# Fluorescence properties of Clevios coatings for noble liquid TPC experiments

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*Cryogenic Apparatus for Fluorescence Experiments:
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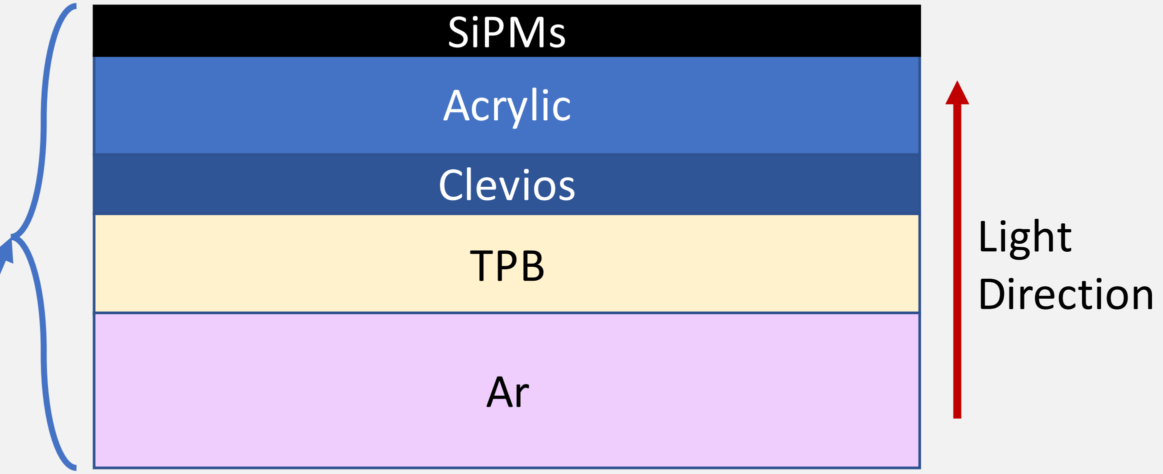
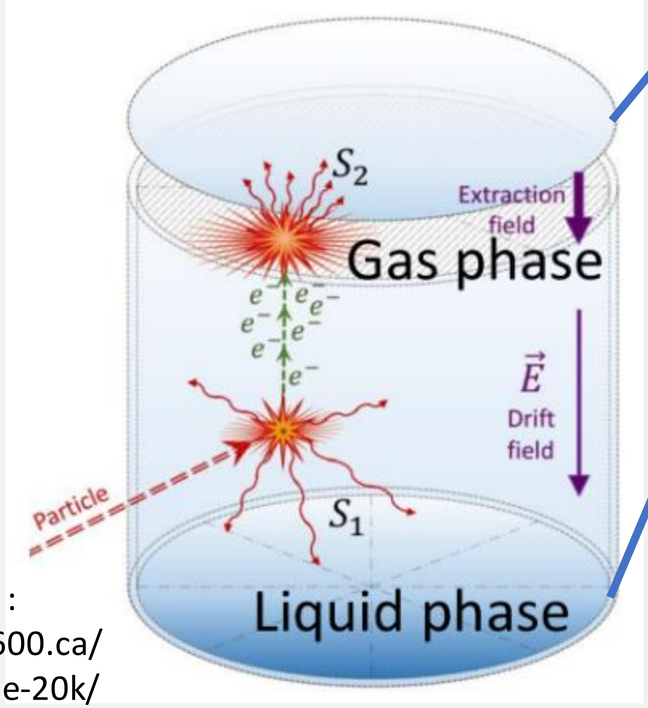
# Motivation




- Clevios™ is a conductive organic polymer that can be used on experiments like DarkSide-20k for electrodes and field shaping rings. It is transparent in thin coatings.




Source : deap3600.ca/darkside-20k/

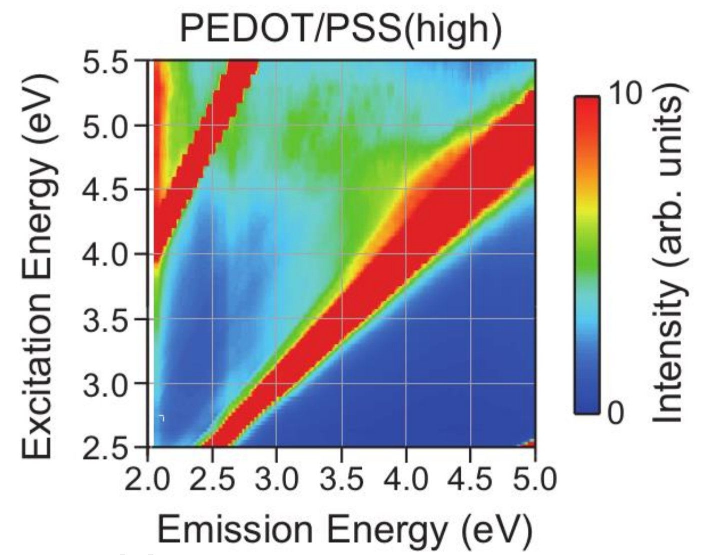
- Nuisance fluorescence from detector components like Clevios could contribute to the light seen in detectors.

**Main questions for this study:**

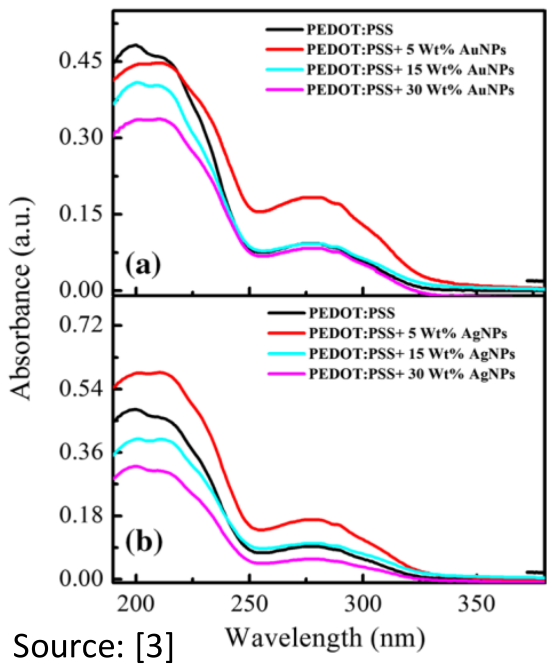
1. Is there any UV-stimulated fluorescence from Clevios?
2. If there is fluorescence, what is the emission wavelength range?
3. How does Clevios' fluorescent light yield compare to TPB?

# Literature review

- (T. Koyama et al., 2015) [2] suggests that with a UV excitation of 260nm (4.77 eV), some UV fluorescence may be visible around 350nm (3.6 eV) to 400nm (3.1 eV).
- Spectra from (A.C. Bhowal et al., 2019) [3] study of PEDOT:PSS in the presence of gold and silver nanoparticles showed an increase in the absorbance of the material around 278nm.




Source: [2]




Source: [3]

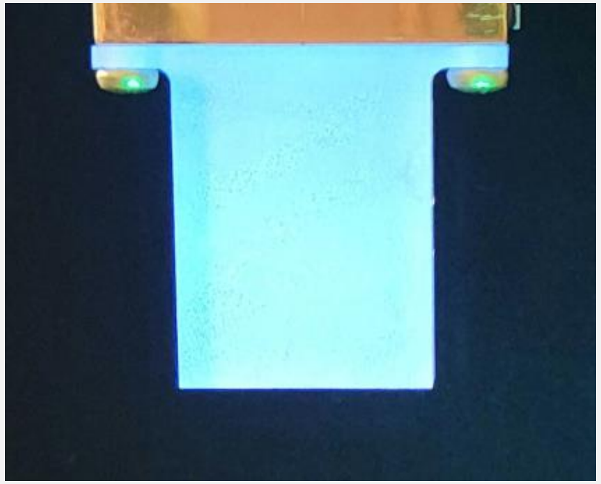
# Samples

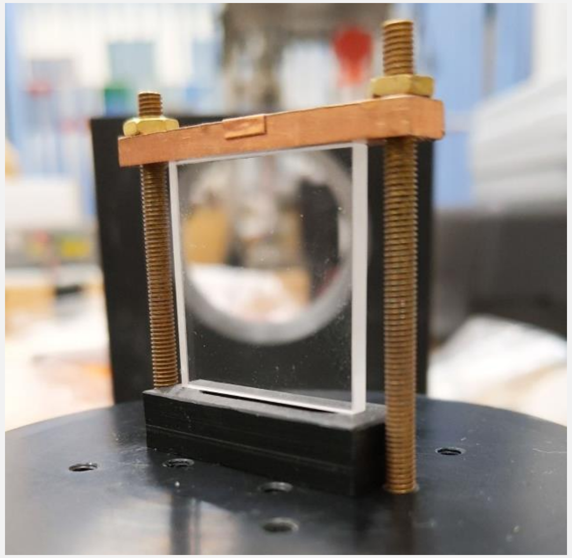
**Acrylic Substrate**

- Properties: 5mm thick UV absorbing commercial acrylic (Trotec)

**Fused Silica Substrate**

- Properties: 2mm thick Corning 7980 fused silica window





| | Acrylic Substrate | Fused Silica Substrate |
|---|---|---|
| Blank (No Coating) | ✓ | ✓ |
| ~10 nm Clevios Coating | ✓ | ✓ |
| ~100 nm Clevios Coating | ✓ | ✓ |
| 3 µm TPB Coating | ✓ | |

# Absorbance spectroscopy

**Setup**

- Agilent Cary 60 UV-Vis Spectrophotometer
- Wavelength range: 190-900 nm
- Xenon flash lamp light concentrated on sample.
- Measurements compared to a blank substrate reference sample.

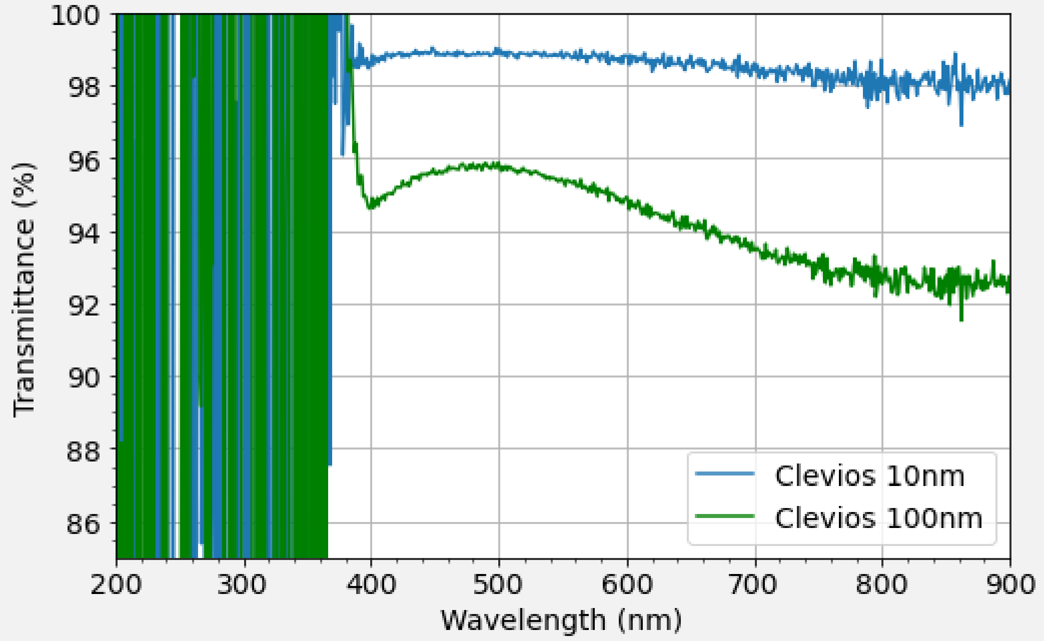
**Purpose**

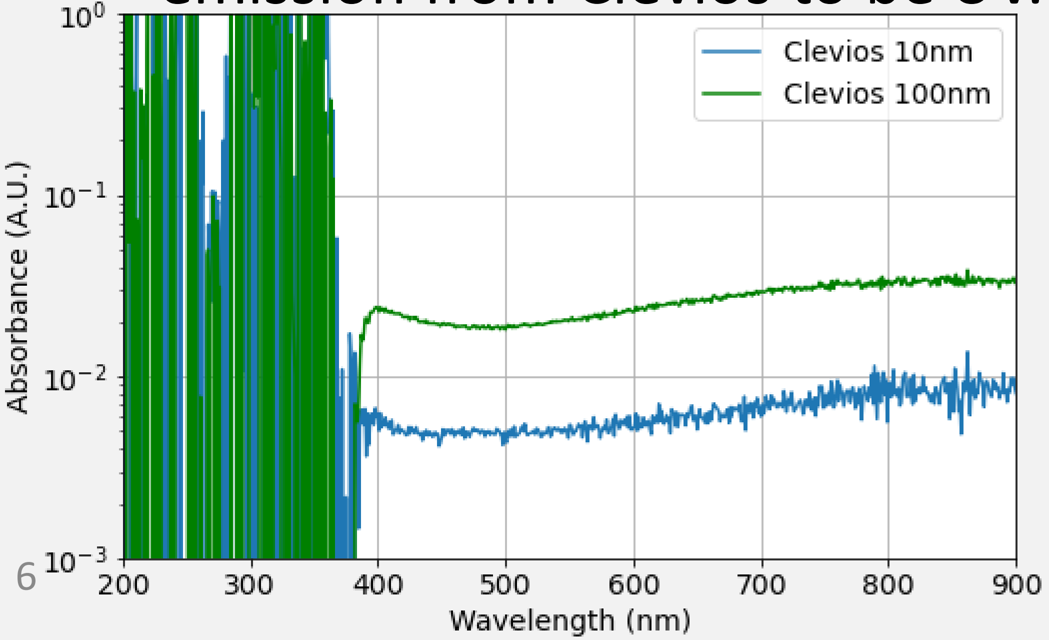
- To determine if the Clevios is absorbing certain wavelengths of light.
- Study absorbance of the combination of substrate and Clevios.

Source: Agilent

# Acrylic substrate spectroscopy results

- At UV wavelengths the UV-absorbing acrylic prevents an accurate measurement of the absorbance, cannot see any UV absorbance from Clevios.
- This is an issue because we expect any emission from Clevios to be UV.



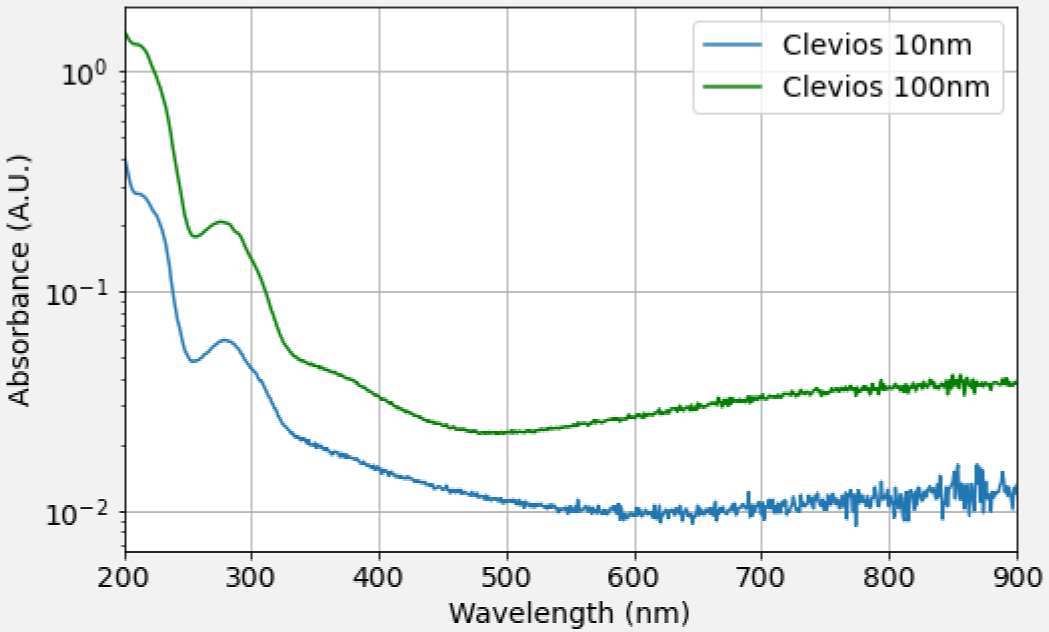



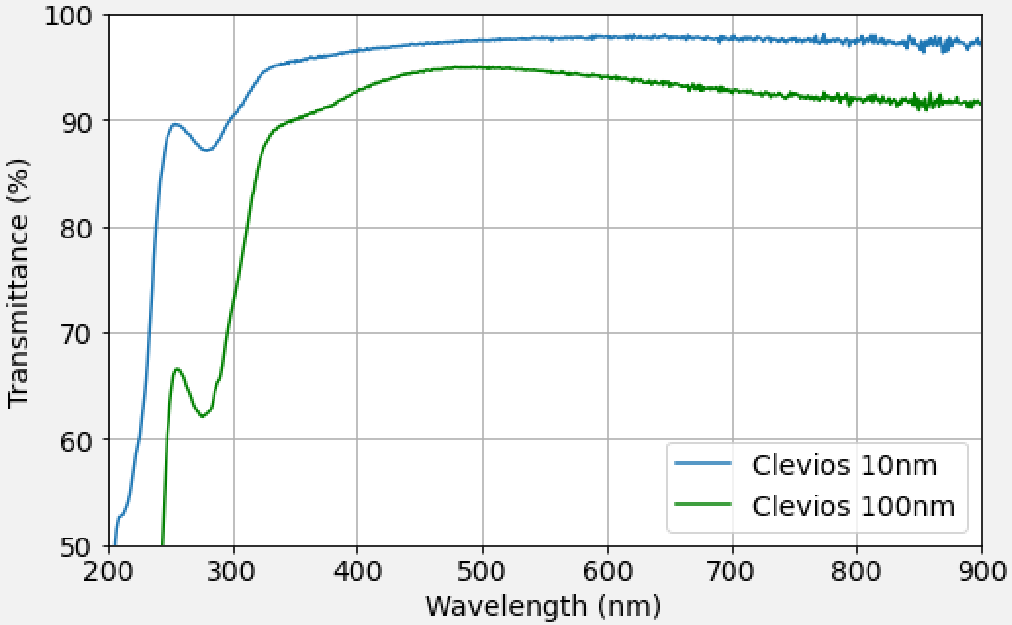

Outcome:

- Thicker Clevios coating produces a high absorbance/lower transmittance.
- Light exciting the Clevios causing it to UV fluoresce will likely be absorbed by UV absorbing acrylic.

# Fused silica spectroscopy results

- To study the coating in the UV we got sample of Clevios coated fused silica.

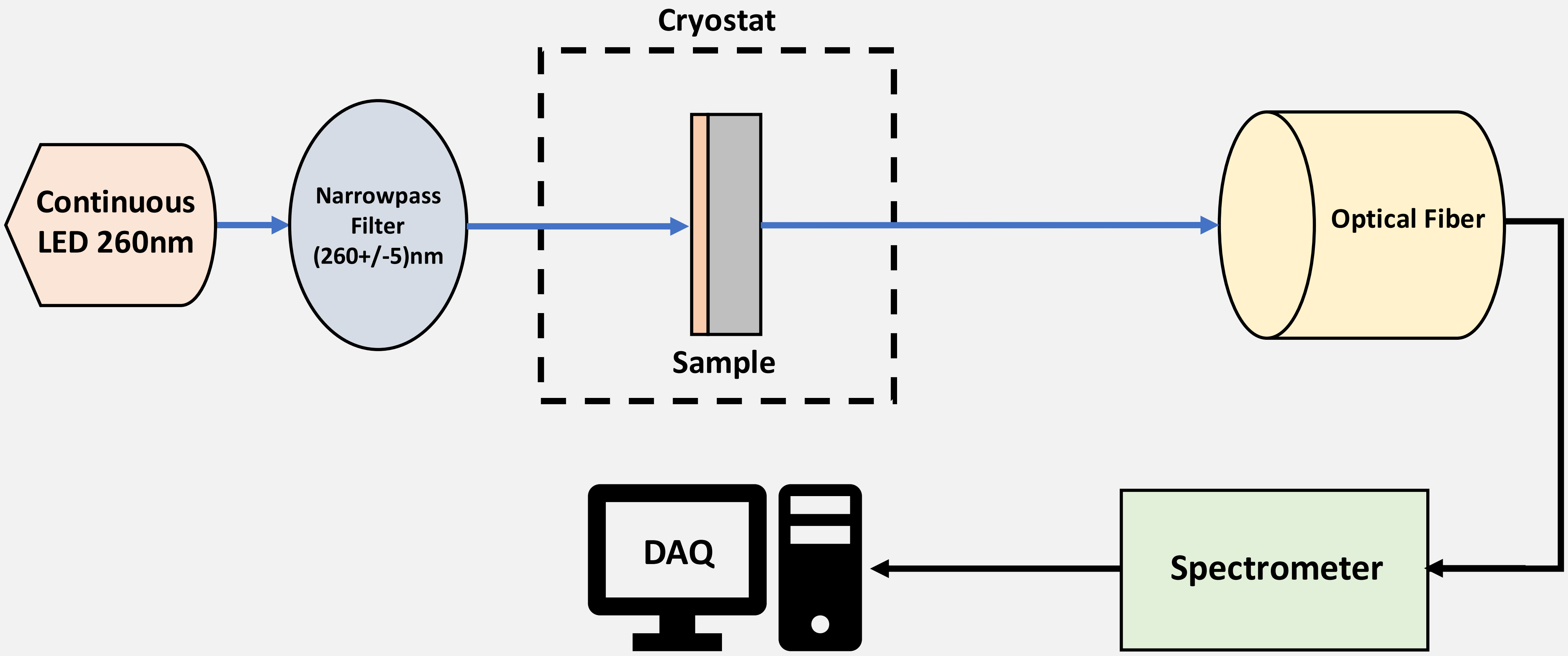



Outcome:

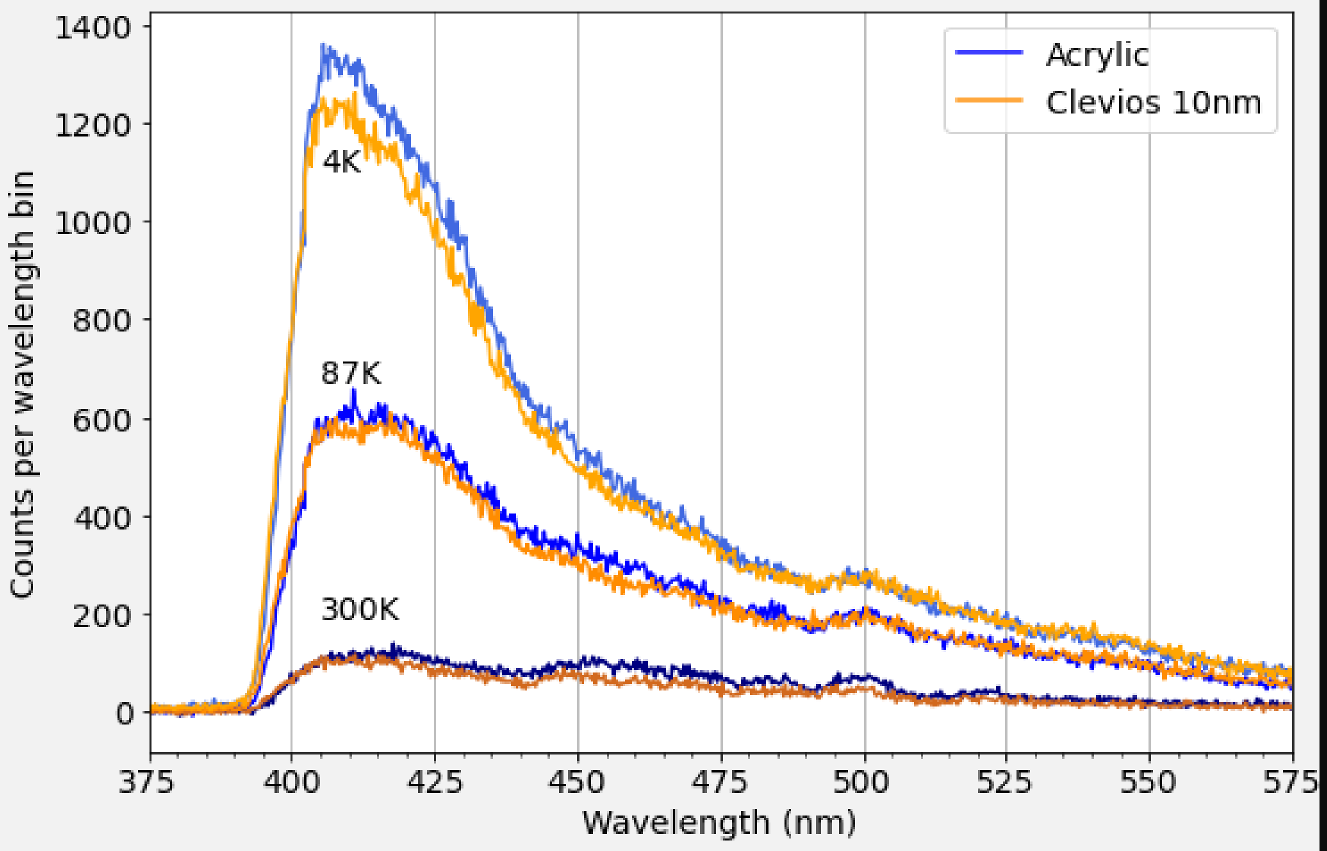
- Fused silica has greater UV transparency compared to acrylic.
- Two peaks in the absorbance (230nm & 280nm) are consistent with expected absorption wavelength of Clevios from literature.

# Cryostat setup - spectrometer



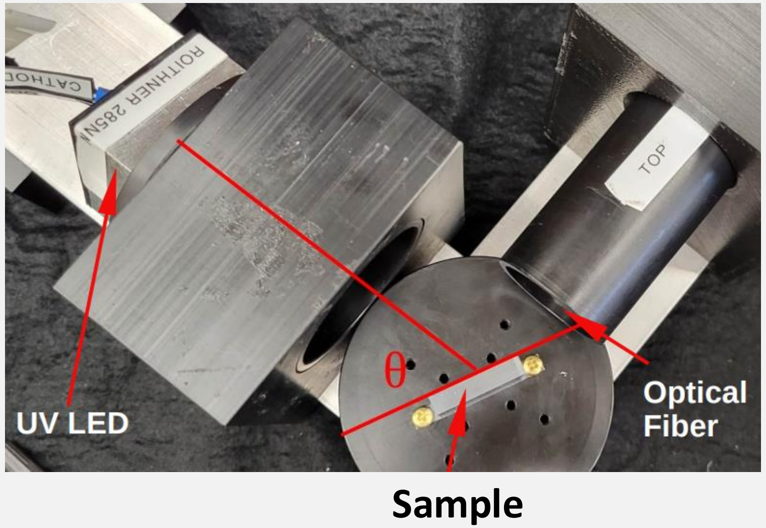
# Cryostat spectrometer results

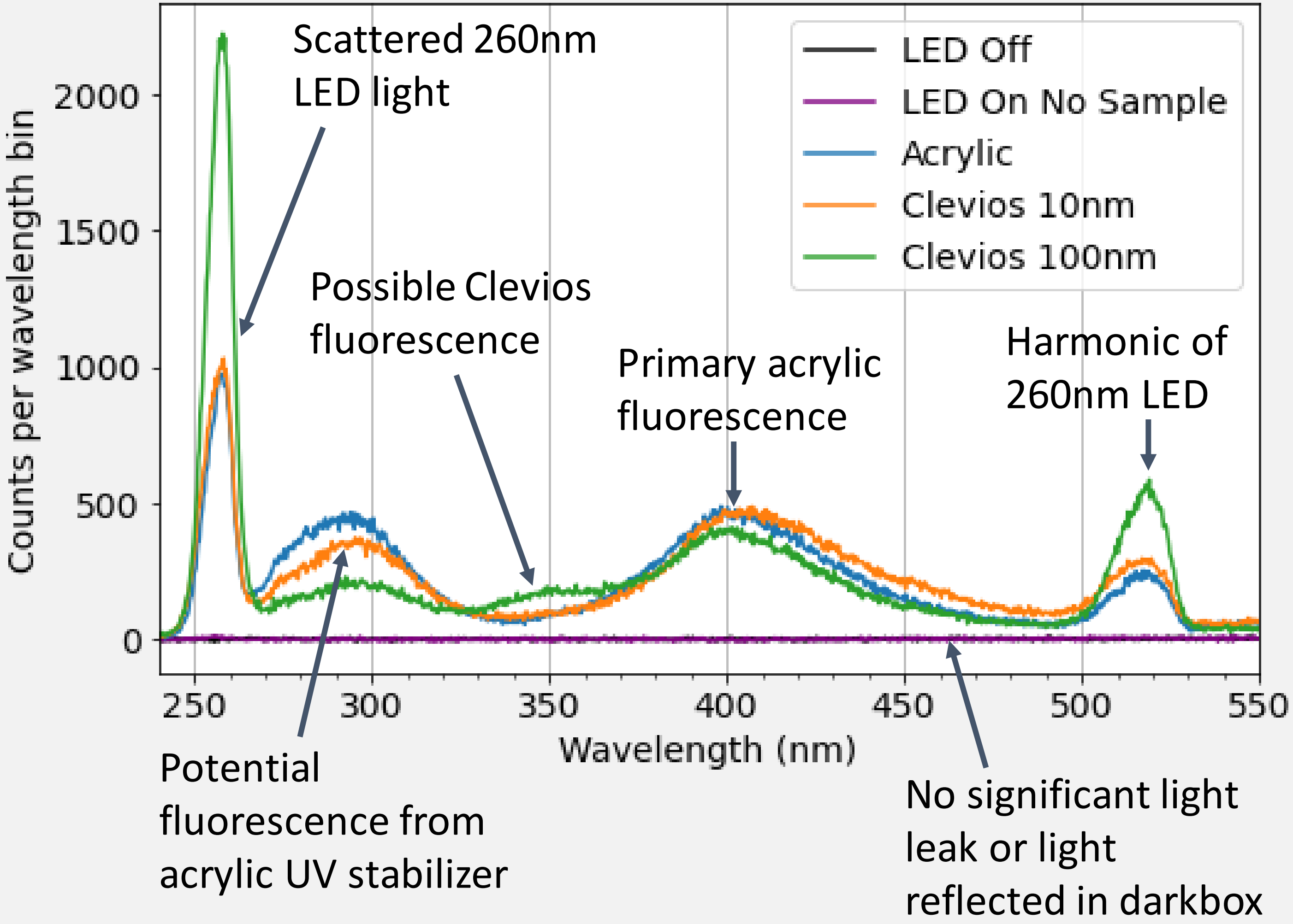
- Using Horiba spectrometer to measure spectral changes of materials in our cryostat in response to temperature changes.
- In the visible range, there does not appear to be any obvious spectral features unique to the 10nm Clevios coated sample spectra compared to the blank acrylic spectra.



# Acrylic reflection mode

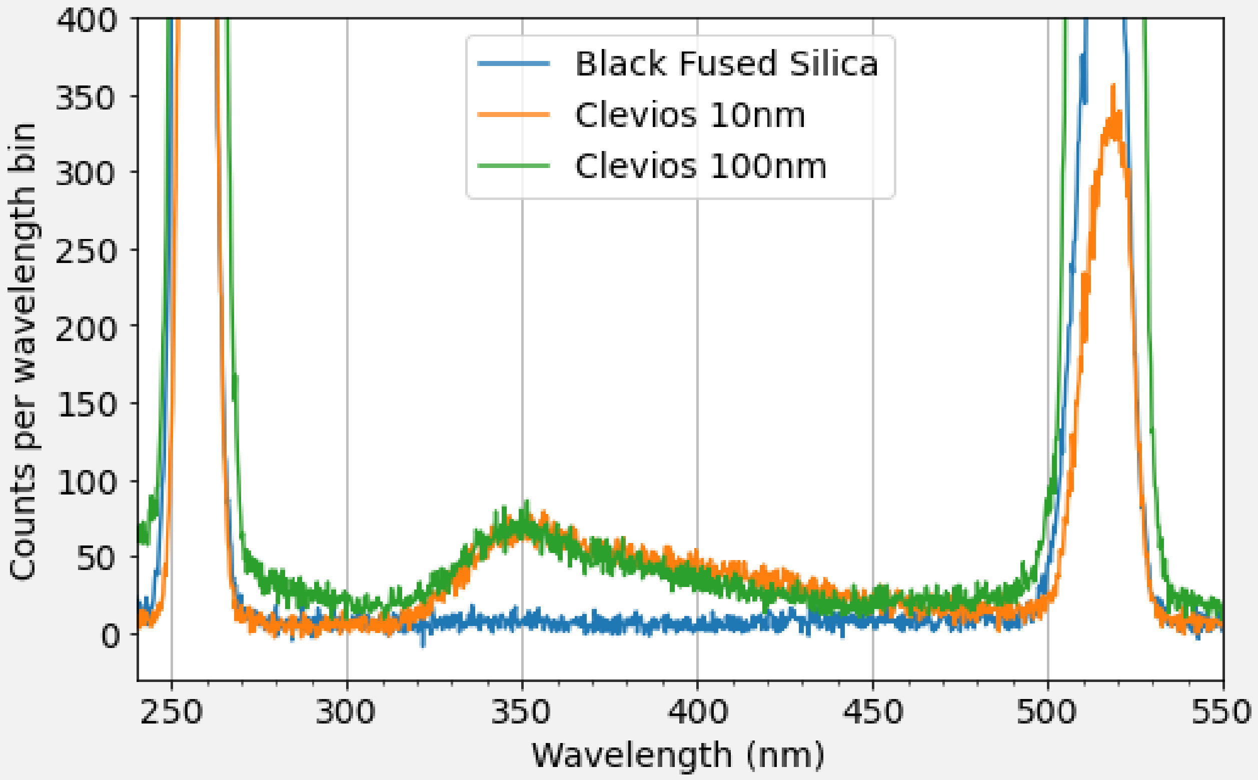
- Purpose: Take spectra in the UV while minimizing interference of the UV absorbing acrylic.
- Sample positioned at θ=65°.



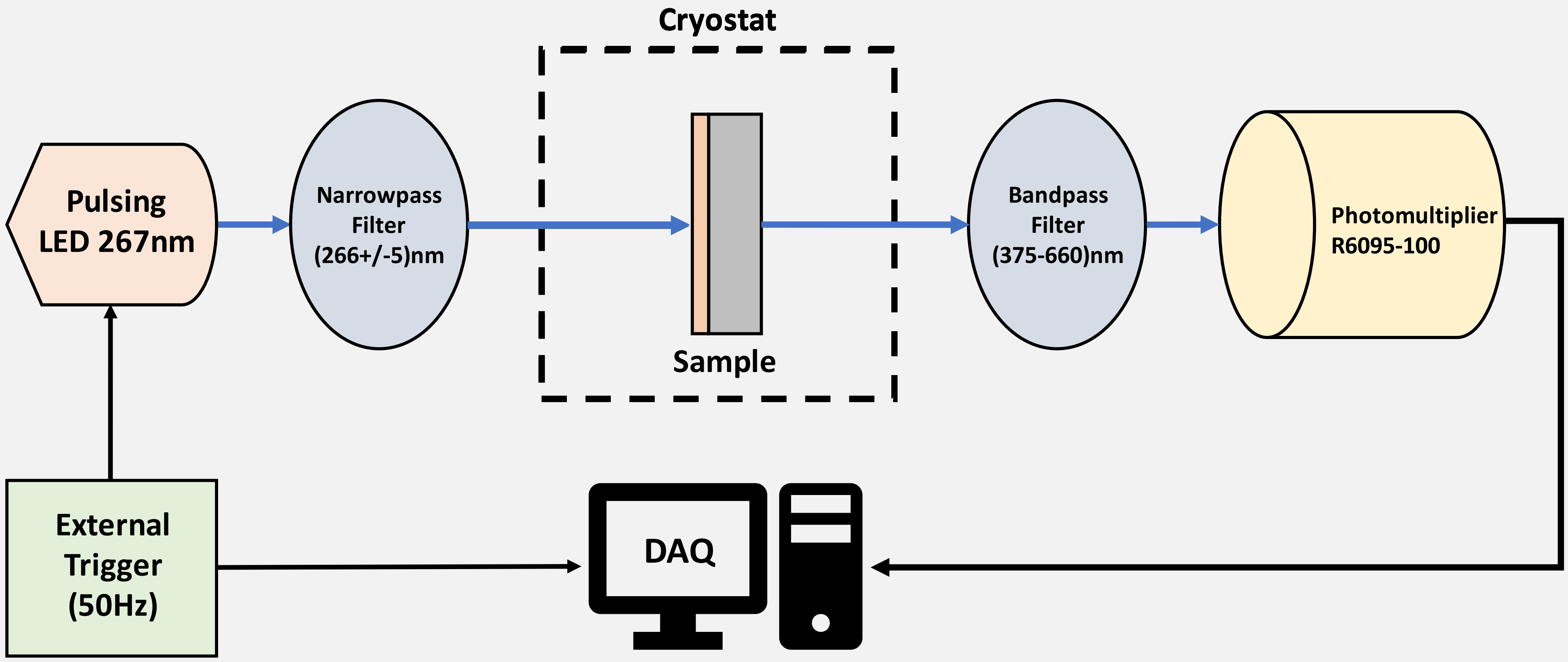



# Fused silica reflection mode

- Attempts to make a transmission measurement (θ=90°) required to low a LED voltage and too low an exposure to see fluorescence from Clevios.
- The setup is identical to the acrylic substrate sample test.

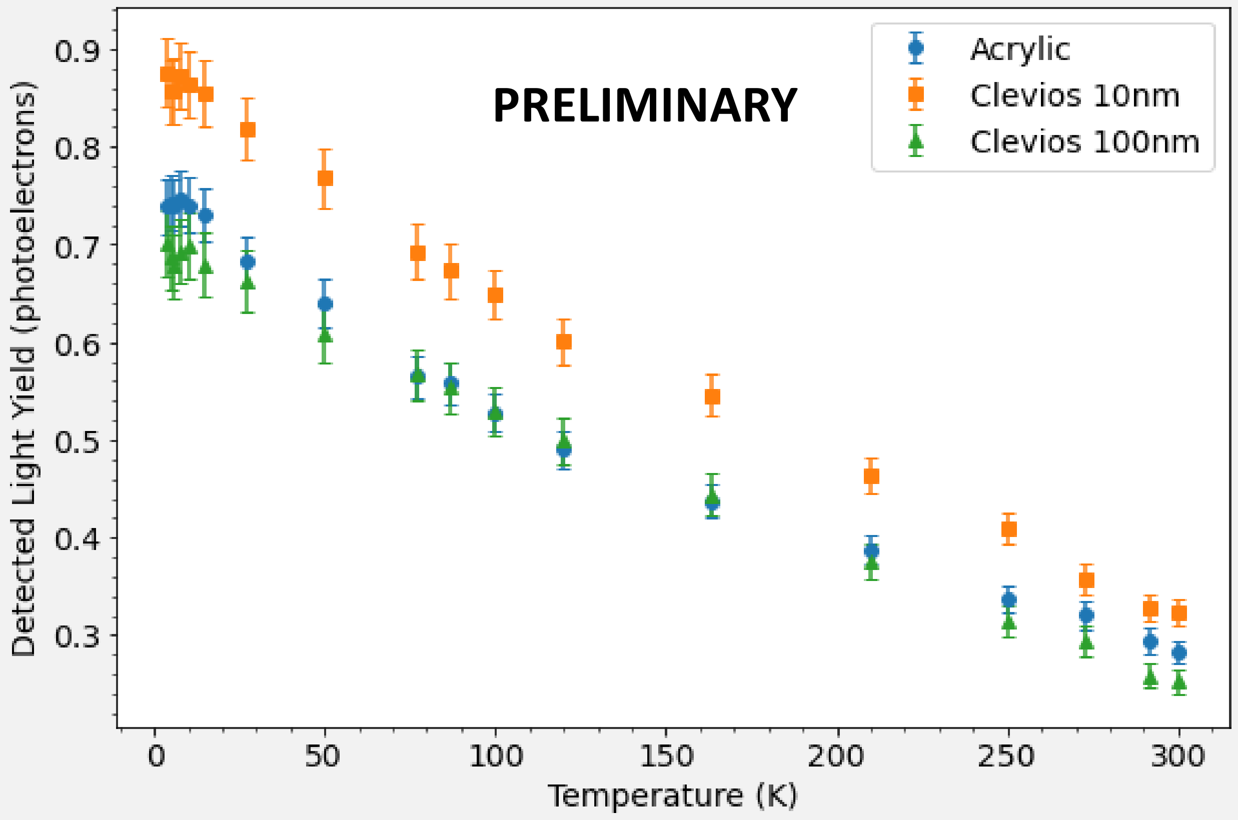


# Cryostat setup – time-resolved

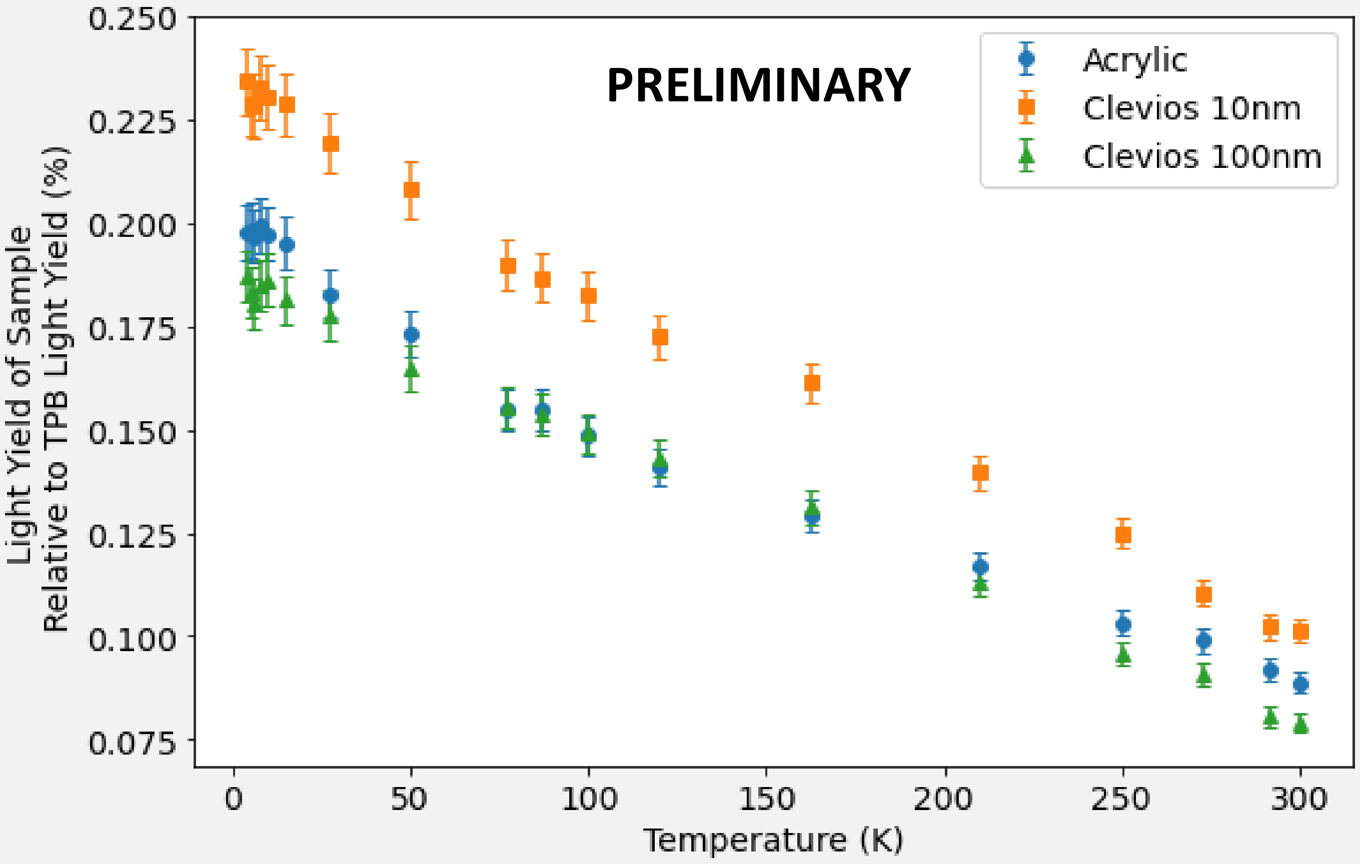


# Detected light-yield vs. temperature

- More fluorescence in all samples as temperature decreases/
- From these measurements it appears thin Clevios is more fluorescent than acrylic or thicker Clevios coating. Under investigation but possibly due to high absorption with thicker sample.



# Relative light-yield vs. temperature




- The relative light yield of 10nm coating on acrylic is 0.19% that of TPB at 87K.
- Clevios may be slightly more fluorescent than acrylic.

# Summary

Reflection mode spectral measurements of Clevios suggests that there may be **faint fluorescent emission from Clevios** which extends to the visible region. Consistent with literature.

We observe a **0.19% relative light yield of 10nm Clevios compared to 3µm of TPB** on acrylic suggesting minimal impact of Clevios to the light output of experiments which utilize this material.

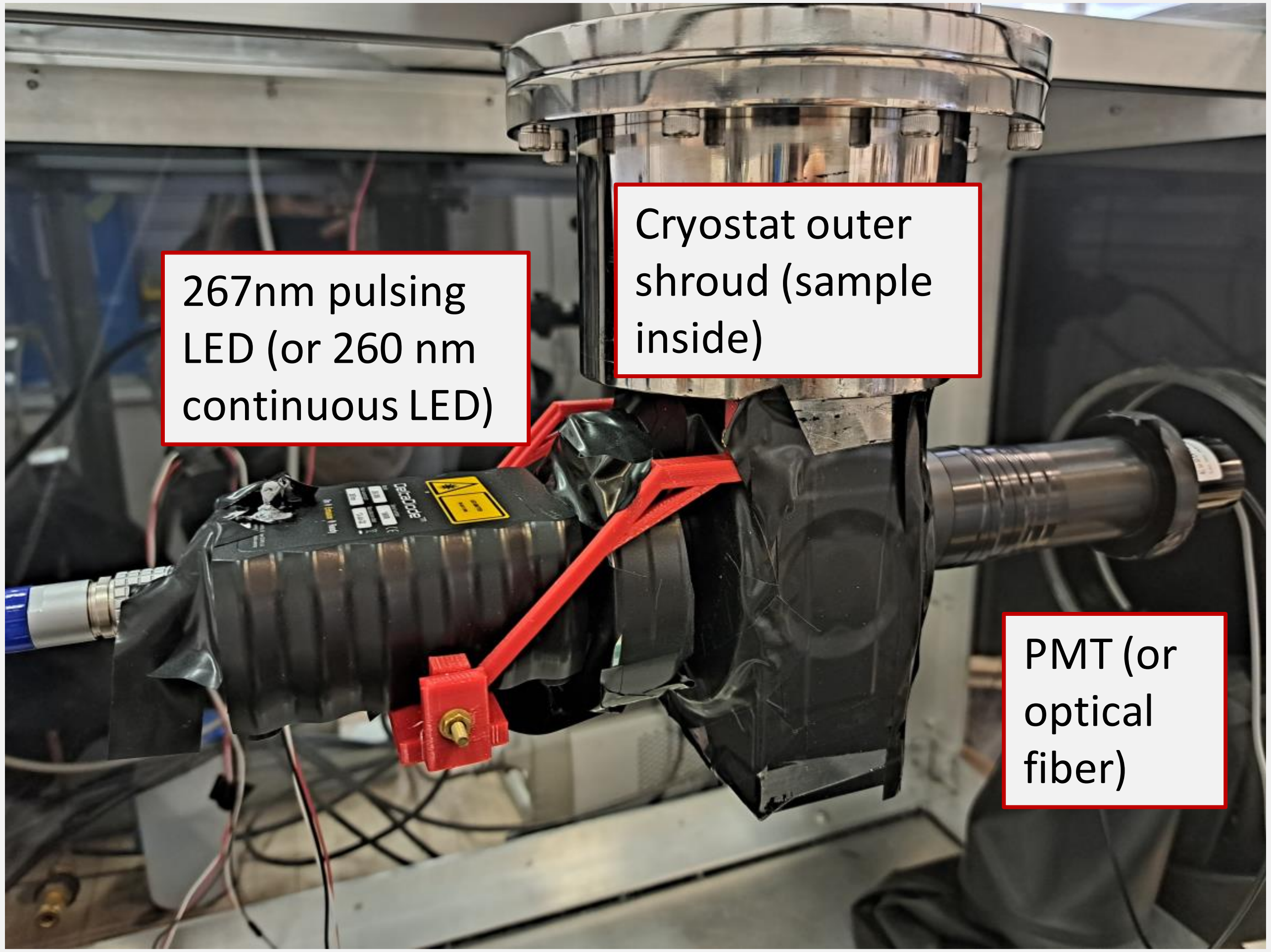
Absorbance measurements suggest that the **thicker coating transmits less light at the 267nm excitation wavelength** than the thinner coating, might explain the lower visible light yield.

# References


- [1] E. Ellingwood et al., Ultraviolet-induced fluorescence of poly(methyl methacrylate) compared to 1,1,4,4-tetraphenyl-1,3-butadiene down to 4 K, Nuclear Instruments and Methods in Physics Research Section A, Volume 1039, 167119.(2022)
- [2] T. Koyama et al. Photoluminescence of poly(3,4-ethylenedioxythiophene)/poly(styrenesulfonate) in the visible region (supplementary information). J. Mater. Chem. C, 3(32):8307–8310. (2015)
- [3] A.C. Bhowal, H. Talukdar & S. Kundu. Preparation, characterization and electrical behaviors of PEDOT:PSS-Au/Ag nanocomposite thin films: an ecofriendly approach. Polym. Bull. 76, 5233–5251 (2019).
- [4] I. Chirikov-Zorin, et al., Method for precise analysis of the metal package photomultiplier single photoelectron spectra, Nucl. Instr. Meth. A 456 (3) (2001) 310–324.
- [5] R. Cheng, Non-Standard Parametric Statistical Inference, Oxford University Press (2017)

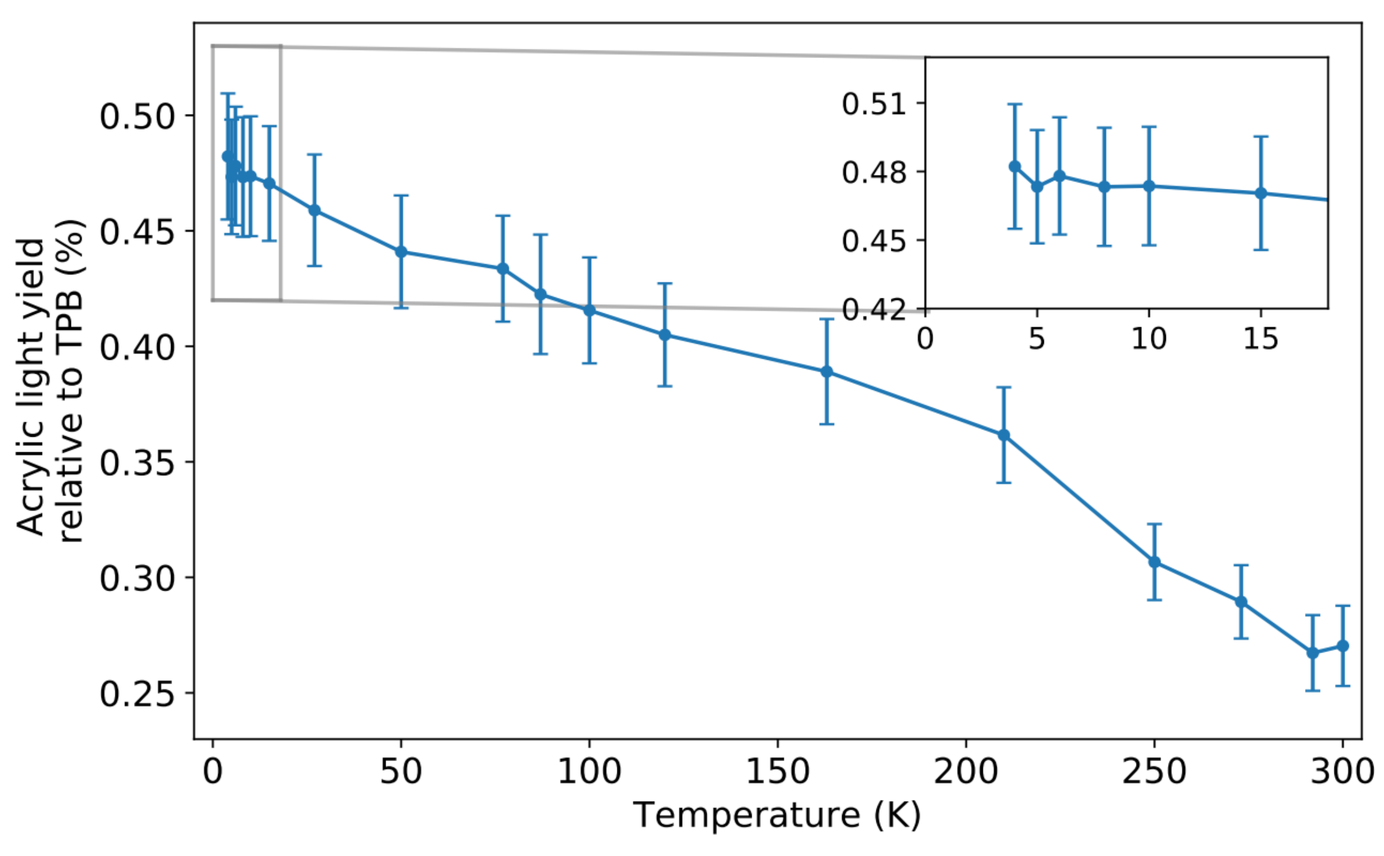
# Backup Slides

# Cryostat setup in lab in time-resolved mode



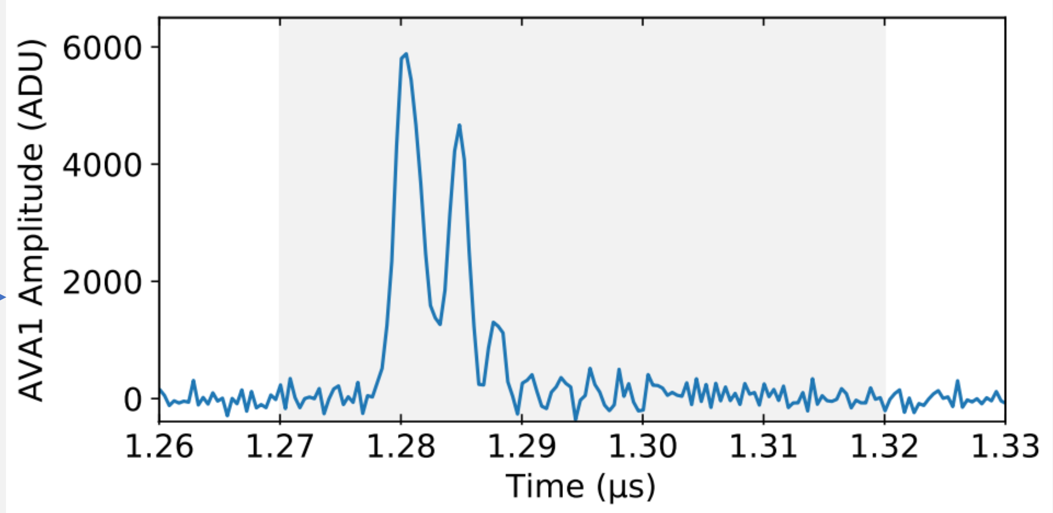
# Review of acrylic/TPB fluorescence

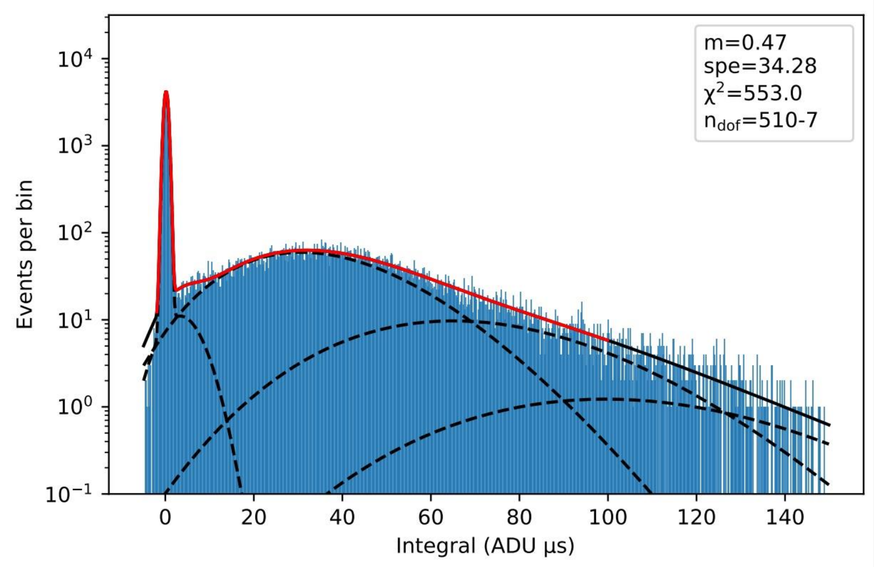
- Other materials commonly used in noble liquid detectors, especially LAr, such as acrylic and TPB both fluoresce.
- The amount of fluorescence in both materials increases with decreasing temperature. (E. Ellingwood et al.,2022) [1]
- Presented at LIDINE 2022.



# Calculating SPE level light yields

1. At each temperature record 45000 individual fluorescence pulses.
2. The light yield is the integral of each PMT pulse in a 50 ns window.
3. Build an integral distribution and fit with a model of single photoelectron distribution [4].
4. Light yield is the mean of this integral distribution.
5. Model also fits the SPE value the integral value per photoelectron.

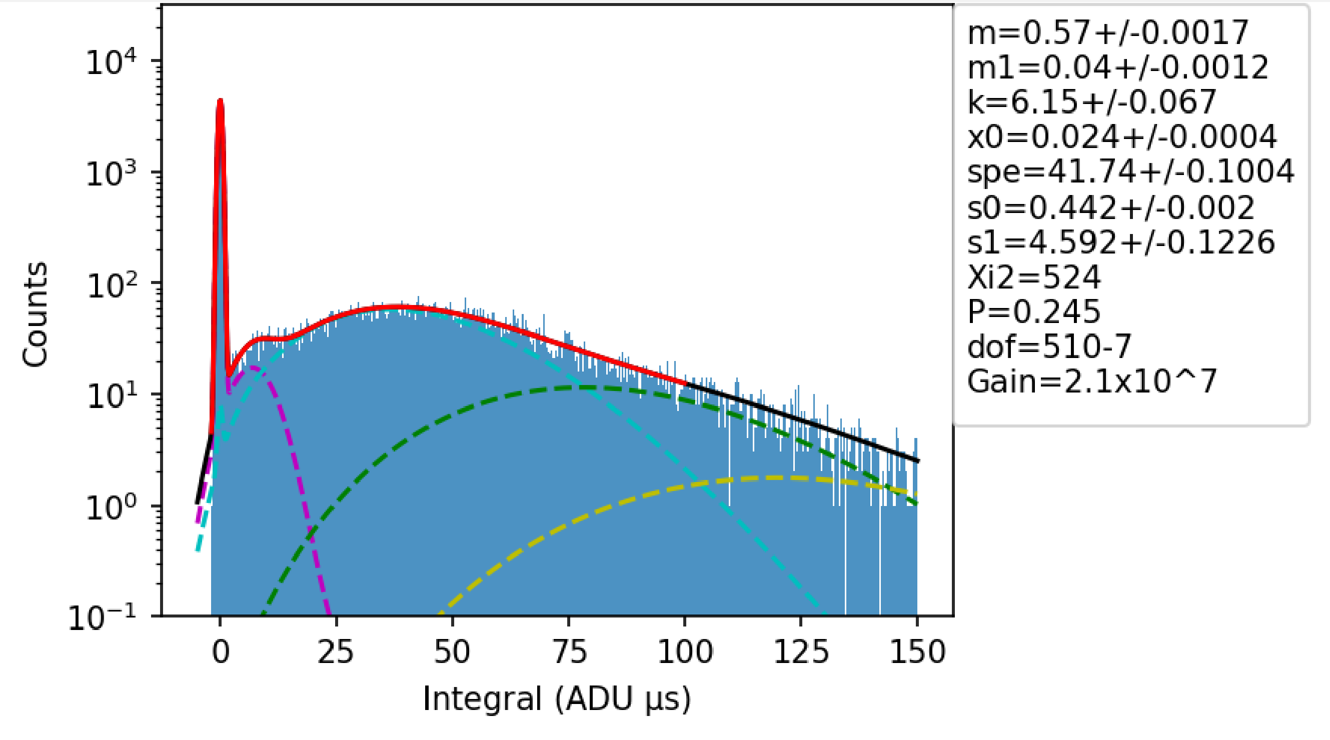


# SPE Spectrum

$$S_r(\varepsilon) = \sum_{n_1,n_2=0}^{\infty} \sum_{k_1=0}^{\infty} \frac{m^{n_1}e^{-m}}{n_1!} \frac{m_1^{n_2}e^{-m_1}}{n_2!} \frac{(n_1 \cdot k)^{k_1}e^{(-n_1 \cdot k)}}{k_1!} \frac{1}{\sqrt{2\pi(s_0^2 + (k_1+n_2)s_1^2)}} e^{-\frac{(\varepsilon-(x_0+(k_1+n_2)x_1))^2}{2(s_0^2+(k_1+n_2)s_1^2)}}$$

- Equation from paper by [4]
- The 'light yield' quoted is m, the average number of photoelectrons generated on the photocathode of the PMT.
- The SPE conversion is also fir as $k*x_1$, the average charge collected at the anode of the PMT initiated by one primary electron from the photocathode.



# NPE spectrum

- Exactly the same data acquisition procedure as acrylic only changing LED voltages or digitizer vertical range due to much larger pulses. These changes are accounted for in the analysis.
- Fit integral distribution with a skew normal function. [5]

$$K(A,\xi,\omega,\alpha,s) = \frac{2A}{\omega\sqrt{2\pi}} exp\left(\frac{(\xi - s)^2}{2\omega^2}\right) \int_{-\infty}^{\alpha\left(\frac{\xi - s}{\omega}\right)} \frac{1}{\sqrt{2\pi}} exp\left(\frac{-t^2}{2}\right)\ dt$$

A = scaling factor
ξ = location on distribution
s = scale of the distribution
α = shape of distribution

- The mean of the fit is the light yield.