Enabling low-mass dark matter searches by detecting xenon infrared scintillation

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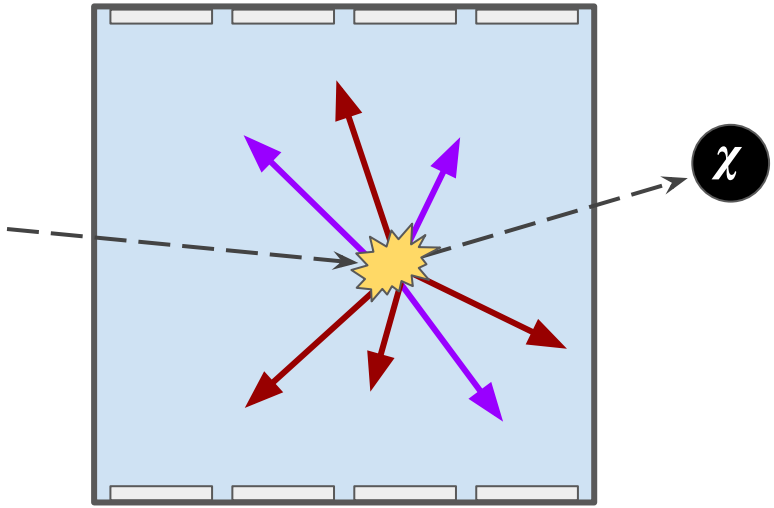
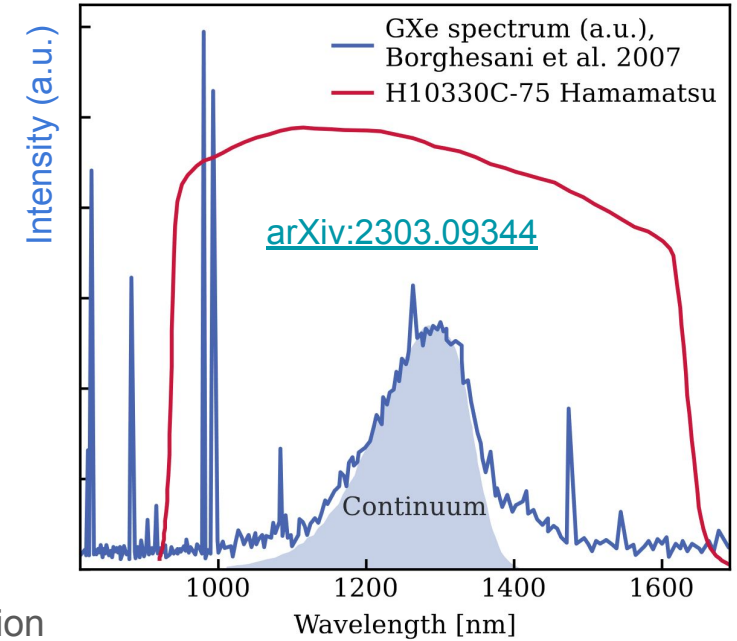


Why measure infrared (IR)?

- Well-known: VUV (175 nm) Xe scintillation
- Less-known: IR (1-1.4 μm) also emitted



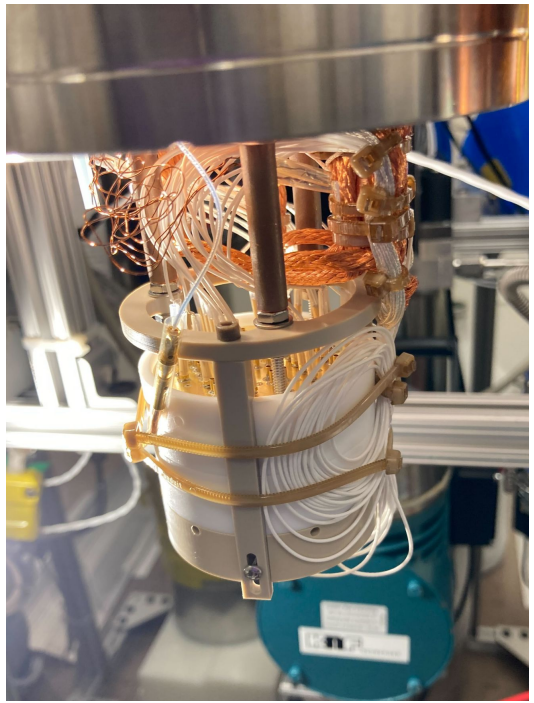
- Application: dark matter detectors (LZ–IR)
- Increase sensitivity to sub-GeV dark matter
  - Boost light yield → lower threshold + better E-resolution
  - New background discrimination quantity?

Goal: measure IR in dual-phase xenon time projection chamber (TPC)

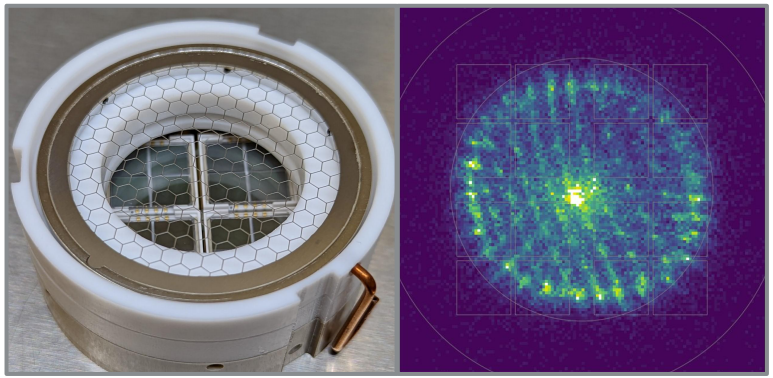
Investigating with TPC test stand at LBNL

- ~700 g dual-phase Xe TPC, PTFE walls
- **Swap SiPMs for IR detectors**
- Multi-purpose detector:
  - Solid Xe TPC (crystaLiZe): arXiv:2312.15082, arXiv:2201.05740
  - H/He-doping Xe (HydroX): arXiv:2308.02430
  - SiPM R&D: arXiv:2309.07913

Assembled TPC



SiPMs and electrode



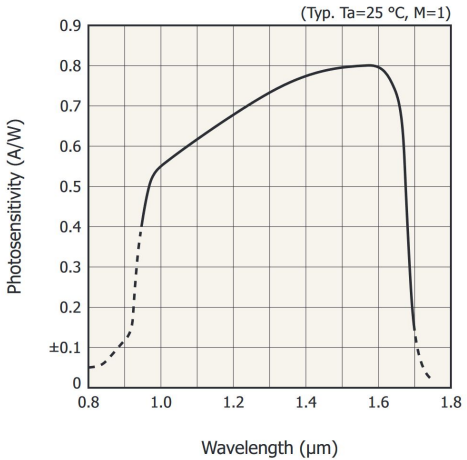
Example (x,y) reconstruction

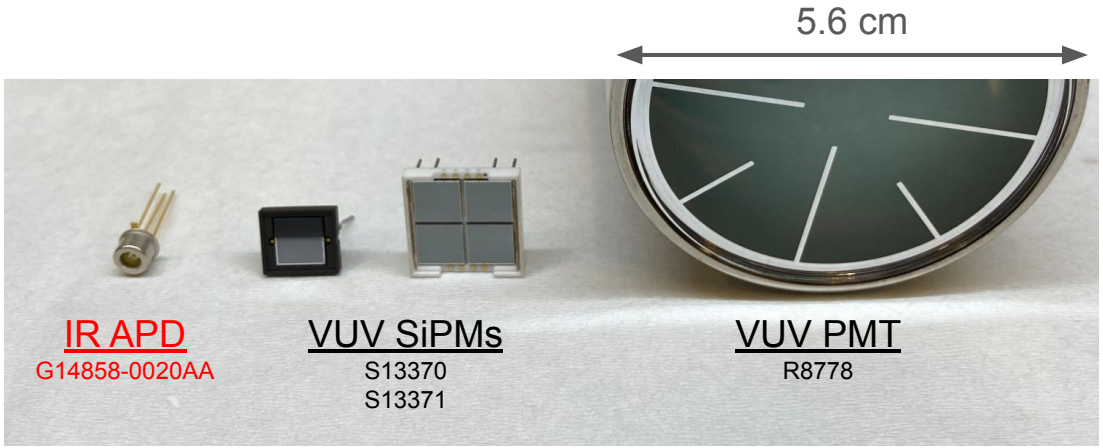
Measuring low-light IR is tricky

Apologies for too many acronyms:

- PMT: photomultiplier tube
- MPPC: multi-pixel photon counter
- SiPM: silicon photomultiplier
- APD: avalanche photodiode
- SPAD: single-photon avalanche diode

- InGaAs detectors are best option
  - IR PMTs awkward to use in TPC (and prohibitively expensive)
  - Christmas wish list: InGaAs MPPC (unavailable commercially)
- **Using InGaAs APDs**

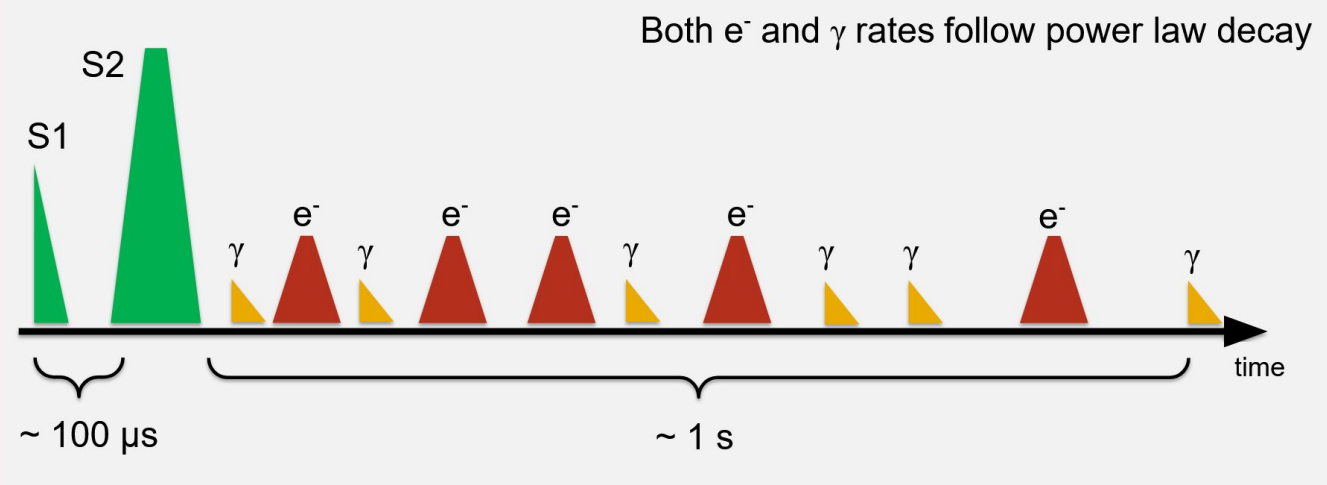




Hamamatsu family at LBNL Xenon Lab

Dominant background: delayed photon emission

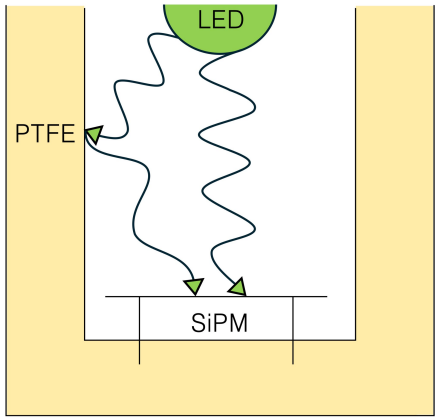
- Delayed photon (and electron) emission plagues dual-phase xenon TPCs
  - Likely has prompt IR component
- Hypothesis of mechanism: **PTFE fluorescence* induced by VUV light**



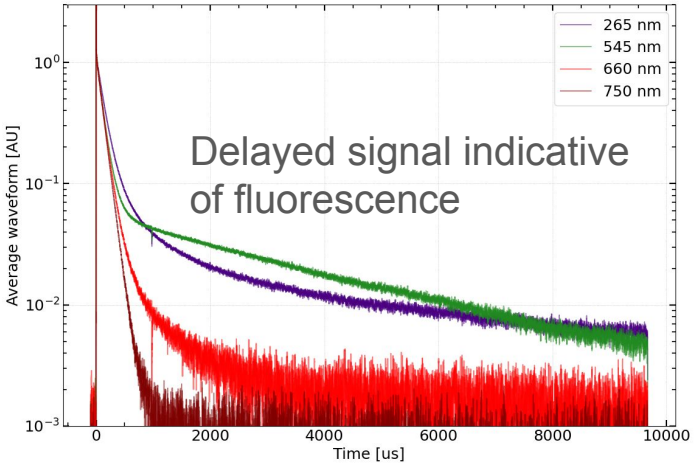
* technically phosphorescence…

New test-stand to characterize PTFE fluorescence

- Use UV LED to stimulate PTFE fluorescence
- Result: **fluorescence from <u>LED glass bulb</u> dominates signal**

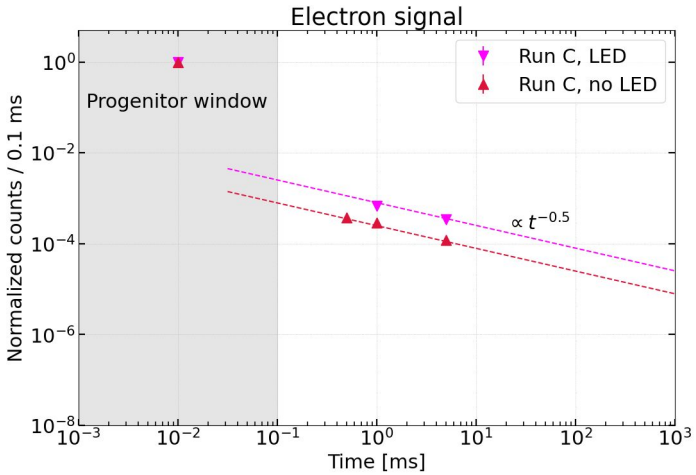


Work with undergrad Leah Douglas



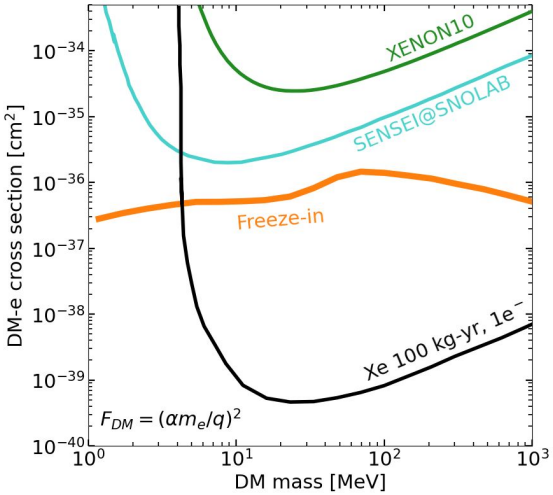
Important aside: delayed photons cause delayed electrons

- UV LED flash induces both delayed photons and delayed electrons
- First conclusive data of dominant mechanism for delayed electrons
- Why it matters: **remove delayed electrons → sub-GeV dark matter search**



Delayed electrons increased with LED flash

Background free Xe TPC potential



More info: [here], [and here]

What's causing delayed photons?

No *shocking* discoveries with aluminum :)

- **Dominant component is not from PTFE**
  - Swapped PTFE for aluminum (no HV!)
  - Delayed photons still present!
  - Also not from stainless steel grids
- What do we know?
  - Seen in both PMTs and SiPMs
  - > 280 nm (no DPE in PMTs)
  - No dependence on impurities in Xe
  - **Nightmare scenario: metastable Xe atomic lines?** (see arXiv:2410.22863)
- Under current investigation

Summary and future work

- Detecting IR scintillation can enhance Xe TPC dark matter search
- Likely background from delayed photon emission
- New results for understanding delayed photon and electron emission
  - Publication forthcoming
- **IR measurements planned in early 2025**

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