

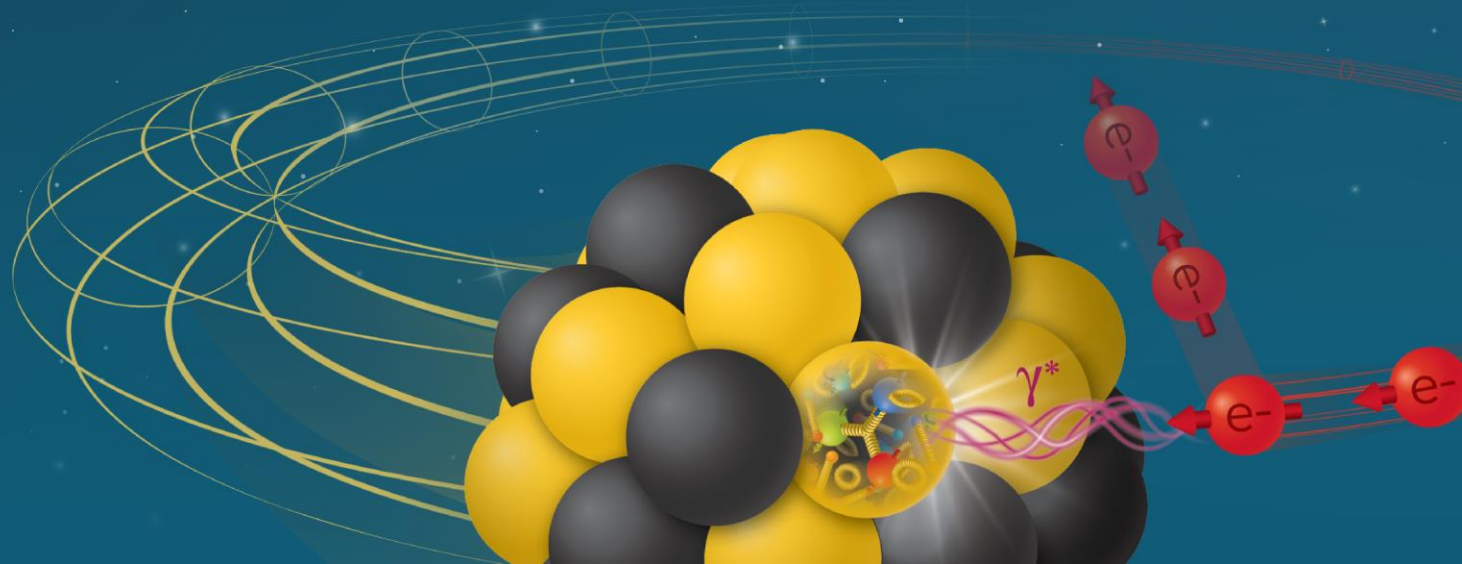
# ePIC MPGD Tracker Status

Kondo Gnanvo (JLab), Annalisa D'Angelo (INFN Roma), Francesco Bossu (CEA Saclay)  
DSL & DSTCs on behalf of the ePIC Gaseous Trackers (MPGD-DSC)

10<sup>th</sup> EIC DAC Review

June 11<sup>th</sup> – 13<sup>th</sup>, 2025

Electron-Ion Collider



# Charge Questions Addressed

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1. Is the design of the ePIC detector and its sub-systems appropriate and progressing well?
2. Are the remaining work and technical, cost and schedule risks adequately understood? Are there opportunities?
3. Will the detector be technically ready for baselining by late 2025?
4. Are the detector integration and planning for installation and maintenance progressing well? Are there areas where further ideas should be pursued?
5. Will the detector be ready for start of construction by late 2026?

# Outline

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## Cylindrical Micromegas Barrel Layer (CyMBaL)

- Detector design: envelope and active regions, dimensions and geometries
- Ongoing activities, Timeline.

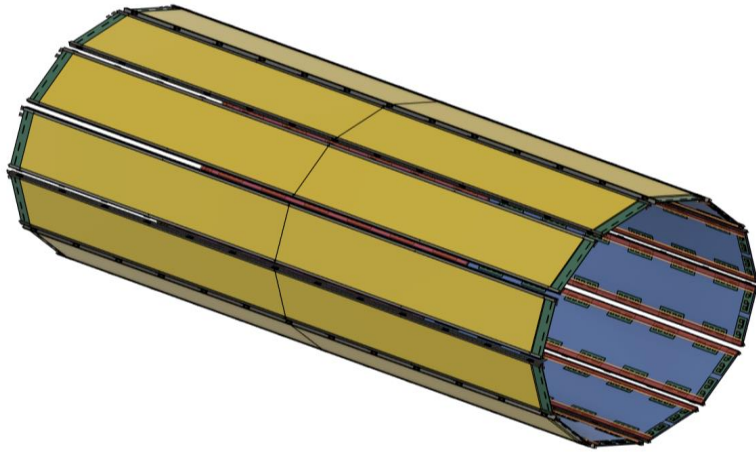
## $\mu$ RWELL Barrel Outer Tracker ( $\mu$ RWELL-BOT)

- Detector design: envelope and active regions, dimensions and geometries
- Ongoing activities, Timeline.

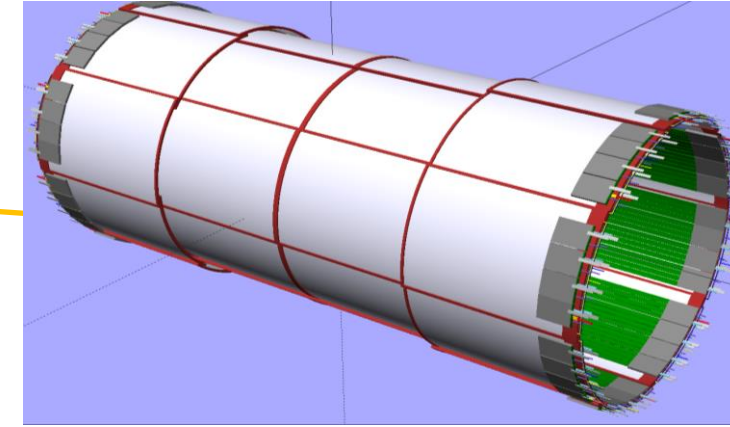
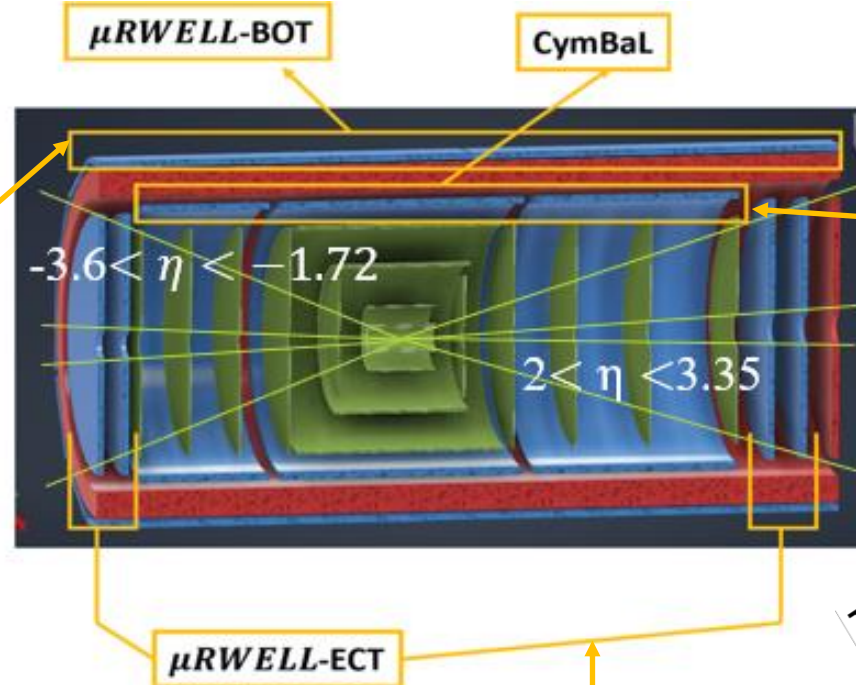
## $\mu$ RWELL End Cap Tracker ( $\mu$ RWELL-ECT)

- Detector design: envelope and active regions, dimensions and geometries
- Ongoing Activities, Timeline.

# Introduction: Overview of MPGD Trackers in ePIC Central Detectors



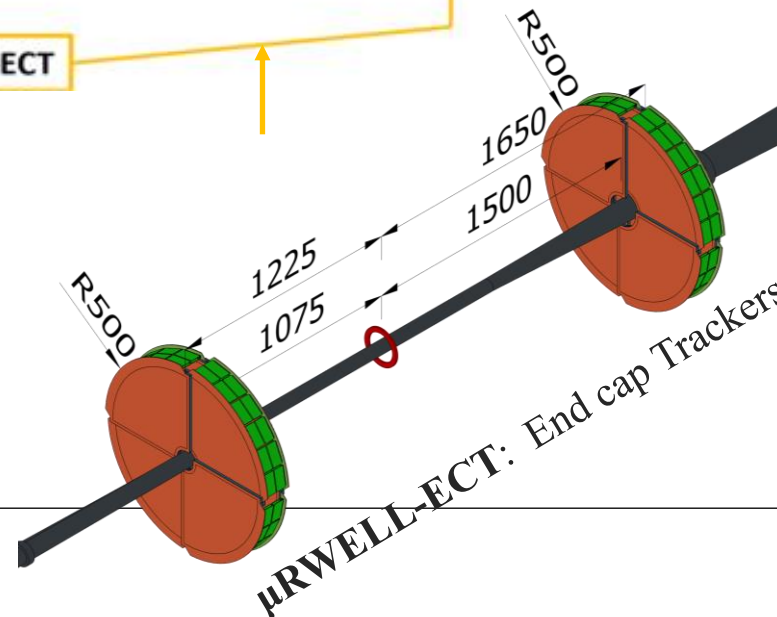
**μRWELL-BOT: Barrel Outer Tracker**



**CyMBaL: Inner Barrel Layer**

## ePIC MPGD trackers provide:

- ❖ Fast timing capability ( $\sim 10 - 20$  ns) to help slow Si trackers with pattern recognition in high background.
- ❖ additional hit points capabilities for tracking
- ❖ Precision tracking to enhance hpDIRC performance



Electron-Ion Collider



# Inner MPGD layer: CyMBaL

Cylindrical Micromegas Barrel Layer



CEA Saclay team

F. Bossù (PI), F. Jeanneau (PL), A. Delbart  
A. Francisco, M. Vandenbroucke, D. Neyret, I. Mandjavidze

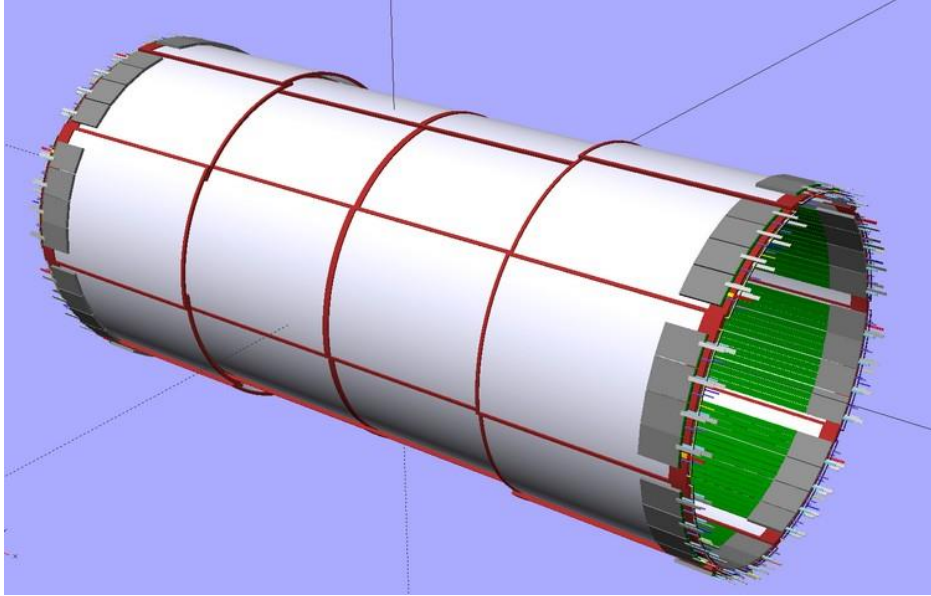
EIC Detector– 10th DAC Meeting  
June 11-13, 2025

Electron-Ion Collider

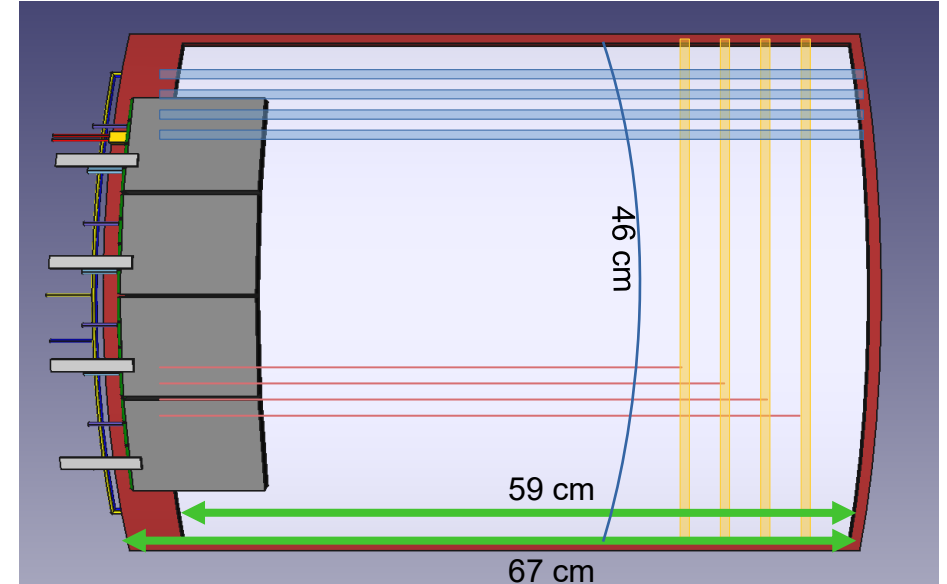


# CyMBaL: Cylindrical Micromegas Barrel Layer Design

CyMBaL: Current design



Design of a module



**32 curved tile modules: 8 modules in  $\phi$   $\times$  4 modules in z**

- ❖  $R_{\min} = 55$  cm;  $R_{\max} = 60.5$  cm
- ❖ Overlaps in  $\phi$  and in z for hermeticity
- ❖ 1024 readout channels/module
- ❖ **32K readout channels**

## Module dimensions

$Z = 67$  cm

$R^*\phi = 48$  cm

## Active zone dimensions

$Z = 59$  cm

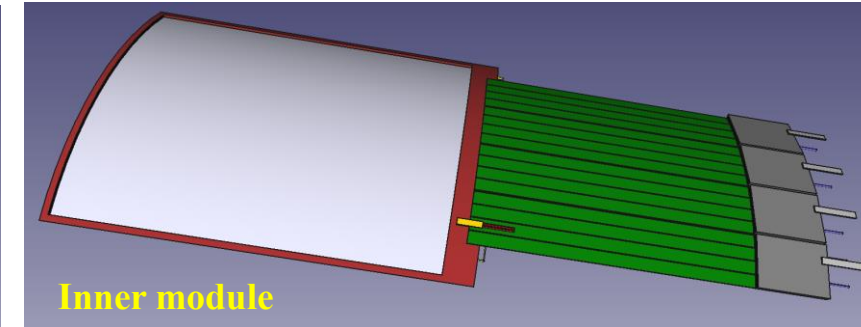
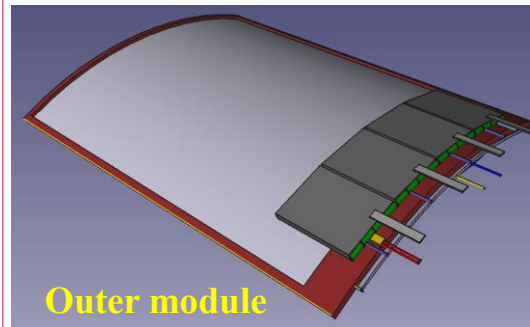
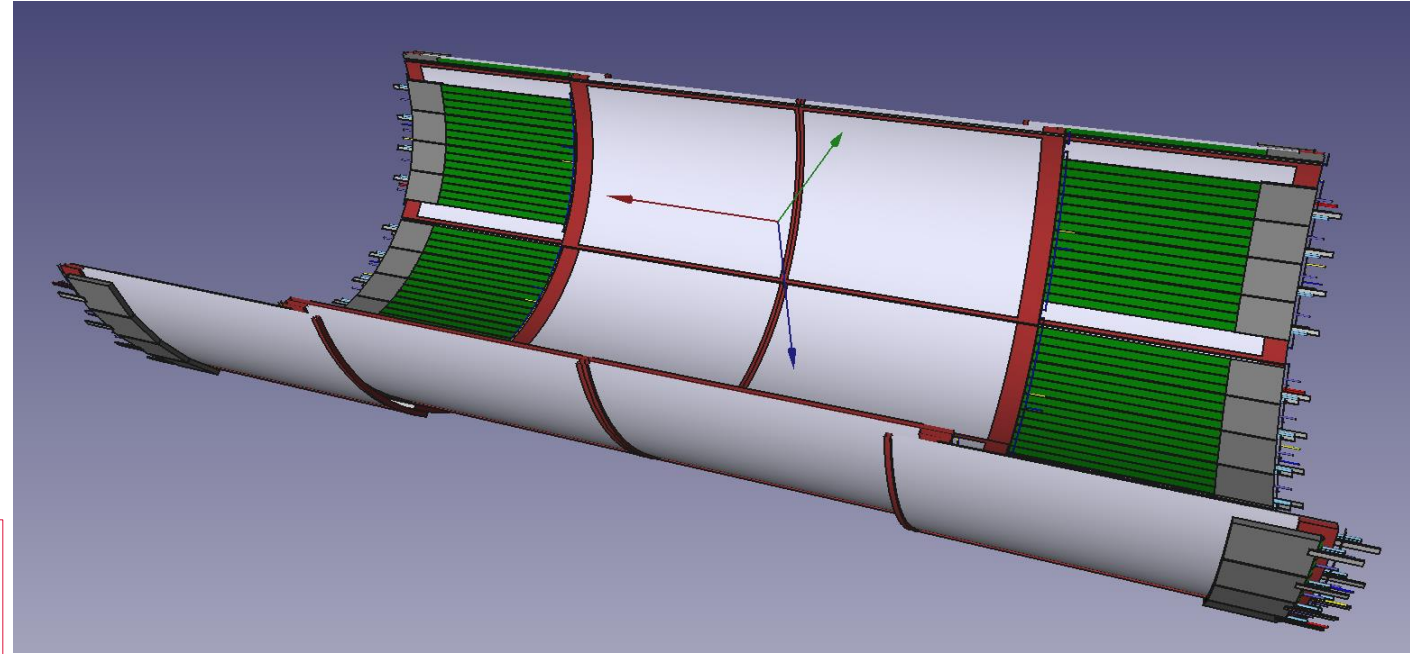
$R^*\phi = 46$  cm

## Expected performances

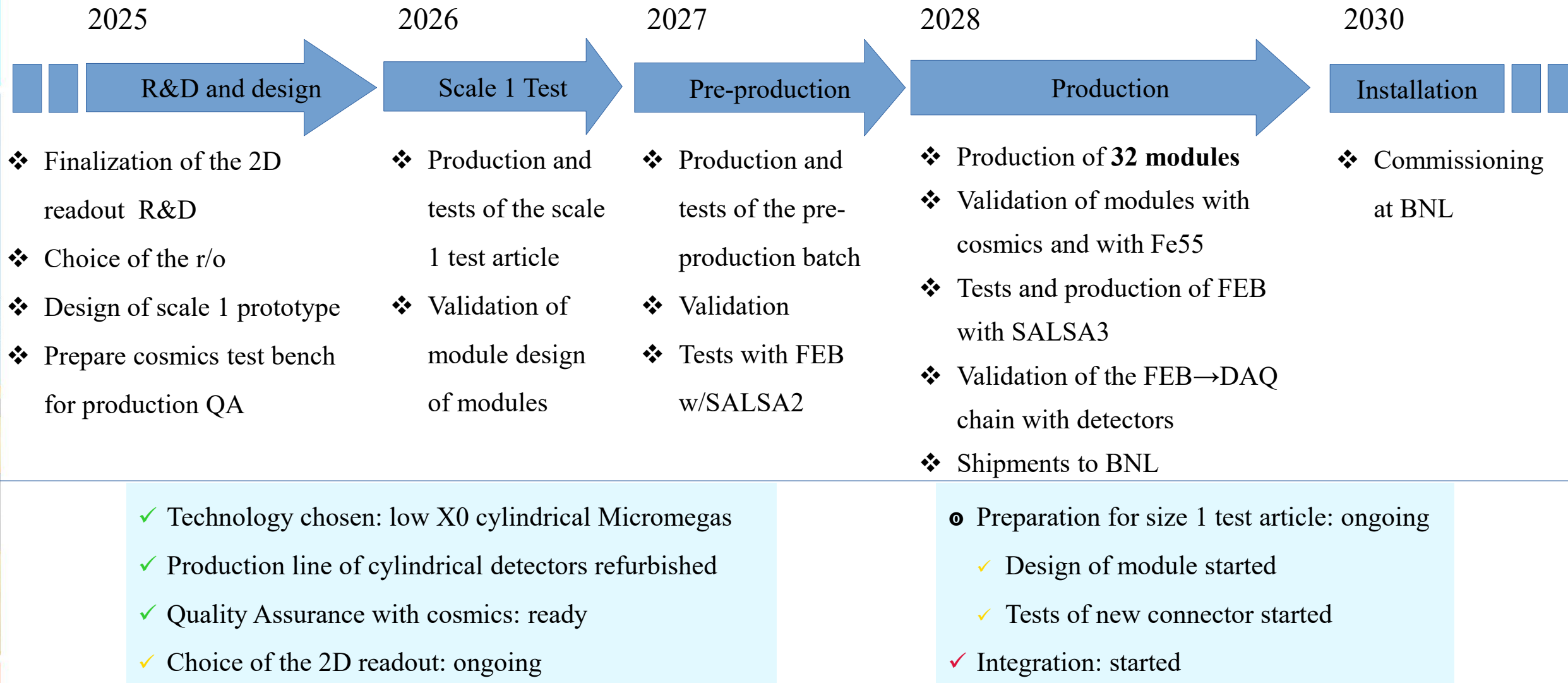
- ❖ Spatial resolution:  $< 300$  (500)  $\mu\text{m}$  in z ( $r^*\phi$ )
- ❖ Time resolution  $\sim 20$  ns
- ❖ Efficiency  $\geq 98\%$
- ❖ Material budget  $\sim 0.5\%$   $X_0$

# CyMBaL: Cylindrical Micromegas Barrel Layer Design

- ❖ Minimize the material budget in the active area: FEB of the inner modules deported using micro-coaxial cables
  - ❖ Mechanical attachments of the FEBs to be defined in synergy with CyMBaL support structure
  - ❖ Tight space: 5.5 cm radial keeping zone. Integration and installation under discussion with the project engineers
- ❖ High voltage: 2 channels / module (drift and resistive)
  - ❖ Readout: 2D “xy” strips of ~1mm pitch
  - ❖ r/o channels per module: 1024
  - ❖ Connectors: 32 channels; 32 connectors/module
  - ❖ ASIC: SALSA (under development): 64 channels
  - ❖ FEB: 4 ASICs per board, optical fiber communication via lpGPT + VTRx



# CyMBaL: Plans, schedule & Timeline



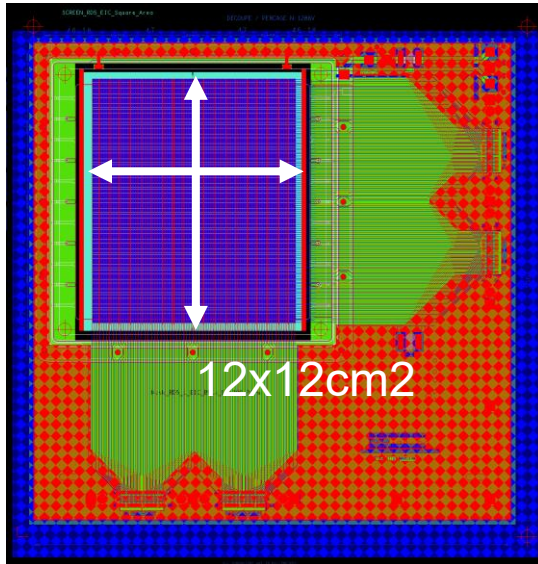


# CyMBaL: Ongoing development – Transition from R&D (eRD108) to PED

## Technology:

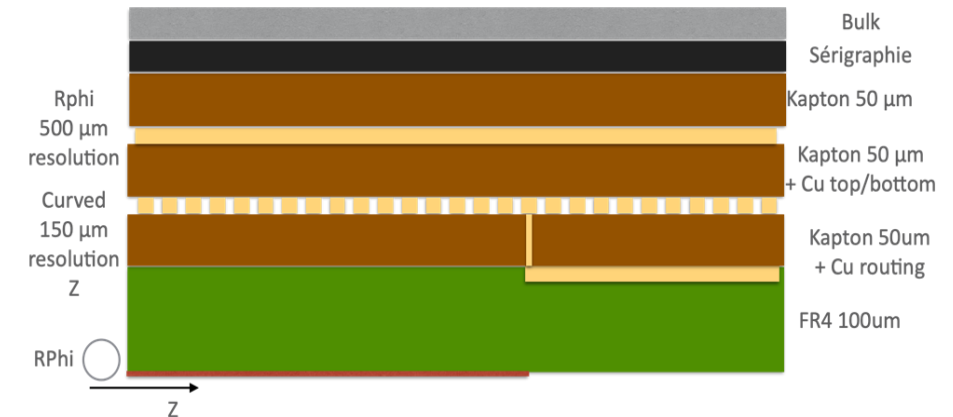
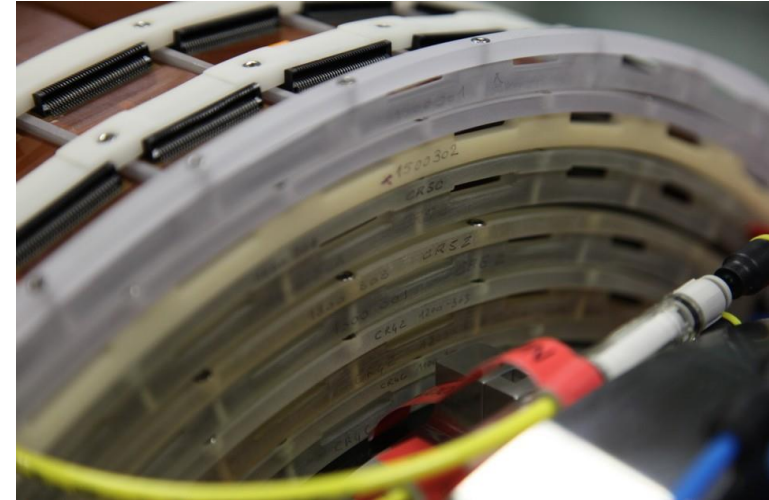
Cylindrical resistive Micromegas technology developed for CLAS12 BMT fits well the requirements:

- Light:  $<0.5\%$  X0 ; Working in high radiation and high magnetic field environment; tight space for integration



## Finalizing the R&D:

- ❖ 2D strip readout with small number of channels
- ❖ Preliminary results from beam tests in 2023:
  - 1 mm pitch provide good spatial resolutions with limited number of readout channels.
- ❖ New design of small prototype to finalize the choice of readout patterns and resistive layer.
- ❖ Same stack as final detector
- ❖ Goal: test beam in 2025.

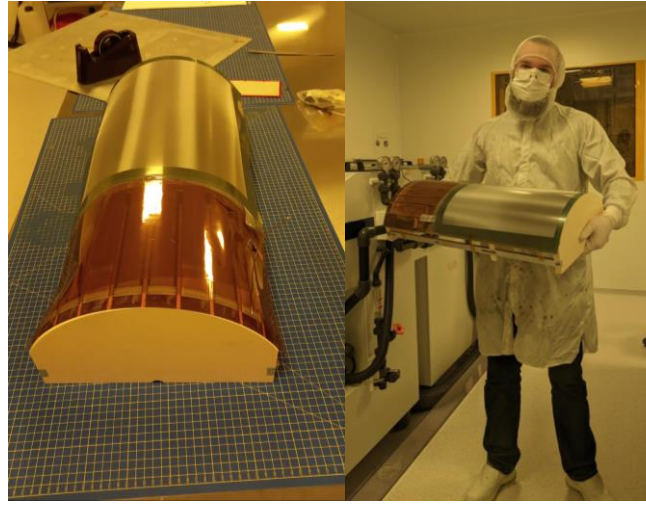
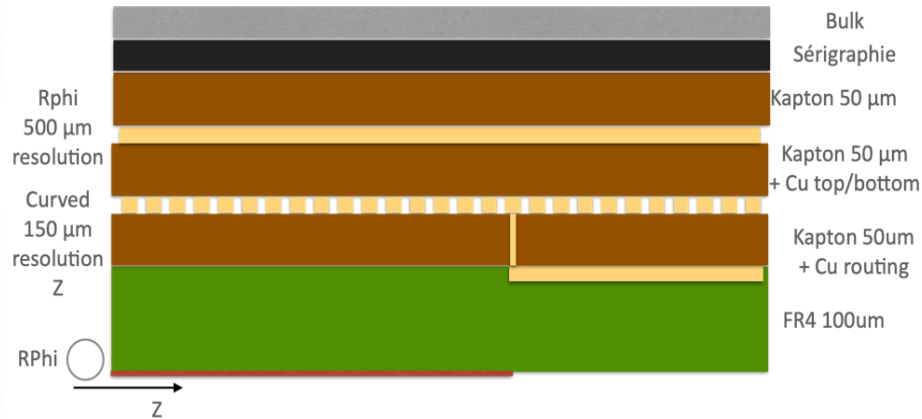


**Schematic representation of the readout PCB stack**

# CyMBaL: Ongoing development - Transition from R&D (eRD108) to PED

## Gearing up for full size prototype:

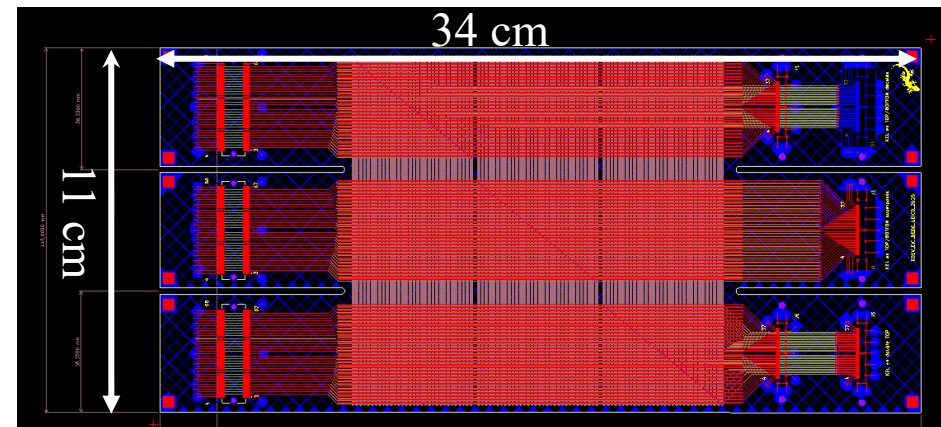
- ❖ Restarting the production of curved detectors
  - CLAS12 spare PCB and mechanics used for refurbishing the procedures
  - In Saclay MPGD Lab
    - Resistive layer serigraphy
    - Micromegas bulk process
    - Cylindrical tile assembly



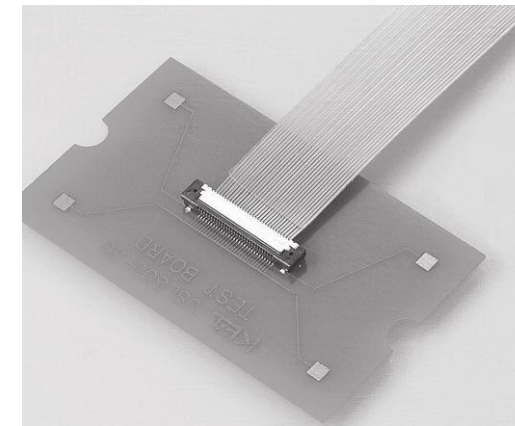
## Engineering tests of new small form factor connectors

- ❖ Dedicated small PCB (with the same stack as the final detector)
- ❖ Interface the new KEL connectors with the “old” MEC8 ones
- ❖ Mechanical, electrical and transmission tests

MEC8 to KEL connectors card



KEL connector



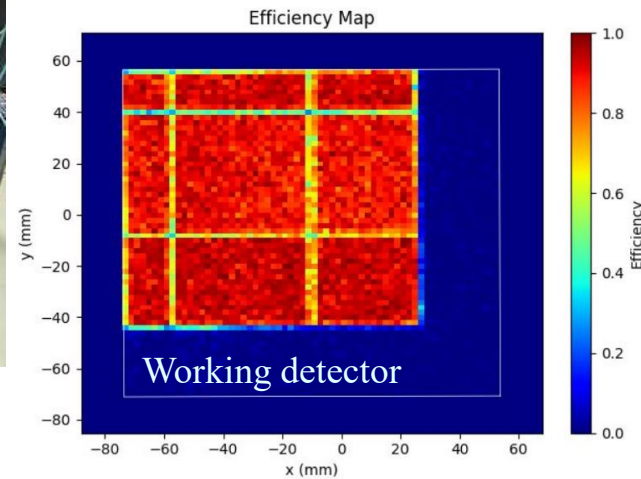


# CyMBaL: Cosmic Test Stand @ Saclay for QA

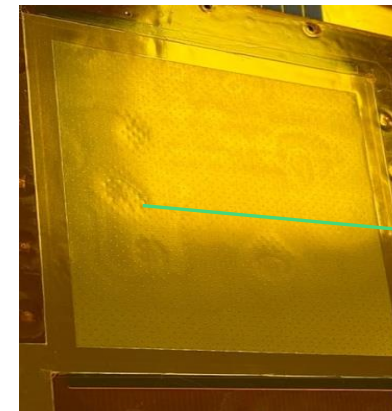


## Cosmic rays test bench refurbished

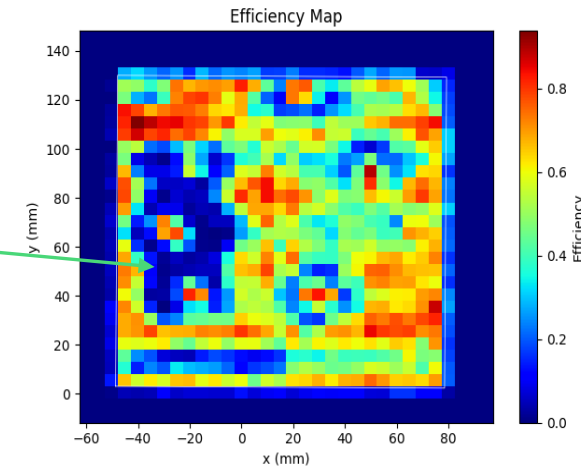
- ❖ Silicon telescope (same as in beam test) added to the system
- ❖ The DAQ system is adapted to be portable to a next beam test
- ❖ Cosmic bench **part of the QA of CyMBaL**
  - Currently used for tests of small prototype
  - **Ready to test production modules**



## Examples



Detector with glue spots



# CyMBaL: Possible changes in Detector Layout

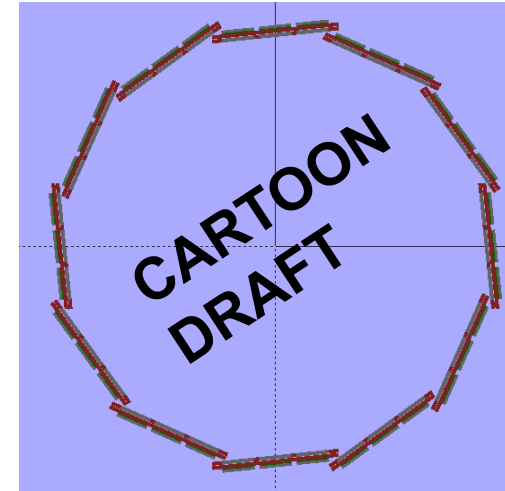
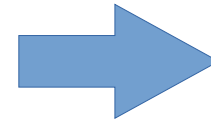
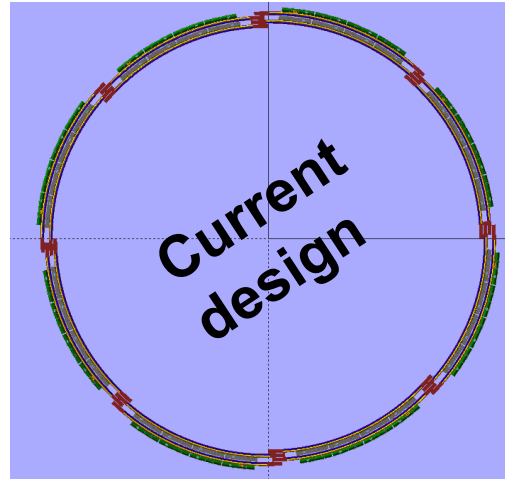
Aiming at simplifying integration, installation and maintenance, the project suggests to change the Inner MPGD layer layout.

**EIC Project proposes to move to a configuration of 12 sectors that can be serviced and accessed independently**

## *Current design:*

8 x 4 = 32 modules

- Hermetic in phi
- r/o pitch ~1mm
- 4 FEB/module → 128 FEBs
- No need for RDOs



## *Proposed change*

- ❖ 12x4 = 48 modules
- ❖ Smaller modules
- ❖ Same keeping zones

## **Consequences of the new design**

- ❖ From 32 to **48 modules**→ **changes in the production schedule** (and costs)
- ❖ Impact on the r/o choice. Possible options:
  - Keeping ~1mm pitch, i.e. 1024 ch/module: **50% more channels** → 50% more FEBs. Space issues.
  - Only 3 FEBs/module, larger pitch ~1.2mm, 12.5% increase in channels and FEBs. Space? OK for physics?
- ❖ More FEBs implies checking if DAQ chain possible without RDOs
- ❖ Due to space constraints, to check if **hermetic in phi is possible?** OK for physics?
- ❖ Flat detectors, then **more material budget**. From ~0.5%X0 to > 1%X0. To check if OK for physics.



# CyMBaL: Summary

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## Current design

- ❖ CyMBaL design based on cylindrical Micromegas advanced.
- ❖ Module design will be ready by the end of 2025. Test article in 2026.
- ❖ Ongoing finalization of the choice of the 2D readout pattern and the resistive layer layout. Beam test foreseen in 2025.
- ❖ QA test bench ready

## Recent news. Configuration change:

Working detector

- ❖ The proposed change of configuration by the EIC Project will impact on the schedule and, possibly, on performance
  - 50% more modules to produce, more readout channels and FEBs
  - If flat modules: major change. To understand also the impact for physics. It may also open new opportunities for technology choices to better address the requirements.
- ❖ Together with the Project and the Collaboration we need to evaluate the best solutions
  - Inputs on requirements and performance from simulation and reconstruction are needed
  - Re-definition of integration and maintenance is crucial for the module design

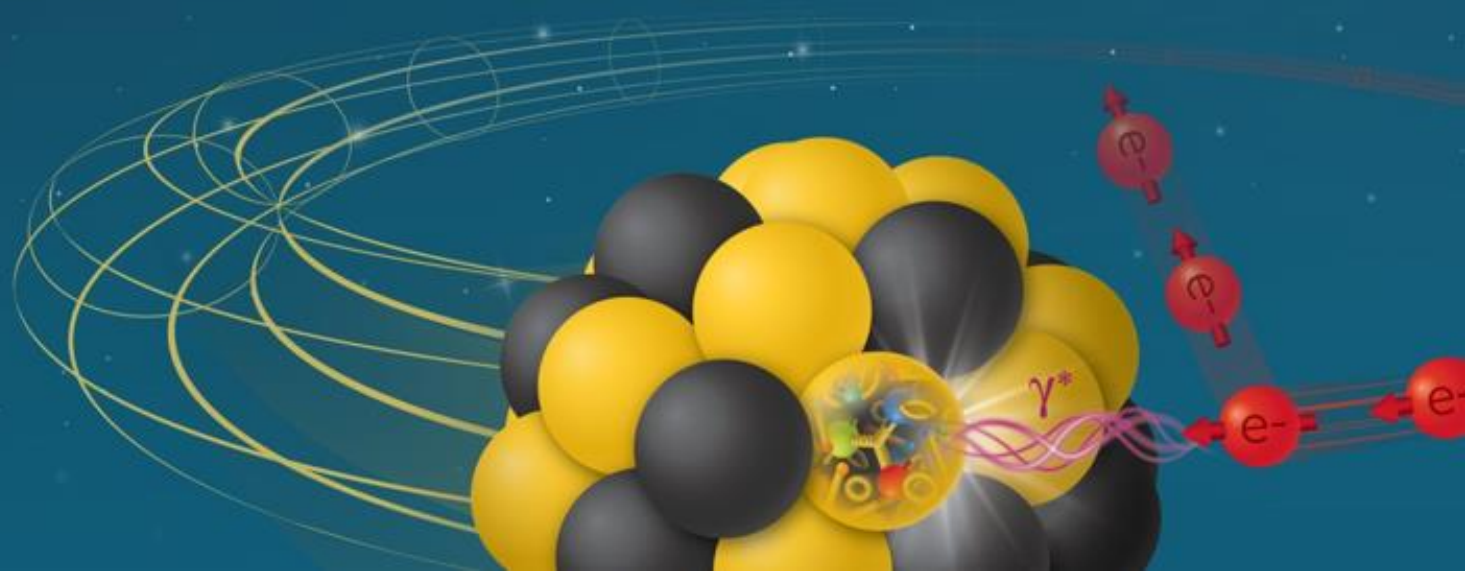
# ePIC MPGD Barrel Outer Tracker ( $\mu$ RWELL-BOT)

Kondo Gnanvo, Seungjoon Lee, Xinzhan Bai

RD&I group @ Jefferson Lab

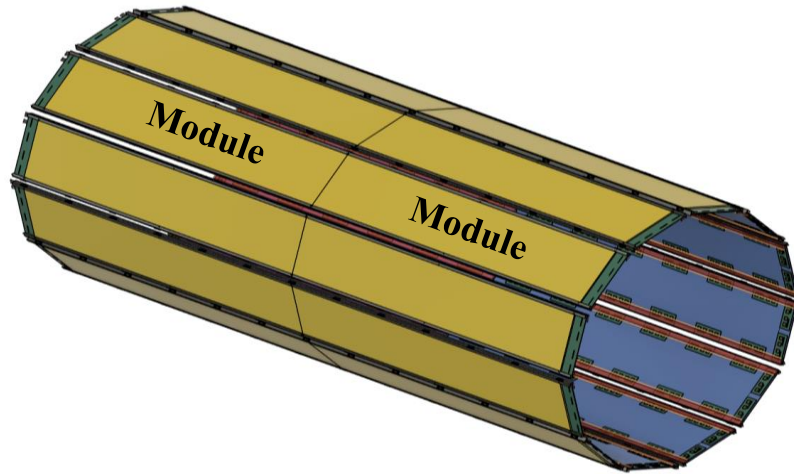
EIC Detector Advisory Committee (DAC)  
Meeting - June 11–13, 2025

Electron-Ion Collider

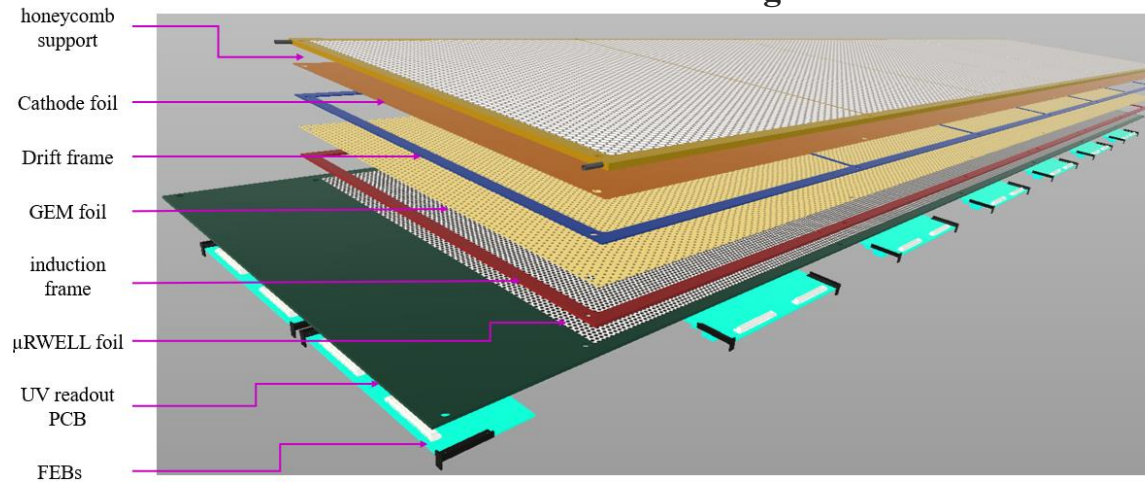


# $\mu$ RWELL-BOT: ePIC MPGD Barrel Outer Tracker

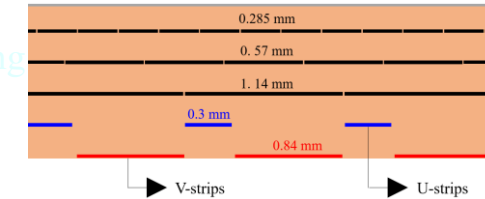
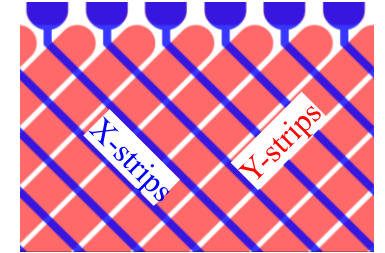
$\mu$ RWELL-BOT layout



Module design



capaSh X-Y strip readout



## 24 planar detector modules:

- ❖ 12 sectors in  $r^*\phi$   $\times$  2 modules in  $z$   $\rightarrow$  No overlaps
- ❖  $R_{\min} = 72.5$  cm;  $R_{\max} = 75$  cm
- ❖ **Novel** Thin-gap GEM- $\mu$ RWELL hybrid technology
- ❖ ASIC: SALSA (under development @ Saclay): 64 chs
- ❖  $\sim 86$ k readout electronic channels

## Module

- ❖ Overall dimension: 180 cm in  $z$   $\times$  36 cm in  $r^*\phi$
- ❖ Active area: 170 cm in  $z$   $\times$  33 cm in  $r^*\phi$
- ❖ Capacitive-sharing “X-Y” strips readout @  $45^\circ$  w.r.t detector
- ❖ 14 FEBs / module Total: 3,584 chs / module
- ❖ Hirose connectors: 140 pins (128 signals + 12 grounds)

## Expected performance

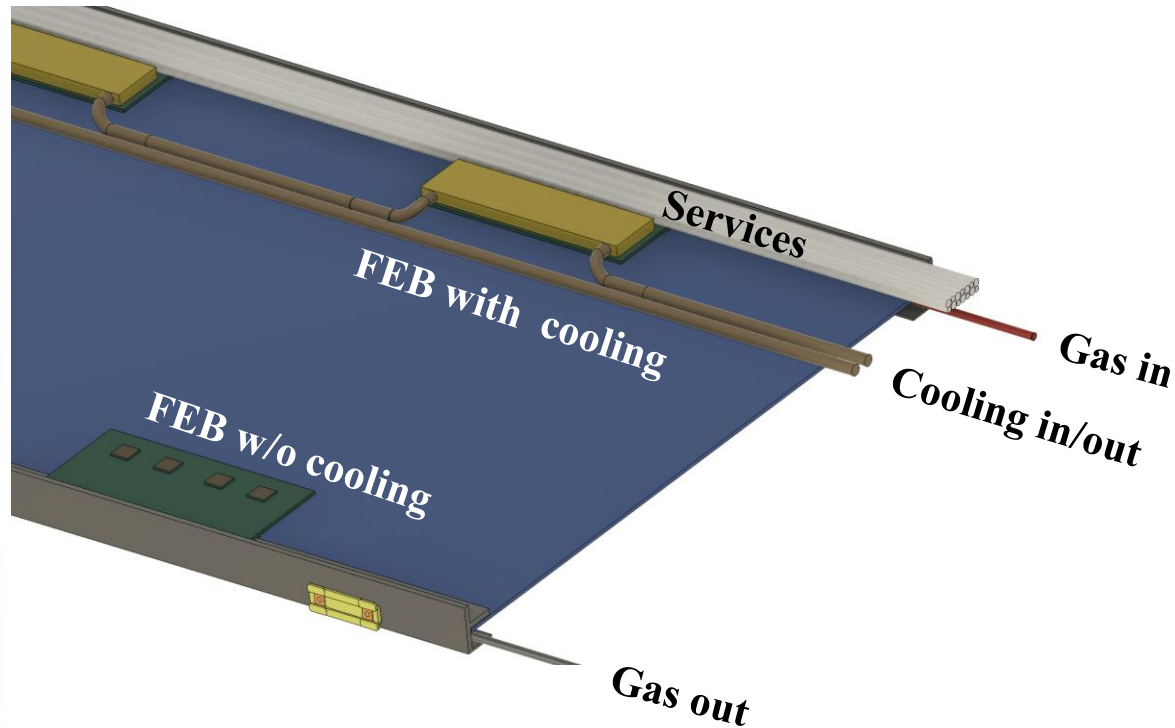
- ❖ Spatial resolution:  $< 100$   $\mu\text{m}$   
in  $r \times \phi$  &  $< 150$   $\mu\text{m}$  in  $Z$
- ❖ Time resolution  $\sim 10$  ns
- ❖ Efficiency  $\geq 95\%$
- ❖ Material budget  $\sim 2\%$  X0

Envelopes available at <https://eic.jlab.org/Geometry/Detector/Detector-20240515102931.html>

# μRWELL-BOT: Front End Readout (FEB) & Services Requirements

## Readout electronics:

- ❖ ASIC: SALSA (under development @ Saclay): 64 chs / ASIC
- ❖ FEB: 4 ASICs optical fiber communication via lpGPT + VTRx
- ❖ 14 FEBs / modules; 256 chs / FEB → Total: 3,584 chs / module
- ❖ FEB: 4 ASICs / board, optical fiber communication via lpGPT + VTRx



Service/Parts	Per Module	Total	Parameter
Frontend Board	14	336	256 Channel / FEB
High Voltage	1 (resistive divider)	24	3.2 mm OD
Low Voltage	14	336	6 mm OD
Gas	2	48	3 mm ID, 4 mm OD
Cooling	4	96	6 mm ID, 8 mm OD
Data Cable	14	336	Optical Fiber
Sensor	2	24	Temp. & Humidity
Ground			Depends on grounding plan

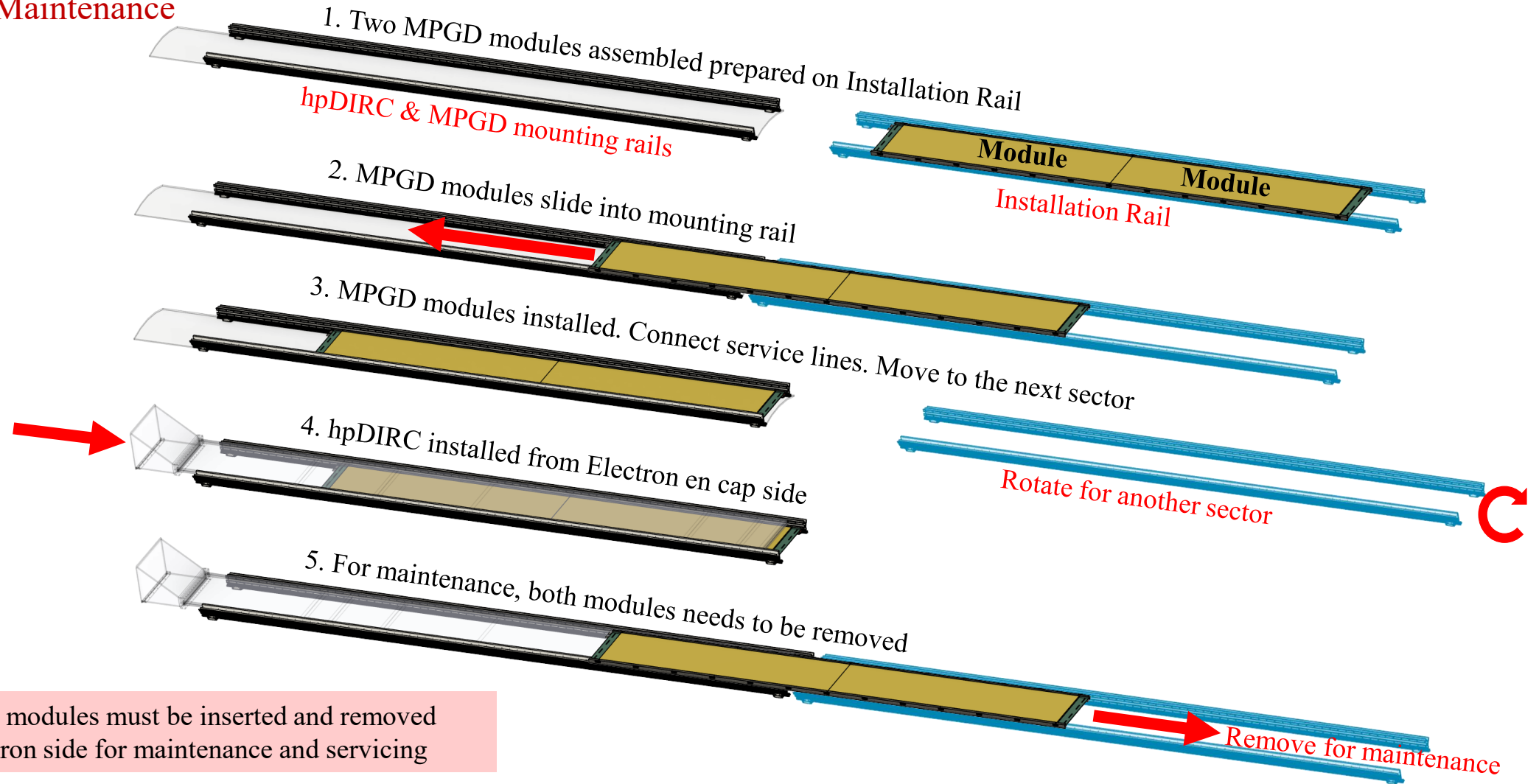
## Services & cabling:

- ❖ The volume & diameter of the service line are subject to change as the FEB design progresses.
- ❖ The cooling requirement has not yet been finalized → The current cooling approach utilizes water cooling with a heatsink.
- ❖ All three subsystems BOT, ECT, and CyMBaL will collaborate on the cooling system design.

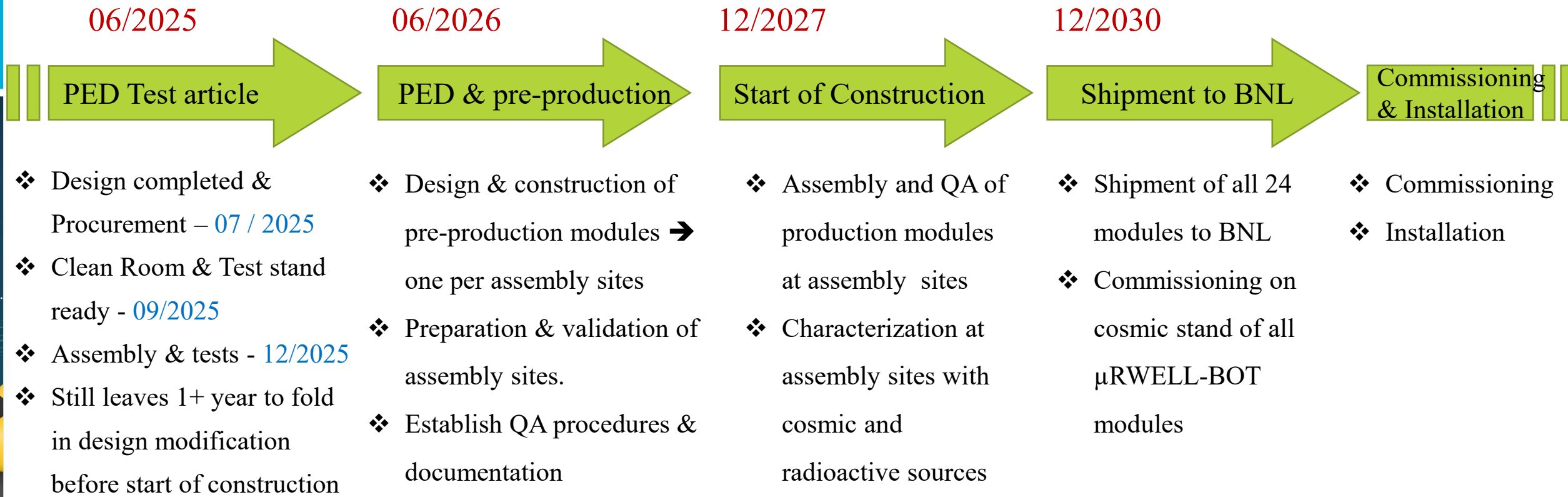


# $\mu$ RWELL-BOT: Integration in ePIC Detector

## Installation & Maintenance



# $\mu$ RWELL-BOT: Production plans & Timeline



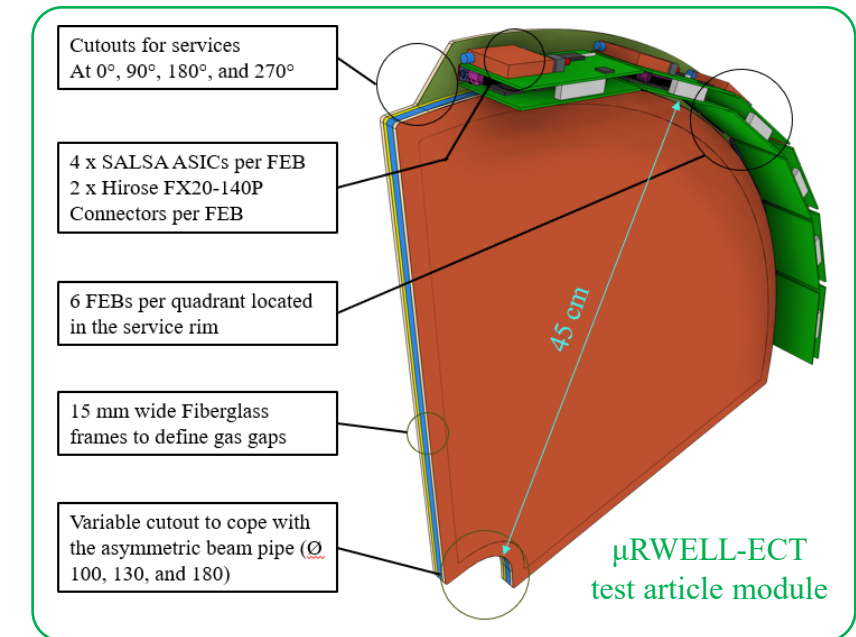
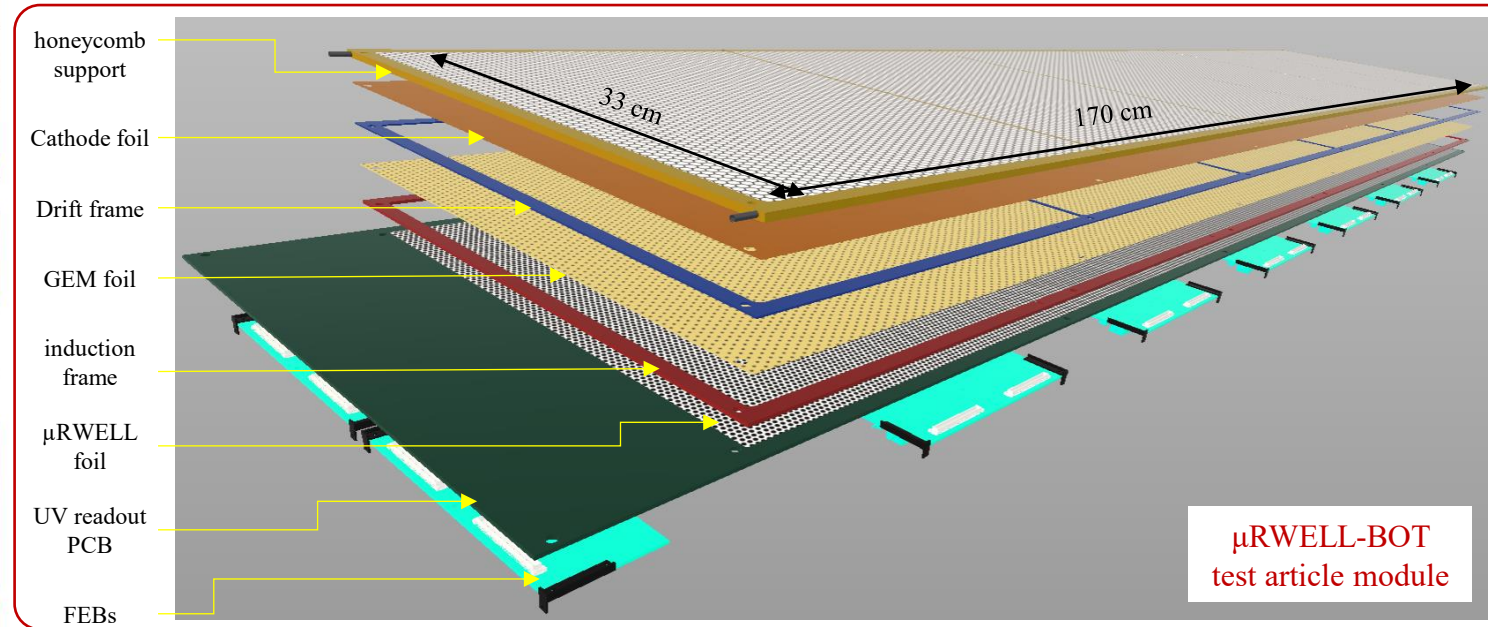
## 3 assembly sites:

- University of Virginia
- Florida Institute of Technology
- Jefferson Lab

# Project Engineering Design (PED) Effort: Synergy between BOT & ECT

Development of full-scale engineering test article modules for both  $\mu$ RWELL-BOT (JLab) and for  $\mu$ RWELL-ECT (INFN Roma II)

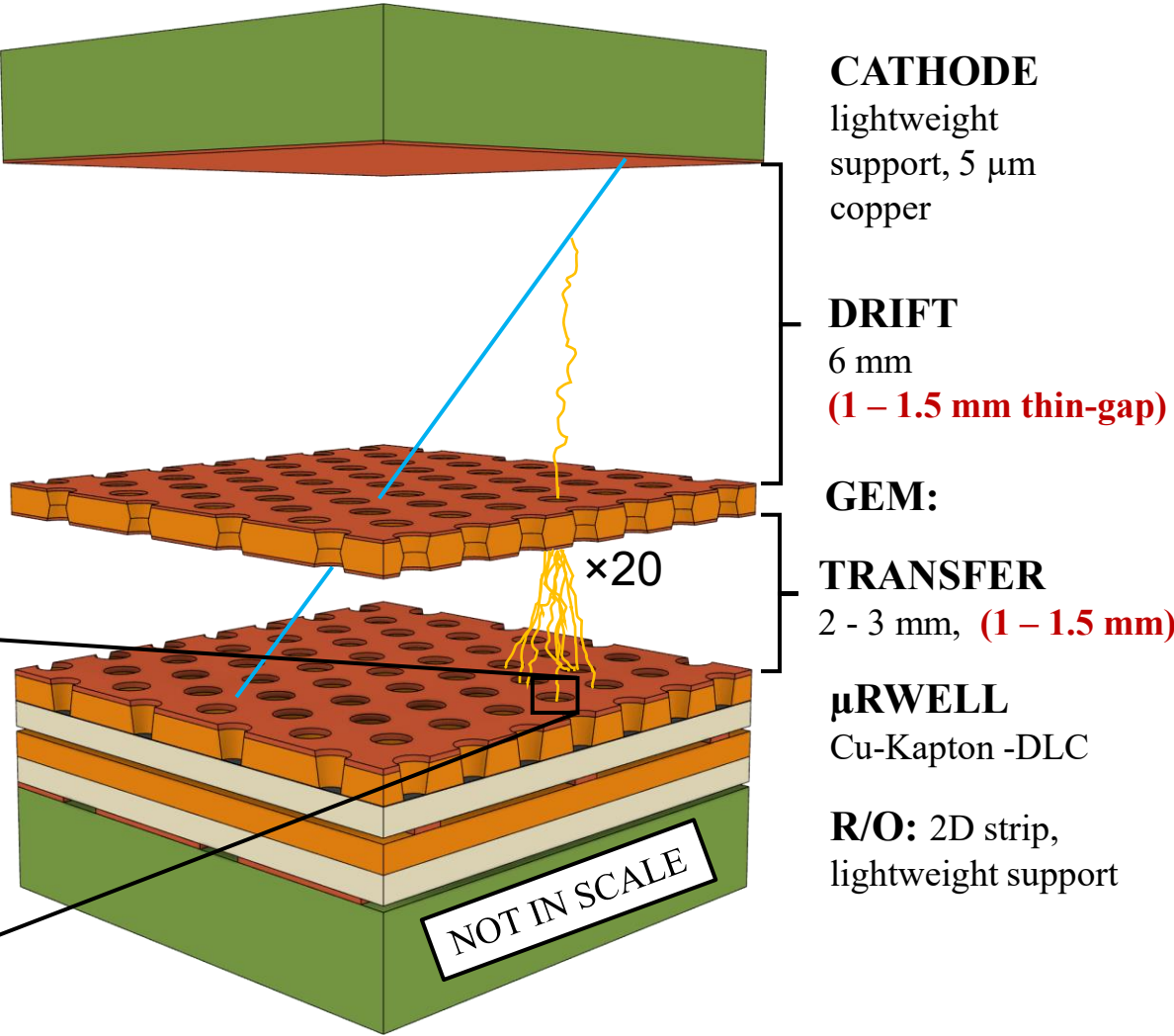
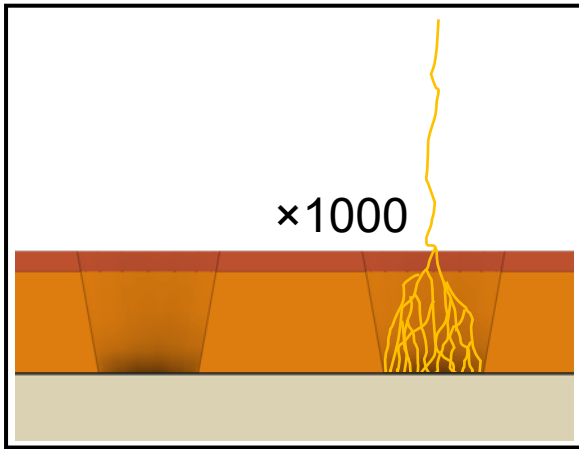
- ❖ New technology: Double & hybrid amplification structure with GEM and  $\mu$ RWELL → Common challenges to be investigated in parallel
  - Stretching of large GEM foil → development of dedicated mechanical stretcher
  - Handling of large  $\mu$ RWELL PCB is an extremely delicate step → requiring new techniques for clean assembly (Laminar flow hood, large ovens ...)
- ❖ Design & drawings of all parts completed for both test articles – procurement of the parts at CERN is ongoing
- ❖ Assembly et preliminary tests of the modules August to October 2025
- ❖ Validation of the two test articles in DRD1 beam test at CERN – November 2025



# New MPGD Technology: - GEM- $\mu$ RWELL Hybrid Detector for BOT & ECT

- ❖ Both Barrel Outer Tracker (BOT) and End Cap Tracker (ECT) are based on the New GEM- $\mu$ RWELL Hybrid Detector concept → only drift gap is different
- ❖ Preliminary studies on GEM- $\mu$ RWELL Hybrid approach initiated with JLab administered FY22 EIC Generic R&D program

Performance Requirements for ECT (BOT)	
Spatial resolution	$\leq 150 \mu\text{m}$
Time resolution	$\leq 20$ (10) ns
Single layer efficiency	$\geq 97$ (95) %
Material budget (per layer)	$\leq 1$ (2) % $X_0$





# $\mu$ RWELL-BOT Test Article: Where Are We As Of Now?

- ❖ Procurements of the parts of the engineering test article:
  - Support frame delivered
  - GEM,  $\mu$ RWELL readout PCB, cathode foil – 07/2025
- ❖ Assembly plans and preparation: 08/2025 – 10/2025
  - Clean room refurbishment ongoing
  - Procurement of major instruments & machine shop job
  - Few instruments in hand (Ultrasonic Bath for frame cleaning, microscopes for GEM foil inspection ..)
- ❖ Test beam plans for characterization and validation:
  - ❖ JLab Test beam for gas choice with small prototypes
  - ❖ CERN test beam plans for the test article – 11/2025



MPGD Clean Room in EEL-121 @ Lab



Ultrasonic Cleaning Bath



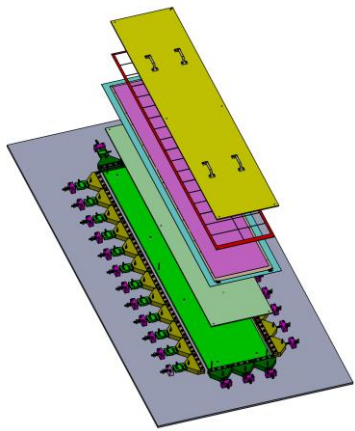
Support frames set for  $\mu$ RWELL-BOT test article module

# $\mu$ RWELL-BOT Test Article: Where Are We As Of Now?

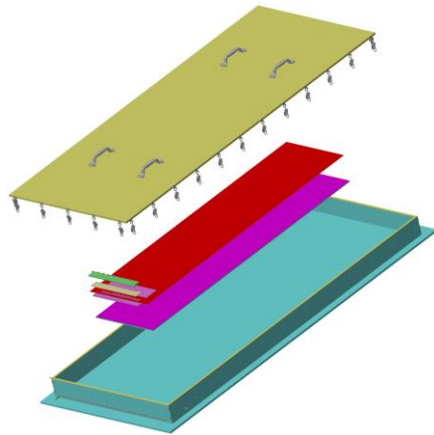
## MPGD Cleanroom in JLab Room EEL121

- ❖ Major instruments order delivered (Ultrasonic bath, Optical microscopes)
- ❖ Major instruments order placed
  - Fume Hood → purchase requisition in JLab procurement system
  - Instruments manufacturing job submitted to JLab machine shop
- ❖ Items to be ordered (in progress)
  - Cleanroom items: HEPA filters, monitor system, DAQ / Control PC
  - Honeycomb support: Flow hood, assembly table, vacuum pump

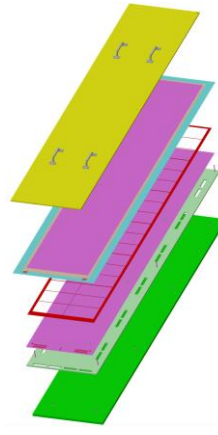
Under fabrication in machine shop @ JLab



GEM Stretcher

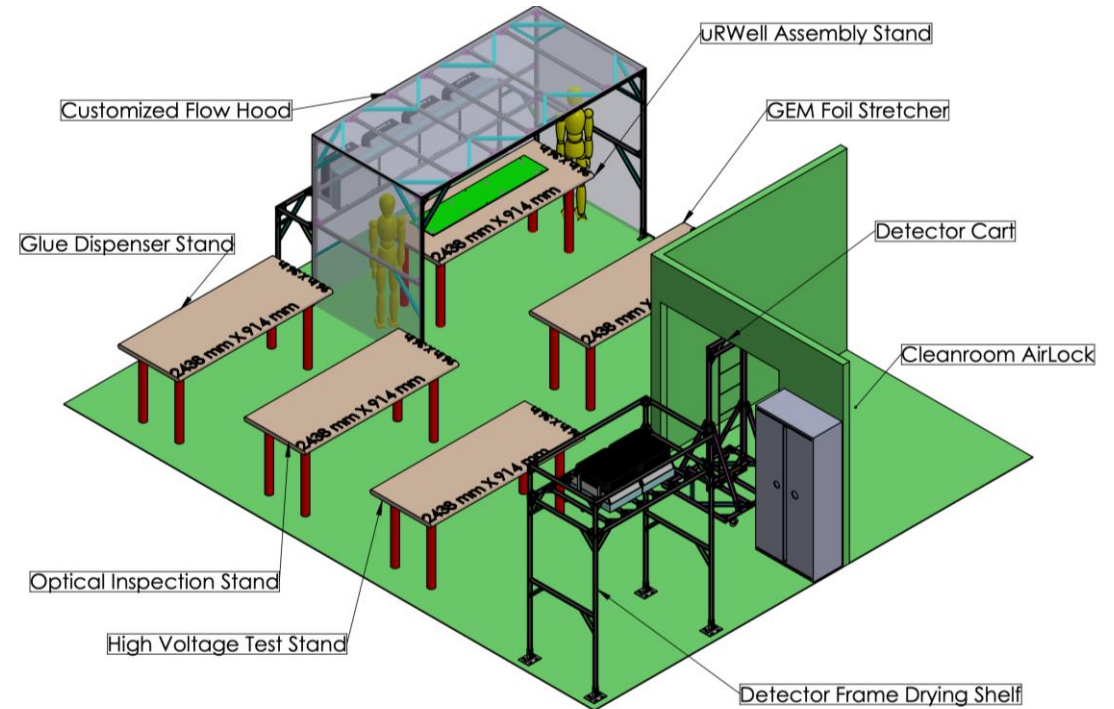


N2 box for HV Test



Assembly Stand

## Cleanroom layout with main equipment & instrumentation



## MPGD lab in JLab room EEL126

- Cosmic stand for ePIC BOT
- X-ray scanner for gain uniformity measurement
- Non clean room assembly tasks

# μRWELL-BOT Test Article: Timeline

- ❖ Detector frames (RESARM) delivered, GEM Foil, μRWELL (CERN) - **expecting early July 2025**
- ❖ Major instruments ordered, construction in progress
  - Infrastructure ready for construction – **mid August 2025**
  - Detector ready for benchmarking – **early September 2025**
- ❖ The timeline is partially driven by our plan to characterize in magnetic field the test article in beam at CERN in November 2025

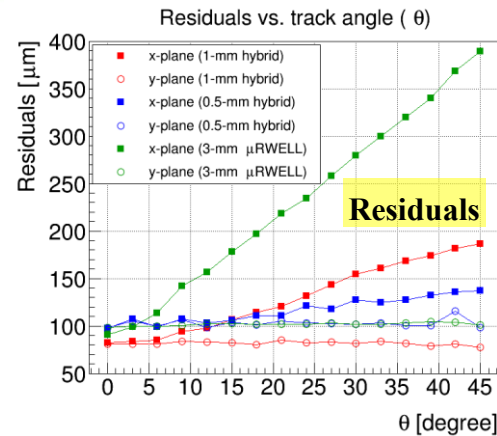
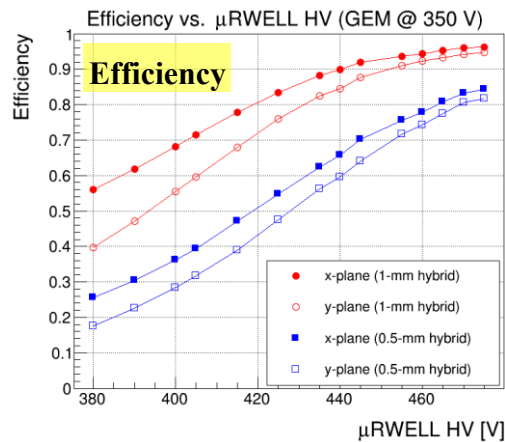
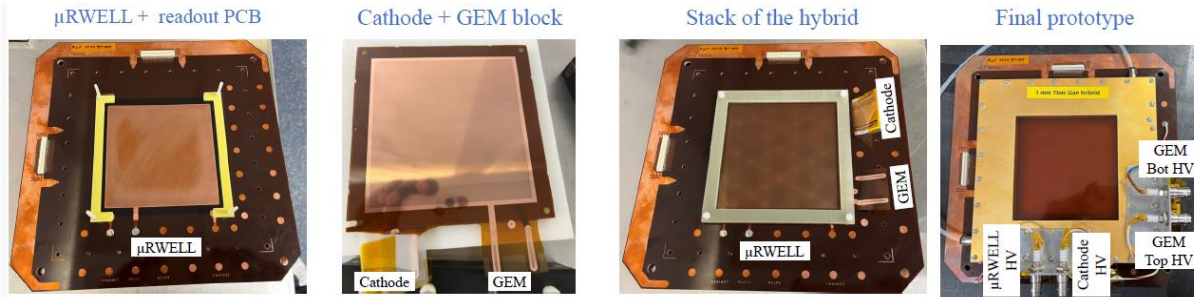
PHASE			DETAILS																														
						May				June					July				August				September					October					
PROJECT WEEK:						12	19	26	2	9	16	23	30	7	14	21	28	4	11	18	25	1	8	15	22	29	6	13	20	27			
1	Instruments Construction	Material Order Delivery	Order Delivery																														
		Manufacturing - Machine Shop					Manufacturing																										
		Assembly															Parts Assembly																
2	Cleanroom Construction	Instrument Design	Instrument Design																														
		Material Order delivery, Aluminum Bars, PVC shields, HEPA Filters					Material Order																										
		Construction					Construction																										
3	Detector Construction & Test	Sanding	Tools Preparation/Design														Sanding																
		Varnish					Fume Hood Delivery					Varnishing																					
		Foil Dilevery from CERN					Foil Delevery from CERN																										
		Cleanroom Construction										Detector Construction																					
		Detector Test														Detector Test																	



# $\mu$ RWELL-BOT: Technology validation & Performance studies

## FNAL Test beam (06/2023): Thin-gap GEM- $\mu$ RWELL hybrids

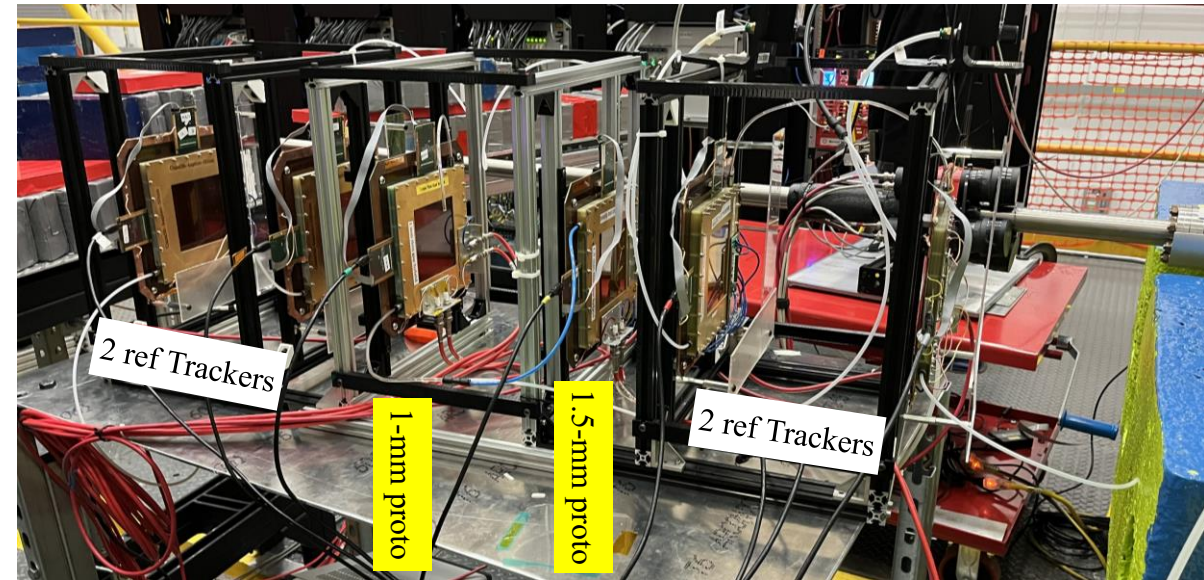
- ❖ Proof of concept established at the FNAL test beam
- ❖ Small thin-gap (1 mm and 0.5 mm gap) prototypes were tested
- ❖ Performances compared to standard gap (3 mm)  $\mu$ RWELL



Final test beam results manuscript under review for publication in NIM A

## JLab Test beam (05/25 – 06/25): Thin-gap GEM- $\mu$ RWELL gas studies

- ❖ 3 small prototypes (0.5, 1 & 1.5-mm gap) under test
- ❖ Different Argon based gas mixtures to be tested
  - ❖  $\text{Ar}:\text{CO}_2 \rightarrow 72:25, 80:20 \text{ \& } 90:20$  mixtures
  - ❖  $\text{Ar}:\text{CO}_2:\text{iC}_4\text{H}_{10} \rightarrow 90:7:3$  mixture
- ❖ HV scans: drift field, transfer field, GEM &  $\mu$ RWELL amplifications
- ❖ Final choice of  $\mu$ RWELL-BOT gas will be based on the test beam results



[https://wiki.bnl.gov/eic/upload/ERD\\_tgMPGD\\_FY22\\_endOfYearReport\\_final.pdf](https://wiki.bnl.gov/eic/upload/ERD_tgMPGD_FY22_endOfYearReport_final.pdf)



# $\mu$ RWELL-BOT: Summary

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- ❖ ePIC Barrel Outer Tracker ( **$\mu$ RWELL-BOT**) is based on the novel **Thin-gap GEM- $\mu$ RWELL** hybrid detector technology
- ❖  $\mu$ RWELL-BOT is instrumented with the SALSA electronics under development at CEA Saclay.
- ❖ The integration of  $\mu$ RWELL-BOT in ePIC detector is understood and is been coordinated with ePIC Integration team
- ❖ PED effort is underway with the development of full-scale engineering test article and characterization in beam at CERN.
- ❖ Cleanroom infrastructure for assembly and the MPGD Lab equipped with large cosmic stand for QA are under construction.
- ❖ Final validation of the test article with the SALSA electronics is expected in 2027 before start of production
- ❖ **Timeline for fabrication of the  $\mu$ RWELL-BOT modules is in accordance with the overall ePIC detector schedule.**



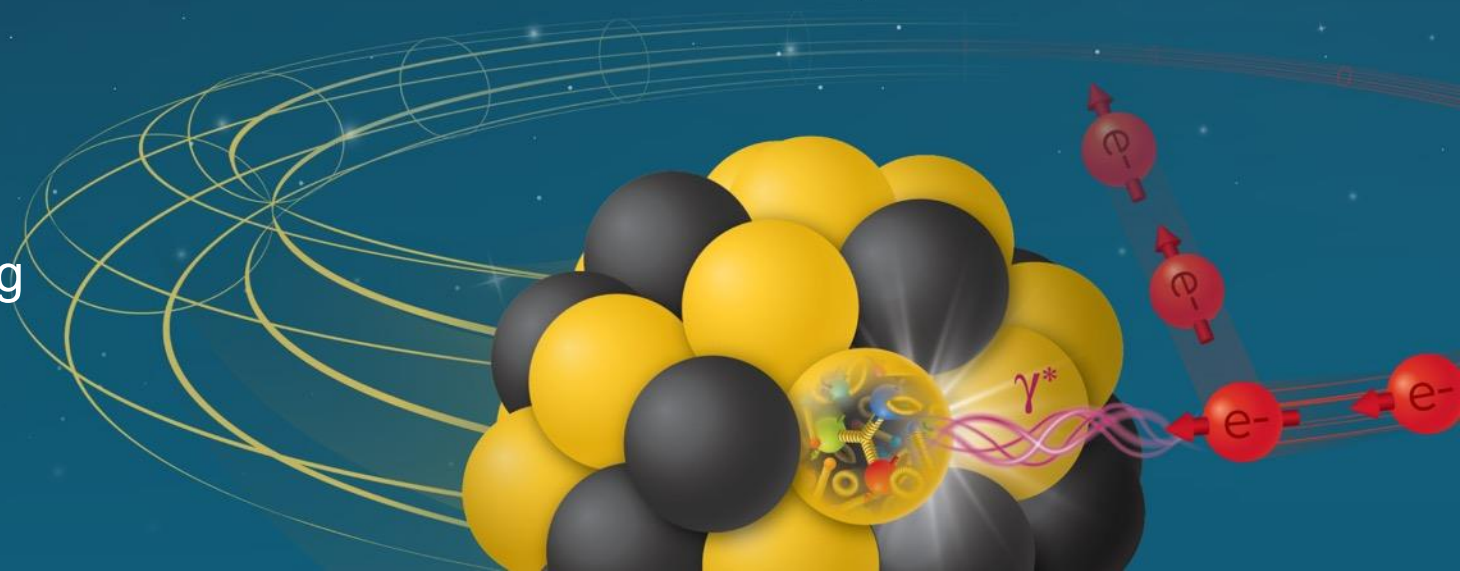
# MPGD ENDCAP Trackers (ECT)

GEM- $\mu$ RWELL technology

Annalisa D'Angelo, Stefano Gramigna, Elena Sidoretti, Mariangela Bondi'  
ECT project group

10<sup>th</sup> Detector Advisory Committee Meeting  
June 11-13, 2025

Electron-Ion Collider



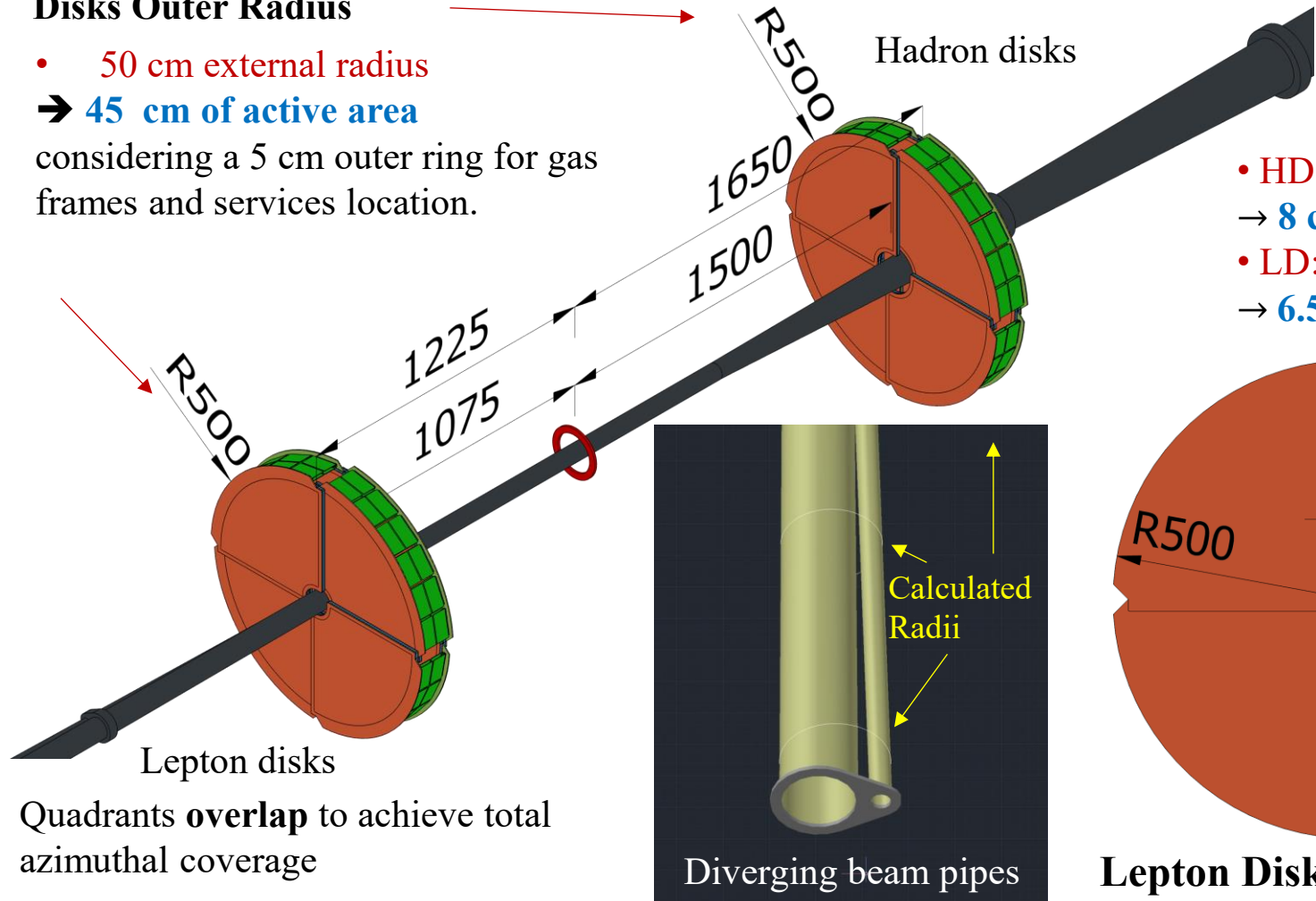
# $\mu$ RWELL-ECT: ePIC Gaseous End Cap Tracker

The geometrical **envelopes** are available at: <https://eic.jlab.org/Geometry/Detector/Detector-20240117135224.html>

## Disks Outer Radius

- 50 cm external radius
- 45 cm of active area

considering a 5 cm outer ring for gas frames and services location.

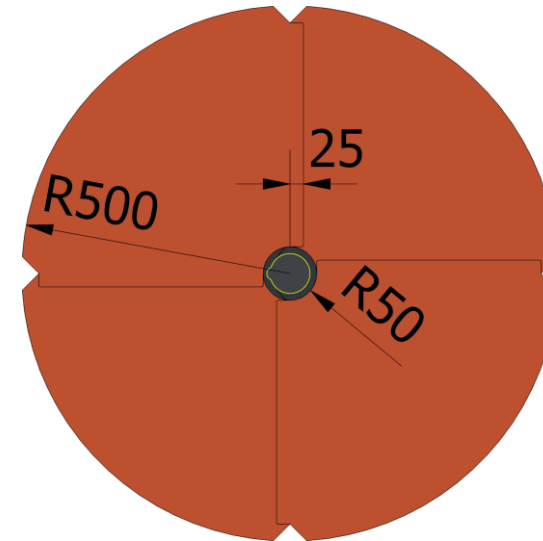


## Disks Inner Radii

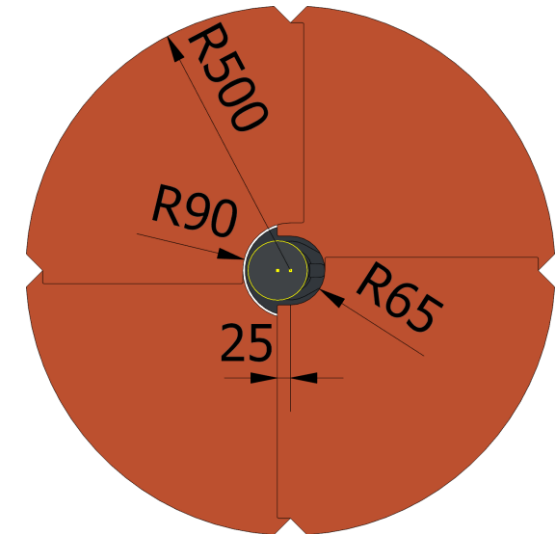
different for the two LD and HD regions to accommodate the beam pipe shape

- HD: 6.5 cm & 9 cm inner radii
- 8 cm & 10.5 cm active area radii
- LD: 5 cm inner radius
- 6.5 cm radius of active area

considering 1.5 cm gas frame



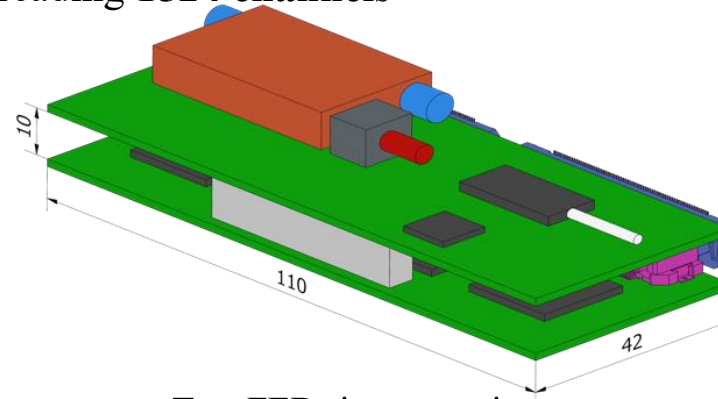
Lepton Disk Backward side



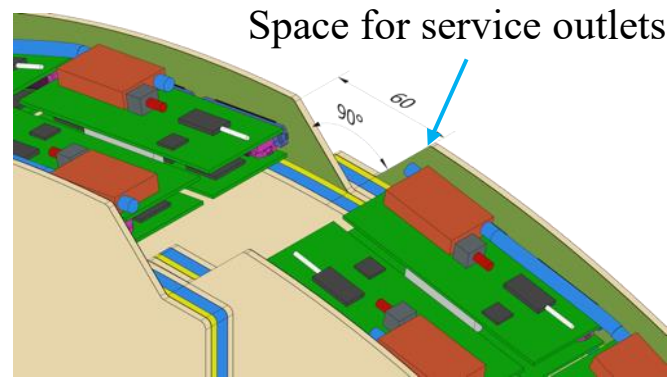
Hadron Disk Forward side

# $\mu$ RWELL-ECT: Front End Boards (FEB) & Services

- ❖ The service rim can accommodate **12 FX20-140P connectors**
- ❖ **6 FEBs per quadrant** reading **1524 channels**



Two FEBs in mezzanine configuration separated by 1 mm



All the service requirements have been communicated to the Integration group

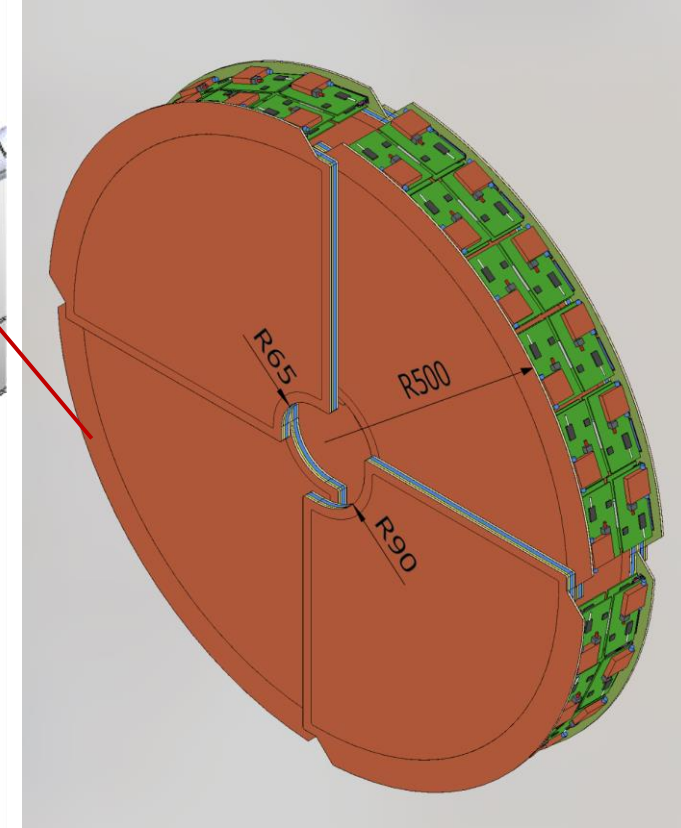
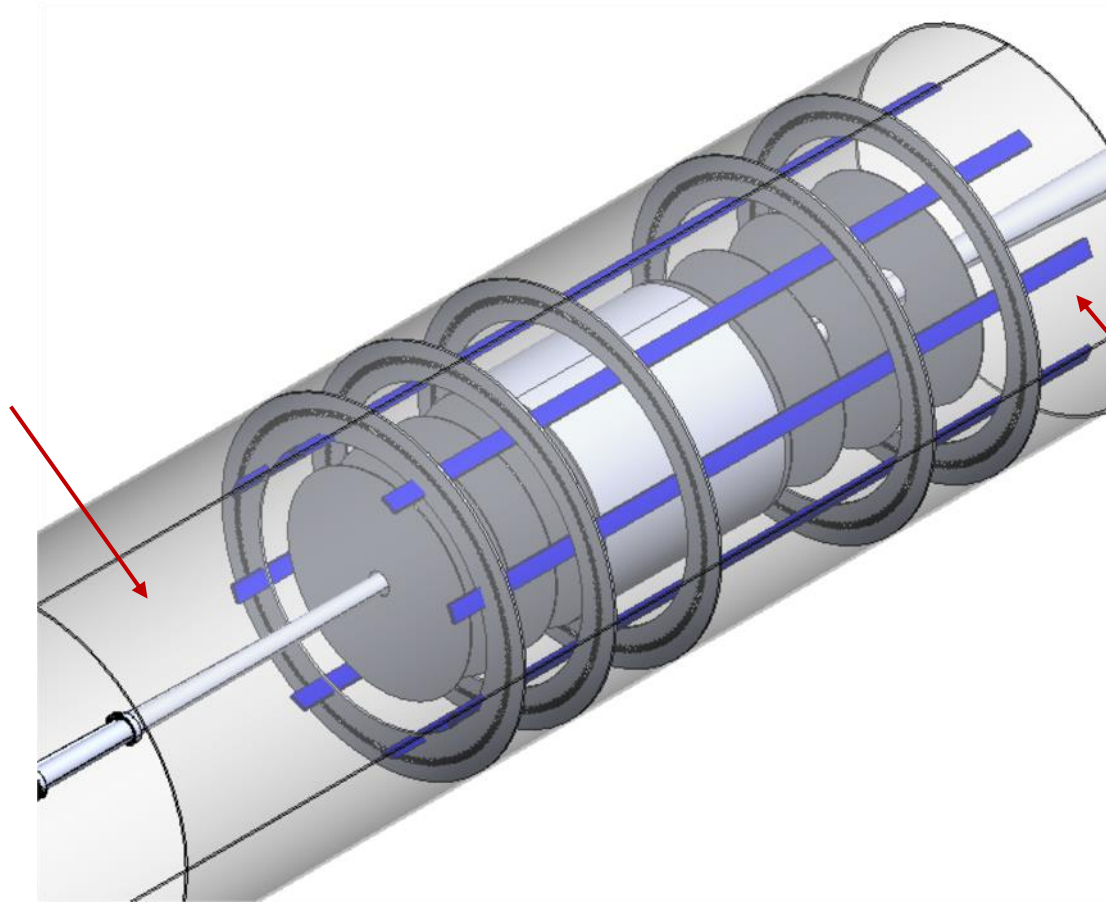
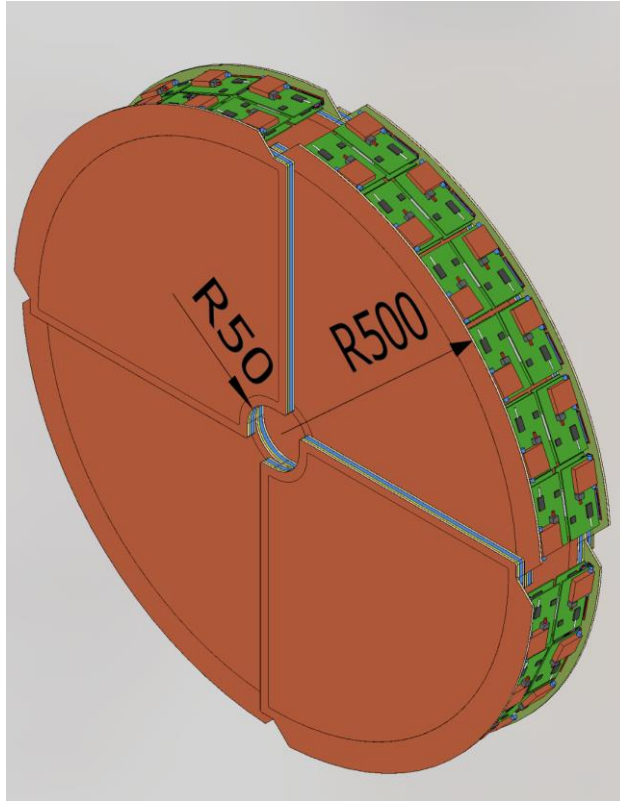
- ❖ **For each endcap disk (4 disks in total):**
- ❖ 16 HV cables
- ❖ 4 gas inlets and 4 gas outlets
- ❖ 24 data cables
- ❖ 24 low voltage cables
- ❖ 2 temperature sensors cables
- ❖ 2 humidity sensors cables
- ❖ 2 inlet and 2 outlet cooling hoses (H<sub>2</sub>O)
- 210 W cooling dissipation



# $\mu$ RWELL-ECT: Integration in ePIC Detector

The assigned envelope will include the detectors and the FEB electronics.

The disks will be attached together and to the support frame under design.



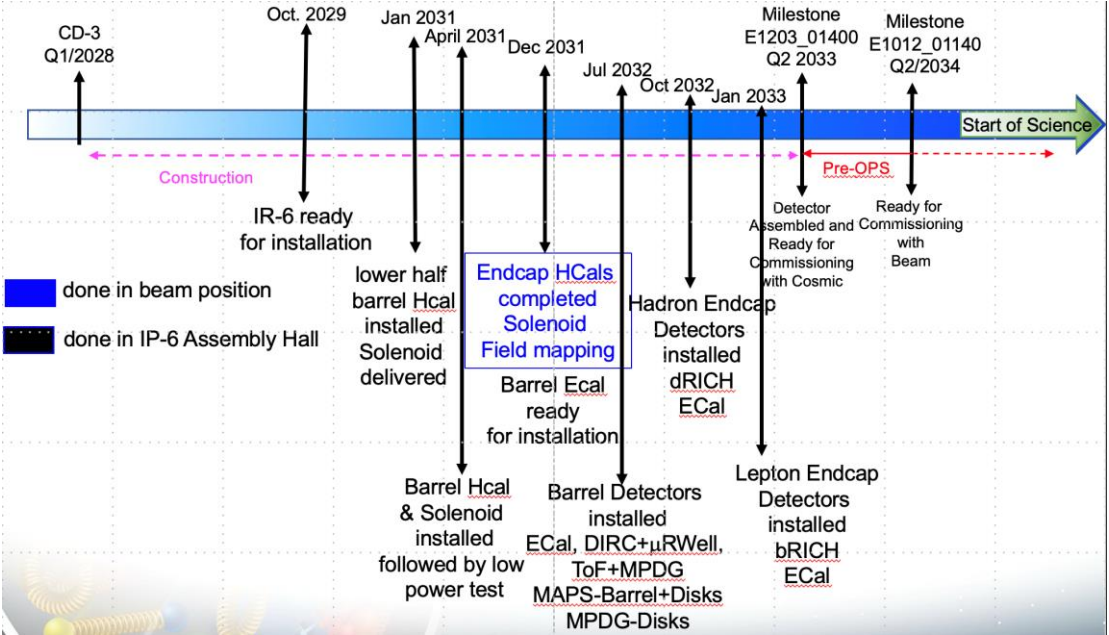
# μRWELL-ECT: Fabrication / Assembly Plans & Timeline / Work-force

Are the fabrication and assembly plans for the various tracking detector systems consistent with the overall project and detector schedule?

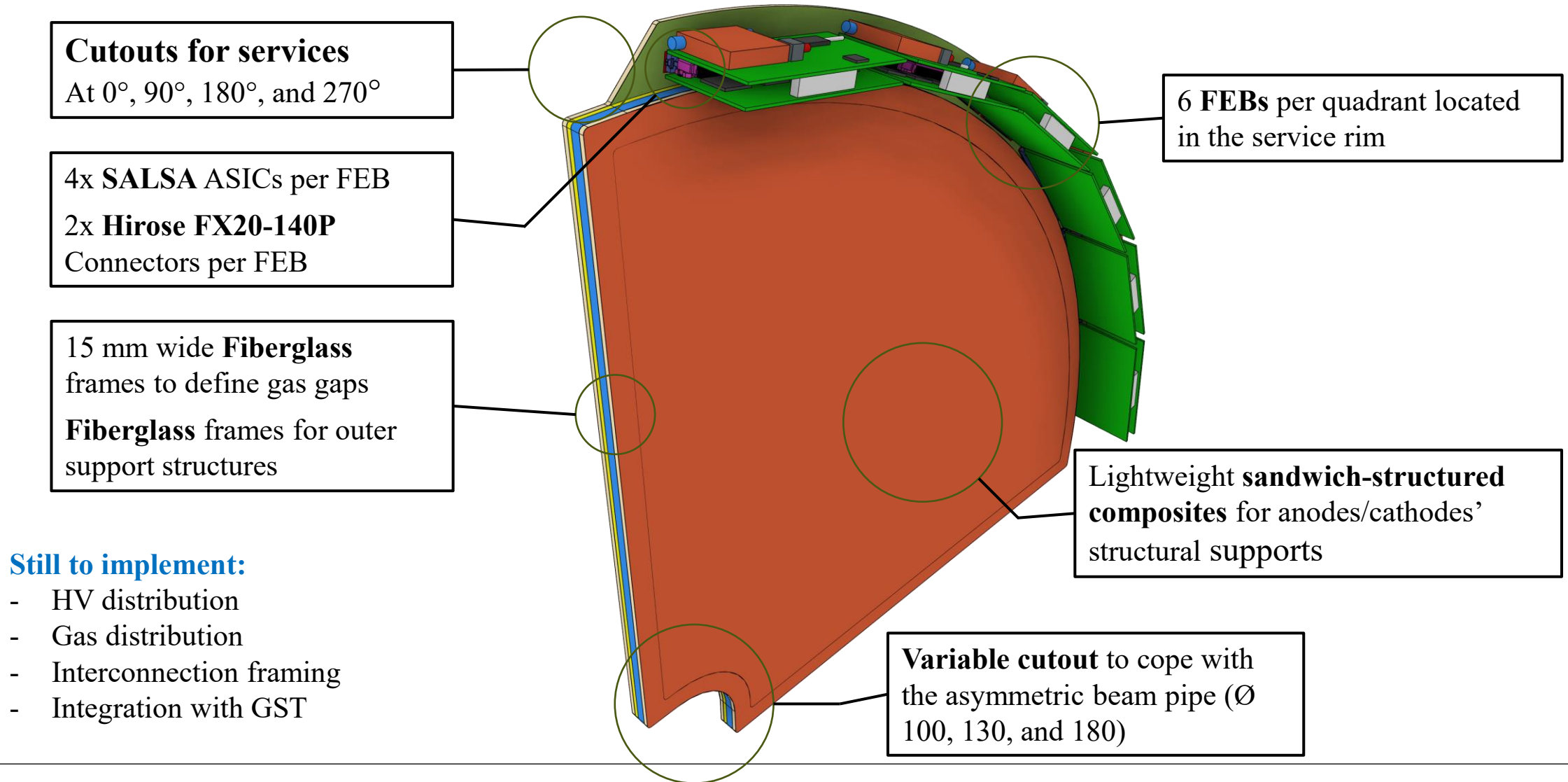
- ❖ 2025 Engineering Test Article Assembly
- ❖ 2026 Engineering Test Article Test & Pre-production
- ❖ 2027 - 2029 Production
- ❖ 2030 - 2031 QA & Commissioning
- ❖ 2032 Installation

MPGD Timeline			DURATION (years)
START DATE	END DATE	DESCRIPTION	
3/1/24	12/31/24	Detectors Overall Design	<1
1/1/25	12/31/26	Pre - Production	2
1/1/27	31/12/29	Production	3
1/1/30	6/1/32	QA, Commissioning & Installation	3

- Workforce** ≈ 5 fte
- INFN Groups:
    - Roma Tor Vergata
    - Genova
    - LNF
  - ❖ JLab
  - ❖ Temple University
  - ❖ Seoul University

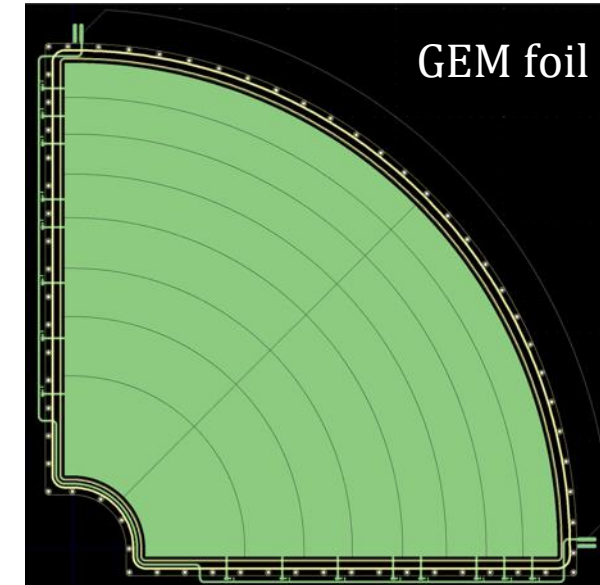
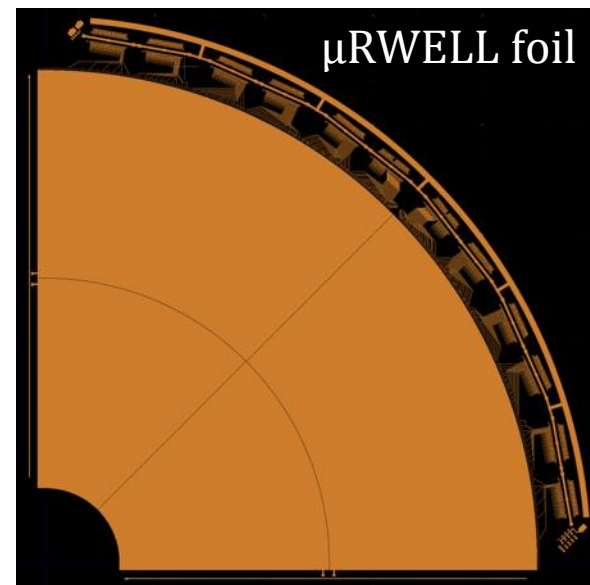
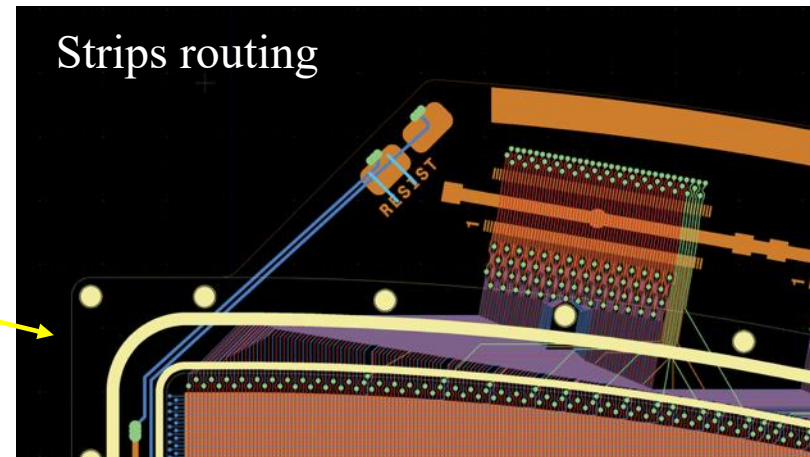
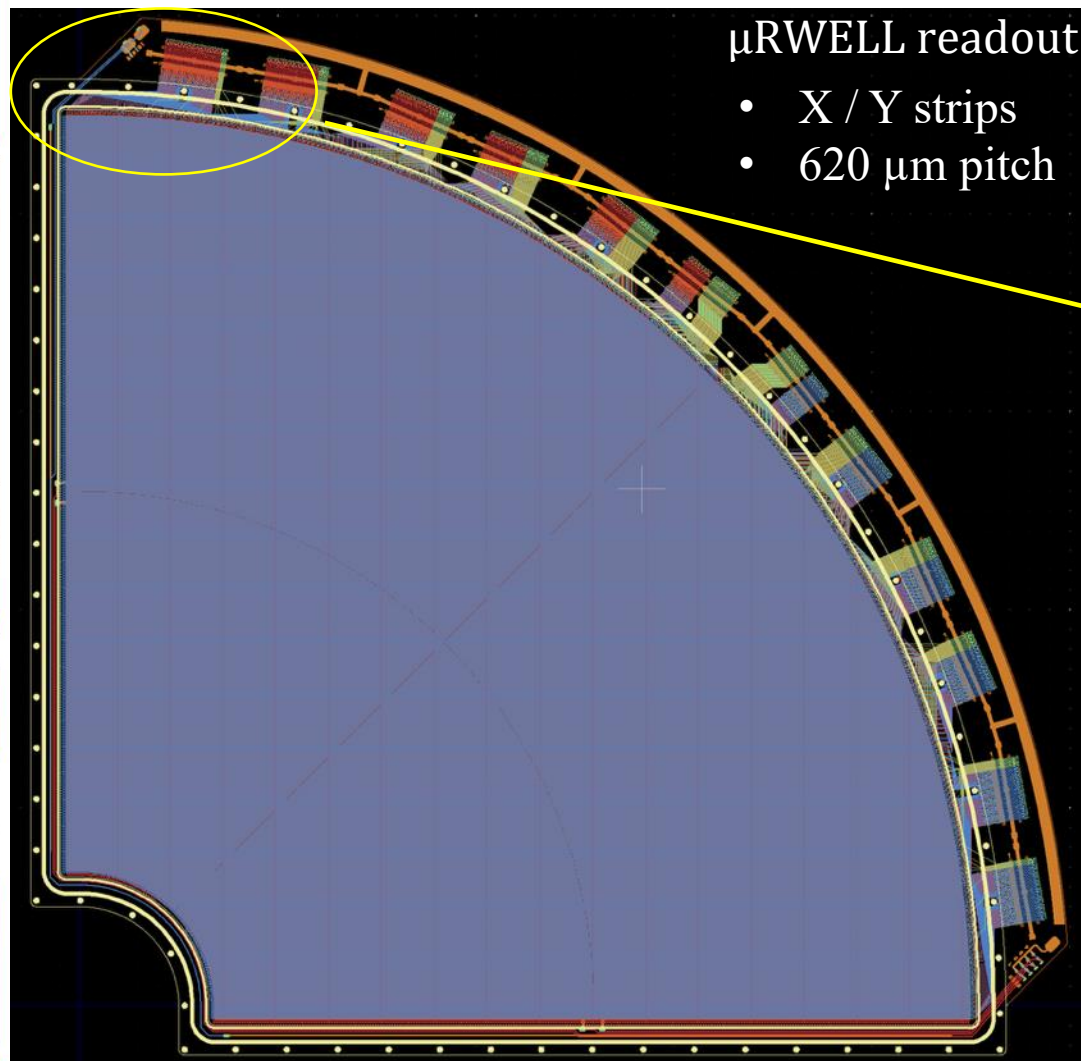


# $\mu$ RWELL-ECT: PED Test Article Module





# $\mu$ RWELL-ECT: PED Test Article Module



(X,Y) strips preferred  
to (R, $\varphi$ )  $\rightarrow$  no FEB  
on the active area

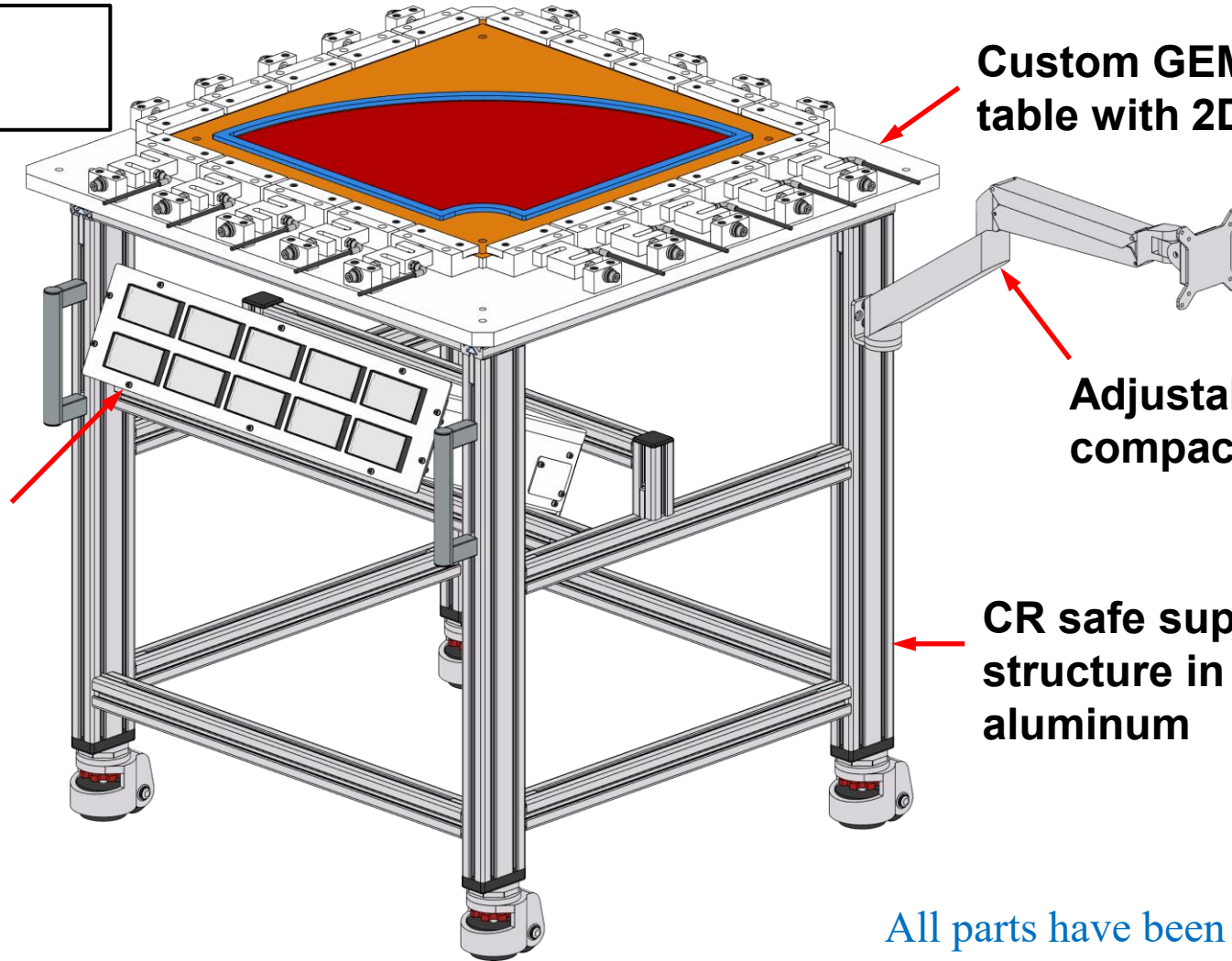
Detector delivery  
expected by Oct. 2025



# $\mu$ RWELL-ECT: GEM Stretcher Design

**Dimensions:  
850x850x920**

**Custom  
module for  
load cell R/O**



**Custom GEM stretching + gluing  
table with 2D tension measurement**

**Adjustable monitor arm for  
compact operator interface**

**CR safe support  
structure in anodized  
aluminum**

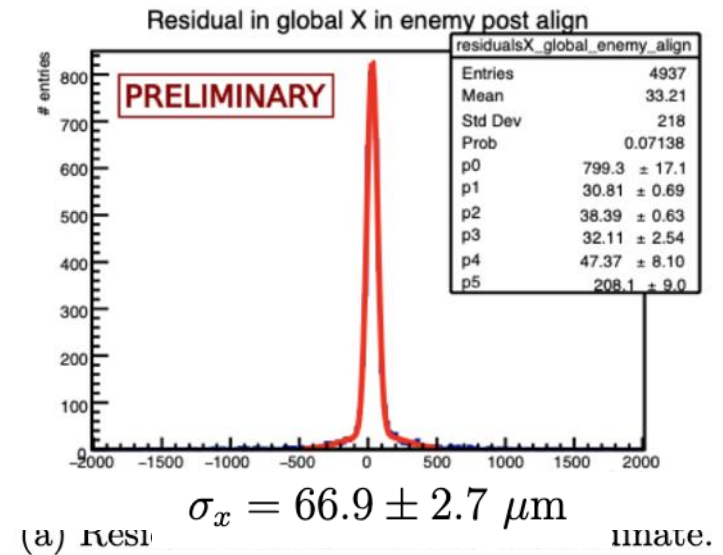
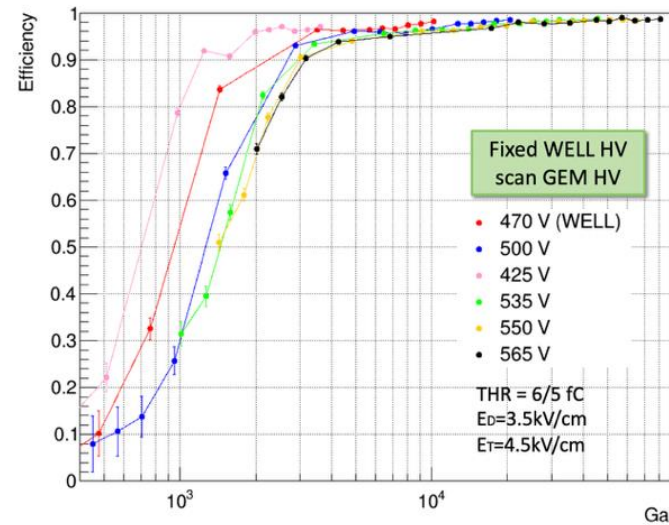
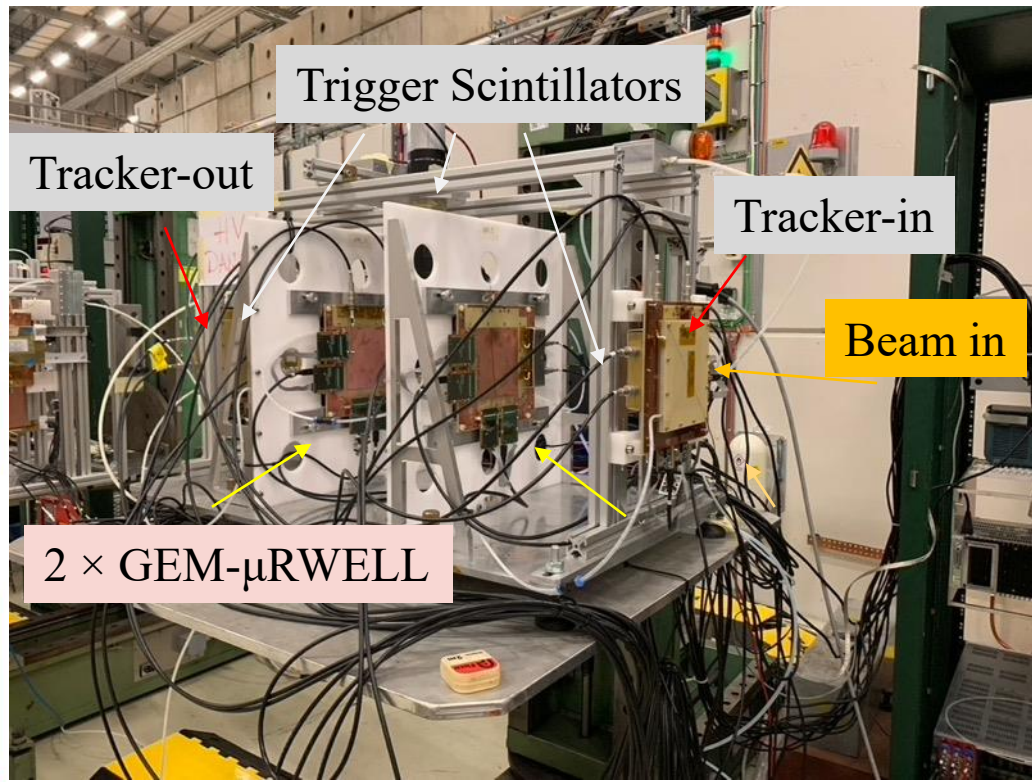
*All parts have been procured and are being assembled*

# $\mu$ RWELL-ECT: GEM- $\mu$ RWELL Hybrid Technology

Tracker-In :  $\mu$ RWELL – 3 mm drift gap

Tracker-Out : GEM- $\mu$ RWELL 6 mm drift + 3 mm transfer gaps

Detectors Under Study (DUT):  $2 \times$  GEM- $\mu$ RWELL prototypes 2D COMPASS-like readout 400  $\mu$ m pitch



- Efficiency at the plateau  $> 96\%$
- Position resolution for straight tracks at the efficiency plateau  $< 70 \mu\text{m}$
- Projected efficiency for 620  $\mu\text{m}$  pitch better than 150  $\mu\text{m}$

# $\mu$ RWELL-ECT: Summary

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- ❖ Geometric acceptance & technical performances of **hybrid GEM- $\mu$ RWELL** endcap trackers have been assessed.
- ❖ A detector layout compliant with **position resolution and tracking efficiency requirements** has been identified.
- ❖ The **disks are segmented into four quadrants**, connected and attached to the inner tracker support, maximizing the azimuthal and polar acceptances.
- ❖ Readout Electronics is based on SALSA ASIC, being developed at Saclay.
- ❖ A SALSA ASIC emulator is being designed at INFN Roma Tor Vergata to test the PED.
- ❖ Workforce has been allocated to meet the timeline of the production and assembly plans.
- ❖ Production timeline is consistent with the overall ePIC detector schedule.

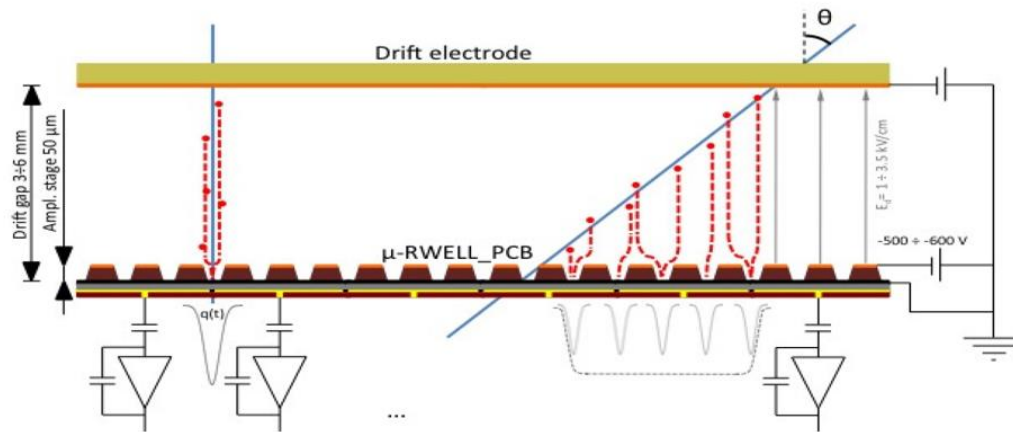
# Backup



# $\mu$ RWELL-BOT Technology: Thin-gap GEM- $\mu$ RWELL Hybrid Detector

## Standard gap MPGD (> 3-mm drift gap):

- ❖ Center of gravity (COG) algorithm does not work for large angle tracks and or track in B field
- ❖ **Degradation of both time and spatial resolution of the detector**

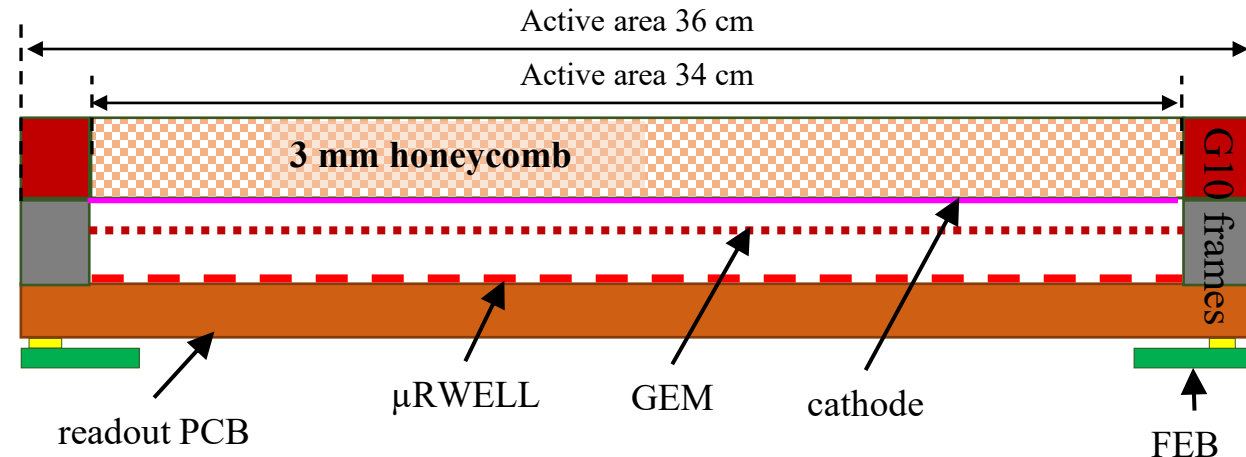


## One solution is the development of Thin-gap MPGDs:

- ❖ Reduce drift gap will improve from 3 mm to  $\sim 1$  mm
- ❖ spatial resolution at large angle tracks (**< 150  $\mu$ m on average**)
- ❖ Time resolution (**< 10 ns**)
- ❖ Minimize the impact of  $E \times B$  for both time and spatial resolution

## Thin-gap GEM- $\mu$ RWELL detector concept

- ❖ 1 mm or 1.5 mm drift gap between cathode and GEM amplification
- ❖ hybrid amplification MPGD:
  - **GEM** (preamplification) and  **$\mu$ RWELL** (main amplification)
  - Allow large detector gain and stable operating HV
- ❖ Readout layer: 3-layer capacitive-sharing U-V strip readout
  - Achieve excellent spatial resolution with thin gap detector

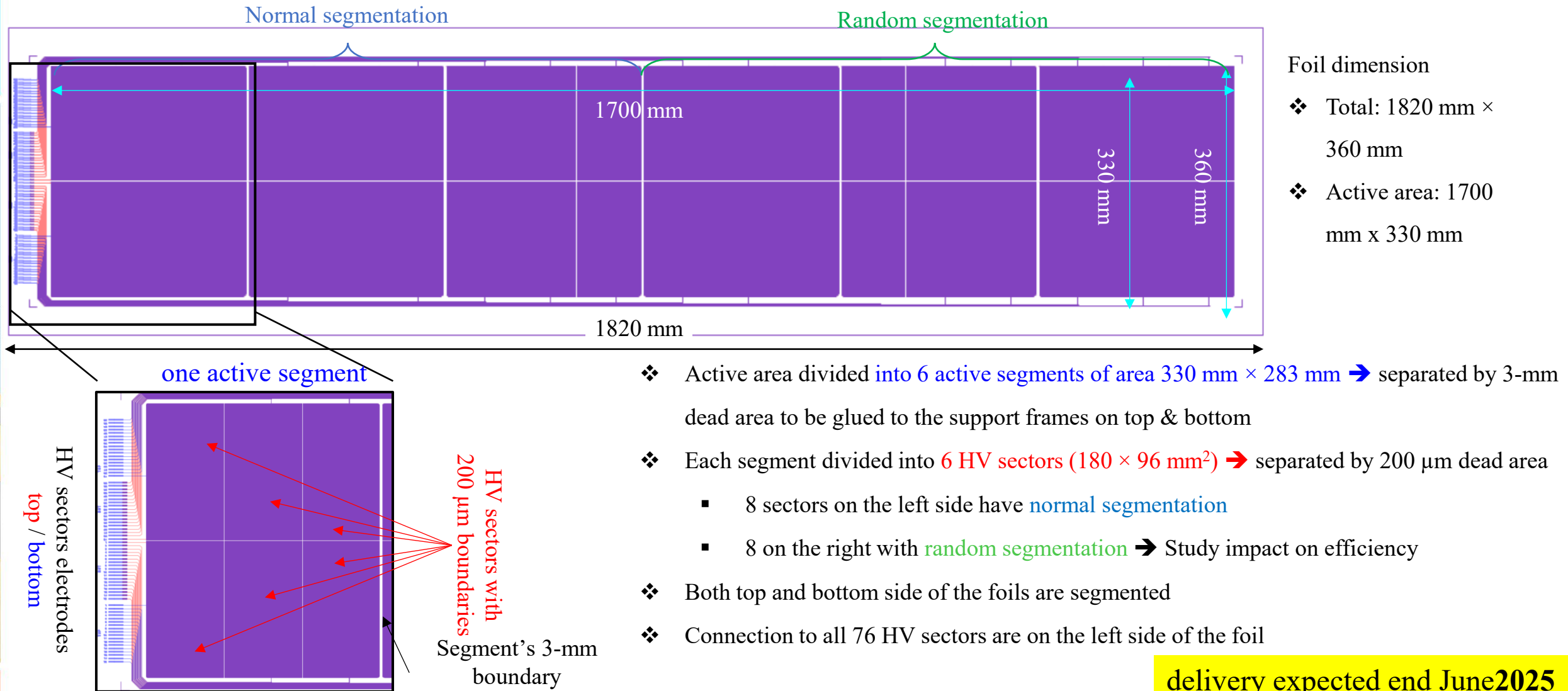


cross-section view of thin-gap GEM- $\mu$ RWELL detector

[https://wiki.bnl.gov/eic/upload/ERD\\_tgMPGD\\_FY22\\_endOfYearReport\\_final.pdf](https://wiki.bnl.gov/eic/upload/ERD_tgMPGD_FY22_endOfYearReport_final.pdf)

# μRWELL-BOT: Test Article – GEM foil design

Charge 3



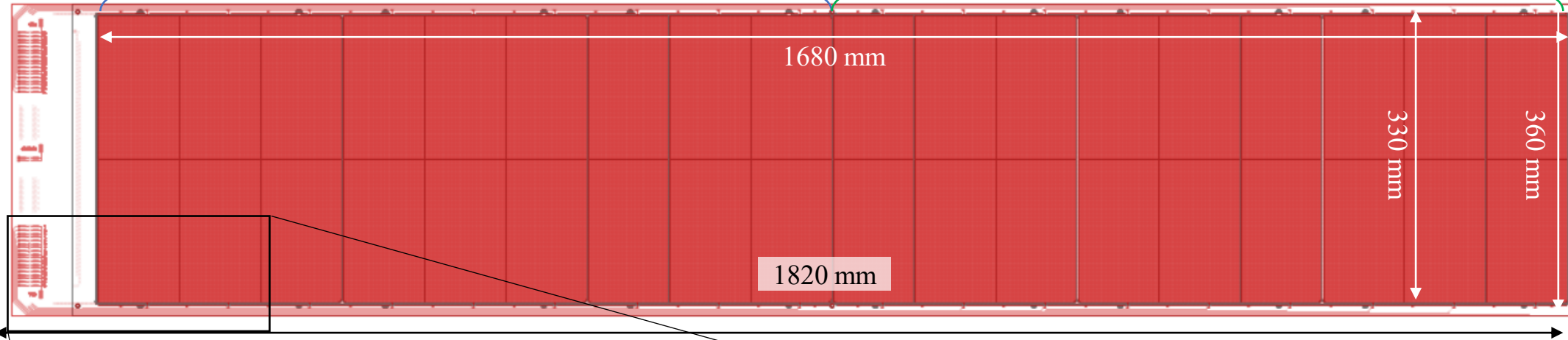
delivery expected end June 2025

# $\mu$ RWELL-BOT: Test Article – $\mu$ RWELL PCB design

Charge 3

Normal segmentation

Random segmentation



$\mu$ RWELL  
dimension

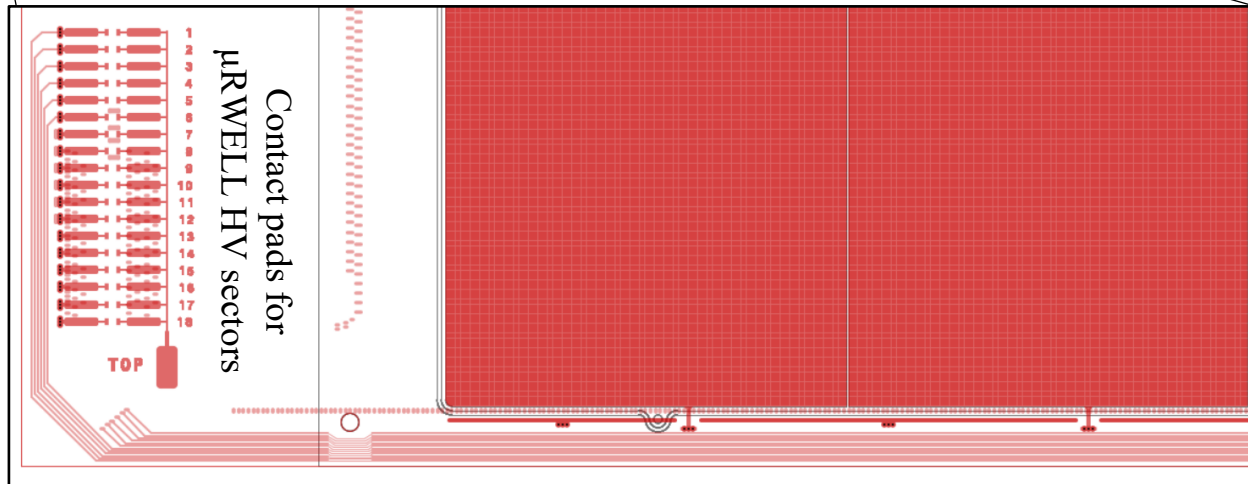
❖ Overall:

182 cm  $\times$  36 cm

❖ Active area:

168 cm  $\times$  330 cm

Two of the 36  $\mu$ RWELL sectors



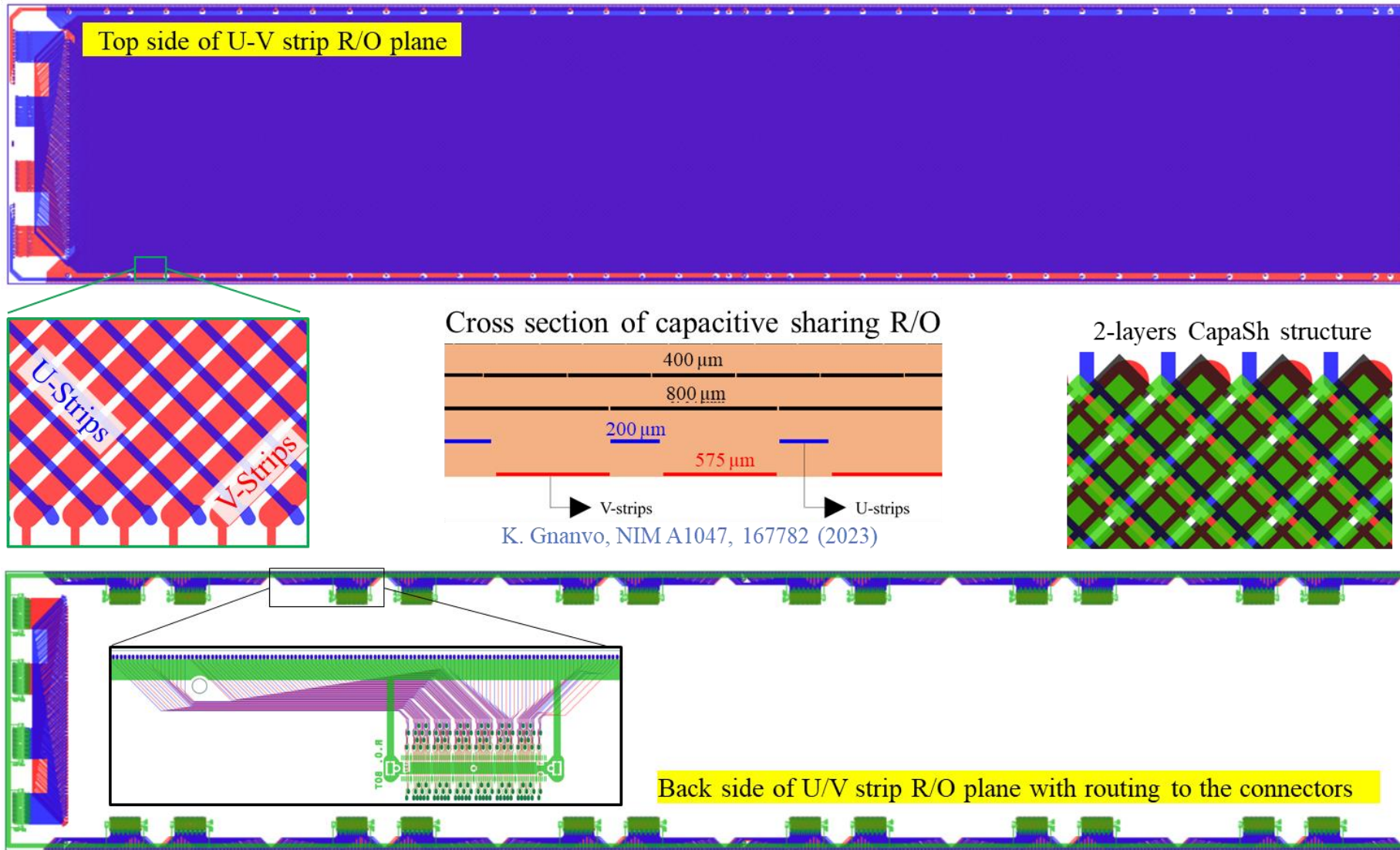
- ❖ The active area of 36 HV sectors (180 mm  $\times$  96 mm) similar to the HV sectors separated by 100  $\mu$ m dead area
  - The 18 sectors on the left side have normal segmentation
  - The 18 on the right have a random segmentation  $\rightarrow$  Study impact on detector efficiency
- ❖ Connection to all 36 HV sectors on the left side of the foil

delivery expected end June 2025

Electron-Ion Collider

# $\mu$ RWELL-BOT: Engineering Test Article – U/V strips readout design

Charge 3



45 degree U / V strips instead of X /

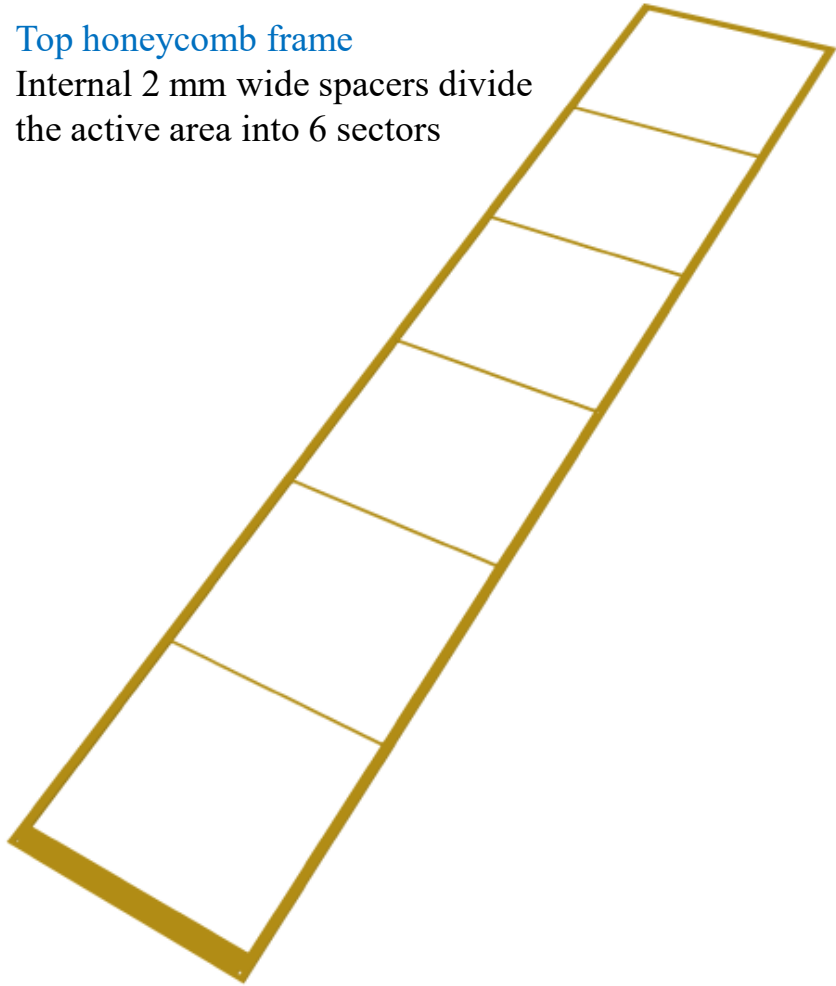
Y

- ❖ All connectors at the edge the long side of the detector
- ❖ Pitch = 800  $\mu\text{m}$  along U / V axis  
→ 1.14 mm along detector edge
- ❖ Strip length = 47 cm limited strip capacitance concerns
- ❖ Width: top strips (U) = 200  $\mu\text{m}$  and bottom strips (V) = 575  $\mu\text{m}$
- ❖ 2 layers of capacitive sharing (400  $\mu\text{m}$  and 800  $\mu\text{m}$ ) → square pads along U and V axis
- ❖ Total of 3,584 strips → 28 × 140-pins Hirose connectors with 12 ground pins on the back of the PCB



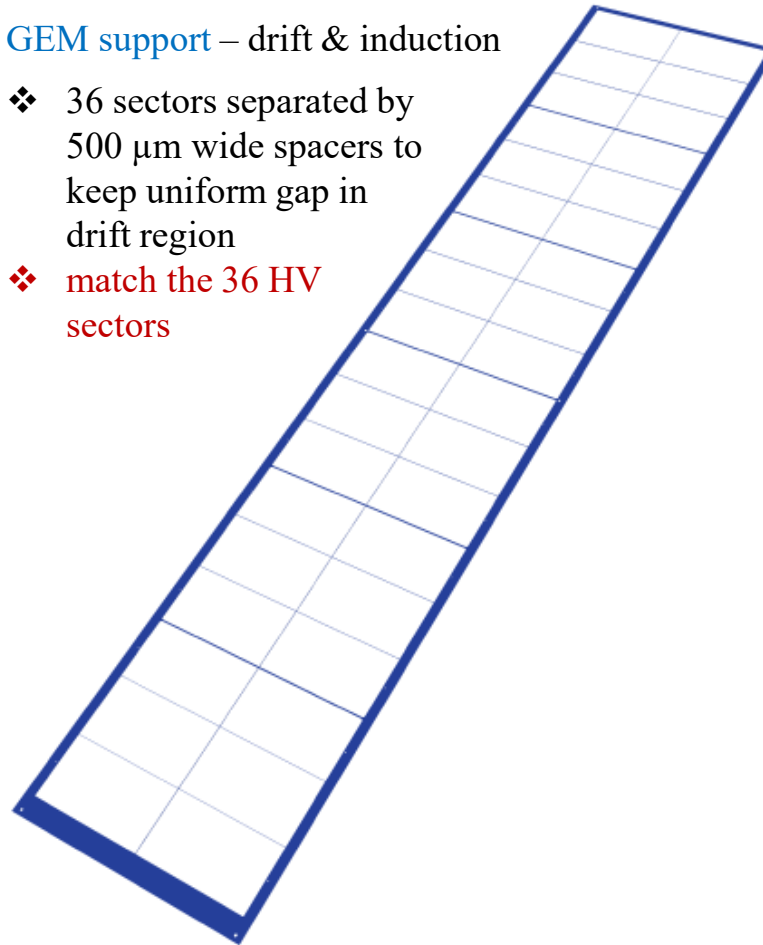
## Top honeycomb frame

Internal 2 mm wide spacers divide the active area into 6 sectors



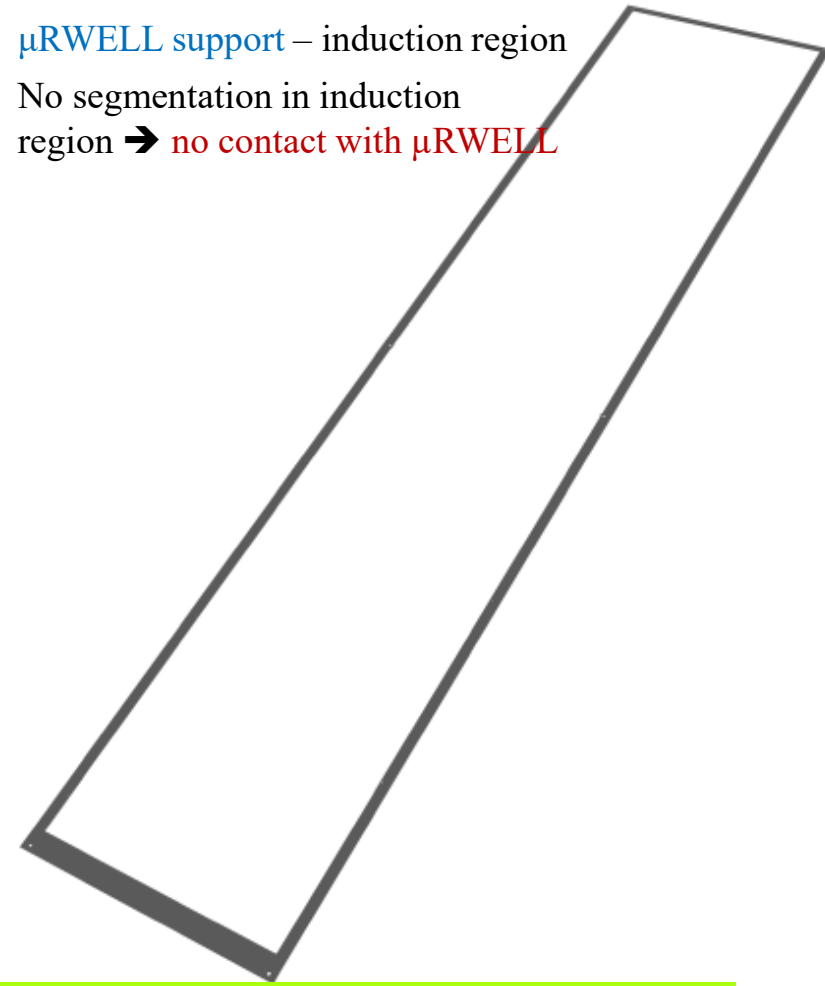
## GEM support – drift & induction

- ❖ 36 sectors separated by 500  $\mu$ m wide spacers to keep uniform gap in drift region
- ❖ match the 36 HV sectors



## $\mu$ RWELL support – induction region

No segmentation in induction region → no contact with  $\mu$ RWELL

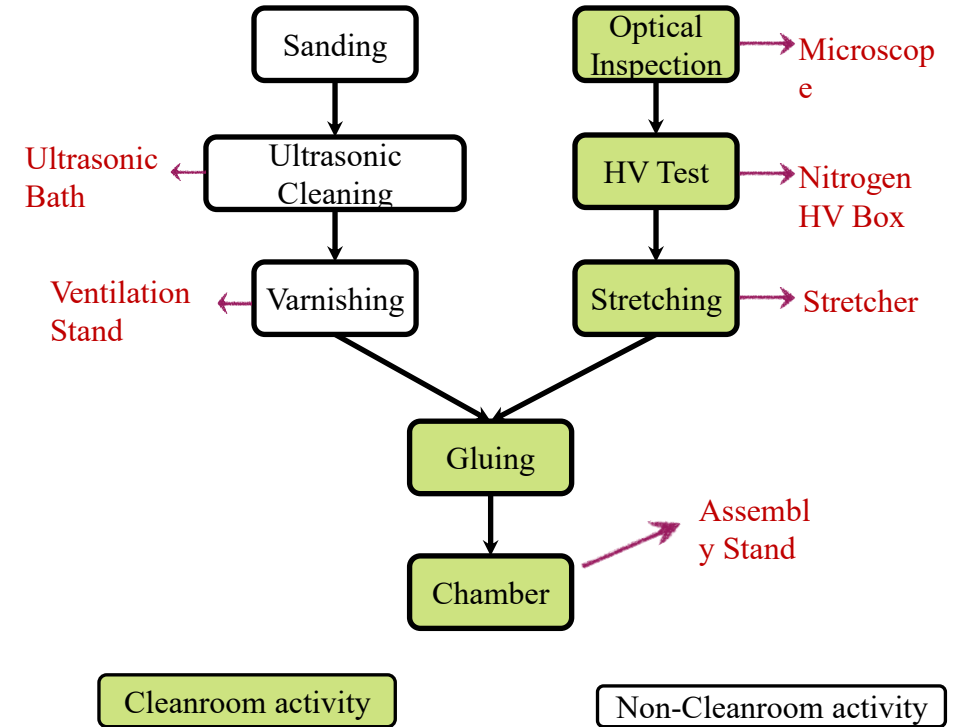


In hand, delivered in February 2025

# μRWELL-BOT: Engineering Test Article – Procurement status

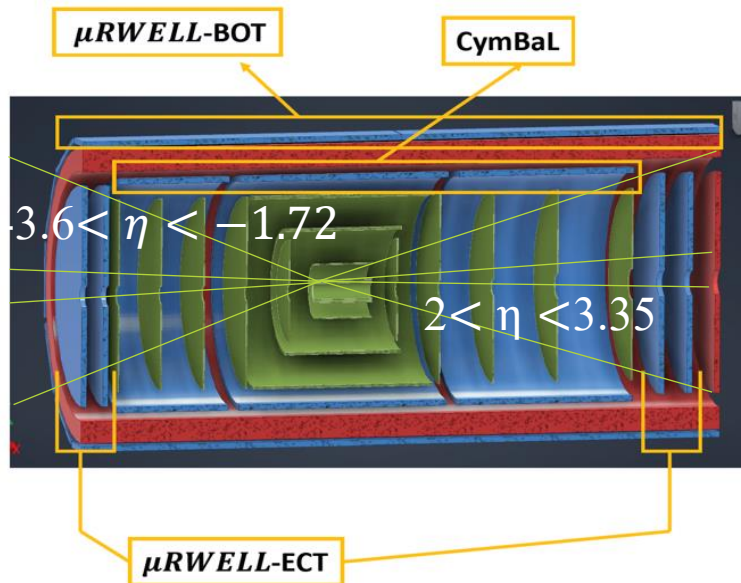
## Procurement status

- Detector frames (RESARM) delivered (February 2025)
- GEM, cathode foil, μRWELL & readout PCB (CERN) ~ mid July 2025
- Major instruments order delivered
  - Ultrasonic bath, Optical microscopes
- Major instruments order placed
  - Fume Hood → purchase requisition in JLab procurement system
  - Instruments manufacturing job submitted to JLab machine shop
- Items to be ordered
  - Cleanroom items: HEPA filters, monitor system, DAQ/Control PC – in progress
  - Fabrication of the Honeycomb support: Flow hood, assembly table, vacuum pump



# $\mu$ RWELL-ECT: Pseudo-rapidity coverage: effective $\eta$ ranges

Component	Z (cm)	Inner Active Reg. Radius (cm)	$ \theta $ min (deg)	$ \eta $ max	Outer Active Reg. Radius (cm)	$ \theta $ max	$ \eta $ min
HD MPGD 2	166	8.0/10.5	2.76/3.62	3.73/3.45	45	15.17	2.0
HD MPGD 1	150	8.0/10.5	3.05/4.00	3.62/3.35	45	16.70	1.9
LD MPGD 1	-107	6.5	3.47	3.49	45	22.80	1.6
LD MPGD 2	-122	6.5	3.04	3.62	45	20.24	1.72



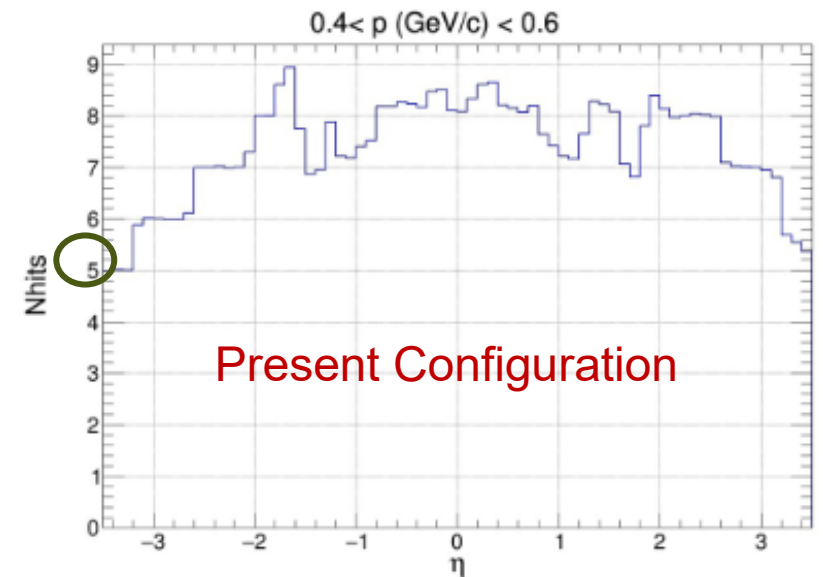
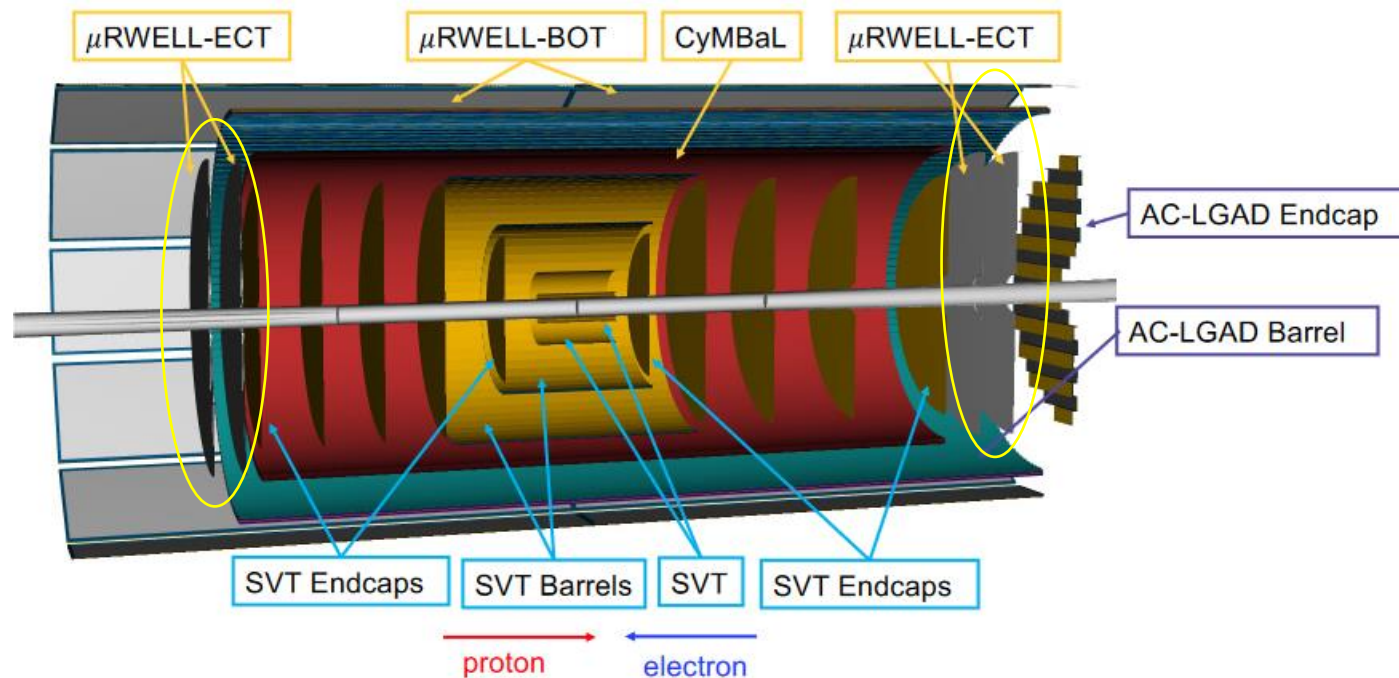
- The minimum  $|\eta|$  value is not larger than 2  
it is limited by the outer HD disk location/dimensions
- The maximum  $|\eta|$  value is not less than 3.35  
it is limited by the inner HD disk location/dimensions

The  $\eta$  range covered by the MPGD Endcap tracking disks is **compliant** with requirements.

# Scope of the MPGD Endcap Trackers

Charge 1

- Adding two MPGD Endcap Tracking (ECT) disks both in the **hadronic** and in the **leptonic** regions increased the number of hits in the  $|\eta| > 2$  region to improve pattern recognition.



Present ePIC tracker geometry

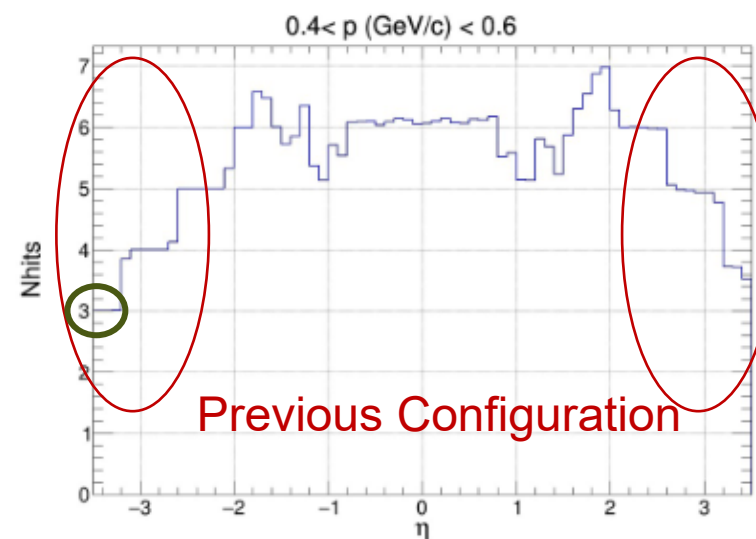
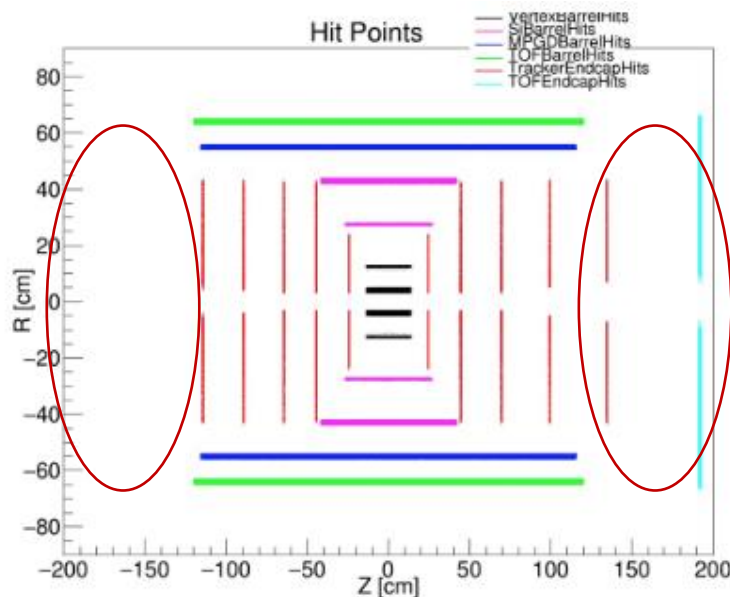


# Scope of the MPGD Endcap Trackers

Charge 1

Are the technical performance requirements appropriately defined and complete for this stage of the project?

- In May 2023, MC simulations showed that the **tracking** configuration in the **endcap** regions of the ePIC detector, which will experience the **highest backgrounds** in the experiment, **would not provide enough hit points** in the  $|\eta| > 2$  region for good pattern recognition



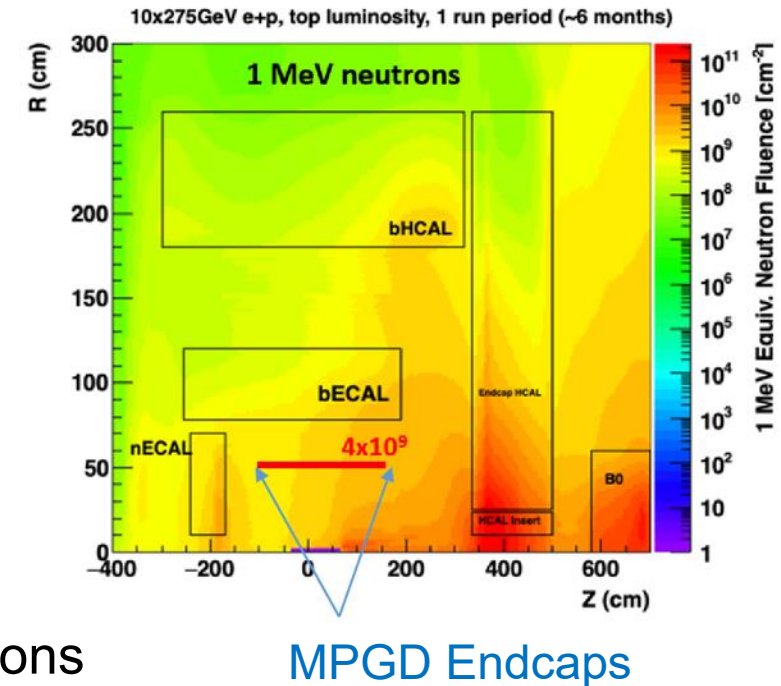
ePIC tracker geometry before June 2023

# Technical performance requirements

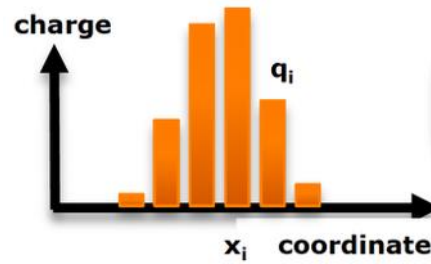
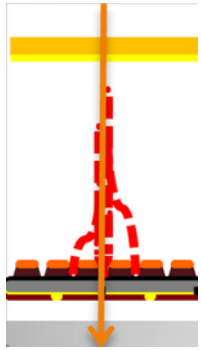
Charge 1

Are the technical performance requirements appropriately defined and complete for this stage of the project?

- **Rate Capability**
  - Not critical  $\sim 1$  kHz/cm<sup>2</sup> or less
- **Radiation Hardness**
  - Not critical for the detectors
  - Important for FEBs and RDO electronics boards
- **Temperature Stability**
  - Not critical for the detector performances
  - Detector calibration should consider gas pressure variations
- **Electronics power consumption and cooling**
  - SALSA ASIC consumption  $\sim 15$  mW/channel at 1.2V  $\rightarrow$  60 W/disk
  - Air vs liquid cooling is under study at Saclay – [see Irakli's talk](#)



# $\mu$ RWELL-ECT: Possible Position Resolution Improvement - $\mu$ TPC

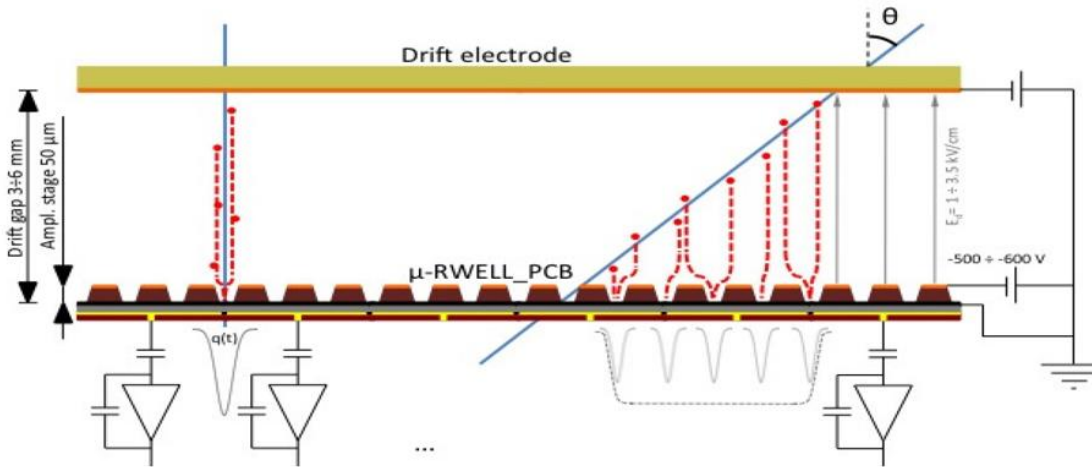


$$x_{hit} = \frac{\sum x_i \cdot q_i}{Q_{tot}}$$

## Charge Centroid (CC) reconstruction method

The track position is determined as a weighted average of fired strips

GOOD FOR ORTHOGONAL TRACKS



## Bended tracks

the Charge Centroid method gives a **very broad spatial distribution** on the anode-strip plane.

**$\mu$ TPC reconstruction**

The spatial resolution is strongly dependent on the impinging angle of the track →

A not uniform resolution in the solid angle covered by the apparatus → Large systematical errors.



