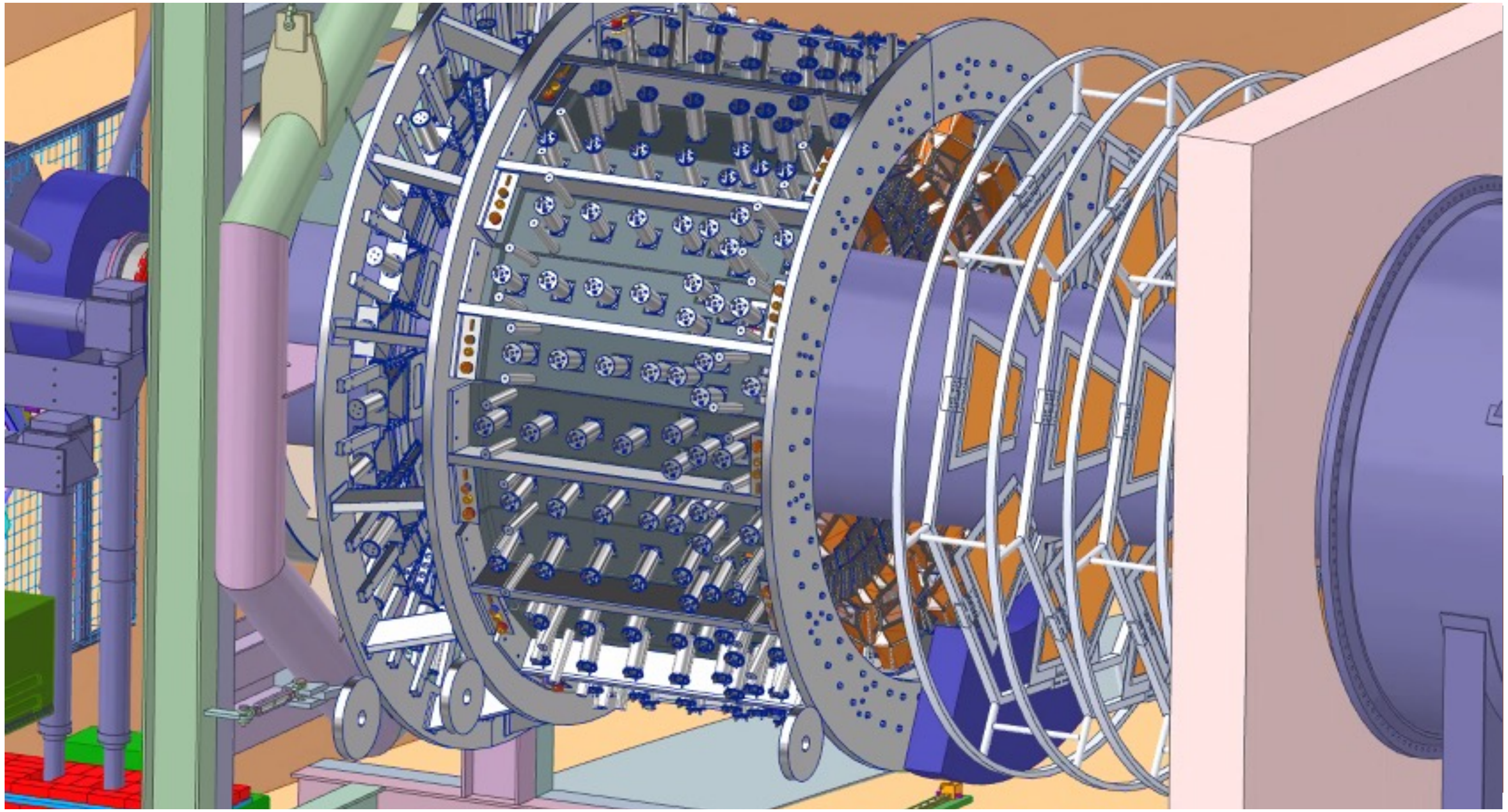
Shower-max Design, Detector Logistics, Radiation Tests

Dustin McNulty – Idaho State University

Students:

Sudip Bhattarai
Justin Gahley
Jared Insalaco
Sagar Regmi
Edwin Sosa
Freddy Kouakou
Coltyn Fisher
Mitchell Frasure
Gabriel Ladipo
Don Sheetz III



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Outline

- Shower-max update
  - Subsystem review
  - New ring support structure concept
  - Module prototyping/testing plans and progress
  - Remoll lifetime dose estimates

- Detector Logistics
  - Main detector patch panel, cable harness, and gas distribution system update
  - High density connectors update and prototyping plans

- Radiation Testing
  - Results for quartz
  - Starting 3D-printed plastic

- Summary and future work

Shower-max Description

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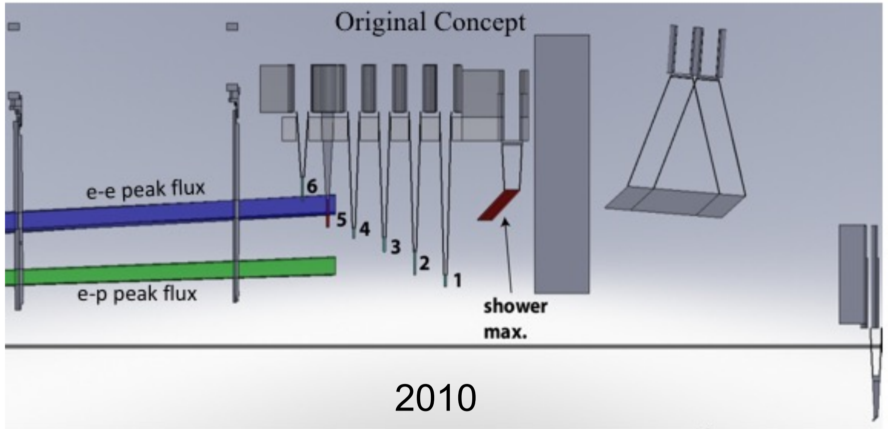
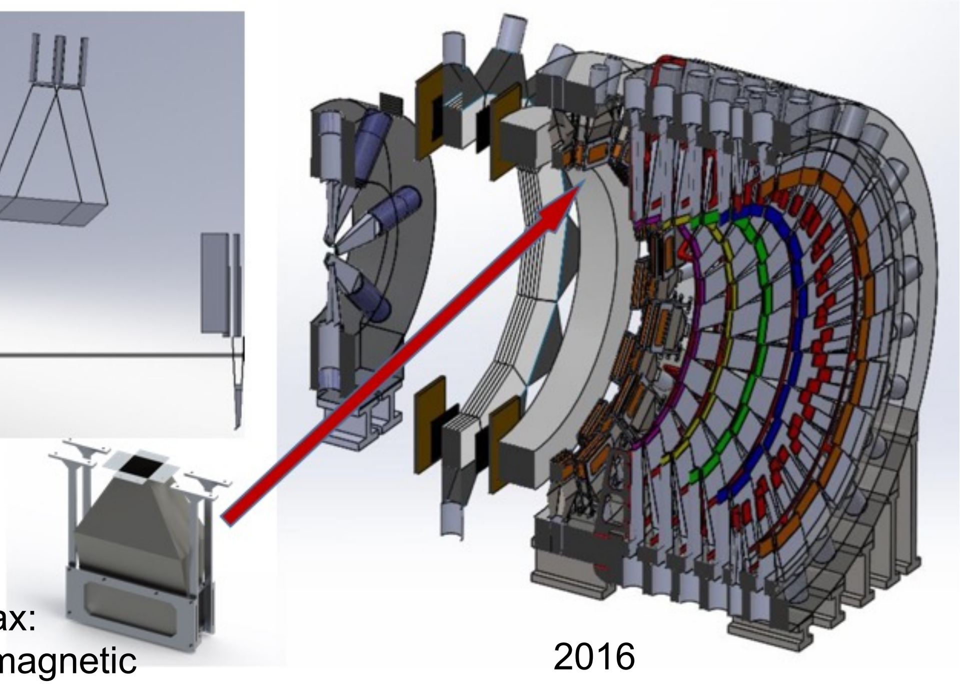
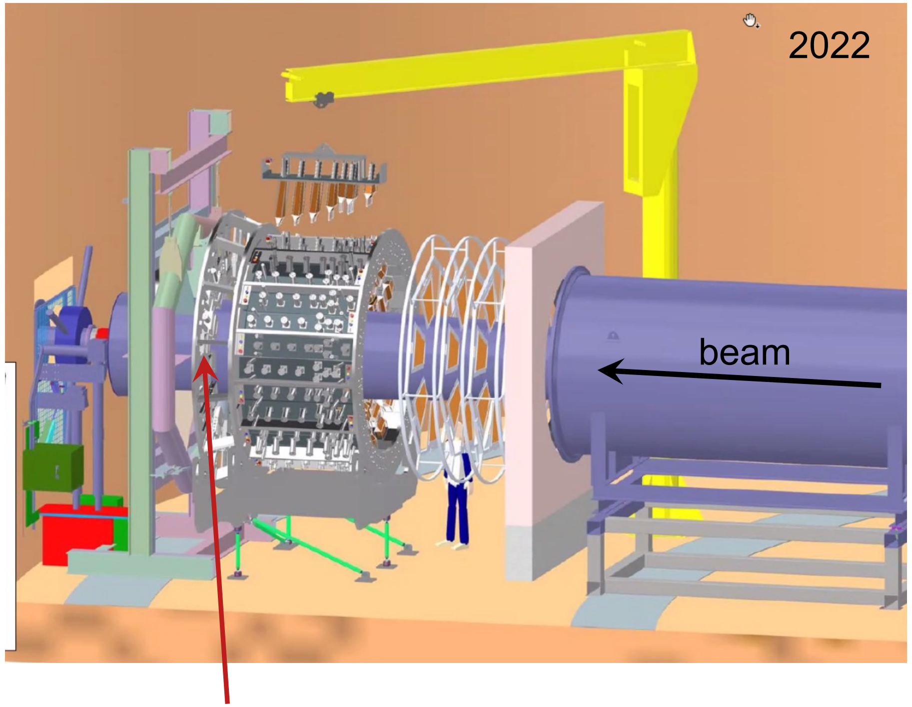
2.04.03	Shower Max Detector	Design, Procurement, Assembly, and Test of the Shower-Max detector system. It is composed of an array interleaved layers of quartz radiatiors and thin tungsten sheets making up an EM shower detector system.





Shower-max:
An electromagnetic sampling calorimeter

2016



Shower-max ring

- Provides additional measurement of Ring-5 integrated flux
- Weights flux by energy ⟹ less sensitive to low energy and hadronic backgrounds
- Will also operate in tracking mode to give additional handle on background pion identification
- Will have good resolution over full energy range ($\lesssim 25\%$), radiation hard with long term stability and good linearity

Shower-max module and ring geometry

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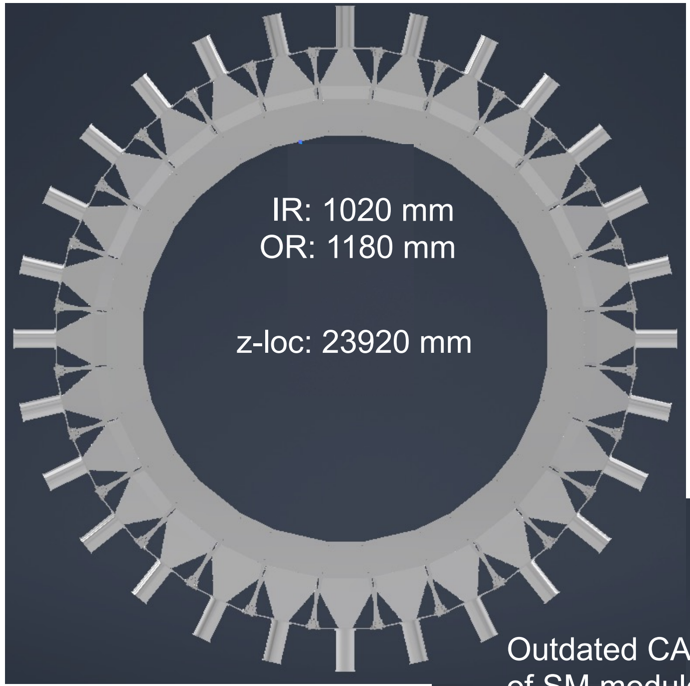
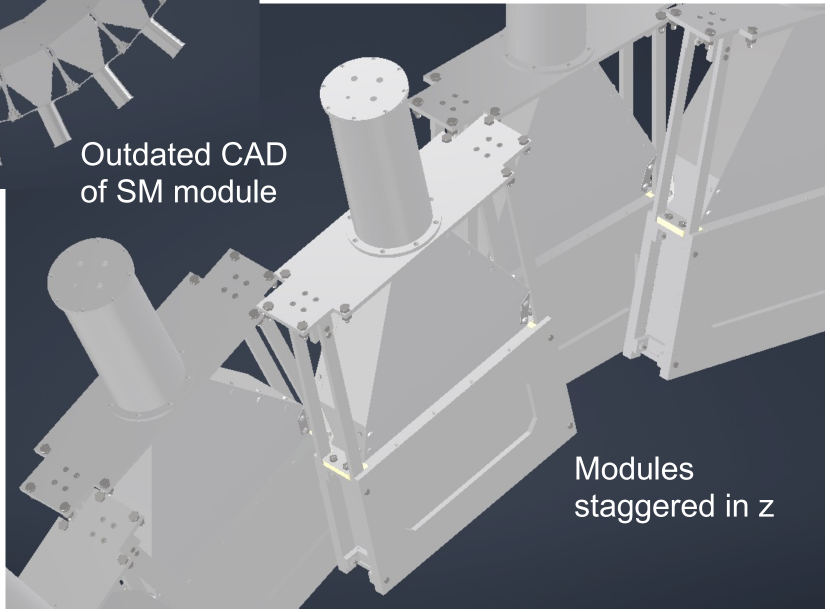
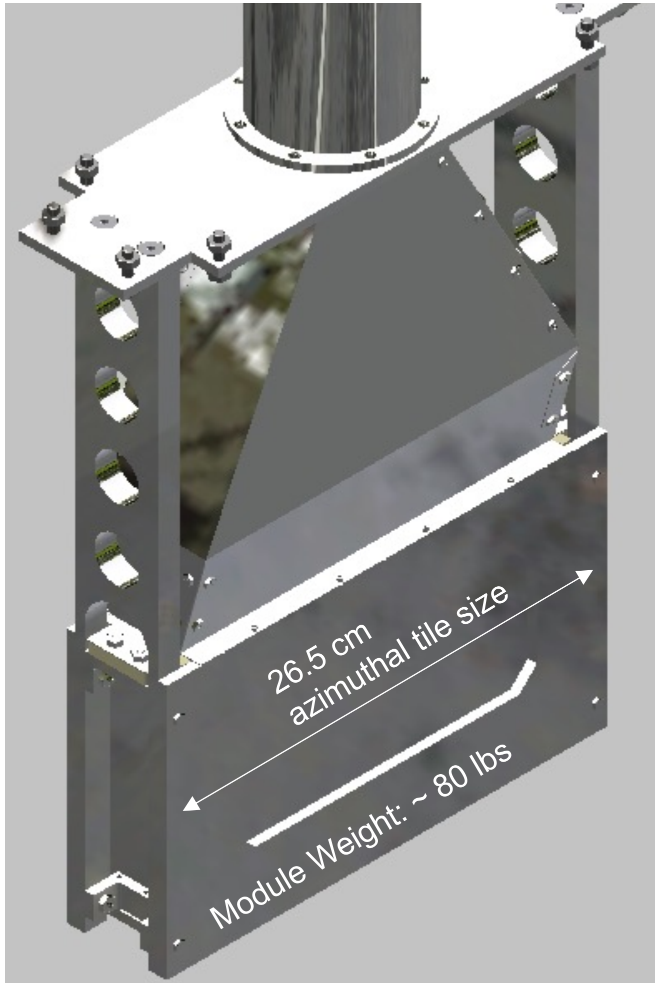
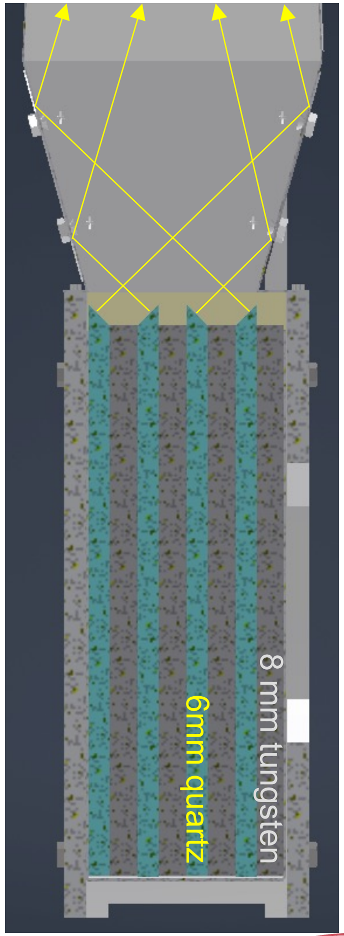
ShowerMax detector: ring of 28 sampling calorimeters intercepting physics signal flux 1.7 m downstream of ring 5

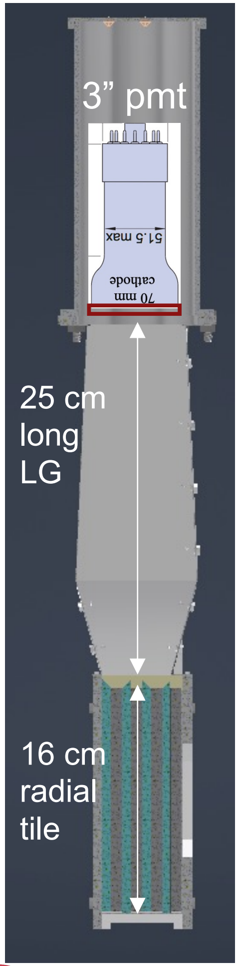


- Aluminum 6061 chassis and air-core light guide
- 99.95% pure tungsten and HPFS radiators
- Radiation length: ~9.5 X_0
- Molière radius ~ 1.1 cm









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Shower-max: prototyping and testing plans

- Following PDR last winter, plans started for constructing two prototype detector modules for testing this summer in preparation for Final Design Review.

Stuff to learn from this 2nd Shower-max prototyping experience:

- Mechanical aspects: the "ledge" part (support) design/function, tungsten-quartz spacer design and material choice; light guide folding process; chassis, stack, and general assembly/disassembly procedures; and simply how to move the detector around and handle it while testing
- Optical and rad-damage aspects: quartz radiator choice (standard or doped HPFS), light guide material (Anolux Miro-IV or Miro-silver), spacer concept and material choice; light guide design

Testing plans (two prototypes, light guides constructed with two materials; different spacer designs):

- We plan to test Shower-max using cosmic rays combined with Monte Carlo. We have test stand and Qsim G4 MC; we're developing a drawer-support system for installing a module in test stand
- We also plan to use MAMI testbeam this fall. We'll do careful MC study to get expectation for Shower-max response to 850 MeV electrons; **the use of Hall D testbeam is a new exciting possibility to pursue**
- We've purchased 3" diameter filters (350 and 400 nm long pass), two of each type for testing.

Shower-max: Prototyping – Chassis parts

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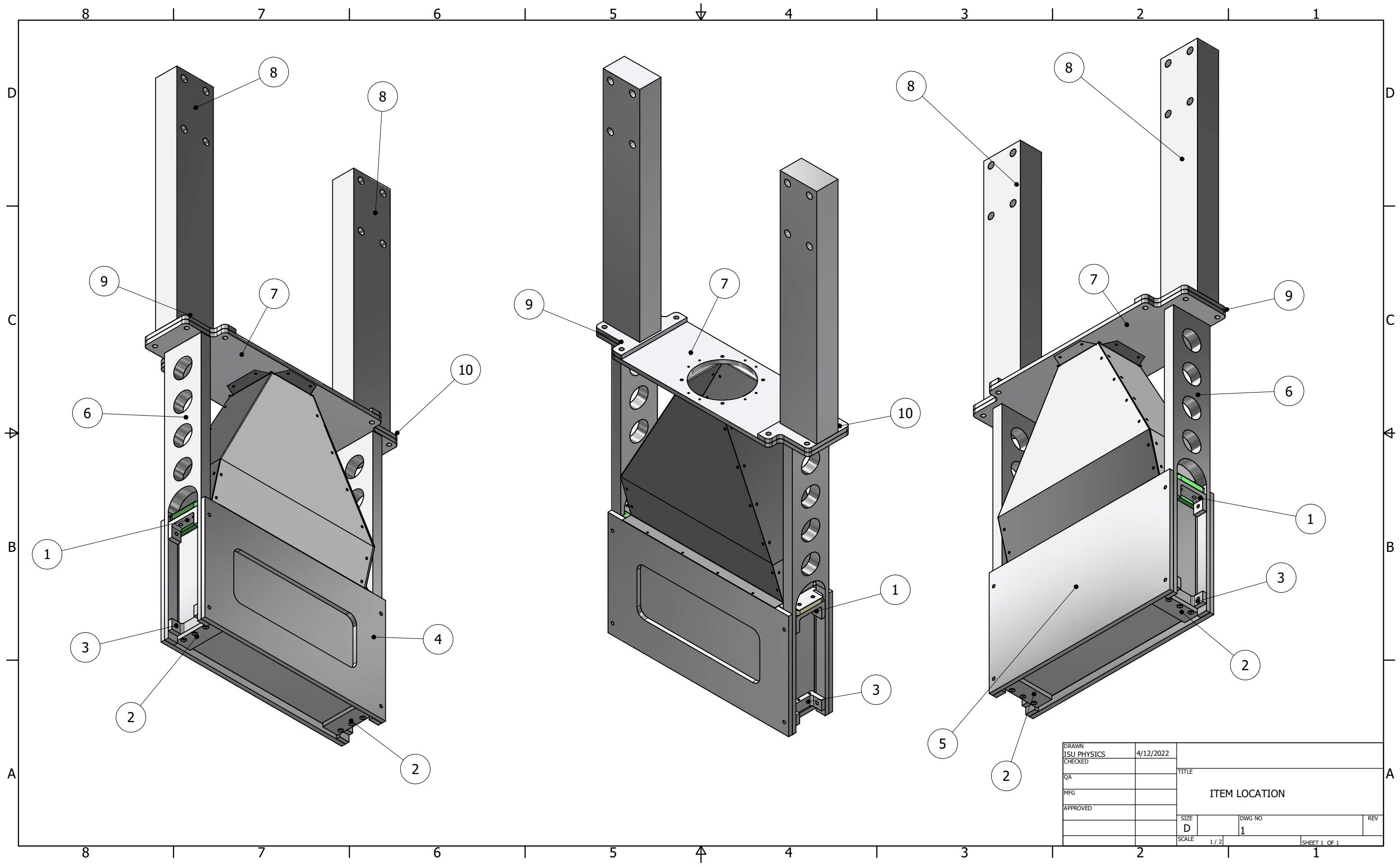
- Shop drawings created and chassis parts for two prototypes received in early June



SHOWER MAX PARTS			
ITEM NO.	PART NAME/MATERIALS LIST	Material	QTY.
1	UPPER U CHANNEL	(1/4)" x 2" ALUMINUM 6061	4
2	FLOOR PLATE	0.25 (1/4) THICK 6061-T651 ALUMINUM PLATE	4
3	LOWER U CHANNEL	0.25 (1/4) THICK 6061-T651 ALUMINUM PLATE	4
4	FACE PLATE	0.25 (1/4) THICK 6061-T651 ALUMINUM PLATE	2
5	BACK PLATE	0.25 (1/4) THICK 6061-T651 ALUMINUM PLATE	2
6	WEB PLATE	0.625 (5/8)" THICK ALUMINUM 6061	4
7	TOP PLATE	0.25 (1/4) THICK 6061-T651 ALUMINUM PLATE	4
8	SUPPORT STRUT	1.5 (3/2)" THICK ALUMINUM 6061	4
9	LEFT FOOT PLATE	0.25 (1/4) THICK 6061-T651 ALUMINUM PLATE	4
10	RIGHT FOOT PLATE	0.25 (1/4) THICK 6061-T651 ALUMINUM PLATE	4

Shower-max: Prototyping – light guide parts

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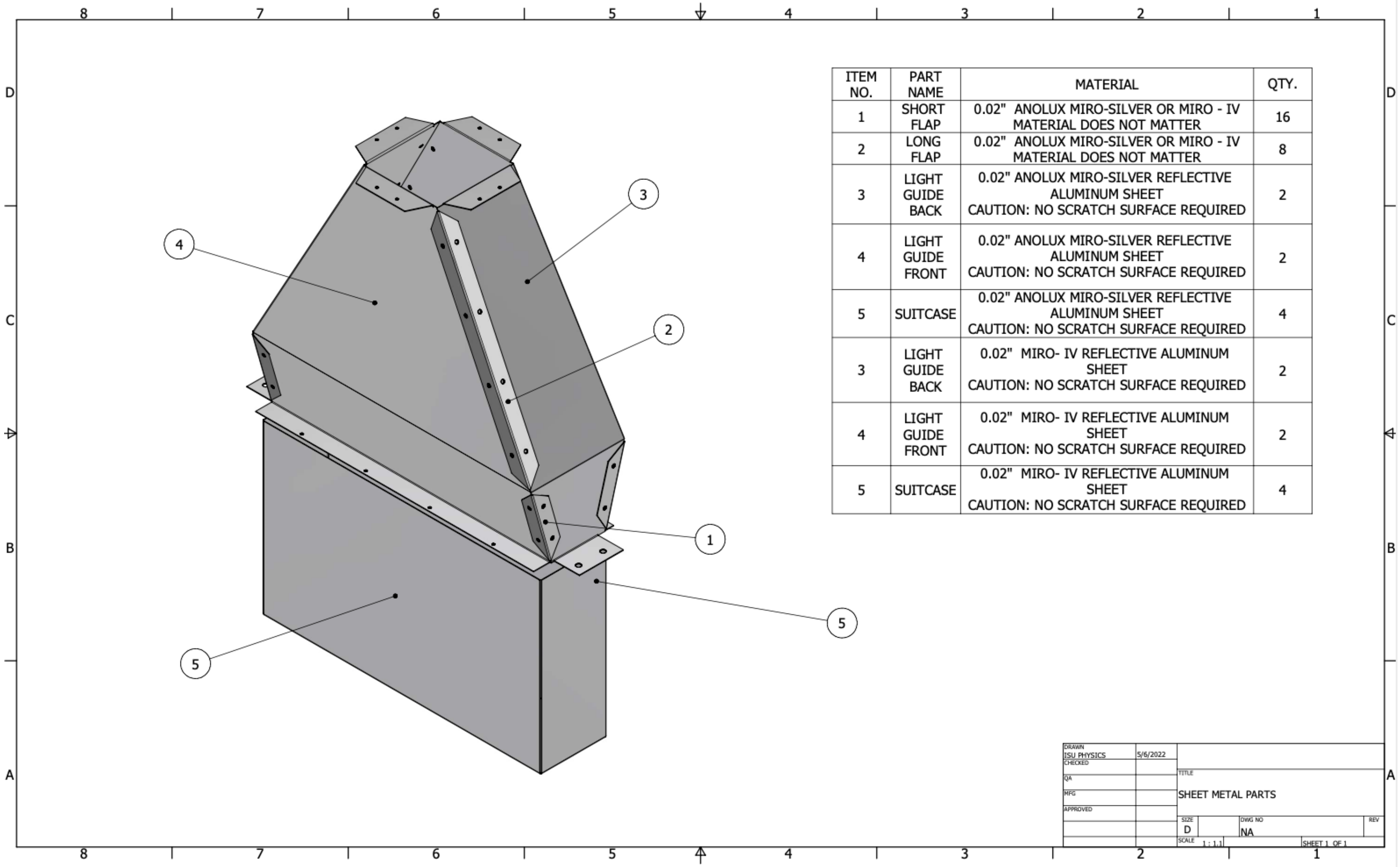
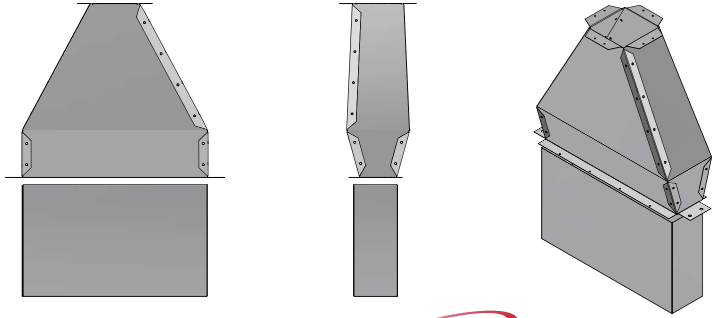


ITEM NO.	PART NAME	MATERIAL	QTY.
1	SHORT FLAP	0.02" ANOLUX MIRO-SILVER OR MIRO - IV MATERIAL DOES NOT MATTER	16
2	LONG FLAP	0.02" ANOLUX MIRO-SILVER OR MIRO - IV MATERIAL DOES NOT MATTER	8
3	LIGHT GUIDE BACK	0.02" ANOLUX MIRO-SILVER REFLECTIVE ALUMINUM SHEET CAUTION: NO SCRATCH SURFACE REQUIRED	2
4	LIGHT GUIDE FRONT	0.02" ANOLUX MIRO-SILVER REFLECTIVE ALUMINUM SHEET CAUTION: NO SCRATCH SURFACE REQUIRED	2
5	SUITCASE	0.02" ANOLUX MIRO-SILVER REFLECTIVE ALUMINUM SHEET CAUTION: NO SCRATCH SURFACE REQUIRED	4
3	LIGHT GUIDE BACK	0.02" MIRO- IV REFLECTIVE ALUMINUM SHEET CAUTION: NO SCRATCH SURFACE REQUIRED	2
4	LIGHT GUIDE FRONT	0.02" MIRO- IV REFLECTIVE ALUMINUM SHEET CAUTION: NO SCRATCH SURFACE REQUIRED	2
5	SUITCASE	0.02" MIRO- IV REFLECTIVE ALUMINUM SHEET CAUTION: NO SCRATCH SURFACE REQUIRED	4

- Shop drawings created and light guide parts for prototypes just received: two Miro IV and two Miro-silver sets
- Starting to fold them this week
  - Unfortunately, machinist did not use sandwiching technique during water jet cutting and protective films were ripped off. We are re-doing them



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Shower-max: Prototyping – Quartz and tungsten

- Quartz quotes obtained from two vendors in April: Glass Fab and Sydor Optics (both out of Rochester, NY); Heraeus and other vendors did not provide quote yet; Larger company such as Zygo said our pieces where too small for their factory
  - Sydor Optics quoted Corning 7980 (UV Homogeneity 5F): $3k/5k per piece for Qty 8/4 plus $1.5k tooling charge for the 45deg cut; SM budget has ~$2k per piece

"As discussed on our first call, these optical components need to be handled by many manufacturing work centers including CNC machining, double-sided polishing, and single-side polishing for the edge and angle polishing. As a result, our lead time is 30+ weeks from receipt of order due to our current backlog", said Sydor

  - Glass Fab would not quote Corning, ..., but only Tosoh HPFS: $990/pc for Qty 4 (265 x 166 x 6 mm^3 –Shower-max tile size); **we purchased 4 of these** (est. ship date June 24)
    - They refused to quote polished chamfers (edges); and increased chamfer width to 0.04 inch (from 0.02 inch); all polishing is done in-house I was told
    - We also purchased 3 Tosoh samples for radiation testing (5 cm rounds, 1 cm thick, polished on round faces only) $0.5k for 3 (est. ship date of July 14)

New prototype chassis

- Tungsten quotes were easy to get and within budget; plates cost ~$1k each (we have 8 in hand; 7 week lead time)

Shower-max Ring Support Structure

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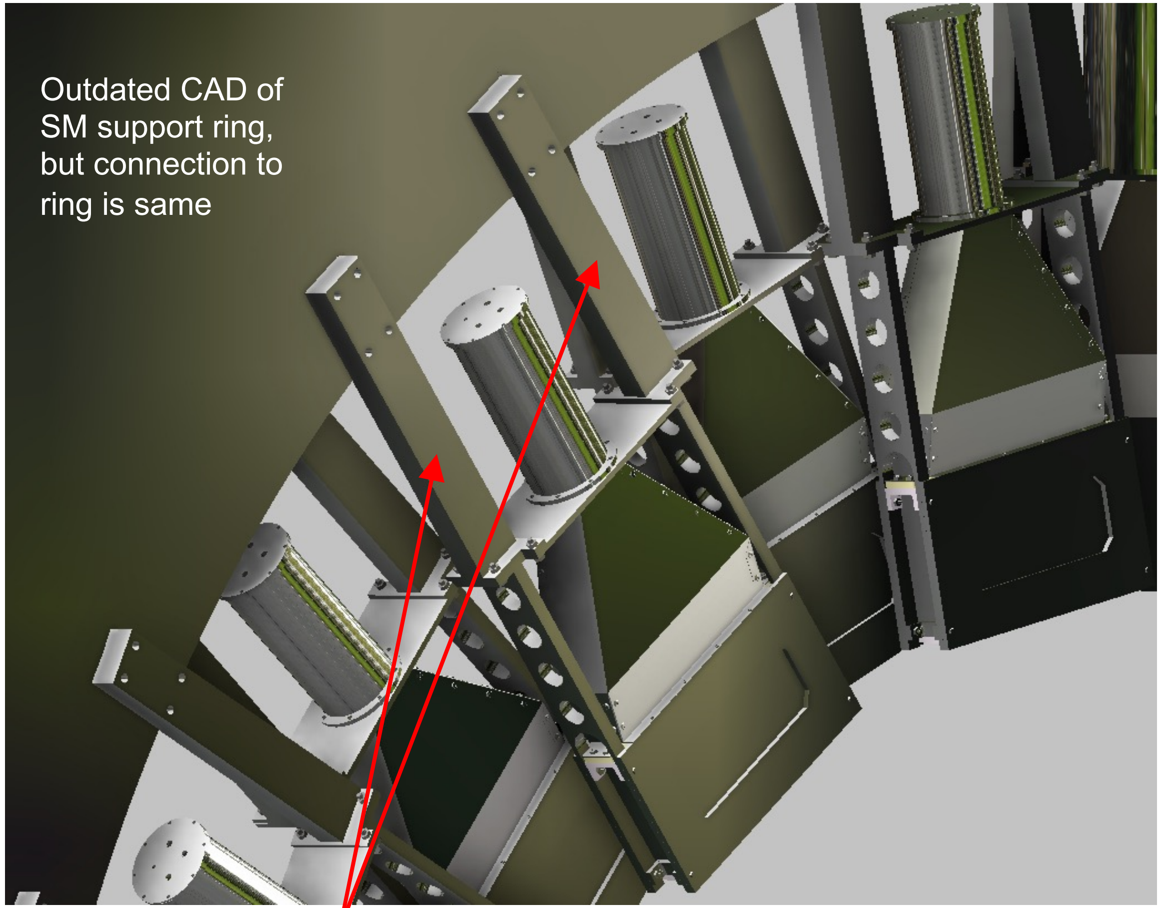
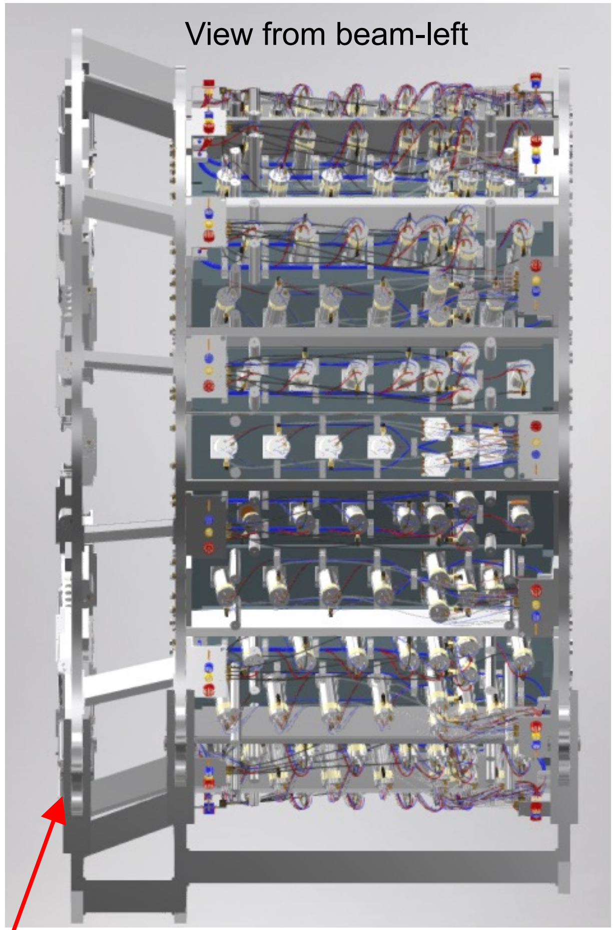
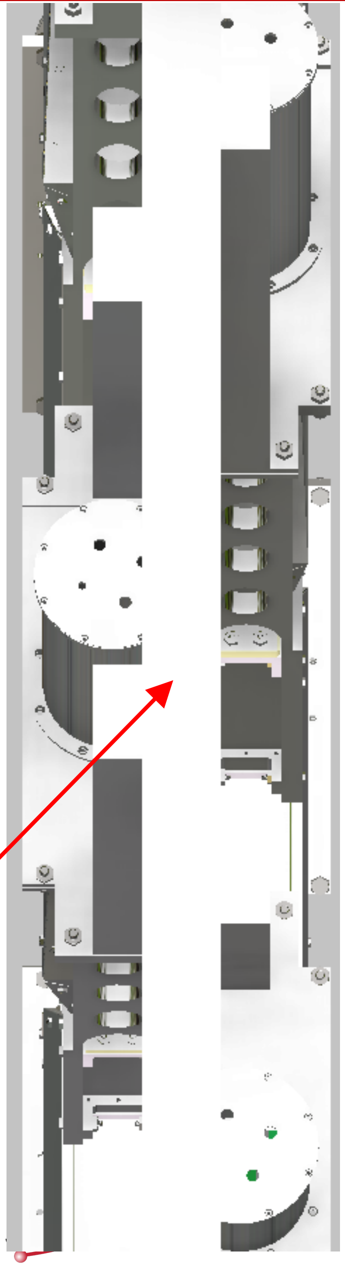


- Aluminum bars (15 x 1.25 x 2.5 in^3) attach modules to ring structure--which is 2 inch thick (along z)
- Staggered modules are mounted to US and DS face of support ring (in alternating pattern)



Shower-max ring



- View looking radially inward along Shower-max ring
- Shows reasonable clearance for cabling

Shower-max dose simulations using remoll

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Shower-max ring in remoll GDML:

- Work done by Sudip

--We have estimated total dose in each quartz layer of Shower-max during MOLLER lifetime

--We also have estimates for the LP filter, PMT window, and pre-amp Si wafers

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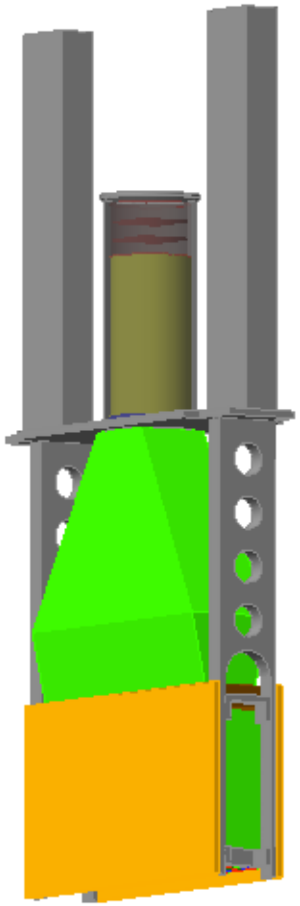
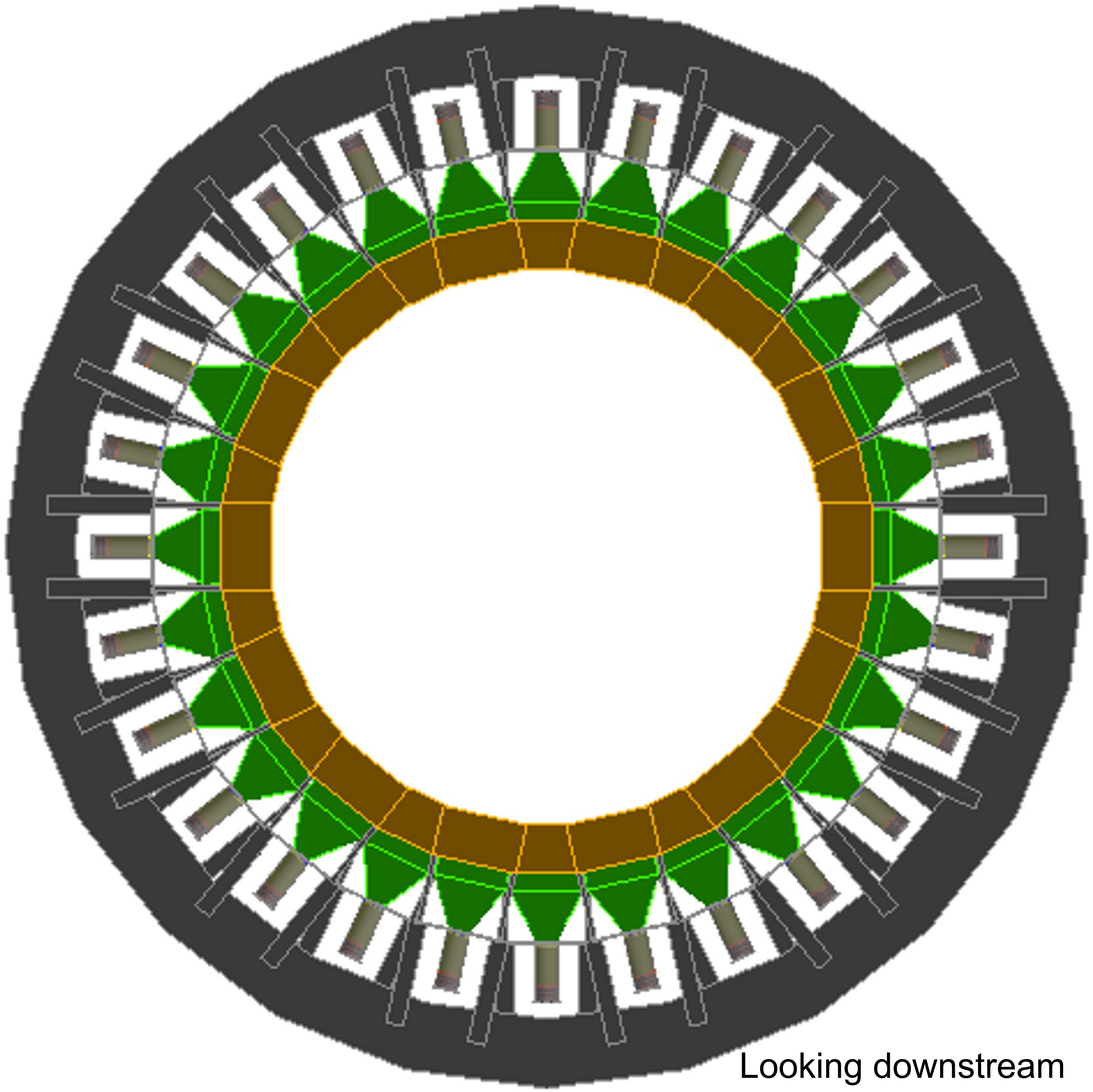
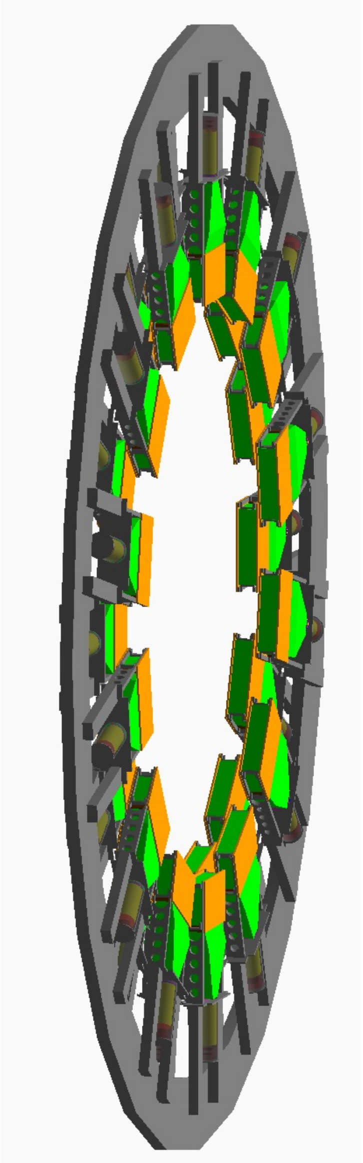




Looking downstream



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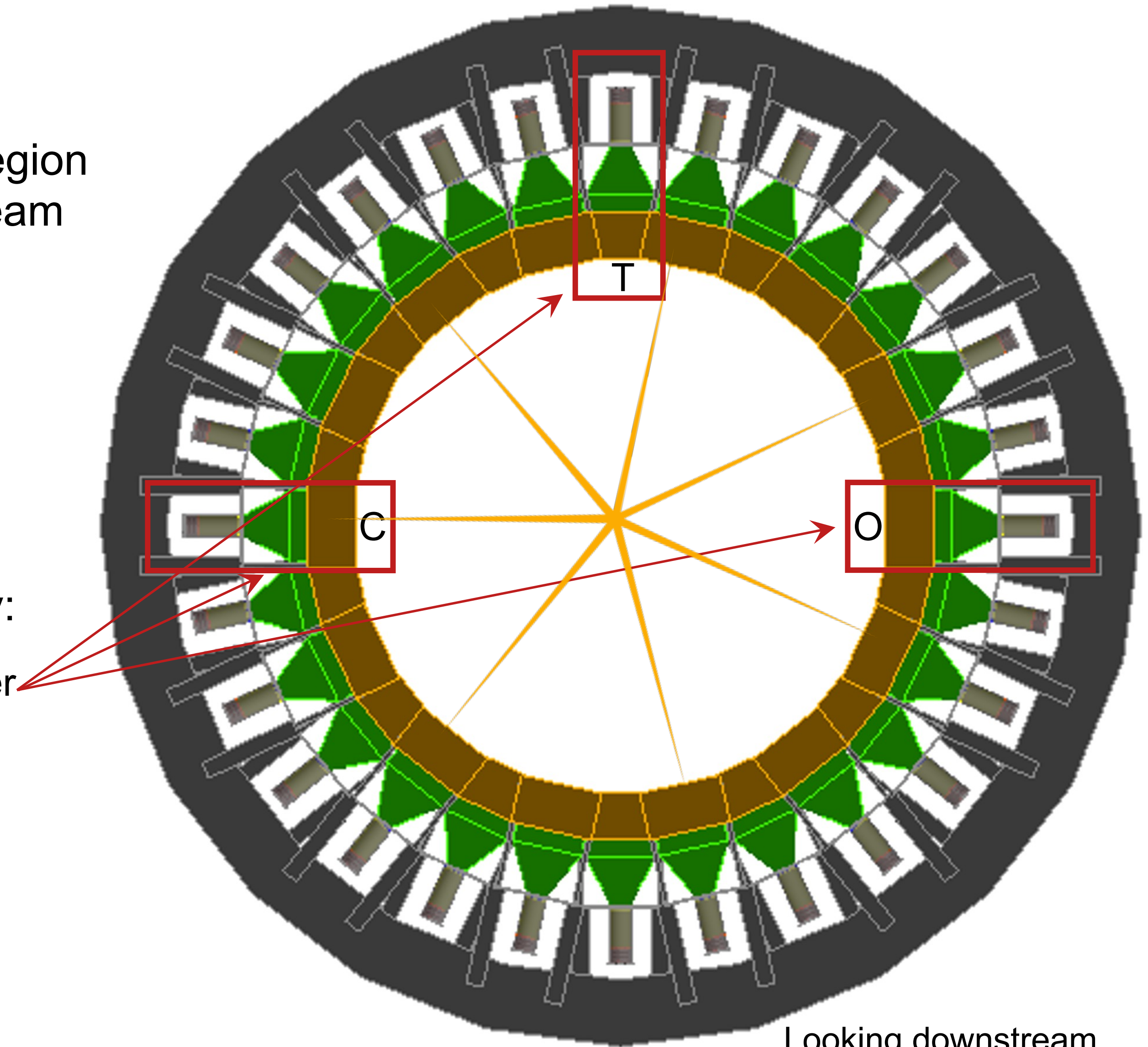
Shower-max dose simulations using remoll

Open and Closed region detectors are upstream of Transition region detectors in the ring

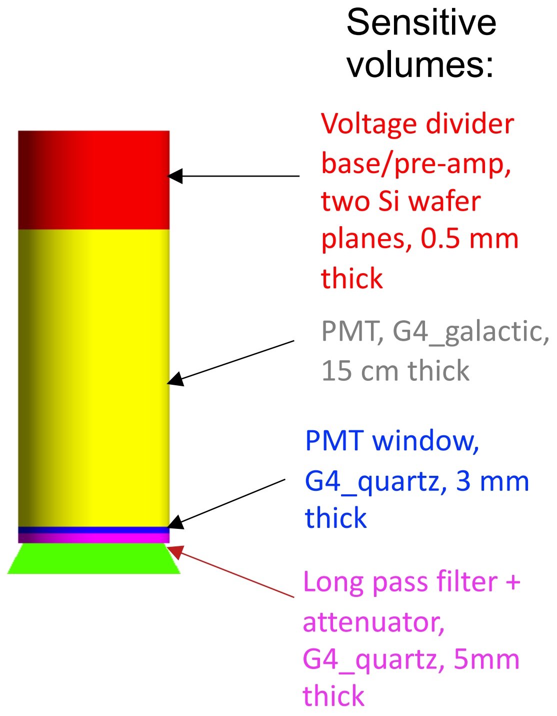
Quartz layer dose study:

Made each quartz layer sensitive for individual Open, Closed, and Transition detectors located at these specific positions



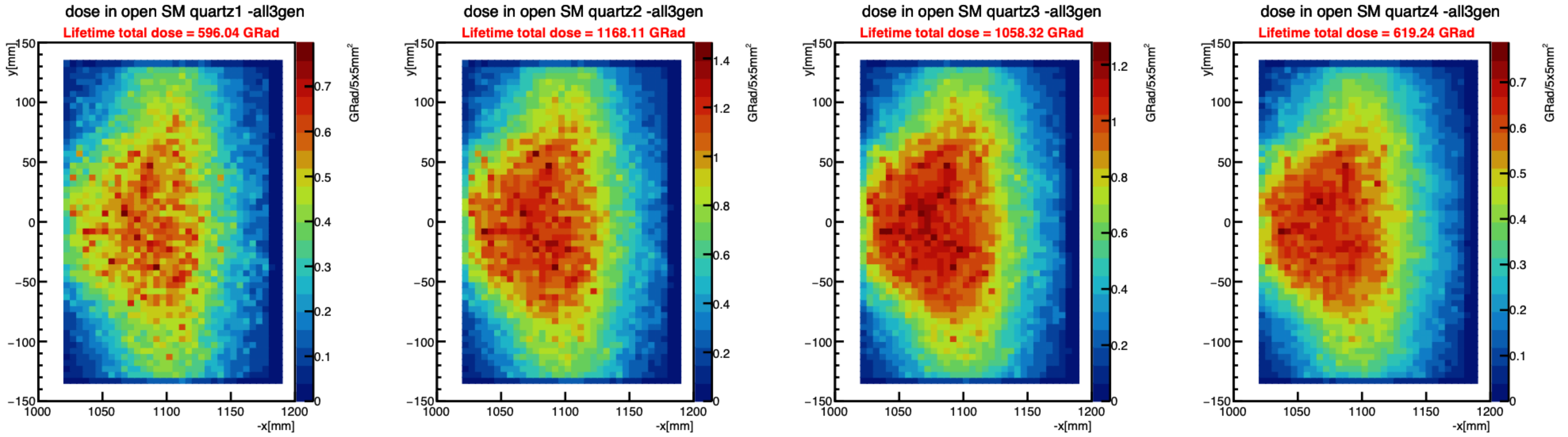
Looking downstream

PMT region dose study:



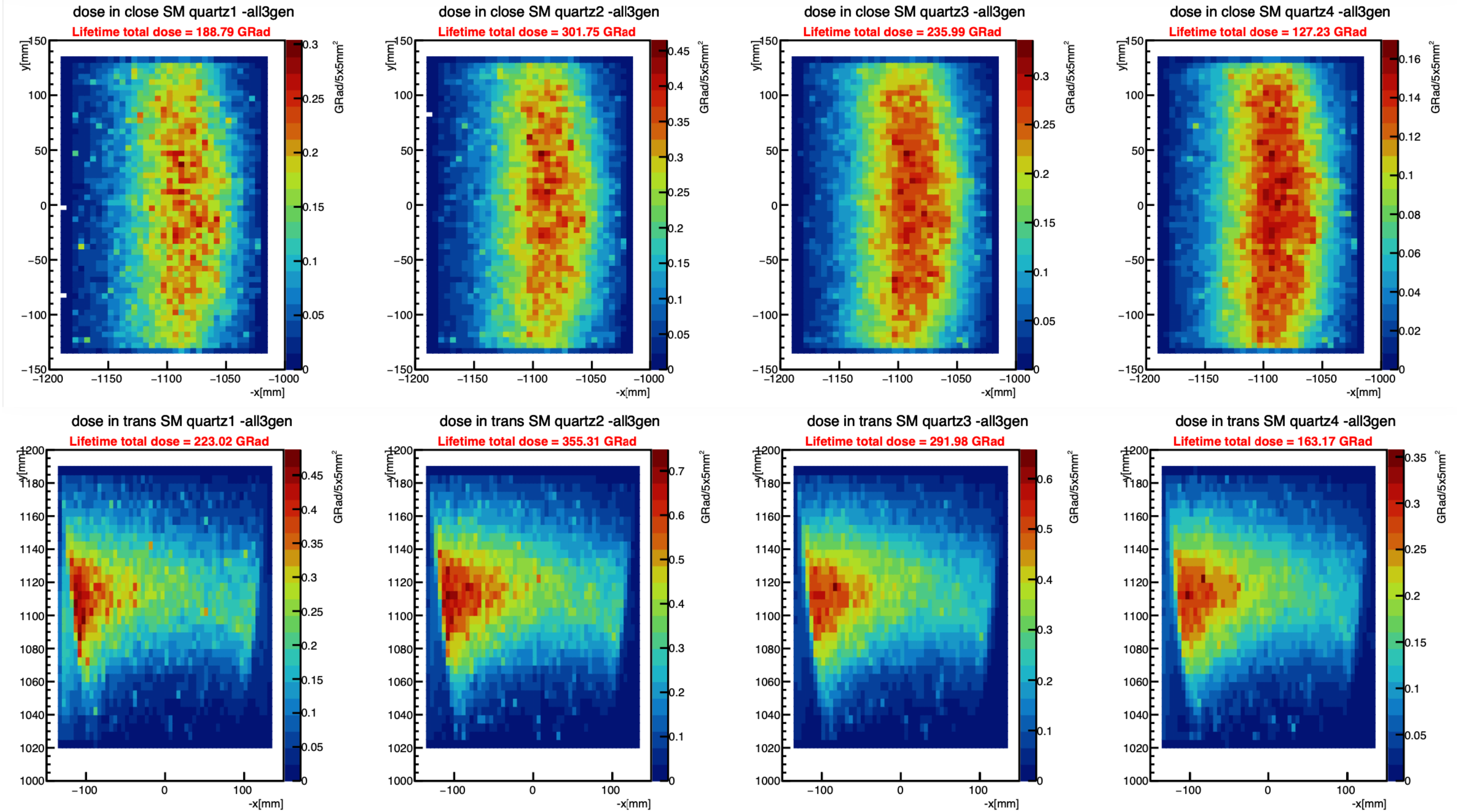
Shower-max quartz layer lifetime dose estimates

- These are Open-region detector results (worst case)



- Ran 5M Moller, ep-elastic and ep-inelastic generator events
- Peak dose density is in 2nd layer at 1.2 Grad/5x5mm^2 pixel
- Closed region are 4x lower and Transition are ~3 times lower

Shower-max quartz layer lifetime dose estimates



Shower-max long pass filter and PMT window lifetime dose

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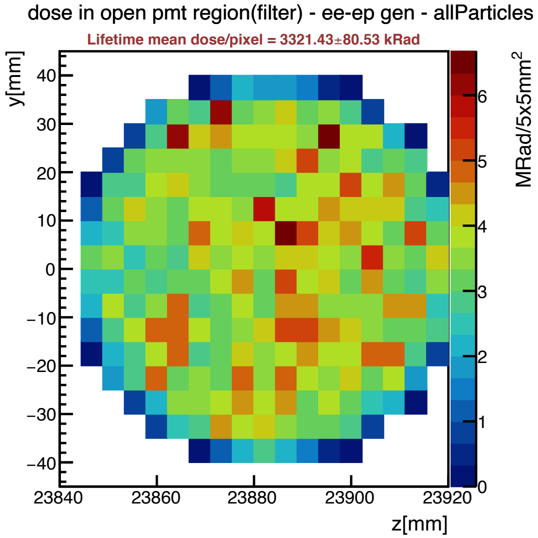
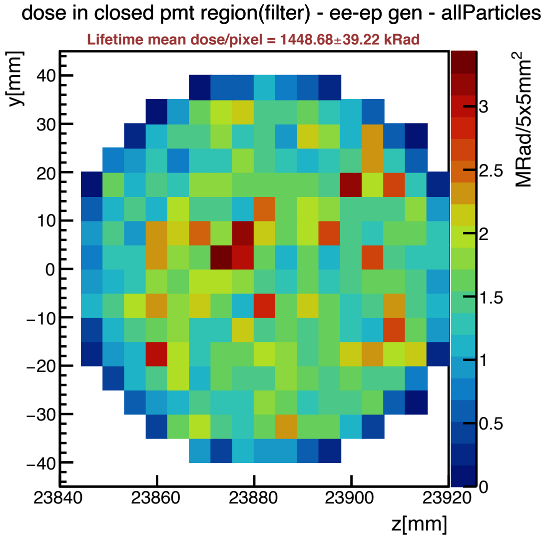
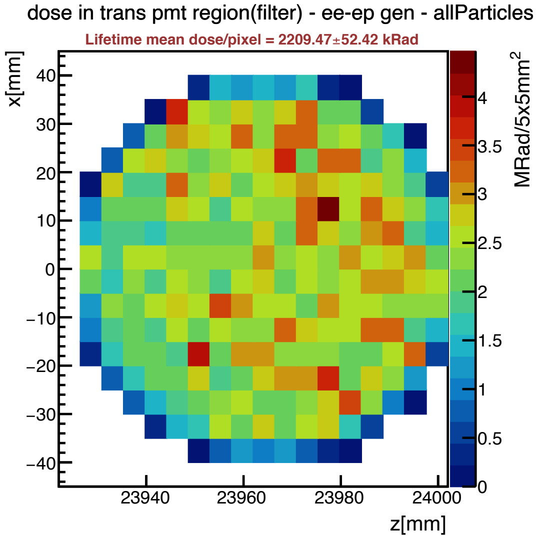
Open region | Closed region | Trans region

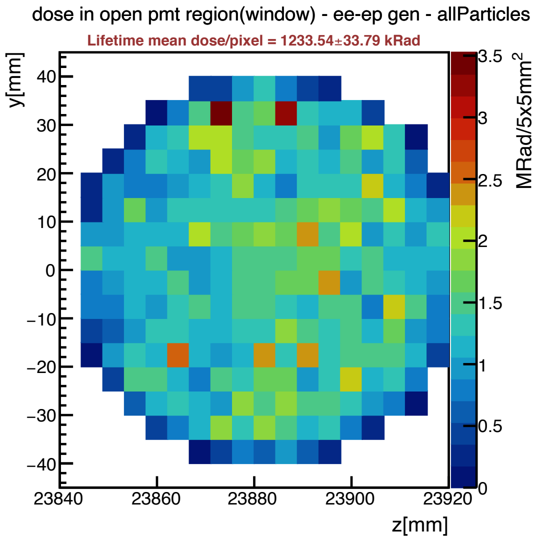
Filter region

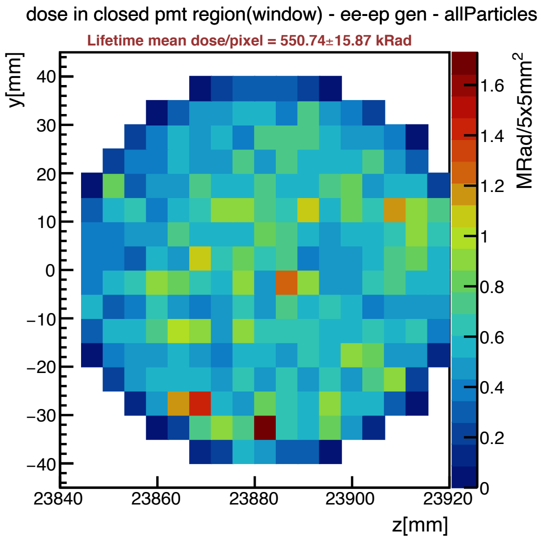


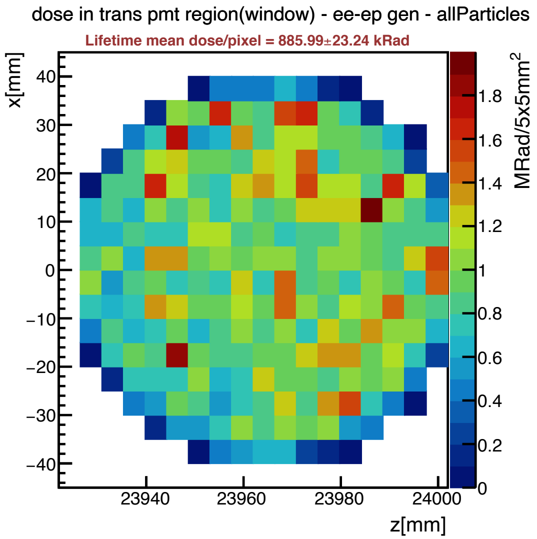




Window







Average lifetime doses (Mrad/pixel):

- Filter region:
  Open: ~3.3
  Closed: ~1.4
  Trans: ~2.2
- The 5 mm thick filter models both a 3 mm LP filter + 2 mm ND filter
- PMT window:
  Open: ~1.2
  Closed: ~0.6
  Trans: ~0.9

Shower-max pre-amp Si chip lifetime doses

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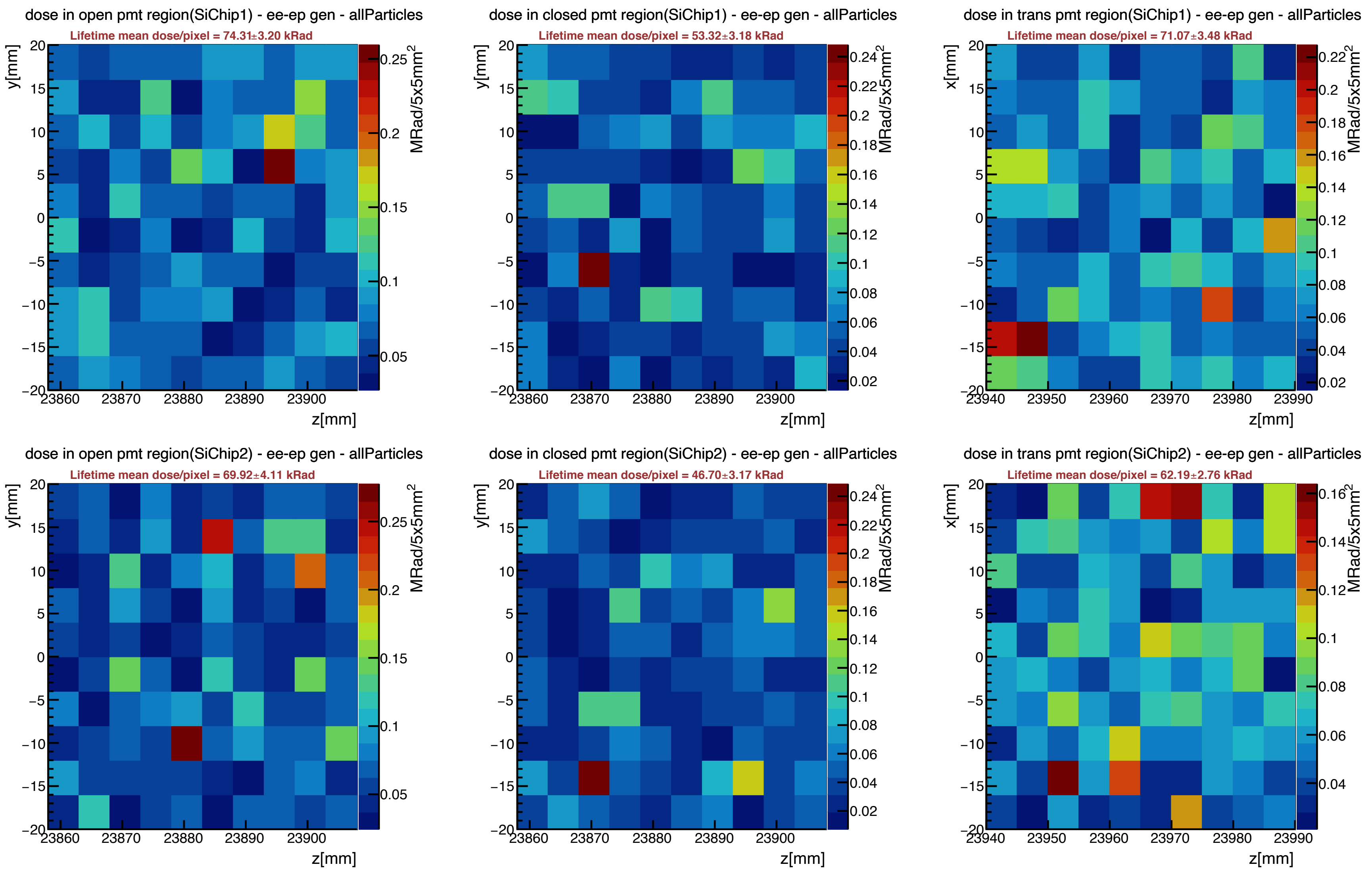
Open region | Closed region | Trans region

Inner chip plane

Outer chip plane



- Average lifetime dose (krad/pixel):

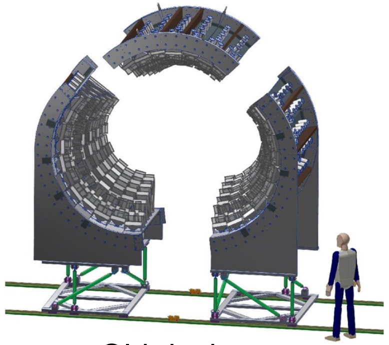
  Open: ~75
  Closed: ~50
  Trans: ~70

- Peak doses per pixel can fluctuate as high as 100 to 200+ krad

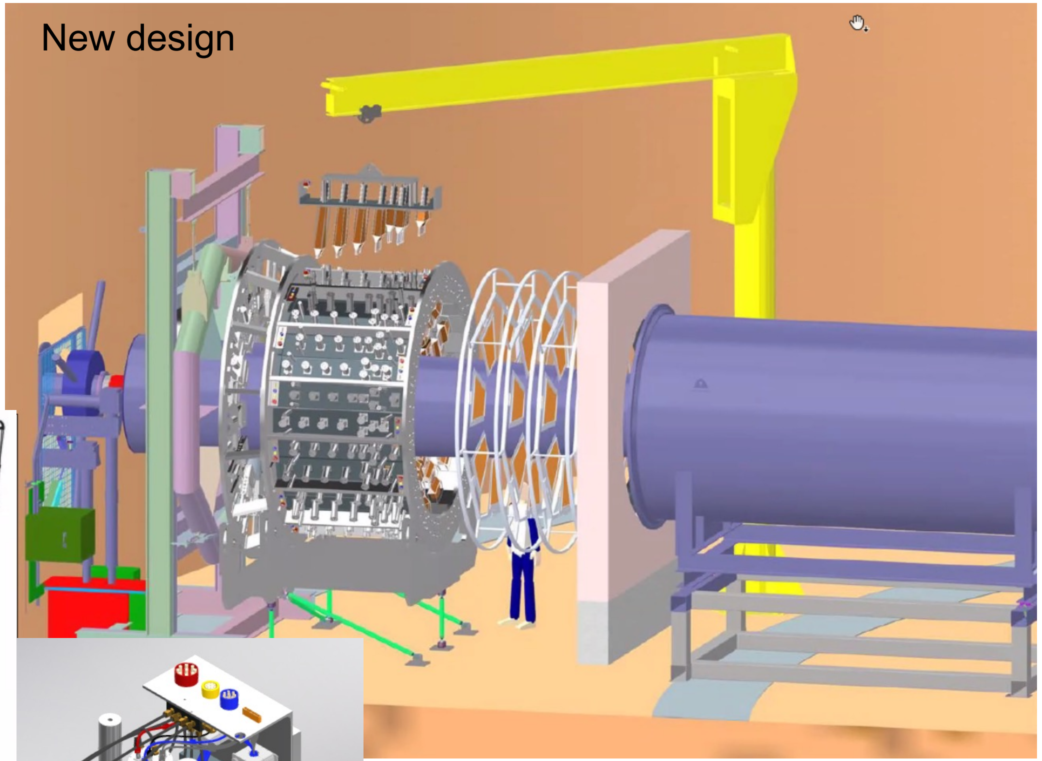
- Simulated Si wafers are 0.5 mm thick but have a huge area (4 x 5 cm^2) to give broad spatial dose sampling

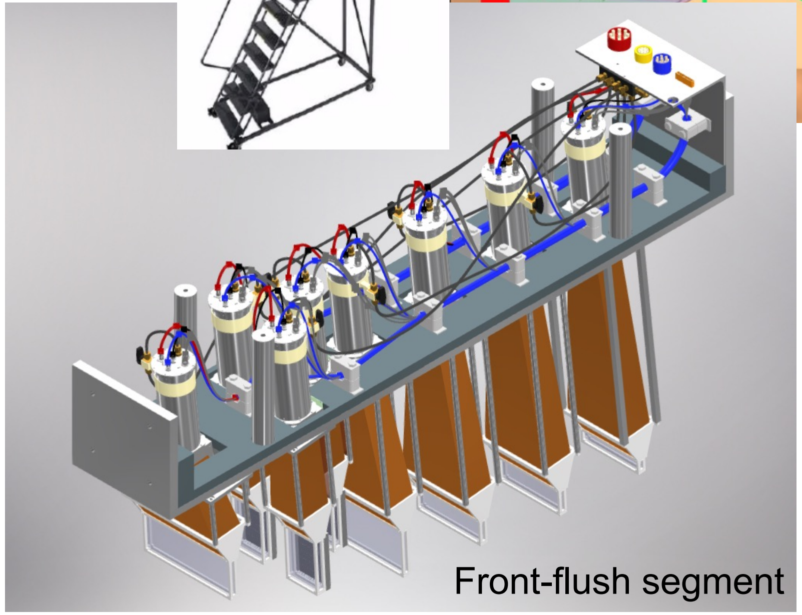
Main detector barrel logistics

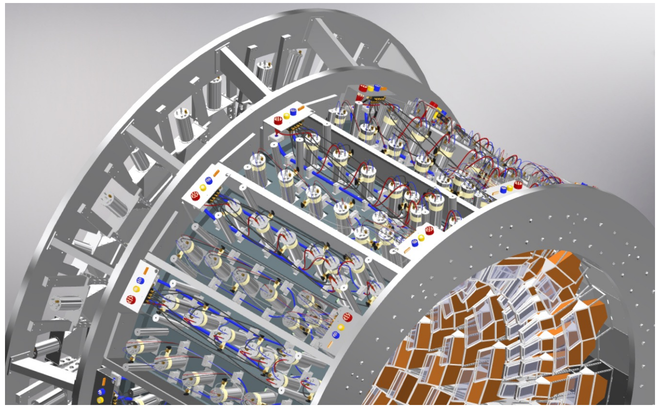
- We moved away from 3 piece design that opens to a “single” support barrel in 2 pieces that bolt around beampipe and can rotate (see Larry’s talk)
- Shower-max ring now attached to main detector barrel and all detectors rotate together
- Assembly rests on a 6 roller bearing system with cart; cart sits on 6 rod attachment support and alignment system
- Main detector lead trays with fully instrumented detector assemblies are lowered into barrel vertically from above one at a time (no robot arm)
- Main detector patch panels modified to route cables radially (not along z as before)
- Cabling harness adapted to new lead tray hole pattern and new patch panel; model for gas distribution system developed
- We are now quoting/sourcing HD plugs and receptacles for a patch panel and cabling harness prototype



Old design







Snapshot of Technical Progress (detector cabling)

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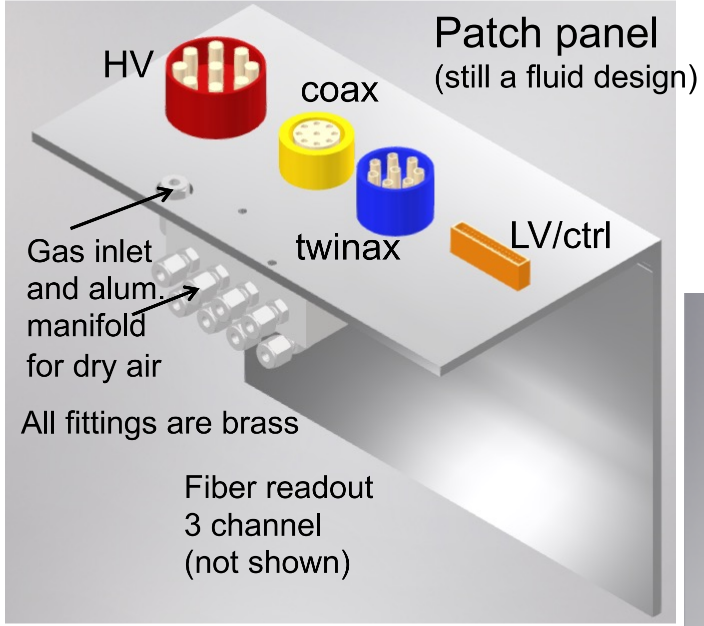


- 8 detectors per tray, each detector requires:

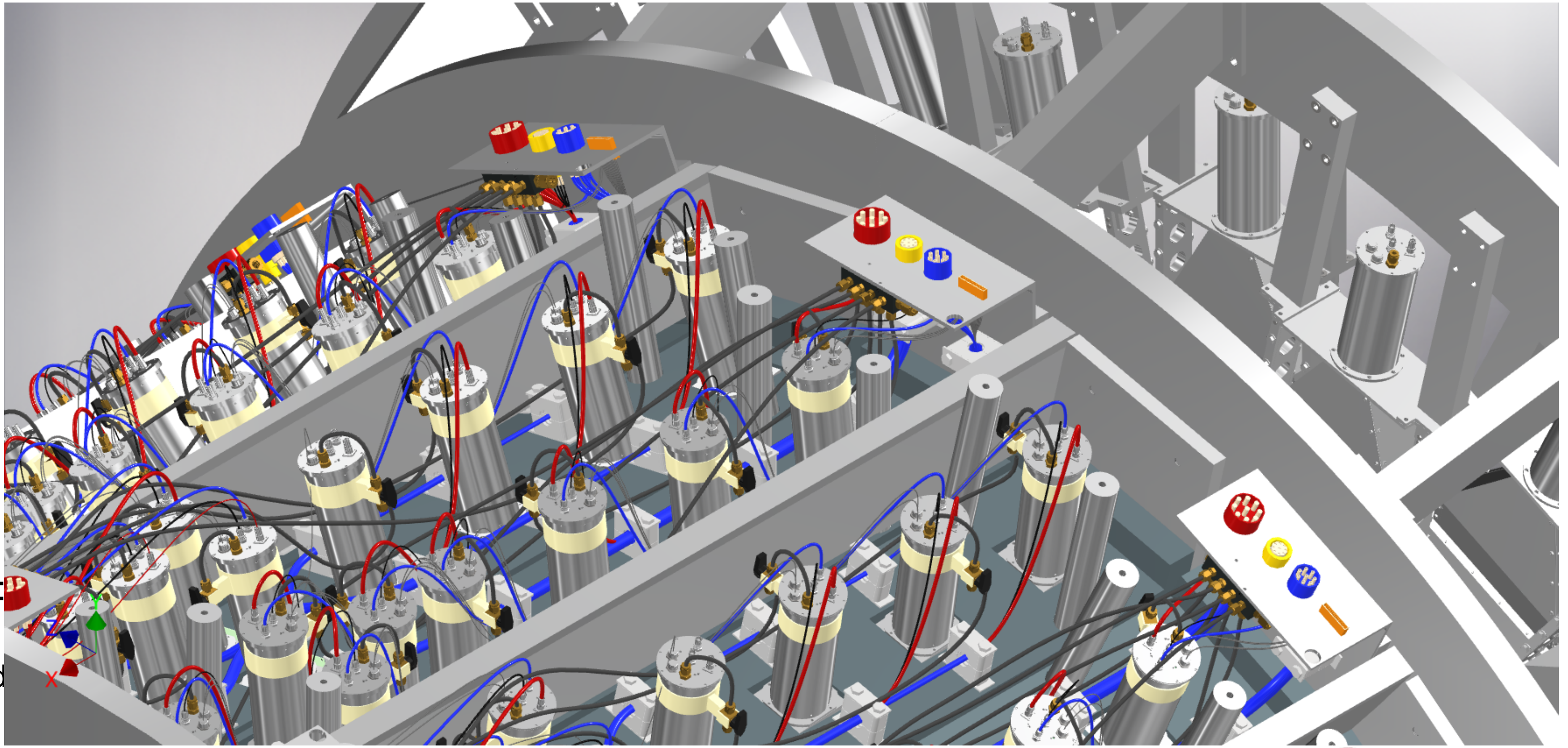
-1 HV cable
-2 signal cables (coax and twinax)
-1(2) LV control wire(s)
-1 gas inlet

- 3 HVMAPs per tray, each needs:

-1 Fiber Optic readout cable
-1 gas inlet (could use separate manifold
-several LV power wires (not shown)

Main detector cabling (CAD work by Edwin Sosa)

- Connector CAD models are place holders, but match dimensionally our candidates
- LV/control HD connector is least developed; we are moving away from ribbon style
- Gas distribution system design (manifold, tubing size, etc.) is very preliminary



Patch Panel and harness views

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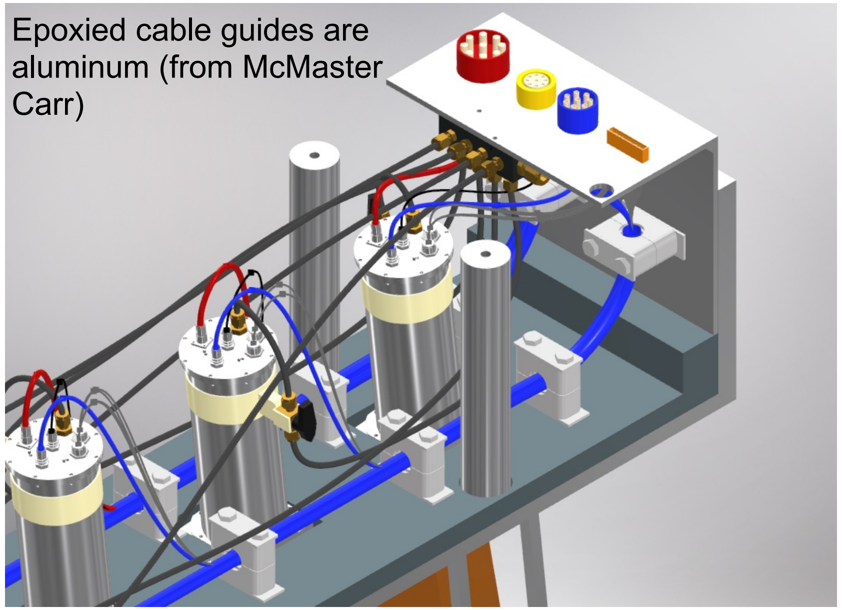
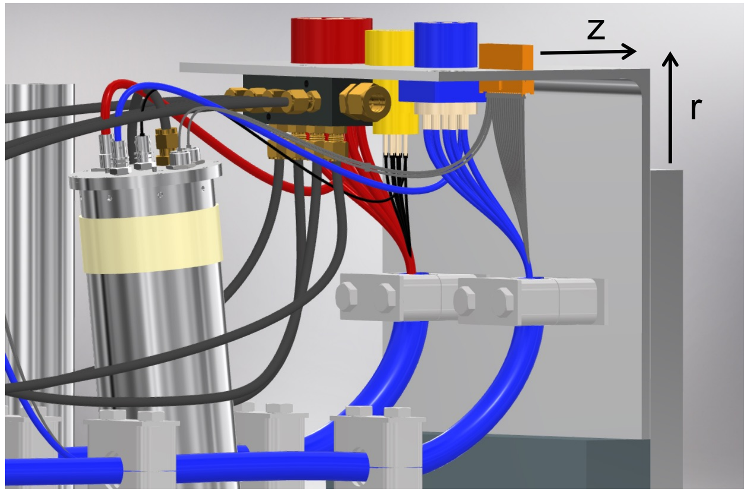
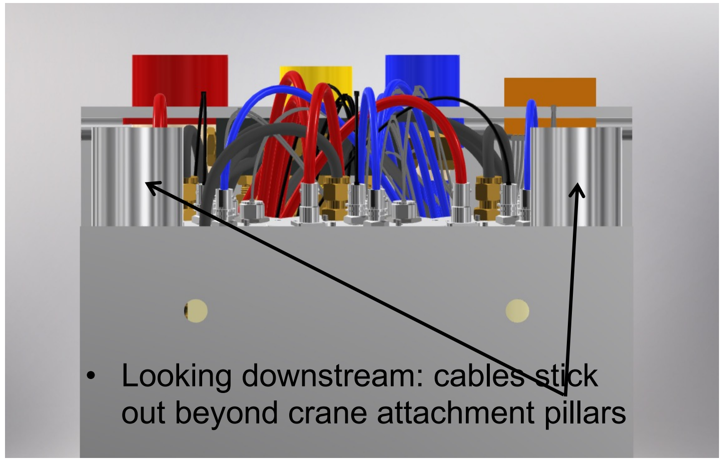


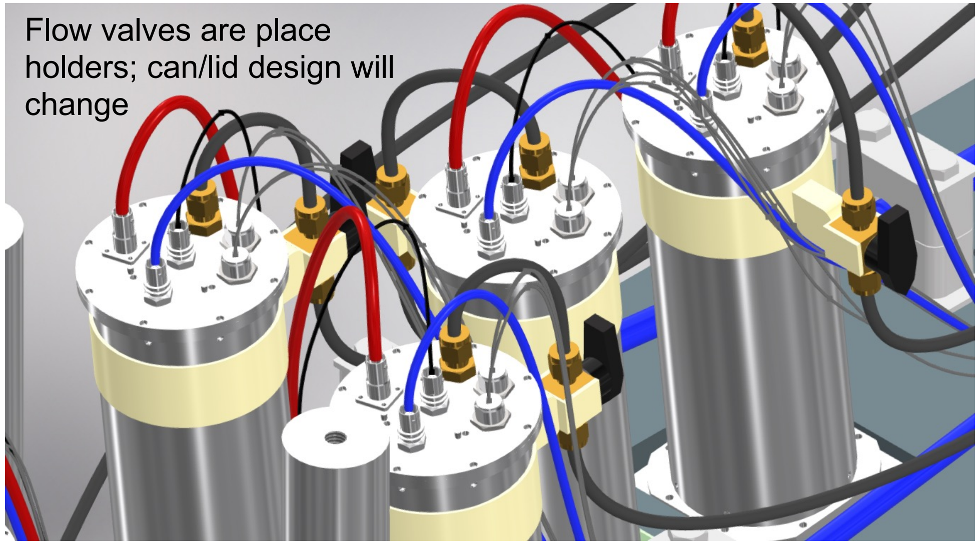
Epoxied cable guides are aluminum (from McMaster Carr)



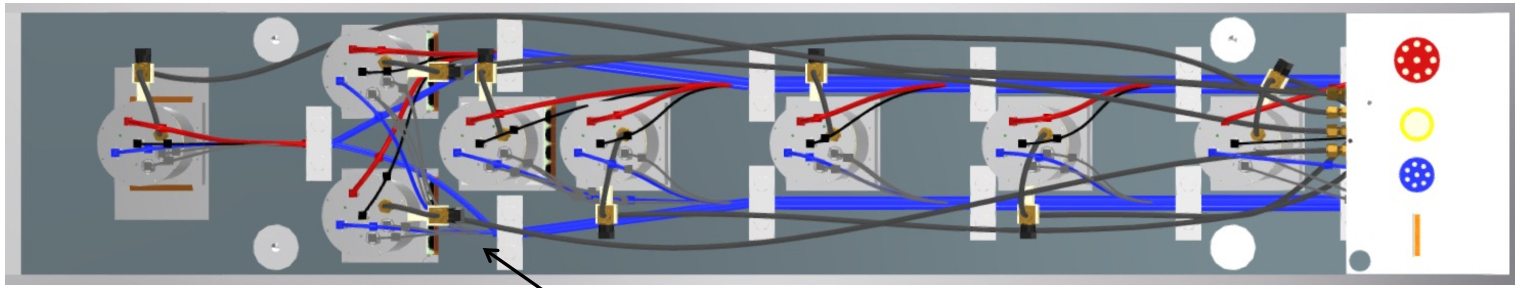
- Patch panel "L" bracket size was increased along both r and z to allow needed space



- Looking downstream: cables stick out beyond crane attachment pillars



Flow valves are place holders; can/lid design will change



- Most challenging or space constrained area is here (especially for back-flush segments)

- Manifold and tubing sizes are not set. We're showing ¼" OD nylon 12 tubing with the smaller manifold which can have 3/8" or ½" OD input tubing
- We need to determine what gas flow rates we need for the detectors and Hvmaps

High Density connectors (some candidates not available)

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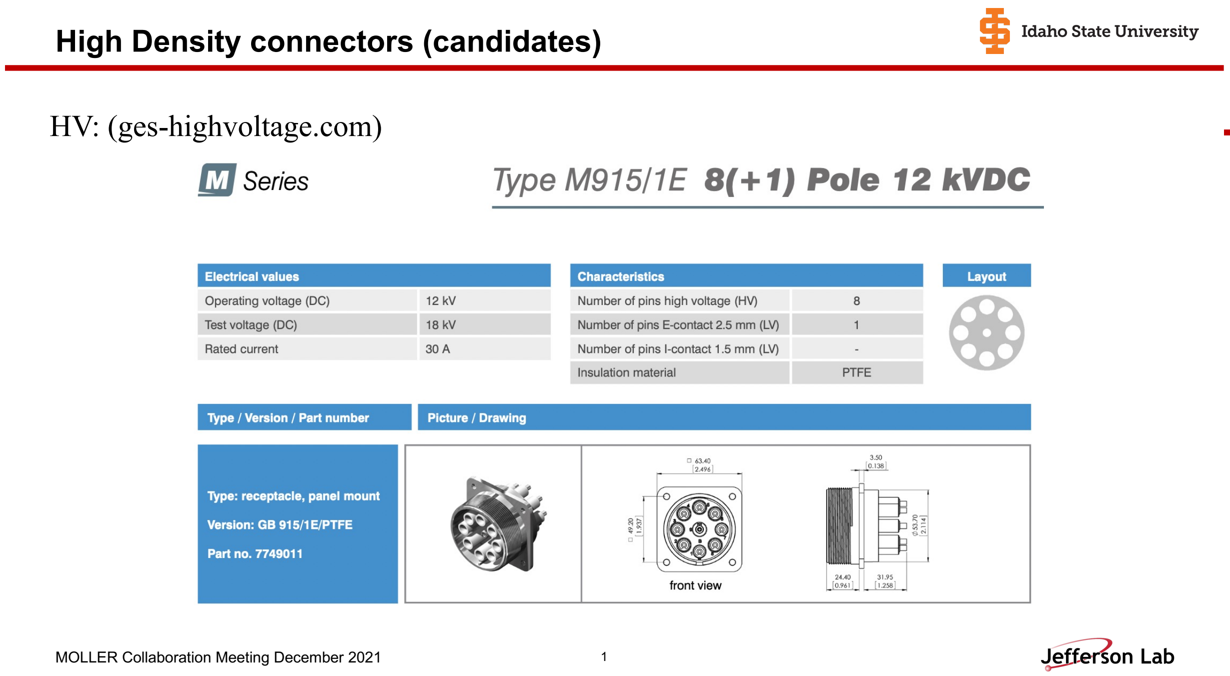
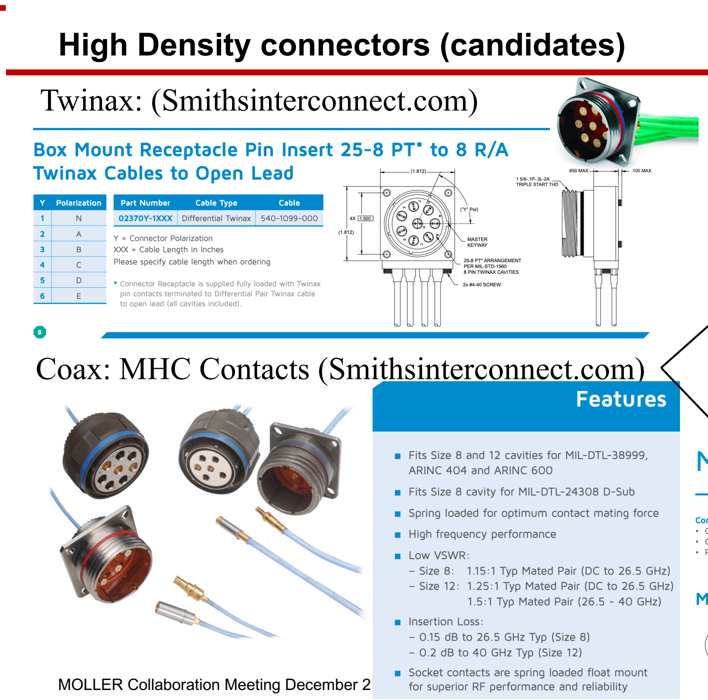
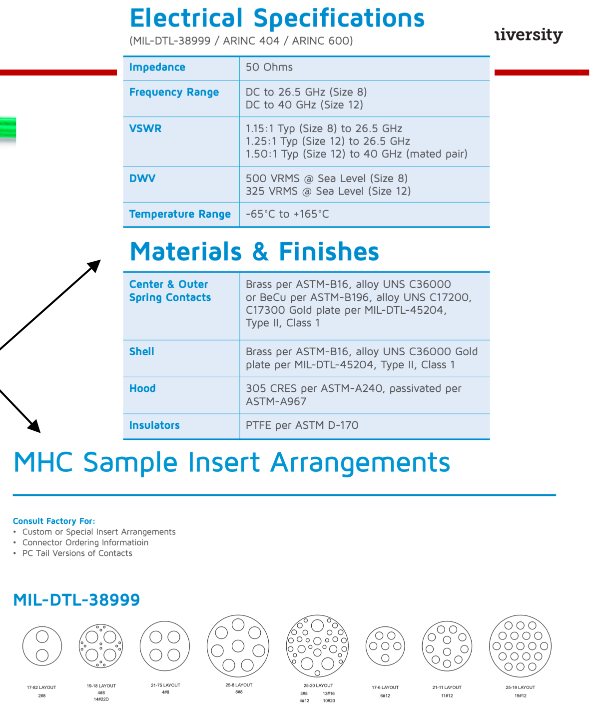






- The HV connector is available and we have a quote for receptacle and plug (we've inquired about insertion test data)

Line	Part No	Description	Qty.	Unit Price	Total
1.	7749011	GB 915/1E PTFE receptacle, panel mount, 9-pole 8x HV pins, female contacts 2.7mm silver plated 1x earthing pin, female contact 2.5mm silver plated	2 ea	$275.55	$551.10
2.	7490417	KS 915/1E PTFE Sym KV plug, cable mount, 9-pole, symetric cable gland 8x HV pins, male contacts 2.7mm silver plated	2 ea	$316.03	$632.06
					$1,183.16 $1,183.16

- There is also an 8 conductor HD HV cable you can get for these which we are investigating (for routing HV inside trays)

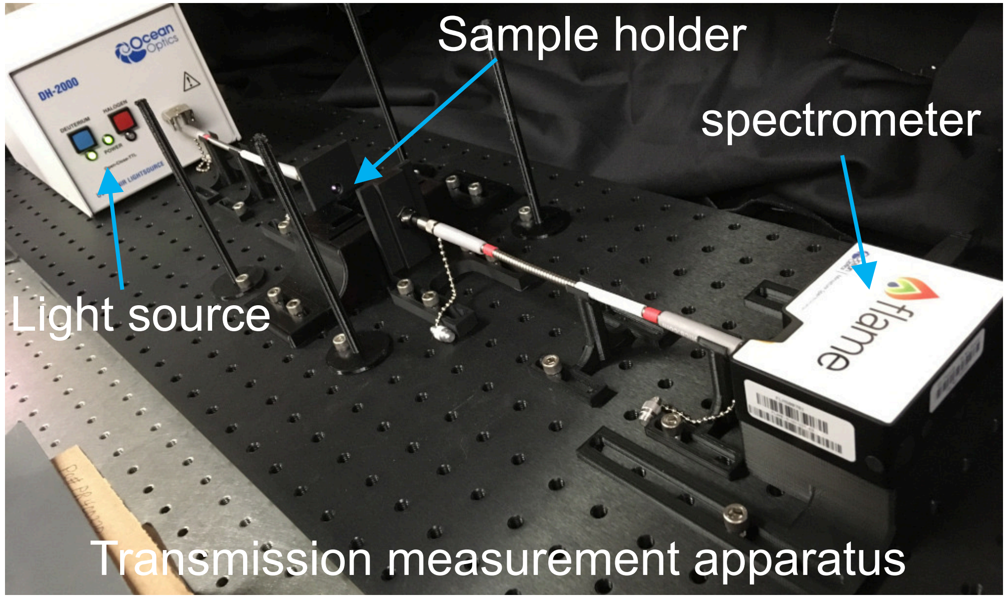
- The twinax connector is no longer actively supported by Smiths Interconnect, but they pointed us to comparable part and supplier (TTI inc.) which we are investigating

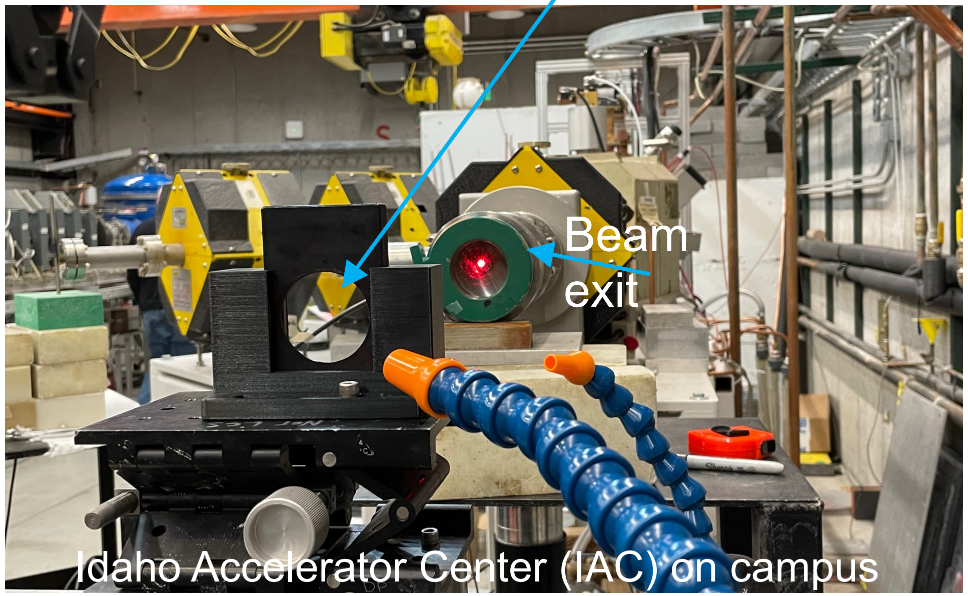
- Still waiting to hear about the coax rec. and plug availability

Quartz radiation tests completed

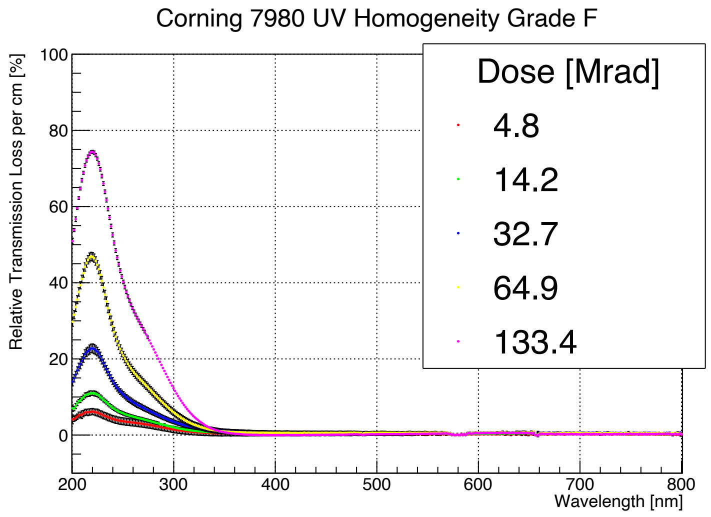
- Goal: quantify light transmission losses in detector radiators due to damage from anticipated radiation dose (for lifetime of MOLLER) – 45 Mrad peak and 120 Mrad peak per 5x5 mm^2 for ring 5 and ring 2, respectively
- Five candidate artificial fused silica (quartz) samples chosen for testing: from Corning, Ohara, and Heraeus
- Irradiations conducted at the Idaho Accelerator Center using 8 MeV pulsed electron beam, ~40 mA peak current, ~1 μs pulse width (~40 nC/pulse) at 200 Hz repetition rate; samples are 50 cm from beam exit window
- Dose deposition quantified with G4 simulation benchmarked to beam dose profile and source measurements
- Work by Justin Gahley; report in [docDB #886]

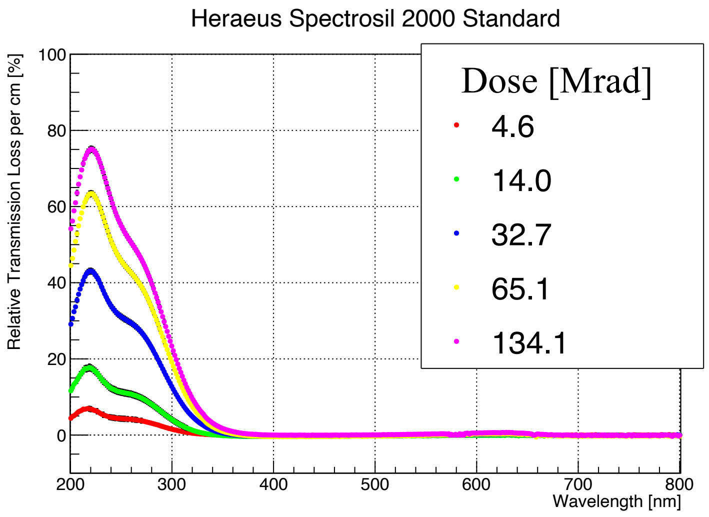
Samples: 5 cm diameter or square, 1 cm thick; polished faces

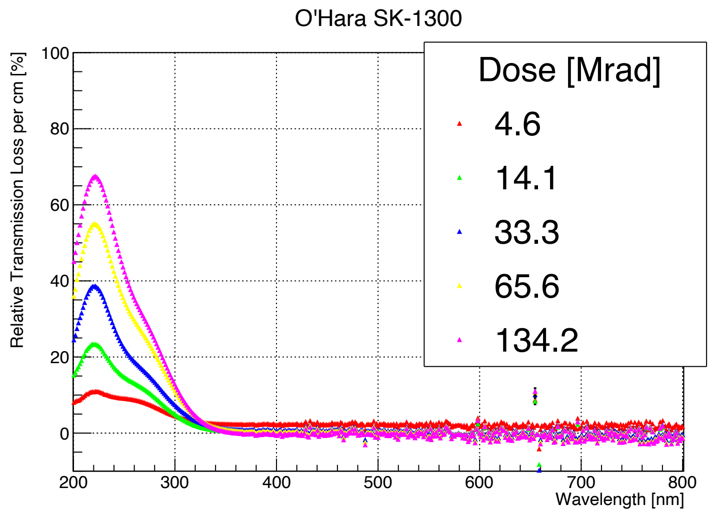


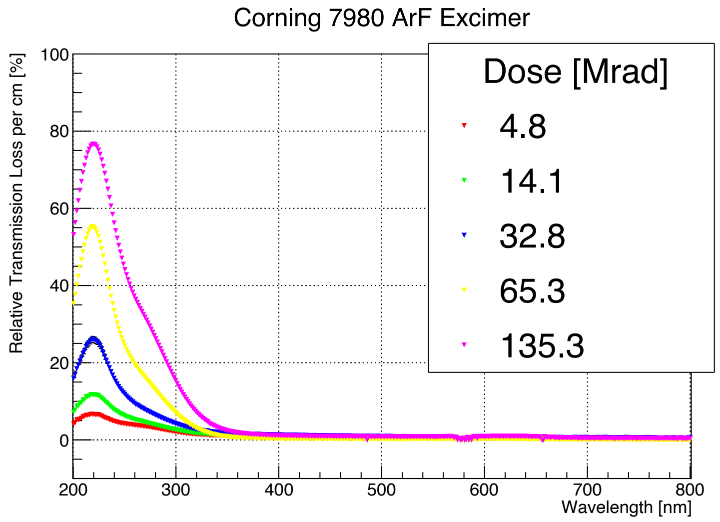


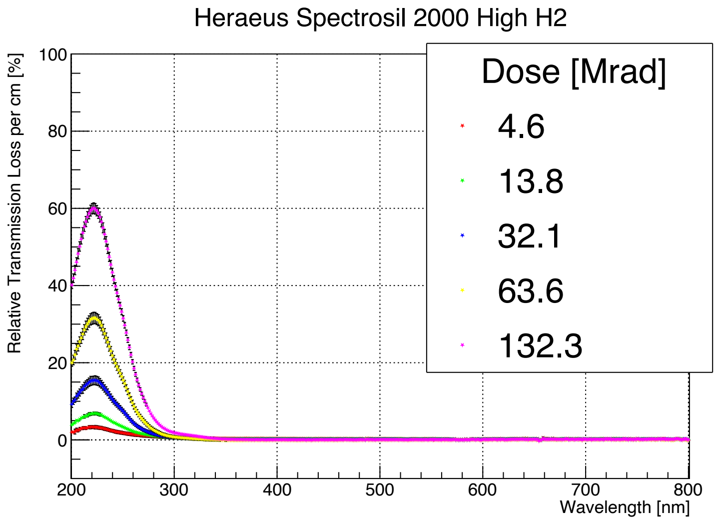
Quartz radiation-hardness results: light loss











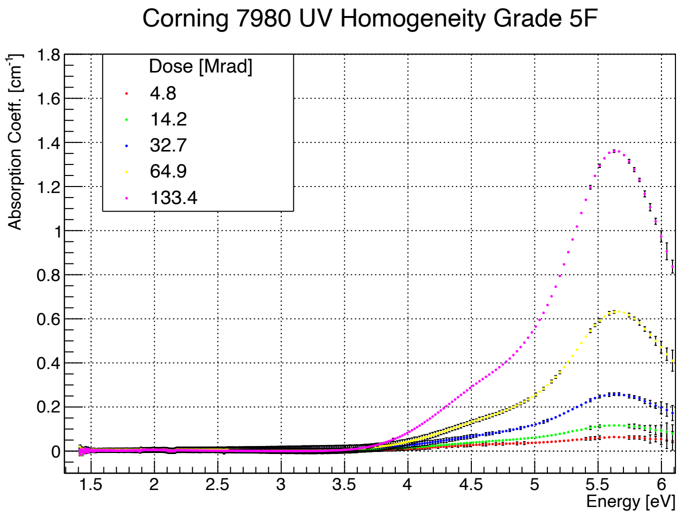
--All samples are wet (> 200 ppm OH content), except SK-1300 which is dry; doped Heraeus has high OH and high H2 content

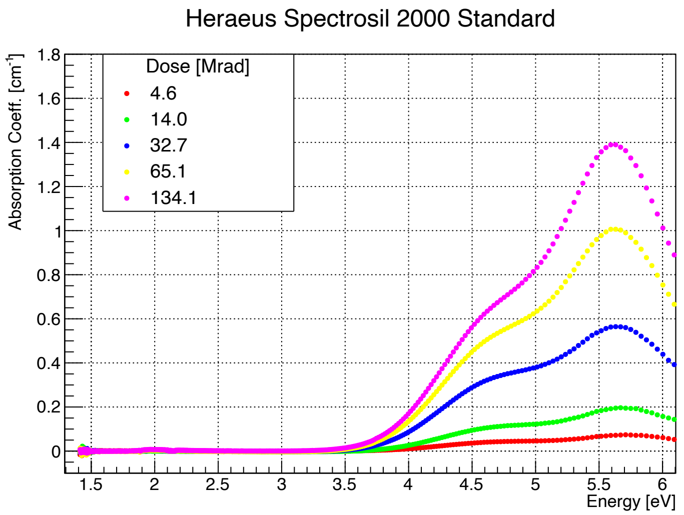
--Main absorption center at 5.6 eV is the E' – unavoidable point-like defects that cause dangling Si atoms which absorb light

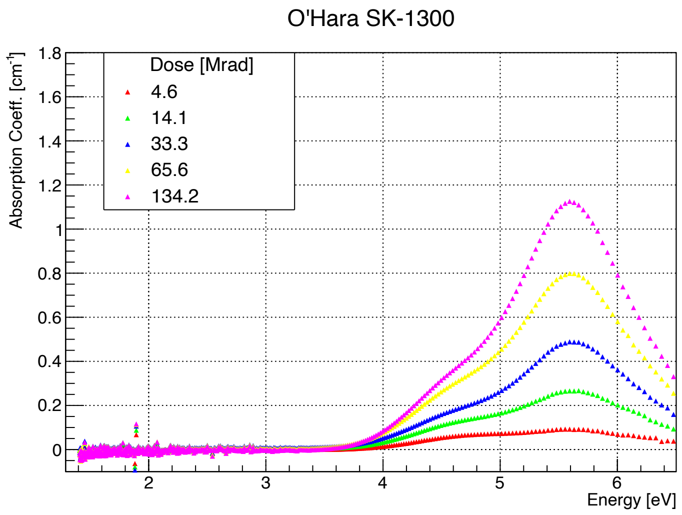
--The shoulder structures are from non-binding hydroxide absorption centers around 4.5 – 5 eV

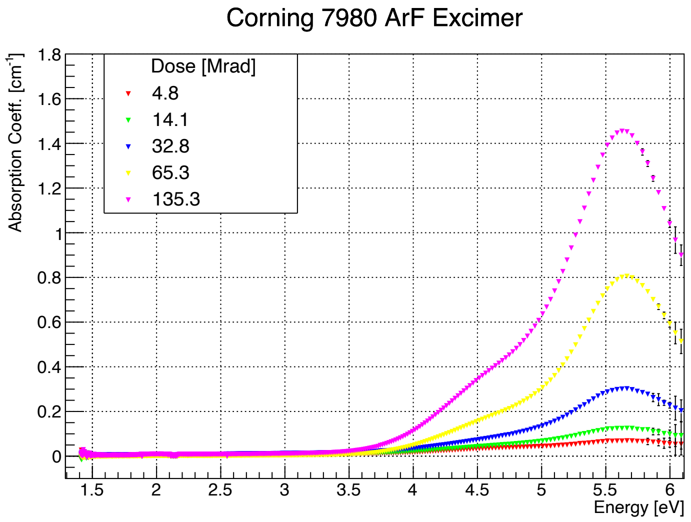
--the doped Heraeus shows very little of this damage center at our doses

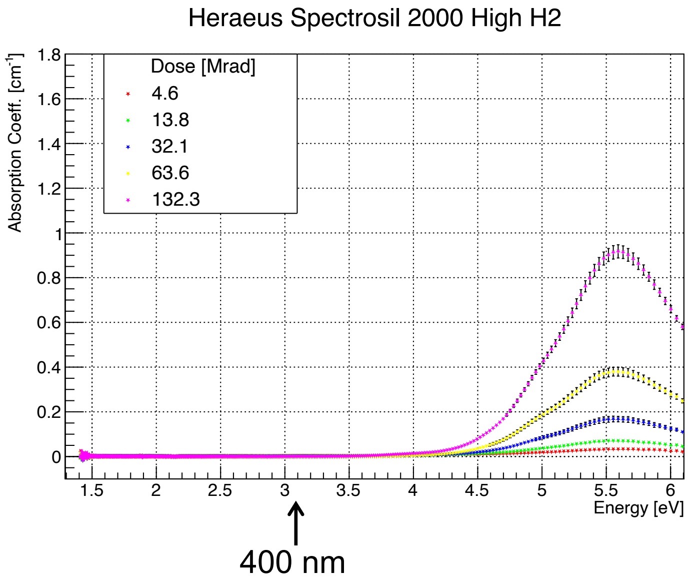
Quartz radiation-hardness results : Absorption Coeff's



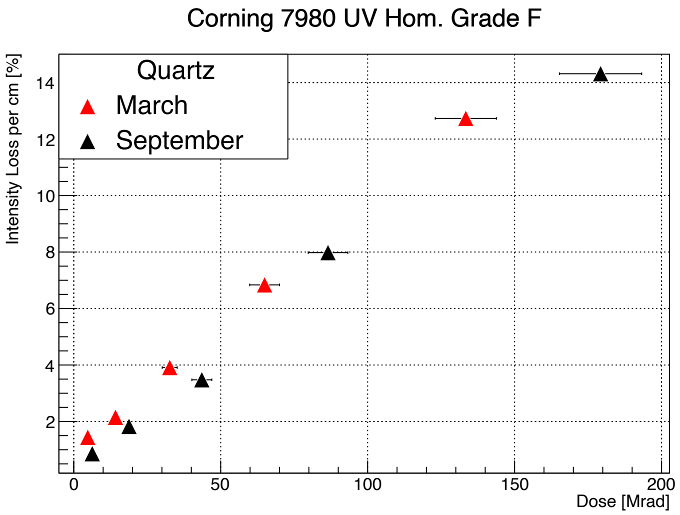


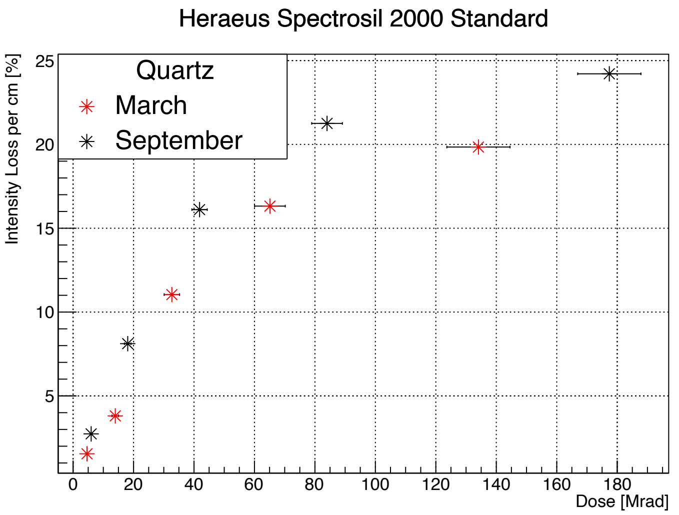


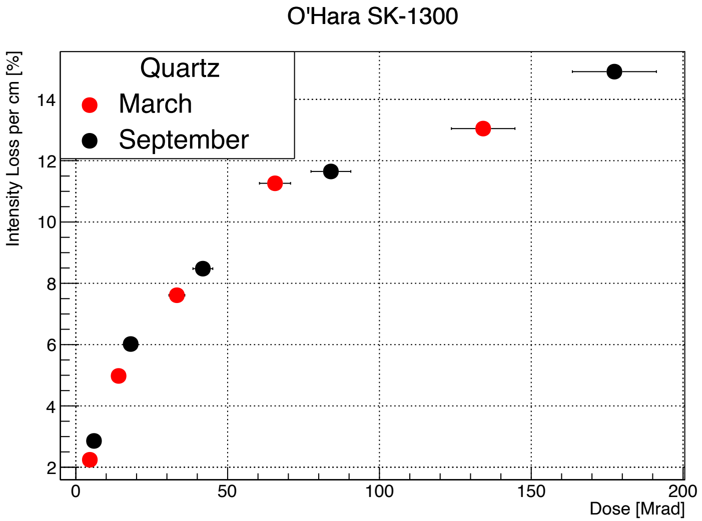


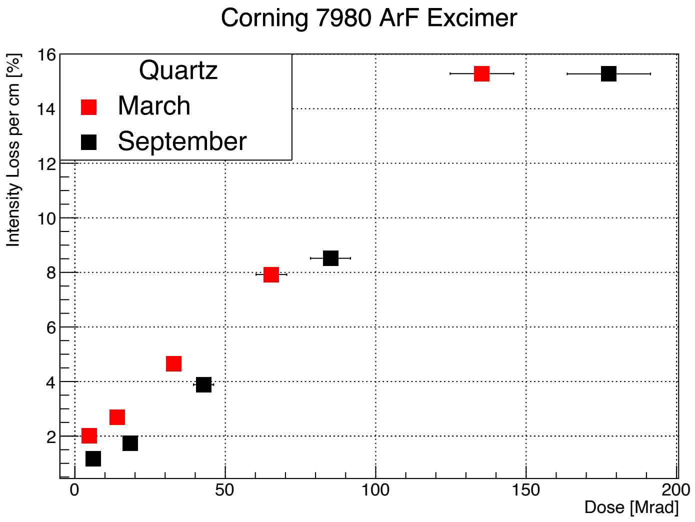


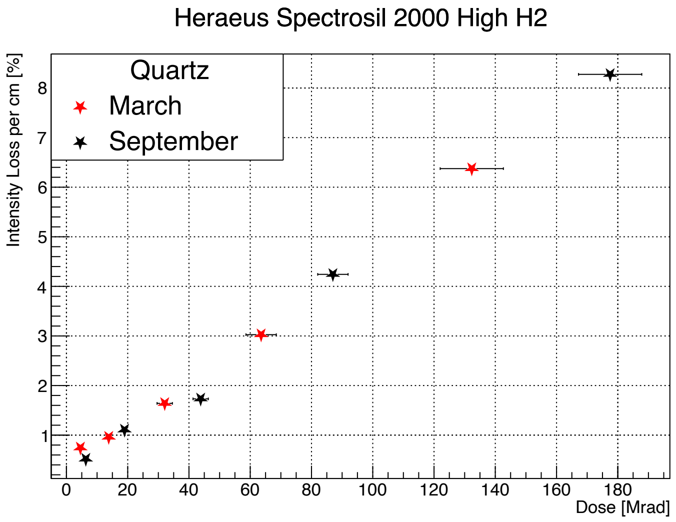
Quartz radiation-hardness results : loss vs. dose

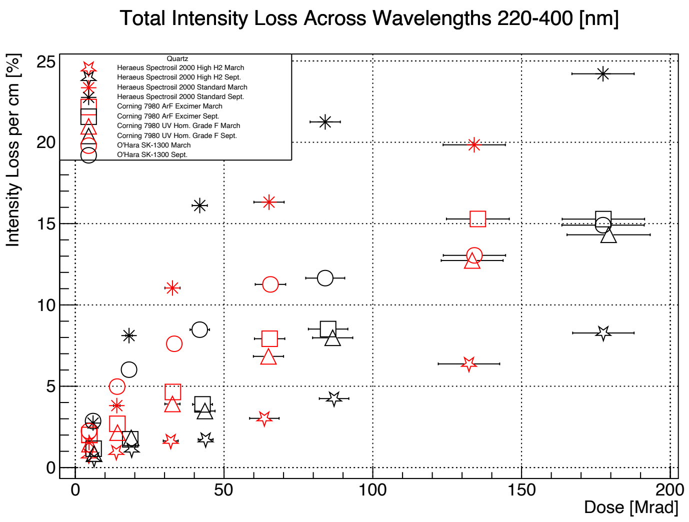










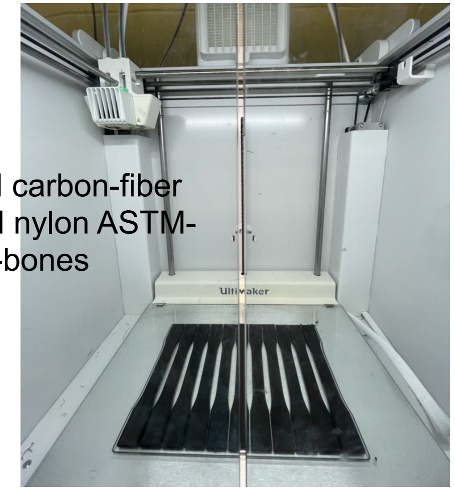


Plastic radiation tests started

- We performed our first radiation test of 3D-printed plastic dog bone samples (ASTM D638) last week
- New student, Jared Insalaco, started working on this last winter
- We printed 30 each of ABS, Nylon, and tough PLA samples, and irradiated 10 of each type to 1, 5, and 20 Mrad
- We break them in tensile strength machine and measure elastic moduli and yield strength. These can be compared to baseline (no beam exposure) samples and maybe literature; will have first results soon
- We also started printing carbon and glass embedded nylon and plan to mainly test these materials moving forward

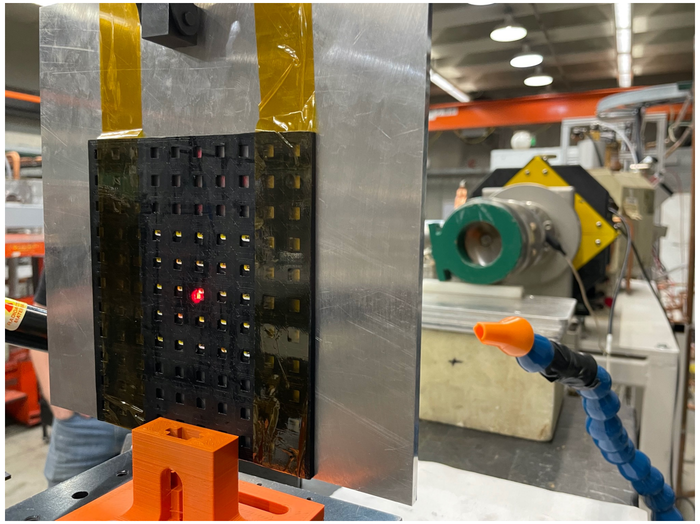
Plastic radiation tests started

Irradiated 90 dog-bone samples on 6/16/2022

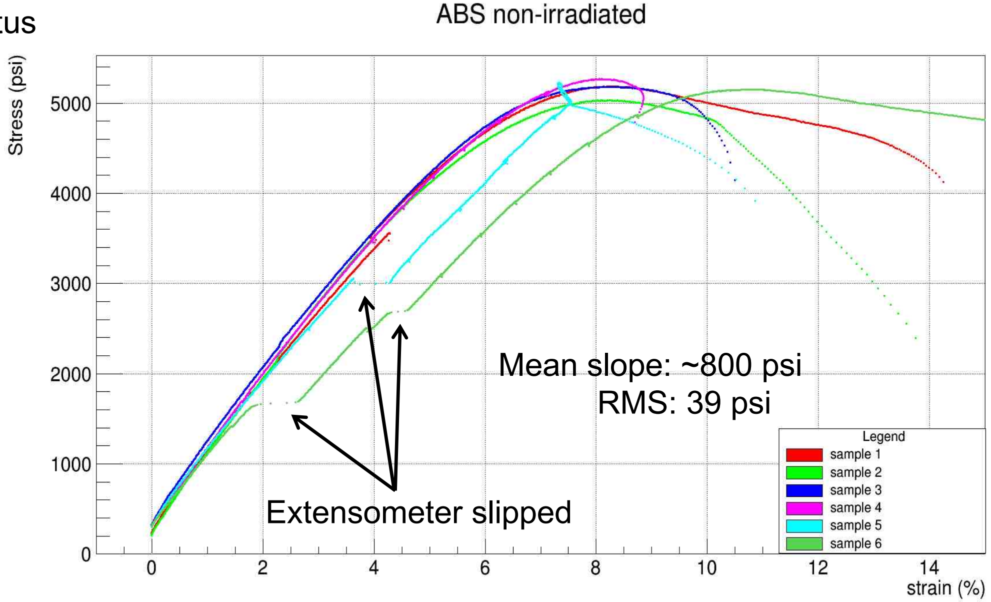


3D-printed carbon-fiber embedded nylon ASTM-D638 dog-bones

Nanodot OSL array beam dosimetry



Tensile testing apparatus



Radiation tests summary and future work

- Quartz radiation damage study completed; the data needed to inform our optical simulations is in hand
- Dose estimates for our radiation tests are at 10% level
- Heraeus high H_2 doped Spectrosil 2000 is best performing (clearly) – ~no shoulder structure in losses. The standard Spectrosil 2000 is worst performing sample – it has greatest light loss above 15 - 20 Mrad dose
- We've tested 2" LP filters made with Corning 7980 to ~10 Mrad; we found no or little measurable loss
- We ordered 3" LP filters, also Corning 7980 (two each: 350 and 400 nm) and will radiation test one of them
- We also ordered three Tosoh fused silica 1 cm thick, 5 cm round samples for radiation testing
- Plastic radiation tests will continue to ramp up over summer and electronics test planning is starting

Detector logistics summary and future work

Idaho State University

- New support ring/barrel model with cart well underway (details in Larry's talk, next)
- Patch panels and cabling harness adapted to new barrel and lead tray design
- We have a first-pass modeling of the gas distribution system for the main detectors; engineer advice welcome
- HD connector vendors have been contacted; some quotes in hand; developing prototyping plan for building a full scale patch panel and cabling harness.
- We plan to revive the z-positions CAD (from last fall) this summer to incorporate all design updates
- Adjustments to the cabling harness will be made following final tweak to the lead tray design; also need to finalize all needed cables, gas lines, and especially LV wiring for each 1/28 segment and then try to make it all fit
- We are ready to start modeling the external barrel cabling, but feel we need some input from engineers related to keep out zones and cable tray location(s)/height, etc.; we could use a brain storming meeting to get going

Shower-max progress summary and future work

Idaho State University

- Shower-max prototyping well underway; hope to have fully functional detector by end of summer
- We plan to test with cosmic-rays combined with simulation and MAMI testbeam; we will implement Qsim for the new shower-max design to get light yield predictions
- Remoll dose simulations for shower-max will continue to be checked and refined. In particular, the dose in shower-max preamp chips could be too high or close to the limit (but not sure yet)
- An important consideration is the anticipated cathode light level for shower-max during production running; this depends on detector light yield which is quite high but not accurately benchmarked in testbeam (yet); we will use ND filters if needed to reduce pmt cathode current to < 50 nA and may need unity gain voltage divider for integration mode for linearity and dynode lifetime considerations
- We have re-established Devi's non-linearity test setup at ISU and new student starting using the system last month (Sagar Regmi); we flash LED at 960 Hz and for now use Qweak/PREX electronics signal chain and factory voltage divider. We've started with 10 nA cathode current and begun a PREX-2 style non-linearity characterization using our assortment of TRIUMF QWeak preamps (from 100k – 1 Mohm); we will replace with MOLLER electronics when available
- ISU group will be advertising for a post-doc to join the project very soon