ECal Status and Installation Plan

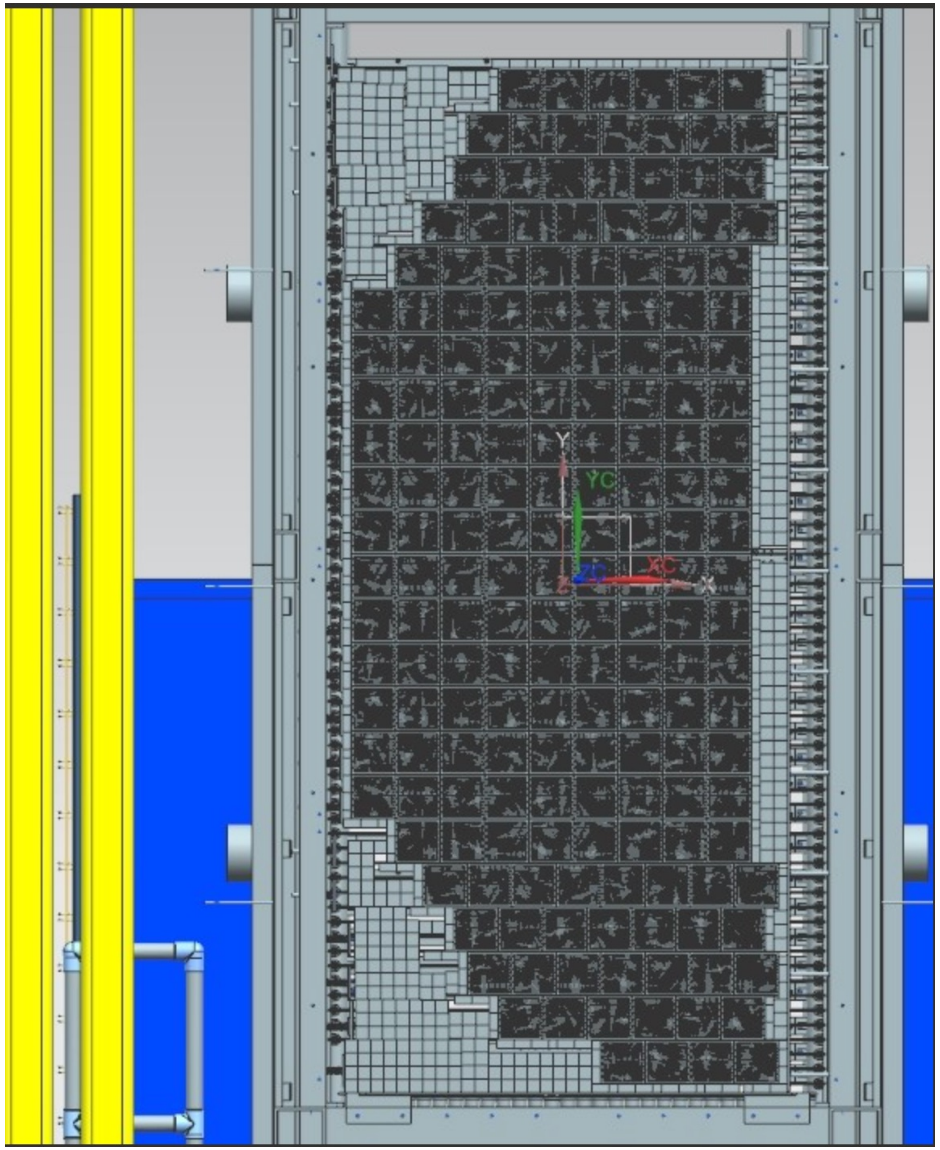
Don Jones

SBS Collaboration Meeting

July 17, 2023

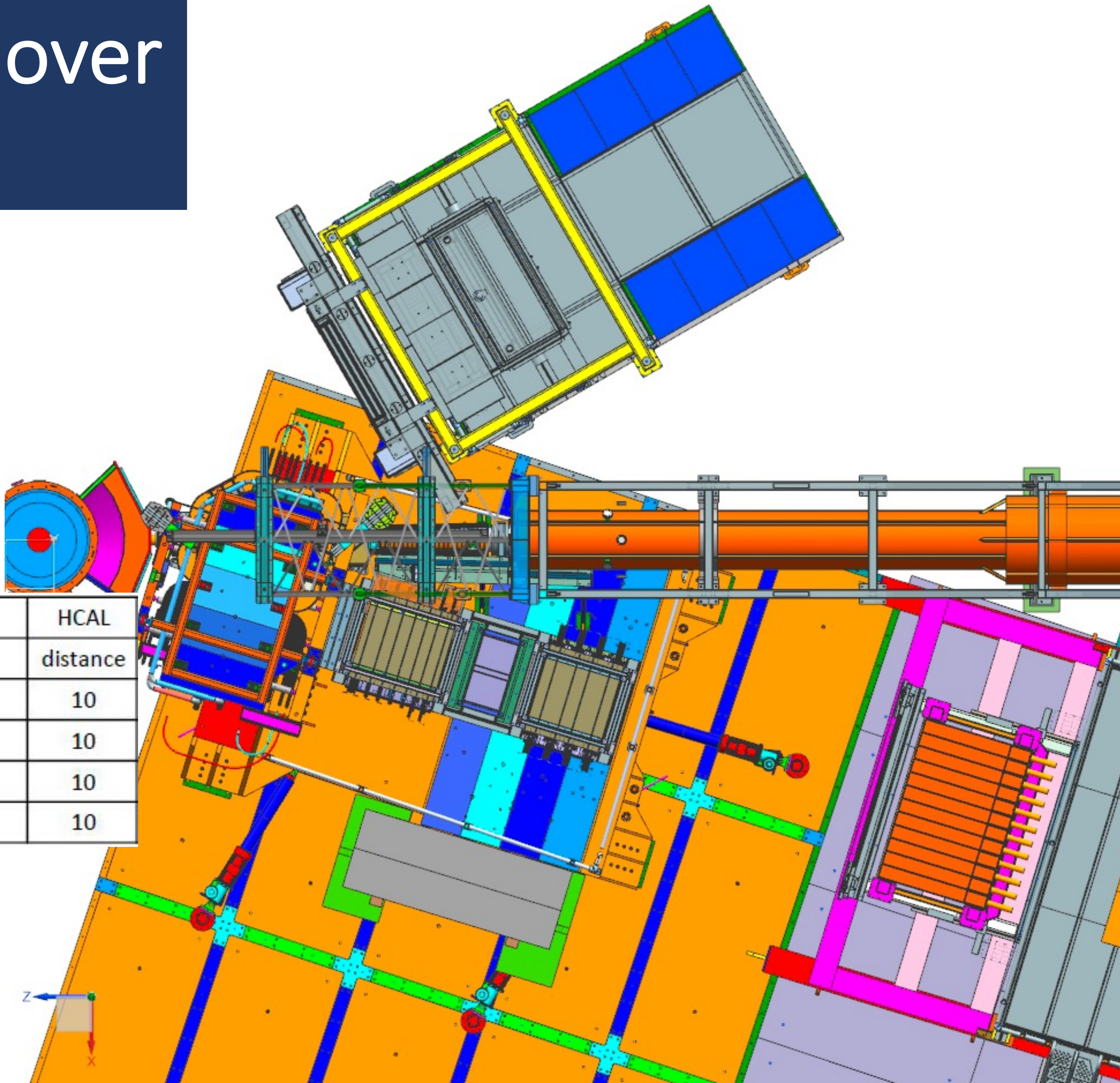
ECal overview

- 180 supermodules
  - Each with 9 crystals and 9 PMTs
  - 5"x 5"
  - 23 tall (9.6') and 9.5 (4.0') wide in active area
- Frame sits on elevated (3' tall) platform.
  - Frame further elevates active area so that bottom row is 5' off the hall floor and the detector is centered on beam line 10' off the floor
- Inactive crystals used for stacking support
- Will be located at three different angles and distances from target so entire platform on Hilman rollers
- Lead glass crystals heated to 220 deg C on front end (180 deg C on back end) to provide continuous annealing.



ECal position and angle over 3 kinematic settings

Name	Energy	Program	ECAL	ECAL	SBS	SBS	HCAL	HCAL
		Q2, GeV2	angle	dist., m	angle	dist., m	angle	distance
GEP-0	6.40	GEp Comm.	29.8	9.5	25.7	1.60	25.7	10
GEP-1	6.40	GEp 5.5	29.8	9.5	25.7	1.60	25.7	10
GEP-2	8.50	GEp 7.8	27.5	6.5	22.1	1.60	22.1	10
GEP-3	10.60	GEp 11.7	30.0	4.5	16.9	1.60	16.9	10



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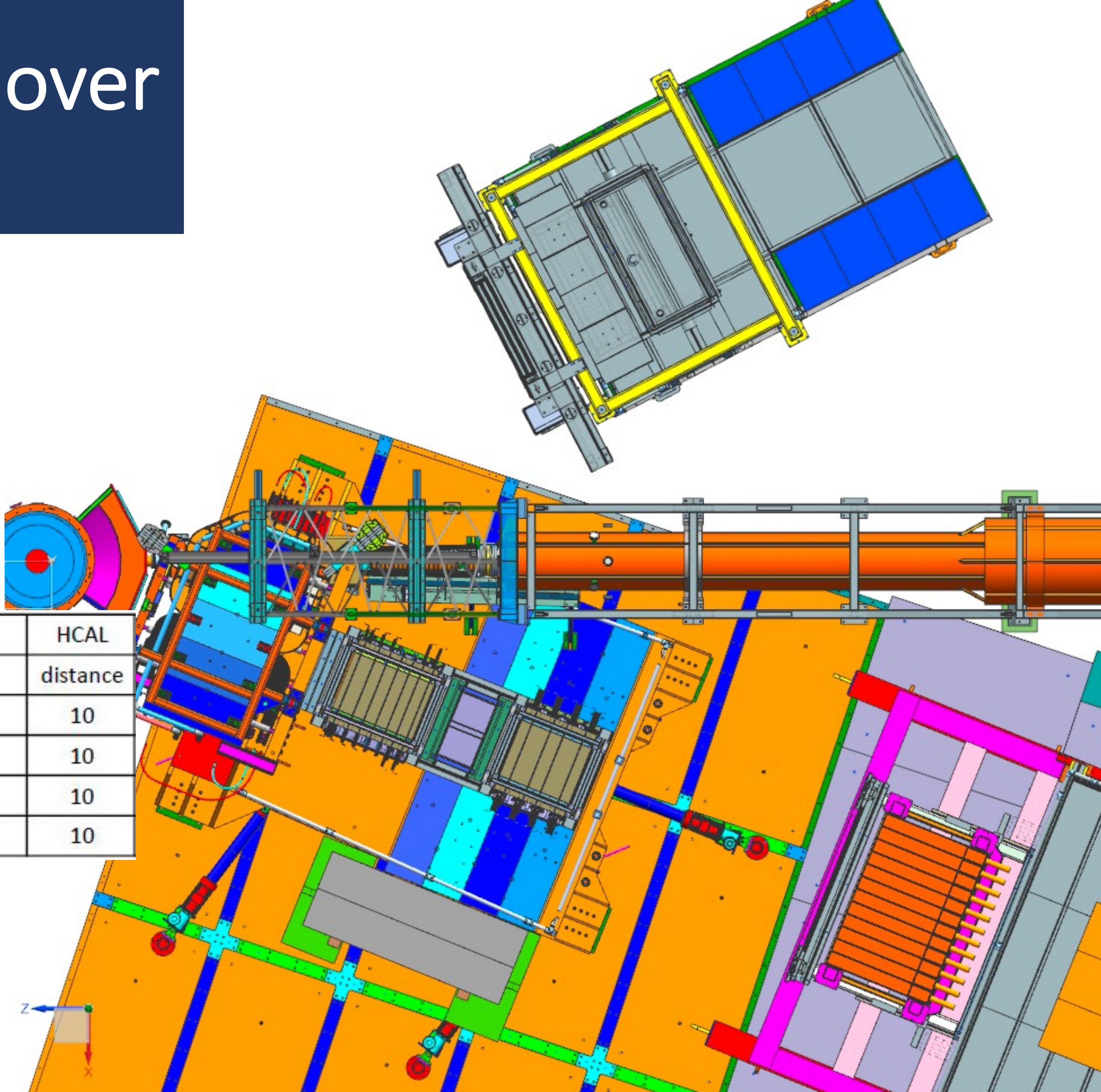

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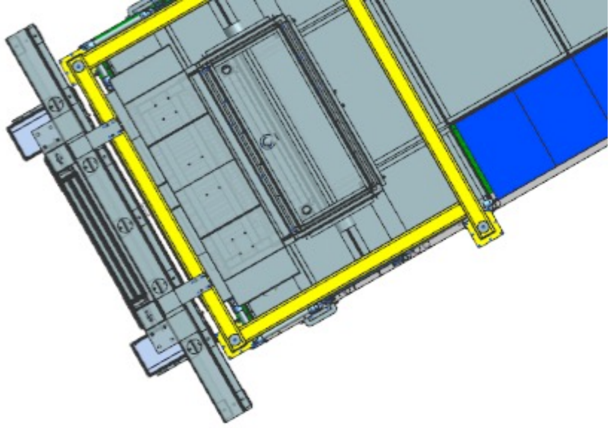

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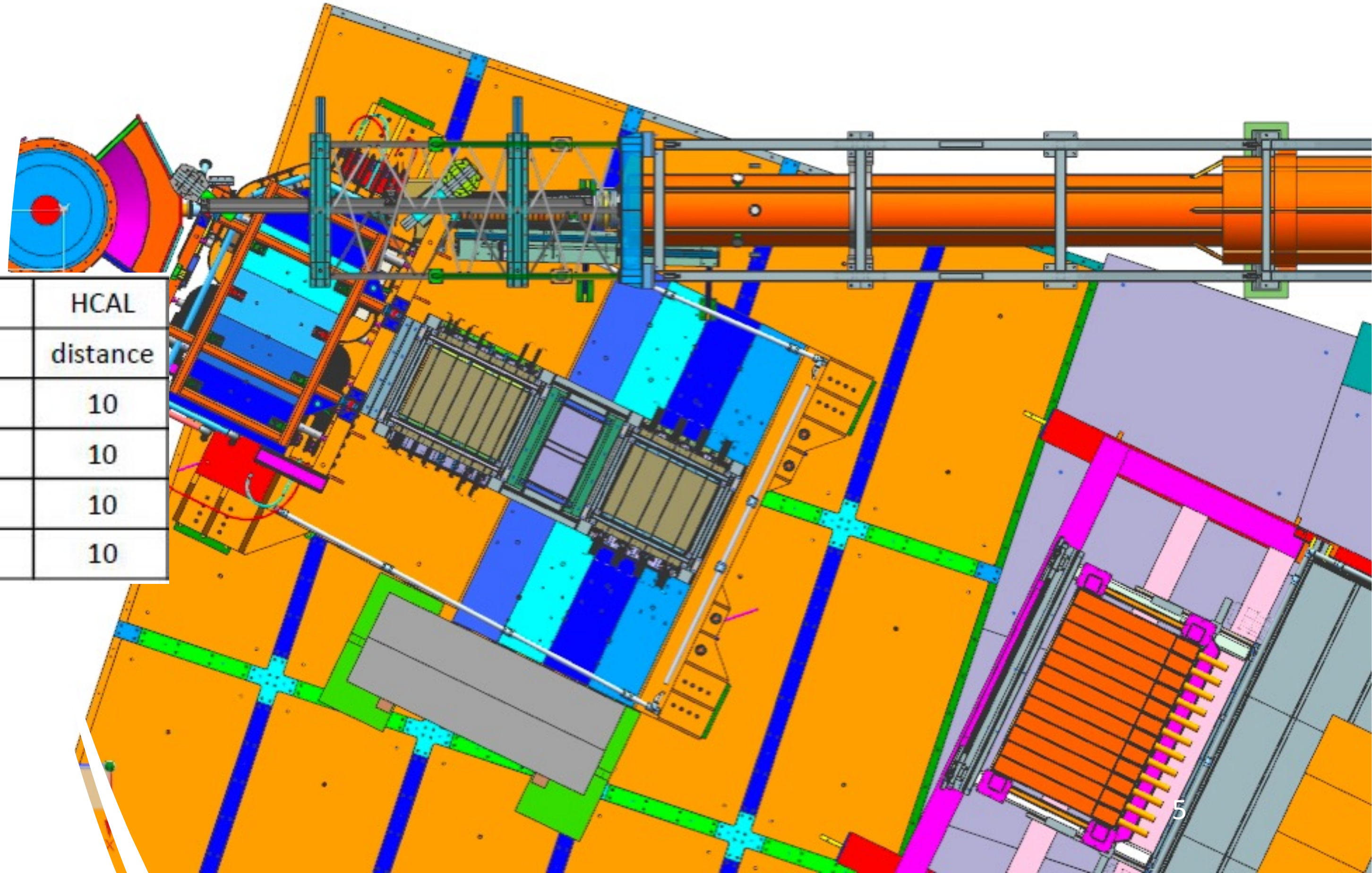
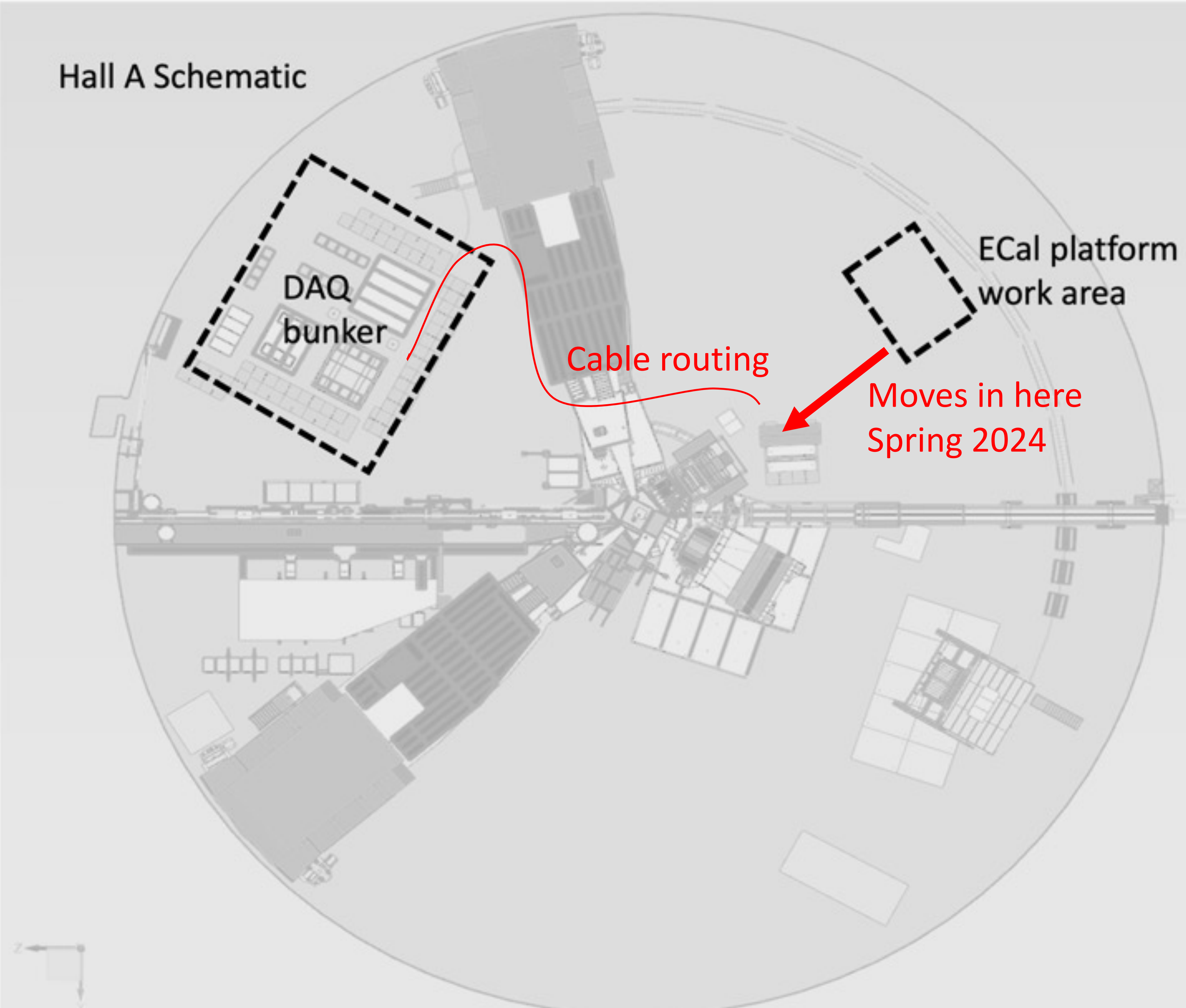


ECal installation

We will build it off to the side and then move it into position after GEn-RP when BigBite is de-installed



ECal installation tasks

Note the still empty frame.

I had hoped/planned on being half done stacking the supermodules by now but delays have largely stalled this effort

- The OSP has been delayed and EH&S will not approved starting the stacking until there is a complete design for the heater system
- The nearly final heater system design is being readied for testing on a prototype before deciding to use on ECal
- After a few days (next week?) of data on the prototype we will decide if it meets our requirements and if so present it to EH&S for approval
- Perhaps start stacking the 1st week of Aug

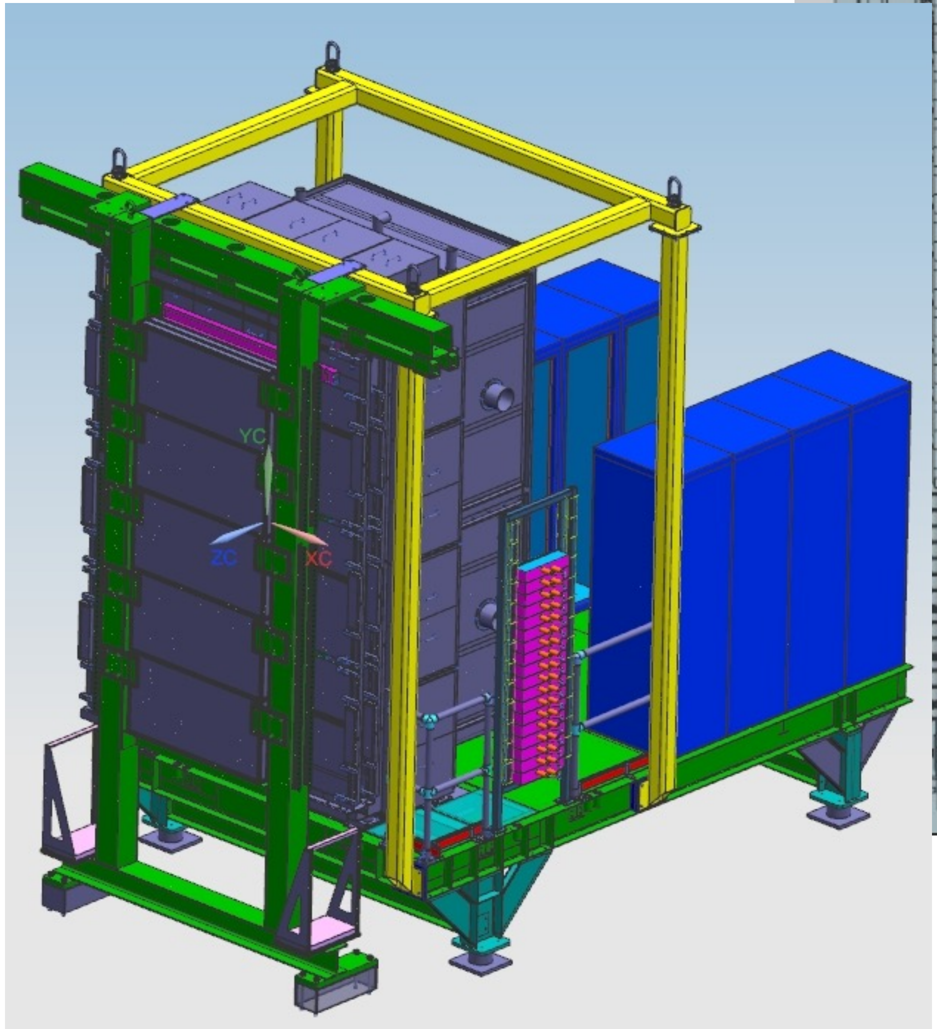
ECal installation tasks

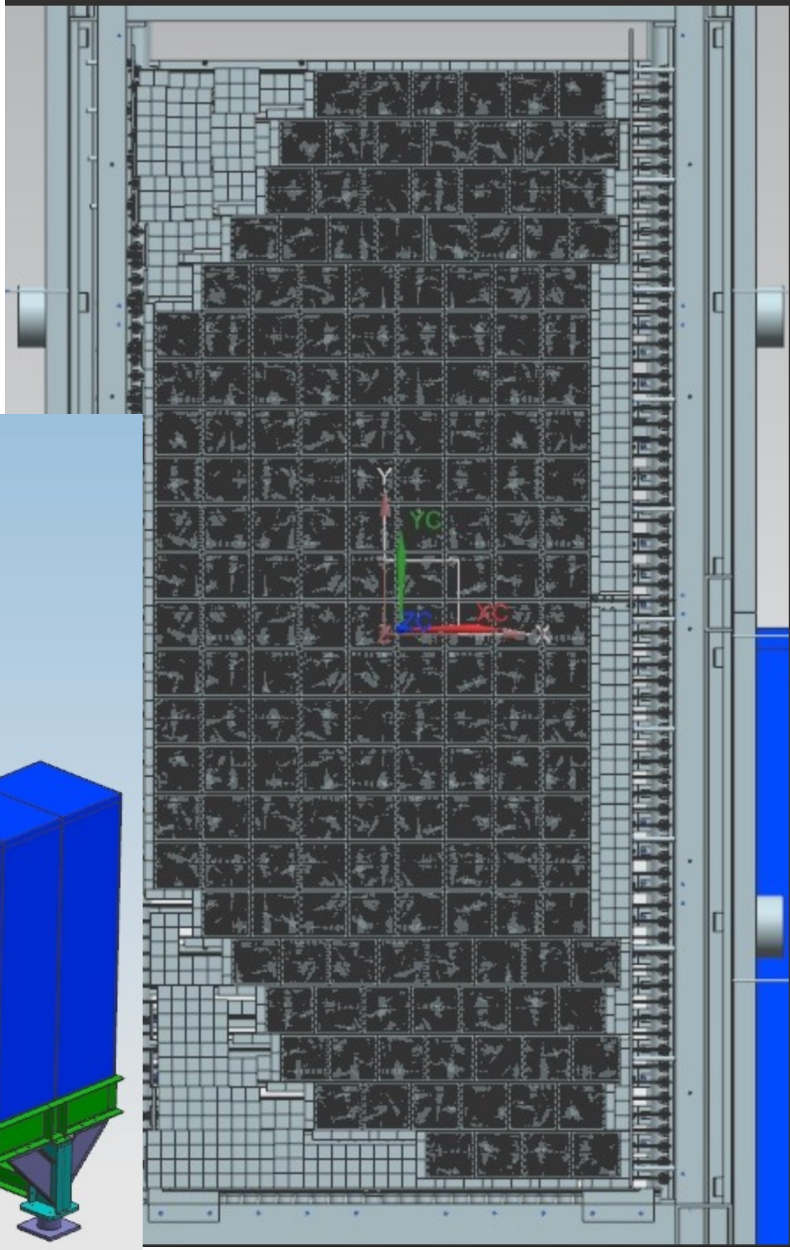
Building calorimeter on platform:

Stack supermodules, install heater system, build walls of insulation, install light-tight enclosure, install PMTs and bases attaching signal (HV) cables from PMT to patch panel and from patch panel to front end electronics (DAQ bunker), install emergency shutdown for HV and for heater system, install front end electronics.

Lead up work (largely complete):

Design for detector, enclosure and cooling system. Test and characterize PMTs, build/modify bases, construct and label 1656 signal and HV cables, design heater system and temperature monitoring and control, getting installation OSP approved.



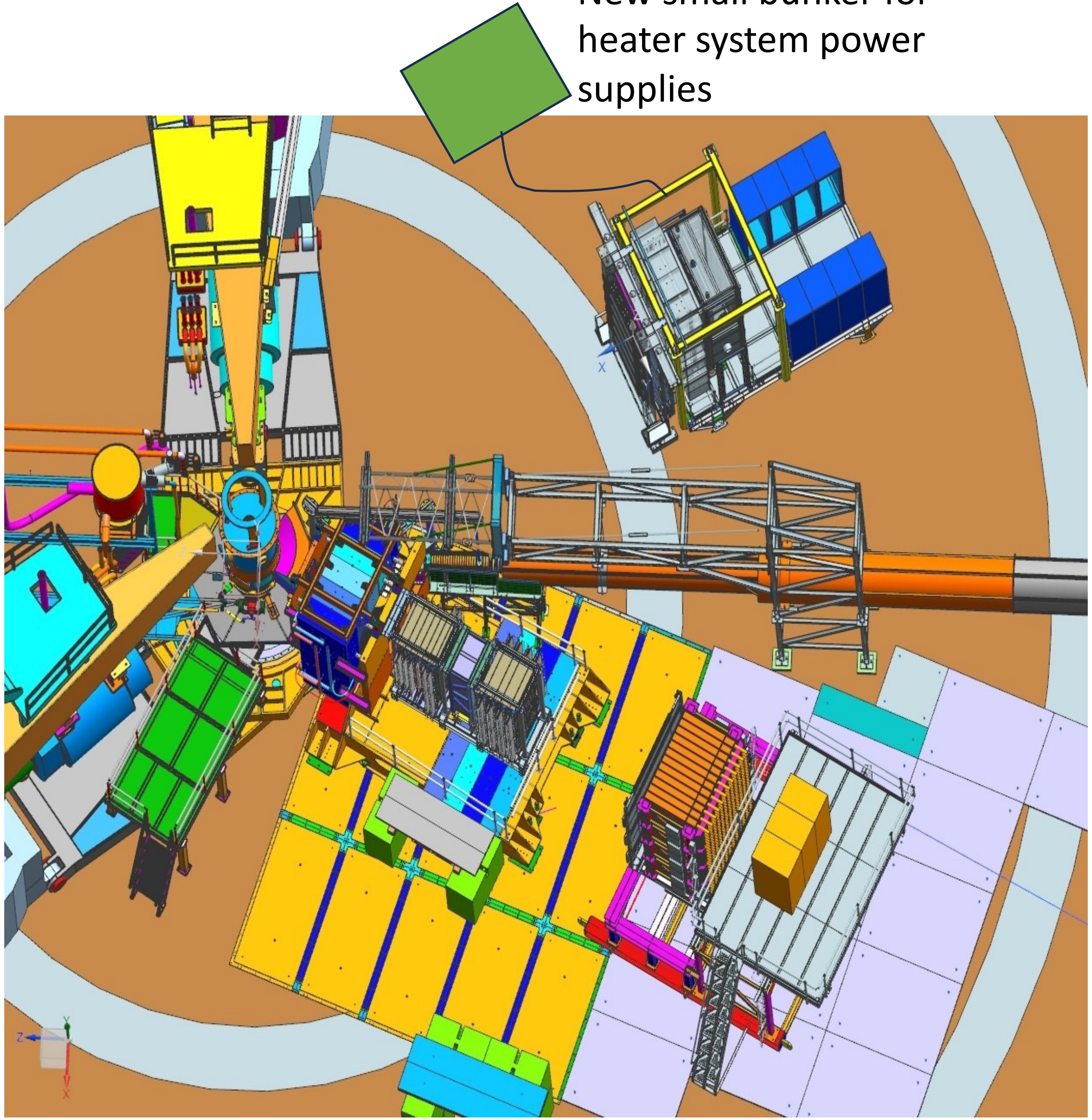


ECal installation tasks

Although the frame is empty the electronics racks are not.

Front end electronics is greatly simplified now with the decision to move to an FADC-based DAQ.
Jimmy Caylor installed summing modules and patch panels which comprise essentially the whole front end now.

ECal installation tasks



Powering heater system:

There will likely be 44 heater zones individually temperature monitored and powered using 44 independent power. This requires 25 kW of power in 44 regular AC outlets which will have to be installed by facilities. A new shielding bunker will be needed.

Lead up work (largely complete):

Designing (and drawing) the electrical system, finding the right components that produce the correct power and will withstand the elevated temperatures. Getting the whole thing approved by ES&H.

ECal installation tasks

Connecting cables from front end to DAQ bunker:

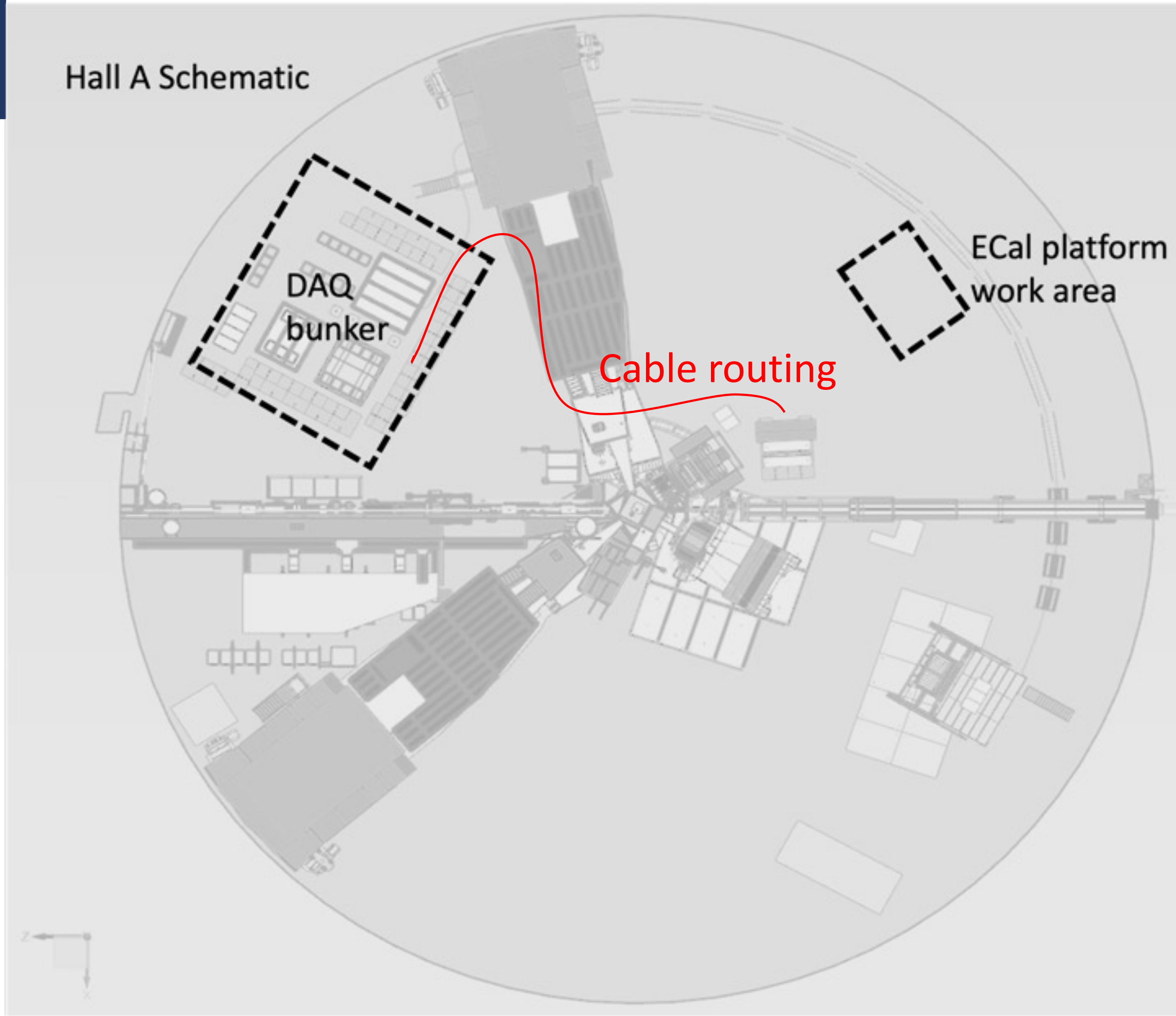
1656 75m-100m BNC cables carry the signal from ECal to the DAQ and 70 24-pin HV cables connect between the two systems.

Lead up work largely complete:

Make 1000 new cables (done) and verify existing ones labeling as required. Mindy completed the HV breakout boxes for installation on the Ecal platform. Getting installation OSP approved.

Lead up work largely incomplete:

Procuring carts for carrying large volumes of cables from ECal and allowing movement of detector platform. Designing sufficiently large cable tray system for the large number of channels. Mindy is building the remaining needed 24-pin HV cables.



ECal installation tasks

Connecting SHV cables in DAQ bunker and setting up remote control

- Jimmy Caylor has taken on this task which is well underway.

Lead up work largely complete:

- Installing HV racks and modules; making and installing converter boxes; making, labeling and installing SHV cables

Lead up work largely incomplete:

- Building remote control. Waiting on facilities to hook up electricity to the rack.

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ECal installation tasks

Installing FADC-based DAQ (next Spring after GEn-RP)

- Need 7 crates and 1656 LEMO signal cables and patch panel connectors

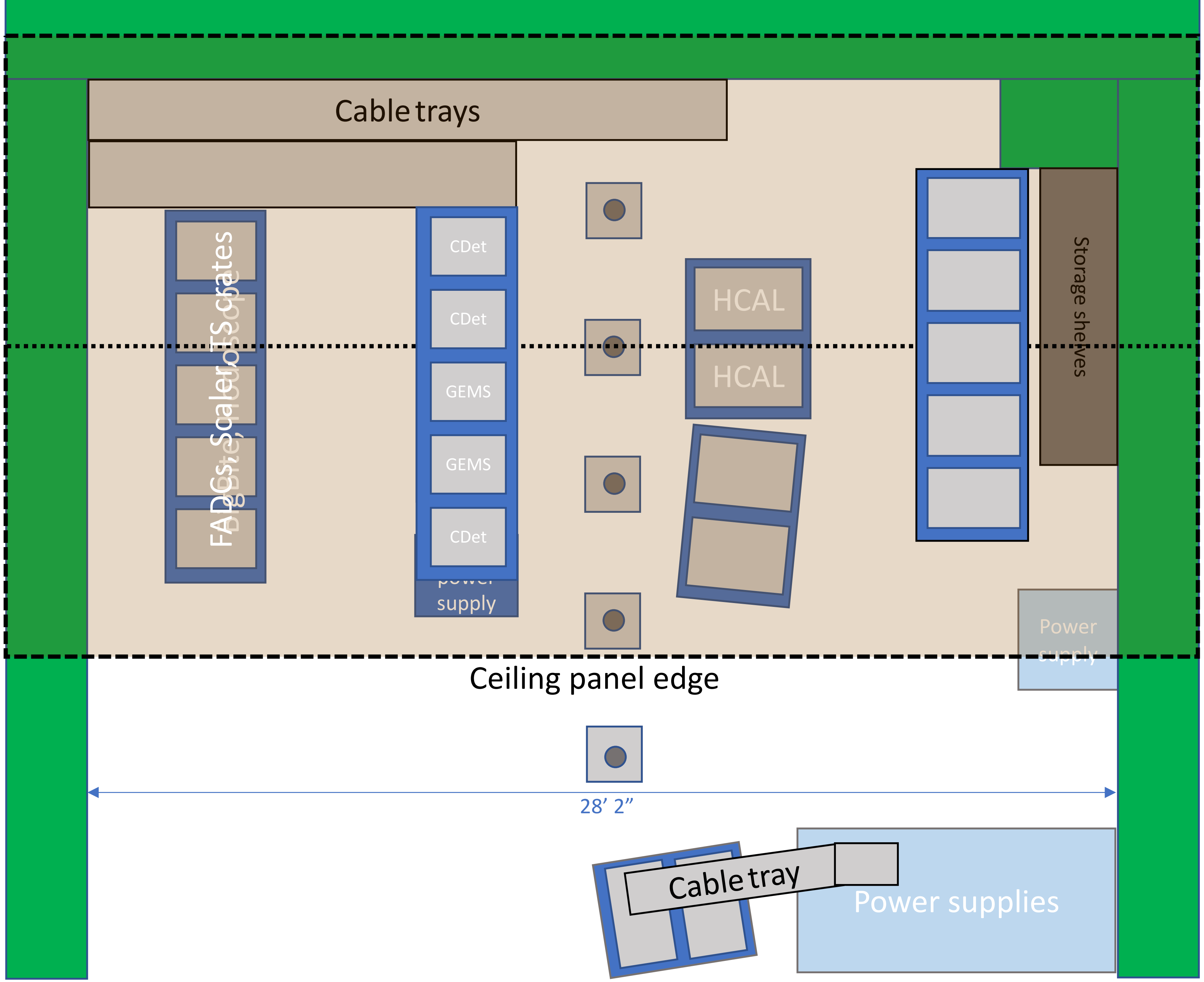
Lead up work largely complete:

- Amassing LEMO cables and patch panels

Lead up work largely incomplete:

- Removing BigBite and reconfiguring existing rack space.
- Installing VME crates and FADCs
- Cabling up signal connections from front end to FADCs

DAQ Bunker in Hall



Current layout

Reconfiguration steps

1. Move storage shelves and install 5 racks for HV in their place. Install HV crates and modules in racks (Summer 2023)
2. Move HCal racks slightly to give more room.
3. De-install BigBite and Hodoscope electronics, HV and cabling (April 2024)
4. Consolidate GEM electronics in two racks (April 2024)
5. Move central racks and power supply outward to allow 3 racks for CDET
6. Install Patch Panels, VME crates for FADCs and Trigger supervisor and install scaler crate.
7. Run cables and connect everything up.

ECal activities calendar

Current activities

Albert S. is organizing a small army of students and researchers from CNU, JMU, Hampton, Yerevan Physics Institute, NCCU and JLab DSG and EG.

- Building the 24 pin HV cables and 48 channel HV boxes.
- Bundling and labeling cables
- Labeling patch panels
- Building the PMT cooling system

Jimmy C. is developing and installing the HV system and controls and front end electronics

Don J. is developing the heater system prototype and full system

Marc M. and DSG are working for develop controls for heater system.

Silviu C. is doing a heat model for ECal to demonstrate the sufficiency of the current design

August

- Continue testing and labeling cables and components
- Finish heater prototype and complete 1 week test run successfully demonstrating it meets our requirements
- Start stacking detector supermodules.

September

- Move 6-supermodule prototype to the hall to demonstrate heaters under beam conditions.
- Continue stacking supermodules until mid-month and then finish up tasks in Hall and get the hall ready for beam.

October

Run GEn and A_LL experiment

ECal activities calendar

- **Nov - Feb (deinstall polarized target and install cryotarget etc for GEn-Rp)**
  - Finish stacking supermodules, install heating system, install PMTs, patch panels and cables
  - Build walls of enclosure
  - Cable up front end electronics
- **Mar Run GEN-RP and K_LL**
- **April – Sept (Install GEP)**
  - Move ECal platform into position for GEp-1 kinematic
  - Run remaining signal and HV cables between ECal platform and DAQ bunker
  - De-install Bigbite: shower&preshower calorimeters, GRINCH, Hodoscope, GEMs
  - Re-arrange GEM DAQ and install ECal FADC-based system in 5 contiguous racks and CDET in 2 racks.
  - Connect all cables according to maps
  - Test and calibrate with cosmics
- **Oct - Jan run GEp**

ERR Summary for ECal

ERR review of ECal on April 24th was largely successful but the committee had reservations about the uncertainties of the heating system as reflected in their 3 recommendations. The committee was not convinced that the heating system design was sufficiently mature, nor that it was sufficiently demonstrated to meet the requirements.

1. Demonstrate the new heater performance in realistic conditions. Install one of the super modules with heaters in the hall during the upcoming runs and monitor gains (like the test with the 16-channel module)

As written, the committee appears to be asking that we build a full prototype detector with signal readout and with the ability to trigger on elastic electrons similar to the 16 channel prototype previously built 7 years ago.

Conversations with the committee since have indicated that they would be satisfied if we can demonstrate the heater system works in beam and that the temperature profile satisfies requirements i.e. matches the previous prototype that demonstrated sufficient crystal clarity.

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1. Demonstrate the new heater performance in realistic conditions. Install one of the super modules with heaters in the hall during the upcoming runs and monitor gains (like the test with the 16-channel module)
2. Perform thermal simulations to show the heating pattern/load of total power consumptions. The total heat load is estimated at 20 kW max.

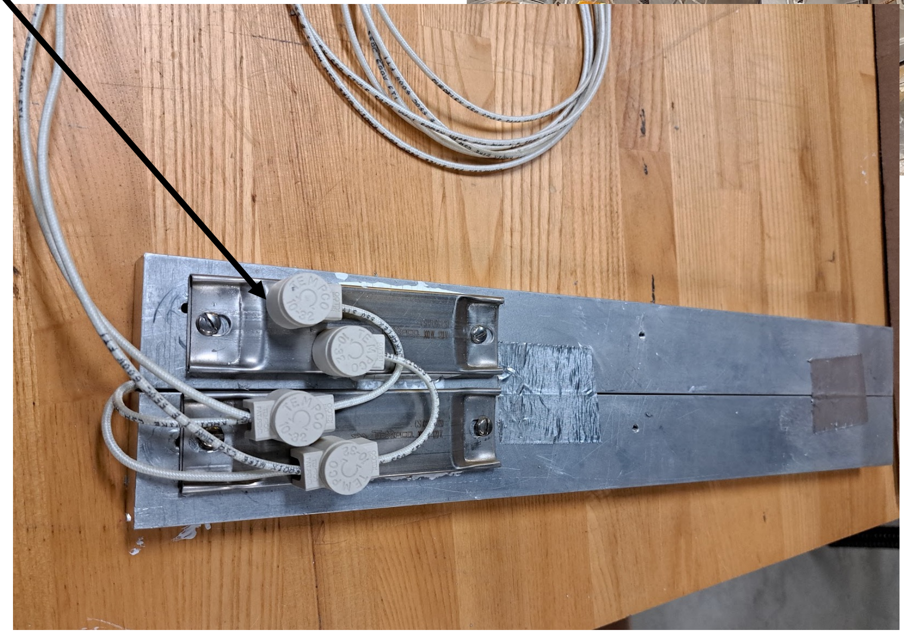
They also want a full heat simulation of the whole detector to demonstrate the temperature distribution and heat load. This is a significant tasks requiring a great deal of time and resources.

- Silviu Covrig has built an individual supermodule unit in his CFD software package which can in principle be used to build the entire detector
- He has shown that even without insulation around the supermodule, the existing heater output (100W/supermodule) is sufficient to reach 220 degC on the front face.
- It is not clear yet how detailed of a heat simulation is required to satisfy the committee, but a full detector temperature profile with insulated walls and realistic boundary conditions will require a significant amount of his time.

Status of heater system design/testing

Basic heater system design is nearly complete

- Two 50W strip heaters on the front of each supermodule
- Supermodules on the boundary have edge(s) heated by a pair of aluminum bars with two 50W plate heaters on the end and a 40W cartridge heater embedded in the center



- Should be ready to test this design on our 6 SM prototype next week.
- If it works as expected then we will document it and seek approval from EH&S to begin building the detector
- This Fall it will also go into the hall to demonstrate it works under radiation/beam

Powering the heater system

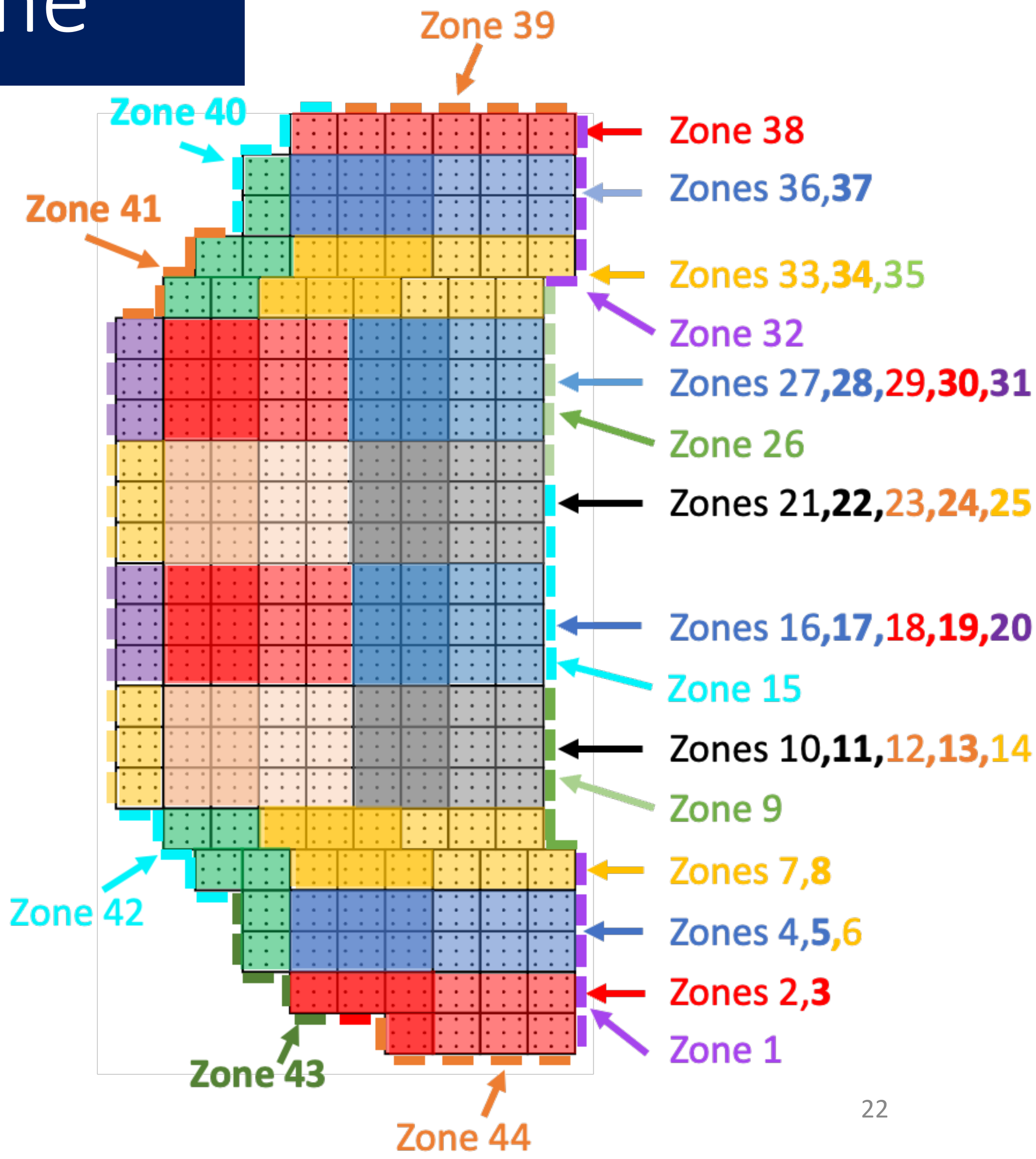
Jack S. highly recommended keeping the voltage <50 VDC to ease the safety concerns and keep us in the low hazard threshold

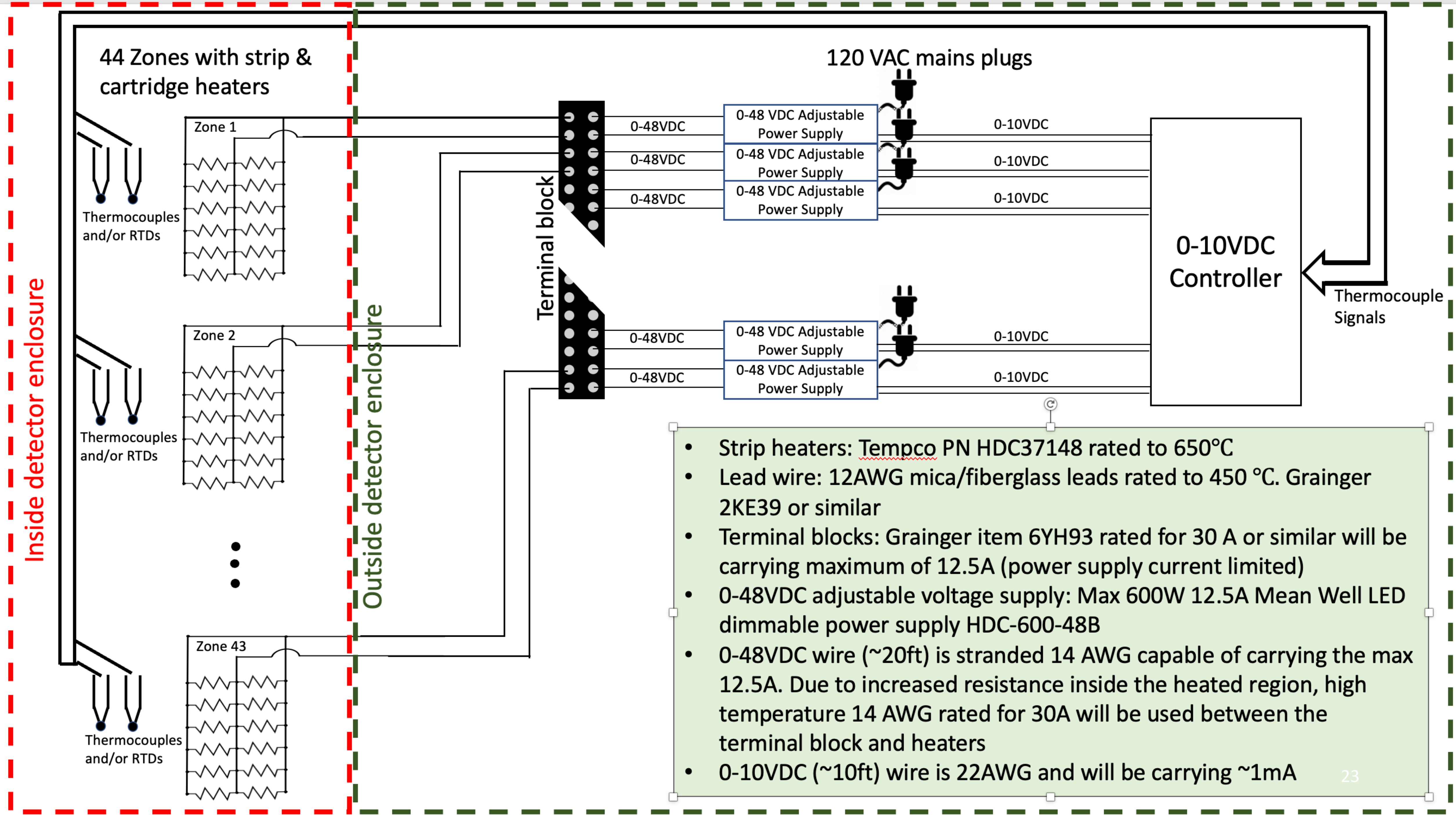
- Adjustable DC power supplies that can produce kW of power are expensive
- Jack also pointed out that there are inexpensive dimmable LED power supplies available commercially and we were able to find a design that produces up to 600W and is adjustable from 0-48V with a maximum current of 12.5 A

- Appears to work with preliminary testing by DSG. It will require 40 to 50 units to power the entire system (25kW)
- Building scalable system for the prototype
- Sensitive power supplies require shielding hut near ECal (Robin?)

Proposed heater zone scheme

- 44 zones (max 25kW) each separately controlled with PID
  - Internal zones have 6 supermodules (12 strip heaters)
  - Edge zones have aluminum bars with strip and cartridge heaters
- Tried grouping SMs into zones in regions expected to have similar temperatures
- Requires 44 AC outlets, 1 per heater with each heater drawing 7.2 A @120VAC
- Working on ideas for implementing emergency high temperature shutdown





- Strip heaters: Tempco PN HDC37148 rated to 650°C
- Lead wire: 12AWG mica/fiberglass leads rated to 450 °C. Grainger 2KE39 or similar
- Terminal blocks: Grainger item 6YH93 rated for 30 A or similar will be carrying maximum of 12.5A (power supply current limited)
- 0-48VDC adjustable voltage supply: Max 600W 12.5A Mean Well LED dimmable power supply HDC-600-48B
- 0-48VDC wire (~20ft) is stranded 14 AWG capable of carrying the max 12.5A. Due to increased resistance inside the heated region, high temperature 14 AWG rated for 30A will be used between the terminal block and heaters
- 0-10VDC (~10ft) wire is 22AWG and will be carrying ~1mA

Remaining large purchases

I believe (hope) that most large scale purchases related to ECal with the obvious exception of the heater system are complete.

Heater system major components

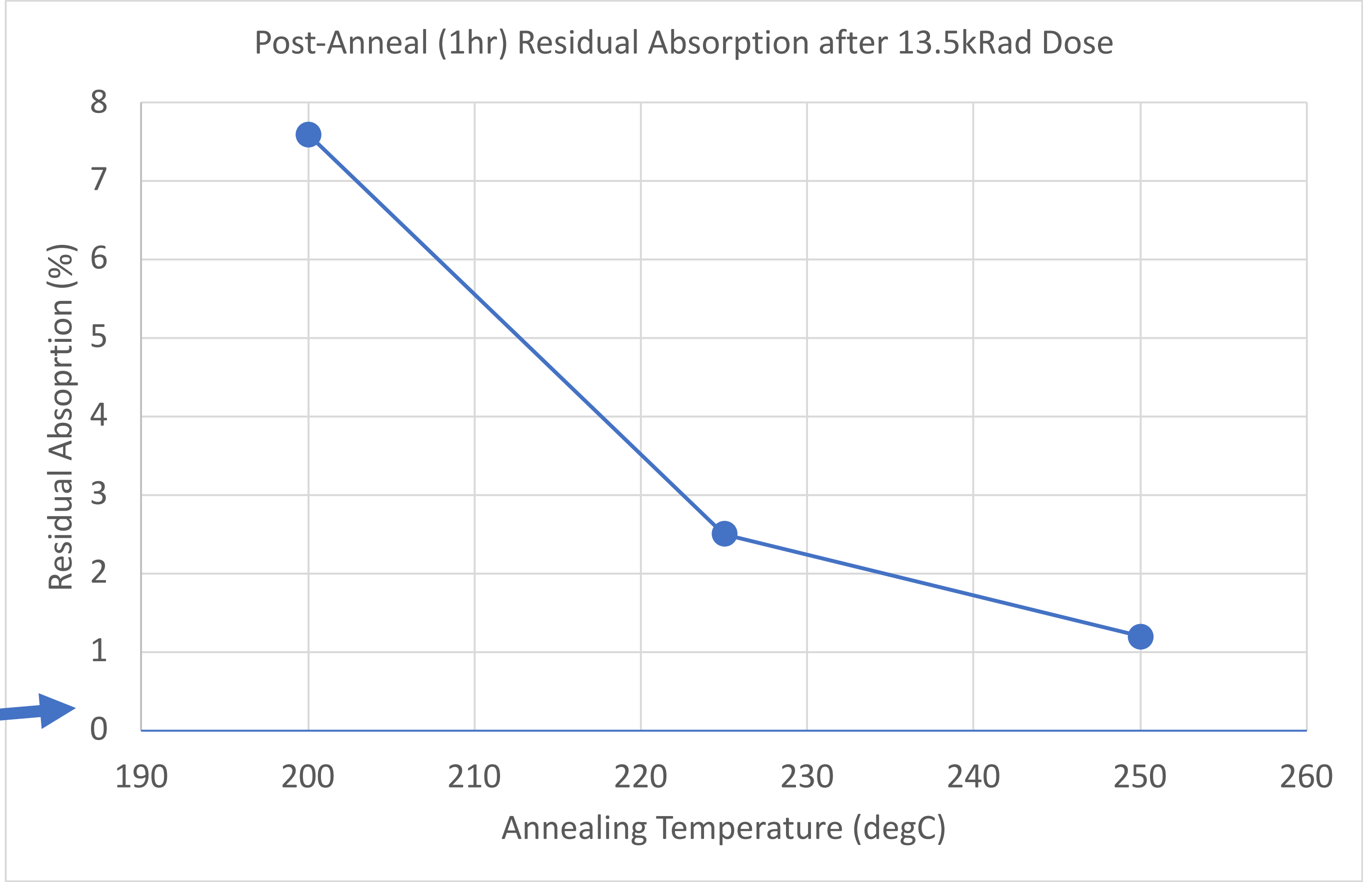
- 500 channel strip heaters@$60 apiece ($30k)
- 70 cartridge heaters@$80 apiece ($6k)
- 50 power supplies@$200 ($10k)
- 150 RTDs @$100 ($15k)
- Temperature control system– not sure but expect $30k-$50k
- Components to wire and connect power supplies ($10k-$15k)
- Wiring up AC power?

Conclusion and Summary

- Planned to start stacking SM in the ECal frame in early June. Now likely early August. Otherwise, efforts are largely on track
- ERR recommendations related to ECal are being addressed with ongoing communications with the committee.
- Immense ongoing efforts preparing PMTs, cables, HV and other components for installation.
- A big thank you to all who are helping in this huge effort

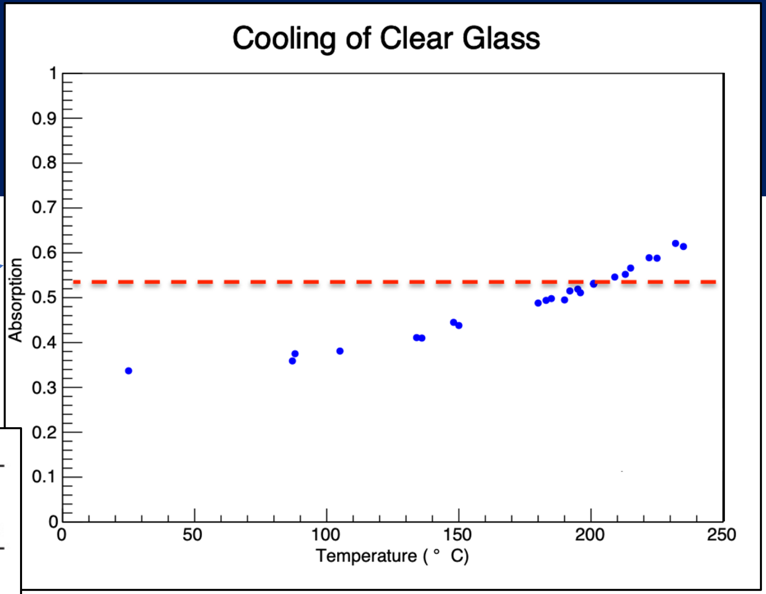
Continuous annealing of ECal

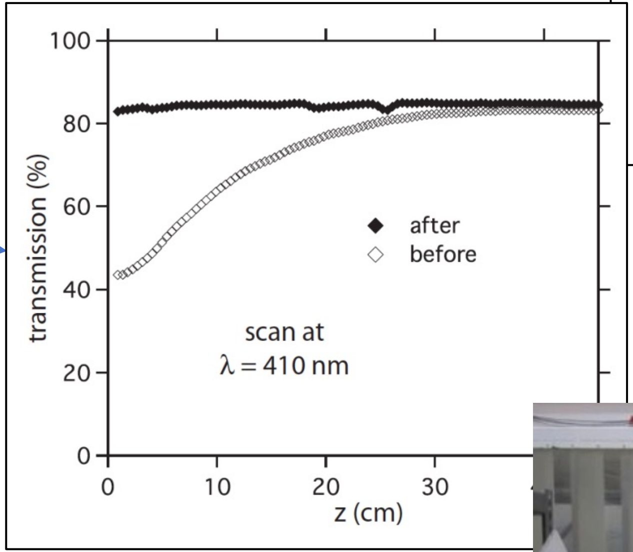
- Early simulations by Seamus Riordan assuming 75uA beam on 40cm target showed 0.5 kRad/hr of radiation on ECal
  - Conservative since now running on 30cm target
- Tests of crystal exposed to 13.5 kRad showed 64% loss of light due to darkening from radiation
  - Crystals would be dark in a few days of GEp production without annealing.
- Recovery rate with annealing is temperature-dependent
- C-16 showed that 220 degC on front end (180 on back end) is sufficient.

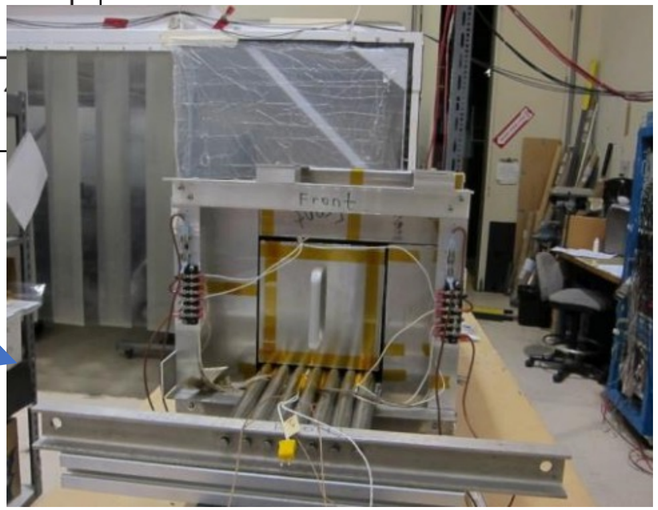


Continuous annealing of ECal

- Hotter crystal = better annealing
- Competing effect from increasing absorption coefficient of crystal with temperature limits the optimal temperature
- Radiation damage reduced with depth into crystal so hotter on front end is preferred
- Demonstrated with C16 prototype that temperature profile 220 deg on front and 180 deg on back of crystal sufficient to reach and maintain 10% resolution @1.5 GeV so expect 6%@ 4GeV
- Recently completed 6 supermodule prototype used to demonstrate use of strip heaters → 70W per supermodule sufficient







2014

All transmission studies were performed for the wave length of 405nm

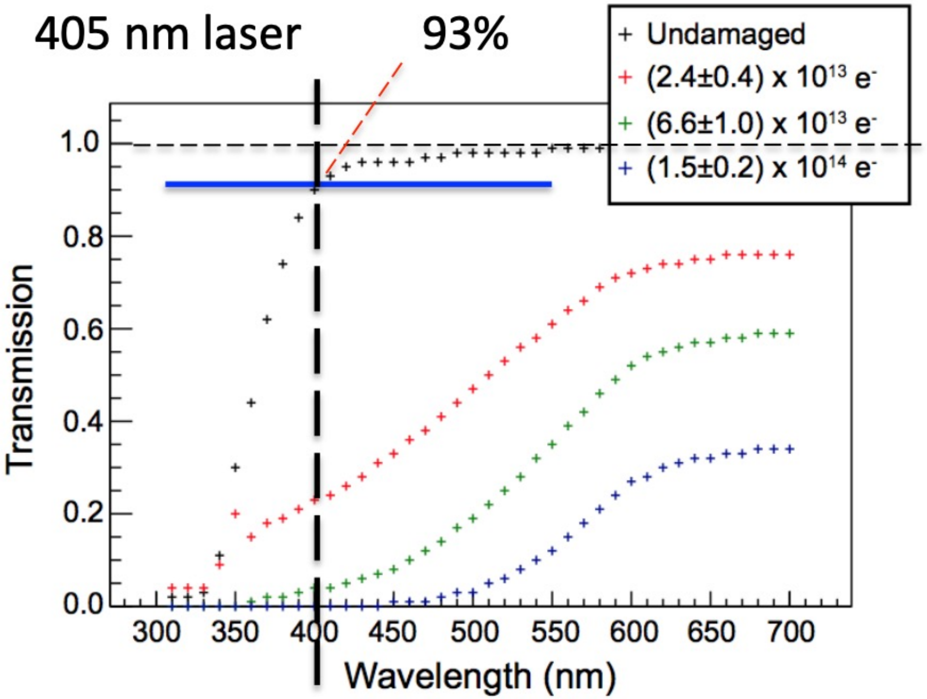


Figure 5: Transmission coefficient of 4 cm of lead glass as a function of wavelength for various amounts of radiation. Estimated errors are 2% (10%) for wavelengths above (below) 380 nm.

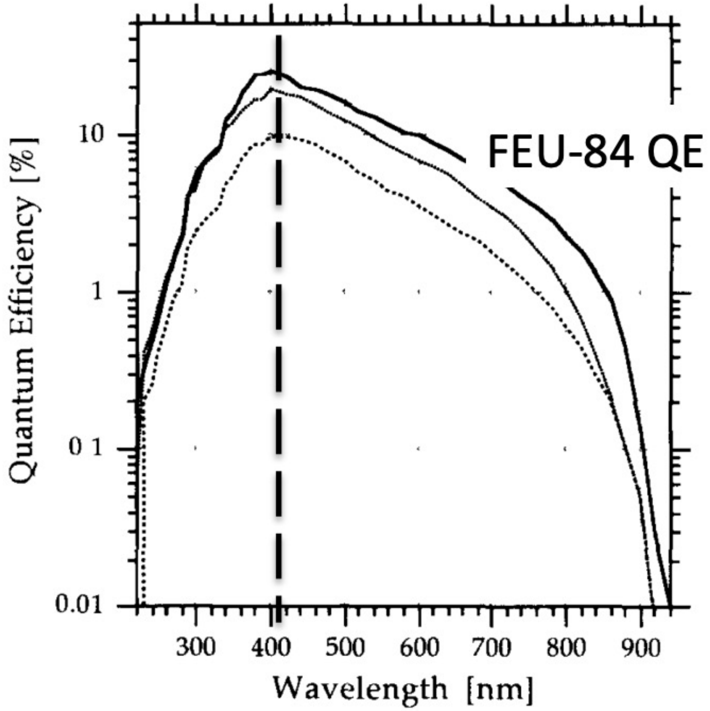
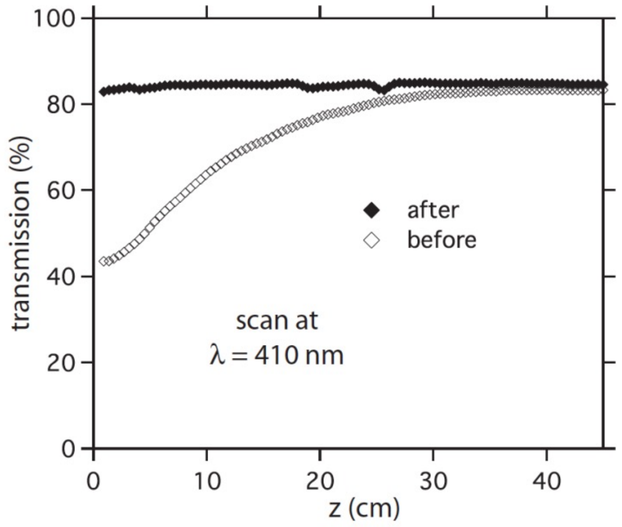


Fig. 4. The absolute quantum efficiency of three FEU-84-3 phototubes as measured by Hamamatsu Inc. using a calibrated source. Three tubes were selected, using the method described in the text, as having relatively high, medium and low relative quantum efficiencies.

Hall D report

Figure 4.4 shows the transmission of light, at $\lambda = 410$ nm, through 4 cm of lead glass as a function of distance along the bar for a radiation-damaged bar before and after heat curing at 260 °C. The $z = 0$ position corresponds to the upstream end of the bar during data taking, *i.e.* the end of the bar closest to the source of the photon beam.



12 hours
at 260 C
household
oven

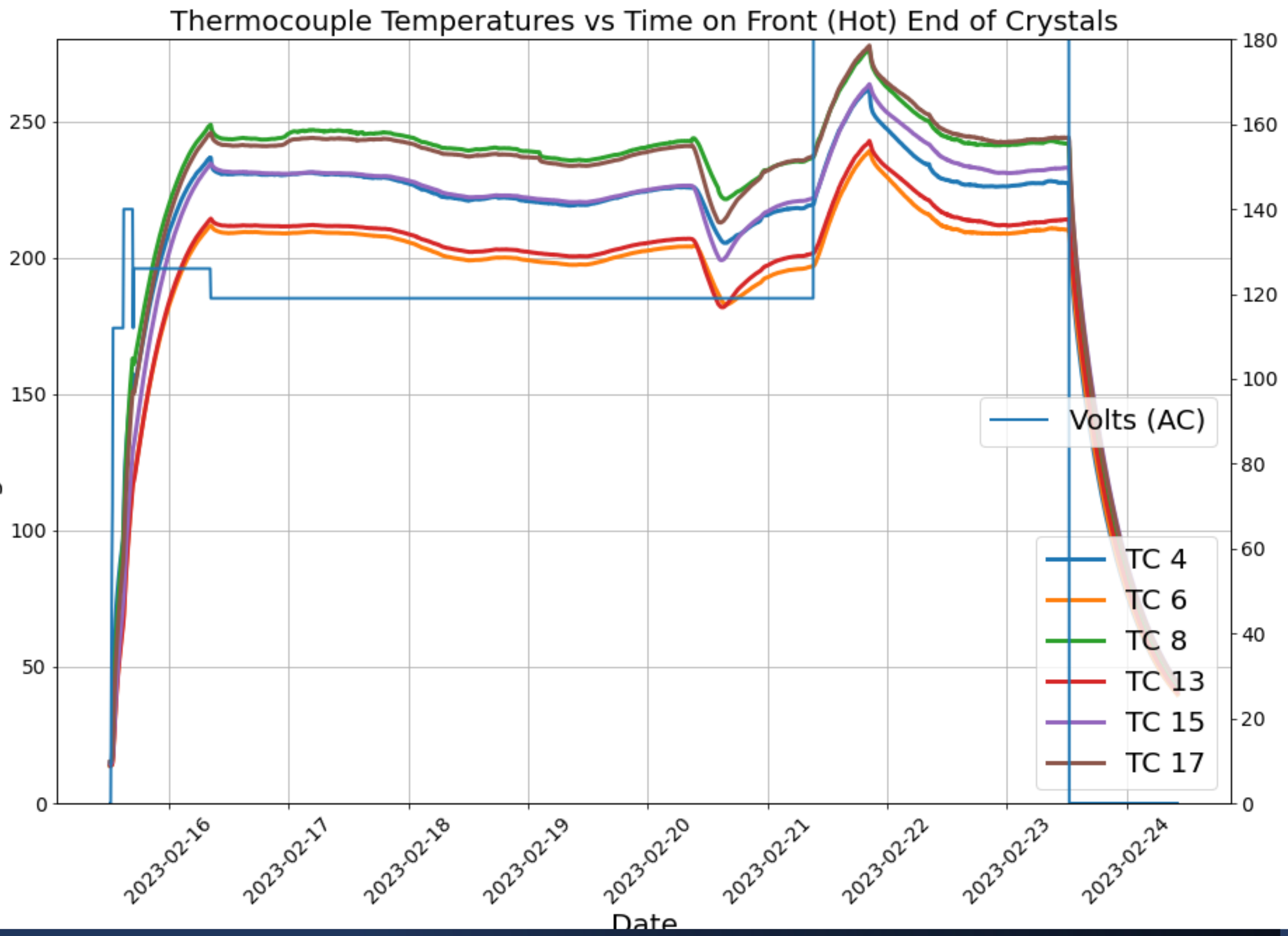
Figure 4.4: Transmission of light, at $\lambda = 410$ nm, through 4 cm of lead glass as a function of distance along the bar for a radiation-damaged bar before and after heat curing at 260 °C.

2014

The ECAL blocks under heat treatment

Three measurements of the PD current: I0 = intensity direct; I1 – intensity through clear area; I2 – intensity through yellow area. I_1(calc) = I_0*0.88*0.93. Abs= $(I_1-I_2)/I_1$

#	Rad or T, C / time	type	I_0	I_1	I_1/calc	I_2	Absorb	comment
8	135 Gy	42	3.06		2.50	0.90	64%	
8	250 / 1	42	3.03		2.48	2.45	1.2%	
3	131 Gy	42	3.26			1.03		
3	225 / 1	42	2.90		2.37	2.31	2.5%	
2	130 Gy	42						
2	200 / 1	42	1.76		1.44	1.33	7.6%	
A	80kRad?	42	2.68			0.07		
A	225 / 1	42	2.53	2.06	2.07	1.95	5.3%	
B	80kRad?	40	2.61			0.05		
B	225 / 1	40	2.61	2.14	2.14	1.86	13%	
C	80kRad?	38	2.66	2.20	2.18	0.48	78%	
C	150 / 4	38	2.57	2.19	2.10	1.8	18%	



Thermocouple Temperatures vs Time on Front (Hot) End of Crystals
0
50
100
150
200
250
0
20
40
60
80
100
120
140
160
180
2023-02-16
2023-02-17
2023-02-18
2023-02-19
2023-02-20
2023-02-21
2023-02-22
2023-02-23
2023-02-24
Date
Volts (AC)
TC 4
TC 6
TC 8
TC 13
TC 15
TC 17