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

C.W. Arnold[4], R.M. Carey[2], S. Cheekatamalla[5], D. Chitwood[3], S.M. Clayton[3], K.M. Crowe[1], P.T. Debevec[3], M. Deka[5], S. Dhamija[5], W. Earle[2], A. Gafarov[2], B. Graf[2], F.E. Gray[1], K. Giovanetti[4], T. Gorringe[5], D.W. Hertzog[3], Y. Jia[5], P. Kammel[3], B. Kiburg[3], B. Lauss[1], I. Logachenko[2], K.R. Lynch[2], J. Mace[4], M. Hance[2], Y. Matus[2], J.P. Miller[2], F. Mulhauser[3], C.J.G. Onderwater[3], M. Ojha[5], C.S. Ozben[3], C.C. Polly[3], B.L. Roberts[2], A. Sharp[3], S. Tripathi[5], J. Wasserman[2], D. Webber[3], A.W. Werner[4], W.R. Wiita[4]

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The goal of PSI Experiment R-99.07.1 is to measure the positive muon lifetime to 1 ppm precision, thus determining the Fermi coupling constant G_F to 0.5 ppm. The experiment requires a high-intensity pulsed muon beam, which can be obtained from the πE3 beamline at PSI with the use of a fast electrostatic kicker. A large-acceptance spectrometer, having a high degree of symmetry, is used to detect positrons from muon decay. Raw signals are digitized at 500 MHz sampling and the information is processed and recorded by a fast data acquisition system. This past year has seen the development, construction and testing of several main components and a first τ_{μ^+} run successfully completed. Delays were incurred in the waveform digitizer production and in the completion of the kicker. Highlights of the effort are described.

Beamline Settings and Measurements: This year we finalized our beamline settings, a challenging effort because of the unusual demands of transporting a near-parallel beam through both the separator and kicker elements. Using a small scintillator attached to a two-dimensional translation stage, we measured a beam spot with horizontal and vertical widths of 1.28 cm and 1.18 cm, respectively. These setting were obtained at our optimal surface muon beam flux of 12 MHz.

Construction of the Electrostatic Kicker: The kicker beampipe, electrodes and the fast-switching high-voltage network were assembled for the first time immediately prior to our summer run. We used the system in two modes. The plate voltages were slowly ramped while we measured the deflection and extinction of the muon beam. An integrated extinction factor of 300 was achieved with the full 25 kV potential difference across the plates. Further optimization efforts were interrupted because a kicker high-voltage power supply failed. Pulsed-mode operation revealed significant high-frequency noise, both radiated and induced on the electrical connections. This noise unacceptably affected our experiment and that of neighboring setups. We removed the kicker, fixed the power supply, and started a noise-debugging program in a remote location. Improvements made reduced the noise by a factor of 100 reduction but we are striving for another factor of 10-50. To that end, the complete system is being transported to TRIUMF where controlled tests and adjustments can be made by the design engineers prior to the fall 2004 running period.

Construction of the μLan Detector: The construction of the μLan detector ball is now complete. All 340 detector elements were individually assembled and tested for light output and uniformity. They were paired and inserted in the 20 hexagon and 10 pentagon houses, which make up the "soccer ball" geometry of the detector. The assembly was fully instrumented and mounted on a custom support, which rests on fixed rails in the beam area. Electronics is located onboard, enabling μLan to be easily inserted or removed from the πE3 line (see Figure below).

Development of Custom Electronics: The experiment requires a bank of 340 waveform digitizers (WFD). A prototype 4-channel board was completed in spring 2003 and has been undergoing tests. However, problems with the software debugging code have stalled progress until quite recently. The debugging is now working and we are finally making rapid progress toward a full production in time for a fall run. Ancillary electronics units associated with the precision clock, its distribution to the WFDs, and programable gate generators associated with the kicker sequencing have been built and are working.

Fall Production Run: A five-week run in fall 2003 was used to commission the detector and to obtain τ_{μ^+} data using an unkicked cw muon beam. Leading-edge discriminators and CAEN multi-hit TDCs substituted for the WFDs. Our MIDAS-based DAQ provided readout and monitoring; data was stored on new RAID systems. Silver and sulfur stopping targets—centered inside a dipole magnet—were used to create data sets with a distinct precession signal. Alternatively, a new target material—Arnokrome 3, a metal composed of chromium, iron and cobalt—was used because its very high internal field of ≈ 1 T causes muons to precess faster than out nominal bin widths, effectively nulling out any residual polarization signal. We are developing our final target strategy around the use both target strategies.

Figure 1: Photograph of μLan detector installed in the πE3 beamline.