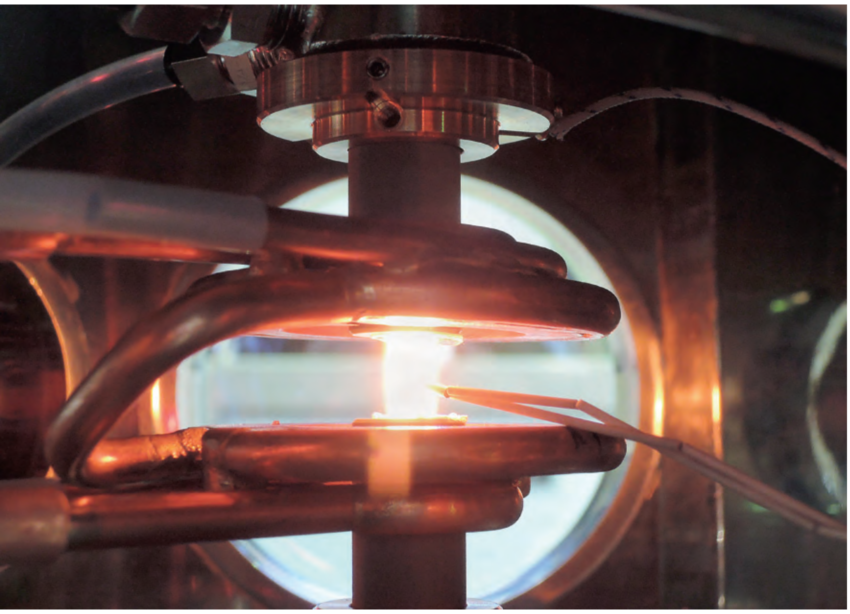
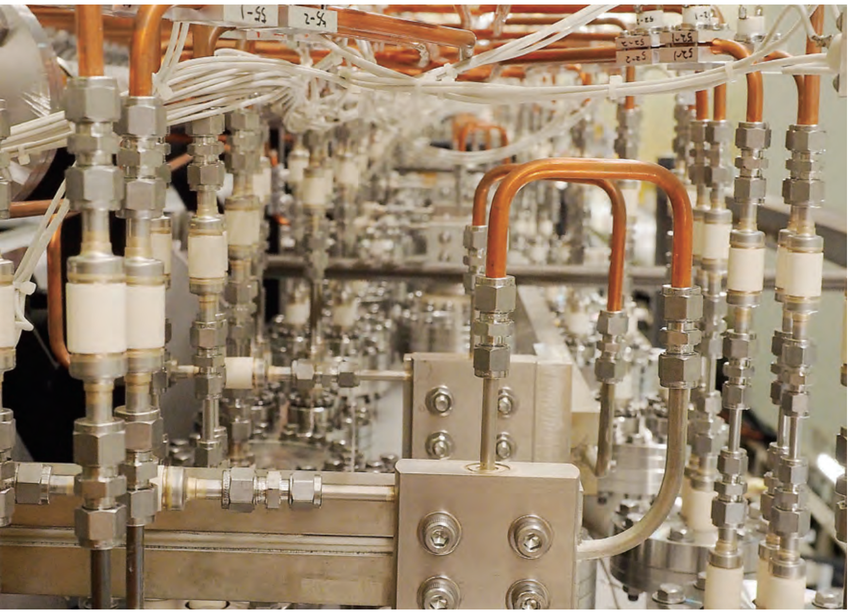
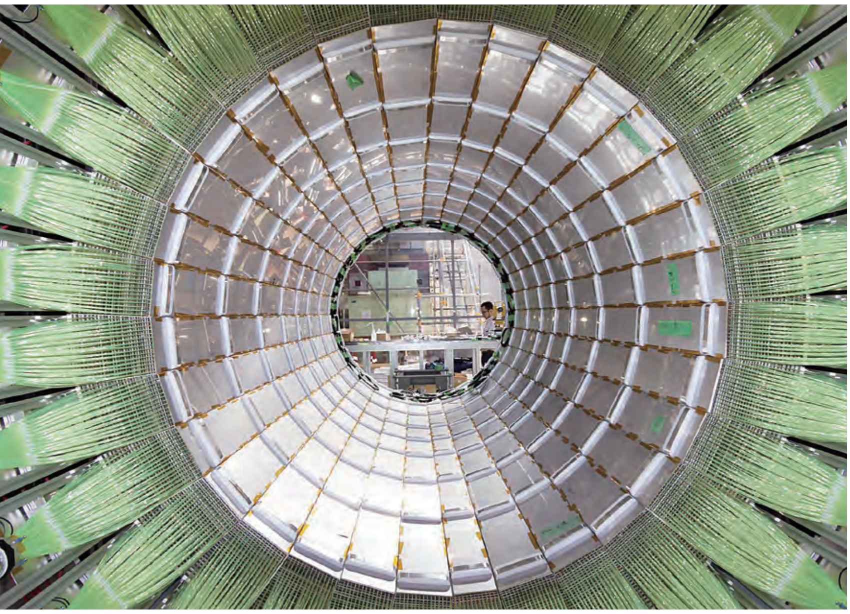






J-PARC

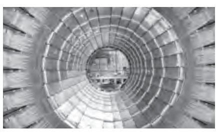
ANNUAL REPORT 2016

Vol.1: Highlight

Cover photographs

Photograph ① : Thermo-mechanical simulator
Image credit: Stefanus Harjo

Photograph ② : High current bus bars and a large number of cooling-water feedthroughs for the septum magnet in MR
Image credit: Masahiko Uota



Photograph ③ : Inner Barrel detector
Image credit: Yasuyuki Sugiyama

J-PARC Annual Report 2016

Contents

Preface

This volume describes the activities of J-PARC from April 2016 through March 2017, Japanese fiscal year 2016 (JFY2016).

J-PARC (Japan Proton Accelerator Research Complex) is a multi-purpose research facility based on world-class high-intensity proton accelerators built through the joint efforts of the High-Energy Accelerator Research Organization (KEK) and the Japan Atomic Energy Agency (JAEA). In a wide range of research fields, including materials and life sciences, elementary-particle and nuclear physics and research and developments for nuclear transmutation, we aim to make significant contributions to the advancement of humankind by promoting diverse research and developments covering basic science to industrial applications.

In JFY2016, the neutrino oscillation experiment T2K reported a hint of CP violation in the neutrino sector. It represents the beginning of another exciting era for the fundamental physics, where one of the major questions is "why our universe is matter-dominant?". Studies to answer the question are also conducted at the Hadron Experimental Facility. The KOTO experiment to search for CP violating decays of neutral kaons has also started to produce its first physics results. In addition, the searches for multi-strangeness nuclei are expanding towards their full-scale investigation, where candidates for double hyper-nuclei are reported. Furthermore, the studies are now extended to cover the muons, including a search for muon-to electron conversion, COMET experiment, and precision measurement of the dipole moments of muons, muon g-2/EDM@J-PARC.

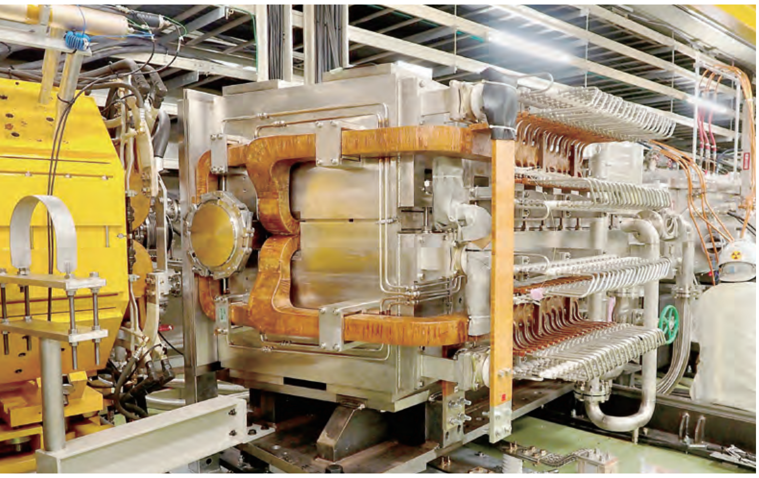
In the Material and Life Science Facility (MLF), we decided to aim for the highest possible availability to provide a stable beam across the neutron and muon beams for users. A new target vessel is under construction with the goal to provide the most robust and power-resistive system, so meanwhile, we have operated the MLF with a power as low as 200 kW to ensure stability and to prolong the life of the target vessel. Even with the low-power operation, we and the users were able to produce many significant results, which were announced in our press releases. The number of those releases has doubled compared to year 2015. Furthermore, the potential industrial applications were explored further. These results are reported briefly in this volume and in more detail in the separate volume dedicated to the MLF results.

In this volume, we also report the various advancements in the R&D for the accelerator driven system (ADS) for nuclear transmutation.

We would like to share all these outcomes widely with the world community. Furthermore, we would like to contribute to the society by enhancing the collaboration with universities, research institutions, and industries not only by producing and sharing our results, but also by creating the next generation of researchers with an extensive experience in cutting-edge facility operation, who can, in turn, produce the next generation of research facility for the future.

"High power beams for the next stage of our life!"

Naohito SAITO
Director of the J-PARC Center



Accelerators

Overview of the Accelerator

The J-PARC accelerator complex consists of a 400 MeV linac, a 3 GeV Rapid Cycling Synchrotron (RCS) and a 30 GeV Main Ring synchrotron (MR). A proton beam from the RCS is injected to the Materials and Life Science Experimental Facility (MLF) for neutron and muon experiments. The MR has two beam extraction modes; fast extraction (FX) for the Neutrino experimental facility (NU) and slow extraction (SX) for the Hadron experimental facility.

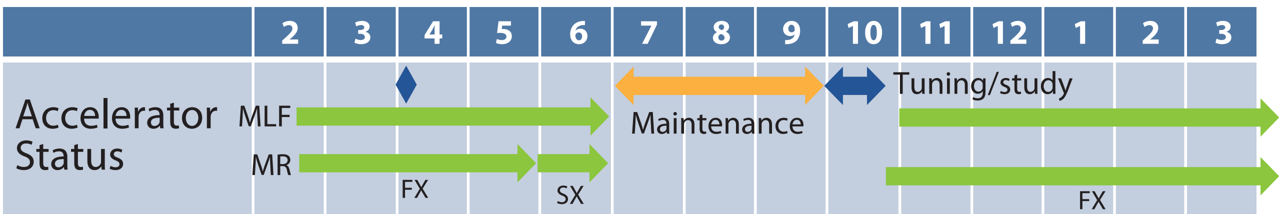


Fig. 1. Accelerator operation in FY2016.

The operation in FY 2016 is illustrated in Fig. 1. The topics related to the beam operation are as follows:

(1) Operation for the MLF

Due to damage incurred in November 2015 at 500-kW power, the neutron target was replaced with a spare one. After that, we delivered beam at the lower risk power of 200 kW. To improve the quality of the experiments even at the lower beam power, the linac and the RCS have provided a one-bunch beam instead of the regular two bunches, which creates a shorter pulse, preferred by some fast-TOF and muon users.

At the beginning of the new fiscal year, we delivered beam to the MLF by April 4, 2016, as scheduled. But during the maintenance period that followed, a vacuum leak occurred at one of the collimators in the RCS and it took about a week to rectify it.

We decided not to replace the target in the summer of 2016. So, the beam power was reduced from 200 to 150 kW in November to expand the target lifetime until a new robust target is ready.

(2) Operation for the Neutrino Experiments

The user run of the MR-FX was started at about 400 kW in April, when the operation resumed after fixing the problem with an MR bending magnet and the RCS collimator. The beam power was gradually increased to 460 - 470 kW by the end of March 2017, thanks to a device upgrade and parameter tuning.

(3) Operation for the Hadron Experiments

We had SX beam time for one month from the end of May to the end of June. The beam power was about 42 kW, the same level as in FY 2015, but the quality of the beam and especially such characteristics as extraction efficiency and duty factor were improved due to some parameter optimizations.

Table 1. Operation statistics in hours in FY2016.

Facility	User Time (hours)	Trouble, Acc.only (hours)	Trouble, Fac.only (hours)	Net Time (hours)	Availability, toral (%)
MLF	3,743	257	2	3,483	93.1
Neutrino (FX)	3,532	570	235	2,726	77.2
Hadron (SX)	612	92	4	515	84.1

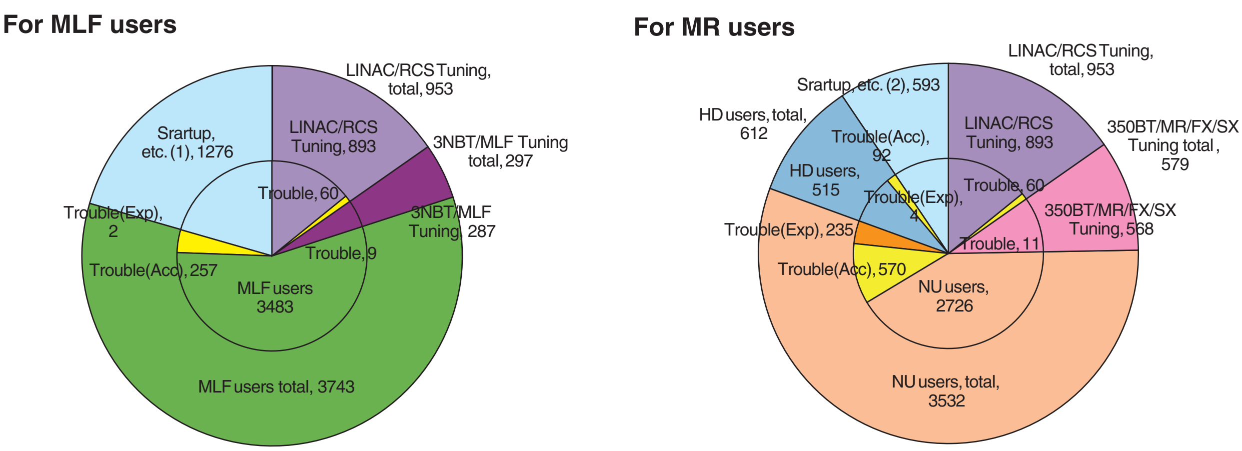


Fig. 2. Operation statistics in FY2016. The total operation time was 6,271 hours.

The operation statistics in FY 2016 are shown in Table 1 and Fig. 2. The total operation time, which was shift leaders' on duty time at the control room, including startup and RF conditioning, was 6,271 hours. The net user operation hours and the beam availability rate for each experimental facility were as follows: 3,483 hours (93%) for MLF; 2,726 hours (77%) for NU; and 515 hours (84%) for HD. These statistics show that the linac and the RCS operated properly.

The down time by components is shown in Fig. 3. There were several causes of downtimes.

Compared to the last year, the linac had generally become more stable. The top cause of the downtime was a group of HVDC (High Voltage DC power supply for klystrons). Several defects in this group included a klystron failure, HV insulation breakdown, and failures of the switching devices and modules. The linac uses twenty 324-MHz klystrons and twenty-five 972-MHz klystrons. Most of the 324-MHz klystrons have been used from the beginning of the linac operation in 2006. We suppose that after over 50,000 hours of operation, these klystrons have come to the end of their lives.

The RCS was generally stable, except for a single vacuum leak at the collimator in April 2016. This is indicated in the "RCS-Others" group in Fig. 3. The leaked collimator unit was replaced with a temporary spare duct and the operation resumed.

There were several downtimes at the MR that lasted a few days. We had a water leakage from a coil at the bending magnet (group in "MR-BM") in March 2016. Also, a small animal entered an outdoor transformer in May (group in "MR-Others"). Some of the troubles came from new components for the performance upgrade. We took care of them, by mostly grounding for noise suppression.

Most of the improvement and upgrade work was carried out during the summer shutdown. These improvement items, major downtime causes, and beam power history are described in further chapters.

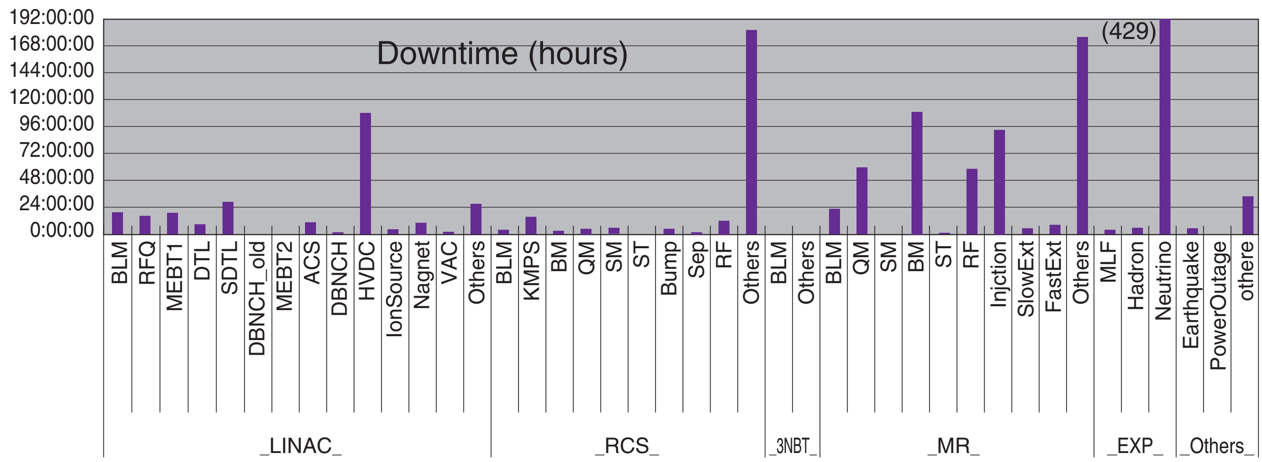


Fig. 3. Downtime by components in FY2016.

Linac

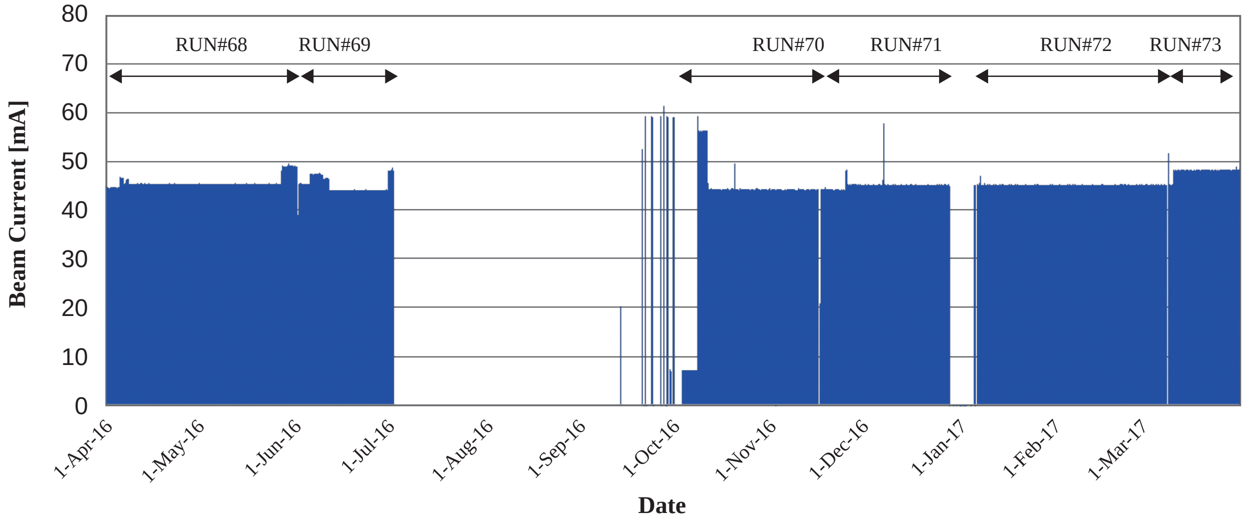


Fig. 4. Operation history of the ion source in FY2016.

The J-PARC linac has been operated with the peak beam current of 40 mA for users' operations. A cesiated RF-driven negative hydrogen ion source has been providing successfully the required beam without any serious problems. The operation history of the ion source in FY2016 is shown in Fig. 4. In RUN#68, the beam run cycle was extended from 1.5 to 2 months. Approximately 1,350 hours continuous operation was achieved with a beam current of 45 mA in RUN#68. The spark rate occurring at the ion source beam extractor is a few times per week, which is an acceptable level for users' operations.

We monitored the RFQ RF-trip approximately 15 times per day and it did not change significantly from the 30-mA operation last year.

The number of trips in the SDTL06 increased significantly just after the 2016 summer maintenance. We assume that the situation was caused by a long-term exposure to the atmosphere during the maintenance period. The trip frequency decreased as the operation went on, and reached an acceptable level. Currently, the total trip rate of all DTL/SDTL cavities is about 0.5 times per day. After the earthquake in 2011, we could not input an rf power into some SDTL cavities in the range of approximately 250 to 450 kW due to the multipactor. In 2015, we confirmed that surface cleaning with acetone solves effectively the multipactor problem by applying it to the SDTL05B cavity. The same treatment was applied to the SDTL05A, 06A and 06B in the summer of 2016, and it has eliminated or reduced the multipactor region to tolerable levels, as shown in Fig. 5.

The ACSs were stably operated in comparison with the other structures. The number of trips of all the ACS cavities was about 0.3 times per day. This trip rate was less than one-third of that observed at the initial operation period of the ACS.

The RF chopper system, which is installed just after the RFQ, consists of two RF-deflecting cavities and a beam scraper. Until the summer of 2016, the cavities were connected in series with a coaxial line and powered by one RF power system. The large ringing on the RF falling of the intermediate-pulse was probably triggered by the reflected wave from the downstream cavity, and it caused beam loss at the RCS. The ringing problem was solved by supplying the RF power to the two cavities independently by installing an additional RF power system in the 2016 summer maintenance. In FY2016, the chopper system was operated for 9 months at 40 mA. The results from the observation of the used scraper surface after 9 months operation using the laser microscope are shown in Fig. 6. A shallow crater of approximately 0.15 mm in depth was generated at the scraper surface, where the beam is irradiated, as we expected.

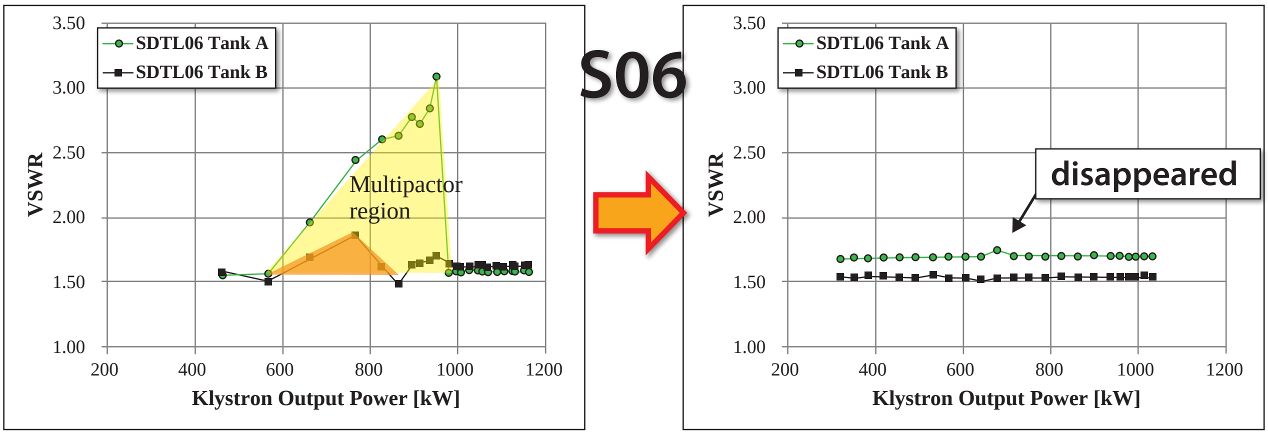


Fig. 5. VSWR as a function of the klystron output power at SDTL06 before (left) and after (right) surface cleaning.

We have been using two types of klystron such as 324-MHz klystron and 972-MHz one. The operation times of the two types of klystrons, as of March 2017, are shown in Fig. 7. Many of the 324-MHz klystrons exceeded 50,000 hours of operation. In FY2016, we replaced two klystrons due to their performance degradation. A total of seven 324-MHz klystrons were replaced from the beginning of the linac operation. We are apprehensive that those klystrons may come to the end of their life in the near future. Most of the 972-MHz klystrons reached 20,000 hours of operation. We replaced one of those klystrons in FY2016.

The linac operation was suspended several times due to the failure of the anode modulator in the klystron RF system. The failure was caused mainly by malfunction of a bias power supply, which is submerged in the modulator oil tank. We estimate that the temperature of the power supply rises to approximately 80°C, therefore the chemical capacitor in the power supply assemblies seems to have deteriorated during the long operation. As a countermeasure, we will develop a new type of power supply with high resilience under high temperature conditions, which will replace the old one. Presently, we are constructing a klystron test-stand in the linac building in order to conduct off-line klystron conditioning and develop various new devices, such as a new bias power supply and so on.

Cooling water issues causing beam stops for several hours occurred after the 2015 summer maintenance. The cooling water flow rate at DTL decreased significantly, especially at DTQ. In the 2016 summer maintenance, we applied extensive countermeasures

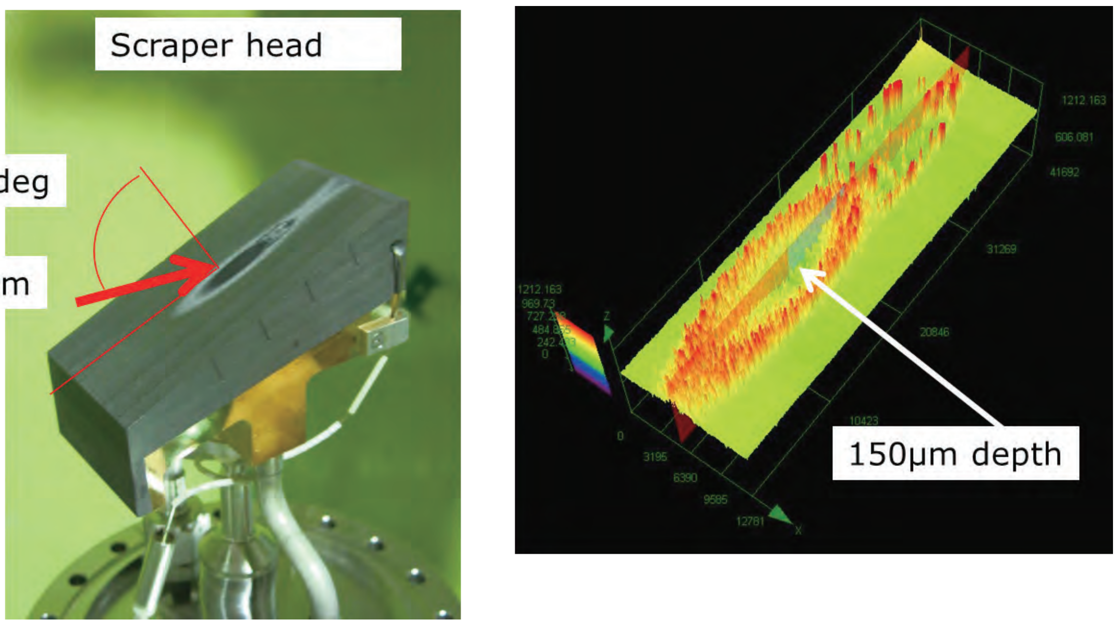


Fig. 6. Observation of scraper surface after 9 months operation.

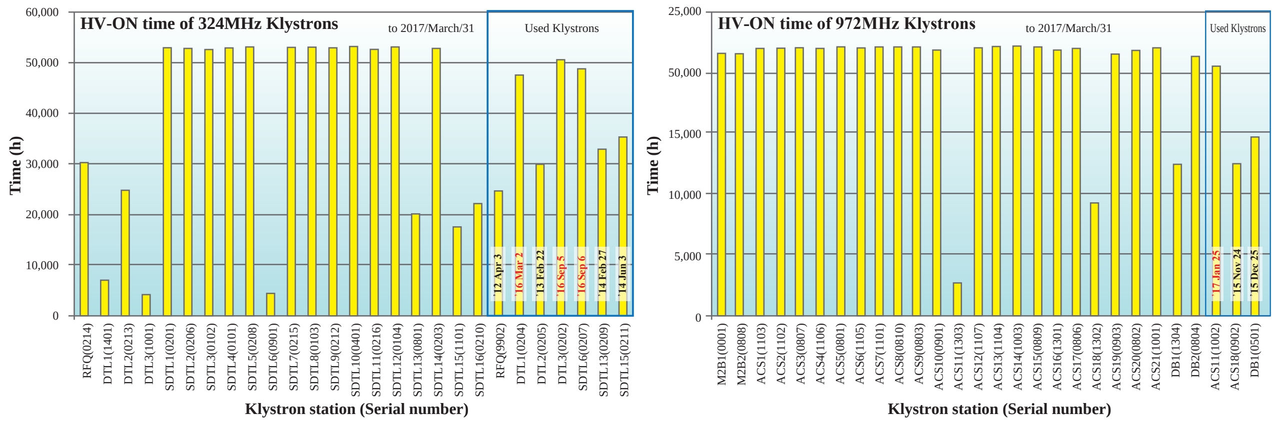


Fig. 7. Operating time of 324-MHz (left) and 972-MHz klystron (right) as of March 2017.

to solve the problem. We used a fiberscope and found obstructions in the DTQ magnet cooling pipes caused by contaminant particles. We also identified the material clogging the SDTL-quadrupole magnet as copper oxide, which was eventually removed. We removed these foreign materials. In addition, the primary cooling water line was split into two parts and an additional water pump was installed to improve the water flow rate. The measures stabilized the flow rates and currently no frequent flow-adjustment work at short intervals is necessary.

We continue to make efforts to mitigate the beam loss. In order to perform the longitudinal beam matching study, bunch shape monitors with improved vacuum behavior and reduced pumping requirements were developed and installed at the MEBT1 and ACS1 sections. To investigate a beam loss caused by a residual gas scattering, the wire-scanner at MEBT2 was replaced with a new version which was designed for profile measurement of the H0 particles.

In the previous theoretical and experimental studies, the Intra Beam Stripping (IBSt) was found to be the dominant source of beam loss in the linac's 200~400 MeV part. To minimize the beam loss due to the IBSt, further beam studies have been carried out for an optimum compromise between linac stability and minimum IBSt. Transverse and longitudinal redesign studies were completed and as the result, we found more candidate settings with IBSt loss mitigated by more than 50% at around 95% of ACS tank level and temperature ratio (Tx/Tz) of 0.3, as shown in Fig. 8. Further studies will be conducted to achieve a full lattice optimization for the beam loss and RCS injection for the coming 50-mA user operation.

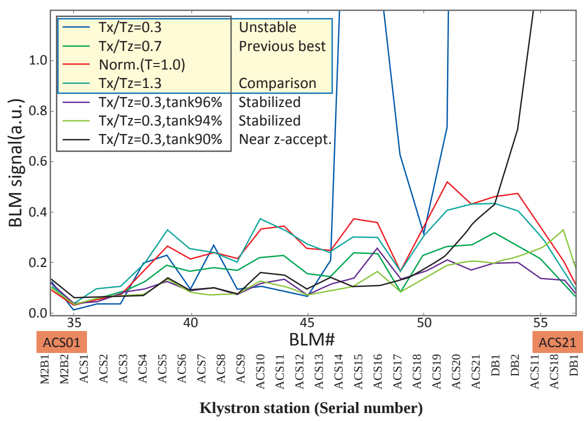


Fig. 8. Measured beam loss at beam loss monitors for the transverse and longitudinal redesigning for the J-PARC linac ACS section.

RCS

Operational status

The output power produced by the RCS in the beginning of fiscal year 2016 was 200 kW for the MLF and 40 kW for the MR (corresponding to an MR output power of 400 kW). Since we did not have a spare neutron target, the output power for the neutron target was suppressed to less than 200 kW for its protection. After MR switched operation to the Hadron Experiment, the radiation dose decreased to 5 mSv/h six hours after the beam stopped. Furthermore, after a two-month cooling-off period, it decreased to less than 1 mSv/h during the maintenance work.

Because the new neutron target was not available on time, the output power was reduced to 150 kW after the summer shutdown period. On the other hand, the MR output power was increased due to the progress of the MR commissioning. Figure 8 shows a history of the output power from the RCS.

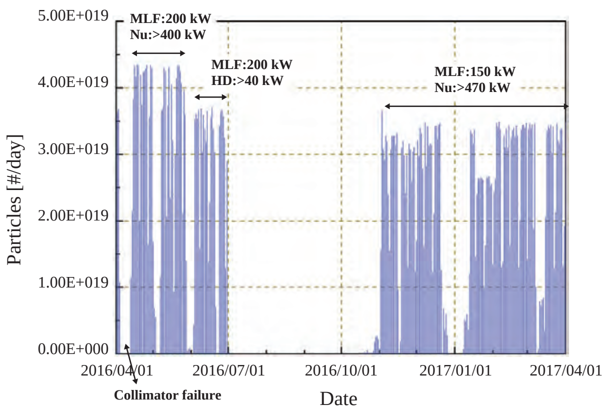


Fig. 8. History of the output power from RCS.

During the short maintenance period in April 2016, one of the ring collimators was broken. A defect of the control system caused a vacuum leak in the fifth secondary collimator chamber. Since the numerical simulation results indicated that the beam loss without this collimator would be acceptable, we installed a spare straight duct instead of repairing the broken collimator. This measure reduced the repair period by 8 days. The availability of the RCS was worse than that in the previous year due to this accident. Its operation time for the MLF over the year was approximately 3484 h, excluding commissioning and start-up time with a down time of approximately 257 h; therefore, its availability was about 93%. The most significant reason for the down time was the collimator failure.

Maintenance and improvements

1) Replacement of the broken collimator

The beam collimation system removes the beam halo and localizes the beam loss to preserve the other accelerator components. The collimation system comprises one primary collimator, which scatters the halo particles, and five secondary collimators, which absorb those scattered particles. The radiation shielding around the collimator chamber was designed in such a way that the collimator system could absorb a halo of at most 4 kW. In April 2016, a malfunction occurred in the VME system, i.e., the collimator's control system. We conducted a performance test to remedy this problem but a vacuum leak occurred during the test. The vacuum pumps stopped abruptly due to sudden vacuum deterioration, and the area around the vacuum deterioration point was immediately isolated by the gate valves.

After an investigation, it was found that the fifth secondary collimator was the source of the leak, which was caused by a collision of the collimator blocks. We needed to repair it quickly, but it was highly activated, and we did not have a spare of the fifth secondary collimator. We then looked for a temporary solution, and the numerical simulation results indicated that the beam loss without this collimator would be acceptable. We therefore installed a spare straight duct instead of repairing the broken collimator.

After the resumption of the user operation, the residual dose in the arc area was not as high as expected. However, there was a step in the new duct due to the difference in the flange diameters of the upstream and downstream ducts, and a dose of at most 10 mSv/h occurred at this point. Following our temporary repair, we made a fixed collimator to replace the spare duct, and it was installed during the summer shutdown period. Figure 9 shows the photographs of the spare straight duct and the fixed collimator. When we installed the new fixed collimator, the residual dose on contact of the collimator was reduced to less than 1 mSv/h. The control system was also replaced with a more robust system. All collimator positions can now be independently monitored by additional potentiometers, and this improvement prevents the collision of the collimator blocks.

Fig. 9. Temporary spare duct and new collimator.

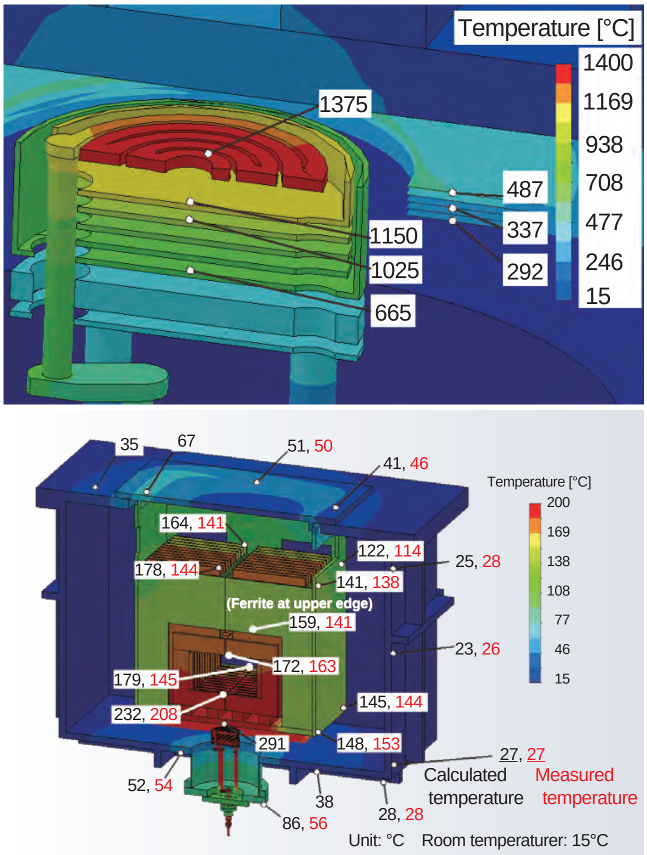


Fig. 10. Kicker baking system.

2) Kicker baking system

To date, vacuum pressure has not been a critical issue in the RCS; however, a demonstration of high power operation indicated that the beam loss was caused by pressure increase. We considered that there are two major sources of outgassing: the injection foil and the ferrite yokes in the kicker magnet chamber. Improvements to the injection foil are now in progress, and an *in situ* bake-out system for the ferrite yokes had been developed and was installed during the summer 2016 shutdown period. In order to achieve effective degassing, the temperature of the yokes should be as high as possible. Moreover, the temperature of the vacuum chamber must be limited to avoid thermal expansion. Thus, we had developed thermal radiation shields to suppress heat transmission from the heater to the chamber wall. The target temperatures are more than 120°C for the ferrite yokes and less than 30°C for the chamber wall.

Figure 10 shows the temperatures of the chamber and yokes with the thermal radiation shields in place, investigated by a calculation and an experiment. The increases in temperature was 140–240°C at the yokes and less than 20°C at the chamber wall, indicating that the target temperature was achieved. After the installation of this system, the ferrite yokes were baked, and the thermal expansion of the vacuum chamber was less than 1 mm. The vacuum pressure was improved from 1×10^{-5} Pa to 1×10^{-6} Pa.

3) Improvement of the sextupole magnet

Previous beam study results indicated that one possible scenario for suppressing beam instability is to import incoherency via large negative chromaticity. Based on these study results, we needed to increase the chromaticity effect during the latter half of the acceleration cycle. In addition, we also needed to correct the chromaticity during the first half of the acceleration cycle to suppress emittance growth. However, only positive or negative chromaticity could be generated by the previous power supply system for the sextupole magnets. We therefore upgraded the power supply system to a bipolar system.

Residual dose distribution and exposure during maintenance

Since the output power for the MLF was limited, the residual doses in the RCS were sufficiently small. A total of 41 workers were exposed to a dose of more than 0.01 mSv during the summer shutdown period, and the corrective dose for these workers was 1.99 mSv. Only three workers were exposed to a residual dose of more than 0.1 mSv, and the maximum dose received by any one worker was 0.19 mSv. The number of workers who were exposed to a dose of more than 0.01 mSv increased compared with the previous fiscal year; however, the collective dose was significantly reduced, which can be attributed to the establishment of a foil maintenance procedure, low output power for the MLF, and no serious work being conducted near the injection area. The maximum dose incurred while replacing the broken collimator with the temporary spare duct was 0.6 mSv, whereas that from replacing the temporary duct with the new collimator was only 0.1 mSv. This was due to thoroughly preparing for the work, having sufficient cooling time, rotating the workers and the presence of local shielding.

Beam commissioning

1) Bipolar sextupole excitation test to suppress instability

We investigated the tune variation during the acceleration process to reduce the beam emittance for reduction of the MR beam loss. A better condition for reducing the beam emittance was obtained; however, this condition enhanced beam instability. A better solution is to correct the chromaticity in the first phase of the acceleration cycle and to enhance it in the middle and final phases. We tested a new power supply system for the sextupole magnets to realize such chromaticity control, and confirmed that the instability had been suppressed.

2) Low beam emittance for the MR

We investigated the mechanism of emittance growth by numerical simulation. The results revealed that the emittance growth was caused by the resonances $\nu_x = 6$, $\nu_y = 6$, and $2\nu_x - 2\nu_y = 0$ during the first 8 ms of acceleration. From this analysis result, we tried to mitigate the emittance growth by adjusting the operation tune away from those resonance lines. The results are shown in Fig. 11. The emittance growth was well mitigated by the new parameter, as predicted by the numerical simulation.

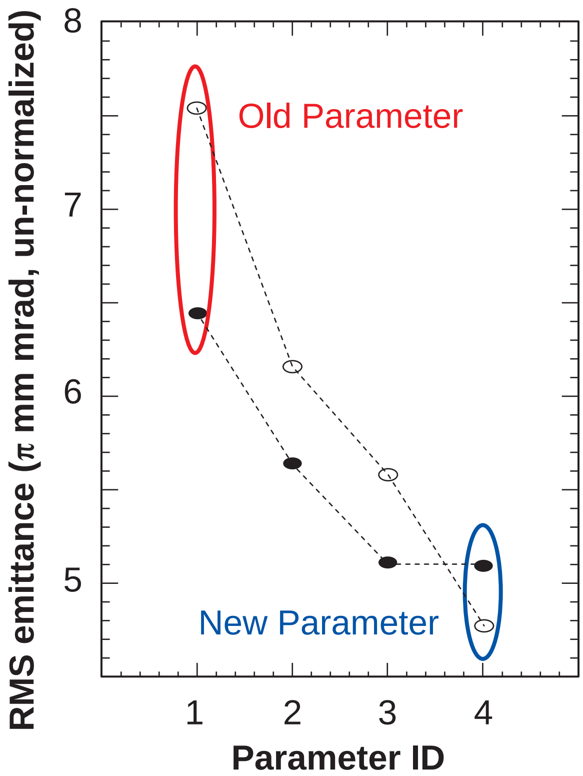


Fig. 11. Extraction beam emittance measurement results.

Summary

In the current year, the output power of the MLF was initially maintained at 200 kW and then decreased to 150 kW after the summer shutdown period. The beam power for the MR, however, was satisfactorily increased to the equivalent of 700 kW. We temporarily substituted a spare duct for a broken collimator, and the spare duct was then replaced by a new collimator in the summer shutdown period. An *in situ* baking system for the kicker magnets and a bipolar power supply system for the sextupole magnets were also installed during the summer shutdown period. The operation tune and chromaticity were adjusted so as to move the beam away from the resonance lines and, as expected, we obtained a small beam emittance.

MR

Overview

The Main Ring synchrotron (MR) of J-PARC supplies the 30-GeV proton beam alternatively to the neutrino experimental facility in a 2.48 s period or also to the hadron experimental facility in a 5.52 s period. The former operation mode is called fast-beam extraction (FX) mode and the latter one is slow-beam extraction (SX) mode.

Figure 12 shows the beam power history of MR in JFY2016, the regular operation for the FX started at 390 kW during JFY2016 and the beam power was finally increased up to 470 kW in February 2017. For the SX mode beam power of 42 kW was also reached.

However, MR had many troubles, which stopped the beam operation for several days. These troubles are described in the next section.

The design beam power for FX is 750 kW. It will be achieved by reducing the beam cycle from 2.48 s to 1.3 s after new magnet power supplies and other new equipment are installed.

Troubles

The main troubles are summarized as follows. The numbers of the items below correspond to ones in Fig. 12.

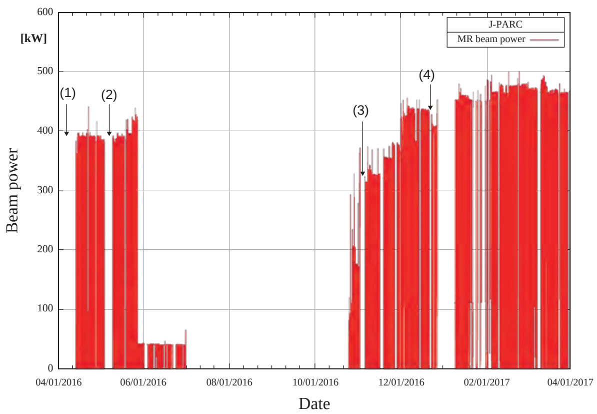


Fig. 12. MR beam power history (JFY2017)
(1)~(4) show the troubles described in the report

(1) The main bending (dipole) magnet BM-67 had a short circuit between the layers of the hollow coils of the magnet caused by leaked water from the brazing point of the coil. The magnet was replaced by a spare one. It was assumed that the brazing material of the hollow coil probably had some defects. However, it is not easy to cut the coil in order to investigate the reason because the BM-67 magnet is a radioactive object.

(2) A short circuit of transformer of the injection septum magnet happened. The circumstantial evidence in the transformer indicated that the trouble was caused probably by an animal entering the active part of the transformer. Thus, after the transformer was replaced, a cover was set in the cable duct to prevent intrusions of wild animals into the equipment.

(3) Electrical trouble occurred in the power supply for the new injection septum magnet installed in the beam line for the future 1.3 s operations. As large noise from grounding turned on some IGBTs simultaneously of the AC-DC converter stage in the power supply of the magnet, huge current flew in the IGBT from the capacitor bank. Eventually, the IGBT sustained serious damages by the temperature rise due to the rushed current. The damaged IGBT stage was removed and the power supply was retuned and operated until the summer maintenance period of 2016 with insufficient number of IGBT stages.

(4) The transformer in the power supply of RF cavity was damaged by significant overheating. Normally, the electric device connected to the transformer is turned on just in the beginning of the operation and turned off automatically by the control system. However, the device was not switched off by the control system because large electric noise from the grounding kept the device turned on. This problem was fixed by adding a second grounding point.

Almost all troubles are triggered by noise from the grounding of the power supply. Recently, many new pieces of equipment were installed in the power supply building. As a result, the wiring of the grounding lines of the power supplies became too cluttered. The rearrangement of the wiring still continues.

SX mode operation

The assigned period for SX mode operation was limited during JFY16. All in all, 515 hours of beam were delivered out of the 612 scheduled hours. This means an availability of the SX mode of 84%, which was less than the J-PARC goal of 90% availability. However, the beam quality was improved in JFY2016, so that the 42-kW beam had a sufficient efficiency (>99.5%) and improved the duty factor (>52%) by suppression control of instabilities and implementation of extraction feedback.

The SX beam studies at 50 and 60 kW were promising. The administrative limit on the present target will be lifted slightly to allow a regular 50-kW operation. Further increases of the beam power will require an upgraded target and further mitigation of the beam loss.

FX mode operation

In JFY2016, the MR delivered beam on target for the T2K neutrino experiment with an availability of 77%. The detail was that 2726 hours of beam were delivered out of 3532 hours scheduled. The availability for FX was insufficient. However, the 14% beam unavailability to the FX users was caused by accelerator problems in 2016, whereas the rate fell to only 4% during the first two months of 2017.

The beam power to T2K increased from 390 kW to 470 kW. This beam intensity is equivalent to 900 kW if the beam cycle time were 1.3 s, instead of 2.48 s.

During the FX operation at 470 kW, the total beam losses were limited below 800 W in one cycle. The loss was localized at the collimation area which can accept a maximum of 2 kW.

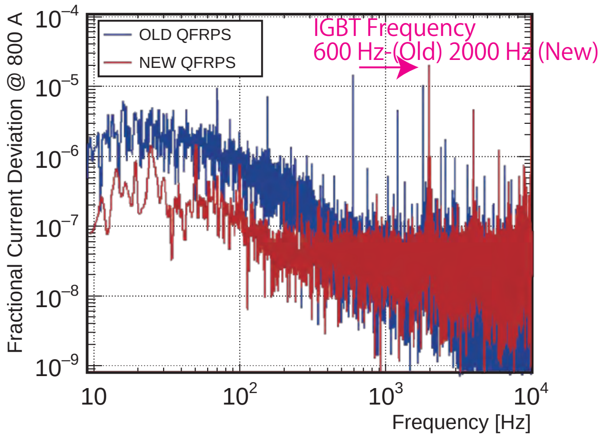


Fig. 13. Spectrums of the current ripple. Blue: Old power supply, Red: New one. Data was taken at the flat top of SX-mode pattern.

The beam study at 496 kW had a beam loss of 1.1 kW in total. Although this is an acceptable loss under the existing collimation system, the loss is not tolerable as nominal operation because a net loss increase in the large dispersive region is not desirable.

Furthermore, the beam studies were carried out with a beam intensity of 140 kW in two bunches, which correspond to a 1-MW beam power with 8 bunches and a faster ramping cycle. As the total losses were 350 W, it was estimated that the loss of the 1-MW operation was 1.4 kW.

New magnet power supply

It is necessary to reduce the cycle period from 2.48 s to 1.3 s in order to increase the repetition rate for the MR and achieve the original beam power goal of 750 kW. However, it is hard to modify the exiting magnet power supplies. Thus, the development of new power supplies had been started. The first new power supply for the Q-magnet has been assembled and tested with a real magnet load in the J-PARC. The stable operation with 1.3 s repetition period was confirmed. Furthermore, it was also confirmed that the current ripple at the flat top for SX mode operation was almost 10 times smaller than that of the old one at the lower frequency region, as shown in Fig. 13.

Summary

MR had many troubles with several power supplies in JFY2016. However, MR increased successfully the beam power up to 470 kW for the FX mode and 42 kW for the SX one. Furthermore, the beam study showed the possibility to accelerate the beam power to 1MW. The first new magnet power supply has been installed and tested with real magnets. The results show sufficiently high performance of the power supply.

Materials and Life Science Experimental Facility

Overview

In January 2016, the neutron target (#7) that had a failure in November 2015 was replaced with a backup target (#2). However, the replaced one did not equip the helium bubbling system so that we restarted the MLF user operation with a beam power of 200 kW from February 20. The operation was conducted in a steady order: 3-week operation plus 6-day maintenance period for purification of the helium refrigerator of the cryogenic hydrogen circulation system. In the summer shutdown period, we made great efforts to recover the helium refrigerator system. After the summer shutdown, the proton beam delivery to the neutron target began for the MLF user programs on November 2 at 150 kW and ended on December 21, achieving a steady operation with the high availability of 95%.

The review of the experimental proposals is an important event for the MLF. In the 2016A and 2016B periods, 97 and 90 proposals were approved, respectively, which were smaller than the usual numbers because all of the suspended proposals approved for 2014B and 2015A periods were carried over to 2016A and 2016B.

There were many activities in the MLF in 2016, some of which were the first workshop for J-PARC/ANSTO MOU collaboration on March 2 and 3, Quantum Beam Science Festa 2015 on March 15 and 16, and the European Spallation Source (ESS) - J-PARC collaboration meeting on June 1 and 2. The Neutron and Muon School, one of the biggest activities in the MLF, was held between November 22 and 26. 29 young researchers and graduate students participated in the school.

As for the Muon Science Facility (MUSE), after the successful optimization of the surface muon beam transport to the S1 experimental area on the S-line, the commissioning was focused on a new μSR spectrometer, named "ARTEMIS", and ARTEMIS started experiments on specimens from Tokyo Institute of Technology. It was a maiden voyage in the quest for innovative materials. At the D2 area, the beam line was operated to extract negatively charged muons with lower energy and narrower momentum spread.

In 2016, the operation of the MLF was rather stable, which was very important for the user program. However, the power was not so high. We will make efforts to achieve a 1-MW operation while keeping the operation stable.

Neutron Source

In JFY2016, the neutron production mercury target (target #2) was operated successfully with power of 200 kW since the previous fiscal year, while the fabrication of a new target vessel with redesigned structure (target #8) was carried out at a vendor's factory. The new target vessel was aimed to reduce the stress in the portion, where high thermal stress could be generated by beam irradiation. Therefore, its fore part of 350 mm length was changed from the previous structure that inner mercury vessel and surrounding water shroud were fixed together with bolts and a diffusion bonding to the monolithic structure with structurally coupled inner mercury vessel and water shroud. For the rear part of 650 mm, the structure of the water shroud composed of internal and external vessel was changed to be the structurally coupled type (monolithic) as well.

Those parts had to be cut out from a big stainless steel block with a wire electric discharge machining (wire-EDM) for the first time in the history of the target vessel fabrication. In particular, the machining process needed to change the wire angle continuously was very difficult and took a long time. This led to a delay of the estimated completion date to the next fiscal year and forced us to extend the use of target #2 for another year. Since target #2 doesn't have the gas micro-bubbles injection system that is needed to suppress the pitting damage at the target front, induced by the proton beam injection, the operational beam power was lowered down to 150 kW from the fall run, as shown in Fig.1.

For the fabrication of target #8, we also improved the testing of welds better than ever. For example, as the target vessel has triple-layered structure with minimum thickness of 3 mm in each layer, we inspected the weld lines with radiographic testing, supplemented by ultrasonic testing. As of the end of March 2017, the fabrication advanced to the stage of welding the beam window parts to the fore part with the monolithic structures.

During the summer shutdown period, we took measures against the performance degradation of the helium refrigerator of the cryogenic hydrogen circulation system. The heat exchangers were removed from the cold box and transported to a vendor's factory for cleaning with Freon. The adsorber installed in the downstream of heat exchangers was replaced with a brand-new one. As a result, 90 g of oil accumulated in those components were extracted. After the maintenance, the differential pressure at the heat exchanger and the adsorber never increased, restoring the reliable performance for a long-term operation. The resultant operation efficiency for the MLF user program remained significantly high at 93.8% through JFY2016.

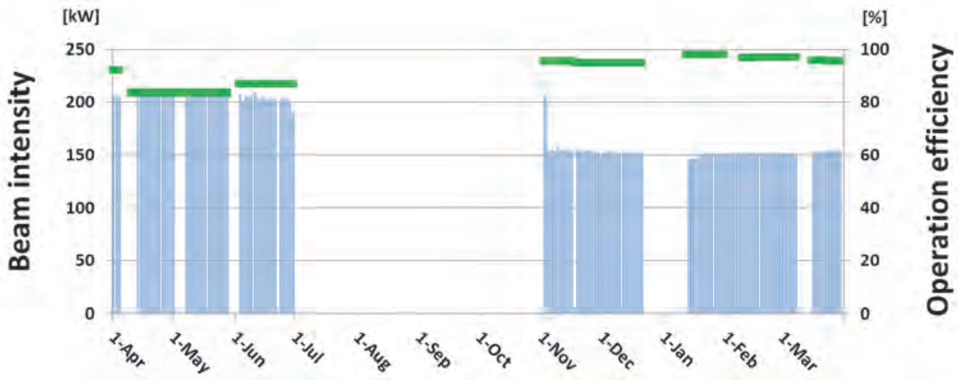


Fig. 1. Target operation history in JFY2016
The blue histogram indicates the incident proton beam intensity and the green lines represent the average operation efficiency in each accelerator run cycle.

Neutron Science

1. User Program

The user program of 2016 was affected by the target incidents that happened in 2015. Since we decided to carry-over all unexecuted experiments in the 2015A term, the total available beamtime was reduced to 42 days for each of the 2016A and 2016B terms. Also, to guarantee the stable operation of the target, the operating beam power was limited to 200 kW and was even further reduced to 150 kW in November.

For the 2016A period, 85 general neutron proposals were approved from 275 by the MLF Advisory Board after the Neutron Science Proposal Review Committee. The total competition rate was as high as 3.2. For 2016B, 90 proposals were approved from 234, so the total competition rate was 2.6.

2. Instruments development and construction

The construction work of the polarized neutron spectrometer POLANO at BL23 was in progress. To examine the radiation safety, POLANO accepted the first neutron beam. On-beam commissioning will be started in JFY2017.

Other instrumental work has also been done. For example, in the backscattering instrument DNA at BL02, the installation of Si-311 analyzer banks was started to extend the energy-momentum space. At the High Resolution Chopper Spectrometer (HRC) at BL12, to improve the gain in the scattering intensities for Neutron Brillouin scattering (NBS) option, the low-angle detectors were modified to be aligned in a double layered configuration. Also, the Fermi chopper and the collimator were improved.

3. International Activities

On June 1 and 2, 16 scientists and technicians from the European Spallation Source (ESS) visited the J-PARC facilities and we had the first ESS - J-PARC Collaboration Workshop to exchange information on broad range of fields, from radiation safety issues to practical matters in construction of neutron instruments (Fig. 2). The second worship will be held at ESS in 2018.

The First Neutron and Muon School, which was the newly reorganized MLF School, was held from November 22 to 26. 8 neutron instruments contributed to hands-on experiments and 25 of 30 participants took part in neutron experiments.

Fig. 2. Prof. Yokoo explains the inside structure of HRC to the ESS participants.

We held the J-PARC Workshop entitled "Neutron Biology for the Next Generation" on March 22. The purpose of the workshop was to promote the investigations related to biology at the MLF. The future prospects of the MLF research in the field of biology were discussed from both scientific and instrumental points of view.

4. Resultant outcomes

The research activities in neutron science at the MLF resulted in more than 80 papers.

The DNA beam line (BL02) group won the Technology Prize of the Japanese Society for Neutron Science for the development of DNA.

The ANNRI beam line (BL04) group was awarded the Culture, Sports, Science and Technology Minister's Commendation of 2016 for the work titled “Significant innovation and application of neutron resonance spectroscopy”.

Sumitomo Rubber Industries Ltd. was awarded as 28th Award of The Society of Rubber Science and Technology, Japan, for the development of high-performance tire technology (ADVANCED 4D NANO DESIGN). Based on this technology, a new tire product was commercialized in November 2016.

Neutron Devices

As one of activities at the Neutron Instrumentation Section of the MLF, the development of scintillation neutron detectors as an alternative to the ^{3}He gas-based detector has been in progress since the ^{3}He gas crisis occurred around 2009. Two types of scintillation defectors, such as large area, two-dimensional (2D) scintillation detectors and one-dimensional (1D) tubular detectors, are aimed to be developed.

Flat neutron-sensitive scintillator screens and wavelength-shifting (WLS) fibers have been used to develop a large area neutron detector. This technology has several advantages over the conventional clear fiber one. They include its simple structure and flexibility in the pixel size. The detector head comprises WLS fiber arrays in x and y directions and scintillator screens. The WLS fibers are placed at a regular pitch with an air gap between each other. Figure 3 shows prototype detectors that have neutron-sensitive areas of 32 × 32 and 64 × 64 cm (denoted as Det 32 and Det 64 in the figure [1]). The pixel size is designed to be 2 × 2 cm for both detectors. It can be reduced to 5 mm. The Det 64 detector is one of the largest 2D detector modules of this type ever built at the MLF. Experiments under neutron irradiation with a ^{252}Cf source showed that the count uniformity over the detector area was 10% as a relative standard deviation. The detector also exhibits detection efficiency of 40-50% for thermal neutrons with a ^{60}Co gamma-ray sensitivity of ~10^{-6}.

As 1D tubular scintillation detectors, we have proposed a scintillator / WLS fiber coil (SFC) detector. The idea of the SFC structure is to make the detector element with a rolled WLS fiber coil sandwiched between two cylindrical scintillator screens [2]. This unique structure yields a neutron absorption probabilty corresponding to that of a 6-bar 1-inch diameter ^{3}He PSD. Hence, the detector's potential is enhanced to exhibit a high detection efficiecy.

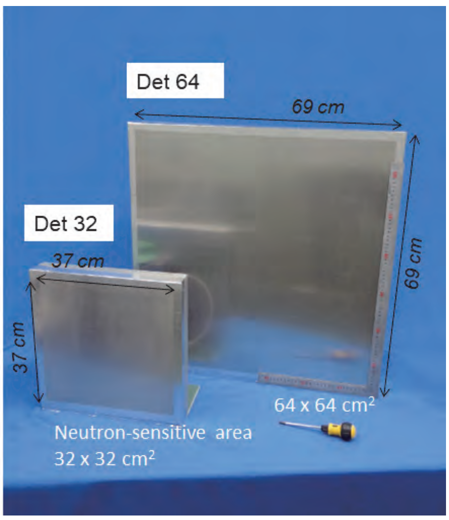


Fig. 3. Prototype detectors with neutron-sensitive areas of 32 × 32 and 64× 64 cm^{2} (Det 32 and Det 64) [1].

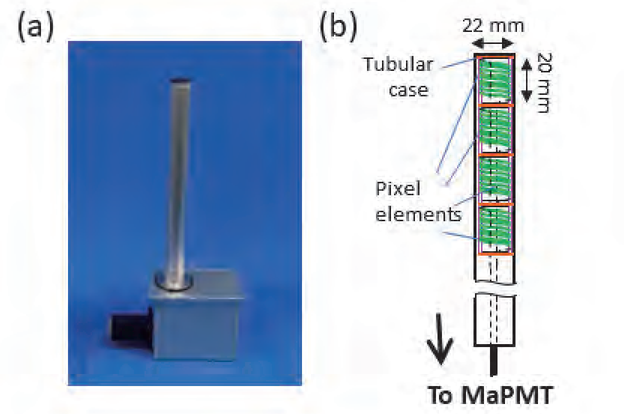


Fig. 4. A 14-element prototype detector. (a) Photograph and (b) a schematic view of the detector

A linear position-sensitive neturon detector can be built by aligning many elements in a tubular case. Figure 4 shows a photograph and a schematic view (inside) of the small prototype detector. 14 SFC elements have been implemented in the cylindrical aluminum tube. The adoption of an individual element readout system makes the detector pixelated in principle, hence assuring a high global count rate capability, which would exceed that of a conventional ^{3}He PSD. The tubular detector makes it easy to be installed mechanically in a high vacuum vessel (<10^{-3} Pa). It is also possbile to tile many detectors side by side with a negligible gap in a way similar to the array of the tubular ^{3}He PSDs. Neutron irraddiation experiments using a Cd mask demonstrated that the proposed detector had a position resolution of 2 cm, and this type of detector would be one of the most promising candiates to be used in vacuum as alternatives to ^{3}He gas-based detector.

References

[1] T. Nakamura, *et. al.*, in the proceedings of 2015 IEEE NSS conference record (2015).

[2] T. Nakamura, *et. al.*,US patent No.9268045, 2016.

Muon Source and Science

Ultra Slow Muons

When the “Ultra Slow Muon Microscope” project was launched in 2011, as a whole-community enterprise, no one imagined the twists and turns of the scale they experienced until recently in reaching the first goal of ultra slow muon (USM) beam production. Apart from the difficulties already conceived in the planning, the project was forced to a slow start under the prolonged consequences of the gigantic East-Japan earthquake, and experienced a sequence of unscheduled long-term disruptions due to incidents in the Hadron hall and the MLF. The e-mail on February 21, 2016, from the experimenters at the U1A cabin, reporting a time-of-flight peak that signaled the generation of USM, brought great satisfaction to those who were concerned and awaited the news impatiently. However, they have also been reminded that much more remains to be done before the delivery of the first real beam to the U1A experimental area. Since then, the struggle to optimize the USM beam has continued over the rest of the year.

New Spectrometer “ARTEMIS” on Stage

Following the successful optimization of the surface muon beam transport to the S1 experimental area on the S-line toward the end of March 2016, the focus of the commissioning work shifted to a new μSR spectrometer, named “ARTEMIS” (an acronym for Advanced Research Targeted Experimental Muon Instrument at S-line, Fig. 5). The spectrometer was built with the support of the Element Strategy Initiative Project for Electronic Materials (headed by H. Hosono, Tokyo Institute of Technology), which is primarily involved in providing evaluation through on-demand μSR for materials development projects. The commissioning work was conducted under the S1-type Inter-University Muon Research Program (Principal Investigator, K.M. Kojima), and it passed a milestone of performance, exceeding that of the twin spectrometer running at the D1 area. Now, ARTEMIS started accepting specimens from Tokyo Institute of Technology for the real μSR runs, contributing to the development of innovative materials. We plan to make the instrument available to the general-use program in 2017, which will provide relief to the μSR users at the overcrowded D1 instrument.

Negative Muons Gear Up

At the D2 area, the beam line was tuned to extract negatively charged muons with lower energy and narrower momentum spread, so that the beam may be applied to non-destructive element analysis for flatter materials. Meanwhile, after some commissioning work on sample environment for the conventional μSR experiment with surface muons, the S-line has been tuned for extraction of negatively charged muons (the so-called “cloud muons”) to examine the possibility of “negative muon spin rotation.” Although the beam intensity is not impressive at this stage, the information would be useful to assess the feasibility of the technique in the forthcoming 1 MW era.

Making the Rad-hard Base of S/H-lines

The radiation shield around the muon beam exit for the H-line in Experimental Hall No.1 was reinforced for the 1 MW proton beam operation coming in the near future. The additional shield was designed by taking account the first phase of the H-line (with one experimental area, H1) as well as the full-fledged S-line (with four branches), so that it would comprise a part of the shields for both beamlines.

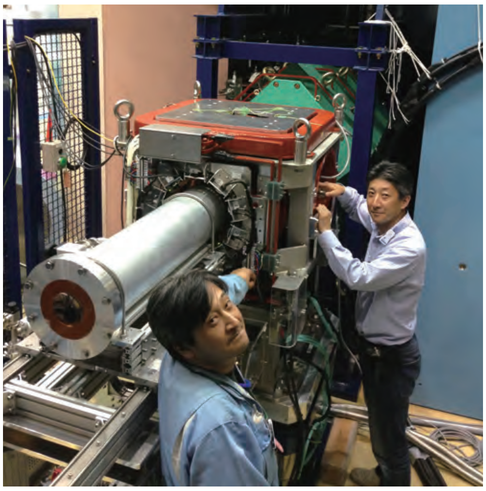


Fig. 5. The S1 instrument “ARTEMIS” viewed from the back of the S1 area.

Technology Development

The technology development section is responsible for the common equipment and development of devices of neutron scattering instruments.

The summary of the common equipment situation is as follows.

An enhanced air conditioner system, which consists of many small air conditioners in the experimental halls was installed, because the original design of the air conditioner system was insufficient due to a limited construction budget, besides there was strong demand from the users. As a result, a drastic improvement was achieved in the experimental halls.

In order to reduce the load of maintenance due to frequent replacement of burned lights, we replaced the ceiling mercury lamp of the west extended experimental hall with LED lighting. The replacement of the ceiling mercury lamps with LED lighting in large experimental halls 1 and 2 will be performed next year.

The J-PARC research building was completed last year. There are many experimental rooms such as deuteration laboratory, sample environment development room, sample preparation room, measurement room, machine shop, etc. Power supplies were installed in individual experimental rooms in the J-PARC research building, then developments of sample environment equipment and sample preparations were started there as well.

Installing alarm indication systems on individual beamlines in the experimental halls was started. This system consists of a signal line of monitoring equipment, connection box, controller, signal light and PC via J-LAN. The schematic of the system is shown in Fig. 6. This system allows the display of the status of individual beamlines' equipment, collectively monitored, at a monitoring room.

One of the purposes of the system is to ensure an unattended operation of various kinds of sample environment equipment, for example, cryofurnace, by observation in the monitoring room.

The summary of the development of devices is as follows.

Radial collimators for the BL18, BL21 and 7 T magnet were assembled by the in-house staffs. Spare disks for the high-speed disk chopper were fabricated. The development of a high-durable chopper has continued. A prototype high-durable T0 chopper was completed and long-term running tests will be performed the next year.

The development of a 30-T pulsed magnet system has continued. The magnet device itself was completed last year. A cryostat insert was fabricated this year and to test the system performance, the first neutron scattering experiment was performed at BL12.

Three new common cryostats were introduced, which brought the total of the operational cryostats to four. These cryostat were used in nine user experiments. The MLF standard device–control software, IROHA2, which enables flexible remote control, was installed into a superconducting magnet system, and an unattended operation was started under magnetic field loading. There are two common high-temperature furnaces, which were used in five user experiments.

Progress was achieved in the development of polarized devices. The first user experiment in the field of fundamental physics by using ^{3}He spin filter was performed at BL04. The first polarized-neutron diffraction verification experiment for material science research was performed by using two on-beam SEOP spin filters at BL18. And the first verification experiment on magnetic imaging for industrial application by using two on-beam SEOP ^{3}He spin filters was conducted at BL22.

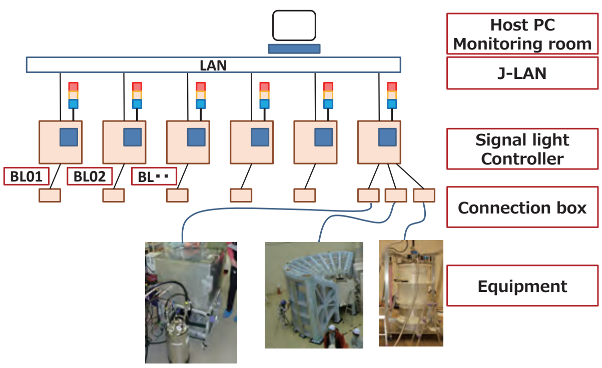
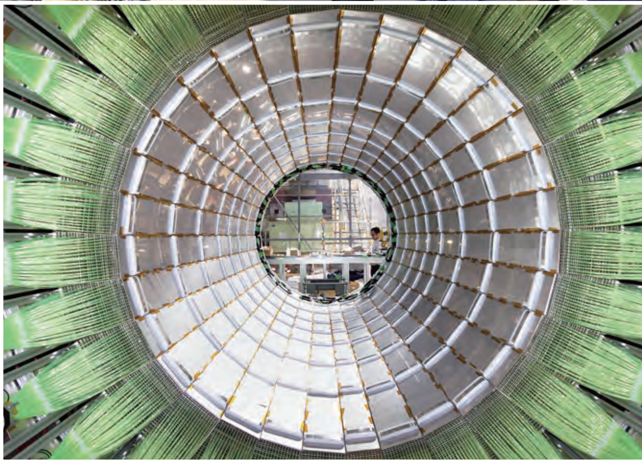


Fig. 6. Schematic of the alarm indication system.

Particle and Nuclear Physics

Neutrino Experimental Facility

The T2K run in Japanese fiscal year (JFY) 2016 consisted of two periods. On April 14, 2016, the first run period started in an anti-neutrino mode, and continued until May 27. The second run period started on October 26 in a neutrino-mode and will continue until April 12, 2017, beyond the end of this fiscal year. The history of the accumulated protons on target (POT) and the beam power are plotted in Fig. 1. Stable operation of 460-kW beam power was successfully achieved, and as of March 31, 2017, T2K accumulated 13.97x10^{20} POT in the neutrino mode, in addition to 7.47x10^{20} POT in the anti-neutrino mode, since the beginning of the experiment.

Using data collected up to May 27, T2K released the world's first constraint on the CP phase of neutrino oscillation. The details are reported in the highlight section of this annual report. T2K also updated the θ_{23} measurement, as shown in Fig. 2, suggesting maximal mixing, which NOvA disfavors. Results with data obtained up to the second-period run of JFY2016 are expected to clarify this situation.

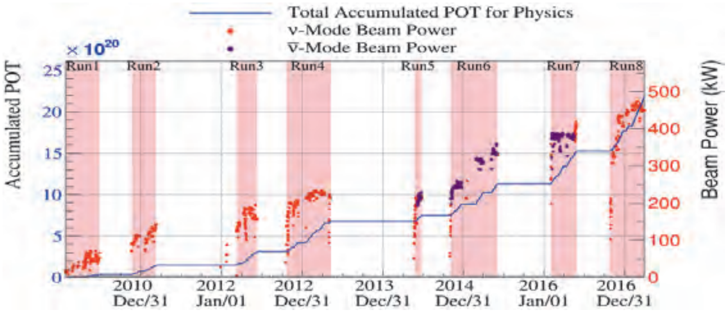


Fig. 1. History of accumulated POT and beam power since the beginning of T2K.

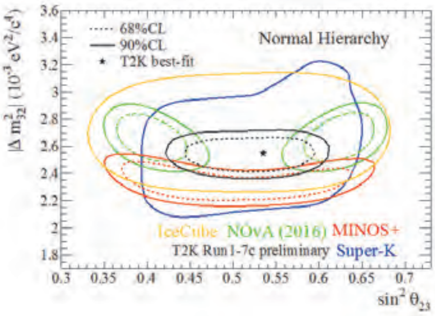


Fig. 2. A plot of $\sin^2\theta_{23}$ vs. Δm^2_{32}. The T2K result (black lines) favors maximal mixing.

Hadron Experimental Facility

The Hadron Experimental Facility (HEF) of J-PARC is used for fixed-target particle and nuclear physics experiments with hadron beams produced by the slowly-extracted (SX) 30 GeV proton beam from the Main Ring accelerator. In JFY2016, a stable user operation of HEF was conducted in June with beam power of 42 kW and repetition cycle of 5.52 second. Three beam lines, K1.8, K1.8BR, and KL for high-intensity K-mesons (kaons), were operated during that period. The total delivered beam power during the JFY2016 operation was 875 kW*days, which is 30% of the total beam power delivered so far to the facility.

From July 2016 to March 2017, the breaking of the south-west wall of the experimental hall and the consolidation work of the vacuum system for the primary beam line in the hall were successfully completed.

The preparation of the new primary beam line, which delivers beams to the high-momentum beam line and the COMET beamline, is also underway.

Strangeness / Hadron Physics Experiments

With these beams, hadron/strangeness physics experiments were conducted, such as the study of a double strangeness system with an emulsion-counter hybrid method (E07), the spectroscopic study of hyperon resonances below the KbarN threshold (E31), and the spectroscopy of kaonic deuterium and kaonic helium (E57 and E62).

While these experiments took pilot data during the JFY2016 operation, remarkable results from the E15 experiment, which took data in JFY2015, were reported. The collaboration proved the existence of a bound state of the K-pp system with relatively smaller binding energy. This result was discussed at a dedicated symposium at the Japan Physical Society's annual meeting in March 2017, and attracted significant attention.

Kaon Decay Experiments

The KOTO experiment is designed to study the rare decay of a long-lived neutral kaon into a neutral π meson and a pair of neutrinos. Detecting this decay is a challenge because only two photons from π^0 are observable, and the decay has not been observed yet. The branching fraction has been theoretically predicted in the Standard Model as $(3.0\pm0.3)\times10^{-11}$.

The activities in FY2016 are described in details in the highlight section.

Muon Experiments

The COMET collaboration aims at searching for the muon-to-electron conversion at sensitivity better than 10^{-14} in its first phase of the experiment. Intensive R&D was carried out in 2016 to prepare the experiment: the construction of the cylindrical drift chamber, the main detector of physics measurement, was successfully completed, followed by a performance test using cosmic rays. A real-size prototype of the Straw-tube tracker [1] and LYSO electron calorimeter was tested in vacuum using an electron beam with power above 100 MeV.

The new experiment for measurement of muon anomalous magnetic moment (g-2) and electric-dipole moment (EDM) is under preparation in the Materials and Life Science Experimental Facility (MLF) of J-PARC.

A technical design report (TDR) was prepared by the collaboration which covered the successful completion of an interdigital H-mode drift-tube linac design with alternative phase focusing for muon linac [2] and a three-dimensional spiral injection scheme [3]. The TDR was inspected by a specialized review committee, which consisted of experts in muon beam, accelerator, and detector technology.

[1] *Nucl. Instrum. Meth.* A845, 269 (2017).
[2] *Phys. Rev. Accel. Beams* 19, 040101 (2016).
[3] *Nucl. Instrum. Meth.* A832, 51 (2016).

Highlights-1: The World's First Indication of Non-conservation of CP Symmetry in the Neutrino Sector

Baryonic matter and its antimatter are believed to have been evenly produced in the early universe. However, the current universe is dominated by matter only, and antimatter is rarely observed. This large deficit of antimatter is one of the most important questions in elementary particle physics. Charge-parity (CP) symmetry breaking (or CP violation) is one of the necessary conditions for this baryon–antibaryon asymmetry in the universe. CP violation was discovered by kaon decay in 1964. The Cabibbo–Kobayashi–Maskawa matrix, by which CP violation in the quark sector can be expressed, is the only known source of CP violation reported so far. However, it is not sufficient to quantitatively explain the observed matter–antimatter asymmetry. On the other hand, CP violation has not yet been discovered in the lepton sector. Therefore, it is important to search for CP violation in the neutrino sector to find other sources of CP violation.

There are three types of neutrinos: electron neutrinos (ν_e), muon neutrinos (ν_μ), and tau neutrinos (ν_τ), which are named after their charged partners. Since neutrinos have finite mass, one type of neutrino can transform to another type, a phenomenon known as neu-trino oscillation. Neutrino oscillation is theo-retically expressed by the Pontecorvo–Maki–Nakagawa–Sakata matrix, parametrized by three mixing angles: θ_{12}, θ_{13}, θ_{23}, and a CP violating phase, δ_{CP}. After the discovery of neutrino oscillation by SK (Super-Kamiokande) experiment in 1998 [1], many experiments have been conducted to determine these neutrino oscillation parameters. All three mixing angles have been determined precisely. However, no definitive measurement of δ_{CP} has been made. At this time, we do not know whether CP symmetry is violated in the neutrino sector. The search for CP violation will have the highest priority in neutrino physics research in the coming decade.

In the T2K (Tokai-to-Kamioka) long-baseline neutrino-oscillation experiment, the $\nu_\mu \rightarrow \nu_e$ oscillation phenomenon in a muon neutrino beam was observed [2], which opened the possibility of searching for CP violation in the neutrino sector. The setup of the T2K experiment is described in detail in [3]. T2K used a high intensity proton beam from J-PARC to produce a muon neutrino beam, and the SK detector, 295 km away from J-PARC, as its far detector. Proton beams of 30 GeV were exposed to a graphite target to produce charged pions and kaons, which were focused by three magnetic horns. The charged mesons decayed in flight to muon neutrinos and muons in a 94 m long decay volume, followed by a graphite beam dump and muon monitors. By selecting the polarity of the horn current, a neutrino or antineutrino beam was selectively produced. An interesting feature of the T2K neutrino beam was the world's first utilization of the off-axis neutrino beam, which was at 2.5° relative to the proton beam direction, resulting in a narrow energy spectrum peaking at 0.6 GeV, where the oscillation probability for a distance of 295 km was maximum.

The T2K experiment started in January 2010 and collected data until May 2013 with the neutrino mode beam. After the discovery of $\nu_\mu \rightarrow \nu_e$ oscillation, data collection with the antineutrino mode beam was performed from May 2014 to 2016. The collected data corresponded to an exposure of 1.51×10^{21} protons-on-target (POT) in total, in which 7.48×10^{20} and 7.47×10^{20} POT were collected with the neutrino and antineutrino mode beam, respectively. The maximum beam power during this period was 425 kW

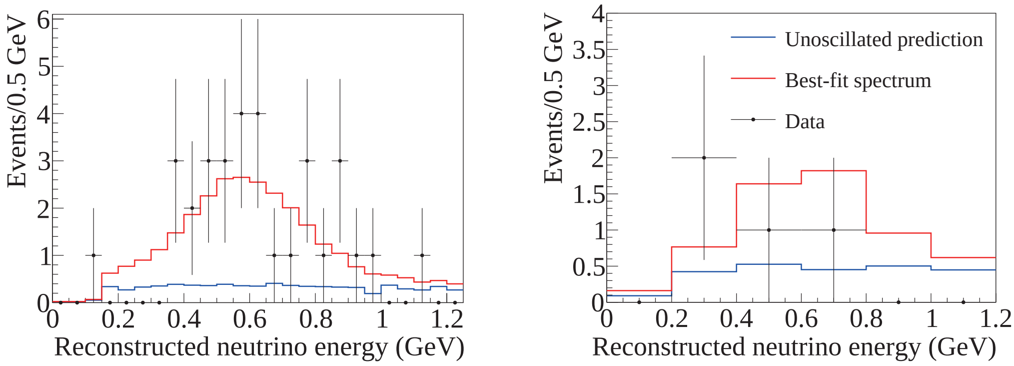


Fig. 3. Reconstructed neutrino energy of the ν_e (left) and anti-ν_e (right) candidate events [4].

and the beam intensity was 2.2×10^{14} protons/pulse, which was the world's highest intensity recorded for a fast extracted beam from a proton synchrotron. In the far detector data, 135 ν_μ, 66 anti-ν_μ, 32 ν_e, and 4 anti-ν_e candidate events remained after all selection criteria were applied (see Fig. 3) [4]. The expected number of ν_e and anti-ν_e events depends on δ_{CP} and mass ordering (i.e., $\Delta m^2_{23} > 0$ or < 0). 28.7 ν_e and 6 anti-ν_e events were expected for $\delta_{CP} = -\pi/2$, and 24.2 ν_e and 6.9 anti-ν_e events were expected for $\delta_{CP} = 0$, respectively, for normal ordering, i.e., $\Delta m^2_{23} > 0$. Four neutrino oscillation parameters, θ_{23}, Δm^2_{23}, θ_{13}, and δ_{CP}, were estimated by a maximum likelihood method using the kinematic information of the candidate events in the four samples (ν_μ, anti-ν_μ, ν_e, and anti-ν_e). Figure 4 shows the resultant confidence regions in the δ_{CP}–$\sin^2\theta_{13}$ plane. The best fit values of $\sin^2\theta_{13}$ are in good agreement with that from reactor measurements. Further constraint on δ_{CP} can be obtained by the reactor constraint (see Fig. 5). The best-fit value of $\delta_{CP} = -1.79$ and -1.41 for normal and inverted ordering, respectively, was obtained. CP conservation ($\delta_{CP} = 0, \pm\pi$) was excluded at the 90% confidence level, which is the world's first indication of non-conservative CP symmetry in the neutrino sector.

In October 2016, T2K restarted data collec-tion with the neutrino mode beam. During this period, a maximum beam power of 470 kW was achieved for continuous beam operation. The data collection was finished on April 12, 2017 and data corresponding to 7.26×10^{20} POT were accumulated in this period. The neutrino mode data were almost doubled compared to the last run. The accumulated POT from the beginning of the T2K experiment is 2.25×10^{21} POT. In summer 2016, the T2K team submitted a proposal for an extended run to 20×10^{21} POT with the J-PARC accelerator upgrade, aiming to perform an initial observation of CP violation at more than a 99.7% confidence level for the case of maximum CP violation [5]. The T2K experiment will continue its data collection for the discovery of CP violation.

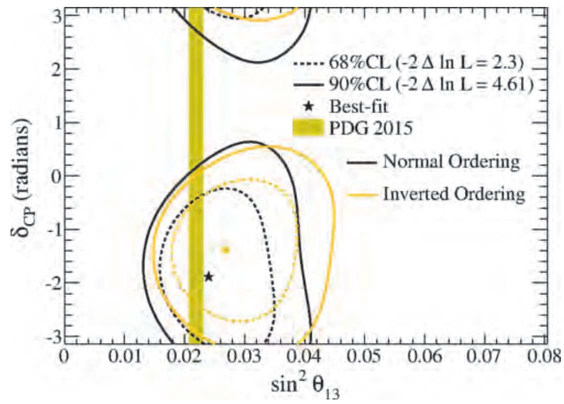


Fig. 4. 68% (90%) confidence regions in the δ_{CP}–$\sin^2\theta_{13}$ plane. 68% confidence region from reactor experiments on $\sin^2\theta_{13}$ is shown by the yellow vertical band [4].

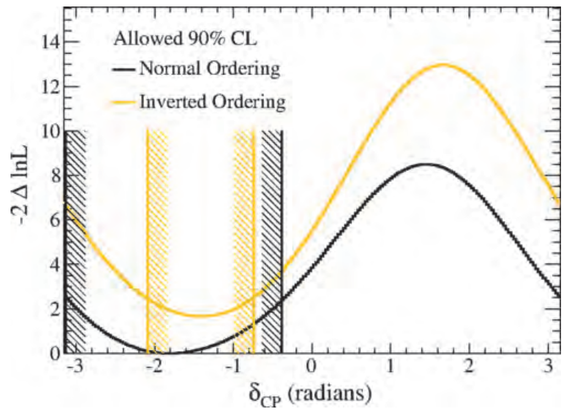


Fig. 5. The curves show a degree of inconsistency with the observed data as a function of δ_{CP} for normal (black) and inverted (yellow) mass ordering. The vertical lines show allowed 90% confidence intervals [4].

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Highlights-2: First strains of KOTO from J-PARC: Exploring new physics through rare kaon decays

An international collaboration consisting of 65 physicists from Japan, Korea, Russia, Taiwan, and the USA has published the first physics results [1] from their experiment KOTO, short for "K0 at Tokai," and continues to make strides toward exploring new physics beyond the Standard Model (SM) through rare K-meson (kaon) decays. The experiment is being conducted at the Hadron Experimental Facility of J-PARC using the slowly extracted high intensity protons with an energy of 30 GeV from the Main Ring accelerator.

The quantum transition of a heavy particle into lighter particles is called "decay" in particle physics. The decay of a particle proceeds via several paths or "decay modes". The KOTO experiment studies the decay of the long-lived neutral kaon (K_L) into a neutral pi meson (π^0) and a pair of neutrinos, represented as $K_L \rightarrow \pi_0\nu\nu$. This decay occurs due to higher-order effects in the neutral current from strange quark to down quark, and breaks the symmetry in the combination of the operations of charge conjugation (C) and spatial inversion (P), CP symmetry, directly. The SM predicts the branching fraction Br ($K_L \rightarrow \pi_0\nu\nu$), once in forty billion K_L decays, very precisely. By examining this ultra-rare decay, new sources of CP symmetry breaking that can explain the matter-antimatter asymmetry in the universe may be revealed most clearly, particularly in the case where the measured Br ($K_L \rightarrow \pi^0\nu\nu$) is much higher than the predicted one. In reality, this decay mode occurs with only two photons from the subsequent π^0 decay detectable in the final state and has so far never been detected experimentally.

The KOTO experiment, proposed in 2006 and approved in 2009, is the only experimental study of the $K_L \rightarrow \pi^0\nu\nu$ decay in the world. The neutral beam line and the detector (Fig. 6) were constructed from FY2009 to FY2012 and the data collection started in May 2013. The crucial feature of the detector employed is the calorimeter at the endcap and the use of 50- cm- long undoped CsI crystals to measure two photons from π^0. The 2716 crystals and phototubes were the ones used in the KTeV experiment at Fermilab, USA, in the 1990s. For hermetic detection of extra particles from K_L-decay backgrounds, e.g. $K_L \rightarrow \pi^0\pi^0$ and $K_L \rightarrow \pi^0\pi^+\pi^-$, and vetoes on them, charged particle and electromagnetic shower counters were installed on the inside of the vacuum vessel of the detector covering the K_L decay volume. Counters were also placed downstream of the vessel to detect particles escaping along the beam line.

The first physics results from KOTO are from the data collected over one hundred hours in 2013, corresponding to 1.6×10^{18} protons-on-target (POT). The single event sensitivity for $K_L \rightarrow \pi^0\nu\nu$ is comparable to the final sensitivity of the previously performed E391a experiment [2] at the KEK Tsukuba campus in 2005, derived with 2.5×10^{18} POT with an energy of 12 GeV over four months. Figure 7 shows the scatter plot of the reconstructed π^0 transverse momentum (P_T) versus the decay vertex position (Z_{vtx}) of the events with all the selection criteria, including extra- particle vetoes. The region surrounded with a thick solid line is the signal

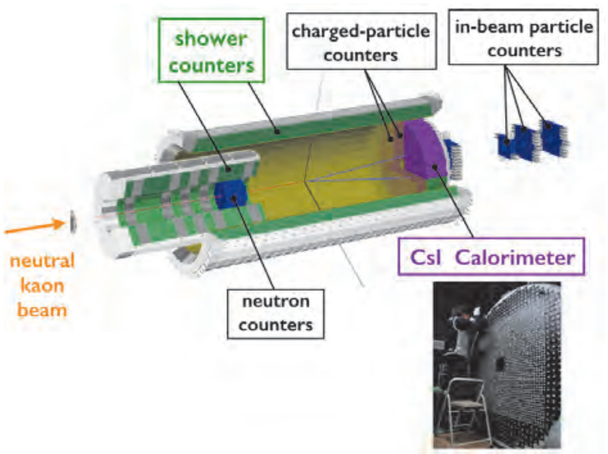

Fig. 6. Schematic drawing of the detector for the KOTO experiment.

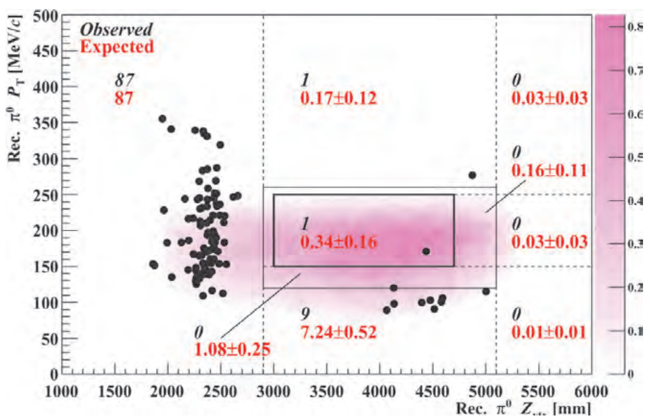

Fig. 7. Scatter plot summarizing the KOTO analysis for the first physics results [1].

region, in which the $K_L \rightarrow \pi^0\nu\nu$ decay should appear as an event with a finite P_T, corresponding to the momentum taken away by two neutrinos, and with Z_{vtx} in the decay volume. The black dots represent the data, and the pink contour indicates the distribution of the $K_L \rightarrow \pi^0\nu\nu$ decay from Monte Carlo simulations. The black italic (red regular) numbers indicate the numbers of observed events (expected background events) for the regions divided by solid and dashed lines. One candidate event was observed while 0.34 ± 0.16 background events were expected, mainly due to halo neutrons in the beam directly hitting the calorimeter, and an upper limit of 5.1×10^{-8} for Br ($K_L \rightarrow \pi^0\nu\nu$) was set. The KOTO experiment also performed the direct search of the two-body decay $K_L \rightarrow \pi^0X^0$, where X^0 is a hypothetical invisible particle [3] with a mass around the nominal π^0 mass, and an upper limit of 3.7×10^{-8} for Br ($K_L \rightarrow \pi^0X^0$) was set for the first time.

KOTO resumed the data taking in April 2015 and, in FY2015 and FY2016, collected twenty times more data than that of the first run. The analysis is currently undertaken intensively. In the meanwhile, large 3-m-long shower counters (Fig. 8) with a diameter of 1.9 m and a weight of 6 tons in total, named "Inner Barrel (IB)", were built at the Tsukuba campus, transported to Tokai, and successfully installed to the KOTO detector in March 2016. The commissioning of the IB counters in FY2016 demonstrated that the counters would improve the veto capability of the KOTO detector and reduce the level of the $K_L \rightarrow \pi^0\pi^0$ background to be below Br ($K_L \rightarrow \pi^0\nu\nu$) in the SM, as designed.

Since 2013, the KOTO collaborators have upgraded several detector subsystems and developed new analysis methods, particularly to discriminate photons from neutrons in the calorimeter, and to reduce the backgrounds. The collaborators are also preparing to modify the calorimeter to add a neutron discrimination capability. With these improvements, they expect to continue the KOTO experiment to explore the wide region in Br ($K_L \rightarrow \pi^0\nu\nu$) to the level of SM prediction, and observe the $K_L \rightarrow \pi^0\nu\nu$ decay for the first time.

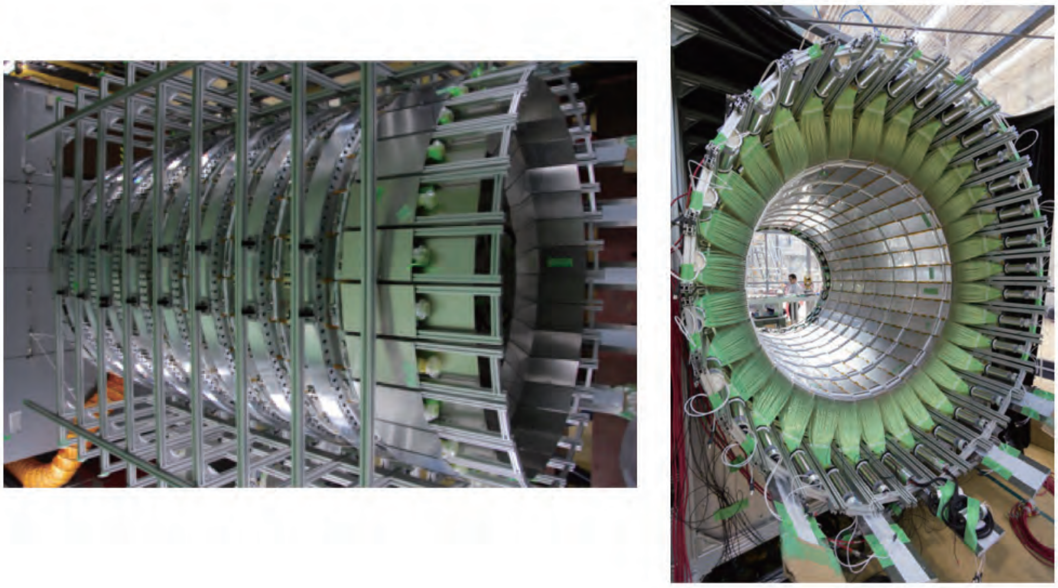

Fig. 8. Photographs of the IB shower counters.

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Highlights-3: Full Scale Investigation of Multi-Strangers' World Has Begun

Understanding both qualitatively and quantitatively the forces acting between nucleons from the basic theory of strong interaction, quantum chromodynamics, is one of the most important problems to be solved in the fundamental physics. An exquisite balance of the repulsive core in the central region and attractive force in the intermediate region, as well as the existence of spin-orbit force in the nucleon-nucleon interaction govern the stability of nuclei and their abundance, and consequently, all baryonic matter of the universe. In the strangeness nuclear physics, we will approach this problem by adding strange quark(s) and extending the nucleon-nucleon interaction in the two-flavor world of up- and down quarks only to interactions among the octet baryons in the three-flavor world with an additional strange quark. The additional six baryons with strange quark(s), Λ, Σ^+, Σ^0 Σ^-, Ξ^0, and Ξ^- in the octet are collectively called hyperons. Due to the difficulty of conducting hyperon scattering experiments, the information about hyperon-nucleon or hyperon-hyperon interaction is obtained from the studies of hyper nuclei made of hyperons in addition to nucleons.

Until recently, only a few doubly-strange nuclei (DSNs) were recognized and, consequently, not much was known about hyperon-hyperon and Ξ-nucleon (ΞN) interactions. Only $\Lambda\Lambda$ interaction is known to be weakly attractive from double-Λ hyper-nucleus, ${}^{6}_{\Lambda\Lambda}$He, which was uniquely identified in the emulsion experiment at KEK 12 GeV proton synchrotron E373 (called NAGARA event) [1]. However, this situation has changed recently.

A new type of DSNs, in which a Ξ hyperon containing two-strange quarks is bound, a Ξ hyper-nucleus, was discovered [2]. This event, called a KISO event, was found using a new method developed for an experiment at J-PARC E07. In this overall scanning method [3], the microscopic images of the emulsions are processed to pick up the vertex-like shapes. The DSNs are characterized by at least three vertices, one for its own production and two more for weak-decays of the two-strange quarks.

The KISO event was uniquely identified when Ξ^- was absorbed by ^{14}N nucleus and decayed into ${}^{10}_{\Lambda}$Be and ${}^{5}_{\Lambda}$He, as shown in Fig. 9. The obtained binding energy of Ξ^- is 4.38 ± 0.25 MeV, assuming that both ${}^{10}_{\Lambda}$Be and ${}^{5}_{\Lambda}$He are in their ground states. Even if the possibility of excited final states is taken into account, it has to be larger than 0.17 MeV, which corresponds to an atomic 3D orbit of Ξ^-. It is likely to be larger than 1.03 ± 0.18 MeV using the mass values of ${}^{10}_{\Lambda}$Be excited states [4] reported after the publication. Therefore, this is not an atomic state but a nuclear bound state. Thus, Ξ^- nucleus potential and the underlying ΞN interaction must be attractive. The paper on the KISO event won the 22nd Outstanding Paper Award of the Physical Society of Japan in March 2017.

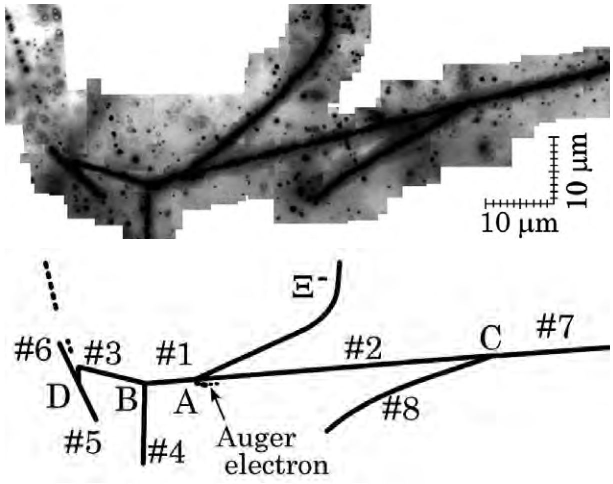

Fig. 9. A superimposed image (upper) and a schematic drawing (lower) of the KISO event. It was uniquely identified as Ξ^- + ^{14}N → ${}^{10}_{\Lambda}$Be(#1) + ${}^{5}_{\Lambda}$He(#2) (A), ${}^{10}_{\Lambda}$Be → ^{8}Li(#3) + p(#4) + n (B), ${}^{5}_{\Lambda}$He → p(#7) + d(#8) + 2n (C), and ^{8}Li → ^{8}Be*(2$^+$) + e^- + anti-ν_e ^{8}Be*(2$^+$) → 2α(#5, 6) (D).

The existence of Ξ hyper nuclei is also suggested by the E05 pilot data obtained in 2015 at the K1.8 beam line of J-PARC Hadron Experimental Facility. This experiment aims to observe Ξ hyper-nuclear states of ${}^{12}_{\Xi}$Be with both high resolution of 2 - 3 MeV_{FWHM} and high statistics using a new K^+ spectrometer currently under construction. The Ξ hyper-nucleus, ${}^{12}_{\Xi}$Be, is produced by K^- beam on ^{12}C target and identified by the missing mass method, where beam K^- and scattered K^+ are measured using beam and K^+ spectrometers, respectively. Fig. 10 shows the missing mass spectrum obtained using the existing Superconducting Kaon Spectrometer (SKS) with 6 MeV_{FWHM} resolution in the pilot run. A large bump above the Ξ^- binding threshold (–B.E. = 0) corresponds to Ξ^- quasi-free production. Despite the improved resolution, the measured spectrum shape in the bound region (–B.E.< 0) looks very similar to the earlier data from the Brookhaven National Laboratory obtained with 14 MeV_{FWHM} resolution [5]. Some excess exists in the bound region, even if the flat unphysical background and the tail of the quasi-free production due to experimental resolution (shown by curves in the figures) are considered. This result strongly indicates the existence of another Ξ hyper-nucleus, $^{12}{}_{\Xi}$Be.

The E07 experiment studying DSNs by emulsion has started taking the data after commissioning of the KURAMA spectrometer, which had been newly installed at the K1.8 beam line in May 2016. The Ξ^- hyperons produced by K^- + p (in a diamond target) → K^+ + Ξ^- reaction were injected into the emulsion stack. In the conventional counter-emulsion hybrid method, Ξ^- stopping points are detected by following Ξ^- tracks using the information on their position and direction measured by the spectrometer system. The DSNs produced by Ξ^- absorption are being searched for X-rays from the Ξ^- atoms of heavy elements, such as Ag or Br are also measured, for the first time, in order to quantify the strong interaction between Ξ^- and nucleus, which causes energy shifts of Ξ^- atomic orbit.

Thanks to the high power of the primary proton beam at J-PARC, K^- beams with intensity of 2.6 × 10^5/spill and purity of 82% were available for the E07 run, whereas only 1.3 × 10^4/spill and ~25% were available for E373 at KEK. In the 2016 run, 18 emulsion stacks out of 118 were exposed. We expect 10-times more events as E373, namely, 10000 stopped Ξ^-, ~100 DSNs and ~10 well-identified DSNs in the hybrid method and further 10-times more events detected in the overall scanning method. Thus, much more information about the multi-strangers' world of double-Λ and Ξ hyper-nuclei and the underlying ΛΛ, ΞN, and ΞN → ΛΛ interactions will come out from J-PARC in a few years.

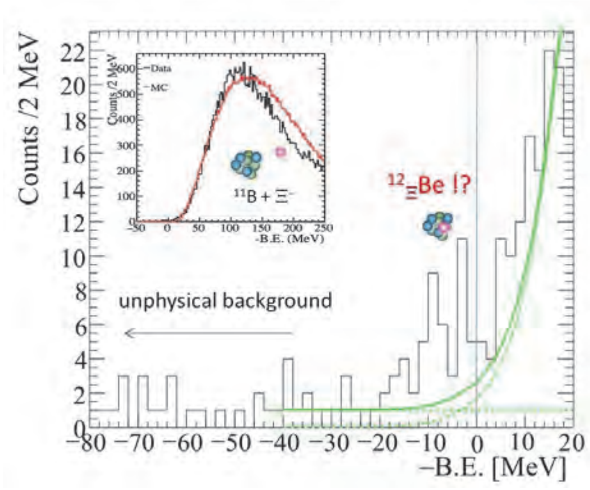

Fig. 10. Preliminary missing mass spectrum of the ^{12}C(K^-,K^+) reaction obtained by the E05 pilot run. The horizontal axis is the opposite of the binding energy (B.E.) of Ξ^-.

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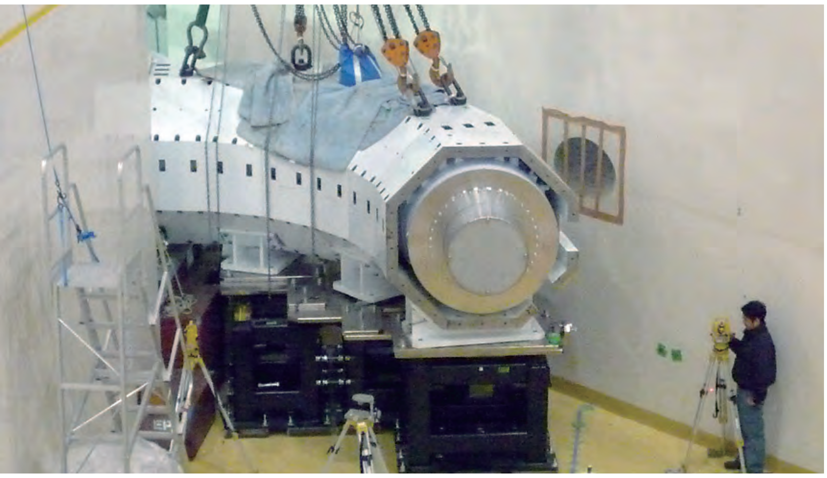
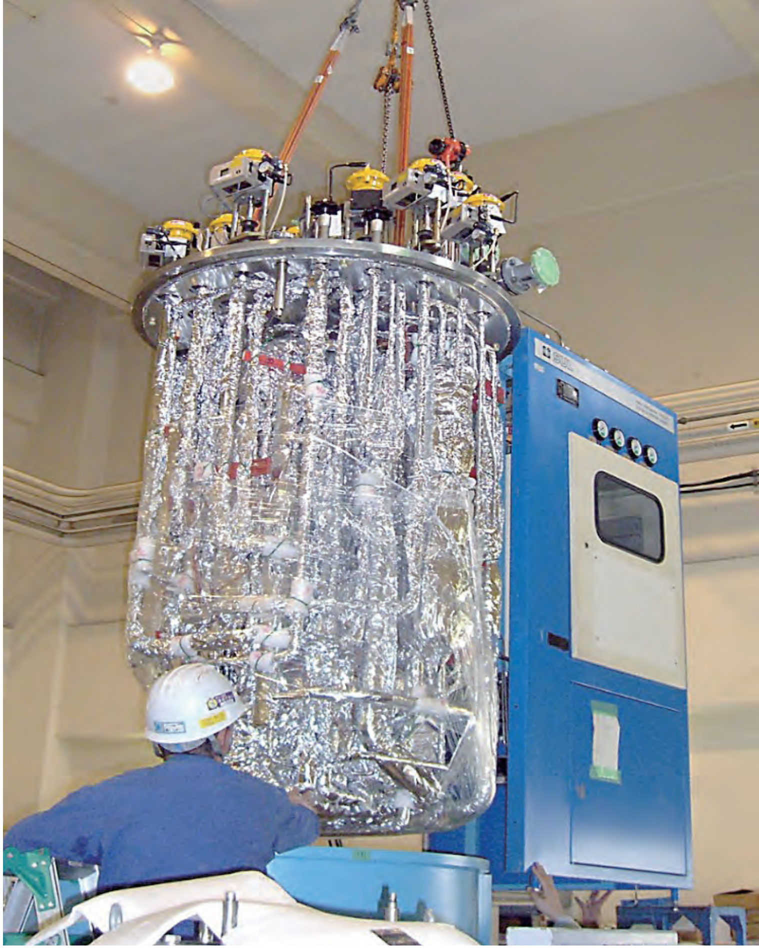




Cryogenics Section

Overview

The Cryogenics Section supports scientific activities in applied superconductivity and cryogenic engineering, carried out at J-PARC. It also supplies cryogen of liquid helium and liquid nitrogen. The support work includes maintainance and operation of the superconducting magnet systems for the neutrino beamline, for the muon beamline at the Materials and Life Science Experimental Facility (MLF) and construction of the magnet systems at the Hadron Experimental Facility (HEF). It also actively conducts R&D works for future projects at J-PARC.

Cryogen Supply and Technical Support

The Cryogenics Section provides liquid helium cryogen for physics experiments at J-PARC. The used helium is recycled by the helium gas recovery facility at the Cryogenics Section. Figure 1 summarizes the liquid helium supply in FY2016.

Liquid nitrogen was also supplied to the users for their convenience. Its amount in FY2016 is summarized in Fig. 2. Liquid nitrogen has been regularly provided to the Radiation Safety Section for operation of a gas chromatograph. Liquid nitrogen was also supplied to the users in MLF and HEF.

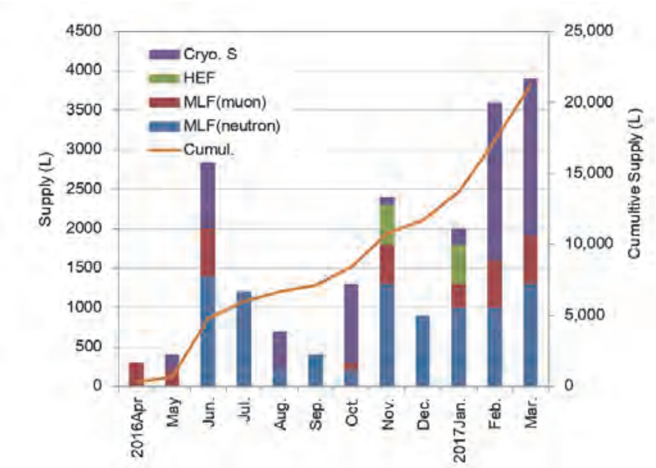


Fig. 1. Liquid helium supply at J-PARC from April 2016, to March 2017.

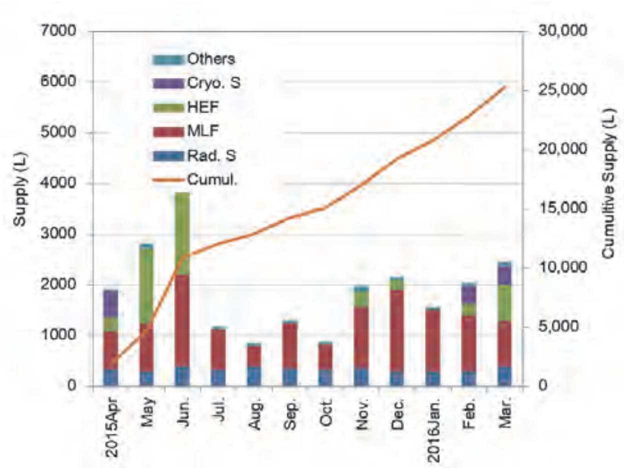


Fig. 2. Liquid nitrogen supply at J-PARC from April 2016, to March 2017.

Superconducting Magnet System for T2K

The superconducting magnet system for the T2K experiment operated during the periods shown in Table 1. The system worked well without disturbing the beam time. In addition to the regular maintenances and inspections in the summer, a screw compressor was overhauled at the factory of the manufacturer, and they did not find any abnormal abrasions and defects (Fig. 3). Also, an activated carbon unit for oil adsorption in the 4th oil separator located at the discharge of the compressor was replaced with a fresh one.

Table 1. Operation history of the T2K superconducting magnet system.

	2016 Apr.	May	June	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	2017 Jan.	Feb.	Mar.
Operation	1/18-5/28						10/5-12/28			1/3-4/1		
Maintenance				↔	↔	↔						

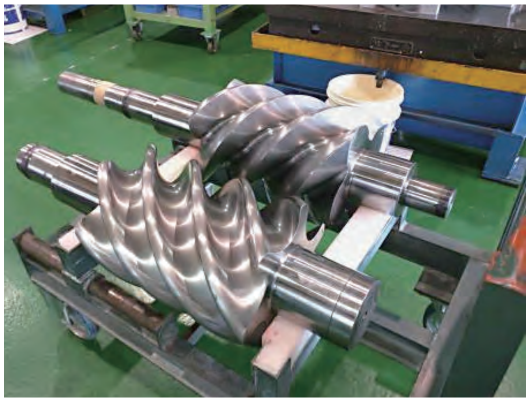



Fig. 3. Picture of the screw compressor to be overhauled (left), and the screws at the inspection (right).

Superconducting Magnet Systems at MLF

The Cryogenic Section contributes to the operation and maintenance of the superconducting magnet systems at the Muon Science Facility (MUSE) in MLF. The superconducting solenoid in the Decay Muon Line (D-line) was operated from February 1 to June 8, and restarted on October 19. It was stopped on December 26 for the New Year holidays, and resumed on January 5. It was scheduled to operate until the end of June 2017. There were two troubles during the beam operation. One was the shutting down of the current source of the magnet by over voltage on May 25. No defects were found in the inspection by the vendor at that time, therefore, the beam operation was restarted soon. In order to investigate the cause, a logging system of output signals in the current control system was added, and continuously monitored. The other was a failure of a valve for the LHe flow control, which caused the coil temperature to rise and quench. The flow channel was changed to bypass the valve, and the system was restarted soon. The failed valve will be replaced in the summer of 2017.

Superconducting Magnet Systems at HEF

The COMET experiment is under construction in the Hadron South Experimental Hall (HDS) of the Hadron Experimental Facility (HEF). The Cryogenics Section was involved in the construction of the cryogenic system and superconducting magnets. The magnets were designed to be cooled by a two-phase flow of liquid helium with 4.5 K temperature and cryogenic helium gas with around 50 K temperature for the shield. The cold box (LINDE TCF-50), which operated for the J-PARC E-36 experiment in FY2015, was relocated in HDS. In the operation for E36, some of the temperature sensors in the cold box had a problem functioning at cryogenic temperature, thus, they were replaced in FY2016. Also, the piping for the high-pressure helium gas between the helium compressor and the cold box and the cabling for the cryogenic system were completed to be ready for the coming test operation (Fig. 4). While the superconducting solenoid magnet for the muon source in HDS is under construction, the muon transport solenoid to deliver muons to the experimental room was aligned with respect to the primary proton beam line (Fig. 5). The design work for the helium transfer lines to the magnets and also elements of the Pion Capture Solenoid have been improved by the Cryogenics Section.

Fig. 4. Cold box with helium piping in HDS.

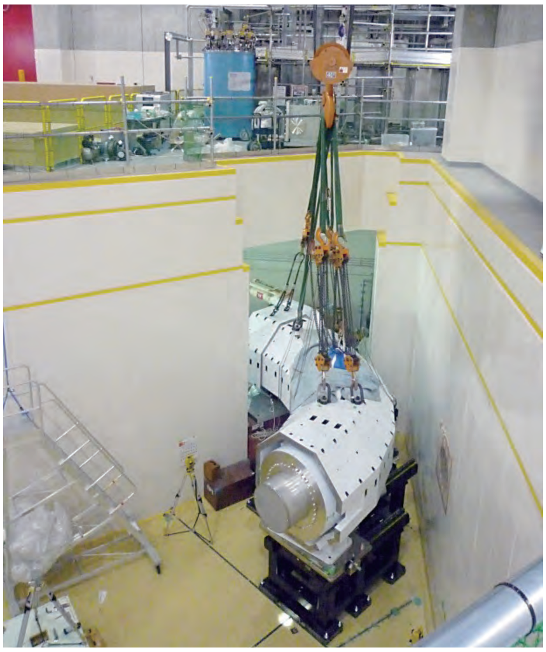


Fig. 5. Alignment of the muon transport solenoid.

R&D for the Future Projects at J-PARC

The g-2/EDM project aims for the precise measurement of the anomalous magnetic moment and the electric dipole moment of muons. This experiment was proposed at the MUSE H-Line. A superconducting solenoid with high field homogeneity, better than 1 ppm locally, plays a very important role as a muon storage ring. The review of the technical design report (TDR) was held on November 15 and 16, 2016. The review committee recommended some points, such as, to seek cost optimization, to reduce the number of cryocoolers, and so on. TDR is being reviewed and modified based on the committee recommendation.

A muonium hyperfine structure measurement, called MuSEUM experiment, is proposed at the same beam line as the g-2/EDM project. In the experiment, the energy state transition in muonium will be observed under a static magnetic field with local homogeneity of 1 ppm. A standard NMR probe to determine the absolute magnetic field is being developed to calibrate other probes. The probe was modified based on the test results in FY2015, and it was tested at the Argonne National Laboratory (ANL) in March 2017. A material effect of the new probe could be reduced to 4.4 Hz by optimizing paramagnetic and diamagnetic material volumes. The cross-calibration between our probe and the pulse NMR probe developed by a US group was carried out and the difference was 0.47 Hz, which was one-fifth of the previous result, 2.73 Hz. The next test is planned for the beginning of 2018.

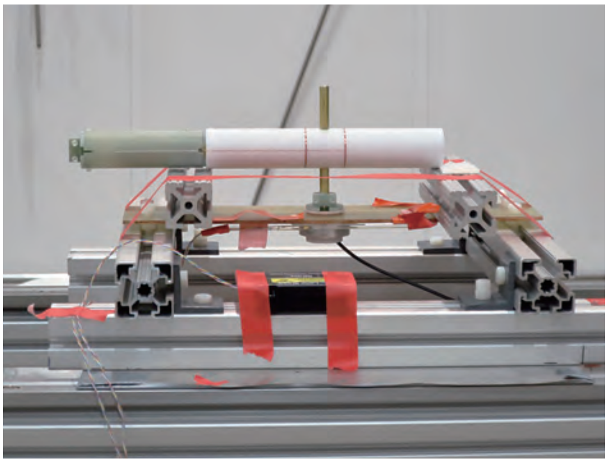
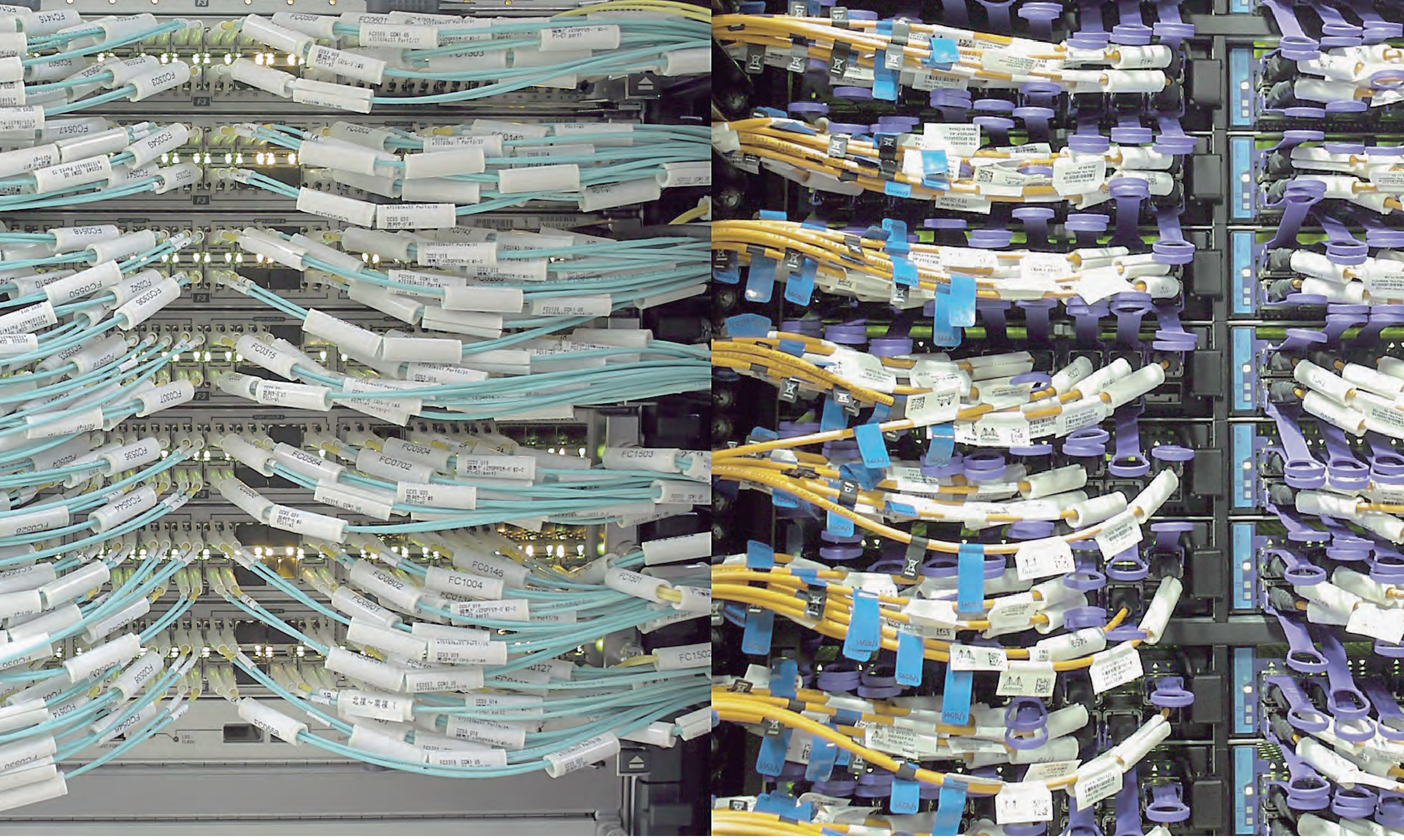


Fig. 6. Material effect measurement of a new standard probe in ANL.



Information System

Overview

The Information System Section plans, designs, manages and operates the network infrastructure of J-PARC and supports to ensure its information security as well. In terms of computing, until now, J-PARC has owed its major computer resource for analyzing and storing data from neutrinos, nuclear physics and MLF experiments to the KEK central computer system. The section connects the J-PARC network to the KEK central computing system directory and helps users to utilize the system effectively.

Status of Networking

Since 2002, the J-PARC network infrastructure, called JLAN, has been operated independently from KEK LAN and JAEA LAN in terms of logical structure and operational policy. In 2016, the total number of hosts on JLAN exceeded 4,800, an increase by 108% from last year's number. The growth curve of edge switches, wireless LAN access points and hosts (servers and PCs) connected to JLAN are shown in Fig. 1.

On April 1, the National Institute of Informatics (NII) has upgraded SINET (Japan Science Information Network http://www.sinet.ad.jp) from version 4 to 5, increasing the backbone network's speed from 40Gbps to 100Gbps. SINET is not only a gateway from JLAN to the internet but also an important connection between

Tokai and the KEK Tsukuba site in J-PARC. According to the SINET upgrade, the network bandwidth between Tsukuba and Tokai was increased from 1Gbps x 8 to 10Gbps. In addition, besides the current bandwidth, the upgrade offers a future option of 20Gbps for both of internet and Tokai-Tsukuba connections, if the J-PARC network can be adapted.

Fig. 2 and 3 show the network utilization of the internet from/to JLAN. Since the bandwidth capacity for the internet through the SINET is 10Gbps, clearly, there is still enough space for additional activity. Fig. 4 and 5 show the statistics of data transfer between the Tokai site and the Tsukuba site. The graphs show that the usage level has been approaching half of the maximum, especially during the period when the Hadron facility was running.

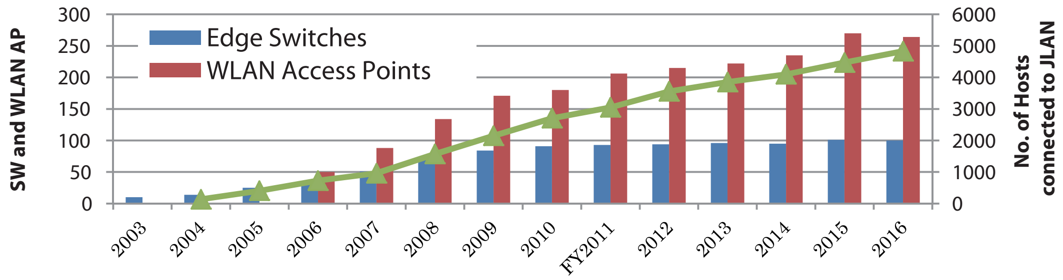


Fig. 1. Number of hosts, edge SW and wireless AP on JLAN.

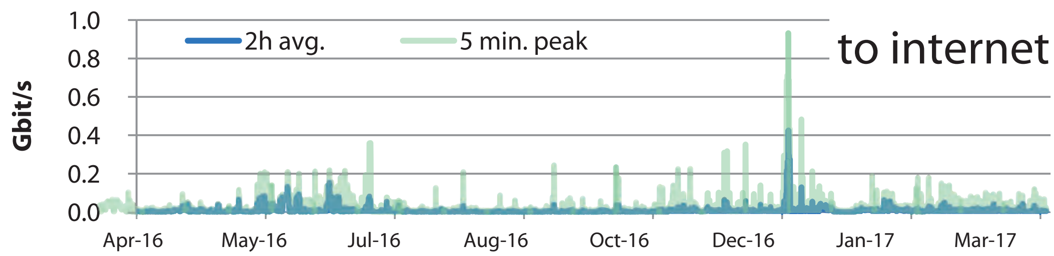


Fig. 2. Network traffic from JLAN to the internet.
(two hours average and five minutes peak value)

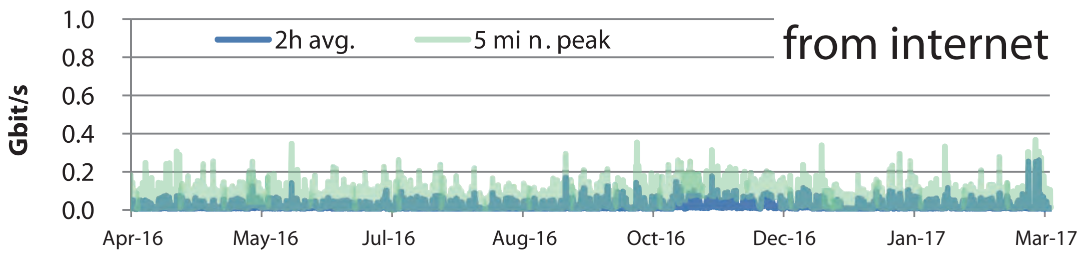


Fig. 3. Network traffic from the internet to JLAN

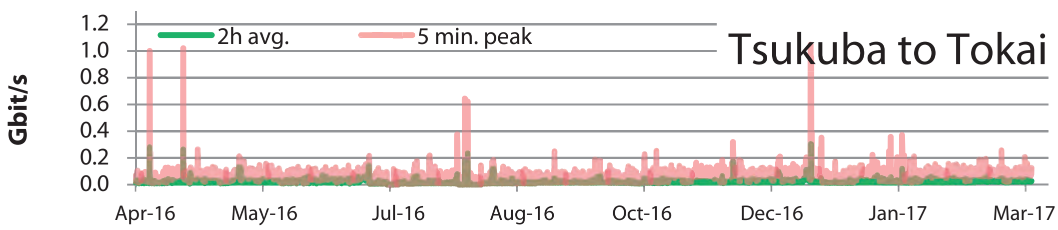


Fig. 4. Network traffic from Tsukuba to Tokai.

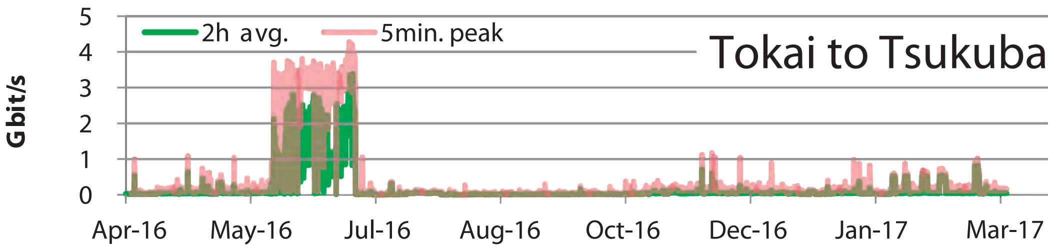


Fig. 5. Network traffic from Tokai site to Tsukuba site.

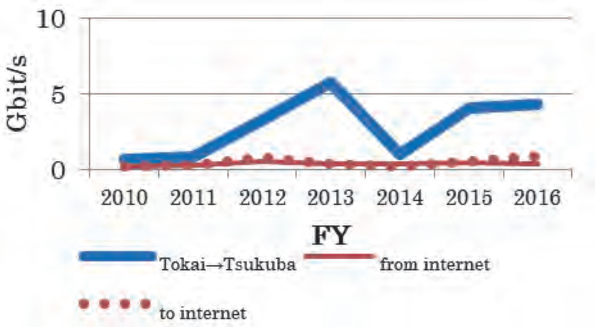


Fig. 6. Peak network traffic for recent years.

Internet Connection Services for Visitors and Public Users of J-PARC

Since 2009, J-PARC has offered a Guest network (GWLAN) service, which is a wireless internet connection service for short-term visitors, available in almost all J-PARC buildings. In the end of 2014, an additional network service called User LAN has started. When using the GWLAN, the users are required to receive a password at the J-PARC Users Office beforehand, while for the User LAN, the users are authenticated by the same ID and password for the User Support System, which is also used for dormitory reservation or so on.

From this March, a new service, called "eduroam", has been started. The eduroam (https://www.eduroam.org/) is the secure roaming access service developed for the international research and education community and used jointly among a huge number of research institutes, universities and others around the world. The eduroam service will be a convenient third option of internet connection service for J-PARC visitors. Fig. 7 shows this fiscal year's usage statistics of GWLAN, User LAN and the newly- started eduroam service.

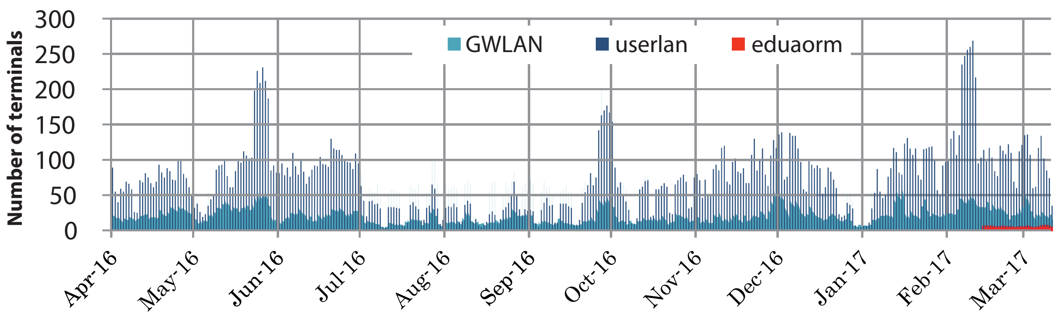


Fig. 7. Use trends of GWLAN, User LAN and eduroam.

Status of Computing

Though J-PARC does not have its own computing facility for physics analysis, since 2009, the KEK central computer system at the KEK Tsukuba site has been mainly used for that purpose. At the Neutrino (T2K experiment) and Hadron experiments, the data taken in the J-PARC experimental hall will be temporarily saved at the Tokai site and then promptly transferred to, stored and analyzed at the system in Tsukuba. The storage of the system will also be utilized as a permanent data archive for the Neutrino, Hadron and MLF experiments.

This September, the second upgrade (the first one was in 2012) of the system was completed. At the new system, larger resources of 3.6 times computing power, 3.8 times disks capacity and 5.4 times tapes capacity, compared with the previous system, have been assigned to J-PARC (Table 1).

Fig. 8 to 10 show the utilization statistics of the computer resources in 2016. The main users who used the CPU and the storage constantly were from the Hadron experiment group (Koto). The MLF group also started to store data to tapes on the system.

Table 1. Assigned computing resources to J-PARC activities in the KEK central computing system.

	before upgrade	after upgrade
CPU	1,300 core	4,700 core（x 3.6）
RAID Disk	1,200 TB	4,500 TB（x 3.8）
Tape	5.0 PB	27.0PB（x 5.4）

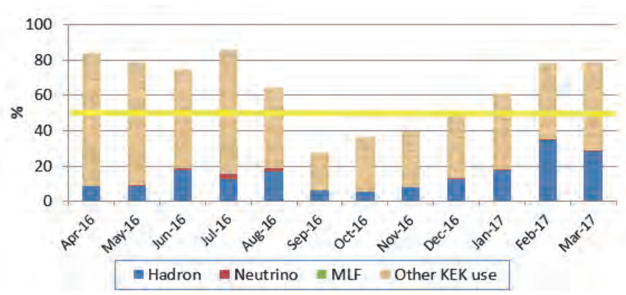


Fig. 8. CPU usage statistics (the yellow line shows resource assignment for J-PARC).

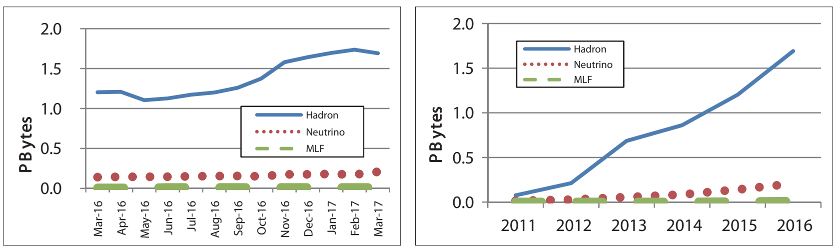


Fig. 9. Disk usage statistics (left: trend for this FY year, right: annual trend).

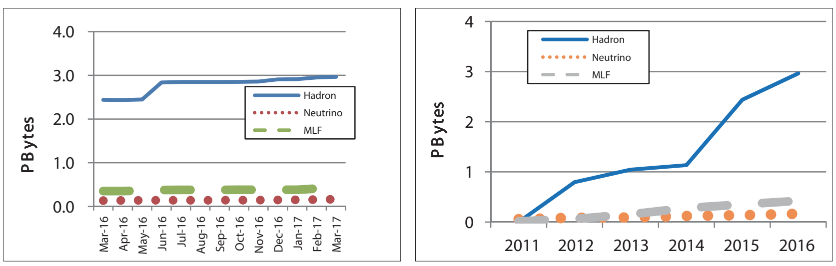
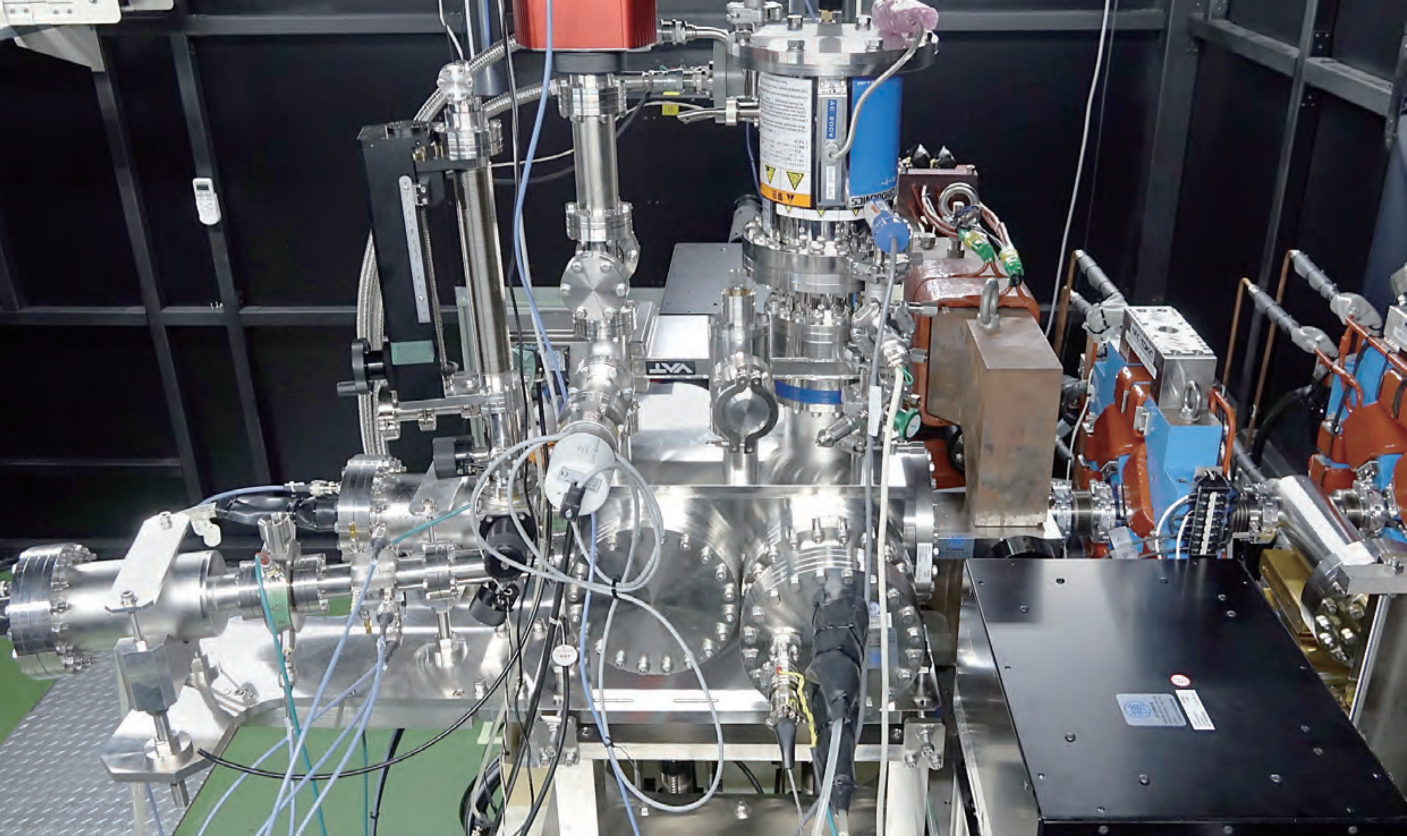


Fig. 10. Tape library usage statistics (left: trend for this FY year, right: annual trend).



Transmutation Studies

Overview

We have been working on developing the Transmutation Experimental Facility (TEF) in J-PARC for R&D on nuclear transmutation technology with using accelerator-driven systems (ADS) for volume reduction and mitigation of harmfulness of high-level radioactive waste.

As a result of detailed design work of TEF over the recent years, we published a technical design report (TDR) for the ADS Target Test Facility (TEF-T) in March 2017 (JAEA-Technology 2017-003, 539 pages). The TDR contains design results for all TEF-T components, such as the liquid lead-bismuth target system, equipment for post-irradiation examination, proton beam line from Linac to TEF, building, ancillary facilities, and control system; it also describes the safety and some remaining issues. In addition, a safety design report of the Transmutation Physics Experimental Facility (TEF-P) is in preparation.

As for the R&D supporting the TEF program, significant progress was achieved in two areas. The first one was the successful liquid lead-bismuth eutectic (LBE) circulation operation of IMMORTAL (Integrated Multifunctional MOckup for TEF-T Real-scale TArget Loop) at 500°C, which corresponds to the operating temperature of commercial ADS plants. A number of flange joints was minimized in the main loop to reduce the risk of LBE leakage. The second area was the successful demonstration of the laser charge exchange (LCE) method by crossing a YAG-laser beam and a proton beam provided by a test stand of Linac. This technique is required to slice a weak proton beam at a maximum of 10 W for TEF-P out of a high-intensity 250-kW proton beam for TEF-T. In addition, several R&D activities supporting both TEF-T and TEF-P advanced steadily, as described in this chapter.

On December 12-14, 2016, the third TEF Technical Advisory Committee (T-TAC), one of the technical advisory committees under the J-PARC International Advisory Committee, was held (Fig. 1). The director of the J-PARC Center defined the goal of this T-TAC as "to point out left issues for completing the TEF design, and to advice on approaches to solve the issues, including international collaboration, PR campaigns, etc." We translated most parts of the TDR in English and submitted them to the T-TAC for a review. In response, the T-TAC gave us the following encouraging evaluation and advice: "*Both systems TEF-T and -P are outstanding and unique in the world*", and also, "*To close the conceptual design phase of TEF-T, T-TAC recommends to complete the draft TDR by including additional sections about instrumentation, waste characterization and dismantling*".

Fig. 1. T-TAC 2015 members and attendees.

Design of the Transmutation Experimental Facility (TEF)

Overview of TEF

The TEF consists of two individual facilities: the ADS Target Test Facility (TEF-T) and the Transmutation Physics Experimental Facility (TEF-P). TEF-T equips with a liquid lead-bismuth spallation target bombarded by a 400 MeV - 250 kW proton beam in which candidate proton beam window materials are irradiated for materials testing. TEF-P equips with a critical/subcritical assembly including minor actinides fuels to investigate physical and dynamic properties of the ADS by using a low power (10W) proton beam. The two facilities are located adjacently as shown in Fig. 2.

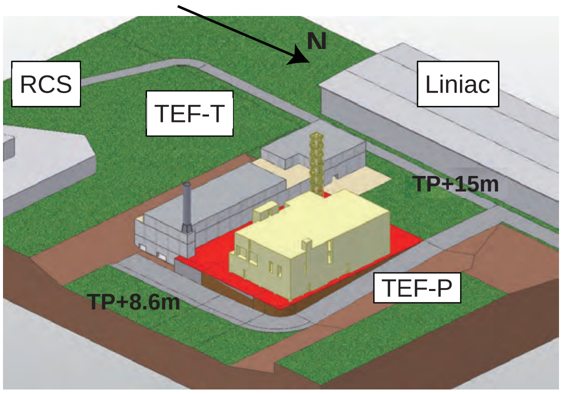


Fig. 2. 3D image view of TEF-T and TEF-P.

TEF-T Design Update

Based on the conceptual design of TEF-T, the facility design was detailed significantly in this fiscal year, and the design was compiled in the Technical Design Report (TDR). A 3D CAD software was used for the design. Figure 3 shows a bird's eye view of TEF-T. The building has 5 floors including 3 underground floors. Thicknesses of the shielding wall shown in blue in Fig. 3 were determined by shielding calculation by using a particle transport calculation code PHITS.

Ancillary systems associated with the LBE target system, such as the cooling water system, machinery system, gas system, electric power system, control system, off-gas processing system and proton beam transport system, were made detailed. Dimensions of every room to accommodate these systems were reviewed with considering actual dimensions of these systems, and the layout of the rooms was adjusted to well fit in the building. Piping routing and traffic line of equipment in the building were considered in the adjustment.

A conceptual system diagram of the off-gas process system was created. The control system was designed

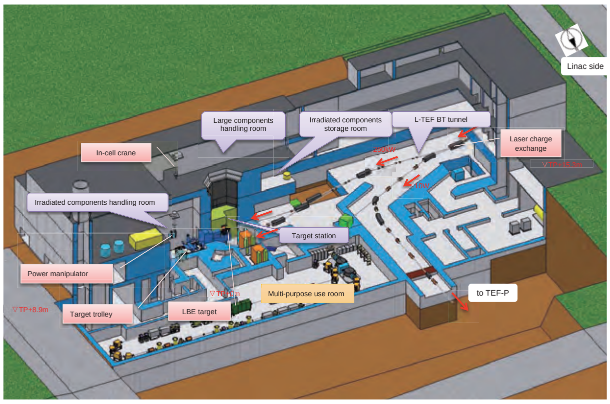


Fig. 3. Bird's eye view of TEF-T.

in detail to match with the existing J-PARC's control system. The irradiated component storage room was allocated on B2F with complying with safety standards for storage and handling of radioactive materials. The irradiated component storage room is connected to the irradiated components handling room (Hot-cell) through a hatch. Irradiated components can be stored without additional shielding in the room.

To make effective use of the fast and high-energy neutrons produced from the LBE target, and even the primary proton beam, we have studied multipurpose use equipment in TEF-T. One of the ideas is to incorporate an Isotope Separation On-Line (ISOL) facility for nuclear physics, nuclear chemistry, material science and others, by using radioactive nuclei produced by ISOL. An ISOL target, as well as the LBE target, was incorporated in the target station in the current design.

To assess safety aspect of TEF-T, under an assumption that an incident of LBE leak from the LBE circulation system occurred during a 250-kW beam operation, an estimation of radiation dose at the site boundary was conducted using various conservative assumptions. As a result, the radiation dose at the site boundary was dominated by mercury, noble gas, and iodine produced as spallation products in LBE. Even though the incident scenario was made rather conservatively, it was shown that the estimated radiation dose was lower than the annual radiation dose due to natural sources, and the TEF-T was sufficient safety margin for the leak of radioactivity.

Classification of the Importance of the Safety Function for TEF-P

TEF-P is designed as a zero-power critical facility referring to an existing Fast Critical Assembly (FCA) in JAEA/Tokai. In TEF-P, the neutronic characteristics of the transmutation systems and operation experiences of ADS are to be studied by introducing a proton beam to a minor actinide loaded core.

The safety design required for the license application were considered: the seismic design classification of the facility and the classification of the importance of the safety functions. In the seismic design, the radioactive exposure to the external public area was evaluated to be less than 5 mSv, even when the three vital functions, to stop the reactor, to cool the reactor, and to confine the radioactive material, have failed. Therefore, the TEF-P facility was classified as Class B.

As for the importance of the safety functions, the classifications of the prevention system for the occurrence of abnormalities (PS) and the mitigation system for the impact of abnormalities (MS) were carried out according to risk evaluations. Because the estimated result of the severest accident was less than 5 mSv, there was no structure, system, or component classified into PS-1 and MS-1 of Class-1 (secure and maintain as high as reasonably achievable level of reliability) in TEF-P. The classifications of PS-2 and MS-2 of Class-2 (secure and maintain a high level of reliability) are listed in Table 1. Based on the classifications, the system design for the main components, e.g. reactor shutdown system (safety rod drive system, movable table drive system), was carried out to determine the system configuration and basic specifications.

Table 1. Classification of importance of the safety functions (MS-2 and PS-2)

Class	*Function* Component, Structure, System,
PS-2	*Prevention of insertion of excessive reactivity* • Control rod drive system • Movable table drive system (forward) *Core constitution* • Matrix tube assembly • Fuel *Storage of radioactive materials* • Fuel storage *Safety handling of fuel* • MA fuel handling equipment
MS-2	*Emergency shutdown of reactor* • Safety rod drive system • Movable table drive system (backward) Sending signal for engineered safety systems and reactor shutdown system • Safety protection system Post-accident measurement • Radiation monitor in reactor building

Activity Related to TEF-P

The TEF-P core accommodates minor actinide (MA) fuel in kg-order. Since the decay heat of MA is high, the core is cooled during the operation. In the risk evaluation, it becomes important to estimate the temperature when the air cooling for the core would stop for a long period of time. The parametric survey to estimate the core temperature was carried out.

ANSYS code was employed for the heat transfer analysis, in which the three-dimensional detail calculation model was used. The following parameters were changed in the analysis: size of the core, amount of heat generation by MA, outside boundary of the core (air or lead). As the limitation of the temperature, the melting point of lead, 327°C, was assumed.

As a result of the parametric survey, it was observed that the size of the core and the amount of heat generation by MA should be reduced and lead blocks should be inserted outside of the core to enhance heat conduction to the outside. By this modification, the maximum temperature of the core became 303°C (Fig. 4) which is less than the melting point of lead. It means the core will not be damaged and MA will not leak from the cladding tube in the case of an accident caused by a failure of the cooling function.

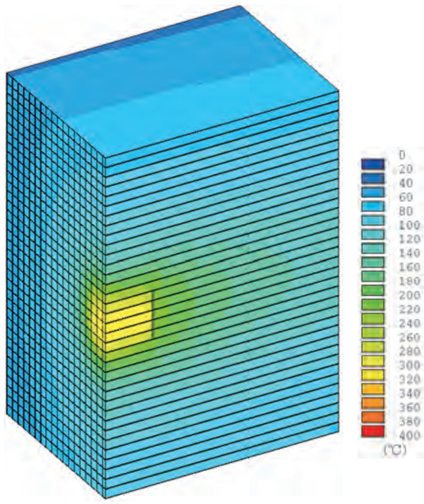


Fig. 4. Temperature distribution of the core in the acceptable case.

Research and Development

500˚C Operation of the IMMORTAL

IMMORTAL (Fig. 5) is a demonstrative test loop of the primary cooling system of the TEF-T target system. Most of its components provide the same performance as those that will be installed into the latest design of the TEF-T target. The purposes of this loop are mainly to assess the thermal-fluid behavior in mock-up scale, to evaluate the performance of individually developed components of the LBE technologies, and the production of a control sample for post-irradiation examination (PIE).

Fig. 5. Photo of IMMORTAL.

We have continued several test operations to confirm the performance of each component installed since 2014. Although the target vessel was connected by remote flanges, we were concerned about the possible LBE leakage during a high-temperature operation according to our experience. In order to avoid the leakage, we changed the connection method of the target vessel to a welded connection at the end of 2016. As a result, it was confirmed that the operation of LBE circulation in TEF-T at the maximum temperature condition (500˚C) could be reproduced (Fig. 6) without significant trouble.

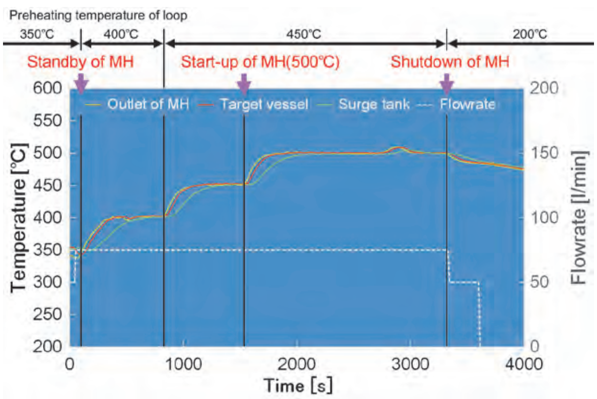


Fig. 6. Temperature history at a high-temperature operation.

Development of an Oxygen Sensor for LBE

We have fabricated several types of oxygen sensors for LBE. So far, we confirmed that the output voltage of the sensor was adequate in a wide temperature range. Since the sensor will be used in the irradiation condition in TEF-T, It was required to confirm effects of irradiation on the oxygen sensor. Hence the oxygen sensors were irradiated by gamma-rays at the Takasaki site, QST, as the first step.

The irradiation dose of the oxygen sensor in TEF-T was estimated to be 1 kGy/h. So, one oxygen sensor was irradiated by gamma-rays at 1 kGy/h for 1000 h. The appearance of the oxygen sensors before and after the irradiation is shown in Fig. 7. The surface color of the sensor head made of yttria-stabilized zirconia (YSZ) turned light yellow and rust was found at a steel housing. Also, the output voltage of the oxygen sensor was changed by the irradiation. We will continue this experiment for a better understanding of the irradiation effects.

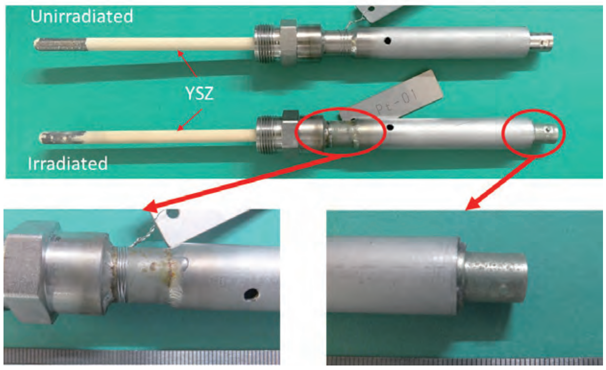


Fig. 7. Oxygen sensors before (upper) and after irradiation (lower) by gamma-rays.

Remote Handling Techniques for LBE System

The replacement method of the target vessel is one of the key technologies to maintain a safe operation of the TEF-T LBE target system. The target system is installed under high radiation environment, hence all components should be maintained by remote handling. We have been developing the applicability of the replacement technology by remote cutting/welding of the system piping. A series of both works was performed by operating with master-slave manipulators (MSM) using a commercially available pipe cutter and an automatic welding machine. Because the weld head was heavy, direct handling of the weld head by using the MSM was difficult and some kinds of support were necessary. Further, setting and positioning the weld head and adjustment of the cut piping required a quite complicated operation, hence we developed a prototype of an auxiliary implement (Fig. 8) to demonstrate the welding procedure.

Using this implement, we performed a demonstration test of the remote welding operation by the MSM. Fig. 9 shows the release procedure of the weld head after welding. As a result, an adjustment of the piping, installation of the weld head and welding of the piping were demonstrated. There were some points to be improved, such as the necessity to install several monitoring devices for a reliable operation.

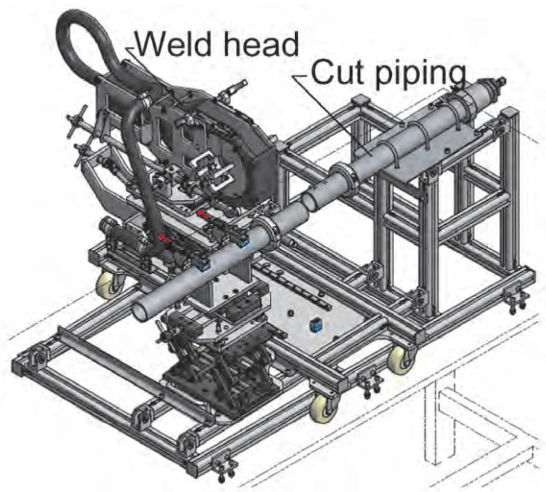


Fig. 8. Sketch of the prototype of the auxiliary implement.

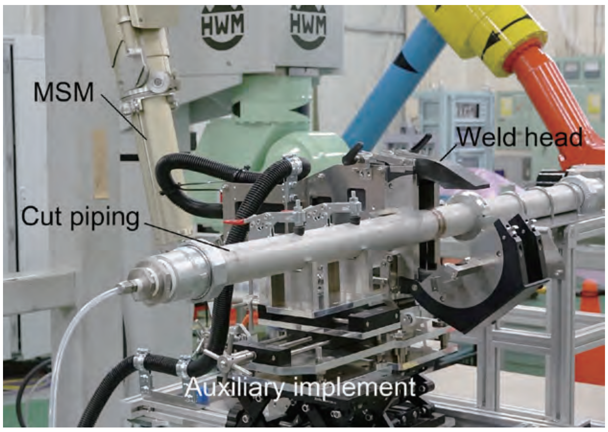


Fig. 9. Photo of the release procedure of the weld head after welding.

Development of the Freeze-Seal Valve

To establish the TEF-T LBE spallation target, a reliable valve system which can be used for LBE, high-temperature liquid metal, is indispensable. One of the desirable options of the valve system, freeze-seal type valve (FV) is under development. The FV has a cooling channel around the piping to freeze the LBE in the piping and block up the piping by frozen LBE. There are no movable parts in the FV.

However, LBE shows re-crystallization with volumetric expansion after solidification. It means that stress will be generated in the FV and the FV may be raptured by the expansion stress. Mockup tests have been started with instrumented strain gauges at realistic and prototypical conditions to measure the stress/strain levels in the piping walls after solidification. This will help to assess the risk and optimize the FV operation. Strain behavior of test-tube samples under various cooling conditions is shown in Fig. 10. Obviously, as the cooling rate slows down, the generated stress decreased.

Stress analysis was performed on the test-tube samples. The generated stresses of the 3-mm thick test-tube were lower than the allowable stress. Stress analysis of the piping of the FV will also be performed.

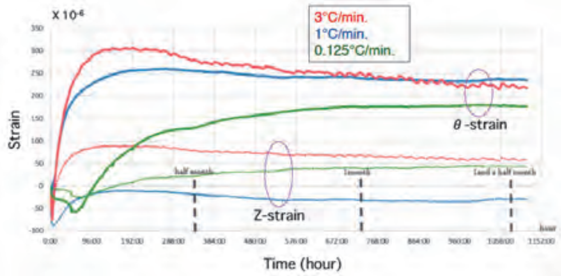


Fig. 10. Strain behavior for the samples under various cooling conditions.

Laser Charge Exchange Technique

A low reactor power of less than 500 W is enough for the reactor physics experiments at TEF-P. Therefore, the power of incident proton beam into TEF-P is sufficient at most 10 W under a typical core condition, i.e. the effective neutron multiplication factor (k_{eff}) of 0.98. It is required to stably maintain the experimental conditions of the incident proton beam and to reproduce the conditions with high accuracy. Accordingly, a highly stable and low-power proton beam extraction device out of a high-intensity 250-kW proton beam for TEF-T is indispensable. To meet this requirement, we are developing a laser charge exchange (LCE) technique. Although the LCE technique was developed originally to measure the proton beam profile, we attempted to apply the LCE technique to extract the low power proton beam for TEF-P from the 250 kW beam for TEF-T. Figure 11 illustrates the concept of the LCE device.

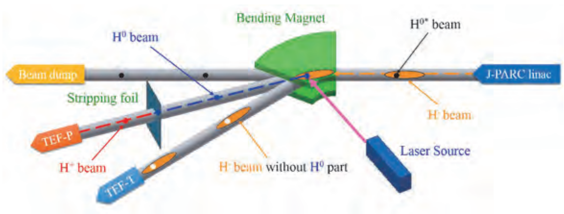


Fig. 11. Conceptual diagram of the LCE device.

The LCE device consists of a bright YAG-laser and a laser transport system with beam position controllers. By exposing the YAG-laser beam to the negative hydrogen (H^-) beam from the J-PARC Linac, one of the two electrons in an H^- ion is stripped to be a neutral hydrogen atom (H^0). After separating the H^0 atoms from the remaining H^- ions by a bending magnet, the other electron of the H^0 atom is finally stripped by a stripping foil made of carbon to produce a proton beam for TEF-P.

To measure the power and stability of the charge-exchanged H^+ beam, an LCE experiment was conducted using the 3-MeV linac. As shown in Fig. 12, the LCE device was installed at the end of the 3-MeV linac (RFQ) in cooperation with the J-PARC accelerator division. As a result, a charge-exchanged H^+ beam with a power of 0.0359 W was obtained. The power corresponded to 7.99±0.22 W under the J-PARC's Linac conditions (400 MeV, 250 kW). Fig. 13 shows power distribution of the charge-exchanged H^+ beam. These results satisfied the power requirement (at most 10 W) of the proton beam for TEF-P.

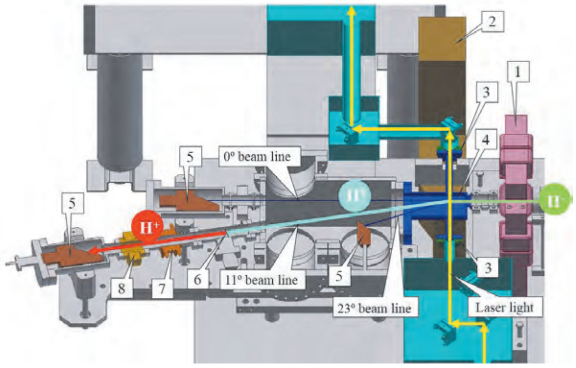


Fig. 12. Schematic view of the LCE system (1- quadrupole magnet, 2- bending magnet, 3- quartz viewing port, 4- vacuum chamber, 5- beam dump, 6- stripping foil, 7- beam position monitor, 8- slow current transformer).

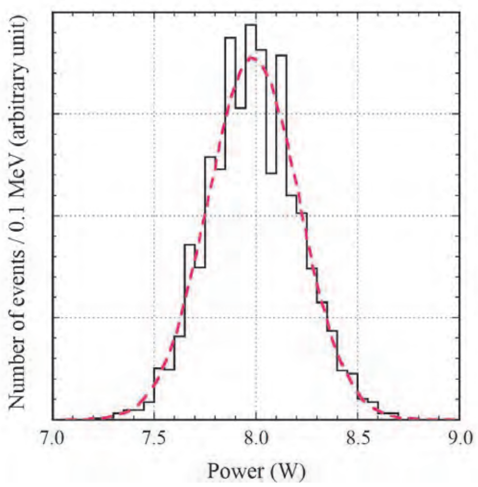


Fig. 13. Power distribution of the charge-exchanged H^+ beam. Here, the value of the horizontal axis represents the converted power under the J-PARC linac beam condition.

Proton-Induced Activation Cross Section Measurement

Proton-induced activation cross section is the probability of producing radioactivity in materials. This is quite important in estimating an amount of radioactive waste and lives of components. The measurement itself is simple: irradiating samples with protons, detecting gamma-rays by a high-purity germanium detector, and evaluating the cross sections. Over the period of more than half a century, enormous measurements have been performed for various nuclides, from light nuclides to heavy ones, with various energies. There are still cross sections which are either unknown or having large uncertainties. Especially, in the GeV energy region which is important for ADS, activation cross section data are scarce for various nuclides. Although it is possible to evaluate the cross-section data by particle transport calculation codes, the calculated values still need to be verified by experiments in the end.

To measure activation cross section data, we have started an experiment at 3 GeV RCS to the Neutron Facility Beam Transport (3NBT) dump (Fig. 14), in which the proton beam energy can be changed from 0.4 GeV to 3.0 GeV by changing the extraction timing of a kicker magnet at RCS. We measured the cross-section data of aluminum for the first at several energies from 0.4 GeV to 3.0 GeV using a vacuum chamber (Fig. 15).

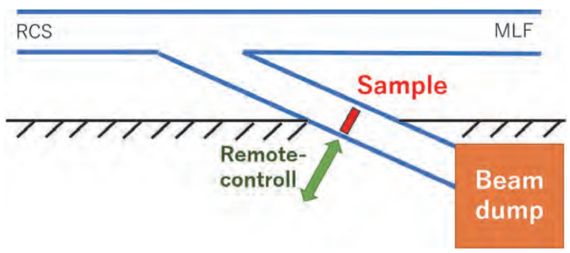


Fig. 14. Schematic view of the experimental area.

Owing to the high-intensity pulse beam of J-PARC, the actual bombardment took around one minute. The cross-section was also calculated by a particle transport calculation code PHITS for comparison. In the calculation, it was found that the general evaporation model (GEM) in PHITS differed from the originally developed one. We implemented successfully the original one. This affected the production of lighter nuclides, such as beryllium-7, since it evaporated from aluminum. The results of the activation cross sections of aluminum, superposing calculations with some models, are shown in Fig. 16.

These results indicate that this experiment at 3NBT is very useful since the experimental uncertainty is lower than the other experimental data, and also that a better intranuclear cascade model is strongly required. As the next step, we will measure the activation cross section data for various structural and target materials, such as Be, Fe, Pb and Bi.

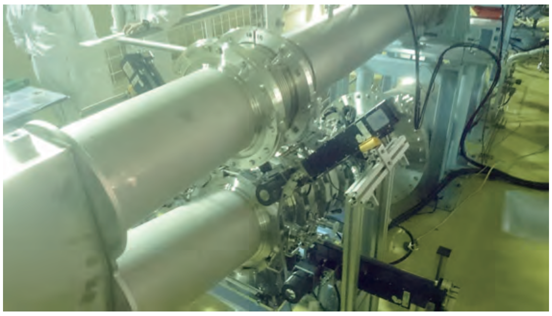


Fig. 15. The vacuum chamber.

High-Intensity Proton Beam Monitors

To observe the profile of the beam introduced to the target at TEF-T, a luminescence beam profile monitor is one of the candidates. Since the TEF-T target will receive 6 times higher than the beam current density at the spallation neutron source of J-PARC, a beam monitor which can withstand the high current density is required. To develop such beam monitors, an experiment was performed by using a low-energy argon beam at Takasaki Ion Accelerators for Advanced Radiation Application (TIARA) of QST, which bring about 10^6 times as much displacements on the materials with respect to the displacements by 3-GeV protons. Some prospective materials were examined concerning degradation of luminescence.

In the experiment, a luminescence plate made of aluminum oxide doped with 0.5% CrO_3 with a thickness of 5 mm was irradiated with the 150-MeV 75 nA $^{40}Ar^{15+}$ beam. During the beam irradiation, the luminescence from the plate was observed with the spectrometer as shown in Fig. 17. The spectrum has a prominent peak at 694 nm with several unresolved shoulder peaks produced by the excitation state of Cr^{3+}. After the irradiation for 2.3 h which was equivalent to 100 hours irradiation of TEF-T, the peak intensity decreased by 35%. The results indicate that further improvement in irradiation resistance is needed to use the luminescence plate for TEF-T. Since the intensity of the unresolved peak with a wavelength region shorter than the 694 nm peak less decreased than the intensity at the peak, the degradation may be mitigated by observing the luminescence only in the shorter wavelength with an optical filter.

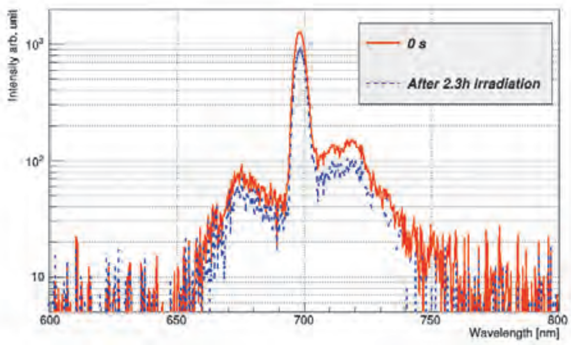


Fig. 17. Observed spectra form the luminescence plate irradiated with $^{40}Ar^{15+}$ beam.

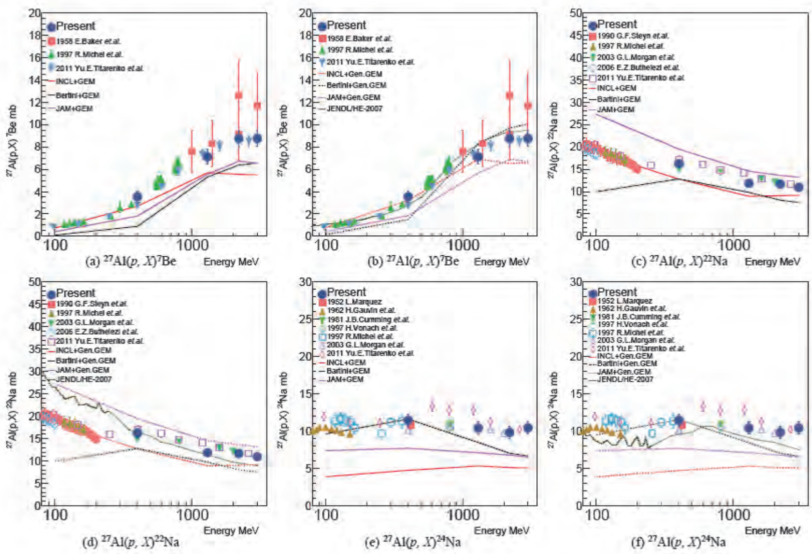


Fig. 16. Comparison of cross sections (this experiment, other experiments, evaluated data, and calculations) taken from H. Matsuda, et al., J. Nucl. Sci. Tech. 2018 (*to be published*)

Other Activities and International Collaboration

Meeting and Workshops

The 14th International Workshop (General Meeting) on Asian Network for Accelerator-Driven System (ADS) and Nuclear Transmutation Technology (NTT) in 2016 (ADS-NTT 2016) was held in Mito on September 5. There were many participants from Korea and China. There were presentations on the R&D situations in Japan, China and Korea, and an exchange of views on future R&D issues for ADS and cooperation necessary to resolve them.

The NEA Third International Workshop on Technology and Components of Accelerator Driven Systems (TCADS-3) was held in Mito from September 6 to 9. There were 58 participants from 13 countries. After the meeting, the participants toured test instruments, such as the liquid lead-bismuth loop in the High Temperature Engineering Test Building of the Nuclear Science Research Institute. They asked questions and exchanged views regarding the equipment and its operation.

Publicity for ADS Transmutation Technology

In order to promote understanding of the nuclear transmutation technology using ADS, various activities were performed using a 1/20 scale-model of the future ADS Transmutor. The nuclear transmutation by ADS was visually simulated in the ADS model by a motion flow of LED lights. The model also had an LCD screen to display a slide show explaining the ADS research activities in JAEA.

At the open campus of J-PARC in July 2016, the Nuclear Transmutation Division opened a booth to show the research activities for ADS and related technology developments in J-PARC. The 1/20-scale ADS model, the inner structure of lead-bismuth eutectic spallation target for material irradiation, and an oxygen concentration sensor were exhibited at the booth. In December 2016, JAEA opened a booth in Eco-Pro 2016 (see Fig. 18), held in Tokyo Big Sight. The ADS model was also exhibited to promote the ADS transmutation technology as a technology useful in reducing the environmental impact of nuclear waste disposal.

At both exhibitions, it became clear that the public was not fully aware of the promising option, nuclear transmutation, which can contribute to solving the problem of nuclear waste for sustainable nuclear energy production.

Fig. 18. Exhibition at Eco-Pro 2016.

Safety

Safety

1. Major Events on Safety Culture and Safety Activities in the J-PARC Center

The major events on safety culture and safety activities in J-PARC center are listed in Table 1. The FY2016 workshops for fostering safety culture at J-PARC and the 4th Symposium on safety in accelerator facilities are described in the chapter "Events"

A practical training course on radiation protection was newly introduced in order to improve the radiation-safety literacy of the J-PARC staff. The theme of the training course this year was how to fit typical protective gears used in radiation control areas. In the training course, the participants learned practical skills on how to put and remove rubber gloves, half-face masks, full-face masks and Tyvek clothes. The training class was held twice, on July 19 and August 5, following the e-learning course on the same topics, which was conducted from May 25 to June 16.

The J-PARC Safety Audit 2016 was conducted by outside auditors (Prof. Takano of Keio University and Prof. Ishibashi of Kyushu University) on November 22. They heard information about the current status of the safety management in the J-PARC Center and the activities in various fields by the facilities, and interviewed the director, the deputy directors, the managers of facilities and other staff members. They evaluated positively our safety management system as a whole. In addition, they gave us valuable suggestions for enforcement of safety activities on a bottom-up and voluntary basis, introduction of an award program for significant contributions to safety and load saving by simplification of some procedures and works.

2. Experience-Based Hazard Training

In order to raise workers' safety awareness and to prevent work-related accidents, experience-based simulated hazard training was introduced for practical safety training in FY2016.

The training courses in FY2016 were conducted on May 25 and November 16 at the Iwaki Factory of KUREHA Corporation, and on August 30 and February 17 at the HITACHI Chemical Techno Service Co., Ltd. A total of 78 staff members attended these demonstration trainings. Judging from the participant's comments, it was confirmed that the trainings were effective for raising their safety awareness. The trainings will be carried out continuously to allow all staff members to gain safety knowledge from the experience-based hazard training.

Fig. 1. Experience-Based hazard training (Flame from a spray product).

3. Radiological License Update and Facility Inspection

Applications to update the radiological license were submitted to the Nuclear Regulation Authority on August 5 and December 14. The major application items are listed in Table 2. The permissions for the applications were issued on September 27 and February 2, 2017, respectively.

In FY2016, we have passed the facility inspections twice. The first one was carried out on June 21 and was passed on June 27. It targeted a change of the entrance of the accelerator room (RFQ-TS) and the construction of the new beamline (BL23) at the MLF. The second inspection was carried out on November 4 and was passed on November 7. It covered a change of the shielding structure to prepare the construction of a new beamline for the high-velocity muon beam.

4. Meeting and Committee on the Radiation Safety Matter

The basic policy on the radiation safety in J-PARC are supposed to be discussed by the J-PARC Radiation Safety Committee (RSC). Meanwhile, the J-PARC Radiation Safety Review Committee (RSRC) is expected to discuss the specific subjects on radiation safety in J-PARC.

The RSC meetings were held three times and those of the RSRC, four times. The major issues are summarized in Table 3.

5. Radiation Exposure of Radiation Workers

Figure 2 shows the variation of the number of radiation workers in J-PARC since 2005. In JFY2016, 3275 persons were registered as radiation workers in J-PARC. Their number increased gradually year by year. The spike in the number for 2014 was caused by the presence of more contractors than usual. They carried out the construction work of the south experimental hall at the HD facility, which is located in a radiation controlled area.

Table 4 summarizes the distribution of annual doses for each category of workers. The exposure dose has been measured with an optically stimulated luminescence (OSL) dosimeter for β-ray and γ-ray and with a plastic solid-state track detector for neutrons. Almost all workers were exposed less than the detection limit (Not Detected, ND). Only one worker was exposed to more than 5 mSv but it did not exceed the administrative dose control value (7 mSv/year) at J-PARC. We should continue to take care about the reduction in radiation exposure by respecting the ALARA ("as low as reasonably achievable") principle.

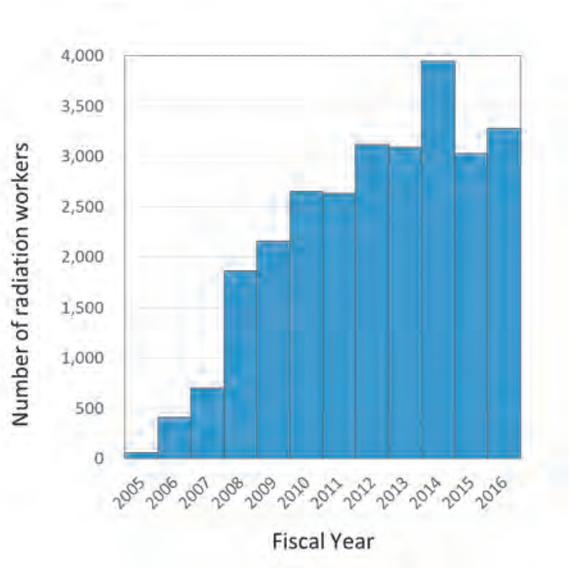


Fig. 2. Variation of the number of radiation workers in J-PARC.

Table 1. List of major events on safety in FY2016

Year	Date	Events
2016	May 20	Workshop for fostering safety culture
	July 19 and Aug. 5	Practical training course on radiation protection
	Sep. 27	Refresher course on radiation safety
	Oct. 28	Emergency drill assuming a fire accident
	Nov. 22	Safety audit
2017	Jan. 26-27	4th Symposium on safety in the accelerator facilities

Table 2. Major application items of the radiological license

Facility	Items of 1st application	Items of 2nd application
Li	• Maximum energy: 400 MeV ⟶ 420 MeV	
MLF	• New shielded radio isotope (137-Cs) • Change of the shield structure (preparation for the high-velocity muon experiment) • Construction and shutdown of the contamination monitoring facility	• Increase of gas-holders at the exhaust facility
HD	• Beam intensity: $3.8 \times 10^{16} \rightarrow 4.0 \times 10^{16}$ protons/hour • Change of the shield structure (preparation for a new primary beamline) • Transfer of exhaust monitoring device (HM2 ⟶ HM3)	

Table 3. Radiation Safety Committee (RSC) and Radiation Safety Review Committee (RSRC) in FY2016

No.	Date	Major Issues
The Radiation Safety Committee (three times)		
25th	12th May 2016	• Policy on the radiological license update for the MLF and HD facilities
26th	25th Oct. 2016	• Policy on the radiological license update for the MLF facility
27th	30th Mar. 2017	• New target system at the HD facility
The Radiation Safety Review Committee (four times)		
12th	15th Apr. 2016	• Update of the radiological license for the MLF and HD facilities
13th	4th Aug. 2016	• Revision of the detailed rule of local radiation protection • Revision of the safety rule for X-ray generators • Use of the X-ray generator at the HD facility
14th	19th Oct. 2016	• Update of the radiological license for the MLF facility • Revision of the operational rule for the MLF facility
15th	13th Mar. 2017	• New target system at the HD facility

Table 4. Annual doses in FY2016

	# of workers	Dose range x (mSv)				Collective dose (person mSv)	Maximum dose (mSv)
		ND	0.1≤x ≤1.0	1.0<x ≤5.0	5.0<x		
In-house staff	655	627	25	2	1	14.9	5.7
Users	1,118	1,118	0	0	0	0	0
Contractors	1,519	1,466	51	2	0	20.5	1.6
Total	3,275	3,194	76	4	1	35.4	5.7

User Service

Users Office (UO)

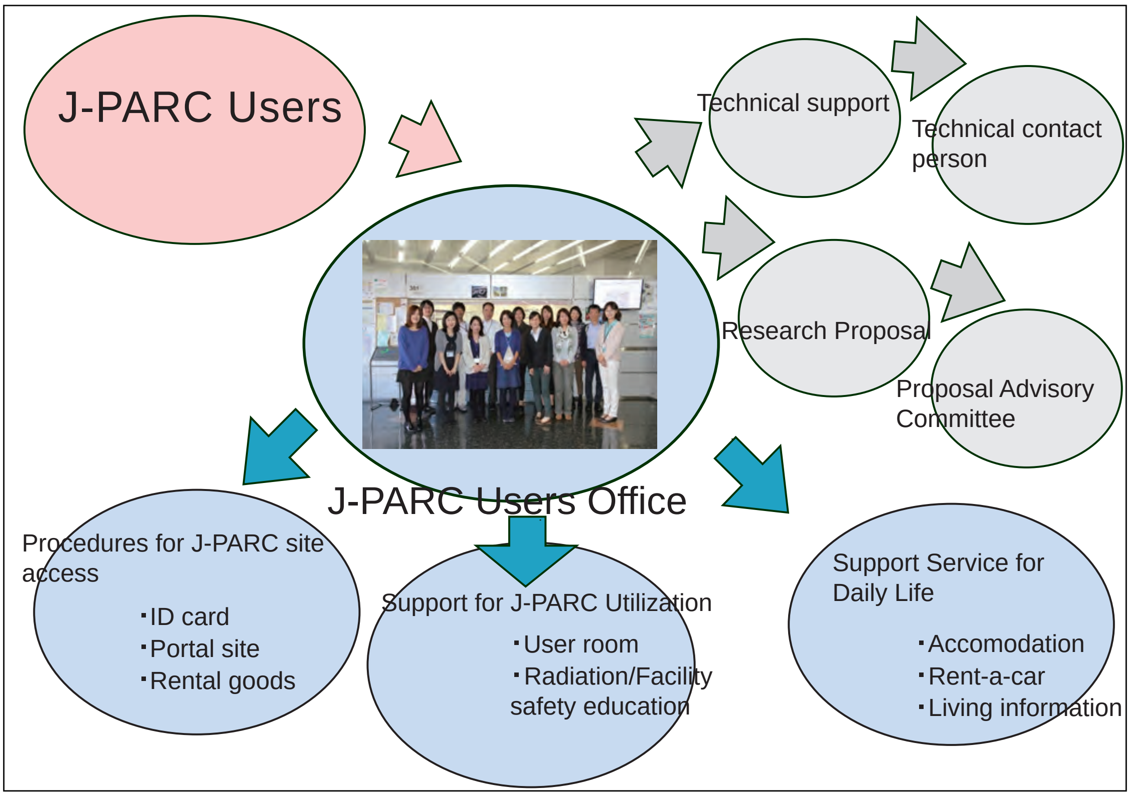
Outline

The J-PARC Users Office(UO) was organized in 2007. It opened an office on the 1st floor of the IBARAKI Quantum Beam Research Center in Tokai-mura, in December 2008. The UO maintains the Tokai Dormitory for the J-PARC users. The UO provides on-site and WEB support with a one-stop service for the utilization of J-PARC. As of March 31, 2017, the UO had 16 staffs and 3 WEB Support SE staffs.

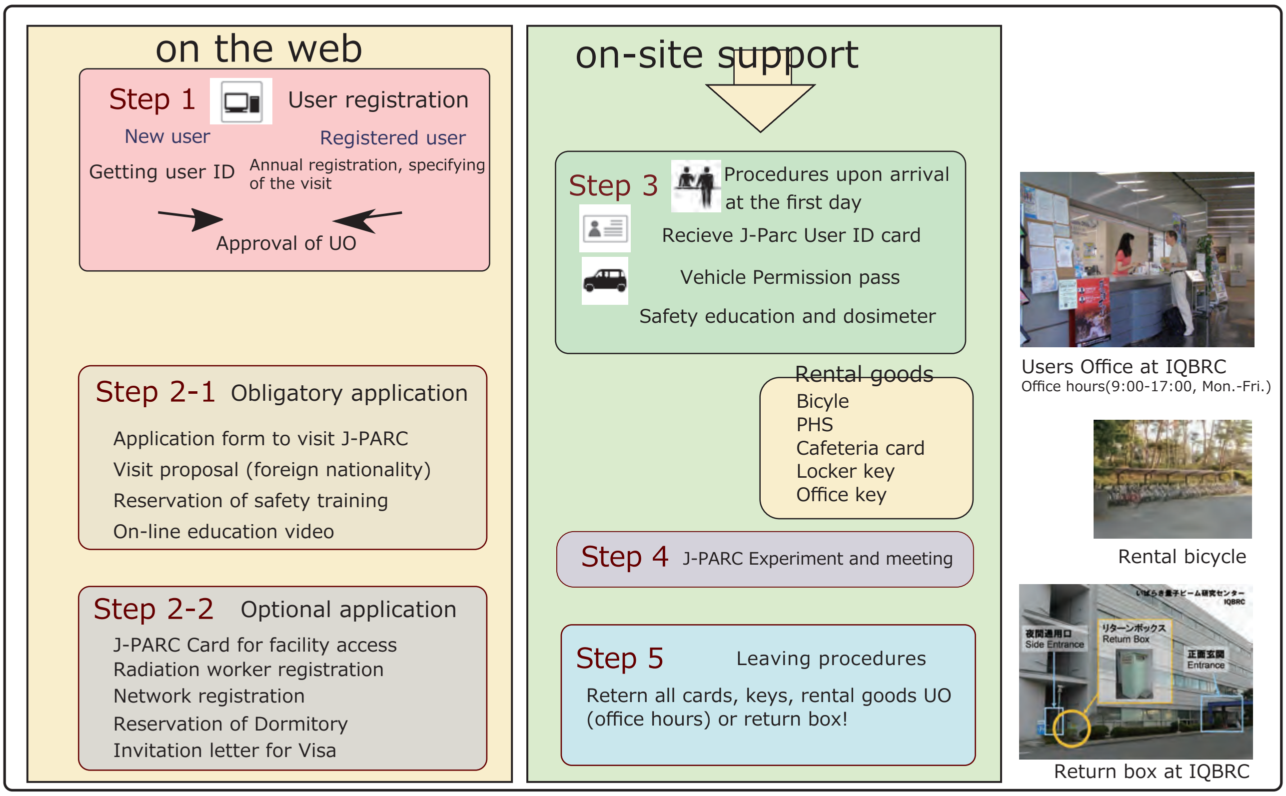
The J-PARC Users, after the approval of their experiment, follow the administrative procedures outlined on the Users Office (UO) WEB portal site, related to the registration as a J-PARC User, radiation worker registration, safety education, accommodation, invitation letter for visa and other requirements. Then the UO staffs provide them with support by e-mail. After their arrival at J-PARC, the UO gives on-site assistance to the J-PARC Users, like receiving the J-PARC ID, glass badge, and safety education. Since 2015, the UO had been doing its part to improve the J-PARC on-line experiment system and make it more user-friendly.

1st row, right to left KAWAKAMI Megumi, ISHIKAWA Taeko, KOBAYASHI Sayuri, ENOKI Kaori, SAKAGAMI Keiichi, KATOGI Aki.
2nd, right to left; SANAO Ai, ONUKI Rika, HANAWA Masahiro, ISOZAKI Mari, NAMIKI Shinji, KIMURA Rie.

Activities of UO

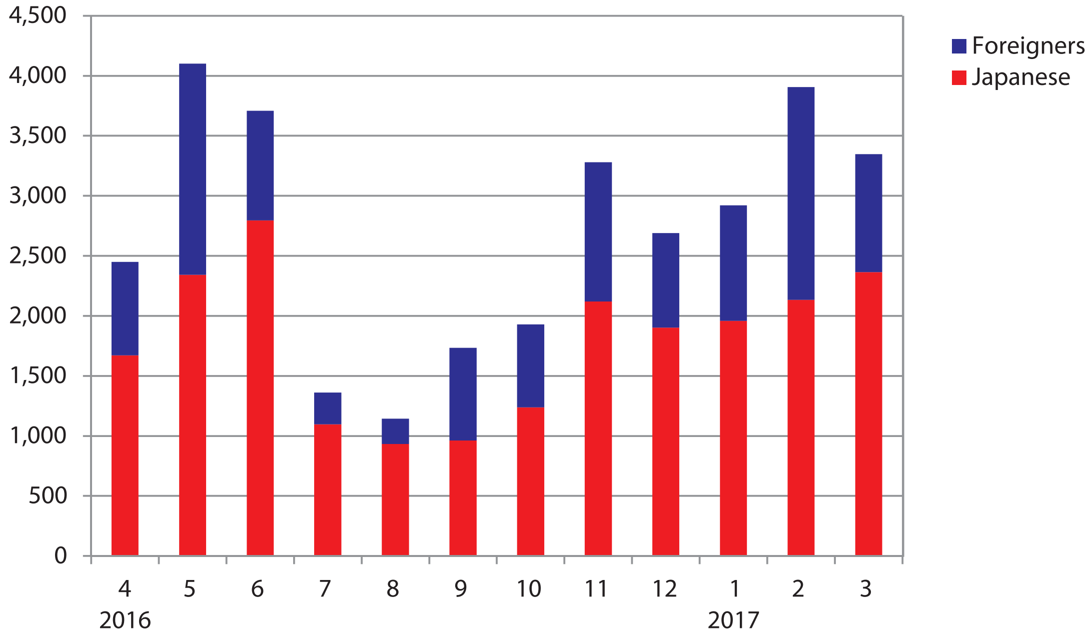


One-stop service for J-PARC users

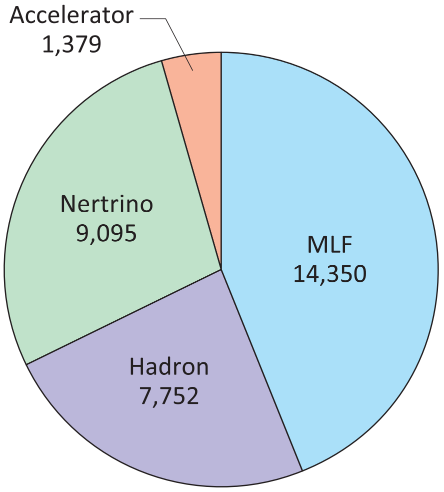


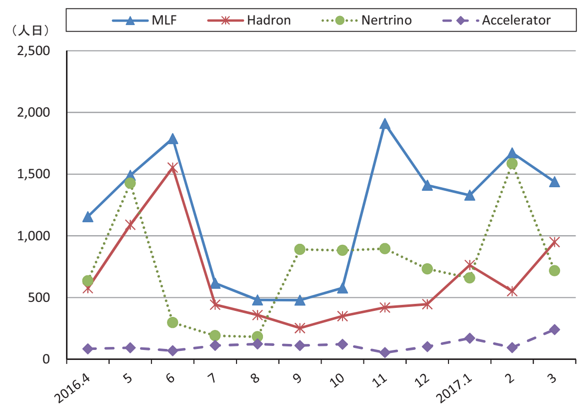
User Statistics

Users in 2016 (Japanese/Foreigners, person-days)

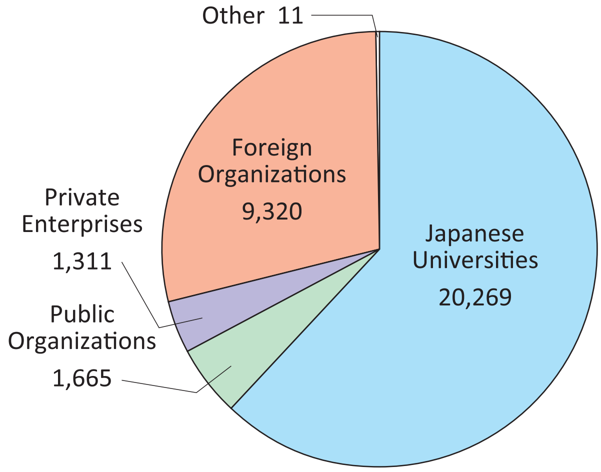


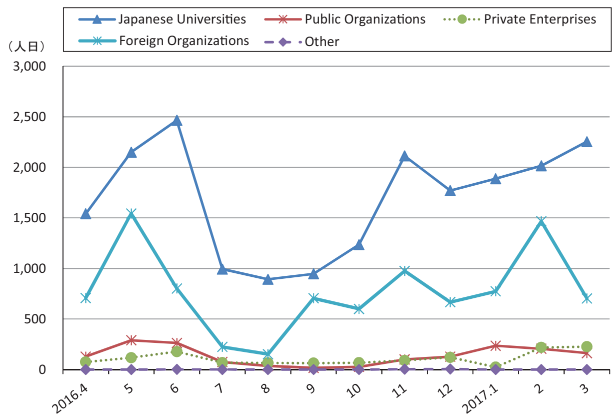
Users in 2016 (according to facilities, person-days)





Users in 2016 (according to organizations, person-days)





MLF Proposals Summary - FY2016

Table 1. Breakdown of Proposals Numbers for the 2016 Rounds

Beam-line	Instrument		2016A		2016B		Full Year					
			Submitted	Approved	Submitted	Approved	Submitted			Approved		
			GU	GU	GU	GU	PU/S	IU	ES	PU/S	IU	ES
BL01	4D-Space Access Neutron Spectrometer - ***4SEASONS***		11(1)	5(1)	15(0)	5(0)	3	1	2	3	1	2
BL02	Biomolecular Dynamics Spectrometer - ***DNA***		16(1)	7(1)	19(1)	8(1)	2	1	0	2	1	0
BL03	Ibaraki Biological Crystal Diffractometer - ***iBIX***	(100-β)‡	8	1	6	0	0	0	0	0	0	0
		(β)†	2	2	0	0	18	0	0	18	0	0
BL04	Accurate Neutron-Nucleus Reaction Measurement Instrument - ***ANNRI***		9	3	12	3	2	1	0	2	1	0
BL05	Neutron Optics and Physics - ***NOP***		6	2	2	2	1	0	0	1	0	0
BL06	Neutron Resonance Spin Echo Spectrometers - ***VIN ROSE***		0	0	0	0	1	0	0	1	0	0
BL08	Super High Resolution Powder Diffractometer - ***S-HRPD***		11	3	12	6(0)	1	0	0	1	0	0
BL09	Special Environment Neutron Power Diffractometer - ***SPICA***		0	0	0	0	1	0	0	1	0	0
BL10	Neutron Beamline for Observation and Research Use - ***NOBORU***		11	5	8	7	3	1	0	3	1	0
BL11	High-Pressure Neutron Diffractometer - ***PLANET***		12(0)	8(0)	12(0)	8	0	1	0	0	1	0
BL12	High Resolution Chopper Spectrometer - ***HRC***		12	4	9	3	1	0	0	1	0	0
BL14	Cold-neutron Disk-chopper Spectrometer - ***AMATERAS***		28	4	22	6	4	1	1	4	1	1
BL15	Small and Wide Angle Neutron Scattering Instrument - ***TAIKAN***		29(3)	9(3)	17(2)	9(2)	4	3	1	4	3	1
BL16	High-Performance Neutron Reflectometer with a horizontal Sample Geometry - ***SOFIA***		19	10	7	7	0	0	0	0	0	0
BL17	Polarized Neutron Reflectometer - ***SHARAKU***		18(2)	8(2)	10(1)	4(1)	1	1	1	1	1	1
BL18	Extreme Environment Single Crystal Neutron Diffractometer - ***SENJU***		23(1)	4(1)	16(0)	5(0)	2	3	1	2	3	1
BL19	Engineering Diffractometer - ***TAKUMI***		23	5	25	7	3	1	2	3	1	2
BL20	Ibaraki Materials Design Diffractometer - ***iMATERIA***	(100-β)‡	13	4	19	4	0	0	0	0	0	0
		(β)†	44	24	20	20	15	0	0	15	0	0
BL21	High Intensity Total Diffractometer - ***NOVA***		19	7	17	7	1	0	0	1	0	0
BL22	Energy Resolved Neutron Imaging System - ***RADEN***		18	6(0)	11(0)	7(0)	2	2	0	2	2	0
BL23	Polarization Analysis Neutron Spectrometer - ***POLANO***		0	0	0	0	1	0	0	1	0	0
D1	Muon Spectrometer for Materials and Life Science Experiments - ***D1***		17(0)	6(0)	18(0)	1(1)	3	1	0	3	1	0
D2	Muon Spectrometer for Basic Science Experiments - ***D2***		13	6	15	7	1	1	0	1	1	0
U	Muon U		0	0	0	0	0	0	0	0	0	0
Total			**362**	**133**	**291**	**125**	**69**	**18**	**8**	**69**	**18**	**8**

GU : General Use **PU :** Project Use or Ibaraki Pref. Project Use **S :** S-type Proposals
IU : Instrument Group Use **ES :** Element Strategy
† : Ibaraki Pref. Exclusive Use Beamtime (β = 80% in FY2016)
‡ : J-PARC Center General Use Beamtime (100–β = 20% in FY2016)
( ) : Proposal Numbers under Trial Use Access System or P-type proposals (D1,D2) in GU

J-PARC PAC Approval Summary after the 23rd Meeting

	(Co-) Spokespersons	Affiliation	Title of the experiment	Approval status (PAC recommendation)	Beamline	Status
E03	K. Tanida	JAEA	Measurement of X rays from Ξ^- Atom	Stage 2 One day beam time shoud be allocated before the summer shutdown	K1.8	In preparation
P04	J. C. Peng, S. Sawada	U of Illinois at Urbana-Champaign; KEK	Measurement of High-Mass Dimuon Production at the 50-GeV Proton Synchrotron	Deferred	Primary	
E05	T. Nagae	Kyoto U	Spectroscopic Study of Ξ-Hypernucleus, $^{12}{}_{\Xi}$Be, via the ^{12}C(K$^-$, K$^+$) Reaction	Stage 2 New proposal based on the S-2S spectrometer is required	K1.8	Pilot run in Nov. 2015
E06	J. Imazato	KEK	Measurement of T-violating Transverse Muon Polarization in $K^+ \to \pi^0 \mu^+ \nu$ Decays	Stage 1	K1.1BR	
E07	K. Imai, K. Nakazawa, H. Tamura	JAEA, Gifu U, Tohoku U	Systematic Study of Double Strangeness System with an Emulsion-counter Hybrid Method	Stage 2 Highest priority for the upcoming running period to complete the measurement	K1.8	5-day physics run in June 2016
E08	A. Krutenkova	ITEP	Pion double charge exchange on oxygen at J-PARC	Stage 1	K1.8	
E10	A. Sakaguchi, T. Fukuda	Osaka U, Osaka EC U	Production of Neutron-Rich Lambda-Hypernuclei with the Double Charge-Exchange Reaction (Revised from Initial P10)	Stage 2	K1.8	Li run finished, Be target run with S-2S
E11	T. Kobayashi	KEK	Tokai-to-Kamioka (T2K) Long Baseline Neutrino Oscillation Experimental Proposal	Stage 2 Two weeks additional beam time in the spring 2017.	neutrino	Data taking
E13	H.Tamura	Tohoku U	Gamma-ray spectroscopy of light hypernuclei	Stage 2	K1.8	Finished
E14	T. Yamanaka	Osaka U	Proposal for $K_L \to \pi^0 \nu$ ν-bar Experiment at J-PARC	Stage 2	KL	Data taking
E15	M. Iwasaki, T. Nagae	RIKEN, Kyoto U	A Search for deeply-bound kaonic nuclear states by in-flight 3He(K-, n) reaction	Stage 2	K1.8BR	Data taking
E16	S. Yokkaichi	RIKEN	Measurements of spectral change of vector mesons in nuclei (previously "Electron pair spectrometer at the J-PARC 50-GeV PS to explore the chiral symmetry in QCD")	Stage 1 A revised proposal for Run-0 is required.	High p	
E17	R. Hayano, H. Outa	U Tokyo, RIKEN	Precision spectroscopy of Kaonic ^{3}He 3d->2p X-rays	Registered as E62 with an updated proposal	K1.8BR	
E18	H. Bhang, H. Outa, H. Park	SNU, RIKEN, KRISS	Coincidence Measurement of the Weak Decay of $^{12}{}_{\Lambda}$C and the three-body weak interaction process	Stage 2	K1.8	
E19	M. Naruki	KEK	High-resolution Search for Θ^+ Pentaquark in $\pi^- p \to K^- X$ Reactions	Stage 2	K1.8	Finished
E21	Y. Kuno	Osaka U	An Experimental Search for $\mu - e$ Conversion at a Sensitivity of 10^{-16} with a Slow-Extracted Bunched Beam	Phase-I Stage 2 8GeV test should be carried out in spring 2017.	COMET	
E22	S. Ajimura, A. Sakaguchi	Osaka U	Exclusive Study on the Lambda-N Weak Interaction in A=4 Lambda-Hypernuclei	Stage 1	K1.8	
T25	S. Mihara	KEK	Extinction Measurement of J-PARC Proton Beam at K1.8BR	Test Experiment (coord'ed by JPNC)	K1.8BR	Data taking
E26	K. Ozawa	KEK	Search for ω-meson nuclear bound states in the $\pi^- + {}^A$Z -> n+$^{(A-1)}{}_{\omega}$(Z–1) reaction, and for ω mass modification in the in-medium $\omega \to \pi^0\gamma$ decay	Stage 1	K1.8	
E27	T. Nagae	Kyoto U	Search for a nuclear Kbar bound state K$^-$pp in the d(π^+,K$^+$) reaction	Stage 2	K1.8	Data taking
E29	H. Ohnishi	RIKEN	Search for ϕ-meson nuclear bound states in the pbar + ^{A}Z -> ϕ + $^{(A-1)}{}_{\phi}$(Z–1) reaction	Stage 1	K1.1	
E31	H. Noumi	Osaka U	Spectroscopic study of hyperon resonances below KN threshold via the (K$^-$,n) reaction on Deuteron	Stage 2 PAC supports requests of a second run	K1.8BR	Data taking
T32	A. Rubbia	ETH, Zurich	Towards a Long Baseline Neutrino and Nucleon Decay Experiment with a next-generation 100 kton Liquid Argon TPC detector at Okinoshima and an intensity upgraded J-PARC Neutrino beam	Test Experiment	K1.1BR	Finished
P33	H. M. Shimizu	Nagoya U	Measurement of Neutron Electric Dipole Moment	Deferred	Linac	
E34	N. Saito, M. Iwasaki	KEK, RIKEN	An Experimental Proposal on a New Measurement of the Muon Anomalous Magnetic Moment g-2 and Electric Dipole Moment at J-PARC	Stage 1	MLF	
E36	M. Kohl, S. Shimizu	Hampton U, Osaka U	Measurement of $\Gamma(K+ \to e+ \nu)/\Gamma(K+ \to \mu+ \nu)$ and Search for heavy sterile neutrinos using the TREK detector system	Stage 2 The analysis status should be reported regularly. Dark photon analysis should be done.	K1.1BR	Finished Data analysis
E40	K. Miwa	Tohoku U	Measurement of the cross sections of Σp scatterings	Stage 2	K1.8	In preparation

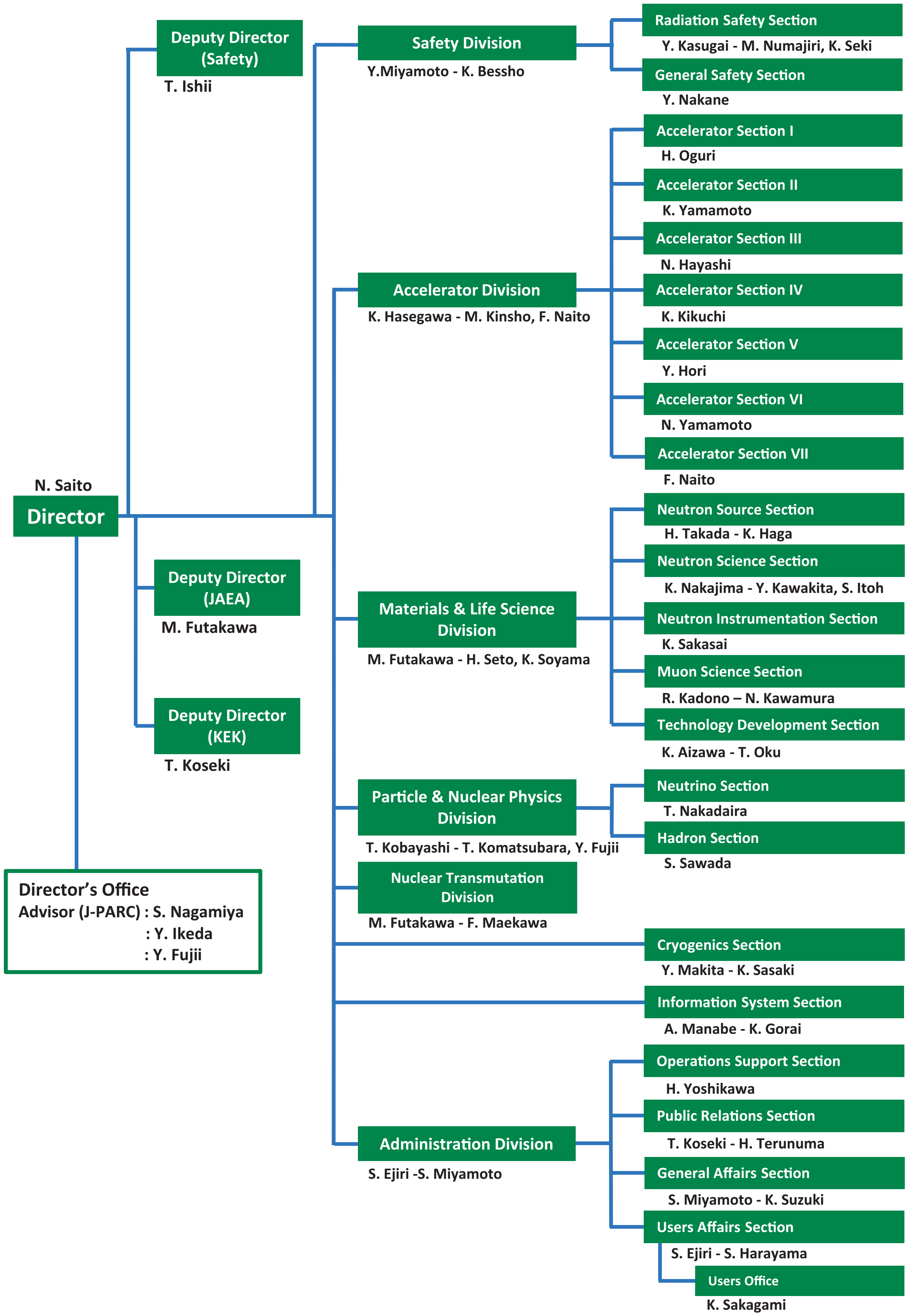
	(Co-) Spokespersons	Affiliation	Title of the experiment	Approval status (PAC recommendation)	Beamline	Status
P41	M. Aoki	Osaka U	An Experimental Search for $\mu - e$ Conversion in Nuclear Field at a Sensitivity of 10^{-14} with Pulsed Proton Beam from RCS	Deferred	MLF	Reviewed in MLF/IMSS
E42	J. K. Ahn	Pusan National U	Search for H-Dibaryon with a Large Acceptance Hyperon Spectrometer	Stage 1 TDR should be updated for Stage 2	K1.8	
E45	K. H. Hicks, H. Sako	Ohio U, JAEA	3-Body Hadronic Reactions for New Aspects of Baryon Spectroscopy	Stage 1	K1.8	
T46	K. Ozawa	KEK	EDIT2013 beam test program	Test Experiment	K1.1BR	Abandonded
T49	T. Maruyama	KEK	Test for 250L Liquid Argon TPC	Test Experiment	K1.1BR	Withdrawn
E50	H. Noumi	Osaka U	Charmed Baryon Spectroscopy via the (π,D*-) reaction	Stage 1 The FIFC, IPNS, and E50 should investigate the feasibility of the beam- line	High p	
T51	S. Mihara	KEK	Research Proposal for COMET(E21) Calorimeter Prototype Beam Test	Test Experiment	K1.1BR	had to be stopped
T52	Y. Sugimoto	KEK	Test of fine pixel CCDs for ILC vertex detector	Test Experiment	K1.1BR	not performed yet
T53	D. Kawama	RIKEN	Test of GEM Tracker, Hadron Blind Detector and Lead-glass EMC for the J-PARC E16 experiment	Test Experiment	K1.1BR	not performed yet
T54	K. Miwa	Tohoku U	Test experiment for a performance evaluation of a scattered proton detector system for the Σp scattering experiment E40	Test Experiment	K1.1BR	not performed yet
T55	A. Toyoda	KEK	Second Test of Aerogel Cherenkov counter for the J-PARC E36 experiment	Test Experiment	K1.1BR	had to be stopped
E56	T. Maruyama	KEK	A Search for Sterile Neutrino at J-PARC Materials and Life Science Experimental Facility	Stage 1 TDR should be submitted before Stage-2 approval	MLF	
E57	J. Zmeskal	Stefan Meyer Institute for Subatomic Physics	Measurement of the strong interaction induced shift and width of the 1s state of kaonic deuterium at J- PARC	Stage 1 It is not possible to accommodate the request in the upcoming running period.	K1.8BR	Commissioning run in 2016
P58	M. Yokoyama	U. Tokyo	A Long Baseline Neutrino Oscillation Experiment Using J-PARC Neutrino Beam and Hyper-Kamiokande	Deferred	neutrino	
T59	A. Minamino	Kyoto U	A test experiment to measure neutrino cross sections using a 3D grid-like neutrino detector with a water target at the near detector hall of J-PARC neutrino beam-line	To be arranged by IPNS and KEK-T2K	neutrino monitor bld	Finished
T60	T. Fukuda	Toho U	Proposal of an emulsion-based test experiment at J-PARC	Arranged by IPNS and KEK-T2K	neutrino monitor bld	Finished
E61	M. Wilking	Stony Brook U	nuPRISM	Stage 1 Cost estimate for the identified Phase-1 site should be done before stage-2 approval.	neutrino	
E62	R. Hayano, S. Okada, H. Outa	U. Tokyo, RIKEN	Precision Spectroscopy of kaonic atom X-rays with TES	Stage 2 PAC recommends the requested beam time when K1.8BR becomes available.	K1.8BR	Commissioning run in 2016
E63	H. Tamura	Tohoku U	Gamma-ray spectroscopy of light hypernuclei II	Stage 2	K1.1	BL not ready yet. Exp. in preparation
T64	Y. Koshio	Okayama U	Measurement of the gamma-ray and neutron background from the T2k neutrino/anti-neutrino at J-PARC B	Arranged by IPNS and KEK-T2K	neutrino	
E65	T. Nakaya	Kyoto U	Proposal for T2K Extended Run	Stage 1	neutrino	
T66	T. Fukuda	Nagoya U	Proposal of an emulsion-based test experiment at J-PARC	Test Experiment	neutrino	

Organization and Committees

Organization Structure

J-PARC Center Organization Chart

as of April 1, 2016



Members of the Committees Organized for J-PARC

(as of March, 2016)

1) Steering Committee

Yuji Fujita	Japan Atomic Energy Agency, Japan
Hisayoshi Ito	Japan Atomic Energy Agency, Japan
Yukihide Kamiya	High Energy Accelerator Research Organization, Japan
Kazuo Minato	Japan Atomic Energy Agency, Japan
Yukitoshi Miura	Japan Atomic Energy Agency, Japan
Naohito Saito	J-PARC Center, Japan
Yasuhide Tajima	Japan Atomic Energy Agency, Japan
Daiji Takeuchi	High Energy Accelerator Research Organization, Japan
Katsuo Tokushuku	High Energy Accelerator Research Organization, Japan
Kazuyoshi Yamada	High Energy Accelerator Research Organization, Japan
Seiya Yamaguchi	High Energy Accelerator Research Organization, Japan

2) International Advisory Committee

Jean-Michel Poutissou	TRIUMF, Canada
Francis Pratt	Science and Technology Facilities Council (STFC), UK
Jun Sugiyama	Toyota Central R & D Labs., Inc., Japan
Thomas Roser	Brookhaven National Laboratory (BNL), USA
Shinian Fu	Institute of High Energy Physics (IHEP), China
Eckhard Elsen	European Organization for Nuclear Research (CERN), Switzerland
Patricia McBride	Fermi National Accelerator Laboratory (FNAL), USA
Robert Tribble	Brookhaven National Laboratory (BNL), USA
Donald F. Geesaman	Argonne National Laboratory, USA
Karlheinz Langanke	GSI Helmholzzentrum für Schwerionenforschung, Germany
Hamid Aït Abderrahim	SCK· CEN, Belgium
Hirotada Ohashi	University of Tokyo, Japan
Paul Langan	Oak Ridge National Laboratory (ORNL), USA
Hidetoshi Fukuyama	Tokyo University of Science, Japan
Dan Alan Neumann	National Institute of Standards and Technology (NIST), USA
Andrew Dawson Taylor	Science and Technology Facilities Council (STFC), UK

3) User Consultative Committee for J-PARC

Tsuyoshi Nakaya	Kyoto University, Japan
Taku Yamanaka	Osaka University, Japan
Hiroaki Aihara	University of Tokyo, Japan
Takashi Kobayashi	High Energy Accelerator Research Organization (KEK), Japan
Hirokazu Tamura	Tohoku University, Japan
Tomofumi Nagae	Kyoto University, Japan
Takashi Nakano	Osaka University, Japan

Kazuhiro Tanaka	High Energy Accelerator Research Organization (KEK), Japan
Hiroyuki Noumi	Osaka University, Japan
Masaki Fujita	Tohoku University, Japan
Mitsuhiro Shibayama	University of Tokyo, Japan
Hideaki Kitazawa	National Institute for Materials Science(NIMS), Japan
Yoshiaki Kiyanagi	Nagoya University, Japan
Masaaki Sugiyama	Kyoto University, Japan
Tosiji Kanaya	High Energy Accelerator Research Organization (KEK), Japan
Jun Akimitsu	Okayama University/Hiroshima University, Japan
Tadashi Adachi	Sophia University, Japan
Yasuhiro Miyake	High Energy Accelerator Research Organization (KEK), Japan
Jun Sugiyama	Toyota Central R&D Labs., Inc.
Hiroyuki Kishimoto	Sumitomo Rubber Industries, Ltd.
Takashi Noma	Canon Inc.
Kenya Kubo	International Christian University, Japan
Toshiro Tomida	Ibaraki Prefecture
Satoru Yamashita	University of Tokyo, Japan
Cheol-Ho Pyeon	Kyoto University, Japan
Yoshiyuki Kaji	Japan Atomic Energy Agency, Japan

4) Accelerator Technical Advisory Committee

Thomas Roser	Brookhaven National Laboratory (BNL), USA
Alberto Facco	Laboratori Nazionali di Legnaro (INFN), Italy
Alan Letchford	Science and Technology Facilities Council (STFC), UK
Subrata Nath	Los Alamos National Laboratory (LANL), USA
Akira Noda	National Institutes for Quantum and Radiological Science and Technology (QST), Japan
Michael Plum	Oak Ridge National Laboratory (ORNL), USA
Jie Wei	Michigan State Univ., USA
Robert Zwaska	Fermi National Accelerator Laboratory (FNAL), USA
Simone Gilardoni	European Organization for Nuclear Research (CERN), Switzerland
Simone Gilardoni	European Organization for Nuclear Research (CERN), Switzerland

5) Neutron Advisory Committee

Robert McGreevy	Science and Technology Facilities Council (STFC), UK
Bertrand Blau	Paul Scherrer Institut (PSI), Switzerland
Mark Wendel	Oak Ridge National Laboratory (ORNL), USA
Yoshiaki Kiyanagi	Nagoya University, Japan
Christiane Alba-Simionesco	The Laboratoire Leon Brilloin (LLB), France
Jamie Schulz	Australian Nuclear Science and Technology Organization(ANSTO), Australia
Dimitri Argyriou	Ames Laboratory, USA
Chang Hee Lee	Korea Atomic Energy Research Institute KAERI), Korea
Mitsuhiro Shibayama	University of Tokyo, Japan
Masaaki Sugiyama	Kyoto University, Japan

6) Muon Science Advisory Committee

Francis Pratt	Science and Technology Facilities Council (STFC), UK
Thomas Prokscha	Paul Scherrer Institut (PSI), Switzerland
Andrew MacFarlane	University of British Columbia, Canada
Klaus Jungmann	University of Groningen, Netherland
Kenya Kubo	International Chiristian University, Japan
Toshiyuki Azuma	RIKEN, Japan
Yasuo Nozue	Osaka University, Japan
Jun Sugiyama	Toyota Central R & D Labs., Inc., Japan

7) Radiation Safety Committee

Seiichi Shibata	RIKEN, Japan
Yoshimoto Uwamino	RIKEN, Japan
Yoshihiro Asano	RIKEN, Japan
Tetsuo Noro	Kyushu University, Japan
Takeshi Murakami	Natinonal Insitute of Radiological Science, Japan
Yoshimoto Namito	High Energy Accelerator Research Organization (KEK), Japan
Shinichi Sasaki	High Energy Accelerator Research Organization (KEK), Japan
Hitoshi Kobayashi	High Energy Accelerator Research Organization (KEK), Japan
Kazuo Minato	Japan Atomic Energy Agency, Japan
Takeshi Maruo	Japan Atomic Energy Agency, Japan
Michio Yoshizawa	Japan Atomic Energy Agency, Japan

8) MLF Advisory Board

Jun Akimitsu	Okayama University/Hiroshima University, Japan
Yuji Kawabata	Kyoto University, Japan
Yoshiaki Kiyanagi	Nagoya University, Japan
Mitsuhiro Shibayama	The University of Tokyo, Japan
Jun Sugiyama	Toyota Central R&D Labs., Inc., Japan
Atsushi Nakagawa	Osaka University, Japan
Masaki Fujita	Tohoku University, Japan
Michihiro Furusaka	Hokkaido University, Japan
Tetsurou Minemura	Ibaraki Prefectural Government, Japan
Toshio Yamaguchi	Fukuoka University, Japan
Hiroshi Amitsuka	Hokkaido University, Japan
Kenya Kubo	International Christian University, Japan
Toshiji Kanaya	High Energy Accelerator Research Organization (KEK), Japan
Hideki Seto	High Energy Accelerator Research Organization (KEK), Japan
Takashi Kamiyama	High Energy Accelerator Research Organization (KEK), Japan
Toshiya Otomo	High Energy Accelerator Research Organization (KEK), Japan
Yasuhiro Miyake	High Energy Accelerator Research Organization (KEK), Japan
Ryosuke Kadono	High Energy Accelerator Research Organization (KEK), Japan
Yasuhiro Miyake	High Energy Accelerator Research Organization (KEK), Japan
Ryosuke Kadono	High Energy Accelerator Research Organization (KEK), Japan

Masatoshi Futakawa	Japan Atomic Energy Agency (JAEA), Japan
Kazuya Aizawa	Japan Atomic Energy Agency (JAEA), Japan
Masayasu Takeda	Japan Atomic Energy Agency (JAEA), Japan
Kazuhiko Soyama	Japan Atomic Energy Agency (JAEA), Japan
Kenji Nakajima	Japan Atomic Energy Agency (JAEA), Japan
Yukinobu Kawakita	Japan Atomic Energy Agency (JAEA), Japan
Jun-ichi Suzuki	Comprehensive Research Organization for Science and Society (CROSS), Japan

9) Program Advisory Committee (PAC) for Nuclear and Particle Physics Experiments at the J-PARC 50 GeV Proton Synchrotron

Nori Aoi	Osaka University, Japan
Ryuichiro Kitano	High Energy Accelerator Research Organization (KEK), Japan
Masahiro Kuze	Tokyo Institute of Technology, Japan
Hirokazu Tamura	Tohoku University, Japan
Kazunori Hanagaki	High Energy Accelerator Research Organization (KEK), Japan
Tetsuo Hatsuda	RIKEN Nishina Center for Accelerator-Based Science, Japan
Junji Haba	High Energy Accelerator Research Organization (KEK), Japan
Thomas E. Browder	University of Hawaii, USA
Simon I. Eidelman	Budker Institute of Nuclear Physics (BINP), Russia
Deborah Harris	Fermi National Accelerator Laboratory (FNAL), USA
Gino Isidori	University of Zurich, Switzerland
Steven Kettell	Brookhaven National Laboratory (BNL), USA
Josef Pochodzalla	University of Mainz, Germany
Wolfram Weise	Technical University of Munich, Germany
William A. Zajc	Columbia University, USA

10) TEF Technical Advisory Committee

Marc Schyns	SCK · CEN, Belgium
Eric Pitcher	Los Alamos Neutron Science Center (LANSCE), USA
Yacine Kadi	European Organization for Nuclear Research (CERN), Switzerland
Yoshiaki Kiyanagi	Nagoya University, Japan
Toshikazu Takeda	Univesity of Fukui, Japan
Juergen Konys	Karlsruhe Institute of Technology, Germany
Minoru Takahashi	Tokyo Institute of Technology, Japan

Main Parameters

Present main parameters of Accelerator

Linac	
Accelerated Particles	Negative hydrogen
Energy	400 MeV
Peak Current	40 mA
Pulse Width	0.225 ms for MLF
	0.5 ms for MR
Repetition Rate	25 Hz
Freq. of RFQ, DTL, and SDTL	324 MHz
Freq. of ACS	972 MHz
RCS	
Circumference	348.333 m
Injection Energy	400 MeV
Extraction Energy	3 GeV
Repetition Rate	25Hz
RF Frequency	0.938 MHz → 1.67 MHz
Harmonic Number	2
Number of RF cavities	12
Number of Bending Magnet	24
Main Ring	
Circumference	1567.5 m
Injection Energy	3 GeV
Extraction Energy	30 GeV
Repetition Rate	~0.4 Hz
RF Frequency	1.67 MHz → 1.72 MHz
Harmonic Number	9
Number of RF cavities	9
Number of Bending Magnet	96

Key parameters of Materials and Life Science Experimental Facility

Injection energy	3 GeV
Repetition rate	25Hz
Neutron Source	
Target material	Mercury
Number of moderators	3
Moderator material	Liquid hydrogen
Moderator temperature/pressure	20 K / 1.5 MPa
Number of neutron beam extraction ports	23
Muon Production Target	
Target material	Graphite
Number of muon beam extraction ports	4
Neutron Instruments*	
Open for user program (general use)	19
Under commissioning/construction	1/1
Muon Instruments*	
Open for user program (general use)	3
Under commissioning/construction	1/0

(* As of March, 2017)

Events

Events

Science Café for Science and Technology Week (April 24)

At a Science Café for the 57th Science and Technology Week organized by the Ministry of Education, Culture, Sports, Science and Technology, J-PARC Center gave a presentation on the topic of neutrinos. The event was held at Science Museum in Kitanomaru Park in Tokyo. There was a higher-than-expected turn-out of 34 attendees with a wide range of ages, from elementary school to adults, and they packed the venue.

Participants challenged quizzes on mystery of neutrinos

Exhibition at the G7 Science & Technology Ministers' Meeting in Tsukuba, Ibaraki (May 15-21)

A meeting of the science and technology ministers of seven advanced countries (G7) was held in Tsukuba Science City, and the J-PARC Center exhibited jointly with KEK at a special exhibition for the meeting. During the meeting on the 15th -17th, the exhibition booth was visited by persons connected with the meeting and participants in a commemorative symposium. After the commemorative symposium on the 15th, the ministers from each country visited the booth, and Naohito Saito, Director of the J-PARC Center, introduced the research being conducted at J-PARC, and J-PARC's system for international cooperation.

J-PARC Neutron Life Science Research Meeting (May17-18)

This research meeting was jointly organized by the J-PARC Center and the National Institutes for Quantum and Radiological Science and Technology(QST) to deepen discussion of the degree to which research using neutron scattering contributes to life science, and its possibilities for the future. The meeting was attended by about 45 researchers being active on the front line in this field.

FY2016 Workshop 5.23 for Fostering Safety Culture at J-PARC (May 20)

To keep fresh the lessons of the radioactive material leak incident at the Hadron Experimental Facility on May 23, 2013, J-PARC holds a workshop every year to raise safety awareness of the staff members. This year, the workshop was held on May 20 with the auditorium of the Nuclear Science Institute as the main venue, and live TV links with KEK Tsukuba Campus and KEK Tokai Campus, Kenji Abe, principal researcher at the Safety Research Institute of West Japan Railway Company (JR West), was invited as a speaker, and he spoke on the topic of "Safety Efforts in Airlines and Railways".

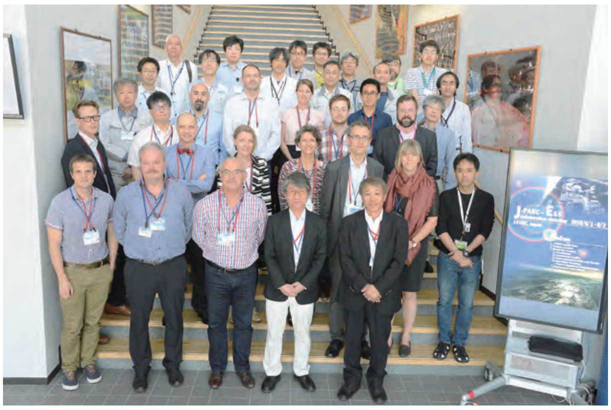
Principal researcher Kenji Abe

KEK-PIP Advisory Committee (May 22-23)

An advisory committee to provide advice on KEK's Project Implementation Plan (PIP) for research planning was held at KEK Tsukuba, with 12 experts invited from both inside and outside Japan. The committee discussed four projects relating to J-PARC: the COMET-II experiment ; the J-PARC accelerator enhancement and Hyper Kamiokande plan; expansion of the Hadron Experimental Facility; and H-line construction and planning of a g-2/EDM experiment plan for the muon facility.

J-PARC-ESS Collaboration Workshop (June 1-2)

Construction of the European Spallation Source(ESS) by 17 European countries is underway in the city of Lund in Scania province, Sweden, with operation scheduled to begin in FY2019. This workshop was held to coincide with a tour of J-PARC by 16 staff from the ESS site in Sweden, primarily engineers. The workshop incorporated oral presentations and lively discussion on the latest development, research, and findings regarding both the technology and operation (including safety) of accelerators, neutron sources, and neutron instruments.



Participants of the workshop

J-PARC Hello Science (June22, July7)

In June and July, the J-PARC Center held J-PARC Hello Science events for the science clubs of two elementary schools in Tokai Village, and students were introduced to the amazing world of batteries and magnets.

Club members challenged quizzes

Lecture by Professor Takaaki Kajita Commemorating his Nobel Prize in Physics "Neutrinos: The Link Between Space and Elementary Particles" (July 16)

The J-PARC Center and Tokai Village jointly held a lecture meeting at the Tokai Culture Center featuring Takaaki Kajita, Director of the Institute for Cosmic Ray Research, University of Tokyo, and winner of the 2015 Nobel Prize in Physics. There were about 700 participants, ranging from elementary and junior high school students to adults, most from Tokai Village but also from outside the prefecture.

Prof. Kajita

J-PARC "Hello Science" Summer Vacation Classes Featuring Scientific Experiments- The Power of Waves is Extraordinary- (July 26, August 5 and 25)

During the summer vacation, J-PARC Hello Science events were held three times for fifth and sixth grade elementary school students in Tokai Village.This year, students studied waves. At each class, there were about twice the original capacity of 12 students, thus showing the high degree of interest among elementary school students in the village.

The experiment with straws to learn propagation of waves

J-PARC Facilities Opened to the Public for the First Time in Four Years (July 31)

J-PARC facilities were opened to the public for the first time in four years(since 2012). At J-PARC, operations were stopped in the summer for maintenance, and various facilities which ordinary people cannot usually enter were opened to the public: the MR (Main Ring) accelerator (50Gev synchrotron), beamlines employing superconducting magnets for neutrino experiments, the Materials and Life Science Experimental Facility (MLF) and Hadron Facility. This event was blessed with fine weather, and about 1,600 people attended, from both inside and outside the prefecture.

Lecture "Neutrino are Amazing! -Nobel Prizewinning Research has Changed the World-" (August 11)

The J-PARC Center held a lecture on the topic of research at J-PARC, as a summer vacation event at the Ibaraki Science Museum of Atomic Energy. Two sessions were held, one in the morning and one in the afternoon, and many children came to listen to the lectures in a hall with capacity for 40.

Explanation on neutrino oscillation

Science Lecture: A Trip through Space-Time Featuring the Neutrino Elementary Particle (September 3 and 17)

An NPO, HSE Risk C3 is engaged in support activities such as the Tokai Nuclear Power Science Town Project promoted by Tokai village.This time, in response to village residents' interest in neutrinos, the NPO held a total of four lectures on the topic of "the neutrino elementary particle", including tours of J-PARC facilities. Shinichi Sakamoto, a public relations advisor of the J-PARC Center worked as a lecturer, and in the two lectures held this month, he explained everything; from the basics of neutrinos to the neutrino research involved Nobel Prize in Physics in last year, and the latest results such as the T2K (Tokai to Kamioka) experiment using J-PARC.

3rd RaDIATE Collaboration Meeting (September 7-9)

A steering meeting of RaDIATE (Radiation Damage in Accelerator Target Environment) in the process of international collaboration by 11 institutions worldwide at present was held for three days with about 30 participants in early September at PNNL (Pacific Northwest National Laboratory) in the U.S. This time, as participants from J-PARC, there were two staff in charge of evaluating items such as beam window and target materials of the Neutrino Experimental Facility, and damage to target vessel materials for the MLF neutron source.

Ozora Marche at the Daijingu and Muramatsu-san Kokuzodo Temple (October 8)

The Ozora Marche is held every year by the Tokai Sightseeing Guide as an event for communicating the attractions of the culture and history of Tokai Village to younger generations. J-PARC began exhibiting at Ozora Marche from two years ago, and continued this year with a Science Experiment Corner where visitors could experience things like the world of low temperatures and experiments using magnetic force. Visitors line up to see the "Super-Conducting Rollercoaster" experiment, where a superconductor magnet cooled with liquid nitrogen at -196 ˚C runs on rails, and the presentation was enjoyed by everyone from children to adults.

13th International Workshop on Spallation Materials Technology (October 31- November 4)

This workshop was held by the Oak Ridge National Laboratory (ONRL) in the U.S., and there were 58 participants from 8 countries. Information was exchanged on topics such as radiation damage to neutron source materials for nuclear spallation, corrosion due to liquid metal, and cavitation damage. There were 54 presentations from different countries, and there were 8 reports from J-PARC on the current state of the MLF mercury target, and the muon target.

Held 1st Neutron and Muon School (November 22-26)

The J-PARC Center held the 1st Neutron and Muon School using MLF beamlines at Ibaraki Quantum Beam Research Center. This school was held for graduate students, young researchers, and similar candidates from the Asia/Oceania region, and is the successor of the MLF School held three times until last year. There were 29 participants, the majority of whom (16) were from overseas.

Participants, lecturers and executive committee members of the school

Held Research Meeting "Towards High-Precision Muon g-2/EDM Measurement at J-PARC" (November 28-29)

At the H Line of the Muon Experimental Facility of the MLF at J-PARC, a project is underway to precisely measure the strength of magnetic force of the muon called the "anomalous magnetic moment (g-2)" using a completely new, previously unavailable experimental technique. To realize this plan, the J-PARC Center jointly held a research meeting, together with the Joint Institute for Computational Fundamental Science (JICFuS), to realize improved precision of g-2 calculations and experiments. At the meeting, there were 54 participants from 12 countries of the world (including 23 from overseas), and there were lively discussions of new theoretical techniques and experimental technologies.

Held J-PARC Hello Science Event "From 'atoms' to 'super strings' – The Scientists Fascinated by Elementary Particles" (December 5)

Starting this month, the J-PARC Center has begun holding "J-PARC Hello Science" events to promote interaction between researchers and local people, using as a venue the food court of the Aeon Tokai Mall in front of JR Tokai Station. From January of next year, the program will also receive support from Tokai Village, and the plan is hold events primarily at Aeon Tokai, while changing the topic each time.

J-PARC Hello Science at the food court of Aeon Tokai

Held International Workshop on Future Potential of High-Intensity Proton Accelerator for Particle Nuclear Physics: HINT2016 (December 5-8)

The international workshop "HINT2016" was held at Ibaraki Quantum Beam Research Center for four days, and brought together 146 participants. This event has been held at J-PARC since last year, and there were various reports and discussions focusing on the future outlook for high-intensity accelerator facilities, and new physics pioneered using high-intensity beams.

Participants of HINT 2016

The 37th REIMEI Workshop on Frontiers of Correlated Quantum Matters and Spintronics (January 13-17)

At Tokai-mura Industry and Information Plaza "iVil" and other sites, the Advanced Science Research Center (ASRC) of the Japan Atomic Energy Agency (JAEA) held the 37th REIMEI Workshop together with University of Tokyo, Columbia University (U.S.) ,and the J-PARC Center. On the first day, Shoji Nagamiya (previous Director of the J-PARC Center) and Naohito Saito(current Director) gave talks to about 40 participants, made up of graduate students and young researchers, providing an overview of state-of-the-art research using quantum beams, and introducing the current status and future outlook for experiments/research being conducted at J-PARC.

J-PARC Hello Science "Chocolate Science"(January 21)

At the second gathering of J-PARC Hello Science, J-PARC Center held a "Chocolate Science" event for scientifically considering the deliciousness of chocolate from the standpoint of crystal structure, and experiencing how the deliciousness changes with different methods of making chocolate. There were 20 participants, ranging in age from children to adults.

Participants tried making chocolate

4th Symposium on Safety in the Accelerator Facilities (January 26-27)

Since the radioactive material leak incident at the Hadron Experimental Facility in 2013, the J-PARC Center has held safety symposiums every year for information-sharing and discussions to improve safety with persons involved with accelerators both inside and outside Japan.The featured topics this time were emergency response and electrical safety in accelerator facilities, and the event was held with the participation of 131 attendees, including 47 from outside organizations such as Japanese accelerator facilities, universities, and companies.

Exhibited Booth at American Association for the Advancement of Science(AAAS) (February 16-20)

At the Annual Meeting of the American Association for the Advancement of Science(AAAS) , the J-PARC Center exhibited a booth jointly with the Japan Society for the Promotion of Science, Institute of Physical and Chemical Research (RIKEN), National Astronomical Observatory, Kyoto University, and others. A variety of visitors came to the J-PARC booth, and many were seen listening intently to the explanations of Saeko Okada, Leader of J-PARC's Public Relations Section.

Ms.Okada, leader of PR section of J-PARC Center, explained J-PARC at the booth

J-PARC Center Kyoto University Branch was established (February 22)

For collaboration and cooperation of High Energy Accelerator Research Organization (KEK) and Kyoto University, a memorandum of understanding (MoU) signing ceremony was held at the J-PARC research building. This memorandum of understanding will establish a J-PARC branch of Kyoto University at KEK Tokai Building No.1 and allow Kyoto University researchers and students to cooperatively research in J-PARC. The branch will foster closer research cooperation between J-PARC and Kyoto University.

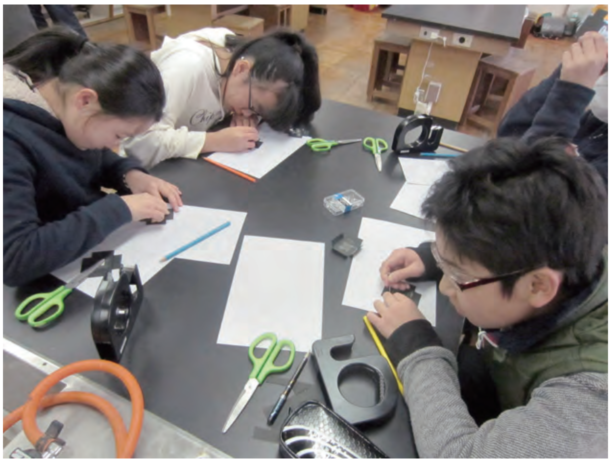

Participants of MOU signing ceremony

J-PARC Hello Science "What is an accelerator?" (February 27)

At the 3rd gathering, J-PARC Center gave a lecture on "What is an accelerator?" and about 15 people attended. J-PARC Center explained the operating principles of the accelerator using a cathode-ray tube television, used in many households until recently, as an example. It also explained the history of accelerator development, and accelerators at J-PARC as well as around world.

J-PARC Hello Science in Muramatsu Elementary School (March 1)

J-PARC Center held "J-PARC Hello Science" at Tokai-village Muramatsu Elementary School's science club. The theme was "the secret of light". For the experiment of the three primary colors of light, participating students were in wonder to see mixing three colors of glowing liquid (blue, red and green) turn white. Following the experiment, the students enjoyed making a kaleidoscope of light using a spectral sheet. Upon leaving school, those participants were proudly showing off their kaleidoscopes to friends.



Students making the kaleidoscope

FY2016 Quantum Beam Science Festa /8th MLF Symposium (March 14-15)

FY2016 Quantum Beam Science Festa was held with sponsors such as J-PARC Center, KEK Institute of Materials Structure Science, and Comprehensive Research Organization for Science and Society (CROSS). The event was successful with as many as 580 participants. The second day, MLF Symposium was held with a theme, "aiming to maximize the performance and ease of use of facility". It had very active discussions on research findings at the facility as well as the status of the facility and areas of improvement, future planning for MLF.

Visitors

Yoichiro Matsumoto, Executive Director, RIKEN (May 24)

Tamar Sanikidze, Minister of Education and Science of Georgia (May 30)

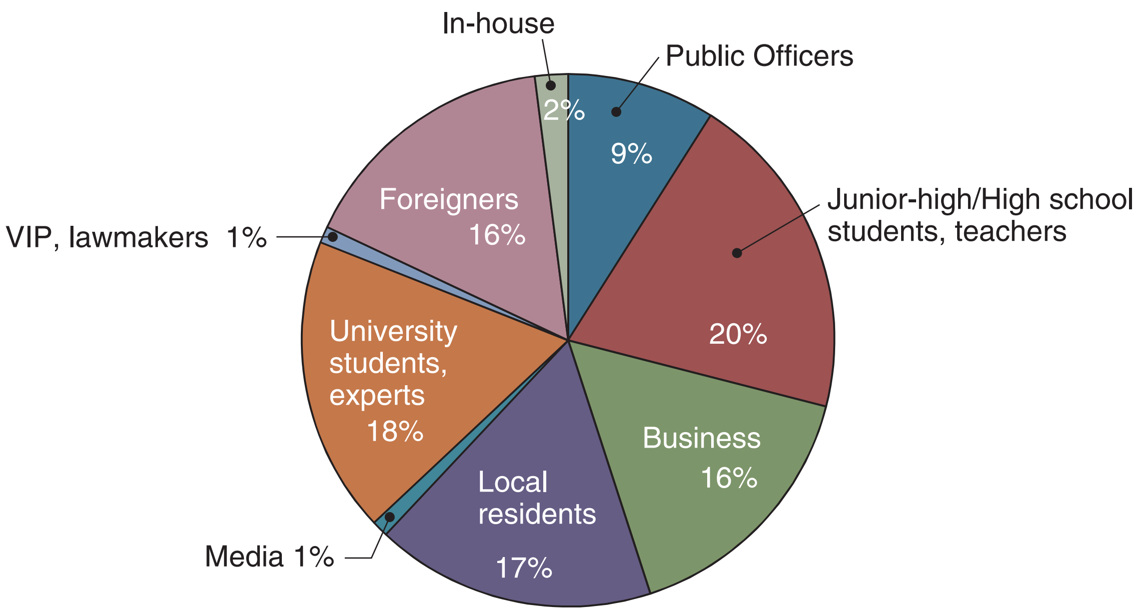
Takashi Fujiwara, Member of the House of Representatives (September 20)

Delegation from the MIRAI Project including staff of Lund University (October 4)

Reynald Pain, Director of IN2P3, CNRS (November 29)

Ingomar Lochschmidt, Head of Advantage Austria Tokyo (January 26)

There were 3,469 visitors to J-PARC for the period from April, 2016, to the end of March, 2017.



Publications

(A) Publications in Periodical Journals

A-001
M. Harada, S. Hasegawa, Y. Kasugai, S. Meigoet *et al.*
Status Report (22th J-PARC PAC): Searching for a Sterile Neutrino at J-PARC MLF (E56, JSNS2)
arXiv:1610.08186 [physics.ins-det]

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Muto, R. *et al.*
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Radiation-Resistant Magnets for J-PARC
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A-004
Kurimoto, Y.
A High Precision Power Supply for Fast Pulse Current With a Digital Control System
IEEE Trans. Appl. Supercond. Vol. 26, 4302904

A-005
Miura, A. *et al.*
Beam profile monitor for intense, negative, hydrogen-ion beams in the J-PARC linac
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A-006
Iinuma, H. *et al.*
Three-dimensional spiral injection scheme for the g-2/EDM experiment at J-PARC
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A-007
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A-008
Chin, Y. H. *et al.*
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A-015
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A-016
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A-017
Matsunaga, T. *et al.*
Dependence of Structural Defects in Li2MnO3 on Synthesis Temperature
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A-018
Tsuchiya, Y. *et al.*
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Chem. Mater., Vol. 28, 7006-7016 (2016)

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Cryogenic system for COMET experiment at J-PARC
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A-022
Masuda, T. *et al.*
Molecular Gyrotops with a Five-Membered Heteroaromatic Ring: Synthesis, Temperature-Dependent Orientation of Dipolar Rotors inside the Crystal, and its Birefringence Change
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A-023
Mibe, T. *et al.*
極冷ミューオンビーム実現のためのミューオニウム標的開発
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A-024
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T2K実験2016年夏のハイライト
High Energy News Vol. 35, p.129

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Nomura, T. *et al.*
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JAPAN PROTON ACCELERATOR RESEARCH COMPLEX

High Energy Accelerator Research Organization (KEK)
Japan Atomic Energy Agency (JAEA)

2-4 Shirakata, Tokai-mura, Naka-gun, Ibaraki 319-1195, Japan

http://j-parc.jp/

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