Development of Large-Size Micromegas Detector for the Upgrade of the ATLAS Muon System

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on behalf of

Arizona, Athens (U, NTU, Demokritos), Brookhaven, CERN, Istanbul (Bogaziçi, Doğuş), Naples, Seattle, South Carolina, St. Petersburg, Shandong, Thessaloniki

https://twiki.cern.ch/twiki/bin/view/Atlas/MuonMicromegas

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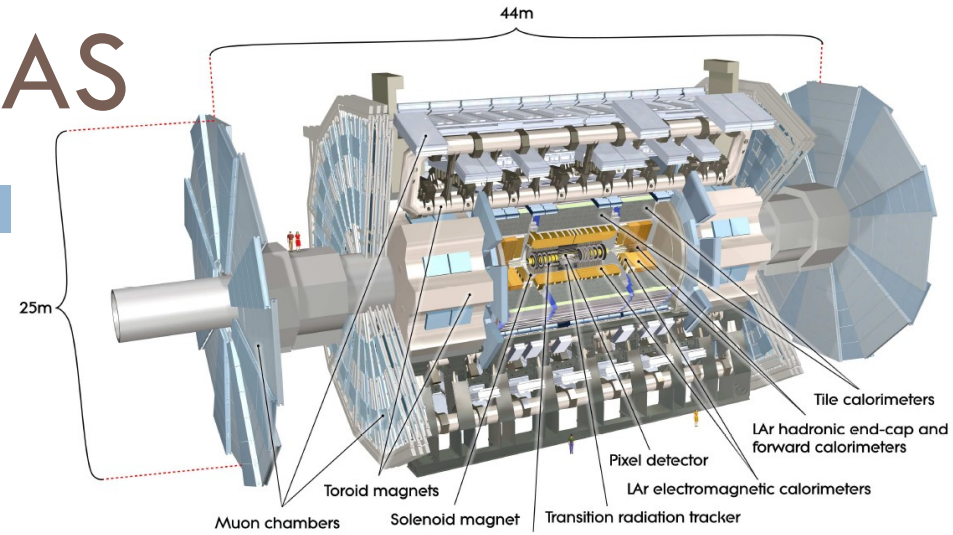
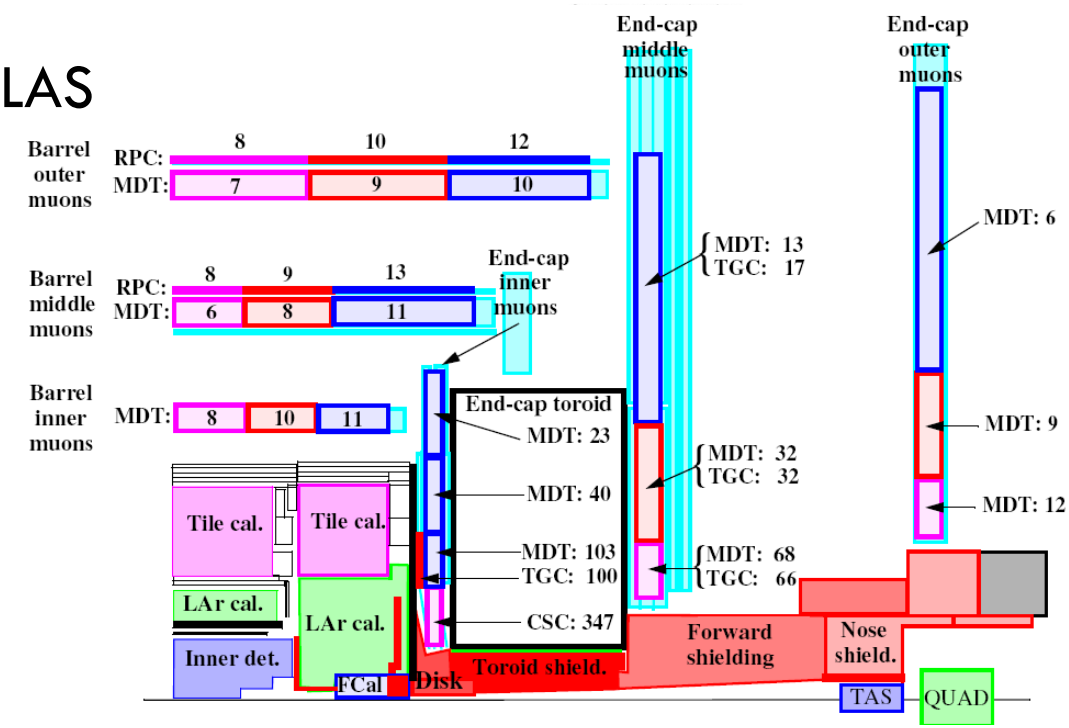
The Upgrade of ATLAS

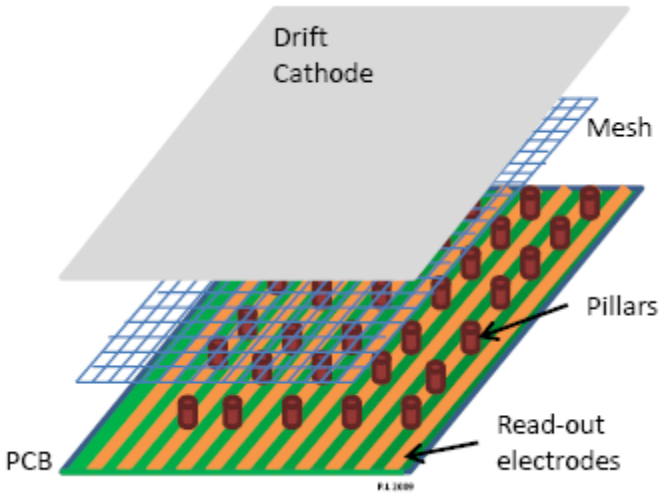


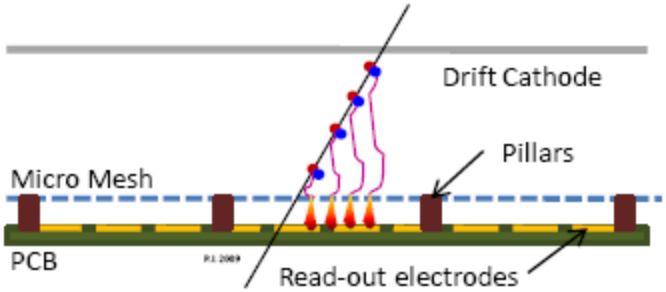
- LHC upgrade
  - $L_{SLHC} \sim 10\ L_{LHC}$ (phase 2)
  - BC time = 50 ns (25 ns)
- Highest rate regions in the ATLAS Muon Spectrometer:
  - EI layer (CSC, MDT, TGC)
  - EM layer $\eta \geq 2$ (MDT, TGC)
  - Total area ~ 400 m^2
- Real rates after first collisions



Micromegas as candidate technology

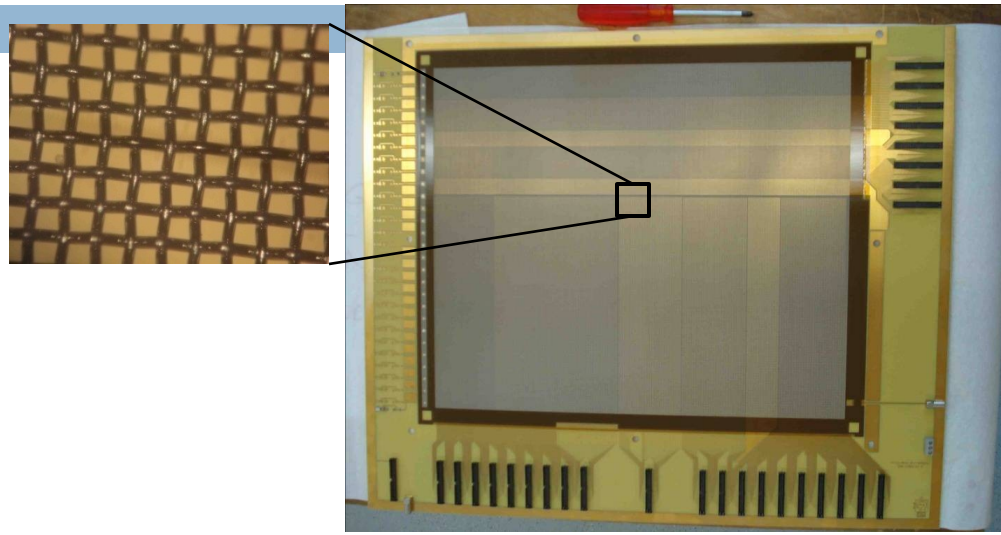
- Combine triggering and tracking functions
- Matches required performances:
  - Spatial resolution ~ 100 μm (Θ_{track}< 45°)
  - Good double track resolution
  - Time resolution ~ 5 ns
  - Efficiency > 98%
  - Rate capability > 5 kHz/cm^2
- Potential for going to large areas ~1m x 2m with industrial processes (bulk-Micromegas)
  - Cost effective
  - Robustness
- Never used in large muon systems

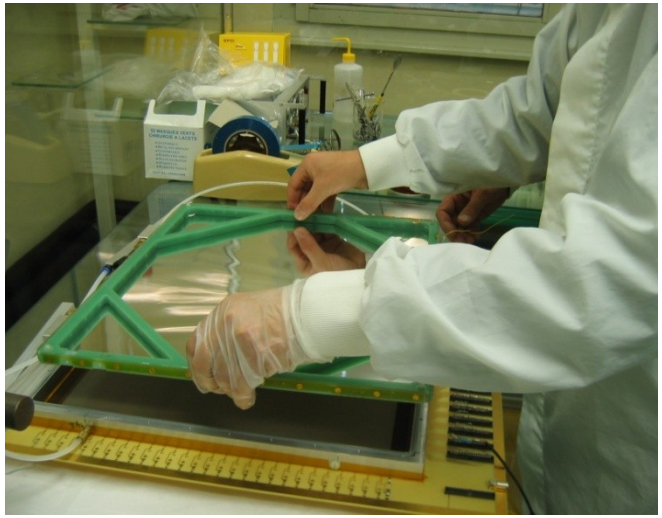




R&D Activity: the first prototype

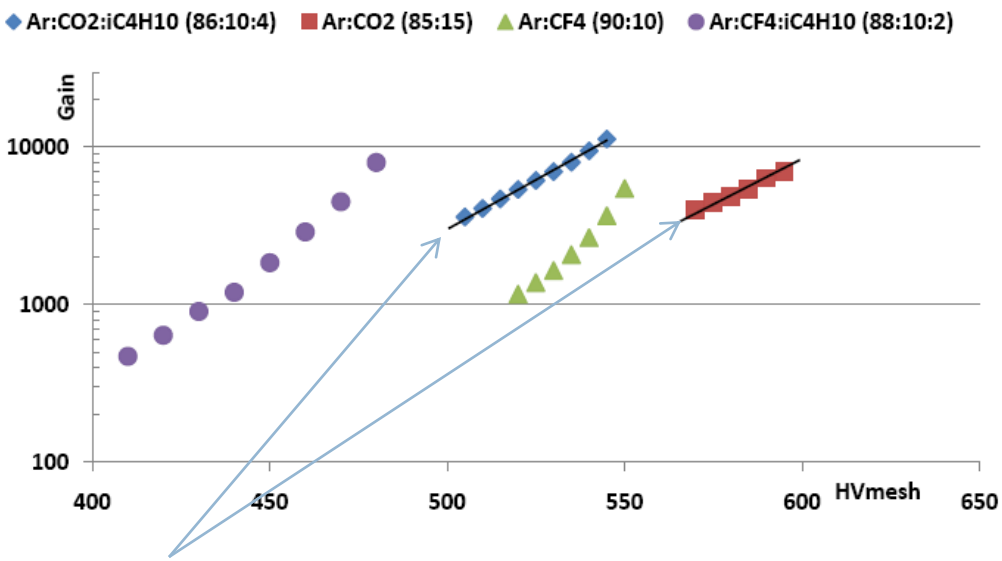
- Standard bulk micromegas fabricated at CERN in 2007
- Homogeneous stainless steel mesh
- 325 line/inch = 78 μm pitch
- Wire diameter ~25 μm
- Amplification gap = 128 μm
- 450mm x 350mm active area
- Different strip patterns (250, 500, 1000, 2000 μm pitch; 450 mm and 225 mm long)
- Drift gap: 2-7 mm
- Characterized in lab and tested on beam

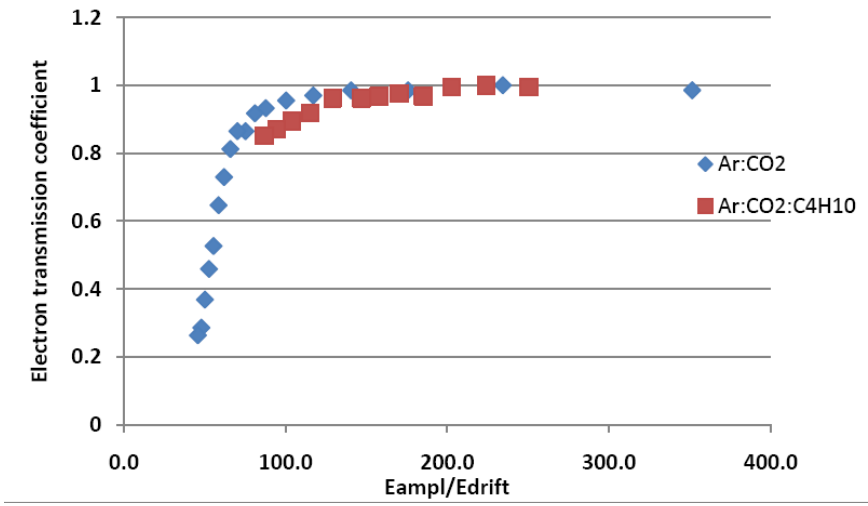




Laboratory test

- Test with ^{55}Fe source
  - Energy resolution $\sigma \approx 22\%$
  - Gas amplification 10^3-10^4
  - Electron transparency > 90% for $E_{amp}/E_{drift} > 100$



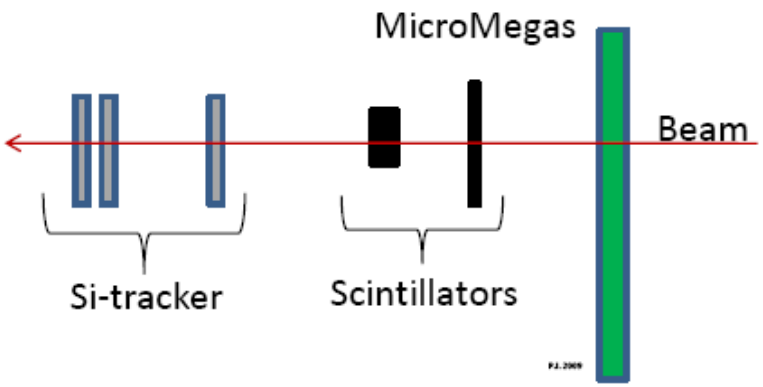


Lines are from GARFIELD simulation

Test beam set up

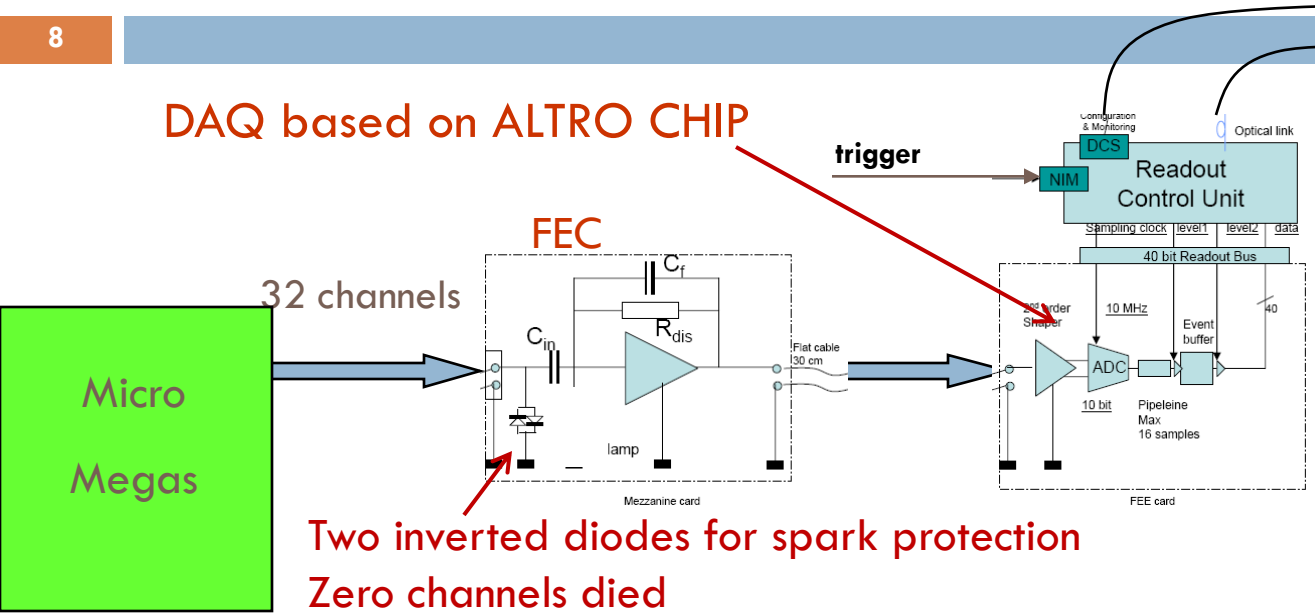
- Detector tested @ CERN H6 beam line in 2008
- 120 GeV pion beam
- Scintillator trigger
- External tracking with three Si detector modules (Bonn Univ.); independent DAQ
- Three non-flammable gas mixtures with small isobutane percentage:

  $Ar:CO_2:iC_4H_{10}$ (88:10:2), $Ar:CF_4:iC_4H_{10}$ (88:10:2), $Ar:CF_4:iC_4H_{10}$(95:3:2)
- Data acquired for 4 different strip patterns and 5 impact angles (90° to 50°)



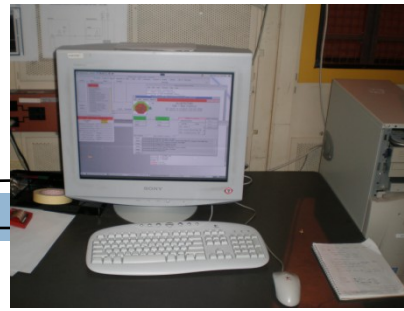
Readout

DAQ based on ALTRO CHIP



Two inverted diodes for spark protection

Zero channels died



DAQ PC (ALICE DATE)

32 channels

200 ns integration time

65 charge samples/ch

100 ns/sample

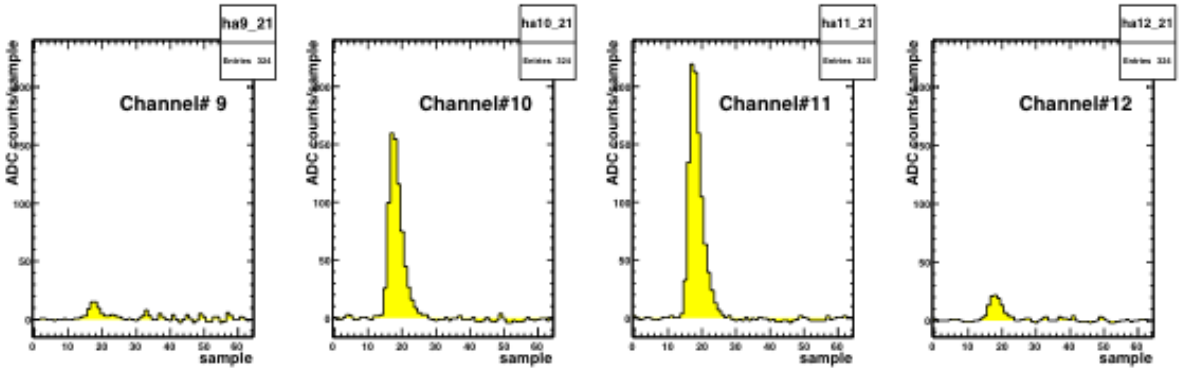
15 pre-samples

1 ADC count ~ 1000 e^-

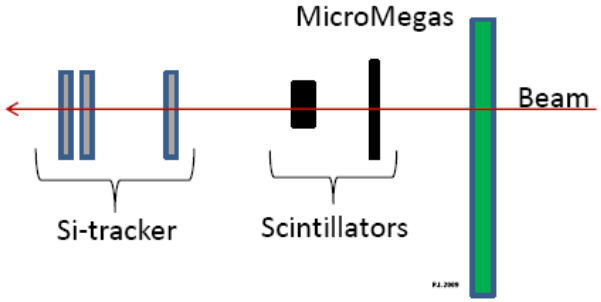
No trigger time info recorded

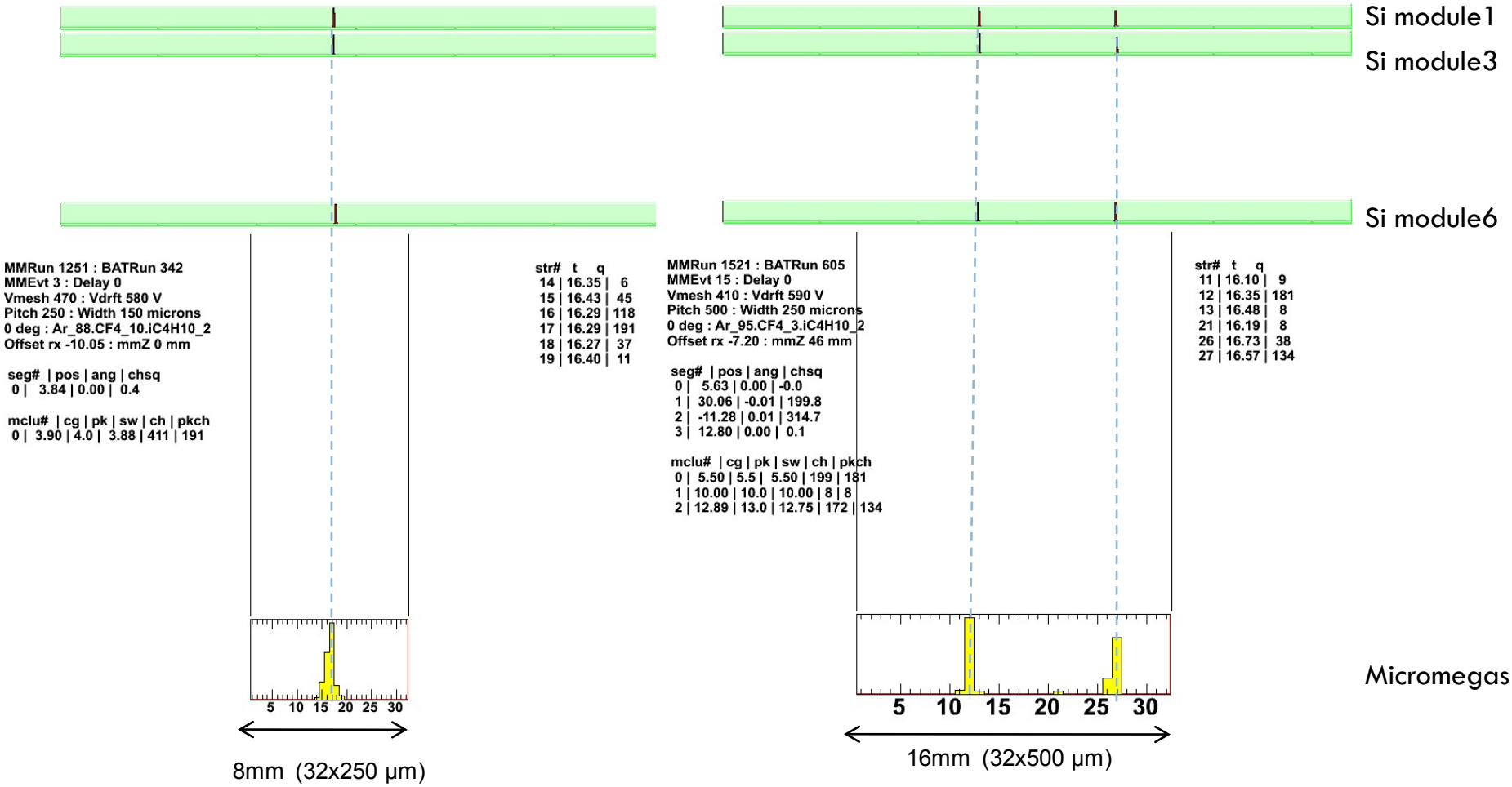
Typical ADC spectra

- Noise subtraction (from 12 pre-samples)
- Custer position from center of gravity



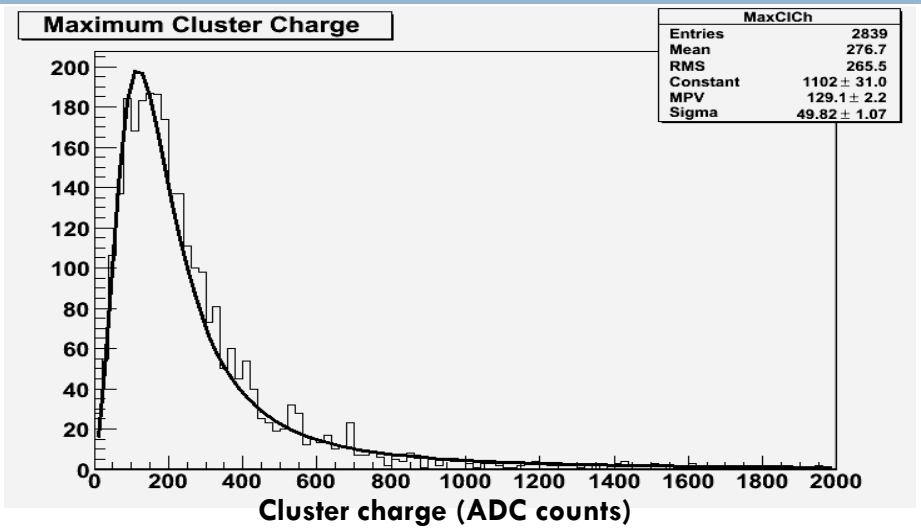
Simple event display

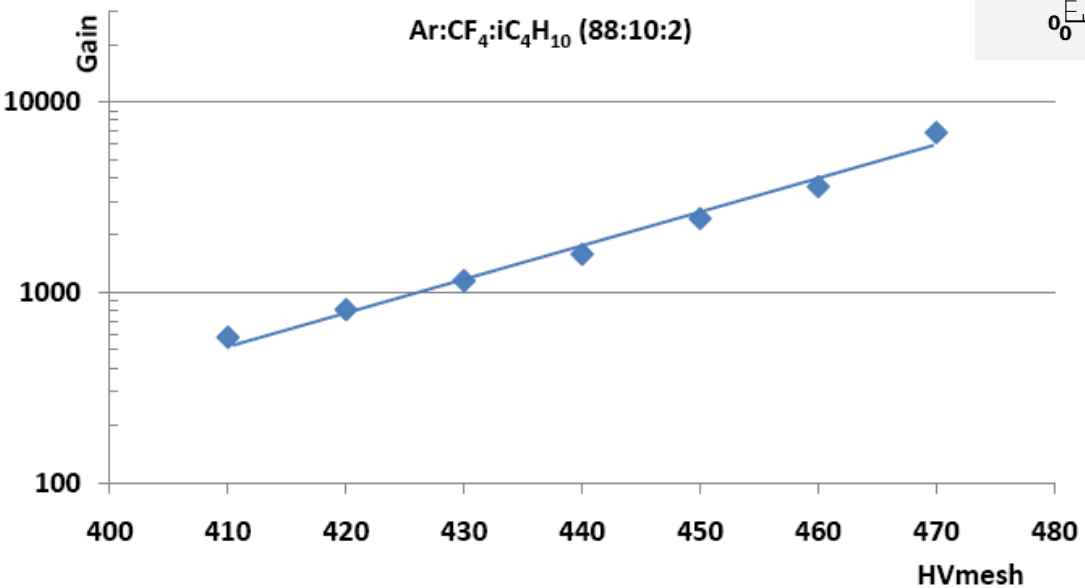




Gain measurement on beam

- Gas mixture: $Ar:CF_4:iC_4H_{10}$ (88:10:2)
- Drift gap 5 mm; drift field = 200 V/cm
- Strip pitch = 250 μm
- 1 ADC count = 1000 electrons

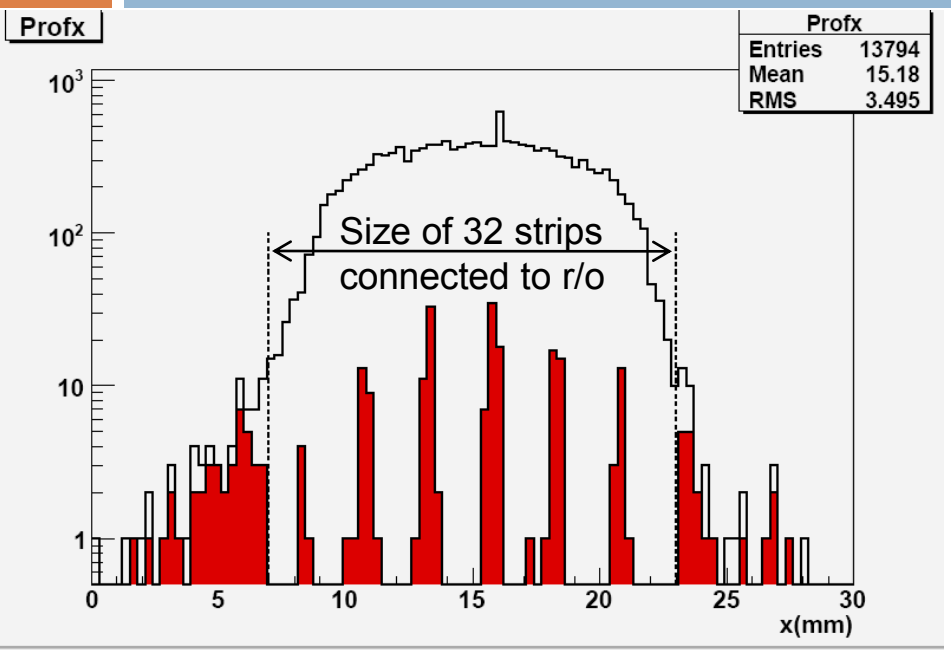


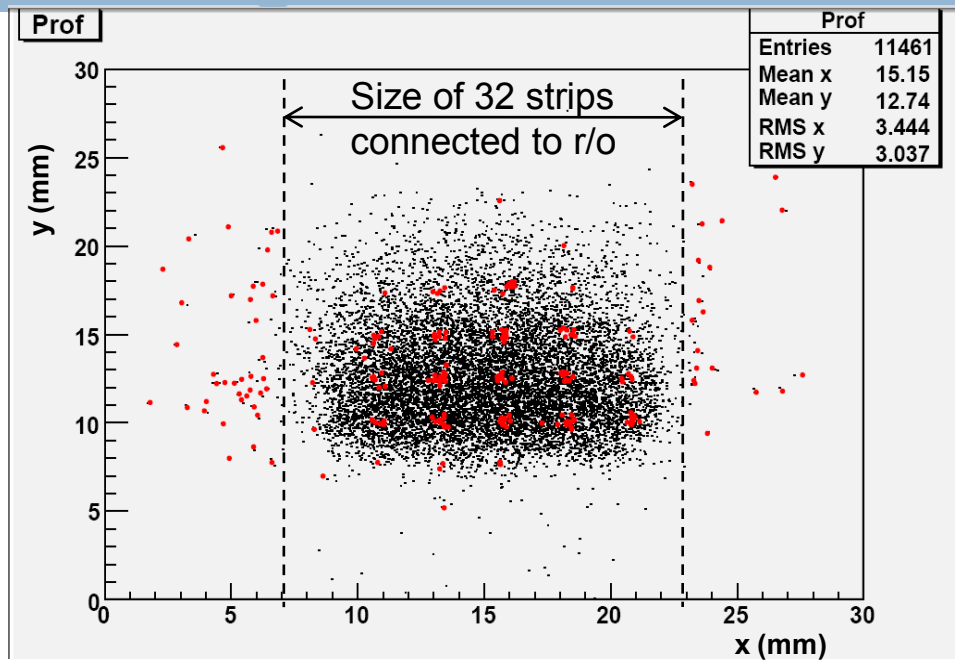


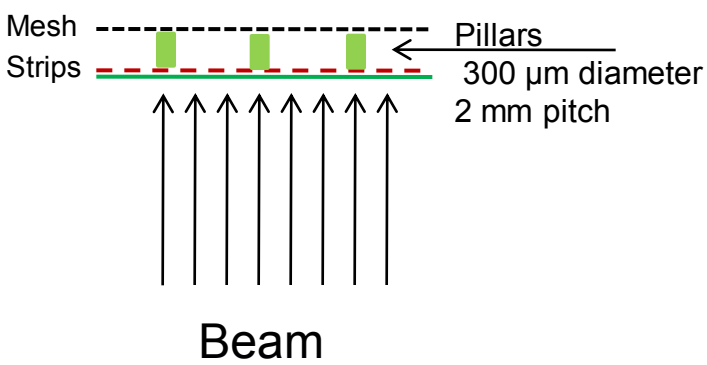
- Good agreement with measurement with ^{55}Fe source
- Stable working point @ gain ~ $3 \cdot 10^3$

Efficiency

- Gas: $Ar:CF_4:iC_4H_{10}$ (88:10:2)
- Strips: 500 μm pitch 400 μm width
- V_{mesh} = 450 V
- Drift field = 200 V/cm



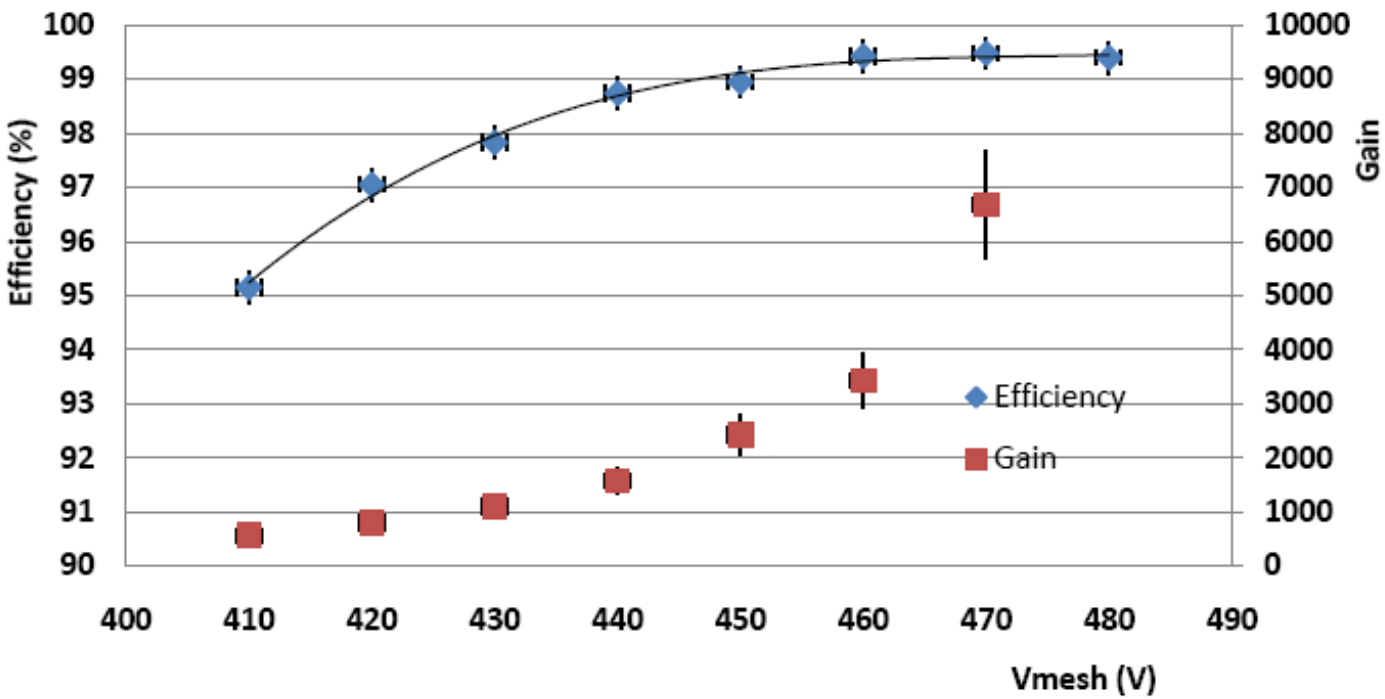




- Black: beam profile
- Red: event with micromegas not efficient

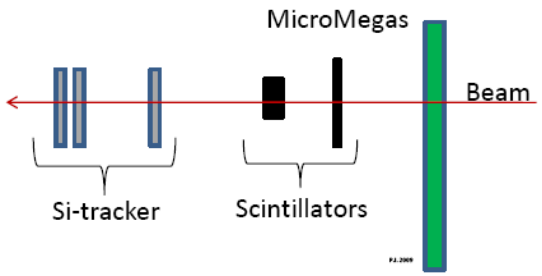
Efficiency vs V_{mesh}

- Gas: $Ar:CF_4:iC_4H_{10}$ (88:10:2)
- Strips: 500 μm pitch 400 μm width
- V_{mesh} = 450 V
- Drift field = 200 V/cm



- Eff > 98% @ V_{mesh} > 430 V (Gas Ampl. > 10^3)
- Working point: V_{mesh} = 440-450 V

Spatial resolution



Gas: $Ar:CF_4:iC_4H_{10}$ (88:10:2) Drift field = 220 V/cm

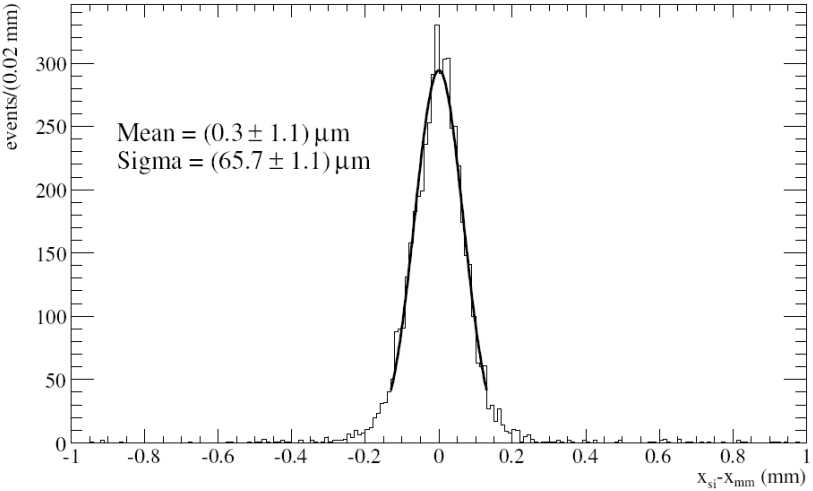
V_{mesh} = 470 V Perpendicular tracks

- Residuals of MM cluster position and extrapolated track from Si
- Convolution of:
  - Intrinsic MM resolution
  - Tracker resolution (extrapolation)
  - Multiple scattering

  } ~61 μm

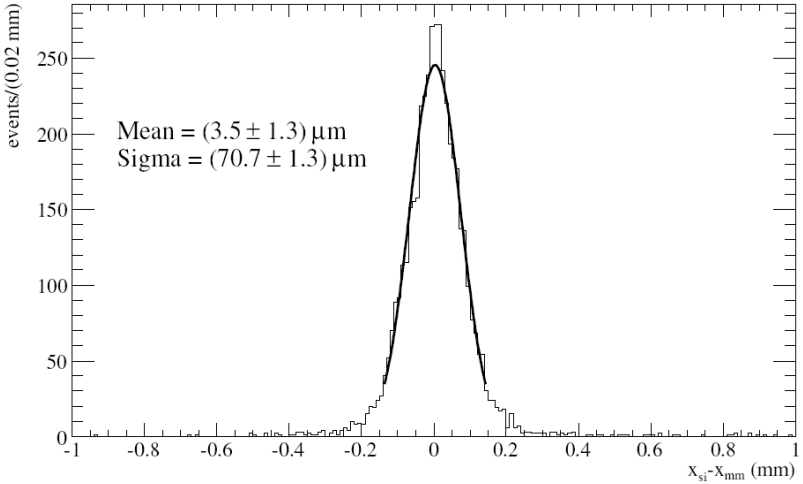
Strip pitch: 250 μm
Strip width: 150 μm

σ_{MM} = (24±7) μm



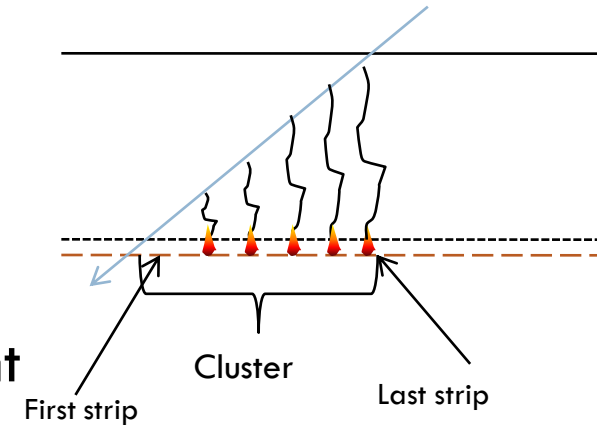
Strip pitch: 500 μm
Strip width: 400 μm

σ_{MM} = (36±5) μm



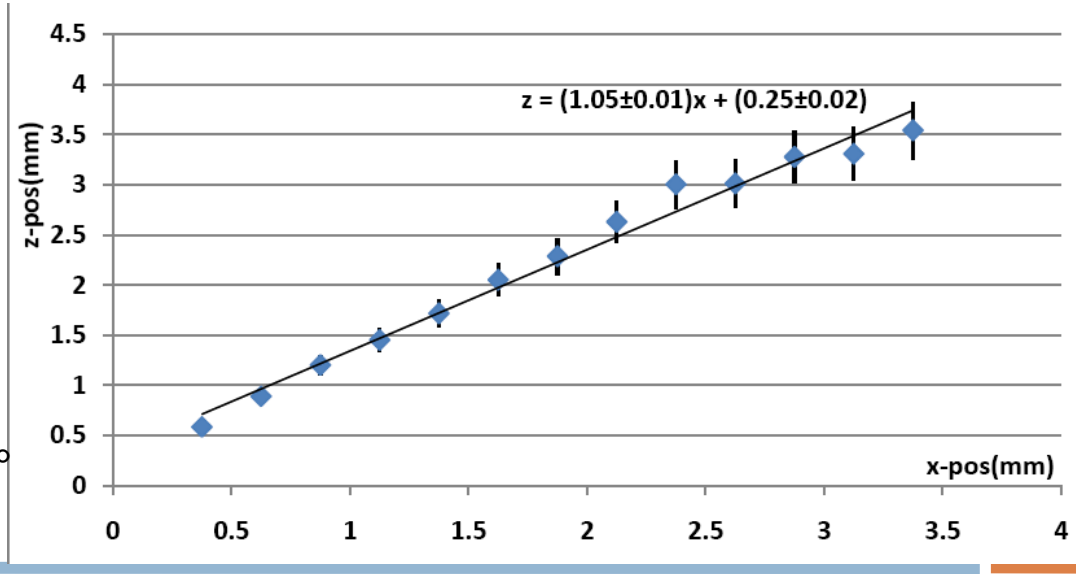
Micromegas as μ-TPC

- Measure arrival time of signals on strips and reconstruct space points in the drift gap
- Solves the problem of spatial resolution for large track inclination
- A time resolution of 1ns results in a space point resolution of 5-10 μm along the drift direction



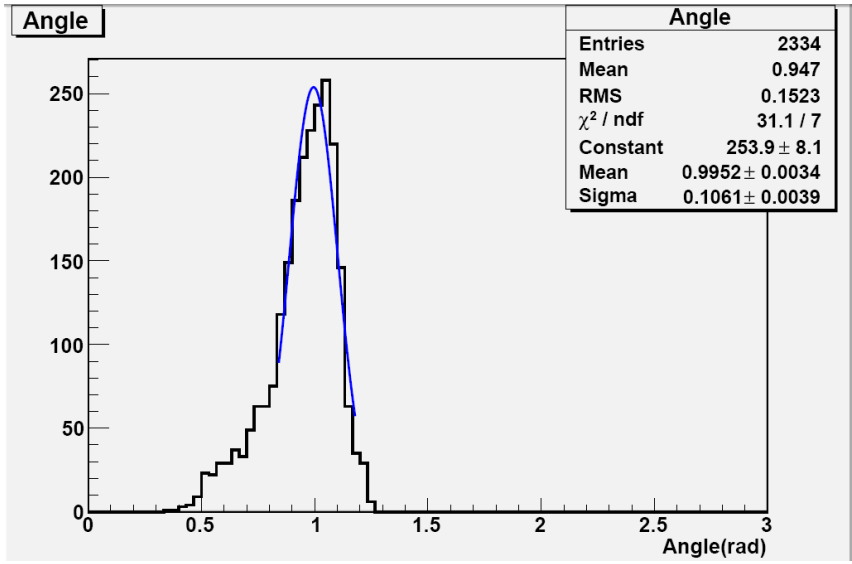
Example on a real event:

- Gas: $Ar:CF_4:iC_4H_{10}$ (95:3:2)
- Drift field = 360 V/cm
- Drift velocity = 7.8 cm/μs (Magboltz)
- Chamber rotation = (50±3)°
- Reconstructed track inclination = (46±4)°



Micromegas as μ-TPC

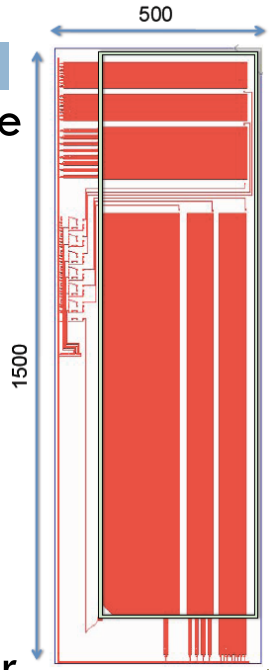
- With a good time resolution a good local track reconstruction is possible
- A (slightly) larger drift gap will help in getting a better time resolution
- Requirement to operate MM in μ-TPC mode:
  - Small strip pitches (250 μm)
  - Time resolution with O(few ns) resolution
  - moderate charge measurement (TOT)



- Gas: $Ar:CF_4:iC_4H_{10}$ (88:10:2)
- Drift field = 220 V/cm
- Drift velocity = 6.8 cm/μs (Magboltz)
- Chamber rotation = (50±3)°
- Reconstructed track inclination = (57±6)°
- Resolution = 11%

Future plans

- New test beam measurement on the first prototype
- A 50% prototype now under construction
  - 400 x 1300 mm^2 active area
  - Segmented mesh
  - One group of strips with resistive coating
  - Strip pitches: 250 μm and 500 μm
  - Long (~100 cm) and short (~40 cm) strips
- Irradiation test in neutron facility on small chamber
- Finalization of construction and working parameters
- Read-out
- Ageing test
- Implementation in ATLAS (?)

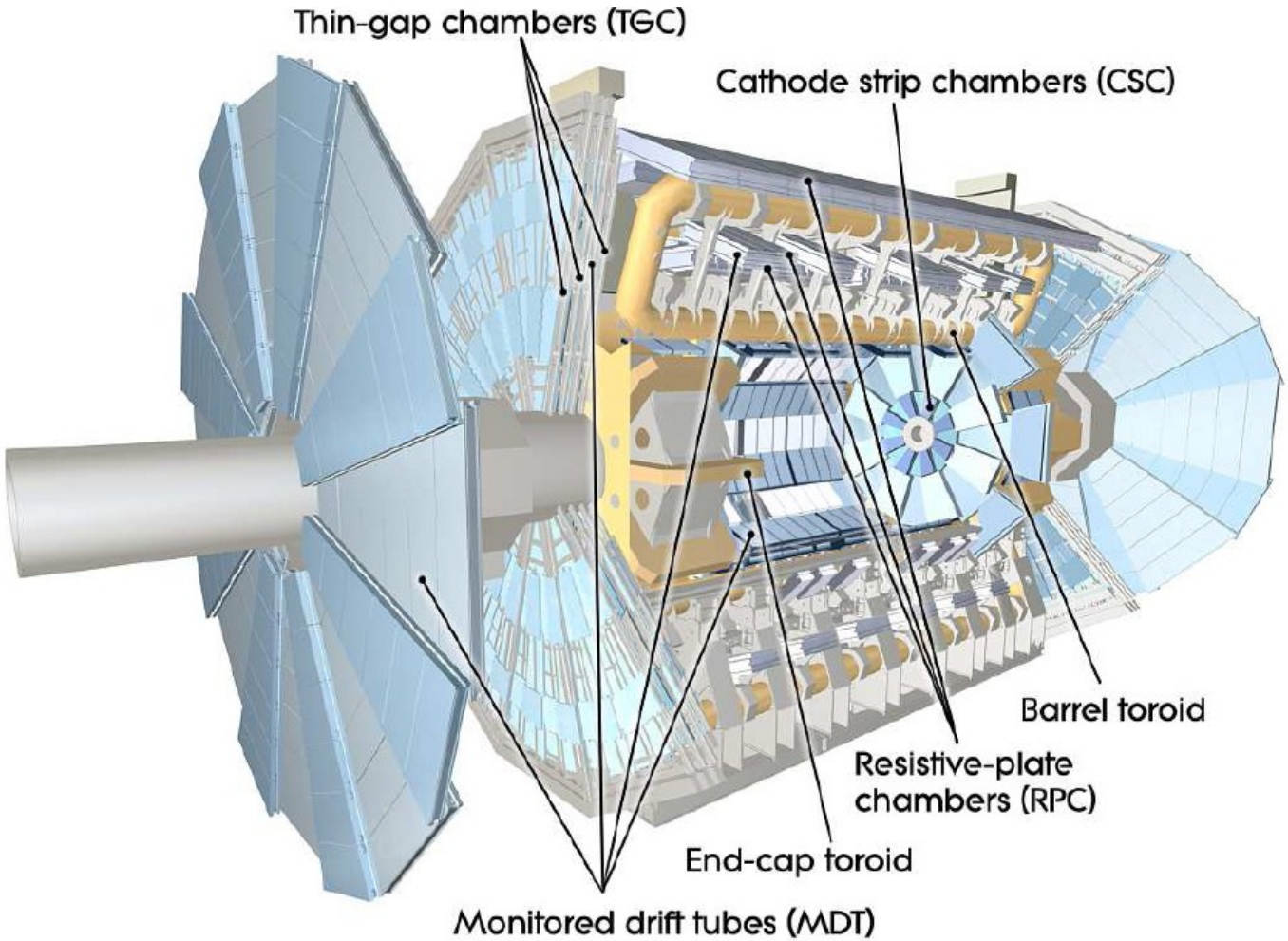


Summary & conclusions

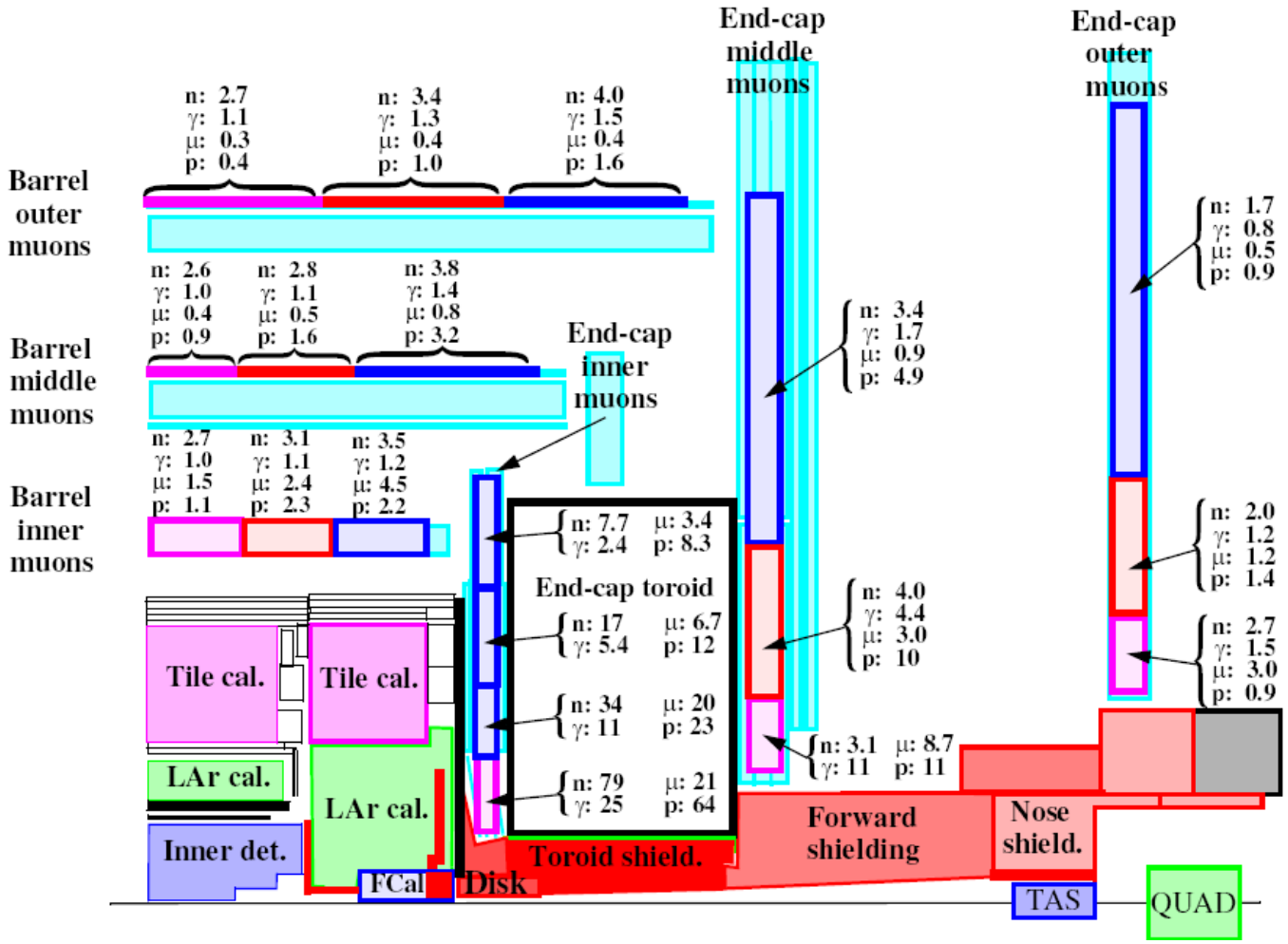
- With SLHC an upgrade of some ATLAS Muon chambers is needed
- Micromegas technology is a good candidate
- 350 x 450 mm^2 prototype built and tested
- Test with encouraging results
  - Good working performance (gas amplification, efficiency)
  - Measured spatial resolution of 24 μm (36 μm) with 250 μm (500 μm) strips
  - For inclined tracks, local track reconstruction is possible: MM in μ-TPC mode
- New test beam campaign now with improved DAQ
- 50% prototype chamber (400 x1300 mm^2) under construction
- Decision about which detector technology will be chosen to be taken "soon" by the ATLAS Muon community (probably this year)

Back-up slides

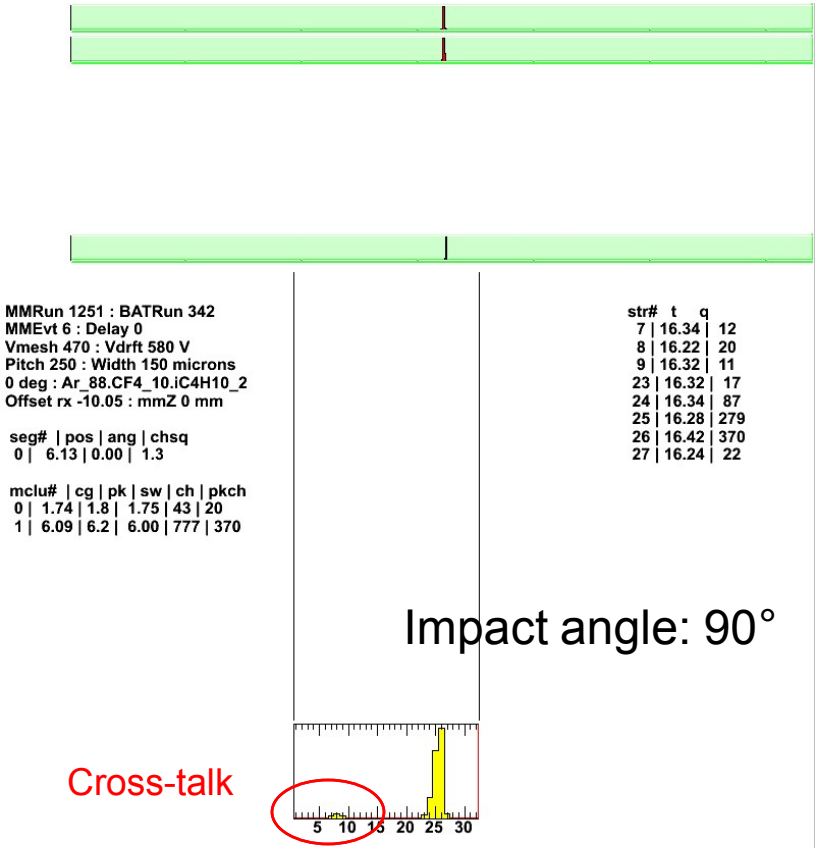
The ATLAS Muon Spectrometer

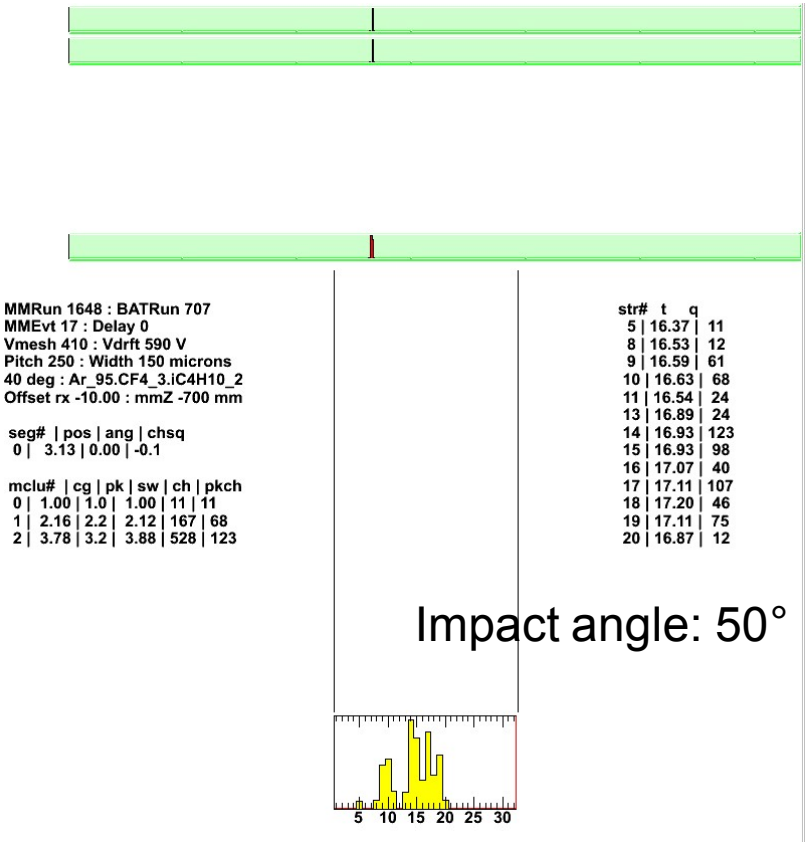


Expected baclground

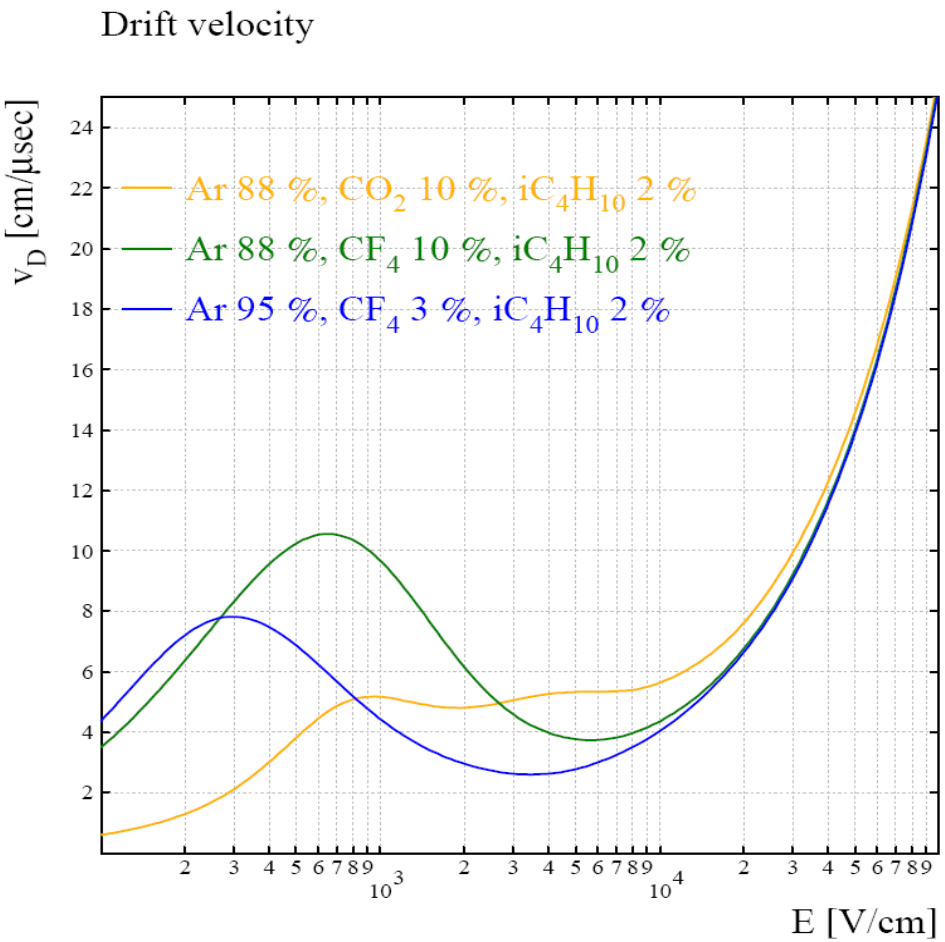


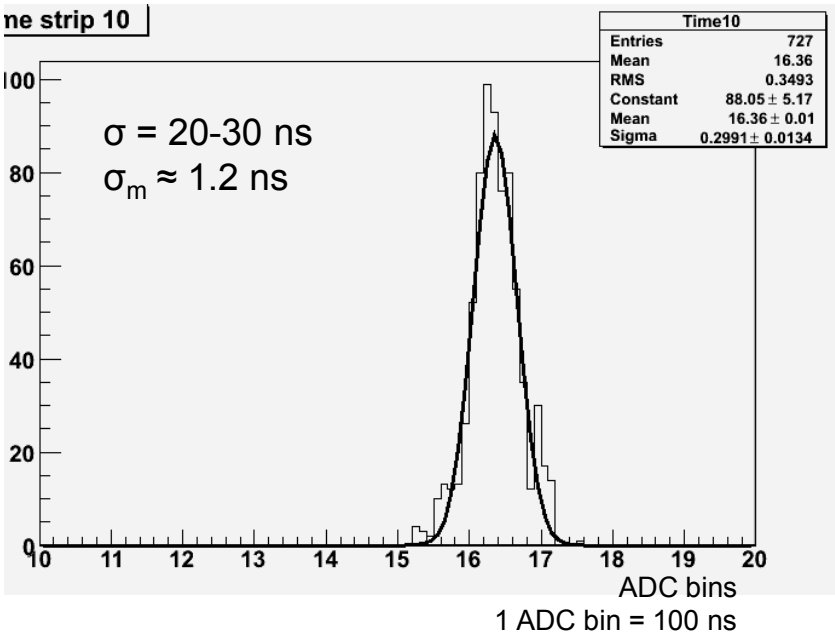
Tracks with different impact angle





Drift velocity from simulation

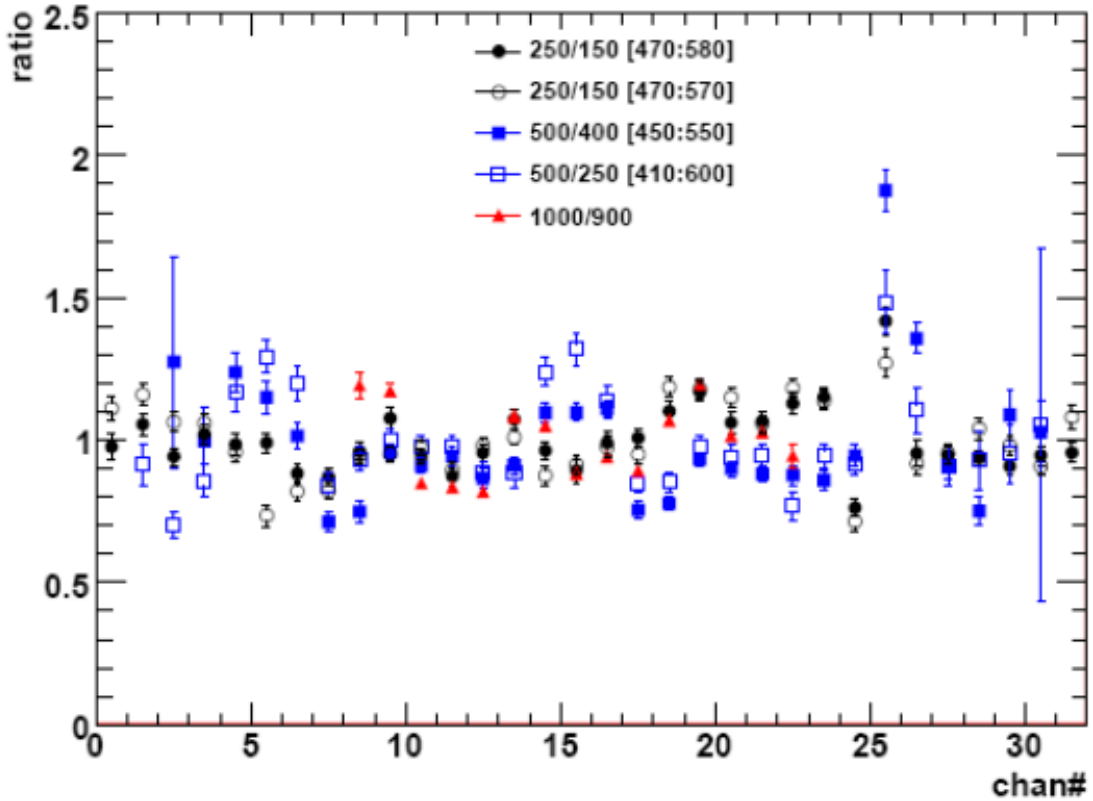




Peak time distribution

Strip response uniformity

Ratio (strip response/average) of MPV of Landau distribution



Similar behavior
for different strips

Small variation mainly
related to electronics
(not to strips)