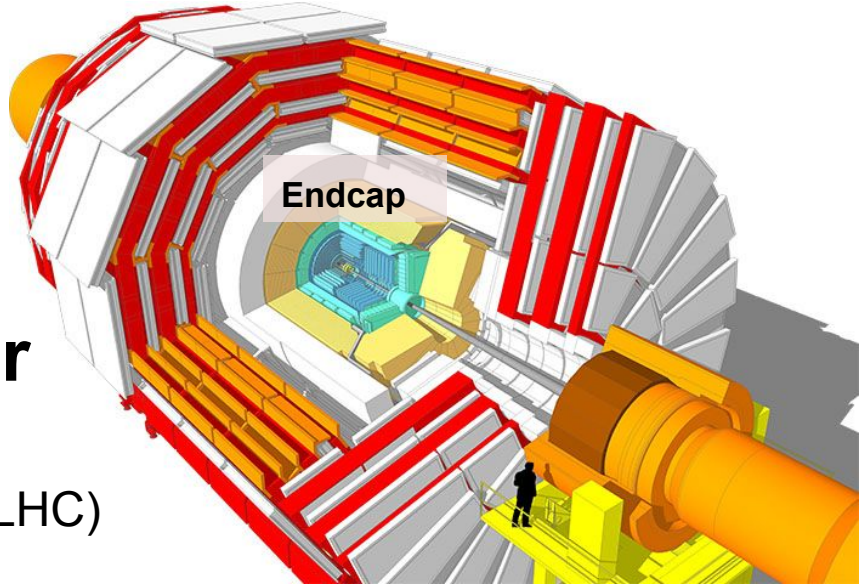
DPF-Pheno 2024

Silicon Module Assembly for CMS High Granularity Calorimeter

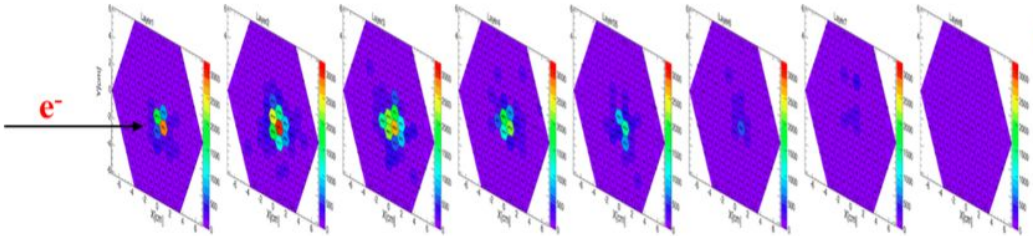
Sindhu Murthy
Module Assembly Center at CMU

CMS
High Granularity Calorimeter

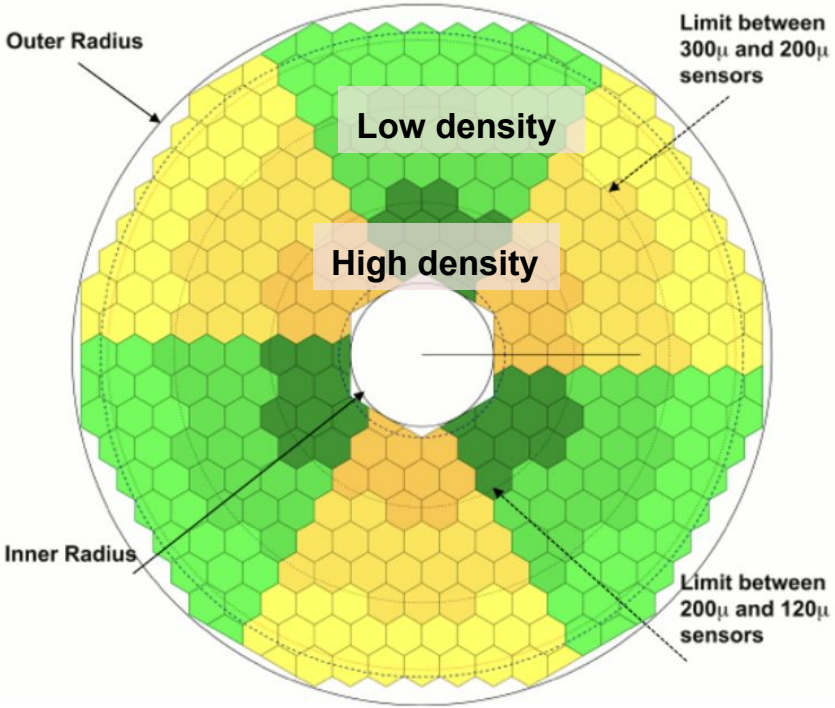


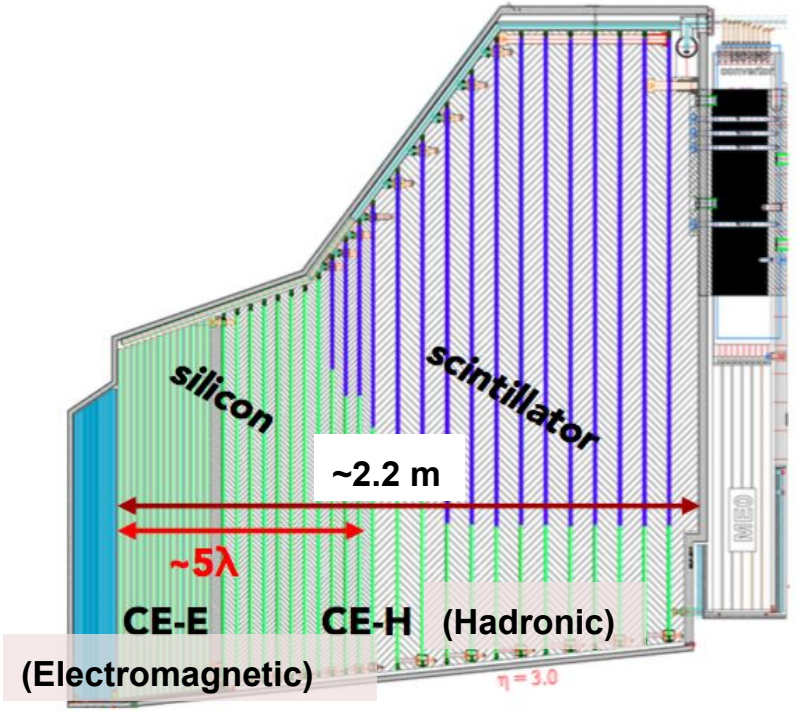
- High Luminosity Large Hadron Collider (HL-LHC)
  - 5-10x integrated luminosity expected
  - 5x number of events per bunch crossing (pileup)

- Compact Muon Solenoid (CMS) detector endcap calorimeter upgrade
  - 4D measurements
  - high-radiation tolerant



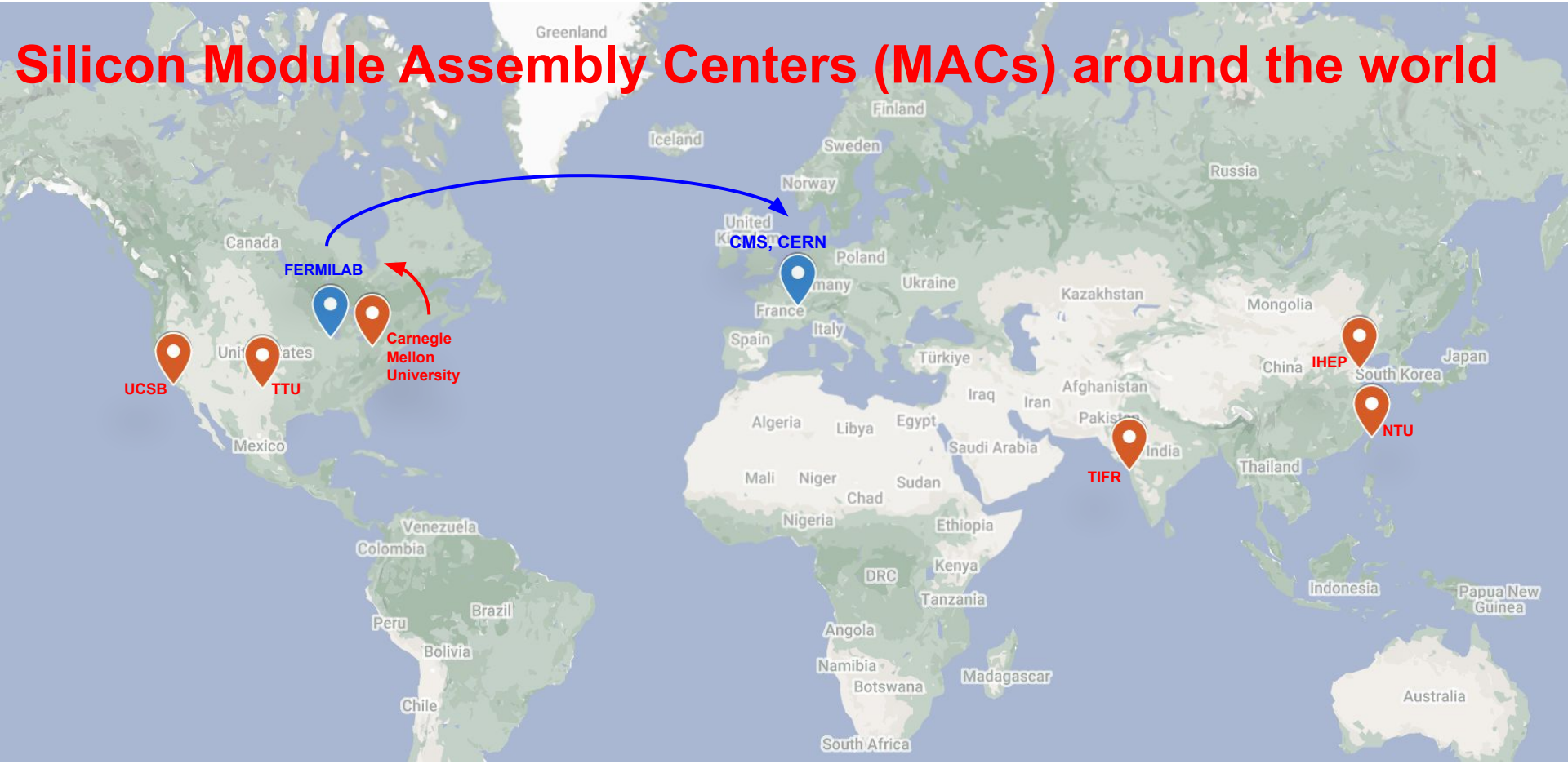
HGCal Silicon modules

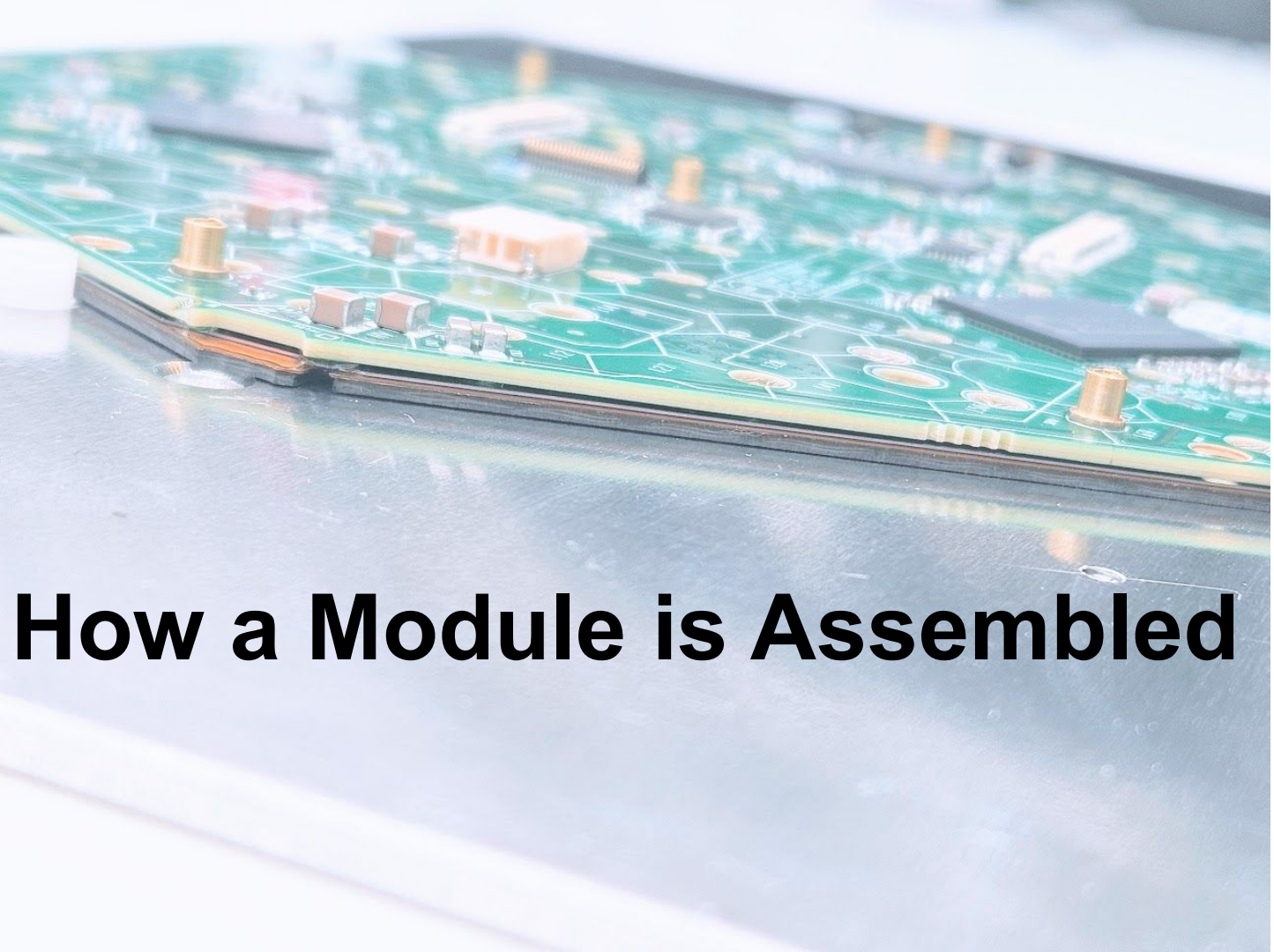




Particle showers leave deposits in the layers as they traverse through the endcap.

Silicon Module Assembly Centers (MACs) around the world

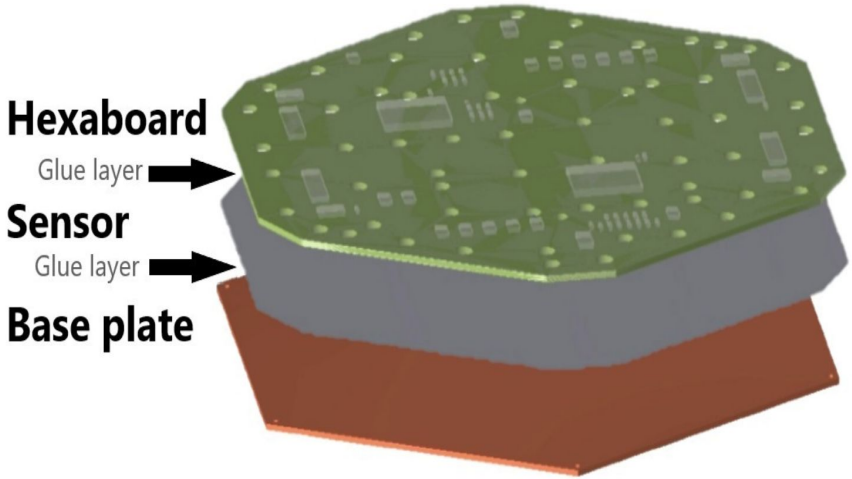




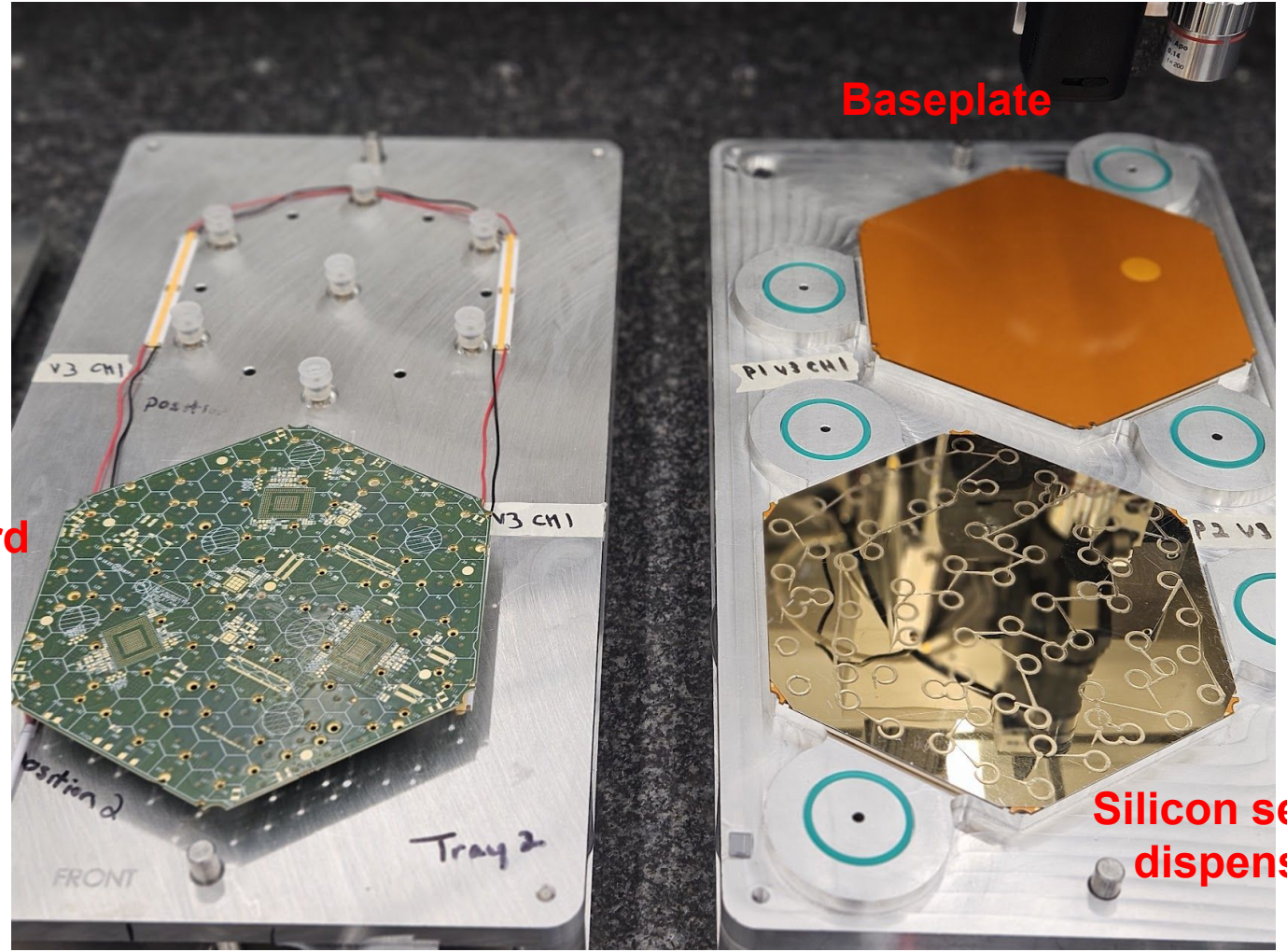
How a Module is Assembled

What makes a module?

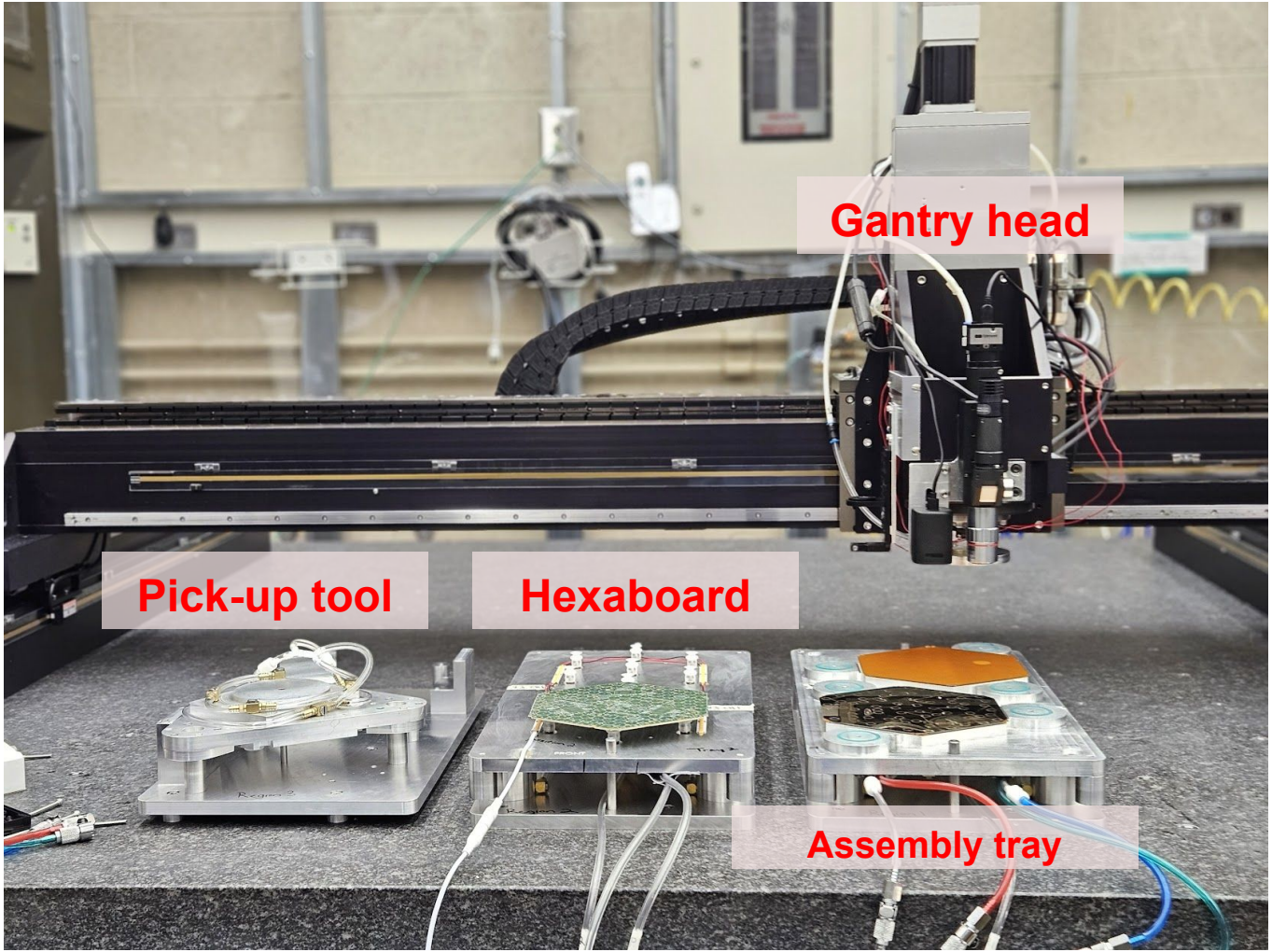
- 8″ modules
- Baseplate made of carbon fiber or CuW
- Silicon sensor
  - 3 thicknesses: 120μm, 200μm, 300μm
- Hexaboard with chips
- Adhesive between layers
- Shapes:
  - Full hexagon
  - Partials: left, right, top, bottom, five



Bare Hexaboard

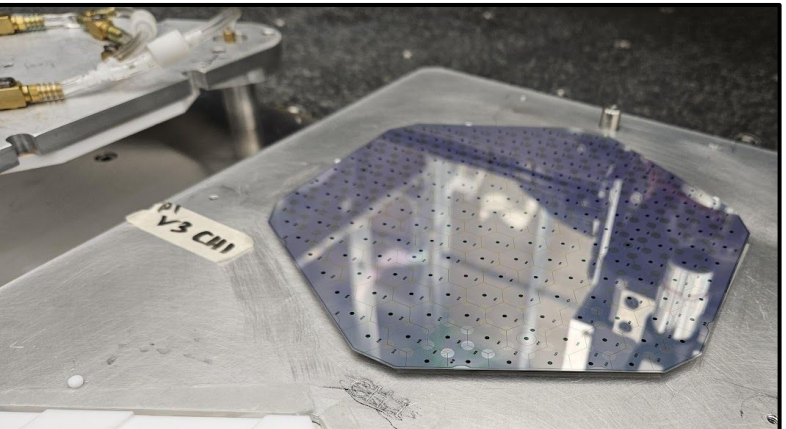


Silicon sensor with dispensed glue

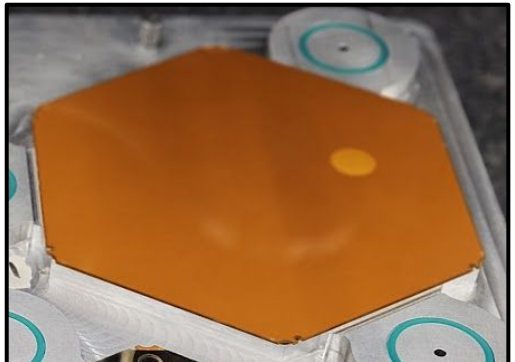

Gantry head
Pick-up tool
Hexaboard
Assembly tray

Assembly of modules

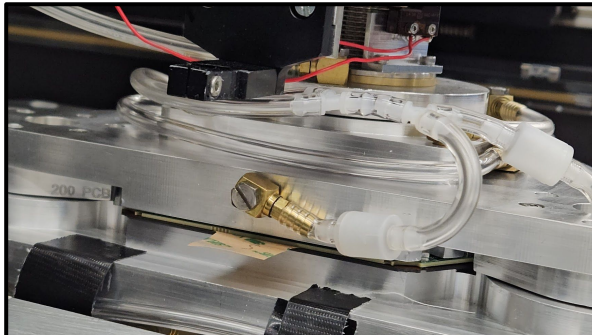
- Assembly done in two stages
  - **Stage 1: Assembly of protomodule**
    - Baseplate with adhesive
    - Sensor picked up + placed on baseplate with pick-up tool
    - ‘Protomodule’ cures under weight of pick-up tool.

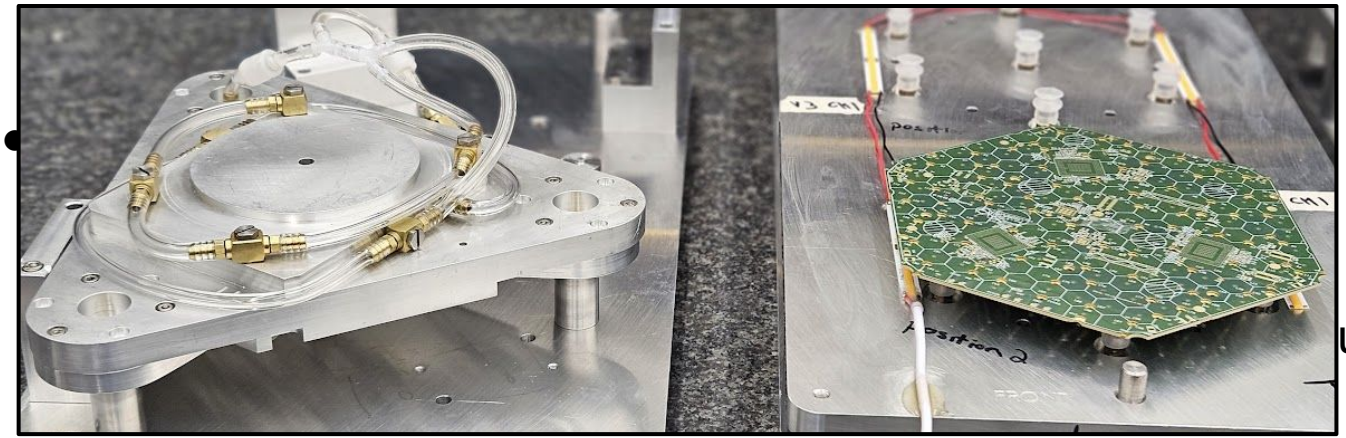


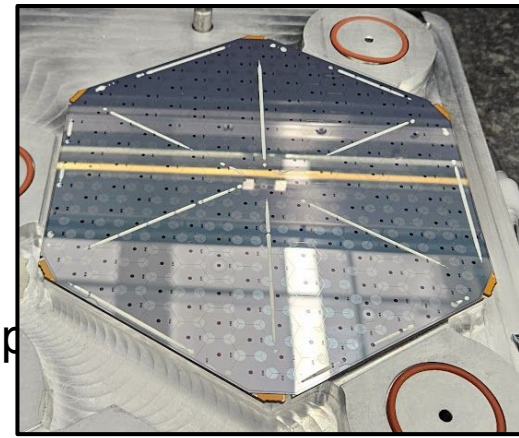
Baseplate



Curing







Hexaboard

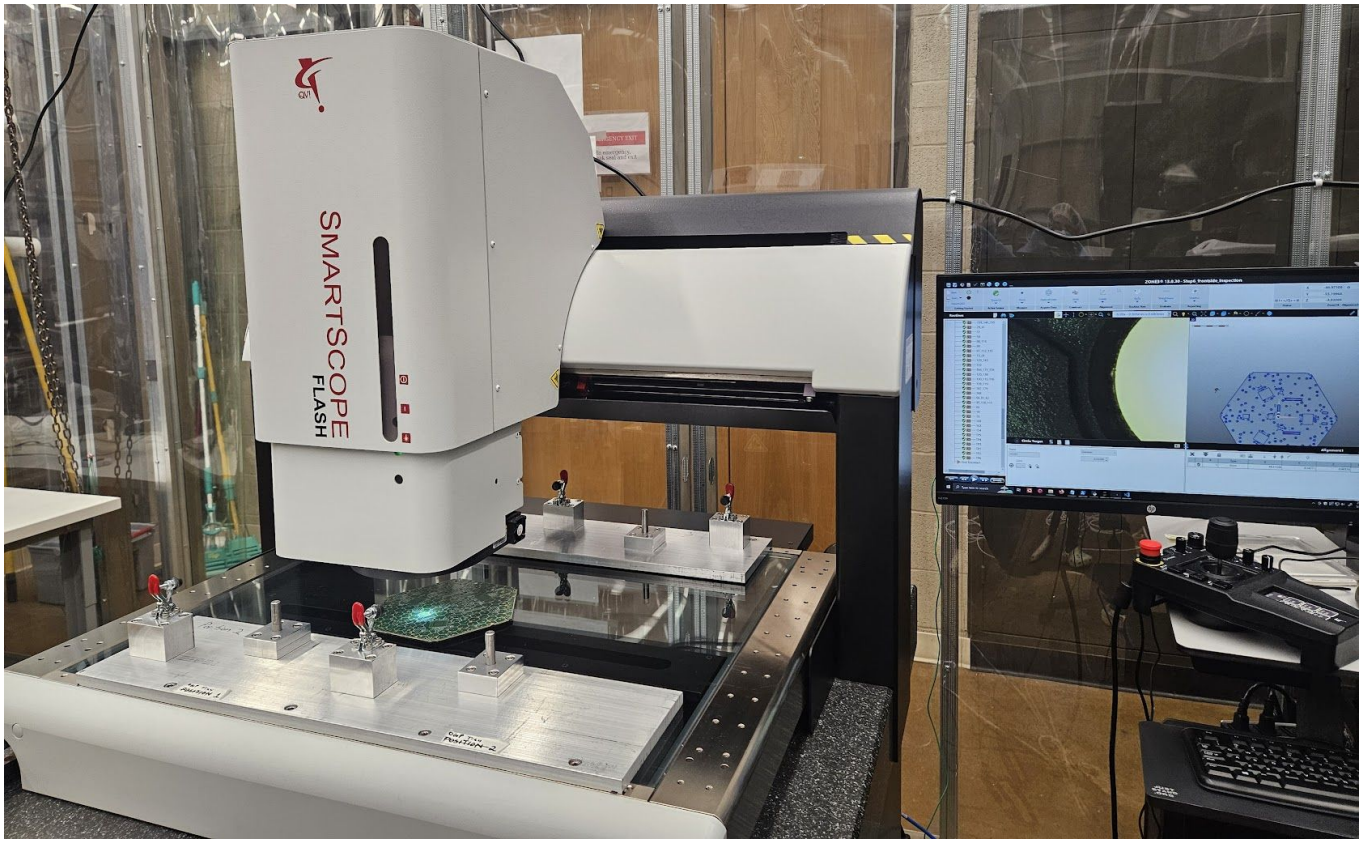
Protomodule with glue

- **Stage 2: Assembly of module**
  - Glue dispensed on protomodule
  - Hexaboard with adhesive in its underside
  - Hexaboard picked up + placed on protomodule with pick-up tool
  - Module cures under weight of pick-up tool.

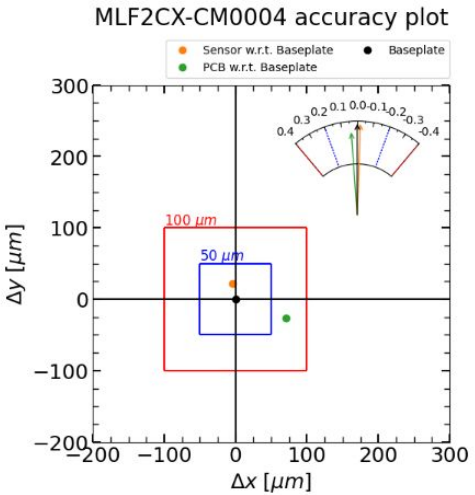
Inspection of modules

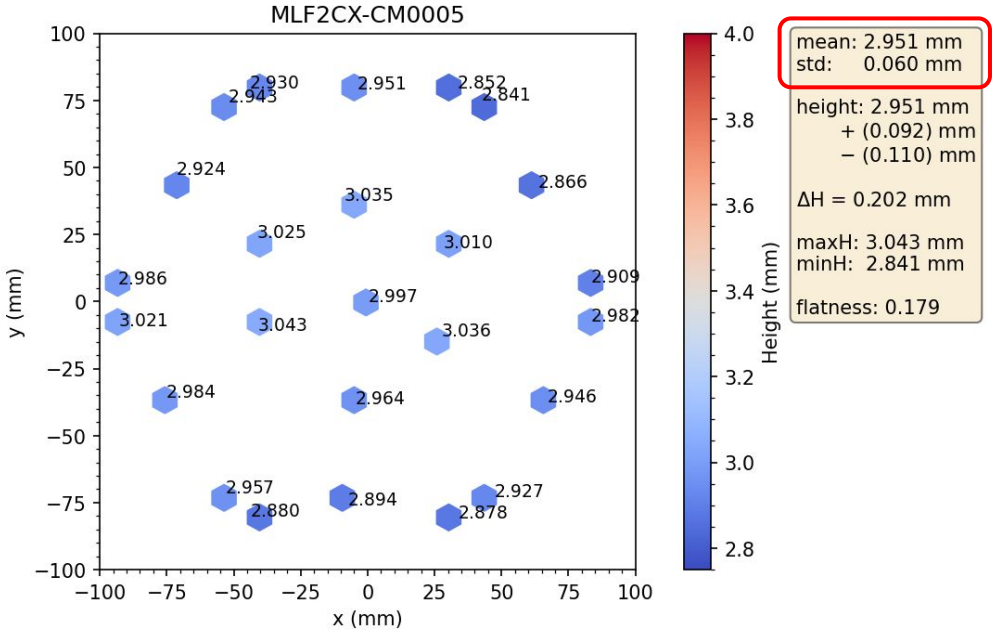
Visual inspection after assembly of (proto)module.

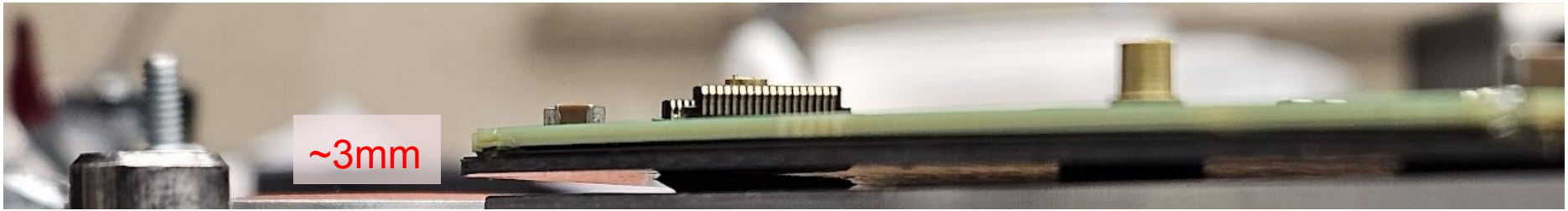
- Flatness
- Thickness
- Rotational offsets

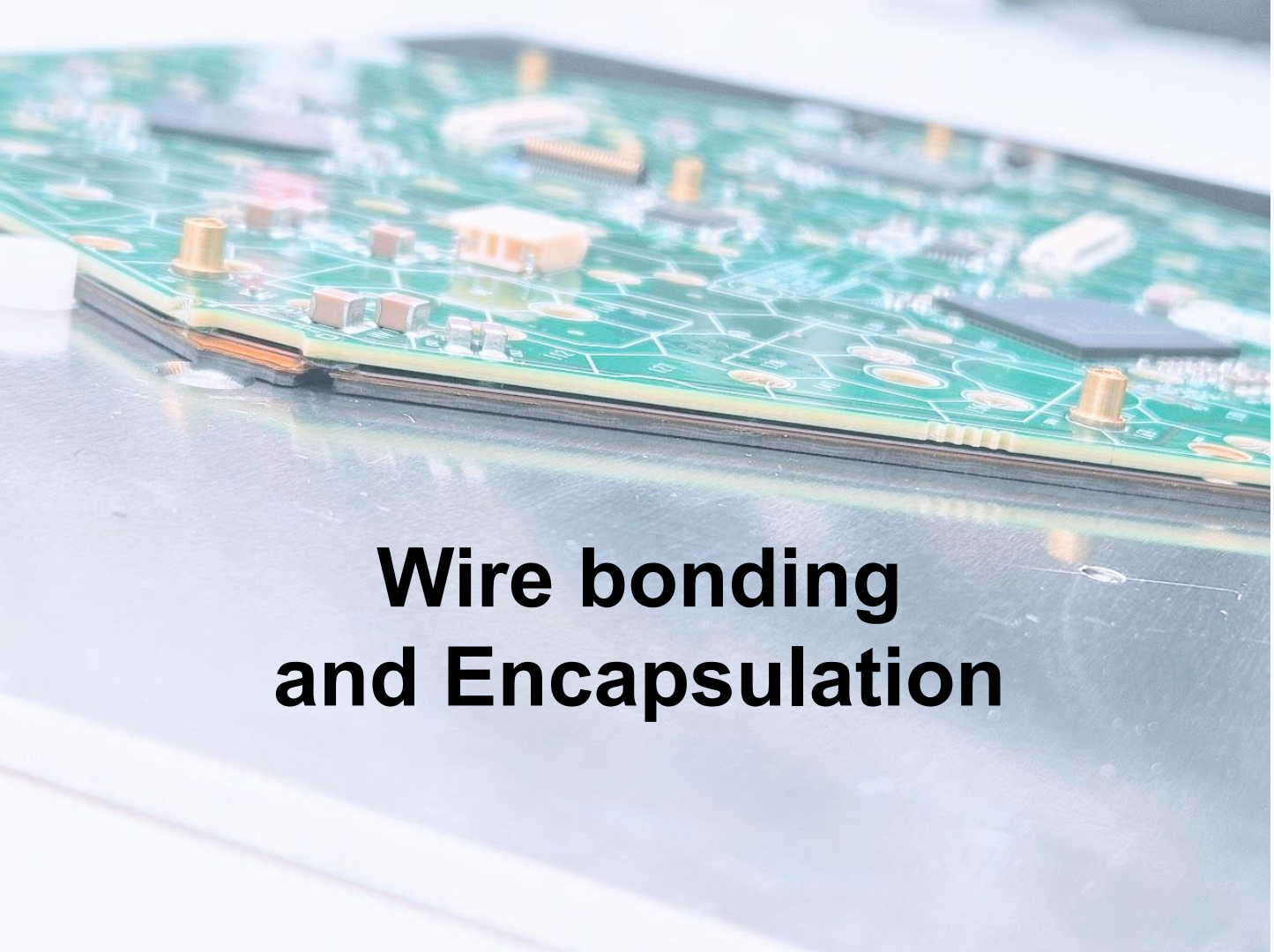


Example:


MLF2CX-CM0004 accuracy plot
Sensor w.r.t. Baseplate
PCB w.r.t. Baseplate
Baseplate
100 μm
50 μm
Δy [μm]
Δx [μm]


MLF2CX-CM0005
mean: 2.951 mm
std: 0.060 mm
height: 2.951 mm
+ (0.092) mm
− (0.110) mm
ΔH = 0.202 mm
maxH: 3.043 mm
minH: 2.841 mm
flatness: 0.179
y (mm)
x (mm)
Height (mm)

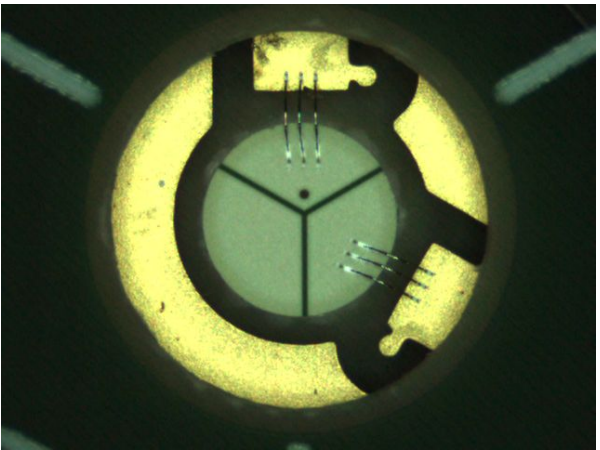

~3mm

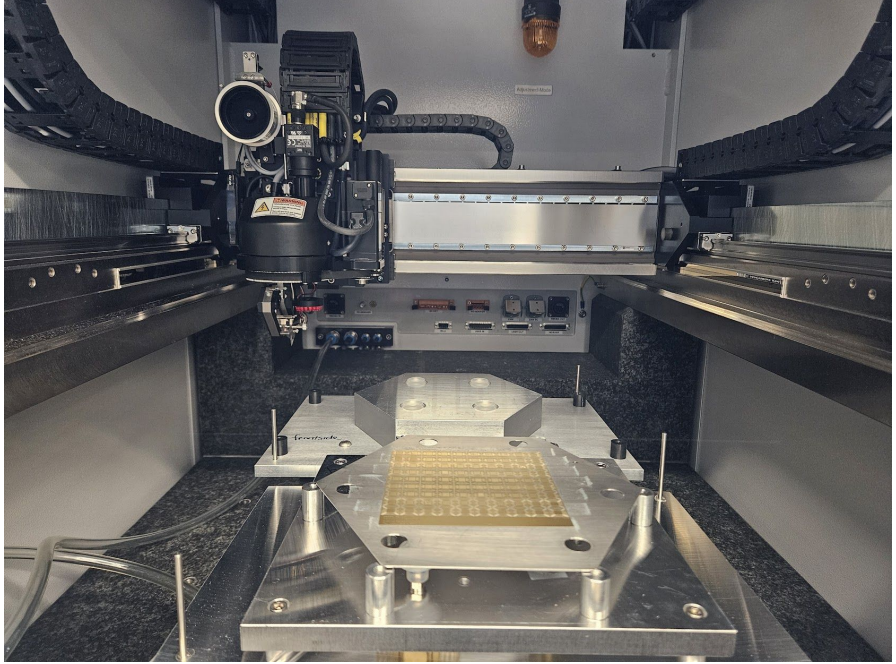


Wire bonding and Encapsulation

Wire bonding

- Wire bonds from baseplate to hexaboard
- Wire bonds from hexaboard to sensor in hexaboard stepholes
- Lay multiple bonds at each spot
- Check strength of bonds by pulling

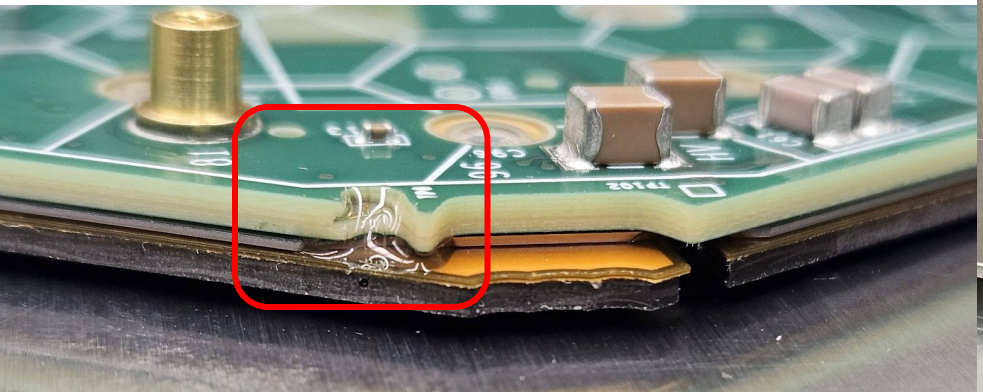


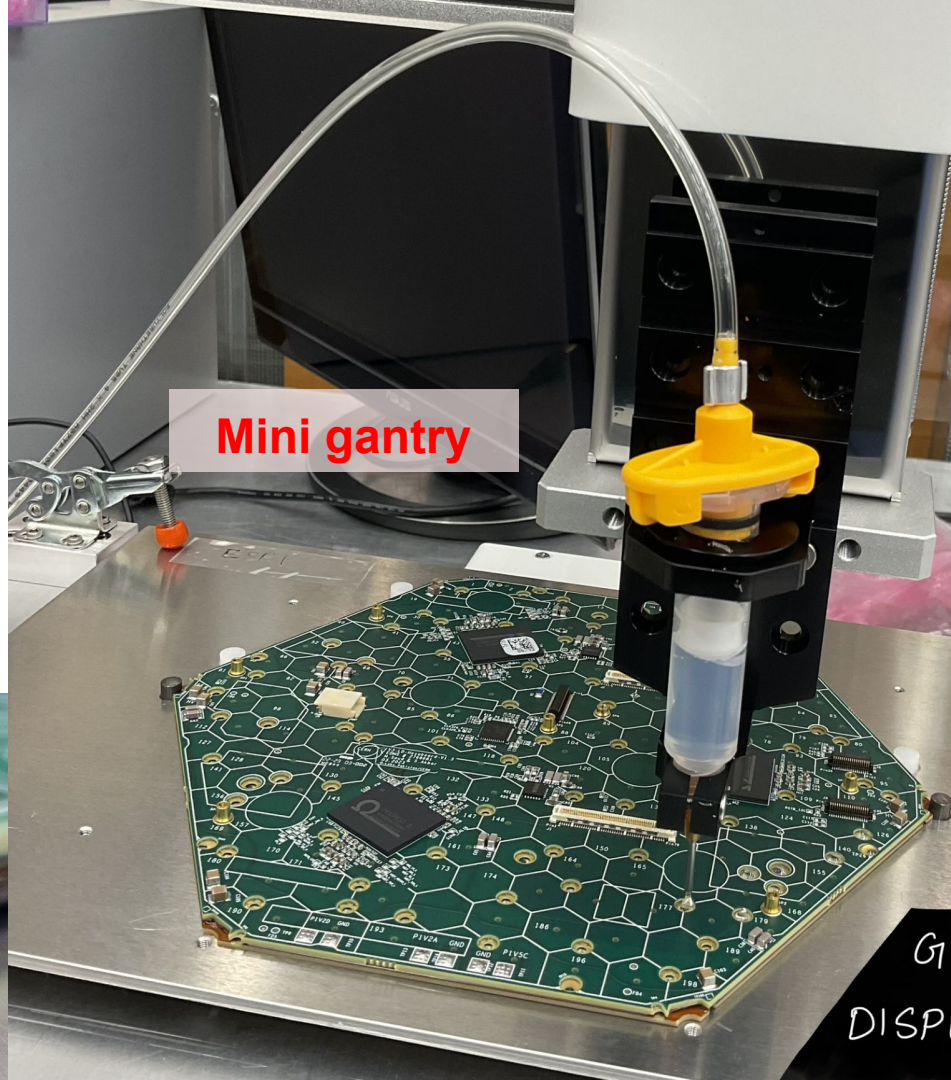


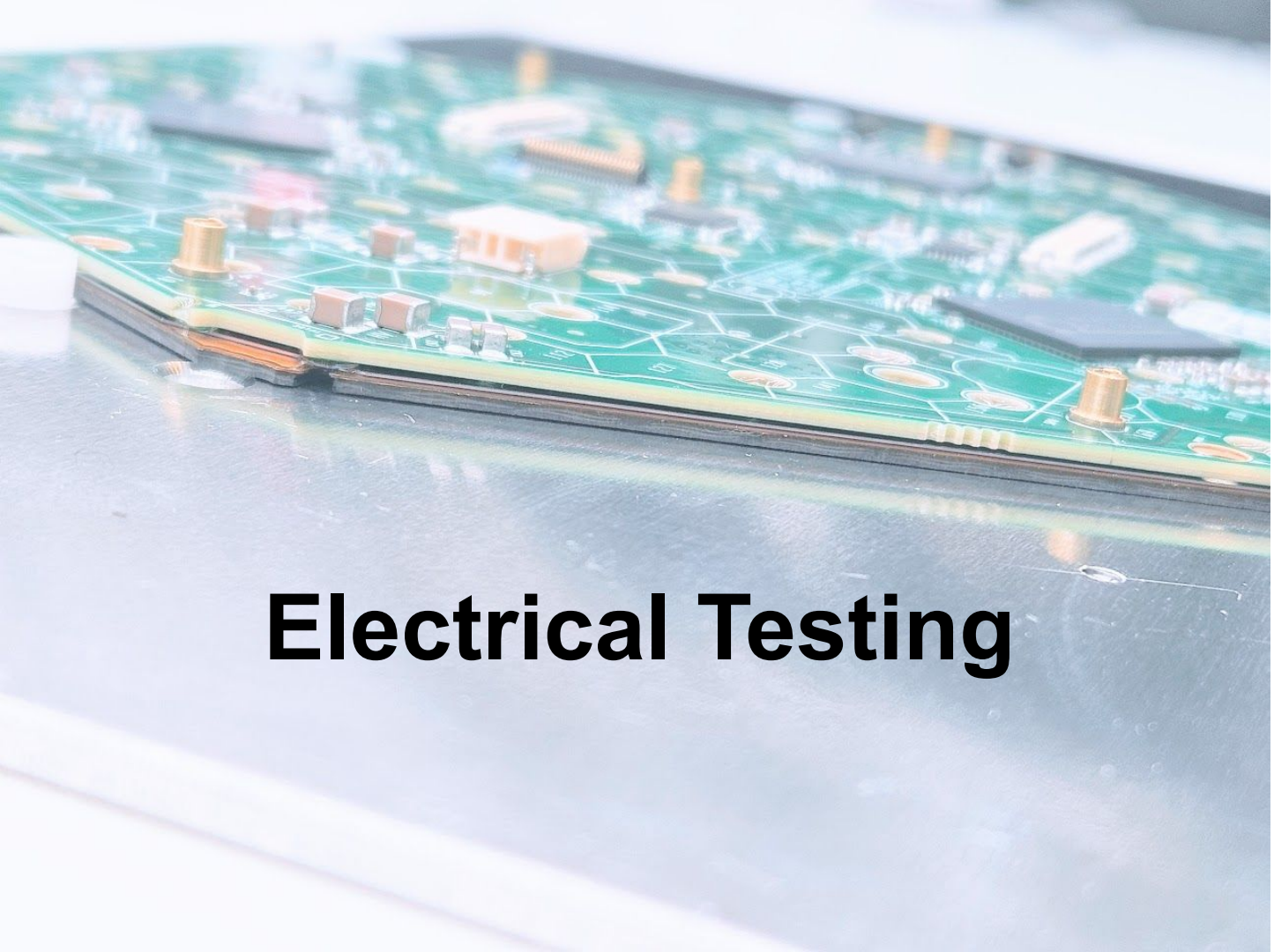
Wire bonder

Encapsulation

- Wire bonds are protected by encapsulating with epoxy.
- Performed manually and automatically on a mini gantry.



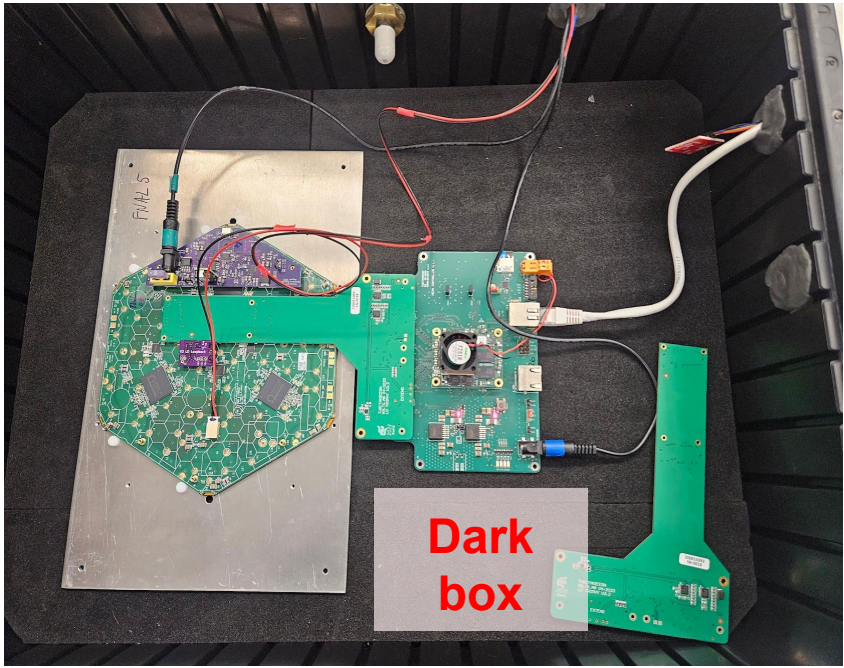


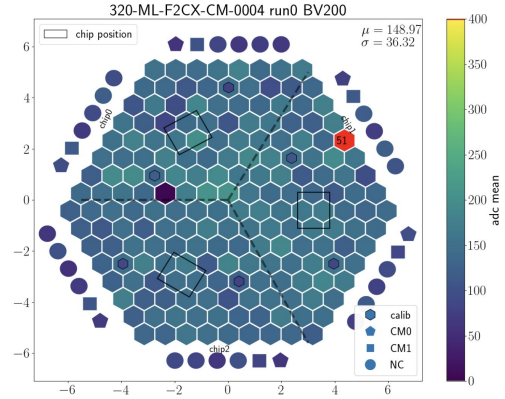


Electrical Testing

Pedestal and Noise

- Nominal measurements in the absence of signal and random fluctuations for each cell in the module
- Measurements done in a dark box
- Apply bias voltage
- Measure analog to digital convertor counts.

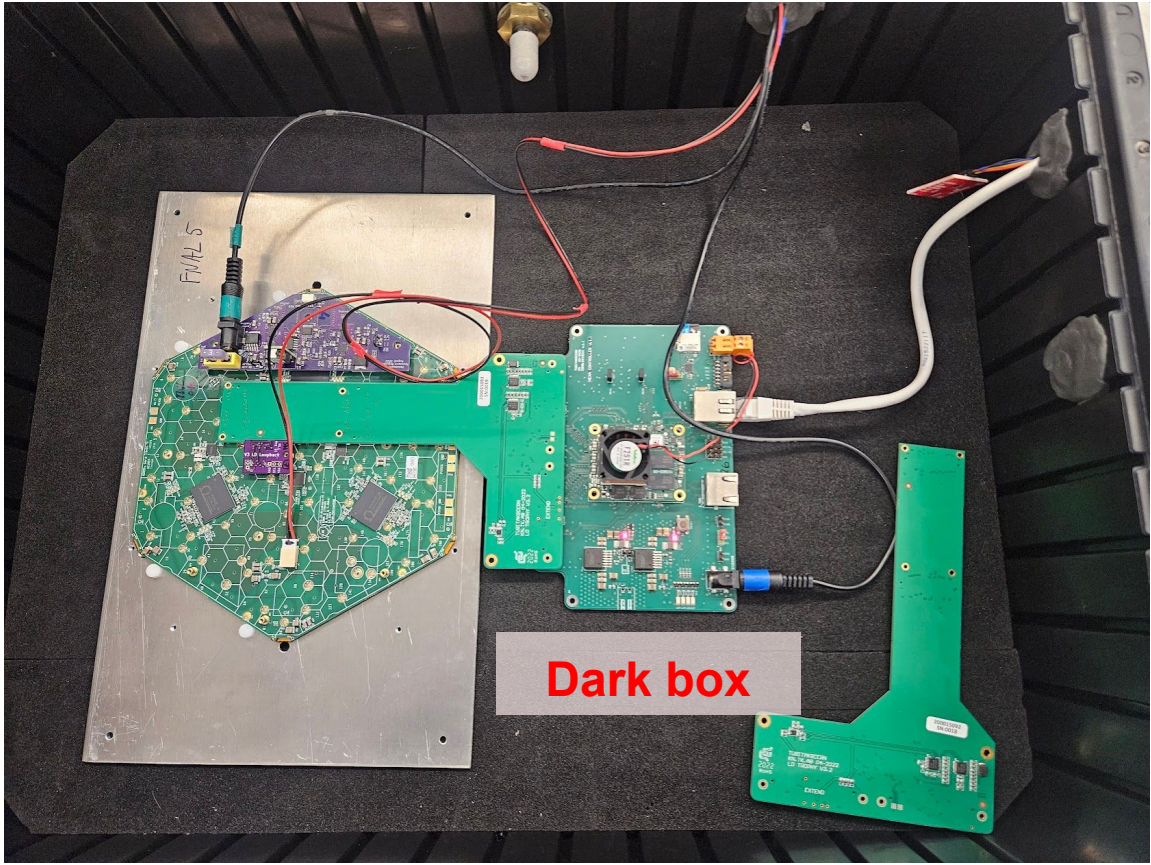


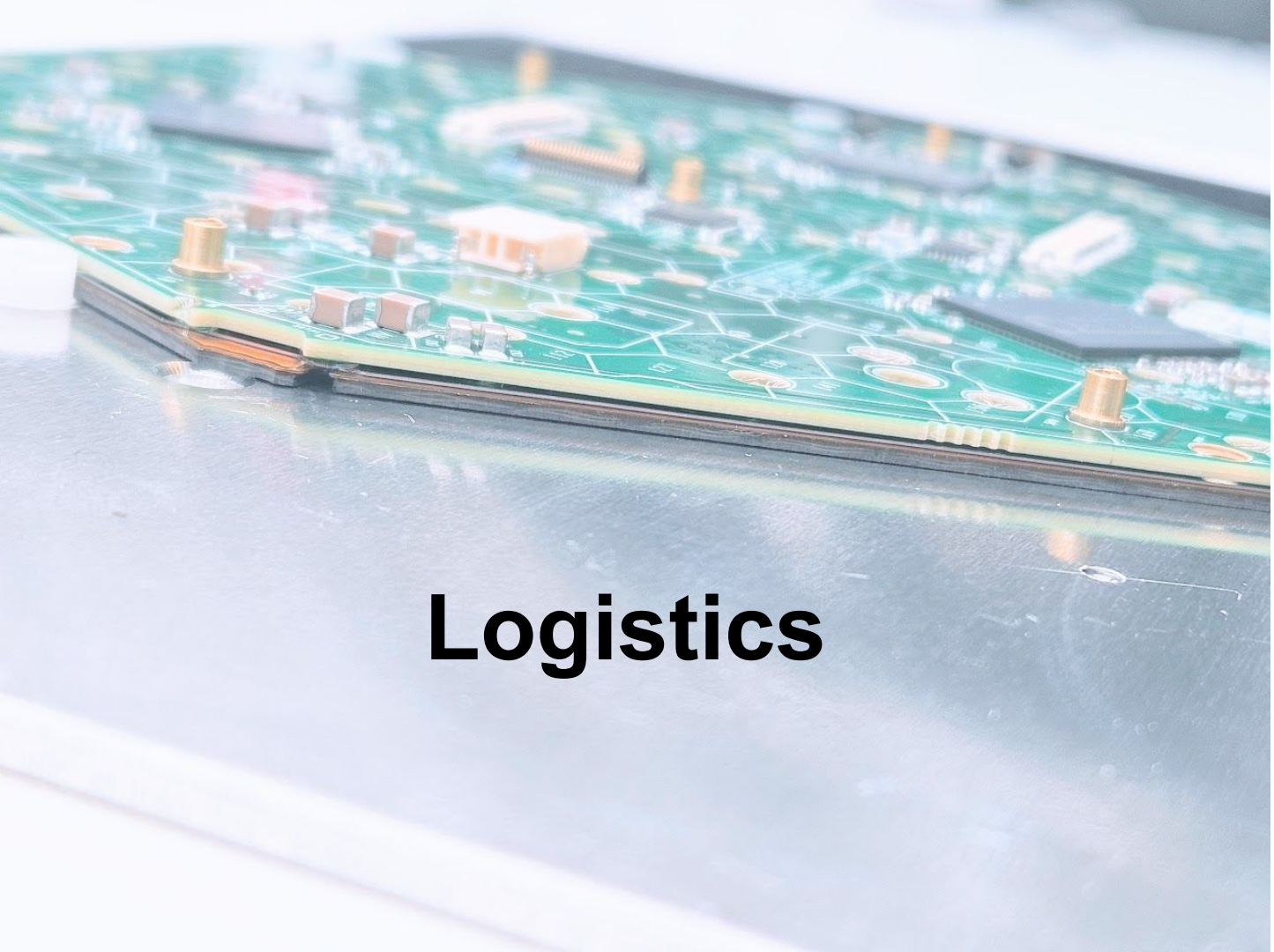


Pedestal per cell

I-V curve

- I-V measurements for module done in a dark box
- Apply varying voltage and measure currents
- Performance will be used to grade the quality of module





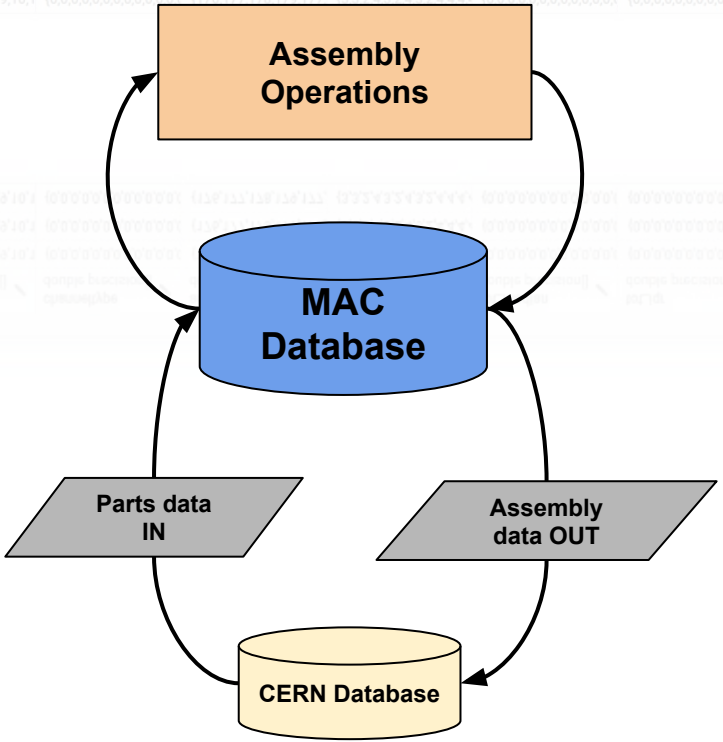
Logistics

Clean room conditions

- ISO 6
- Clean room is maintained at a relatively higher pressure
- Hairnet, facemask, nitrile gloves, cleanroom shoes
- Electrostatic discharge: anti-static lab coats, ESD foot/wrist strap
- All equipment, stations, and cabinets are electrically grounded
- Humidity and temperature monitors

Database

- PostgreSQL database to track data collected at multiple steps:
  - Initial components data from manufacturers
  - Assembly data: position on gantry, date, time, etc. for protomodule and module
  - Inspection: flatness, thickness, offsets for protomodule and module
  - Backside wire bonding and encapsulation
  - Frontside wire bonding and encapsulation
  - Wire bond pull strength
  - Electrical testing: pedestal and noise, I-V curve
  - Inventory
  - QC grades and module final grade
  - ….
- Communicates with various software used around the lab.
- Transfer data to CERN's production database



Shipping

- Modules packed in ESD foam cutout cases.
- Cases stacked in boxes.
- Boxes to be stacked in crates.
- Shipped to Fermilab for assembly on cassettes.

- Boxes + contents tested for impact damage.

Closing comments

- Silicon module assembly entails:
  - Assembly and inspection
  - Wire bonding and encapsulation
  - Pedestal, noise, and IV curve measurements

- Pre-series: build live modules for Fermilab
- Carnegie Mellon University expected to assembly ~5000 modules for HGCal
- Production expected to begin at end of 2024.