TWIST: A High-Precision Study of Normal Muon Decay

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TWIST, the TRIUMF Weak Interaction Symmetry Test, passed several significant milestones during the past year. As of a year ago, nearly all of the wire planes, cathode foils, and front-end electronics had been completed, chamber modules were being assembled, and the mounting cradle that holds the chamber modules was under construction. In parallel, the superconducting magnet was nearing completion and was about to be energized. Since then, we have completed two in-beam engineering runs. For the first, during August, 2001, slightly more than half the wire chambers were mounted in the cradle and operated without magnetic field. For the second, during November-December, 2001, the complete wire chamber system was instrumented and operated within the full 2-T magnetic field.

The TWIST solenoid was powered within its yoke for the first time during late spring, 2001. Initial measurements when the magnet was at half field showed large and unexpected longitudinal and radial asymmetries in the magnetic field shape. It was also found that the power leads could not be retracted from the persistence switch with field on, increasing the liquid helium usage dramatically. Given these problems, the magnet was powered off for further study. Subsequent OPERA-3D simulations were able to reproduce the observed magnetic field shape very well, but only if they assumed the coil was misaligned substantially. The coil manufacturer also informed us that the problem with the power leads was symptomatic of the coil moving within the cryostat. The cryostat was disconnected from the power supply and moved from the yoke to a staging area where it warmed up. When it was opened, we discovered that two of the G-10 braces that support the longitudinal forces on the coil were broken, as were several welds that hold the support system in place. Subsequently, the support system was completely rebuilt, including the addition of load cells so that we can now monitor the forces on the coil as it is energized. The magnet was then reinstalled in the yoke and powered briefly in order to verify that the load cells showed no excessive forces. Then the cradle and detector were installed for the November engineering run. The magnet ran successfully at 2 T for two weeks during that run. Since then, the cradle and detector have been removed, a field mapping system has been installed, and detailed field mapping is underway.

Our original plan for the August engineering run had been to study the performance of half the detector system within a magnetic field, but the goals for that run needed to be scaled back due to the problems with the magnet coil. Prior to the run, slightly more than half of the full detector system, including a total of 3360 sense wires, was assembled in the cradle in the detector test facility. Subsets were powered to study the noise and cross talk of the electronics in detail. We found that the performance improved substantially when both the analog cables that connect the preamps to the postamps and the digital cables that connect the postamps to the fastbus were wrapped with properly grounded copper foil shields. The detector system was then moved to M13, where the electronics operated quietly the first time it was powered up. During the August run, we measured the efficiency and tracking resolution of the system without magnetic field, and found that they exceeded our specifications.

After that run, the detector system was moved from M13 back to the test facility, where the remaining modules were installed. The complete detector system, including a total of 5440 sense wires, was then installed within the magnet in M13 for the first time. When the electronics were powered up, three drift chamber wire planes were found to not work properly. Since the November run was meant to be the first test of the detector system within the magnetic field, and not a physics run, we chose to operate the detector with those three planes powered off, rather than expend the 1-2 weeks that would have been necessary to open the cradle and fix the problems.

The November test run was a substantial success. The wire chambers were found to perform essentially identically within the 2-T magnetic field as they do without field. This goal was one of the primary reasons we adopted DME as our chamber gas. The wire efficiencies for the 53 planes that were operating averaged > 99.7%, and only two wires in the full system were found to have efficiency slightly below 99%. The random noise was found to average < 20 counts/plane/sec at operating voltage. Both of these far exceed our requirements. At present, the drift distance resolution for the November data is 80-85 microns (sigma). This is limited by our knowledge of the differential delays between channels due to cabling and electronics. It surpasses our requirement of 100 micron resolution, and it continues to improve as the analysis proceeds. We also found that we could use our gas degrader system to adjust the muon range so that the surface muons stop reliably within the 18-mg/cm^2 thick target plane at the center of the detector. Figure 1 shows the positron energy spectrum from muon decay that was obtained in the counting house 6 hours after the first time the detector system was powered up at full magnetic field.

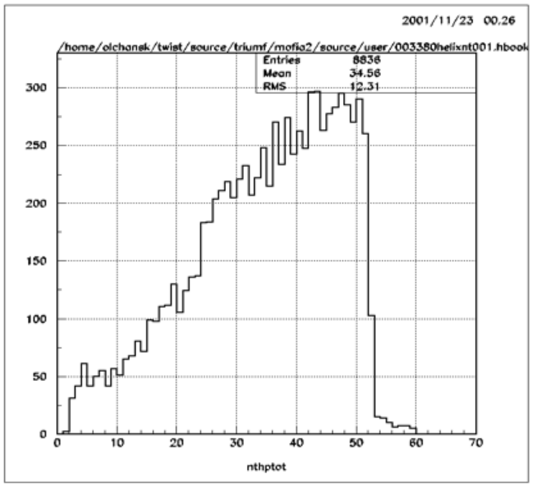

Figure 1: Positron energy spectrum from muon decay obtained 6 hours after the TWIST detector system was powered up at full magnetic field for the first time.

Our group continues to have major responsibilities for the TWIST tracking software. J. Musser has written the “first guess” pattern recognition code that isolates the positron hits in the wire chambers. K. Olchanski of TRIUMF has written the helical tracking code that takes the output from the first guess, resolves the left-right ambiguities in the drift chambers, and obtains the best fit. B. Jamieson has focused on code and cut verification, primarily through tests with Monte Carlo generated events, but recently also with real data from November. This team has made significant improvements in the analysis code recently, both by increasing the efficiency and improving the resolution for determining the kinematic properties of the decay positrons. At present, the code reconstructs ~99.5% of the positron decays that fall within our fiducial decay time, spacial and kinematic cuts. It performs extremely well on events that don’t contain delta rays or hard scatters of the positron. Figure 2 shows a recent positron reduced energy spectrum from the November data as the analysis has proceeded.

At present, final preparations are underway for the first TWIST physics run. It will begin in May. The goals of this run are to measure the Michel parameters rho and delta to 0.001 and to identify those problems that must be resolved to achieve another order of magnitude greater precision in the future.

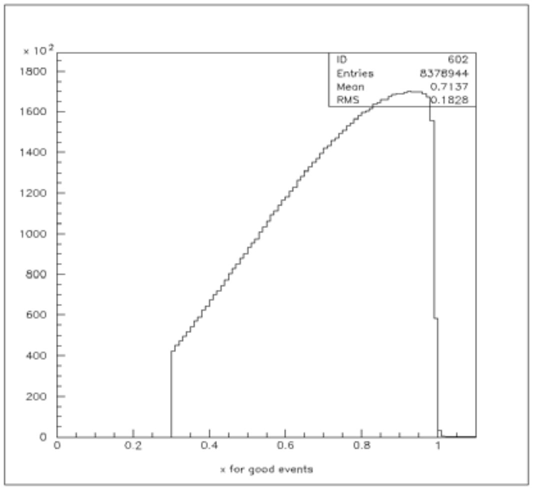

Figure 2: A recent positron reduced energy spectrum ($x = E/E_{max}$). This represents the subset of the data from the November engineering run that has been through the most recent full production analysis.