

ProtoDUNE-SP Argon-39 Analysis Update

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ProtoDUNE Sim/Reco Meeting

July 8, 2020

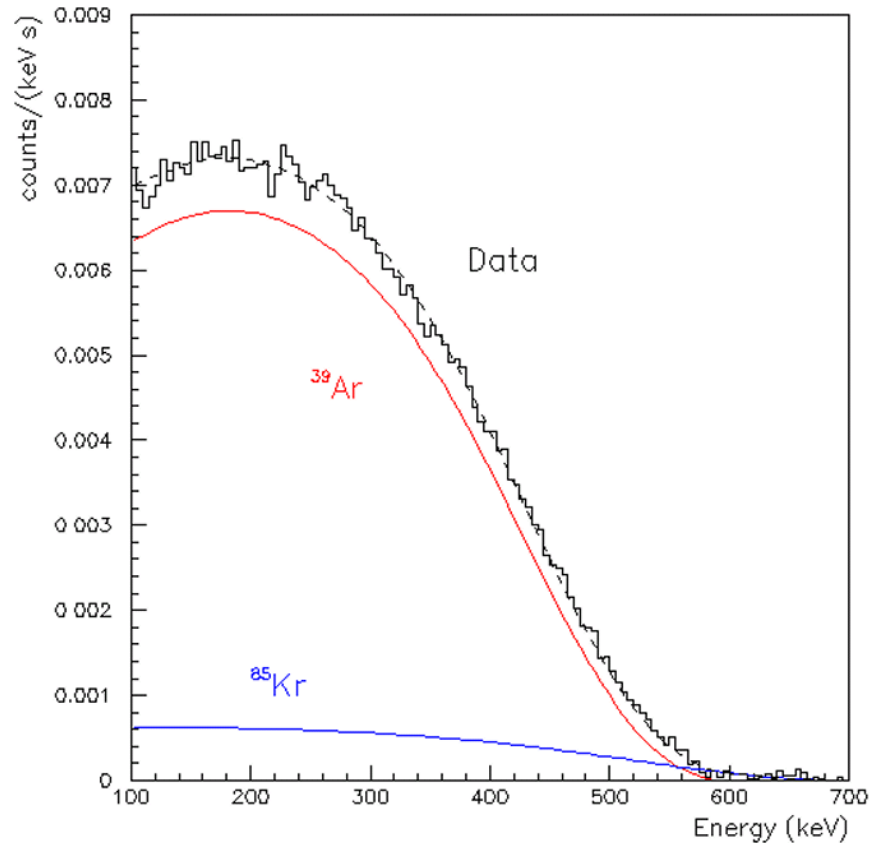


Summary of ^{39}Ar Beta Decay Studies:

- Presently, calibrations (e.g. electron lifetime) in large LArTPCs utilize cosmic rays
- DUNE Far Detector?
 - 4000 cosmics / day compared to MicroBooNE's 4000 cosmics / second
 - ~ 5 cosmics / day / m^3 (for each 10 kiloton module)
- ^{39}Ar beta decays could help supplement the low cosmic rate for calibrations
 - Expect 50000 decays on any DUNE FD readout



Summary of ^{39}Ar Beta Decay Studies:

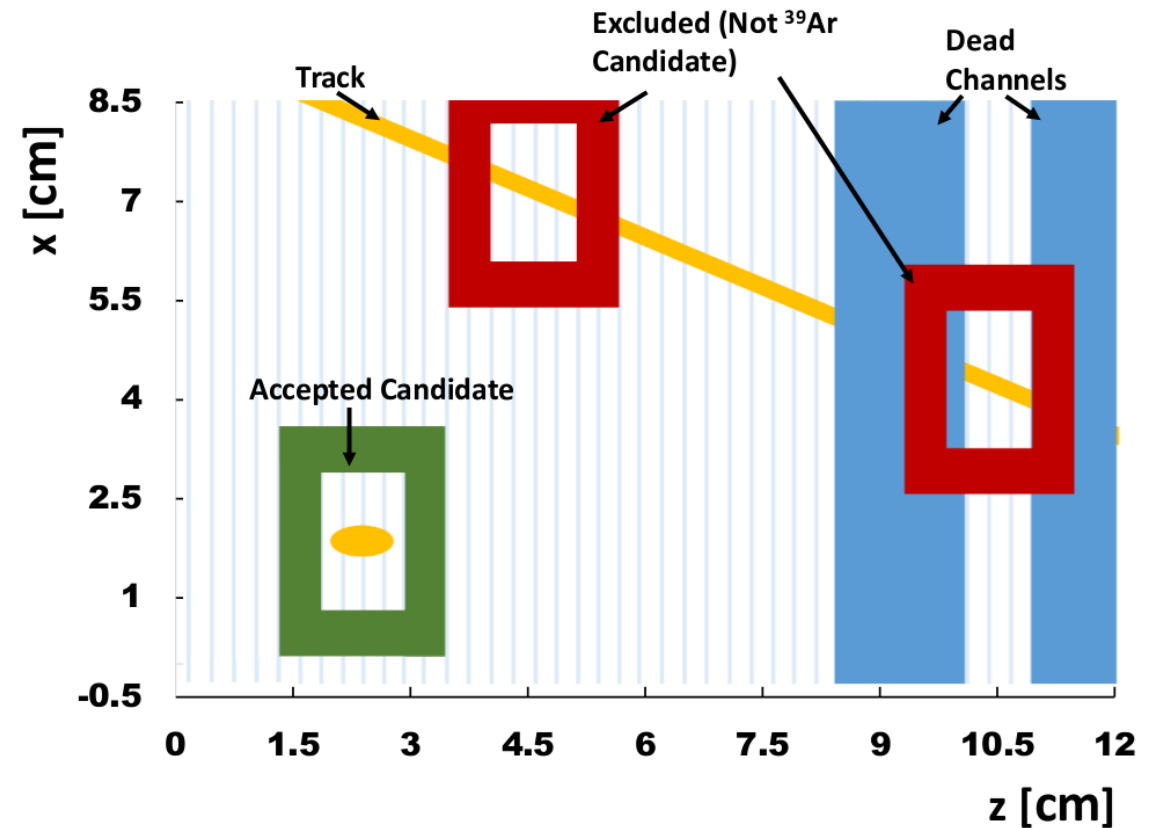


- ^{39}Ar beta decay cut-off at 565 keV (about half of the energy deposited by a MIP on a single wire at DUNE)
- Decay events should be uniform in x
 - Can make measurement without knowing t_0 of individual Ar-39 decay events



Summary of ^{39}Ar Beta Decay Studies:

- Only studying the collection plane in the following results
- ^{39}Ar beta decays will look point-like
- Reject tracks, being careful of dead channels (that might fake a point-like signal)
- Record charge in a window of 3 wires by 40 time ticks around accepted candidates
- [See MicroBooNE Public Note 1050](#)





Summary of ^{39}Ar Beta Decay Studies:

- Reconstruct candidate charge into energy via

$$E = \frac{GI}{RK} \times Q$$

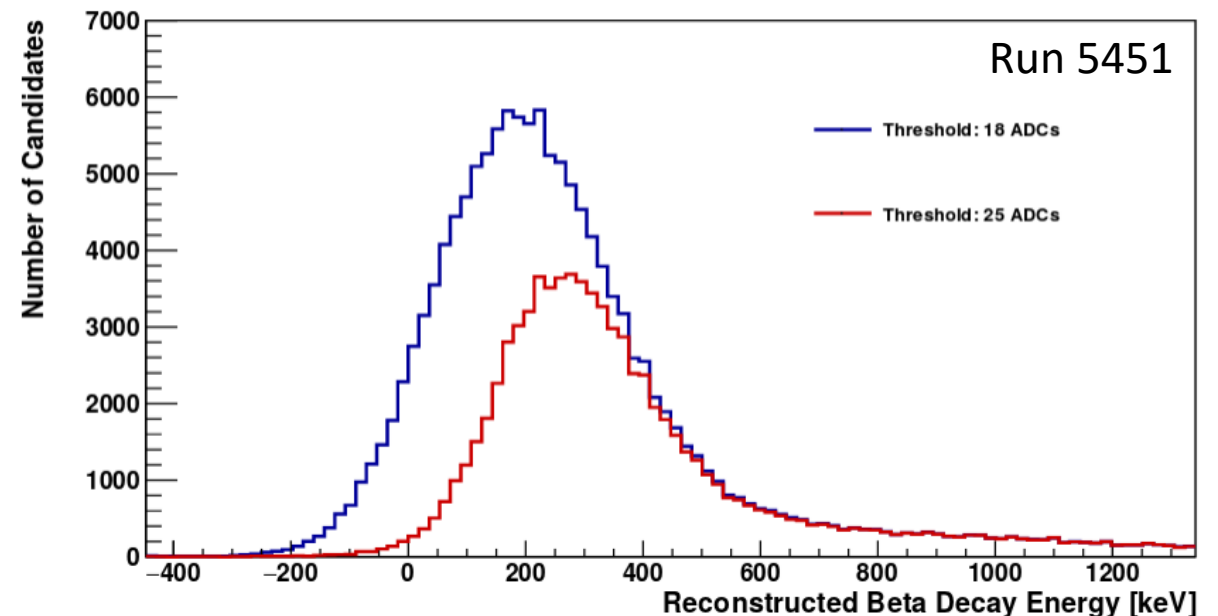
G = Gain [e^-/ADC]

I = 0.0236 keV/ e^-

R = Recombination Factor (calculated near the end-point for now)

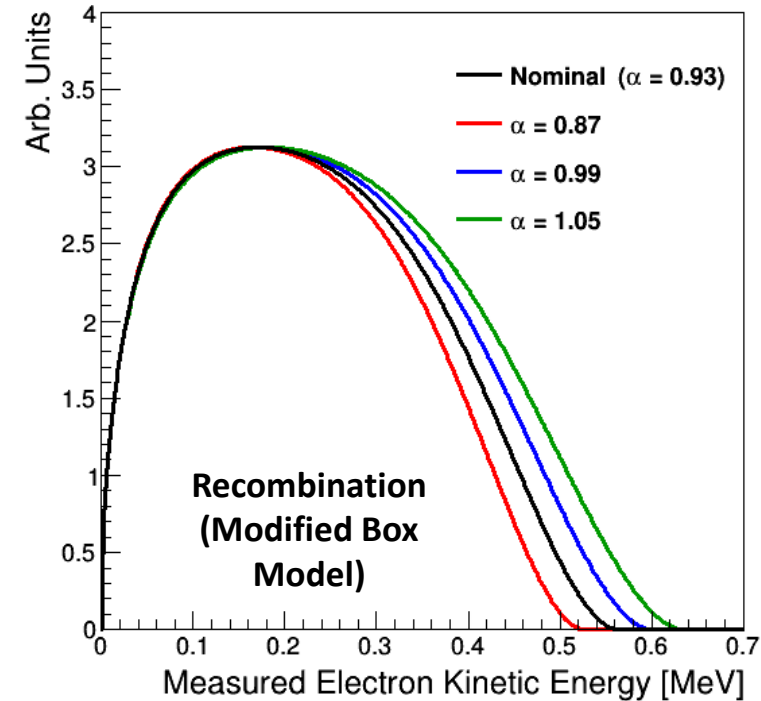
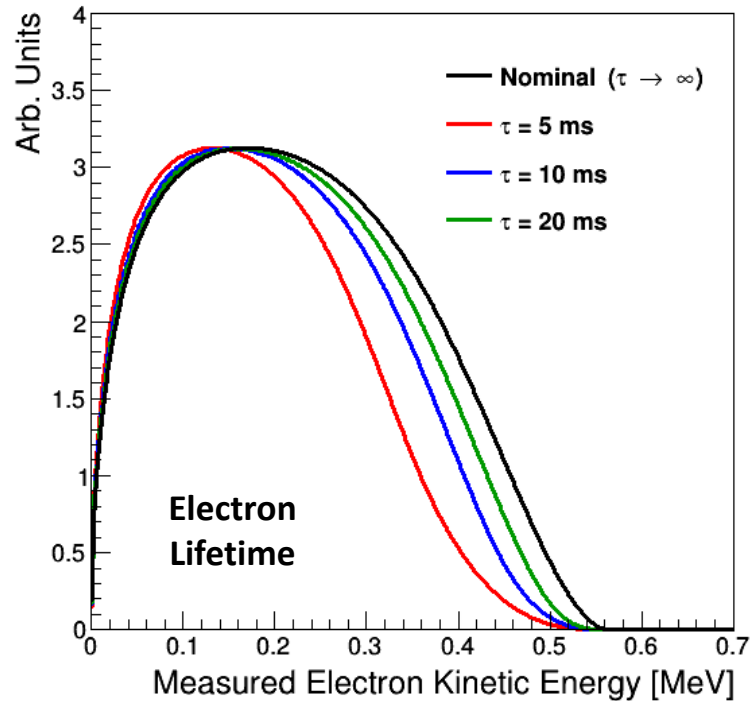
K = Electronics response Area-to-Amplitude Ratio

- High energy tail is due to cosmogenic background
- Minus the tail, the reconstructed end-point is in the correct place (~ 565 keV)





Summary of ^{39}Ar Beta Decay Studies:



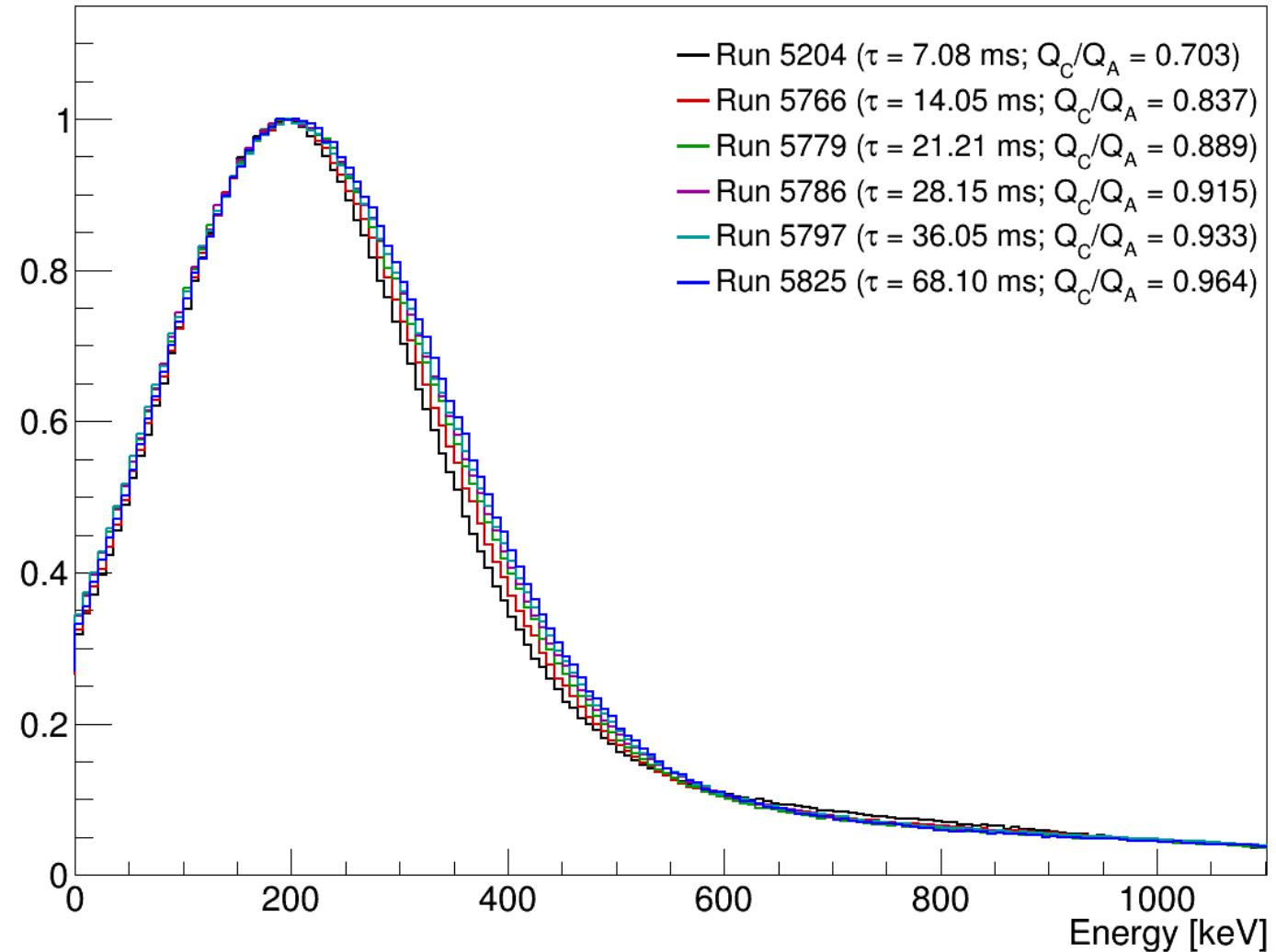
- Effects of Electron Lifetime and Recombination on the beta decay spectrum are mostly distinct and separable
- Noise will also contribute, but the effect can be precisely measured
- More on this, see my June 2020 DUNE physics week slides: <https://indico.fnal.gov/event/24397/>



Electron Lifetime Proof of Concept:

- For the first time with ^{39}Ar : qualitative study of electron lifetime
- Spectra normalized to the same height
- Still not utilizing track bubble veto yet

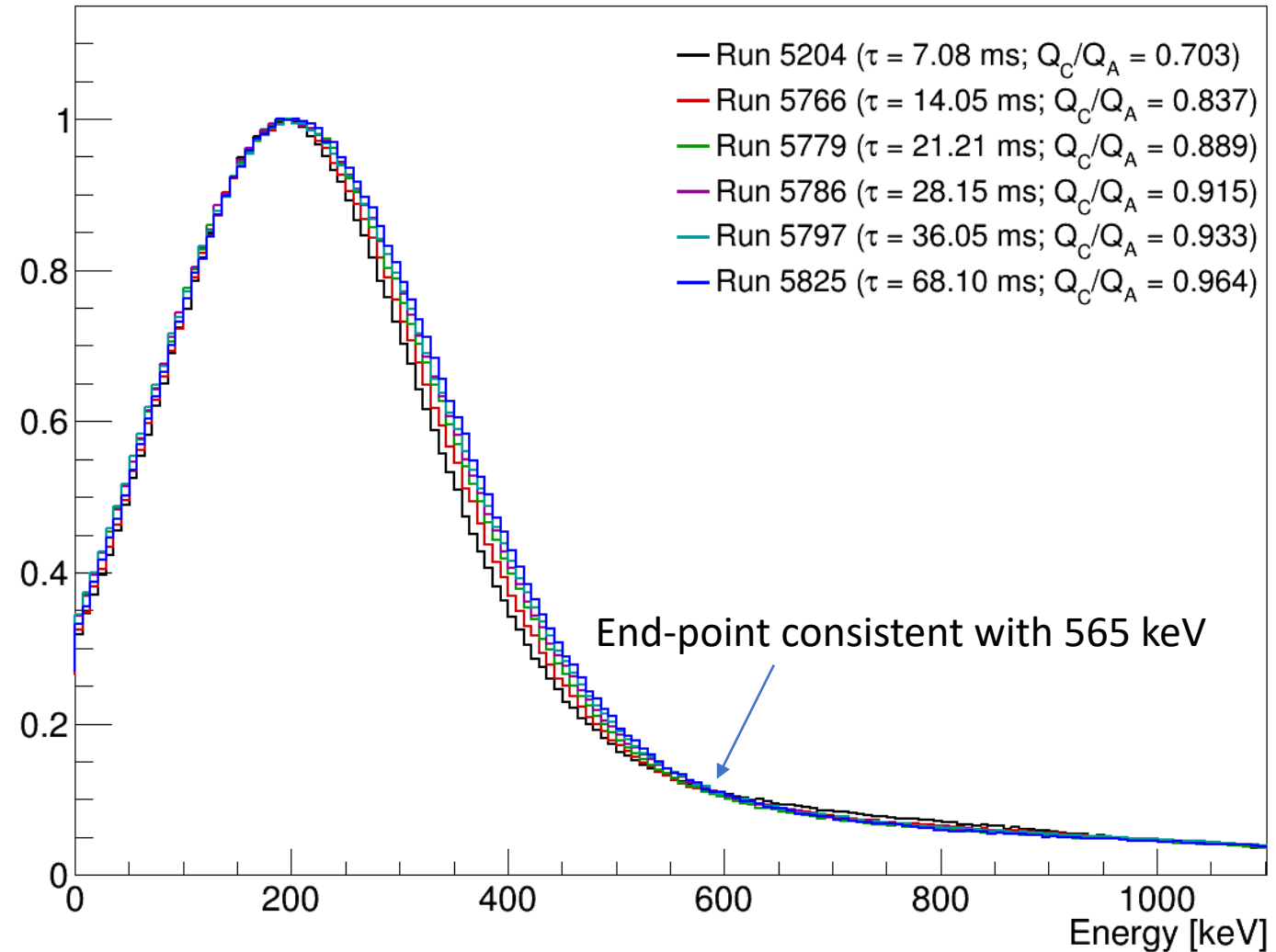
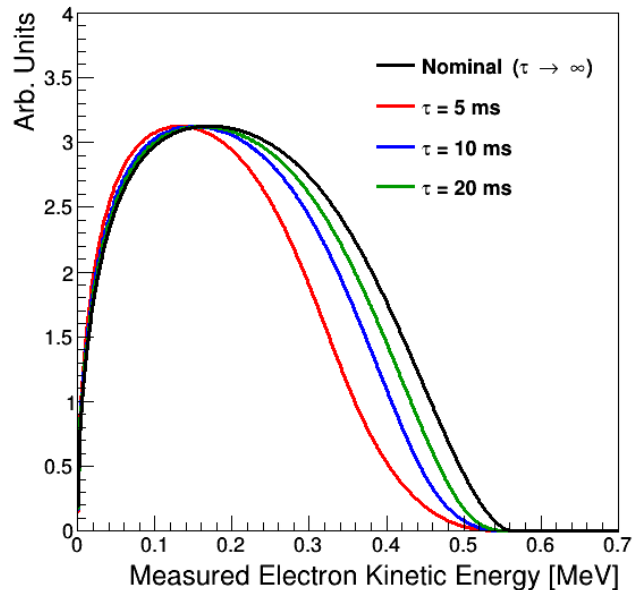
5243 events from Run 5204 (7.08 ms)
6580 events from Run 5766 (14.05 ms)
6574 events from Run 5779 (21.21 ms)
6568 events from Run 5786 (28.15 ms)
6566 events from Run 5797 (36.05 ms)
5247 events from Run 5825 (68.10 ms)





Electron Lifetime Proof of Concept:

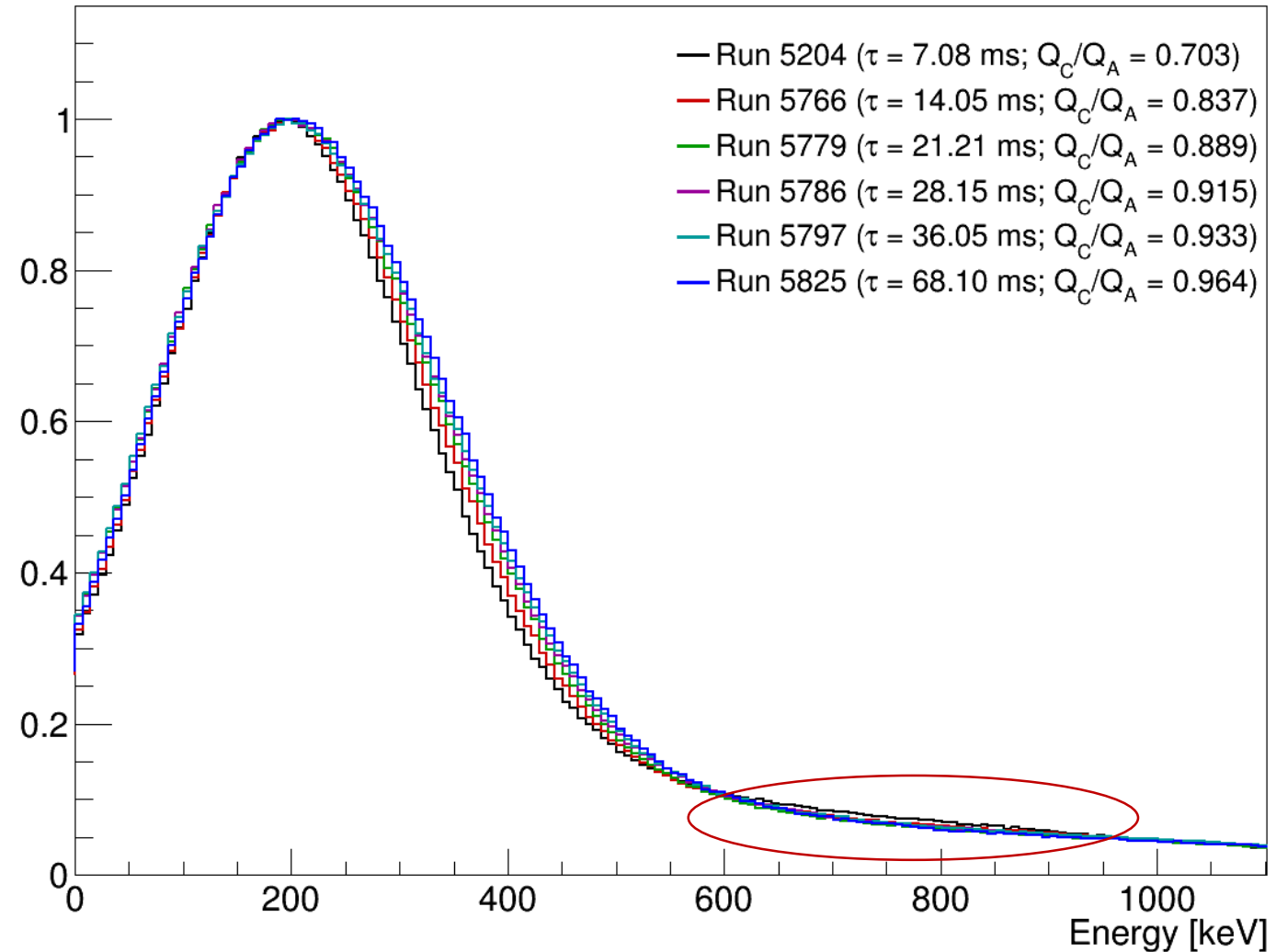
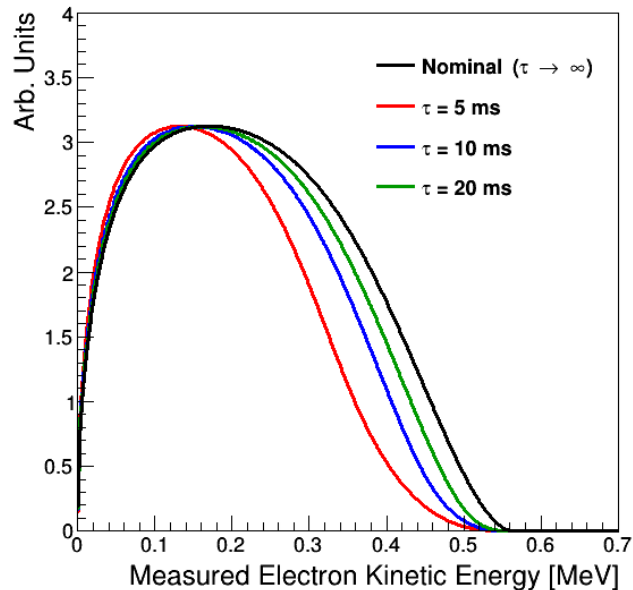
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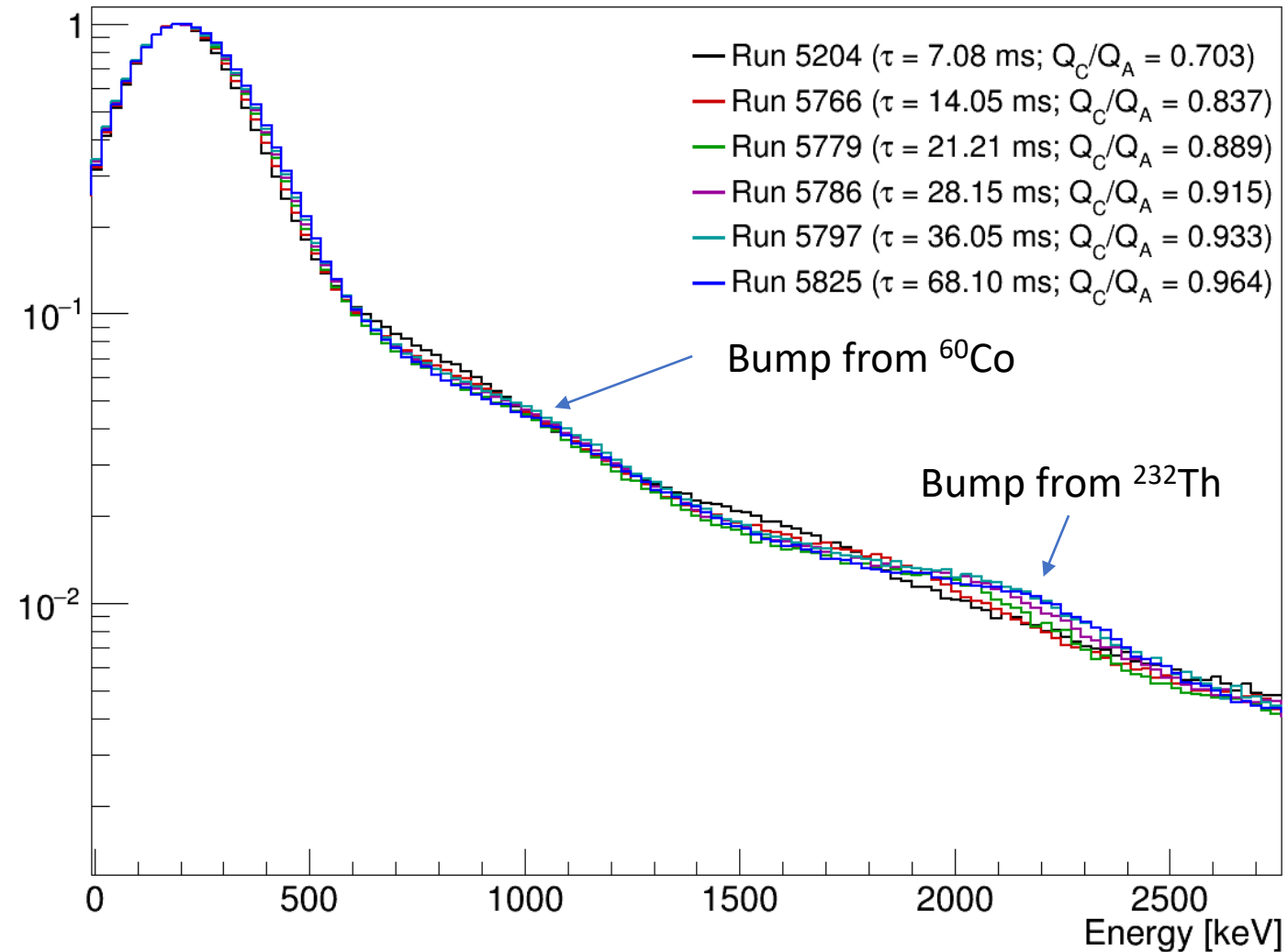
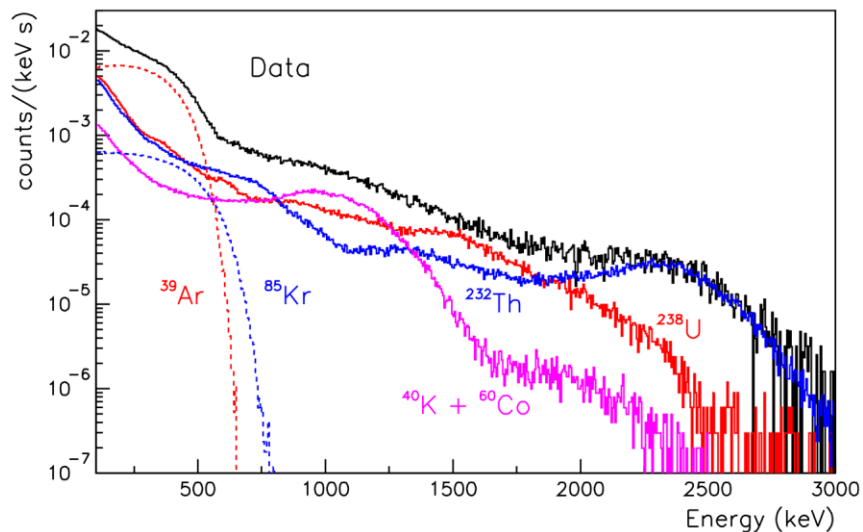
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Radiological Backgrounds:

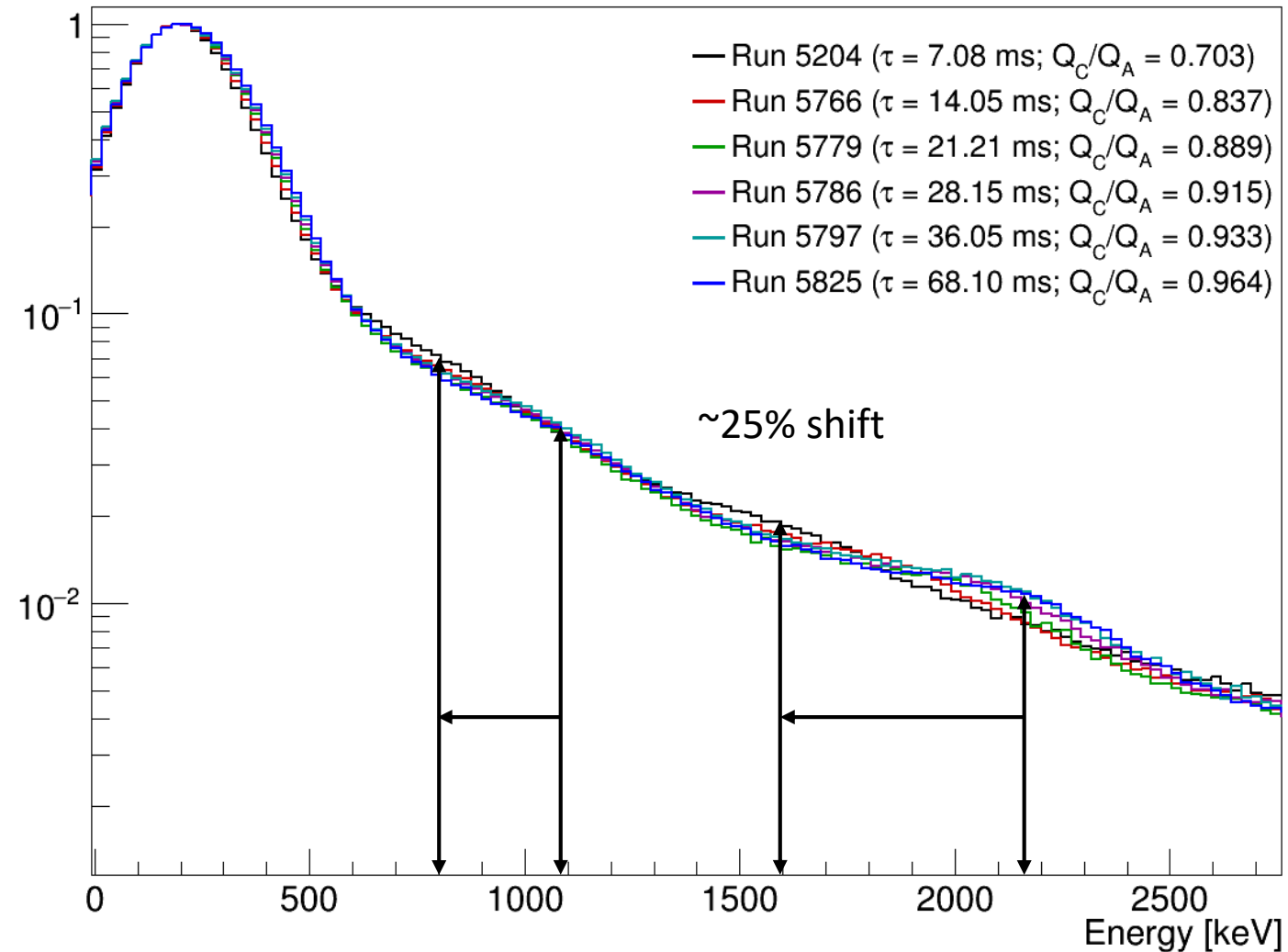
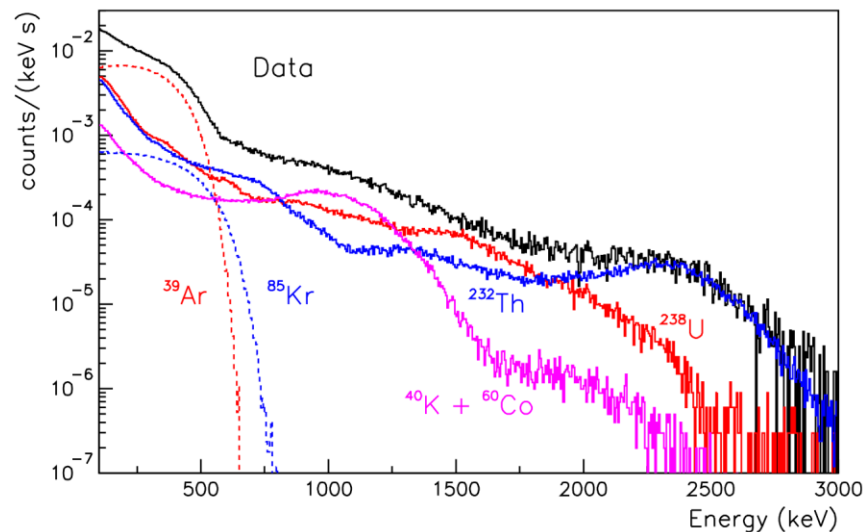
- Portions of spectra could show effects from other radiological sources
- Other radiological sources show effects of electron lifetime differences





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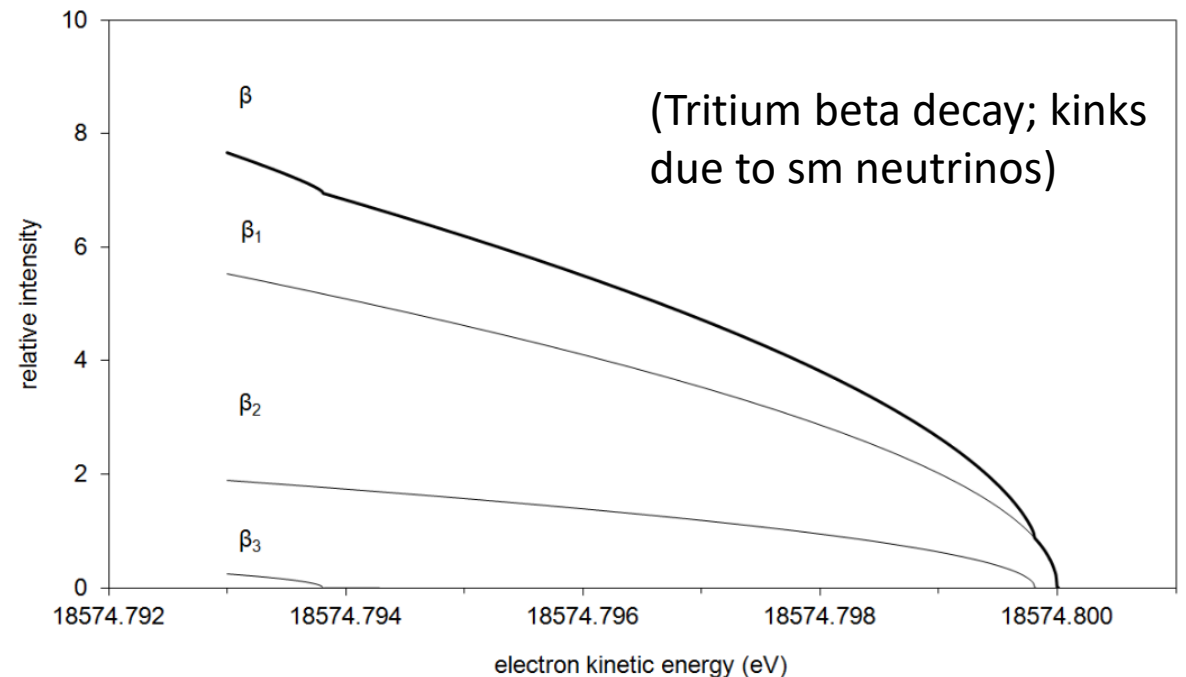
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Something Completely Different:

- Investigating a new use for beta decay signal
 - Look for a kink in the beta decay spectrum; amplitude depends on mixing angle
- Utilize the DUNE FD to constrain keV-scale sterile neutrino masses, similar to the KATRIN experiment
 - KATRIN sensitive up to 18 keV
 - DUNE sensitive between 20 keV and 300 keV?
 - Energy range well motivated by theory <https://arxiv.org/pdf/1911.01447.pdf>
- Mixing angle is small, but we get 10^{19} ^{39}Ar beta decays at DUNE FD (assumes 400 kt-year of running, continuous readout of DAQ)
 - **Utilize ProtoDUNE data for a preliminary result?**



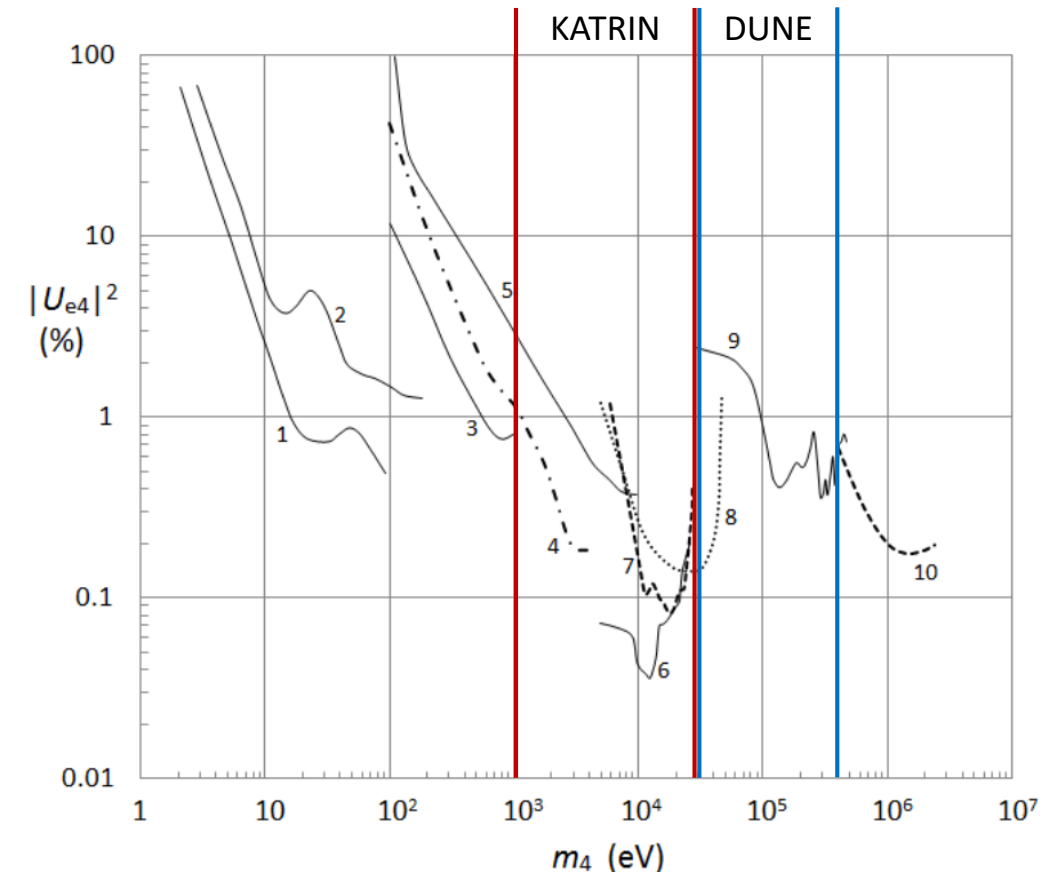
Credit: Dragoun and Vénos (2015).

<https://arxiv.org/ftp/arxiv/papers/1504/1504.07496.pdf>



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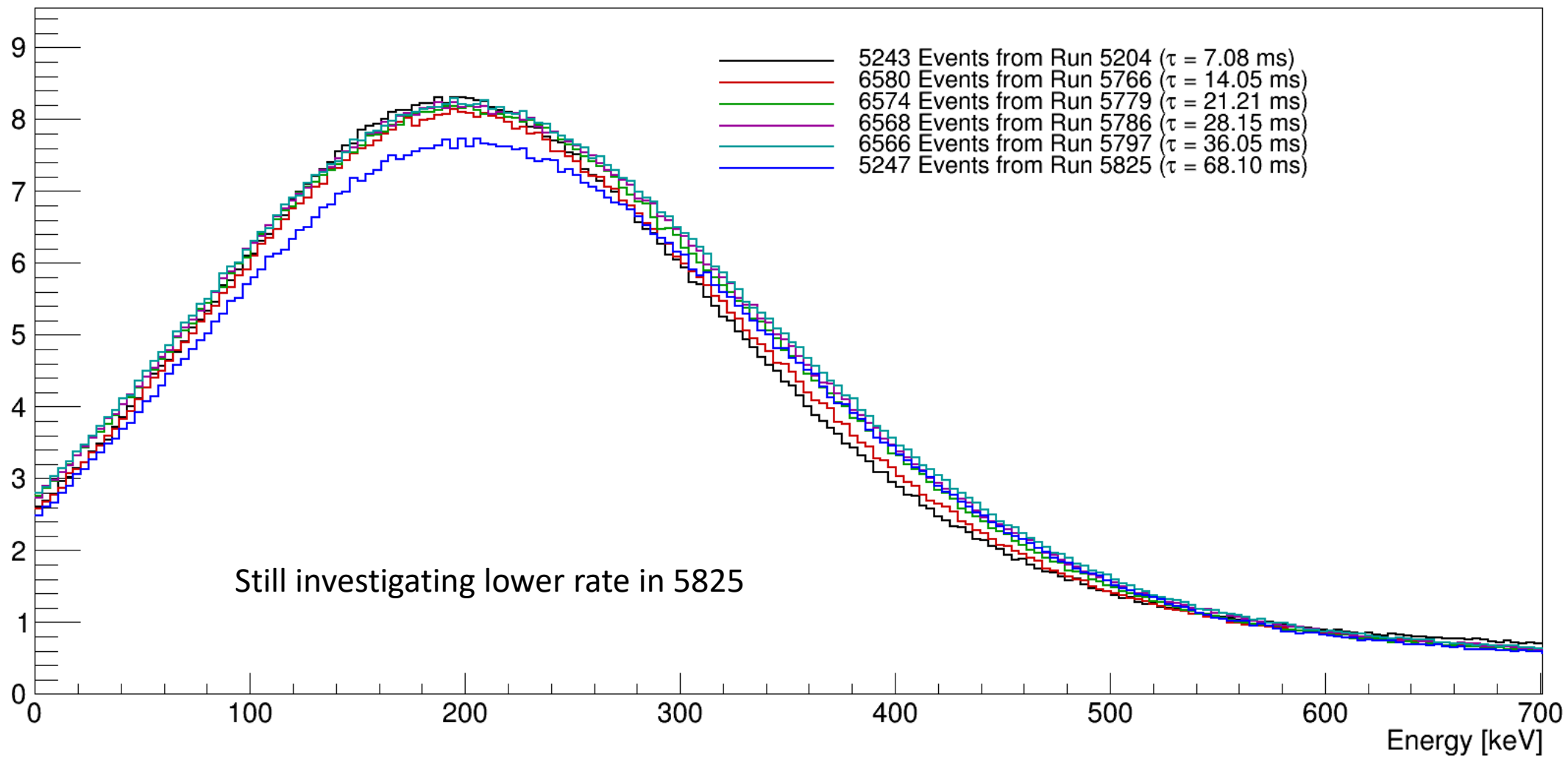
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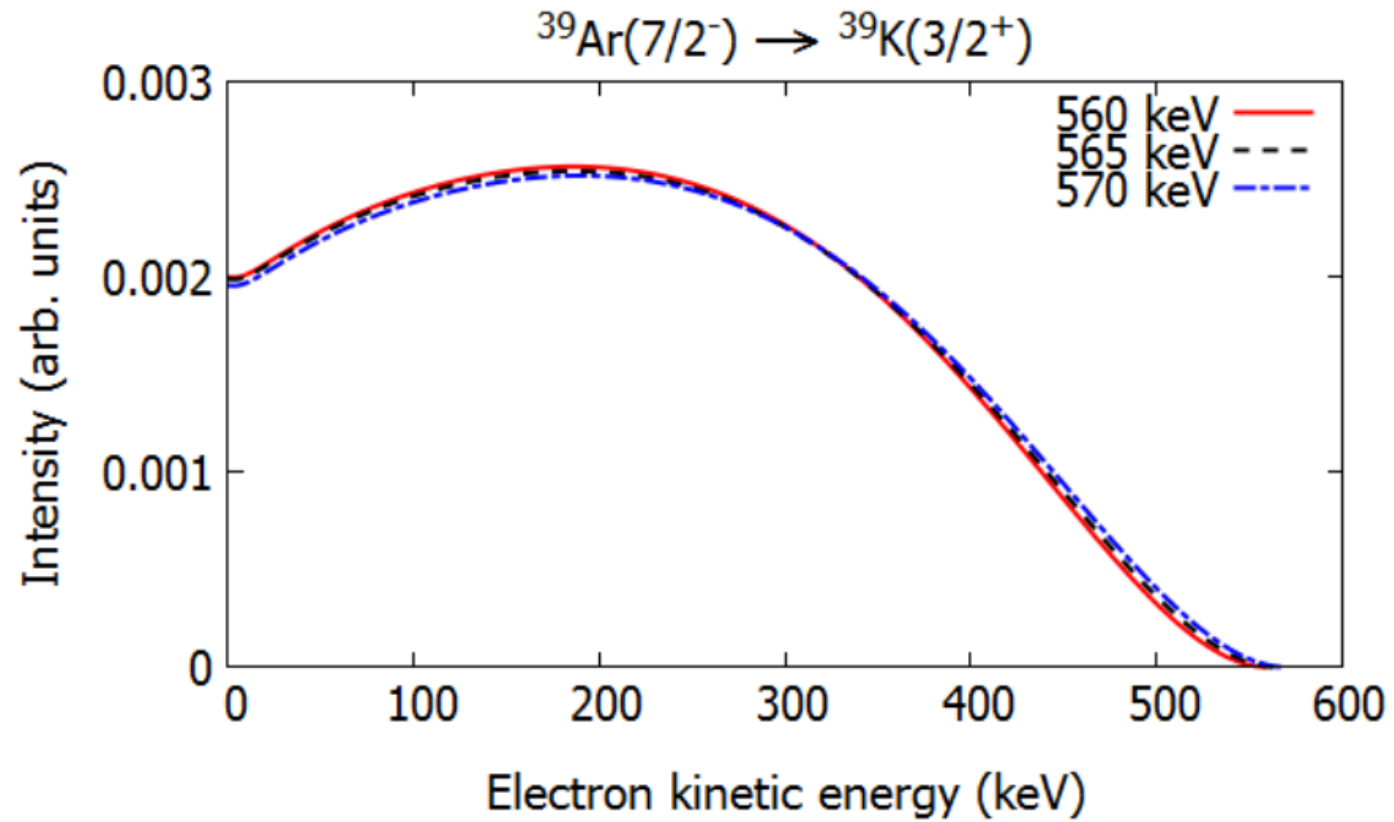
Conclusion:

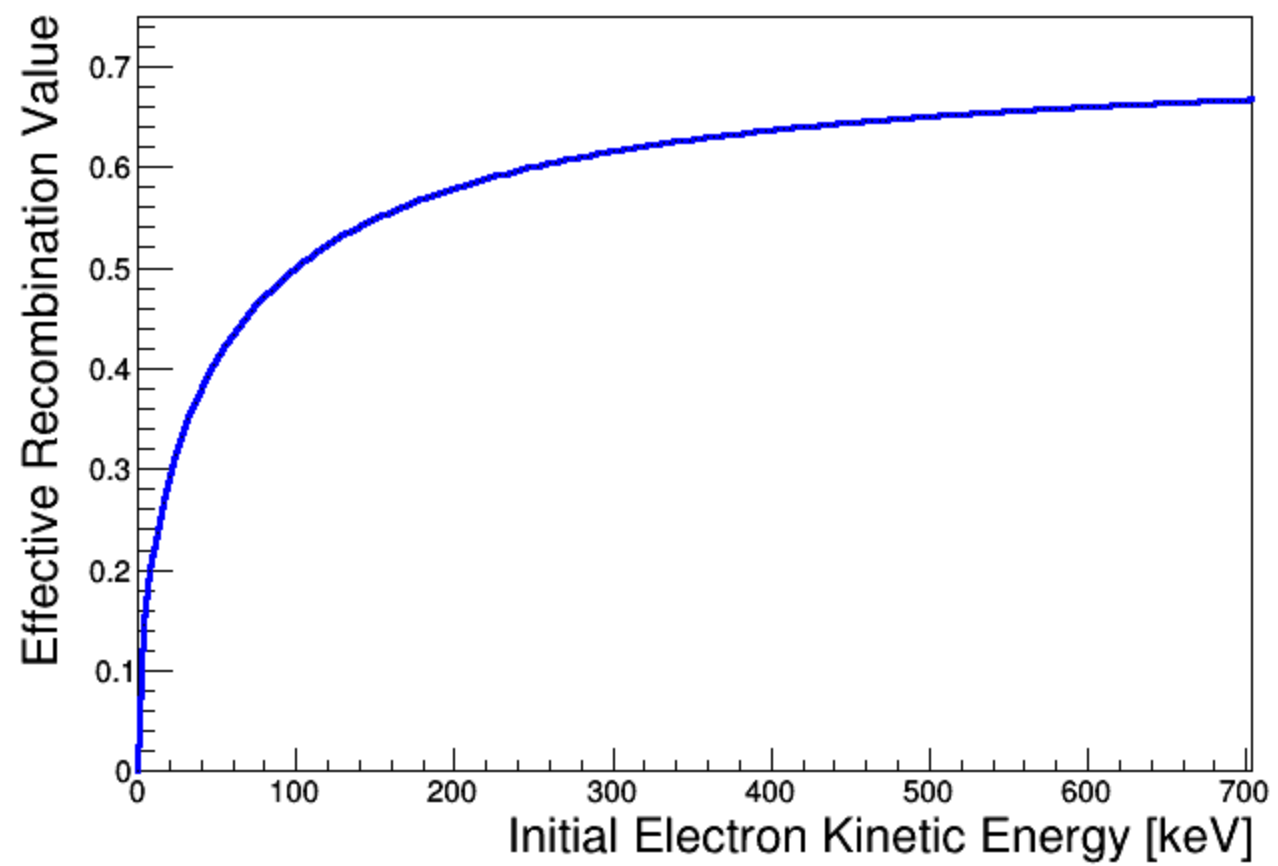
- Visible radiological background in ProtoDUNE-SP
- Demonstrated the potential of measuring electron lifetime using radiological sources
- We're investigating a new way to utilize ^{39}Ar for measurements of keV-scale sterile neutrinos using the DUNE far detector and maybe ProtoDUNE
- Next: look into using deconvolved data products (inherent thresholding?), tightening charge integration window, implement cosmic veto bubble

Normalized by number of readouts instead of by height

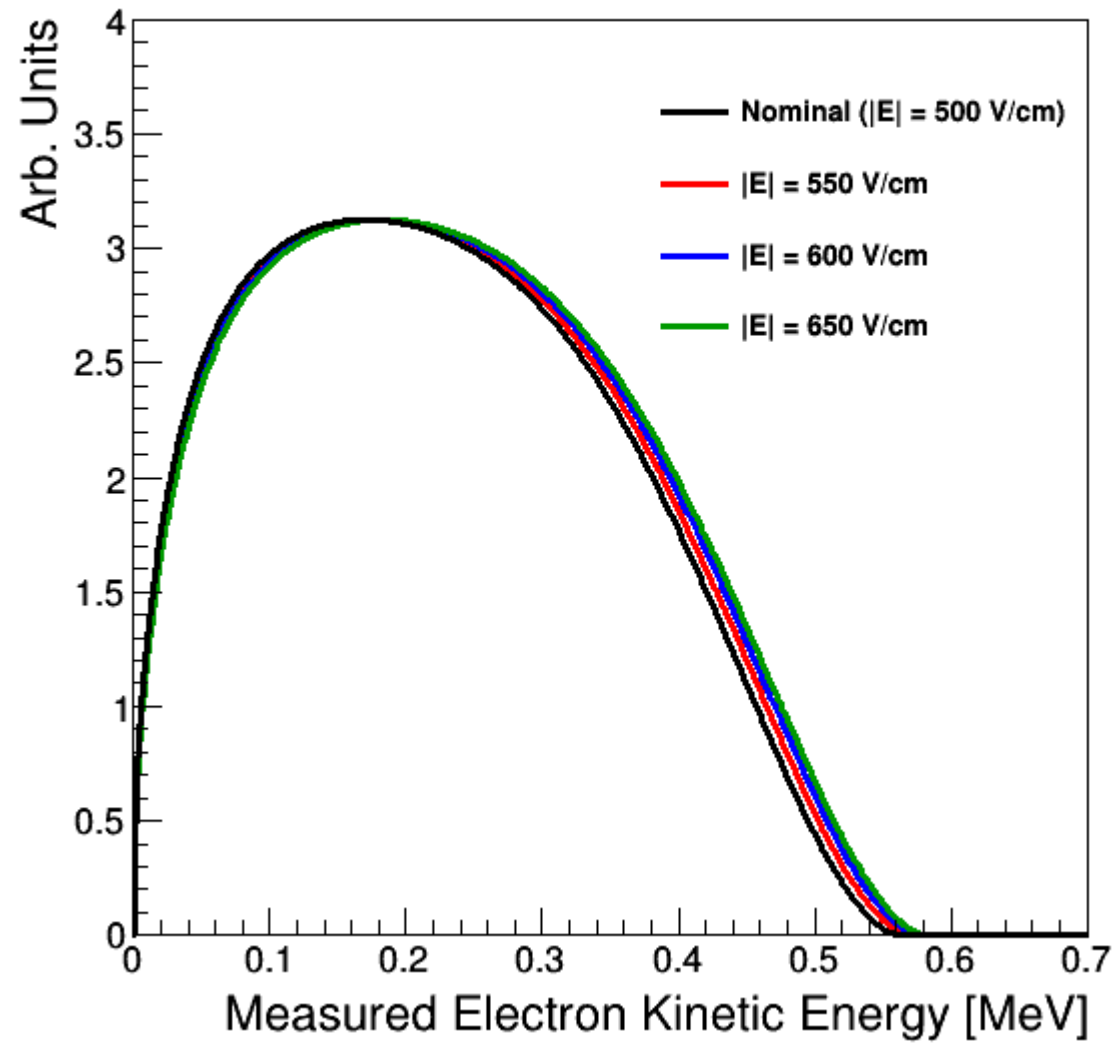


Theory uncertainties





Effective E field distortions



- Average signal shape also shows the effect of induced charge on the collection plane
- Investigating tightening integration window

