Scintillator-SiPM Hadron Calorimetry

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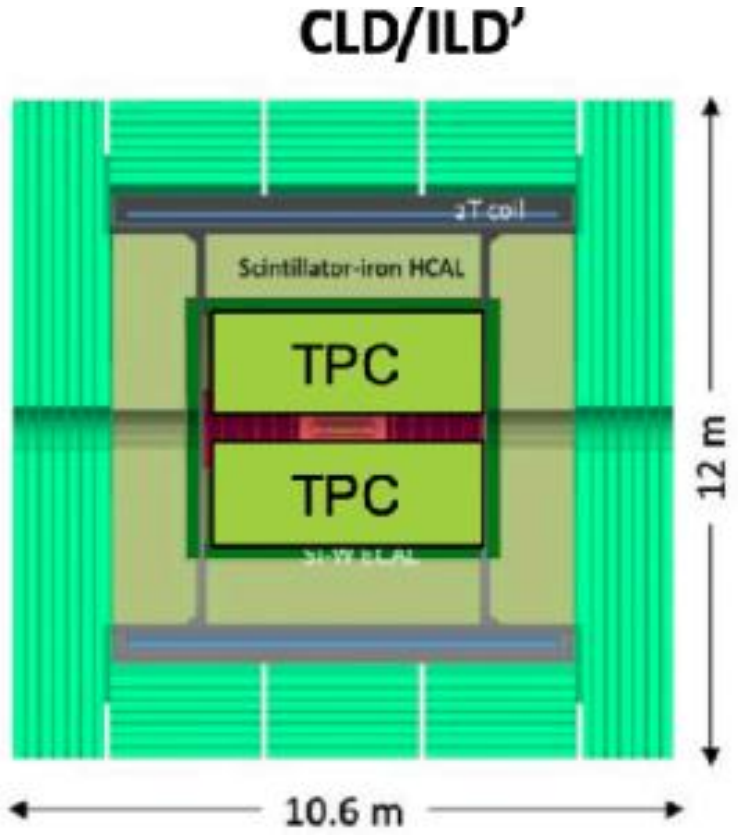
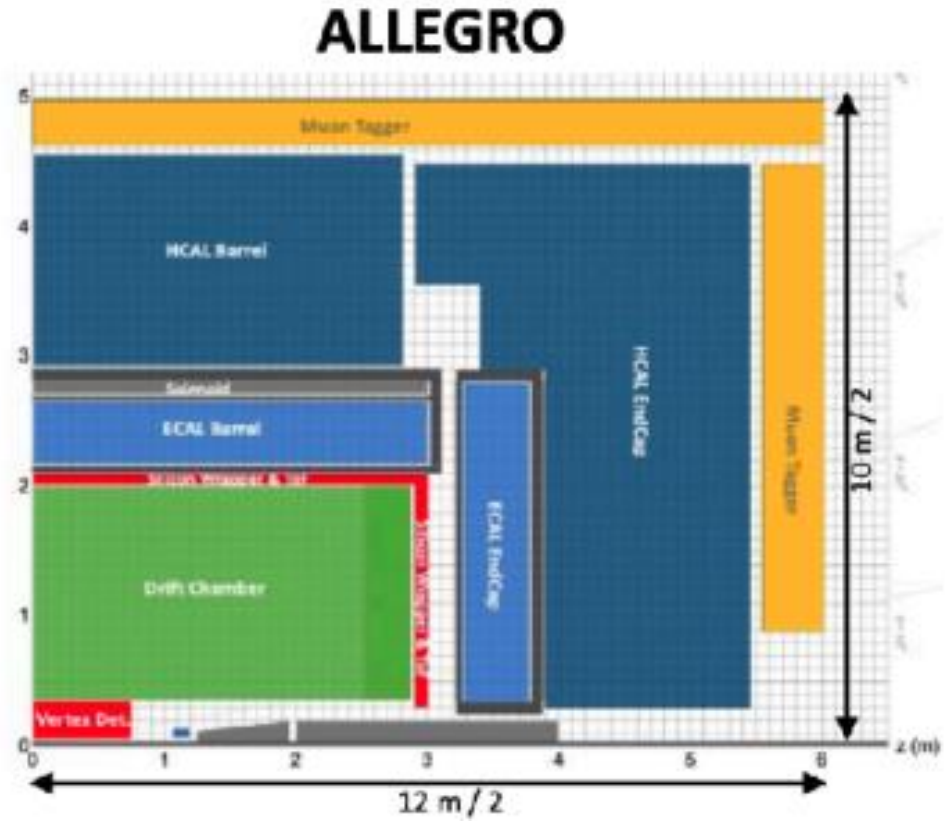
FCC Detector Models



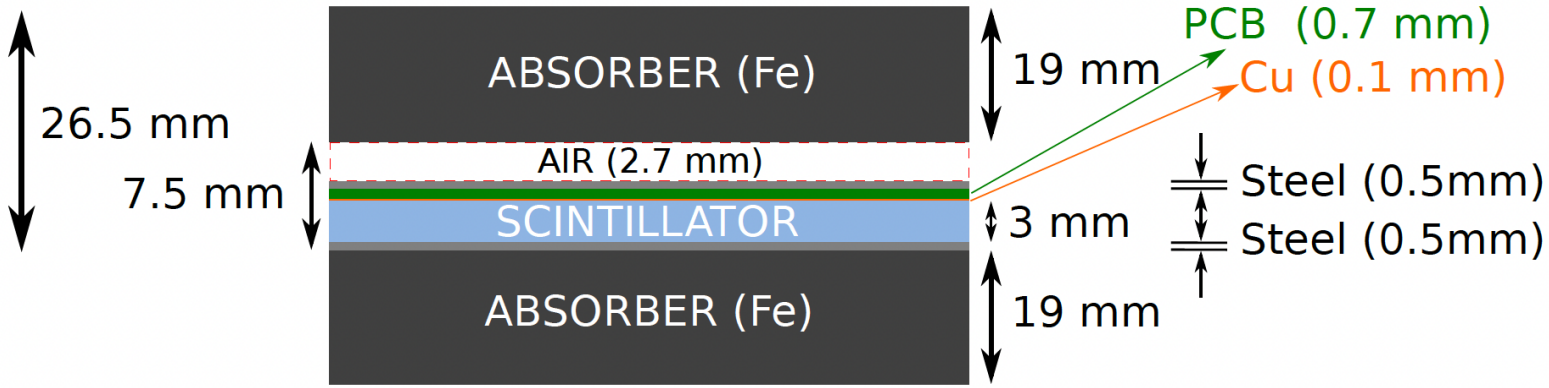


Currently features as a sub-detector in atleast two of them
Was part of both ILC detector concepts
Potential synergies with dual-readout

Strawman Design

~ 44 Scint-Steel layers
5.5 Interaction lengths
Default tile sizes are 30 mm x 30 mm
Looking at a few million channels

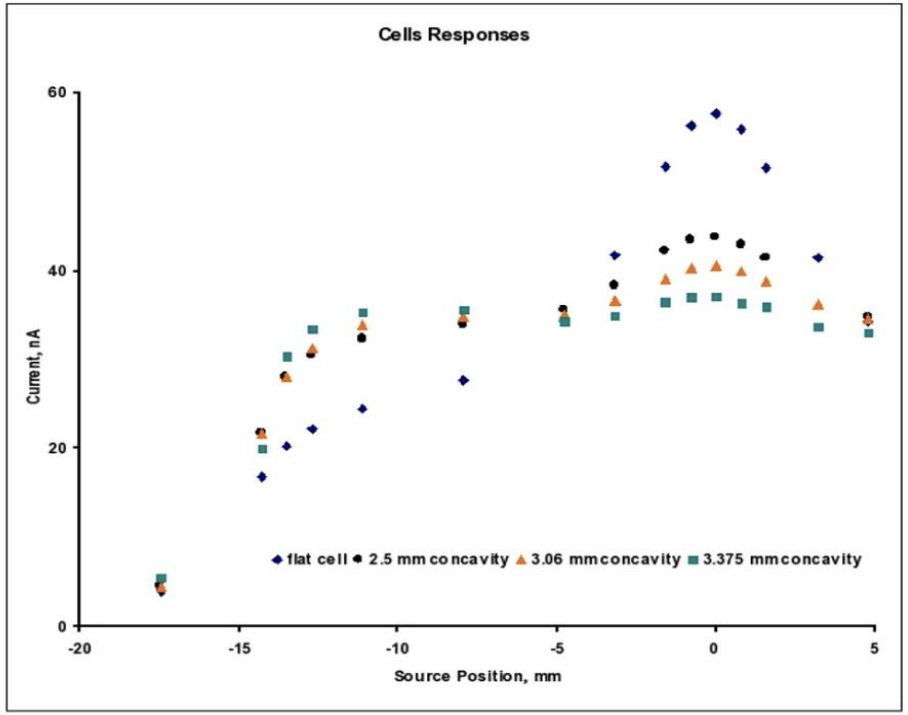
Significant challenges:
- Channel counts
- Electronics for continuous readout
- Cooling
- System integration and design

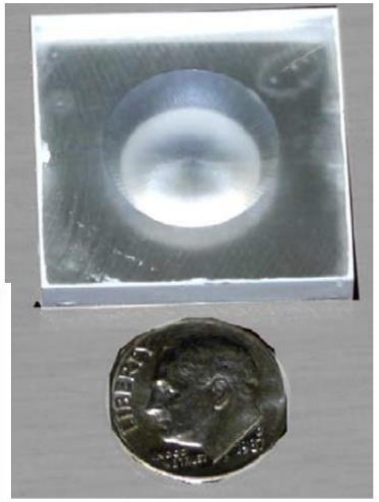


US Involvement (ILC/SiD/CALICE)

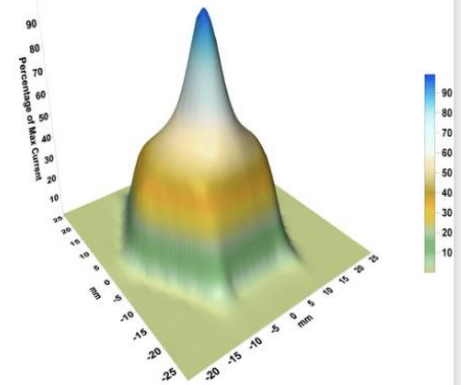
Defined by making some interface choices:

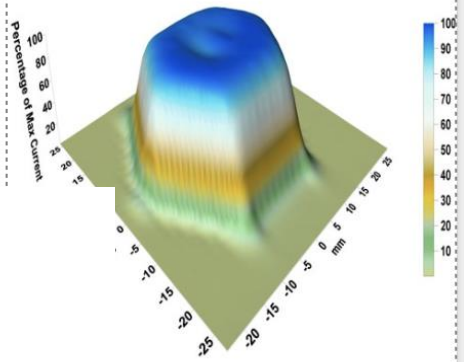
- Scintillator-sensor: fiber or fiberless
- Sensor-PCB: in-tile or surface-mounted on PCB
- Scintillator-PCB: tiles or tile arrays
- Scintillator-LED: light or pulse distribution





Robust w.r.t. tile shape

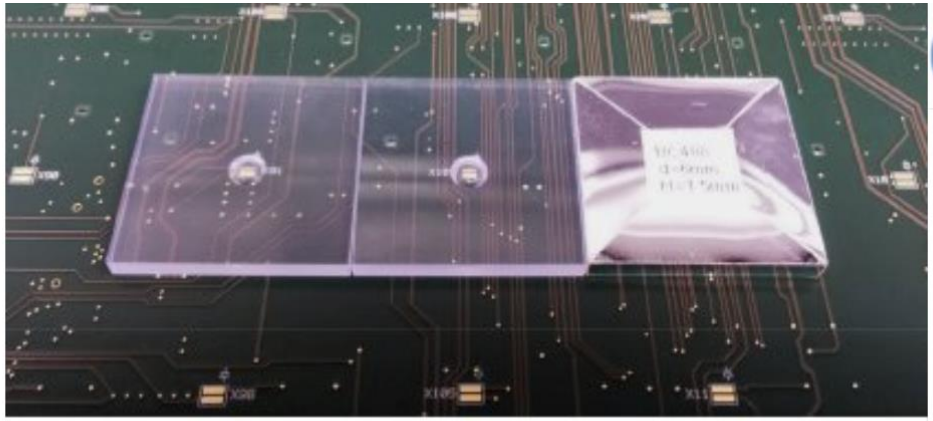


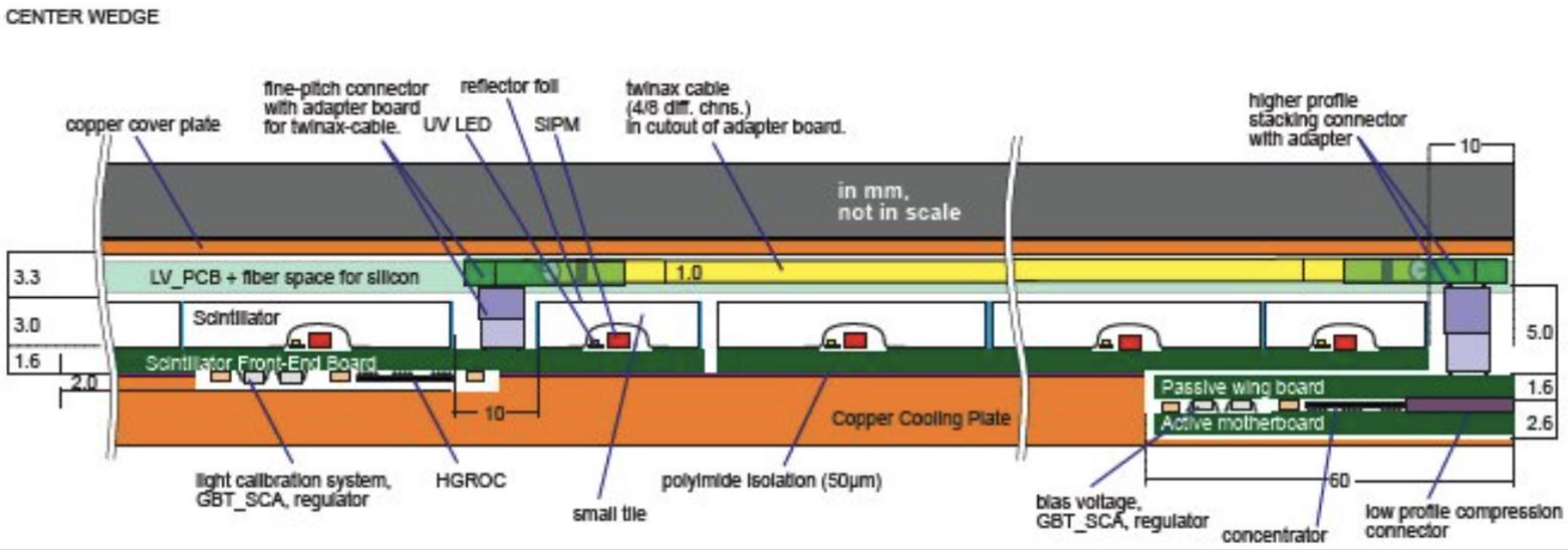


Source and test beam measurements

US (NIU) played a pioneering role in most of these design aspects

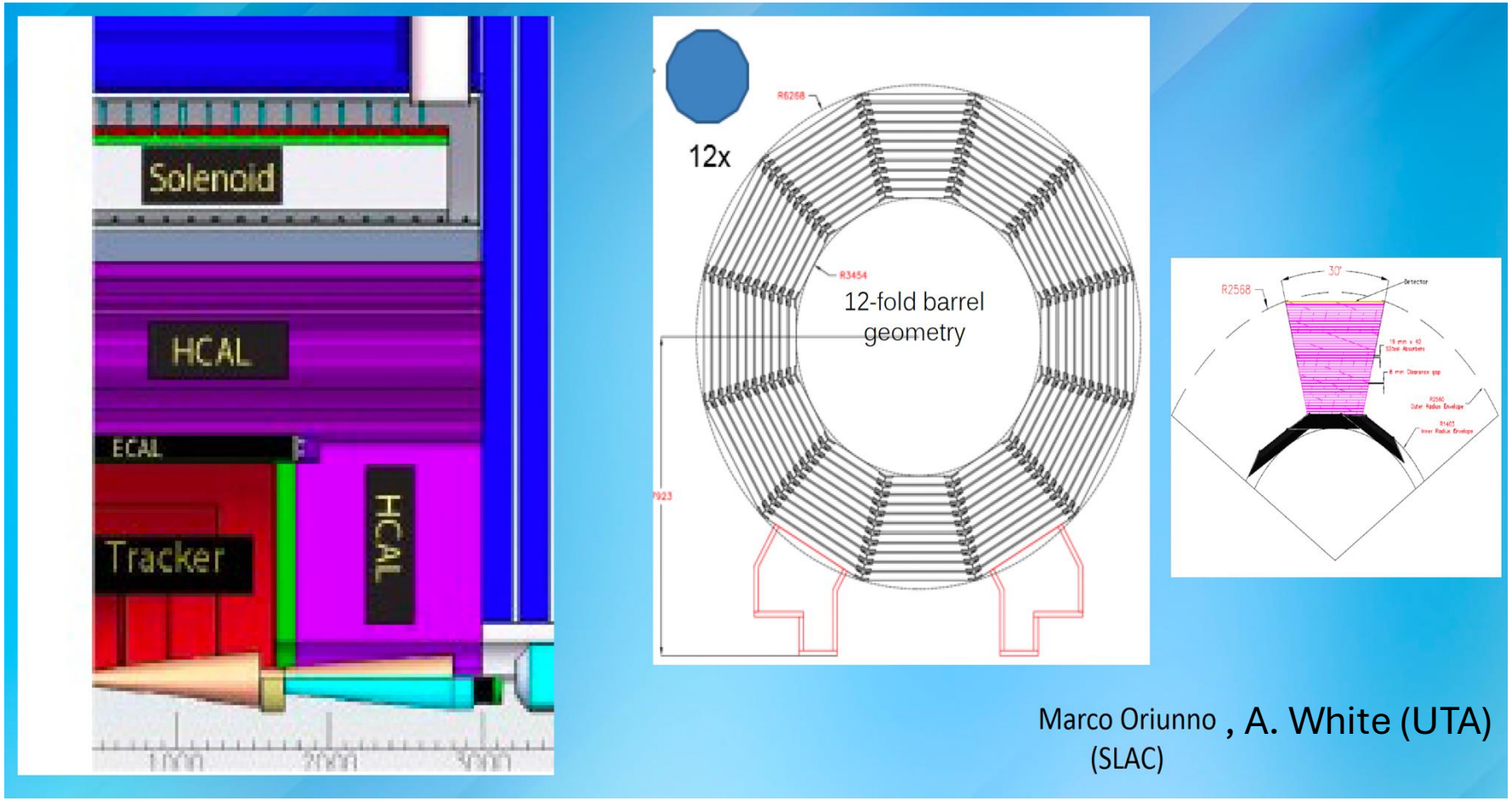
Main Design Elements





M. Reinecke, DESY

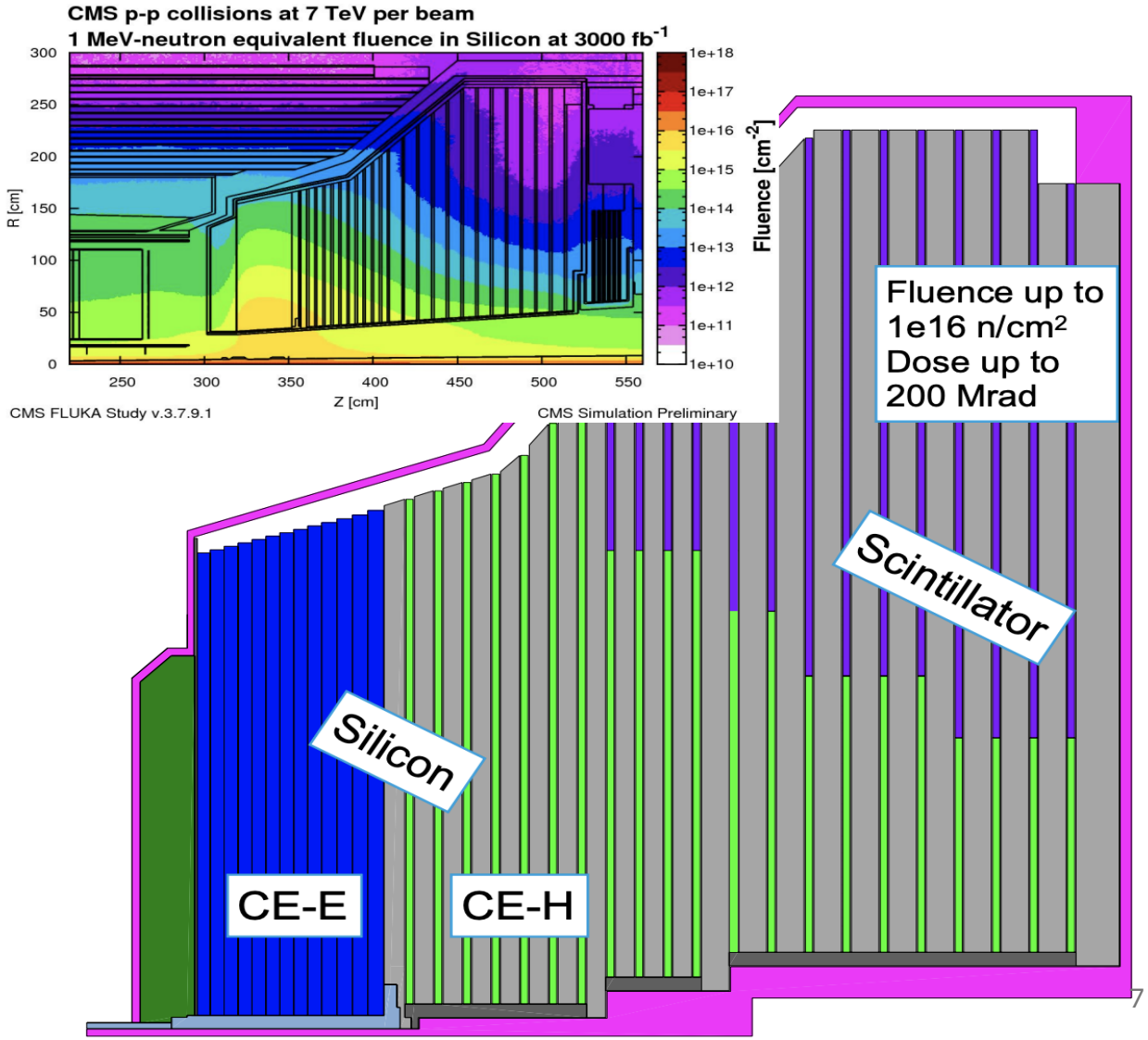
US Involvement (ILC/SiD/CALICE)



US Involvement (CMS → HGCal)

CE-H is 21 Steel absorbers with Si and/or scintillator readout
Around 9 interaction lengths
270 m^2 of scintillator in ~280k tiles
Tile sizes vary from ~3 cm^2 to ~ 30 cm^2
Cast and injection molded tiles
Detector has CO_2 cooling

US Institutions have very significant responsibilities on the Scint-SiPM HGCAL

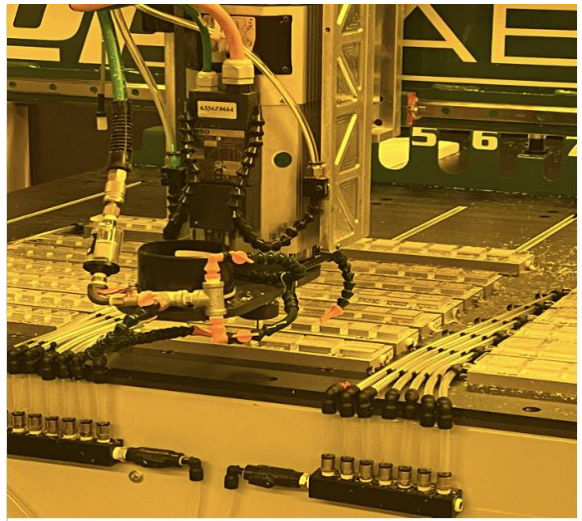


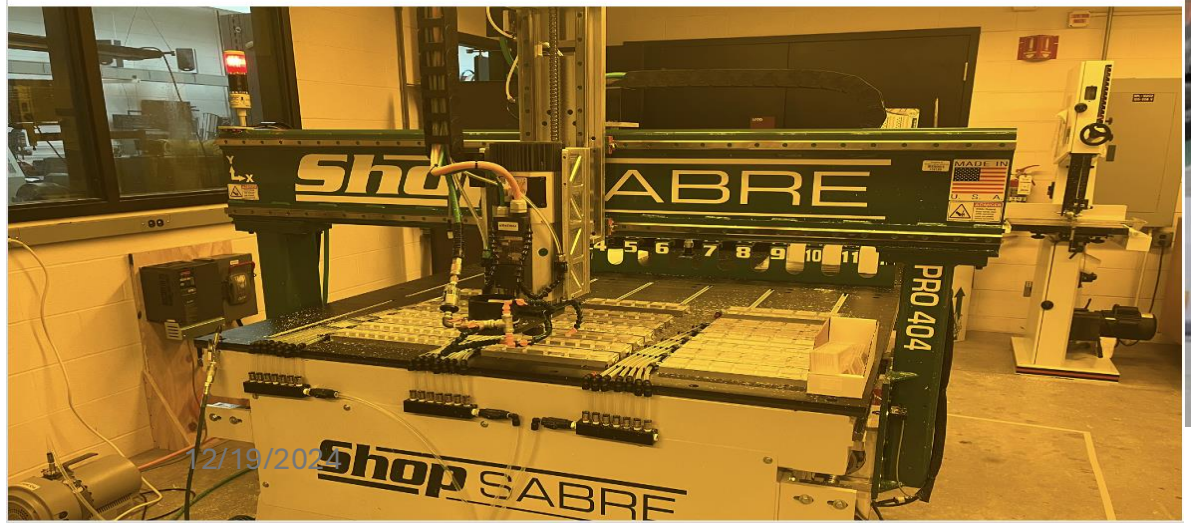
US Involvement (CMS → Scint-SiPM HGCal)

- Tiles
  - ➢ All cast tiles machined at NIU (~200 k)
  - ➢ All injection molded tiles fabricated at Fermilab (~ 100 k)
- SiPMs : Notre Dame responsible for testing and QC
- Wrapping: ~ half at NIU (other half at DESY)
- Tileboard procurement and testing : University of Maryland
- Tileboard assembly: Fermilab responsibility (shared with DESY)
- Common w/ the Si parts:
  - ➢ Cassettes : Fermilab
  - ➢ Electronics : Minnesota and Florida State
  - ➢ Overall management: Minnesota and Florida State

Most of these institutions have expressed interest in USFCC Scint-SiPM calorimetry. In addition, Iowa and UTA.

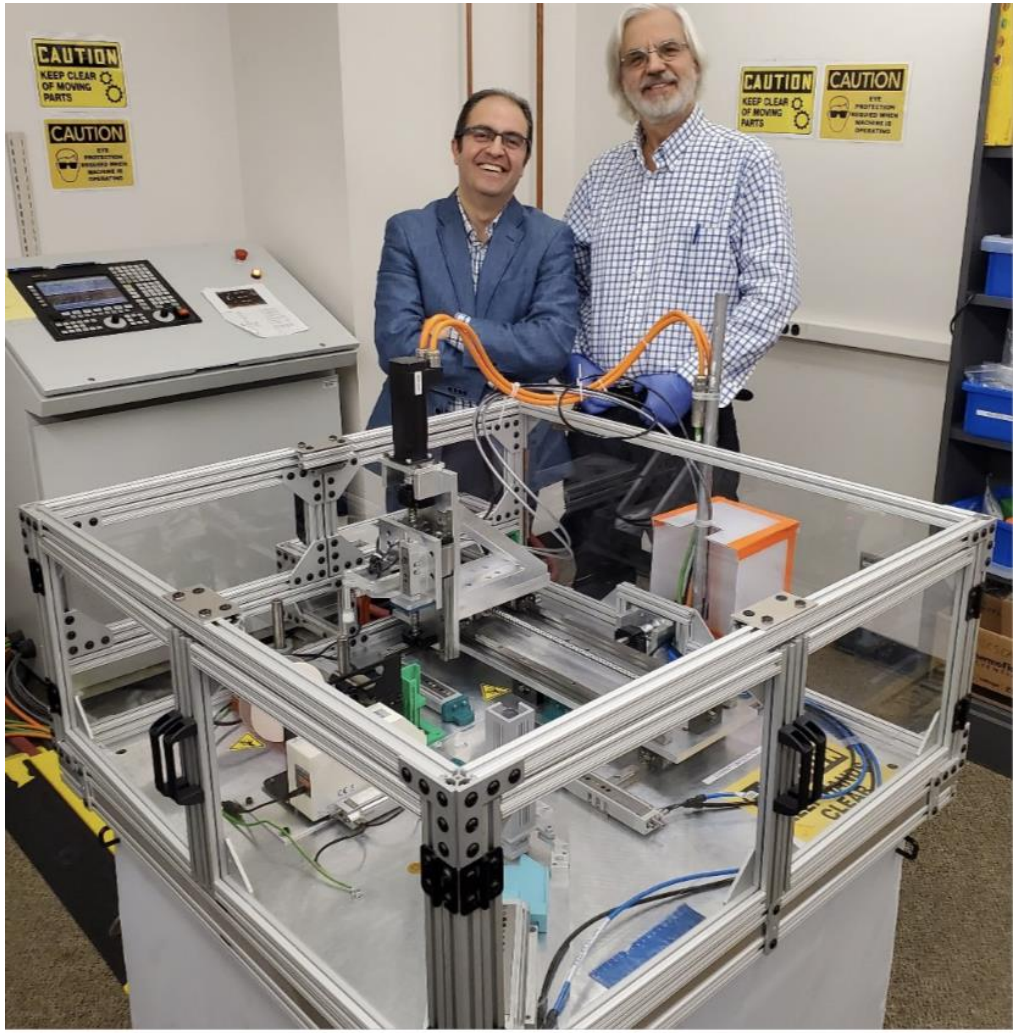
Tile Fabrication

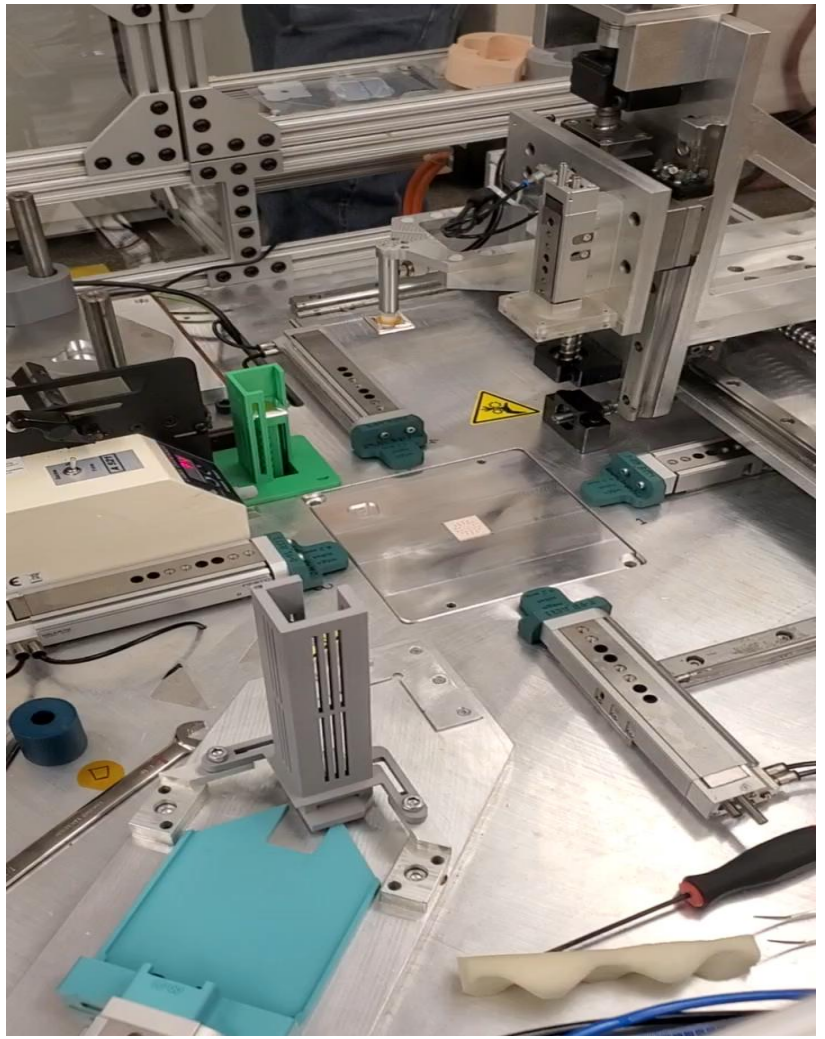




J. Freeman, Fermilab

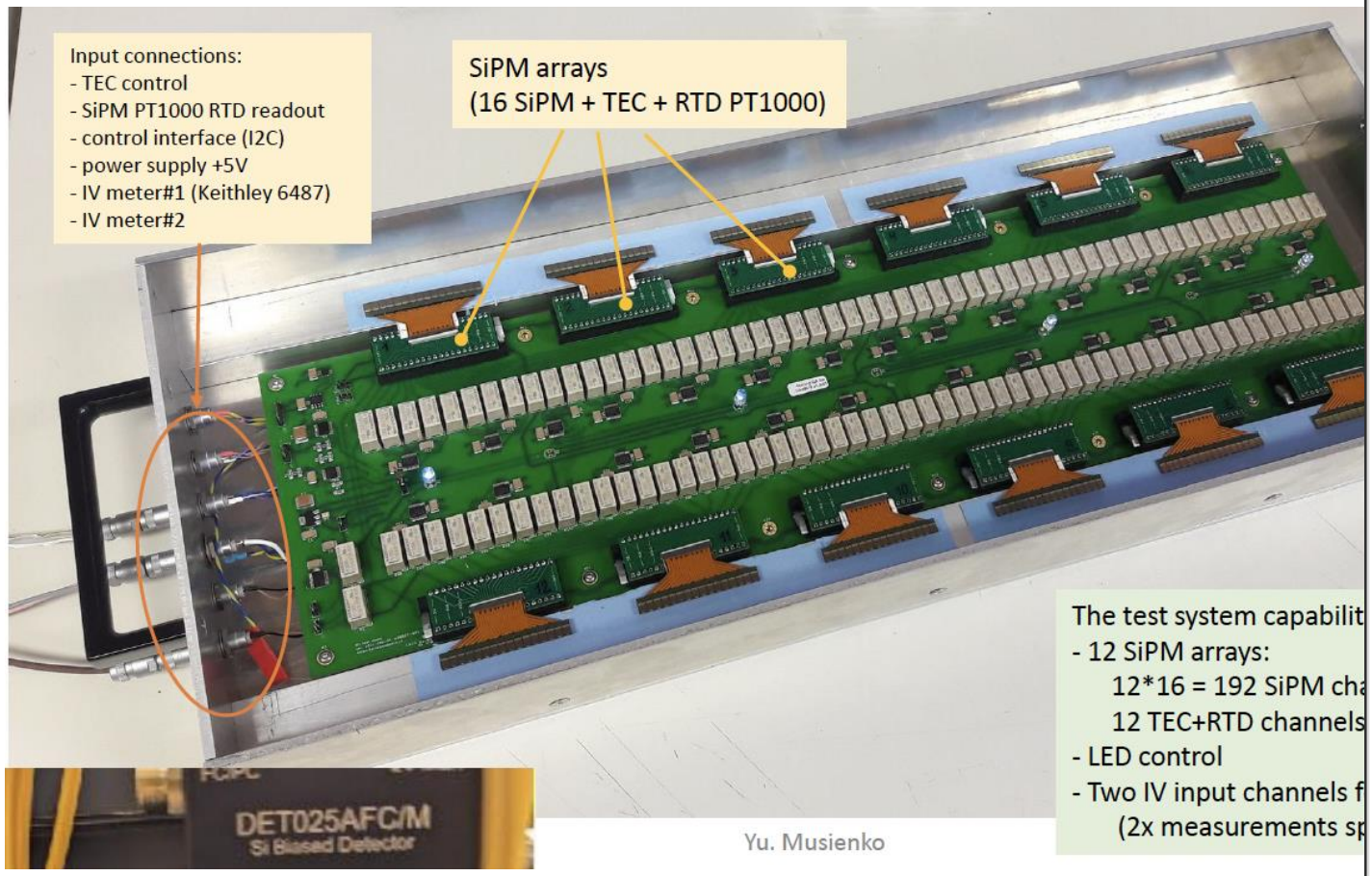
Wrapping

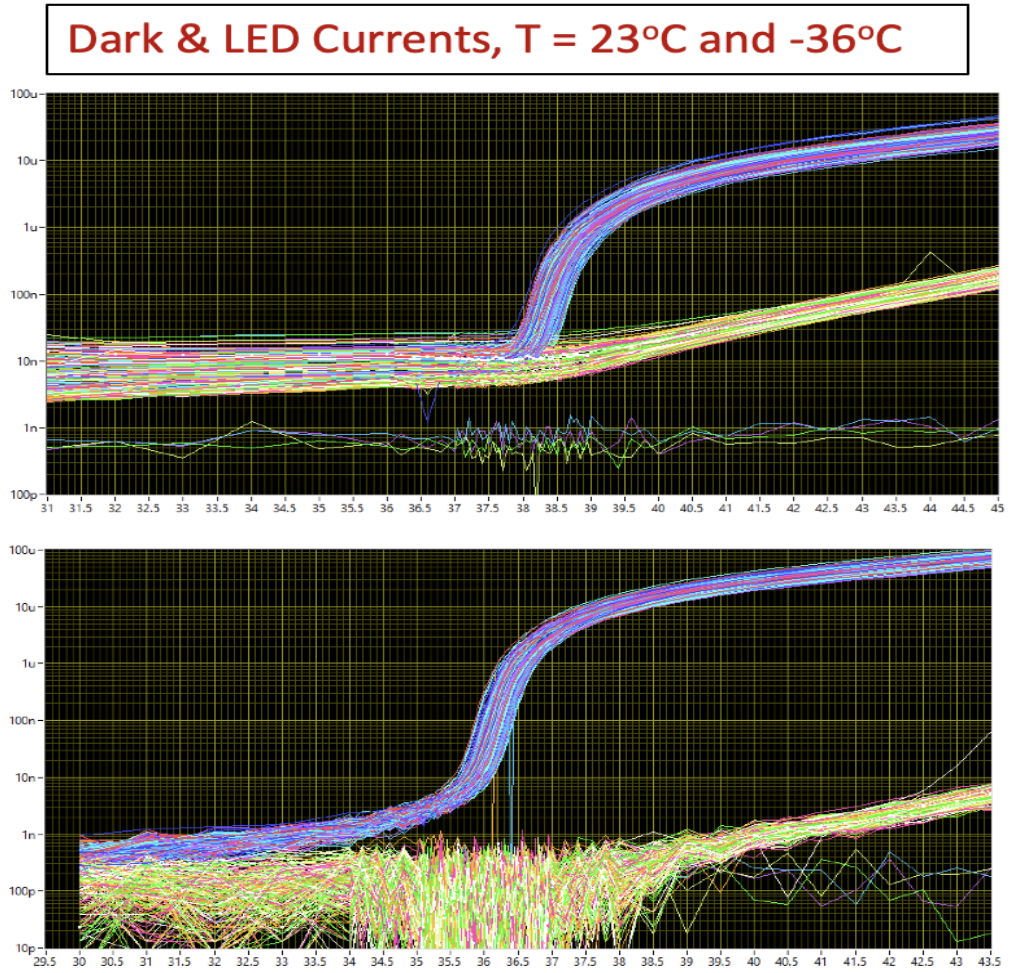




In collaboration with DESY

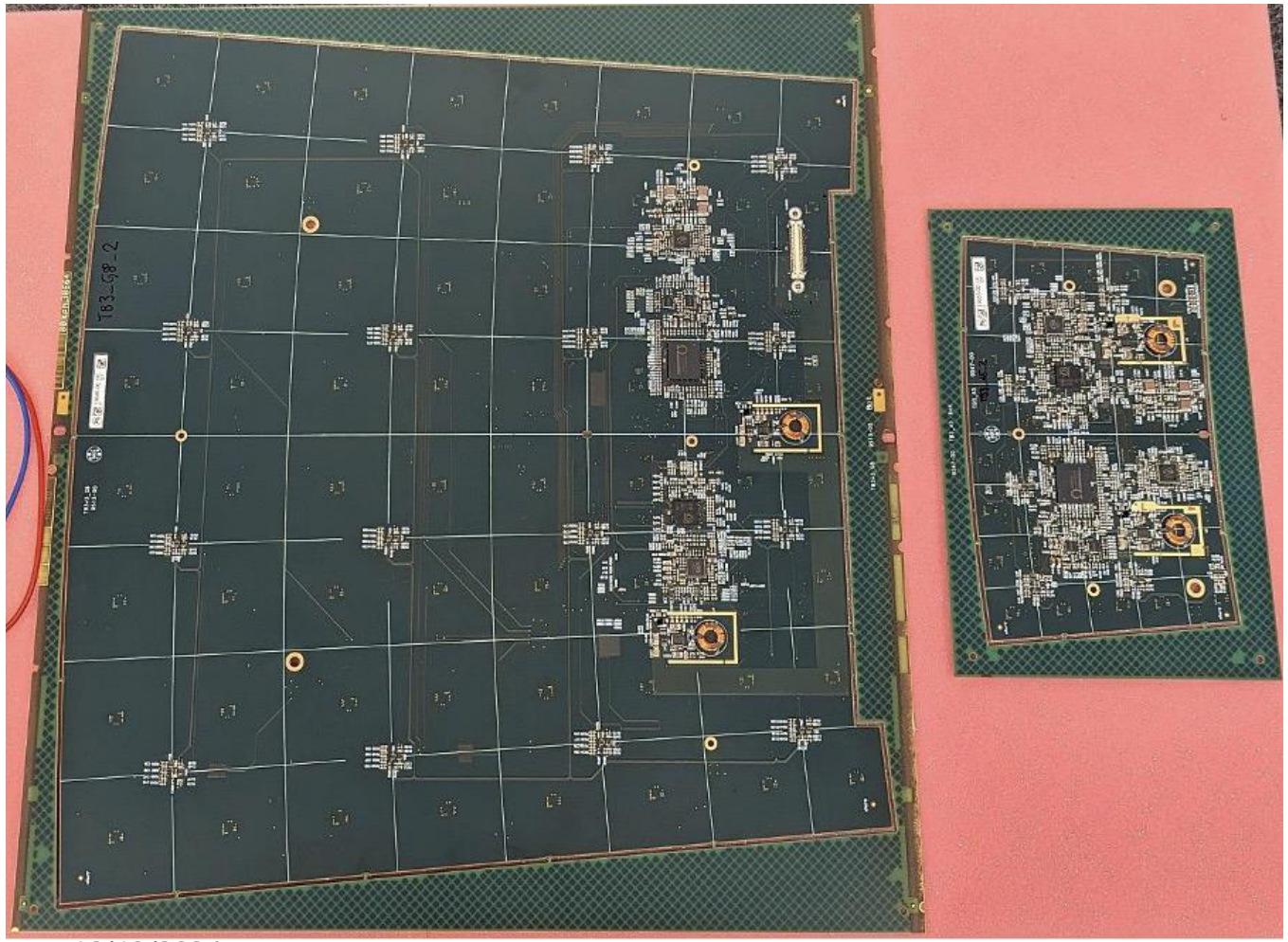
Silicon Photomultipliers





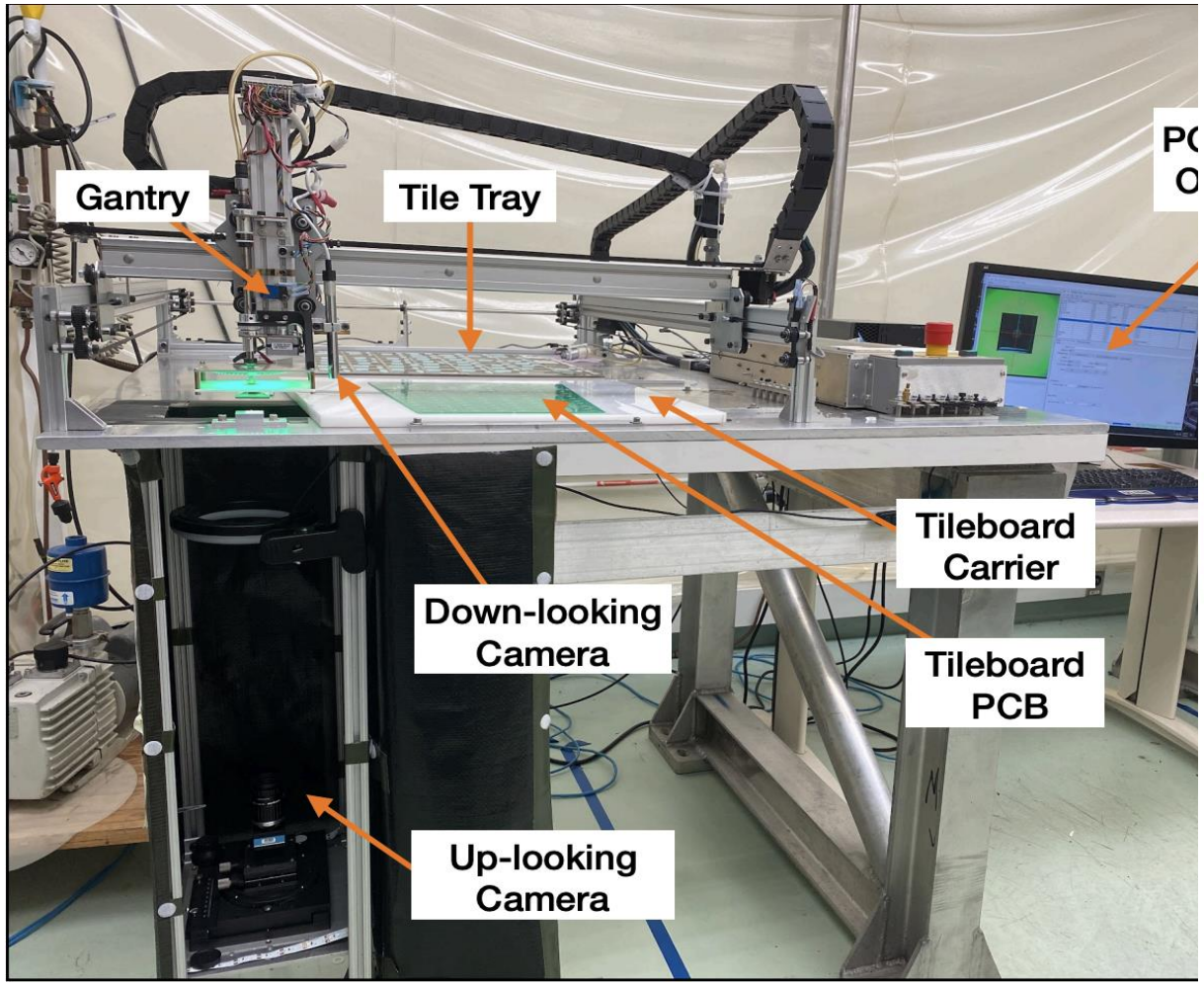
M. Wayne, Notre Dame

Tileboard Testing



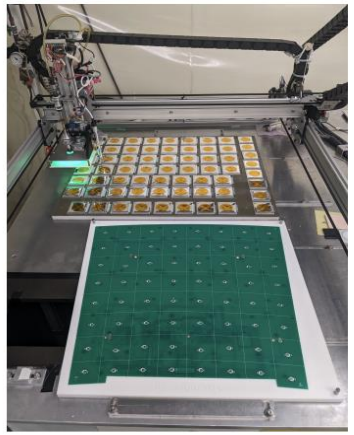
T. Edberg, UMD

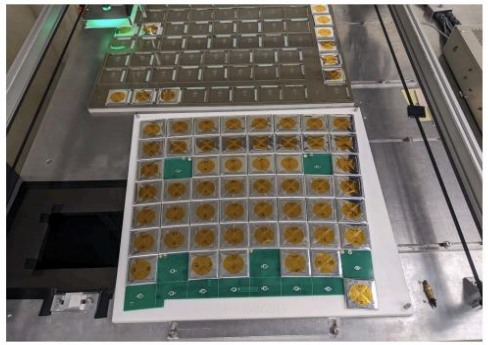
Tileboard Assembly



Assembly Steps ~ 30 mins

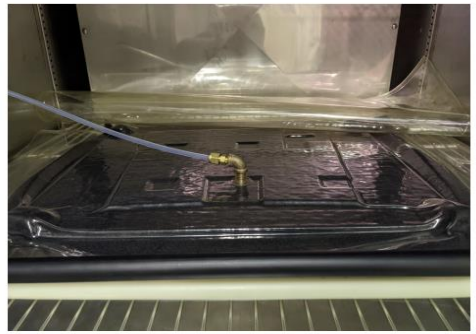
Step 1:
Assembly trays are placed on the PnP machine

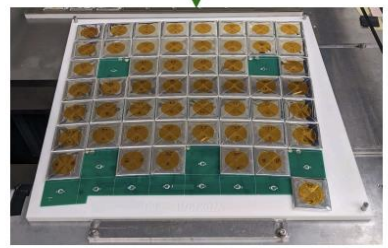




Step 2: 15-20 mins
Tiles are picked, QCed, and placed on tile-board using PnP machine

Step 3: 10 mins
It's transferred to vacuum bag for bonding strength for 10 mins





Step 4
It is returned and protected by a cover plate and recored in DB

Tasks Ahead

- Simulation and Design Optimization
  - ➢ full design specification (layers, tile size, cracks, modules etc.)
  - ➢ interface to Ecal
  - ➢ refinements ? (precision tracking layers, timing etc)
  - ➢ shower simulations and testbeams
- Prototyping and scalability
  - ➢ still more than an order of magnitude more channels than the HGCal → fabrication, assembly and QC scalability
  - ➢ applies to all active elements

Tasks Ahead

- Front-end Electronics
  - ➢ no power pulsing
  - ➢ new ASICs and concentrators (common with ECal?)
  - ➢ dead zones, power consumption
- Cooling and System Integration
  - ➢ active cooling needed
  - ➢ absorber structure, module segmentation, Barrel-encap transition, services
  - ➢ validation by prototypes

Summary

- Long history of US experience and innovation in all aspects Scintillator-SiPM Hadron calorimetry
- Experience spans prototyping and actual detector construction and assembly
- Around half-a-dozen institutions with strong involvement in Scint-SiPM hadron calorimetry have already expressed interest
- US institutions can make a significant impact on the interesting R&D questions