Search for the coherent neutrinoless transition of a muon to an electron in a muonic atom with the COMET experiment at J-Parc

Master 2 Research Internship at Laboratory of Physics of Clermont (LPC)
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Several experiments are looking for Beyond the Standard Model signals through charged lepton flavour violation (cLFV) searches. Being forbidden in the Standard Model (SM), and strongly suppressed in minimal SM extensions capable of accounting for neutrino oscillation data, cLFV is a particularly powerful probe for New Physics.

The neutrinoless muon-electron conversion of a muonic atom ($\mu^- + (A, Z) \rightarrow e^- + (A,Z)$) was already used to put stringent bounds on cLFV (7 x 10^{-13} presently). It is a coherent process that might occur for a muon on the 1s state of a muonic atom, that produces an electron with a well-defined energy (~the muon rest energy, 105 MeV). Of course, the 1s muon can also decay in orbit ($\mu^- \rightarrow e^- \nu_\mu \bar{\nu}_e$), or be captured by the nucleus, $\mu^- + (A, Z) \rightarrow \nu_\mu + (A, Z-1)$, but these SM processes either lack the electron signal in the final state or produce lower energy electrons. The muonic atoms are created by capturing muons at rest in a standard atom.

Since the limit on neutrinoless muon-electron conversion is very stringent already, the way to further improve it is to create as many muonic atoms as possible by using very intense beams of low energy muons. The upcoming experiment COMET (COherent Muon to Electron Transition) at the Japan Proton Accelerator Research Complex (J-PARC) is expected to push it by four orders of magnitude by taking advantage of the highest intensity muon beam in the world.

This muon beam is obtained from the decay of low energy pions produced in the interaction of 8-GeV protons with a C or W-target. To increase the number of low-energy, negative muons, the proton target is surrounded by a superconducting solenoid that concentrates efficiently the created pions into a second superconducting solenoid where they decay. The magnetic fields are carefully chosen to optimize the number of low-energy μ^- at the end of the transport solenoid. Subsequently, the muons are sent on an Al target to create the muonic Al-atoms. The Al-target itself is surrounded by a cylindrical drift chamber that will measure very precisely the 104.497 MeV electrons that are the signature of the coherent μ–e conversion.

COMET will start data taking in 2023 but given the importance of the muon beam for reaching the expected sensitivity, a first step will be characterizing the muon transport. To this end, simplified detectors will be used in December 2022 to characterize a lower intensity version of the COMET beam. The LPC group will participate to this effort by deploying at J-Parc Glass Resistive Plate Chambers (GRPCs), gaseous trackers that can measure very precisely muons.

The M2 candidate will work on the Geant-4 simulation of the muon transport and of the detection setup to optimize the beam characterization. Since the GRPCs will be available at LPC during the internship, he/she could also get involved in their qualification in a cosmic test.

The internship will be performed in close interaction with COMET collaborators from KEK and Imperial College London and it can be followed by a summer internship at KEK and a PhD on cLFV search within the COMET group at LPC.