TWIST: measuring the space-time structure of muon decay

C. A. Gagliardi, R. E. Tribble, K. Williams, and the TWIST Collaboration

This past year, TWIST published 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 $P_\mu\xi = 1.0003 \pm 0.0006(\text{stat.}) \pm 0.0038(\text{syst.})$ [1], consistent with the Standard Model expectation that $P_\mu\xi = 1$ and a factor of two more precise than the previous best direct measurement [2]. The measurement was based on an analysis of muon decay data that TWIST recorded during Fall, 2004.

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. 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 [3,4]. They also permit an expansion of the experiment fiducial. This is illustrated in Fig. 1, which shows the difference between the measured downstream tracking efficiencies in data and Monte Carlo vs. polar angle. The match is excellent over the range $0.5 < |\cos\theta| < 0.92$, whereas previous TWIST analyses only considered $0.5 < |\cos\theta| < 0.84$. This leads to a significant reduction in the statistical uncertainty for the same number of recorded events. Mr. MacDonald is expected to complete his analysis this coming Fall. One of us (CAG) has been working with Dick Mischke and Art Olin of TRIUMF to advise Mr. MacDonald during his analysis.

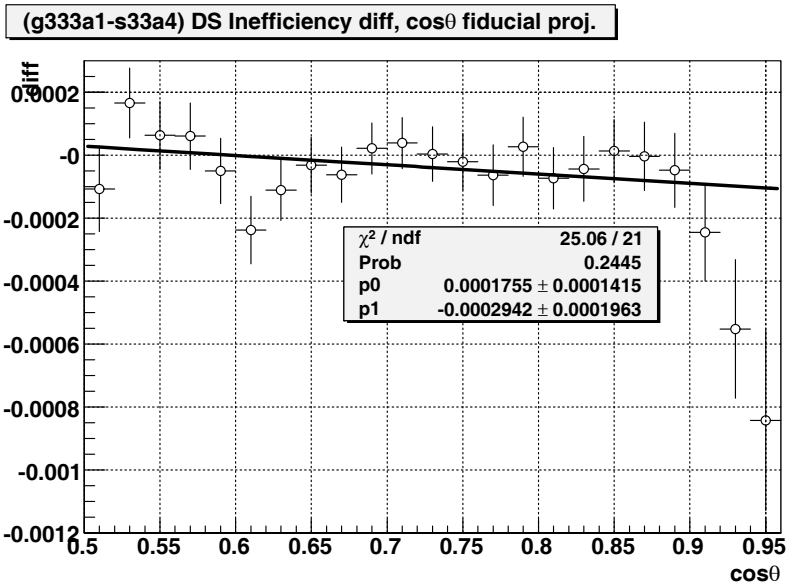

Figure 1. Difference between data and Monte Carlo for the efficiency of tracks in the downstream half of the detector as a function of polar angle. Each cos θ bin is integrated over the corresponding fiducial momentum range. The difference is essentially the same for upstream tracks.

During Summer, 2006, Ms. Kristen Williams, an REU student with our group, estimated the sensitivity of TWIST to a proposed non-local tensor interaction in muon decay [5]. The effects of this interaction are described in terms of a new muon decay parameter κ. κ makes a quadratic contribution to the normal Michel parameters ρ, δ, and $P_\mu\xi$, and also introduces additional linear terms in the unpolarized and polarized spectra. Previously, TWIST set a limit $|\kappa| < 0.024$ with 90% confidence, based on its quadratic contribution to δ [4]. Ms. Williams explored the contribution that κ would make to TWIST measurements of ρ, δ, and $P_\mu\xi$ when both the linear and quadratic effects are considered. She found that TWIST is more sensitive to positive values of κ than had been realized previously, and less sensitive to negative values. Overall, she found the previous TWIST measurements of ρ and δ limit κ to the 90% confidence range $-0.031 < \kappa < 0.012$. Ms. Williams' analysis procedures will be applied to determine κ in all future TWIST measurements.

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] B. Jamieson *et al*. (TWIST Collaboration), Phys. Rev. D **74**, 072007 (2006).

[2] I. Beltrami *et al*., Phys. Lett. B **194**, 326 (1987).

[3] J.R. Musser *et al*. (TWIST Collaboration), Phys. Rev. Lett. **94**, 101805 (2005).

[4] A. Gaponenko *et al*. (TWIST Collaboration), Phys. Rev. D **71**, 071101R (2005).

[5] M.V. Chizhov, hep-ph/0405073.