Julius-Maximilians-
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Bundesministerium
für Bildung
und Forschung

Readout and precision calibration of square meter sized micromegas detectors using the Munich cosmic ray facility

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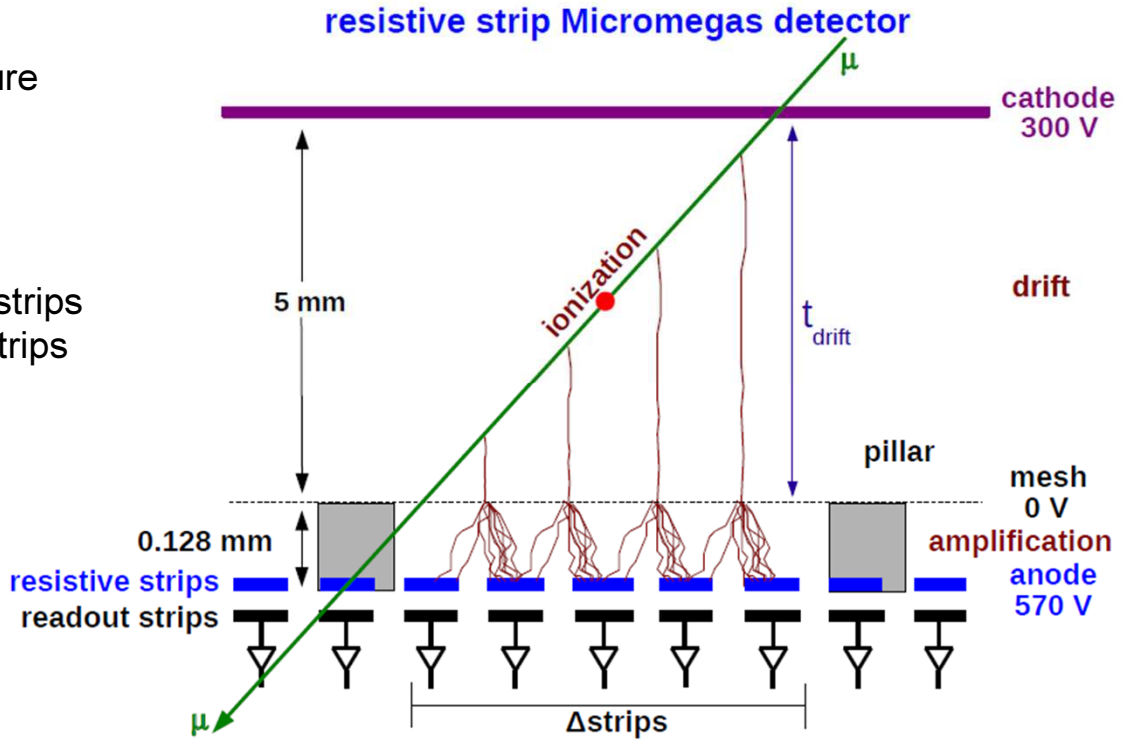
Micromegas principles

- MICROMEsh Gaseous Structure

- Electron drift region
- Amplification region

- Charge collection on resistive strips
- Charge detection on readout strips by capacitive coupling



Centroid method

$$x_{\text{cen}} = \frac{\sum_{\text{strips}} x_{\text{strip}} \cdot q_{\text{strip}}}{\sum_{\text{strips}} q_{\text{strip}}}$$

μTPC method: angle reconstruction

$$\Rightarrow \Theta = \arctan\left(\frac{1}{slope_{fit}} \times \frac{pitch}{v_{drift}}\right)$$

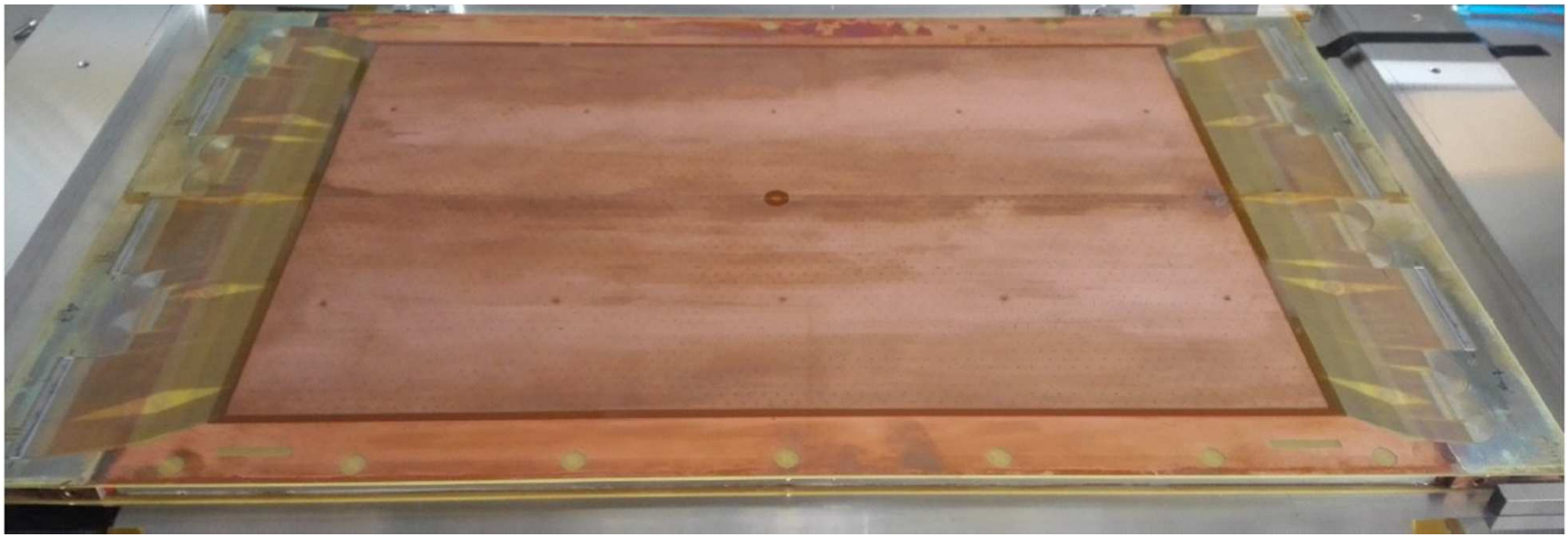
$$slope_{fit} = \frac{t_{drift}}{\Delta strip}$$

Large micromegas

- Small micromegas detectors up to 50 cm x 50 cm size are well understood and proven to work with high precision.

- Going to larger detectors requires precise assembly of multiple printed circuit boards in order to maintain the precision

⇒ A calibration method is needed



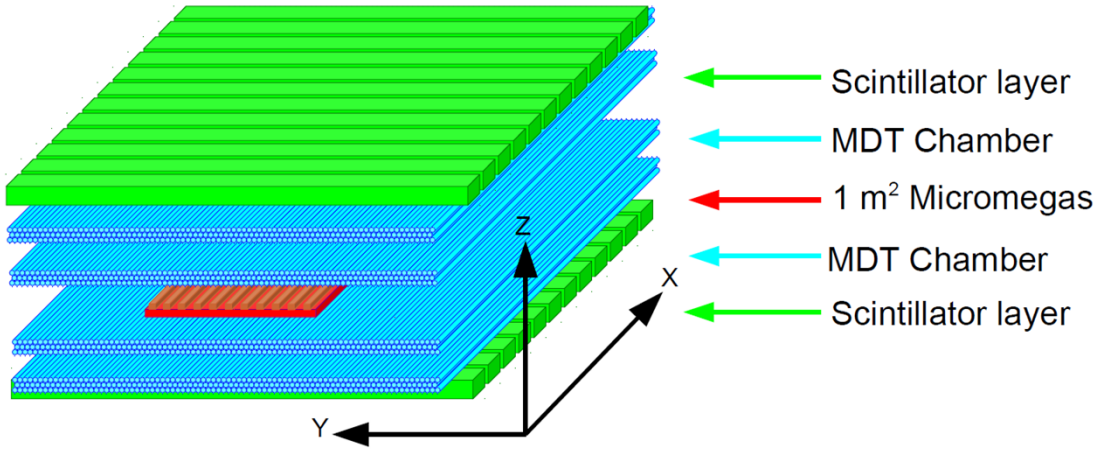
Munich cosmic ray facility

- Two Monitored Drift Tube chambers (MDT)
  => two reference tracks

- Two trigger scintillator Hodoscopes
  ⇒ second coordinate
  ⇒ segmentation of detector under test
  in 10 cm wide segments

- 34 cm iron absorber ⇒ E_μ > 600 MeV

- Active area of 9 m², $\Theta \in [-30°, 30°]$



Scintillator layer
MDT Chamber
1 m² Micromegas
MDT Chamber
Scintillator layer

⇒ Investigation of the whole active area of 2-3 m² micromegas

1m² L1 micromegas detector

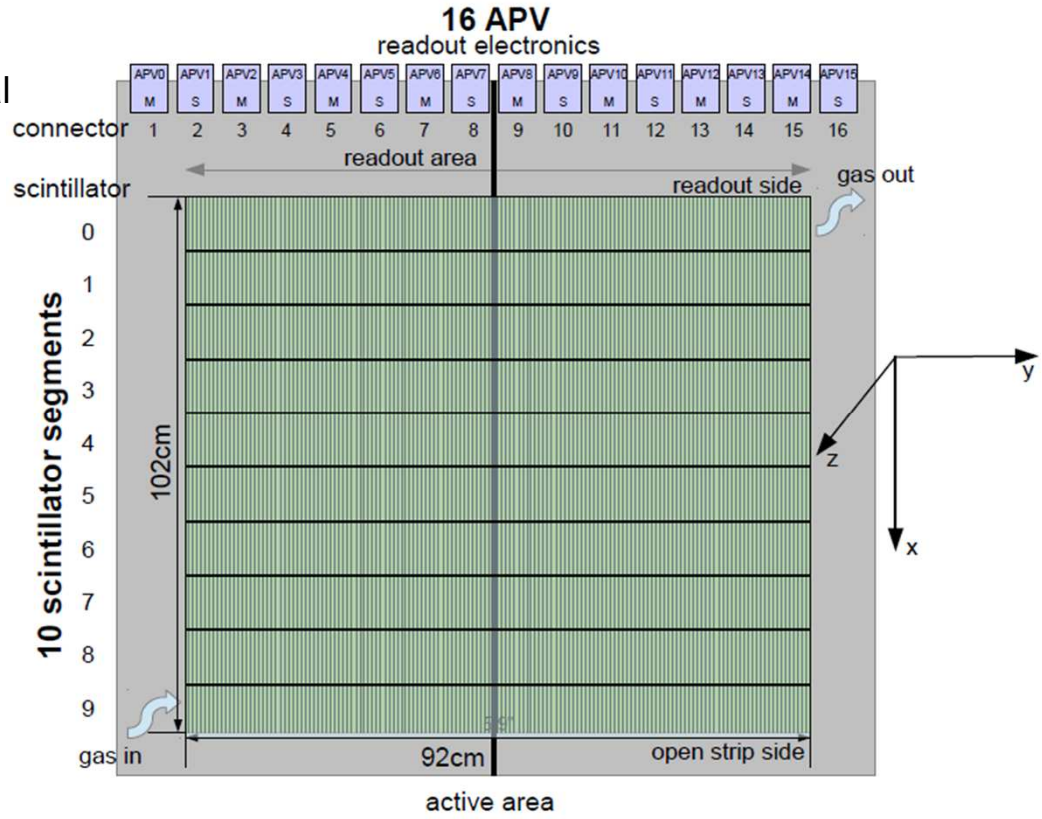
- Resistive strip technology

- Active area: 0.92 x 1.02 m²
- Two readout boards with 2048 strips total
- Pitch: 0.45 mm

- Ar:CO_2 93:7 @ atm. Pressure

- 16 APV25 frontend boards
  57.6 mm wide (y - coordinate)
- 10 scintillator segments
  100 mm wide (x - coordinate)

=> Subdivision of detector in
16 APV * 10 scintillator
= 160 partitions



⇒ Calibration and alignment for each of the 160 partitions

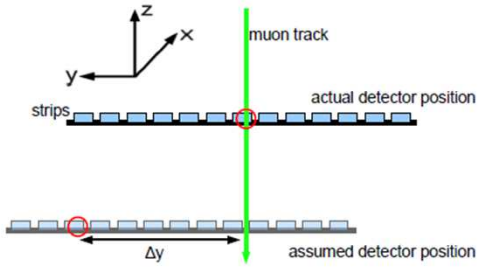
Calibration using reference tracks

- Measurement of y-position (perpendicular tracks)
  residual via centroid method
  $res = y_{measured} - y_{predicted}$
  $\Delta y = res$

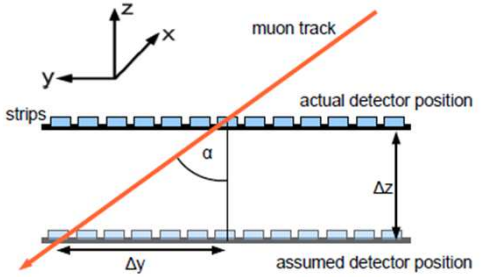
- Measurement of z-position (inclined tracks)
  $\Delta z = res / \tan\alpha$
  $res = m_y * \Delta z$

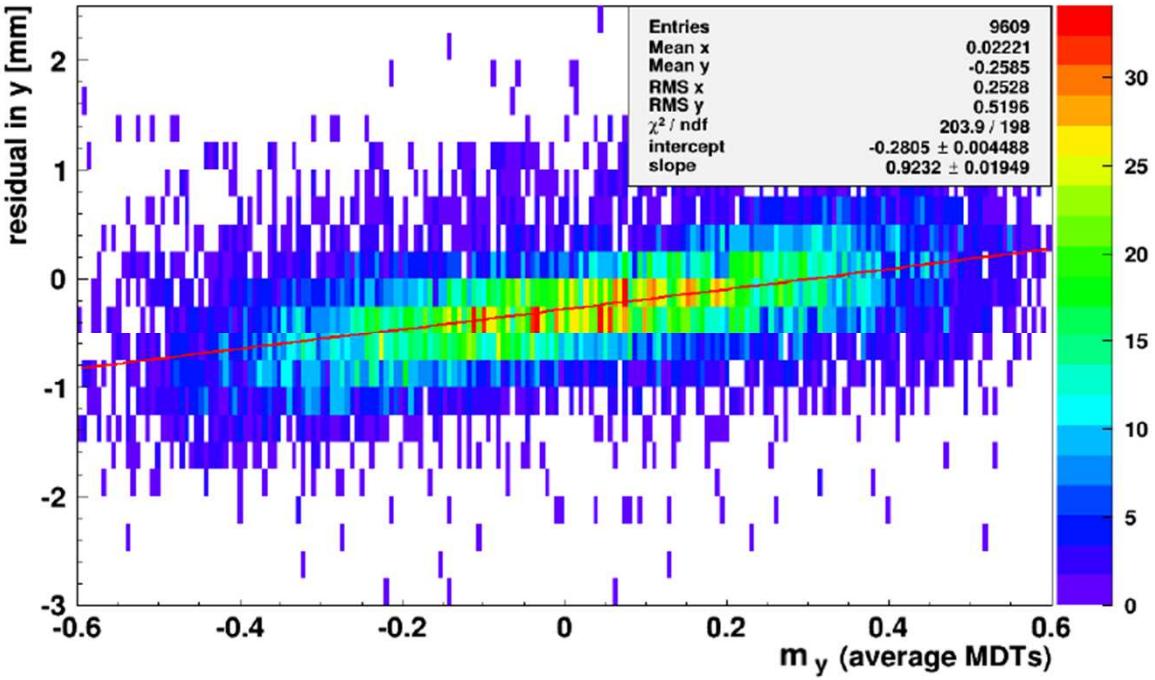
- Fit with straight line
  $\Rightarrow$ Δz = slope
  Δy = intercept

measurement of y-position



measurement of z-position

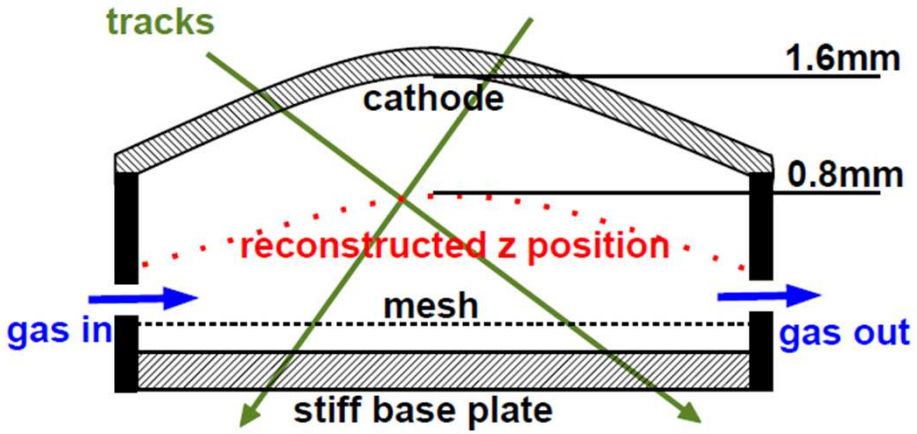




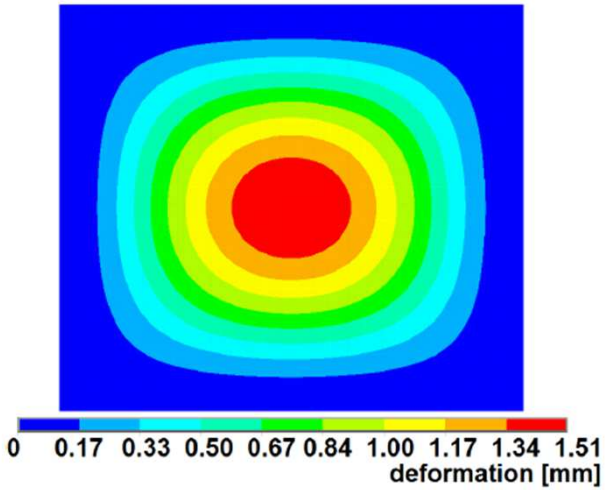
Chamber deformation in z

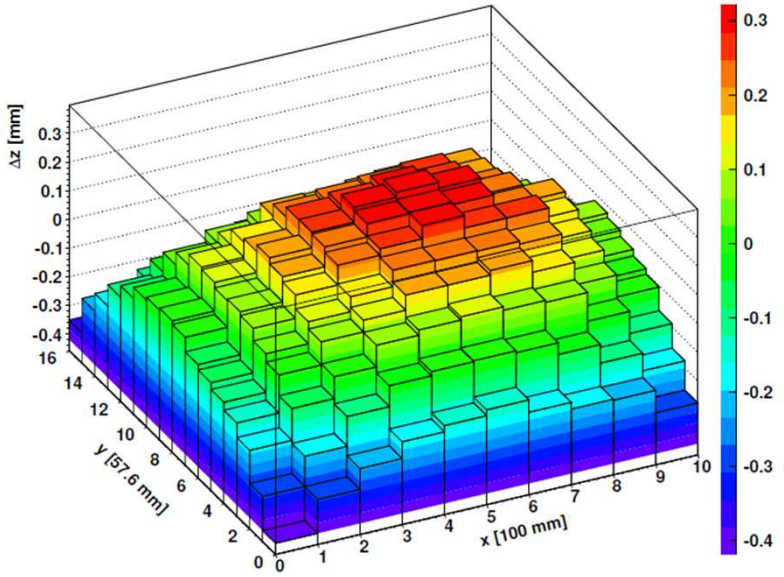
- Inclined muon tracks:
  - Drift gap deformation due to slight overpressure (10 mbar)
  - Maximum deviation from plane measured ~0.8 mm

    ⇒ 1.6 mm cathode deformation due to stiff base plate
  - Resolution better 0.1 mm



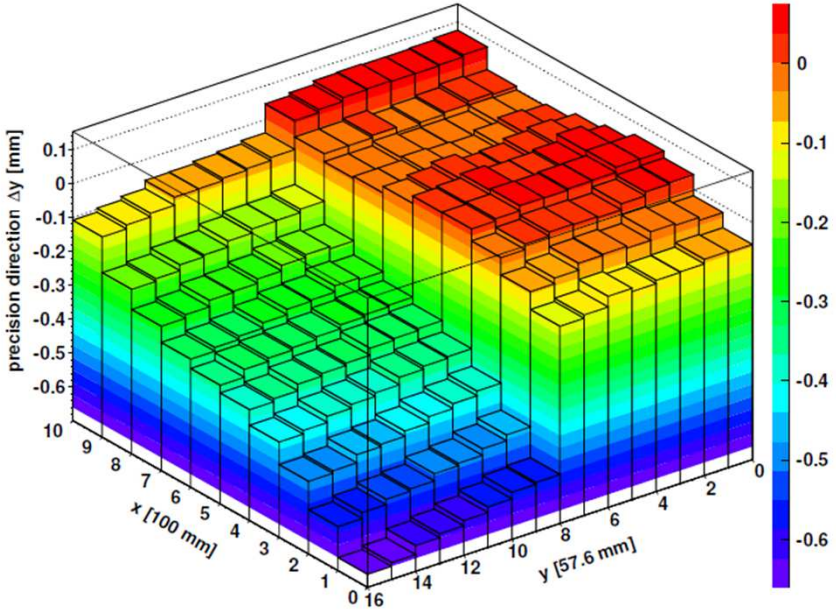
Finite elements simulation (ANSYS)

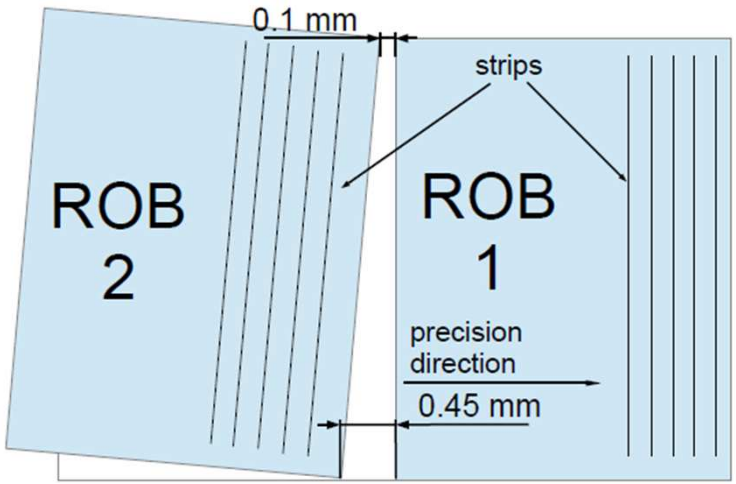




Readout board alignment

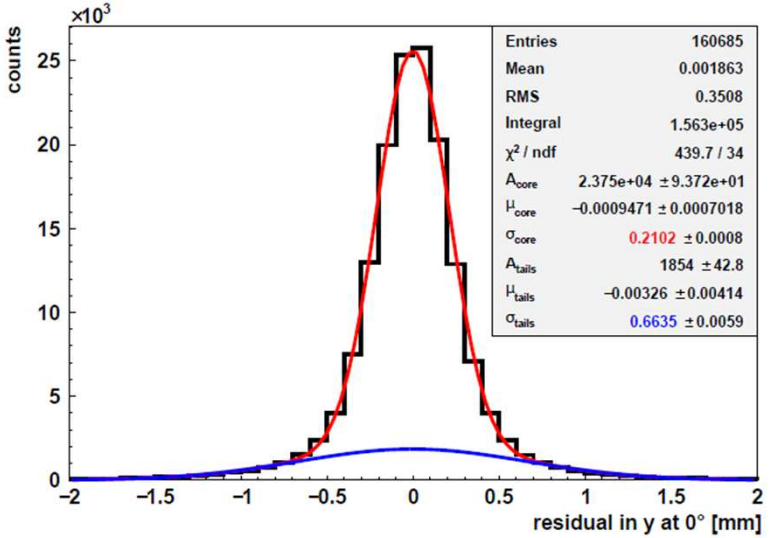
- L1 micromegas chamber:
  - 2 readout boards with resistive and readout strips
  - No dedicated alignment tooling used during the construction
  - Variation of gap size in between boards
- Using perpendicular tracks:
  - Shift: 100 μm
  - Rotation: 350 μm/m
  - Determination of strip position within 15 μm



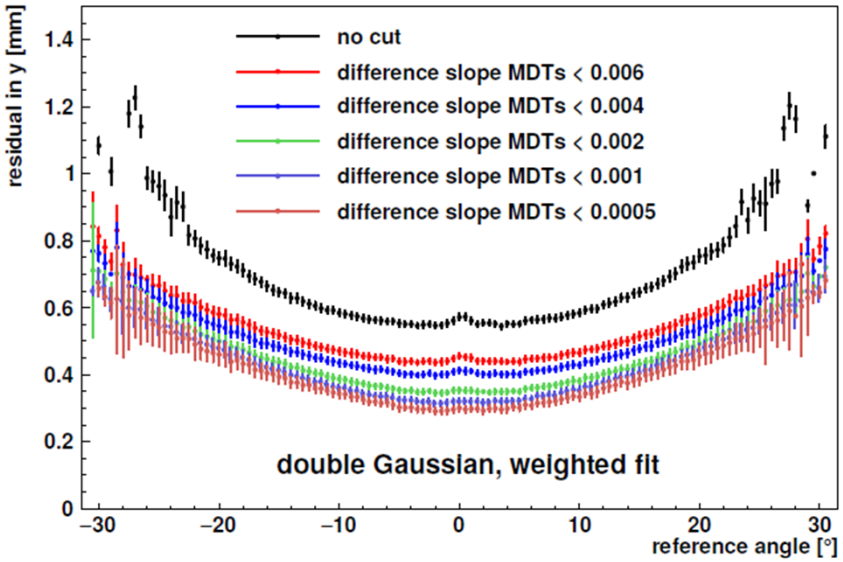


Spatial resolution

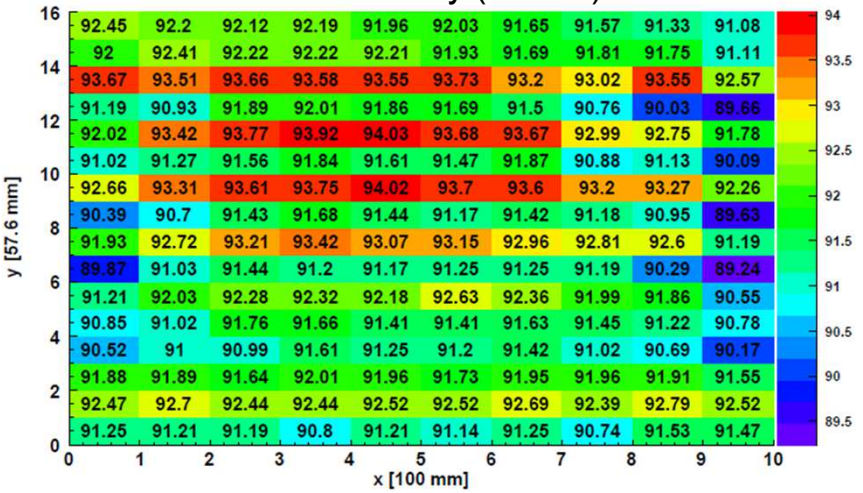
- Determination of spatial resolution:
  - Residual with centroid method
  - Fitted with double Gaussian function
  - Sigmas weighted by integral
- Spatial resolution limited by:
  - Multiple scattering of cosmic muons
  - Extrapolation of MDT tracks



Cut on slope difference of reference detectors

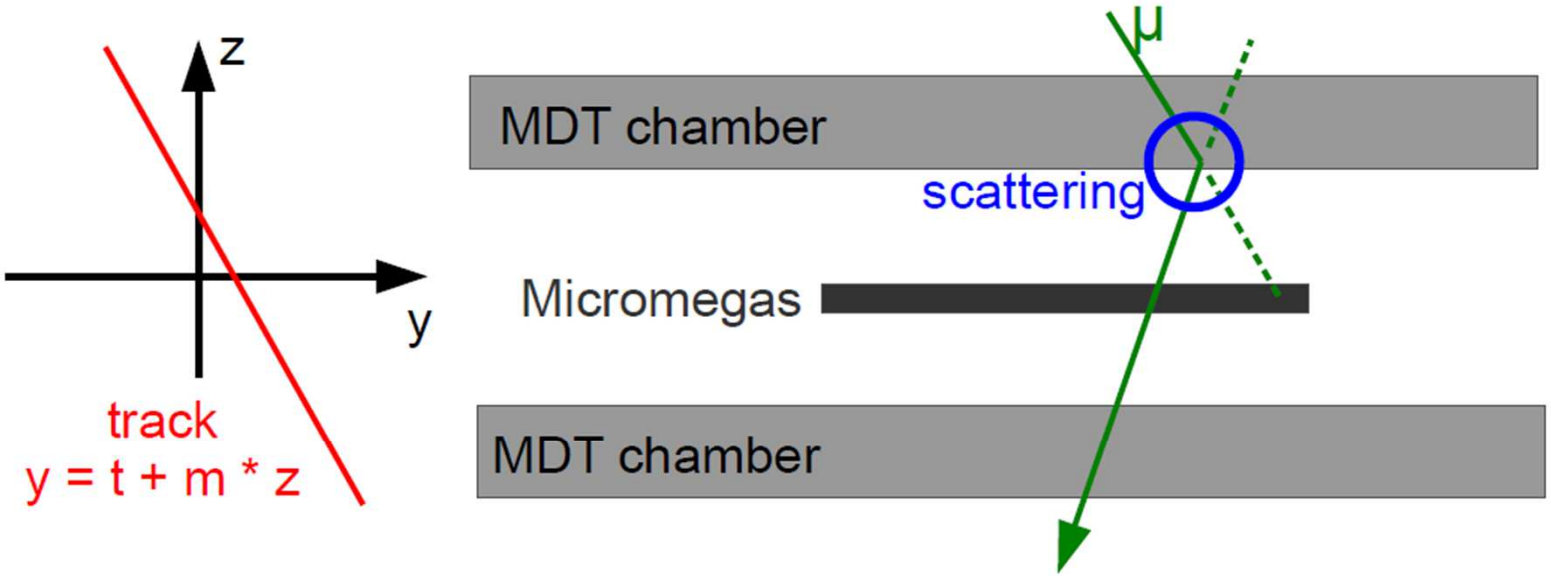


3σ efficiency (92 ± 1)%



Cosmic muon scattering

- Two track segments with different slope
  ⇒ reconstruct the deflection point in space



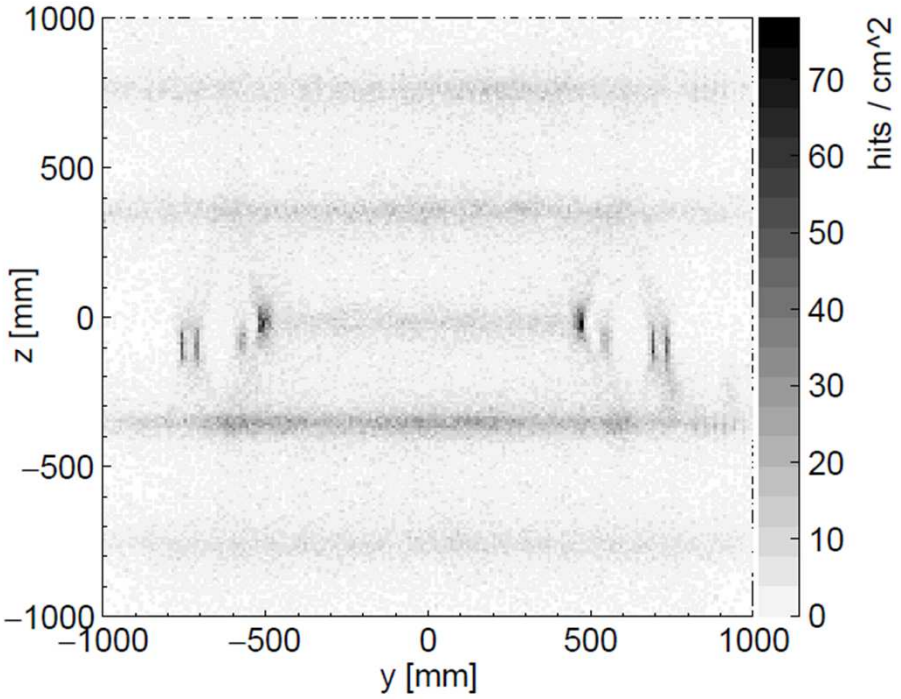
$$\Rightarrow \quad z_{\text{scattered}} = \frac{t_{\text{track1}} - t_{\text{track2}}}{m_{\text{track2}} - m_{\text{track1}}}$$

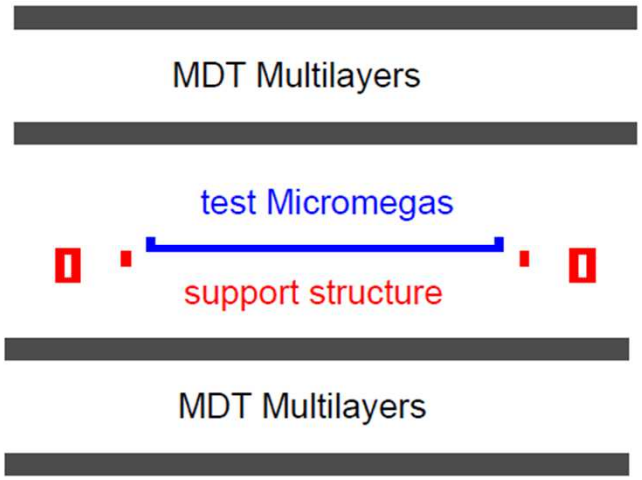
$$\Rightarrow \quad y_{\text{scattered}} = t_{\text{track1/2}} + m_{\text{track1/2}} \cdot z_{\text{scattered}}$$

Muon tomography in the y-z-plane

- Reconstruction of track deflection point in the y-z-plane
- Track slope difference > 0,03 selected

⇒ 2D image of the detectors and support structure

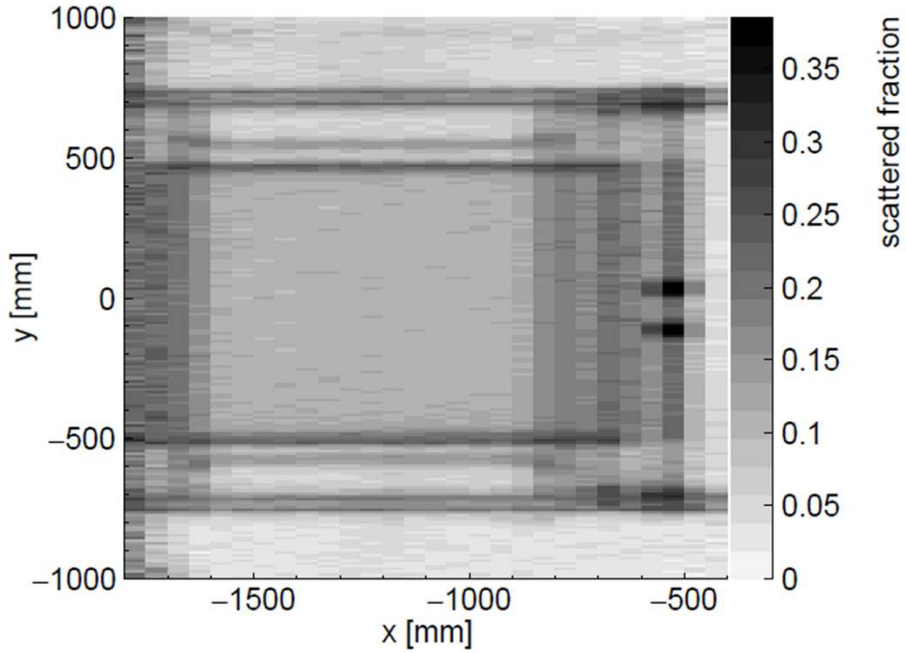


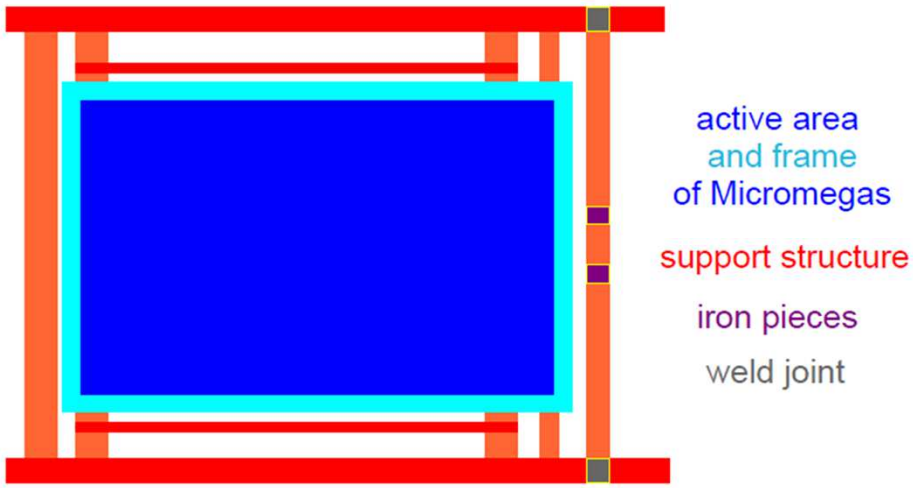


Muon tomography in the x-y-plane

- Coarse segmentation of the scintillator hodoscope along the x-axis
  ⇒ reconstruction of the scattering in the x-y-plane

- Only a slice in z is considered

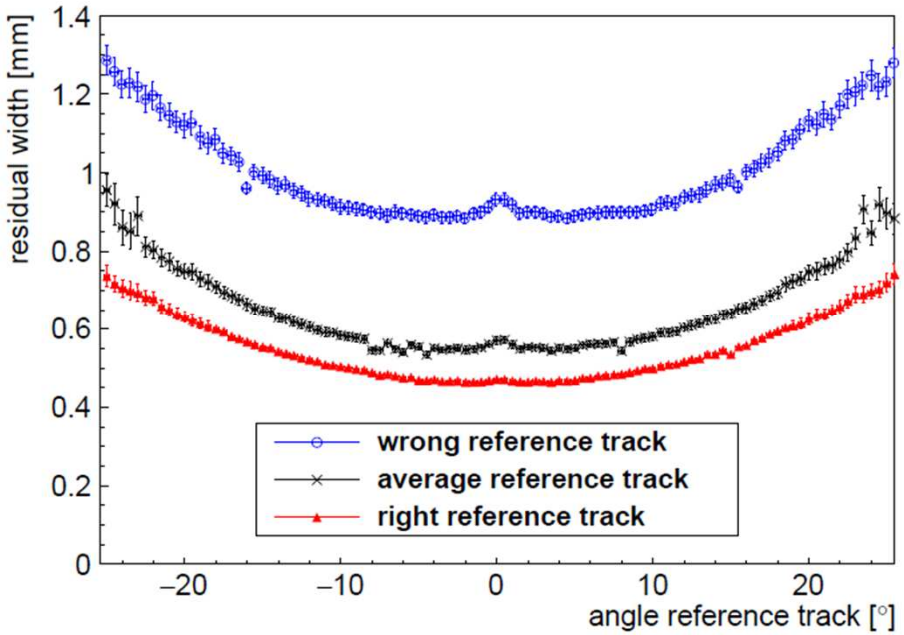


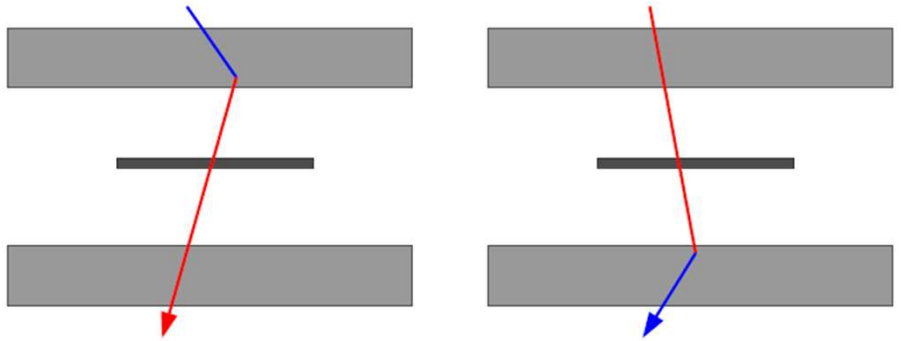


Influence on spatial resolution

- Scattering point known
  ⇒ select just the track segments through the detector under test

- Better residual width distribution without loss of statistics

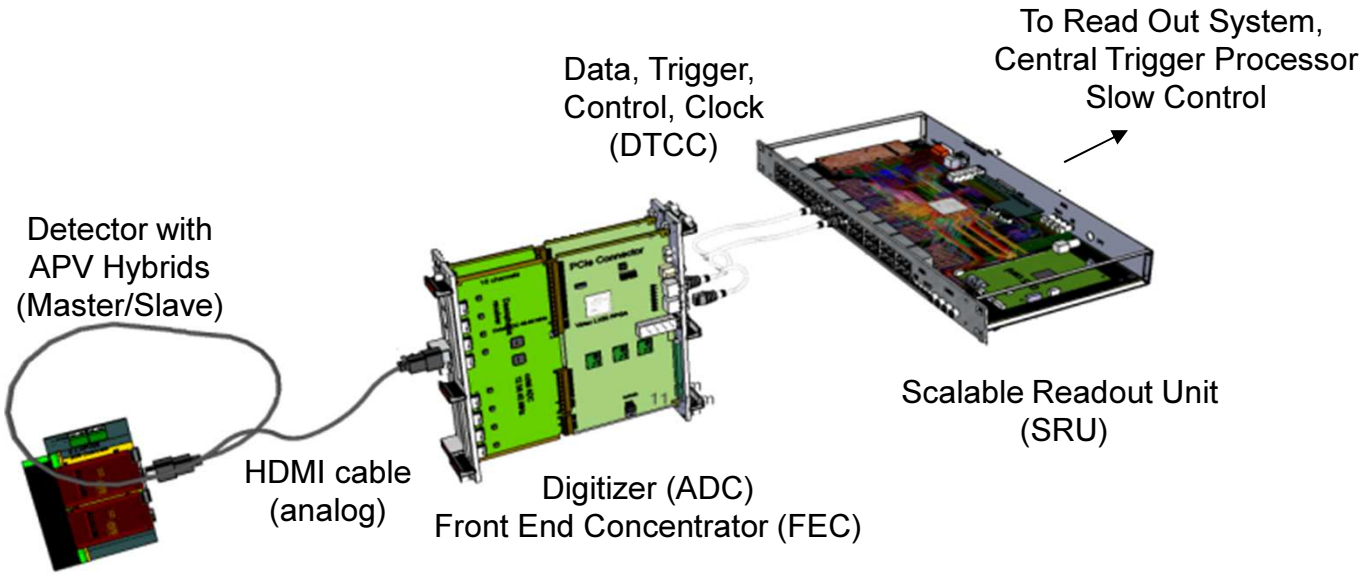




Readout synchronization

- MDT readout:
  - similar fashion as in the ATLAS detector
  - Clock and trigger distribution via optical TTC fiber

- Micromegas readout:
  - RD51 Scalable Readout System (SRS) with APV25 hybrids
  - Multiple FEC cards for larger detectors (>2048 channels)
    ⇒ Including the optional Scalable Readout Unit (SRU) for synchronization

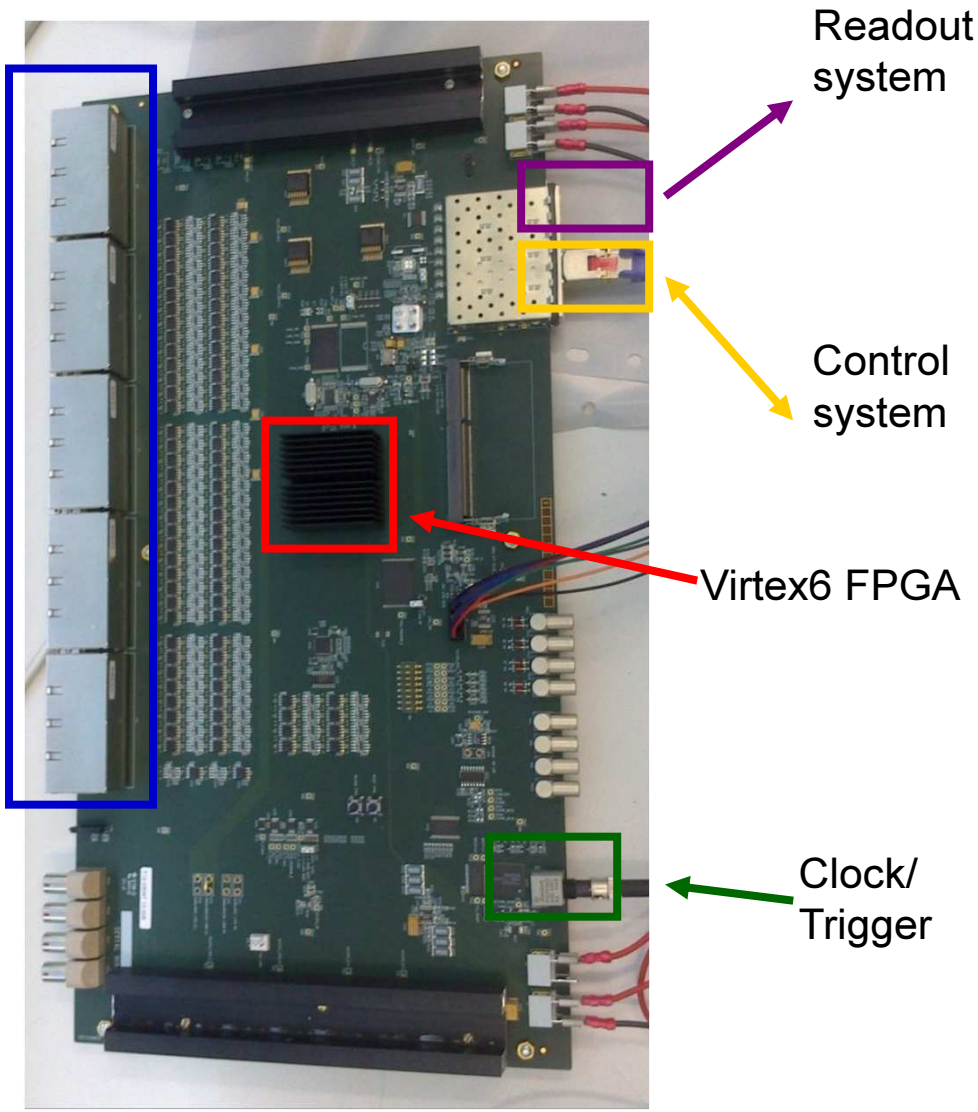


S. Martoiu, H. Muller, A. Tarazona, J. Toledo: Development of the scalable readout system for micro-pattern gas detectors and other applications, Journal of Instrumentation, Vol. 8 C03015 (2013)

Scalable Readout Unit (SRU)

Event building and
Interface to CRF infrastructure:

- Detector synchronization and
  data collection(**DTCC**, A. Martinez)
- Event building, data formatting and **ROD Firmware** (A. Zibell)
  (correlation MDT ⇔ Micromegas)
- Data transmission to PC (ROS)
  via **SLINK** (M. della Volpe et al.)
- Slow control, data preview
  via Ethernet:
  configuration data: Register settings on Frontend chip, SRS, SRU, ...
- Reception and distribution of
  triggers, synchronization (**TTC**)



Summary

- Calibration of the whole active area of large micromegas detectors in a cosmic ray facility with accuracy better than 30 μm

- Measurements include:
  - Homogeneity of efficiency and charge distribution
  - Determination of z position with 100 μm resolution
  - Calibration of readout strip position every 10 cm with an accuracy of 15 μm

- L1 micromegas (1 m²)
  - Shift and rotation between readout boards calibrated
  - 1.6 mm deformation of the drift gap due to 10 mbar overpressure
  - Spatial resolution limited by multiple scattering, also in the MDTs

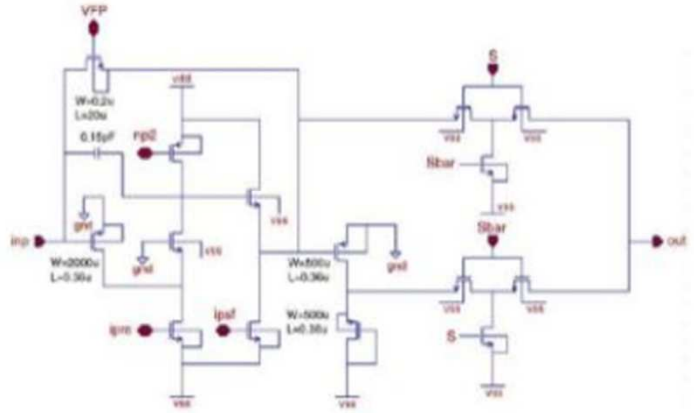
- Muon tomography with the system is possible with enough statistics

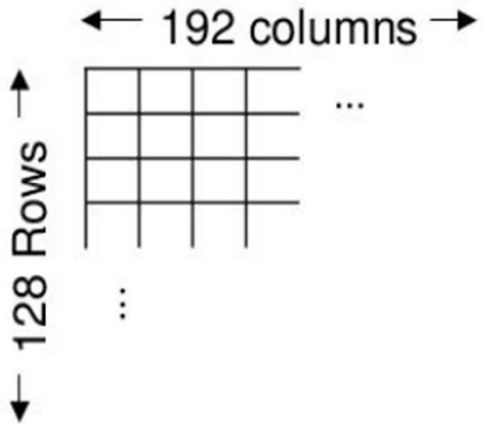
- Micromegas readout using APV25 chips and SRS electronics

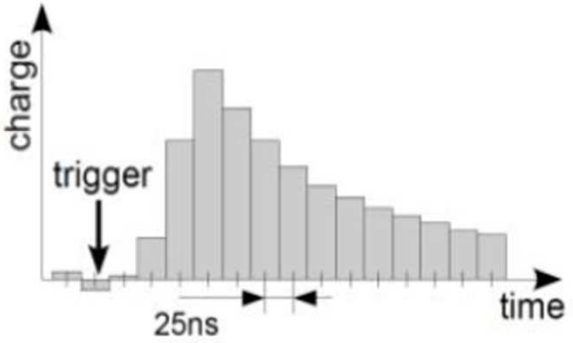
- Synchronization in between multiple micromegas FEC cards and MDTs
  using a SRS SRU unit with custom firmware

Backup

128 preamplifier channels → Analogue pipeline buffer → Selected columns output







Backup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