Precision Measurement of the Positive Muon Lifetime with the μLan Detector

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The μLan collaboration is measuring the lifetime of the positive muon, τ_μ, to a precision of one part per million (ppm). This quantity is closely related to the Fermi constant G_F, which describes the strength of the weak interaction:

$$\frac{1}{\tau_\mu} = \frac{G_F^2 m_\mu^5}{192\pi^3}(1+\delta q) \; .$$

The theoretical uncertainty of the QED radiative corrections included in δq has been improved from 30 ppm to 0.3 ppm by the work of van Ritbergen and Stuart [1], so the extraction of G_F is now limited by the experimental error of 18 ppm on the muon lifetime. In addition, a precise measurement of τ_μ is needed in our determination of the rate of muon capture on the proton [2].

The μLan experiment uses a fast electrostatic kicker to impose a bunched structure on the continuous muon beam at the Paul Scherrer Institute, with $\sim$20 muons per bunch and a 5 μs/22 μs beam-on/beam-off cycle. The muons are stopped in the target region shown in Figure 1. The Michel electrons from the muon decay are then observed by the "soccer ball" of 174 scintillating tile pairs, shown in Figure 2, that surround the target.

One of the largest potential systematic errors arises from the "searchlight" rotation of the cone of decay positrons as the muon polarization is turned by the magnetic fields present in the target region. This uncertainty is minimized by choosing a target material, such as amorphous sulfur or the ferromagnetic alloy Arnokrome-3, with large, inhomogeneous internal magnetic fields in order to scramble the muon polarization.

In fall 2004, the experiment was successfully commissioned following substantial effort to reduce electromagnetic interference generated by the kicker modulator circuit to an acceptable level. Sufficient data were accumulated for a 5 ppm measurement of G_F and are presently being analyzed. Figure 3 shows a small sample of the lifetime spectrum which was collected. New 500 MHz waveform digitizer boards, which will provide improved timing and pileup rejection, are being prepared for installation, and production running time for the 1 ppm precision goal is anticipated to start in late 2005.

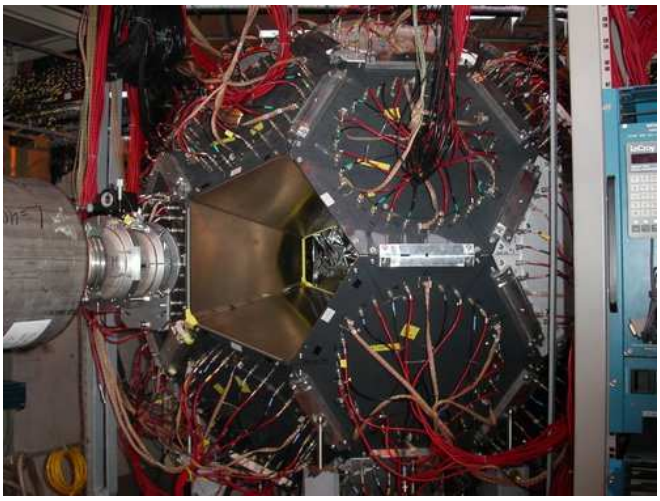

FIG. 2: The μLan apparatus, showing the end of the beamline and the positron detector housing.

[1] T. van Ritbergen and R. G. Stuart, Nucl. Phys. **B564**, 343 (2000).
[2] T.I. Banks et al., "The MuCap Experiment: A Precision Measurement of Muon Capture in Hydrogen", this volume.

FIG. 1: Inner region of the μLan detector, illustrating the AK-3 target produced by the Berkeley group.

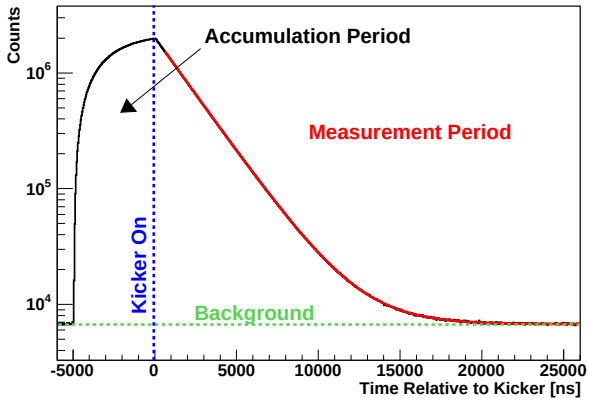

FIG. 3: Lifetime spectrum from a $\sim$10 minute run in fall 2004.