Research and Development of Micro-Pixel Multilayer Charge Sharing Micromegas Detectors

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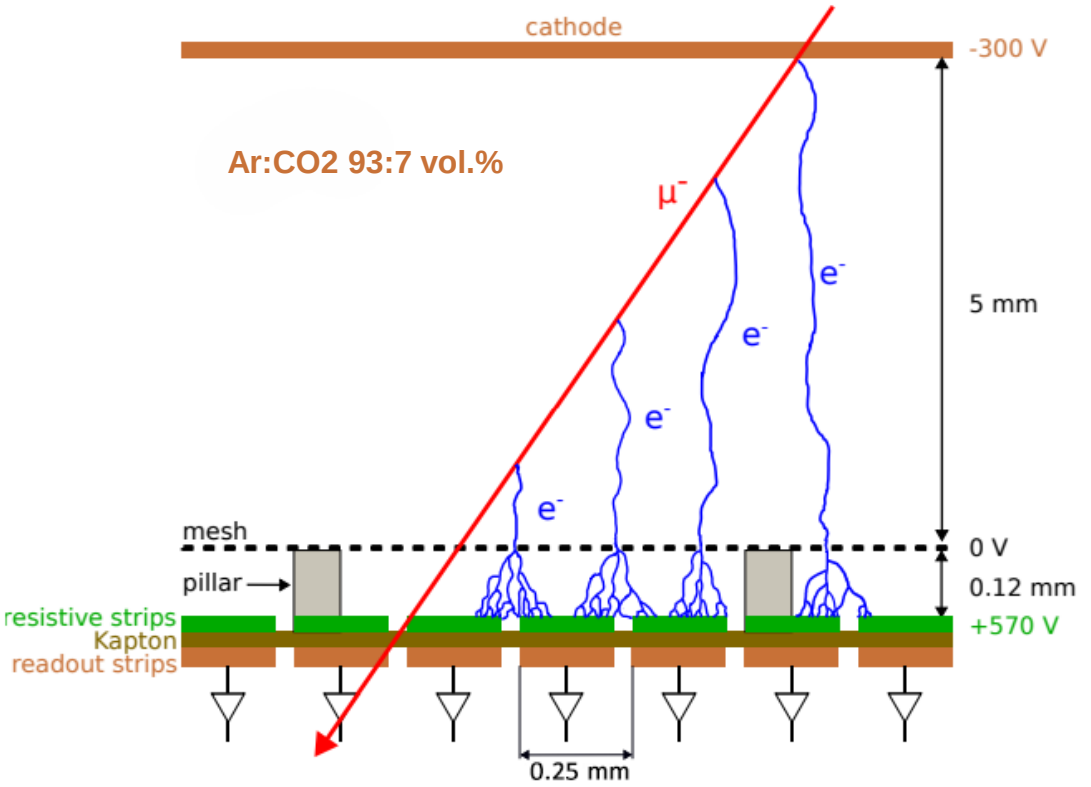
DRD1 COLLABORATION MEETING

LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

Resistive Micromegas

- Gas used: Ar:CO_2 in 93:7 vol. %
- Drift region= 5 mm
- E_{drift} = 600 V/cm
- Grounded stainless steel mesh
- Amplification region= 120 μm
- E_{amp} = 50 kV/cm
- Gain = 5-10k
- Resistive strips (ATLAS) or DLC resistive layers
- Strip pitch = 250 μm
- Spatial resolution σ < 100 μm attainable



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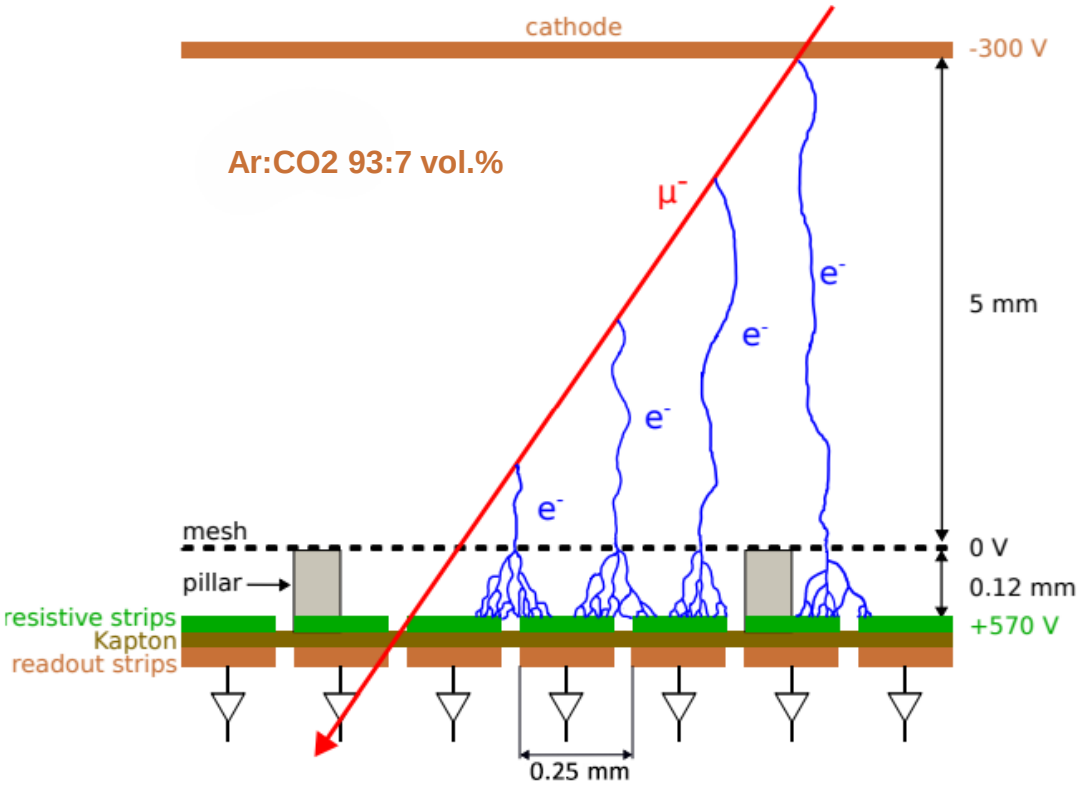
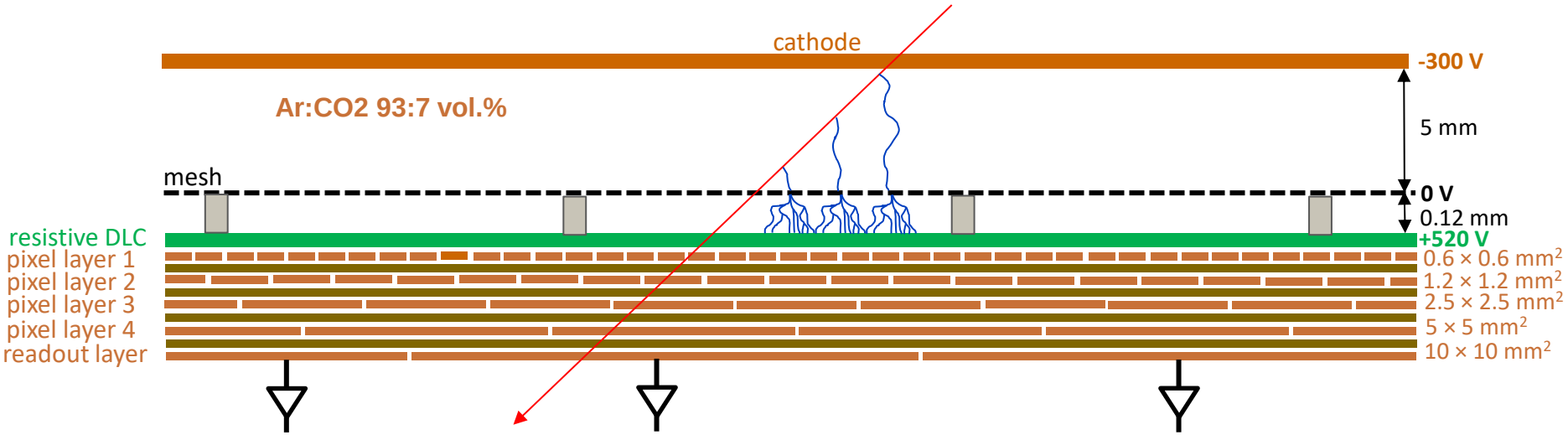


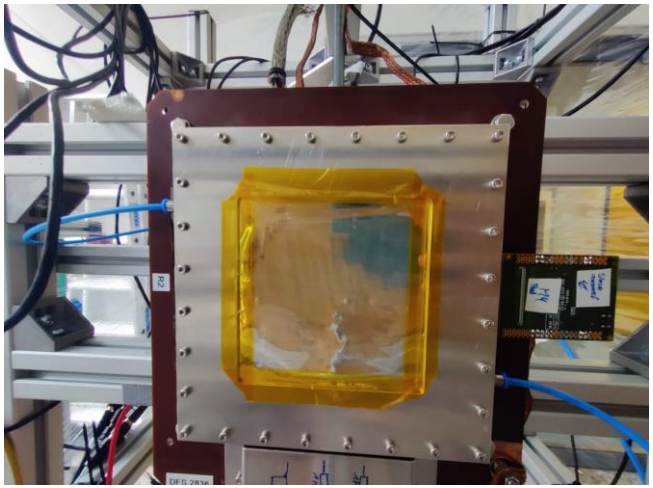
- Micro-pixel detectors with σ < 100 μm need pixels of 0.3 × 0.3 mm^2
- For a 10 × 10 cm^2 detector: 333 × 333 pixels = 100 k readout channels needed
- Cost and power intensive

5 Layer Charge Spreading Anode

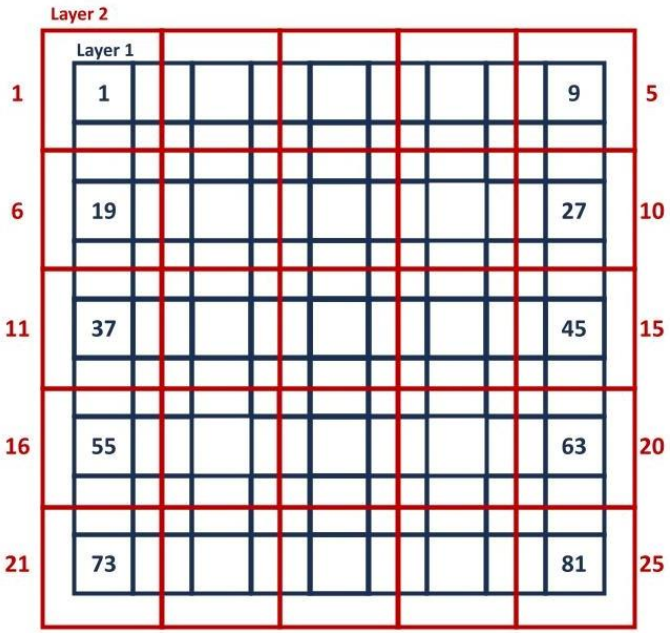


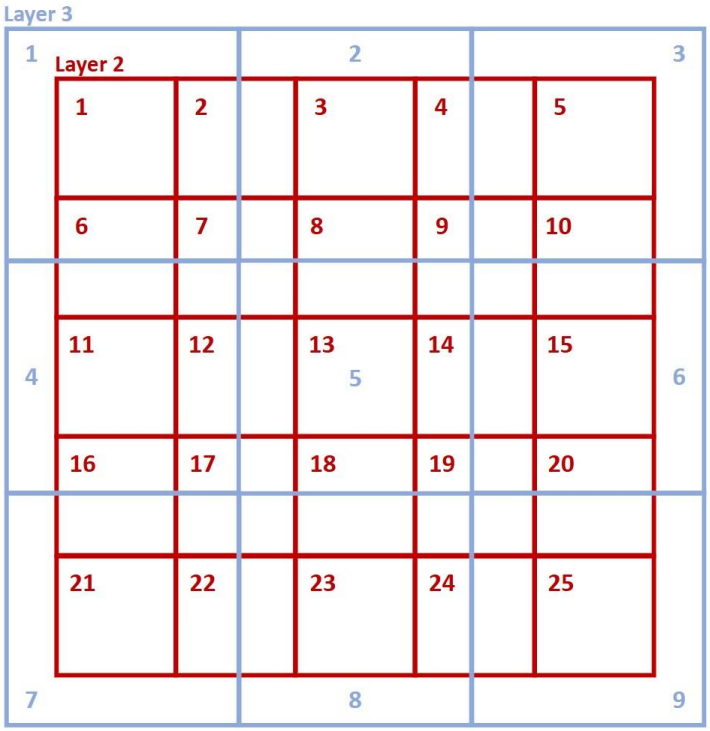
Basic Idea:

- Prototype 1: Reduce the number of readout channels strongly via charge sharing on several stacked readout layers
- Prototype 2: Reduce it further by a pixel-strip hybrid readout structure



Charge Sharing Concept: Prototype 1



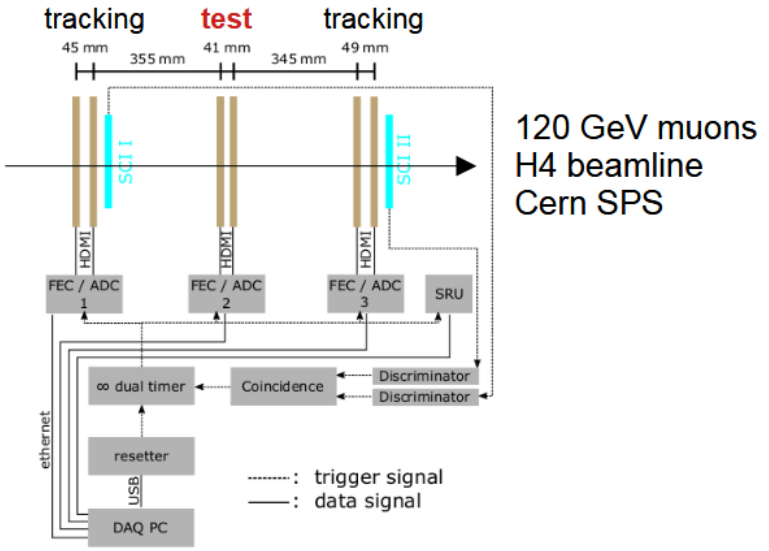


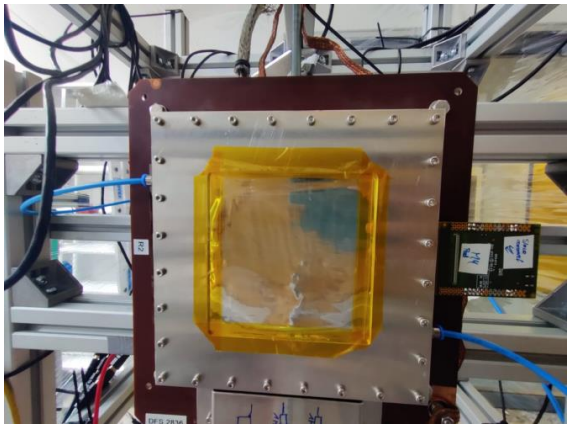
Concept:

- Pixels of layer n are double in length and width to the pixels in layer n - 1
- Pixels of layer n start in the center of the pixels in layer n - 1
- Position is contained in the pulse height distribution of the neighbouring pixels

Test Beam Setup

- Five stacked pixelised layers in a 10 × 10 cm^2 detector
- Pixel pitch increasing from 0.625 mm, 1.25 mm, 2.5 mm, 5 mm to 10 mm
- Total readout channels reduced from 100 k to just 100 channels
- 1 APV25 hybrid used to read the complete detector





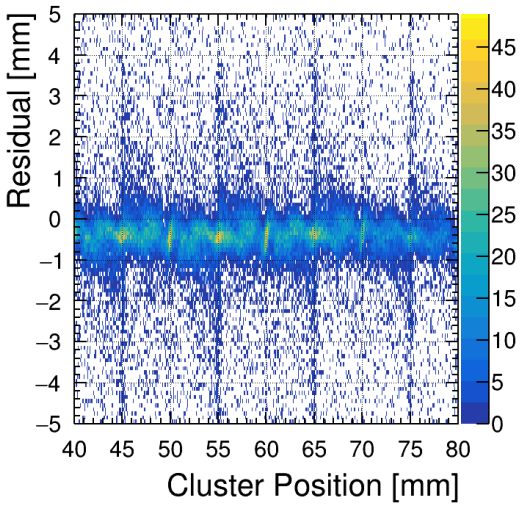
- Gas used: Ar:CO_2 in 93:7 vol%
- Detector tested with 120 GeV muons from the H4 beamline from SPS
- 4 reference Micromegas detectors used to build tracks
- Scintillators in coincidence used for triggering events

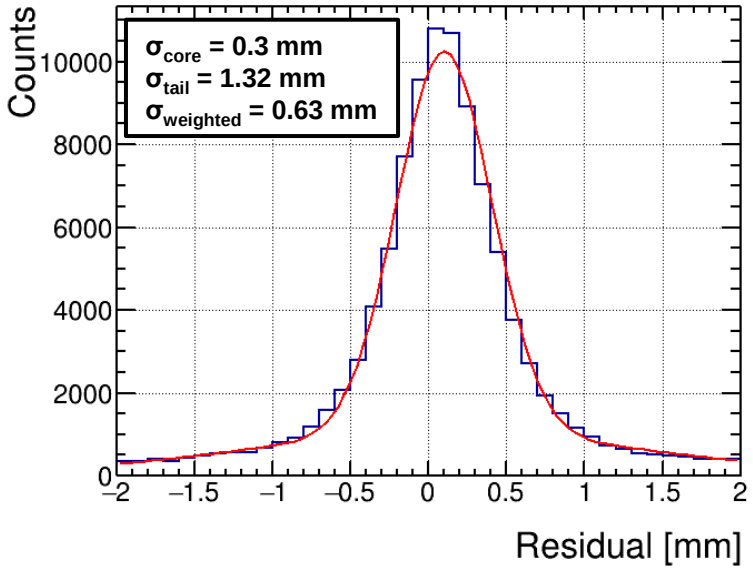
Spatial Resolution

- Residual = $pos_{track} - pos_{pixel\_det}$
- Residuals determined by a double Gaussian fit:

$$\sigma_{weighted} = \frac{\sigma_{core} \times a \int e^{\frac{(x-b)^2}{2\sigma_{core}^2}} + \sigma_{tail} \times c \int e^{\frac{(x-d)^2}{2\sigma_{tail}^2}}}{a \int e^{\frac{(x-b)^2}{2\sigma_{core}^2}} + c \int e^{\frac{(x-d)^2}{2\sigma_{tail}^2}}}$$

- Track error unaccounted for, σ_{track} O(50 μm)





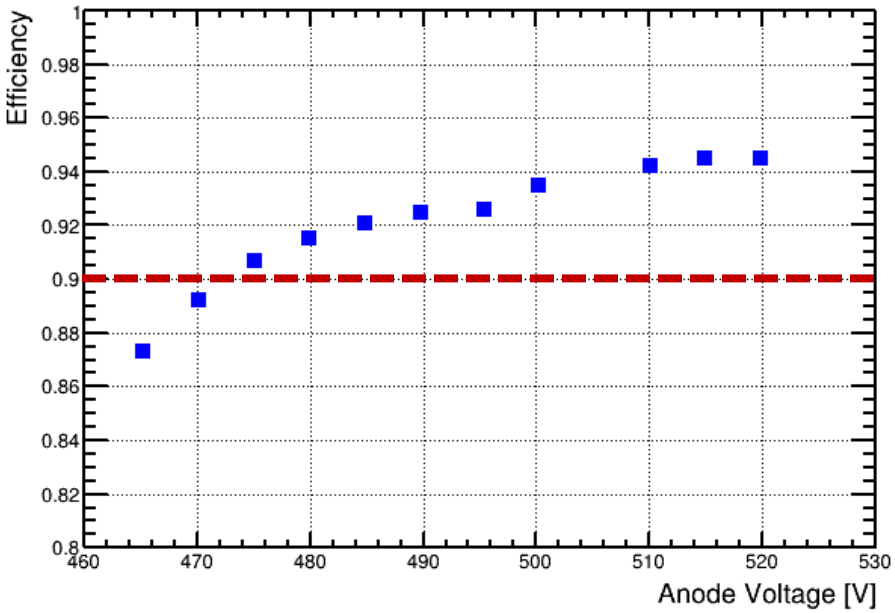
- Sub-structures observed at every 10 mm periodically (under investigation; simulation studies planned)
- Resolution much better than the expected $\frac{10\ mm}{\sqrt{12}} \approx 2.89\ mm$, but long tails observed

Efficiency

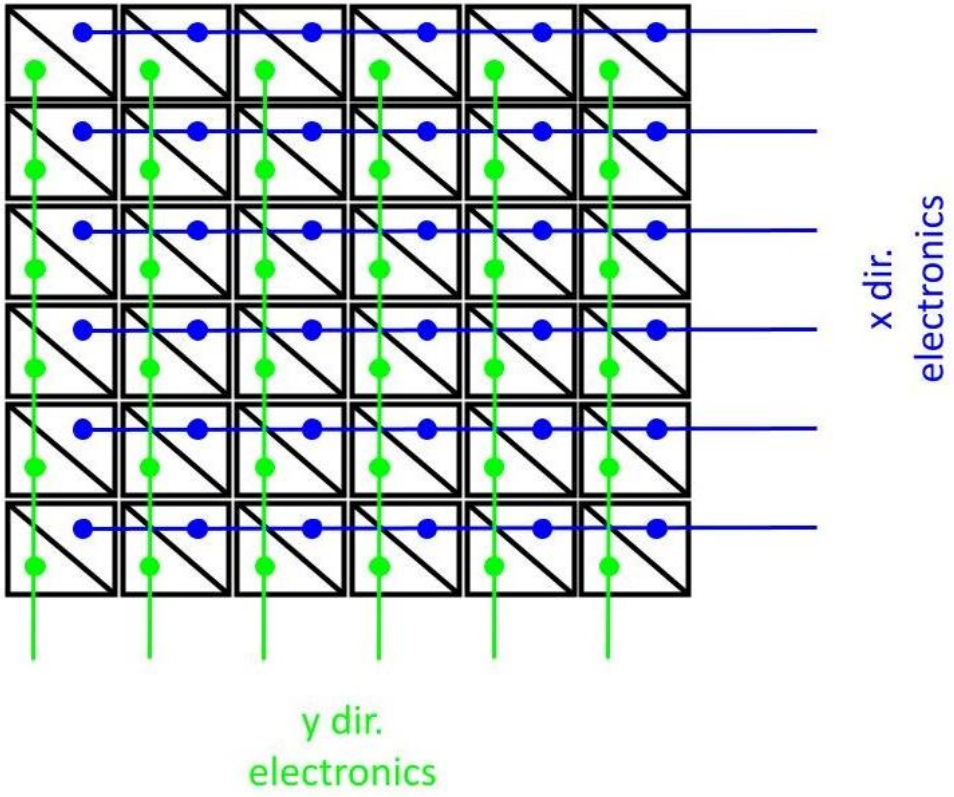
- Efficiency :

$$\frac{\#\ of\ reconstructed\ events\ in\ investigated\ det.}{Total\ \#\ of\ reconstructed\ tracks}$$

- Obtained efficiencies of > 90% for voltages above 475 V



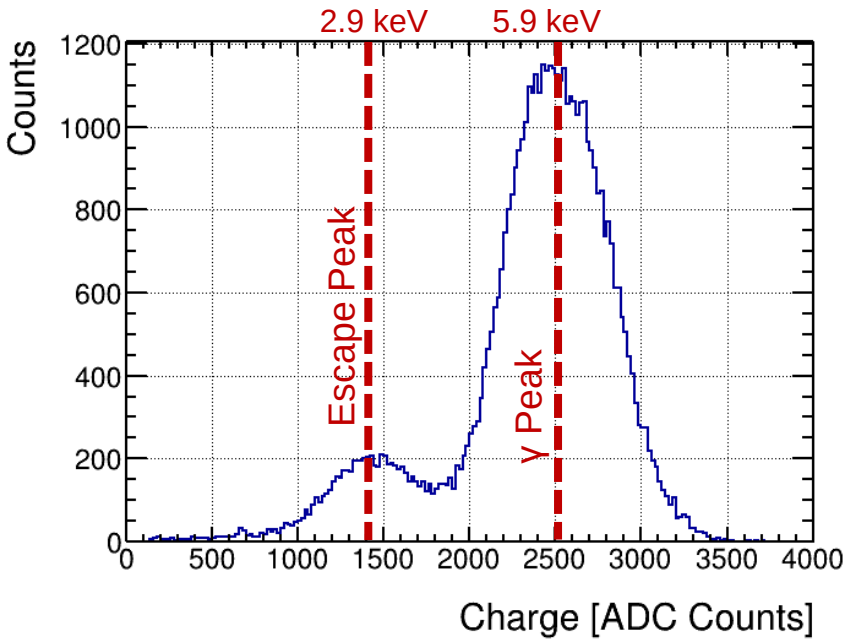
3 layer Charge Spreading Anode with Strip-like Readout



- 3 layer pixel detector with 0.3 mm, 0.6 mm and 1.2 mm pixel pitch
- readout layer pixels subdivided into 2 halves with interconnected rows and columns readout by a single channel
- For standard pixels of 1.2 mm pitch, total number of readout channels = 84 × 84 = **7056 channels**
- For strip-like readout, total number of readout channels = 84 + 84 = **168 channels**

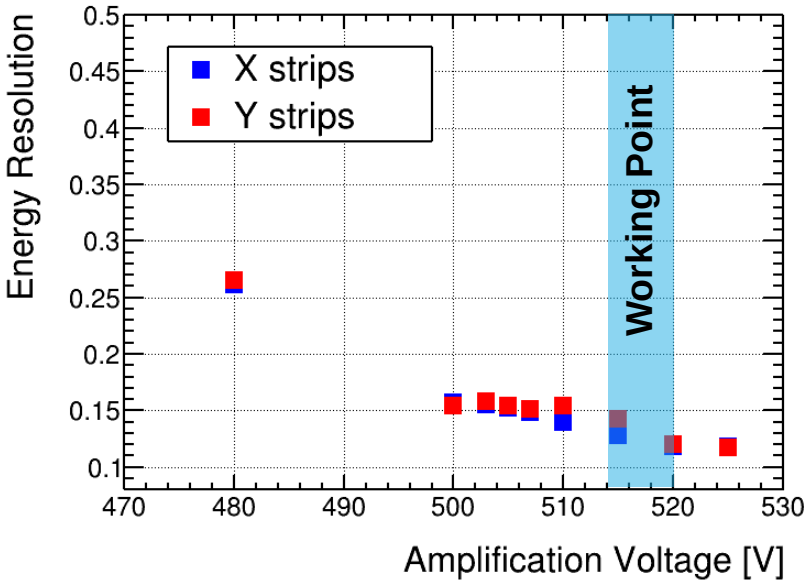
Characterisation using ^{55}Fe source

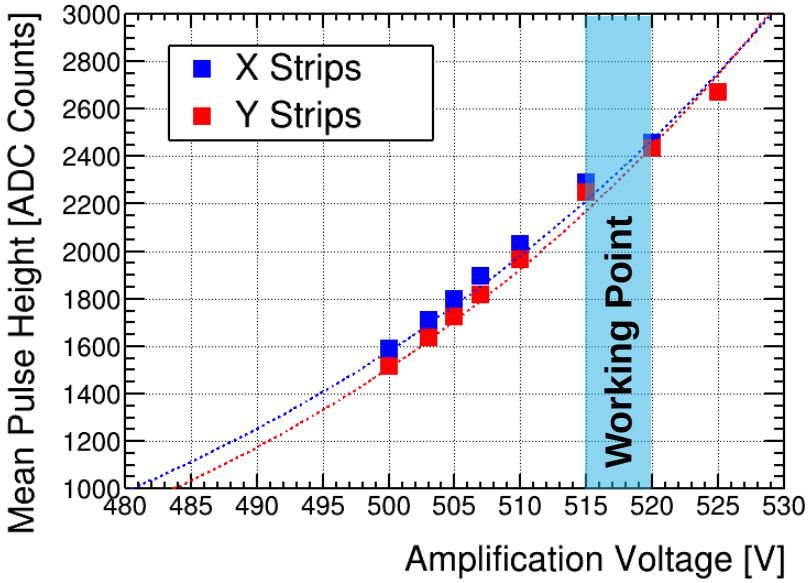
- Investigation of energy spectrum using an ^{55}Fe source
- Two peaks observed:
  - 5.9 keV γ peak of ^{55}Fe
  - 2.9 keV Argon escape peak
- Expected peak ratio: $\frac{5.9\ keV}{2.9\ keV} = 2.03$
- Reconstructed ratio: 1.8
- Energy resolution: $\frac{\Delta E}{E}$ = 12.27%



^{55}Fe: Detector Optimisation

- Determination of pulse height and energy resolutions for different anode voltages
- Pulse height distribution rises exponentially as expected

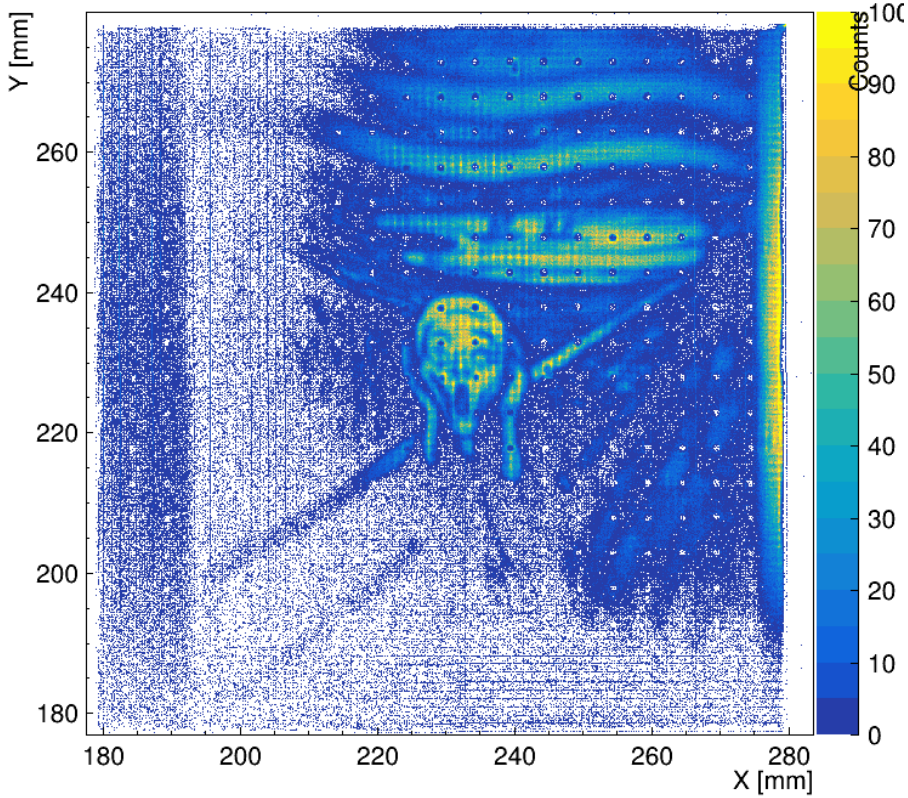




- Current working point: between 515 and 520 V; starting from 525 V readout electronics saturation arises

^{55}Fe: The Scream

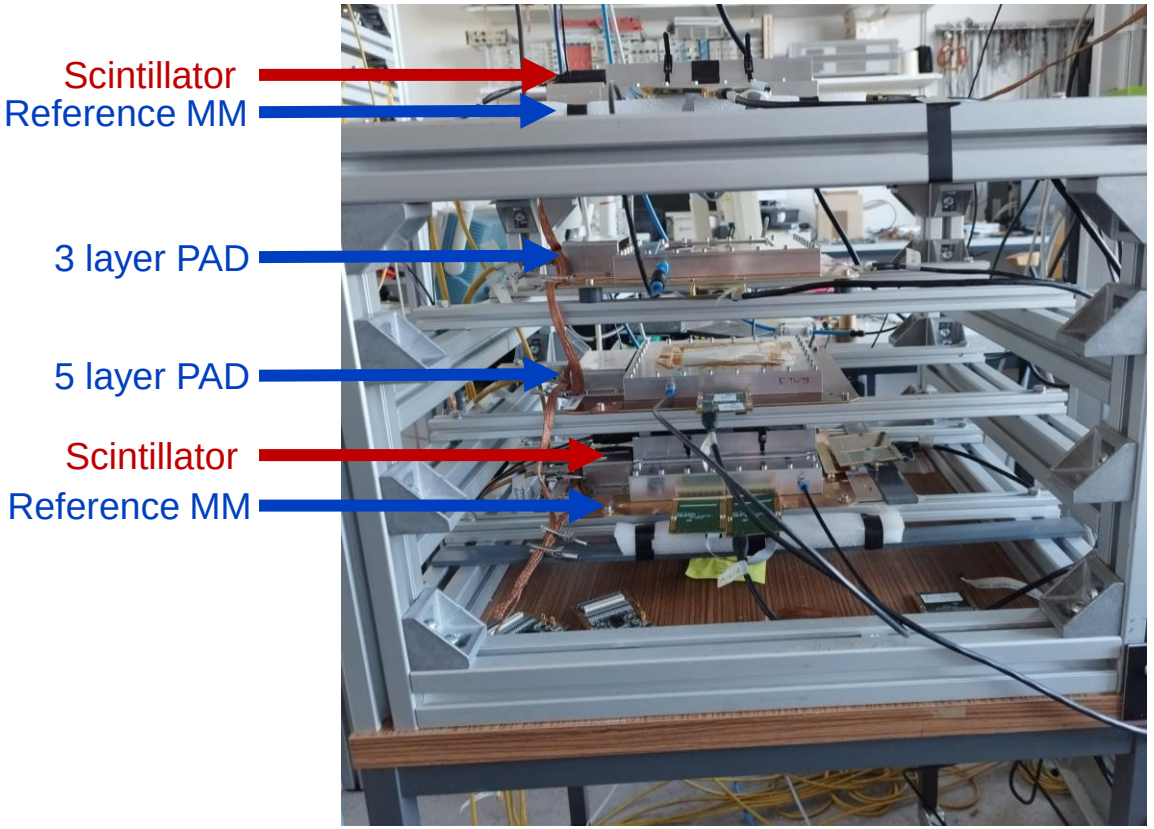
- 3D printed “The Scream” by Edvard Munch placed in between the source and the detector
- Good resolution of the detector can be observed; pillars holding the mesh can also be seen (A_{pillar} = 1.2 × 0.2 mm^2)



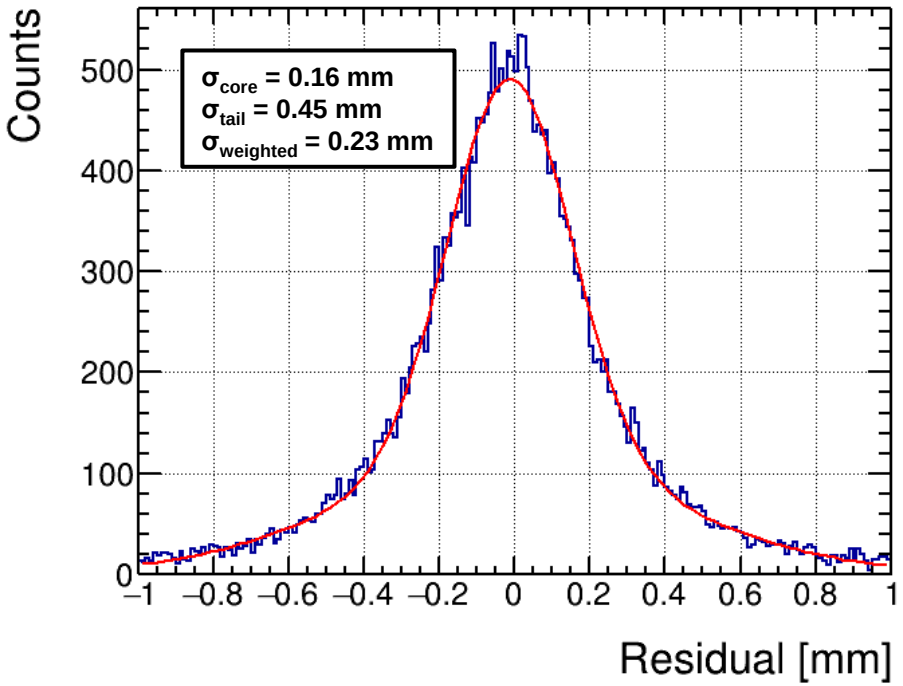
- V_{drift} = 480 V; V_{amp} = 520 V
- Gas used: Ar:CO_2 in 93:7 vol.%

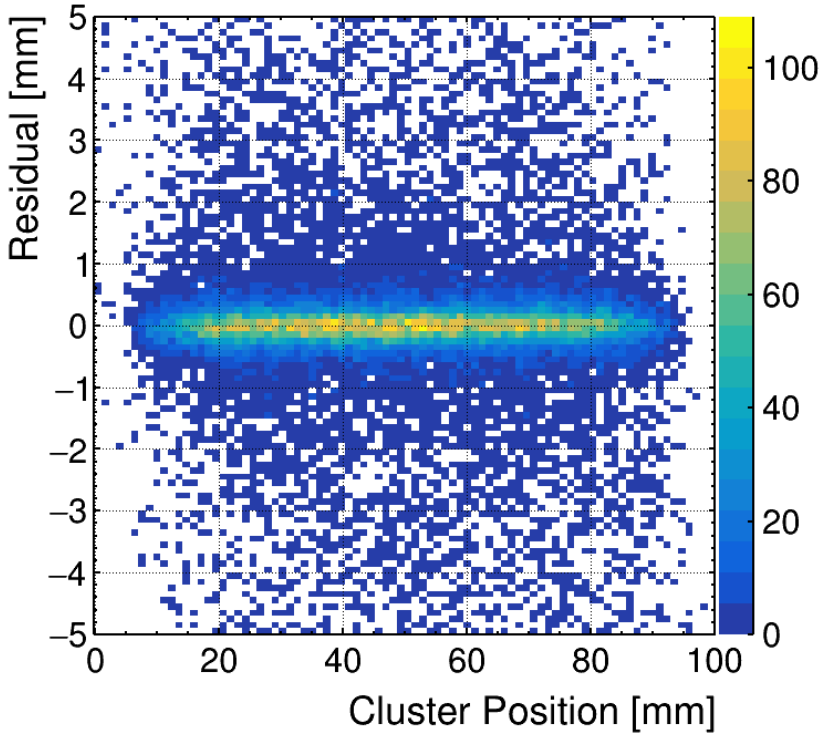
Cosmic Muons: Test Setup

- Telescope setup with two 9 × 9 cm^2 scintillators for triggering
- Two 10 × 10 cm^2 reference detectors used to track cosmic muons
- Gas used: Ar:CO_2 in 93:7 vol. %
- V_{drift} = 480 V; V_{amp} = 520 V
- Angle of acceptance: ±19º



Prototype 2: Spatial Resolution





- Core residual ~ 160 μm achieved ($\pm 5°$ i.e. perpendicular incidence)
- Track error not accounted for
- No substructures observed with the hybrid detector

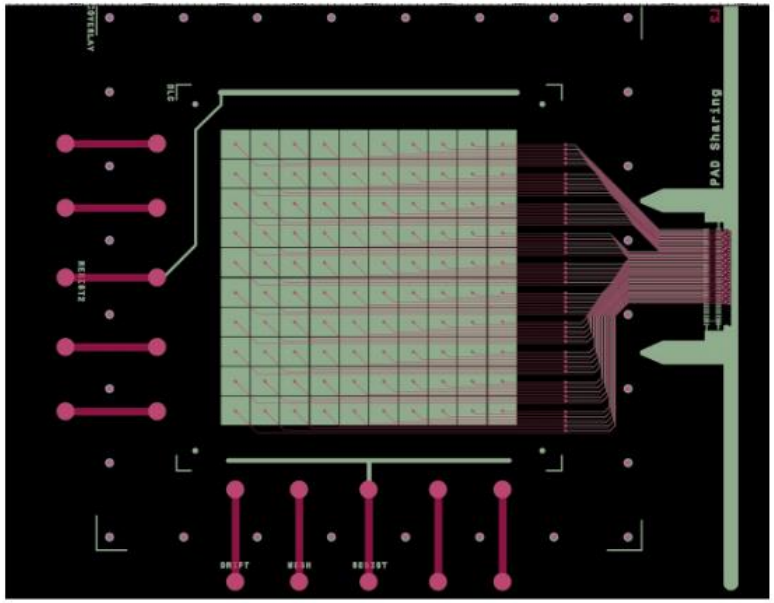
Summary and Outlook

- Micro-pixel detectors with σ < 100 µm need extremely high number channels, making them cost and power intensive
- Idea: Reduce the number of readout channels strongly via charge sharing on several stacked readout layers and reduce it further by a pixel-strip hybrid readout structure
- Two protypes tested: 5 layer detector tested with 120 GeV muons from the H4 beamline from SPS; core spatial resolutions of ~ 300 µm achieved but some substructures observed (under investigation)
- 3 layer detector optimised using an ^{55}Fe source and tested using cosmic muons; core spatial resolutions of ~ 150 µm achieved
- Inclined tracks analysis still ongoing for both detectors; but promising results obtained for both!
- Additionally, extensive simulation studies of the charge sharing between layers as well as studies using different gas mixtures are starting right now
- Lots of useful insights obtained from the DRD1 Gaseous Detectors school (thanks to the organisers!)

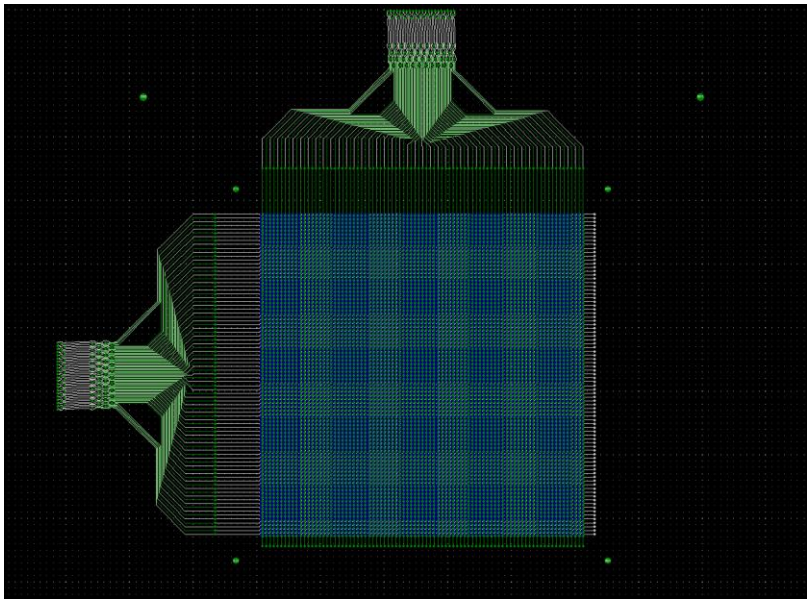
THANKS!

Backup: Pixel layout

5 layer PAD detector



3 layer PAD detector



Pixel Readout

- Expected no. of pixels hit in the smallest pixel layer for an area of 1.8 mm^2: 9
- Expected no. of pixels hit in the readout layer: 4-8