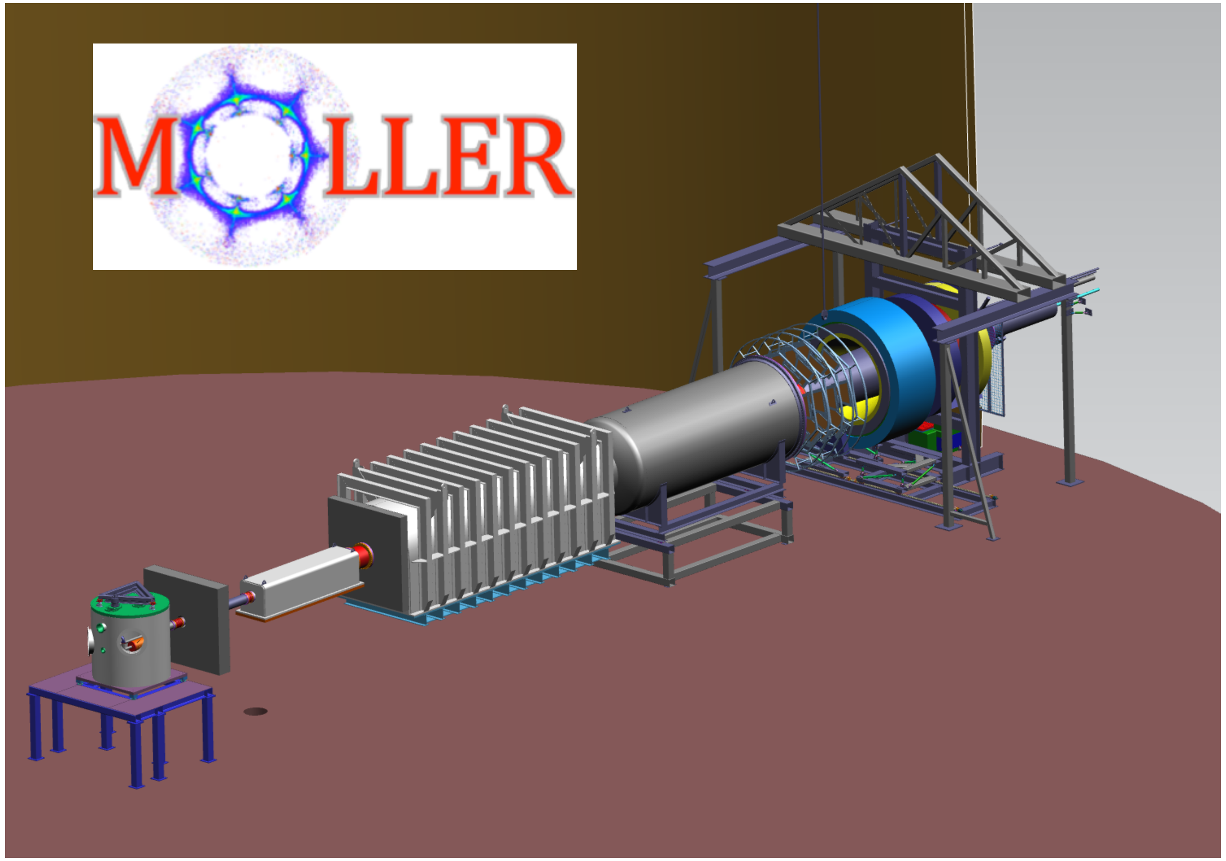
Integrating Detector Update

December 2020 Collaboration Meeting

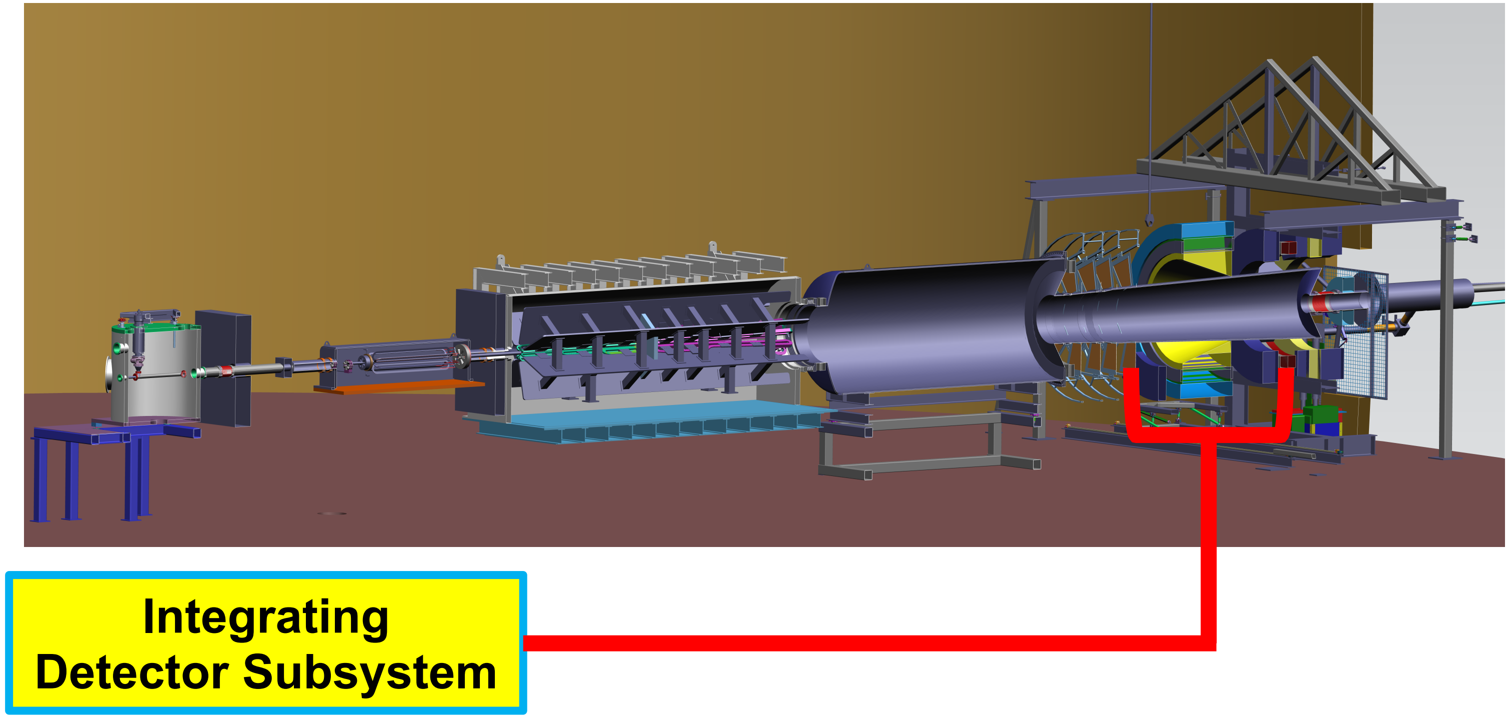


Dustin McNulty

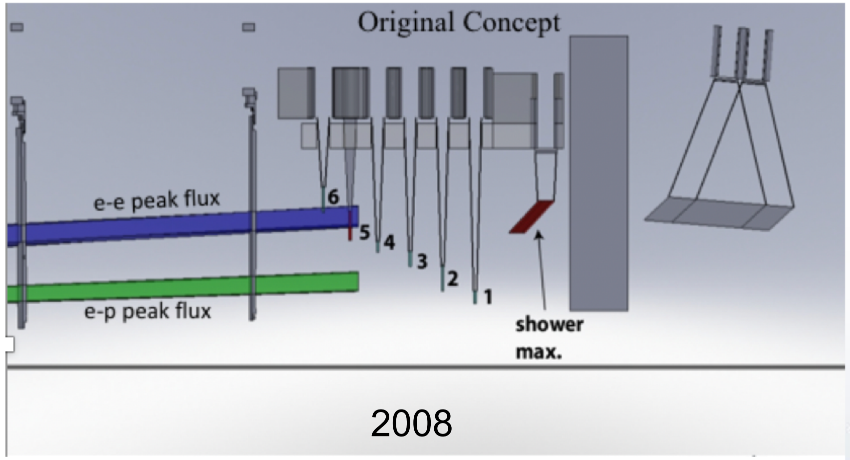
Idaho State University

Outline

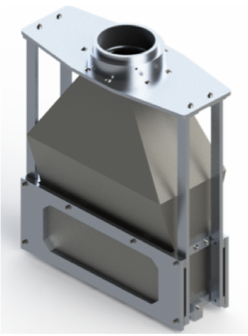
- Subsystem and design overview
- Schedule and plans
- Design updates:
  - Engineering support structures
  - Detector rings and individual modules
- Aux. Support Studies
  - Quartz irradiations (QA studies)
  - PMT non-linearity characterizations
- Summary



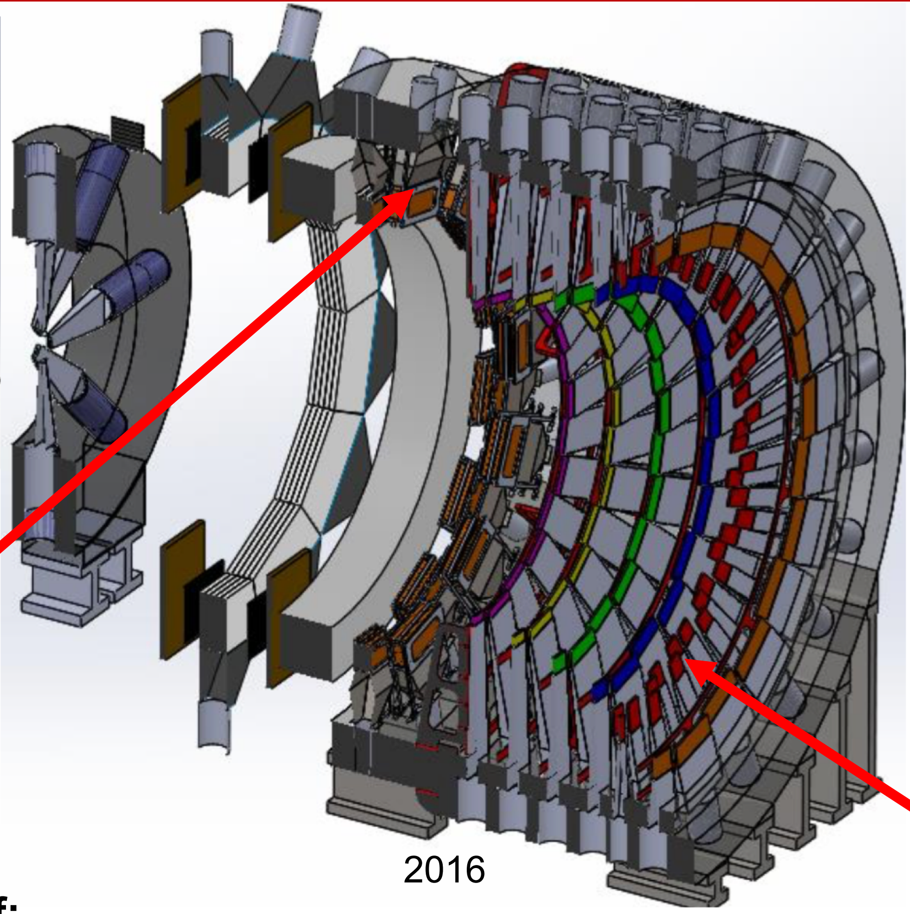
Subsystem Overview



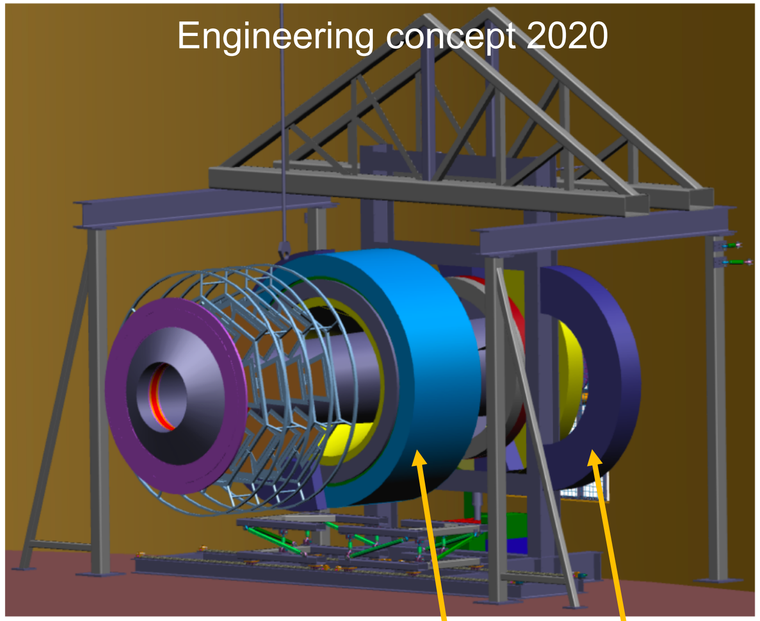
2008



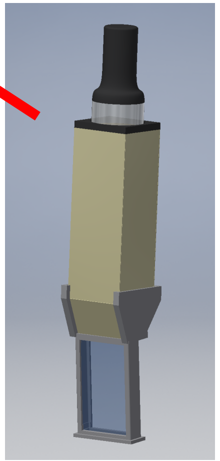
Shower-max:
Electromagnetic
sampling
calorimeter
(ring of 28 modules)



2016



Main & Shower-max
Clam shell support
'place-holders'



Main:
Thin quartz
Detectors
(6 ring array of
224 modules)

Integrating detector package consists of:

- Main thin quartz Čerenkov detector array
- Shower-Max Čerenkov detector ring
- Scanner detector system
- Mounting structure and shielding
- Front-end Electronics (up to Preamp) – see Michael's Talk

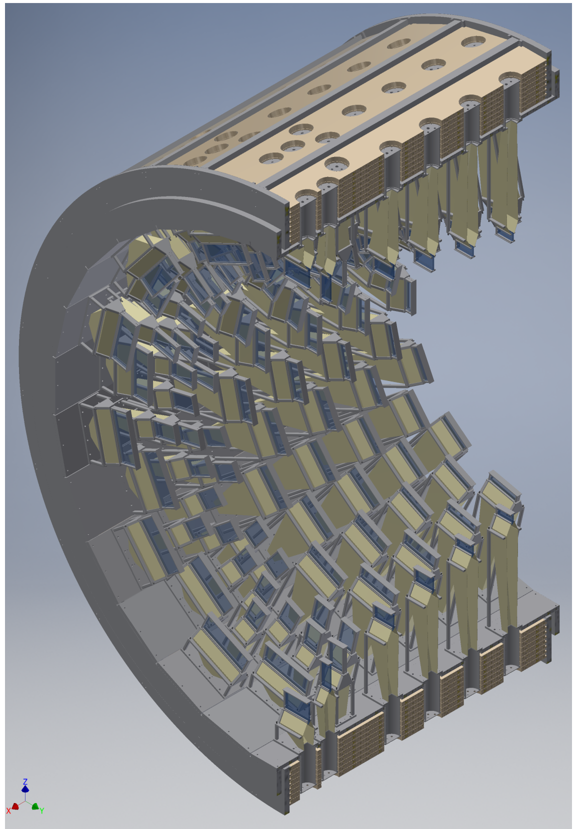
Design Overview: Main integrating detector array

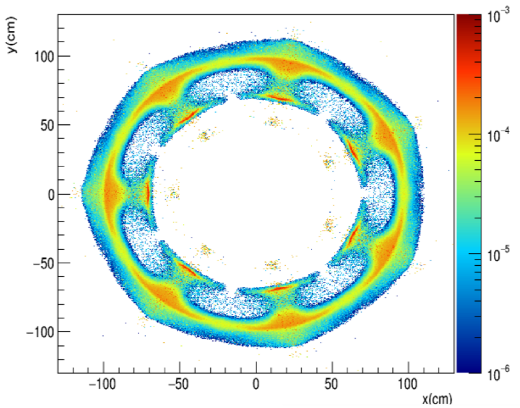
Thin detector :

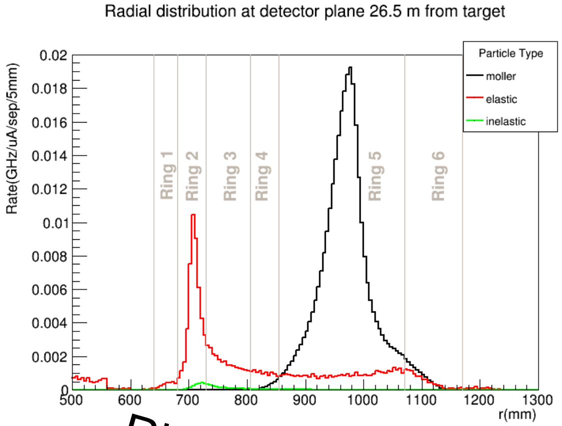
- Thin detector has 224 detector tiles
  - To keep rate per detector down
  - Resolve phi dependence
  - Allow background deconvolution
- Rate per tile:
  - few MHz to 4 GHz
    (up to 1 MHz / mm^2)
- Acquisition modes:

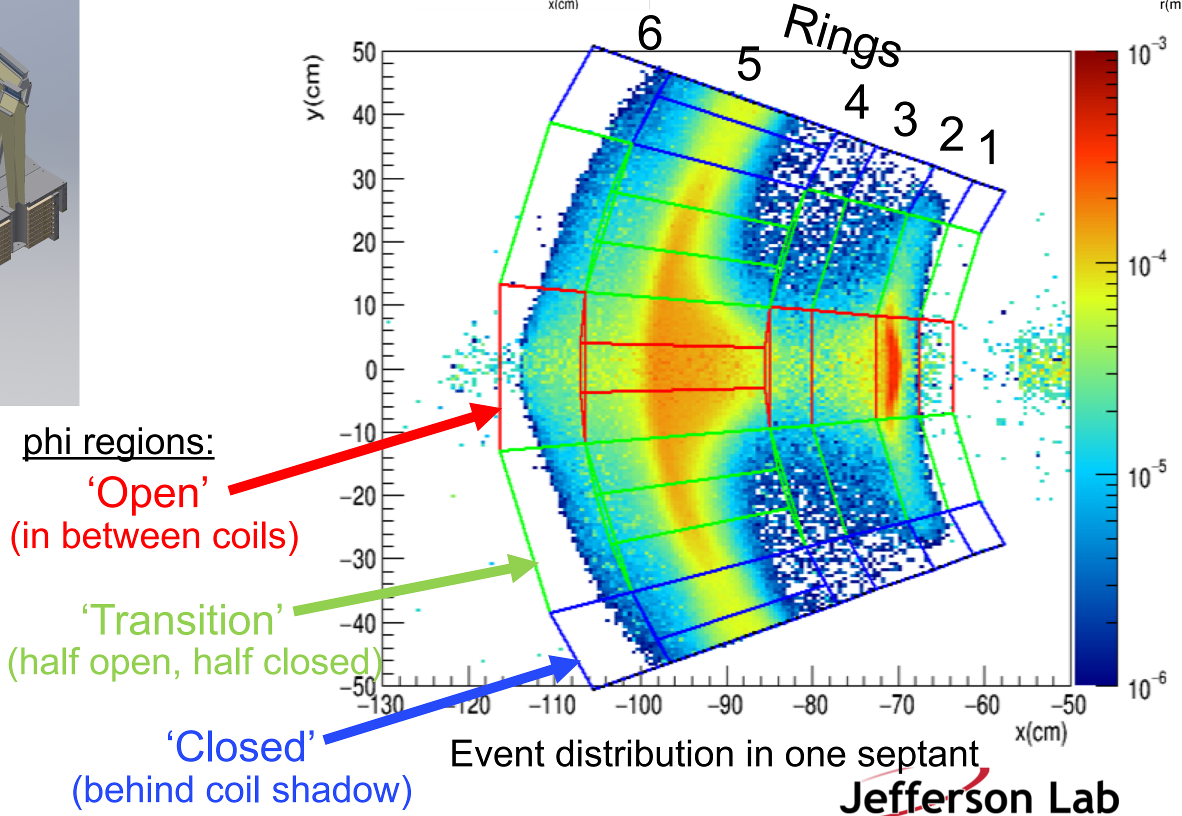
  Flux Integrating (production)
  - No event cuts possible
  - Need to ensure low background by design

  Event Sampling (with tracking GEMs)
  - Commissioning apparatus
  - Detector tile kinematic acceptances
  - Systematics control









Event distribution in one septant

Design Overview

Thin detector module geometry:

- Design based on TIR Cerenkov with air-core light guide:
  --3 inch photomultiplier tubes (e.g. ET 9305QKB)
  - Fused silica window
  - High and low gain switchable voltage divider; preamps

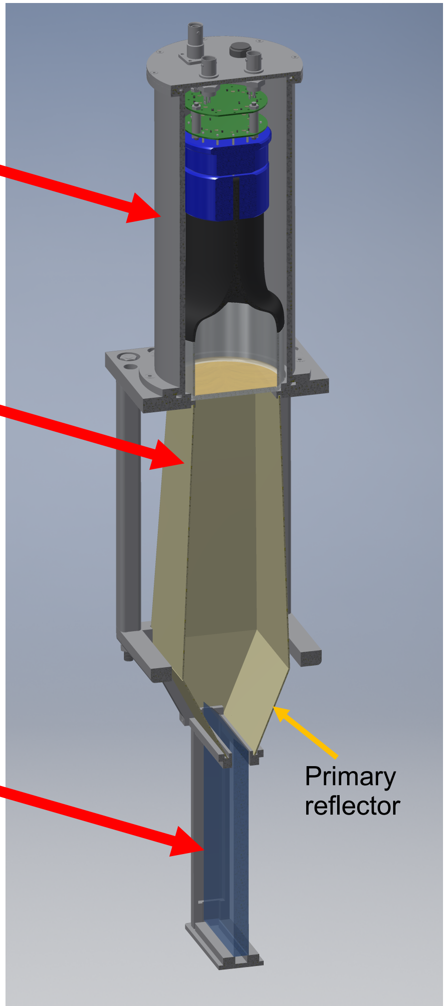
--Air-Core light guides: (0.5 mm thick aluminum; one-bounce)

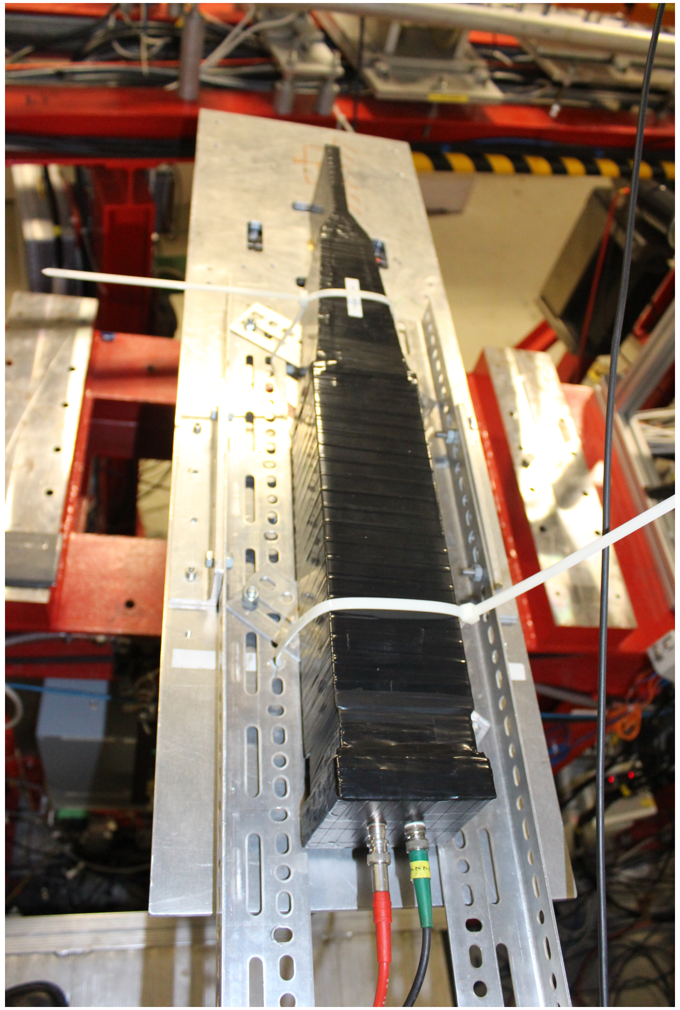
- Anolux Miro-silver 27 (top candidate material)
- Low soft background sensitivity
- Low scintillation background (using dry air flow)

--Quartz (fused silica):

- Radiation hard, synthetic fused silica such as Spectrosil® 2000 by Heraeus
- High purity to ensure low scintillation
- High OH **and** $\mathbf{H_2}$ content (improved radiation-hardness)
- High polish and parallelism for TIR
- Low soft background sensitivity

- Mounting structure that satisfies
  - Mounting precision
  - Rigidity w\o strain on light guide or quartz
  - Low background (small material budget)
  - Light sealing; dry-air flow path (from pmt to quartz)



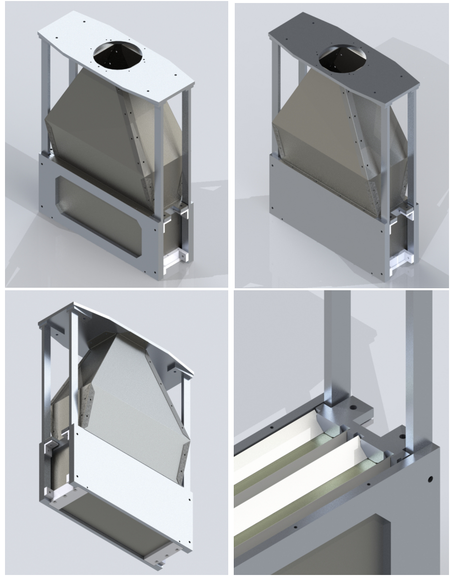


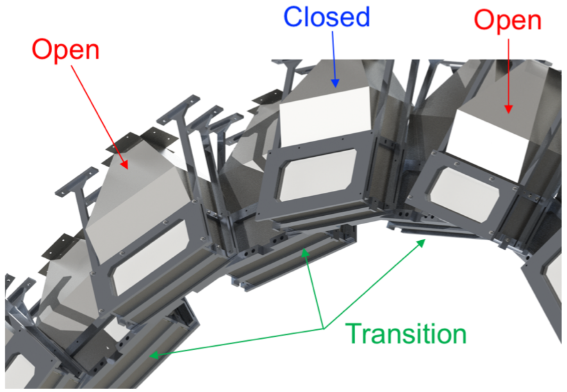
Prototype tests at MAMI and SLAC

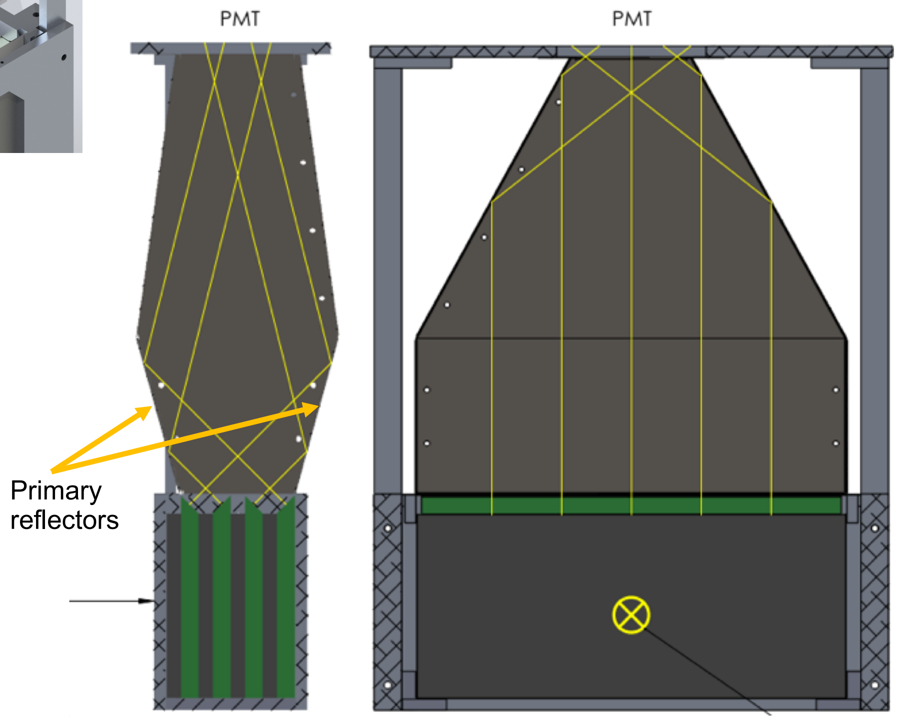
Design Overview: Shower-max integrating detector ring

Shower max detector module and ring geometry:

- Detector concept uses a layered “stack” of tungsten and fused silica (quartz) to induce EM showering and produce Cherenkov light
  - Design uses a **4-layer stack** with **8 mm tungsten** and **10 or 6 mm quartz** pieces (~9 X_0; R_M ~1.1 cm)
  - Cherenkov light directed to **3 inch PMT** using **air-core, aluminum light guide**
- Rad-hard Materials
  - Tungsten is high purity (99.95%) and quartz is optically polished synthetic fused silica (e.g Spectrosil® 2000)
  - Light guides are aluminum specular reflectors (Anolux Miro-silver 27)
- Detector ring consists of 28 modules (staggered in $\hat{z}$)
  - Located ~28.5 m from target center (~2 m downstream of ring 5)
  - Active region of SM ring spans radially from ~1 m to ~1.16 m





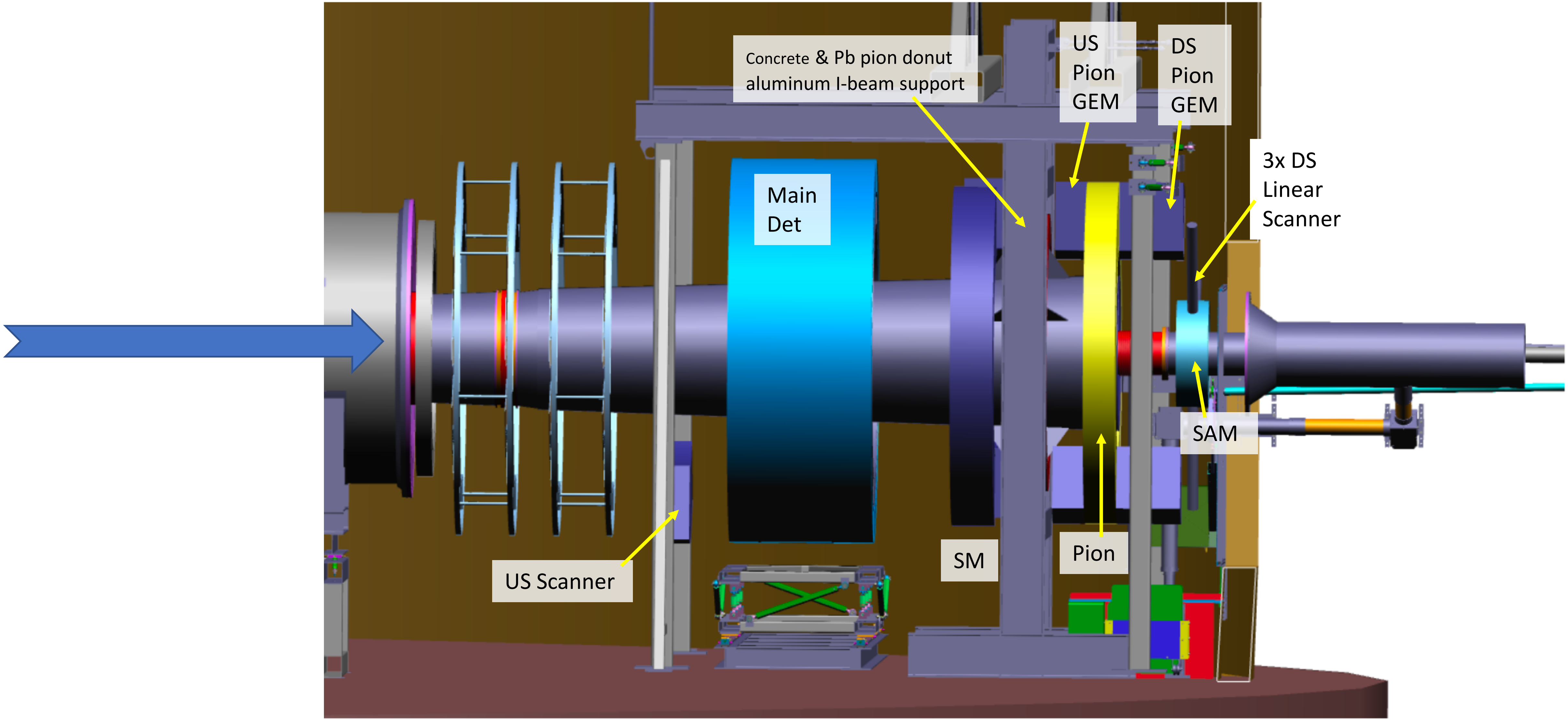


Schedule and plans

Integrating Detector Subsystem design, construction and testing

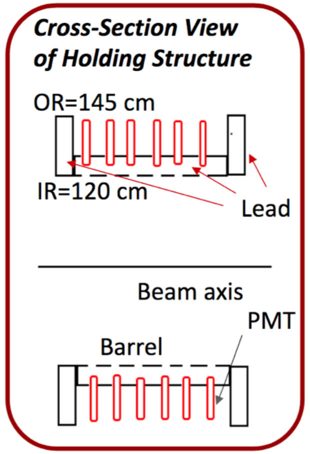
Activity ID	Responsible Groups	Activity Name	Start	Finish
Integrating Detector support structures (NSF, CFI)	Manitoba - UMass, Amherst - Syracuse	**(these activities are only for sub-assembly and support structure designing, constructing and testing)**	**16-Aug-19**	**3-Oct-22**
Int. Detector S.S. Design			15-Dec-20	2-May-22
Int. Detector S.S Procurements			16-Aug-19	8-Sep-22
Int. Detector S.S Construct and Test			14-Jul-22	3-Oct-22
Thin Quartz Detector (CFI)		**(design, construct and test individual thin quartz detectors)**	**1-Apr-21**	**19-Jan-24**
Thin Quartz Detector Design			1-Apr-21	28-Mar-22
Thin Quartz Detector Procurement			1-Apr-21	18-May-23
Thin Quartz Detector Construct and Test			10-Nov-21	19-Jan-24
Shower Max Detector (NSF)	Idaho State	**(design, construction and test validation of all SM modules)**	**15-Dec-20**	**24-Jul-23**
Shower Max Detector Design			18-May-21	15-Oct-21
		Shower Max Detector 60% Design Effort	18-May-21	25-Jun-21
		Shower Max Detector 90% Design Effort	8-Sep-21	15-Oct-21
Shower Max Detector Procurements			15-Dec-20	3-Nov-22
Shower Max Detector Construct and Test			22-Mar-21	24-Jul-23
Scanner Detector (NSF)	Va. Tech	**(design, construction and test validation of all scanner modules)**	**15-Dec-20**	**10-Jul-23**
Scanner Detector Design			15-Dec-20	24-Jan-22
		Scanner Detectors (Including Mounting Structure) 60% Design Effort	19-Mar-21	12-Jul-21
		Scanner Detectors (Including Mounting Structure) 90% Design Effort	3-Nov-21	24-Jan-22
Scanner Detector Procurements			13-Jul-21	3-Nov-22
Scanner Detector Construct and Test			6-Oct-21	10-Jul-23

MOLLER beamline layout – Detector Region



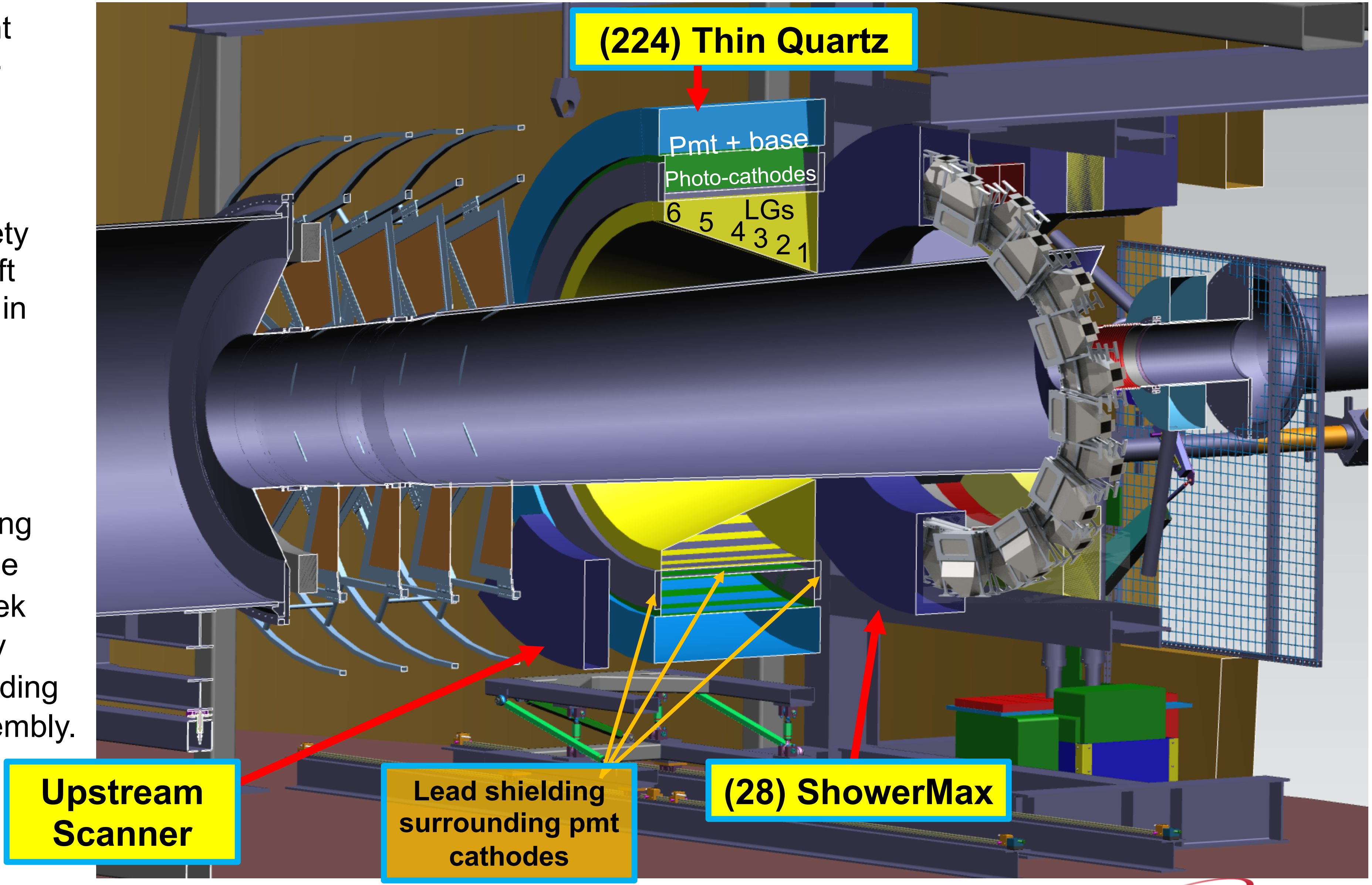
Moller Layout – Integrating Detector Subsystem

Main detector assembly weight dominated by pmt Pb “shell” -- weighs between 6 and 7 tons

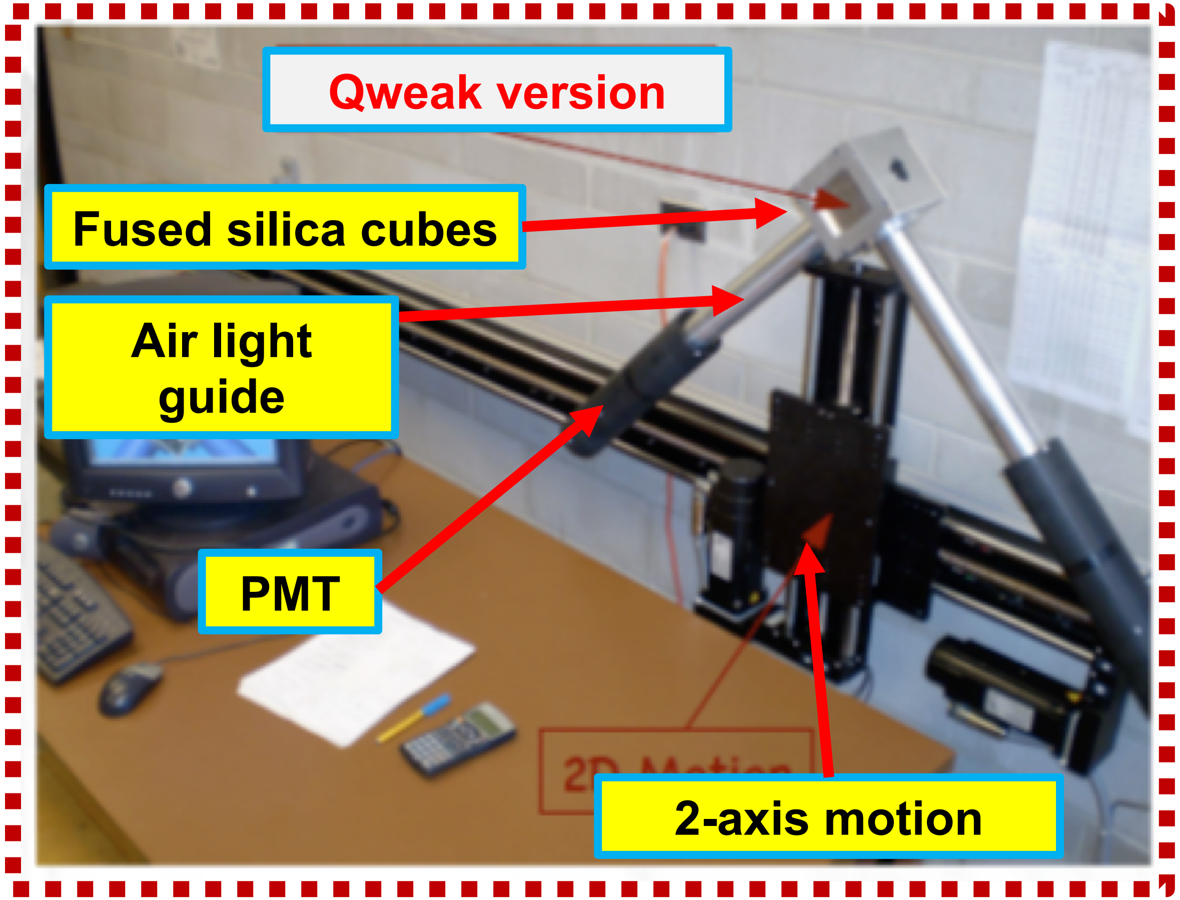


Provides safety margin for soft backgrounds in pmt region

Umass-Syracuse groups working with Jim and Robin to define the Statement of Work for Bartoszek Engineering to start preliminary design concept for external holding structure of main detector assembly.



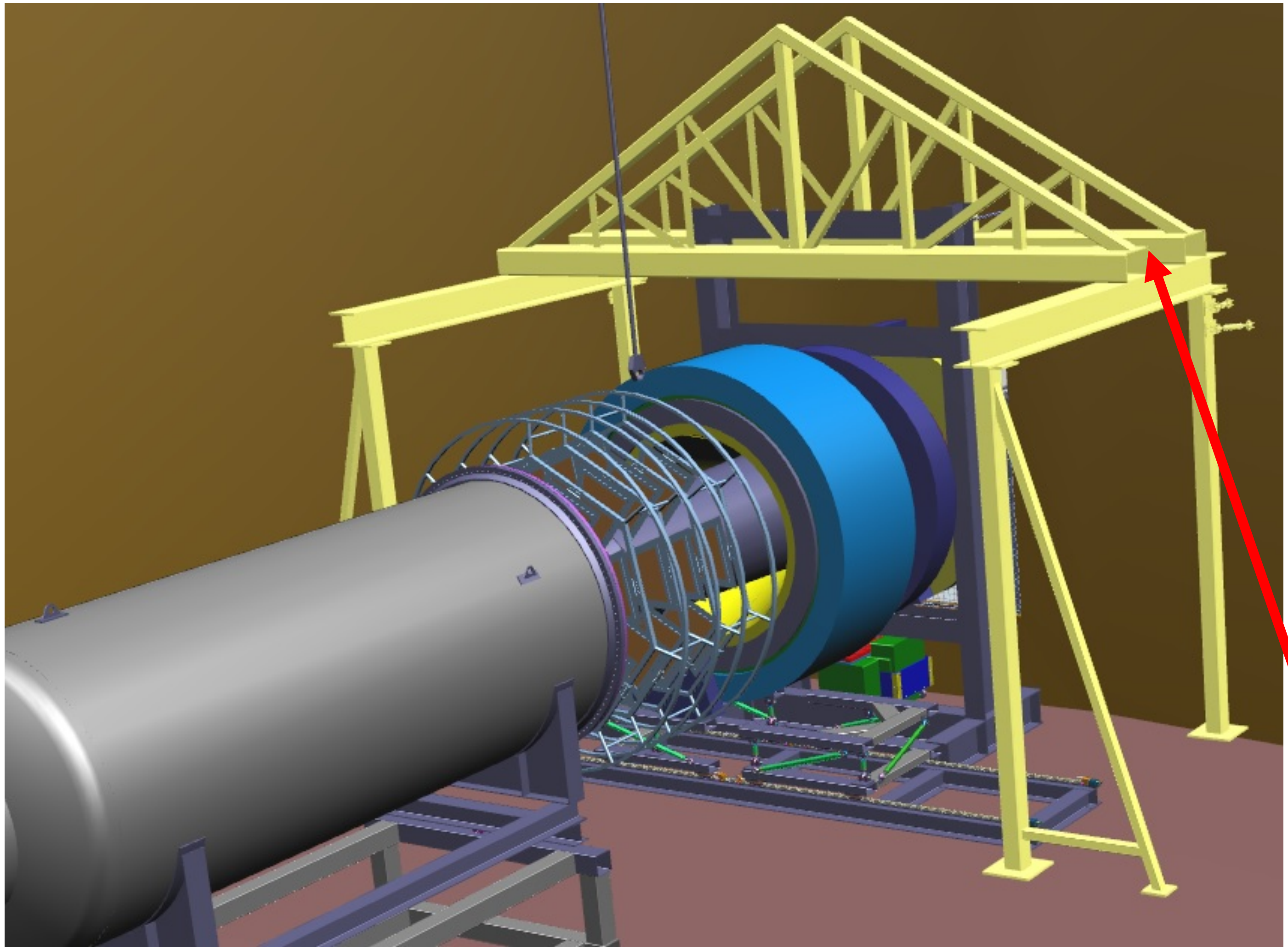
Upstream Scanner detector concept

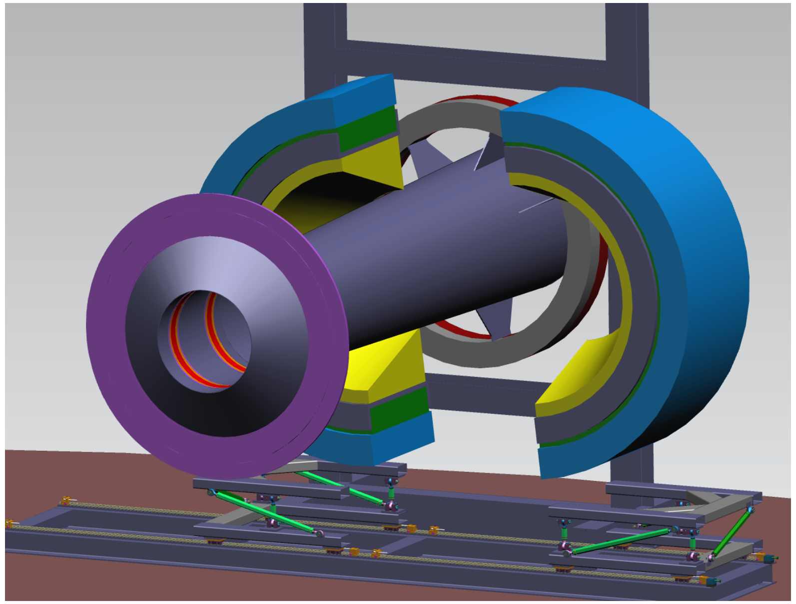


More details of the scanner detector given in Mark's talk tomorrow

Scanner
- Small cerenkov counter upstream of thin quartz det
- Provides detailed 2D profile of beam intensity

Support structures for integrating detectors





- Main detector clam shell supported from below using rail and cart system similar to Hall B's solenoid and HTCC, respectively

  --Both Main and SM ring assemblies split and separate from beamline for module maintenance

- Yellow I-beams with trusses support the SM and Pion detector rings from above.

  --SM motion system possibly based on PrimEx's Hall B HyCal transporter system

Thin detector module and ring assembly concept

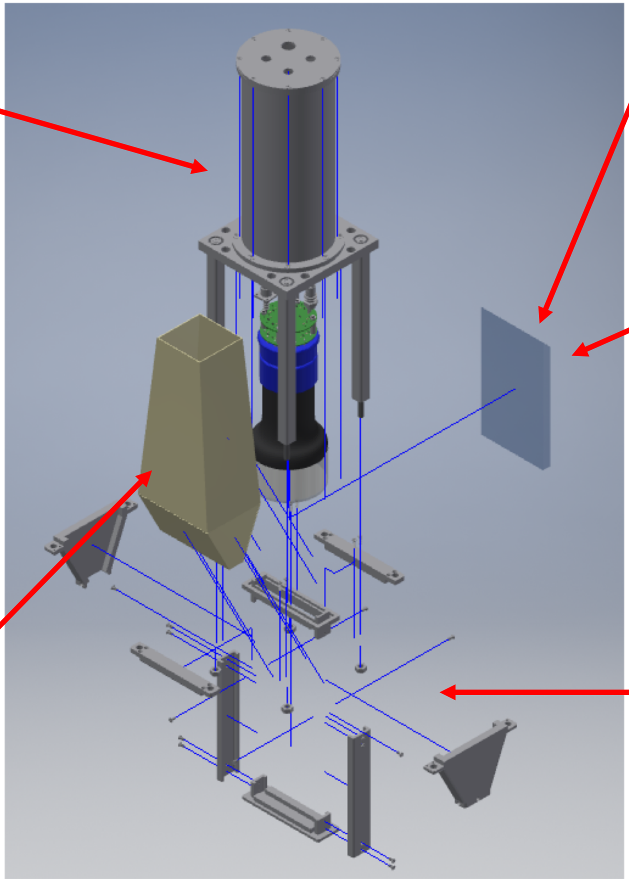
Detector Module Design Concept:

PMT + base housing:

- Spring loaded or similar to hold PMT at all angles
- Possibly Ventilated/cooled
- Light tight sealed independently from rest of assembly
- Cable strain relief

Light guide:

- High reflectivity (soft UV through visible)
- Radiation hard (aluminum)
- Light tight



SiO2 active detector material:

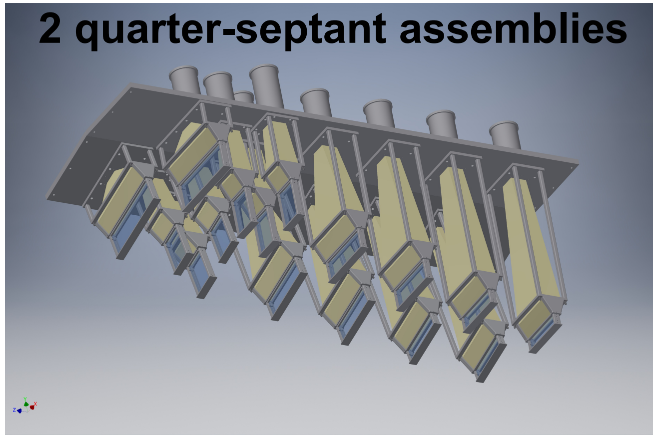
- Radiation hardness – irradiation/transmission loss studies planned

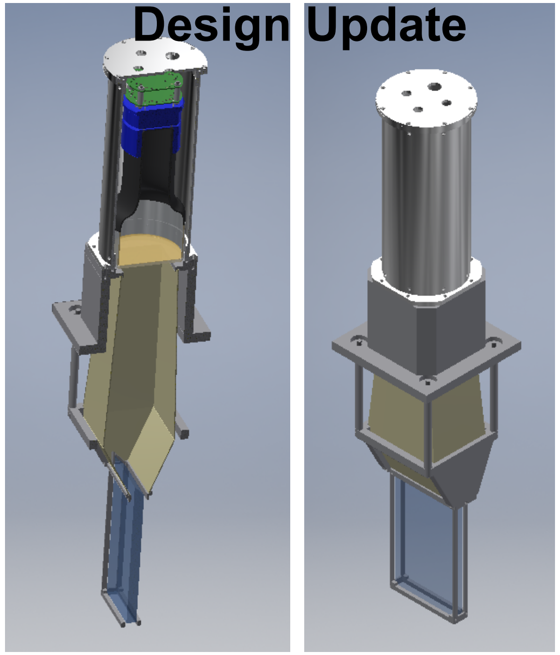
HVMAPS: solid state pixel det (not shown – see Michael's talk)

- Funding now in place to instrument the DS face of each ring 5 tile with HVMAPS chips

SiO2 tray:

- Various options possible, but needs to be accessible without removing other detector parts.
- SiO2 could slide out toward smaller radius
- Aluminum or some rad hard low Z material (carbon fiber)



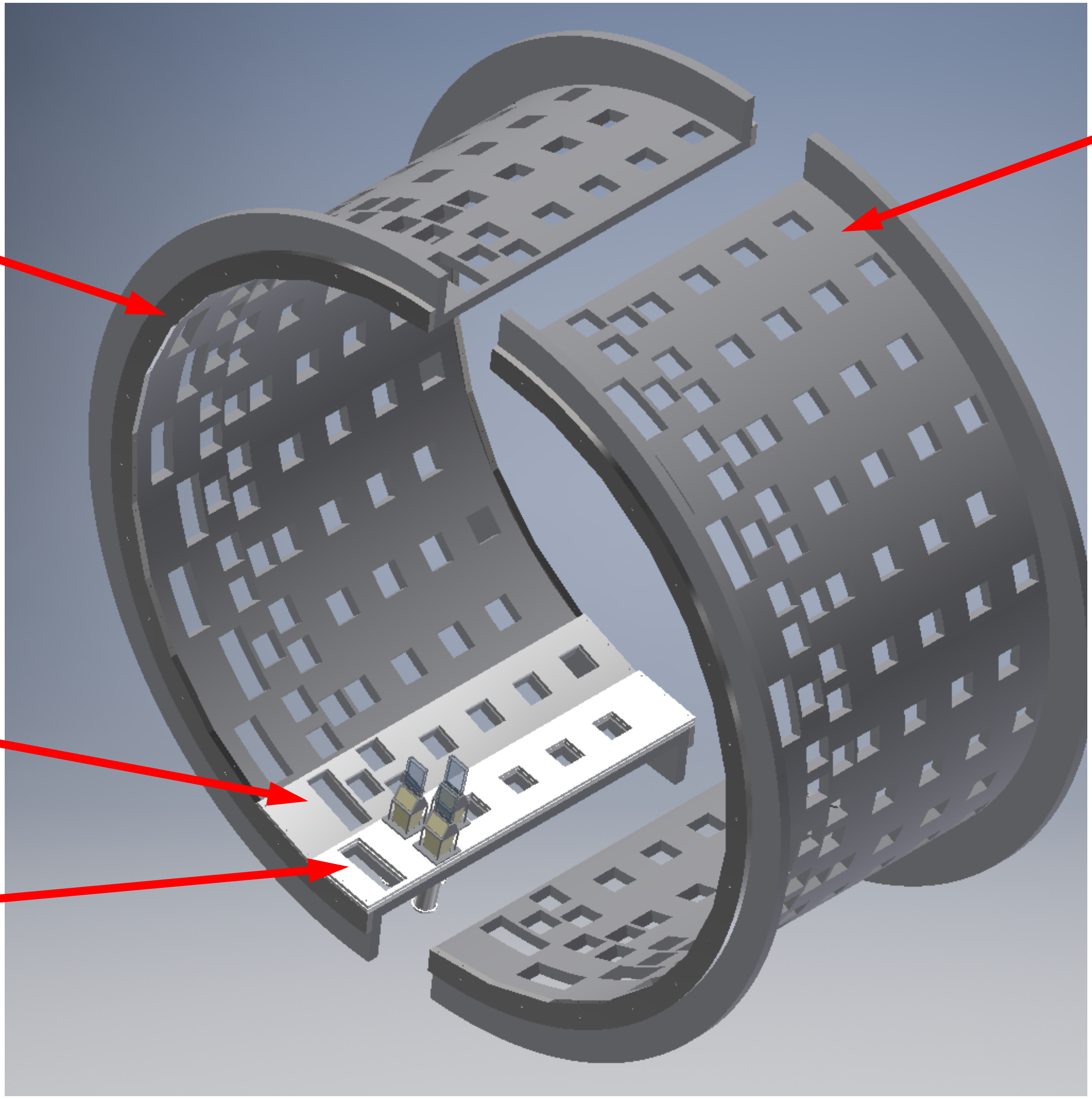


Thin detector assembly concept with lead shell

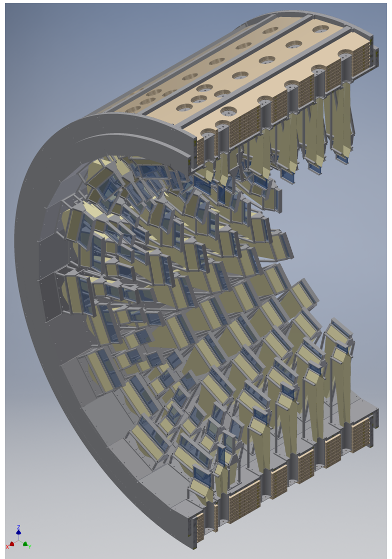
Some sort of mounting ring to attach the sector plates

Sector/lead interface plate

Sector to detector module interface plate



Lead 'shell'



The two detector halves separate to facilitate installation of the detector sector modules.

The sector modules are assembled completely, ahead of installation in the array.

Thin detector assembly concept with lead shell

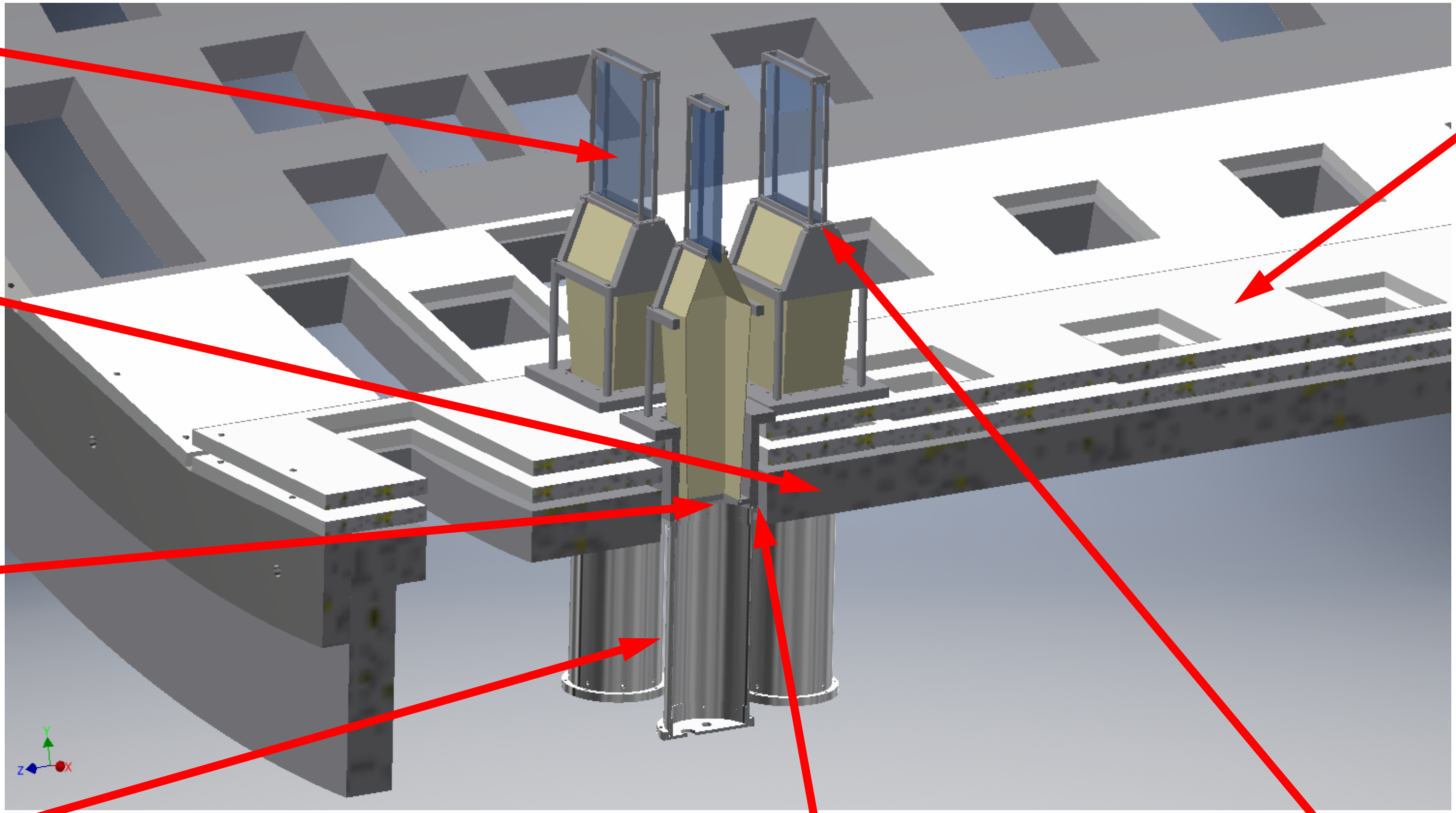
MOLLER

The entire inner module can be light sealed with a Kapton bag around the SiO2 and light guide.

In this CAD, this is 5 cm of lead.

This is where the PMT window (not shown) is located. So the PMT is partially surrounded by lead in this design.

The PMT housing can be attached/removed from the outside radius, without the need to break any light seals on the rest of the modules.



Detector module interface plate:

--allows angular position adjustment on a sector by sector basis (use Belville washers)

--survey and alignment fiducials attached to this plate.

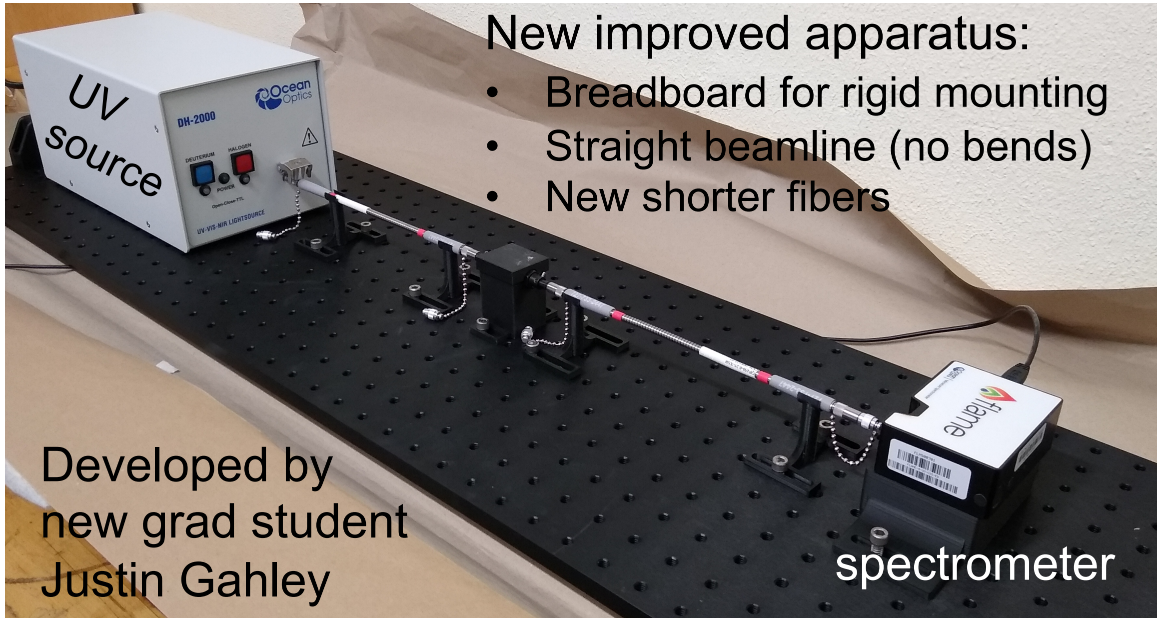
There is an O-ring seal between the PMT housing and the rest of the assembly.

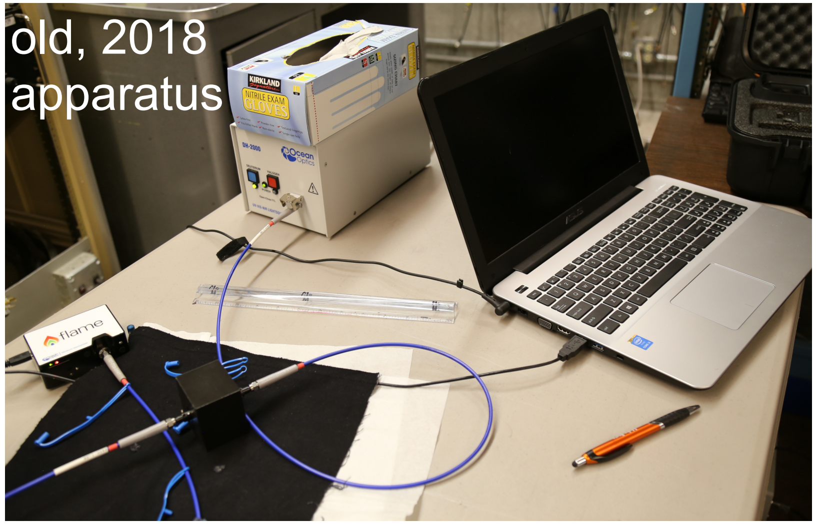
Significantly reduced material budget around the quartz and light guide, compared to previous design.

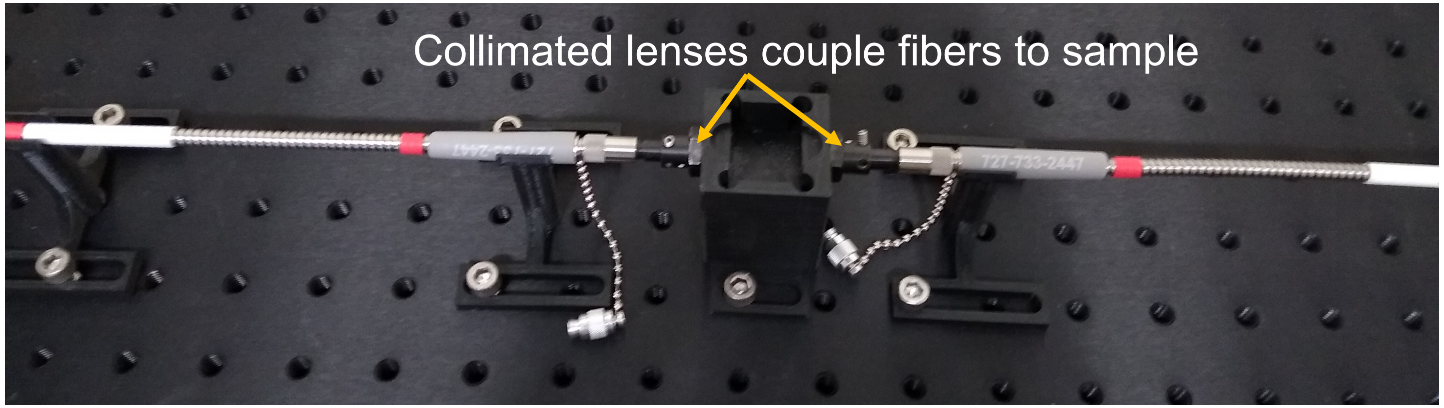
Auxiliary support studies: quartz irradiation studies

- Peak (open region) dose exposure analysis (C. Gal) shows that quartz tiles in ring 5 and ring 2 will receive ~70 Mrad and 170 Mrad, respectively per 5x5 mm^2; 70 krad in pmt region
- Quartz light transmission losses due to radiation damage expected and will be quantified; develop mitigation strategy
- Several fused silica samples will be irradiated at the Idaho Accelerator Center (IAC) and transparency tested over the next 6 months – to choose quartz type for MOLLER

https://moller.jlab.org/DocDB/0006/000631/002/irradiationPlans.pdf





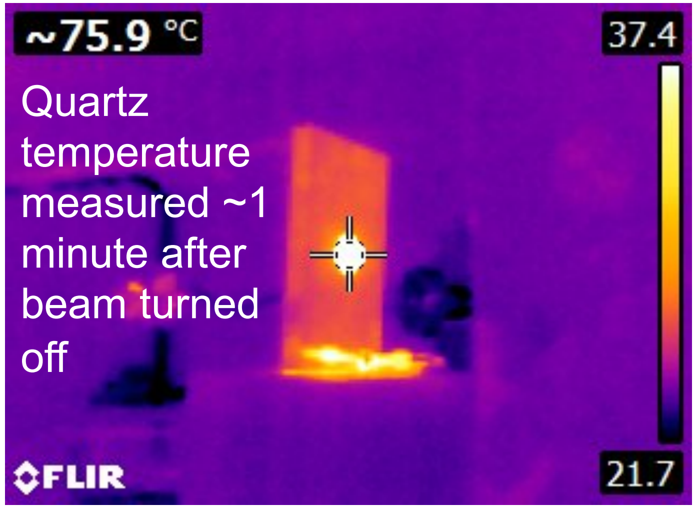


New 3D-printed sample holders – can fabricate for any sample geometry

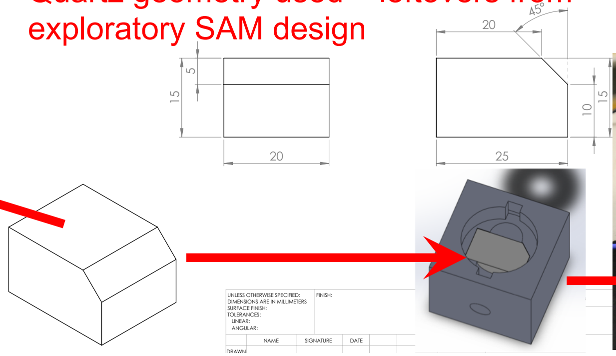
Auxiliary support studies: quartz irradiations

Quartz Irradiations at IAC (May 2018)

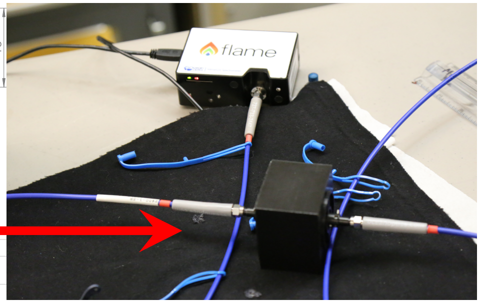
- **Beam setup: 8 MeV, 50 mA I_{peak}, 500 ns pulse width at 250 Hz rep-rate**
- Quartz sample mounted 0.5 m from beampipe exit window
- Dose exposure calibrations give ~250 Rad/pulse
- Irradiated sample for 3, 8, and then 12 minutes
- Measured light transmission (four times) after each irradiation and averaged

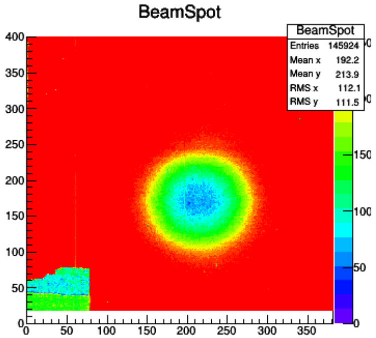


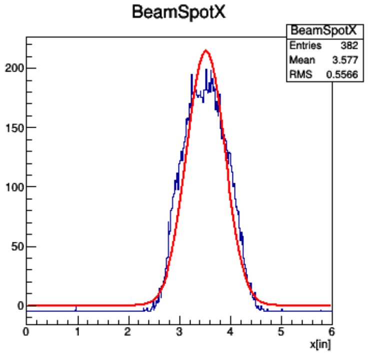
Quartz geometry used – leftovers from exploratory SAM design

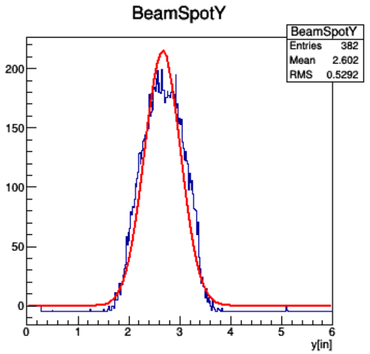


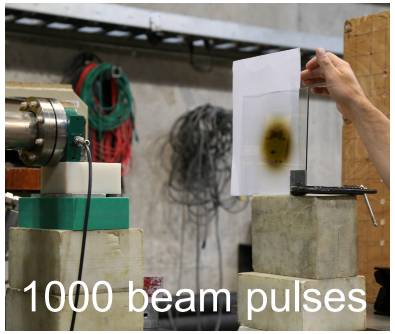
Transparency Meas.

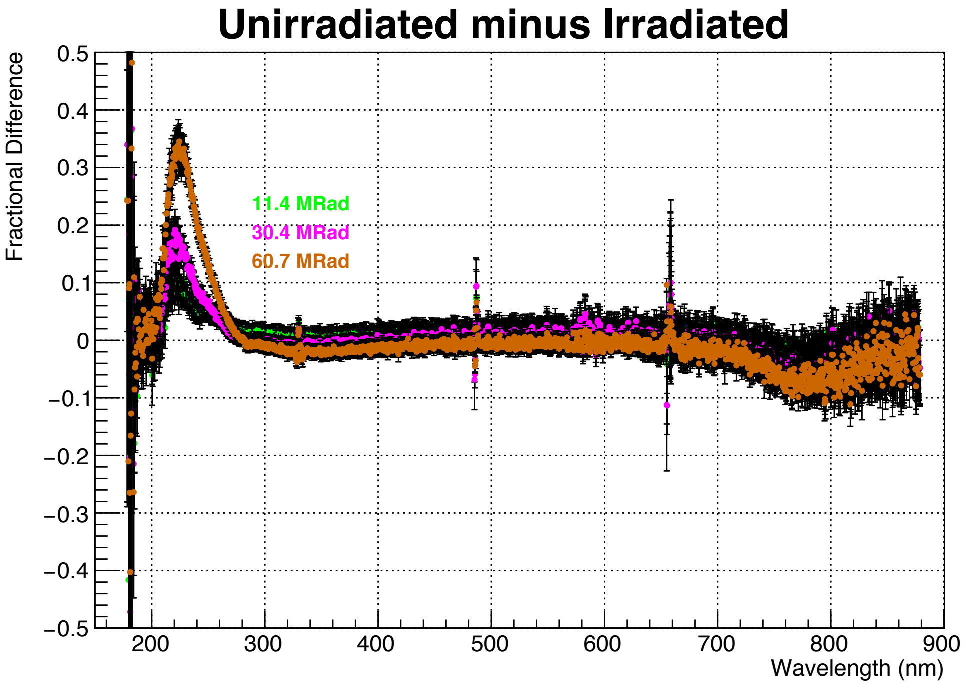








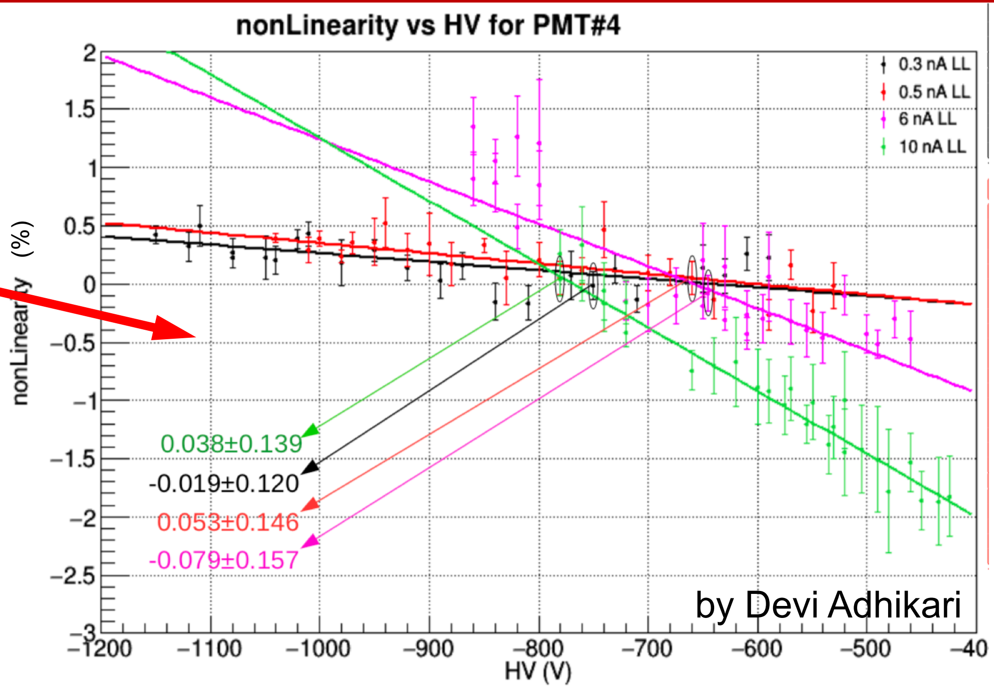




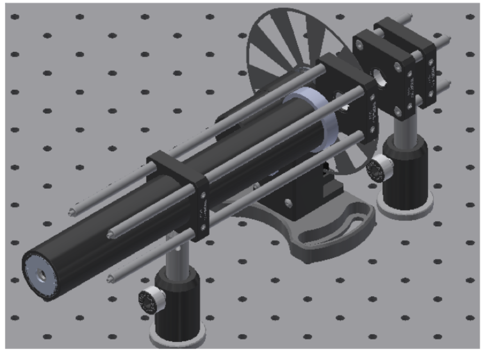
Auxiliary support studies: pmt non-linearity

*Want to suppress the non-linearity to $\varepsilon \leq 0.5 \pm 0.1\ \%$

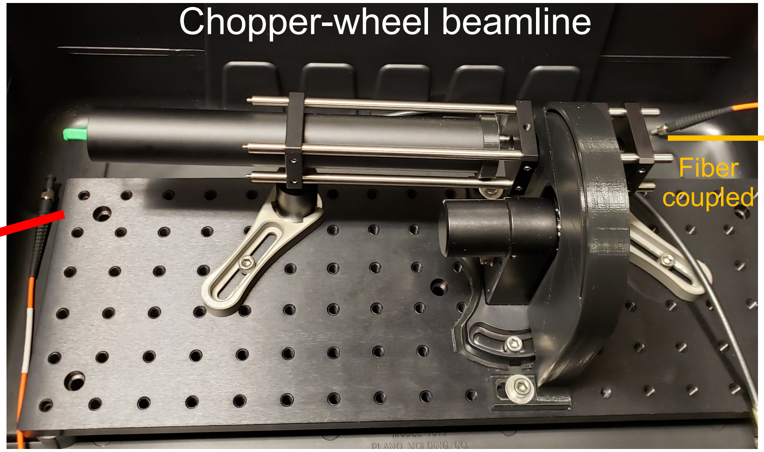
- New apparatus based on PREX-2 experience
- Uses same technique and apparatus except for flashing LED
- New system uses a chopper-wheel to 'flash' LED at 960 Hz (Conventional LED flashing becomes unstable above ~480 Hz)

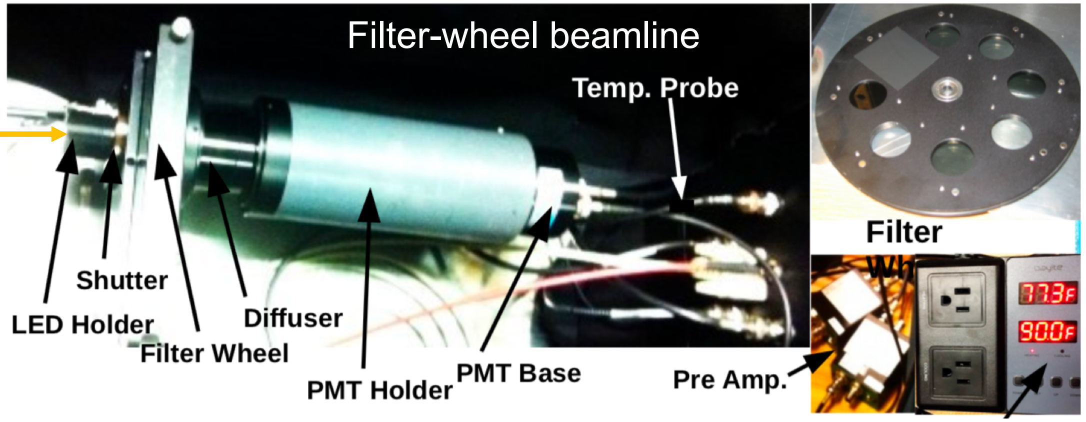


Sample data from PREX-2 system (240 Hz flashing)



Developed by new grad student Sudip Bhattarai





Summary and next steps

Summary:

- All funding in place and our schedules and plans defined. It's time to roll-up sleeves…
- Detector region beamline layout in focus and engineering design work underway (fortnightly meetings)
- Much progress made in mechanical design concepts for Main detector module and ring assemblies
- Shower-max module design tweaks ongoing. Using remoll to determine optimal size and position of ring
- Quartz irradiation studies ~ready to go; new apparatus in hand; IAC available anytime over next 6 months; test samples from different vendors starting to be acquired; will also dose electronics, …
- New pmt non-linearity apparatus under development; expect first data within few months

Some next steps:

- Continue and ramp-up mechanical design work: Main det sub-assemblies and support structures, SM and Pion det support structures; clam-shells -- rails, carts, transporters, …
- U. groups setup cosmic-ray stands for prototype det tests; continue to pursue testbeam opportunities
- Continued remoll development and simulations to refine precise detector geometries and positions
- Carry-out quartz irradiation/transmission studies and start pmt non-linearity measurements