Muon Precision Measurement with the Penning Trap at J-PARC

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Muon precision measurements constitute a powerful probe in the search for new physics beyond the Standard Model of particle physics. A prominent example is the measurement of the muon anomalous magnetic moment $(g-2)$, which exhibits a 4.2σ discrepancy between theoretical predictions and experimental results. This deviation is regarded as a potential indication of new physics [1]. In previous precision measurements, muons were either in an accelerated state or in a muonium state.

In this study, a novel method is proposed to precisely measure slow free muons by confining them in an electromagnetic field utilizing the Penning trap technique. This represents the first application of a Penning trap to particles with lifetimes as short as that of muons (2.2 μs). The experiment will be conducted using the high-intensity pulsed muon beam at J-PARC H-Line [2]. The ultimate goal is to measure the muon mass and magnetic moment with a precision of 1 ppb and the muon lifetime with a precision of 1 ppm.

A schematic representation of the experimental setup is provided in Fig. 1. Muons are initially injected into a degrader or an ultra-slow muon-producing target within a 3 T superconducting magnet to decelerate them. The resulting slow or ultra-slow muons are subsequently transported to the trap region via an electric field. During transport, an RF magnetic field is applied to rotate their spin direction by $\pi/2$, aligning it perpendicular to the magnetic field to facilitate the observation of Larmor precession. The muon spins and positions are precisely controlled by the electromagnetic field, and their oscillation frequencies are measured using upper and lower detectors via the detection of decay electrons or positrons.

At present, the development of electrodes, which are integral to the trap, as well as detectors for measuring rapid spin precession, is underway. The current status of these developments will be reported.

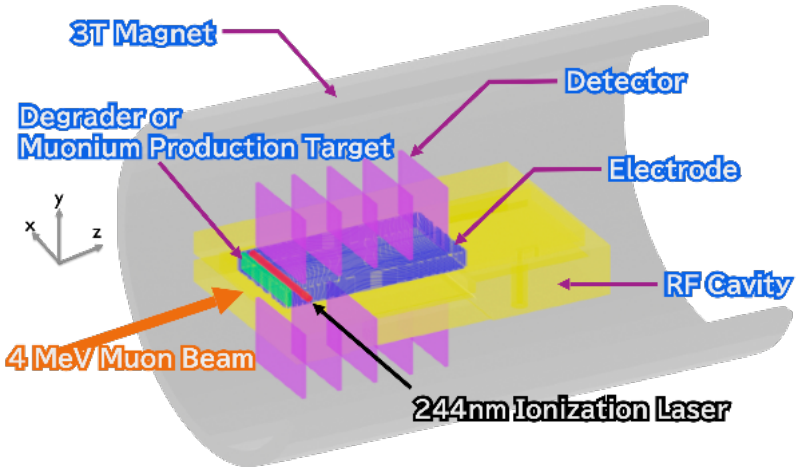

Figure 1: Schematic view of the muon trap experiment.

References

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[2] T. Yamazaki, *et al.*, EPJ Web Conf. **282**, 01016 (2023).