BEAM COMMISSIONING OF SPALLATION NEUTRON AND MUON SOURCE IN J-PARC

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Abstract

In J-PARC, Materials and Life Science experimental Facility (MLF) is aimed at promoting experiments using the world highest intensity pulsed neutron and muon beams which are produced at a thick mercury target and a thin carbon graphite target by 3-GeV proton beams, respectively. The first beam was achieved at the target without significant beam loss. To obtain the beam profile at the target, we applied an activation technique by using thin aluminum foil and imaging plate. It is found that the beam profile shows good agreement with the calculation.

INTRODUCTION

In the Japan Proton Accelerator Research Complex (J-PARC) [1], a MW-class pulsed neutron source, the Japan Spallation Neutron Source (JSNS) [2], and the Muon Science facility (MUSE) [3] will be installed in the Materials and Life Science experimental Facility (MLF) shown in Fig. 1. The 3-GeV proton beam is introduced to the mercury target for a neutron source and to a carbon graphite target of 20 mm thickness for a muon source. In order to efficiently utilize the proton beam for particle productions, both targets are aligned in a cascade scheme, where the graphite target is located 33m upstream of the neutron target.

For both sources the 3-GeV proton beam is delivered from a rapid cycling synchrotron (RCS) to the targets. Before injection to the RCS, the proton beam is accelerated up to 181MeV by a LINAC. The beam is accumulated in short bunches width less than 100 ns duration and accelerated up to 3 GeV in the RCS. After extraction, the 3-GeV proton beam is transferred to the muon production target and the spallation neutron source.

Recently it became evident that pitting damage appears in the target container of the mercury target [4]. Several facilities are studying the effect; Alternating Gradient Synchrotron (AGS) and Weapon Neutron Research facility (WNR) are pursuing off-beam experiments [5]. It has been reported that the damage is proportional to the 4th power of the peak current density of the beam [5]. Beam profile monitoring plays an important role in comprehending the damage to the target. It is necessary to know the characteristics of the projectile on the target.

In this paper, beam commissioning is described for the spallation neutron and muon sources at the J-PARC, which has begun in May 2008. As the beam commissioning, turning of the beam orbit and the beam monitor were performed.

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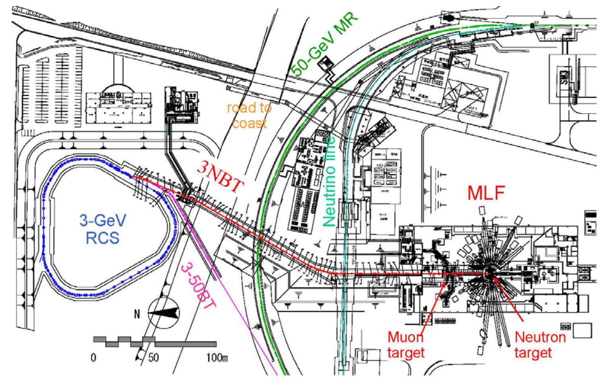

Figure 1: Layout of RCS, 3NBT and MLF at J-PARC. The beam transport line (3NBT) introduces the beam to both targets located at the MLF building.

BEAM OPTICS

Details of the design of the beam optics are described in Refs. [6, 8], the concept is described briefly here. In order to allow hands-on maintenance, acceptable beam loss is limited to 1W/m except close to the targets. At the RCS, a beam collimator with an aperture of 324 π·mm·mrad is installed for shaping the beam. During acceleration at the RCS, the beam emittance shrinks to 54 and 81 π mm mrad by adiabatic dumping for 181 and 400 MeV injections, respectively. However, a small fraction of the beam may exist having an emittance up to 324 π·mm·mrad due to blow-up by space charge. Therefore we decided to have an aperture larger than 324 π·mm·mrad along the entire beam line.

In Fig. 2, D_x and D_y represent the dispersion function in the horizontal and vertical directions, respectively. In order to coordinate other accelerator facilities in the J-PARC such as 50 GeV synchrotron and neutrino beam tunnel, the proton beam is bent to upper direction. In the design, an achromatic beam transport line was aimed at to suppress the expansion of the beam due to momentum spread for both horizontal and vertical directions.

Alignment

In order to carry out the beam commissioning efficiently, exact alignment of the magnets is important. Using a laser tracker (Leica LTD-500), all magnets except around the

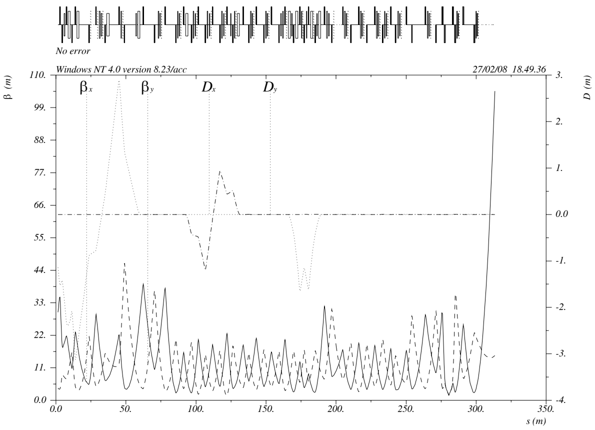

Figure 2: Beam optics from the exit of RCS to the JSNS.

muon target area were aligned precisely. All components were aligned to the designated position within accuracy of 0.1mm.

BEAM MONITORS FOR DIAGNOSTICS

Beam Current Monitor

To measure the beam intensity, current transformers (CTs) are installed in the beam line. Inside the current transformers, a titanium duct is attached for connecting to other vacuum equipment. For the reduction of gas emission, the duct has been baked out. Normally, the vacuum components for the beam transport system are baked out at a temperature of 150°C. Because the insulator material of the current transformer cannot stand at 60°C, the combined assembly was baked out at a temperature less than 60°C. Data of the monitors are acquired by a network-based CAMAC controller (cc/NET TOYO) via the Experimental Physics and Industrial Control System (EPICS) standard.

Profile Monitors

To measure the beam position and shape, multi-wire profile monitors(MWPMs) are installed in the beam line. In the sensors, silicon carbide (SiC) wires are utilized due to their small interaction with the primary beam. Because the Rutherford scattering cross-section is proportional to the square of the atomic number of the wire material, a low atomic number material has been selected to minimize beam scattering. The wire frame can be moved out so that the beam can pass without interaction when no measurement is performed.

For the safety of the operation, it is very important to watch the beam profile on the target. In order to watch the profile continuously, a stationary type of beam profile monitor was located at the proton beam window, which is located 1.8 m upstream of the neutron target. From the view point of the easiness of the maintenance, the profile monitor is combined with the proton beam window. As for muon production target, a movable type of the profile monitor is located.

Beam Position Monitor

In order to watch the center position of the beam without disturbance, beam position monitors (BPMs) are installed. Beam position monitors consist of quadruple electrodes. The position of the beam is measured by the induction of wall currents in the electrode. The center position of the beam is derived from difference among the signals.

Beam Loss Monitor

During beam operation, it is important to know the beam-loss status. If the amount of beam loss exceeds the allowable value of 1 W/m, the beam should be stopped immediately. Loss monitors are located at the front of all quadrupole magnets where the beam diameter is relatively large.

BEAM COMMISSIONING

Result of Beam Commissioning to the MLF

Without significant beam loss, the first beam could be introduced to the MLF on 30 May 2008 without any adjustments. The intensity of the first proton beam was approximately 4×10^{11} ppp, which can be succeeded to deliver with the transmission efficiency larger than 90 %. After beam orbit adjustment, the beam profile was measured by the MWPM located at the proton beam window. For the first neutron beam observation, it was planned to carry out measurement employing the current mode time-of flight (CTOF)[11] technique because of its reliability and convenience. In Fig. 3, the neutron TOF spectrum is shown, which could be observed by only one shot of the proton beam and without any adjustment of the electronics. It is found that the intensity of the neutron shows good agreement with the calculation.

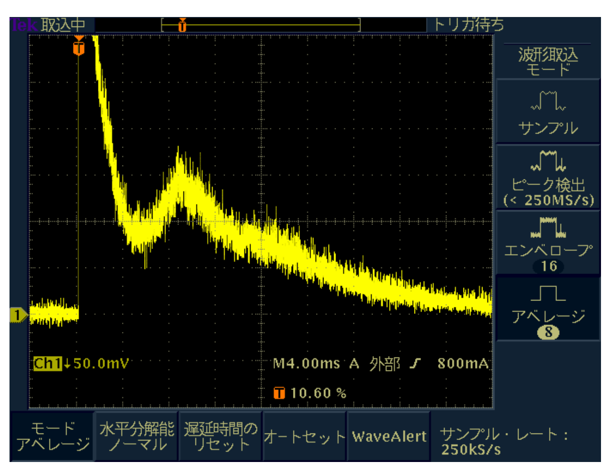

Figure 3: TOF spectrum for the first neutron beam measured by the CTOF technique

Since the profile on the spallation neutron target is very important, we applied to measure the beam profile on the target. In order to achieve good performance at the neutron source, enough space is not remaining around at the target to put any devices for the beam profile measurement. To fit the requirement with the tiny space around the target, we performed activation technique which requires only thin foil space. Placing an aluminum foil (0.3mm in thickness) on the target, the beam profile was obtained from the residual dose distribution on the foil. After irradiation, the foil is removed from the target then foil is attached to the imaging plate (Fuji firm BAS-SR 2040) to read the dose distribution. Figure 4 shows the observed result. It is found that the beam shape was Gaussian having width of 42.5 and 18.8 mm in FWHM for horizontal and vertical, respectively. These width shows quite good agreement with the data obtained by the β function of optics and the beam emittance obtained by the SIMPSONS[6] including the scattering on the proton beam window. The center position of the beam is continuously observed by BPM. It is found that the stability of beam position is good and the deviation of the center position is typically 0.6 mm at BPM position. In Fig. 4, it is also found that beam is not skewed in real space. This implies that the beam current density can be derived from the result of the MWPM, which gives the beam profile projected on the horizontal and vertical axis.

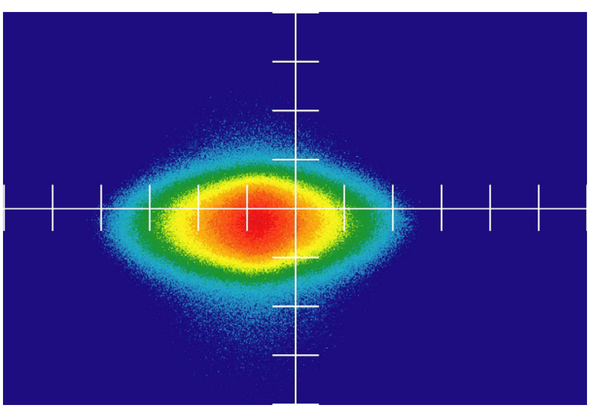

Figure 4: Beam profile observed by the activation of the aluminum foil(0.3mm-t) located on the spallation neutron target (one division in figure is 10mm)

Measurement of Transverse Emittance of the Beam

In order to obtain beam characteristics, Q-scan is performed at the upstream of the spallation neutron target, which is observed the beam width dependence on the field of quadrupole magnet. The result of the Q-scanning is shown in Fig. 5. As the preliminary result, it is obtained that the root mean square (RMS) beam emittance is 1.6 π·mm·mrad. Calculation by the SIMPSONS shows that the emittance is 1.5 π·mm·mrad in horizontal, which shows good agreement with the observed result.

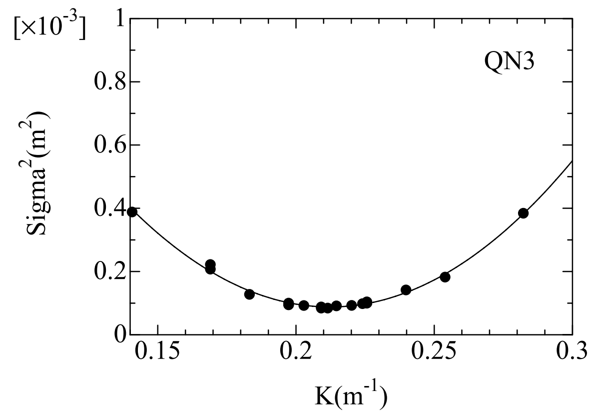

Figure 5: Result of Q-scan (Horizontal axis shows focus length of the quadrupole magnet of QN3, vertical axis shows the square of the RMS width of the beam.

SUMMARY

The beam commissioning to the spallation neutron target of J-PARC has started on May 2008. The muon facility of MUSE has begun operation on September 2008. The first beam on the target was achieved at the target without significant beam loss. To obtain the beam profile at the target, an activation technique was applied by putting thin aluminum foil on the target. Since beam monitors works very well located at the beam transport line even in the first beam, the beam centralization can be finished by very small number of shots. It is found that the observed profile shows good agreement with the prediction calculation including the beam scattering at the proton beam window. It is also found that the RMS-beam emittance agree with the calculation by the SIMPSONS.

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