MICROMEGAS FOR THE UPGRADE OF THE ATLAS MUON CHAMBERS FOR THE SLHC

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

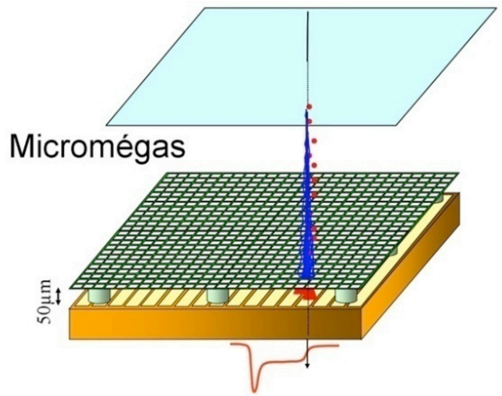
https://twiki.cern.ch/twiki/bin/view/Atlas/MuonMicromegas

Content

- Introduction
- Test beam 2008 results
- Projects for 2009 and beyond

Micromegas for ATLAS Muon upgrade

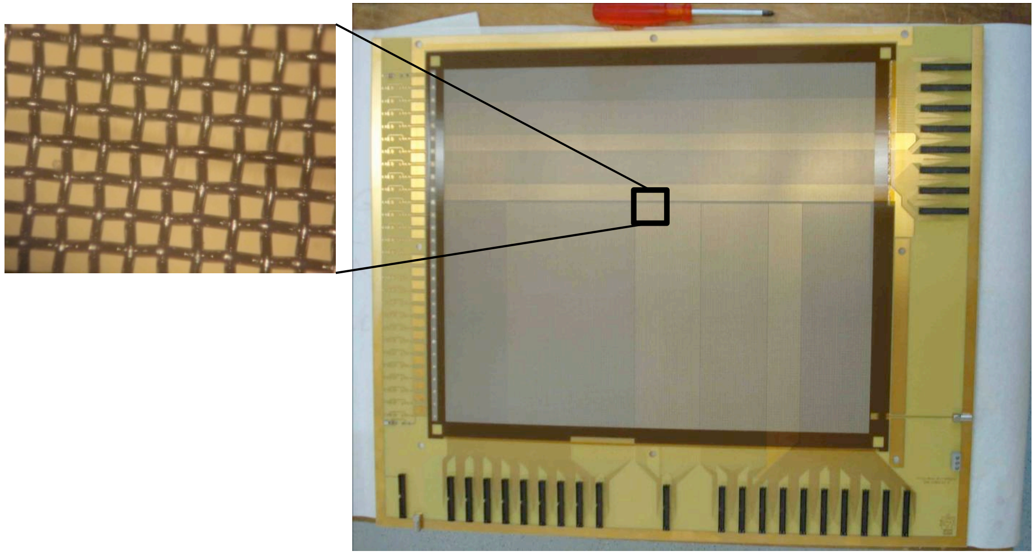
- Combine triggering and tracking functions
- Matches required performances:
  - Spatial resolution ~ 100 μm (Θ_{track}< 45°)
  - Good double track resolution
  - Time resolution ~ 5 ns
  - Efficiency > 98%
  - Rate capability > 5 kHz/cm^2

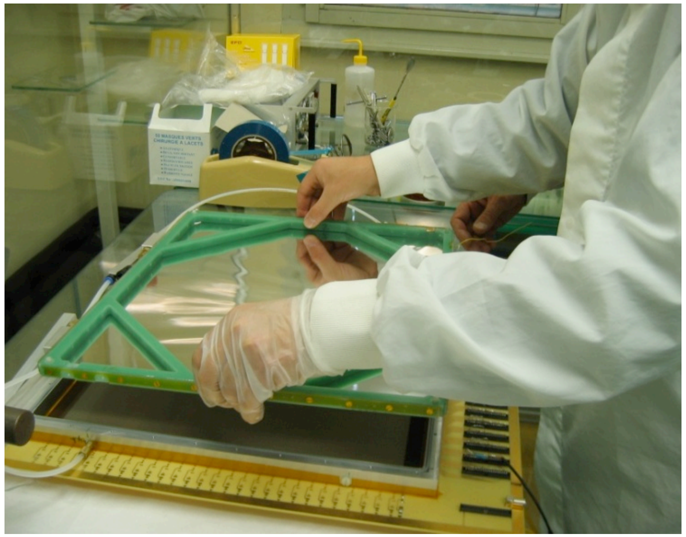


- Potential for going to large areas ~1m x 2m with industrial processes
  - Cost effective
  - Robustness

Prototype P1

- Standard bulk micromegas fabricated at CERN-TS/DEM
- 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; 450mm and 225 mm long)
- Drift gap: 2-5 mm
- Characterized in lab and tested on beam





Test beam set up

- P1 tested @ CERN H6 beam line in June to August 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 used in 2008:

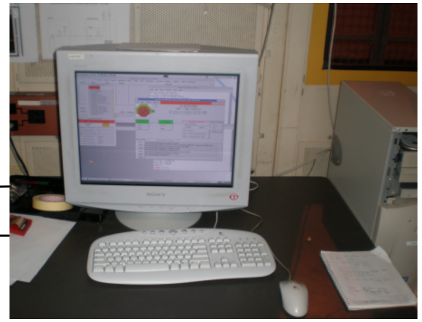
  $Ar:CO_2:iC_4H_{10}$ (88:10:2)

  $Ar:CF_4:iC_4H_{10}$ (88:10:2)

  $Ar:CF_4:iC_4H_{10}$(95:3:2)
- Data acquired for 4 different strip patterns and 5 impact angles (0° to 40°)

2008 Test beam set up

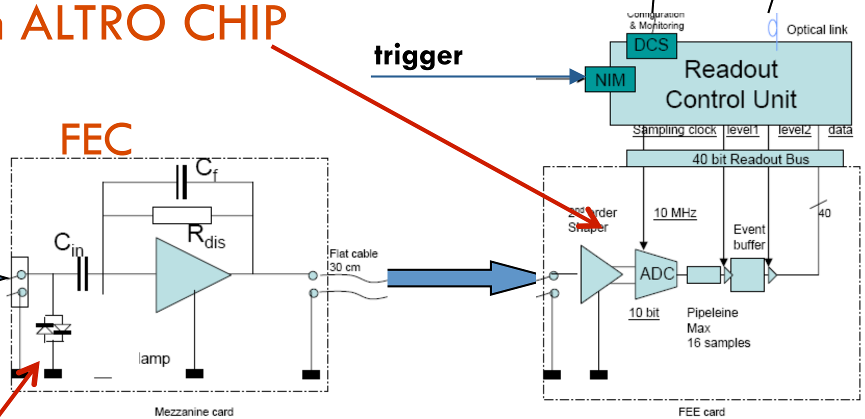
Readout



DAQ PC (ALICE DATE)

DAQ based on ALTRO CHIP

trigger



FEC

32 channels

Micro

Megas

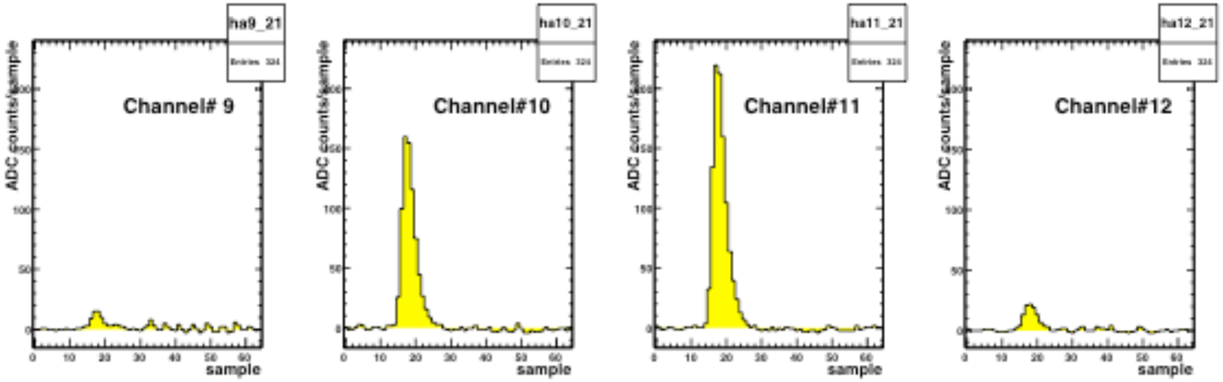
Two inverted diodes for spark protection

Zero channels died

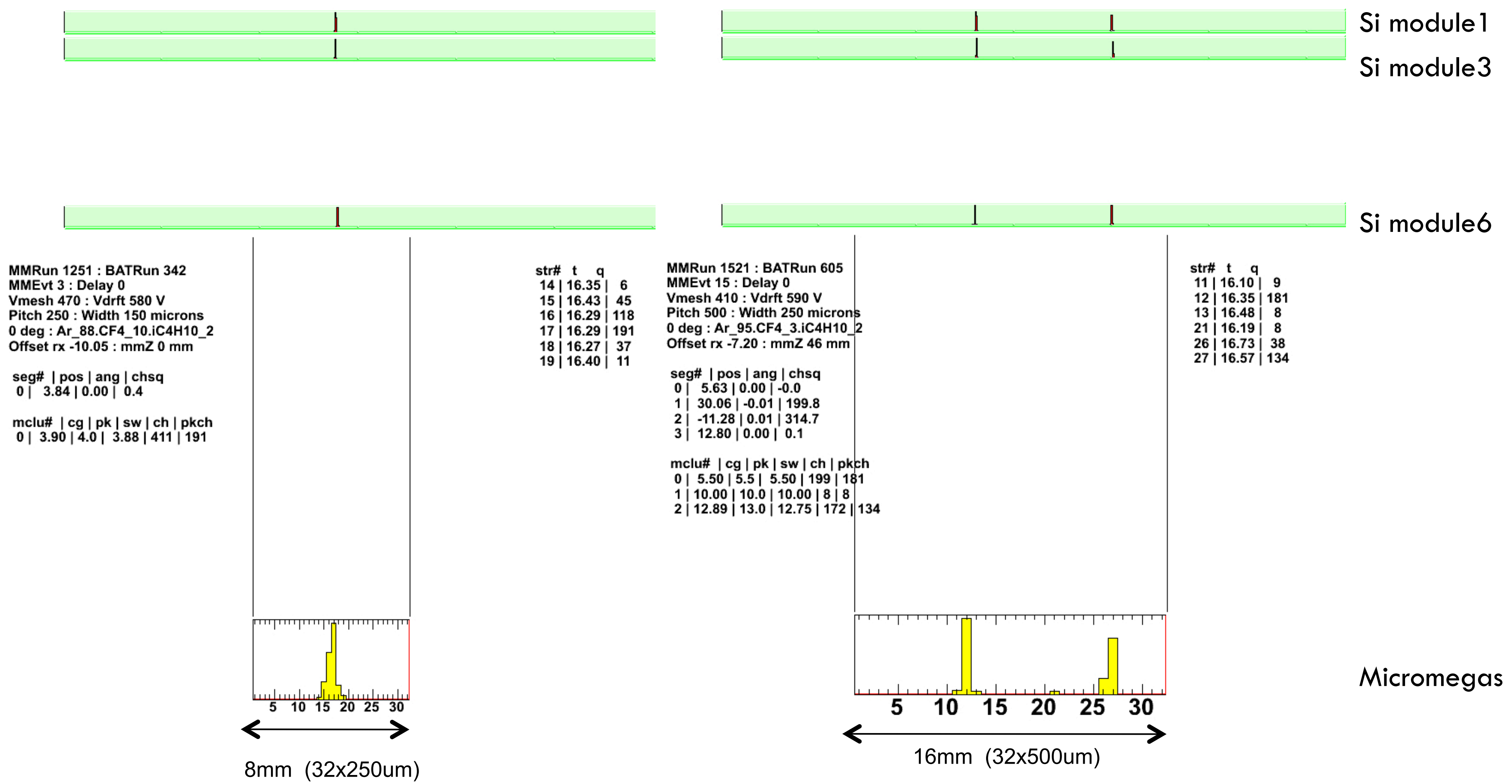
32 channels
200 ns integration time
64 charge samples/ch
100 ns/sample
15 pre-samples
1 ADC count ~ 1000 e$^-$

Typical ADC spectra

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

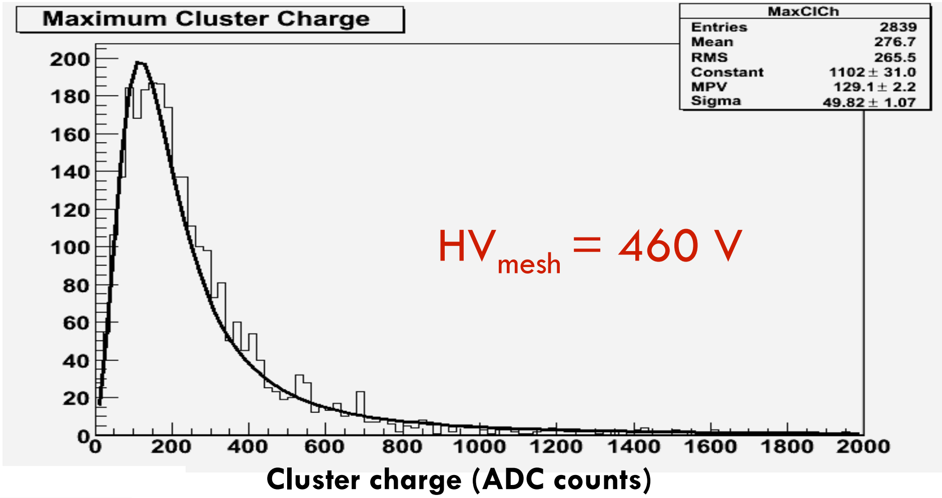


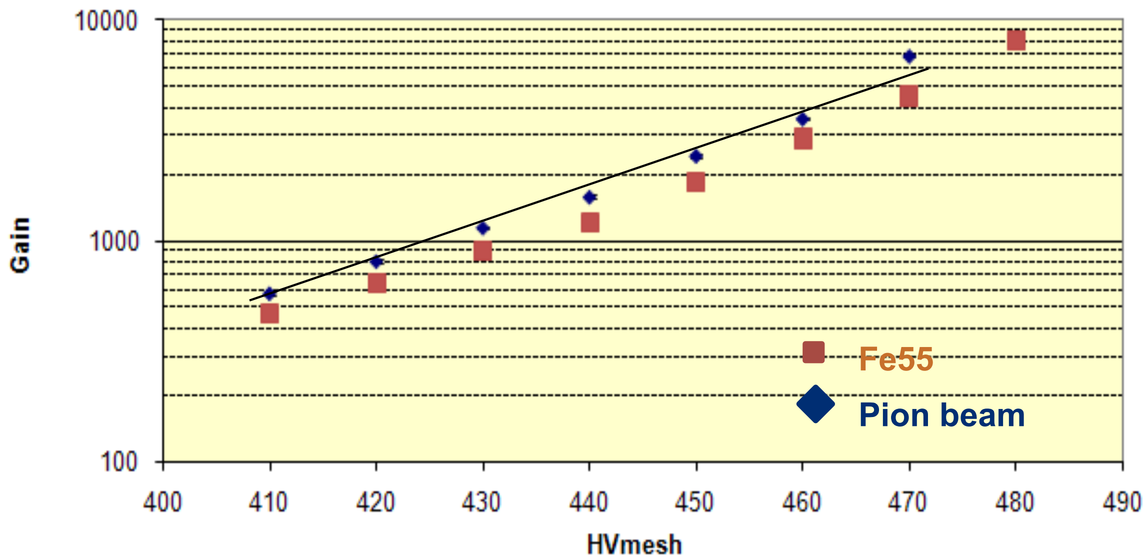
Simple event display



Gain measurement from HV_{mesh} scan

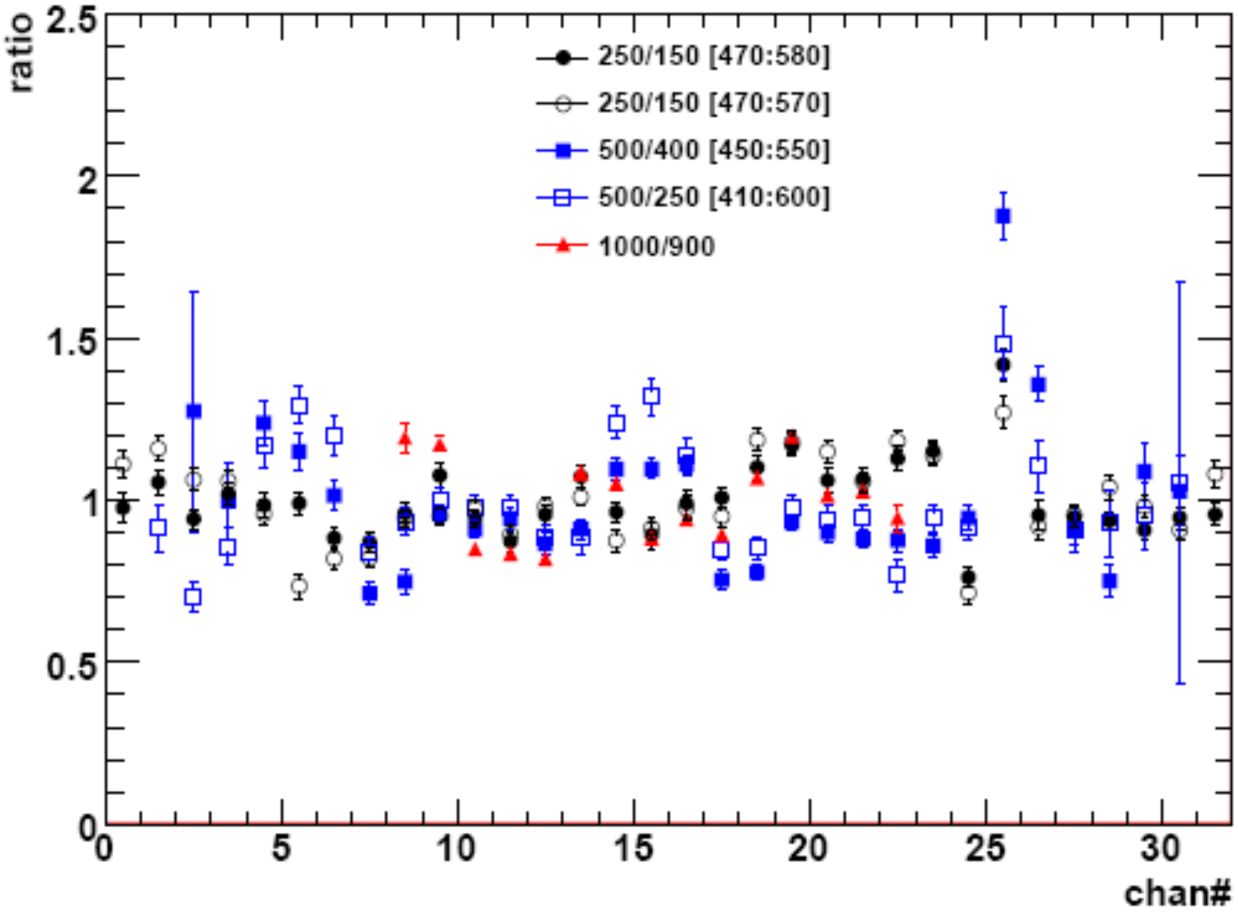
- Gas mixture: $Ar:CF_4:iC_4H_{10}$ (88:10:2)
- Drift gap 5 mm; drift field = 200 V/cm
- Strip pitch = 250 µm
- 1 ADC count = 1000 electrons





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

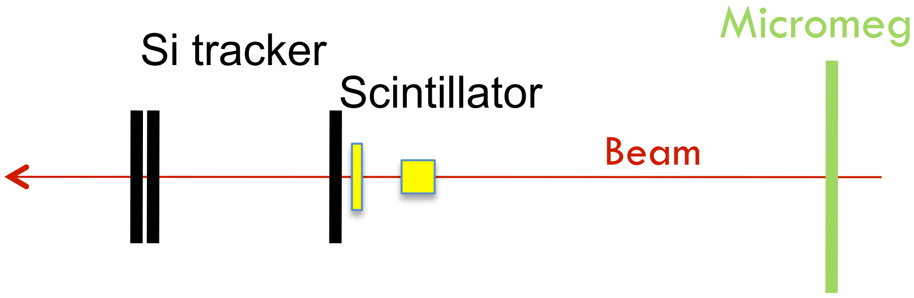
Strip response uniformity



Similar behaviour for different strips
→ small variations mainly related to electronics (not to strips)

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

Spatial resolution – 'online'

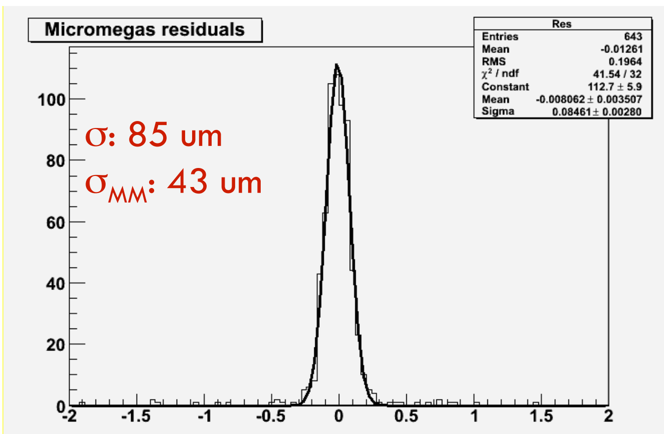


Gas: $Ar{:}CF_4{:}iC_4H_{10}$ (88:10:2)
Drift field: 200 V/cm

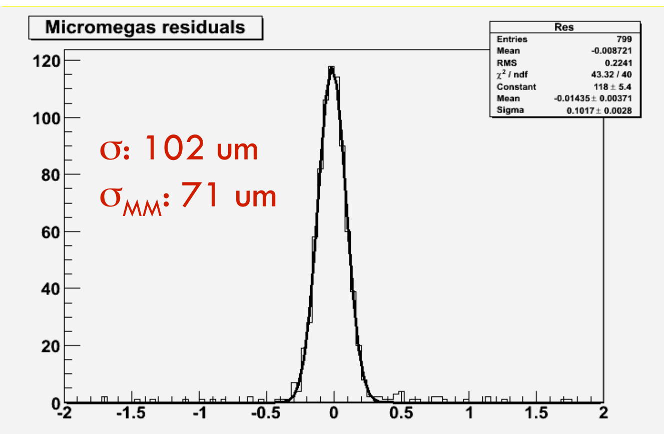
- Residuals of MM cluster position and extrapolated track from Si
- Convolution of:
  - Intrinsic MM resolution
  - Tracker resolution (extrapolation)
  - Multiple scattering

  } ~73 um

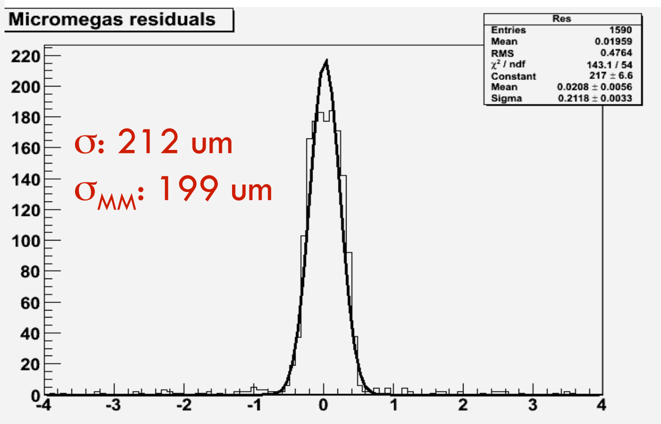
Strip pitch: 250 um
Strip width: 150 um



Strip pitch: 500 um
Strip width: 400 um



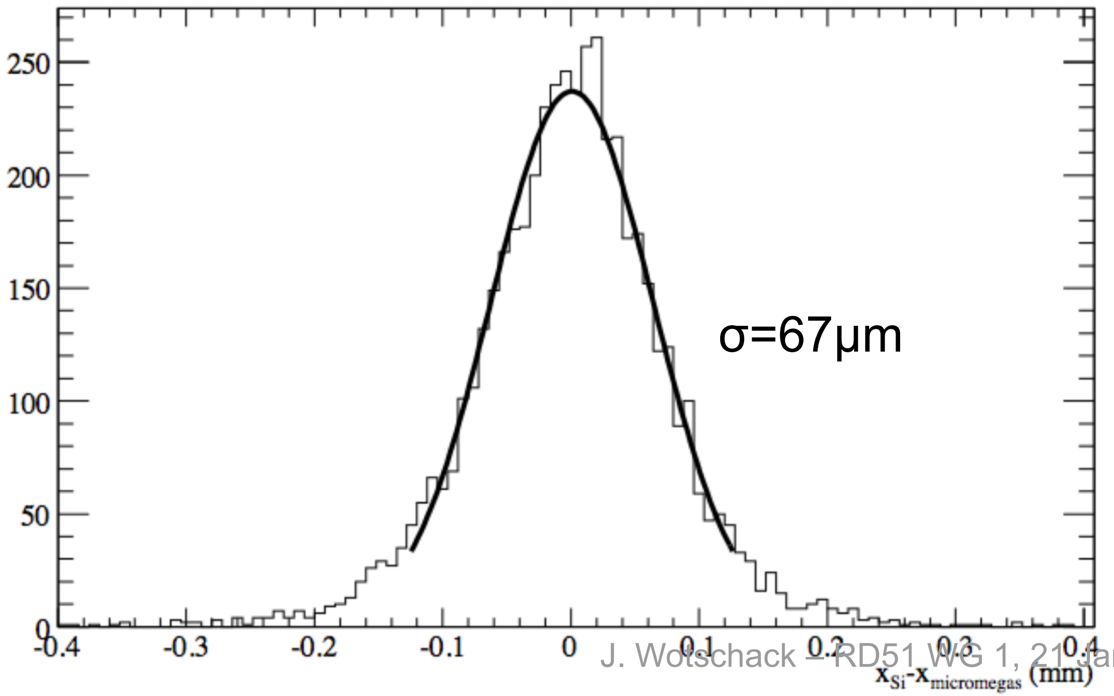
Strip pitch: 1000 um
Strip width: 900 um



Spatial resolution – more refined

- Improved handling of Si tracker data
  - Extrapolation
  - Multiple scattering

  (σ_{extr}= 55 μm)
- Improved calculation of MM cluster position

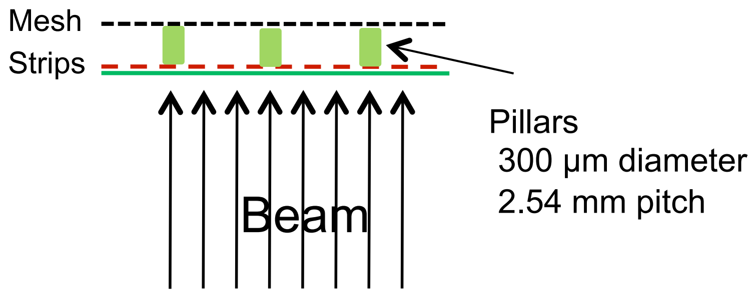


Strip pitch: 250 μm
Gas: $Ar:CF_4:iC_4H_{10}$ (88:10:2)
Track impact angle: 90°

Convoluted resolution of Si tracker + extrapolation
σ(Si+MM) = 67μm

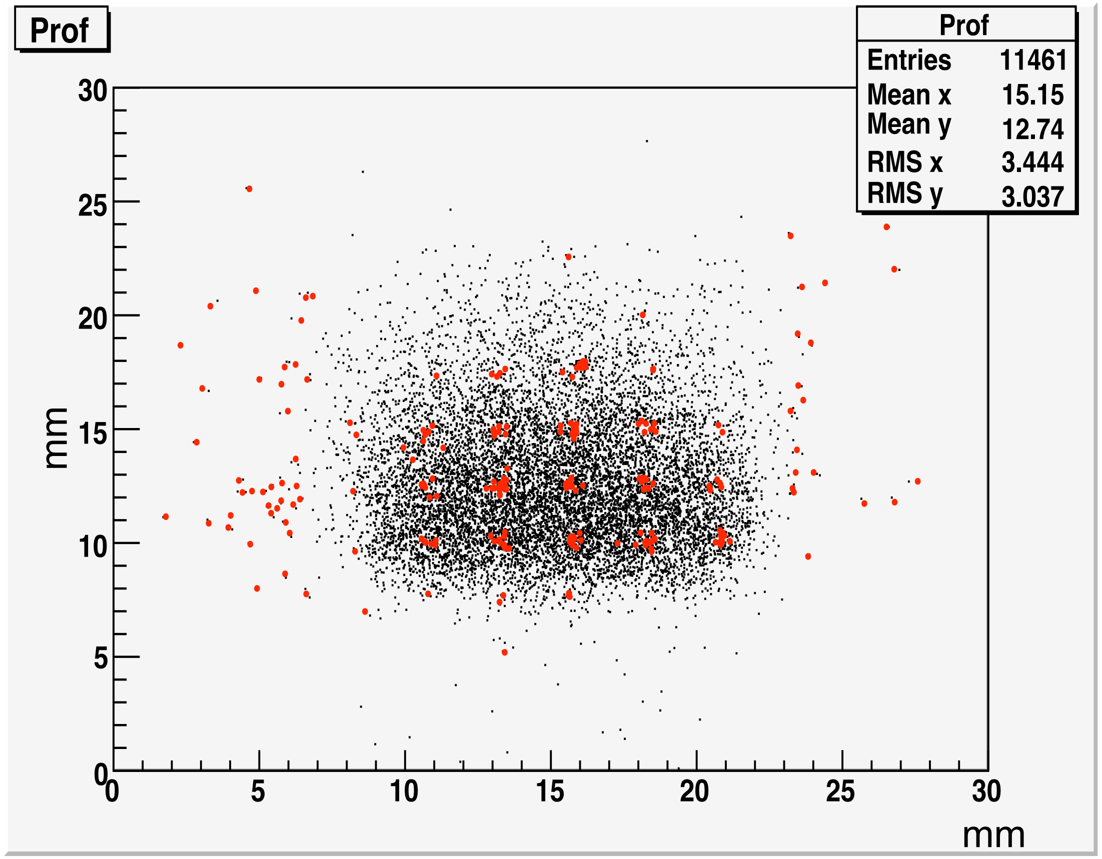
MM intrinsic resolution
⇒ σ(MM) = 38 μm

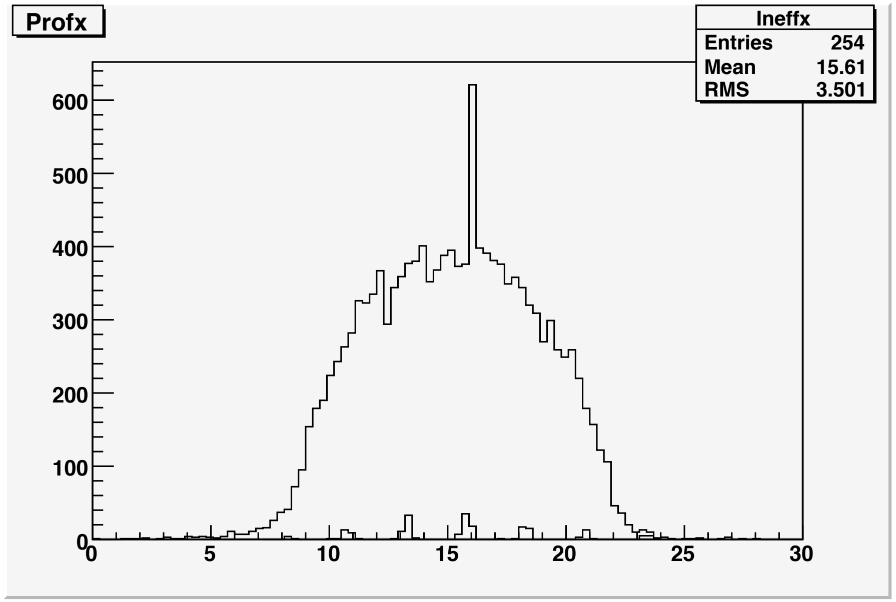
Micromegas Efficiency



Ar:CF_4:Isob (88:10:2)

V_{mesh} = 450 V; V_d = V_{mesh} + 100 V

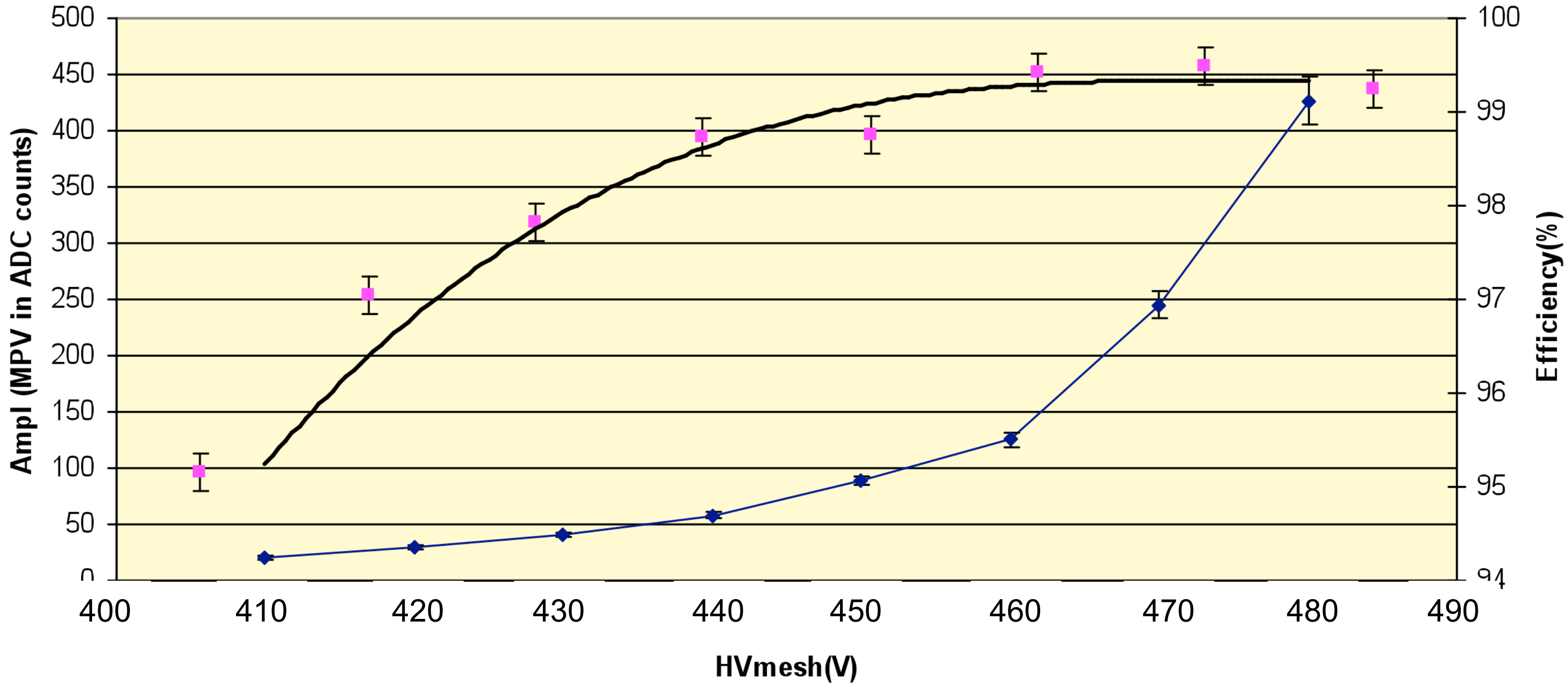


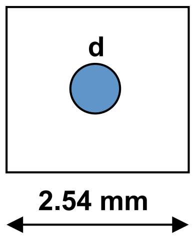


Practically 100% efficient outside the pillars

Reconstructed tracks as measured in Si tracker that give no hit in the MM

Efficiency & Amplification vs HV



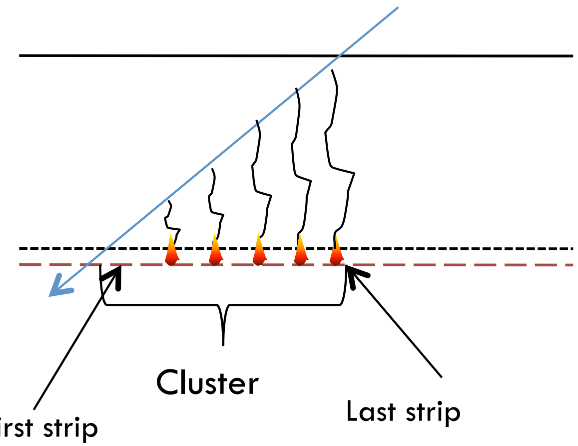


Ineff ≈ 0.5%

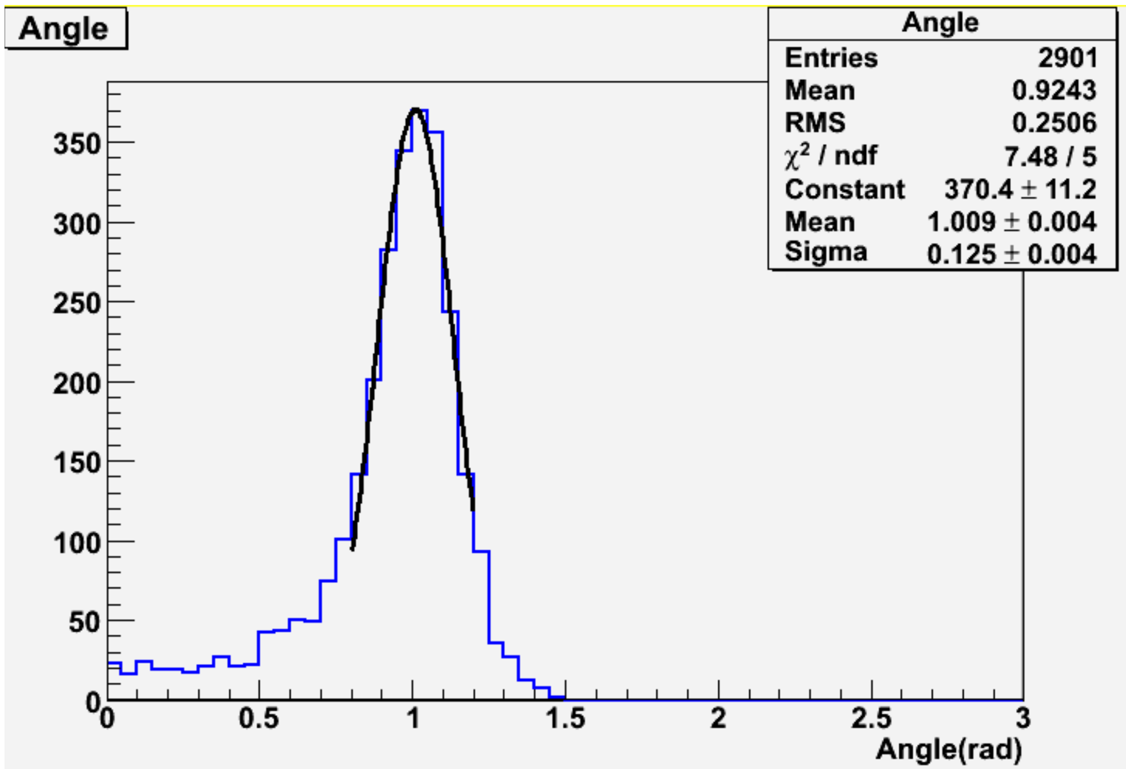
d estimated = 2 * 2.54 * √(Ineff)/π) = 202 µm

d real ~ 300 µm → diffusion ~ 150-200 µm

Micromegas as µ-TPC



With electronics used in 2008 we can only measure the relative times from strip to strip.
There is a jitter of 100 ns on the absolute time.
This allows us (for the 2008 data) to reconstruct the track angle but not the track position.



- Track inclination: 55°
- $Ar:CF_4:iC_4H_{10}$ (95:3:2)
- Drift field: 360 V/cm
- v_D = 6.8 cm/µs

Next steps

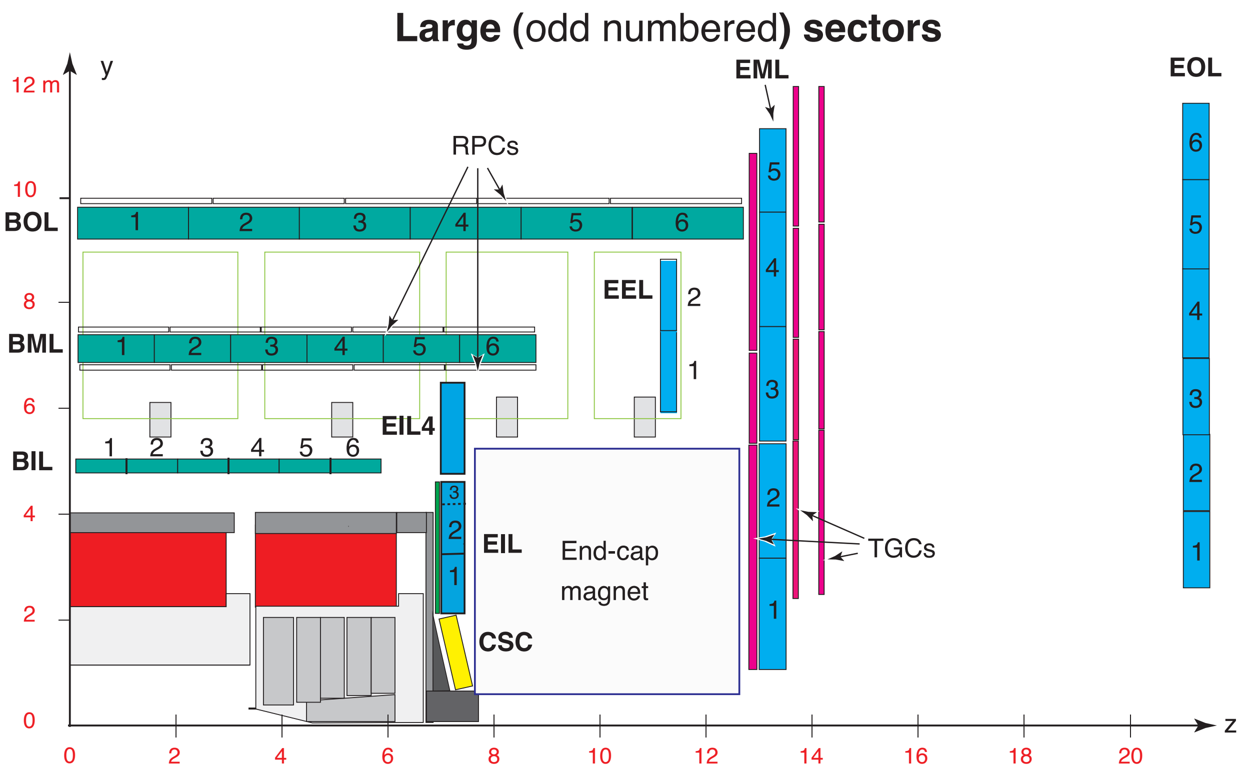
LHC upgrade scenario

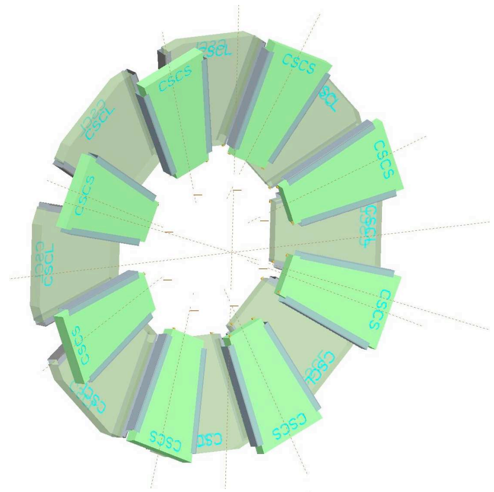
- Phase I:
  - New Linac & new quadrupole triplets on both sides of ATLAS with larger aperture
  - Max luminosity: 2–3 · 10^{34} cm^{-2}
  - Earliest date: winter shut down 2012/2013, extended to 8 months
- Phase II:
  - New PS
  - Max luminosity: 10^{35} cm^{-2}
  - Date: >2016

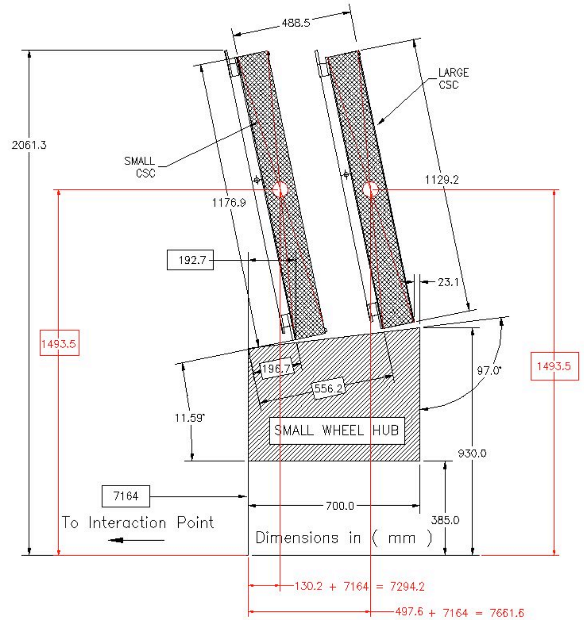
ATLAS upgrade

- New ATLAS pixel detector layers at time of Phase I LHC upgrade
- Possibly also upgrade/replacement of innermost ring of first layer of muon chambers in forward direction (now: Cathode Strip Chambers) – under discussion
  - If backgrounds considerably higher than estimated and/or performance not sufficient; will only been known (approximately) after first collisions

CSC replacement

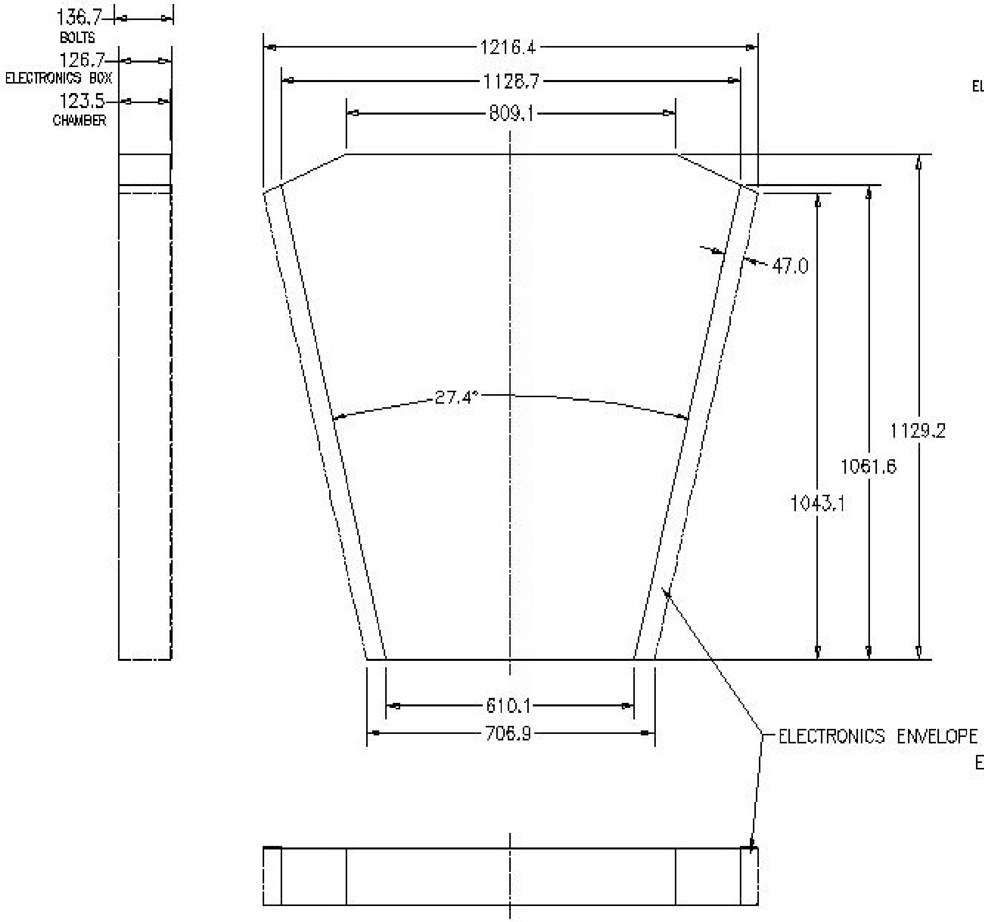




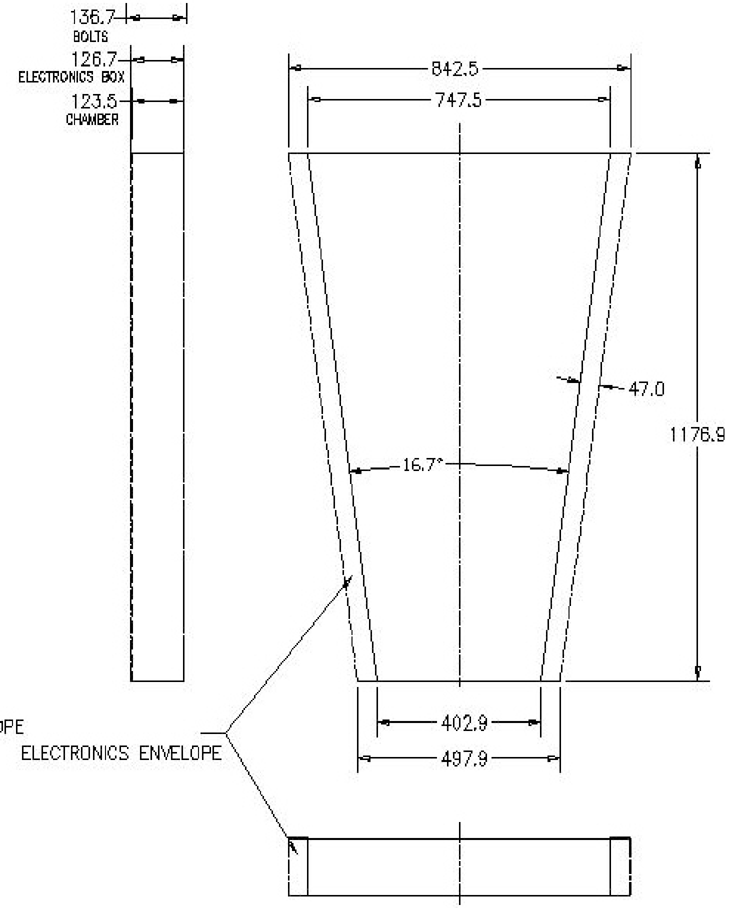


CSC chambers

CSC chamber
(large sector)



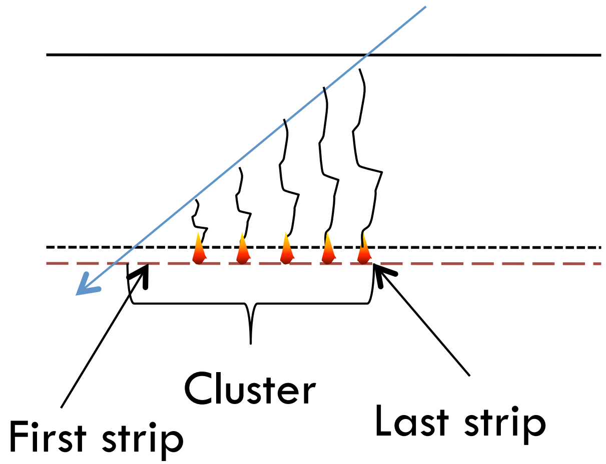
CSC chamber
(small sector)



CSC replacement scenario

- Remove present CSCs
- Add some borated polyethylene for neutron absorption
- Substitute CSCs with micromegas chambers (or other technology) of similar size
  - Large: W_{max}=1200; H=1100
  - Small: W_{max}= 800; H=1100
- Micromegas would/should add better pattern recognition and reconstruction performance, as well as trigger capability

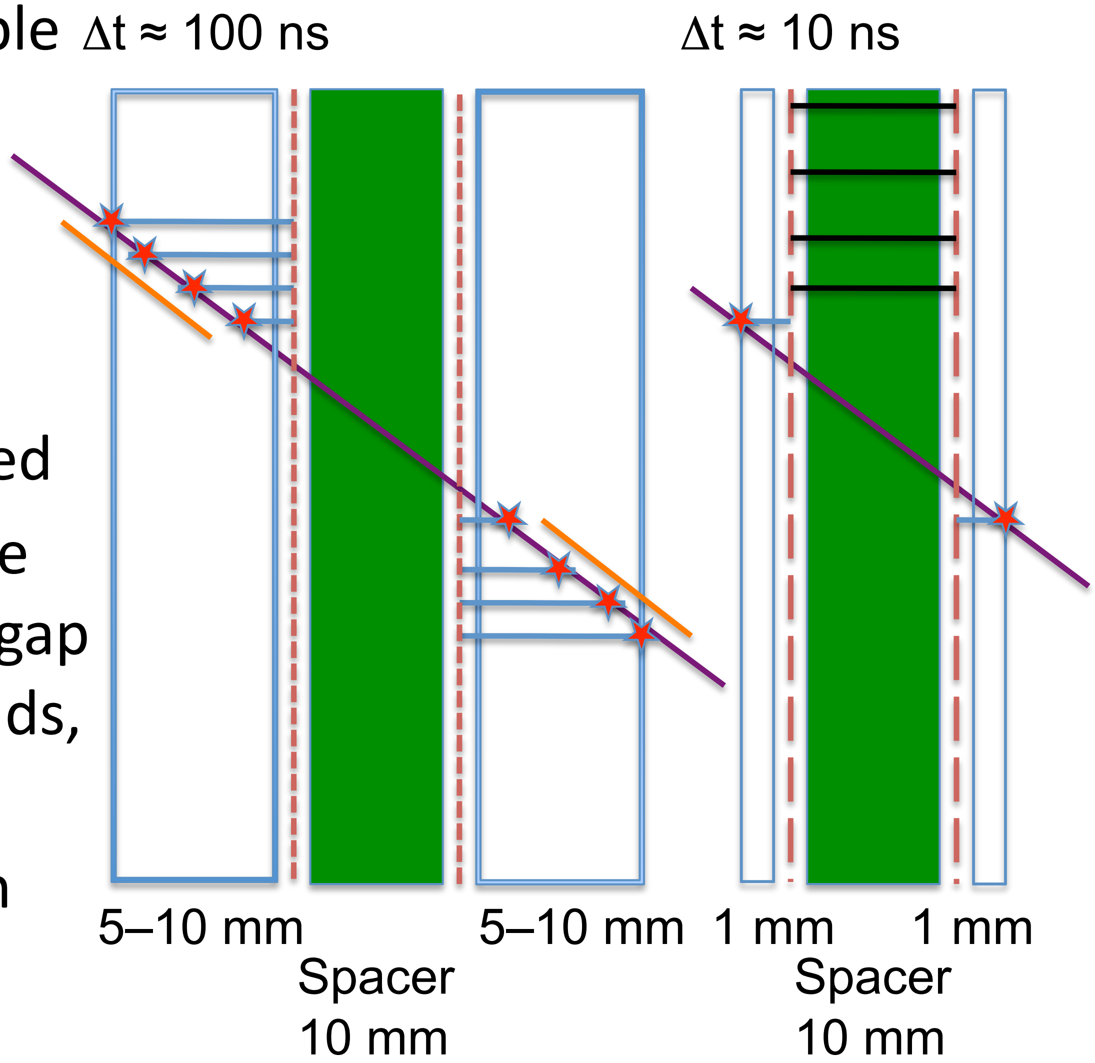
Micromegas as μ-TPC



- Use MM like a TPC
  - measure arrival time of signal on strips and reconstruct space point in the drift gap
  - Series of space points per drift gap => vectors
  - Spatial resolution independent of impact angle
  - Requires
    - small strip pitches = large number of electr channels
    - time measurement with O(few ns) resolution
    - moderate charge measurement (ToT probably OK)

Possible layout

- Self-supported units of double MMs (back to back)
- Number of space points is function of track angle and strip pitch
- Out-of-time tracks not aligned
- Trigger and/or 2nd coordinate by thinner separate double-gap units, wider strips and/or pads, possibly interconnected
- Precision and trigger units in single module ?



Typical parameters

- Track angles for CSC coverage: 10–20°
- Drift gap: 7 mm => footprint: 1 mm (10°)
- Strip pitch: 250 μm = typically 4 strips see signal (+side strips)
- Average number of primary electrons (clusters): 15–20
- Max drift time: 140 ns (v_{drift} = 5 cm/μs)
- Drift time range 'per strip': 35 ns
- Average number of clusters 'per strip': 4–5 distributed in 35 ns

⇒ Want time measurement of average time/strip

Time resolution of a few ns should be sufficient

Integration time order a few 10 ns OK

Charge measurement is needed but can be coarse

Expected performance

- Track angle 10°, 7 mm drift gap, 250 μm strip pitch
- With σ(t) = 5 ns the spatial resolution along the drift path is ≈ 200 μm
- Over 5 mm drift the error on the angle measurement is <2%
- Determination of position from strip positions only (w/o time measurement) gives σ(x) ≤ 100 μm (to be used in parallel or if track angles are too small)
- The 2^{nd} drift gap at 10 mm distance will help to solve ambiguities and improve the resolution further

Implementation in ATLAS

- Three double gap modules spaced by 200 mm each
- Number of channels/ module (250 µm pitch):
  - 1200 x 4 x 2 = 10 k (precision)
  - O(250) strips for 2nd coordinate
  - O(1000) pads for space points

  Total/module: 11.5 k channels
- Three modules/station
- 32 stations
- Total # of channels : 1 M

- Trigger options:
  - Dedicated planes together with 2nd coordinate measurement

    Bunch crossing time from first time signals (5 ns)
  - Extract track angle from time measurement on precision strips (O(µs))

Test beam 2009

- Three dedicated periods of one week each in H6 beam (as last year)
  - 27 May – 03 June
  - 15 – 22 July
  - 22 – 28 October
- More beam time as parasitic users likely
- Scanning table (x,y)
- External Si telescope (BAT), as in 2008

Gas

- 2008
  - Ar:CO_2:isobutane (88:10:2)
  - Ar:CF_4:isobutane (88:10:2)
  - Ar:CF_4:isobutane (95:3:2)

  No measurement of T, p, humidity
- 2009
  - May want to go back to pure Ar:CO_2 (80:20 or 70:30)
  - Not a large difference in achievable gains (higher HV)

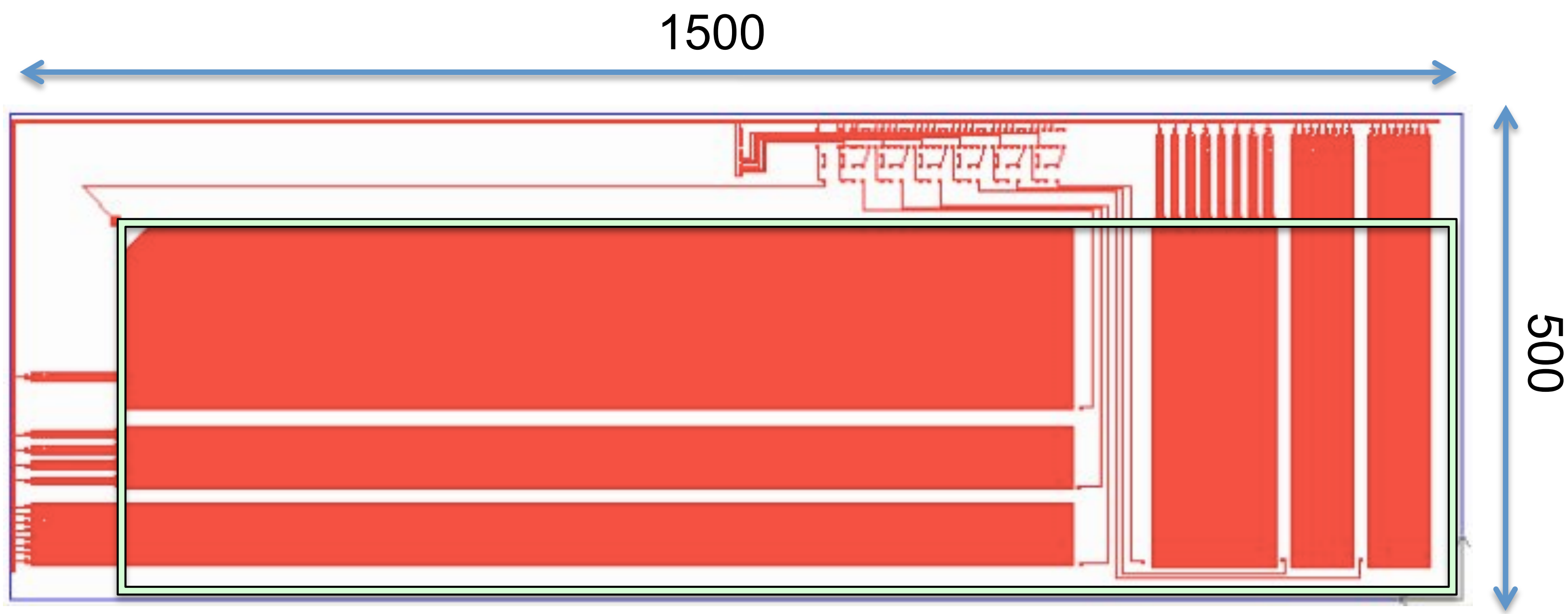
  Also: measure and record T, p, humidity

DAQ and readout

- Same electronics as in 2008 (ALICE DATE)
  - 64 (+ 32) channels
  - Convert one channel to measure trigger arrival time; this should give us a time resolution of few ns
- Possibly also BNL electronics (128 channels)
- Other ?
- Separate data streams for Si telescope and MM and DCS (temperature, atm pressure, humidity)

New prototypes in 2009

- Small (100 x 100 mm^2) with T2K grid and 250 µm strip pitch
- Half-size (under construction at CERN/EN-ICE)
  - Strips with 250 and 500 µm pitch (long and short)
  - One group of strips with resistive coating (~ 1 MOhm pillars)



The 50% prototype

- Active area: 1.3 x 0.4 m^2
- Segmented mesh (cut) to reduce mesh capacity
- 250 and 500 µm strip pitches
- Long and short strips
- Construction has started in CERN/EN-ICE
- Chamber to be completed for test beam in May 2009