Letter of Interest

Search for μ-e Conversion by using Muonic Atoms Produced in a Primary Production Target

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Muon to Electron Conversion

A charged-lepton flavor violation (CLFV) is one of hopeful phenomena that can provide us a breakthrough toward the physics beyond the Standard Model of particle physics (SM). Among many CLFV processes, a muon-to-electron (μ-e) conversion is thought to be the most promising channel due to its discovery potential: sensitivity to physics models not limited to particular processes[1], and experimental method that can improve the current upper limit by several orders of magnitude with realistic technology of today[2].

Two flag-ship experiments (COMET[3] and Mu2E[4]) succeeding to the basic idea firstly shown by MELC[5] are under construction. The main idea of the MELC-type experiments is excellent and its ultimate sensitivity will reach a level of 10^{-17} in the branching ratio of μ-e conversion. The major issue haunting the MELC-type experiment is its expensive cost to produce a beam line, and rather longer period of its construction.

It is needless to say that the MELC-type experiments should be realized to achieve the ultimate sensitivity. In addition to that, it is also good to push the forefront forward in timely manner with small-sized experiments. It is noteworthy that a quarter

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century has passed without any new experiments realized since the last experiment (SINDRUIM-II[6]) was performed.

Muonic Atoms in a Primary Production Target

A study performed in J-PARC MLF in 2009 mentioned that the existence of muonic atoms in a primary production target, and these muonic atoms can be used for a μ-e conversion experiment. The yield of muonic carbon atoms produced in the production target were estimated to be 5×10^9/s for 1 MW operation of J-PARC RCS with a graphite target[7].

DeeMe Experiment

Figure 1 shows a concept of the muon-to-electron conversion experiment by utilizing a muonic atoms in the production target. The keys to realize the experiment with this method are three: 1) a high-power high-quality pulsed proton beam, 2) a large-acceptance secondary beam line, and 3) the way to survive the prompt burst of the secondary beam. The number of muonic atoms produced per proton-beam-power with this method is almost 1/100 compared to the MELC-type experiment, therefore the high-power proton beam is indispensable. In order to achieve a physics sensitivity at level of 10^{-15}, the proton beam power shall be 1 MW. The quality of the proton pulse, which is evaluated by using a fraction of residual protons outside of the main pulse, should be smaller than 10^{-17}[8], which is much severe than the extinction requirement for MELC-type due to a lack of a muon beamline suppressing the unwanted particles entering to the muon stopping target.

The second requirement is to increase the signal electron acceptance. A new beam line at J-PARC MLF, H-line, has designed for DeeMe and has 110 msr of geometrical acceptance[9]. H-line is currently under construction. Please note that using MELC-type pion-capture solenoid beamline to increase the geometrical acceptance may not work with DeeMe-type measurement due to the contamination of delayed backgrounds coming from particles trapped in the solenoid.

The third requirement is necessary in the DeeMe-type method, since the detector is directly exposed to the charged particles, including prompt bursts, coming from the production target. This issue can be solved by either installing a beam-kicker system or using high burst-tolerance detectors[10].

Future Prospects

J-PARC RCS is the only available accelerator facility in the world that can provide a high-quality high-power pulsed proton beam for DeeMe-type experiment at the time DeeMe was proposed in 2010. The expected physics sensitivity of DeeMe is 1×10^{-13} for a muonic carbon atom with one year of beam time at 1 MW operation. The physics sensitivity would be improved by factor 6 or so if the target material can be changed to SiC, but no concrete plan of the facility modification exists.

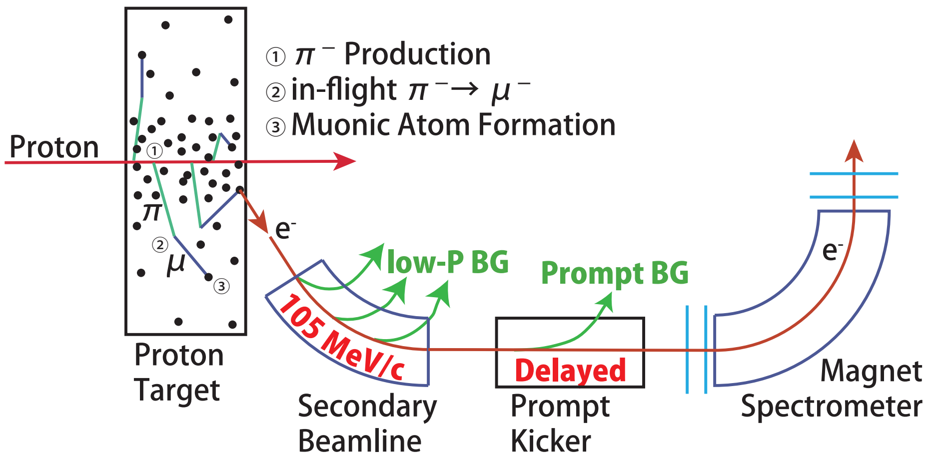

Figure 1: Concept of DeeMe-type experiment searching for μ-e conversion.

The first motivation of DeeMe was to produce physics result in timely manner and activate this research field in order to increase the urgency and momentum for the realization of the MELC-type flag-ship experiments. We are hoping to start physics data taking soon after the completion of the H-line construction, which is expected to come in a few years.

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