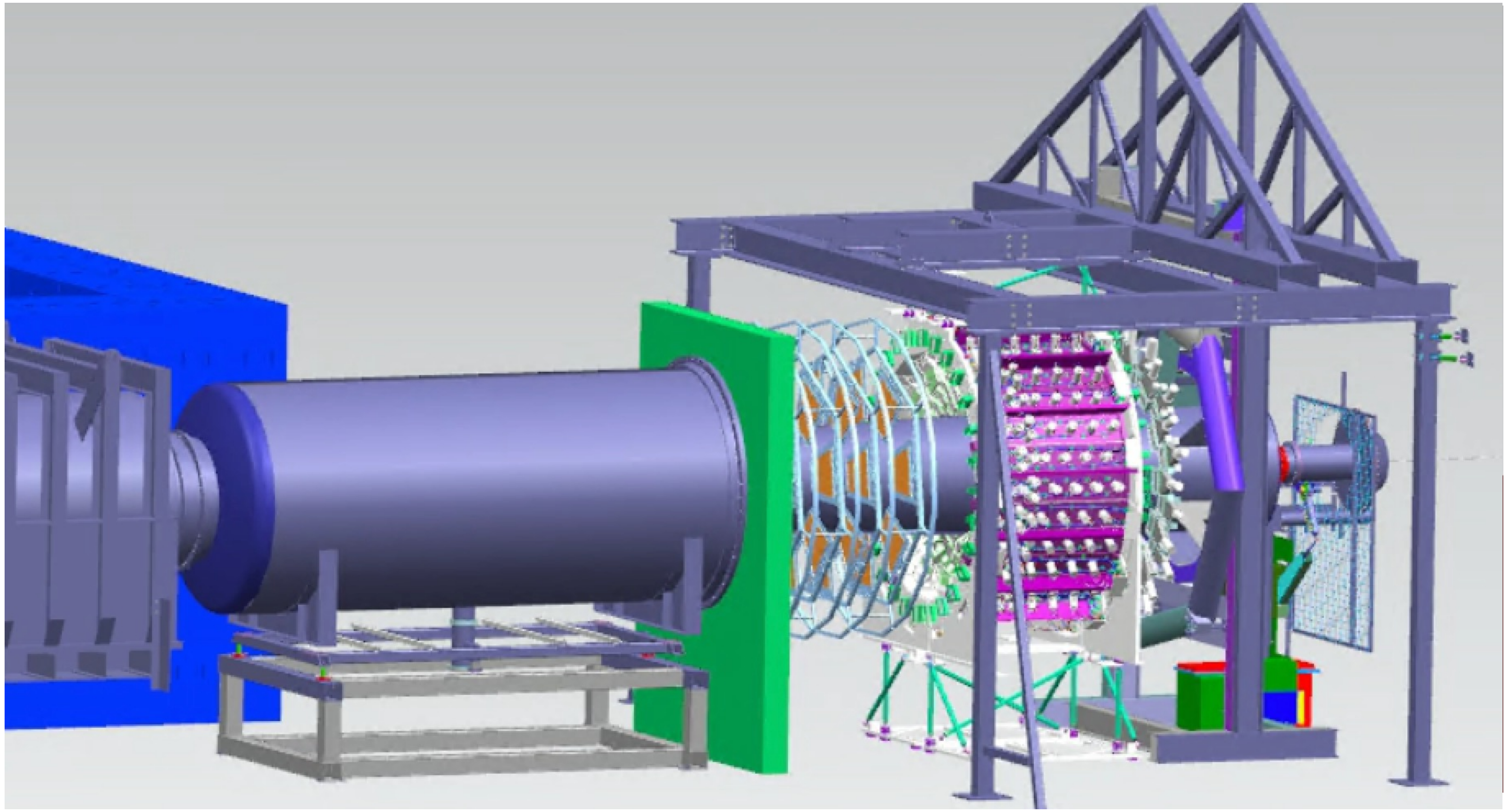
Shower-max, Detector Logistics, Quartz Irradiation Tests



Dustin McNulty – Idaho State University

Sudip Bhattarai – grad student
Justin Gahley – grad student

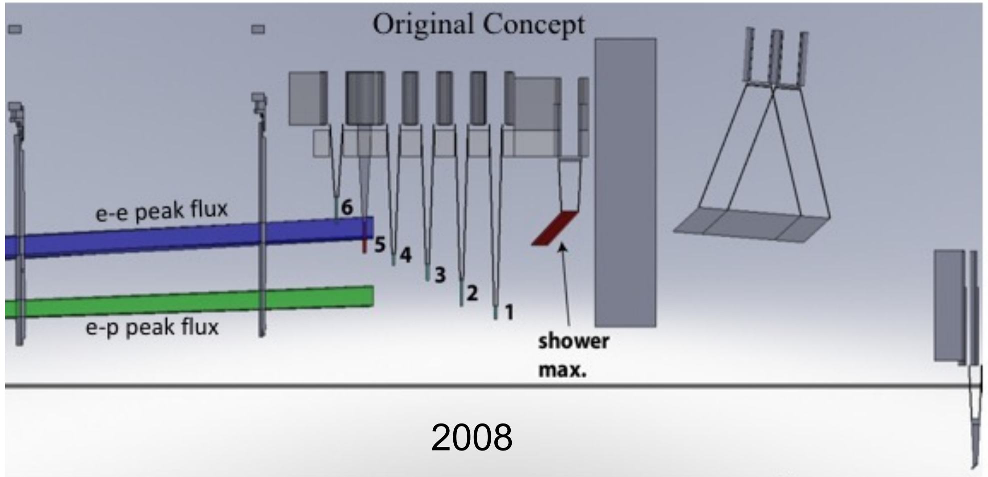
undergraduate students:
Edwin Sosa
Freddy Kouakou
Coltyn Fisher

Outline

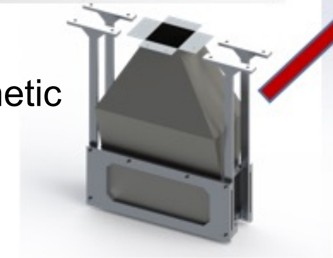
- Shower-max update
  - Subsystem review
  - Schedule timeline and budget
  - Recent design updates and preparations for 60% Design Review
  - Summary and future work
- Detector Logistics
  - Overview: z-locations
  - cabling infrastructure
  - Patch panels and cable routing/harness plans
  - Summary and future work
- Quartz Irradiation Testing
  - Overview:
  - Recent Tests: details and data
  - Summary and future tests

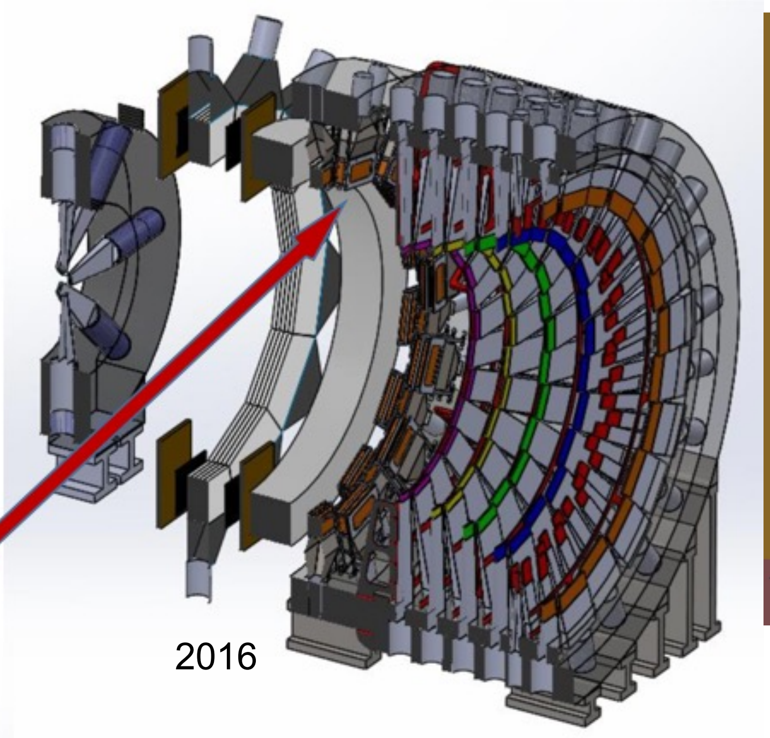
Shower-max Description

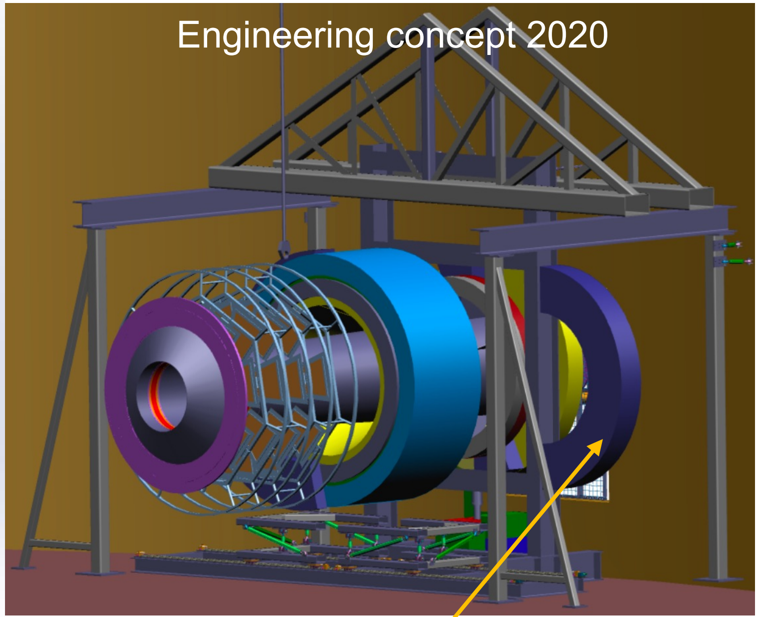
2.04.03	Shower Max Detector	Design, Procurement, Assembly, and Test of the Shower-Max detector system. It is composed of an array interleaved layers of quartz radiatiors and thin tungsten sheets making up an EM shower detector system.



Electromagnetic sampling calorimeter







Shower-max Clam shell

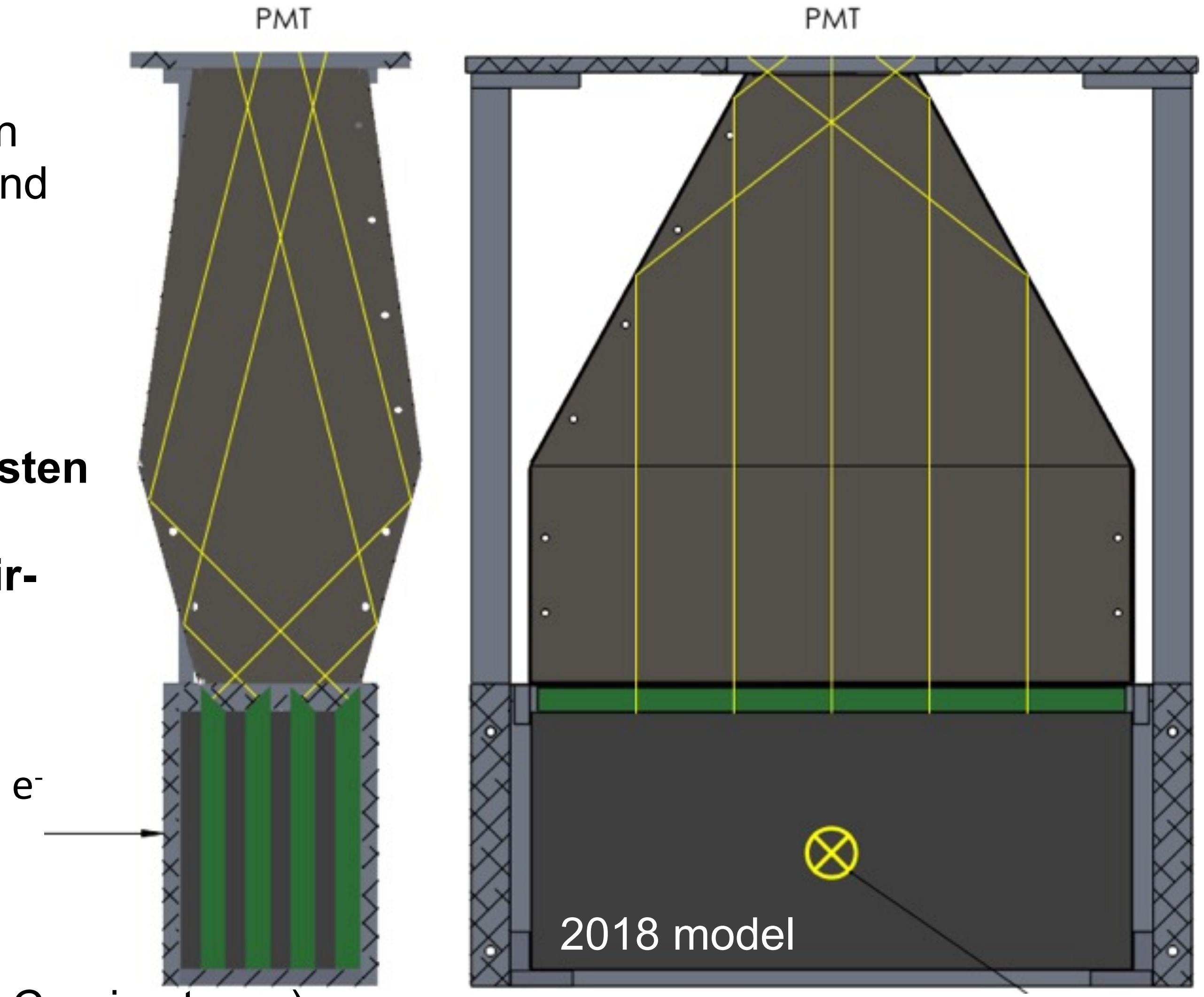
- Provides additional measurement of Ring-5 integrated flux
- Weights flux by energy $\Longrightarrow$ less sensitive to low energy and hadronic backgrounds
- Will also operate in tracking mode to give additional handle on background pion identification
- Will have good resolution over full energy range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

Shower-max: Detector Concept and Materials

Idaho State University

- 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 **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 or Alzak-type)
- High purity tungsten and quartz (Heraeus, Ohara, or Corning types)
- Total radiation length: 9.1 X_0 tungsten + 0.4 X_0 quartz = 9.5 X_0; Molière radius ~ 1.1 cm

Shower-max: Past Prototyping and Testbeam

Idaho State University

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

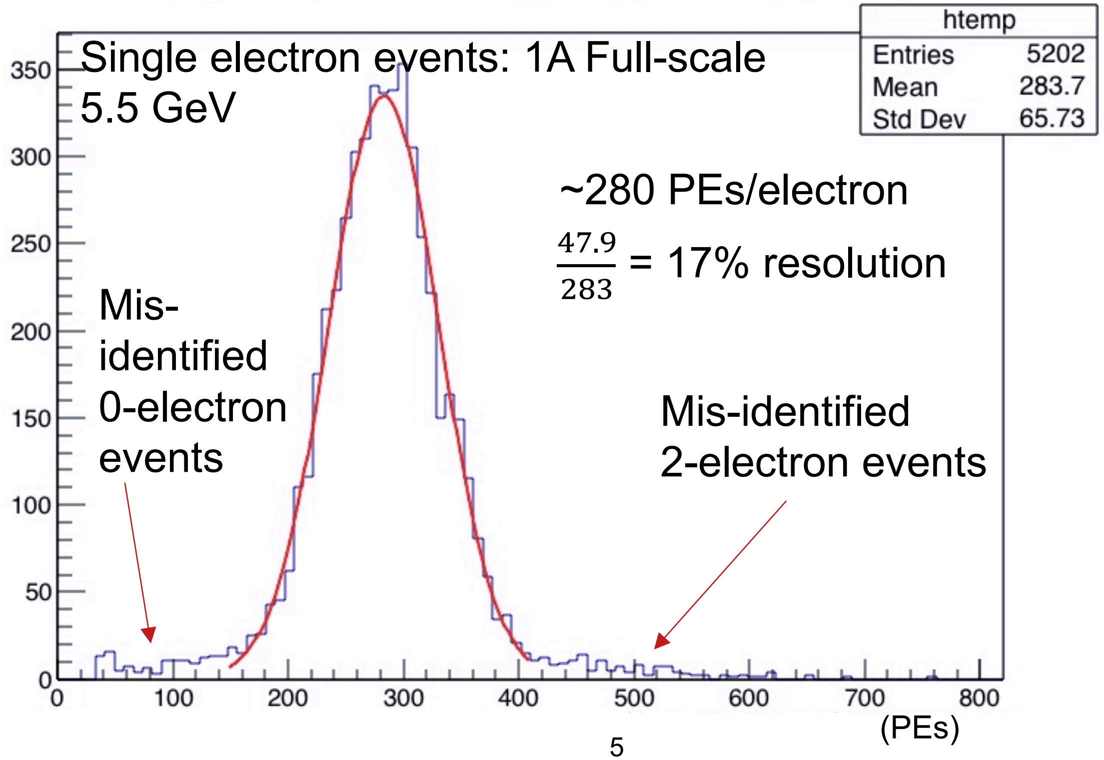
- Exposed prototypes to 3, 5.5, and 8 GeV electrons
- Validated our optical Monte Carlo with benchmarking prototype

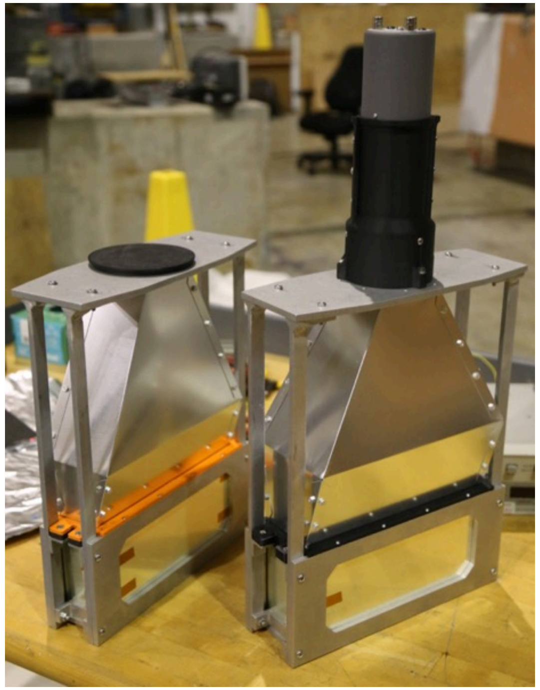
--Stack design validated: number of layers/thicknesses; yields and resolutions match G4 predictions

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

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

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





Jefferson Lab

Shower-max Construction Timeline

- Year-1: includes design tweaks, optical and mechanical, based on SLAC testbeam results and engineering analysis; construction of “production-level” prototypes and testing in early (-mid) 2022. Year-1 for NSF funding ends on 2/25/2022
- Year-2: finalize and review design, place planned large orders of components and parts; start construction and testing
- Year-3: construction/assembly and testing of all 28 production + 7 spare modules
- Year-4: shower-max modules delivered to Virginia.   Note that shower-max *stack layers* will need to be disassembled for transport and reassembled in Va; lightguides stas intact but separated from chassis--which also stays mostly fully assembled

Shower-max NSF Budget – components and materials

Equipment & Materials Budget for WBS 2.04.03 Shower Max Detector

Item	Cost (FY20$)	Cost (at-year $)
Quartz (127 pieces)	$200K (VE, PE)	$212K (FY22 $)
Tungsten (124 pieces)	$118K (VE, EJ)	$125K (FY22 $)
PMTs (31)	$51.5K (VE)	$55K (FY22 $)
PMT bases (31)	$10.7K (VE)	$11K (FY22 $)
Light Guides (31)	$12.5K (EJ, VE)	$13K (FY22 $)
Module chassis (31)	$15.5K (EJ, VE)	$16.5K (FY22 $)
Misc. consumables	$1.7K (EJ, PE)	$1.8K (FY22 $)

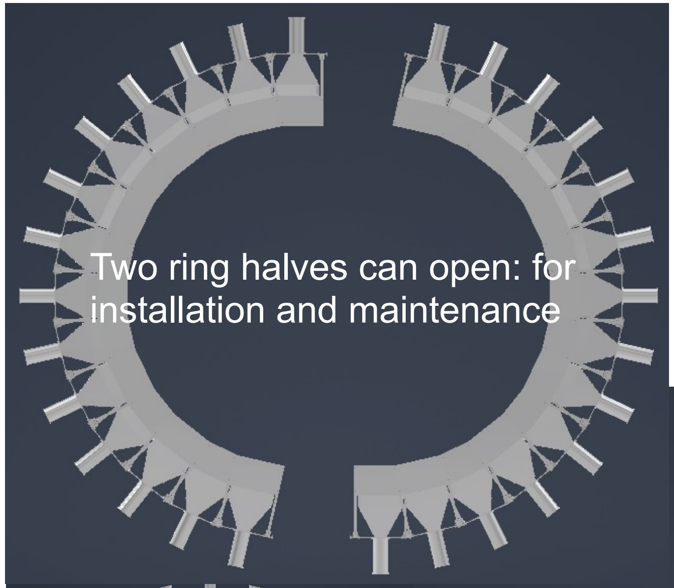
- Large cost items, requiring formal review before purchase, are high-lighted
- FY20 costs were increased by 3% per year to account for expenditures in FY22. The predicted equipment and material cost per module is $14K (FY22 $)

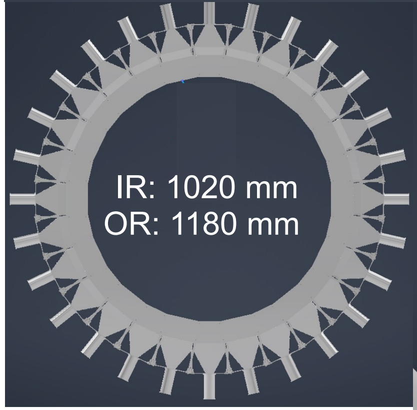
Technical Progress Since CD-1 (Shower-max)

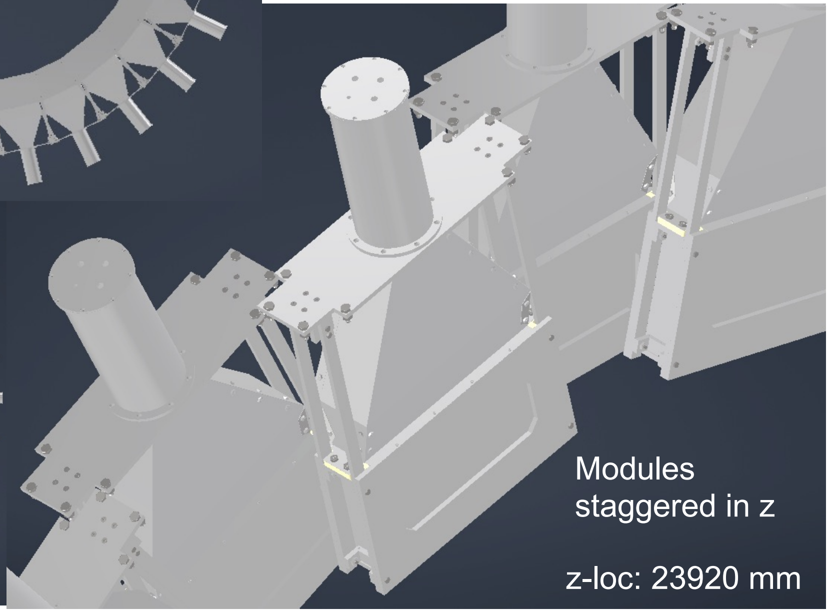
Idaho State University

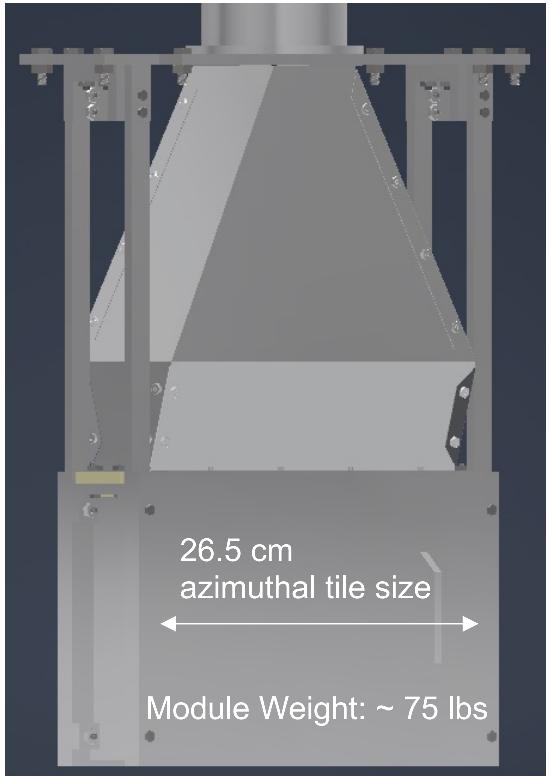
ShowerMax detector: ring of 28 sampling calorimeters intercepting physics signal flux 1.7 m downstream of ring 5

- Detector z location and radial acceptance near finalized
- New (final) 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

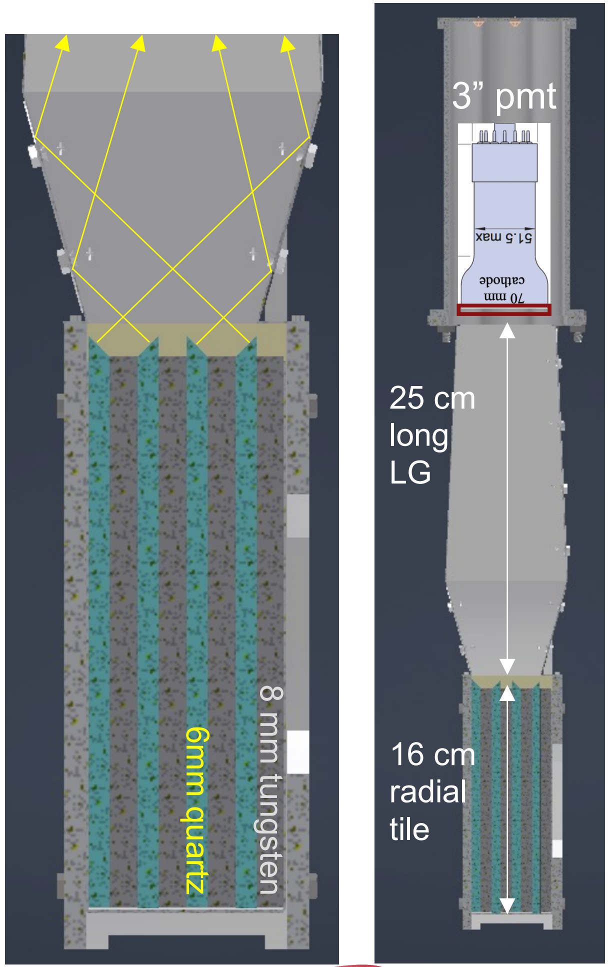








~All aluminum chassis and air-core light guide



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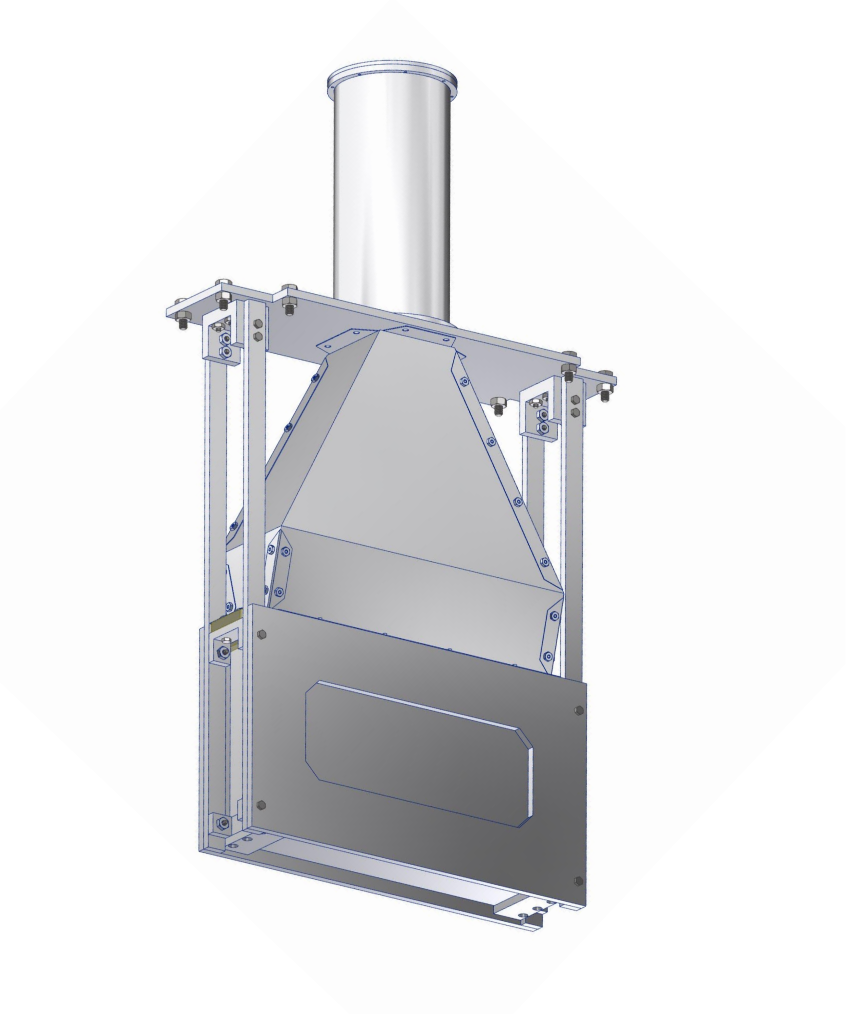
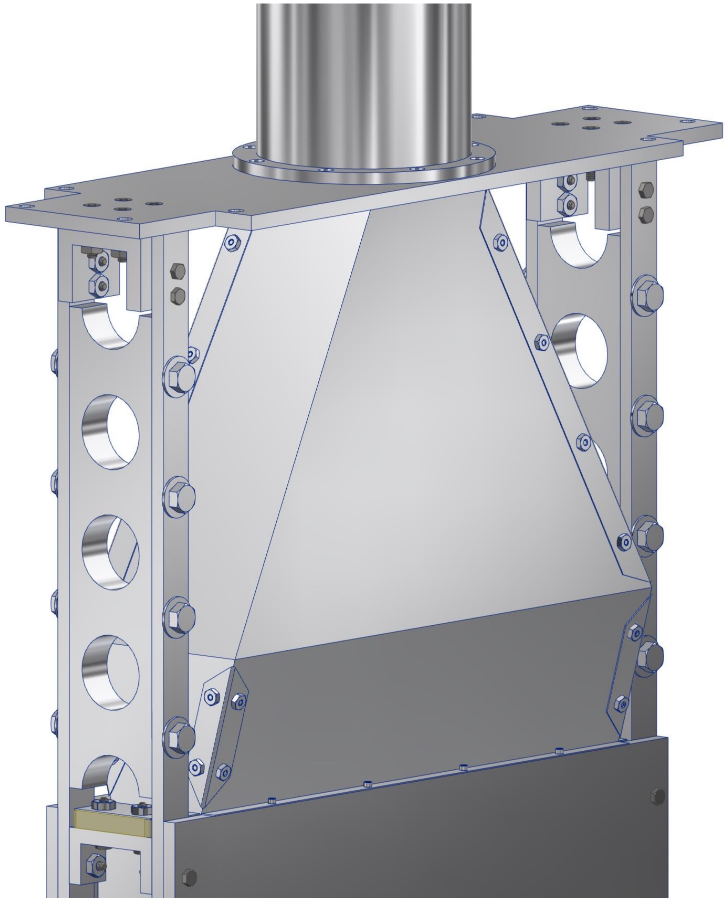
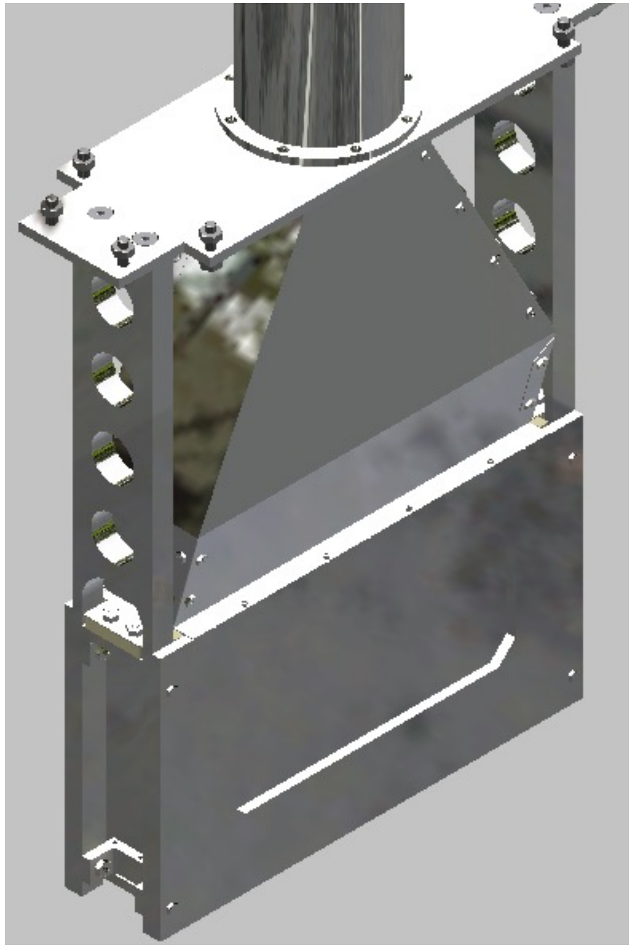
Recent Shower-max chassis mods



SM Model passed to Larry



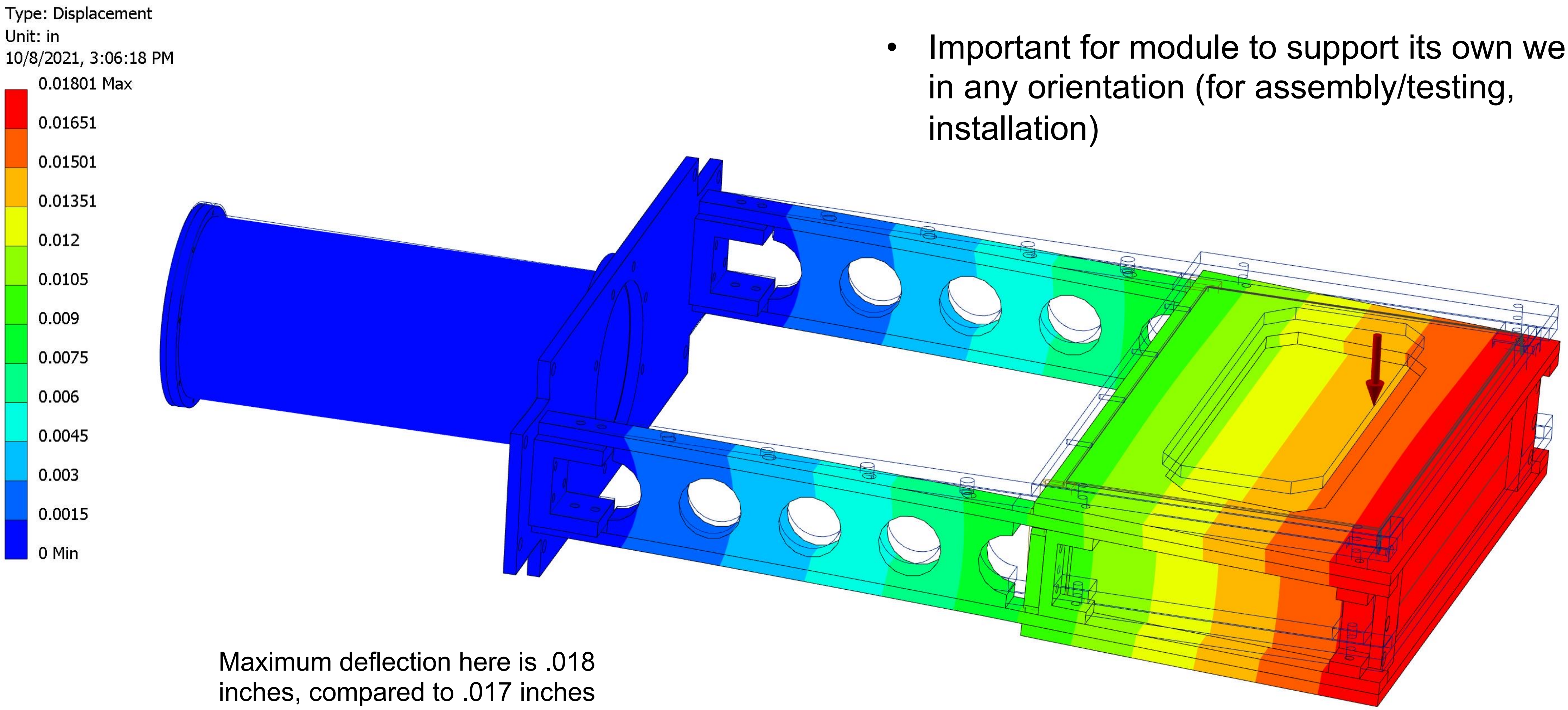
Modifications by Larry: New webbed plate with bolts



Current Model: Updates made following engineering advice—consolidate and regularize parts

Shower-max Chassis FEA (by Larry Bartoszek)

Deflection ("weak-axis") plot for module with holes in assembly position



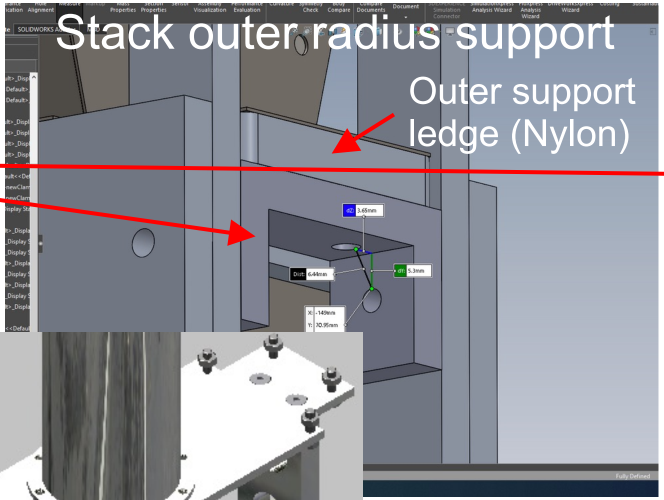
- Important for module to support its own weight in any orientation (for assembly/testing, installation)

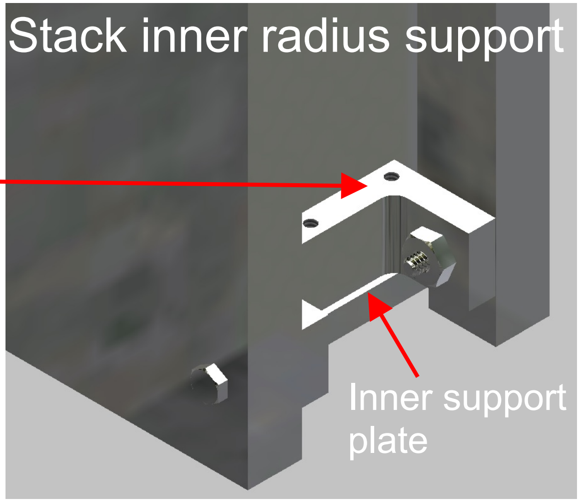
Maximum deflection here is .018 inches, compared to .017 inches without holes. Insignificant difference.

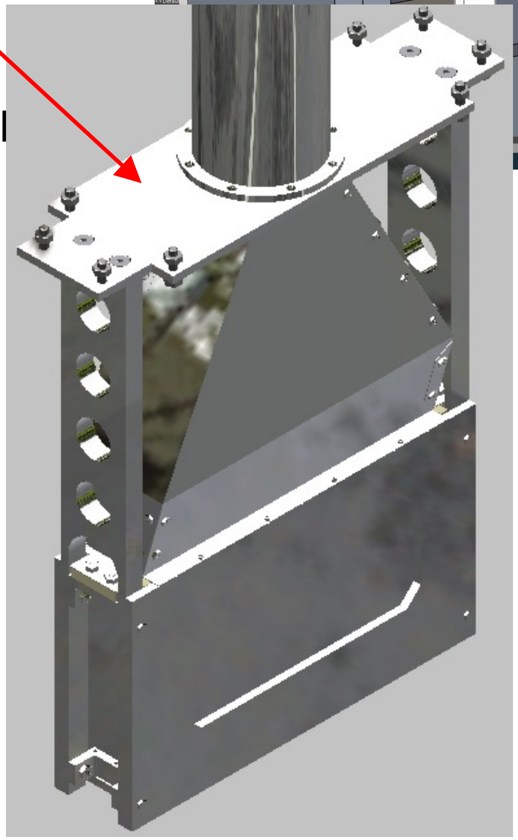
Shower-max Design Updates

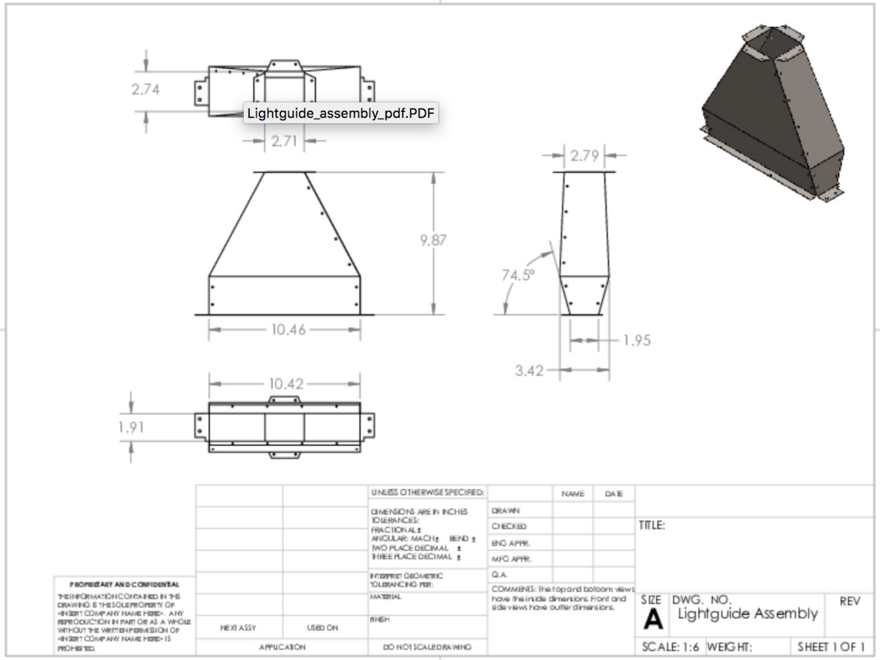
Idaho State University

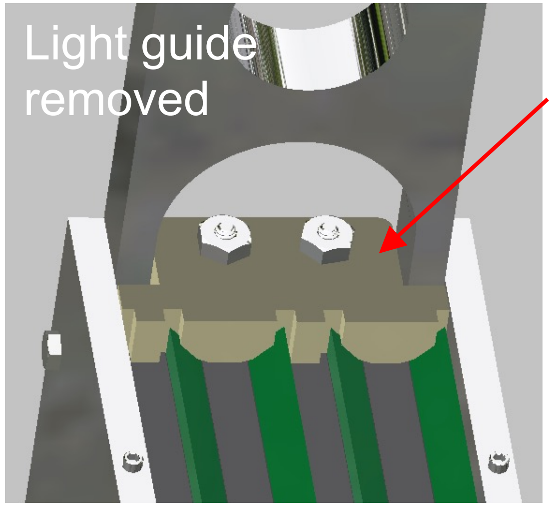
- New webbed plate added to improve weak axis deflections; one piece design with struts to reduce parts
- Cross-strut (U-channel) supports made unform
- Outer plate re-implemented with modifications
- Two piece LG design (20 mil thick aluminum mirror)
- Active area 16 cm x 26.5 cm
- 6 mm thick quartz and 8 mm thick tungsten; uses 3 mil thick quartz wrapping (needed to protect polish)
- Planning to test/use 350 nm or 400 nm long pass filter and ND filter to stabilize and reduce PE yields







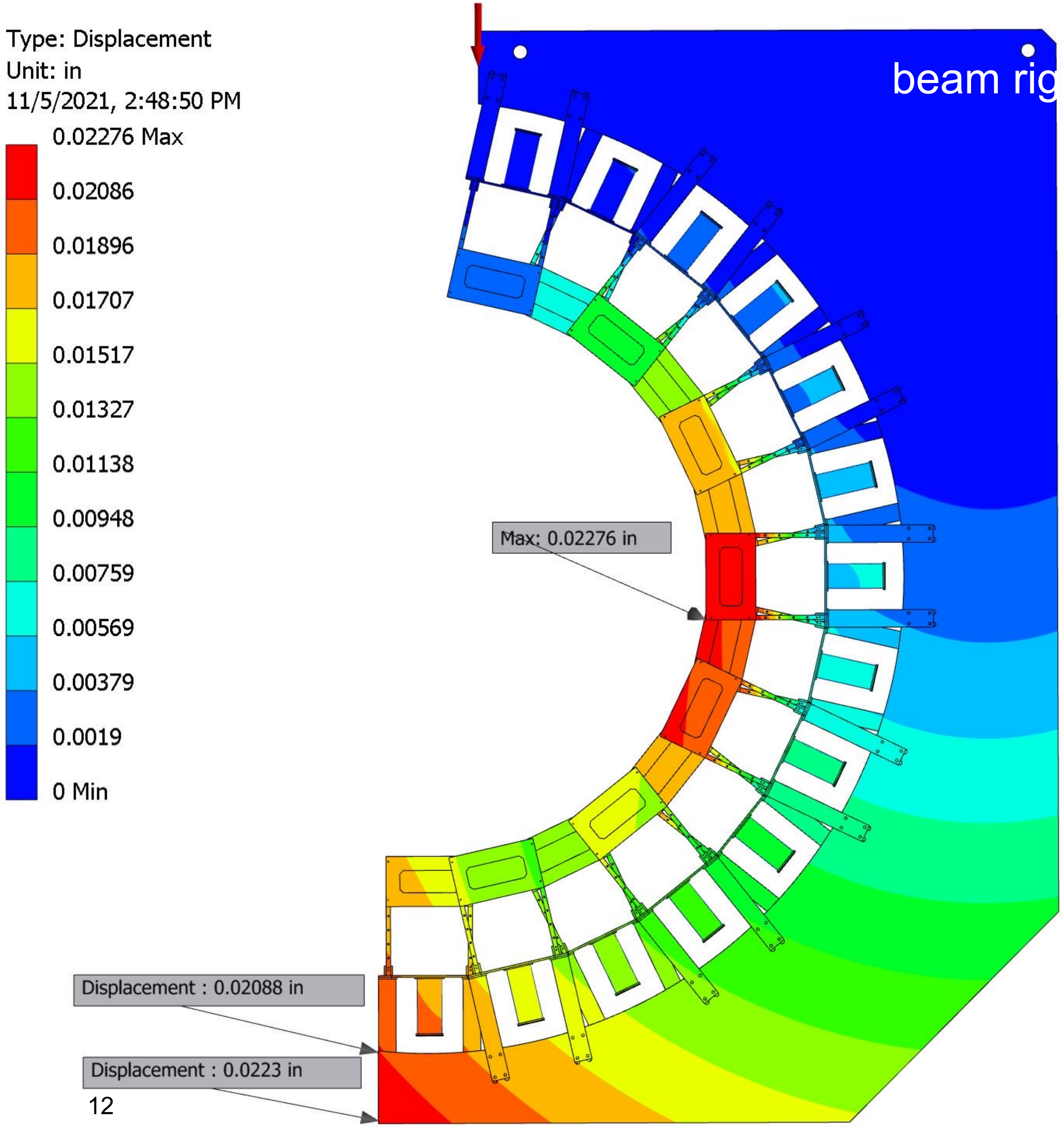




Outer support ledge:
--grabs 2 mm on each end
--Plan to 3D print with Nylon, fiber-embedded nylon, or ASA
--Shear strength is very high; issues are scratching quartz, UV resilience, and rad hardness

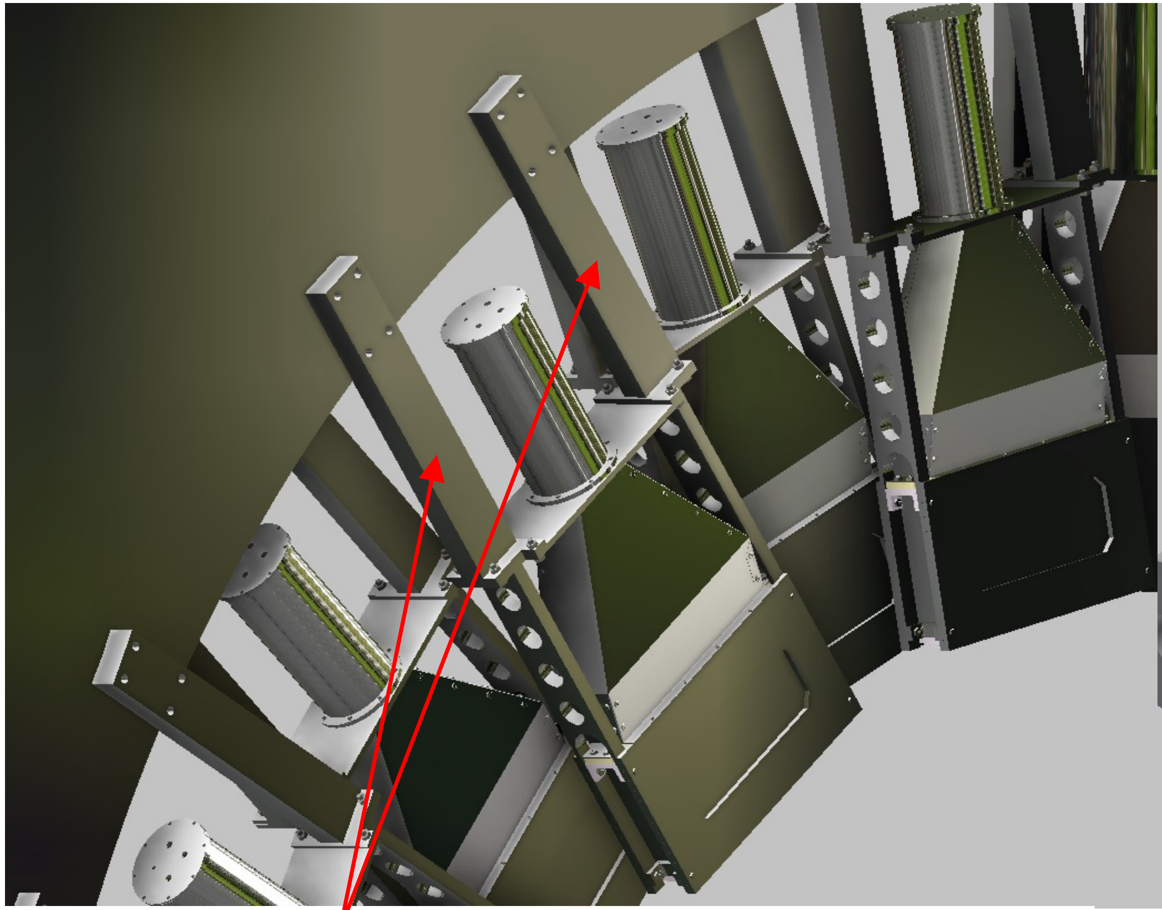
Shower-max Ring Support Structure (by Larry B.)

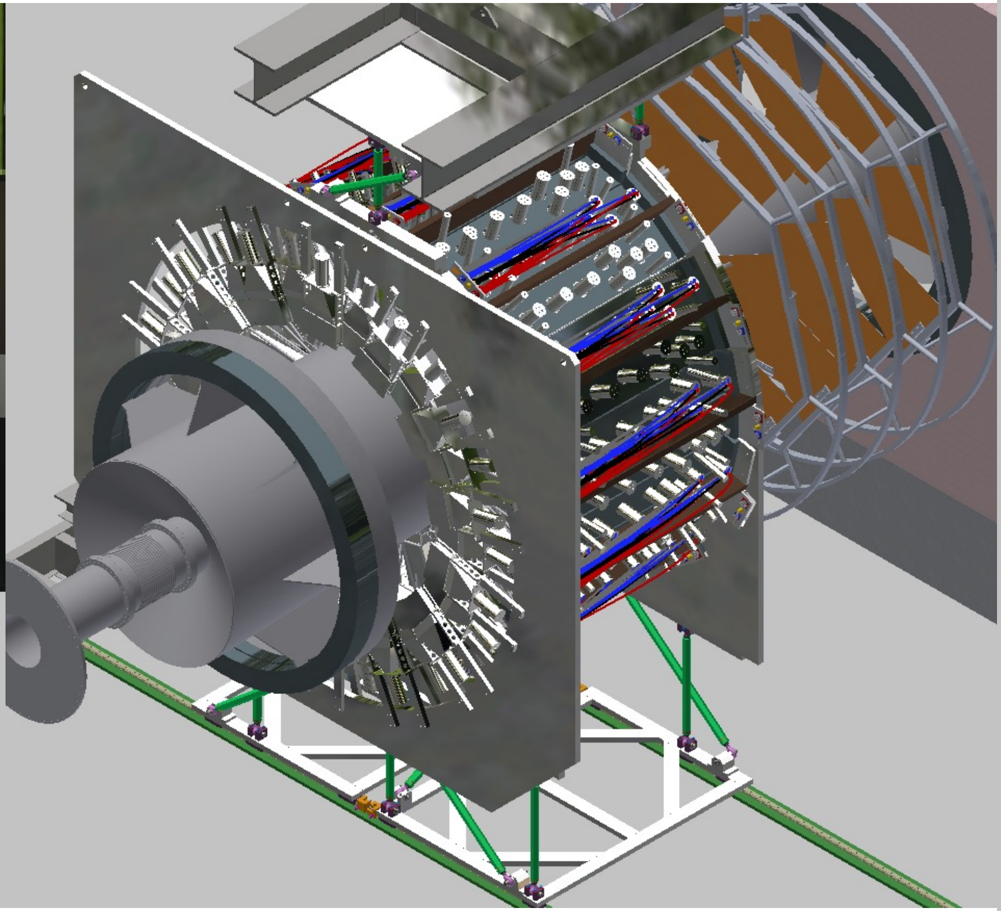
- Maximum deflection is in the horizontal mid-plane module (mostly vertical deflection at the level of 0.5 mm)
- The relatively small deflection at the lower support structure will allow more straight-forward left-right mating/separating of the two halves
- Each half weighs 1230 lbs without detectors, and 2400 lbs with detectors
- Each module weighs ~75 lbs plus 8 lbs including the two aluminum "C" attachment bars
- Both halves of the fully loaded structure with no cabling or hanging support hardware is 4800 lbs

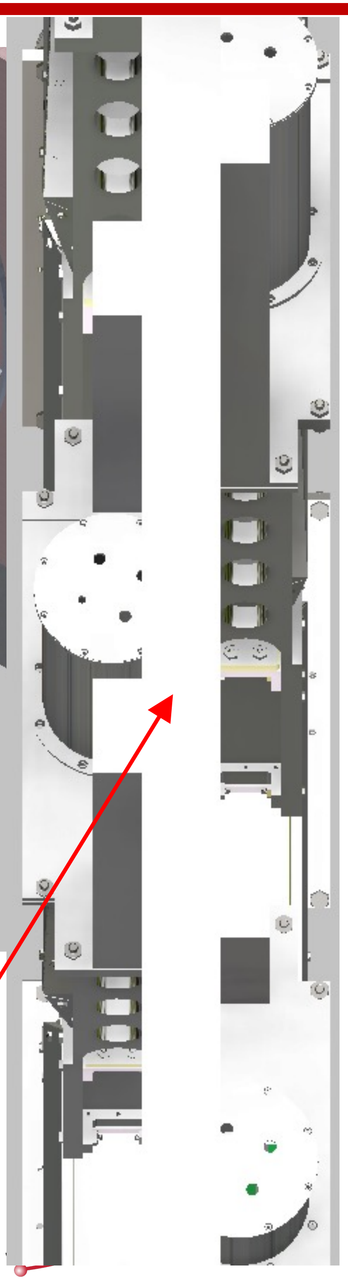


Shower-max Ring Support Structure

Idaho State University







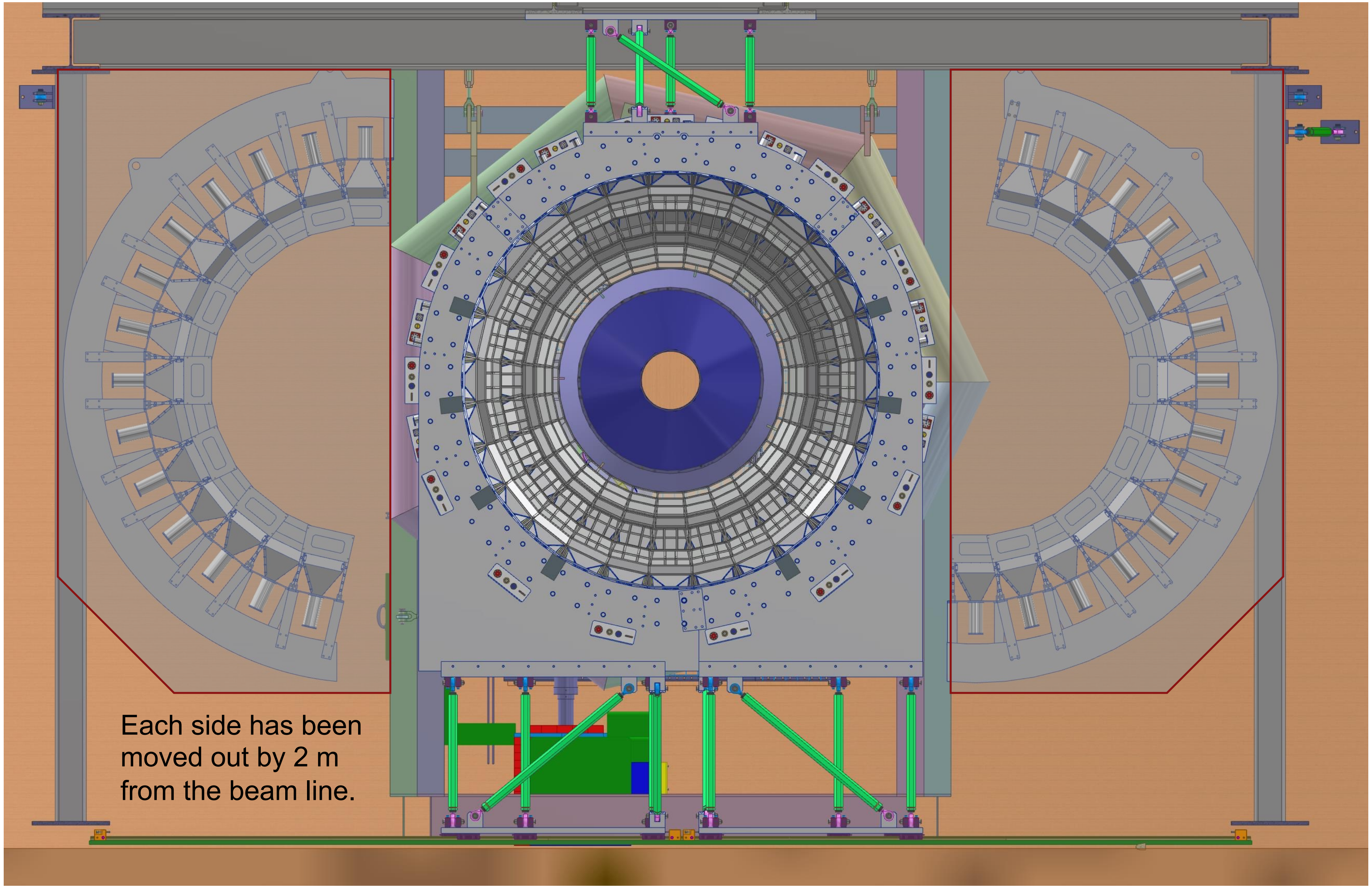
- Aluminum bars (15 x 1.25 x 2.5 in^3) attach modules to "C" structure--which is 2 inch thick (along z)
- Staggered modules are mounted to US and DS face of "C's" (in alternating pattern)

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

Shower-max detector retracted off the beam line Plans

Idaho State University

View from Larry

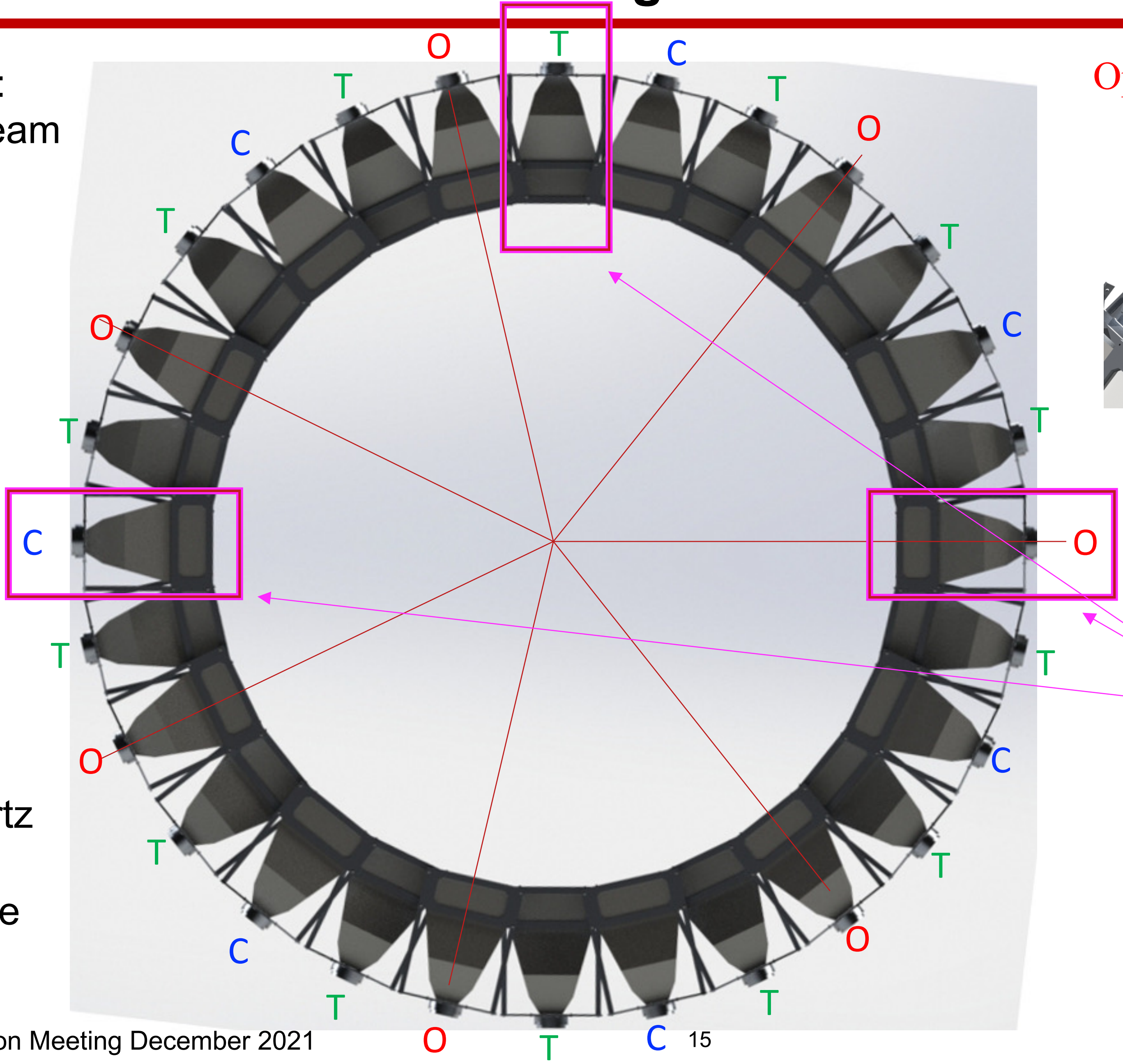


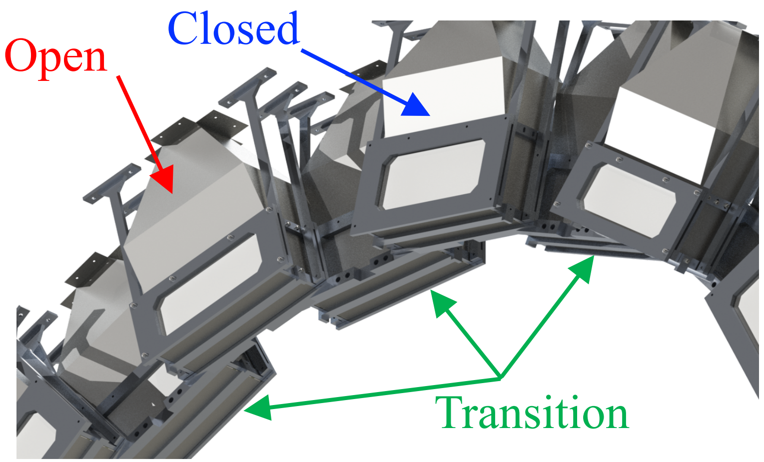
Shower-max dose simulations using Remoll

Idaho State University

Shower-max ring:
Looking downstream

C – Closed
O – Open
T – Transition





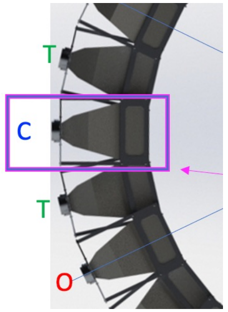
- Work done by Sudip

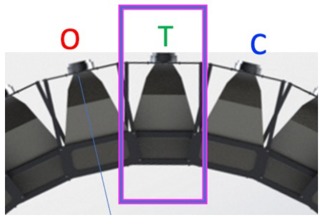
This is a study to determine the anticipated total dose in each quartz layer of Shower-max during lifetime of MOLLER

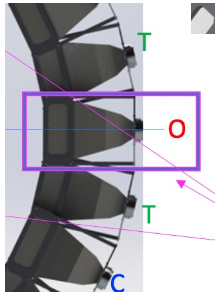
Made each quartz layer sensitive for individual Open, Closed, and Transition detectors located at these specific positions

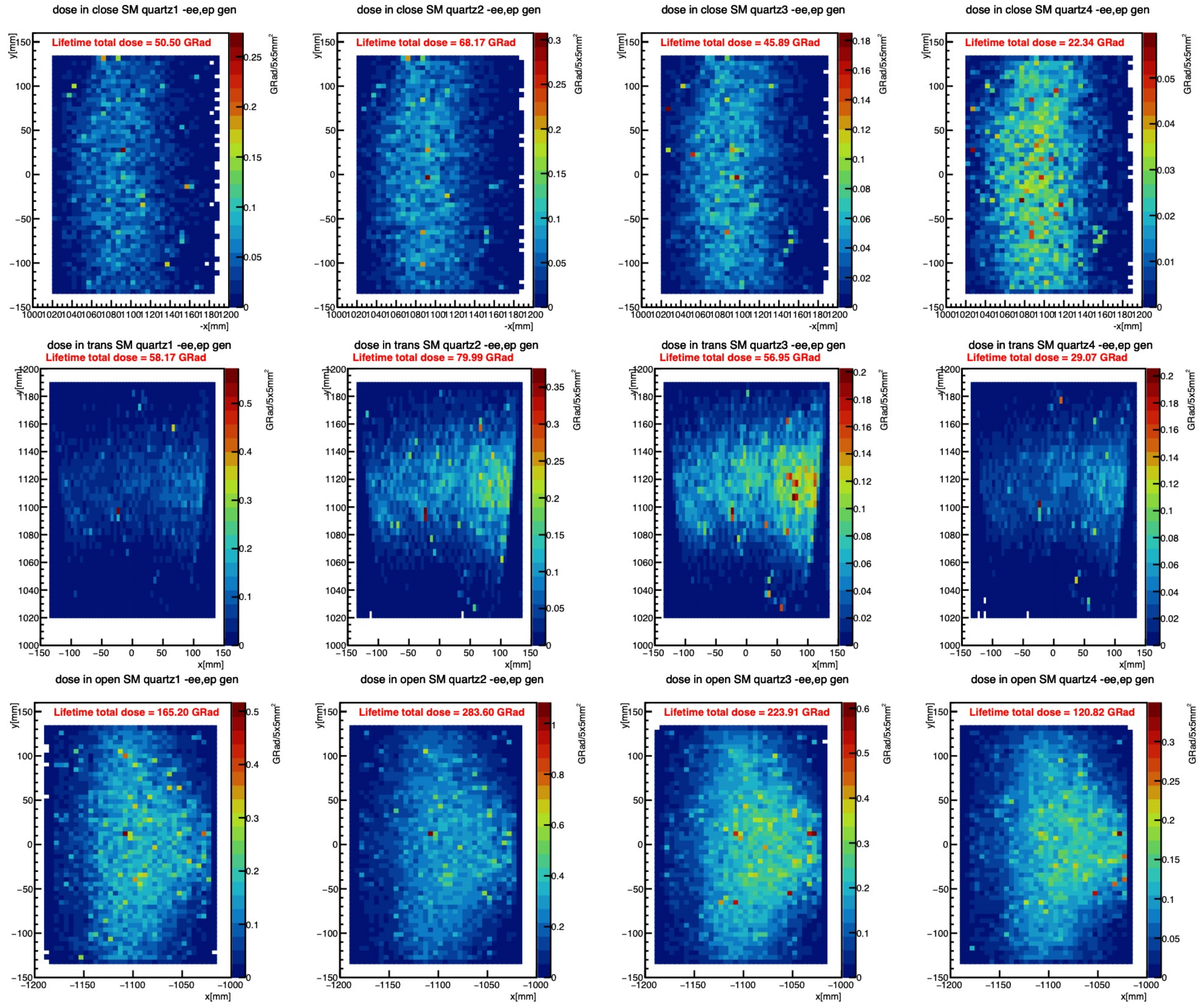
Shower-max dose simulations using Remoll

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 (10/2021)

- 2nd tile has greatest dose; 4th tile has lowest dose.
- Peak dose per 5x5 mm^2 is in Open tile#2 and is ~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.

Cosmic-ray stand for Shower-max testing in Idaho

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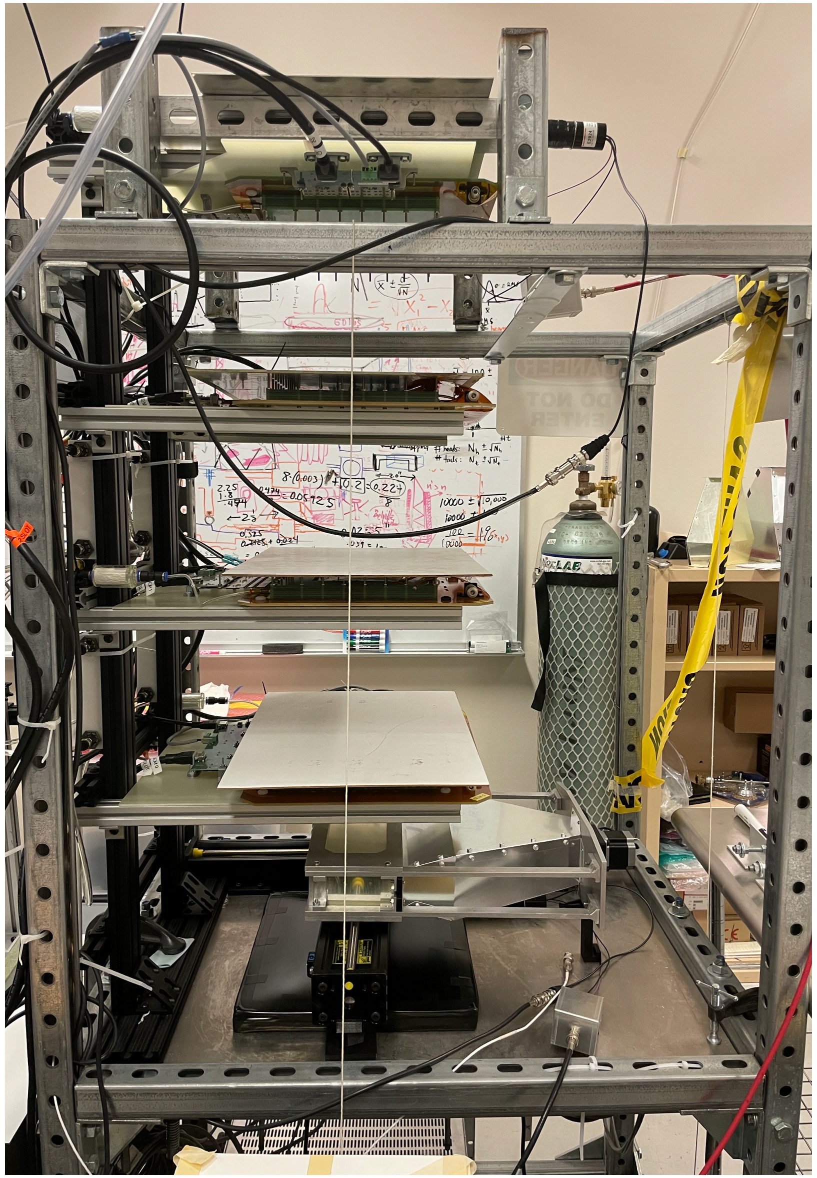
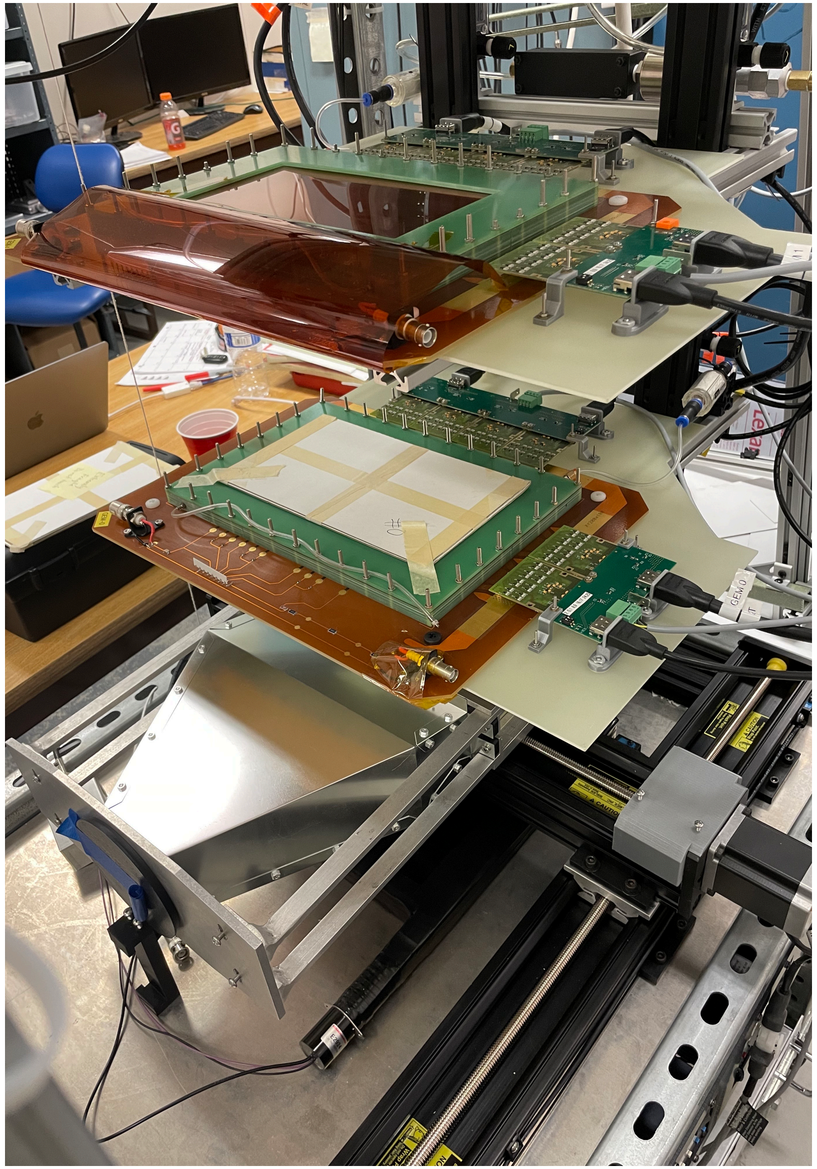
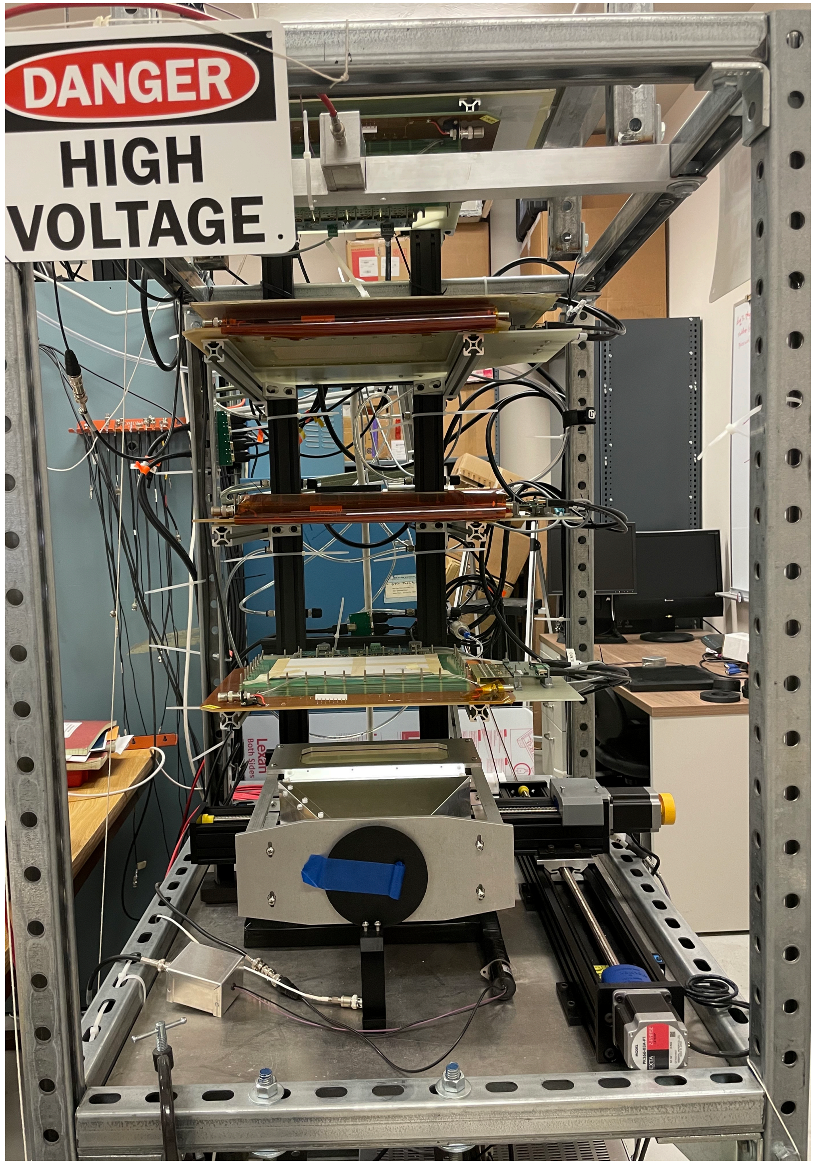






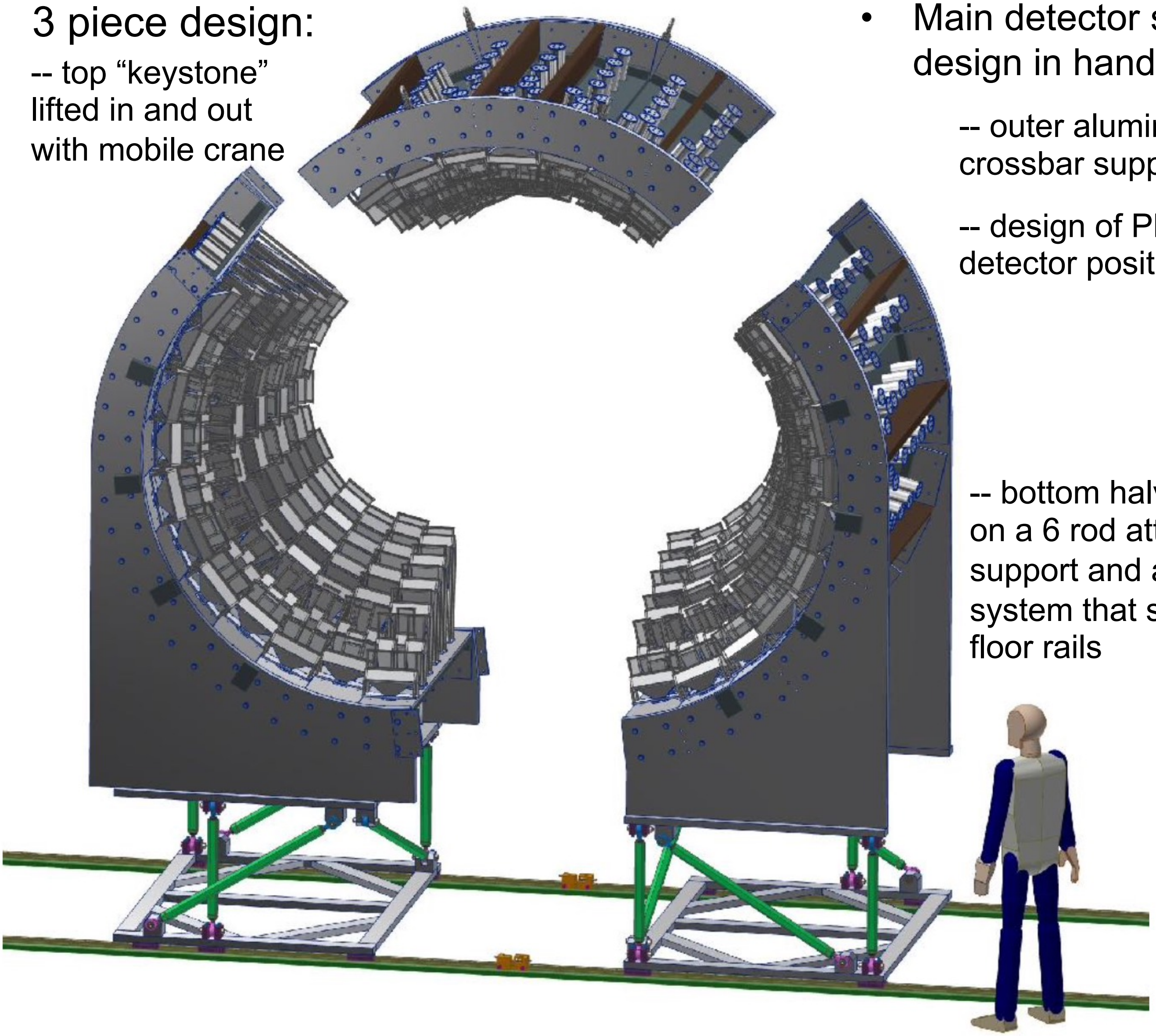
Shower-max Summary and future work

- Shower-max needs a testbeam somewhere, but can use cosmic-ray test stand for MIP signal and connect measurements to electron response using 2018 SLAC testbeam results and optical sims
- Shower-max z-location and radial acceptance ~finalized – will double check correspondence with latest ring 5 positions from Michael
- Preparing for preliminary design review in mid January 2022:
  --Chassis FEA complete and design revisions have been made; still some details to finalize
  --SM ring support structure design flushed-out
  --SM cabling ideas starting
  --Machine shop drawings to be produced by early January
  --Considering further modifications to help reduce costs and mitigate risks
- Remoll radiation dose simulations for shower-max quartz layers have been performed. Further studies still in progress; also need to assess dose in SM PMT region; understand expected rates in the 3 phi regions
- Devising plans for the assembly and testing procedures; also exploring alternatives to wrapping, such as 3D printed spacers (with framed/gasket design)

Technical Progress Since June 2021 (Detector Mechanics)

3 piece design:

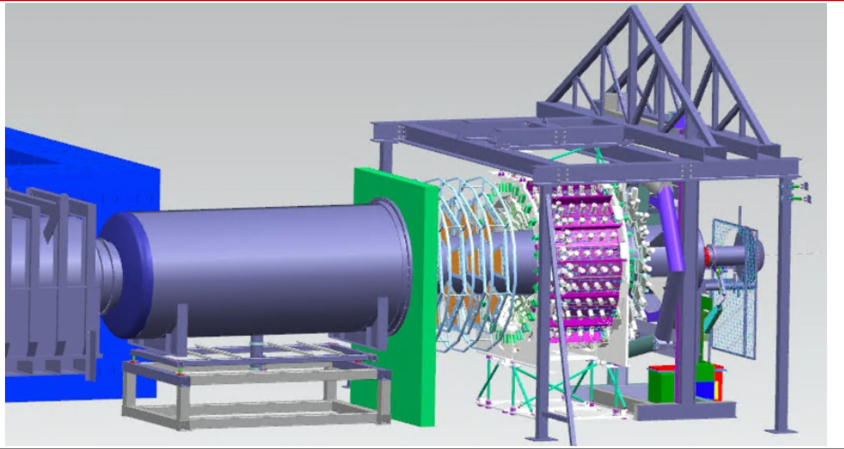
-- top “keystone” lifted in and out with mobile crane



- Main detector support structure design in hand:

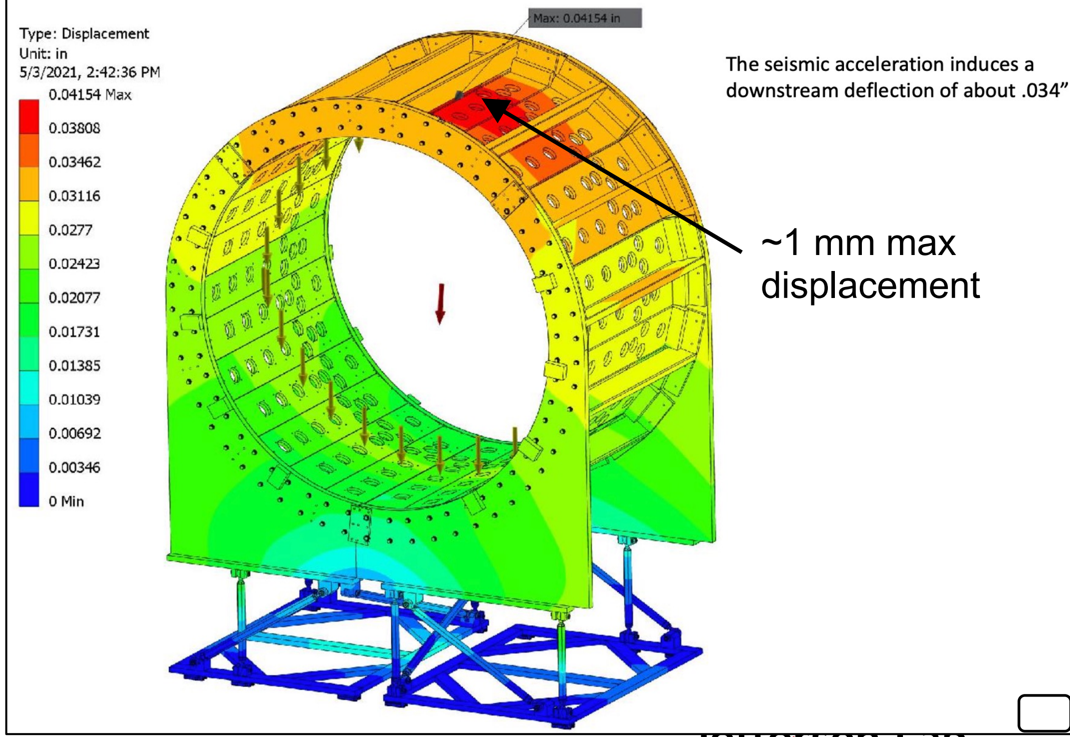
  -- outer aluminum framing and crossbar supports quoted

  -- design of Pb trays with detector positions near complete



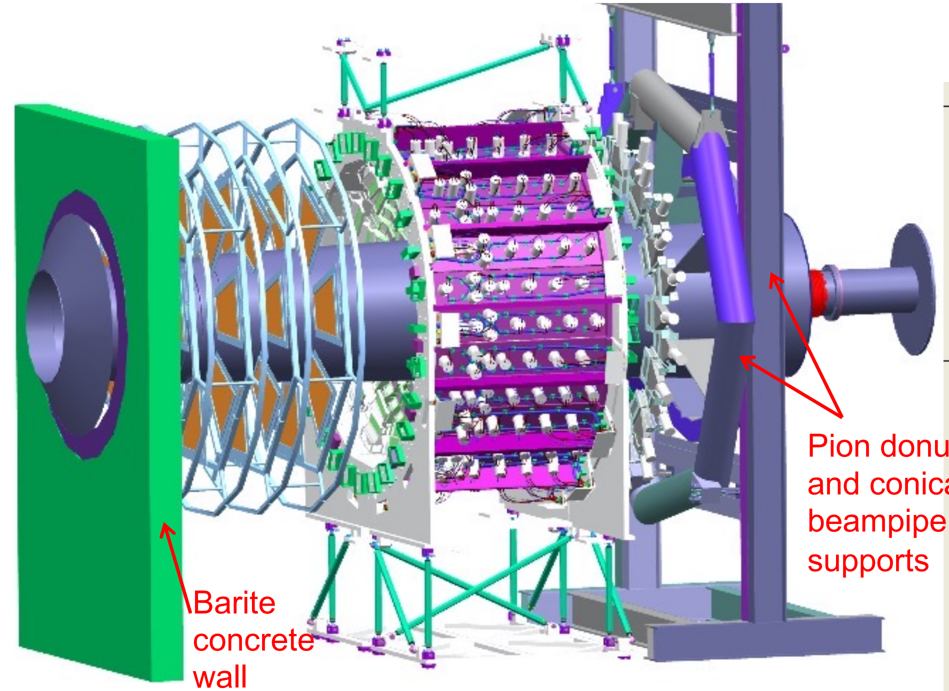
-- bottom halves rest on a 6 rod attachment support and alignment system that slides on floor rails

Deflection plot with 1 gee vertical, 15% gee pointing DS along beam axis

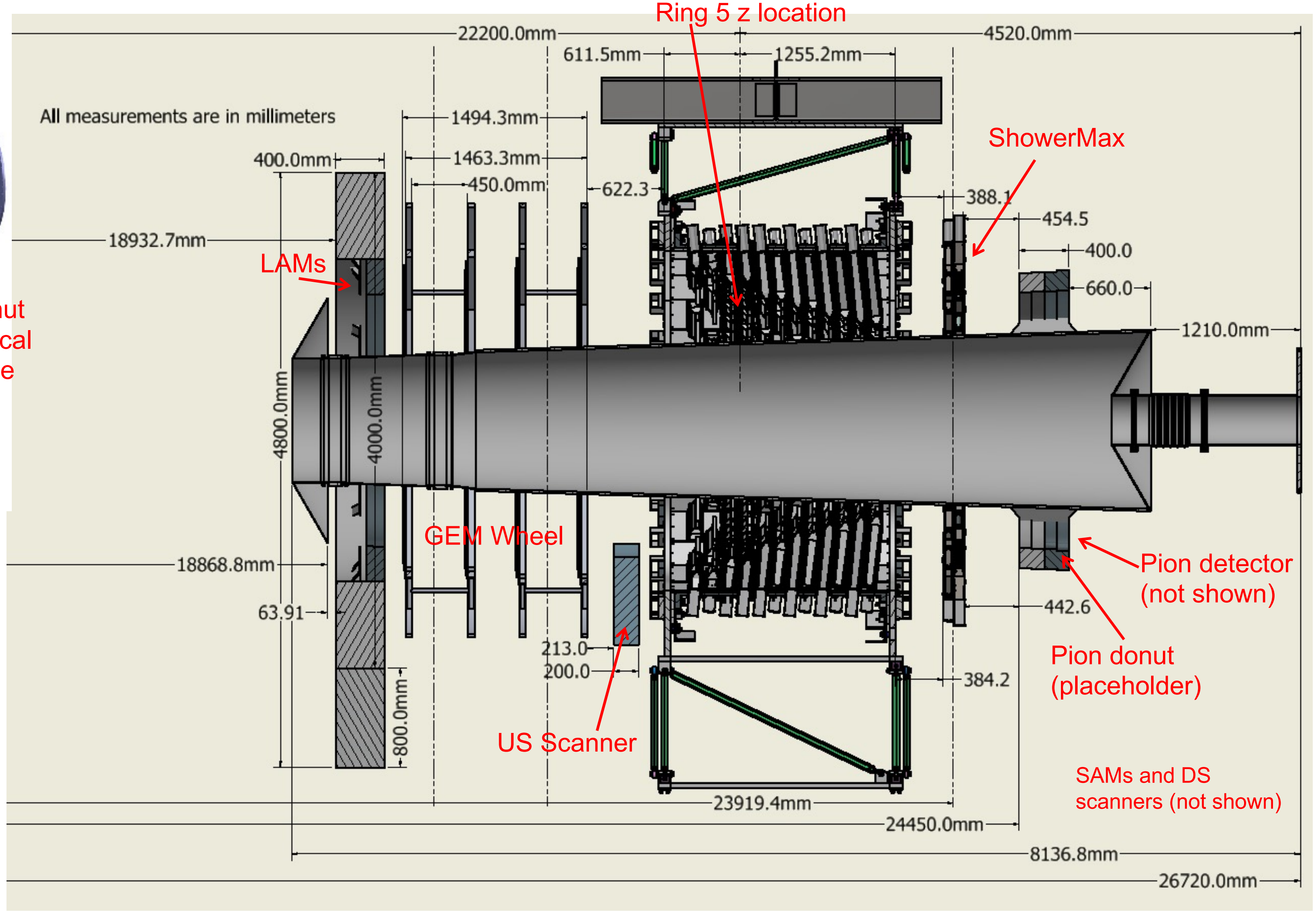


Technical Progress Since June 2021 (Detector Mechanics)

Idaho State University



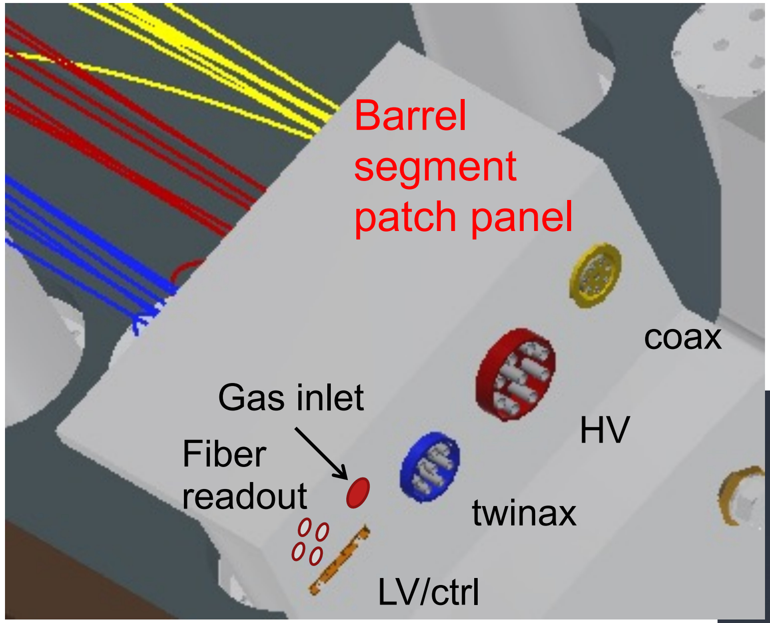
Downstream beamline detector layout (z-locations)



- Detector system locations getting settled
  -- Minding stay-clear areas and coordinating with engineers (real designs) and physicists (simulated geometries)
- Main barrel and ShowerMax detector support structure designs in hand; pion detector structure started
- Combined PDR for all detector systems in mid January 2022

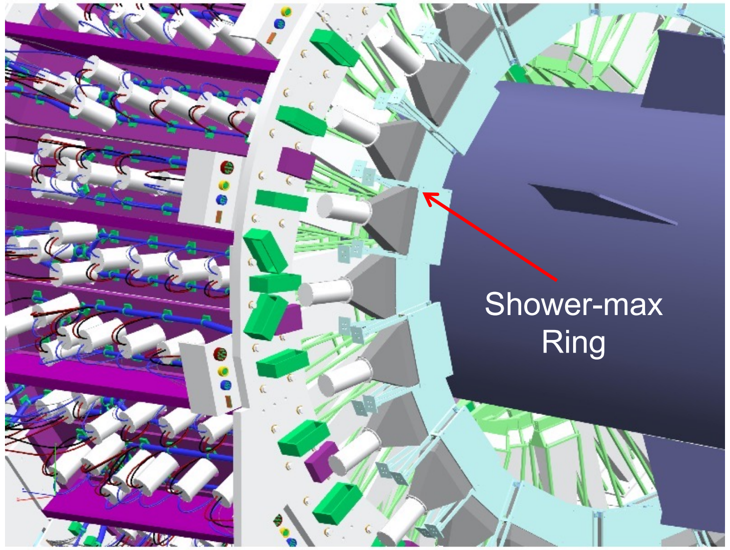
Technical Progress Since CD-1 (Detector Mechanics)

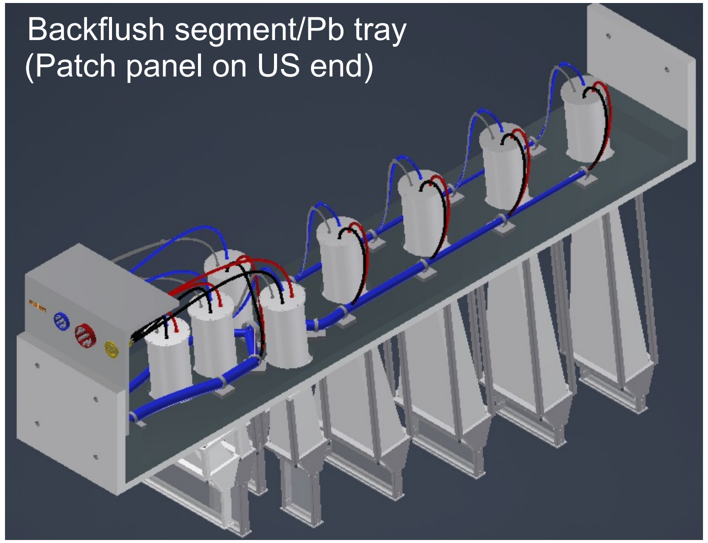
Idaho State University

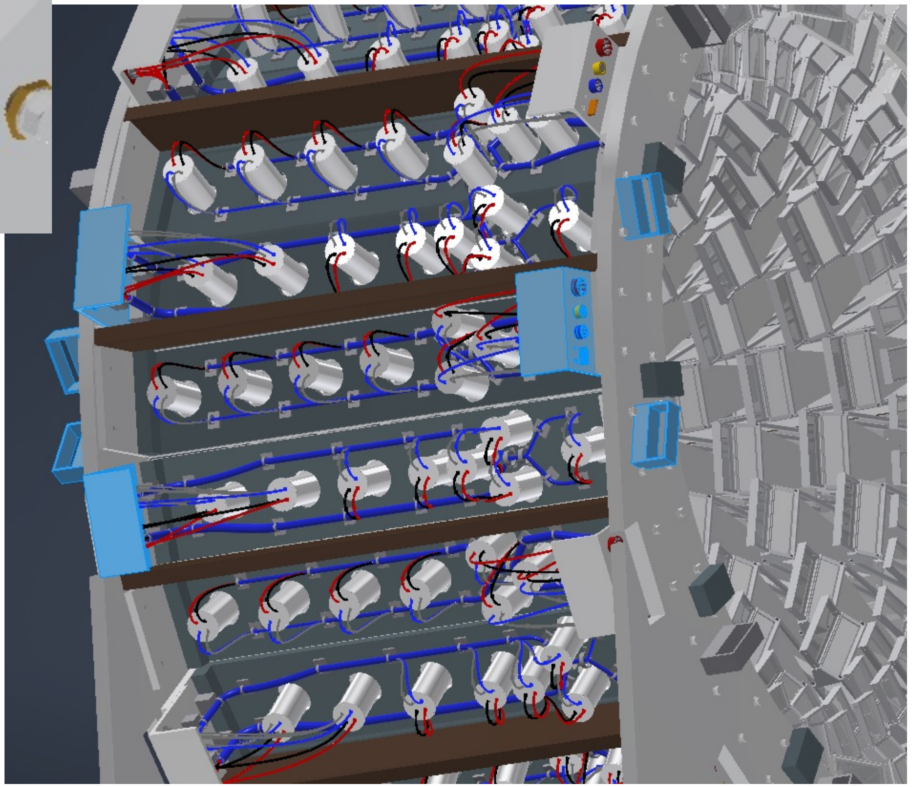


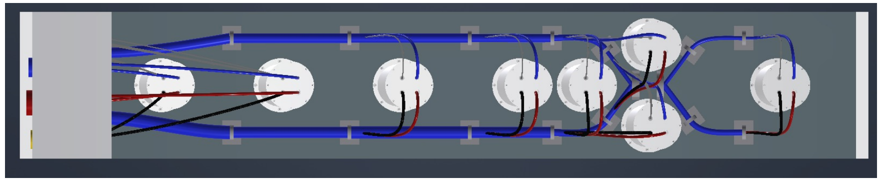
Main detector cabling (CAD work by Edwin Sosa)

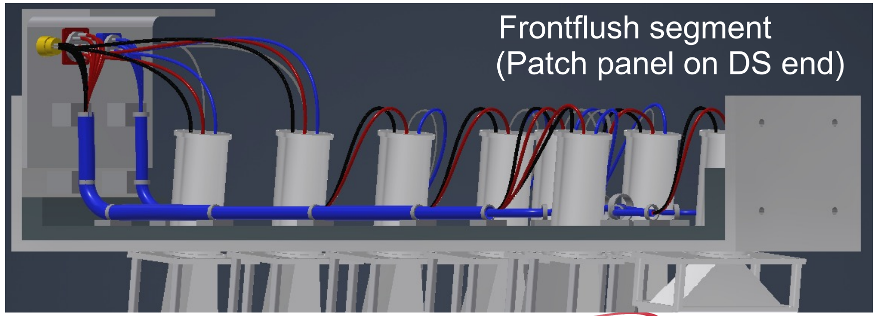
- Internal barrel segment patch panel and cabling harness concept developed
- High Density connector candidates identified
- External barrel cable routing and management concept started











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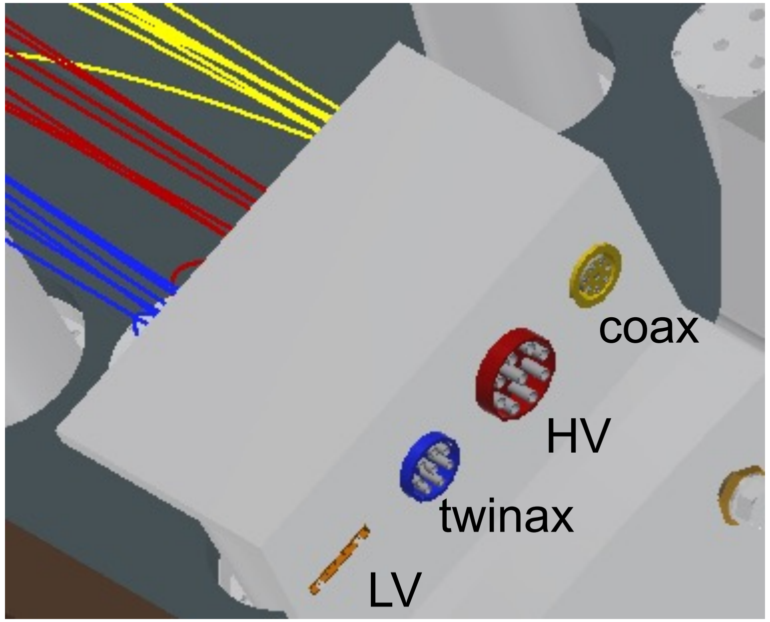
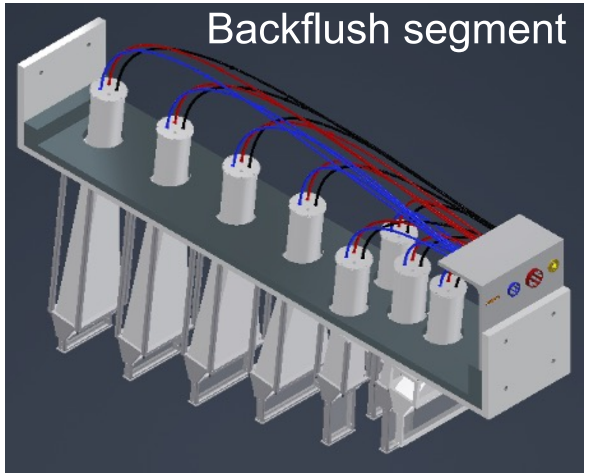
1/28 Segment Patch Panel

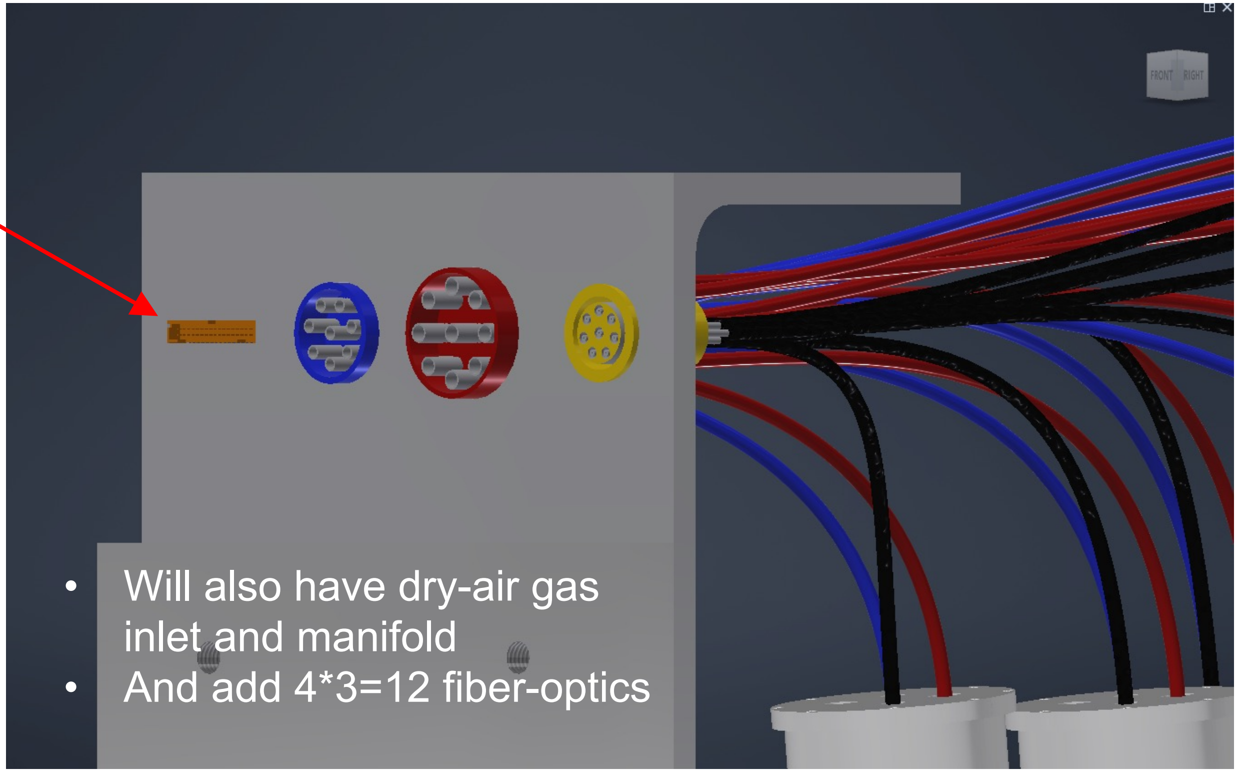


There are 8 detectors per segment



- Each segment's patch panel is essentially a ½ in thick aluminum plate with 4 or 5 high density connectors for passing signals
- Patch panels are installed on alternating, up- and down-stream faces

LV 32 ch ribbon cable connector needs to be replaced with larger connector for 18 AWG wires



Each det requires:

1 HV cable
2 signal cables (coax and twinax)
4 LV and control wires
1 gas inlet

In addition, each 1/28 segment needs 12 fiber optic cables for ring 5 dets

High Density connectors (candidates)

iversity

Twinax: (Smithsinterconnect.com)

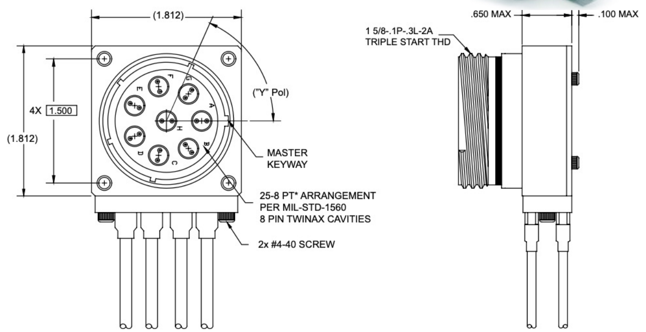
Box Mount Receptacle Pin Insert 25-8 PT* to 8 R/A Twinax Cables to Open Lead

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).



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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

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

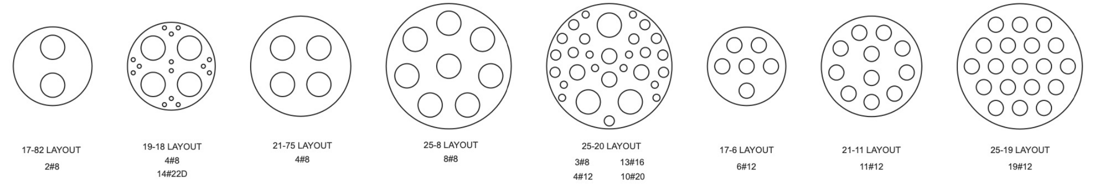
Materials & Finishes

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



High Density connectors (candidates)

Idaho State University

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

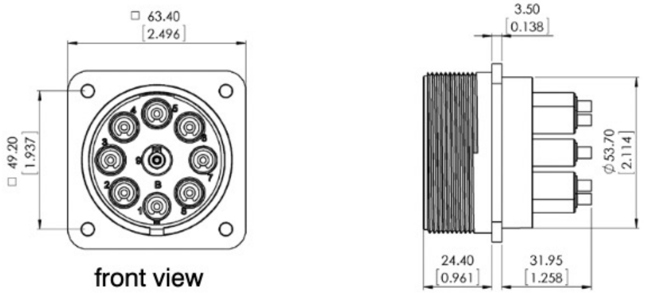
Type / Version / Part number

Type: receptacle, panel mount

Version: GB 915/1E/PTFE

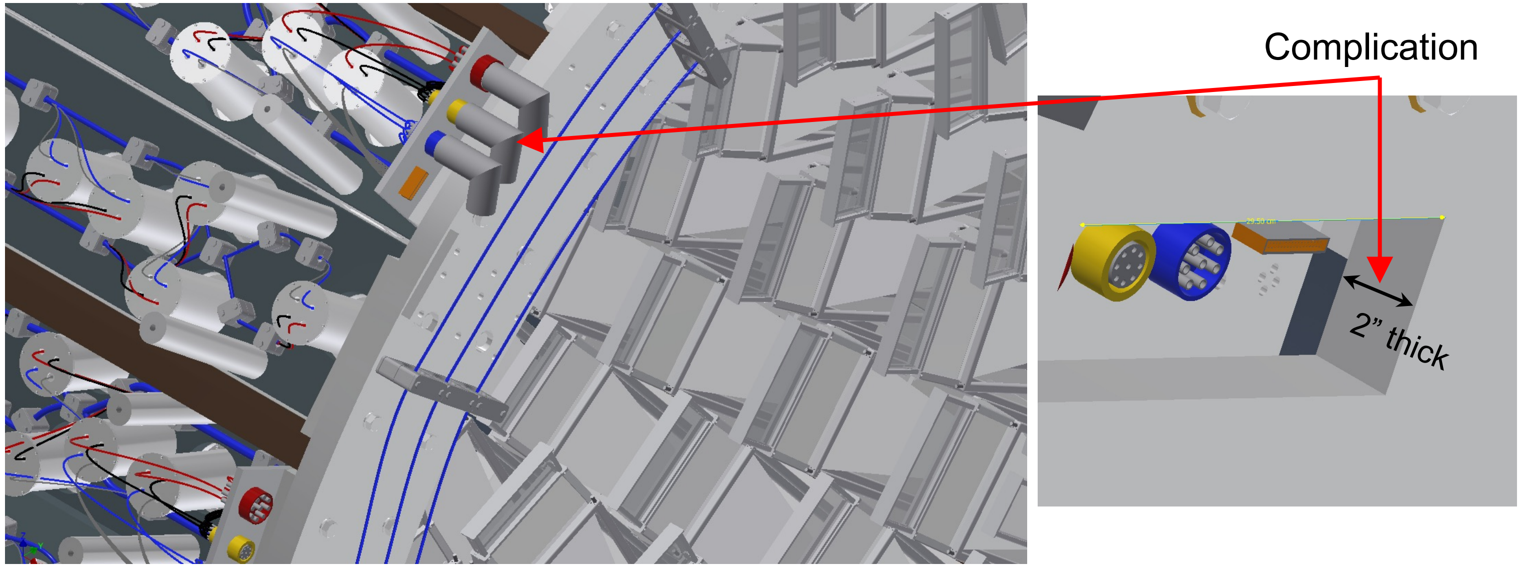
Part no. 7749011

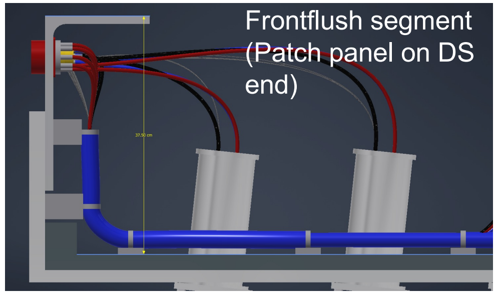
Picture / Drawing

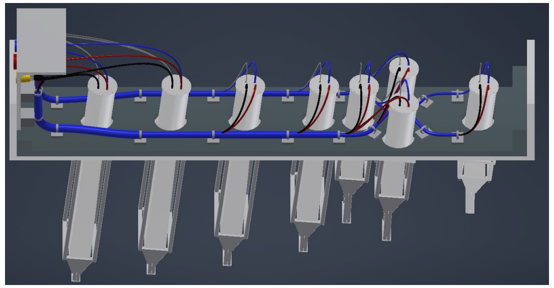


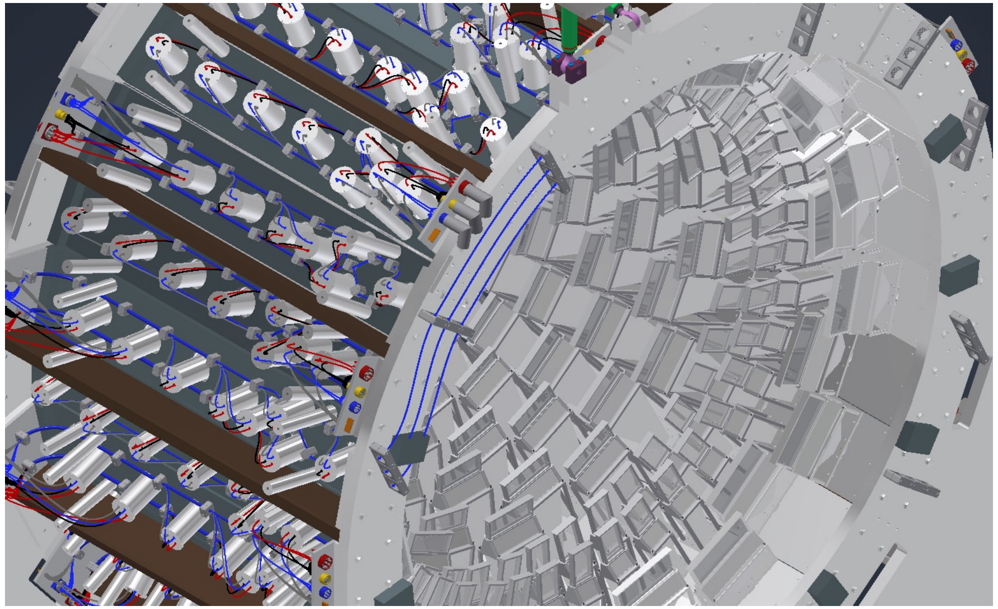
Main Detector Barrel Cabling

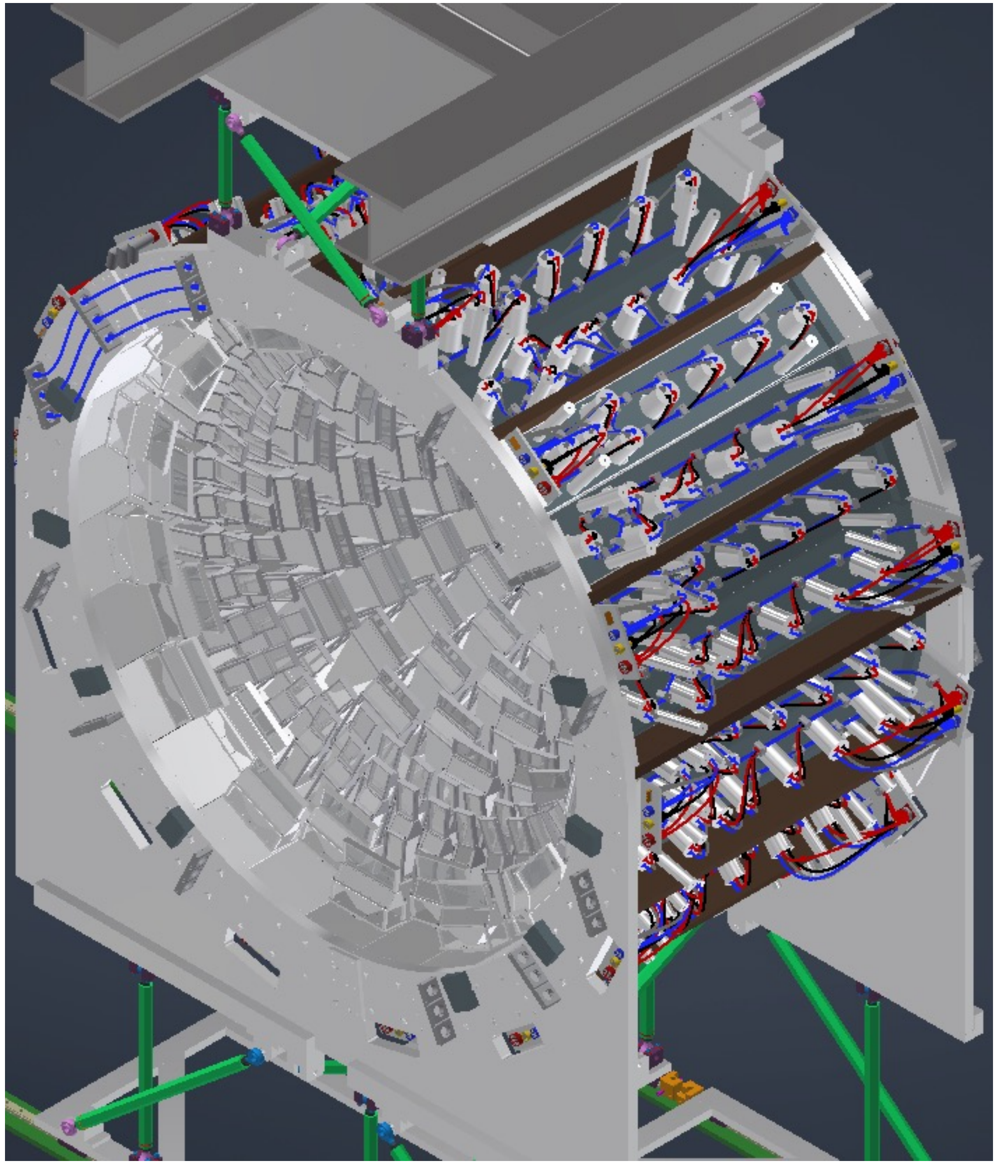
Idaho State University











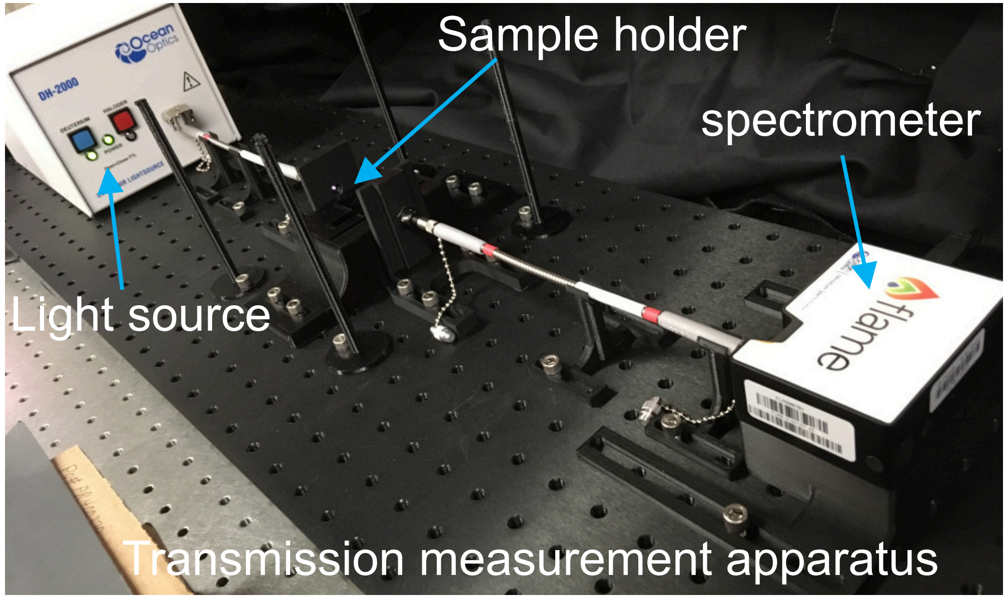
Detector Logistics Summary and future work

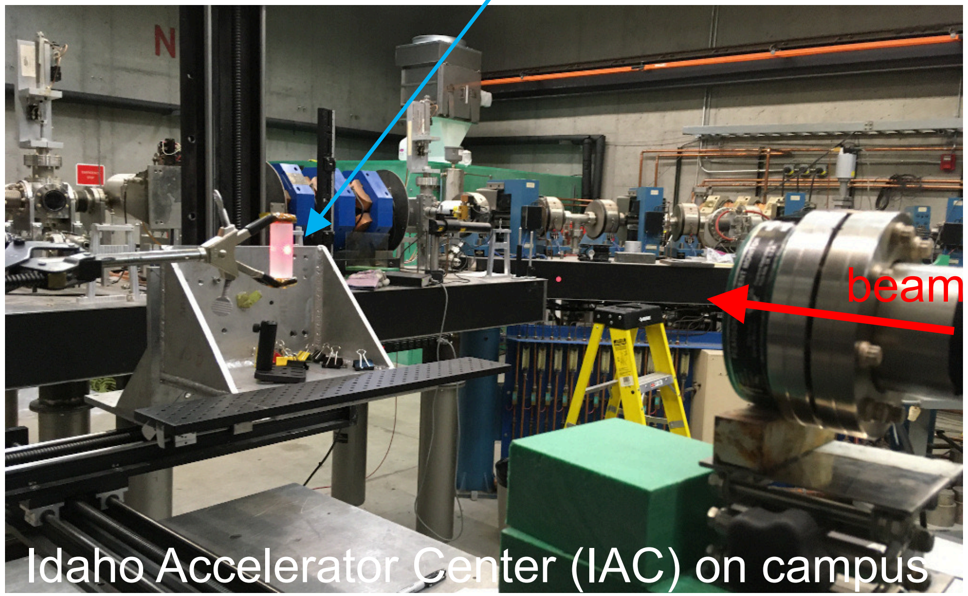
- Detector system z-locations are tight and close coordination required to avoid interferences and maintain consistency between CAD and simulated geometry
- There are many details still evolving or needed: keep-out areas around detector area
  --Multi-level scaffolding around the main detector barrel that can move in and out for human access
  --Robot arm with platform on beam-left and right side of barrel for installation (Larry)
  --Cabling strain relief/curtain system and floor patch panels
- "A"-frame support concept/design for hanging SM and Pion detectors, and how it interfaces with main barrel keystone support I-beams, is under investigation (Larry)
- Pion detector, LAMs, SAMs and Scanner details are maturing and precise z-locations and detector geometries are getting set and support structure plans starting; need to keep Physicists CADs, GDMLs, and official Jlab engineering CAD all in sync.
- Need to find HD connectors we can purchase and build a complete 1/28 patch panel prototype. **New recommendation from last review is to perform HD connector insertion test** or have manufacturer's specs
- Revisit Pb tray cabling harness design now that Michael has finalized pmt locations; much more work needed to develop outer barrel cable routing and strain-relief mechanics

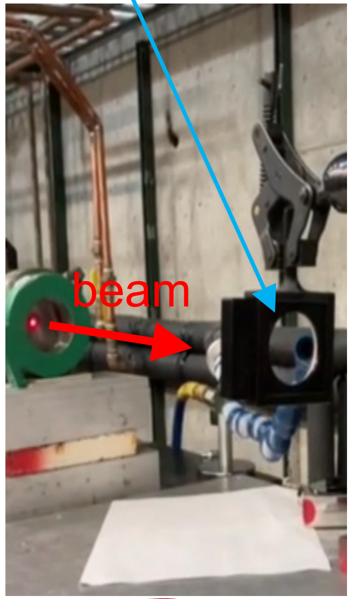
Quartz Irradiation Tests

- Goal: quantify light transmission losses in detector radiators due to damage from anticipated radiation dose (for lifetime of MOLLER) – 25 Mrad peak and 60 Mrad peak per 5x5 mm^2 for ring 5 and ring 2, respectively
- 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
- Master's thesis project for Justin Gahley

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



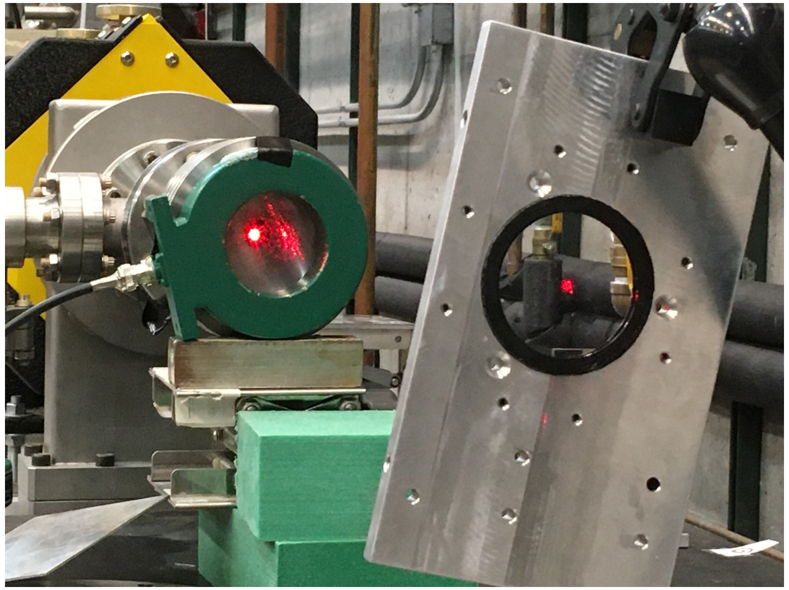




Quartz Irradiation Tests

- We have also tested two types of longpass filters (Schott glass and Corning 7980 types)
- Careful alignment and characterization of beam's radiation field on dosimeter arrays and samples is critical for benchmarking simulation to dosimetry measurements and to then use simulation to get accurate dose estimates on our samples
- Radiator samples tested (1 cm thick, 5cm diameter rounds or squares):
  --Corning 7980 UVHGrade-F
  --Corning 7980 Eximer
  --Ohara SK-1300
  --Heraeus Spectrosil2000 standard
  --Heraeus Spectrosil2000 doped
- Filters: (low dose 50krad up to 1Mrad)
  --UV cutoff filter made of optical glass (not good)
  --Edmund optics 400nm longpass UV grade fused silica (good)
  --Isuzu glass (from Jim); ready to make measurement but haven't yet.
  --Have quotes for custom 78 mm diameter 350nm and 400nm LP filters. Price ranges from $350 to $500 each depending on quantity (these are Corning 7980 substrate)
  --Also want to test some ND filters

Longpass filter dose test



Dose and beamspot measurements for G4 simulation

Idaho State University

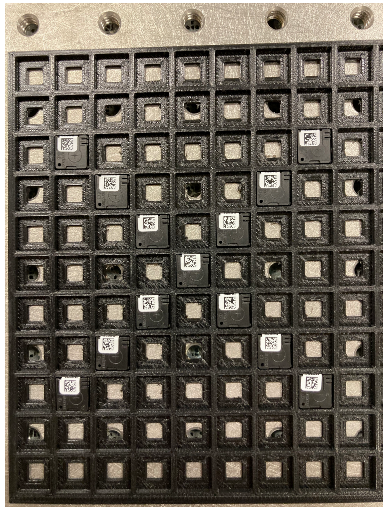
50 cm

OSL dosimeter array (old method)

beam

(new method)

7.2 cm



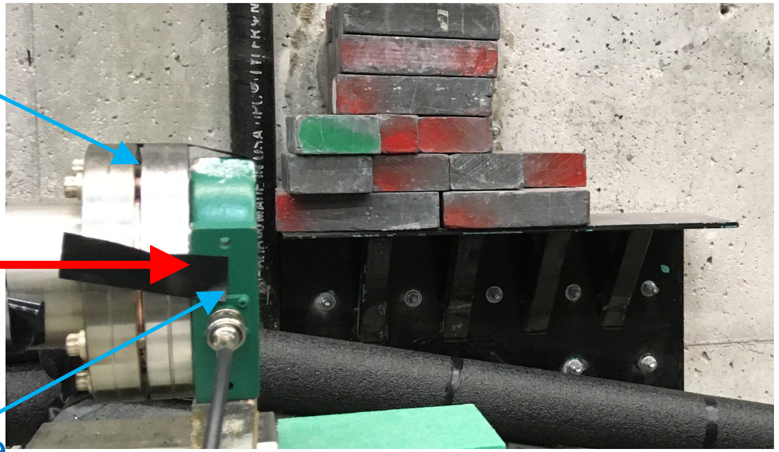
Controlled alignment

OSLs read using microStar

Titanium window

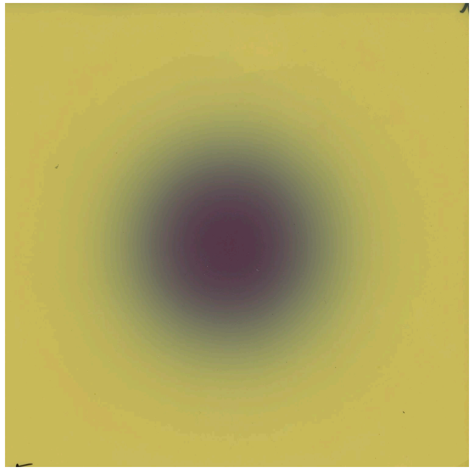
beam

Pearson Coil (beam charge monitor)

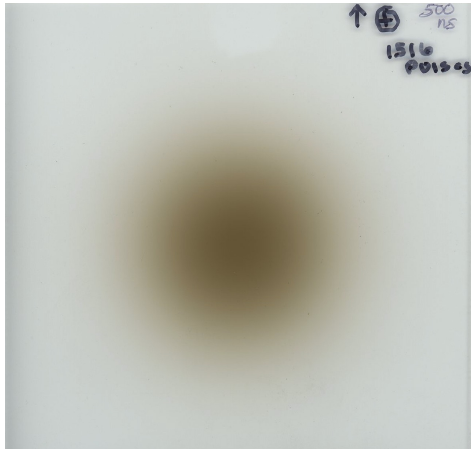


Purchased two varieties: sensitive from 1 to 10 and from 5 to 200 beam pulses

Gafchromic film



Glass slide



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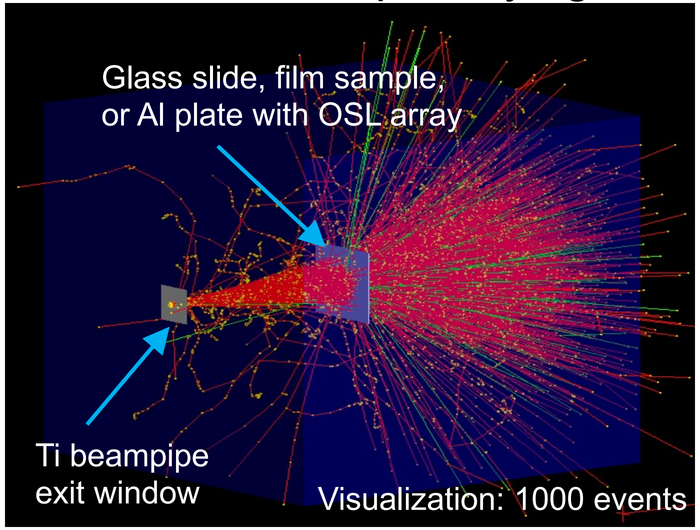
Quartz Irradiation Tests (Dose benchmarking)

- Why do we need Gafchromic film? Because we think beam's radiation field for single-level pulses is tighter than what we see using the 100's of pulses needed for the glass slides
- Using the film we can benchmark the beamspot size and divergence during the OSL measurements at 25, 50, and 75 cm distances (using 1 – 5 pulses)
- Preliminary results from Dec 9, 2021 run show nice agreement between film exposure spots and OSL array counts; this was not the case in the past when using the glass slide data to characterize the beam on OSL
- We can now optimize the simulated beam parameters for benchmarking the OSL dosimetry measurements
- We also measured the signal loss in the long cable used for beam charge measurement (found a 7% loss – so charge/pulse is 7% higher than measure)
- OSL response calibrated using Cs137 source measurements and simulation; uncertainty/reproducibility of the calibration is better than 5%
- We're hoping to convince ourselves that the quartz peak dose estimates from simulation are accurate at the +- 10% level

Dose simulation (for Sep 2, 2021 run)

Idaho State University

G4 simulation for quantifying dose



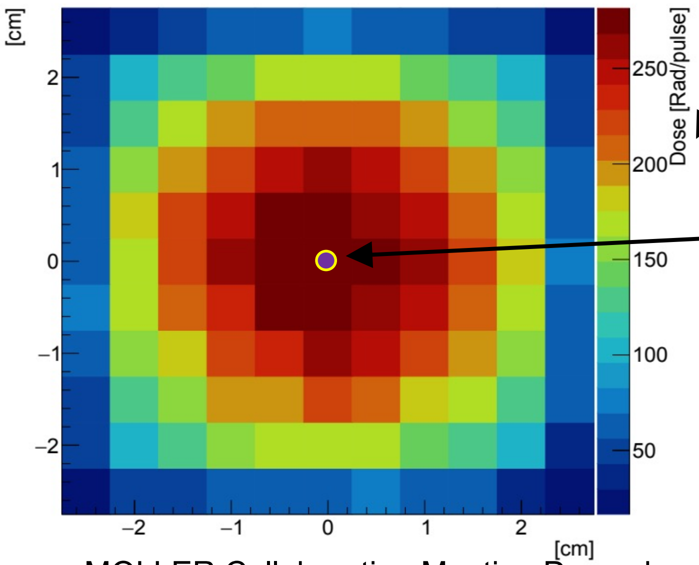
Simulated beam calibrated with beamspot measurements at 3 distances

Sample irradiated at 50 cm

Beam energy scans taken at beginning and end of tests

Beam charge data acquired throughout exposures

Dose Profile Quartz 5x5x10 [mm]

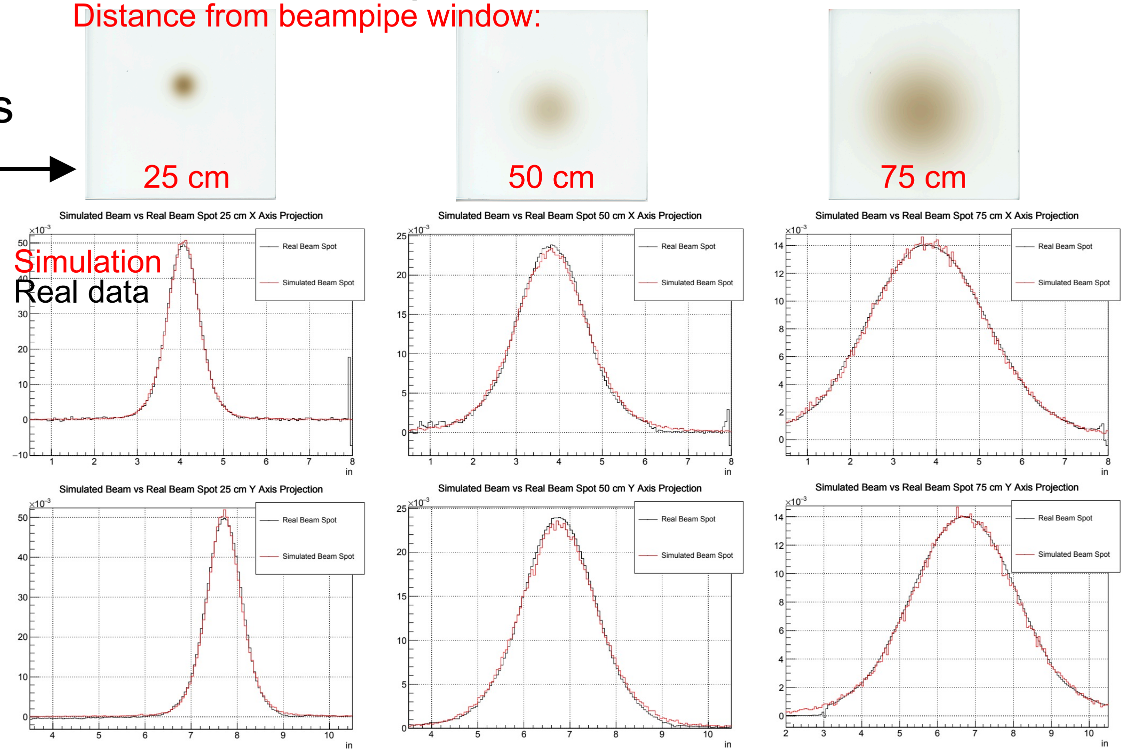


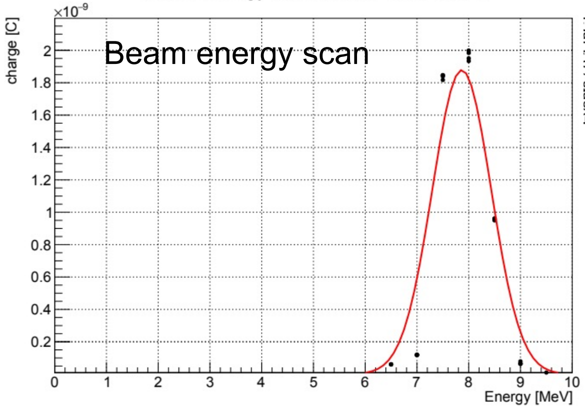
Simulated dose per 5x5 mm^2 normalized to average charge per beam pulse

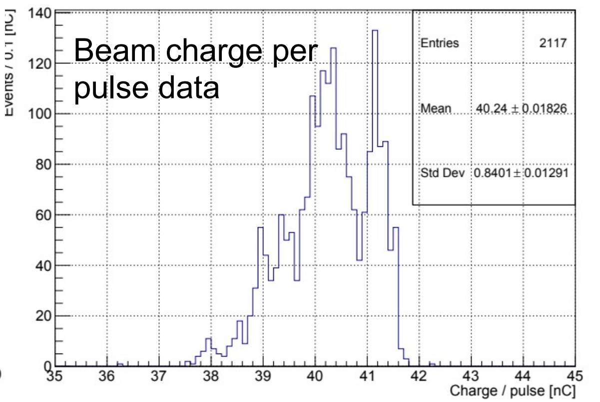
Sample thickness is 10 mm

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

Beamspot measurement scans







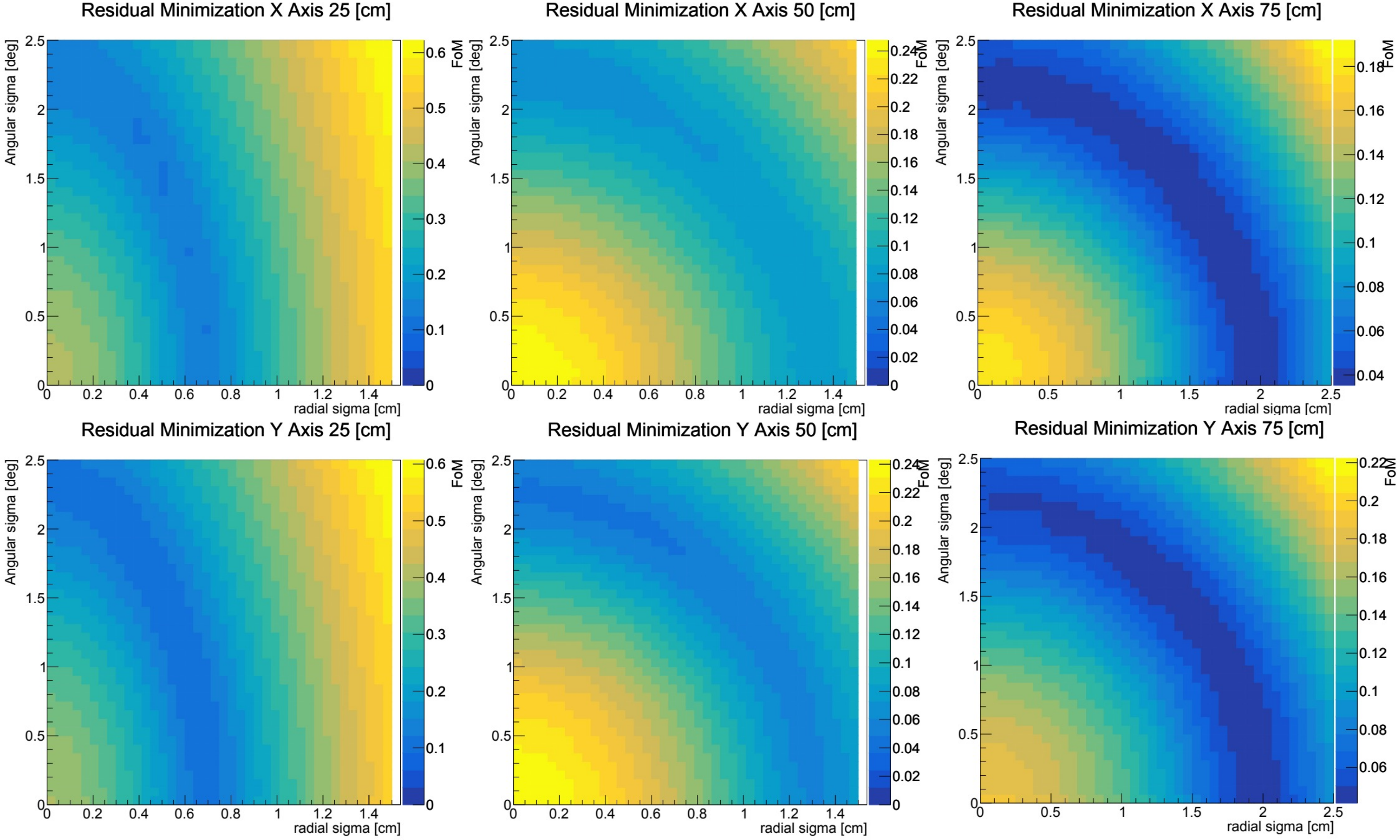
Benchmarking simulated beamspot

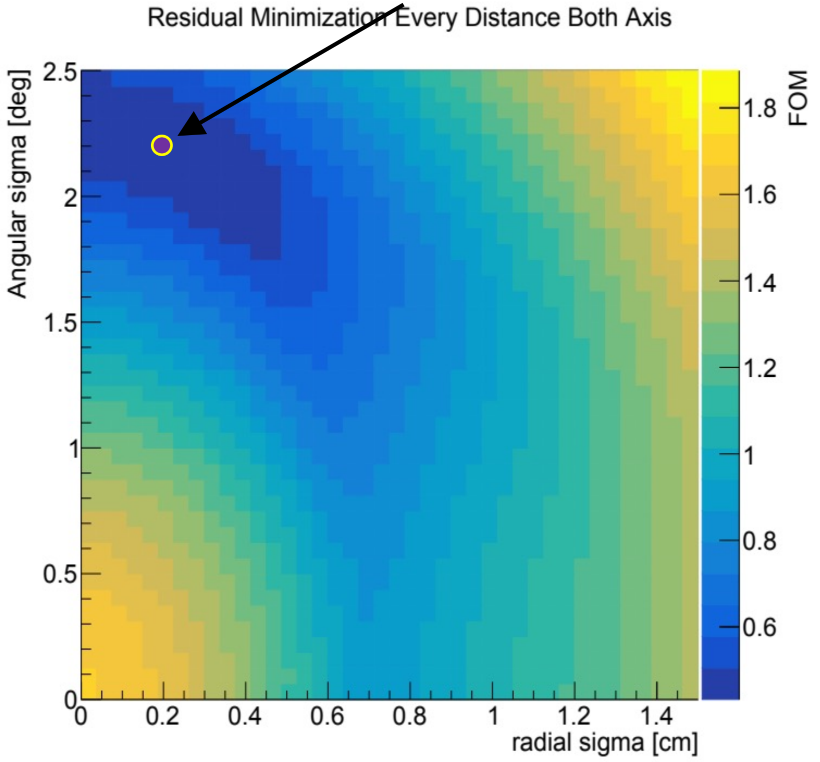
Idaho State University

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:

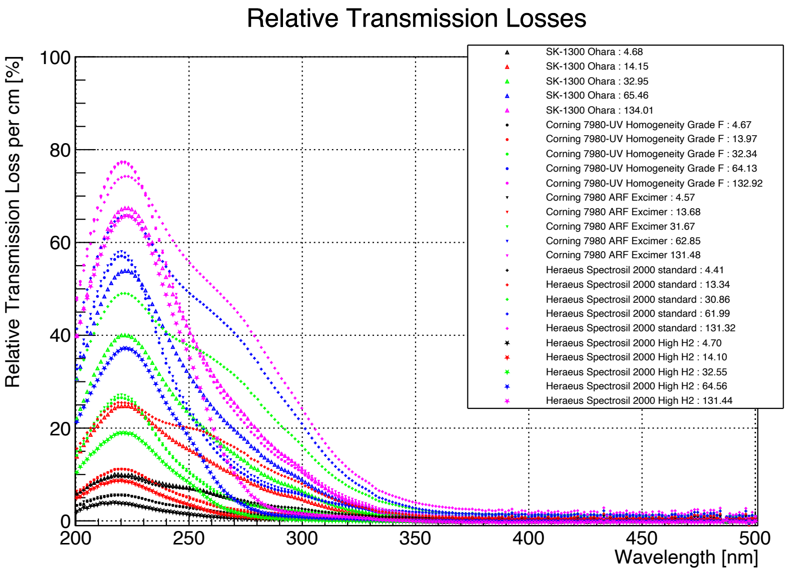
25 cm 50 cm 75 cm

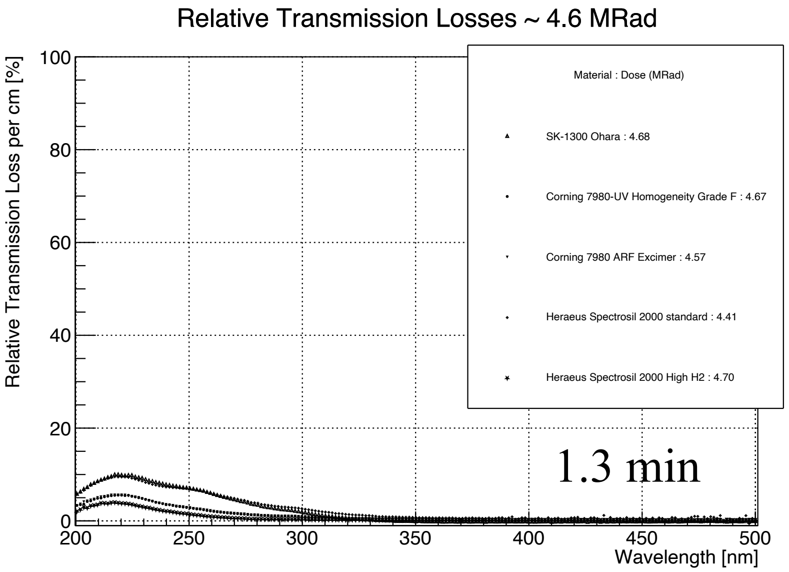


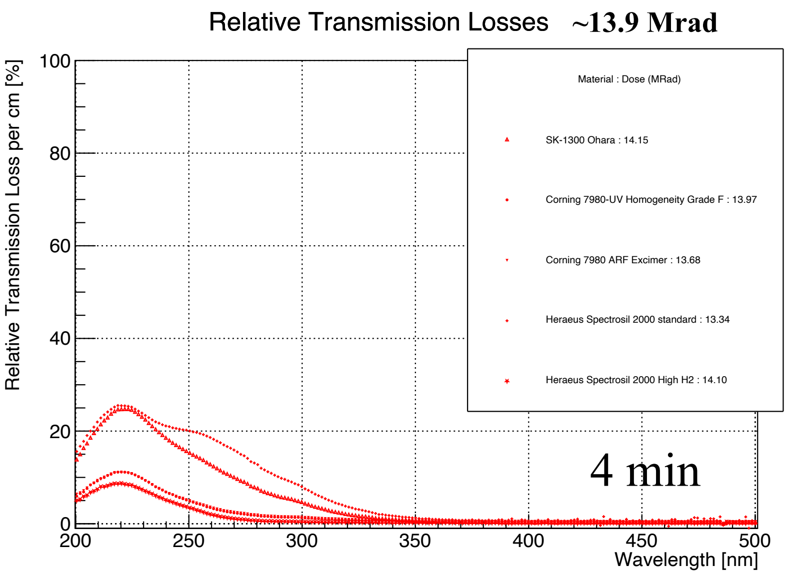


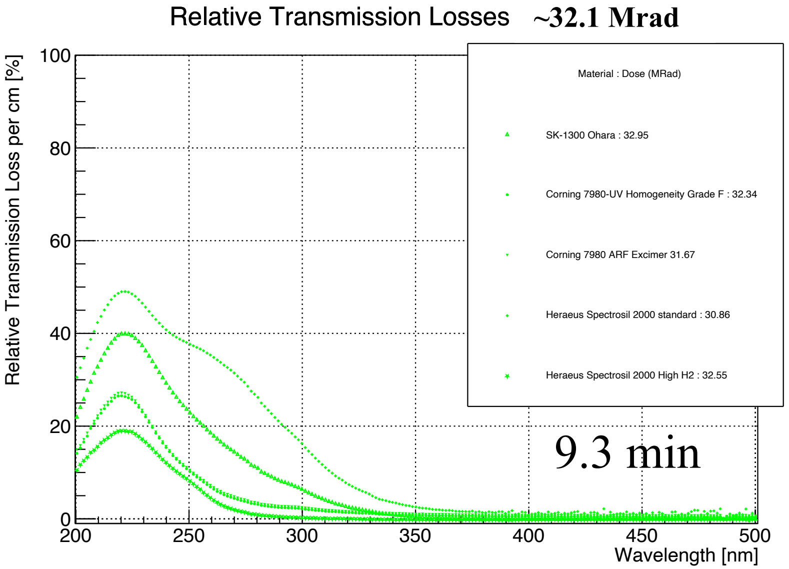
FOM = RMS of residual between real and simulated beamspot.
Summary plot above sums FoMs from both x and y plots for all (25, 50, and 75 cm) distances and gives the optimal parameters for simulating beam size and divergence at sample location

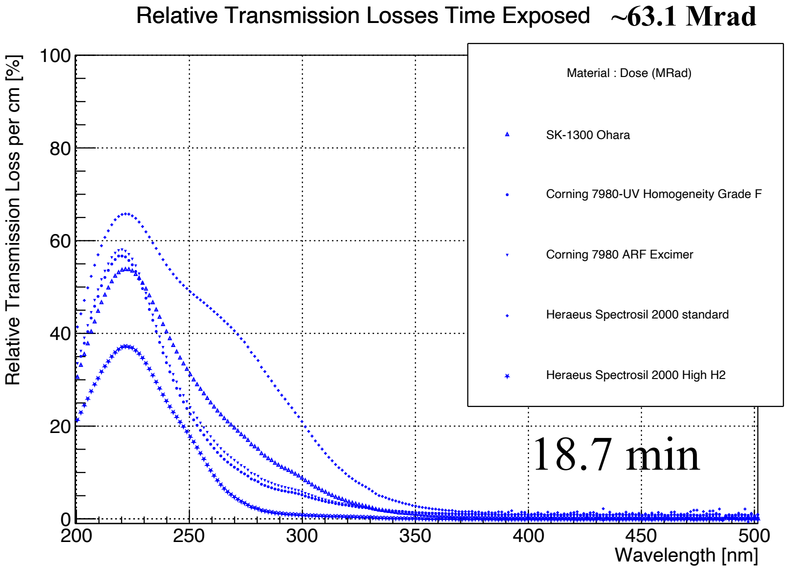
Results from measurements on all 5 sample types

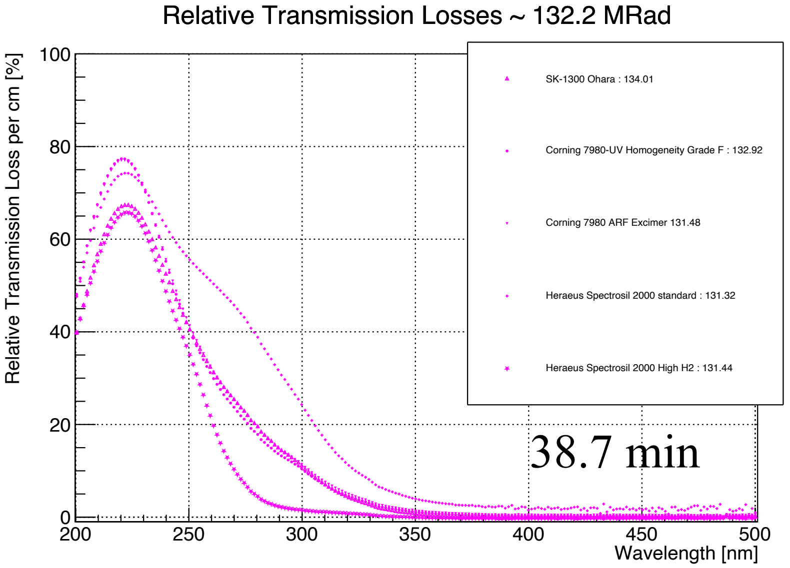












Technical Progress Since CD-1 (Quartz Irradiations)

Idaho State University

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

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

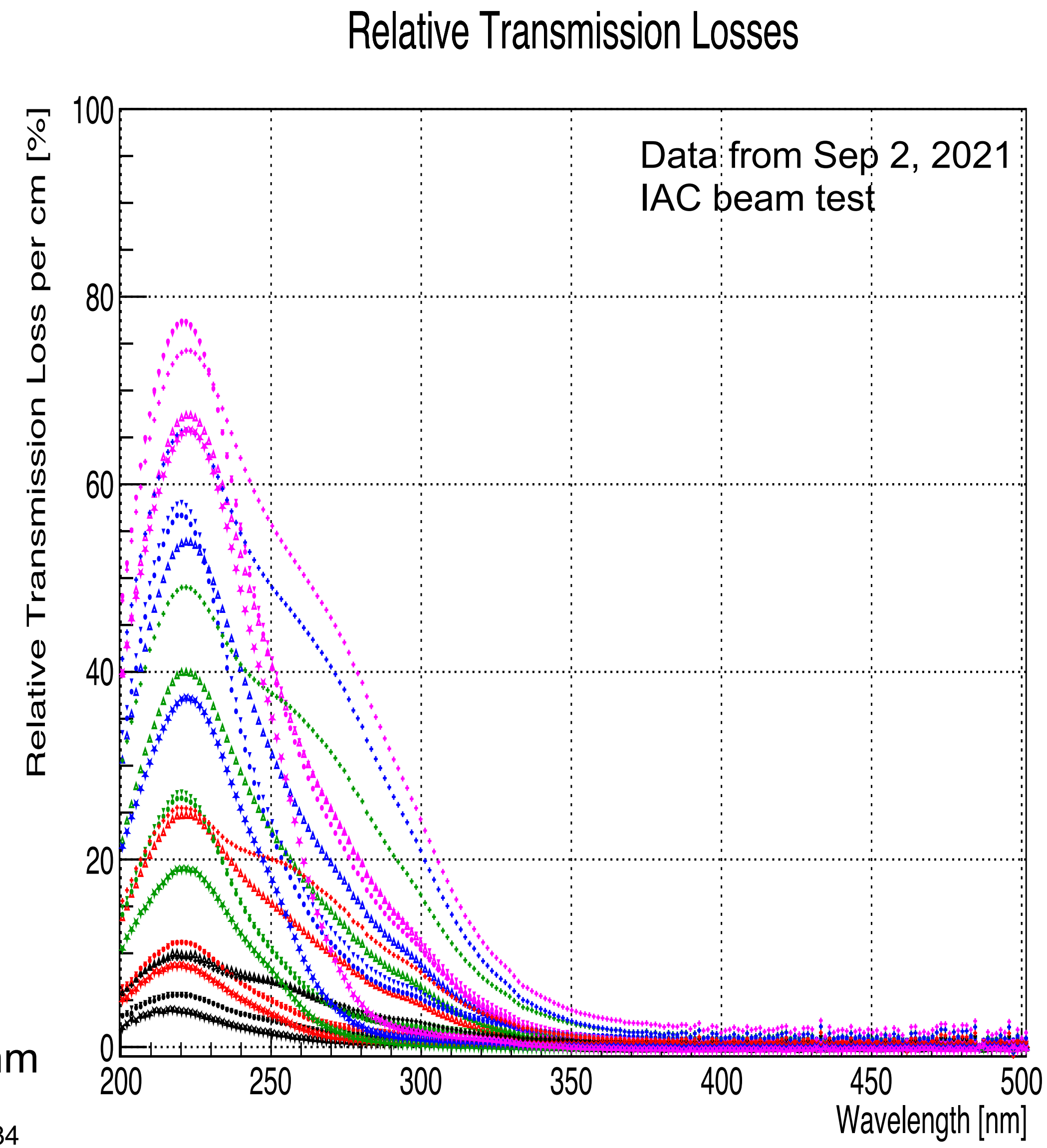
This is total accumulated time and dose at each transmission measurement

- 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



...son Lab

Quartz Irradiation Summary and future work

Idaho State University

- Light source drift and measurement reproducibility errors are typically at ~0.5% level
- New transmission apparatus (linear static arrangement) has greatly reduced repeatability systematics! Justin has continued to refine it. Samples have there own unique holders and go from beamline to transmission apparatus without mechanical fiddling
- Both Corning sample transmission losses very similar; Corning is second best up to ~60 Mrad and then Ohara SK-1300 becomes better, although most all samples show similar loses for λ > ~350 nm
- Heraeus doped Spectrosil2000 is the best performing (clearly) – no shoulder structure in losses. The standard Spectrosil2000 is the worst performing sample – it consistently has the largest shoulder
- OSL responses carefully calibrated; G4 dose simulation benchmarking to OSL measurements underway (using new film spots and OSL arrays). Simulations of sample exposures being refined (beam parameters)
- Possibly one more beam size/dose and systematic error study run and then perform a final irradiation run for the 1 cm thick rounds or square samples (we think we'll be ready next month)
- If had to decide today, then considering costs and delivery times? Spec2000 doped for ring2 and 5, Corning for all other rings and Ohara for SM; prototypes could all use Corning or Ohara if much easier to get

Shower-max: possible design tweaks for cost savings and risk mitigation

Idaho State University

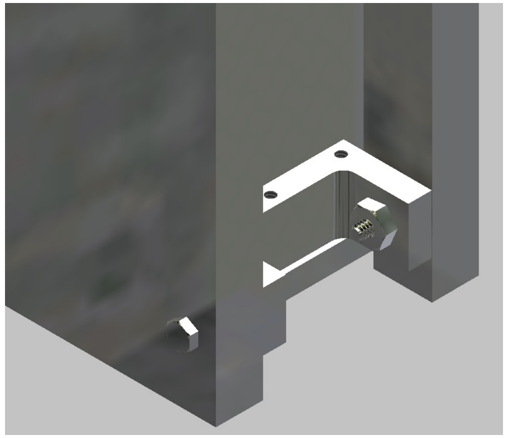
- Current (nominal) design uses 3 mil thick quartz wrapping (needed to protect quartz polish)

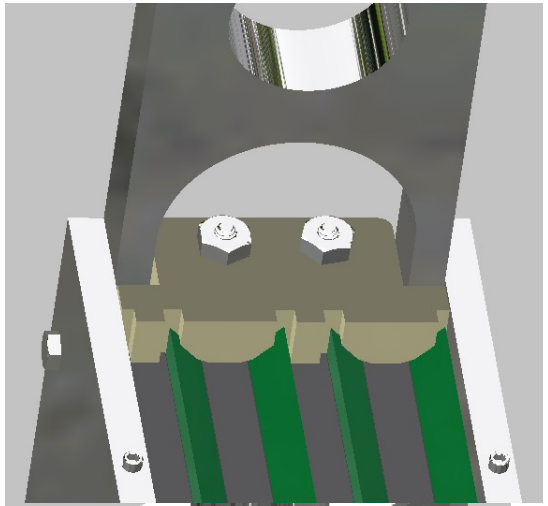
  --If go this route then need to test what is best wrapping; black/smooth wrappings may be problematic for this application (but not sure yet); may want aluminized mylar

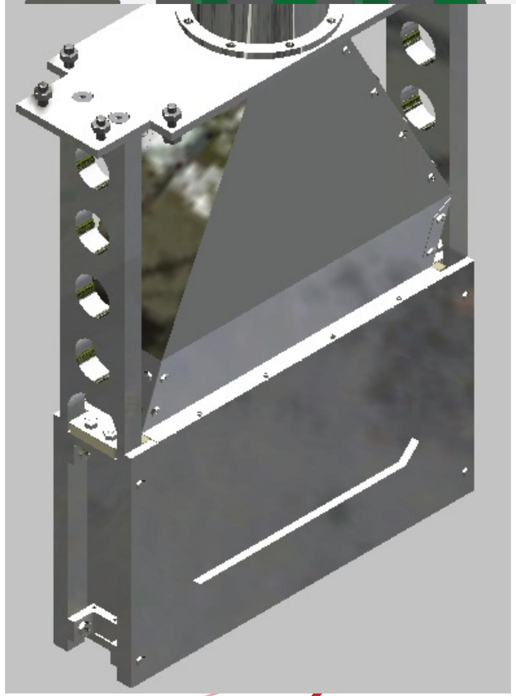
- Potential risk/problems with wrappings:

  --could break TIR if pressed too tight to quartz (how to prevent this?)

  --Doesn't allow as much forgiveness in assembly torque settings; if there is unexpected topology in tungsten plates, for example, this could cause both TIR lose and possibly birefringence effects







Idea for tweaks:

- U-channel supports are ¼ in thick and 1.8" long (along beam z)—this makes them a fully custom expensive part (we need 140 of them)

  --We can standardize their length to 2.0" or 2.125" and probably save $ (there are 4 per module)

- Considering 3D printed spacers (framed/gasket design) to replace wrapping, account for the extra 0.2" or 0.315" of chassis thickness, and allow for a more uniform/consistent detector build/operation

  --Minimum thickness and design of spacers under investigation:

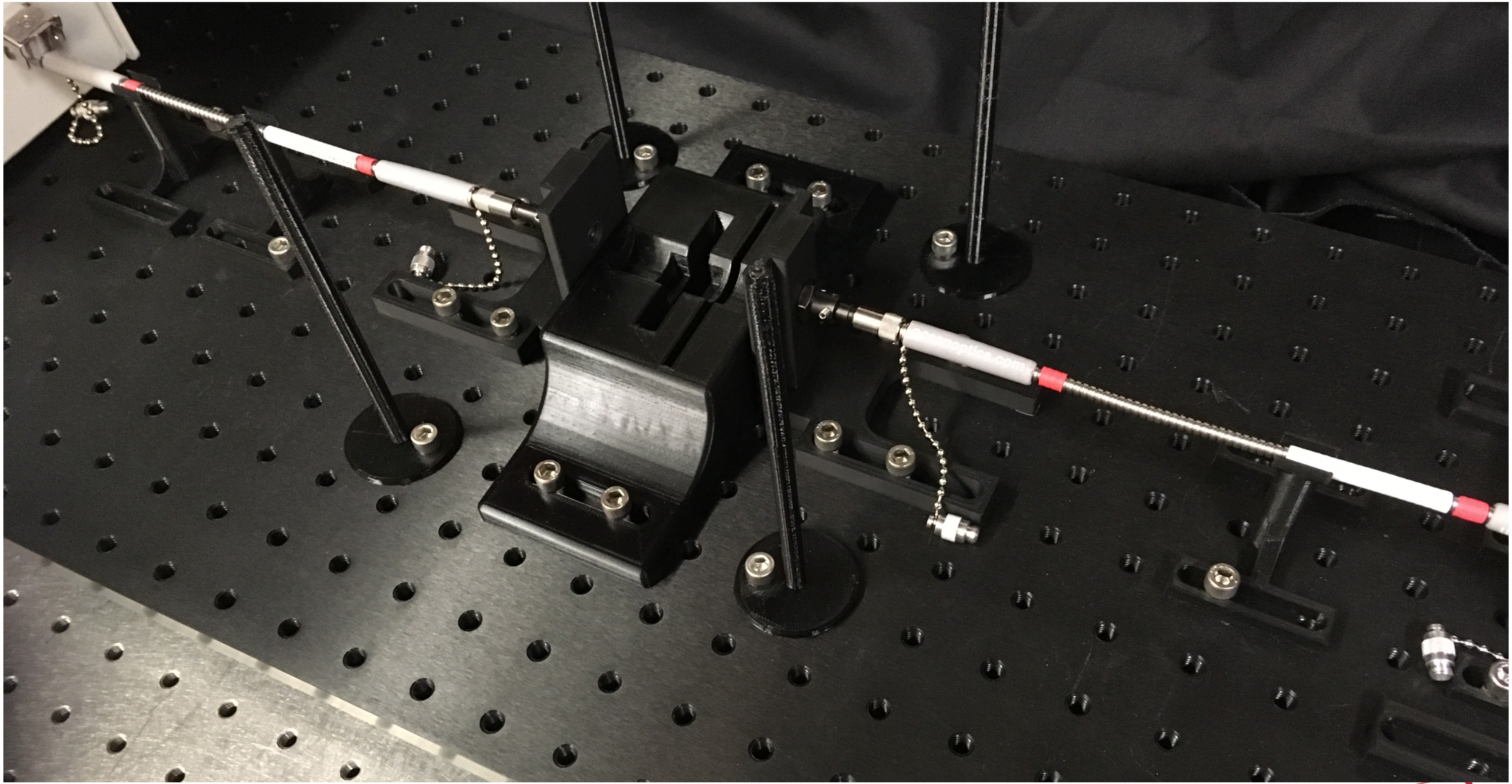
  2.0" long U-channel ➔ 28 mil thick spacer

  2.125" long U-channel ➔ 44 mil thick spacer (can definitely make)

- Webbed struts, lightguides and many parts will need adjustment as well as Larry's support bar's that attach SM to the ring support structure -- they may need to get a little thicker along z

Jefferson Lab

Backup slides: Light transmission apparatus

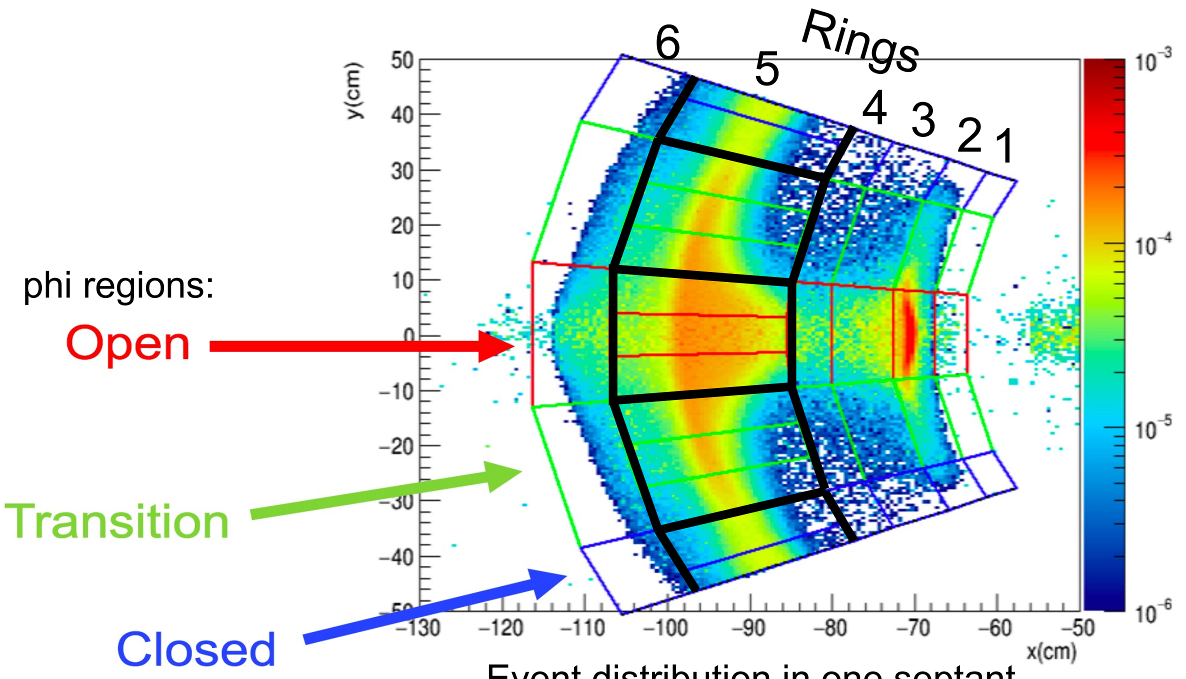


Backup Slides: Requirements on Shower-max

Idaho State University

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



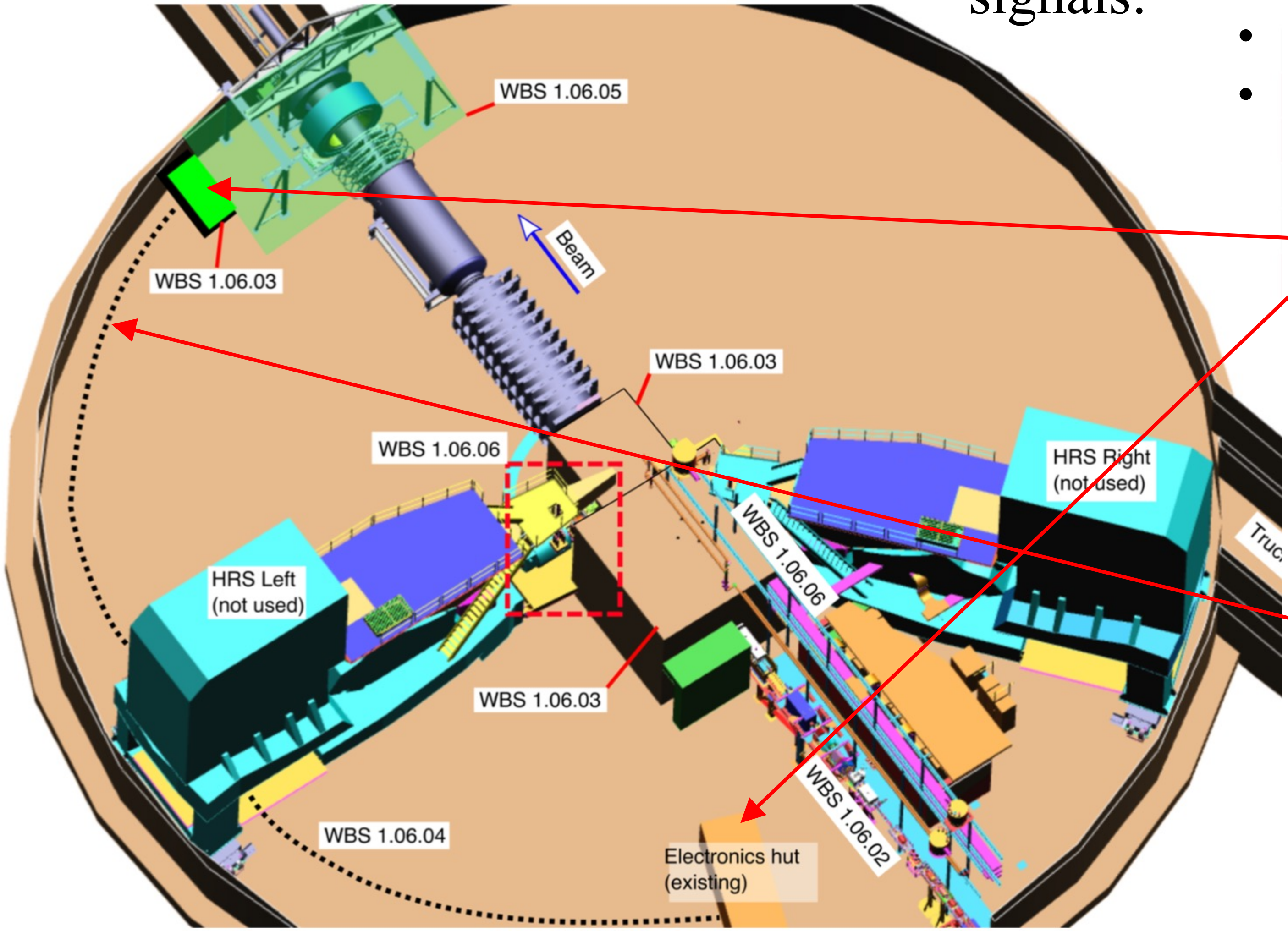
Event distribution in one septant

- 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

Backup Slides: Detector Cabling

Idaho State University

MOLLER Hall Layout



--400 (300) channels integration (counting) mode signals:

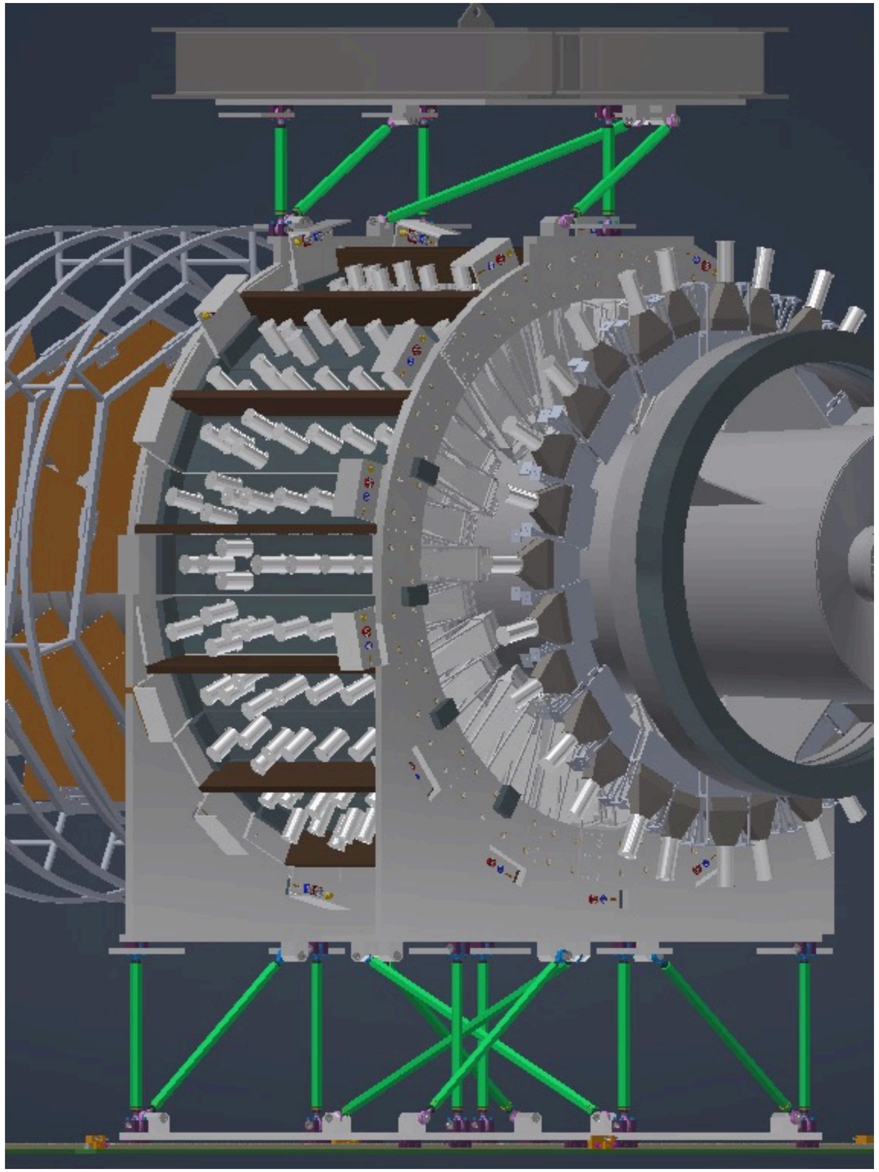
- 224 main detector channels
- 28 SM channels, 14 pion, 8 SAM, LAMs, DBMs, US and DS scanners

- Two electronics huts – one downstream and one upstream for shielding
- ~50 ft runs from detectors to 'near' patch panels
  - --Counting signals go to DS hut fast amps
  - --Integrated signals go to US hut ADCs
- 320 ft runs go between US and DS huts

--HV (Radiall BB's) and LV(18 AWG)

- For powering PMT, divider relay, and pre-amplifier
- And for switching between dividers (high and low gain) and preamp settings

Backup Slides: Signal breaks/patch panels



Integration mode signals

--Two patch panels for 400 det channels: one near detectors and other in US hut

If pre-amp is integrated into PMT enclosure (for main dets):

--25 m long, 9 ch high density twinax cable from each 1/28 segment patch panel to patch panels on floor near the detectors
--then use 100 m cables from here to US hut patch panels (RG-108 twinax)
--15 m cable from US hut patch panel to integrating ADC (twinax)

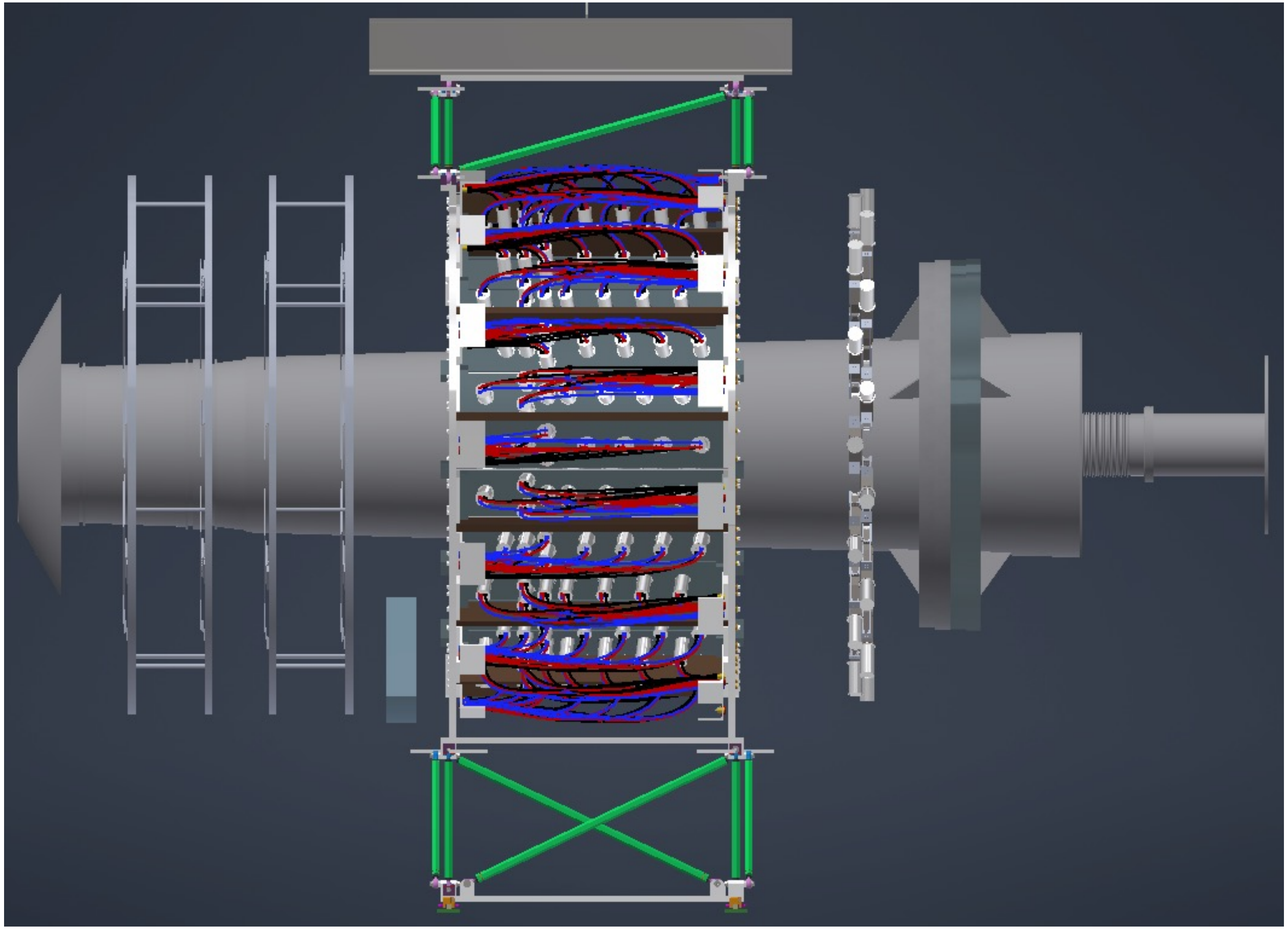
Counting mode signals

--Two patch panels for 302 det channels: one near detectors? and other in US bunker

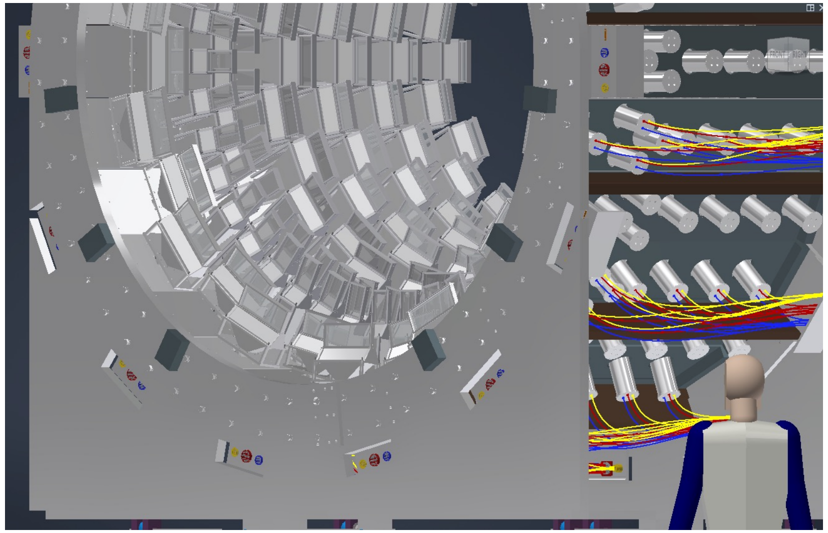
*The near detector PP needs to be close to the fast amplifiers

--25 m long, 9 ch high density coax cable from each 1/28 segment patch panel to the patch panel on floor near the detectors and fast amps*
--then use 100 m cables (RG58) between fast amps and US hut patch panels(?)
--15 m cable from US hut patch panel to flash ADC (RG-58)

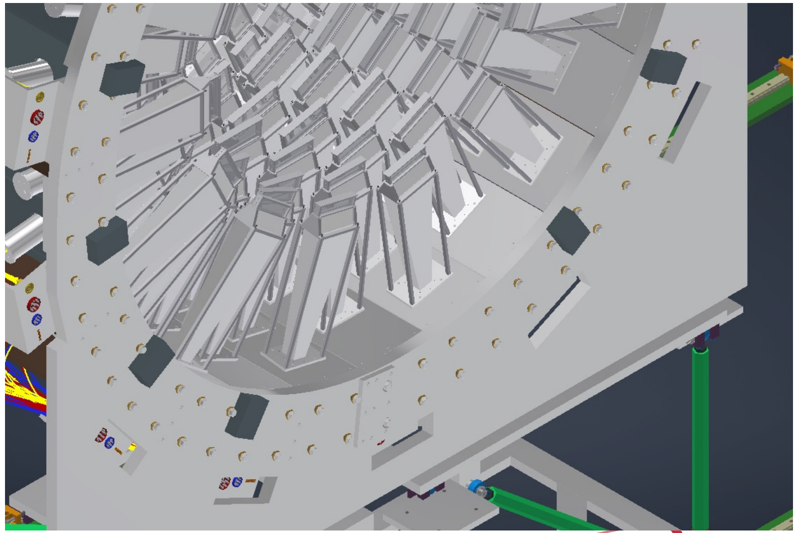
Backup Slides: More views



Upstream Face View

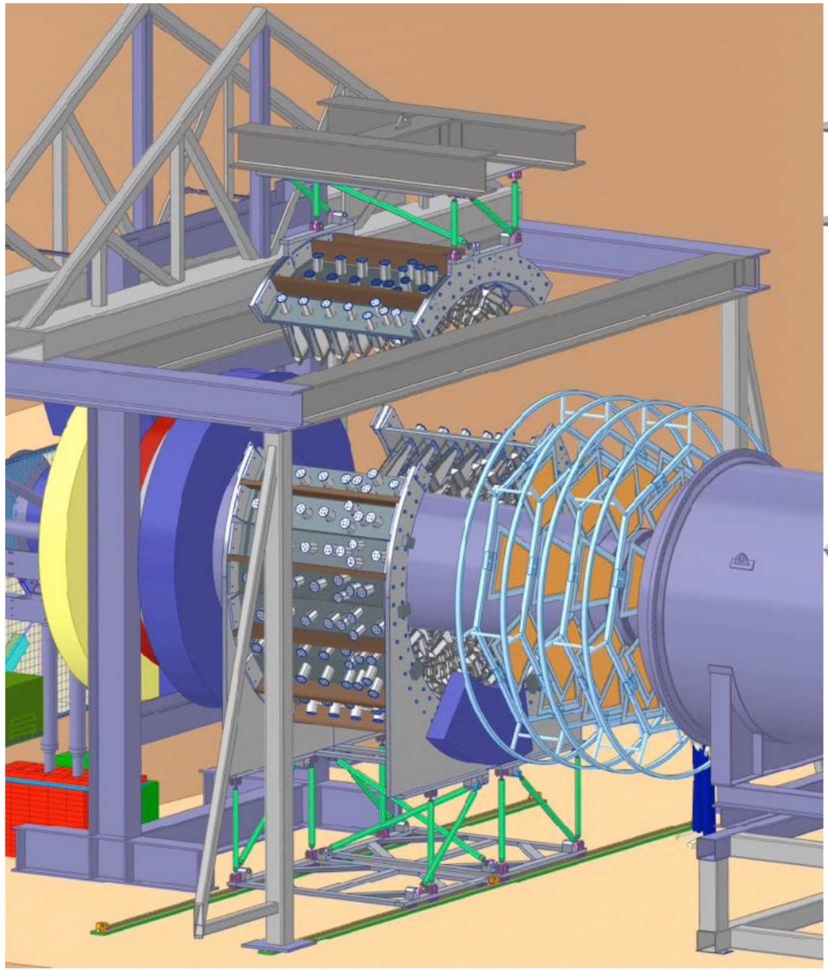


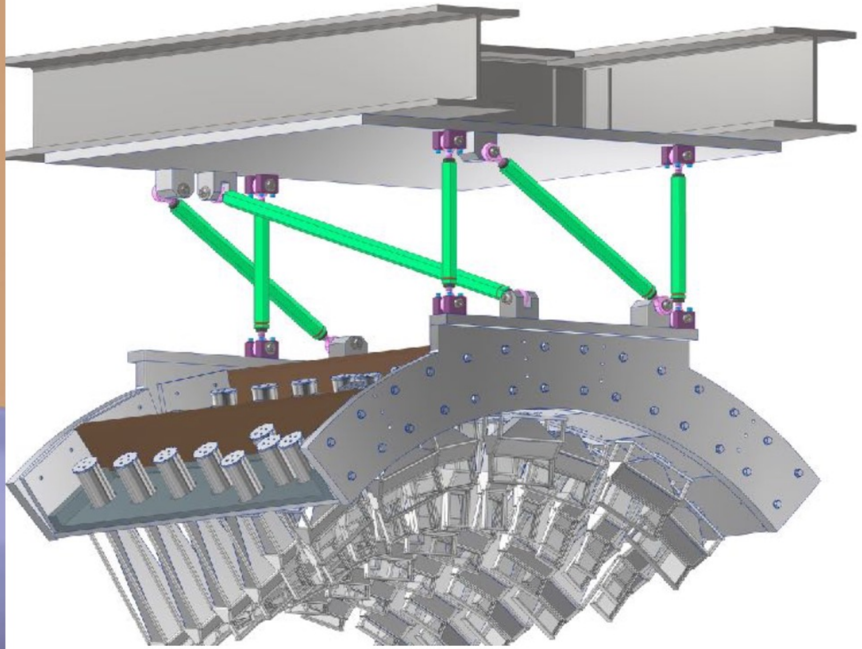
Downstream Face View

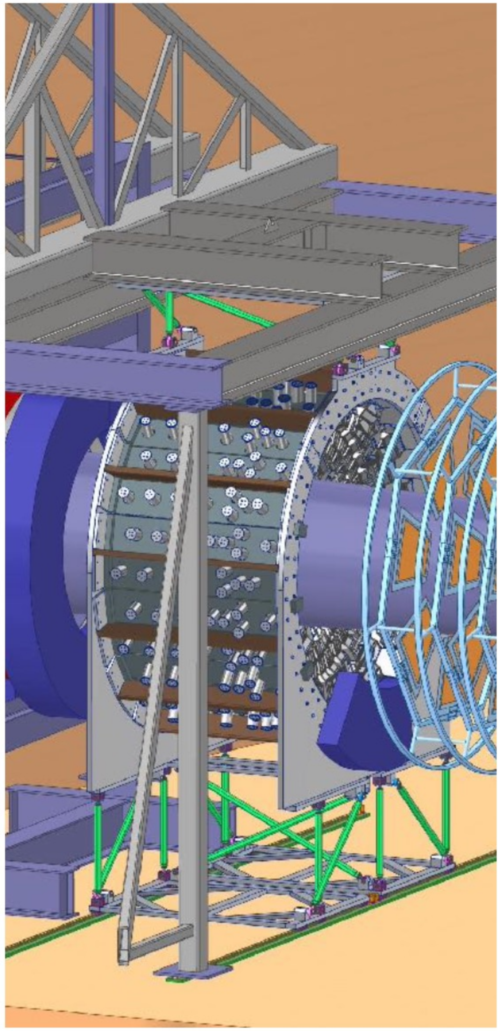


Latest Development: Coupling to A-Frame

Larry Bartoszek, Robin Wines, Ryan Biraben, Danovic Spell



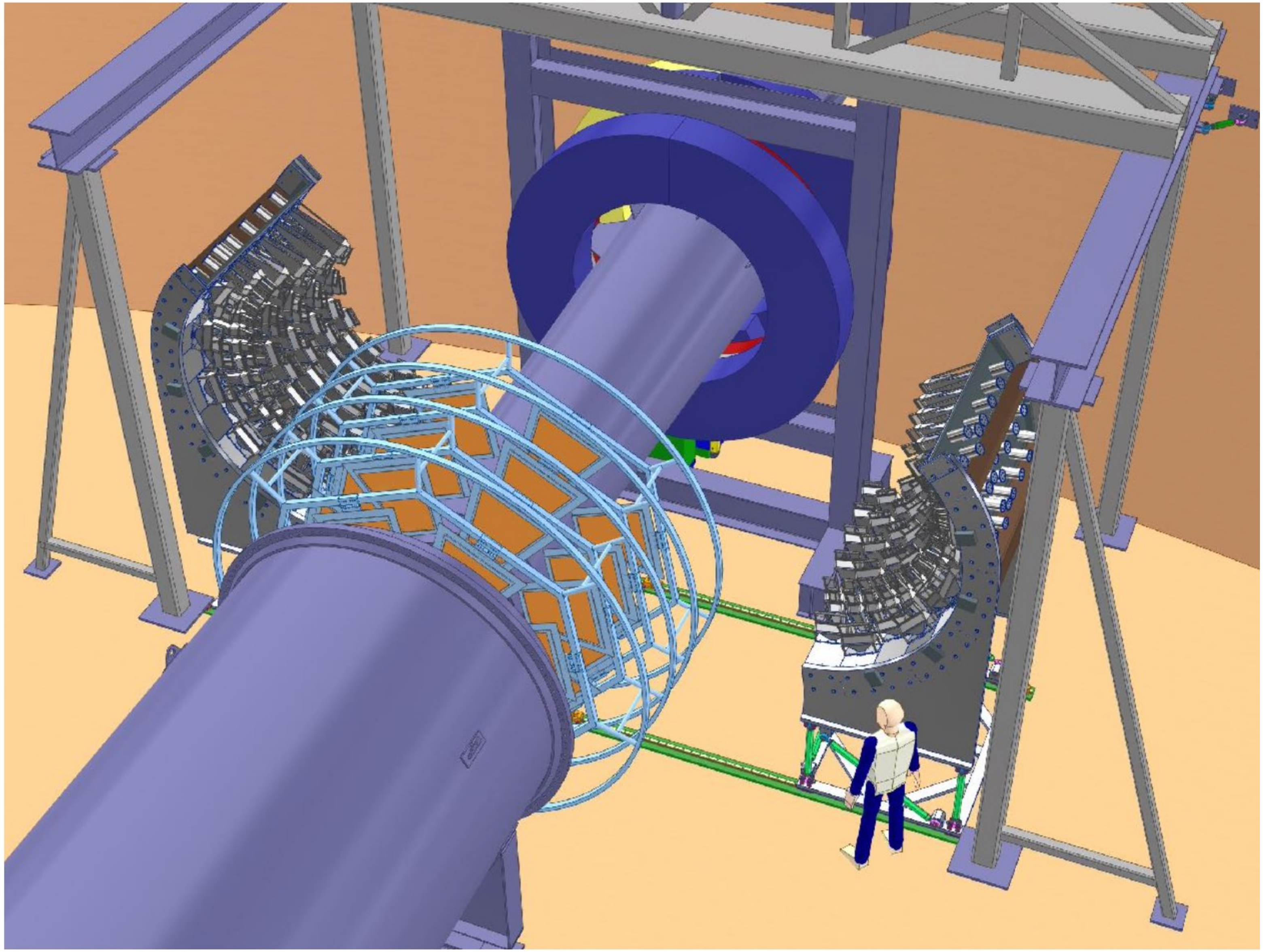




Appendix Slides (Detector Mechanics)

Idaho State University

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



Backup Slides (Detector Mechanics)

Idaho State University