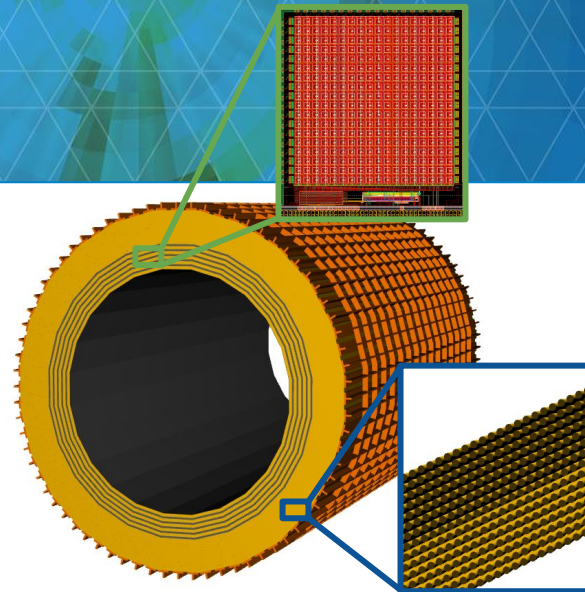


Barrel Imaging Calorimeter Meeting,  
June 27, 2023

# Barrel Imaging Calorimeter Meeting Summary & Work Packages



**Maria Żurek & Sylvester Joosten**  
PHY, Argonne National Laboratory

# In-person Barrel Imaging Calorimeter Meeting

<https://indico.bnl.gov/event/19689/timetable/#all.detailed>

**12-16 June 2023**

- Mon-Tue: ScFi/Pb
- Wed: Integration
- Thu-Fri: AstroPix

Talks uploaded to the Indico + detailed live notes finalized

20+ participants

## In-Person Barrel Imaging Calorimeter Meeting

12-16 Jun 2023  
Building 241  
US/Central timezone

Enter your search term

Overview

Timetable

An in-person meeting to make rapid progress toward the next milestones for the imaging calorimeter. Each meeting day has a different focus (e.g., AstroPix, silicon readout, engineering, Pb/ScFi, integration, ...). The meeting is primarily in-person, with some hybrid components. The schedule is as follows:

- Monday, June 12: Pb/ScFi
- Tuesday, June 13: Pb/ScFi, first engineering session
- Wednesday, June 14: Integration/global engineering
- Thursday, June 15: silicon/AstroPix, parallel engineering session
- Friday, June 16: silicon/AstroPix

The following time slots are fully hybrid:

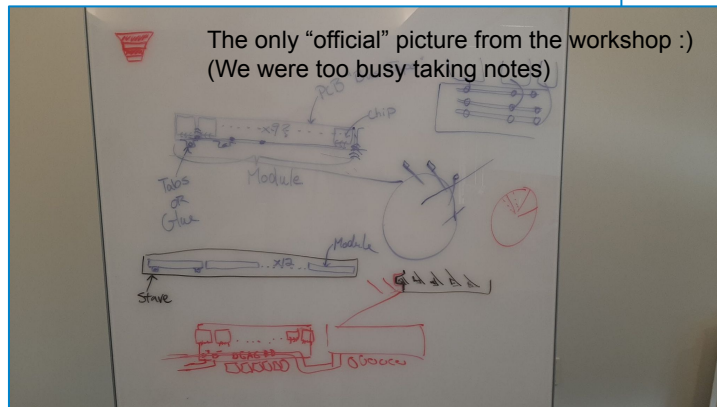
- Tuesday, June 13 afternoon
- Wednesday, June 14, all day
- Friday, June 16, the first morning session.

Zoom link: [Click here for the link to the hybrid sessions](#)

🕒 Starts 12 Jun 2023, 02:30  
Ends 16 Jun 2023, 20:00  
US/Central

📍 Building 241  
[Go to map](#)

📎 There are no materials yet.



# Barrel Imaging Calorimeter Meeting - Participants

**UC Santa Cruz:** T. Affolder, V. Fadeyev

**NASA Goddard\*:** R. Caputo, A. Steinhebel, D. Violette

**U of Regina:** Z. Papandreu (on-line), J. Zarling

**ANL:** M. Zurek, S. Joosten, T. O'Connor, K. Bailey, Z.-E. Meziani, M. Jadhav, J. Metcalfe, P. Reimer, C. Peng, J. Xie, J. Kim, M. Castro, W. Armstrong, M. Scott

**BNL:** S. Bazilevsky, D. Cacace (on-line)

**ISU:** J. Lajoie

**ORNL:** N. Novitzky (on-line)

**KIT\*:** N. Striebig (on-line), I. Peric (on-line)

**Oklahoma State University\*:** Flera Rizatdinova (on-line)

**Pusan National University:** S. Lim (on-line)

**DAQ WG** (on-line for joined sessions): J. Landgraf, F. Barbosa, K. Reed...

+ **3 Summary Sessions with Elke Aschenauer and Rolf Ent**

\*Expressed interest in  
officially joining ePIC

Participants intro talks: <https://indico.bnl.gov/event/19689/contributions/77334/>

# Mon-Tue: SiFi/Pb

Assembly Procedure, Schedule  
and realistic production strategy

Mon 12/06

13:00	<b>GlueX Barrel ECAL - Production and Assembly</b> <i>Room A323, B241</i> <i>13:00 - 13:30</i> <b>ePIC Barrel ECAL - Schedule and SciFi/Pb budget summary</b> <i>Room A323, B241</i> <i>13:30 - 13:50</i> <b>Discussion</b> <i>Room A323, B241</i> <i>13:50 - 14:10</i> <b>Working Session: Task, Schedule and Workforce Spreadsheet</b> <i>Room A323, B241</i> <i>14:10 - 15:00</i> <b>Coffee Break</b> <i>Building 241</i> <i>15:00 - 15:30</i> <b>Working Session: Task, Schedule, and Workforce Spreadsheet</b> <i>Room A323, B241</i> <i>15:30 - 16:15</i> <b>Working Session: Production Sites and Collaborations</b> <i>Room A323, B241</i> <i>16:15 - 17:00</i>	<i>Zisis Papandreou</i> <i>Maria Zurek</i> <i>Maria Zurek</i>
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Tue 13/06

08:00	<b>Welcome and Coffee</b> <i>Room D173, B241</i> <i>08:30 - 09:00</i>	
09:00	<b>Working Session: Finalizing budget table</b> <i>Room D173, B241</i> <i>09:00 - 10:00</i>	
10:00	<b>Coffee Break</b> <i>Building 241</i> <i>10:00 - 10:30</i> <b>Fermilab AstroPix Setup</b> <i>Room D173, B241</i> <i>10:30 - 10:50</i> <b>GlueX Baby BCAL Prototype</b> <i>Room D173, B241</i> <i>10:50 - 11:10</i> <b>Integrated Prototype Planning - Discussion Kick-off</b> <i>Room D173, B241</i> <i>11:10 - 11:30</i> <b>Task and Schedule Planning</b> <i>Room D173, B241</i> <i>11:30 - 12:30</i> <b>Lunch</b> <i>Building 241</i> <i>12:30 - 13:30</i> <b>Overview of the readout of the GlueX Barrel</b> <i>Room D173, B241</i> <i>13:30 - 14:00</i> <b>HGCROC and Readout of Barrel ECAL</b> <i>Room D173, B241</i> <i>14:00 - 14:30</i> <b>Discussion</b> <i>Room D173, B241</i> <i>14:30 - 15:00</i> <b>SIPM and fiber testing plans</b> <i>Room D173, B241</i> <i>15:00 - 15:30</i> <b>Coffee Break</b> <i>Building 241</i> <i>15:30 - 16:00</i>	<i>Manoj Bhanudas Jadhav</i> <i>Zisis Papandreou</i> <i>Maria Zurek</i> <i>Maria Zurek</i> <i>Zisis Papandreou</i> <i>Norbert Novitzky</i> <i>Zisis Papandreou</i>

Talk count  
Zisis: 4  
Maria: 2

Prototyping  
strategy  
discussion

Readout

# SiFi/Pb Discussions

## Construction Facility @ Regina

ROLLING



GLUING



QUALITY CONTROL AT EVERY STEP

SWAGGING



PRESSING



### Selected Discussion Items

Realistic production strategy and workforce requirements discussed

- Production rates estimated in the bottom up schedule

### Strategy for prototyping

- Short term R&D (testing of fibers light output in Regina, small scale prototype in FNAL)
- Engineering test article (mechanical properties testing, readout testing, shelf-SiFi/Pb integration)
- First article

Possible strategy of reading out SiPMs with HGCROC

# Wed: Integration

Detector sector geometry and assembly

Integration Discussion

What have we learned from GlueX and sPHENIX and Discussion about the installation

Tue 13/06

Coffee Break	
Building 241	15:30 - 16:00
Discussion on PbScFi Sector Assembly	
Room D173, B241	16:00 - 17:30

Wed 14/06

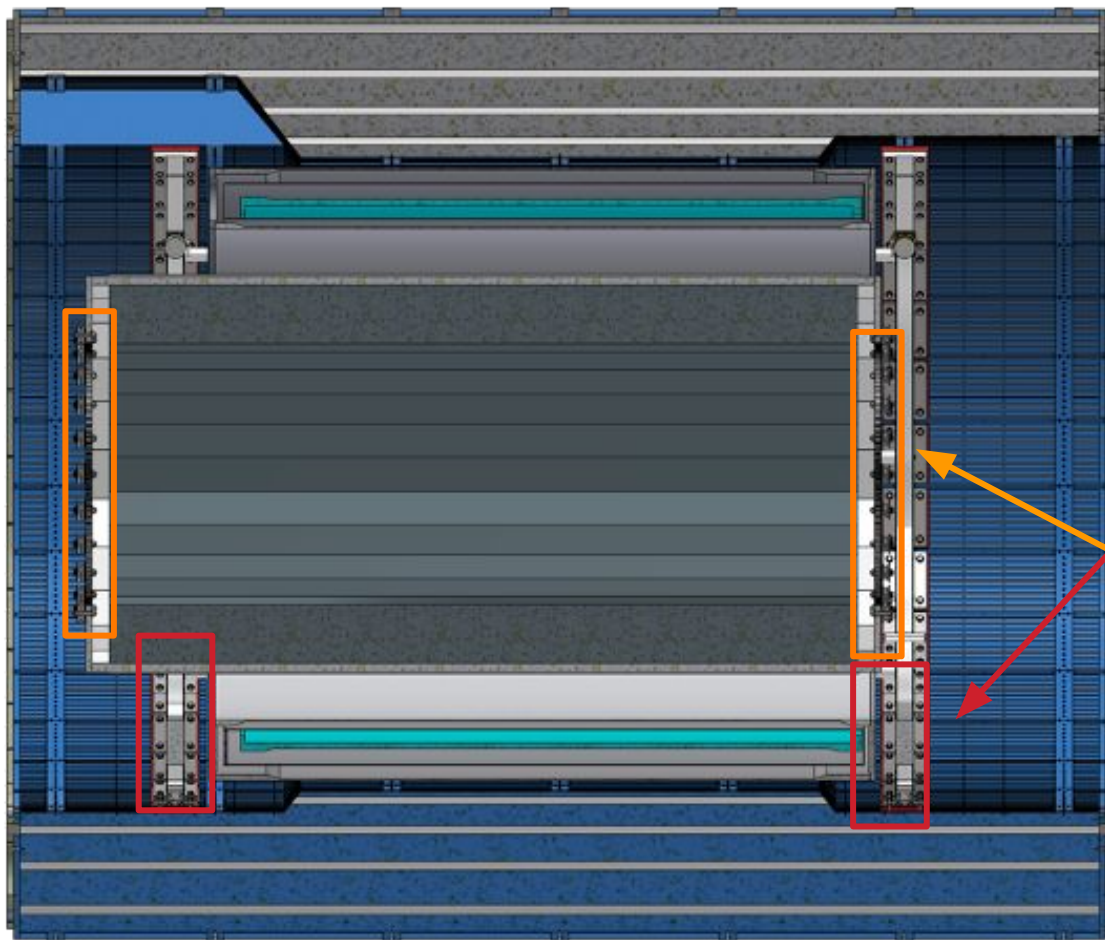
Discussion on existing interfaces and integration	
Room D173, B241	09:00 - 10:30
Coffee Break	
Building 241	10:30 - 11:00
GlueX BCAL Installation	
Room D173, B241	Zisis Papadreas
Installation concept based on sPHENIX	
Room D173, B241	Dan Caceres
Discussion on Barrel Assembly and Installation	
Room D173, B241	11:40 - 12:30
Lunch	
Building 241	12:30 - 13:30
Discussion on Mechanical and Electrical Engineering tasks	
Room D173, B241	13:30 - 15:00
Coffee Break	
Building 241	15:00 - 15:30
Discussion: Action items and priorities	
Room D173, B241	15:30 - 16:30

Talk count  
Zisis: 5  
Maria: 2

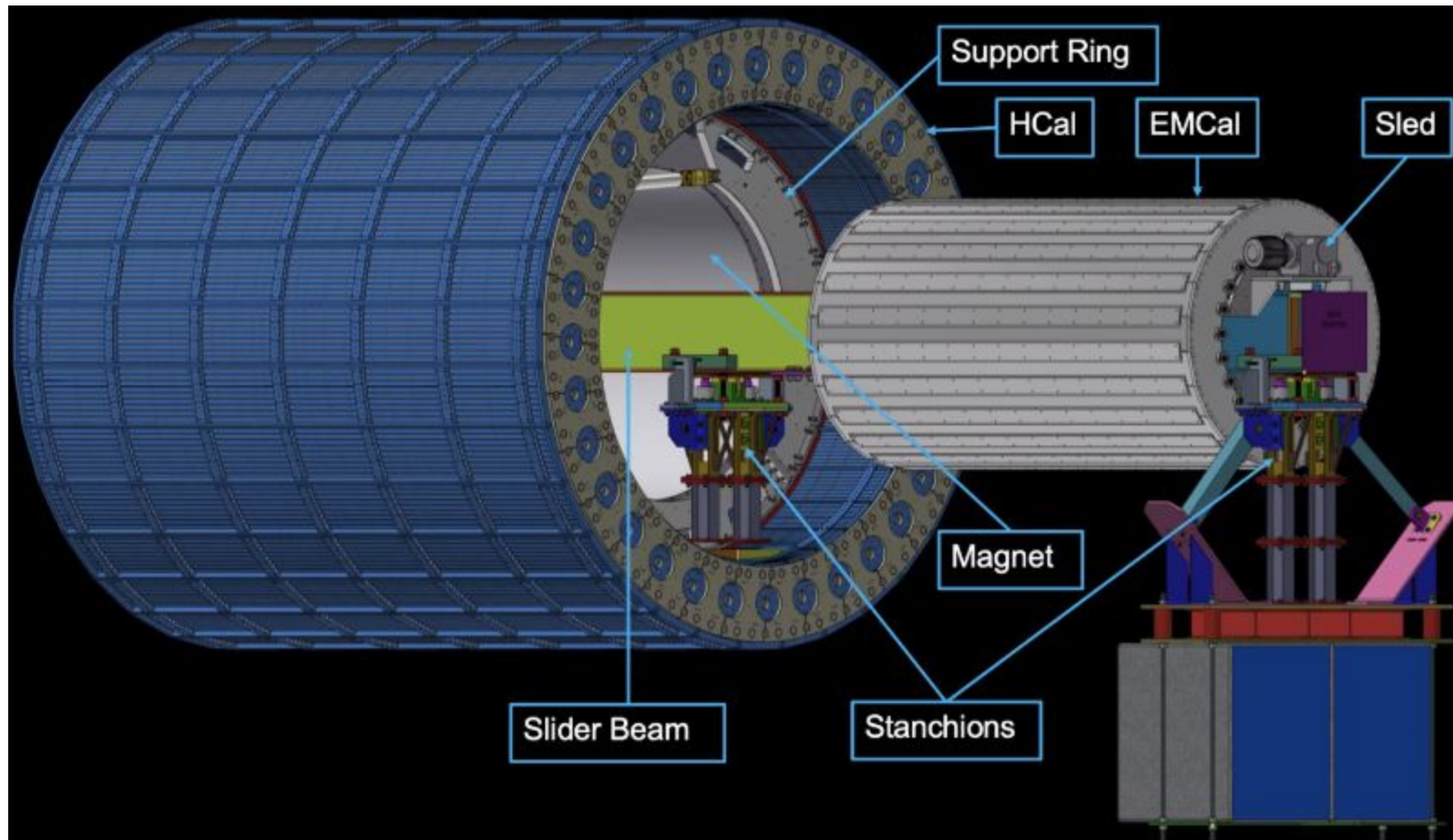


# Support Structure and Integration

Installation based on sPhenix:  
<https://indico.bnl.gov/event/19689/contributions/77698/>  
Summary of engineering tasks:  
<https://indico.bnl.gov/event/19689/contributions/77384/>



- **Design rapidly evolving**
- Installation follows the sPHENIX Barrel Calo Strategy at the current stage
- Support strategy still being evaluated
  - Tightly coupled whole system integration
- Current picture after the workshop:
  - **Barrel EMCal** rests on Barrel HCal support rings
  - Only **two points of contact** (versus rails in GlueX) requires a bit more work to evaluate rigidity and need for outside support
  - **Inner detector suspended off inner support** rings at the end of the Barrel EMCal
  - **Service access to the imaging layers discussed** in the current installation scheme discussed and reworked during the workshop





# Thu-Fri: AstroPix

Thu 15/06

08:00	ePIC DAQ Meeting (hybrid) Room A323, Building 241	08:00 - 08:45
09:00	Welcome Coffee Room A323, B241	09:00 - 09:30
	AstroPix / AMEGO-X Intro Room A323, B241	09:30 - 10:00
10:00	EIC Intro Room A323, B241	10:00 - 10:15
	ePIC Barrel Imaging Calorimeter Overview Room A323, B241	10:15 - 10:30
	Coffee break Building 241	10:30 - 10:45
	Attendee introduction talks	
11:00	Room A323, B241	10:45 - 11:15
	ePIC Imaging Calorimeter Intro: Facts & Figures Room A323, B241	11:15 - 11:45
	Integration and engineering priorities Room A323, B241	11:45 - 12:15
12:00	Lunch Building 241	12:15 - 14:00
13:00		
14:00	Module design and stave assembly Room A323, B241	14:00 - 14:30
	Tray assembly and integration Room A323, B241	14:30 - 15:00
15:00	Discussion Room A323, B241	15:00 - 15:30
	Coffee break Building 241	15:30 - 15:45
	FPGA board requirements Room A323, B241	15:45 - 16:15
16:00	Discussion Room A323, B241	16:15 - 17:00
17:00	Silicon / AstroPix Lab tour Room A323, B241	17:00 - 18:00
18:00		

Joined session with DAQ

Introductions

Introductions and Summaries from previous days

Discussion about AstroPix module, and stave assembly

Lab tour

Fri 16/06

08:00	AstroPix v1v5 overview Room A323, B241	Nicolas Streibig @ 08:30 - 09:00
09:00	AstroPix test results (NASA) Room A323, B241	Amanda Steinhebel @ 09:00 - 09:30
	AstroPix test results (Argonne) Room A323, B241	Morgan Steinhebel @ 09:30 - 10:00
10:00	Coffee Break Building 241	10:00 - 10:15
	CompPari/AMEGO-X prototype overview Room A323, B241	Regina Caputo @ 10:15 - 10:45
	EIC prototype overview Room A323, B241	Maria Zurek @ 10:45 - 11:15
11:00	Discussion and organization Room A323, B241	11:15 - 12:00
12:00	Working lunch Building 241	12:00 - 14:00
13:00		
14:00	Working session: tasks and efforts Room A323, B241	14:00 - 15:15
15:00	Coffee Break Building 241	15:15 - 15:30
16:00	Working session: Finalize production plan Room A323, B241	15:30 - 17:00
17:00		
18:00	Happy Hour Building 241	18:00 - 19:00
19:00		

Talk count

Zisis: 5

Maria: 4

Sylvester: 30  
pages of live notes



Chip discussion

Prototyping Plans

Tasks and efforts  
Budget/Production plan

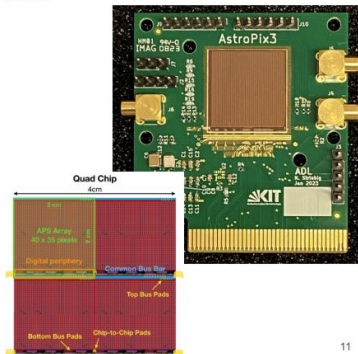
# AstroPix Discussions

## AstroPix v3: Design and Fabrication

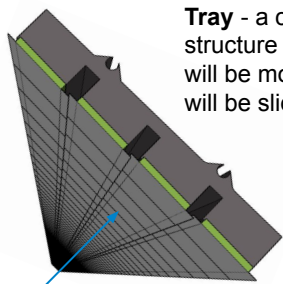
### Pixel Matrix:

- 500um<sup>2</sup> Pixel Pitch, 300um<sup>2</sup> Pixel Size
- 35 x 35 pixels
- first 3 cols PMOS amplifier others NMOS
- Pixel Comparator Outputs Row/Column OR wired
- Goal:
  - Pixel Dynamic Range 20keV - 700keV
  - Noise Floor 5 keV (2% @ 662keV)

ASTROPIX



11



**AstroPix Stave**

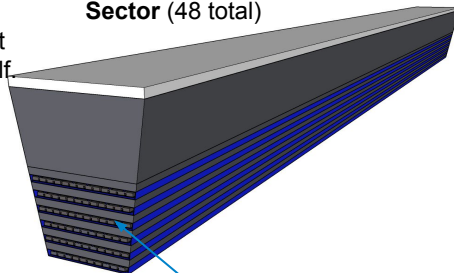
Consists of 1 x 108 chips with the support structure, "turbofanned"

**AstroPix Module**

Subset of chips

**Tray** - a carbon fiber structure the staves will be mounted on. It will be slid into a shelf.

**Sector (48 total)**



**Shelf** - a carbon fiber structure that is glued to the Pb/ScFi layers, that we will slide trays with AstroPix staves on.

See Thu and Fri sessions:

<https://indico.bnl.gov/event/19689/timetable/#20230615.detailed>

- Strategy for testing discussed: test at wafer level, then at stave-level
- "baseline" model of modules on staves established
  - 108 chips per stave, 12 modules x 9 chips
  - 12 or 14 tracker staves per AstroPix layer per Calorimeter sector
  - Bottom-up schedule and budget estimate based on this model
- Discussions about the AstroPix v4/v5 specification and readout requirements
- Results from testing v3 at NASA and ANL/FNAL beamtest
- Prototyping strategy and complementarity of tasks on the NASA and ANL tasks
  - short term R&D and small-scale prototype at FNAL
  - Engineering test article of full stave with v3
  - First article of shelf with AstroPix v5 chip

# Summary

- 5 days of discussion Pb/ScFi (Mo-Tue), Engineering (We), and AstroPix/silicon (Thu-Fri)
- Highly productive meeting, up to > 20 in-person people at the meeting, and with hybrid component for most sessions.
- In-person representatives from Project (Sasha) and ePIC management (John), active remote participation by Project engineer (Dan), regular check-ins with Elke & Rolf
- ~ 30 pages of live notes documenting action items and discussion, many presentations on Indico
- Collected wealth of information for a bottom-up cost estimate, short-term engineering tasks and needs, realistic production strategy and workforce requirements, timeline, ...
- Should have everything in hand for Change Control, and to fill out the work packages based on this meeting!

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US/Central time zone

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US/Central

 **Building 241**  
[Go to map](#)

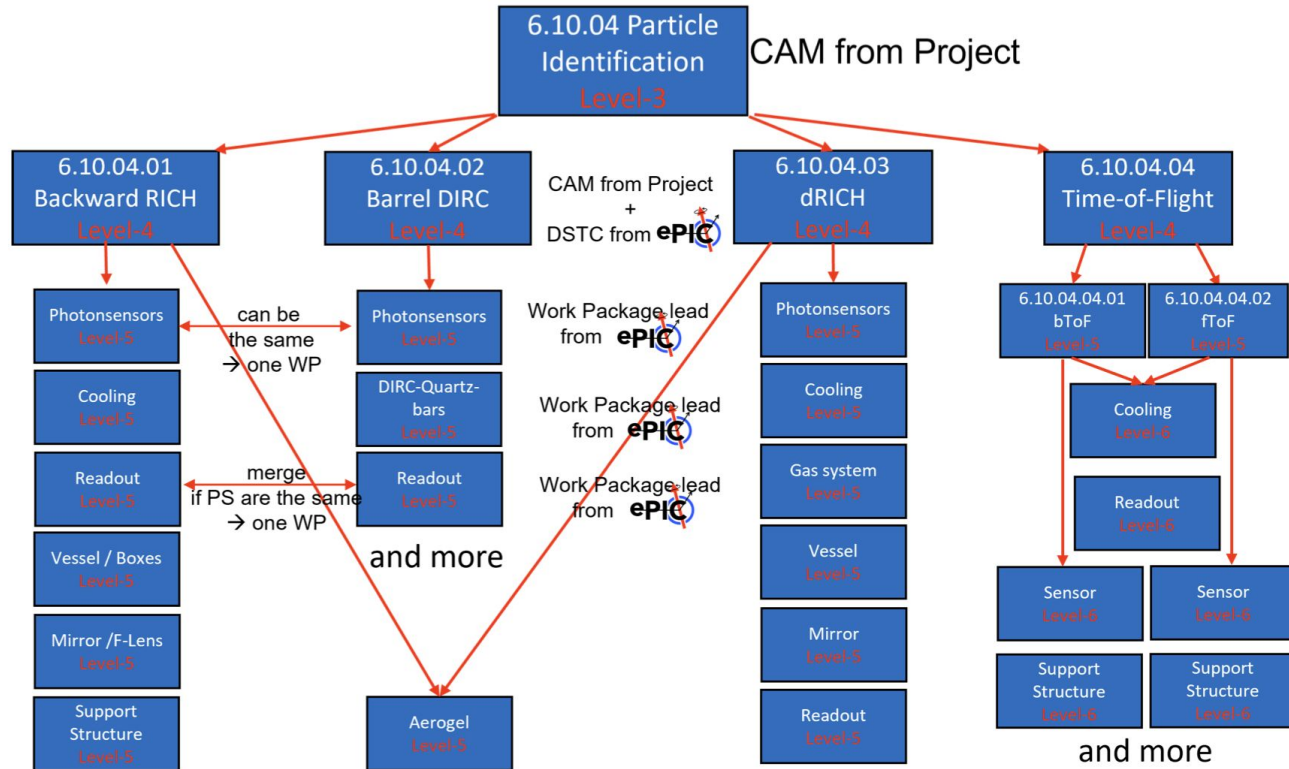
 There are no materials yet.



# Progress since the meeting and next steps

- Re-costed calorimeter based on engineering tasks and realistic production flows determined during the workshop (bottom-up)
- Communicated to Project last Friday (June 23), important first step to pass the Change Control milestone
- Next step from our side:
  - Determine Work Packages based on our engineering and production flow. Work Packages have both a “scope” and a “lead institution”. Some packages can cross institutional boundaries.
  - This is requested by ePIC at this point, and will be needed by the Project in the preparation towards CD3
  - This is a good time to distribute tasks and discuss institutional responsibilities and leadership.
  - We can take the tasks we used for the “bottom-up” costing

# Example work packages: PID detectors





# Tasks: PED

***Project Engineering & Design (PED), due by CD3 reviews (Fall 2024)***

- Pb/ScFi:
  - Final sector design, including CF frame design and Si integration
  - Final barrel design, including integration and assembly
  - End-of-sector readout box final design, including SiPM test procedures and optical element design and validation
  - Integration of a minimal imaging layer
- Imaging
  - Mechanical final design:
    - Tracker stave design, stave/tray integration, layer 1 mechanical structure, tray integration, cooling analysis, structure for end-of-stave readout, ...
  - Electrical final design:
    - Module design & bus tape, end-of-stave FPGA, readout validation, design of production QC procedure, calibration procedure

# Tasks: preproduction

***Assemble & commission production tooling, first article. Starts ASAP after CD3 ~ early 2025***

- Pb/ScFi:
  - Sector construction:
    - Build tooling for Pb/ScFi matrix construction & CF integration; Produce first article
  - End-of-sector readout:
    - Build tooling for readout assembly and testing, establish test procedure, produce first article
  - Full assembly:
    - Integrate matrix with readout and imaging layer first article, conduct tests
- Imaging
  - Chip reception and component QC:
    - Setup production QC lines, build first article(s)
  - Module assembly
    - Setup module assembly lines and test stands, build first article(s)
  - Stave & tray assembly
    - Setup assembly lines and test stands with integrated calibration procedure

# Tasks: production

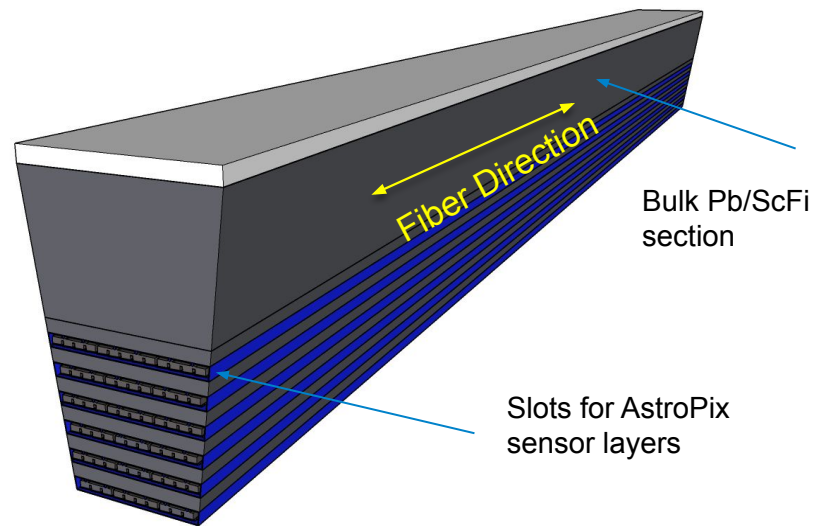
***Starts when production money is available (~Feb 2026), until delivery in 2029***

- Pb/ScFi:
  - Sector construction:
    - Build 48+1 full sectors; ship to BNL
  - End-of-sector readout:
    - Build (48+1) x 2 readout boxes, including all SiPM and readout electronic tests; ship to BNL
- Imaging
  - Build, test, and calibrate fully assembled imaging trays for all imaging layers
    - Chip reception and component QC:
    - Module assembly
    - Stave & tray assembly

# Tasks: Installation

*Installation in BNL after delivery, starts ~ late 2029*

1. Prepare and mount sectors into barrel:
  - a. Unpack sectors
  - b. End-of-sector readout installation (glue light guides, attach readout boxes including LMS)
  - c. Assemble the full barrel
2. Insert full barrel into the solenoid
3. Finalize:
  - a. Insert imaging layer trays into shelves (slots)
  - b. Wire readout boxes



# Towards Work Packages...

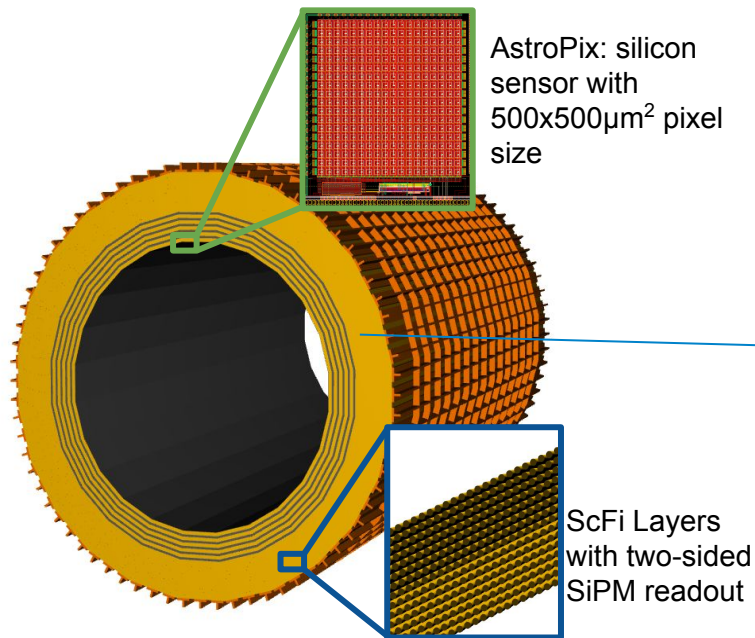
- We have all needed information in principle in our task list
- We mostly have the (urgent) PED needs covered, some remaining engineering tasks related to the readout box/LMS need a home
  - Need to discuss options here, crucial that the work can start in a few months (due only ~ 1 year from now)
- Need to separate list into distinct Work Packages with their own institutional lead
  - Could see smaller sub-packages where relevant (e.g. “light guides”, LMS, ...) instead of a monster “end-of-sector-box” work package.
  - In parallel we also need to finalize production sites and fully define the role of our international partners.
- We (as a Barrel Imaging Calorimeter Collaboration) need to finalize this work soon



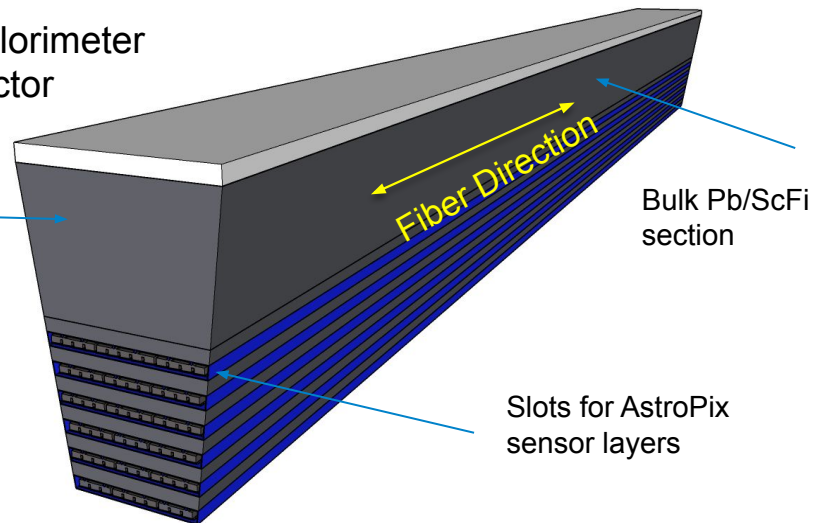
# Backup

# Geometry

- **4(+2) layers of imaging Si sensors interleaved with 5 Pb/ScFi layers**
- **Followed by a bulk section of Pb/ScFi section**



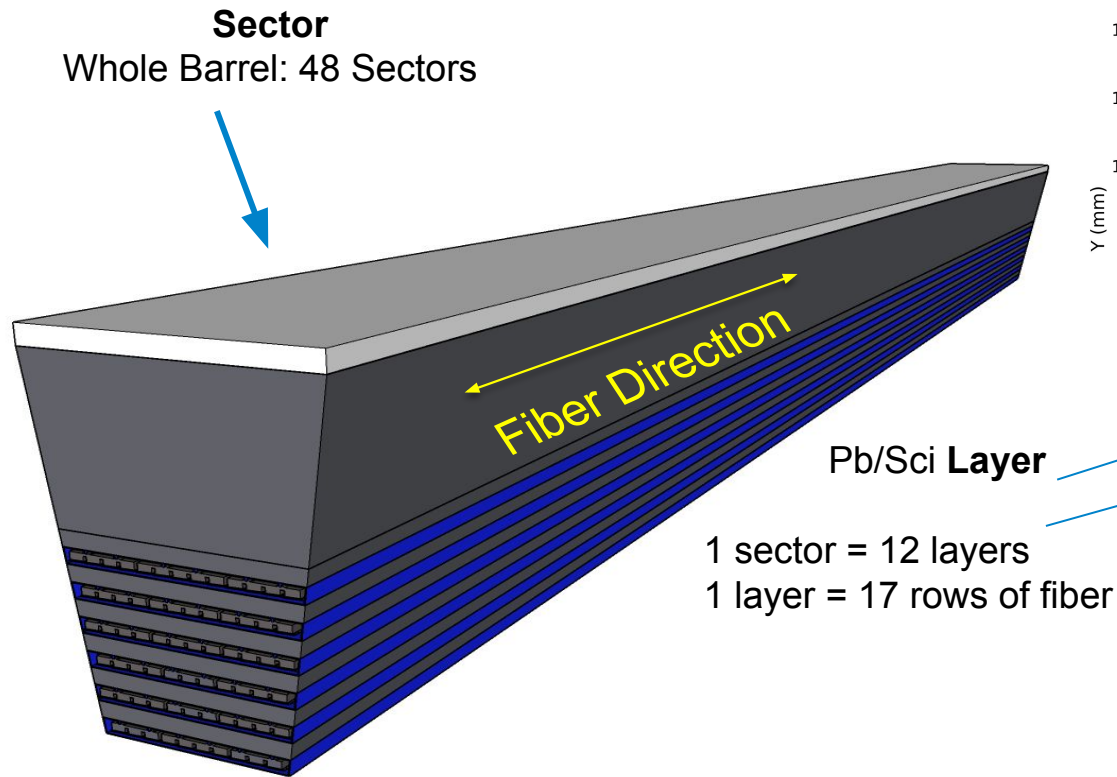
Calorimeter sector



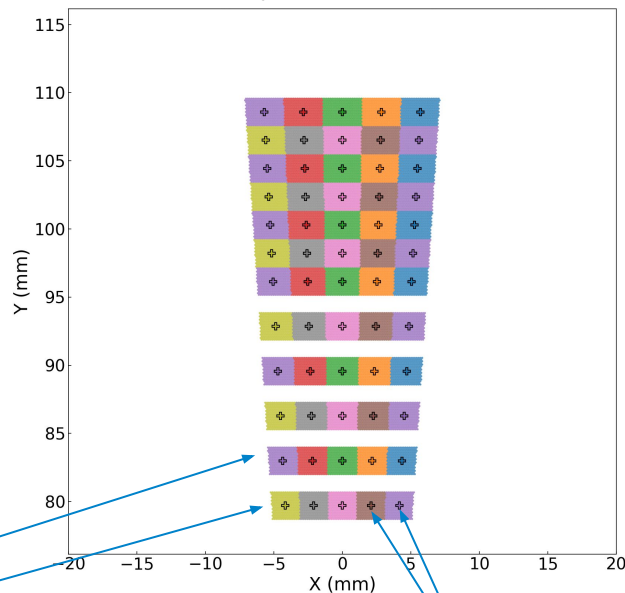
**Energy resolution** - Primarily from Pb/ScFi layers (+ Imaging pixels energy information)

**Position resolution** - Primarily from Imaging Layers (+ 2-side Pb/ScFi readout and radial segmentation)

# Geometry and Naming Scheme



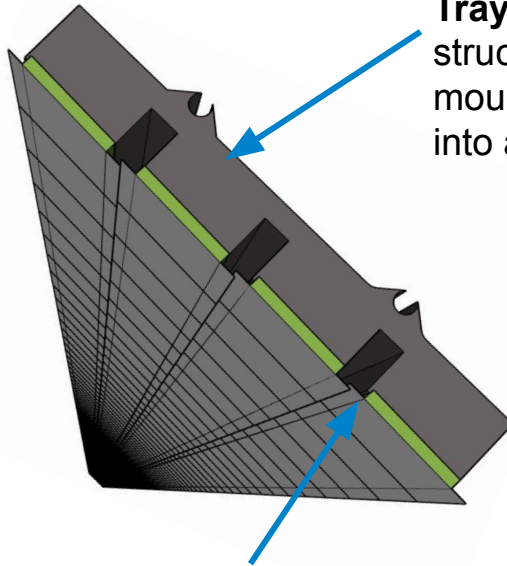
Sector End View  
(x-y plane view)



**Readout Cell**  
Layer = 5 cells

*The area 1 light guide is attached*

# Geometry and Naming Scheme



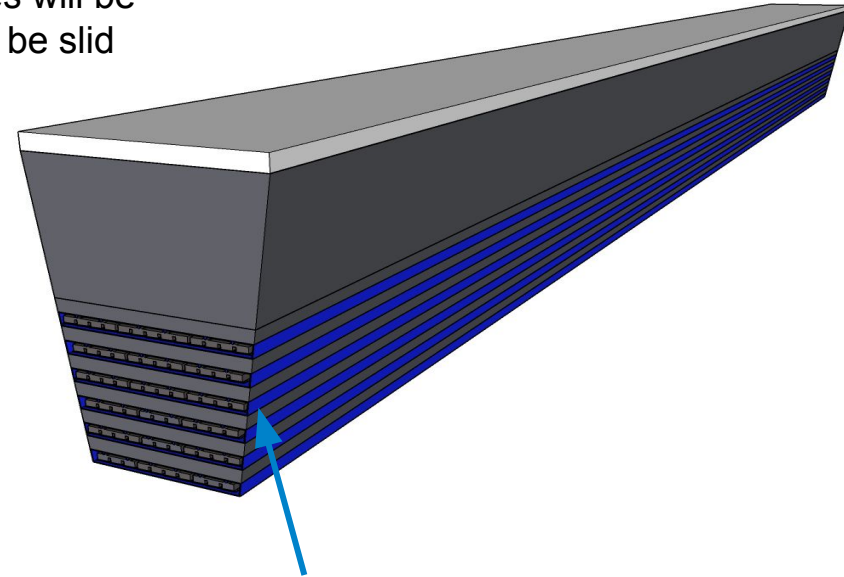
**Tray** - a carbon fiber structure the staves will be mounted on. It will be slid into a shelf.

## AstroPix **Stave**

Consists of 1 x 108 chips with the support structure

## AstroPix **Module**

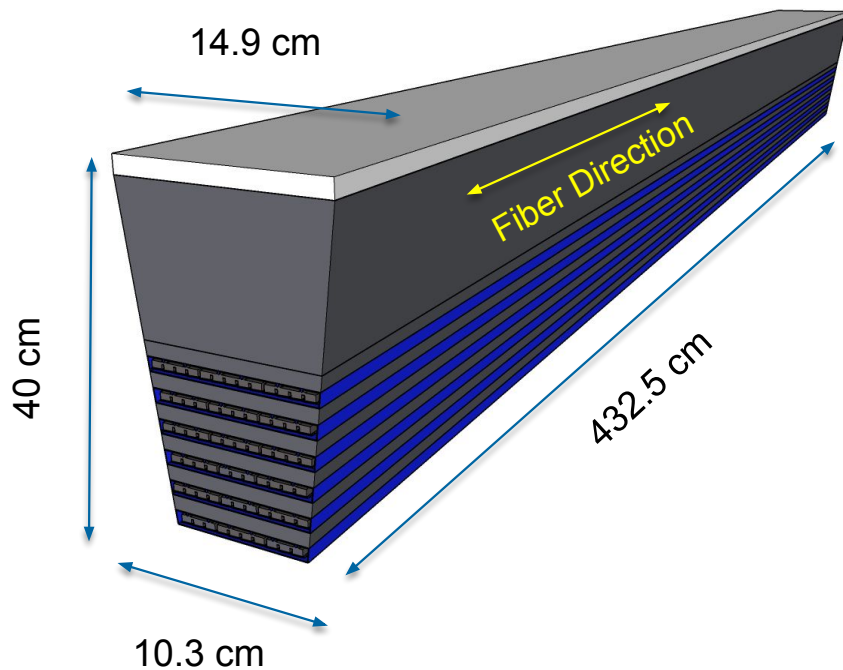
Subset of chips that will be mounted on one stave support structure



**Shelf** - a carbon fiber structure that is glued to the Pb/ScFi layers, that we will slide trays with AstroPix staves on.

\*The designs presented on these slides are not final but for illustration only

# Dimensions

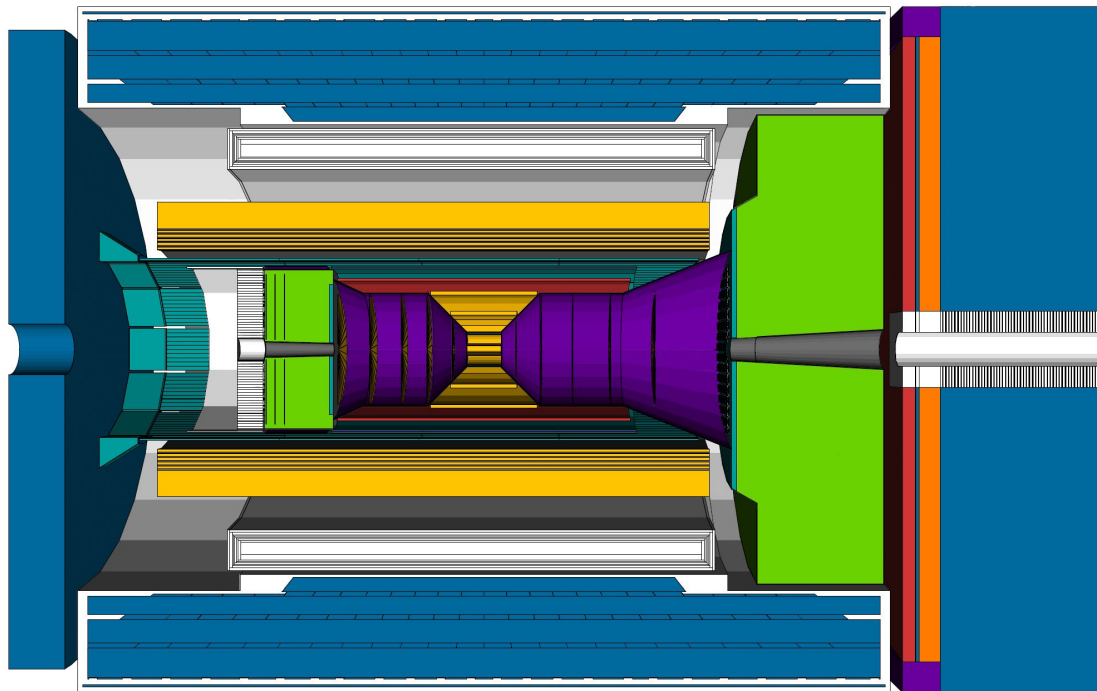


Dimensions at the current stage of the design

<b>inner barrel radius</b>	78.3 cm
<b>nb of sectors</b>	48
<b>length</b>	432.5 cm
<b>AstroPix slot thickness</b>	2 cm
<b>SciFi/Pb Layer 1-5 thickness</b>	2 cm
<b>Total weight</b>	~36 t
<b>1 sector weight</b>	~750 kg



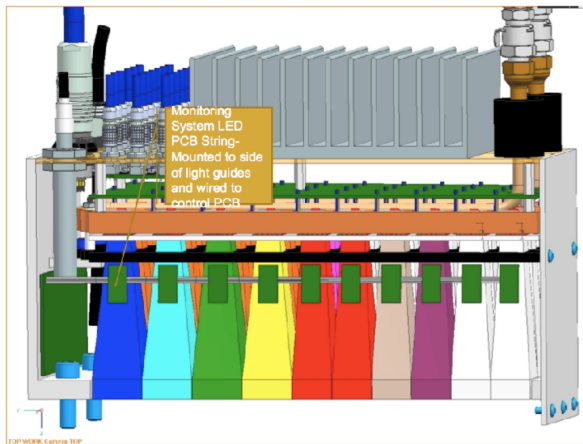
# Overall space considerations



- Lots of space between the barrel EMCal and the solenoid cryostat ( $\sim 20$  cm)
- Forward region under heavy pressure, space needed for:
  - Barrel EMCal readout box
  - Inner detector services
  - Barrel EMCal and inner detector support
  - dRICH
- Situation a bit more relaxed in the backward region

# GlueX BCAL Readout Design

- Pb/ScFi readout based on the GlueX BCAL readout
- Footprint excluding external connectors of GlueX BCAL readout box about 14cm
  - Dominated by light guides (~ 8 cm)
- We will likely be able to shrink this somewhat to < 12 cm
  - Space pressure in the forward direction, where space is limited.

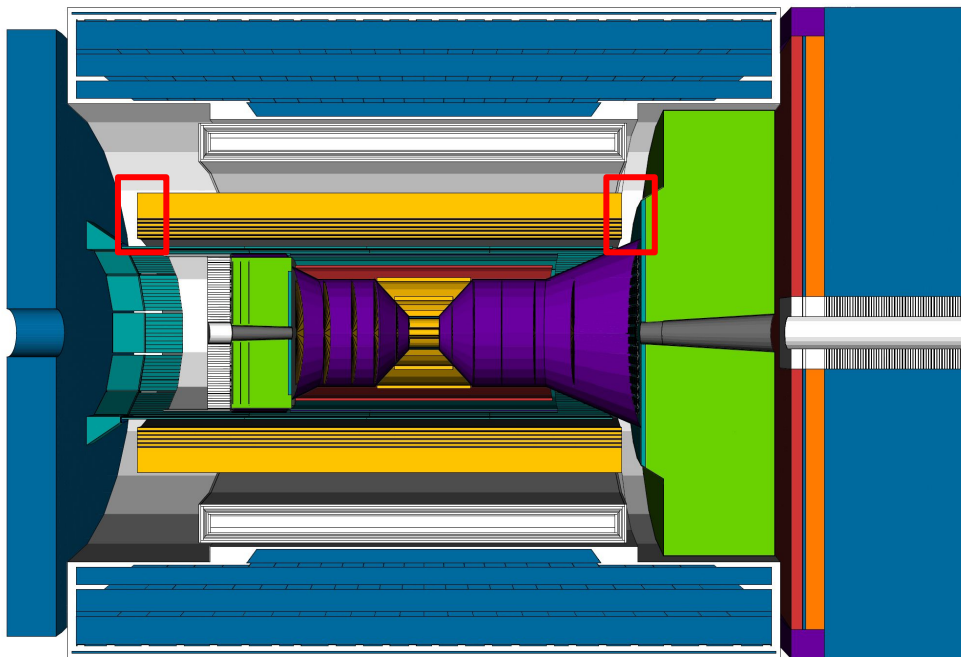


CAD drawing of GlueX readout box



“BabyBCAL” prototype readout box

# Barrel ECal Readout & Services



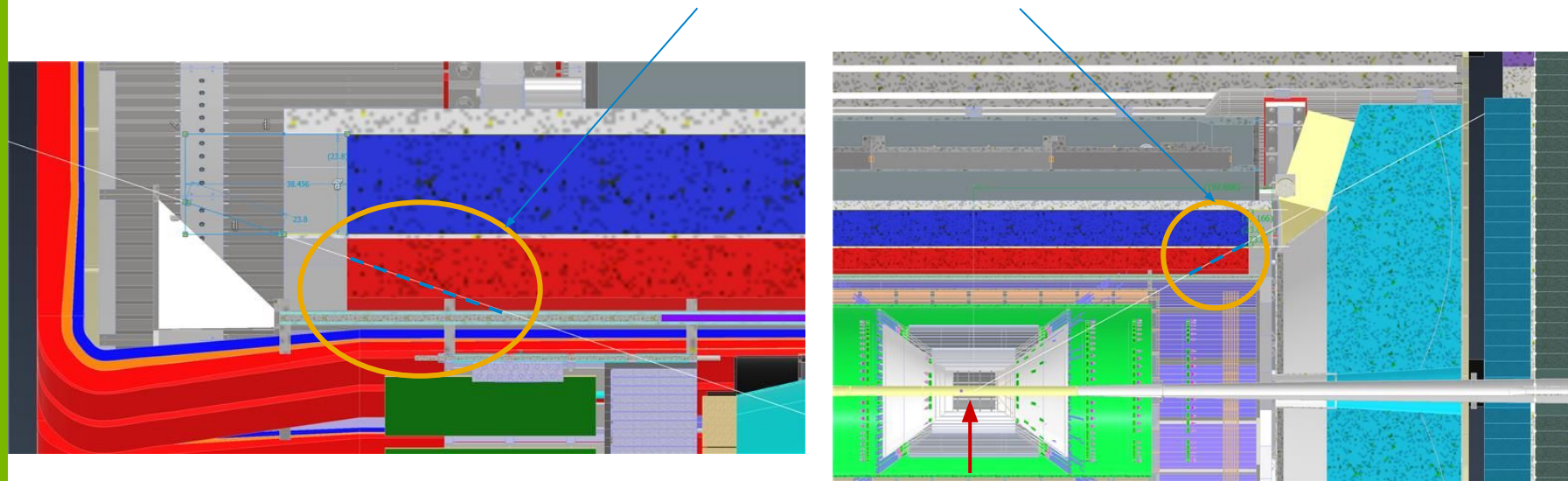
- Nominal 10cm service box at the end of each sector, may have to grow slightly
  - This would put (more) space pressure in the hadron-going direction.
  - May need to shorten calorimeter by a few cm to compensate
- Readout box includes:
  - Pb/ScFi readout components based on the GlueX design (including light-monitoring system)
  - 4 6x6mm<sup>2</sup> SiPMs with 50  $\mu$ m pixel per lightguide (“project” Hamatsu meets the performance requirements)
  - 1 x HGCROC per sector-end for SiPM readout
  - End-of-tray FPGAs for each of the silicon layers
- Readout boxes at both sides of the calorimeter are identical.

How is your system integrated with the overall ePIC design, i.e., what is the envelope occupied, is there possibly overlap with other subsystems, and is the design consolidated, ...

From Menagerie Tables:

- negative ecal front face at z -174 cm, up to r = 63 cm
- positive ecal front face at z 329.5 cm, up to r = 195 cm
- backward block size = 2 cm, forward module size = 2.5 cm

$\eta = -1.77$  and  $+1.31$  for those lines assuming *one block size less than maximum radius*



$\eta = -1.77$  and  $+1.31$

