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J-PARC Status and Lessons Learnt from Commissioning

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ABSTRACT

J-PARC neutron muon facility, MLF, has been operated since 2008. Although the proton power stays at considerably low power. However, commissioning during these periods have given indispensable operational experiences not only on the accelerator but the target, instruments and even user programme. Here we report the current status of the facility and experiences we have come across.

1. Introduction

The construction of J-PARC was started in 2001 and the first neutron beams were created in May 2008 at only 4kW. In December 2008 the beam power increased to 20kW, when we started user progamme. Right after then, a problem on the RFQ of the Linac was closed up, sparking between the electrodes. Since it was a tedious work to open up the RFQ cavity, but we assumed that the culprit could be a roughness of the electrodes inferred from studying the prototype of the RFQ, and we made conditioning for several months and installed additional vacuum pumps in parallel. Since then the accelerator has become very stable, and reached 120kW in December 2009. In February in 2010, however, we got another problem at the accumulator in the cryogenic moderator cooling system. Since volume expansion of super-critical hydrogen at 120kW is well below the tolerance of the system, we made a short cut bypass to the accumulator. Eventually, all of those problems are sorted out then the accelerator and the neutron source is very stable at 120kW with more than 93% reliability. However, actual pitting/hole evidence at the target container was demonstrated in SNS, we are now very sensitive how to increase the power from the view point from the target safely.
As for neutron instruments, 18 instruments have been already funded by some different budget bodies, 8 out of those are under operation for the user programme. In this report, here we give the status and experiences we have got during commissioning.

2. Neutron Source Characteristics

J-PARC introduced three cryogenic-hydrogen moderators [1]. Those are poisoned decoupled, decoupled and coupled moderatos. After a serious survey of user demands on the instrument suit, we decided those three moderators and number of ports for each and spatial separation between each port. The design simulations were done by PHITS code and McStas. Figure 1 show the energy spectrum and the peak structures at 5 and 25meV respectively at BL10, which was designated to measure characteristics of neutronic performance of the source.

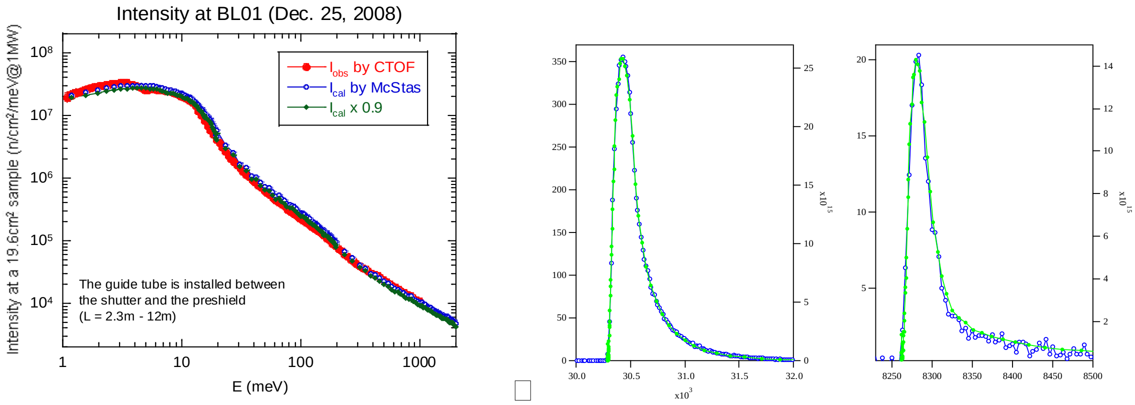

Fig. 1 Neutron energy spectrum at BL10 and Peak structure at 5(left) and 25(right) meV at BL10.

The calculations, in a very wide energy range from GeV to meV and in intensity ranging from 10^17 to 10^9, give a surprisingly good agreement with actual observation even at the tails of the peak structure. The observation was done at most of beam ports by a combination of Au-foil irradiation, current Mode TOF methods and calibrated helium detectors to confirm consistency among them to assure the precision of the observations. Therefore, we have convinced that the neutron source has been properly constructed as we designed and intended.

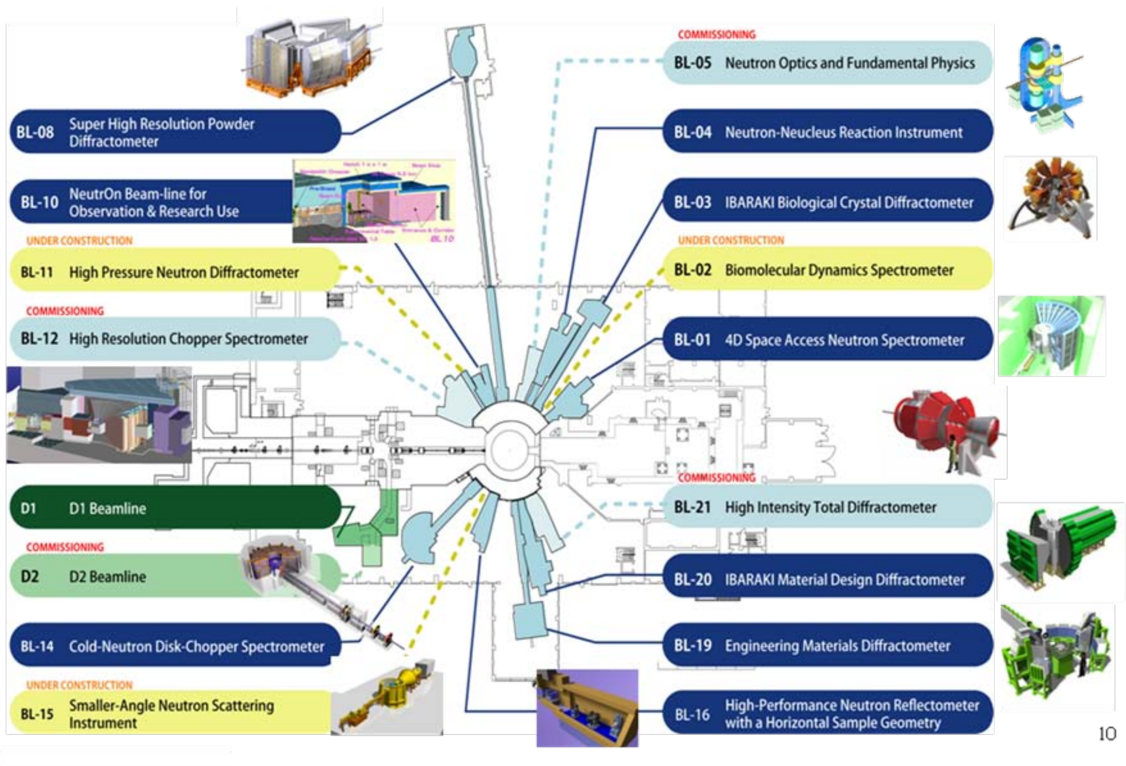

Fig. 2 Instrument suit in the Material Life Science Facility of J-PARC.

3. Neutron Instrument Suit [2]

Several years before the construction, we formed a bunch of instrument groups composed of users and facility staffs. They made a draft plan of the instrument suit, which became the preliminary but strategic foundation to design neutron source characteristics, experimental hall, utilities, etc. This draft has become a base of the current instrument grand design approved by the community. We have selected instruments to be constructed essentially according to it. Now 18 instruments have been funded and some are under planning, Fig.2. Those are also listed in the Table 1. We have already 4 inelastic neutron scattering instruments, three of them are direct geometry chopper instruments and another is an inverted geometry back scattering instrument. One of the Fermi chopper instruments was installed at the coupled moderator port to benefit high flux from the moderator contrarily to a common prejudice recognized that a decoupled moderator is good for such an instrument [3]. The backscattering instrument will be equipped with a pulse shaping disk chopper to realize 1μeV even with 40m of the flight path [4]. Now we have six powder diffractometers including one under planning. This is a natural consequence of high achievable performances of this kind of instrument at a sharp pulsed source [5].

Table1. Instrument suit of the Material Life Science Facility, J-PARC

Beam Line	status	kind	instrument	Owner	Moderator	user programme since
1	completed	Inelastic	4SEASONS (Fermi chjopper)	JAEA	Coupled	2009
2	Constructi	Inelastic	DNA(back scattering, Si	JAEA	Coupled	2011
3	completed	Diffraction	iBIX (protein single crystal)	Ibaraki Pref.	Coupled	2009
4	completed	gamma	NNRIM (neutron cross-section)	JAEA	Coupled	2011
5	completed	3-ports	Fundamental Physics	KEK	Coupled	Commissioning
8	completed	Diffraction	SuperHRPD (powder)	KEK	Poisoned	2009
9	designing	Diffraction	powder (Li battery)	KEK	Poisoned	tbd
10	completed	test port	NOBORU	JAEA	Decoupled	2009
11	Constructi	Diffraction	PLANET(high pressure)	Tokyo Univ.,	Decoupled	2012
12	Constructi	Inelastic	HRC(Fermi chopper)	KEK, Tohoku	Decoupled	Commissioning
14	completed	Inelastic	AMATERAS(cold disk chopper)	JAEA	Coupled	2009
15	Constructi	Diffraction	TAIKAN(SANS)	JAEA	Coupled	2011
16	upgrading	reflection	ARISA-II(horizontal geometry)	KEK	Coupled	2009
17	Constructi	reflection	reflectometer(vertical	JAEA	Coupled	2011
18	Constructi	reflection	single crystal	JAEA	Poisoned	2011
19	completed	Diffraction	TAKUMI (stress analysis)	JAEA	Poisoned	2009
20	completed	Diffraction	iMATERIA(powder)	Ibaraki Pref.	Poisoned	2009
21	completed	Diffraction	NOVA (PDF, S(Q))	KEK	Decoupled	2010
tbd	developing	imaging	imaging instrument	JAEA	Decoupled	tbd

Two reflectometer, one is a horizontal scattering type for liquid free surface, another is a vertical type with polarized neutrons under construction. Two single crystal diffractometers, one is dedicated for protein crystal [6] and another is a conventional/versatile type.

4. Accelerator Frequency and Controlling Timing

We adopted 25Hz in accelerator frequency to have a wide dynamical range in one frame. As we anticipated most of the instruments listed in Table 1 are enjoying this frequency, although it compels the accelerator to be more intense for each pulse to keep the required power. We have been also very careful on a synchronization scheme between accelerators and instruments. Especially this is worth considering for instruments, which use a fast chopper system, such as Fermi chopper. Our benchmark of the timing ambiguity is less than 0.3μsec to realize a target energy resolution above 1eV. Partly, because of this argument, J-PARC accelerator had adopted an IGBT switching system with a crystal master clock through whole accelerator systems, and could realize the timing ambiguity less than +-15nsec. Now any instrument runs in synchronizing to the accelerator with very good precision without any timing problems.

5. Event Recording Data Acquisition

Here we would like to emphasize the importance of the new data acquisition scheme in J-PARC, what is called "EVENT RECORDING". After a study on experienced data acquisition in KENS and the ISIS facility, we anticipated importance of flexible experiments in the future, and we decided to introduce the event recording system for the data acquisition scheme. Although data volume can become huge and data reduction software needs sophisticated developments, now we are really admiring and proud of the system we realized for its flexibility, adaptability and usefulness for any kind of instruments and experiments. Exaggeratedly speaking, it is not necessary to keep a temperature of sample, to lock a chopper in phase and to care about sudden accidental noise in a detector. We can just let instruments go without taking care of the above cases. Figure 3 shows one of the examples come from the benefit of the event recording. This is a result from the muti-Ei method [7]. Now we do not need to define time-bins beforehand for time axis. Just measure scattered neutrons, which come through a chopper window. Define time-bins afterward to make them match a required energy resolution.

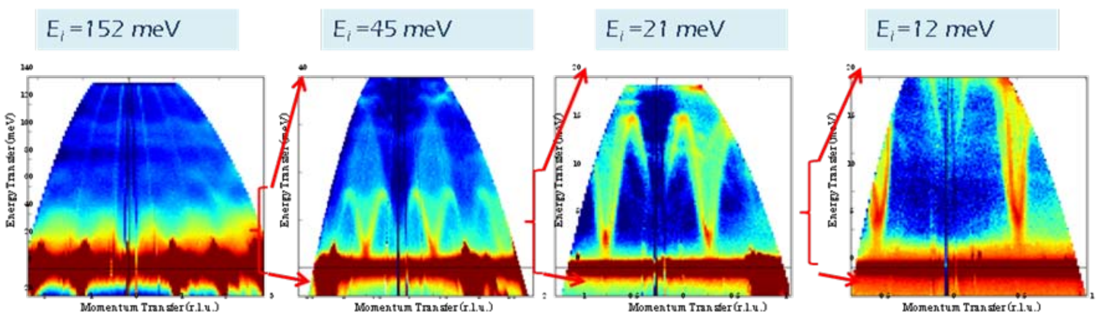

Fig. 3 Results from a multi-Ei method. This was, firstly, realized because of flexibility of the event recording. Data in one frame can create several incident energies through a chopper and give several different energy windows in the S(Q,E).

6. R&D for sustainability

Research and Development works have been carried out on supper mirror, detector, chopper, data acquisition system, software and shielding.

Before we started the construction, supper mirrors to exceed m=4 were not commercially available in reasonable price, hence, we equipped our own spattering machine and developed a method of ion polishing to make the surface smooth and have high reflectivity for high-m mirrors [8]. We transferred our technique to a company to make mass production of mirrors and to align them. Guides of some of the beam lines were made by this way. However, still we have miss-alignment of guides due to a possible premature alignment skill.

6.1. Detectors

As for helium detectors, we worked with companies, Toshiba Co. and GE Co. and tested them in neutron sources, JRR3 and Hokkaido Univ. Linac Facility. Long PSDs, 2.5m and 3m tube developed through the R&D, are installed in chopper instruments. We have also developed two kinds of scintillation detector systems. One is an extended type of ISIS-GEM detector (3mm resolution, 70% efficiency at 1.8A) under ISIS-J-PARC collaboration[9] and another is a wavelength-shifting fiber type detector (1mm resolution, 50% efficiency at 1.8A)[10]. Those are installed in the Engineering Diffractomenter and the Protein Crystal Diffractometer respectively. Now, we are developing large area scintillation detector (30cm X 30cm, 4mm resolution) for a newly coming single crystal diffractometer. We hope this type detector can be an alternation in the recent helium shortage.

6.2. Chopper System

We reckoned that more than 50 chopper systems will be operated in MLF in the end, and fast rotating choppers likely need annual regular maintenance. Hence, although there are good companies in abroad making high- performance chopper system, we decided to work on R&D internally by taking local maintenance scenario into account. We worked on a slim-To chopper (50Hz, in-wheel motor), fast disk chopper (70cm in diam. 350Hz) and slow disk chopper (70cm in diam. 25Hz) with Kobe Steel Co., and KEK worked on a 100Hz-To chopper. Those are already installed in instruments and working properly so far, except for the slim-To chopper with a minor vibration problem[11]

6.3. Data Acquisition System

Based on the electric engineering developed in the KENS facility, we have improved data acquisition electronics under support of the On-Line Engineering Group of Institute of Particle and Nuclear Studies (IPNS) of KEK. The system is essentially based on internet frame work system by introducing Si-TCP system. This system is indispensable to realize the EVENT RECORDING strategy.

6.4. Software Development

Since chronic manpower shortage in engineering, this is a typical feature of Japanese institutions, we started with a voluntary scientist group to work on software developments with a help of contracted companies. The backbone “Framework Software” has been developed under collaboration with the One-Line Group of IPNS, KEK and Advanced Industry Science and Technology (AIST) [12] based on the PYTHON software language. Instrument specific analysis software has been developed in connection with the Framework Software by each instrument group with help of contracted companies. In general the whole system is still on the way of development, and we need collaboration internally and internationally.

6.5. Shielding

Spallation neutron source can produce neutrons in a vast range of energies ranging from one as high as the injected proton energy to cold neutron energy. Therefore, we need to consider proper materials and arrangements to realize low enough radiation level and background in measurement by keeping cost minimum. We have developed materials and manufacturing procedures for several kinds of shielding, such as B4C-Epoxy resin[13] in scattering chamber, Polyethylen-B4C-resin, B4C-contained concrete[14], Concrete with B-contained stones [15]. However, most effective cost reduction of the shield has come from an arrangement of proper materials. After serious simulation calculations, we could find a good arrangement of steel and concrete, for instance, and could reduce the amount of expensive steel to 1/10 from an original design and 1/3 in the cost [16]

7. User Programme

Probably, one of the uniqueness of J-PAR/MLF is its attitude for industrial use of neutrons. When the government approved the construction budget of J-PARC, it claimed us extended efforts to popularize the neutron science, especially to industries. After enormous efforts, Forum of Neutron Utilization for Industries, Industrial User Group organized by the Ibaraki Prefecture, which is the local government, and MLF User Association were formed. Figure 4 shows recent statistics of proposals to MLF, which call for proposals biannually since December 2008. A prominent fraction of proposals has come from industries, especially to powder diffractometers and the Engineering diffractometer.

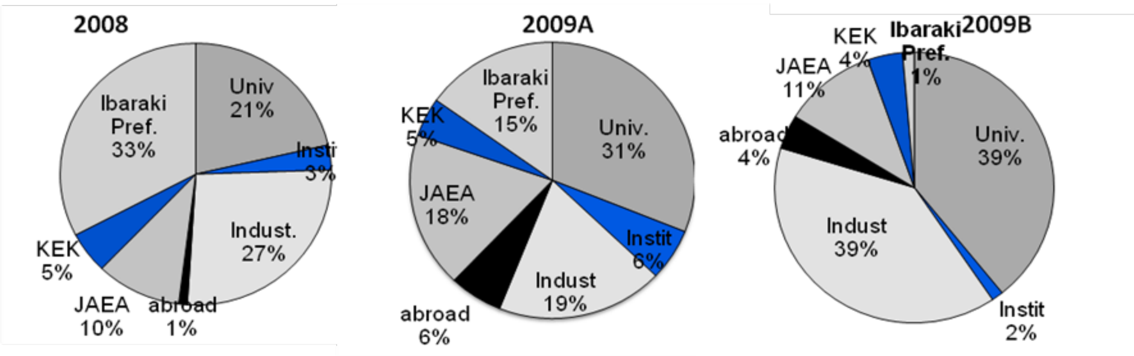

Fig. 4 Statistics of proposals to MLF. The total number of proposals is about 220 in 2009 and is gradually increasing.

8. Summary

J-PARC MLF has started operation since May 2008. The accelerator power is gradually increasing, and now it is 120kW with significant stability. Although we all the time had problems, we are managing them and keep user operation. Most of the components in the target and instruments are working reasonably, and we are keeping track of them, but we have observed needs of improvement in the future. User programme is fairly going well with a substantial use from industries, as we intended.

9. References

[1] M. Teshigawara, et al., ICANS-XVII, (2006) 365-373.
[2] Strategy and Performance of Instrument suite for JSNS, J-PARC
Masatoshi Arai et al., ICANS-XVI, (2003) 157-175

[3] High Intensity Chopper Spectrometer 4SEASONS at J-PARC
R. Kajimoto et al., *Journal of Neutron Research,* **15** (2007) 5—12
[4] Repetition rate multiplication capability for a high energy resolution mode of DIANA at J-PRAC
N. Takahashi et al., *Journal of Neutron Research,* **15** (2007) 61-67
[5] T.Kamiyama et al., ICANS-XVI (2003) 309-314,
T.Otomo et al., *Journal of the Crystall. Soc. Japan*, **50** (2008) 13-17
[6] Overview of a new biological neutron diffractometer (iBIX) in J-PARC
Ichiro Tanaka et al., *Nucl. Instr. Meth. A* **600** (2009) 161-163
[7] First Demonstration of Novel Method for Inelastic Neutron Scattering Measurement Utilizing the Multiple Incident Energies
M.Nakamura et al. *Journal of Physical Society of Japan*, **78** (2009) 093002
[8] Development of neutron supermirrors with large critical angle
R. Maruyama et al., *Thin Solid Films*, **515** (2007) 5704-5706
[9] Development of neutron detector for engineering materials diffractometer at J-PARC ,
K. Sakasai et al., *Nucl. Instr. & Meth. A*, **600** (2009) 157-160
[10] A compact neutron detector using scintillators with wavelength shifting fibers by backside readout method , M. Katagiri et al., *Nucl. Instr. & Meth. A*, **529** (2004) 313-316, Development of a new detector and DAQ systems for iBIX , T. Hosoya et al., *Nucl. Instr. & Meth. A*, **600** (2009) 217-219
[11] Neutron Chopper Developmnet at J-PARC
Kentaro Suzuya, Kenji Nakajima, Quarterly Journal of Industrial Users Society for Neutron Application *-Siki-* **2** (2009)7-7
[12] S. Satoh et al., *Nucl. Instr. and Meth. A* **600** (2009) 103
K. Nakayoshi et al., *Nucl. Instr. and Meth. A* **600** (2009) 173.
[13] Neutron Studies of High Boron Carbide Content, Resin Bonded, Neutron Shielding Materials: KENS Original B_4C-resin
K. Suzuya et al., *KEK Progress* **2006-4 M** (2006) 318-319.
[14] Practical Application of New Shielding Material for Background-Suppressed Measurements in Neutron Scattering Researches
Fujita Corporation and J-PARC Center, Press Release, June 6, 2009
[15] Development of Novel Neutron Shielding Concrete
K. Okuno, M. Kawai and H. Yamada, *Nuclear Technology*, **168** (2009) 545-552.
[16] Neutron Beam-Line and Shield Design for Neutron Scattering Instruments at JSNS J-PARC Project , K. Niita et al., ICANS-XVII (2006) 640-647