Photoluminescence of detector components under UV and VUV light

Anna Hurhina, Pranati Kharbanda, Tina Pollmann

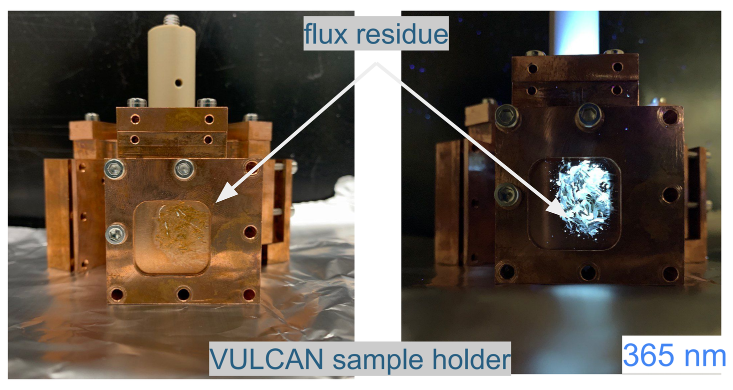
University of Amsterdam and Nikhef

Photoluminescence (**PL**) is the emission of lower-energy photons from a material following the absorption of higher-energy photons. In liquid xenon time projection chambers (**LXe TPCs**), materials exposed to xenon's vacuum ultraviolet (**VUV**) scintillation light may photoluminesce (contributing to the lone-S1 rate), and these delayed photons can photo-ionize impurities in the LXe, leading to lone S2s.

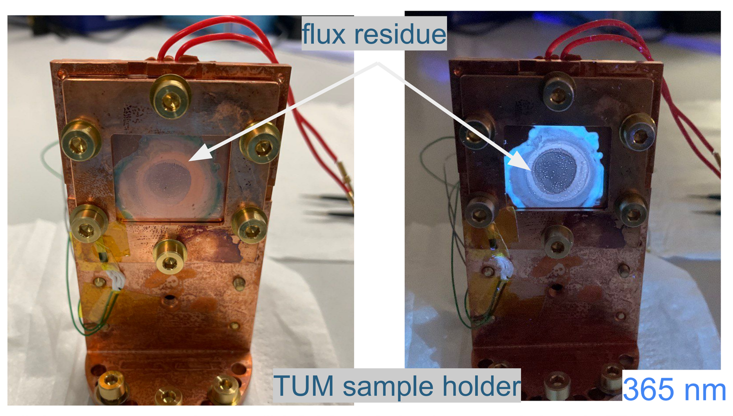
When a lone S2 is mistakenly paired with an uncorrelated S1 signal (an 'accidental coincidence') the resulting fake event can mimic a genuine low-energy interaction. Such backgrounds limit sensitivity to rare events and understanding them is critical for ensuring adequate performance of next-generation LXe TPCs. We have measured the PL response of key materials used in LXe TPCs.

UV-A inspection of detector materials

Solder flux residues



Stannol KS115 (used in XENONnT)



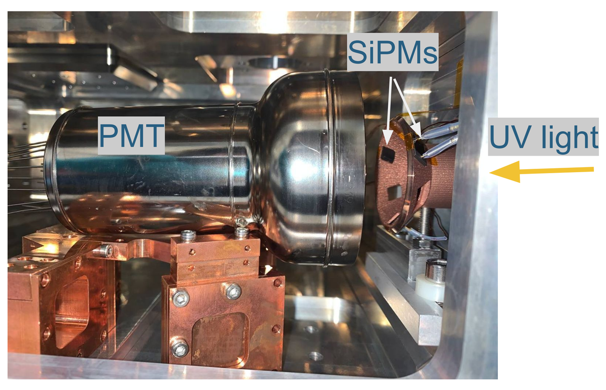
Chemtronics CW8400 (used in LZ)

The residue from rosin and resin-based solder flux (classified RO** and RE** respectively) contains polycyclic aromatic hydrocarbons (PAHs) [pah] as well as other PL chemicals.

These flux residues are soluble in LXe [sol], and can flake off when cooled.

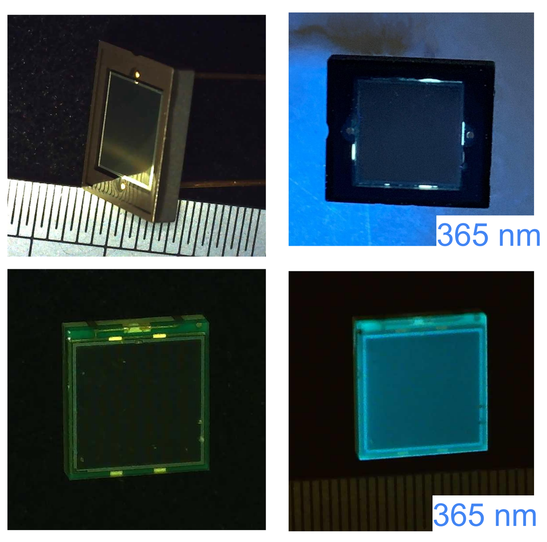
Samples were prepared by melting the solder wire on a copper sheet and then removing the molten alloy, leaving only the flux residue behind.

Photo sensors



Hamamatsu R11410-21 PMT, shown installed in VULCAN

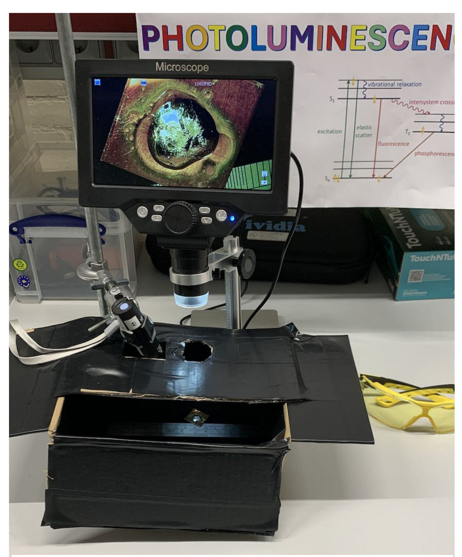
The quartz glass window on Hamamatsu R11410-21 PMTs can exhibit PL due to impurities and defects [qua], and this has recently been proposed as the source of lone S1 and S2 signals in LXe TPCs [sor].



Hamamatsu S13360-6050CS (top) and S13360-6050PE (bottom) SiPMs

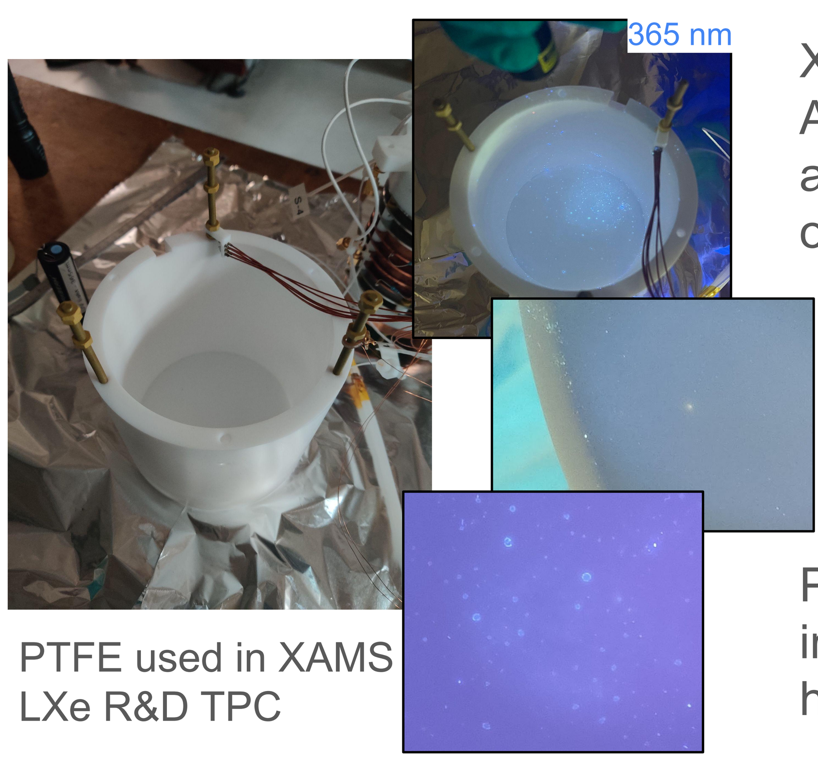
Epoxies, glues, and flux used in SiPM housing can exhibit PL. The 6050CS model shows PL spots at the SiPM–frame interface, likely from an adhesive or from flux.

The 6050PE model has a photoluminescent epoxy resin window.



DIY UV-A fluorescence microscope

PTFE (Teflon)



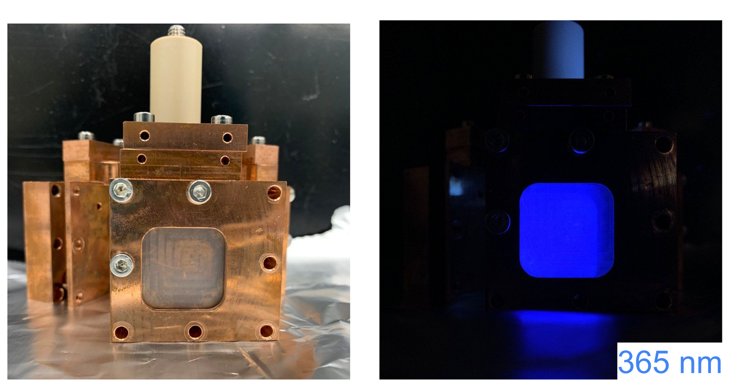
PTFE used in XAMS LXe R&D TPC

XAMS is an R&D LXe TPC in Amsterdam. We inspected the PTFE after it came out of the LXe. Many types of PL stains were observed:

1) Embedded mm-size spots
2) Surface mm-size specks
3) Surface cm-sized stains

PTFE can be contaminated with PL impurities during production, cleaning, handling or operation in the LXe TPC.

Reference scintillator

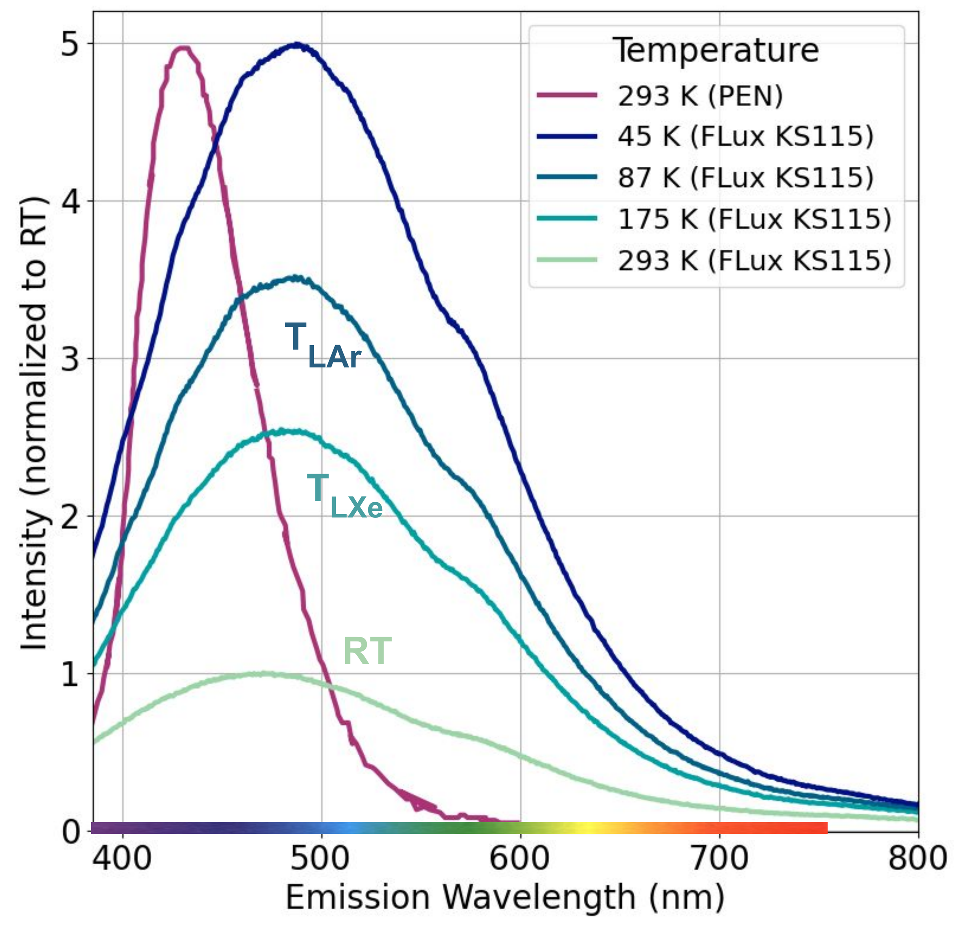


Polyethylene Naphthalate (PEN)

We use a sheet of scintillation-quality PEN produced by the LEGEND collaboration [pen] as a reference sample.

PEN contains a PAH, similar to flux residue, and at RT has a wavelength-shifting efficiency on the order of O(10%).

PL spectra of solder flux under UV-B light



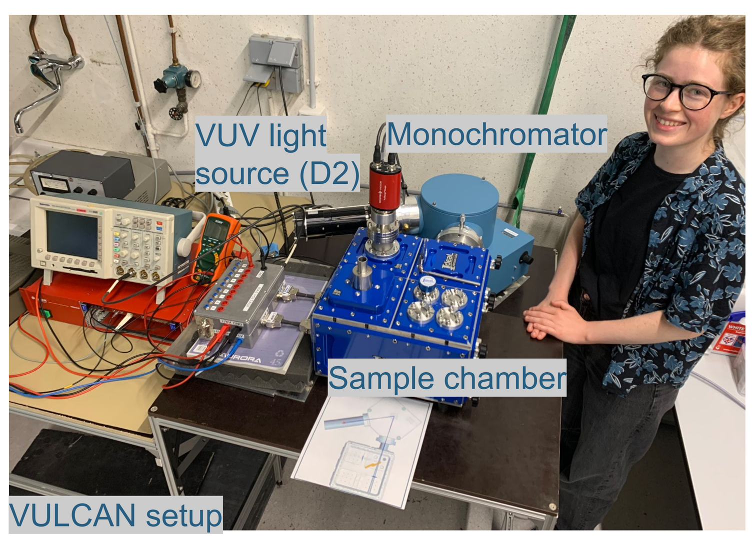
Stannol KS115 flux residue was excited with a 310 nm LED in the optical cryostat at TUM [tum], and the PL spectrum recorded with an OceanOptics spectrometer.

The spectral shape of the PL emission is consistent with typical PAHs.

PL intensity increases by a factor of approximately 2.5 between room temperature and LXe temperature.

The PEN spectrum from [tum] is shown for comparison, and given an arbitrary normalization.

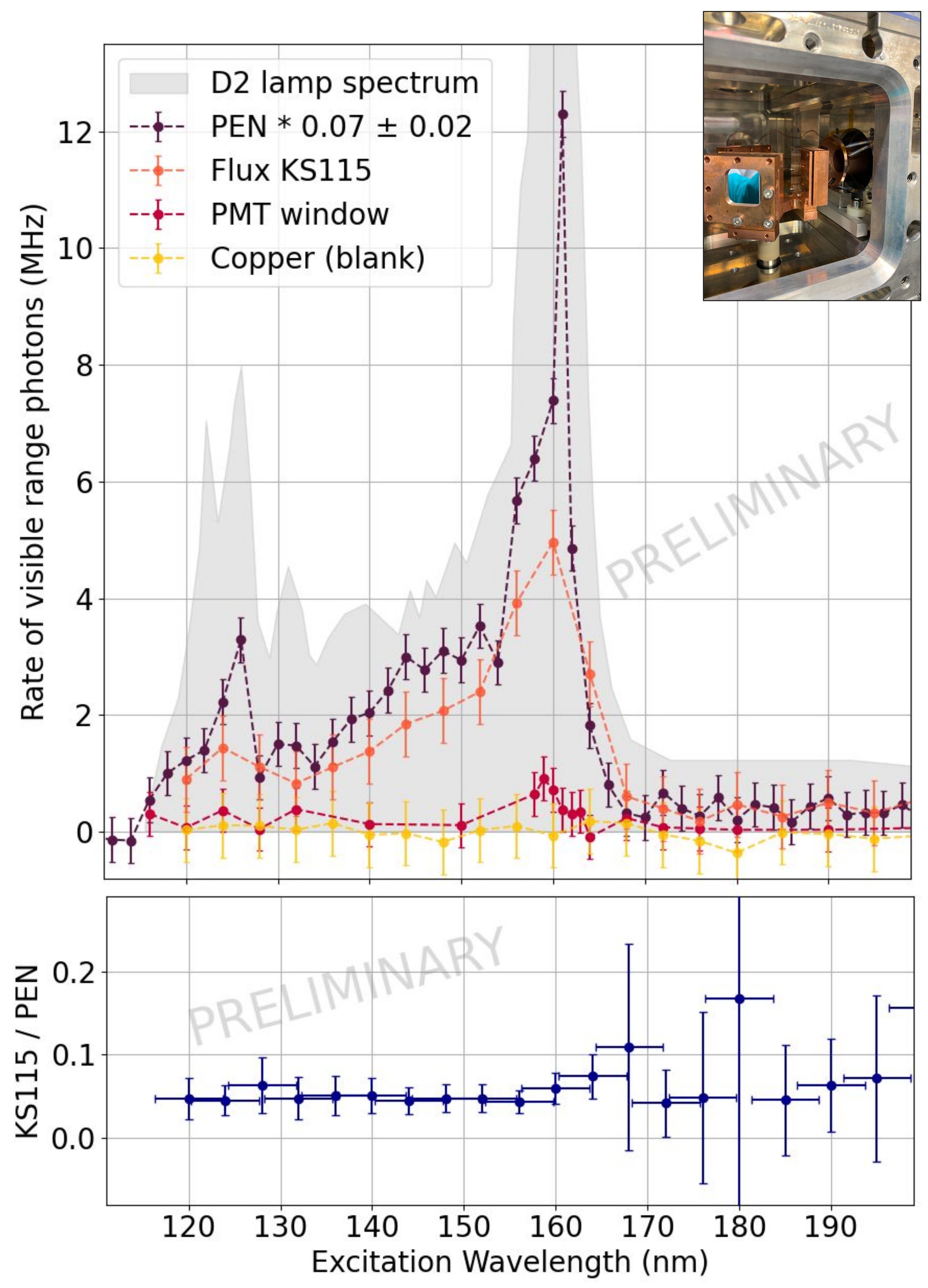
PL intensity of materials under VUV light



In the VULCAN setup, samples are excited with VUV light from a D2 lamp. The PL response is measured by three Hamamatsu S13360-6050CS SiPMs, which are most sensitive in the 300 nm – 750 nm wavelength range [ham].

We observed PL from Stannol KS115 flux residue, averaging about 7% of the PEN reference.

The response from the PMT is inconclusive at the current sensitivity of the setup.



Conclusions & next steps

- UV-A inspection of detector materials reveals many PL impurities
- Solder flux residue shows PL under both UV-A and VUV excitation and is thus a candidate source of delayed photons in LXe TPCs
- To understand the connection to accidental coincidences, next steps include:
  - Measure PL decay times and spectra under VUV excitation
  - Increase the sensitivity of the setup
  - Measure the photoionization in LXe in response to flux residue PL
  - Model the impact of PL in LXe TPCs

References

[tum] Leonhardt, A., Goldbrunner, M., Hackett, B. & Schönert, S., J. Inst. 19, C05020 (2024); arXiv:2311.1590.
[sol] Emsley, J. Science: Xenon chemistry comes out of the cold, New Scientist vol.1695 (1989)
[sor] Sorensen, P., and R. Gibbons, arXiv:2505.08067 (2025).
[qua] Schreiber, A, B Kühn, E Arnold, F-J Schilling, and H-D Witzke, *Journal of Physics D* 38, no. 17 (2005)
[ham] Hamamatsu S13360 Series datasheet
[pah] Ramdahl, T., *Nature* vol. 306, 580–582 (1983)
[pen] Manzanillas, L. et al., JINST vol. 17, no. 09 (2022); arXiv:2204.13747