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Micromegas for the upgrade of the ATLAS muon chambers for the SLHC

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on behalf of

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

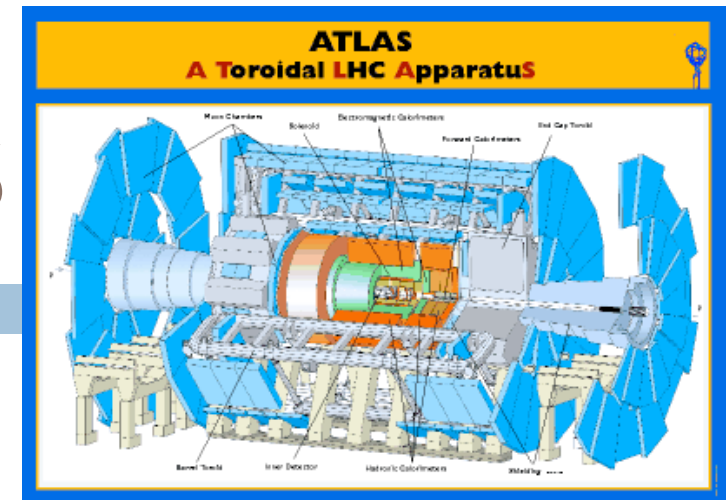
<https://twiki.cern.ch/twiki/bin/view/Atlas/MuonMicromegas>

*) Thanks to Paolo Iengo for preparing the talk

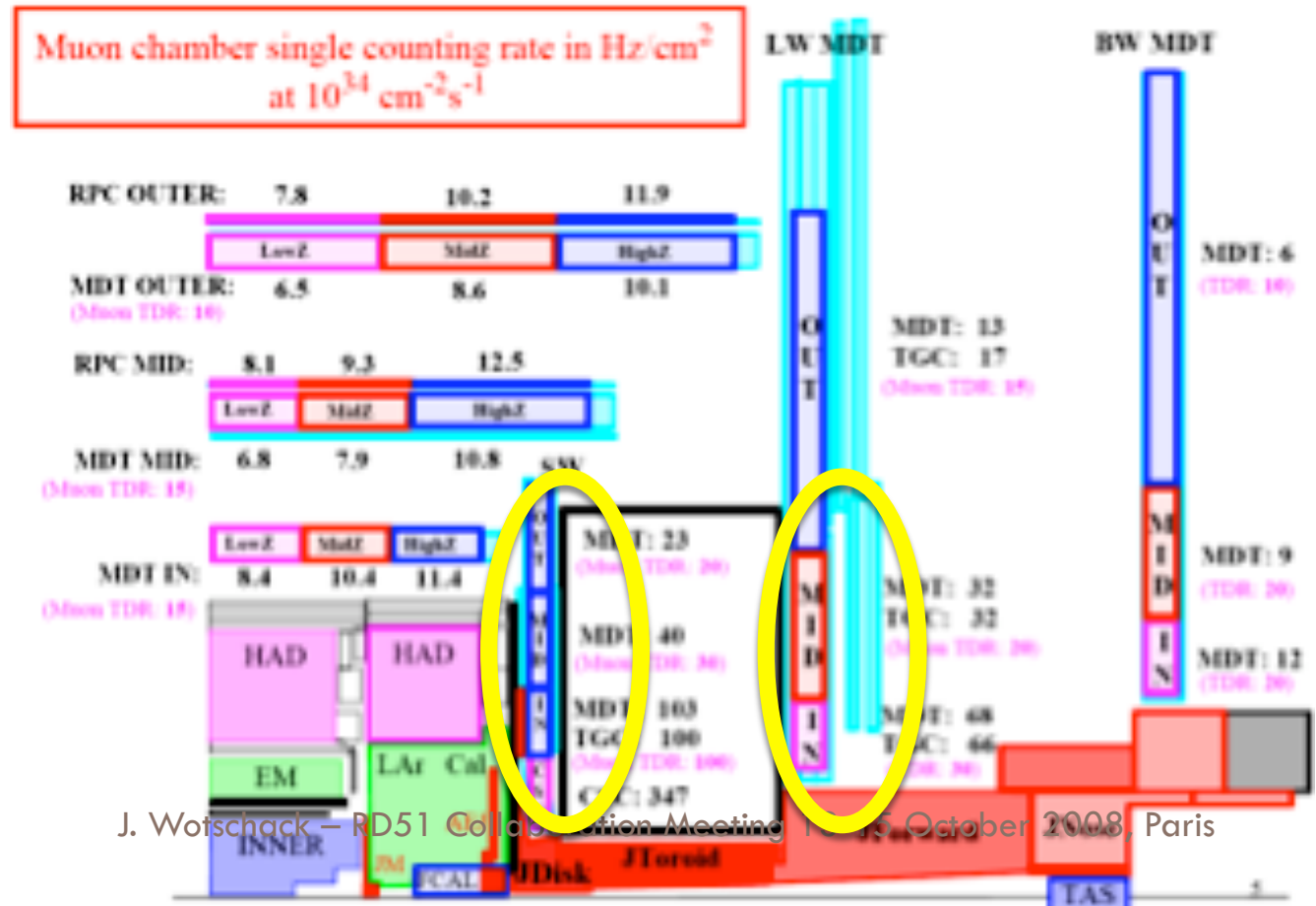
J. Wotschack – RD51 Collaboration Meeting 13-15 October 2008, Paris

The Upgrade of ATLAS

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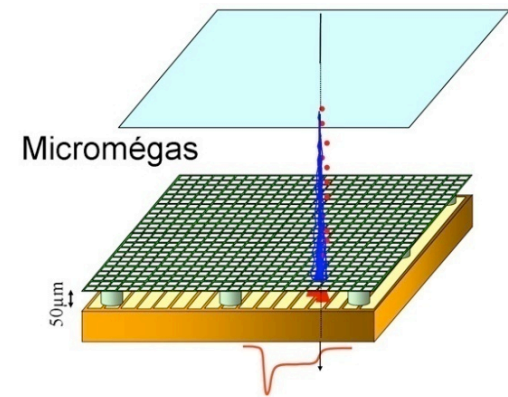
- LHC upgrade
 - $L_{SLHC} \sim 10 L_{LHC}$
 - bunch crossing time: 50ns (25 ns)
- Critical regions in ATLAS Muon Spectrometer:
 - EI layers:
 - CSC(27m²)
 - EIS/L1(54m²)
 - EIS/L2 (68m²)
 - EM $\eta > 2$: EMS/L1(85m²)



Micromegas as candidate technology

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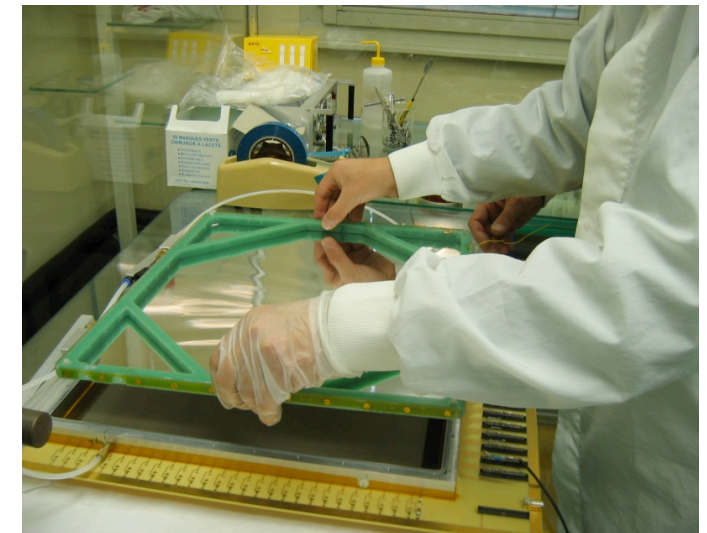
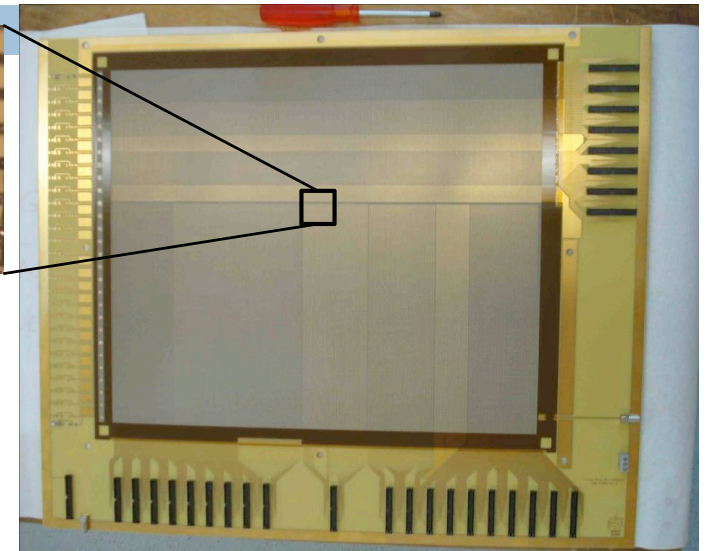
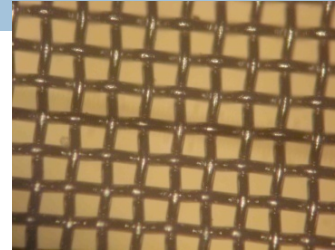
- Combine triggering and tracking functions
- Matches required performances:
 - ▣ Spatial resolution $\sim 100 \mu\text{m}$ ($\Theta_{\text{track}} < 45^\circ$)
 - ▣ Good double track resolution
 - ▣ Time resolution $\sim 5 \text{ ns}$
 - ▣ Efficiency $> 98\%$
 - ▣ Rate capability $> 5 \text{ kHz}/\text{cm}^2$
- Potential for going to large areas $\sim 1 \text{ m} \times 2 \text{ m}$ with industrial processes (cost effective)



Prototype P1

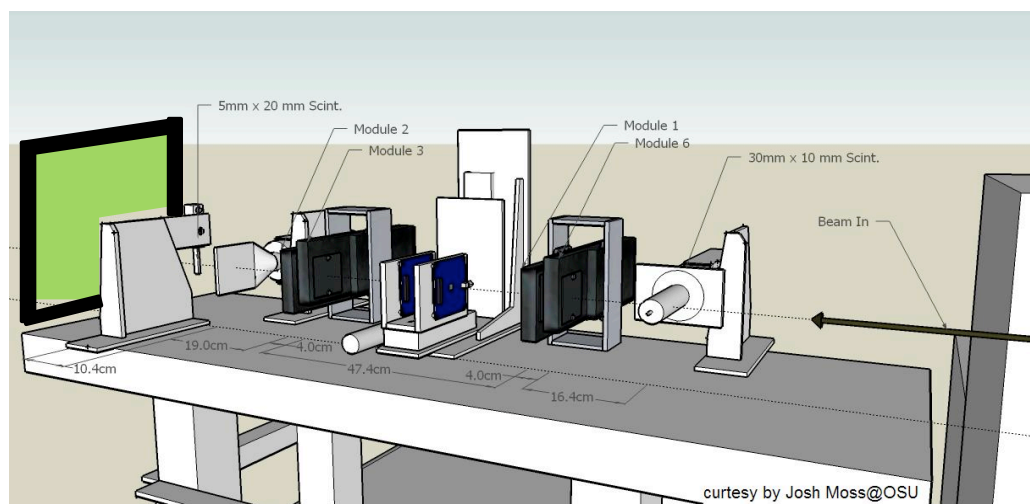
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- Standard bulk micromegas fabricated at CERN-TS/DEM
- Homogeneous stainless steel mesh
- 325 line/inch = 78 μm pitch
- Wire diameter $\sim 25 \mu\text{m}$
- Amplification gap = 128 μm
- 450mm x 350mm active area
- Different strip patterns (250, 500, 1000, 2000 μm pitch; 450mm and 225 mm long)
- Drift gap: 2-5 mm



Test beam set up

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2007 Test beam set up



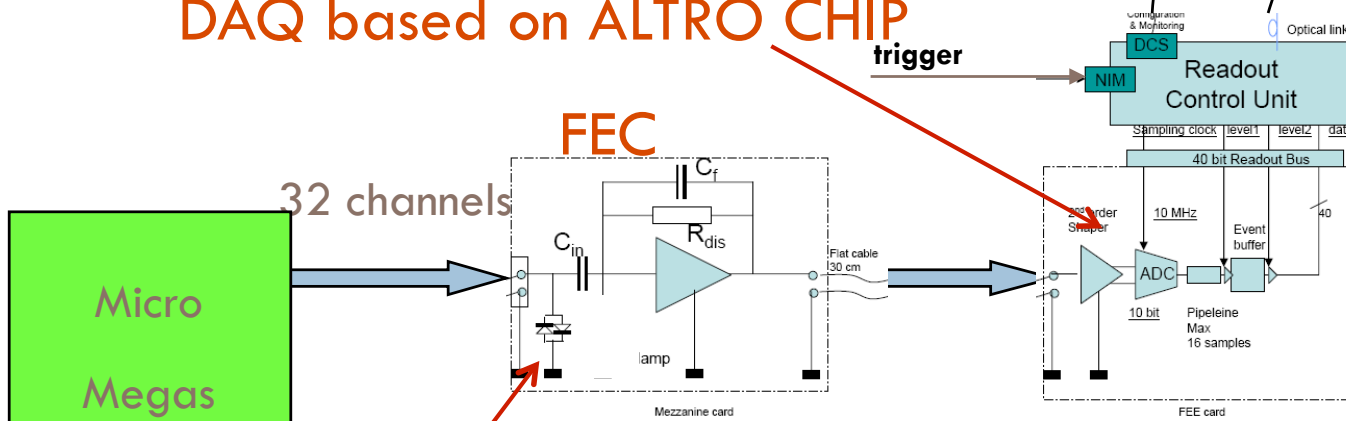
2008 Test beam set up

- ❑ P1 tested @ CERN H6 beam line in November 2007 & 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 admixture used in 2008:
Ar:CO₂:iC₄H₁₀ (88:10:2), Ar:CF₄:iC₄H₁₀ (88:10:2), Ar:CF₄:iC₄H₁₀ (95:3:2)
- ❑ Data acquired for 4 different strip patterns and 5 impact angles (0 to 40 degrees)

Readout

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DAQ based on ALTRO CHIP



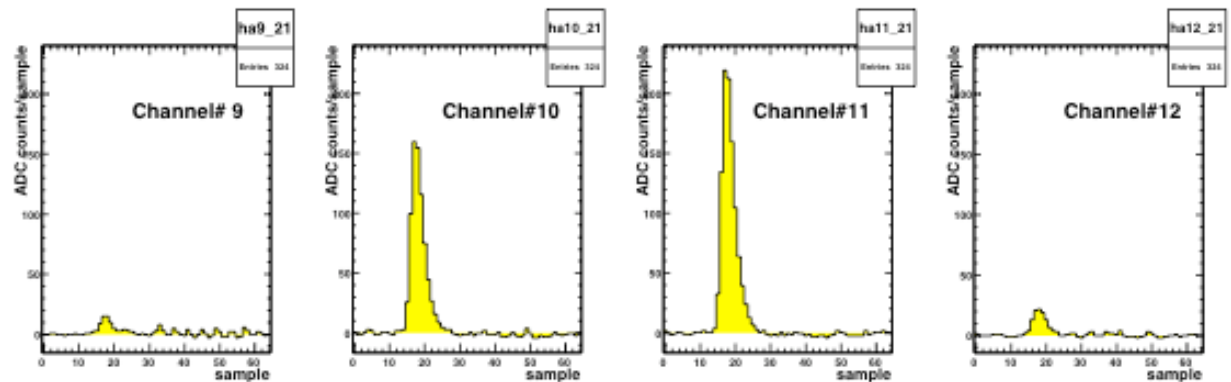
DAQ PC (ALICE DATE)

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 $\sim 1000 e^-$

Typical ADC spectra

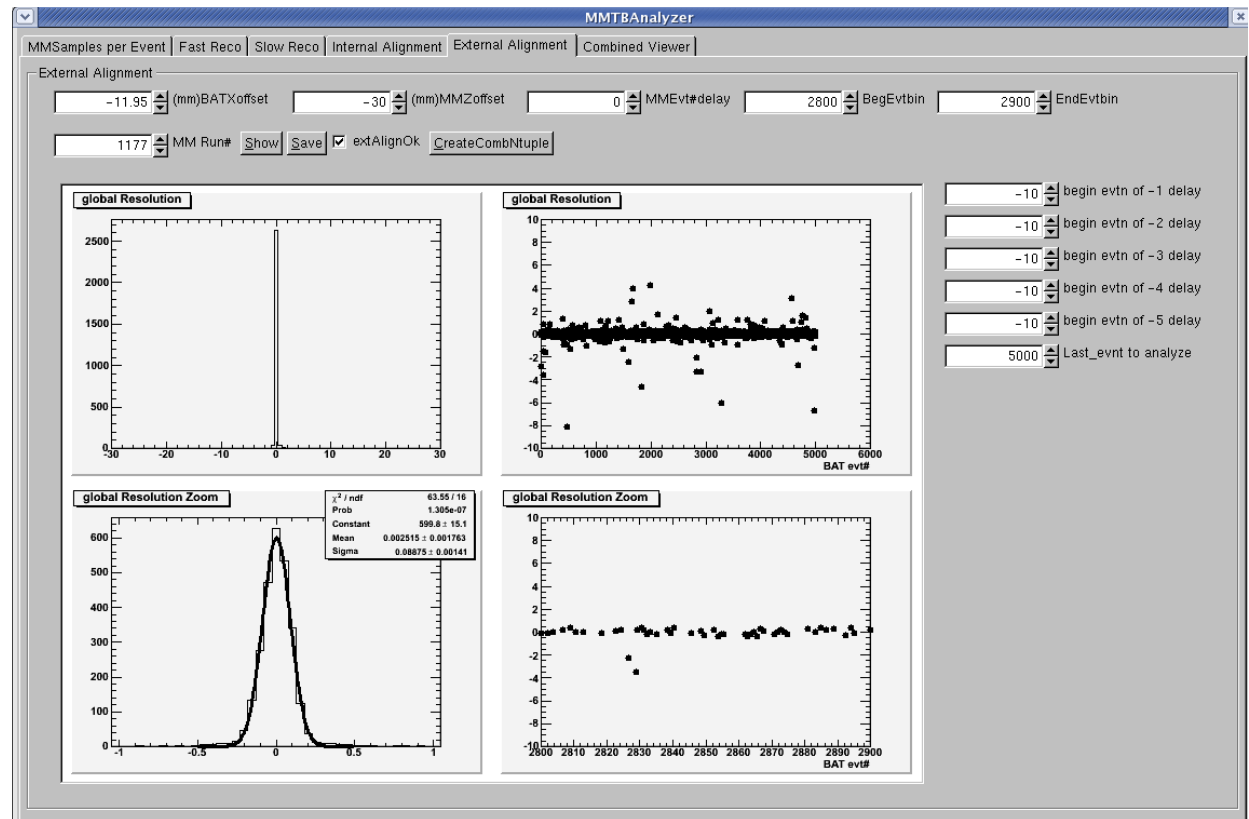
- Noise subtraction (from 12 pre-samples)
- Custer position from center of gravity



Software tool

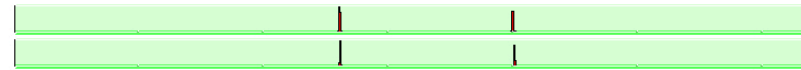
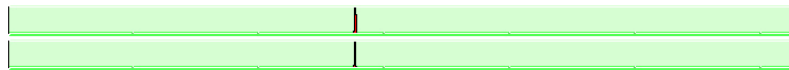
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- Software tool for quasi online and off-line reconstruction (based on ROOT)
- Permits alignment of Si tracker modules with MM chamber
- Combines data from Si tracker and MM
- 'online' resolution
- Also: simple event display

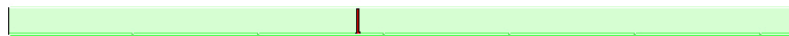


Simple event display

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Si module1
Si module3



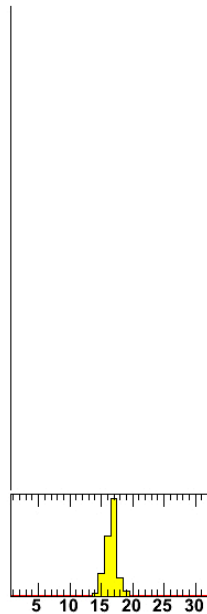
Si module6

MMRun 1251 : BATRun 342
MMEvt 3 : Delay 0
Vmesh 470 : Vdrft 580 V
Pitch 250 : Width 150 microns
0 deg : Ar_88.CF4_10.iC4H10_2
Offset rx -10.05 : mmZ 0 mm

seg#	pos	ang	chsq
0	3.84	0.00	0.4

mclu#	cg	pk	sw	ch	pkch
0	3.90	4.0	3.88	411	191

str#	t	q
14	16.35	6
15	16.43	45
16	16.29	118
17	16.29	191
18	16.27	37
19	16.40	11

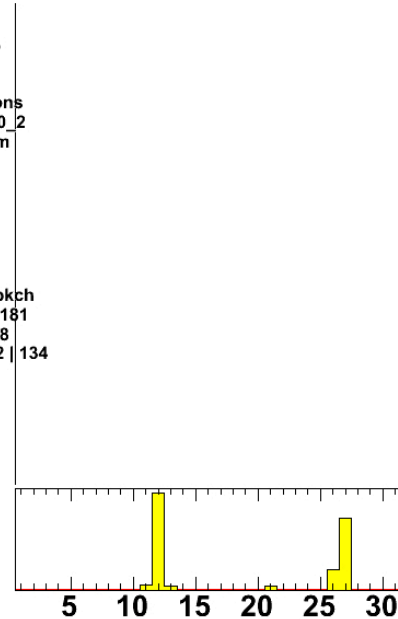


MMRun 1521 : BATRun 605
MMEvt 15 : Delay 0
Vmesh 410 : Vdrft 590 V
Pitch 500 : Width 250 microns
0 deg : Ar_95.CF4_3.iC4H10_2
Offset rx -7.20 : mmZ 46 mm

seg#	pos	ang	chsq
0	5.63	0.00	-0.0
1	30.06	-0.01	199.8
2	-11.28	0.01	314.7
3	12.80	0.00	0.1

mclu#	cg	pk	sw	ch	pkch
0	5.50	5.5	5.50	199	181
1	10.00	10.0	10.00	8	8
2	12.89	13.0	12.75	172	134

str#	t	q
11	16.10	9
12	16.35	181
13	16.48	8
21	16.19	8
26	16.73	38
27	16.57	134

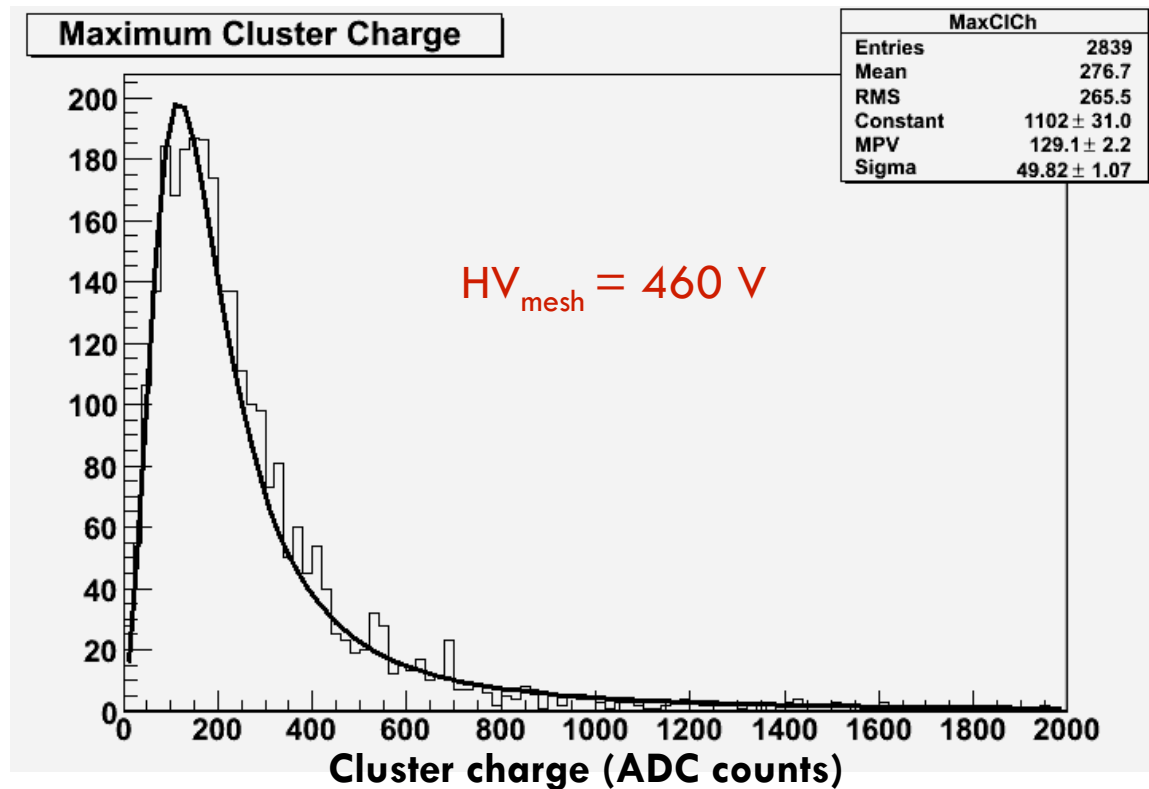


Micromegas

Cluster charge distribution

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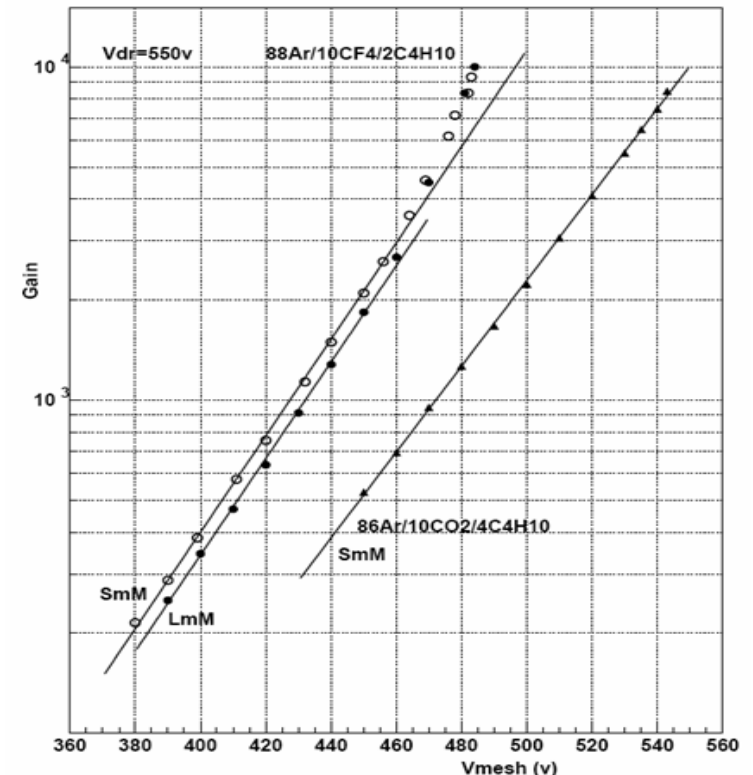
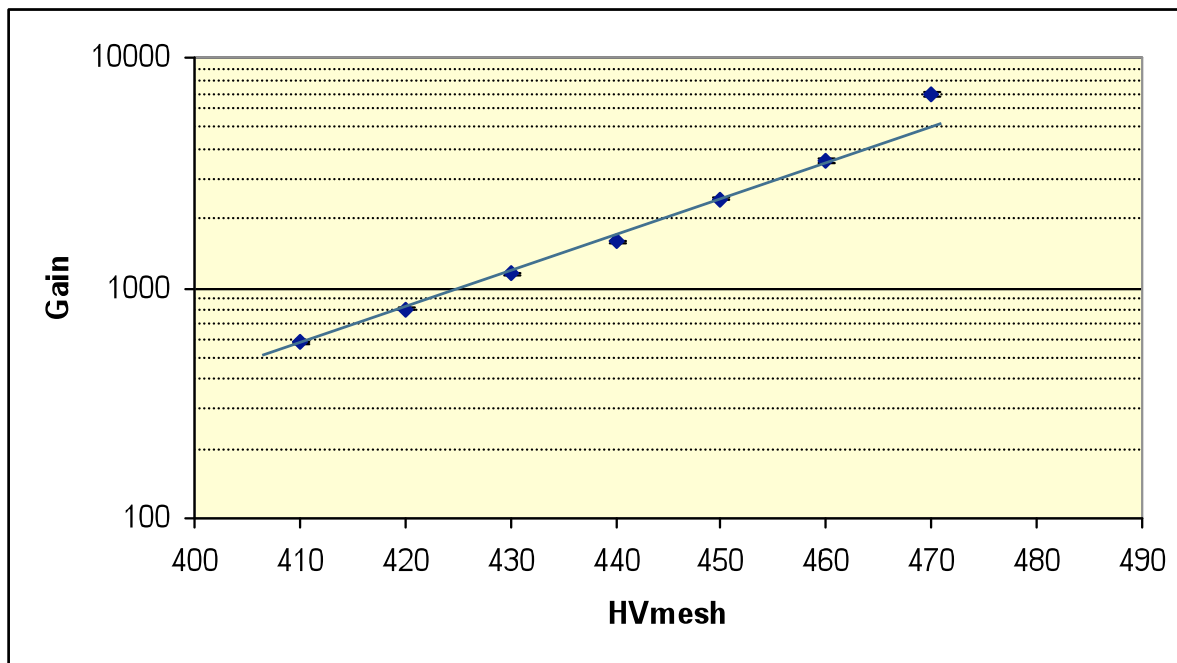
- Gas mixture: Ar:CF₄:iC₄H₁₀ (88:10:2)
- Drift gap 5 mm; drift field = 200 V/cm
- Strip pitch = 250 μm
- Horizontal axes: ADC counts
- 1 ADC count = 1000 electrons



Gain measurement from HV_{mesh} scan

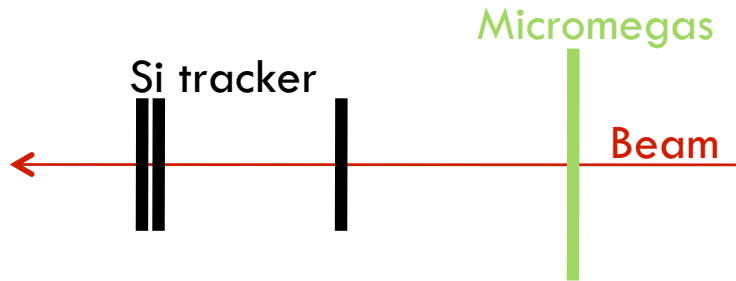
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- Good agreement with measurement with ⁵⁵Fe source
- Stable working point @ gain $\sim 3 \cdot 10^3$



Spatial resolution – ‘online’

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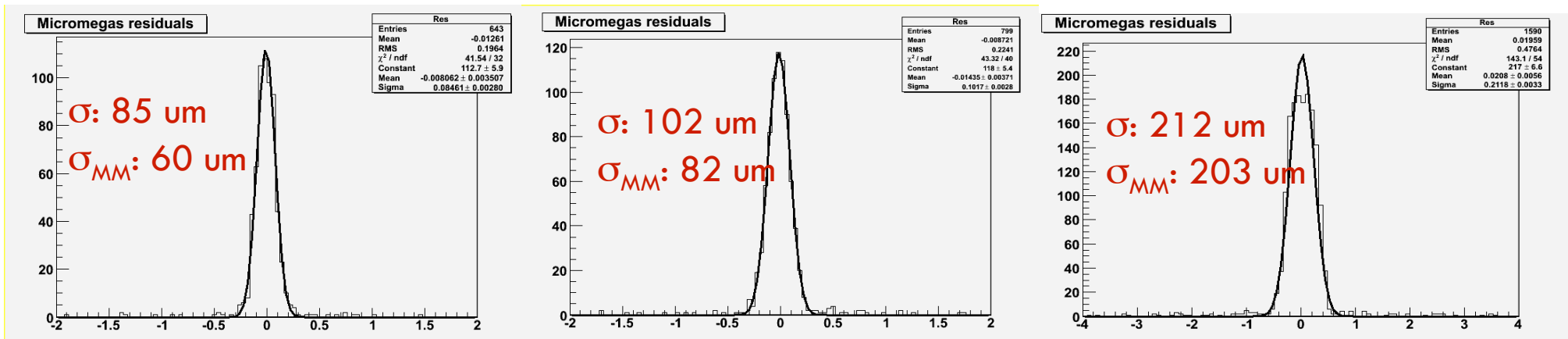
- Residuals of MM cluster position and extrapolated track from Si
- Convolution of:
 - ▣ Intrinsic MM resolution
 - ▣ Tracker resolution (extrapolation): ~ 60 μm

Gas: Ar:CF₄:iC₄H₁₀ (88:10:2)
Drift field: 200 V/cm

Strip pitch: 250 μm
Strip width: 150 μm

Strip pitch: 500 μm
Strip width: 400 μm

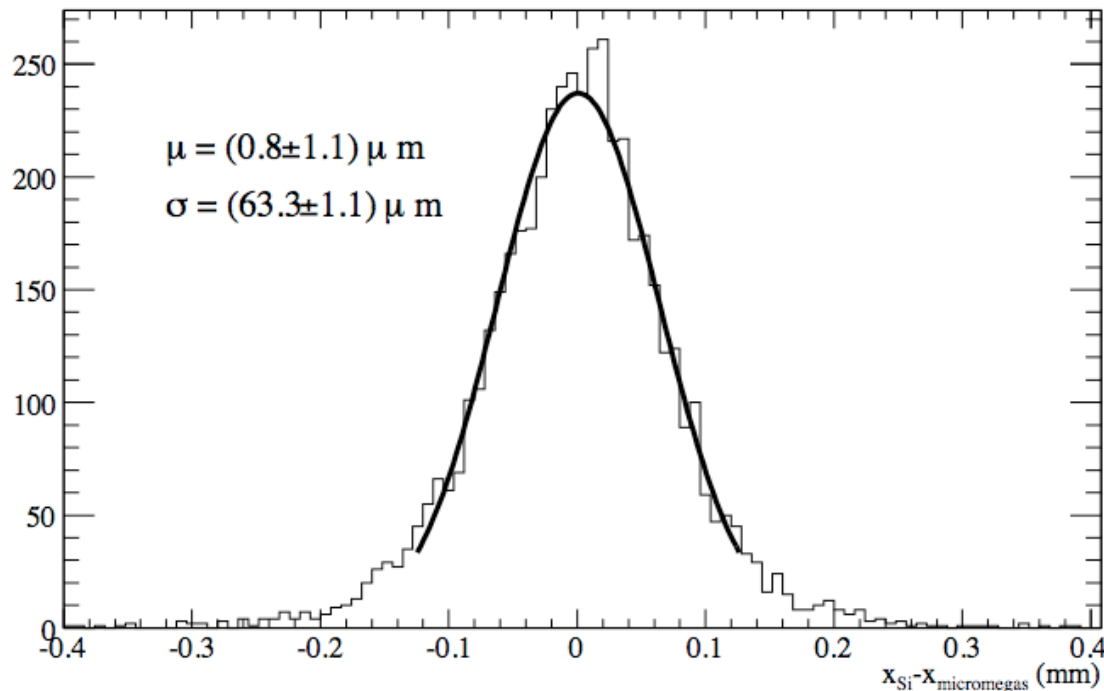
Strip pitch: 1000 μm
Strip width: 900 μm



Spatial resolution – more refined

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- Improved handling of Si tracker data ($\sigma_{\text{extr}} = 33 \mu\text{m}$)
- Improved calculation of MM cluster position



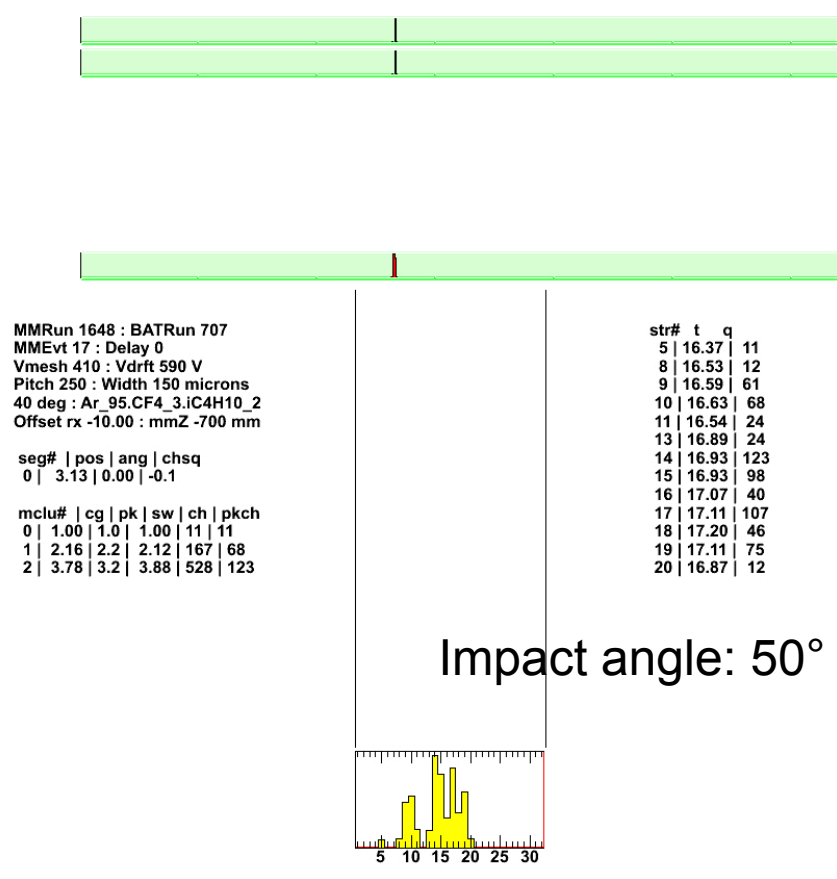
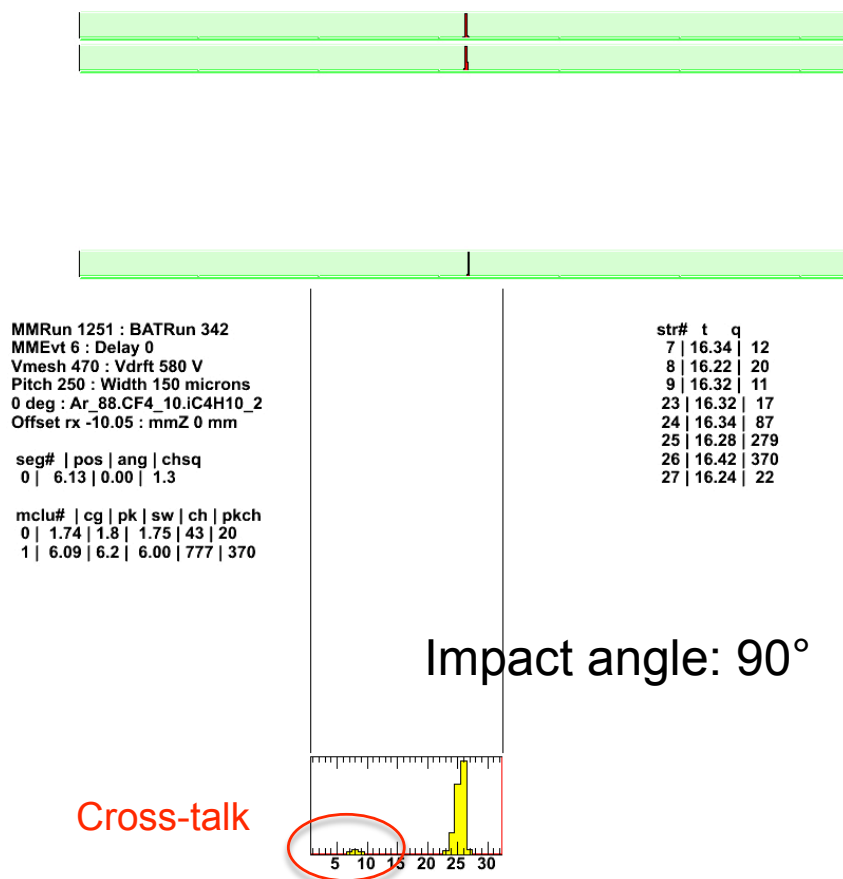
Strip pitch: $250 \mu\text{m}$
Gas: Ar:CF₄:iC₄H₁₀ (88:10:2)
Track impact angle: 90°

Convolved resolution of Si tracker + extrapolation
 $\sigma(\text{Si}+\text{MM}) = 63 \mu\text{m}$

MM intrinsic resolution
 $\Rightarrow \sigma(\text{MM}) \leq 55 \mu\text{m}$

Tracks with different impact angle

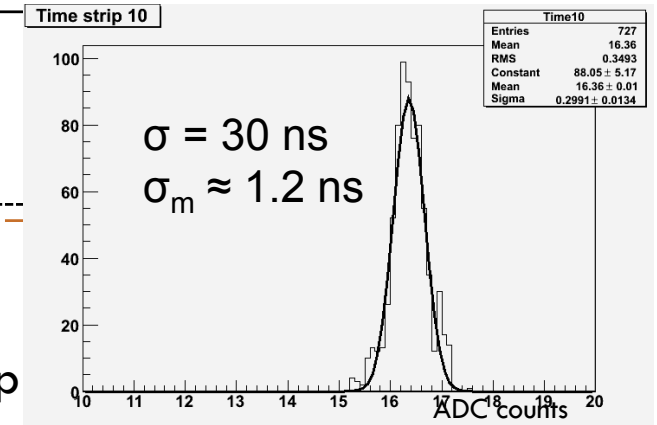
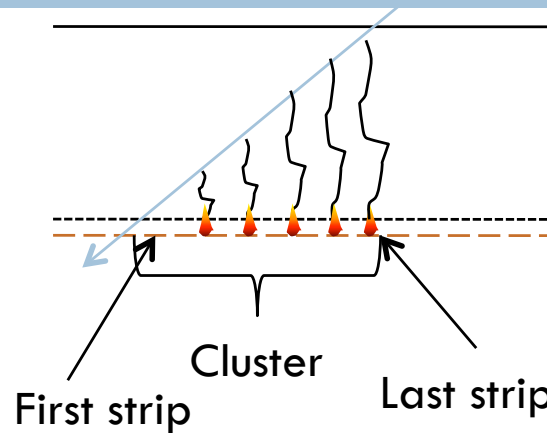
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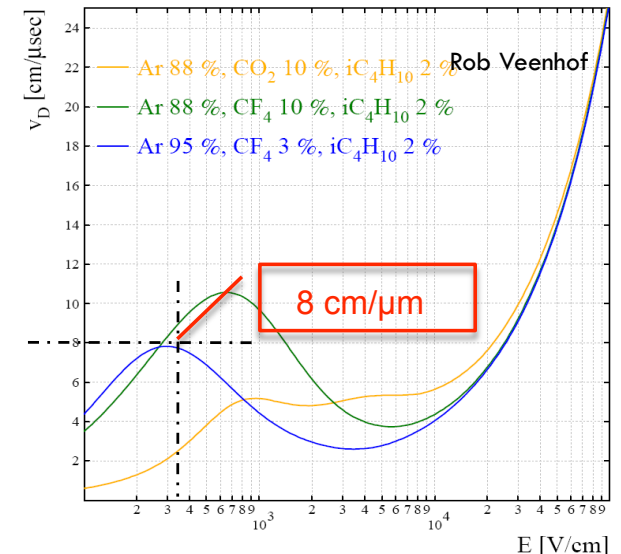
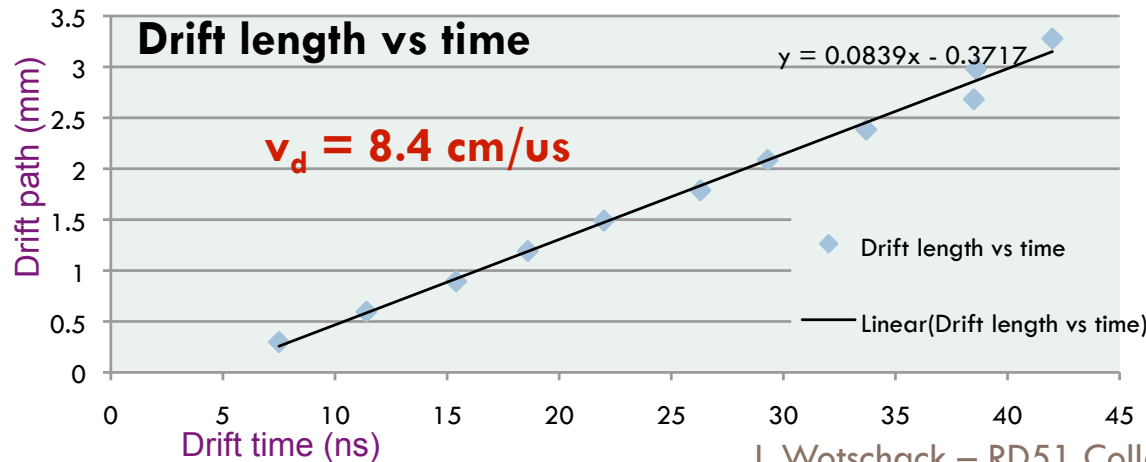
Micromegas as a TPC (I)

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- Track inclination: 40°
- Ar:CF₄:iC₄H₁₀ (95:3:2)
- Drift field: 360V/cm



Even with non-optimal r/o electr. measuring the arrival time on each strip it is possible to measure the drift velocity or, with known drift velocity, the drift distance



Micromegas as TPC (II)

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- A time resolution of a nanosecond results in space points with a resolution along the drift direction of 100 μm
- Each micromegas gap delivers a set of space points, the more the track is inclined the more space points are available
- Solves the problem of spatial resolution for large track inclination
- Most likely the direction we want to take

What next ?

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- Test beam stopped; set up cosmics test stand in lab
- Analysis of test beam data taken in 2008 with goals:
 - ▣ Definition of readout segmentatio
 - ▣ Definition of requirements for r/o electronics
- Study of resistive coating (mainly for spark protection) with 100 x 100 mm² prototype chambers
- Construction and test of 1300 x 400 mm² prototype (Rui de Oliveira)

Summary & conclusions

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- With SLHC an upgrade of some ATLAS Muon chambers is needed
- Micromegas technology is a good candidate
- R&D activity started in 2007; approved by ATLAS Upgrade Office; by now 16 participating institutes
- 350 x 450 mm² prototype built and tested
- Test beam with encouraging results
- New test beam campaign in 2009
- 50% prototype chamber (400 x 1300 mm²) under construction (R. De Oliveira)