Commissioning at MuSIC in 2016: spin precession measurement for μSR and preparation for upgrades of MuSIC beamline with 1 μA proton beam operation

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The new DC muon beamline, MuSIC (MUon Science Innovative muon beam Channel) was constructed in the west experimental hall. Installation of all beamline components was almost completed [1] and beam commissioning of the MuSIC beamline has been in progress with 20 nA primary proton beam. Major progresses in 2016 are (1) to demonstrate fast muon spin precession measurement with the μSR (Muon Spin Rotation/Relaxation/Resonance) method for the condensed matter physics, and (2) to upgrade the MuSIC beamline to provide an intense muon beam with a 1 μA primary proton beam. In this article, we will briefly report current statuses of these issues at MuSIC.

1 Measurement of fast spin precession for μSR

In the beamline commissioning in June, the first priority was to observe a fast spin precession spectrum in a large transverse magnetic field for proving feasibility of μSR. We have already shown that the spin polarization of the muon beam at MuSIC was reduced due to contamination of backward-decay and forward-decay muons [1]. At the 60 MeV/c muon beam, the spin polarization was about 60 %. By using this polarized beam, we observed the fast spin precession. In general, in the pulsed muon beam case, a large pulse width of typically 100 nsec limits timing resolution of the muon spin precession spectra. In the continuous muon beam case, the muon injection timing to the target can be precisely determined with a start counter for MuSIC. It enables us to observe the fast spin precession with a good time resolution. This is a practical advantage to probe a strong internal magnetic field in matters with μSR.

For this measurement, a dedicated setup was installed as shown in Fig. 1(a). For brevity, a pair of permanent magnets was mounted at the top and bottom of a sample. Without any large power supply units, it produces a strong external magnetic field of 0.058 Tesla, which is a similar order of an internal magnetic field of typical ferromagnets and antiferromagnets. Figure 1(b) shows an asymmetry spectrum of the left and right counters with this setup. It shows that the fast spin precession is clearly observed in the time resolution of typically 1 nsec with plastic scintillation counters. Figure 1(c) shows an asymmetry spectrum in the transverse field of 0.004 Tesla observed with the conventional spectrometer [1] as a reference of the fast spin precession in Fig. 1(b).

2 Preparation for upgrade of the MuSIC beamline

Until the commissioning in June, 20 nA primary proton beam was used to avoid contamination in the hall. In the next commissioning in February 2017, we were planning to increase the primary proton beam up to 1 μA for providing more intense muon beam at MuSIC. A key for the beamline upgrade is to enforce radiation shields especially around the beam dump and the pion capture solenoid with thick irons and concrete blocks as shown in Fig. 2(a). These will be able to reduce neutron radiation outside of the shields in less than a few of hundred μSv/h. The other is to install the new remotely-controlled target system as shown in Fig. 2(b). Since we could not access to the target after the upgrade due to very high radiation, we must remotely control the system to remove a used graphite target and then, to install a new target to the original position inside the pion capture solenoid. In addition, associated apparatuses were also improved to monitor remotely. In the next commissioning in February, the MuSIC beamline will provide the intense muon beam with 1 μA proton beam operation. These upgrade will facilitate all experiments at MuSIC within limited beam time from 2017.

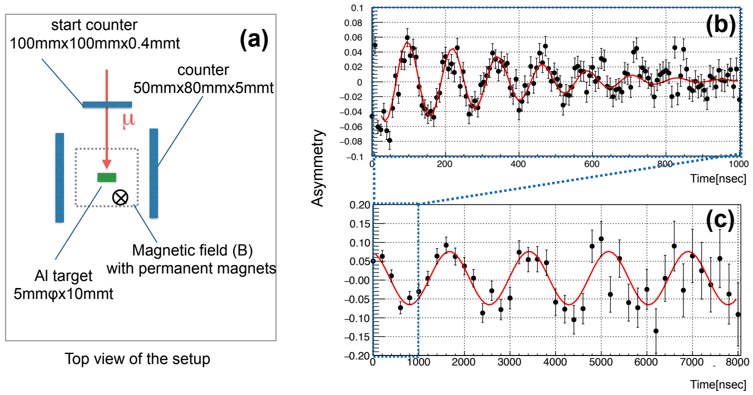

Figure 1: (a) Schematic top view of the experimental setup for the fast spin precession measurement. In order to produce a larger magnetic field without any large power supply units, a pair of permanent magnets (10cm×10cm×1cmt) was employed. It produced a transverse magnetic field of 0.058 Tesla with approximately 10 % uniformity on the target of 10 mmϕ. Muons stop at the aluminum target and their spins rotate on the horizontal plane. Their decay positrons are observed with a left or right counter. (b) Spin precession spectrum in the high field of approximately 0.058 Tesla with a dedicated setup shown in Fig. (a). Note that an amplitude of the asymmetry is dumping due to low uniformity of the magnetic field. (c) Spin precession spectrum in the low field of 0.004 Tesla with a conventional μSR spectrometer. The dashed square region indicates a full range of the spectrum shown in Fig. (b) to emphasize the fast precession. Both spectra were measured with 60 MeV/c muon beams which were generated by the 20 nA primary proton beam.

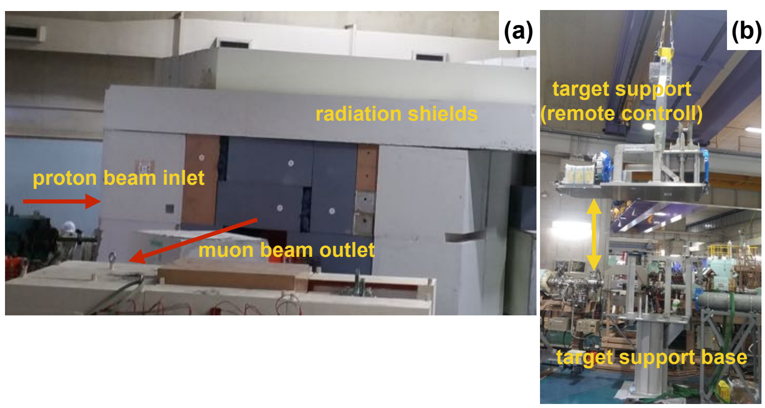

Figure 2: (a) Photograph of radiation shields around the pion capture solenoid. The large number of radiation shields covered over the capture solenoid and the beam dump to prevent high radiation with neutrons. (b) Photograph of remotely controlled target system. A target support base was installed at the backward of the pion capture solenoid. A target support was mounted on the base and a graphite target was inserted into the solenoid remotely. Note that this photograph was taken in a test operation near the beamline before mounting the solenoid.

References

[1] D. Tomono *et al.*, RCNP Annual Report (2015).