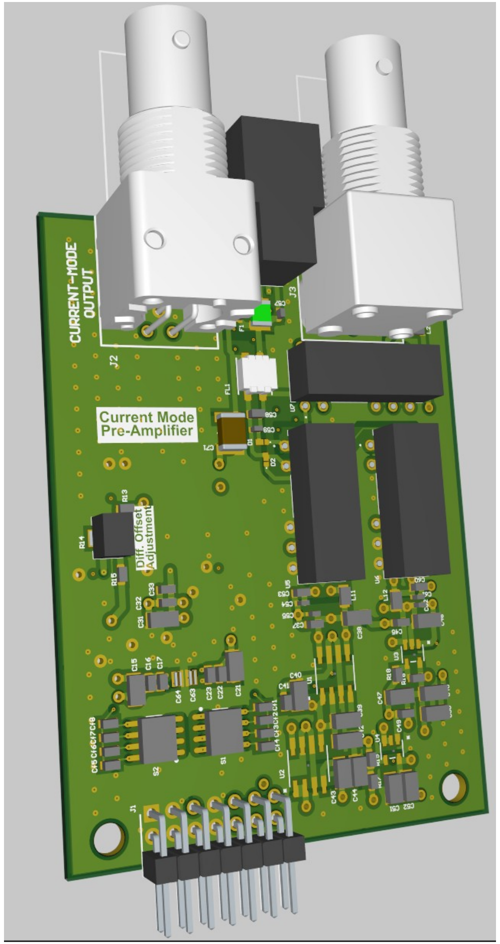
Main Detector Cooling and Air Flushing

PMT Base Cooling



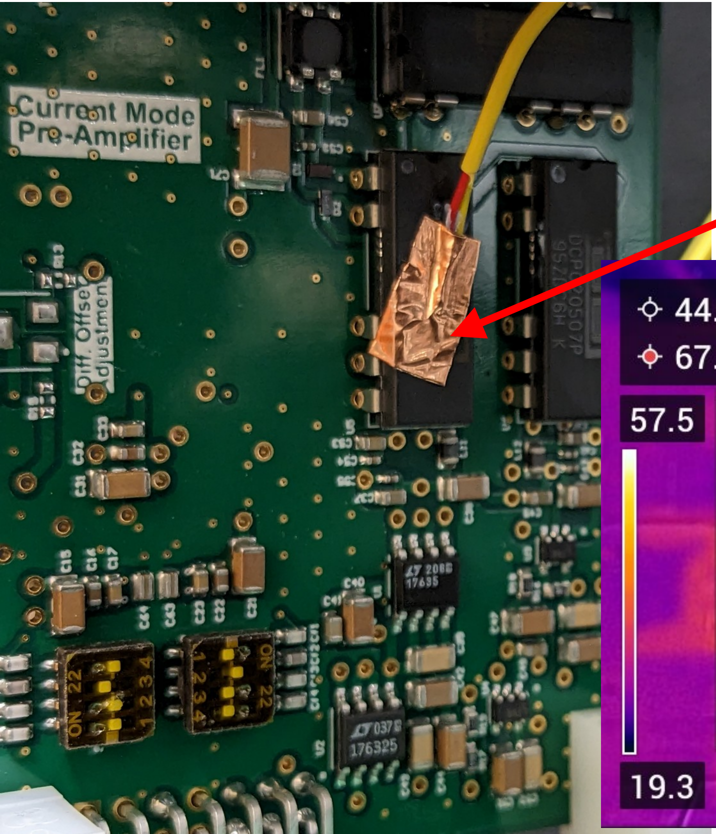
The PMT housing has been reported to warm up considerably after prolonged use.

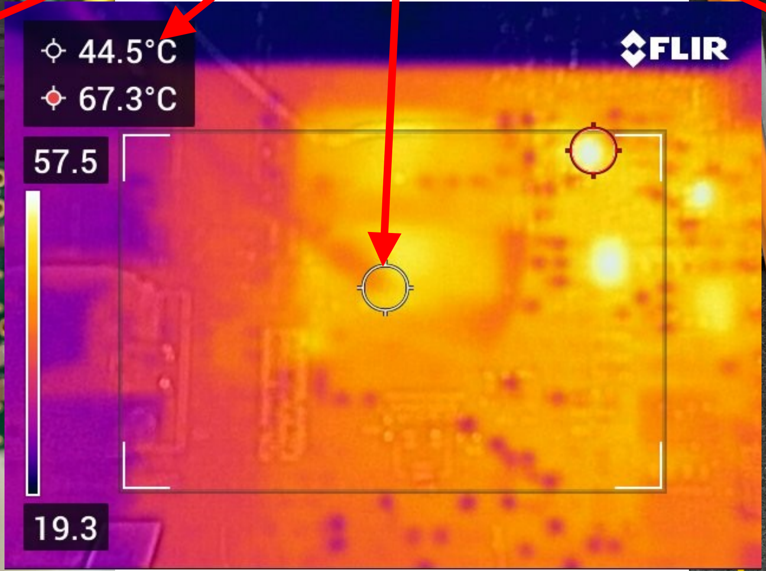
Main culprits are the DC-DC converters which operate at a 70-75% efficiency. In current mode, this means ~0.58 – 0.69 W of heat generated.

Not a problem in open air, but when enclosed might overheat.

PMT Base Cooling: Temperature Measurement

DC-DC converter (DCP020507P)
Surface temperature (°C) after ~2 hours in open air





PMT Base Cooling: Temperature Measurement

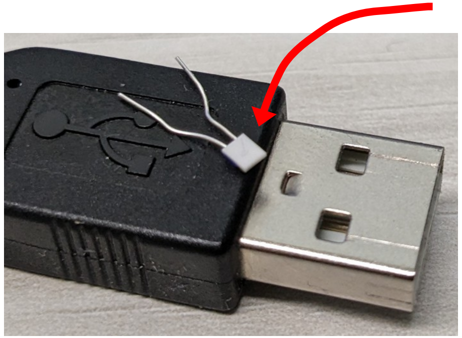
DC-DC converter (DCP020507P)

Surface temperature (56.0 °C) after 24 hours enclosed

- No PMT attached
- No inner housing tube

After 2 days: ~58 °C

Temperature of smaller ICs not measured as the thermocouple acts as a heatsink. The bead type thermocouple is also difficult to mount on to smaller surfaces.



PT100
2.0 x 2.3 mm

Future work:
Temperature measurement of all heat generating ICs using smaller surface mounted RTD elements.

PMT Base Cooling: Temperature Measurement

DC-DC converter (DCP020507P): The measured enclosed temperature, without any cooling, is within recommended limits. At a surface temperature of 60 °C, the junction temperature is estimated to be ~82 °C. Not likely to fail or shutdown at this point, but the output voltage does go down at higher temperatures. (Does the efficiency go down after irradiation?)

This component might be replaced by a more radiation resistant model: Measurements and simulations will be redone.

The smaller components (op-amps) might be a bigger concern, with surface temperatures approaching 60-70 °C in open air (as seen via thermal imaging). Looking to more accurately model the heat generation of these components.

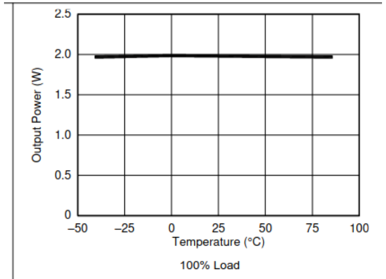


Figure 6-2. Output Power versus Temperature

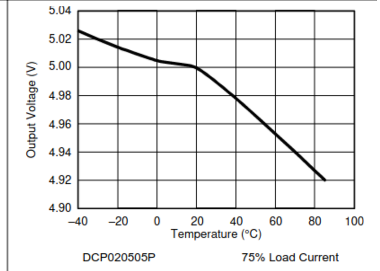


Figure 6-4. Output Voltage versus Temperature

6.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

		MIN	NOM	MAX	UNIT
Input Voltage	5-V input devices	4.5	5	5.5	V
	12-V input devices	10.8	12	13.2	
	15-V input devices	13.5	15	16.5	
	24-V input devices	21.6	24	26.4	
Operating temperature		–40		85	°C

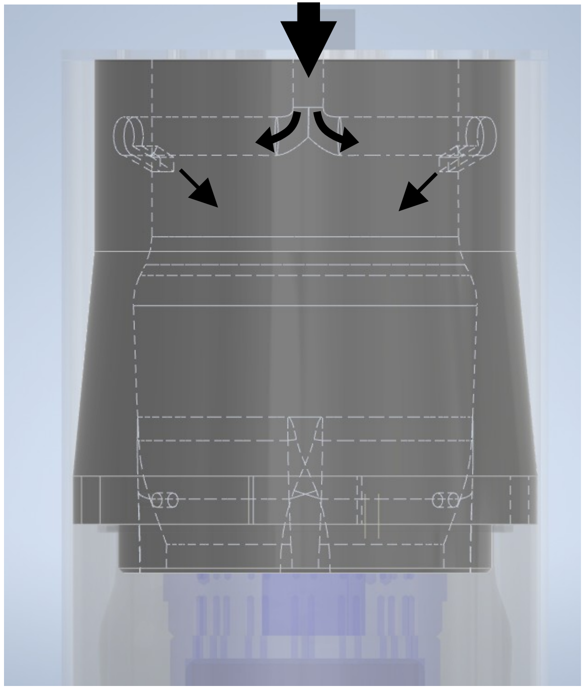
6.4 Thermal Information

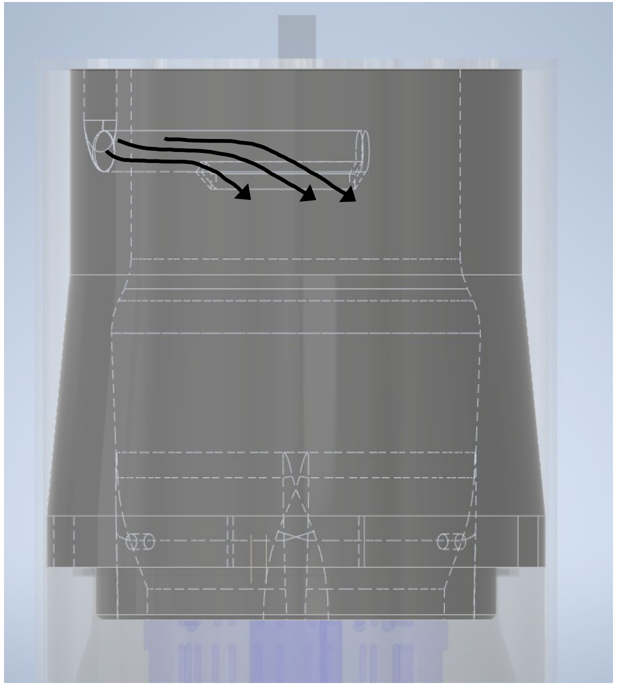
THERMAL METRIC[1]		DCP020x NVA (PDIP) 7 PINS	DCP020x DVB (SOP) 12 PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	61	61	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	19	19	
$R_{\theta JB}$	Junction-to-board thermal resistance	24	24	
ψ_{JT}	Junction-to-top characterization parameter	7	7	
ψ_{JB}	Junction-to-board characterization parameter	24	24	
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	N/A	N/A	

RELIABILITY				
	Demonstrated	T_A = 55°C	75	FITS
THERMAL SHUTDOWN				
T_{SD}	Die temperature at shutdown		150	°C
I_{SD}	Shutdown current		3	mA

PMT Base Cooling: Airflow

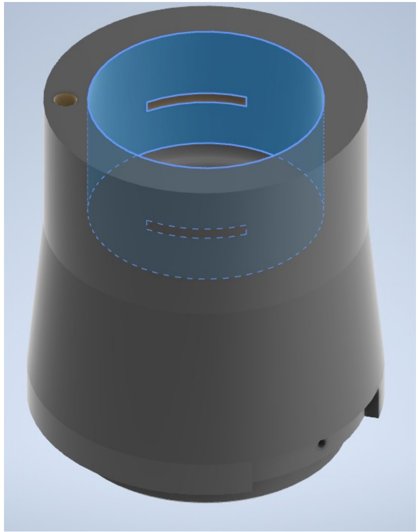
Current air inlet design: Single inlet leading to two slots to direct airflow onto the two sides of the Current Mode Amplifier PCB

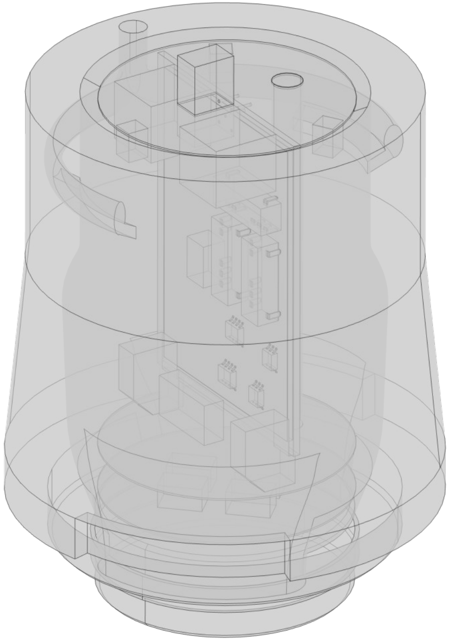


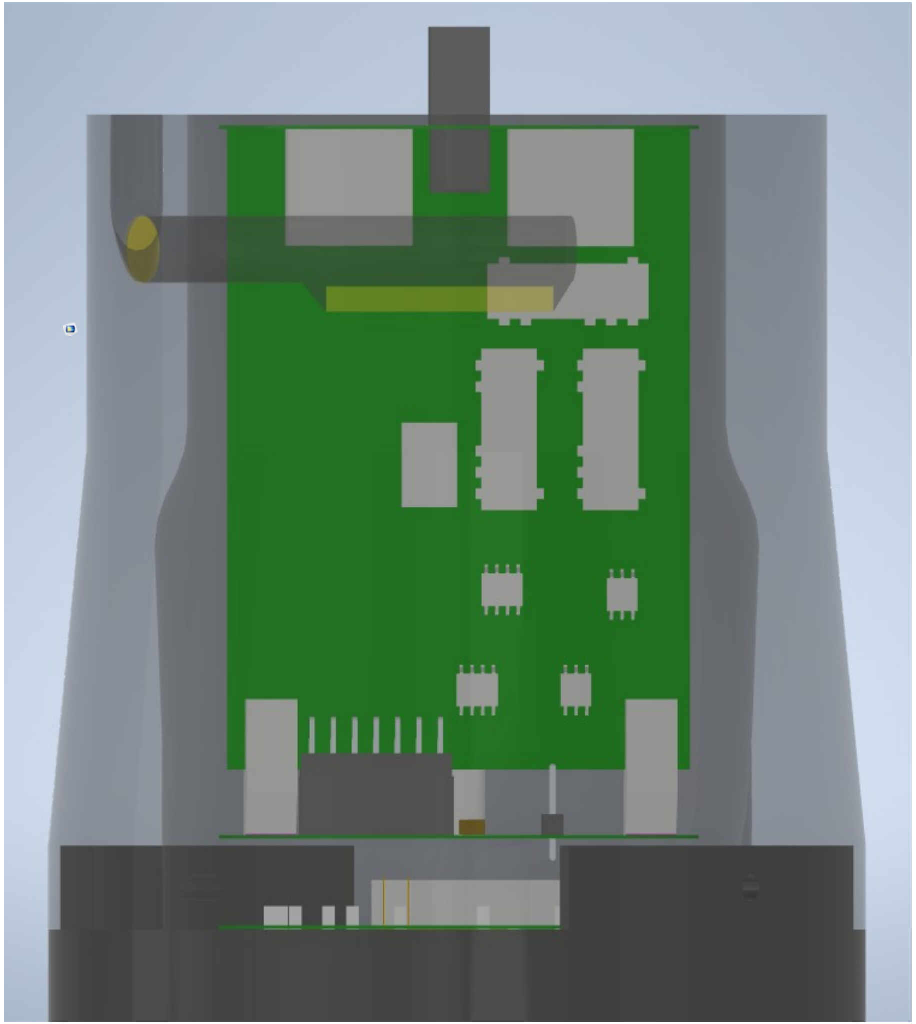


PMT Base Cooling: Airflow

Current air inlet design: Single inlet leading to two slots to direct airflow onto either side of the Current Mode Amplifier PCB



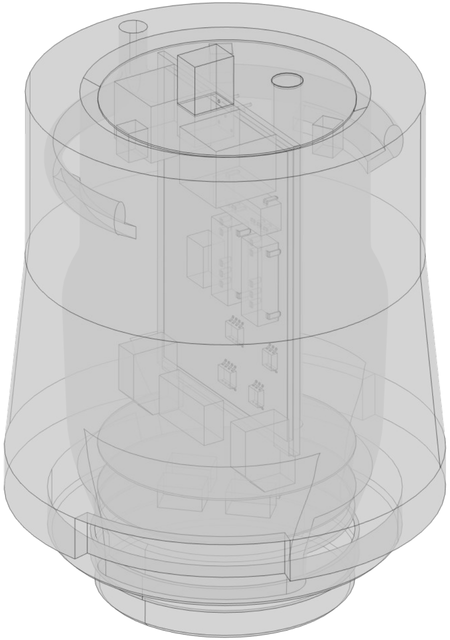


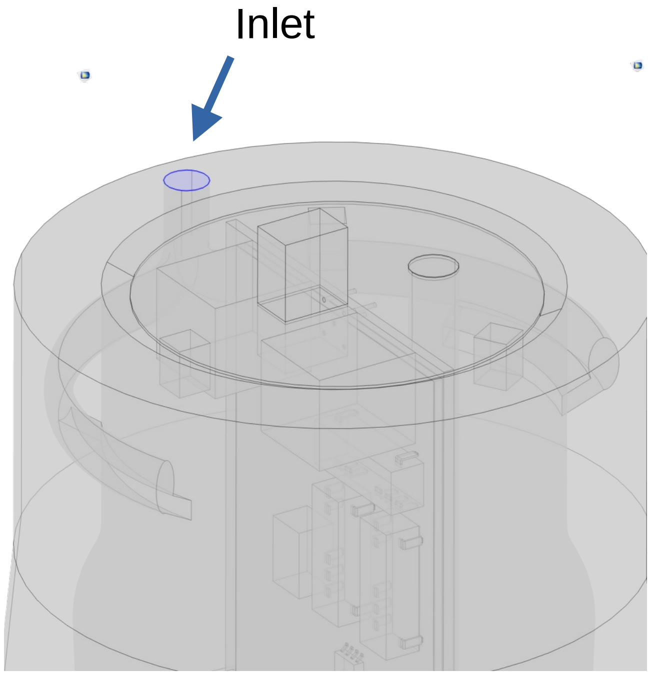


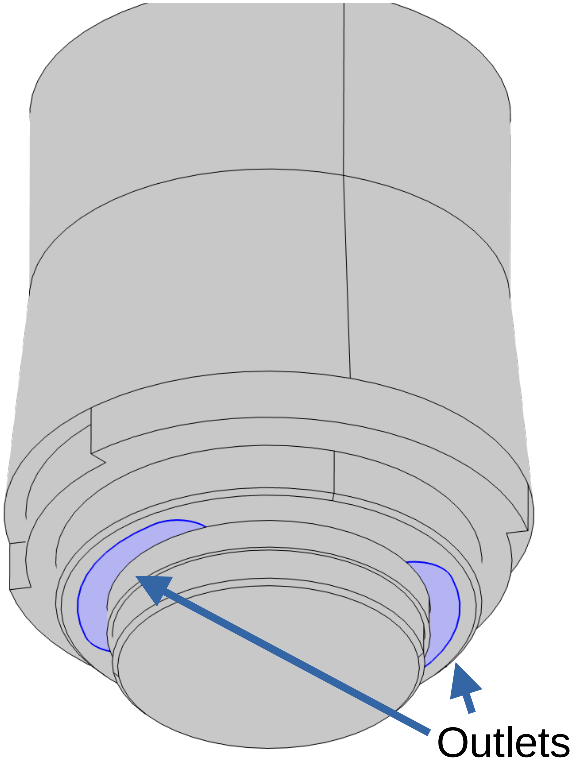
PMT Base Cooling: Airflow

Inlet: single inlet face on the top of the housing tube

Outlet: two outlet faces on either side of the PMT base



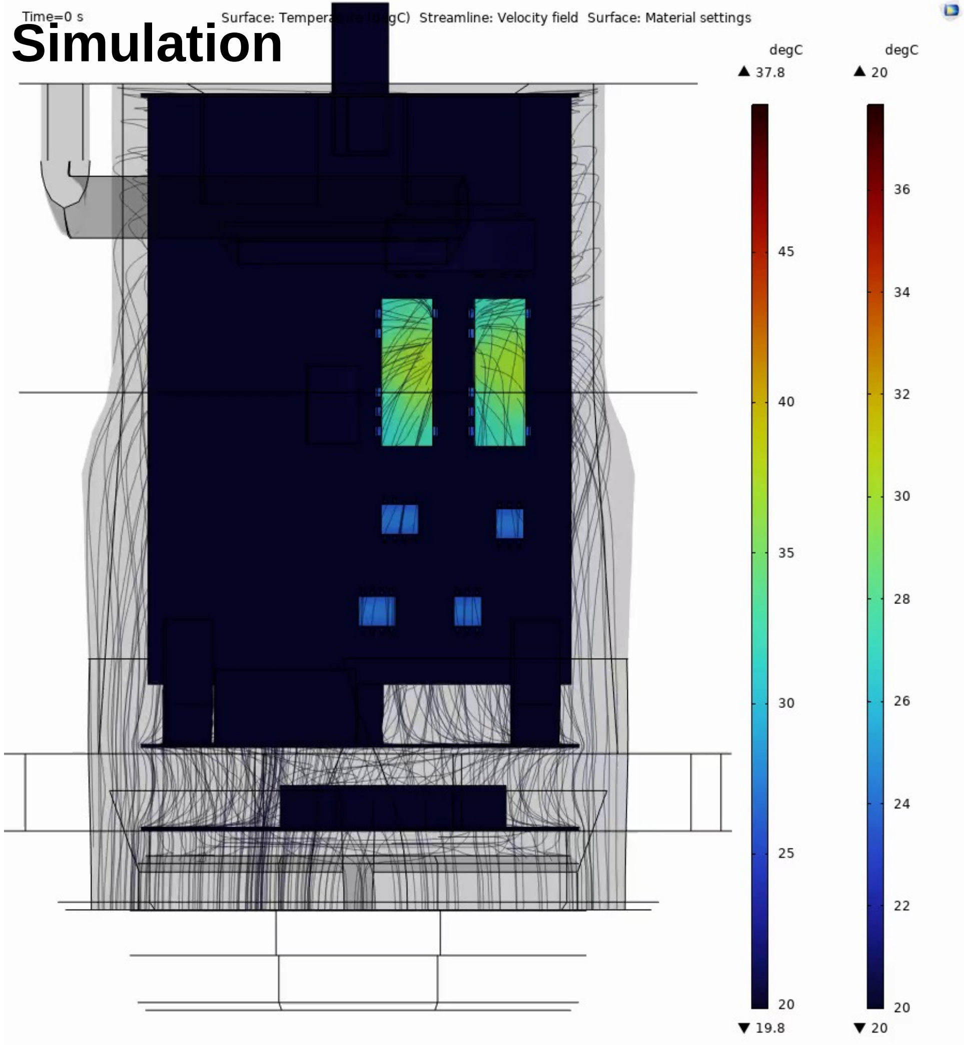




PMT Base CFD and Heat Transfer Simulation

Simulated using COMSOL Multiphysics 6.1.2

- Turbulent flow (k-epsilon model)
  - Flow rate: 2500/300 = 8.33 ft^3/h = 6.5548E-5 m^3/s
- Heat Transfer in Solids and Fluids
  - Heat sources:
    - 2.4 * 0.3 W (70% efficiency)
    - 2.4 * 0.7 * 0.2 (assuming 80% efficiency)
      - Inaccurate results, will need updating
- Surface-to-Surface Radiation
  - IC surfaces: ε = 0.93
  - PCB and plastic surfaces: ε = 0.5
- Simplified model:
  - Removed pins and small components not generating heat
  - Four copper planes for PCB heat transfer, not the entire circuit.



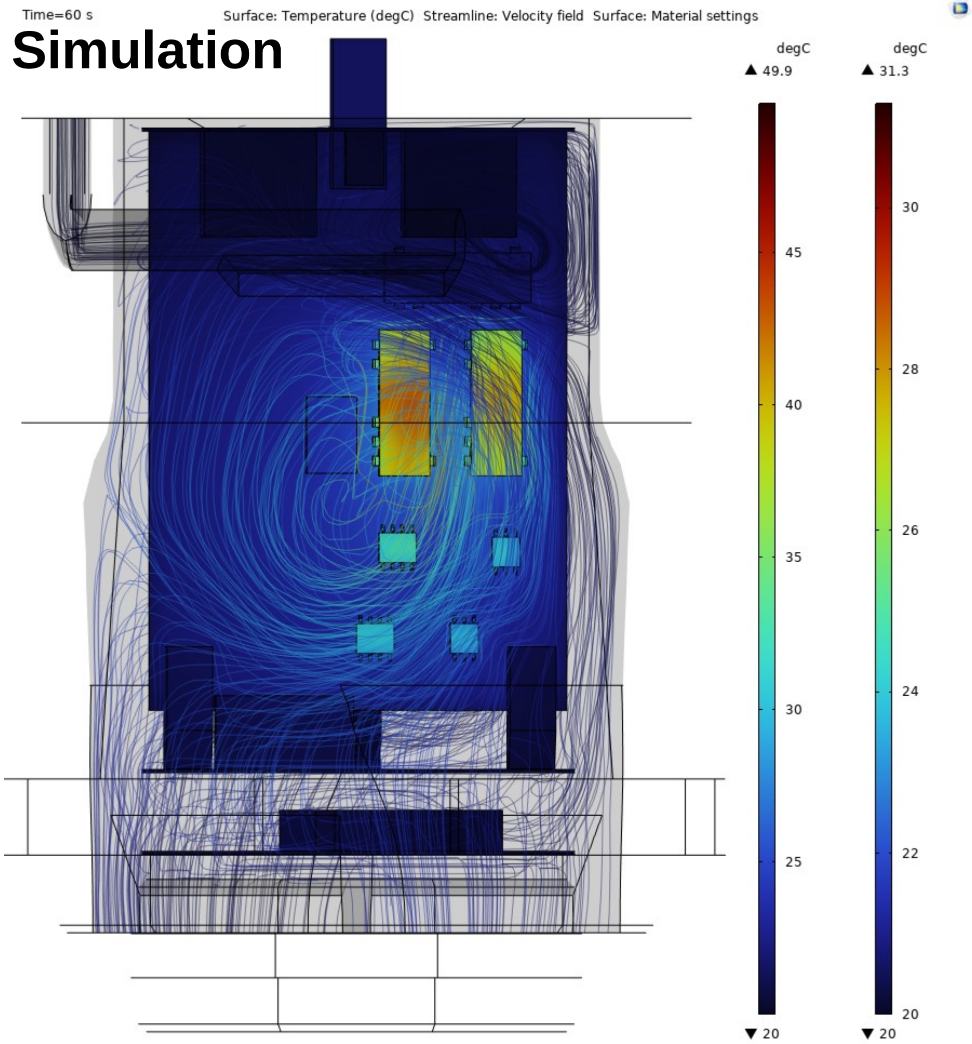
PMT Base CFD and Heat Transfer Simulation

Maximum simulated surface temperature on DC-DC converter (left):

- 43 °C at 60 s
- Extrapolated to ~47 °C at 10 min
  - actual longer simulation still underway

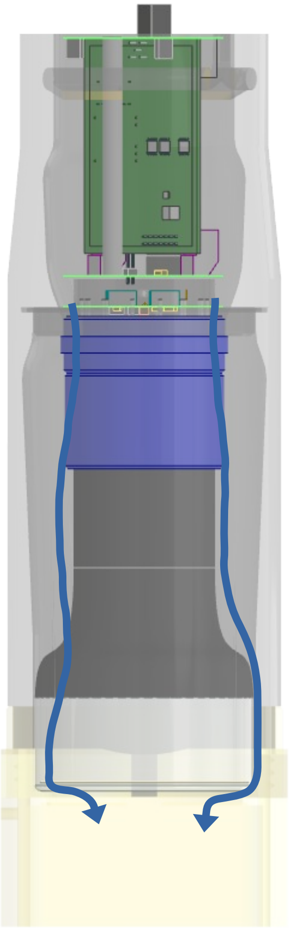
Future work:

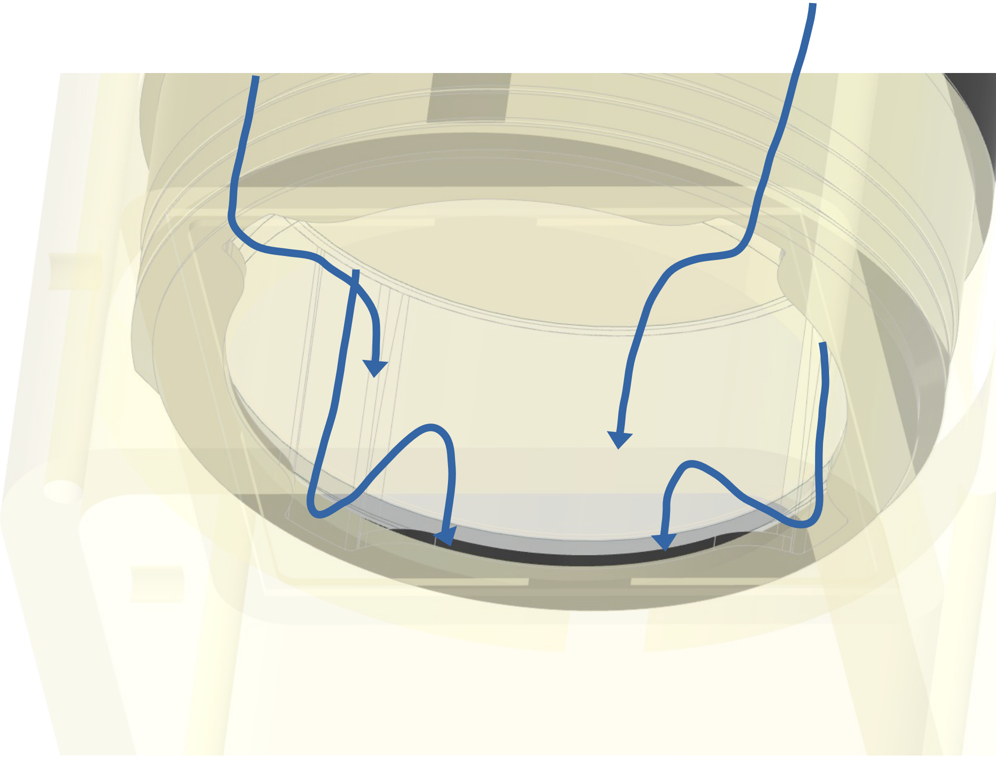
- Validation of CFD results with airflow experiments
  - 3D printing of test housings to begin this week
- Tweaking of inlet positions to improve direct airflow onto the chips
- Redo CFD simulation with new DC-DC converter if changed.



PMT Module Airflow

The air flowing out of the PMT base area flows down around the PMT, then out horizontally from under the PMT through four outlets, and into the light guide.

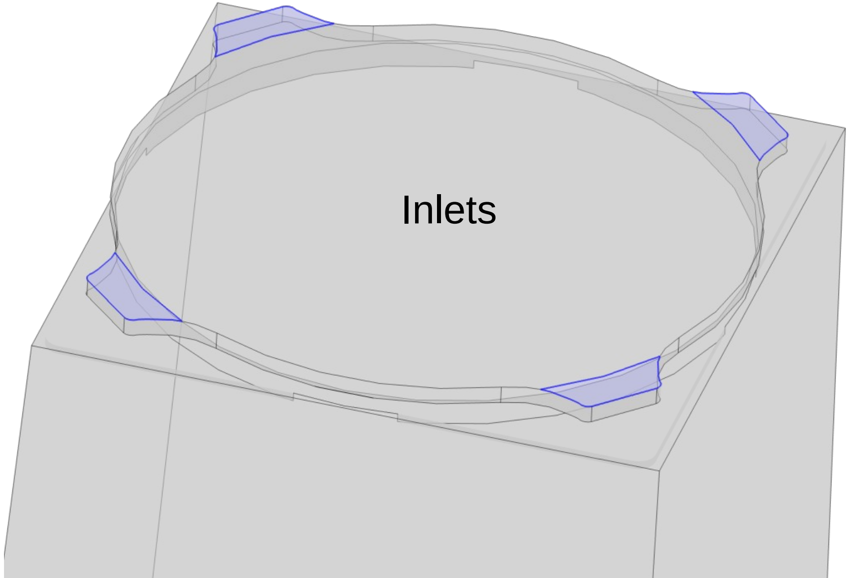


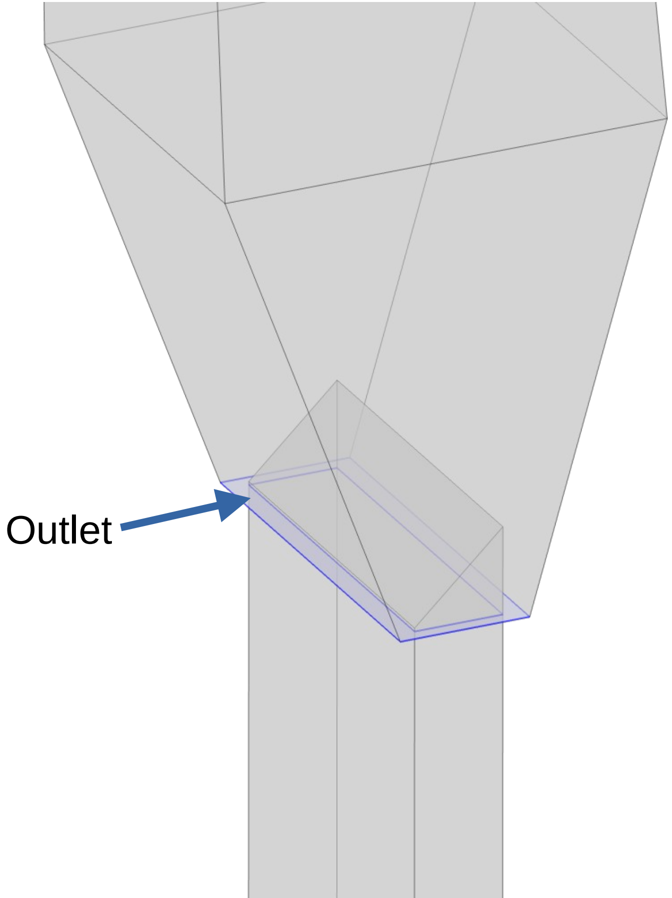


Light-guide Air Flushing Simulation – Ring 5 and 6

In the simplified CFD model, the four selected faces are used as inlets.

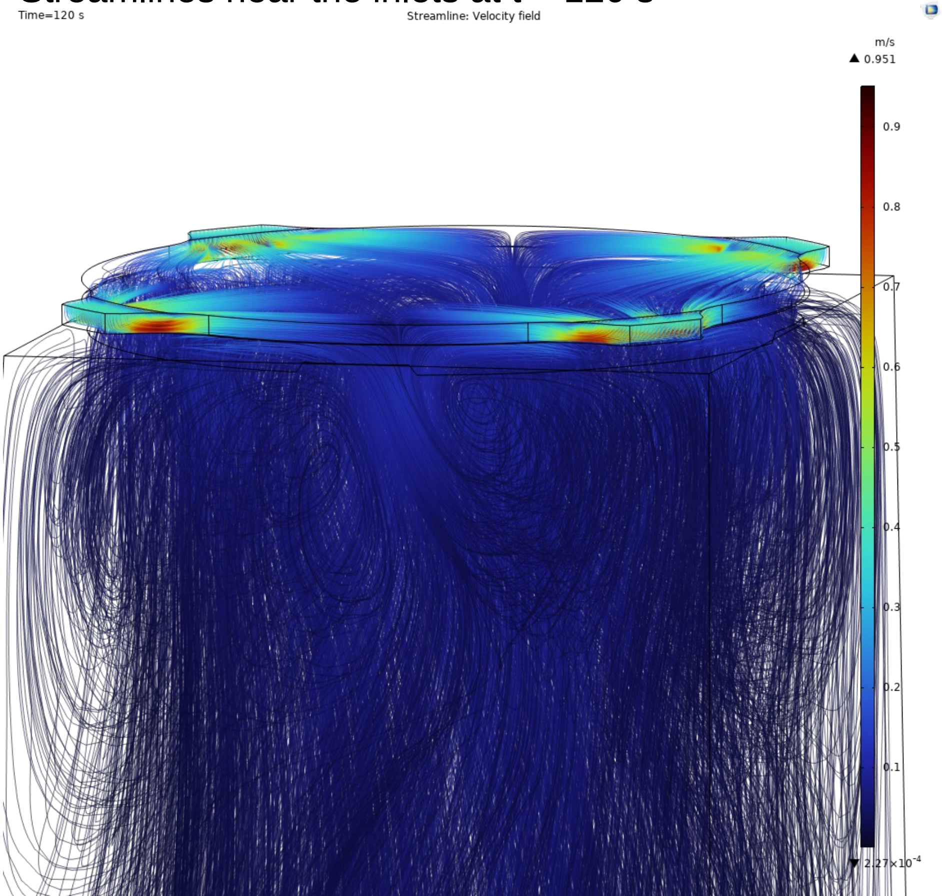
One outlet face surrounding the quartz tile acts as the outlet for the air domain.

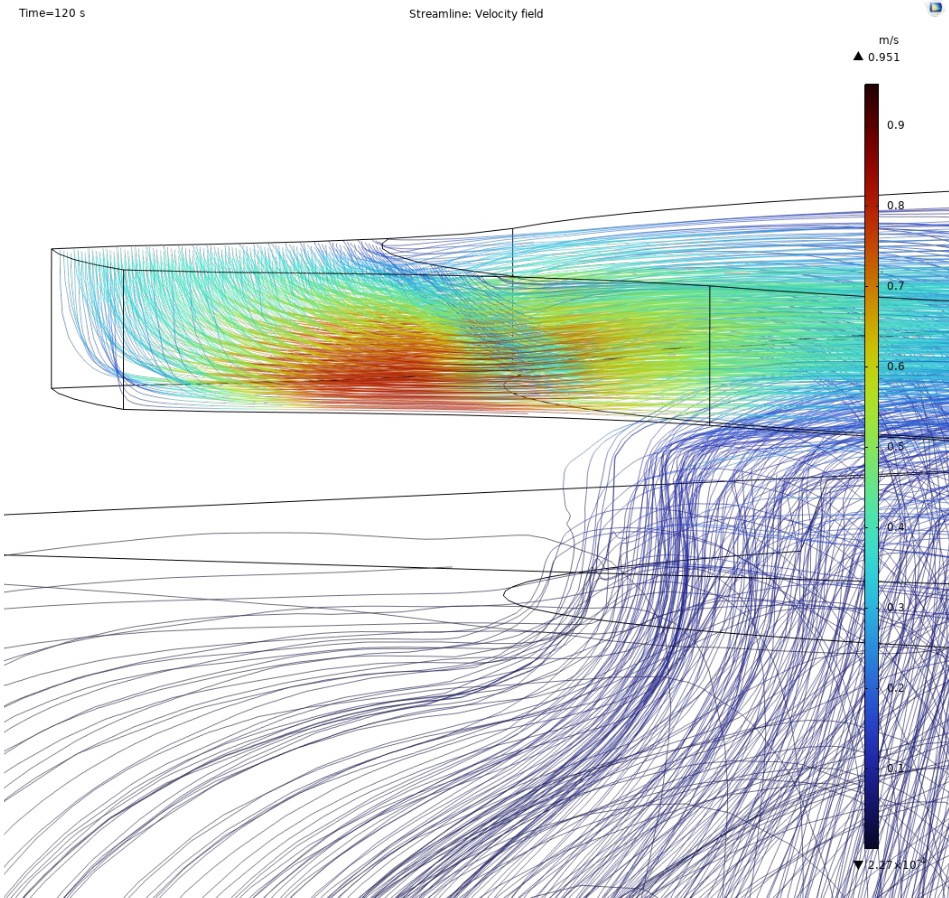




Light-guide Air Flushing Simulation – Ring 5

Streamlines near the inlets at t = 120 s





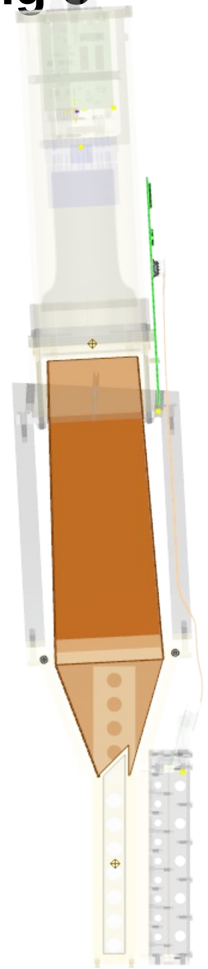
Light-guide Air Flushing Simulation – Ring 5

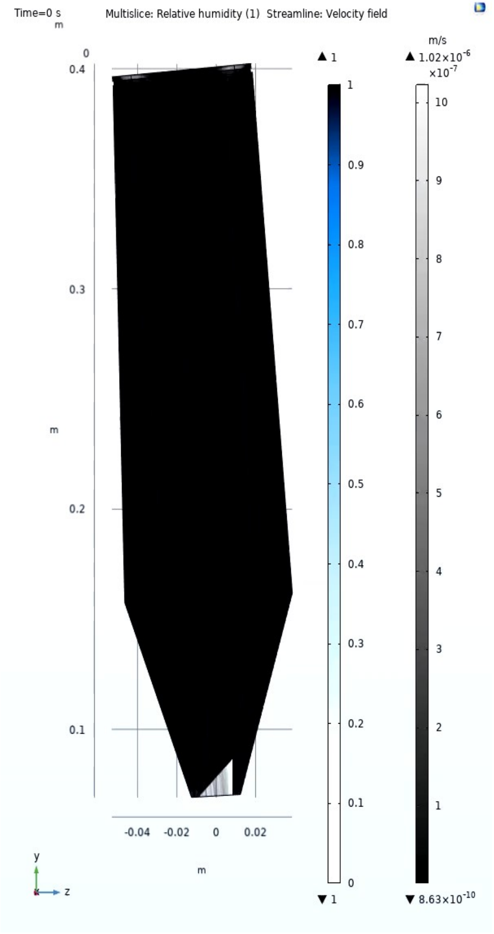
Simulated using COMSOL Multiphysics 6.1.2

- Turbulent flow (k-epsilon model)
- Moisture Transport in Air

- Initial Conditions: 100% Relative Humidity
- Inlet humidity: 0%

- Result: Ring 5 light guide needs ~85 s for the humidity to drop below 1%





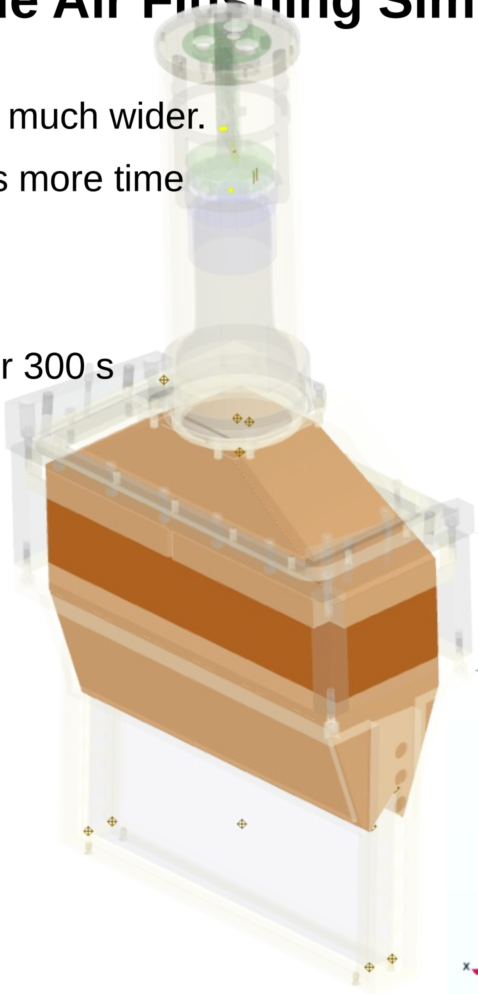
Light-guide Air Flushing Simulation – Ring 6

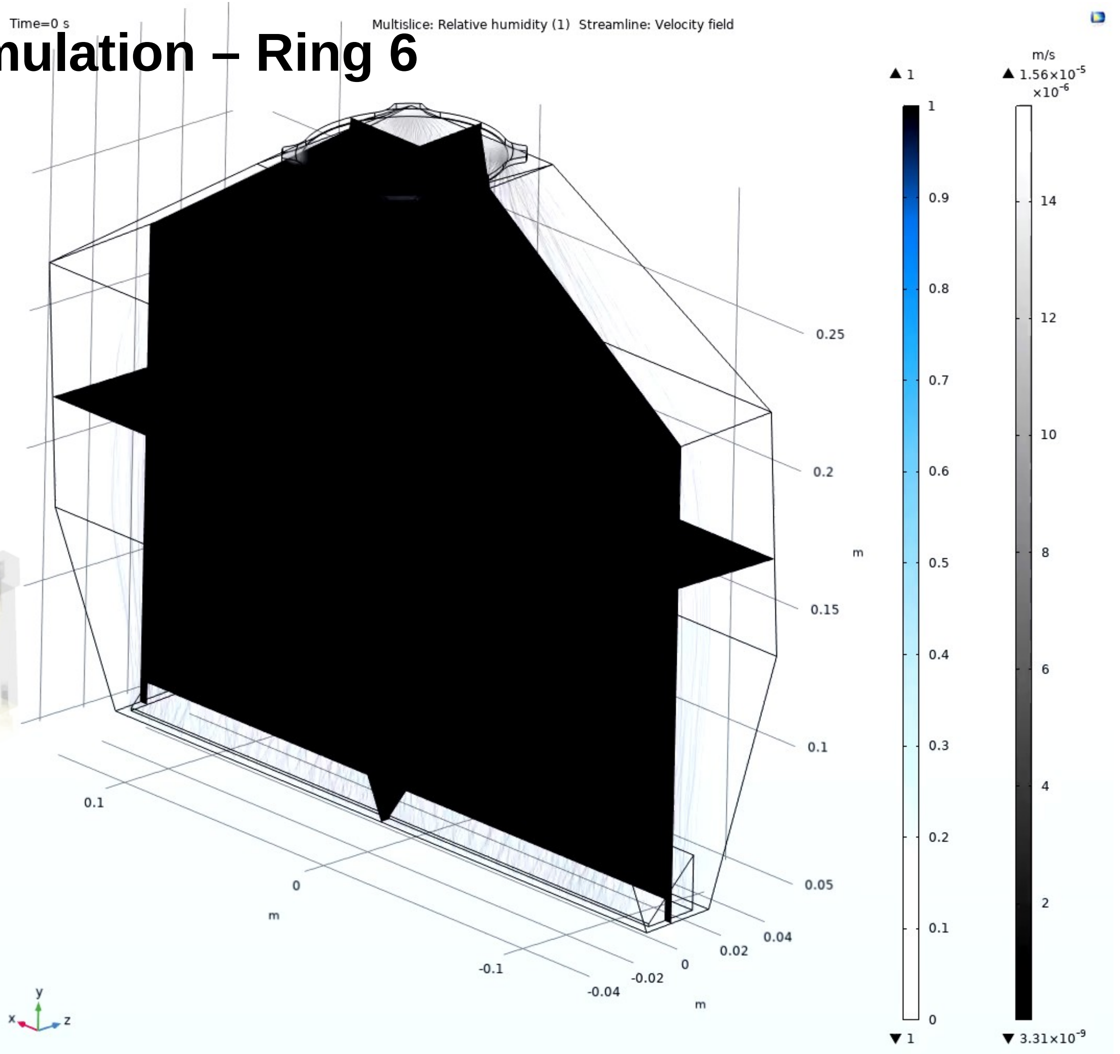
Ring 6 light guide is much wider.

The air inside needs more time

to mix.

~2.5% humidity after 300 s





PMT Cooling and Light-guide Air Flushing

Future work:

- Design changes:
  - Minor tweaks to inlet and outlet positions for optimized airflow for both PMT cooling and light guide flushing
  - Redo simulations in case of changes in electronics

- Experimental:
  - Air flow experiments with 3D printed housing parts to validate the simulations will begin this week.
  - Will be monitoring:
    - Temperatures of components on the PMT base
    - Humidity within the light guides
    - Air flow magnitude

Thank you