

Evaluation of the Fluorescence Properties of PMT Quartz Window for the XLZD Liquid Xenon Dark Matter Experiment

^ANagoya Univ. ISEE, ^BScience Tokyo, ^CNagoya Univ. KMI
A. Takeshita^A, S. Kazama^B, K. Kobayashi^A, M. Yamashita^{AC}

Abstract

Quartz is used as the window material of photomultiplier tubes (PMTs), making it important to understand its properties for future experiments. In recent years, delayed photon noise following S1 and S2 scintillation signals has become a significant concern, and fluorescence from the quartz window is considered to be one of its possible sources. In this study, we evaluate several quartz glass samples as candidate window materials for next-generation PMTs by comparing their fluorescence properties.

1 Direct Dark Matter Detection

Dark matter : An unknown form of matter that is thought to be abundant throughout the Universe but has not yet been directly observed.
Candidate : Weakly Interacting Massive Particles (WIMPs)

1-1 Major Backgrounds

- High-mass dark matter searches → Electron recoils and neutrons
- Low-mass dark matter searches → Accidental coincidences

[1] XLZD Collaboration, Eur. Phys. J. C 85, 1192 (2025).

1-2 Future Experiment: XLZD

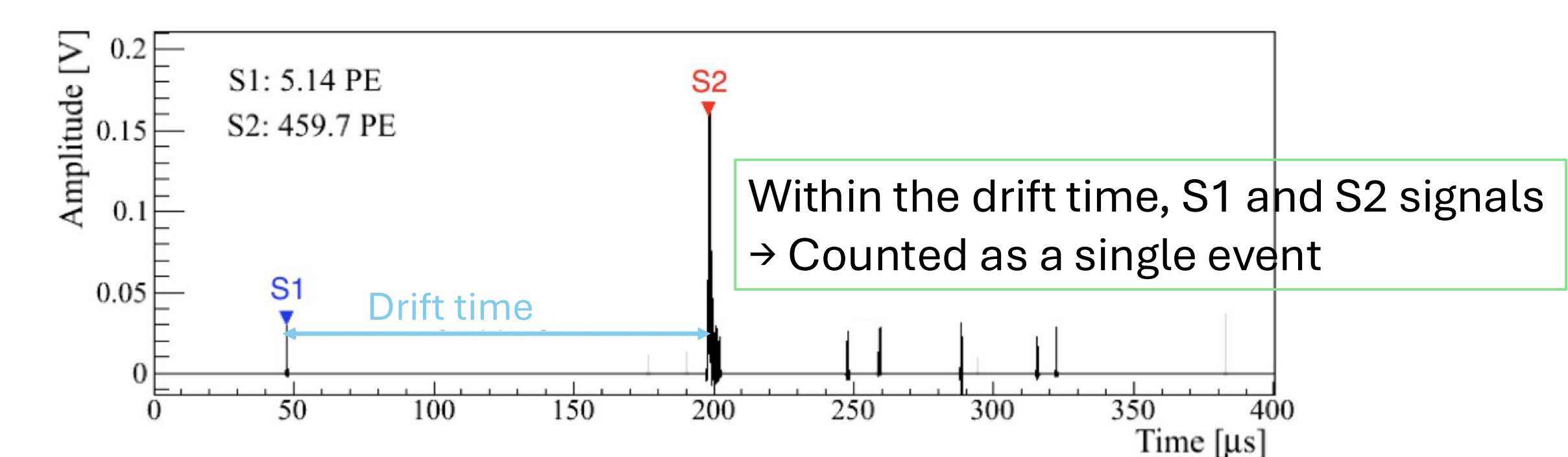
Aim to reach the “neutrino fog,” where neutrino-induced events become a significant background.

Radioactive backgrounds are expected to be suppressed to a low level. However, accidental coincidences may not be reduced accordingly.

Therefore, further reduction of accidental coincidences is necessary.

2 Accidental Coincidence

An event in which an **isolated S1 signal** and an **isolated S2 signal**, originating from different physical processes, are accidentally detected within a short time interval.



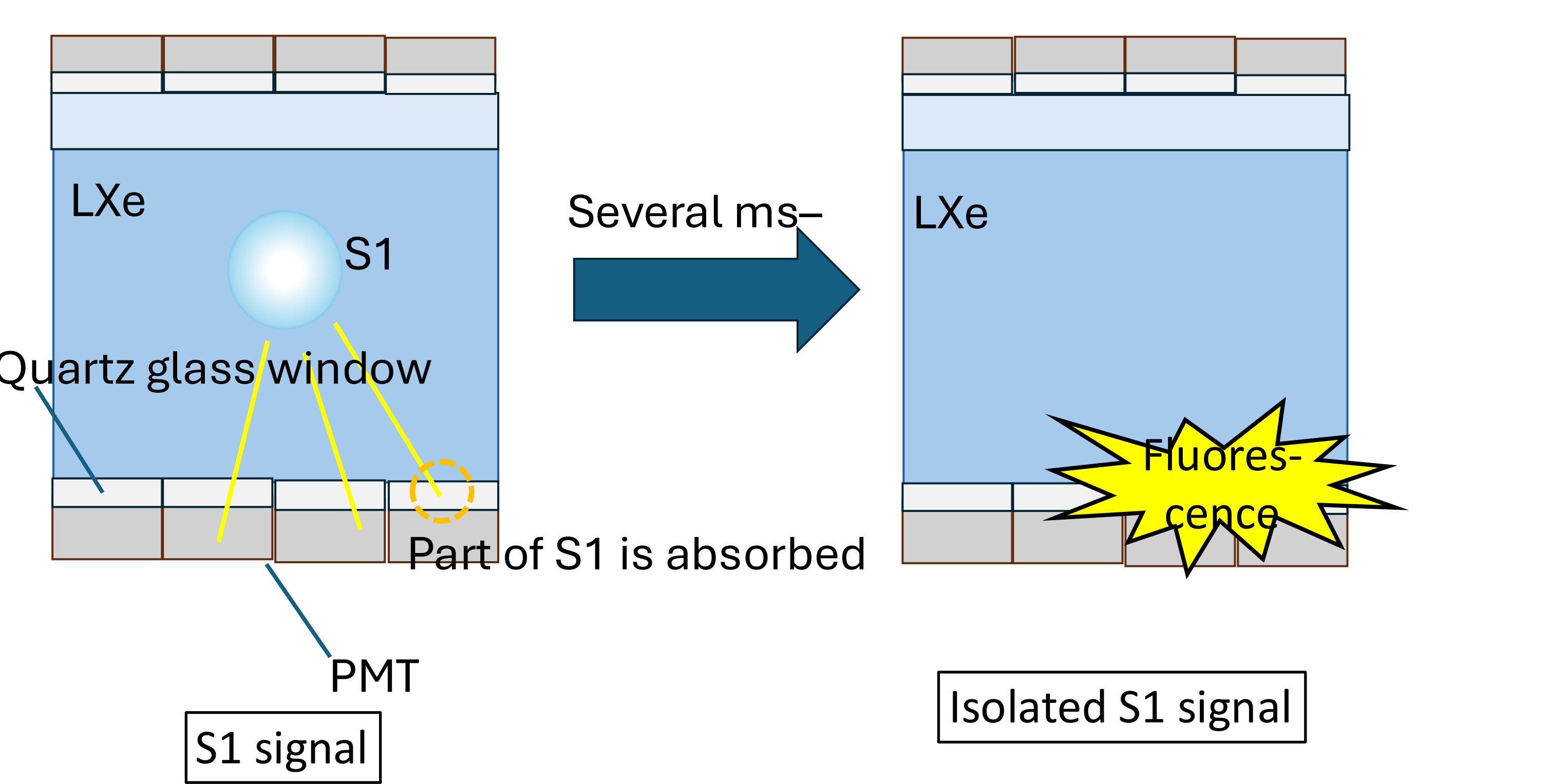
However, isolated S1 and S2 signals are known to persist for several to hundreds of milliseconds following the primary S1 and S2 signals.

Fluorescence from quartz glass has been proposed

[P. Sorensen and R. Gibbons, Phys. Rev. D 112, 052004 (2025)]

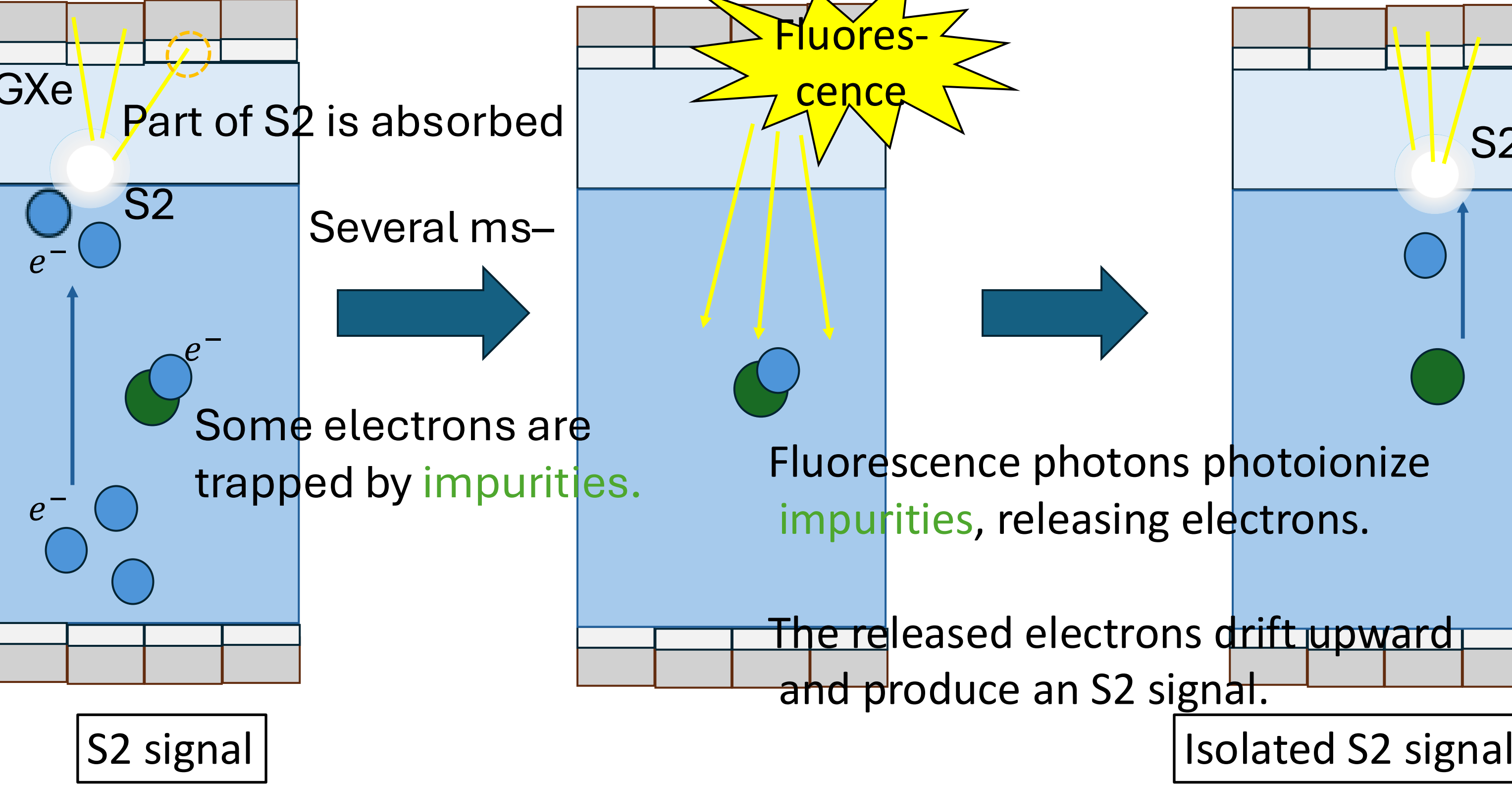
Possible source of isolated S1 signals

PMT dark noise, fluorescence, etc.



Possible source of isolated S2 signals

Impurities in liquid xenon capture and re-release drift electrons.



3 Fluorescence

Fluorescence from quartz glass:

***Defect structures** in quartz glass are excited by VUV–UV light and re-emit near-UV to visible light. The fluorescence persists from μ s to s.

Characteristics of fluorescence:

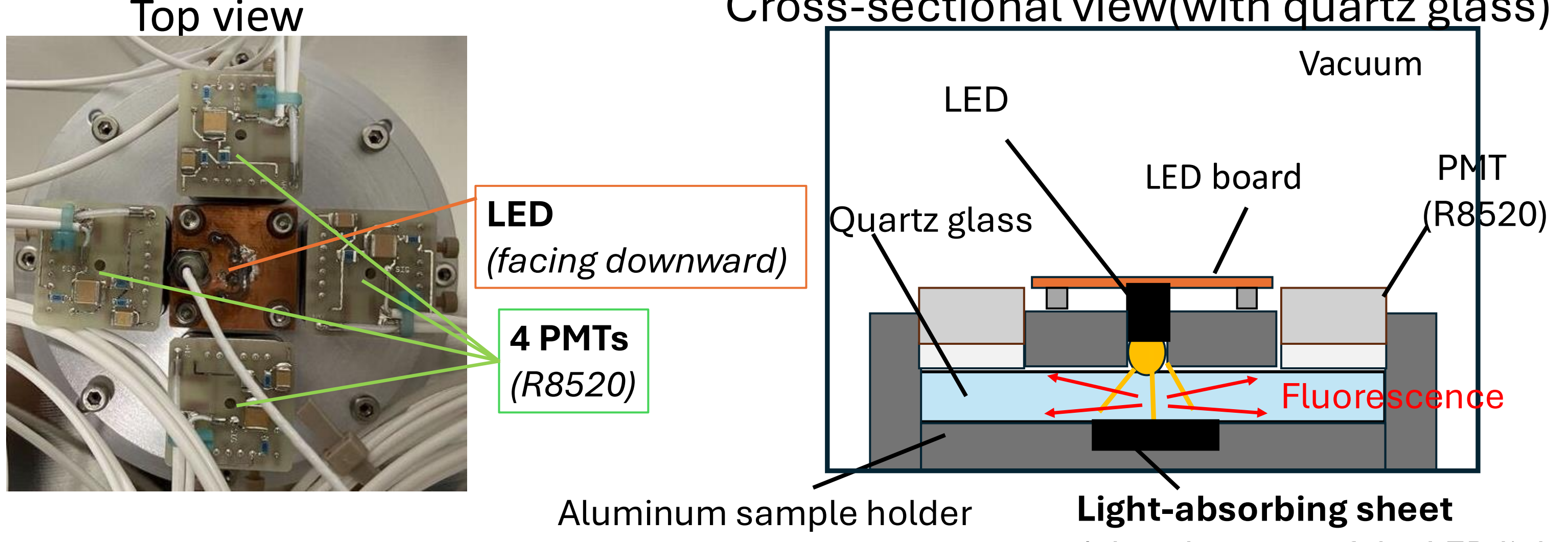
- The emission rate decreases as a **power law**.
- Different defect structures produce different emission wavelengths.
- The emission rate is proportional to the incident light intensity.

*** Defect structures:** Structures in which the original crystal structure (Si–O–Si) is disrupted.

4 Objective of This Study

To establish a custom setup for measuring fluorescence from quartz glass and identify quartz glass suitable as a window material for next-generation PMTs by relatively comparing the fluorescence of multiple quartz glass samples.

5 Fluorescence Measurement Setup

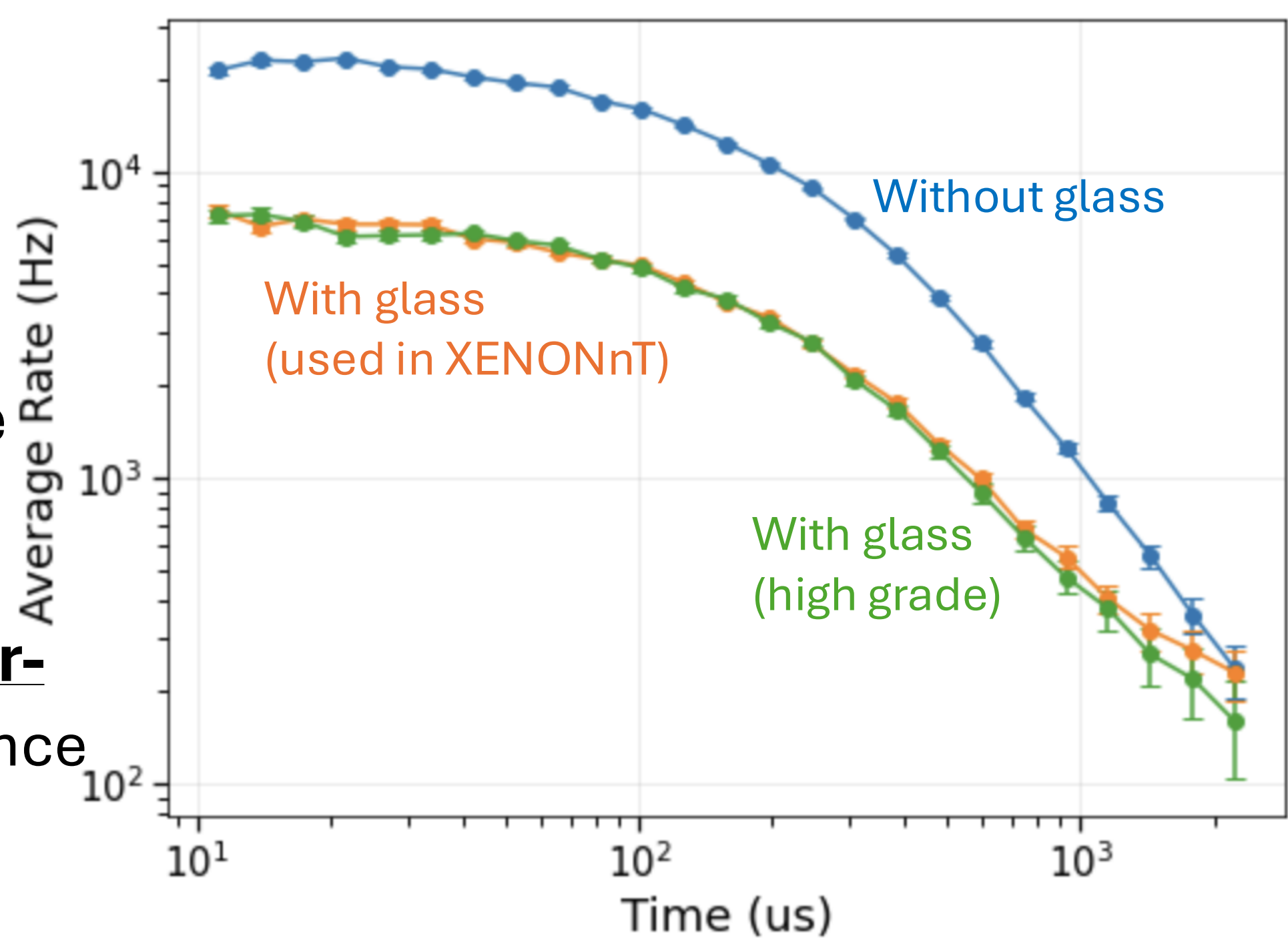


Illuminate the sample with light at approximately **240 nm** from an LED → Measure fluorescence lasting for several ms after LED emission.

6 Results

- The higher-grade quartz glass showed a slightly lower rate, but **no significant difference** was observed.

- The characteristic **power-law decay** of fluorescence was observed.



Challenges:

- The measurement **without glass** also showed power-law decay, similar to the measurement with glass.
- The **no-glass measurement showed the strongest fluorescence**, suggesting a significant contribution from components other than the glass.

LED fluorescence may be a significant contribution.

7 Summary and Future Prospects

- Evaluate quartz glass as a low-fluorescence PMT window for XENONnT and XLZD.
- Fluorescence from non-glass components limited the current measurement.
- A new setup is under construction.