TRIUMF Weak Interaction Symmetry Test (TWIST)

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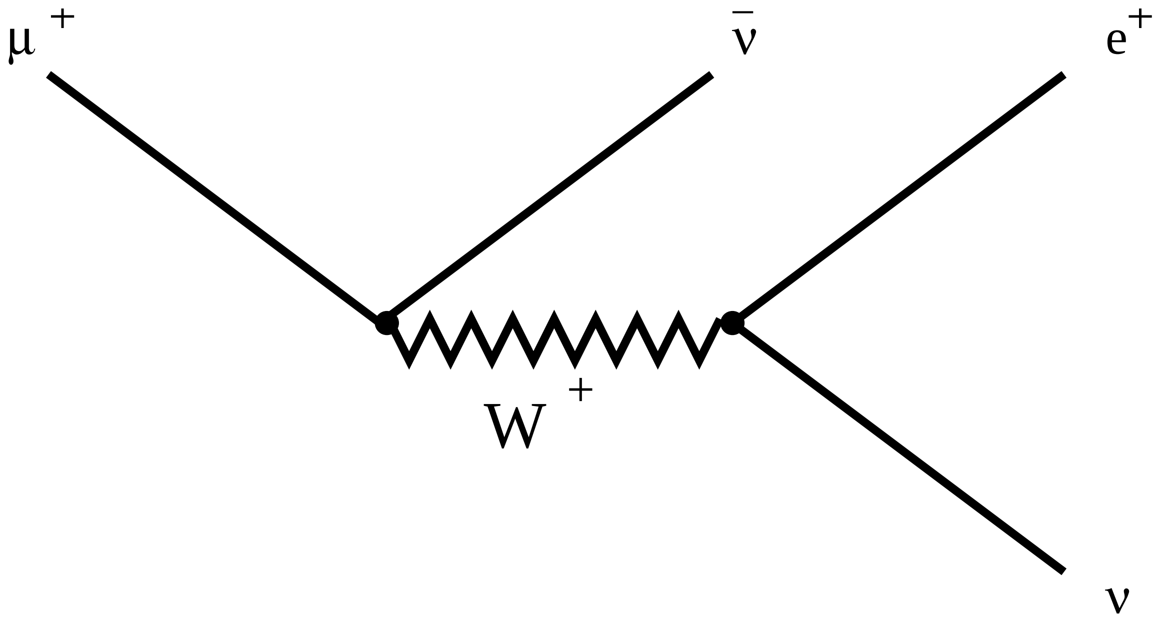
- Physics of μ^+ decay
- TWIST Detector
- Analysis
- Summary

Normal μ^+ decay



$$\frac{4G_F}{\sqrt{2}} \sum_{\substack{\gamma=S,V,T \\ \epsilon,\mu=R,L}} g^{\gamma}_{\epsilon\mu} \langle \overline{e}_\epsilon | \Gamma^\gamma | (\nu_e)_n \rangle \langle (\overline{\nu}_\mu)_m | \Gamma_\gamma | \mu_\mu \rangle$$

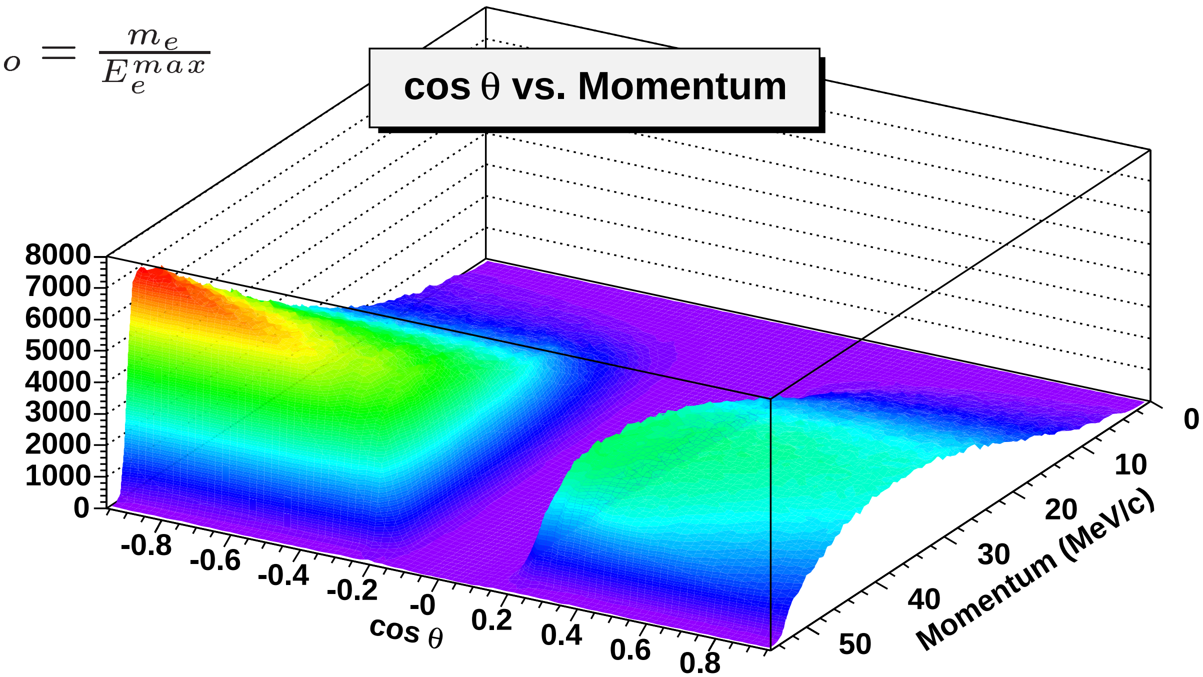
Muon Decay Distribution

$$\frac{d^2\Gamma}{dx\,d(\cos\theta)} \propto x\left[F_{IS}(x,\rho,\eta) + P_\mu \cos\theta F_{AS}(x,\xi,\delta)\right]$$

$$F_{IS}(x,\rho,\eta) = (x - x^2) + \frac{2}{9}\rho(4x^2 - 3x) + \eta x_o(1 - x)$$

$$F_{AS}(x,\xi,\delta) = \frac{1}{3}\xi(x - x^2) + \frac{2}{9}\xi\delta(4x^2 - 3x)$$

$x = \frac{E_e}{E_e^{max}}$ $\qquad x_o = \frac{m_e}{E_e^{max}}$



Muon Decay Parameter Values

$$\rho = \frac{3}{4} - \frac{3}{4}|g^V_{LR}|^2 - \frac{3}{4}|g^V_{RL}|^2 - \frac{3}{2}|g^T_{LR}|^2 - \frac{3}{2}|g^T_{RL}|^2 - \frac{3}{4}Re\left[g^S_{LR}g^{T*}_{LR} + g^S_{RL}g^{T*}_{RL}\right]$$

Standard Model: $g^V_{LL} = 1$, all others are zero

Parameter	Standard Model	World Average	(Year)
ρ	$\frac{3}{4}$	0.7518 ± 0.0026	(1969)
η	0	-0.007 ± 0.013	(1985)
ξ	1	$(P_\mu \xi)$ $1.0027 \pm 0.0079 \pm 0.0030$	(1987)
δ	$\frac{3}{4}$	$0.7486 \pm 0.0026 \pm 0.0028$	(1988)
$\frac{P_\mu \xi \delta}{\rho}$	1	> 0.99682 90% CL	(1986)

Standard Model Extensions

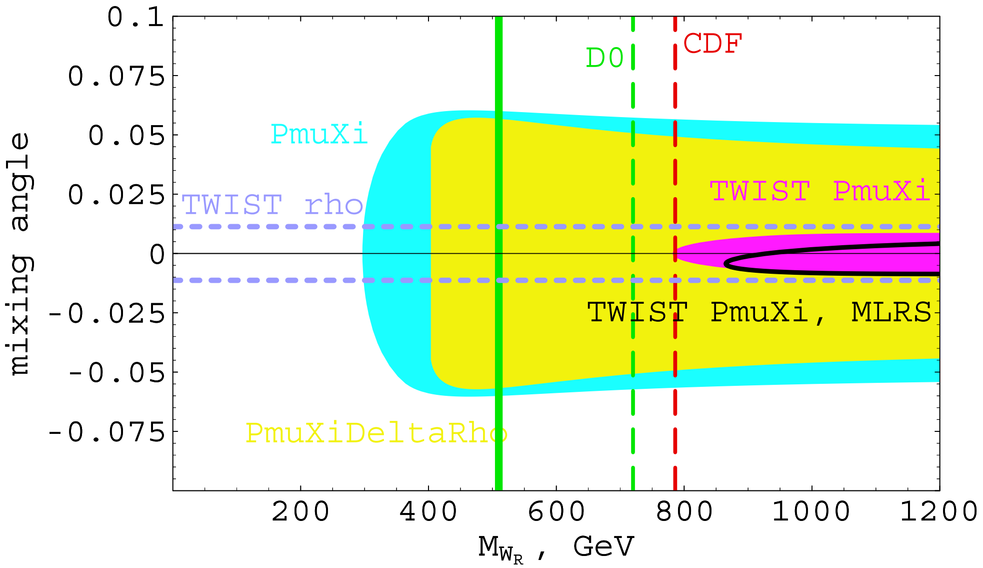
Example: Left-Right Symmetric Models

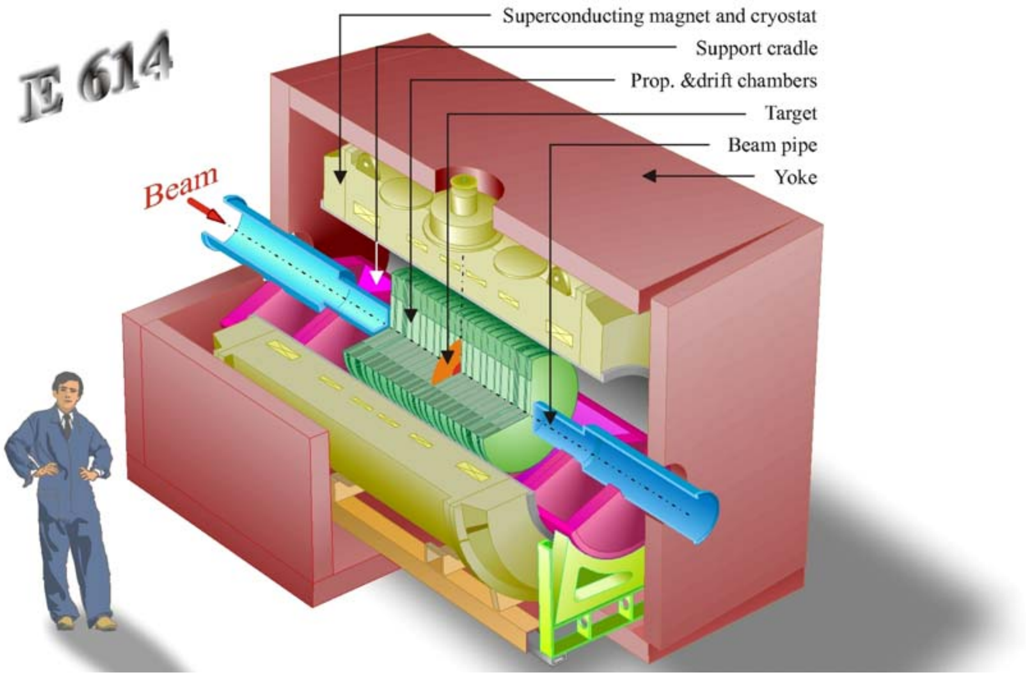
$$W_L = W_1 \cos\zeta - W_2 \sin\zeta \qquad W_R = e^{i\omega}(W_1 \sin\zeta + W_2 \cos\zeta)$$

$$\epsilon = \frac{M_1^2}{M_2^2} < 1$$

$$\zeta = \sqrt{\frac{1}{2} - \frac{2}{3}\rho}$$

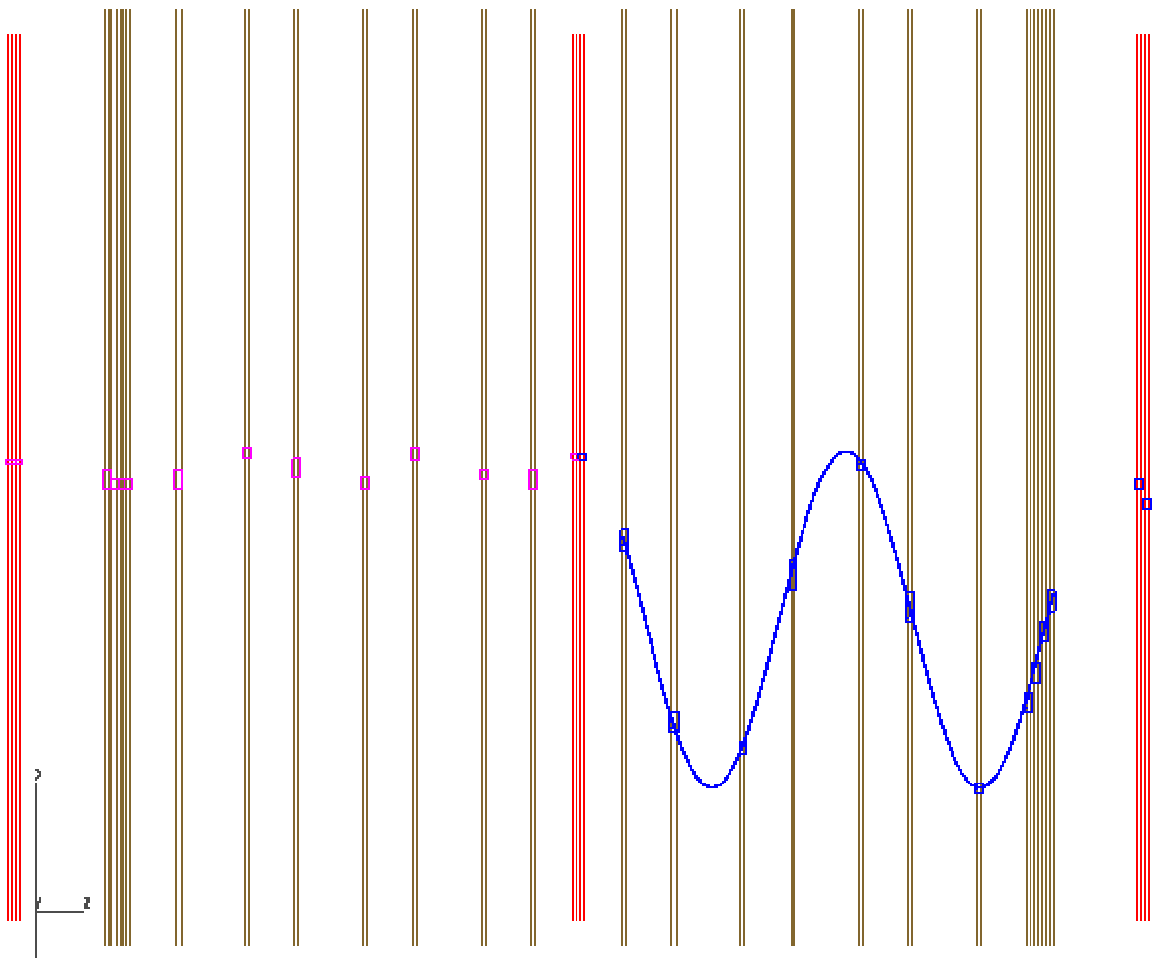
$$\epsilon = \sqrt{\frac{2}{3}\rho - \frac{1}{2}\xi}$$





- 44 drift chambers and 12 multiwire proportional chambers
- Thin – only $\sim 5 \times 10^{-5}$ X_o per chamber
- $\sim$ 5000 wires positioned with $\sim 3\mu m$ accuracy
- Longitudinal and transverse distances known to < 5 parts in 10^5.

Muon Decay Event



Analysis

- Data was collected in fall, 2002 for measurements of ρ and δ.
- Each data set has $\sim 6 \times 10^7$ events within the fiducial volume, sufficient for a statistical precision of better than a part in 10^3.
- Data will be fit with Monte Carlo generated spectra.

$$\left[\frac{d^2\Gamma}{dx\,d(\cos\theta)}\right]_{Data} = N\left\{\left[\frac{d^2\Gamma}{dx\,d(\cos\theta)}\right]_{(\rho_o,\eta_o,\delta_o,\xi_o)} + \sum_{\alpha\in\{\rho,\eta,\delta,\xi\}} \frac{\partial}{\partial\alpha}\left[\frac{d^2\Gamma}{dx\,d(\cos\theta)}\right]_{(\rho_o,\eta_o,\delta_o,\xi_o)} \Delta\alpha\right\}$$

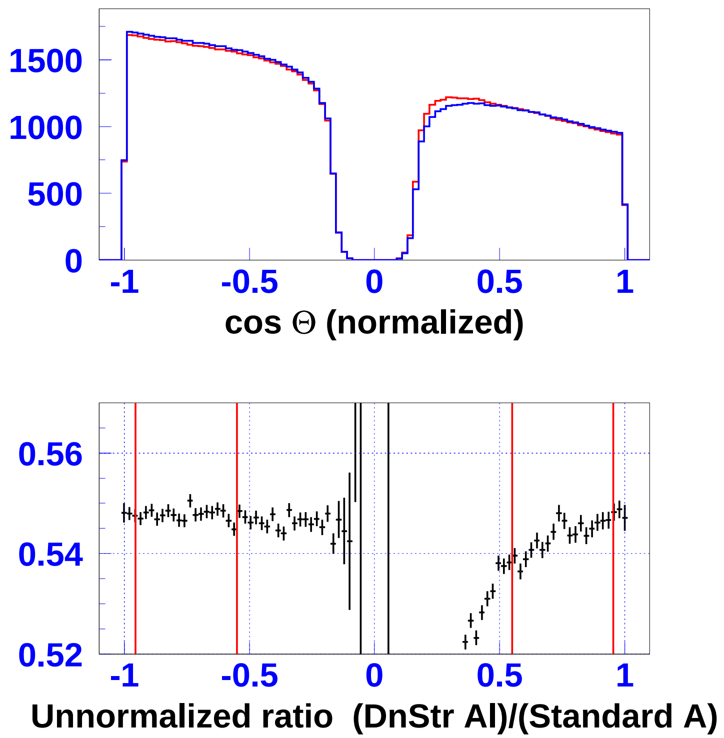
Evaluating Systematic Errors

Methodology: Exaggerate possible sources of error and measure the effect on the fit of the decay parameters.

Systematic Data Sets (Each a full data set)

- Drift chamber high voltage reduced by 50V and 100V–drift chamber efficiencies
- Proportional chamber high voltage reduced by 50V and 100V–proportional chamber efficiencies
- Different chamber gas density–μ^+ stopping position
- Various μ^+ trigger rates–separation of time overlapped events
- Different μ^+ polarization–upstream/downstream asymmetries
- Different beam e^+ rate–separation of extra particles
- Modified M13 beamline steering–transport of polarization and stopping position
- Aluminum and lucite installed downstream–effect of scintillator package
- Slightly upstream and downstream μ^+ stops–e^+ interactions in target
- Field varied by $\pm 2\%$–energy calibration

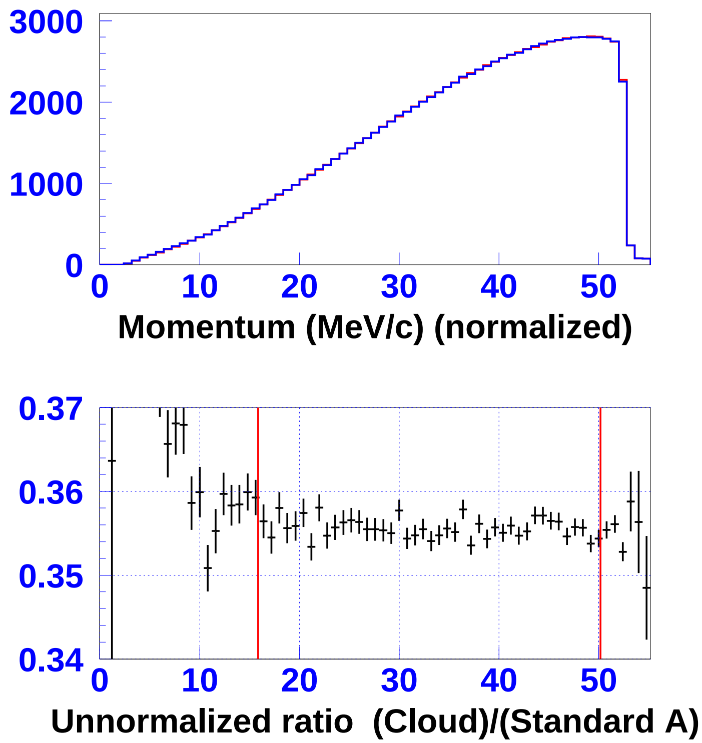
DnStr Al vs. Standard A



Events in Standard A data set 30534801

Events in DnStr Al data set 16499435

Cloud vs. Standard A



Events in Standard A data set 16112307

Events in Cloud data set 5730232

Summary

- The TWIST measurements will improve the limits on various extensions to the Standard Model
- TWIST has the opportunity to observe physics beyond the Standard Model
- The data has been taken for measurements of ρ and δ with statistical precision of better than a part in 10^3
- Full data sets have been taken to study a variety of possible sources of systematic errors
- Analysis of the data is underway

Right-handed Content of the Muon

The probability that the muon is right-handed, Q_R^μ, can be expressed as

$$Q_R^\mu = \frac{1}{4}|g_{RR}^S|^2 + \frac{1}{4}|g_{LR}^S|^2 + |g_{RR}^V|^2 + |g_{LR}^V|^2 + 3|g_{LR}^T|^2$$
$$= \frac{1}{2}\left[1 + \frac{1}{9}(3\xi - 16\xi\delta)\right]$$

(W. Fetscher and H.-J. Gerber)

Left/Right Symmetric Model Exclusion Plot