Strongest Pulsed Muon Source at J-PARC MUSE

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Abstract. The muon science facility (MUSE, abbreviation of MUon Science Establishment), along with the neutron, hadron, and neutrino facilities, is located in the Materials and Life Science Facility (MLF), which is a building integrated to include both neutron and muon science programs. On the November, 2009 beam cycle, we achieved extraction of the world's strongest pulsed muon beam at J-PARC MUSE by beam tuning at the Decay-Surface muon beam line (D-line). Surface muons (μ^+) as much as 1.8 x 10^6/s were extracted with the use of 120 kW of protons from the Rapid Cycle Synchrotron (RCS), which corresponds to 1.5 x 10^7/s surface muons when a future proton beam reached at the intensity of 1MW. These intensities, at the future 1 MW operation, will correspond to more than ten times those at the RIKEN-RAL Muon facility.

Keywords: muon, J-PARC, MUSE, proton accelerator
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INTRODUCTION

The muon science facility (MUSE, abbreviation of MUon Science Establishment), along with the neutron, hadron, and neutrino facilities, is under construction at the Japan Proton Accelerator Research Complex (J-PARC) in Tokai. The MUSE facility is located in the Materials and Life Science Facility (MLF), which is a building integrated to include both neutron and muon science programs. About 85% of the 3 GeV, 333 μA (1 MW) beam from the Rapid Cycle Synchrotron (RCS) is sent to the MLF for the production of intense pulsed neutron and muon beams, while the remaining 15% is sent to the 50 GeV ring for further acceleration for the kaon and neutrino physics programs.

EDGE COOLED MUON TARGET

On the way towards the neutron source at MLF, one edge cooled graphite target with a thickness of 20 mm was installed, in order to produce charged pions both positively (π^+) and negatively (π^-) through nuclear reactions between the 3 GeV proton beam and the nucleus of carbon. In order to prevent focusing stress on the graphite, we inserted a buffer layer of Ti at the interface between the copper frame and the graphite.

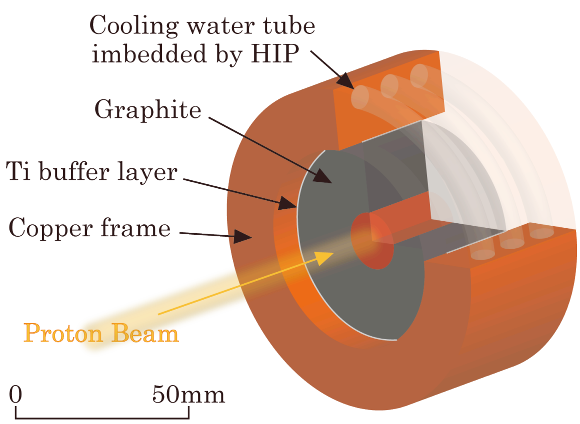

FIGURE 1. A schematic view of the 20 mm thick edge-cooled graphite muon production target.

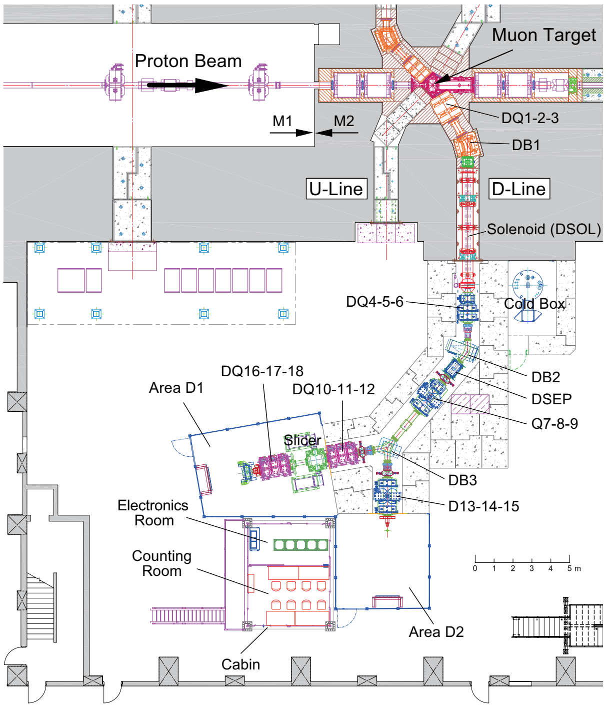

FIGURE 2. Layout of the decay muon line (D-Line) in the experimental hall No. 2 of the MLF building.

The Ti material was selected to have a rather small, thermal expansion, Young's modulus; 9 ppm/K and 102 GPa, respectively. We adopted silver brazing in vacuum to bond between the graphite disk and the Ti layer, and the Ti layer and the copper frame. Figure 1 shows the 20-mm-thick edge-cooled non-rotating graphite muon target.

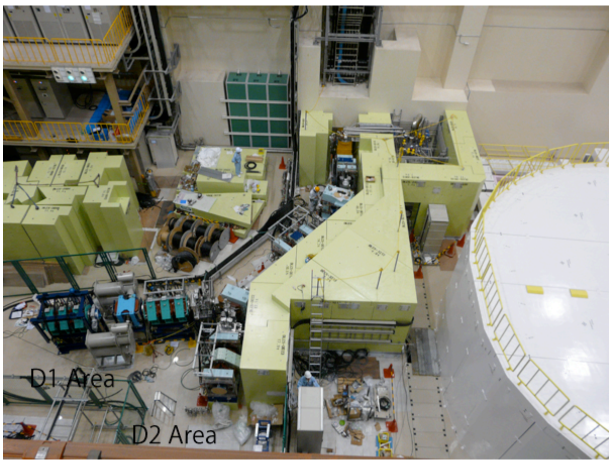

FIGURE 3. A picture of the D-Line during construction

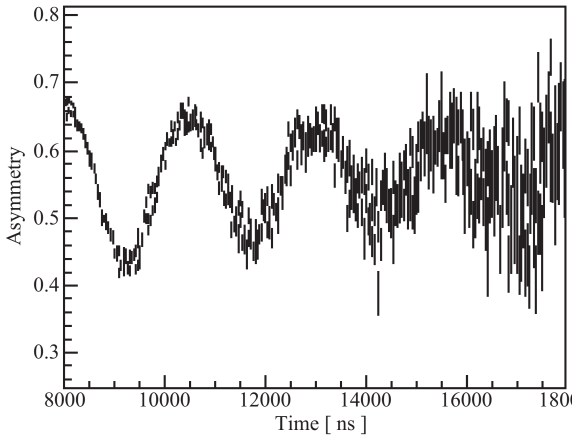

FIGURE 4. The first μSR asymmetry spectrum demonstrated by using an aluminum sample.

MUON BEAM AT D-LINE

For phase 1, the MUSE team managed to install one superconducting decay/surface muon channel, the so called D-Line, with a modest-acceptance (about 45 mSr) pion injector. At D-Line, either surface muons, which are obtained from the decay of π^+ stopped near the surface of the graphite target in the proton beam line, or decay muons, which are obtained through the in-flight decay of π^{+}/π^{-} confined by a strong longitudinal magnetic field of several T from a superconducting solenoid magnet, can be extracted. Figures 2 and 3 show a schematic layout and a picture of the D-line under construction.

On September 19th, 2008, the muon target was, for the first time, placed into the 3GeV proton beam line. During the first beam, we tried to extract "**surface muons** (μ^+)". At the beginning, we commissioned the D-line optics by tuning the superconducting magnet, the quadrupole and bending magnets, and the DC separator in order to optimize the transportation of the surface muon beam and to eliminate the e^+ contamination. As a result of the commissioning of the D-line optics, we managed to deliver the first surface muon beam to the D1 muon experimental area at 12:10 on September 26th, 2008 [1]. In front of a live audience, we demonstrated a μSR asymmetry measurement under a weak transverse magnetic field adopting an aluminum plate as a sample, using the 128 × 2 channels DΩ μSR spectrometer. Afterwards, together with the audience, we celebrated the extraction of the first muon beam. Figure 4 shows the μSR spectrum witnessed by an audience of about one hundred people. The profile of the muon beam was also measured by a profile monitor and an imaging

FIGURE 5. A picture celebrating the first Muon beam production at J-PARC MUSE.

plate (IP). Figure 5 shows a picture celebrating the first Muon beam production at J-PARC MUSE.

STRONGEST PULSED MUON BEAM

In November 2009, the surface muon (μ^+) extraction rate was significantly increased up to 1.8×10^6/s with use of a 120 kW proton beam from the RCS. The achieved intensity is equivalent or even larger than that at the RIKEN-RAL muon facility [3]. This is the reason why that the world's strongest pulsed muon source was claimed to be achieved at MUSE, even with using a 120 kW proton beam intensity. This intensity would correspond to 1.5×10^7/s surface muons when in the future the proton beam will reach a power of 1MW.

With use of this world's strongest pulsed muon beam at MUSE, Takeshita et al. have already published a paper demonstrating the presence of a macroscopic phase separation between the superconducting and magnetic phases in Co-doped iron pnictide $CaFe_{1-x}Co_xAsF$ [4].

We also succeeded in the extraction of a "decay muon (μ^+/μ^-)" beam, which is obtained through the in-flight decay of π^+/π^-, on December 25th, 2008. As a demonstration of extracting decay μ^- toward the D-Line, non-destructive element analysis for Tempo-Koban (supplied by Prof. S. Saito) was performed by utilizing Ge-detectors. Figure 6 shows a set-up for the Muonic X-ray measurement at the D2 area.

SUMMARY

Construction of the D-Line at MUSE was completed in the summer of 2008, as scheduled. And we succeeded in the extraction of a "surface muon (μ^+)" beam on September 26th, 2008. We also succeeded in the extraction of a "decay muon (μ^+/μ^-)" beam, on December 25th, 2008. Finally, we achieved the world's strongest pulsed muon source at MUSE in November 2009, using a 120 kW proton beam.

FIGURE 6. Muonic X-ray measurement system at the D2 area as a demonstration of extraction of negative decay muons. Tempo-Koban (supplied by Prof. S. Saito) was placed in front of the Ge-detector.

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