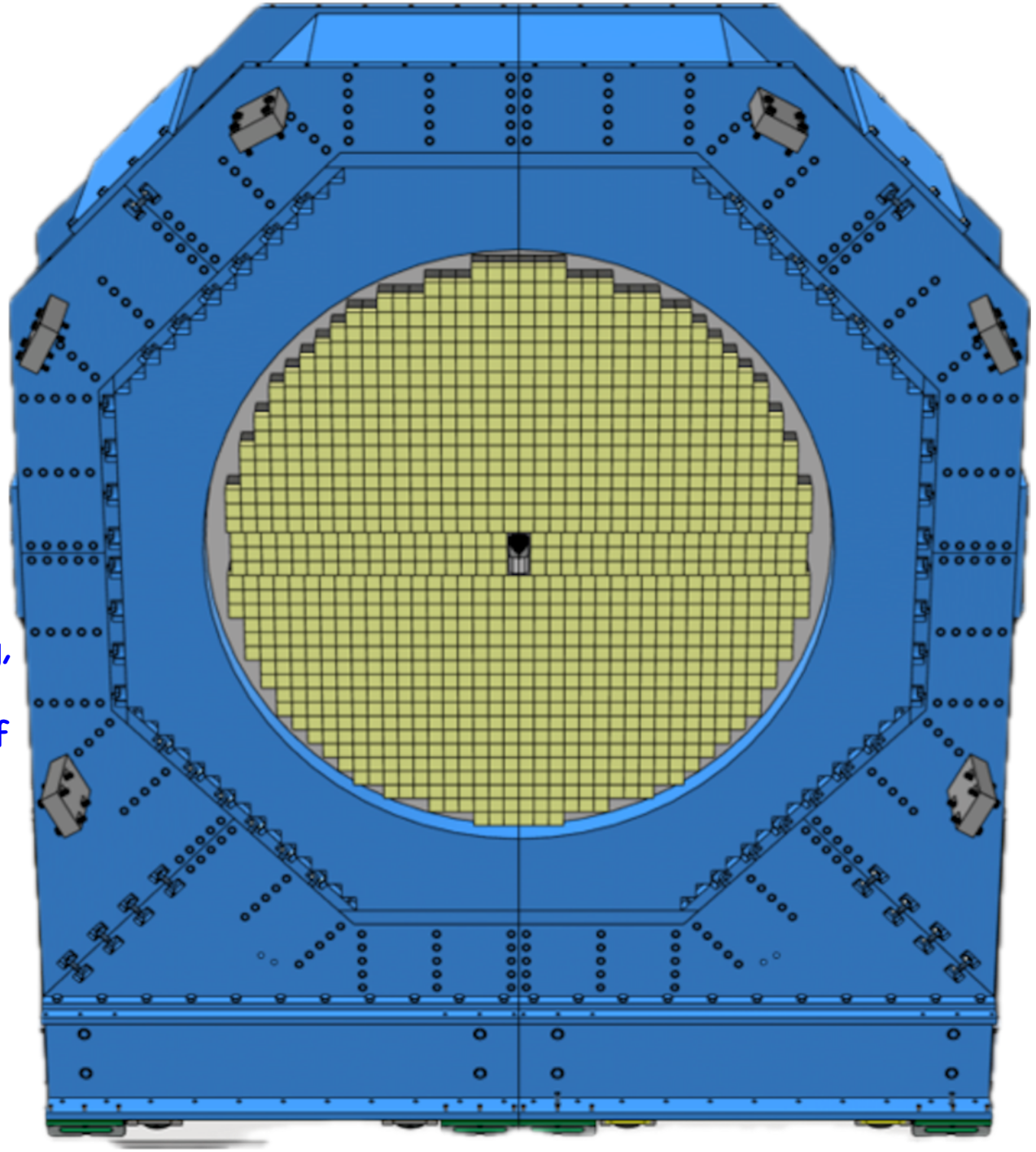
eRD106 - Forward EM Calorimeter

Status Report

O. Tsai (UCLA/BNL) for eRD106 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)



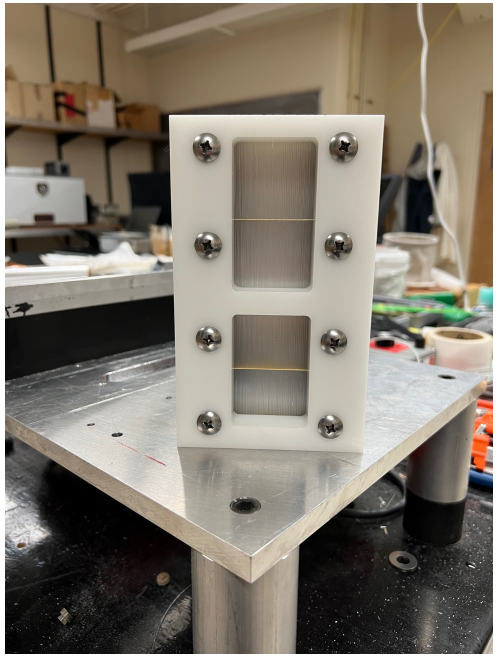
Milestones for FY24:

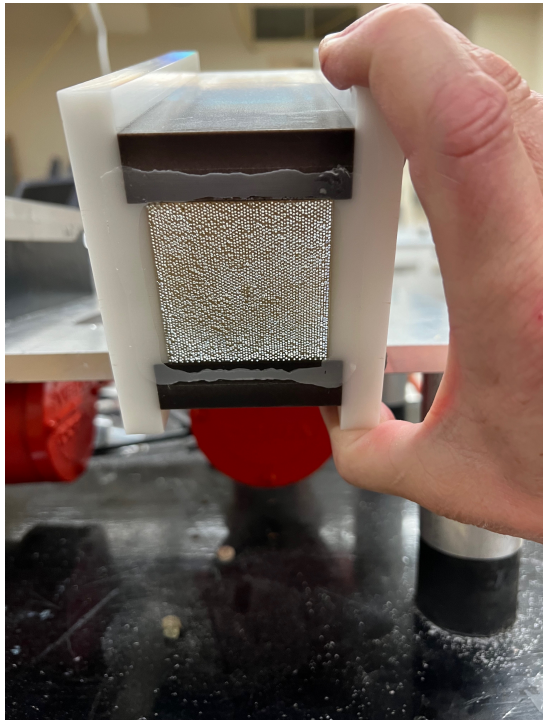
To address the remaining technological questions:

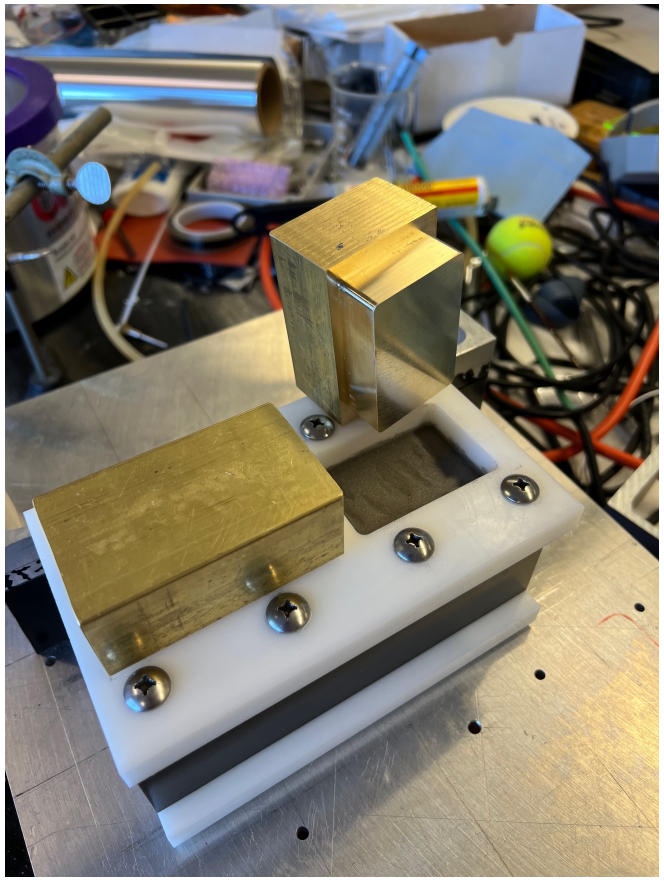
- Construct 64 channel ECal prototype, using latest method developed by eRD1.
- Optimize light guides.
    1. Uniformity of light collection
    2. Efficiency of light collection
- Test detector at FNAL.

Moving toward CD2/3A:

- Mechanical integration of ECal into ePIC.
- Structural tests (sheer and compressions).
- Comparison of 'EIC specs' Luxium and Kuraray fibers.
- Optical/mechanical/electrical integration of readout (with eRD109)
- SiPM testing (with eRD110) was not funded. (UC EIC @ Davis)



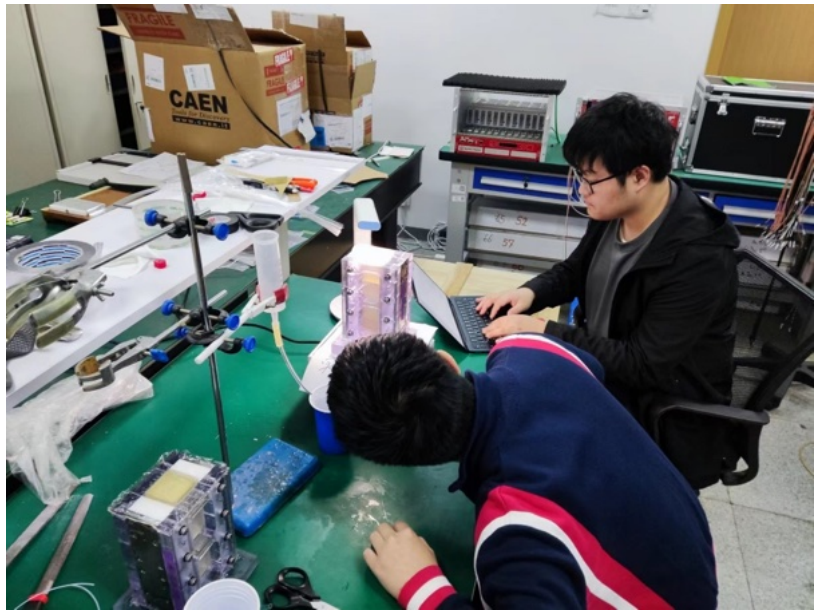


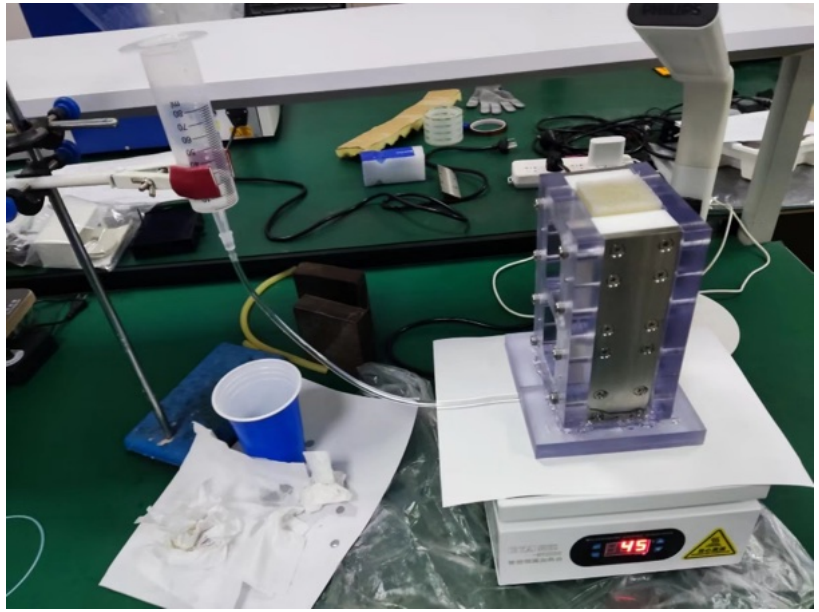


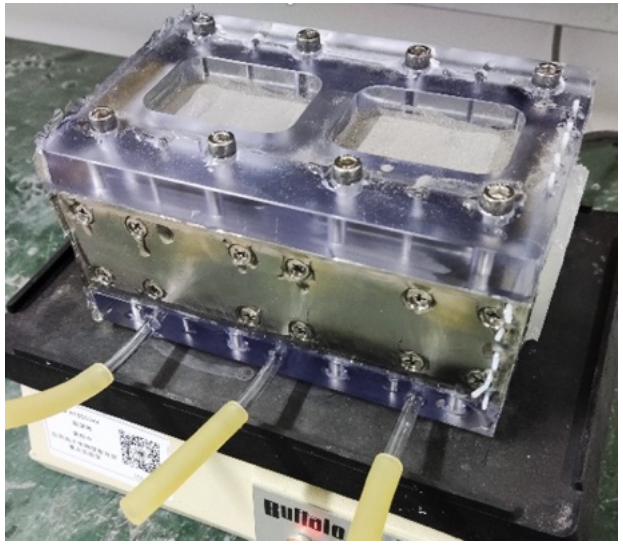
eRD106 UCLA production of fEMcal blocks

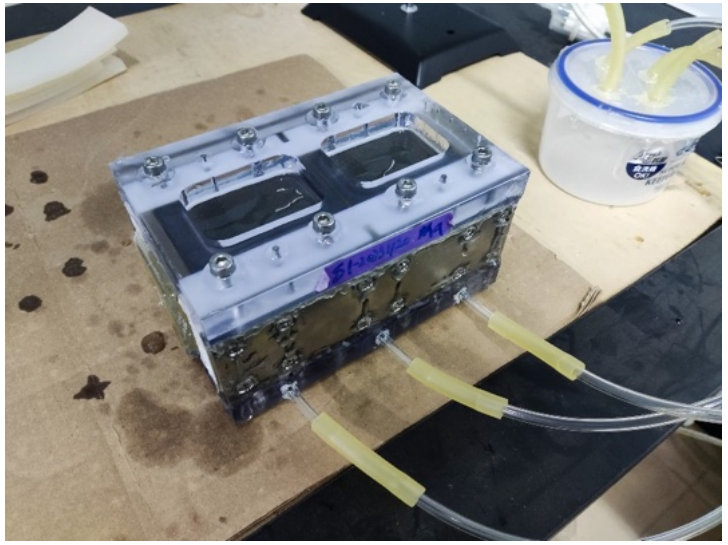
- Mold similar to Fudan's molds (next slide)
- Simplified
- Five blocks made. Four used for mechanical tests at BNL

eRD106 Protype Production at Fudan



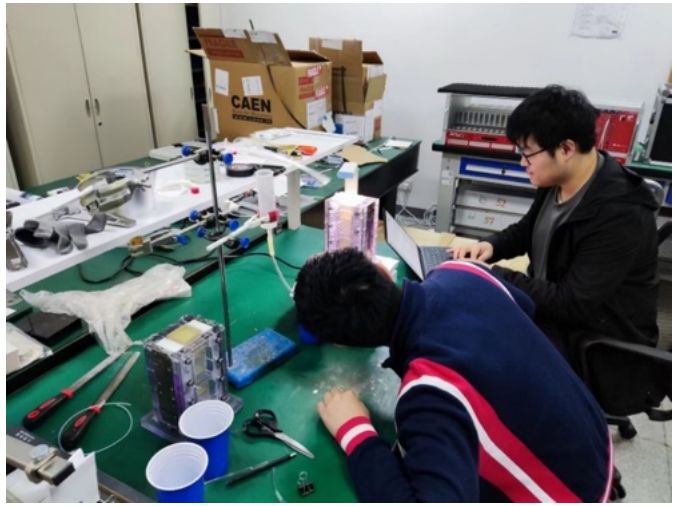


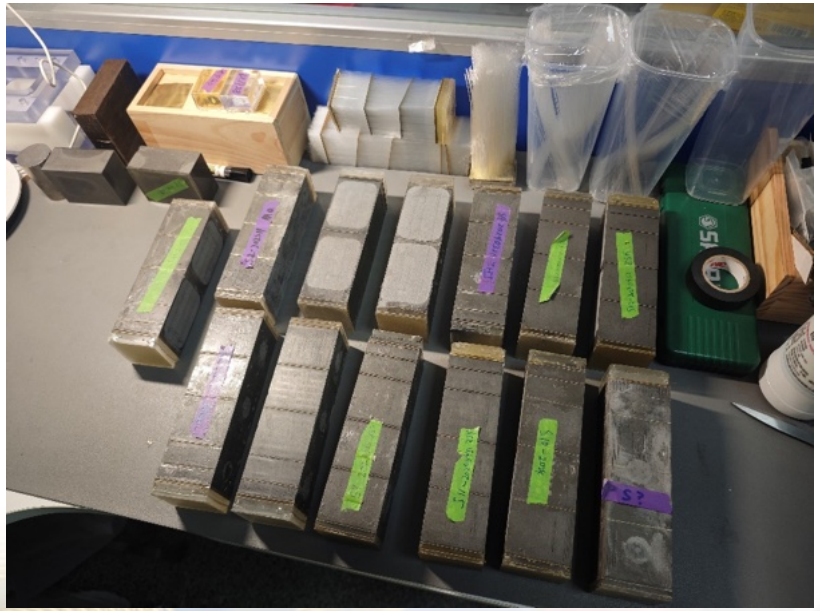


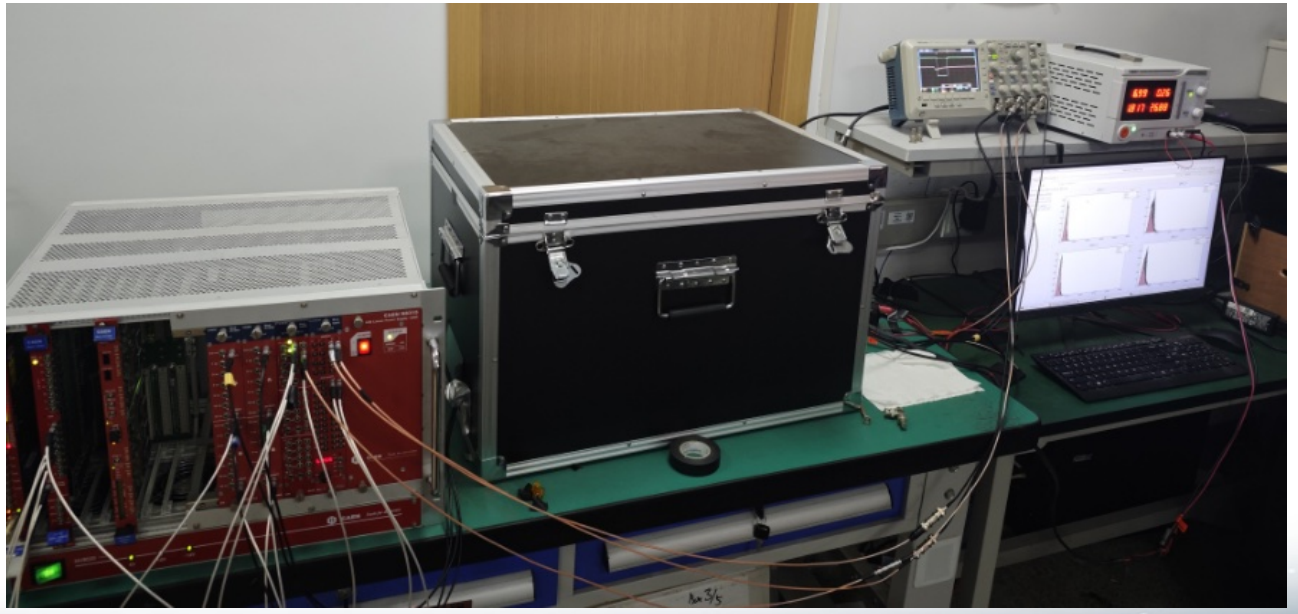


ePIC-fEMCal block: prototypes at Fudan

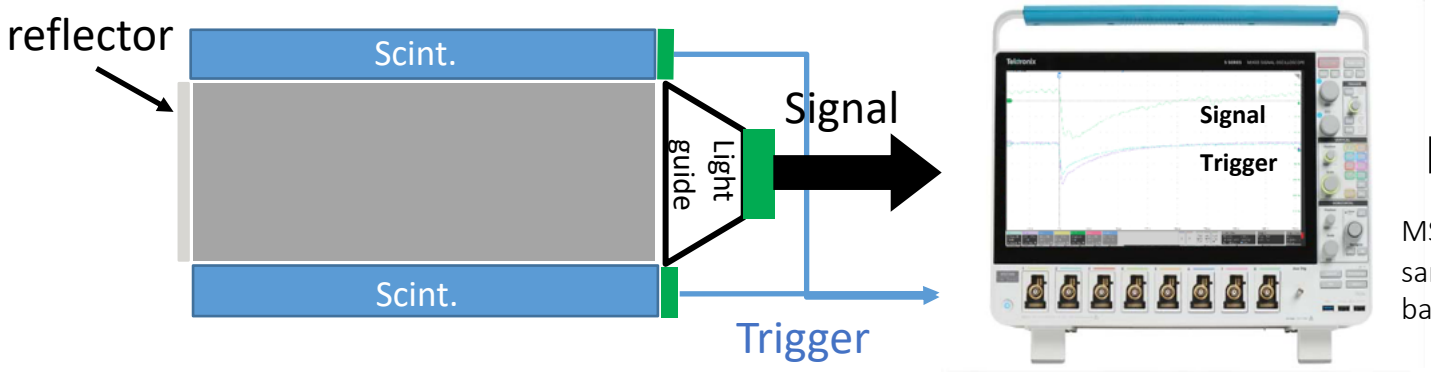
- We finished the prototypes production flow.
- Got manpower from Tsinghua and Shandong Uni.
- Engineers and students were trained
- We got 12 blocks ready.





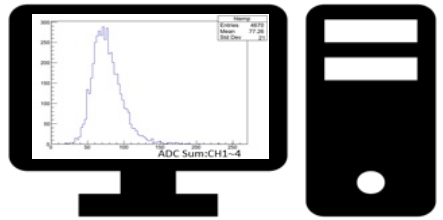


ePIC-fEMCal: Cosmic ray test at Fudan

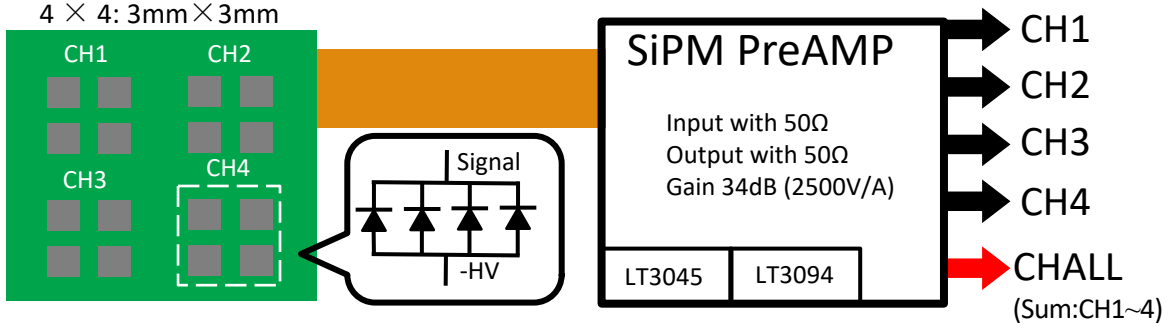


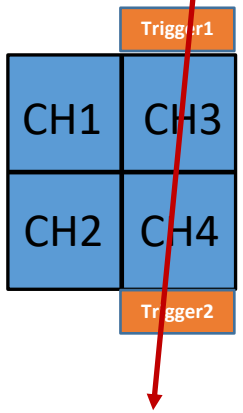
USB

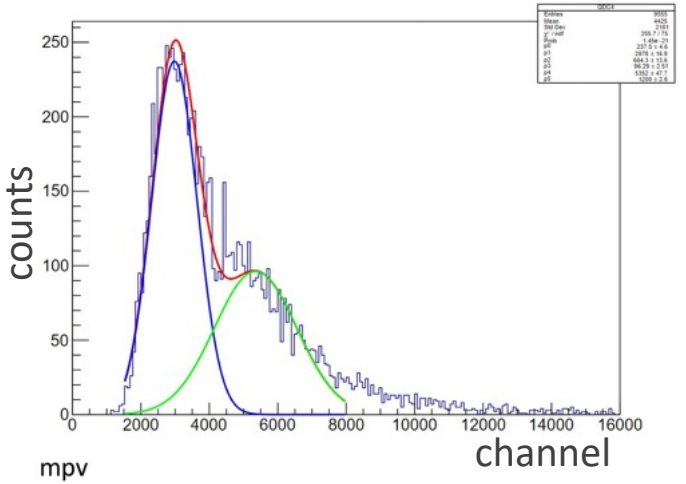
MSO58
sampling rate：6.25GHz
bandwidth： 2 GHz

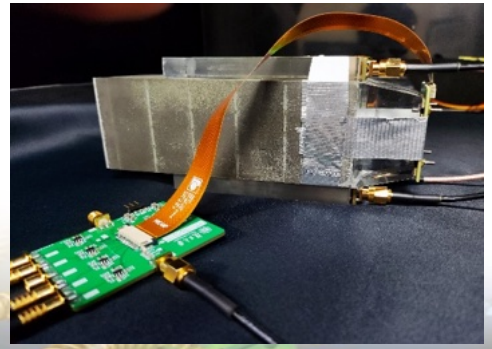


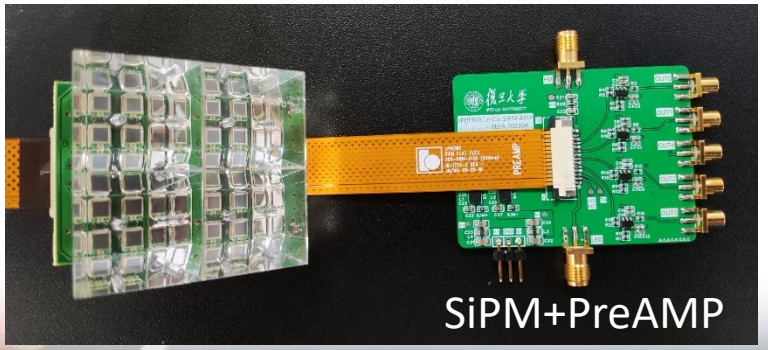
SiPM: S12572 (Hamamatsu)
4 × 4: 3mm×3mm

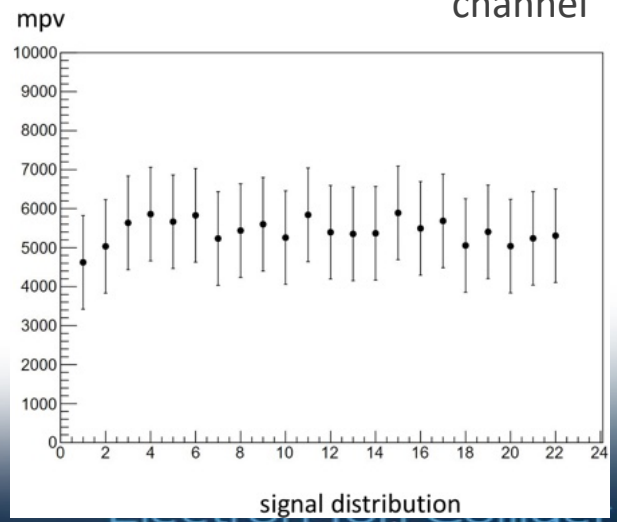




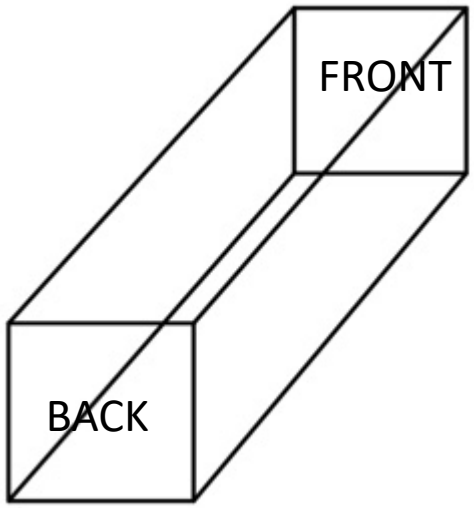








ePIC-fEMCal: Dimension and density



TF:TOP FRONT, TM:TOP MIDDLE, TB:TOP BACK

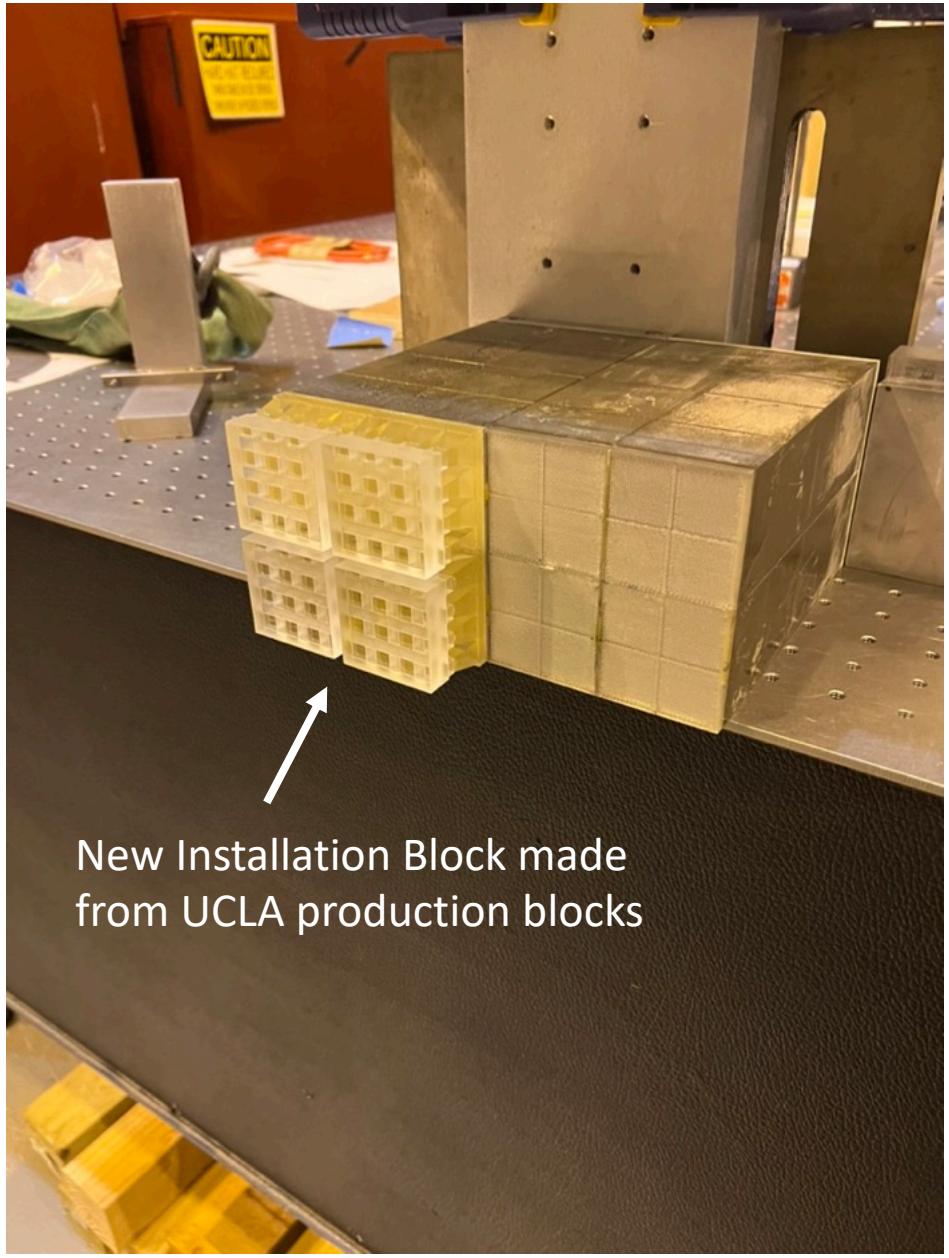
BF:BOTTOM FRONT, BM:BOTTOM MIDDLE, BB:BOTTOM BACK

LF:LEFT FRONT, LM:LEFT MIDDLE, LB:LEFT BACK

RF:RIHGT FRONT, RM:RIHGT MIDDLE, RB:RIHGT BACK

Prototypes	TF	TM	TB	BF	BM	BB	LF	LM	LB	RF	RM	RB	LENHTH1	LENHTH2	MASS(g)	VOLUME(mm^3)	DENSITY(g/ml)
S1	50.04	50.07	50.19	49.99	50	50.08	50.08	50.13	50.04	50.12	50.02	49.97	183.51	183.52	3878	459904.5619	8.432184242
S2	50.08	50.04	50.2	50.01	50.09	50.07	49.98	49.97	49.97	50.1	50.05	49.96	183.28	183.29	3779	459006.8098	8.232993322
S3	50.06	50.13	50.17	50.01	50.03	50.09	50.16	50.16	50.17	50.12	50.15	50.18	184.83	184.85	3893.6	464305.0416	8.385866297
S4	50.05	50.06	50.14	49.99	49.92	50.00	49.93	49.96	49.93	50.00	50.03	49.99	184.71	184.72	3871.1	461787.3686	8.382862466
S5	50.22	50.18	50.35	50.25	50.11	50.17	49.96	50.02	49.97	50.00	49.98	50.02	183.64	183.64	3850.8	460981.9835	8.353471801
S6	50.16	50.11	50.16	50.02	50.05	50.04	50.06	49.99	50.02	49.98	50.03	50.08	183.37	183.37	3951.8	459495.0984	8.600309369
S7	50.05	50.05	50.25	50.28	50.18	50.20	50.10	50.05	50.00	50.08	50.04	50.08	184.44	184.41	3906.5	463154.461	8.434551169
S8	50.28	50.33	50.48	50.26	50.17	50.47	50.02	50.01	50.16	50.01	50.03	49.99	183.17	183.17	3910.7	461300.6084	8.477552227
S9	50.3	50.08	50.2	50.23	50.13	50.3	50.16	50.12	50.04	50.11	50.18	50.22	184.47	184.49	3871.9	464387.5541	8.337648083
S10	50.12	50.10	50.17	50.07	50.08	50.11	50.06	50.11	49.96	50.27	50.15	50.11	184.90	184.85	3986.4	464207.9218	8.587531174
S11	50.13	50.26	50.22	50.1	50.22	50.21	50.2	50.19	50.07	50.12	50.1	49.99	184.91	184.88	3941.2	465030.2558	8.475147479
S12	50.33	50.20	50.45	50.38	50.18	50.42	50.31	50.26	50.16	50.46	50.42	50.25	183.59	183.52	3993	464749.2555	8.59172974

Weihu Ma (FUDAN) was visiting UCLA in early Aug. to discuss production details.

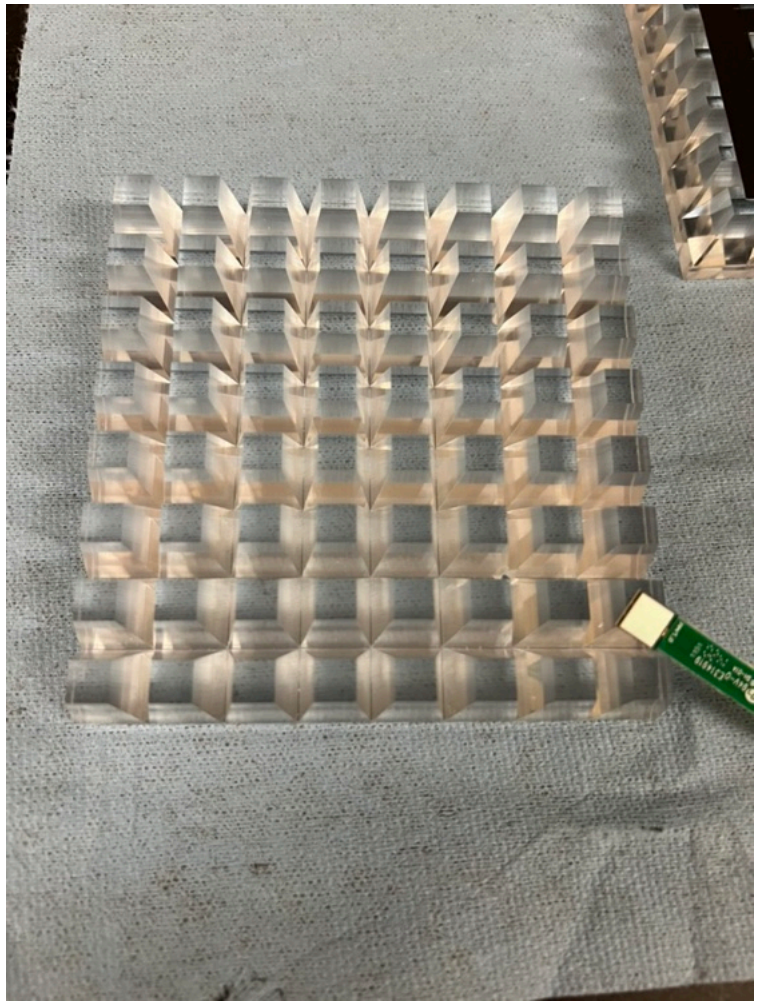


Structural and other mechanical tests at BNL.

Installation test was needed to:

1. Finalize design of lightguides
2. SiPM currying boards
3. Integration with FEEs
4. Assembly sequence of the installation block

- Initially Injection molding (IM) and machining were considered for LG. IM was dropped as unpractical.
- Eight different light guides were produced at UCLA, BNL, Indiana machine shops using different methods.
- Best method were developed by Indian shop.



Result: Efficiency

- **Efficiency was measured with HPK 6x6 mm SiPM. Light source 1mm diameter plastic optical fiber, 35 cm away from SiPM. 2% light lost in 19 mm Acrylic (PMMA) and Sylgard coupling.**
- **Two versions of light guide were tested. One straight after machining (M), another with additional polishing after machining (P).**

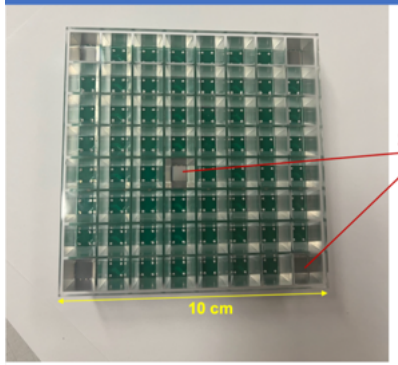
Type of Light Guide	LG efficiency	Light Collection Efficiency (transmittance and geometrical efficiency added)
Machined	84%	70%
Machined + Polished	95%	80%

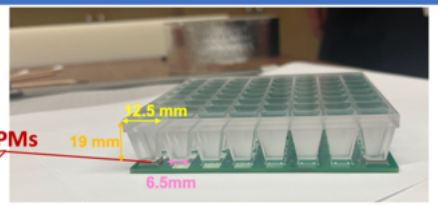
- **FNAL test run measures light yield ~ 400 pixels/GeV with efficiency at ~ 21%. Scaling this for ePIC gives about 1600 pixels/GeV light yield for forward EMCal.**
- **This will be verified in another test run.**

Confirmed at Test Run (~1580 pixels/GeV)

- First results from light guide scanner at UCLA.
- Setup is being improved now to reduce PMT photocathode non-uniformities.

Prototype of lightguide for ePIC Forward EMCal

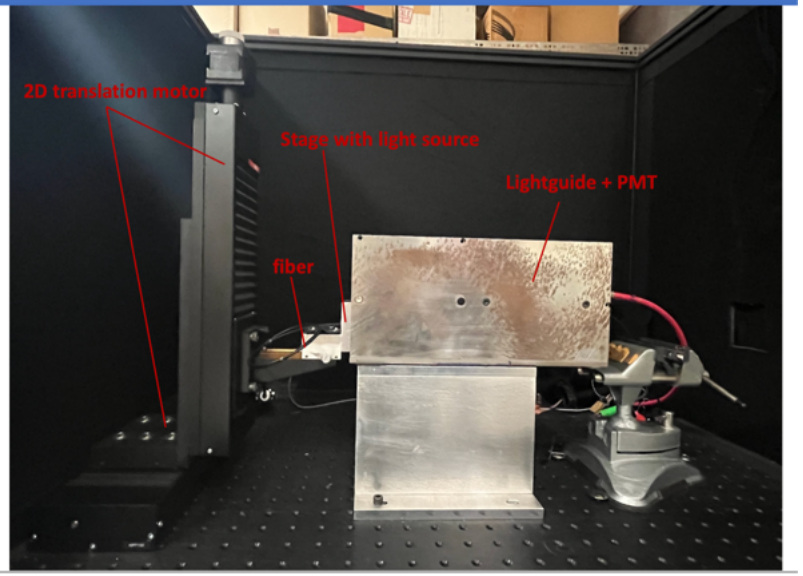




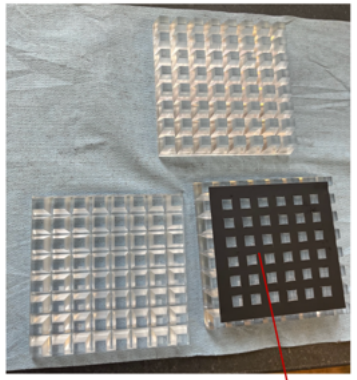
- A single lightguide per installation block. It has 64 pyramids to collect light from 10 cm x 10 cm area of W/ScFi block to 64 SiPMs 6 mm x 6 mm.
- Thickness of light guide is 19 mm, reduction area is 12.5 mm x 12.5 mm to 6.5 mm x 6.5 mm.
- Optical coupling between SiPMs and lightguide is Sylgard 3145 RTV.
- Not enough calibrated SiPM chips for now.

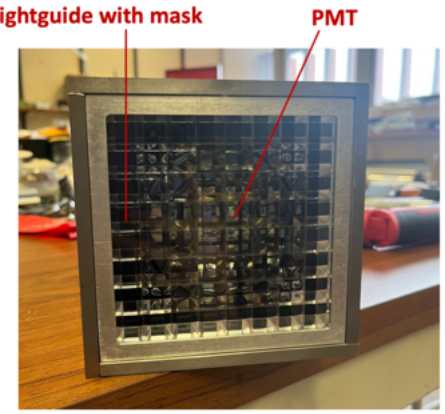
2

2D scan setup for uniformity test



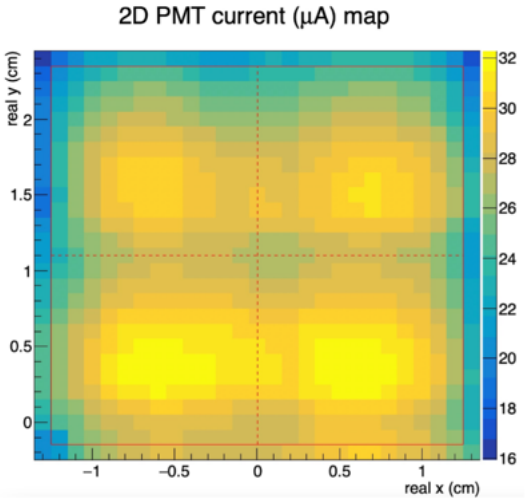
PMT + lightguide for uniformity test

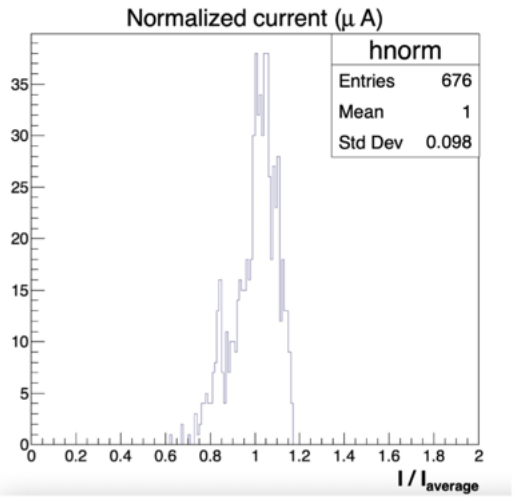


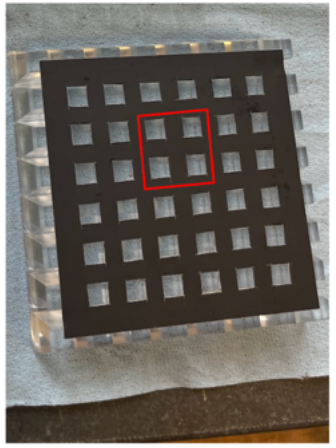


- PMT + Masked lightguide to mimic the SiPM detection
  - A SiPM is smaller than the transverse area of each grid (trapozoid shape).
  - Incident light that hits the edge (black masked area) won't be detected by PMT.
- Lightguide and PMT are glued to ensure optical contact.

3

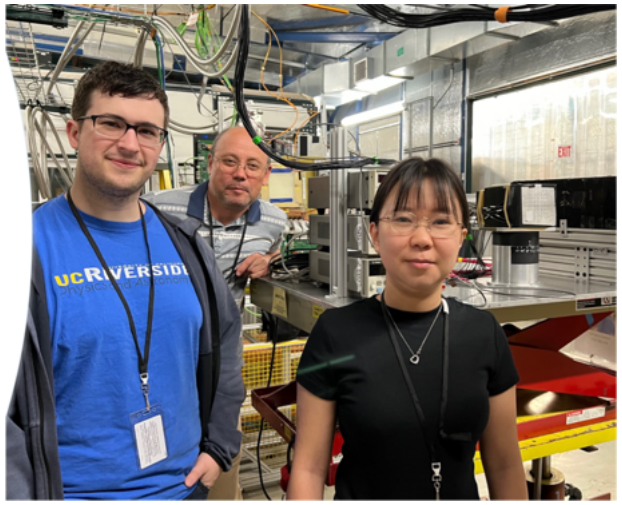




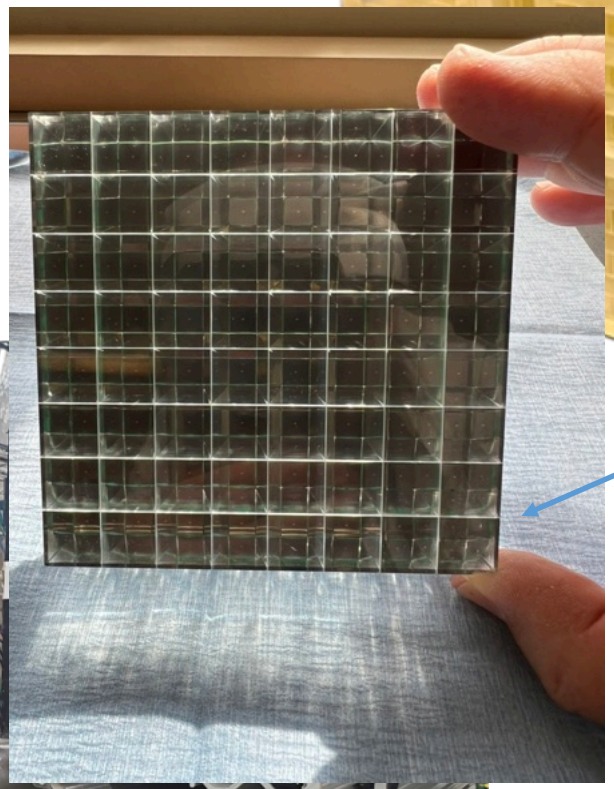


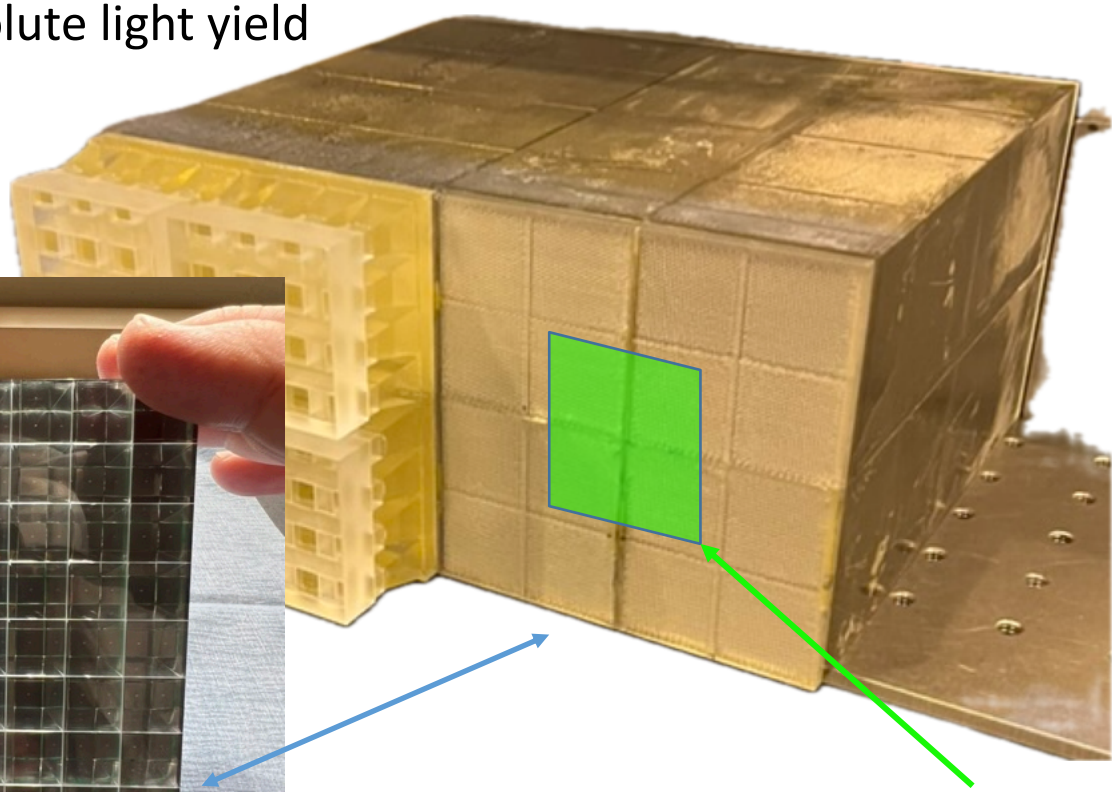
Test Run at FNAL, June 2024, ~48 hours of beam time. (UCR + UCLA)

- Check uniformity.
- Measure absolute light yield



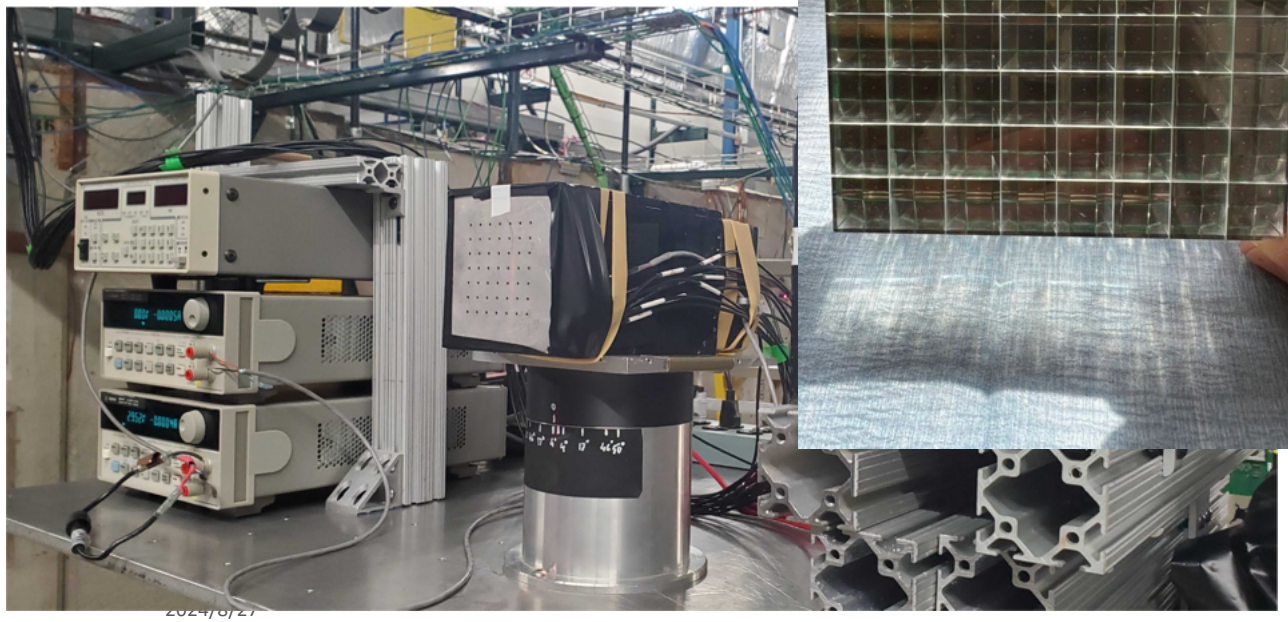
Yunshan Cheng (UCLA)
Sean Preins (UCR)
Miguel Arratia (UCR)
Oleg Tsai (UCLA)





- **Scanned area**
- **Between four production blocks**
- **Sc. Hodoscope 8x8 ~ 5x5 mm**
- **For different impact angles**

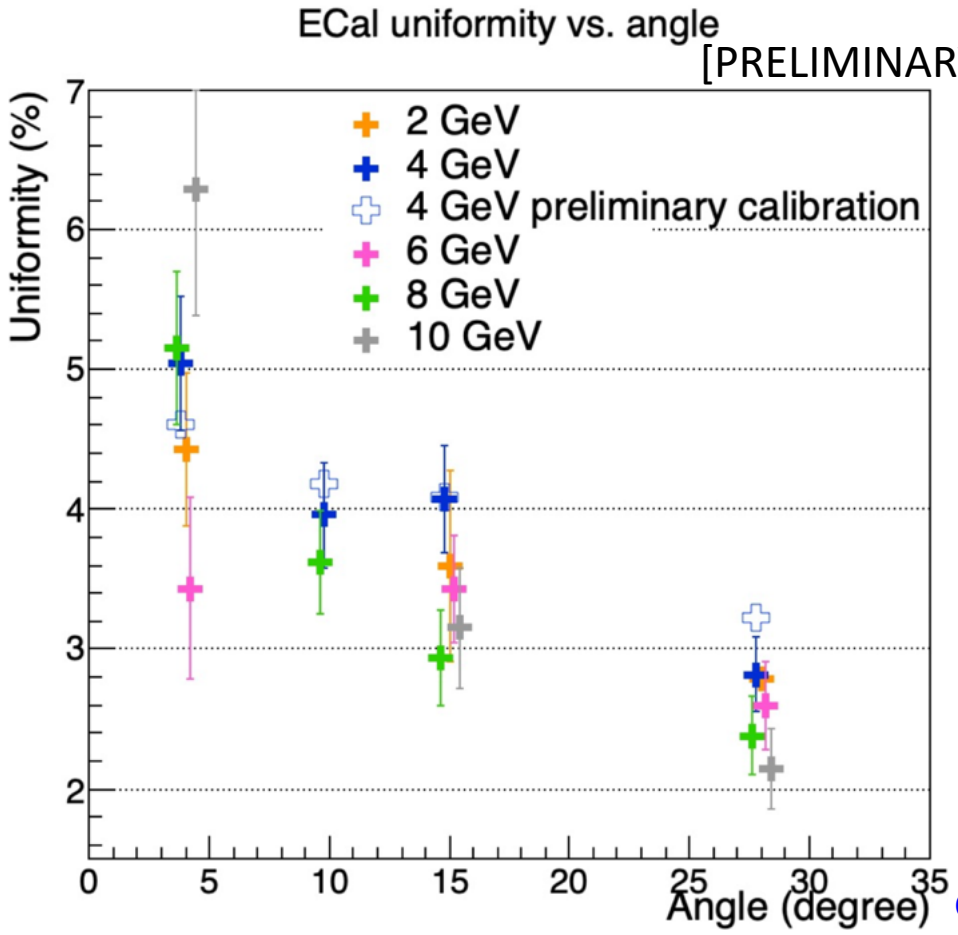
Indiana University LG +
64 6x6 SiPMs



Uniformity

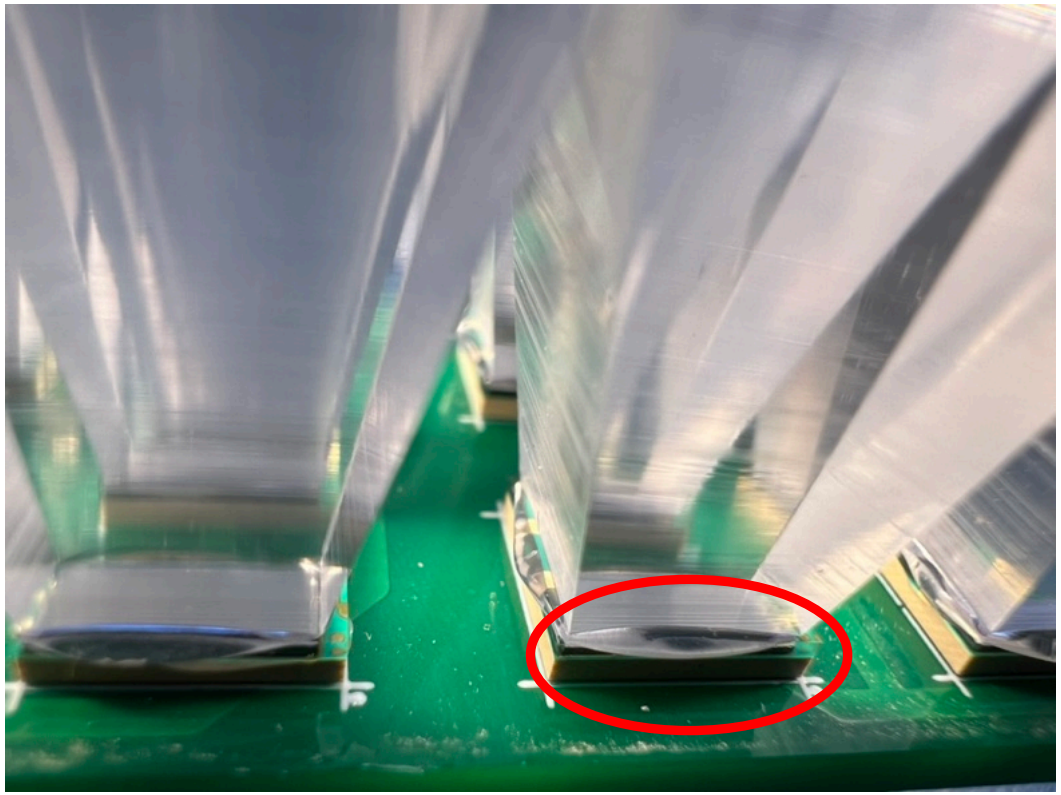
64 impact position by Sc Hodoscope, each ~ 5 mm x 5 mm

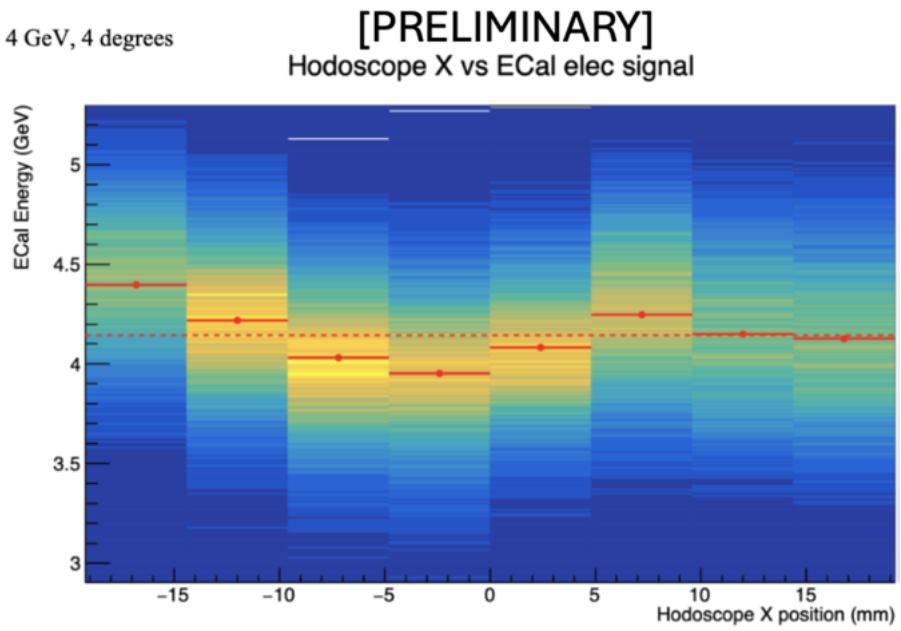
- **Definition:**
  8 x 8 hodoscopes with 4.8 mm width
- **➔ 64 position bins, each with mean ADC**
- **➔ 64 mean ADC values**
- **➔ Get the average and standard deviation of mean ADC**
- **Uniformity =** $\frac{sigma\ of\ mean\ ADC}{average\ of\ mean\ ADC}$

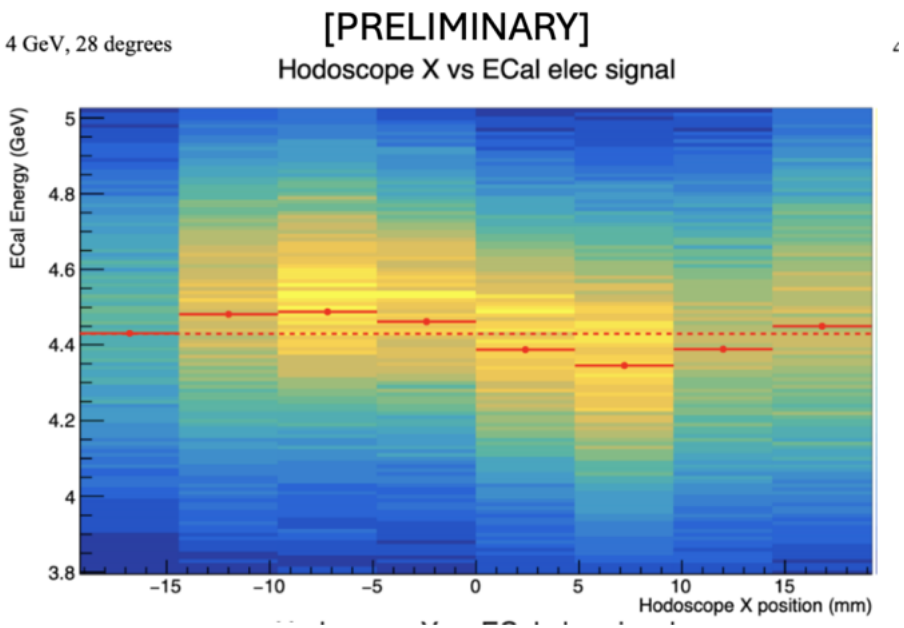


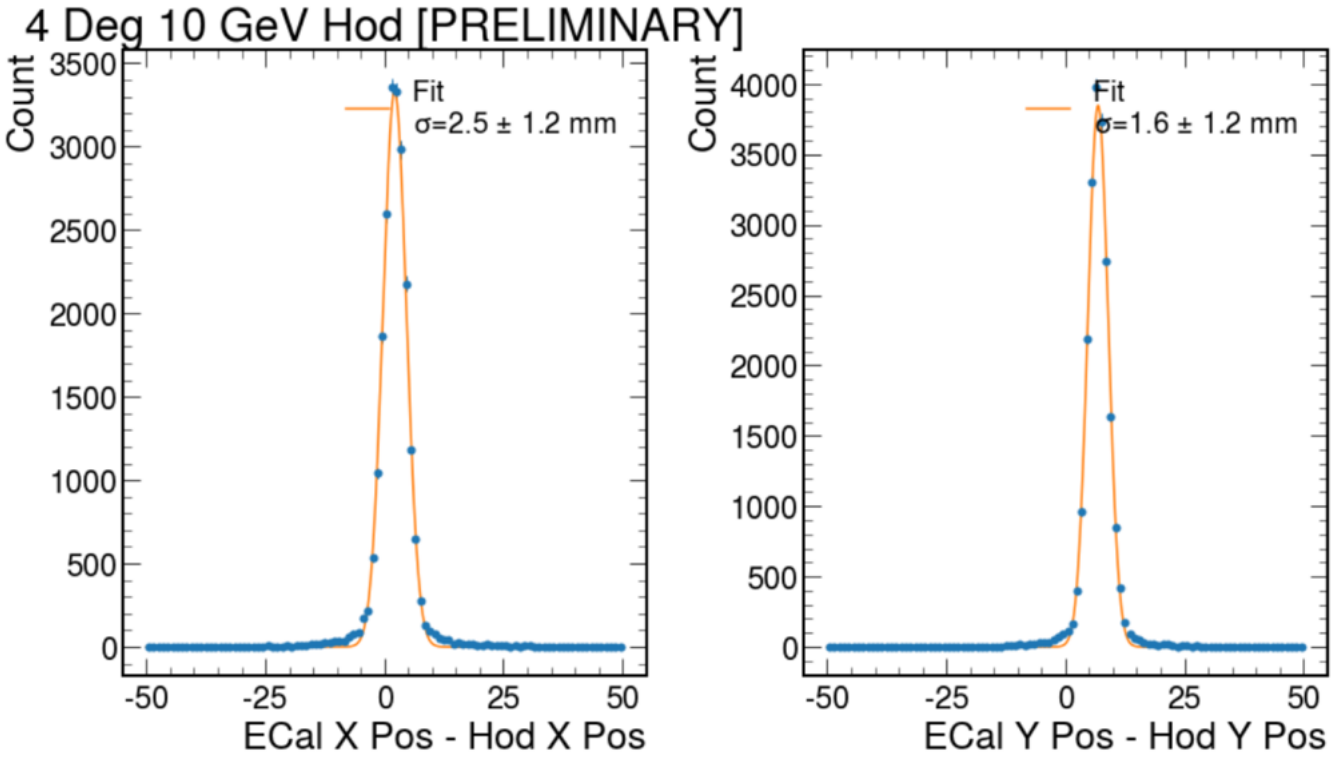
Sources of non-uniformity:

- Short LG
- Mixed SiPMs (Vop) used in test run – Calibration.
- Gluing imperfections (SiPM Boards/LG)
- Production blocks boundaries

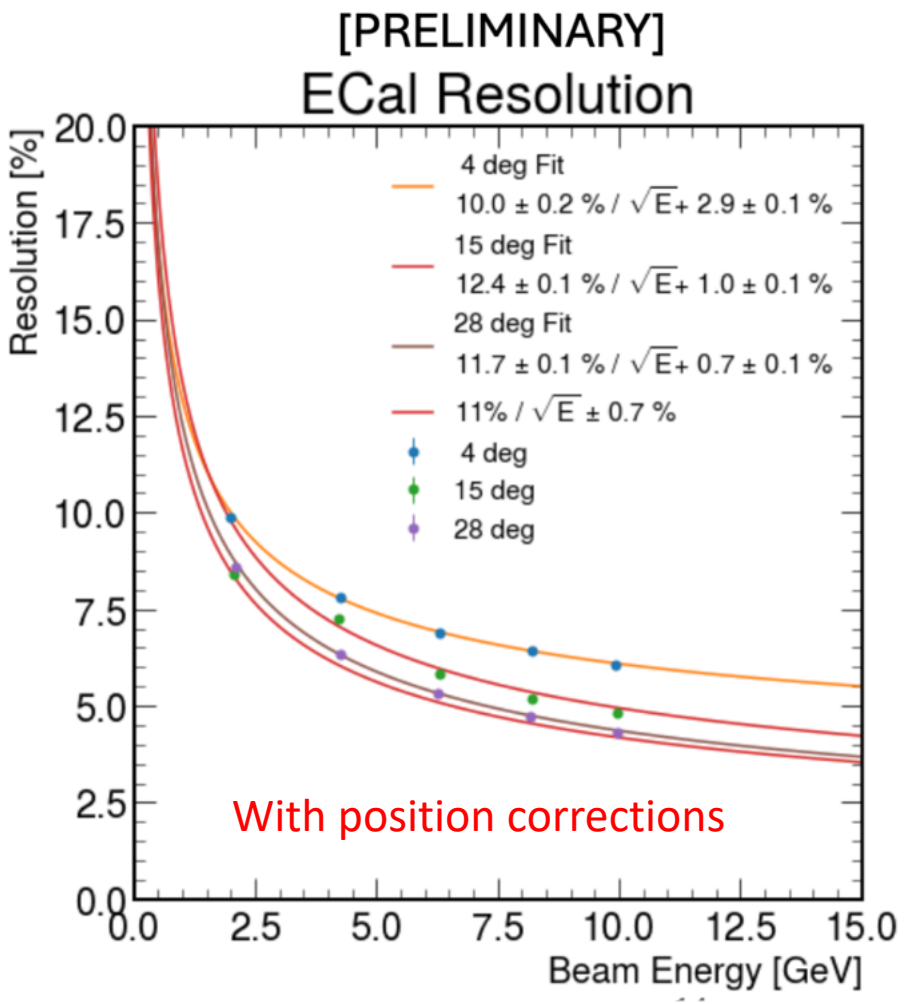


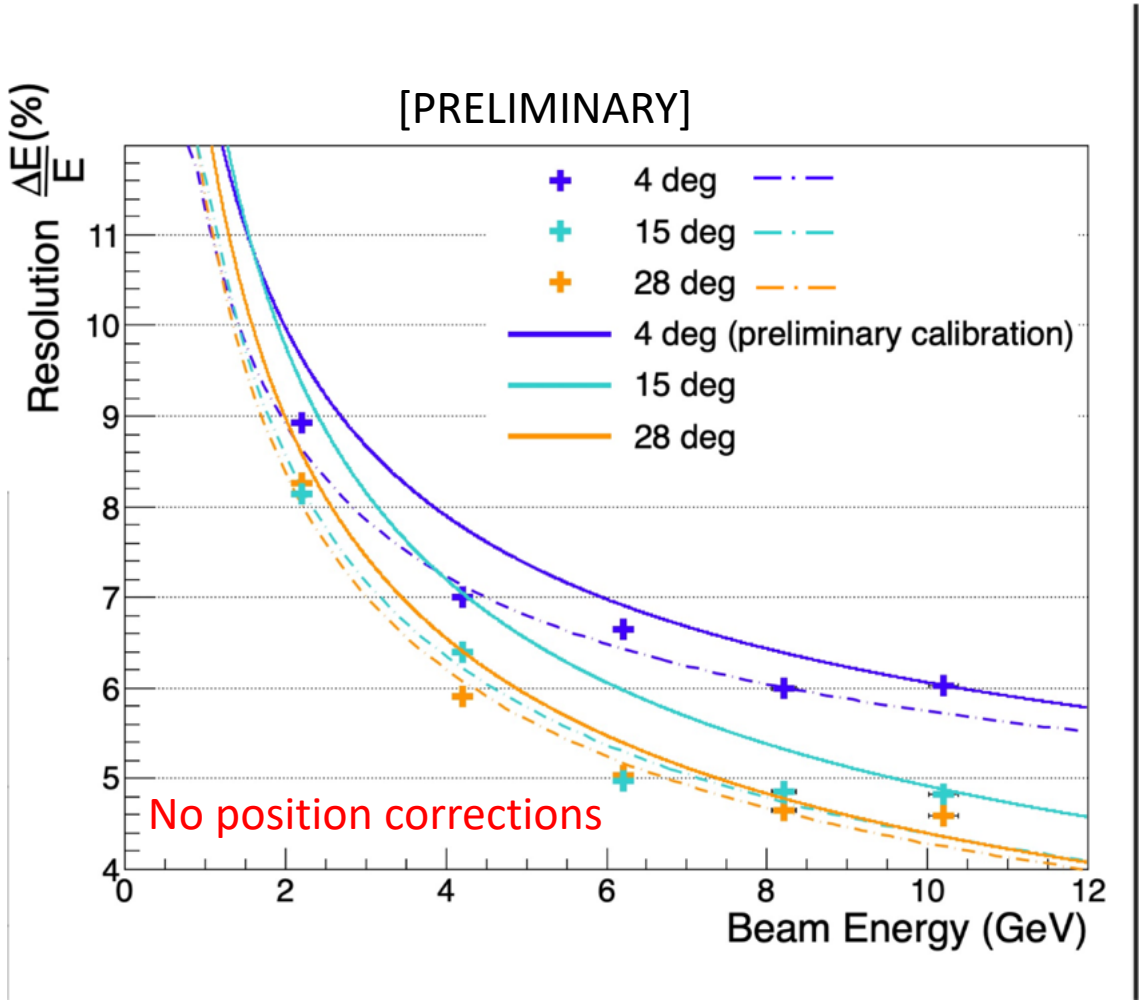






- fEMCal good position resolution can be used to do position dependent corrections of response.
- Position dependent corrections are common for ScFi calorimeters (H1, eRD1, sPHENIX…)

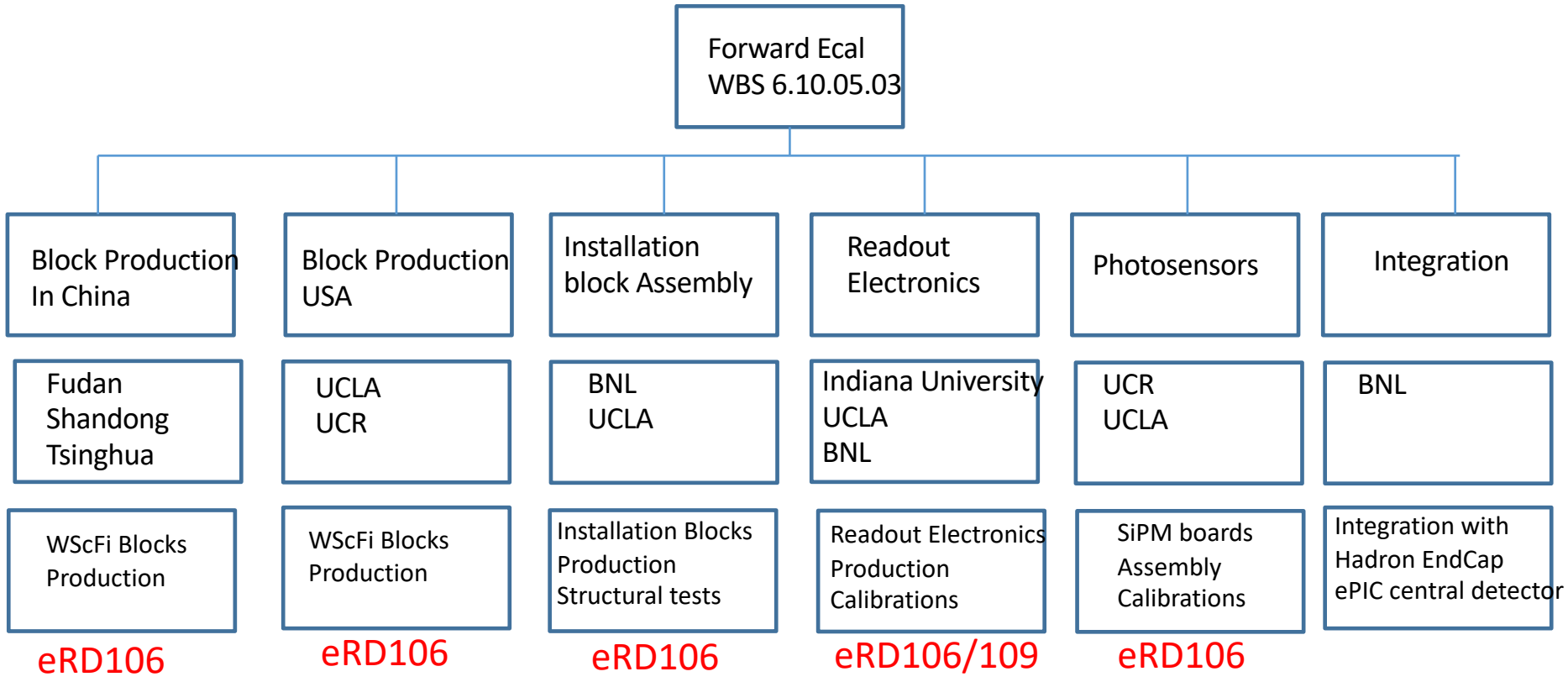




Incident angle	Resolution (Current) With position corrections	Resolution (Preliminary) No position corrections
4 deg	$f(E) = \frac{8.10}{\sqrt{E}} + 3.18$	$f(E) = \frac{10.0}{\sqrt{E}} + 2.9$
15 deg	$f(E) = \frac{10.67}{\sqrt{E}} + 1.02$	$f(E) = \frac{12.4}{\sqrt{E}} + 1.0$
28 deg	$f(E) = \frac{10.45}{\sqrt{E}} + 0.98$	$f(E) = \frac{11.7}{\sqrt{E}} + 0.7$

- Constant term from fits should be taken with a grain of salt.
- It will be more accurately determined from uniformity studies. After calibration will be finished.

Forward ECal WBS, Workforce



- N.B. SiPMs/SiPM board assemblies are for the test run only to match existing DAQ.
- A single 16 towers readout block, which can be swapped for WSc/Fi installation blocks.
- All HPK SiPMs for the test run received by UCR.
- A second version 4x4 SiPM currying board produced at UCLA, tests next week. Then final board will be assembled during April.

Summary/Outlook

- Production of fEMCal blocks at UCLA completed.
- Production of fEMCal blocks at Fudan completed.
- Light Guide for ePIC prototype produced, tested.
- Mechanical and installation tests at BNL completed.
- Integration of SiPM/FEEs were iterated and converging to a final scheme.
- Short Test Run at FNAL completed. Data analysis in progress.
- Remaining production ‘tweaks’ is moved to PD.

Thanks!