【Grant-in-Aid for Scientific Research (S)】

Broad Section B

Title of Project： **Precise measurement of the mass and magnetic moment of muon using electromagnetic traps and the search for new physics**

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Research Project Number: 20H05646 Researcher Number：60242103

Keyword：muon, muonium, Penning Trap

【Purpose and Background of the Research】

The Standard Model of elementary particles, which describes the basic building blocks of matter and their dynamics, was completed not only theoretically but also experimentally with the discovery of the Higgs boson. However, the model contains a number of problems, such as the fact that it contains too many parameters and does not include particles that are responsible for dark matter. There should be a new physics beyond the Standard Model of elementary particles that solves these problems. An experimental technique that is gaining more and more attention as an effective method to look for signs of this is the ultra-precise measurement of a single particle or two body systems. Muons, with their moderate mass and lifetime, are ideal for verifying the Standard Model to the highest degree and, above all, as probes to search for new physics. In fact, the muons have been studied for many years in the world, and nowadays, there are some physical phenomena, including the muons, that are difficult to explain by the Standard Model.

【Research Methods】

Our ultimate goal is to carry out two interrelated precision measurement on muons. The first is to measure the Zeeman sub level of muons (positive muon and electron bound system) under precise high magnetic field, to determine the hyperfine structure of muons (1 ppb) and the magnetic moment and mass of muons (about 5 ppb) with an accuracy of more than an order of magnitude higher than that of the previous studies. The other is a new measurement of single-particle muons by combining an ultra-slow muon beam and the Penning trap technique to determine the magnetic moment and mass of the muons with the highest accuracy (2 ppb), completely independent of muonium. The measurements will utilize the ultra-slow muons that have been developed at J-PARC. The muons are almost stationary and, in the case of our measurement, the generation and transport of the muons are carried out under a high magnetic field, which allows us to use a 100% polarized beam. The superconducting magnet used in the muon hyperfine structures measurement can provide a uniform static field up to 2.9 T and will be used as a spin-polarizing and trapping field for very slow muons (Fig. 1). In addition, the distance from the very slow muon source to the measurement area is as short as 50 cm, and it can be transported without beam loss at a low accelerating voltage of about 5 keV. The decay positrons are used as the muon spin signal. We ensure high accuracy by ensuring that the positron statistics are available. Preliminary simulations show that if, for example, an ultra-slow muon is rotated by a magnetic field flipper with 90° of polarization, and 10^{12} rotations under high magnetic fields are observed, the magnetic moment can be determined with an accuracy of 1 ppb from the statistics alone. This is achieved in about 100 days. The muon masses can also be measured independently with the same accuracy by measuring the 180° reversal of the muon spin in the trap.

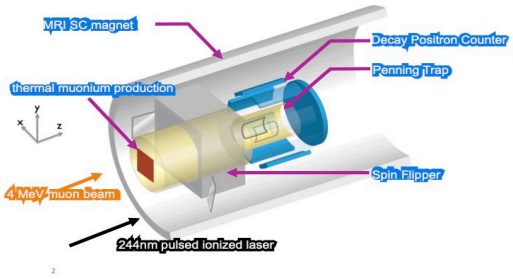

Figure 1 Concept of Muon Trap

【Expected Research Achievements and Scientific Significance】

We will synthesize these results and compare them with the ongoing muonium 1s-2s energy level difference and muon anomalous magnetic moment measurements, as well as with various theoretical models, in order to search for new physics beyond the Standard Model.

【Publications Relevant to the Project】

・K. Shimomura, *Muonium in J-PARC; from fundamental to application* Hyperfine Interactions 233,89-95 (2015)

・H. A. Torii, S. Kanda, K. Shimomura, P. Strasser *et al. Precise Measurement of Muonium HFS at J-PARC MUSE*, JPS Conf. Proc. 8 (2015) 025018(1-6).

【Term of Project】 FY2020-2024

【Budget Allocation】 151,100 Thousand Yen

【Homepage Address and Other Contact Information】

https://www2.kek.jp/imss/msl/