PTFE Reflectance for Xenon Scintillation Light

Wolfgang Lorenzon

University of Michigan

(for the Michigan Dark Matter Group)

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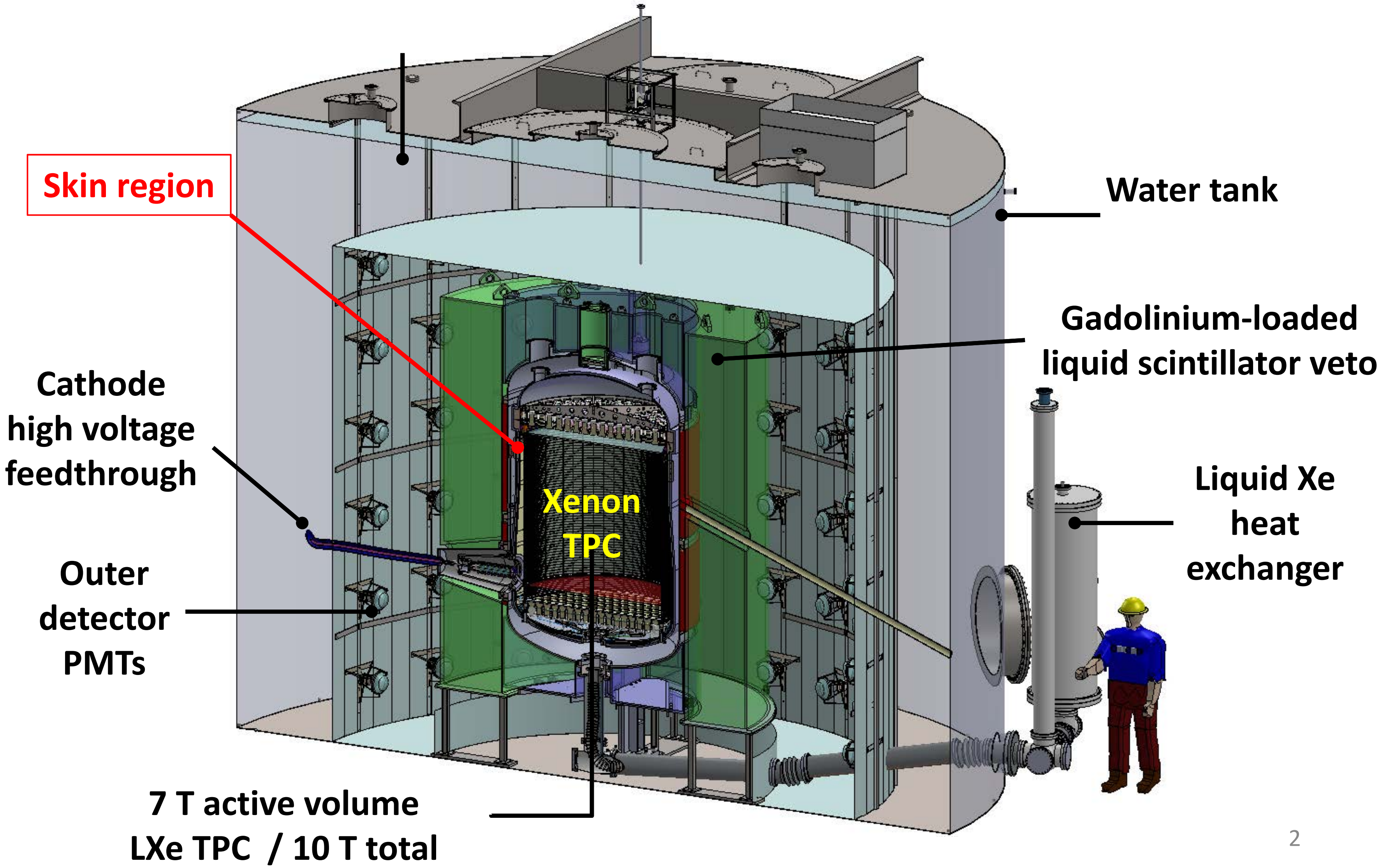
Motivation

- Many rare event searches (DM direct detection, $0\nu\beta\beta$) take advantage of high VUV reflective surfaces made from PTFE materials to achieve light collection efficiency (LCE)
  - detector performance strongly affected by xenon scintillation LCE
    - small difference in PTFE reflectance has a noticeable impact on the performance of a LXe detector
  - PTFE known to be highly reflective in visible and NIR regions [$\mathcal{O}$ (99%)]
  - in VUV ($\lambda \approx 175$ nm) PTFE reflectance in
    - GXe: $\mathcal{O}$ (55%)
    - LXe: $\mathcal{O}$ (97%) as recently measured [F. Neves, et al. arXiv:1612.07965]
- Need for thinner detector walls without significant loss in reflectance to reduce
  - dead volume around active noble liquids
  - outgassing
  - potential backgrounds
- Lower limit on thickness determined by need for optical isolation b/w active and passive (or two isolated active) regions

LZ Detector

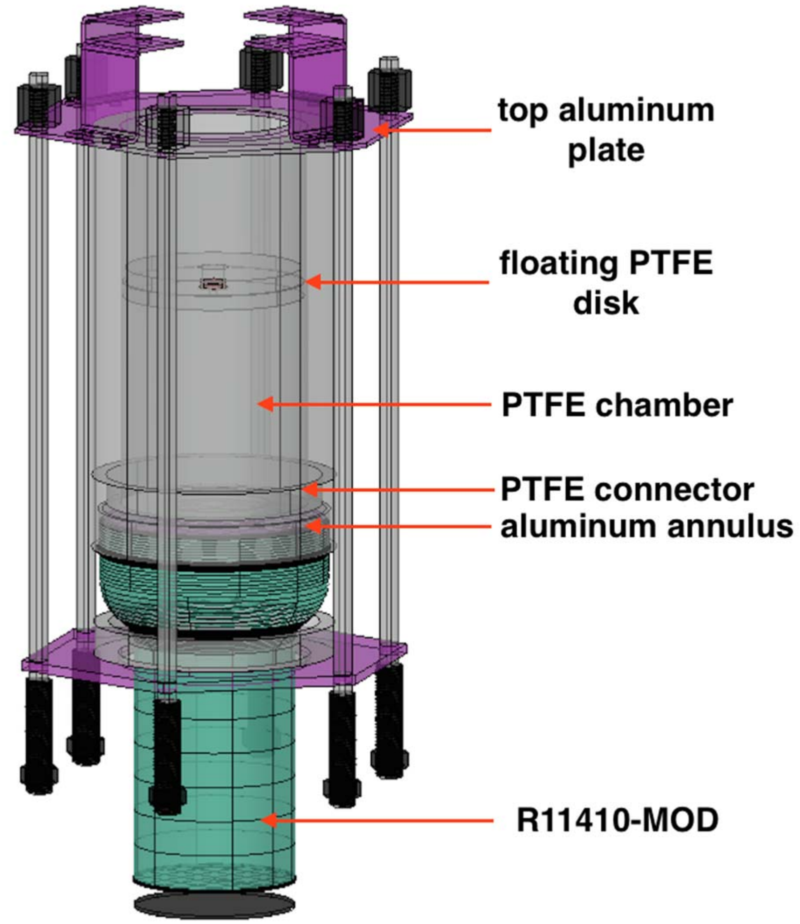

Skin region
Water tank
Gadolinium-loaded
liquid scintillator veto
Cathode
high voltage
feedthrough
Xenon
TPC
Liquid Xe
heat
exchanger
Outer
detector
PMTs
7 T active volume
LXe TPC / 10 T total

Measurements

- determine dependence of reflectance on PTFE thickness
- use 175 nm VUV xenon scintillation light
- PTFE materials investigated with Michigan Xenon Detector (MiX):
  - APT 807NX, (1mm - 9.5mm)
  - APT NXT85, (1mm - 9.5mm)
- Kapton, as a low reflective material

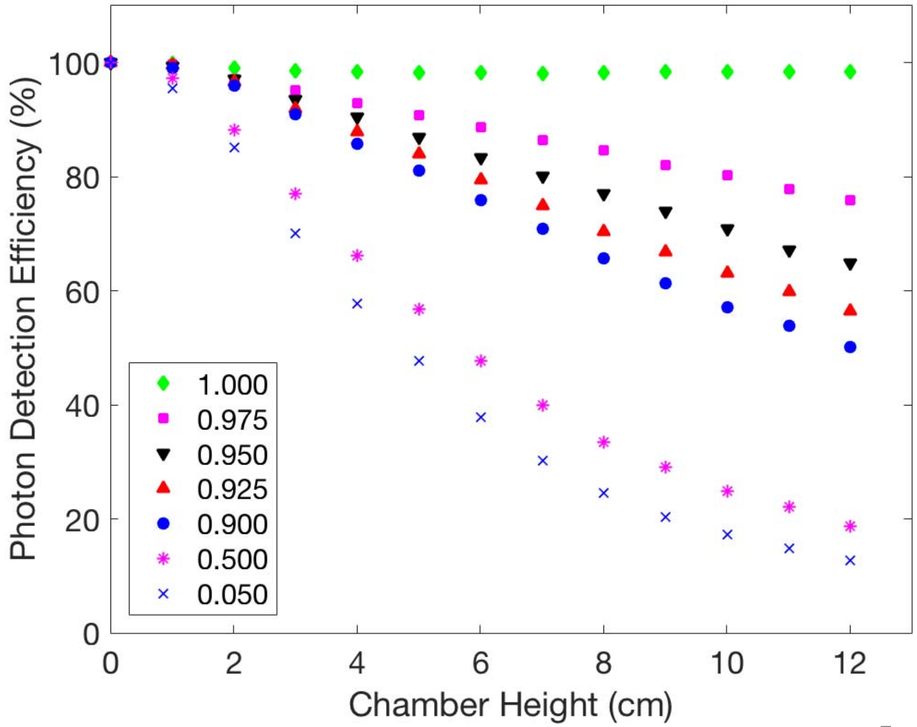
Experimental Setup

- MiX detector used for the reflectance measurements
- Procedure:
  - measure scintillation light yield while varying reflective (ie. PTFE) surface area
  - as surface area increases (ie. floating disk rises), light yield decreases
- Xe scintillation from 5.304 MeV mono-energetic (0.1 μCi = 3.7 kBq) ^{210}Po α source in floater
- 117 mm cylindrical PTFE height
- PTFE wall thickness reduced by milling from the outside
  - internal surface of PTFE cylinder remains unchanged



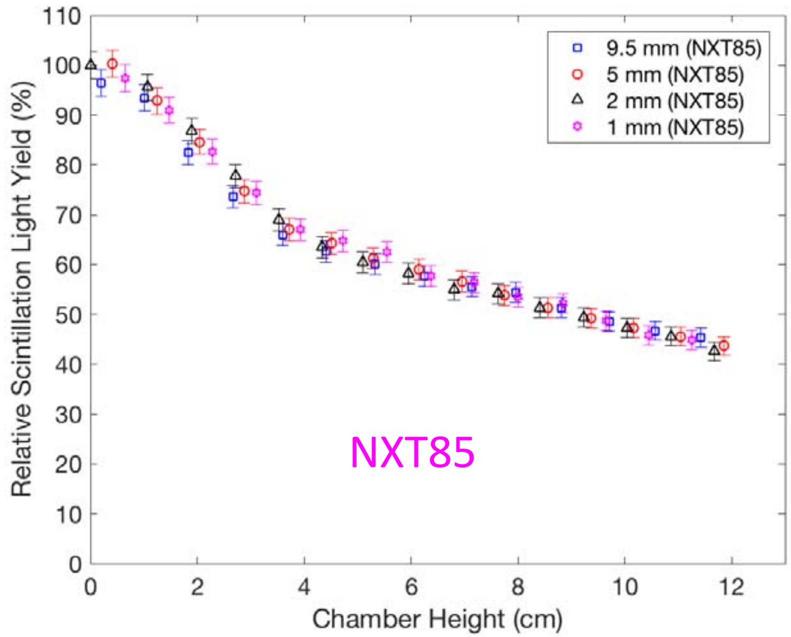
Simulating Sensitivity of Method

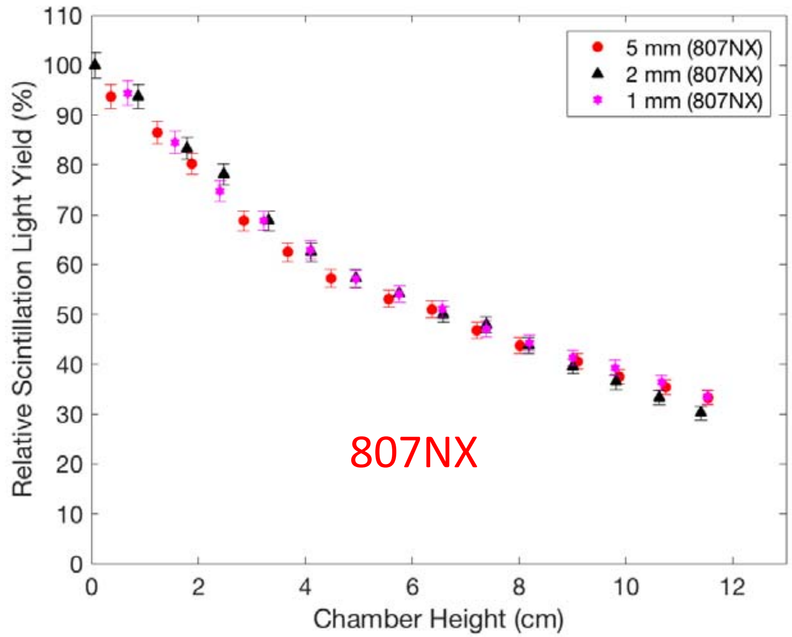
- Simulations of scintillation light yield versus chamber height for various PTFE reflectances
- Simulations do not account for Rayleigh scattering and light absorption in LXe
  - only accounts for diffuse reflections, not specular.
- Method very sensitive to high reflectance materials
  - well-suited to detect small variations in reflectance with PTFE thickness
- But poorly-suited for low reflectance materials.



Results: NXT85 and 807NX PTFE

scintillation light yield versus chamber height



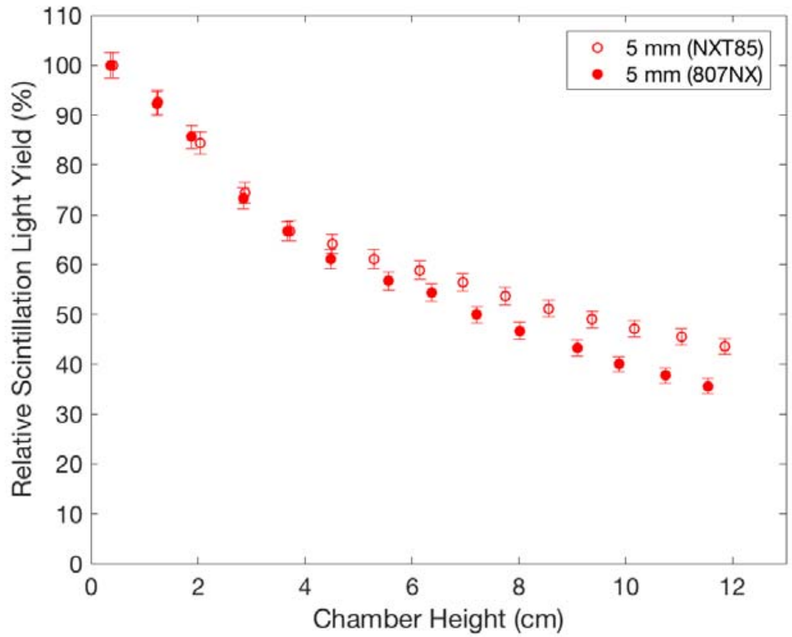


- 0.4% fluctuations in reflectance between sets
- Factor 2.3 drop in light yield

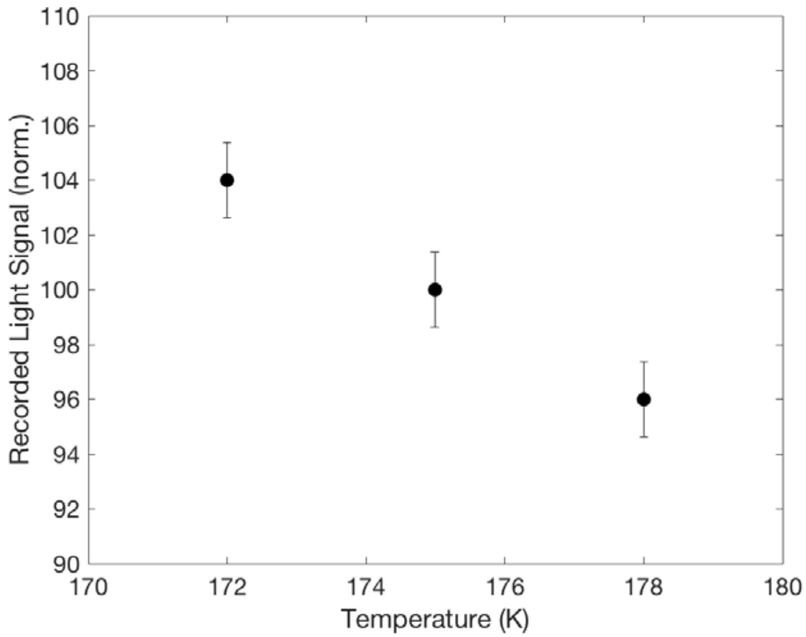
- 0.5% fluctuations in reflectance between sets
- Factor 3 drop in light yield

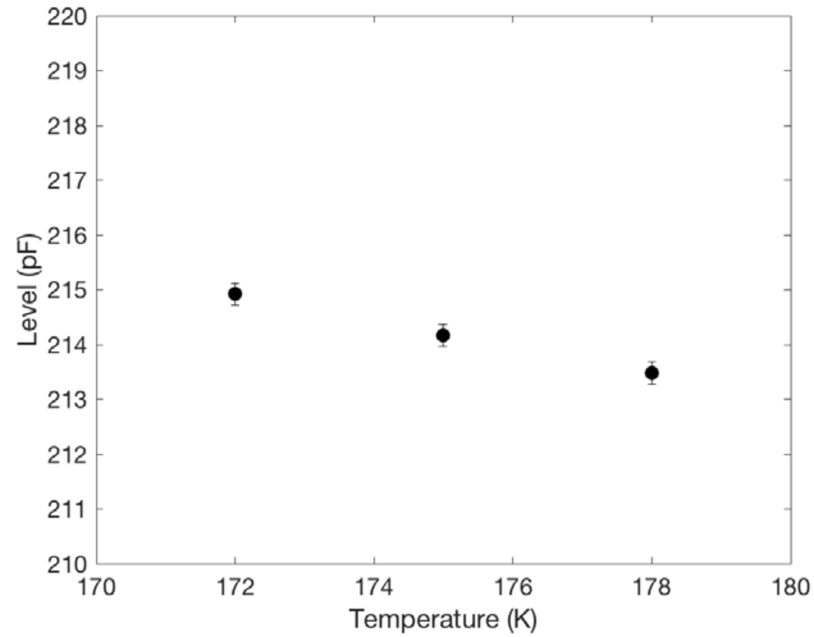
Comparison: NXT85 and 807NX PTFE

- Data sets normalized to unity at PMT surface
- NXT85 has greater light yield at larger chamber heights (above 4cm) than 807NX (at 5mm PTFE thickness)
- Absolute reflectivity measurements for NXT85 and (807NX) PTFE are 97.5% and (96.1%), respectively.
- 1.4% difference in absolute reflectance for NXT85 and 807NX allows to estimate fluctuations in reflectance for the two PTFE data sets.



Temperature Dependence



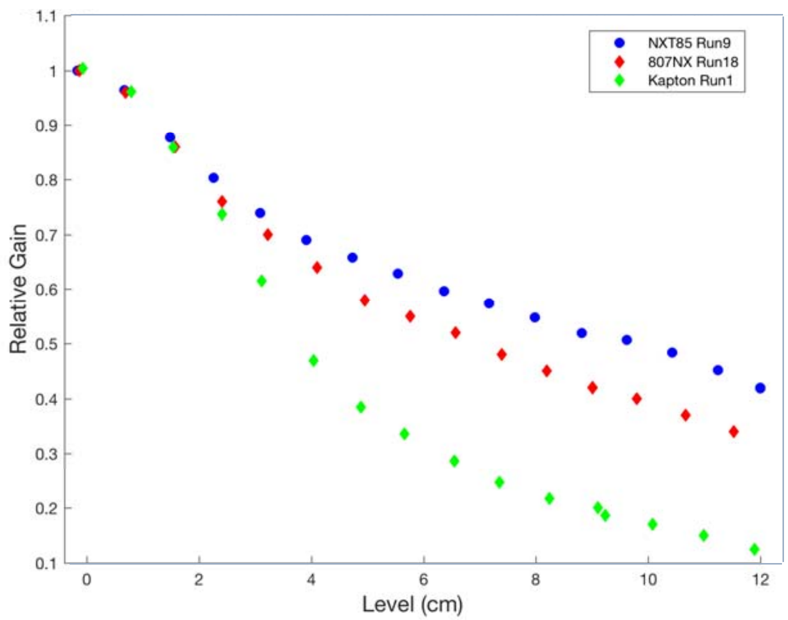


- light signal in LXe increases as temperature decreases
- signal variation for T = (175 ± 3) K is -1.3%/K
  - factor 3 larger than typical values
  - maybe due to PMT gain dependence in T

- capacitive level meter reading decreases as temperature increases
- variation is -0.1%/K
  - agrees with drop in dielectric constant as T increases

Comparison to Kapton

- Method:
  - line inside of PTFE cylinder with 0.127 mm thick Kapton sheet
  - repeat set of measurements as with PTFE cylinders
- Kapton has much lower reflectance than NXT85 or 807NX PTFE
- Current method does NOT allow to determine reflectance of Kapton to 175 nm xenon scintillation light
  - Remember: method is inadequate for low-reflectance materials
  - Reflectance appears to be below 50%.



Summary

- Studied change in reflectance of PTFE immersed in LXe at $\lambda \approx 175$ nm as PTFE thickness was reduced from 9.5 mm to 1 mm
- No reduction on reflectance observed for NXT85 and 807NX PTFE down to 1 mm wall thickness within uncertainties
  - Combined with absolute measurements, fluctuations are less than 0.5%
  - Published: arXiv:1608.01717 and NIMA, 856, 2017,86
  - Method used is well-suited for high reflectance materials (ie. PTFE), but poorly-suited for low reflectance materials (ie. Kapton, PEEK).
- Ability of PTFE to maintain good reflectance (ie. LCE) even at very thin thicknesses instrumental to next generation DM and $0\nu\beta\beta$ experiments
  - requirements: large size detectors; small dead space; low outgassing; minimal potential radioactive backgrounds; and good optical isolation b/w active and passive regions
  - all these requirements are met by thin sheets of PTFE

Thank you