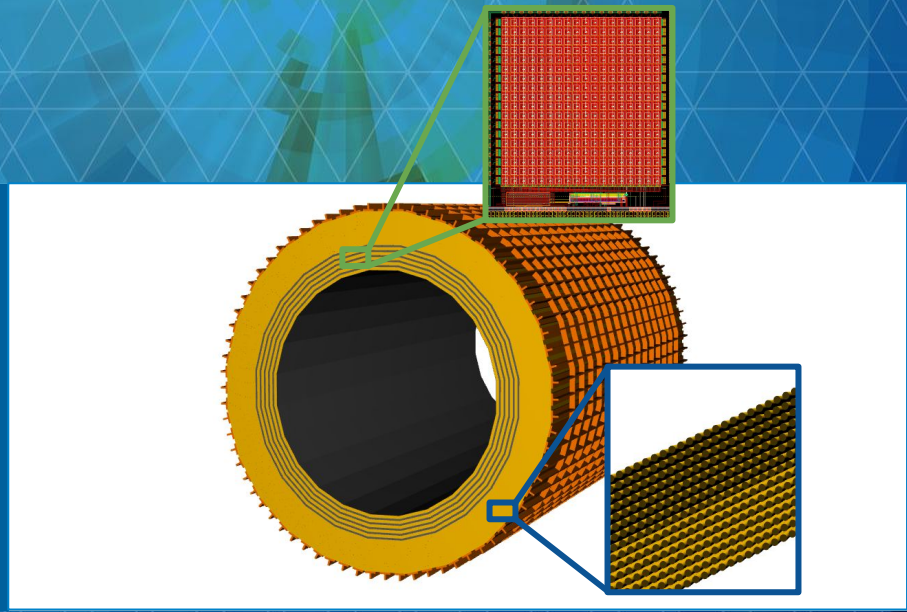
Barrel Imaging Calorimeter Meeting,
June 27, 2023

Barrel Imaging Calorimeter Meeting Summary & Work Packages



Maria Żurek & Sylvester Joosten
PHY, Argonne National Laboratory

In-person Barrel Imaging Calorimeter Meeting

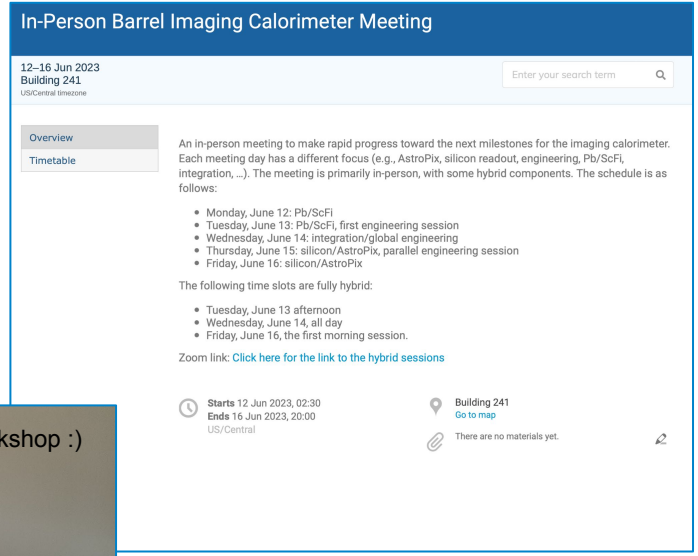
https://indico.bnl.gov/event/19689/timetable/#all.detailed

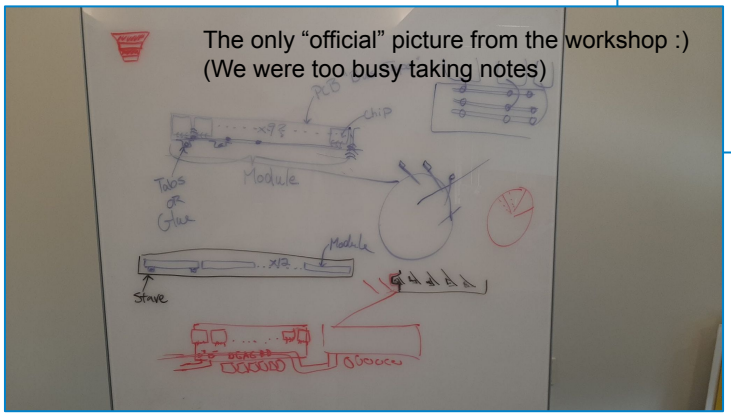
12-16 June 2023

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

Talks uploaded to the Indico + detailed live notes finalized

20+ participants





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…

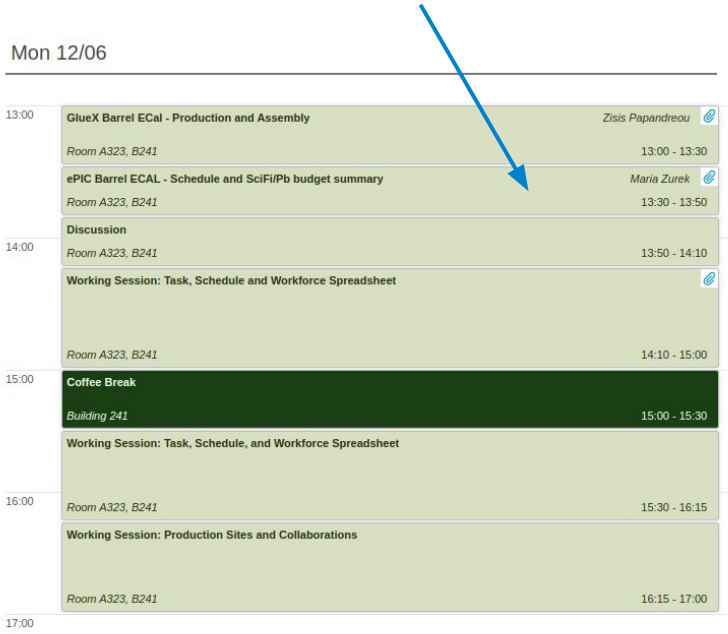
+ **3 Summary Sessions with Elke Aschenauer and Rolf Ent**

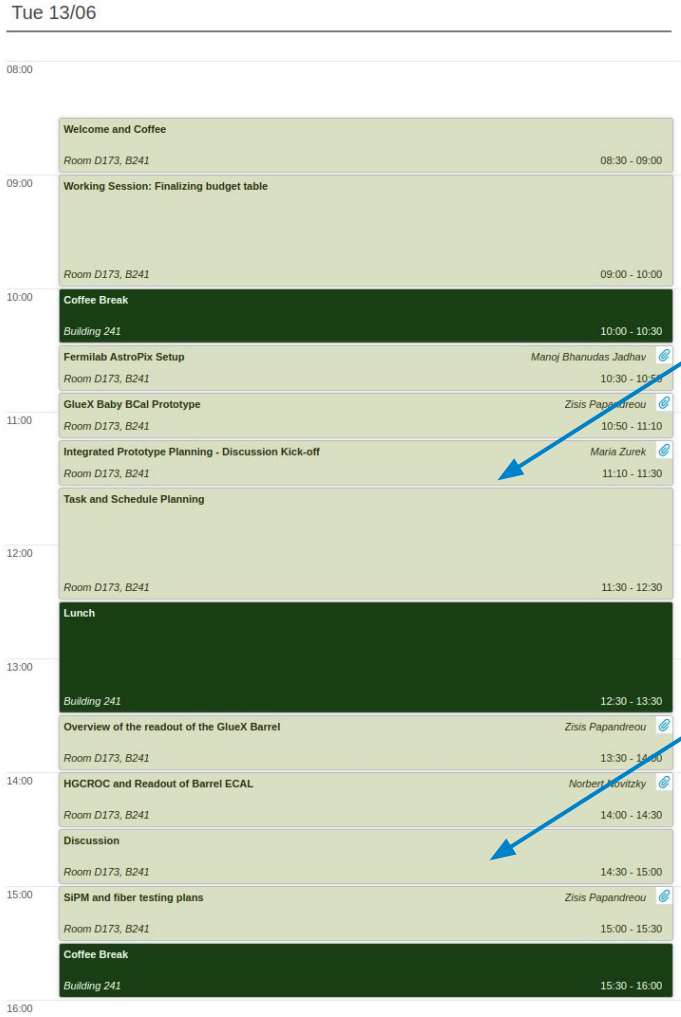
Participants intro talks: https://indico.bnl.gov/event/19689/contributions/77334/

*Expressed interest in officially joining ePIC

Mon-Tue: SiFi/Pb

Assembly Procedure, Schedule and realistic production strategy





Talk count
Zisis: 4
Maria: 2

Prototyping strategy discussion

Readout

GlueX Production (Zisis): https://indico.bnl.gov/event/19689/contributions/77399/
HGCROC Readout (Norbert): https://indico.bnl.gov/event/19689/contributions/77418/

SiFi/Pb Discussions

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

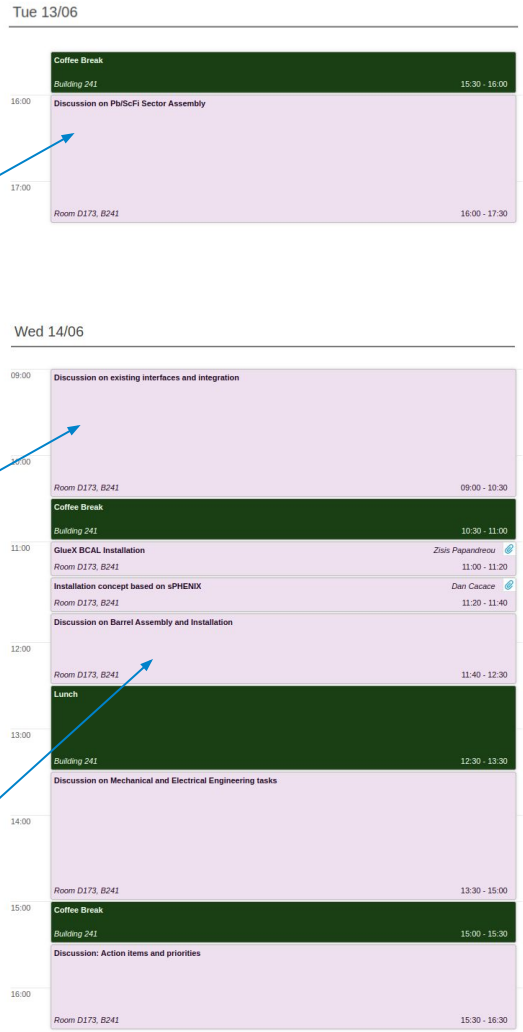
Wed: Integration

Talk count
Zisis: 5
Maria: 2

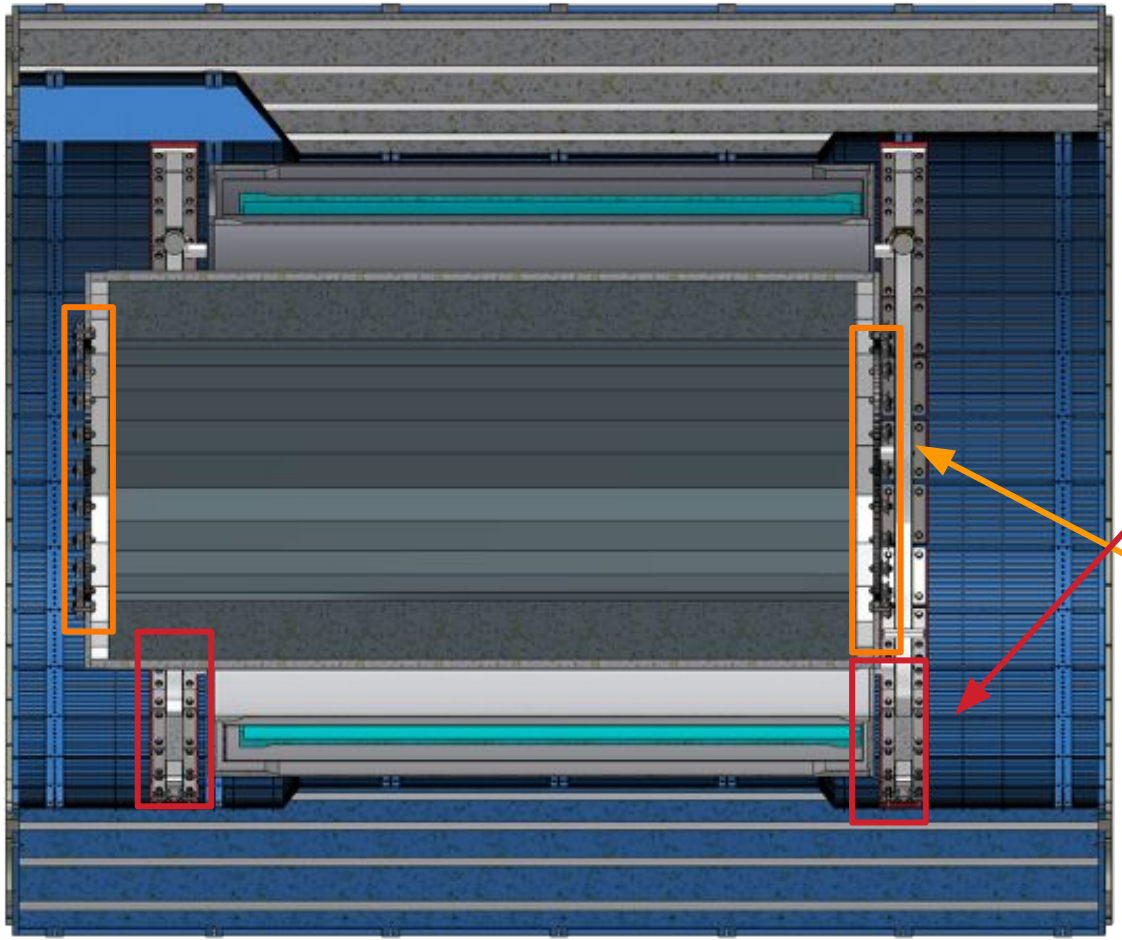
Detector sector geometry and assembly

Integration Discussion

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



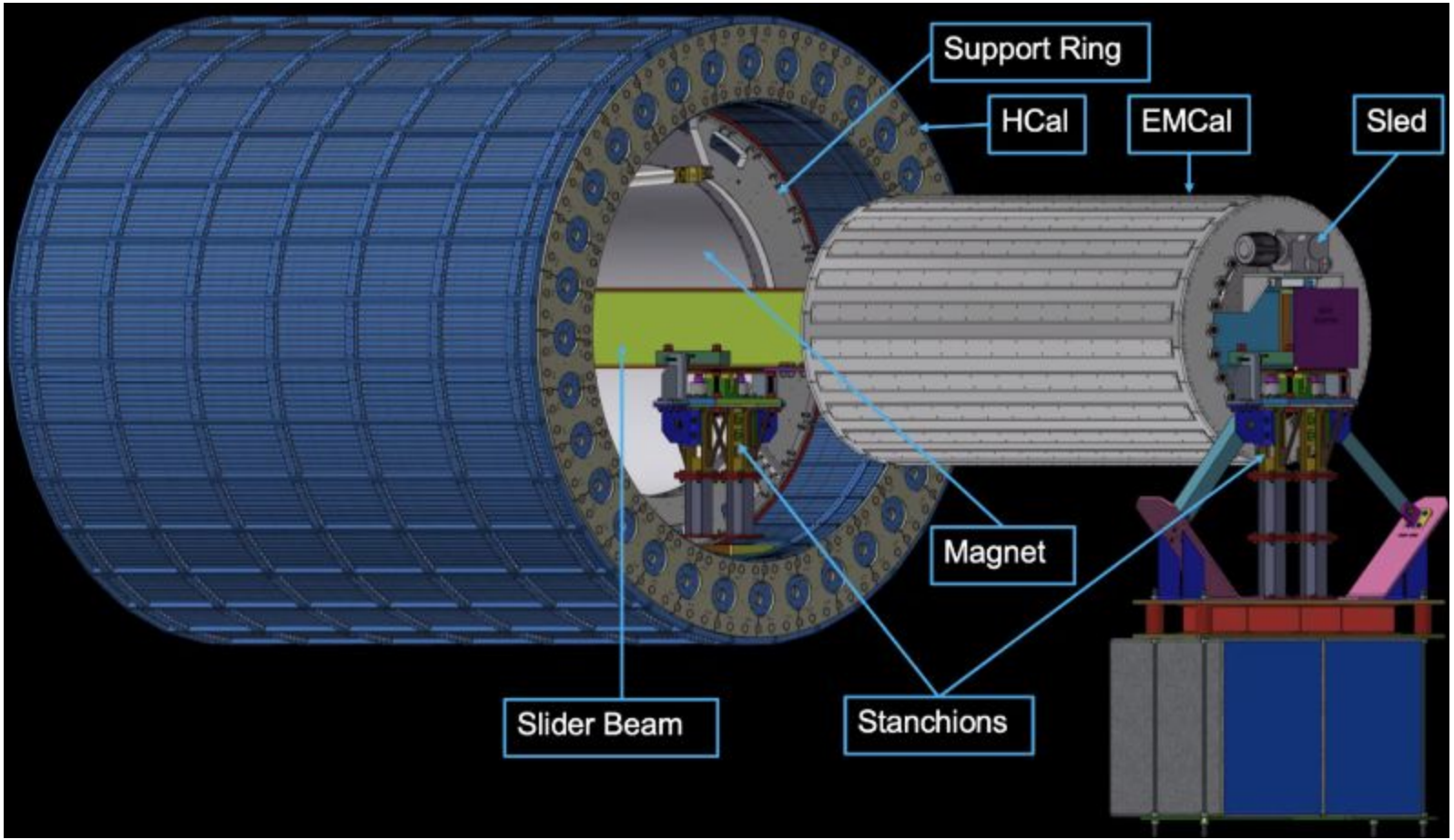
Support Structure and Integration



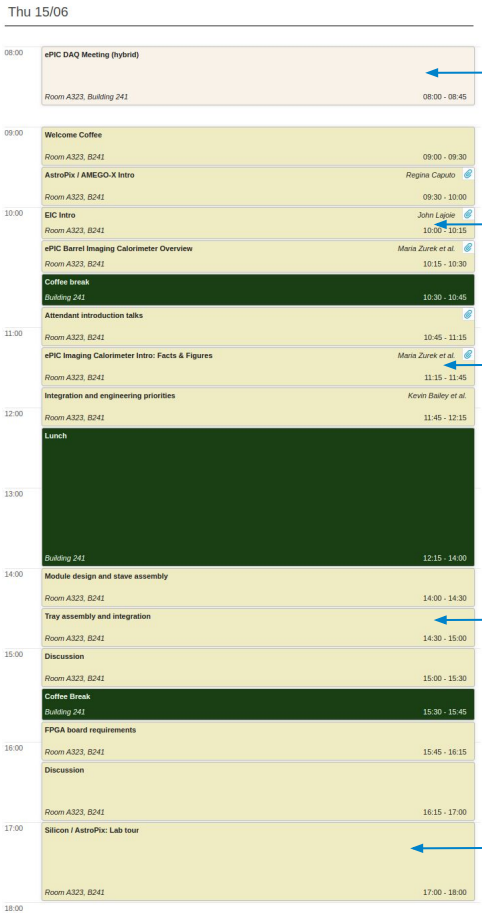
Installation based on sPhenix:
https://indico.bnl.gov/event/19689/contributions/77698/
Summary of engineering tasks:
https://indico.bnl.gov/event/19689/contributions/77384/

- **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


Support Ring
HCal
EMCal
Sled
Magnet
Slider Beam
Stanchions

Thu-Fri: AstroPix



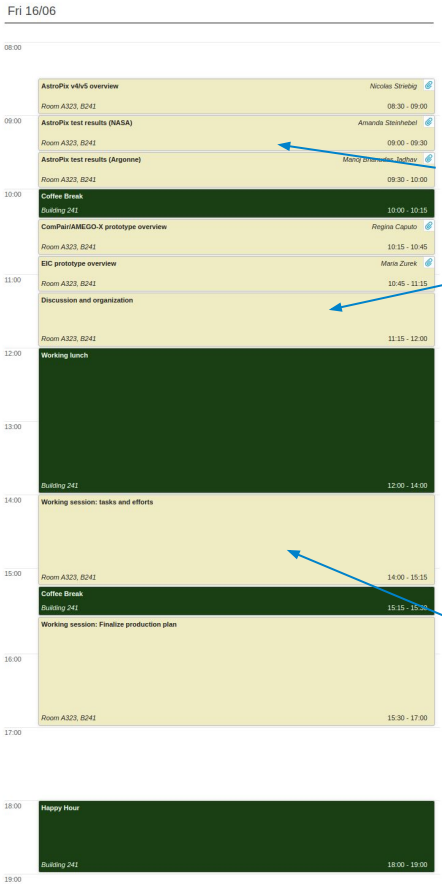
Joined session with DAQ

Introductions

Introductions and Summaries from previous days

Discussion about AstroPix module, and stave assembly

Lab tour



Chip discussion

Prototyping Plans

Tasks and efforts Budget/Production plan

Talk count
Zisis: 5
Maria: 4
Sylvester: 30 pages of live notes

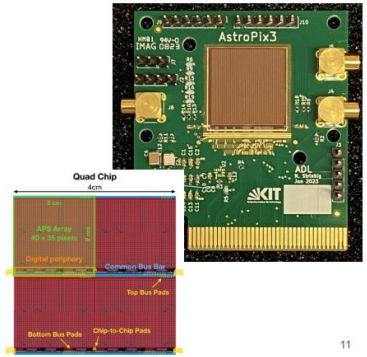
AstroPix Discussions

See Thu and Fri sessions:
https://indico.bnl.gov/event/19689/timetable/#20230615.detailed

AstroPix v3: Design and Fabrication

Pixel Matrix:

- 500um² Pixel Pitch, 300um² 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)



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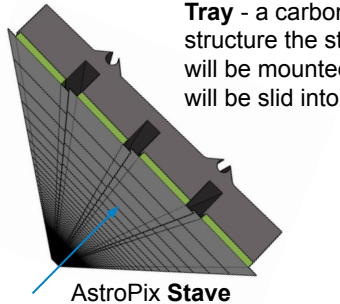
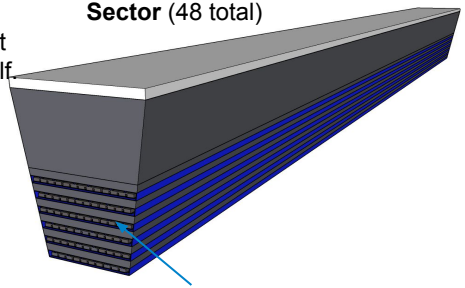


Tray - a carbon fiber structure the staves will be mounted on. It will be slid into a shelf.

AstroPix **Stave**
Consists of 1 x 108 chips with the support structure, "turbofanned"
AstroPix **Module**
Subset of chips

Sector (48 total)



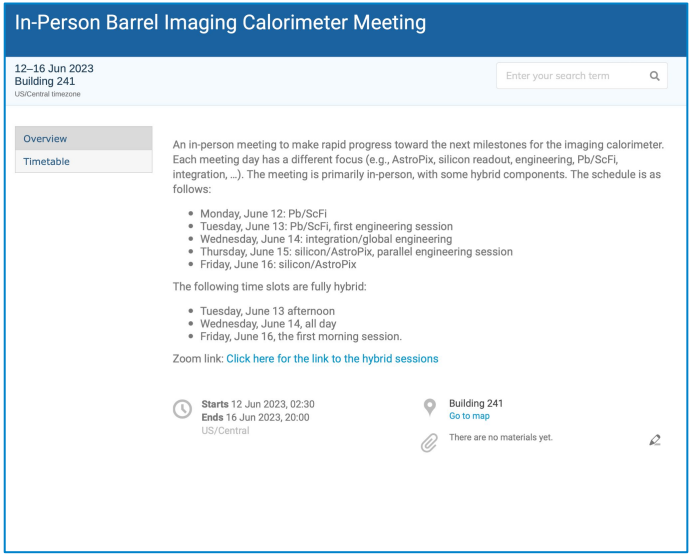
Shelf - a carbon fiber structure that is glued to the Pb/ScFi layers, that we will slide trays with AstroPix staves on.

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

- 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

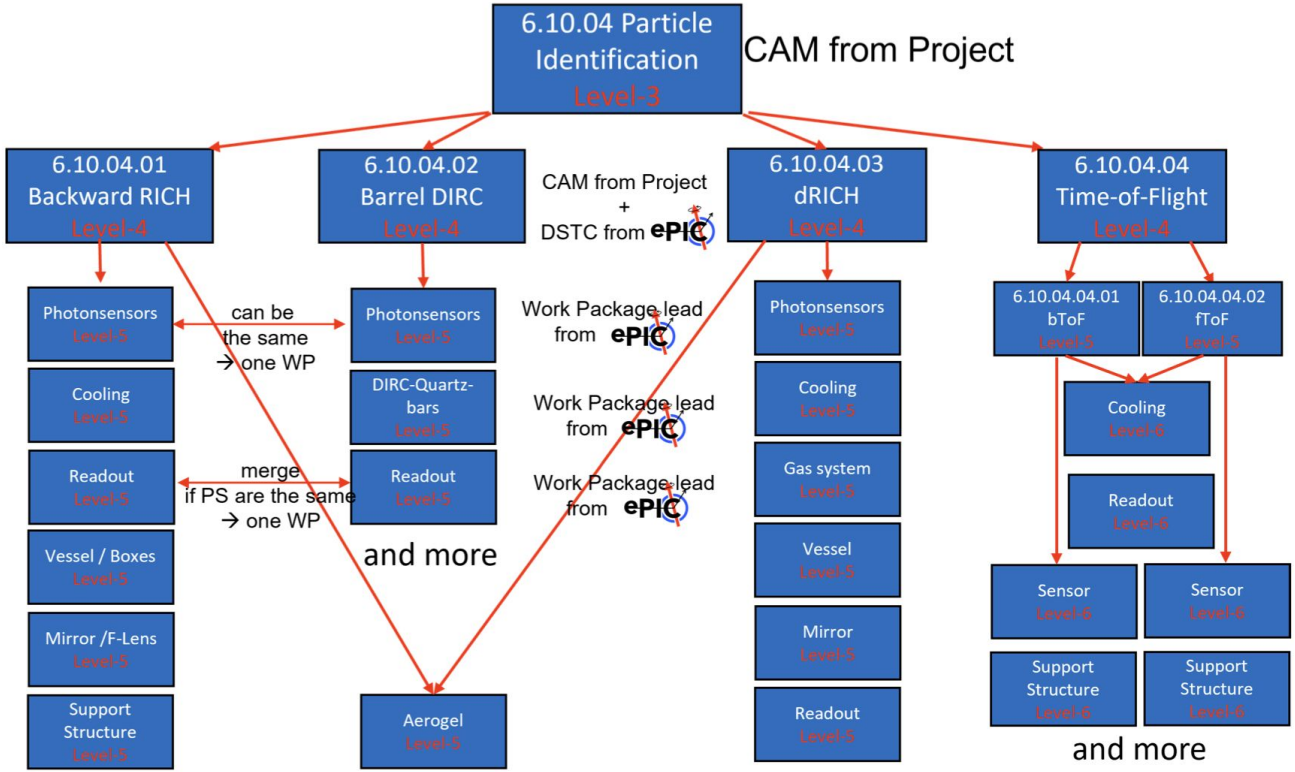
- 5 days if discussion Pb/ScFi (Mo-Tue), Engineering (We), and AstroPix/silicon (Thu-Fri)
- Highly productive meeting, up to > 20 in-person people at the meeting, and with hybrid component for most sessions.
- In-person representatives from Project (Sasha) and ePIC management (John), active remote participation 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!



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

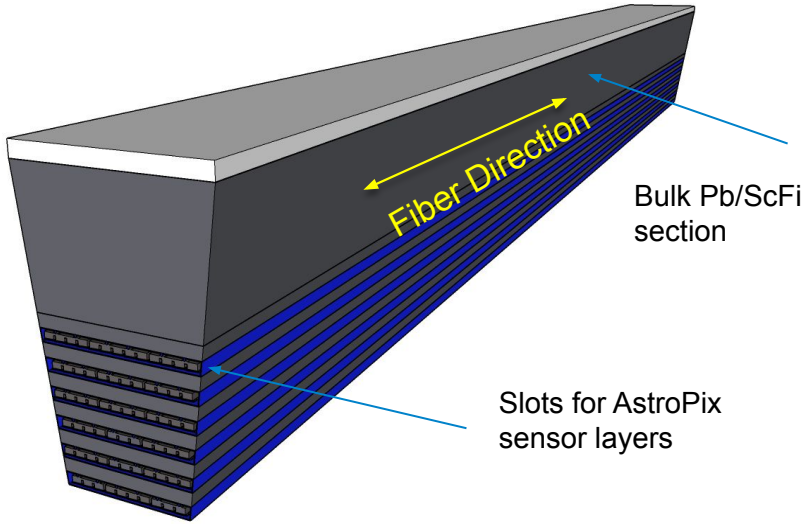
Starts when production money is available (~Feb 2026), until delivery in 2029

- 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



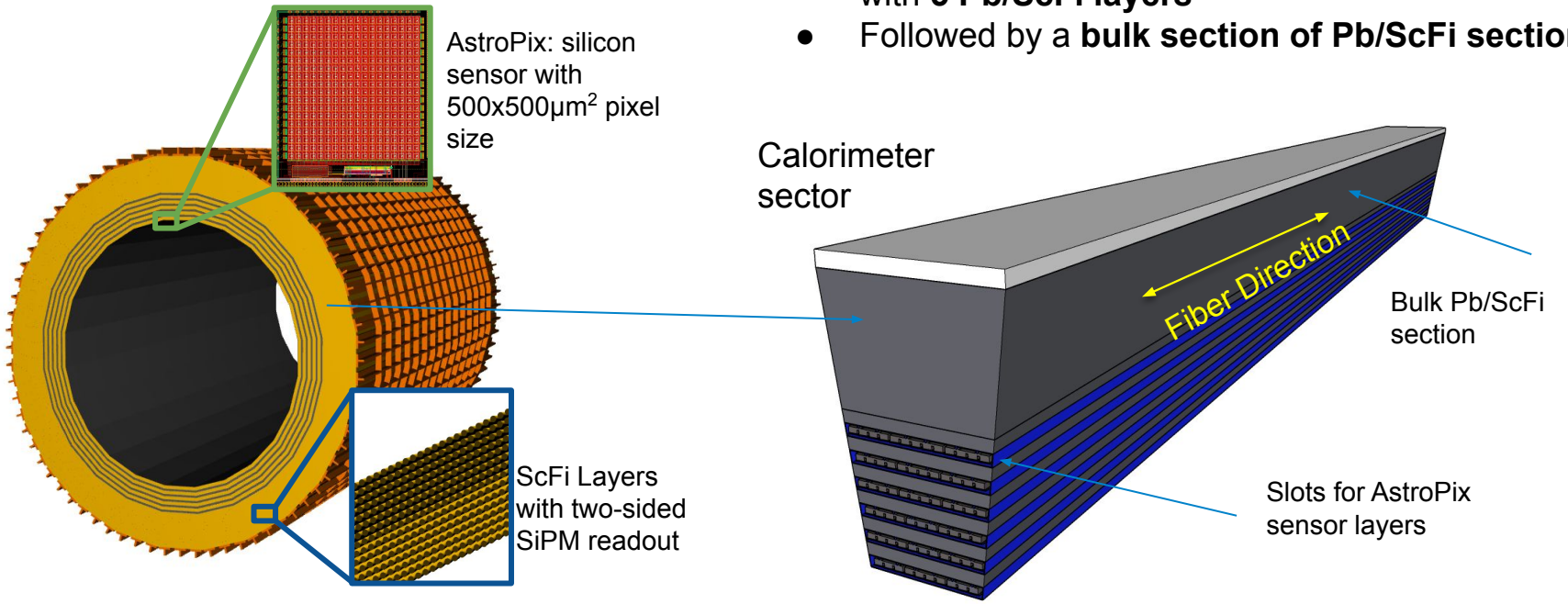
Towards Work Packages…

- 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

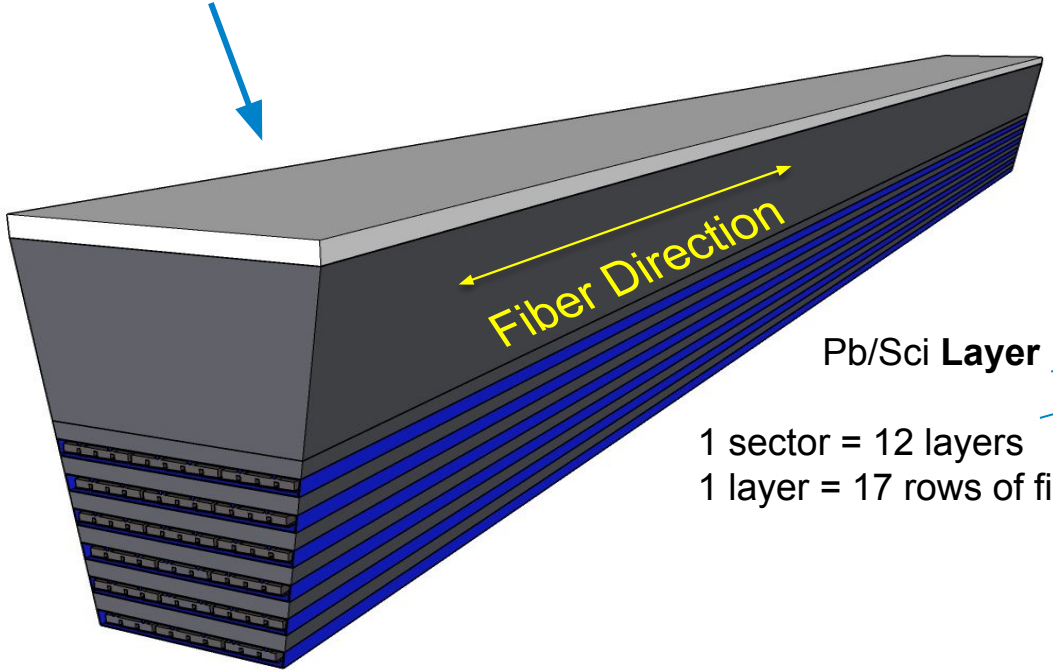
- **4(+2) layers of imaging Si sensors** interleaved with **5 Pb/ScFi layers**
- Followed by a **bulk section of Pb/ScFi section**



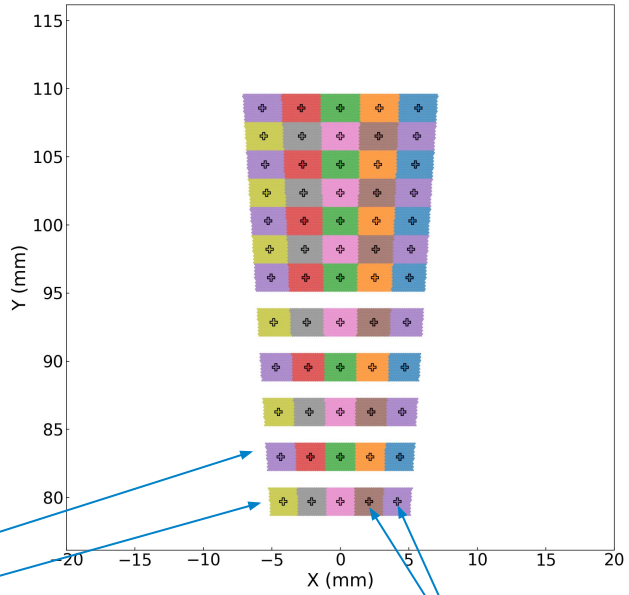
Energy resolution - Primarily from Pb/ScFi layers (+ Imaging pixels energy information)
Position resolution - Primarily from Imaging Layers (+ 2-side Pb/ScFi readout and radial segmentation)

Geometry and Naming Scheme

Sector
Whole Barrel: 48 Sectors



Sector End View
(x-y plane view)



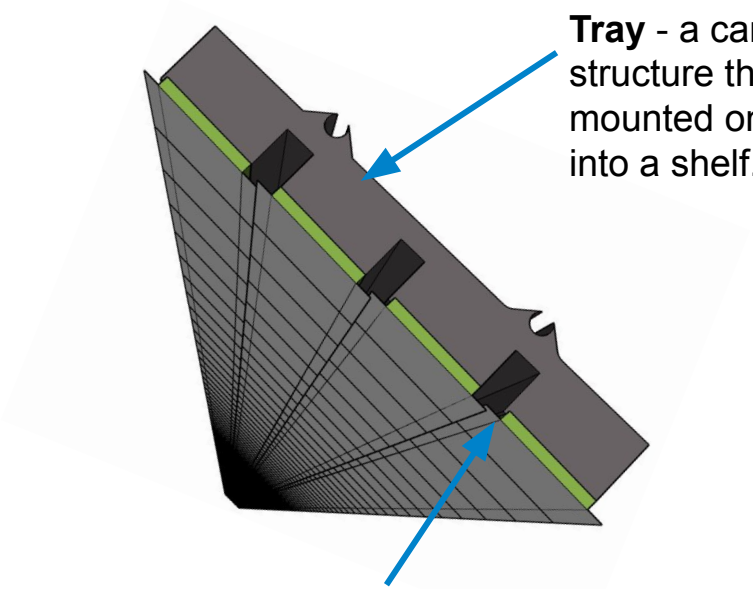
Pb/Sci **Layer**

1 sector = 12 layers
1 layer = 17 rows of fiber

Readout **Cell**
Layer = 5 cells

The area 1 light guide is attached

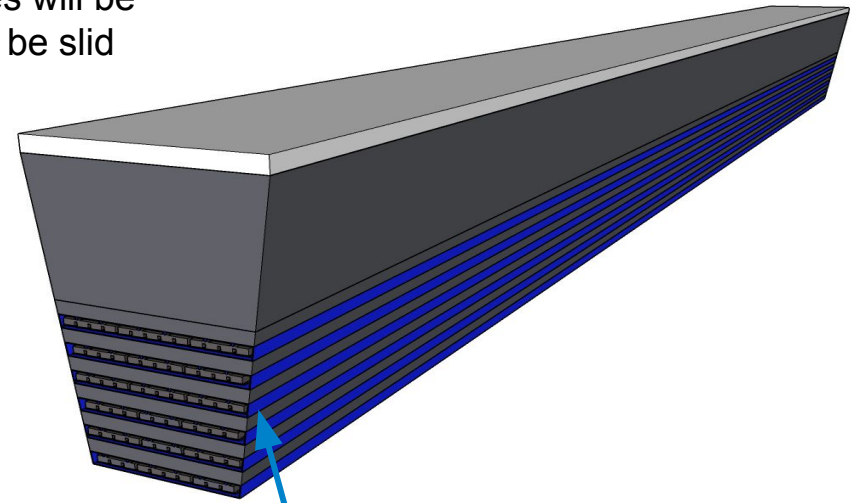
Geometry and Naming Scheme



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



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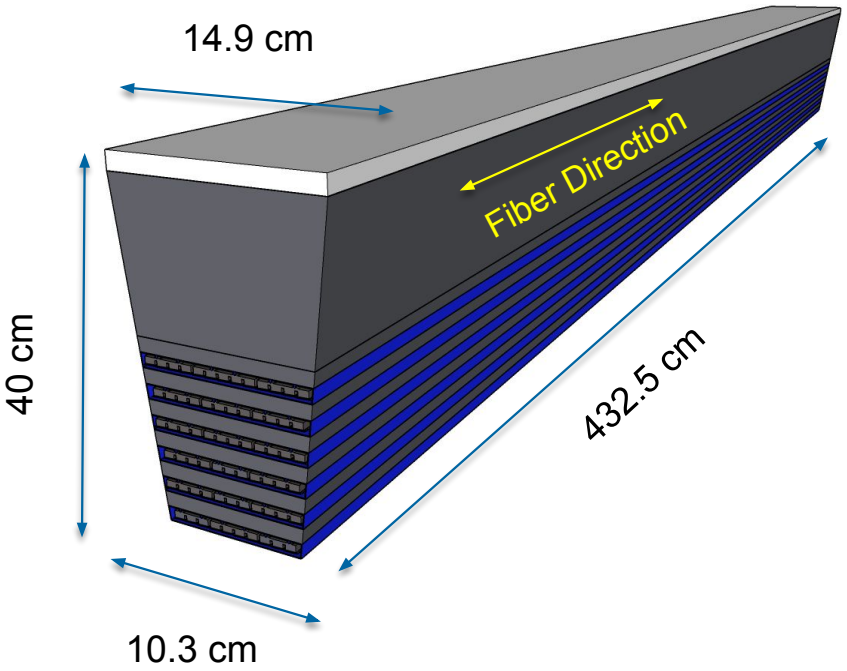
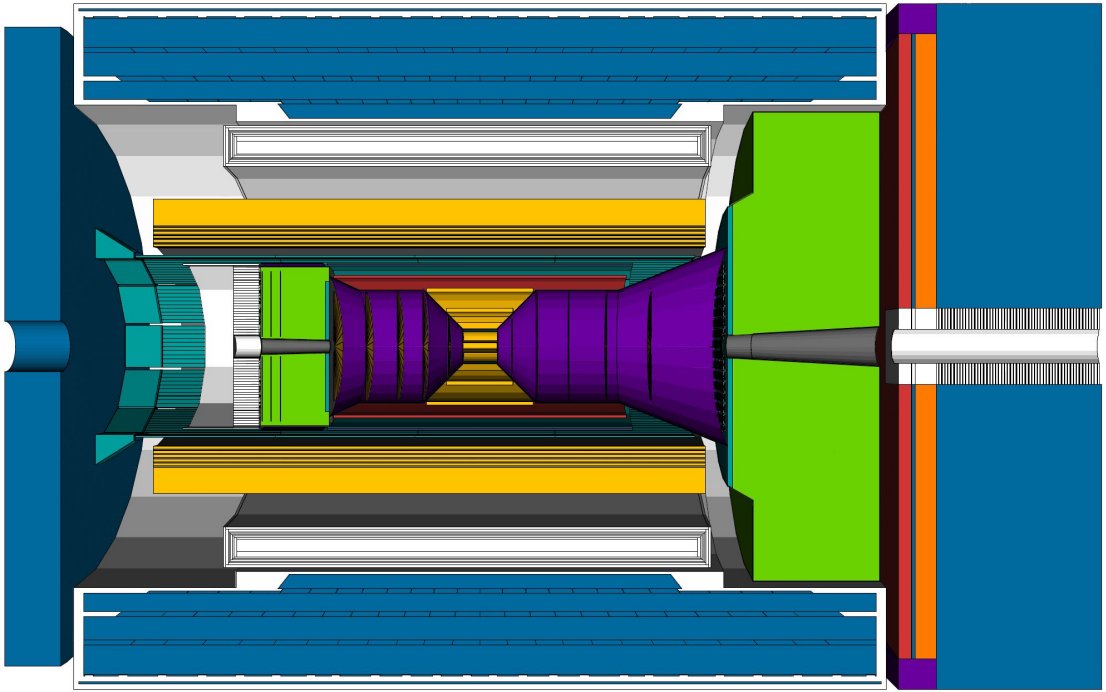
Dimensions



Dimensions a the current stage of the design

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

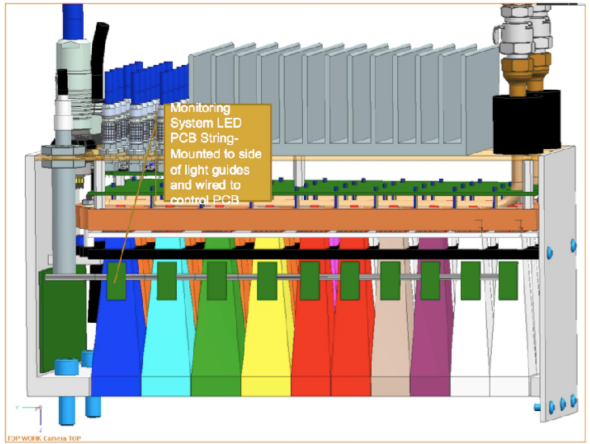
Overall space considerations



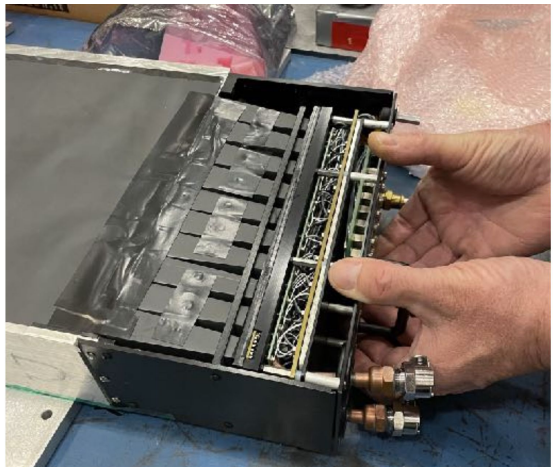
- Lots of space between the barrel EMCal and the solenoid crystat (~ 20 cm)
- Forward region under heavy pressure, space needed for:
  - Barrel EMCal readout box
  - Inner detector services
  - Barrel EMCal and inner detector support
  - dRICH
- Situation a bit more relaxed in the backward region

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.

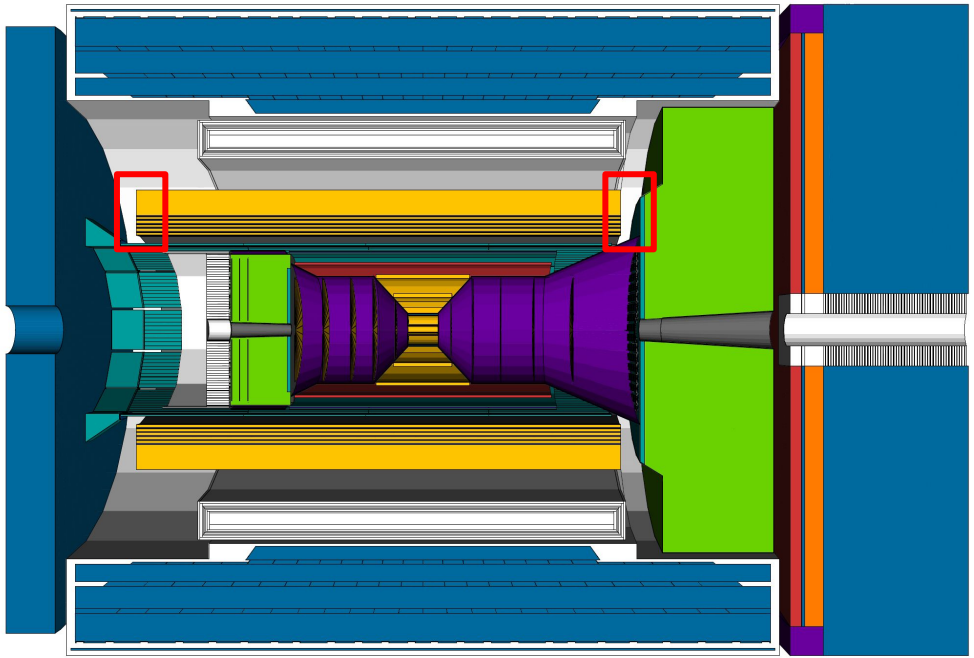


CAD drawing of GlueX readout box



“BabyBCAL” prototype readout box

Barrel ECal Readout & Services



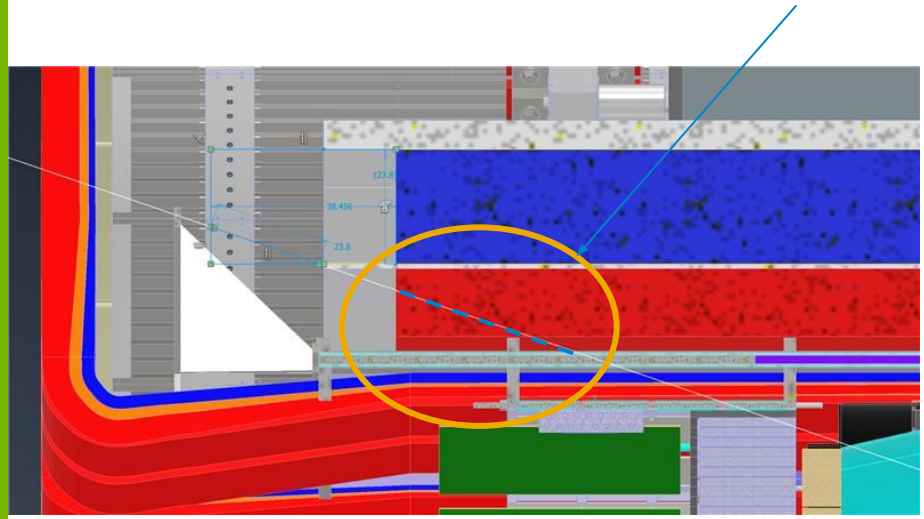
- Nominal 10cm service box at the end of each sector, may have to grow slightly
  - This would put (more) space pressure in the hadron-going direction.
  - May need to shorten calorimeter by a few cm to compensate
- Readout box includes:
  - Pb/ScFi readout components based on the GlueX design (including light-monitoring system)
  - 4 6x6mm2 SiPMs with 50 um 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.

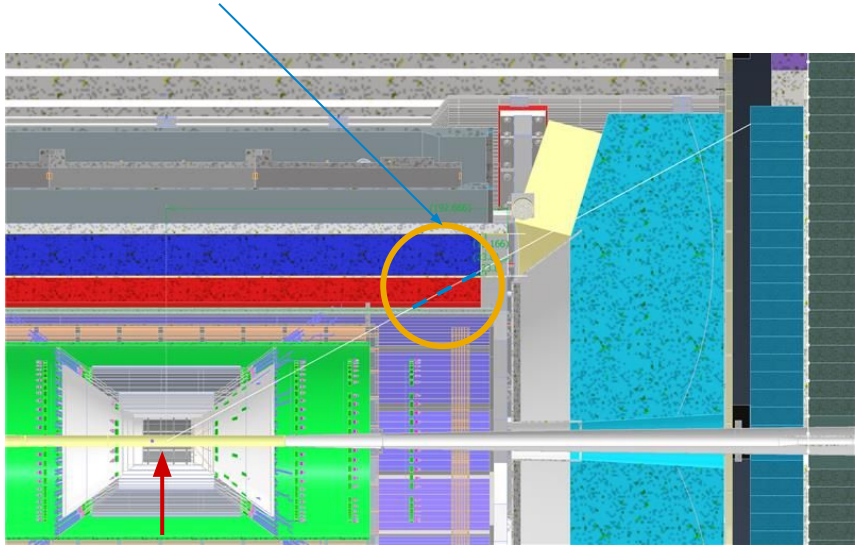
How is your system integrated with the overall ePIC design, i.e., what is the envelope occupied, is there possibly overlap with other subsystems, and is the design consolidated, ...

From Menagerie Tables:

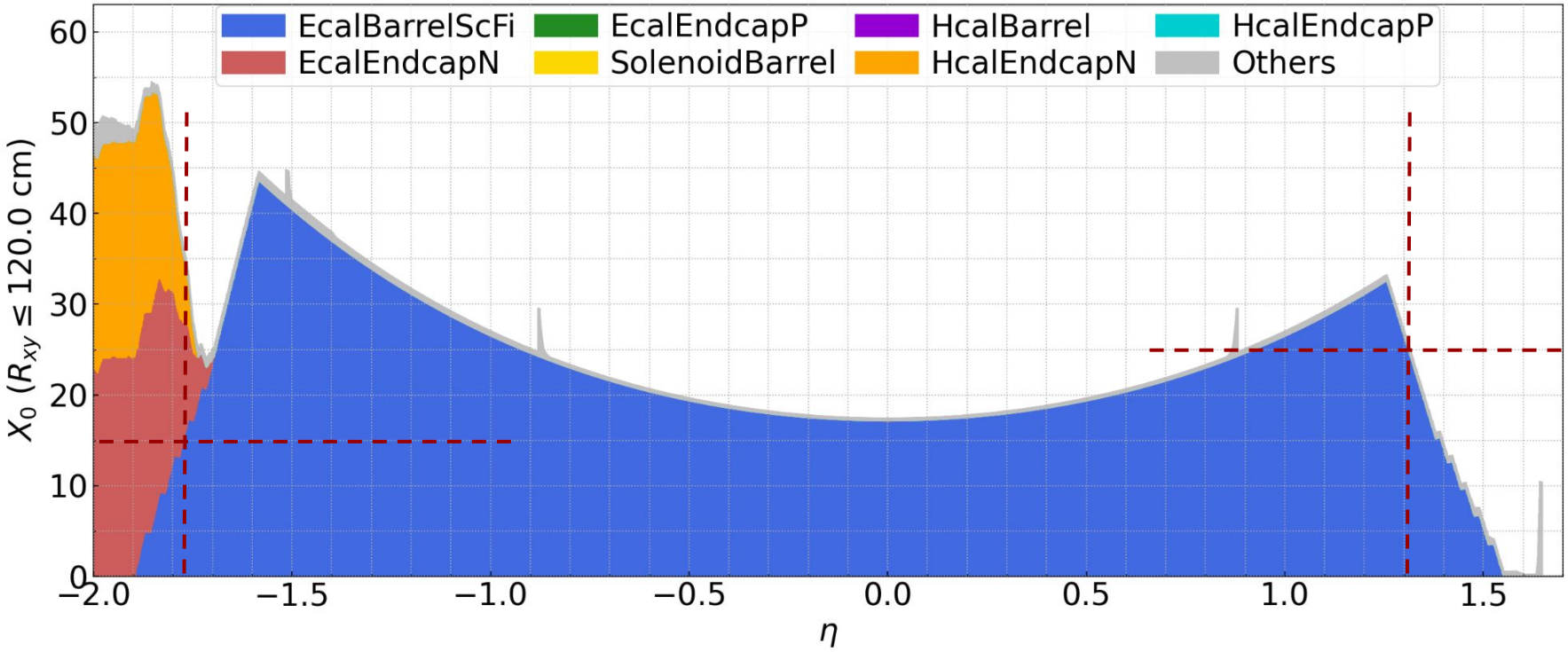
- negative ecal front face at z -174 cm, up to r = 63 cm
- positive ecal front face at z 329.5 cm, up to r = 195 cm
- backward block size = 2 cm, forward module size = 2.5 cm

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





η = -1.77 and +1.31


EcalBarrelScFi
EcalEndcapN
EcalEndcapP
SolenoidBarrel
HcalBarrel
HcalEndcapN
HcalEndcapP
Others
X_0 ($R_{xy} \leq 120.0$ cm)
0
10
20
30
40
50
60
−2.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
η