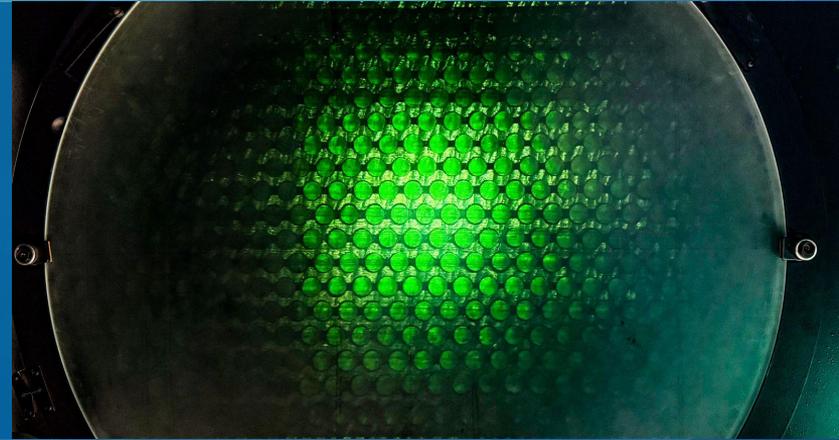


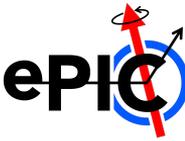
# Mechanics and Sectors



**Sylvester Joosten**  
Argonne National Laboratory  
on behalf of the BIC DSC

**BIC PDR**  
September 17-18, 2025

# CHARGE

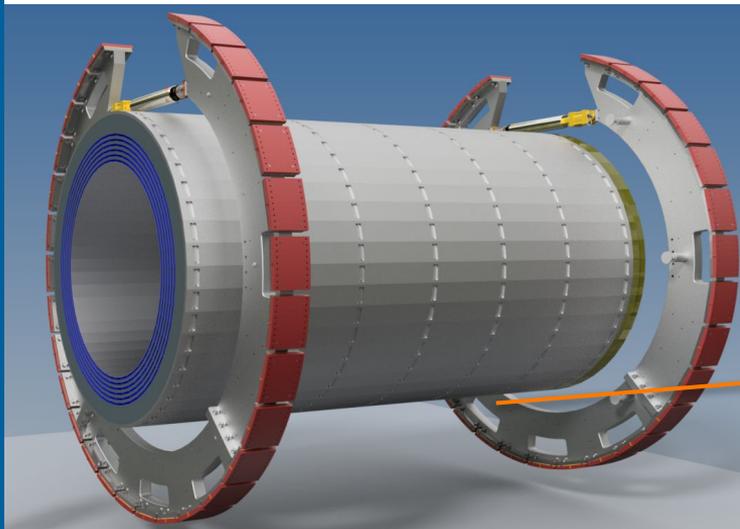


## Charge:

1. Is the progress and design maturity of the barrel electromagnetic calorimeter systems aligned with being baselined in June 2026 (>60% maturity is required)?
2. Are the technical performance requirements appropriately defined and complete for this stage of the project?
3. Are the plans for achieving detector performance and construction sufficiently developed and documented for the present phase of the project?
4. Are the current designs and plans for detector and electronics readout likely to achieve the performance requirements with a low risk of cost increases, schedule delays, and technical problems?
5. Are the calorimeter fabrication and assembly plans consistent with the overall project and detector schedule?
6. Are the plans for detector integration in the EIC detector appropriately developed for the present phase of the project?
7. Have ES&H and QA considerations been adequately incorporated into the designs at their present stage?
8. Have the recommendations from previous reviews been adequately addressed?

# Global Design

## Envelopes well-defined together with EIC Project

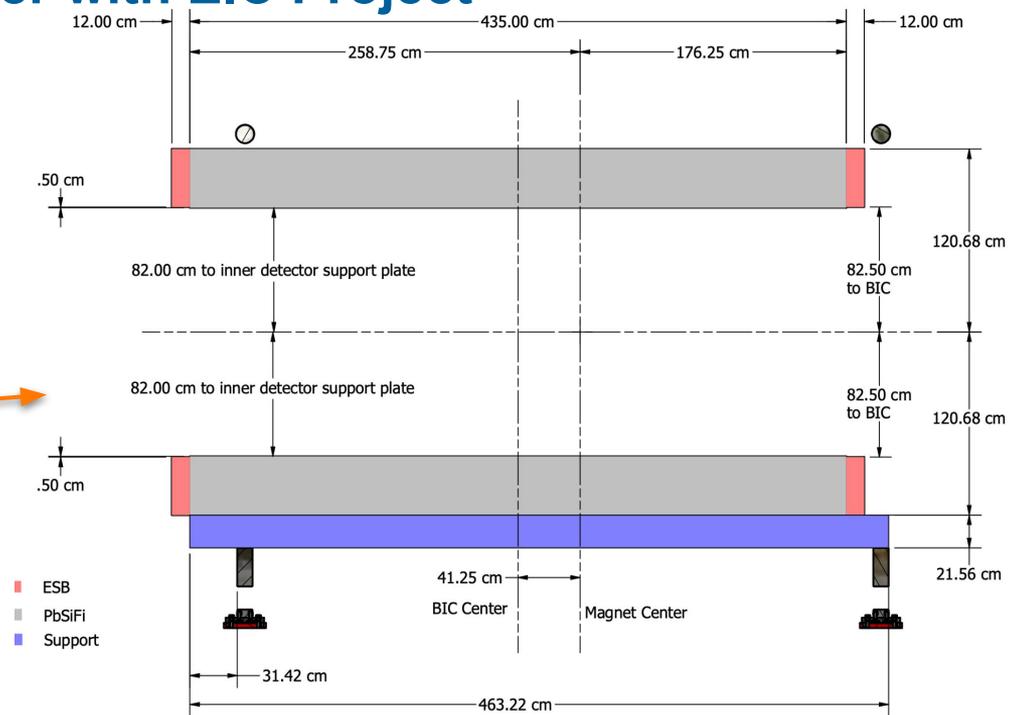


Sector weight: 1769 pounds (not including ESBs)

Total BIC weight: 84,912 pounds (42.5 US tons)

Fibers per sector: 21,981

Total number of fibers: 1,055,088



Main priority is system FEA to demonstrate self-supporting design.  
Pending destructive delamination testing of CF/PbScFi and internal Pb/ScFi

# Engineering Envelopes

## Global BIC Envelopes



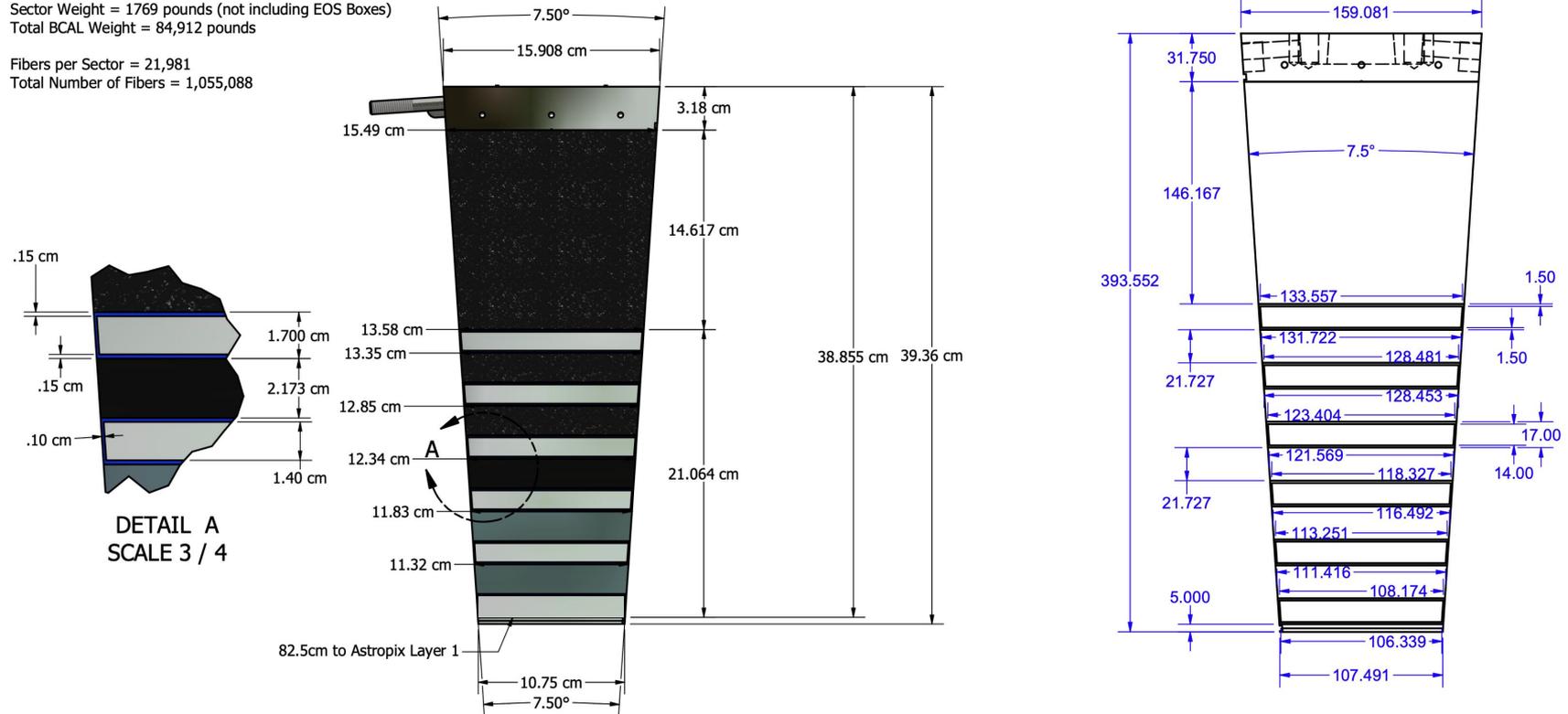
### 82.5cm Inner Radius:

Sector Weight = 1769 pounds (not including EOS Boxes)

Total BCAL Weight = 84,912 pounds

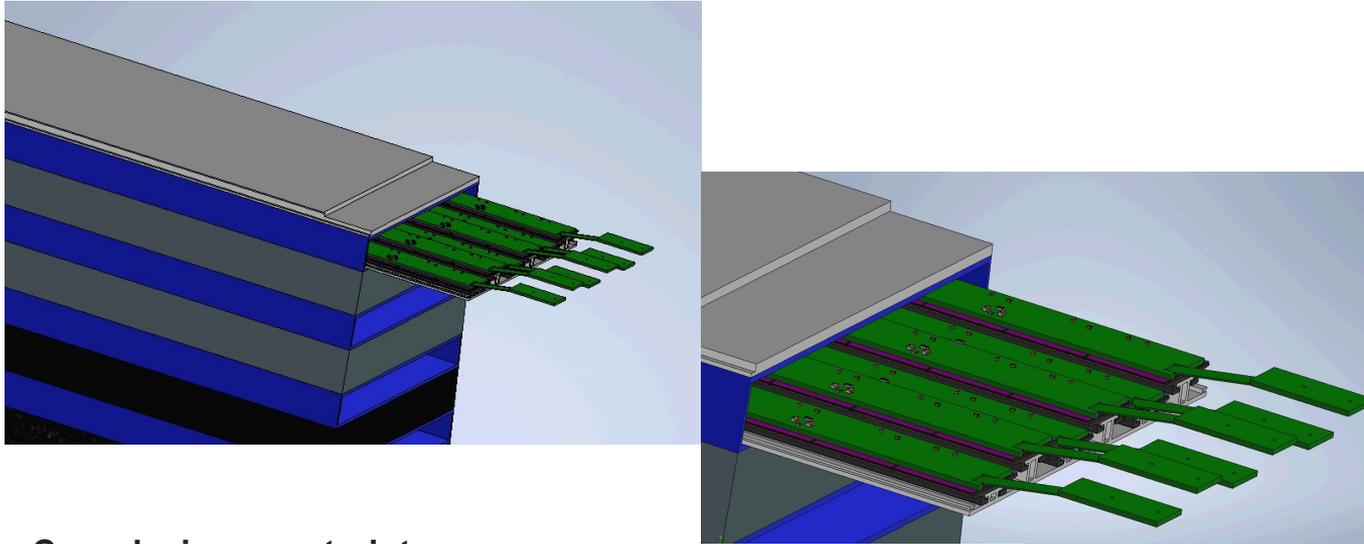
Fibers per Sector = 21,981

Total Number of Fibers = 1,055,088



# Tracker Mechanics

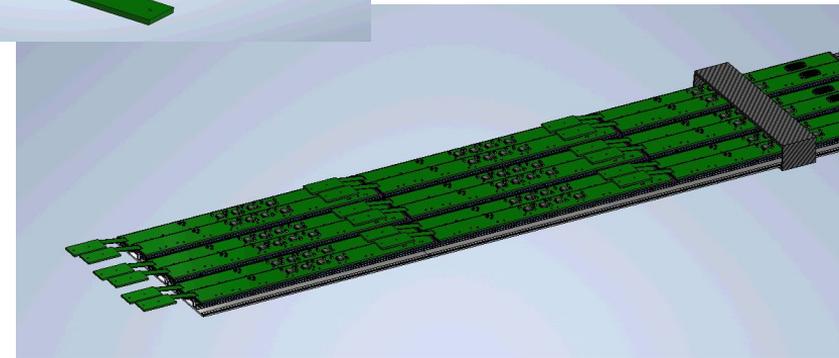
# AstroPix Module and Tray Design



## Core design constraints:

- 2 back-to-back trays inside a CF slot (each 2.175m long)
- Modules directly mounted on the tray
- 6 slots (slots 1-3-4-6 instrumented in baseline design)

**FY25 Strategy included targeted test articles and design iterations to come to a “buildable” design.**



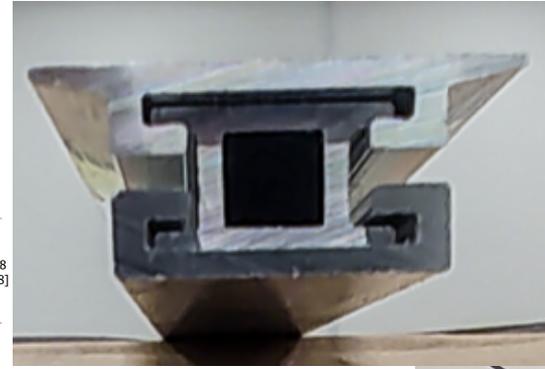
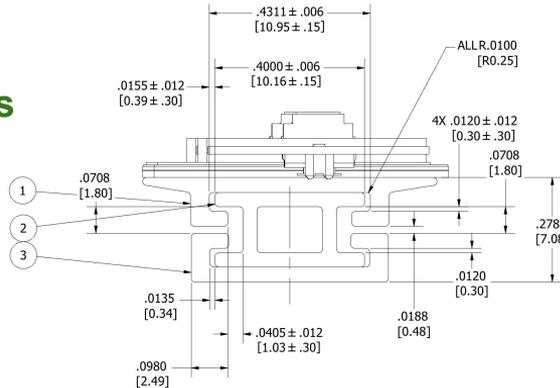
# AstroPix Module and Tray Design



## First test articles

First iteration of mechanical test articles

- Initial design: mount 9-chip AstroPix **modules** on **staves**, then slide **staves** on **rails** integrated in the CF frames
- Components made out of extruded aluminum to minimize cost
- Known that design has some issues (stack height too tall), but important to validate tolerances (and rigidity) with extruded aluminum are acceptable
- Full-size extrusions (2.175m), modules are cut from long extrusions



**First test articles validated extruded aluminum as viable production method. Module base design can be considered final.**

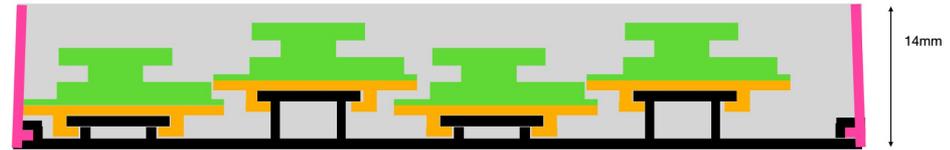
Open design question: method to prevent movement of modules on rail during install.

# AstroPix Module and Tray Design



## Preliminary tray design: super-staves

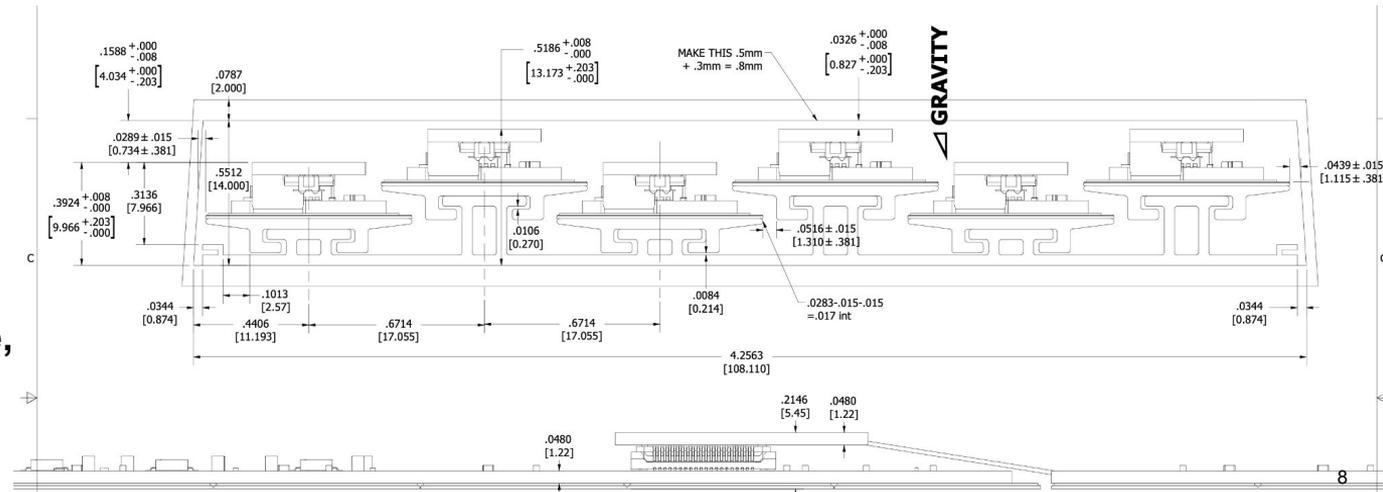
- Staveless design to minimize height and number of components
- Leverage trapezoidal shape of CF frame together with simple feature to act as rail
- Can use same extrusion process as validated by first test article
- Next steps: second test articles for integration testing with CF frame



Early sketch



Engineering Drawings



Design in advanced shape, ready for validation and integration testing

# Pb/SciFi Matrix Production Design

# Pb/ScFi Matrix Production Design Strategy

## Staged approach toward full-size 4.5m sectors

Preliminary

### 1. Short 0.5m Pb/ScFi test articles

- ✓ a. Using inert fibers to commission equipment and acquire skills
- ✓ b. Using scintillating fibers to validate against GlueX performance

### 2. Short 0.5m test articles with CF frames

- a. “Hamburger” configuration (Pb/ScFi-Frame-Pb/ScFi) to determine production flow, assembly procedure
- b. “Club Sandwich” configuration (one more layer of each) to scale up procedure and demonstrate tolerances

Final

### 3. Long 3m Pb/ScFi test articles

- a. Scale-up to production-like size

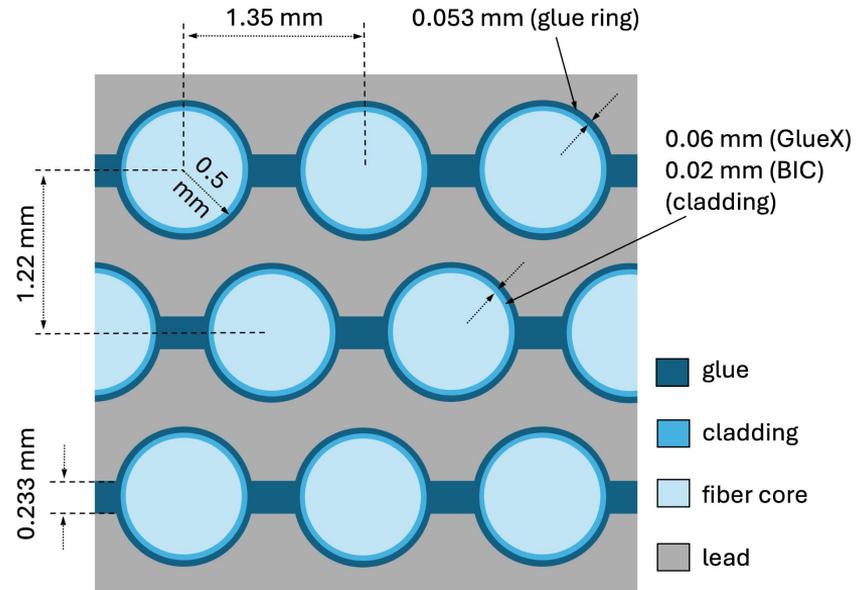
### 4. Long 3m integrated test articles

- a. Using the hamburger configuration

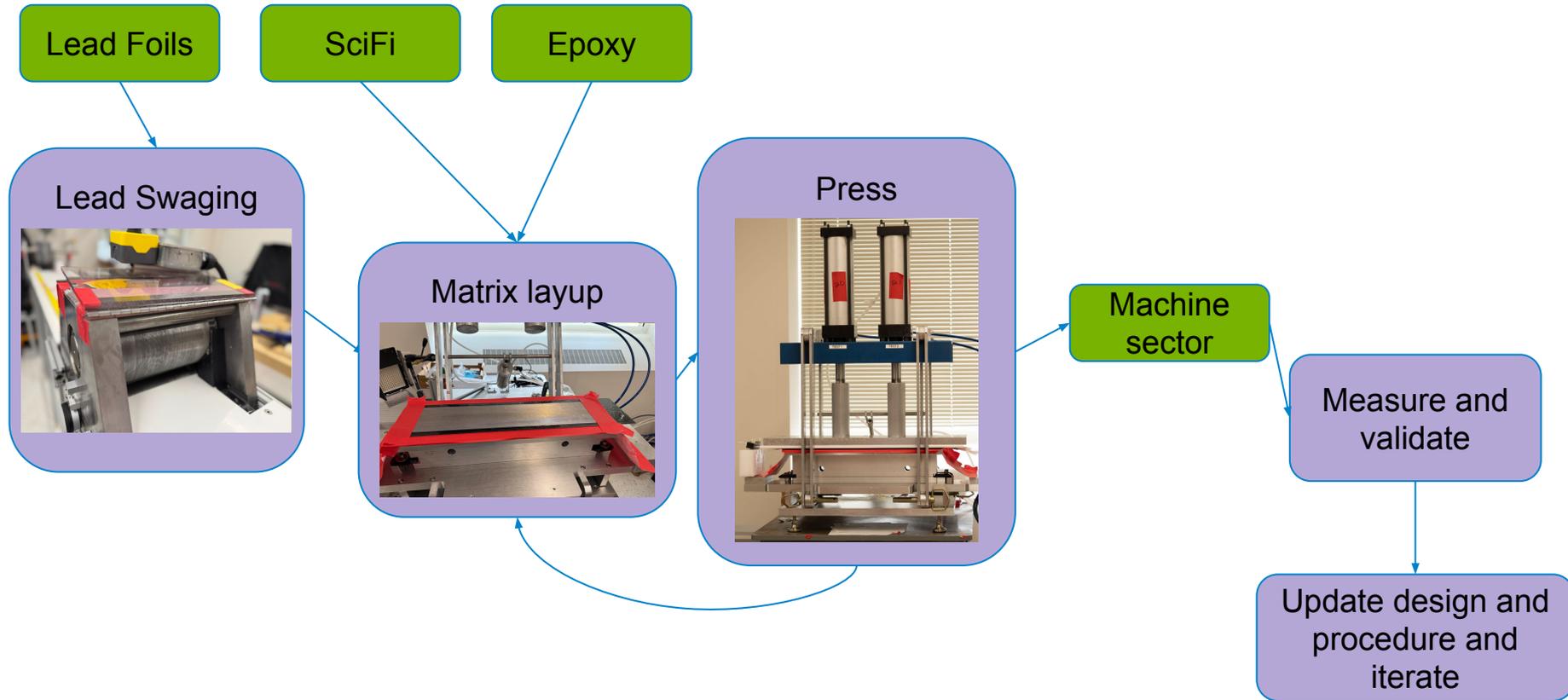
Preprod.

### 5. Full-size 4.5m sector

- a. Validate process at scale



# Production Flow for Pb/SciFi Layups



# First Short Test Articles

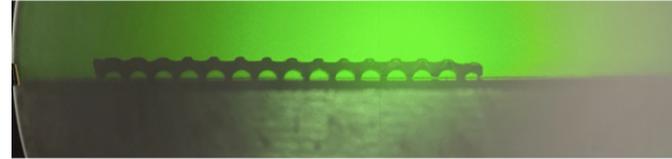
## From learning equipment to optimizing tolerances

- Produced 2x 0.5m test articles with inert fibers, and 1x 0.5m test article with old double-clad GlueX fibers
- Characterized matrix structure in detail to continuously improve our process
- Need precise tolerance control for CF frame integration

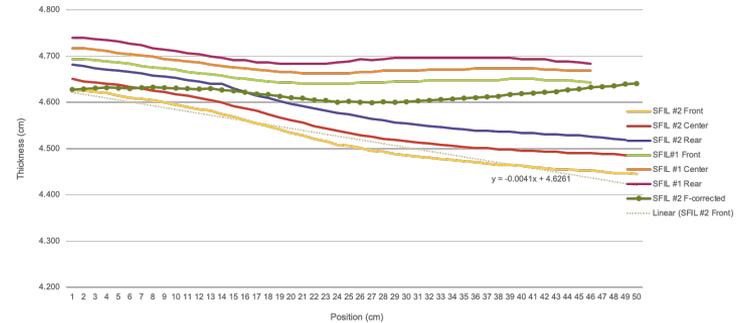
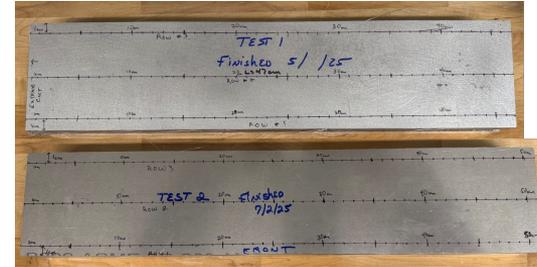


# First Short Test Articles

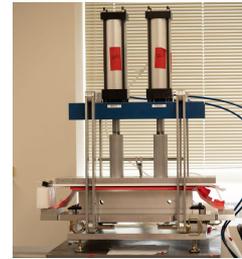
## Towards improved tolerance control



- Characterizing all mechanical features of test articles and their components, including corrugated lead after swaging
- Earliest test showed signs of uneven pressure in test press going from article #1 to article #2
- In response, we improved our process (e.g. more precise press ram control, make press alignment reproducible, validate all components such as press plates are within tolerance, which resolved the issue)
- We track lessons learned by continuously updating our procedure documents
- Lessons port one-to-one from test-press to full-size production press



**We are in a crucial phase where every test article provides us with invaluable lessons. This is exactly the point of our test article strategy.**

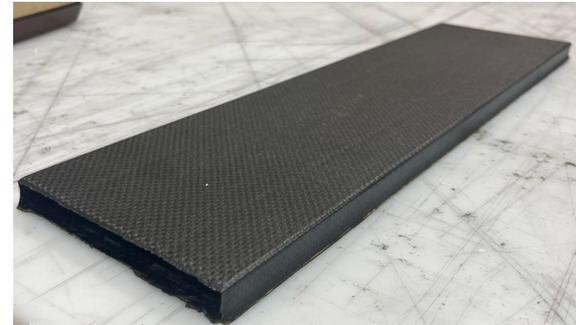
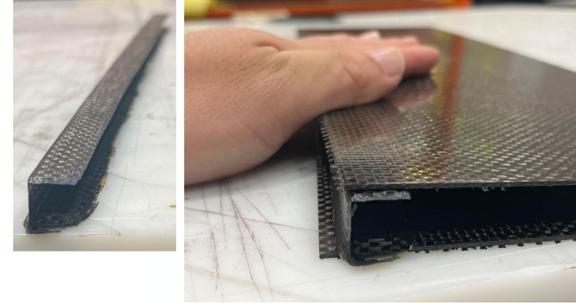


# CF Frame Design and Destructive Testing

# CF Frame Design Status

## Towards composite frame test articles

- Last year we introduced a 4-component frame design to be integrated during matrix building
- Evolved the design together with collaborators at Purdue to consider two avenues with pre-assembled frames
  - Baseline: frame constructed from four components
  - Alternate: One-piece frame layup
- Purdue in progress of fabricating both using aerospace-grade prepreg CF
- **Status:**
  - Purdue received molds to manufacture frames, first layups completed, true first frame test articles expected October
  - Developing fixtures for frame/matrix alignment



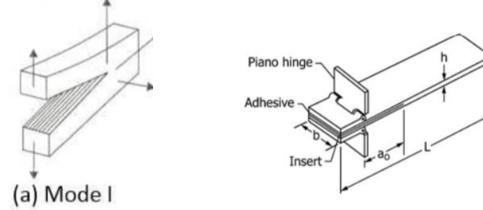
**Close to first CF test articles to validate design and integration concept, expect one more iteration before final design**

# Destructive Testing

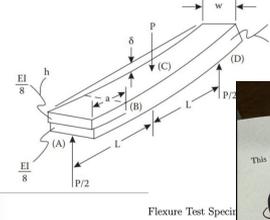
## Input for detailed FEA

- Need measurements of material properties for Pb/ScFi matrix and Pb - CF frame interface
- Measurements needed are both interfaces for peel (mode 1) and shear (mode 2) testing
- We built test articles for destructive testing; tests took place at Purdue early September 2025

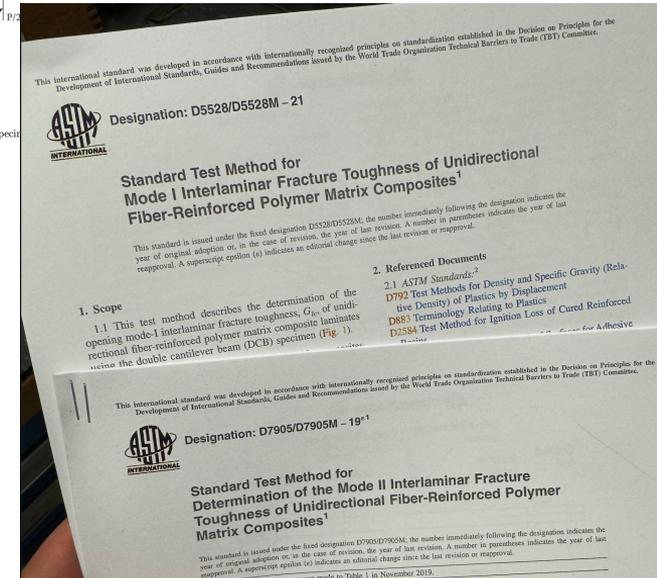
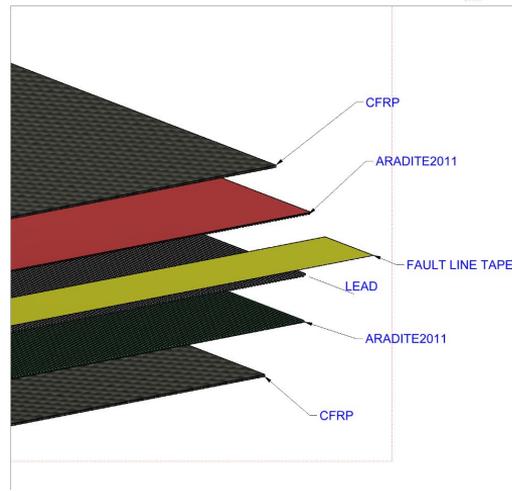
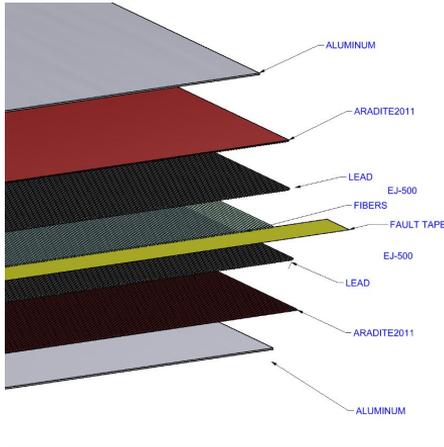
Mode 1 (peel)



Mode 2 (shear)



Flexure Test Specimen

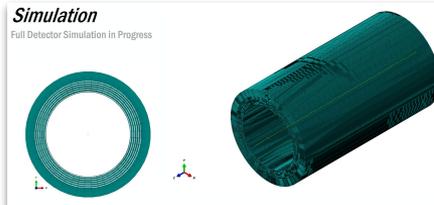
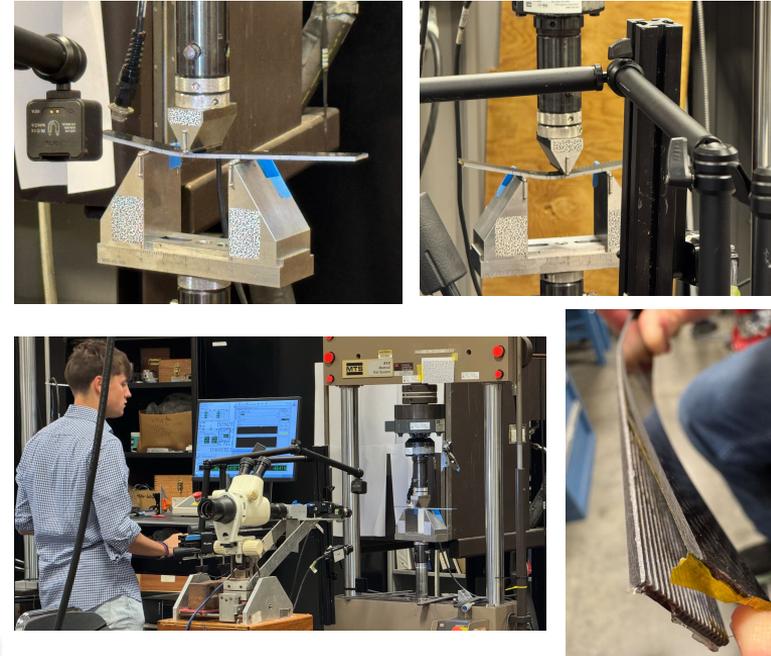


# Destructive Testing at Purdue

Mode 1 (peel)



Mode 2 (shear)



**FEA simulations for sectors and the full BIC system will follow Q1 FY26**

# SECTOR QC AND ENVIRONMENT, HEALTH AND SAFETY

# QC à la BCAL/GlueX

- **Scope**
  - **Dimensional uniformity:** QC required in Pb sheets, fiber handling, gluing, fiber lay up, alignment checks
  - **Optical quality:** QC of ScFi's, machining and polishing of the sector ends
  - **Documentation:** QA/QC plan, how-to manuals, travellers
- Fiber QC is presented under ScFi talk
- Mechanical QC follows



# QC à la BCAL/GlueX

## Steps and methodology



- **Steps**

- **Press Leveling and Base Plate Alignment:** table height variation < 0.004” across surfaces. Al base plates and cold-rolled steel bars machined flat to avoid ‘crowning’.
- **Lead Sheets:** inspect sheets from vendor, swager alignment and calibration, student training, marking Pb sheets to avoid stacked tolerances, alignment of grooves.
- **Epoxy:** inspect vendor shipment and expiration date, ratio of hardener to resin, monitor viscosity.
- **Fibers:** presorted canes, antistatic and clean measures.

- **Methodology**

- **Critical references:** matrix-base plate alignment on centreline of the Al base plate. Top Al plate tolerance.
- **Dimensional controls:** lead sheets rolled onto the build to ‘lock’ into place on top of fiber layer; piano wire runner; matrix height monitored along 40 points on perimeter.
- **Pressing:** press from in to out; minimize epoxy migration.
- **Machining:** machine 4 modules in sequence to the dimensions and tolerances specified in the contract drawings and record final dimensions into travelers. Keystone module?
- **Optical quality:** visual inspection and transmission checks.

# Environment, Health & Safety at Argonne

## General considerations and collaboration with EIC



- Every task to be performed in the context of BIC work is subject to a detailed Work Control Document which details scope of work, operational procedures, hazards, controls, and required training. We employ targeted safety training based on complexity of tasks. All work requires that the worker be properly trained and authorized to conduct said work.
- Argonne EH&S and QA already in close contact with BNL/EIC ES&H and QA
- Argonne requires us to follow BNL/EIC ES&H procedures, EIC QA Plan and EIC Code of Record for all BIC related work. The EIC Code of Record specifies which standards we are to use.


Task-Based Work Package


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WCD 82562.2 EIC Detector R&D and Testing Hazard Level: Moderate M

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WCD Status: Approved Status Date: 03/20/2025

Authorization Status: See Authorization Package

Revision Type: Full

Minor Revision Reason: N/A

---

Responsible Individual: Joosten, Sylvester Johannes

Work Planner: Joosten, Sylvester Johannes ESH Coordinator: Gombosi, Erika Lyn

Approving Division: BSV Approver: Maslwi, Zain-Edana

Next Review Date: 03/20/2028

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**Scope**

The Barrel Imaging Calorimeter Test Lab (BICLab) is for general R&D, and particle detector assembly and testing for the ePIC Barrel Imaging Calorimeter.

All Apparatus/Equipment Manuals and other documentation are stored electronically on the lab network filesystem which is also mirrored with the git repository found here: <https://icweb.phy.anl.gov/control/manuals/>

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**Scope Limits**

Other limits:

- Tasks 3 and 5 require dedicated instruction by Kevin Balay or Thomas O'Connor for authorization.
- Students are not permitted to work in the lab alone outside the normal working hours of ANL. Additional information can be found on each task.

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**Working Alone**

Is working alone allowed? Yes

Working alone requirements: Working alone is allowed for Argonne postdocs, scientists, technicians, and engineers. Those working outside normal working hours need approval by Sylvester Joosten (sjoosten@anl.gov) or Maria Zurek (zurek@anl.gov). Normal working hours are Monday-Friday 6 am to 7 pm.

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For Argonne-site emergency, dial 911 from a landline or 630-260-1911 from a cell phone. For off-site emergencies, dial 911. Aware Worker Output v3.0.11 08-28-2025 11:55 AM Page 1 of 15

### BICLAB WORK PROCEDURES V2.0

#### BICLab Work Procedures

Barrel Imaging Calorimeter Test Lab

The Barrel Imaging Calorimeter Test Lab (BICLab) is for general R&D, and particle detector assembly and testing for the ePIC Barrel Imaging Calorimeter.

**Workers MUST be authorized for General Lab Tasks (Task 1) before authorization can be granted for any additional tasks. Workers may only perform tasks for which they have received explicit authorization via AWARE.**

All Apparatus/Equipment Manuals and other documentation are stored electronically on the lab network filesystem which is also mirrored with the git repository found here: <https://icweb.phy.anl.gov/control/manuals/>

- Pre-job Briefing**
1. Before any work begins, all personnel should review all relevant safety documents, understand rules and procedures for the work to be performed, and walk-through the lab with an expert on potential safety hazards and safe and proper use of equipment.
  2. Meet with Sylvester Joosten (sjoosten@anl.gov) or Maria Zurek (zurek@anl.gov) for orientation to discuss the lab layout and to receive project background training
    - a. Tour the lab during this meeting
    - b. Locate the nearest phone for emergency use
    - c. Learn the lab computing infrastructure and basic computer account information
  3. **Pause or Stop Work: Everyone at Argonne has the authority and obligation to pause or stop any task or operation where concerns or questions exist, such as those related to safety, environmental impact, or reputation.**

# Environment, Health & Safety at Argonne

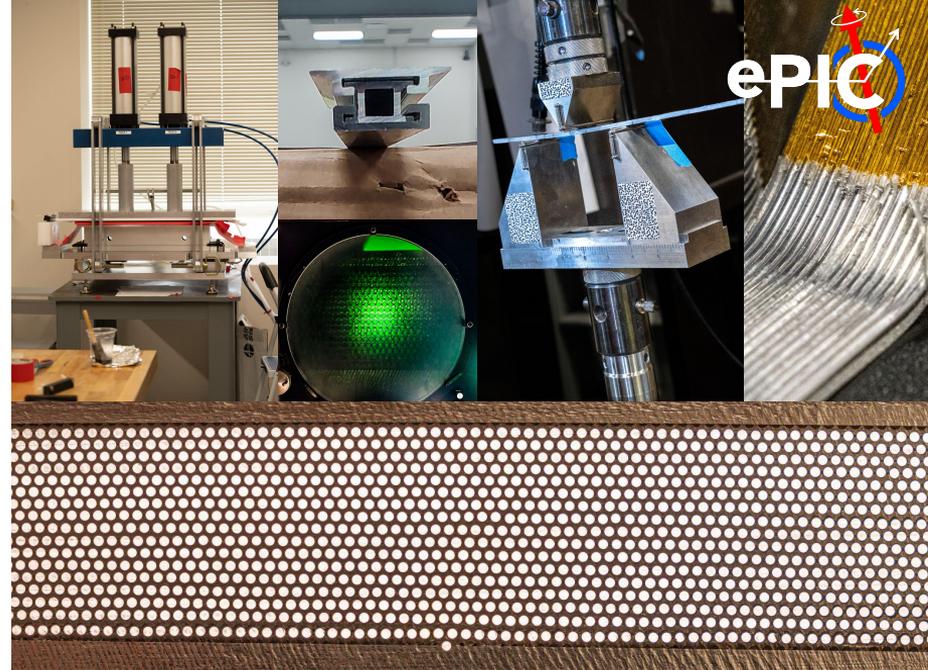


## QA considerations for Pb/ScFi Matrix Activities

- Our work guidelines are based on a detailed hazard analysis of our workflow, where each hazard has been mitigated through specific controls determined together with EH&S coordinator and subject matter experts from Industrial Hygiene, Health Physics (radiation), Physical Safety, Stored Energy (pressure), ergonomics, and lead safety
- Examples of EH&S considerations:
  - Work with lead is under high levels of scrutiny. We have strict PPE requirements, and strict guidelines for dealing with lead waste (lead only, and mixed with other materials), and items that have been in contact with lead. Industrial Hygiene has taken measurements of lead levels in the air during our regular operations to ensure all work occurs in safe conditions
  - Our choices for materials, e.g. epoxies, factor in the potential health impact of the chemicals. Industrial Hygiene also measured air quality and hazards during epoxy mixing prior to signing off on our work control document
  - Going forward towards larger test articles will see us use a 5 ton crane. We are working with subject matter experts and external companies to make sure we deal appropriately with the rigging safety considerations
- EH&S is a continuous conversation and integral part of our work

# CONCLUSION

# Summary: Learning by building to converge on a final BIC design



## Sector Test Articles

Test Article	Date	Status
0.5m inert SFIL	Q3 FY25	Done
0.5m SFIL with GlueX fibers	Q4 FY25	Done
CF frame test article	Q1 FY26	Ongoing
0.5m multi-layer test article ("Hamburger", "Club Sandwich")	Q1-2 FY26	
3m SFIL	Q2 FY26	
3m 2-layer test article	Q3 FY26	
Full-size sector (recommendation from PDR2)	Q2 FY27	

Preliminary Design

Final Design

Preproduction

## Tracker Mechanics Test Articles

Test Article	Date	Status
First extruded test articles	Q2 FY25	Done
Superstave test articles	Q1 FY26	Ready for fab
Trays (superstaves) for full-size sector	Q3 FY26	