論文題目要旨

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論文題目：A Study of Optimization of Sensitivity and Backgrounds for the COMET Phase-II

論文要旨：

The "COherent Muon-to-Electron Transition" (COMET) experiment, conducted at the Japan Proton Accelerator Research Complex (J-PARC), aims to detect the rare Charged Lepton Flavor Violation (CLFV) process $\mu^- N \to e^- N$ conversion in a muonic atom of aluminium. This process, suppressed in the Standard Model to $\mathcal{O}(10^{-54})$, serves as a sensitive probe for new physics beyond the Standard Model. COMET is conducted in phases, with Phase-II being the focus of this thesis following COMET Phase-I. The initial goal of COMET Phase-II was to achieve an upper limit sensitivity of $\leq 7 \times 10^{-17}$ at 90 % confidence level (C.L.), which is four orders of magnitude better than previous measurements. This thesis presents significant refinement to the COMET Phase-II project, enhancing experimental sensitivity through improvements in muon beam intensity and muon stop rate. Firstly, this thesis investigate high-efficiency pion production. The analysis shows that the production of low-energy pions is limited by the compromise between the range-momentum curve of low-energy pions and the initial pion momentum spectrum. The results reveal that the pion production spectrum at higher momentum cannot compensate for the limitations given by the range-momentum curve of pions. A potential further improvement in low-energy pion production could be achieved with an ideally narrow proton beam. In order to enhance muon stop rate, significant advancements have been made in the optimization of the muon stopping target system. This includes a detailed analysis of the system, focusing on the muon yields in stopping target and signal acceptance in the detector. The combination of these refinements yields a final expected Single Event Sensitivity (SES) of $\sim 7 \times 10^{-18}$ or an upper limit of $\leq 1.6 \times 10^{-17}$ at 90 % confidence level, assuming no background events are observed. This corresponds to an overall improvement factor of about four compared to the previous sensitivity of COMET Phase-II. A detailed analysis of background source, including intrinsic physics, Beam-related Delayed, Beam-related Prompt, and Cosmic-ray induced backgrounds, along with their estimation methodologies, provide an estimated background of 0.49 events. With the heightened sensitivity, COMET Phase-II will become competitive in high-intensity measurements, positioning itself as a leading contender among future CLFV searches. These refinements enhance the potential for discovering new physics beyond the Standard Model.