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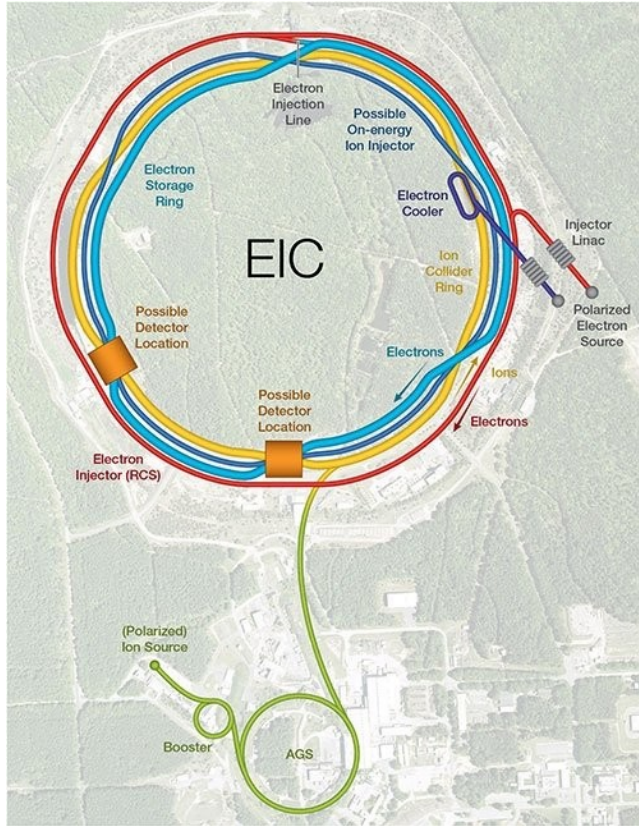
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CyMBal: Micromegas for EIC

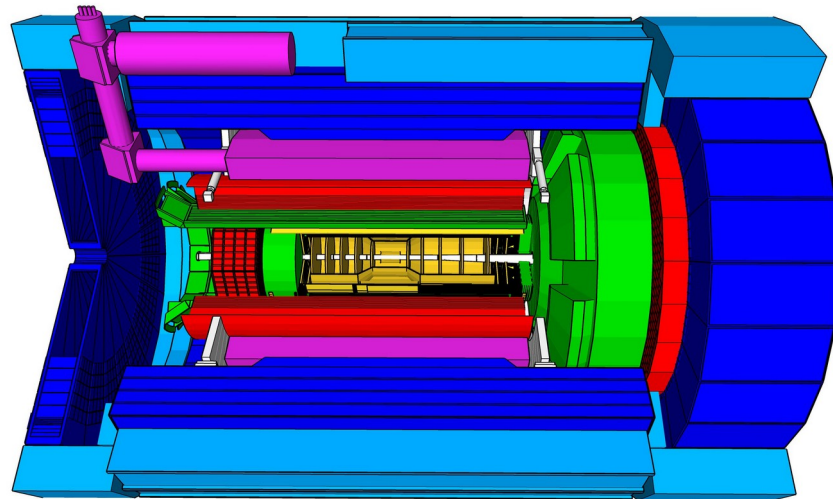


S. Polcher Rafael,
F. Bossù, A. Bonenfant, M. Boonekamp, A.
Francisco, C. Goblin, C. Libourel, V.
Maâch, I. Mandjavidze, M.
Vandenbroucke, D. Neff

The future Electron Ion Collider



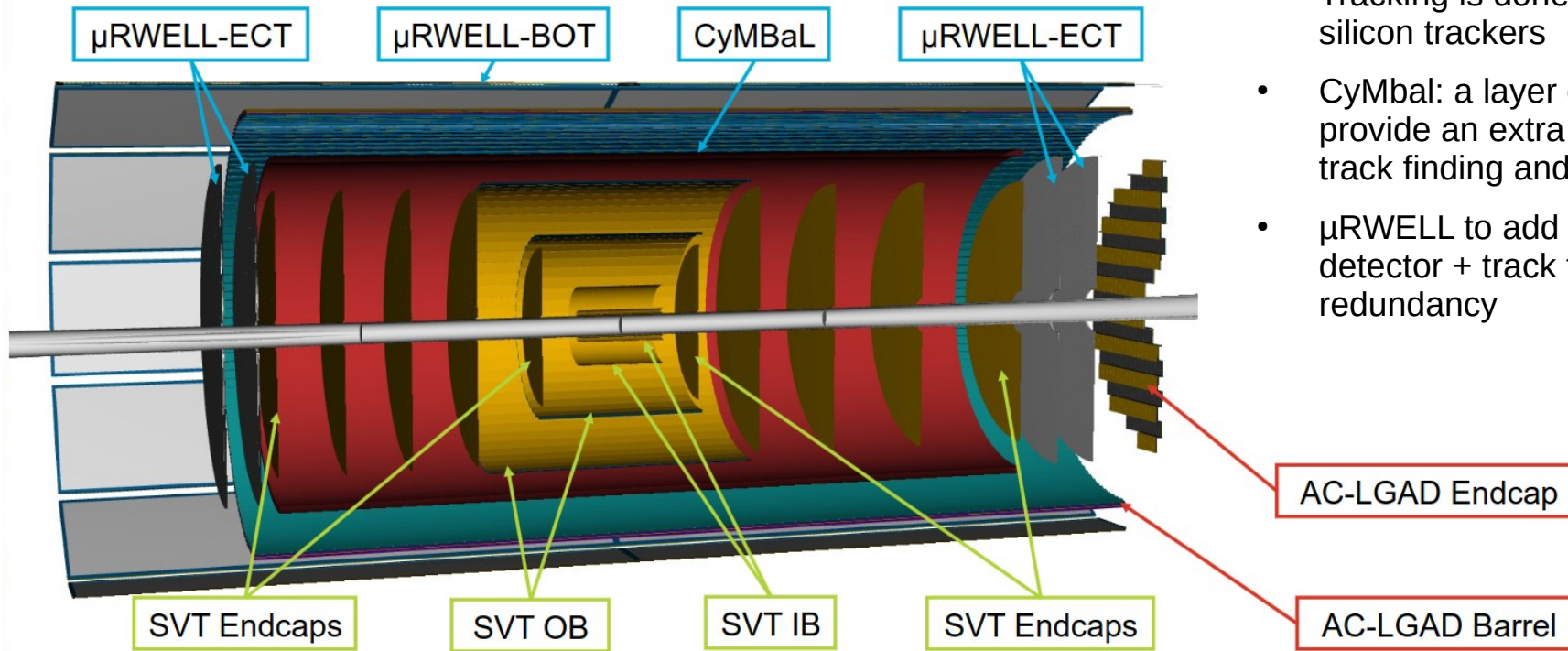
- Electron ion collider: Future collider in Brookhaven, NY, USA built on the basis of the current RHIC facility. First beam expected ~2033
- High luminosity $\sim 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$, e+p center of mass energy 20-140 GeV
- High polarization of electron and proton/ion beams $\sim 70\%$
- ePIC will be the first experiment at EIC, the goal is to study how quarks and gluons behave in, interact with, and form hadronic states



ePIC detector diagram, E. Aschenauer



Tracking at ePIC

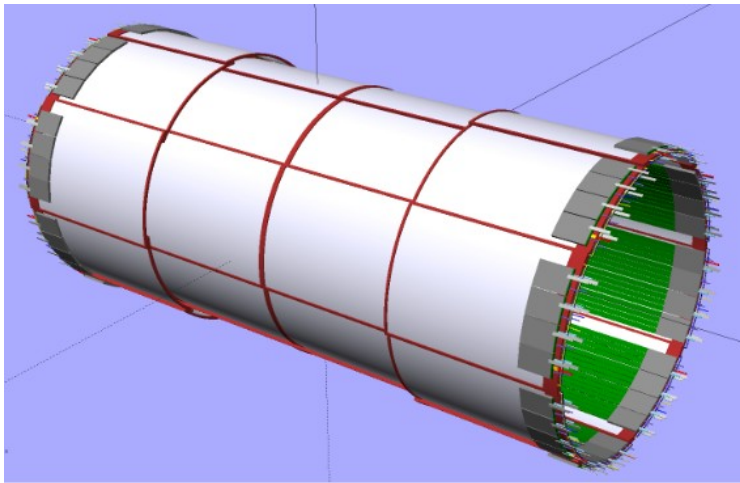


- Tracking is done by multiple layer of silicon trackers
- CyMbal: a layer of Micromegas to provide an extra tracking point for track finding and redundancy
- μRWELL to add a hit near PID detector + track finding and redundancy

ePIC tracking diagram, B. Eng TDR talk

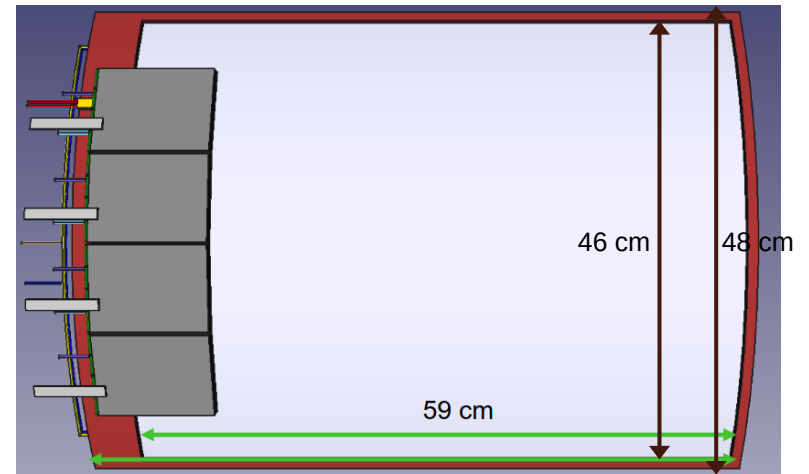
CyMBaL

- Low material budget: $0.5\%X_0$ in the active area
- Spatial resolution of $\sim 150\mu\text{m}$
- Timing resolution $\sim 10\text{ns}$
- Needs to fit in a tight space, $\sim 5\text{cm}$ wide
- Inside a $\sim 2\text{T}$ magnet



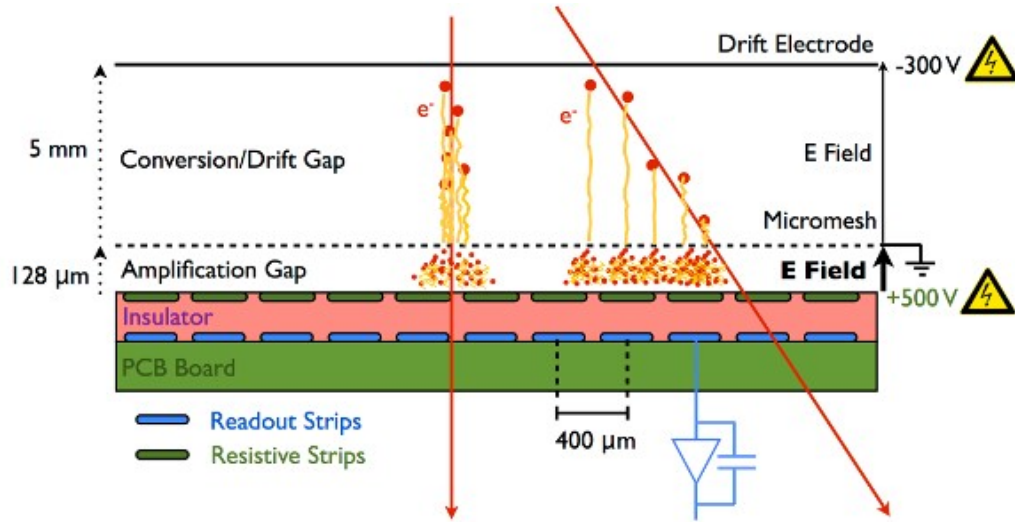
CyMBaL diagram, F. Bossù

- Cylindrical Micromegas tiles based on the CLAS12 BMT
- They already work in a high magnetic field with a higher rate than expected in ePIC
- Update CLAS12 design to have a 2D readout on one tile \rightarrow Current R&D work



Single tile, F. Bossù

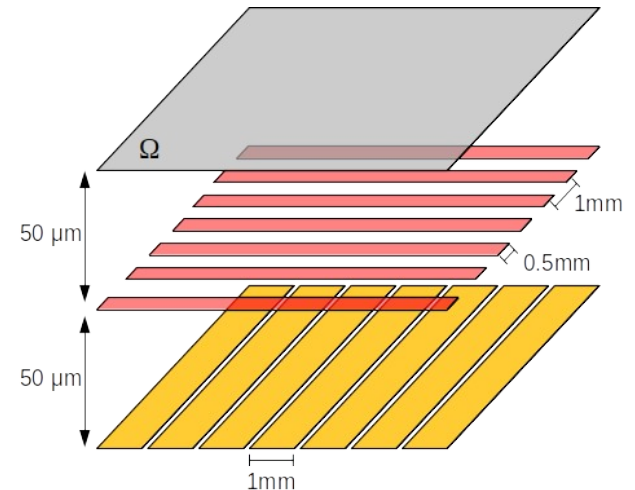
Micromegas trackers



Acker, A. et al. The CLAS12 Micromegas Vertex Tracker. Nucl. Instrum. Methods (2020).

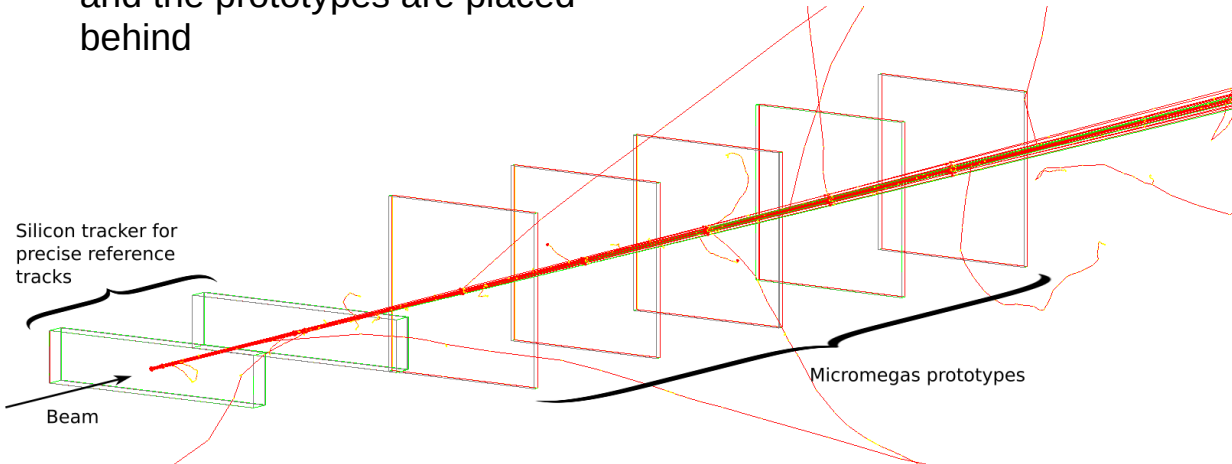
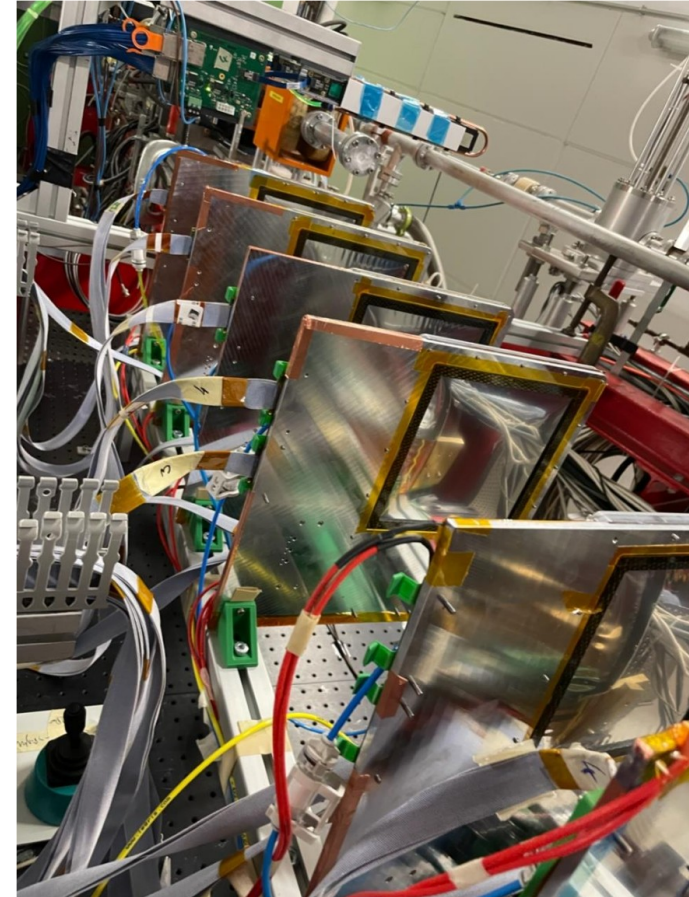
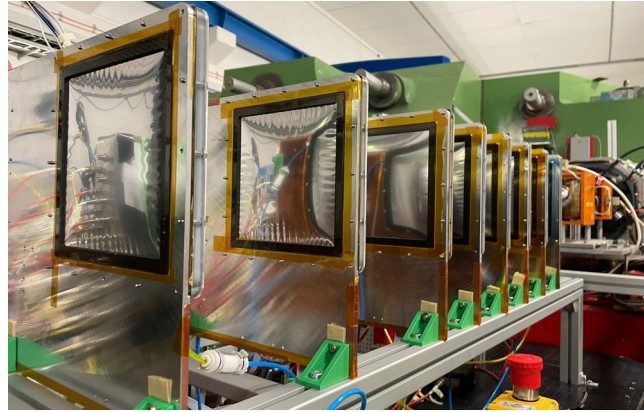
- To meet ePIC's needs: 2D trackers with low material budget and strip readout to limit the number of readout channels
 - Resistive layer above the readout.
 - Signal is induced on the resistive and read by strips in both directions through capacitive coupling.

- A low field region where crossing particles ionize the gas. The electrons created are guided to the mesh.
- High field region below the mesh for amplification.
- The signal is induced on readout strip or pads at the bottom.



Beam test at MAMI

- In June 2023, beam test on a 880MeV electron beam at MAMI in Mainz
- We tested prototypes build at CEA's MPGD Lab
- Different variations of readout patterns and resistive patterns
- Setup: reference silicon tracker and the prototypes are placed behind



Banco reference tracker

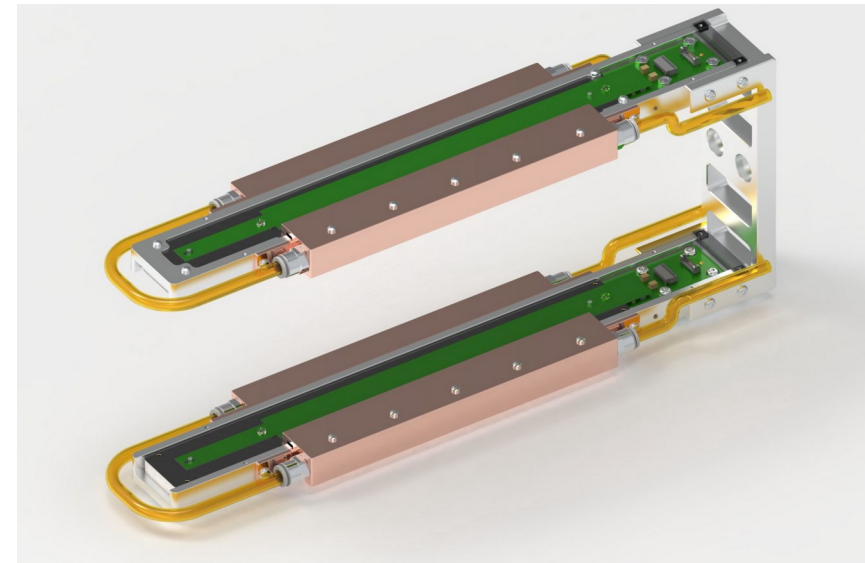
- The Banco tracker is made from ALPIDE silicon chips developed for the ALICE experiment
- The chips are made of $29.24 \times 26.88 \mu\text{m}^2$ pixels, we use ladders of 5 chips for an active area of $15 \times 1.5 \text{cm}^2$
- Banco has two arms each made of 2 ladders and a water cooling system to keep the temperature of the sensor steady



Alice MFT 4 chip ladder, <https://cds.cern.ch/record/2748315>



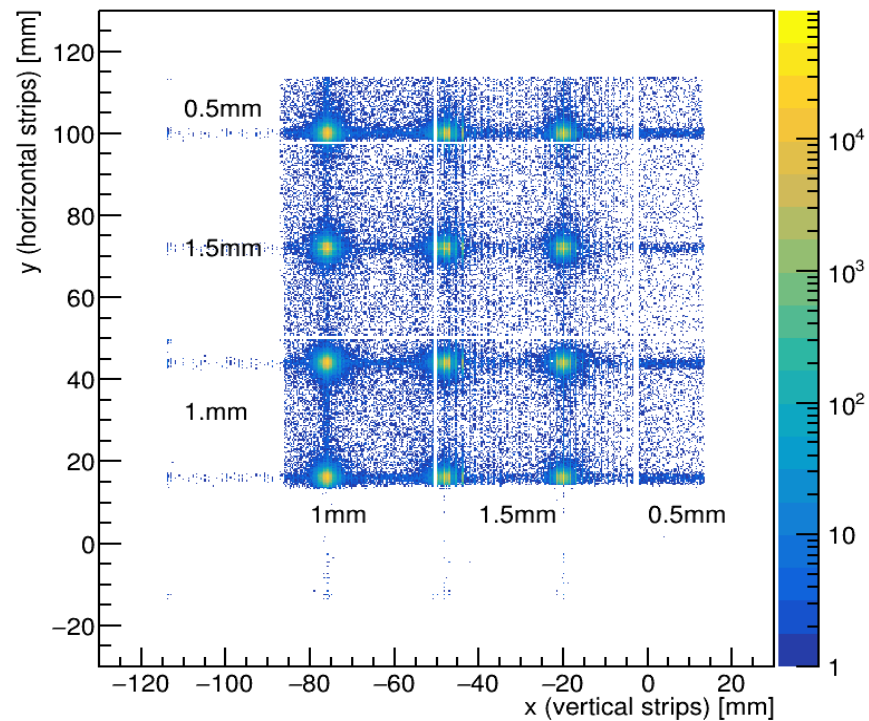
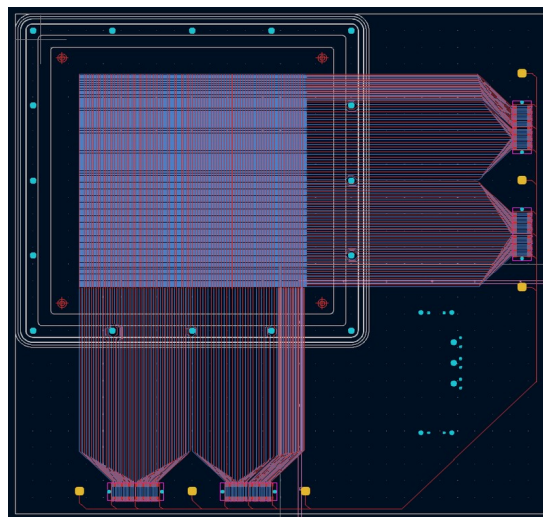
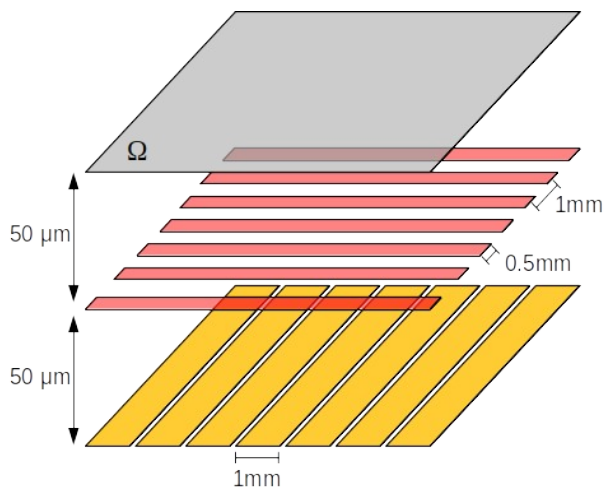
Diagram of one banco arm, V. Maâch



Full banco tracker, V. Maâch

D1 & D2 prototypes

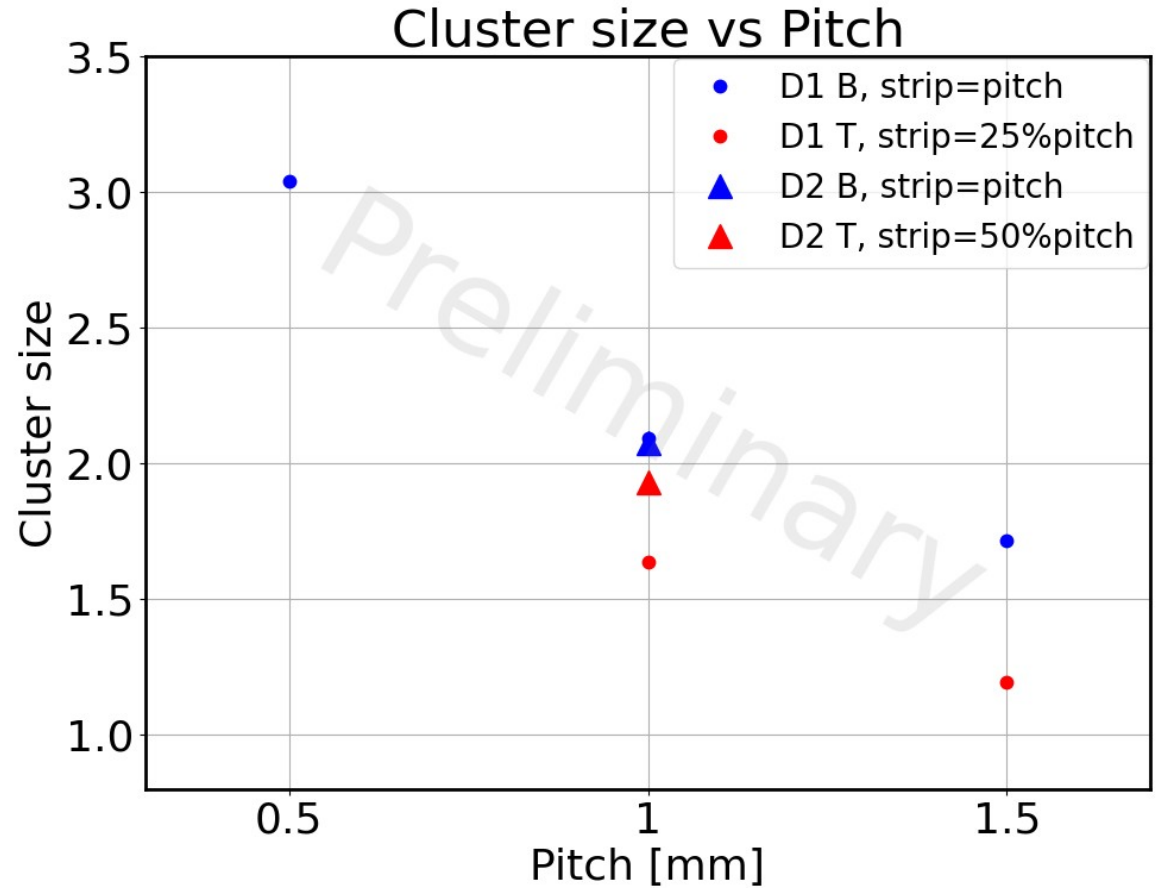
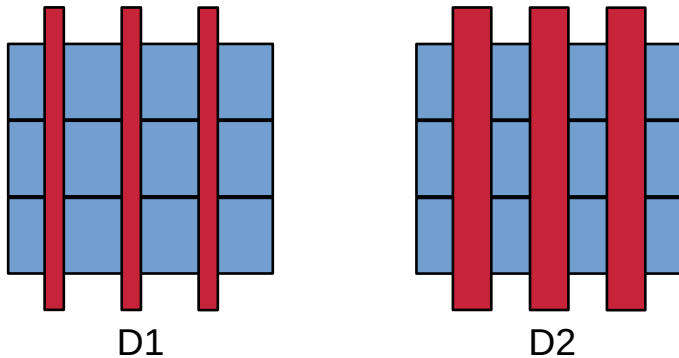
- Prototypes with an active area of 10x10cm²
- X and Y strips on two different layers
- D1 has multiple strip pitches on the same detector
- D2 has multiple inter-pitch
- High resistivity $\sim 10 \text{ M}\Omega/\square$



We took runs moving the detector to hit the different regions

D1 & D2 cluster size

- Cluster size: number of strips fired per event and per layer
- Smaller pitch \rightarrow larger cluster size
- Strips on top with large inter-strip have a significantly smaller cluster size
- Increasing the the width of the top layer strips reduces the difference between the two layers

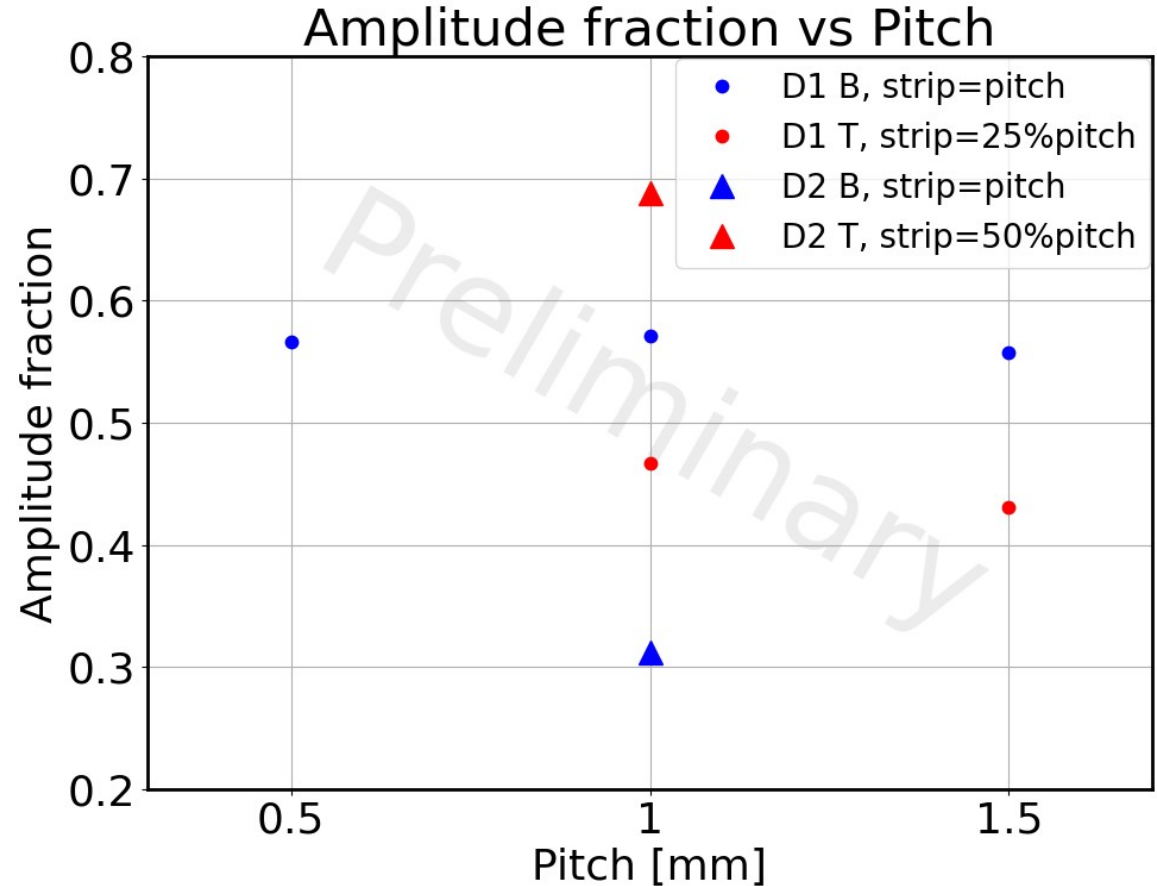


D1 & D2 amplitude fraction

- The signal amplitude is proportional to the charge collected
- Amplitude fraction: fraction of the total event amplitude carried by one layer

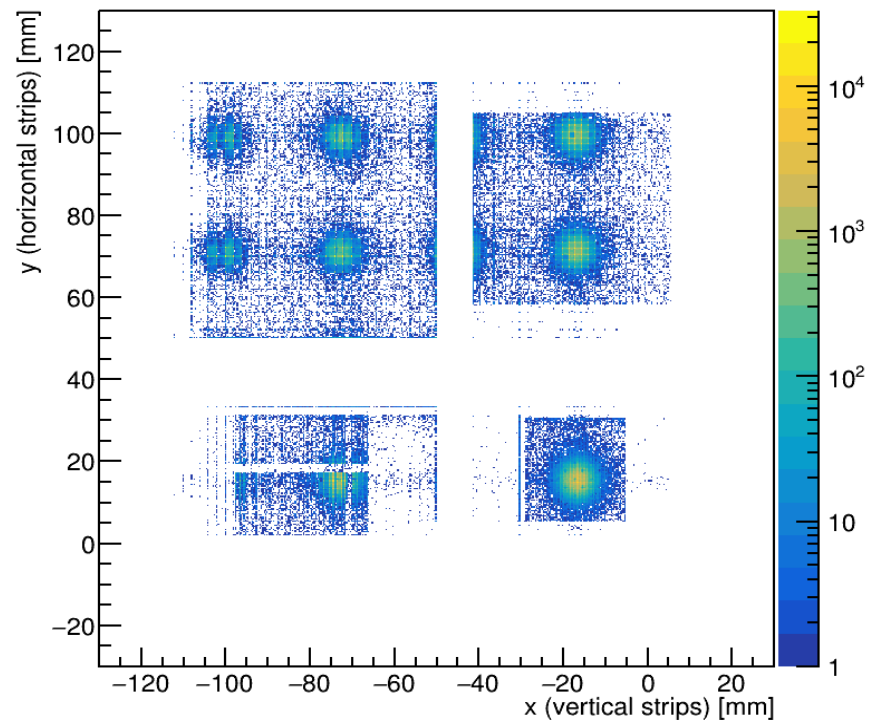
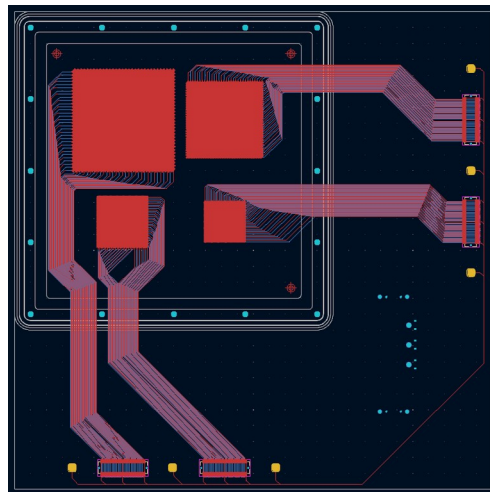
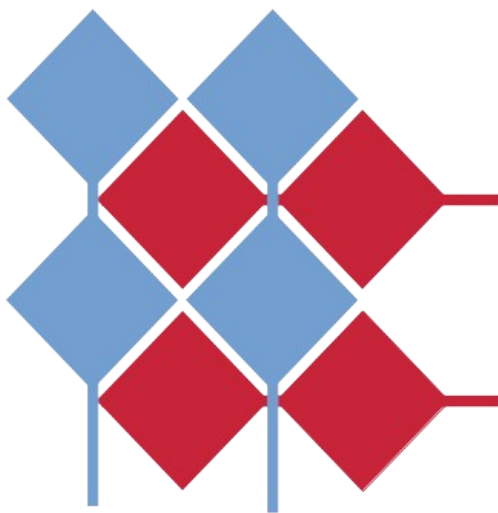
$$\text{AmplitudeFraction} = \frac{\sum_{\text{layerstrips}} \text{maxAmp}}{\sum_{\text{allstrips}} \text{maxAmp}}$$

- Strips on the bottom are further away from the resistive layer so they collect less charges and are screened by the top layer
- D1 the top strips are not wide enough, D2 they are too wide



D3 & D4 prototypes

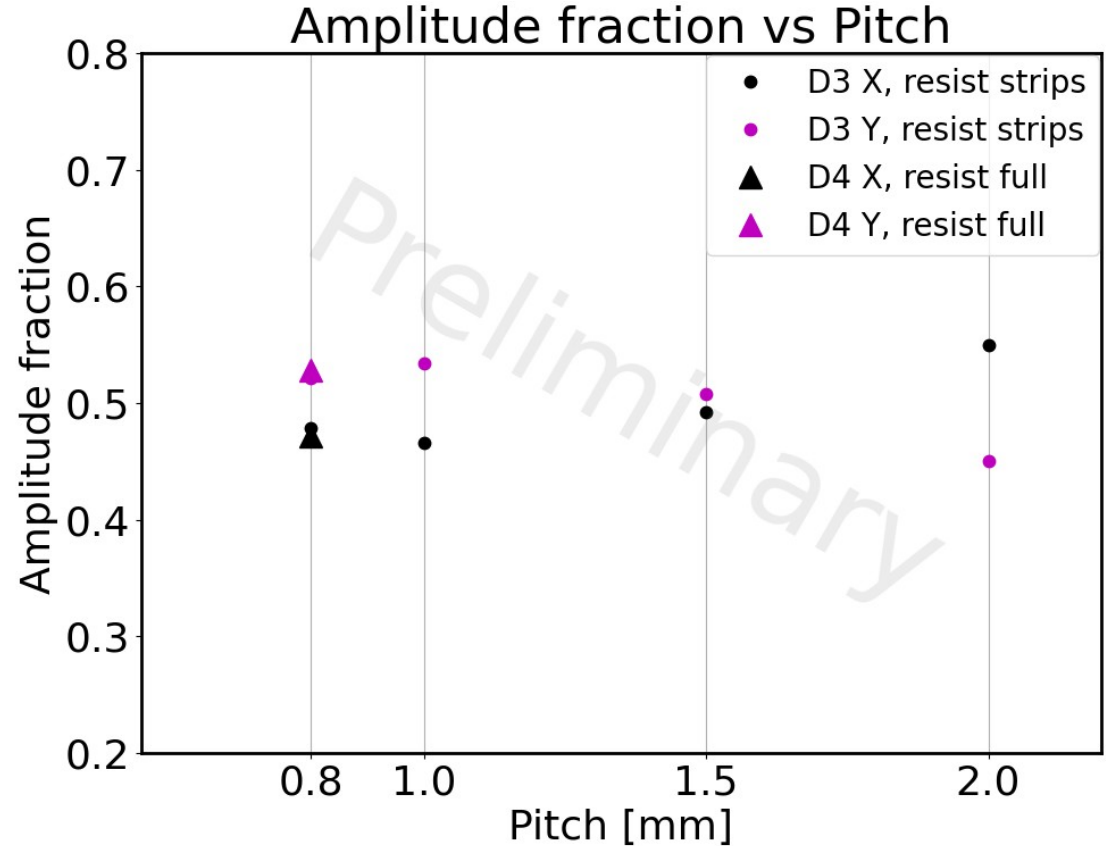
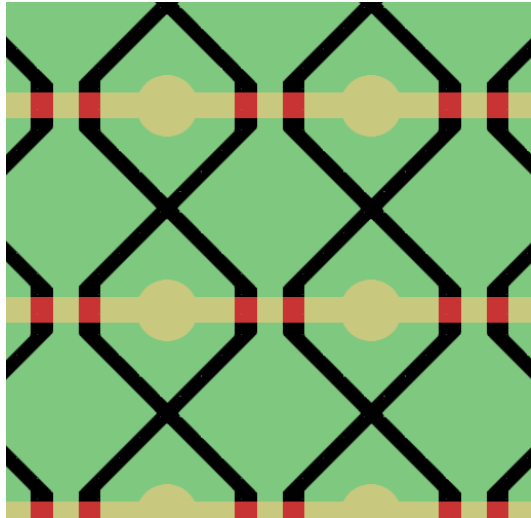
- Prototypes with an active area of 13x13cm with 3 different pitches
- Strips made of interconnected square pads. X and Y on the same plane
- Low resistivity $\sim 300 \text{ k}\Omega/\square$



We took runs moving the detector to hit the different regions

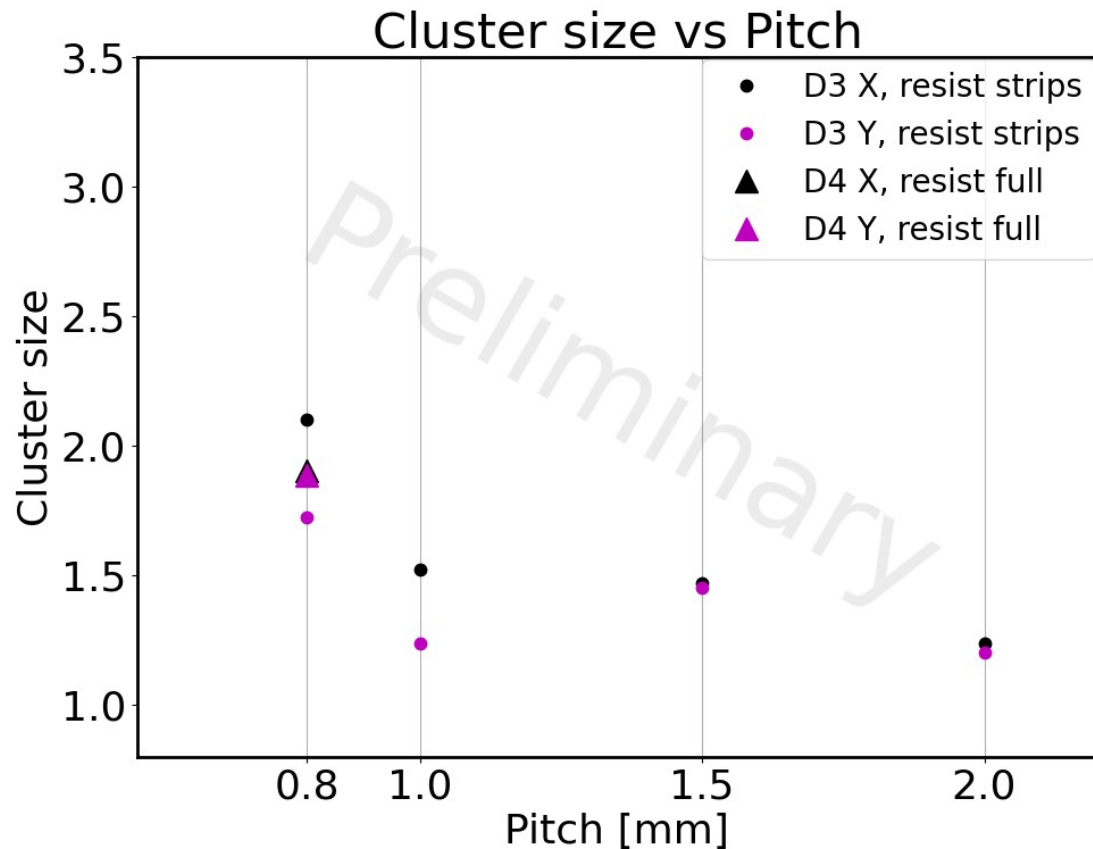
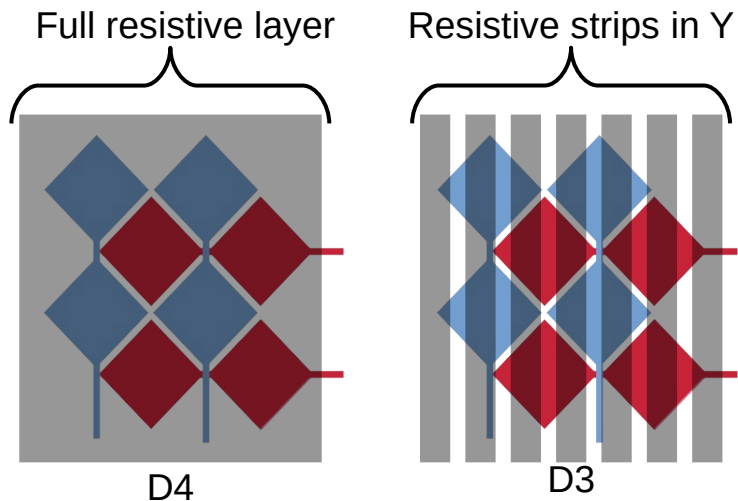
D3 & D4 amplitude fraction

- The charge collection on X and Y strips is even
- There is a bit more charge collected on the Y strips because they cover a larger surface

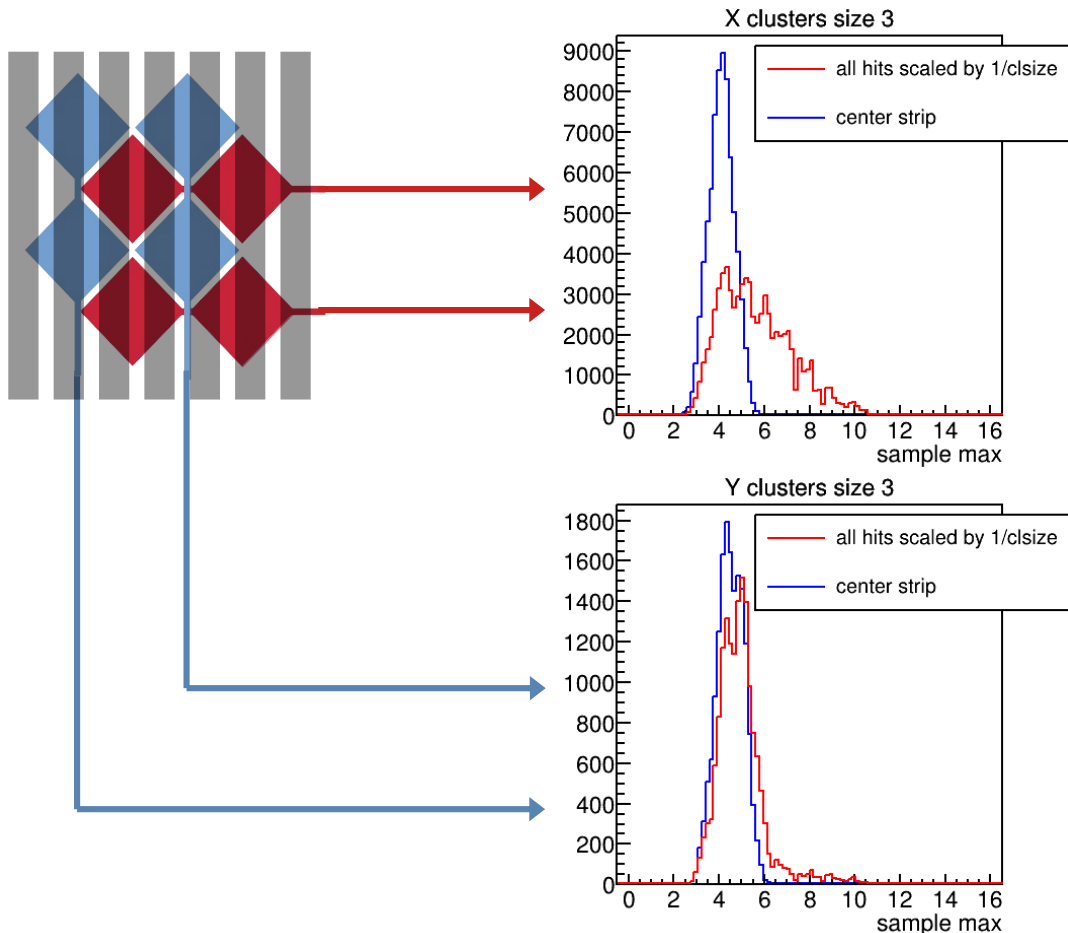


D3 & D4 cluster size

- Only the smallest pitch can provide the sufficient cluster size of ~ 2
- D3, the cluster size is larger in X where the charges can spread along the resistive strips



D3, closer look at charge spreading



Time of arrival of the signal:

- On the strip in the center of the cluster
- On all other strips in the cluster

Strips orthogonal to the resistive strips
→ charge spreading.

Strips in the direction of the resistive strip
→ no charge spreading.

Multiple scattering influence

Residues: difference between the position of the reference track and the position measured on the prototype

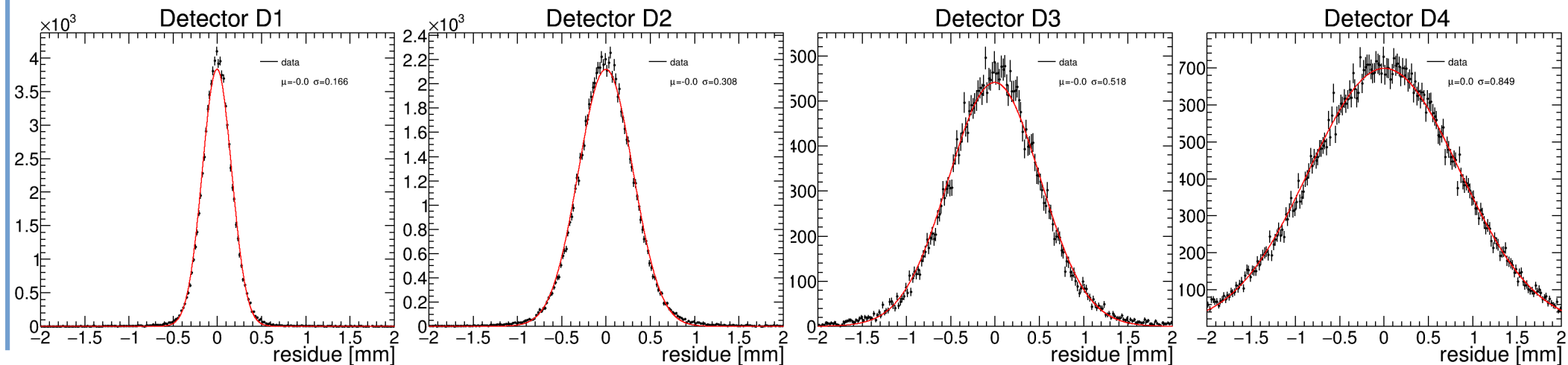
Banco
0mm

305mm

425mm

545mm

785mm



Residues: 166 μ m

308 μ m

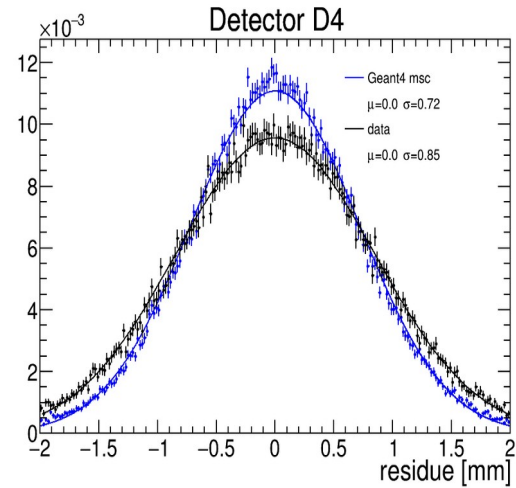
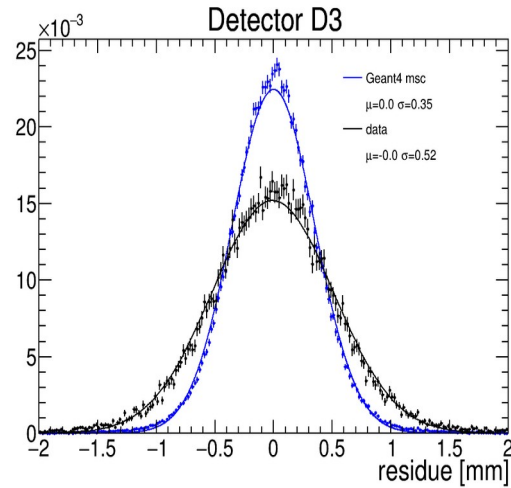
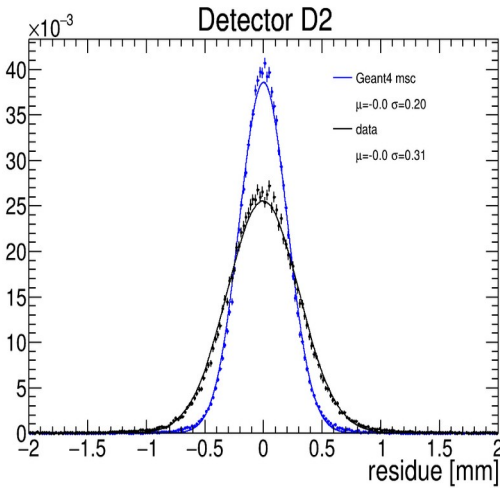
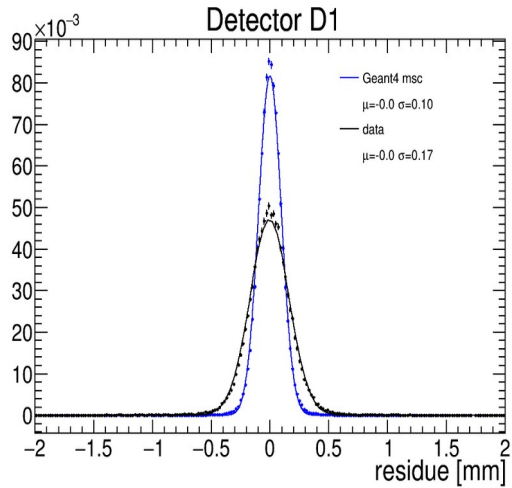
520 μ m

850 μ m

Large multiple scattering contribution

Geant4 simulation

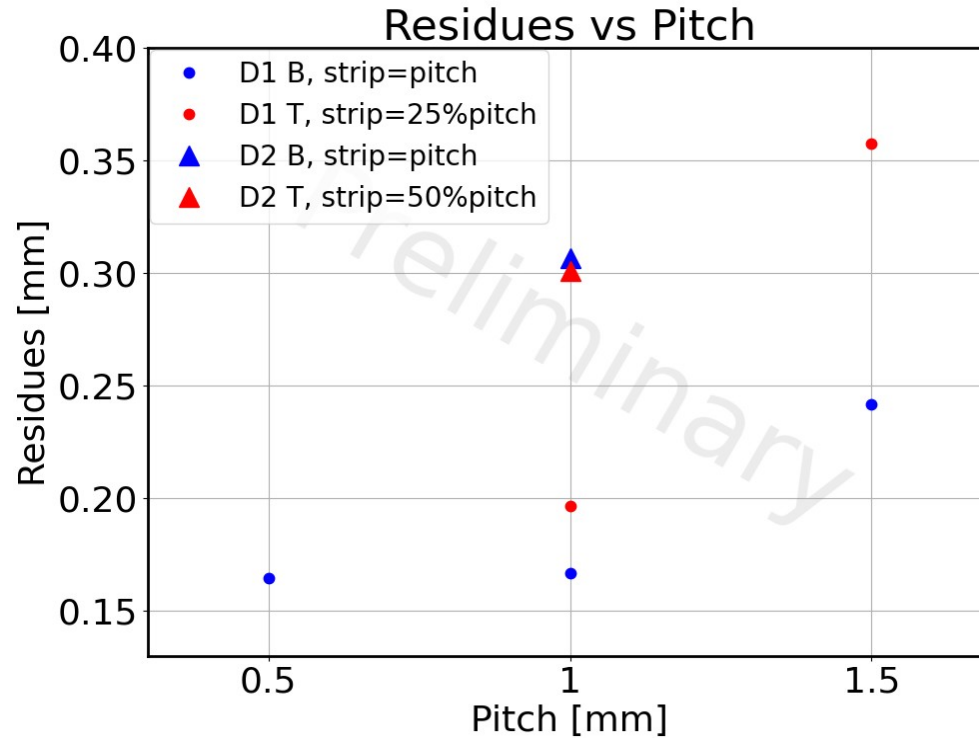
- Beam test geometry and beam implemented in Geant4
- Output: position of the electrons on each banco ladder and on each prototype
- Contribution of MSC estimated with the distribution of residues reconstructed track – exact position on the prototypes



Residues

- Strips with 1mm or smaller provide a good resolution for the needs of ePIC

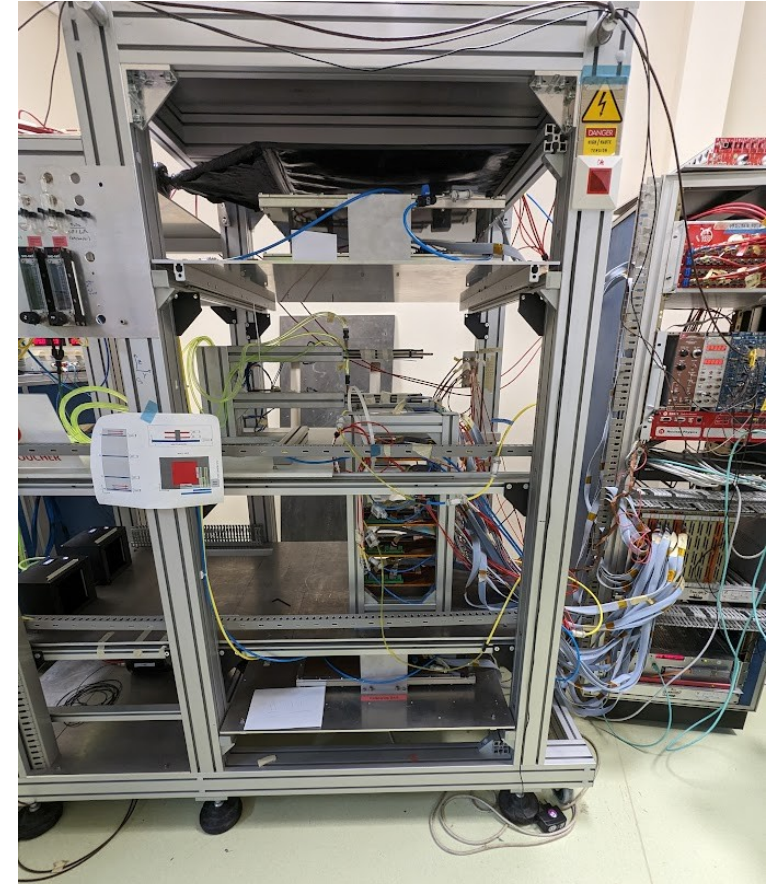
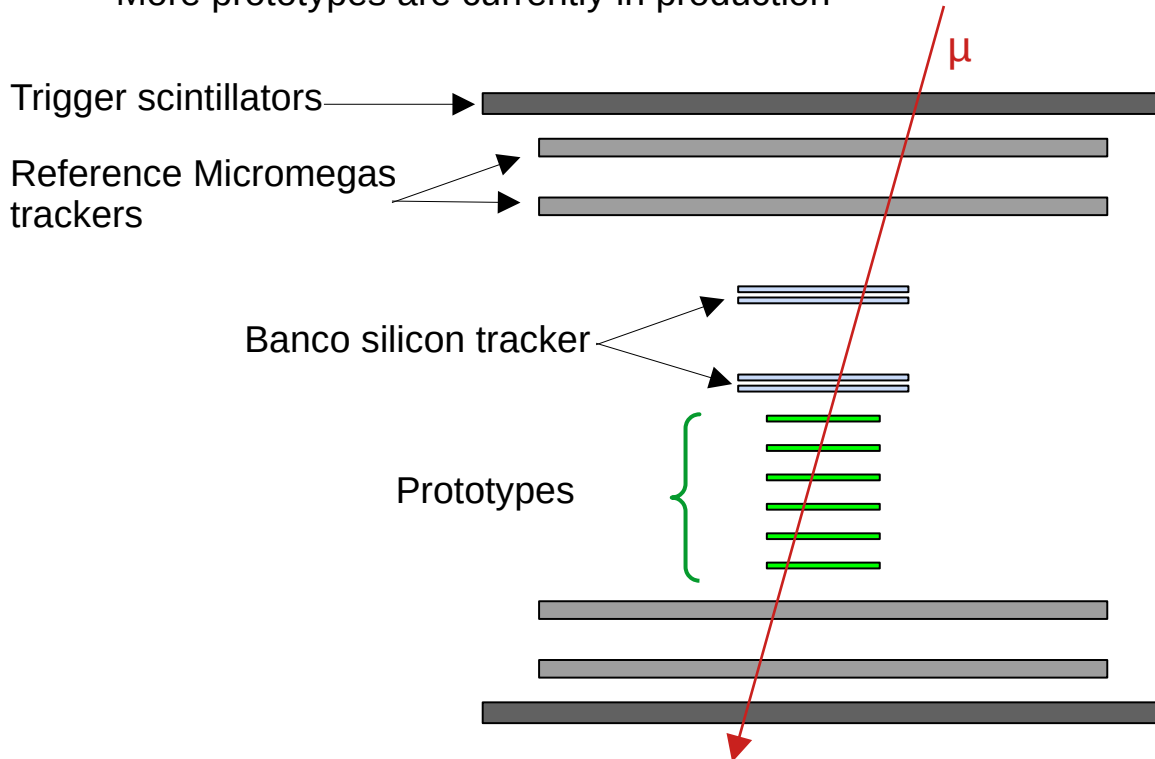
Detector	G4 msc [μm]
D1	96
D2	205



Cosmic test bench @ CEA Saclay

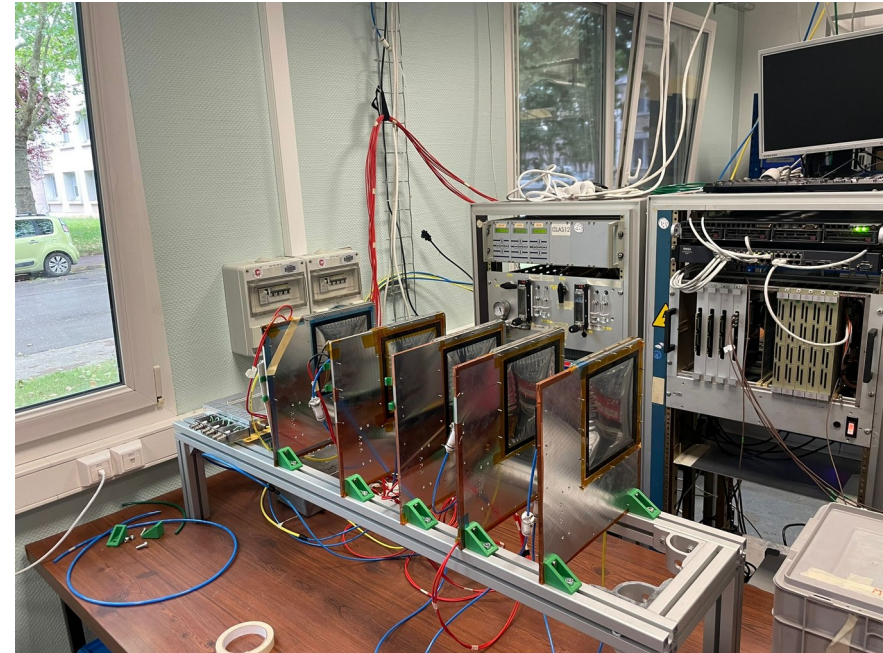
D. Neff

- A cosmic test bench is setup at the lab to perform further tests
- More prototypes are currently in production



Outlook

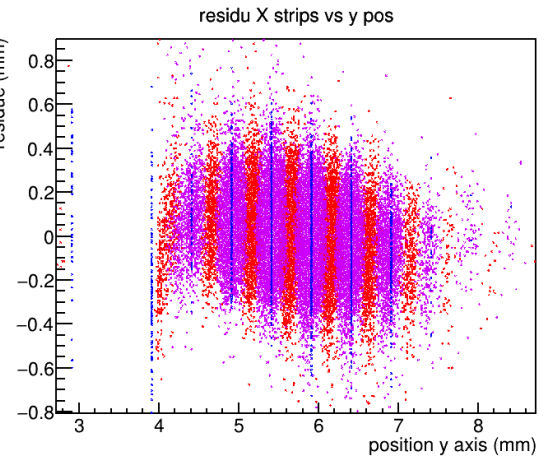
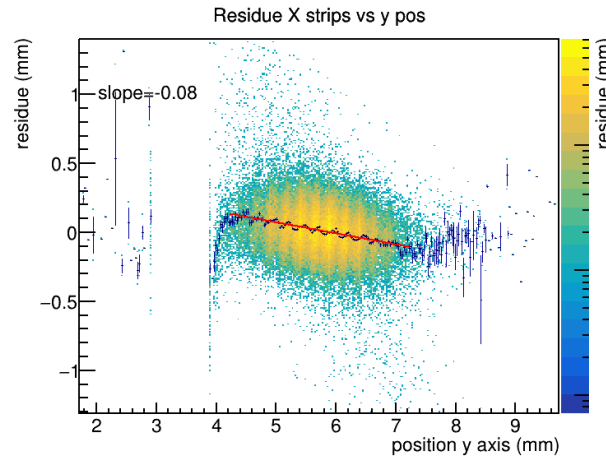
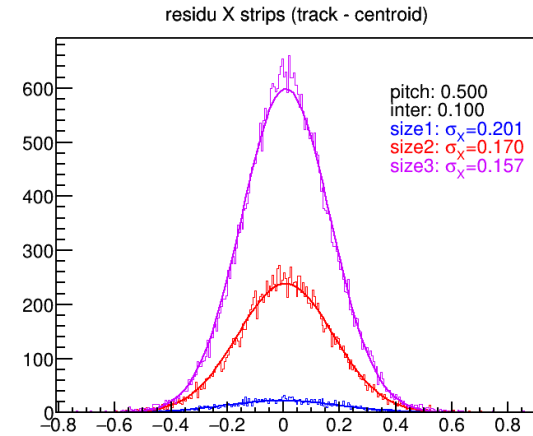
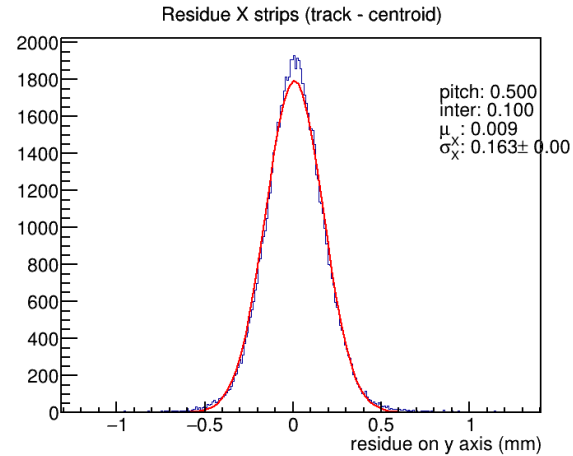
- D1 with 1mm strips or smaller is a good starting point to meet ePIC requirements. But the strip to inter-strip ratio needs to be adjusted.
- More data taking with muons to avoid MSC and to complete testing is ongoing at DEDIP.
- More prototypes are in construction to test more resistive layer designs.
- A second beam test is being prepared for Fall 2024.



Backup slides

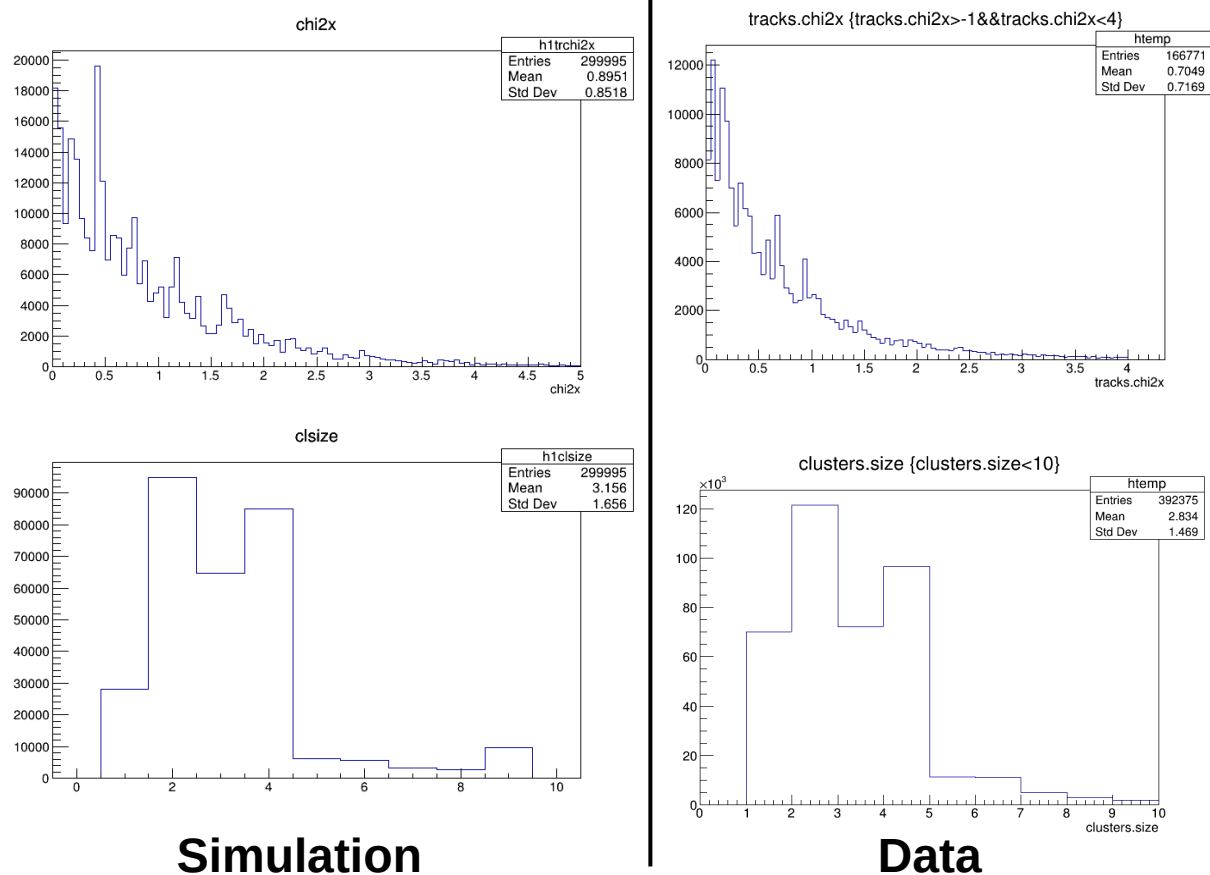
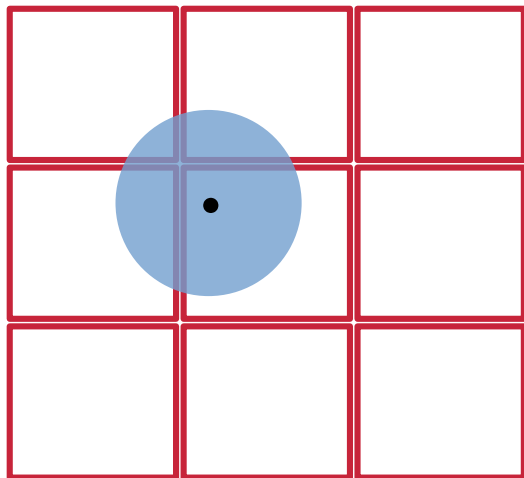
D1, a detailed look at residues

- Looking at the distribution of residues as a function of the position on the prototype structures appear
- They are due to events of different cluster sizes

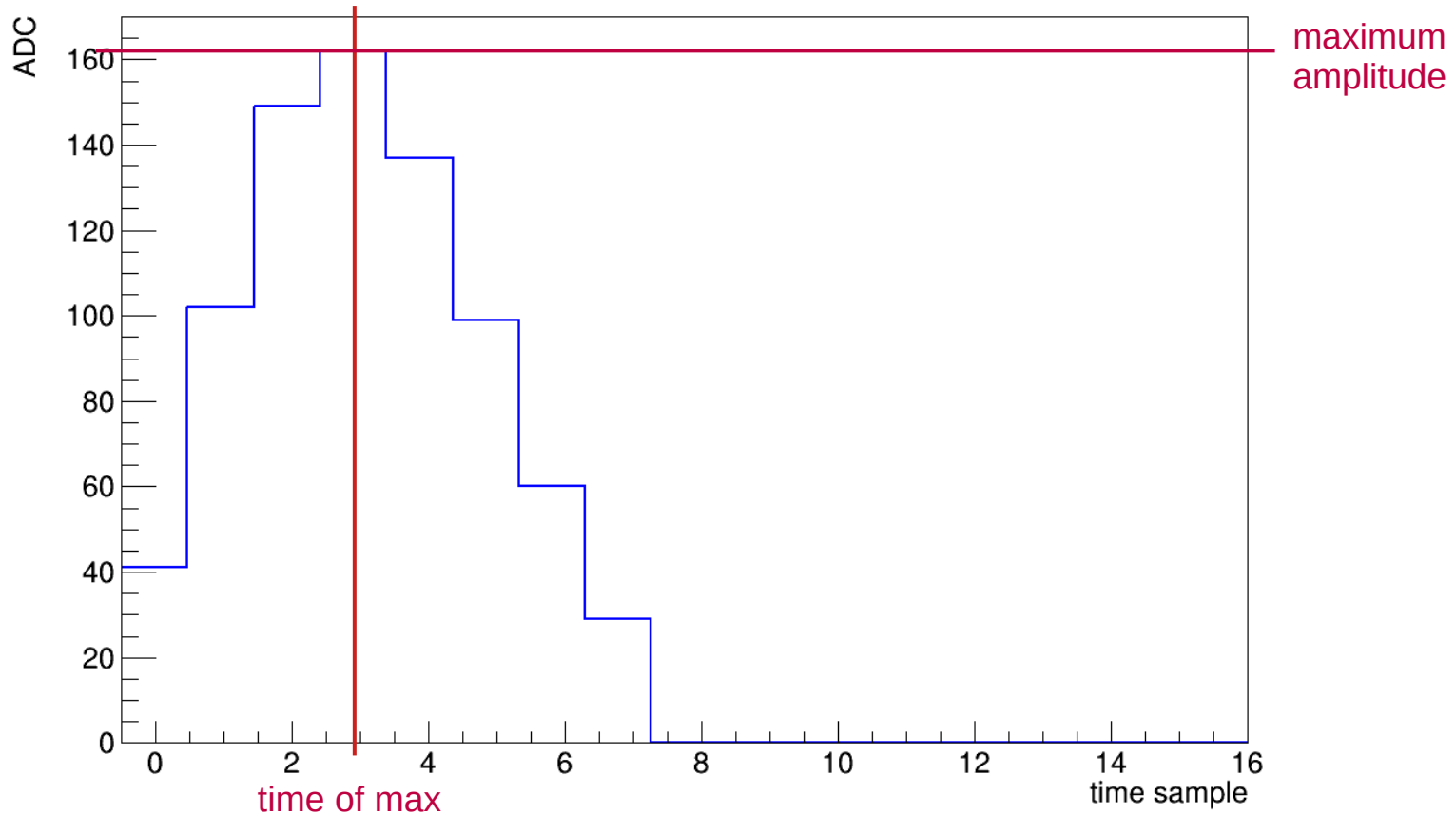


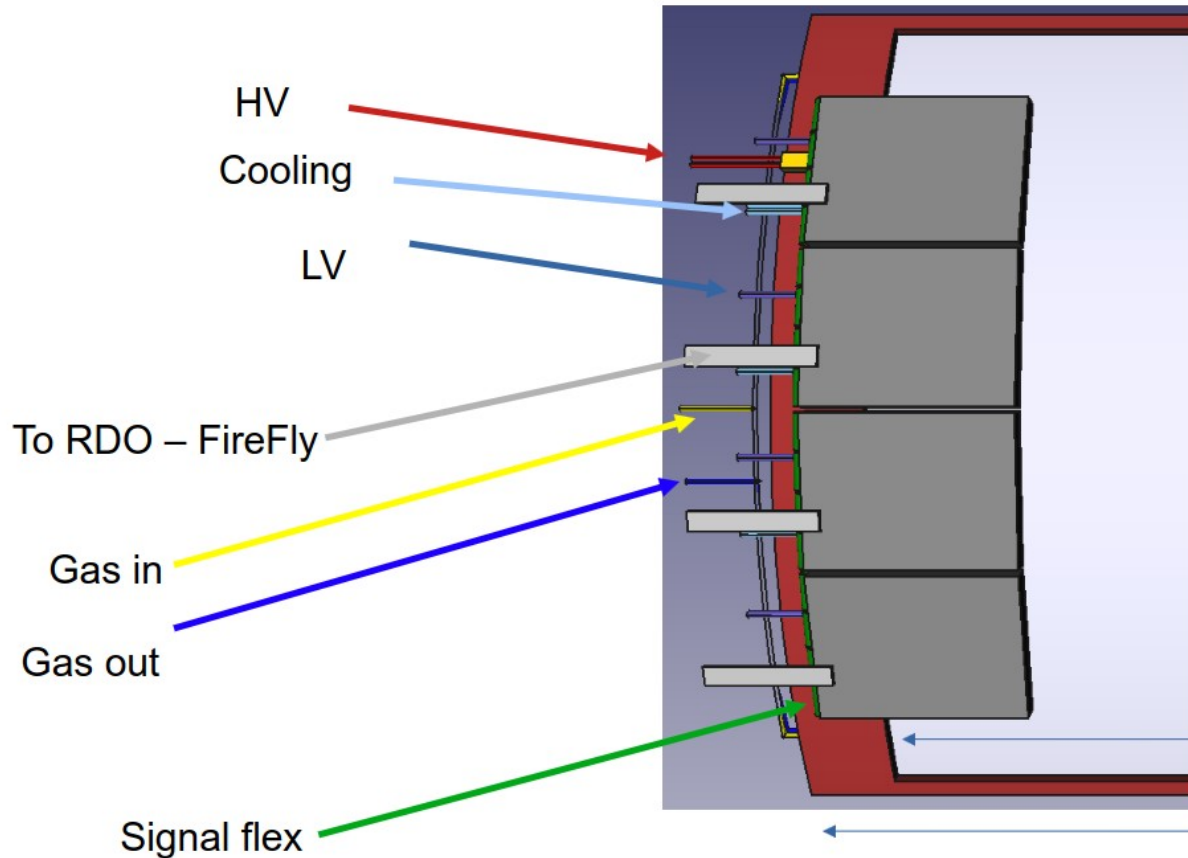
Banco model

- To make build a more realistic track, for each banco ladder we define a circle of radius $cste \cdot Edep$ centered on the real track position
- If the circle overlaps a pixel, the pixel is fired and added to the cluster
- To have size 3 clusters, extra condition on corner pixels. The signal must reach more than $2\mu m$ inside the pixel.



Typical Micromegas waveform



**Dimensions:**

- Size: 65 x 46 cm²
- Active area: 59x44 cm²
- r/o strips: ~1 mm pitch in both directions
- Readout strips per module: 1024
- 32 channels per connector → 32 connectors

Services:

- HV: 2 channels (drift and resistive layer)
- Gas: 2 tubes (in and out)
 - Two tiles can be in series
- 4 FEBs per module
- 4 ASICs per FEB:
 - 4-lines bidirectional optical fiber FireFly to RDO
 - 2 short flex cables per ASIC
 - Low voltage
 - Cooling in and out, possibly in series

CyMBaL needs already taken into account in ePIC general service plans