PERFORMANCE OF MICROMEGAS DETECTORS FOR INCLINED TRACKS AND IN MAGNETIC FIELDS

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On behalf of the
MAMMA Collaboration

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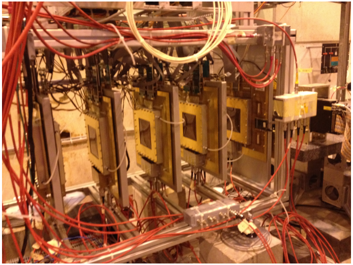
Outline

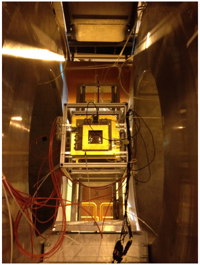
1. 2012 Micromegas Performance Analysis Outline
2. Inclined Tracks Reconstruction
   - Test Beam @ H6
   - Track Reconstruction
   - Reconstructed Track Angle
   - Spatial Resolution Studies
   - Combining μTPC & Centroid Information
3. Micromegas in Magnetic Field
   - Motivation
   - MC simulation of Micromegas under Magnetic Field
   - Test Beam @ H2
   - Track Reconstruction with Micromegas under Magnetic Field
4. Conclusions

Micromegas Performance Studies in 2012

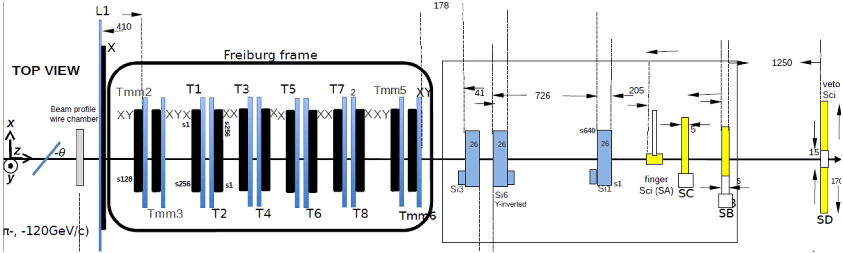
Huge effort by many people from various institutes to demonstrate the excellent performance of Micromegas detector under different data taking conditions!

- Continuous Test Beam periods June-December 2012
- Detailed Simulation Analysis has been carried out
- New Hit/Track reconstruction techniques have been developed
- The Good performance of the detector for inclined tracks was a point to prove.
- Performance of the Micromegas Chamber under Magnetic FIeld was an item of special interest and has been thoroughly investigated.



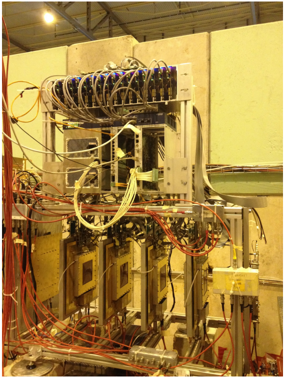


Inclined Tracks Studies



Setup

- 4 Doublets of X Precision Chambers (0.4 mm strip pitch, 5 mm Drift Gap)
- 2 Doublets of XY Reference Chambers (0.25 mm strip pitch, 5 mm Drift Gap)
- $Ar : CO_2$ - 93:7 Gas Mixture (Gain $\simeq 10^4$)
- APV25 Electronics - read out with the SRS
- 120 GeV π^+ beam

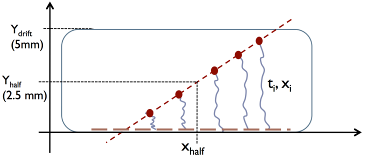


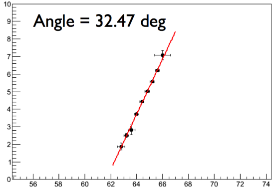
Drift Time & Chamber Hit Estimation

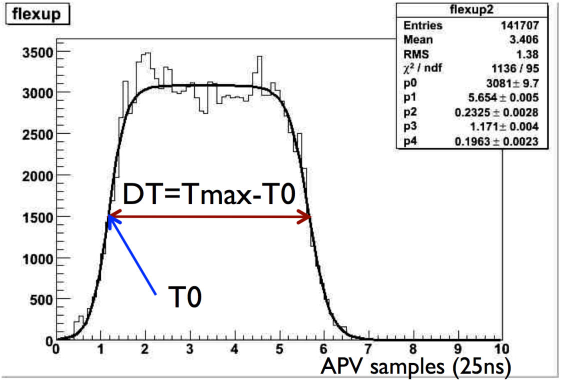
Track Parameters

$$\theta = arctan(\frac{1}{slope})$$

$$x_{half} = \frac{y_{half} - (t_i - T_0)\, v_{drift}}{slope}$$





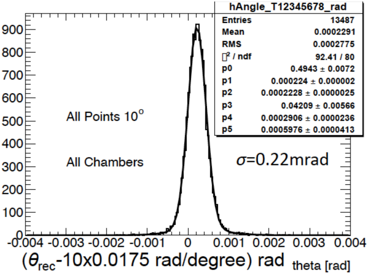


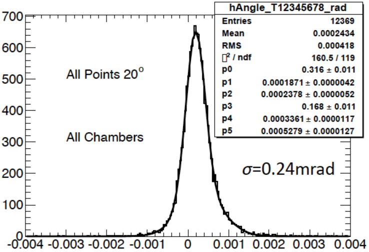
Time Information

Fitting the full time distribution the minimum time (T_0) of each chamber and the "actual" drift velocity can be extracted

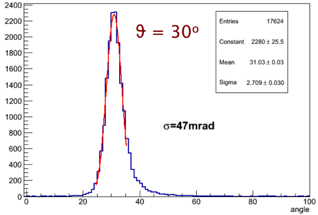
Angular Resolution

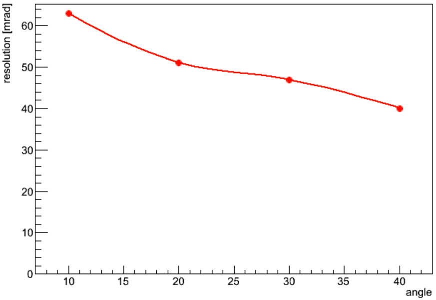
Telescope Reconstruction (8 Planes)





Single Plane Reconstruction





Position Difference Technique

Method Description

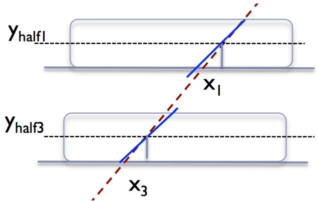
Computing the combined spatial resolution from two chambers with the same orientation

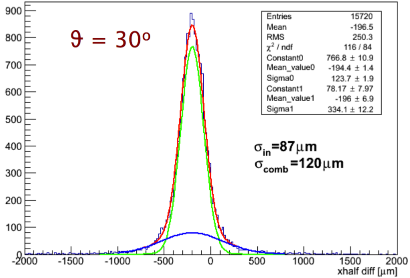
- Time jitter is equal in both chambers and is removed by the position difference among the two
- Both chambers have the same resolution

$$\sigma = \frac{\sigma(X_1 - X_3)}{\sqrt{2}}$$

"Tails' Manipulation"

Careful treatment of the distributions' tails. Results are presented for both fitting the "core" of a double Gaussian as well as weighted average of the two Gaussians.

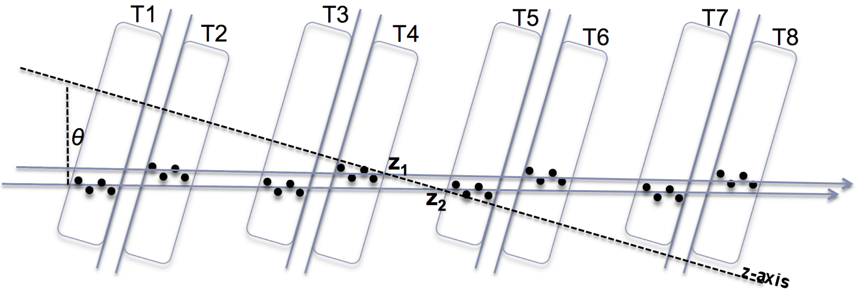




Global Fit Technique

Method Description

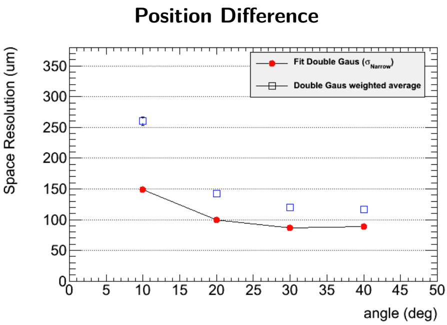
- Correcting the time jitter for even and odd chambers separetely by fitting an odd and an even track
- A Global Fit is then applied to all the μTPC hits of all the chambers but the one under study
- The local μTPC track is reconstructed in the chamber under study
- Calculate the x_{half} residuals between the global and the local track

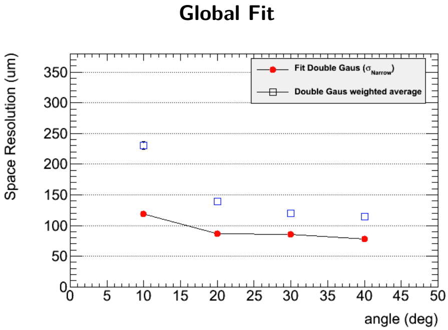


Spatial Resolution (Position Difference/Global Fit)

Summary of the 2 Techniques

Both techniques produce similar residual distributions for the different angles. Weighted Average distribution always a bit wider than the σ from the core distribution of the double Gaussian!



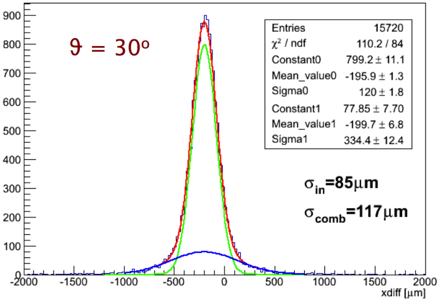


Combined Method Description

μTPC+Centroid

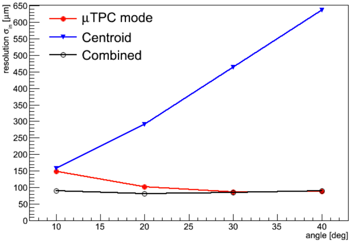
Pure μTPC track reconstruction produces already very promising results. But is not ideal for angles $< 10^\circ$ where a simple centroid hit reconstruction method is still sufficient. Why not try to exploit this information which comes for free. First try is a simple weighted average of the hits from the two different methods using the cluster size of each track as weight.

- $$x_{comb} = \frac{w_{half} x_{half} + w_{cent} x_{cent}}{w_{half} + w_{cent}}$$
- $$w_{half} = \left(\frac{N_{strip}}{N_{cut}}\right)^2, w_{cent} = \left(\frac{N_{cut}}{N_{strip}}\right)^2$$
- N_{strip} : Cluster Size of each Track,
  N_{cut} : Constant
  if $N_{strip} > N_{cut} x_{half}$ dominates
  if $N_{strip} < N_{cut} x_{cent}$ dominates

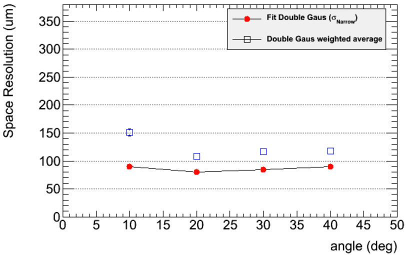


Results look exciting! There is a lot of room for optimisation and simulation studies on a unique hit reconstruction algorithm are ongoing.

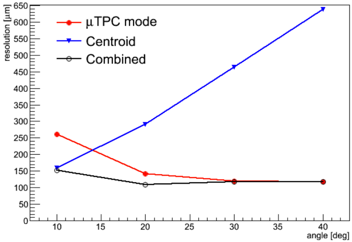
Inner Gaussian



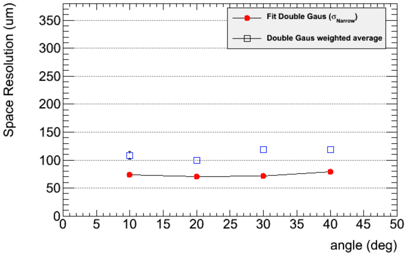
Position Difference



Weighted Gaussian



Global Fit

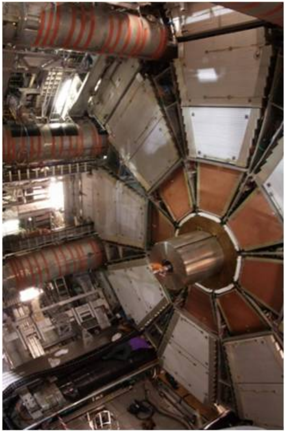


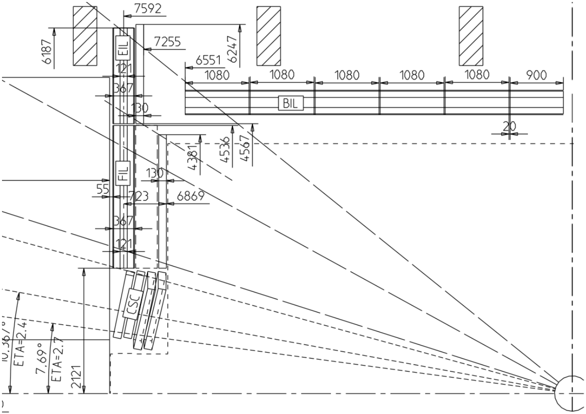
Micromegas In Magnetic Field

Motivation

Micromegas Technology qualified for the New Small Wheel of the ATLAS experiment!

Current Small Wheel

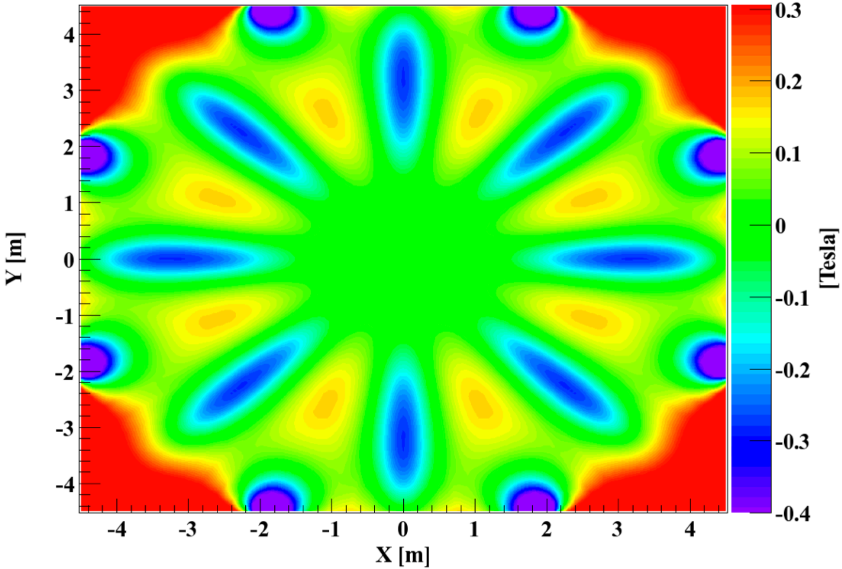




But B-Field in this area is non 0 and non uniform due to EndCap Toroid Magnet

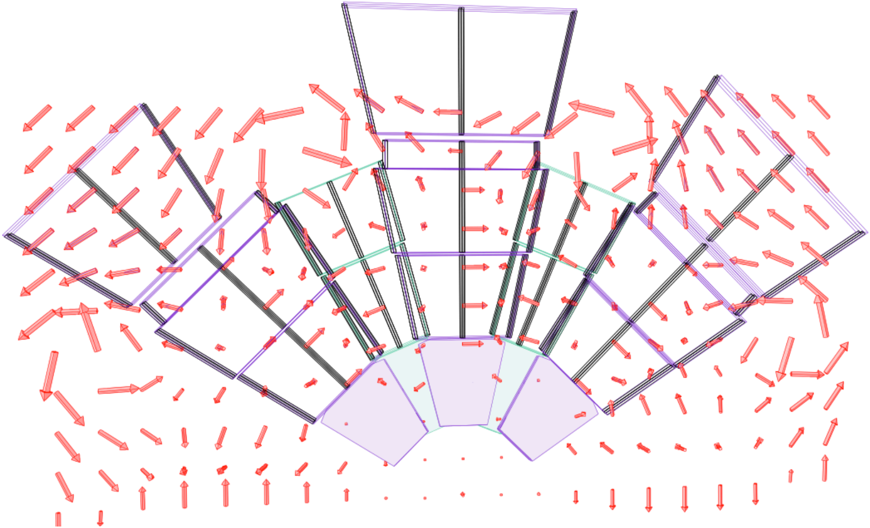
Magnetic Field Map in ATLAS SW

Simulation with PERSINT - Phi Component of the Magnetic Field - Z=7800 mm



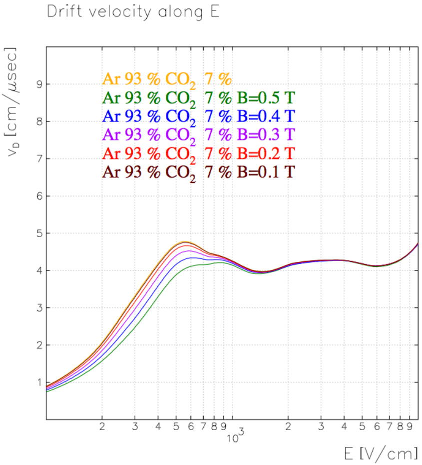
Magnetic Field Vector in ATLAS SW

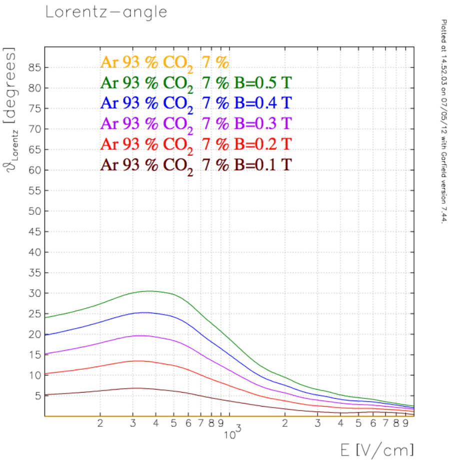
Simulation with PERSINT - Phi Component of the Magnetic Field - Z=7800 mm



Garfield Simulation

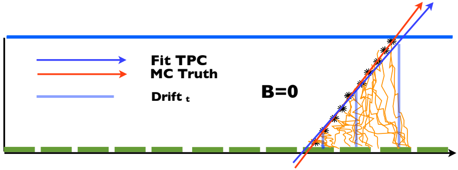
Drift Velocity / Lorentz Angle vs Electric Field for different Magnetic Field Configurations

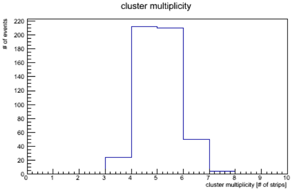


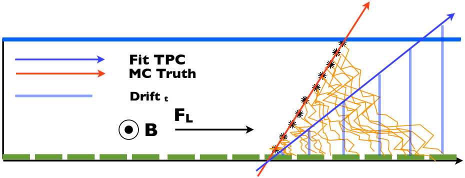


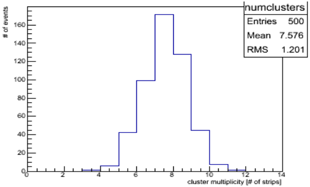
Standalone MC Tool (Garfield parameters as input)

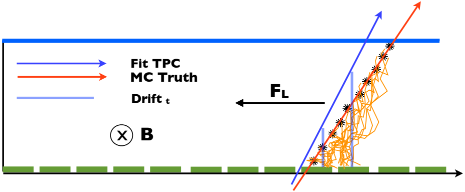
Cluster Size Effect

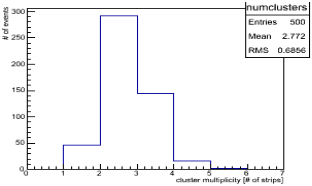






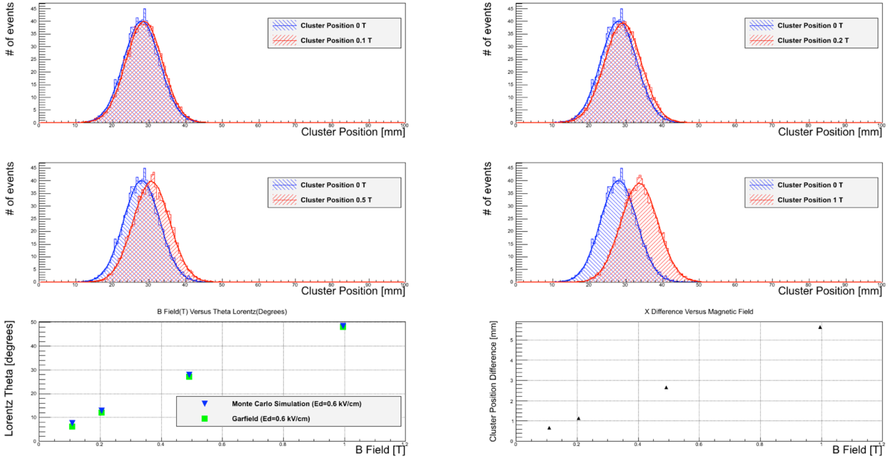






MC Validation - Cluster Position Effect

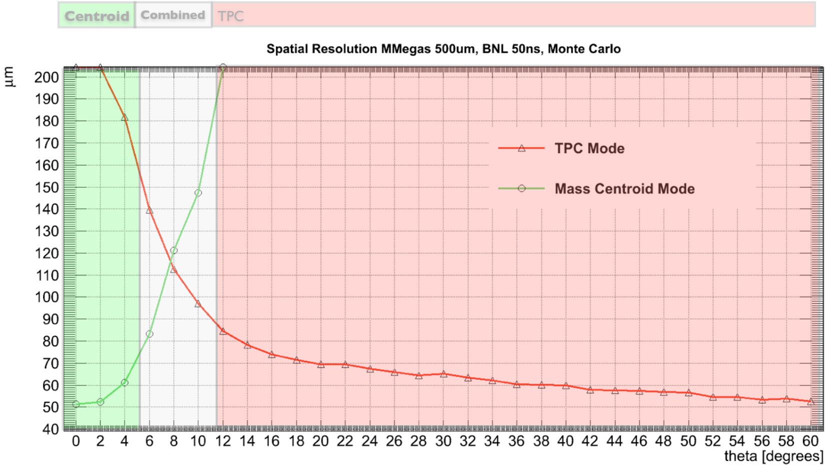
Garfield vs MC



Combined Technique For Spatial Resolution Determination

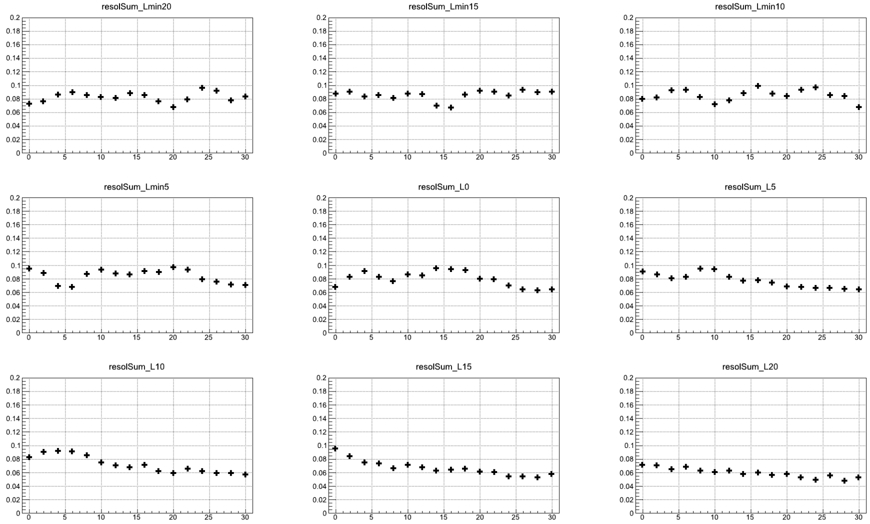
Weight μTPC & Centroid Techniques in a Combined Reconstruction Algorithm

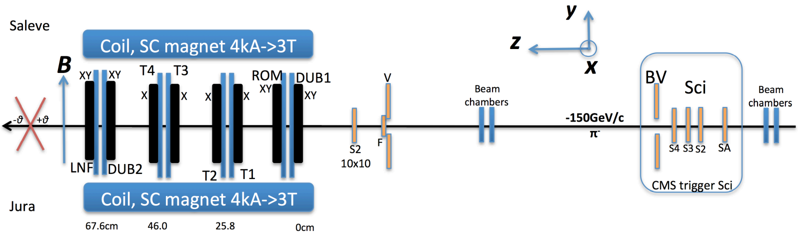
- Only Centroid Method For Small Angles (GREEN AREA) $w_{cent} = 1, w_{tpc} = 0$
- Only TPC Method For Large Angles (RED AREA) $w_{cent} = 0, w_{tpc} = 1$
- Combine Both Methods In The Middle Area $w_{cent} = \frac{1}{2}, w_{tpc} = \frac{1}{2}$



μTPC - Centroid Combined Spatial Resolution

Combined Method demonstrates spatial resolution $< 100\ \mu m$ and is independent of the Incident Angle and the Magnetic Field



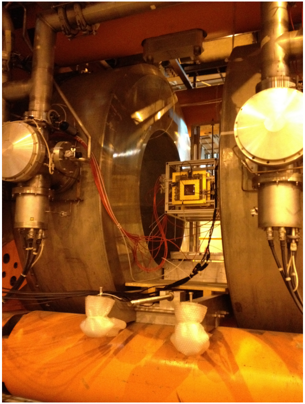


Setup

- 2 Doublets of XY Precision Chambers (0.4 mm strip pitch, 5/10 mm Drift Gap)
- 2 Doublets of X Reference Chambers (0.25 mm strip pitch, 4/5 mm Drift Gap)
- APV25 Electronics - read out with the SRS

Goals

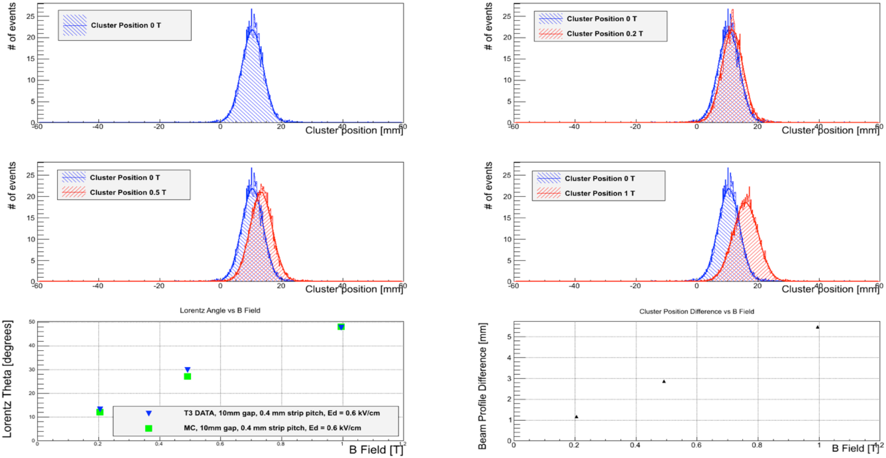
- Cluster Size & Position Measurement
- ExB effect & Lorentz Angle Study
- Monte Carlo Validation
- Spatial Resolution Study



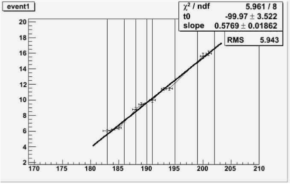
Magnetic Field Data - Cluster Position Effect

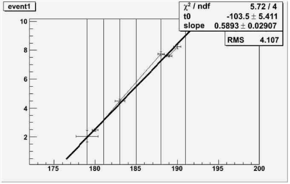
Data vs MC

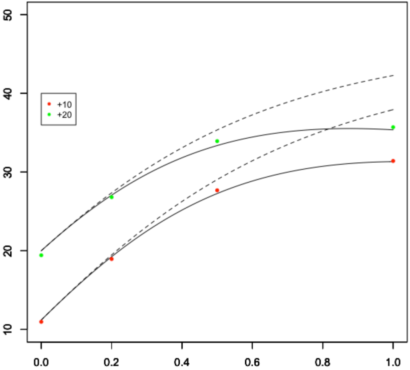
Data show good agreement with MC!



Effective Angle Reconstruction







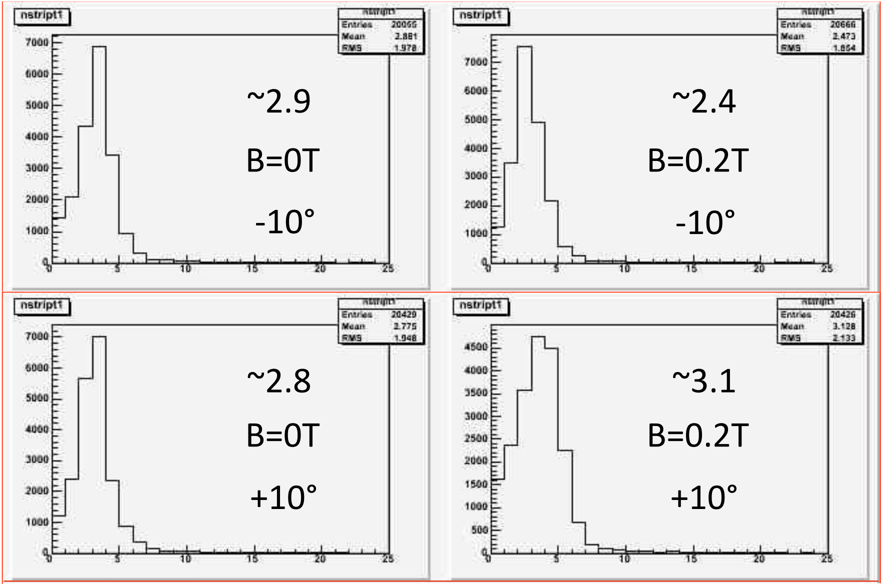
- Comparison of the effective track angle shows good agreement with theoretical expectation
- +/- stands for Charge Spreading/Squeezing respectively because of B-Field

Formulation

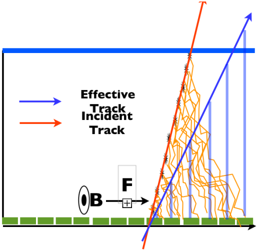
λ : effective track angle
ϕ : incident track angle

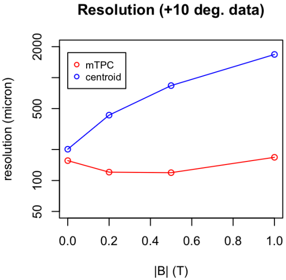
$$\lambda = arctan(sin\theta_{lorentz} + cos\theta_{lorentz} tan\phi)$$

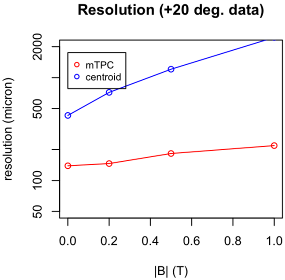
Magnetic Field Data - Cluster Size Effect

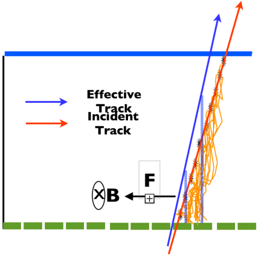


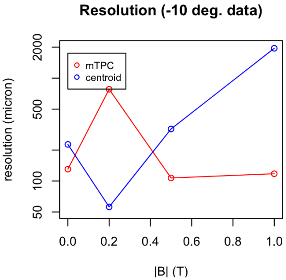
Spatial Resolution

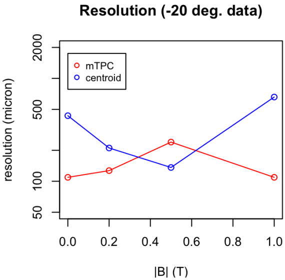












Performance for Inclined Tracks

- The Micromegas Spatial Resolution has been proved to be close to 100 μm for different track angles & for 2 different methods used.
- Method of Combining μTPC & Centroid Hits gives very promising results.
- Angular resolution per plane is satisfying (40-60 mrad), while by using the full telescope (8 planes) one can reconstruct the track angle with accuracy of 0.2-0.3 mrad.
- Improvements
  - Error Treatment
  - Pattern Recognition Techniques can compliment the track reconstruction procedure
  - Combination of μTPC and Centroid can be optimised

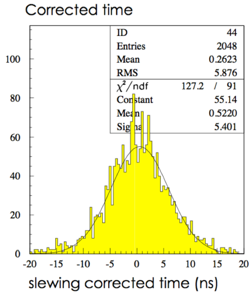
Performance in Magnetic Field

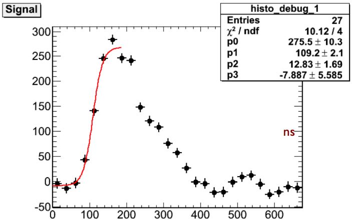
- Micromegas Chambers have been tested under Magnetic Field up to 1T without any problem
- Lorentz Angle has been reconstructed successfully
- Resolution with combined Centroid & μTPC modes provides a unique hit reconstruction algorithm for every orientation of the Magnetic Field and for all the possible track incident angles.
- Monte Carlo Simulation is valid showing good agreement with Garfield and Data
- Good understanding of the chamber's performance under Magnetic Field!

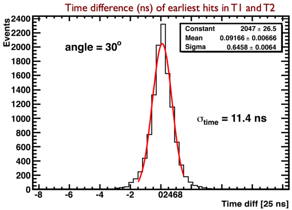
BackUp Slides

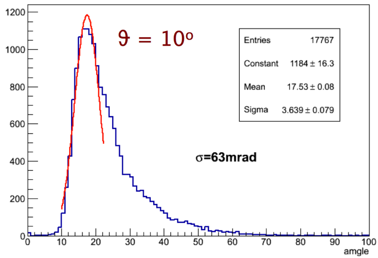
Time Resolution Issues

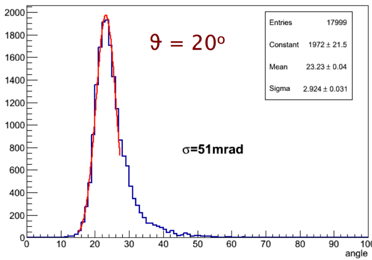
- For the μTPC mode operation a good time resolution is essential (<10 ns)
- APV 25 samples signal at 25 ns
- Extracting the time by fitting the signal limits our time resolution to 11-12 ns (first hit time difference between 2 chambers)
- Intrinsic Micromegas time resolution measured in Frascatti TB to be in the order of 5-6 ns

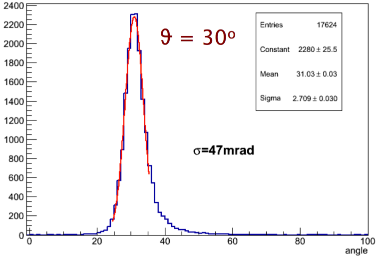


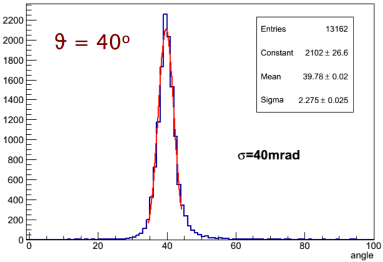




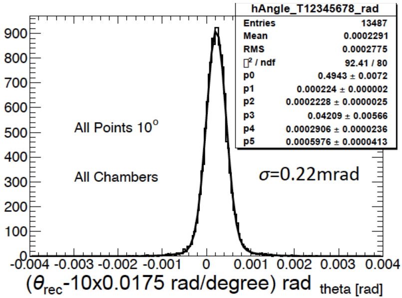

ϑ = 10º
Entries 17767
Constant 1184 ± 16.3
Mean 17.53 ± 0.08
Sigma 3.639 ± 0.079
σ=63mrad
amgle

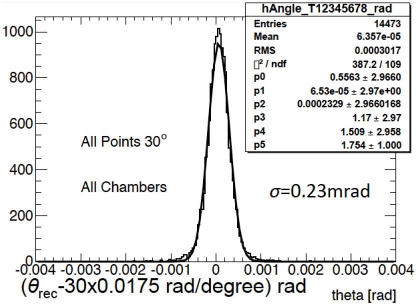

ϑ = 20º
Entries 17999
Constant 1972 ± 21.5
Mean 23.23 ± 0.04
Sigma 2.924 ± 0.031
σ=51mrad
angle

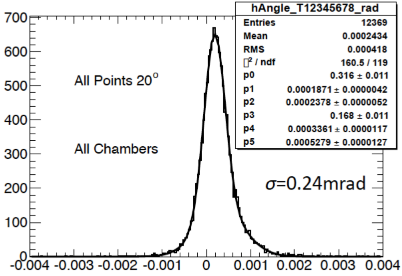

ϑ = 30º
Entries 17624
Constant 2280 ± 25.5
Mean 31.03 ± 0.03
Sigma 2.709 ± 0.030
σ=47mrad
angle

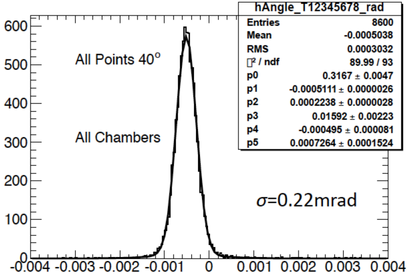

ϑ = 40º
Entries 13162
Constant 2102 ± 26.6
Mean 39.78 ± 0.02
Sigma 2.275 ± 0.025
σ=40mrad
angle

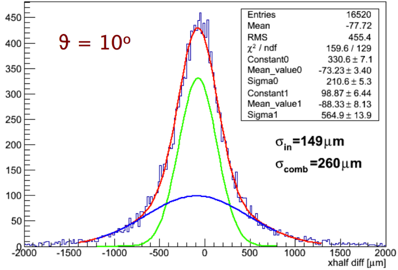
Global Fit Angular Resolution

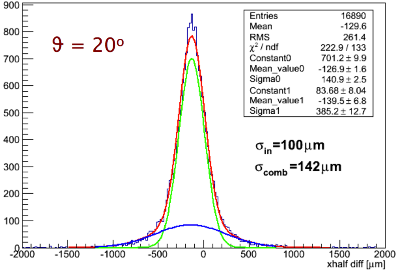


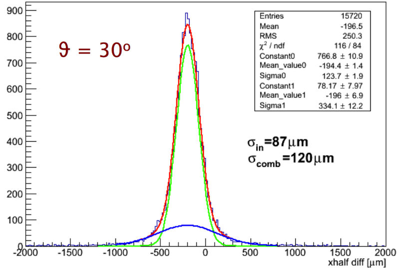


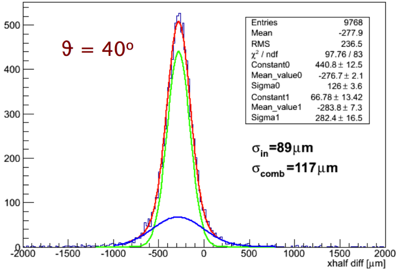




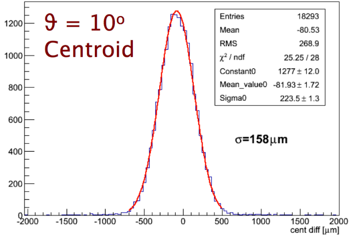

ϑ = 10°
Entries 16520
Mean -77.72
RMS 455.4
χ² / ndf 159.6 / 129
Constant0 330.6 ± 7.1
Mean_value0 -73.23 ± 3.40
Sigma0 210.6 ± 5.3
Constant1 98.87 ± 6.44
Mean_value1 -88.33 ± 8.13
Sigma1 564.9 ± 13.9
σin=149μm
σcomb=260μm
xhalf diff [μm]

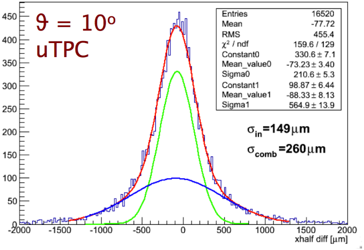

ϑ = 20°
Entries 16890
Mean -129.6
RMS 261.4
χ² / ndf 222.9 / 133
Constant0 701.2 ± 9.9
Mean_value0 -126.9 ± 1.6
Sigma0 140.9 ± 2.5
Constant1 83.68 ± 8.04
Mean_value1 -139.5 ± 6.8
Sigma1 385.2 ± 12.7
σin=100μm
σcomb=142μm
xhalf diff [μm]

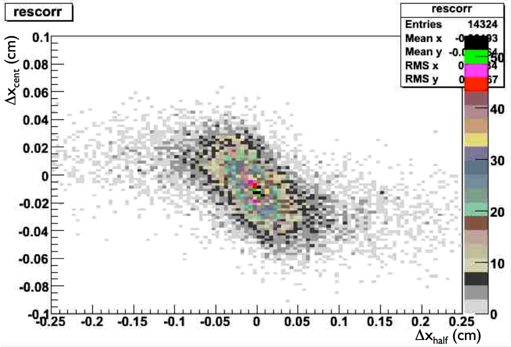

ϑ = 30°
Entries 15720
Mean -196.5
RMS 250.3
χ² / ndf 116 / 84
Constant0 766.8 ± 10.9
Mean_value0 -194.4 ± 1.4
Sigma0 123.7 ± 1.9
Constant1 78.17 ± 7.97
Mean_value1 -196 ± 6.9
Sigma1 334.1 ± 12.2
σin=87μm
σcomb=120μm
xhalf diff [μm]


ϑ = 40°
Entries 9768
Mean -277.9
RMS 236.5
χ² / ndf 97.76 / 83
Constant0 440.8 ± 12.5
Mean_value0 -276.7 ± 2.1
Sigma0 126 ± 3.6
Constant1 66.78 ± 13.42
Mean_value1 -283.8 ± 7.3
Sigma1 282.4 ± 16.5
σin=89μm
σcomb=117μm
xhalf diff [μm]

Anti-Correlation Between μ *TPC* & Centroid

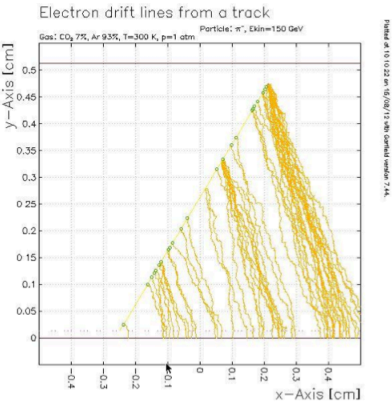




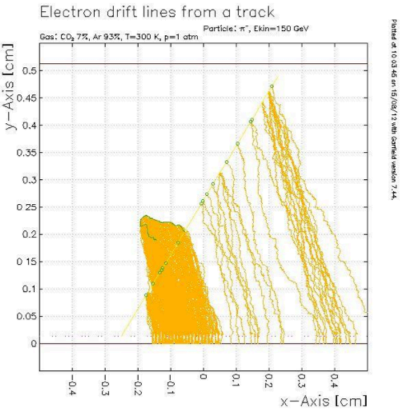


Ionization Electrons In Micromegas Under Magnetic Field

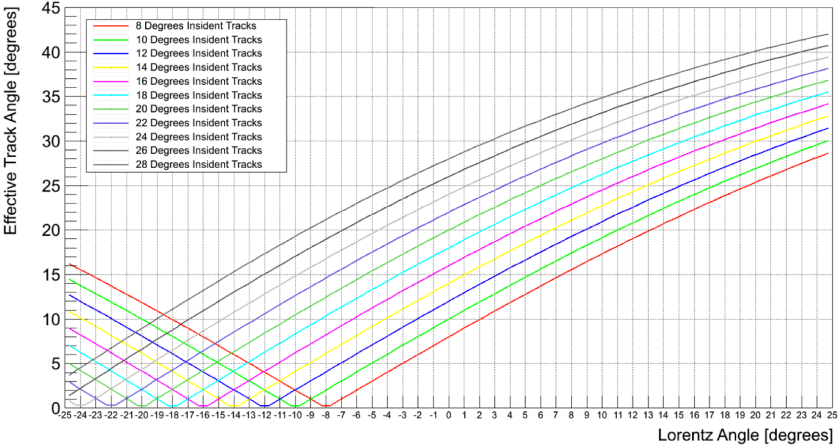
With B-field



Delta-ray event

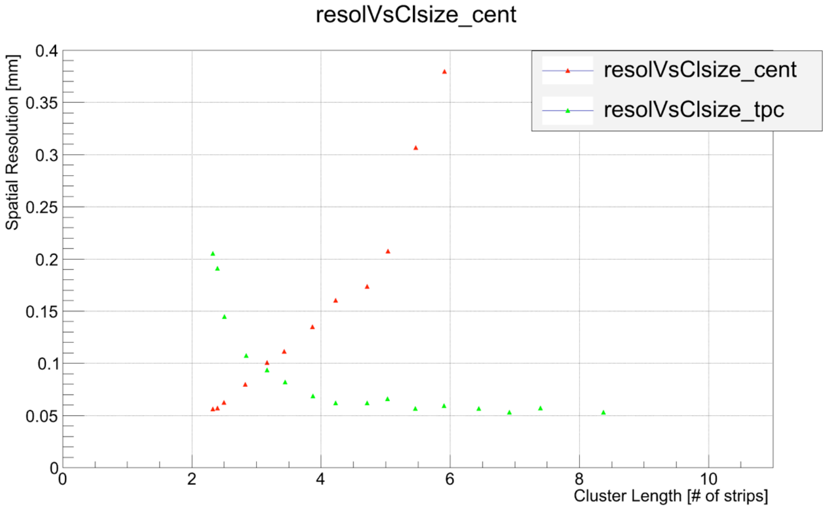


Effective Angle Simulation For NSW Tracks

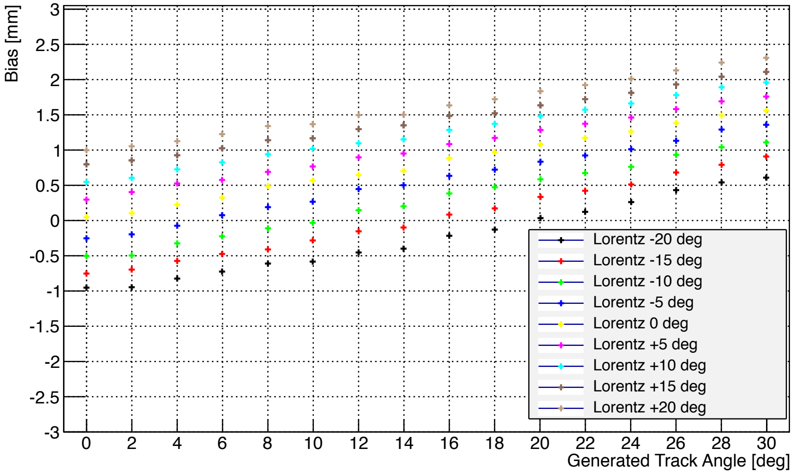


Resolution vs Cluster Length

Cluster Length follows track angle trend, and should represent the "effective track footprint".



Systematics Due To Magnetic Field



H2 Magnetic Field

The z-component of the magnetic field in M1, shown as a function of x and z. The x-direction is parallel to the beam, while z-direction is transverse to the beam.