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# Progress of Muonium-to-Antimuonium Conversion Experiment (MACE)

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In the standard model (SM), neutrinos are massless and lepton flavor is conserved. However, the discovery of neutrino oscillations indicates that neutrinos are massive and there is lepton mixing. On the one hand, tiny neutrino masses result in extremely low weak-interaction-induced lepton flavor violation branching ratio, making it impossible to observe. On the other hand, if the tiny neutrino masses are generated in the SM, the corresponding Yukawa coupling strength would be extremely weak. Therefore, it is believed that there are new physics related to the neutrino masses. The new particles and interactions in these new models may induce the charged lepton flavor violation (cLFV). The lepton flavor experiment searching for these processes is a sensitive probe for new physics. Muonium is a bound state consisting of a positive muon and an electron, and can be considered as a leptonic isotope of hydrogen. There are new physics predicting the existence of the muonium conversion process, a cLFV process that a muonium spontaneously converts into an anti-muonium, which violates the lepton flavor or lepton number by 2 units. The search for this process can further constrain the parameter space of related new scalar or vector bosons that carrying two $\mathrm{U}(1)$ charges. Therefore, it can be complementary to the search for the $\mu e$ conversion, $\mu \to e\gamma$, $\mu \to eee$ and other cLFV processes that violate the lepton flavor by only 1 unit. The latest result of the muonium conversion was established in 1999, and no new experiments have been proposed for more than 20 years thereafter. The sensitivity of muonium conversion experiment is limited by the background level and muon yield. Over the past 20 years, with the development of detector technology, muon targetry, and muon beam, we believe there is a great opportunity to do substantially better. The proposed MACE experiment aims to improve the upper limit of muonium conversion by more than two orders of magnitude by improving muon yield and detector performance, and is expected to reach the order of $10^{-14}$, providing more evidence for new physics related to cLFV.

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