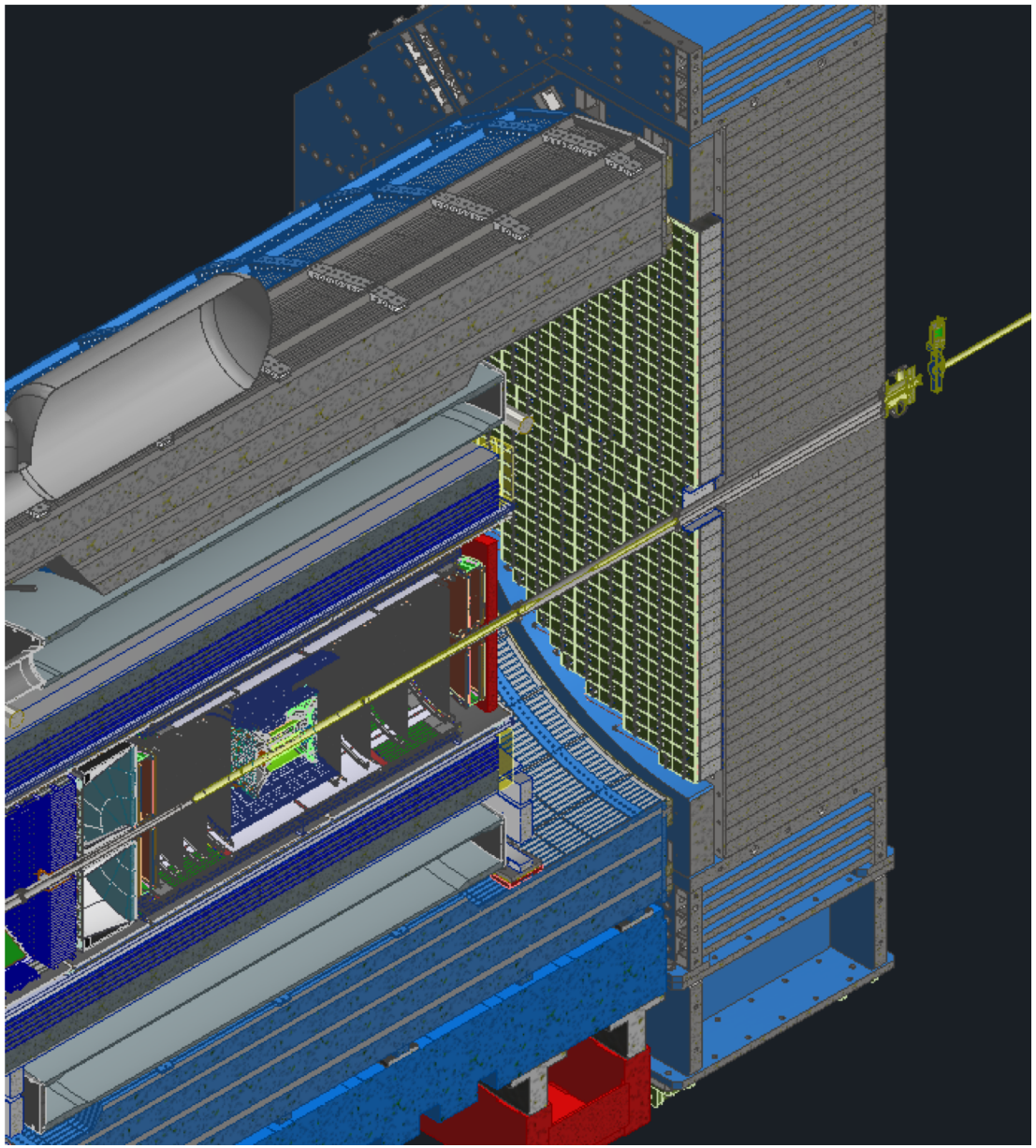
Forward EM Calorimeter Status Report

O. Tsai (UCLA/BNL)

for FEMC Consortium

BNL, Chinese EIC ECal Consortium (Fudan, Shandong, Tsinghua and South China Normal Universities), Indiana University, UC EIC Consortium (University of California at Los Angeles, University of California Riverside), Indian ePIC Consortium.



10th EIC DAC Meeting, June 11th-13th, 2025

Charge Questions Addressed

- Is the design of the ePIC detector and its sub-systems appropriate and progressing well?
- Are the remaining work and technical, cost and schedule risks adequately understood? Are there opportunities?
- Will the detector be technically ready for baselining by late 2025?
- Are the detector integration and planning for installation and maintenance progressing well? Are there areas where further ideas should be pursued?
- Will the detector be ready for start of construction by late 2026?

FEMC Detector Parameters Table. Pre-TDR Version 1.

Table 8.28: Some requirements on performance of fEMCal and its parameters

Parameter	Requirements	Comments
Geometrical Acceptance	$1.4 \lesssim \eta \lesssim 3.9$	$R_{out} \sim 190$ cm, $Z_{frontface} \sim 341$ cm
		Hole for the beam pipe $30 \times 30\ cm^2$
Integration envelope	R_{max}=205 cm, Depth = 27 cm	
E_{min} in a single tower	15 MeV	Minimal shower energy 50 MeV
E_{max} in a single tower	100 GeV	18×275 GeV, ep
Maximum rate in a single tower	10 kHz	E_{thr}=15 MeV, 10×275 GeV ep
		500 kHz collision rate
Radiation doses	15 kRad	Integrated over 10 years
Neutron fluxes	4×10^{11} n/cm^2	1 MeV eq, integrated over 10 years
Energy resolution	$\lesssim 12\%/\sqrt{E} \oplus (2)\%$	Verified in the test beams
γ/π^0 separation	up to 50 GeV	$\sim 5\%$ mis-identification at 50 GeV
Depth	23 X_0	Minimize leakages
Detector parameters	**Units**	**Comments**
X_0, R_m	7 mm, 19 mm	Rad. length, Moliere radius
f_{samp}	2%	e/h $\simeq$1 above 10 GeV
Scintillating Fibers	$\varnothing$ 0.47 mm	Single clad sc. fibers
Light yield	$\sim$ 1600 pixels/GeV	Test beam results.
Transverse size of tower	2.5 cm $\times$ 2.5 cm	Matches R_m
Transverse size of installation block	10 cm $\times$ 10 cm	Block of 16 towers
Total number of towers	18320	
Photodetector	S14160-6015PS	Four 6×6 mm^2 SiPMs per tower
		15 um pixels size
Monitoring system	Blue LED	LED integrated on SiPM board.
		One LED per four towers

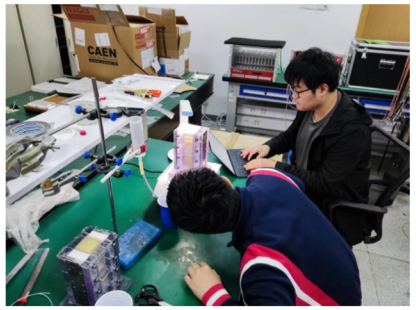
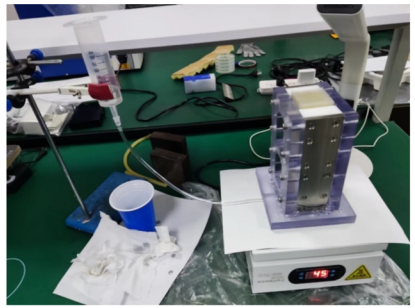
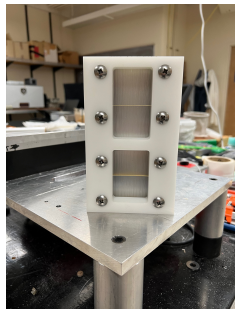
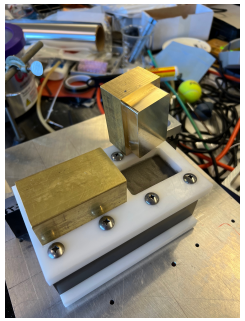
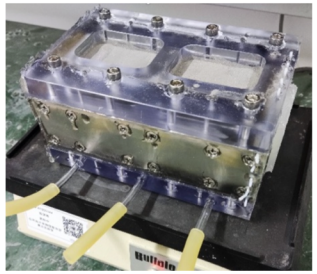
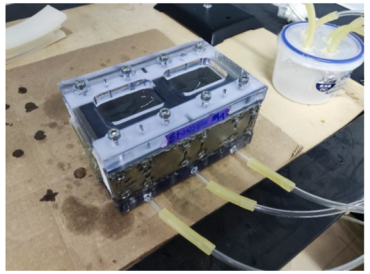
FEMC Status Summary:

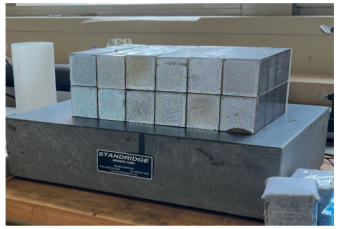
1. FDR SiPMs - completed
2. FDR Sc. Fibers - completed
3. eRD106 Test Run to validate LY collection/uniformity - completed
4. eRD106 Validation of module production – completed
5. eRD106 Structural tests - completed
6. Detailed Mechanical Design – approaching to ~90%
7. Front End Readout – at different stages - (~50%-95%)
8. CD3A QA on sc. fibers - ongoing
9. Production planning – in progress

In the pipeline for 2025:

1. FEMC FDR
2. TDR Version 2
3. Complete FEB tests in the lab
4. Continue development of mechanical models and finalizing production drawings.

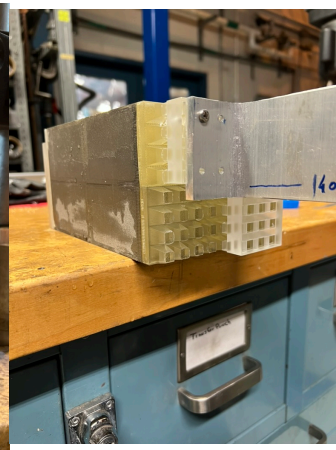
Some Completed Tasks

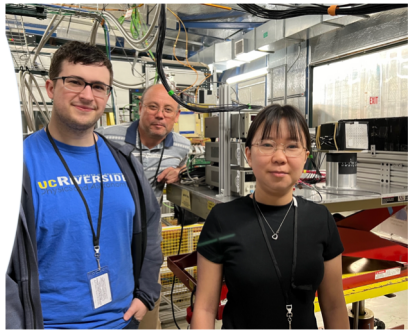
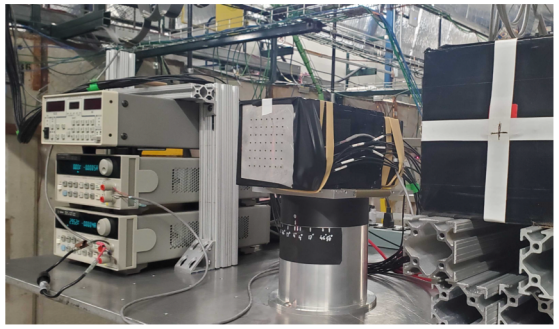


Block productions at Fudan and UCLA

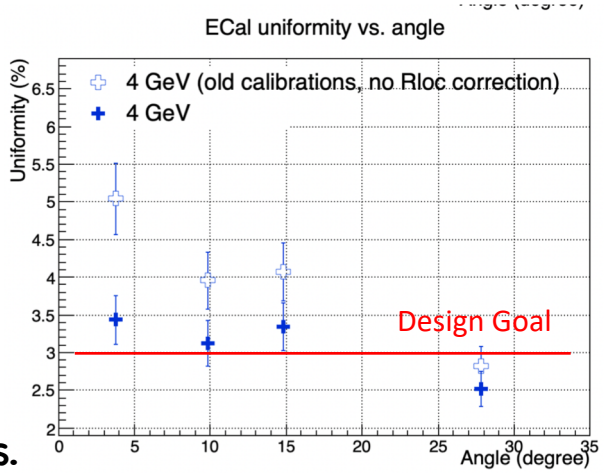


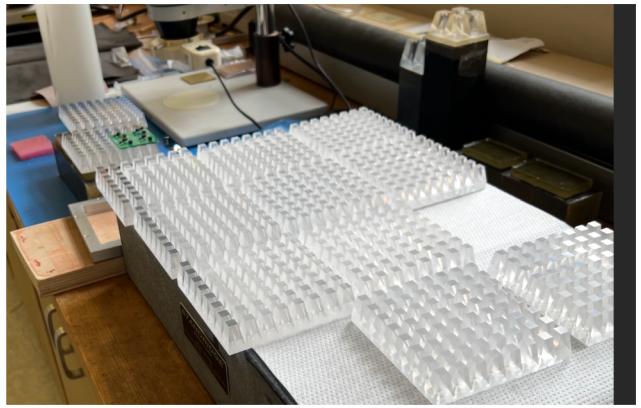


Structural tests at BNL
De-paneling SiPM boards

Test Run at FNAL by UC EIC consortium members.





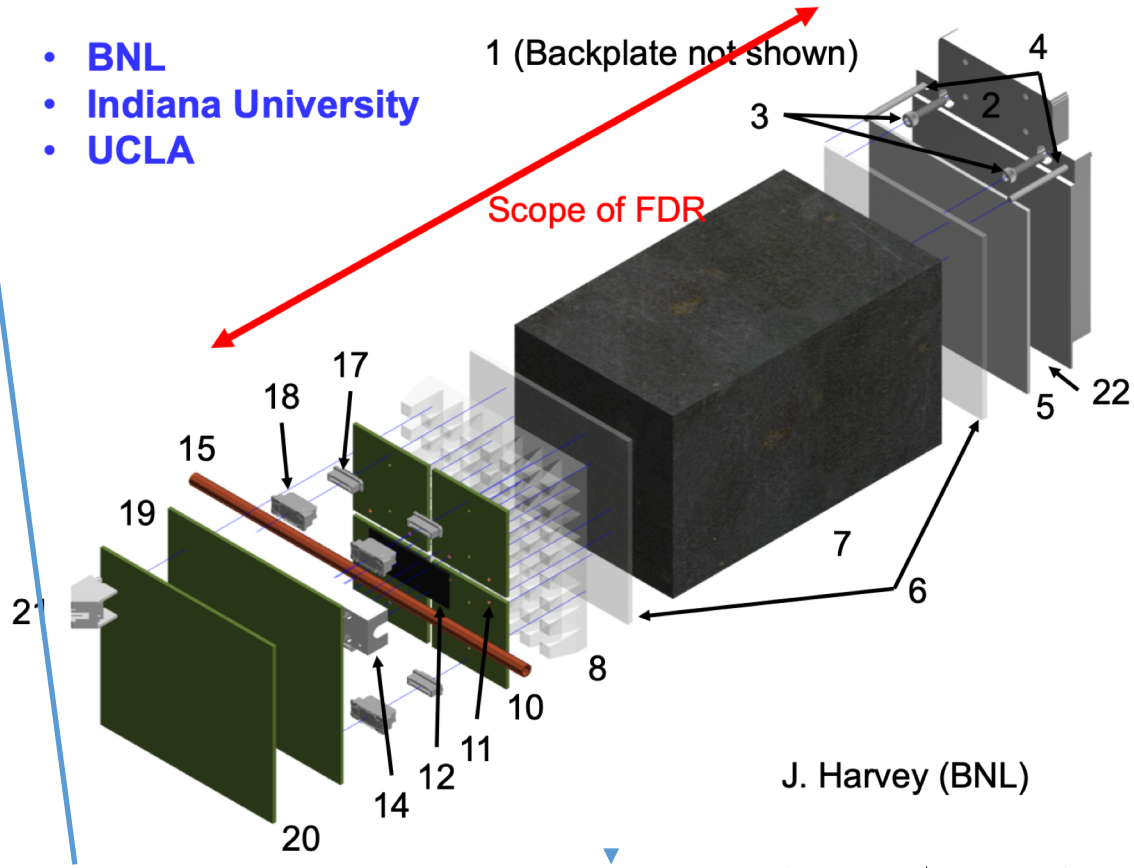
Light Guides Produced at Indiana University

FEMC FDR Scope

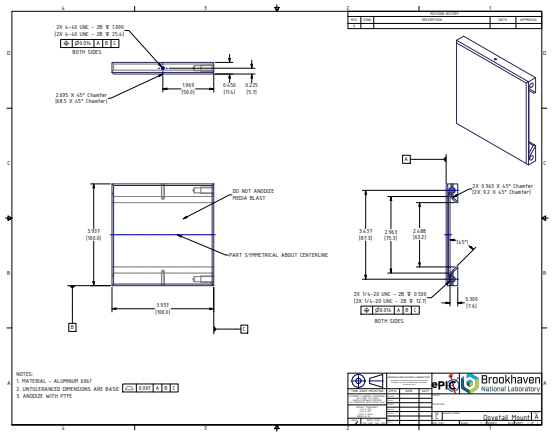
- WScFi Blocks
- LG
- SiPM Boards
- Mounting to HCal

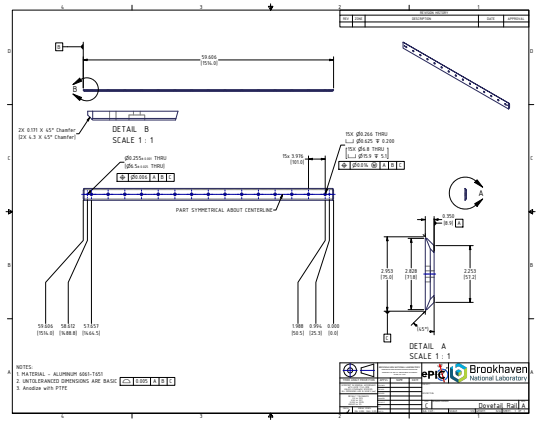
Part Number	Component
1	Backplate
2	Mounting Plate
3	8-36 UNC Socket Head Screws
4	1/8" Dowels
5	Titanium Dioxide Epoxy
6	Epoxy (Part of Tungsten Mold) (Epotek 301-1)
7	Tungsten Sci-Fi Block
8	Light Guide (Acrylic)
9	SiPM
10	SiPM Board
11	U-164-0 PEM Nut
12	Thermal Pad
13	1-64 UNC Socket Head Screw
14	Aluminum Heat Sink
15	Copper Tube Heat Sink
16	4-40 UNC Socket Head Screw
17	Connector MA01F030VABBR300
18	Connector MA01R030VABBR600
19	Pre-Amp Board
20	Bias Board
21	Ethernet 615008145121
22	Epoxy Glued Connection

- **BNL**
- **Indiana University**
- **UCLA**



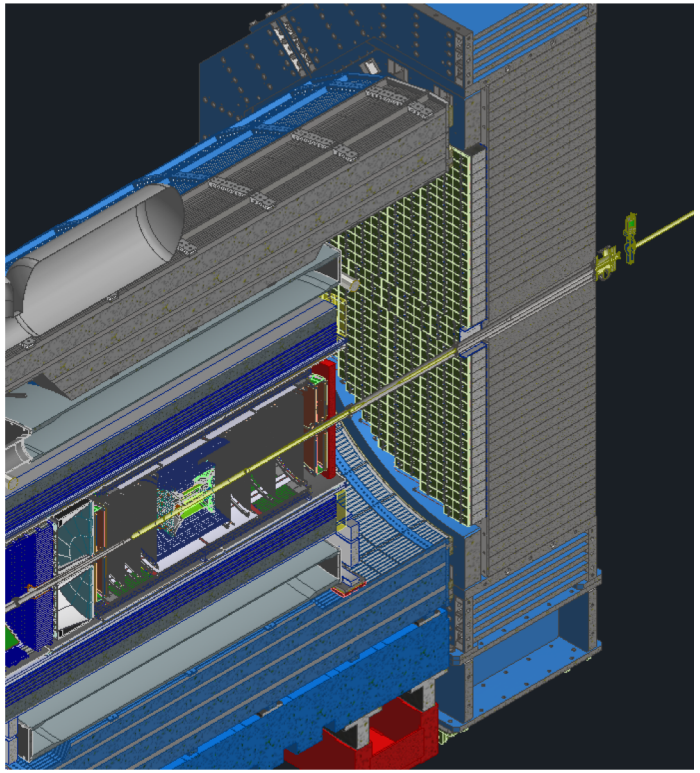
- Mounting to HCAL was iterated to simplify installation procedures. Driven by BNL 3I group.
- New parts were ordered. Tests projected to be completed by the end of summer.
- This change does not affect FDR or previous structural tests.

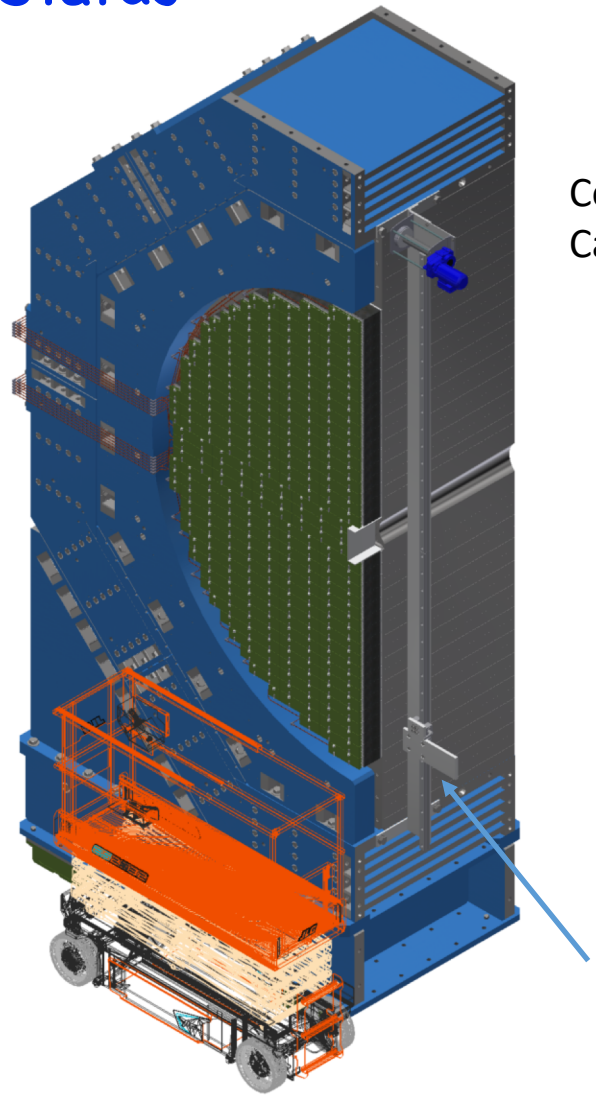




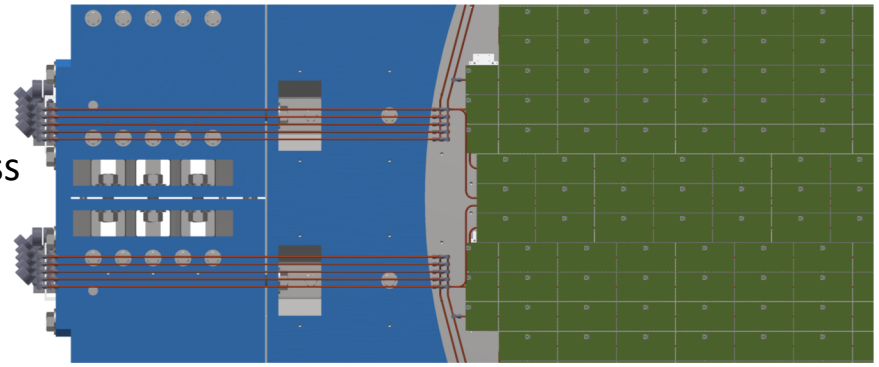
Detail Mechanical Model Status

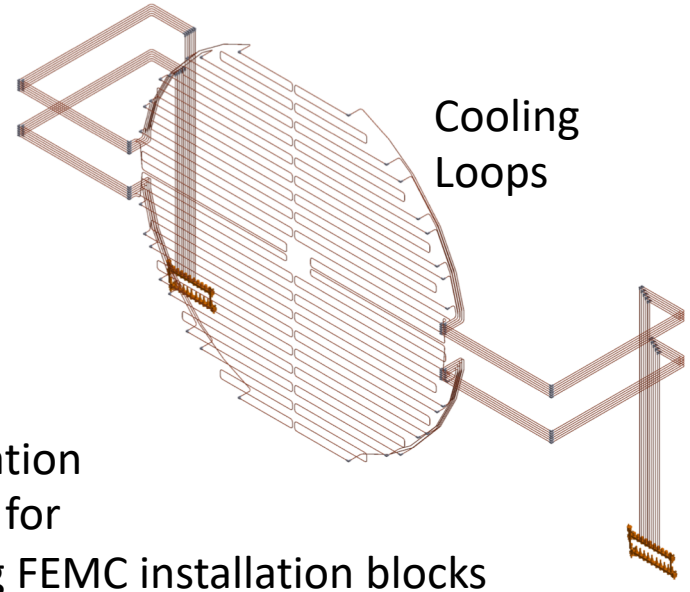
- Integration
- Installation
- Maintenance





Cooling
Cabling Pass

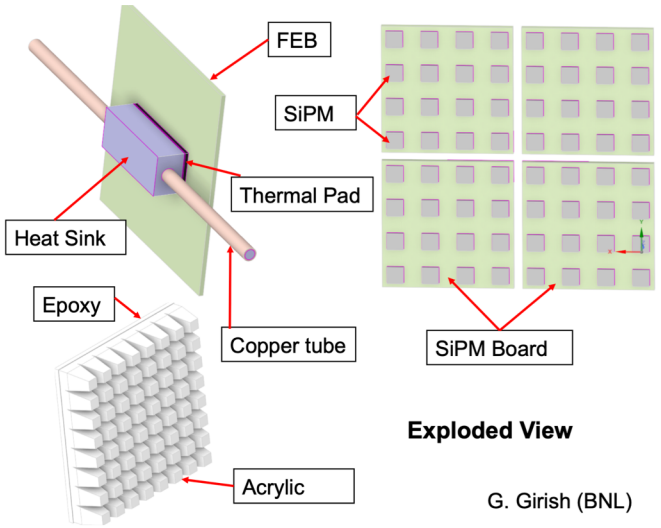




Cooling
Loops

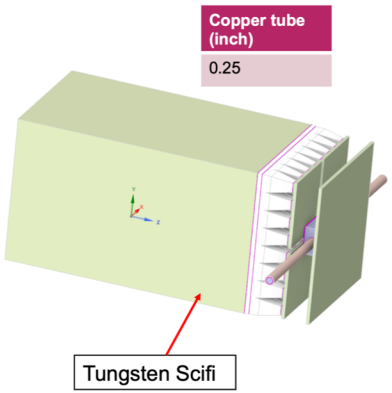
Installation
fixture for
~ 20 kg FEMC installation blocks
with SiPM boards glued.

Mechanical Model, Cooling simulations. Examples.

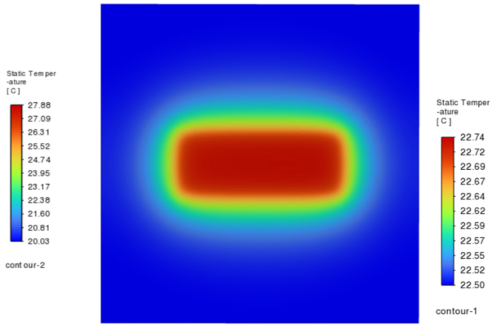


Exploded View

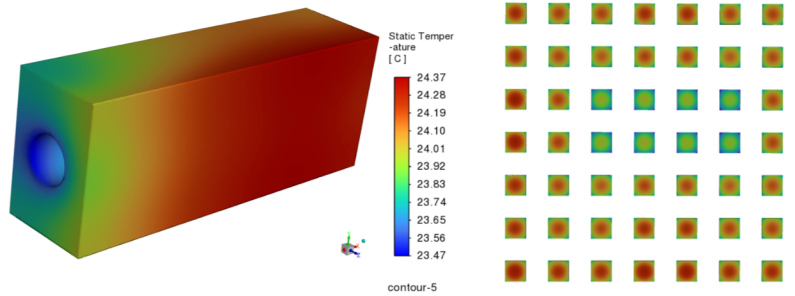
G. Girish (BNL)



Sector Geometry



FEB Temperature



Heat Sink Temperature

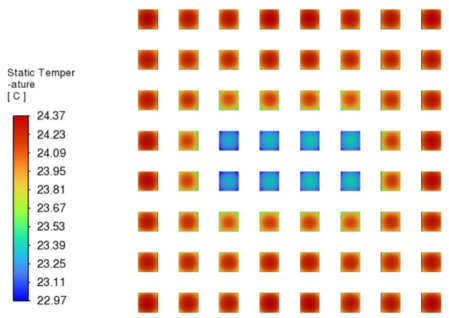
SiPM Temperature

Ambient Temperature (C)	Flow velocity (m/s)	Half FEB Heat load (W)	SiPM Heat load (W)
20	0.76	2.25	0.17

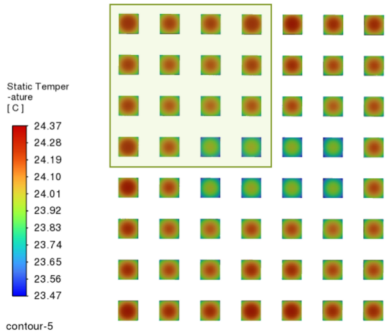
Relative Humidity (%)	Dew Point Temperature (C)	Water Inlet Temperature (C)	FEB Temperature (C)	SiPM Temperature (C)
100	20	22	27.88	24.37

G. Girish (BNL)

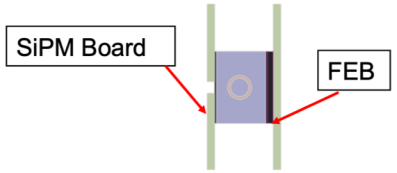
Design :



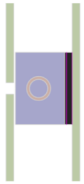
FEB Temperature



SiPM Temperature



Requirement:
T variation on SiPM boards
+- 0.6 C SiPM FDR



G. Girish (BNL)

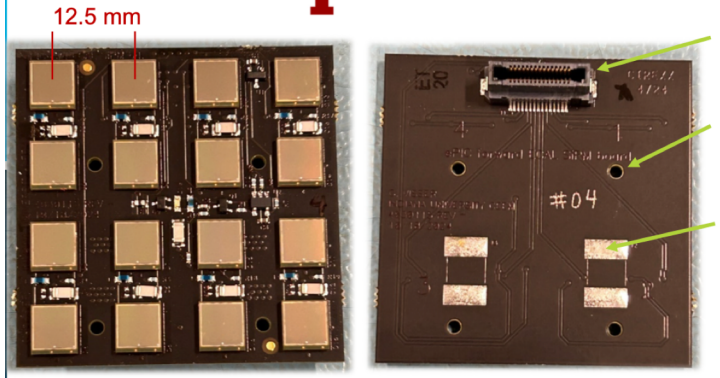
Simulations will be augmented with bench test measurements at Indiana University.

SiPM Boards FDR Status

- 5 SiPM Board final design.
- S14160-6015PS
- Boards assembled at UCLA electronics shop

SiPM board

have 5 fully assembled boards, plus ~27 bare PCB



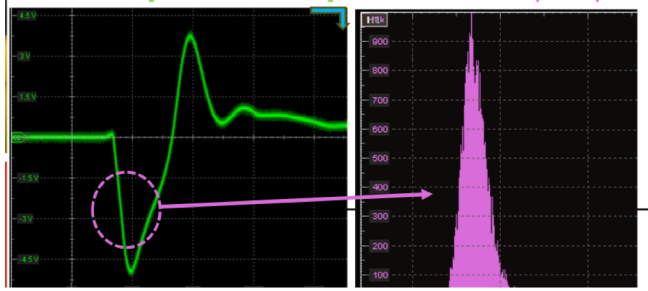
Connector to FEB

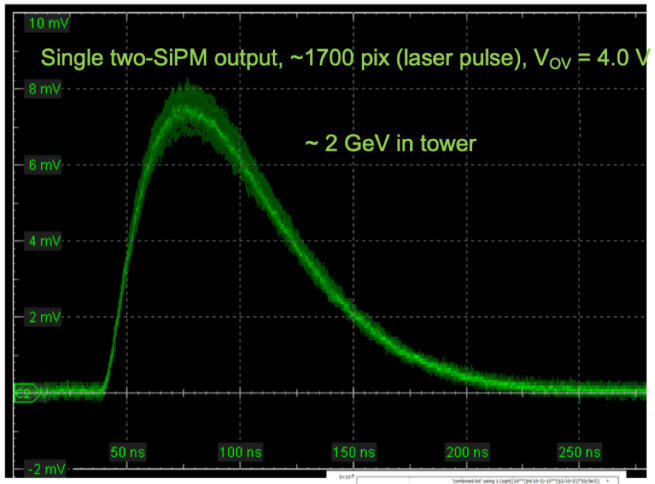
Holes for gluing fixture & for removal tool (rivets)

Cooling tab solder pads

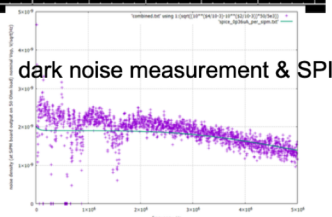
Use is under study (not baseline)

- 2×2 calo. towers
- 8× (2×6×6 mm^2 SiPM channels), 2 ch. combined on FEB
- Passive shaping, no amplifier on SiPM board
- LED and driver circuit
- Thermistor
- E-Serial number





SiPM's in new package **w/ thermal connection!**

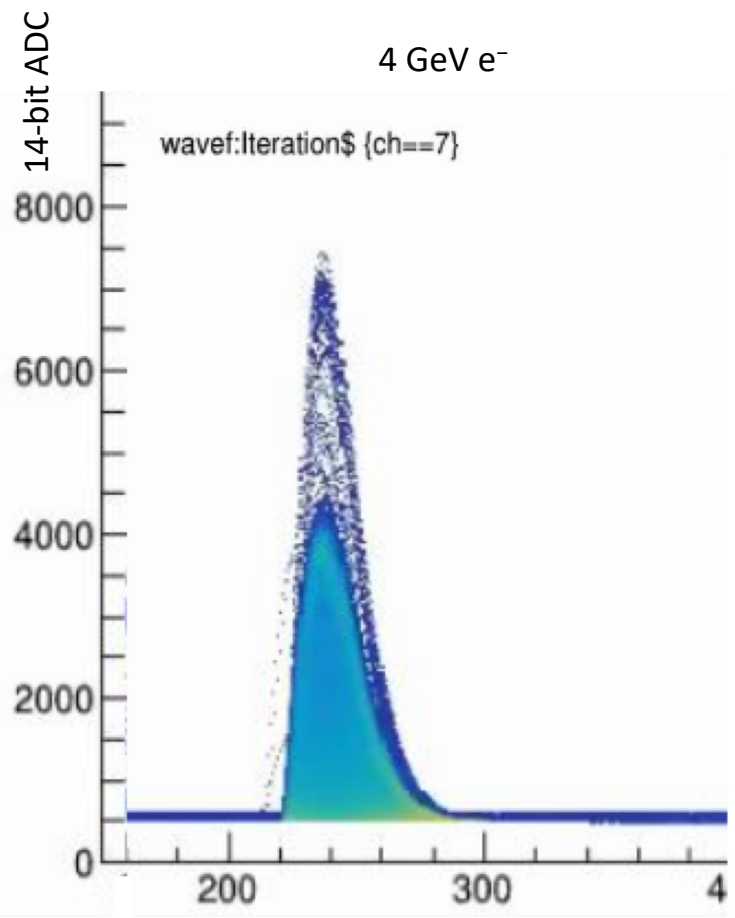


Next steps:

- Optimize 2nd stage of shaping (on FEB)
- Measure thermal resistance SiPM to board
- Measure thermal gradients on board
- Temperature of SiPM's in a mock-up system (w/ DC LED simulating rad. dama
  - w/o cooling
  - same with cooling (which is not baseline plan)
- DCR vs. temperature
- Mechanical fit of blocks/lightguides/SiPM board to FEB w/ floating connectors
- Test removal of glued SiPM board (UCLA/BNL)
  - meaning w/o damage to neighbors or lightguide!
- Evaluation of LED uniformity / need to adjust amplitude in system

Front End Electronics Developments Status

- Completed SiPM board design & prototype production (Cirexx Inc.); five boards assembled at UCLA Electronics Shop. 97% final completion.
- FEB cooling and cable integration designed, and FEB PCB design modified for the change to final block spacing 101.0 mm and cooling interface. 85% complete on FEB interface (IU), ~60% complete water sys. (BNL).
- First stage of readout (shaping and preamplifier) validated in ePIC backward ECAL application (February test beam @ DESY), w/ CAEN ADC
- Two-channel prototype full signal chain including ADC and streaming readout: Design to finish in June, tests starting late July. 75% design complete.
- Full FEB: Main board 50% design complete, SiPM bias daughterboard 70% design complete. Finalize after 2-ch prototype tests, September. Full readout tests complete November 2025
- Key components for prototype & FEB are in hand



1st stage signals into ADC
(bwd ECAL @ DESY)

Software Developments Status

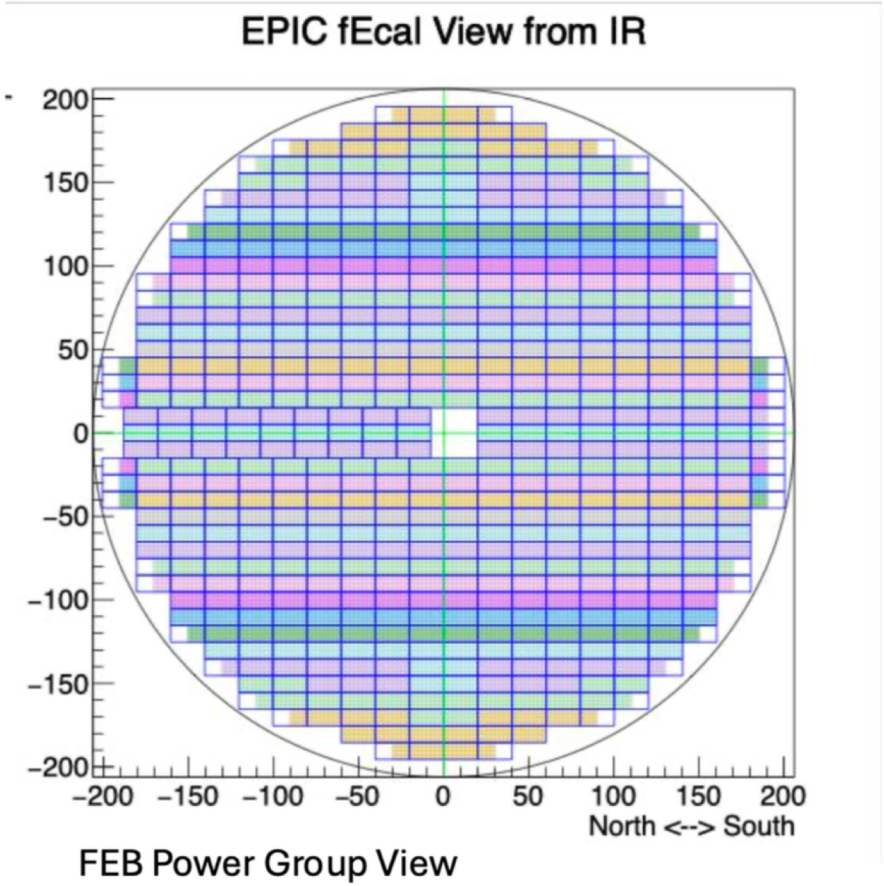
Akio Ogawa (BNL) is new fEMCal software coordinator.

- Expert in calorimetry software at STAR (FMS, FCS).

- Stability
- Structured Approach
- Documented

Map and Numbering

https://www.star.bnl.gov/~akio/epic/map/index.html
https://github.com/eic/epic/blob/fEcal_update/src/forwardEcalMap.h



Simple C++ class to convert between :

- Human readable Id (north/south, row, column)
- Human readable Id (north/south, block, tower)
- Local XY
- Global XYZ
- CellID in MC
- DAQ Id (ROC, FEB, SiPMBd, Ch…)
- Slow Control Id (Power Group, FEB Addr, SiPMBd…)

This also help to provide basic constants and functions for

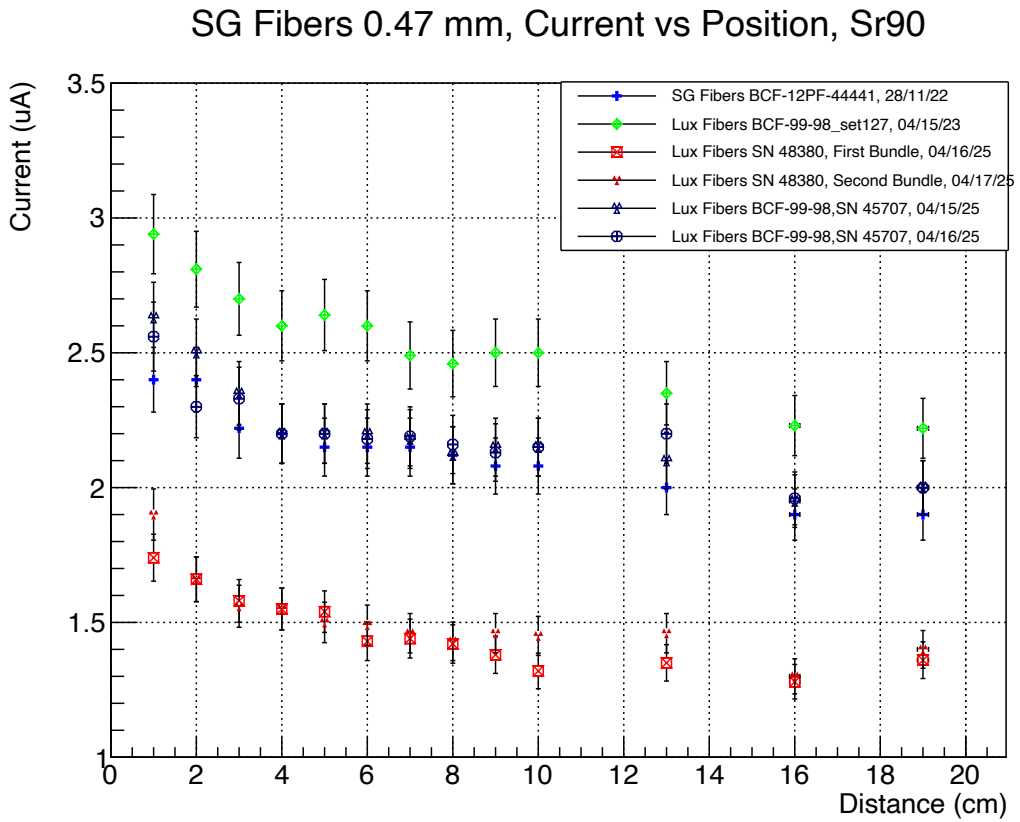
- Drawings
- MC geometry
- Reconstruction
- QA plots

Sc. Fibers, First Article QA

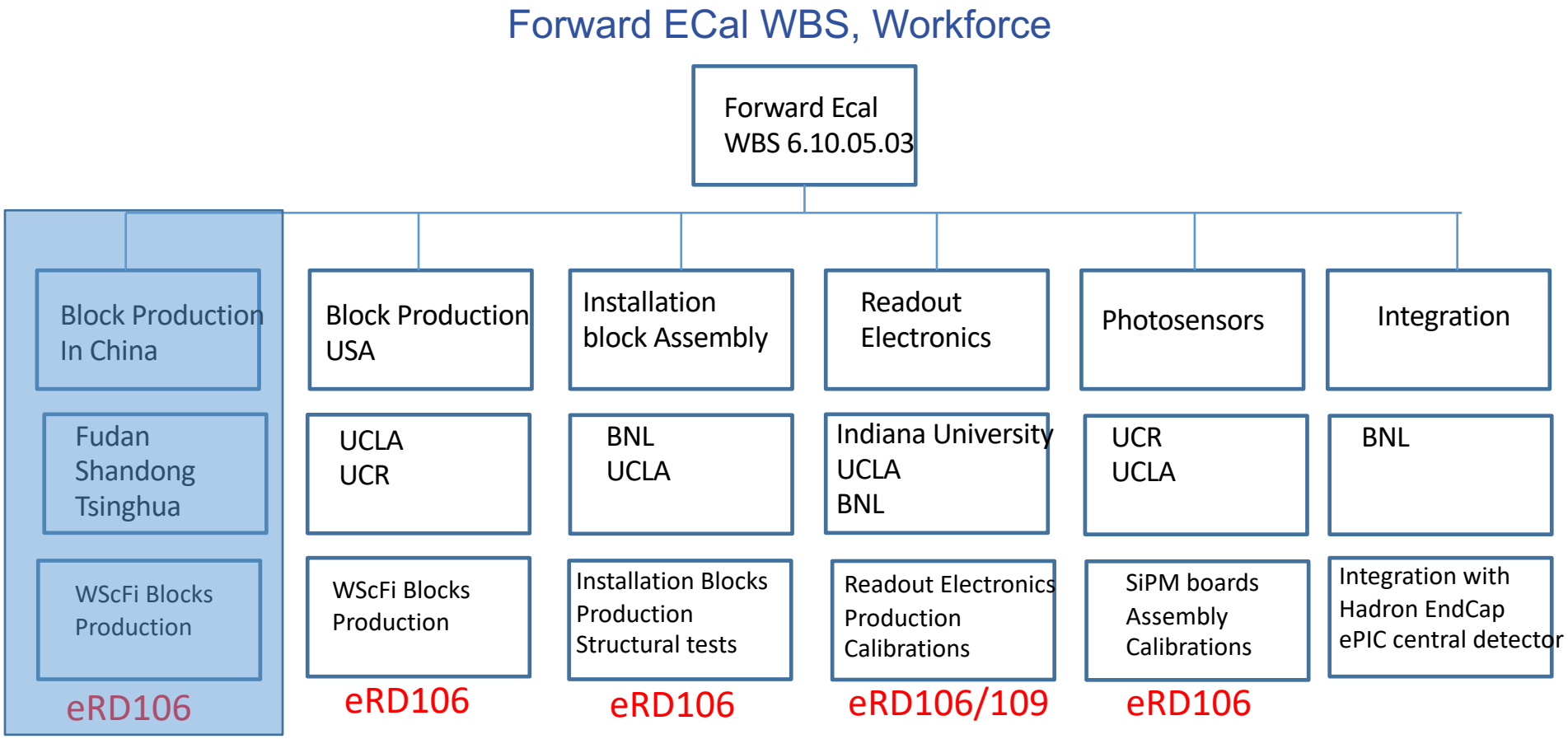
- Sc. Fibers CD3A item.
- First Article Fibers at UCLA at mid April 2025. Did not passed QA, LY is 40% lower than expected. That was an unexpected surprise to us and Luxium.

Status Update: Collaboration with Luxium

- Holding weekly meetings with Luxium to address and resolve production issues
- UCLA QA procedures successfully duplicated at Luxium
- Sample exchanges between Luxium and UCLA confirm consistent measurement results at both sites
- Recent Luxium samples passed UCLA QA tests
- Agreed to use common reference samples at both locations moving forward
- Luxium to perform full QA testing on first two shipments following UCLA protocols
- First shipment approved by BNL, expected arrival: late June
- Open issue: Root cause of poor quality in the initial 100 fibers remains unclear



Production Planning Status

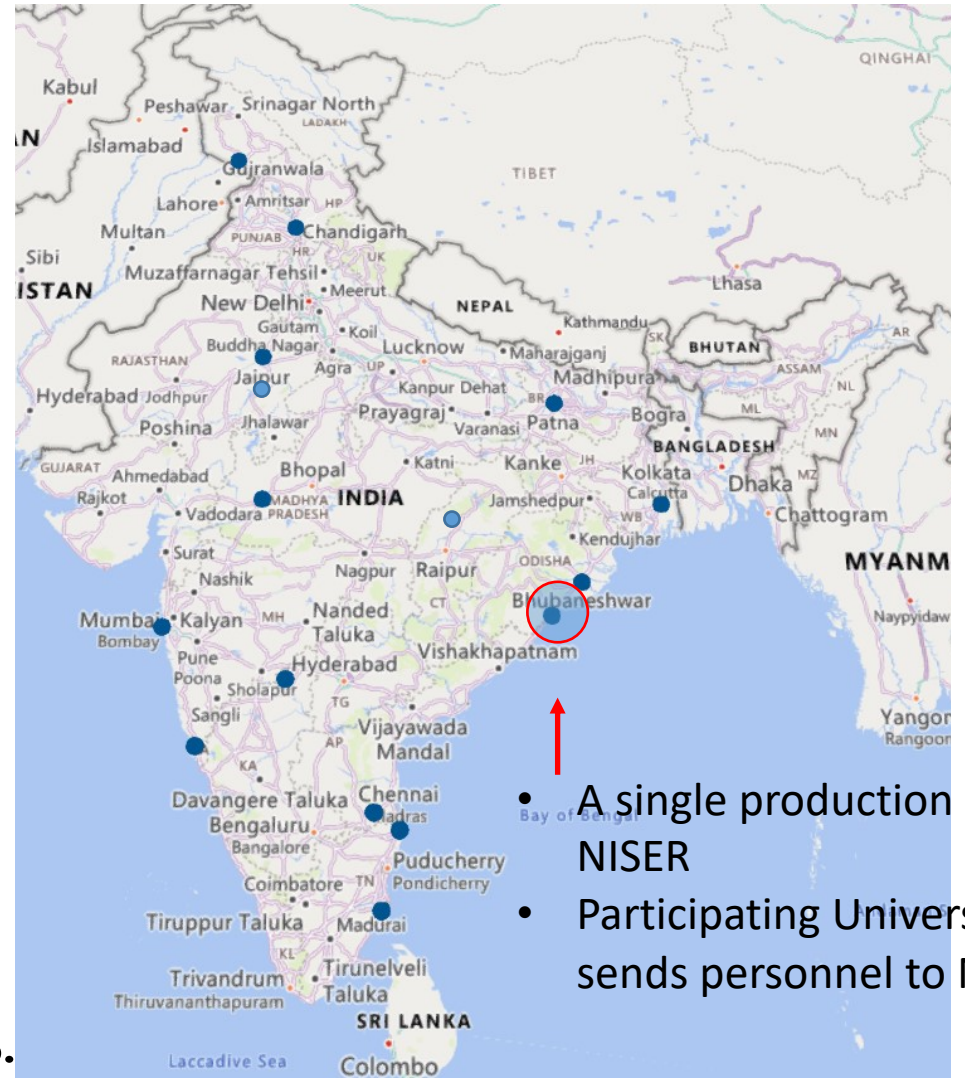


- Original plan benefited from experienced Chinese production site. This is not possible now.
- Indian Consortium expressed interest about a year ago to participate in FEMC project.

Production Planning Status

Indian Institutes interested in ePIC at EIC

- 20 Institutes from all around India have shown interest. More are willing to join.
- Interests in the following hardware and software activities.
  - PID – dRICH
  - Forward ECAL
  - ToF – AC LGAD
  - Simulation studies



- A single production site at NISER
- Participating Universities sends personnel to NISER

Two scenarios:

- Block production site in India + assembly site in the US.
- Full production in the US

Summary

- The design of the FEMC is nearing 90% completion.
- The remaining technical work, particularly in areas such as front-end electronics, is progressing well and expected to reach the 90% mark soon.
- The FEMC is on track to be technically ready for baselining by the end of the year.
- All aspects of integration, installation, and maintenance have been thoroughly discussed and iterated with the 3I group, and these considerations have been incorporated into the design.
- Two production scenarios are currently under consideration.

Thanks!