ePIC MPGD Tracker Status

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

10th EIC DAC Review
June 11th – 13th, 2025

Electron-Ion Collider

Charge Questions Addressed

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

Cylindrical Micromegas Barrel Layer **(CyMBaL)**

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

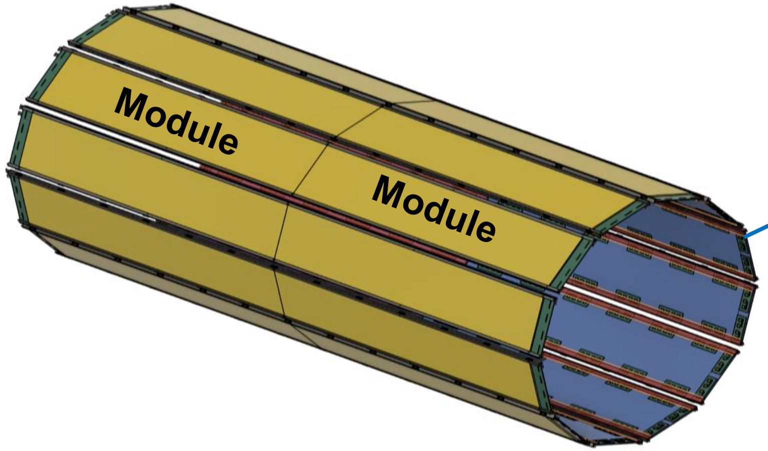
μRWELL Barrel Outer Tracker **(μRWELL-BOT)**

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

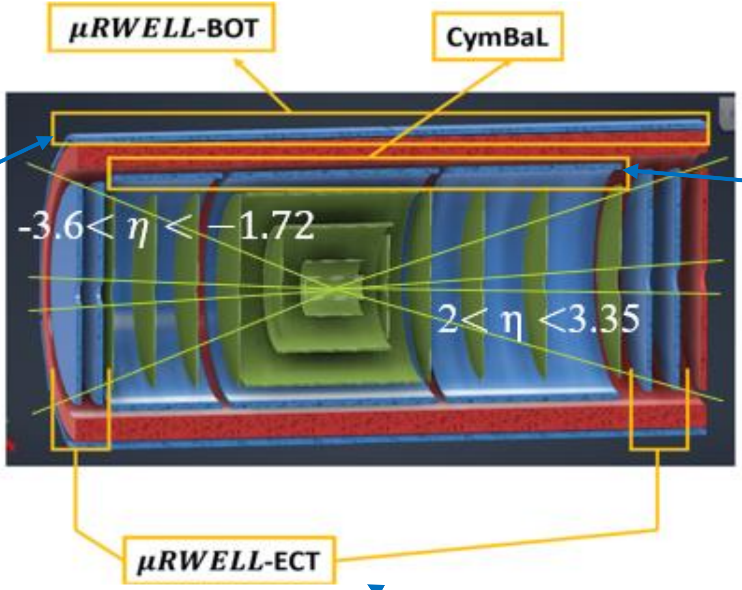
μRWELL End Cap Tracker **(μRWELL-ECT)**

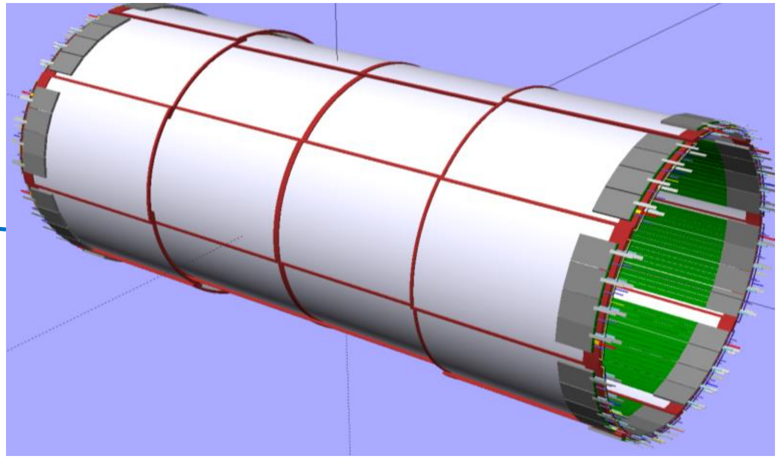
- Detector design: envelope and active regions, dimensions and geometries
- Ongoing Activities, Timeline.

MPGD Trackers in ePIC Detector



µRWELL-BOT: Barrel Outer Tracker

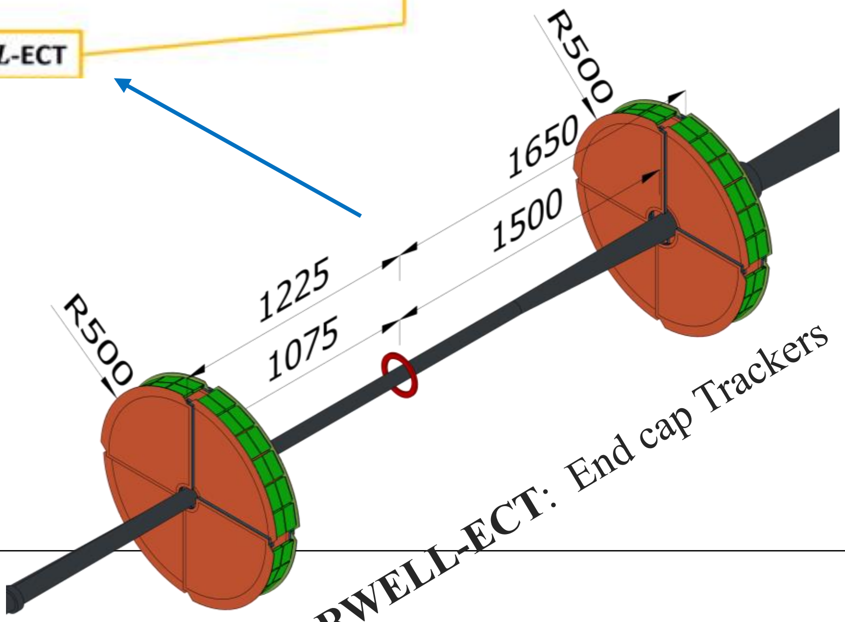




CyMBaL: Inner Barrel Layer

ePIC MPGD trackers provide:

- Fast timing capability (~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



µRWELL-ECT: End cap Trackers

Inner MPGD layer: CyMBaL

Cylindrical Micromegas Barrel Layer

CEA Saclay team

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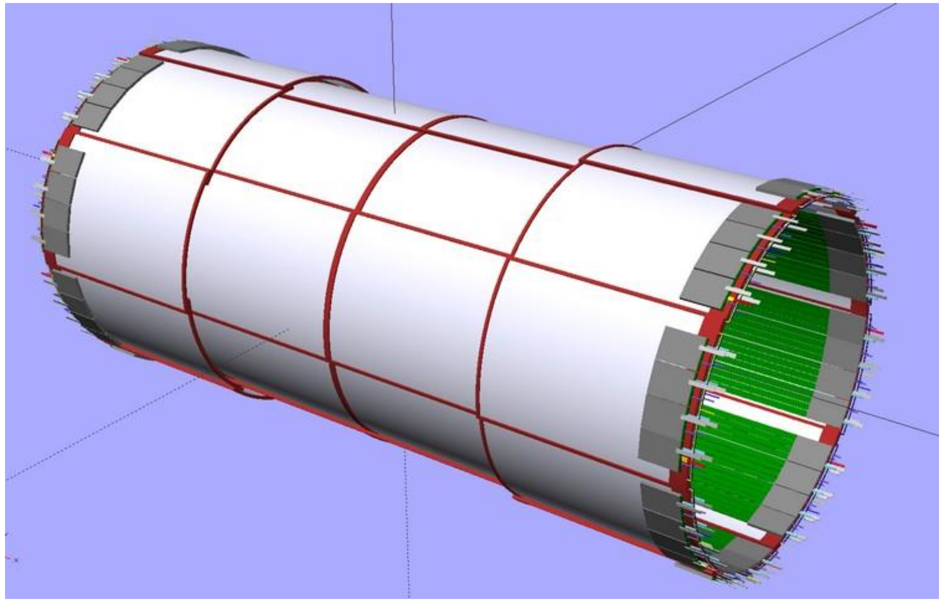
EIC Detector– 10th DAC Meeting
June 11-13, 2025

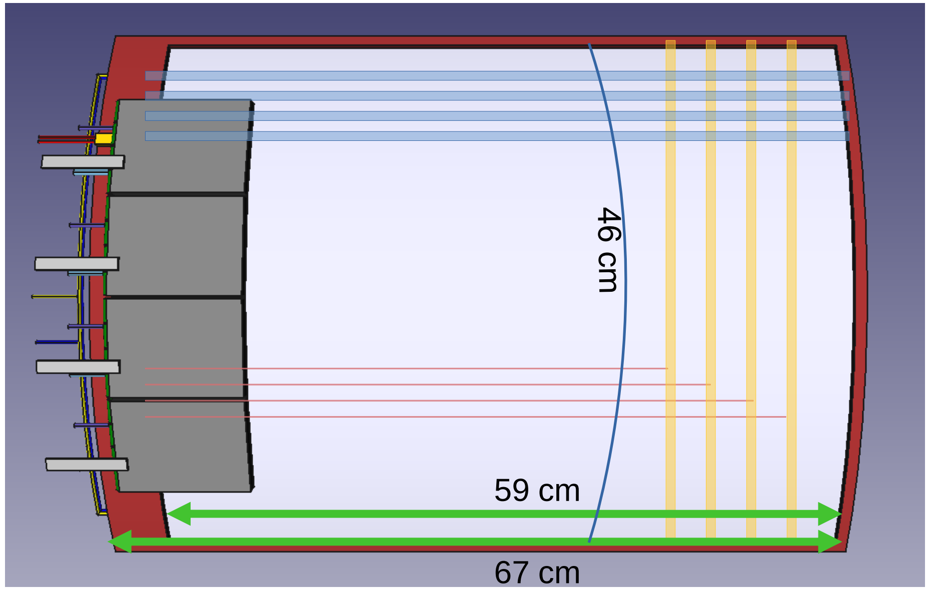
Electron-Ion Collider

CyMBaL: Cylindrical Micromegas Barrel Layer Design

CyMBaL: Current design



Design of a module



32 module: 8 modules in ϕ × 4 modules in z

- R_{min} = 55 cm; R_{max} = 60.5 cm
- Overlaps in ϕ 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

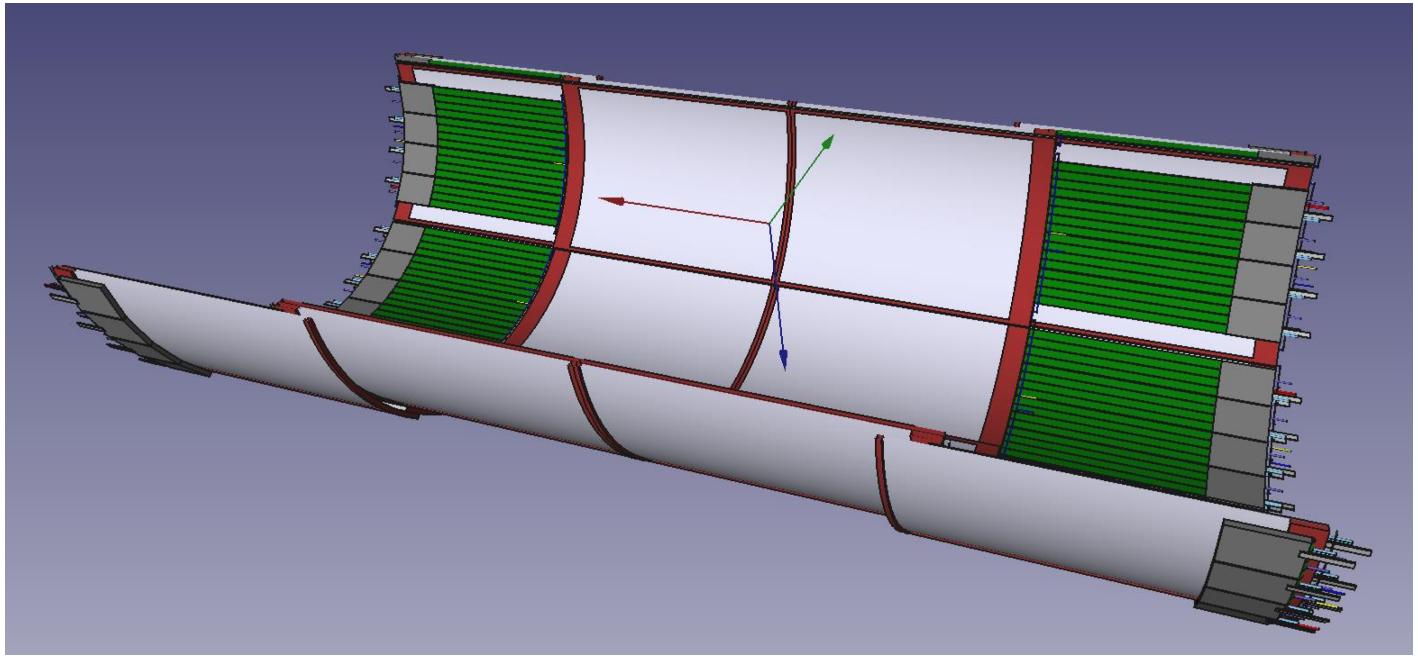
R*phi = 46 cm

Expected performances

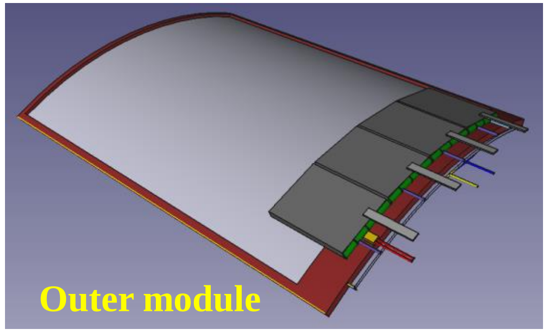
- Spatial resolution: < 300 (500) µm in Z (r*phi)
- Time resolution ~20ns
- Efficiency ≥ 98%
- Material budget ~0.5% X0

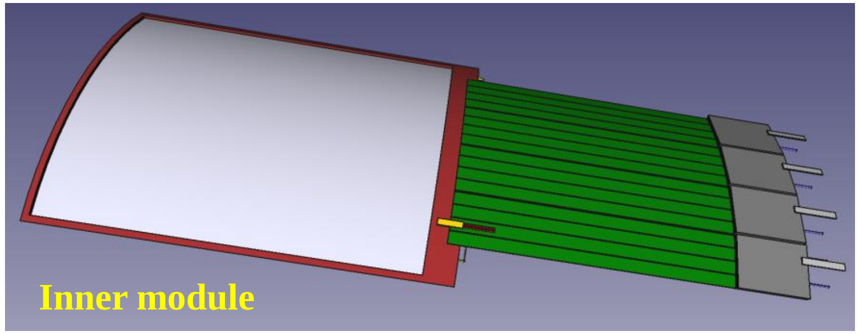
CyMBaL: Cylindrical Micromegas Barrel Layer Design

- 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

2025	2026	2027	2028	2030
R&D and design	Scale 1 Test	Pre-production	Production	Installation
❖ Finalization of the 2D readout R&D ❖ Choice of the r/o ❖ Design of scale 1 prototype ❖ Prepare cosmics test bench for production QA	❖ Production and tests of the scale 1 test article ❖ Validation of module design of modules	❖ Production and tests of the pre-production batch ❖ Validation ❖ Tests with FEB w/SALSA2	❖ Production of **32 modules** ❖ Validation of modules with cosmics and with Fe55 ❖ Tests and production of FEB with SALSA3 ❖ Validation of the FEB→DAQ chain with detectors ❖ Shipments to BNL	❖ Commissioning at BNL

- ✓ Technology chosen: low X0 cylindrical Micromegas
- ✓ Production line of cylindrical detectors refurbished
- ✓ Quality Assurance with cosmics: ready
- ✓ Choice of the 2D readout: ongoing

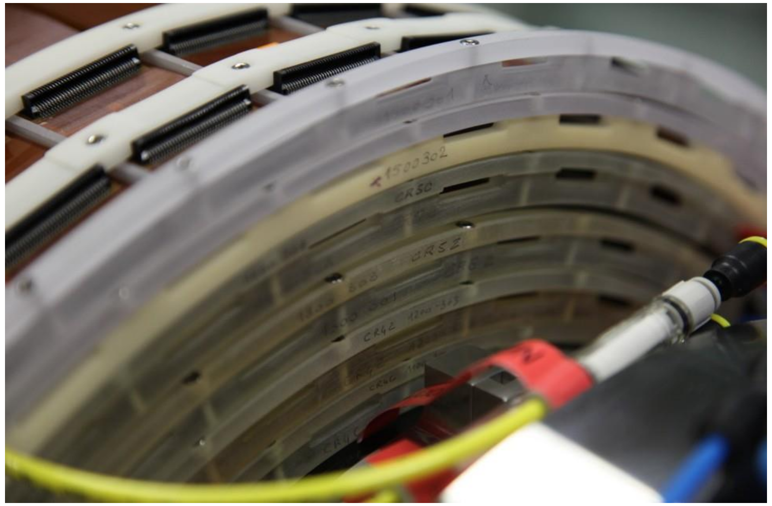
- Preparation for size 1 test article: ongoing
  - ✓ Design of module started
  - ✓ Tests of new connector started
- ✓ Integration: started

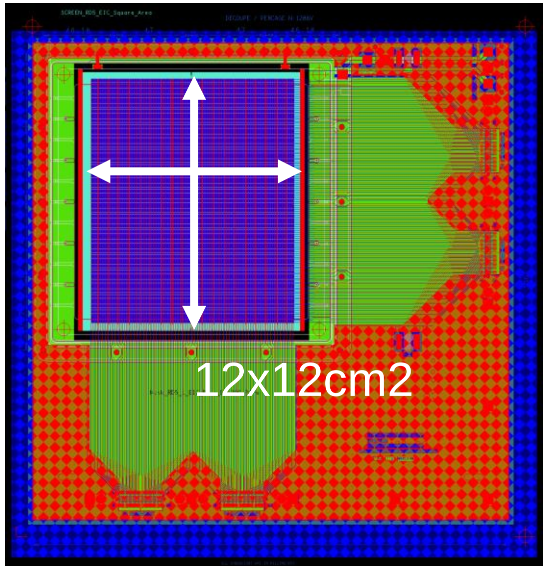
CyMBaL: Ongoing development – Transition from R&D (eRD108) to PED

Technology:

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

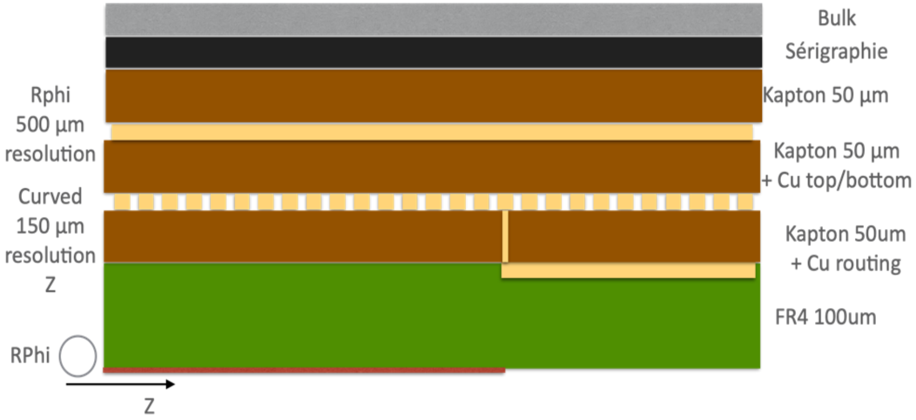
- Light: <0.5% X0 ; Working in high radiation and high magnetic field environment; tight space for integration





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.

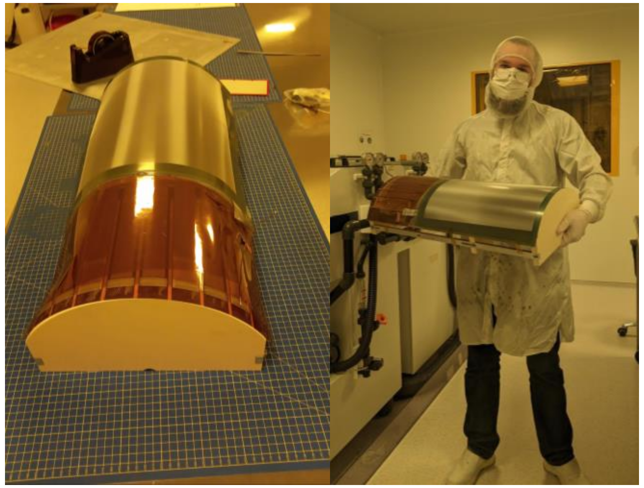


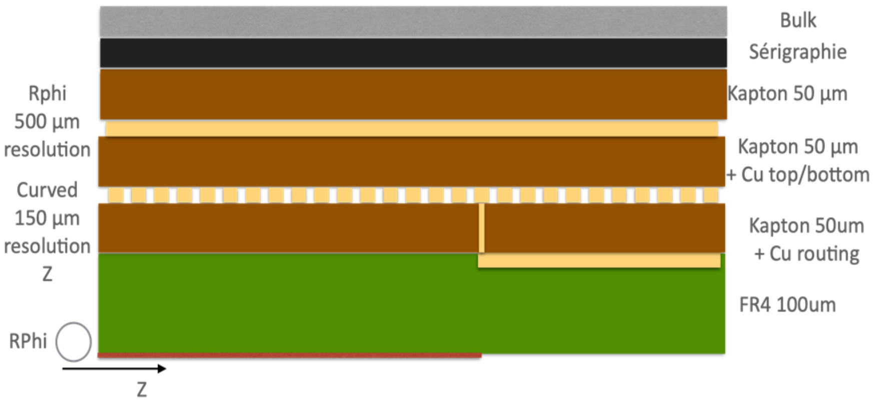
Schematic representation of the readout PCB stack

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

Gearing up for full size prototype:

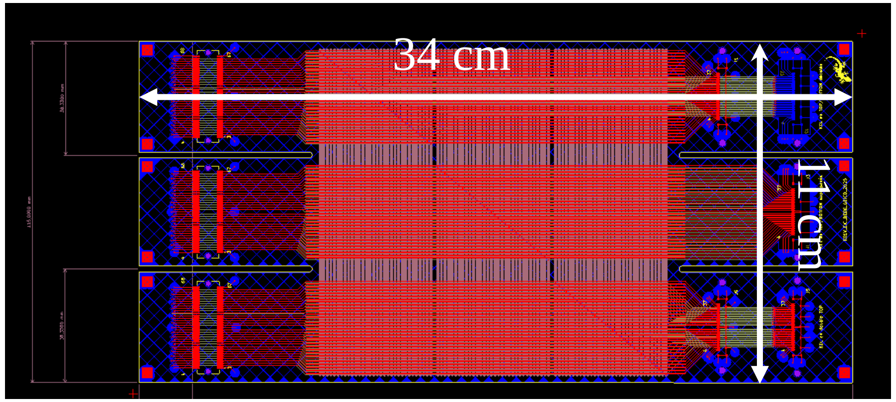
- Restarting the production of curved detectors
  - CLAS12 spare PCB and mechanics used for refurbishing the procedures
  - In Saclay MPGD Lab
    - Resistive layer serigraphy
    - Micromegas bulk process
    - Cylindrical tile assembly



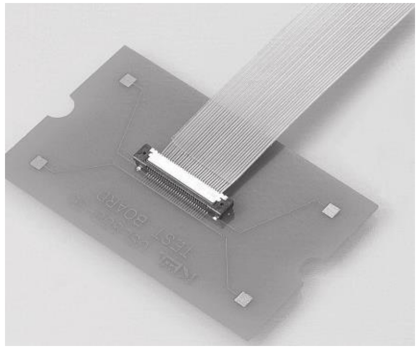


Engineering tests of new small form factor connectors

- 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

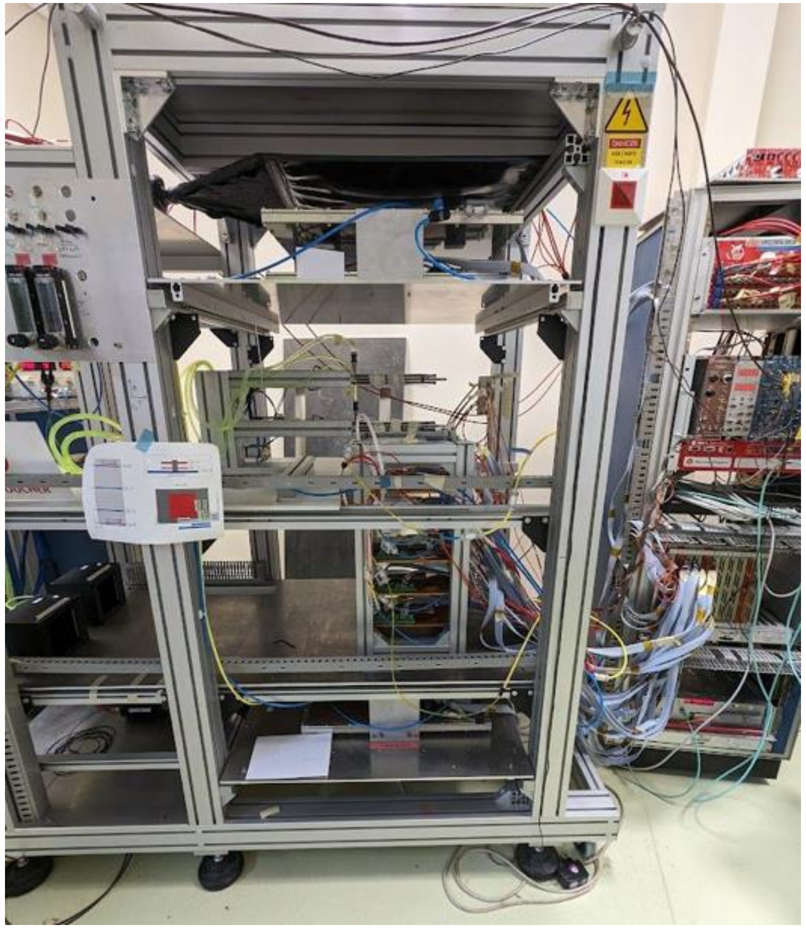


MEC8 to KEL connectors card



KEL connector

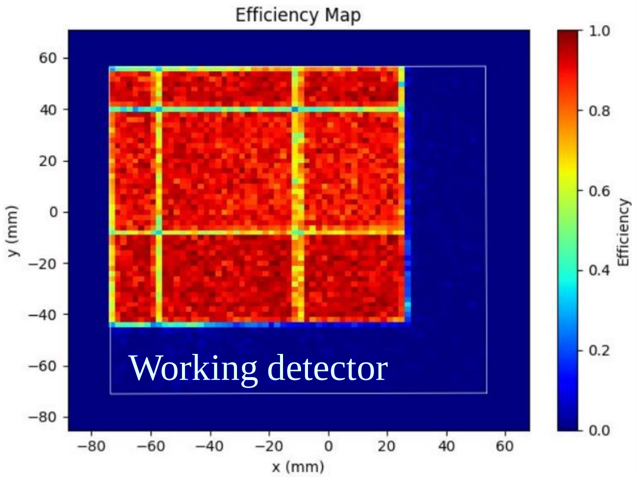
CyMBaL: Cosmic Test Stand @ Saclay for QA

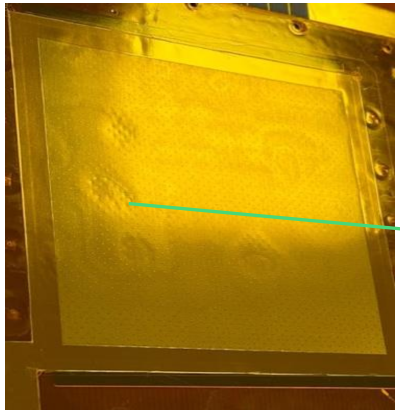


<u>Cosmic rays test bench refurbished</u>

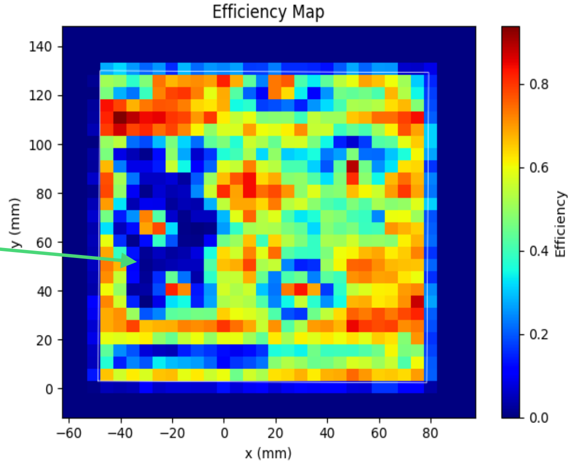
- Silicon telescope (same as in beam test) added to the system
- The DAQ system is adapted to be portable to a next beam test
- Cosmic bench **part of the QA of CyMBaL**
  - Currently used for tests of small prototype
  - **Ready to test production modules**

Examples





Detector with glue spots



CyMBaL: Possible changes in Detector Layout

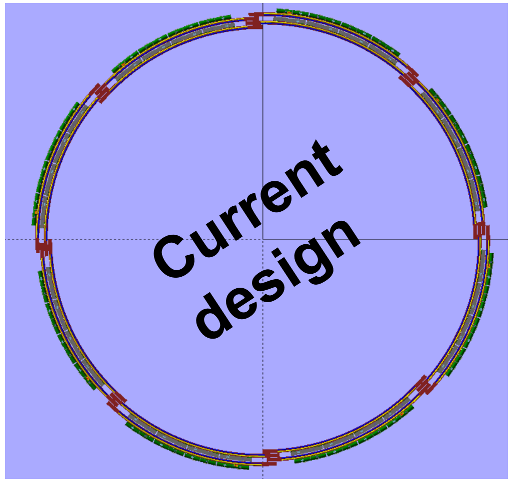
Aiming at simplifying integration, installation and maintenance, the project suggests to change the Inner MPGD layer layout.

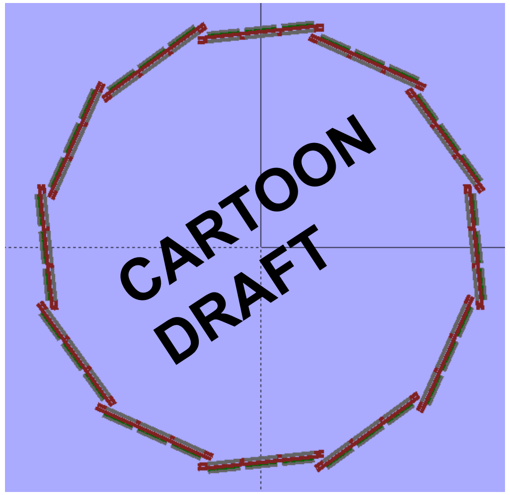
EIC Project proposes to move to a configuration of 12 sectors that can be serviced and accessed independently

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

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

Brookhaven National Laboratory

Jefferson Lab

U.S. DEPARTMENT OF ENERGY

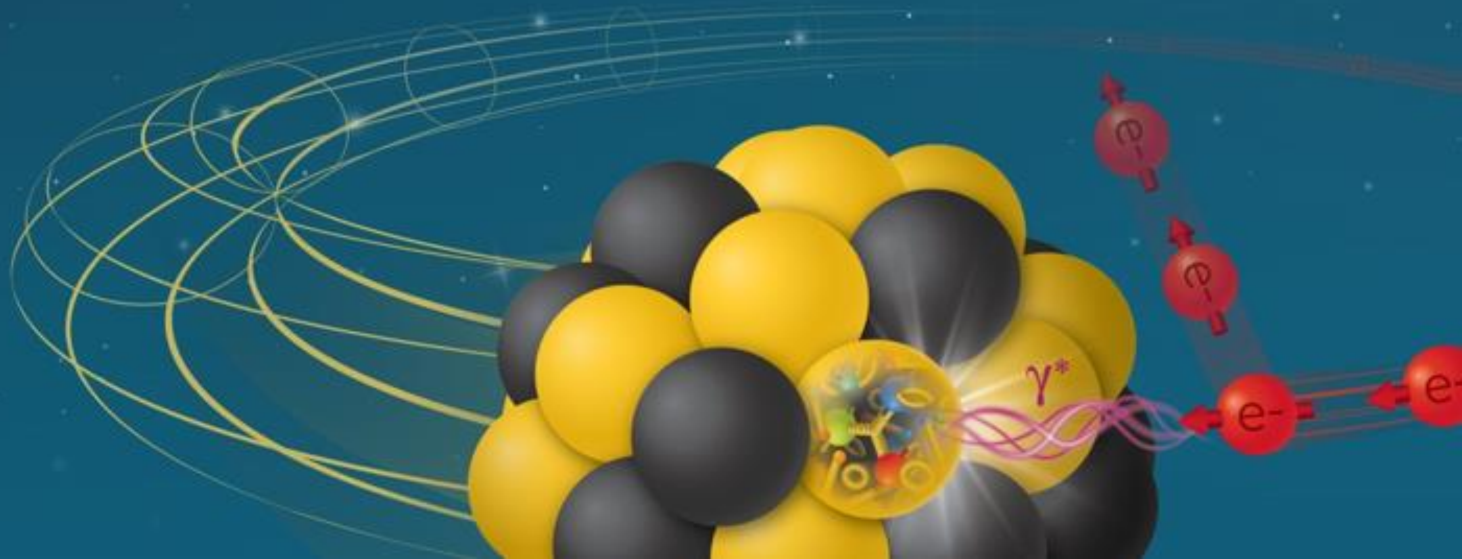
ePIC MPGD Barrel Outer Tracker (µRWELL-BOT)

Kondo Gnanvo, Seungjoon Lee, Xinzhan Bai

RD&I group @ Jefferson Lab

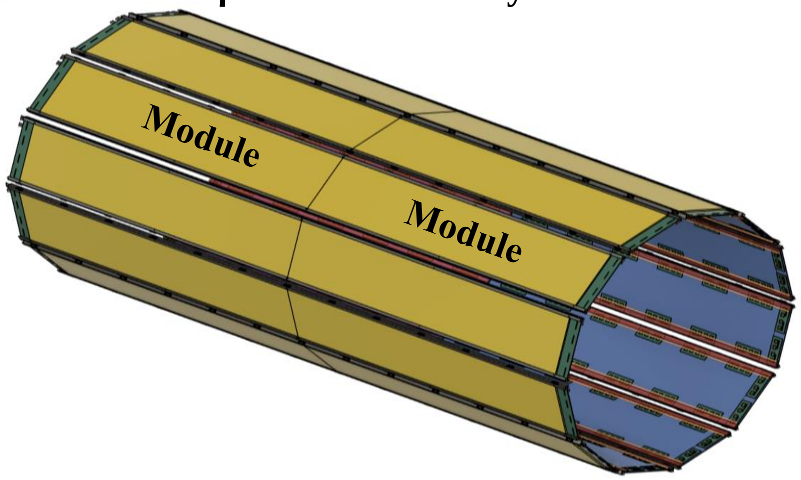
EIC Detector Advisory Committee (DAC) Meeting - June 11–13, 2025

Electron-Ion Collider

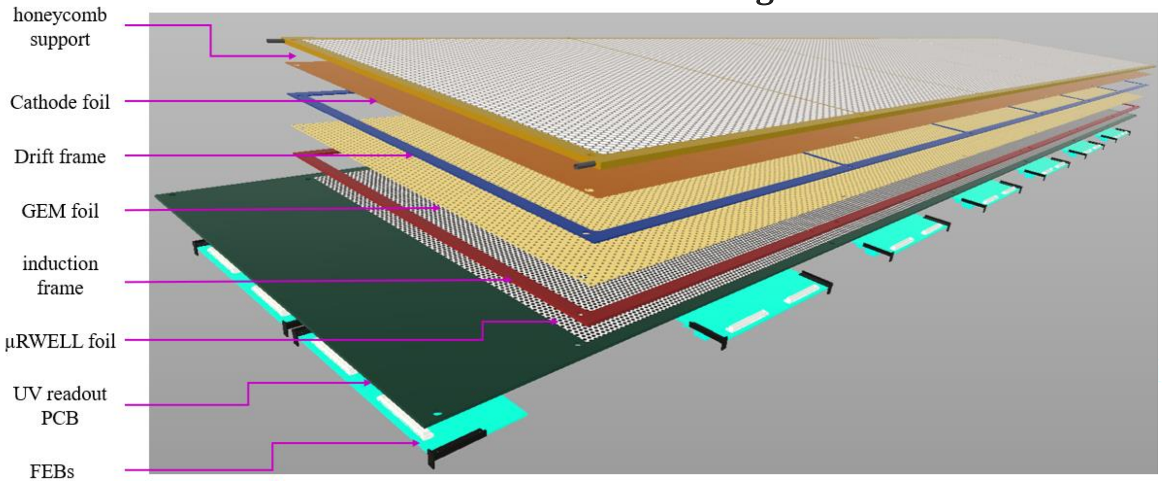


μRWELL-BOT: ePIC MPGD Barrel Outer Tracker

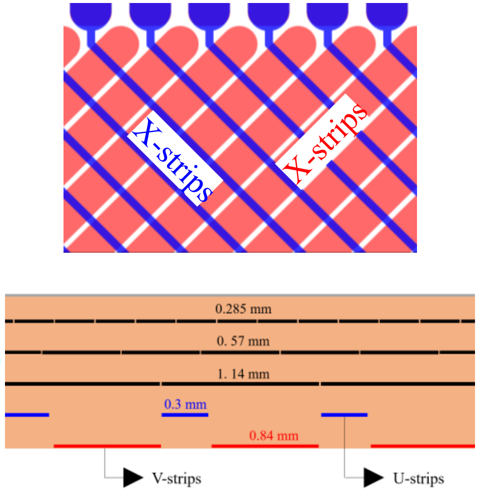
μRWELL-BOT layout



Module design



capaSh X-Y strip readout



24 planar detector modules:

- 12 sectors in r*φ × 2 modules in z ➔ No overlaps
- R_{min} = 72.5 cm; R_{max} = 75 cm
- Novel Thin-gap GEM-μRWELL hybrid technology
- ASIC: SALSA (under development @ Saclay): 64 chs
- ~86k readout electronic channels

Module

- Overall dimension: 180 cm in z × 36 cm in r*φ
- Active area: 170 cm in z × 33 cm in r*φ
- Capacitive-sharing "X-Y" strips readout @ 45° w.r.t detector
- 14 FEBs / module Total: 3,584 chs / module
- Hirose connectors: 140 pins (128 signals + 12 grounds)

Expected performance

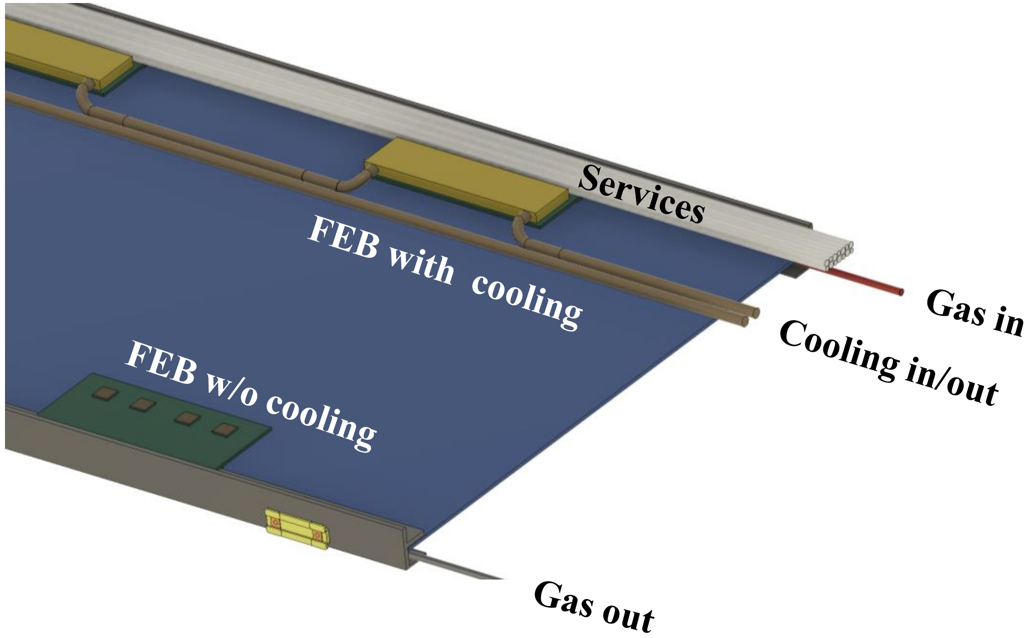
- Spatial resolution: < 100 μm in r × φ & < 150 μm in Z
- Time resolution ~10ns
- Efficiency ≥ 95%
- Material budget ~2% X0

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



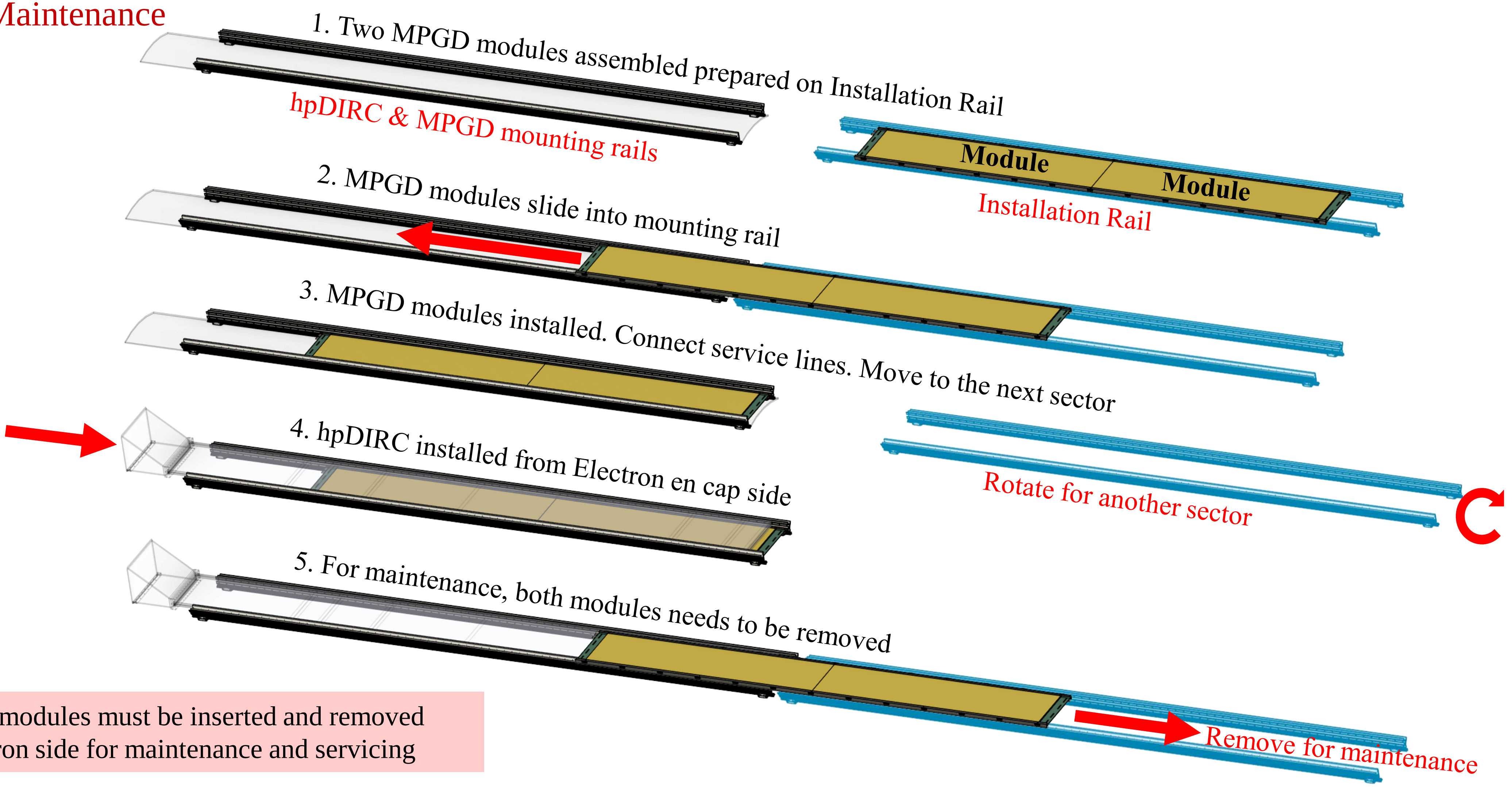
Service/Parts	Per Module	Total	Parameter
Frontend Board	14	336	256 Channel / FEB
High Voltage	1 (resistive divider)	24	3.2 mm OD
Low Voltage	14	336	6 mm OD
Gas	2	48	3 mm ID, 4 mm OD
Cooling	4	96	6 mm ID, 8 mm OD
Data Cable	14	336	Optical Fiber
Sensor	2	24	Temp. & Humidity
Ground			Depends on grounding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

μRWELL-BOT: Integration in ePIC Detector

Installation & Maintenance



Both MPGD modules must be inserted and removed from the hadron side for maintenance and servicing

μRWELL-BOT: Production plans & Timeline

06/2025	06/2026	12/2027	12/2030	
PED Test article	PED & pre-production	Start of Construction	Shipment to BNL	Commissioning & Installation

PED Test article (06/2025)

- Design completed & Procurement – 07 / 2025
- Clean Room & Test stand ready - 09/2025
- Assembly & tests - 12/2025
- Still leaves 1+ year to fold in design modification before start of construction

PED & pre-production (06/2026)

- Design & construction of pre-production modules ➔ one per assembly sites
- Preparation & validation of assembly sites.
- Establish QA procedures & documentation

3 assembly sites:

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

Start of Construction (12/2027)

- Assembly and QA of production modules at assembly sites
- Characterization at assembly sites with cosmic and radioactive sources

Shipment to BNL (12/2030)

- Shipment of all 24 modules to BNL
- Commissioning on cosmic stand of all μRWELL-BOT modules

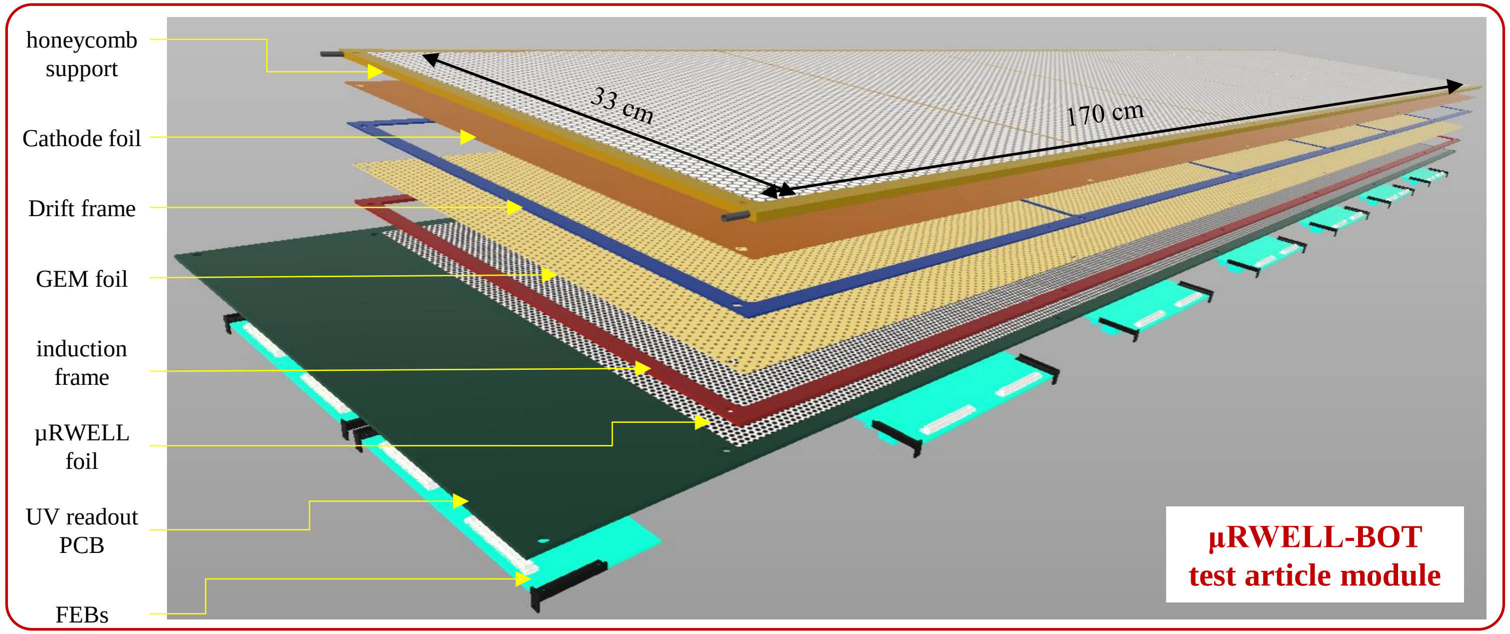
Commissioning & Installation

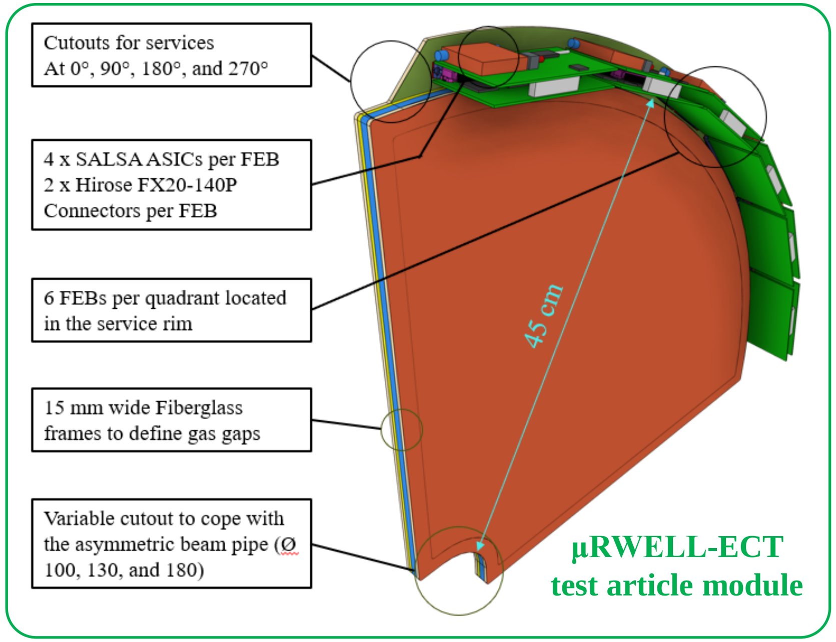
- Commissioning
- Installation

Project Engineering Design - Test Article Modules: Synergy between BOT & ECT

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

- New technology: Double & hybrid amplification structure with GEM and µRWELL ➔ Common challenges to be investigated in parallel
  - Stretching of large GEM foil ➔ development of dedicated mechanical stretcher
  - Handling of large µRWELL 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

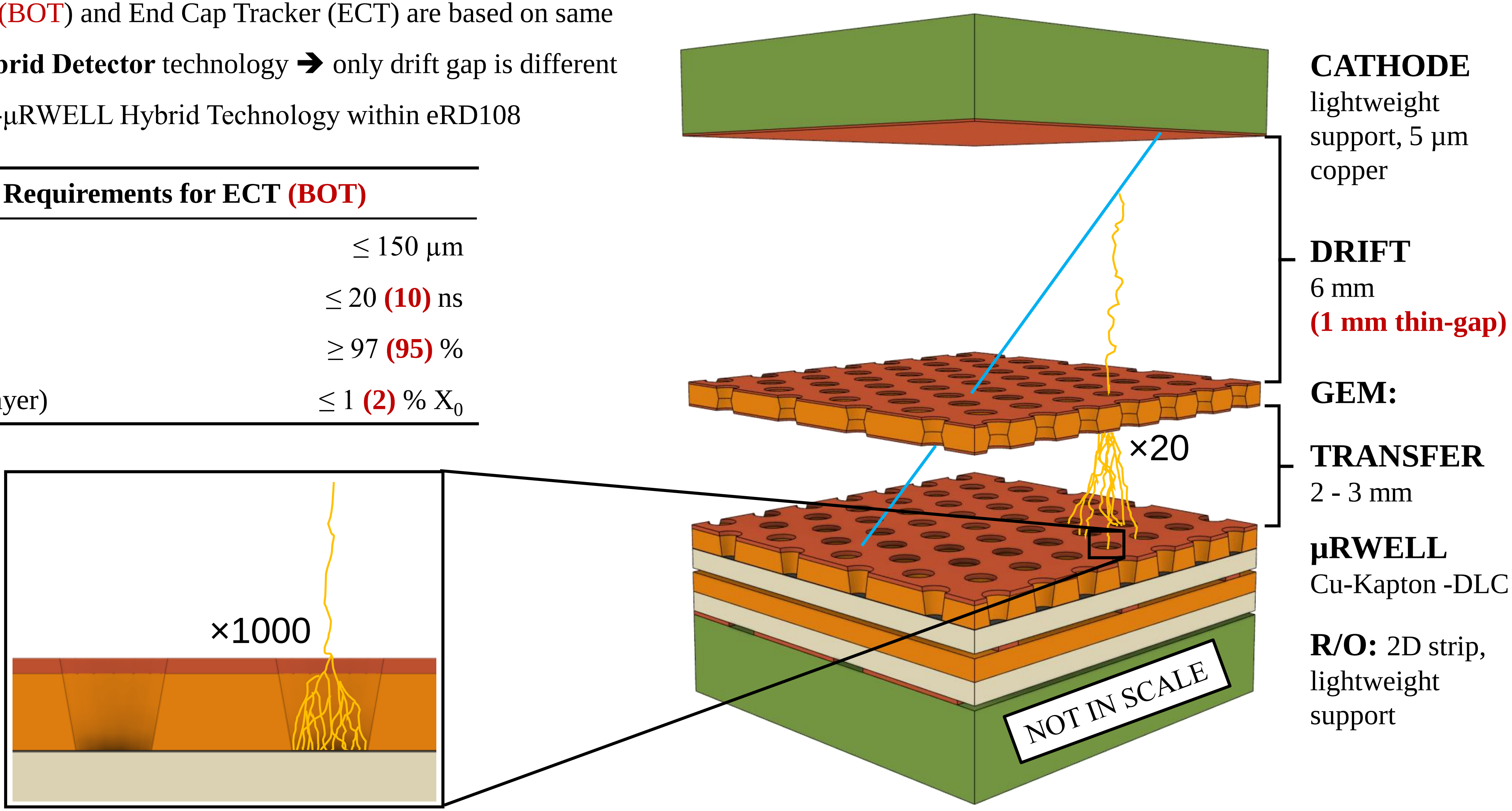




New MPGD Technology - GEM-µRWELL Hybrid Detector for ECT & BOT

- Both Barrel Outer Tracker (BOT) and End Cap Tracker (ECT) are based on same **New GEM-µRWELL Hybrid Detector** technology ➔ only drift gap is different
- All R&D Studies on GEM-µRWELL Hybrid Technology within eRD108

Performance Requirements for ECT (BOT)	
Spatial resolution	≤ 150 µm
Time resolution	≤ 20 **(10)** ns
Single layer efficiency	≥ 97 **(95)** %
Material budget (per layer)	≤ 1 **(2)** % X_0



μRWELL-BOT: PED Test Article Activities - Where Are We As Of Now?

- Test article module:
  - Support frame delivered
  - GEM, μRWELL / readout PCB, cathode foil – 07/2025
- Assembly of the test article module: 08/2025 – 10/2025
  - Clean room refurbishment ongoing
  - Procurement of major instruments & machine shop job
  - Some instruments in hand (Ultrasonic Bath, oscilloscope ..)
- Test beam with test article
  - Ongoing JLab Test beam for gas choice with small prototype
  - Planned CERN Test beam for full scale test article – 11/2025

MPGD Clean Room in EEL-121 @ Lab

Large Ultrasonic Cleaning Bath

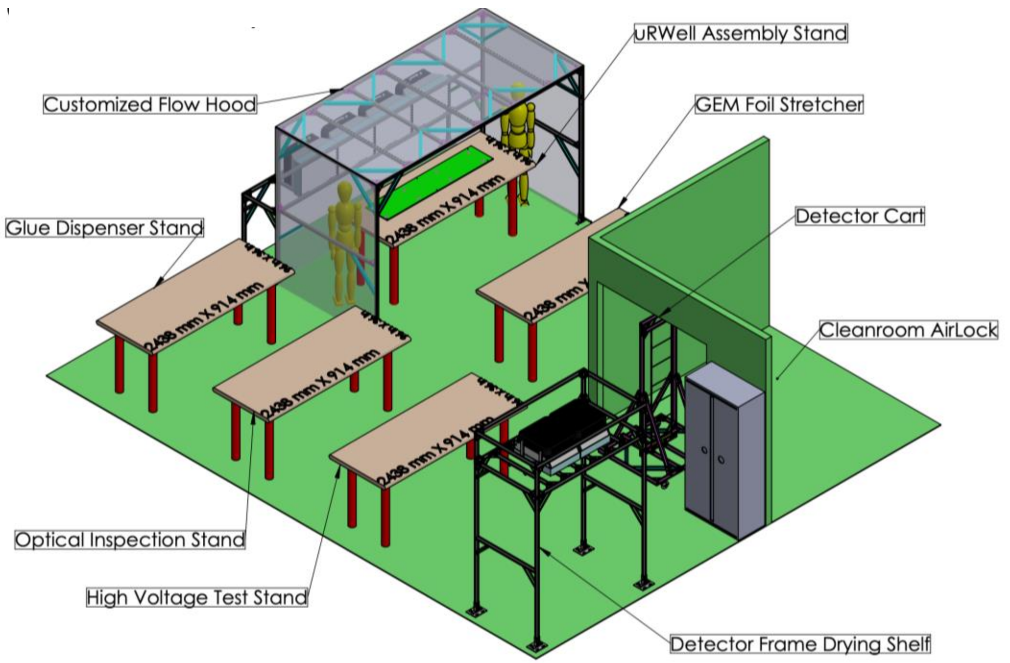
Support frames set for μRWELL-BOT test article modul

µRWELL-BOT: PED Test Article Activities - Where Are We As Of Now?

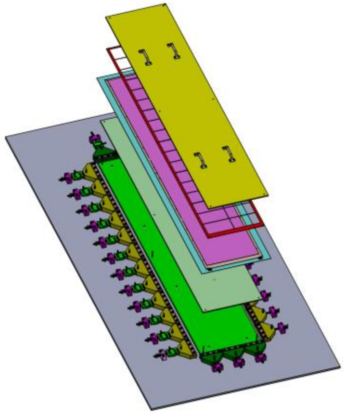
MPGD Cleanroom in JLab Room EEL121

- ❖ 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

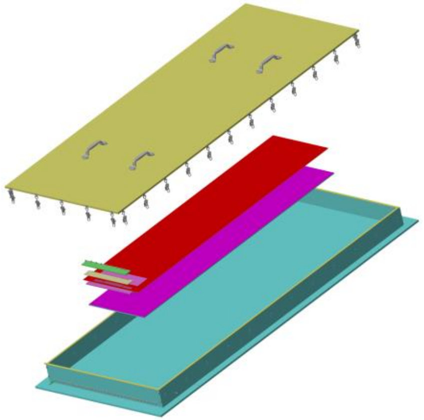
Cleanroom layout with main equipment & instrumentation



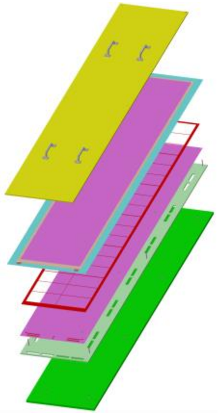
Machine shop jobs



GEM Stretcher



N2 box for HV Test



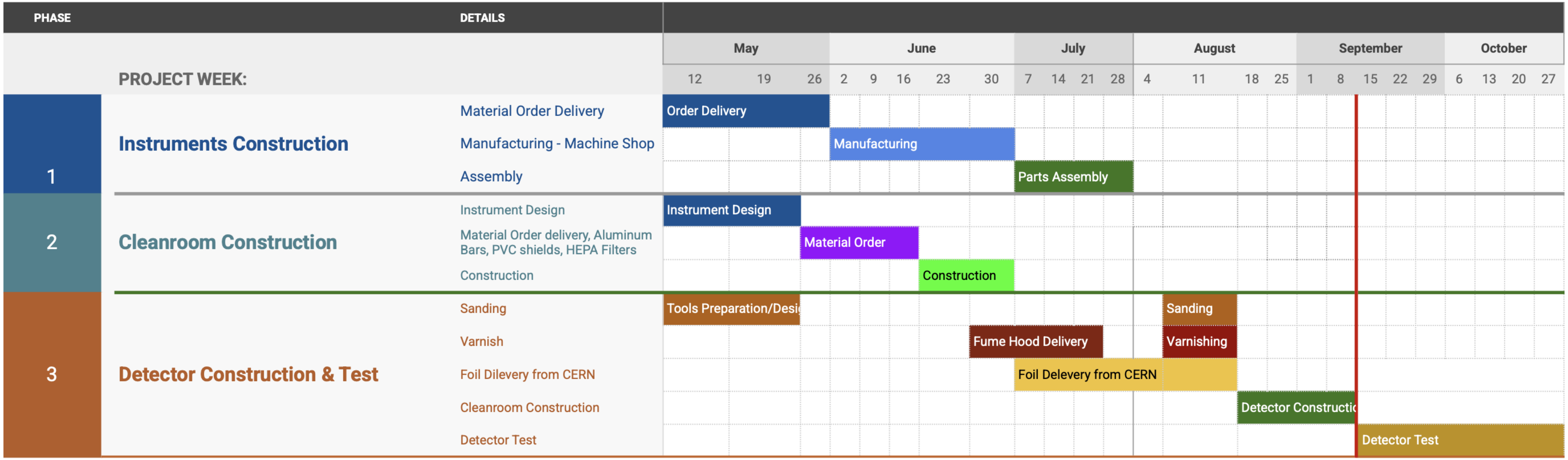
Assembly Stand

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: Timeline for the assembly of the test article module

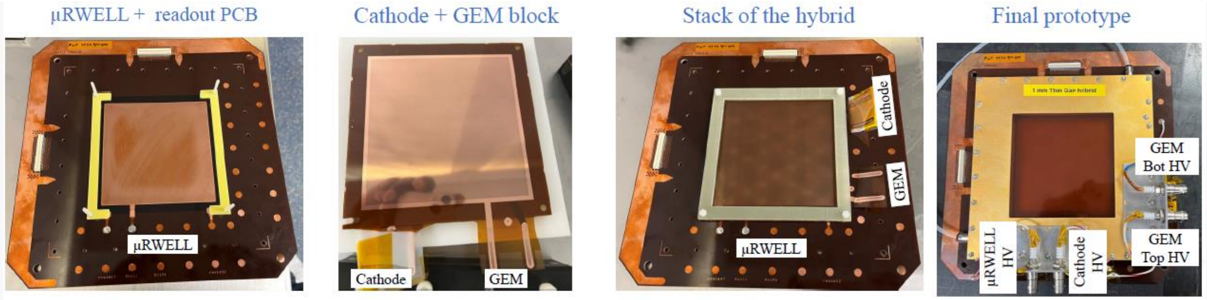
- ❖ Detector frames (RESARM) delivered, GEM Foil, µRWELL (CERN) - expecting early July 2025
- ❖ Major instruments ordered, construction in progress
  - ▪ Infrastructure ready for construction – mid August 2025
  - ▪ Detector ready for benchmarking – early September 2025
- ❖ The timeline is partially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

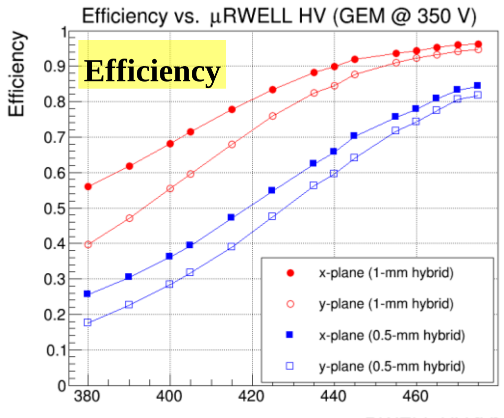


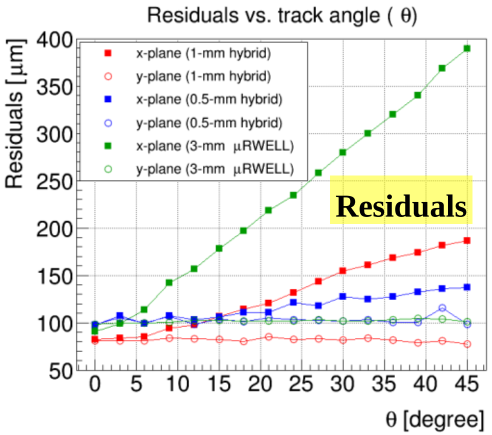
µRWELL-BOT: Technology validation & Performance studies

FNAL Test beam (06/2023): Thin-gap GEM-µRWELL 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) µRWELL





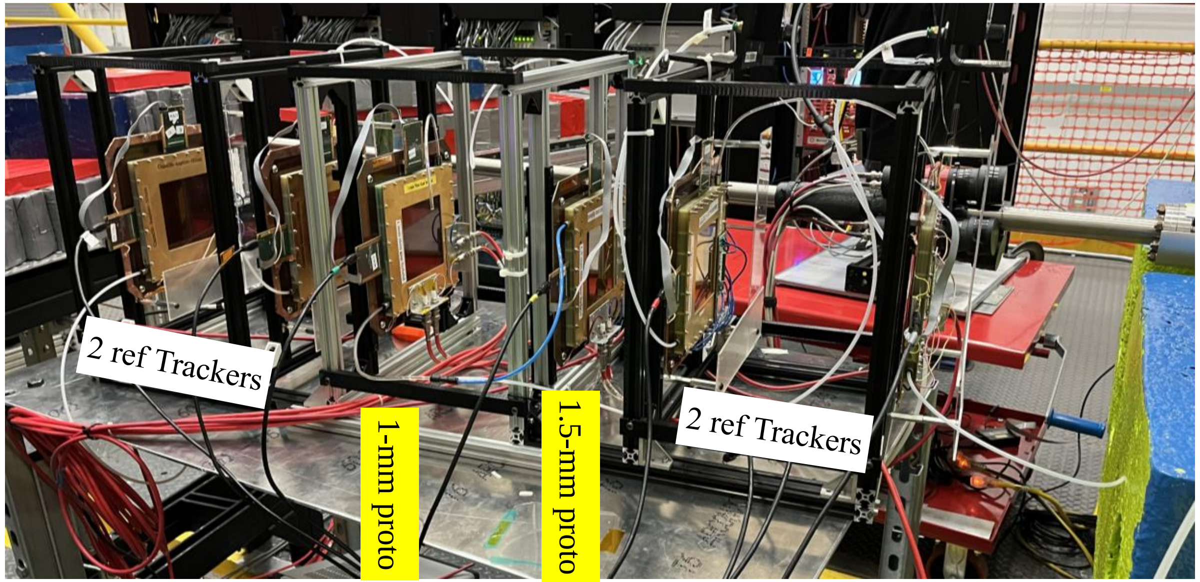


https://wiki.bnl.gov/eic/upload/ERD_tgMPGD_FY22_endOfYearReport_final.pdf

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

JLab Test beam (05/2025): Thin-gap GEM-µRWELL gas studies

- 3 small prototypes (0.5, 1 & 1.5-mm gap) under test
- Different Argon based gas mixtures to be tested
  - $Ar:CO_2$ ➔ 72:25, 80:20 & 90:20 mixtures
  - $Ar:CO_2:iC_4H_{10}$ ➔ 90:7:3 mixture
- HV scans: drift field, transfer field, GEM & µRWELL amplifications
- Final choice of µRWELL-BOT gas will be based on the test beam results



µRWELL-BOT: Summary

- ePIC Barrel Outer Tracker (**µRWELL-BOT**) is based on the novel **Thin-gap GEM-µRWELL** hybrid detector technology
- The basic design features and parameters of µRWELL-BOT module is well defined and understood.
- µRWELL-BOT is instrumented with the SALSA electronics under development at CEA Saclay.
- The integration of µRWELL-BOT in ePIC detector is understood and is been coordinated with ePIC Integration team
- Timeline for fabrication of the µRWELL-BOT modules is in accordance with the overall ePIC detector schedule.
- The full-scale engineering test article of the PED is underway for the design validation and detector performances.
- Cleanroom space for the assembly of the test article has been secured in EEL-121 at Jlab.
- Cosmic test stand for characterization and QA of the test article and production chambers is under construction.
- Final validation of the test article with the SALSA electronics is expected in 2027 before start of production

MPGD ENDCAP Trackers (ECT)

GEM–µRWELL technology

Annalisa D'Angelo
ECT project coordinator

10th Detector Advisory Committee Meeting
June 11-13, 2025

Electron-Ion Collider

µRWELL-ECT: ePIC Gaseous End Cap Tracker

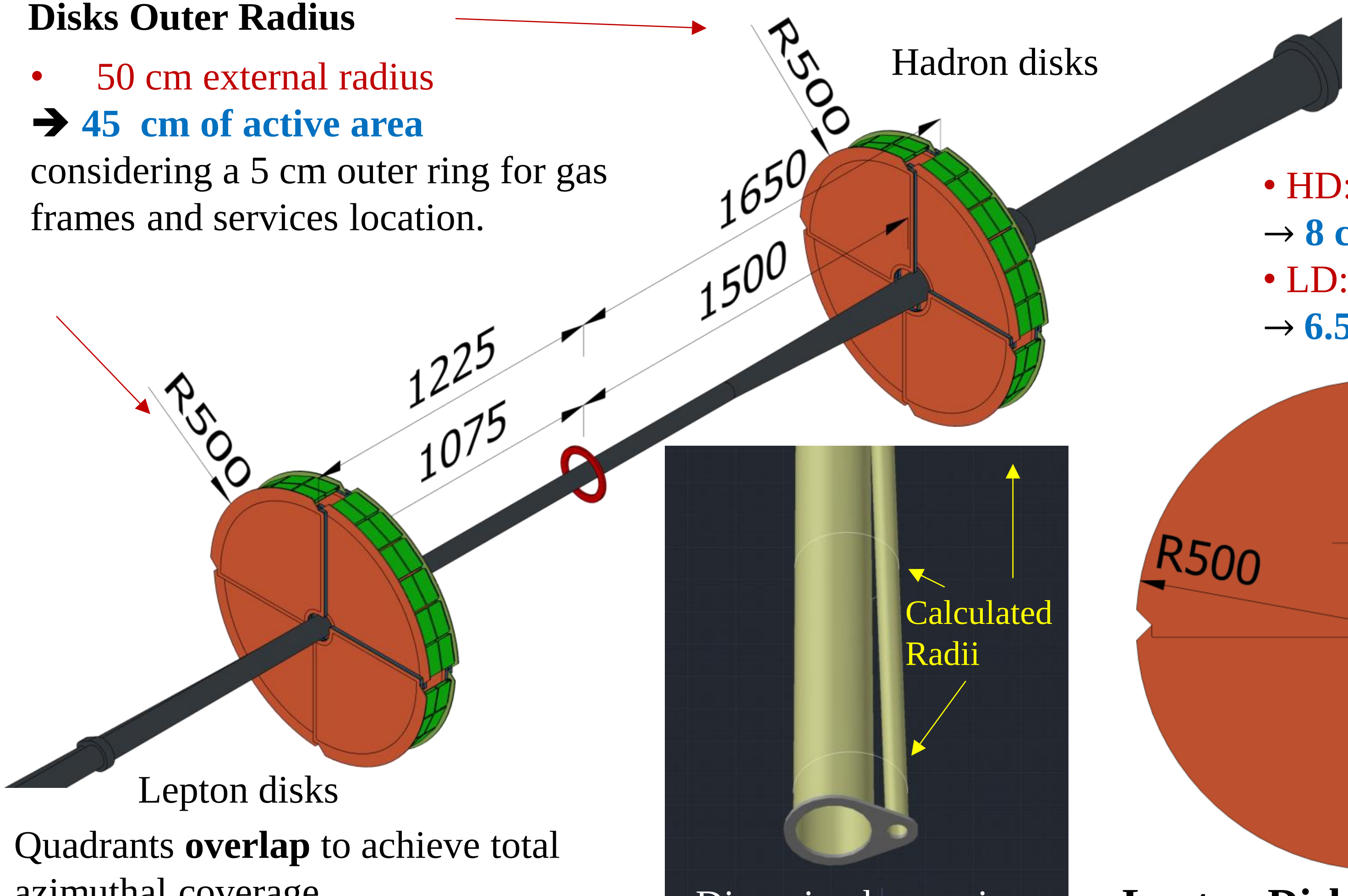
The geometrical envelopes are available at: https://eic.jlab.org/Geometry/Detector/Detector-20240117135224.html

Disks Outer Radius

- 50 cm external radius

➔ **45 cm of active area**

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



Quadrants **overlap** to achieve total azimuthal coverage

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

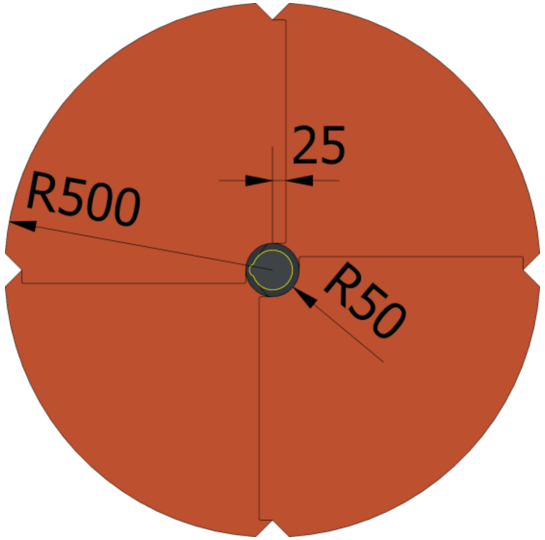
→ **8 cm & 10.5 cm active area radii**

- LD: 5 cm inner radius

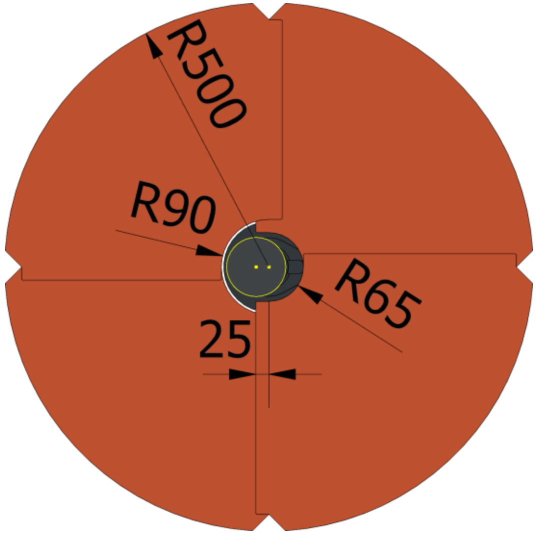
→ **6.5 cm radius of active area**

considering 1.5 cm gas frame

Diverging beam pipes



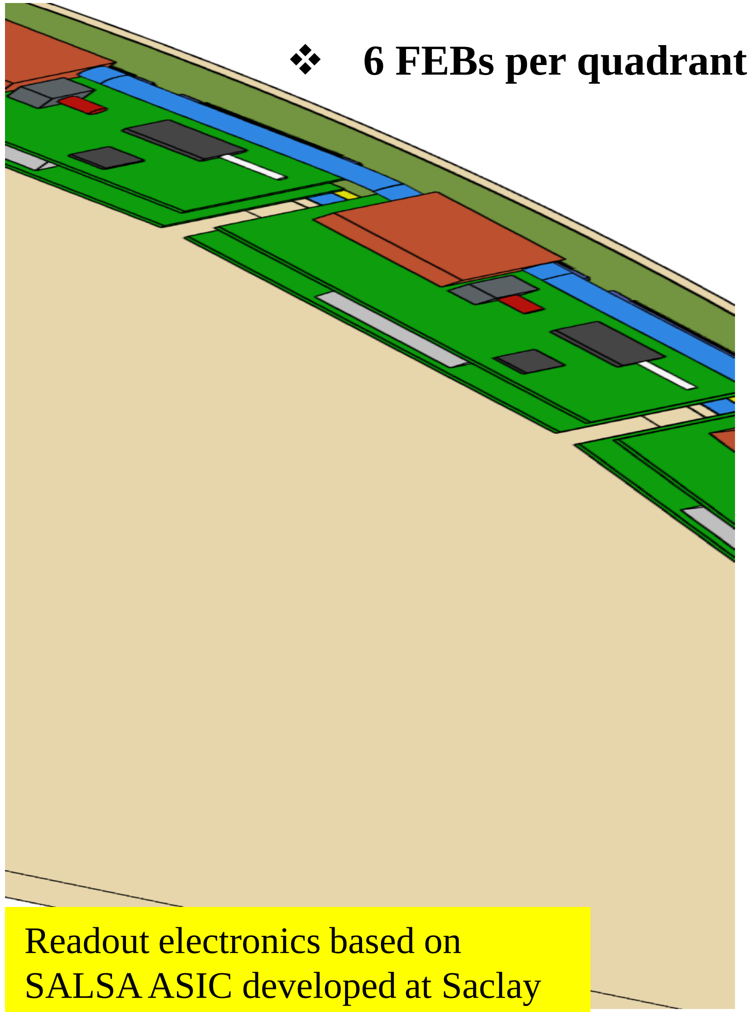
Lepton Disk Backward side



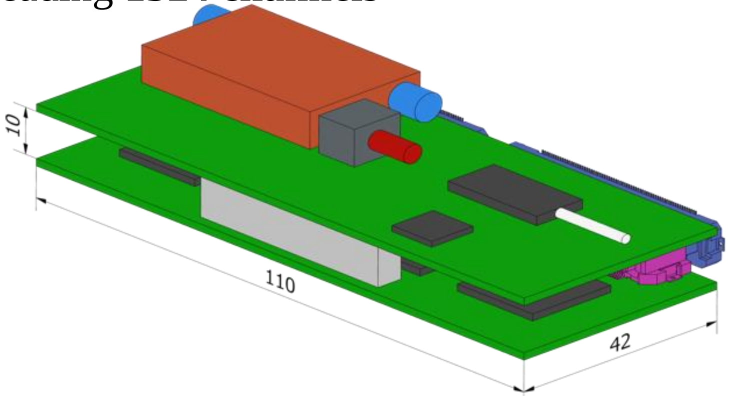
Hadron Disk Forward side

µRWELL-ECT: Front End Boards (FEB) & Services

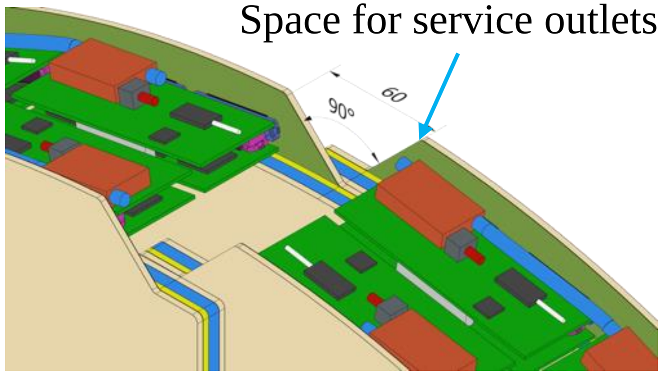
- The service rim can accommodate **12 FX20-140P connectors**
- **6 FEBs per quadrant** reading **1524 channels**



Readout electronics based on
SALSA ASIC developed at Saclay



Two FEBs in mezzanine
configuration separated by 1 mm



All the service requirements have been communicated to the Integration group

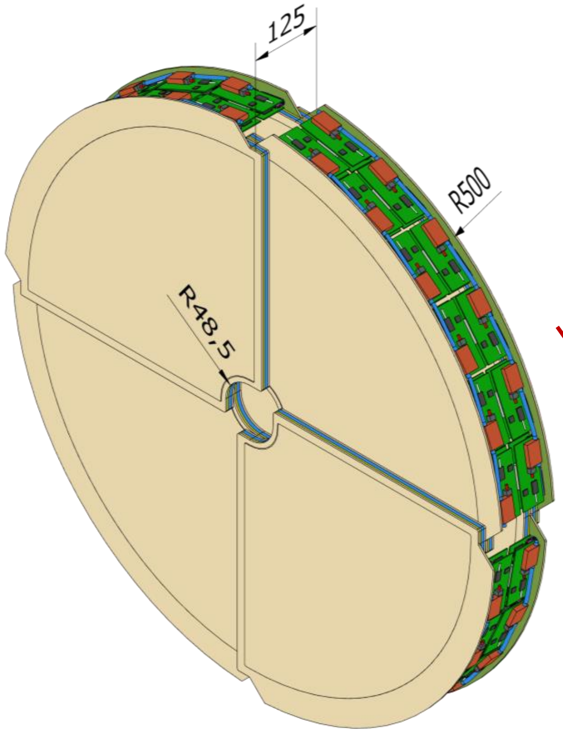
- **For each endcap disk (4 disks in total):**
- 16 HV cables
- 4 gas inlets and 4 gas outlets
- 24 data cables
- 24 low voltage cables
- 2 temperature sensors cables
- 2 humidity sensors cables
- 2 inlet and 2 outlet cooling hoses (H2O)

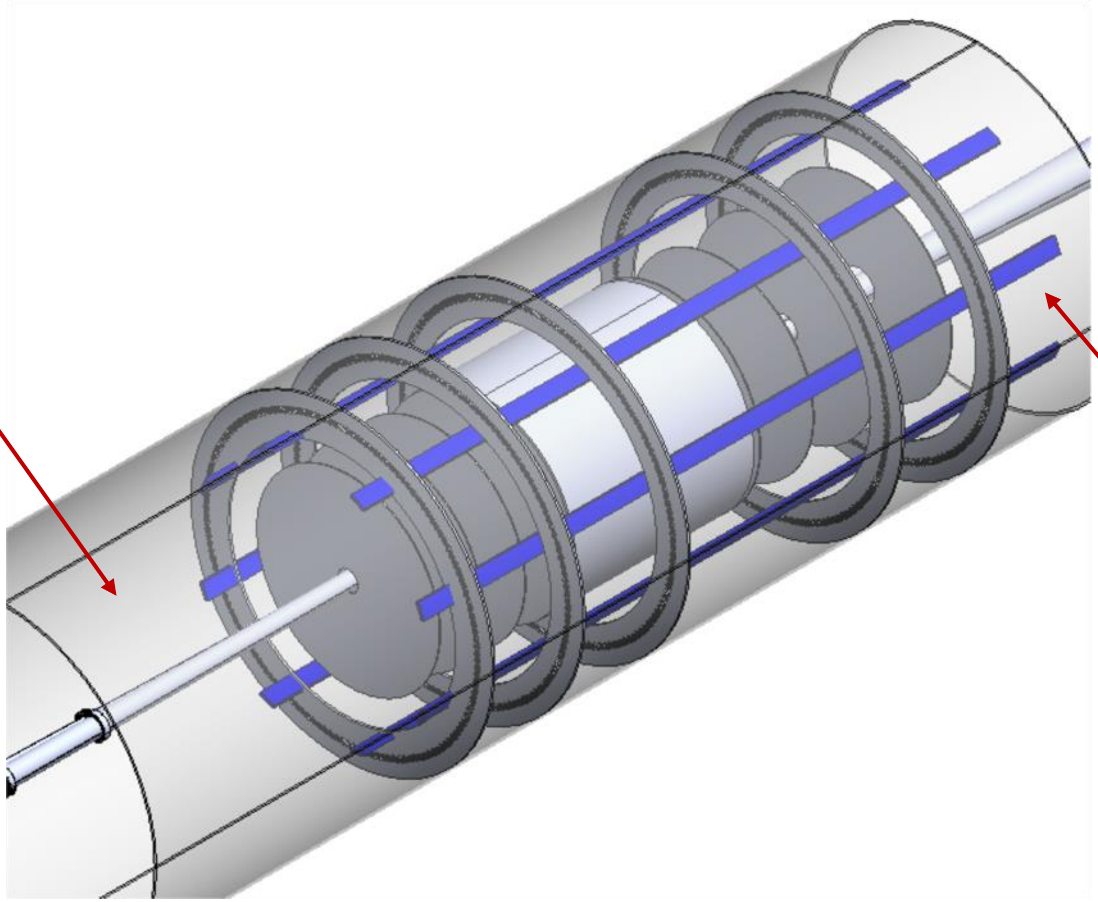
  210 W cooling dissipation

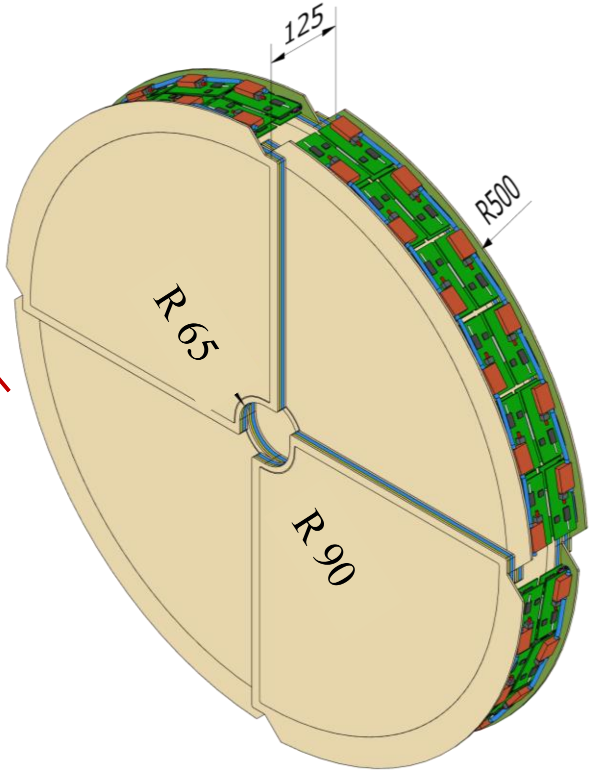
μRWELL-ECT: Integration in ePIC Detector

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

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



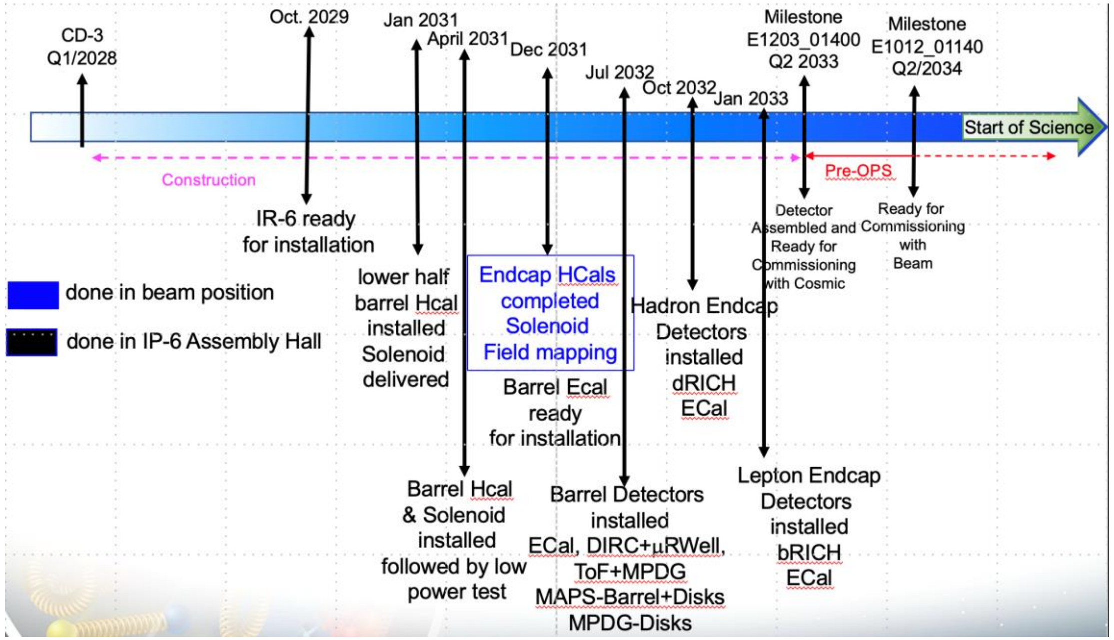




μRWELL-ECT: Fabrication / Assembly Plans & Timeline / Work-force

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

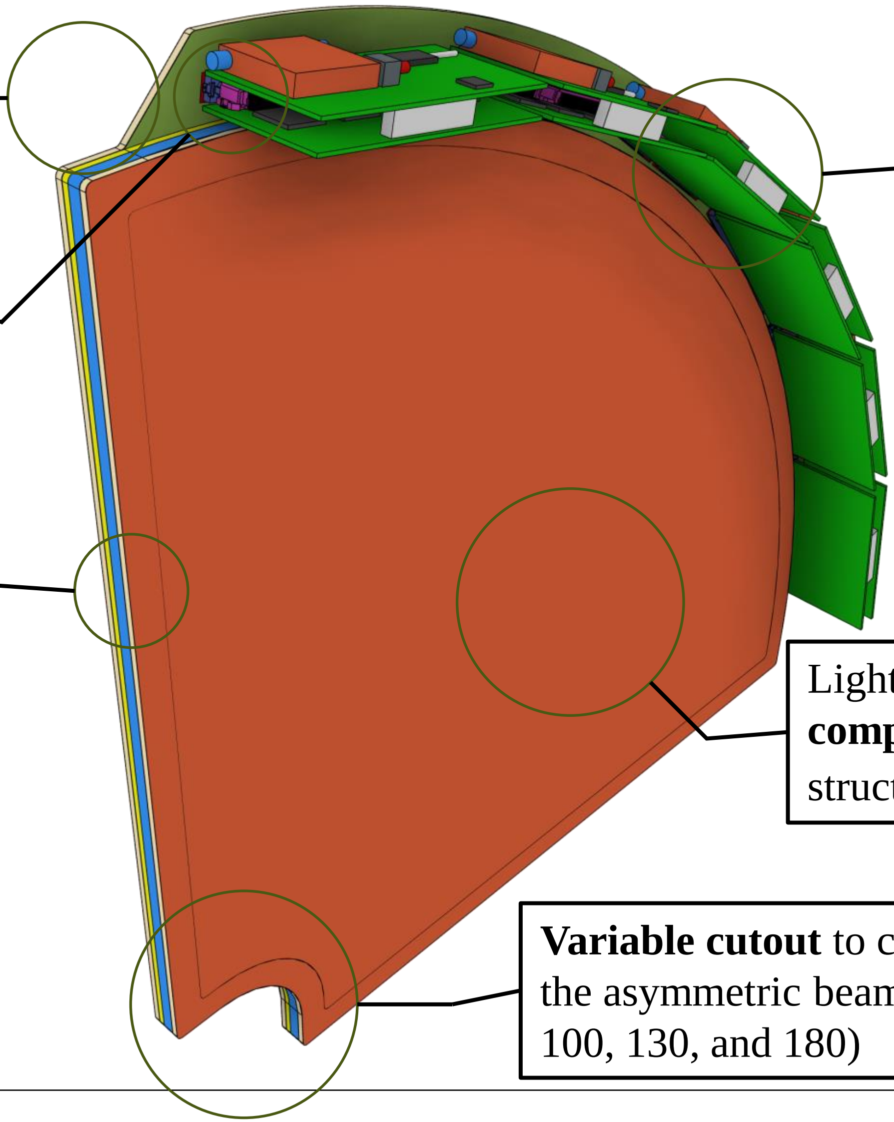


MPGD Timeline			DURATION (years)
START DATE	END DATE	DESCRIPTION	
3/1/24	12/31/24	Detectors Overall Design	<1
1/1/25	12/31/26	Pre - Production	2
1/1/27	31/12/29	Production	3
1/1/30	6/1/32	QA, Commissioning & Installation	3

Workforce ≈ 5 fte

- INFN Groups:
  - Roma Tor Vergata
  - Genova
  - LNF
- JLab
- Temple University
- Seul University

µRWELL-ECT: PED Test Article Module



Cutouts for services
At 0°, 90°, 180°, and 270°

4x **SALSA** ASICs per FEB

2x **Hirose FX20-140P** Connectors per FEB

15 mm wide **Fiberglass** frames to define gas gaps

Fiberglass frames for outer support structures

6 **FEBs** per quadrant located in the service rim

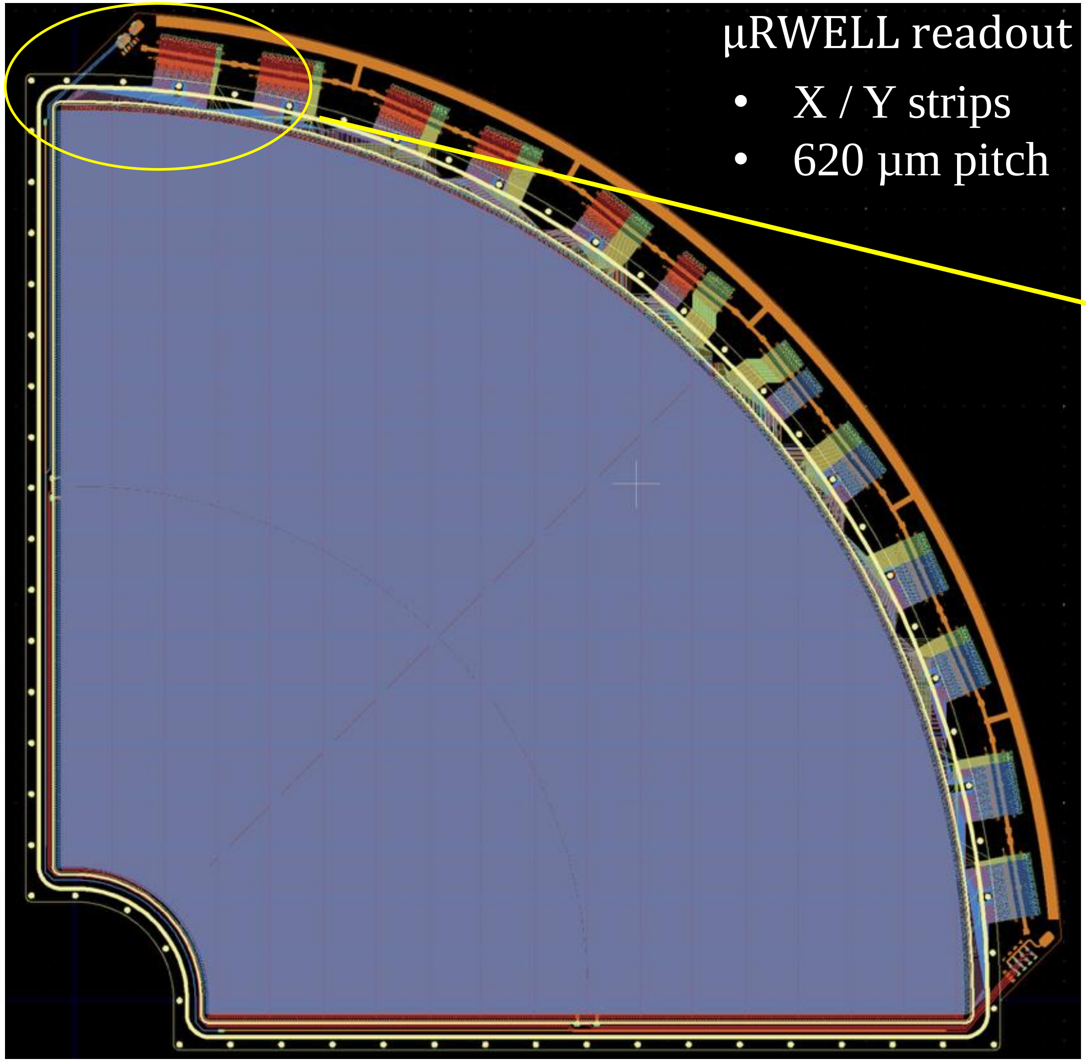
Lightweight **sandwich-structured composites** for anodes/cathodes' structural supports

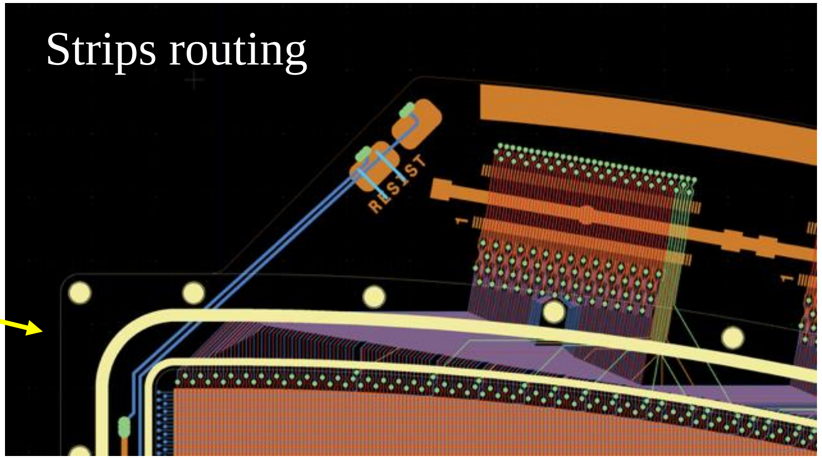
Variable cutout to cope with the asymmetric beam pipe (Ø 100, 130, and 180)

Still to implement:

- HV distribution
- Gas distribution
- Interconnection framing
- Integration with GST

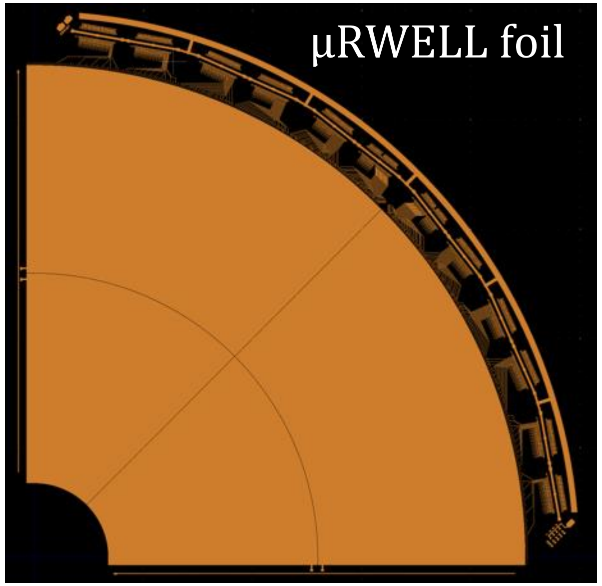
μRWELL-ECT: PED Test Article Module

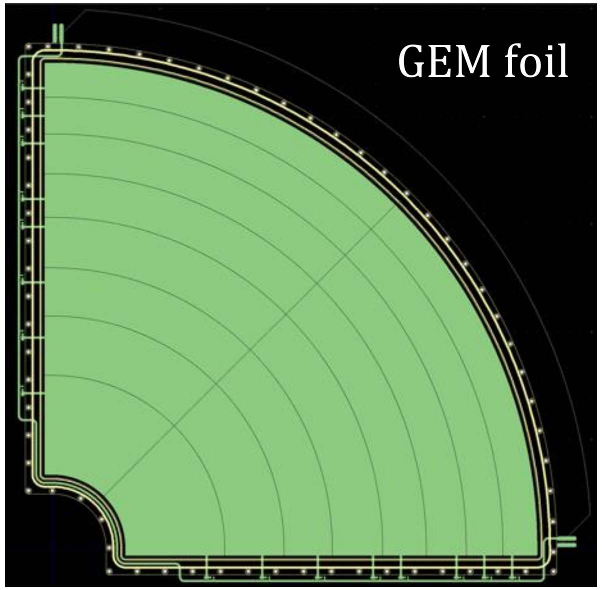




(X,Y) strips preferred to (R,φ) ➔ no FEB on the active area

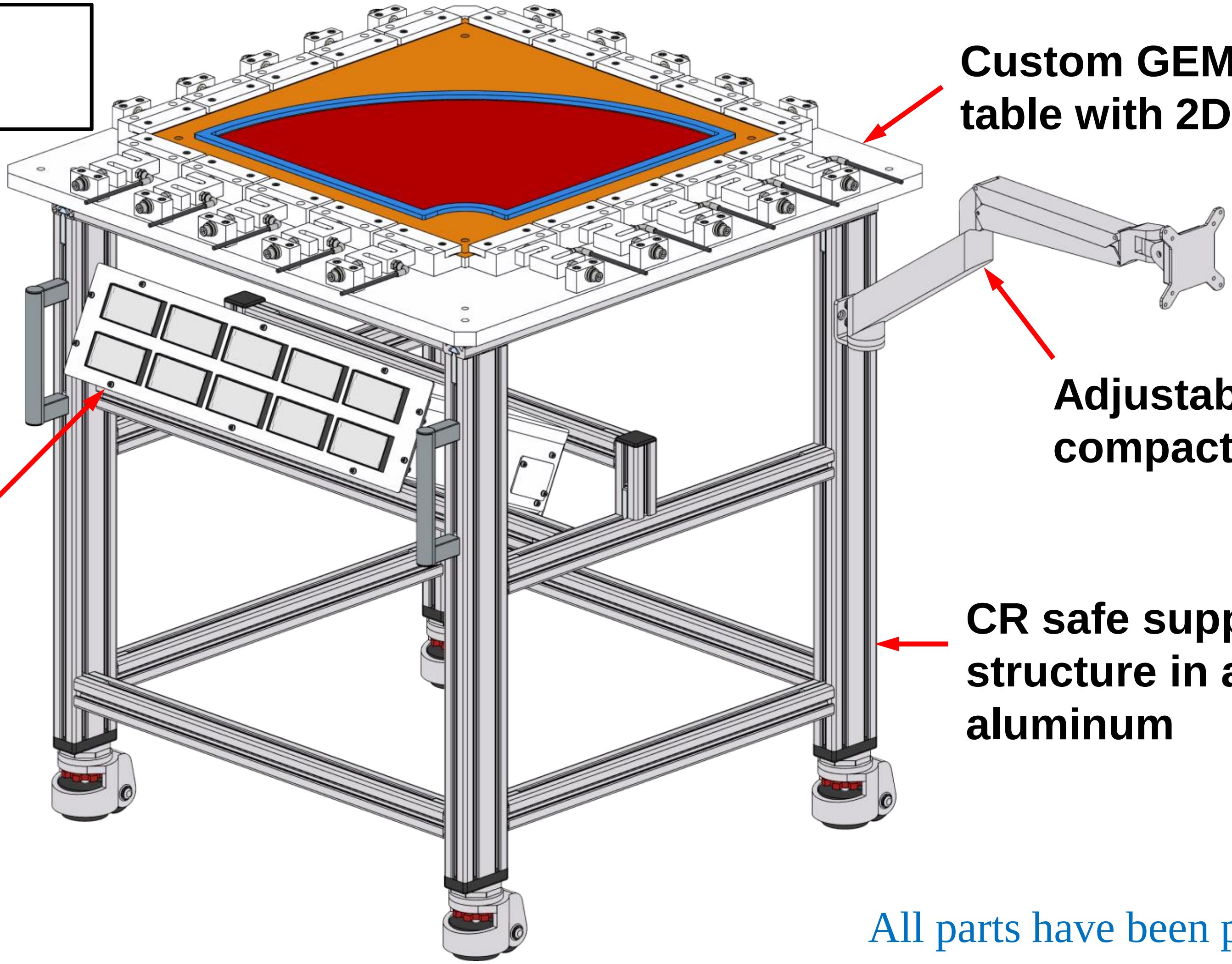
Detector delivery expected by Oct. 2025





μRWELL-ECT: GEM Stretcher Design

Dimensions:
850x850x920



Custom GEM stretching + gluing table with 2D tension measurement

Adjustable monitor arm for compact operator interface

Custom module for load cell R/O

CR safe support structure in anodized aluminum

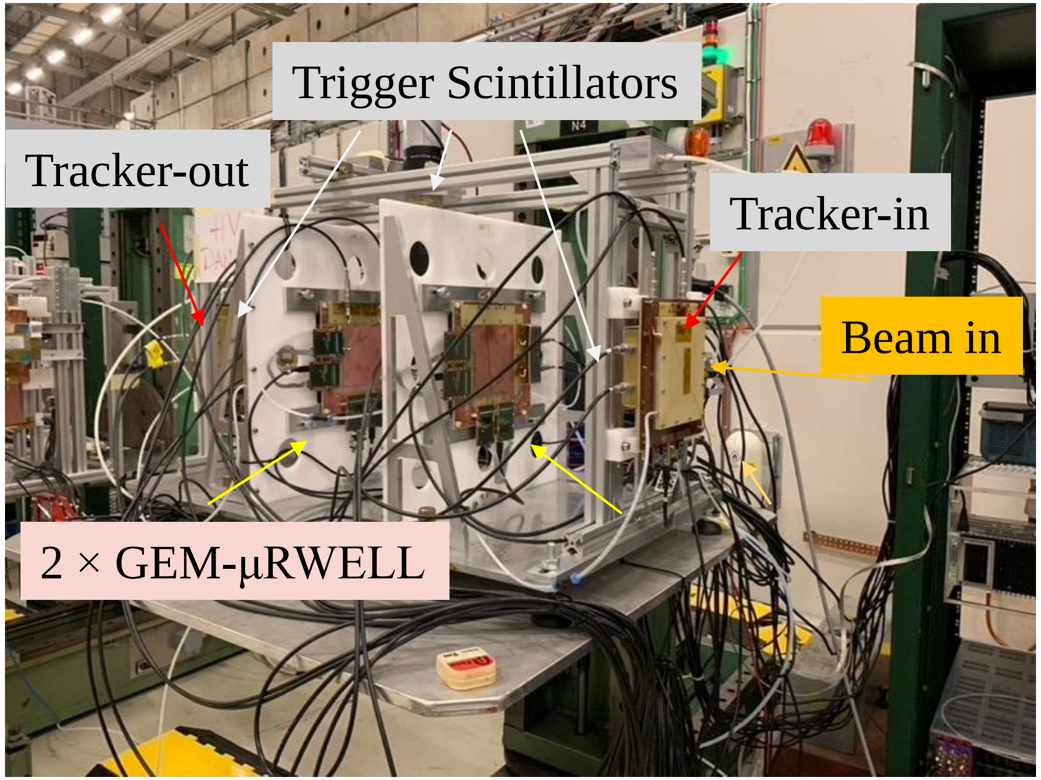
All parts have been procured and are being assembled

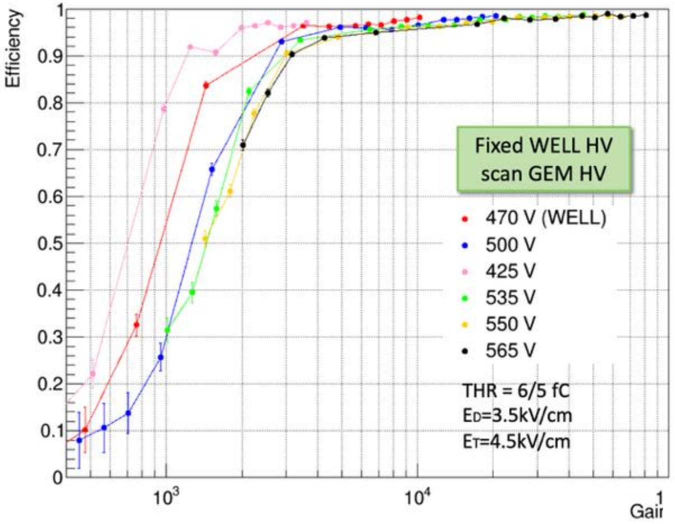
μRWELL-ECT: GEM-μRWELL Hybrid Technology

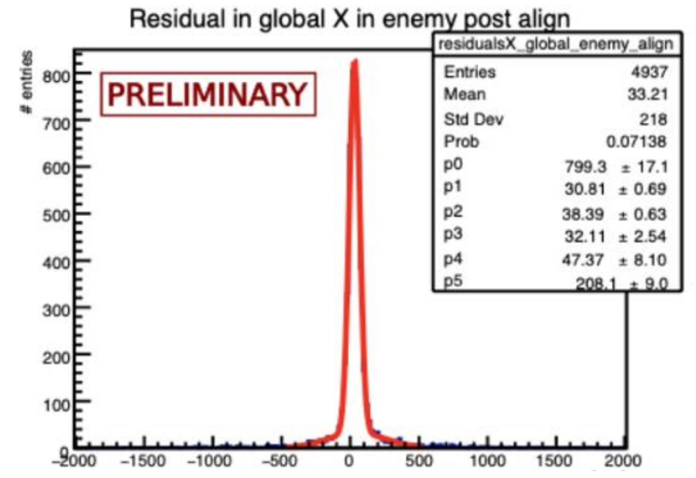
Tracker-In : μRWELL – 3 mm drift gap

Tracker-Out : GEM-μRWELL 6 mm drift + 3 mm transfer gaps

Detectors Under Study (DUT): 2 × GEM-μRWELL prototypes 2D COMPASS-like readout 400 μm pitch







$\sigma_x = 66.9 \pm 2.7\ \mu m$

- Efficiency at the plateau > 96%
- Position resolution for straight tracks at the efficiency plateau < 70 μm
- Projected efficiency for 620 μm pitch better than 150 μm

µRWELL-ECT: Summary

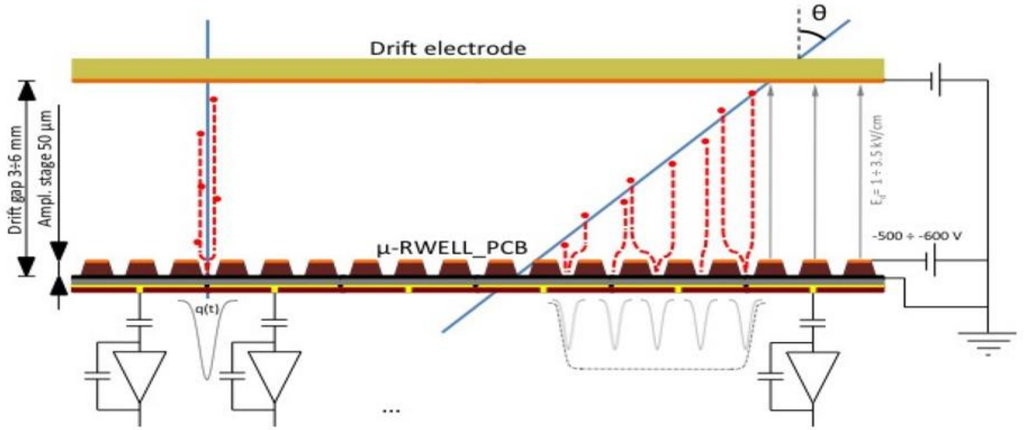
- ❖ Geometric acceptance & technical performances of hybrid GEM-µRWELL endcap trackers have been assessed.
- ❖ A detector layout compliant with position resolution and tracking efficiency requirements has been identified.
- ❖ The disks are segmented into four quadrants, connected and attached to the 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

μRWELL-BOT Technology: Thin-gap GEM-μRWELL 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**

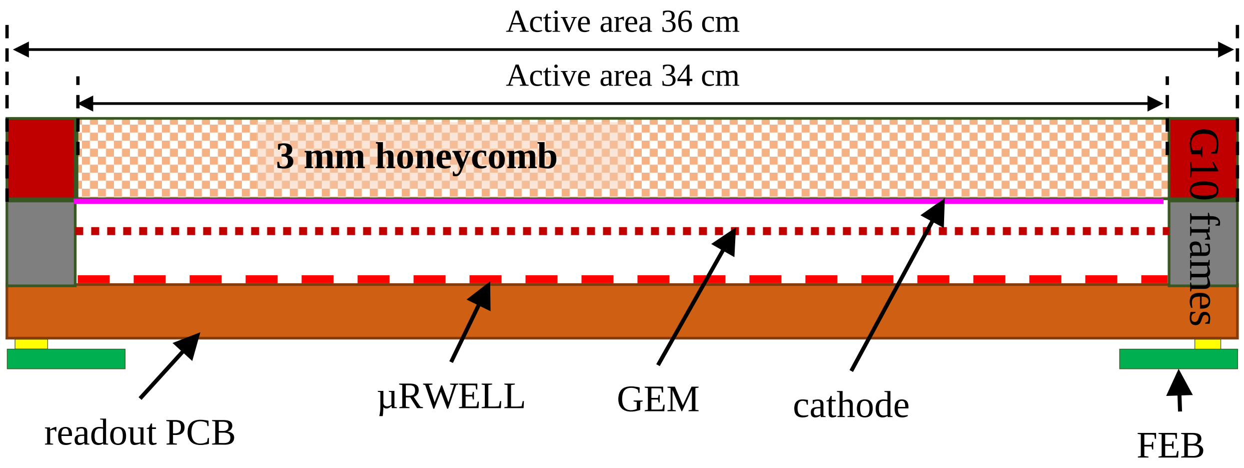


One solution is the development of Thin-gap MPGDs:

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

Thin-gap GEM-μRWELL detector concept

- ❖ 1 mm or 1.5 mm drift gap between cathode and GEM amplification
- ❖ hybrid amplification MPGD:
  - ▪ GEM (preamplification) and μRWELL (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

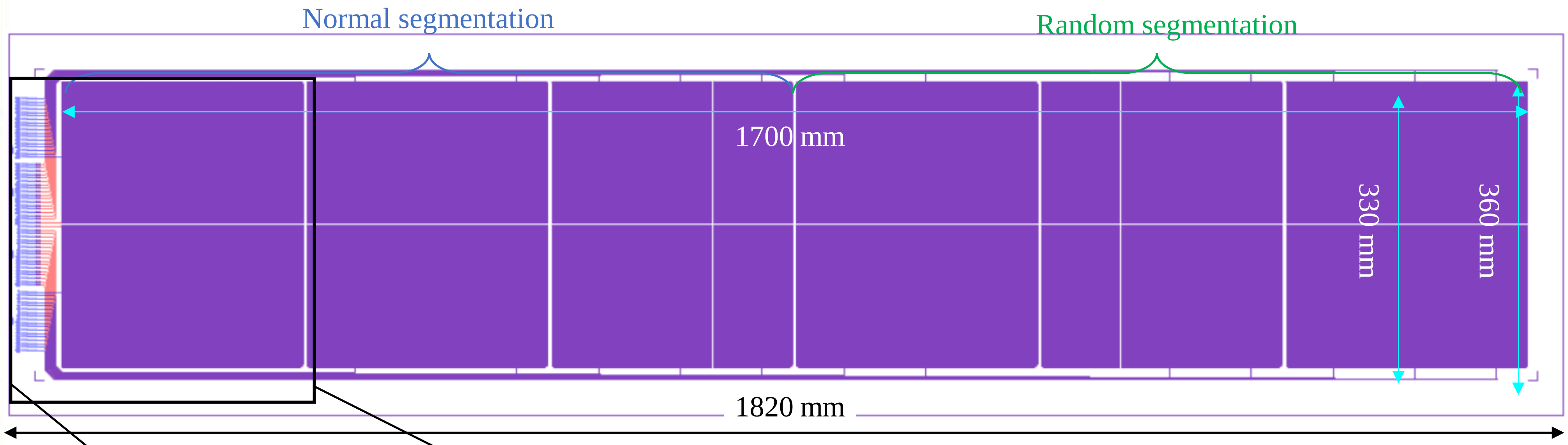


cross-section view of thin-gap GEM-μRWELL detector

https://wiki.bnl.gov/eic/upload/ERD_tgMPGD_FY22_endOfYearReport_final.pdf

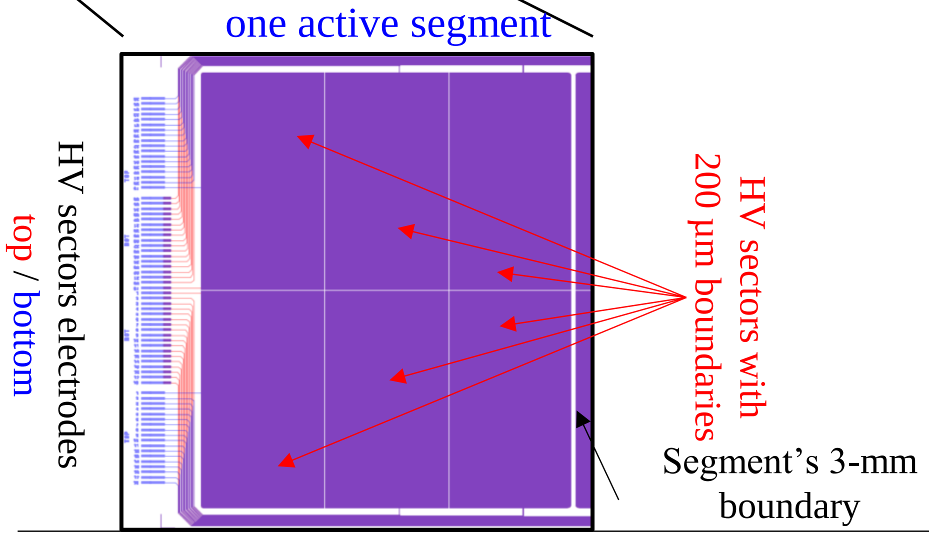
µRWELL-BOT: Test Article – **GEM foil design**

Charge 3



Foil dimension

- Total: 1820 mm × 360 mm
- Active area: 1700 mm x 330 mm

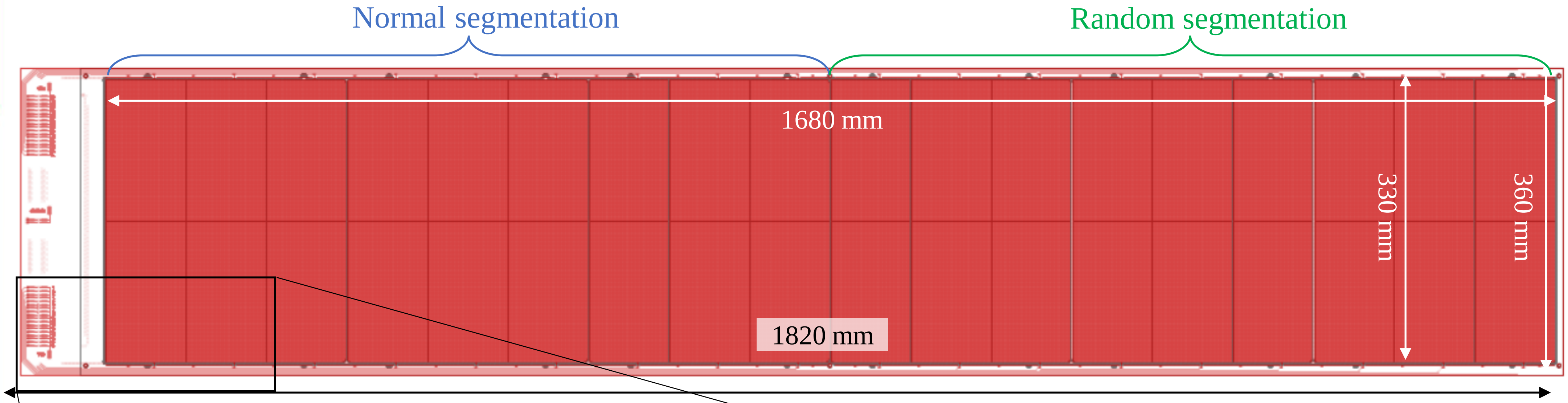


- Active area divided into 6 active segments of area 330 mm × 283 mm ➔ separated by 3-mm dead area to be glued to the support frames on top & bottom
- Each segment divided into 6 HV sectors (180 × 96 mm^2) ➔ separated by 200 µm dead area
  - 8 sectors on the left side have normal segmentation
  - 8 on the right with random segmentation ➔ Study impact on efficiency
- Both top and bottom side of the foils are segmented
- Connection to all 76 HV sectors are on the left side of the foil

delivery expected end June**2025**

µRWELL-BOT: Test Article – **µRWELL PCB design**

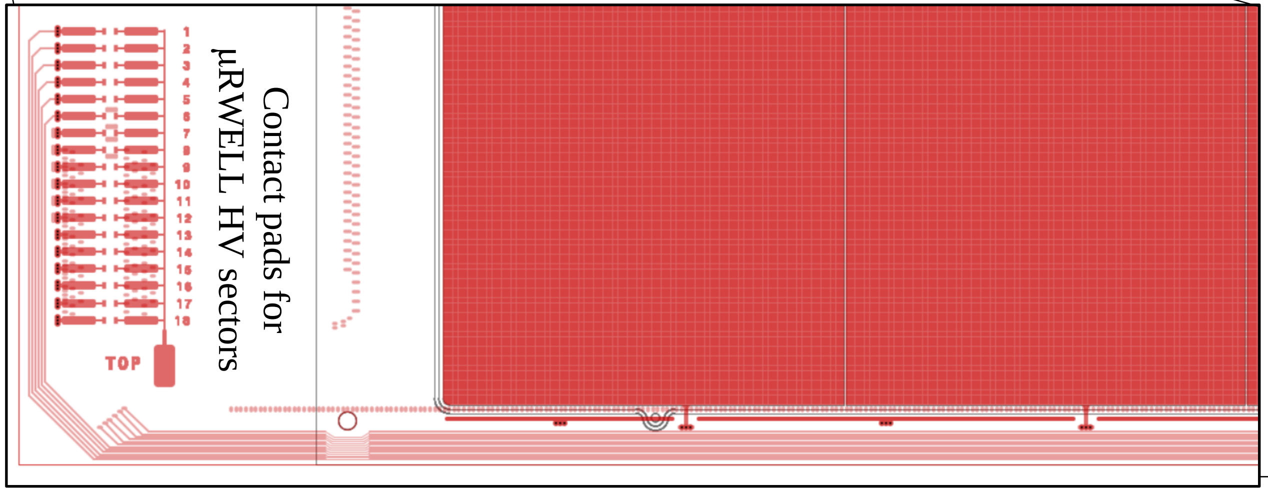
Charge 3



µRWELL dimension

- ❖ **Overall:** 182 cm × 36 cm
- ❖ **Active area:** 168 cm x 330 cm

Two of the 36 µRWELL sectors

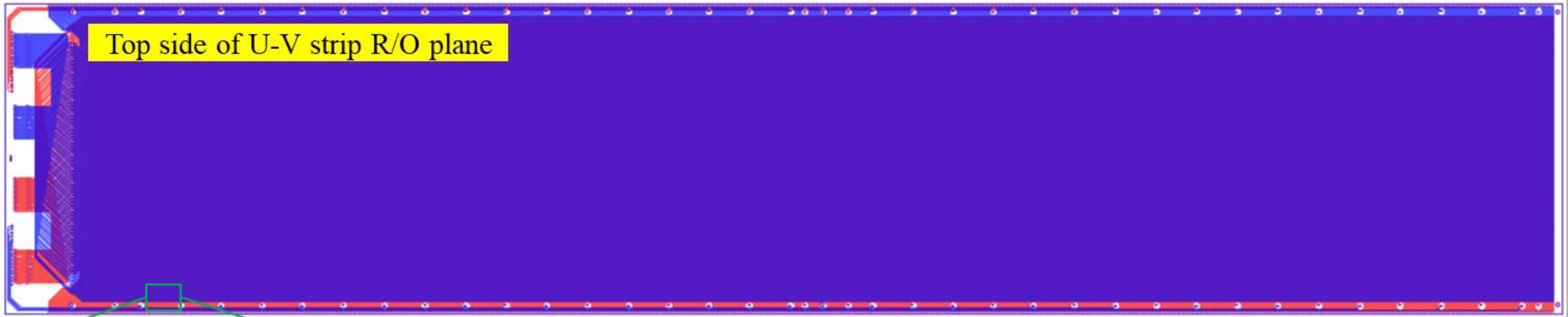


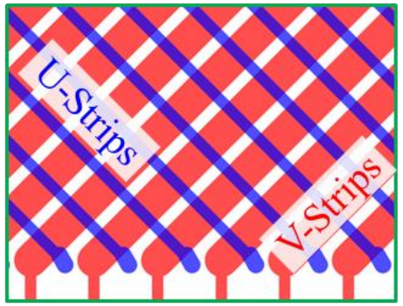
- ❖ The active area of 36 HV sectors (180 mm× 96 mm) similar to the HV sectors separated by 100 µm dead area
  - The 18 sectors on the left side have normal segmentation
  - The 18 on the right have a random segmentation ➔ Study impact on detector efficiency
- ❖ Connection to all 36 HV sectors on the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

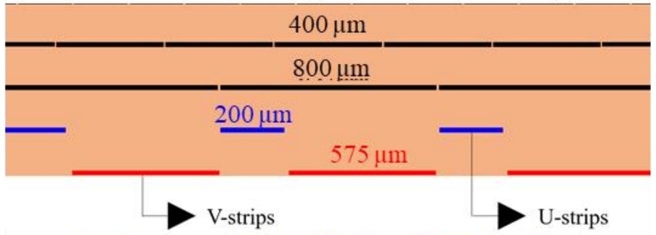
delivery expected end June**2025**

µRWELL-BOT: Engineering Test Article – **U/V strips readout design**

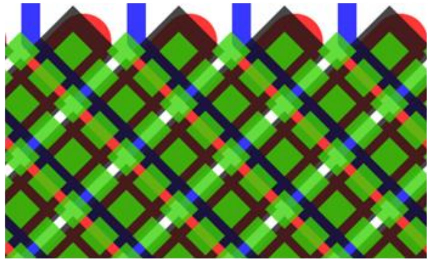
Charge 3

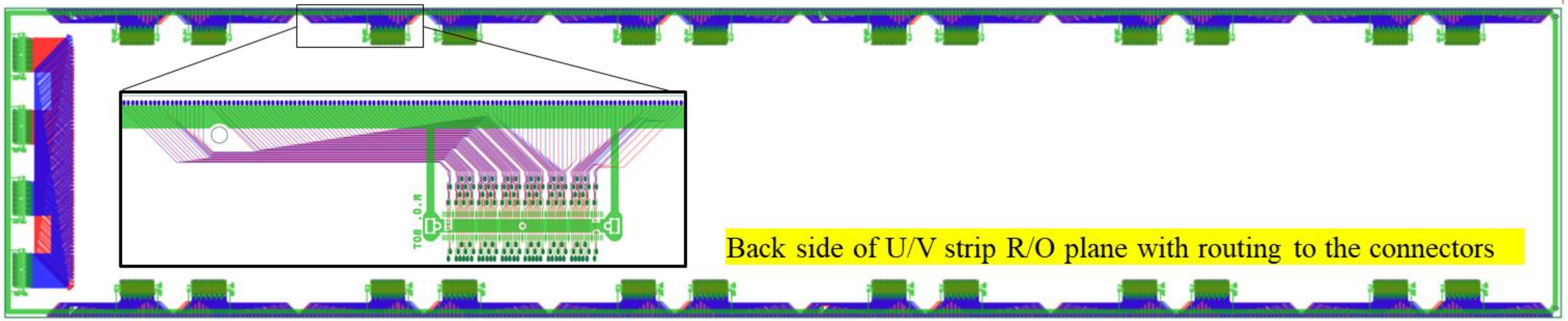






K. Gnanvo, NIM A1047, 167782 (2023)





45 degree U / V strips instead of X / Y

- All connectors at the edge the long side of the detector
- Pitch = **800 µm** along U / V axis ➔ 1.14 mm along detector edge
- Strip length = **47 cm** limited strip capacitance concerns
- Width: top strips (U) = 200 µm and bottom strips (V) = 575 µm
- 2 layers of capacitive sharing (400 µm and 800 µm) ➔ 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

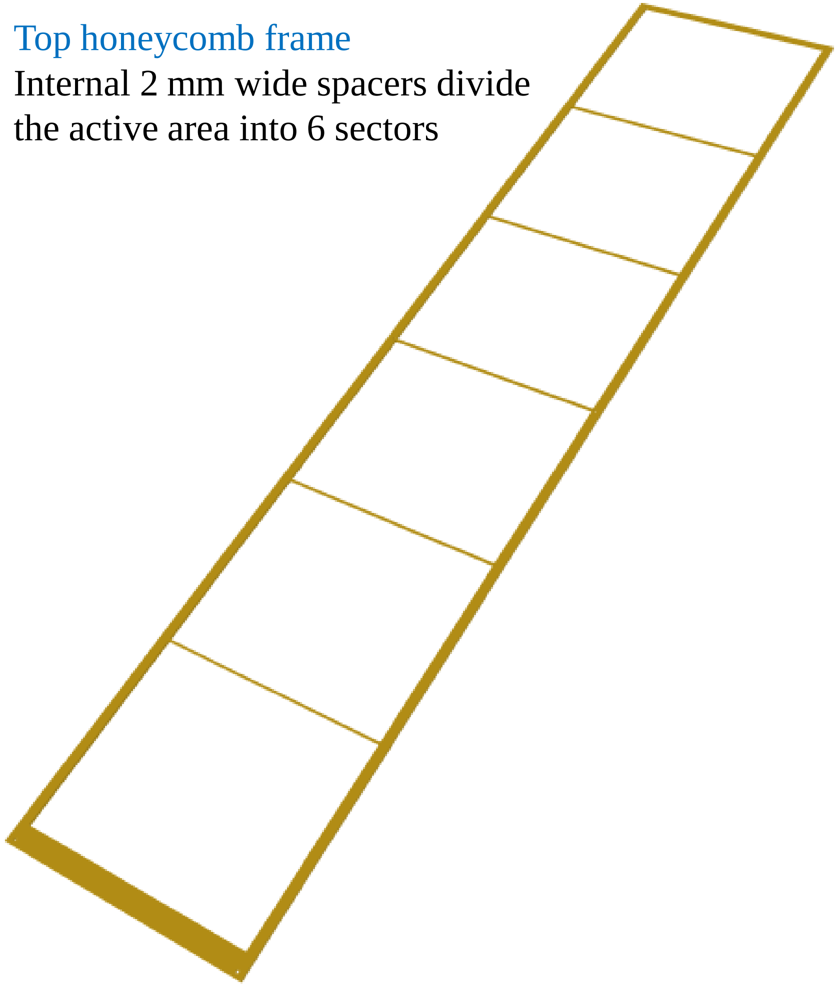
delivery expected end June**2025**

µRWELL-BOT: Test Article – **Detector support frames**

Charge 3

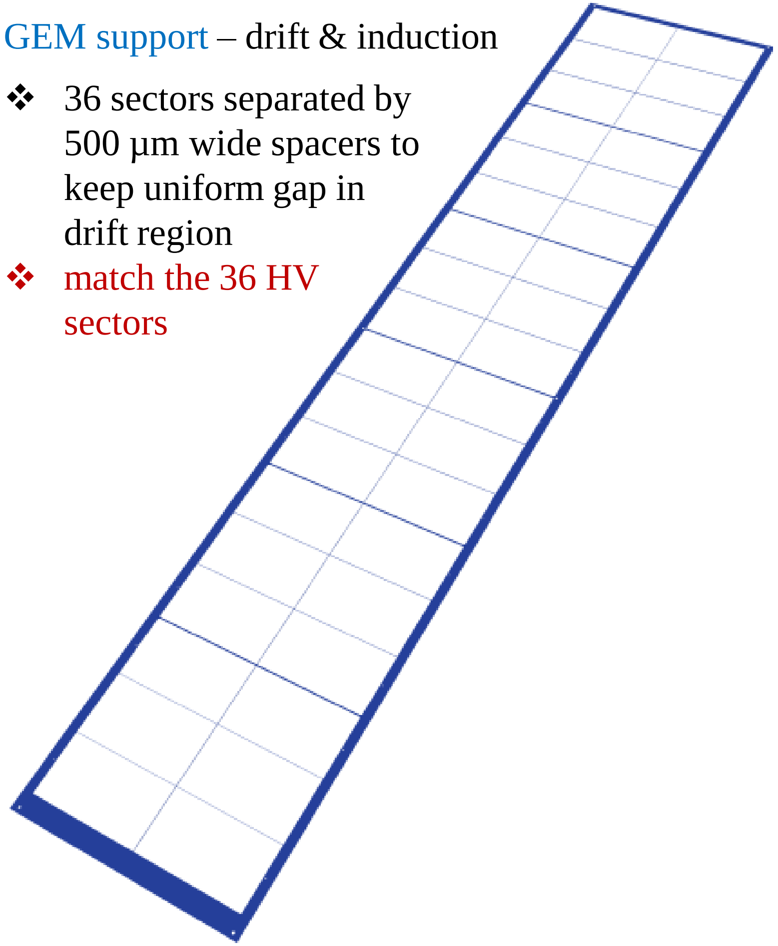
Top honeycomb frame

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



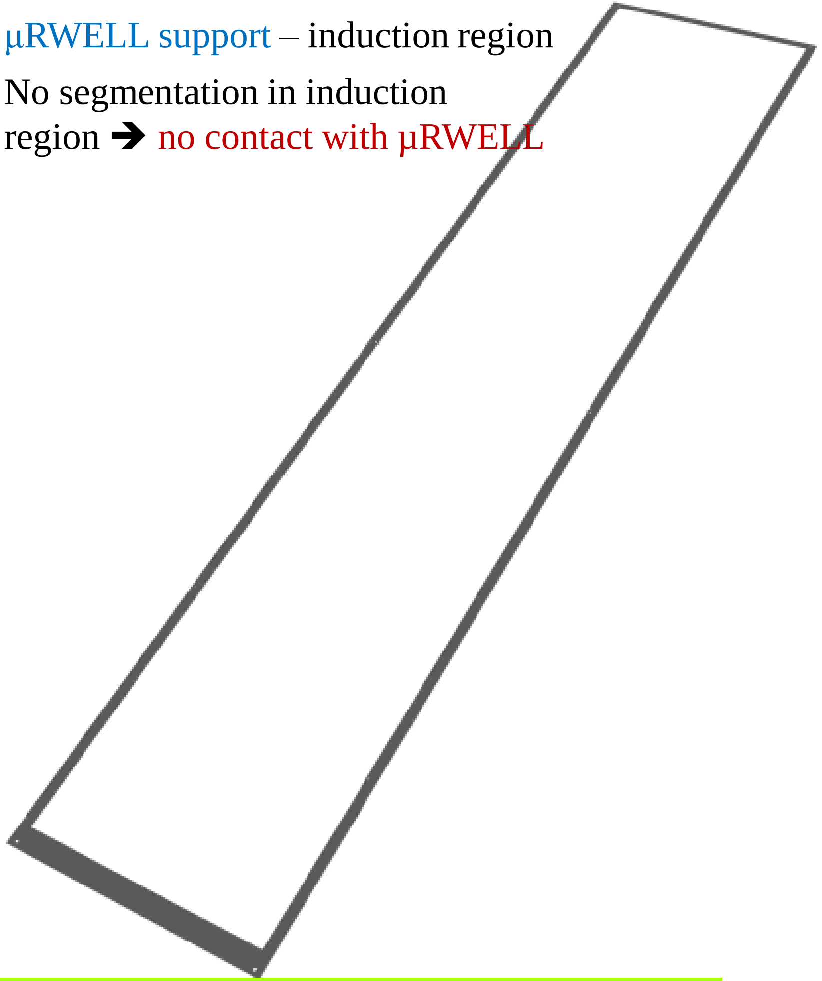
GEM support – drift & induction

- ❖ 36 sectors separated by 500 µm wide spacers to keep uniform gap in drift region
- ❖ match the 36 HV sectors



µRWELL support – induction region

No segmentation in induction region ➔ no contact with µRWELL

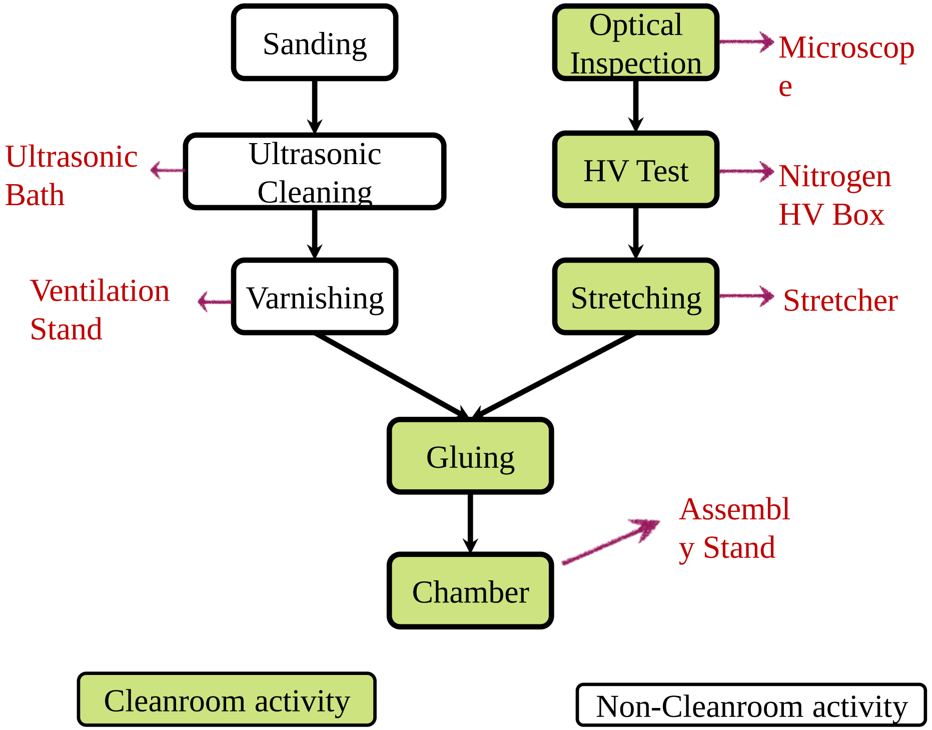


In hand, delivered in February 2025

µRWELL-BOT: Engineering Test Article – **Procurement status**

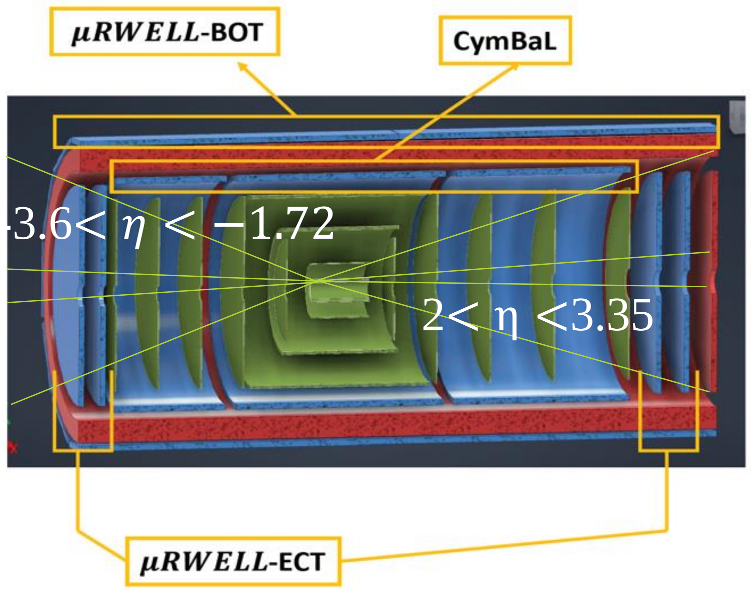
Procurement status

- 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



µRWELL-ECT: Pseudo-rapidity coverage: effective $\boldsymbol{\eta}$ ranges

Component	Z (cm)	Inner Active Reg. Radius (cm)	$\lvert\theta\rvert$ min (deg)	$\lvert\eta\rvert$ max	Outer Active Reg. Radius (cm)	$\lvert\theta\rvert$ max	$\lvert\eta\rvert$ 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

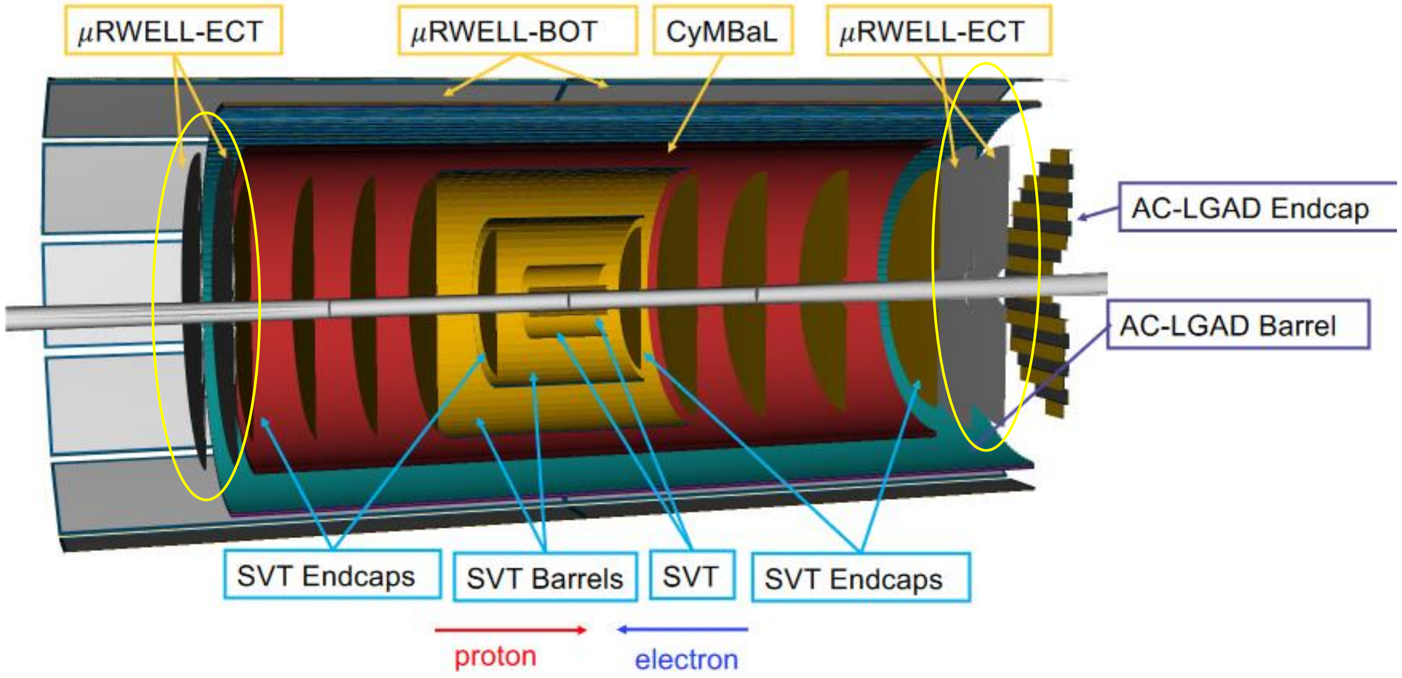
it is limited by the inner HD disk location/dimensions

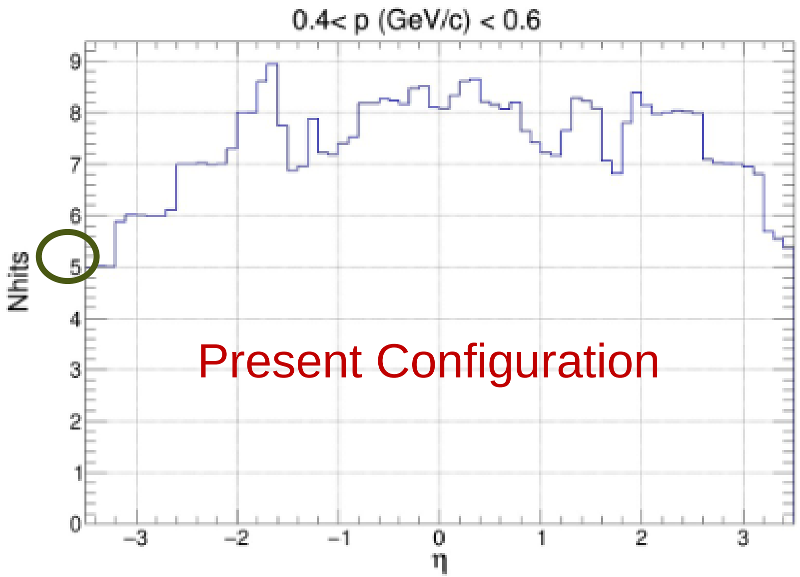
The $\boldsymbol{\eta}$ **range** covered by the MPGD Endcap tracking disks is **compliant** with requirements.

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.





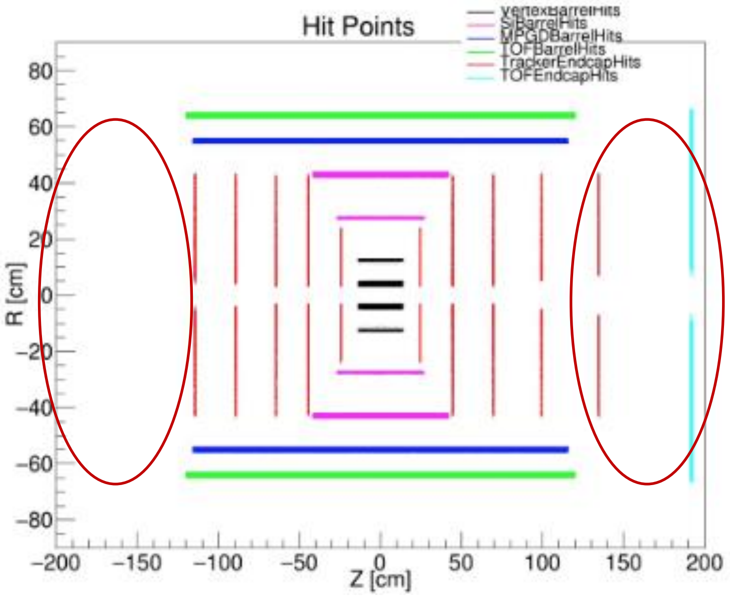
Present ePIC tracker geometry

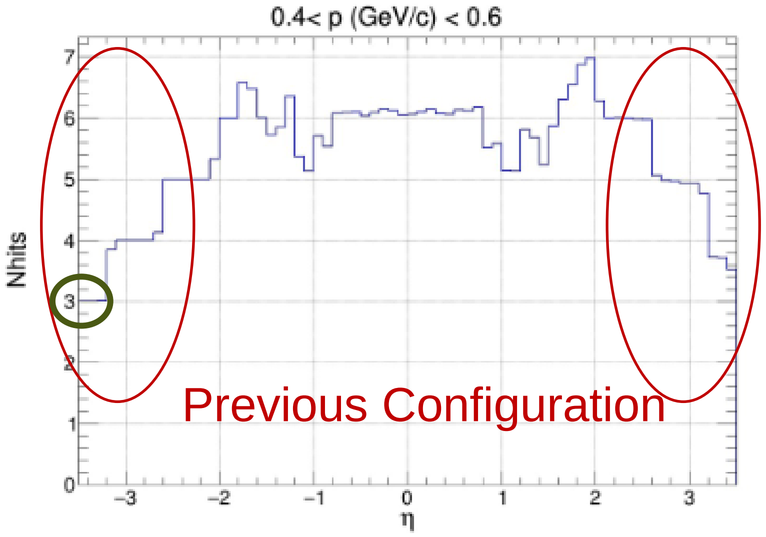
Scope of the MPGD Endcap Trackers

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 |η| > 2 region for good pattern recognition





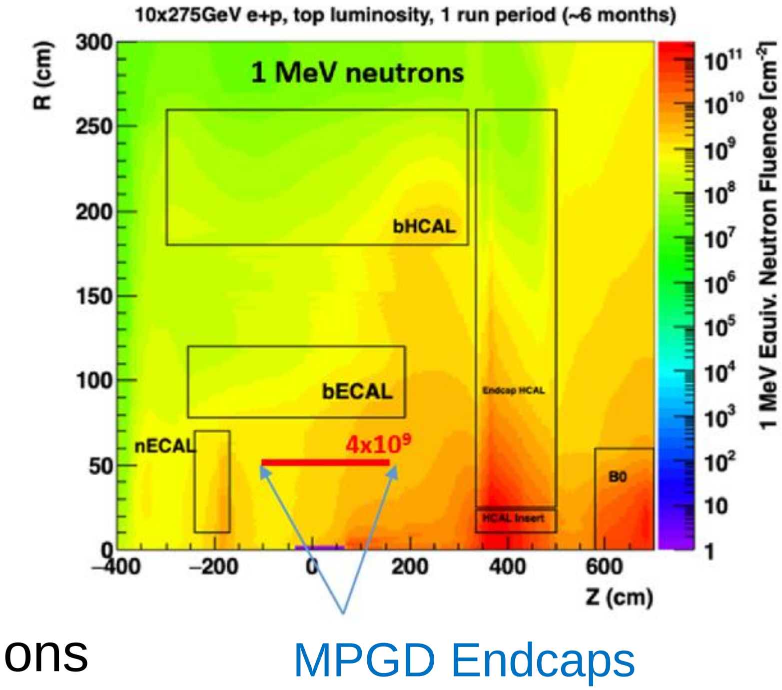
ePIC tracker geometry before June 2023

Technical performance requirements

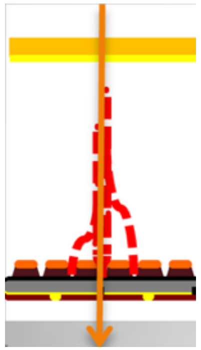
Charge 1

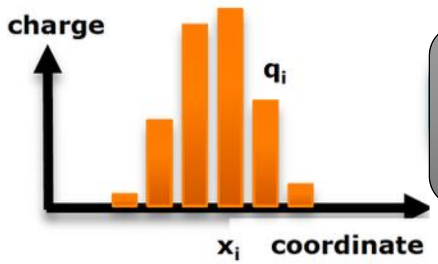
Are the technical performance requirements appropriately defined and complete for this stage of the project?

- **Rate Capability**
  - Not critical ~ 1 kHz/cm^2 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 ~ 15 mW/channel at 1.2V → 60 W/disk
  - Air vs liquid cooling is under study at Saclay – see Irakli's talk



µRWELL-ECT: Possible Position Resolution Improvement - **µTPC**



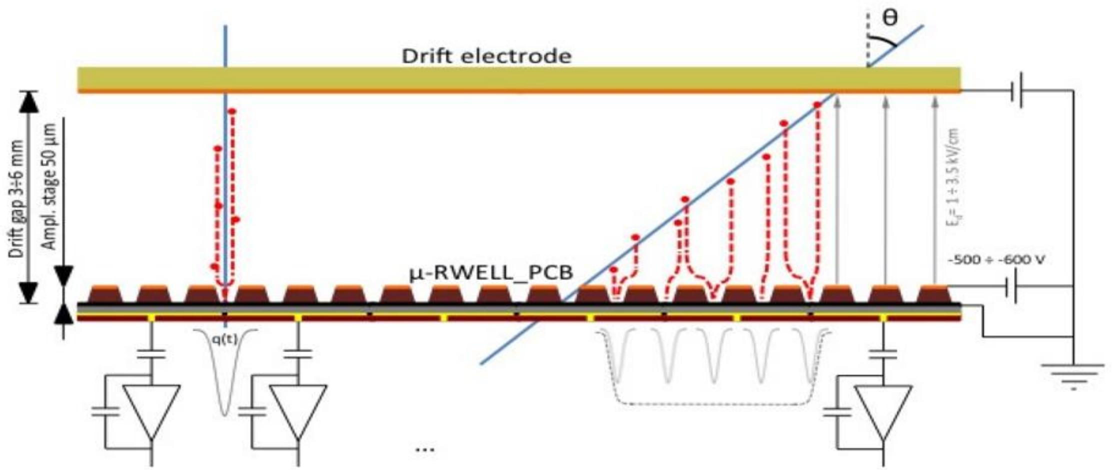


$$x_{hit} = \frac{\sum x_i \cdot q_i}{Q_{tot}}$$

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.

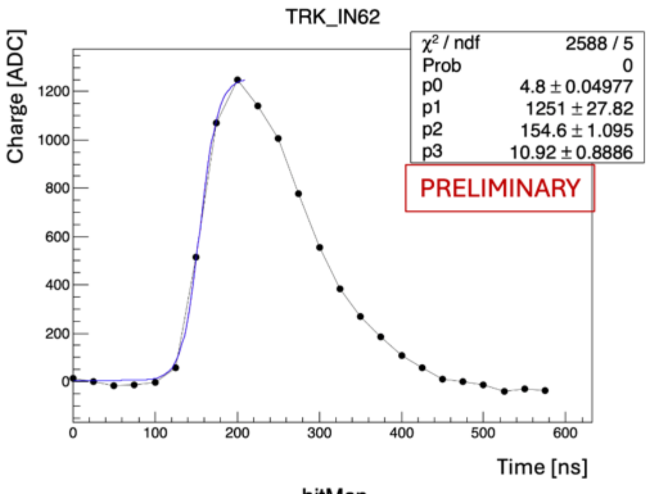
µTPC reconstruction

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.

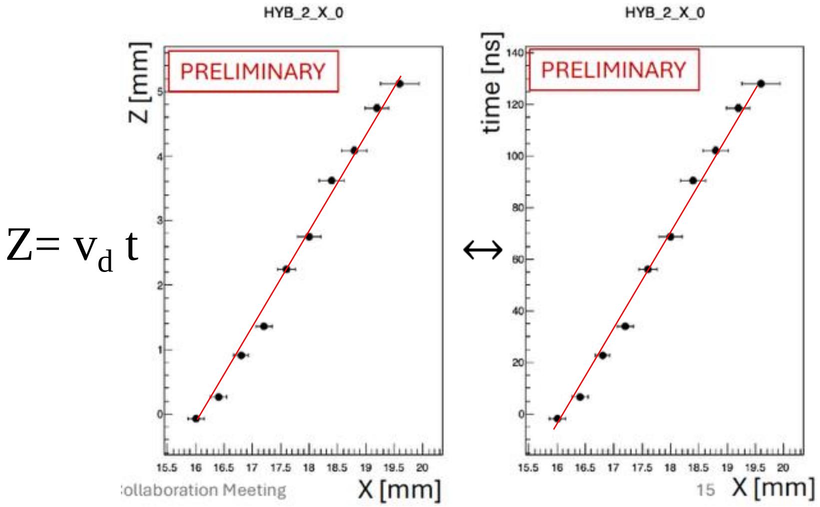
μRWELL-ECT: Possible Position Resolution Improvement - **μTPC**

- The electrons created by the ionizing particle drift towards the amplification region
- In the μTPC mode from the **knowledge of the drift time** and the **measurement of the arrival time of electrons**, the **track segment in the gas gap is reconstructed**
- The **fit of the analog signal** gives **the arrival time of drifting electrons**.
- By the knowledge of **the drift velocity,** the 3D trajectory of the ionizing particle in the **drift gap** is reconstructed.



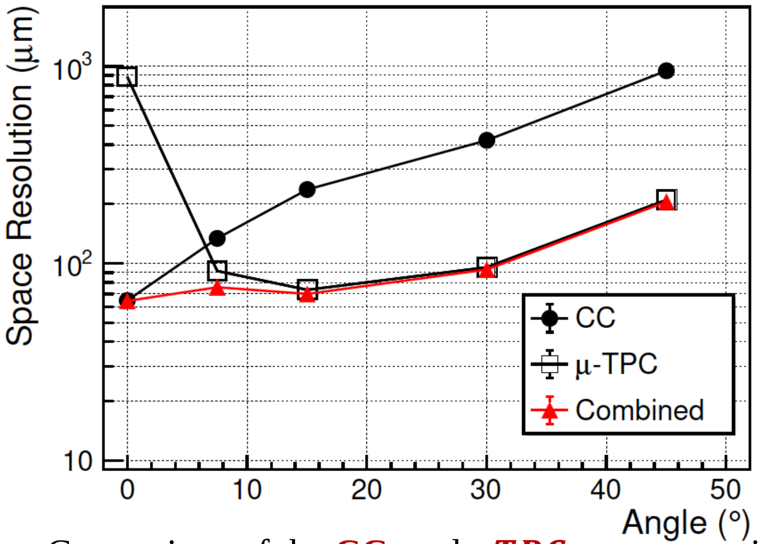
Integrated charge as a function of the sampling time

Thanks to Riccardo Farinelli (INFN Bologna)



Example of a track reconstruction using the TPC algorithm.

drift field $E_D = 1\ kV/cm$



Comparison of the **CC** and ***μTPC*** reconstruction algorithms in function of the impinging angle