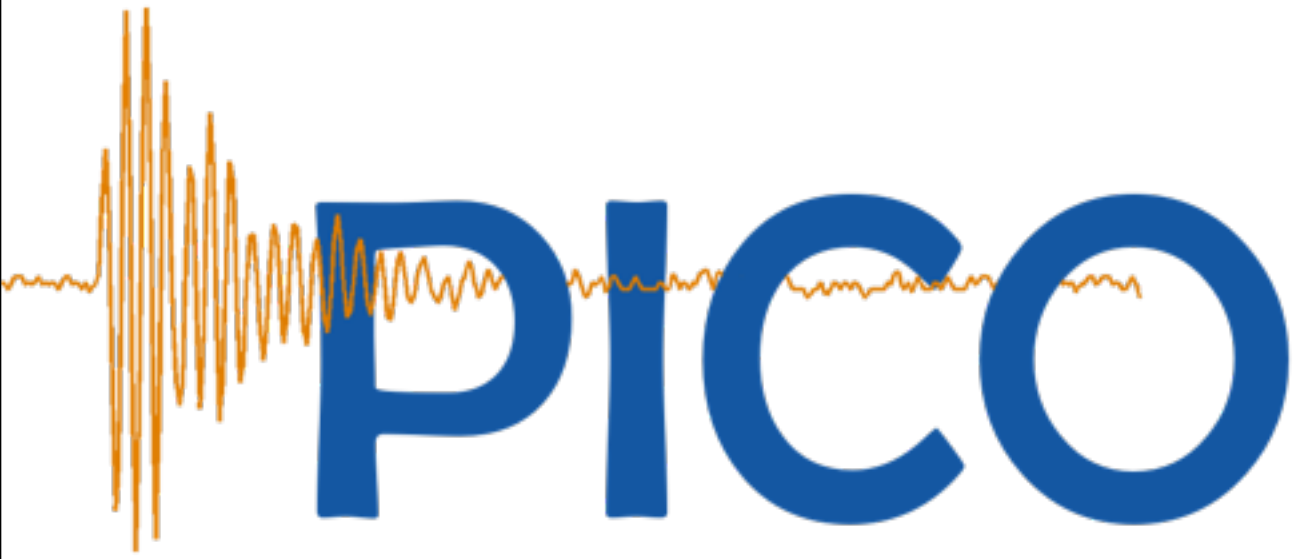


Improving the Optics and Fiducial Volume of the PICO Bubble Chamber Dark Matter Detector

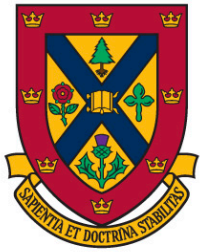
Clarke Hardy

Supervisor: Prof. Tony Noble

PICO Collaboration

Winter Nuclear and Particle Physics Conference

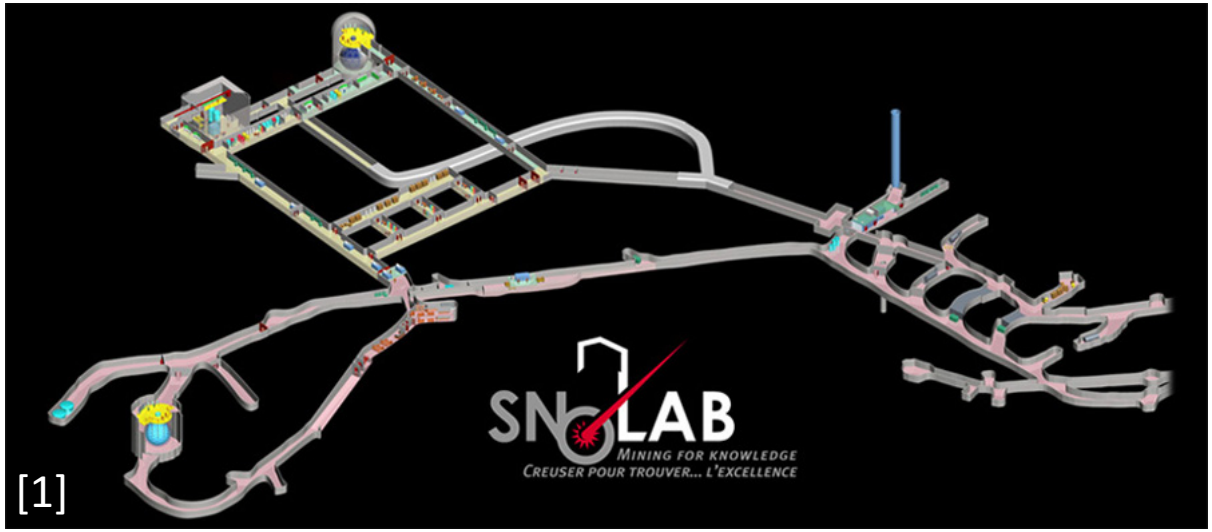
February 16, 2018



Queen's UNIVERSITY

Background

- PICO Experiment
  - Experiment at SNOLAB in Vale's Creighton mine near Sudbury
  - Search for WIMP dark matter
  - Design of new PICO-40L detector to replace PICO-60 detector
  - Goal is to improve optics and other aspects of the design



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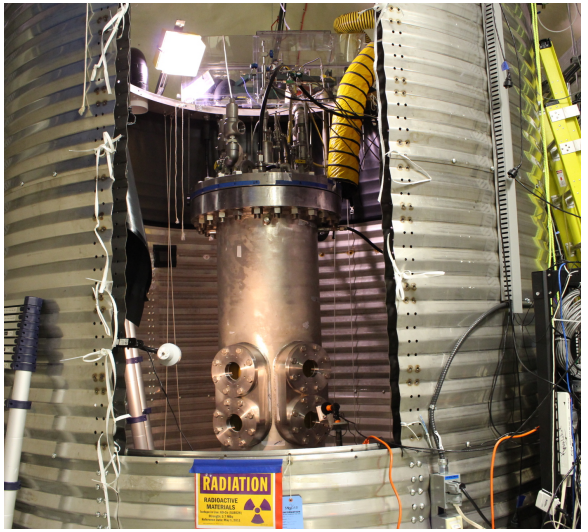
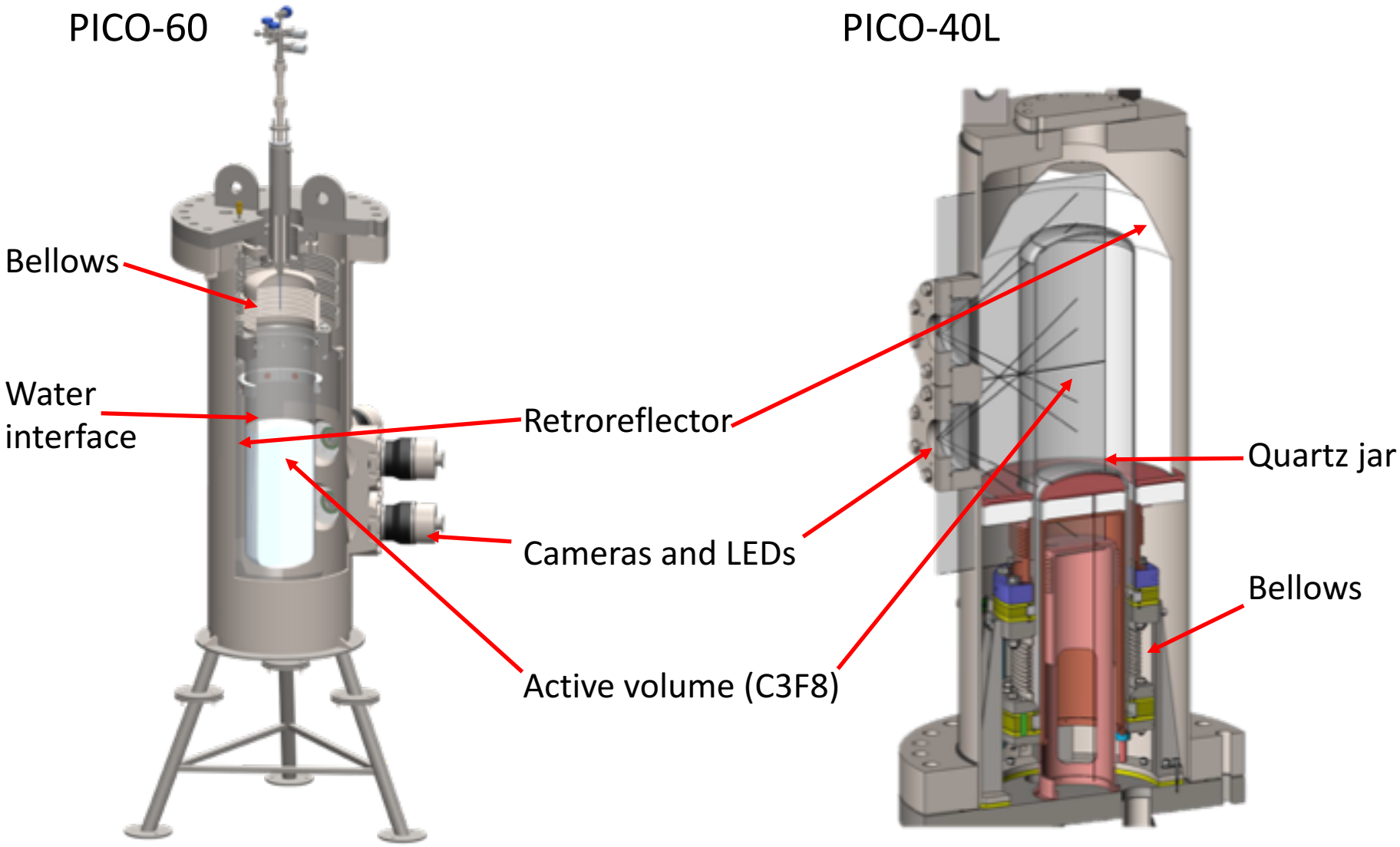


PICO Detectors

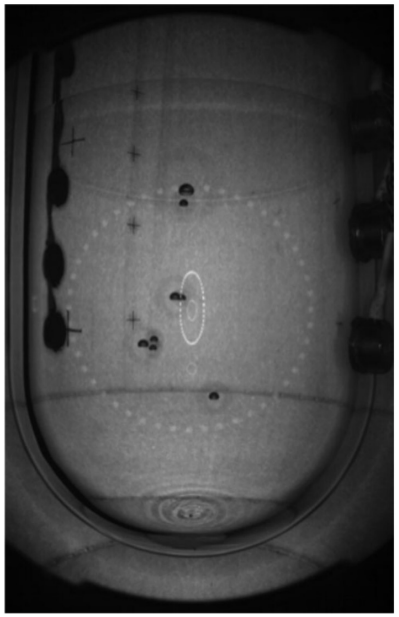
PICO-60

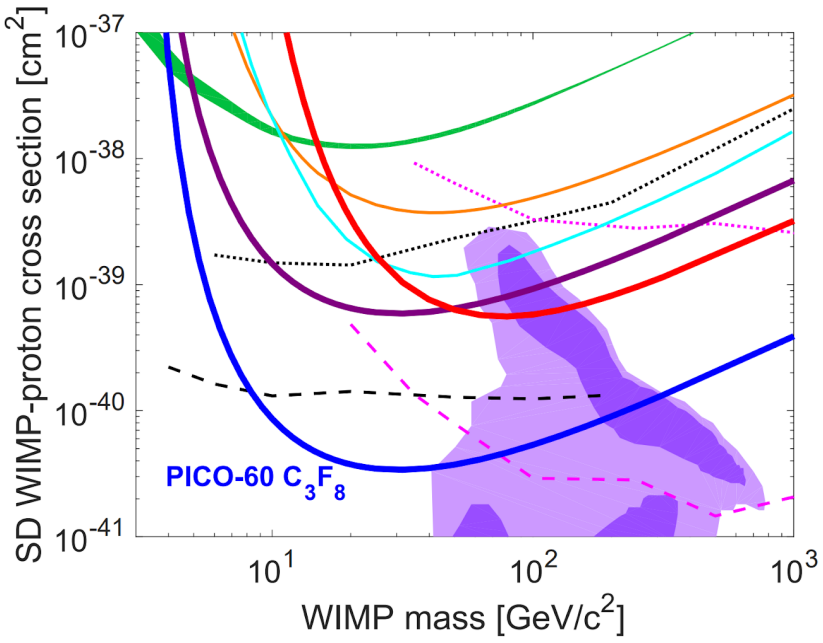
PICO-40L

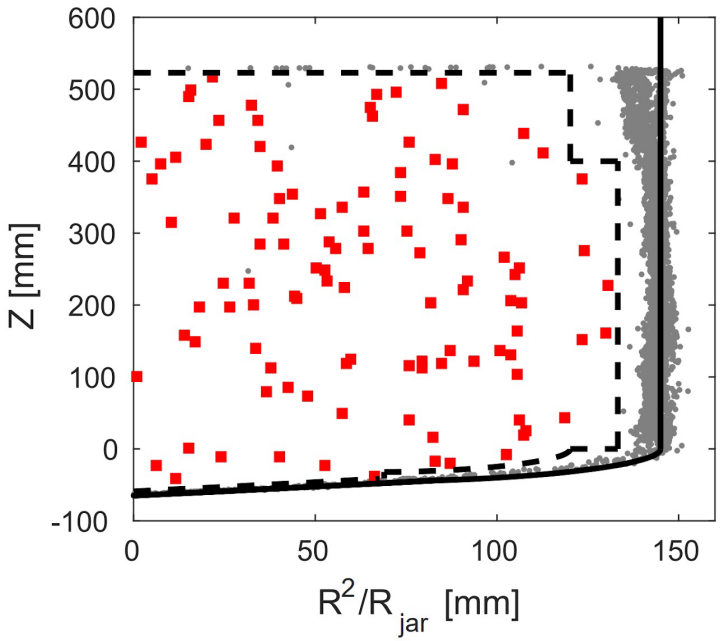


Motivation for PICO-40L

- PICO-60
  - Excess events near chamber walls in PICO-60
  - Poor optics in parts of the chamber
  - Limited fiducial volume
- New exclusion limits on mass and cross section
- Establish proof-of-concept for right-side-up design

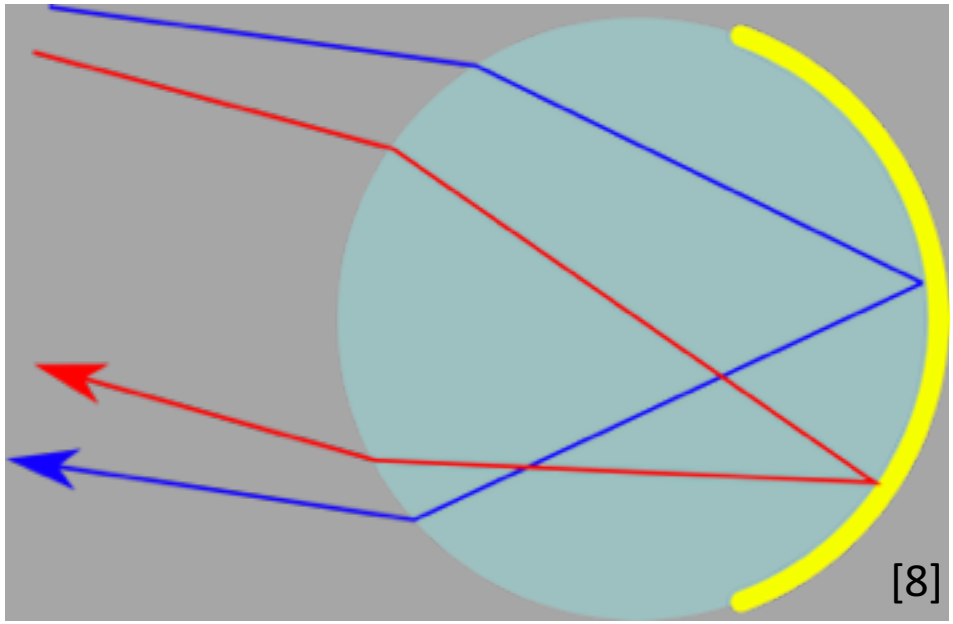






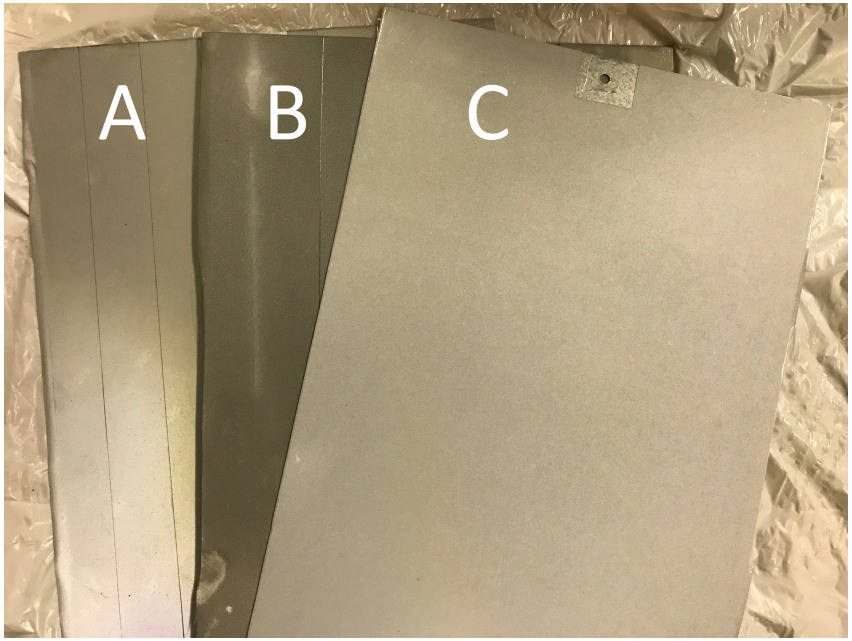
Retroreflectors

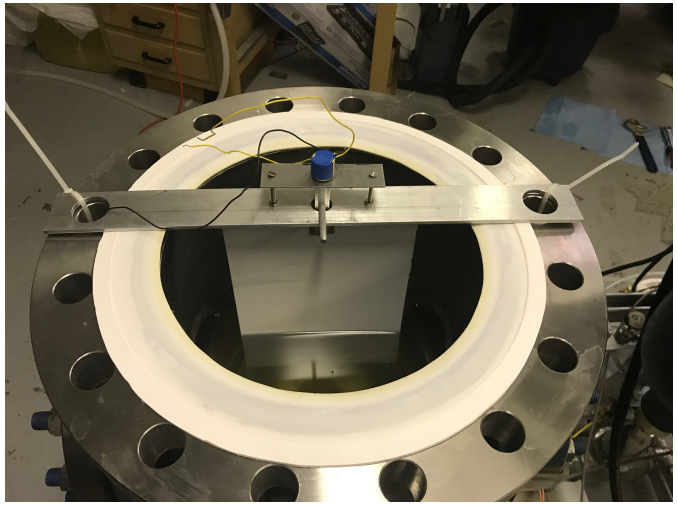
- Reflect light in direction of source
- Tiny beads in a clear adhesive film on backing
- Used in PICO to ensure maximal illumination of pressure vessel

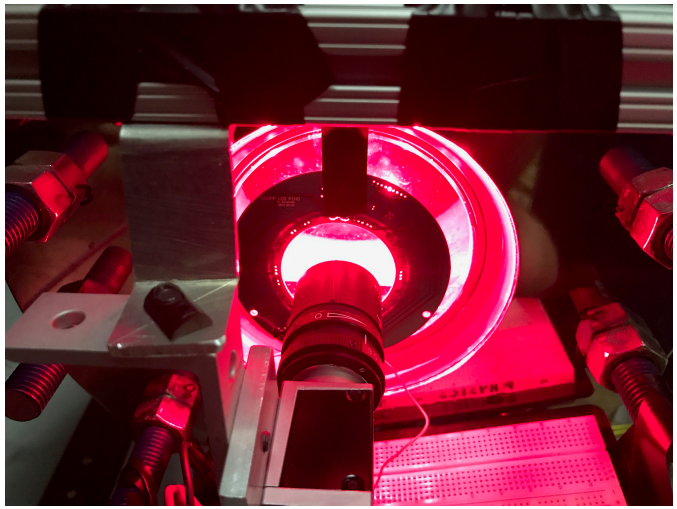


Testing Retroreflective Materials

- Objectives
  - Compare 3 candidate retroreflective materials
  - Understand reflected intensity by incident angle for use in simulations
  - Ensure materials meet constraints

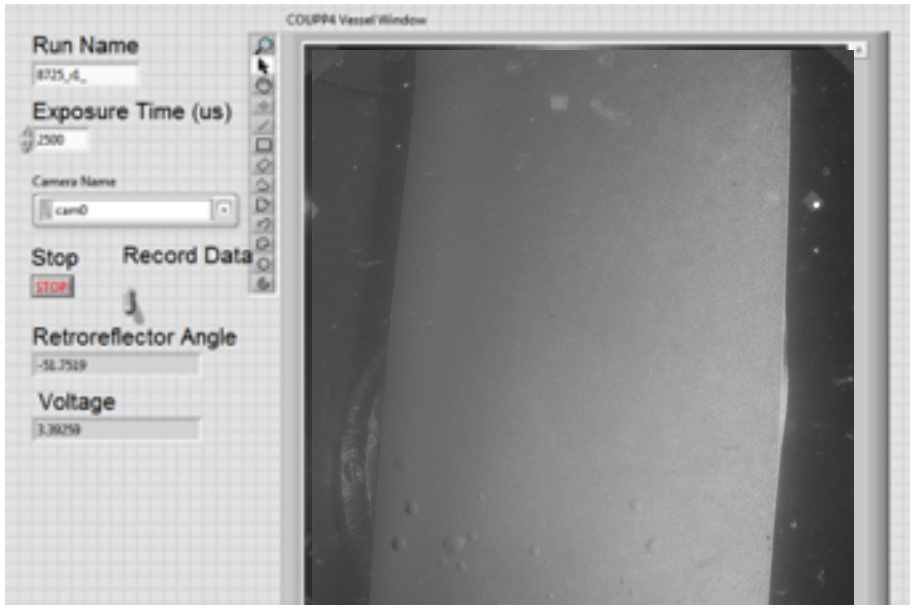


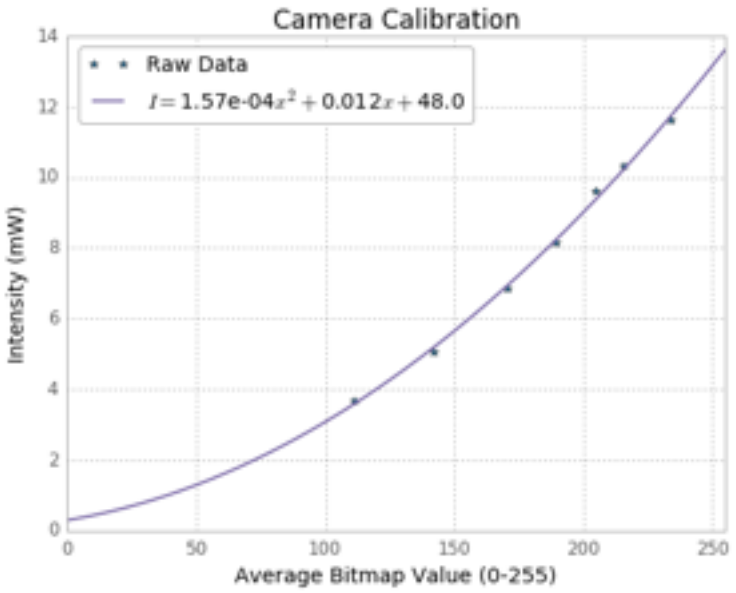


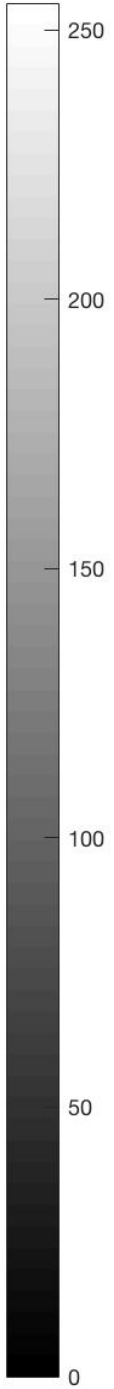


Measuring Intensity by Incident Angle

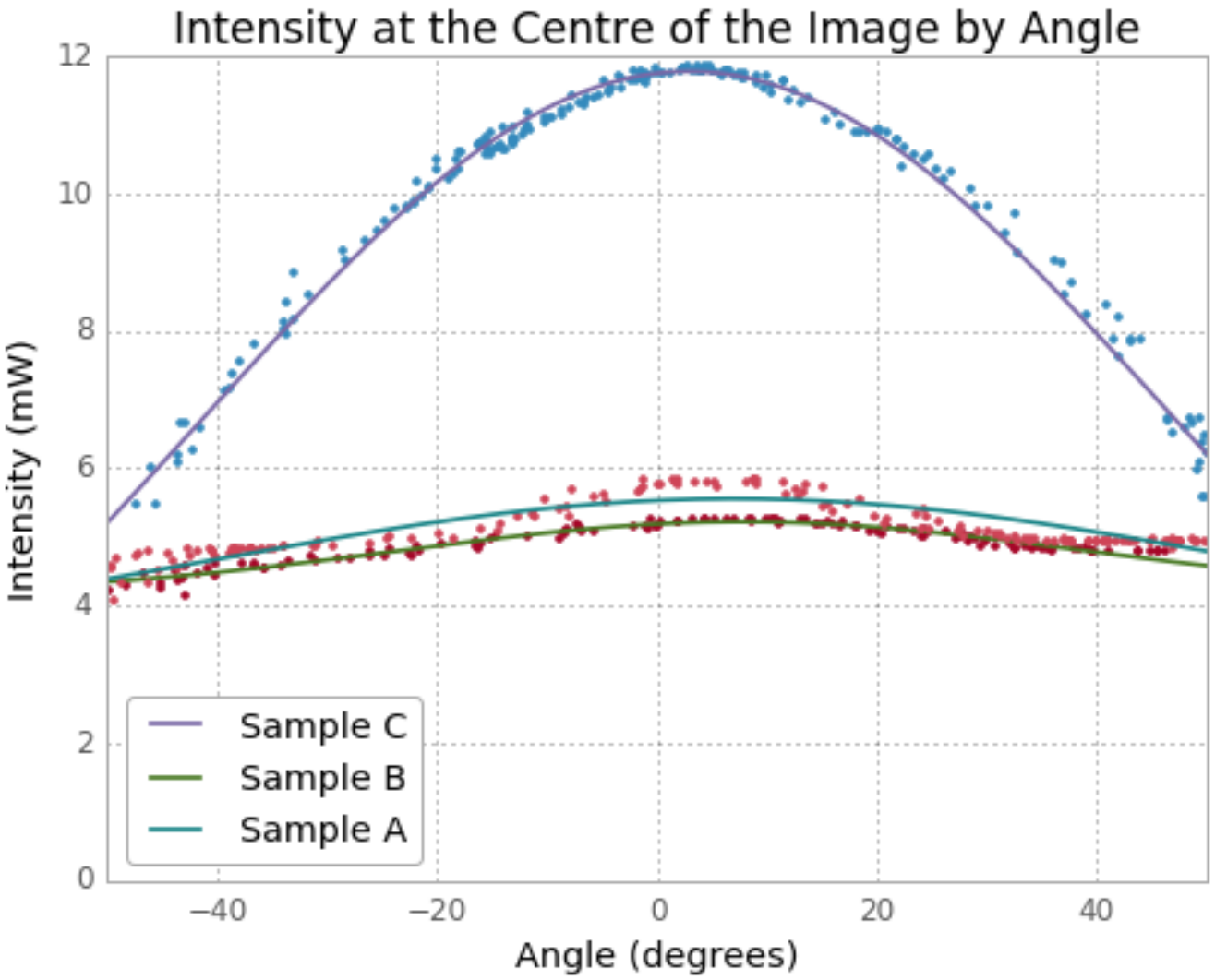
- Bitmap images saved using LabVIEW
- Correlate intensity with pixel value (0-255)
- Intensity measurements taken with optical power meter
- Pixel value of bitmap image averaged over region of interest





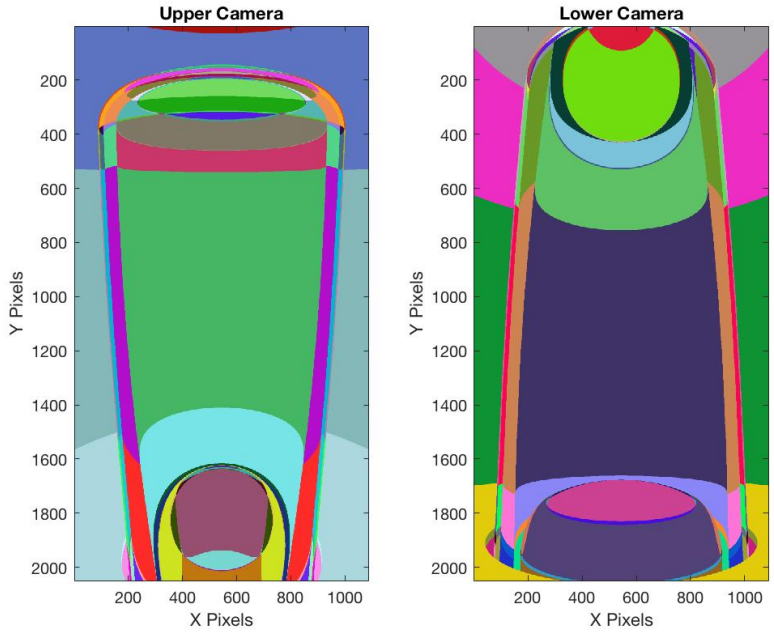


Experimental Results



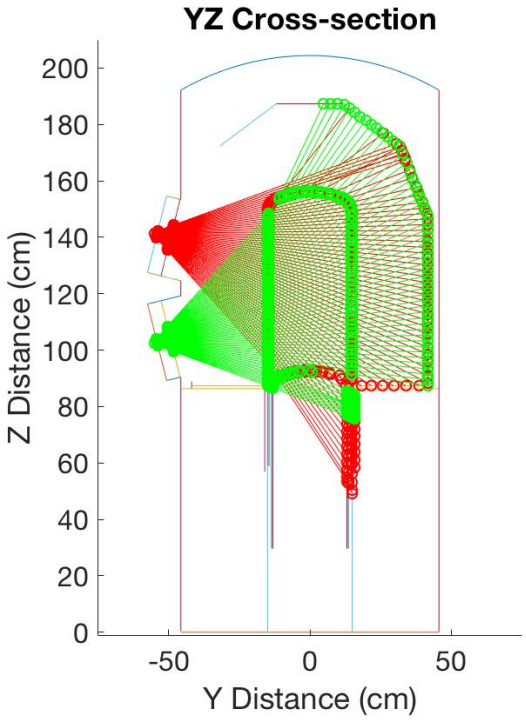
Ray Tracing

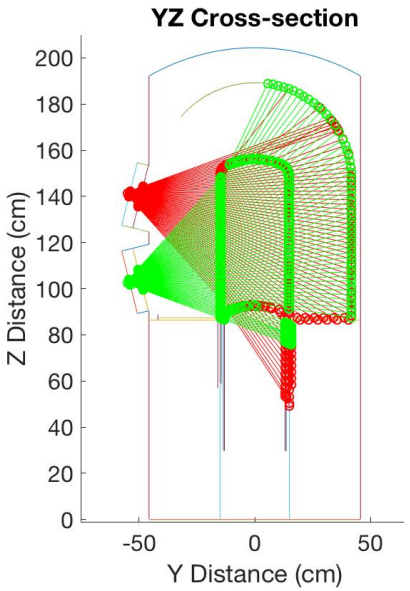
- Trace light rays from pixels in an image plane through interactions with objects and media
- Generates simulated images captured by a camera
- Can inform the retroreflector design
- Right image: pressure vessel components

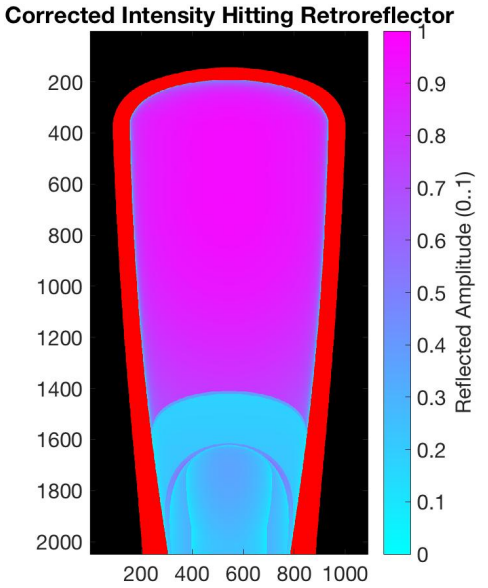


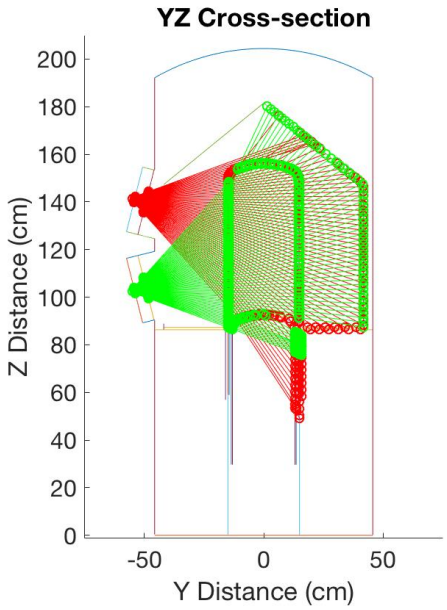
Optimal Geometry

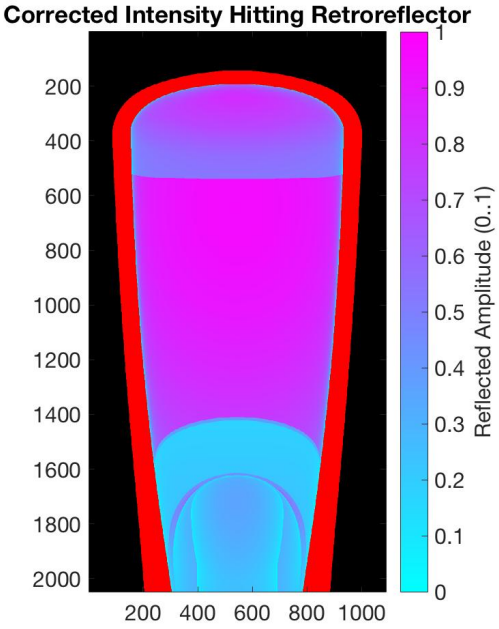
- Cone top creates sharp change in intensity
- Hemisphere keeps angle of incidence roughly constant





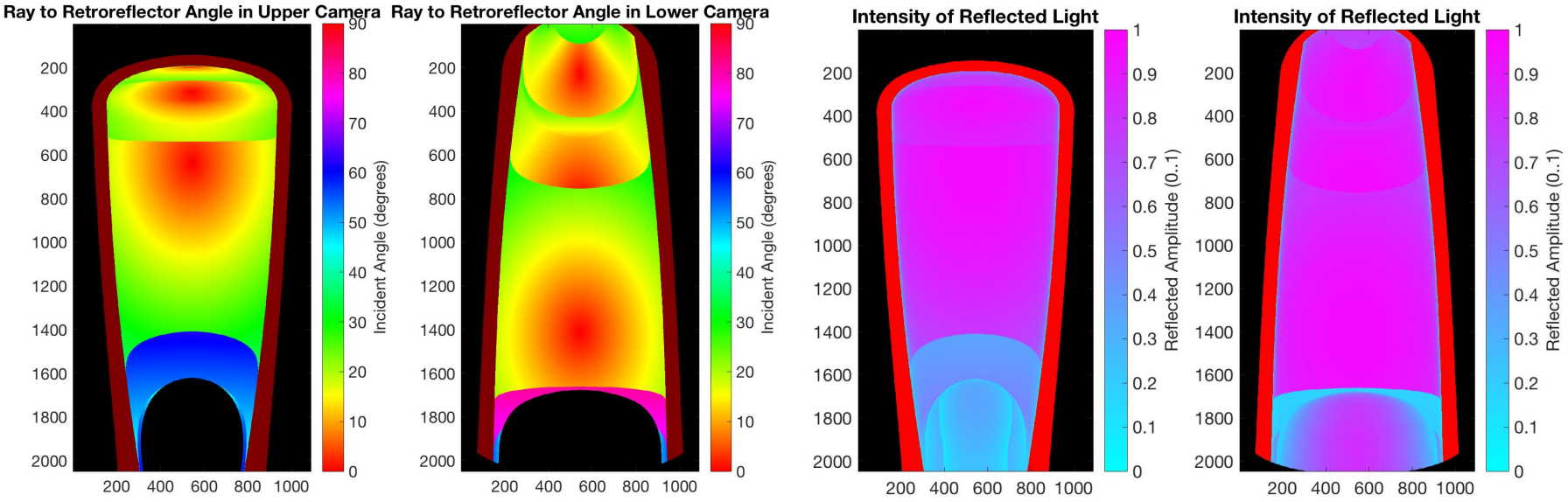






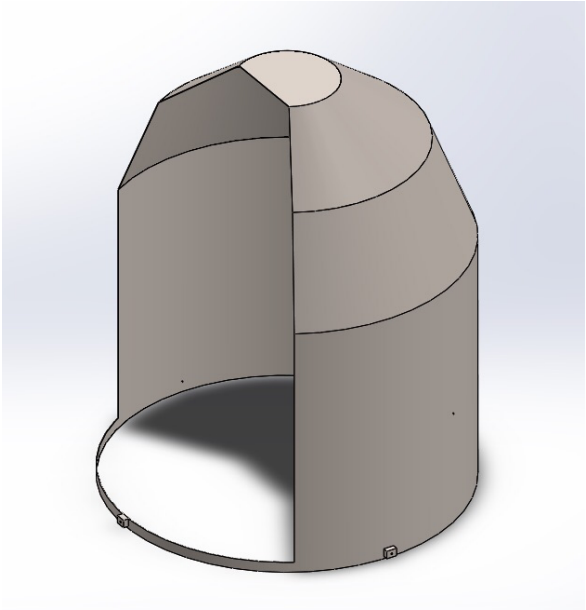
Results of Optics Simulations

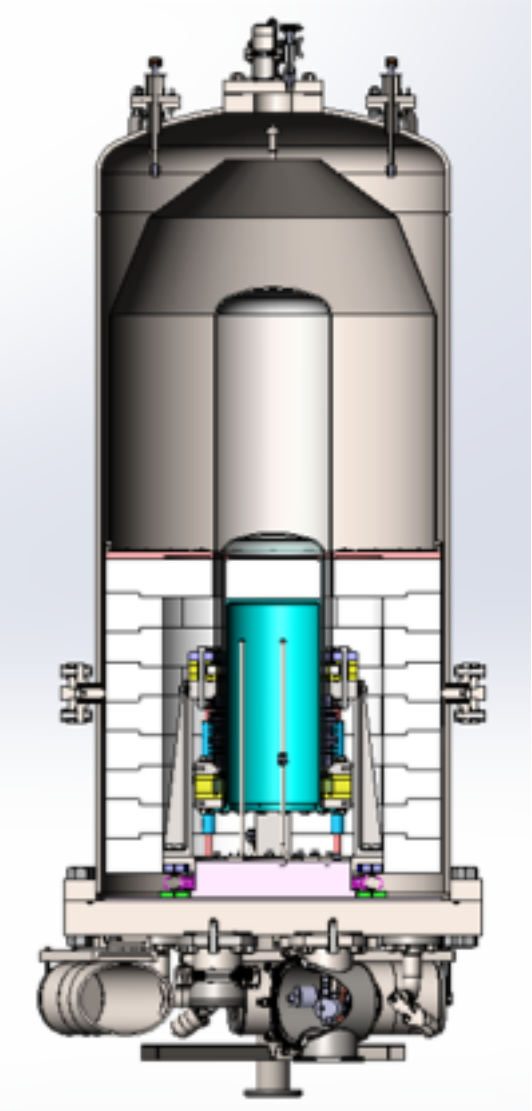
- Want small angle between surface normal and incoming light
- Intensity corrected for incident angle using experimental results
- Left: Incident angle of light hitting retroreflector in top and bottom camera
- Right: Intensity of light received in top and bottom camera



Previous Design

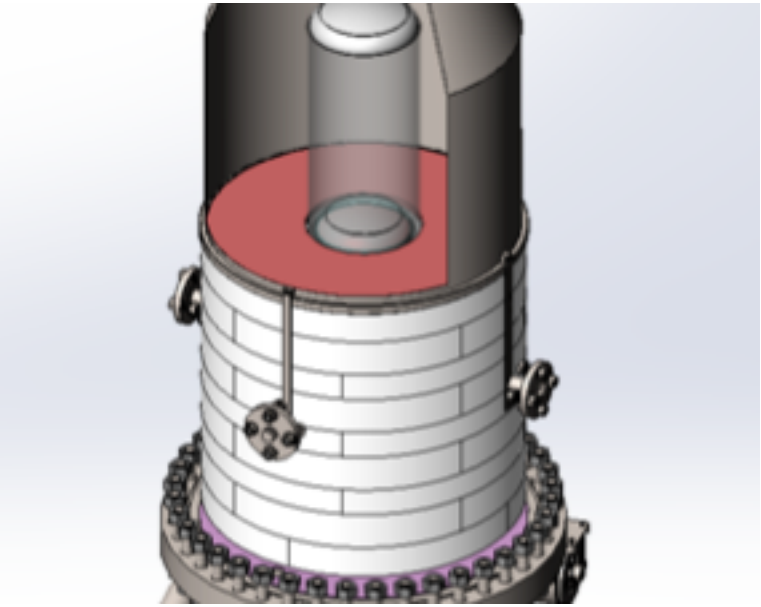
- Two cone stages on top of a cylindrical base
- 120 degree opening facing viewports
- 18 gauge 316 stainless steel
- Tack welded together at interface
- Retroreflective sheeting coating inner surface

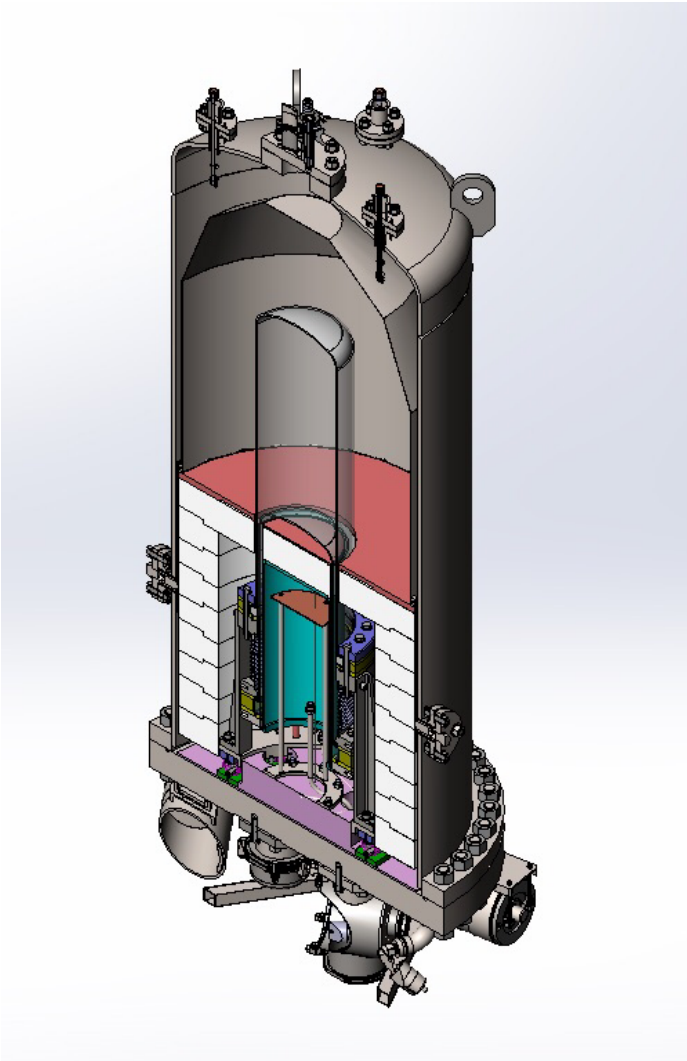




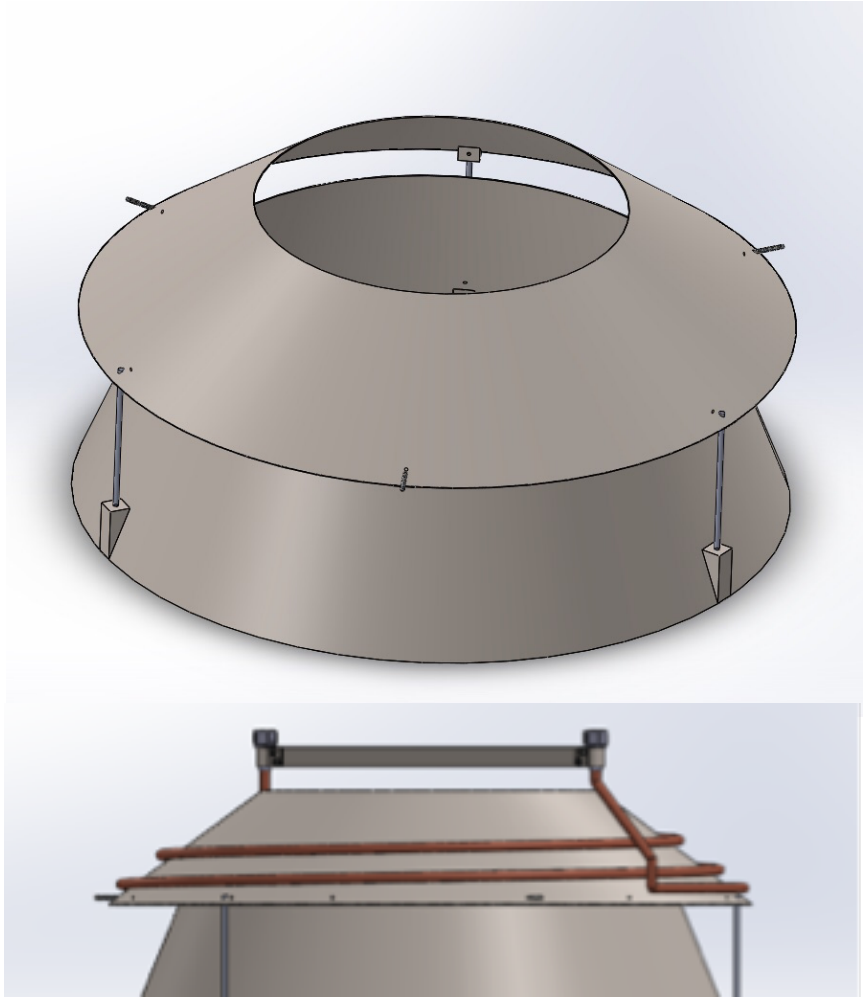
Problems with Previous Design

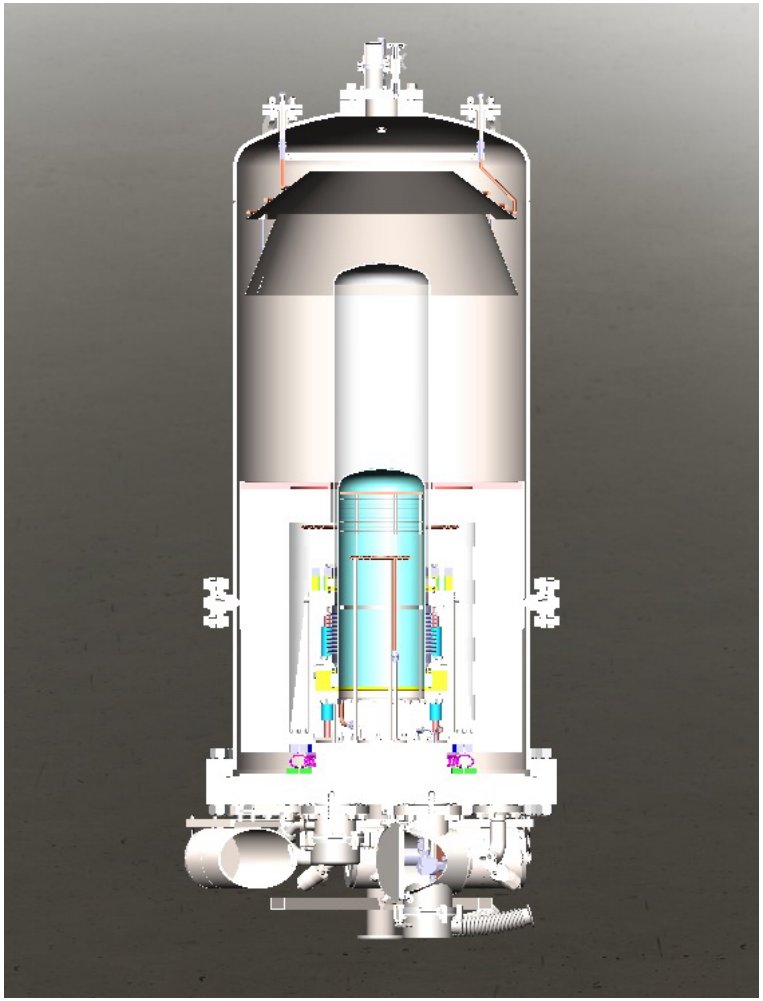
- Uneven venting of mineral oil near top of retroreflector
- Mounting temperature sensors connects pressure vessel dome and base flange, preventing easy access





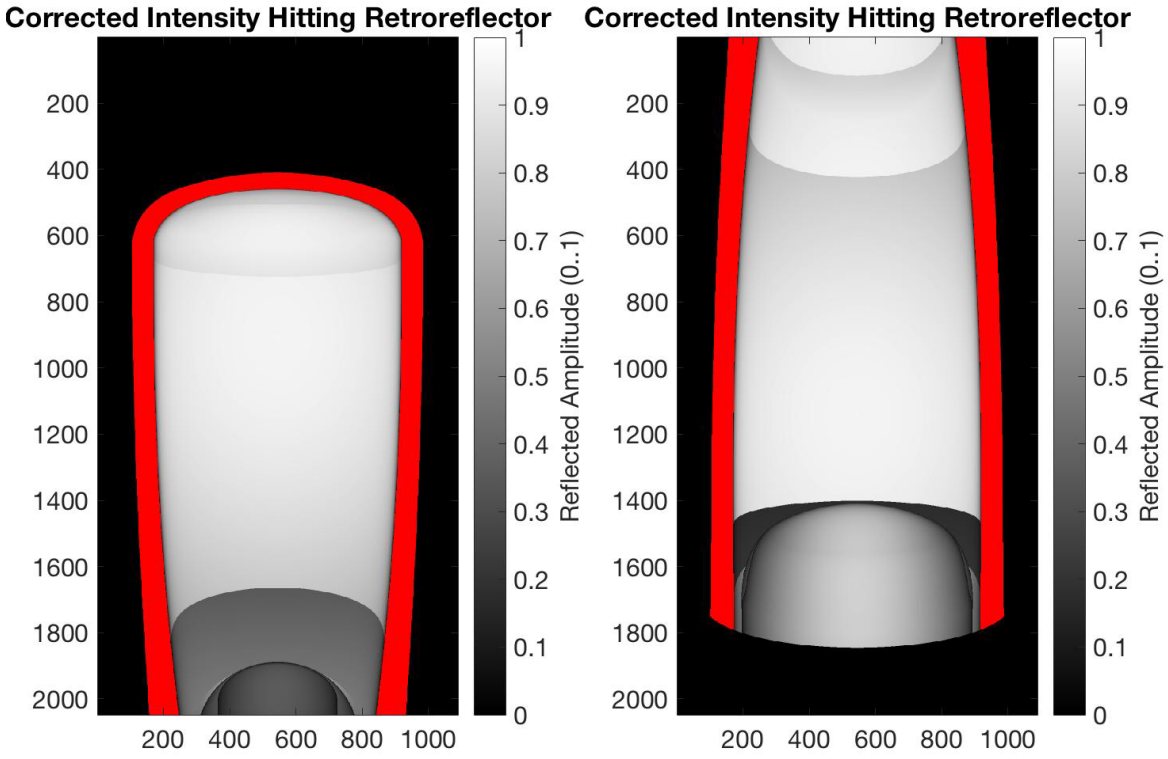
Final Design

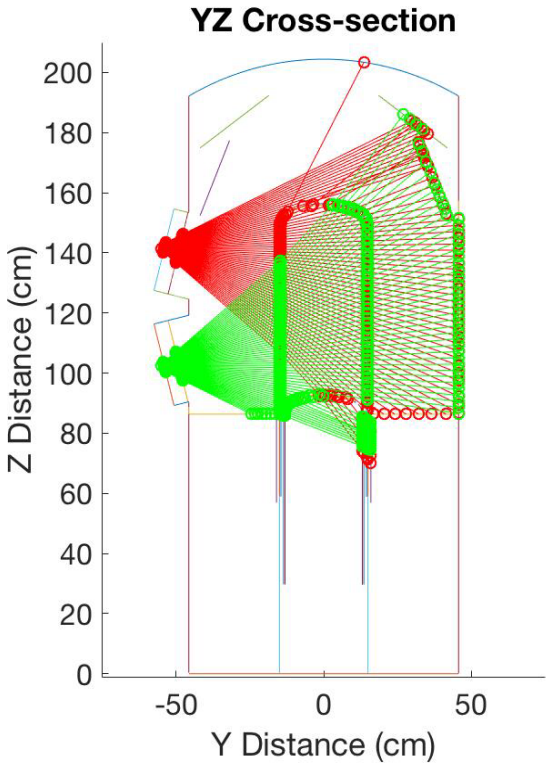




Optics of New Design

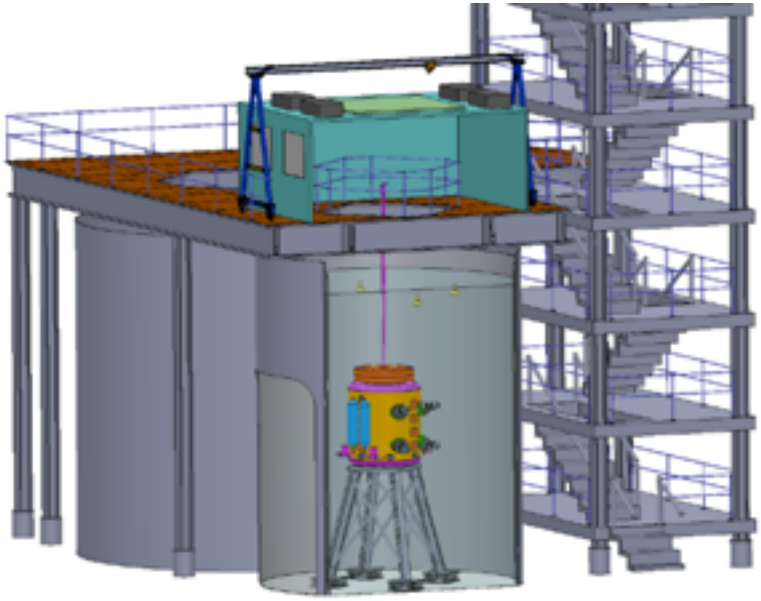
- Incident angles and visible faces preserved
- Optical distance increased slightly
  - Lower expected background rate from retro reflective sheeting





Summary

- Completed new retroreflector design with improved optics
  - Drawings sent to fabricator for construction
  - Beginning assembly and integration into pressure vessel next week
  - Waiting on flanges, copper tubing, other miscellaneous parts
- PICO-40L to be commissioned in the next couple months
- Looking ahead: PICO-500, tonne-scale detector in 2019



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