On track for discovery of sub-GeV dark matter with liquid xenon TPCs

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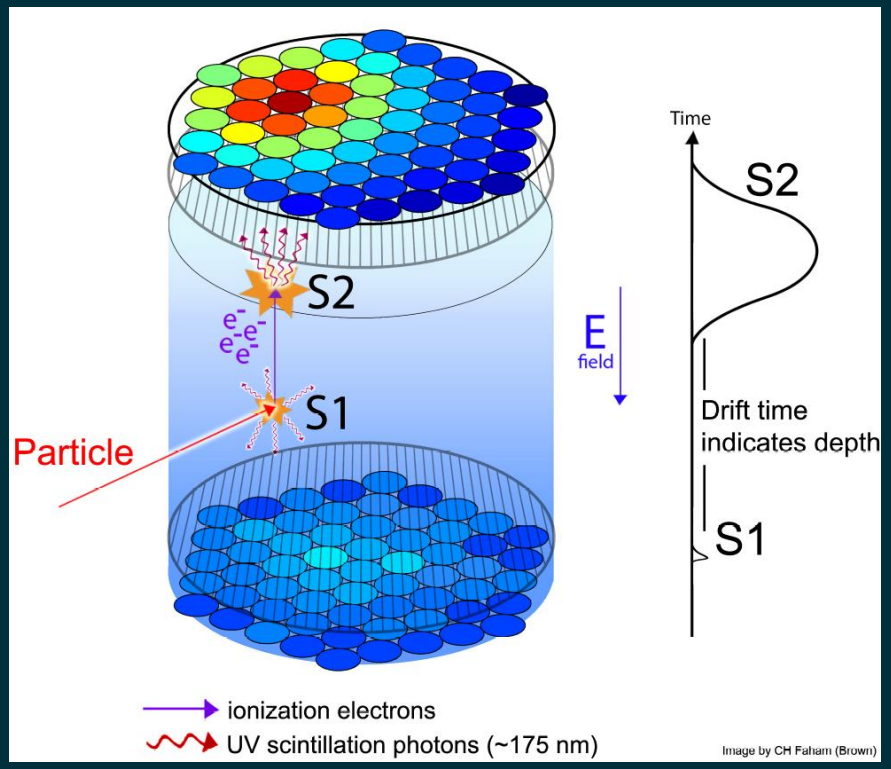
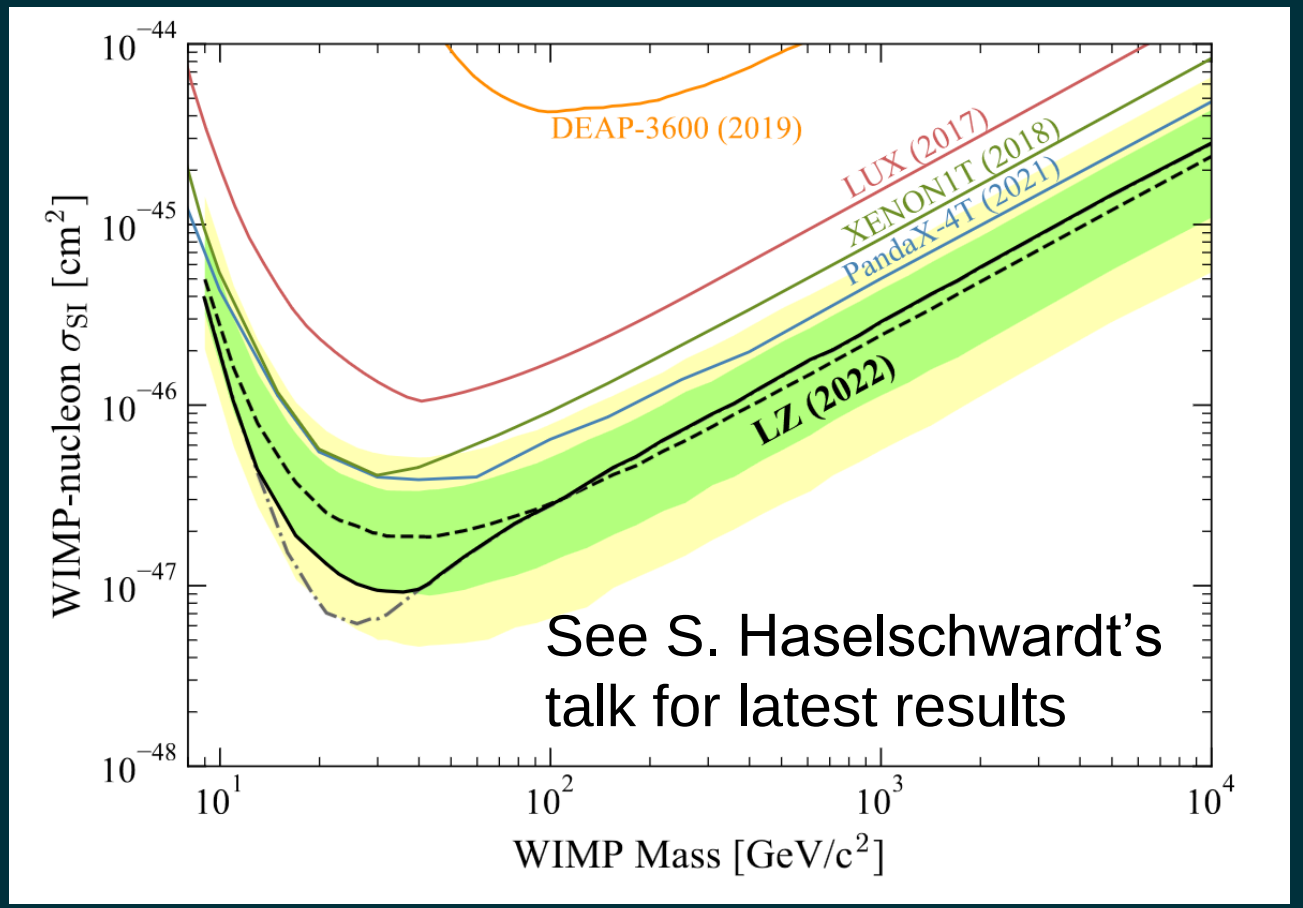
Xenon TPCs – leading the way in WIMP sensitivity

LZ: *2207.03764*

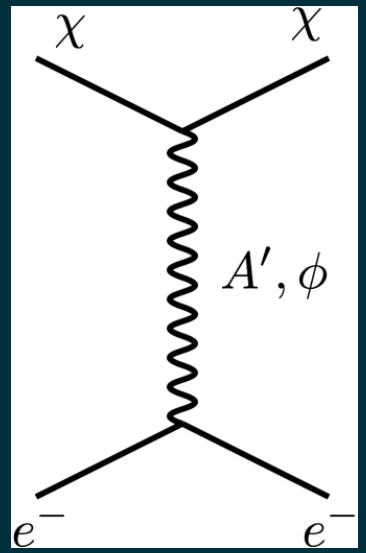


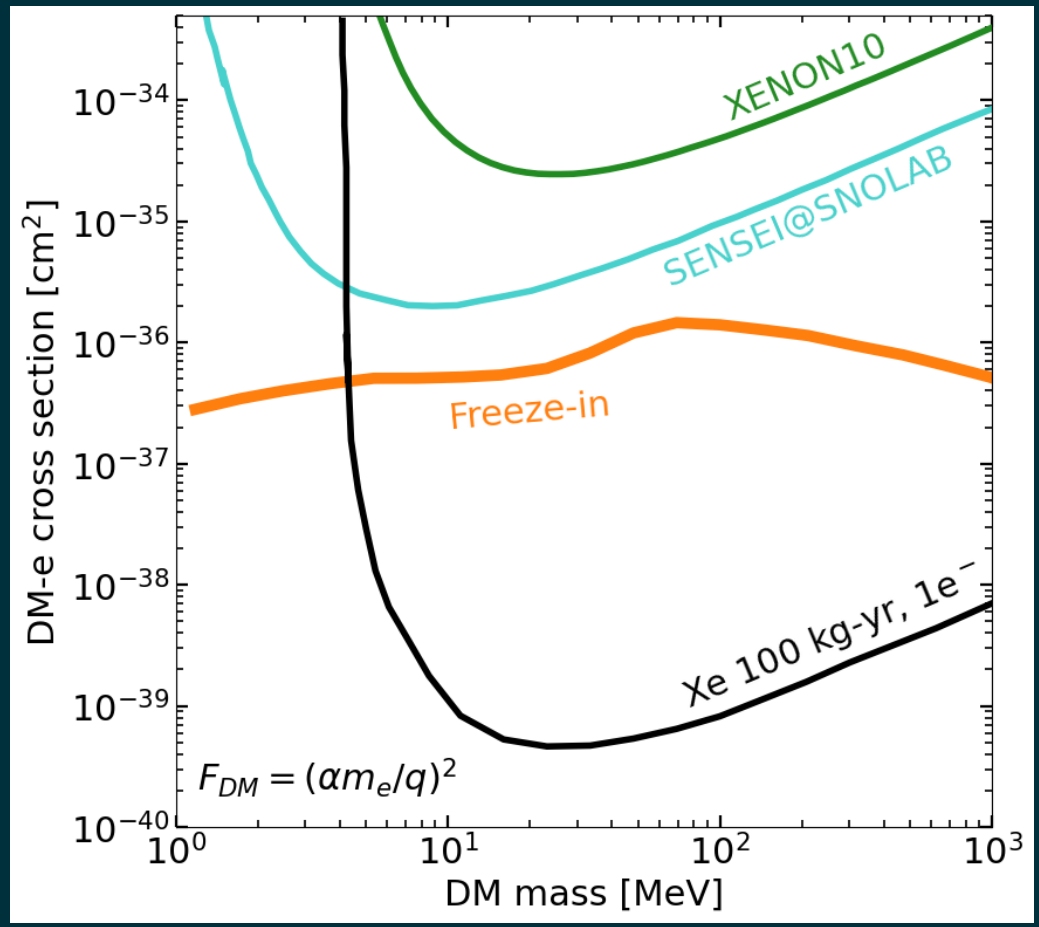
S1: light signal
S2: charge signal



Low-mass dark matter with charge-only signal

- Min. low-energy threshold, E_g = 9.2 eV
- Attractive for DM-electron scatter searches
  - E.g., hidden sector models

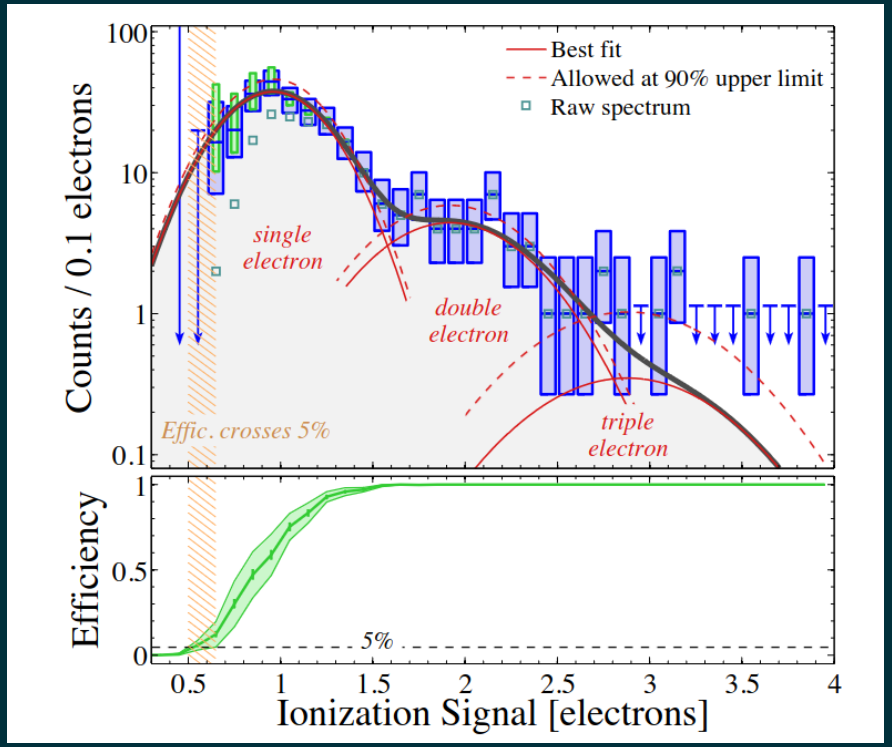




Dominant background – delayed electron emission

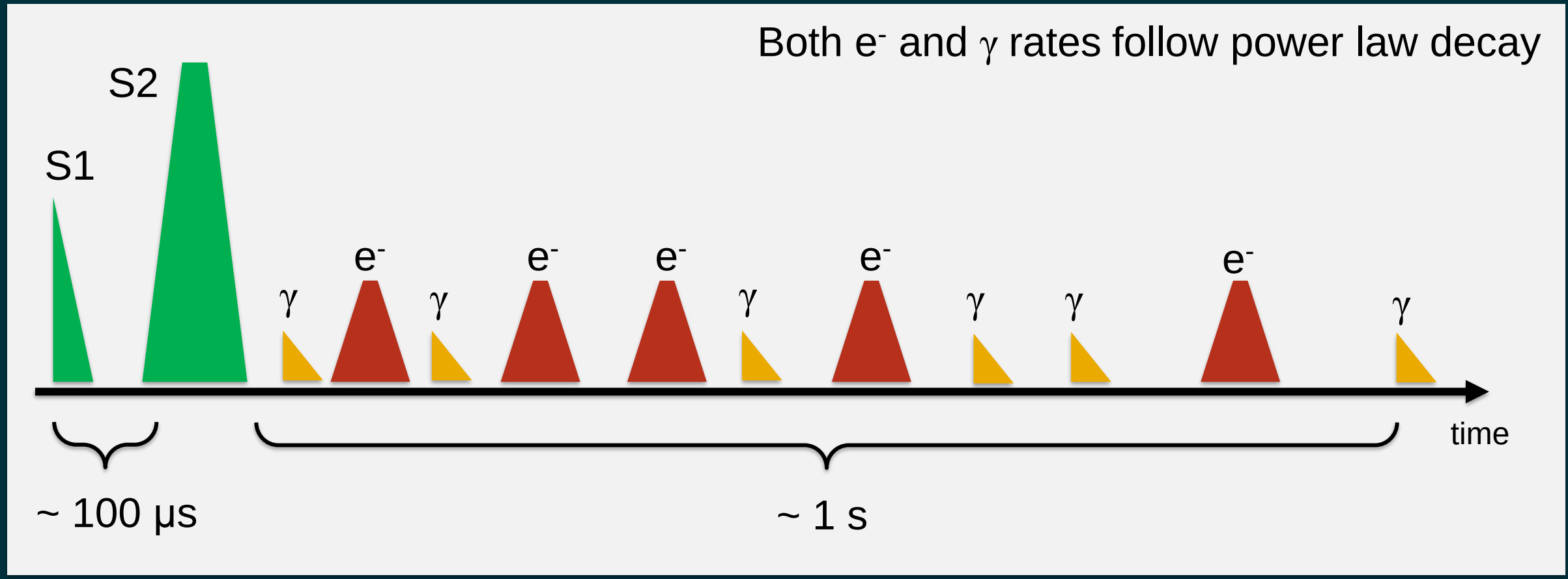
- Delayed electron emission – “electron trains”
  - Radioactive backgrounds (Rn) subdominant for few-electron signals
- **Remove detector backgrounds, the next stop is either dark matter or the neutrino fog***
  - The origin of electron trains has remained elusive

XENON10 data: *1206.2644*
See also *1104.3088*



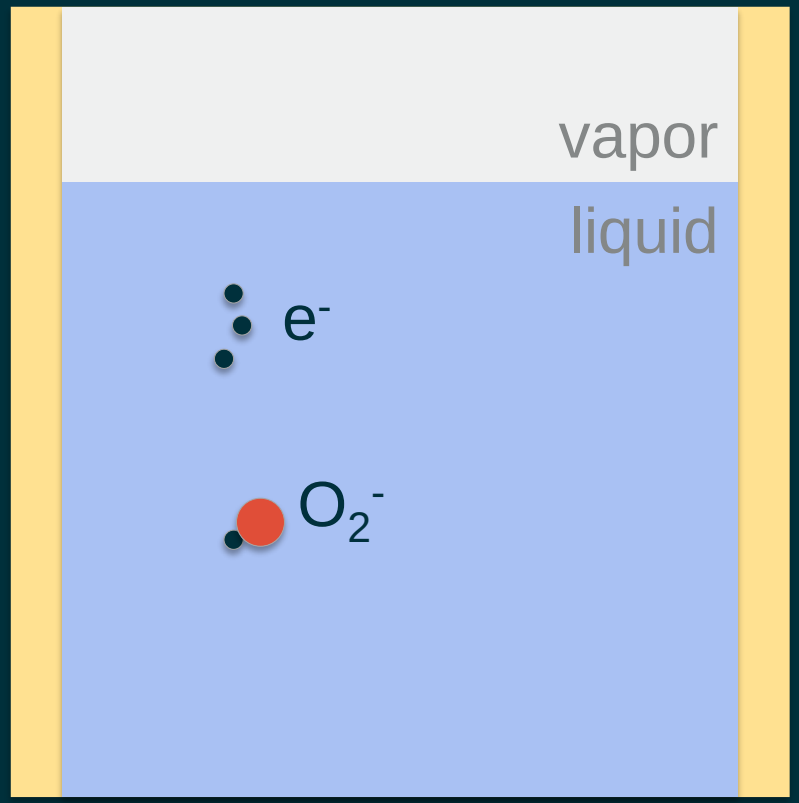
Events are due to electron trains

Delayed emission – electron and photon “trains”

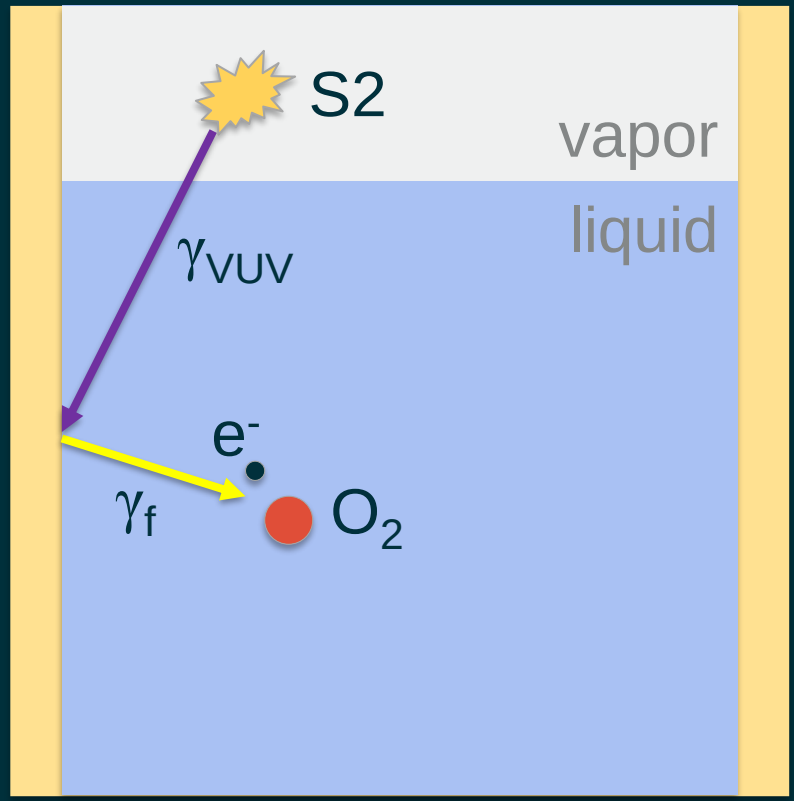


Conclusion first: what causes electron trains?

1. Drifting electrons are trapped on impurities in xenon



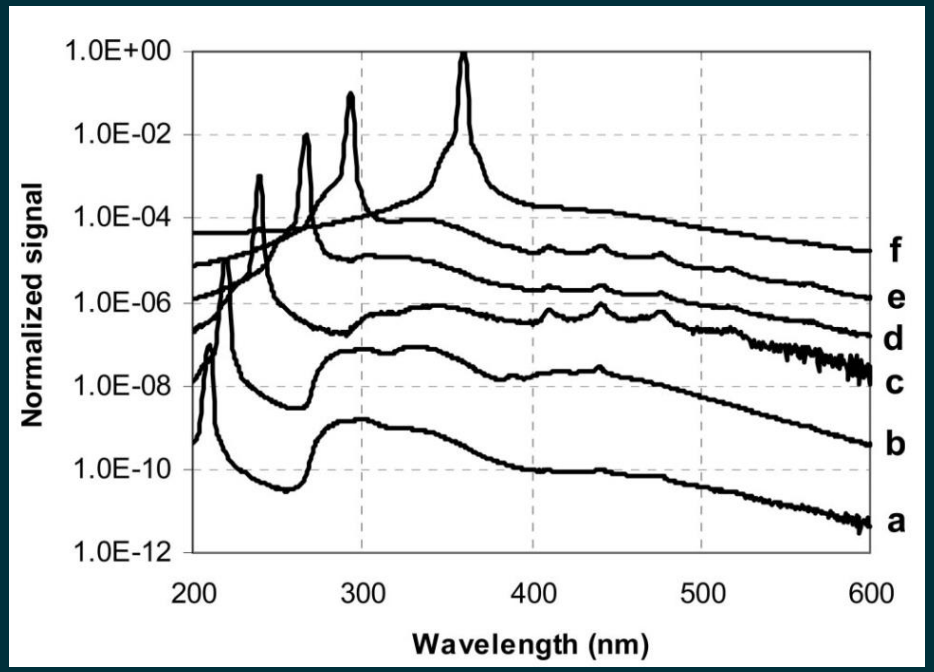
2. Trapped electrons are released via photoionization from fluorescence



What causes photon trains?

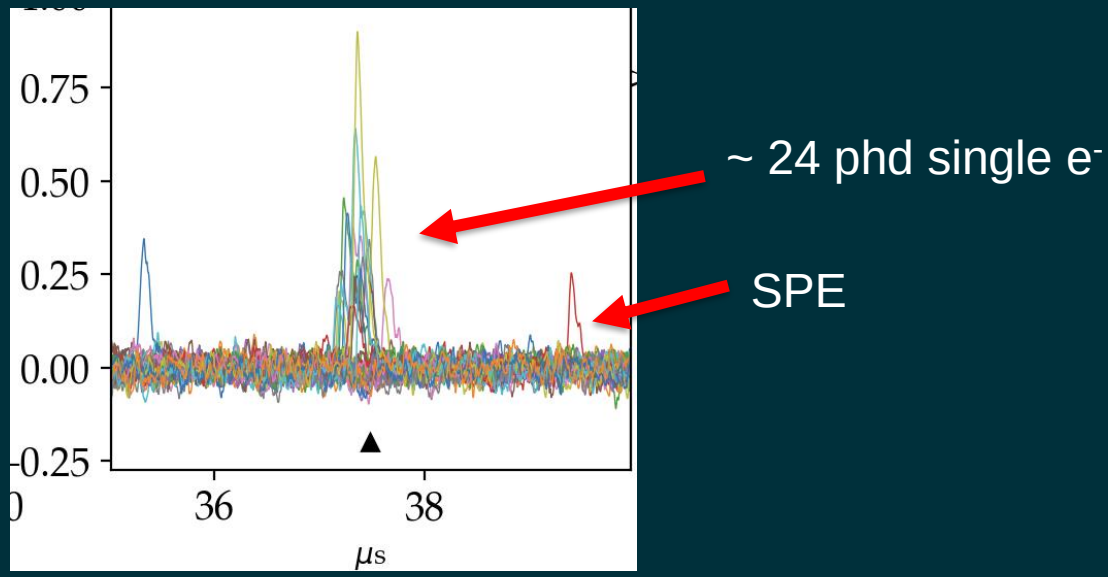
- Impurities in detector materials fluoresce from Xe VUV light
- PTFE is likely dominant source in Xe TPCs
- All dielectrics are suspect (PEEK, acrylic, …)

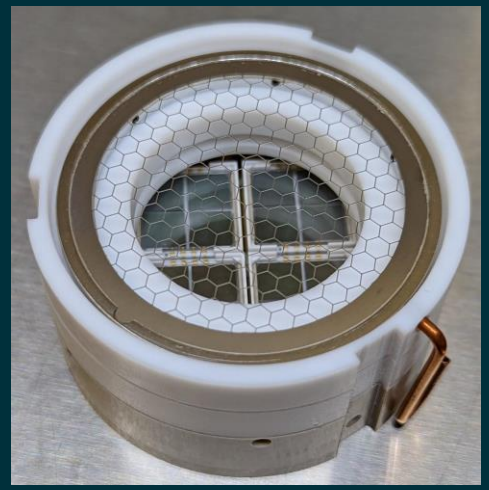
Shaw et. al. (2007)
Fluorescence spectra of PTFE at varying UV energy excitations

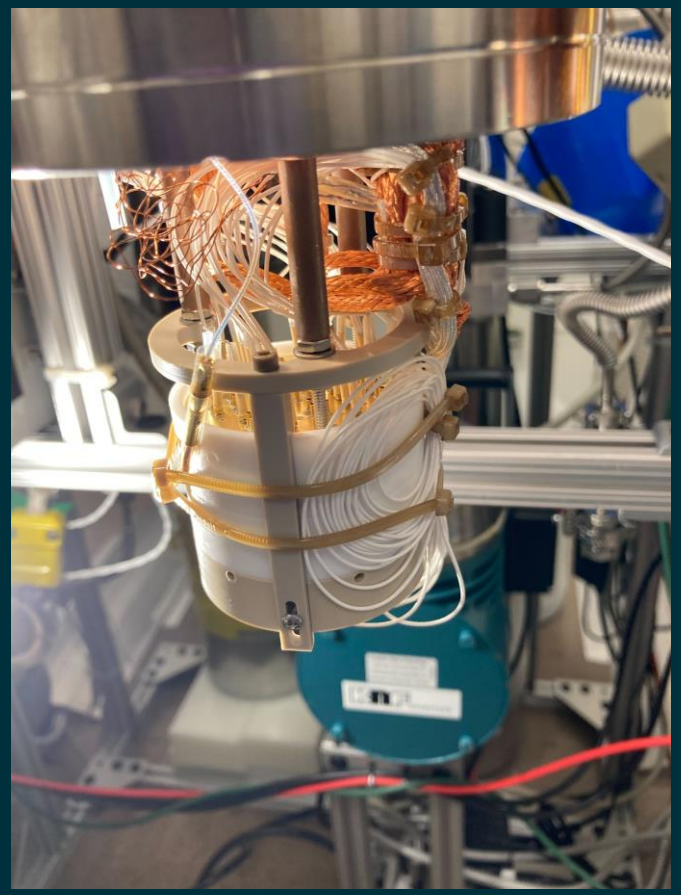


Investigations with xenon TPC at LBNL

- ~ 700 g dual-phase xenon TPC
- 32 SiPM channels
- Typical single electron ~ 20-30 phd





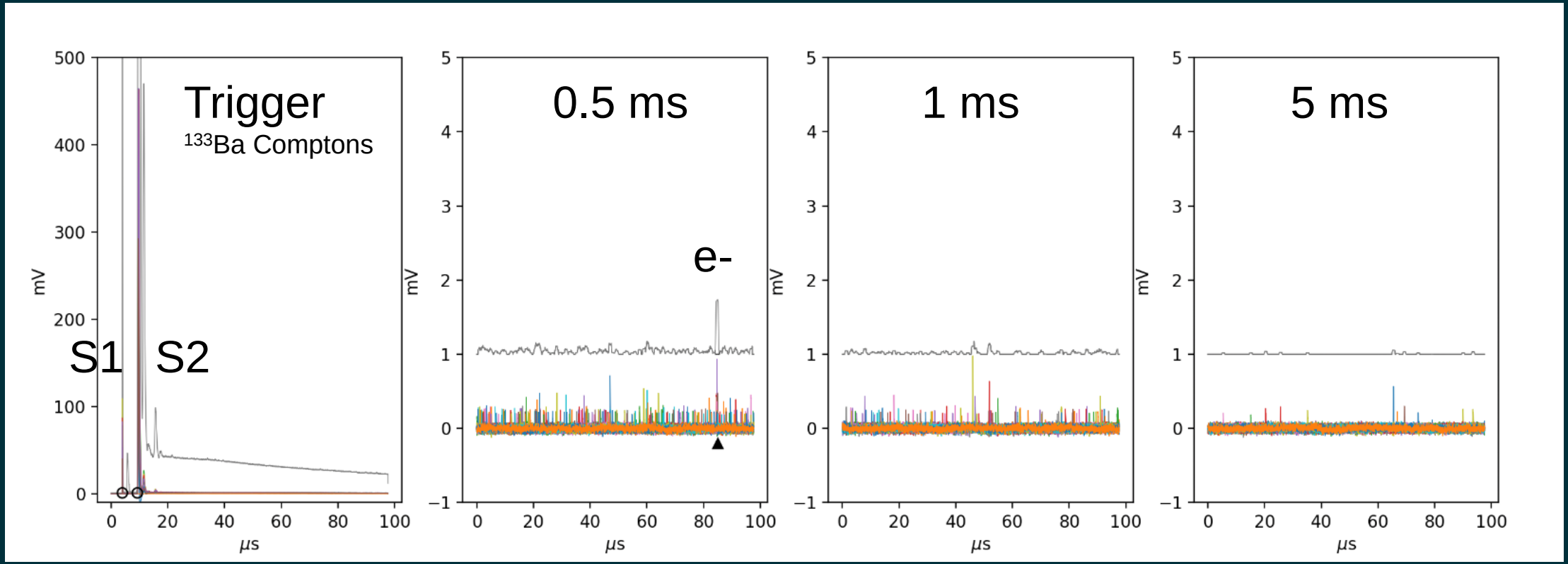


More work from this test stand:

- Solid Xe TPC (crystaLiZe): *2312.15082*, *2201.05740*
- H/He-doping Xe (HydroX): *2308.02430*
- SiPM G3 R&D: *2309.07913*

Delayed signal in liquid/vapor xenon TPC

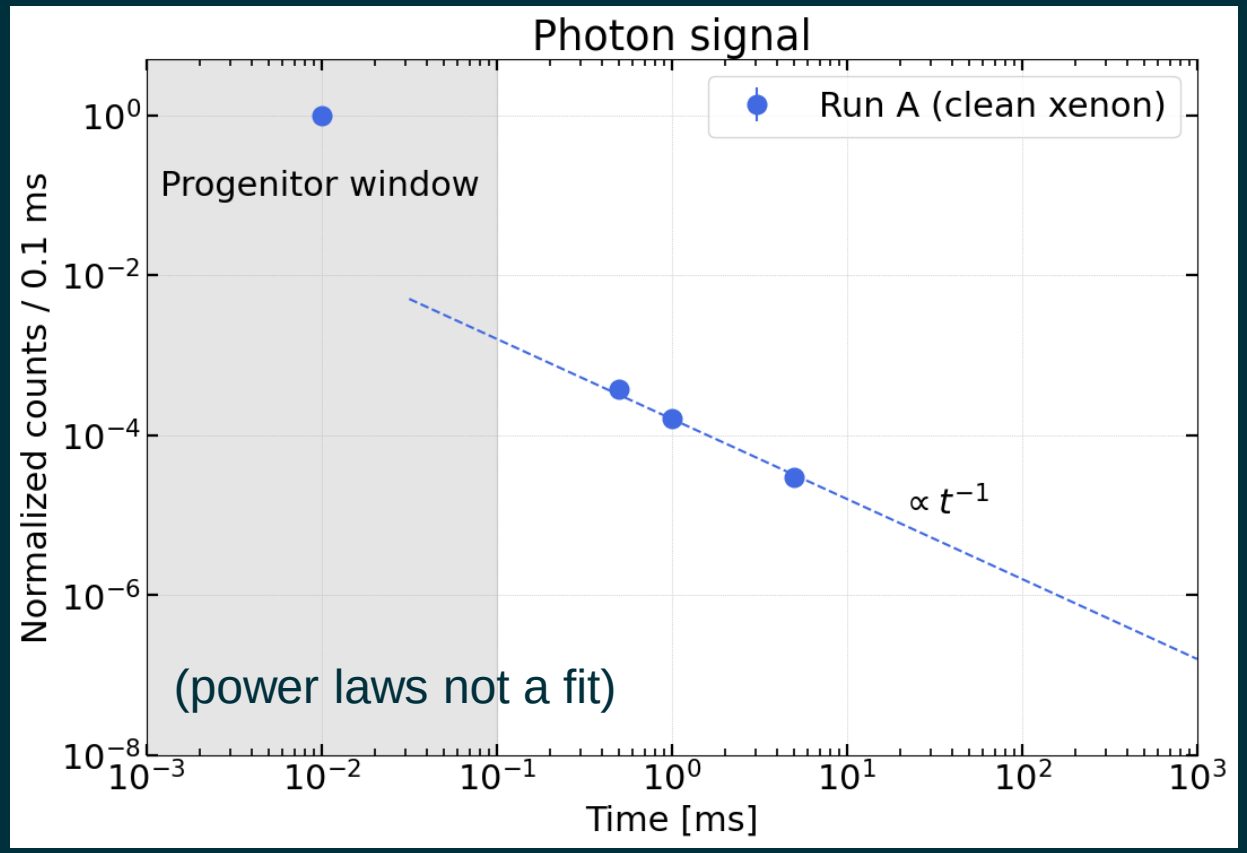
Observe delayed electrons and photons



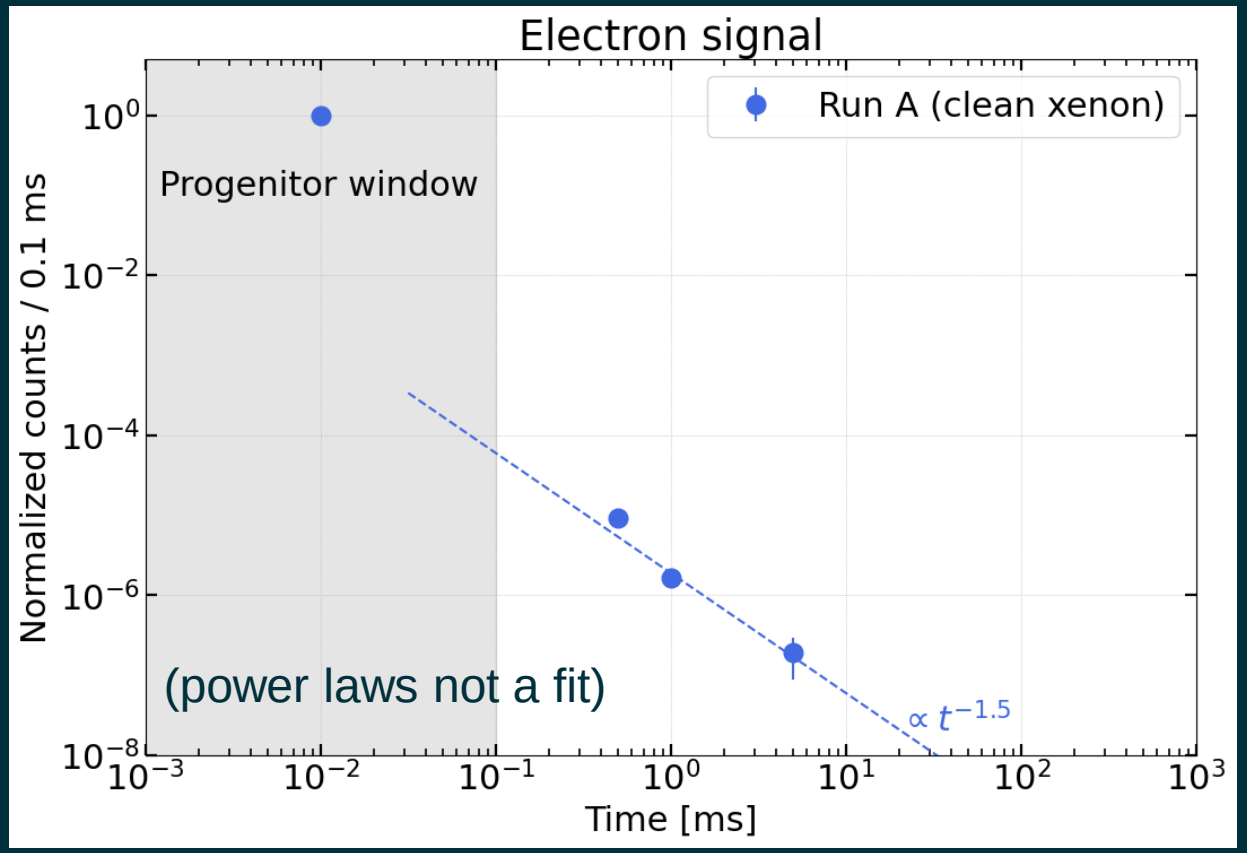
Using “cascade trigger” to sample delayed times

Nominal delayed emission rates

Delayed photon emission



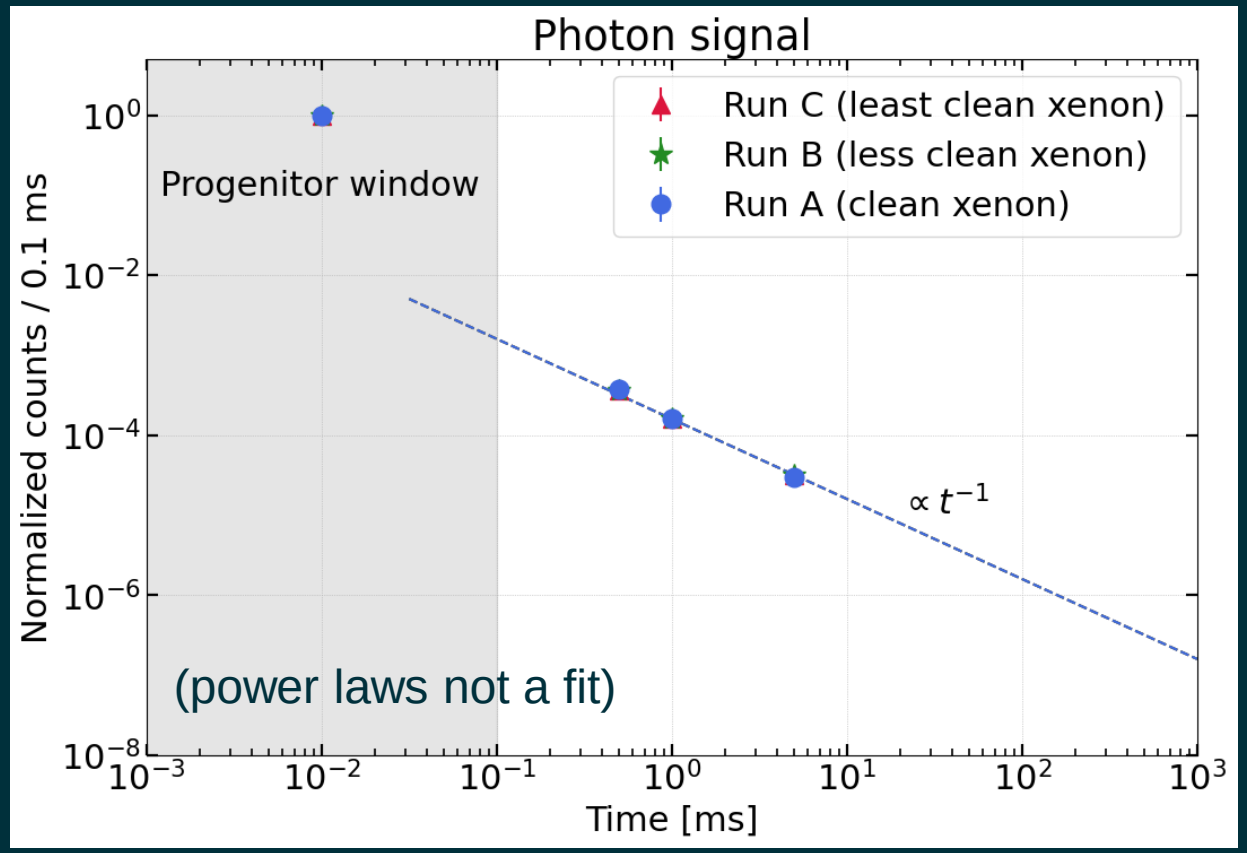
Delayed electron emission

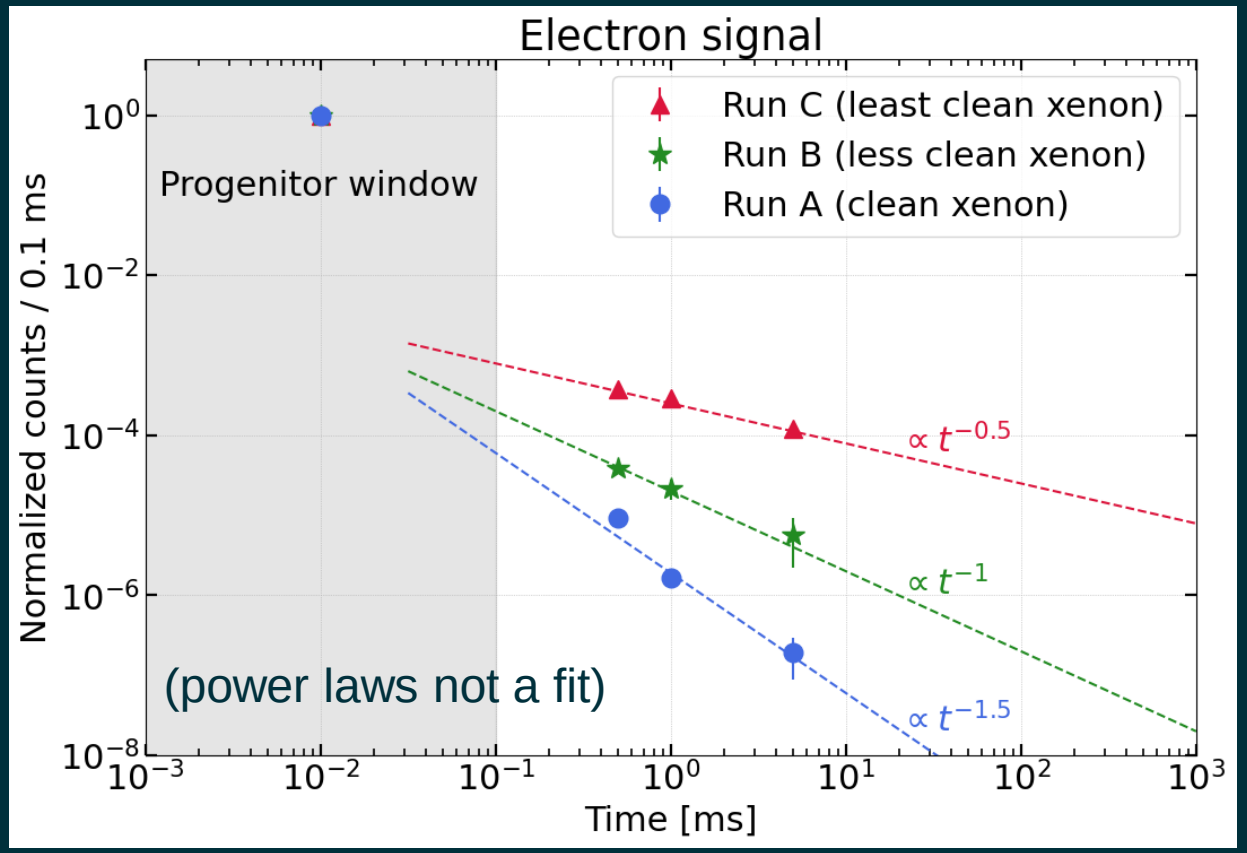


Increase impurities in xenon → increase electron trains

Photon trains unaffected by xenon impurities

Increase in electron trains, agreeing with prior work

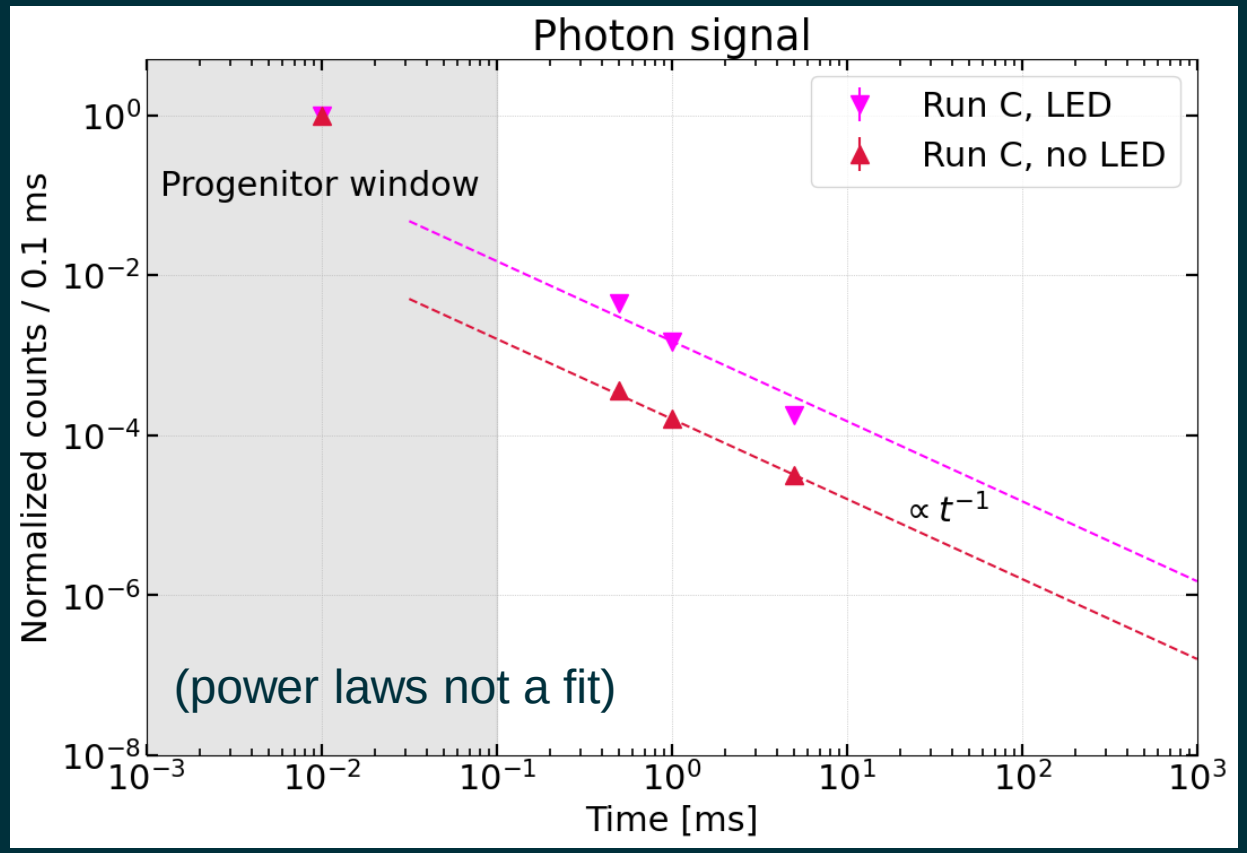


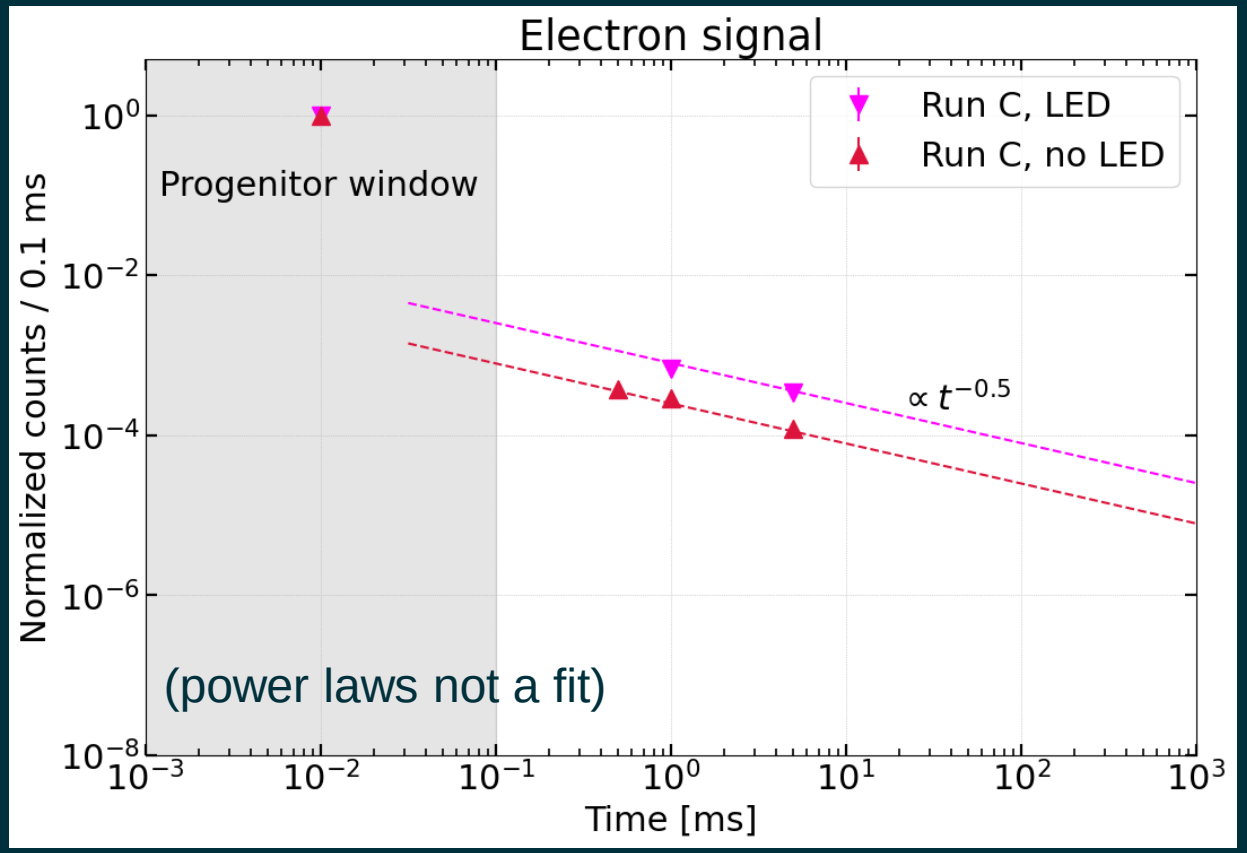


Adding 235 nm LED flash after particle scatter

Photon emission ~x5 increase

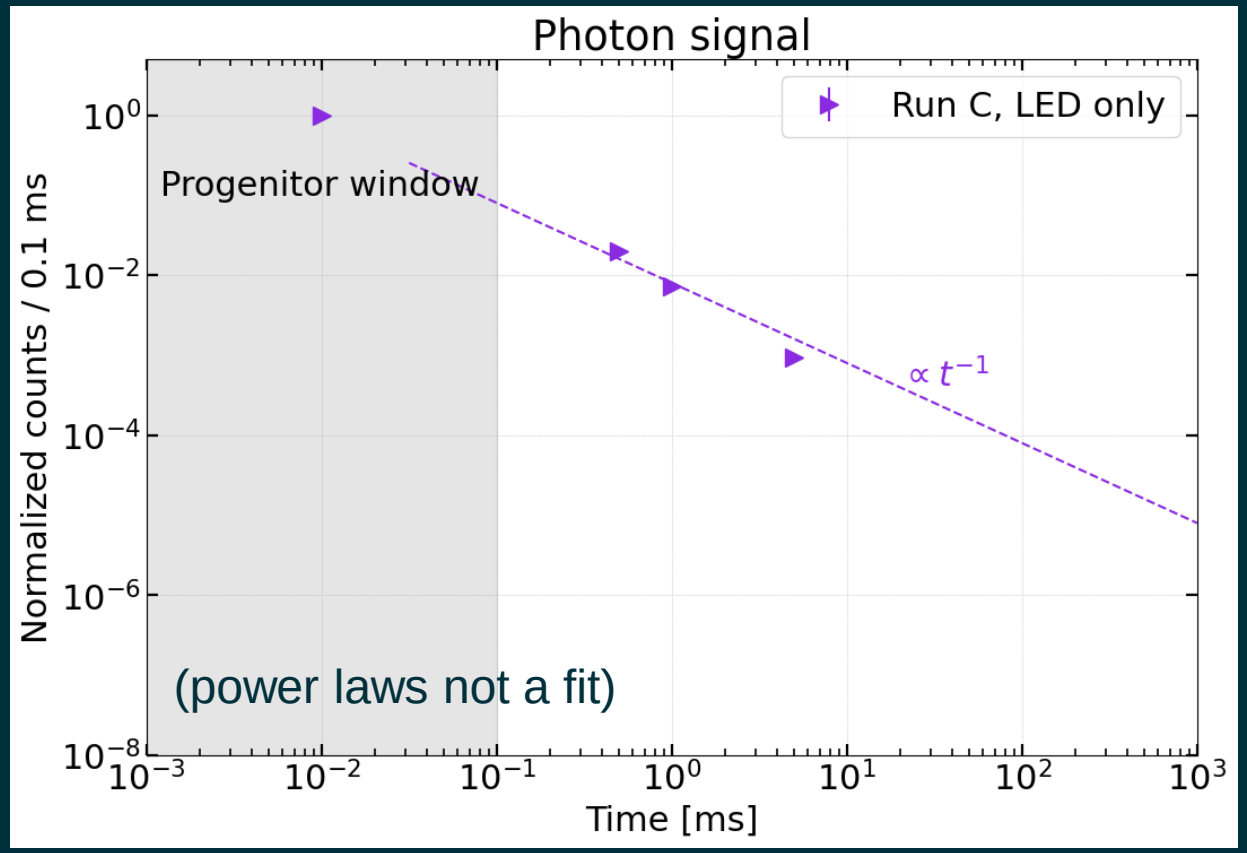
Electron emission ~x3 increase!



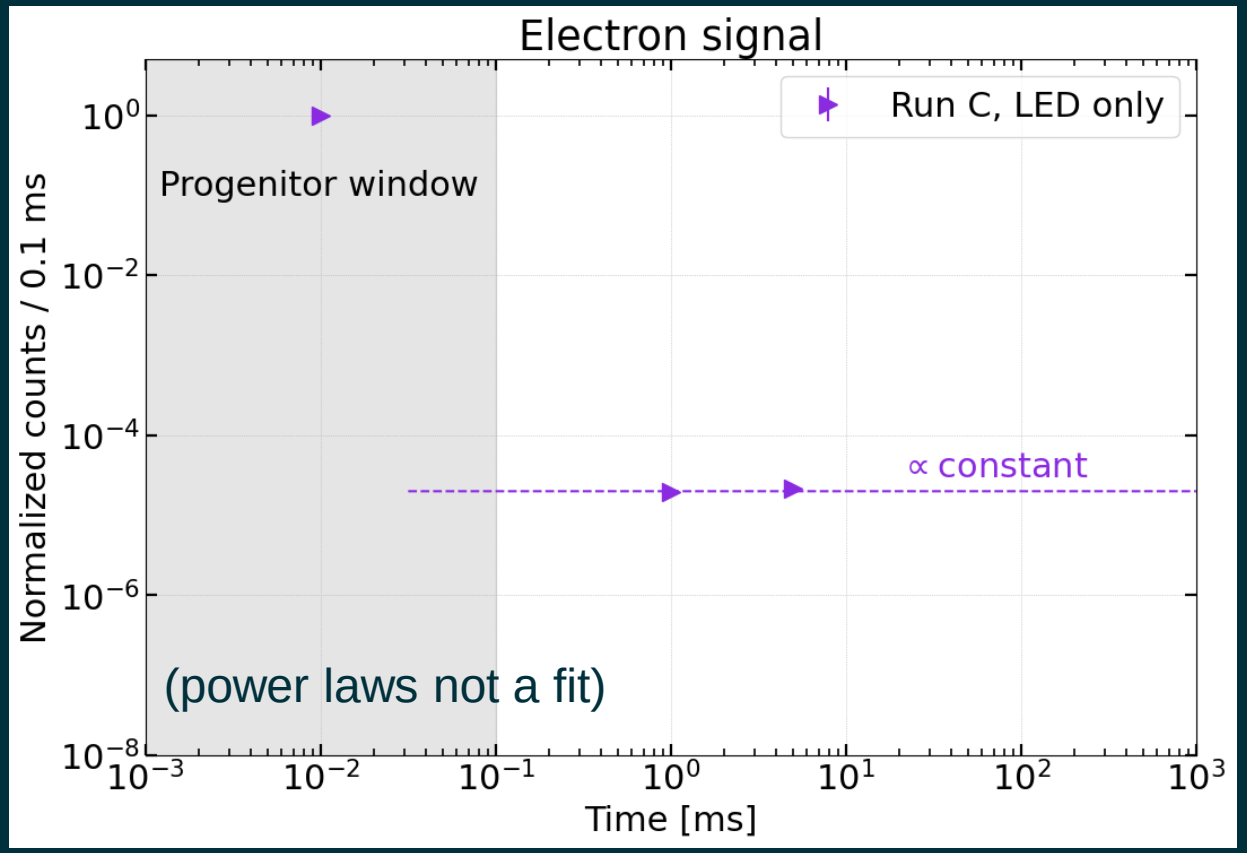


LED-only → no electron trains

Still see photon trains!
Indicative of UV induced fluorescence



Electron rate constant
→ background e- noise

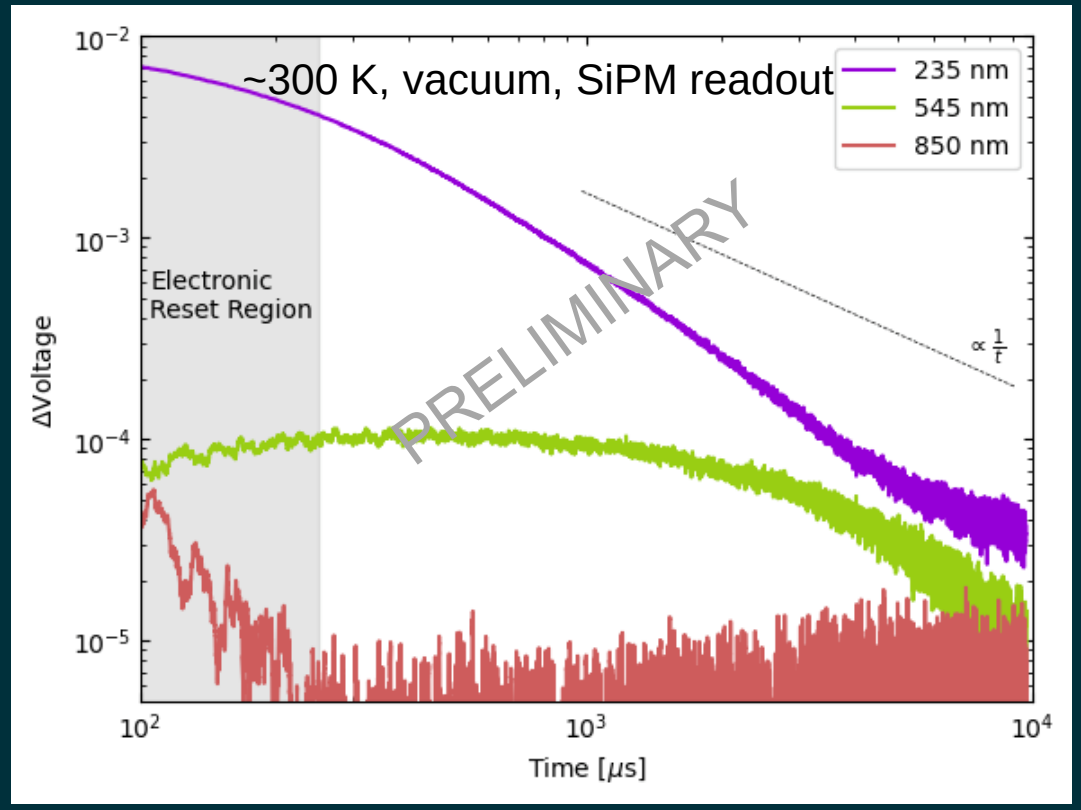


Photon trains cause electron trains

given impurities in xenon bulk

Characterizing fluorescence (photons trains) at LBNL

- Small vacuum/Xe test chamber to measure delayed photon emission
  - PTFE, PEEK, acrylic, ...
- Identify the main source(s) of photon trains



Difference between PTFE and control →

Work with undergrad Leah Douglas

Implications for GeV WIMP dark matter searches

- Electron/photon trains are major contributor to accidental coincidences
  - Cause significant cut to detector livetime
- Accidentals rate has increased with size of detector
  - Reducing delayed emission necessary for XLZD/G3

Summary

- Dual-phase xenon TPCs have sensitivity to sub-GeV dark matter
  - Currently hindered by delayed electron emission
- Delayed electron emission caused by delayed photon emission
  - Given impurities in the bulk xenon
- Work ongoing at LBNL to characterize delayed electron and photon emission

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