

eRD107: Longitudinally separated Forward HCal (LFHCal)

August 28, 2024

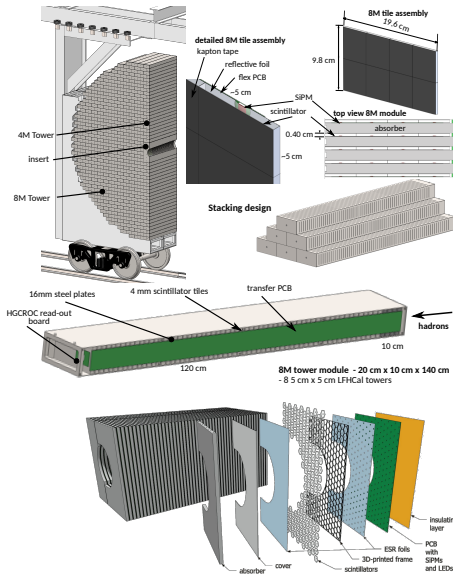
**Friederike Bock (ORNL)
for the eRD107 consortium**

Participating institutes: ORNL, BNL, FNAL, ISU, GSU, Yale, UCR, UTK, UTA, Valpo, Debrecen

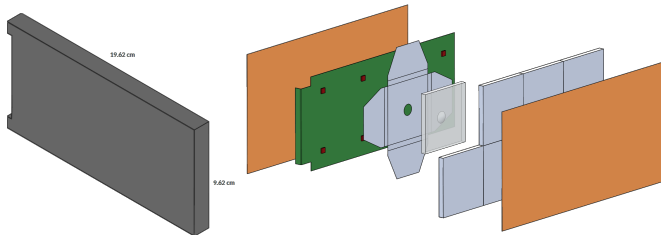
The General Idea

Concept:

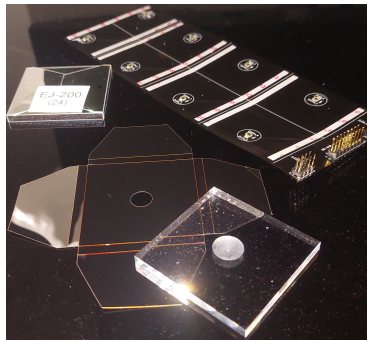
- CALICE AHCAL inspired Fe-Scintillator calorimeter with SiPM on-tile-readout (modification since last review)
- Two main parts:
 - ▶ LFHCal built mostly out of $10 \times 20 \times 132 \text{ cm}^3$ 8M modules (modified length to accommodate larger amount of services in barrel)
 - ▶ Insert built out of 2 halves surrounding the beam pipe
- **LFHCal:**
 - ▶ 60 layers of steel interleaved with scintillator material
 - ▶ Transverse tower size $5 \times 5 \text{ cm}^2$
 - ▶ Multiple consecutive tiles summed to 7 longitudinal segments per tower
- **Insert:**
 - ▶ 60 layers of steel interleaved with scintillator
 - ▶ Hexagonal tiles of 8 cm^2 each read-out individually

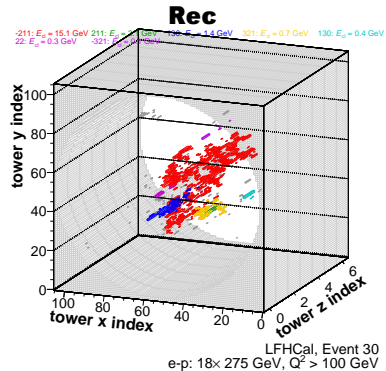


LFHCal 8M Scintillator Tile assembly

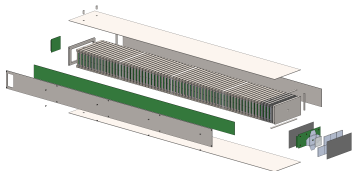


- Tiles of $\approx 0.4 \times 5 \times 5 \text{ cm}^3$ with dimples individually wrapped in ESR foil assembled in a grid of 4x2 tiles
- 8 tiles are backed by a flexible PCB equipped with 8 SiPMs and LEDs sandwiched with Kapton foil
- Flexible PCB wrapped around side of absorber to connect with long PCB along the side of the module
- Tiles either injection molded or machined out of cast sheets





- High granularity needed to try to distinguish shower maxima close to beam pipe
- **LFHCal:**
 read out in 7 layers longitudinally (5 or 10 SiPMs summed)
 desirable min measurable tower energy 3-5 MeV, max 20-30 GeV in single tower segment
- **insert:**
 read out every single tile
 desirable min measurable tower energy $\sim 0.1 - 0.5$ MeV/ tile
- SiPMs mounted to flexible PCBs, passive signal transfer to back side of calorimeter using long transfer PCB
- 1 SiPM-HGCROC (up to 70 channels) per 8M module (56 channels) in the back, 320 HGCROCs for insert readout



1 Reconstruction optimization

- ▶ Realistic implementation of geometry in ePIC software stack
- ▶ ML assisted absorber optimization in full geometry setup

2 Prototype tile production using machining & injection molding

- ▶ Ongoing machining studies for tile production
- ▶ First tile production with injection molding at Fermilab with different tile chemistries

3 Tile Characterization

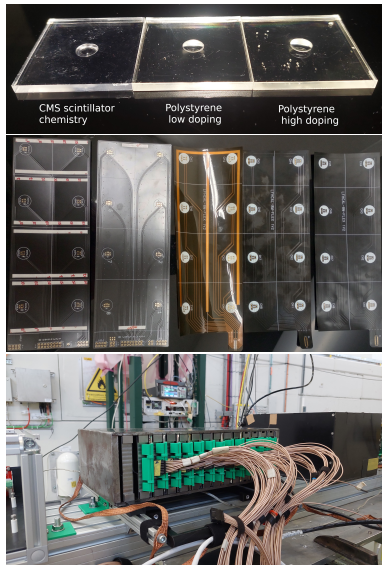
- ▶ Light yield studies of machined & injection molded tiles with different dimple sizes, machining techniques and wrappings ongoing
- ▶ Position scan of response on-going

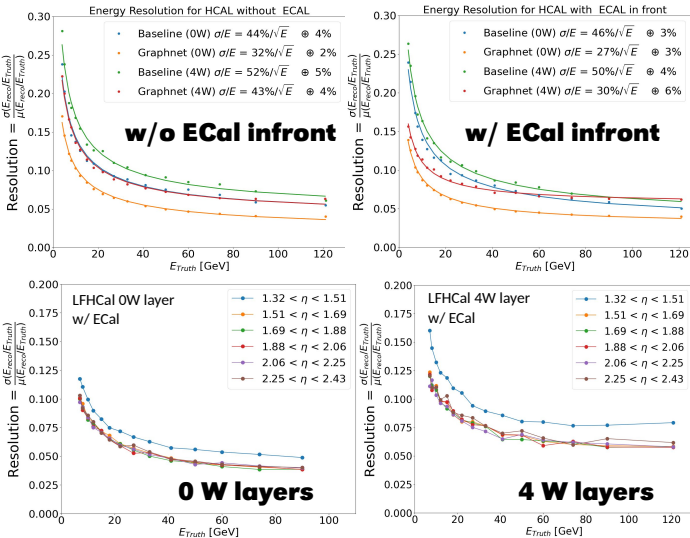
4 Sensor board development

- ▶ Third iteration of sensor board produced in three different processes
- ▶ Tests of calibration circuits ongoing

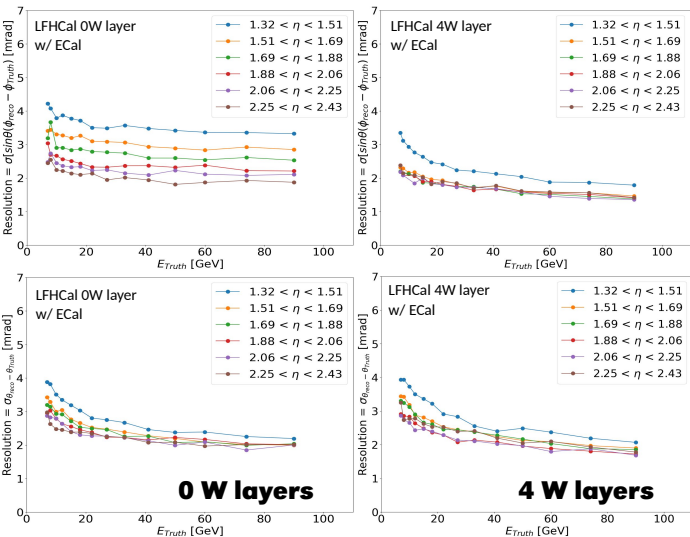
5 Preparations for 2024 TB-campaigns & 2023 TB analysis

- ▶ Test beam analysis from Sept. & Oct. 2023 on-going
- ▶ All components for test beam campaign ordered and on time for being tested ahead of time





- Implementation of realistic geometry in ePIC software stack
 - First version of clusterization algorithm working well at high E
 - Absorber optimization with ML assistance and full software compensation
 - Software compensation with full detector system optimized with graphnet-algorithmn
 - Improved E -resolution w/o tungsten layers
 - Little impact on spatial resolutions w/ or w/o tungsten layers
- ⇒ Tungsten layers removed & replaced with steel

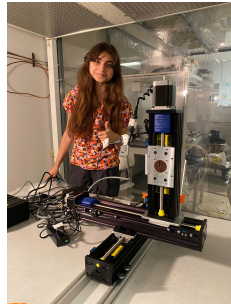


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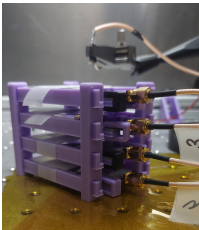
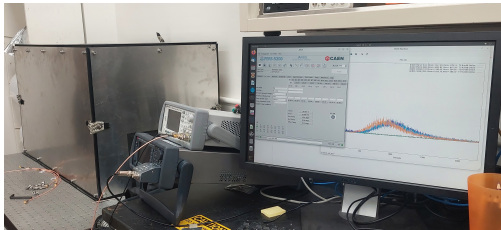
Scintillator Characterization - Test Stands

Yale

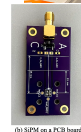
- Three parallel test setups for tile characterization (Yale, ORNL, Valpo)
- 3D-printed tile and assembly holders developed for effective tile scanning
- Yale setup extended for $X - Y$ scanning of tiles
 - ▶ 1st version with slotted $X - Y$ scanning option
 - ▶ 2nd version fully automated $X - Y$ scanning stage
- Yale setup further extended to do automated measuring of machined tile sizes
- Further test stands being setup at GSU



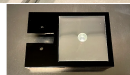
ORNL



(a) Light-tight Faraday box with connector panel



(b) SiPM on a PCB board



(d) Tile-SiPM holder with scintillator tile



(e) Tile-SiPM holder with SiPM board

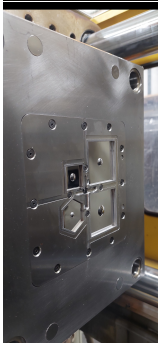
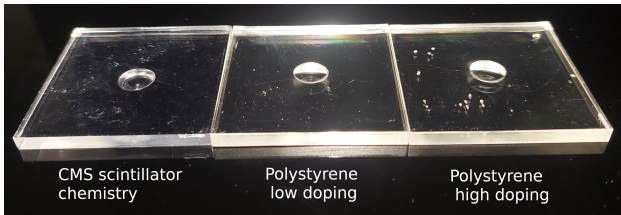


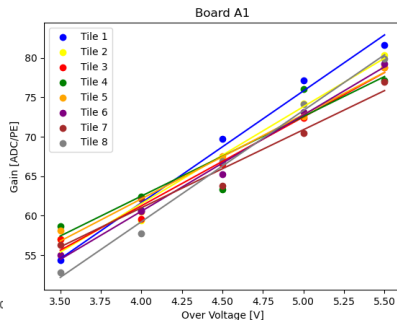
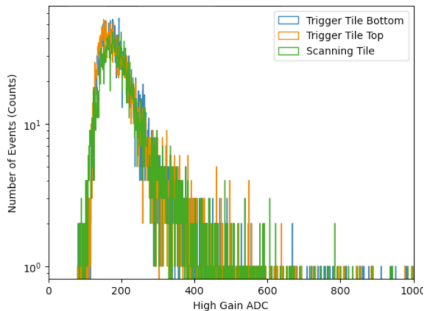
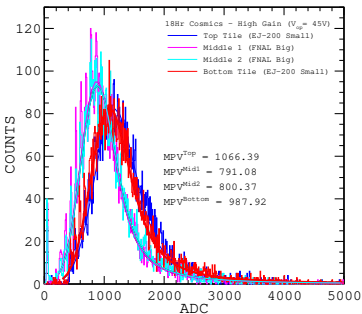
(c) SiPM holder with hole to shine 400 nm LED photons



(f) Two Tile-SiPM holders on shelf

- First larger scale injection molding production by Fermilab with 3 different chemistries
- Additional scintillator machining studies on the way
- Produced tiles with different dimple sizes
- Additional production to come in the coming months to equip August test beam modules





- Started measuring cosmics MIP light yields for different SiPMs types
 - 1.3×1.3 mm
 - $\rightarrow \approx 12 - 14$ p.e. for machined tiles
 - $\rightarrow \approx 11 - 13$ p.e. for injection molded tiles,
 - 3×3 mm
 - $\rightarrow \approx 60 - 76$ p.e for machined tiles

- Testing different scintillator materials (EJ-200, BC-408 & Fermilab injection molded with different chemistries)
- Systematic evaluation of impact of machining defects ongoing and large scale sample on-going
- Single photon spectra for every SiPM of the TB assemblies vs V_{ov}

LFHCal: Test beams 2023

Dates:

- **SPS:** 6th – 13th Sept.
- **PS:** 11th – 18th Oct.

Setup:

- Parasitic to FoCal-H/FoCal-E at SPS and PS
- Setup consists out of maximum 14 layers of 8M tile assemblies

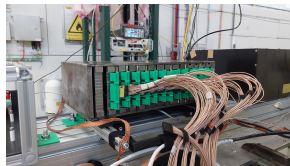
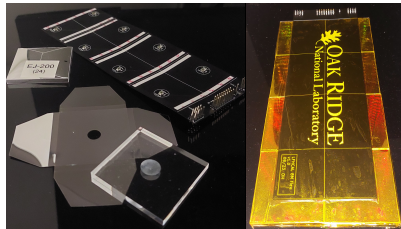
Sept: w/o absorber layers

Oct: w/ absorber layers (4 tungsten, 10 steel)

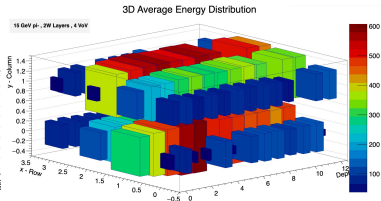
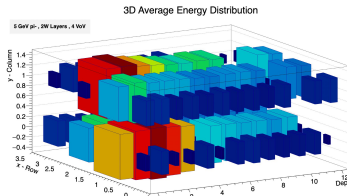
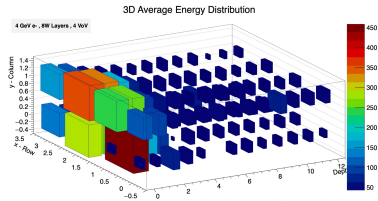
- Read-out: CAEN DT5202 64ch CITIROC SiPM readout unit or H2GCROC

Main expected measurements:

- Light yields per tile
- Shower profile measurements with different absorbers
- Cross talk estimates of different tiles
- Use it as testing setup for SiPM-H2GCROC
- If placed behind FoCal-H, measure part of leakage



October campaign



September campaign - Hodoscope setup

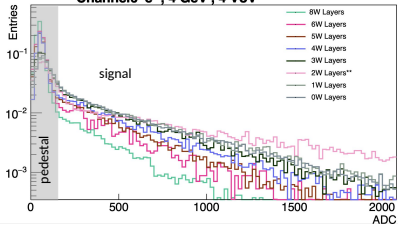
- Full V_{ov} scan e^-/h
- Gain-scan
- Position scan
- Possibly leakage measurement of FoCal-H

October campaign - mini-LFHCal

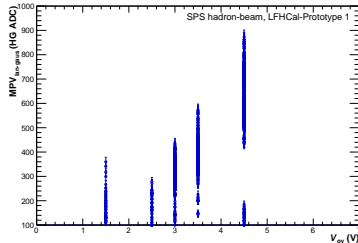
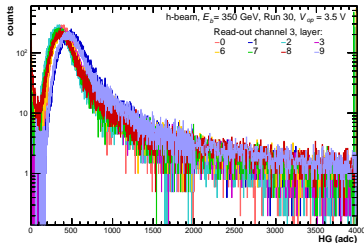
- Full V_{ov} & gain scan e^-/π^-
- Position scan
- Scan with additional W-plates upfront (e^-)
- e^- shower development (1-5 GeV)
- π^- shower development (5,10,15 GeV)

Additional W-plate scan

Channel6 e⁻, 4 GeV, 4 VoV

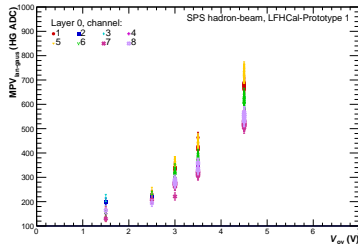
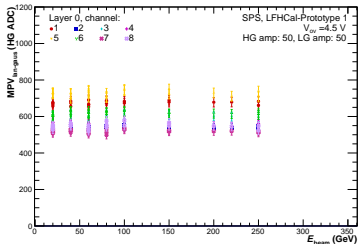
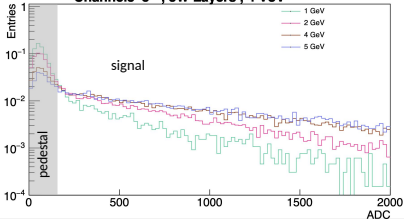


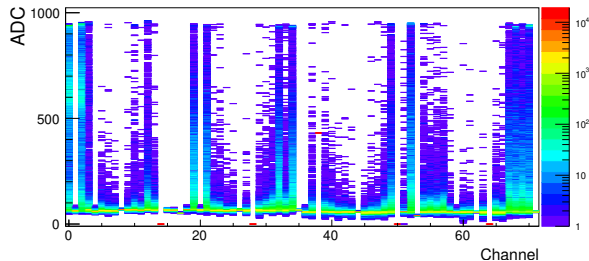
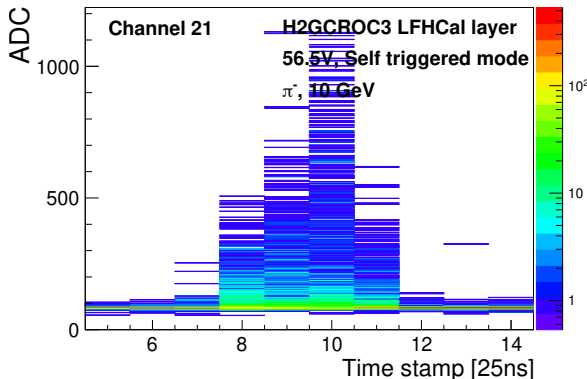
MIP response for scintillators



e⁻ Energy scan

Channel3 e⁻, 3W Layers, 4 VoV





- H2GCROC read-out ready just in time for last 1.5 days of data taking (Oct.)
- Self-triggered data obtained
- Unfortunately externally triggered setup couldn't be operated due to beam stop of PS during last night
- New prototype board on time for delivery for testing significantly ahead of TB

Test beam plans - August 2024

Dates: 28th Aug-11th Sept **Location:** PS - T09

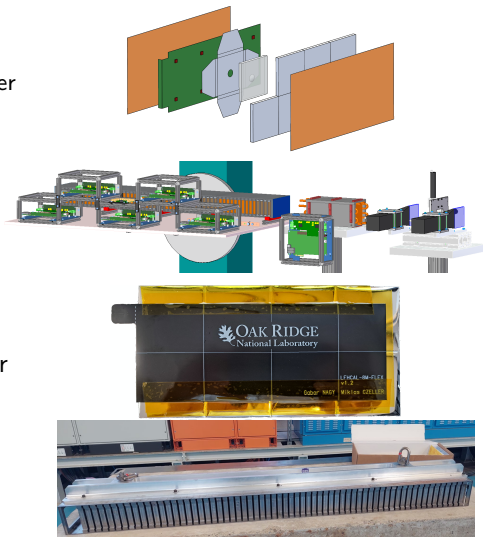
Main purpose: First full module test & H2GCROC tests

Setup:

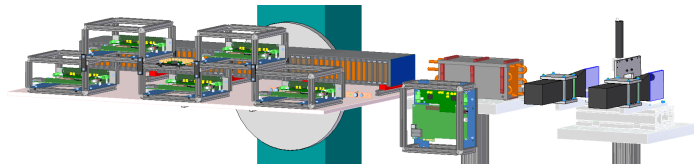
- Full 8M module testing 65 layers of absorber & scintillator per layer 8 channels (swapping scintillator geometry either 8M module or insert)
- Readout with multiple CAEN DT5202 64ch CITIROC SiPM readout units (2nd week) and H2GCROCs (1st week)
- Had to be postponed from May to August due to delays in deliveries of components & new H2GCROC firmware and boards tested during the ALICE FoCal TB in May

Main expected measurements:

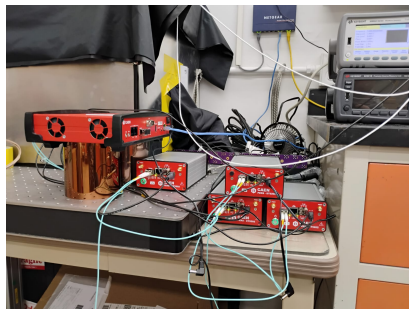
- Energy resolution estimates for hadrons and electrons for full length module with both read-out versions
- Assessment of longitudinal leakage
- Longitudinal shower development
- Read-out validation
- Part of campaign with EEEMC in front



Test beam preparation



- 3rd iteration of SiPM-carrier board developed and produced in 3 different processes
- Full testing and taking of calibration data for all 85 prepared layer assemblies at ORNL
- First version of *short* long-transfer board produced and tested in cosmics data taking
- First full 8M absorber assembly produced and currently being setup in T09 with all components
- Full read-out chain tests performed for both read-out versions at ORNL
- Test beam starts today



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- Realistic implementation of geometry in ePIC software stack
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2 Prototype tile production using machining & injection molding

- Ongoing machining studies for tile production
- First tile production with injection molding at Fermilab with different tile chemistries

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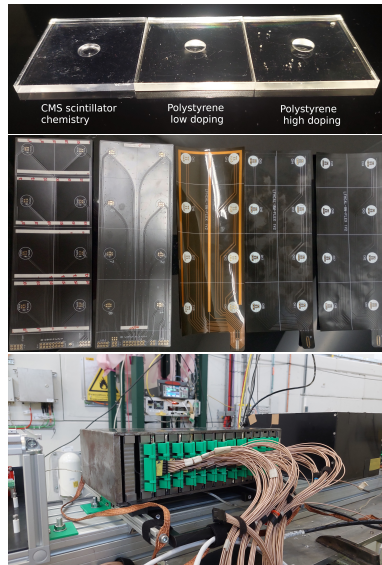
- Light yield studies of machined & injection molded tiles with different dimple sizes, machining techniques and wrappings ongoing
- Position scan of response on-going

4 Sensor board development

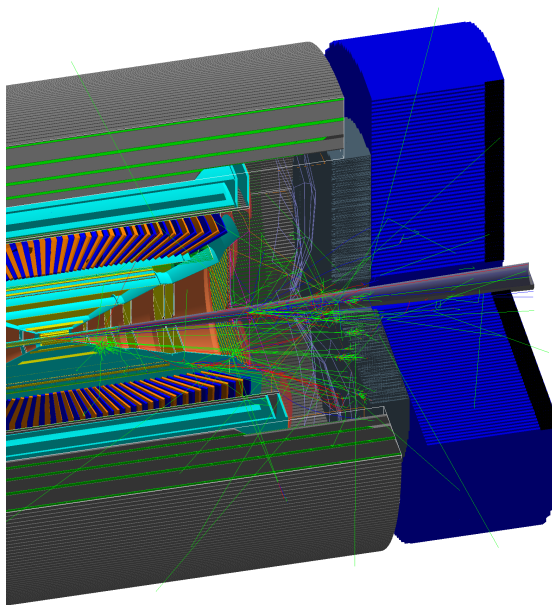
- Third iteration of sensor board produced in three different processes
- Tests of calibration circuits ongoing

5 Preparations for third TB-campaign (Aug 2024) & TB analysis

- Test beam analysis from Sept. & Oct. 2023 on-going
- Currently setting up in PS beam line, TB starting today

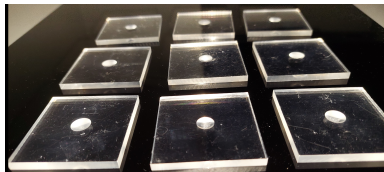


Thanks!



1 Tile production optimization using machining & injection molding (04/24)

- ▶ Evaluation of different scintillator machining techniques
- ▶ Comparative review of different vendor capabilities regarding adherence to tolerances as well as optimizing the light yield and its stability for large number of tiles
- ▶ Documentation of procedures for optimizing the light yield of injection molded tiles during the production process
- ▶ High quality prototype tiles to equip two 8M modules for test beam studies

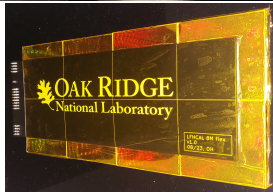


2 Reconstruction optimization (09/24)

- ▶ Write-up of optimization results from simulations

3 Sensor board development (03/24)

- ▶ First prototype of sensor board for Si-PM readout (together with eRD109)



4 Test module assembly (04/24)

- ▶ First prototype of full 8M module

5 Tile Characterization (08/2024)

- ▶ Write-up of test bench & test beam measurement for all assembled tile-prototypes
- ▶ First concept of a monitoring system to be installed in the LFHCAL

