Discussion about next HPK productions for EIC

Koji, Artur, Zhenyu

11/14/2023

Next HPK Production (update on 11/14)

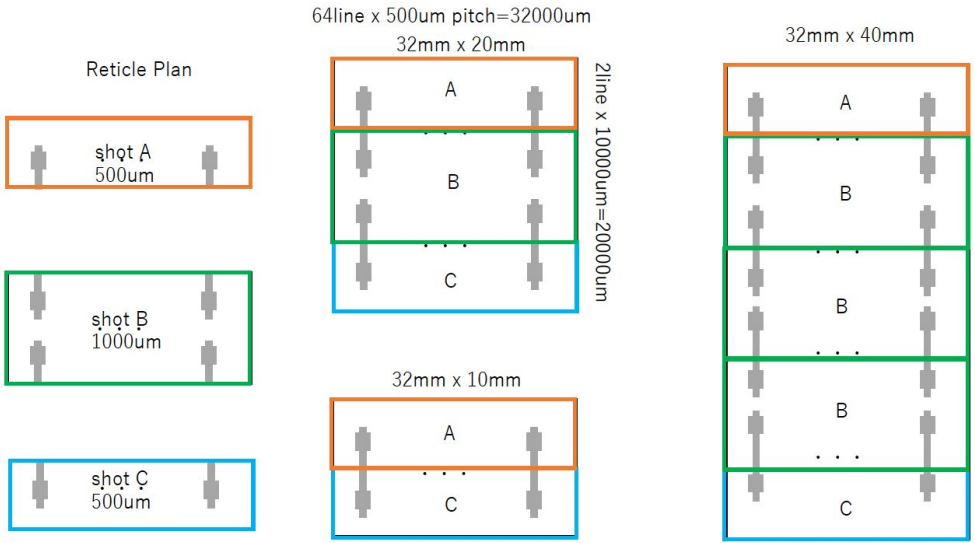
- Improve timing and spatial resolutions
  - 1-cm long, 50-um thick, E-type strip: need to improve timing resolution from ~35 to <30 ps
    - Suffer from small amplitude, increasing sensor thickness and/or reducing charge sharing (higher resistivity or lower interstrip capacitance, or wider metal width) can help?
    - Smaller electrodes to reduce interstrip capacitance,

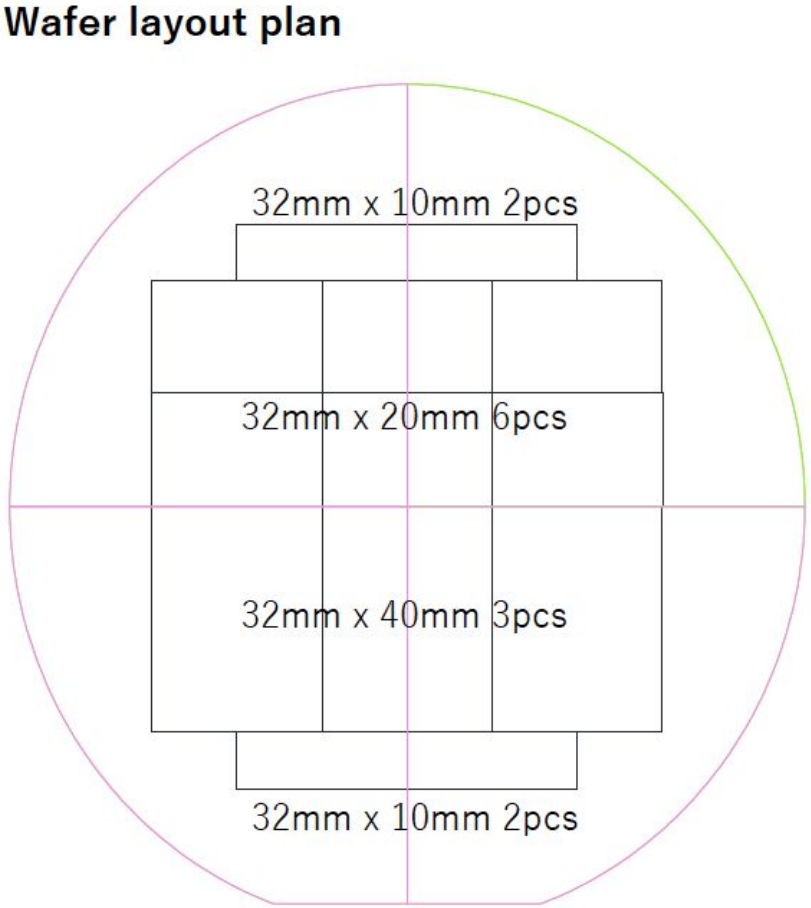
      -> reduce metal width from 50 um to 40 um? (possible down to 10 um but increased resistivity)

      -> shorten the electrodes and increase pitch?

      -> reduce the thickness from 50 um to 35/40 um? Ask HPK
  - 150-um metal, 20-um thick, pad: improve spatial resolution under metal from ~50 to 20 um
    - Reduce metal electrode width from **150 to 100-75-50 um -> Doable**
    - **20/50->20/30 um thick? -> Doable**
- Produce large sensors for module assembly
  - Strip baseline: 64*4 strips with 500-um pitch and 1-cm length, with active area 3.2x4 cm^2
    - **One wafer can include four 3.2x1 + six 3.2x2 + three 3.2x4 cm^2**
  - Pad baseline: 32*32 pads with 500-um pitch, with active area 1.6*1.6 cm^2
    - **One wafer can include twenty 1.6x1.6 cm^2, two types**
  - Previous production 2x2 cm2 yield was low. No guarantee in good yield for test production
    - **Purchase good dies instead of number of wafers**

Proposal to Stitch Strip Sensors by HPK (11/14)





Discussion about next HPK productions for EIC

Koji, Artur, Zhenyu

11/1/2023

Early Summary

- By CD2/3 review (10/2024), the EIC detector design should be 90% final (70-80% is not ideal but acceptable).

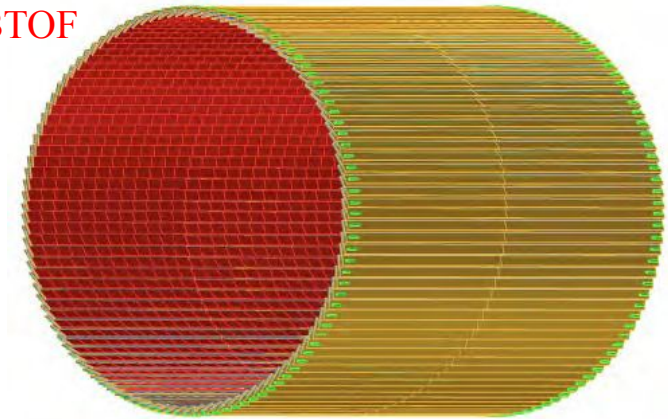
- Encouraging results from the sensors from the first HPK production.

- Next HPK production(s), ideally tested in Spring 2024 focus on
  - Improve timing resolution for strip sensor, and spatial resolution under the metal for pad sensors
  - Produce large sensors in preparation for CD2/3 (module prototyping, cost/yield estimates)

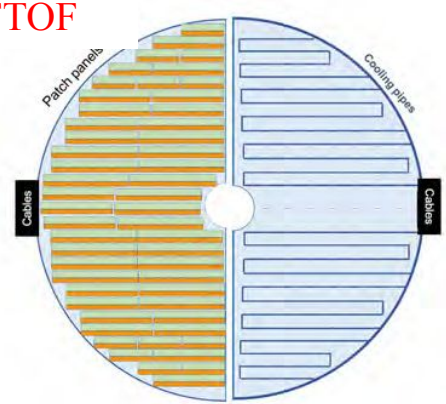
- Question: schedule/cost of such productions, cost for construction

AC-LGAD Detectors for ePIC

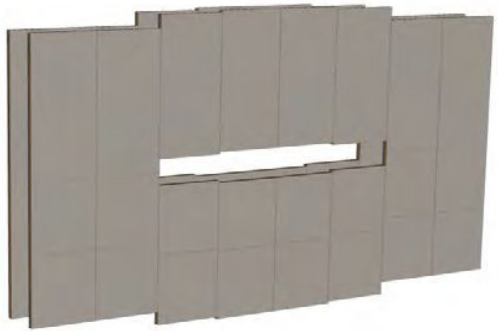
BTOF



FTOF



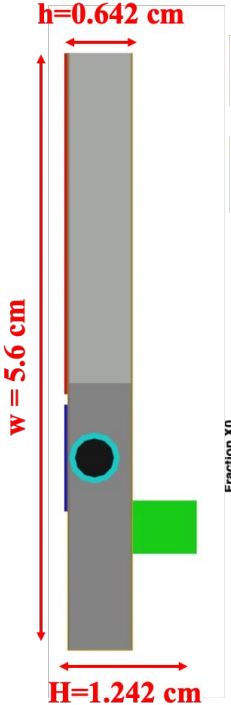
Roman Pots

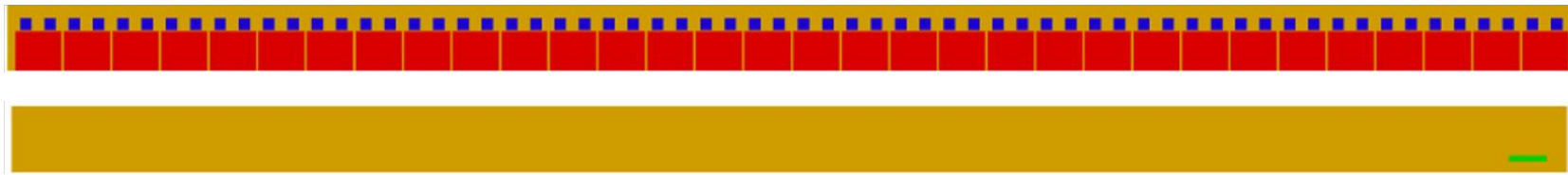


	Area (m^2)	Channel size (mm^2)	# of Channels	Timing Resolution	Spatial resolution	Material budget
Barrel TOF	10	0.5*10	2.4M	35 ps	30um	0.01 X_0
Forward TOF	1.4	0.5*0.5	5.6M	25 ps	30um	0.025 X_0
B0 tracker	0.07	0.5*0.5	0.28M	30 ps	20 um	0.05 X_0
RPs/OMD	0.14/0.08	0.5*0.5	0.56M/0.32M	30 ps	30um	no strict req.

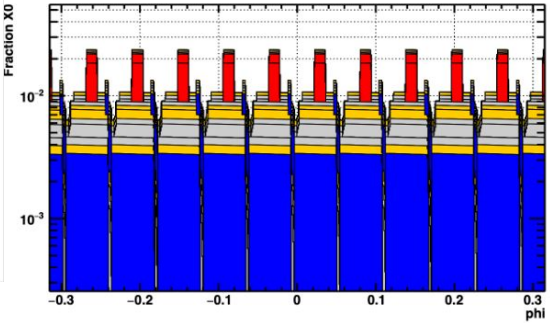
the design matures, and we will continue to explore common designs for these detectors where possible to reduce cost and risk.

ePIC BTOF Detector Module Conceptual Design





- **64 AC-LGAD strip sensors**, each 3.2*4 cm^2 read out by **2 ASICs**
- **Low mass flexible Kapton PCB** distributes power and I/O signals from connector
- **Liquid coolant** in **Al tube** embedded in CF light-weight structure for heat removal

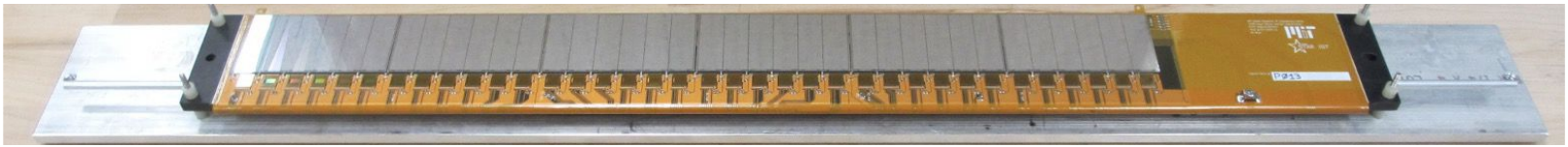


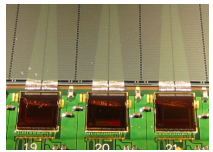
144 modules, each with 2 readout boards with 2 LV+HV cables, 2 DAQ fiber, and 1 cooling line

Power consumption: ~4 kW (2.4kW for ASIC, 1 kW for DC-DC, 0.6kW for sensors+cable)

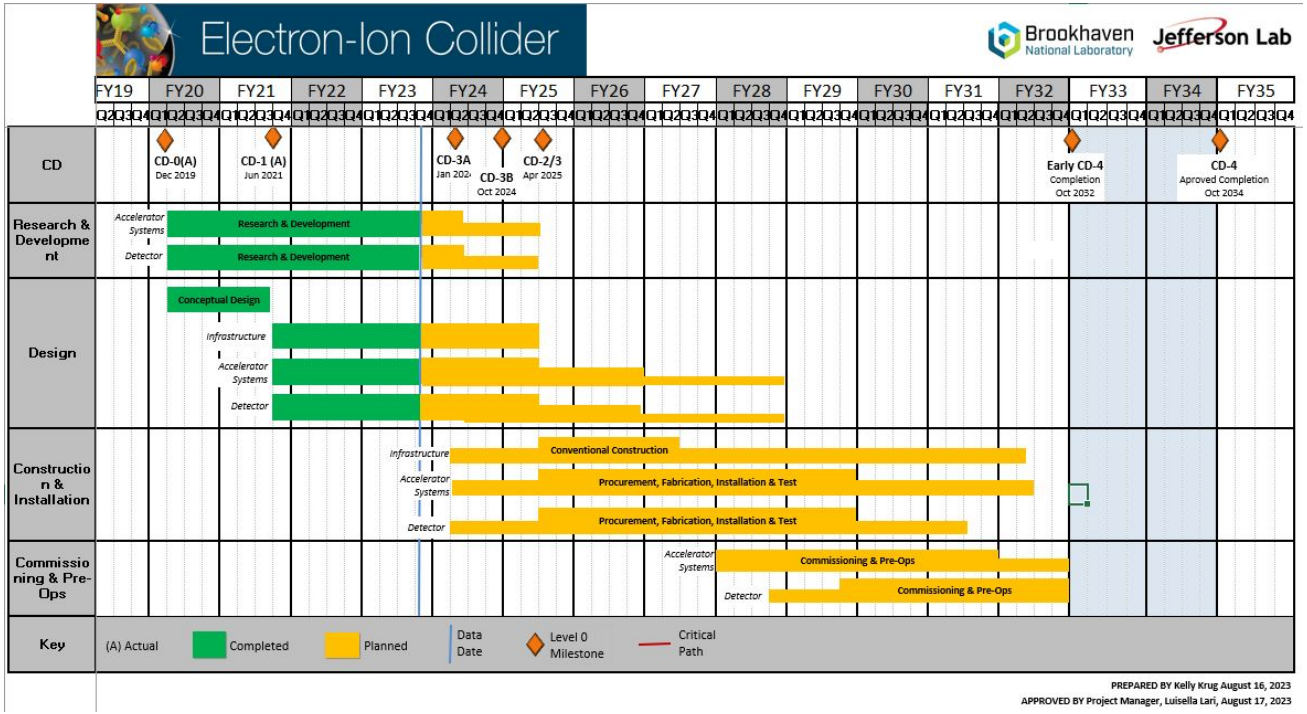
Total weight: ~70 kG

STAR IST

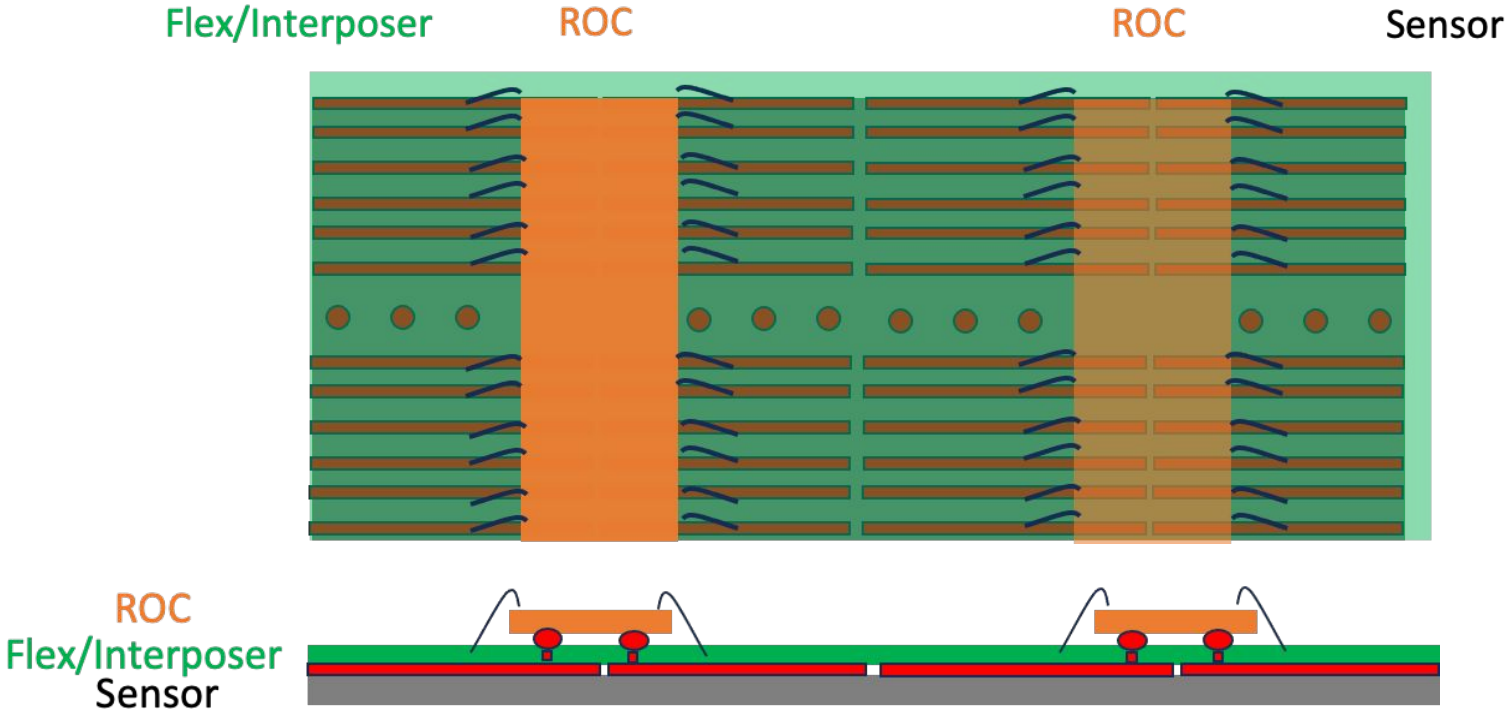




EIC Project Schedule



- R&D – to April 2025 (CD-2/3)
- Design – to October 2028
- Construction & Installation – to April 2031
- Commissioning & Pre-Ops – to October 2032

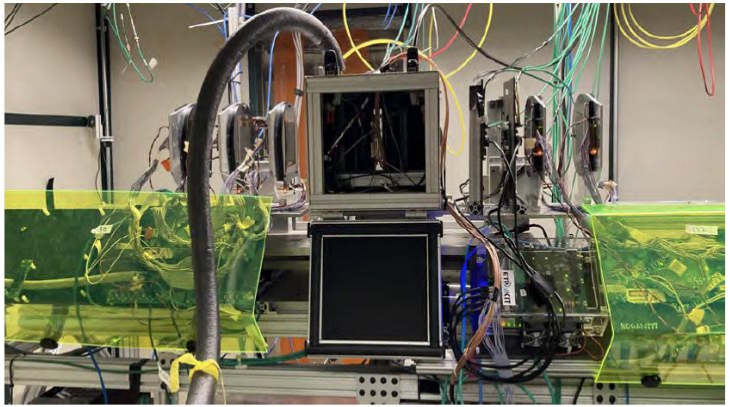

Flex/Interposer
ROC
ROC
Sensor
ROC
Flex/Interposer
Sensor

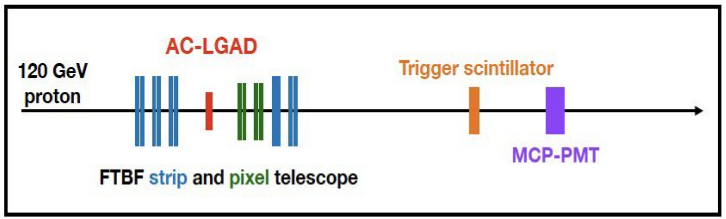
AC-LGAD Sensor R&D

- **Sensor**
  - Sensors with different configurations produced by BNL-IO and Hamamatsu, and tested with 120GeV protons
  - Prototype strip sensors with ~34 ps time resolution and 12-15 um spatial resolution for BToF.
  - Prototype pixel sensors with ~20 ps time resolution and ~20* um spatial resolution for FToF, B0, RPs/OMD.

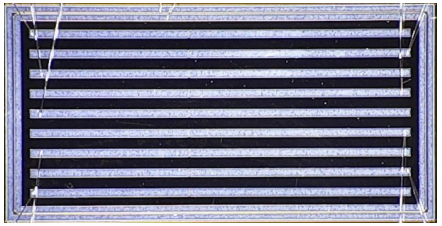
* ~50 um under the metal eletrode. To be improved

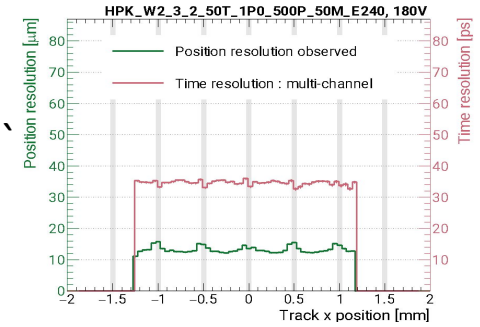
Fermilab Test Beam Setup



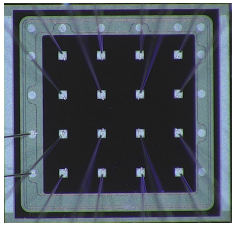


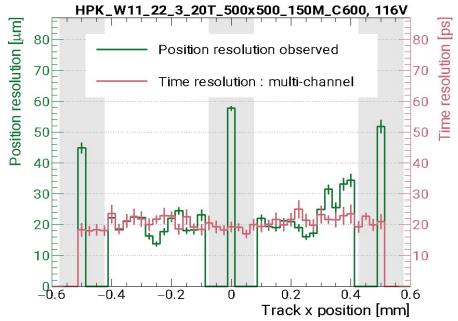
HPK Strip Sensor (4.5x10 mm^2)





HPK Pixel Sensor (2x2 mm^2)





Two? HPK Productions

- Improve timing and spatial resolutions
  - 1-cm long, 50-um thick, E-type strip: need to improve timing resolution from ~35 to <30 ps
    - Suffer from small amplitude, increasing sensor thickness and/or reducing charge sharing (higher resistivity or lower interstrip capacitance, or wider metal width) can help?
    - E-type is the highest resistivity HPK, 50 um dominated by Landau so not thicker
    - Smaller electrodes to reduce interstrip capacitance

      -> **reduce metal width from 50um? Shorten the electrodes and increase pitch?**
  - 150-um metal, 20-um thick, pad: improve spatial resolution under metal from ~50 to 20 um
    - Reduce metal electrode width from **150 to 100-75-50 um -> Doable**
    - **20->30 um thick? -> Doable**
- Produce large sensors for module assembly
  - Strip baseline: 64*4 strips with 500-um pitch and 1-cm length, with active area 3.2x4 cm^2
    - Start from 1.6x2, **3.2x2?**, or 3.2x4 cm^2
  - Pad baseline: 32*32 pads with 500-um pitch, with active area 1.6*1.6 cm^2
    - Start from **1.6x1.6?**, 1.6x3.2, or 3.2x3.2 cm^2
    - Previous production 2x2 cm2 yield was low, cracks in wafer materials, will try to avoid but not guaranteed. **Ask HPK**

Summary

- By CD2/3 review (10/2024), the EIC detector design should be 90% final (70-80% is not ideal but acceptable).

- Encouraging results from the sensors from the first HPK production.

- Next HPK production(s), ideally tested in Spring 2024 focus on
  - Improve timing resolution for strip sensor, and spatial resolution under the metal for pad sensors
  - Produce large sensors in preparation for CD2/3 (module prototyping, cost/yield estimates)

- Question:
  - schedule/cost of such R&D productions
  - cost for construction (HPK-US)