fourteen talks (Appendix 2) and three homework assignments presented at this review.

Key technology development, resource build up, and prioritized prototyping for major new capability extensions like heavy ion beam technology, superconducting RF (SRF) for transmutation and accelerator aspects of second target station usually take more than ten years of strategic planning, intense R&D and focused preparation. It would be important for the J-PARC Accelerator Division to work with the laboratory leadership to identify strategic directions and areas of development that are aligned with J-PARC's long-term missions. As an example, a second target station would require beam sharing from the RCS or a more ambitious development of a long pulse scheme using the beam directly from the LINAC with additional SC cavities and operation at a higher LINAC duty cycle.

R01: Work with J-PARC leadership to identify accelerator development initiatives to be aligned with J-PARC's long term missions, and present at A-TAC2024.

Operating hours were significantly limited by high electricity prices and the upgrade work in the MR. High electricity prices are poised to reduce operating hours in JFY2023 by more than half, without additional funding. Substantially reducing operating hours may have major impacts on the expectations of the funding agencies, user communities, and other stakeholders. Their early involvement may help improve the running situation for JFY2023.

R02: Communicate in a timely way with stakeholders the plan for reduced beam operations in JFY2023 due to increased electricity prices, with the existing budget.

The challenge of high electricity prices is unlikely to subside in the future and J-PARC could benefit from strategies to reduce electrical usage and to procure electricity in alternative ways. J-PARC has approaches to reduce RF and magnet power usage. Better reliability of future pricing could benefit planning. Local production of energy, through photovoltaics for example, could reduce dependence on volatile energy markets and reduce risks in future years.

R03: Investigate long-term alternatives for electricity supply, such as predetermined fixed-price contracts, energy-efficient accelerator solutions, and possibilities for complementary photovoltaic installations on site, etc.

The period from summer to the end of JFY2023 is presently planned to have no beam operations, due to the above-mentioned electricity costs and funding limitations. Alternative technical plans should be formulated to make the best use of this period with the existing personnel and equipment. Some upgrades have been limited due to the availability of time in the accelerator enclosures, and could be accelerated in this period.

R04: Develop a plan for optimizing J-PARC technical activities in JFY2023 in case extended shutdown time is available after the summer.

The Hadron Hall Extension is prioritized in the long-term planning for J-PARC. This extension would be a significant investment that may also create new requirements for the MR slow extraction system. An assessment of such new requirements and possible R&D to meet these requirements will prepare for the Hadron Hall Extension.

R05: Develop concepts for the future slow-extraction system to accompany the major future investment of the Hadron Hall Extension, and report at the next A-TAC.

The J-PARC team has completed heat runs and ripple current measurements on all the new MR quadrupole and sextupole power supplies. No unexpected temperature increases were observed, and ripple was as expected for the QDN, QDR, SFA and SD power supplies. Ripple on the QFN power supply was, however, worse than expected.

R06: Further investigate the ripple on the MR QFN power supply (including harmonic analysis), quantify the resultant beam loss and find a suitable mitigation strategy.

Failures of individual MR power supply components could potentially cause more extensive damage to the systems as a whole.

R07: Enhance the device protection and controls of the MR power supplies to minimize damage from individual failed components.

Failures of components, particularly during commissioning of the new MR power supplies, have resulted in an acute shortage of stocks of some spares. Replacement of stocks must now be a priority, particularly given quoted lead times of up to 1.5 years on some items.

R08: Purchase an inventory of long lead-time components that have a new history of individually failing (e.g. MR power supply IGBTs and fuses).

The root cause of one of the MR power supply failures during commissioning has not yet been fully explained and therefore the J-PARC team think that there is a possibility it could happen again. Until spares stocks can be replenished, there remains a risk that a further failure will compromise operations.

R09: Carry out a full analysis of the residual risk to operations of the current MR spares situation, investigating all possible additional mitigations (e.g. reconfiguration of power supplies to share the load, borrowing suitable spare components from other facilities, etc.).

The J-PARC team has been forced to be very reactive to the issues with the FX septum magnets and has found a solution at every point. However, the system configuration has moved further and further away from its intended design. While the recovered system will likely be able to operate at high-power, it will be susceptible to further disruptions. It may be beneficial to reconceptualize the system for a long-term solution, perhaps with interchangeable and/or spare devices.

R10: Develop a plan for an optimal fast-extraction septum-magnet array, incorporating all lessons learned. Prioritize shorter-term actions to move towards the optimal design.

The MR LLRF system is being replaced with a modern MTCA.4 system using multi-harmonic Vector IQ feedback control. The new LLRF system has demonstrated that coupled dipole oscillations can be managed but potentially quadrupole oscillations could also turn out to be an issue.

R11: Make an in-depth study of potential coupled bunch quadrupole oscillations with the new MR LLRF system.

The work to complete the MR RF system upgrade in a timely manner will require substantial resources.

R12: Ensure that sufficient resources and staff effort are available to complete the RF system upgrade for the MR to the required schedule.

During the high-power RCS trial held in June 2022 it was not possible to achieve 1 MW operation because of exceptionally high ambient temperatures (> 30°C). It is likely that, because of climate change, such extraordinary temperatures will become normal in future years, so until the required cooling demand has been reduced by the installation of the new design of RCS RF cavities this will continue to be an issue.

R13: Until all the new design RCS RF cavities have been installed, consider scheduling high-power trials at > 1 MW so that they do not coincide with the hottest part of the summer and > 30°C ambient temperatures.

Items for the next meeting (A-TAC 2024)

The committee would like to hear from the J-PARC accelerator team in particular to:

1. Present accelerator development initiatives aligned with J-PARC's long term missions.
2. Present progress on the delayed MR hardware and beam commissioning activities and compare with the adjusted plan made at A-TAC 2023.
3. Present concepts for the future slow-extraction system to accompany the major future investment of the Hadron Hall Extension.
4. Present the plan for an optimal fast-extraction septum-magnet array, incorporating all lessons learned.
5. Elaborate a long-term strategy for the maintenance or replacement of the power converters that were reused in the MR upgrade.
6. Present the upgrade plans for the MR beam dump, including the design and construction timeline and budget needs.

02 J-PARC Accelerator Overview (RZ, ML)

Findings

J-PARC, in JFY2022, delivered high-quality beam to the MLF and completed the installation of the major power supply upgrades to the Main Ring. This was the third year of the COVID-19 pandemic and J-PARC is operating with only nominal impacts. The RCS operated regularly, achieving record 800 kW beam power to the MLF with high availability. The MR was being upgraded for most of the year to enable future beam power in excess of 1 MW – sort periods of commissioning and beam studies occurred for the upgrades. Commissioning the new, very large magnet power supply system has required quick action by J-PARC to address issues. J-PARC has plans to increase user time in future years, but elevated electricity prices may substantially reduce scheduled operations in the near future.

[statistics JFY2022 through January 2023]

RCS for MLF:

- The RCS provided 730 – 830 kW to the MLF in the previous year, limited by the MLF target capability and RCS cooling capacity during the summer. J-PARC intends to increase beam power by ~ 100 kW each year, as allowed by the target and maintaining high availability. Future running of 1.5 – 2 MW is anticipated to support a second target station.
    - J-PARC is estimated to deliver 6.5 cycles (143 days) out of 7.2 cycles (159) originally planned for JFY2023. Highly elevated electricity costs threatened to reduce operation by 51 days, but additional funding was secured to reduce the impact to 16 days. The availability remained high at 96%, well exceeding the goal of 90%.
    - 159 days (7.2 cycles) were anticipated for JFY2023 – that amount has been typical in recent full years of operations. However, high electricity costs could limit that operation to 60 days (2.7 cycles) before the summer shutdown, without additional funding. With additional funding, the RCS/MLF could optimally run at 9 cycles per year.

MR with fast extraction for neutrinos:

- Scheduled beam delivery was minimal due to the substantial MR power supply upgrade underway. Beam capability was maintained at up to 510 kW during this period. The new power supplies were demonstrated at a 1.36 s cycle time, with beam accelerated to 8 GeV.
    - Power supply commissioning started before the summer shutdown, demonstrating acceleration of beam to 8 GeV. Studies were delayed by four separate issues with the MR systems. Beam delivery restarted for studies Jan. 21.
    - For the remainder of JFY2022, the MR will concentrate on studies to commission beam with the new power supplies and slow extraction.

    - 143 days (6.5 cycles – combined with SX) were anticipated for JFY2023 – significantly greater than had occurred in recent years with the PS upgrade. However, high electricity costs could limit that operation to 60 days (2.7 cycles) before the summer shutdown, without additional funding.
    - JFY2023 activities will include 30 days of tuning and operation for FX.
- J-PARC will reduce the MR cycle time to 1.36 s to achieve > 750 kW in the MR. Reducing the cycle time is the most straightforward path to higher power. Combined with other improvements to loss control and RF power and further cycle time reduction to 1.16 s, J-PARC should be able to produce high-power beam for the Hyper-K experiment, and be capable of 1.3 MW by 2028.
    - Power supplies have all operated with the desired 1.36 s cycle time, and beam was accelerated to 8 GeV. Challenges were encountered with the commissioning, and the system is presently operating. A substantial increase in beam power should be available when commissioning is complete.
    - Upgrades to the fast extraction septum magnets have encountered failures of a conductor solder joint that will require extensive additional work (though beam operation is presently possible). The success of this additional work could affect the available beam power.
    - A further program of modest improvements to the MR will result in increased beam intensity. When combined with the power supply upgrade (and further extension to 1.16 s cycle time), 1.3 MW should be available from the MR for fast extraction. These plans are now well understood and underway, though additional funding is required for the full suite of upgrades. The mid-term plan has been consistent with a gradual rise to 1.3 MW in JFY2028 to be available for Hyper-K, as upgrades are sequentially performed.

MR with slow extraction to the Hadron Facility:

- Scheduled beam delivery was minimal due to the substantial MR power supply upgrade underway. Capability of up to 64.5 kW was maintained to the Hadron Facility in JFY2022. Further improvements are planned to > 80 kW in the next few years.
    - Planned operation after the summer shutdown was delayed due to problems with the MR PS and extraction septum magnets.
    - Operation time during February and March will be shared with FX commissioning. SX activities will be studies at 8 and 30 GeV, an engineering run to COMET.
    - 99 days of MR user operation is planned for JFY2022 after the long summer outage for the MR PS upgrade commissioning. The time will be split between neutrino and hadron operation.

- 143 days (6.5 cycles – combined with SX) were anticipated for JFY2023 – significantly greater than had occurred in recent years with the PS upgrade. However, high electricity costs could limit that operation to 60 days (2.7 cycles) before the summer shutdown, without additional funding.
- JFY2023 activities will include 16 days of SX tuning and up to 14 days of Hadron operation.

The JFY2022 MR operation was substantially interrupted by four separate system disruptions during commissioning of upgrades: three with the MR power supplies, and one with the extraction septum magnet system. Commissioning activities were limited in scope:

- 31 May 2022: BM6 power supply unit failed due to misaligned transformer assembly at the manufacturer. The core is to be movable (variable separation of core halves), but they were further misaligned, leading to excess heating. Delayed commissioning by ~ 2 weeks.
- 16 June 2022: MR PS timing adjustments caused IGBT misfires and many subsequent failed fuses and other IGBTs.
- 3 November 2022: MR PS Control board failed with IGBT failure, causing further failures. The cause of the initial failure is unclear. Few spares exist, with > 1-year lead-time.
- 14 December 2022: MP FX Septum Magnet (SM31) failed on a broken conductor. Poor solder junction quality.

Electricity prices have become prohibitively high, reducing anticipated JFY2023 beam time by more than half. Additional funding has been requested.

Accelerator R&D has been prioritized with an internal procedure. Mentioned examples were semiconductor switches, laser charge conversion, and SRF for ADS.

J-PARC is at risk of losing key expertise in the next 10 – 15 years as it may have a large portion of its staff retire. J-PARC recently hired four new staff members, and will continue efforts on recruiting and outsourcing.

Comments

J-PARC continues to make progress by delivering high-intensity and quality of beam to the MLF, and installing major upgrades to the MR. The RCS stands ready to provide 1 MW when the target facilities are available, however there is continued difficulty in regulating temperature during warm and/or moist weather. Rapid increases in beam power to the neutrino beamline can be expected when the MR upgrades are commissioned, and powers exceeding 1 MW can be expected within a few years, with additional upgrades underway.

Recommendations

Operating hours were significantly limited by high electricity prices and the upgrade work in the MR. High electricity prices are poised to reduce operating hours in JFY2023 by more than half, without additional funding. Substantially reducing operating hours may have major impacts on the expectations of the funding agencies, user communities, and other stakeholders. Their early involvement may help improve the running situation for JFY2023.

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The challenge of high electricity prices is unlikely to subside in the future and J-PARC could benefit from strategies to reduce electrical usage and to procure electricity in alternative ways. J-PARC has approaches to reduce RF and magnet power usage. Better reliability of future pricing could benefit planning. Local production of energy, through photovoltaics for example, could reduce dependence on volatile energy markets and reduce risks in future years.

R03: Investigate long-term alternatives for electricity supply, such as predetermined fixed-price contracts, energy-efficient accelerator solutions, and possibilities for complementary photovoltaic installations on site, etc.

The period from summer to the end of JFY2023 is presently planned to have no beam operations, due to the above-mentioned electricity costs and funding limitations. Alternative technical plans should be formulated to make the best use of this period with the existing personnel and equipment. Some upgrades have been limited due to the availability of time in the accelerator enclosures, and could be accelerated in this period.

R04: Develop a plan for optimizing J-PARC technical activities in JFY2023 in case extended shutdown time is available after the summer.

The Hadron Hall Extension is prioritized in the long-term planning for J-PARC. This extension would be a significant investment that may also create new requirements for the MR slow extraction system. An assessment of such new requirements and possible R&D to meet these requirements will prepare for the Hadron Hall Extension.

R05: Develop concepts for the future slow-extraction system to accompany the major future investment of the Hadron Hall Extension, and report at the next A-TAC.

03 Status of MR (WF, RZ)

Findings

With a cycle time of 2.48 s the MR has demonstrated a maximum beam power of 510 kW in FX operation, and 64.5 kW in SX operation with an extraction efficiency of 99.5% and a spill duty ratio of 50 – 55%. The goal remains a beam power of 1.3 MW in FX operation with a cycle time of 1.16 s and a 30% increase in the beam intensity. While the new power supply system for the main magnets is largely complete and allowing for a cycle time of 1.36 s, the RF system upgrade, BPM upgrade, and SX upgrades still need to be completed.

Three events have created delays in the commissioning of the new main PS, namely a misaligned contactor that lead to overheating of an electrical bus, the loss of an global timing signal leading to blown fuses in a quadrupole circuit, and a failure of IGBT gate driver failure. These events created delays of between 7 and 30 days. The fuses blown in the second event have lead times of 15 – 18 months. In addition, common noise disabling the fast (10 μs) PS interlock (silent stop) was discovered and is being addressed.

Of the 11 fundamental and 2 harmonic cavities needed for 1.3 MW, there are now 9 fundamental and the 2 harmonic cavities installed, and the anode power supplies are to be upgraded.

A water leak developed in a coil of an FX extraction magnet (SM32), and a recovery plan was developed, with which all coils will be replaced eventually. The collimation system was upgraded from 4 to 6 collimators, and 1 more collimator is planned to be installed in the summer of 2023. The fully upgraded collimation system allows for scraping of beams with a power of 3.5 kW instead of 2.0 kW previously.

With the new main power supplies the ripple in the bending magnets is lower by an order of magnitude for frequencies lower than 200 Hz. Dispersion and beta-function measurements agree well with models, and a new LLRF system has been commissioned. The FX extraction septum magnets now create a smaller beta beat, and although the injection beam lifetime for high intensity bunches ($2.7\text{x}10^{13}$ ppb) is lower, losses are well localized at the collimators. The new PS wiring scheme breaks the 3-fold symmetry and makes the tuning more difficult.

A new protection mechanism is implemented for short pulse beam extraction in SX.

The beam tuning with the new power supplies started in January and will continue until May. With the anticipated resolution of the extraction systems issues, tuning will then continue with the extraction energy of 30 GeV, and for SX operation.

Comments

With the MR power supply upgrade nearly complete a significant step in the upgrade path to 1.3 MW has been achieved. To date the new power supply system has met almost all specifications, with only one quadruple circuit having higher ripple than planned. It is likely that this can be resolved also.

Three events, all unrelated, delayed the commissioning of the new MR power supplies by days or weeks. Some unforeseen events should be expected in the commissioning of a complex new system. The root cause of these events has not been determined in all cases, and some created a shortage of spare parts with long lead times. Without a full understanding of all of these failures and the spare shortage, risk exists for the future operation of the MR.

Good progress was also made in the installation of the cavities needed for higher beam power, the collimator upgrades, and the beam tuning.

Despite some recent setbacks, the MR is well positioned to increase the beam power level.

Recommendations

R06: Further investigate the ripple on the MR QFN power supply (including harmonic analysis), quantify the resultant beam loss and find a suitable mitigation strategy.

R07: Enhance the device protection and controls of the MR Power Supplies to minimize damage from individual failed components.

R08: Purchase an inventory of long lead-time components that have a new history of individually failing (e.g. MR power supply IGBTs and fuses).

R09: Carry out a full analysis of the residual risk to operations of the current MR spares situation, investigating all possible additional mitigations (e.g. reconfiguration of power supplies to share the load, borrowing suitable spare components from other facilities, etc.).

04 PS commissioning (JT, WF)

Findings

In response to Recommendation 10 from A-TAC 2022, the J-PARC team has completed heat runs and ripple current measurements on all the new quadrupole and sextupole power supplies. No unexpected temperature increases were observed, and ripple was as expected for the QDN, QDR, SFA and SD power supplies. Ripple on the QFN power supply was, however, worse than expected.

All the new power supply installation, wiring and rearrangement of existing power supplies was completed on time for commissioning to begin as planned in June 2022. During commissioning, good progress has been made in improvement of tracking error suppression, ripple reduction and power control optimization.

There were three specific failures of power supplies during commissioning, each of which took several days to rectify, and which contributed to an overall project delay of about 6 weeks. In order of occurrence these were:

- 31 May 2022 – a broken contactor in the BM6 power supply, caused by misalignment of one of the coils. This was resolved by replacing the contactor coil (recovery time 14 days).
- 16 June 2022 – accidental disconnection of a fiber optic cable resulting in loss of the reference clock in a QFN, QDN AC/DC converter. This led to a rapid rise in incoming current, and in order to protect the IGBT power unit several fuses were blown. Fuses were replaced and clock compensation was added in the controller (recovery time 11 days).
- 3 November 2022 – damage to one IGBT power unit (4 IGBTs) in the BM4 power supply and 24 fuses in the capacitor bank caused by arcing. Spare IGBTs and fuses were in stock at KEK or with the manufacturers, so a repair was possible, but now spares stocks for both items are very low (recovery time 30 days).

Some progress has been made in addressing the “silent stop” problem, where common-mode noise caused by switching of converters can trigger a spurious alarm signal to the E/O board. A low pass filter in the input signal of the E/O board has been fitted temporarily and the longer-term plan is to introduce insulation between those boards and reinforce their grounding.

Beam commissioning at 1.36 s / cycle recommenced in January 2023.

In preparation for 1.2 s / cycle operation an increase in capacitance from 480 mF to 510 mF in the capacitor bank is planned.

Comments

The committee congratulates the J-PARC team on their success in pursuing the MR power supply upgrade and in solving all the problems they have encountered so that beam commissioning can now begin in earnest.

The first two power supply failures during commissioning appear to be well understood and have been satisfactorily resolved. The J-PARC team is confident that there is little chance of recurrence and quality assurance has been carried out on all the undamaged power supplies.

The root cause of the third power supply failure has not been fully explained and therefore the J-PARC team think that there is a possibility it could happen again. Analysis of the IGBT failure mode is being carried out by the manufacturer. It is fortunate that sufficient stocks of spares were available at KEK and the manufacturers in order to make an effective repair, but replacement of stocks of fuses and IGBTs must now be a priority, particularly given a quoted lead time on these items of up to 1.5 years.

Failures of individual MR power supply components could potentially cause more extensive damage to the systems as a whole.

There is some concern from the committee that while the current focus is on the new power supplies, some of the older power supplies that have been reconfigured may be reaching end of life. Some of the MR quadrupole power converters are not going to be replaced or upgraded but re-used also for future operation. Considering their aging and the risk associated, a long-term strategy for their maintenance, or eventually their replacement, should be proposed.

Recommendations

R06: Further investigate the ripple on the MR QFN power supply (including harmonic analysis), quantify the resultant beam loss and find a suitable mitigation strategy.

R07: Enhance the device protection and controls of the MR Power Supplies to minimize damage from individual failed components.

R08: Purchase an inventory of long lead-time components that have a new history of individually failing (e.g. MR power supply IGBTs and fuses).

R09: Carry out a full analysis of the residual risk to operations of the current MR spares situation, investigating all possible additional mitigations (e.g. reconfiguration of power supplies to share the load, borrowing suitable spare components from other facilities, etc.).

05 Extraction magnets and PS (RZ, SG)

Findings

The Main Ring Fast Extraction (FX) and Abort systems have been upgraded over the last several years to accommodate the planned higher beam powers, and to deal with equipment disruptions. Several more upgrades are planned over the next several years. Some equipment downtimes have resulted in unplanned beam outages, but clever reuse of the existing magnets allowed J-PARC to recover a large fraction of the beam time.

The kicker magnets for fast extraction have all been prepared for 1 Hz operation. Low-field septum magnets of the eddy field style were also prepared and installed.

New high-field septum magnets were planned for 1 Hz operation and installed, but equipment breakdowns have occurred and are the subject of present attention. Analysis of the system has allowed for operation with three out of four of the magnet systems (SM30, SM31, SM32, SM33). Re-use of removed magnets have also allowed greater operation.

The extraction region magnet upgrades have several components:

- Large-aperture quadrupole before the septa (Installed)
- SM30 magnet (Installed)
- SM31 magnet (Installed, and failed Dec. 2022 on conductor failure)
- SM32 magnet (Installed, and failed in 2021, partially repaired for late 2022)
- SM33 magnet (consists of various sub-magnets which have been extensively reconfigured).

The SM31 and SM32 failures were both related to the brazing (soldering) approach of the conductors at the manufacturer. J-PARC worked with the manufacturer to make several improvements to the soldering procedures. A full recovery plan exists to sequentially upgrade the conductors of all the affected magnets by summer of 2024, and to return to the full complement of septum magnets. Adjustment to the design of some of the coils is required to minimize resistance. Instrumentation was added to monitor magnet performance and input to the MPS.

J-PARC has identified the reuse of ceramic beam ducts in the septum magnets as a challenging issue for magnet upgrades. Ceramic ducts are desired to reduce the eddy currents produced at high-rate operation (1 Hz). Generally, the ceramic ducts are not removable without great effort. New ducts are also quite expensive, and J-PARC is looking into alternatives. As these ducts need to be reassembled into the rebuilt magnets, the system may not be ready for summer 2023.

A backup plan was prepared for summer 2023, which involves using the original SM31 with new flange connections for the newer ducts, and additional connecting ducts to the other magnets. This would involve a metallic interior duct, and thus only capable of a 2-second cycle, significantly limiting FX beam power for the next year until the full recovery plan is installed.

Comments

The J-PARC team has been quite inventive in developing short-term solutions to allow beam operation with the disruptions to this system which has no spare magnets. That resourcefulness has required a great degree of work and has allowed significantly more beam operation than would be otherwise possible. A long-term plan may be desirable to guide short-term actions.

The repair of the solder joints appears much more robust than the previous approach. These magnets were built to J-PARC specifications by a manufacturer who produced the design and performed the design analysis. There may be forces (thermal or electromagnetic) that pulls these conductors apart, and could cause future failures even with the improved solder joints. A mechanical finite-element analysis (FEA) could estimate the involved forces, and the integrity of the solder joints in long-term operation. Connections of this type sometimes require some clamping force to maintain compression, but the existing conductor geometry does not have space for this type of retrofit. Inadequate electrical connections can sometimes be identified through use of thermal imaging (inexpensive FLIR cameras) during beam-off testing.

The issue of ceramic duct reuse and expense is common among accelerator facilities. In this case, the dominant eddy current loop is around the combined array of ducts, and not the individual beam ducts themselves. Therefore, the use of metallic ducts may be possible with only implementing short ceramic breaks at one or both ends of the ducts.

J-PARC has formulated a Full Recovery Plan to be complete by 2024, with a temporary fix for SM31 this summer. This plan is contingent on reusing ceramic ducts, which is uncertain, and therefore there is a Backup plan which would be limited in performance until the repair is complete. Each of these plans involves using magnets in locations or ways not initially intended.

Recommendations

The J-PARC team has been forced to be very reactive to the issues with the FX septum magnets and has found a solution at every point. However, the system configuration has moved further and further away from its intended design. While the recovered system will likely be able to operate at high-power, it will be susceptible to further disruptions. It may be beneficial to reconceptualize the system for a long-term solution, perhaps with interchangeable and/or spare devices.

R10: Develop a plan for an optimal fast-extraction septum-magnet array, incorporating all lessons learned. Prioritize shorter-term actions to move towards the optimal design.

06 RF system upgrade plans (ML, JT)

Findings

The RF system will need significant modifications to enable the upgrade of the MR from 500 kW to 1.3 MW cycling at 1.16 seconds. The faster cycling requires a higher RF voltage which requires more cavities, and more protons will require more anode power supply output current for beam loading compensation and a LLRF system capable of suppressing coupled bunch oscillations.

New cavities are being added to two sections in the MR with space being created in one section by replacing long 4-gap cavities with new short 4-gap cavities using FT3L cores rather than FT3M cores. There is no observed degradation at J-PARC of the FT3 cores from radiation.

New RF power supplies for cavities 10 to 13 built by industry have been added and 6 out of 9 anode power supplies will be modified with additional inverter units.

The LLRF system is being replaced with a modern MTCA.4 system using multi-harmonic Vector IQ feedback control. The first test with the new LLRF system shows that the wake voltages for h=8,10 components are well suppressed and that it can address the issues of coupled bunch (CB) oscillations.

Extensive simulations have been done, demonstrating that the RF system upgrade can meet the requirements for the MR upgrade which includes beam loading compensation for h=6, 7, 11, 12, and that RF voltage of 510 kV is high enough to accelerate 3.3×10^{14} ppp for both 650 ms and 580 ms acceleration. The required anode power supply current is around 120 A.

Comments

The new LLRF system has demonstrated that coupled dipole oscillations can be managed, but what about quadrupole oscillations?

Many labs suffer from very long lead times for the order of MTCA.4 hardware. Are enough of these systems available at the lab to avoid delays?

The scope of the RF upgrade is ambitious - are the necessary resources and staff effort available at the lab to achieve this to schedule?

Recommendations

R11: Make an in-depth study of potential coupled bunch quadrupole oscillations with the new MR LLRF system.

R12: Ensure that sufficient resources and staff effort are available to complete the RF system upgrade for the MR to the required schedule.

07 MR upgrade plans (SG, WF)

Findings

The upgrade of the MR made important progress towards the future 1.3 MW FX operation, with some difficulties as explained in a number of presentations. For the 1.3 MW operation, the following systems have been or are being modified: the main PS to reduce the cycle time, the RF systems, the collimation system, some quadrupoles to increase the available aperture, the 3-50BT pulse dipole magnet power supplies, and some correction magnet systems.

The QDTs quadrupole aperture is going to be enlarged to reduce losses during the FX extraction. The future aperture will be in the shadow of the aperture as defined by the main collimation system. All similar quadrupoles of the machine will be replaced to maintain the lattice periodicity, while the power supplies will be reused. The magnet coils are being manufactured.

The power supplies of the 3-50BT pulse dipole magnets have to be upgraded to cope with the faster MR repetition rate. The existing power supplies are 15 years old and now reaching the fill lifespan and being replaced. The new power converters are already available for testing on site.

The existing external beam dump is limited to 7.5 kW deposited by the beam, which allows only a limited number of shots per hour. The iron and shielding block do not have any active cooling. The shielding has been well over-dimensioned with respect to the maximum beam power that the iron block could receive. For future operation, a maximum beam power of 30 kW would be preferable, allowing for more than 19 shots per hour. The new dump will make use of the existing iron core and shielding, with new absorbing cores, one in copper and the second in graphite, both added in the existing beam pipe in front of the existing one. The new dump design is developed in collaboration with RAL High Power Target Group & J-PARC NU group. Detailed FLUKA simulations of the new device show that the radiation levels, the backscattered neutrons as the maximum number of shots are consistent with the specifications. The new dump will be able to receive 81 consecutive shots while maintaining 7.5 kW in the existing core and shielding, the other 22 kW of beam power being absorbed by the new insert. The new dump sections in graphite and copper need an active cooling system, which will use nitrogen as coolant. The new dump design should be finished by the end of 2024 to have the new one operational in fall 2026.

The quadrupole and sextupole magnet correctors are going to be upgraded, the first to compensate mainly for the leak field of FX septa causing large beta beating, the second for the third order resonance compensation generated mainly by the magnetic multipoles of the main bends. Particular effort was done to improve the machine optics modeling taking into account a new evaluation of the magnetic errors. The errors have been estimated by beta beat and driving terms measurements.

Simulations are used to identify the beam population causing beam losses and emittance growth during high intensity operation. In particular, the simulations could well reproduce beam losses evolutions all along the magnetic cycle, and guided the strategy for loss reduction by resonance compensation. Resonance compensation reduced losses already significantly, however the simulations indicate the need of extra sextupoles to fully compensate for all the relevant resonances interacting with on-momentum and off-momentum particles.

Comments

A long-term strategy is needed for the maintenance of the power converters that were reused.

The optics model of the MR has been significantly improved, thanks to a new and detailed evaluation of the different magnetic errors. An updated version should be prepared based on the expected or measured errors introduced by the new enlarged quadrupoles.

The committee recognises the importance of the possible deployment of new trim sextupoles for an optimized resonance compensation.

The new dump design should consider the risk of Nitrogen leaks into the tunnel and the consequent risk of air contamination in the tunnel. Proper shielding should be foreseen in the tunnel, conceived to preserve the access to the dump and the machine components for adequate maintenance while minimizing dose to personnel.

The committee would like to have a presentation on the upgraded beam dump, including the design and construction timeline and budget needs.

Recommendations

None.

08 Maintenance plans of utility (ST, AA)

Findings

Maintenance scenarios of utilities (especially, air conditioning system and water-cooling system) at J-PARC MR were presented. There are two types of buildings at J-PARC MR. Ones are Machine Buildings which are connected to the MR accelerator tunnel. The utilities for MR adopt a redundant system to avoid the long shutdown for the MR operation. For example, an additional water pump is on standby in case of failure of operating ones.

The others are power supply buildings. The redundant system works well and the long shutdown has been avoided due to the utility trouble. According to the MR power supply upgrade, the utilities have also been upgraded. For example, some air conditioners are replaced to the larger ones, and some are added to increase the cooling capacity. It should be praised that there is no long shutdown due to the MR utilities under the limited budget.

Comments

Due to the upgrade of the J-PARC MR power supplies, the shortage of cooling water flow and the lack of redundancy are foreseen. The replacements of the old utilities and spares are not enough due to the budget limitation. The anti-aging and the upgrade plan of the utilities should be prepared toward the MR 1.3 MW operation. It also needs to be discussed the required specifications of the utilities and the budget with the MR machine group.

Recommendations

None.

09 Slow extraction status and plan (WF, SG)

Findings

In SX operation a beam instability appearing about 60 ms after debunching, triggered by electron clouds, has limited the SX beam power. It is planned to increase the stability threshold by increasing the momentum spread through a phase offset upon injection. In addition, a larger chromaticity, an active damper, and VHF cavity are considered.

The impedance increase due to the newly installed collimators has not been measured yet, but was calculated with CST.

Electron cloud detectors exist in the straight sections and electron cloud suppression through low SEY coating was discussed as a further mitigation measure.

To reduce the risk associated with kicker pre-fires, the replacement of the present thyratron switches through solid state switches is investigated. The R&D effort needs to result in a SS switch with the required voltage and rise time that also works reliably in the MR environment with noise and possibly radiation.

A system was developed so that the beam can be aborted quickly after a trip of dipole or quadrupole magnet PS so that it can be aborted much faster than the presently 10 – 15 ms, dominated by the response time of the fault system and PLC system for the main PS interlock system. A new Electro-Static Septum (ESS) has been manufactured, and the damaged ESS will be repaired in the tunnel.

With the new MR PS the SX operation, which reached 99.5% efficiency, has to be tuned again as it is sensitive to dipoles and quadrupole strength errors. This requires tuning for extraction at 8 GeV for COMET, and later at 30 GeV.

Comments

The plan to address the beam instabilities observed after debunching has multiple levels, and starts with a change in the longitudinal injection conditions in the MR as a cost effective solution. Several other mitigating measures are available to suppress the instability, or the electron clouds that trigger the instability. An active damper, VHF cavity or low SEY coating require investments.

The fast abort system reacting to trips of bending or quadrupole magnets gives a higher level of protection, and should avoid target damages as have been experienced in 2013. This is especially important with the raised extraction beam power of up to 100 kW.

Recommendations

R05: Develop concepts for the future slow-extraction system to accompany the major future investment of the Hadron Hall Extension, and report at the next A-TAC.

10 Status of linac (ML, AA)

Findings

The LINAC has successfully been operated with high reliability with very few unscheduled stops.

The H- source is operating at 60 mA and had in the last year a record continuous operation period of 4001 hours (350 hours longer than the previous record). After the long continuous operation of the ion source an in-depth study was made of the coating on the antenna showing that the elemental composition of it originates from the steel components and the Cs injection.

The RFQ re-start system has reduced the down time from RFQ trips even though the total number of trips remain constant. If the RFQ re-start system is re-triggered within a minute it generates an MPS event and such MPS events occur typically every second day.

The new MEBT development has been put on hold as it seems to not be necessary at this time even though some question remarks regarding the emittance evolution at 60 mA remain.

The diluted acid cleaning of multipacting cavities S05A, S04A and S04B has successfully addressed this issue and all SDTL cavities are now operating at the design gradients.

The trip rip rate in DTL/SDTL typically occurs 0-1-0.2 times per day and is understood. The same is true for the ACS.

The accumulated operation time of klystrons is high with one 324 MHz klystron having been replaced last year. The stock of conditioned spares is continuously increasing and there is now an inventory of 40% for the 324 MHz klystrons and 48% for the 972 MHz klystrons. The plan is to continue to purchase spare klystrons.

The LLRF Interlock management system is a big help to understand interlocks and sets prioritize for maintenance and component replacements.

Comments

The high accumulated operation time of the klystrons will eventually require most of the klystrons to be replaced so it is important to continue to accumulate spares. This is particularly true for the 972 MHz where most klystrons have a similar accumulated number of operation hours.

Recommendations

None.

11 Beam study results of linac (AA, SW)

Findings

Several examples of beam measurements in the linac were presented.

A full two-dimensional scan of the LEBT parameters allows one to find the global maximum for the beam transmission. The old method resulted in finding a local maximum.

The transverse RMS emittance in the MEBT is derived by fitting a numerical model to the quad scan data. The emittance values are close for 50 mA and 60 mA beams.

The longitudinal beam profiles are measured using the RF deflector and the wire scanner in the MEBT. The longitudinal RMS emittance can be derived by fitting a numerical model to several profiles measured with different buncher settings. The longitudinal RMS emittance doesn't change over several years of operation.

A new Beam Shape Monitor in the MEBT was successfully commissioned with 50 mA and 60 mA beams. There is an operational BSM at the linac exit as well. The BSMs data are not used for the linac tuning yet.

The MEBT chopper extinction ratio is measured using a beam stop in the linac. This allows to tune the buncher before injecting the beam to the RCS.

A new digital adaptive feed forward algorithm was developed for the LLRF system. It reduces the cavity amplitude and phase distortion due to beam loading to the negligible level.

Comments

Most of the measurements presented at the review do not show error bars or confidence intervals. Some of the measurement methods are known to have significant uncertainty. For example, RMS Twiss parameters derived from a quad scan data can have large errors if space charge is strong. Beam measurements are typically sparse along the linac, therefore they need to have small uncertainty to be useful for constraining numerical models.

It was not shown how the measured RMS beam parameters measurements are used for the linac tuning or loss reduction.

Recommendations

None.

12 Beam loss in the linac (AA, ST)

Findings

The dominating beam loss mechanism in the low energy part of the linac is scraping of the beam edges on the vacuum chamber aperture. It is believed the losses are increased by the beam trajectory distortion due to misalignment and the transverse emittance larger than the design value. Plausibility of this mechanism is confirmed by numerical simulations

The dominant beam loss mechanism in the DTL and SDTL is stripping on the residual gas. An experiment with varying gas pressure provides convincing evidence.

The intra-beam stripping is proposed as the dominant beam loss mechanism in the ACS. The argument for this proposal is inverse dependence of the losses on the focusing strength: the beam loss is reduced with reduced focusing strength, e.g. increased beam size. However, there can be other explanations for this dependence.

There is a strong correlation between the BLMs signal and the residual activation. However, the units for the residual activation are not spelled out on the figures. If these units are μSv/hour, the residual activation is quite high compared to what would be expected from the stripping on the residual gas and intra-beam stripping.

The application of the machine learning technology to the J-PARC linear accelerator is making steady progress. The goal setting of Linac centroid momentum compensation is also reasonable, because enough amounts of the measured and simulated data as teaching data are available. Due to the many tuning factors in the acceleration cavity, this automation also has significant operational benefits. The J-PARC team has developed the deep neural network (DNN) to model the correlation between the cavity amplitude/phase error and the beam phase/energy offset. Using the trained DNN model, the compensation scenario is successfully calculated on the simulation study in a short time (within a few seconds).

Comments

There is a significant discrepancy between the ratio of the residual activation to the beam loss power observed at some other facilities and presented at the review. For example, a loss of ~1 W/m typically produces ~1 mSv/hour in SNS linac. This ratio seems to be ~10 times higher in the presented comparison of the simulated beam loss and the measured activation in the JPARC linac.

In order to use machine learning in the J-PARC operation, it is necessary to further improve its accuracy and reliability with more measured and simulated data. At the same time, the research on ensuring the safety of the J-PARC linac when machine learning makes mistakes is also important. The technology of the explainable AI is developed recently in various applications. It may be an alternative solution.

The proposed machine learning application relies on the cavity phase error determination using the beam loading measurement. This approach has been tried before and proved to be very difficult. An experimental demonstration should be done before proceeding with further development.

Recommendations

None.

13 Status of RCS (JT, SW)

Findings

The RCS has remained in stable user operation, delivering 730 – 830 kW beam to the MLF during the periods January to June and November to December. Availability for the RCS only has again been excellent, at 98.7%. The majority of the 26:49 hours of downtime for the RCS was due to RF systems and the kicker magnet power supplies.

During the high-power trial held 24 - 26 June 2022 it was not possible to achieve 1 MW operation because of exceptionally high ambient temperatures (> 30°C). There was insufficient cooling capacity to maintain vacuum tube operation, so beam power was reduced from the initial 910 kW to 800 kW, and then to 600 kW. On 25 June an over-current occurred in the transformer-rectifier assembly for RF system 10.

It has been possible to reconfigure the RCS to accelerate 800 kW beam with only 11 (of 12) RF cavities. The spare transformer-rectifier assembly will be installed in March 2023.

Although high-intensity operation with a smaller foil causes more rapid foil degradation, this appears to be well understood and can be recovered by adjusting the foil position. The 30% reduction in circulating beam hits results in higher quality beam and considerably reduced beam loss in the RCS.

In response to Recommendation 4 from A-TAC 2022, the J-PARC team has now installed new diode units to 2 (of 8) kicker PSUs in the RCS. Simulations have shown that installation of a total of 4 diode units will be sufficient to mitigate the source of instability and extend the parameter windows for commissioning in anticipation of future high-power operation.

In response to Recommendation 5 from A-TAC 2022, the J-PARC team has concluded that, even after recovering Φ_h to > 0.9, there is not sufficient cooling for continuous > 1 MW operation. Reinforcement of the cooling water system is likely to cost ~several $M and is not considered cost effective for the few days each year when extra capacity is required. Therefore, the team will prioritize installation of the new design of RF cavities, which it is anticipated will reduce the load on the cooling water system sufficiently.

Comments

The committee congratulates the RCS team on another year of stable user operations, with excellent availability.

It is good news that it has been demonstrated that the RCS can be reconfigured to accelerate 800 kW beam with only 11 RF cavities. This mode of operation provides a useful fallback position in the event of any future RF equipment failures.

It is likely that, because of climate change, the extraordinary ambient temperatures seen in June 2022 will become normal in future years, and that this may compromise operations on an increasing number of days each year. The J-PARC strategy for cooling water capacity for > 1 MW operations should take this into account.

When the foil position is adjusted to avoid the deformation point, the position of the foil is no longer optimal, so the traversal number will be increased and the beam loss induced by foil scattering will be increased. Please pay attention to the relation between the foil position and the beam loss (measured by residual radiation) in the injection area.

Recommendations

R13: Until all the new design RCS RF cavities have been installed, consider scheduling high-power trials at > 1 MW so that they do not coincide with the hottest part of the summer and > 30°C ambient temperatures.

14 Beam study results of RCS (SW, JT)

Findings

A great deal of progress has been made in RCS machine study in 2022. By continuous efforts, beam power to MLF of up to 1 MW has been demonstrated, with very well controlled beam loss of less than 0.05%. The beam loss is reduced by 80% compared with the beam commissioning results from 2020.

The uncontrolled beam loss in the injection area has been reduced by reducing the injection beam size, and accordingly a smaller foil can be used. With the smaller foil, the traversal number can be decreased and this effectively reduces the foil scattering beam loss.

For the MLF mode, the transverse painting and longitudinal painting were improved. By painting the hollow beam in the vertical direction, a more uniform distribution is obtained, and by shrinking the horizontal painting area, the emittance is well controlled. By using momentum offset instead of RF bucket offset, the longitudinal distribution is further optimized.

To decrease the perturbation of the SB magnet, machine study was done with decreased SB magnetic field. With this SB setting, the beam loss in the RCS was significantly decreased. The reason for this is worthy of further study.

A trial extending the use of the 2nd harmonic cavity from 6 ms to 7 ms was also done, and showed promising results to further mitigate the beam loss.

Progress has also been made in MR mode commissioning. Proton beam power of 750 kW has been achieved. By optimizing the painting area for the MR, a significant beam loss reduction was obtained, while keeping the rms emittances unchanged.

By using bipolar sextupoles to increase the chromaticity, the instability is well damped in the high energy part.

Comments

As mentioned in the presentation, the hollow vertical painting beam is good for obtaining uniform beam and emittance control. The horizontal hollow beam is also good for beam distribution and beam loss control. A further trial for different painting curves is worth doing in the next machine study.

A 20% reduction of the SB field significantly reduces the beam loss - the explanation given is the decrease of the sextupole components in SB. However, the sextupole component in SB is a higher order component, and it seems this couldn’t bring such strong effects. Considering the SB also brings other effects, such as beta beating due to fringe fields, the effect of the lower SB field needs to be studied further. Simulation could easily show a more convincing explanation of this effect, both in MLF mode and MR mode.

In the MR mode commissioning, instability occurred after 10 ms of an RCS cycle. This instability was damped by increasing the chromaticity. Optimizing tune in the whole RCS cycle is another effective tool to damp the instability. Slowly moving down the tune by using the trim quadrupoles or by setting the head and tail tune of a cycle should be very helpful to suppress the instability.

Recommendations

None.

Homework 1: List both hardware and beam commissioning activities that were planned and are achieved, delayed, or not-yet-achieved for the upgrade of the MR to the 1.36 s cycle time. (ML)

Findings

A clear and concise list of achieved, delayed or not-yet-achieved were presented for the MR upgrade. The main topics with issues to still be addressed are the MR fast-extraction septum magnets, the MR RF systems, the MR main magnets and the remaining beam commissioning activities.

The achieved activities are for the fast extraction system the ejection to abort at 8 GeV and for the RF systems 8 GeV acceleration. For the main power supply 1.36 s operation has been achieved and for the beam commissioning activities the 8 GeV acceleration, tuning and optics tuning has been done.

The not achieved issues for the fast extraction magnets are the 4 kA operation for SM 30, 31, 32 and the 30 GeV extraction to the neutrino target and to abort. For the RF system the 30 GeV acceleration has not yet been done and for the Main Power supply the QFN ripple still needs to be addressed. Furthermore, for the beam commissioning at 30 GeV the acceleration, the extraction and tuning for user operation is still to be done.

Comments

If there is an extended shutdown in the coming year, the lab should assure that all MR 30 GeV upgrade activities not requiring beam should be prioritized to assure a timely completion of the upgrade.

Recommendations

None.

Homework 2: Present the current understanding of the MR critical challenges and risks that can lead to long downtime. Show planned mitigations and milestones, and items for which funding still needs to be secured. (WF)

Findings

Critical challenges with the potential of creating long downtime include IGBTs and gate modules with lead times of 15 months, fuses with a lead time of 15 – 18 months, extraction system magnet coils used in FX operation, and the electro-static septum for SX operation.

The risk for these items is mitigated by restocking low inventories with the same or substituted items, or manufacturing of replacement items (coils in FX extraction magnets, ESS).

Comments

The initiated actions will address the risks eventually. Due to the long lead time of some items a risk remains while these are on order or manufactured but not yet received. Some contingency plans should be made for the case that failures occur while components are still on order or being manufactured.

Recommendations

R09: Carry out a full analysis of the residual risk to operations of the current MR spares situation, investigating all possible additional mitigations (e.g. reconfiguration of power supplies to share the load, borrowing suitable spare components from other facilities, etc.).

Homework 3: Show how the MR progress aligns with the HyperK completion. (SG)

Findings

The Upgrade program has been conceived to achieve 1.3 MW operation by JFY2028. The budget to implement the system modifications listed below is partially already secured by the Hyperkamiokande project, but not entirely for all the systems.

Considering the worldwide financial situation and the general cost increase of raw materials, the cost to completion is also expected to increase.

The priority assigned to each of the systems depends on the impact on beam performance if not realised or partially realised, being the maximum impact priority 1.

- RF (priority 1), which includes:
    - New Cavities
    - Anode P.S. Upgrade for Rack (15 unit → 19 unit) for #3 ～ #8 (6 p.s.)
    - Unit production: 32 units = 4×8 p.s.
    - Funded by Hyper-K until 2025. More funding is necessary for 25 units from 2026. The current estimate is approximately 2.5 oku-yen for 25 units.
- Main Magnet P. S. (priority 2), which includes:
    - Capacitor bank upgrade (480 mF → 510 mF)
    - Not funded by Hyper-K. Funding is necessary by JFY2025.
- Trim Sextupole Correction P. S. (priority 3) , which includes:
    - Not funded by Hyper-K. Funding is necessary for 24 sets of p.s. by 2028.
    - 8 sets per year
- Abort Dump (priority 4)), which includes:
    - Not funded by Hyper-K. Funding is necessary to be completed by Fall 2026.
- QDT (priority 5)), which includes:
    - Funded by Hyper-K, more funding is necessary to complete all 6 magnets. The current estimate is approximately 3.8 oku-yen for 6 magnets.
    - Funding is necessary for steering magnets, vacuum chambers, BPMs.

Comments

The committee acknowledges the large amount of work realised so far and recognises the importance of proper funding to complete the machine upgrade to deliver the 1.3 MW by 2028 necessary for the success of the Hyperkamiokande scientific program.

Recommendations

None.

Appendix 2 – Agenda

Agenda for A-TAC2023 (Q&A included for each report) 2023/1/6

January 26, Thursday Venue: a conference room on the 2nd floor of theJ-PARC Research Building and Remort

Time(JPN.ST)		Period	Category	Title	Speaker	
8:00			*Departing the hotel, "Terrace Inn Katsuta"*			
9:00	9:20	0:20	Time for LAN Connection			
9:20	9:35	0:15	**Executive Session**	*Closed*		
9:35	10:15	0:40	**Project Status**		T. Kobayashi	
10:15	10:45	0:30	**Accelerator Overview**	J-PARC accelerator overview	M. Kinsho	including item#1
10:45	11:05	0:20	**Group Photo and coffee break**			
11:05	11:45	0:40	**MR**	Status of MR	S. Igarashi	including item#5
11:45	12:30	0:45		PS commissioning	T. Shimogawa	including item#4
12:30	13:20	0:50	***Lunch***			
13:20	14:05	0:45	**MR**	Extraction magnets and PS	K. Ishii	
14:05	14:35	0:30		RF System upgrade plans	Y. Sugiyama	
14:35	14:55	0:20	**coffee break**			
14:55	15:25	0:30	**MR**	MR-Upgrade plans	H. Hotchi	
15:25	15:55	0:30		Maintenance plans of utilities	M. Shirakata	including item#6
15:55	16:25	0:30		Slow extraction status and plan	M. Tomizawa	
16:25	17:10	0:45	**Executive Session**	*Closed*		
<<Reception>> 18:00 - 19:30 at the KEK 1-gou kan						

January 27, Friday Venue: a conference room on the 2nd floor of theJ-PARC Research Building and Remort

Time(JPN.ST)		Period	Category	Title	Speaker	
8:00			*Departing the hotel, "Terrace Inn Katsuta"*			
9:00	9:10	0:10	Time for LAN Connection			
9:10	9:25	0:15	**Executive Session**	*Closed*		
9:25	9:55	0:30	**LINAC**	Status of LINAC	T. Morishita	
9:55	10:35	0:40		Beam study results of LINAC	M. Otani	
10:35	11:15	0:40		Beam loss in the LINAC	Y. Liu	including item#2,#3
11:15	11:30	0:15	**coffee break**			
11:30	12:00	0:30	**RCS**	Status of RCS	K. Yamamoto	
12:00	12:30	0:30		Beam study results of RCS	P. Saha	
12:30	13:30	1:00	***Lunch***			
13:30	17:00	3:30	**Executive Session**	*Closed*		
<< dinner >> 19:00 - 20:30 at the restaurant in Katsuta						

January 28, Saturday Venue: a conference room on the 2nd floor of theJ-PARC Research Building and Remort

8:00			*Departing the hotel, "Terrace Inn Katsuta"*			
8:40	10:30	1:50	**Executive Session**	*Closed*		
10:30	11:30	1:00	**Recommendations to J-PARC**		J. Wei	
adjourn						

Tour(optional)

Required items from last ATAC	1.prioritized lists of the R&D and AIP	M. Kinsho	in Overview
	2.beam loss in the linac	Liu	in LINAC
	3.Present plans for the use of Machine Lernig	Liu	in LINAC
	4.Report on the MR PS commissioning	T. Shimogawa	in MR
	5.Present MR beam studies and commissioning plai	S. Igarashi	in MR
	6.multi-year maintenance and upgrade plan pertaining to utilities and infrastructure.	H.Hotchi, M.Shirakata	in MR