STATUS OF THE J-PARC FACILITY

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Abstract

J-PARC (Japan Proton Accelerator Research Complex) consists of three accelerators (Linac, 3 GeV RSC and Main Ring (MS)) and three experimental facilities (Materials and Life Science, Neutrino and Hadron). In this talk I would like to firstly describe typical results obtained before the earthquake. The entire facility was seriously damaged due to the huge earthquake in Japan last year. The recovery history as well as performance since then is described in the second. In the third, future prospects are described.

WHAT IS J-PARC?

J-PARC consists of three accelerators and three experimental facilities. In calendar year of 2007 the Linac and the 3 GeV synchrotron (Rapid Cycle Synchrotron, and hereafter RCS) were completed. Then, in fiscal year 2008 the 50 GeV synchrotron (called Main Ring, and hereafter MR) and two experimental facilities, the Materials and Life Science Facility (hereafter MLF) where is conducted experiments with neutron and muon beams, and the Hadron Facility with primarily kaon and pion beams were completed. Finally, in April of 2009, the Neutrino Facility to send neutrino beams to the Super Kamiokande was completed. The entire facility is shown in Figure 1.

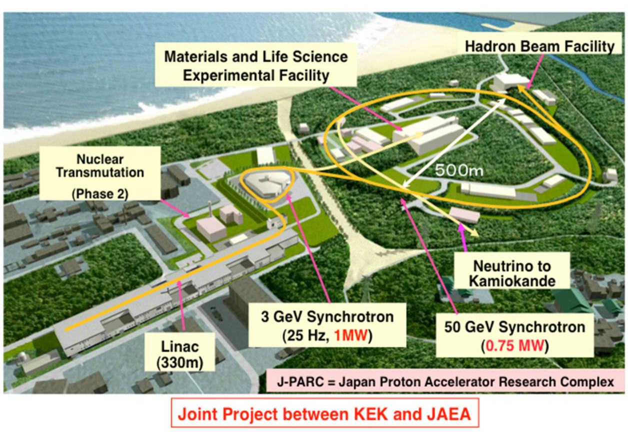

Figure 1: The entire view of the J-PARC.

ACCELERATOR POWER

The entire accelerators started to run in 2009. All experimental facilities had been in operation until the huge earthquake hit the north-eastern coast on March 11 of 2011. Figure 2 shows both estimated and measured power of proton beams at J-PARC. In 2009 we encountered a trouble in RFQ of the Linac, but this problem was resolved during the 2009 summer shutdown through improving vacuum. In the fall of 2010 we achieved a very stable operation at 200 kW for RCS. Since then, we had kept this very stable mode, which was 90-95% availability. We also achieved 400 kW for a short period before March of 2011. Note that the intensity of the KEK-PS was 3 kW. So this is a significant improvement, although our goal is 1 MW. The MR was steadily operated at 30 GeV. We achieved 145 kW to the neutrino beamline in March of 2011. Slow extraction at 5 kW to the Hadron Facility is still very low as compared to the anticipated level of 30 kW or more.

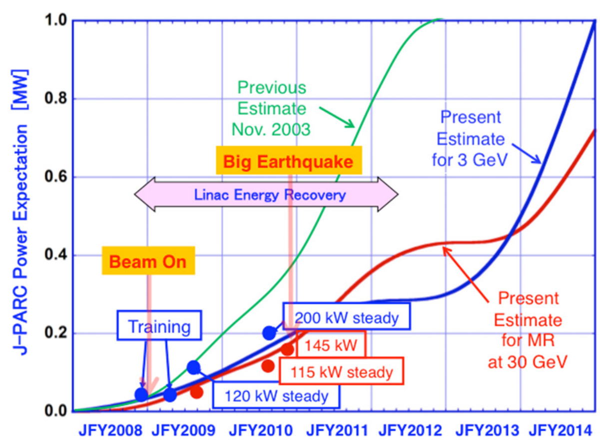

Figure 2: Power capabilities at 3 GeV RCS and MR.

SELECTED RESULTS

The number of publications from the Materials and Life Science Facility now reaches to ~100 papers per year. Here, I show two scientific results obtained before the earthquake in 2011 to provide a flavour of scientific outcome.

Neutrino

For the neutrino program, the muon neutrinos are produced at J-PARC. While traversing from J-PARC to Super Kamiokande located at 295km in distance, muon neutrino may convert to electron neutrino. It depends on a mixing angle between the 1st and the 3rd neutrinos θ_{13}. This is a brand new approach to determine this parameter θ_{13}. Clearly, strong competition exists with other facilities such as Double Chooz in France, Daya Bay in China, Reno in Korea and Fermilab in the USA, in regard to the determination of θ_{13}.

Detailed studies on the data, which were collected at Super Kamiokande before the earthquake, revealed that there were 6 possible events of the appearance of electron neutrinos (ν_e) from the J-PARC muon neutrinos (ν_μ), as shown in Figure 3.

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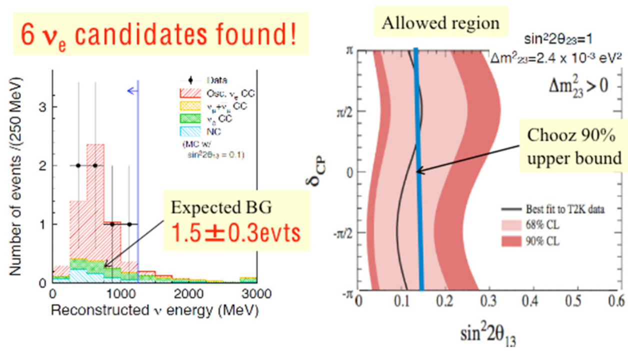

Figure 3: T2K result for electron neutrino appearance.

This result encourages us enormously because of two reasons. Firstly, it indicates that we can pursue more quickly the data taking to pin down the value of θ_{13}, since getting a lager value of θ_{13} requires a less amount of the beamtime. Note that recently Daya Bay [2] and Reno [3] obtained higher statistics data from disappearance experiments from reactor neutrino, ν_e. Secondly, a large value of θ_{13} will enable us to proceed to the next step to measure CP violation in the neutrino sector, by comparing ν_e appearance from ν_μ with ν_e-bar appearance from ν_μ-bar.

Neutron

At the Materials and Life Facility many neutron beam lines are in operation. Numerous data have been accumulated before the earthquake. Up to now, over 100 papers per year have been published, as described before.

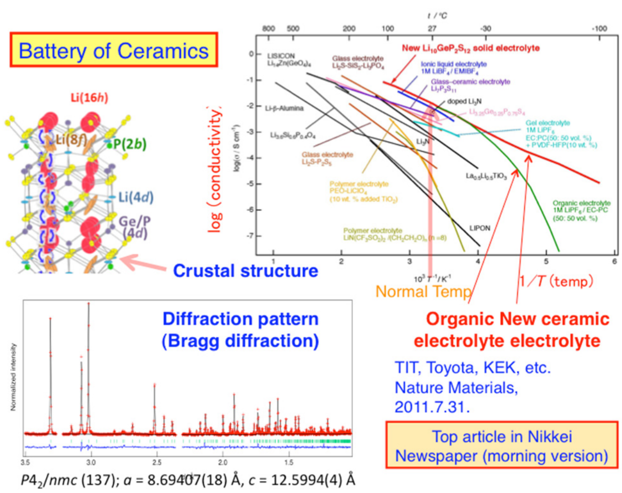

Figure 4: New ceramic battery observed by neutrons.

Figure 4 shows a new ceramic material that can be used for a Li-battery material [4]. The diffraction pattern shown in the left bottom spectrum determines the crystal structure of the battery material. The top right figure shows its physical property. The ceramic electrolyte indicates a better performance than that of the organic electrolyte, which is commonly used for a Li-battery. Because that an organic electrolyte commonly is liquid, a material for a solid electrolyte is highly desired by industry. Note that the work was done by collaboration between a university (Tokyo Institute of Technology), an institution (High Energy Accelerator Organization) and an industry (TOYOTA).

So far the usage of MLF is split into three major categories of users: University (1/3), Institution (1/3), and Industry (1/3) in terms of number of users in parenthesis..

Summary Before the Earthquake

Below is the summary of the J-PARC Facility before the earthquake.

- Beam power has steadily increased: 200 kW for 3 GeV RCS and 145 kW for MR at 30 GeV.
- Neutrino facility: 6 candidate events changing from muon to electron neutrino were detected. Possibility of a large value of θ_{13}. It also encourages moving to the CP violation experiment.
- Hadron facility: About ready to run for many experiments. First data of the penta quark search were obtained.
- Materials and Life Facility: Many data were already obtained using neutron and muon beams and the results are being published.

EFFECTS OF THE EARTHQUAKE

A big earthquake hit the north-eastern Japan on March 11, 2011. The J-PARC is located at about 200 km from the canter of the earthquake, and had significant damages.

Linac

Figure 5: Linac tunnel immediately after the earthquake.

A road in front of the Linac was severely cracked, and a certain area in front of the Linac sank by 1.5 m. The damage inside the accelerator tunnel was fortunately minimal, because the main building had been built with many underpins to support it. But, the earthquake effect at Linac was the most serious among all buildings. Immediately after the earthquake, 100 tons of groundwater was spilled out into the tunnel, as shown in Figure 5. Since the water was highly alkali, we had to use many tons of acids to neutralize it. It took over one week to pump out the water. The next big issue was the problem of ground sank along the Linac tunnel. The middle of the building sank about 4 cm even though there were many underpins. For the moment, we plan to tune beams toward the downstream to 2.6 cm and then to move them up to the normal height at the end of Linac, as described later.

3 GeV RCS

The damage around 3 GeV RCS was also serious. The surrounding road was waving. The repair of the road was done as the first priority for RCS, since otherwise further repair work could not be proceeded. For example, a power generator was leaned toward one edge. With modern technology to jack up the entire floor, the repair work has been done.

Shown in Figure 6 is an example. The capacitor bank was severely bent due to the drop of the ground level. We repaired it by adding a concrete shield, as shown in the lower part of Figure 6. A significant amount of concrete support was needed

In contrast, inside the building fortunately had no serious problems, again due to many underpins.

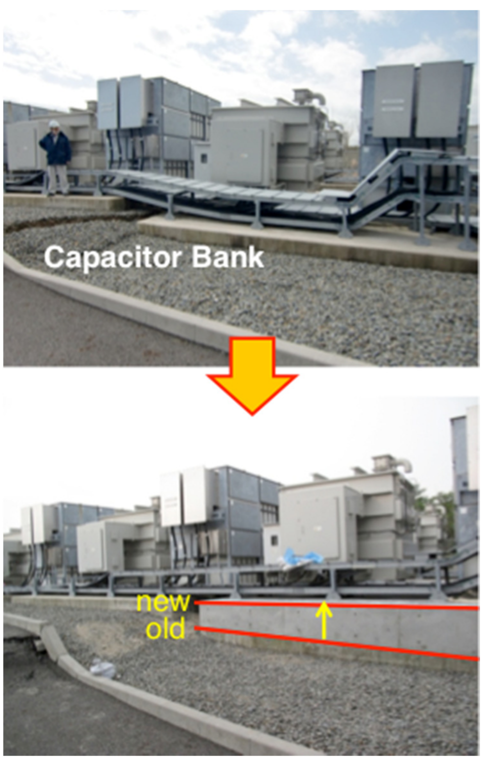

Figure 6: Around 3 GeV a significant amount of concrete shield had to be added to bring it to the normal level.

Main Ring

In the MR, many magnets were forced to move by the earthquake. Magnets moved by 2-3 cm at the maximum. The total 400 magnets had to be carefully realigned to the original positions and the work has been very time consuming. Within 1 cm movement, the adjustment was rather easy but beyond 2 cm the entire magnet stand had to be replaced.

Experimental Facilities

The Materials and Life Science Experimental Facility was relatively in a better condition. The problem here was a significant movement of shielding blocks. For example, 2,800 tons of iron shields near the neutron target area had moved out and, then, were restacked again piece by piece. Other major repair was needed on added buildings. On both sides of the main hall, neutron lines were extended for some equipment into the outside of the main building. For those beam lines we added buildings without many underpins. These buildings sank by 30 cm, so that we had to jack them up to the same level as the main building.

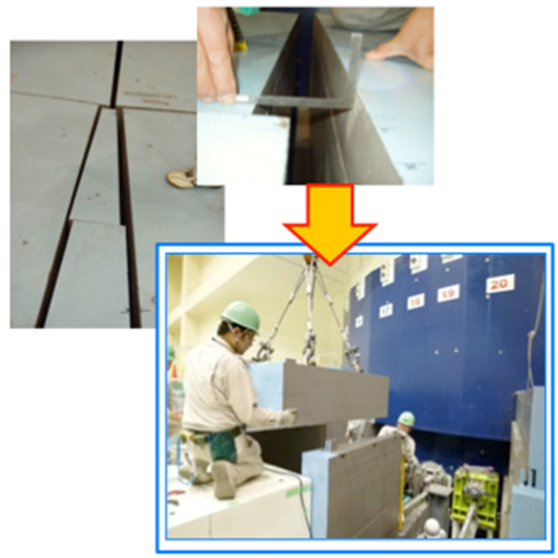

Figure 7: Movement of ion shield. 2,800 tons of irons have to be removed and restacked.

The Neutrino and the Hadron Experimental Facilities have been also damaged, but the damage level was minimal. In the neutrino area an air condition unit fell down. There was a unit called "electric horn" to focus pion beams toward Super Kamiokande. Due to the high radiation level this element was carefully examined, but no damages were detected. Concerning the Hadron Facility, the outside area sank significantly. Inside the experimental hall, many shield blocks had to be adjusted, so that over 3,000 tons of concrete shield blocks had to remove and they were restacked. This work was time consuming. On the other hand, no significant damages were observed in the main experimental hall.

Summary for the Earthquake Effects

The summary of damages by the earthquake is as follows:

- There were no tsunami effects by the earthquake. We prepared up to 8 m tsunami protection and the actual tsunami level was much lower at the level of 3 m.
- Main buildings were almost OK due to many underpins for major buildings.

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- However, many utility buildings, roads and extended buildings had significant damage.

DECEMBER RECOVERY

From April to May we surveyed the technical availability for the repair work including infrastructure and outside companies, repair cost, etc. We studied in depth how we would be able to recover from the damage. Finally, in May, we decided the repair schedule. Of course, some elements have been delayed and some elements have been advanced, but overall repair schedule has been maintained reasonably well. In September we set a goal to accelerate the first Linac beam on December 12, and, then, to tune the beam through the RCS and MR until December 27.

Linac

On December 9th, which is three days in advance, the Linac was switched on. Although many places such as roads, crane, doors, etc. have not been repaired by this date, we were able to turn on the accelerator itself.

Figure 8: On December 9 of 2011 on the occasion of Linac turn on.

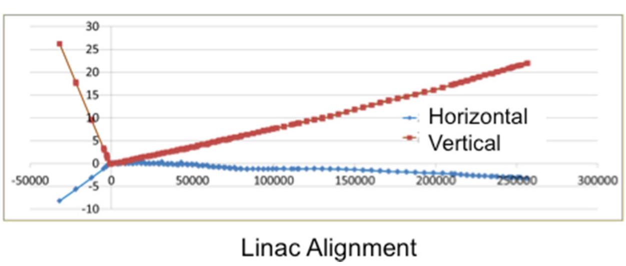

Figure 9: Linac tuning, It was 2.6 cm down in the middle and, then moved up (Linac is no longer linear).

3 GeV RCS and Main Ring

On December 17 the Linac beam was sent to RCS, the second synchrotron. If one looks at details, this synchrotron was also damaged, in particular, in the ring, since it was distorted rather significantly to the level of 5 mm maximum. However, without major troubles the acceleration up to 300 kW was succeeded on December 21. Note that this value is higher by 50% as compared to the power before the earthquake. There were no secrets about this performance, since we installed many improvement elements during the shutdown.

On December 22 the beams were extracted to the neutron area very successfully and, in addition, to the MR. On that day the acceleration to 30 GeV was achieved.

On December 24 (Christmas Day) the beam was extracted to the neutrino area and, finally, on December 27 all the tuning work was successfully finished, exactly on time.

Summary for the Recovery

- We recovered from the damage by the end of 2011.
- We thus expect about 2 month operation of beams for users in fiscal year of 2011 which ends on March 31 of 2012.

FUTURE SCOPE

From the spring of 2012 a normal operation of J-PARC has been started. Issues which must be solved from now on toward the 1 MW operations for RCS and 0.75 MW operations for MR are described in this section

Linac

The most important element that has to be implemented for Linac is 400 MeV ACS. The construction is progressing smoothly. It will be completed by the end of 2012. Due to the users request to run fully during JFY2012, the installation of 400 MeV Linac is planned in the summer of 2013.

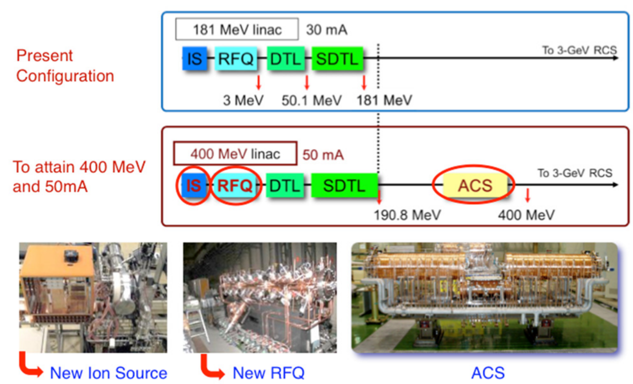

Figure 10: 400 MeV Linac which is under construction.

In addition, RFQ has to be replaced to a new one to allow an acceleration of higher current. Also, the ion source must be replaced. Everything is under control at this moment. An actual installation of all the elements, as shown in Figure 10, will occur in the summer of 2013, during somewhat a scheduled long shutdown period.

3 GeV RCS

The performance of 3 GeV RSC is gradually improved to a better direction. For example, failure rate at the kicker magnet has been decreased drastically as time proceeded, as shown in Figure 11.

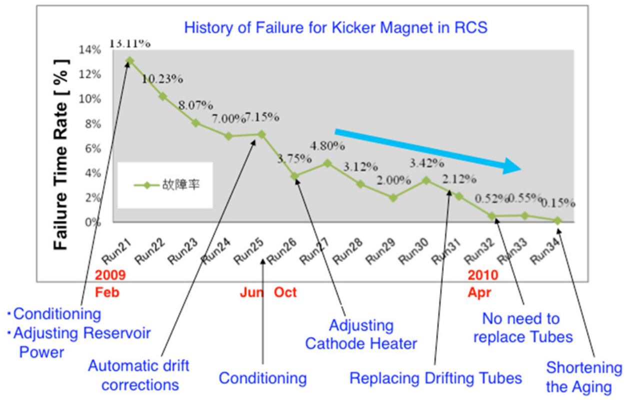

Figure 11: An example of trouble rate for 3 GeV RCS.

As mentioned before, the RCS can accelerate up to 300 kW at this moment. The neutron people do not like to take such a high intensity beam, since they are studying very carefully the damage due to pitting of a Hg target. We will test the performance of 600 kW for RCS in the fall of this year.

Main Ring

The power of the MR has been gradually increasing to 200 kW for fast extraction, as shown in Figure 12. On the other hand, a series of serious studies must be performed to attain 750 kW.

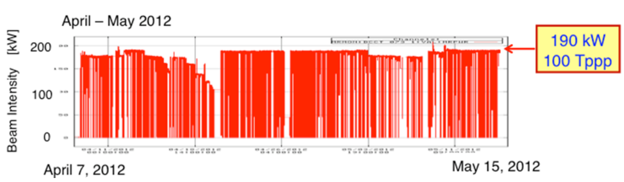

Figure 13: MR performance now.

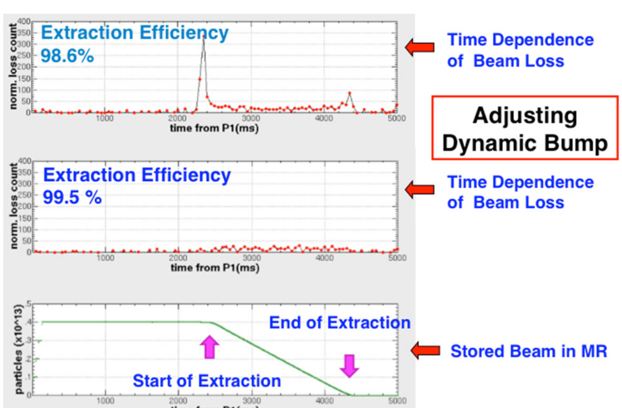

Figure 14: Performance of slow extraction at MR.

For example, during the coming five years we plan to construct new power supplies to reduce ripples from the power supplies. We plan to attain higher voltage per meter by a factor of two by increasing cavity (finemet) impedance. We also plan to improve injection and extraction and, finally, improve shielding for an injection collimator to reduce the beam loss from the present 450 W to 2 kW. By doing these, we plan to attain 750 kW for fast extraction by 2017.

Concerning slow extraction, the present power is limited to 5 kW. The major improvement has been attained recently to obtaining 99.5% extraction efficiency by adjusting a dynamic bump magnet, as shown in Figure 14.

Figure 15 shows a record of beam time for users. We plan to provide 180 days operation for users in JFY2012. By 2015 we plan to provide 1 MW at RCS for neutron and muon users. In terms of MR, we plan to provide 750 kW (fast extraction) for neutrino users and 100 kW (slow extraction) for hadron users by 2017.

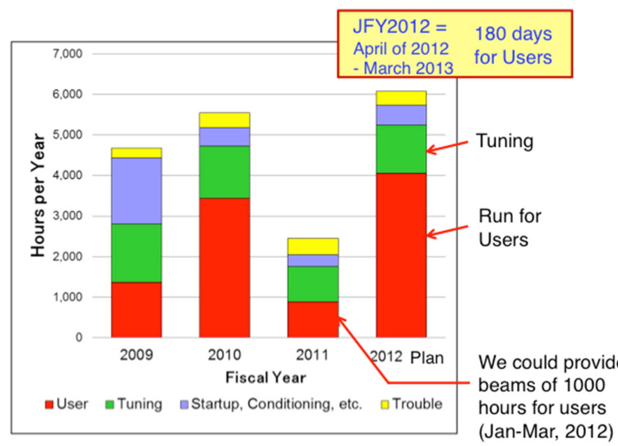

Figure 15: Plans in JFY2012 to run 180 days for users.

ACKNOWLEDGMENT

I would like to thank all J-PARC staff members, in particular, during the process of recovery from earthquake. All of them worked very hard even for weekends and holidays. With such a coherent and collaborative work, the recovery was possible, exactly on schedule.

Also, I would like to thank accelerator group to provide me many data, in particular, for Dr. K. Hasegawa and Dr. T. Koseki.

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