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

T. Banks[1], *E. Bartel*[5], *R.M. Carey*[2], *S. Cheekatamalla*[6], *D. Chitwood*[3], *C. Church*[5], *S.M. Clayton*[3], *K.M. Crowe*[1], *P.T. Debevec*[3], *S. Dhamija*[6], *M.L. Dantuono*[5], *W. Earle*[2], *R. Esmaili*[5], *A. Gafarov*[2], *B. Graf*[2], *F.E. Gray*[1], *K. Giovanetti*[5], *T. Gorringe*[6], *D.W. Hertzog*[3], *P. Kammel*[3], *B. Kiburg*[3], *B. Lauss*[1], *K.R. Lynch*[2], *R. McNabb*[3], *Y. Matus*[2], *J.P. Miller*[2], *F. Mulhauser*[3], *C.J.G. Onderwater*[7], *M. Ojha*[6], *C.S. Özben*[4], *Q. Peng*[2], *S. Rath*[6], *B.L. Roberts*[2], *D. Webber*[3],

R-99-07, BERKELEY[1] – BOSTON[2] – ILLINOIS[3] – ITU[4] – JAMES MADISON[5] – KENTUCKY[6] – KVI[7]

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 we have 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. Discriminated signals are processed by multi-hit TDCs (to be replaced, along with the discriminators, by 500 MHz waveform digitizers in the next production run) and the information is processed and recorded by a fast data acquisition system.

Beamline Settings and Measurements: We continued to develop and study optimal beam tunes, seeking maximal flux with the kicker off and excellent extinction with the kicker on. Additional work will be carried out in 2005, however, we have achieved useful tunes with extinction factors exceeding 500 and a flux of ≈ 10 MHz. The final quadrupole triplets were installed and the beam spot is approximately circular with a measured radius below 1 cm.

Repair of the Electrostatic Kicker: The four kicker modulators, beampipe and deflection plates were shipped to TRIUMF in January 2004 for a program of revisions aimed at RF reduction. The noise radiated by the kicker into the air and surrounding power grid is now 5000 times lower than generated by the original device. After these changes, no significant level of noise was detected with the kicker operated at full voltage at PSI, even in a wire chamber placed a few meters downstream. A new circuit was added to keep the flattop kicking voltage constant to better than 4×10^{-6} on each plate. In November, our first physics runs using the kicker began. After several days, a stack of high-speed MOSFET switching cards failed catastrophically, a problem that continued to reoccur every few days until the end of the run. Two of the four modulator cabinets were disabled and their MOSFET cards were used to supply the two active cabinets with working cards. The system was run at reduced voltage. The problems included inadequate high-voltage feedthroughs, which will be replaced, and a high sensitivity to any timing mismatch from the optical drivers that initiate switching. The engineers at TRIUMF have designed two protection mechanisms that also serves to reduce the sensitivity to timing errors. New MOSFETs have been ordered and the repair program has begun.

The μLan Detector: The μLan detector ball was completed in the summer of 2003 and first used in Fall 2003. Many PMTs exhibited occasional breakdowns, which were traced to a wrapping problem; in summer 2004, all assemblies have been modified. Clip lines were installed on the output of every PMT to reduce the pulse widths. A new entrance muon chamber (EMC), designed and built in collaboration with the PSI detector group, was successfully commissioned and used in the physics run. It performed flawlessly, even at rates exceeding 10 MHz. It is used to detect any muons that arrive during the measuring period, and it also provides the main beam diagnostic tool.

Development of Custom Electronics: The experiment requires a bank of 340 waveform digitizers (WFD). Problems with the first prototype prevented production in 2004 but initial tests on a recently fabricated prototype make us optimistic that all boards will be ready by the fall running period.

Fall Production Run: We took data for five weeks in the fall of 2004, dividing the time between setup, production, and dedicated systematic studies. Greater than 4×10^{10} positron events were recorded with the kicker in operation. Two stopping targets were employed: Arnakrome-3 (an alloy with a very strong internal B-field) and sulfur, which is well known for its small residual polarization. Our DAQ system was live more than 85% of the time and the raw data written to new local multi-TB RAID farms, and later transported to the PSI archive. The analysis is in progress and we aim for a physics result by the end of this year. An online lifetime plot, representing roughly 10 minutes of data taking, is shown in Figure 1. The filling and measuring periods are evident by the "charging" and "decaying" exponential shapes. The lifetime includes a secret offset, so the time unit is only approximately in ns.

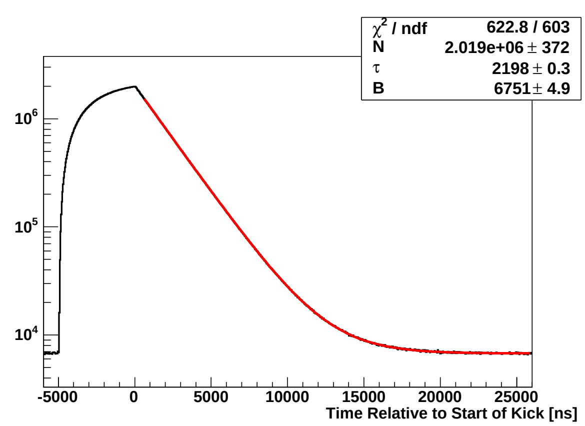

Figure 1: A typical online positron distribution with respect to the kicker cycle. A 3-parameter function is used to fit the decay portion of the histogram. To avoid bias, the time scale shown is only approximate.