A PRECISION MEASUREMENT OF THE POSITIVE MUON LIFETIME USING A PULSED MUON BEAM AND THE μLAN DETECTOR

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R-99-07, BERKELEY[1] – BOSTON[2] – ILLINOIS[3] – JAMES MADISON[4] – KENTUCKY[5]

The goal of μLan (Muon Lifetime ANalysis) is a 1-ppm measurement of the positive muon lifetime, τ_{μ^+}, resulting in a 20-fold improvement over previous efforts. This will lead to an increased precision in the determination of the Fermi constant, G_F, by an equal amount. The rate of any electroweak process is determined by G_F. Such an undertaking is challenging and in keeping with a recent trend to improve the precision of measurement of the fundamental parameters of the standard model. Until recently the extraction of G_F from muon lifetime data has been restricted by uncertainties in the standard model theory. With modern calculations, this roadblock has been removed, and the only factor limiting further improvement is the experimental precision on the muon lifetime measurement.

In order to carry out the experiment, and to anticipate future related efforts such as high-precision μp capture, we are designing a beamline appendage for πE3 and a state-of-the art decay spectrometer. The idea is to impose a time structure on the πE3 surface muon beam by introducing a fast "kicker" similar to the successful MORE development. The new kicker parameters are being designed to transmit beam to target for 1 μs, followed by a beam-off time of 20-50 μs with an extinction factor aimed at better than 0.1%. During the beam-on collection period, approximately 15-20 muons will arrive on a depolarizing, solid target located at the center of a symmetric detector. The decay period, with beam off, is used to measure positrons in the 180 individual triangular-shaped scintillator pairs. The global structure of the detector was slightly modified to a 32-faced truncated icosahedron as shown in Fig. 1. The PMTs will be read out by custom 500 MHz waveform digitizers and a bank of online processors will be employed to fit pulse shapes in order to determine decay times. Due to the immense data volume, only a fraction of the data will be permanently stored.

Since R-99-07 was approved, we have made three short runs in πE3 in order to study the beam and to test prototypes of our detector and target designs. Our most recent 2001 runs were used to measure carefully beamline properties of πE3. In particular, a direct measurement of the phase space under a variety of slit configurations. We have also spent considerable time modelling the beam with standard tools such as Transport and Turtle and part of our beamtime was used to test various predictions of these model tunes. With the accumulated information, we are confident that a kicker design can be made in 2002 and we plan to test a mock-up kicker during our next beamtime allocation.

Based on initial studies both at PSI and at our laboratory, we have evolved the original μLan detector design. The individual detectors have proceeded through five iterations in order to optimize the lightguides and minimize their mass. The present version exceeds specifications outlined in the proposal. The global counter geometry has been modified from an original icosahedron superstructure to the 32-sided shape shown in Fig. 1. We have conducted PMT stability tests and have identified good candidate tubes.

Specific accomplishments since the initial submission of the proposal include:

- A thorough investigation of both old and new πE3 tunes has been made and the phase space and muon flux have been measured as a function of horizontal and vertical slit settings.
- Sulfur and silver targets, located inside magnetic fields, were used to study the stopped muon residual polarization using two magnet designs. Detector prototypes were read out using waveform digitizers. Design work on the new digitizers has reached the "schematic for prototype" stage.
- A GEANT4 simulation of the experiment has been developed.
- Funding for the experiment has been obtained from a U.S. National Science Foundation Major Research Instrumentation award.
- The Collaboration has been strengthened significantly with the inclusion of experienced groups from UC-Berkeley, James Madison, and Kentucky.

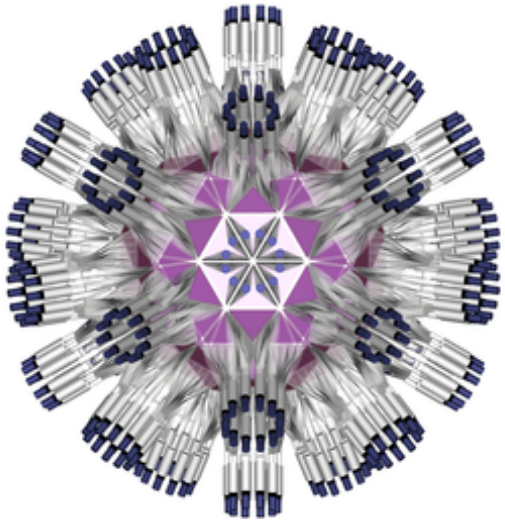

Figure 1: 3D view of the μLan detector.