Technical Progress Since CD-1

Detector mechanics update:

- Main detector support structure designed: 2” thick aluminum barrel framing in three sections; supports 28 Pb-shield segments (trays) having 8 individual thin quartz detector assemblies each (total of 224 detectors)
- Beamline z-locations of various detector systems are set; in coordination with engineers/drawings and physicist’s simulation geometries
- Cabling considerations incorporated into main detector support structure; have first design of patch-panel and internal cabling harness for barrel Pb trays
- External cabling considerations for main barrel underway: cable bundles route along outer faces of Al. frame and come out radially on each side of beamline in two groups; a cable relief system with curtaining allows opening and closing the lower two barrel portions.

ShowerMax update:

- Detector ring location and size near finalized; updated CAD model with reinforced module support chassis passed on to engineering support for a FEA and to design the clam-shell ring support structure.

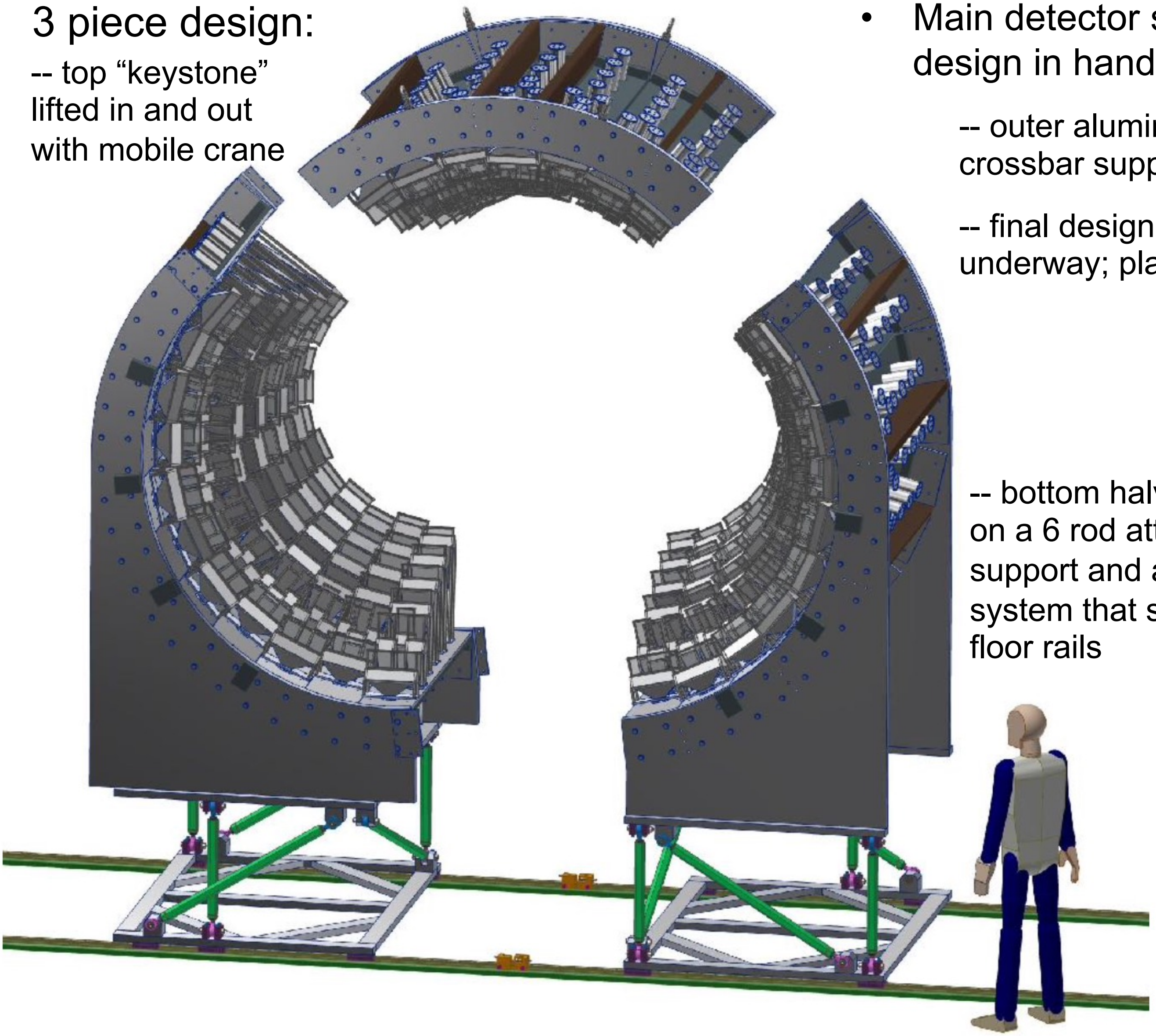
Quartz radiation hardness update:

- Testing five different types of artificial fused silica for use as radiators in Main detector and Shower-max
- Measure light transmission loss versus λ (200 – 800 nm) following peak dose exposures of 70 – 170 Mrad per 5x5 mm^2 active radiator area

Technical Progress Since CD-1 (Detector Mechanics)

3 piece design:

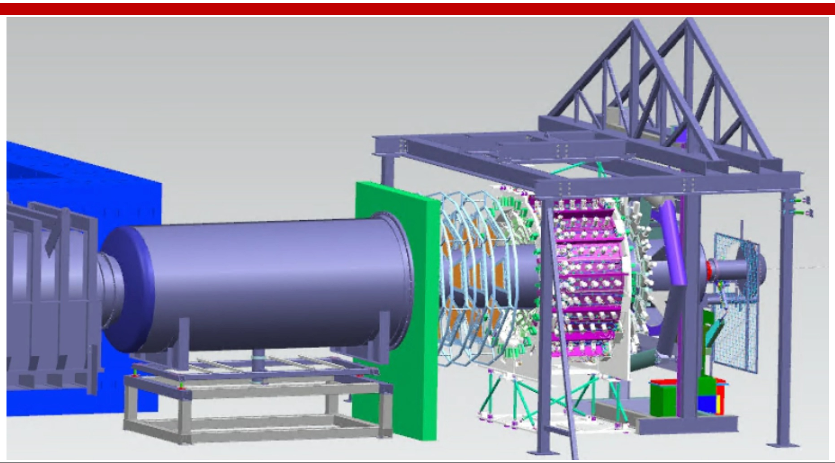
-- top “keystone” lifted in and out with mobile crane



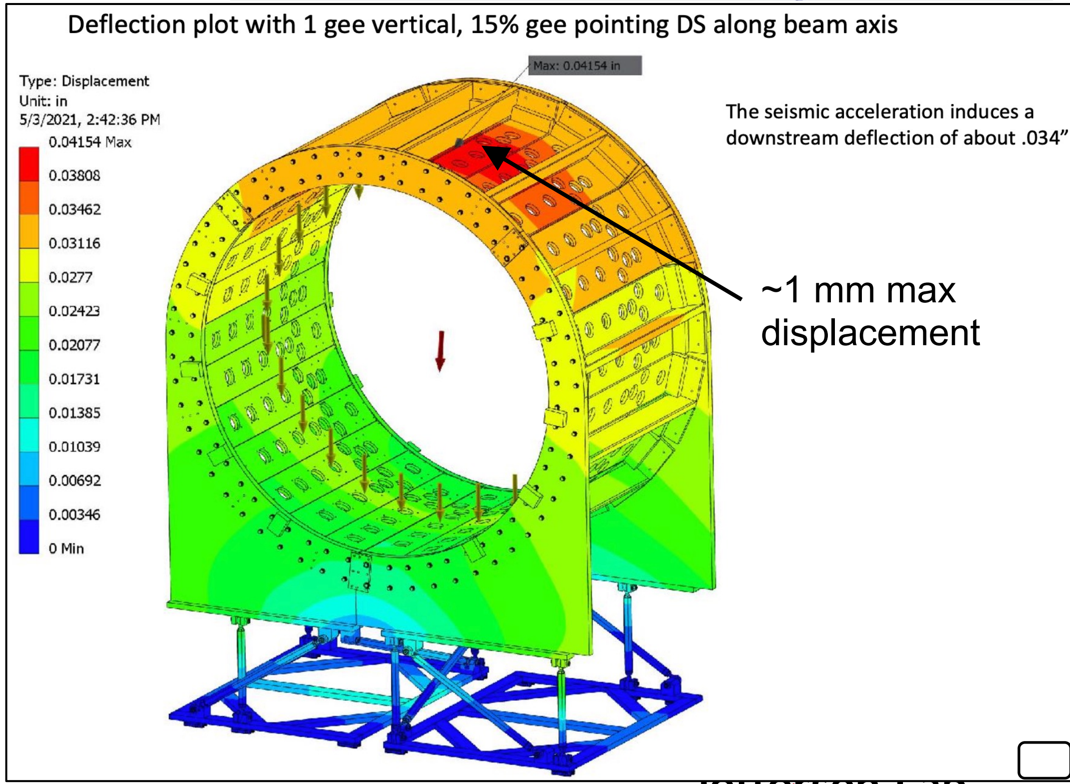
- Main detector support structure design in hand:

  -- outer aluminum framing and crossbar supports quoted

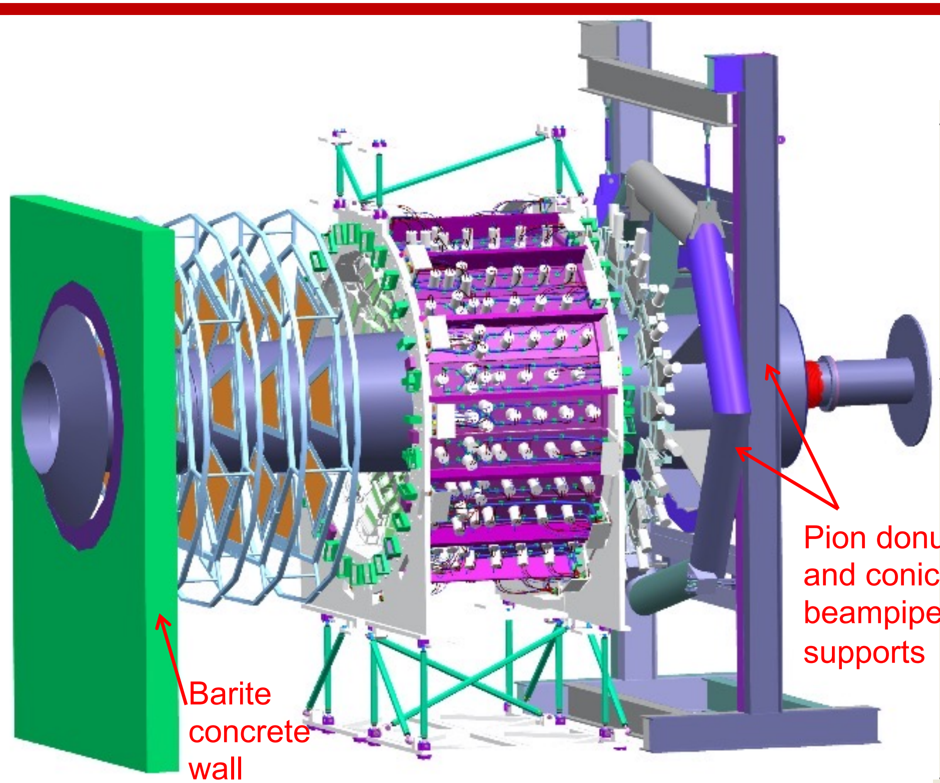
  -- final design of Pb trays underway; plan to quote next



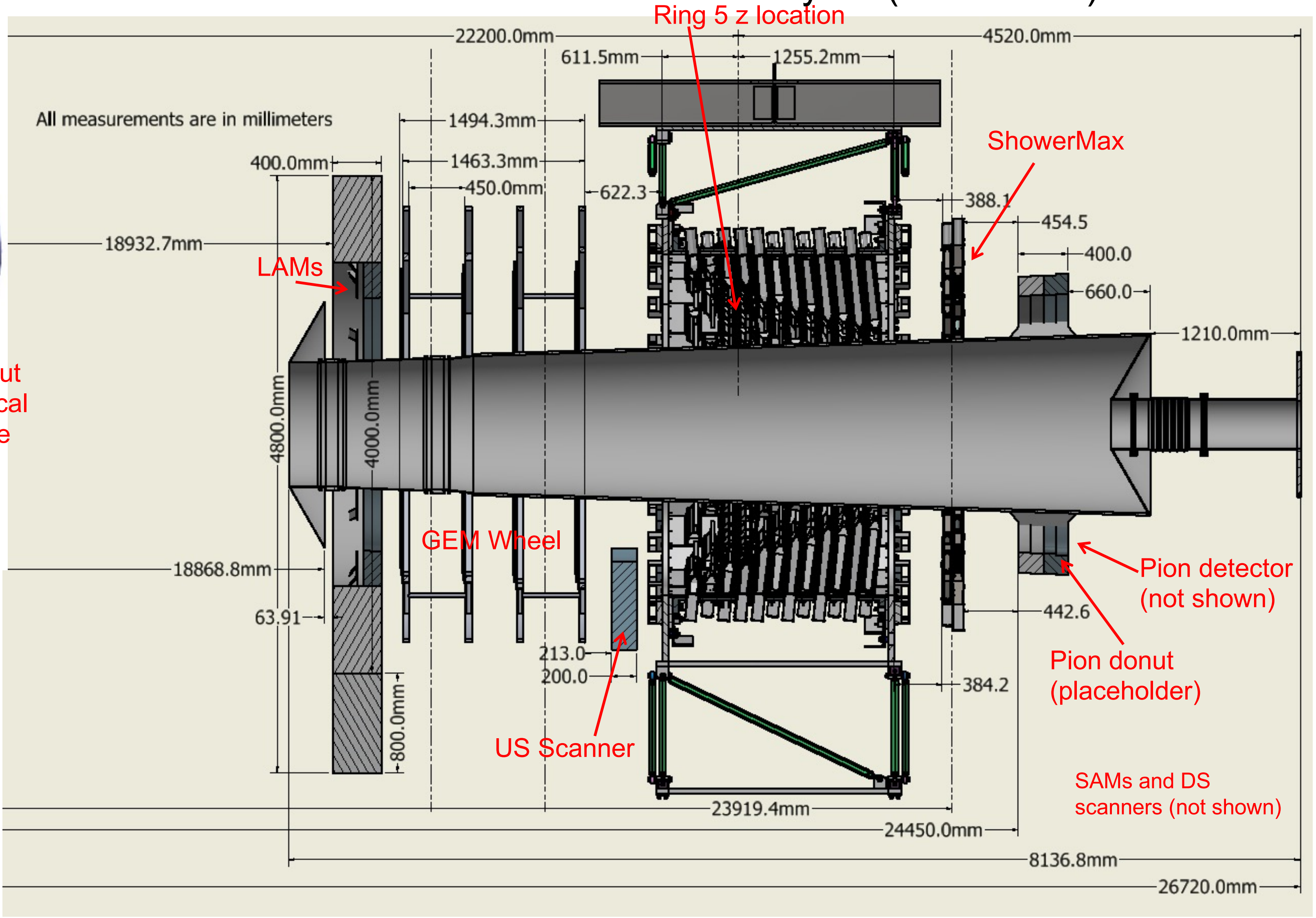
-- bottom halves rest on a 6 rod attachment support and alignment system that slides on floor rails



Technical Progress Since CD-1 (Detector Mechanics)

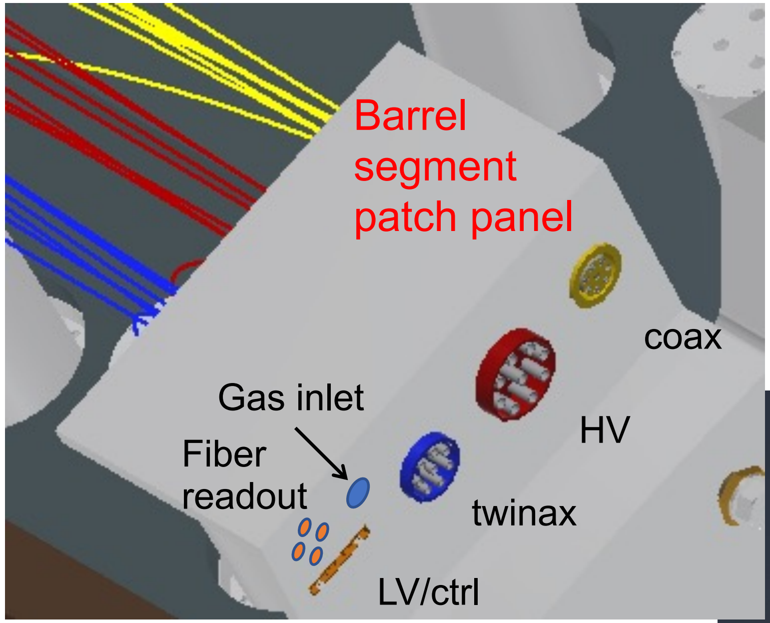


Downstream beamline detector layout (z-locations)



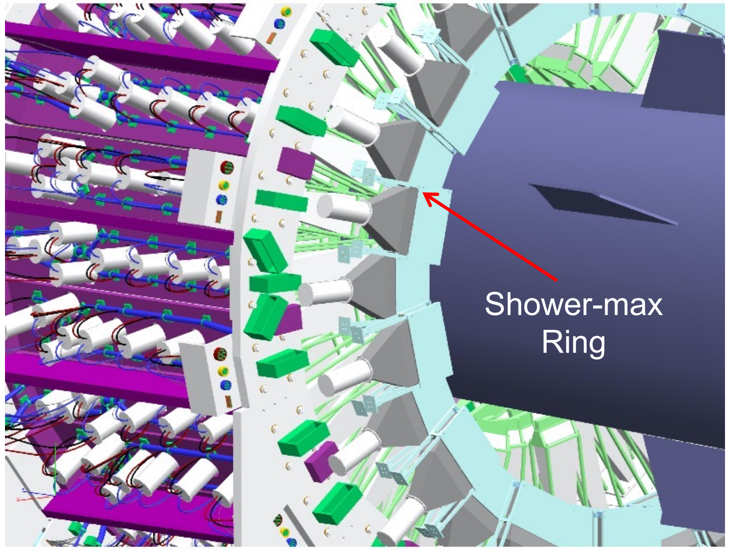
- Detector system locations are set
  -- Minding stay-clear areas and coordinating with engineers (real designs) and physicists (simulated geometries)
- ShowerMax ring support structure design started; pion detector structure next
- On track for combined PDR for all detector systems in early January 2022

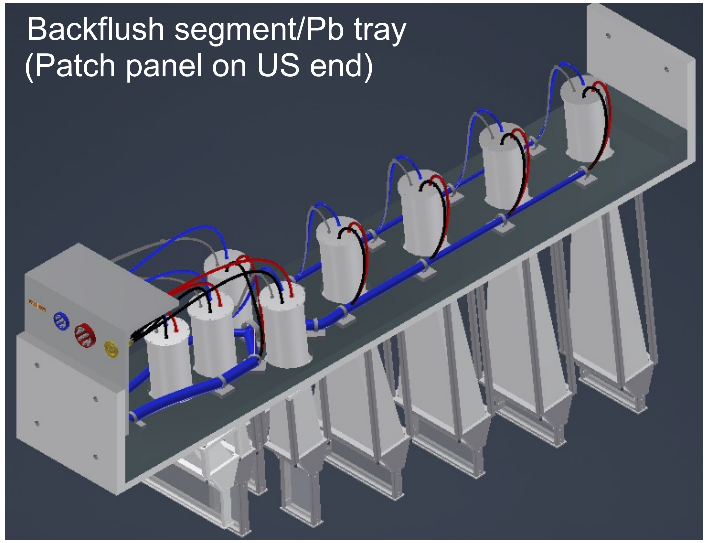
Technical Progress Since CD-1 (Detector Mechanics)

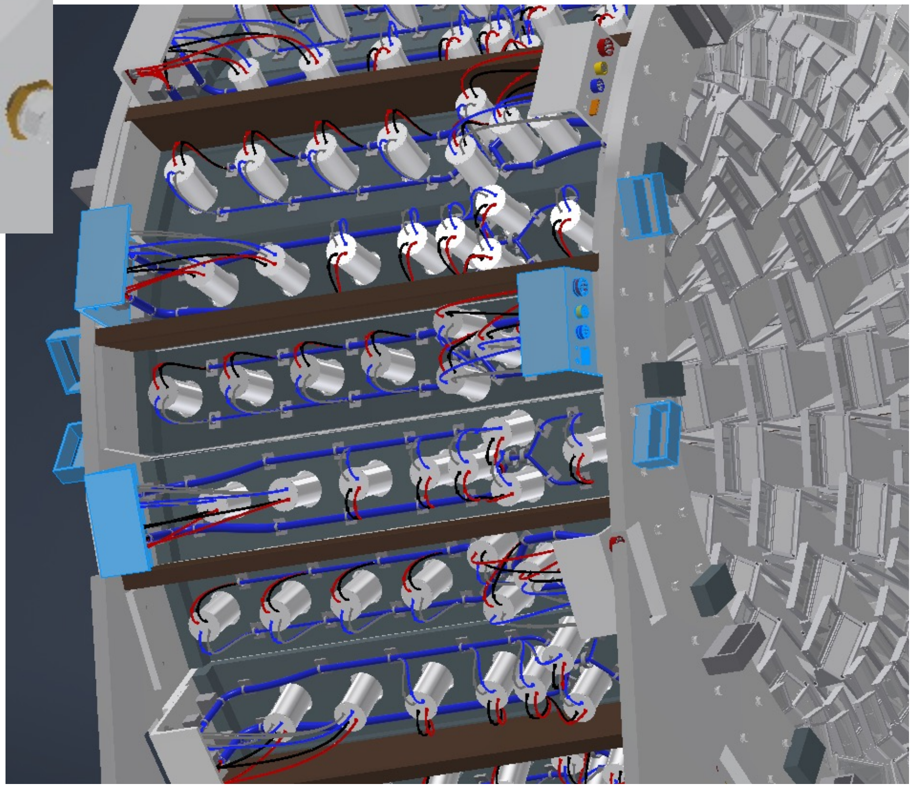


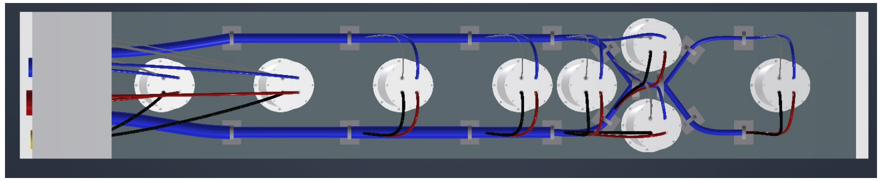
Main detector cabling ("snapshot" of evolving ideas and development)

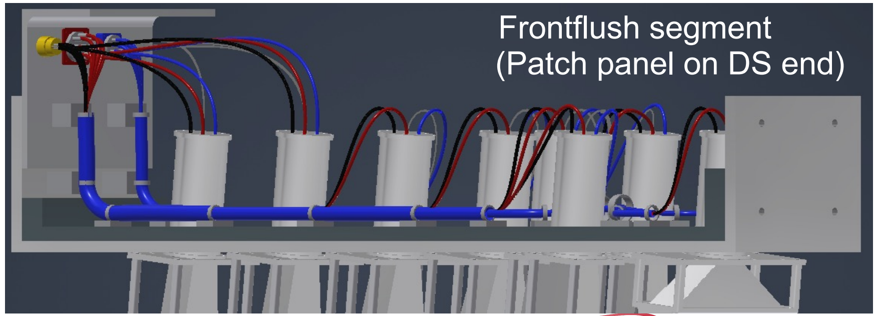
- Internal barrel segment patch panel and cabling harness concept developed
- High Density connector candidates identified
- External barrel cable routing and management concept started







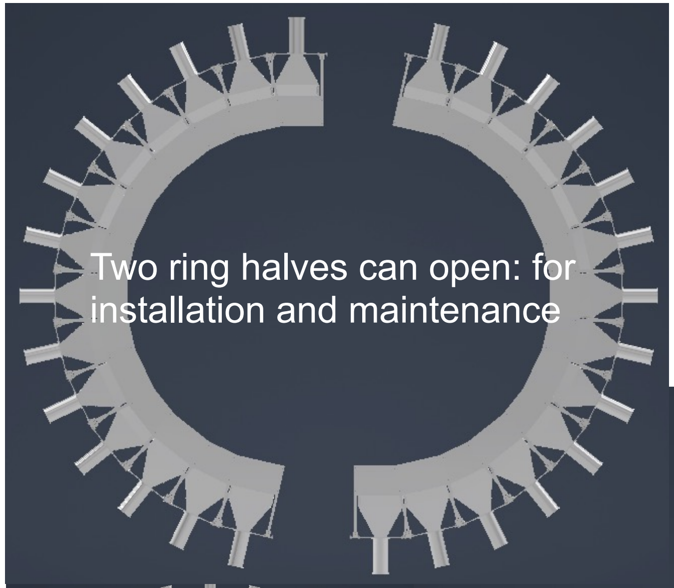


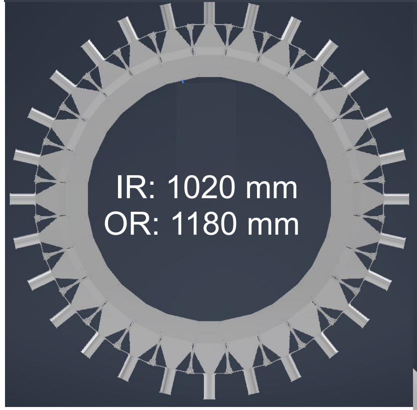


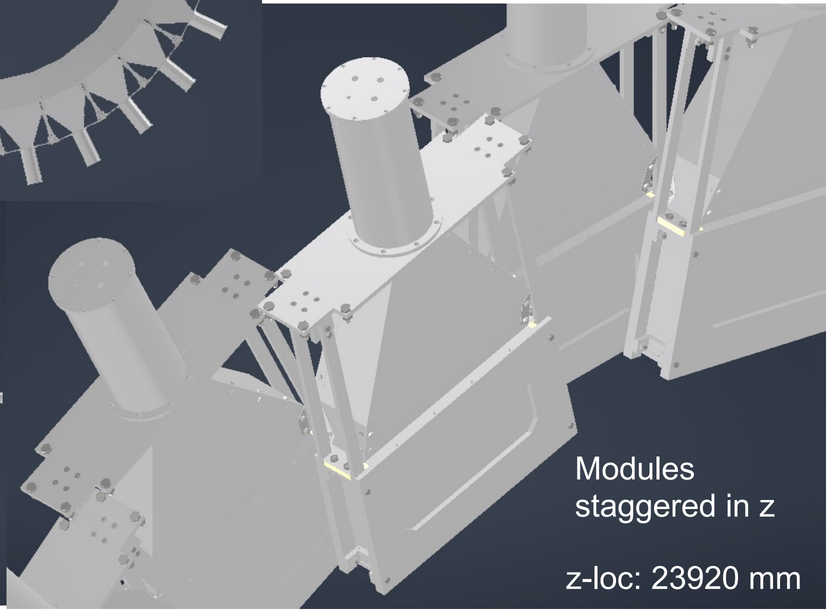
Technical Progress Since CD-1 (Shower-max)

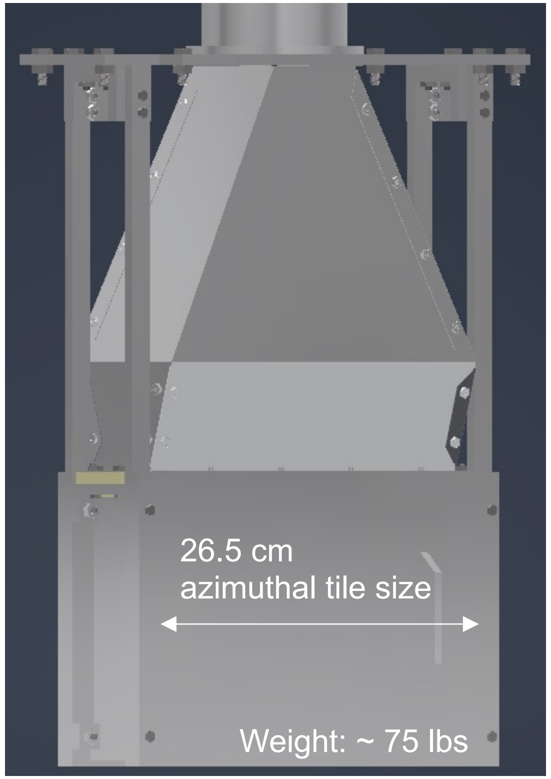
ShowerMax detector: ring of 28 sampling calorimeters intercepting physics signal flux 1.7 m downstream of ring 5

- Detector z location and radial acceptance near finalized
- New quartz and tungsten tile sizes determined
- CAD model updated and passed to engineer (Larry Bartoszek) for FEA and external ring support structure design
- Simulations of expected radiation loads in each quartz layer have been performed

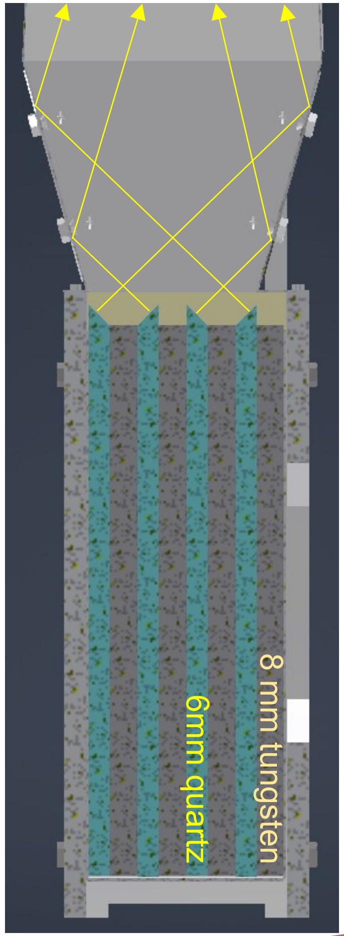


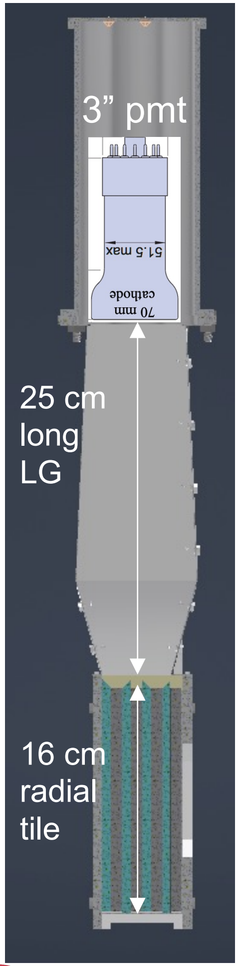






All aluminum chassis and air-core light guide

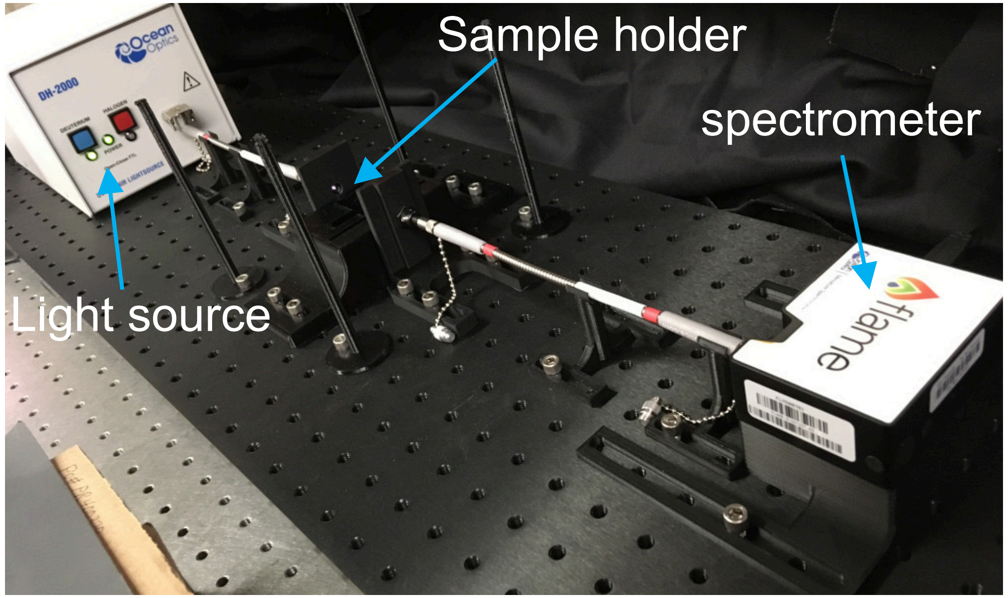




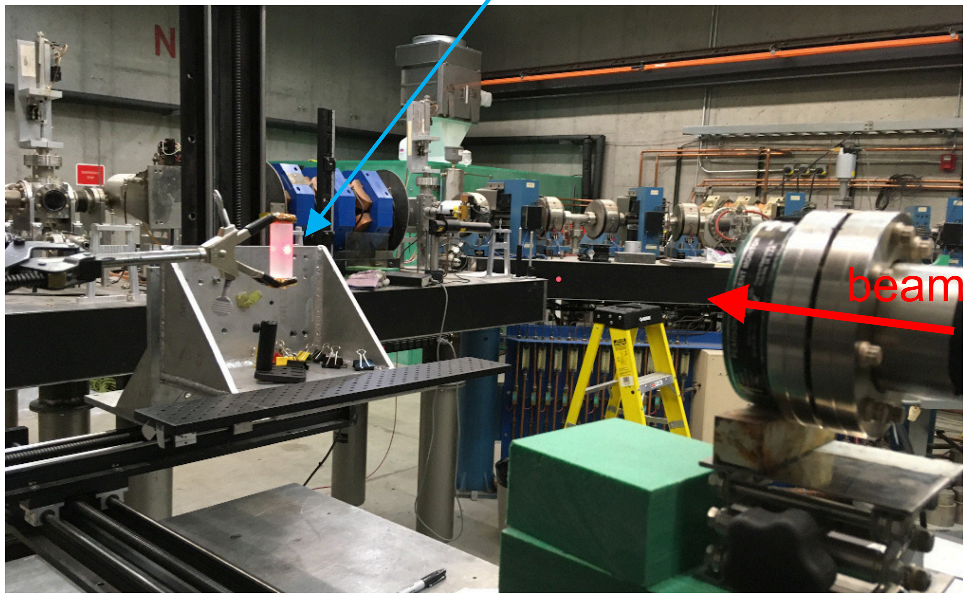
Technical Progress Since CD-1 (Quartz Irradiations)

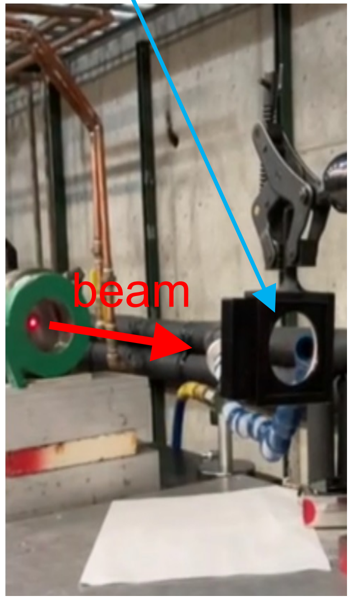
- Goal: quantify light transmission losses in detector radiators due to damage from anticipated radiation dose
- Several candidate artificial fused silica (quartz) samples chosen for testing: from Corning, Ohara, and Heraeus
- Irradiations conducted at the Idaho Accelerator Center using 8 MeV pulsed electron beam, ~50 mA peak current, ~1 μs pulse width (~40 nC/pulse) at 200 Hz repetition rate
- Dose deposition quantified with G4 simulation benchmarked to beam properties and dosimetry measurements

Samples: Two geometries -- 5 cm diameter or square, 1 cm thick and 2 cm diameter, 5 cm long cylinders



Transmission measurement apparatus

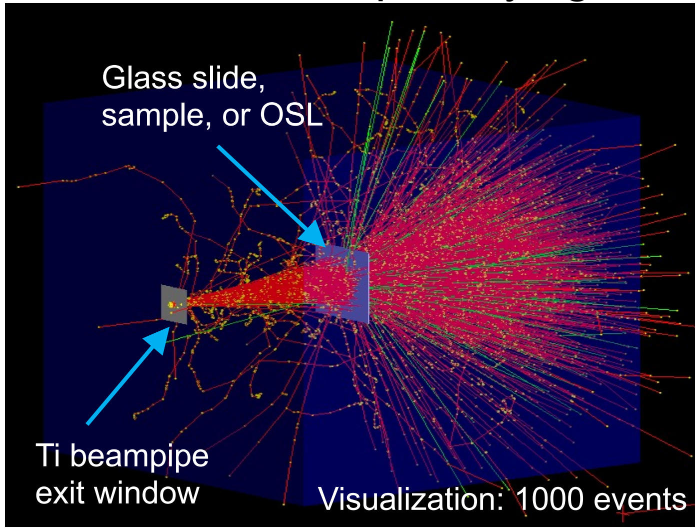


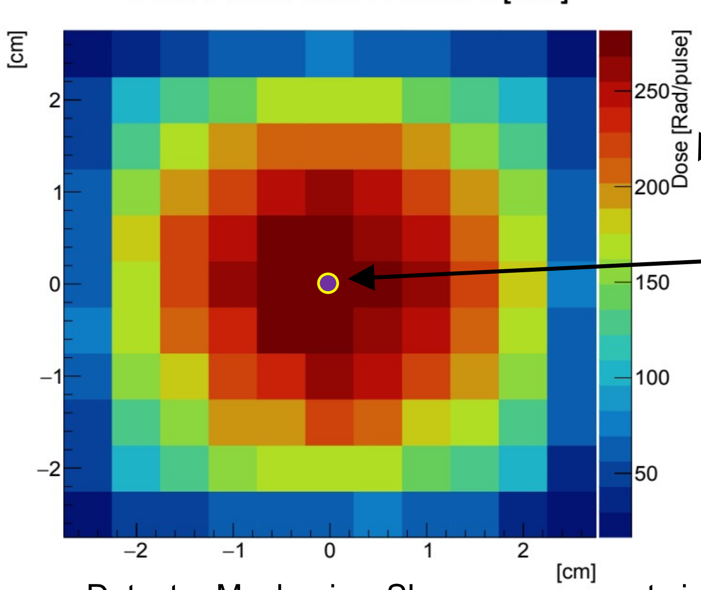


Idaho Accelerator Center (IAC)

Technical Progress Since CD-1 (Quartz Irradiations)

G4 simulation for quantifying dose





Simulated beam calibrated with beamspot measurements at 3 distances

Sample irradiated at 50 cm

Beam energy scans taken at beginning and end of tests

Beam charge data acquired throughout exposures

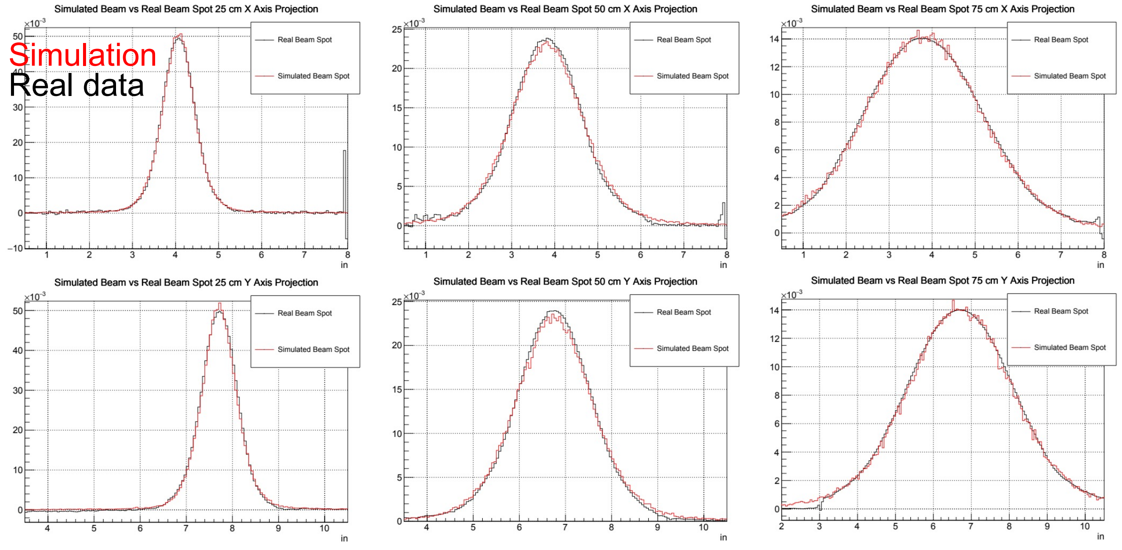
Simulated dose per 5x5 mm^2 normalized to average charge per beam pulse

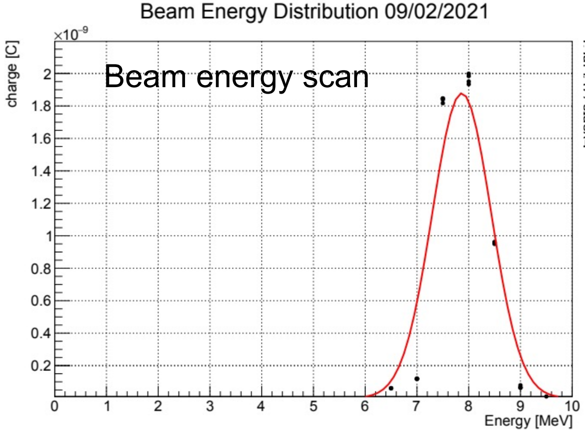
Sample thickness is 10 mm

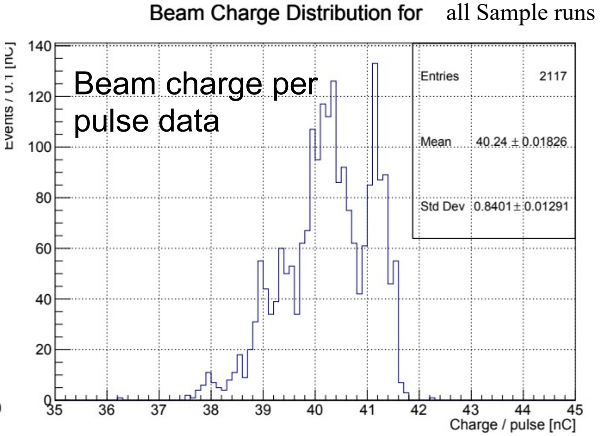
Location of light transmission measurements (within single 5 x 5 mm^2 pixel)

Beamspot measurement scans

Distance from beampipe window:





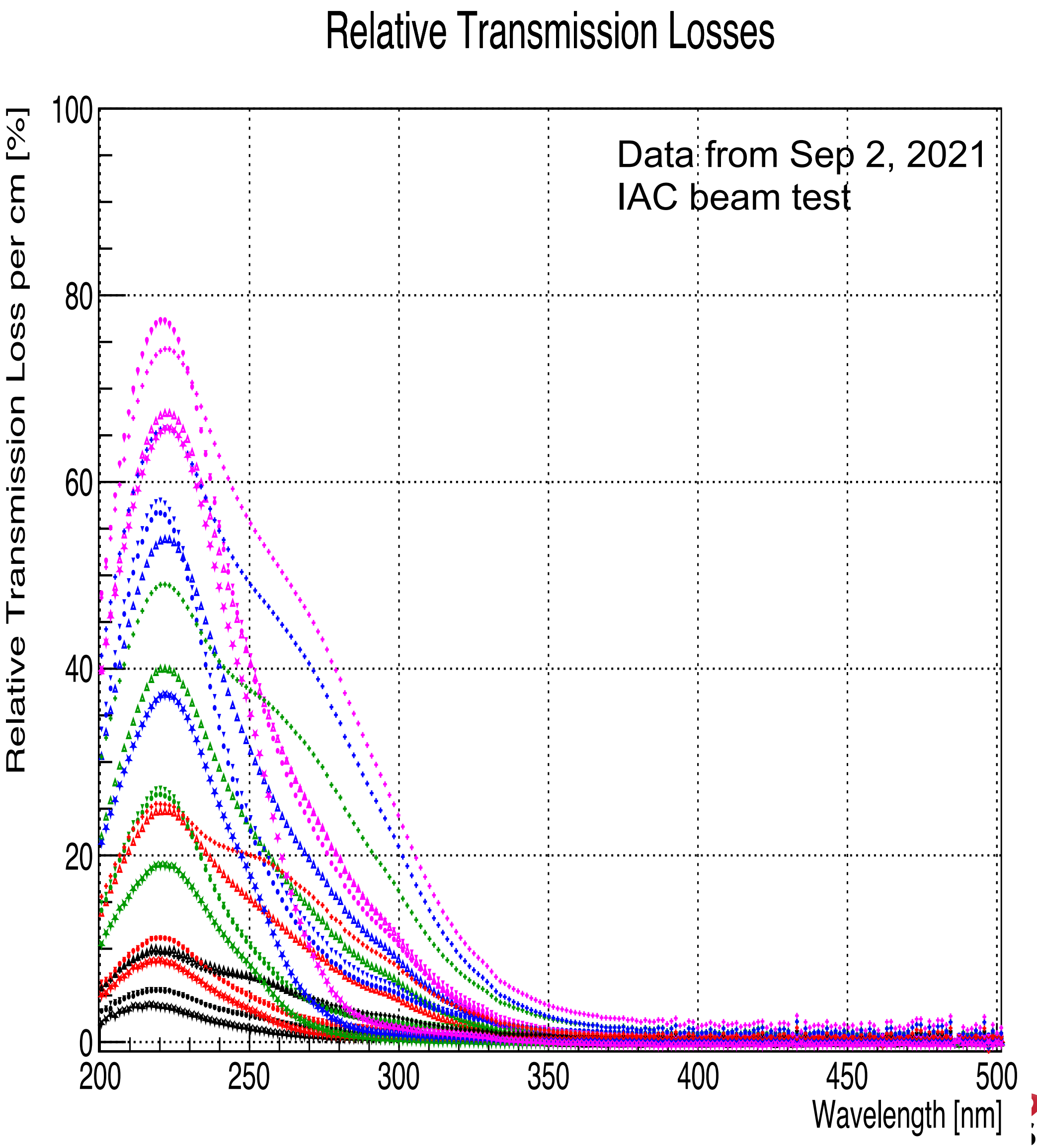


Technical Progress Since CD-1 (Quartz Irradiations)

- Several candidate artificial fused silica (quartz) samples tested (5 cm OD rounds or squares and 1 cm thick):
  - Corning 7980 (UVHGF)
  - Corning 7980 (ARF Eximer)
  - Ohara (SK-1300)
  - Heraeus Spectrosil2000 (standard)
  - Heraeus Spectrosil2000 (high OH,H_2)

Exposure time		Preliminary peak dose estimates (per 5x5 mm^2):
1.3 min	--	5 Mrad
4 min	--	15 Mrad
9.3 min	--	32 Mrad
18.7 min	--	65 Mrad
38.7 min	--	130 Mrad

This is total accumulated dose at each transmission measurement



- Clear differences can be seen between different sample types:

  -- All have a dominant peak loss below 250 nm but with different RMSs and shoulder structure

  -- Obviously, samples with larger RMS or shoulders are less desirable

  -- 4 out of 5 samples showed no losses for λ > ~350 nm

Appendix Slides (EH&S Considerations)

Detector Modules:

– Working with common tools (e.g. potential for cutting) – implement best practices

– PMT HV – implement electrical and on the job training for workers

Mechanical:

– Working with common tools as well as Shop tools– workers must pass Machine Shop safety course

Electronics:

– Working with common tools (e.g. potential for cutting) – implement best practices

– Soldering may be necessary – implement electrical and on the job training for workers (use fume hoods, etc.)

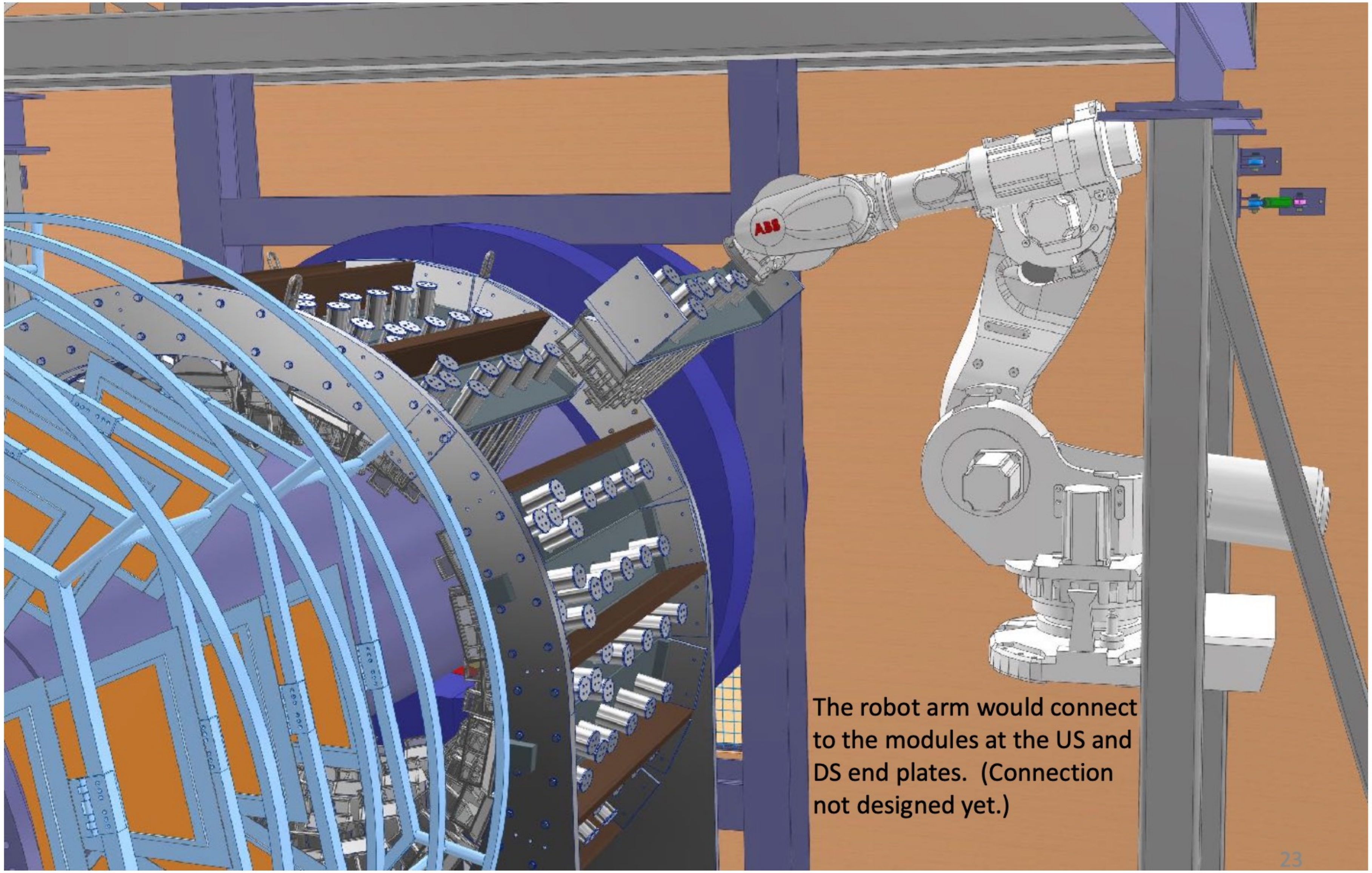
Radiation:

– All workers will have ISU radiation safety training -- https://www.isu.edu/radiationsafety/

- All activities and deliverables in accord with Jlab EH&S manual and Jlab's Integrated Safety Management System
- All institutional EH&S rules will be followed (Idaho State University EH&S: https://www.isu.edu/ehs/)

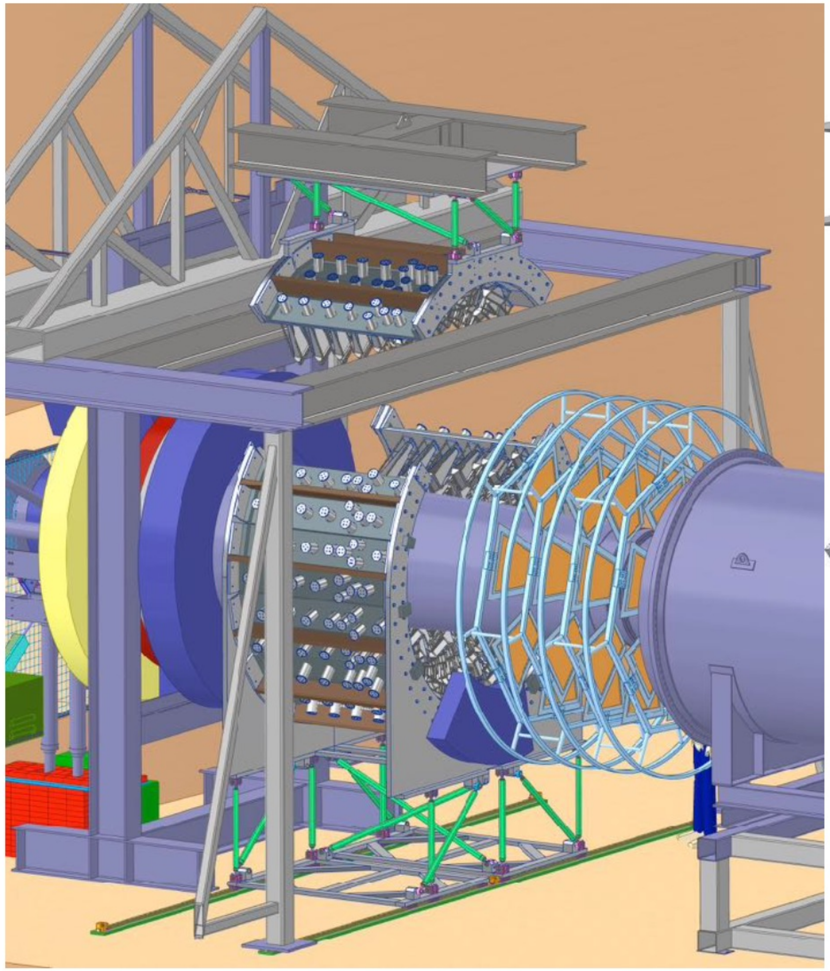
Appendix Slides (Detector Mechanics)

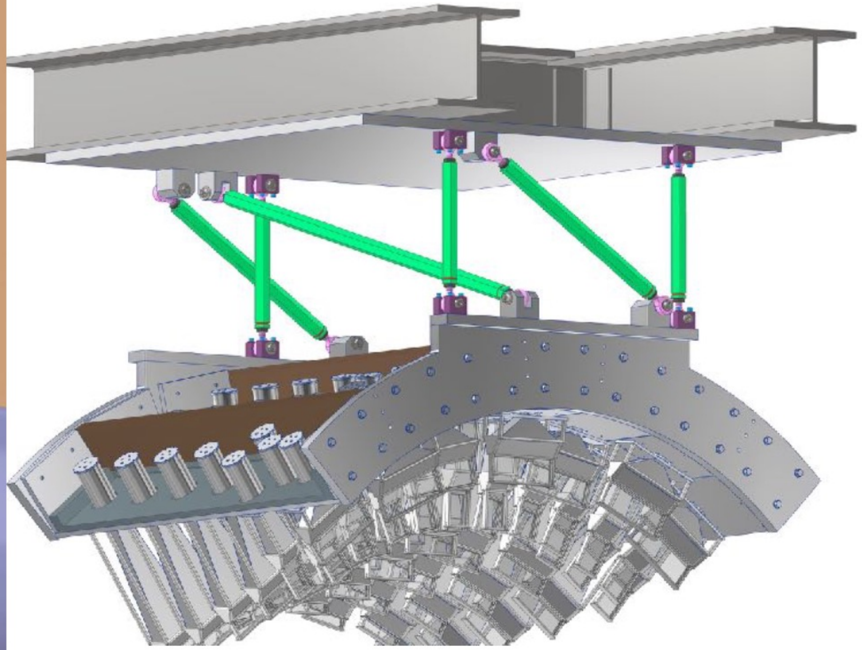
A concept for robotic insertion of barrel segments

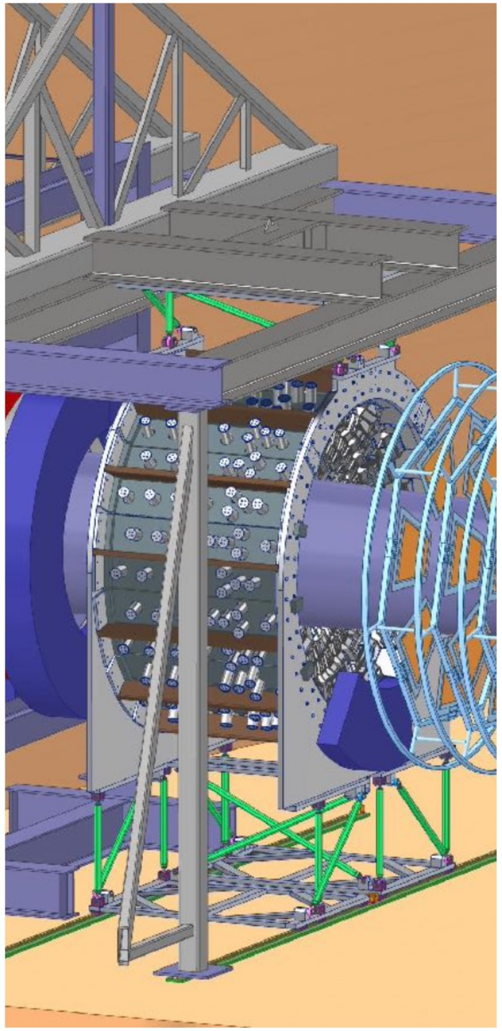


Latest Development: Coupling to A-Frame

Larry Bartoszek, Robin Wines, Ryan Biraben, Danovic Spell

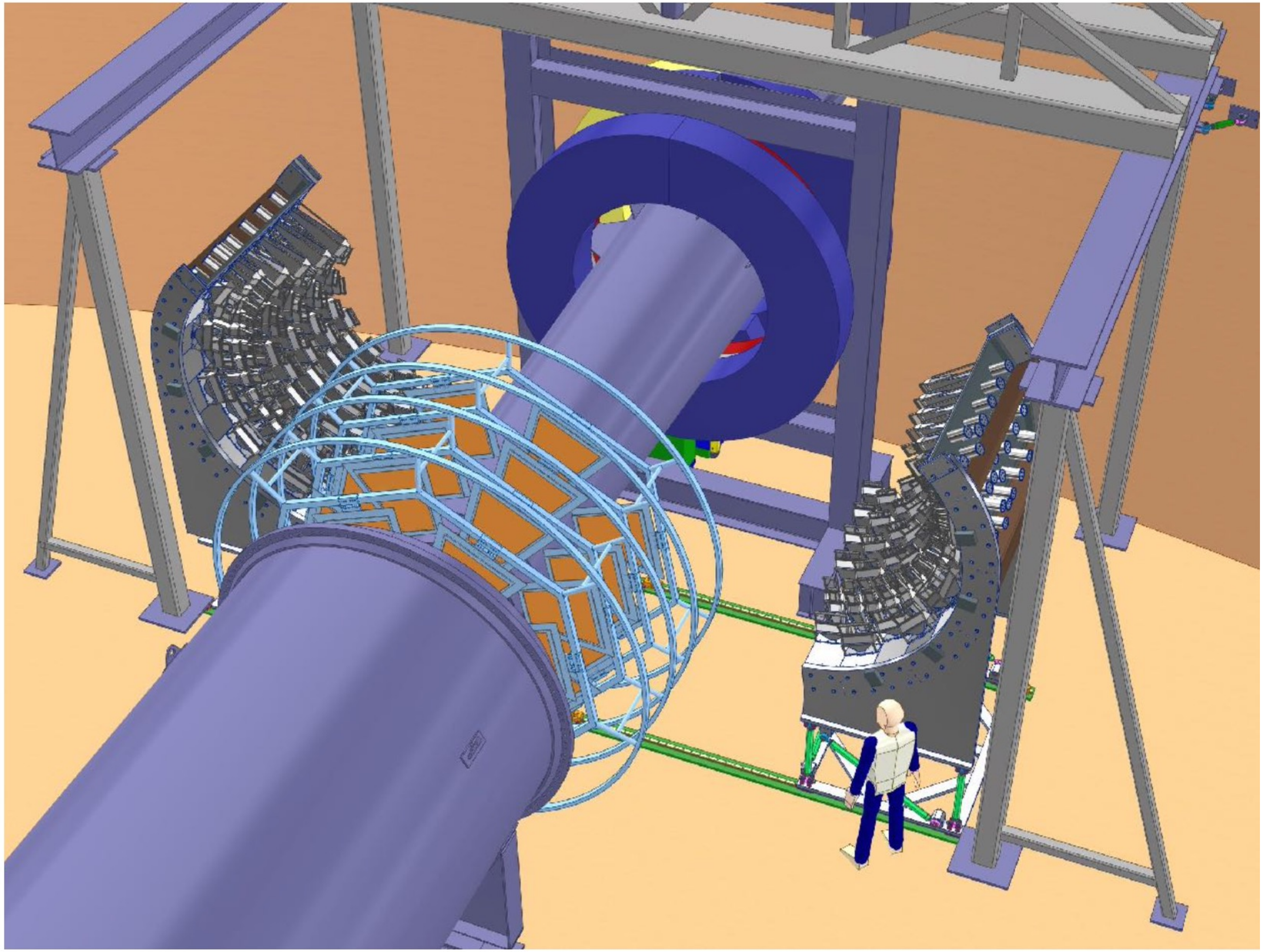






Appendix Slides (Detector Mechanics)

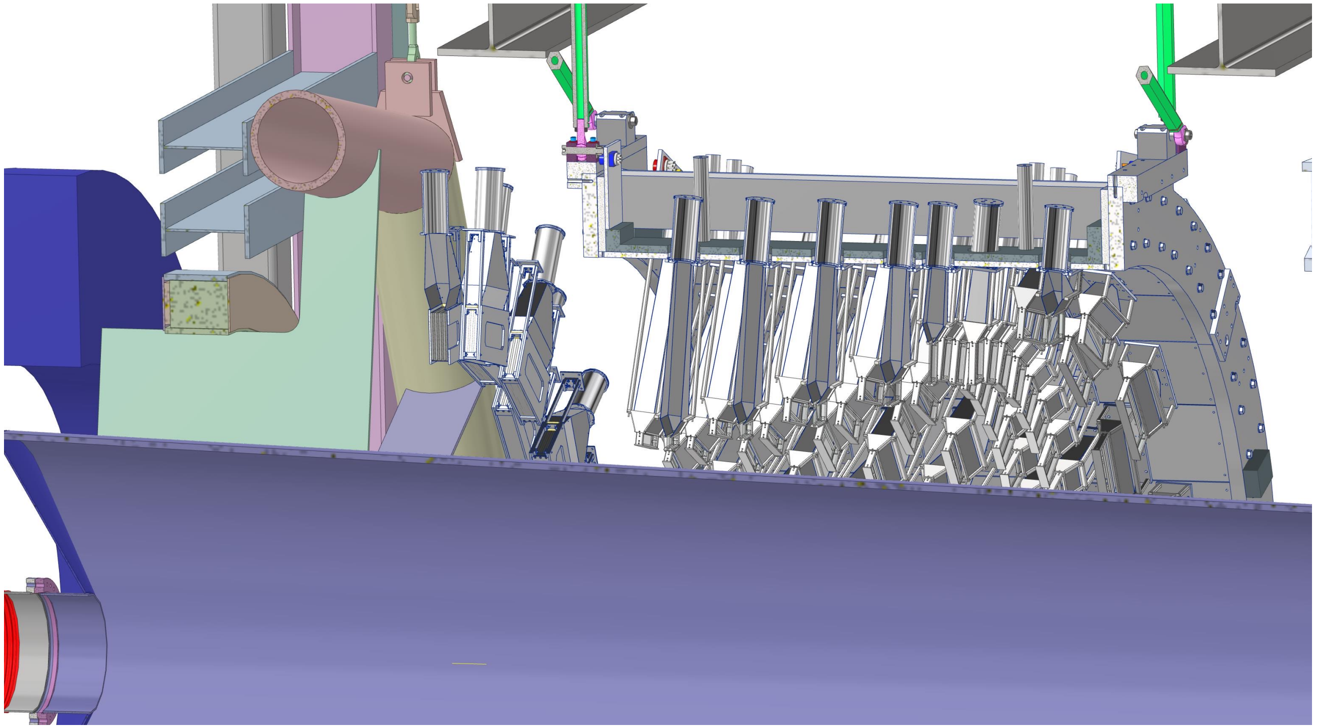
Beam-left and beam-right halves retracted from beam position

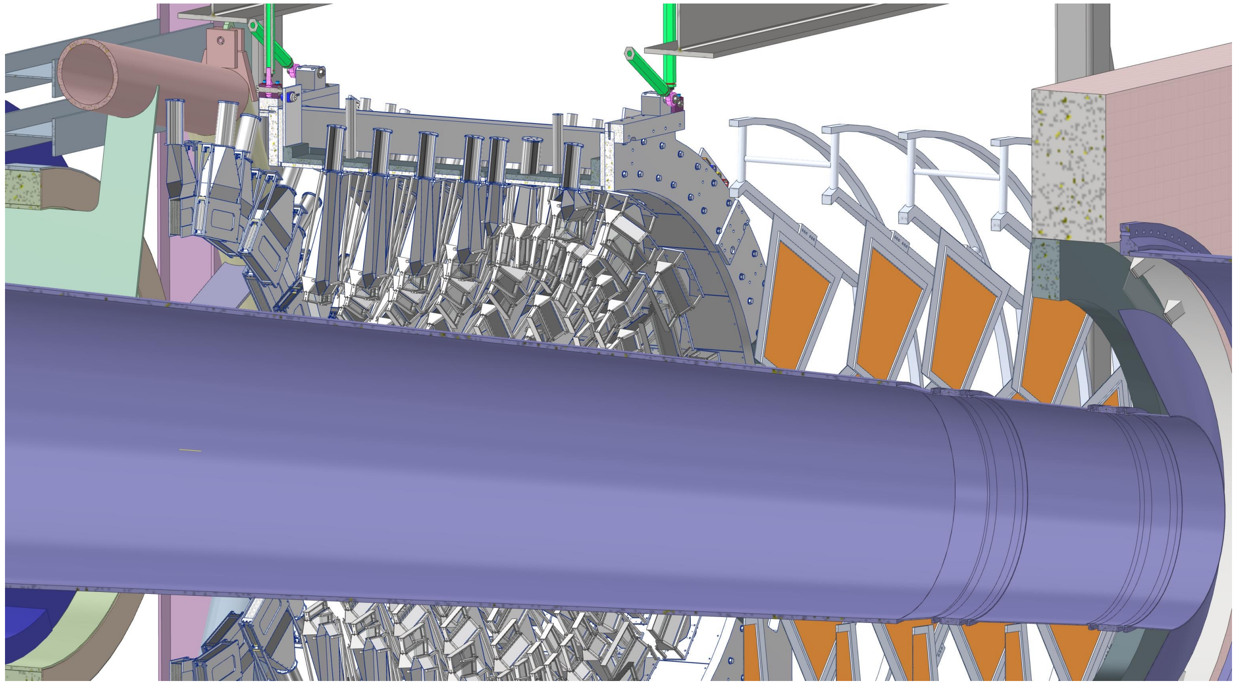


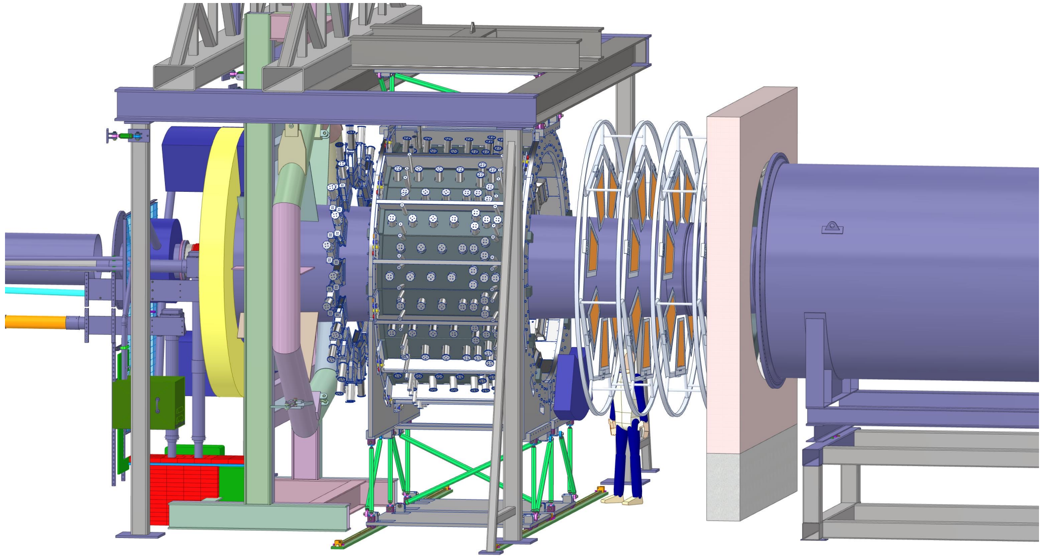
Jefferson Lab

Appendix Slides (Detector Mechanics)

More Views

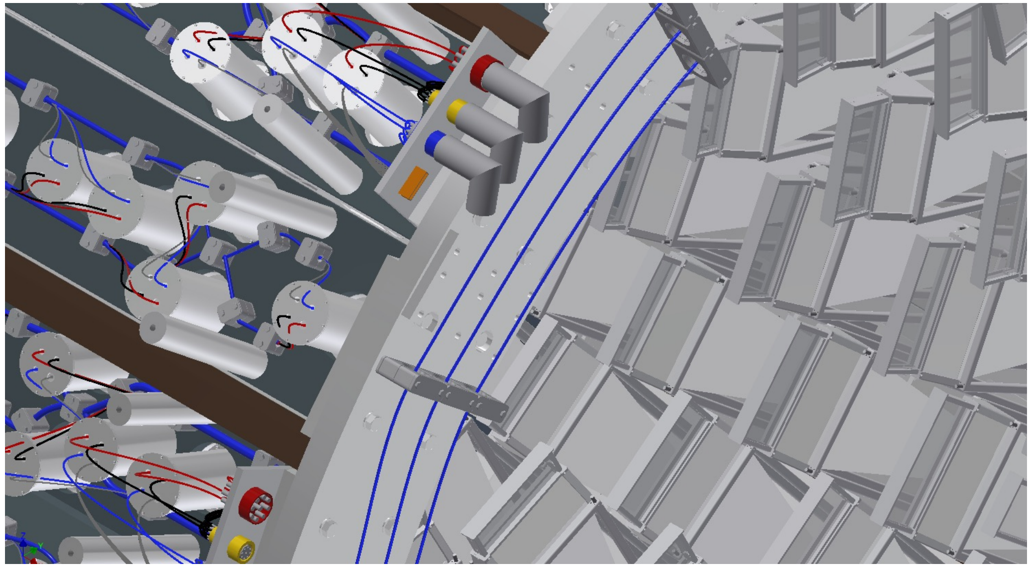


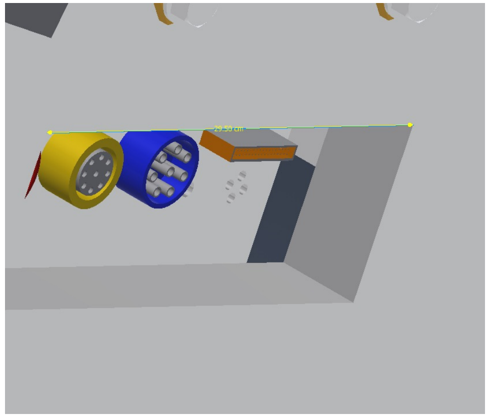


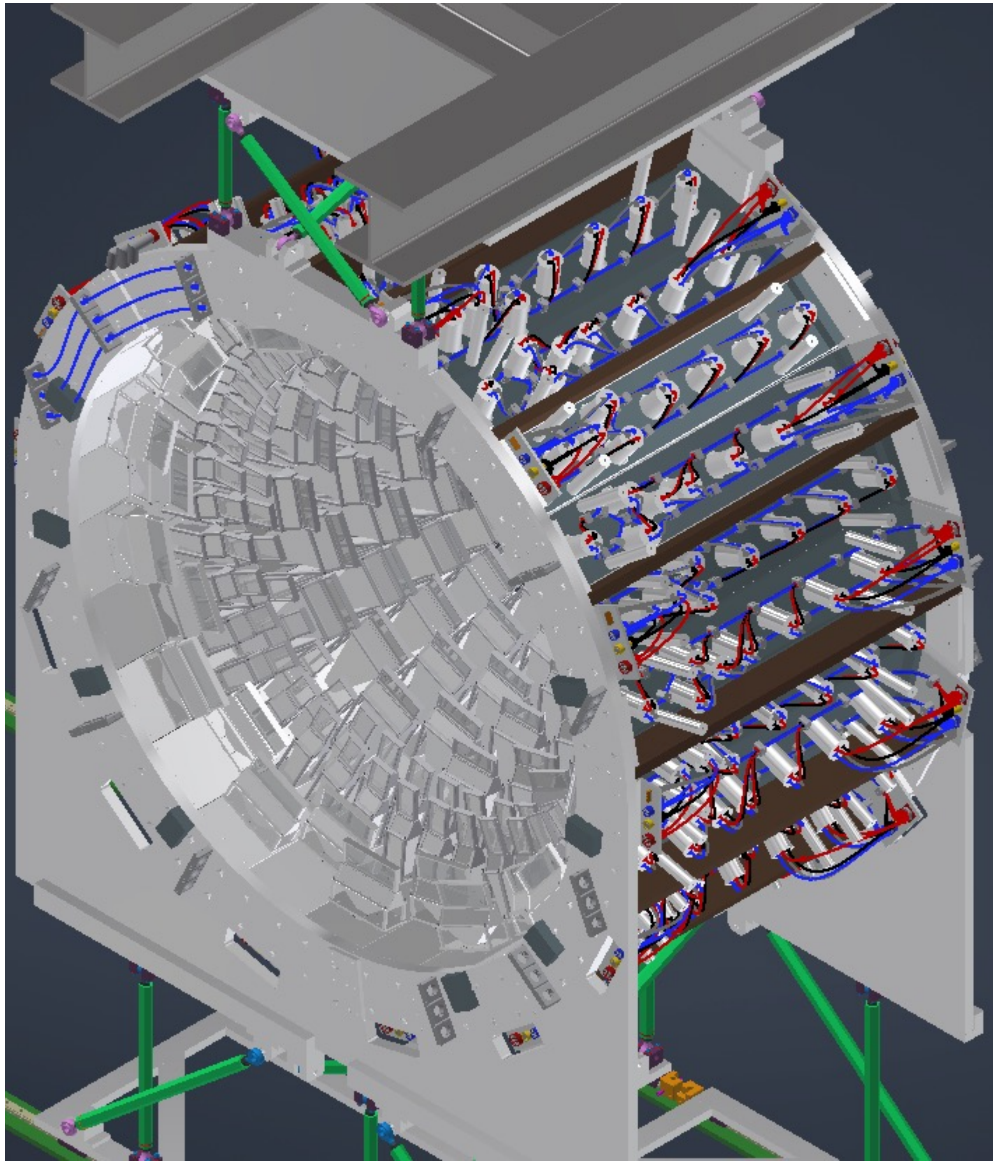


Appendix Slides (Detector Mechanics)

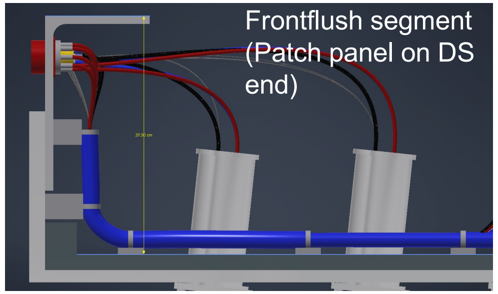
Barrel cabling

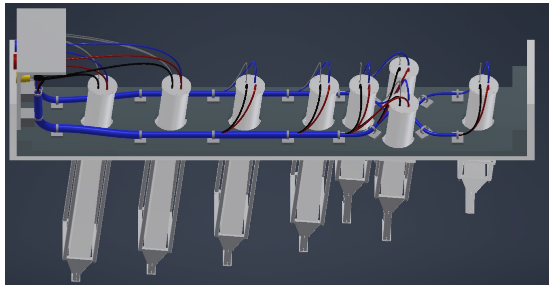


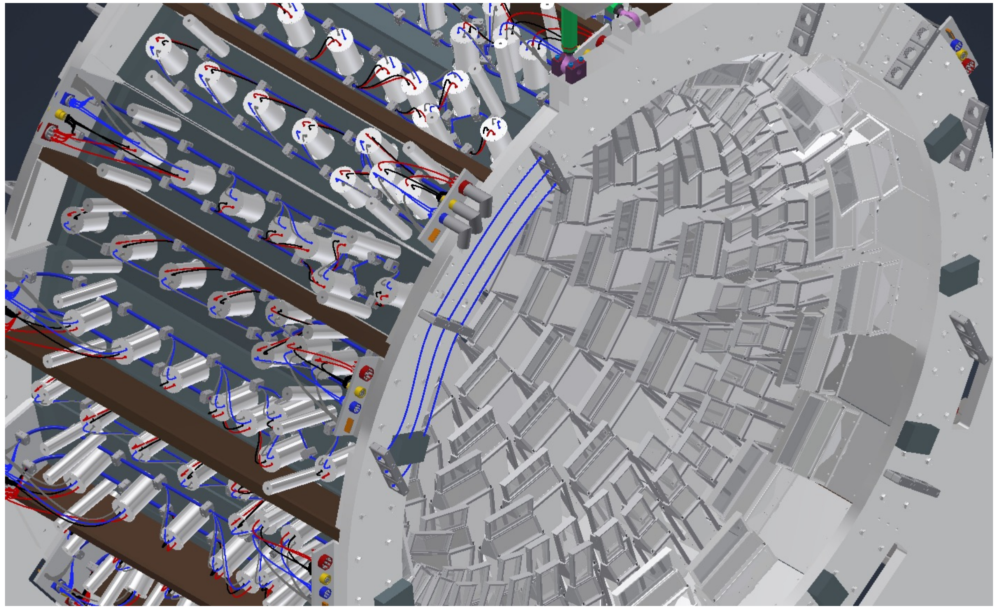




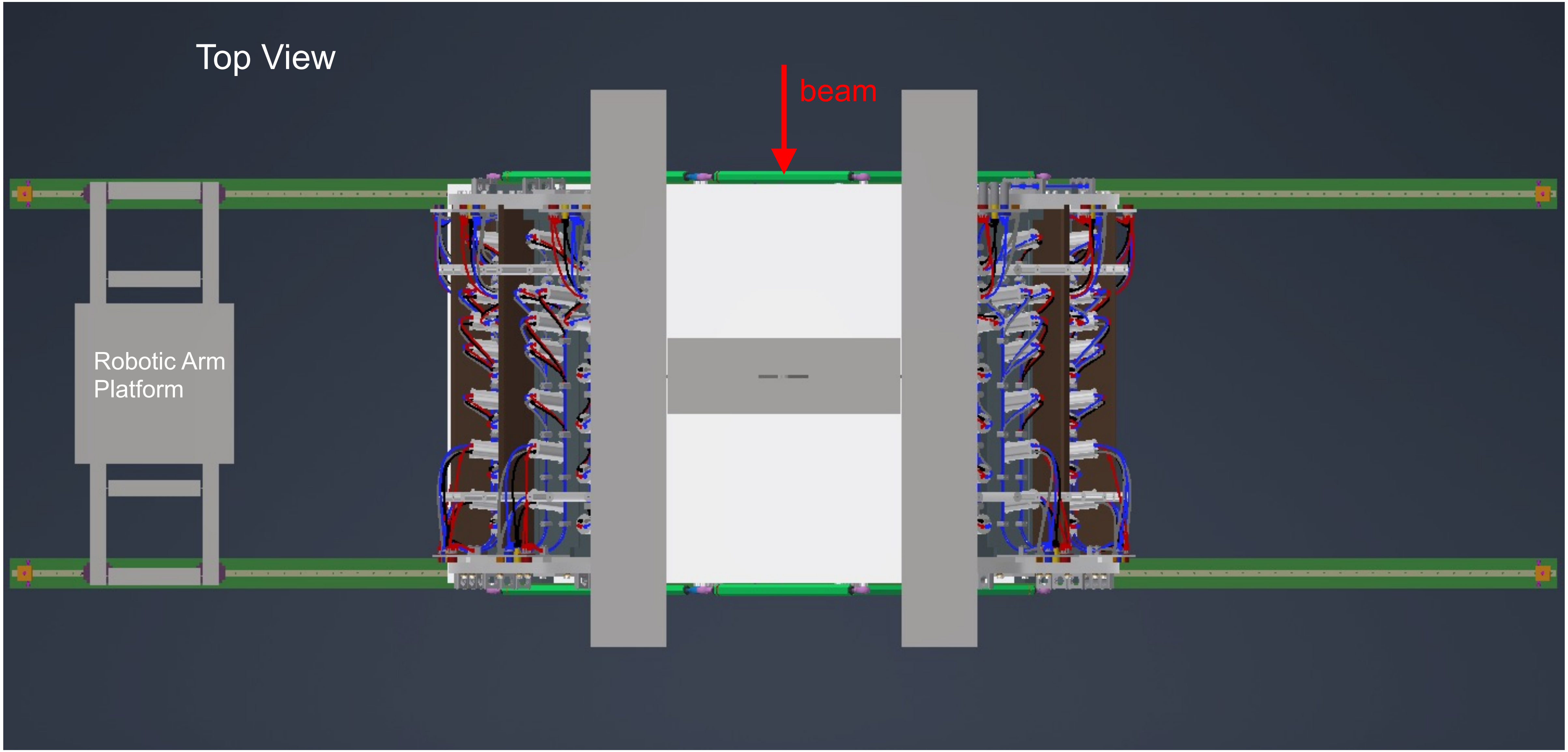
Frontflush segment
(Patch panel on DS
end)







Appendix Slides (Detector Mechanics)



Appendix Slides (HD connector candidates)

Twinax: (Smithsinterconnect.com)

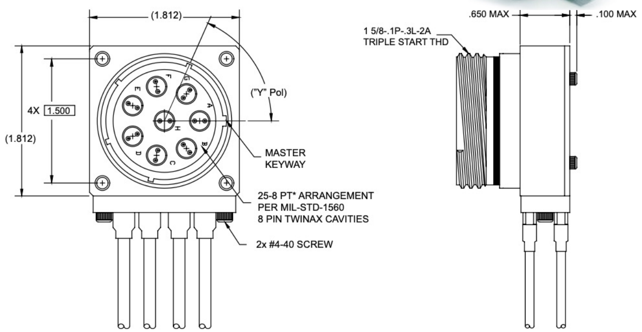
Box Mount Receptacle Pin Insert 25-8 PT* to 8 R/A Twinax Cables to Open Lead

Y	Polarization
1	N
2	A
3	B
4	C
5	D
6	E

Part Number	Cable Type	Cable
02370Y-1XXX	Differential Twinax	540-1099-000

Y = Connector Polarization
XXX = Cable Length in Inches
Please specify cable length when ordering

- Connector Receptacle is supplied fully loaded with Twinax pin contacts terminated to Differential Pair Twinax cable to open lead (all cavities included).



8

Coax: MHC Contacts (Smithsinterconnect.com)

Features

- Fits Size 8 and 12 cavities for MIL-DTL-38999, ARINC 404 and ARINC 600
- Fits Size 8 cavity for MIL-DTL-24308 D-Sub
- Spring loaded for optimum contact mating force
- High frequency performance
- Low VSWR:
  - Size 8: 1.15:1 Typ Mated Pair (DC to 26.5 GHz)
  - Size 12: 1.25:1 Typ Mated Pair (DC to 26.5 GHz)
    1.5:1 Typ Mated Pair (26.5 - 40 GHz)
- Insertion Loss:
  - 0.15 dB to 26.5 GHz Typ (Size 8)
  - 0.2 dB to 40 GHz Typ (Size 12)
- Socket contacts are spring loaded float mount for superior RF performance and reliability

Detector Mechanics, Shower-max, quartz irra

Electrical Specifications

(MIL-DTL-38999 / ARINC 404 / ARINC 600)

Impedance	50 Ohms
Frequency Range	DC to 26.5 GHz (Size 8) DC to 40 GHz (Size 12)
VSWR	1.15:1 Typ (Size 8) to 26.5 GHz 1.25:1 Typ (Size 12) to 26.5 GHz 1.50:1 Typ (Size 12) to 40 GHz (mated pair)
DWV	500 VRMS @ Sea Level (Size 8) 325 VRMS @ Sea Level (Size 12)
Temperature Range	-65°C to +165°C

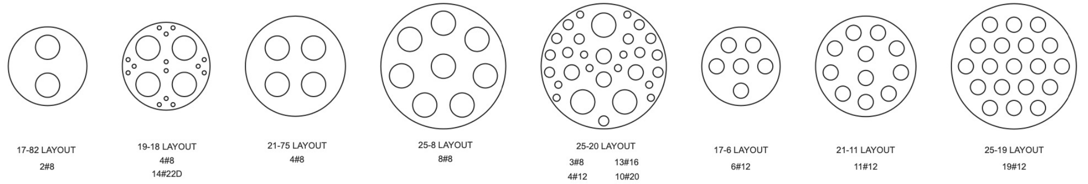
Materials & Finishes

Center & Outer Spring Contacts	Brass per ASTM-B16, alloy UNS C36000 or BeCu per ASTM-B196, alloy UNS C17200, C17300 Gold plate per MIL-DTL-45204, Type II, Class 1
Shell	Brass per ASTM-B16, alloy UNS C36000 Gold plate per MIL-DTL-45204, Type II, Class 1
Hood	305 CRES per ASTM-A240, passivated per ASTM-A967
Insulators	PTFE per ASTM D-170

MHC Sample Insert Arrangements

Consult Factory For:
- Custom or Special Insert Arrangements
- Connector Ordering Informatioin
- PC Tail Versions of Contacts

MIL-DTL-38999



Appendix Slides (HD connector candidates)

HV: (ges-highvoltage.com)

M Series

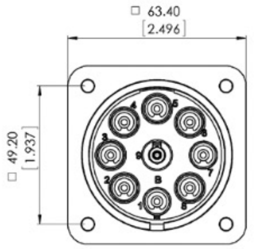
Type M915/1E **8(+1) Pole 12 kVDC**

Electrical values	
Operating voltage (DC)	12 kV
Test voltage (DC)	18 kV
Rated current	30 A

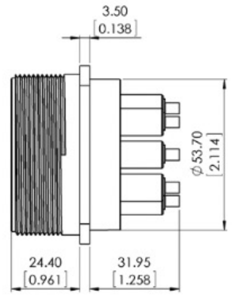
Characteristics	
Number of pins high voltage (HV)	8
Number of pins E-contact 2.5 mm (LV)	1
Number of pins I-contact 1.5 mm (LV)	-
Insulation material	PTFE

Layout

Type / Version / Part number	Picture / Drawing
Type: receptacle, panel mount **Version: GB 915/1E/PTFE** **Part no. 7749011**	



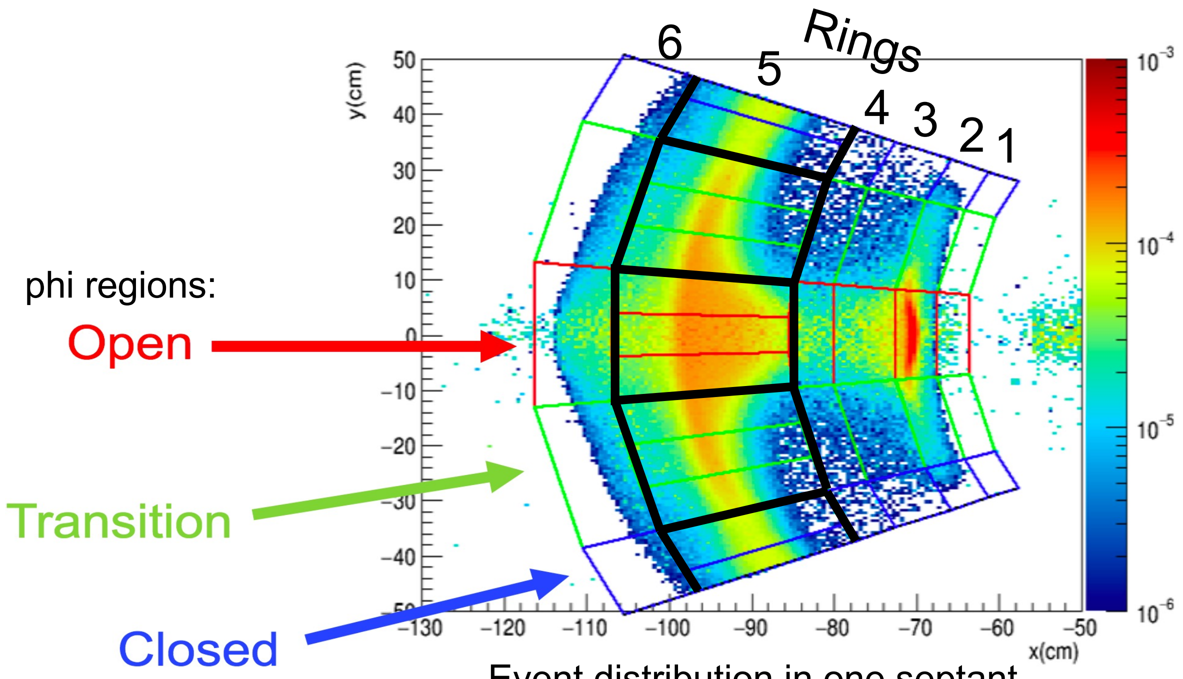
front view



Appendix Slides (ShowerMax)

Requirements Table from MOLLER-NSF CDR

Parameter	Value
Radial segmentation	1
Azimuthal segmentation	28
Total number of detector channels	28
Quartz element sizes	$\sim$ 12 cm x 25 cm x 1.0 cm
Quartz surface polish	20 Angstroms or better
Quartz bar parallelism	3 arc minutes between faces
Quartz bar perpendicularity	15 arc minutes
Tungsten element sizes	$\sim$ 11 cm x 25 cm x 0.8 cm
Detector resolution from 2 - 8 GeV	$\sim 25\%$
Radiation hardness of detector elements	$>$ 70 MRad



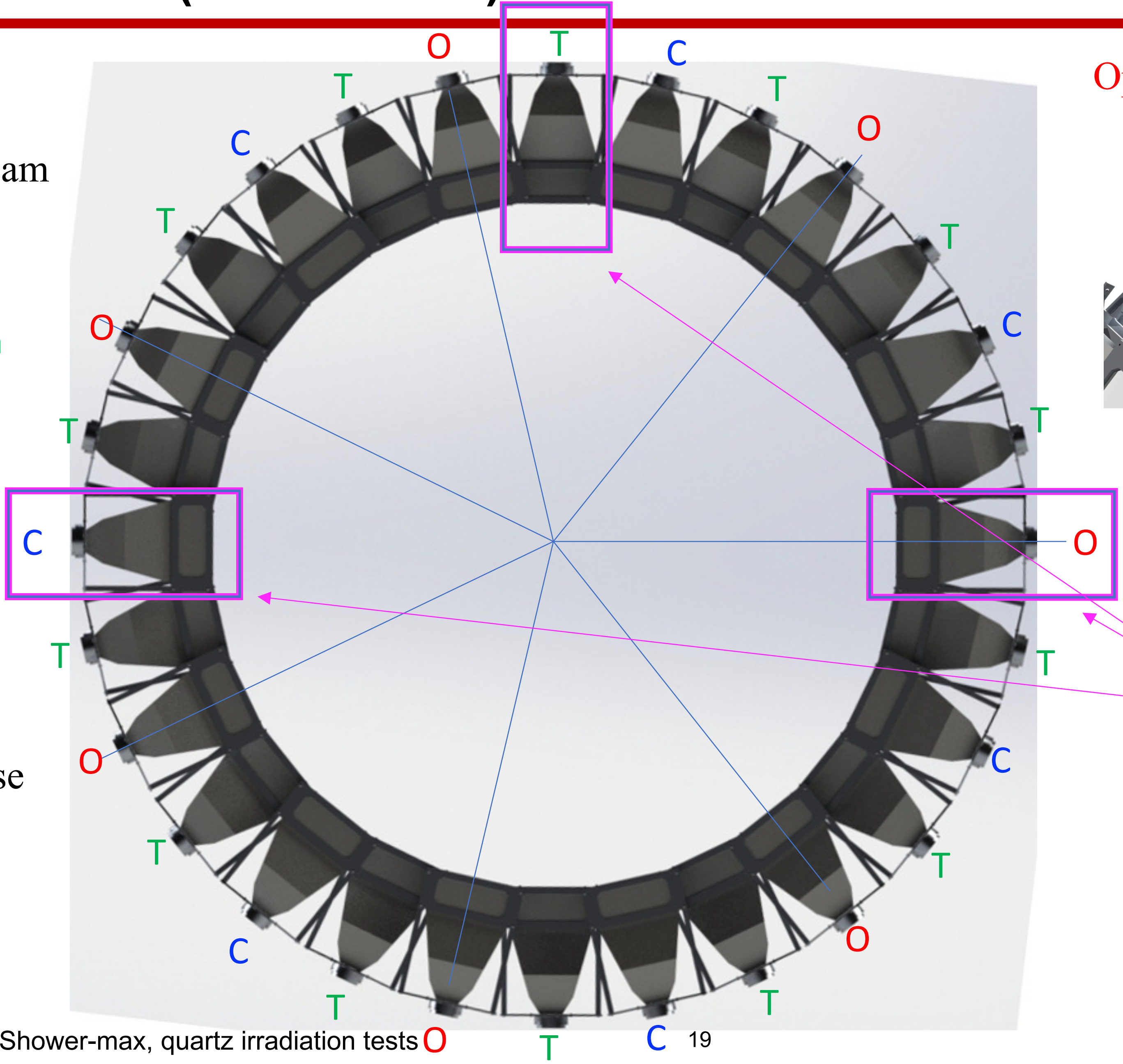
Event distribution in one septant

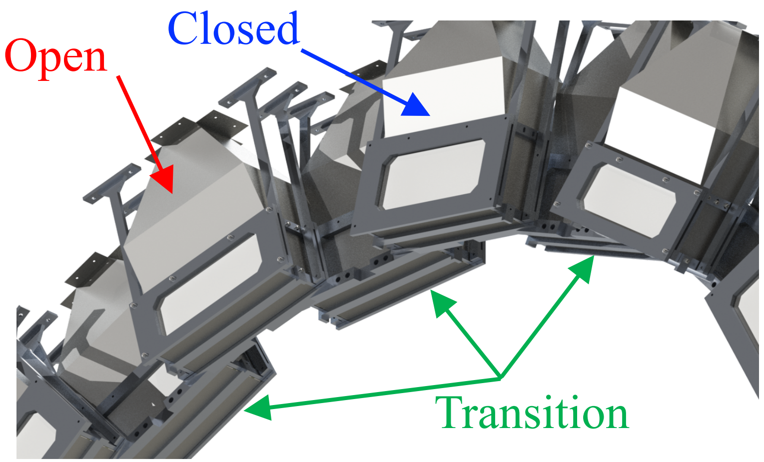
- Shower-max required to ~match flux acceptance of Ring-5 but with a 3:1 reduction in azimuthal segmentation
- Quartz elements optically polished with stringent geometrical tolerances for TIR considerations
- Tungsten is high purity (99.95%) with dimensional tolerances of $\pm$0.005 inch
- Detector resolution for single-electron response at least 25% to avoid excessive error inflation
- Optical detector elements must be sufficiently radiation-hard to allow Shower-max to preform as required for the duration of the experiment

Appendix Slides (ShowerMax)

ShowerMax ring:
Looking downstream

C – Closed
O – Open
T – Transition



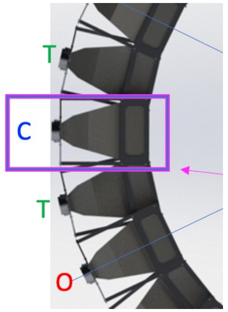


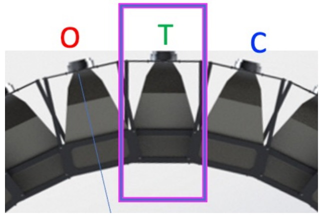
This is a study to determine the anticipated total dose in each quartz layer of ShowerMax during MOLLER

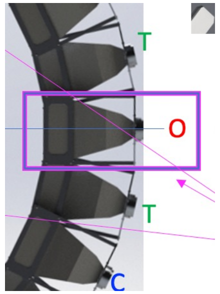
Made each quartz layer sensitive for individual Open, Closed, and Transition detectors located at these specific positions

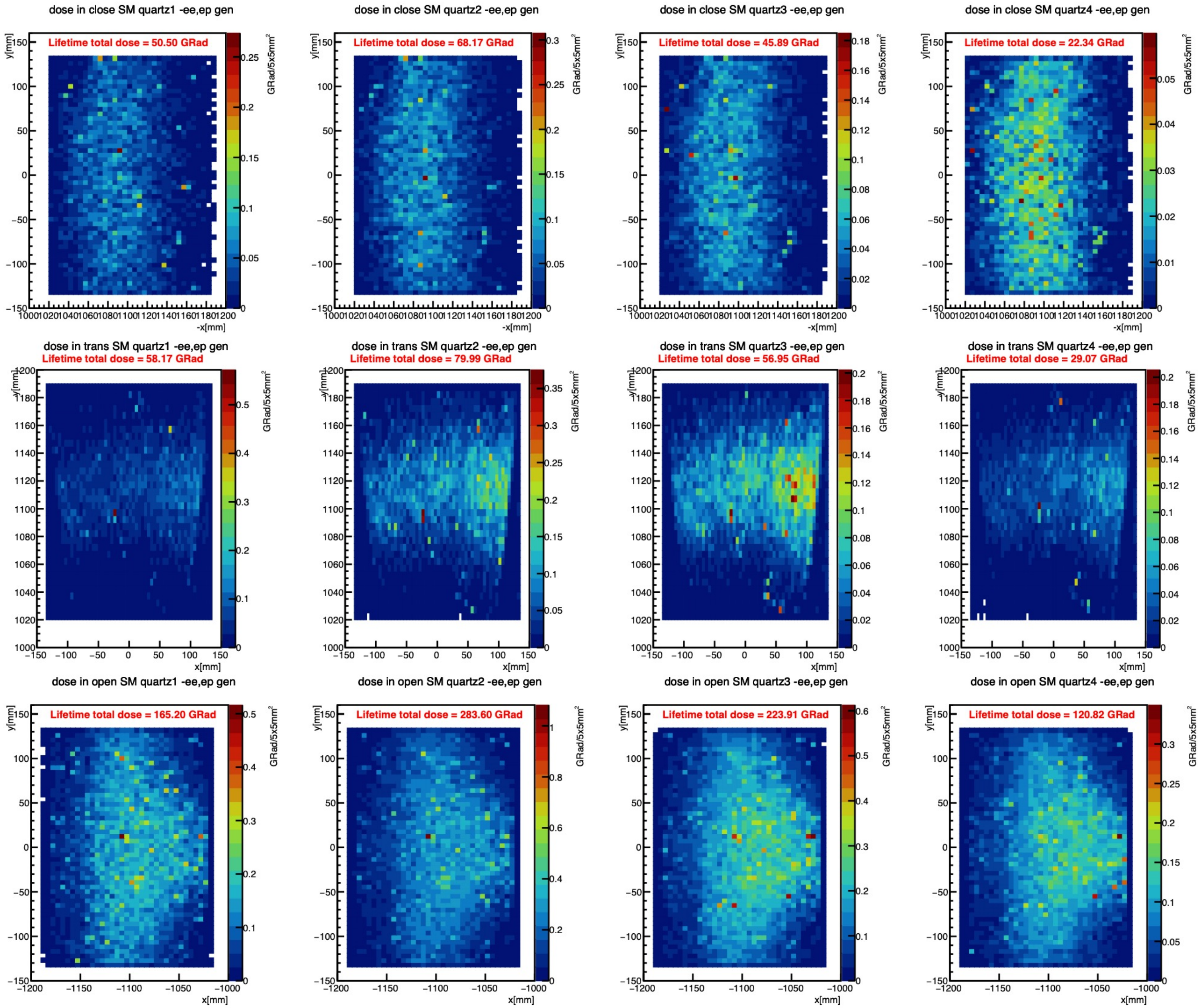
Appendix Slides (ShowerMax)

1st 2nd 3rd 4th ← Quartz Layer









Lifetime MOLLER dose calculation

```
double mipF = 2.4; // MeV/(g/cm2)
double PACdays = 235  + 95 + 14;
double h2s = 3600;
double hIn1day = 24;
double area = 0.5*0.5; //cm2
double MeV2rad = 100/6.24e9; //100rad = 1 Gy = 6.24 10^12 MeV/kg
double doseScale = mipF * PACdays * hIn1day * h2s / area * MeV2rad / 1e6; // [Mrad]
```

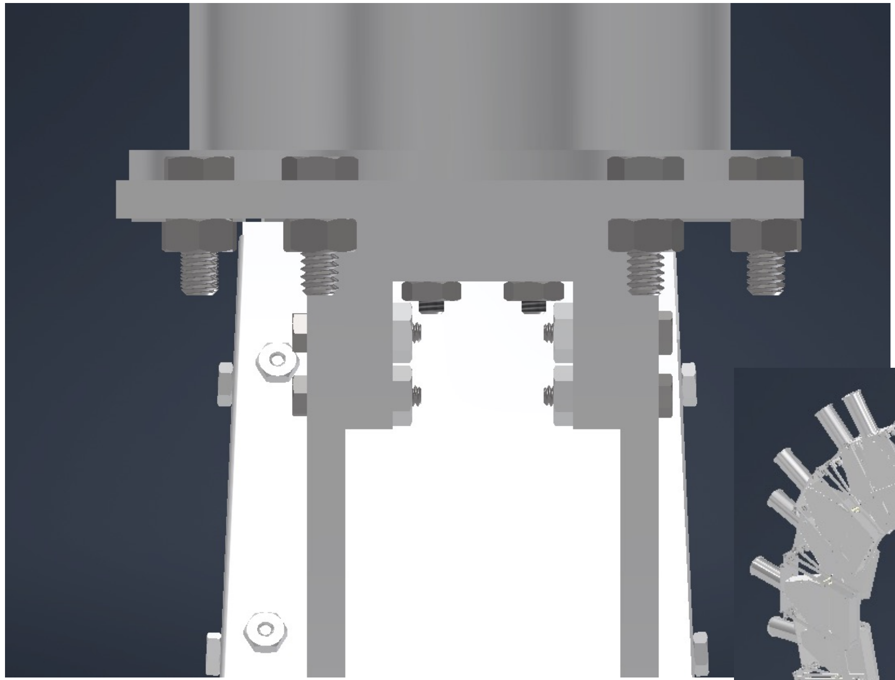
https://github.com/Jeffe
shield-design/analysis/n

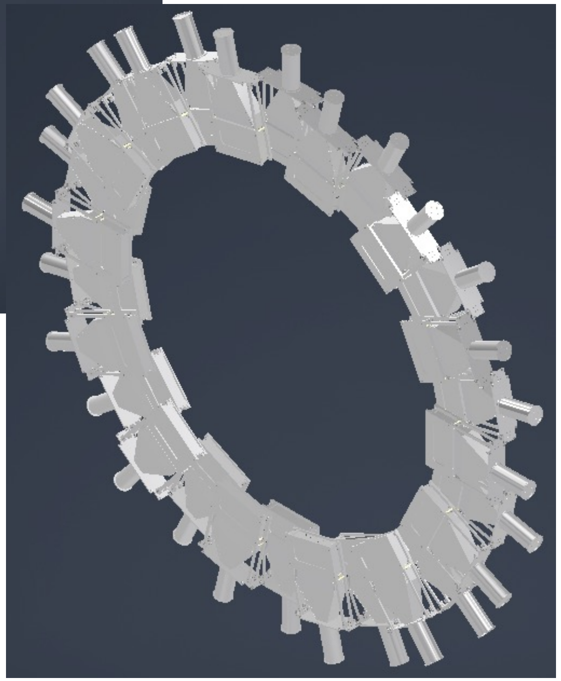
- Use same above calculation numbers, except mipF is replaced with simulated edep
- Also, no particle type or energy cuts of any kind for this analysis.

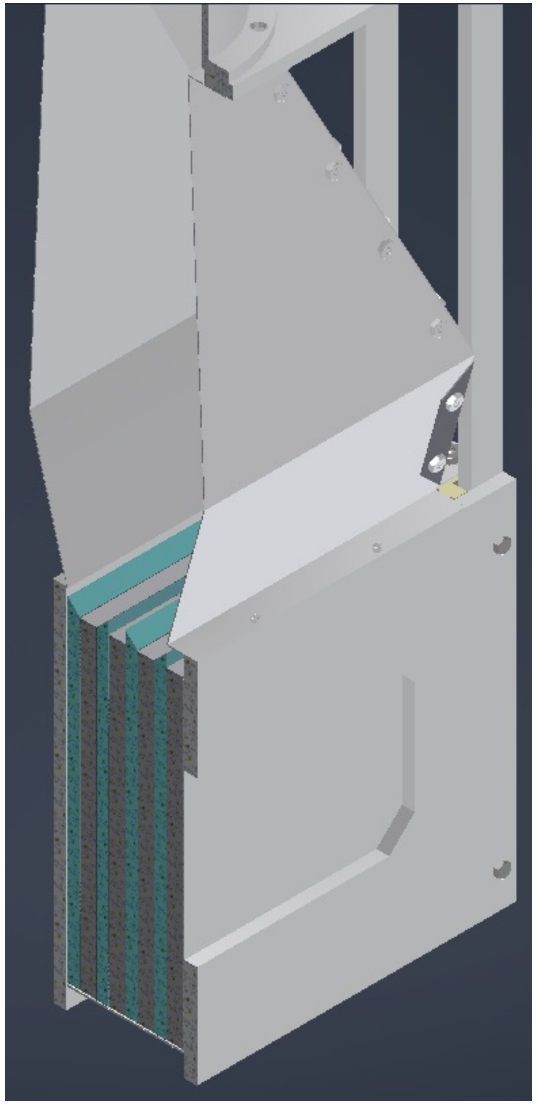
Summary (9/2021)

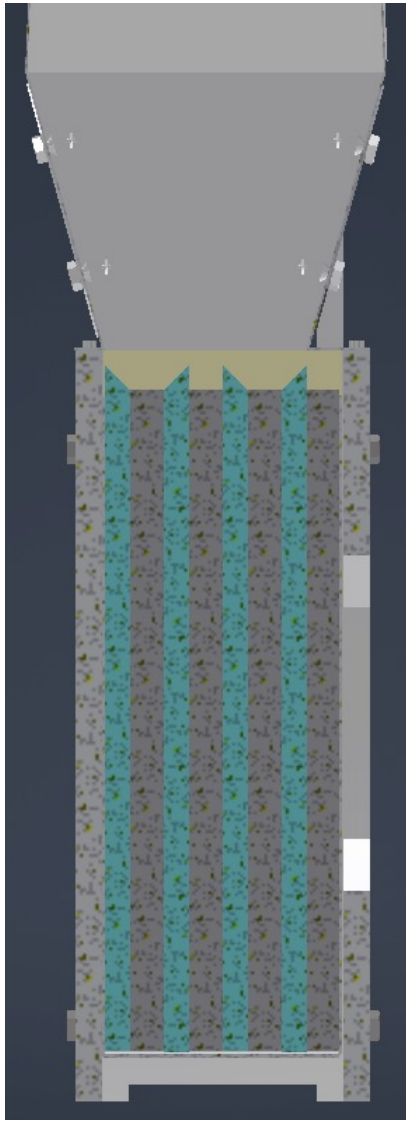
- 2nd tile has greatest dose; 4th tile has lowest dose.
- Peak dose per 5x5 mm^2 is in Open tile#2 and is at least ~500 Mrad
- Runs with greater statistics for background generators are underway—to reduce possibly large stat fluctuations
- We irradiated one of our Heraeus samples to > 500 Mrad (per 5x5 mm2) and it still transmitted light well for 400 nm and up. We're working to quantify light loss in this extreme case.

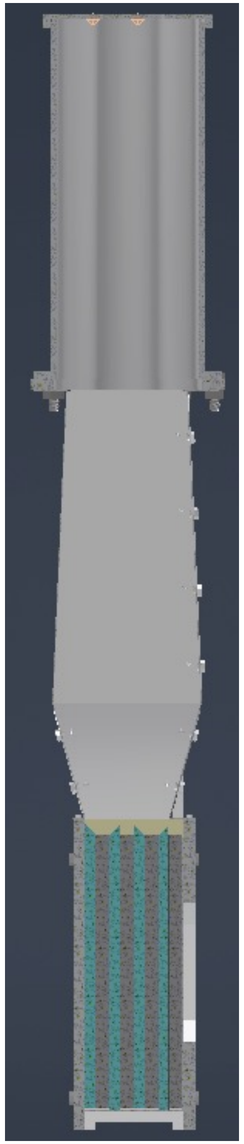
Appendix Slides (ShowerMax)





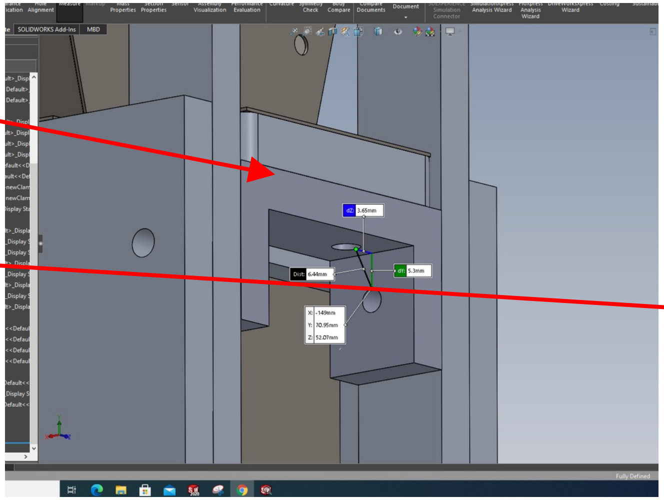


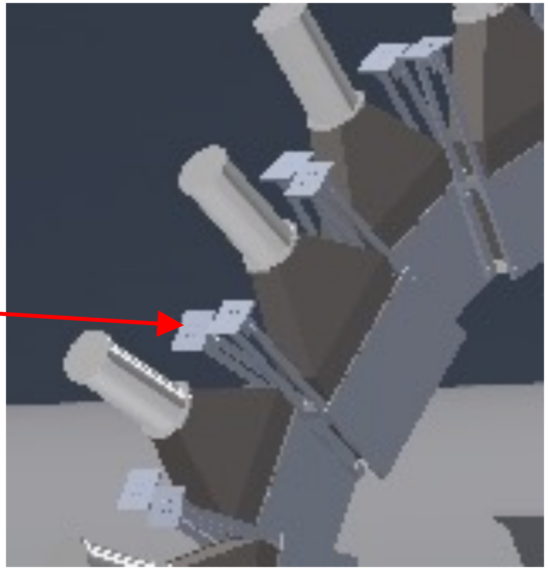


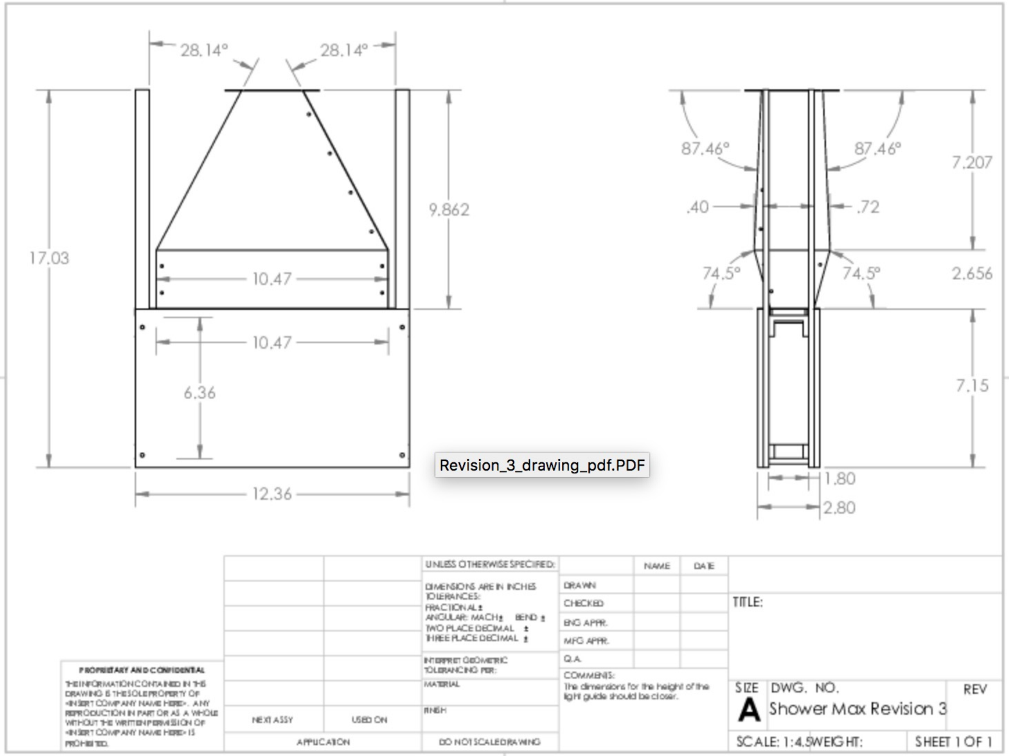


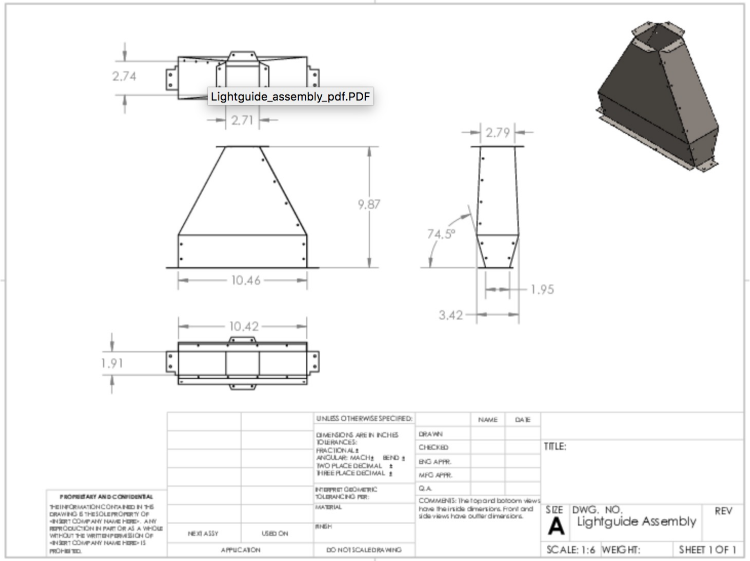
Appendix Slides (ShowerMax)

- Beefed up chassis cross-strut supports
- Welds are no longer used on the outer supports, instead use a U-channel cross-strut support with square mounting plate
- Active area 16 cm x 26.5 cm
- 6 mm thick quartz and 8 mm thick tungsten





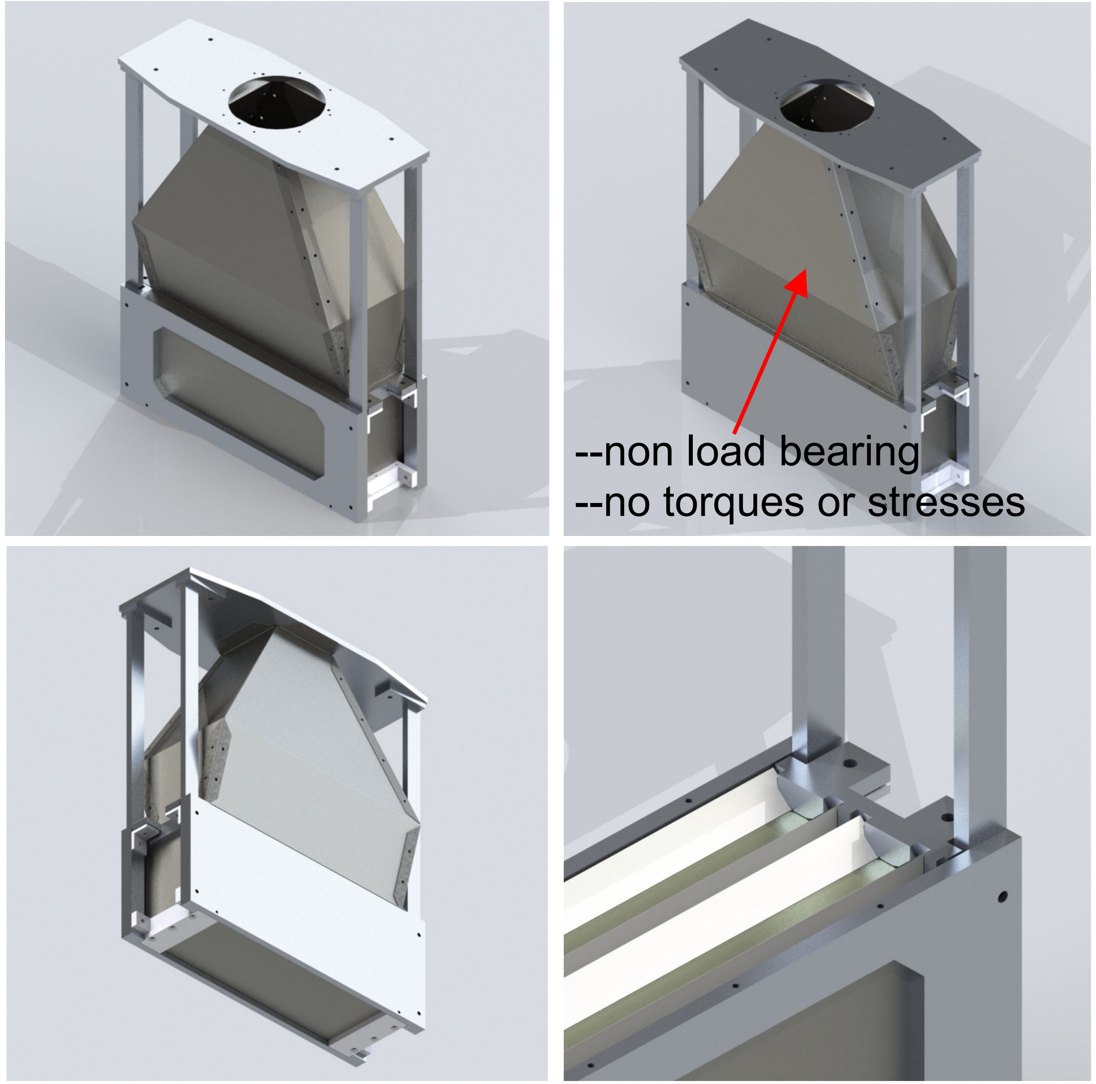




- Two piece LG design

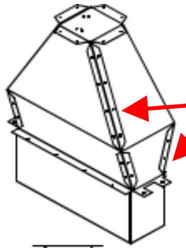
Appendix Slides (ShowerMax)

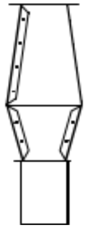
ShowerMax light guide



--non load bearing
--no torques or stresses

ITEM NO.	PART	MATERIAL	QTY.
1	Light Guide - Back	0.020 ANOLUX MIRO-SILVER REFLECTIVE ALUMINIUM SHEET	1
2	Light Guide - Front	0.020 ANOLUX MIRO-SILVER REFLECTIVE ALUMINIUM SHEET	1
3	Long Flap	0.020 ANOLUX MIRO-SILVER REFLECTIVE ALUMINIUM SHEET	2
4	Short Flap	0.020 ANOLUX MIRO-SILVER REFLECTIVE ALUMINIUM SHEET	4
5	Suitcase	0.020 ANOLUX MIRO-SILVER REFLECTIVE ALUMINIUM SHEET	2

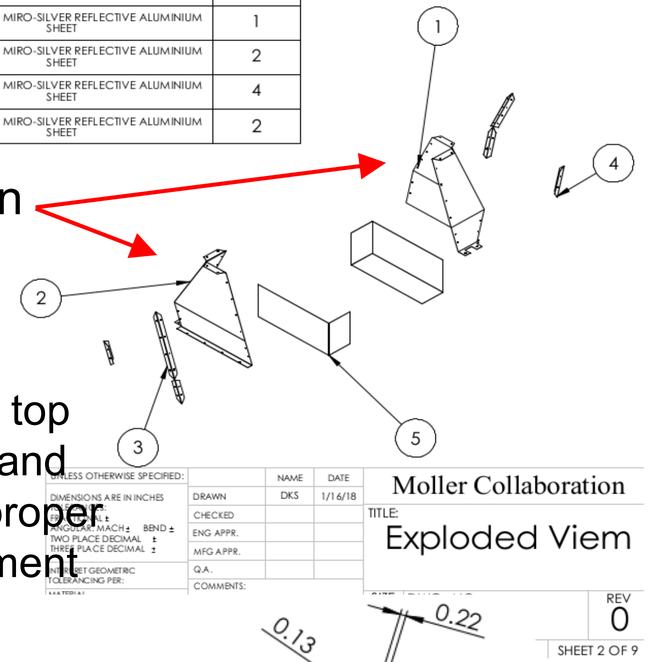


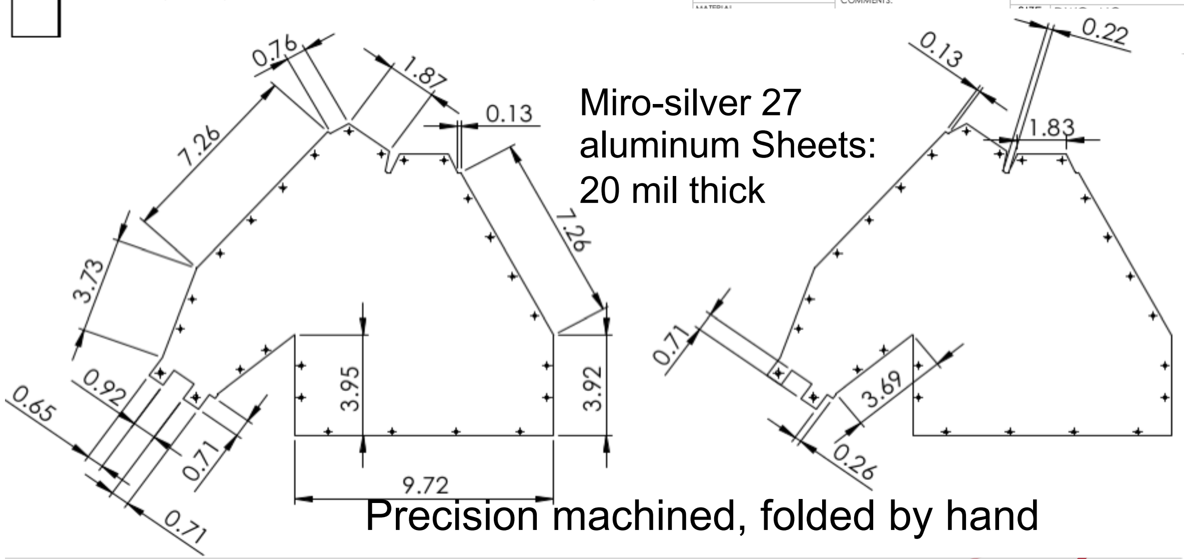


--Two-piece design

Folded alum. flaps hold two pieces together

--attachment points around top plate hole and along front- and back-plate edges enforce proper lightguide shape and alignment



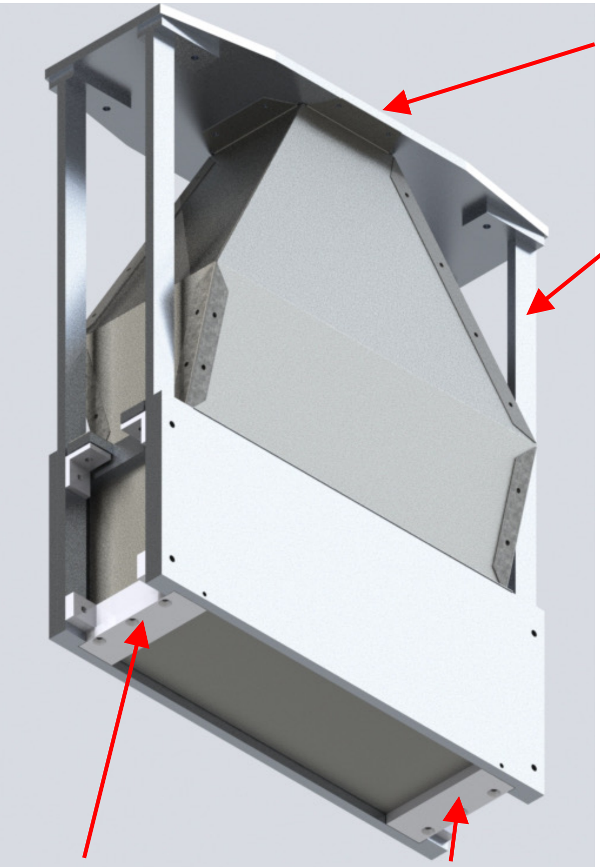


Miro-silver 27 aluminum Sheets: 20 mil thick

Precision machined, folded by hand

Appendix Slides (ShowerMax)

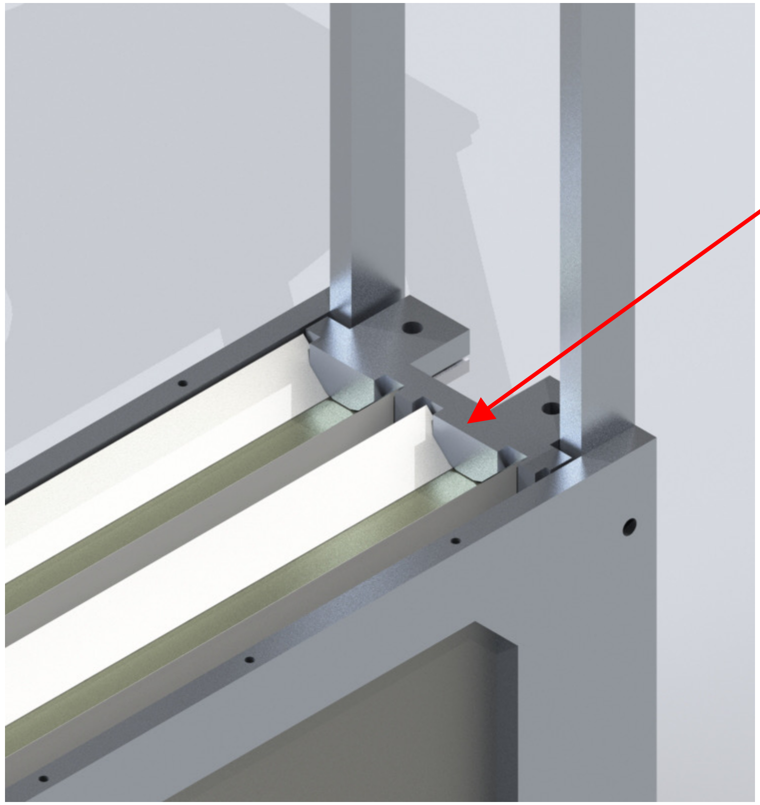
360° Stack support concept (from Nov 2020)



‘Top plate’ for prototype only

‘Struts’
--4 total: run the entire radial extent of detector (¼ inch thick 6061)

--welded supports on outer end
(note: with no top plate, welded supports are reinforced)



‘The Ledge’
--grabs the outer end of stack at the edges (~3 mm bite)
--precision machined aluminum
--can be shimmed for perfect height/pressure fit

‘The Floor’: supports inner end of stack at edges

Each consists of two aluminum parts:
-- ¼ inch thick 6061 plate (3 counter sunk through holes)
-- ¼ inch thick 6061 U-channel (3 tapped holes, 2 through holes)
--U-channel with floor plate attaches to struts and front and back plates

- Lateral or phi-direction stack support relies on precision fit of stack coffin into aluminum chassis

Appendix Slides (Shower-max)

Prototypes constructed in 2018: both Full-scale and Benchmarking versions with two different "stack" configurations:

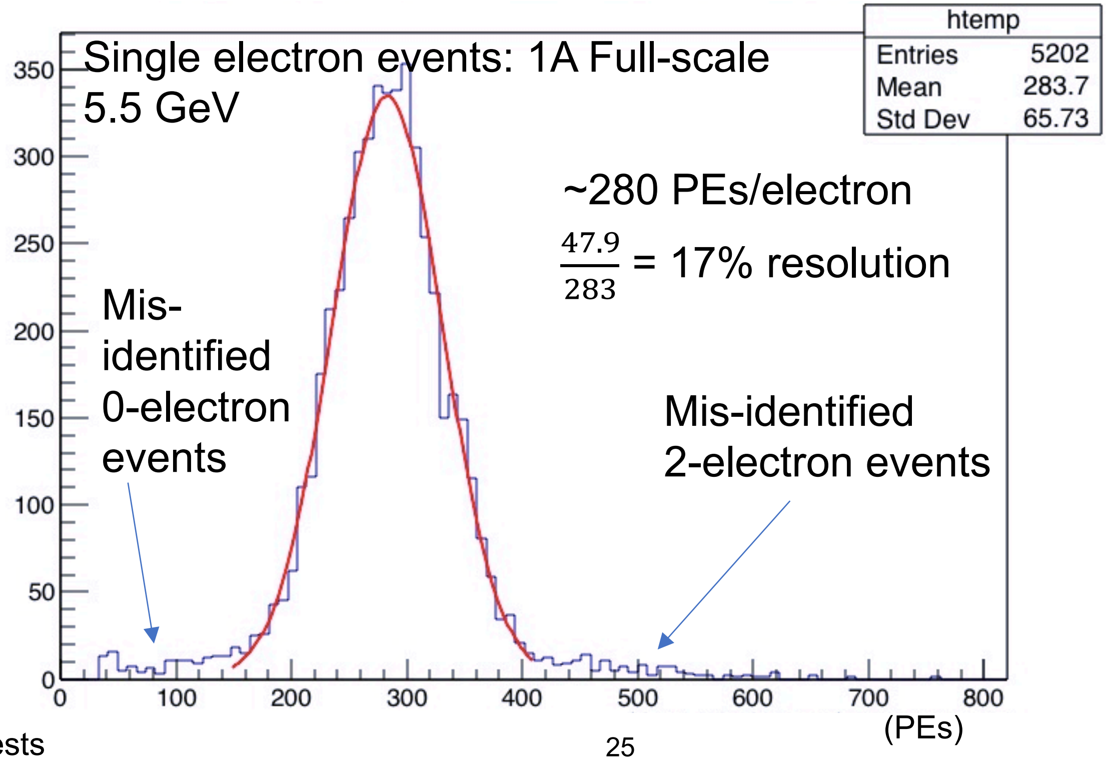
- 8 mm thick tungsten and 10 mm thick quartz (1A)
- 8 mm thick tungsten and 6 mm thick quartz (1B)

SLAC testbeam T-577 run: Dec 6 – 12, 2018

- Exposed prototypes to 3, 5.5, and 8 GeV electrons
- Validated our optical Monte Carlo with benchmarking prototype

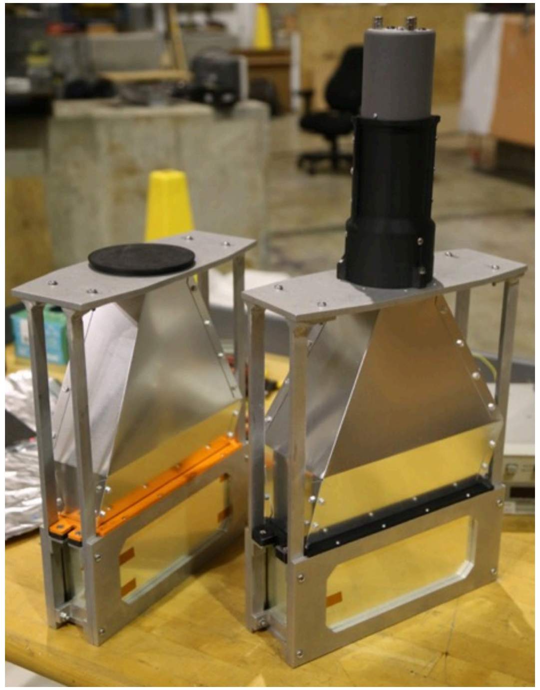
--Stack design validated: number of layers/thicknesses; yields and resolutions match G4 predictions

- Prototype beam performance sufficient for MOLLER and 2nd pass mechanical design improvements underway →



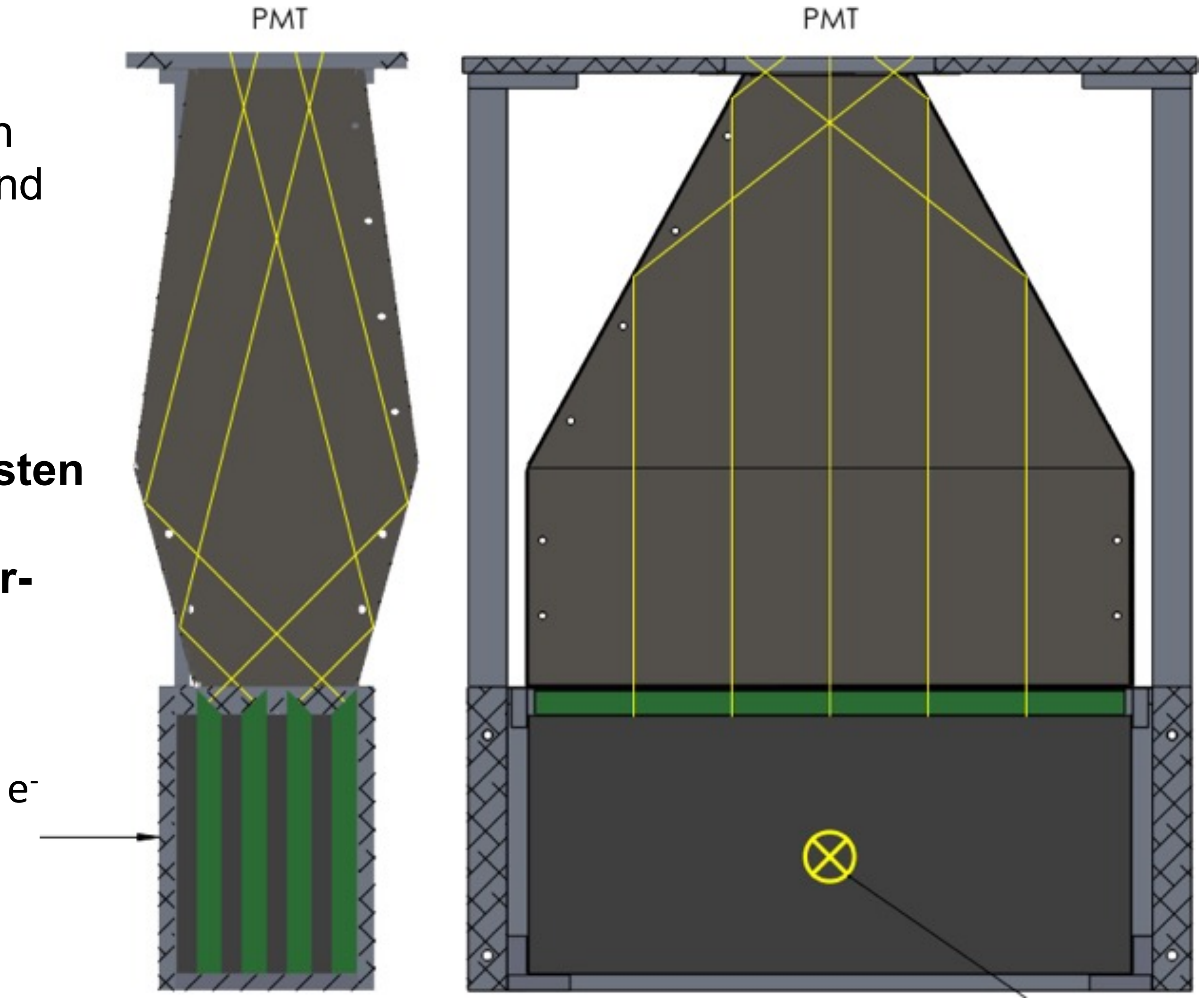
Full-scale prototype: 12 cm x 25 cm active area

- 1st-pass engineered design concept vetted
- Light guide construction techniques developed



Appendix Slides (Shower-max)

- Detector concept uses a layered "stack" of tungsten and fused silica (quartz) to induce EM showering and produce Cherenkov light
  - "Baseline" design developed using GEANT4 optical MC simulation:
    - Design uses a **4-layer "stack"** with **8 mm tungsten** and **10 (or 6) mm quartz** pieces
    - Cherenkov light directed to **3 inch PMT** using **air-core, aluminum light guide**



Materials:

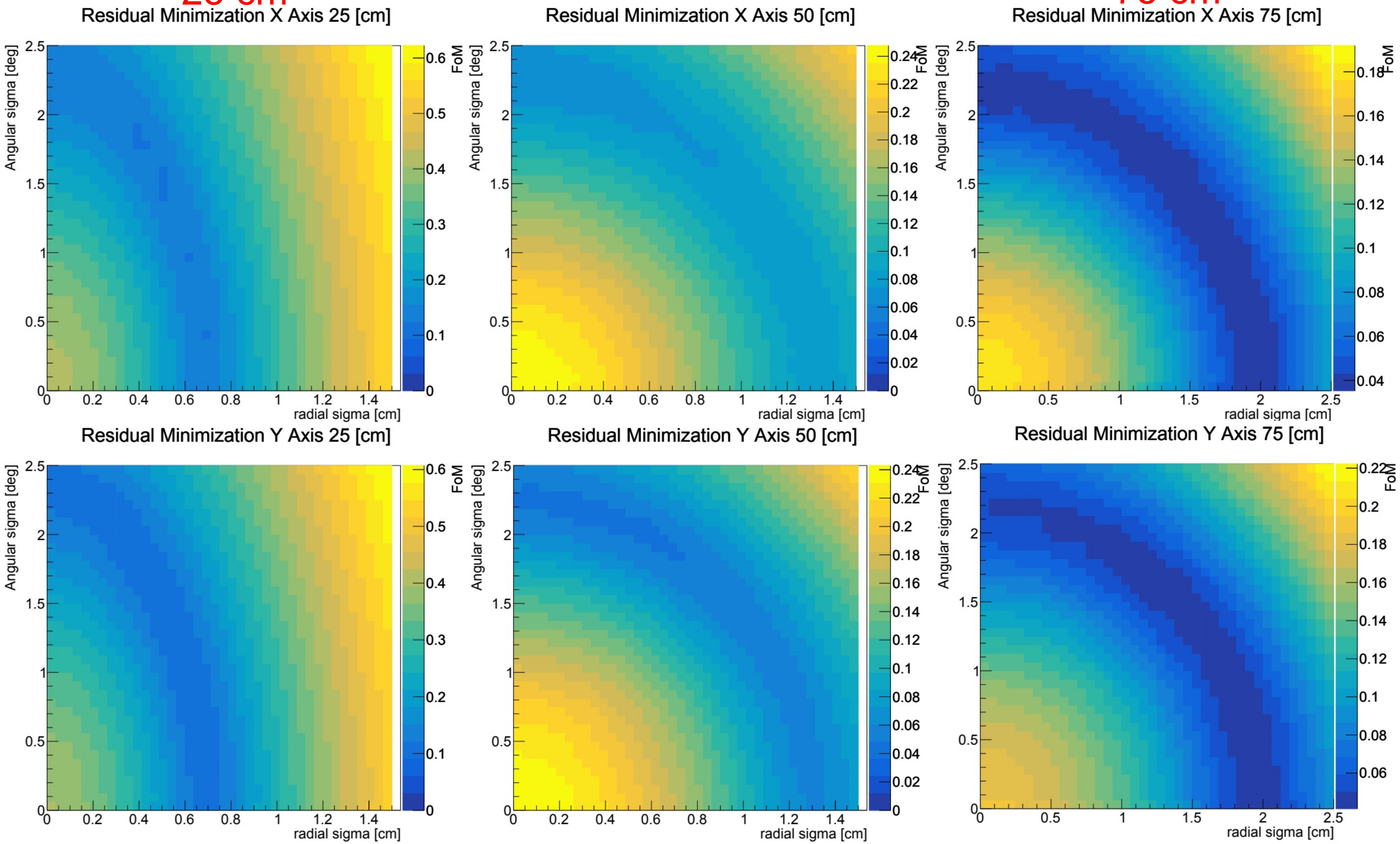
- Aluminum chassis
- Light guides are aluminum specular reflectors (Anolux Miro-silver 27)
- High purity tungsten and quartz
- Total radiation length: 9.1 X_0 tungsten + 0.4 X_0 quartz = 9.5 X_0; Molière radius ~ 1.1 cm

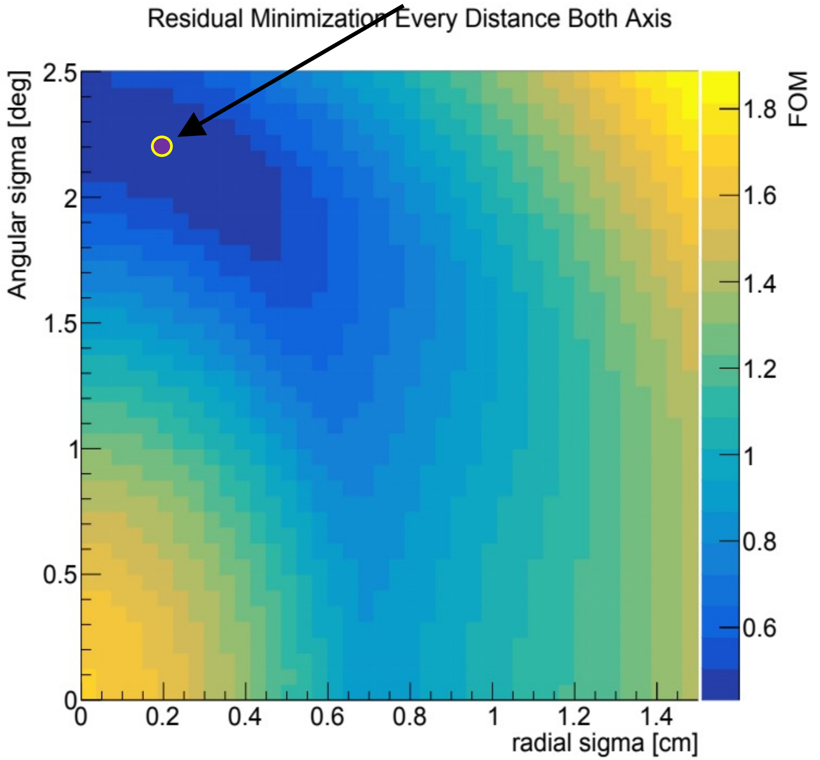
Appendix Slides (Quartz rad-hard tests)

Dose-sim G4 beam generator parameters: radial and angular sigma – optimized at (0.2 cm, 2.2 deg)

Beamspot distance from beam exit vacuum window:

25 cm 50 cm 75 cm



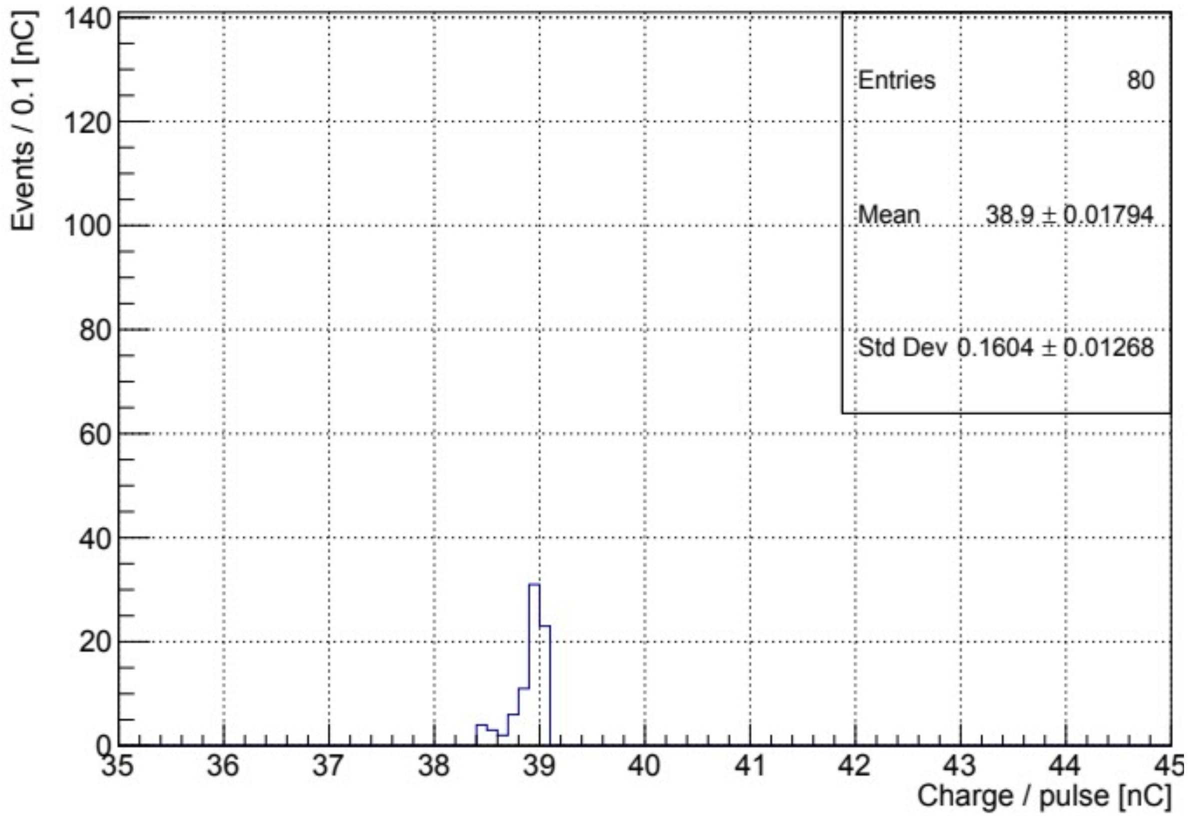


FOM = RMS of residual between real and simulated beamspot.
Summary plot above sums FoMs from both x and y plots for all (25, 50, and 75 cm) distances and gives the optimal parameters for simulating beam size and divergence at sample location

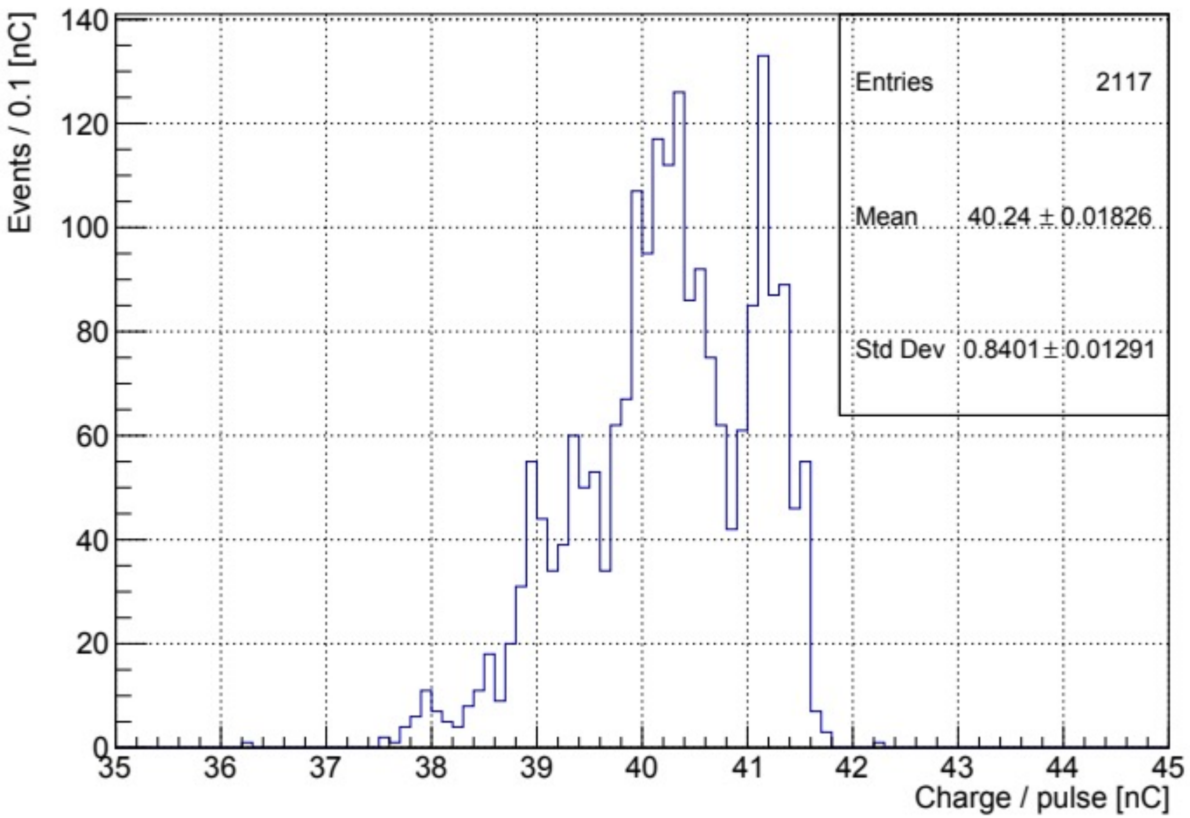
Appendix Slides (Quartz rad-hard tests)

Beam charge data (Sep 2, 2021)

Beam Charge Distribution for Run 1



Beam Charge Distribution for all Sample runs



Appendix Slides (Quartz rad-hard tests)

Dose and beamspot measurements for G4 simulation

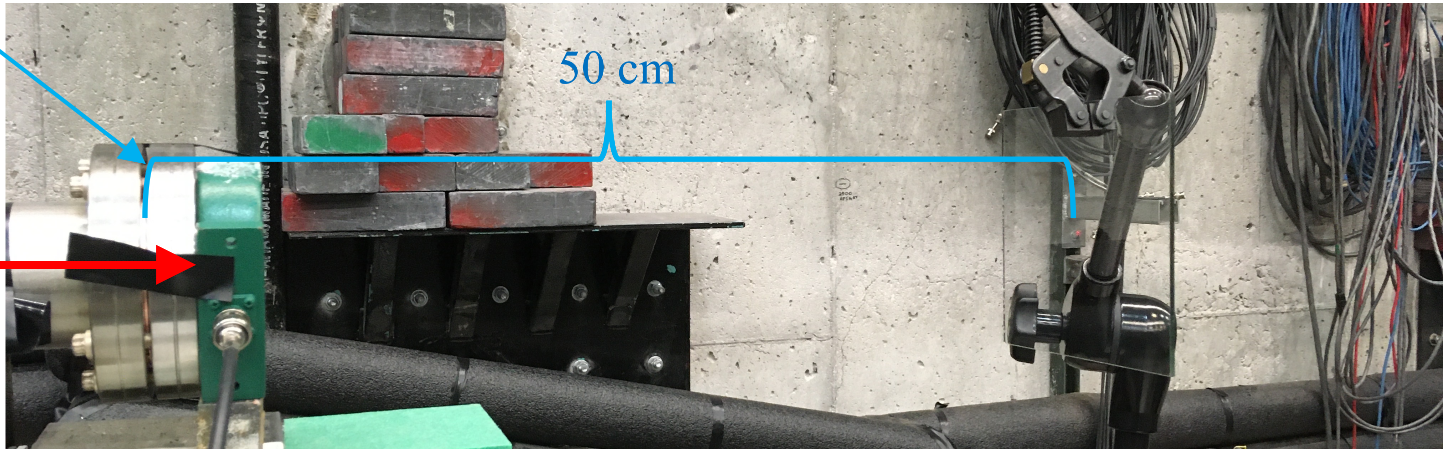
Nanodot OSL dosimeter array
array

beam

Titanium window

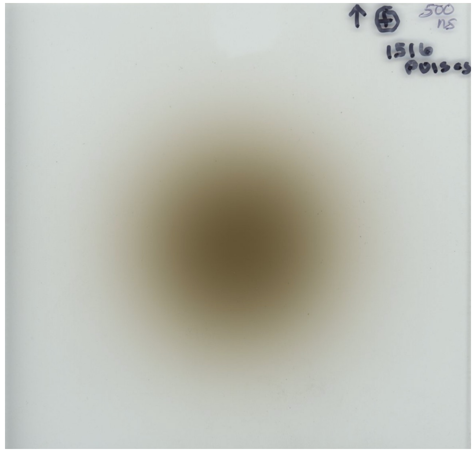
50 cm

beam



OSLs read using microStar

Glass slide



6 in