EVERGREEN: IMPROVING THE LIFETIME OF PLASTIC SCINTILLATORS

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BACKGROUND: Thousands of plastic scintillators are deployed outdoors where they are subject to conditions of high humidity and drastic temperature changes.

The Problem: Plastic scintillators may fog at low temperature

Plastics absorb water vapor. At low temperatures the vapor can condense and form a haze inside the scintillator.

" Fogging in polyvinyltoluene scintillators used in outdoor environments", R Cameron et. al. IEEE NSS 2014

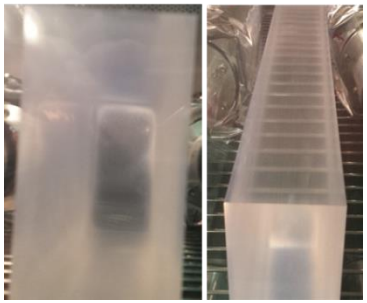
After 88 hours at 55C and 85% relative humidity the plastic has absorbed enough water to cause hazing at -30C

Initially, the plastic clears upon returning to 25C.

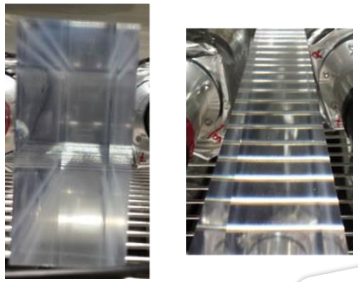
Initial at 25C

@ -30 for 16 hrs.

Back at 25C, 2 hrs.



25C for 20 hrs.



THIS STUDY

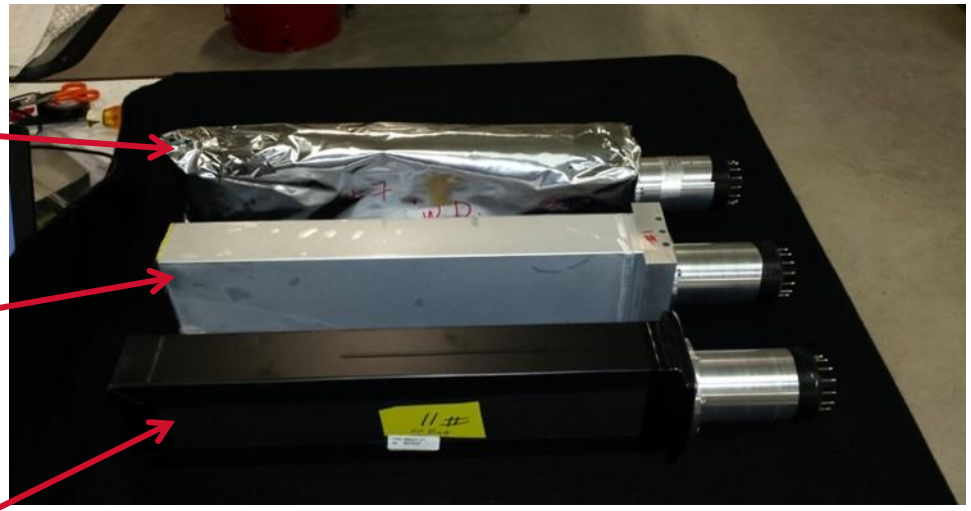
Answer these questions

How does haze effect the performance of plastic scintillators?
What protection is afforded by the standard wrapping?
Is there a cost effective solution that prevents haze formation?

Standard Wrapping + Saint-Gobain XV* wrap with hermetic seal at PMT

Hermetically sealed Aluminum housing (expensive for large pieces)

Standard Wrapping, foil and black plastic. (Thousands of pieces deployed)



Test pieces: 5 x 10 x 40 cm^3

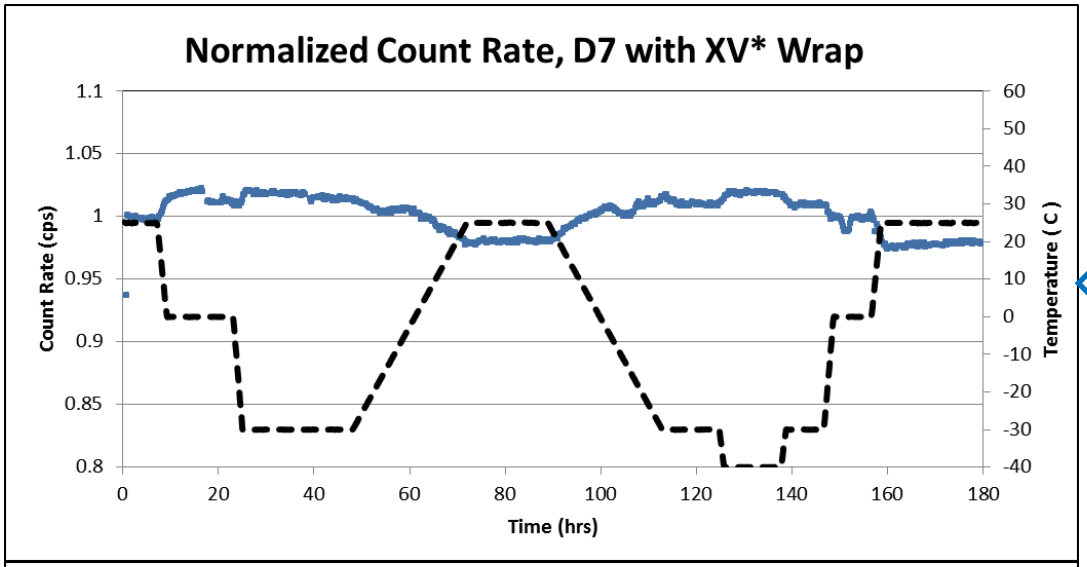
XV wrap* heat sealable barrier film
M.V.T.R.: 1 x10^{-2} g/m^2/day
Thickness: 91 microns
Gamma Transmission: >99%/layer @ 60 keV

*** Saint-Gobain proprietary, patent pending**

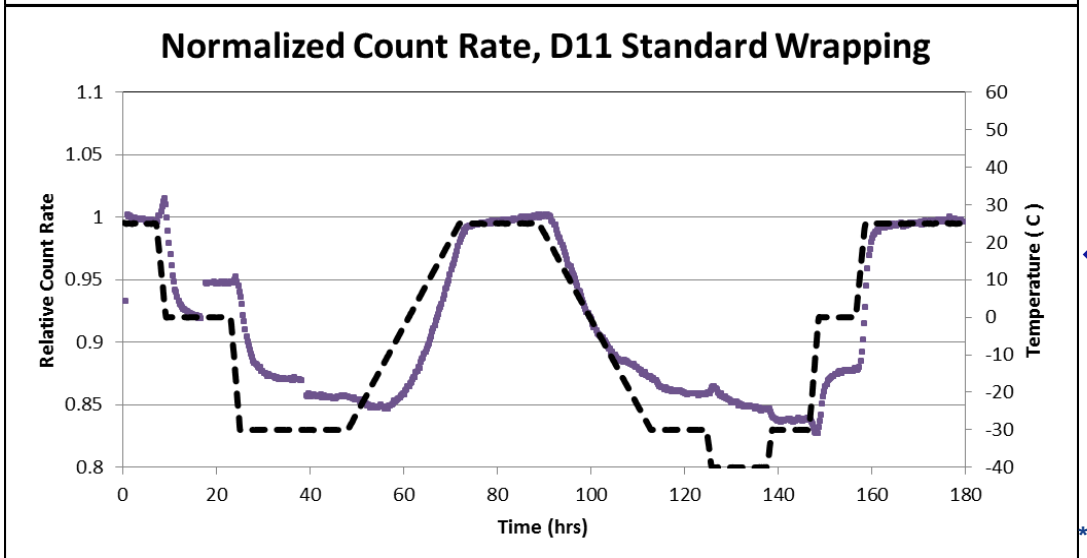
LOW TEMPERATURE RUN

DETECTORS HAVE ACCUMULATED 1000 HOURS AT 55C AND 85% RELATIVE HUMIDITY

Count Rate Profile for Cs-137normalized to that at room temperature.
Temperature indicated by dashed line



For the hermetically sealed detectors, the count rate increases as the temperature decreases. This behavior follows the PMT gain changes with temperature



For detectors with only foil and vinyl wrapping, the count rate falls as the temperature decreases indicating a loss of signal

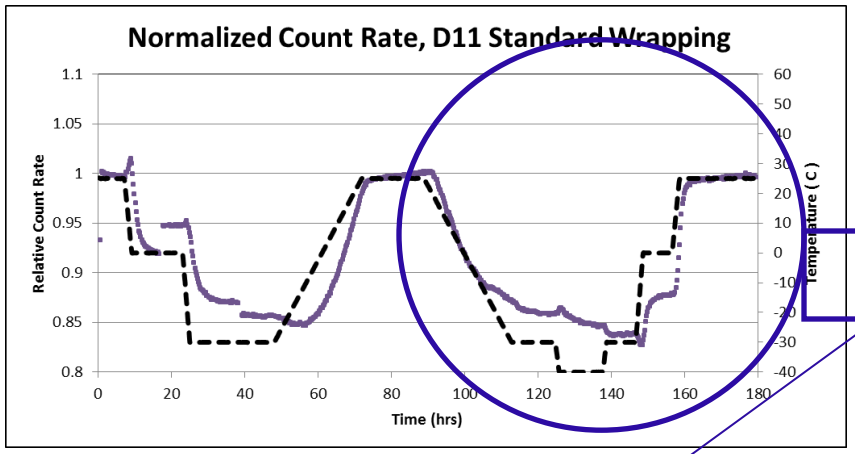
CRYSTALS

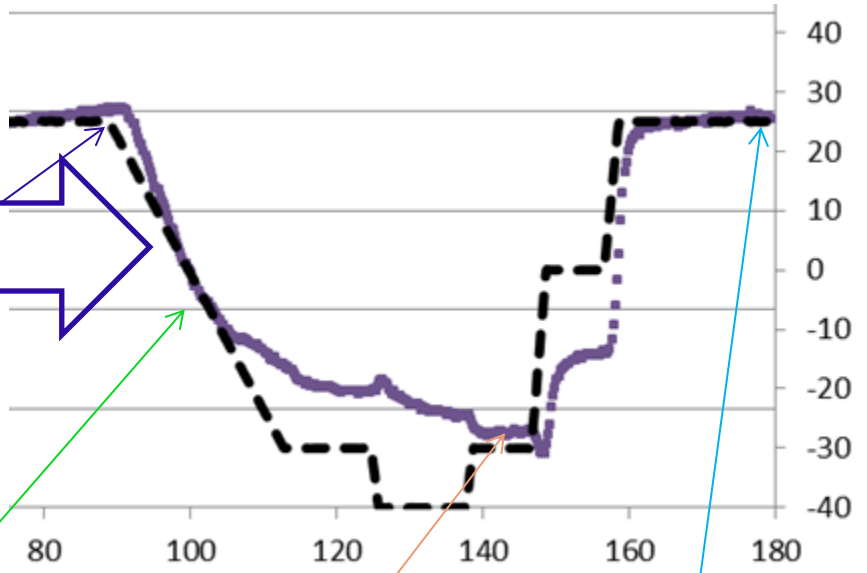
SAINT-GOBAIN

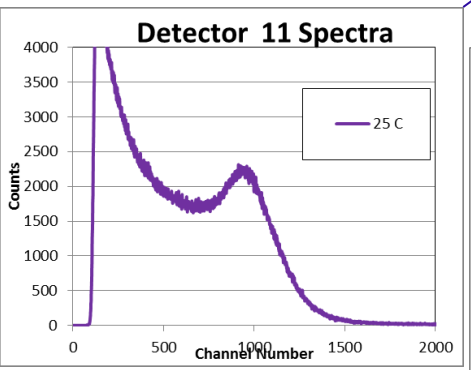
* Saint-Gobain proprietary, patent pending

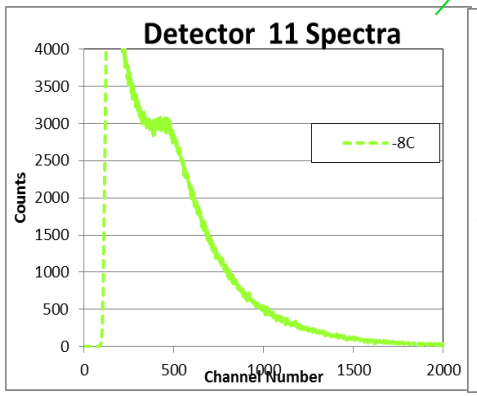
A CLOSER LOOK AT THE DECREASE IN COUNT RATE

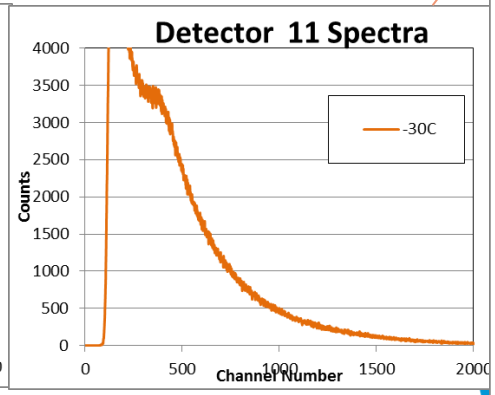
The spectrum shifts to the left as the temperature decreases. The loss of definition in the Compton edge indicates increased non-uniformity of light collection.

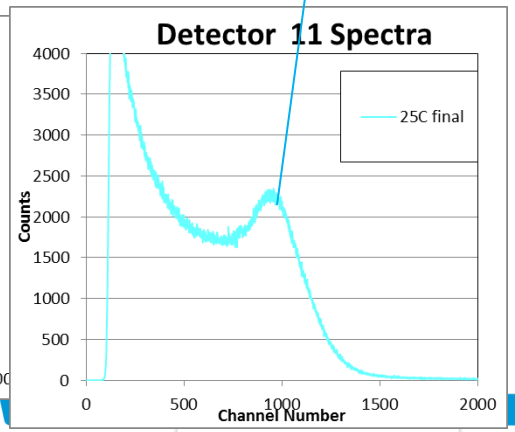






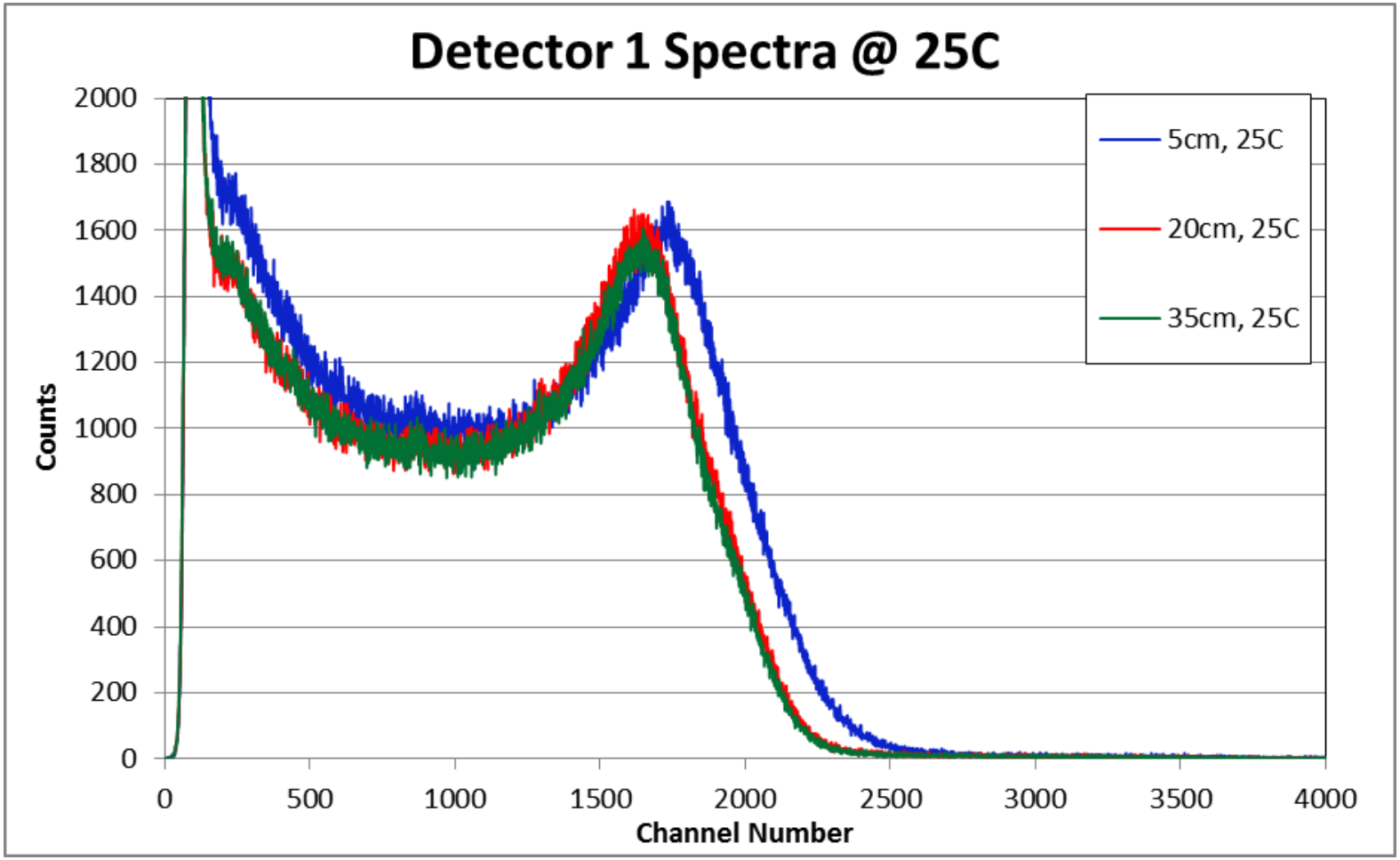






LIGHT COLLECTION UNIFORMITY

Measured by recording spectra for a Cs-137 source placed at 5cm, 20cm, and 35cm from the PMT



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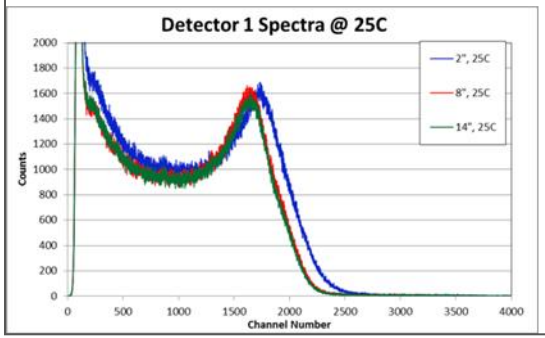
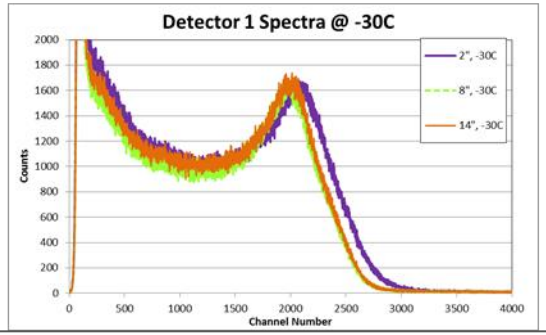
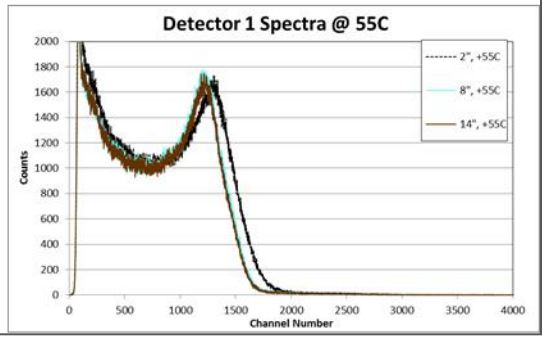
RESULTS: 3 POINT TEST AT TEMPERATURE

Measurements after **1450 hours** at 55C & 85% RH

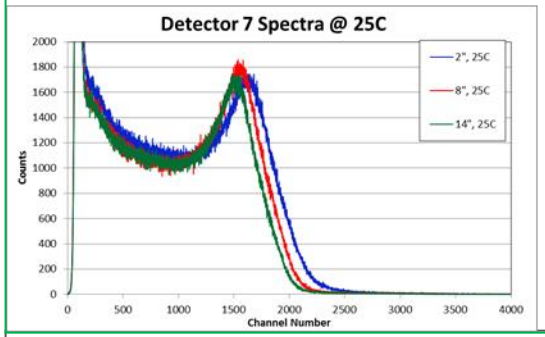
Aluminum Housing

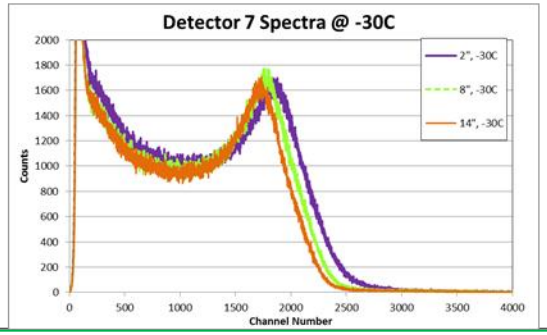


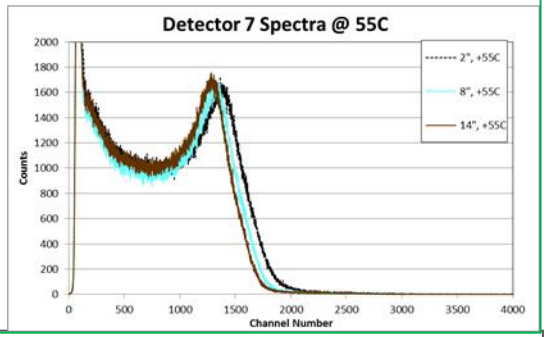




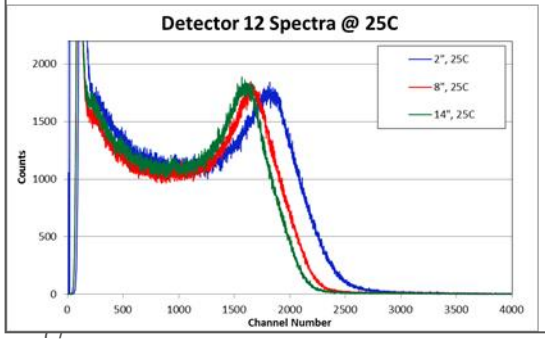
With XV* wrap

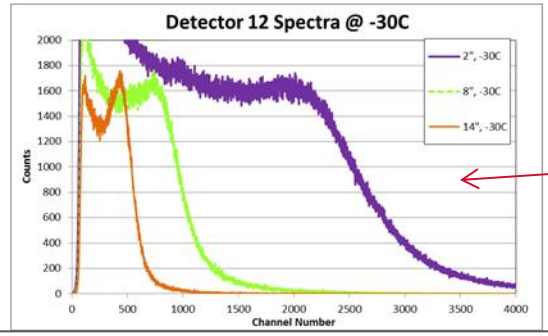


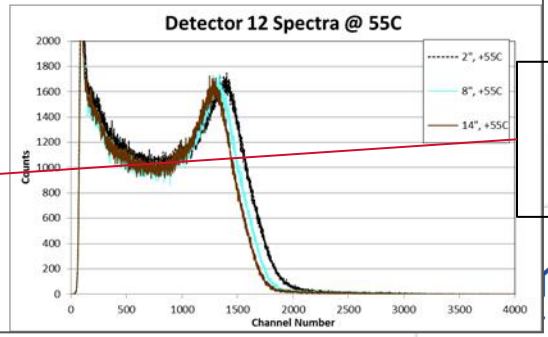




Standard Wrapping





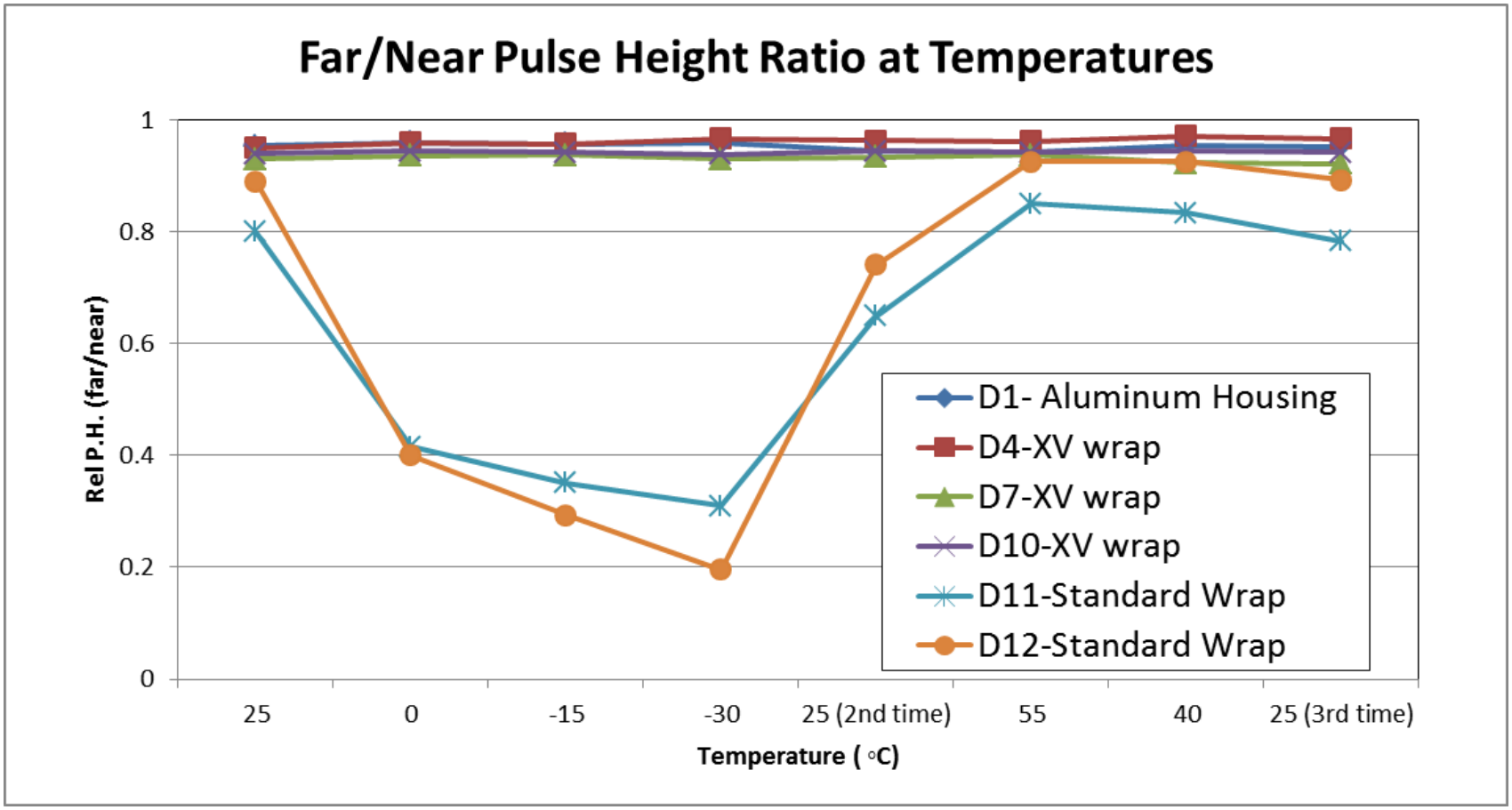


Poor uniformity at -30C

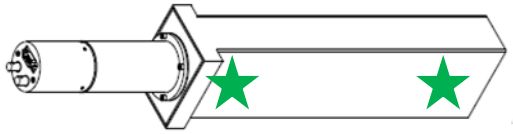
GOBAIN

LIGHT COLLECTION UNIFORMITY: CHANGES WITH TEMPERATURE

Measurements after **1450 hours** at 55C & 85% RH



Hermetically seal detectors, aluminum housing or XV wrap remain uniform within 10% between +55 and -30◦C. The uniformity of the stand wrapped detectors decreases at cold temperatures indicating internal fogging is occurring.



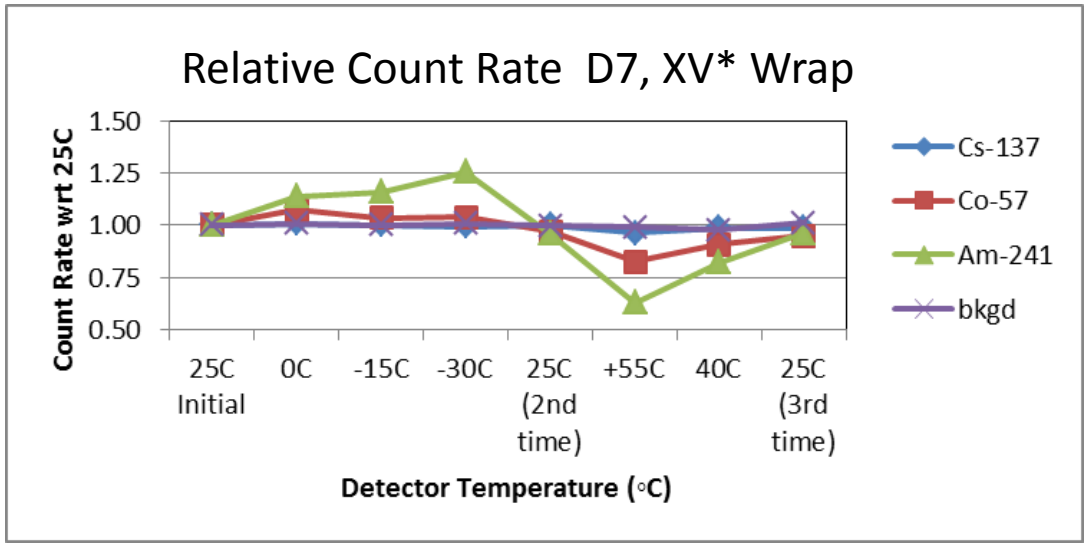
CRYSTALS SAINT-GOBAIN

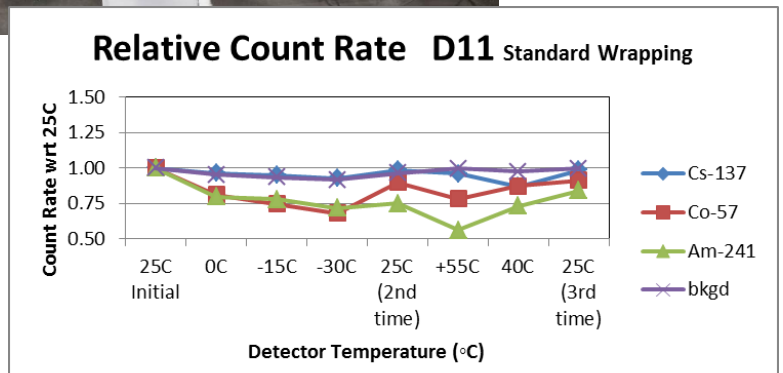
RESULTS: DETECTION SENSITIVITY AT TEMPERATURE

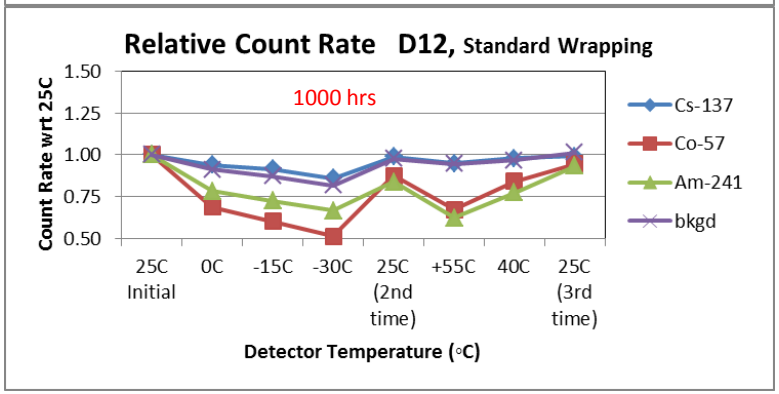
Measure the relative change in sensitivity to different gamma energies at various temperatures. Measurements made after the detectors have accumulated1450 hours at 55C and 85% RH. A low level discriminator of ~30 keV was employed

6 detectors positioned for efficiency measurements

Cs-137
Co-57
Am-241







EVERGREEN: PHASE 2

2 Areas Currently in Development

Move hermetic barrier inside the vinyl wrapping
- Protection
- Appearance

Larger Scintillators with Multiple PMTs, (2.25” x 14” with multiple PMTs)
- Self-contained hermetic package, includes optical windows
- Use PMT sub-assemblies to complete the hermetic seal

New prototypes with hermetically sealed with optical windows

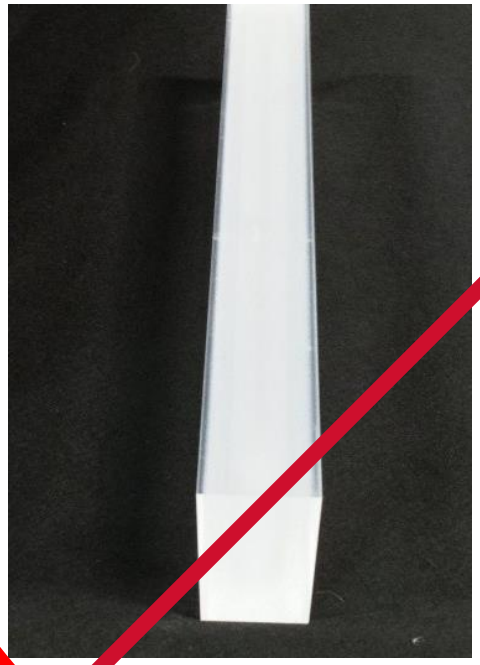
CONCLUSIONS

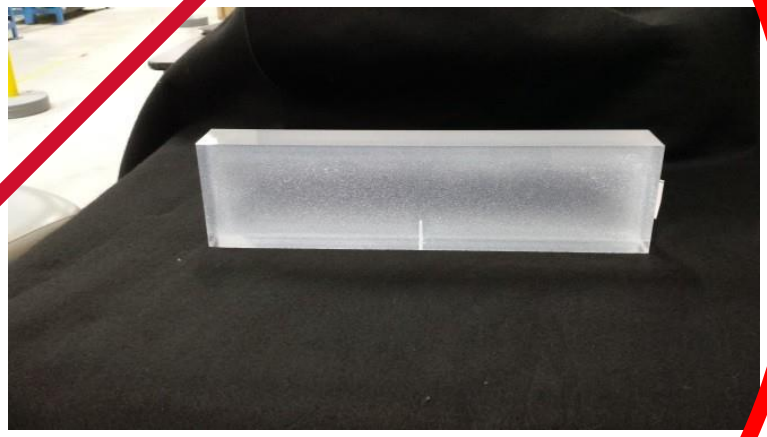
Moisture absorption in plastic scintillators can cause fogging in the volume when the plastic experiences a negative change in temperature.

Degradation in detection efficiency is due to increased non-uniformity in light collection over the scintillator volume.

Detection efficiency for low energy events is decreased more severely than for higher energies

The Saint-Gobain XV* wrap along with a hermetic seal at the PMT were as effective as an aluminum housing in preventing moisture intrusion over the span of this test.





Fogged plastic that has not recovered after 1 month at 25C