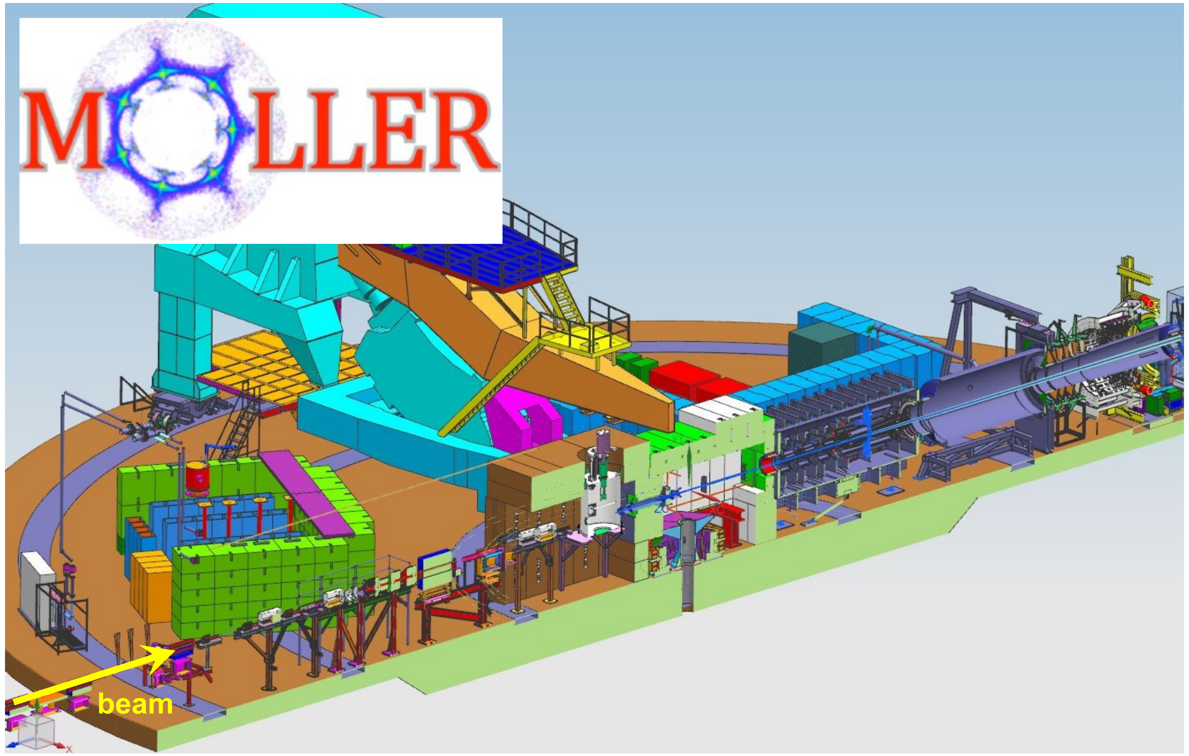
MOLLER CD-2/3 Independent Project Review

L2 Technical Presentation - Infrastructure



Dustin McNulty, L2 Technical Lead

Idaho State University

Oct 3 – Oct 5, 2023

Outline

- Subsystem Overview and Status
  - 1.06.02 Incoming Beamline Modifications
  - 1.06.03 Particle Shielding Around Target and Beamline
  - 1.06.04 Cables
  - 1.06.05 Detector Frames and Supports
  - 1.06.06 Hall Modifications
- Summary

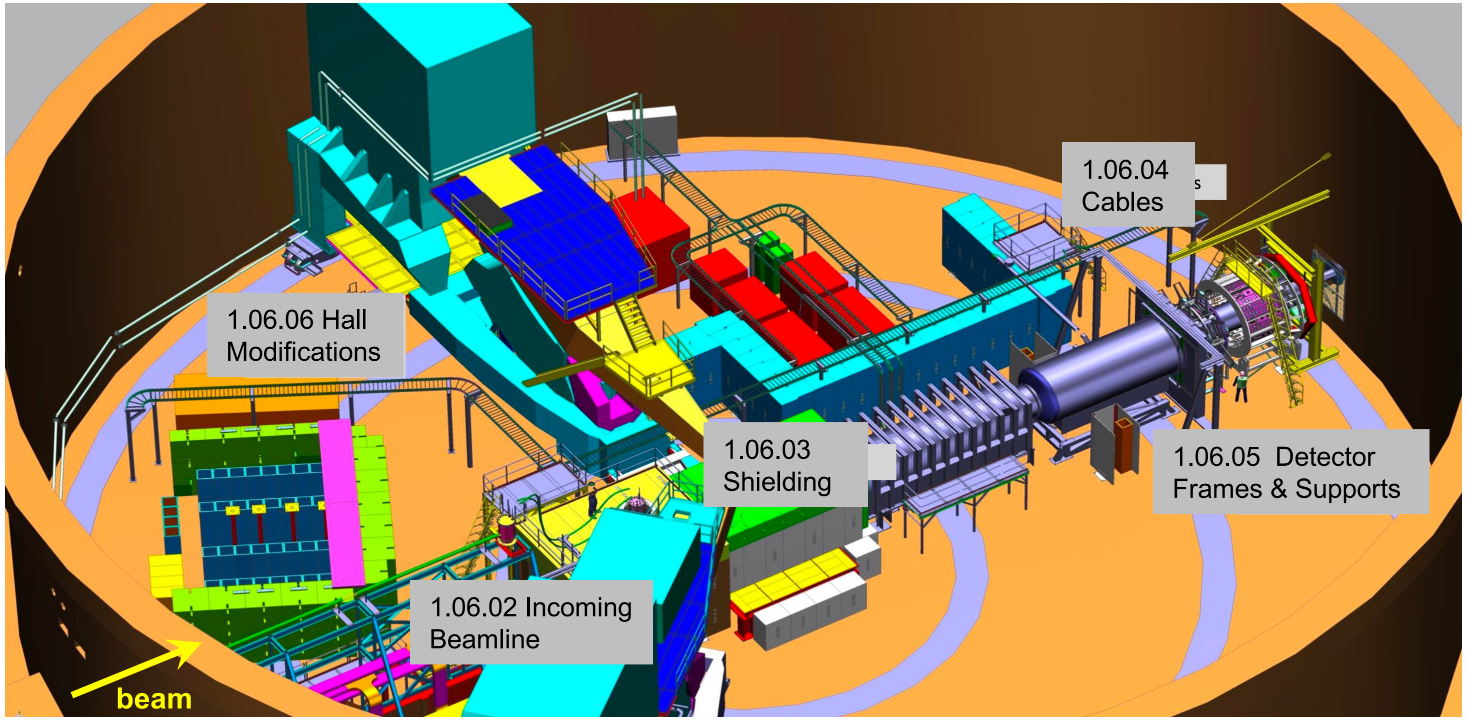
- Team Members:
  - L2 Manager, Control Account Manager
    - Ciprian Gal, Jefferson Lab
  - L2 Technical Lead
    - D. McNulty. Idaho State University
  - Technical contributors:
    - Robin Wines, JLab
    - Jay Benesch, JLab
    - Yves Roblin, JLab
    - Zuhal Demiroglu, Stony Brook University
    - Kent Paschke, University of Virginia
    - Chase Dubbe, JLab
    - Ryan Biraben, JLab
    - Dan Spell, JLab

1.06 Overview

WBS 1.06 Includes:

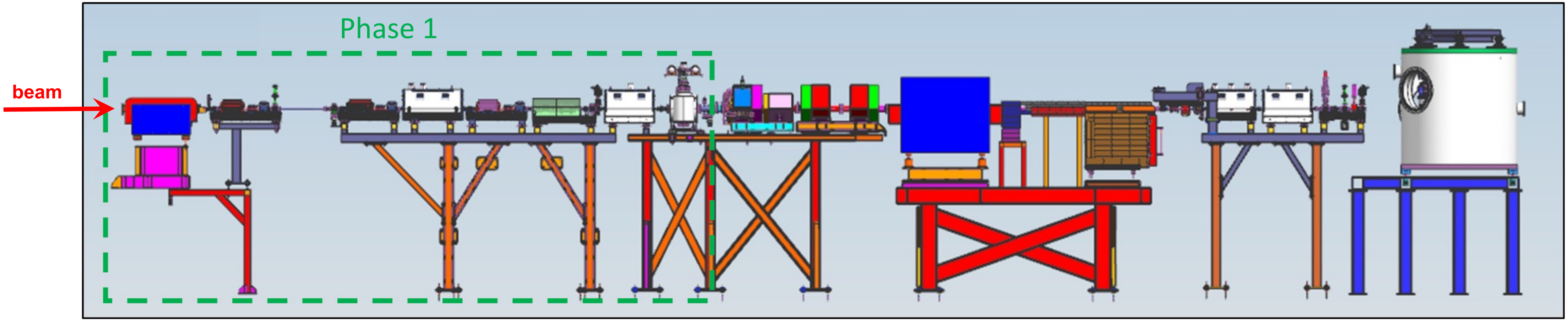
- Incoming beamline mods: diagnostics and beam transport magnets from Hall entrance to target. Target position requires reconfiguration of beam line elements

- Shielding to keep radiation levels within limits:
  - Target region bunker
  - Spectrometer region bunker
  - Detector wall
  - MPS bunker, existing electronics bunker and small GEM electronics bunkers



- Cables, cable routing and electronics power supplies for detector power and readout
- Support of detectors from base to floor mounting including GEMs, Main Detector, and Shower Max
- Access platforms for assembly and maintenance of target, spectrometer and detectors; crane for detector assembly
- Design connection to utilities for power, LCW and detector gas systems

1.06.02 Incoming Beamline Design Modifications

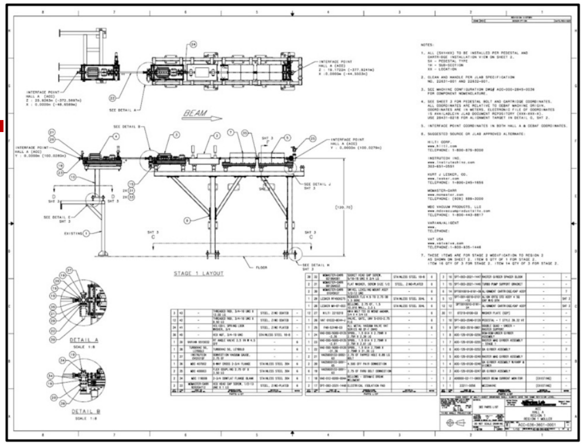


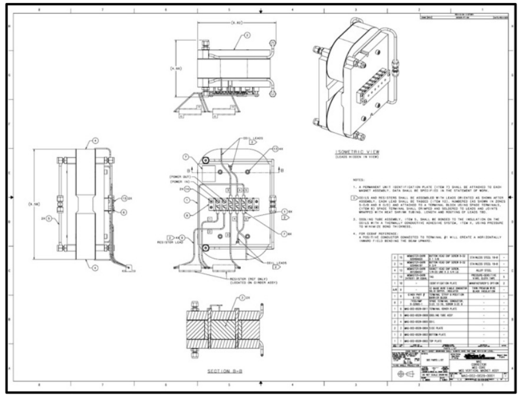
- **Upstream beam line changes are defined.**
  – Reduce beam line length to fit MOLLER target location 4.5 m upstream of the usual target location
  – Improve beam line optics and be able to obtain desired beam profile at MOLLER target position
  – Relocate & electrically isolate current monitors. Relocate cavity BPMs to maximize lever arm within a shorter beam line.

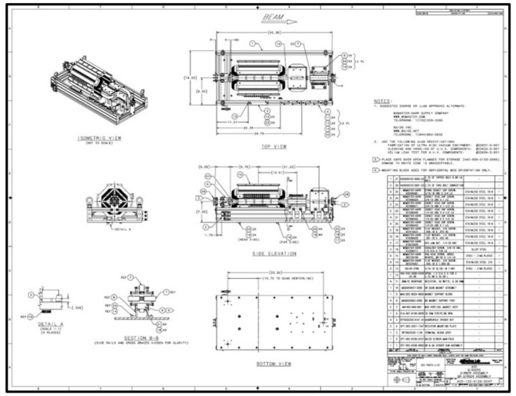
- Prototype assembly Phase 1 was developed to install a portion of the Moller Incoming Beamline ahead of assembly date. This was proposed as a benefit for operations to run the beam with the Moller target in the final location, along with the additional quads and stronger MCG correctors.

1.06.02 Incoming Beamline

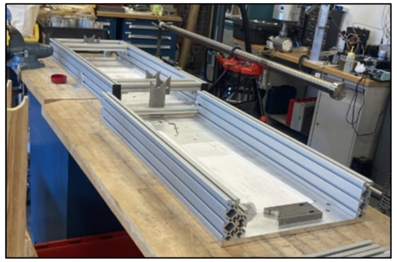
- Incoming Beamline 3D model finalized and all design drawings detailed:
  - ~82 total drawings currently in doc. repository
  - Utilizing existing stand legs for girder platform, without relocation or removal
- Completed design of the new corrector, along with new QQQ diagnostic girder, and new UNSER
- Structural analysis of stands and vacuum analysis of beamline completed
- The Phase I beamline is constructed but cannot be assembled in Hall ahead of the MOLLER assembly date


Region 1 Assembly Drawing

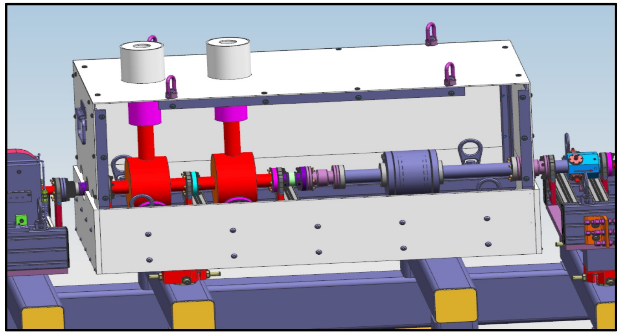

MCG Assembly Drawing

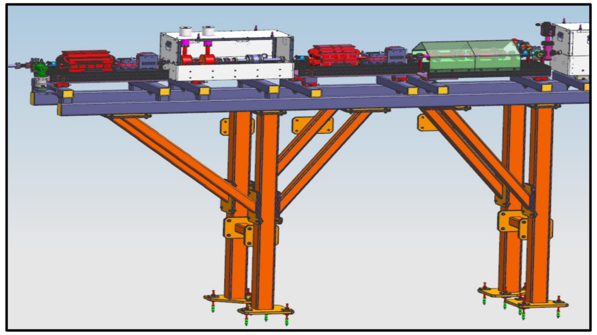

Girder Assembly Drawing


Vacuum spools leak tested


Girder sub-assemblies


Stands in Storage

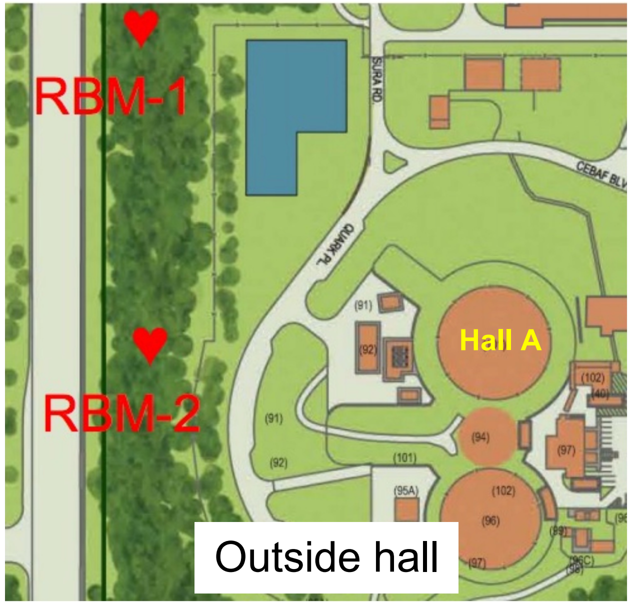

New Prelim. UNSER Design

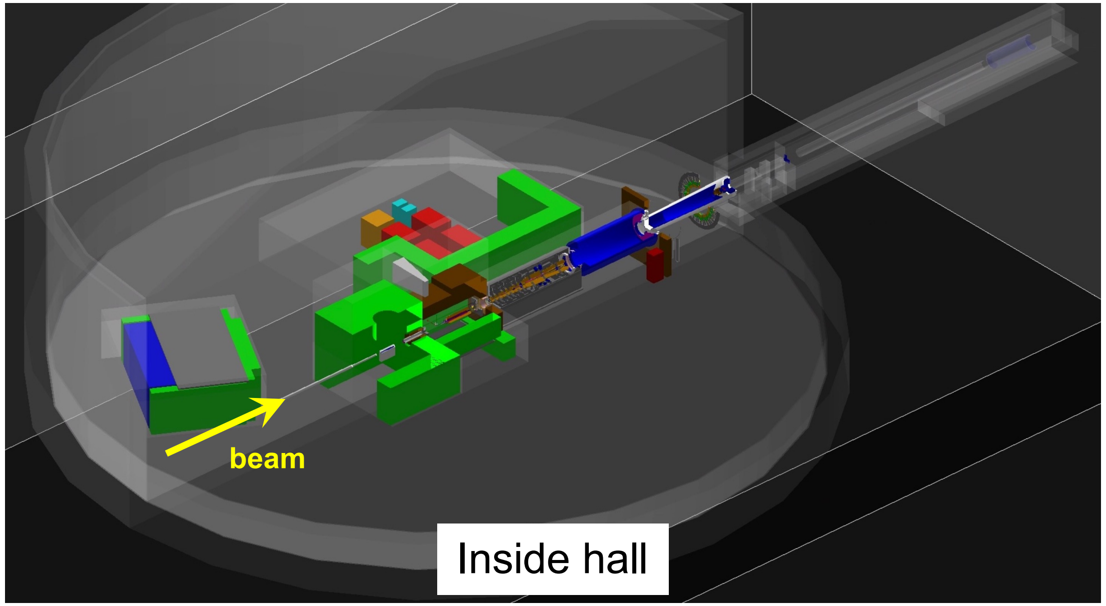

Utilizing Existing Stand Legs

1.06.03 Shielding

- Considerations: personnel and equipment protection, boundary dose estimation, Hall beamline component activation--for efficient access/maintenance
- Additional considerations: minimizing ferrous material in shielding components
- Simulations of longterm electronics damage performed in different areas inside Hall
- These studies have informed decisions on shielding placement/location, type of shielding material and thickness

Radiation Levels during MOLLER





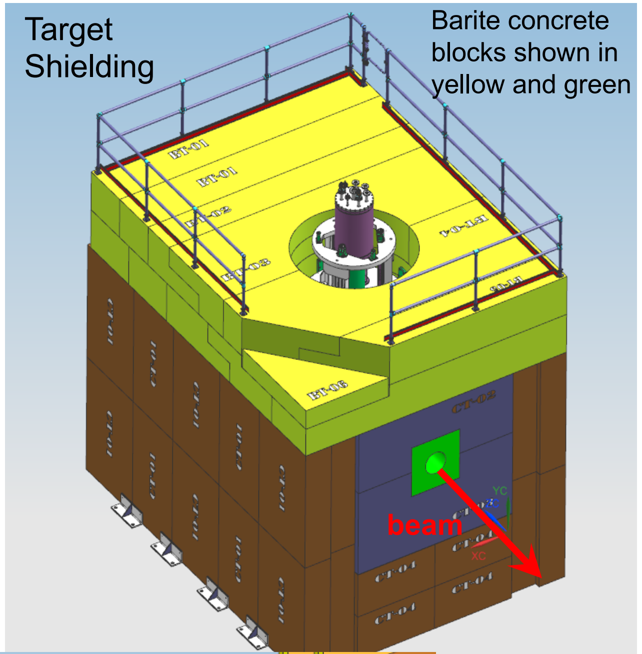
- Estimations done with G4 and FLUKA
- Simulation framework benchmarked to PREX-2 and CREX data

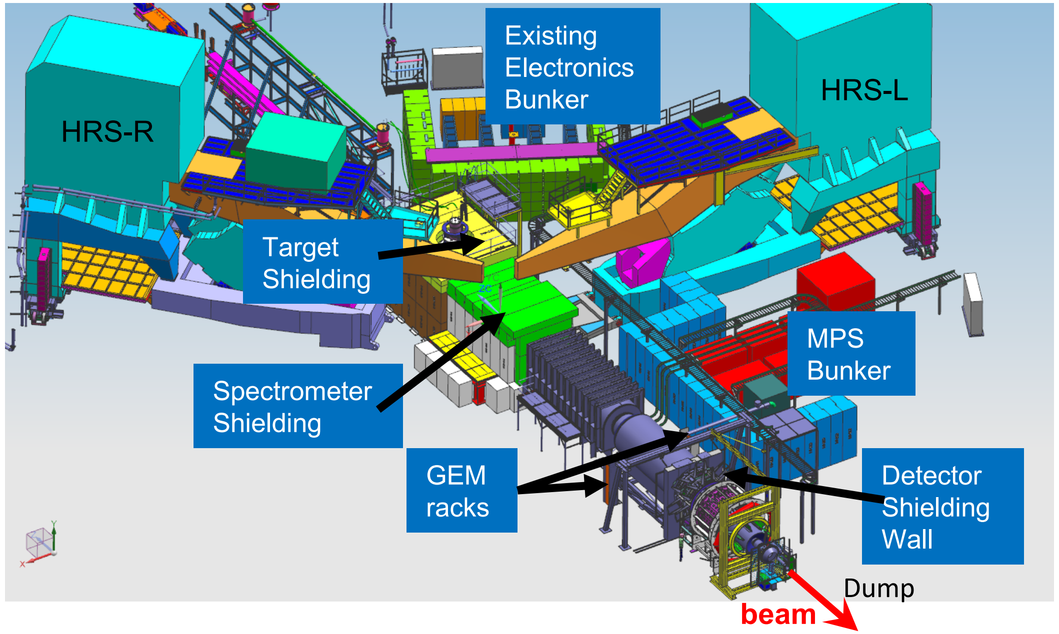
- Estimations done with G4
- Shielding is located around components that absorb significant power: target, collimators
- Sensitive components, detectors/electronics also shielded

- See later talk by Ciprian Gal for more details
  --SC 2: Topic 5: Shielding Physics Design

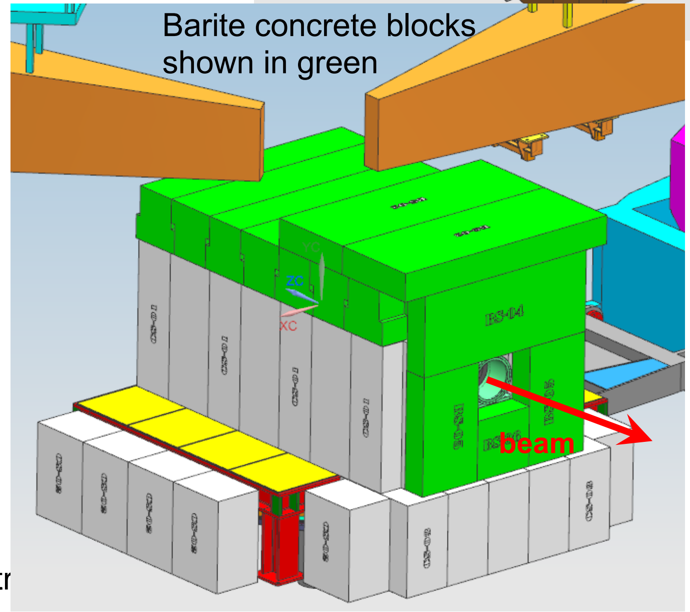
1.06.03 Shielding

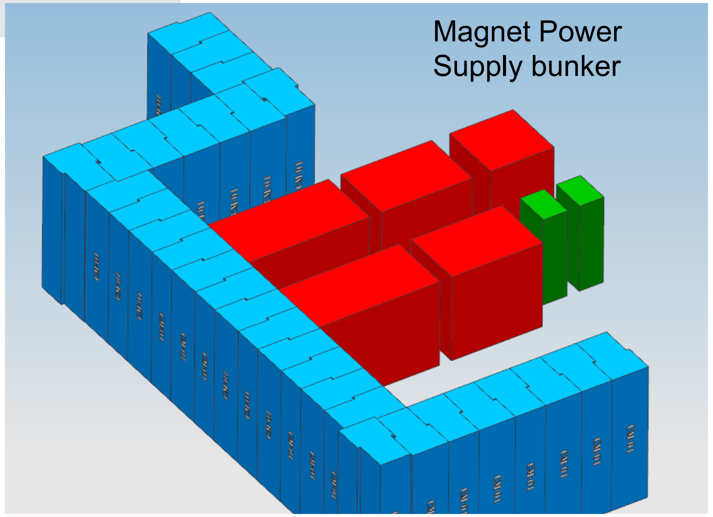
- Passed all design reviews and starting procurement phase
- Target, spectrometer, MPS, and detector wall shielding designs complete
- GEM hut design complete
- Detector wall support structure redesign nearly complete





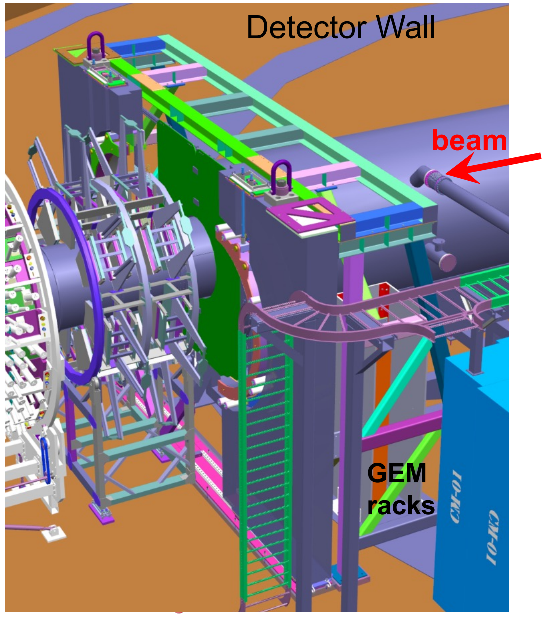
- See later talk by Robin Wines for more details
  --SC 2: Topic 6: Shielding Engineering





MPS Region Block Data

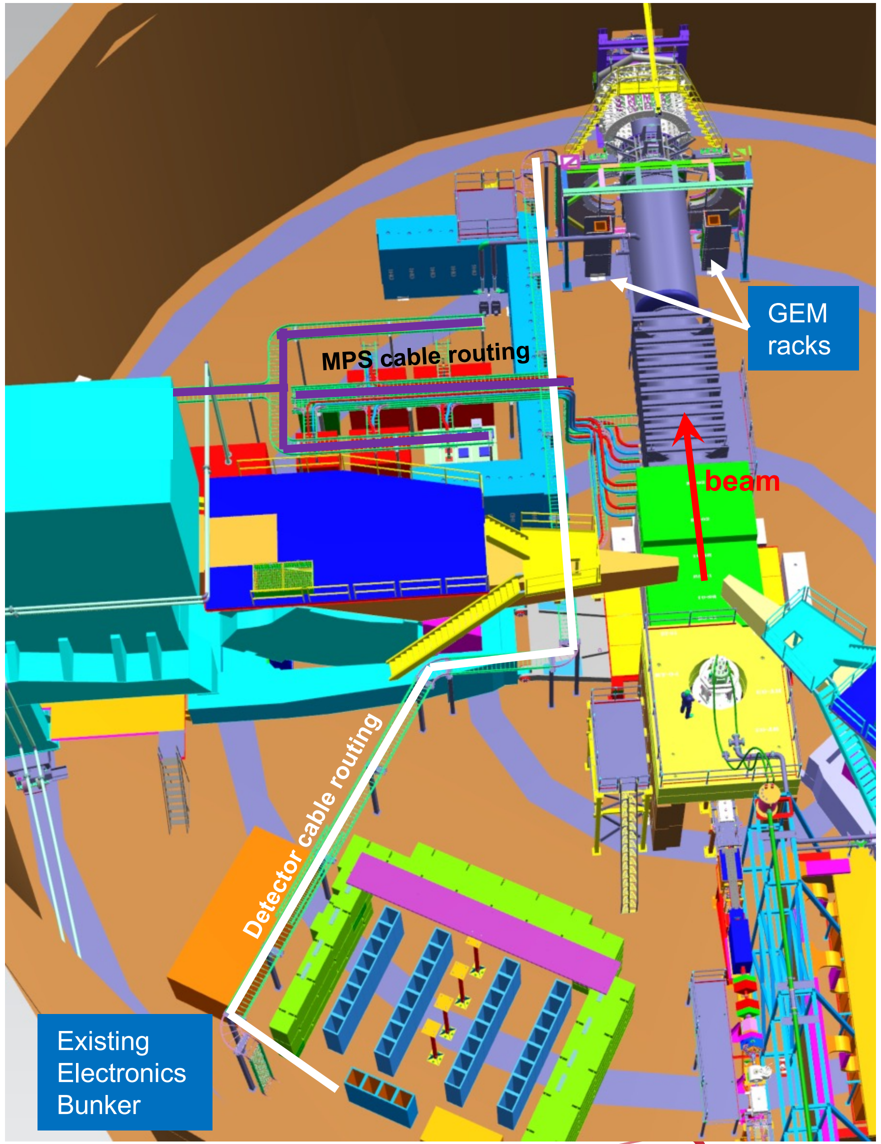
Name	Material	Quantity	Size (inch)		
CM-01	Std Concrete	30	135	60	36



1.06.04 Cables

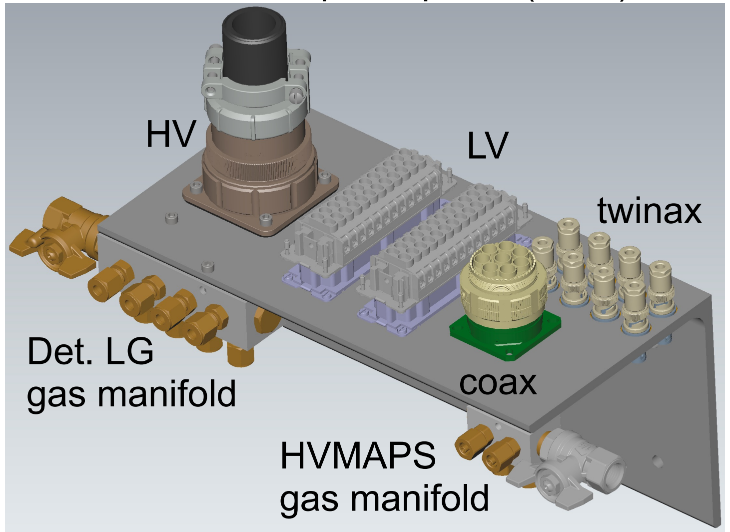
- Cables/connectors defined by collaboration
- Cable and power supply line routing finalized
- MPS cables route between bunker and US and DS torus
- Long detector cable runs are DOE/MIE scope
  - 250 ft planned routing
  - Layout of cable tray routing complete
  - Design of cable strain relief supports in process
- Bundled cable runs (8 cables each) will be used for long cables:
  - High Voltage (HV) will use RG-59
  - Counting mode signals use coax RG-58
  - Integrating mode signals use twinax RG-108
  - LV power to preamps use twisted pair or RG-58/174
- Detector power supplies (both HV and LV) are defined
- A detailed accounting of all detector cables/connectors required is given in MOLLER docDB #1050

Cable routing for detectors and magnet power

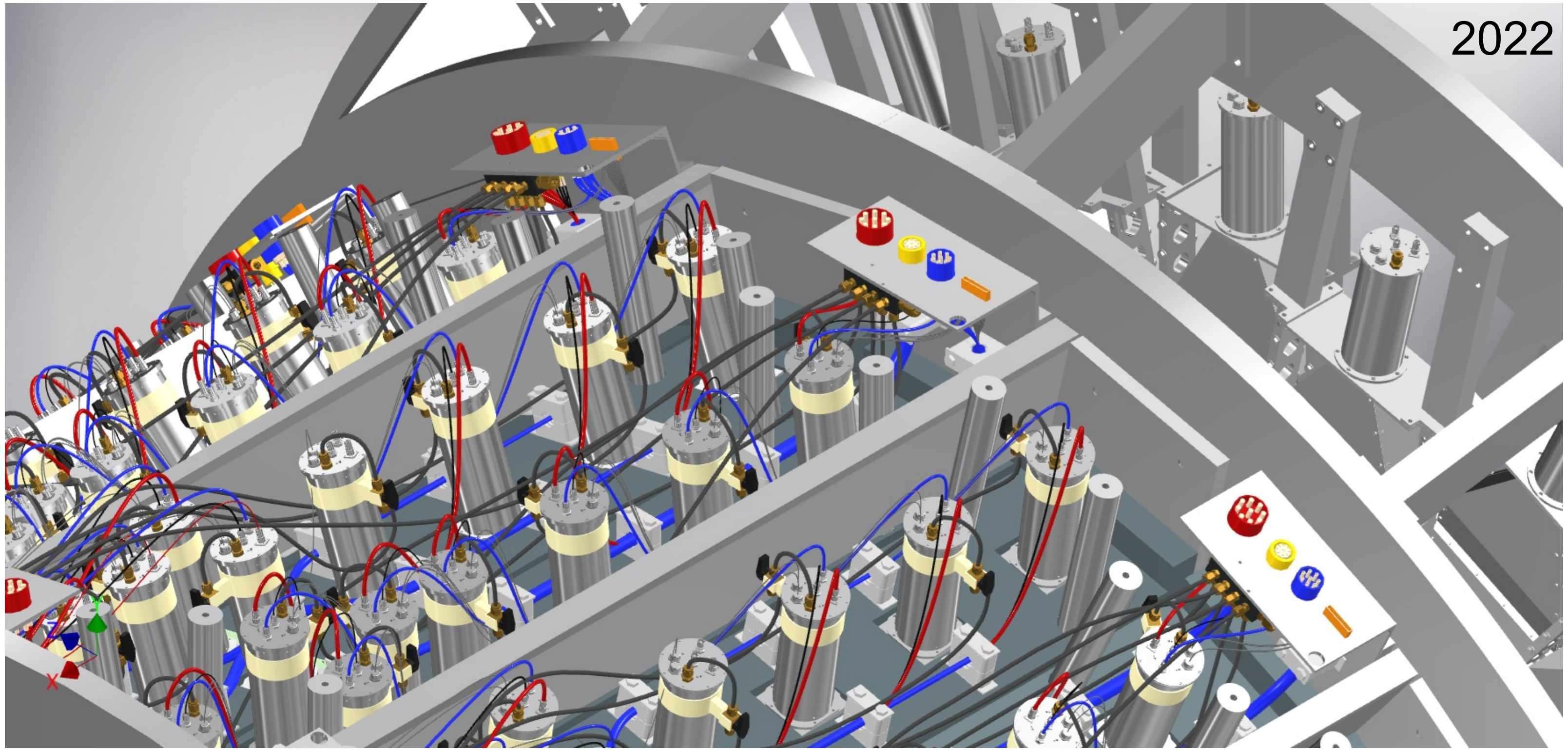


1.06.04 Cables

Main detector patch panel (2023)



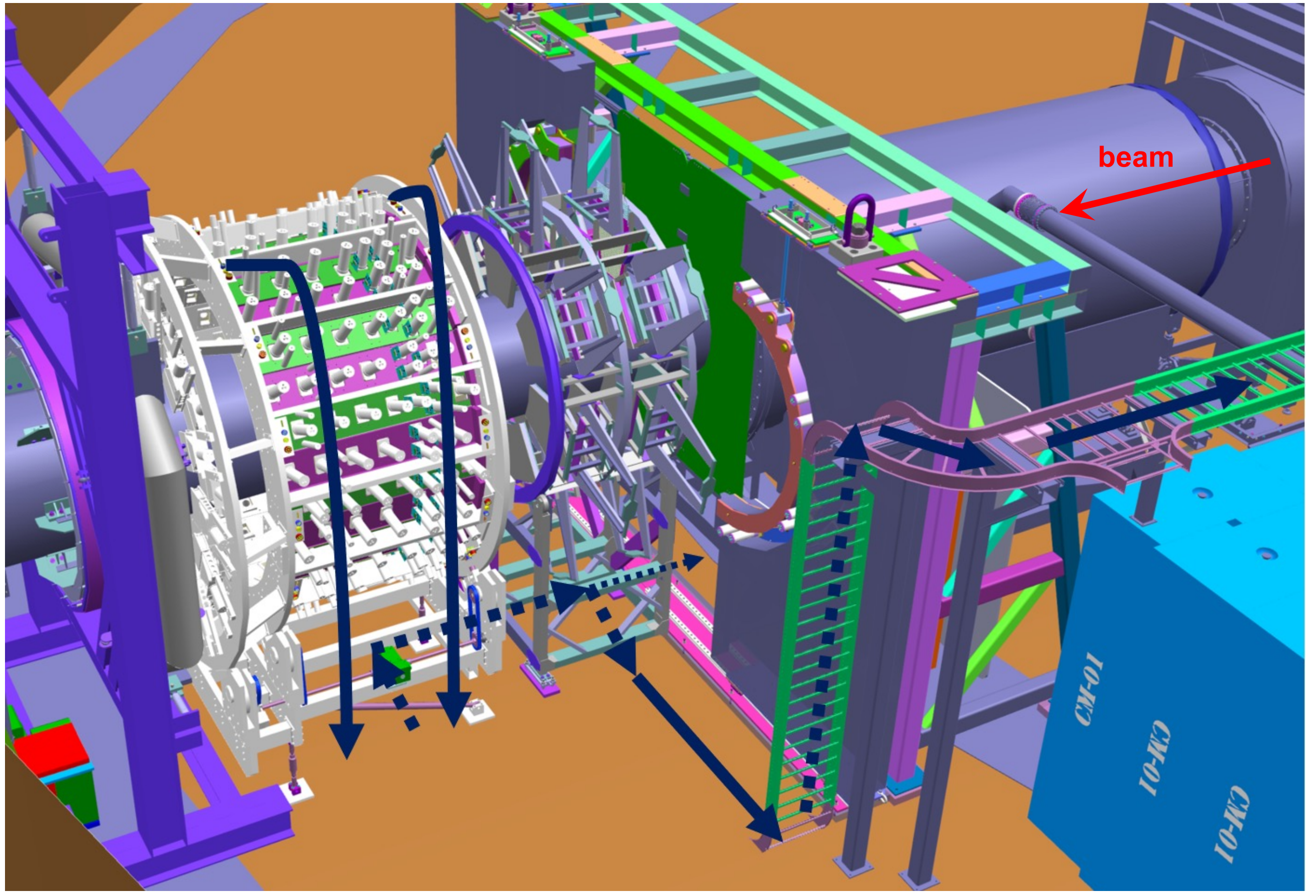
- Connectors:
  - 1 HD GES HV, 8 conductor
  - 2 HD Weidmüller LV, 24 cond.
  - 8 twinax bulkhead feed-throughs
  - 1 HD Amphenol coax, 8 conductor



Internal detector cabling harness and gas distribution concept

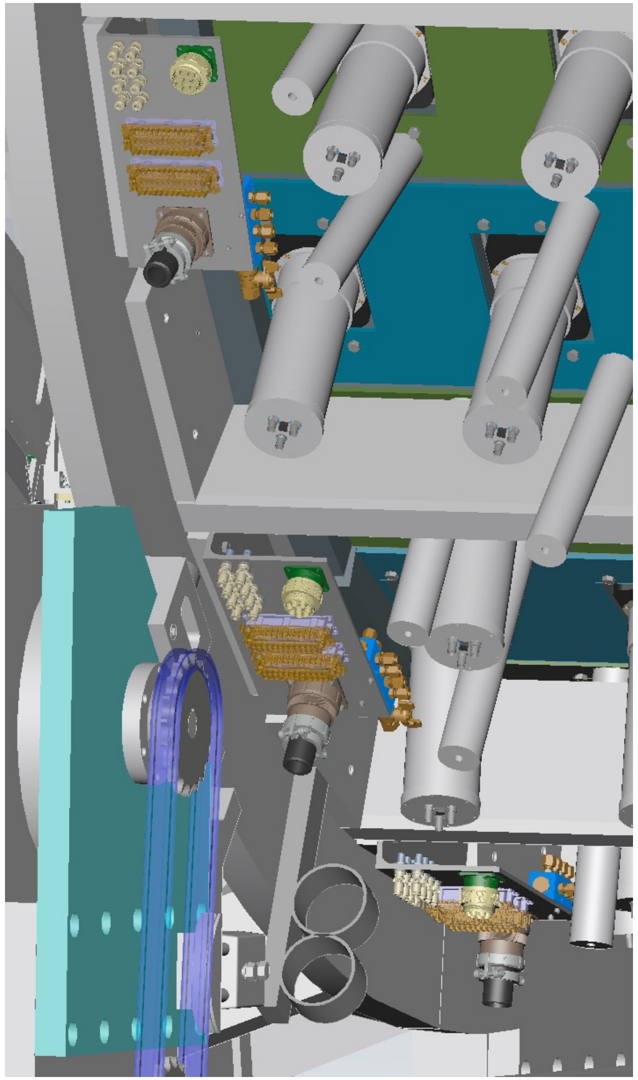
- Insertion loss/minimum mating cycle specifications from manufacturer are sufficient
- Gas needs are defined for detectors and HVMAPS
- Main detector patch panel prototyping underway

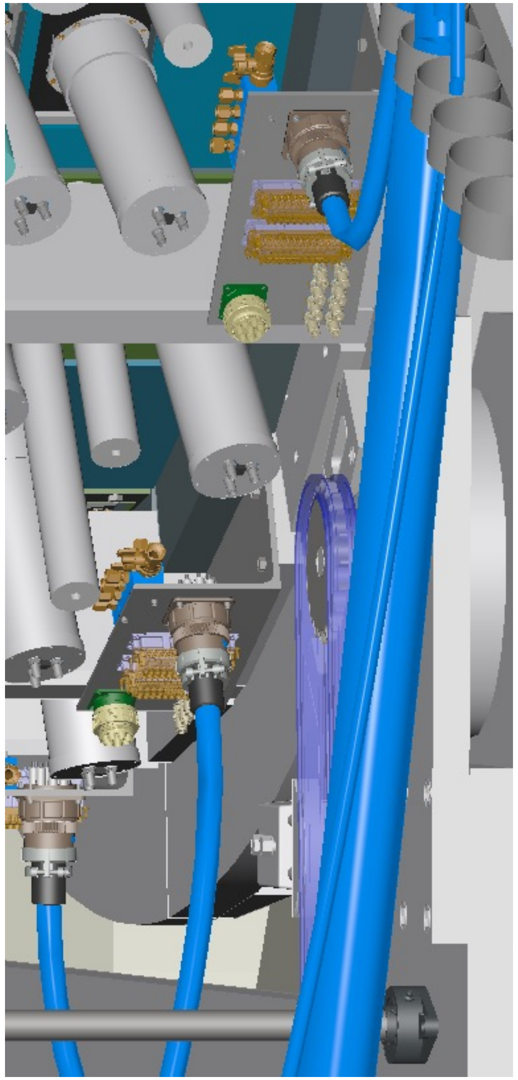
1.06.04 Cables



- Cables route from detector or patch panel down to floor and then into cable tray to existing electronics bunker.
- GEM signals and HVMAPS power route to GEM racks

Cable supports/strain relief for main detector patch panels



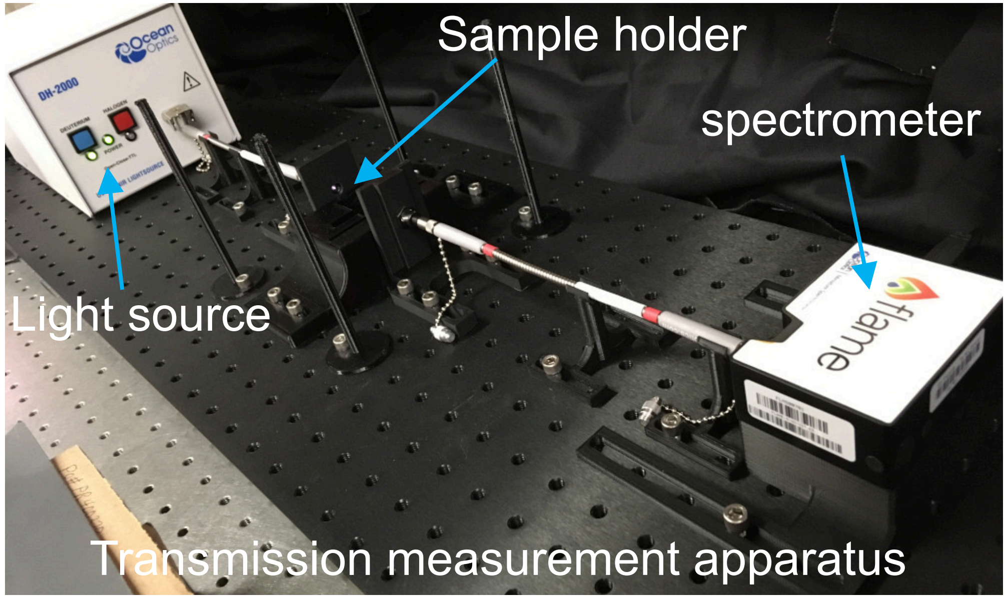


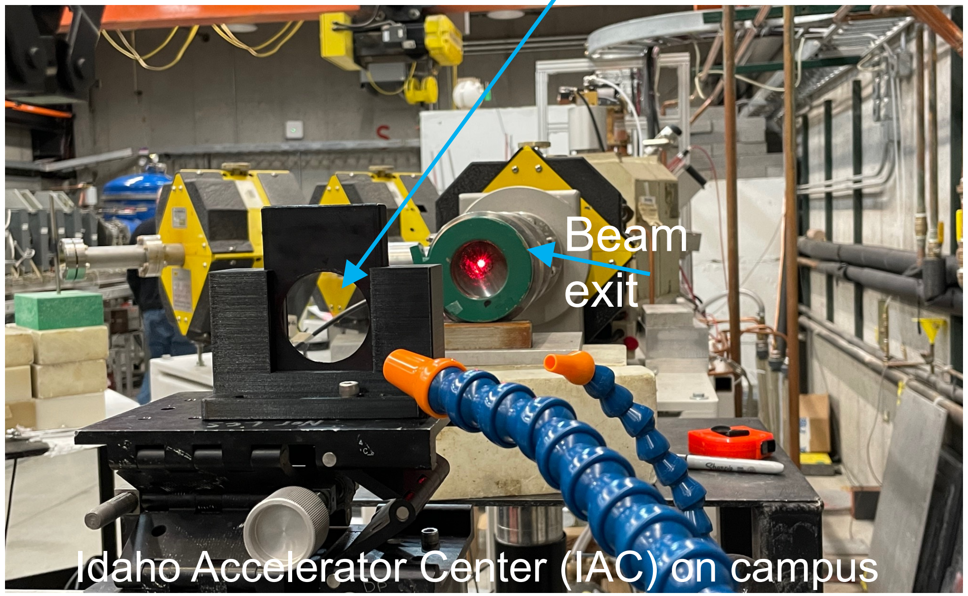
Design and drawings under development

Detector Radiation Harness Qualification Studies at ISU

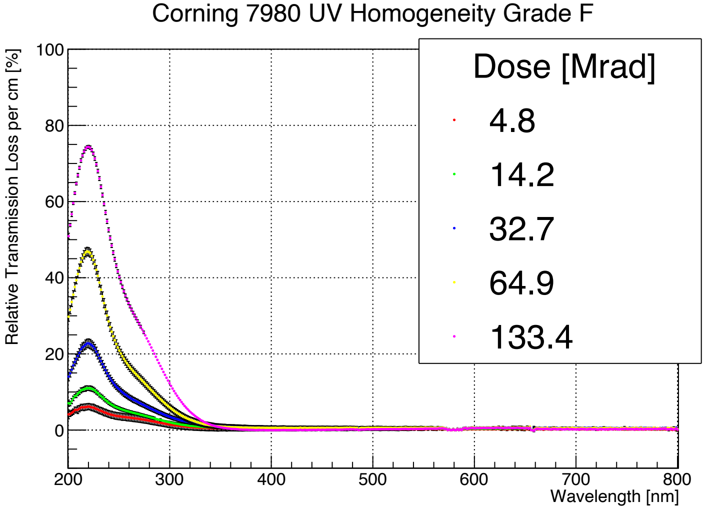
- Goal: quantify light transmission losses in detector radiators due to damage from anticipated radiation dose (for lifetime of MOLLER) – 45 MRad peak and 120 MRad peak per 5x5 mm^2 for ring 5 and ring 2, respectively
- Five candidate fused silica (quartz) samples chosen for testing: from Corning, Ohara,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

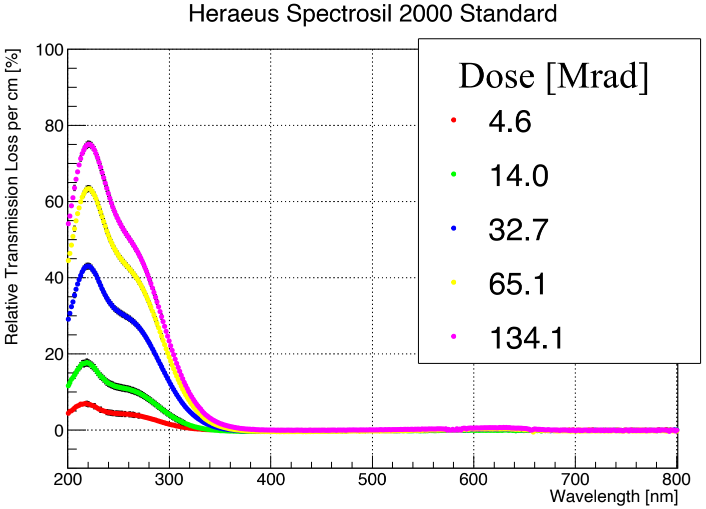
Samples: 5 cm diameter or square, 1 cm thick; polished faces

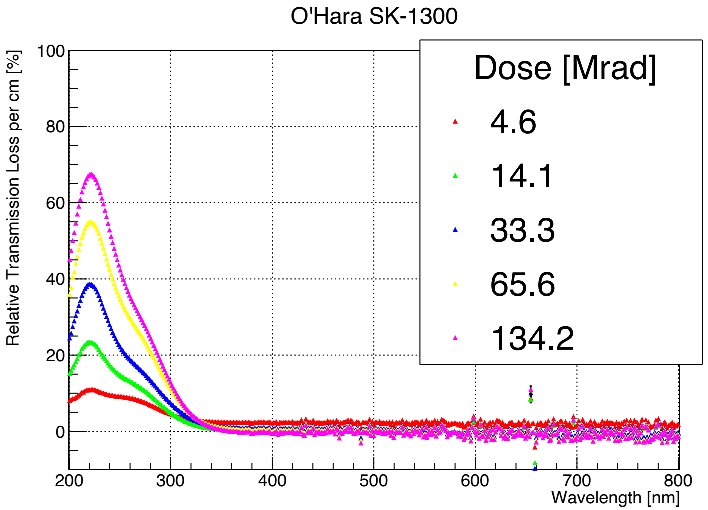


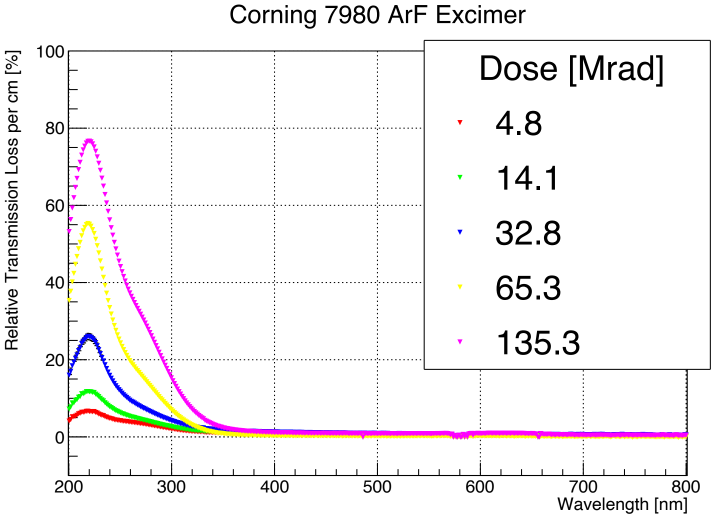


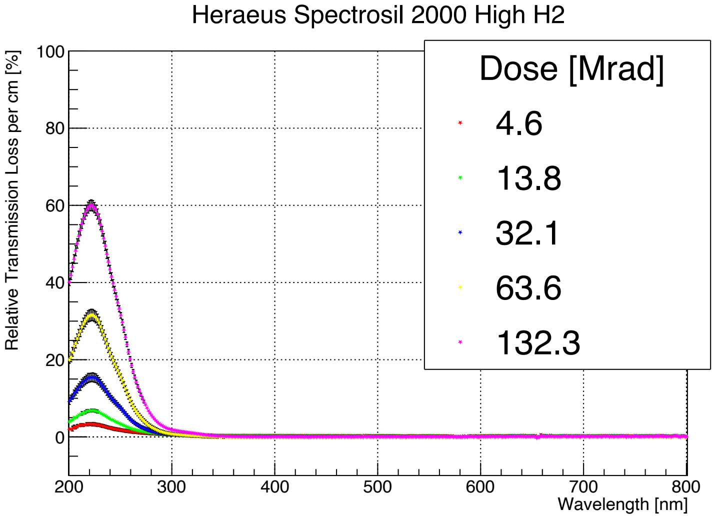
Quartz Radiation Hardness Results: Light Loss











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

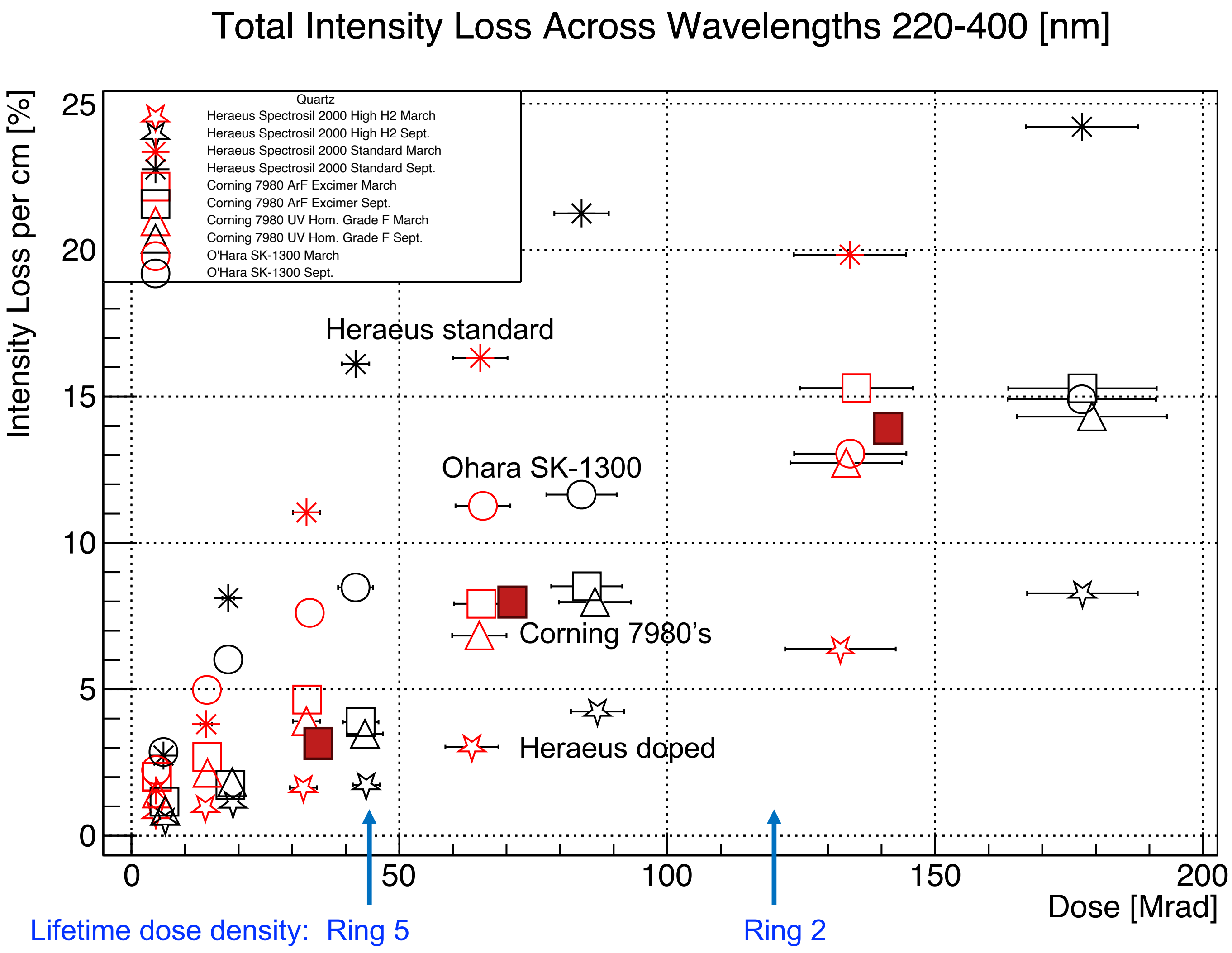
--Main absorption center at 5.6 eV is the E' – unavoidable point-like defects that cause dangling Si atoms which absorb light

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

--the high H_2 doped Heraeus shows very little of this damage center at our doses

Quartz Radiation Hardness Summary

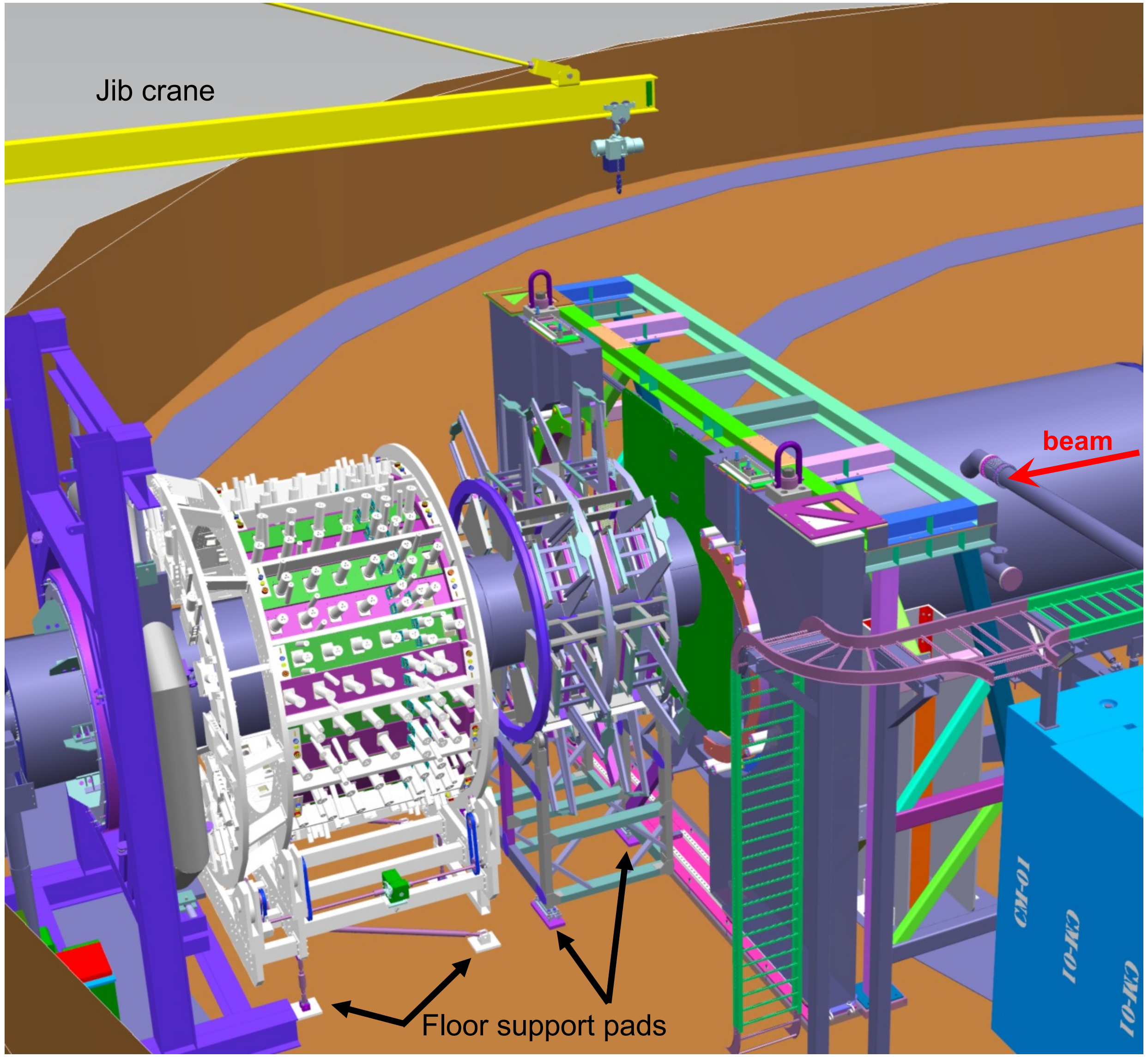
- Quartz radiation damage study is completed; the data needed to inform our optical simulations is in hand
- Dose estimates for radiation tests are at 10% precision level
- Heraeus high H_2 doped Spectrosil 2000 is best performing (clearly) – ~no shoulder structure in losses.
- Heraeus standard sample is worst performing – it has greatest light loss above 15 - 20 MRad dose
- Recently QA tested Corning 7980 samples from new vendor (■)



Jefferson Lab

1.06.05 Detector Frames and Supports

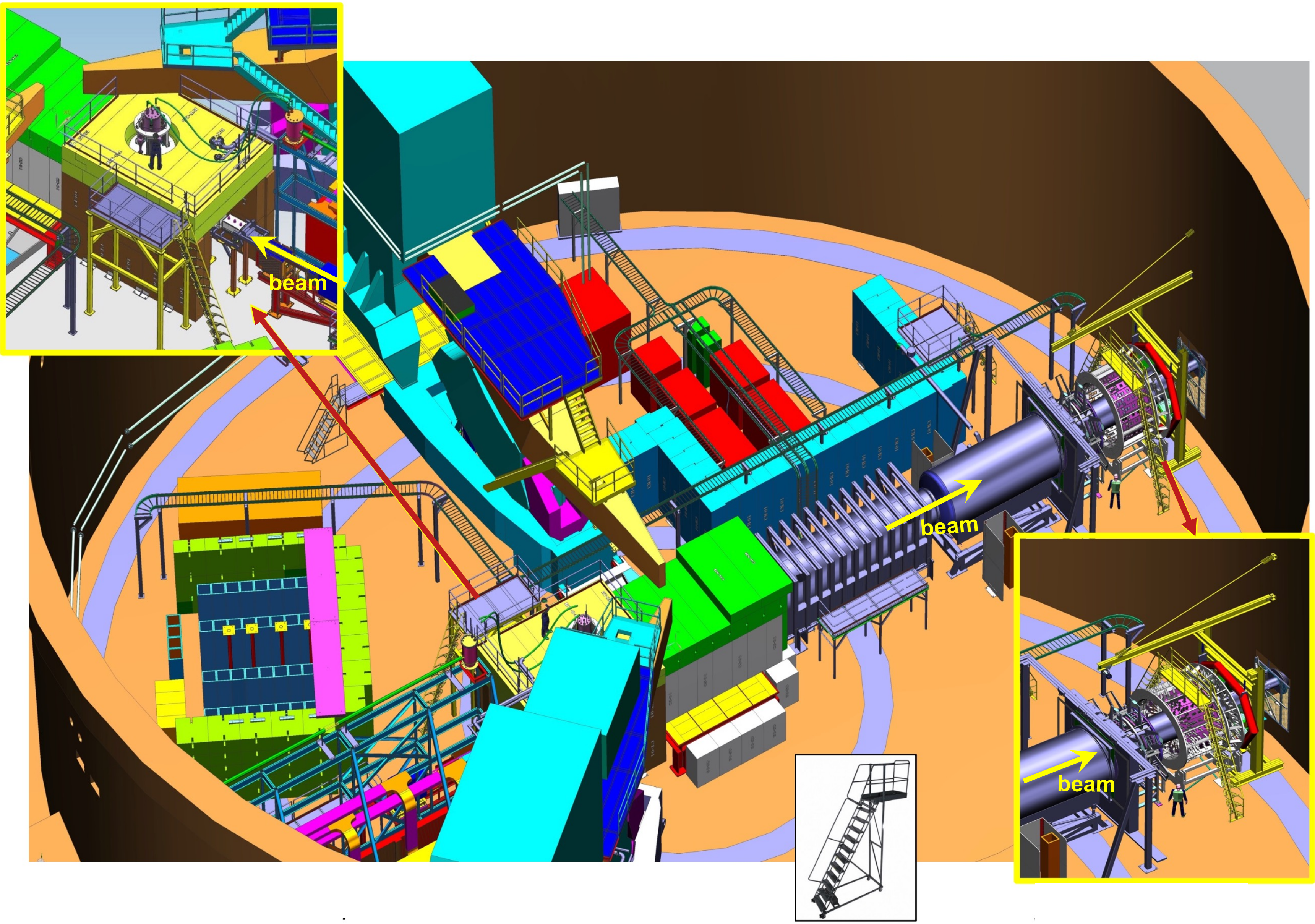
- Main Detector and Shower Max Detector support concept developed by collaboration and contract engineer Larry Bartoszek
  (See later talk by Larry for more details
  --SC 2: Topic 4: Detector Mechanics)
- Detectors mounted on rotating ring with cradle support
- Structure utilizes 6 strut support to pads mounted to Hall floor
- Similar concept developed by collaboration for GEM rotator support (uses alignment cartridge pads)
  (See later talk by David Armstrong for more details
  --SC 2: Topic 1: Tracking Detectors)
- LAMs supported in detector shield wall
- Pion detector supported in Pb Donut
- SAMs built into beampipe penetrations
- Floor elevation survey conducted to define the floor mounting specification for detectors
- Vendor cost estimates have been updated



Jefferson Lab

1.06.06 Access Platforms

- Hall overhead crane (which is now repaired) does not reach to the Hall wall
- Plan to mount Jib crane in detector region for detector assembly
- Jib crane defined as commercially available wall mount 2-ton crane, 20’ span
- Target and detectors require access platforms. Plan to utilize OSHA standard commercially available rollup stairs/platforms
- Will use rollup stairs for access around spectrometer magnets
- Access platforms defined. Main detector access platform design in process.

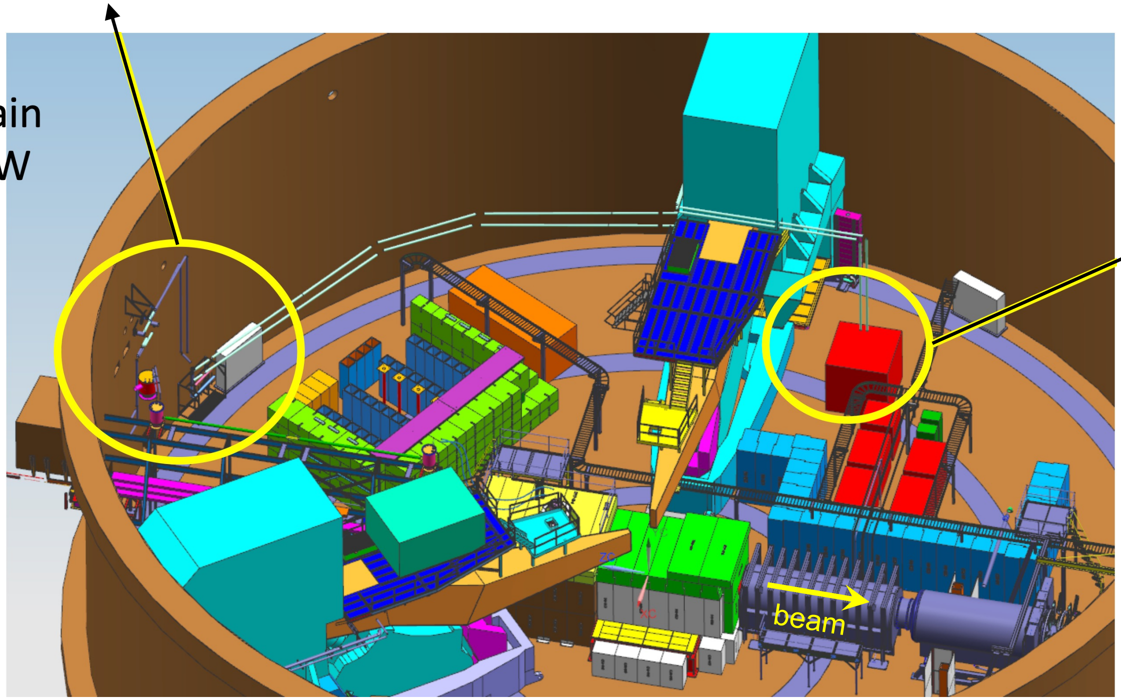


1.06.06 Hall Modifications (Utilities)

- LCW design modifications and layout required for MOLLER are in process
- Power routing to power supplies defined and cost estimate updated
- Detector and GEM gas systems to utilize existing Hall A gas systems

LCW inlet to Hall

Main LCW



- Originally planned for a closed loop LCW system for spectrometer magnets due to potential tritium and beryllium activation, but this is no longer the case

--Analysis by Lorenza Zana (JLab RadCon group)

--Examined the US Torus which sees the most flux; simulated magnet coils including water channels

--Tritium production dominated by neutrons on water and found to be 1000x lower than safety limit

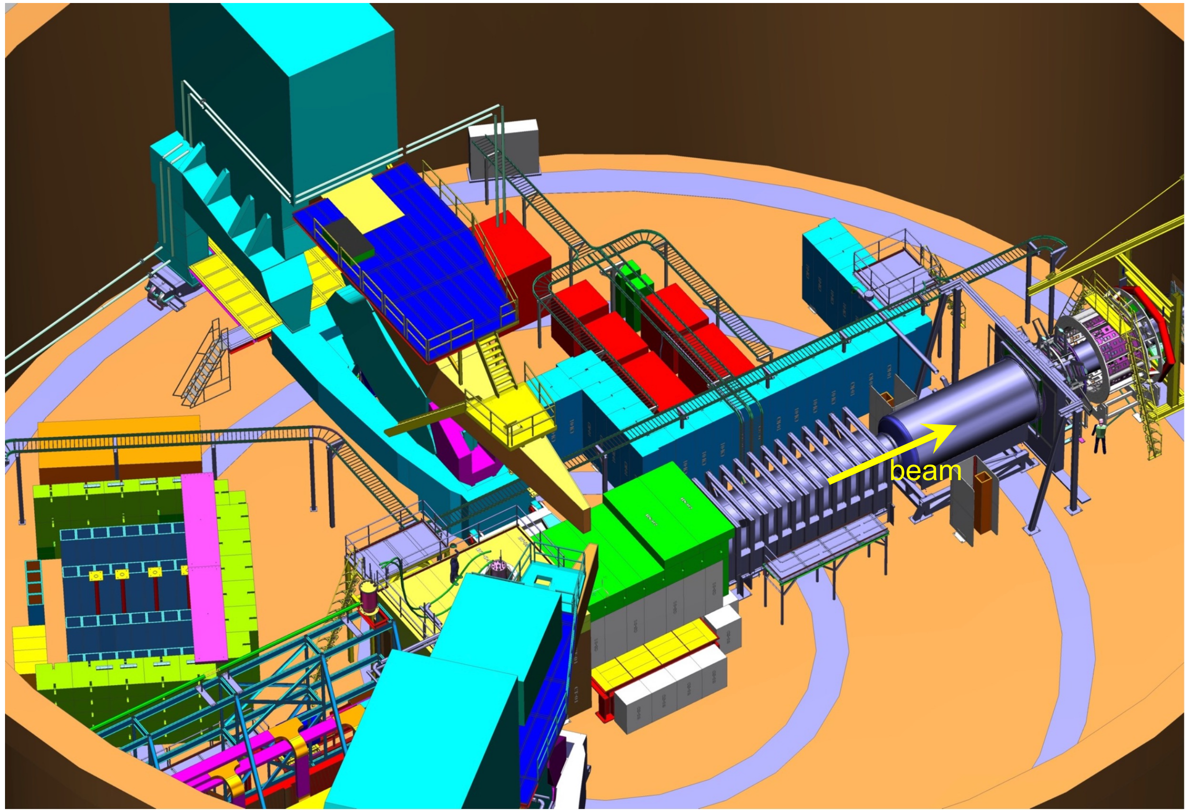
	MDA limit (μCi/ml)	EPA limit (μCi/ml)	Moller LCW (μCi/ml)	Total Moller value (μCi)
^{3}H	1.0E-06	2.0E-05	2.7E-08	0.51
^{7}Be	6.0E-07		5.37E-08	1.02
^{22}Na	4.0E-08		< 5.0E-10	< 0.01

--Conclusion is that we can use the standard Hall A LCW system

Infrastructure Summary

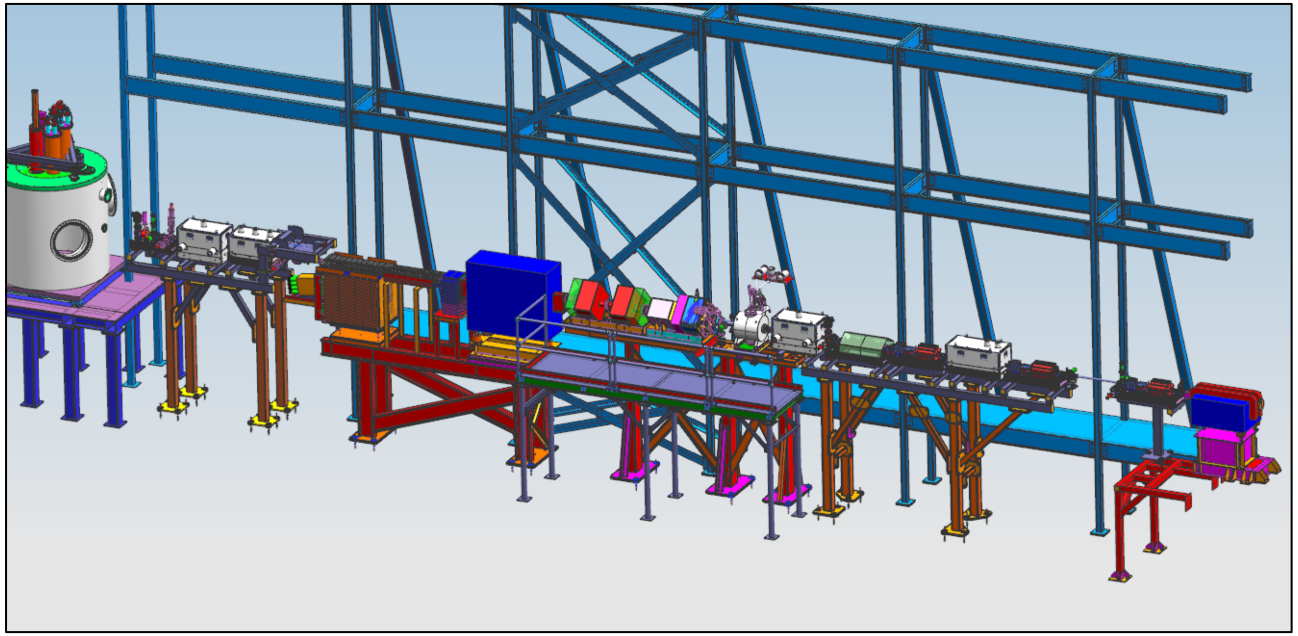
Dustin McNulty
mcnulty@jlab.org

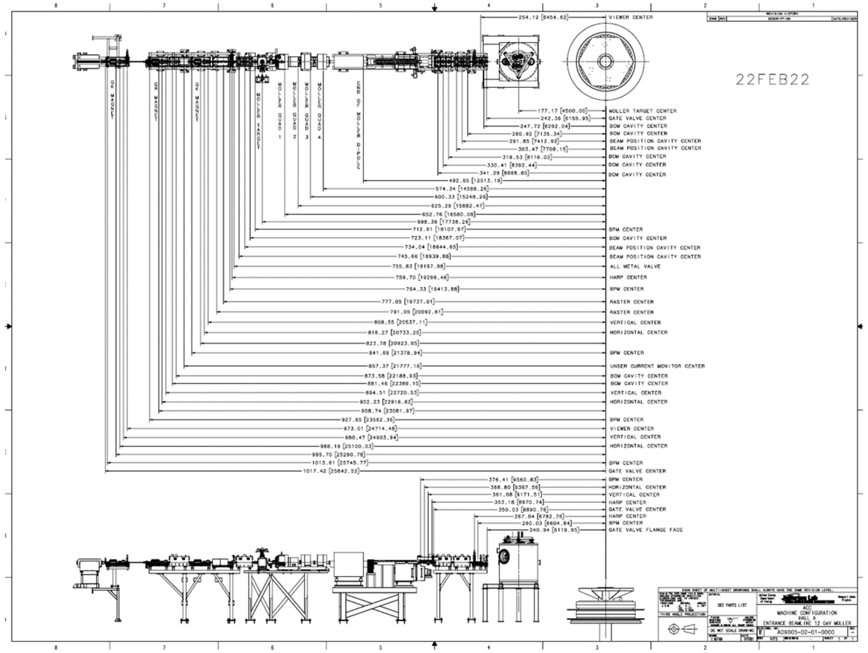
- Beamline elements defined and procurements started
- Cables and cable routing defined. Main detector patch panel prototyping started
- Cable tray layout and supports completed; connector strain relief design in process
- Detector support designs nearly completed. Mounting to Hall A floor defined.
- Access platforms defined. Main detector access platform design in process.
- Hall Modifications are defined
- Utilities defined. LCW modification layouts in process. Detector and GEM gas systems defined and will use existing systems.



Appendix Slides

1.06.02 Incoming Beamline Design Modifications



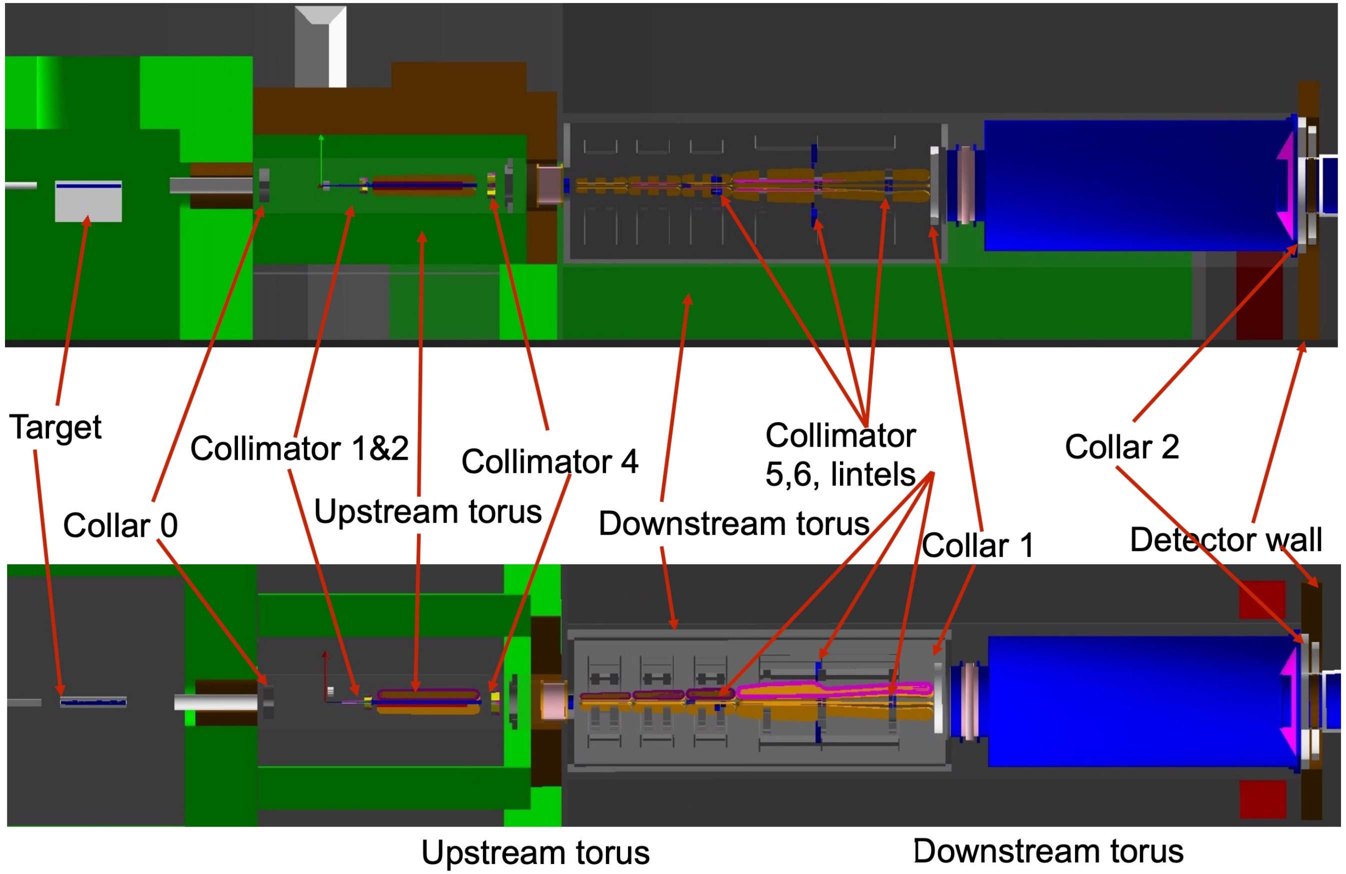


- ME group consisted of Mike Bevins, Kris Cleveland, Chase Dubbe, Chuck Hutton, and Cameron Sutton.
- Worked closely with Jay Benesch who provided the beamline design and feedback, while ME group created the mechanical design
- Scope included overall beamline design, mechanical design of new corrector dipole, MCG, designed by Jay, new QQQ girder, nAmp BPM and Unser boxes. Along with associated support structures and bracketry.
- A combination of new support structures and modifications to existing stands were designed and optimized to support the new beamline design
- ME group also worked with other Hall A groups to ensure no interferences with other existing or future geometry

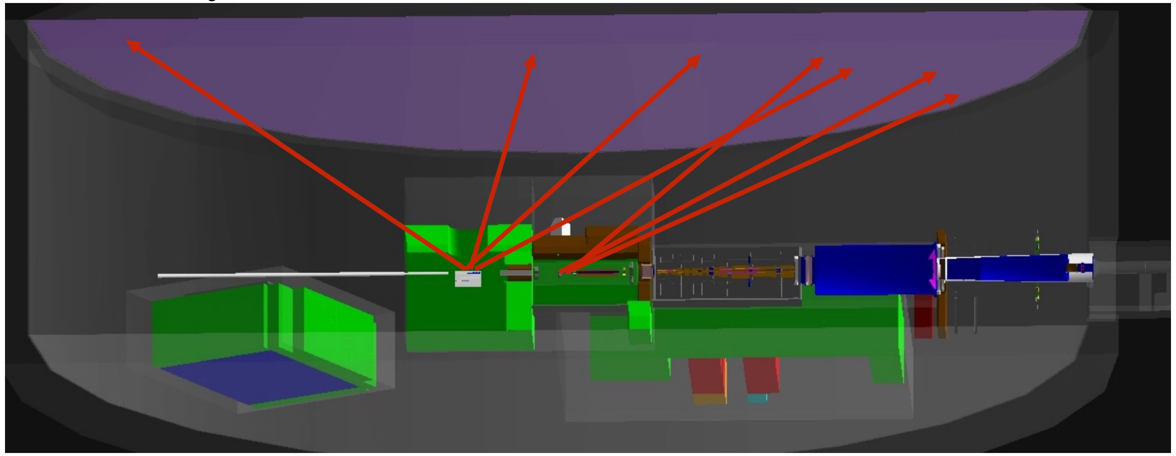
1.06.03 Shielding

- Shielding is located around components that absorb significant power:
  - Target
  - Collimators (Spectrometer)
- Sensitive components, detectors/electronics also shielded
  - Existing and MPS Bunkers
  - Detector wall and Pb trays

Component	Power @65uA, 1.25m Tgt
Target	3100 W
Collar 0	275 W
Collimator 1	3700 W
Collimator 2	950 W
Collimator 4	60 W
Coll 5,6, Lintel	<55 W



Boundary dose estimation



Sim. framework benchmarked to PREX-2 and CREX data

- See later talk by Ciprian Gal for more details --SC 2: Topic 5: Shielding Physics Design

1.06.04 Cables (Channel Accounting)

Idaho State University

- Both integrate- and event-mode:

(needs HV, twinax, coax, and base LV)

--Main Detectors: 224
(8 per segment, 28 segments)

--Auxiliary Detectors: 112
LAMs (7x2), US scanner (2), beam halo monitors (2x14), Shower-max (28), Pion detector (28), DS scanners (4), and SAMs (8)

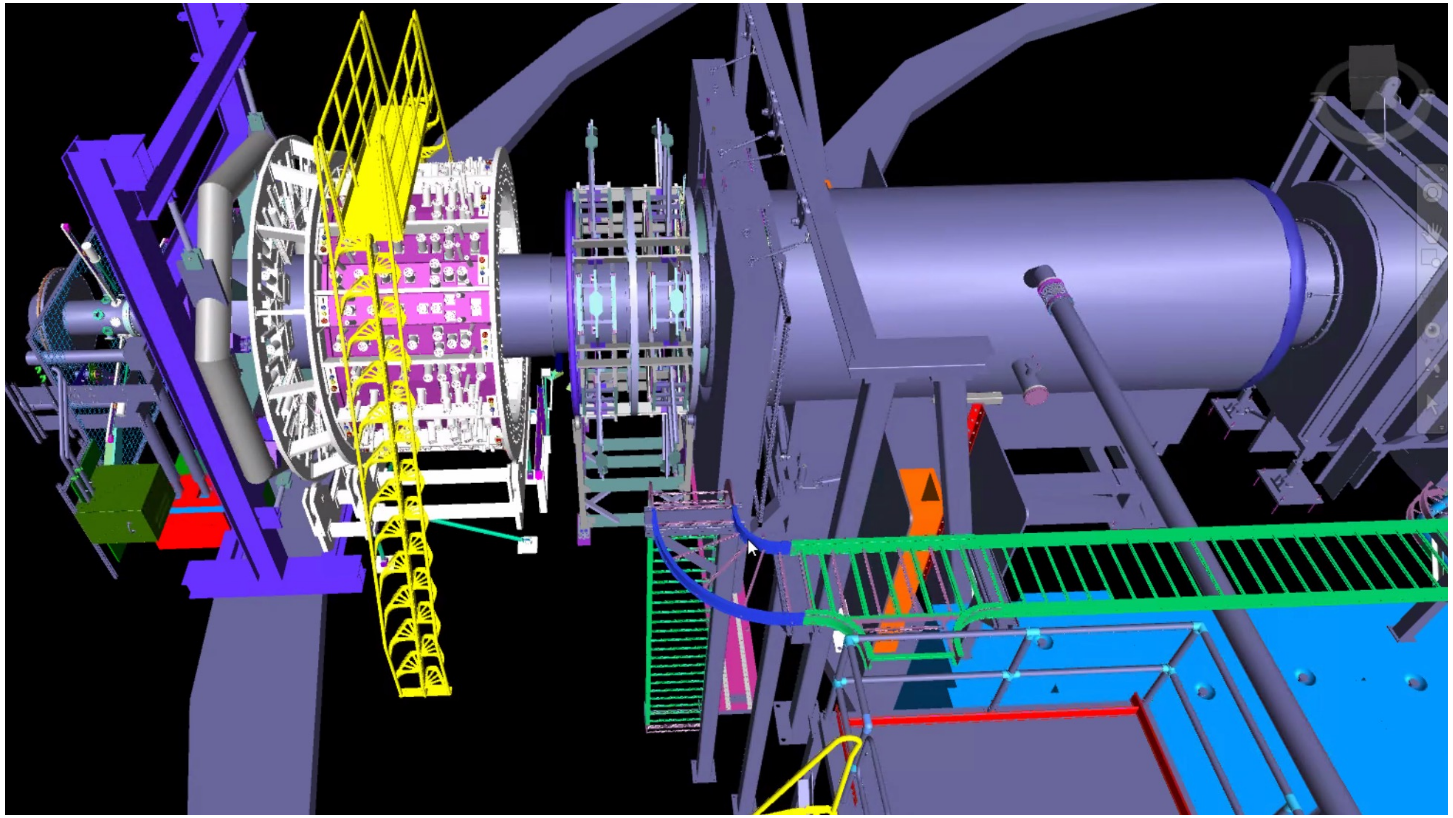
- HVMaps Detectors: 84 (3 arrays per Main detector Segment (power, fiber RO))

- Event-mode only:

(needs HV, coax, fiber RO, and power)

--GEM Detectors: 28 (7 GEMs per wheel, all 4 wheels (HV and fiber RO))

--Trigger Scintillators: 14 (7 paddles per wheel for 2 wheels (HV and coax signal))



❖ All these cables except HVMaps' power route from detector to the SBS bunker

❖ GEM fiber interconnects between GEM electronics racks and SBS bunker electronics

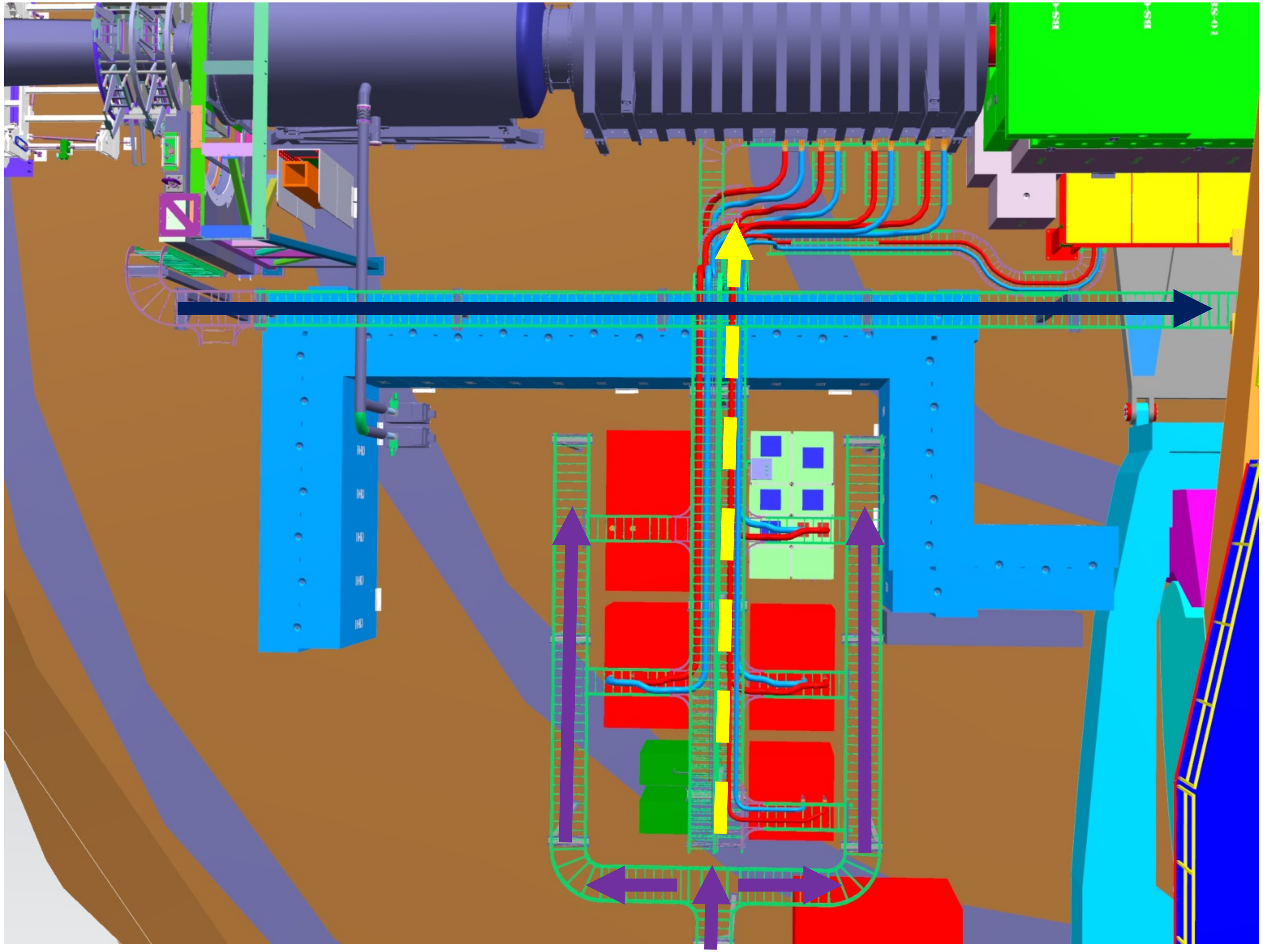
Detailed presentation in docDB # 1050

1.06.04 Cables

- All signal and power cables (both counting and integrating) have been defined in concert with the collaboration and will be purchased by this CA
  - The HVMAPS detector system is the exception (CFI scope)
- The main detector signal cables will have a patch panel next to the detector where we can transition to ~250ft long cables to the SBS bunker
- Additionally, ~1/3 of the power supplies (112 auxiliary detector channels) have been identified and we will purchase similar systems as for the main detectors
- We are going to purchase a set of connectors to assemble a prototype patch panel together with long cables
  - Will increase confidence in design and allow for detector segment readout tests

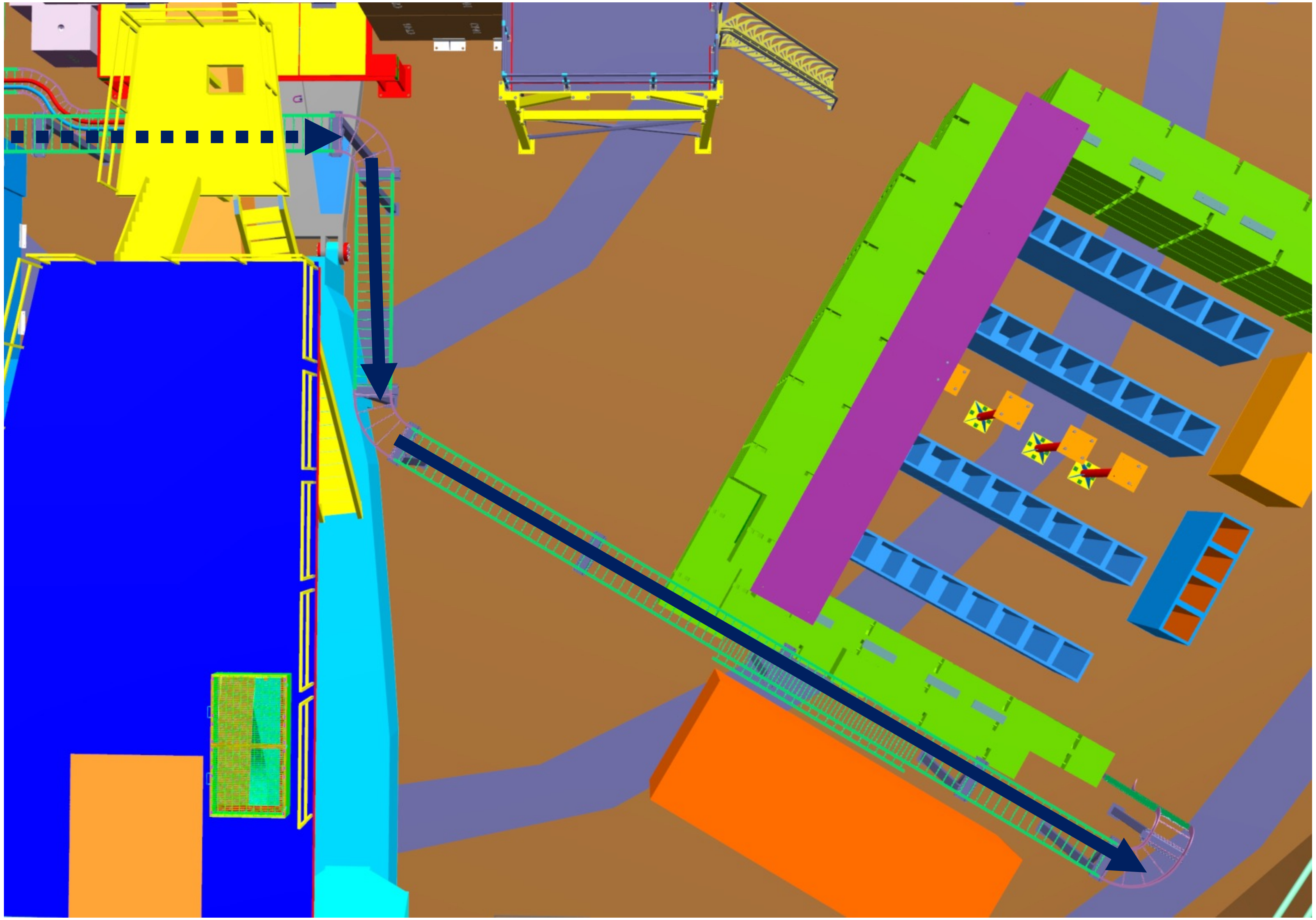
	All Detectors		70% packing fraction: 30 bundles				
			group	group	group		
	Bundle		area (sq.in)	diam (in)	width (in)		
	No.	purpose	70%	70%	70%		
	1	PMT HV	19.90	5.03	24.19		
	2	PMT twinax	19.90	5.03	24.19		
	3	PMT Coax	12.74	4.03	19.35		
Main detectors	4	pmt base power	2.25	1.69	8.13		
	5	HVmaps fiber RO	1.87	1.54	7.41		
	6	Hvmaps power	19.10	4.93	23.70		
	7	Hvmaps pow sigs	3.18	2.01	9.67	in feet	
	Groups 1 - 5 sum		56.65	17.33	83.26	6.94	
	Groups 6 - 7 sum		22.29	6.95	33.37	2.78	Not included in cable tray sum
	8	PMT HV	9.95	3.56	12.09		
Aux detectors	9	PMT twinax	9.95	3.56	12.09		
	10	PMT Coax	6.37	2.85	9.67		
	11	pmt base power	1.12	1.20	4.06	in feet	
	Groups 8 - 11 sum		27.39	11.16	37.92	3.16	
GEM detectors	12	PMT HV	3.98	2.25	4.84		
	13	PMT Coax	0.85	1.04	1.29		
	14	GEM fiber RO	1.45	1.36	3.77	in feet	
	Groups 12 - 14 sum		6.28	4.65	9.90	0.82	8
	Total sum in cable tray		**90.32**	**33.15**	**131.08**	**10.92**	

1.06.04 Cables (Cable paths)



- Detector cables (black) will travel over the MPS bunker and pass over the MPS cables trays
- The MPS are supplied (purple) from the distribution panel at the hall edge
- The power cables and instrumentation readout (yellow) for the magnets will go over the MPS bunker wall and fan out to the different magnets

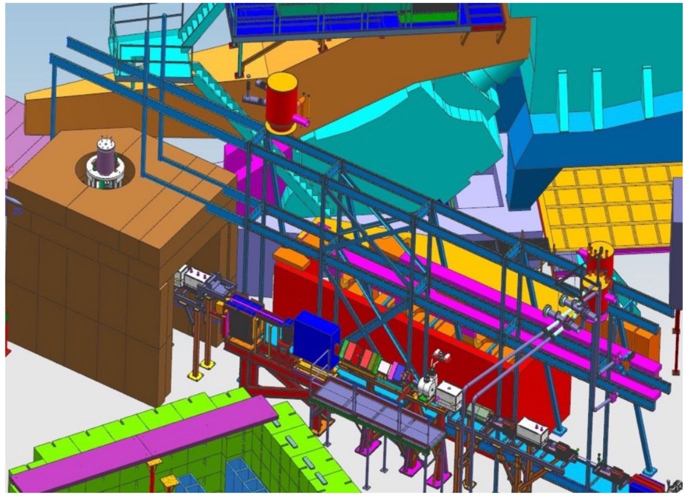
1.06.04 Cables (Cable paths)



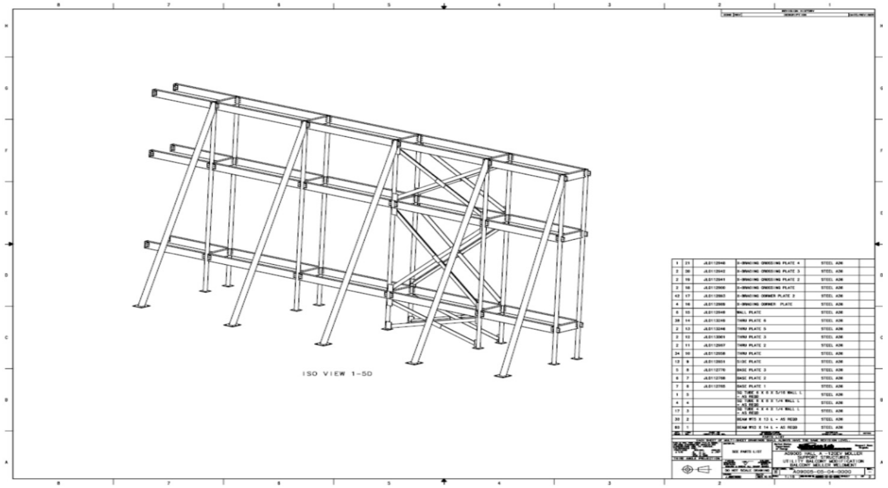
- The detector cables are routed to the SBS bunker where racks are going to be available for the readout and power supplies

1.06.06 Hall Modifications

Existing Utility Platform

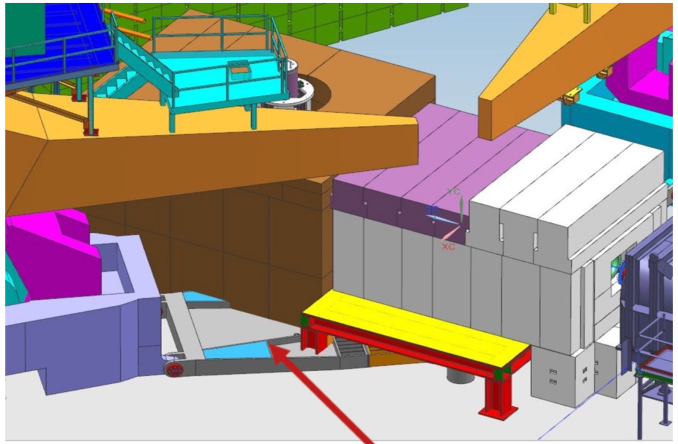


Utility Platform as needed for Moller



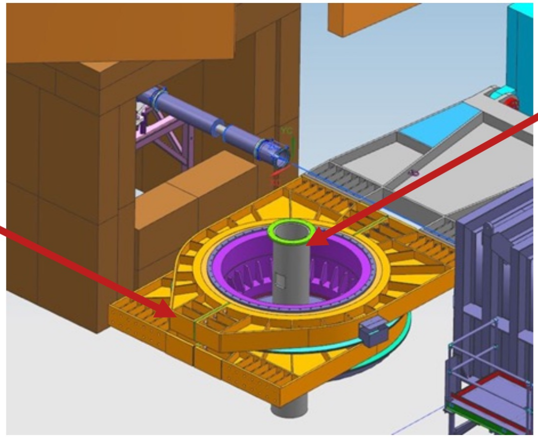
- Approximately 30’ of blue utility platform needs to be removed, including utilities on structure
- Design has been analyzed and modification drawing is complete
- Removal and relocation of utilities to be done in-house, labor included in assembly plan

1.06.06 Hall Modifications (HRS pivot removal planning)



Existing HRS-R link to pivot bearing is not designed to carry additional vertical loading. Link interferences with target support, shielding and shielding support

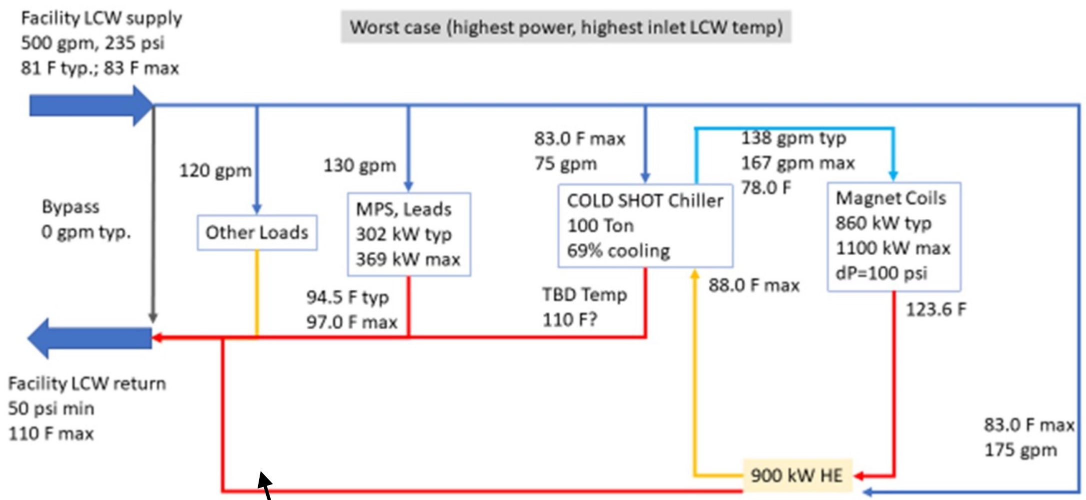
Solution- HRS-R remains stationary. Plan to remove HRS-R link and rotate bearing connection to remove interferences.



Existing pivot platform interferes with spectrometer shielding region, plan to remove.

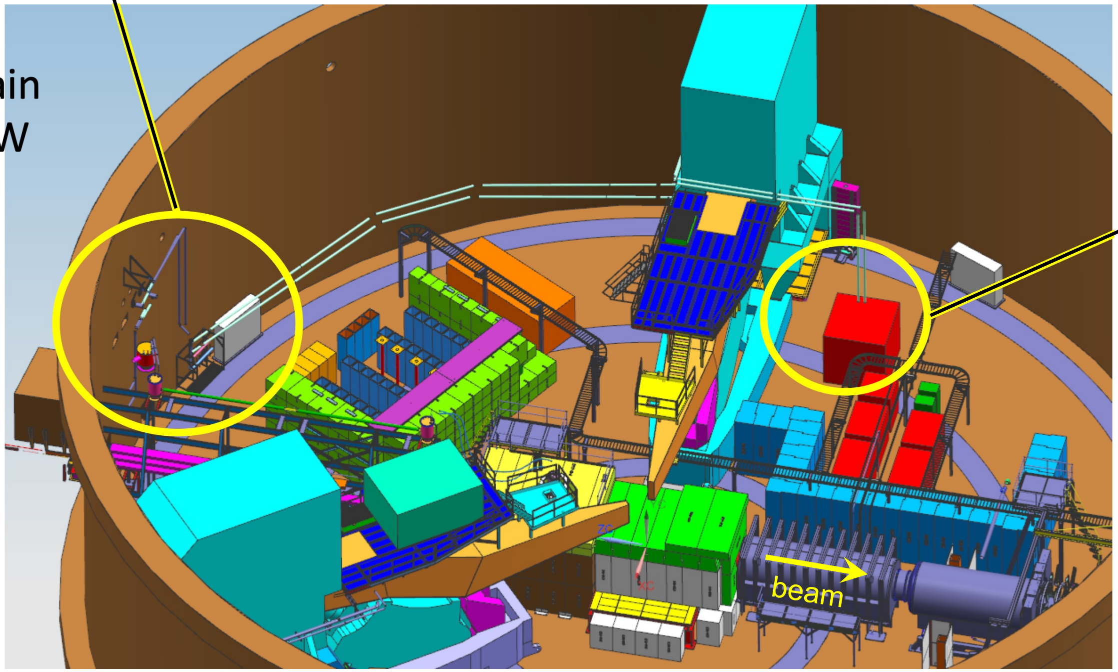
- Local rigging contractor provided estimate to complete
- Documentation of link analysis and Statement of Work completed

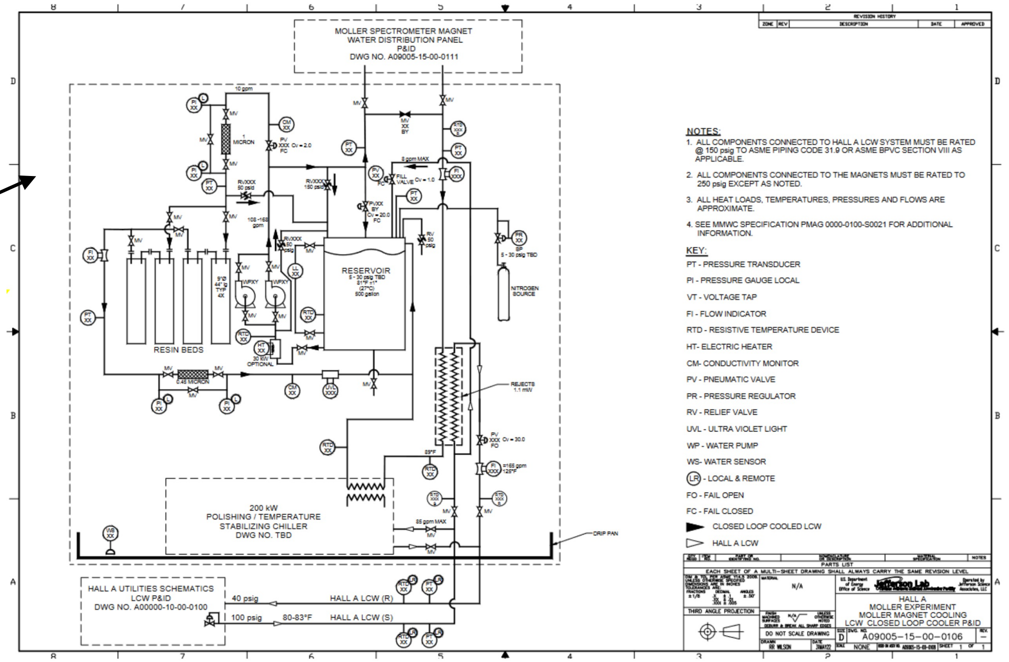
1.06.06 Hall Modifications (Utilities) – Closed loop LCW no longer required



- LCW design modifications and layout required for MOLLER are in process.
- Power routing to power supplies defined and cost estimate updated
- Detector and GEM gas systems to utilize existing Hall A gas systems

Main LCW





MOLLER Magnet LCW

1.06.06 Hall modifications (gas systems)

- The gas system for MOLLER will reuse as much of the existing equipment as possible
- For the GEMs the SBS experiment already has a gas system that has been used for much larger area GEMs
  - We will reuse the basis setup and redo the piping in the hall leading to the detectors
- The main detectors will use the existing Hall A gas system
  - Calculations were done that showed the current compressor provides enough flow to purge the air in all the detector lightguides

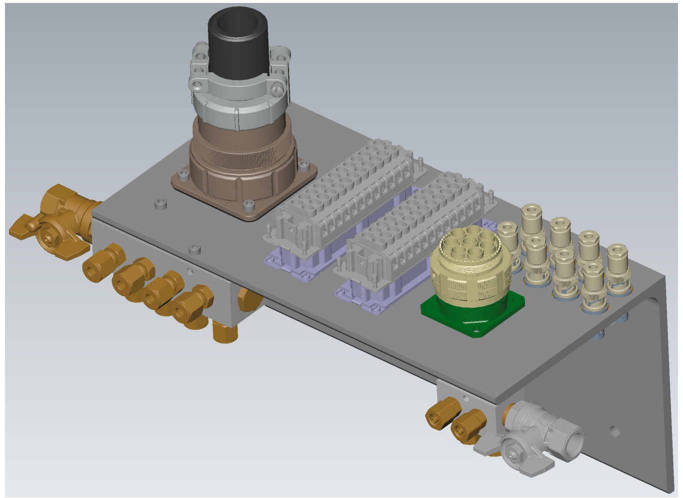
GEM gas system already used in SBS

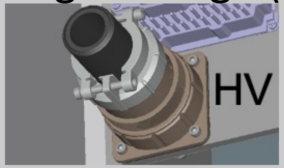
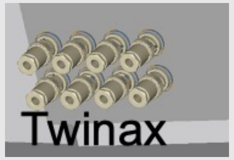
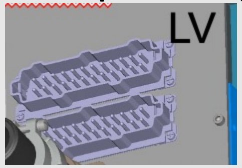
Infrastructure ES&H and QA

- All components governed by JLab ES&H manual requirements and JLab QA program
- Shielding specification and fabrication defined by structural concrete building codes: ACI318-11, ACI 117, ACI 301-10 and SF-2.0
- Shielding materials require material certifications
- Structures fabricated and inspected according to JLab Welding Specifications
- LCW and gas systems designed according to ASME Pressure System codes
- Access platforms and shielding access require JLab fall protection and elevated work regulations
- Utilizing commercially available platforms and ladders fabricated to OSHA standards
- Cables, connections and cable supports defined by JLab Electrical Hazard Program
- ODH and flammable gas hazards minimized in design of shielding areas
- Confined space hazards minimized in design of shielding areas

Minimum mating cycle specs for main detector patch panel connectors

Main detector patch panel



Connector purpose	Connector description	Manufacturer Specs: Insertion Loss/min. mating cycles
PMT high voltage (HV) 	GES High Voltage Inc. --Panel mount receptacle 8pin, 2.7mm female contacts Ag-plated --Cable mount plug, male contacts	"High quality contacts for up to 100 tsd. mating cycles"
Integrate mode signal 	8 standard, individual twinax female-to-female feed throughs with male cable connectors on each end (Twin-BNC, bayonet)	Amphenol website says their standard Twin-BNC connectors have 500 minimum mating cycles
Event mode signal 	Amphenol --Panel mount receptacle 8pin, RG58 female contacts Au-plated --Cable mount plug, male contacts	"1500 connector and contact couplings minimum" --Mil-approved plating process
PMT base power (LV) 	Weidmüller: HDC HE 24 --panel mount 24 pin receptacle --cable mount 24 socket plug	"Plugging cycles, silver ≥ 500"