CyMBal: Micromegas for EIC

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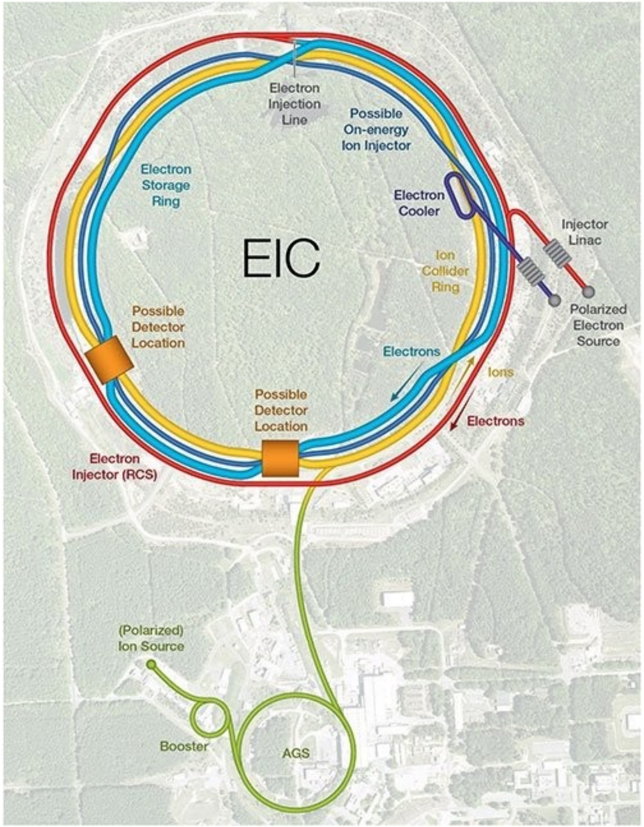
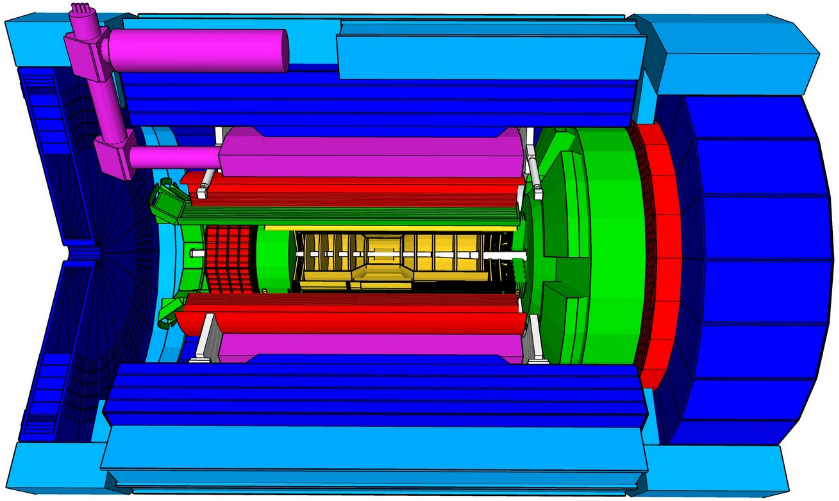
The future Electron Ion Collider

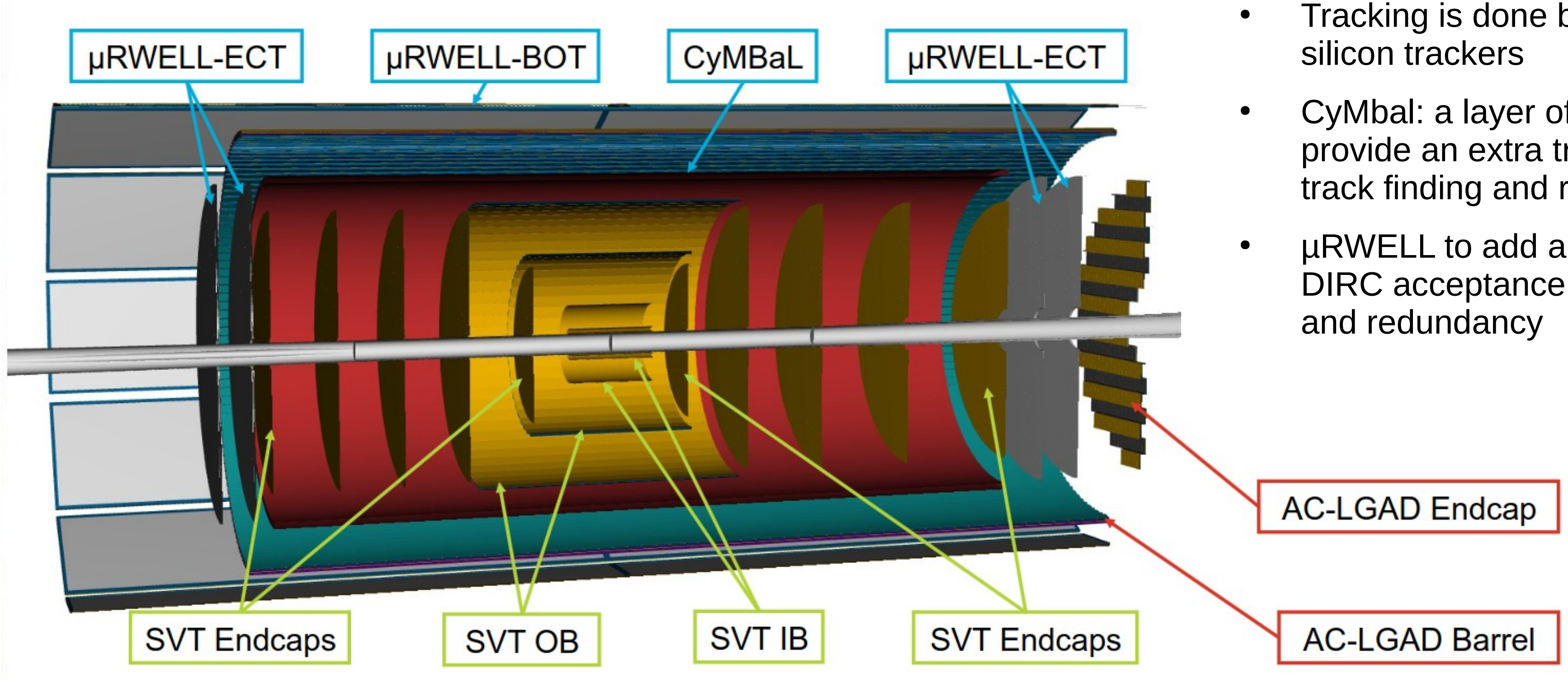


- Electron ion collider: Future collider in Brookhaven, NY, USA built on the basis of the current RHIC facility. First beam expected ~2033
- High luminosity ~10^{33} cm^{-2} s^{-1}, e+p center of mass energy 20-100 GeV
- High polarization of electron and proton/ion beams ~70%
- ePIC will be the first 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



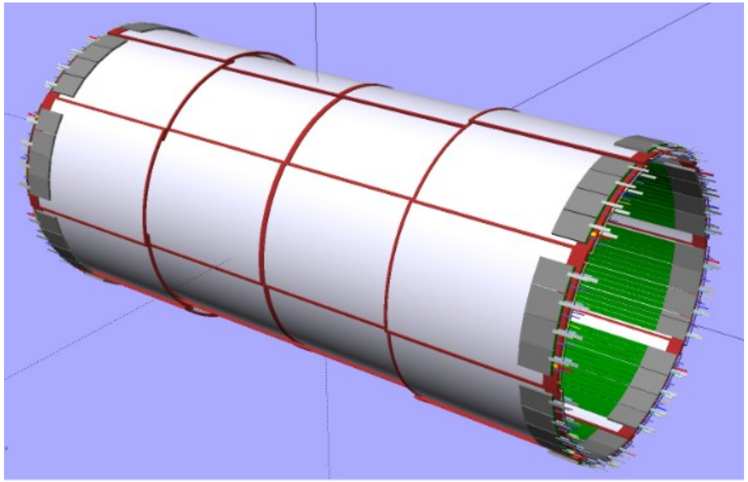
ePIC tracking diagram, B. Eng TDR talk

- 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 matching the DIRC acceptance + track finding and redundancy

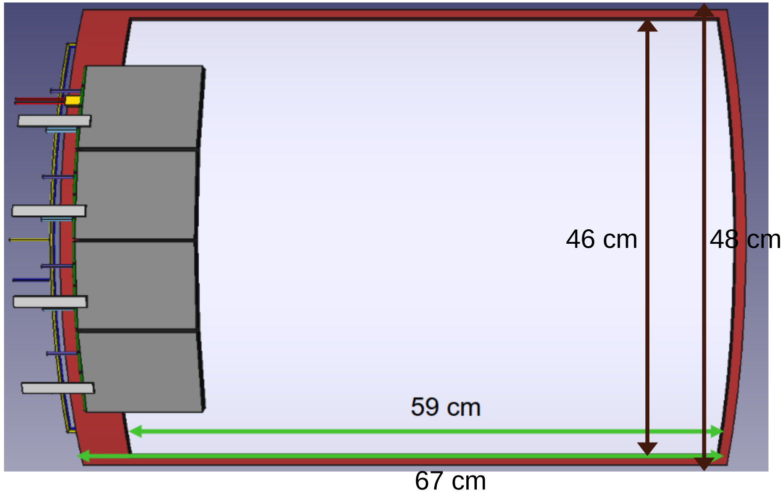
CyMBaL

- Low material budget: 0.5%X_0 in the active area
- Spatial resolution of ~150µm
- Timing resolution ~10ns
- Needs to fit in a tight space, ~5cm wide
- Inside a ~2T magnet

- 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 → Current R&D work

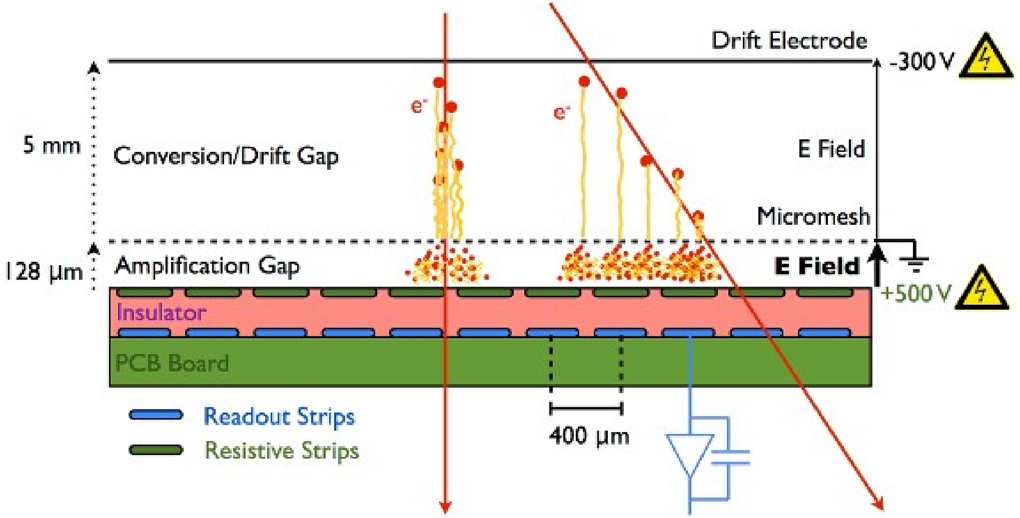


CyMBaL diagram, F. Bossù



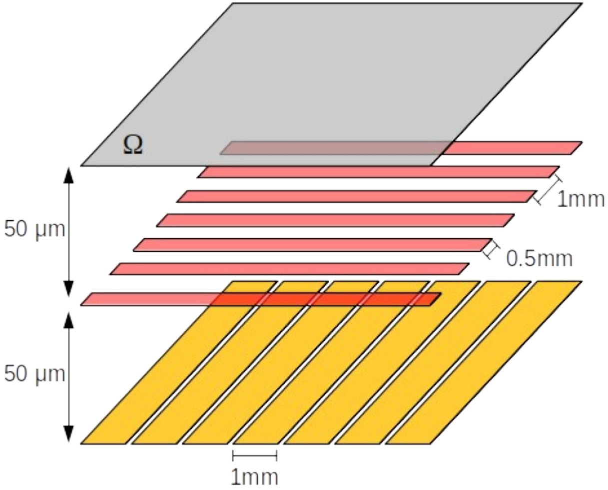
Single tile, F. Bossù

Micromegas trackers



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

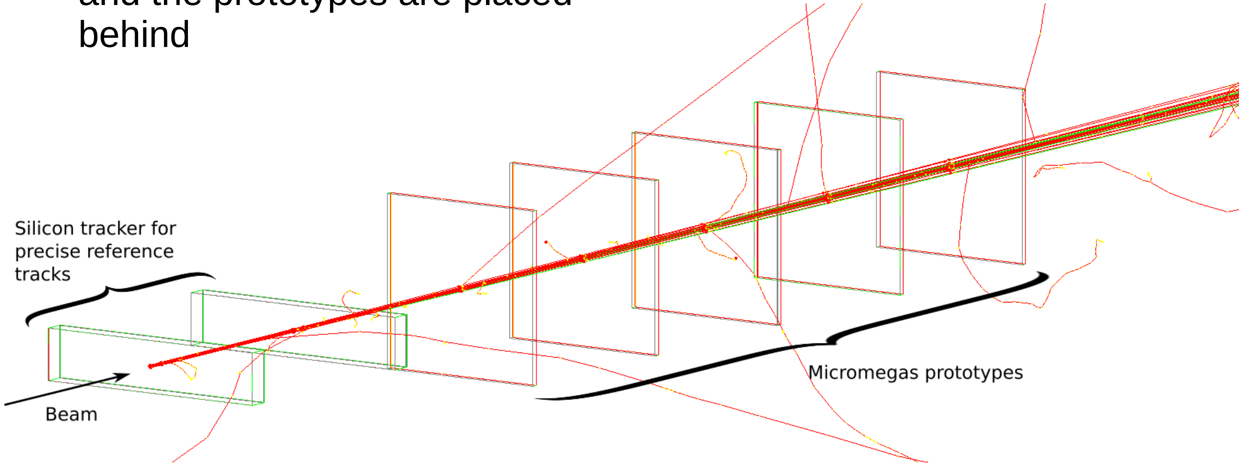
- A low field region where crossing particles ionize the gas. The electrons created are guided to the mesh.
- High field region below the mesh for amplification.
- The signal is induced on readout strip or pads at the bottom.

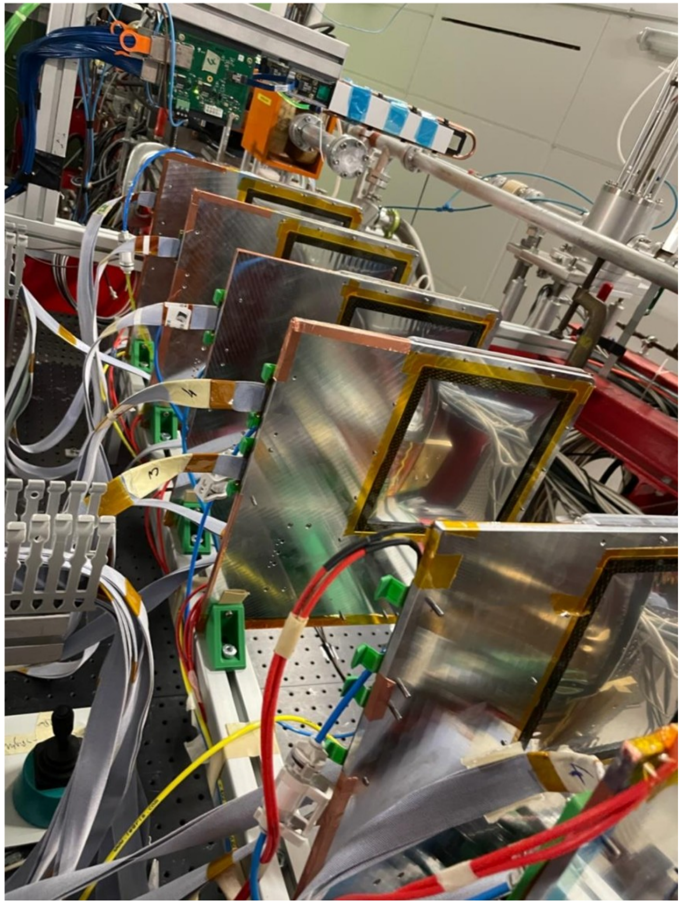


- To meet ePIC's needs: 2D trackers with low material budget and strip readout to limit the number of readout channels
  - Resistive layer above the readout.
  - Signal is induced on the resistive and read by strips is both directions through capacitive coupling.

Beam test at MAMI

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

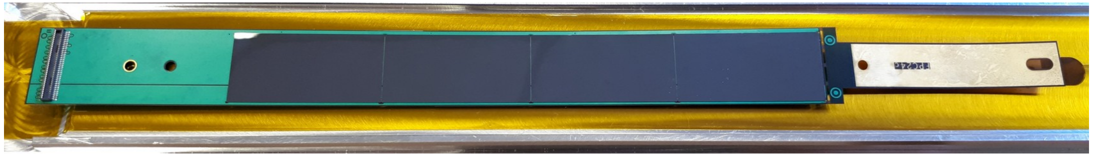


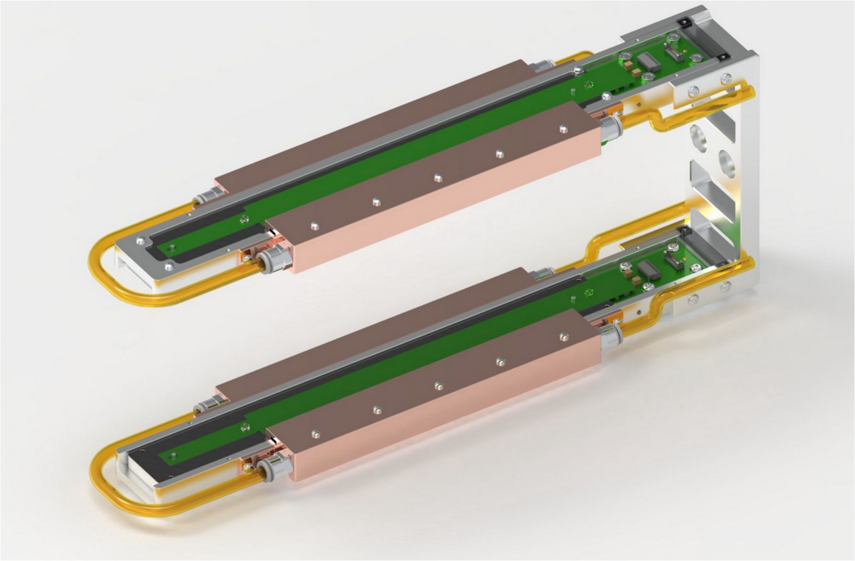


Banco reference tracker

- The Banco tracker is made from ALPIDE silicon chips developed for the ALICE experiment
- The chips are made of 29.24x26.88μm^2 pixels, we use ladders of 5 chips for an active area of 15x1.5cm^2
- Banco has two arms each made of 2 ladders and a water cooling system to keep the temperature of the sensor steady

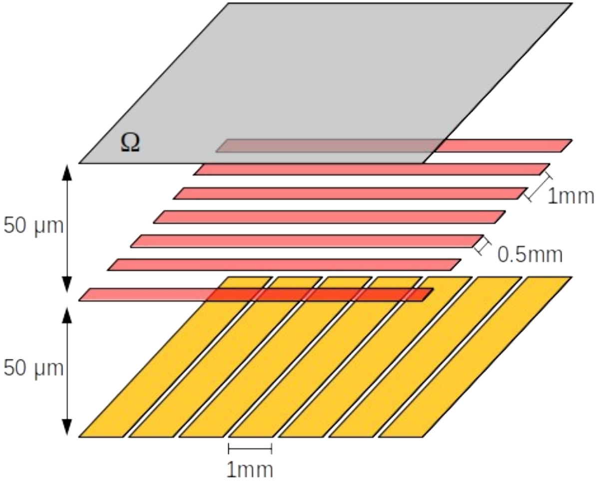
Diagram of one banco arm, V. Maâch

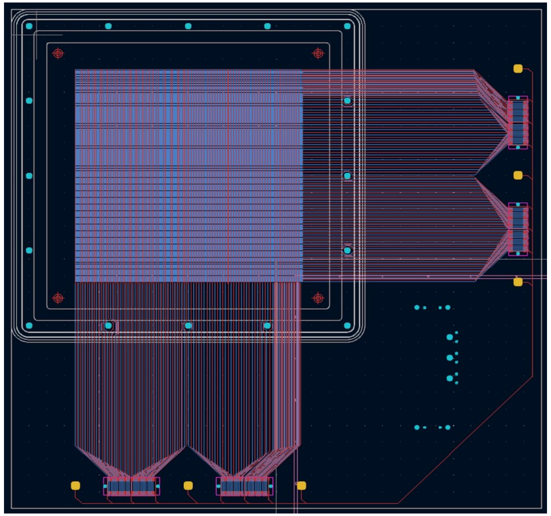

Alice MFT 4 chip ladder, https://cds.cern.ch/record/2748315

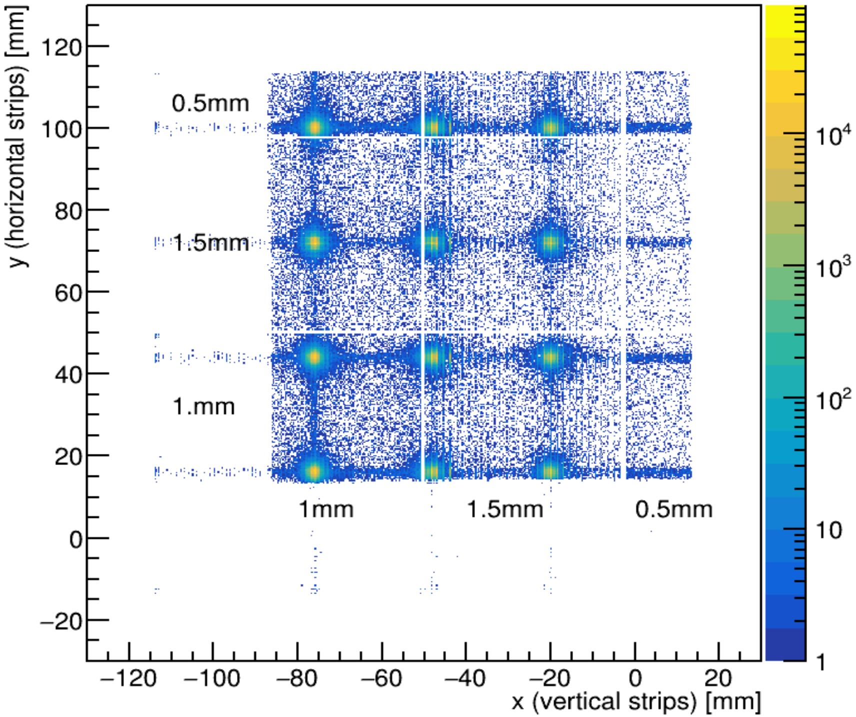

Full banco tracker, V. Maâch

D1 & D2 prototypes

- Prototypes with an active area of 10x10cm
- High resistivity ~10 MΩ/□
- X and Y strips on two different layers
- D1 has multiple strip pitches on the same detector
- D2 has multiple inter-strip



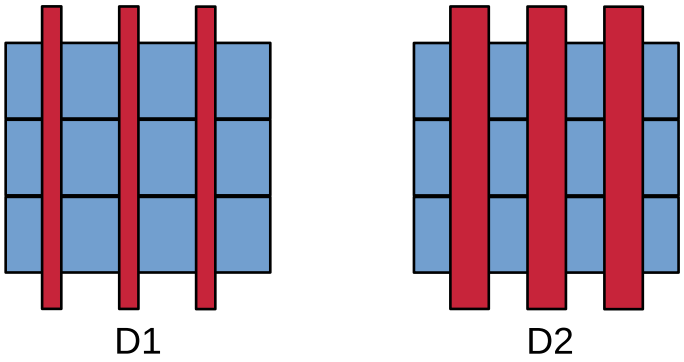


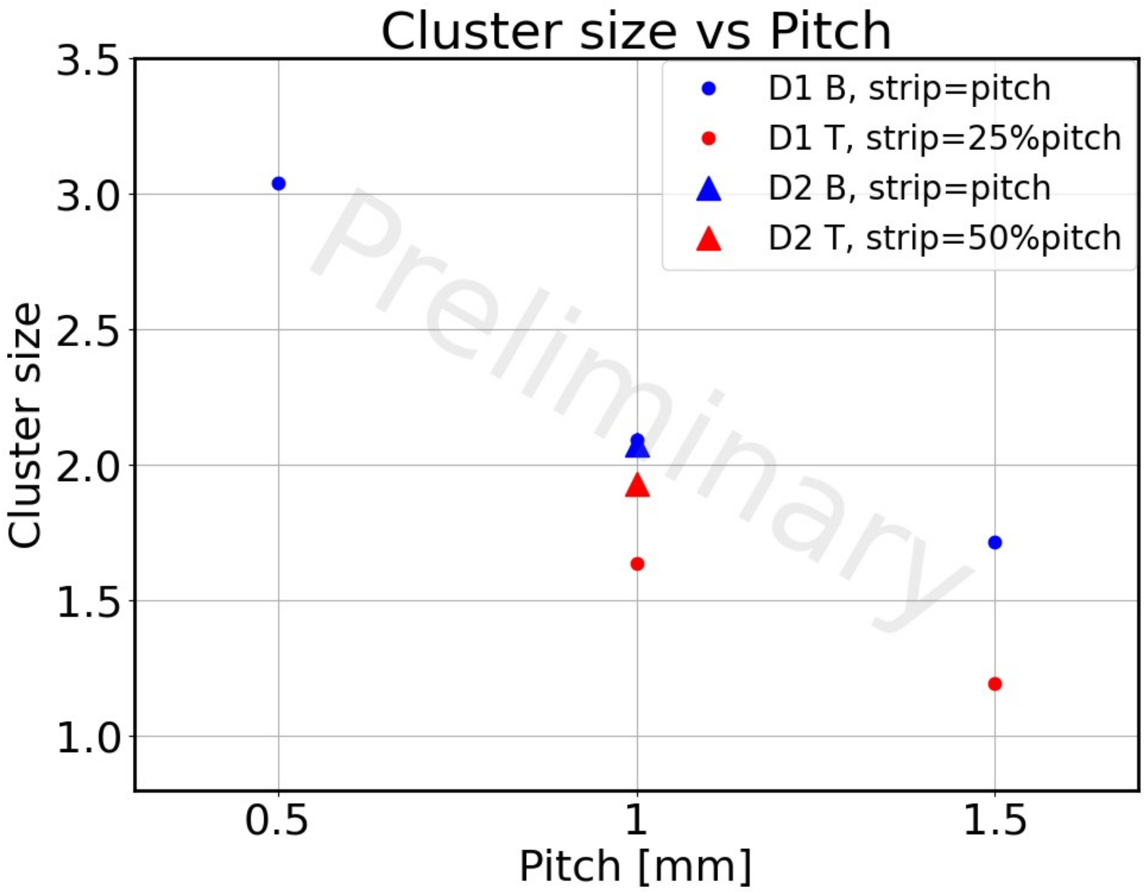


We took runs moving the detector to hit the different regions

D1 & D2 cluster size

- Cluster size: number of strips fired per event and per layer
- Smaller pitch → 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



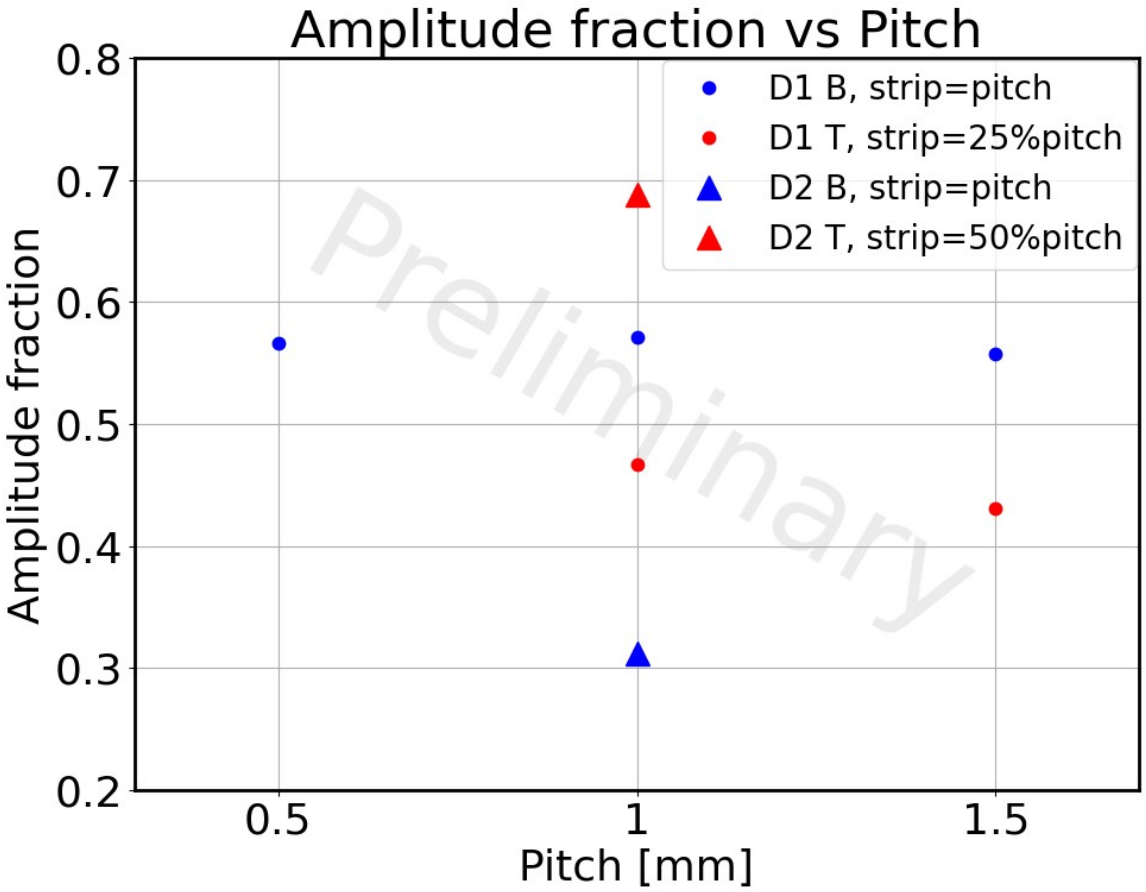


D1 & D2 amplitude fraction

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

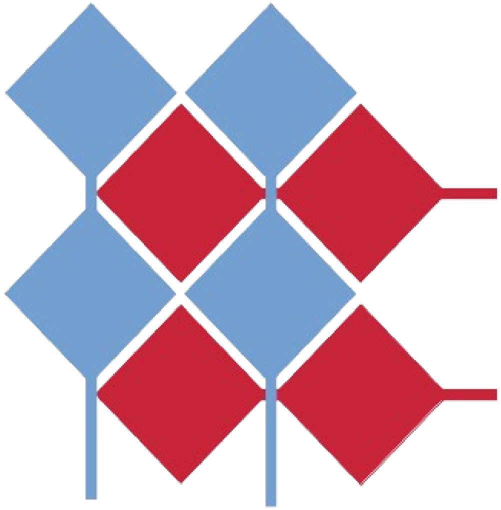
$$\text{AmplitudeFraction} = \frac{\sum_{layerstrips} maxAmp}{\sum_{allstrips} maxAmp}$$

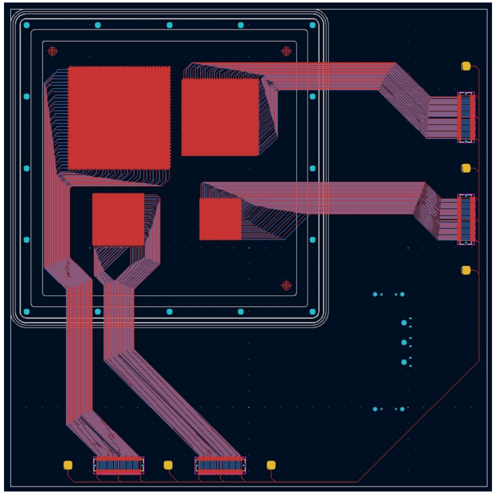
- Strips on the bottom are further away from the resistive layer so they collect less charges and are screened by the top layer
- D1 the top strips are not wide enough, D2 they are too wide

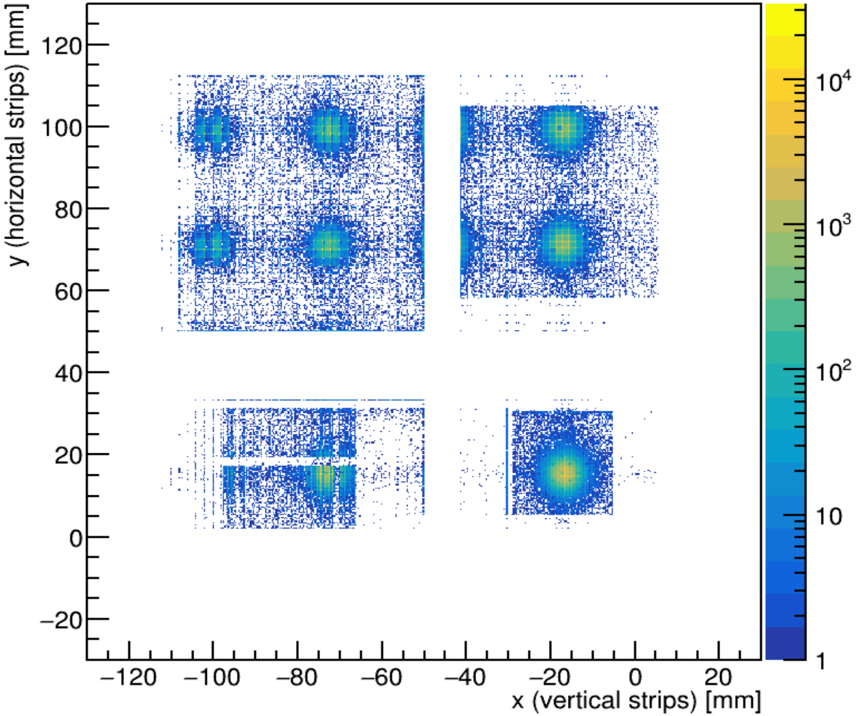


D3 & D4 prototypes

- Prototypes with an active area of 13x13cm with 3 different pitches
- Low resistivity ~300 kΩ/□
- Strips made of interconnected square pads. X and Y on the same plane



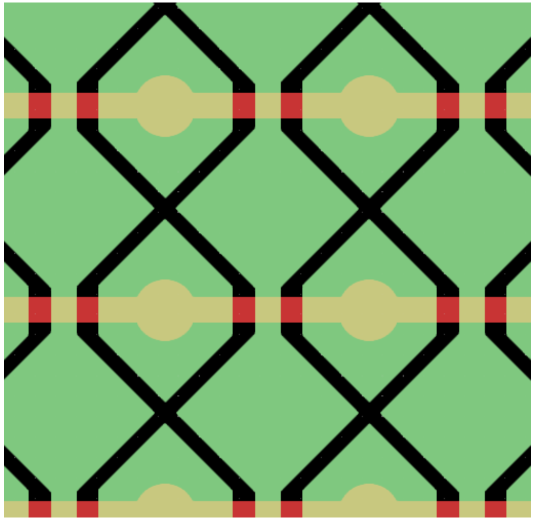


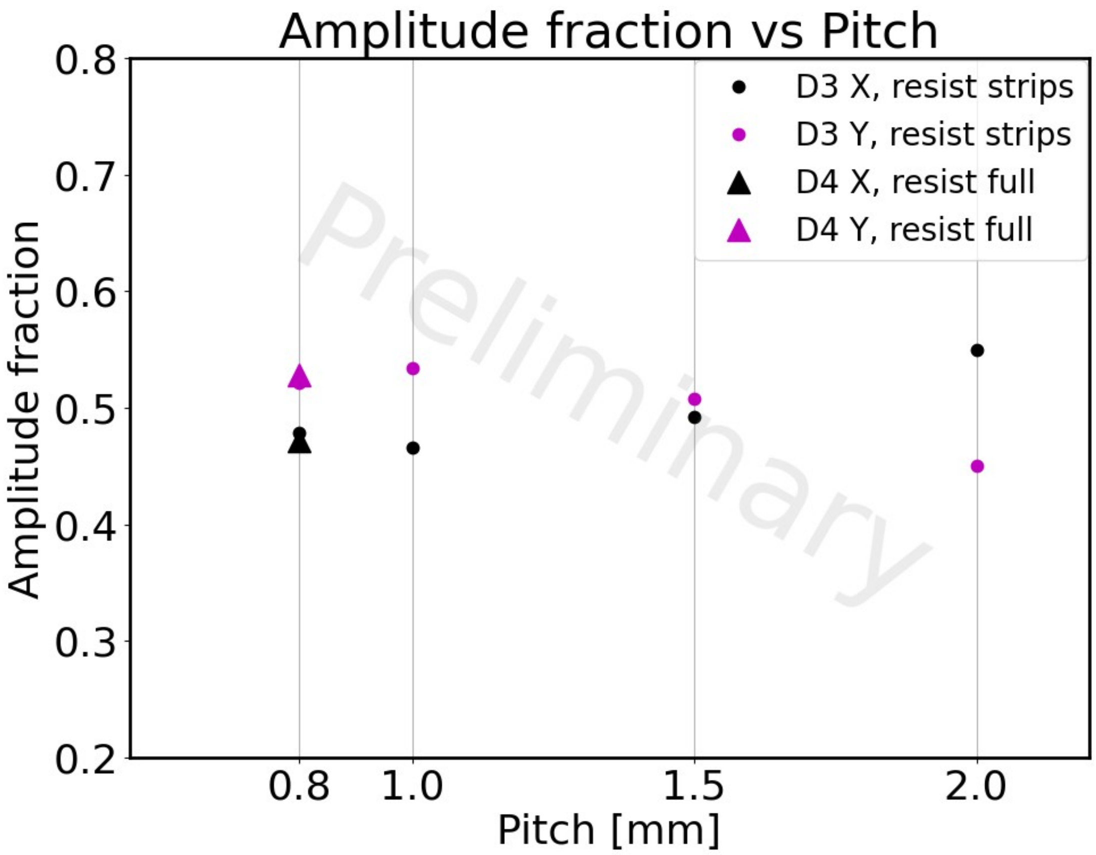


We took runs moving the detector to hit the different regions

D3 & D4 amplitude fraction

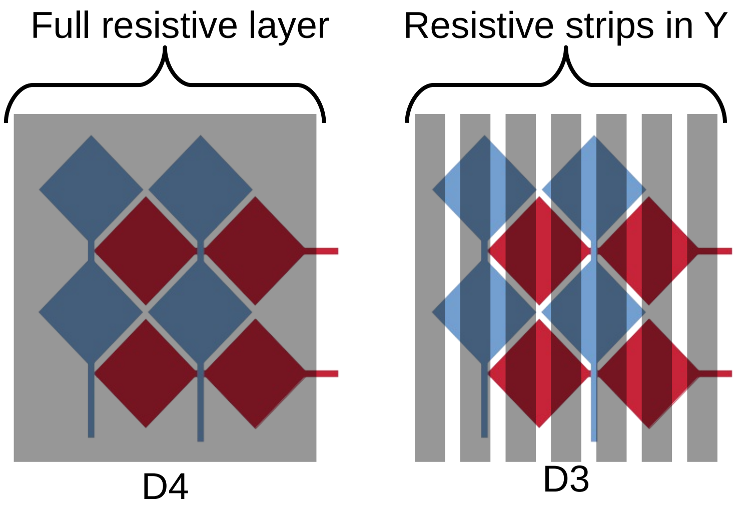
- The charge collection on X and Y strips is even
- There is a little more collected in Y strips because they cover a larger surface

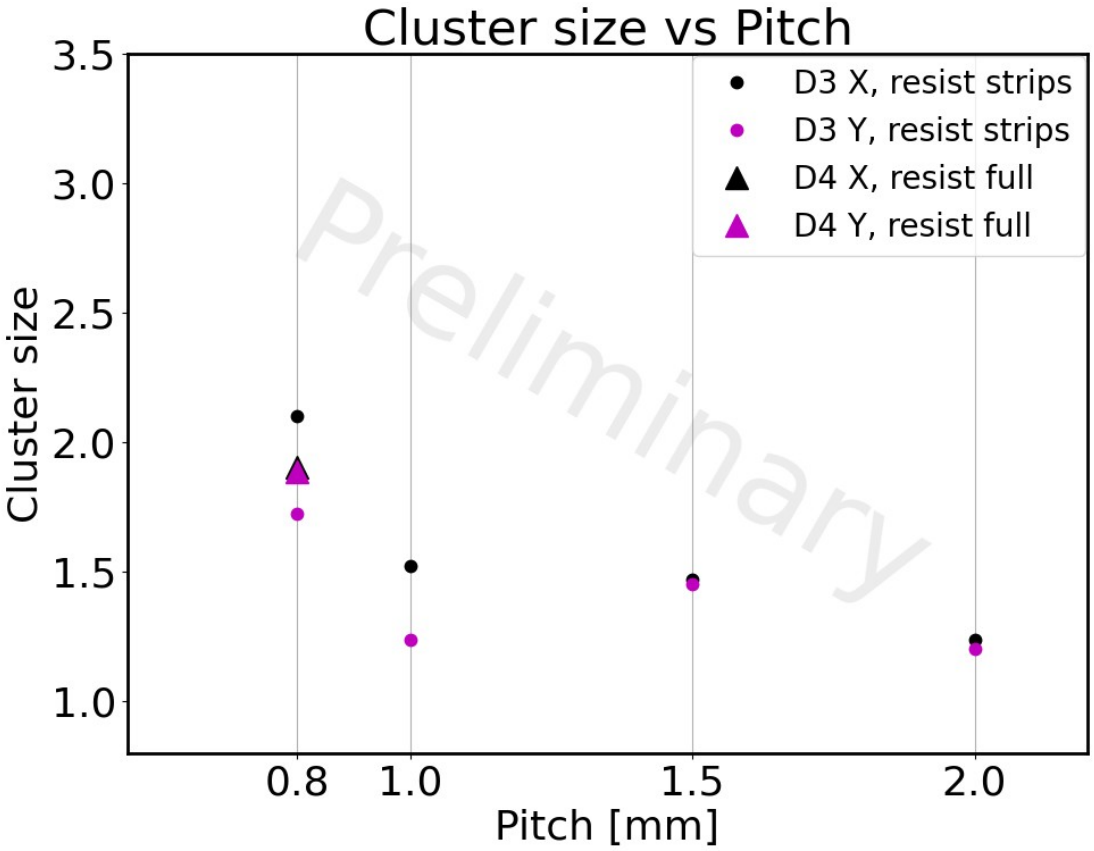




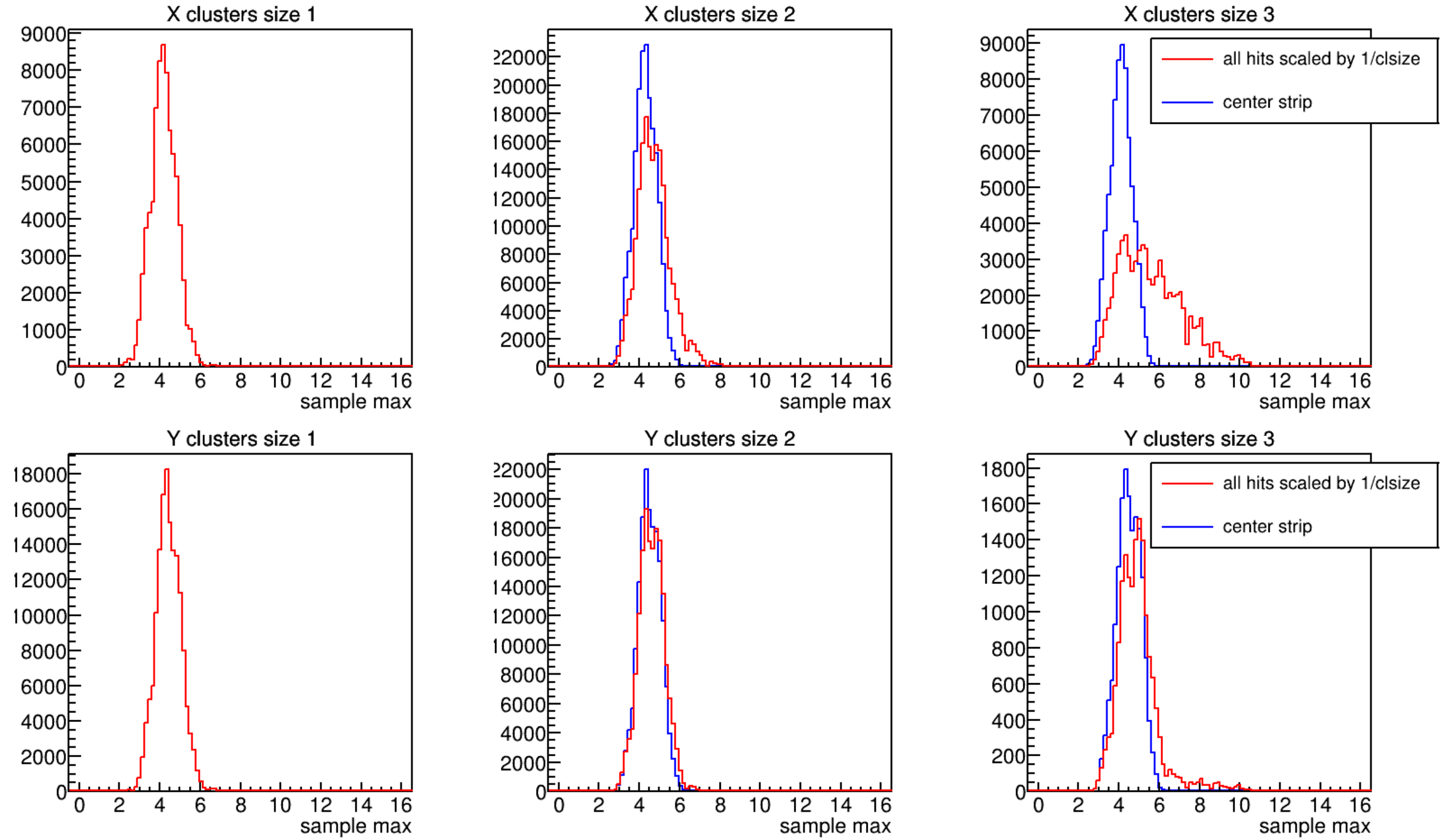
D3 & D4 cluster size

- 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

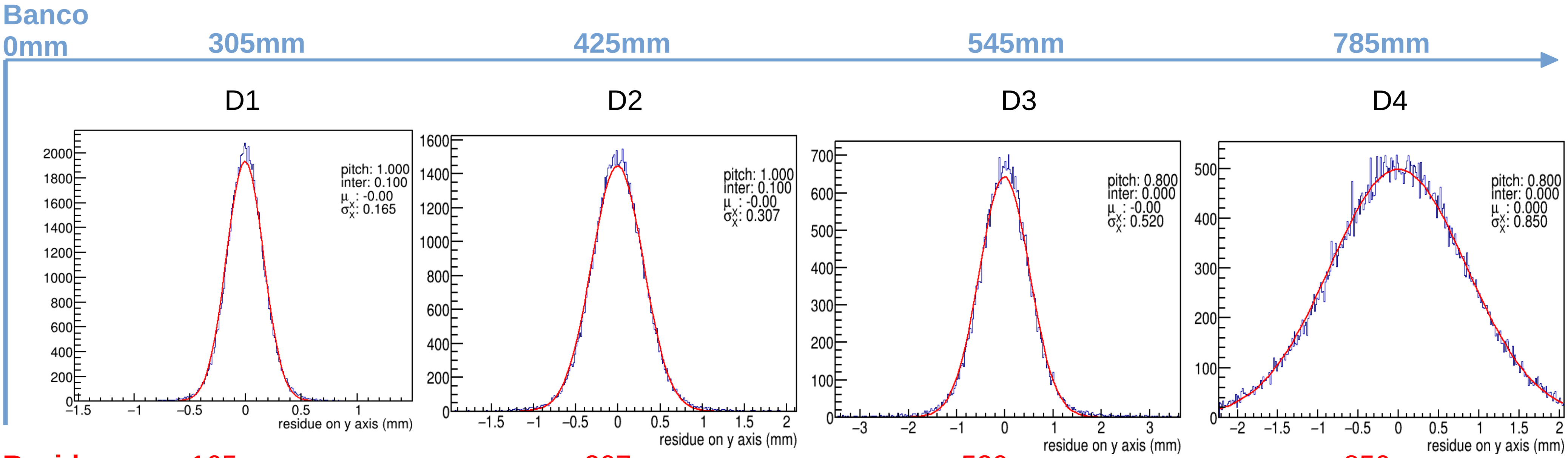


X strips are orthogonal to the resistive strips → charge spreading.

Y 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

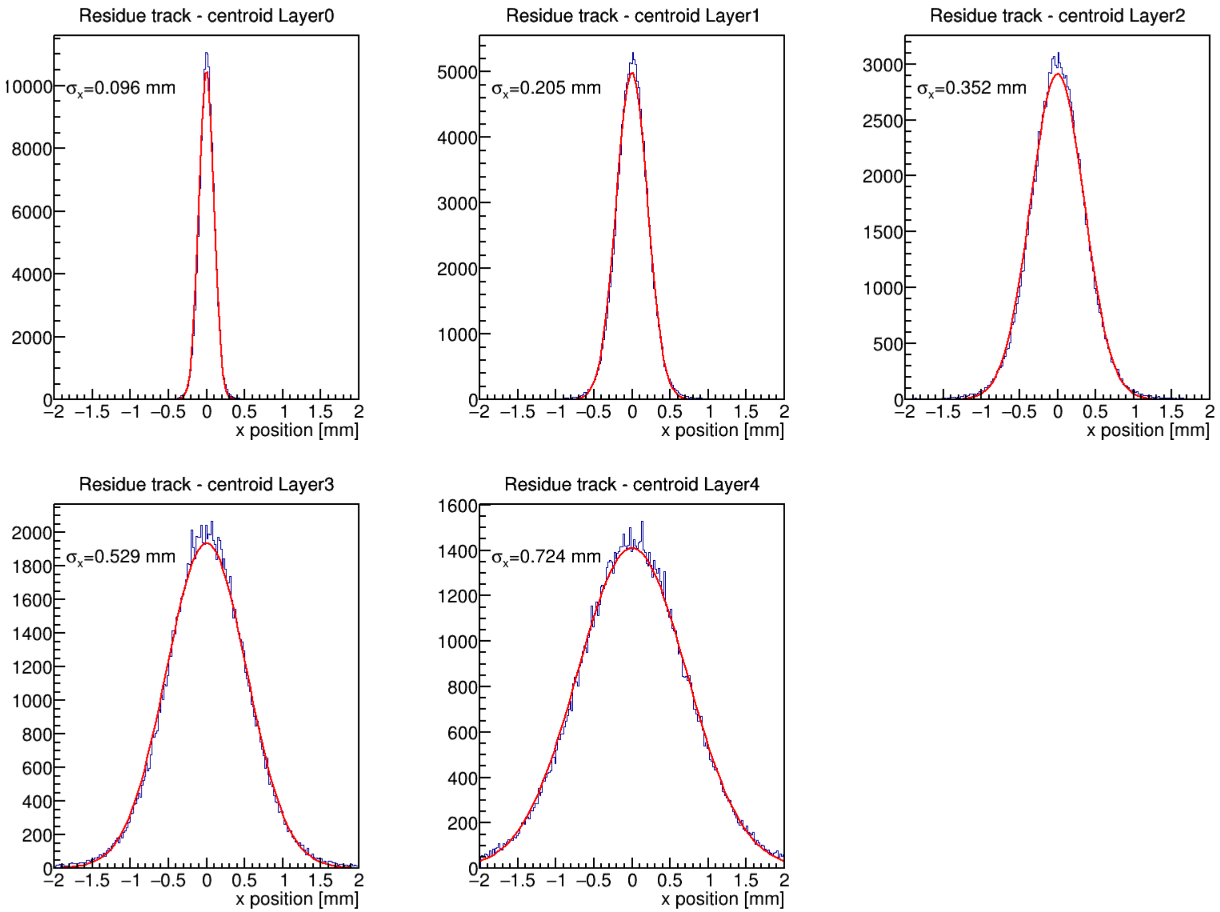


Residues: 165µm 307µm 520µm 850µm

→ Large multiple scattering contribution

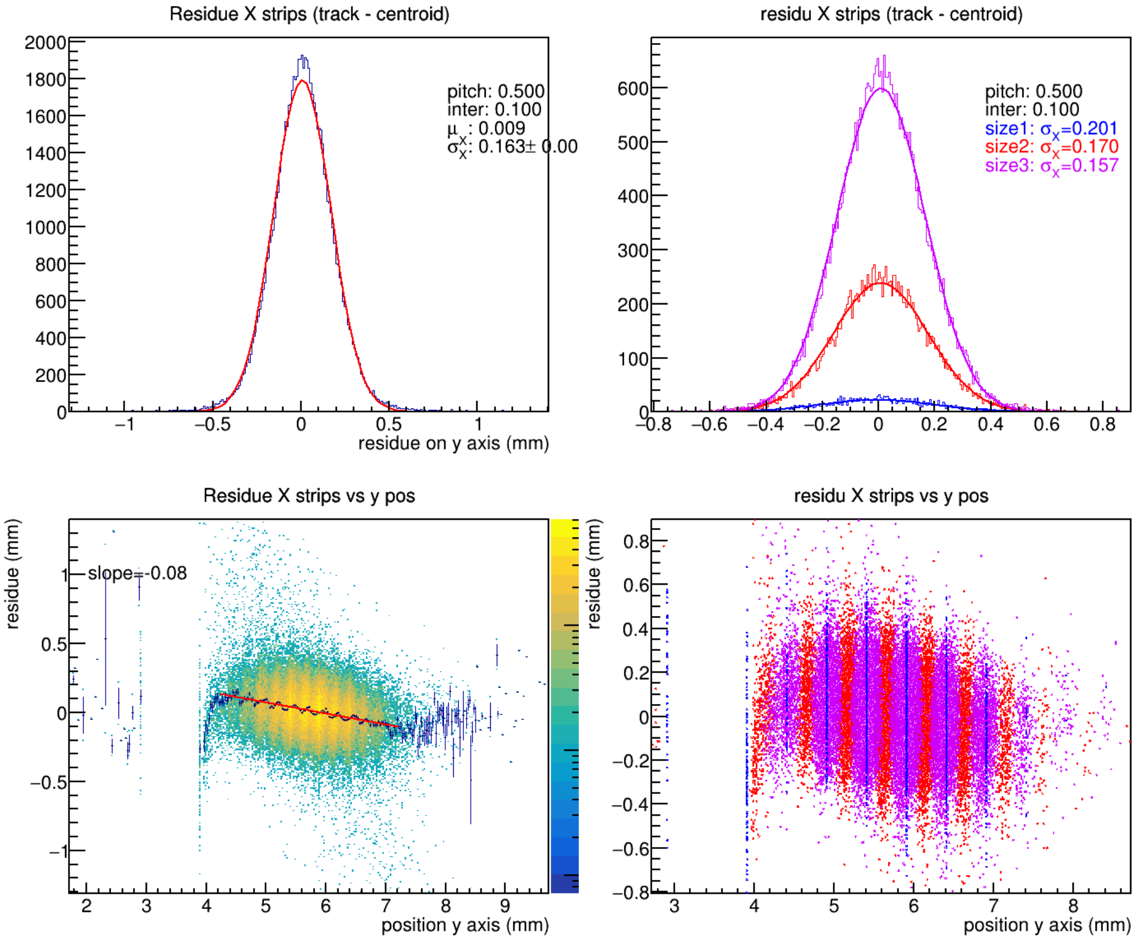
Geant4 simulation

- Beam test geometry implemented in Geant4
- Banco: materials and geometry taken from Alice MFT and Inner Tracker reference papers
- Output: position in each banco ladder and on each prototype
- Contribution of MSC estimated with the residue distribution banco track – exact position on the prototypes



D1, a detailed look at residues

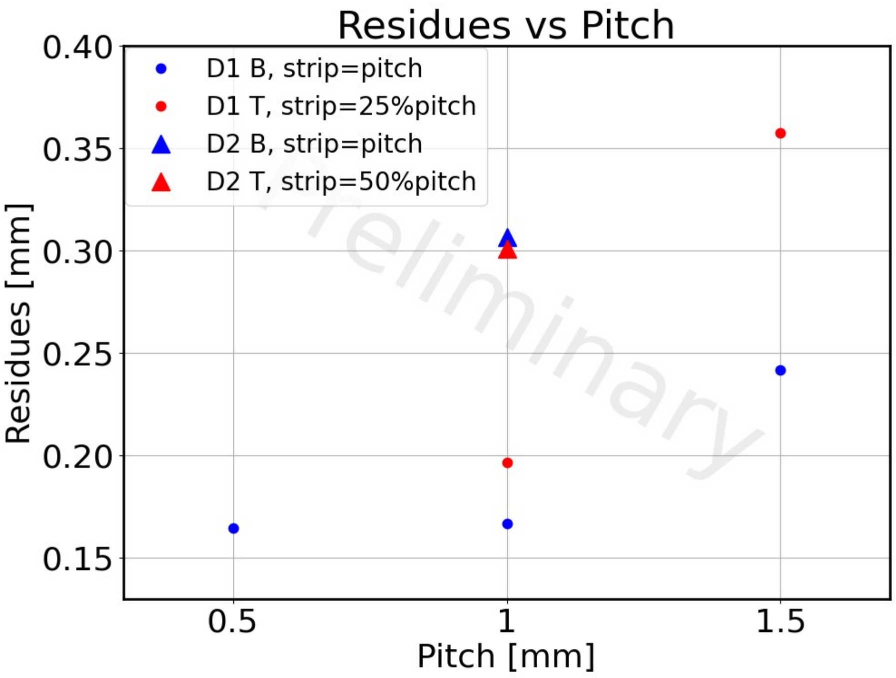
- Looking at the distribution of residues as a function of the position on the prototype structures appear
- They are due to events of different cluster sizes

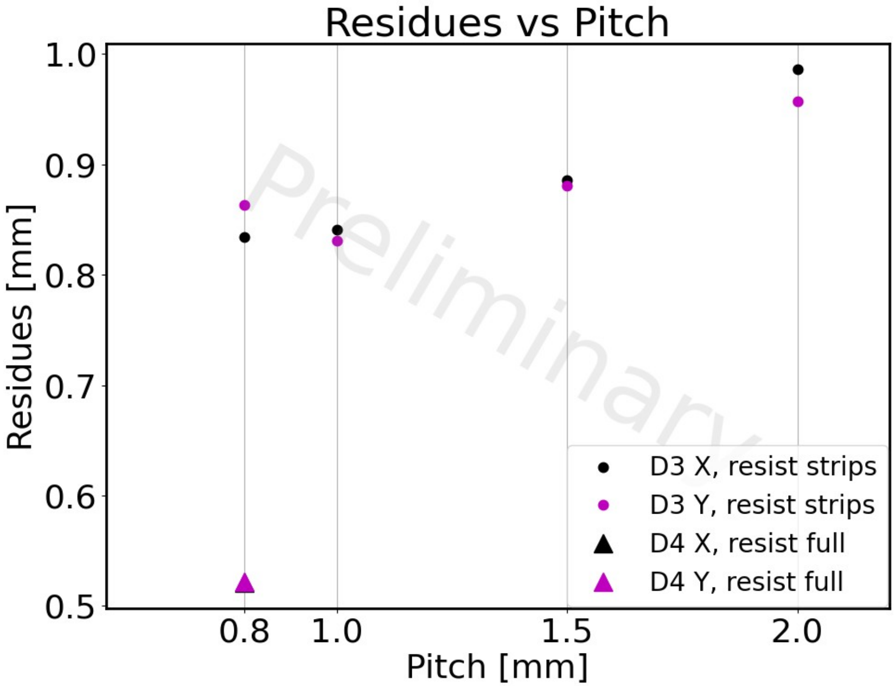


Residues

Detector	msc [µm]
D1	96
D2	205
D3	352
D4	724

- Residues are dominated by multiple scattering
- Strips with 1mm or small provide a good resolution





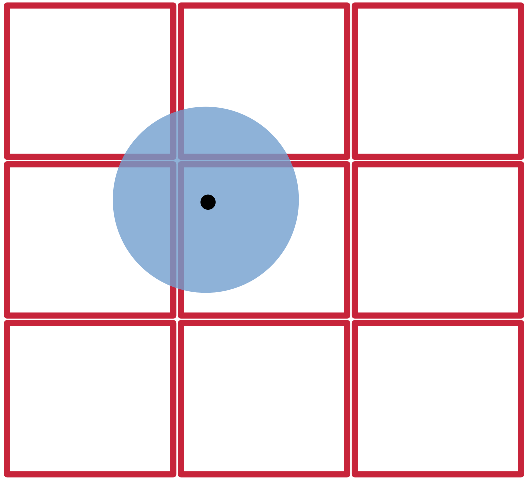
Outlook

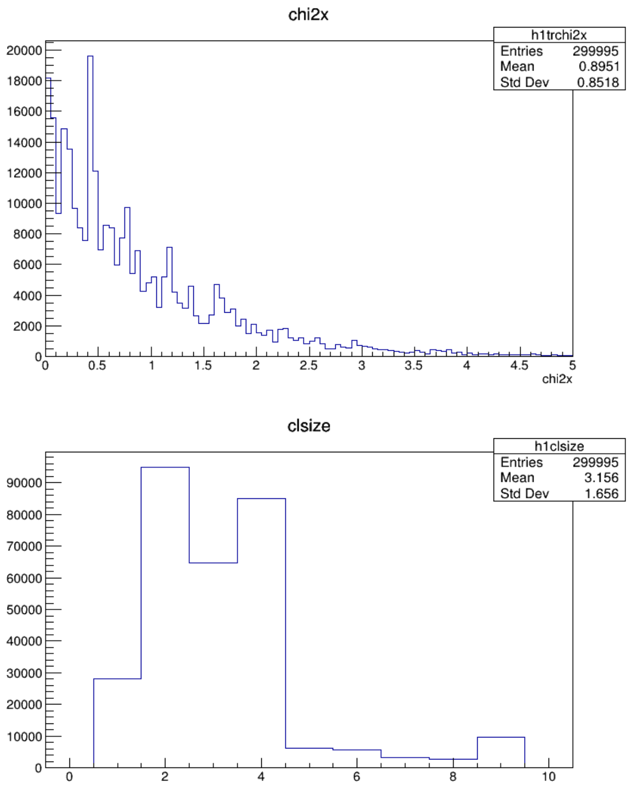
- D1 with 1mm strips or smaller is a good starting point to meet ePIC requirements. But the strip to inter-strip ratio needs to be adjusted.
- The pad-like design with a full resistive layer has the most even sharing between the two directions.
- More data taking with muons to avoid MSC and to complete testing is ongoing at DEDIP.
- More prototypes are in construction to test more resistive layer designs.
- A second beam test in Mainz is planned for September 2024.

Backup slides

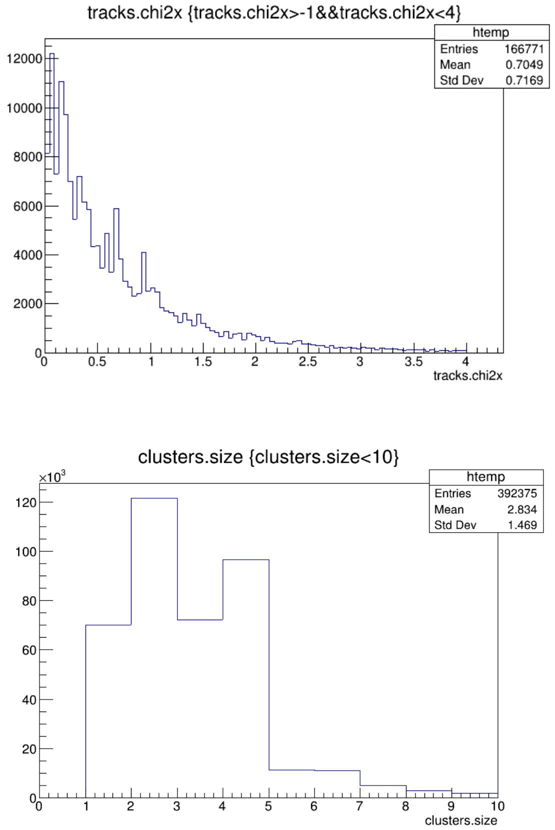
Banco model

- To make build a more realistic track, for each banco ladder we define a circle of radius cste*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 that 2µm inside the pixel.



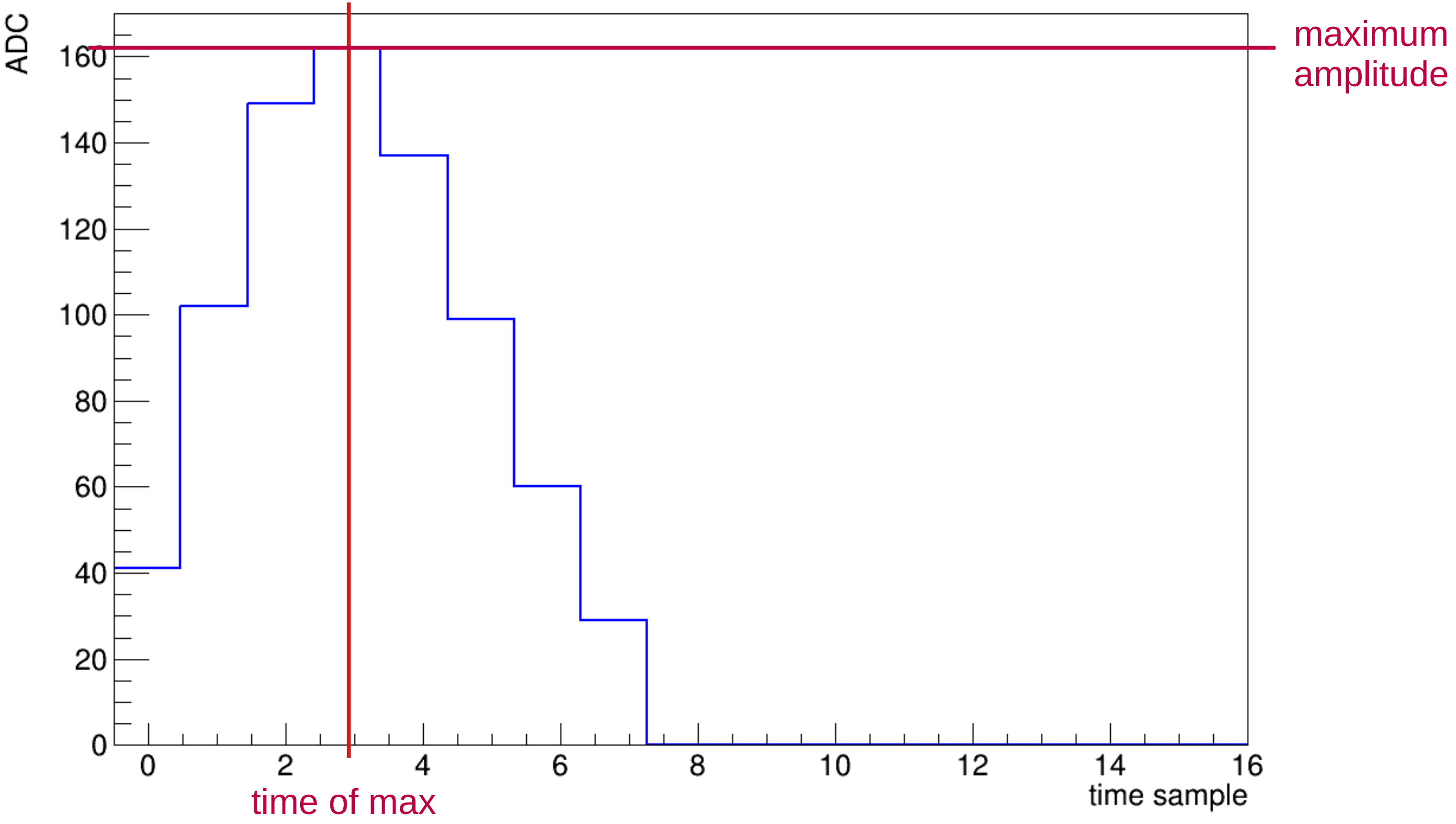


Simulation



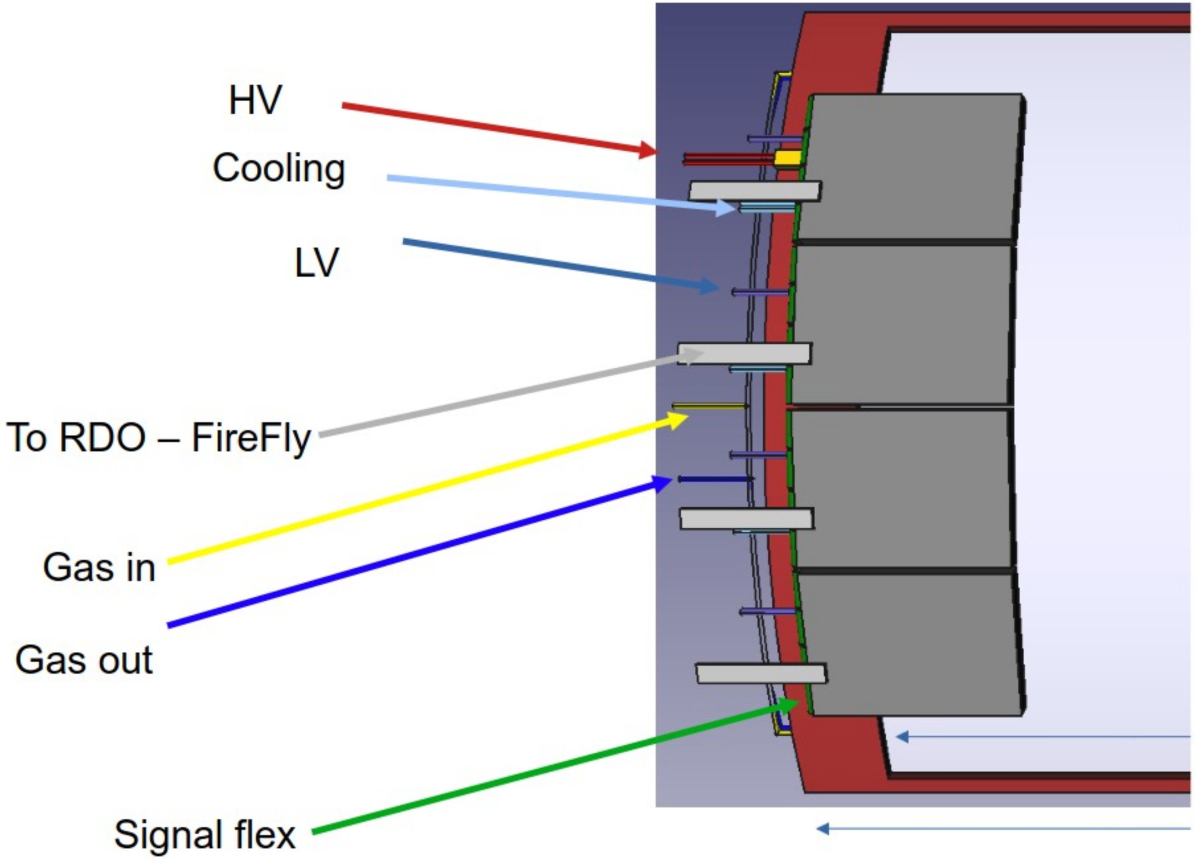
Data

Typical Micromegas waveform



CyMBaL – Module

Charge 3



Dimensions:

- Size: 65 x 46 cm^2
- Active area: 59x44 cm^2
- 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