A Two Body Decay Search in the TWIST Spectrum

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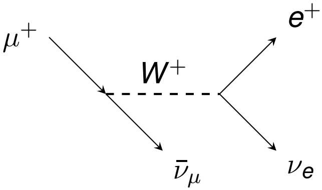
Outline

Flavour Violation in Muon Decays

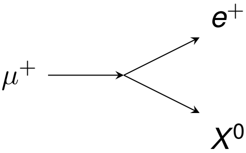
Standard model muon decay



- flavour symmetry an experimental requirement

General cLFV decays in vacuum

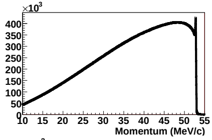
- flavour symmetry breaking results in the production of a boson



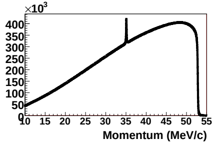
Kinematics of Two Body Decays

- Signal composed of decay positrons recoiling off X^0 at a single momentum

$m_X = 0$ global symmetry breaking



$m_X > 0$ local symmetry breaking

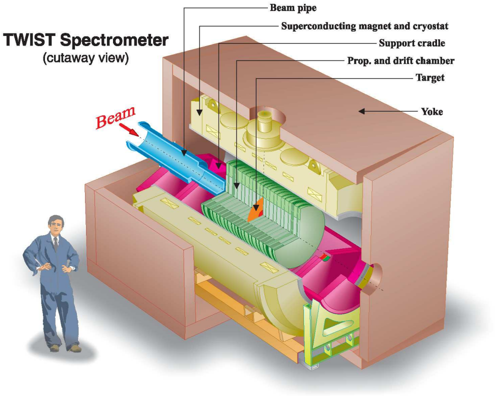


- Special case: In the presence of SUSY R-Parity breaking [1]

$$\frac{\partial \Gamma}{\partial \cos\theta} \propto (1 + A\cos\theta) \text{ where } A = \pm\mathcal{P}_\mu$$

[1] M. Hirsch and A. Vicente, PRD **79**,(2009) 055023

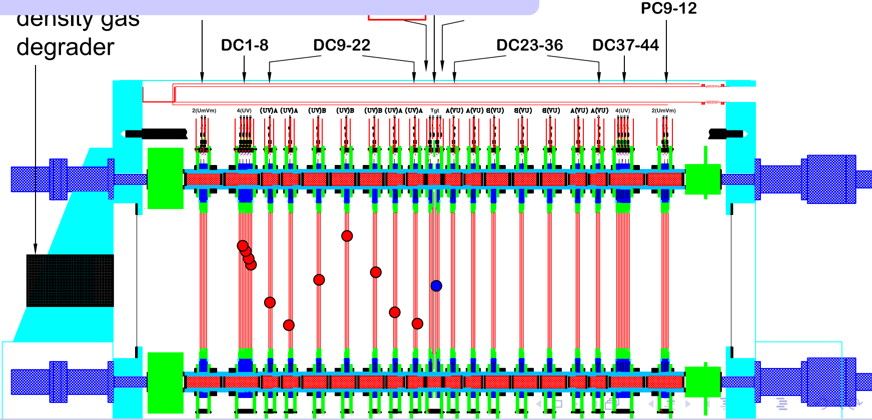
TWIST Experiment



- 44 planar drift chambers(DC), 12 proportional chambers(PC
- detector contained in 2 Tesla solenoidal magnet
- 29.6 MeV/c muons stop in high purity metal foil
- Decay positrons tracked through symmetric DC stack.

Detector Operation

- Dimensions known to parts in 10^5.
- Magnetic Field known to 0.5 Gauss.



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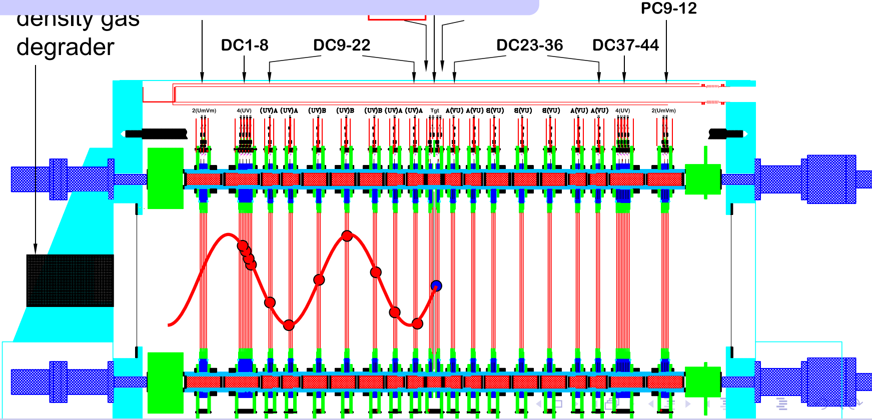

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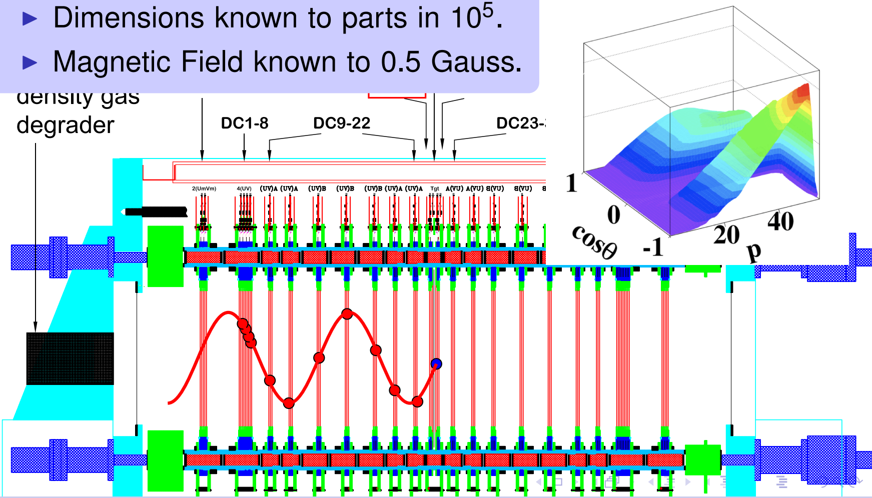
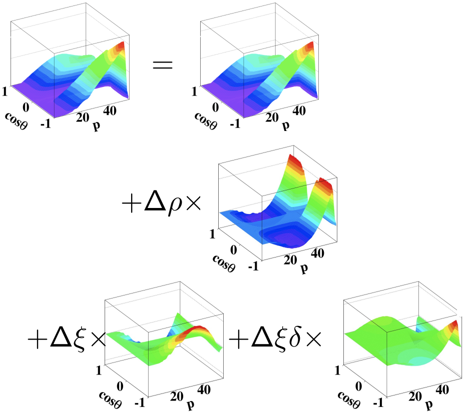
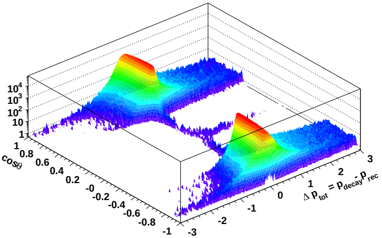


TWIST Analysis

- Data spectrum fit to a sum...



- simulation of the detector used to account for reconstruction biases and efficiencies



- Long lived X^0 signal dominated by the detector response

Spectra Used in Search

- All data from TWIST experiment combined for fit
- Simulated muon decay used as background
- The detector response models $\mu \rightarrow e^+ X^0$ signal.
- Determine $\mathcal{B} = \frac{\Gamma(\mu^+ \rightarrow e^+ X^0)}{\Gamma(\mu^+ \rightarrow e^+ \nu_e \bar{\nu}_\mu)}$ from response amplitude

Events collected after cuts

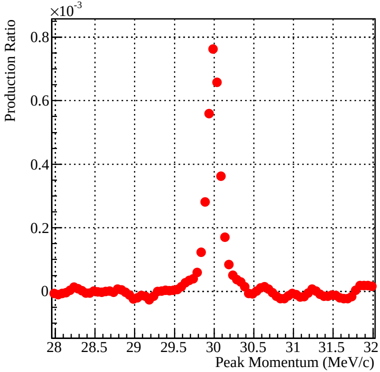
Silver	2.96×10^8
Aluminum	2.46×10^8
Total	5.42×10^8

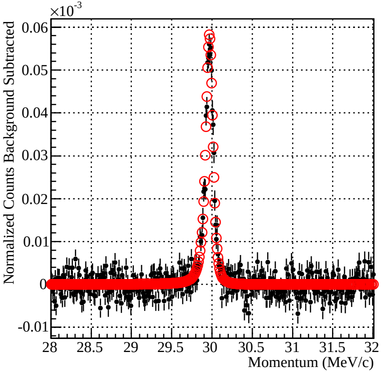
Estimated Branching Ratio

- $\sigma \sim$ 100 - 200 keV/c
- $\mathcal{B} \propto \frac{\sigma}{\sqrt{N}} \sim \mathcal{O}(10^{-6})$

Validation of Method

Large signal added to simulation

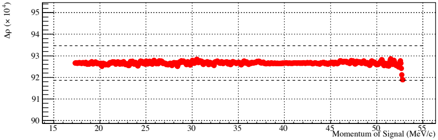


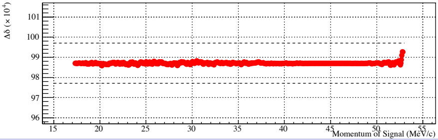


- Expected $\mathcal{B} = 7.6 \times 10^{-4}$

Treatment of Systematic Effects

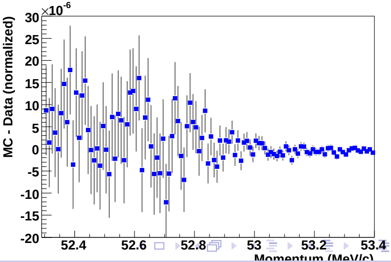
- Systematic effects are smooth changes in the spectrum
  - Can only affect signal amplitude
  - Absorbed by decay parameter corrections





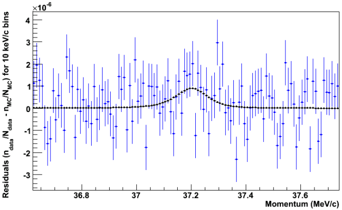
Exception: Signals at endpoint

- Decay endpoint very sensitive to systematic effects
- Changes in endpoint look like $\mu^+ \rightarrow e^+X^0$ signal

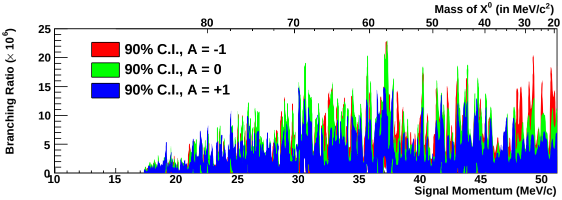


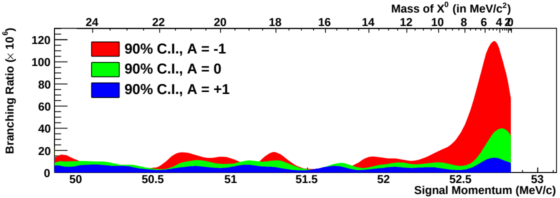
Branching Ratios

- Signals fit in 50 keV/c steps
- Confidence intervals from method by Feldman and Cousins [a]



[a] *PRD* **57**, (1998),3873





- Systematic errors included in confidence band

Results Summary

- Average $\mathcal{B}$ compiled for $p \in$[20 MeV/c,52 MeV/c]

Decay signal		90% Upper Limit
A = 0	Average	8.1×10^{-6}
	Endpoint	3.3×10^{-5}
A = -1	Average	8.4×10^{-6}
	Endpoint	6.7×10^{-5}
A = +1	Average	5.7×10^{-6}
	Endpoint	8.5×10^{-6}
Bryman, 1986 [2]	Average	3×10^{-4}
Jodidio, 1986 [3]	Endpoint	2.5×10^{-6}

[2] *PRL* **57**, (1986) 2787
[3] *PRD* **34**, (1986) 1967

Conclusions

- 5×10^8 muon decay events used to estimate $\mathcal{B} = \frac{\Gamma(\mu^+ \to e^+ X^0)}{\Gamma(\mu^+ \to e^+ \nu_e \bar{\nu}_\mu)}$
- Discriminate isotropic and anisotropic decay signals
  - First direct measurement
- Improved upper limit in massive X^0 case by a factor of 32
  - No evidence of signals when $A \geq 0$
  - Average of 90% upper limit between 5.7 and 8.4 ppm
- Limits set on massless X^0
  - 90% upper limit between 8.5 and 33 ppm

The *TWIST* Collaboration

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