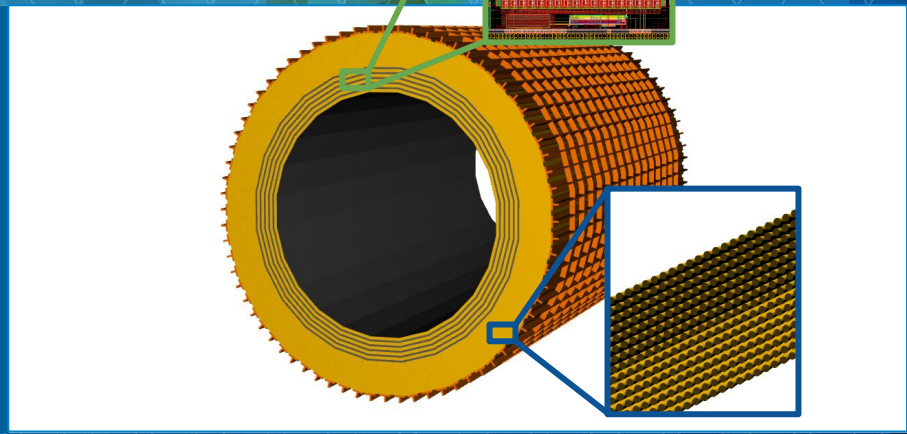
ePIC Collaboration Meeting

January 13, 2024



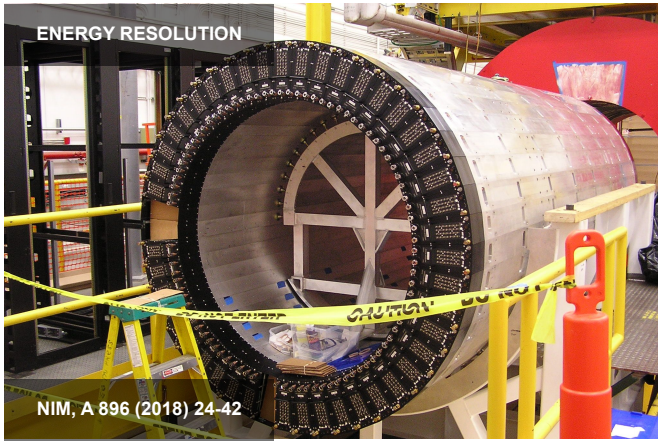
Report:

Barrel ECal DSC Workfest

Jessica Metcalfe
Argonne National Laboratory

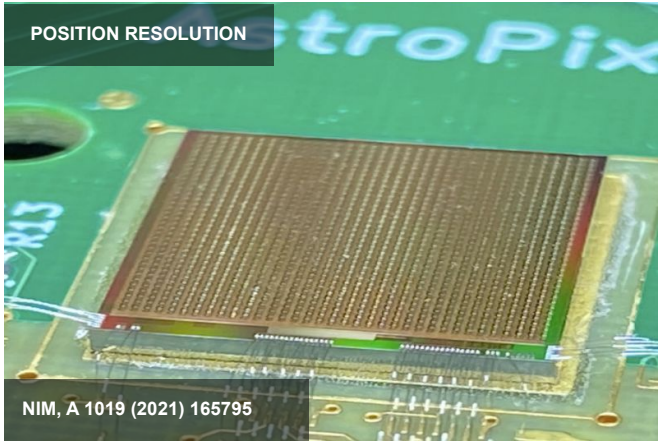
CONCEPT: A HYBRID IMAGING CALORIMETER

Pb/ScFi Sampling Calorimeter



Start from mature layered Pb/ScFi technology with side-readout (same as the GlueX calorimeter) for state-of-the-art sampling calorimeter performance

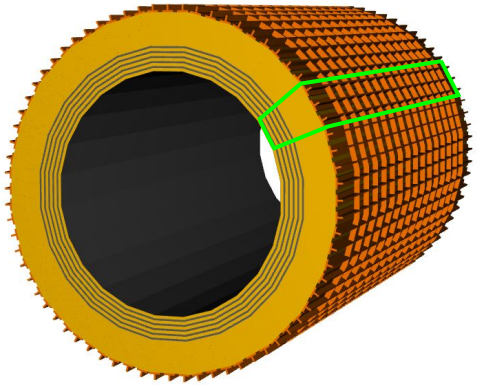
Si CMOS ‘Tracking’ Layers



Insert layers of monolithic AstroPix sensors (inexpensive ultra-low-power silicon sensor developed for NASA) in the first half of the calorimeter to capture a 3-D image of the developing shower

BARREL IMAGING CALORIMETER (BIC)

Components

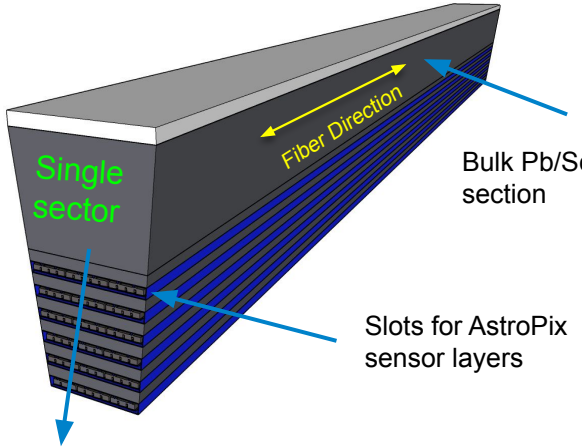


Length: 432.5 cm

Radius: ~ 80 cm radius,

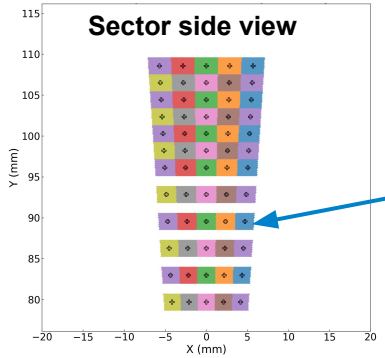
Structure: 48 sectors

η Range: -1.71 < η < 1.31



Bulk Pb/SciFi section

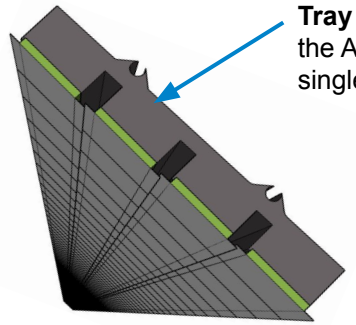
Slots for AstroPix sensor layers



Pb/SciFi **Layer** - 12 layers per sector

Structure: 5 readout cells (one light-guide per readout cell)

Construction: 17 rows of fiber

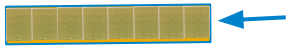


Tray - Structure holding the AstroPix staves for a single layer

Length: ~ 200 cm (half length)

Structure: 6-7 “turbofanned” staves per tray

Stave Structure: ~ 13 **Modules** per stave



Module - Several AstroPix chips daisy-chained together on Flex PCB

Length: ~ 16 cm

Width: ~ 2 cm

Gaps: < 200 μm

Structure: ~ 8 chips/module

USA

Argonne National Laboratory

NASA Goddard Space Flight Center

Oklahome State University

University of Connecticut

University of California Santa Cruz

Canada

University of Manitoba

University of Regina

Mount Allison University

NSERC

Canada Fund for Innovation

Korea

Kyungpook National University

Yonsei University

University of Seoul

Pusan National University

Korea University

Sungkyunkwan University

Hanyang University

Gangneung-Wonju National University

Germany

Karlsruhe Institute of Technology

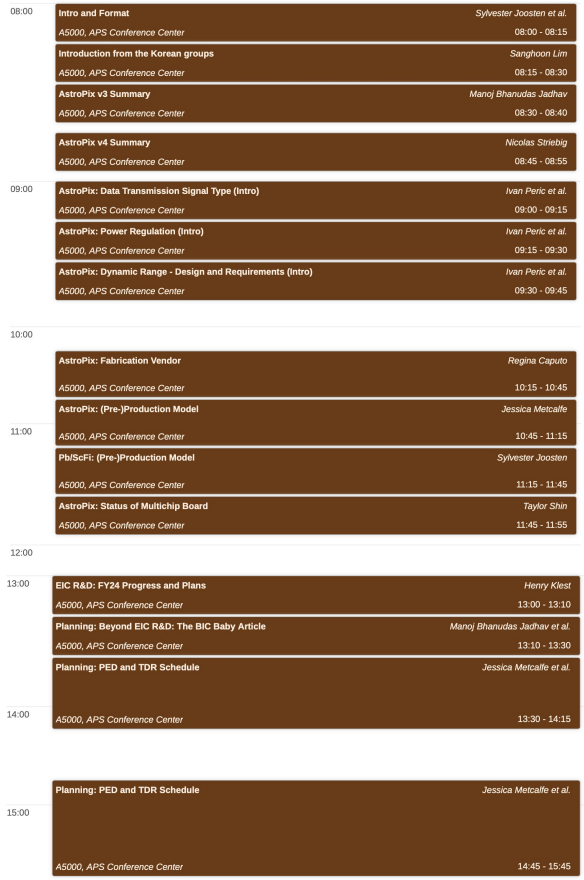
University of Giessen

ePIC BIC Detector Subsystem Collaboration

SCHEDULE

- AstroPix status update
  - v3, v4, vendor fabrication
- AstroPix advanced prototype status/plans
  - wafer probing, multichip boards
- AstroPix Design open technical points
- PbSciFi open technical points
- Readout/DAQ: End-of-Sector Box
- Mechanical Design
- Planning
  - baby BeCal
  - (pre) Production Planning

Agenda:



(day 1)

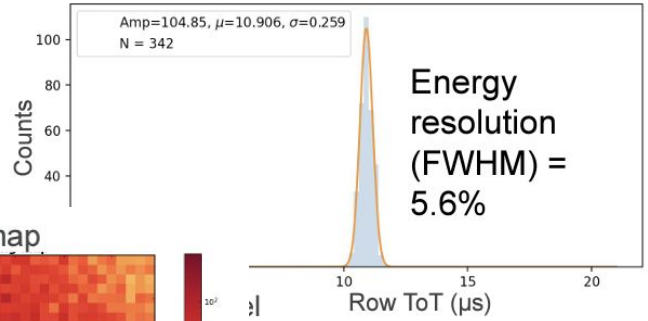
ASTROPIX STATUS

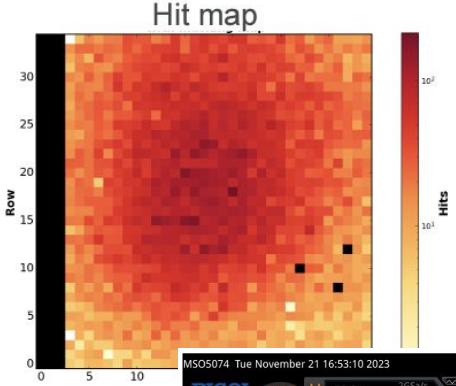
V3 (First full-size 2 cm x 2 cm version)

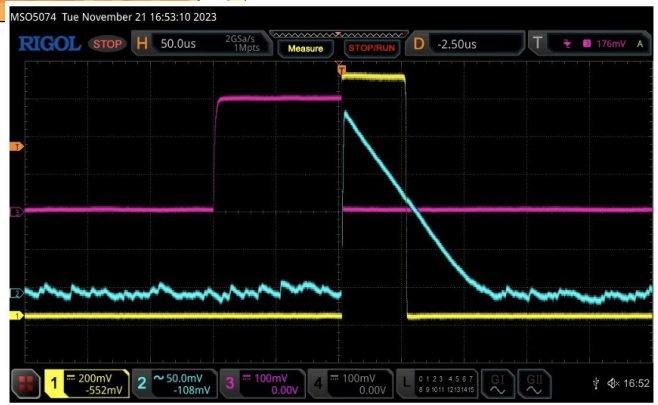
- summary of advanced testing status
  - energy resolution, test beam, irradiations

V4 (Final design, MPW, 1 cm x 1 cm)

- Summary of updates from v3
- First functionality tests
  - all major basic functionalities tested
  - one bug identified: TDC reset too early
    - easily fixed in next version







AstroPix Development Schedule

EIC Project Milestone
New AstroPix version

Not shown:
Early CD4 (Oct 2032)
CD4 (Oct 2034)

We are here

FY19 | FY20 | FY21 | FY22 | FY23 | FY24 | FY25 | FY26 | FY27 | FY28 | FY29

Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3

v3 has comprehensive test program: benchtop and testbeam, irradiation, quad-chip readout for NASA payload mission (A-STEP), integration with Pb/SciFi for ePIC (R&D studies and test article production)

Test
Test
n & Fabr.
Test

first v5 wafers used for preproduction

AstroPix v5
Design & Fabr.

Start of production driven by project fund availability (estimated ~ 1 year after CD2/3)

AstroPix v5 (production)
Production Fab.

Final design and EIC R&D
BIC Preproduction
BIC Production

CD3a
CD3b
CD2/3

Start of BIC installation at BNL

Fabrication Vendor Update

- TSI made v1-v4
- TSI was purchased by Bosch
- Bosch is closing the line to make SiC
- Purchased additional 25 v3 wafers as a backup plan
- Identified several potential new vendor options
- Planning to go ahead with AMS
- Doing an extra run with AMS
  - full size v5 to submit in Spring 2024
- Keep the existing schedule with the final submission in late 2024

AstroPix v3
First full-size chip

2 x 2 cm² chip, 500 µm pixel pitch
Row/column readout
Power dissipation <1 mW/cm²
2.5 MHz timestamp, 200 MHz ToT

AstroPix v4
Final design but smaller size

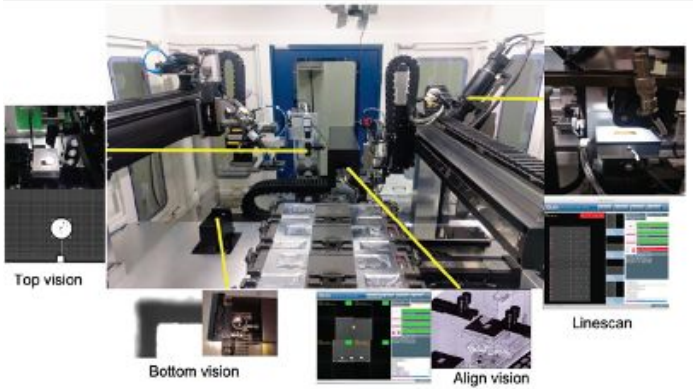
1 x 1 cm² chip, 500 µm pixel pitch
Individual pixel readout
3 timestamps, 3.25ns time resolution
TuneDAC for pixel-by-pixel thresholds

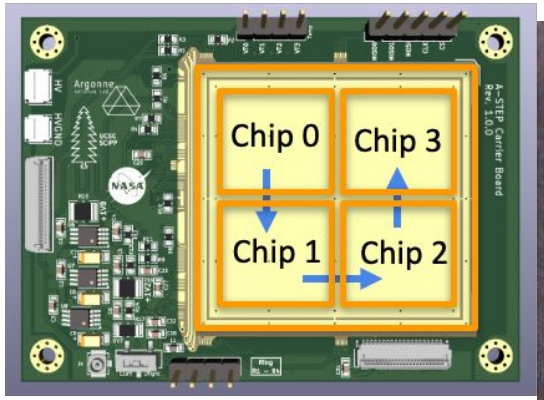
AstroPix v5
Full-size production chip

2 x 2 cm² chip, 500 µm pixel pitch
Design identical to v4 (with bug fixes)

ASTROPIX Advanced Prototype Plans

- Chip/wafer probing is being explored by the Koreans
  - expect to make a first test probe card this year
  - working on a prototype chip testing machine
  - take 1-2 machine to test all in 1 year
- First multi-chip board for a quad chip already made
  - test daisy chaining
  - basis of a module
  - use in larger scale R&D prototypes
- Larger scale version with 8 single chips coming next





ASTROPIX TECHNICAL DISCUSSION

Discussed technical solutions where a modification to the AstroPix chip design might be desired

Dynamic Range: Should we increase the dynamic range?

- Optimized for space application 20 keV - 700 keV
- still get a signal above 700 keV, but the signal saturates and the energy calibration is not as good
- Most hits are below the 700 keV threshold
- Simulation showed a negligible impact on performance

Power Regulation: Should we add on-chip power regulation?

- Off-chip solution is very reasonable
- LDO's on module, power supply sense lines on end-of-tray card

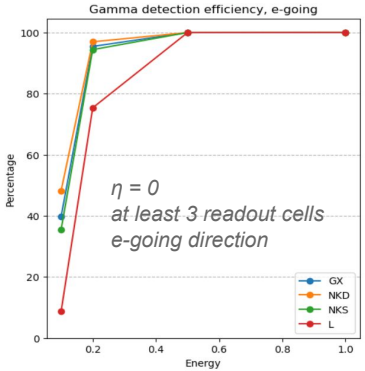
Data Transmission: Should we add the option for differential pair signals?

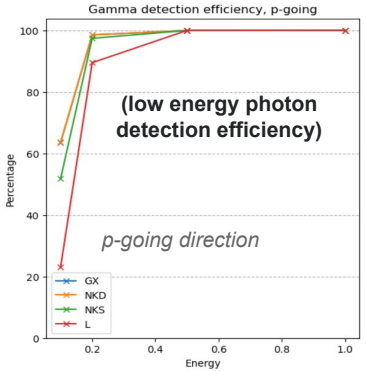
- Modified SPI format should be fine
- Probably want to increase the number of bits for chip ID's

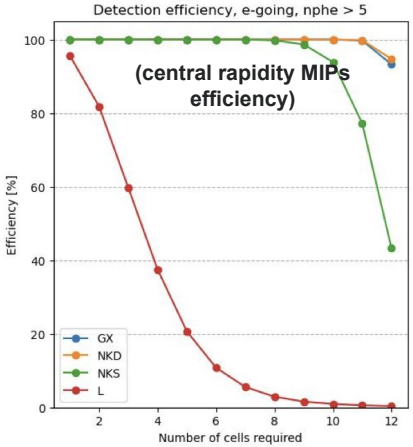
SCINTILLATING FIBER CHOICE FOR LLP (CD3a)

Aim: address final remaining questions

- Large quantity (4500 km) of 1mm fiber
- Candidates:
  - Single-clad (S) versus double-clad (D) fibers:
    Luxium S, **Kuraray S**, and **Kuraray D**
- Projections made based on recent attenuation and light yield measurements (U. Regina, Korea)
- Choice mostly impact low-energy performance:
  - Physics: low-energy photon efficiency and resolution
  - Calibration: MIP efficiency (most stringent requirement)
- **Conclusions:**
  - Luxium S much worse than either Kuraray product → not an option
  - Kuraray D better than Kuraray S (as expected), but 30% more expensive (and more time consuming to produce)
  - **Select: Kuraray single-clad best compromise**



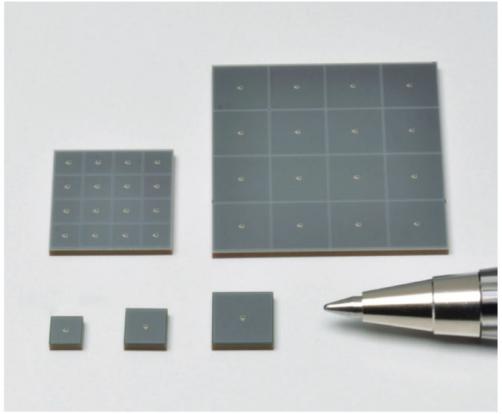


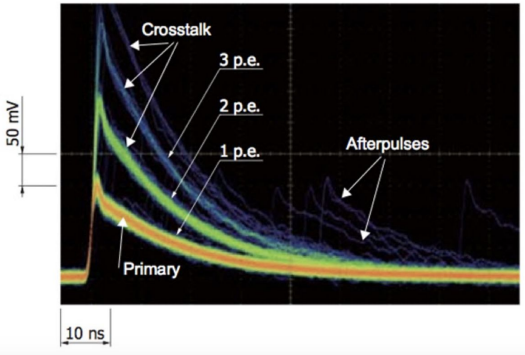


SIPM CHOICE FOR LLP (CD3a)

Aim: define roadmap to come to a decision

- SiPMs choice considerations:
  - Photon detection efficiency (PDE)
  - Dark count rate (DCR), and dark current
  - Pulse shape
  - Temperature dependence
- Candidates: Hamamatsu S13660 (older) and S14160 (newer) series
  - **S13360 → 40% PDE, lower noise, less crosstalk**
  - **S14160 → 50% PDE, likely higher noise, more crosstalk**
- Timeline: Need final decision by Fall 2024
- Strategy:
  - Measure S14160 (and S13360) Dark Count Rate for our case
  - Irradiation test and noise projections for ePIC
  - DAQ considerations (rates, potential coincidence requirement in DAM)
  - Lessons learned from GlueX (e.g. self-annealing analysis)
  - Aim to finish by June

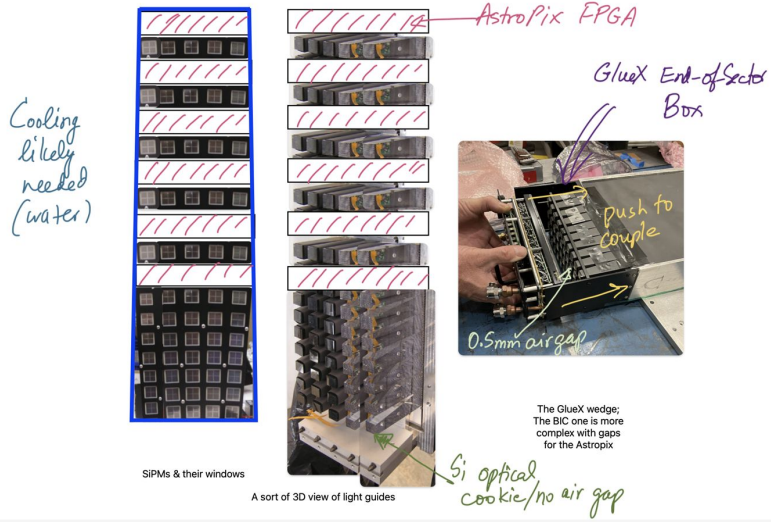


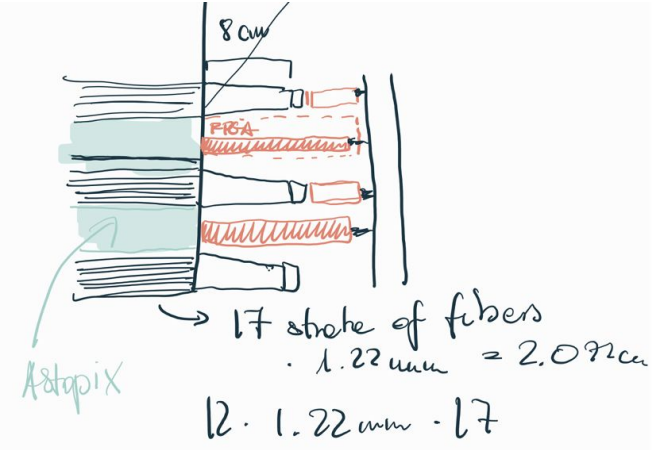


READOUT DISCUSSION

End-of-Sector Box

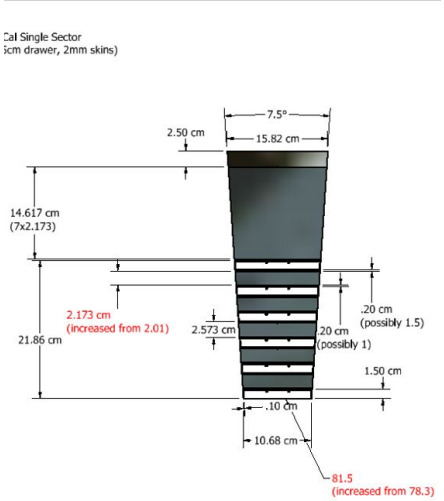
- Consists of readout and services panel for SciFi and AstroPix
  - SciFi with light guides and SiPM's
  - AstroPix end-of-tray card with FPGA
  - patch panel for off-detector cooling, power, signal lines, monitoring (temperature,interlock,...)
- Discussed HGCROC as a solution for SciFi/SiPM readout
- Heat from AstroPix End-of-tray card FPGA has the potential to have a major impact on fiber read-out performance
- Top priority to establish envelope interfaces, and heat/cooling interfaces for the EoS Box

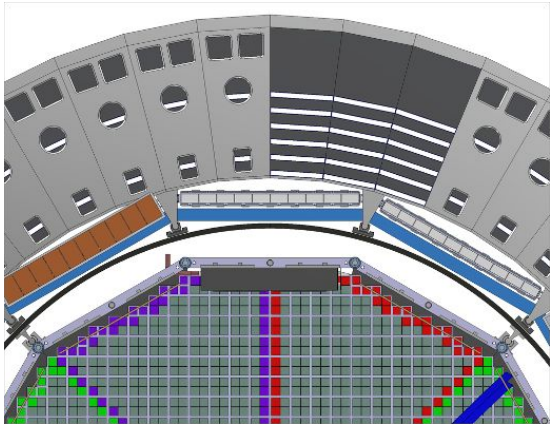


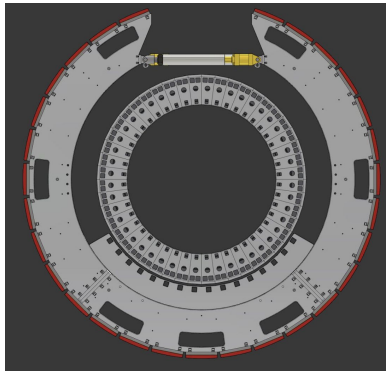


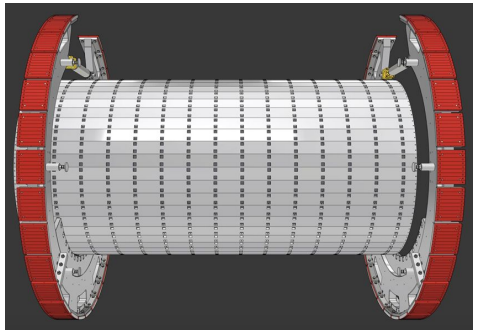
MECHANICAL ENGINEERING

- Reviewed the updates since last meeting
  - triangular supports for the tracker support
  - Al plate thickness
  - expect additional updates due to AstroPix module design
- Reviewed integration procedures
- Support scheme is different from GlueX + we support the Inner Detector
- Generally we have a lot of work to finalize designs to make sure the loads are properly supported



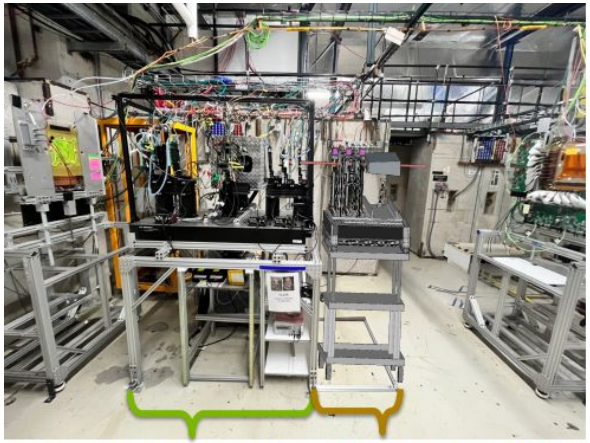






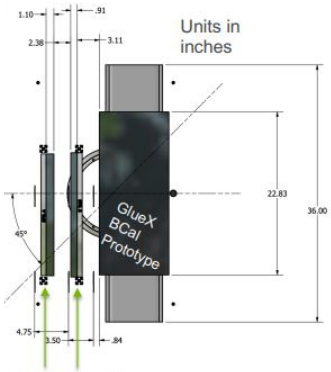
sPHENIX support rings

R&D AND BEYOND



Current ANL AstroPix Telescope Setup

Planned BIC Setup



Integrated rotatable setup of Baby BCal, AstroPix boards, and thin SciFi layers

- With limited beamtest capabilities at FNAL in FY24 main focus on i**ntegration of SciFi Baby BCal** (60 cm long) **with AstroPix** (single or quad chip) **on bench**
  - **Main tasks:** synchronization of SiPM and AstroPix signals and DAQ
  - Simple test article benchmark (SiPM with HGCROC + AstroPix) in beam test environment at CERN - Possible collaboration with ORNL group
- Simulation benchmark of SciFi/Pb matrix response to pions: possibility to use GlueX data (pion-enhanced sample from decays?)
- Baby BCal setup will serve to test and integrate different components of BIC: AstroPix octo-board, module test articles, end-of-sector box, readout integrations

(PRE-) PRODUCTION MODEL DISCUSSION

- Discussed PED planning
  - transition from R&D efforts
  - roadmap to complete final designs
- Discussed the production model
  - assembly procedures
  - yield models
  - single flavor and other choices to simplify production procedures
  - automated industrial style assembly for the BeCal tracker
- Items to keep an eye on
  - AstroPix yield model
  - wafer testing time
  - precision needed for last sector assembly

NEXT STEPS

Toward the Final Design

- Finalize all specifications (internal interfaces) and freeze in mid-March
  - Designers/engineers can work in parallel towards a first draft of final designs
- Informal internal review and update of interfaces in early summer
  - Document and prepare for PDR in summer/fall
- Validation test articles for final desings will be made during 2024
  - Validation testing complete by the end of year
  - Any updates to the final designs complete by CD2

Next Workshops

- Online mini-workshop in March to freeze designs
- In-person workshop at Argonne the week of **May 13th (2.5 days)**
- PDR in summer/fall 2024

SUMMARY

- PbSciFi design mature thanks to GLUE-X experience
- AstroPix chip design is also very mature
- AstroPix services at a conceptual stage
  - need to advance the designs quickly
  - designs are not overly complex or constrained
  - once funds become available this should move fast
- End-of-sector box is fairly constrained
  - not a lot of space
  - heat from Tracker end-of-stave cards needs attention
- Mechanics design, especially load bearing interfaces needs to finalized as soon as possible
  - large scale engineering test articles are needed/planned
- We have a general work plan for 2024 complete and will finalize a more detailed one soon
- We have a lot of work ahead of us, but we have a good team in place, a solid plan, and excitement is high
- We welcome new collaborators!

BACKUP

MEETING FORMAT

What do we want to accomplish with this meeting?

- Capitalize on having many key people here in person, so favor discussion over presentation
  - **Targeted technical discussions** on key items, such as technical discussions on the AstroPix sensor, the Pb/ScFi LLP items, Readout, Mechanical Design
  - For many of our technical discussion, we have short intro talks, followed by a discussion later, sometimes even the next day (to allow for homework)