MuSIC in 2017: upgrades of the beamline for intense muon beam with 1.1 μA proton beam and start of μSR and new scientific programs

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The new muon beamline, MuSIC (MUon Science Innovative beam Channel) provides an intense DC muon beam at the west experimental hall, RCNP. The most remarkable feature of the MuSIC beamline is to produce the intense muon beam from a low-current proton beam very efficiently. The pions are produced with a very thick (20 cm-thick) graphite target and then, pions and decayed muons are collected with a large solid-angle superconducting solenoid magnets [1, 2]. Until 2016, beamline commissioning experiments were performed under a proton current of 20 nA [3]. In February, 2017, beamline shields and associating other components around the muon production target were improved to provide the 1.1 μA muon beam. Owing to this upgrades, more intense muon beam was successfully delivered to the experimental port. The present MuSIC beamline provides approximately 10^5-10^6 counts/sec positive and 10^4-10^5 counts/sec negative muon beams in a momentum range from 28 to 110 MeV/c. A part of the proposed scientific programs was started in 2017.

Experiments with the negative muon beam started prior to various proposed experiments to take advantage of a time structure of the DC beam combined with germanium detectors. A nuclear physics experiment (E475, T. Matsuzaki *et al.*) [4] in February and a non-destructive analysis in astronomy (E490, K. Terada *et al.*) [5] in June were performed with the intense muon beam. On the other hands, using the positive muons beam, a practical tests of a μSR (muon spin rotation, relaxation and resonance) measurement with a cryostat were started for condensed matter physics. In this article, we will briefly report present statuses of the beamline upgrade and μSR preparation at MuSIC.

The radiation shield is one of the main components to be improved for 1μA proton beam operation. Figure 1(a) shows a photograph of radiation shields using thick irons and concrete blocks surrounding the pion

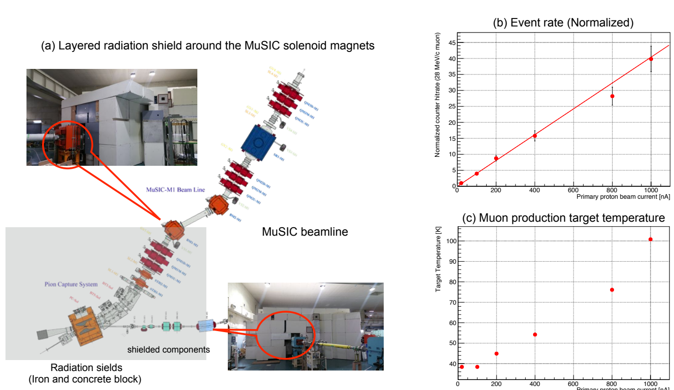

Figure 1: Upgrade of beamline for 1.1 μA-proton beam operation. (a) Schematic figure and photographs of enforced radiation shields around superconducting solenoids. (b)(c) Proton beam current dependence of a muon yield (normalized with the yield at the proton beam current of 20 nA) and muon production target temperature, respectively.

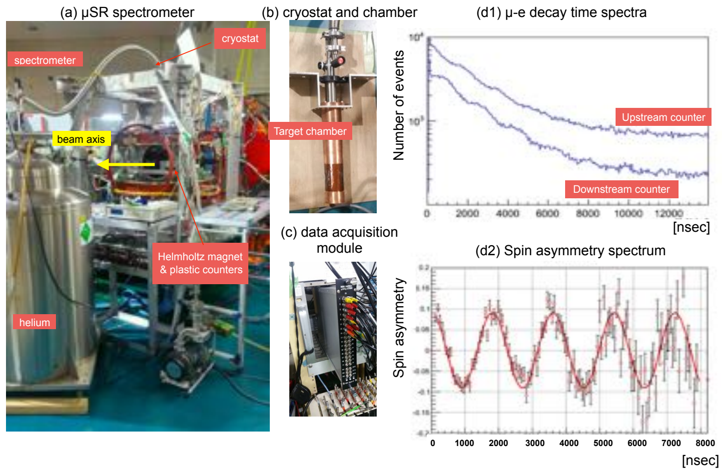

Figure 2: (a) Photograph of new μSR spectrometer fabricated with a helium flow cryostat and sample chamber connected with a cooling system with liquid helium. (b)(c) Photographs of the helium flow cryostat and a data acquisition module, Kalliope-DC. (d1) μ-e decay time spectra observed with upstream and downstream counters in the transverse field of 0.004 Tesla, respectively. (d2) Spin asymmetry spectra calculated with the time spectra in Fig.(d1).

capture solenoid. Especially we increase shielding blocks at the inlet and outlet of the beams, and at the top of the solenoid magnets, which enabled us to reduce neutron radiation outside of the shields. In the following beam commissioning test, we carefully increased the proton beam current up to 1.1 μA and measured the muon yield. Figure 1(b) shows proton beam current dependence of the positive muon yield normalized with the yield at the proton beam current of 20 nA. We confirmed that the muon yield linearly increased to the proton beam current up to 1 μA. We checked temperature of the muon production target shown in Fig. 1(c). It also increased linearly to the proton beam current. We successfully obtained an intense muon beam as we expected with 20 nA proton beam. This upgrade enabled us to perform various experiments with reasonably short beam time.

A feasibility of μSR have been investigated in the beam commissioning tests. We newly fabricated a cryostat and a cooling system in the μSR spectrometer in the experimental area. Figure 2(a) shows the new spectrometer with the helium flow cryostat (MicrostatHe, Oxford Instruments) and a sample chamber (Fig. 2(b)). A new data-acquisition module (Kalliope-DC Fig. 2(c)) was employed to measure μ-e decay positrons timings. Their time spectra (Fig. 2(d1)) and a calculated spin asymmetry spectrum from these time spectra (Fig. 2(d2)) are shown. We achieved to cool a sample around 4 K with this setup. We are continuing further commissioning and improvement for practical μSR experiments.

In summary, we successfully provided the intense muon beam by upgrading the beamline. Some scientific programs started this year with the negative muon beam. For the μSR study with the positive muon beam, we installed the spectrometer with new apparatuses for practical experiments. In 2018, we are planning various scientific program: μSR experiments, other elemental analysis with negative muons, particle and nuclear physics experiments and radiation test of semiconductor devices for industrial application.

References

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