TWIST: Measuring the Space-Time Structure of Muon Decay

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This past year, TWIST completed its first measurement of $P_\mu\xi$, where P_μ is the polarization of the muon in pion decay and ξ is one of the four Michel parameters that characterize the energy and angular distributions of the positrons emitted in polarized muon decay. We find $P_\mu\xi = 1.0003 \pm 0.0006(\text{stat.}) \pm 0.0038(\text{syst.})$, consistent with the Standard Model expectation that $P_\mu\xi = 1$ and a factor of two more precise than the previous best direct measurement [1]. This analysis, which is based on data that were taken in Fall, 2004, was the Ph.D. research of Dr. Blair Jamieson of University of British Columbia. Our group did not play as direct a role in the $P_\mu\xi$ analysis as we have in previous and on-going TWIST measurements of the Michel parameters ρ and δ, but we nonetheless made important contributions during the estimation of the systematic uncertainties. A paper describing this measurement is being prepared.

The leading systematic uncertainties in the initial $P_\mu\xi$ measurement involve our understanding of the depolarization of the muons as they cross the fringe field of the solenoid magnet (±0.0033) and when they interact with the Al stopping target after they have come to rest (±0.0012). To evaluate and minimize these systematic uncertainties, it's valuable to have a reliable method to estimate relative changes in the muon polarization independent of our Michel parameter fits. For the initial $P_\mu\xi$ measurement, the integral forward-backward asymmetry within the Michel fit fiducial region was used for this purpose. Figure 1 illustrates its application to the 2004 data. After the black box had been opened and we were no longer blind to the value of $P_\mu\xi$, we proposed that an alternative calculation, performed by optimizing the fiducial and weighting each event with a power of the expected Standard

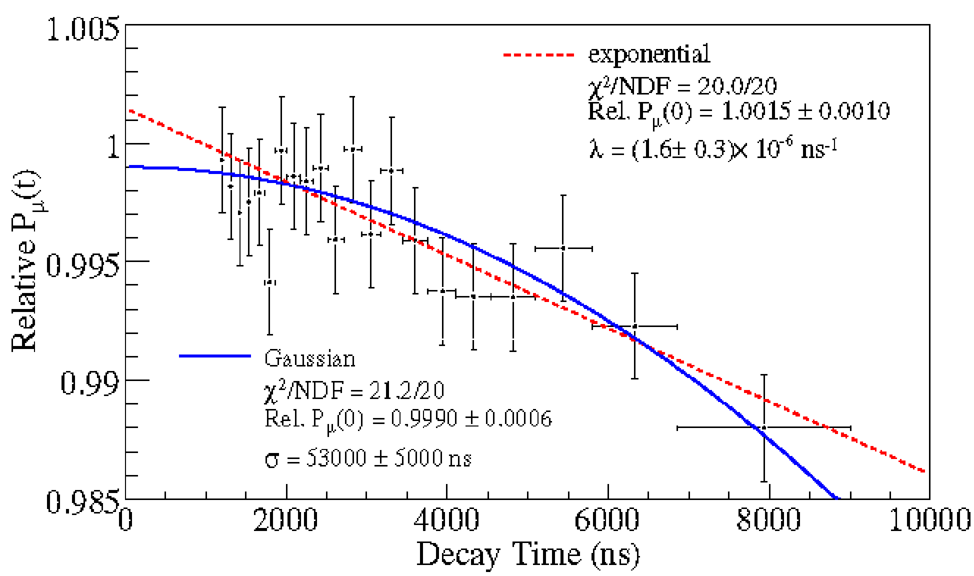

Figure 1. The relative muon polarization vs. decay time for the 2004 data, measured using the integral forward-backward asymmetry. The curves show two different extrapolations to t=0, assuming exponential and Gaussian forms for the depolarization.

Model asymmetry, would reduce the size of the statistical uncertainties by a factor of ~2. This new asymmetry calculation has now been adopted by the Collaboration for all future analyses.

During Fall, 2005, TWIST had an engineering run to see if more careful procedures for beam emittance measurements using the Time Expansion Chamber could reduce the uncertainties in the muon depolarization when crossing the fringe field. Two data sets were taken under "standard" conditions, and two additional data sets were taken with the field in the last beam line dipole magnet shifted by +6 Gauss. The results were very encouraging. The apparent polarization was consistent for each pair of data sets taken under similar conditions, as expected, and the change in the average polarization for the two data sets taken with the last dipole shifted agreed with the Monte Carlo prediction.

In parallel, Mr. Robert MacDonald of University of Alberta is reanalyzing the 2004 data to obtain improved measurements of ρ and δ. Several significant improvements have been implemented in our Monte Carlo simulation and helix fitting codes. Overall, these improvements are expected to reduce the systematic uncertainties in ρ and δ by a factor of ~2, compared to those in the analysis of the TWIST 2002 data [2,3]. The statistical uncertainties will be comparable to those in the previous analyses. One of us (CAG) has been working with Dick Mischke and Art Olin of TRIUMF to advise Mr. MacDonald during his analysis.

TWIST expects to take its final data during 2006-07. We anticipate the final precisions for the Michel parameters ρ and δ will be approximately ±0.0003. The final precision for $P_\mu\xi$ will be ±0.001 or better.

[1] I. Beltrami *et al*., Phys. Lett. B **194**, 326 (1987).
[2] J.R. Musser *et al*. (TWIST Collaboration), Phys. Rev. Lett. **94**, 101805 (2005).
[3] A. Gaponenko *et al*. (TWIST Collaboration), Phys. Rev. D **71**, 071101R (2005).