Overview of CMS Activities at SiDet

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Fermi National Accelerator Laboratory

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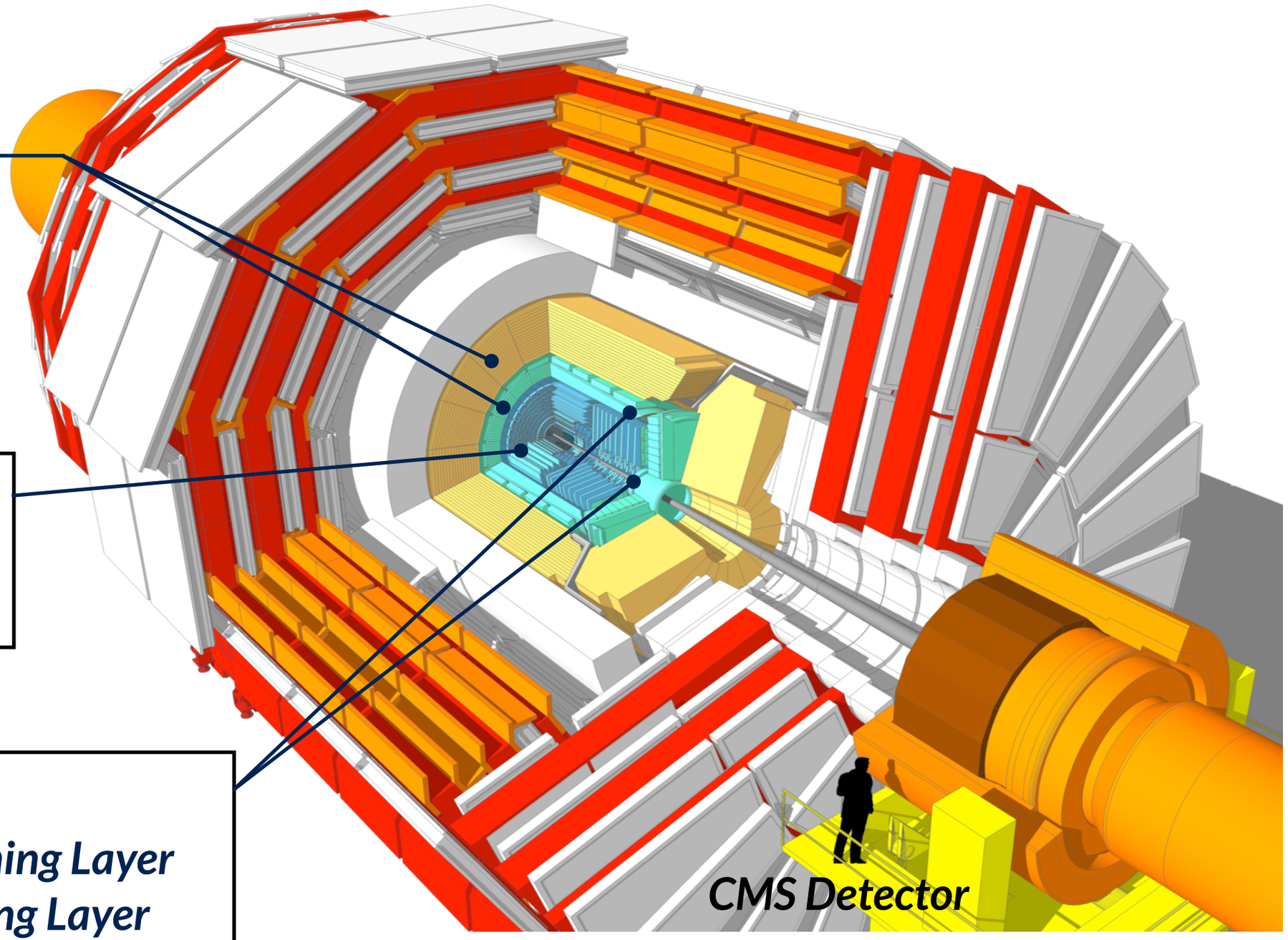
Overview

- CMS activities at SiDet are currently focused on the HL-LHC upgrade of CMS sub-detectors

Calorimeter
- ***High Granularity Calorimeter***

Tracker
- ***Outer Tracker***
- ***Pixel Detector***

Timing Detector
- ***Endcap Timing Layer***
- ***Barrel Timing Layer***

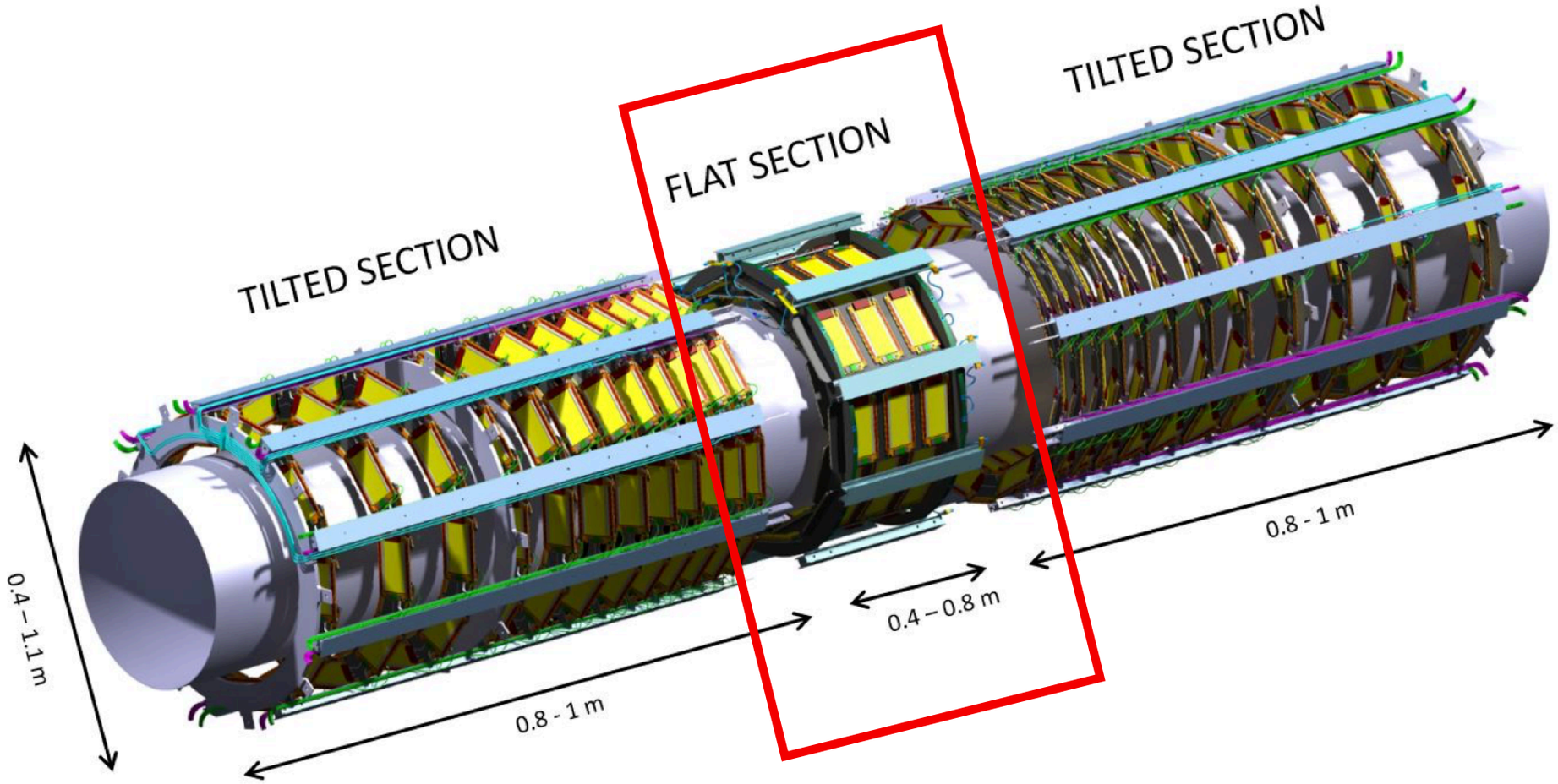


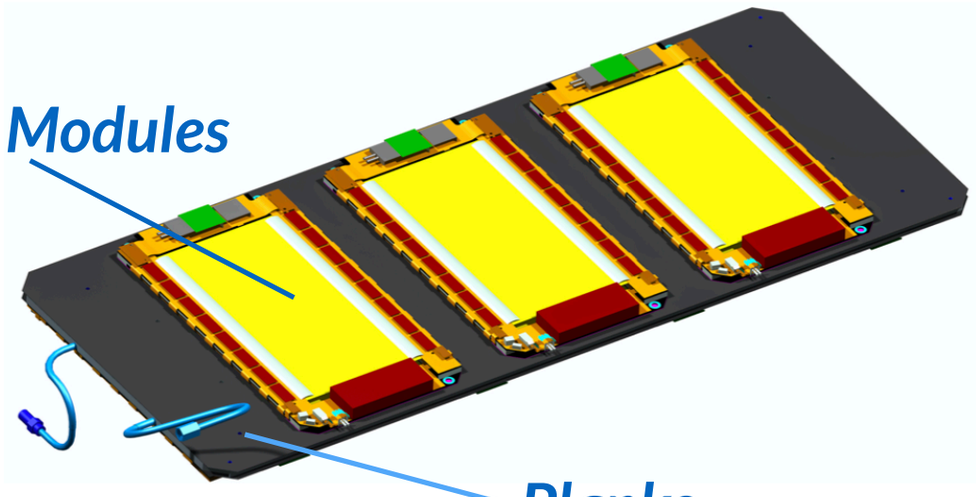
Outline

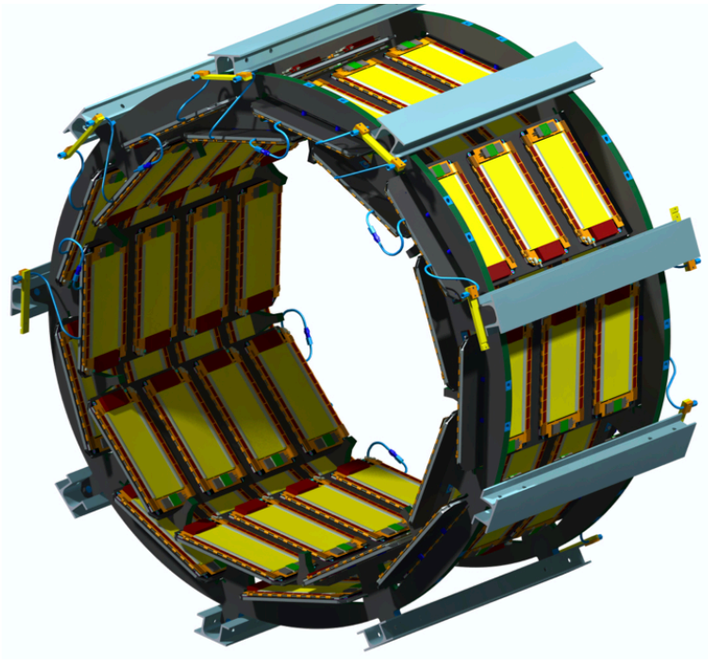
- For each sub-detector:
  - Rough time-line and space utilization at SiDet for HL-LHC upgrade
  - Current R&D and pre-production phase activities
  - Plans for the production phase activities
  - Points of contact

Outer Tracker

Outer Tracker Detector

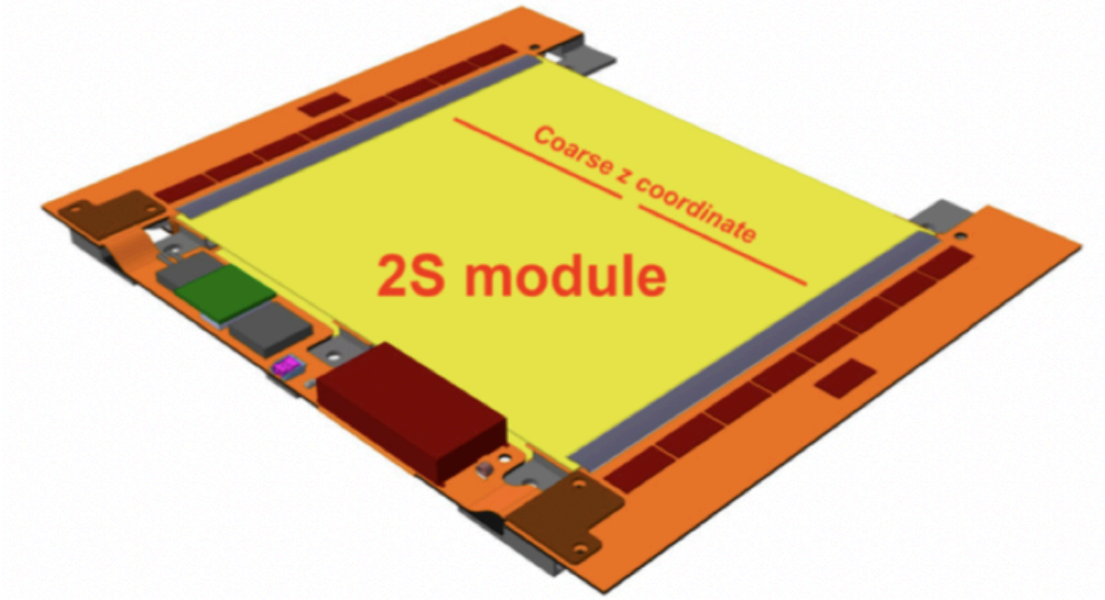


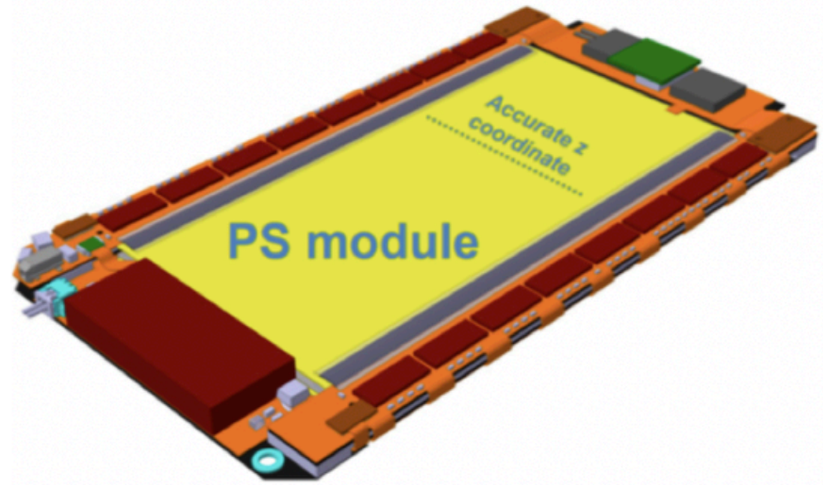


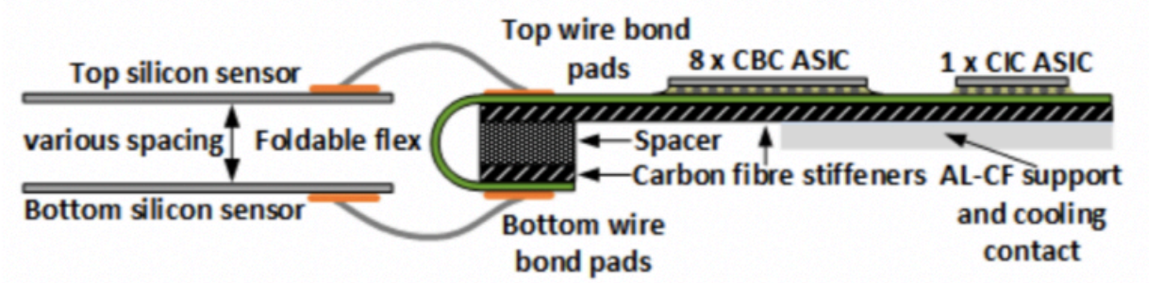


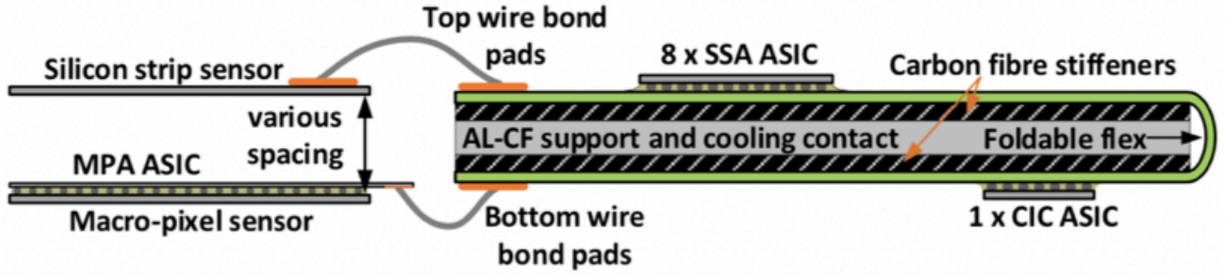
Flat barrel (layer 1)

Outer Tracker Production Scope at SiDet









- Fermilab responsibilities at SiDet:
  - Silicon sensors and hybrids testing
  - Assembling ~ 1000 2S modules and QC + ~10% spares
  - Assembling ~ 1250 PS modules and QC + ~10% spares
  - Assembling PS modules on planks
  - Shipping planks to Cern
  - Shipping 2S modules & remaining PS modules to Europe integration centers

Overall Time-line

Now

Mid 2022

2025

- Prototyping and R&D phase
- Preparing SiDet for production

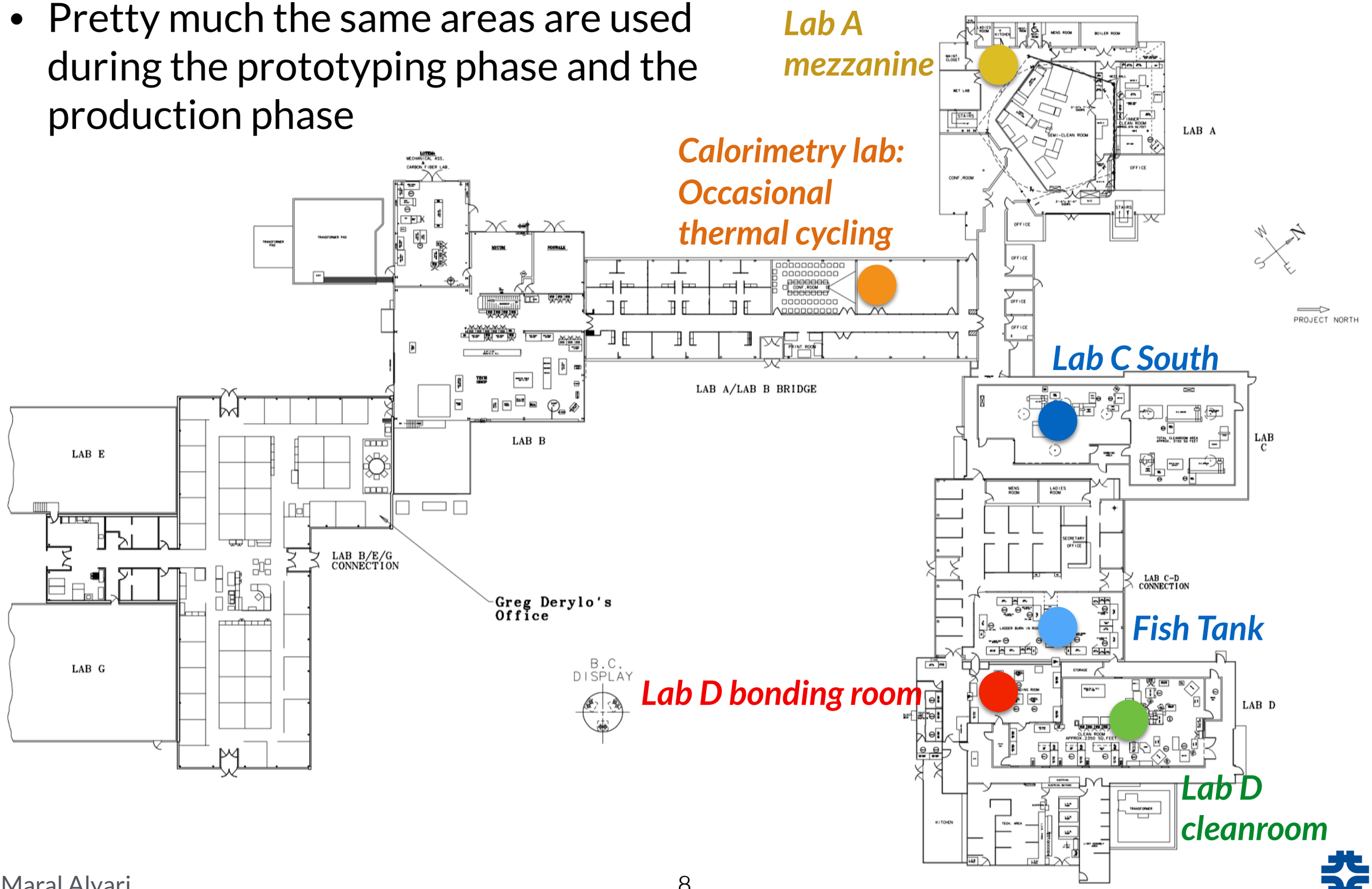
- Production phase
- Preproduction: 5%

Production starts

- Next slides will cover:
  - The areas at SiDet utilized by the Outer Tracker
    - The current activities in each area
    - Activities planned during the production phase in that area

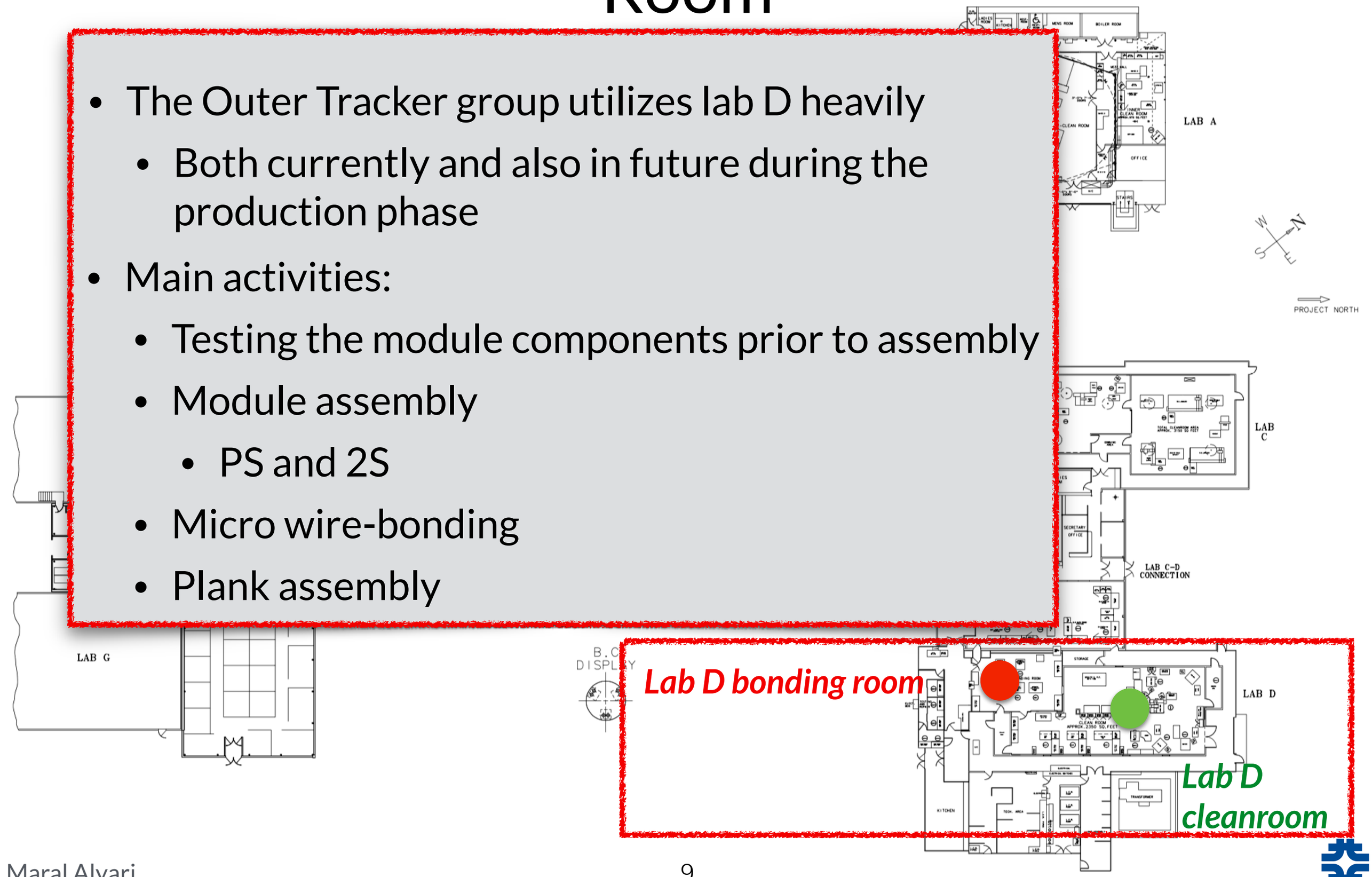
Outer Tracker at SiDet

- Pretty much the same areas are used during the prototyping phase and the production phase



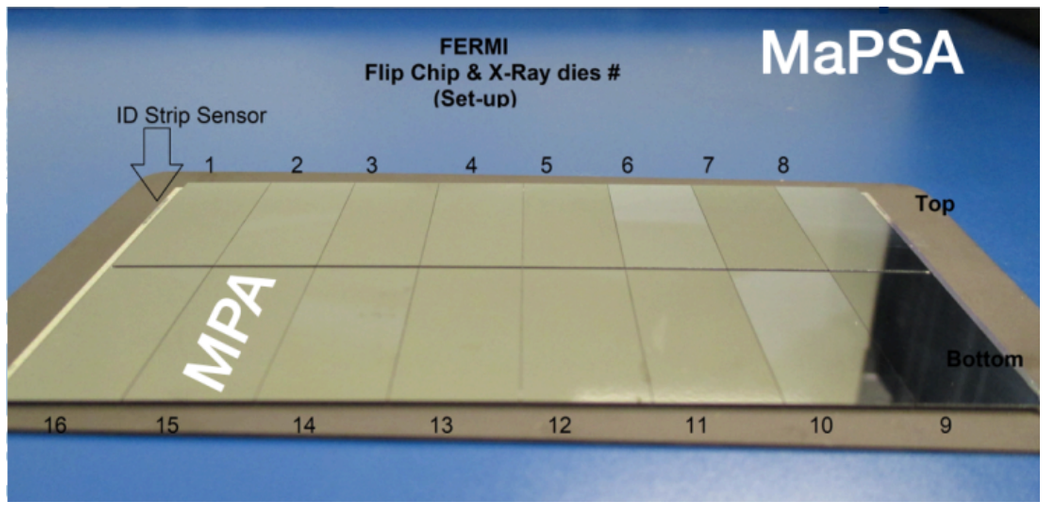
Outer Tracker: Lab D and Lab D Wire-Bonding Room

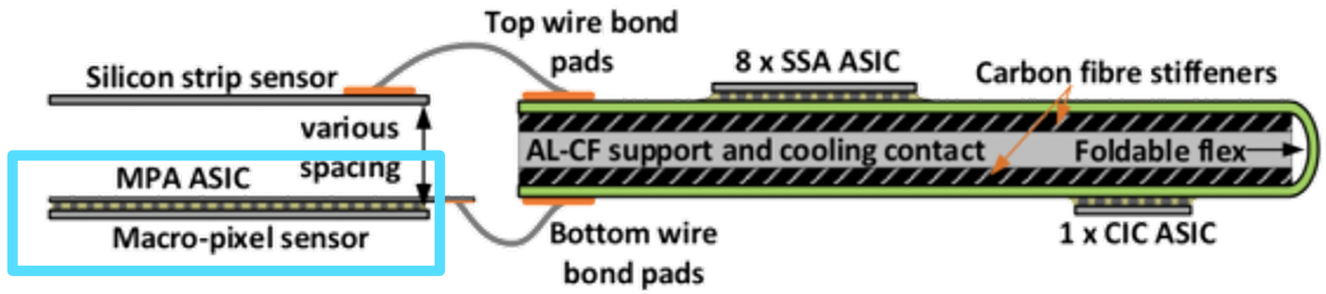
- The Outer Tracker group utilizes lab D heavily
  - Both currently and also in future during the production phase
- Main activities:
  - Testing the module components prior to assembly
  - Module assembly
    - PS and 2S
  - Micro wire-bonding
  - Plank assembly



MaPSA Testing in Lab D

- MaPSA = **Ma**cro **P**ixel **S**ub-**A**ssembly
  - Silicon macro-pixel sensor + 16 macro-pixel ASICs (MPAs)
  - Part of CMS Phase 2 Outer Tracker PS module:





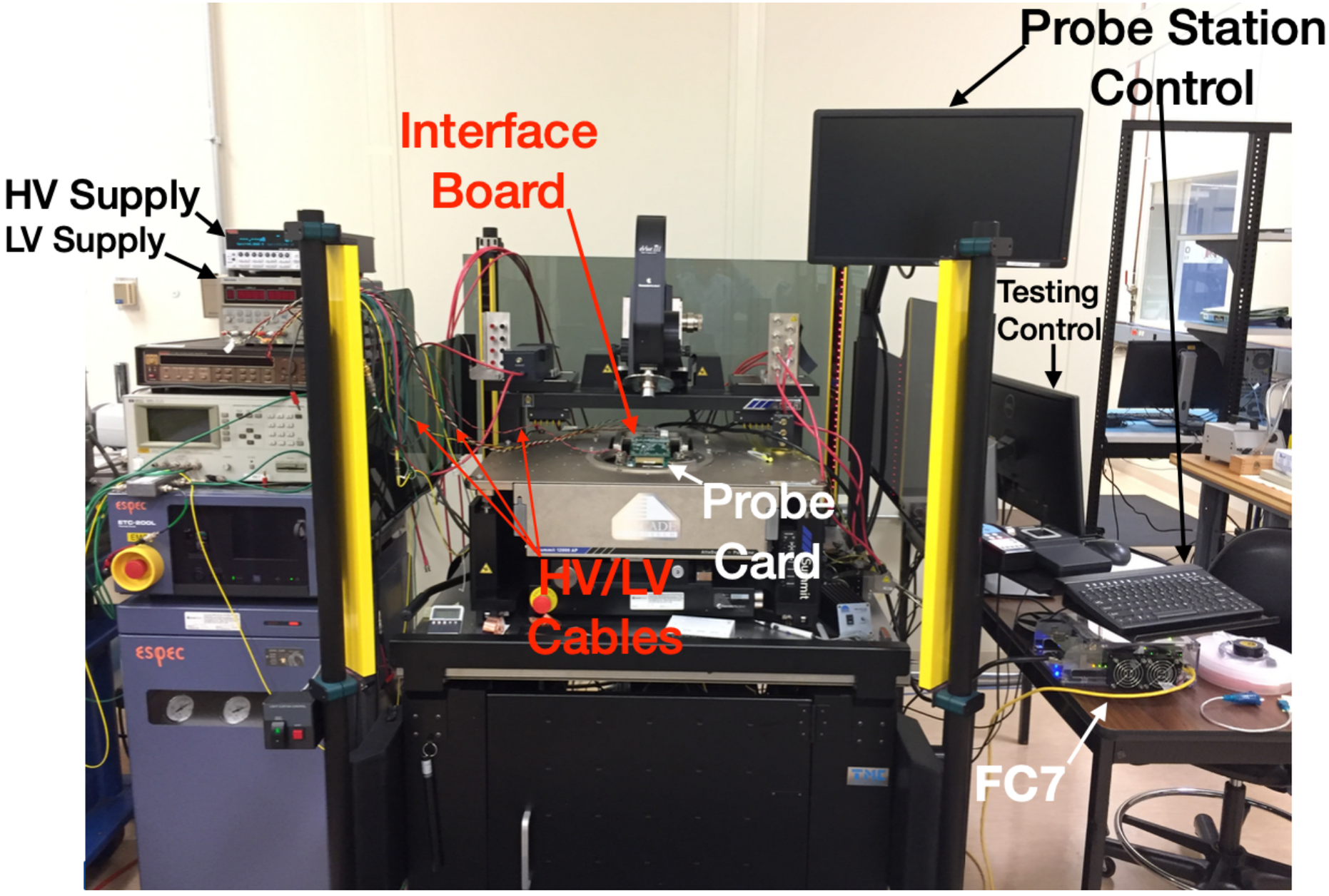
  - MaPSA tests measure
    - IV and current draw
    - Memory and register tests
    - Pixel efficiency masking, trimming, noise, threshold

- MaPSA testing is currently going on in lab D and will continue during the production phase

MaPSA Testing in Lab D

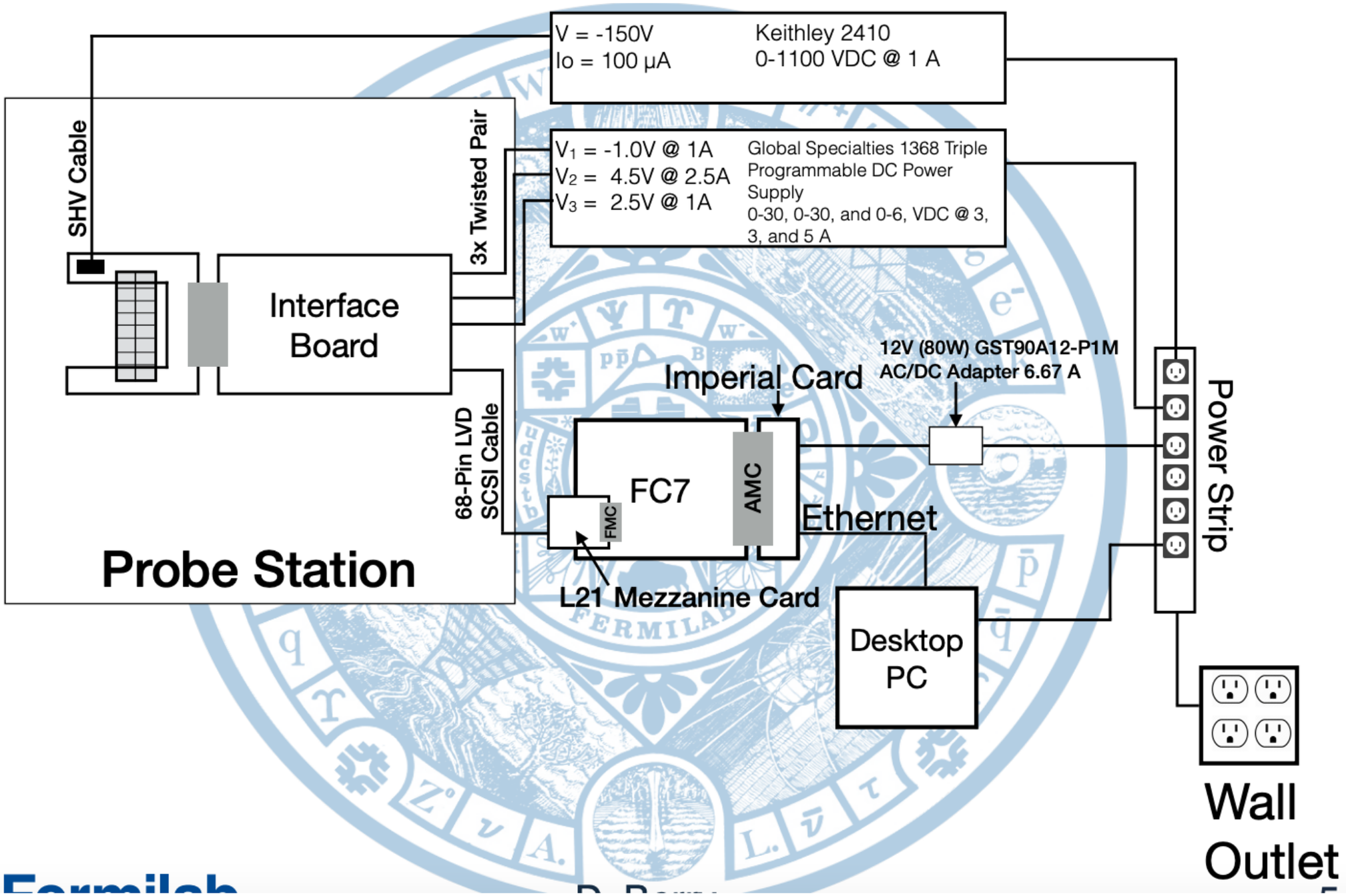
MaPSA probe station in Lab D, Zone 3

- Passed ORC in May, 2020 (ORC-1737)



MaPSA Testing in Lab D

MaPSA probe station schematic



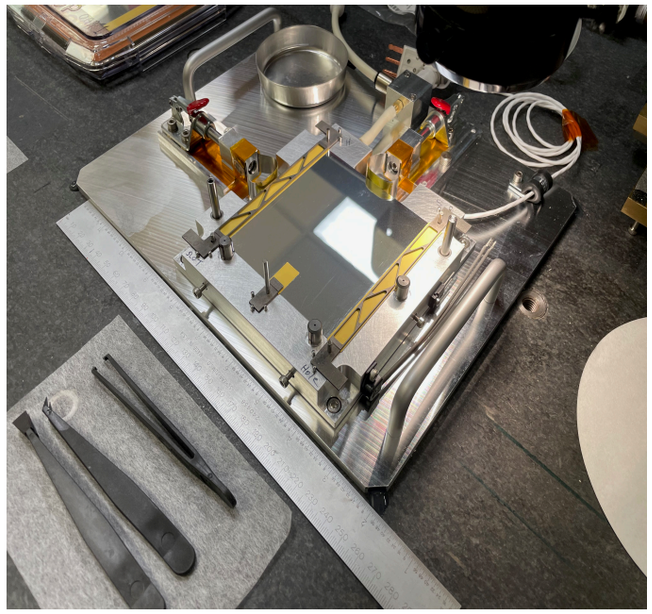
MaPSA Testing in Lab D

MaPSA testing schedule

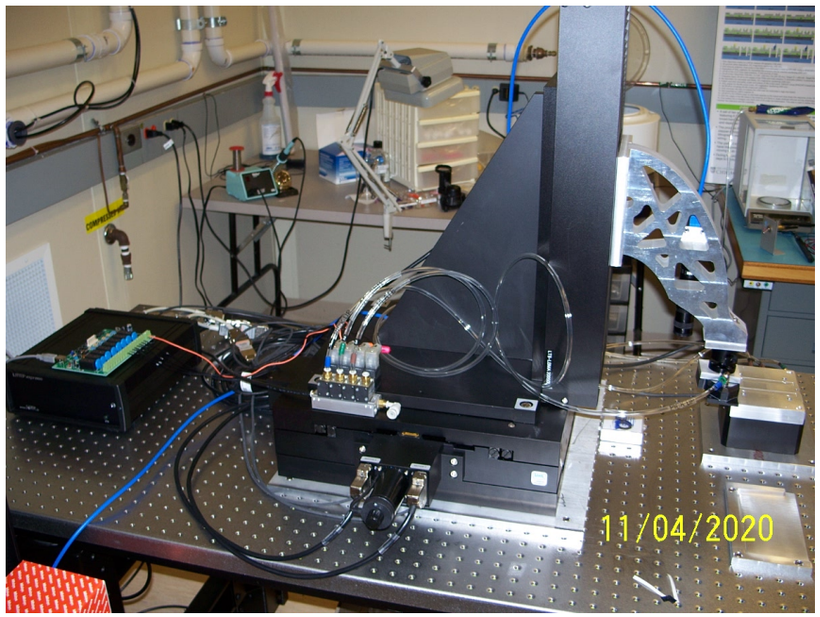
- Testing responsibilities shared among 1 scientist and 1-2 postdocs since fall 2020
- Lab D zone 3 is used for MaPSA testing typically 3-4 days per week (scheduled ahead of time)
- Can usually test 1.5-2 MaPSAs per day
- Plan to finish Round 2 testing by the end of May
  - Have tested 44 Round 2 MaPSAs since Jan. 2021
  - Only 12 Round 2 MaPSAs remain to be tested
- Will continue to use probe station occasionally throughout Outer Tracker project (until 2025)

Wire-bonding and Module Assembly

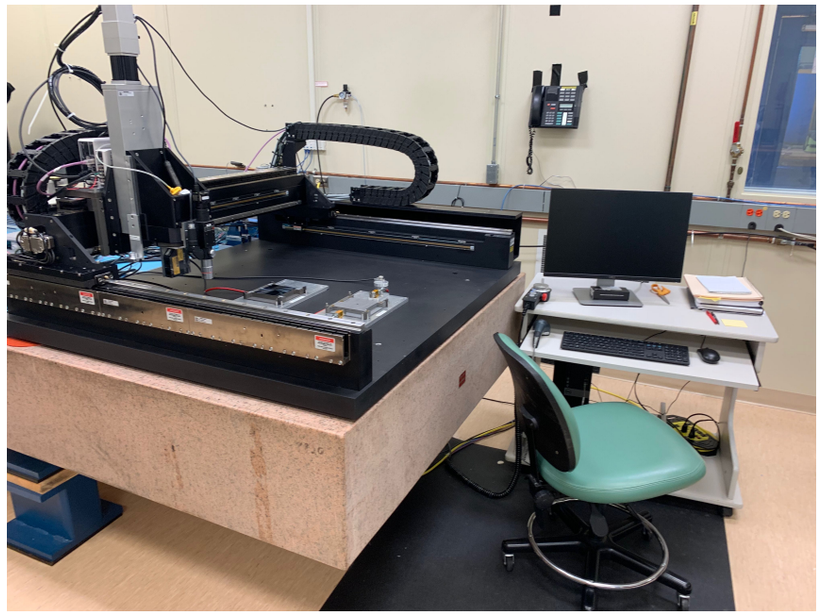
- Currently at the prototyping and preparation phase



Manual fixture assembly on a CMM



Lang stage automated assembly for PS modules



Metrology with an Aerotech gantry and Keyence laser

- Starting in 2022 US CMS will assemble and test at SiDet
  - 1250 PS modules plus spares
  - 1000 2S modules plus spares

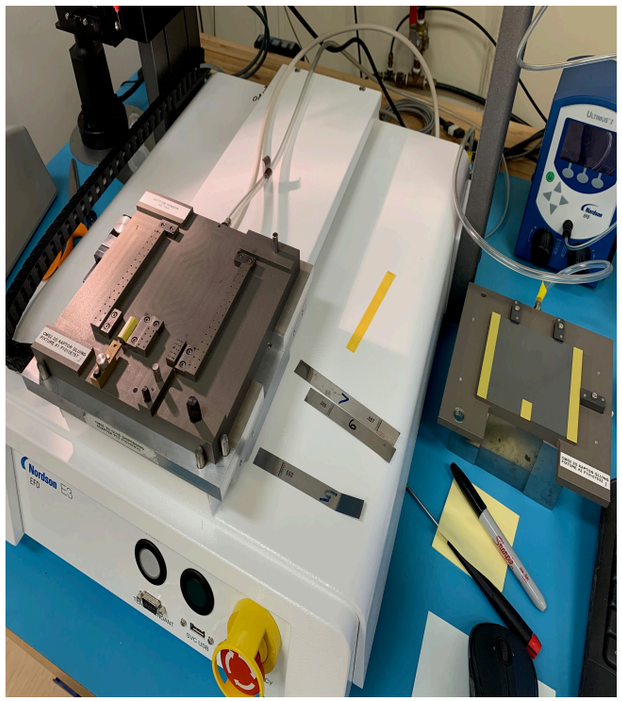
10M wire bonds!

- Lead Engineer: Greg Derylo

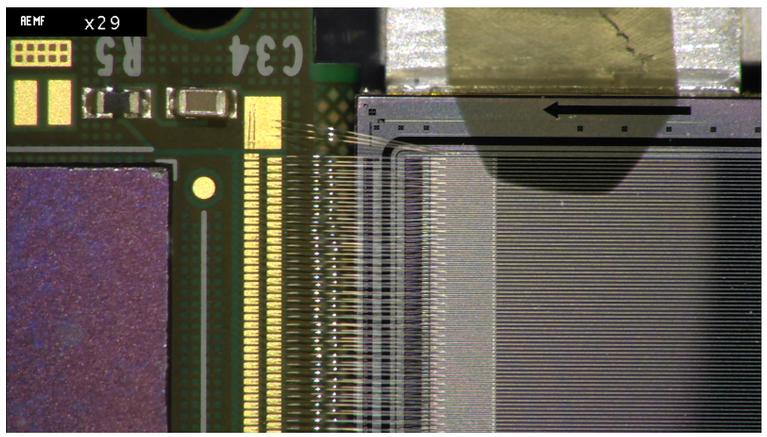
Lead Tech: Bert Gonzalez

Wire-bonding and Module Assembly

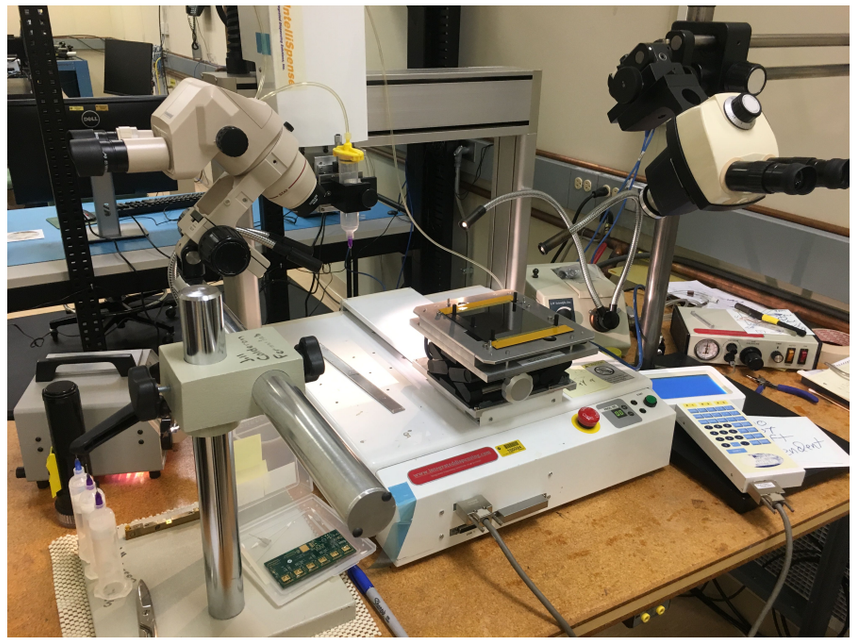
- Currently at the prototyping and preparation phase



Nordson gluing robot

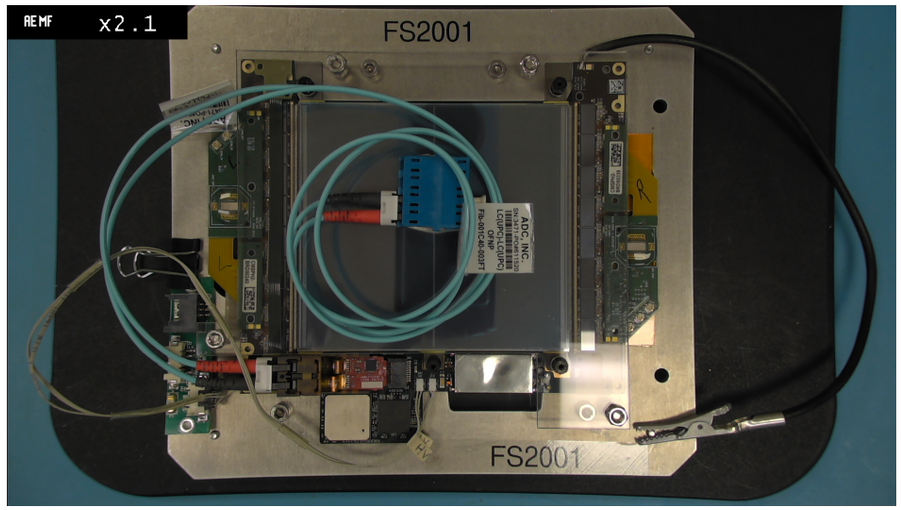


Wire bonding



Wire bond encapsulation

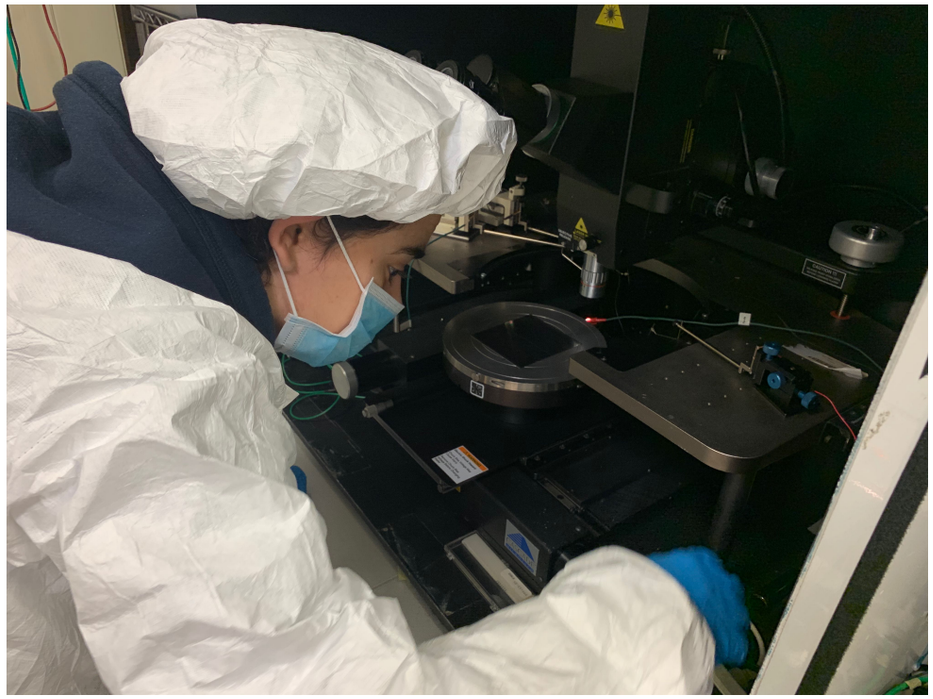
- The effort will be spaced over 2.5 years
- Technicians will handle assembly (gluing) operations
- Testing will be done by postdocs and students
  - The plan is to have students operate the Aerotech and PS automation systems



2S carrier plate design

Reception Tests

- Reception testing of Hybrids will be taking place in lab D when production starts
- Sensor measurements will be done prior to module assembly and before adding the hybrids
  - Manual probe station in lab D

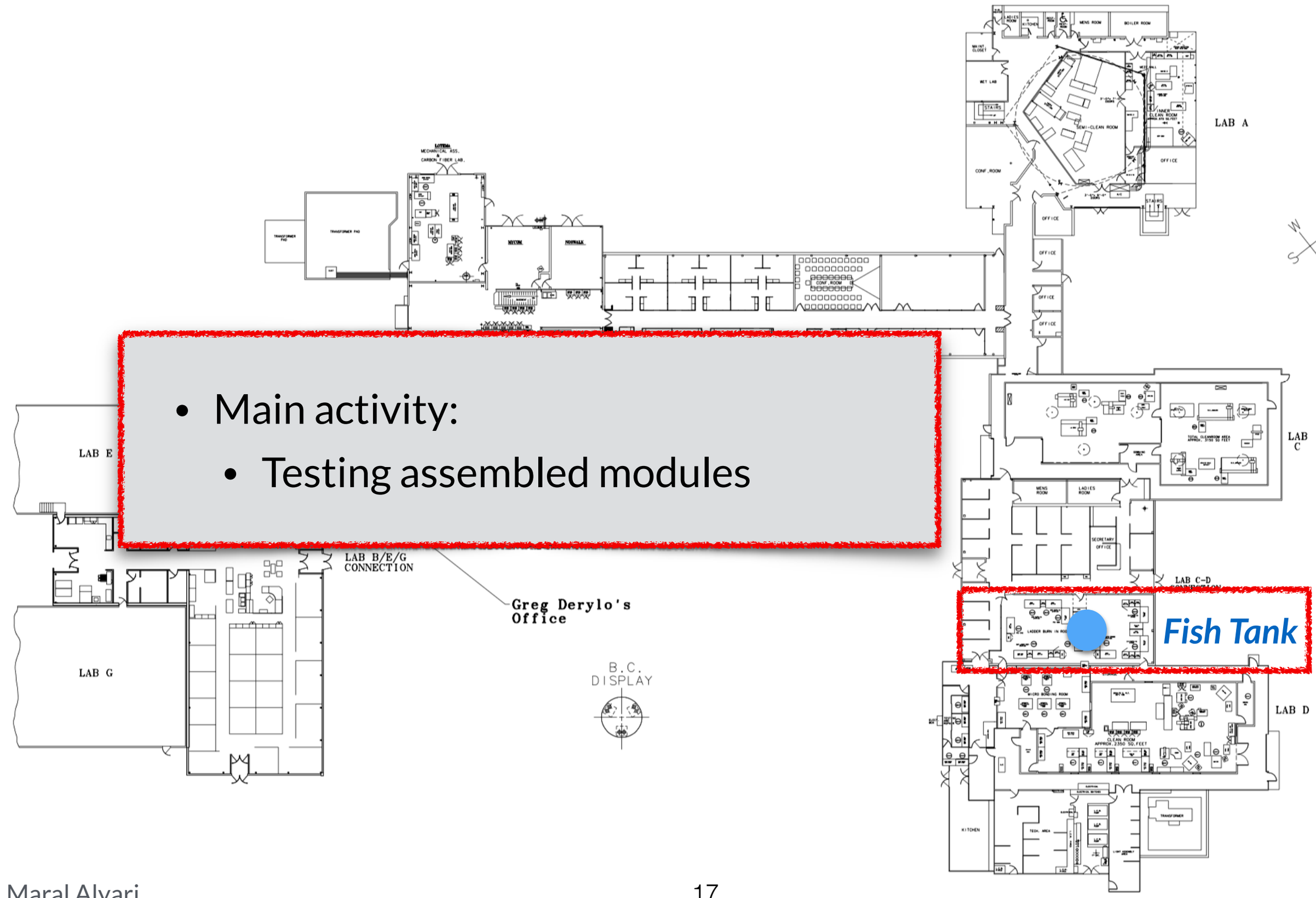


Sensor reception IV measurements

Reception testing of hybrids

Outer Tracker: Fish Tank

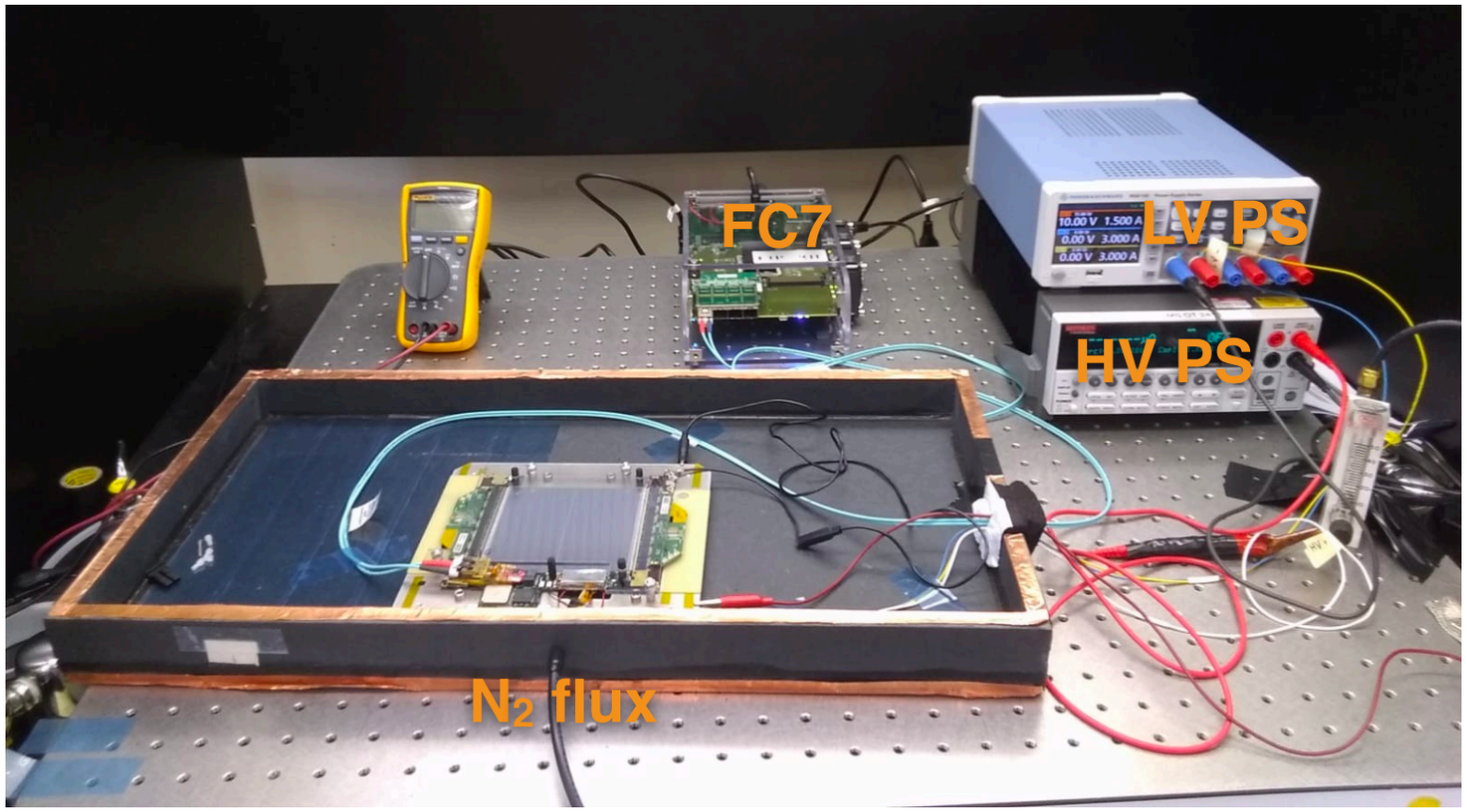
- Main activity:
  - Testing assembled modules



Fish Tank

Pre production activities - Module test setup

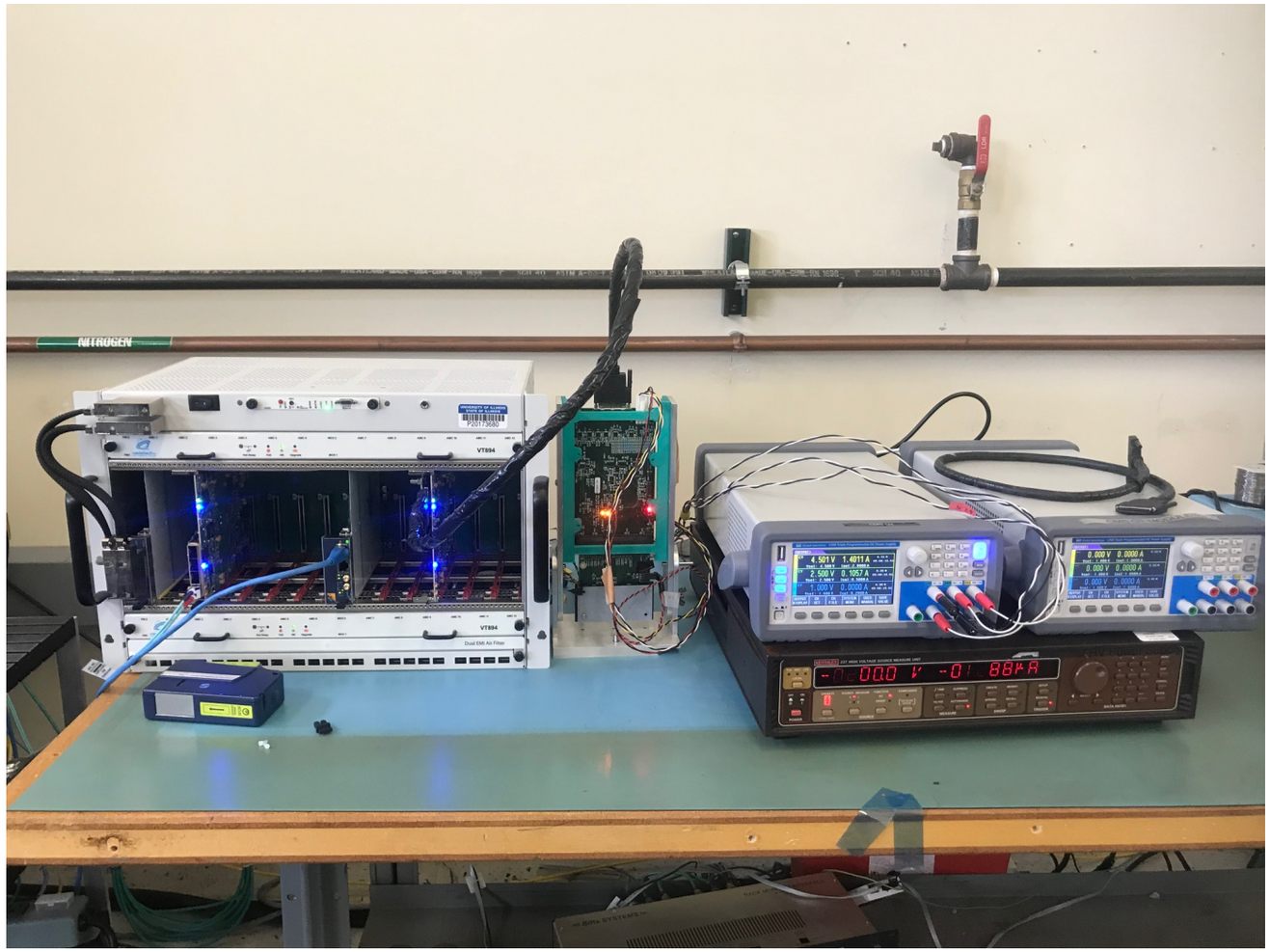
- Test stand to characterize Strip-strip and Pixel-strip modules
- FC7 DAQ card used in many test beams and certified in many ORCs
- Low voltage power supply with current limits
- High Voltage power supply 10uA@300V



Fish Tank

Pre production activities - uTCA test setup

- Test stand to characterize Strip-strip and Pixel-strip modules based on uTCA DAQ hardware
- FC7 DAQ card used in many test beams and certified in many ORCs
- Low voltage power supply with current limits
- High Voltage power supply 5uA@200V



Fish Tank

Production readiness - Burnin system

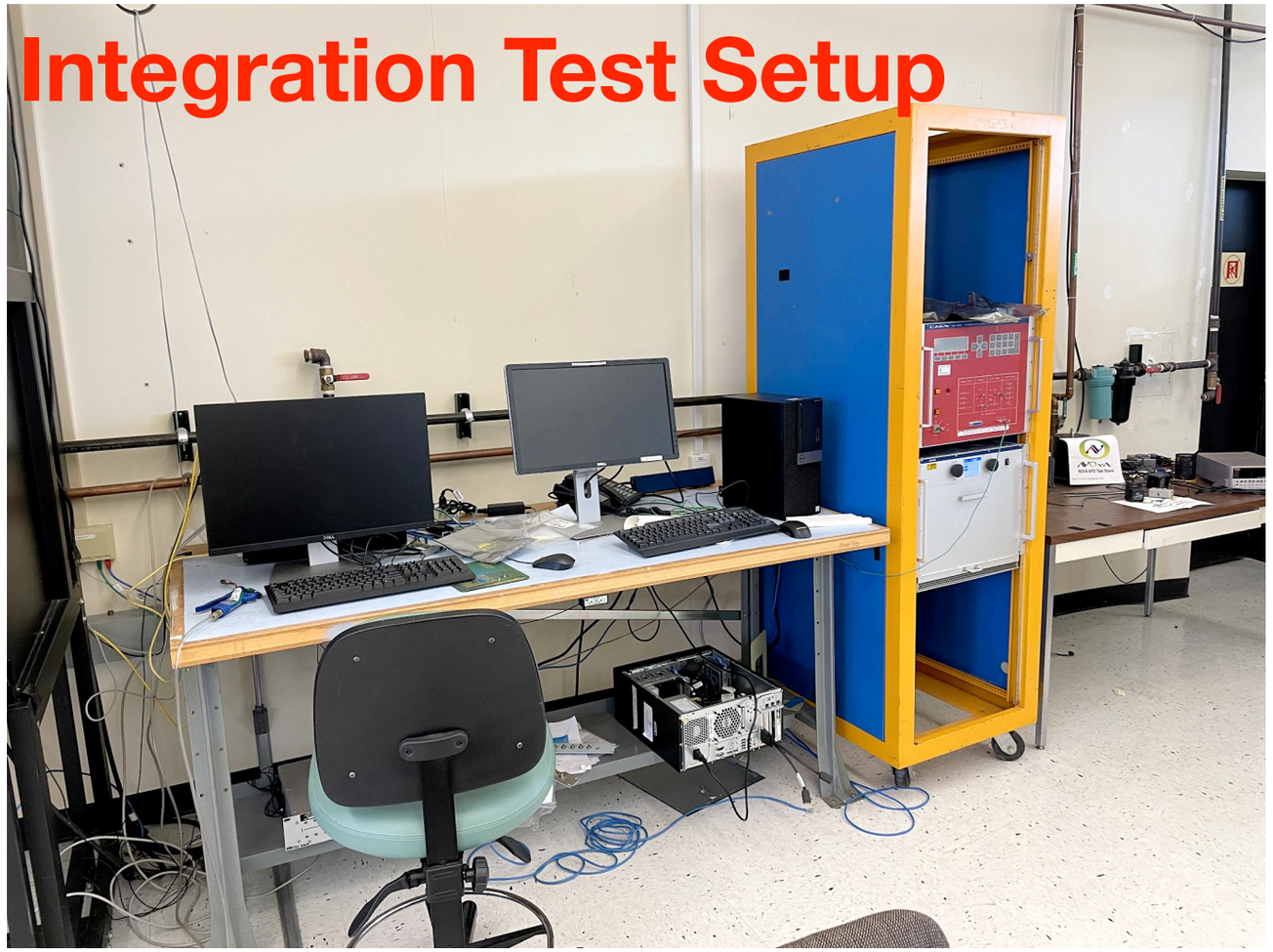
- Burnin box system for module production testing
- Running commissioning tests of the software system with one strip strip module
- Low voltage power supply with current limits
- High Voltage power supply 5uA@200V

- ORC-1663
- https://fermipoint.fnal.gov/service/tsworc/Lists/tsworc/EditForm.aspx?ID=3149&Source=https://fermipoint.fnal.gov/service/tsworc/SitePages/Home.aspx

Fish Tank

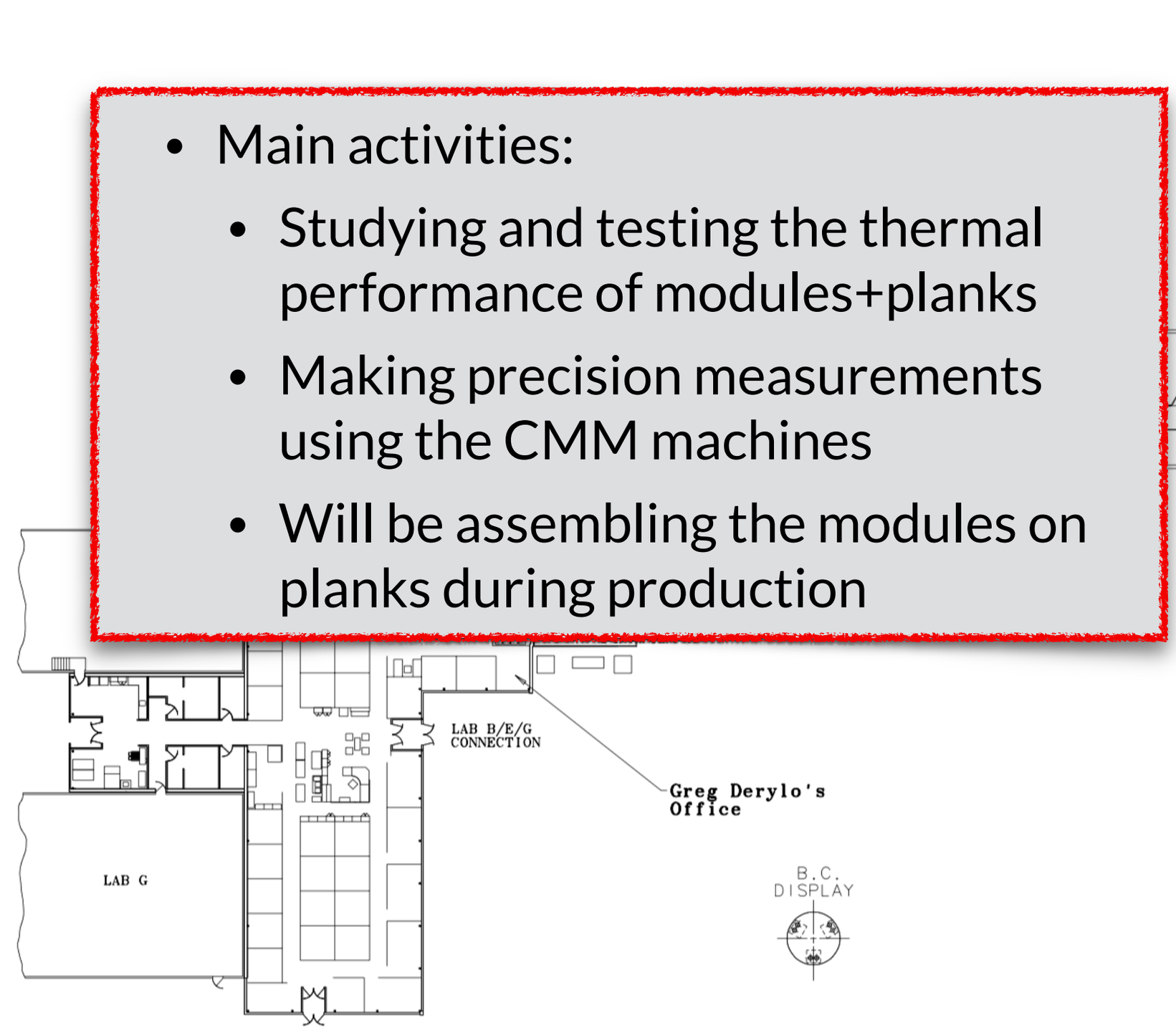
Production readiness: Integration testing

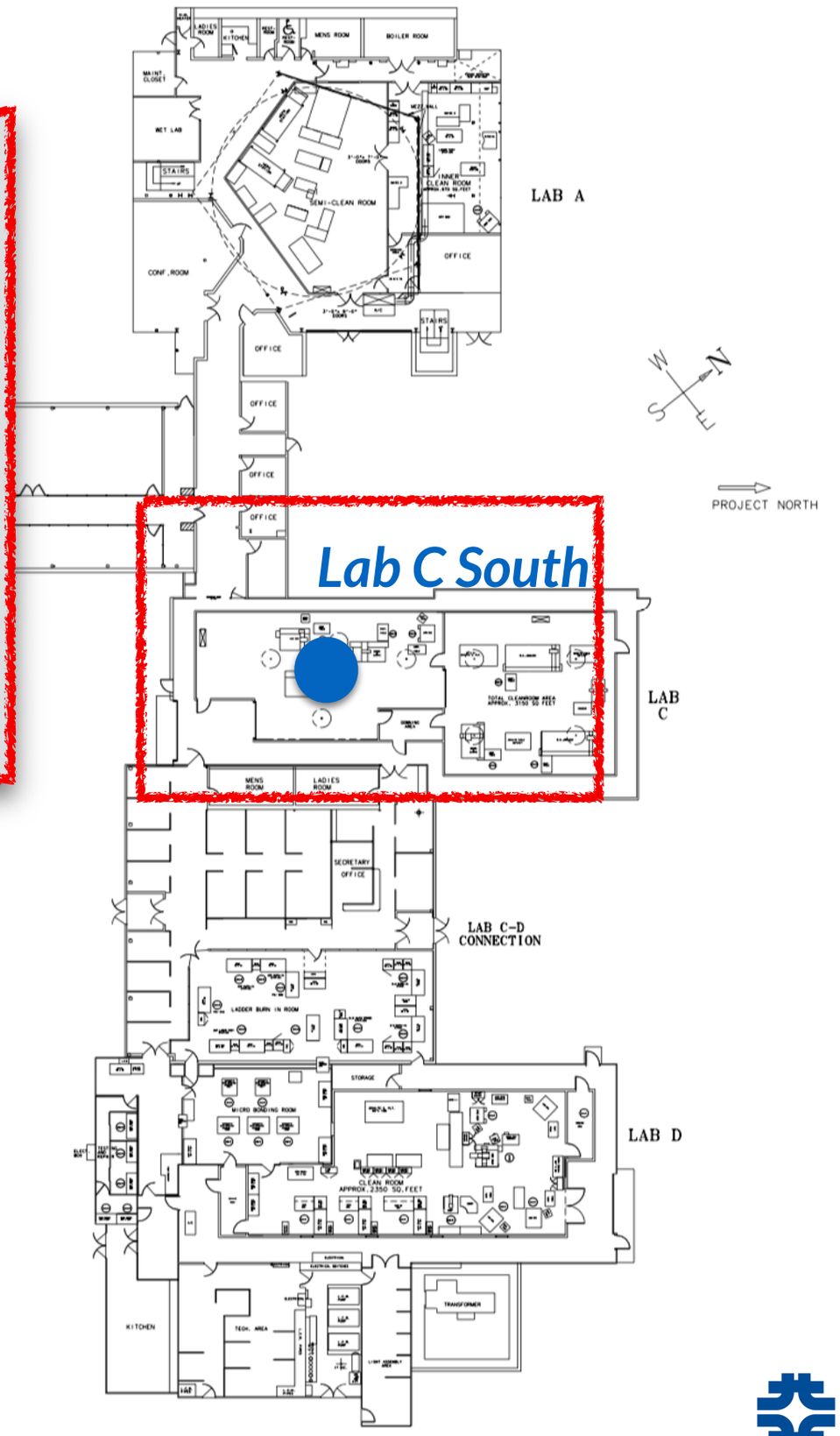
- Creating a multiple channel outer tracker module testing system in the Fish Tank
- Currently just power but will include optical readout system when modules become available
- System will be moved to lab C when modules integrated onto planks
  - Likely in winter of 2022
- Only one person working on it at a time



Outer Tracker: Lab C South

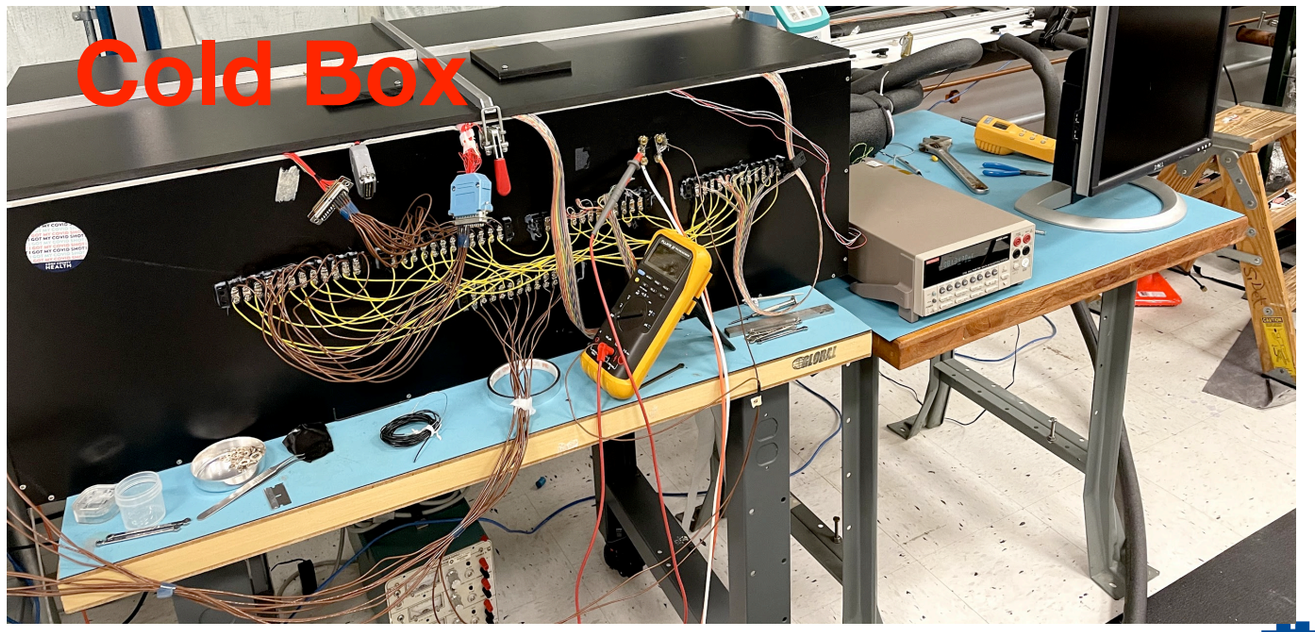
- Main activities:
  - Studying and testing the thermal performance of modules+planks
  - Making precision measurements using the CMM machines
  - Will be assembling the modules on planks during production





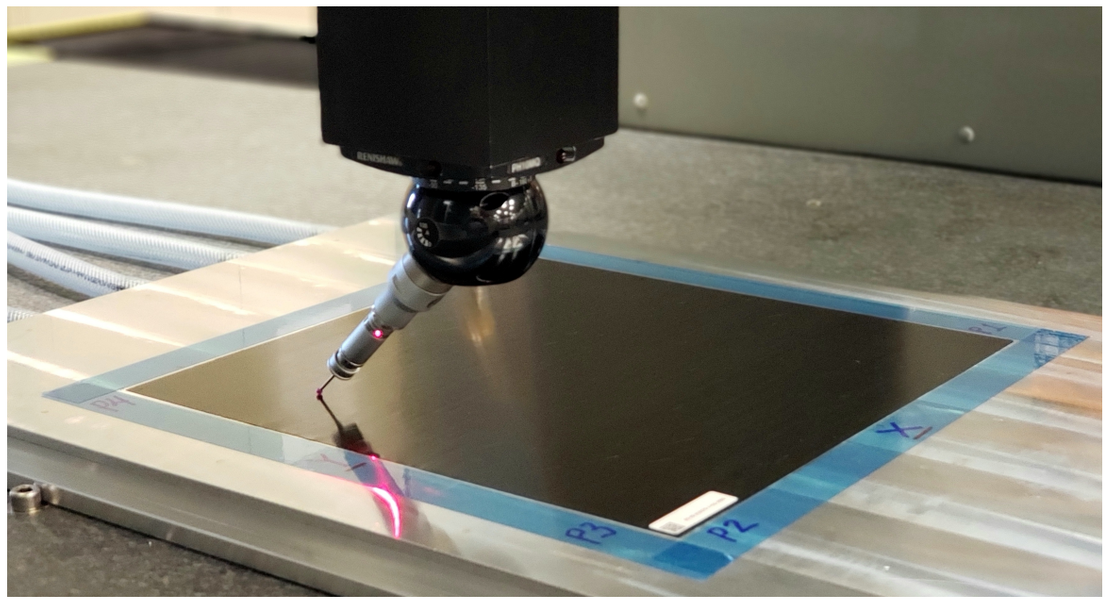
Lab C South

- CO2 cooling system configured for cooling PS-module after being mounted on planks
- CO2 system commissioned and completed ORC
- Currently used by one person with remote support from another
- System will be used from now until completion of the TBPS (Outer tracker flat barrel) integration (2025)



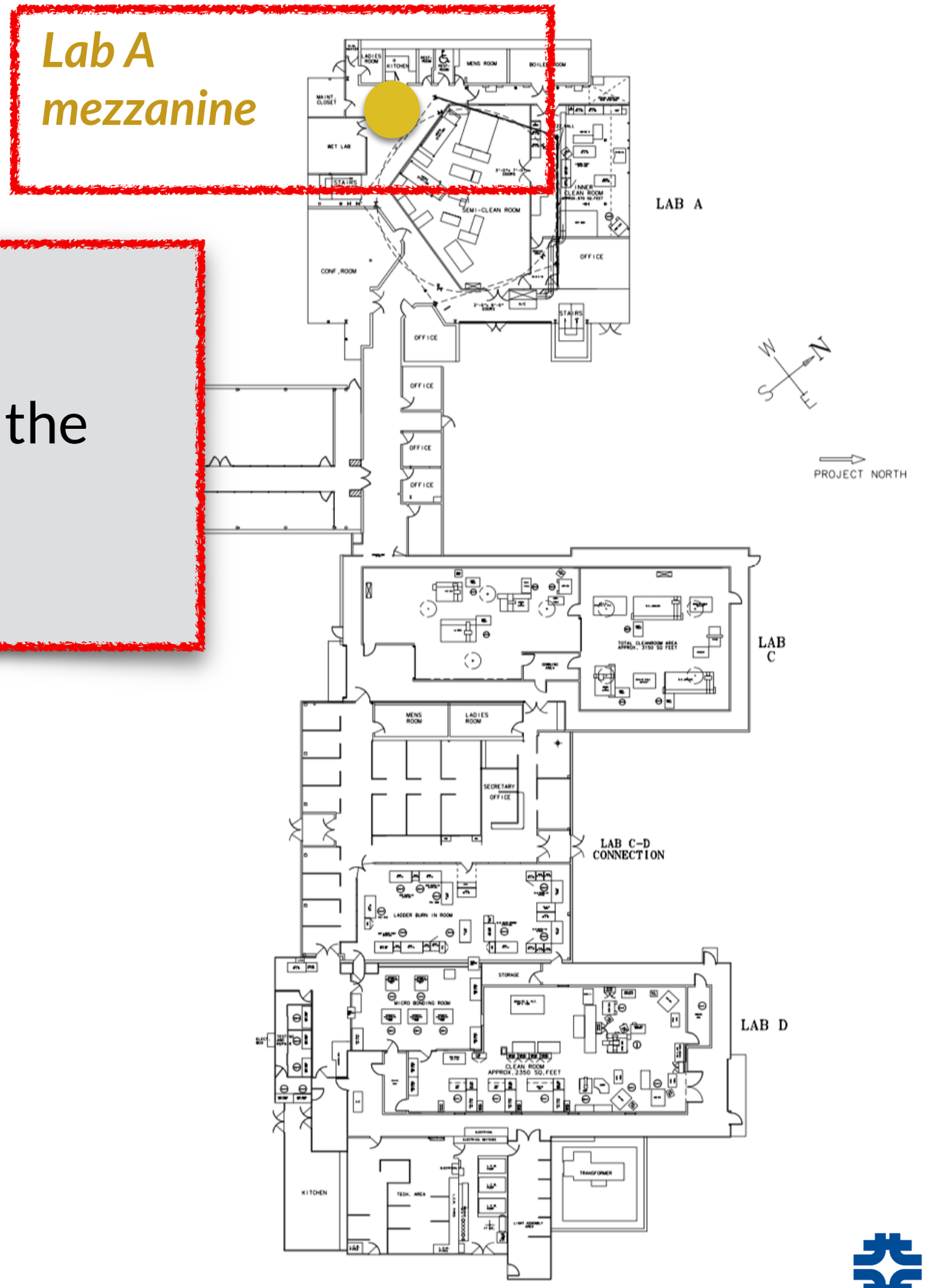
Lab C South

- Outer tracker is responsible for providing carbon fiber panels for all (iCMS) PS base-plates
  - Layup at MAB
  - QC in lab C South



Lab C: CMM measurements of CF panels.

Outer Tracker: Lab A Mezzanine

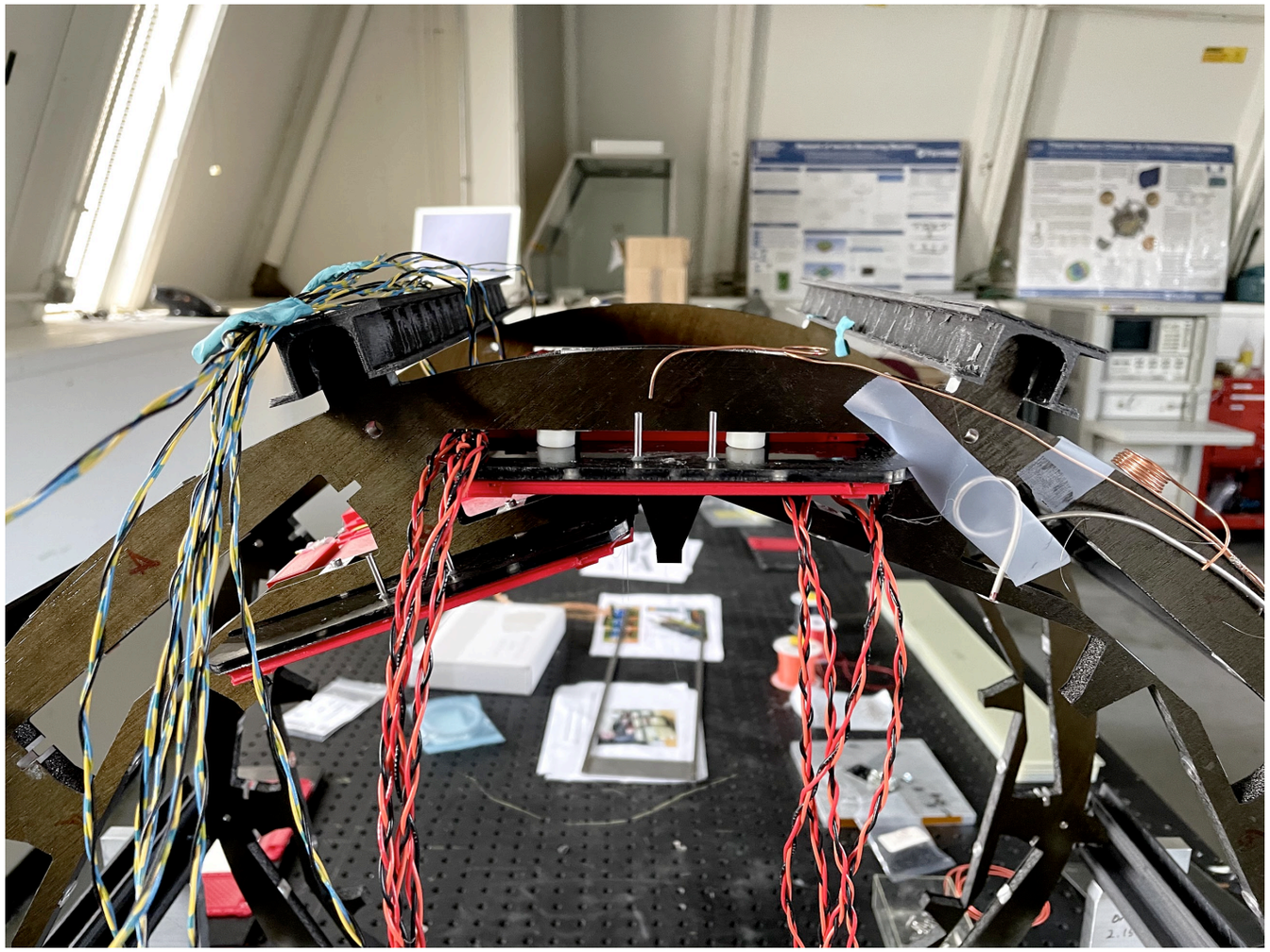


- Main activity:
  - Mechanical mock-up to study the services

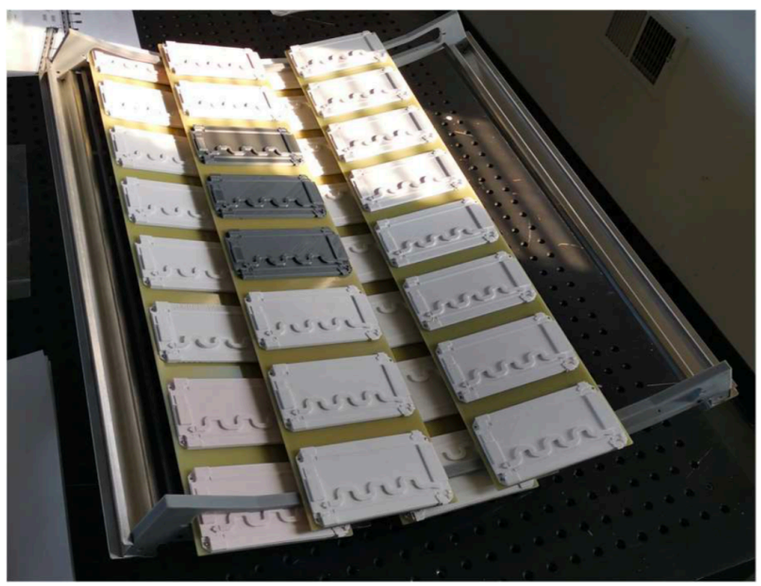
Lab A Mezzanine

- Mock-up to verify and debug the CAD service routing of the TBPS (Outer tracker flat barrel)
  - Currently working in Lab C Mezzanine
  - Building mock-up with 3D printed models from CAD
  - 1-2 person working on the structure at a time
    - 1 person for long duration work
      - Completing HA for 2 person work
  - May move the setup to a more easily accessed area
  - Routing to be determined before integration
    - Likely before July 2022

Lab A Mezzanine



Layer 1 Mockup



Layer 3 Mockup

Outer Tracker Points of Contact

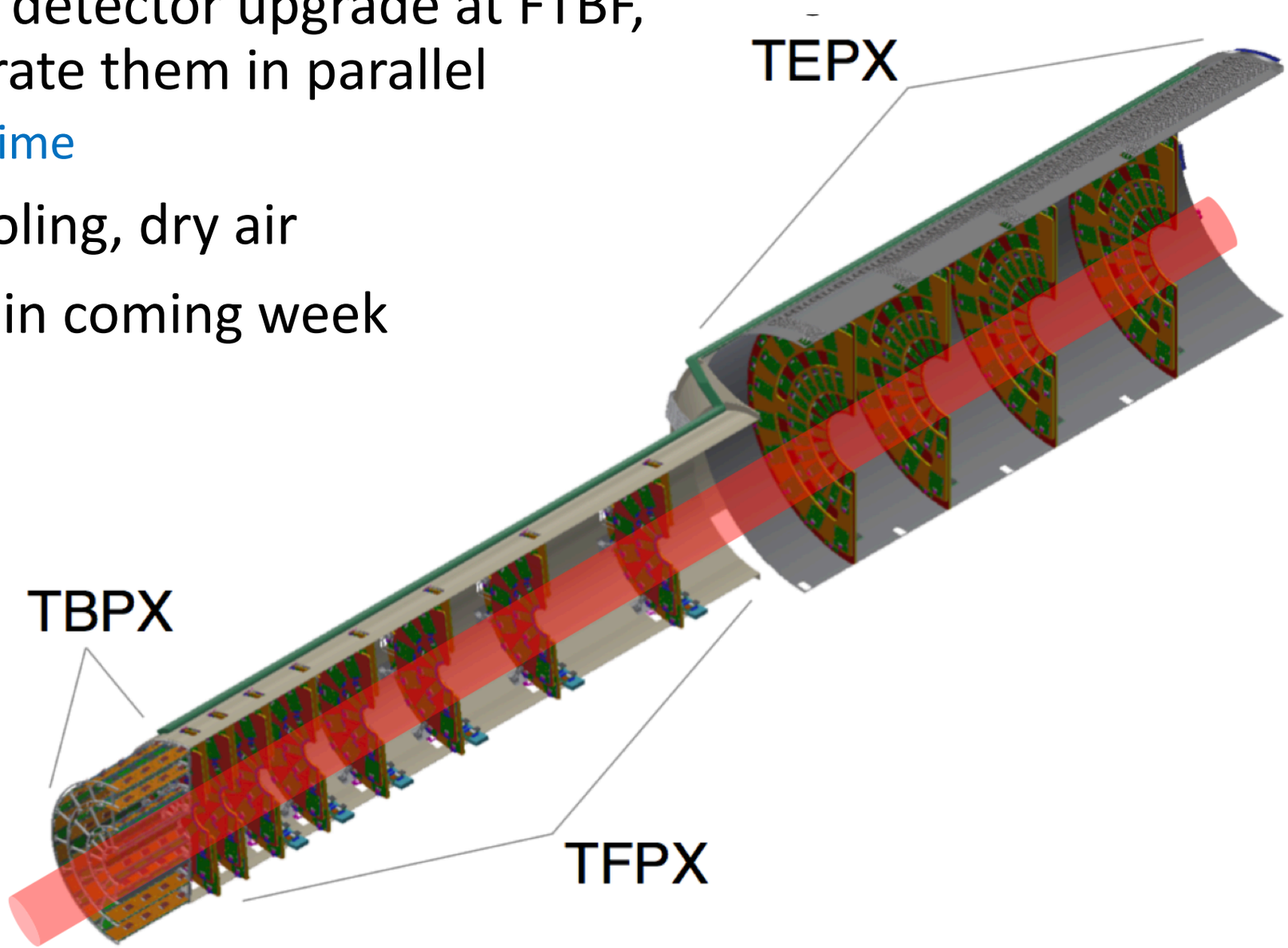
- For more information or planning an on-site visit please contact:
  - Lenny Spiegel
    - lenny@fnal.gov
  - Doug Berry
    - drberry@fnal.gov
  - Pasha Murat
    - murat@fnal.gov
  - Lorenzo Uplegger
    - uplegger@fnal.gov

Pixel Detector

Pixel Detector

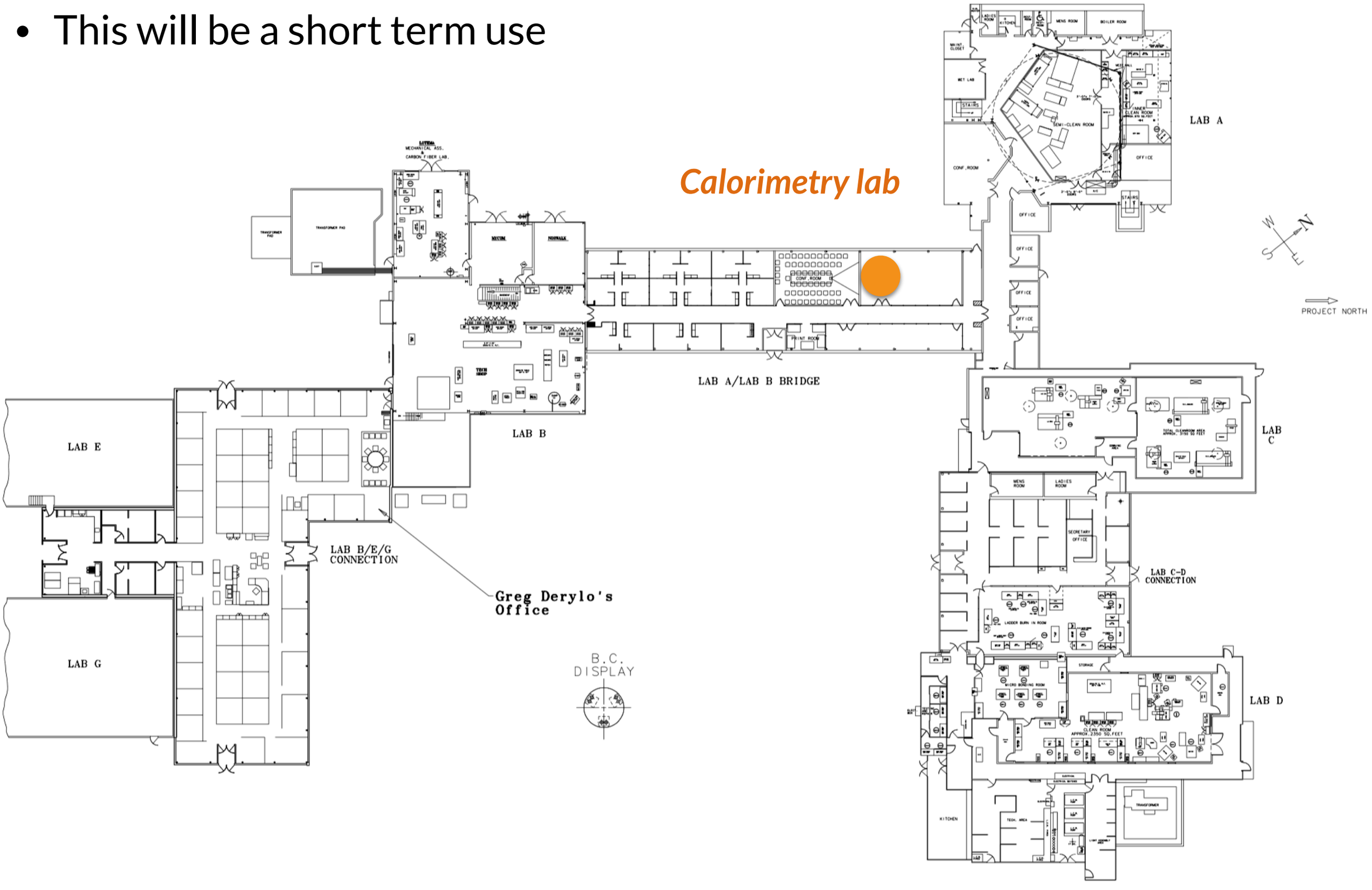
- Pixel detector work at SiDet is only focused on sensor studies

- Working with irradiated and unirradiated sensors for Phase2 (HL-LHC) pixel detector upgrade at FTBF, useful to test, tune, calibrate them in parallel
  - Otherwise we use beam time
- Need readout, power, cooling, dry air
- Goal to be ready for ORC in coming week

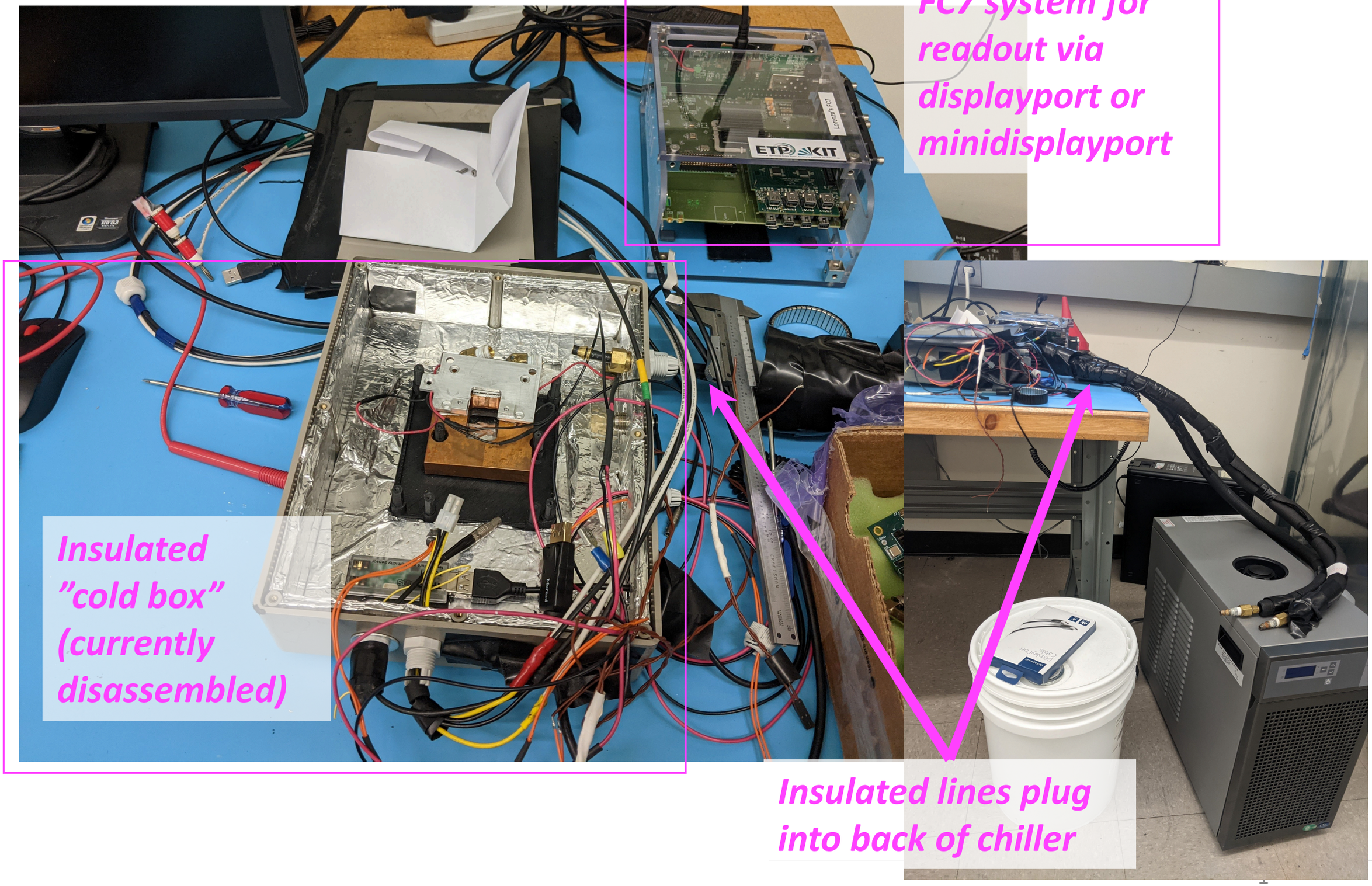


Pixel Detector at SiDet

- This will be a short term use



Calorimetry Lab



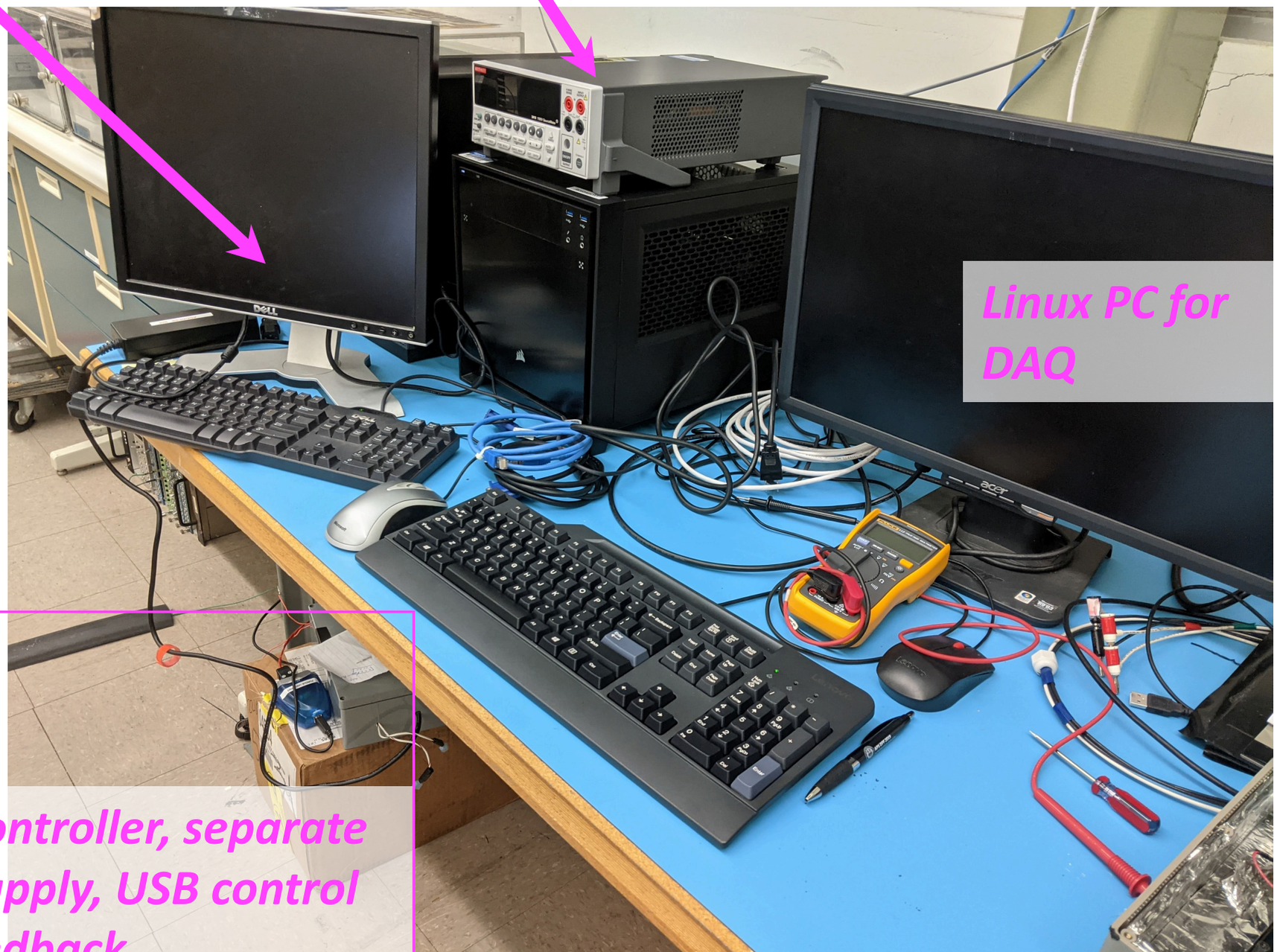
FC7 system for readout via displayport or minidisplayport

Insulated lines plug into back of chiller

Calorimetry Lab

Windows PC to control Peltier

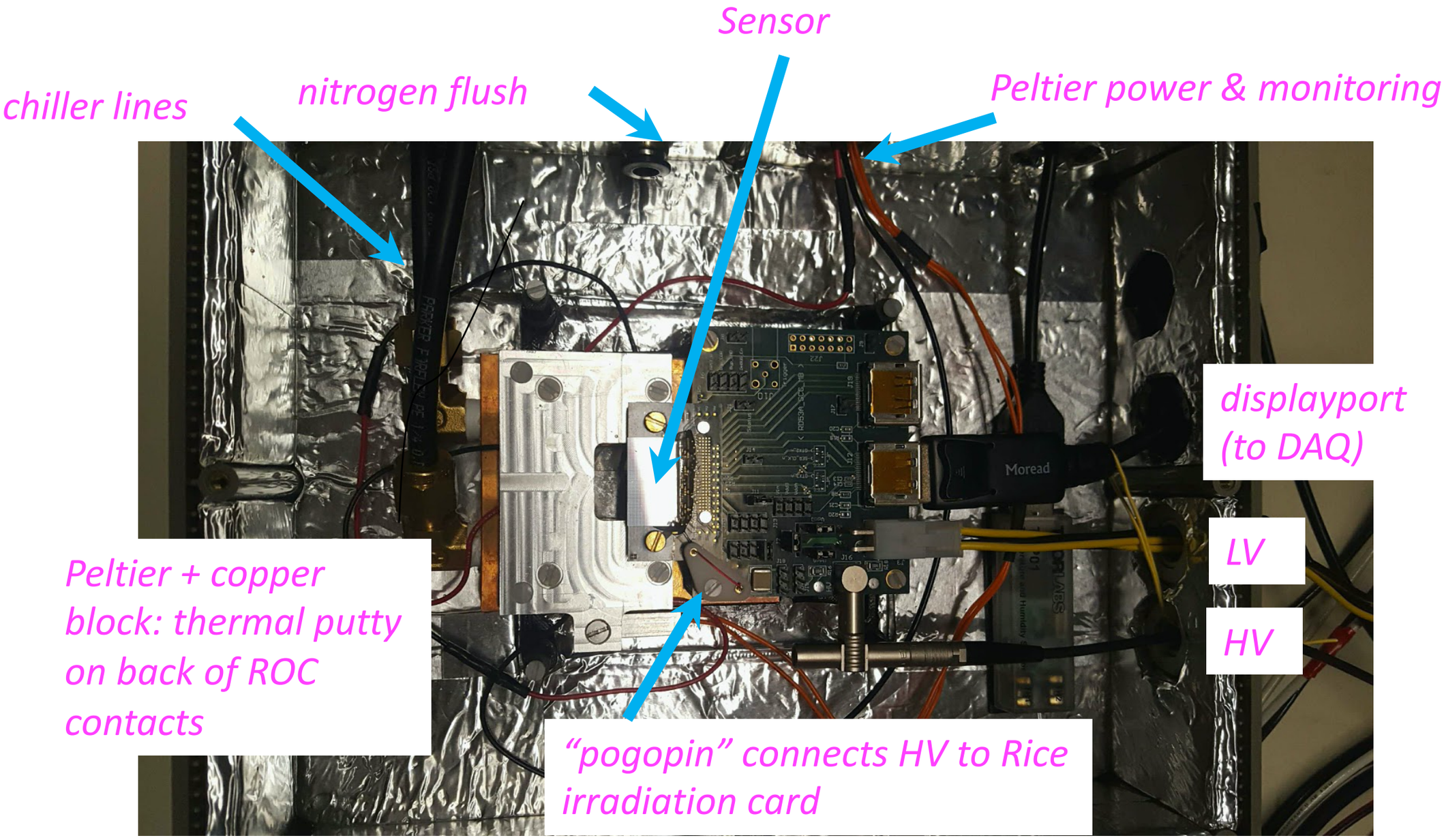
power supply for DUT



Peltier controller, separate power supply, USB control using feedback

Calorimetry Lab

- Details of INFN “cold box”

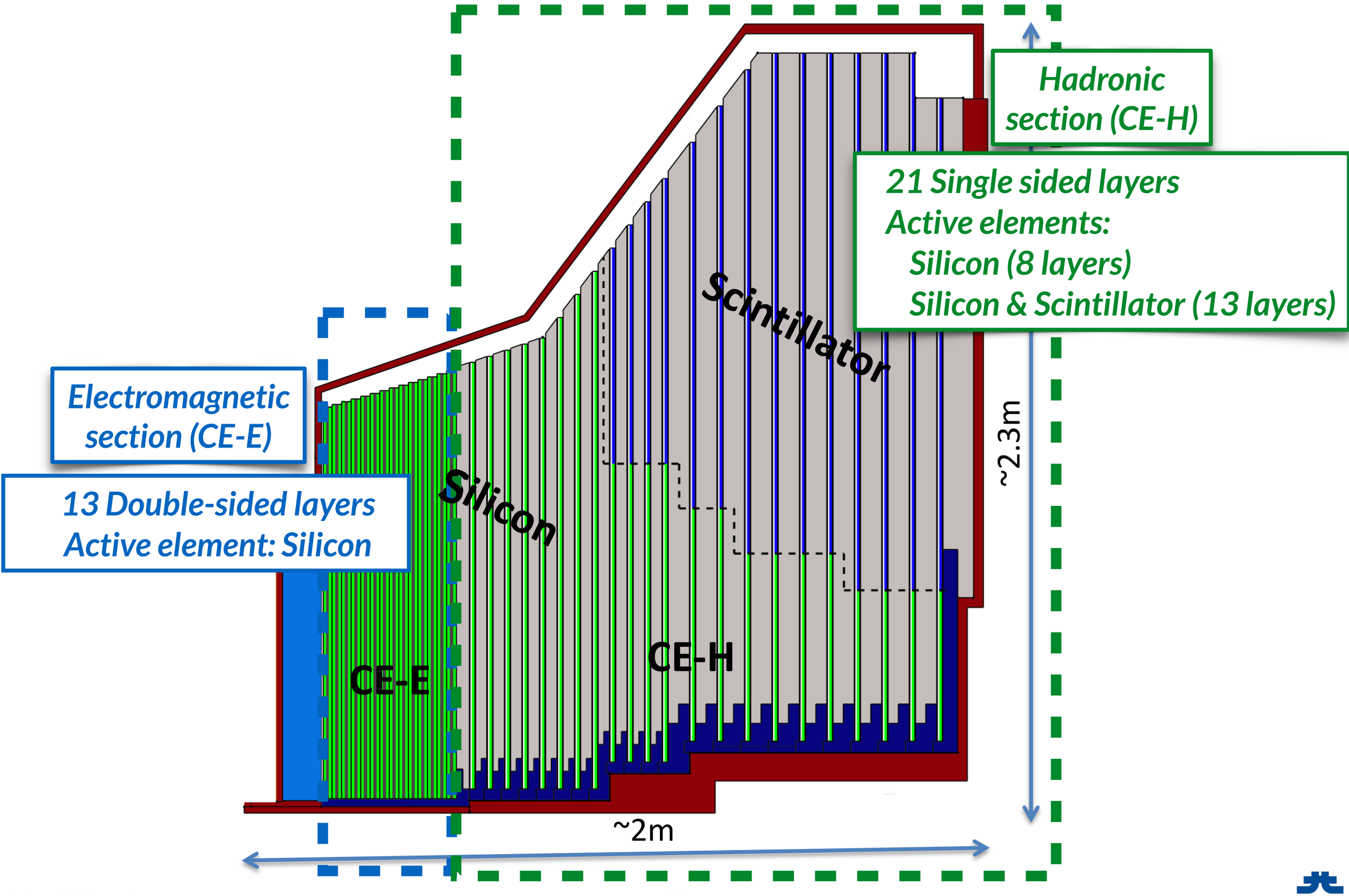


Pixel Detector Point of Contact

- For more information or planning an on-site visit please contact:
  - Corrinne Mills
    - cmills10@uic.edu

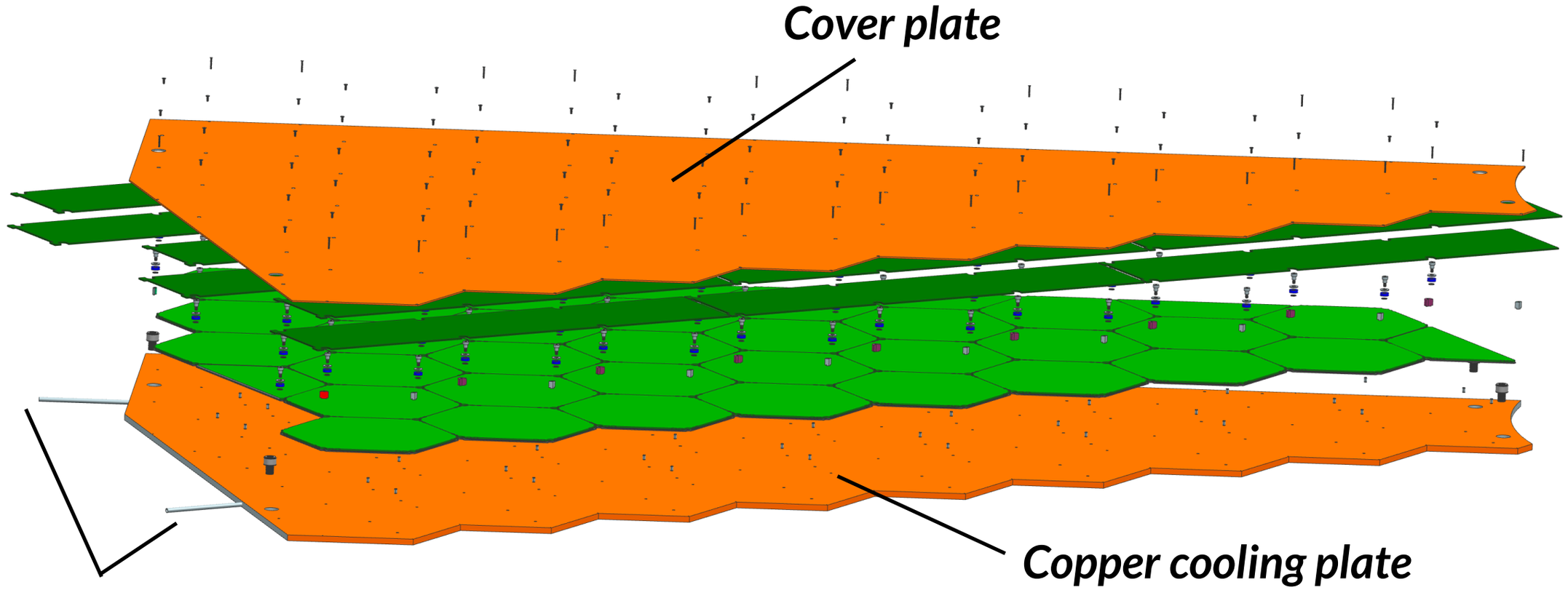
High Granularity Calorimeter

High Granularity Calorimeter (HGCal)



High Granularity Calorimeter (HGCal)

- Cassettes = HGCal installation unit at CMS

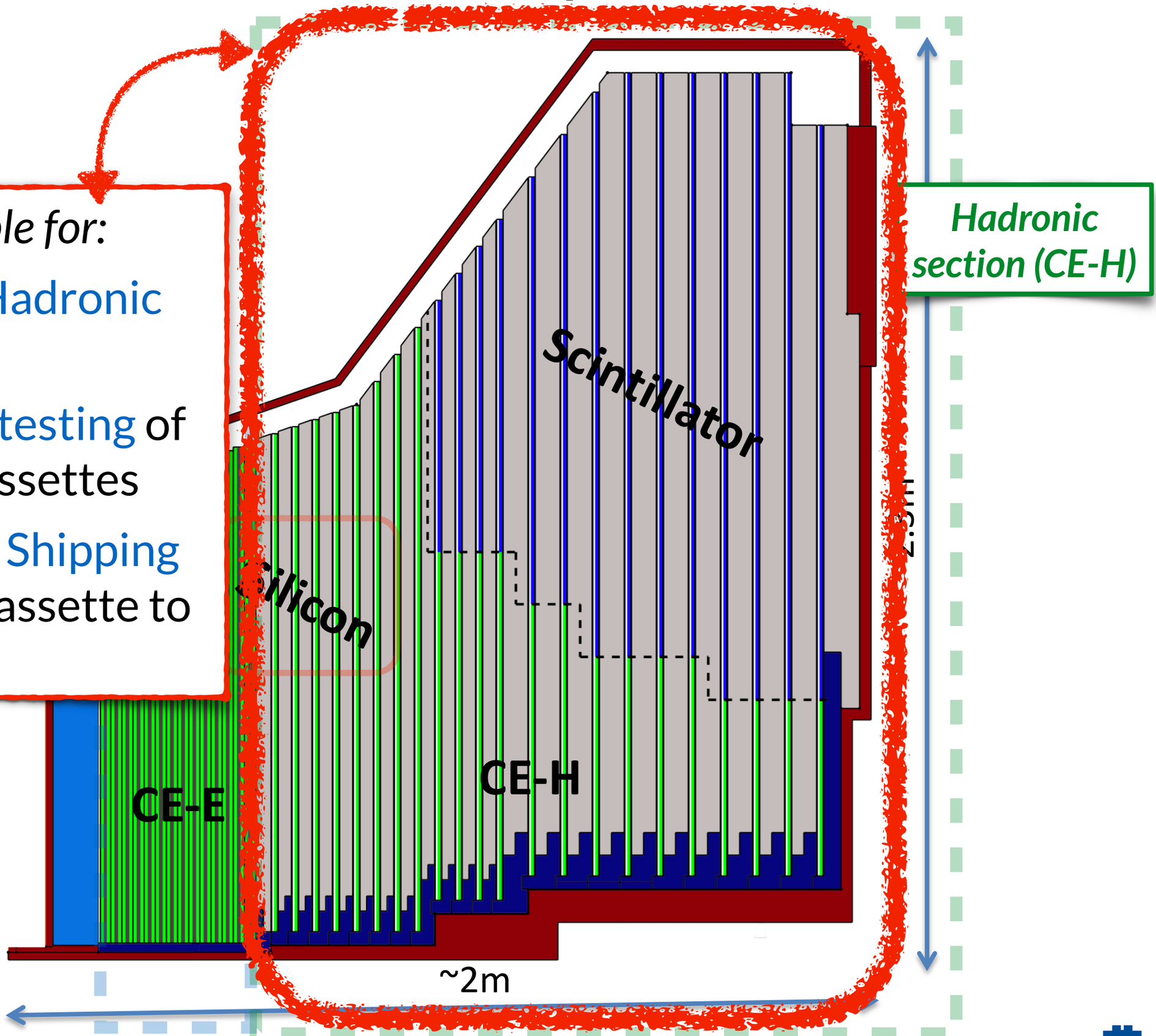


Active elements, modules and readout components and electronics are sandwiched between the cooling plate and the cover plate

HGCal Production Scope at SiDet

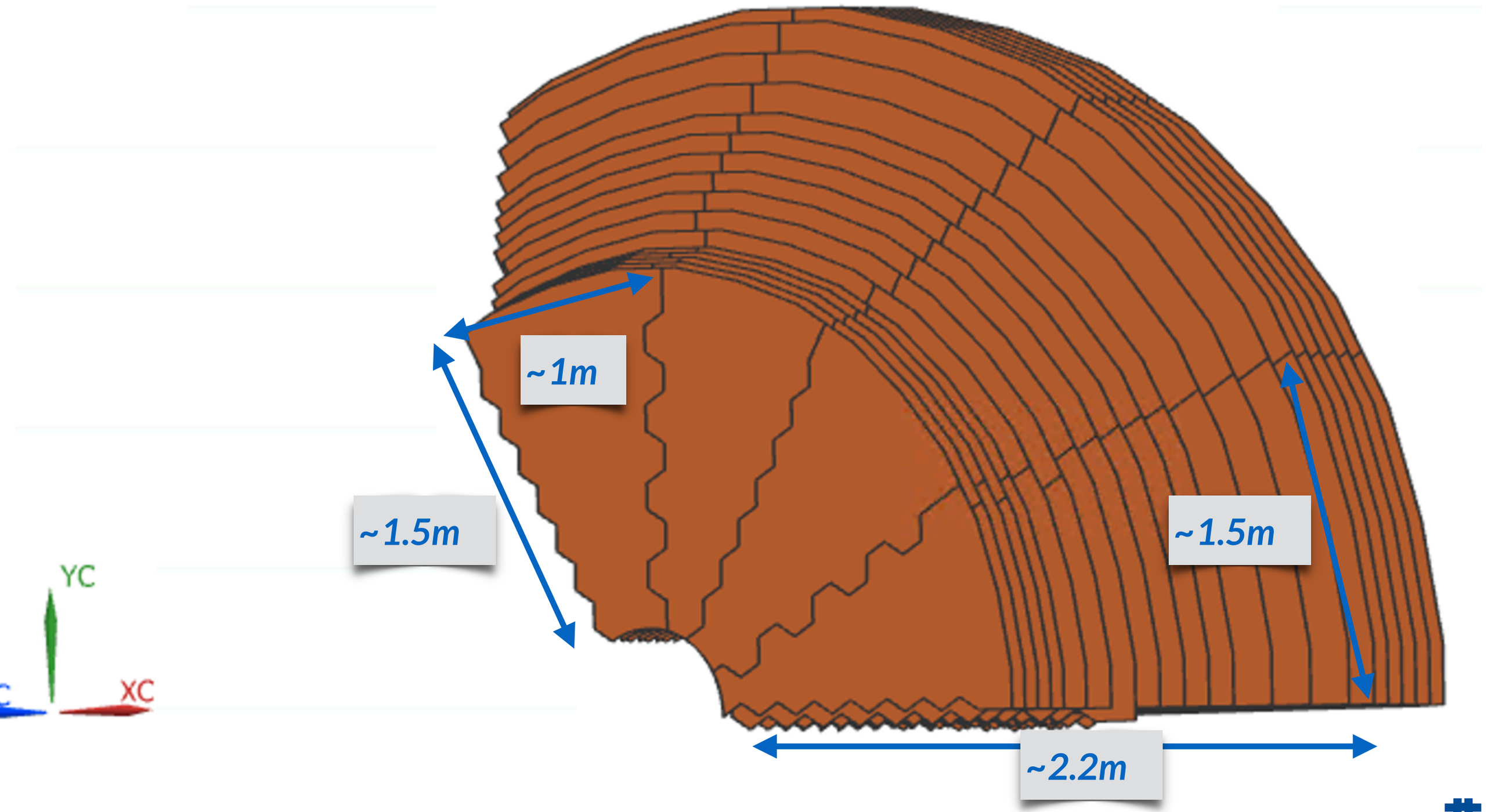
Fermilab is responsible for:

- Designing all Hadronic cassettes
- Assembly and testing of all hadronic cassettes
- Packaging and Shipping the hadronic cassette to Cern

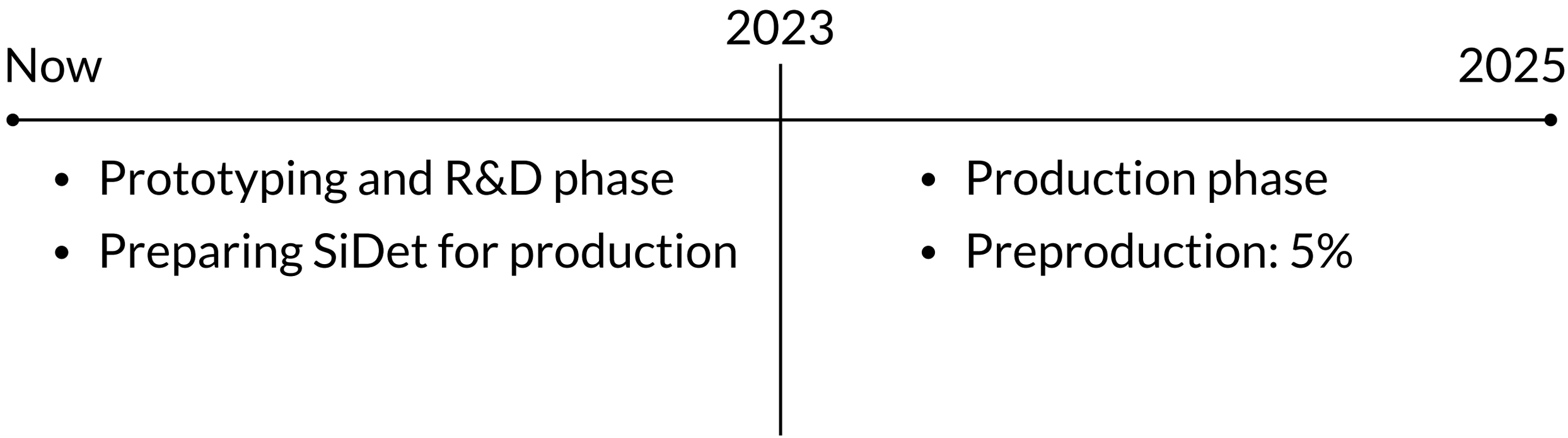


HGCal Production Scope at SiDet

Assembly and cold testing of ~550 cassettes at SiDet



Overall Time-line



- Prototyping and R&D phase
- Preparing SiDet for production

- Production phase
- Preproduction: 5%

- Next slides will cover:
  - The areas at SiDet utilized by HGCal
    - The current activities in each area
    - Activities planned during the production phase in that area

HGCal at SiDet

Lab A, second floor: Possible storage area for light objects during production

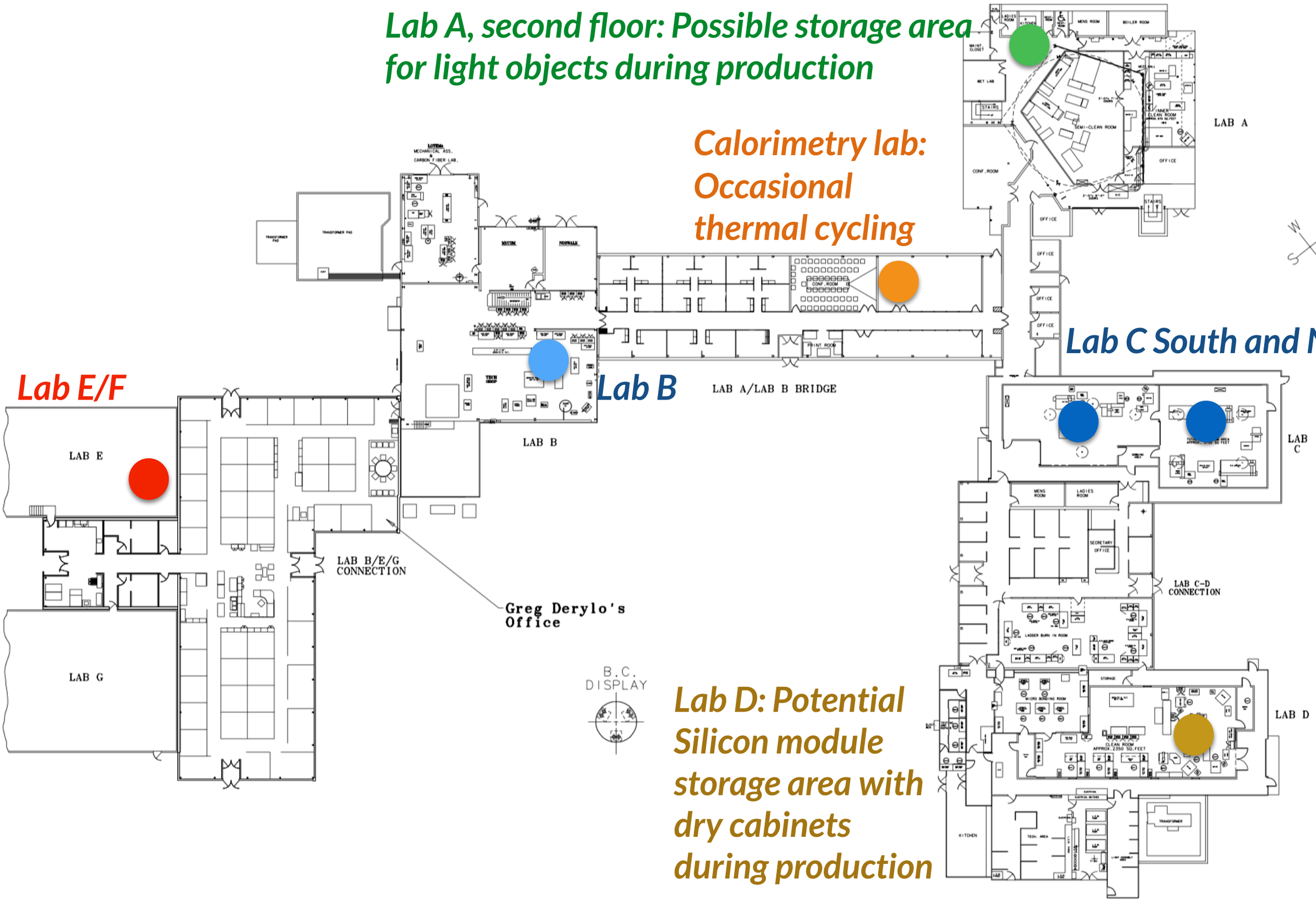
Calorimetry lab: Occasional thermal cycling

Lab E/F

Lab B

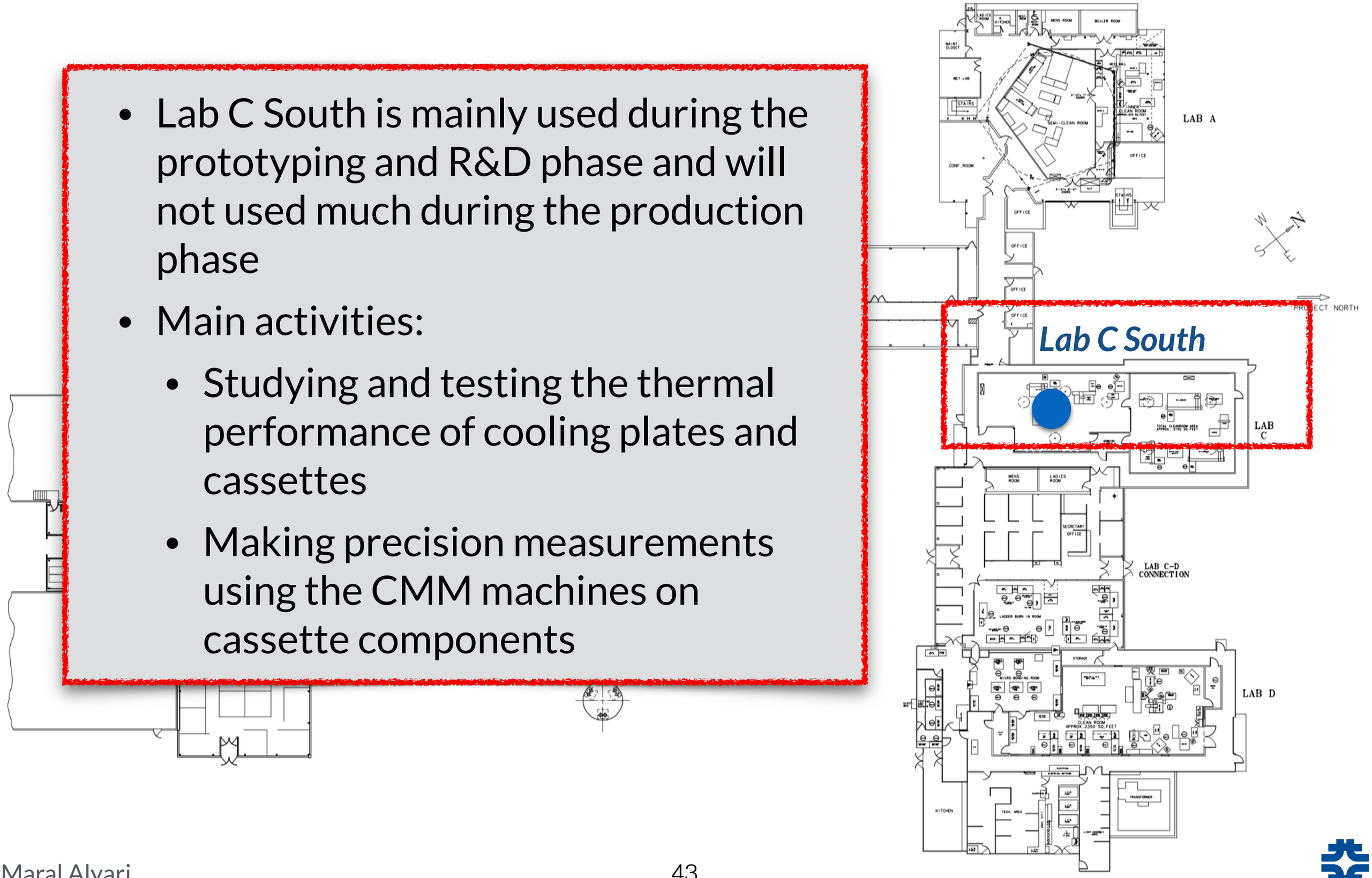
Lab C South and North

Lab D: Potential Silicon module storage area with dry cabinets during production



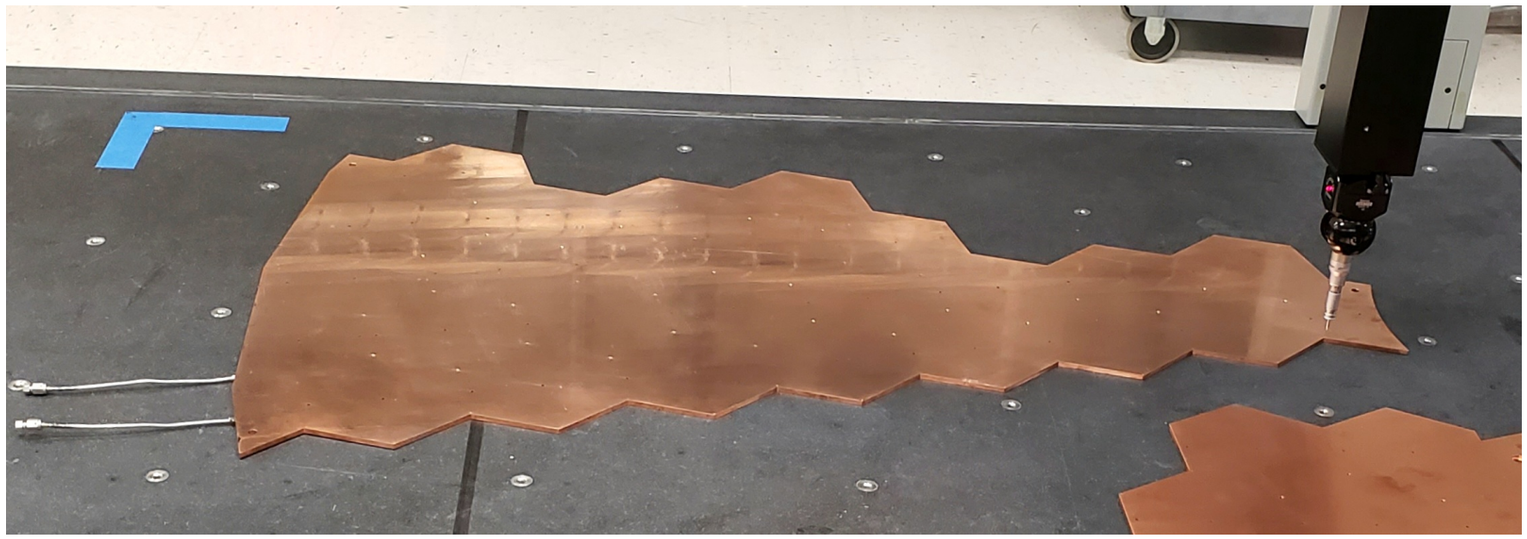
HGCal: Lab C South

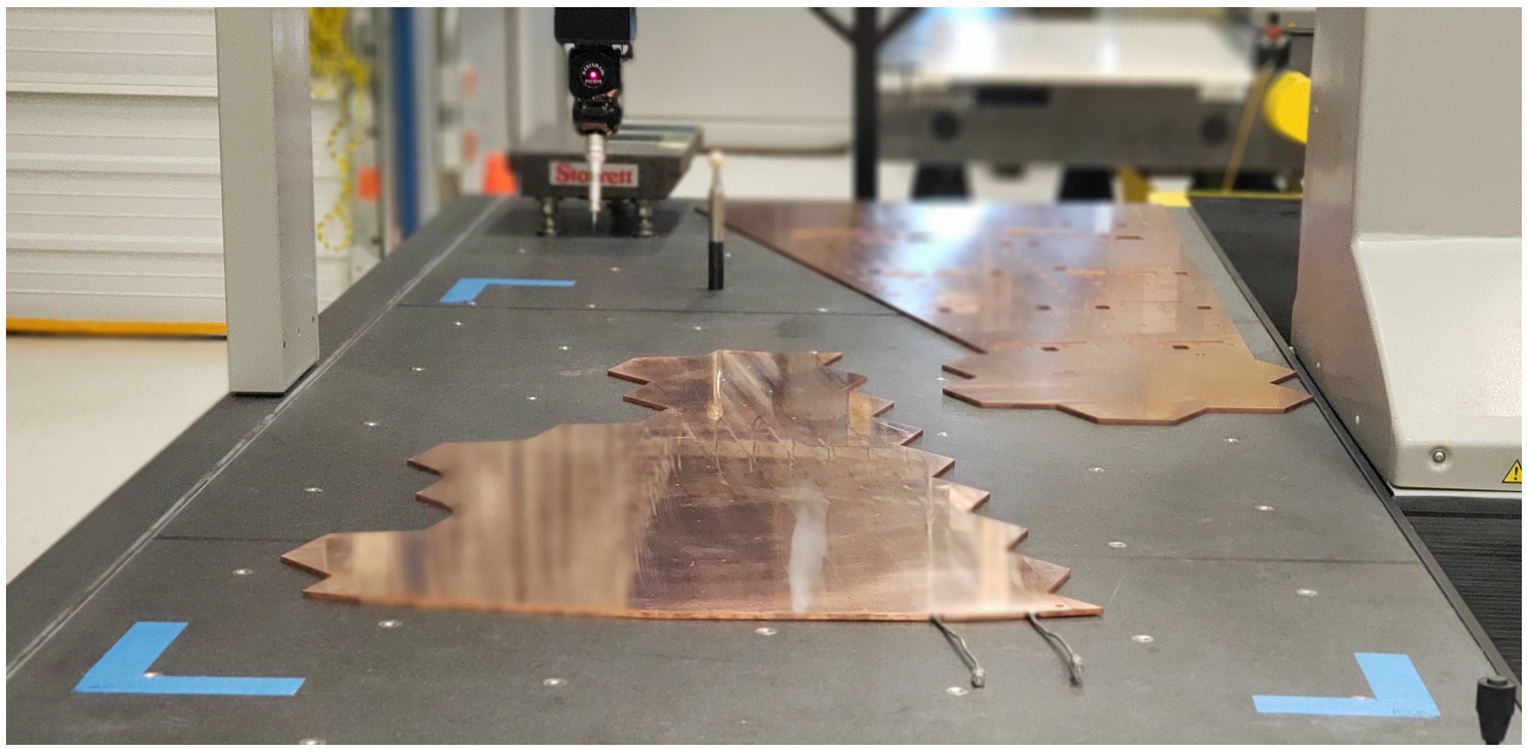
- Lab C South is mainly used during the prototyping and R&D phase and will not used much during the production phase
- Main activities:
  - Studying and testing the thermal performance of cooling plates and cassettes
  - Making precision measurements using the CMM machines on cassette components



Lab C South

- Currently we're making QC measurements on smaller Copper plates with the CMM

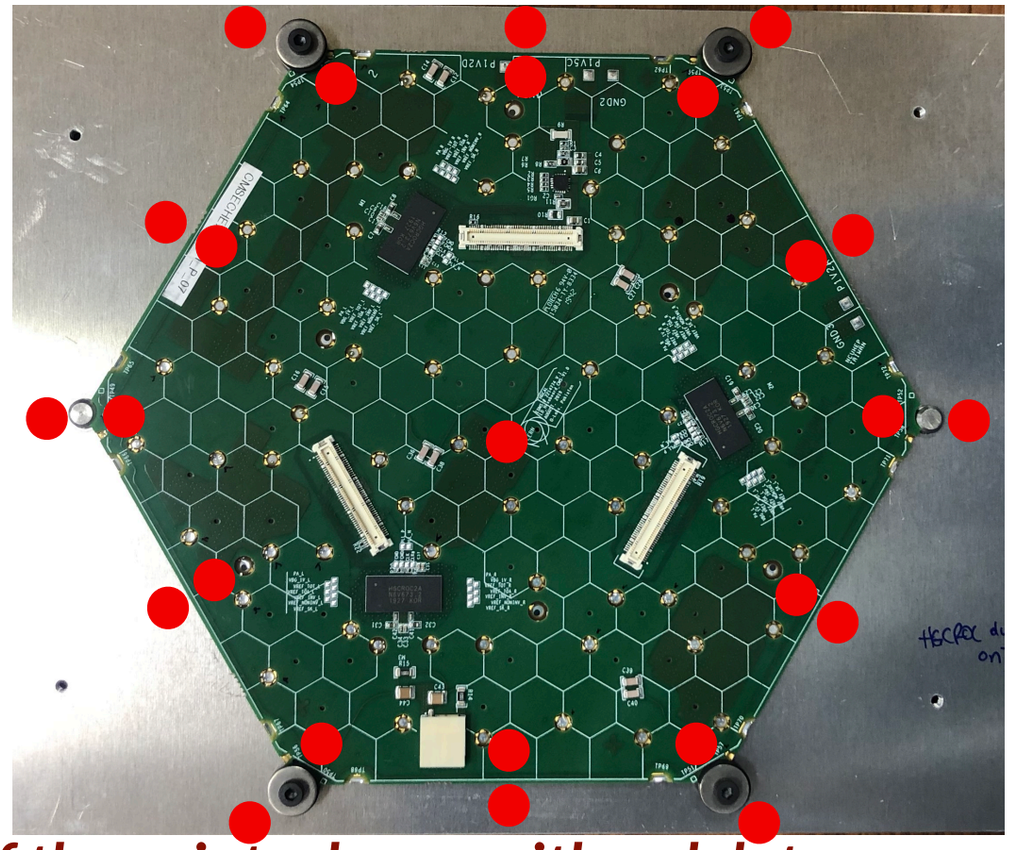




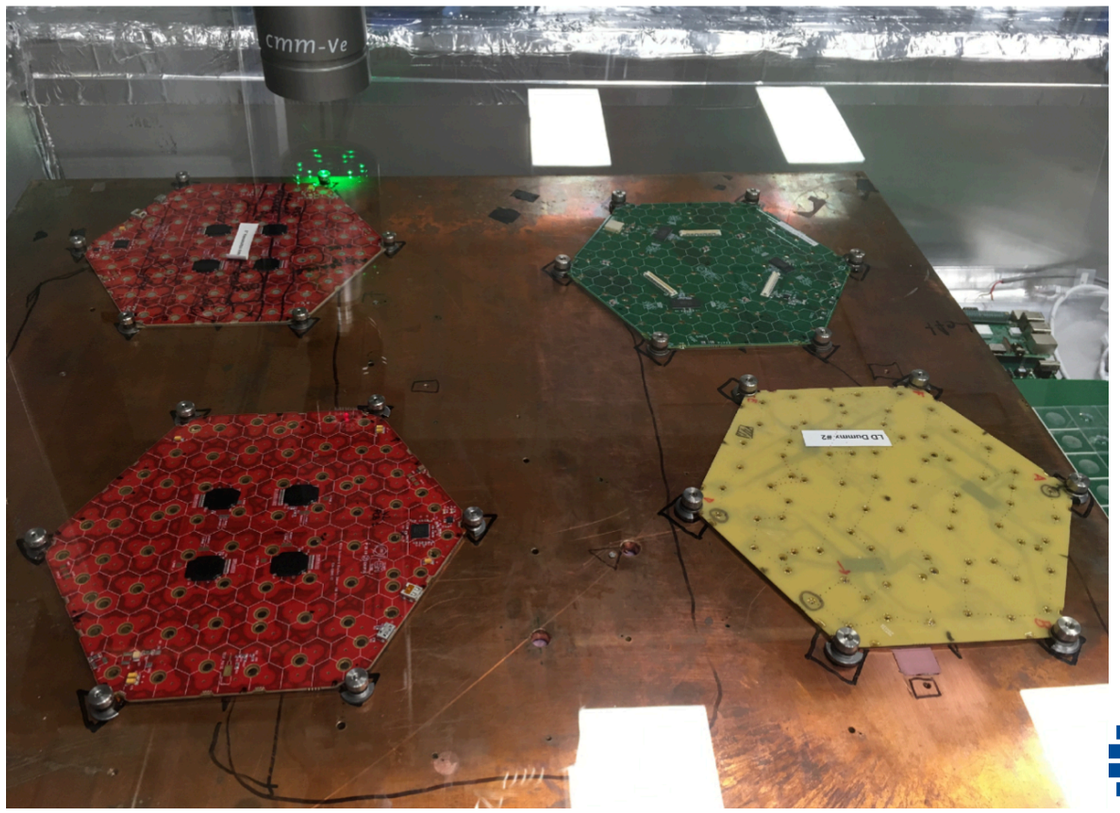
Lab C South

- Another recent study is studying the deformation of mechanical modules at cold temperatures with CMM
  - CO2 is used for cooling

The insulated box has a transparent lid and can be placed on the CMM granite table

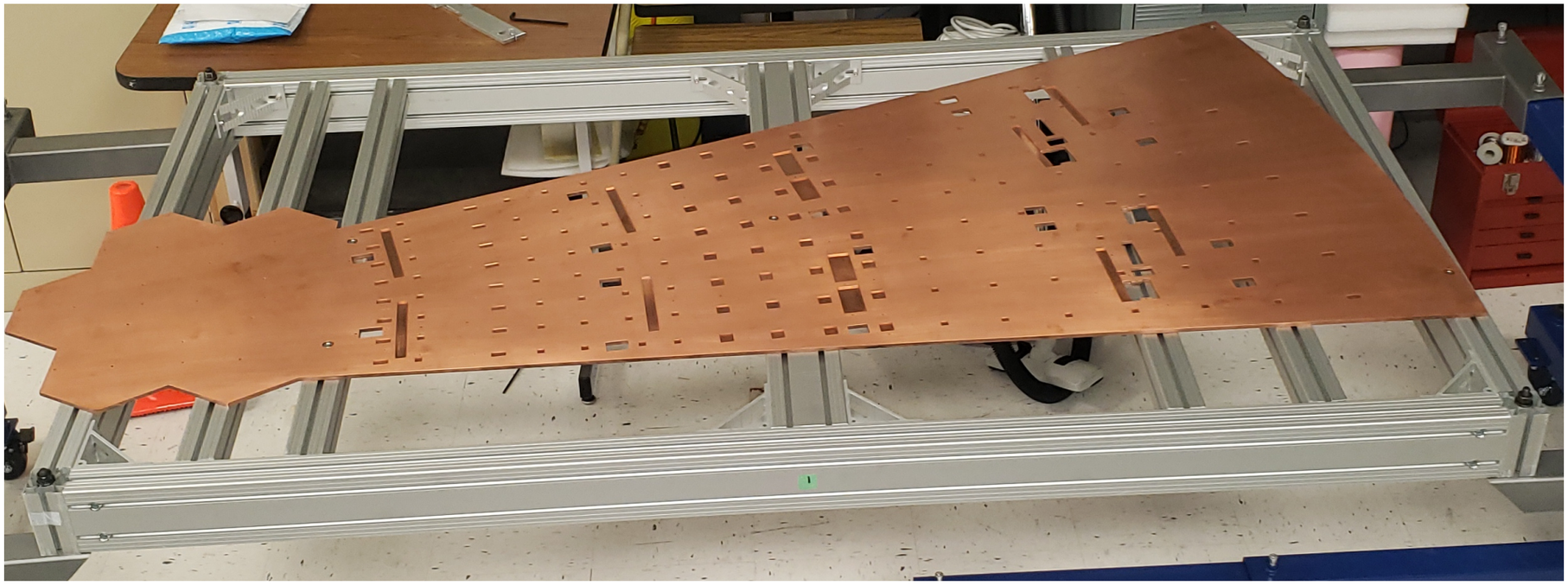


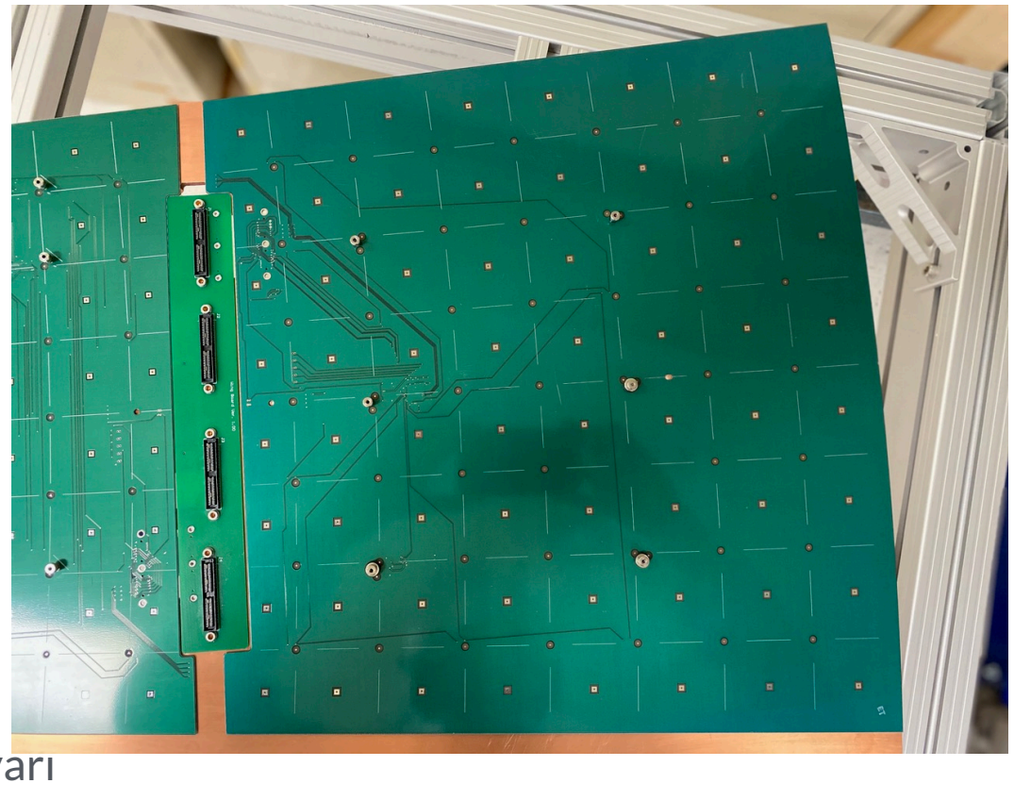
Height of the points shown with red dots are measured

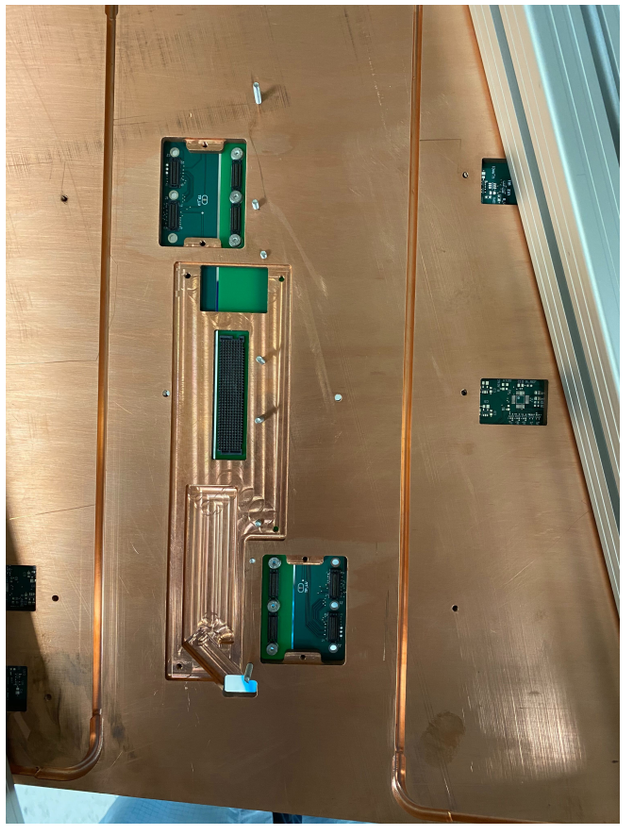


Lab C South

- Studying the mounting of scintillator tile-modules on the copper cooling plate

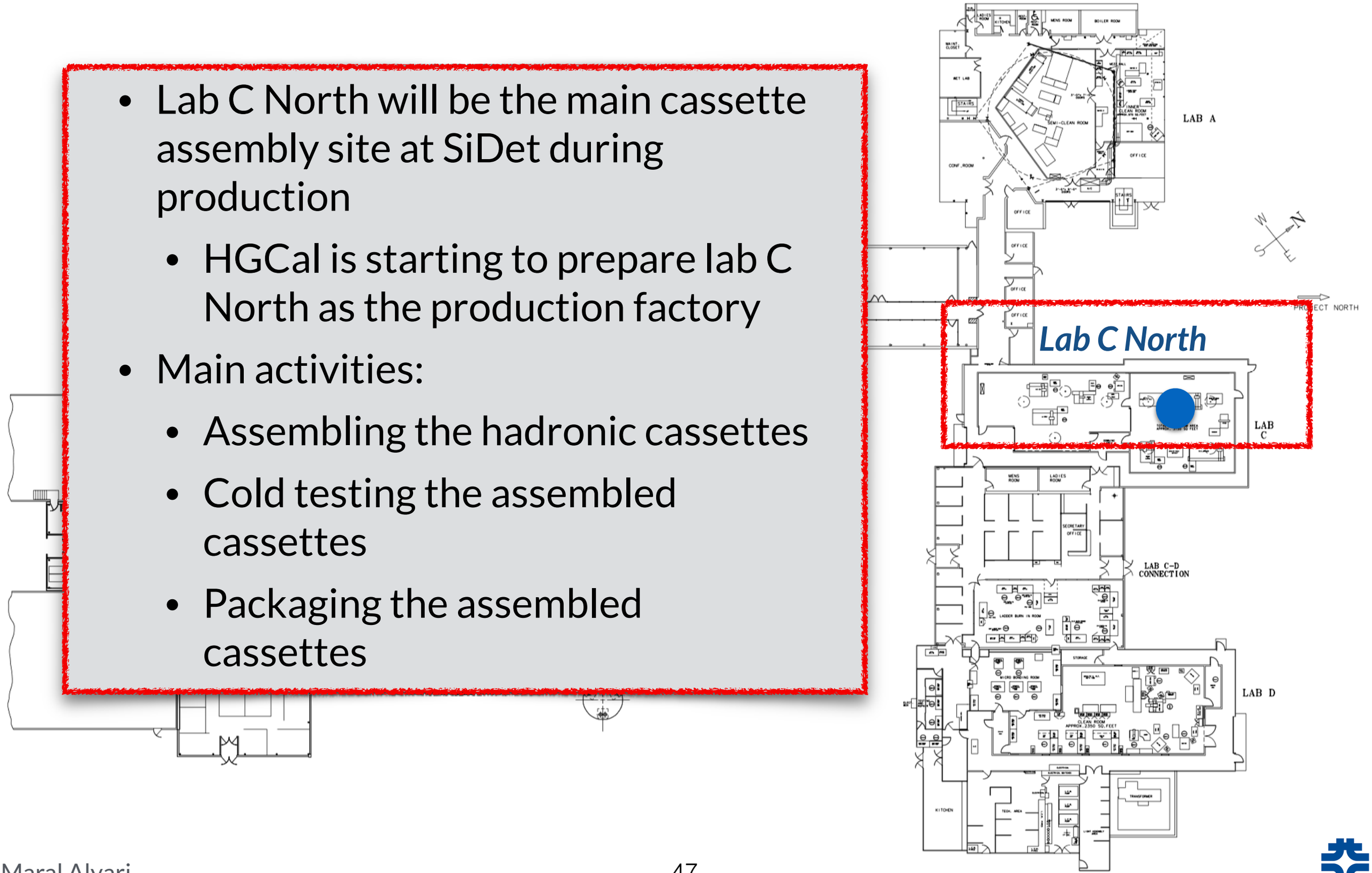




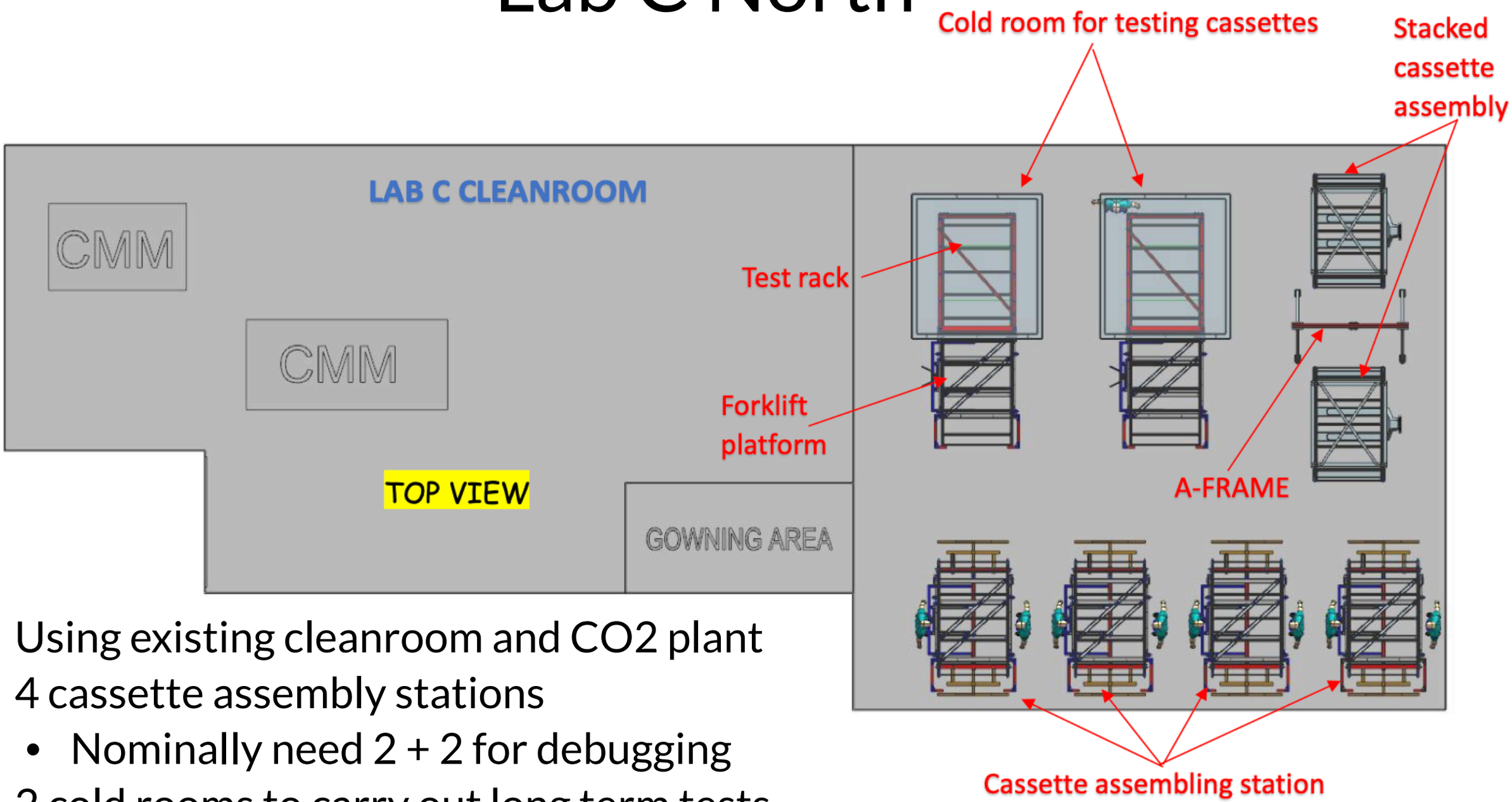


HGCal: Lab C North

- Lab C North will be the main cassette assembly site at SiDet during production
  - HGCal is starting to prepare lab C North as the production factory
- Main activities:
  - Assembling the hadronic cassettes
  - Cold testing the assembled cassettes
  - Packaging the assembled cassettes

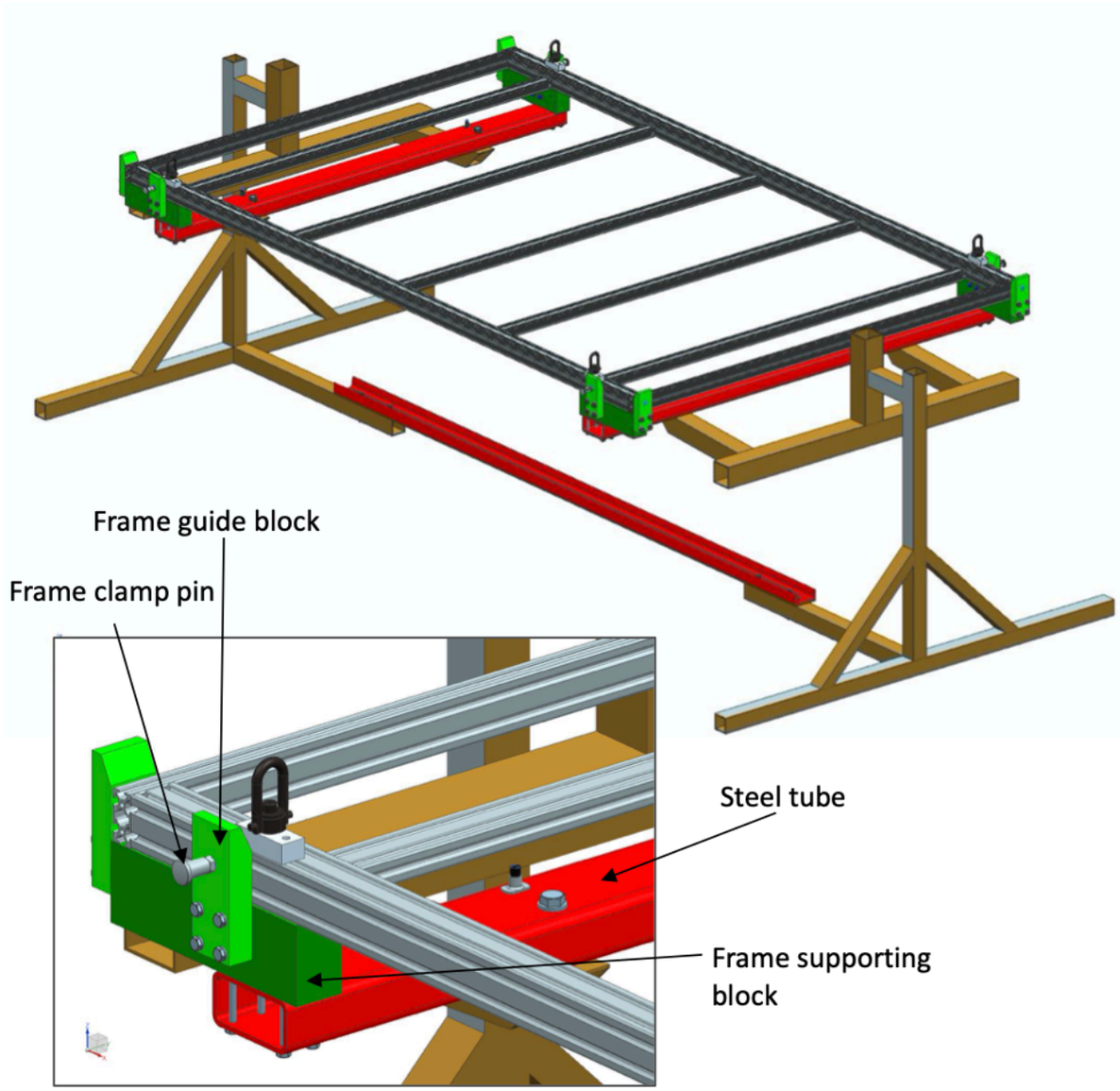


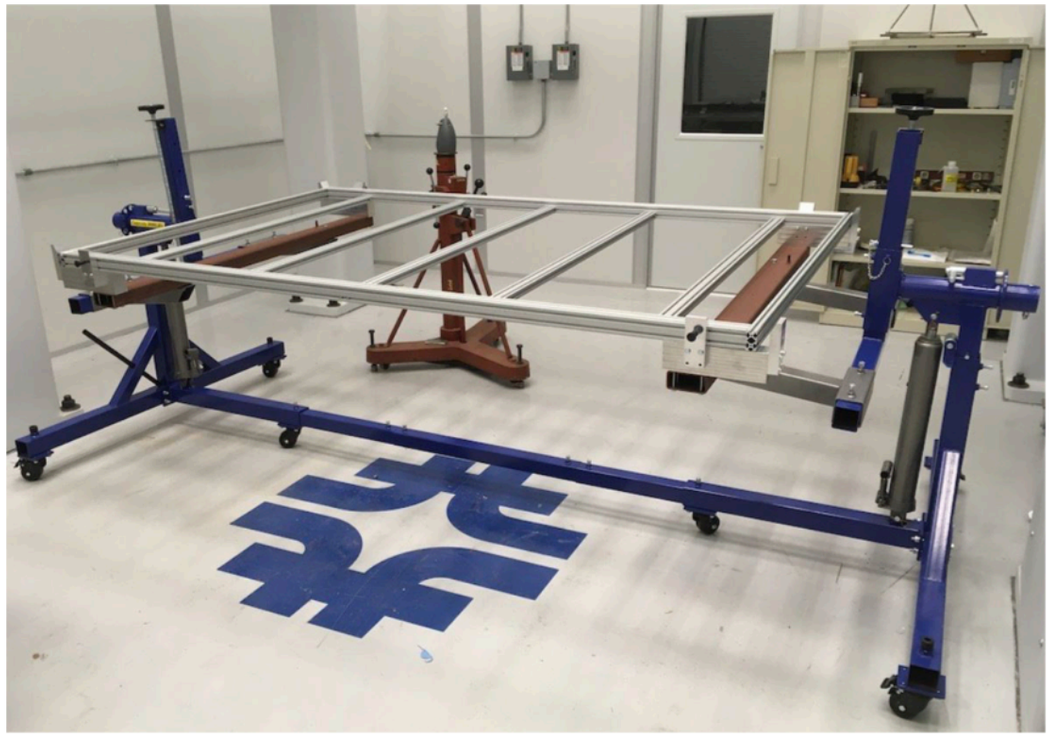
Lab C North

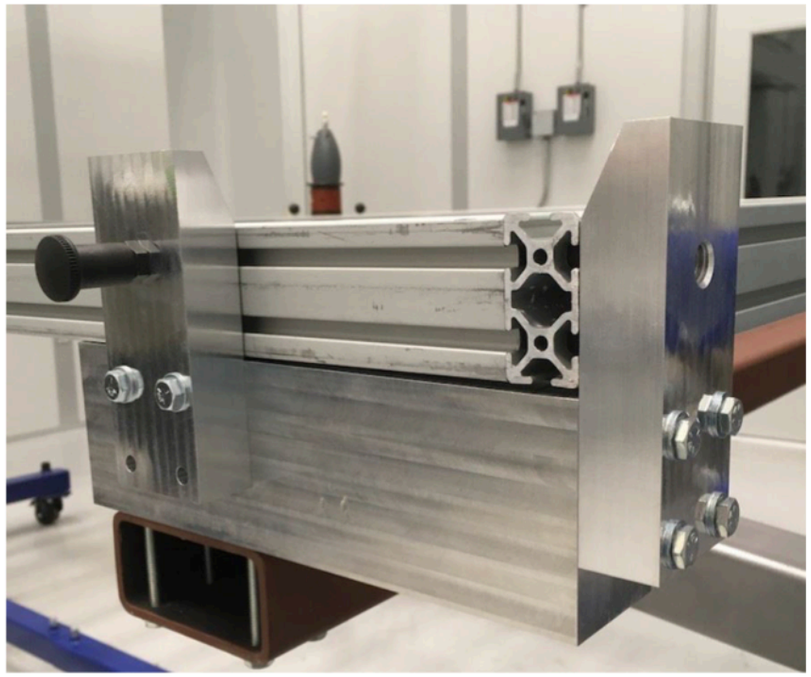


- Using existing cleanroom and CO2 plant
- 4 cassette assembly stations
  - Nominally need 2 + 2 for debugging
- 2 cold rooms to carry out long term tests
  - Nominally need 1 + 1 for staggering
- 1 forklift for loading frames into cold rooms
- 2 cassette stacks + A-frame crane
  - 1 for empty cooling plates
  - 1 for assembled cassettes

Lab C North

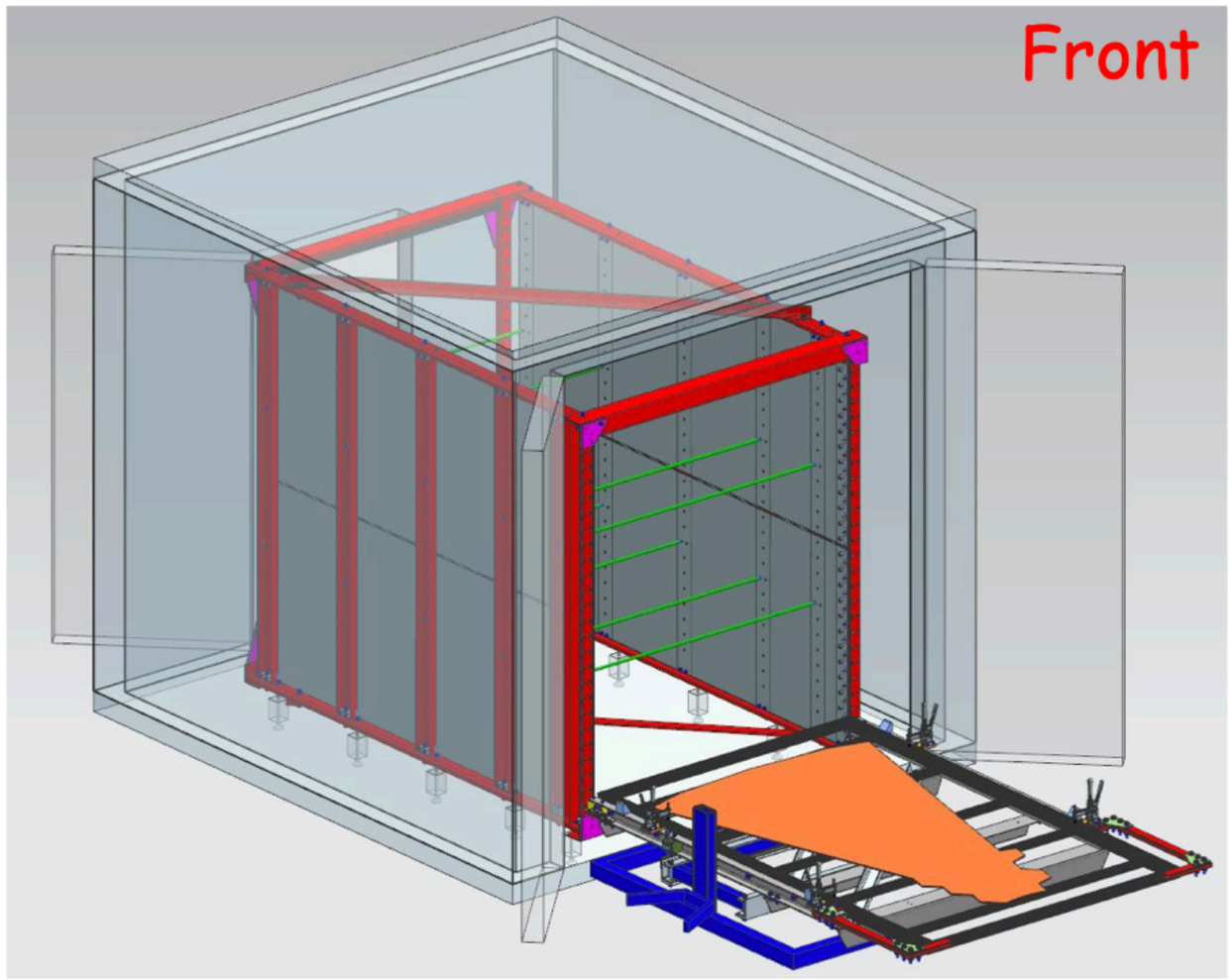


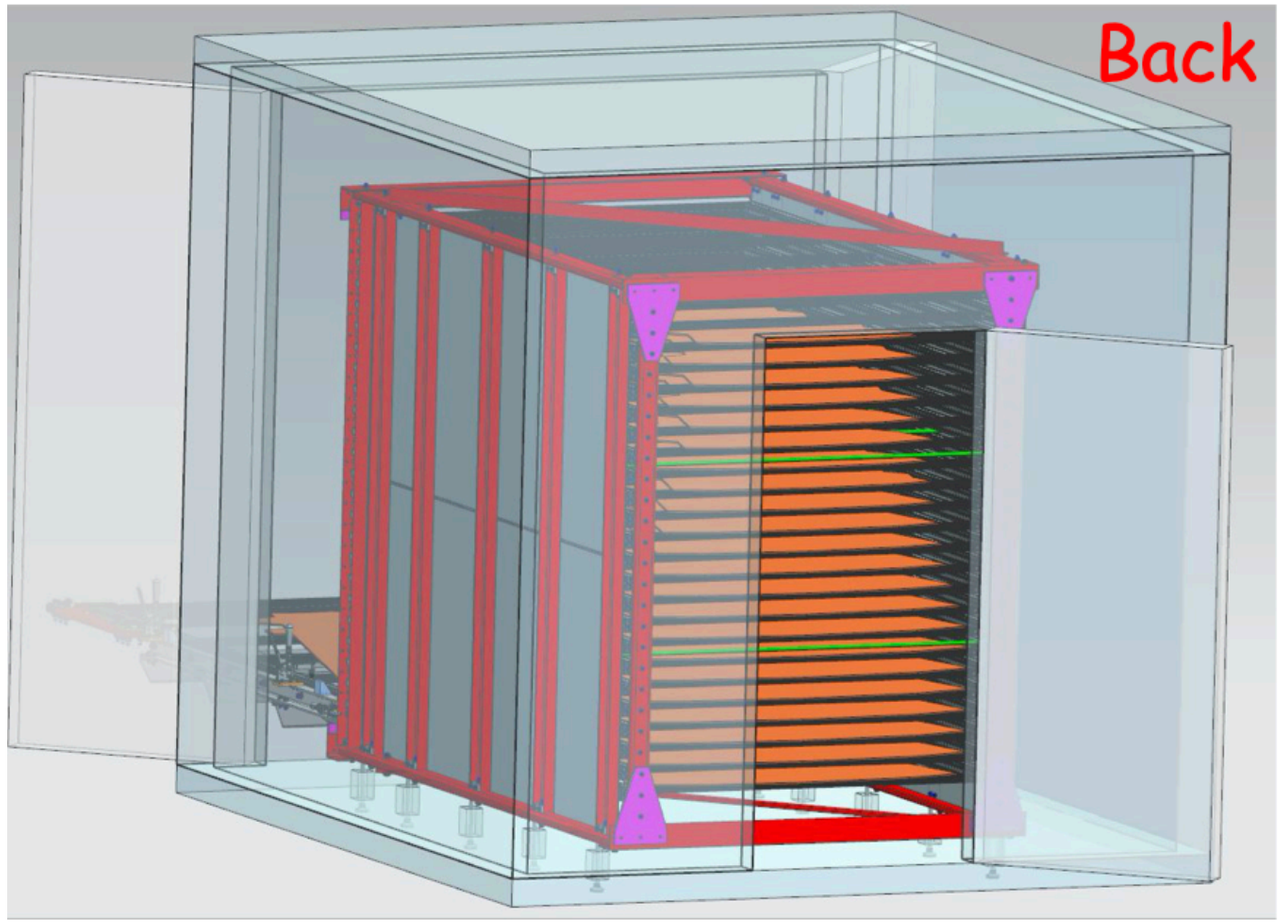




- 4 commercial car rotisseries are purchased
- Frames are designed to carry the cassettes
- Frame supporting attachments are designed and prototyped
  - Greg Derylo and Parth Gandhi
- Supports need to be fabricated for the remaining 3 rotisseries

Lab C North

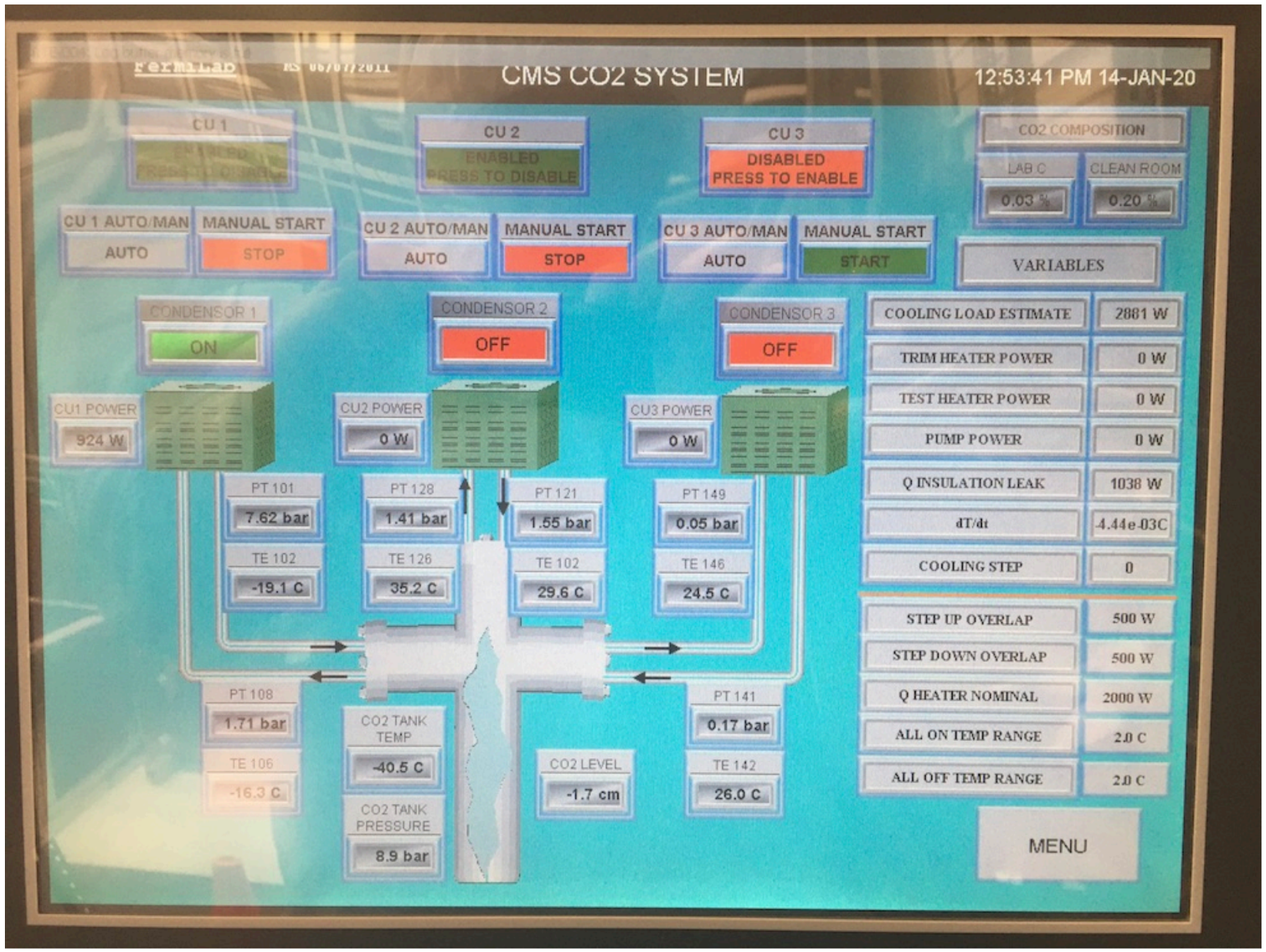




- One insulated room is purchased and delivered to shipping and receiving
- Cassette rack is designed
  - Greg Derylo; Parth Gandhi
  - Engineering note is being prepared
- Mini version is prototyped
  - See lab B activity ; slide 54
- Full size rack needs to be fabricated

Lab C North

- The current CO2 plant needs to be upgraded to accommodate the needs of all HGCal and Outer Tracker during production
  - Right now:
    - 3 condensors:
      - 1.1 kW
      - 2 kW
      - 4 kW
  - Planning to upgrade to:
    - 3 x 4 kW = 12 kW



- Erik Voirin and Del Allspach and his group are working on routing the piping to lab C North and upgrading the system
  - An ORC review and ODH/CO2 analysis will be completed

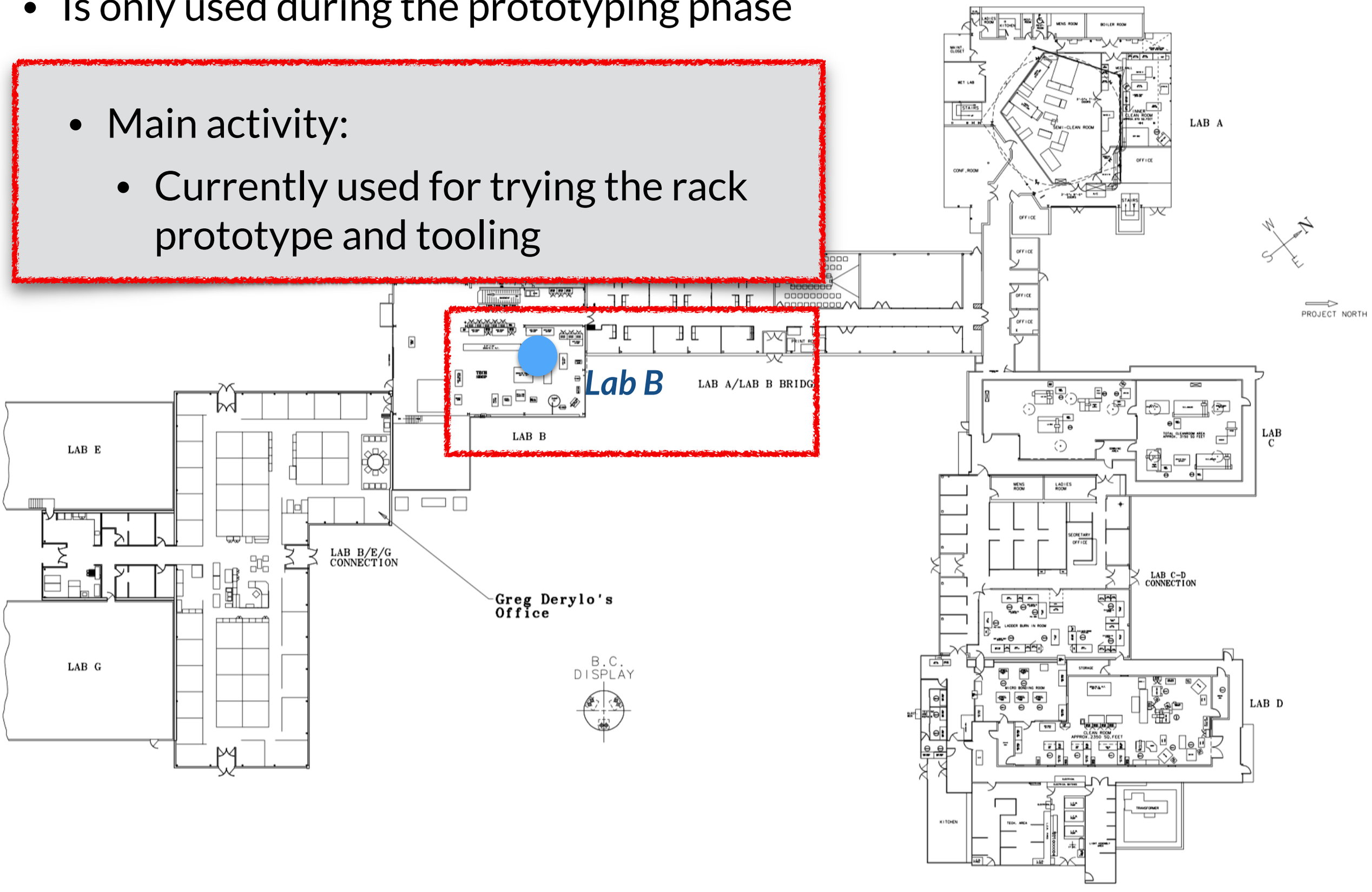
Lab C North

- After the routing of the CO2 tubing is done and one of the cold racks is functional, HGCal plans to do cold test on prototype cassettes
  - ORC will be completed
- The main use of lab C will be during the production phase

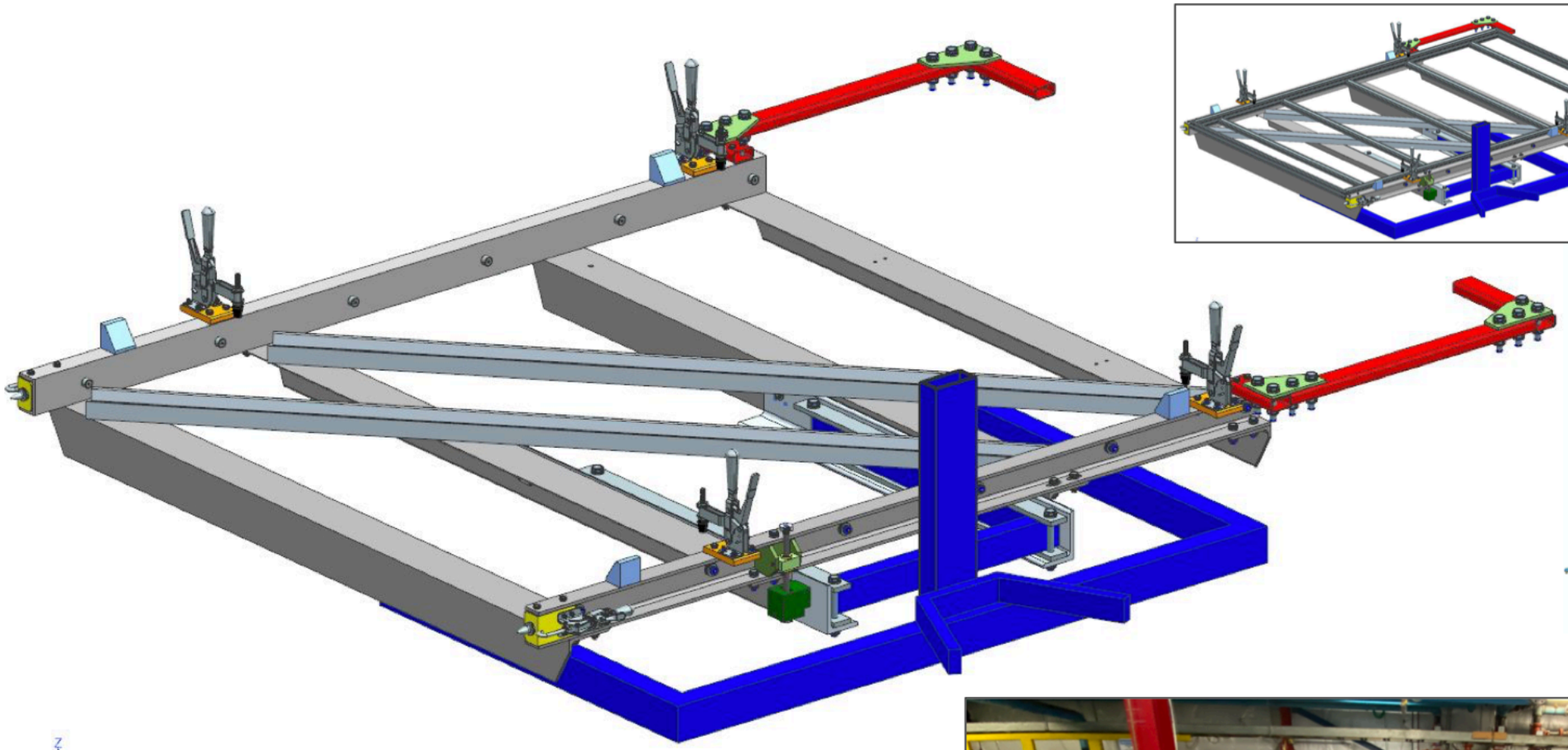
HGCal: Lab B

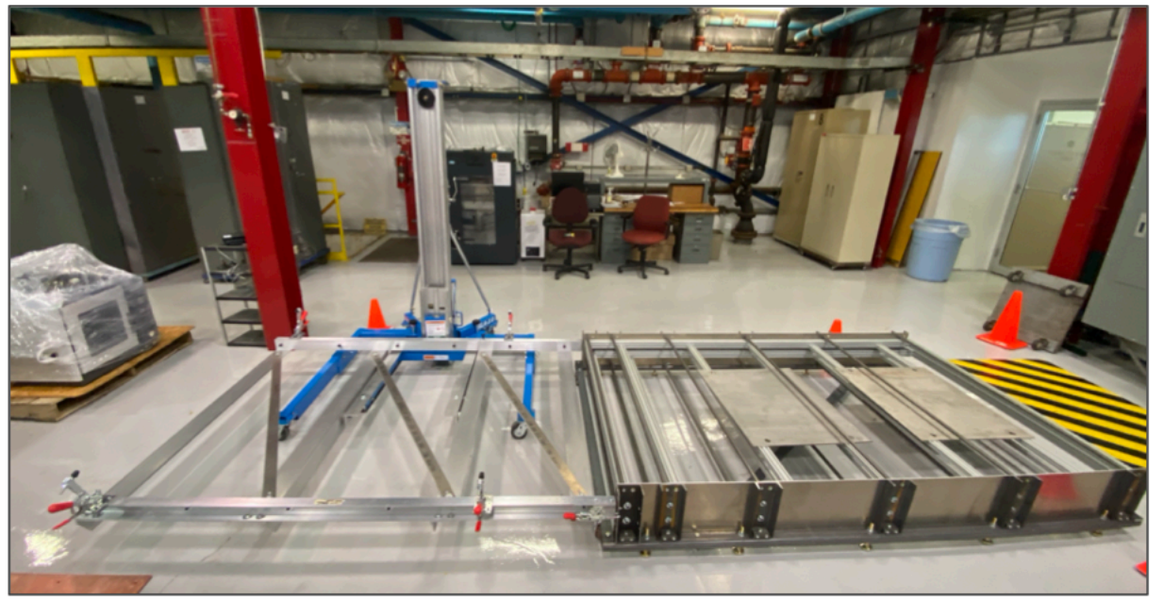
- Is only used during the prototyping phase

- Main activity:
  - Currently used for trying the rack prototype and tooling



Lab B

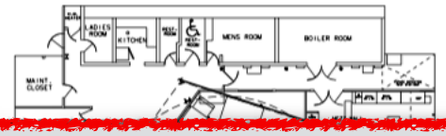




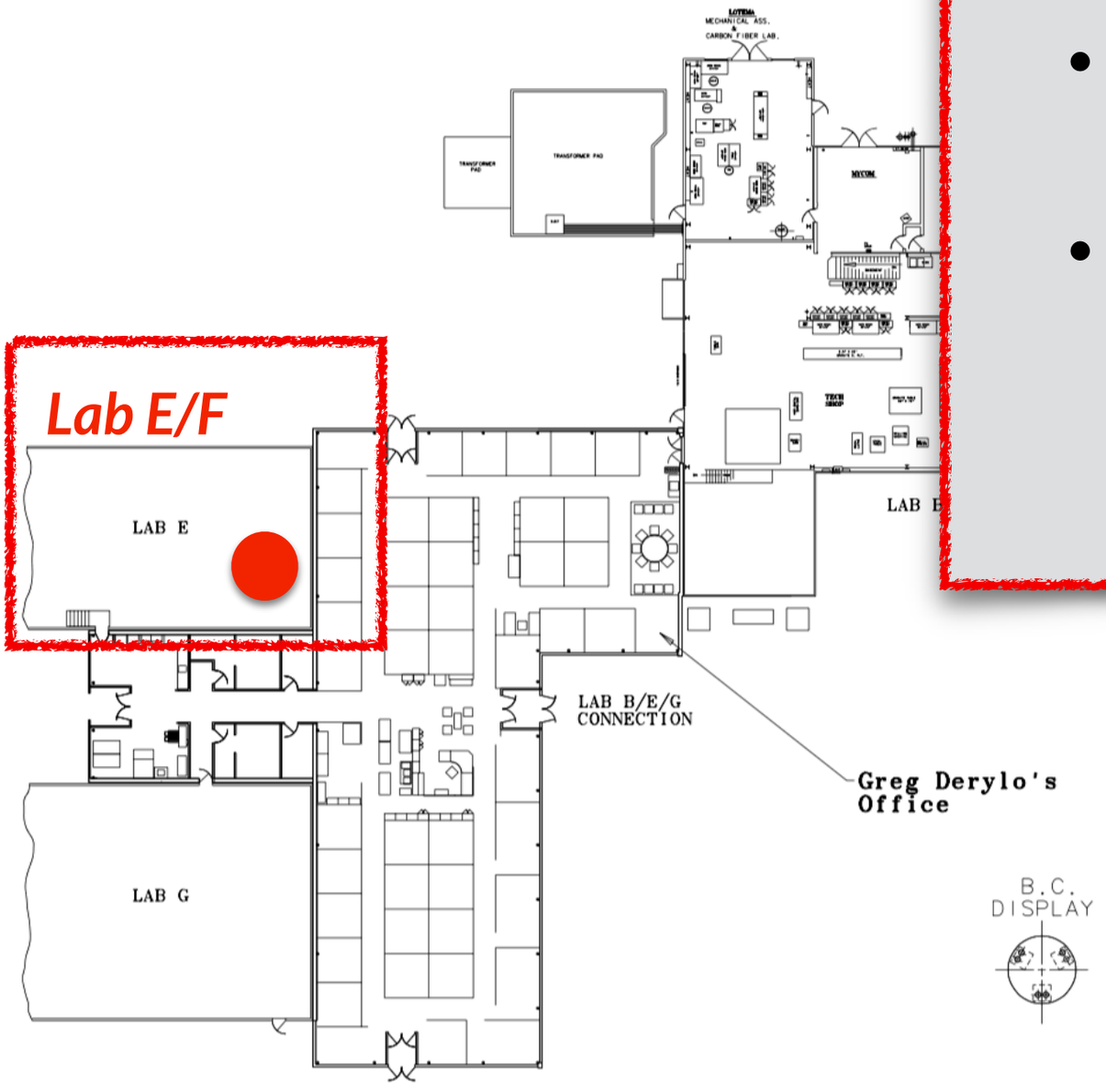
- Purchased commercial fork lift
- Designed and fabricated fork lift platform
- Tested frame insertion into the mini rack
  - overall works well, identified minor issues
- Updated the design and fabricating new platform now

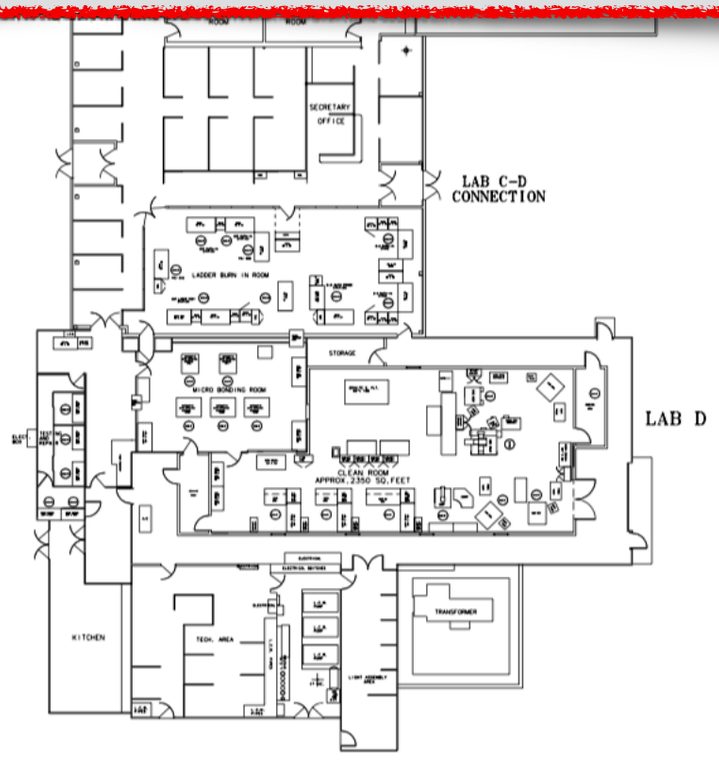
- Engineering note is released
  - (Ed0012382)
- HGCal is not planning to use lab B during production

HGCal: Lab E/F



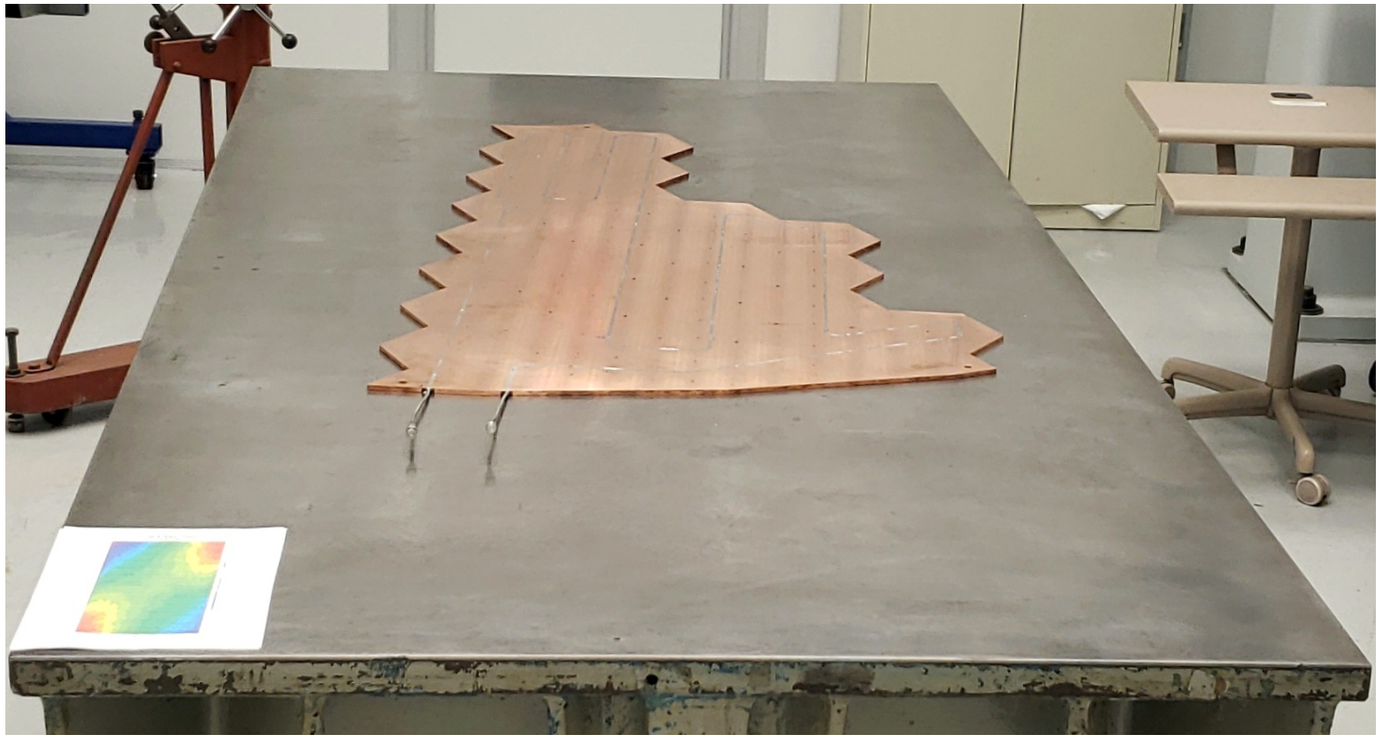
- Main activities:
  - Making precision measurements using the CMM machines
  - During production will be used more broadly to receive and test the cooling plates and store the cassettes prior to shipping





Lab E/F

- Currently using the CMM in lab E to qualify the prototype cooling plates
  - Will be moving a granite table in the CMM room to be used instead of the Stainless Steel table



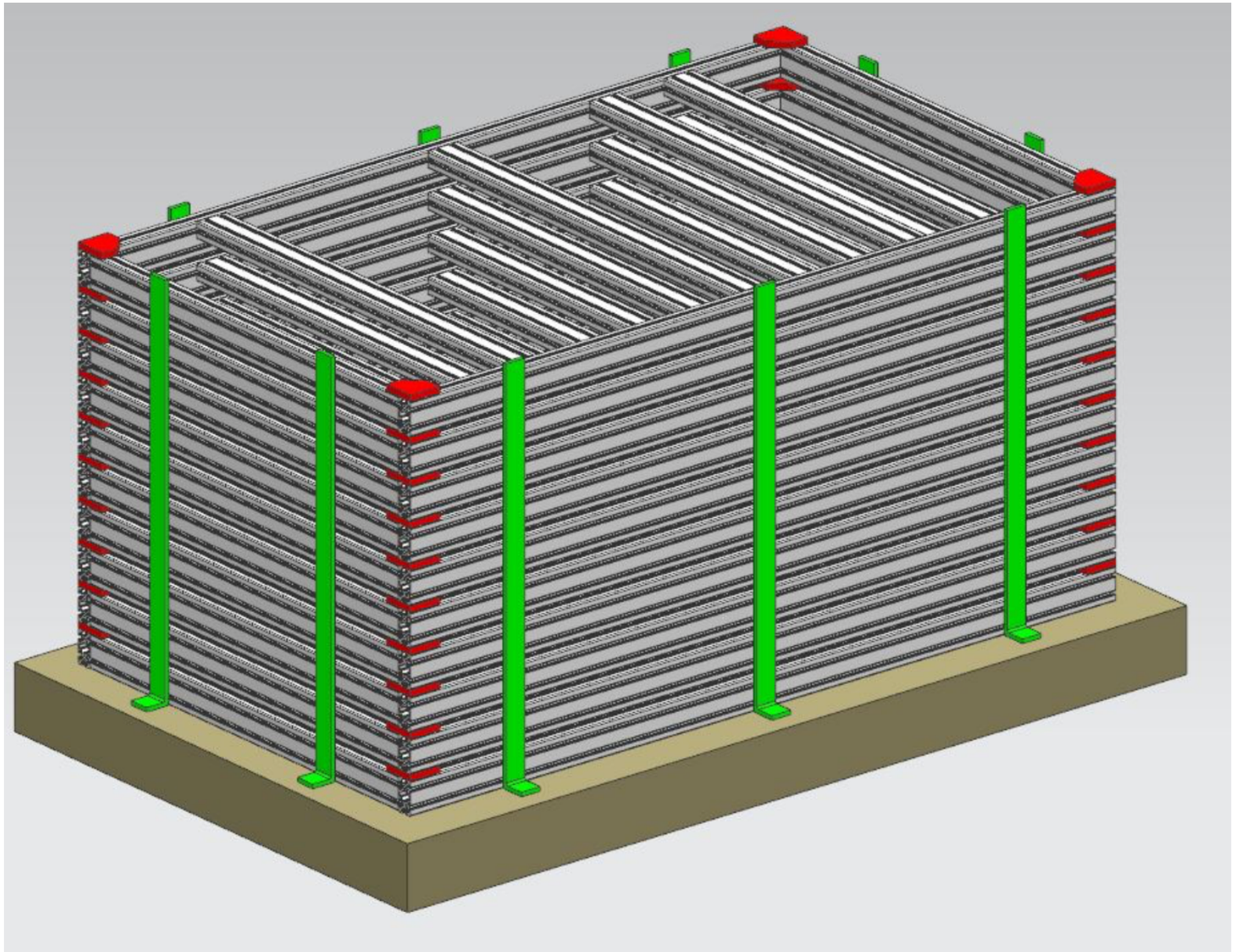
CMM

Lab E/F

- Planning to use the lab E/F area during the production phase
  - Receive Copper cooling plates and cassette Copper covers in lab E/F
    - Large space for safe and easy handling and storage
    - Crane is available
  - Make QC reception measurements on the plates
    - Large CMM
  - Pressure test the embedded tubing

Lab E/F

- Possibly store the stacks of assembled and packaged cassettes in lab E/F after they are out of the factory in lab C and while they’re waiting to be shipped

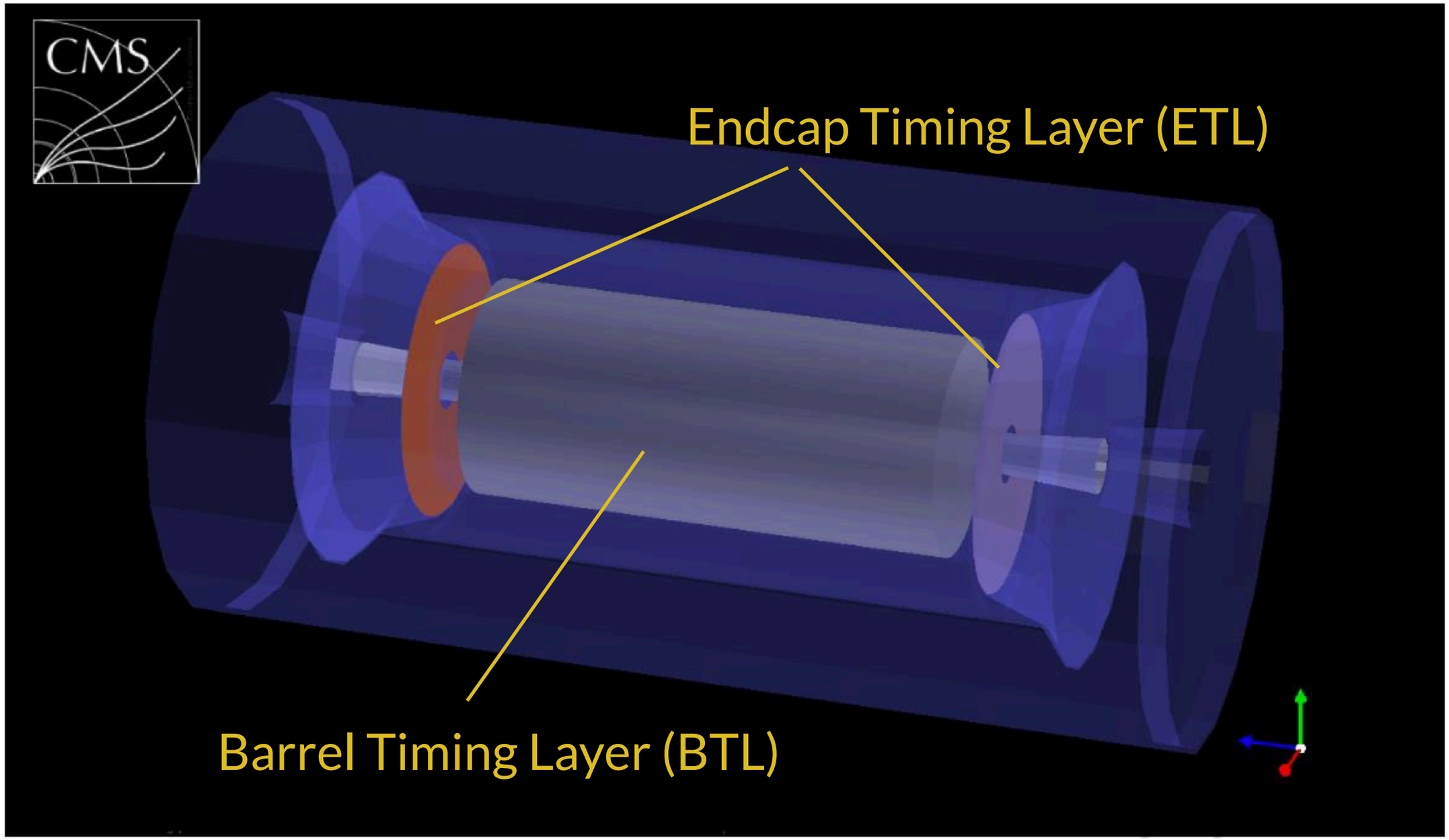


HGCal Points of Contact

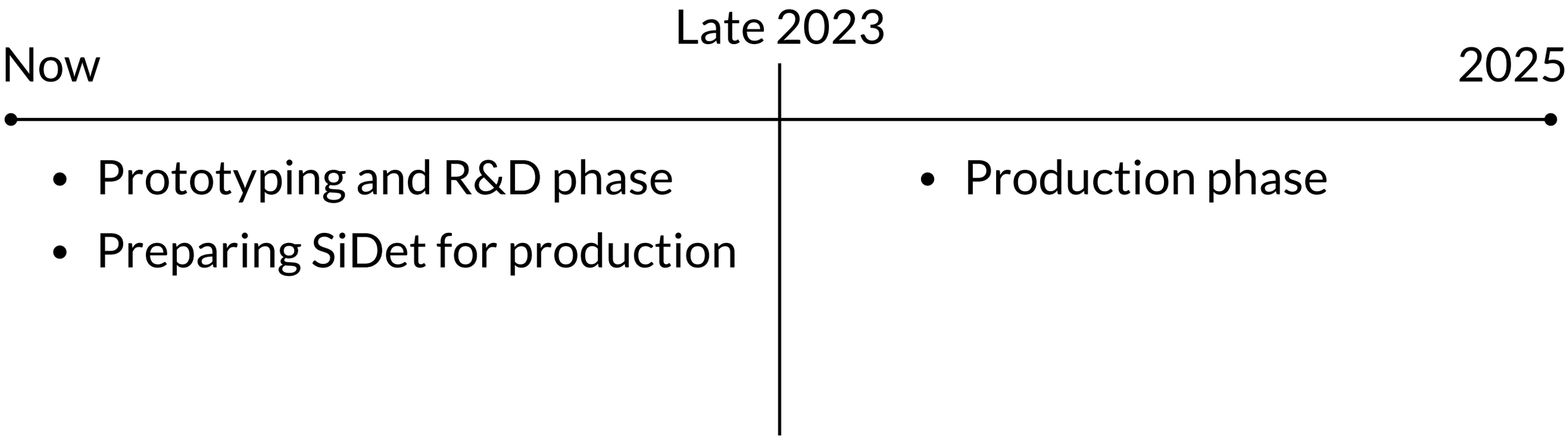
- For more information or planning an on-site visit please contact:
  - Zoltan Gecse
    - zgecse@fnal.gov
  - Maral Alyari
    - maral87@fnal.gov

MIP Timing Detector

MIP Timing Detector (MTD)

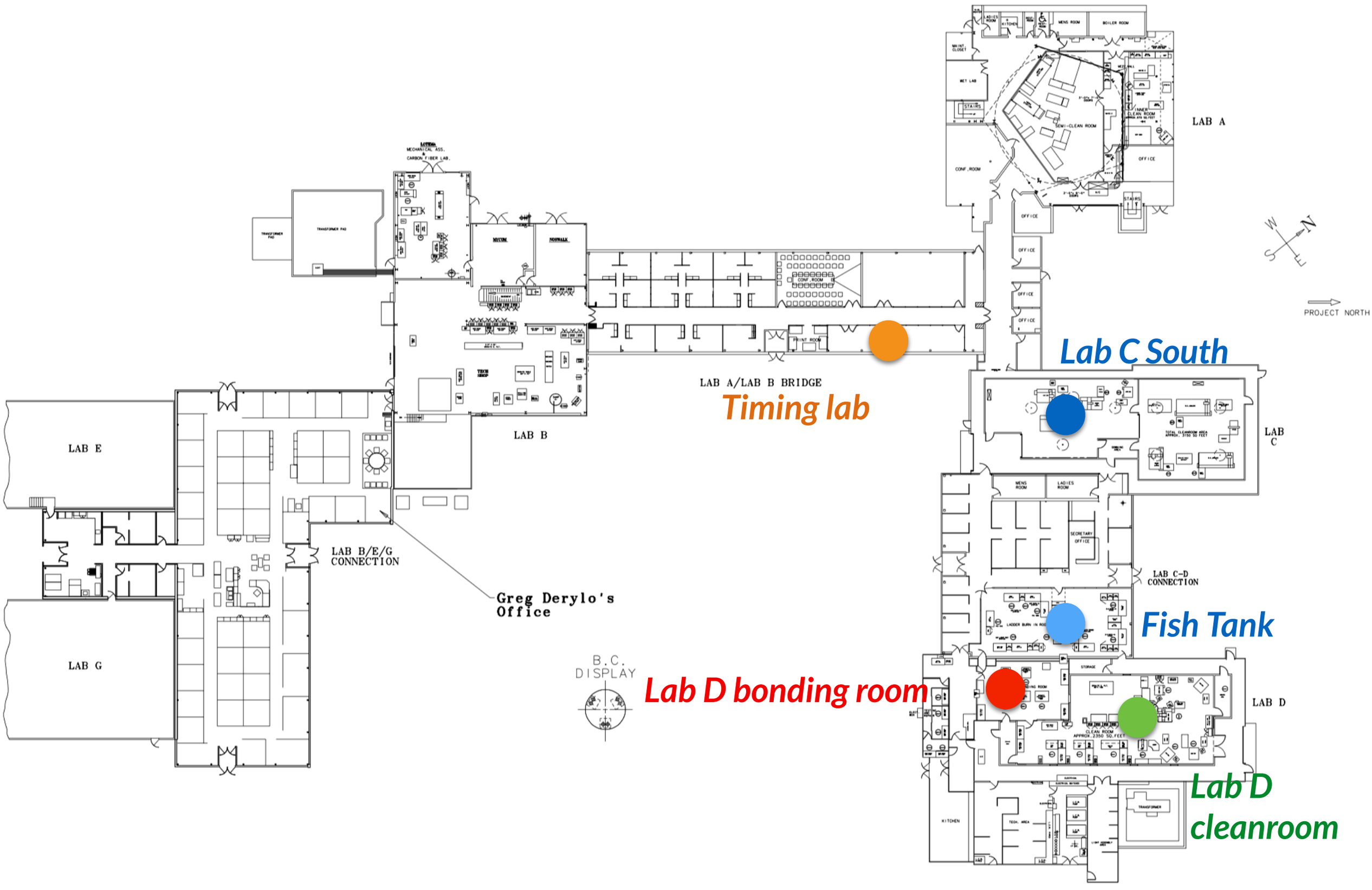


ETL Overall Time-line



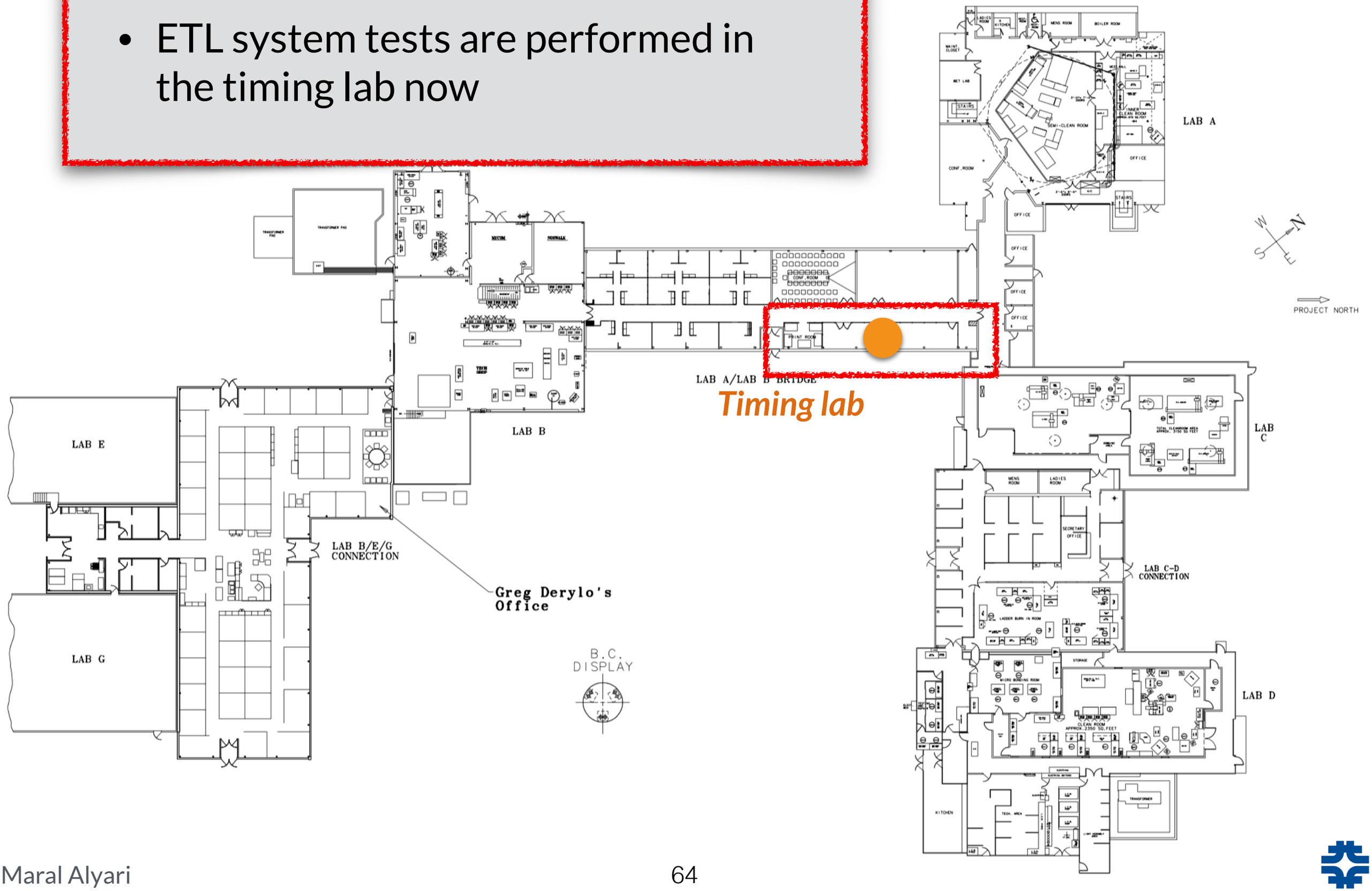
- Next slides will cover:
  - The areas at SiDet utilized by ETL
    - The current activities in each area
    - Activities planned during the production phase in that area

ETL at SiDet


LAB A
LAB A/LAB B BRIDGE
LAB B
LAB E
LAB G
LAB B/E/G CONNECTION
Greg Derylo's Office
B.C. DISPLAY
LAB C
LAB C-D CONNECTION
LAB D
PROJECT NORTH
Lab C South
Timing lab
Fish Tank
Lab D bonding room
Lab D cleanroom

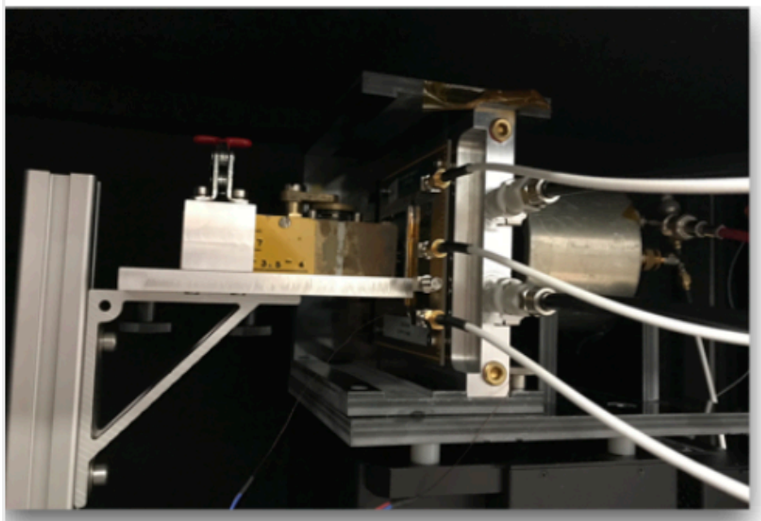
ETL: Timing Lab

- ETL system tests are performed in the timing lab now

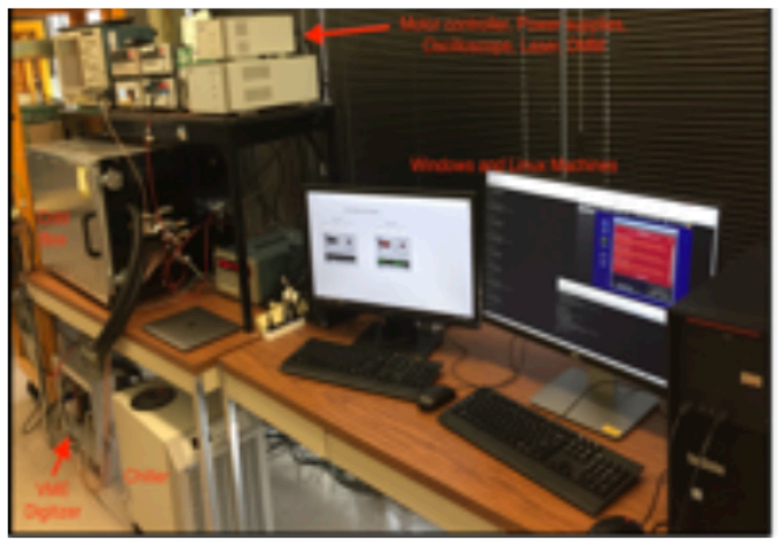


Timing Lab

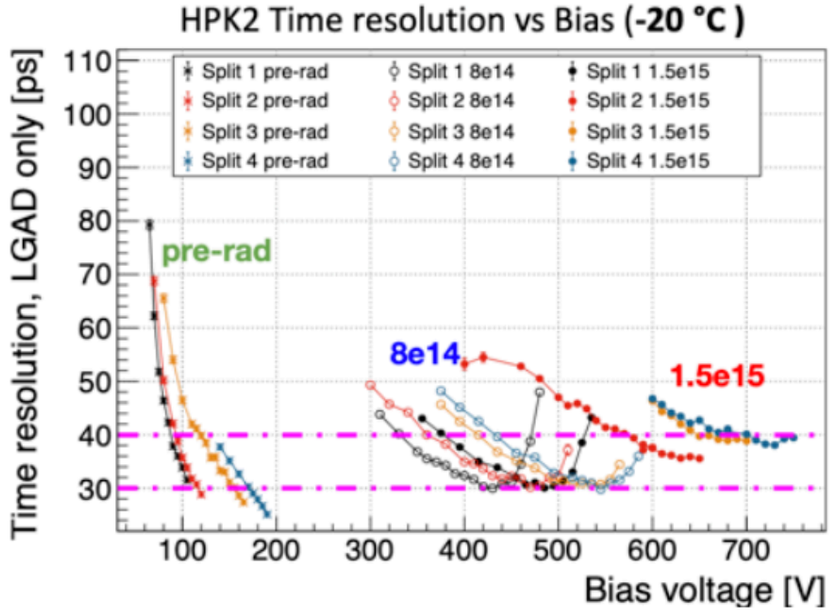
- Sensor work in the timing lab: study of HPK and FBK sensors (both pre- and post-irradiation) using the beta-gun setup, preparation for test beam campaign to characterize large number of sensors.



FNAL β source box



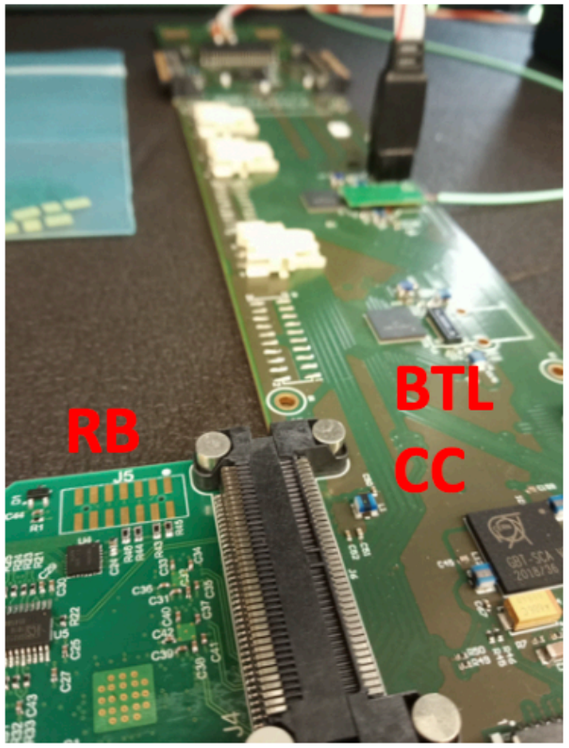
Testing setup in SiDet

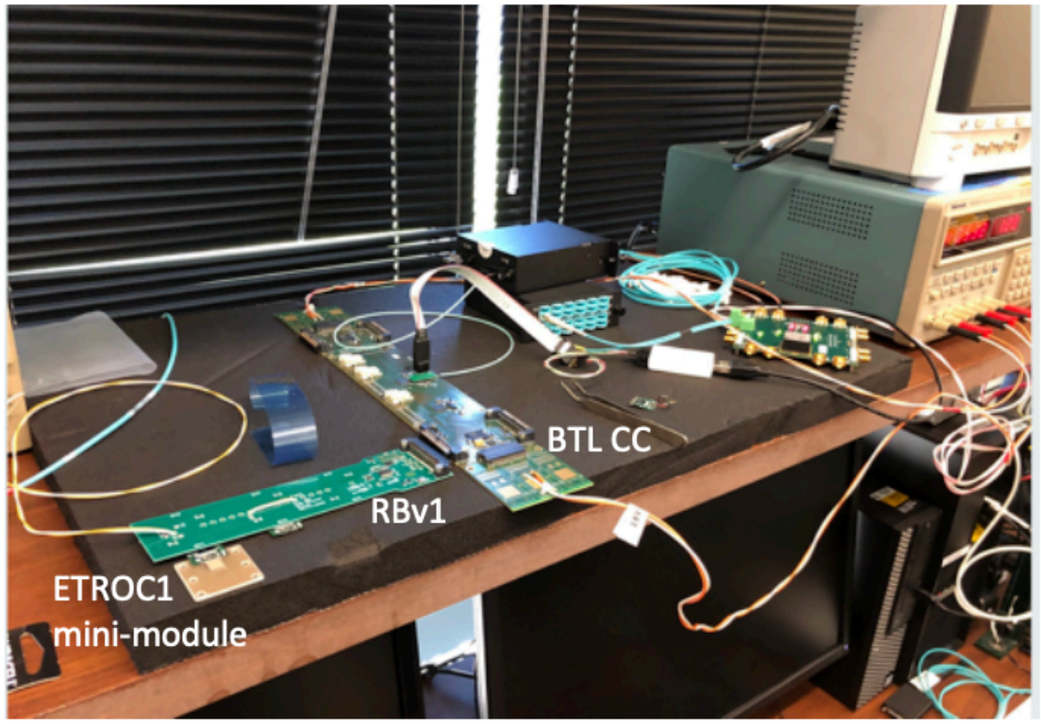


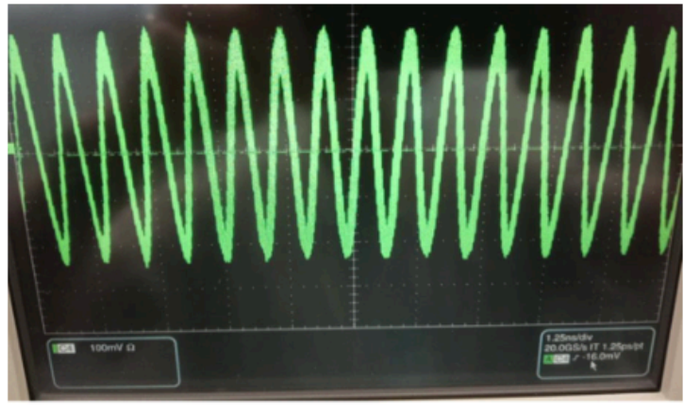
Measurements in SiDet

Timing Lab

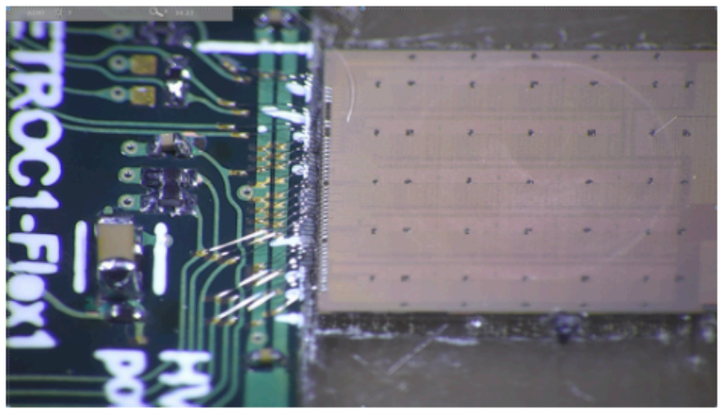
- Module electrical testing in the timing lab: system tests using ETROC1-based modules connected to the readout board prototype v1.







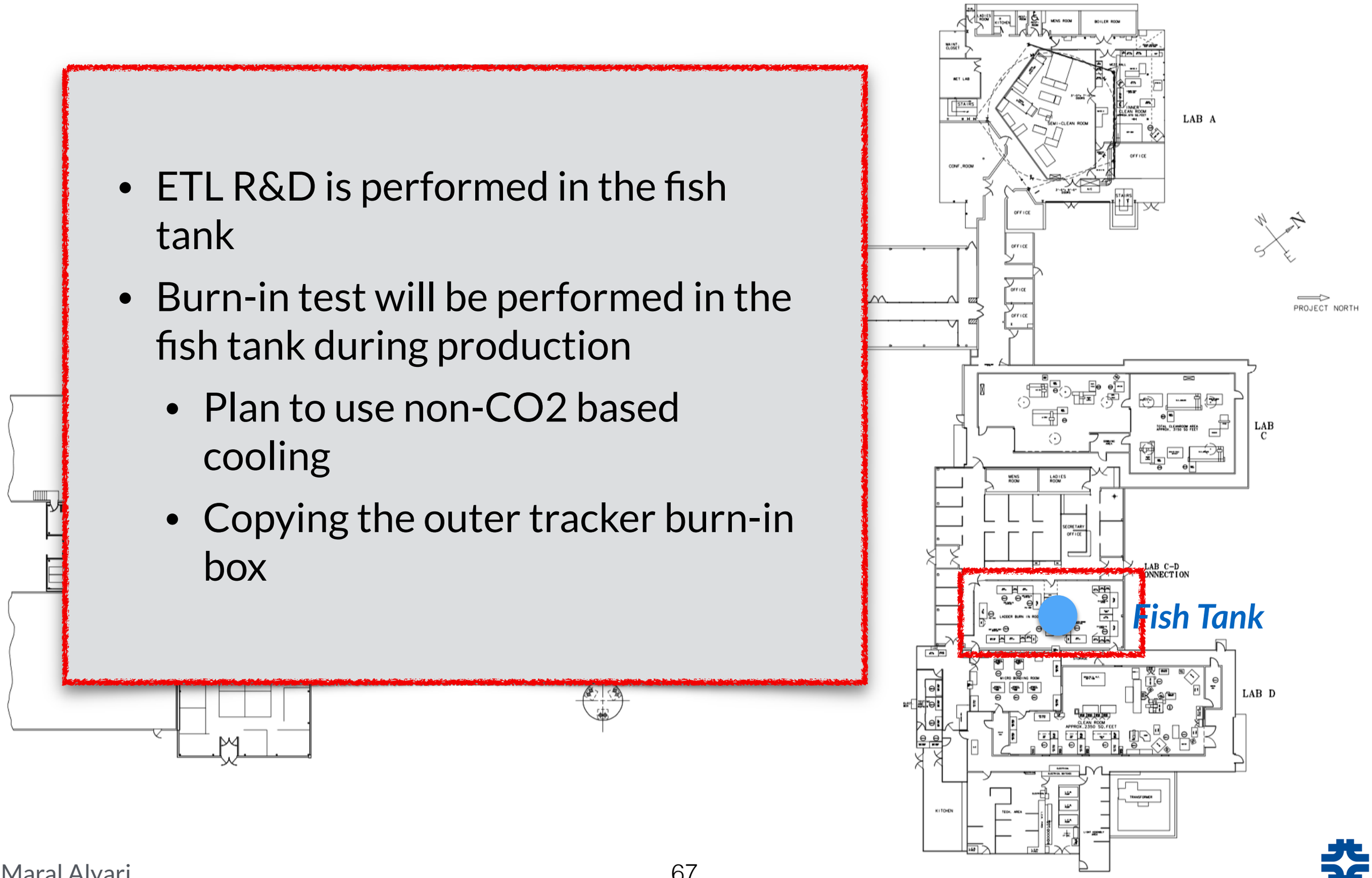
Clock at the flex output



Wire-bonded ETROC1 on mini-module

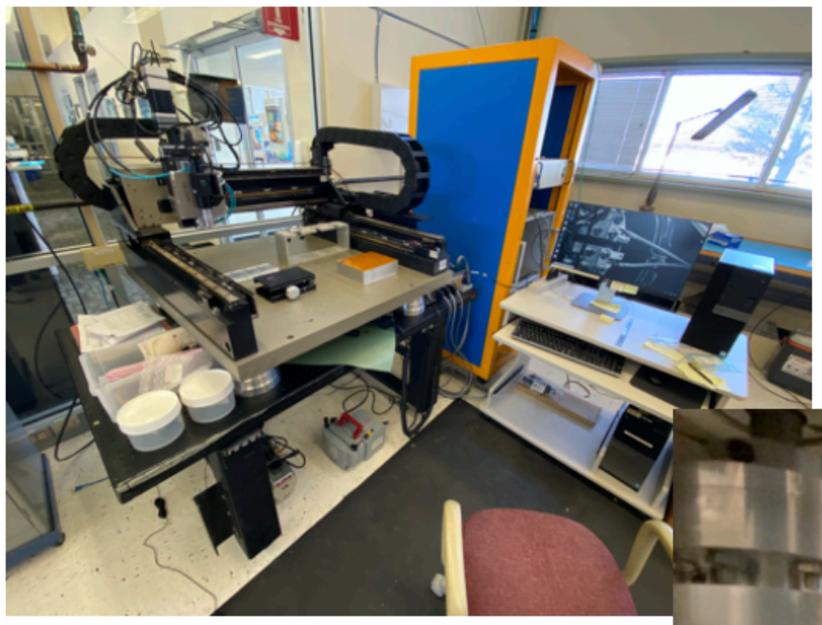
ETL: Fish Tank

- ETL R&D is performed in the fish tank
- Burn-in test will be performed in the fish tank during production
  - Plan to use non-CO2 based cooling
  - Copying the outer tracker burn-in box

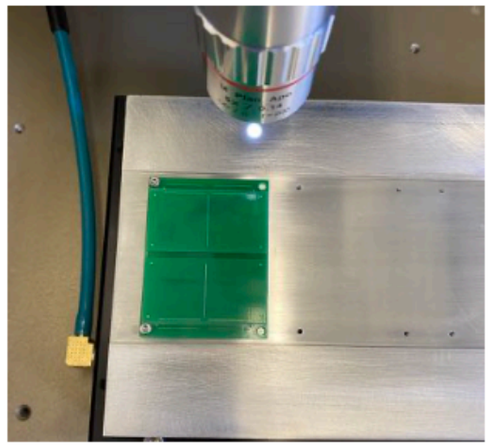


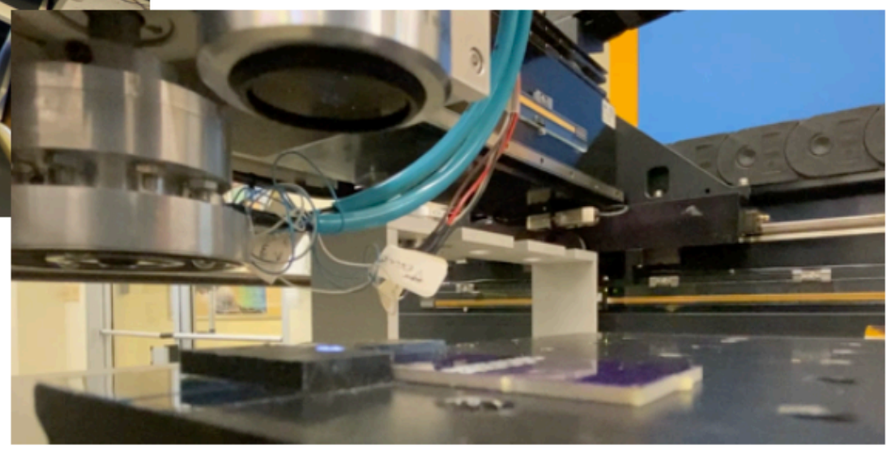
Fish Tank

- Module assembly work in fish tank: development of the software framework for the gantry, assembly of dummy modules using gantry and mechanical jigs.



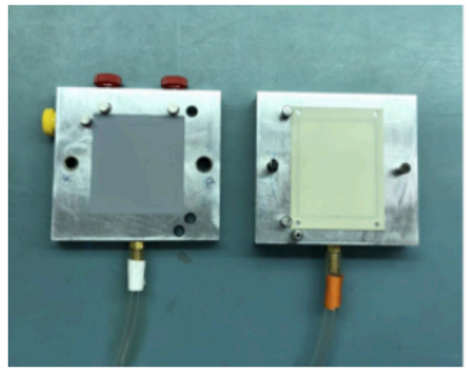
Gantry in fishbowl

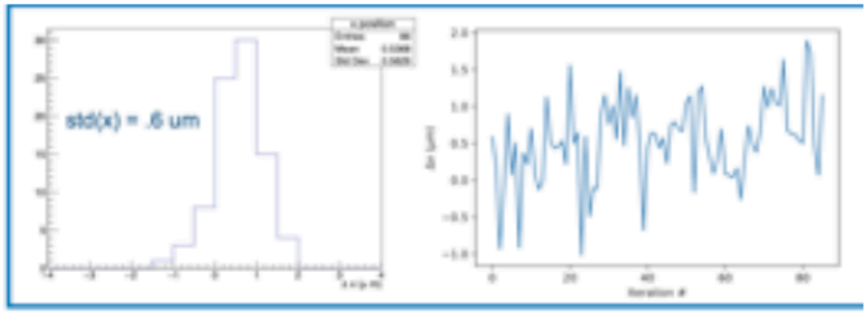




ETL dummy modules

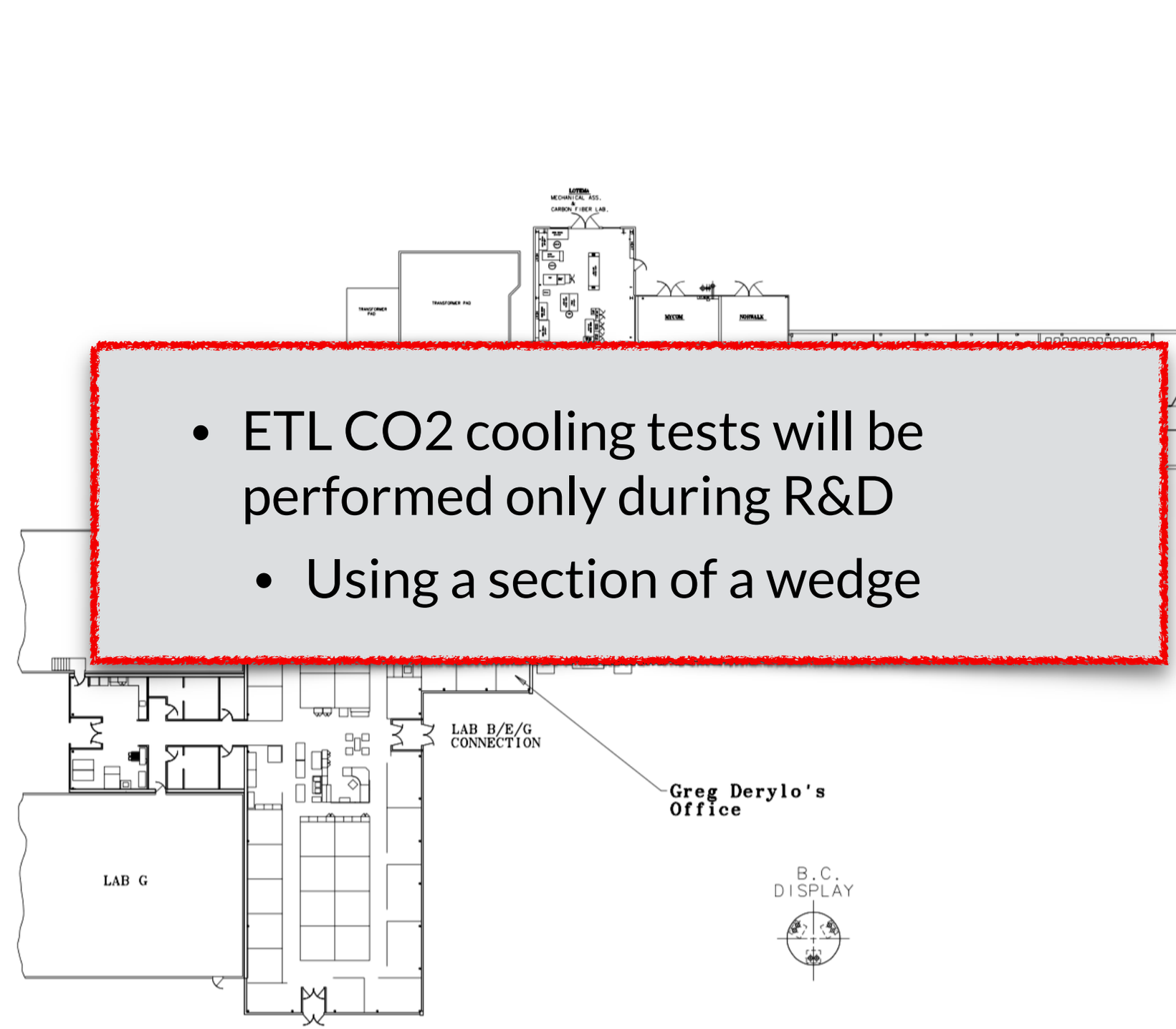
Modules assembled with a jig

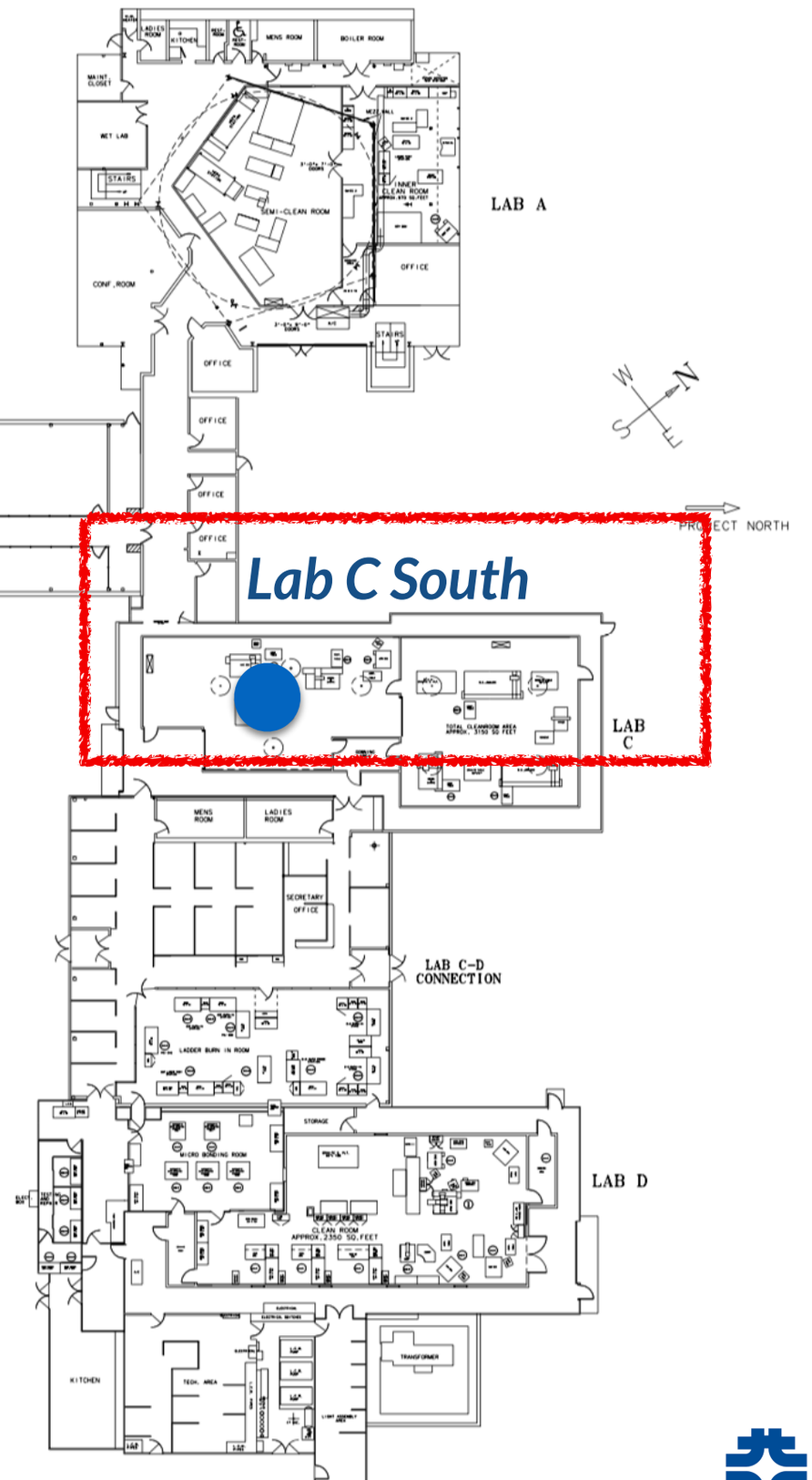




ETL: Lab C South

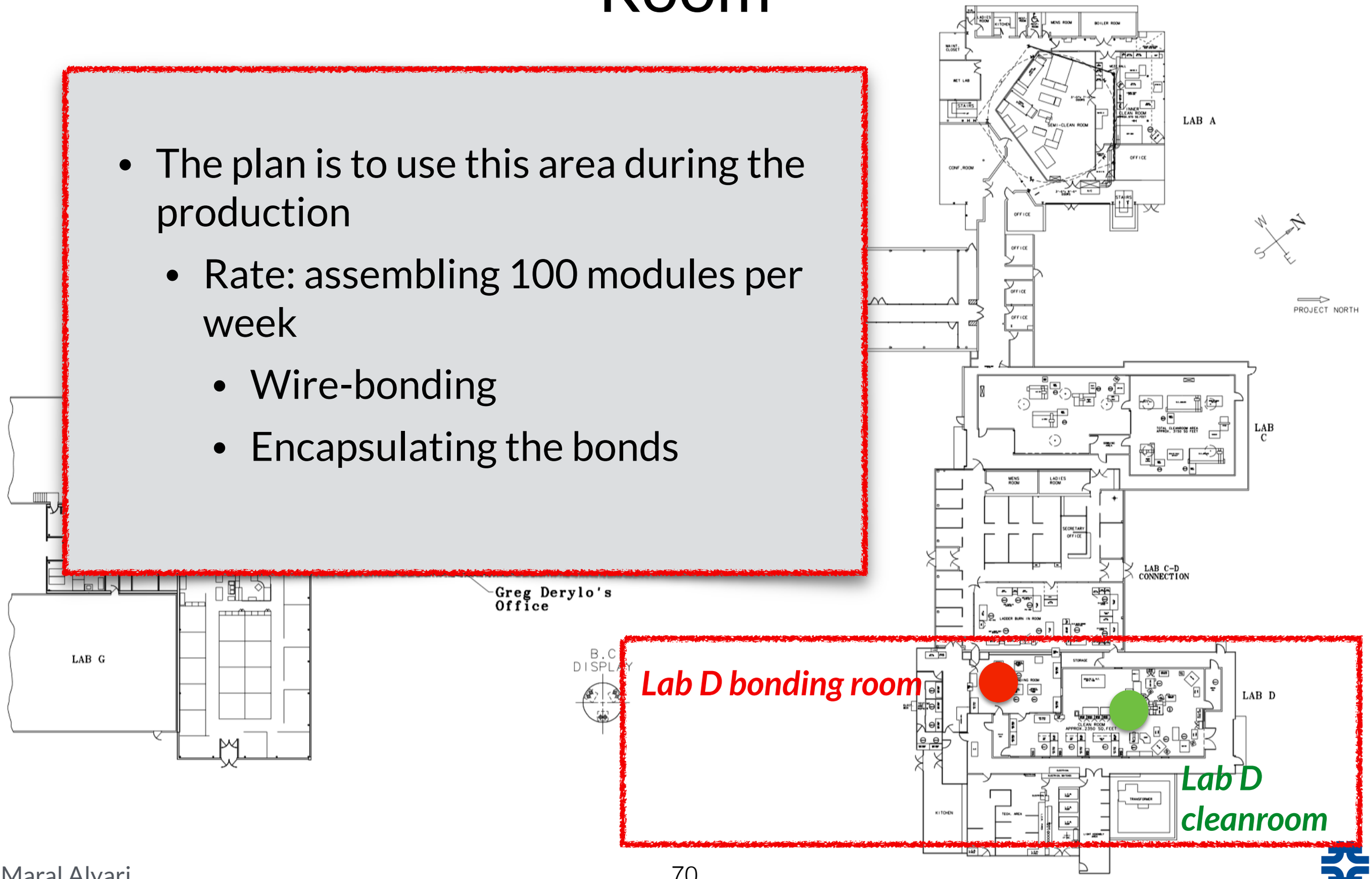
- ETL CO2 cooling tests will be performed only during R&D
- Using a section of a wedge





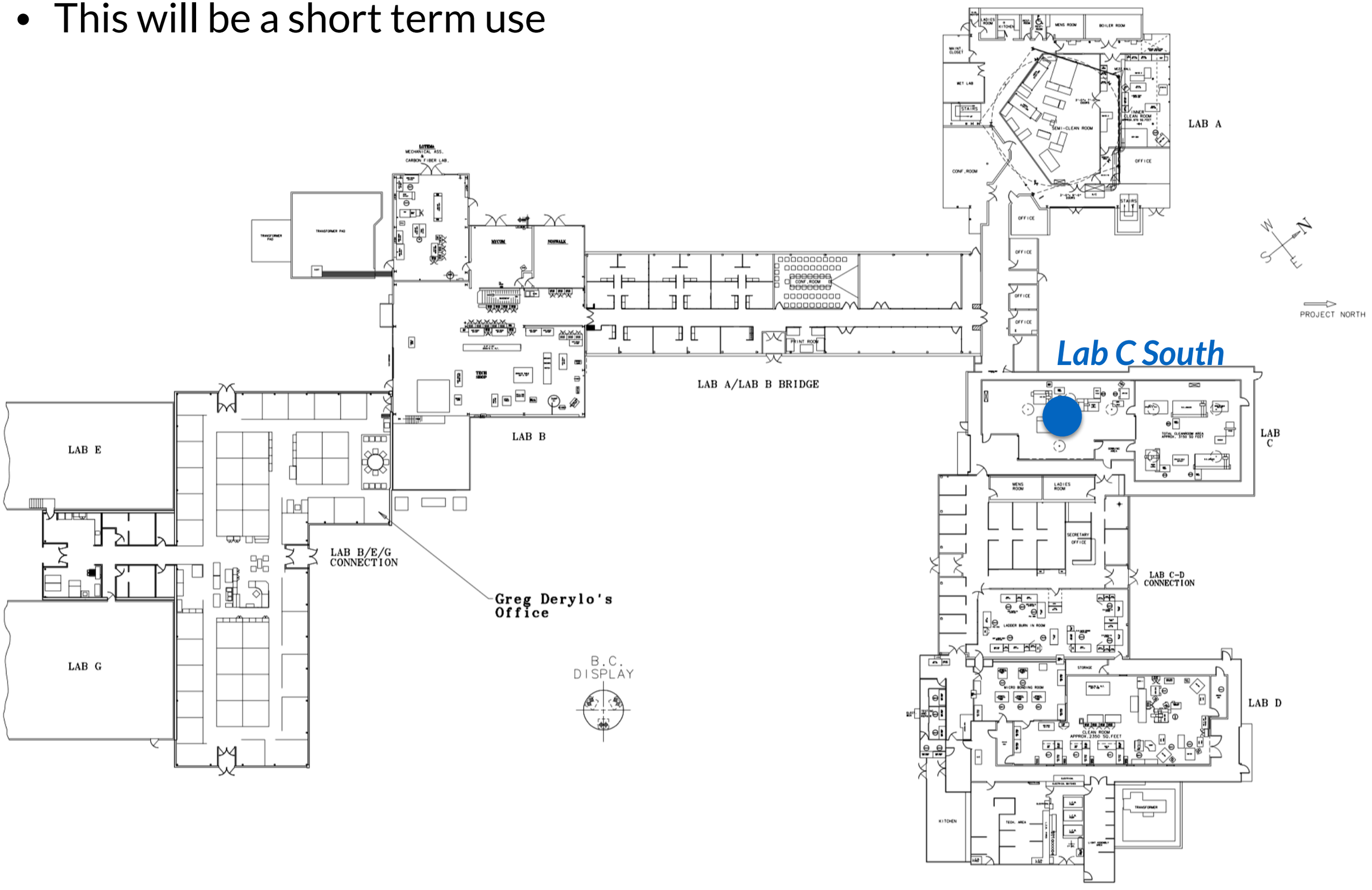
ETL: Lab D Cleanroom and Wire-bonding Room

- The plan is to use this area during the production
  - Rate: assembling 100 modules per week
  - Wire-bonding
  - Encapsulating the bonds



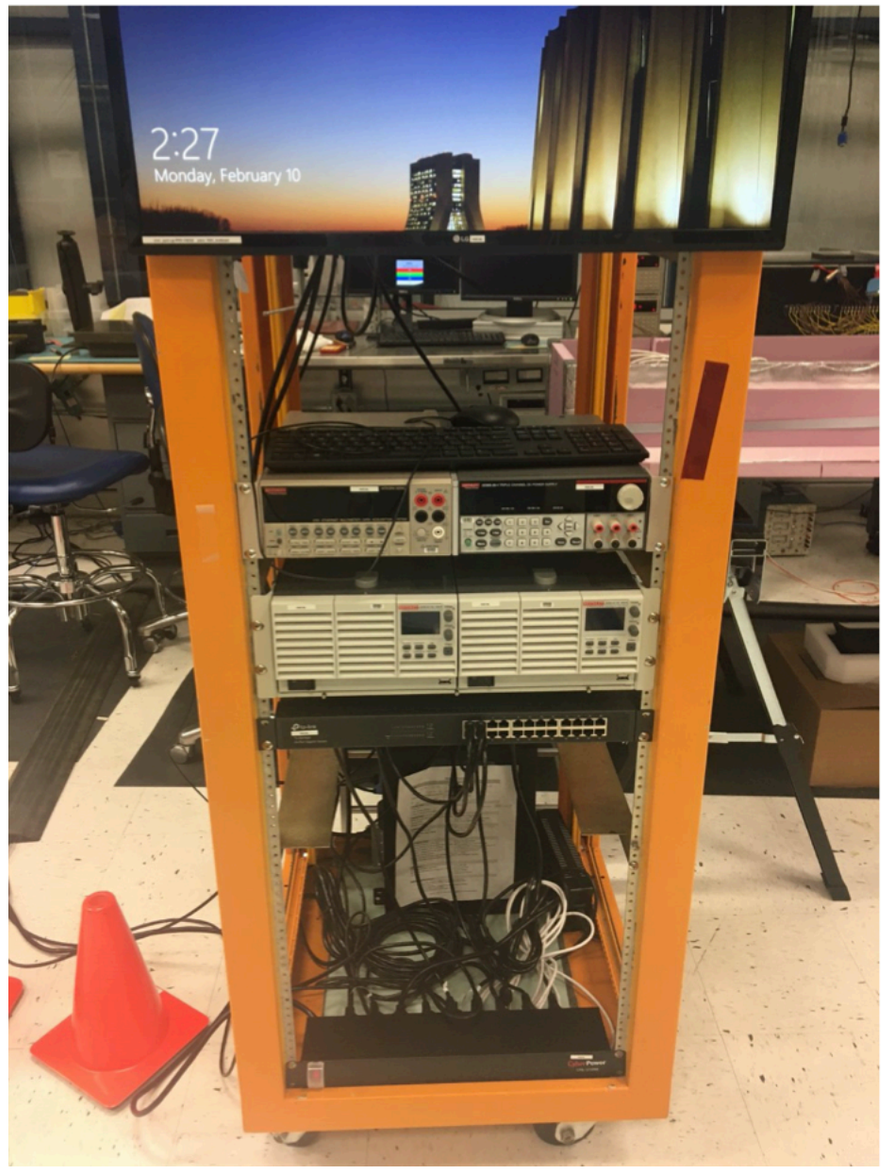
BTL at SiDet

- This will be a short term use



BTL Lab C South

- Will be bringing the tray and set-up to lab C on May 1st
- The goal is to characterize the temperature as a function of the CO2 flow and the injected power into the tray
- Will be completing an ORC prior to operation



MTD Points of Contact

- For more information or planning an on-site visit please contact:

  ETL:

  - Artur Apresyan
    - apresyan@fnal.gov

  BTL:

  - Frank Chlebana
    - chlebana@fnal.gov

Back-up