Muχe
A Familon Search Experiment Using HPGe Detectors

D. Koltick, S. Huang, J. Chen, F. Bergin, H. Cao

Department of Physics and Astronomy, Purdue University
West Lafayette, Indiana, USA 47907
April 21, 2021

Fermilab Workshop: Potential Fermilab Muon Campus and Storage Ring Experiments

Abstract

A major puzzle of the standard model is the observation of quark and lepton replicated families. There are 3 possible options to explain family symmetry [1-4], via; discrete symmetries, continuous and local gauge symmetries, or finally, continuous and global gauge symmetries. The first leads to Domain Walls outside the research of particle experiments. The second is highly constrained. It is the possibility of broken global family symmetries which leads to Nambu-Goldstone bosons, called ***Familons***. Such a symmetry can be Abelian or non-Abelian.

The coupling of Familons at low energy is determined by the non-linear realization of the family symmetry,

$$\frac{1}{F}\partial_\mu f^a \bar{\varphi}_L^i \gamma^\mu T_{ij}^a \varphi_L^j$$

Where F is the family symmetry breaking scale, f ^{a} are the Familons, and T ^{a} are the generators of the broken symmetry. Such an interaction leads to the decay

$$\mu \rightarrow \chi_{familon} + e$$

A number of searches have been carried out [5-9] for Familons with the best limits at $\sim 10^{-5}$ muon braching ratio. However, these are set by observing stopped muons in magnetic spectrometers. The failing of these instruments is the inability to track low energy positrons having kinetic energy in the sub-MeV to several MeV range. This deficiency leaves a hole in the search window for Familon masses near the mass of the muon. This region is accessible to scintillation or crystal detectors which contain the stopped muon and observe its decay products. The most accurate experiment reported in the search window hole was completed in the 1960s using a bubble chamber [7].

We propose to search for two body muon decay to a Familon in the mass range from 90 to 105 MeV/c^2, by observing stopped positive muons. This mass region is the search window blind spot of magnetic spectrometers. The search signal will be a mono-energetic positron peak on top of the standard model muon Michel decay spectrum. The decay positron spectrum will be measured in HPGe detectors surrounded by large volume NaI detectors and a charged particle tracking system used to help reduce false triggers. This short-term experiment requests 10^8 stopped positive muons at a rate of 200cps over a period of 2-weeks with a trigger to stopped muon ratio of 10:1 or better. This experiment will reach branching ratio sensitivities of 10^{-6} for Familon mass near the muon mass.

References

[1] F, Wilczek, Phys. Rev. Lett. **49** (1982) 1549
[2] D. Dicus et. al., Phys. Rev. D **18** (1978) 1829
[3] S. Adler et. al., Phys. Rev. Lett. **79** (1997) 2204
[4] J.L. Feng, T. Moroi, H. Murayama, and E. Schnapka, hep-ph/9709411
[5] D. Bryman and E. Clifford, Phys. Rev. Lett. **57** (1986) 2787
[6] R. Bilger et. al., Phys. Lett. B **446** (1999) 363
[7] S. Derenzo, Phys. Rev. **181** (1969) 1854
[8] R. Bayes et. al., Phys. Rev. D **91** (2015) 052020
[9] A. Aguilar-Arevalo, et. al., Phys. Rev. D **101** (2020) 052014