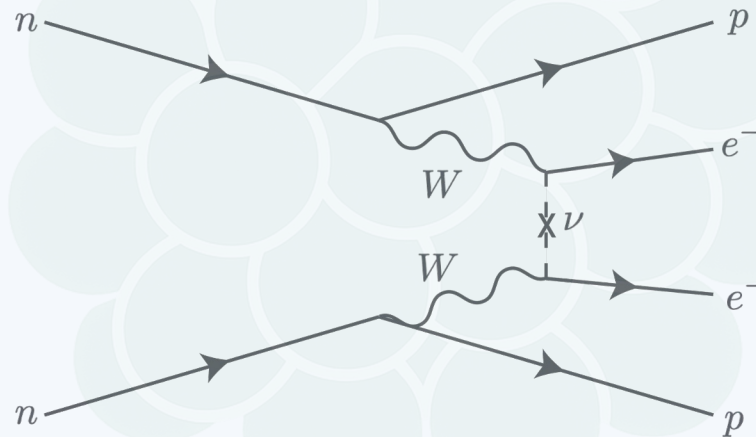


Can Event Topology Enable a Tonne-Scale Xenon Gas TPC Experiment?

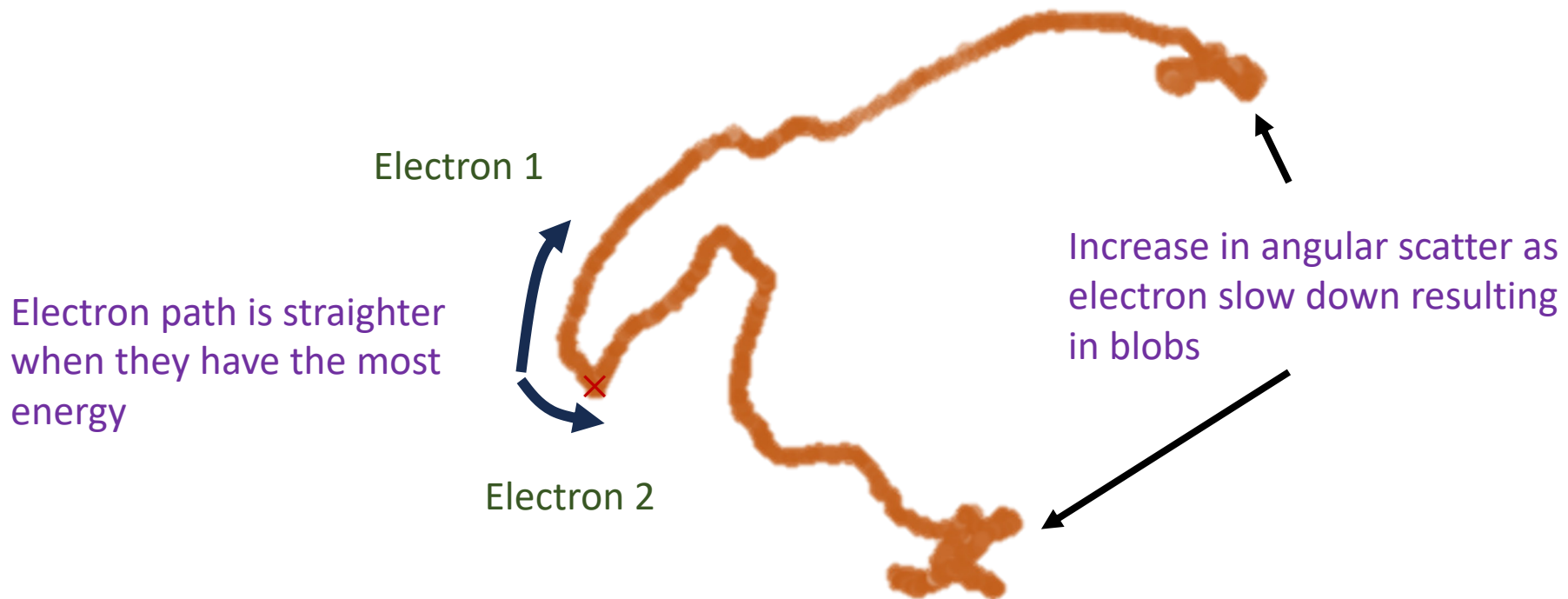
Krishan Mistry

$0\nu\beta\beta$ Search in Xe – Next Gen Workshop, McGill University



The Signal: $^{136}\text{Xe} \rightarrow ^{136}\text{Ba}^{2+} + 2e^-$

AKA Spaghetti and two Meatballs



Main backgrounds arise from ^{214}Bi and ^{208}Tl gamma and beta decay of ^{137}Xe

What mimics this signal and can we leverage topology to reduce them?

Background Rejection in Gas TPC

Gas TPC rejection power broken down by three stages:

1. Background Containment – Function of pressure balancing cross section and detector size
2. Energy Resolution – Resolution 0.75% FWHM assume
3. Topological Selection – Use detailed track information for signal background discrimination

We need to be able to reject backgrounds using topology with at least a factor of 100-1000x for sensitivities towards $10^{27}/10^{28}$ years

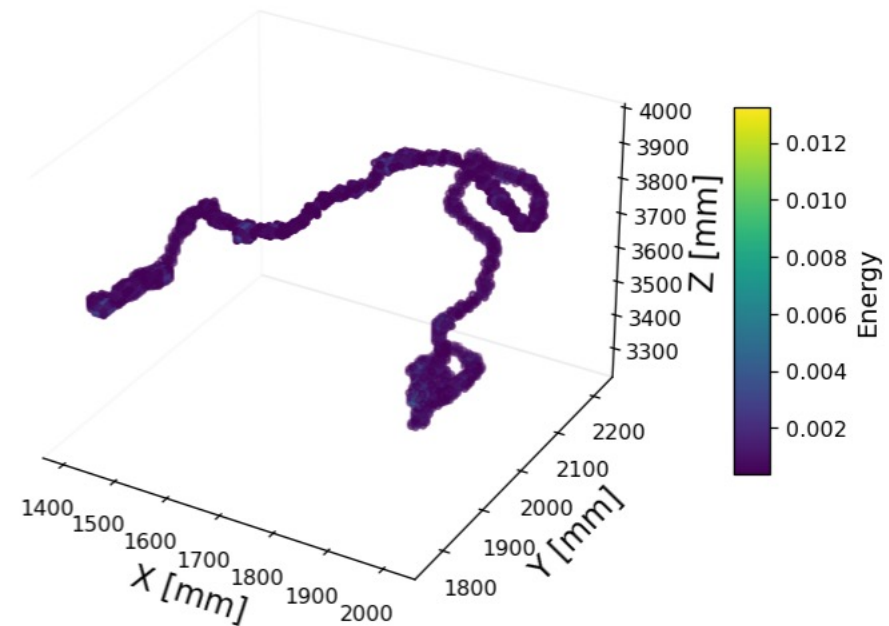
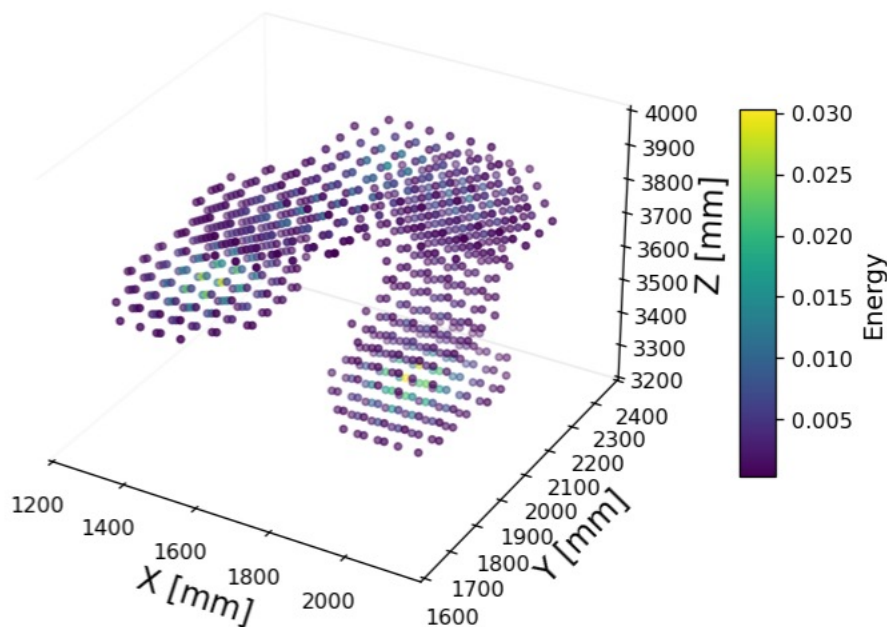
Track Clarity

- Suppose we can operate a gas detector in **low diffusion mode** e.g. with a molecular additive such as CO_2 /TMA meeting requirements such as energy resolution* ...
- Track clarity - the ratio of diffusion to length - favours lower pressure, so consider 1 bar in this exercise

Pure Xe



+ Molecular Additive



* To be demonstrated...

The Problematic Backgrounds

Classical Analysis

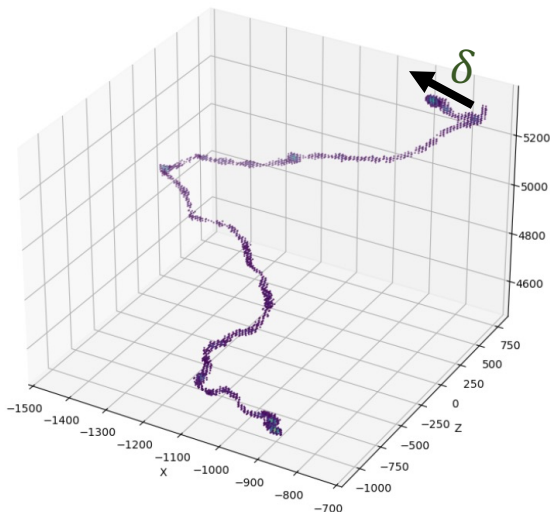
(assuming 1 bar 5% CO₂ Additive)

Background	Topology Rejection Power
²¹⁴ Bi	77x (99%)
²⁰⁸ Tl	370x (99.7%)
¹³⁷ Xe	35x (97%)

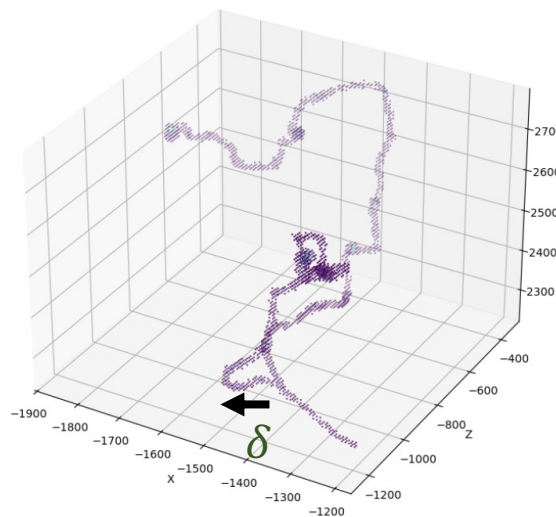
The remaining stuff falls under these categories

1. Delta electron created near track start
2. Gamma interacts near track start
3. Looping/Complicated Topologies
4. Misreconstruction
5. Other

Delta at Start
“Challenge”



High energy Delta
“Rejectable”

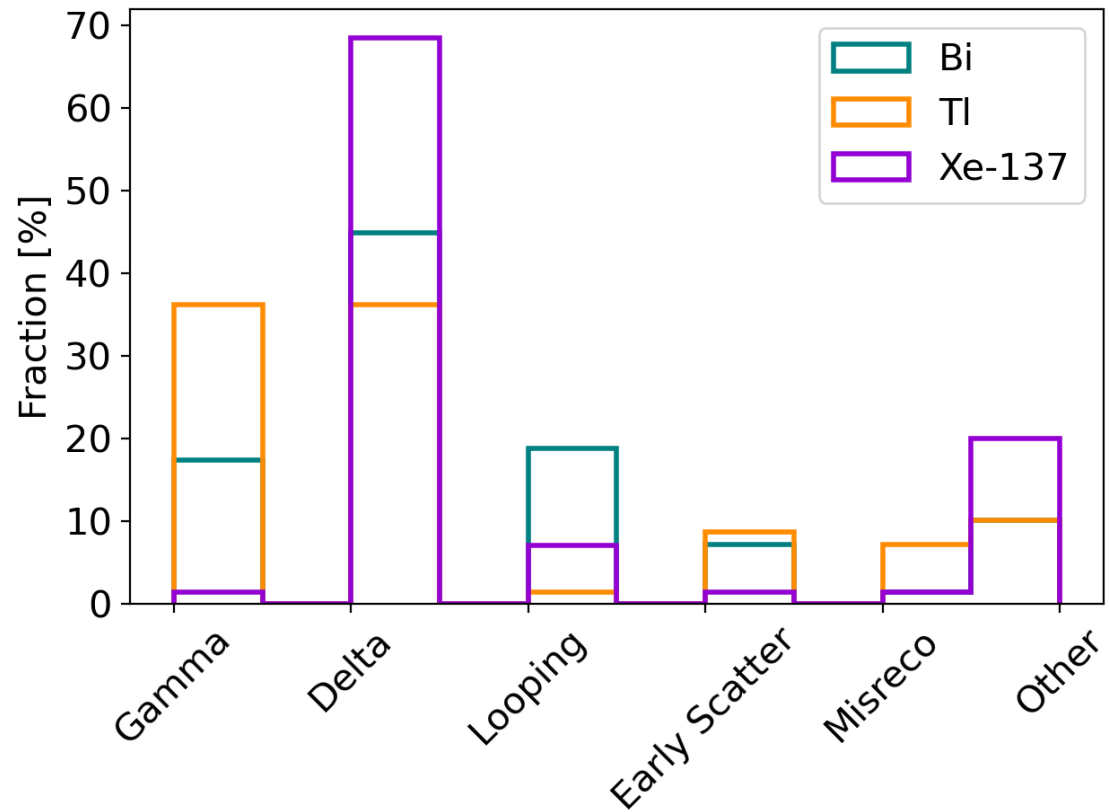


Hand scan ~70 selected
events in each
background category

**~50% could be better
rejected with improved
reconstruction (by eye)**

Breakdown of Selected Events

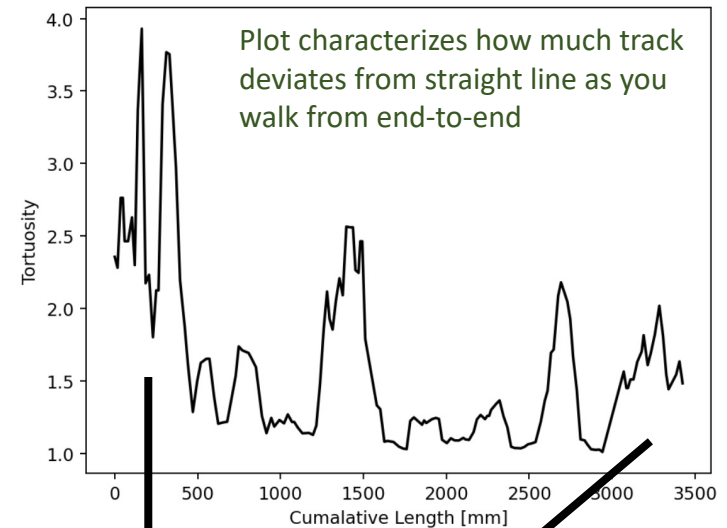
- Largest backgrounds are from deltas and gamma interactions near the track beginning
- ^{137}Xe have the lowest background rejection power and highest delta population



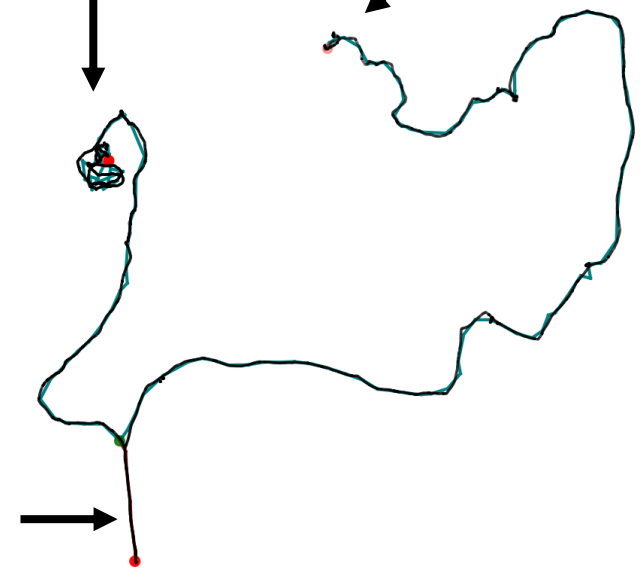
Fractions from hand scan of 70 selected events

Getting at the other 50%

- Angular information from track with new reconstruction tools
- Characterize track forking better and look for “straight segments”
- Combine with machine learning to use full topology vs ends



Straight Segment
Mis-IDs as Delta



Summary

1. Surveyed backgrounds that can produce event topologies appearing signal-like considering low diffusion Gas TPC
 - These are rare, 0.1-3%, but enough to impact the sensitivity
 - Challenging topologies predominantly come from gamma and deltas near track start
2. Event topology rejection power of Gas TPC can enable a tonne-scale experiment with factor 100x obtainable, factor 1000x harder challenge
 - Scope for improvement with better reconstruction tools at least factor 2 for “rejectable” events
 - For “challenge” events could use angular information and track straightness for improvement
 - Potentially more signal efficiency reclaimable too
3. Room for more magic with topology?
 - <your idea here>
 - ...