Calibration of Detector Parameters and Detector Geometry of Large Area Micromegas using Cosmic Rays

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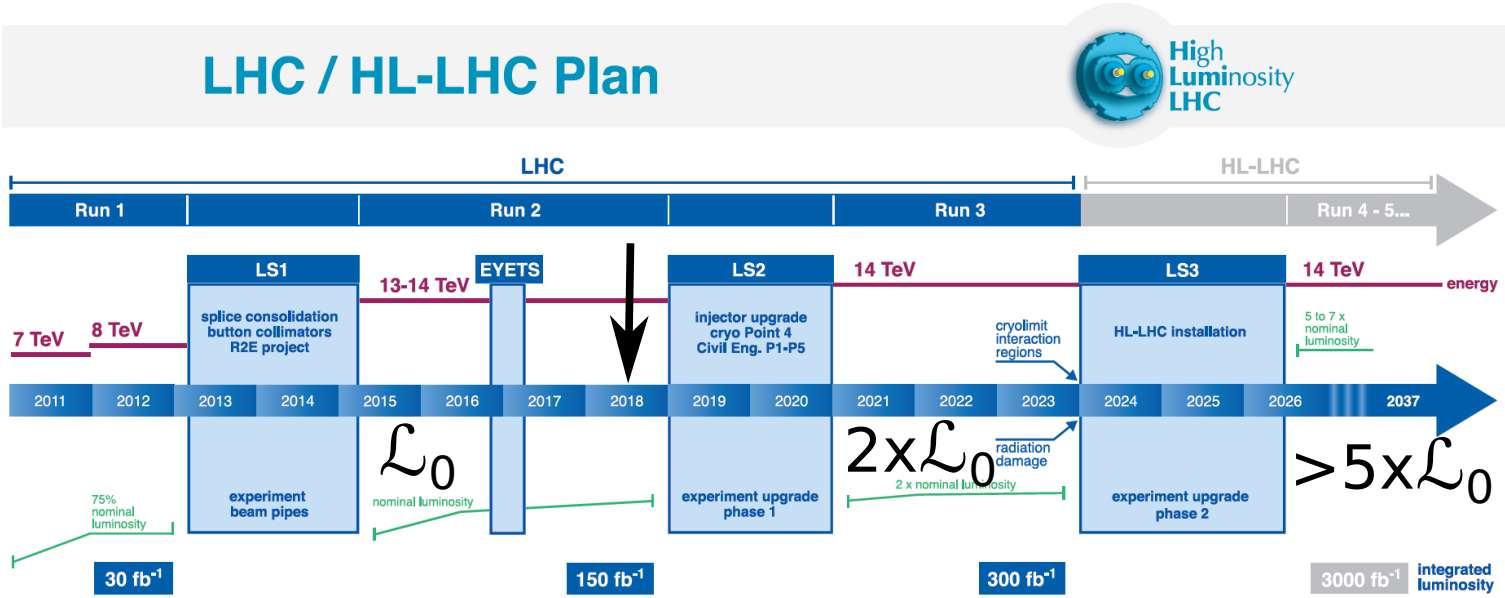
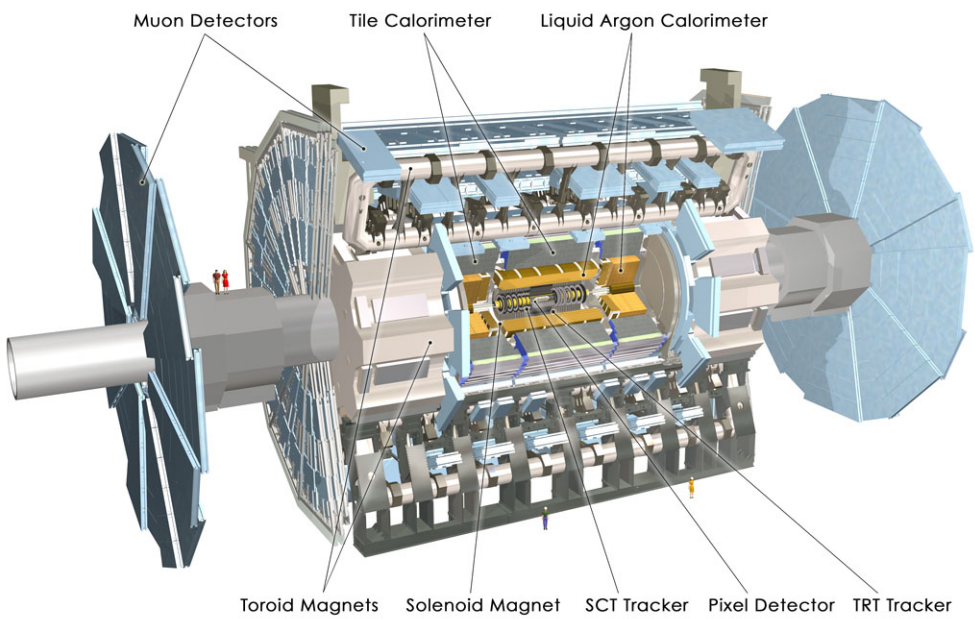
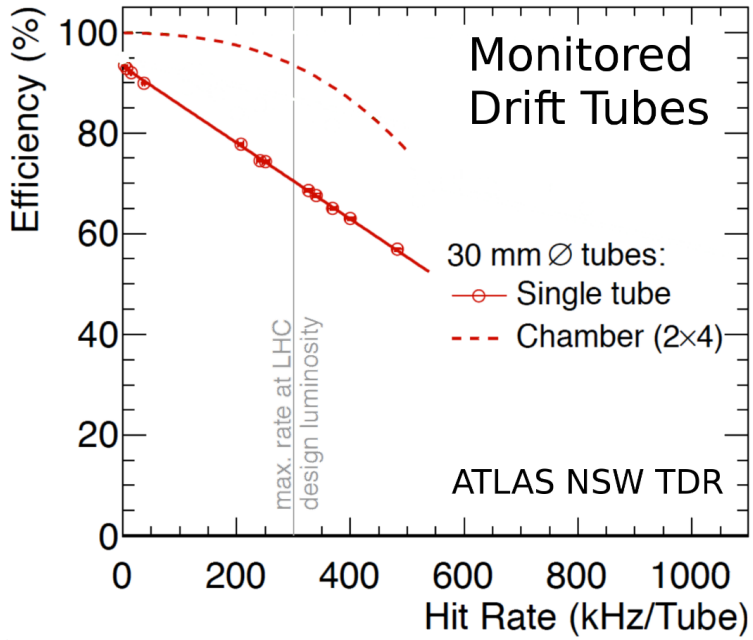
Bundesministerium
für Bildung
und Forschung

LHC Upgrade Status



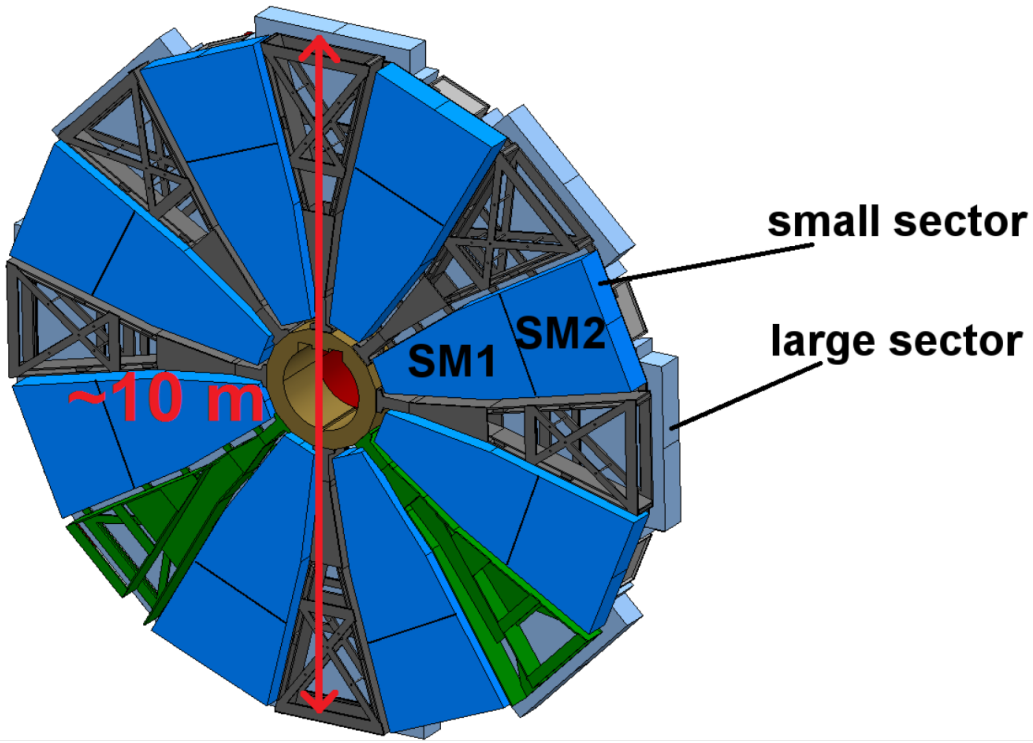




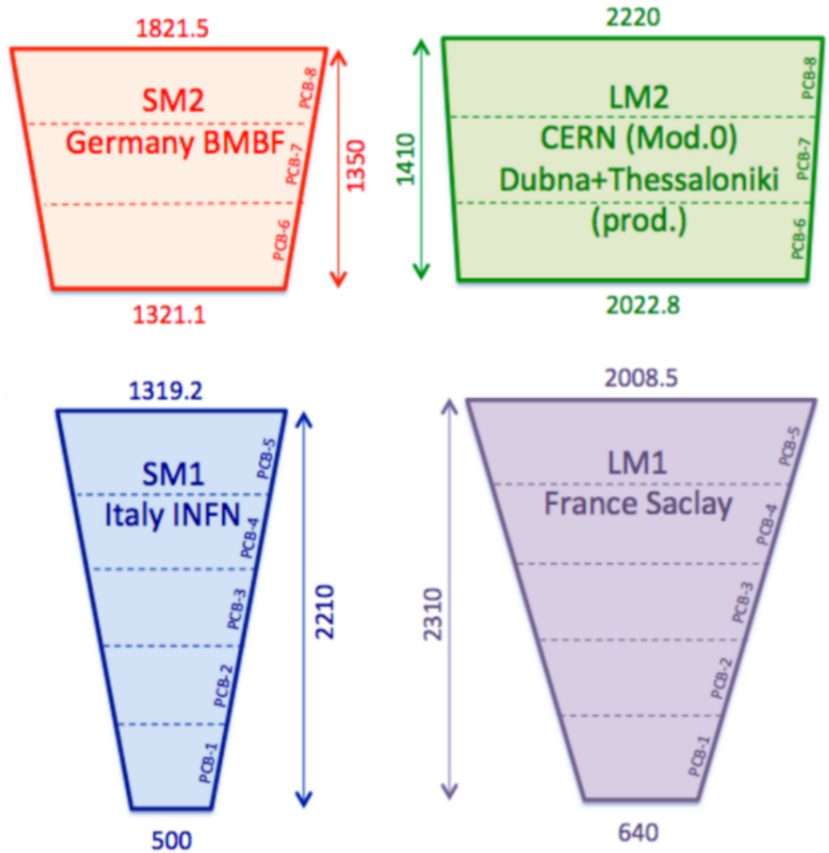
Upgrade of the Muon Small Wheels

replacement of the current end caps of the muon spectrometer by small-strip Thin Gap Chamber (sTGC) and Micromegas quadruplets

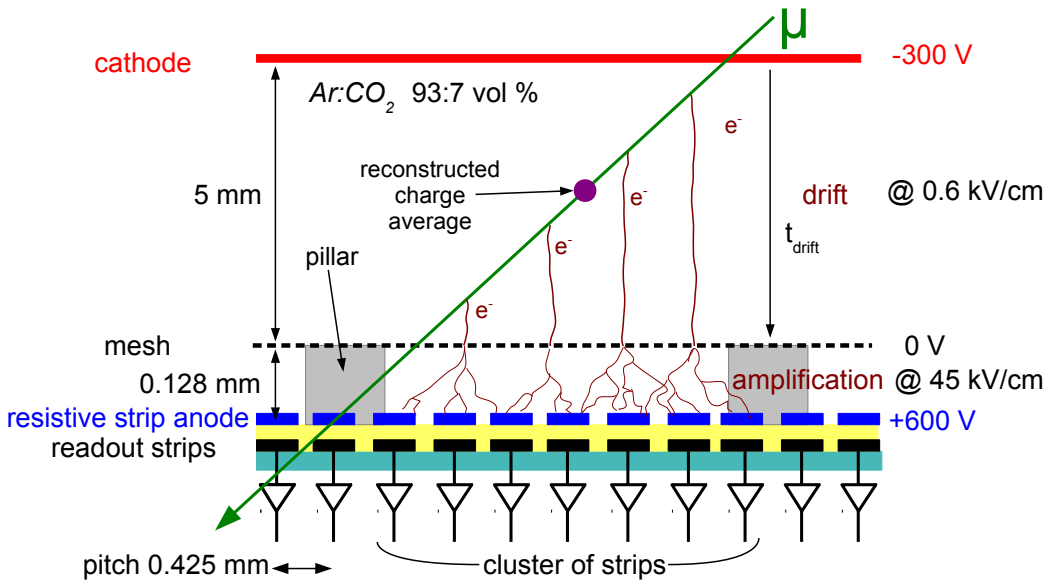
New Small Wheel Sectors



Micromegas quadruplets

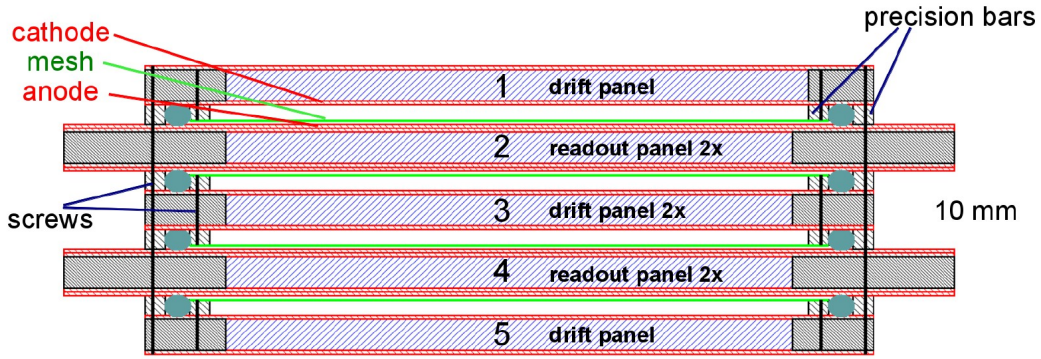


MICROMEGAS - MICROMEesh GAseous Structure



- drift region for electron and ion transport
- high field in amplification region to create electron avalanches
- position reconstruction using charge weighted mean of hit strips
- reconstruction of incident angle using drift time measurements

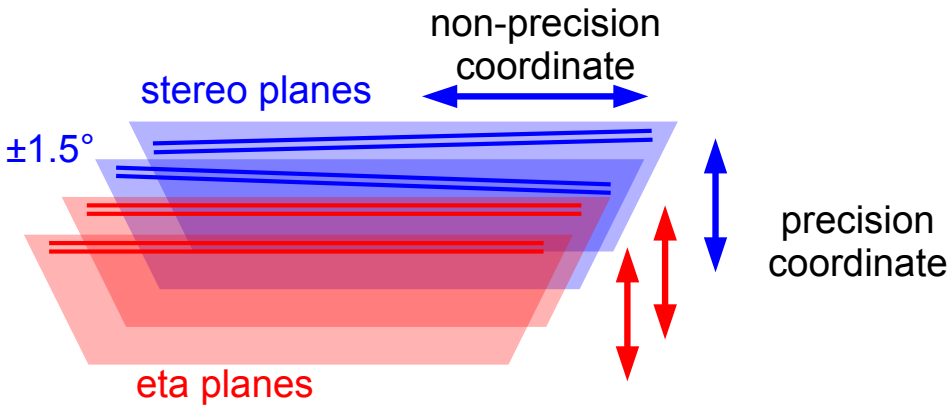
Micromegas Quadruplet



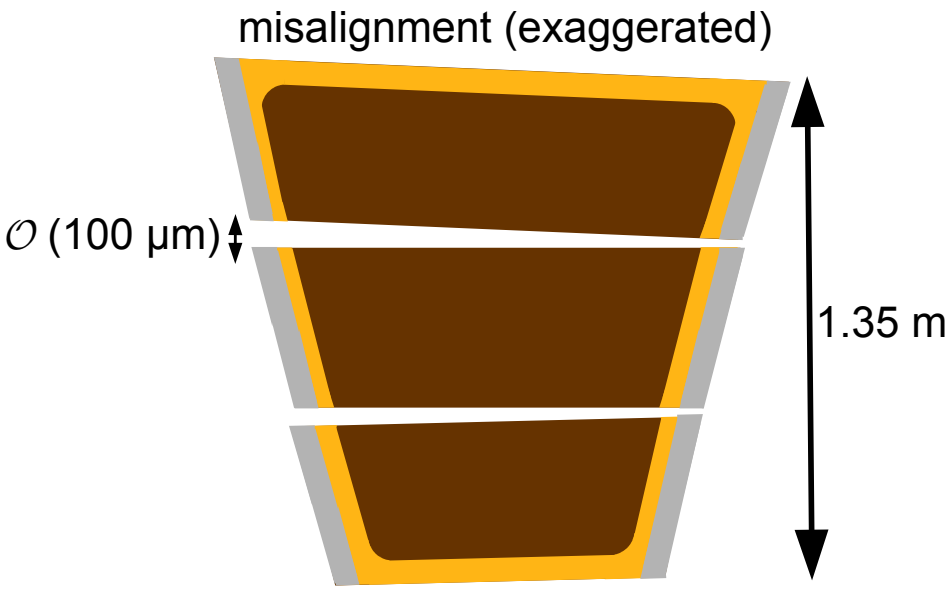
4 active layers of Micromegas

$\Rightarrow 2 \times$ back-to-back

Design of Readout Anodes



- eta planes for precision reconstruction in pseudorapidity direction perpendicular to anode strips
- stereo planes for additional coarse position information along the anode strips



limitations by industry
micropattern readout anode: width $\leq$ 50 cm

$\Rightarrow$ 3 printed circuit boards (PCB) per active layer

$\Rightarrow$ reconstruction and calibration of alignment errors (during production) required

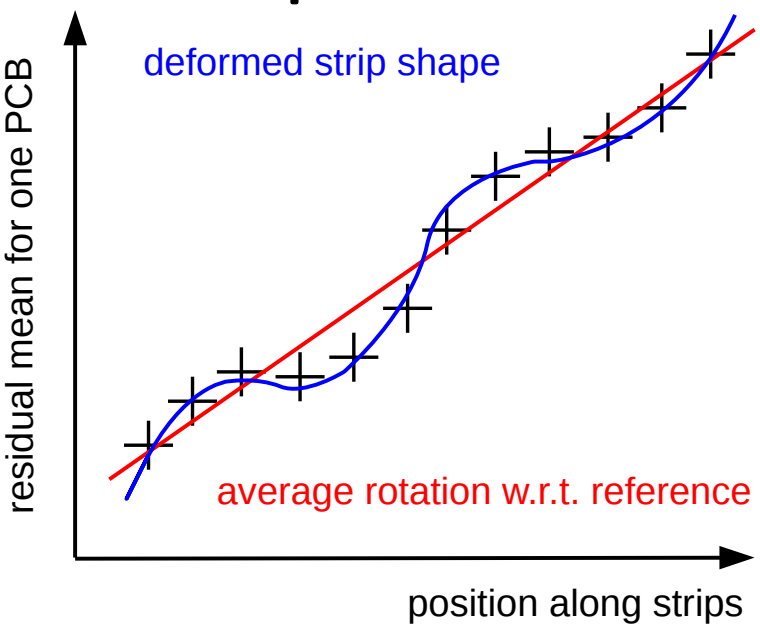
Precision Reconstruction of Geometrical Properties

Boards of the Readout Anode can have:

$\Rightarrow$ rotations and shifts w.r.t. each other

$\Rightarrow$ non-straight strip shape and pitch deviation

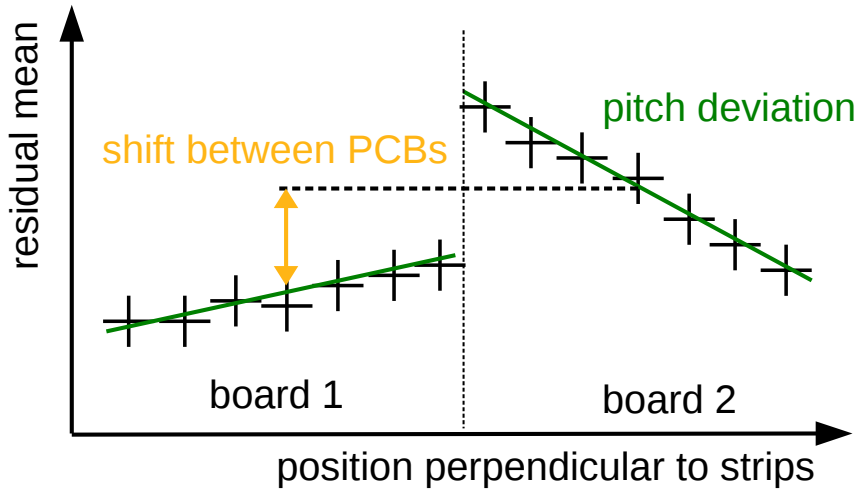
residual mean VS non-precision direction



$\Rightarrow$ slope indicates rotations

$\Rightarrow$ strip shape is given by deviation from straight line

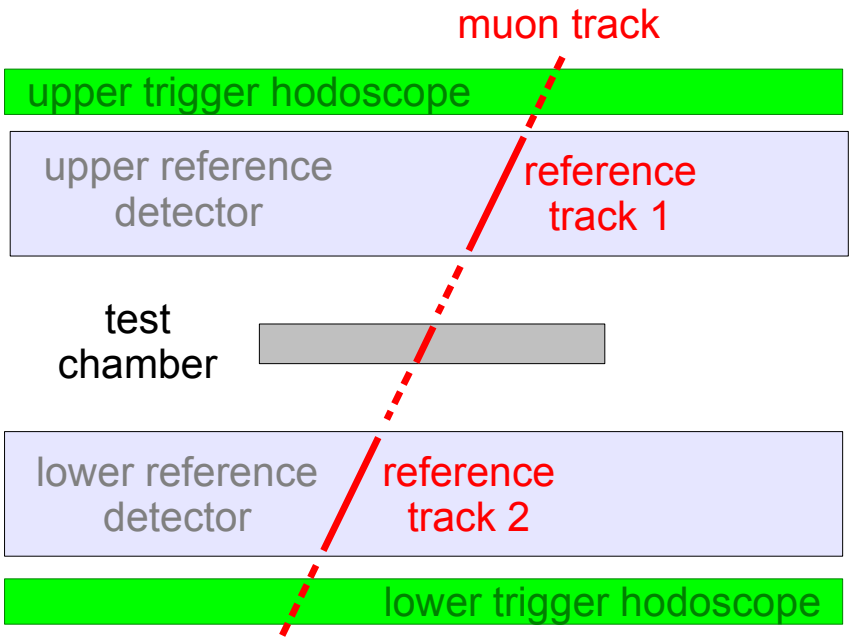
residual mean VS precision direction



$\Rightarrow$ shift between boards is given by difference of the centers

$\Rightarrow$ slope indicates deviation to nominal pitch

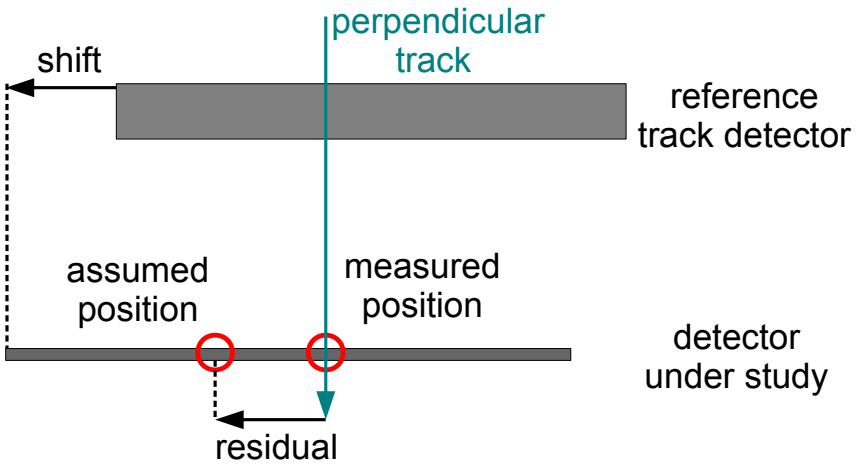
LMU Cosmic Ray Facility in Garching

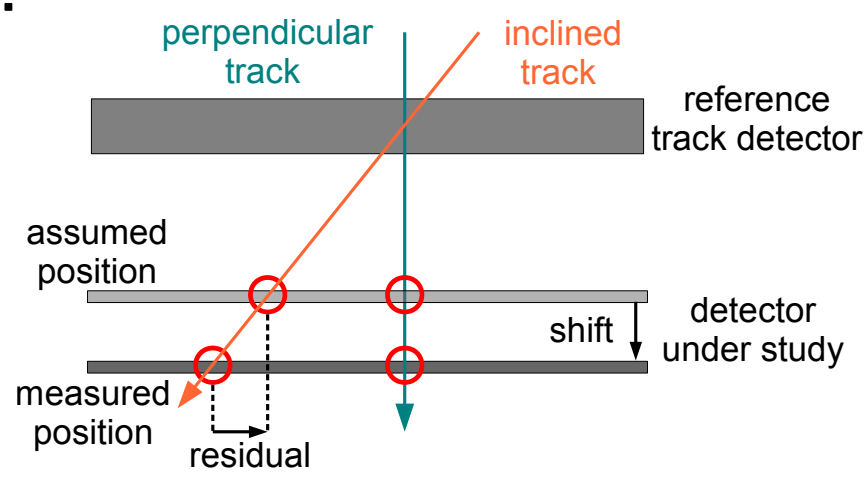


- 2D track reconstruction with two Monitored Drift Tube (MDT) chambers
- trigger via scintillator hodoscope with $\approx 10\,\text{cm}$ resolution in direction along the wires
- MDT chambers : $2.2\,\text{m} \times 4\,\text{m}$
  $\Rightarrow$ active area : $8\,\text{m}^2$, angular acceptance : $\pm 30^\circ$
- readout of the full module (12288 channels) with 96 APVs connected to 6 FECs @ full 130 Hz µ-rate (tested up to 500 Hz with random trigger)

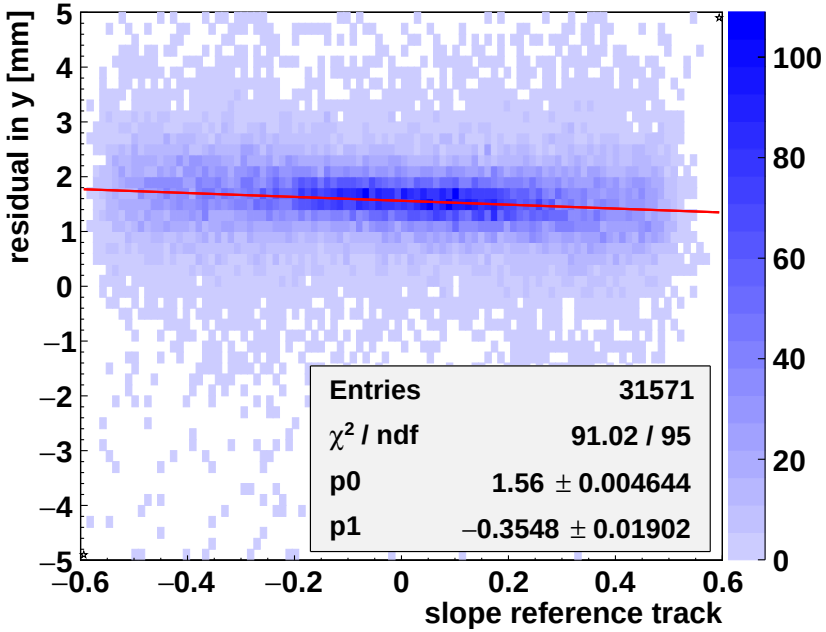
Alignment using Reference Tracks

Idea:





Implementation:



residual = $pos_{measured}$ - $pos_{reference}$

$\Rightarrow$ residual vs. slope (reference track)

$\Rightarrow$ linear fit

$shift_{horizontal} = intercept_{fit}$

$shift_{vertical} = slope_{fit}$

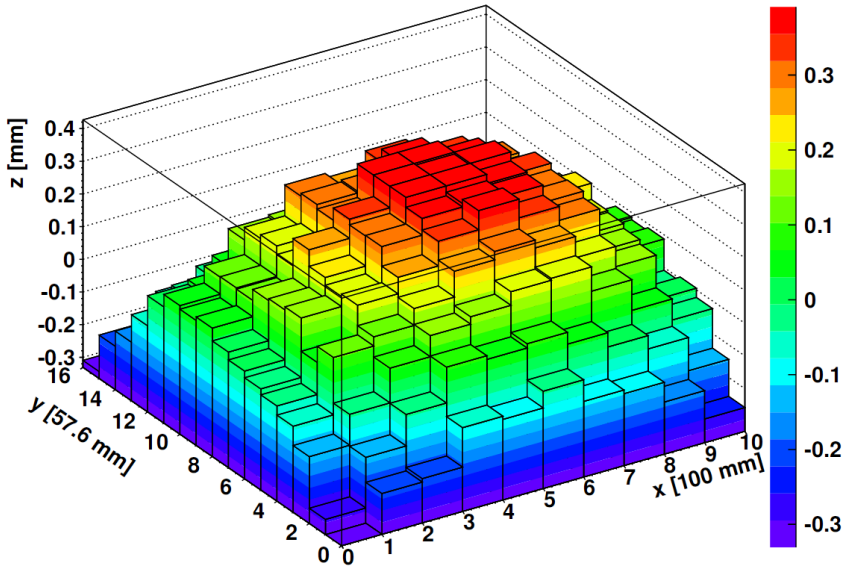
Measurement Overview

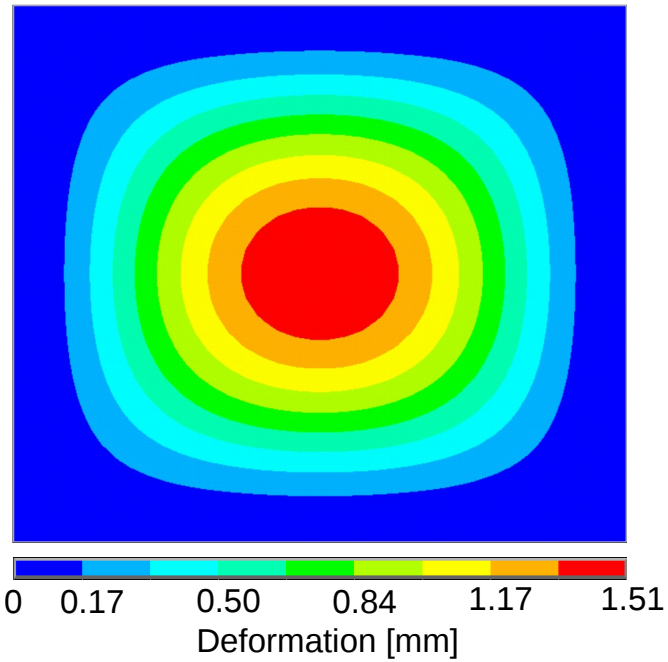
- $1\,m^2$-sized prototype detector called L1
  $\Rightarrow$ proof of principles
- $2\,m^2$-sized 4-layer prototype chamber called Module 0
  $\Rightarrow$ first working quadruplet
- $2\,m^2$-sized 4-layer series chamber for NSW called Module 1
  $\Rightarrow$ first series module

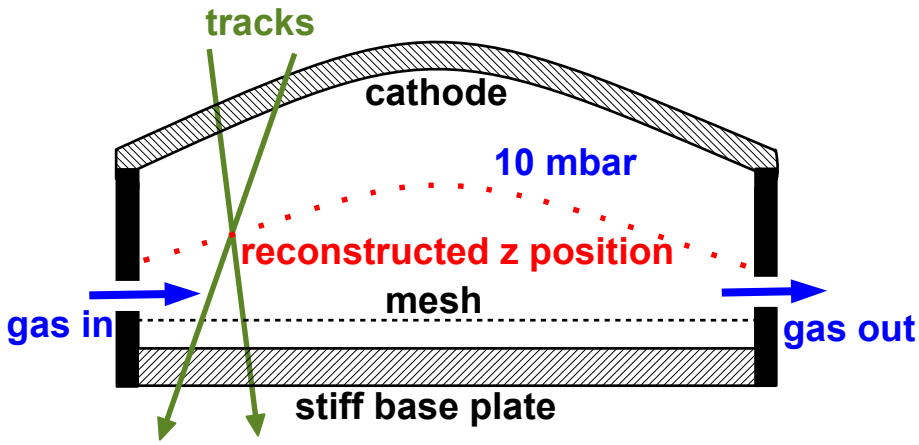
L1

1 m^2-sized Micromegas

Deformation of the Drift Region due to Overpressure (L1)





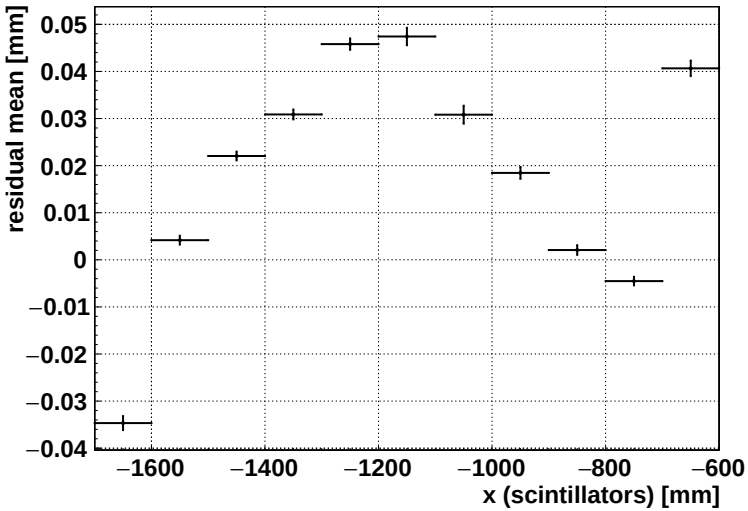


- drift gap deformation due to small overpressure (no interconnections)
- maximum deviation of 0.8 mm from central plane
  $\Rightarrow$ 1.6 mm at cathode
  (stiff base plate support)
- deformation in agreement with finite element simulation (ANSYS)
- for NSW Micromegas interconnections will reduce deformation to about 50 µm

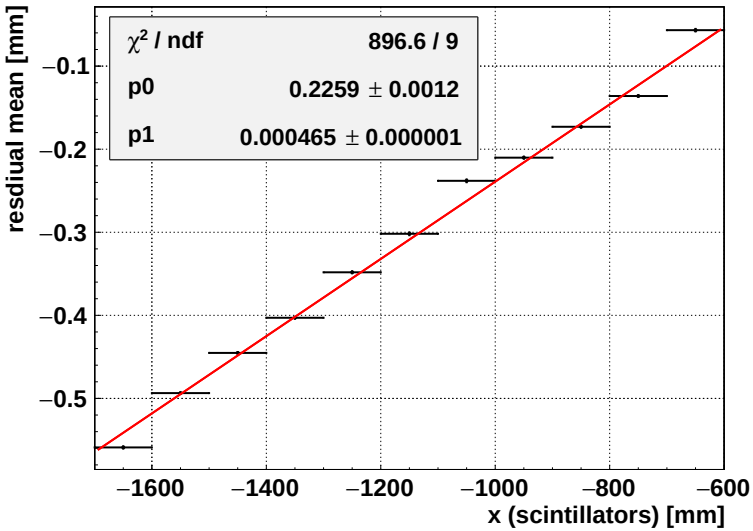
Rotations and Shifts between Anode Boards (L1)

residual mean VS non-precision direction

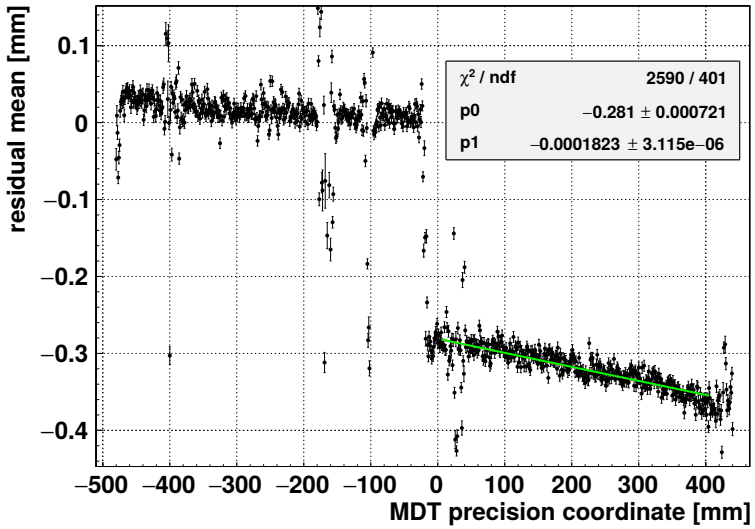
board 1



board 2 (**not aligned during assembly**)



residual mean VS precision direction

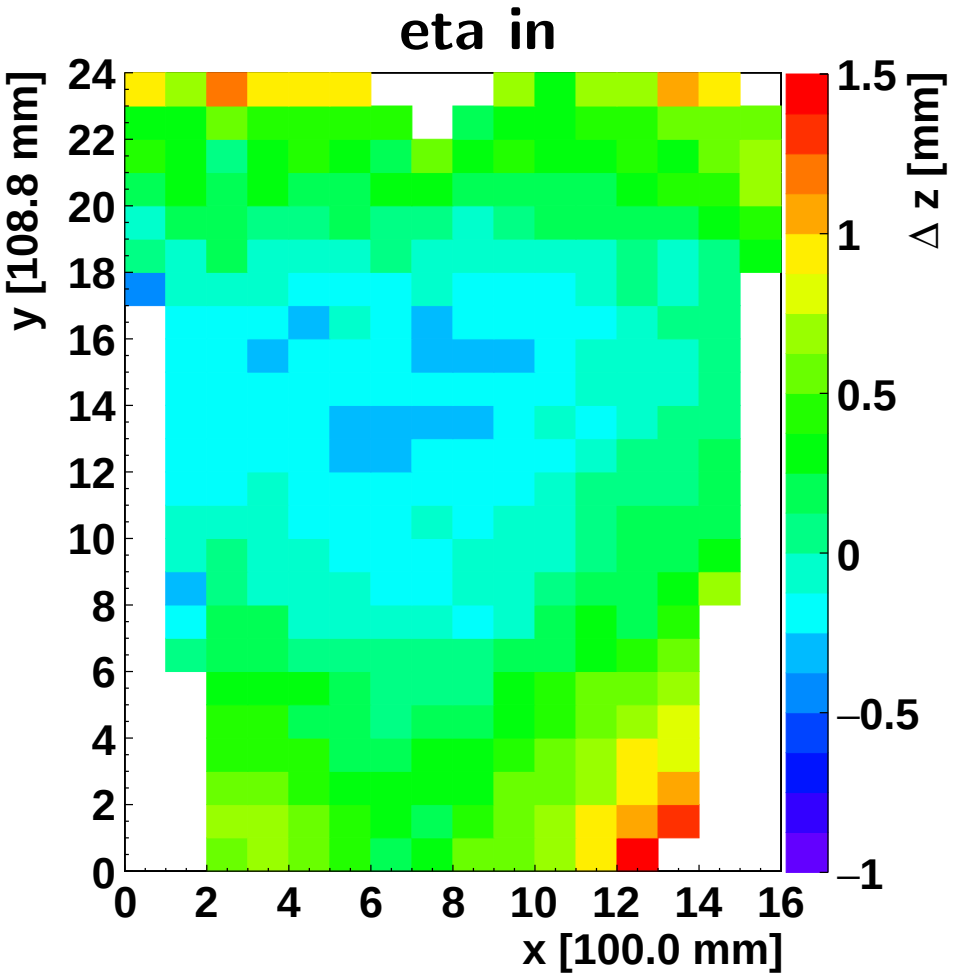


- board 1 shows deformed strip shape of about 50 µm
- board 2 is rotated w.r.t. board 1 of about 470 µm/m (≙ 0.027°)
- board 2 is shifted w.r.t. board 1 of about 320 µm
- board 2 has a pitch deviation of about 0.2‰ (≙ 80 nm @ nominal pitch of 450 µm)

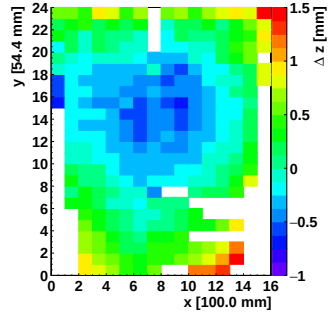
Module 0

$2\,\mathrm{m}^2$-sized Micromegas Quadruplet Prototype

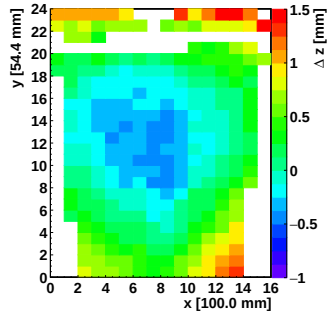
Reconstruction of the Gravitational Sag (Module 0)



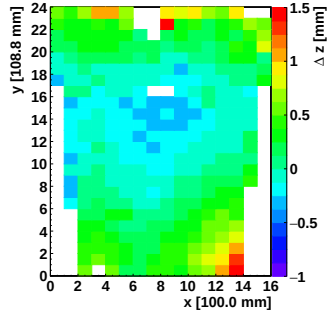
stereo in



stereo out



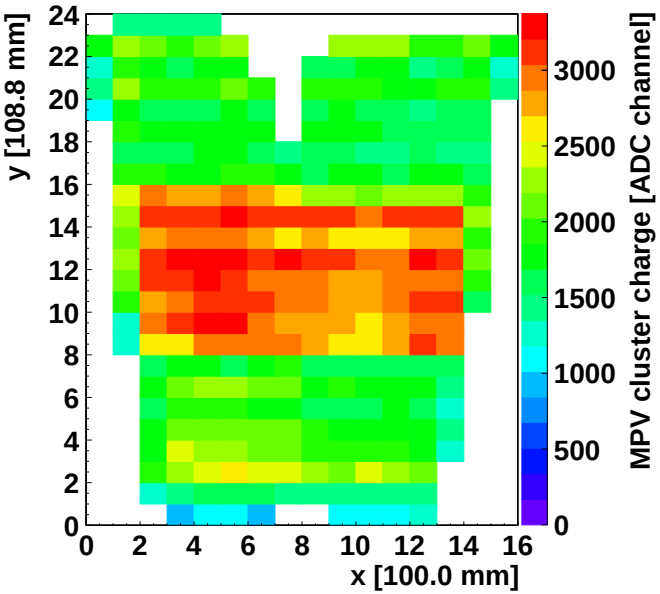
eta out



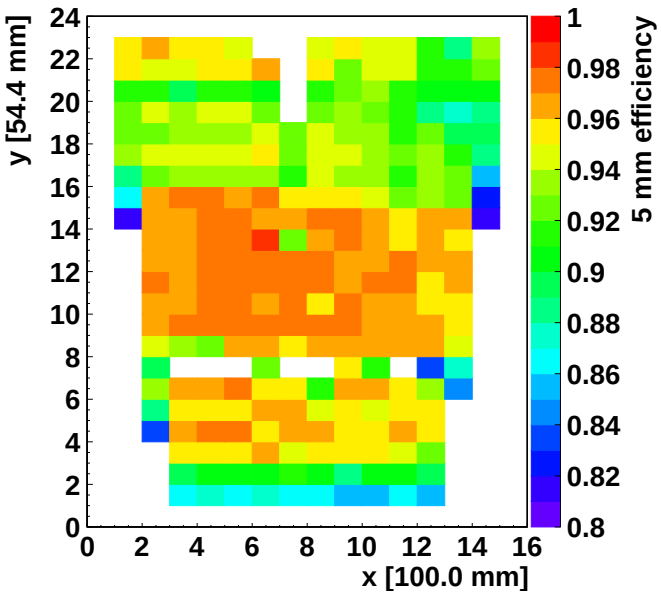
⇒ all layers show gravitational sag due to insufficient support structure, detectors at the experiment will be used vertical

Full Area Pulse Height and Efficiency (Module 0)

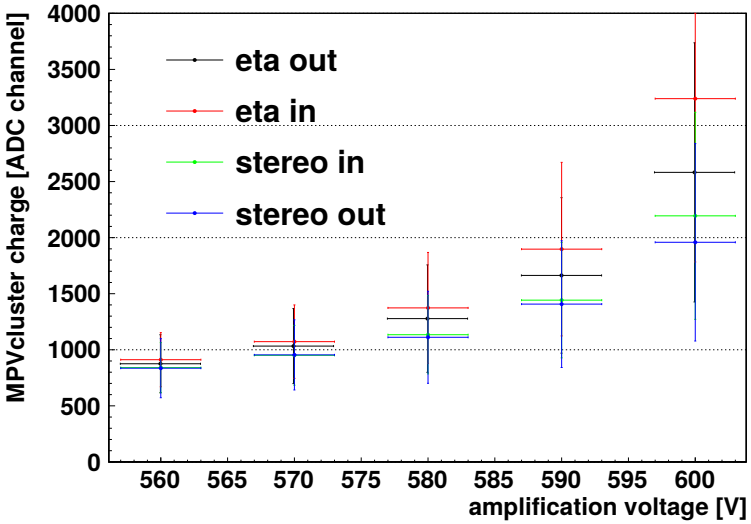
eta in cluster charge

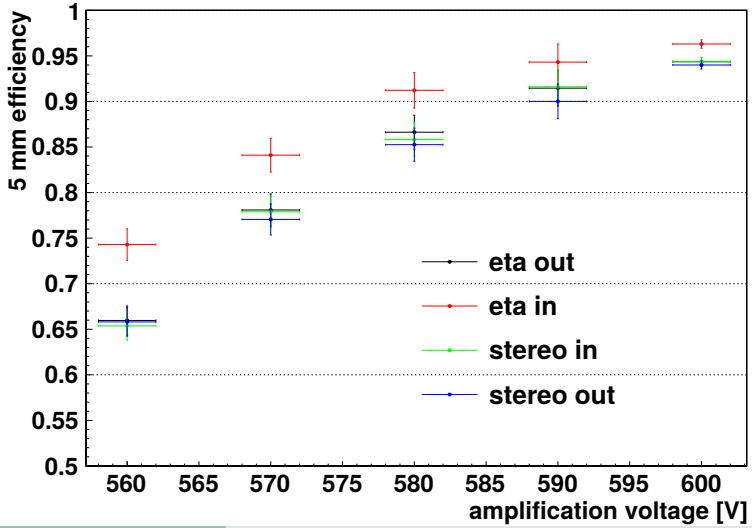


eta in 5 mm efficiency



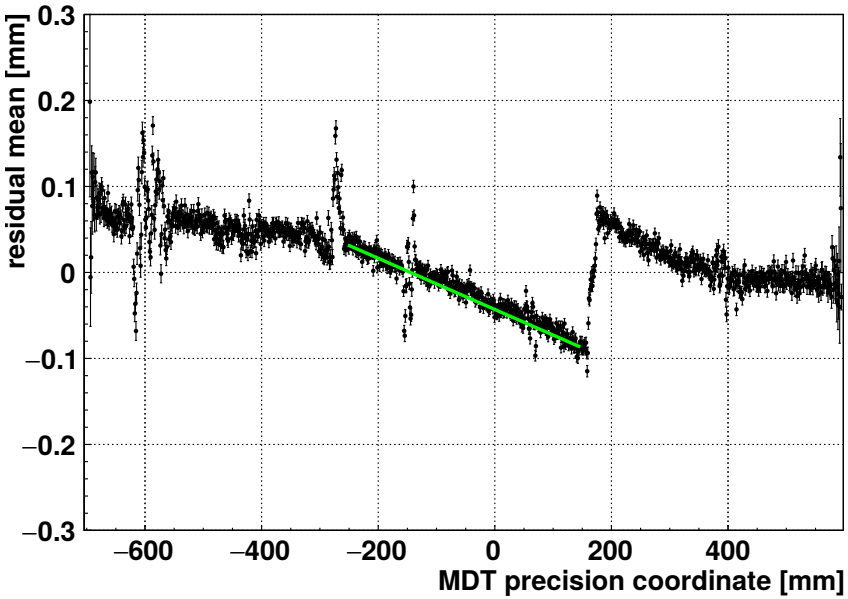
amplification scan for the central area of all layers



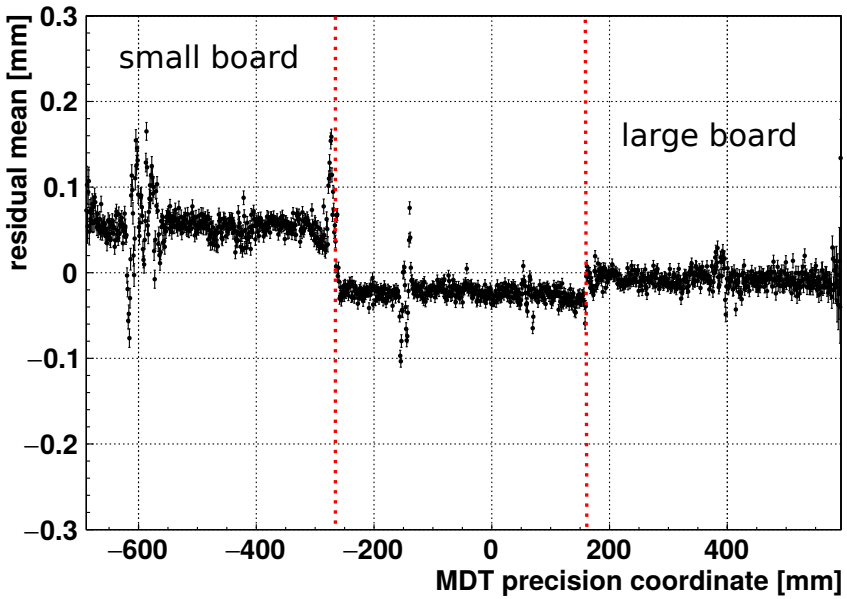


Reconstructed Pitch Deviation and Board Alignment per Plane (Module 0)

pitch deviation



corrected pitch



pitch deviation $[10^{-4}]$

panel	side	small	middle	large
stereo	out		1.4	0.7
stereo	in	5.2	4.7	5.4
eta	in	0.7	2.8	3.3
eta	out	1.4	3.8	4.9

shift [mm]

panel	side	small	large
stereo	out	0.10	-0.06
stereo	in	-0.16	0.22
eta	in	-0.08	0.02
eta	out	-0.17	0.11

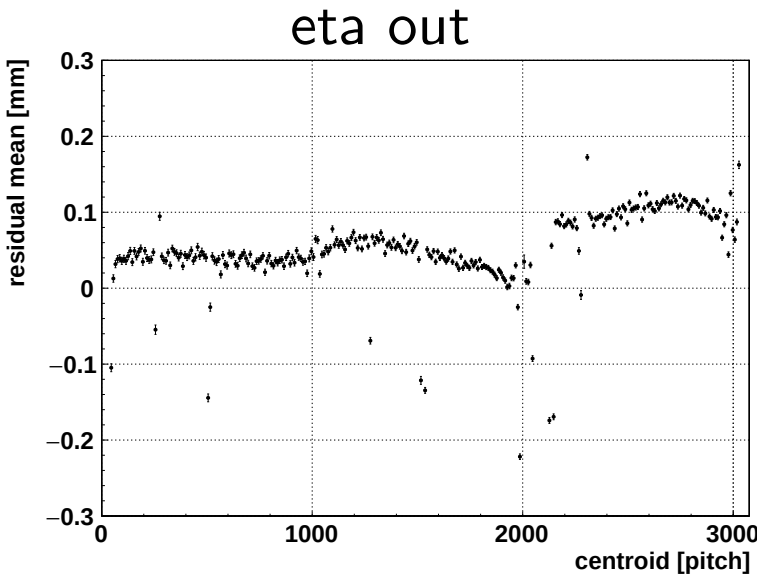
$\Rightarrow$ better construction equipment will be used for series detectors to avoid shifts

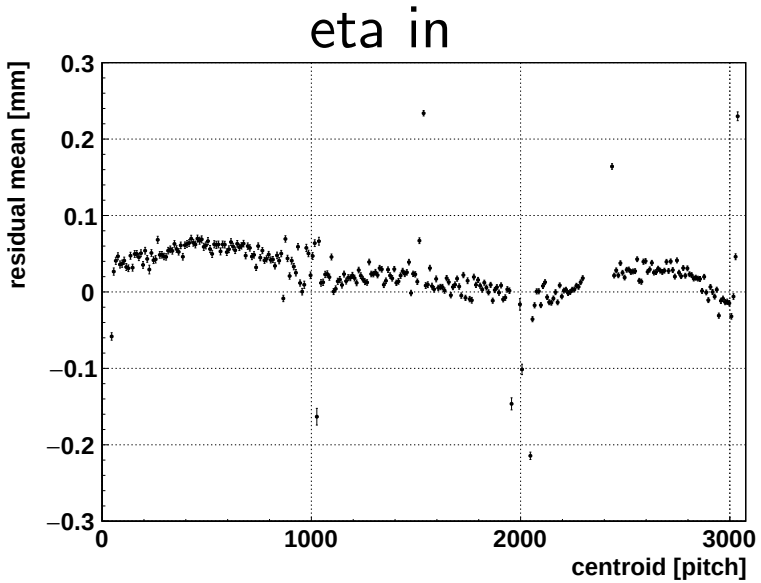
$\Rightarrow$ humidity control of readout boards to avoid pitch deviation

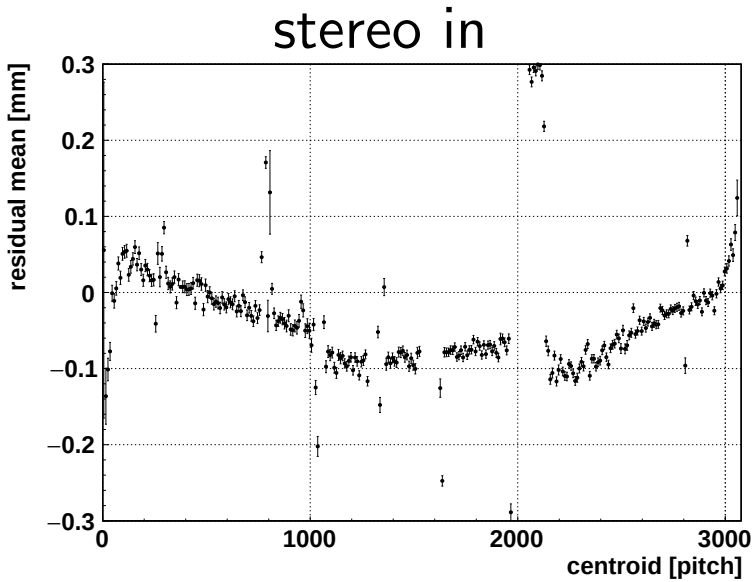
Module 1

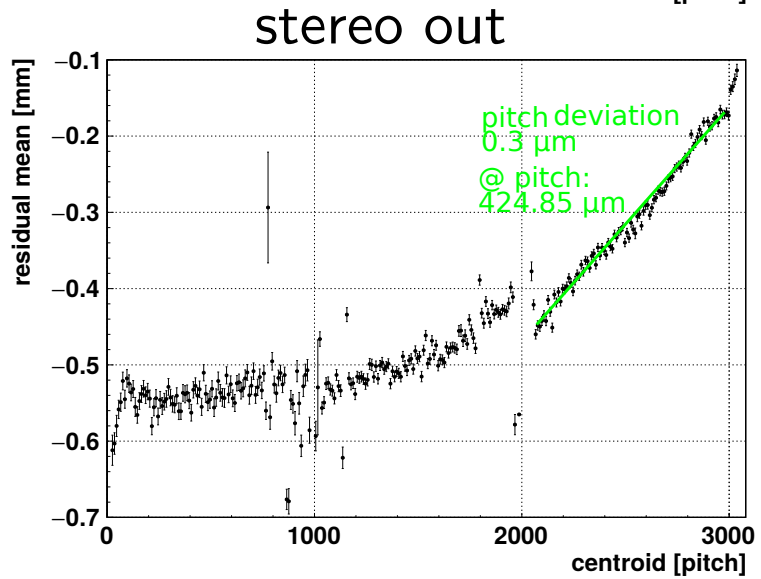
first Series $2\,\mathrm{m}^2$-sized Micromegas Quadruplet

Reconstructed Pitch Deviation and Board Alignment per Plane (Module 1)



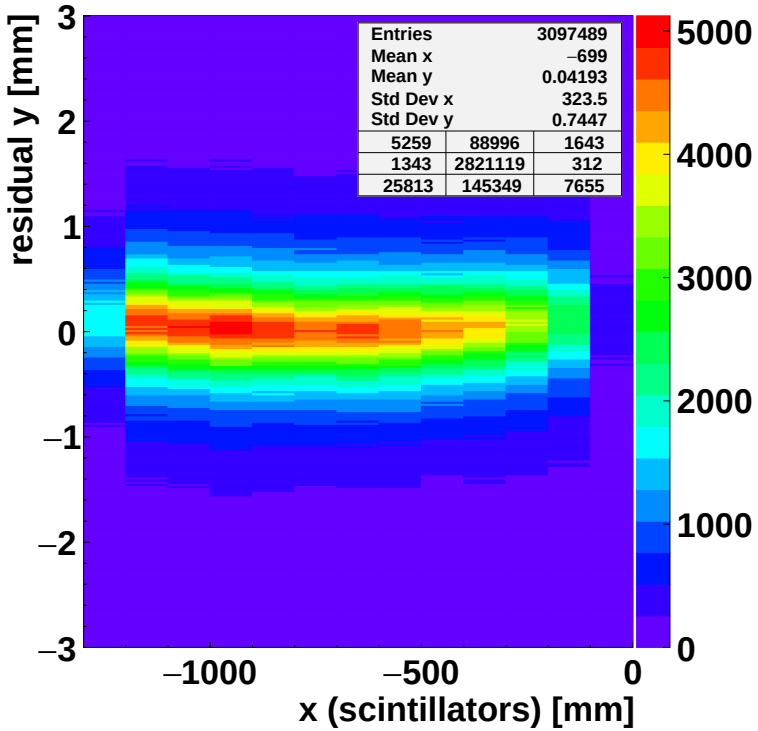


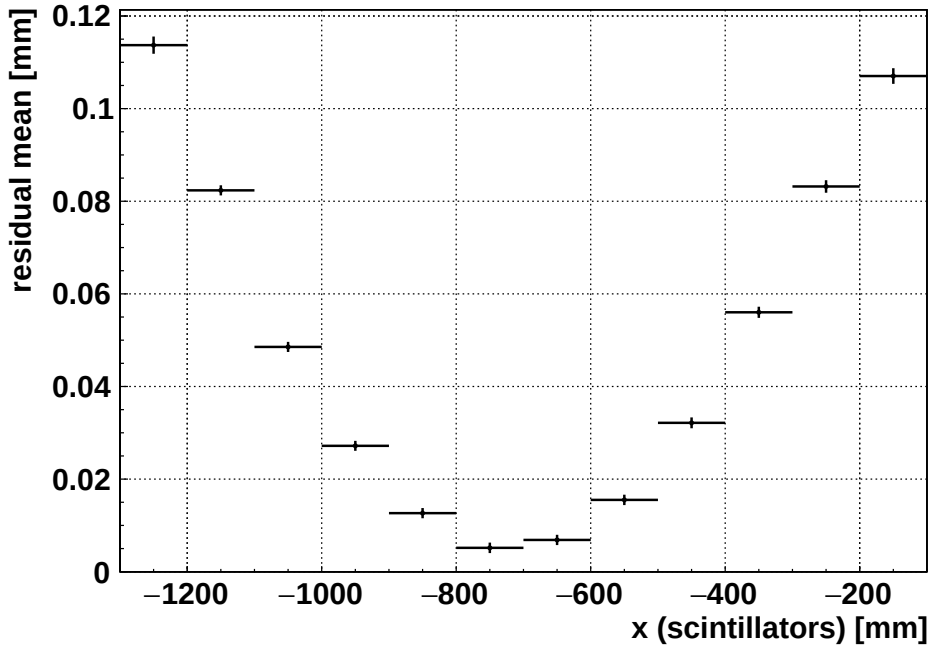




misaligned during gluing

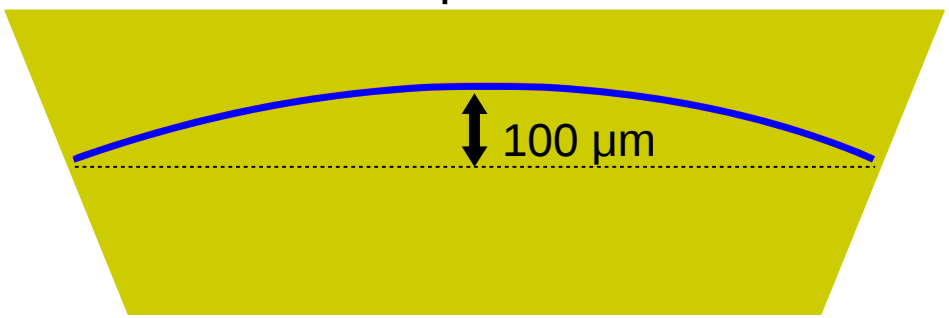
Strip Shape (Module 1)



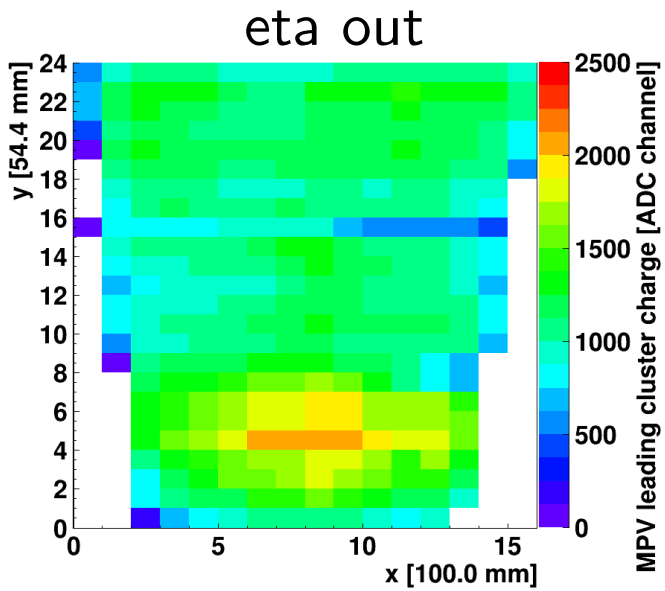


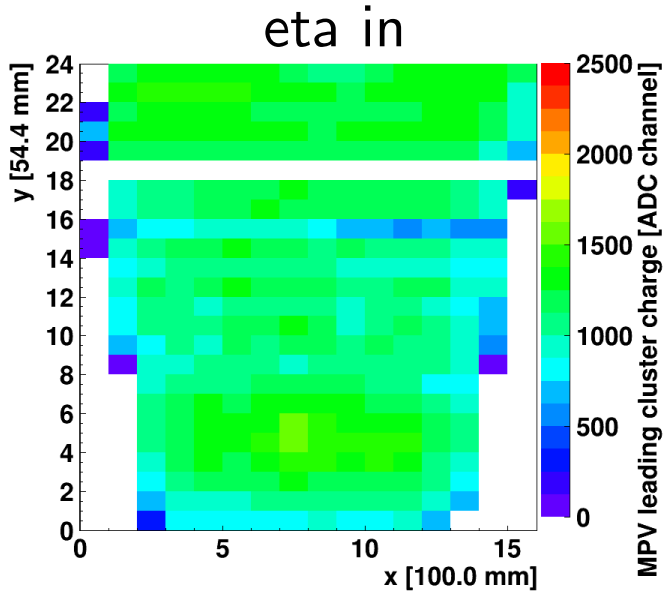
- residual VS position along strips
  (by scintillator hodoscopes)
- deformed strip shape
  also measured by optical inspection
  (CMM Saclay)
- further investigation required

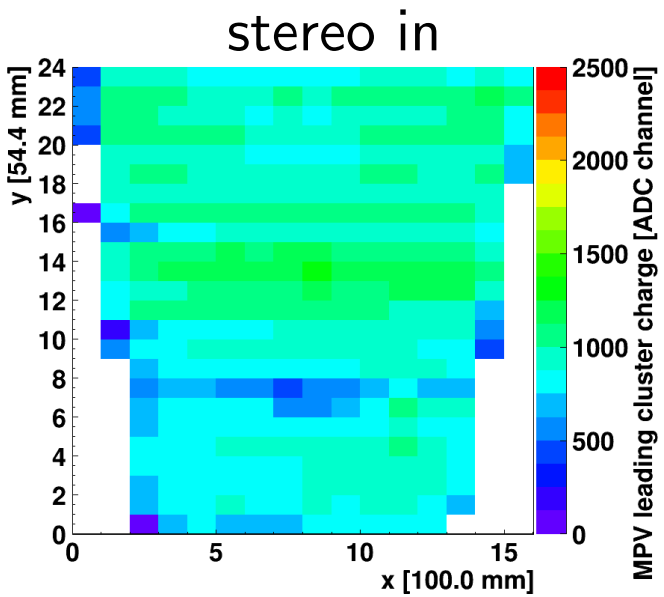
corresponds to

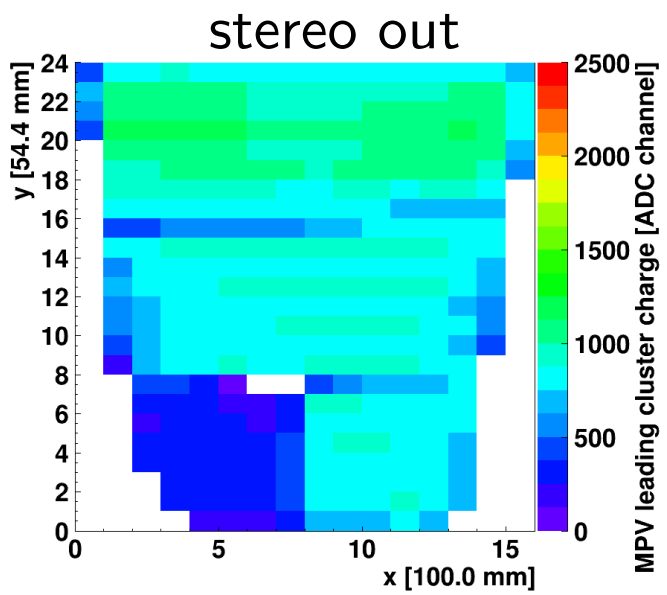


Most Probable Value of Cluster Charge by Landau Fit (Module 1)

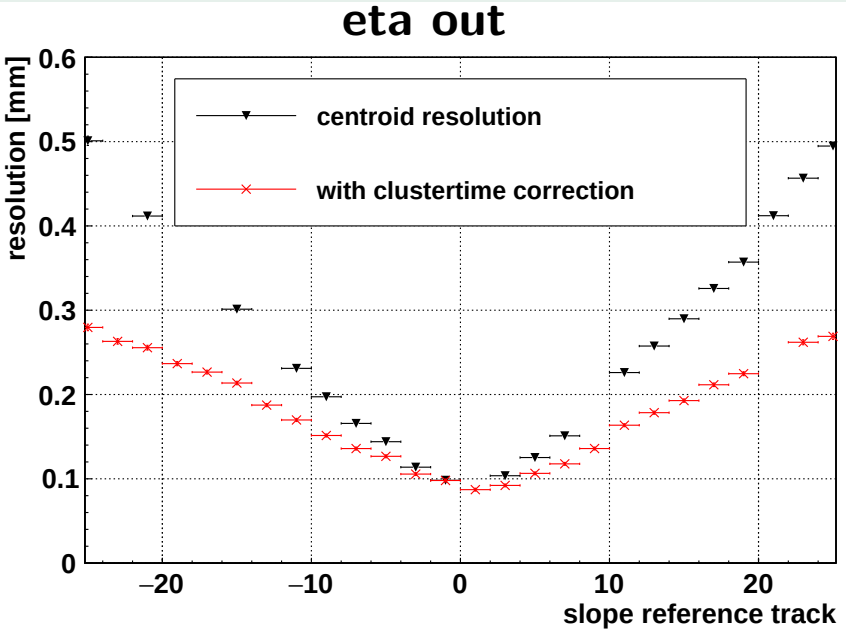


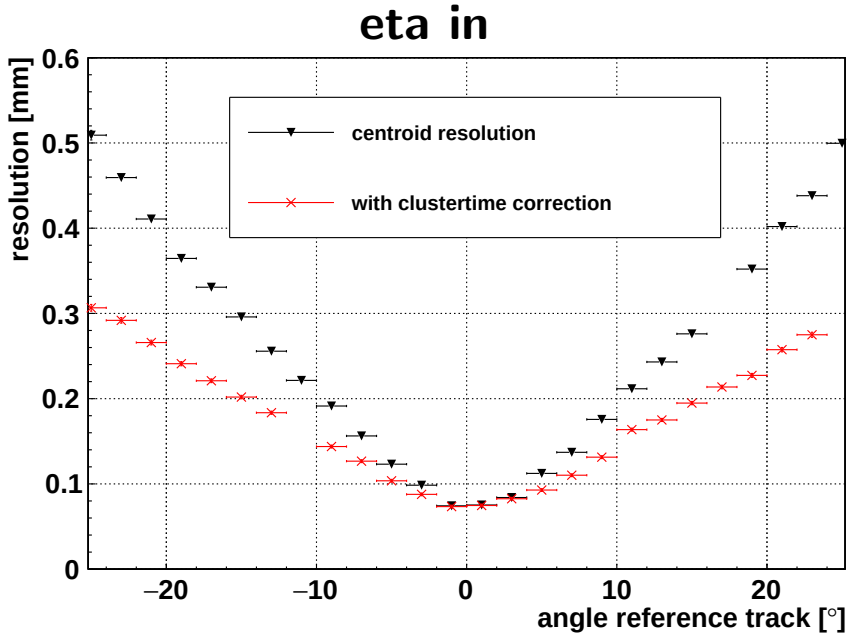






Position Resolution as Function of the Incident Angle (Module 1)





- residual distribution for each angle separately
- fit with double Gaussian

  analysis sigma narrow Gaussian only (reject multiple scattering)
- consider track uncertainty of reference chambers:

  $\sigma_{\mathrm{micromegas}} = \sqrt{\sigma^2_{\mathrm{res}} - \sigma^2_{\mathrm{track}}}$
- resolution is for perpendicular incident close to expectation
- charge weighted clustertime correction improves residual distribution considerably

Summary

- replacement of the ATLAS muon spectrometer inner end cap
  - sTGC and Micromegas quadruplets
  - Micromegas SM2 Modules will be built by a German collaboration
  - segmented readout structure due to limitations by industry
    $\Rightarrow$ reconstruction and calibration is required after construction
- Investigation at the Cosmic Ray Facility in Garching
  - 1 m^2-size Micromegas (L1) for proof of principles
    - reconstruction of deformation due to overpressure
    - rotation of about 0.027° and shift of about 320 µm reconstructed
    - deviation to nominal pitch of about 0.2‰
  - 2 m^2-size 4-layered Micromegas Prototype (Module 0)
    - gravitational sag due to insufficient support
      $\Rightarrow$ modules used vertical in ATLAS
    - pulse height and efficiency behave as expected
      $\Rightarrow$ 5 mm efficiency reaches more than 90% for all layers
  - first 2 m^2-size 4-layered Micromegas series module (Module 1)
    - alignment better than for prototype module
    - measured strip shape in agreement with optical inspection
      $\Rightarrow$ further investigation required
    - homogeneous pulse height over large area
    - position reconstruction for perpendicular incident below 100 µm
      $\Rightarrow$ resolution for inclined incident behave as expected,
      but can be improved further

Backup

Anode : 570 V, Cathode : 300 V, Ar:CO_2 93:7 vol%
Mean Cluster Charge