The Search for Lepton Flavour Violating Decays in $\mathcal{TWIST}$

R. Bayes [1 2]
For the $\mathcal{TWIST}$ Collaboration
rbayes@triumf.ca

[1] Department of Physics
University of Victoria

[2] TRIUMF

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Outline

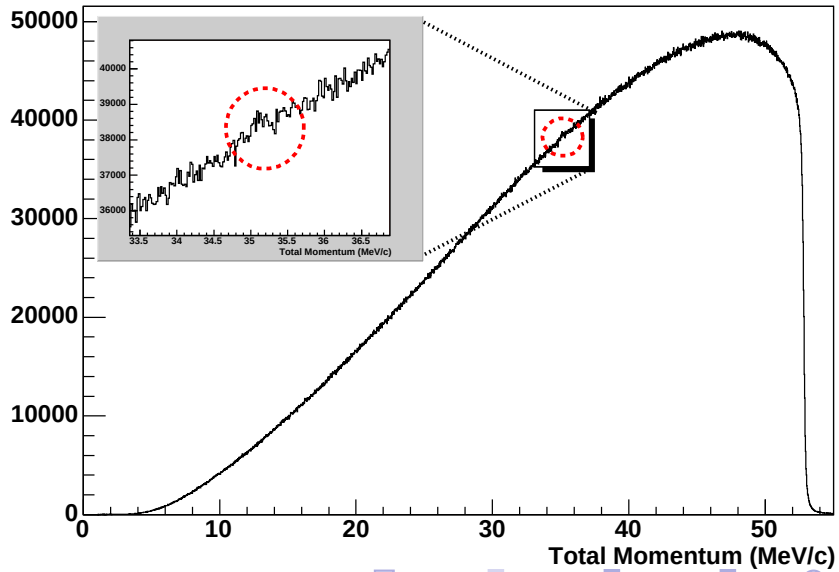
Two Body Decay Modes

- Implies a violation of lepton flavour symmetry.
  - Such interactions mediated by bosons including photons, familons, axions and quintessons.
  - Such interaction take the form

$$\Delta\mathcal{L} = F_{\mu e}^{-1}\,\bar{\mu}\gamma_\rho e\partial_\rho X_{\mu e}$$

  - $\mathcal{TWIST}$ can only usefully measure “invisible” bosons
    - $\mathcal{TWIST}$ does not have the capablity to observe photons

- The signal of the decay will be a peak at a momentum dictated by the mass of X^0



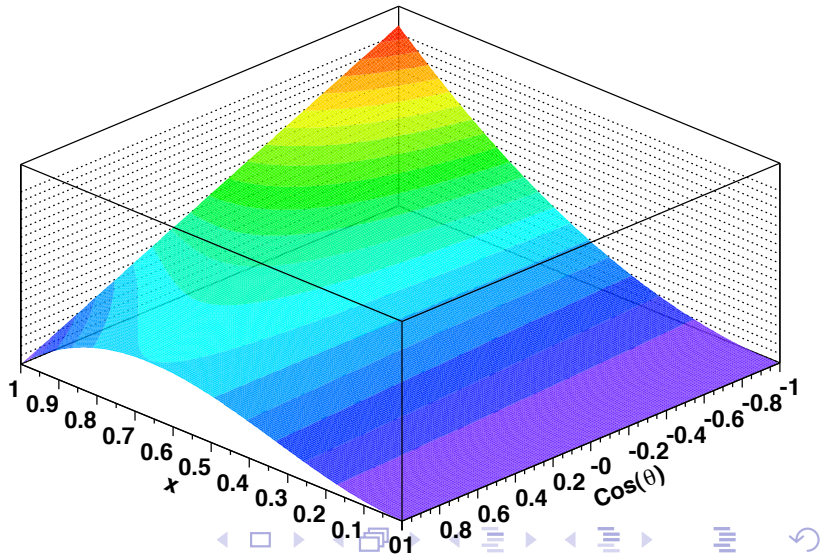
Other Experiments

- Two previous measurements of this type (reported as 90% upper limits)

$$\frac{\Gamma(\mu^+ \to e^+ X^0)}{\Gamma(\mu^+ \to e^+ \bar{\nu}_\mu \nu_e)} < 3 \times 10^{-4} \text{ [Bryman:1986] (} X^0 \text{ massive)}$$

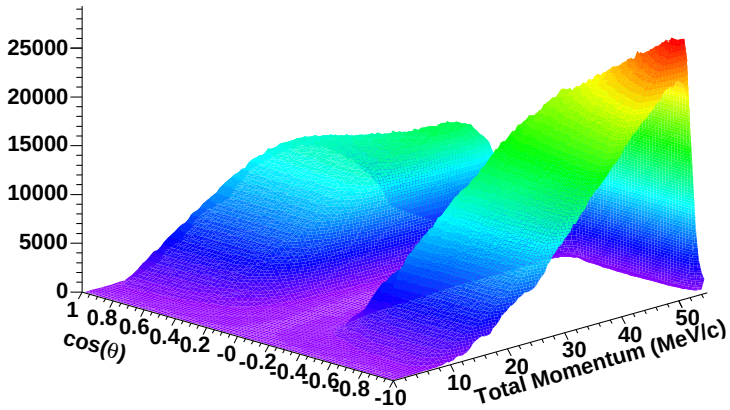
$$\frac{\Gamma(\mu^+ \to e^+ X^0)}{\Gamma(\mu^+ \to e^+ \bar{\nu}_\mu \nu_e)} < 2.6 \times 10^{-6} \text{ [Jodidio:1986] (} X^0 \text{ massless)}$$

- Jodidio measurement involved a smaller phase space than $\mathcal{TWIST}$
- Proposal has been submitted to measure familon production in muon decay at JINR (hep-ex/0612064)



Method for search

- $\mu^+ \rightarrow e^+ \bar{\nu}_\mu \nu_e$ is the background for any exotic decay search
  - the muon decay spectrum is very well understood from Monte Carlo simulations
  - changes in the spectrum shape can be made with the addition and subtraction of simulated derivatives



- Assume the particle is long lived
  - detector resolution dominates the signal width
- constrain peak mean to a given subrange during fit.
- Goal is to define a branching ratio

$$\mathcal{B} = \frac{\text{number of events in peak}}{\text{total number of events collected}}$$

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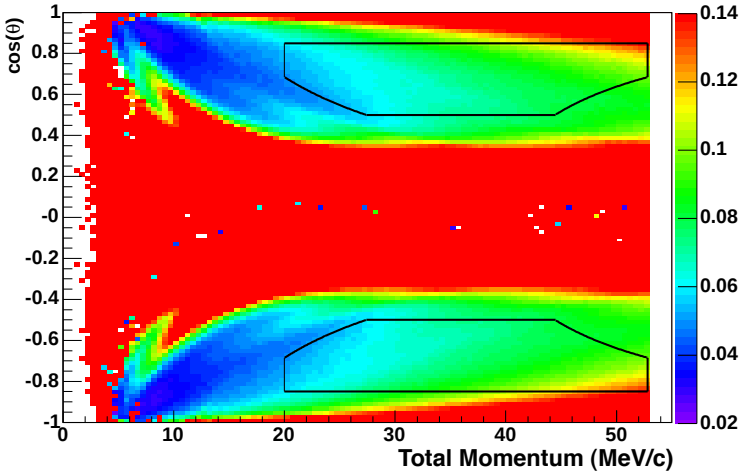

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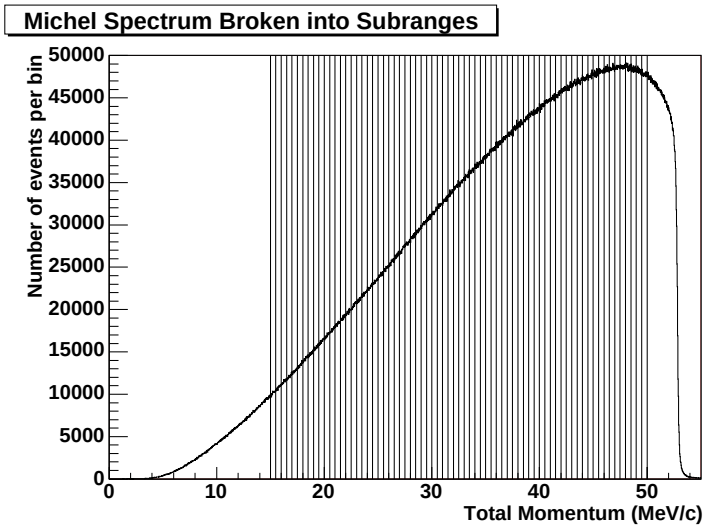

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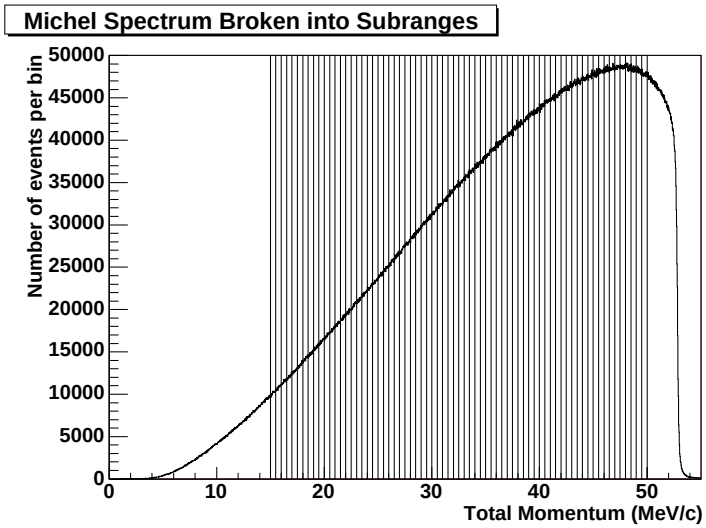

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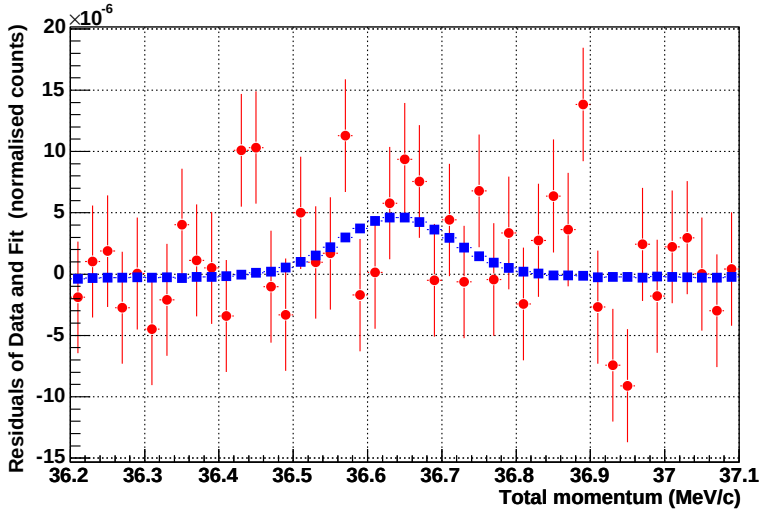
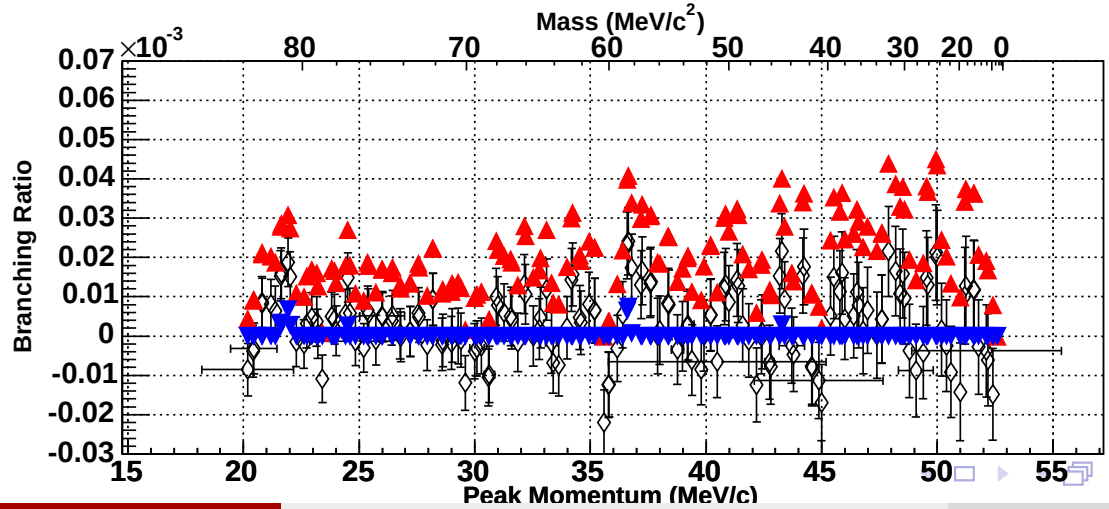
Isotropic Results using the 2002 $\mathcal{TWIST}$ data

- Used data sample of 6×10^7 muon decay events
  - A given peak has branching ratio on the order of 10^{-5}
  - For the available masses the 95% upper limit (▲) for the branching ratio is 4.5×10^{-5}





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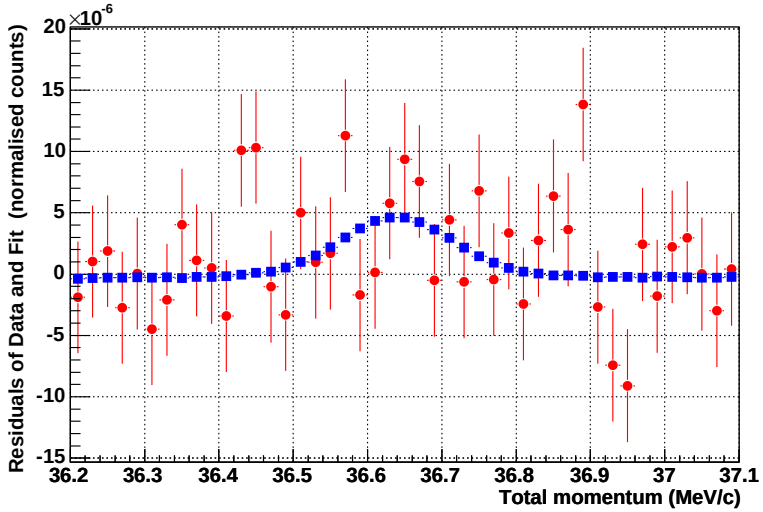

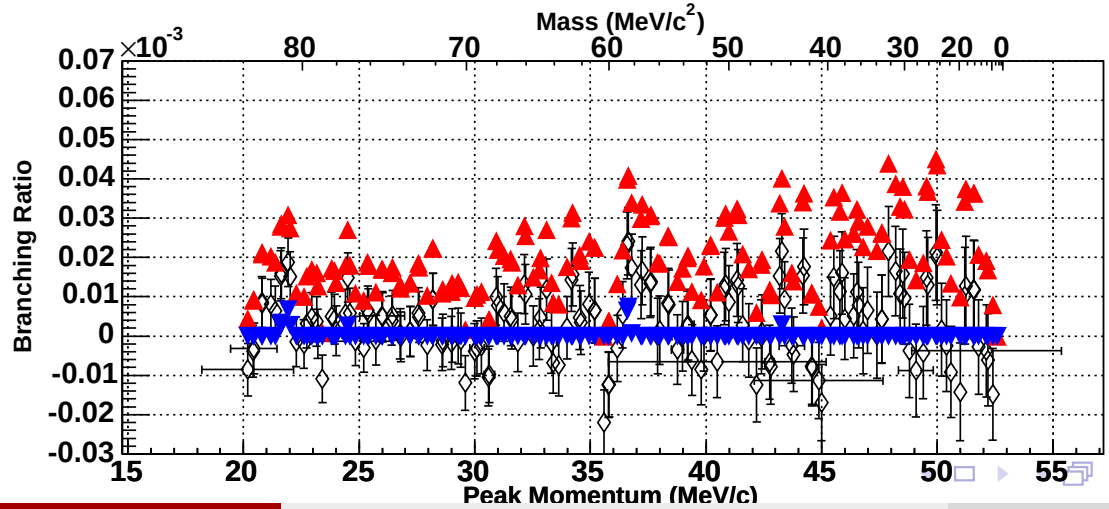

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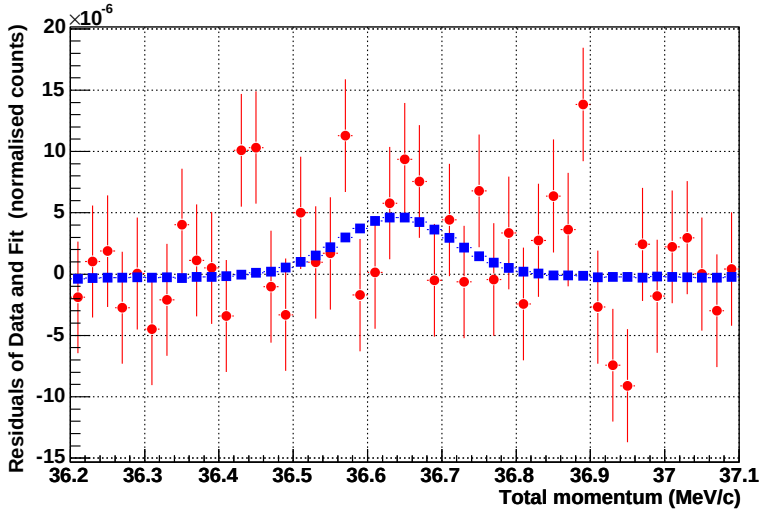

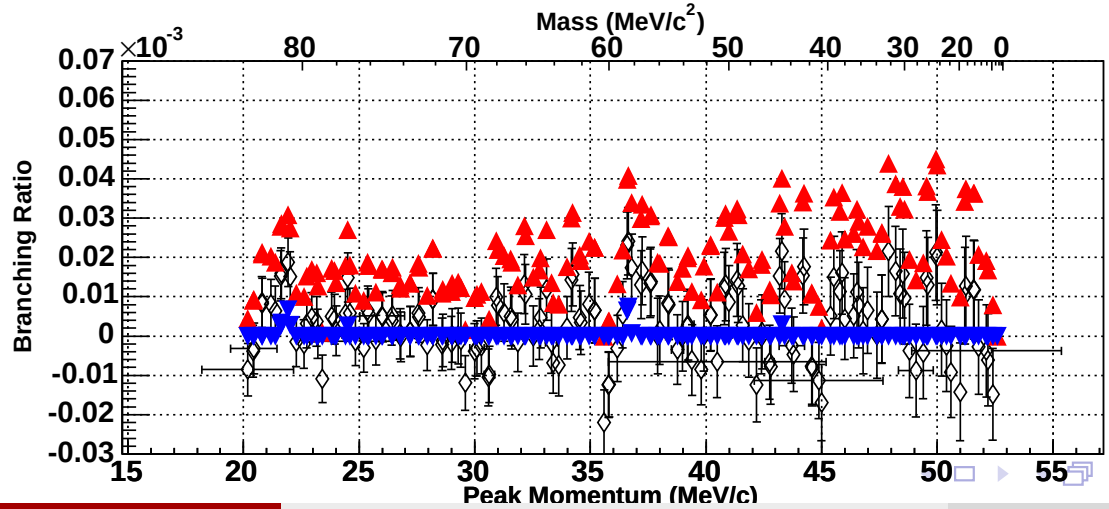

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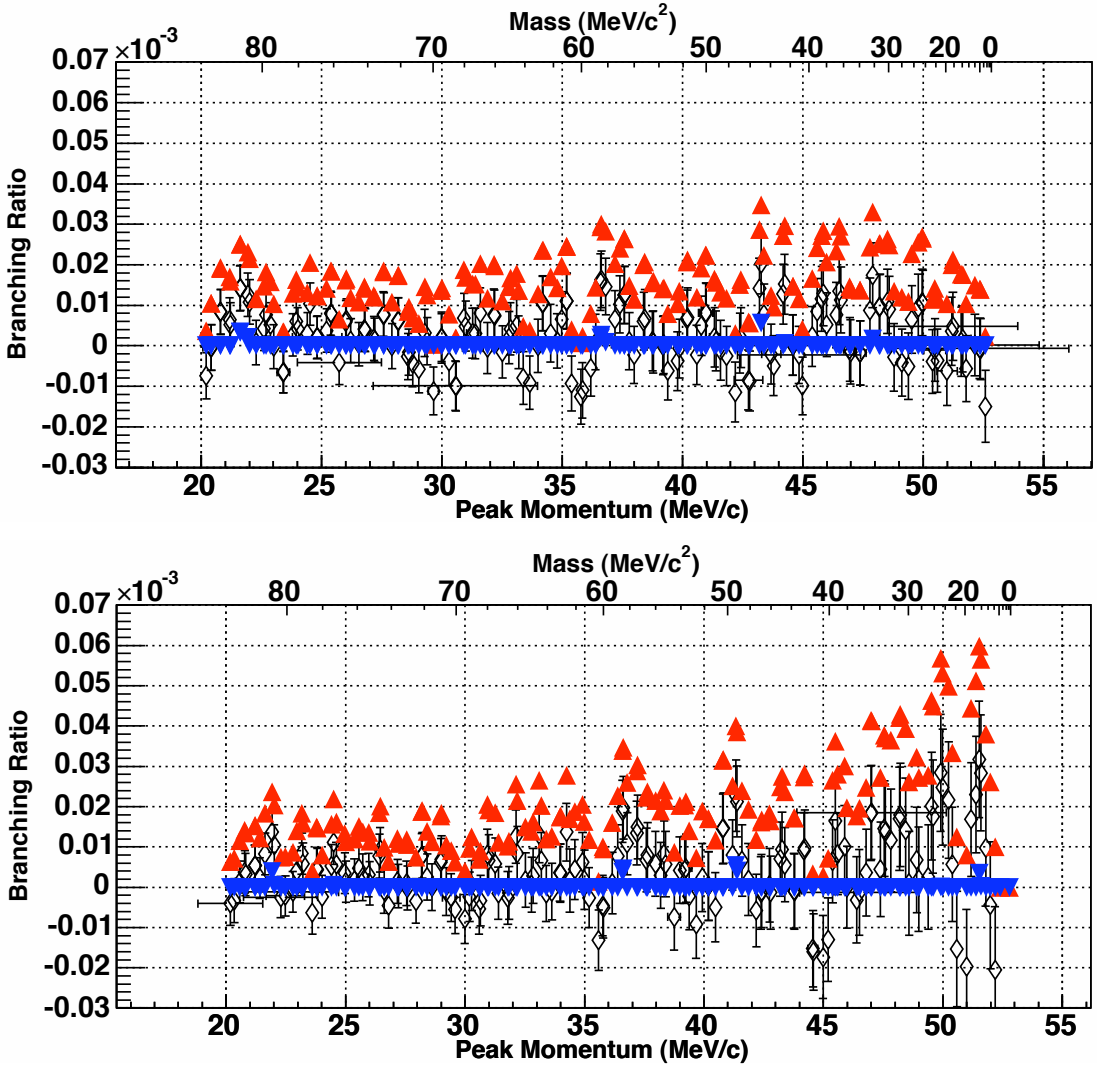

- If there is some parity non-conservation in the interaction then we might anticipate an anisotropic peak
- The input peak can be generated with a $\cos\theta$ dependence
- Positive anisotropy generates a smaller upper limit
- Negative anisotropy generates a larger upper limit

Massless Exotic particles

- A massless particle should produce a signal at the endpoint
- There is a 5 keV/c resolution mismatch ($\sigma_p \approx 70 keV/c$) in the 2002 data and Monte Carlo at the endpoint
- Produces a trough below and a peak above the endpoint
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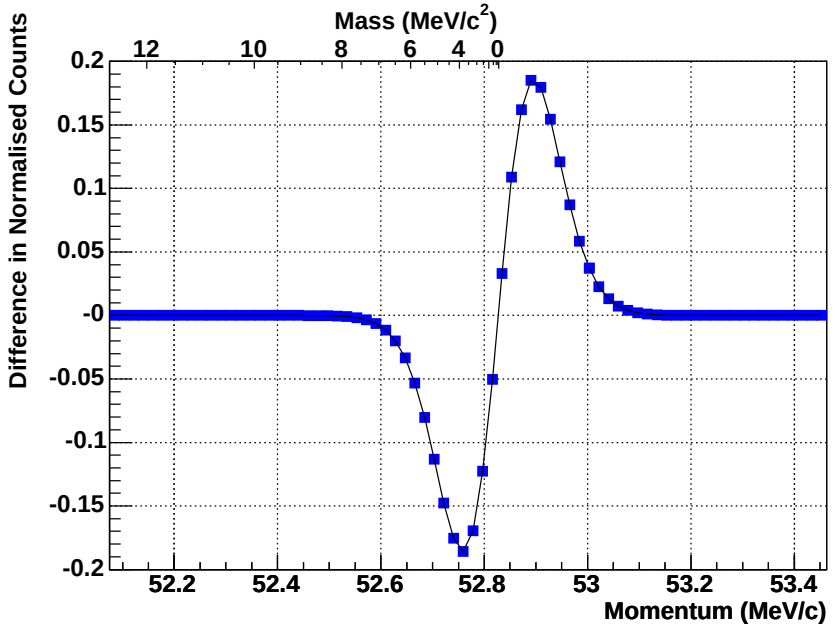

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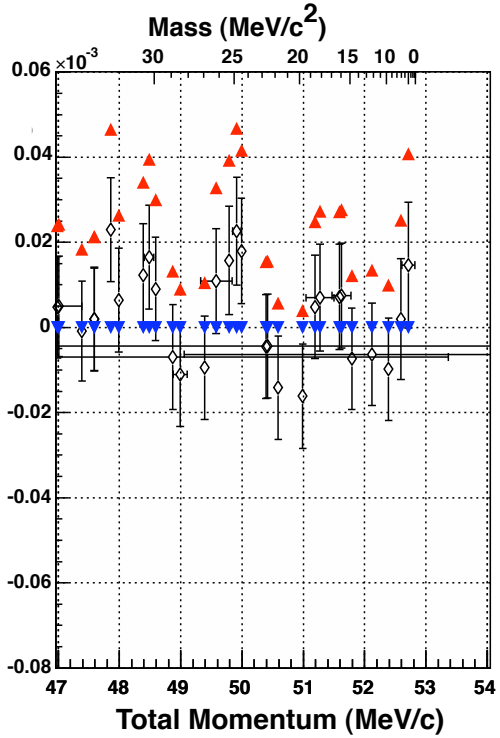

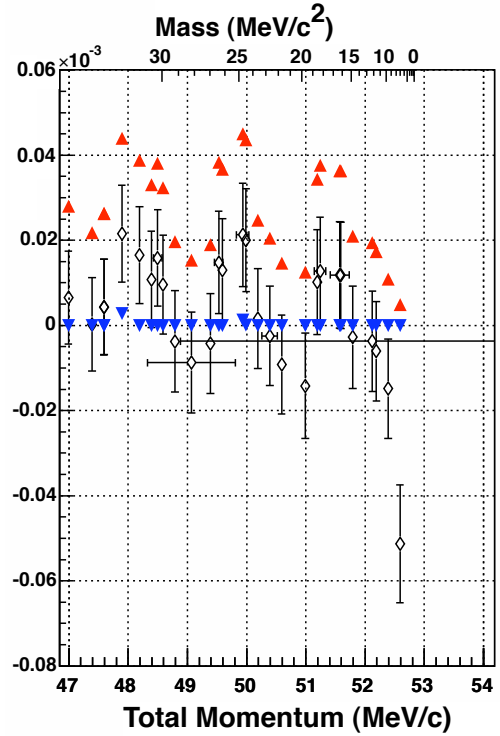

Improving the Measurement

- More data has been taken by $\mathcal{TWIST}$ since this estimate was completed
  - New data are
    - of better quality
    - a larger sample of events ($\approx 6 \times 10^9$ events)
  - analysis has improved since 2002 analysis
  - better quality data means less events are lost in cuts

	2002 Data	2006 Data
Events Collected	2.6×10^8	6×10^9
% Events After Event Cuts	12 %	17 % (current analysis)
% Events After Fiducial Cuts	34 %	48 % (current analysis)

- This indicates a factor 5 improvement is possible based on statistics alone

Improving the Limit on Massless Exotics

- Factor of 5 not sufficient to be competitive with the pre-$\mathcal{TWIST}$ result
- More complicated statistical analysis may be required
- eg. Use "signature" of the resolution mismatch to locate the endpoint and isolate peaks
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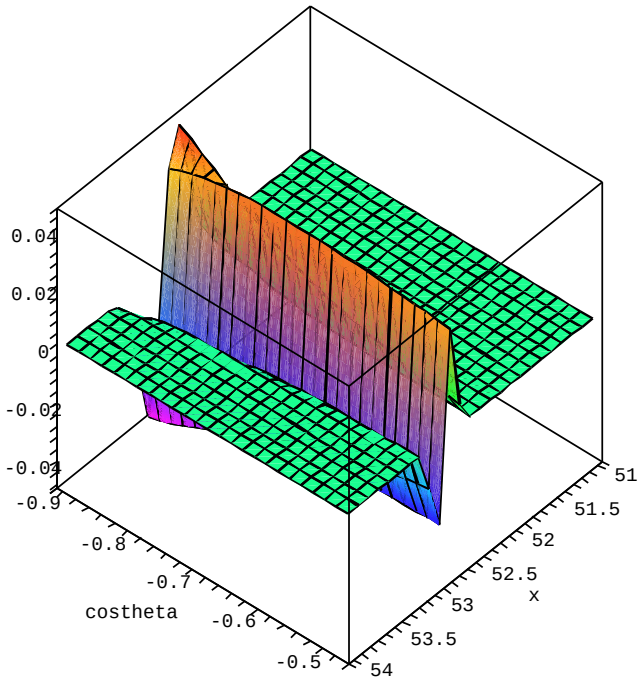

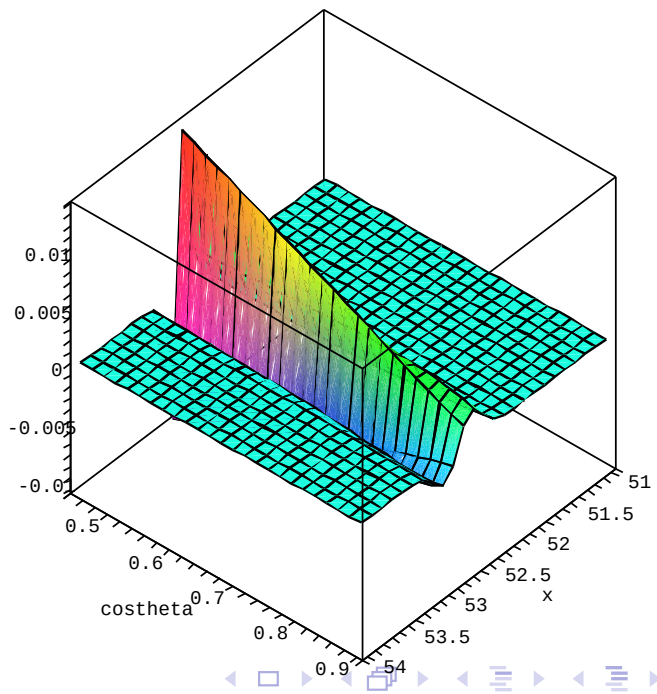

Conclusions

- Measurement has been completed in 2005
- 95 % upper confidence limits have been set
  - isotropic decays at $\mathcal{B} \leq 3.4 \times 10^{-5}$
  - positive anisotropic decays at $\mathcal{B} \leq 2.0 \times 10^{-5}$
  - negative anisotropic decays at $\mathcal{B} \leq 5.0 \times 10^{-5}$
  - decays at the endpoint are of the same order
- No statistically significant decays have been found
- Improvements in available statistics and $\mathcal{TWIST}$ analysis suggest that the limits can be further decreased by a factor of 5.
- Further refinements to this analysis need to be made before a competitive limit can be set on massless exotic particles.