Transportation of Ultra Slow Muon on U-line, MLF, J-PARC

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In order to study the surface and interface properties, and novel three-dimensional (3D) imaging of materials using spin polarized muon, we have been developing ultra slow muon microscope on U-line, MLF, J-PARC. Among its two legs, a leg, U1A area where ultra slow muon beam of ~ mm size with energy 20 eV – 30 keV will be available, is dedicated to surface and nano-science studies, whereas another leg, U1B area where muon micro beam will be available, is dedicated to novel 3D imaging of materials with μm spatial resolution. We have generated ultra slow muon and successfully transported to both areas (U1A and U1B). We have also performed simulation study using a Monte Carlo based code, musrSim, to improve the transportation efficiency and achieve intense ultra slow muon at sample positions in both areas. The measurement at different focusing points on the beam line, measurement and simulation study, and preliminary beam profile are reported.

KEYWORDS: ultra slow muon, beam transport

1. Introduction

Ultra slow muons generated by laser resonant ionization of muonium (Mu) [1] evaporated from the surface of hot tungsten are considered as promising tool for microscopic study of materials from surface, interface, layerwise/multilayers and visualization of 3D image with depth resolution (μm). Adopting the similar technique initiated in KEK [1] and later in RIKEN-RAL [2], we have been developing ultra slow muon microscope (USMM) on U-line, Materials and Life Science Facility (MLF), Japan Proton Accelerator Research Complex (J-PARC) [3, 4] . USMM has two legs: one for nano-science study and another for 3D imaging of samples (Fig. 1). The former one, which is known as U1A area, is dedicated to ultra slow muon beam with tunable energy 20 eV – 30 keV and beam size of 1 – 10 mm while in the latter one known as U1B area is dedicated to micro muon beam (energy 200 keV – 1 MeV with beam size 10 to several tens of μm, after reacceleration of beam).
We have observed ultra slow muon (USM) initially at F3 for the first time in J-PARC (Feb. 2016). With gradual increase of intensity of USM, we have successfully transported them to both U1A and U1B areas. The proton beam intensity was 150 kW during USM commissioning (2016/10 to 2017/6). In order to understand the beam at different points on beam line and support the transportation, we have performed simulation study using musrSim [5]; a Monte Carlo simulation based on Geant4