

ESTIMATION AND MEASUREMENTS OF RADIATION DOSE DISTRIBUTION FOR THE RADIATION TEST AREA IN J-PARC MAIN RING

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Abstract

The J-PARC main ring has a beam collimator system in the first straight section for the beam halo rejection. Though it makes a high radiation area in the ring which requires a serious maintenance scheme, a high radiation dose can be applied to the tests of radiation resistible devices. The radiation dose distribution was estimated by using PHITS code, and it was confirmed by dose measurements using RadMon, nanoDot OSL dosimeters with continuous monitoring of beam losses. The availability of the radiation test area in the accelerator ring is reported in this paper.

INTRUDUCTION

The devices in proton accelerators are damaged by the secondary particles induced by beam losses. Usually, many materials and devices are tested by using gamma rays from the nuclear reactor before the installation into the accelerator tunnel. However, the radiation environment is largely different in the nuclear reactor and the particle accelerator. There are high energy neutrons and charged particles, especially in proton accelerators. It is better to use the real environment for the device and material test for use in the accelerators. The beam collimator section is suitable for this purpose, which has the largest radiation dose in the accelerator ring. The last part of the collimator section of J-PARC main ring is shown in Fig. 1. The last collimator (Col-3) is surrounded by the wall-type iron shield and there is a shield block of 80 cm height on the floor between collimator (Col-3) and quadrupole magnet (QFR010). This shield is installed in order to prevent the neutron flux toward the floor direction. The following two large iron blocks installed in the beamline in order to protect the downstream area from the radiation. The area from Col-3 to QFP012 can be utilized as a radiation test area. Especially, the place between Col-3 and QFR010 is used for high radiation dose investigation.

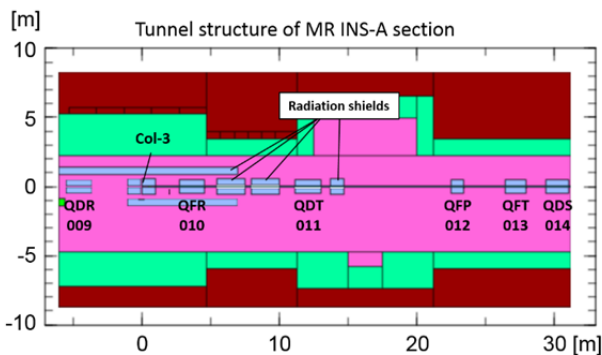


Figure 1: Last part of the collimator section in injection straight of J-PARC main ring.

RADIATION TEST AREA

The following place of a collimator has very large radiation dose. On the other hand, the following place of the radiation absorbers is expected to have a moderate radiation dose. At the present time, two places are utilized to the device test.

High Radiation Test Table

The high radiation test table is prepared at just downstream position of the last collimator (Col-3) as shown in Fig. 2 in order to evaluate the radiation damage on target devices.

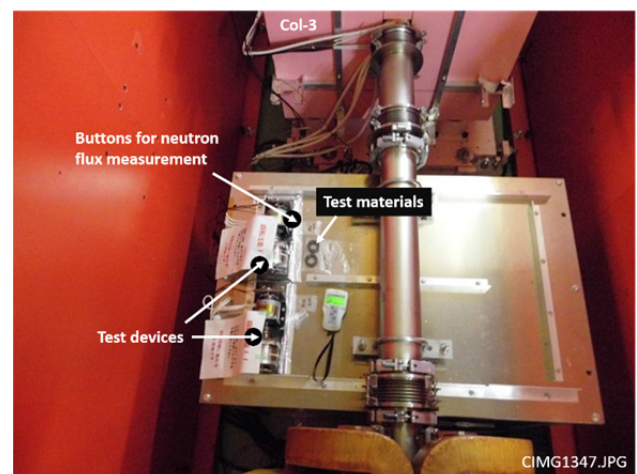
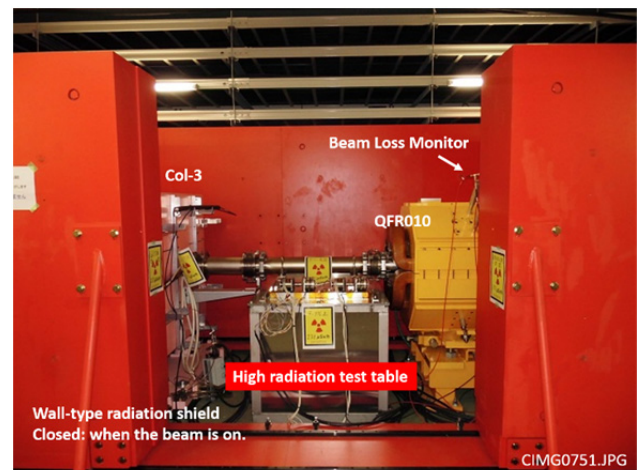


Figure 2: High radiation test table.

This table includes radiation shields which consists of 20 cm height of lead blocks over 60 cm height of polyethylene plates. The table top size is 1,354 x 926 mm. There is an angular dependence on expected radiation dose from the collimator exit, the test place are divided to four regions: 20 to 60 cm in every 10 cm from the beam-

line. The estimated radiation fluxes by PHITS2.60 [1] on the table are shown in Fig. 3 which corresponds to 20-30 cm region 1. The source proton energy is 3 GeV which corresponds to the injection beam energy of J-PARC main ring. The characteristics are:

- Protons and pions are the main fraction of the high energy (>10 MeV) charged particles.
- Neutrons and photons distribute in wide range of energies.
- Radiation flux decreases according to the distance from the beam line in every particle case as shown in Table 1.

Table 1: Radiation Flux in Regions

Reg	Proton	Neutron	Pi+	Pi-	Photon
1	1.81e-5	8.13e-4	2.15e-6	1.66e-6	1.46e-4
2	9.05e-6	7.37e-4	1.01e-6	1.16e-6	1.13e-4
3	6.20e-6	6.68e-4	9.31e-7	9.71e-7	9.09e-5
4	4.35e-6	6.09e-4	6.60e-7	6.71e-7	8.18e-5

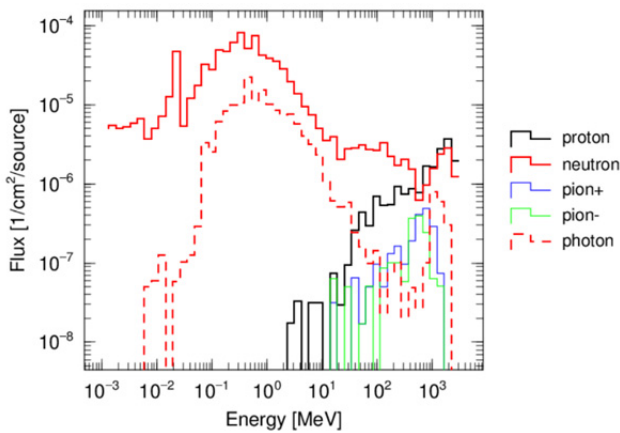


Figure 3: Radiation fluxes on high radiation test table.

The radiation dose on this table was measured by using a radiation monitor RadMon [2] which was developed at CERN. The radiation damage on FET devices were investigated in 2013 [3], and the typical radiation dose during the fast extraction (FX) operation was 500 Gy per a day. Since the measurement of radiation dose by RadMon was limited up to 6 kGy at that time, the accumulated dose was estimated by using beam power record. However, the beam loss amount changes according to the beam tuning condition. The typical beam power was 220 kW in the early 2013. On the other hand, it increased to 460 kW with a small increase of beam losses in these days in 2017. The proportional beam loss signal is more suitable in order to estimate the radiation dose, and the actual accumulated absorbed dose are measured by using test pieces of aluminium buttons. The radiation damage investigation on stepping motors and rotation sensors is still going on. The radiation dose is expected to be 500 to 1,000 Gy per a day in usual FX operation.

Moderate Radiation Area

In order to investigate the lifetime of LED, the place just before the quadrupole magnet (QFP012) was chosen as a moderate radiation area, where was about 20 meter away from the high radiation test table as shown in Fig. 4. In this area, a few charged particles and relatively low energy (<10 MeV) neutrons and photons are expected. The radiation dose can be measured by using nanoDot which is an Optically Stimulated Luminescence (OSL) dosimeter. In order to measure the neutron flux, the aluminium plates are also placed with nanoDot as shown in Fig. 5. The set (1) faces to the beamline. Sets (2) and (3) are placed on the top of the test LED light. The Set (4) faces to the downstream direction of the ring.



Figure 4: Test LED light in the moderate radiation area.

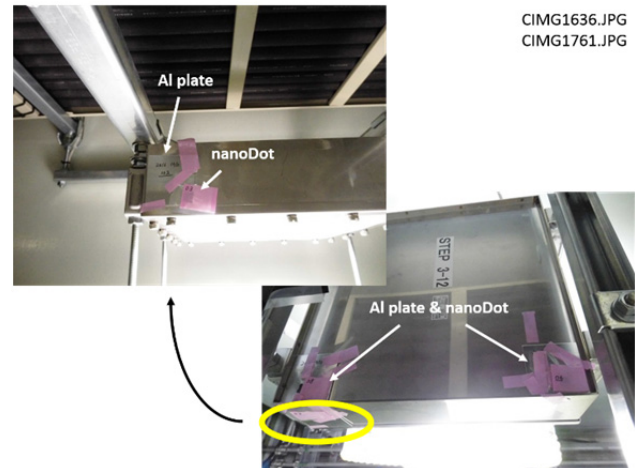


Figure 5: NanoDot OSL dosimeter chips and aluminium plates on test LED light.

Though the linearity of nanoDot is insured for absorbed dose up to 10 Gy, it can be applied more than 100 Gy in actual. It is calibrated by using RadMon as shown in Fig. 6. The measured values of OSL chips are corrected by using this curve. The absorbed doses on test LED light are shown in Fig. 7. The set (1) which faces to the beamline shows 20% larger dose compared to the others. The

coefficient is estimated to be 1.13±0.23 Gy/count for set (2-4) with respect to new proportional BLM system [4] which was installed in summer 2016.

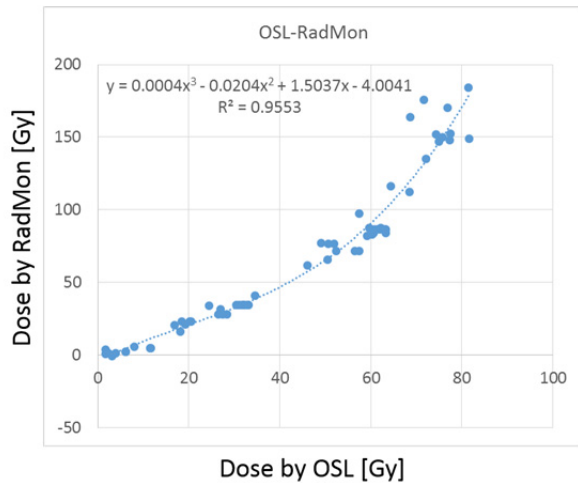


Figure 6: nanoDot calibration curve.

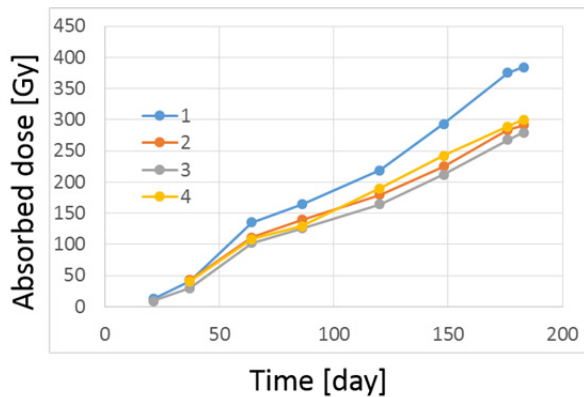


Figure 7: Measured absorbed doses on test LED light.

Thermal Neutron Measurement

The spatial distribution of thermal neutron flux along the main ring tunnel was measured by neutron activation analysis (NAA) method with gold leaf flakes [5] as shown in Fig. 8. The measurement sets were placed on tunnel wall around the test LED light, and the results are listed in Table 2. Though the total radiation becomes very large in close to the beamline, the thermal neutrons have a flat distribution in cross section of an accelerator tunnel.

SUMMARY

The radiation damage investigations are going on at the J-PARC main ring. High and moderate radiation places are utilized for the stepping motor and LED. The radiation dose can be estimated by using beam loss monitors. Because the accelerator operation is stable for the physics runs, the absorbed doses increase linearly. The radiation doses are 500 to 1,000 Gy per a day for the high radiation test table, and 0.8 Gy per a day for the moderate radiation

area. They are useful in order to test the devices and materials which will be used in proton accelerators.

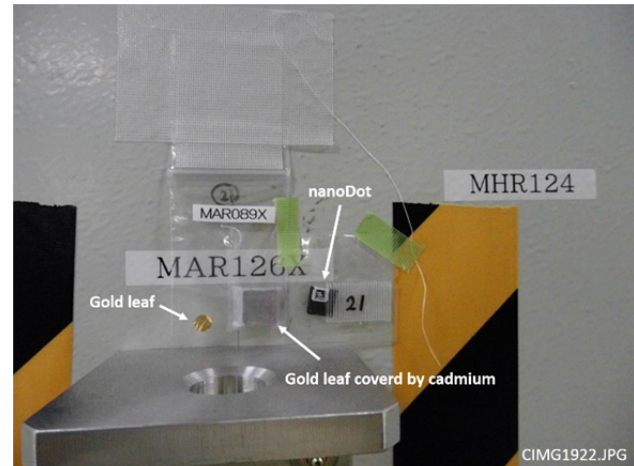


Figure 8: Gold leaf flakes and nanoDot for thermal neutron measurement.

Table 2: Measured Dose and Flux in Regions

Reg	Location, height	nanoDot [Gy]	Au-leaf [cm ⁻² s ⁻¹]
1	Out, beamline	8.922	9.25e+4
2	Near beamline	254.6	8.36e+4
3	Out, floor	7.338	8.23e+4
4	Out, 2 m height	8.773	8.54e+4
5	In, beamline	9.594	7.41e+4

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