【Grant-in-Aid for Specially Promoted Research】

Science and Engineering

Title of Project： Advance on the Research of Charged Lepton Flavor by using a High-Intensity Muon Source

AOKI Masaharu
(Osaka University, Graduate School of Science, Professor)

Research Project Number : 21H04971 Researcher Number : 80290849
Term of Project : FY2021-2025 Budget Allocation : 488,300 Thousand Yen
Keyword : particle physics, muon, rare decay, charged-lepton flavor

【Purpose and Background of the Research】

The Standard Model of Particle Physics (SM) has been successfully established by many experimental evidences including the discovery of a Higgs particle. However, it does not mean that we understand and can-explain every phenomenon in the universe. Everyone believes the existence of new physics beyond the Standard Model of Particle Physics (BSM), and is groping how to break through toward it. A Charged-Lepton Flavor Violation (cLFV) is strongly suppressed in SM, while there is no primary principle that forbid cLFV in the universe. It is conceivable that well-designed experiments will achieve sensitivities high enough to observe cLFV eventually.

The purpose of our project is, in order to advance the forefront of our knowledge toward BSM domain, to realize an experiment searching for one of cLFV processes, a muon-to-electron (μ-e) conversion, and make progress in physics of charged-lepton flavor. We aim to achieve 3×10^{-15} of a single-event sensitivity for the μ-e conversion, and shall look-over BSM in the energy scale over PeV.

【Research Methods】

A negative-charged muon (μ^-) hit on an aluminum plate loses its energy and is trapped in the 1s atomic orbit of an aluminum atom. The atom with a μ^- in the orbit is called a "muonic atom", and the μ^- in the ground state of the muonic atom is usually "sinking in" the nuclear field of the nucleus. If there exist any cLFV processes, the muonic atom shall go through $\mu^- + \mathrm{Al} \longrightarrow e^- + \mathrm{Al}$ reaction to produce a mono-energetic election with 104.97 MeV. This characteristic electron is the signal of the μ-e conversion we are searching for.

Comparing to the other types of cLFV reactions and experiments other than the μ-e conversion, there are two big advantages in our method: unprecedented sensitivity by using light-particle muons that can be mass-produced, and utilization of muon reaction in the nuclear field. These allow us to research BSM more comprehensively.

The experimental setup that we will construct and use is shown in Figure 1. We will utilize the innovative high-intensity muon beamline (μBL) at J-PARC, will construct an experimental platform (μEP) optimized for it, and will install a radiation-tolerant detector system to precisely measure the momentum of electrons. We will perform physics data taking and analysis to discover the rare event that unambiguously prove the existence of the μ-e conversion. Based on the wisdom of our group accumulated in past experiences, we aim to improve our physics sensitivity from lesser to greater step-by-step as we produce physics results and learn the behavior of the experimental method and the nature of the backgrounds.

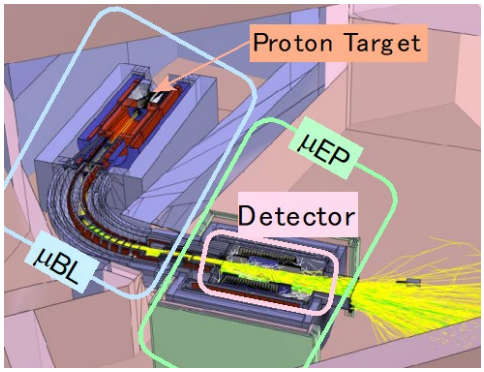

Fig. 1 Experimental Setup

【Expected Research Achievements and Scientific Significance】

It is conceivable that the cLFV signal shall be observed firstly in the world with this project. Its impact on the field of particle-, nuclear- and cosmological-physics is quite significant. Even if it is not observed, the improved upper-limit should provide us indispensable information to understand the nature of BSM. By taking combination between our result with $\mu^+ \longrightarrow e^+\gamma$, $\mu^+ \longrightarrow e^+e^+e^-$, τ-LFV and lepton-universality observations, remarkable progresses in our understanding to the physics at high-energy scale that we cannot directly reach yet shall be expected.

【Publications Relevant to the Project】

- The COMET Collaboration, "COMET Phase-I technical design report", Prog. Theor. Exp. Phys. 2020, 033C01 (2020).
- A. Aguilar-Arevalo, M. Aoki, M. Blecher *et al.*, "Improved Measurement of the $\pi \rightarrow e\nu$ Branching Ratio", Phys. Rev. Lett. 115, 071801 (2015).
- The COMET Collaboration, "Conceptual Design Report for Experimental Search for Lepton Flavor Violating $\mu^- e^-$ Conversion at Sensitivity of 10^{-16} with a Slow-Extracted Bunched Proton Beam (COMET)", a document submitted to J-PARC PAC, 23rd June 2009.

【Homepage Address and Other Contact Information】

https://comet.kek.jp
aokim@phys.sci.osaka-u.ac.jp