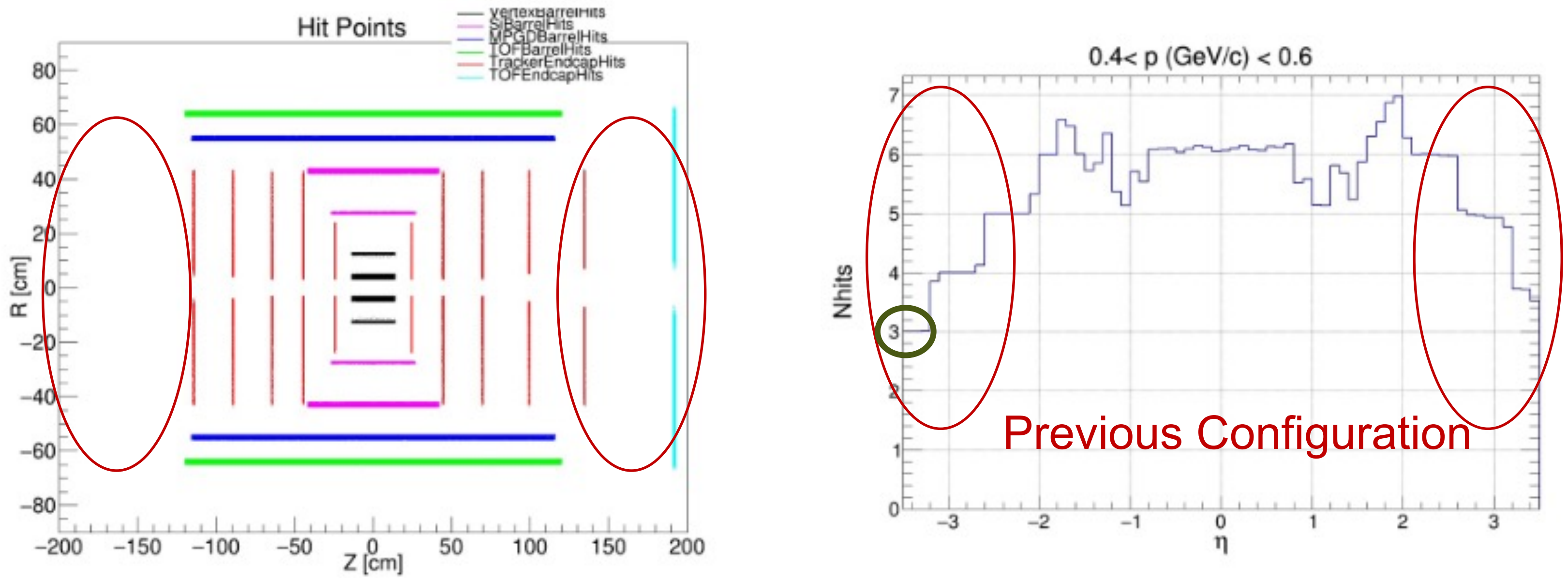
Scope of the MPGD Endcap Trackers

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

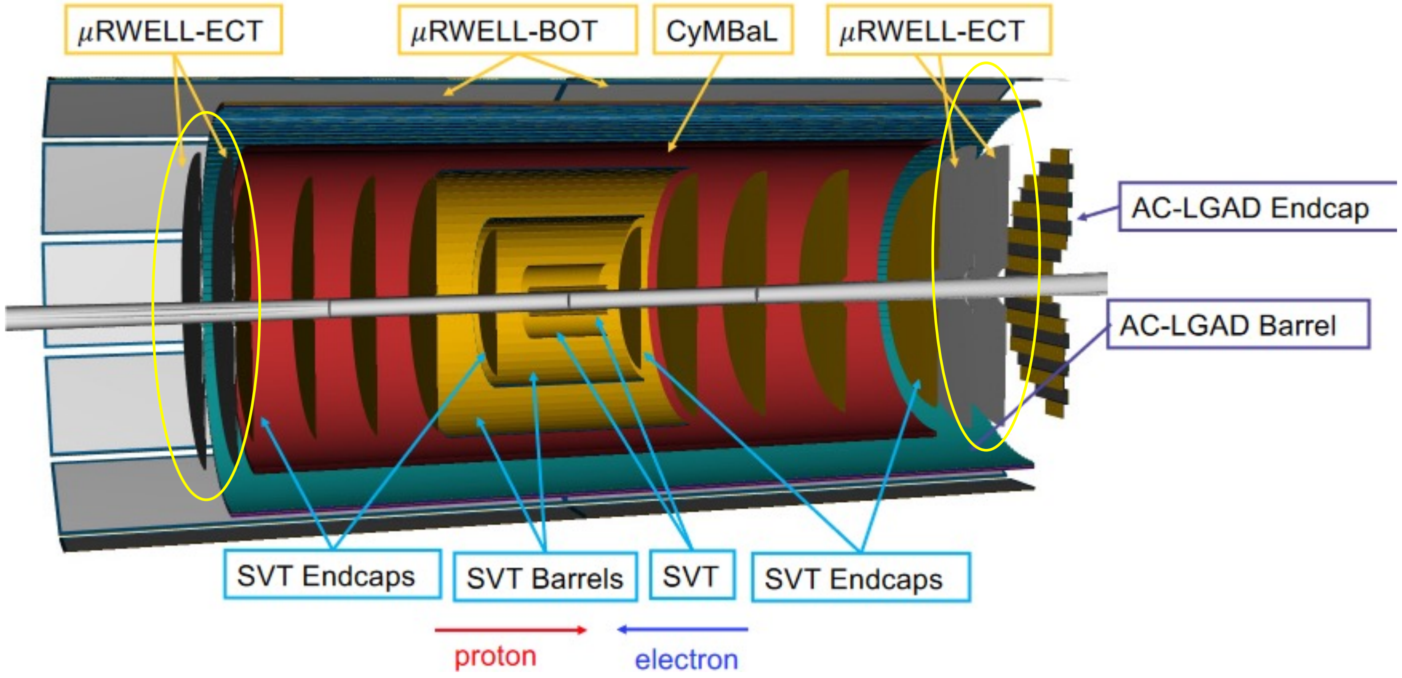


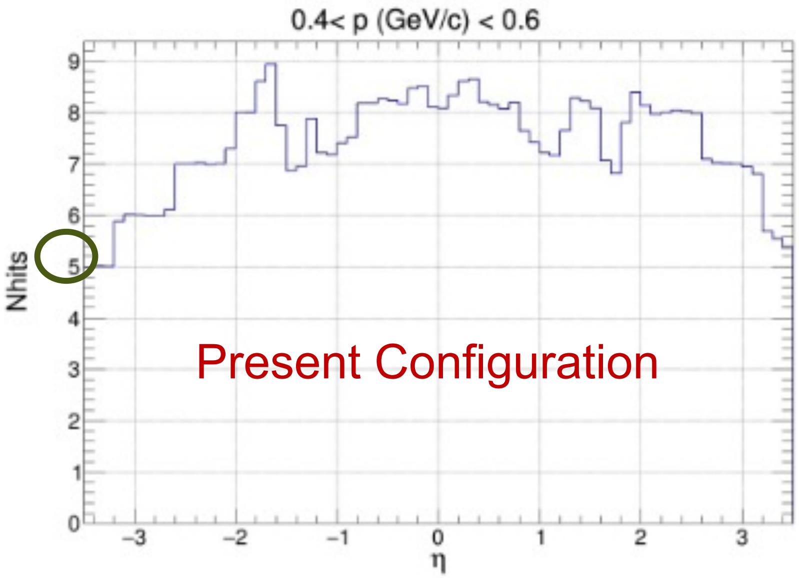
Previous Configuration

ePIC tracker geometry before June 2023

Scope of the MPGD Endcap Trackers

- 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 Configuration

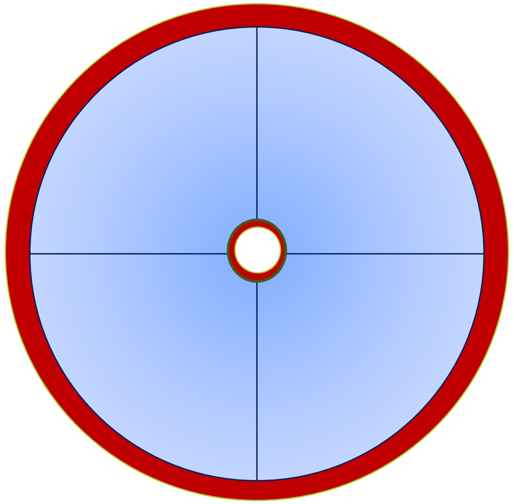
Present ePIC tracker geometry

Detector Geometry: Envelope and Active Regions

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

Endcaps Envelope Dimensions - Beam Pipes Envelope Radii and Offsets

MPGD Disk	Max Z Pos (cm)	Disk Outer Radius (cm)	Outer Active Reg. radius (cm)	Calculated Beam pipes radii (mm)	Offset (mm)	Disk Inner Radius (cm)	Inner Active Reg. radius (cm)
HD MPGD 2	163.5	50	45	55.8	22.5	8	9.5
HD MPGD 1	150.5	50	45	53.1	19.9	8	9.5
LD MPGD 1	-112.5	50	45	37.7	-3.1	4.5	6.0
LD MPGD 2	-122.5	50	45	39.2	-3.4	4.5	6.0

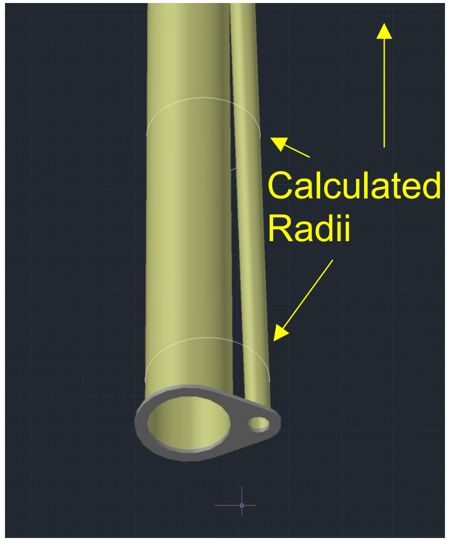


Disks Outer Radius

- 50 cm external radius

→ **45 cm of active area**

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



Disks Inner Radius
different for the two HD and LD regions

- HD: 8 cm inner radius

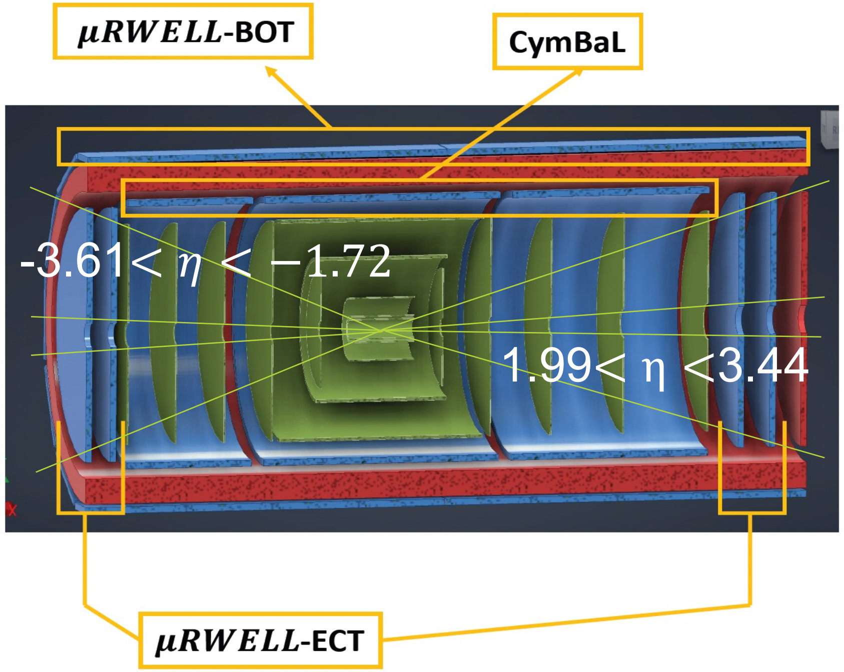
→ **9.5 cm radius of active area**

- LD: 4.5 cm inner radius

→ **6 cm radius of active area**
considering 1.5 cm gas frame

Pseudo-rapidity coverage: effective η 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	162	9.5	3.35	**3.53**	45	15.52	1.99
HD MPGD 1	148	9.5	3.67	**3.44**	45	16.91	1.9
LD MPGD 1	-111	6	3.09	3.61	45	22.07	1.63
LD MPGD 2	-121	6	2.83	3.69	45	20.40	1.72



- The minimum $\lvert\eta\rvert$ value is not larger than 2

it is limited by the outer HD disk location/dimensions

- The maximum $\lvert\eta\rvert$ value is not less than 3.44

it is limited by the inner HD disk location/dimensions

The η **range** covered by the MPGD Endcap tracking disks is **compliant** with requirements.

Technical Performance Requirements

Time resolution 10 ns time to provide tracking timing

- Fast rise time ~ 20 ÷ 50 ns
- Peaking time 50 ns
- Sampling faster than 50 MHz

Low material budget

- 1-2 % X_0 - it will be the minimum compatible with the chosen technology (to be detailed!)

Spatial resolution: 150 μm or better

- <150 μm intrinsic spatial resolution for perpendicular tracks
- Technological optimizations to retain 150 μm resolution for inclined/curved tracks

High Efficiency

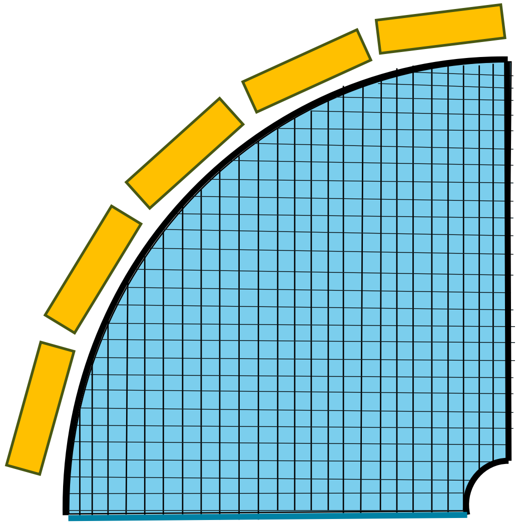
- Single detector efficiency ~ 96 –97 % → 92 –94 % combined efficiency for two disks

Detector performance and construction plans

Are the plans for achieving detector performance and construction sufficiently developed and documented for the present phase of the project?

(X, Y) read-out geometry

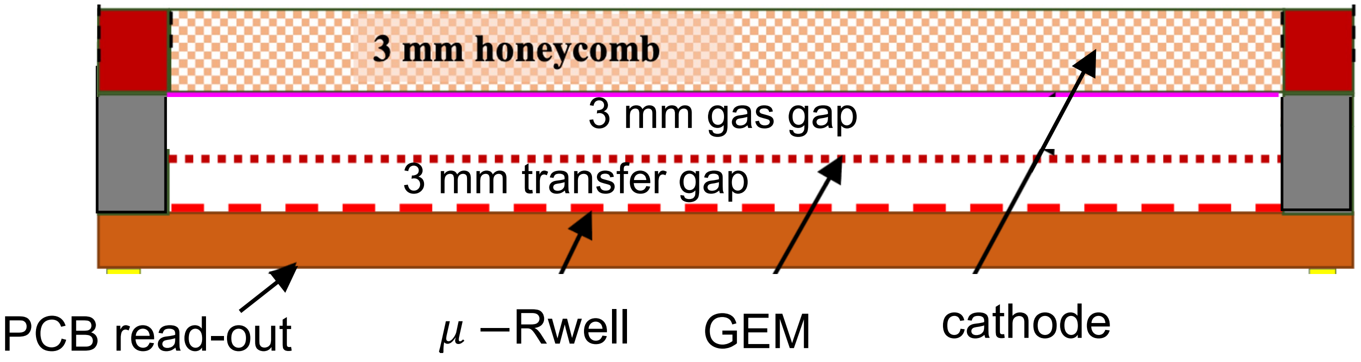
PROs	CONs
The strip length does not vary much along the active area	Alignment is critical
All readout FE hybrids may be located outside the active area	Routes to read-out connectors must be accurately studied

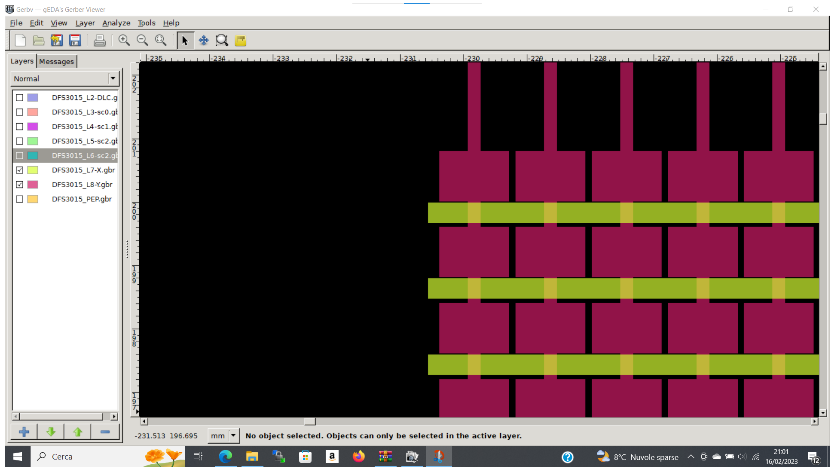


- (X, Y) readout is preferred vs (R,φ) – no FEB on the active area
- 500 μm pitch → better than 150 μm intrinsic position resolution
  - **Strips routing details need to be studied** – we need to start

Detector Technology

GEM - μRwell Technology





☐ DFS3015_L2-DLC.g
☐ DFS3015_L3-sc0.gb
☐ DFS3015_L4-sc1.gb
☐ DFS3015_L5-sc2.gb
☐ DFS3015_L6-sc2.gb
☑ DFS3015_L7-X.gbr
☑ DFS3015_L8-Y.gbr
☐ DFS3015_PEP.gbr

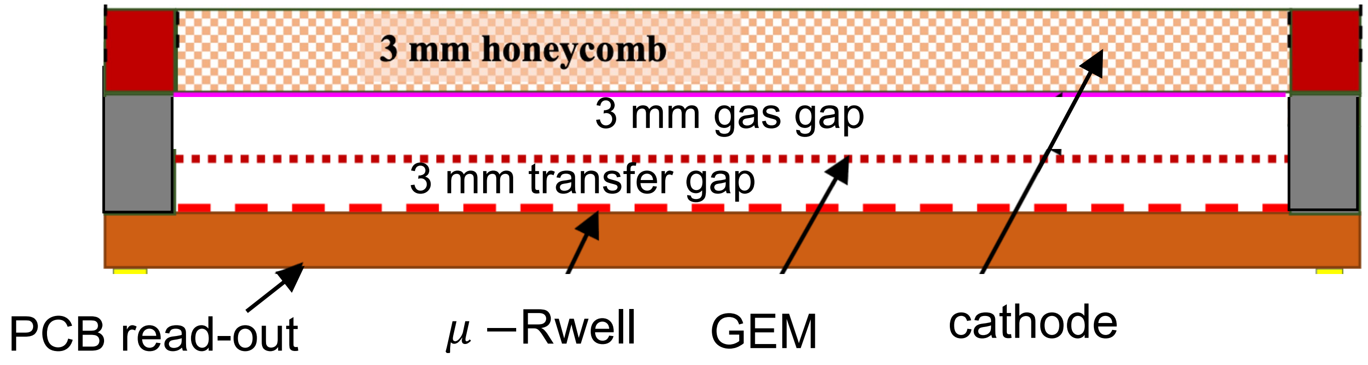
-231.513 196.695 mm No object selected. Objects can only be selected in the active layer.

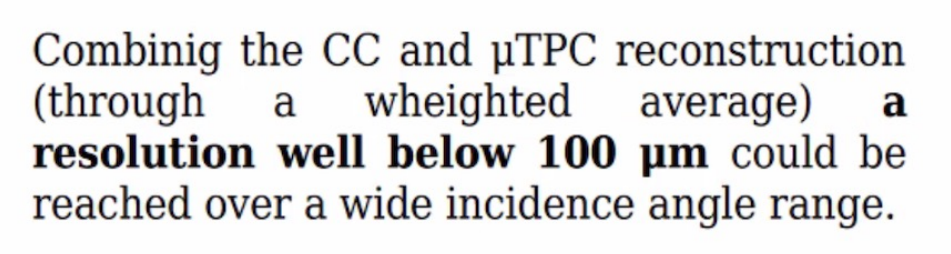
- GEM- μRwell hybrid configuration has been chosen to increase the gain in the 10 000 ÷ 20 000 range
- 2D strip read-out using a “COMPASS-like” scheme
- 500 μm pitch guarantees a spatial resolution better than 150 μm (no need of capacitive sharing)
- Technological solutions exist to retain 150 μm position resolution also for inclined/curved tracks ($\theta < 25$ deg)
- A gas gap lager than 3 mm is compatible with single detector efficiency larger than 96%

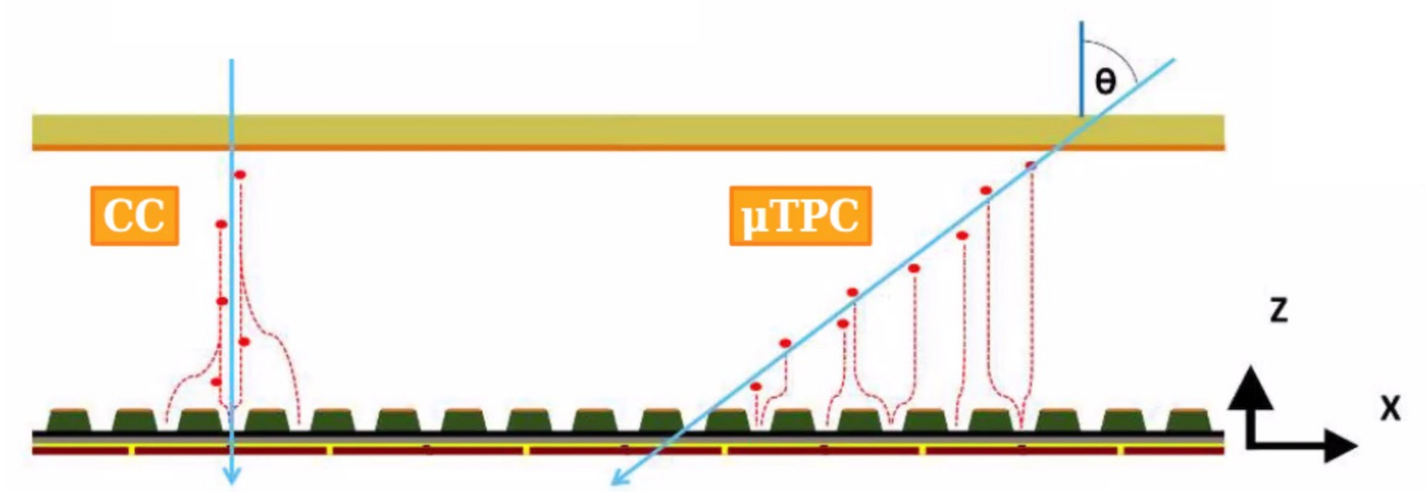
All R&D Studies for EIC disks performed within eRD108 and in synergic collaboration with INFN-LNF and JLAB

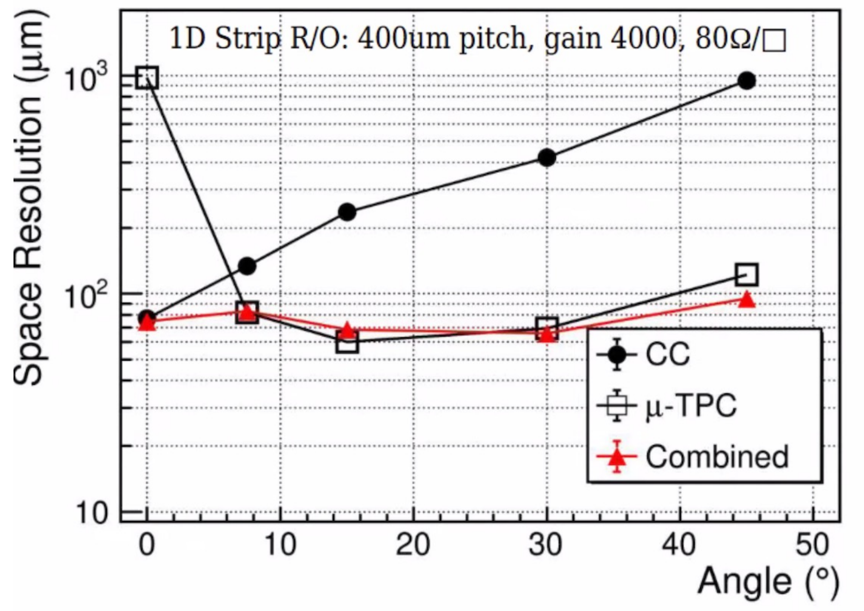
Detector Technology

GEM - μRwell Technology + μTPC reconstruction




Combinig the CC and µTPC reconstruction (through a wheighted average) **a resolution well below 100 µm** could be reached over a wide incidence angle range.



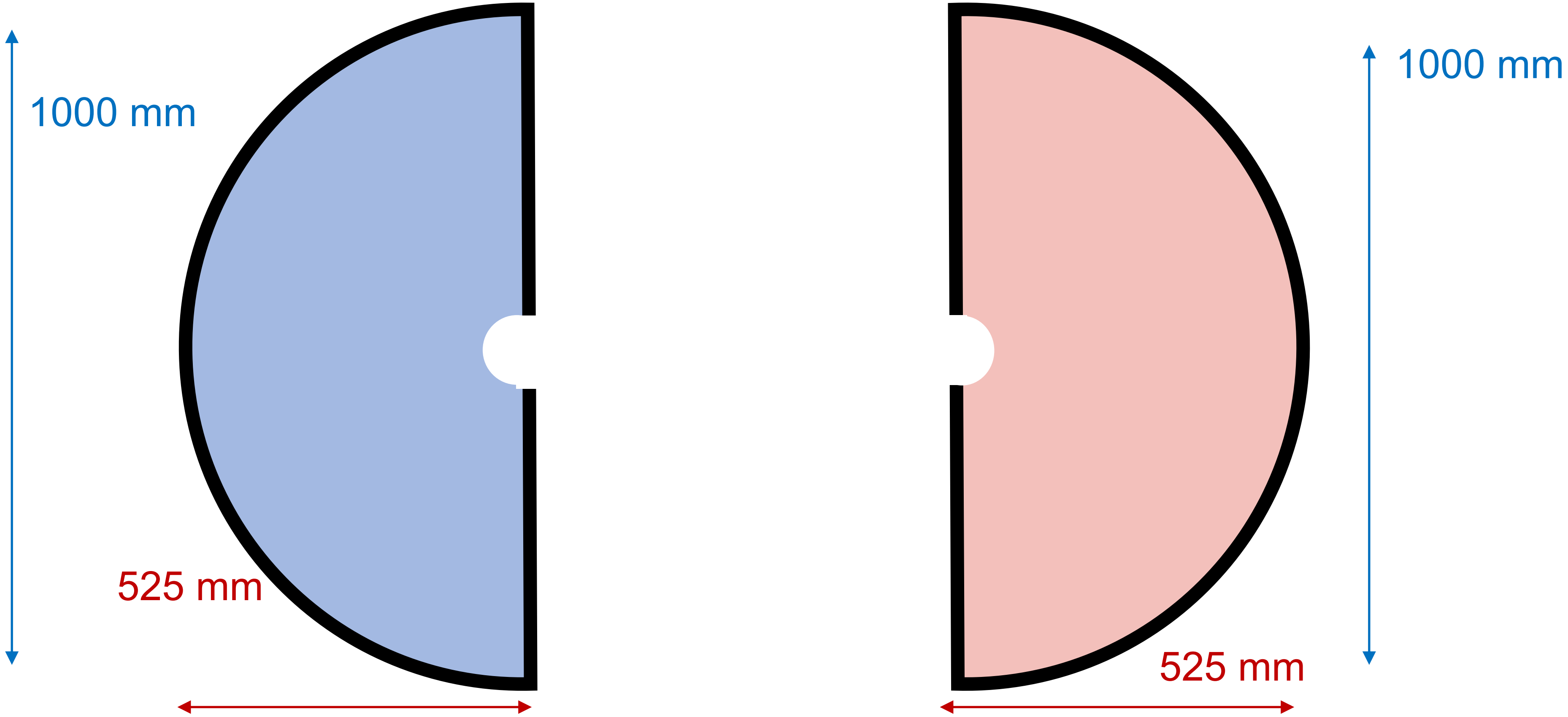


Detector, Electronics Readout, and Services

Are the current designs and plans for detector, electronics readout, and services sufficiently developed to achieve the performance requirements?

MPDG Endcaps semi-detectors overlap

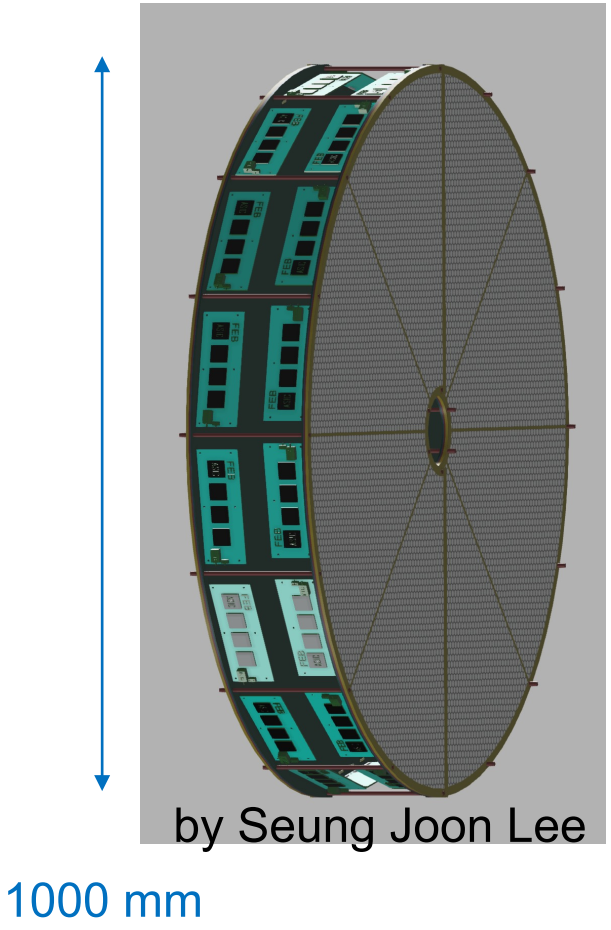
The split may be mounted to be either horizontal or vertical



The two half disks will have 2 cm of active area overlap

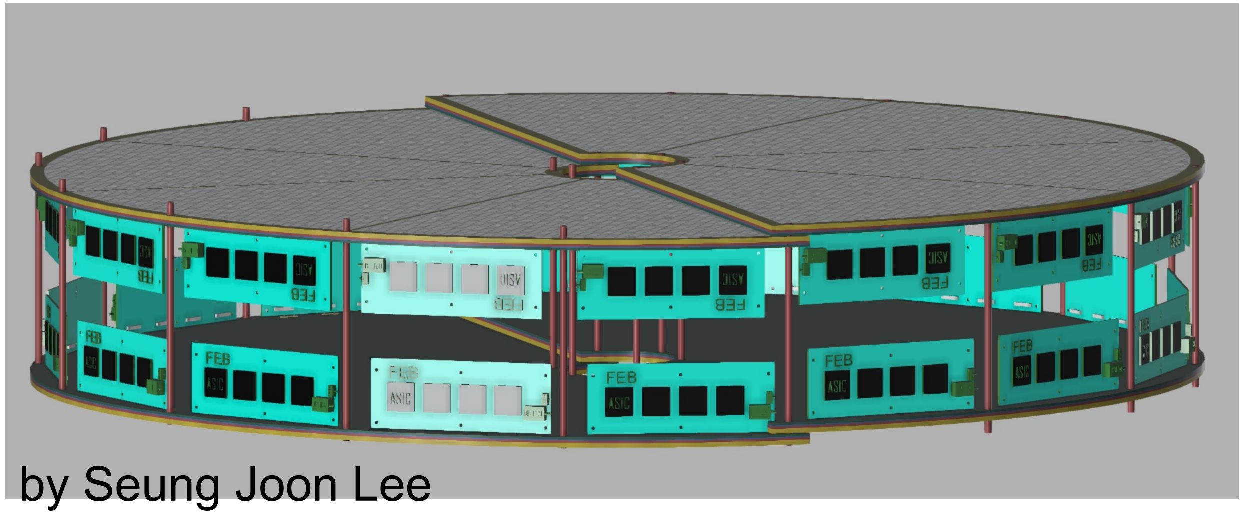
Detector, Electronics Readout, and Services

Are the current designs and plans for detector, electronics readout, and services sufficiently developed to achieve the performance requirements?



by Seung Joon Lee

MPGD Endcaps configuration

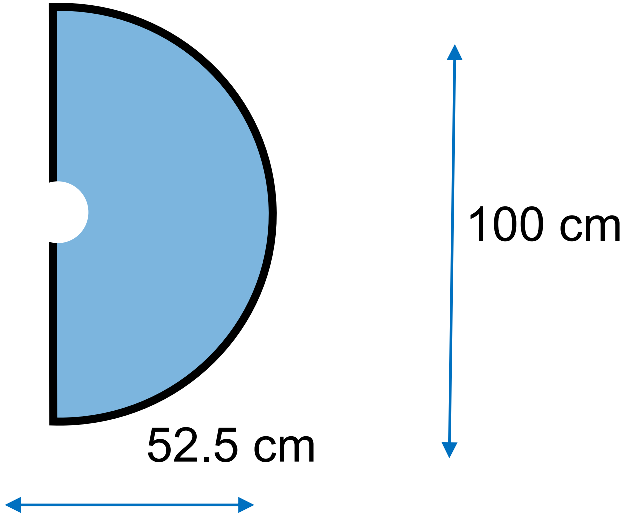


by Seung Joon Lee

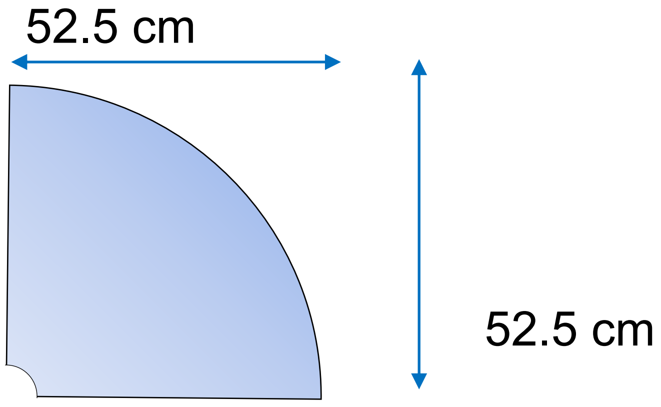
- The two disks are mounted facing each another
- The FEBs are connected perpendicularly to the disks and will not overlap the active area

EIC Endcaps – open options

2 semi-circles



4 Quadrants



PROs	CONs
One vertical/horizontal overlap only – less material	Larger detector surfaces are more difficult to handle.
The two endcaps may be rotated by 90° one respect to the other to recover overall symmetry	Longer strips: → Readout should be segmented into two sectors to avoid too long strips

PROs	CONs
Smaller dimensions are easier to handle	Two vertical and horizontal overlapping regions – more material
Each endcap is intrinsically symmetric	We need to study how to attach two quadrants in a semi-circle
Strips length are shorter	
GEM foils are easier to stretch	

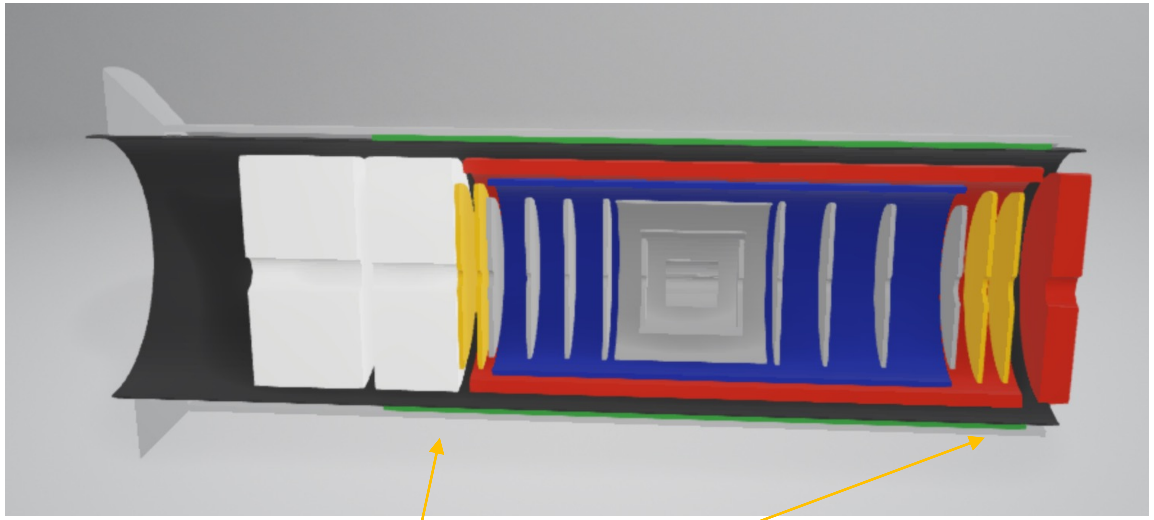
Services

Charge 3

Electronics Readout based on SALSA ASIC developed at Saclay

For each endcap disk (4 disks in total):

- 16 HV cables
- 4 gas inlets and 4 gas outlets
- 32 data cables
- 32 low voltage cables
- 2 temperature sensors cables
- 2 humidity sensors cables
- 2 inlet and 2 outlet cooling hoses (dry-air or liquid)
- Space for 32 RDO cards



4 disks

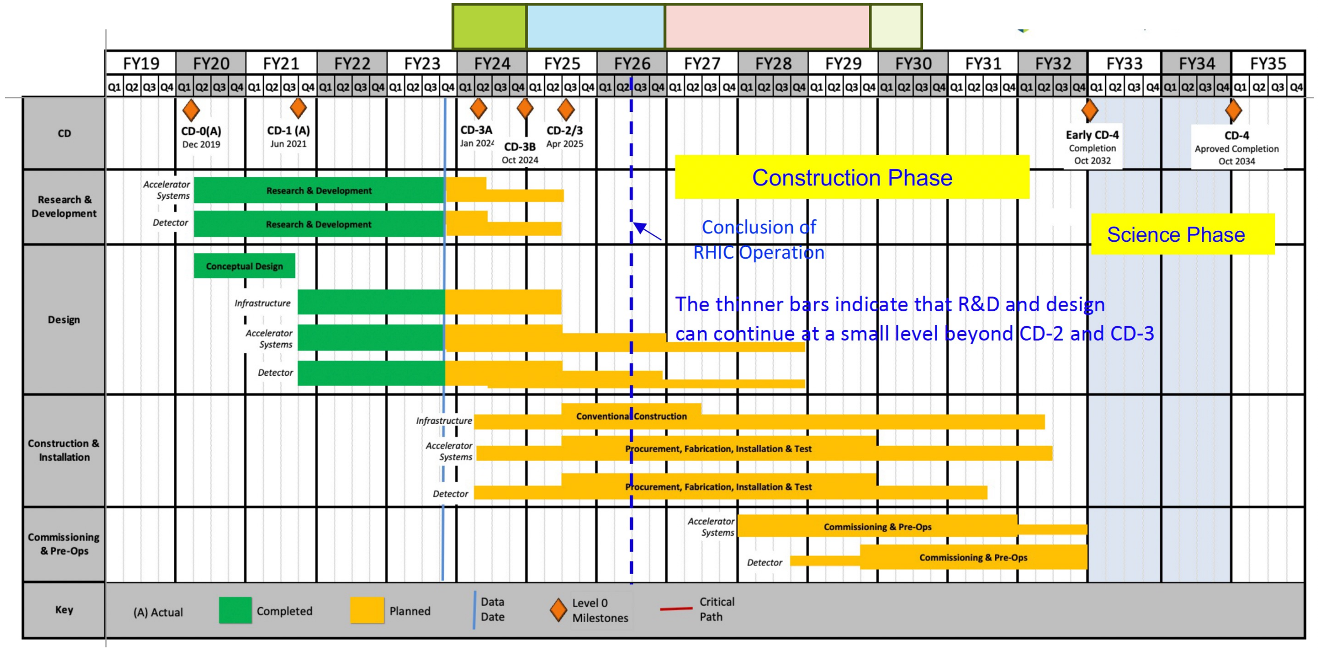
All the service requirements have been communicated to the Integration group

Fabrication and Assembly Plans

Charge 5

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

- Design by end of 2024
- 2025 - 2026 pre-production and Engineering Test Article
- 2027 - 2029 production & QA
- 2030 Commissioning & 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 & QA	3
1/1/30	6/1/30	Commissioning & Installation	0.5

Involved Institutions & Workforce

Charge 5

INFN Workforce:

- **Roma Tor Vergata**

Coordinator**:** A. D'Angelo,
Detector Hardware and QA: E. Sidoretti (PhD) A. Fantini, L. Lanza
Simulation & Reconstruction: L. Lanza, A. Fantini, R. Di Salvo
FEB Electronics: R. Ammendola

- **Genova**

FEB Electronics: Paolo Musico, M. Battaglieri (streaming ro)

- **Catania**

Simulation & Reconstruction: Mariagela Bondi'

The work will be performed in **close connection** with:
the group of Gianni Bencivenni @ INFN LNF and with the JLab detector group (Kondo Gnanvo, Seung Joon Lee)

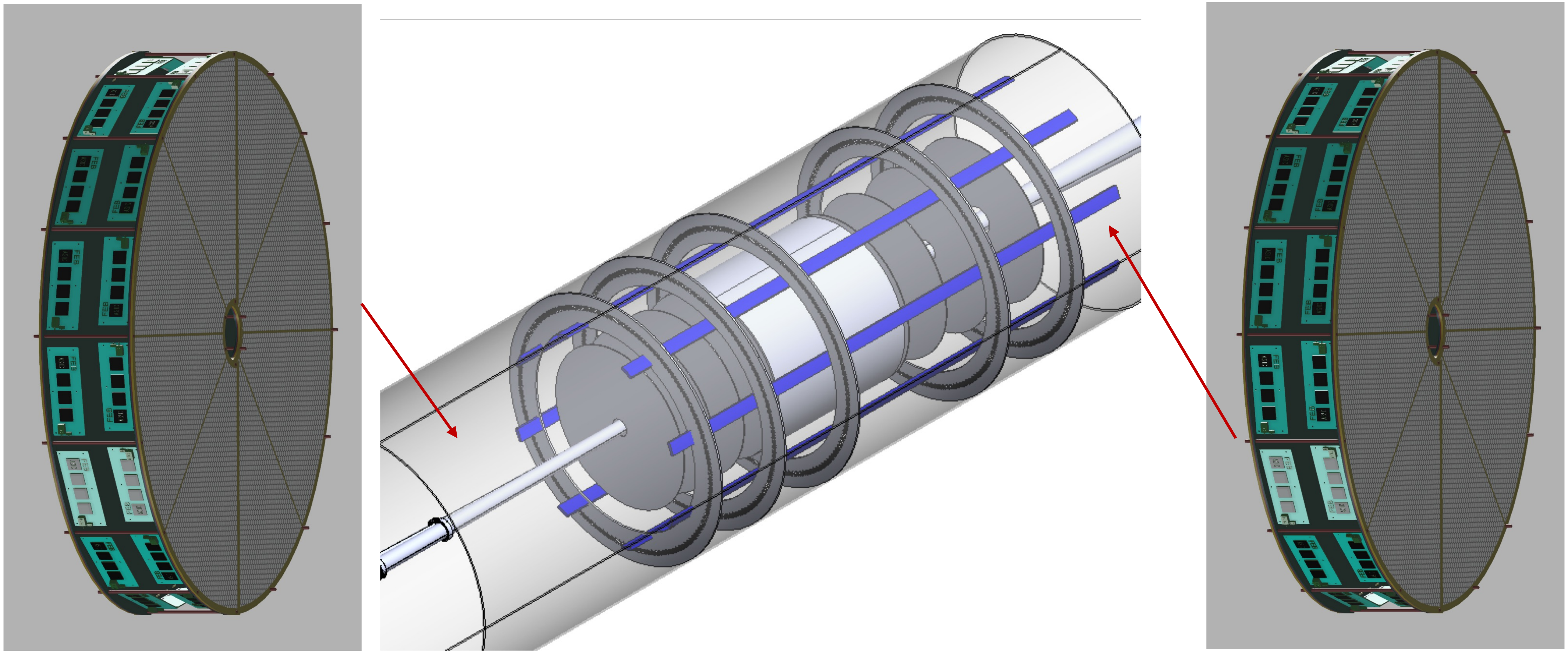
Interest in the project has been expressed also by:
BNL (A. Kiselev et al.), **Florida Tech**.(M. Hohlmann et al.), **Temple U.** (M. Posik, et al.)

Detector Integration in ePIC

Charge 6

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

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



To Do List

- Test beam in Fall 2024 to charecterize the μRwell + GEM configuration:
  400 μm pitch: 250 μm w x – 80 μm w y: 6 mm drift gap+3 mm transfer gap
- Test beam in Fall 2024 to characterize the μRwell + GEM configuration in μTPC mode
- Decide about the 4-quadrants option (GEM foil is easier to stretch uniformly)
- Work on the 500 μm pitch routing to the connectors
- Calculate the material budget of the final configuration

Summary

- Geometrical Acceptance and Technical Performances of hybrid GEM-μRwell endcap trackers have been defined.
- A detector layout compliant with requirements has been identified.
- Readout Electronics is based on SALSA ASIC developed at Saclay.
- Production timeline is consistent with the overall ePIC detector schedule.
- The two disk couples are rigidly connected and attached to the inner tracker support via multiple points (~ 6 points/disk).
- INFN workforce and laboratories are involved in the construction + BNL, Florida Tech and Temple U. have expressed their interest in the project

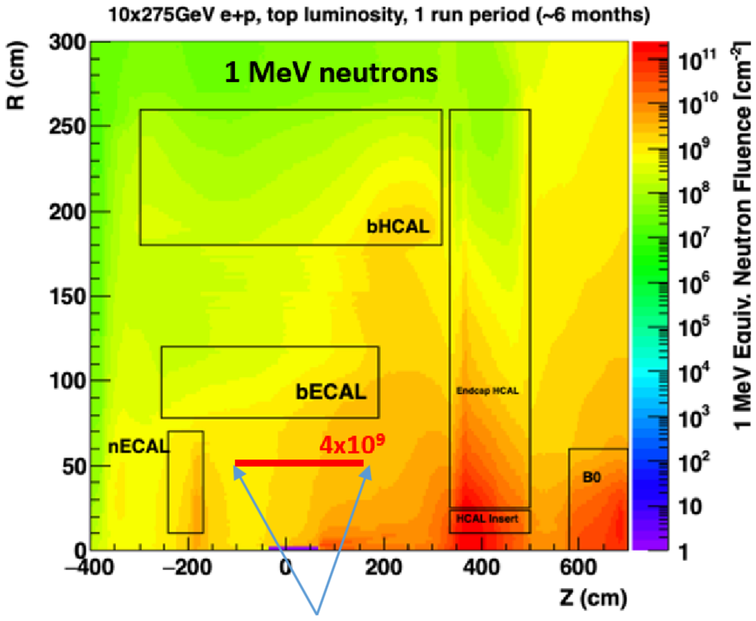
Back-up Slides

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

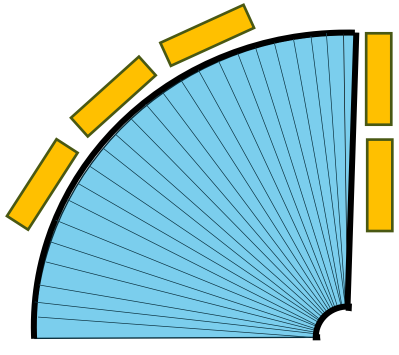


MPGD Endcaps

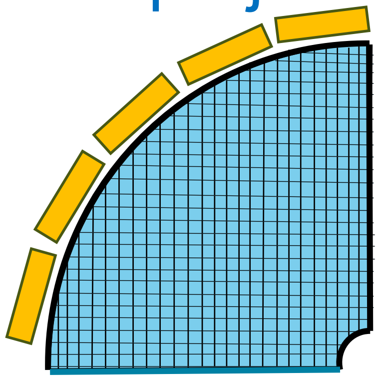
Detector performance and construction plans

Charge 2

Are the plans for achieving detector performance and construction sufficiently developed and documented for the present phase of the project?



(R,φ) vs (X, Y)



PROs	**CONs**
Direct radial and azimuthal information	The linear density of the azimuthal strips increases by a factor 10 on the inner hole
	The radial readout hybrid FE overlaps the active area or long flex cables should be used.
	Radial strip length varies by a factor 10.

PROs	**CONs**
The strip length does not vary much along the active area	Alignment is critical
All readout FE hybrids may be located outside the active area	Routes to read-out connectors must be accurately studied

- (X, Y) readout is preferred vs (R,φ) – no FEB on the active area
- 500 μm pitch → better than 150 μm intrinsic position resolution

Risks Mitigation

Charge 4

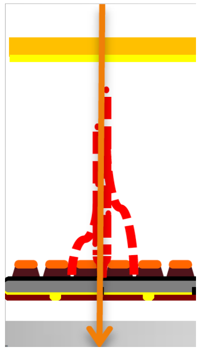
Are plans in place to mitigate risk of cost increases, schedule delays, and technical problems?

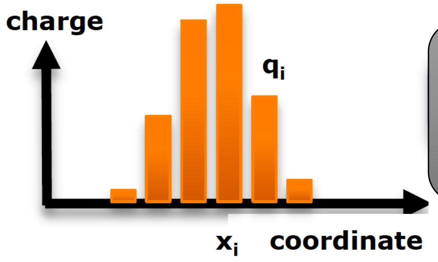
Main risk is related to CERN being the unique producer of μ-Rwell detector layer

Risk Mitigation: accurate planning

- Early procurement
- In-house detector assembly
- Technology transfer to external manufactures
- Person at CERN to supervise the μ-Rwell /GEM foils production
- Continuous QA tests

Spatial Resolution



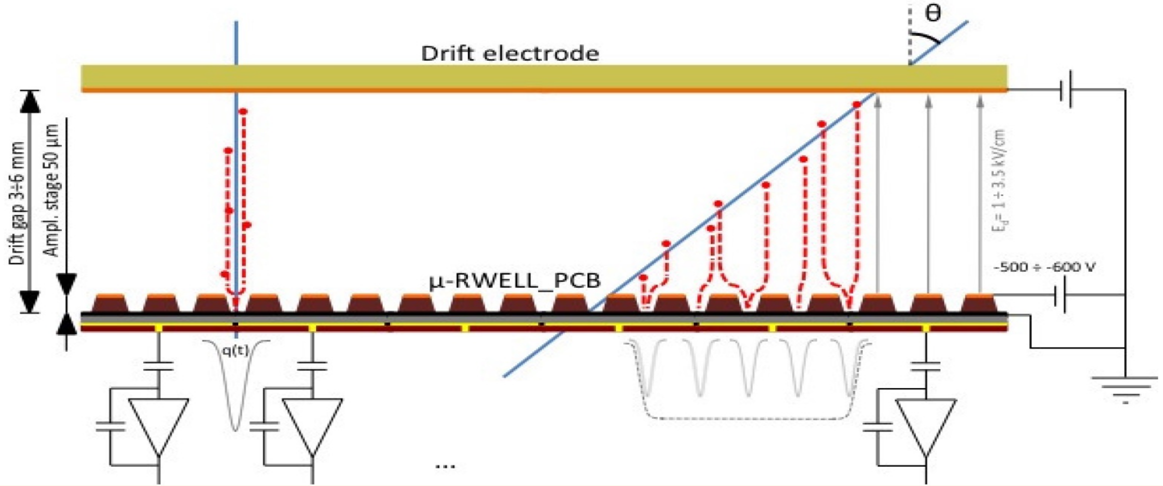


$$x_{hit} = \frac{\sum x_i \cdot q_i}{Q_{tot}}$$

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

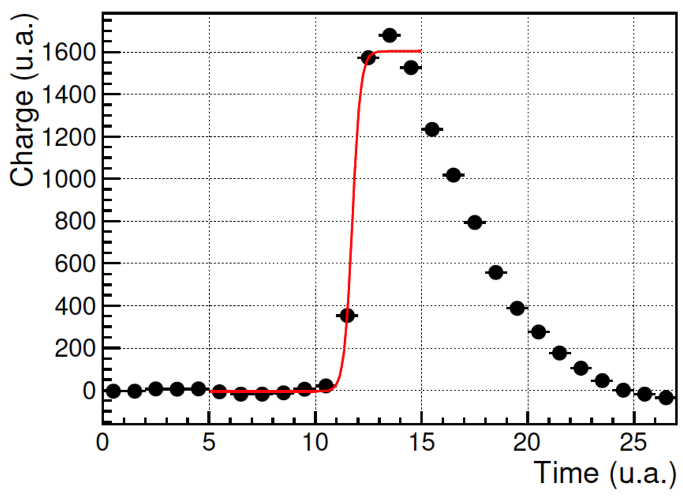
The spatial resolution is strongly dependent on the impinging angle of the track =>

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

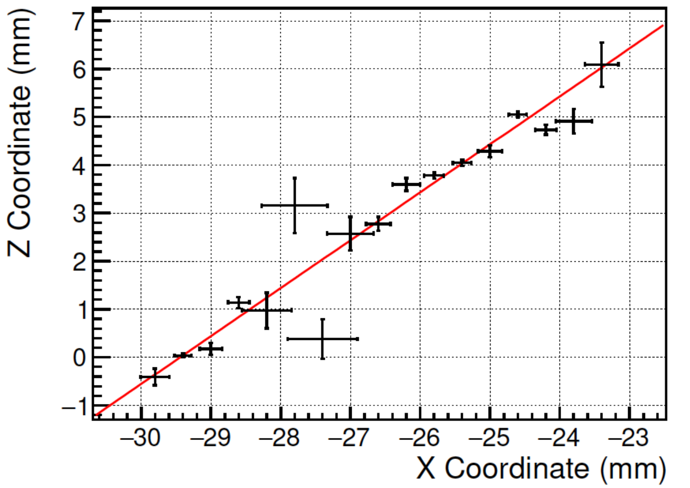
μTPC reconstruction

A possible solution :

- 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.

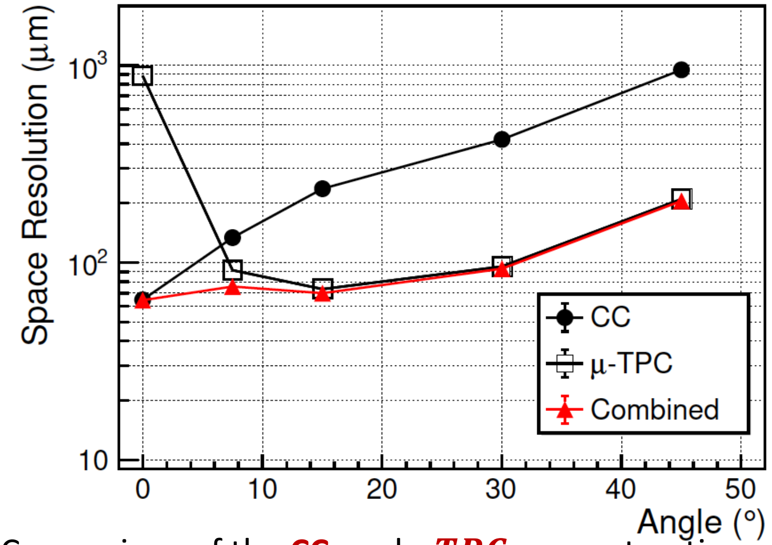


Integrated charge as a function of the sampling time



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