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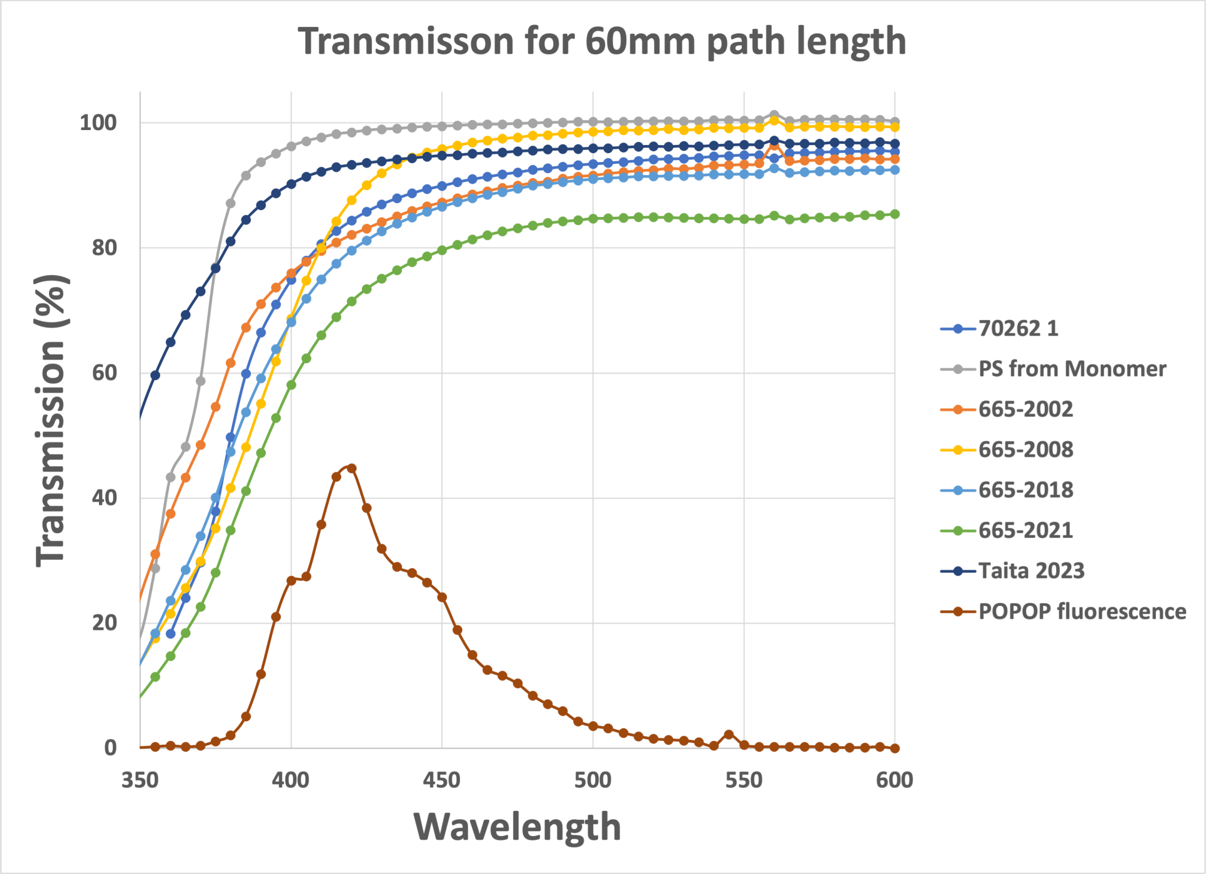
R&D Overview

Plastic scintillator

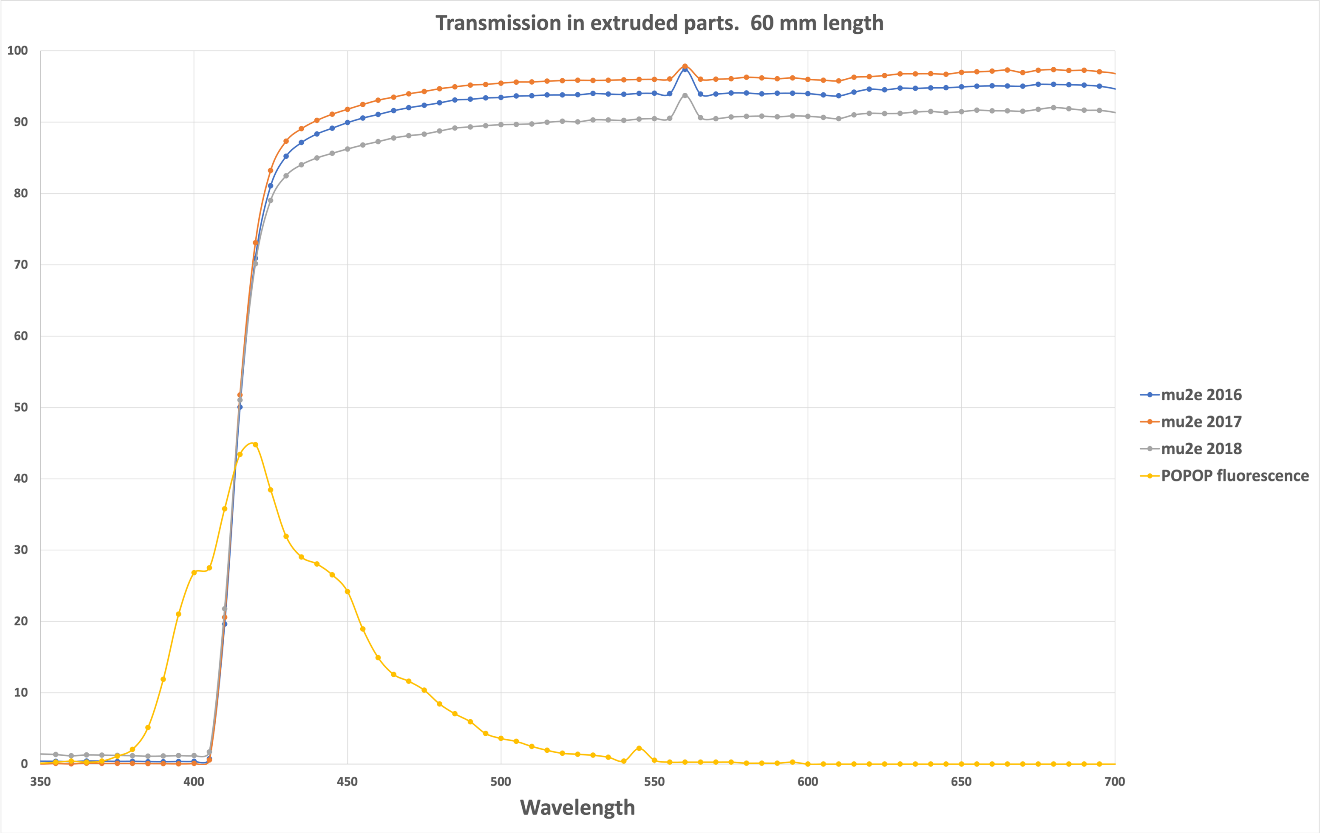
- Fermilab has been producing plastic scintillator for close to 25 years
- However, fundamental R&D on the process has not happened for over 10 years
  - And issues have come up that indicate that a fresh look is urgently needed
- Areas to explore
  - Polymer
    - US supplied material is not meeting spec **& by a large margin**.
    - Find new source and test
  - Cladding
    - Recent MC studies indicate that small changes in reflectivity can have big impact on LY
    - Potentially 2-3X increase in light yield can be obtained for extruded scintillator
      - TiO_2 cladding yields ~ 90% reflectivity in wavelength region of interest. New coatings (paints) achieve > 98%
  - Tooling
    - Recent measurements on extruded scintillator produced outside the US indicated that better control on the WLS fiber channel dimensions can improve light yield by 1.5X without the need for optical coupling fluid.
- A detailed investigation in all these areas will not only yield much higher quality scintillator with extended functionality but can also help solve (or at the very least reach an understanding) of the ageing problem seen in the mu2e scintillator.

The Polymer

Polymer Transmission



Polymer Transmission II: A subtlety



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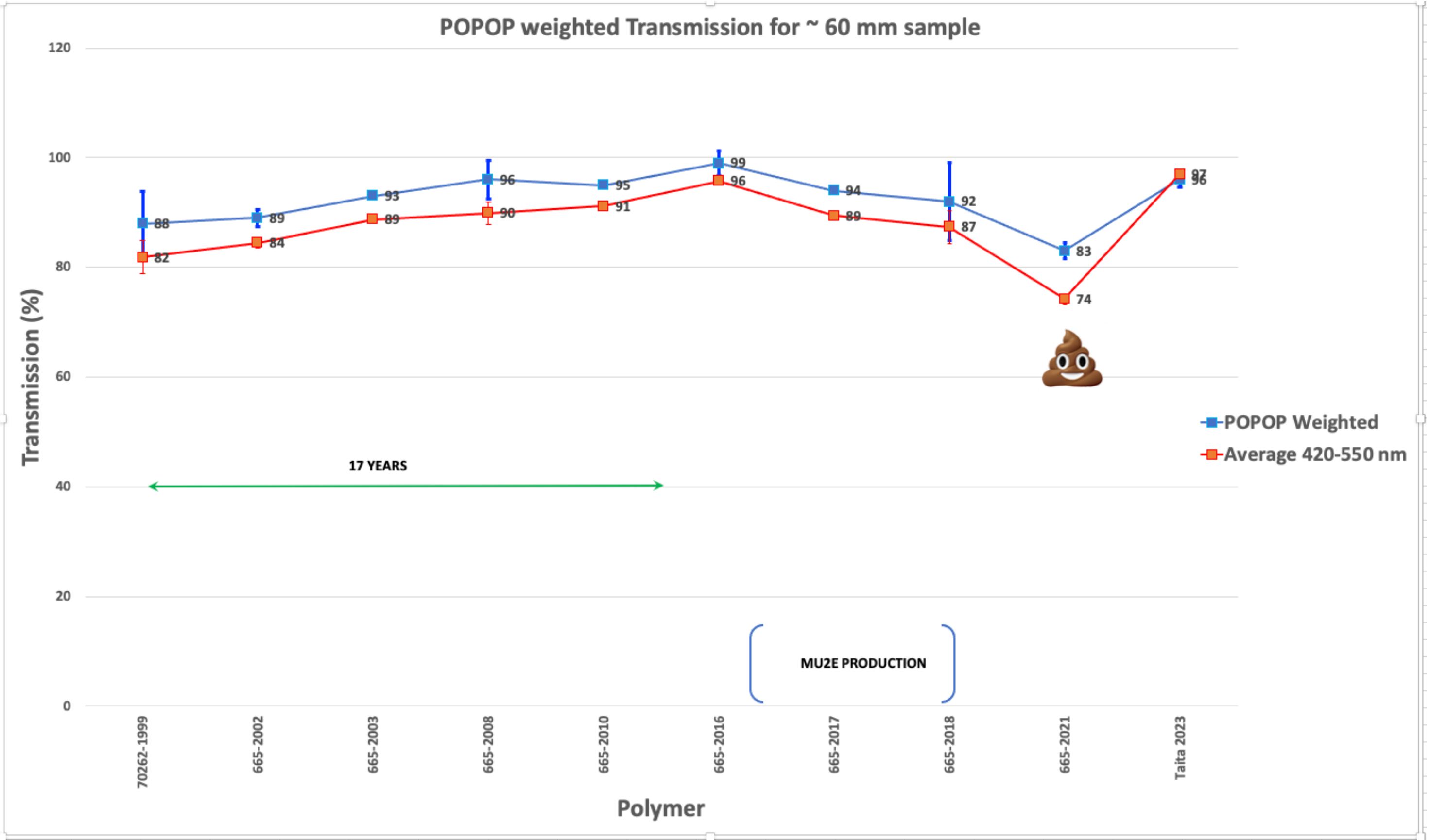
Summary: Polymer Ageing?



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Scintillator light yield

- In 1999 we made scintillating pellets for D0
  - Same "process" as for extrusion
  - We still have some
  - Made casting and compared scintillation light yield to reference

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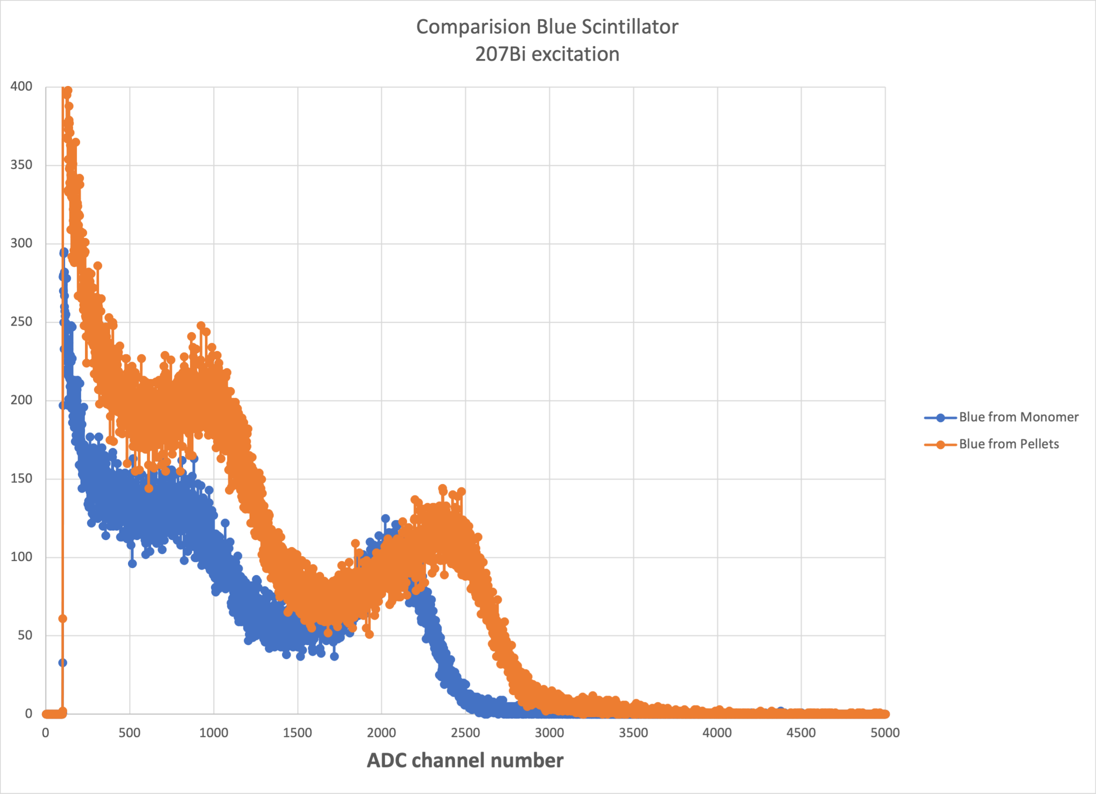
Light yield from 25-year-old scintillating pellets



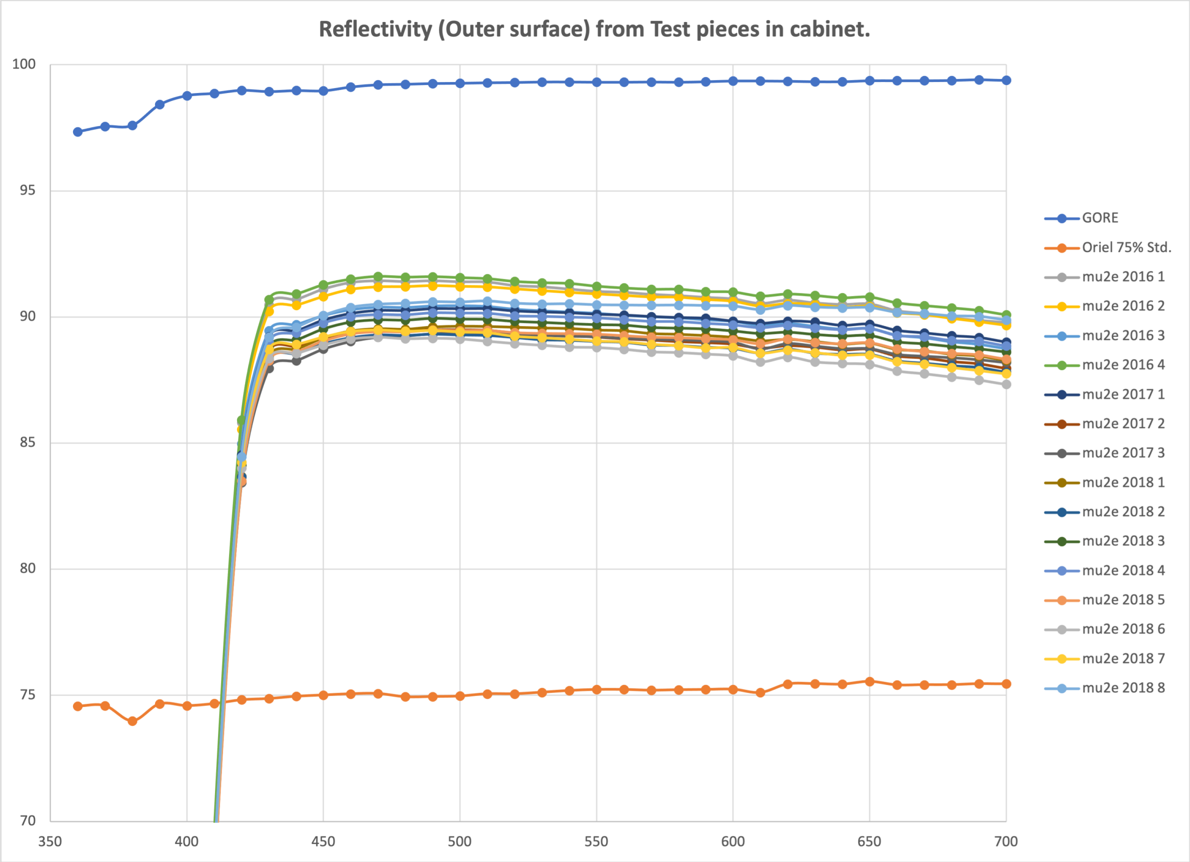
To first order
25-year-old material
is the same

Conclusion so far: Polymer does not age, certainly not enough to account for losses seen in mu2e CRV extrusions

Cladding

- Issues with the cladding (TiO_2) have come up periodically which prompted a detailed study
  - More from Mackenzie and Brian
- I will show some “high-level” plots
- Also, preliminary work with a $BaSO_4$-based coating

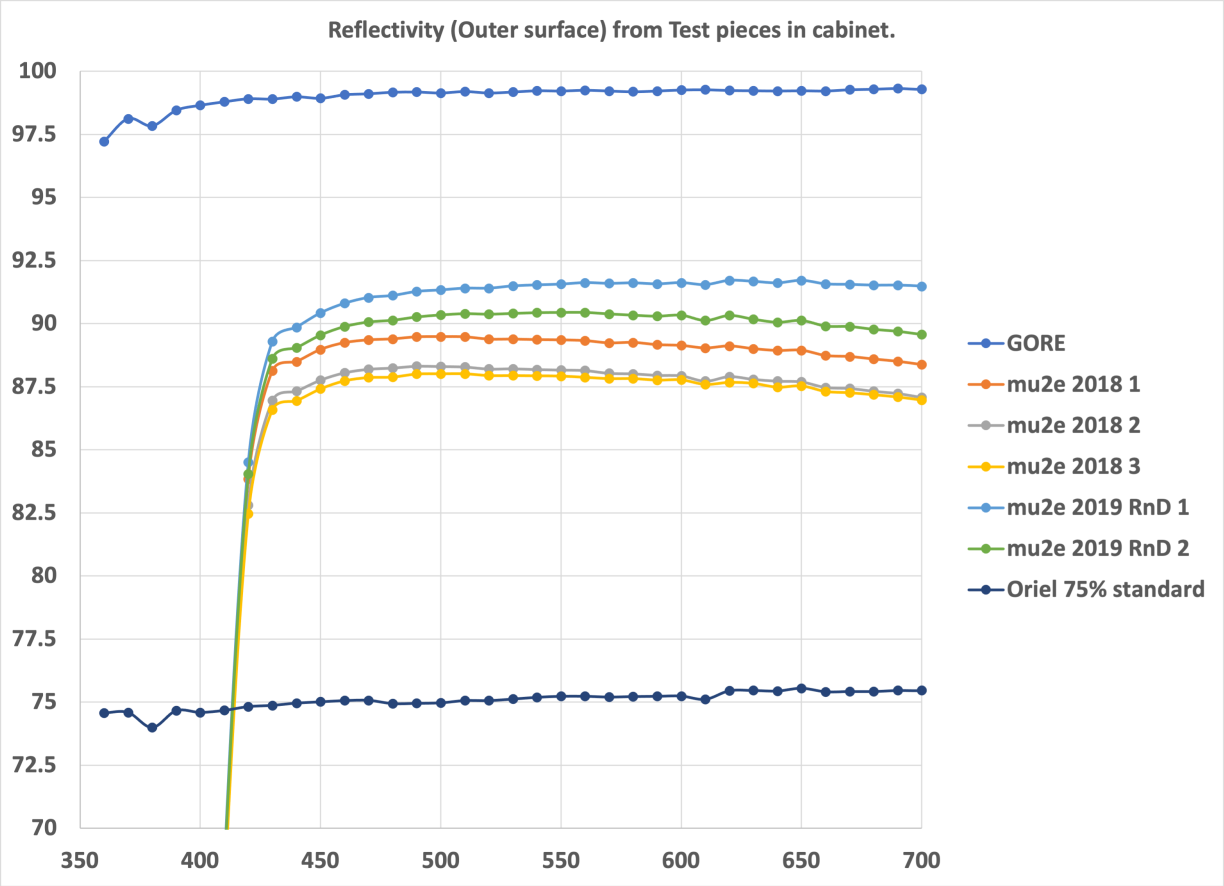
Measurements (outer surface): mu2e production samples



Note: All samples stored in closed cabinets

No light

Measurements (outer surface) II: mu2e production samples



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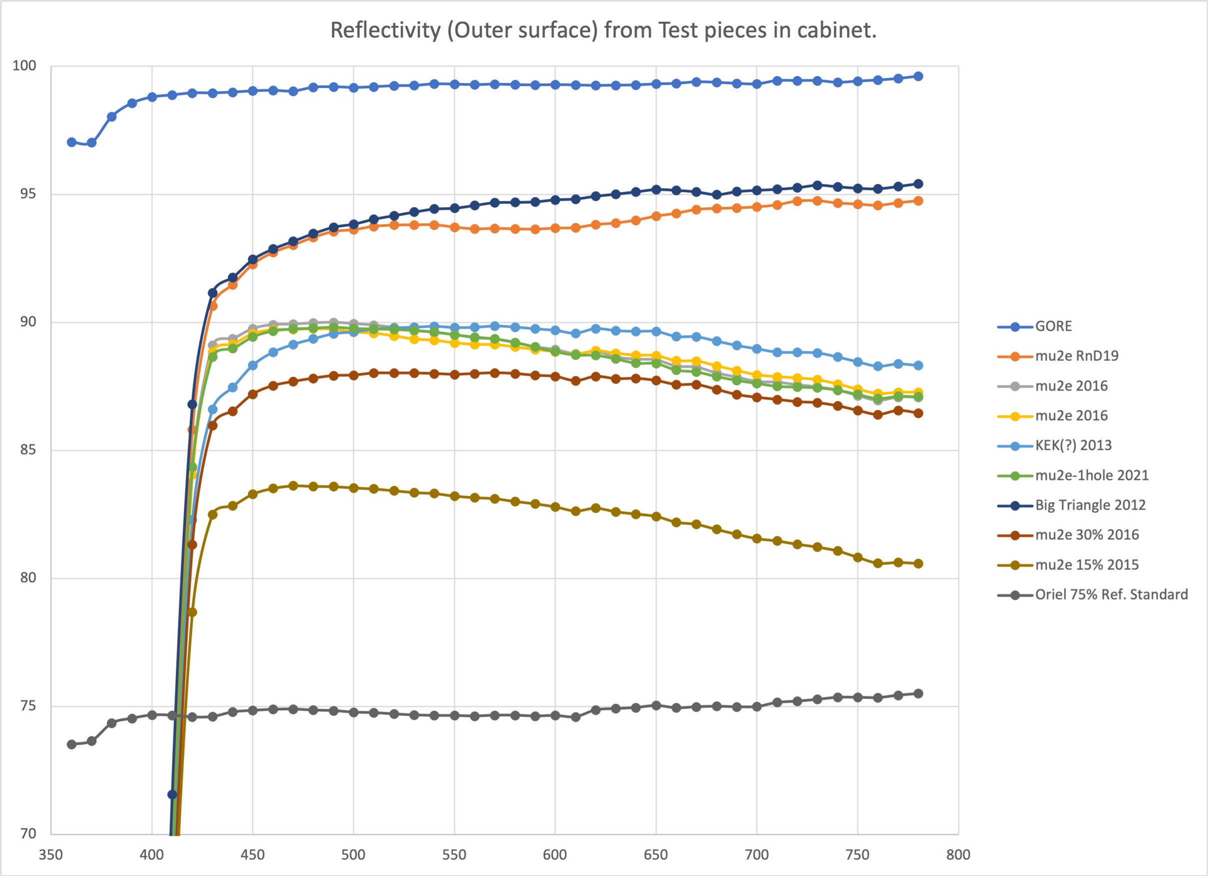
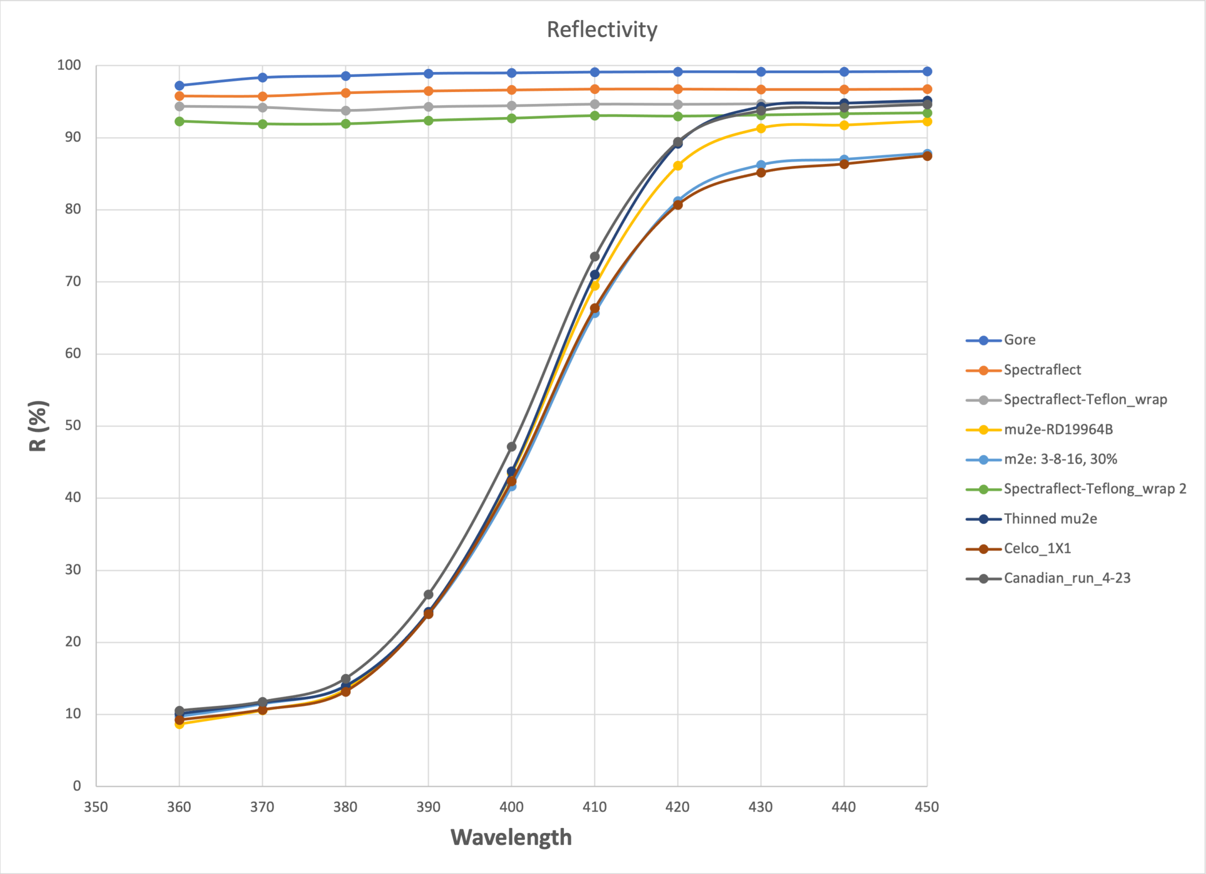
Additional R measurements



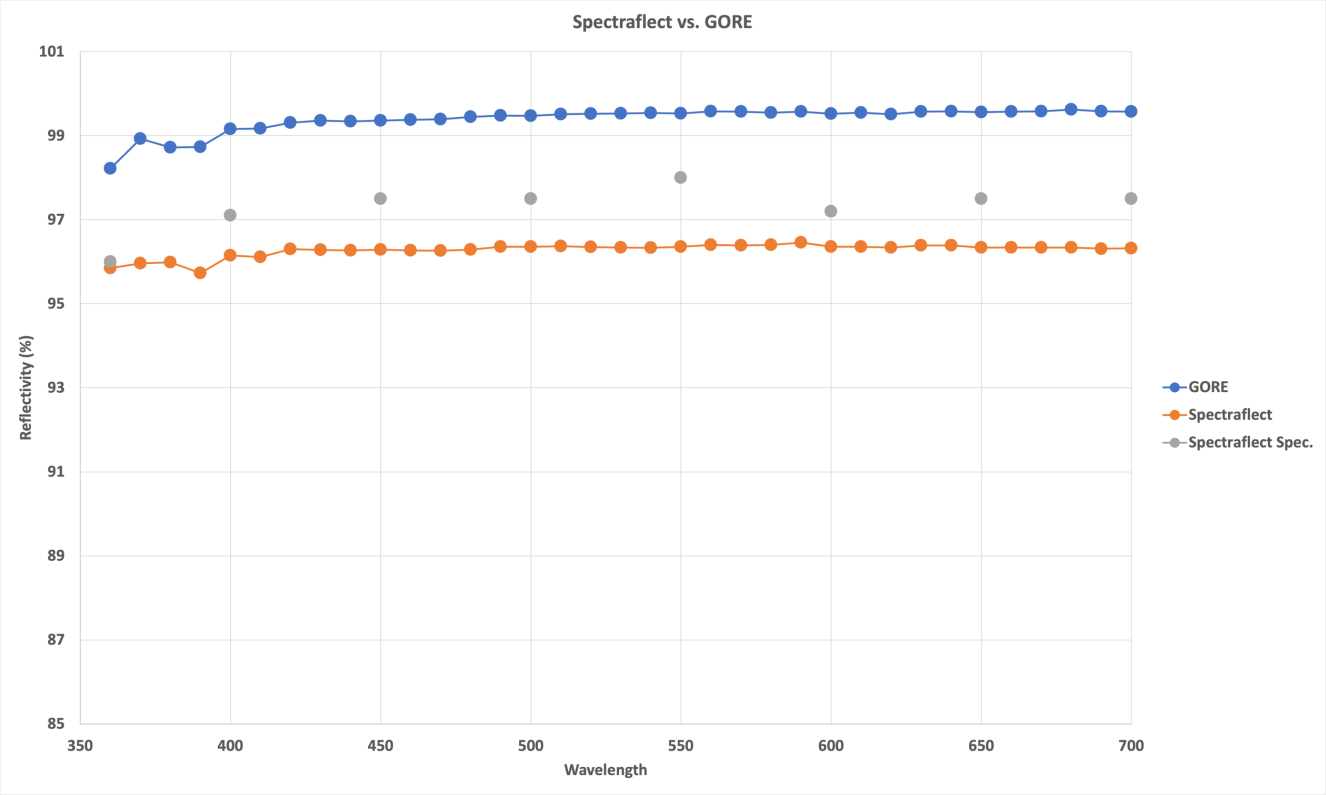
TiO_2 Cladding

- Difficult to draw conclusions
- See large differences
  - –Correlations ?
  - –MC can help inform
    - Tell us how much we should worry

$BaSO_4$ cladding



$BaSO_4$ cladding results from 3rd trial (Spectraflect3)



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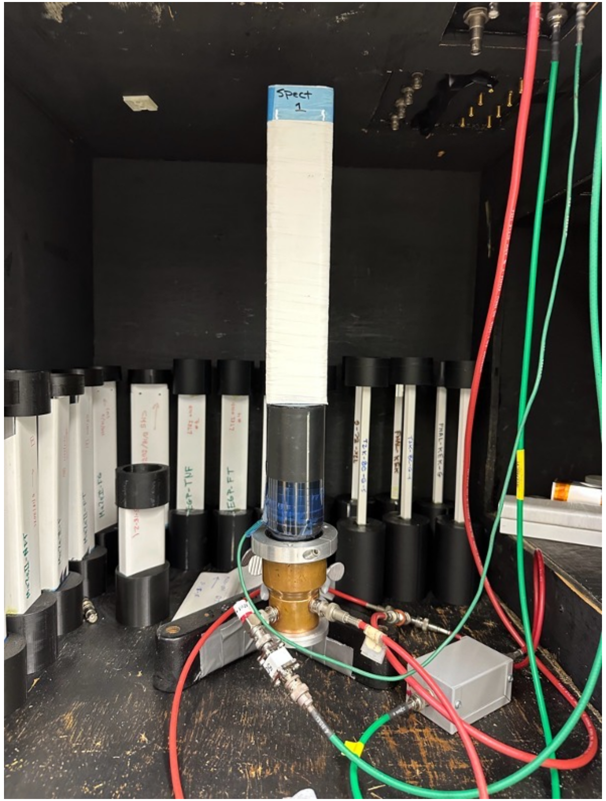
$BaSO_4$ cladding test: Overview

- All samples are mu2e extrusions that are 25 cm long
- Two WLS fibers in each sample, potted at ends with 5 min epoxy and then diamond polished
- Far end has aluminized mylar tape
- Readout end also has aluminized mylar tape covering region away from fibers
- Data were taken with Bismuth 207, Cesium 137 and Cobalt 60
- Hamamatsu R669 PMT with output coupled to Ortec 672 shaper amp. Output of 672 goes to Ortec EasyMCA (data)
- Sample mu2e is a standard extrusion from 2019 R&D run
- All the others are extrusions that had no cladding and cladding was added:
  - ESR: Dow material
  - Teflon: Teflon tape wrap
  - Spect 1-3: 3 trials at spraying on Lapshere's Spectraflect BaSO4 coating

$BaSO_4$ cladding test



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Results

	Bi207	Ratio Bi207	Cs137	Ratio Cs137	Co60	Ratio Co60
mu2e	37,231,419	1.00	82,863,217	1.00	8,513,570	1.00
ESR	39,211,149	1.05	82,846,294	1.00	9,173,855	1.08
Teflon	42,542,011	1.14	92,528,190	1.12	9,616,354	1.13
Spect1	55,259,388	1.48	135,864,714	1.64	12,627,371	1.48
Spect2	52,524,355	1.41	126,552,480	1.53	12,187,327	1.43
Spect3	57,124,737	1.53	139,524,725	1.68	16,432,507	1.93

Note: We are ready to send samples to Avian to have them coated With their $BaSO_4$ material.

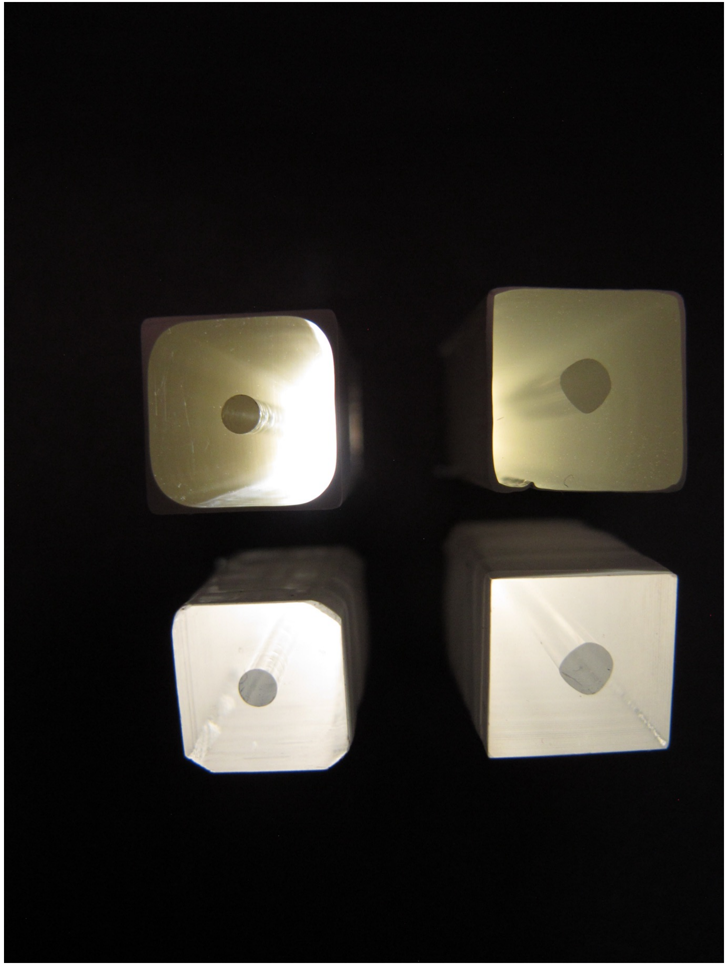
Cladding: Ruminations

- A fresh look at what the cladding should be and how it is applied is needed
- Options:
  - 1. New material based on $BaSO_4$ or Boron Nitride
  - 2. Co-extrusion or post-extrusion processing? Paint/coating vs. loaded PS
    - Each has advantages/disadvantages. Separate steps may deliver better control
  - 3. Study the impact of tooling design on cladding efficiency in the case of co-extrusion

Tooling

- The results using ^{207}Bi obtained with extrusions made in Canada in 2008 (T2K) indicated that injecting glue into the channel did not improve LY.
  – MC does not agree
  – Results with cosmic-rays that Jim took did not agree
- Never Mind!
  – Artifact: due to the very close fit between fiber (1.4 mm) and channel (1.8 mm), the glue used to pot the fiber prior to diamond polishing wicked along the fiber quite some distance. ^{207}Bi (1 MeV e^-) deposits charge in very small volume (10s of mm^3), so glue was there unintentionally.
  – With ^{60}Co the effect went away: LY with glue > LY without glue
- HOWEVER:
  – The tooling used for the Canadian part produces a much more precise part than the tooling procured locally and used at Fermilab.

- After a bit of detective work, I was able to track down the tooling that was used in Canada and we purchased it from the company that bought out the company that made the part for T2K.
- We have now tested this tooling (after a year delay) and have reproduced the results.
- I have identified a new tooling vendor and will be procuring (hopefully) new tooling for a 4cm X 2 cm triangle using a design philosophy following the Canadian tooling in the near future.



Conclusions

- Making progress
- Much, much more to do

- Let's hear from Mackenzie and Brian next.