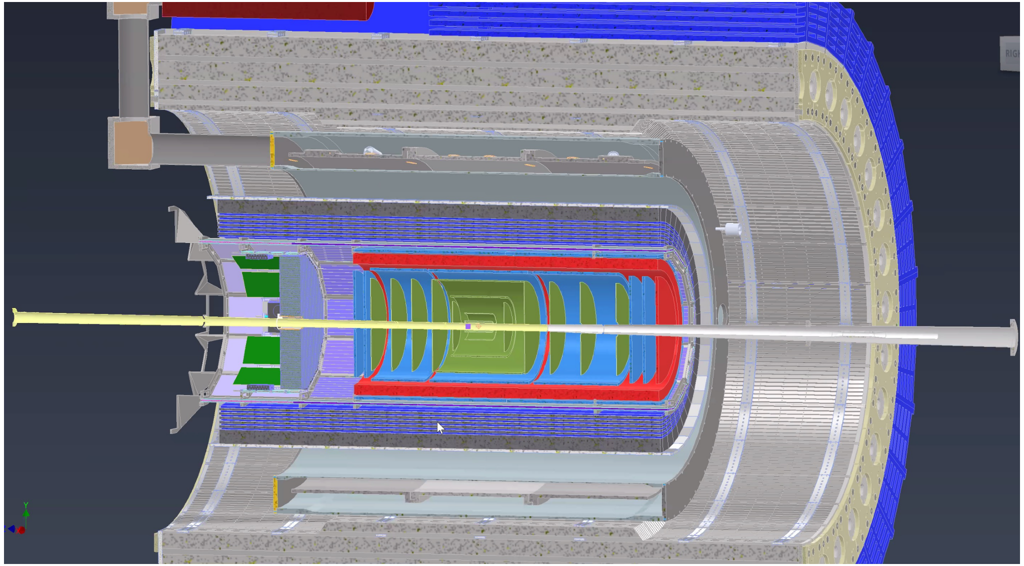


$\mu - $ Rwell detectors for the EPIC tracking at EIC – eRD108

Alessia Fantini – Annalisa D'Angelo

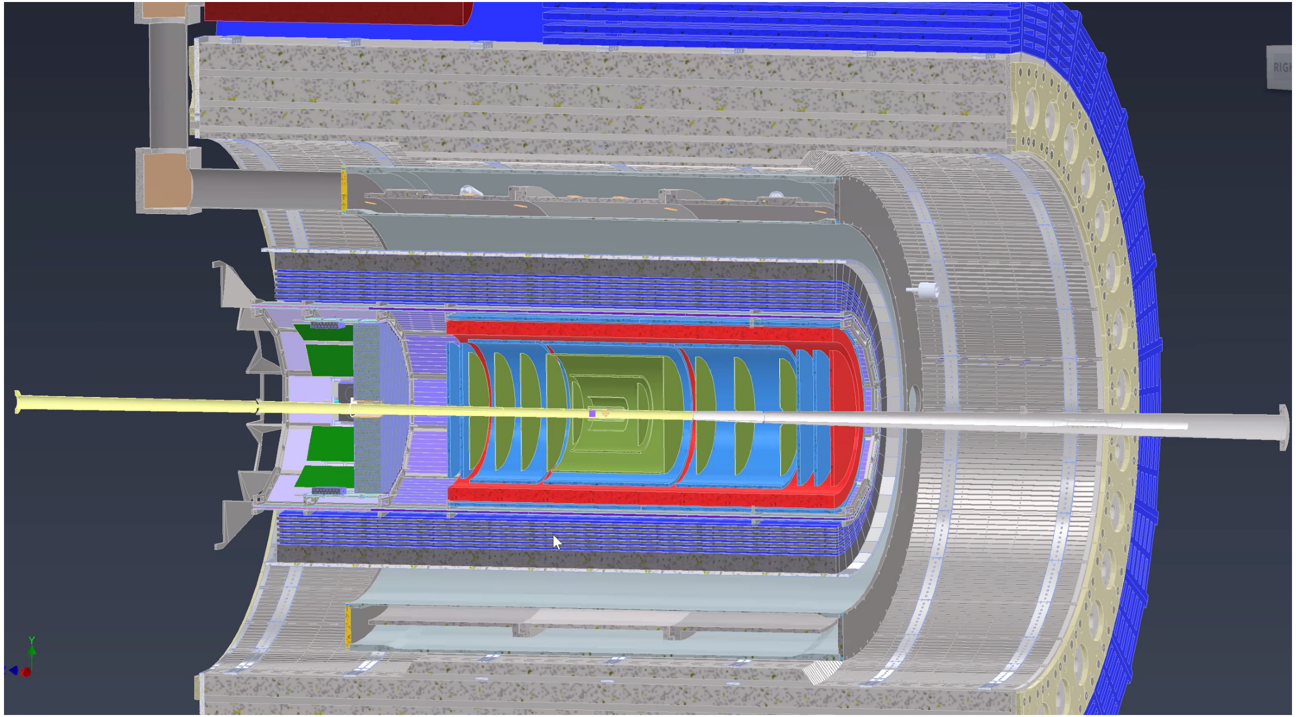
University of Rome Tor Vergata & INFN Rome Tor Vergata Rome – Italy

for the EIC Collaboration

Outline

- The MPGD scope in the EPIC detector: latest tracking configuration (June 15th 2023)
- μ –Rwell technology
- Ongoing developments
    - 2D readout scheme: capacity sharing and strip width optimization
    - Large area detectors
- Future developments for EPIC@EIC tracking
    - μTPC reconstruction vs thin drift gap
- Possible involvement of INFN groups: Roma Tor Vergata (with LNF support), Genova
    - Synergies with on-going activities at JLab12
    - Collaboration with Gianni Bencivenni's Group
    - EIC MPDG WG– e RD108 and the tracking WG welcomes the possible contribution
    - A possible INFN scope can be easily identified with the available budget.

The Latest Configuration of ePIC detector tracking



Colour code:

green → silicon trackers

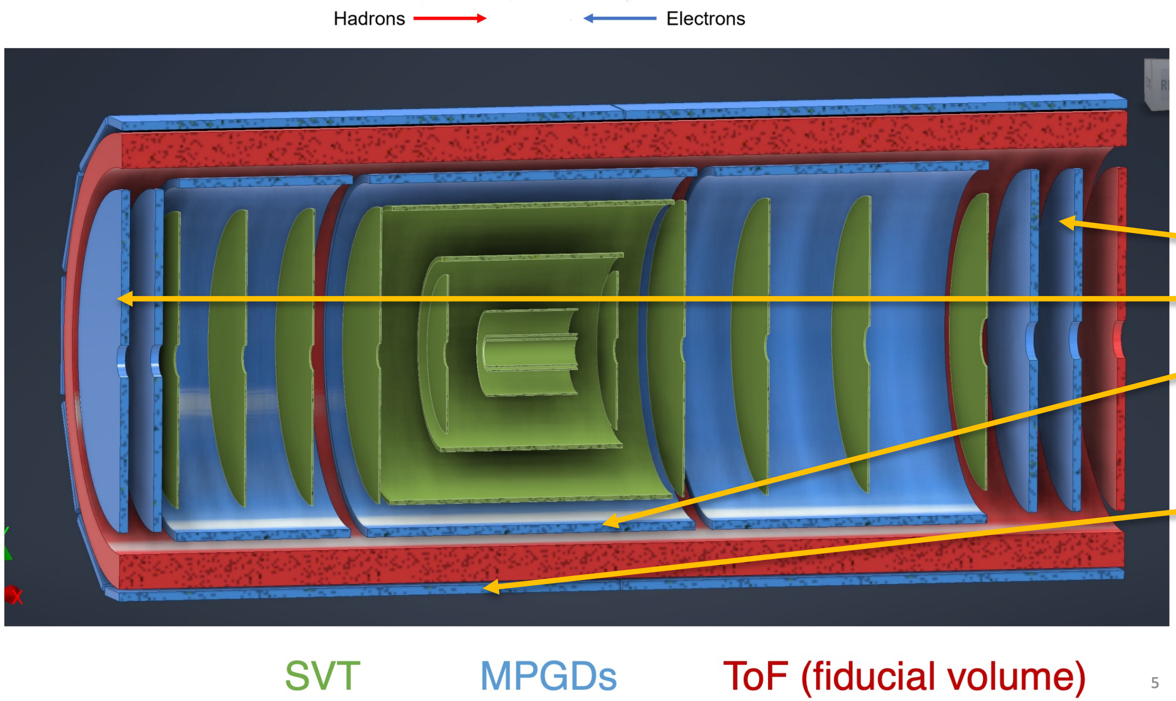
light blue → MPGDs

red → Time of Flight

purple → DIRC

June 15th 2023 – Tracking working group meeting – re-inforced role of MPGD

The Latest Configuration of ePIC detector tracking



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- Two forward discs
- Two backward discs
- Cylinder inside the ToF, segmented in three longitudinal sectors
- Barrel inside the DIRC: same DIRC segmentation in planar tiles, divided into two longitudinal sectors

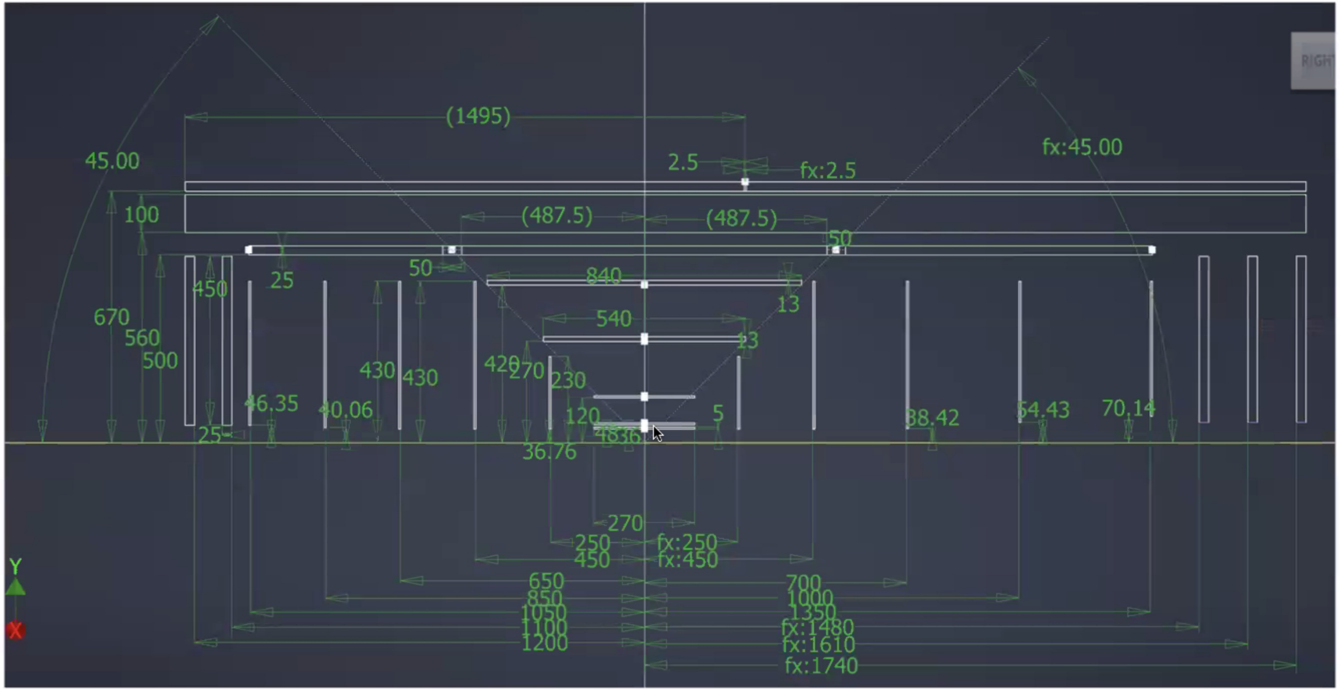
re-inforced role of MPGD

Its primary roles are : - Provide additional fast points for pattern recognition

- Aid PID subsystems tracking

The Latest Configuration of ePIC detector tracking

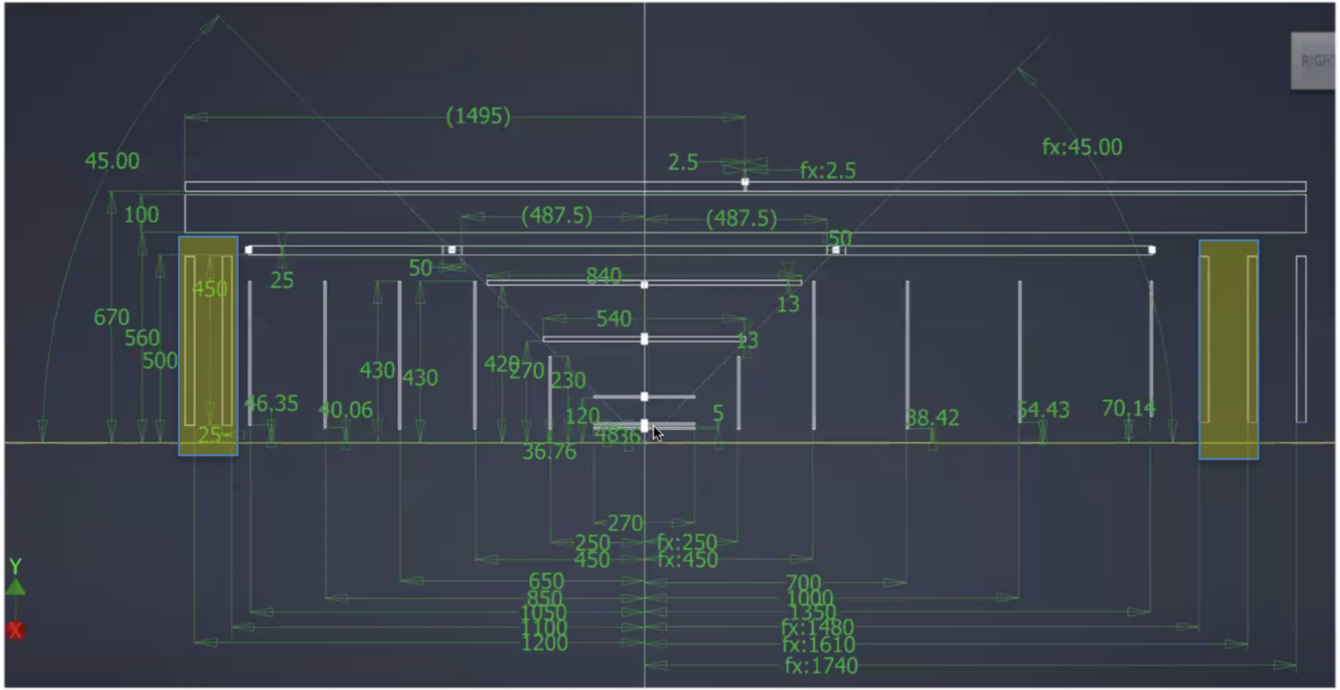
Tentative:



- 150 μm space resolution
- low material budget 1÷2% X/X_0

The Latest Configuration of ePIC detector tracking

Tentative:



- Two forward discs
  50 cm radius → *μRwell*
- Two backward discs
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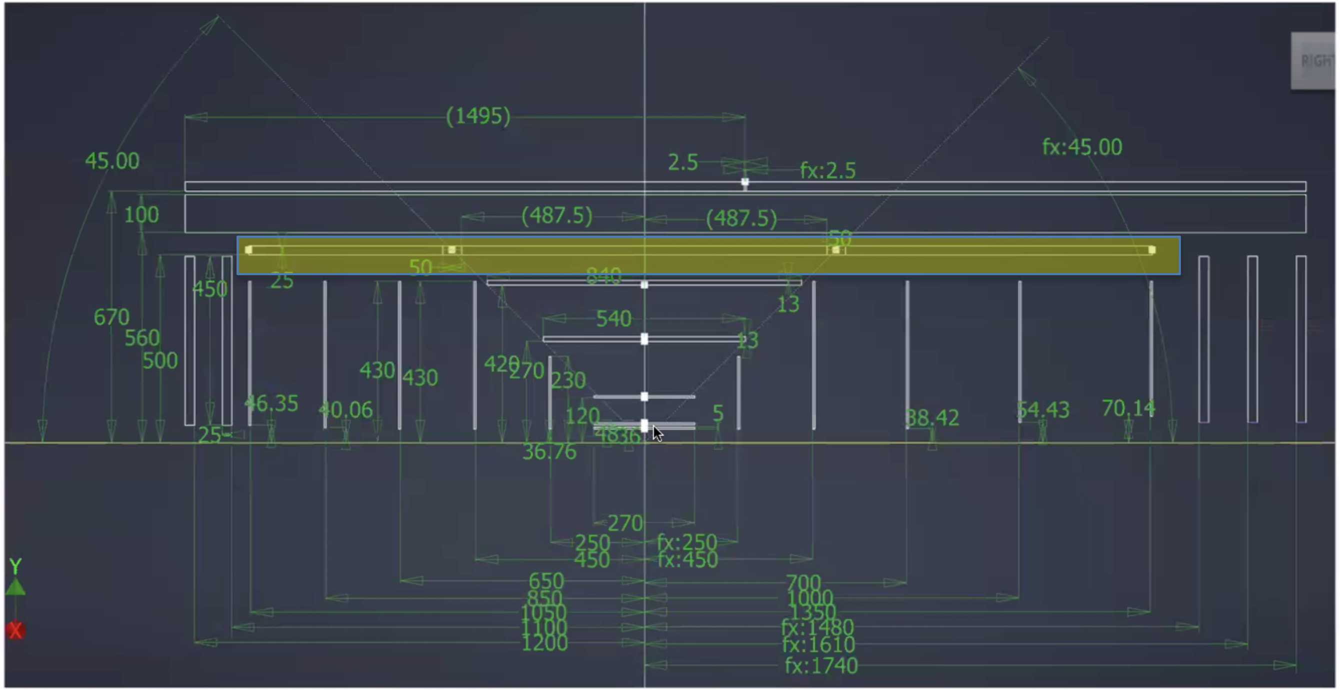

- Two forward discs
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  56 cm radius
  → Micro Megas

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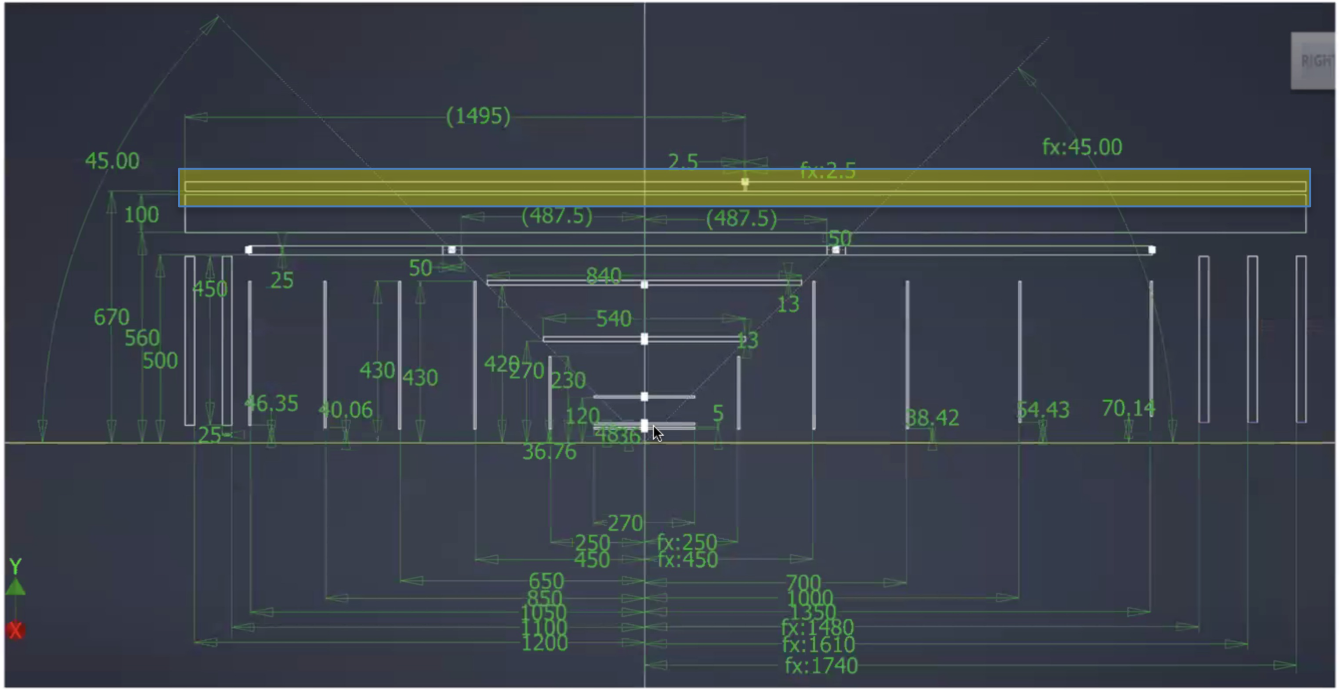

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  50 cm radius → *μRwell*
- Cylinder inside the ToF, segmented in three longitudinal sectors
  56 cm radius
  → Micro Megas
- Barrel inside the DIRC:
  67 cm radius
  → *MicroMegas/μRwell?*

- 150 μm space resolution
- low material budget 1÷2% X/X_0

The μ-RWELL features & performances

The μ-RWELL exhibits several interesting features:

- Compactness
- Easy assembly
- Easy powering
- Intrinsic spark quenching

μ-RWELL performances:

- Gas gain → 10^4
- Rate capability HR version →10 MHz/cm2
- Spatial resolution → down to 60 μm
- Time resolution → 5-6 ns

The µ-RWELL (Micro Resistive Well Detector)

The **µ-RWELL** is a Resistive MPGD detector (Micro Pattern Gas Detector)

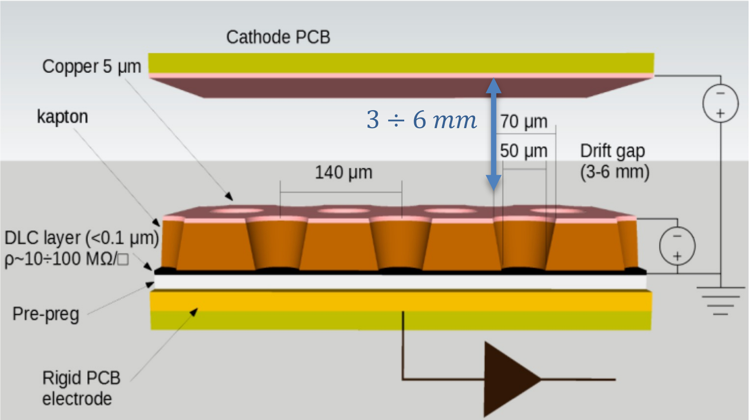
Used Gas : $Ar:CO_2:CF_4$ 45:15:40 mixture

The device is composed of two elements:

- **drift/cathode PCB**
- **µ-RWELL_PCB (detector core)**

Multilayer circuit (realized by means Photolithography):

- **Amplification stage:** → Well matrix patterned Kapton foil *With a Cu layer on the top side*
- **Resistive stage:** → DLC *(Diamond-Like-Carbon)* film sputtered on the bottom side of the Kapton foil connected to the ground
  Surface resistivity: $\rho = 10 \div 100\ M\Omega/\square$ the resistivity is function of DLC thickness
- **Readout stage:** → Standard PCB, segmented as strip, pixel or pad electrodes



G. Bencivenni et al.; 2015_JINST_10_P02008

!!!! The resistive layer strongly suppresses the transition from streamer to spark

=> *This Allows to achieve large gains (> 10^4),* *without affecting the capability to operate with* high particle fluxes

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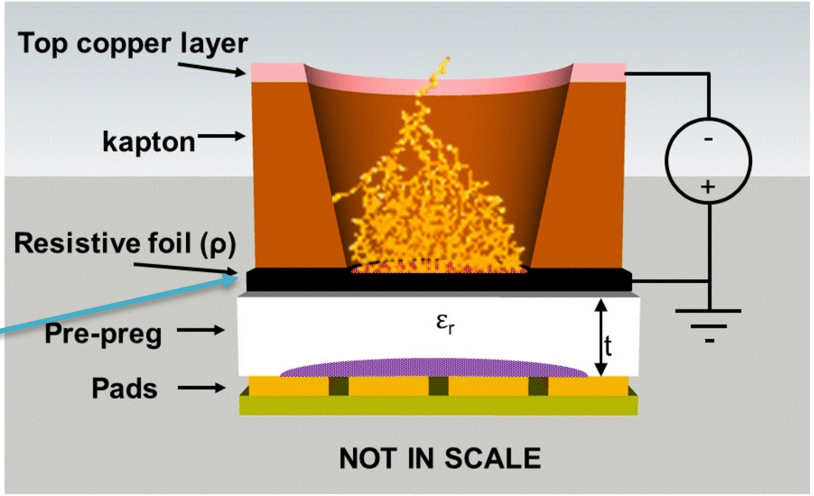

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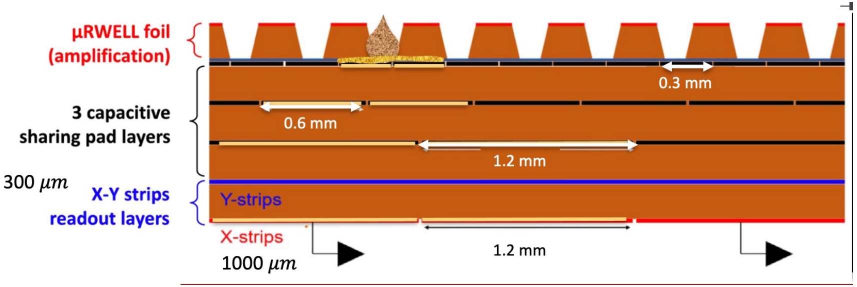
The µ-RWELL Developments: 2D readout scheme: capacity sharing & strip width optimization

develop low channel counts and high-performance readout PCB structures for large-area MPGDs

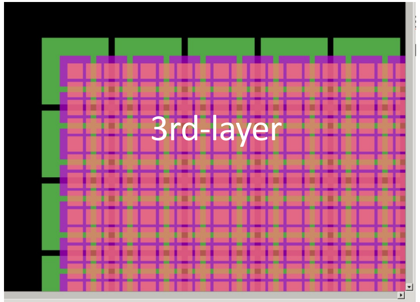
"capacitive-sharing readout structures"

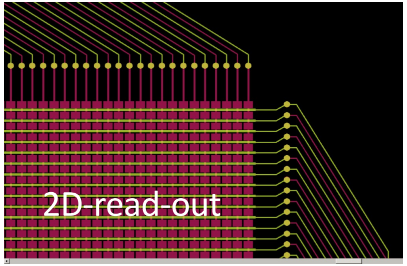
- charge transfer and charge sharing to large pitch (strip or pad) anode readout PCB layers using capacitive coupling between a stack of layers of pads.



- **The Cu on each layer is chemically etched into pads with their pitch doubling in size from the layer i to the layer i+1**
- **The pads size of the 1° layer defines the spatial resolution performance**
- **The pads size of the last layer (readout layer) defines the total number of electronic channels required for readout**

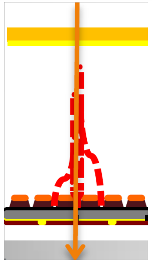
For n transfer layers, only a fraction 1/n of the number of pads along the same axis of the first transfer layer

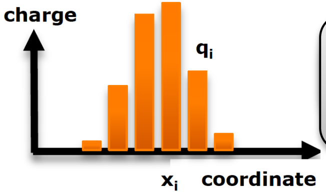




- very good spatial resolution capability
- significant reduction of electronic channels required to read out large-area MPGD trackers

The µ-RWELL Development for Large Area Detecors : *Spatial Resolution* → *µ*TPC reconstruction



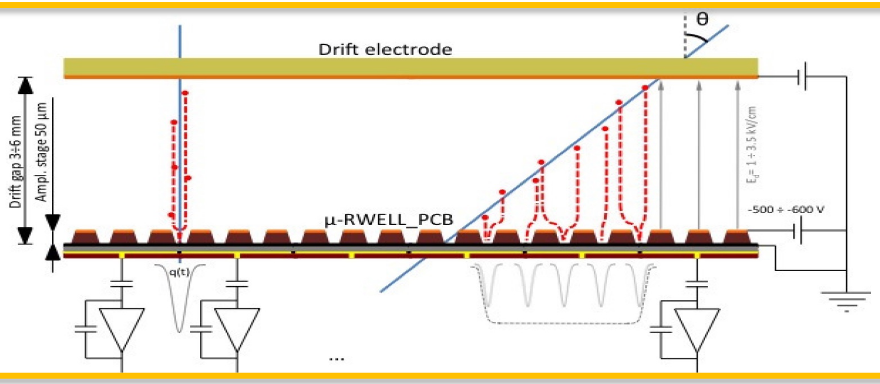


$$x_{hit} = \frac{\sum x_i \cdot q_i}{Q_{tot}}$$

Charge Centroid reconstruction method

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

GOOD FOR ORTHOGONAL TRACKS



FOR INCLINED TRACKS &/or HIGH B FIELD

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

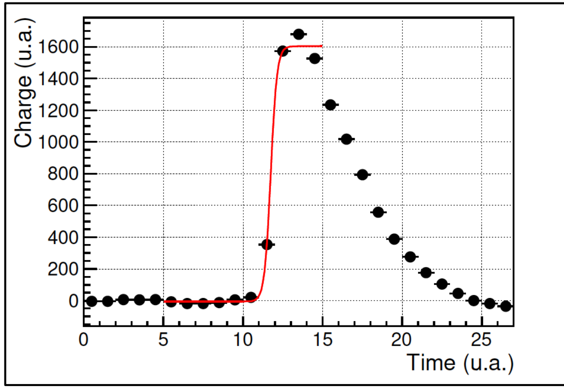
µTPC reconstruction

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

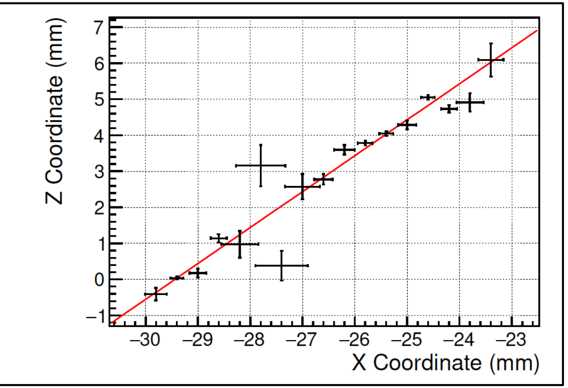
A not uniform resolution in the solid angle covered by the apparatus => Large systematical errors.

A possible solution : *μTPC reconstruction*

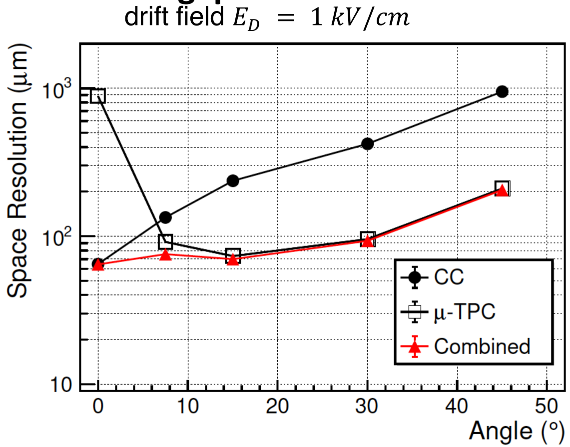
- The electrons created by the ionizing particle drift towards the amplification region
- In the μTPC mode from the **knowledge of the drift time** and the **measurement of the arrival time of electrons**, the **track segment in the gas gap is reconstructed**
- The **fit of the analog signal** gives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



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

Possible Involvement of INFN Groups

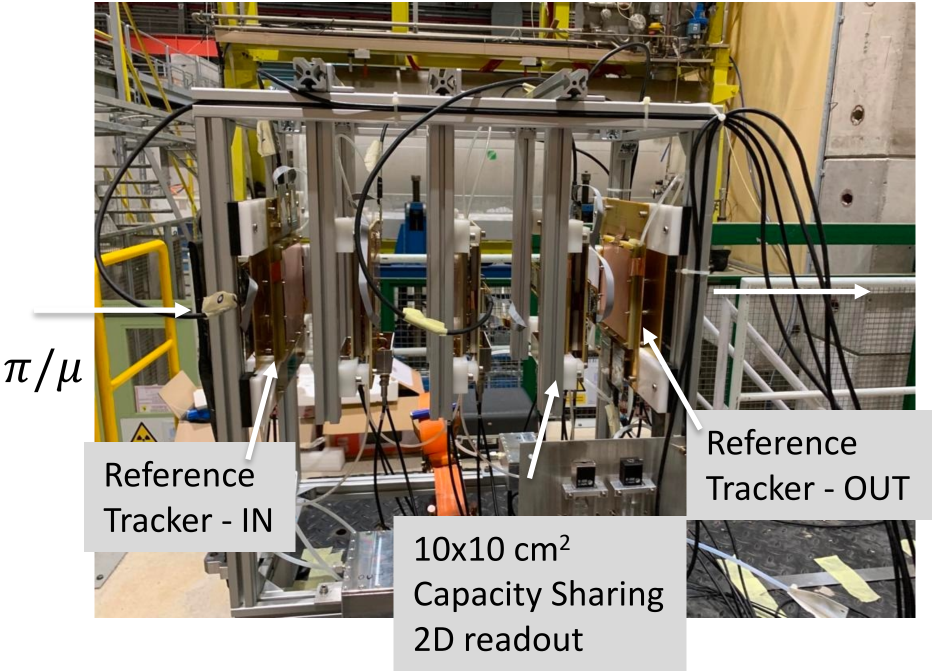
Synergies

- The Roma Tor Vergata and the Genova groups are presently involved in the development of μ-Rwell detectors for the high luminosity upgrade of the CLAS detector at Jlab
- The work is performed in close connection with the group of Gianni Bencivenni @ LNF and with the Jlab detector group (Kondo Gnanvo => EIC-MPGD WG)

- The Roma Tor Vergata group is developing the detectors, and is working on:
  - 2D read-out
  - Large area applications
  - Light weight cathodes (mounted on honeycomb support)

- The Genova group is working on:
  - Front-end read-out electronics: based on VMM3/SALSA (future SAMPA evolution for MPGD)

On-going activities



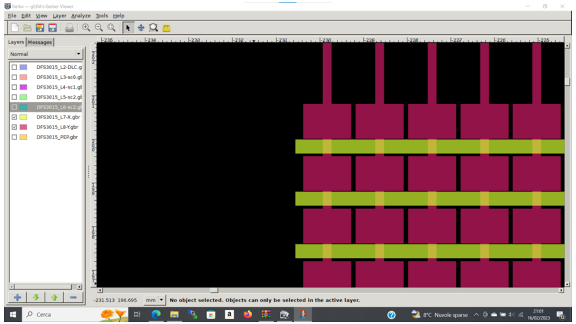
TEST BEAM at CERN SPS North Area H8:
October 2022
June 2023

Large area detector

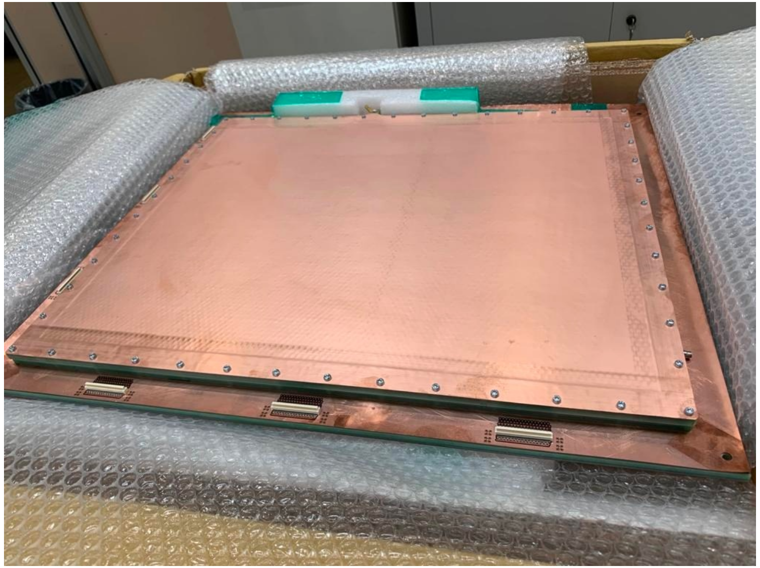
- A 40 x 46 cm ^{2} detector has been purchased from Rui De Oliveira @ CERN by Roma Tor Vergata
- The detector has the same 2D read-out scheme as the 10x10 cm^2 capacity sharing version prototype (being tested during at SPS - NA- H8 at CERN)

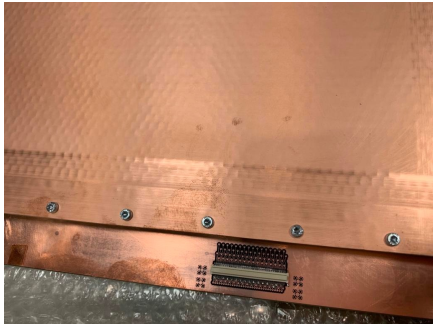
$1200\ \mu m\ pitch$

6 mm gas gap



$300\ \mu m\ \ vs\ \ 1000 \mu m$ strips





Light – cathode
on honeycomb support

Will be tested with X-rays and cosmic rays
At LNF and Roma Tor Vergata

Possible collaboration with EIC MPGD group

INFN Manpower:

- **Roma Tor Vergata:** A. D'Angelo (PO), R. Di Salvo (I ric), A. Fantini (RU), L. Lanza (RTDa), E. Sidoretti (PhD)
- **Genova:** M. Battaglieri (DR), Paolo Musico (INFN)
- Roma 1: Evaristo Cisbani (GEM expert)?

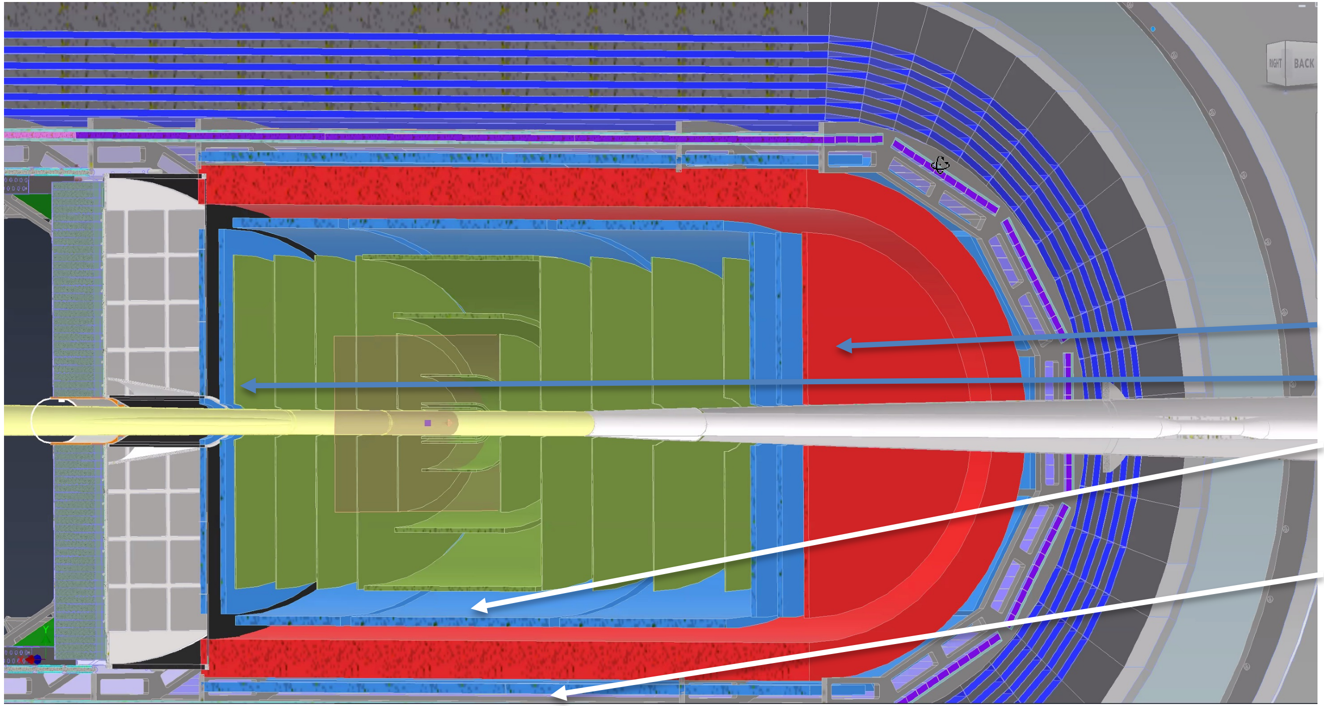
- We have contacted Kondo Gnanvo to explore a possible space in the EIC MPGD working group:
  - a first informal meeting last week (Pietro A. , Kondo G., Annalisa D. & Alessia F.) proved a positive response to a collaboration proposal
  - It could be possible for INFN to build the 2 forward discs using μ-Rwell technology with ~ 500 Keuro budget
  - Yesterday evening Annalisa officially presented to the MPDG WG meeting our collaboration proposal and our candidacy to participate to eRD108 =>

WE ARE WELCOME

Thank you

- SPARES

The Latest Configuration of ePIC detector tracking



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purple → DIRC

light blue → MPGDs

- Two forward discs
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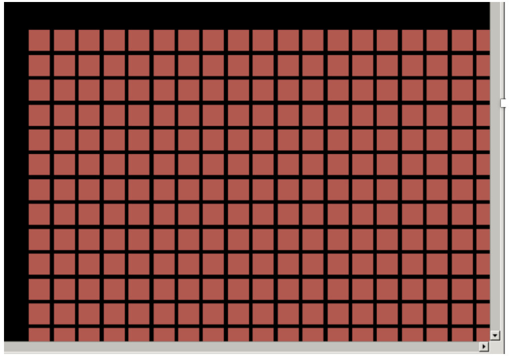
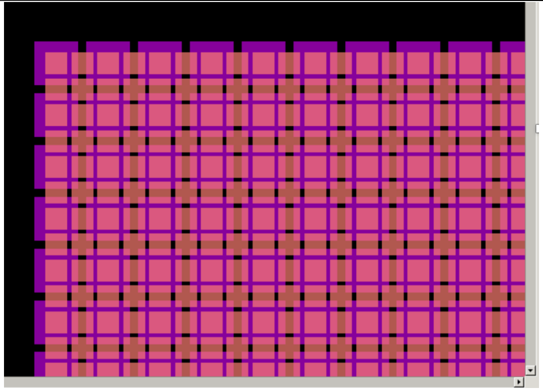
- Cylinder inside the ToF, segmented in three longitudinal sectors
- Barrel inside the DIRC: same DIRC segmentation in planar tiles, divided into two longitudinal sectors

re-inforced role of MPGD

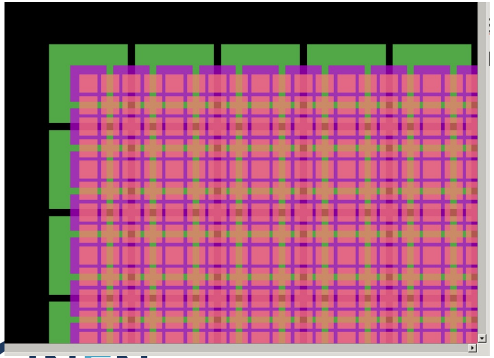
- 46 x 40 cm^2 2 D detectors with 3 layers of capacitive sharing
  300 μm strip 1200 μm $pitch$



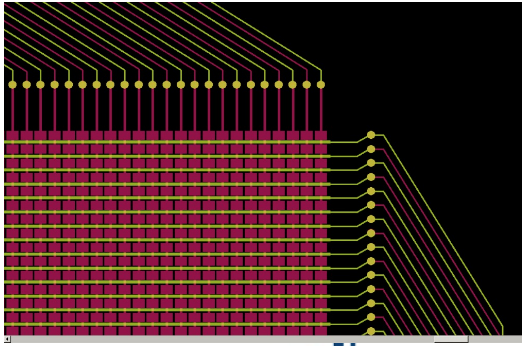
1st-layer



2nd-layer



3rd-layer



2D-read-out

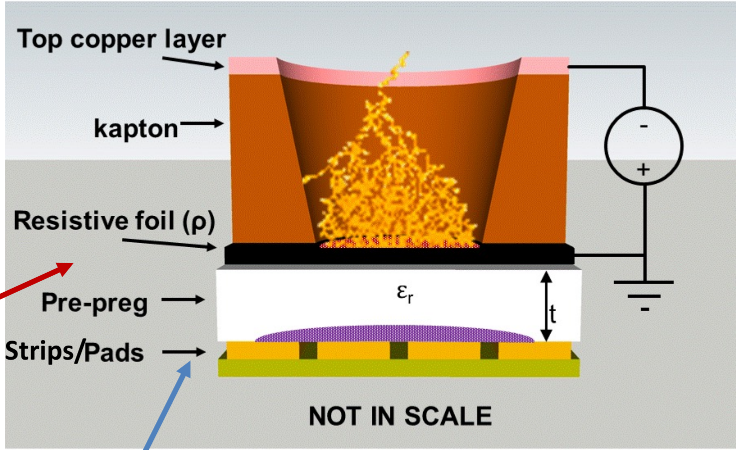
The µ-RWELL principle of operation

The “WELL” acts as a multiplication channel for the ionization produced in the gas of the drift gap

The charge induced on the resistive layer is spread with a time constant,

$$\tau \sim \rho \times C$$

[M.S. Dixit et al., NIMA 566 (2006) 281]:



$\rho \rightarrow$ the DLC surface resistivity

$C \rightarrow$ the capacitance per unit area, depending on the distance between the DLC and the readout plane

$$C = \varepsilon_0 \times \varepsilon_r \times \frac{S}{t} = 70\, pF \times L(m) - w{=}0.2\, mm, \quad p{=}0.4\, mm$$

- The resistive stage ensures the quenching of the spark amplitude
- As a *drawback,* the capability to stand high particle fluxes is reduced, but appropriate grounding schemes of the resistive layer solves this problem