A Search for Rare Decays in the *TWIST* Muon Decay Spectrum

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Outline

- *TWIST*
- Motivation for the Exotic Decay Search
- Methodology
- Results and Conclusions

The *TWIST* experiment

*T*riumf *W*eak *I*nteraction *S*ymmetry *T*est

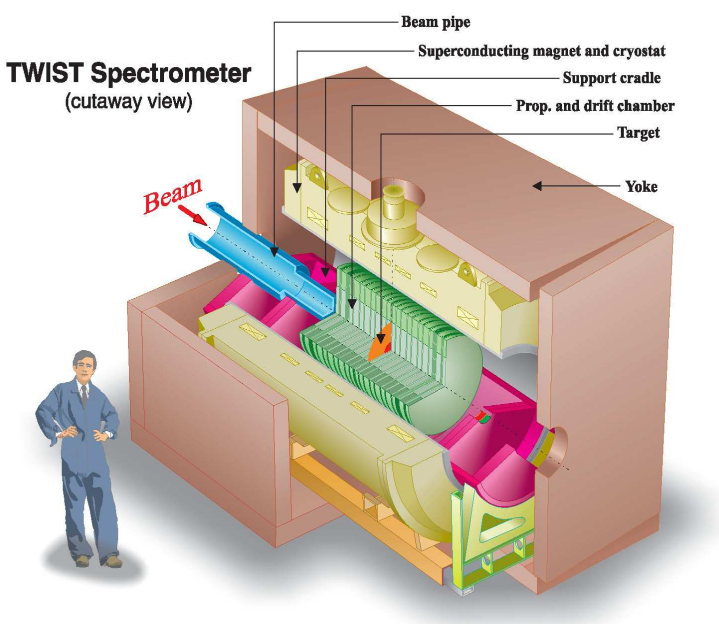
A collaboration of 40 members in Canada, Russia, and the United States.

- Tests the weak nuclear interaction through the process.

$$\mu^+ \to e^+ \nu_e \bar{\nu}_\mu$$

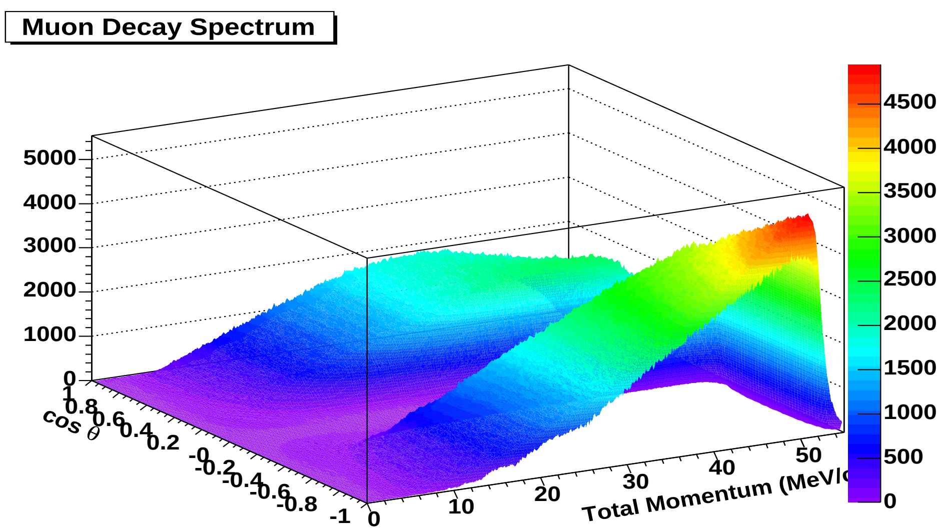
  by measuring the momentum and angle of e^+

- *TWIST* has produced a detailed measurement of the muon decay spectrum.
- Goal of *TWIST* is to measure the Michel parameters describing the decay spectrum to an unprecedented accuracy



Motivation

- Large statistical sample of muon decay events allows for a more comprehensive search for rare (or forbidden) muon decays than any previous search.
- No strong argument currently exists for the forbidding lepton flavor violating processes.



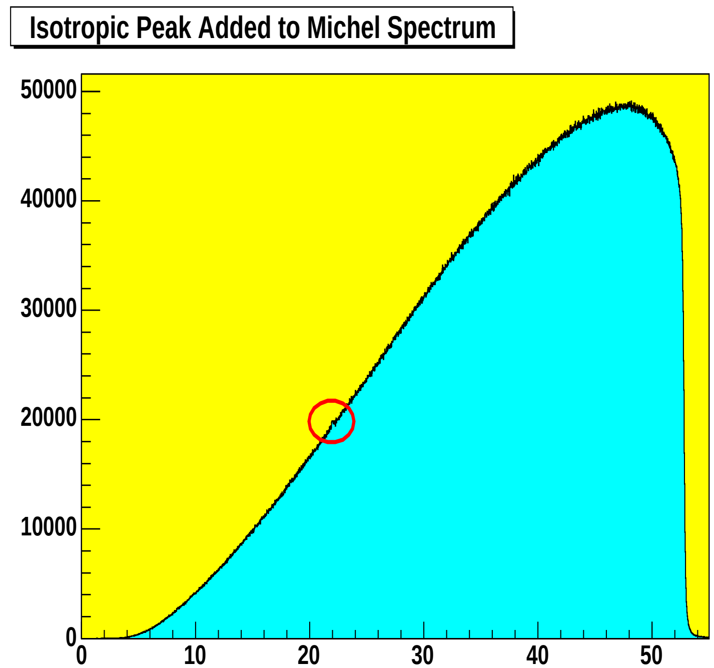
Search for Two Body Decays

Target decay is

$$\mu^+ \rightarrow e^+ X^0$$

where X^0 is an unknown boson mediating lepton flavor violation

- Assume the decay is isotropic.
- Assume the decay products are long lived.
  If $\tau >> 2.8 \times 10^{-21}$s the instrument response dominates the peak width.



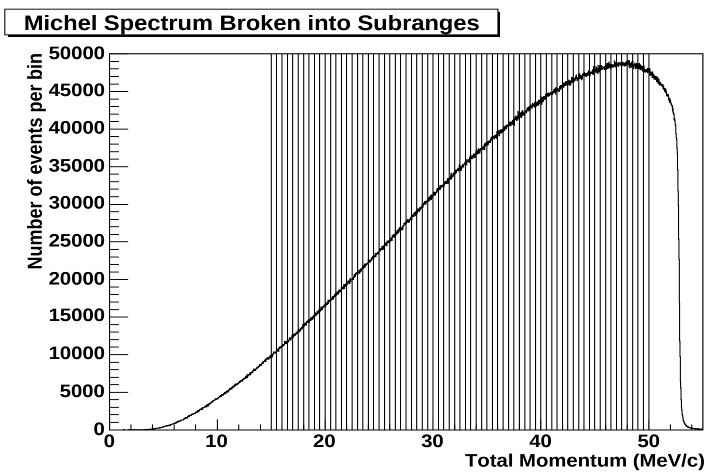
Branching ratio of shown peak: 8.37×10^{-6}

We want a confidence interval for the branching ratio of all accessible particle masses.

Previous 90% upper limit on this process is 3×10^{-4} (Bryman 1986)

Methodology for Our Search

- Divide momentum range into 70 subranges on the order of the momentum resolution.
- Fit the Michel spectrum plus a peak constrained to be within the each subrange.
- Define a confidence interval for the branching ratio corresponding to the peak.



Fitting Function

$$f(p,\cos\theta) = N_\mu(F(p,\cos\theta;\rho,\eta,\xi,\delta) + \Gamma_{X^0} H(p;\bar{p},\sigma(\bar{p},\cos\theta))\kappa(p,\cos\theta))$$

$F(p,\cos\theta;\rho,\eta,\xi,\delta)$ is the normal muon decay spectrum (Michel spectrum).

$H(p;\bar{p},\sigma(\bar{p},\cos\theta))$ represents the instrument response function

$\kappa(p,\cos\theta)$ represents the acceptance of the detector

Note that the parameters varied during the fit are

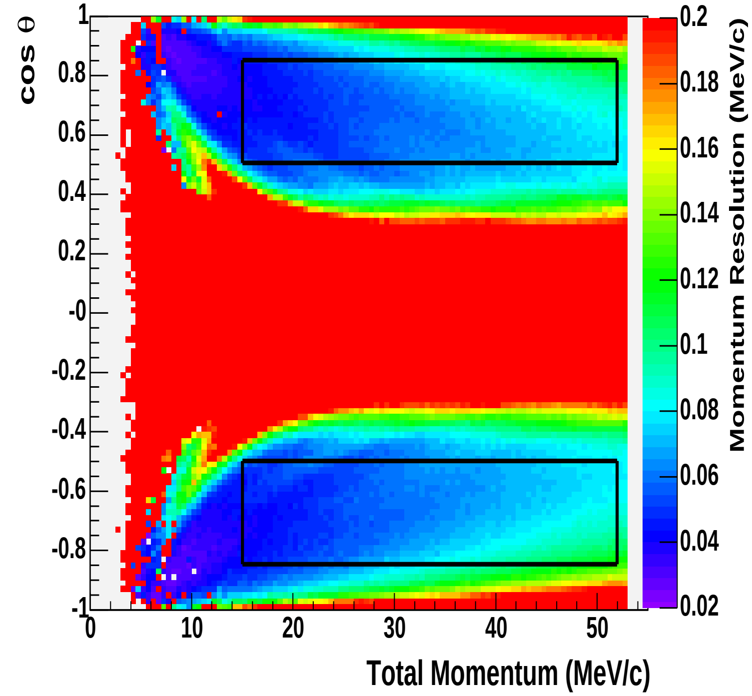
- The Michel Parameters; ρ, η, ξ, δ and the normalization N_μ.
- The mean peak momentum; $\bar{p}$
- The branching ratio for the unknown particle; Γ_{X^0}

This fitting method has been validated using Monte Carlo simulations.

Defining the Resolution

Momentum resolution of the detector measured using Monte Carlo

- Directly compare thrown track momentum to the reconstructed momentum
- Resolution dependent on the momentum and the angle of the positron



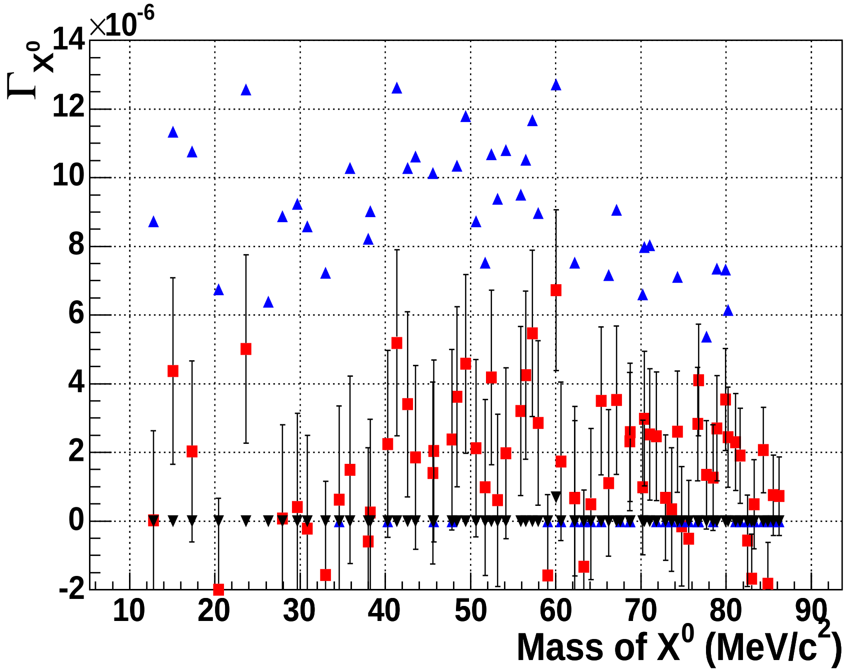
Confidence Intervals

Definition: The interval that has a given probability of containing the real value of an experimentally determined parameter

- Classical Neyman (frequentist) intervals do not necessarily cover the required intervals correctly; can lead to non-physical answers in the case of small signals
- Feldman Cousins method: Requires no *a priori* assumption on whether we are defining a interval or an upper limit. By construction requires the interval to be physically bounded.

  Calculation of the confidence interval separated from the fitting procedure.

Results



- Plot shows the branching ratios of 70 independent fits within fiducial range.
- Results indicate a 99% upper limit for the branching ratio on the order of 10^{-5}.
- Plot represents a fifth of the total data available.

Conclusions

- We can set a 99% upper limit for the branching ratio of a isotropic two body muon decay at a part in 10^5 for the available mass regime.
- No new statistically significant particles have been found so far.
- We can further restrict the branching ratio by using the full amount of data available from *TWIST*. This should increase our sensitivity by a factor of $\sqrt{5}$

Acknowledgments

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