A Two Body Decay Search in the TWIST Spectrum

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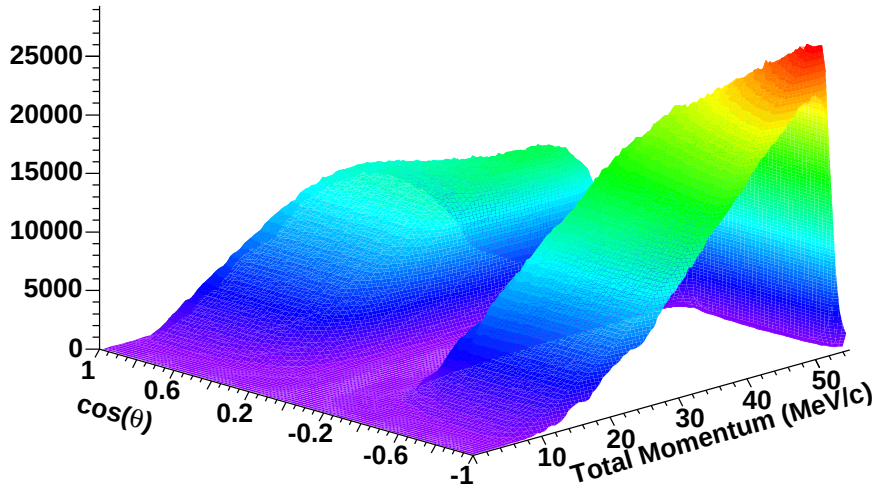
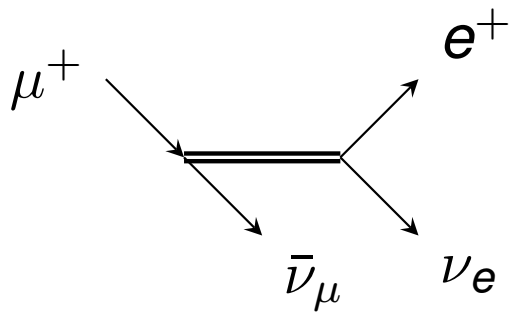
Rare Decay Search in TWIST Data

- Good reconstruction for wide range of momenta and angles.
- Polarized muon decay event sample exceeds previous decay experiments.

- Main decay mode: $\approx 100\ \%$





- $\mu^+ \rightarrow e^+\nu_e\nu_\mu e^+e^-$: $(3.4 \pm 0.4)\times 10^{-5}$
- Other rare decay modes should be visible in TWIST spectrum.

Two Body Muon Decays

- A result of symmetry breaking: ie Lepton Number or Family
- Effective Lagrangian [1]: $\Delta L = F_{e\mu}^{-1}\,\mu\gamma^{\rho}e\partial_{\rho}f_{e\mu}$

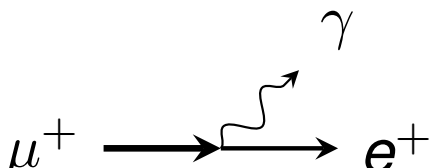
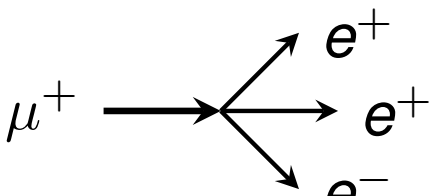
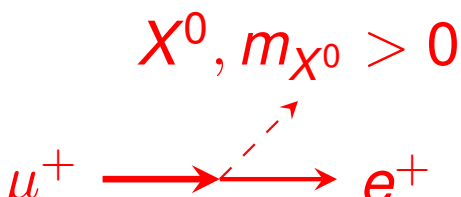
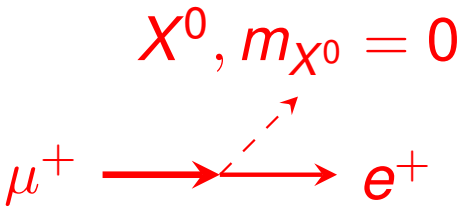
Nambu-Goldstone Bosons	Pseudo Nambu-Goldstone Bosons
• Massless X^0 • Due to global symmetry breaking	• Massive X^0 • Due to local breaking of the symmetry

- Surplus of e^+ appear at momentum

$$p = \sqrt{\left(\frac{M_\mu^2 - m_X^2 + m_e^2}{2M_\mu}\right)^2 - m_e^2}$$

[1] F. Wilczek, PRL **49** 1549, 1982

Measurements of Rare μ decay

Decay process	Upper Limit	Conf. level	
	1.2×10^{-11} 3×10^{-11}	90 %	Brooks, 1999 Adams, 2009 [2]
	1.0×10^{-12}	90 %	Bellgardt, 1987
	3.4×10^{-4}	90 %	Bryman, 1986
	2.6×10^{-6}	90 %	Jodidio, 1986

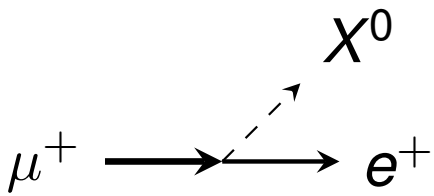
[2] Pre-print: arXiv:0908.2594

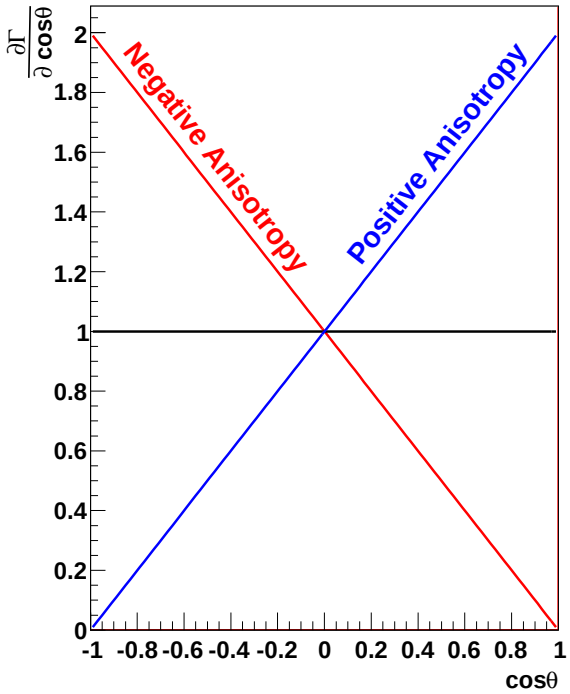
A Special Case: Anisotropic Decays

- Lepton number violation will produce Majorons.
- Decay mode can be enhanced in MSSM models with *R*-parity breaking. [3]
  - Will occur with a distribution

$$\frac{\partial \Gamma}{\partial \cos\theta} \propto [1 \pm P_\mu \cos\theta]$$

  - Has not been measured directly.
  - Can be observed directly in TWIST data



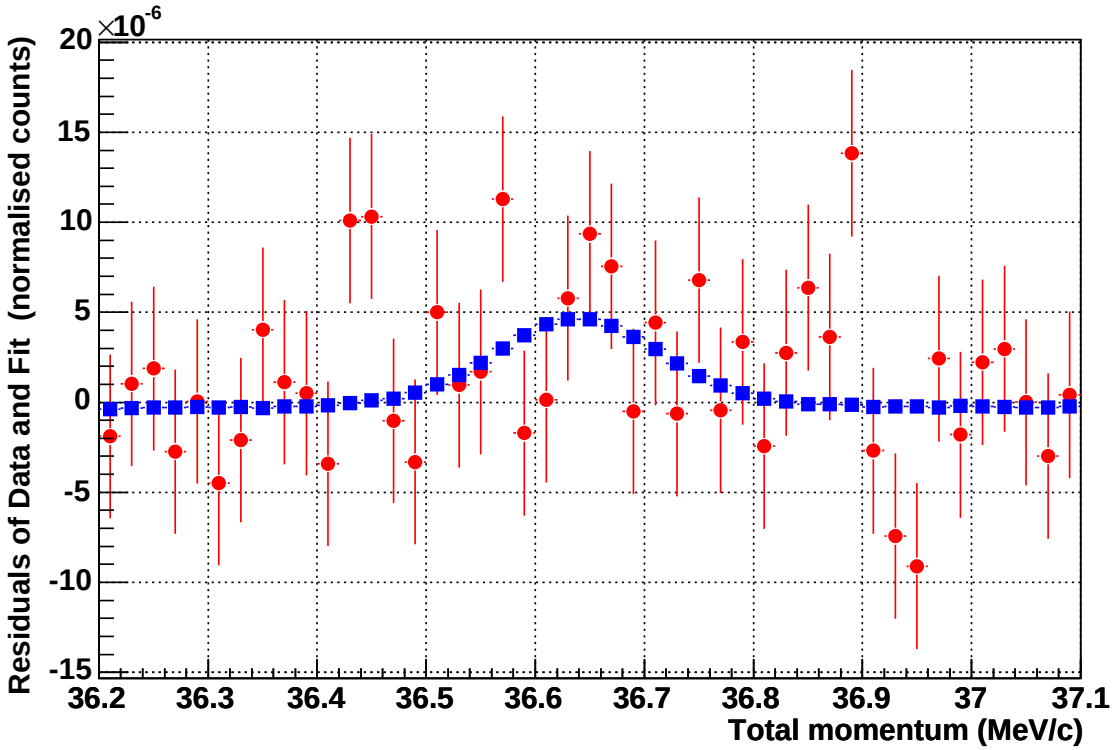


[3] M. Hirsch and A. Vicente, PRD **79**, 055023 (2009)

Method of $\mu^+ \to e^+ X^0$ Search

TWIST momentum response function is used to model two body decays.

- Assumes momentum response dominates



- True if decay time

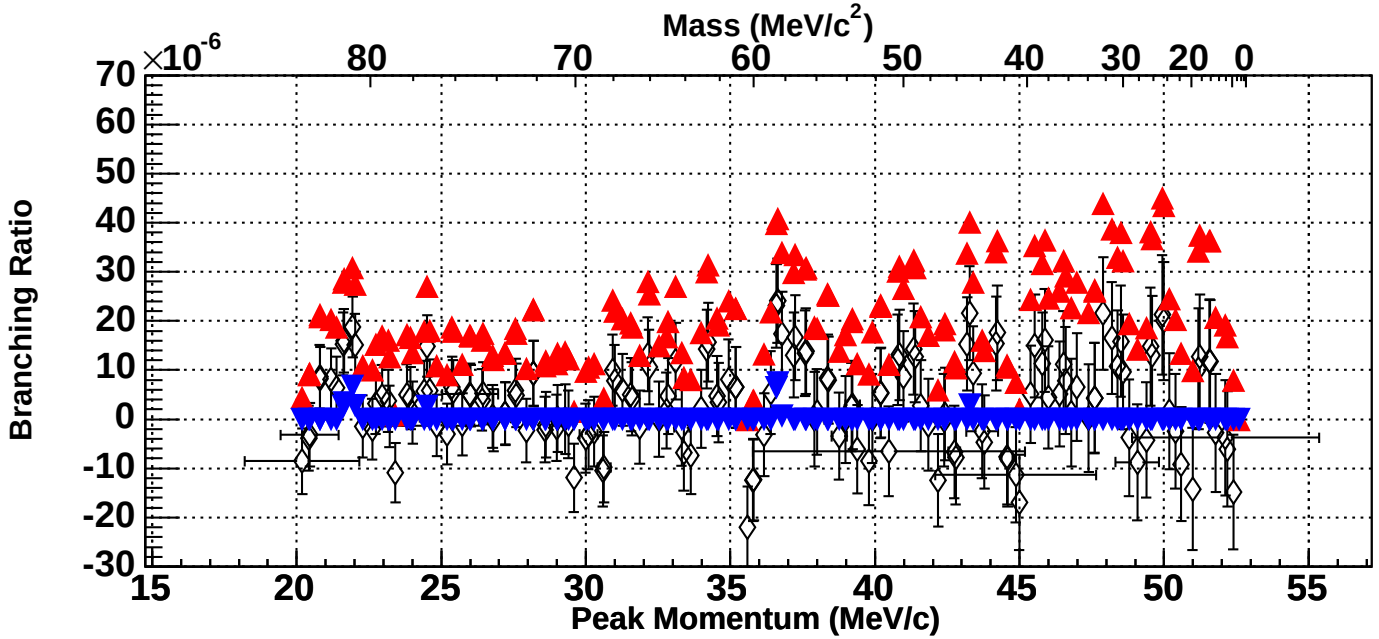
$$\tau > \frac{\hbar}{\sigma} \approx 10^{-22}\text{s}$$

assuming $\sigma \sim 100$ keV/c

- Peak fit to Decay Par. Fit residuals
- Determine a branching ratio, $\mathcal{B}$

Results from Search in Initial Physics Data

Search for Massive X^0 was conducted in 2005

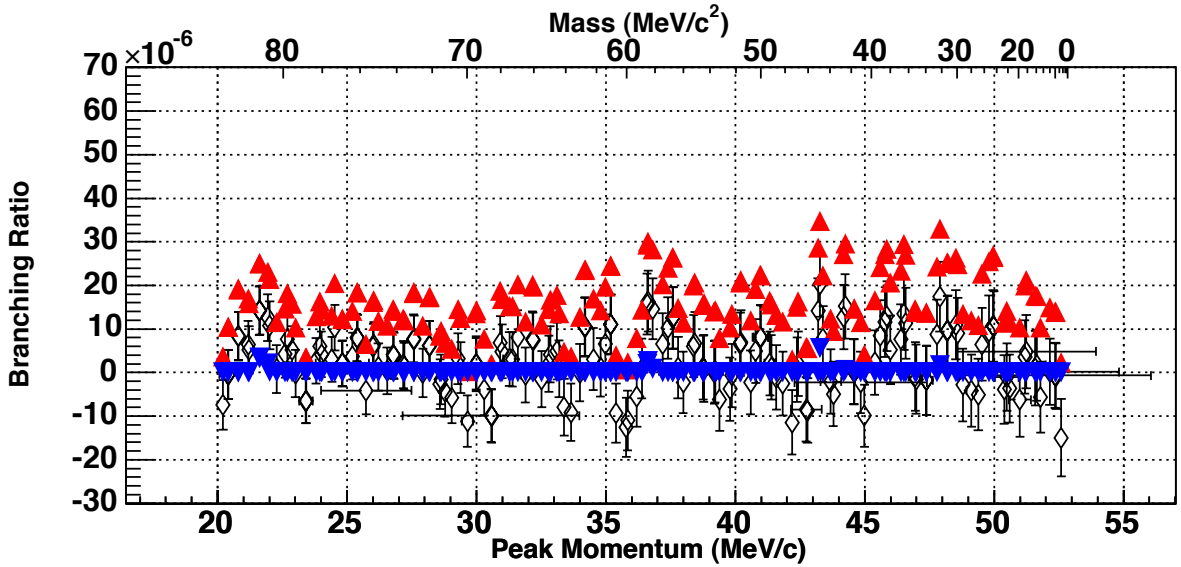


- Competed using 5.3 $\times 10^7$ muon decay events
- 95% limit on isotropic, massive X^0 production: $\mathcal{B} < 4.5 \times 10^{-5}$
- Observed peaks expected: $\sim$4 for $\sim$60 uncorrelated trials

Anisotropic Decays from Initial Physics Data

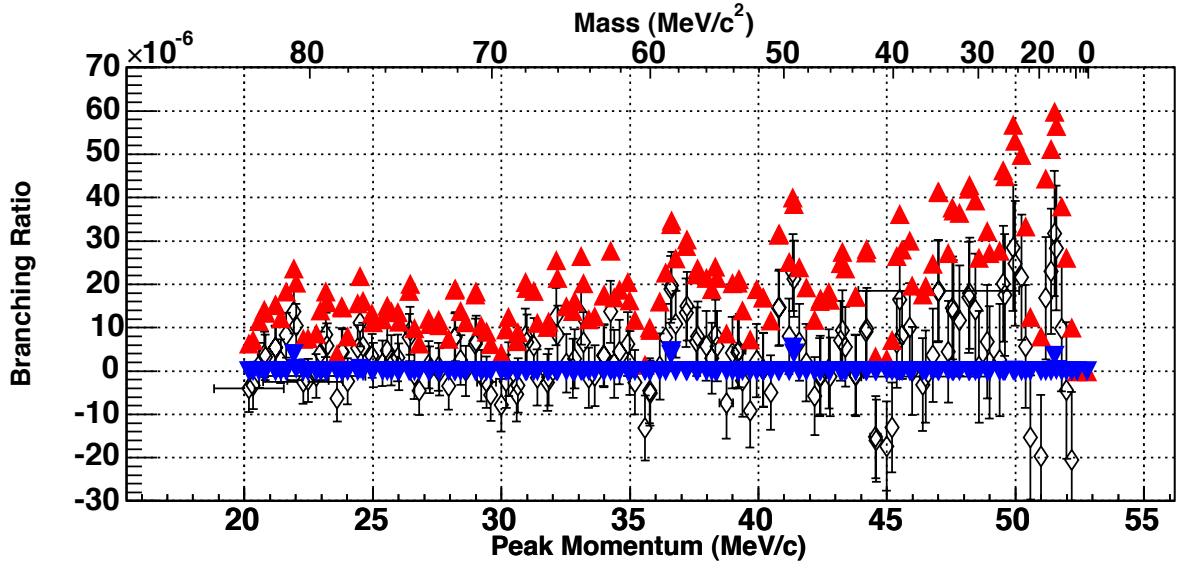
Positive anisotropy:

- decay probability $\mathcal{B} < 3 \times 10^{-5}$



Negative anisotropy:

- decay probability $\mathcal{B} < 5 \times 10^{-5}$



Improvement in Statistics

	Initial Data	Final Data
Events Collected	1.3×10^9	9.0×10^9
Events Left Cuts	12 %	13 %
Events Left by Fiducial Cuts	34 %	41 %
Total Events	5.3×10^7	5.5×10^8

- Branching ratio sensitivity decreases as $\sqrt{N}$, N is the number of background events
- Factor of 3 improvement expected

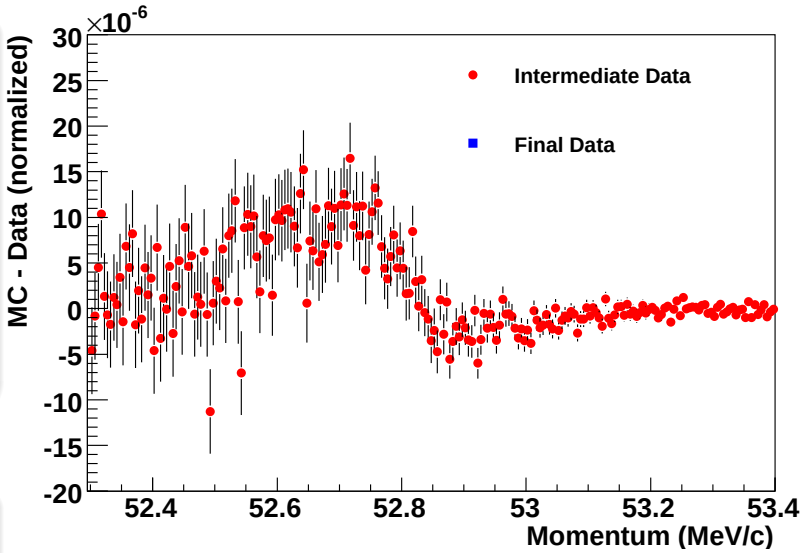
Systematic Effects at Endpoint

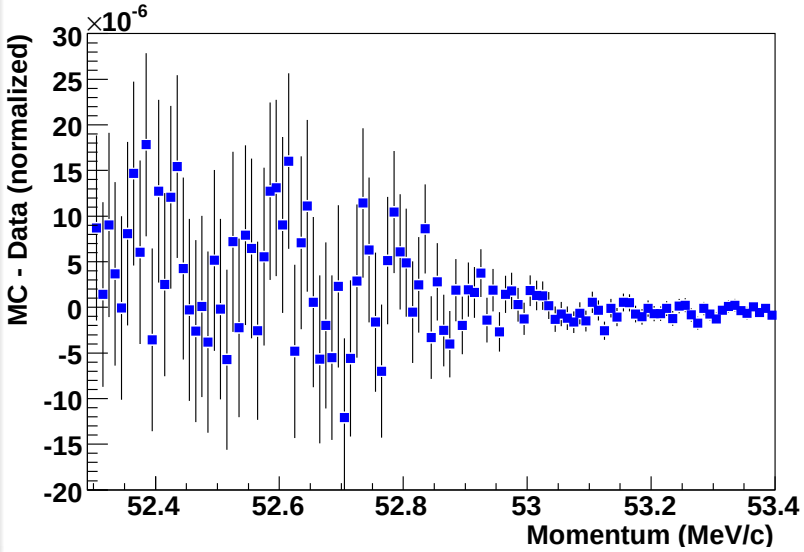
Initial data results not reliable.

- Momentum resolution was not well matched
- $\Delta\sigma \approx 5$ keV, where $\sigma_0 \approx 70$ keV.

Better control of systematics in Final Data

- Resolution consistent between data and MC
  - Difference < 1 keV/c
- Momentum calibration less critical
  - Corrections < 10 keV/c, out of 90 keV/c





Conclusions

- Proposed search for rare decay signals will be completed on TWIST final data

Limits on two body signal set using TWIST initial physics data

Isotropic	$\mathcal{B} < 4 \times 10^{-5}$	(95% Confidence)
Positive anisotropy	$\mathcal{B} < 2 \times 10^{-5}$	(95% Confidence)
Negative anisotropy	$\mathcal{B} < 6 \times 10^{-5}$	(95% Confidence)

- Factor 3 decrease in limits expected in TWIST final analysis
- Most significant sensitivity to anisotropic signal of massless X^0

The $\mathcal{TWIST}$ Collaboration

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★ graduate student
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