Optimizing Muon Path Reconstruction for Micromegas in the ATLAS NSW

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Purpose

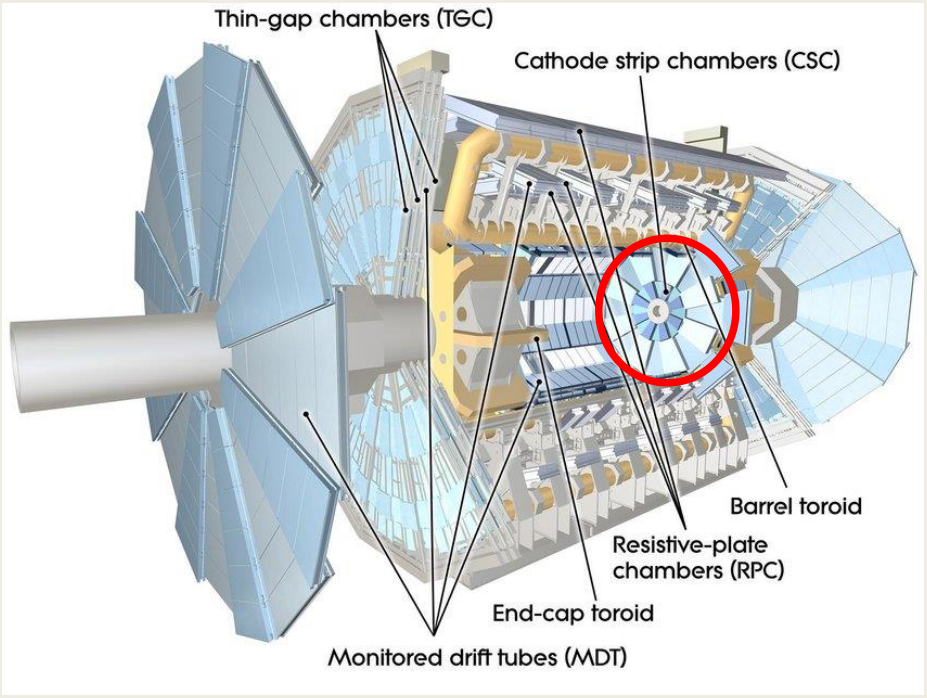
Picture: New Small Wheel construction [1]

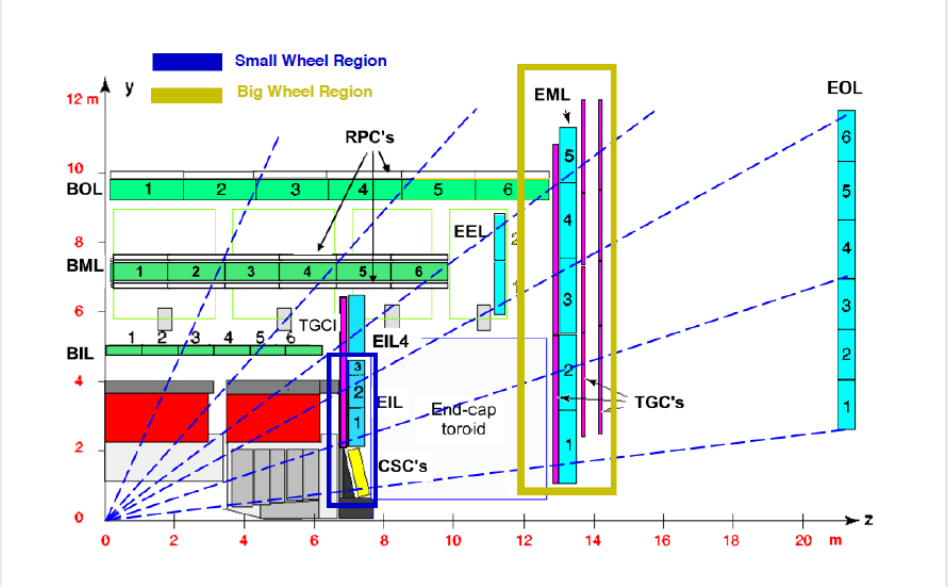
- Team:
  - *Optimize muon path reconstruction in the Micro-mesh gaseous structures (Micromegas or MM) of the New Small Wheel (NSW) detector.*
- Individual:
  - *Learn tools and techniques*
  - *Analyze muon event data from Monte-Carlo simulations*
  - *Build an algorithm capable of applying the best suited muon reconstruction technique to an event.*

Background – NSW

[2]

- Issues
  - Expected degradation of muon tracking in current Small Wheel to due increasing luminosity in LHC run-3
  - large fake muon trigger rate in endcaps (~90%)
- Solution: New Small Wheel
- Pictures
  - Top: Small Wheel Region circled in red[3]
  - Bottom: Small Wheel Region outlined in blue[2]

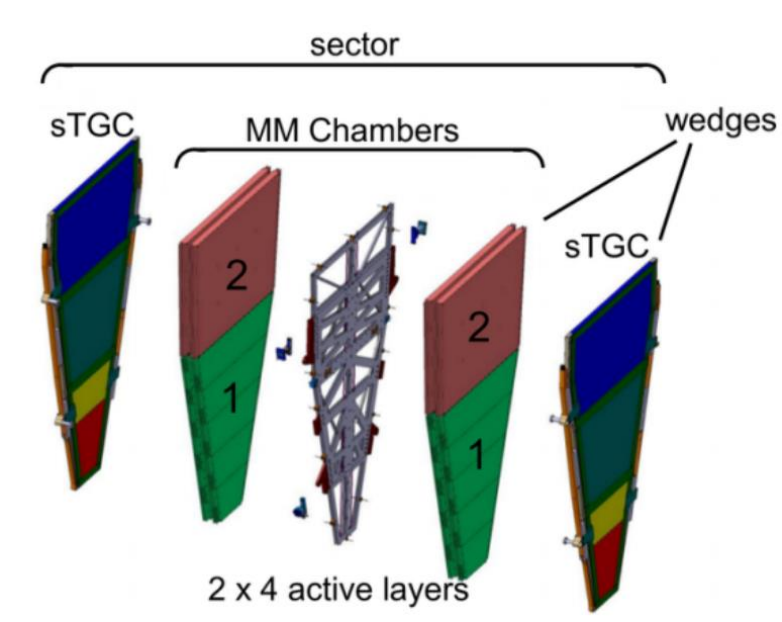




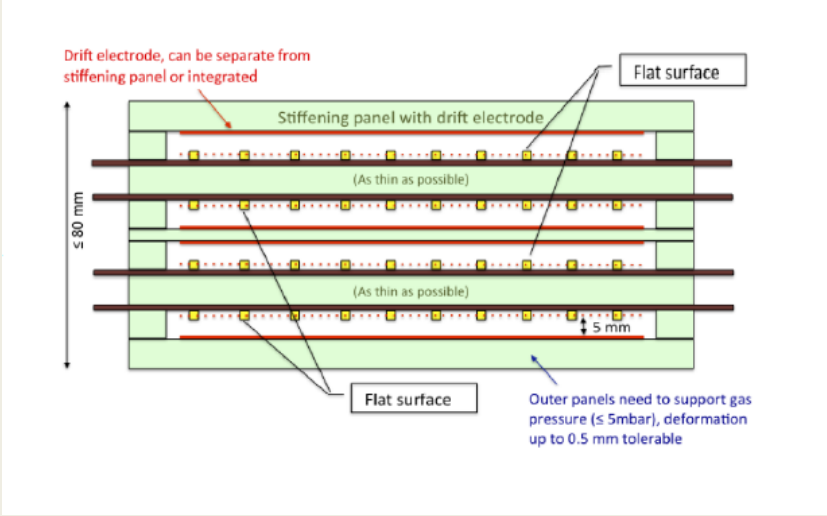
Background – NSW

[3]

- NSW Sector layout
  - *1 sTGC wedge*
  - *2 MM wedges*
  - *1 sTGC wedge*
- MM layout
  - *1 MM wedge = type 1 module + type 2 module*
  - *1 module = 4 layers of MM*



- Left: NSW schematic showing sector layers and mm module types[3]
- Right: Micromegas layout showing the 4 layers in one module[2]



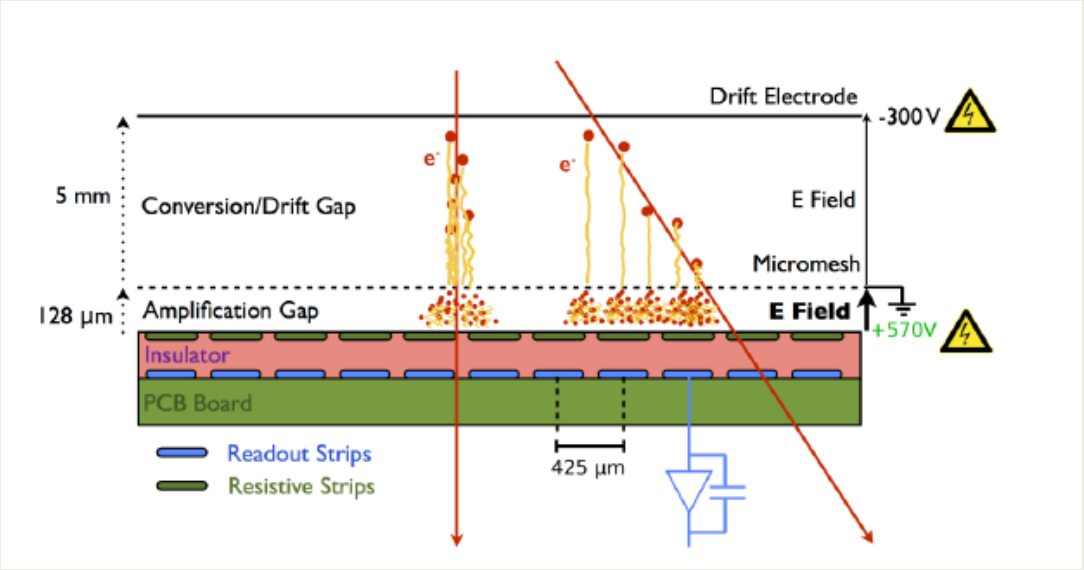
Background – Micromegas

[3]

General Principles of MM

- Two main areas separated by micro-mesh
  - *Drift Gap: initial ionization occurs here*
  - *Amplification Gap: avalanche of secondary ionizations allow for easier acquisition of data*
- Insulators reduce the probability of sparking

Picture [1]

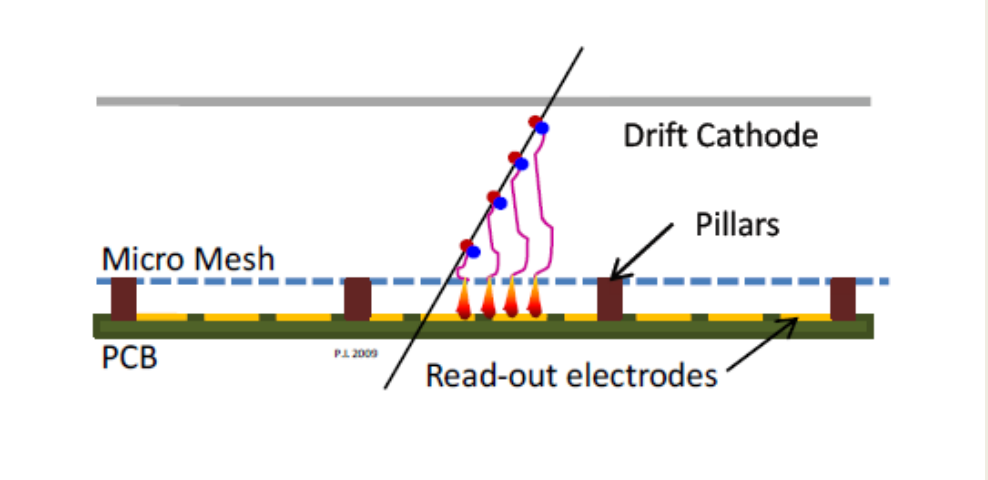


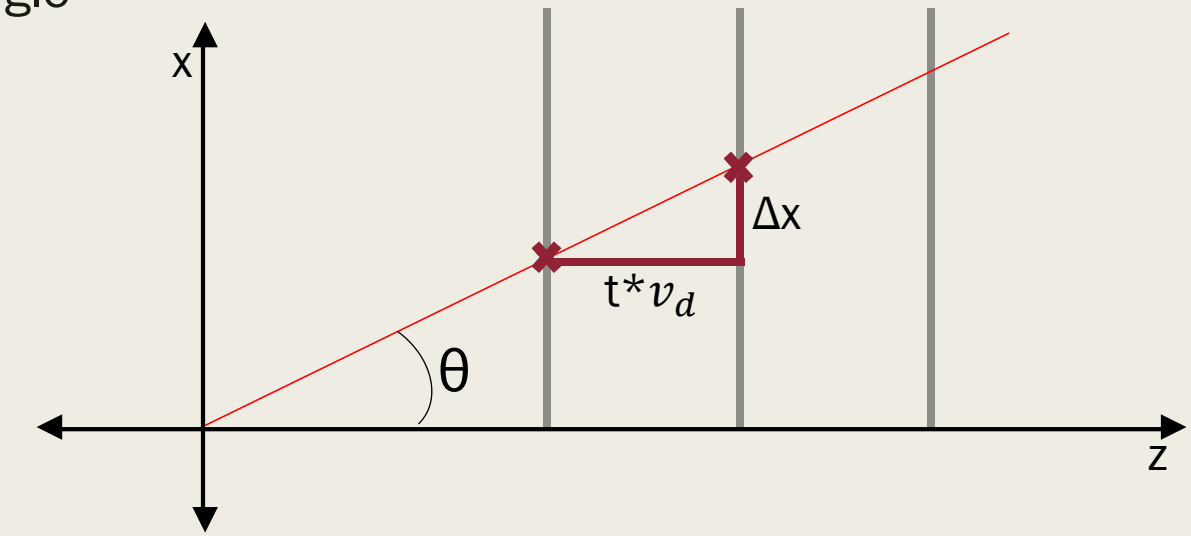
Reconstruction Methods

[4]

- Centroid
  - Charge weighted mean of activated strip positions
  - $x = \sum_i (\frac{q_i x_i}{q_i})$
- Projection
  - Geometric method using drift time and velocity, as well as incident angle of the muon
  - $\Delta x = (t * v_d)(tan\theta)$
- Micro-Time-Projection-Chamber (µTPC)
  - Drift time-based method

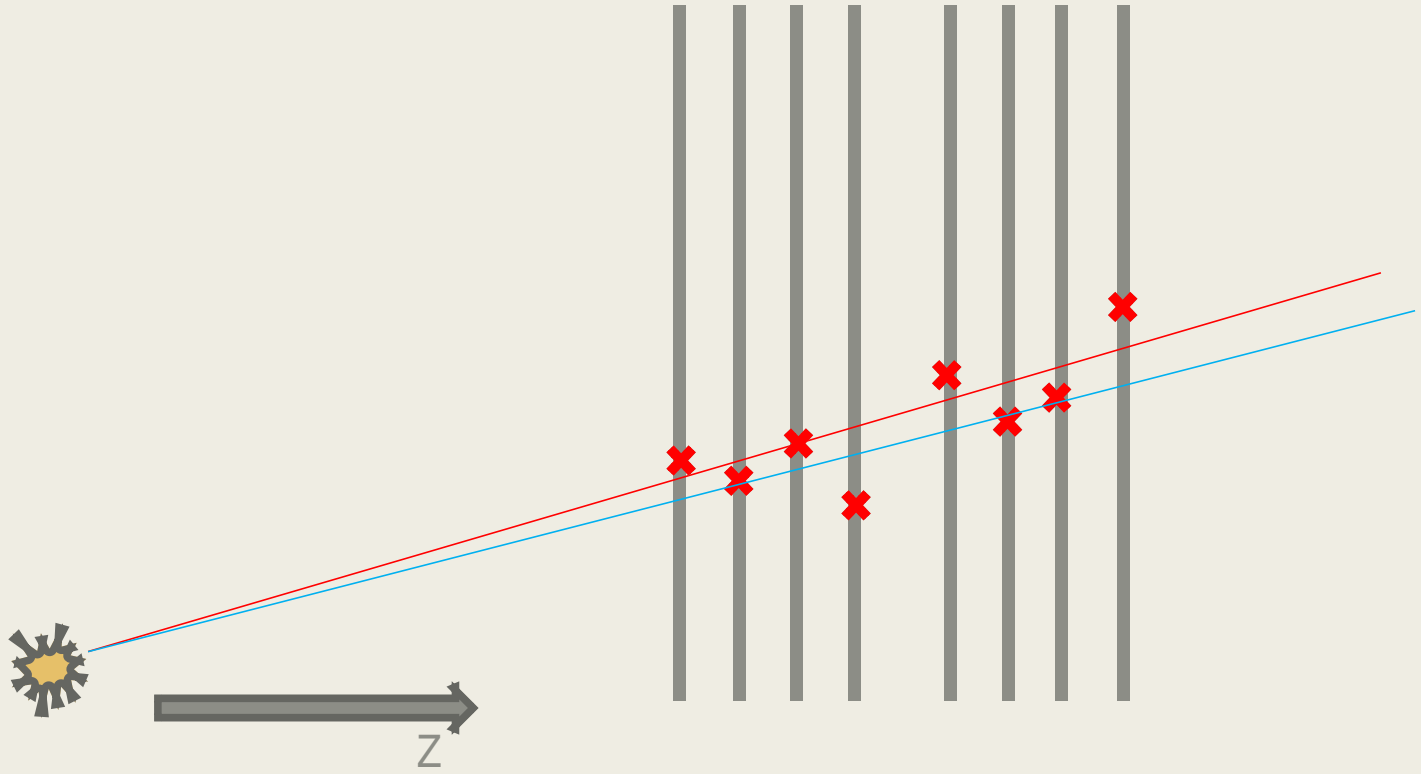
Picture [2]





Residuals and Error

- Difference between reconstructed path and cluster positions is the RESIDUAL TRACK
- Difference between true path and cluster positions is the RESIDUAL TRUTH (not available with real data)
- Comparing the residuals to each other and against error data provides information on the tracking method's accuracy.



Key:

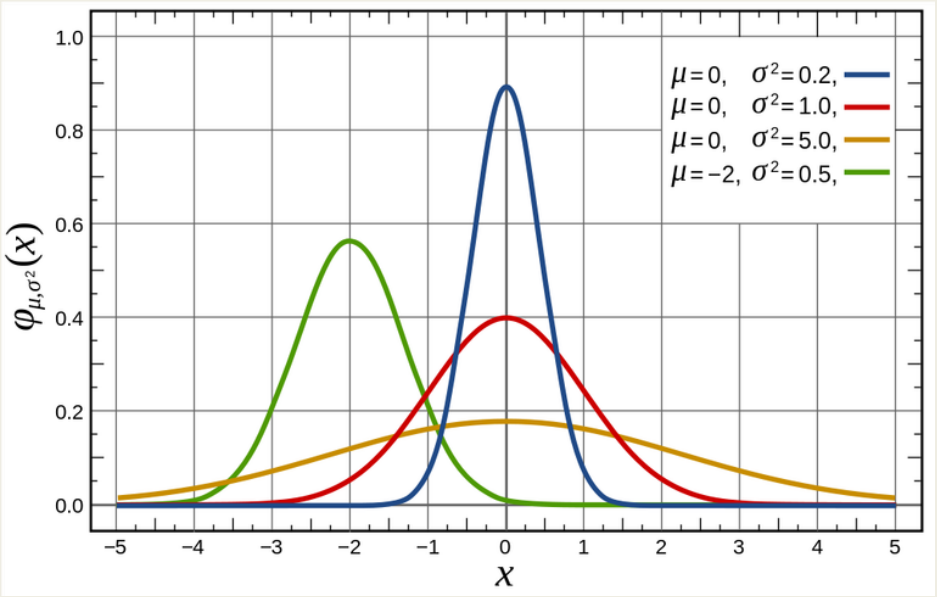
= cluster position

= reconstructed path

= true path

Residual Pull Histograms

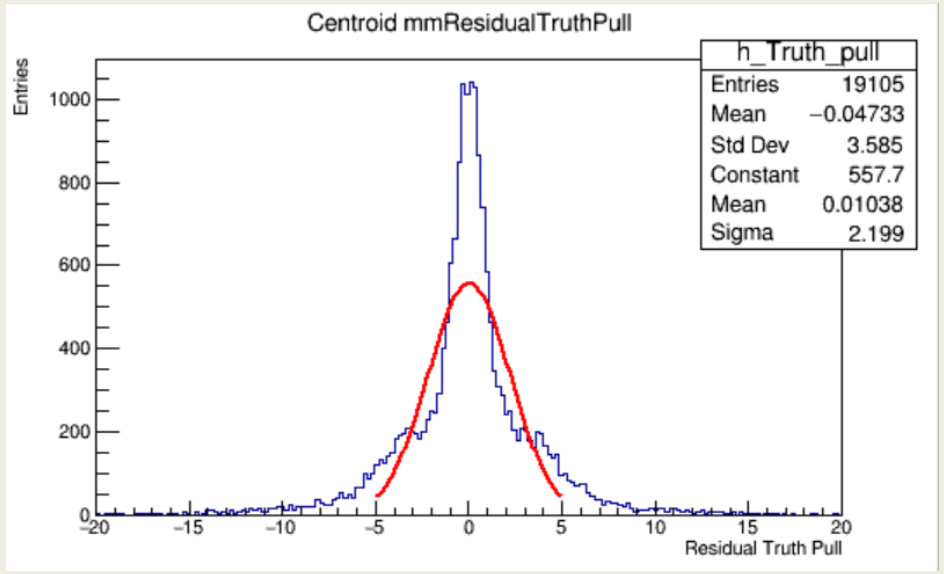
- $\text{Pull} = \frac{\text{Residual}}{\text{Error}}$
- Expected to be a gaussian with mean = 0 and σ = 1
  - *Mean = 0 when residuals are equally positive and negative*
  - *σ = 1 when the error is correctly estimated*
- Abnormalities
  - *Shifts in mean*
  - *Shifts in σ*



https://thecuriousastronomer.wordpress.com/2014/06/26/what-does-a-1-sigma-3-sigma-or-5-sigma-detection-mean/

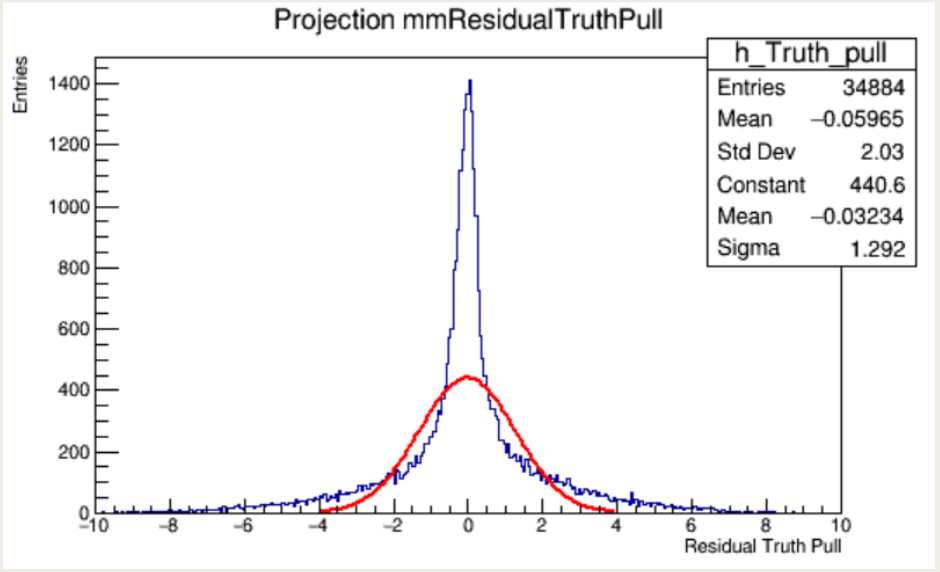
Residual Truth Pull

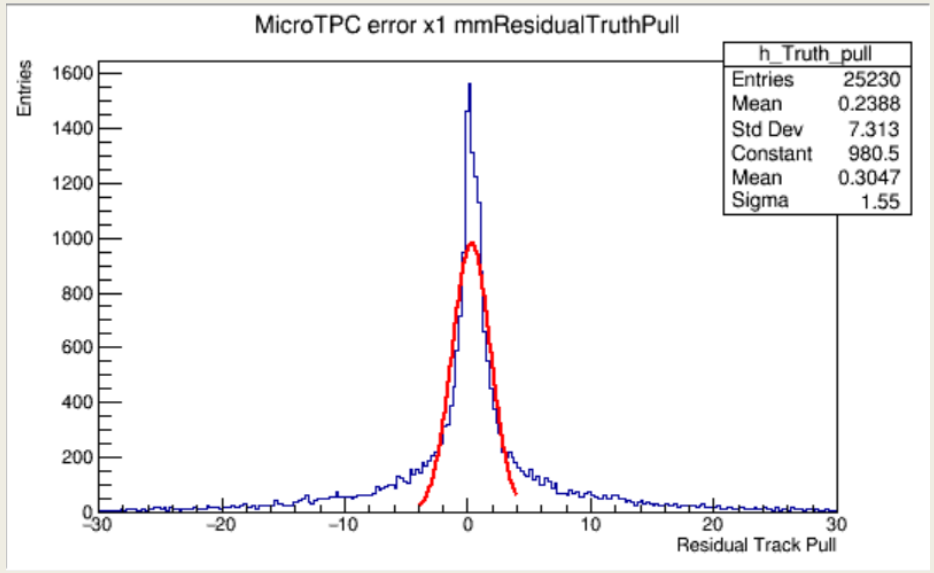
$$\text{Pull} = \frac{\text{Residual}}{\text{Error}}$$



<u>Left:</u> Centroid

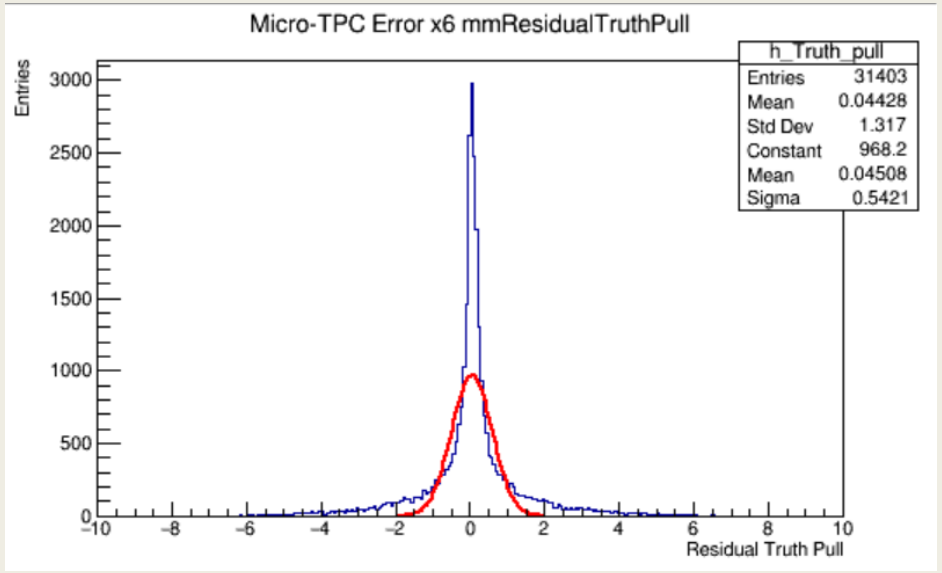
<u>Right:</u> Projection





<u>Left:</u> Micro-TPC w/ Error x1

<u>Right:</u> Micro-TPC w/ Error x6



Residual Track Pull

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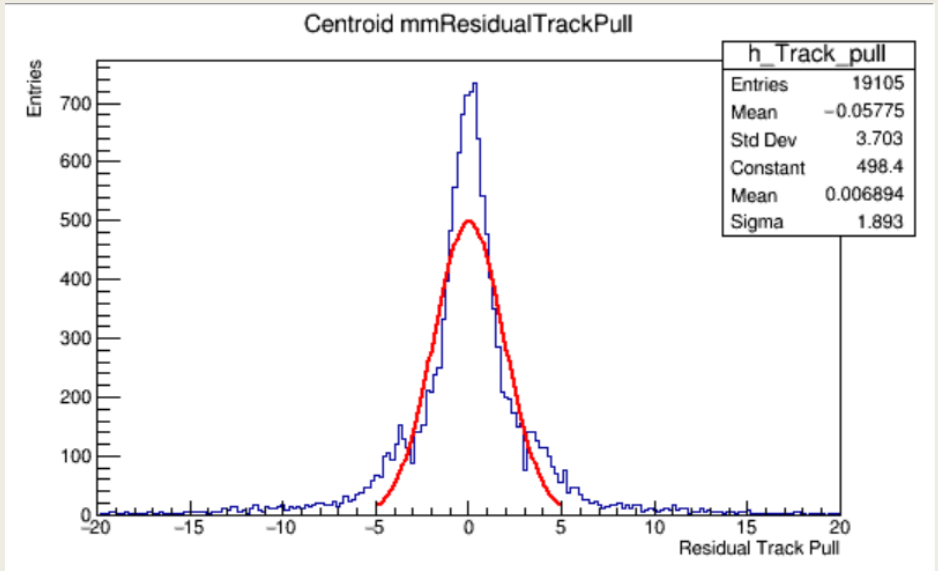

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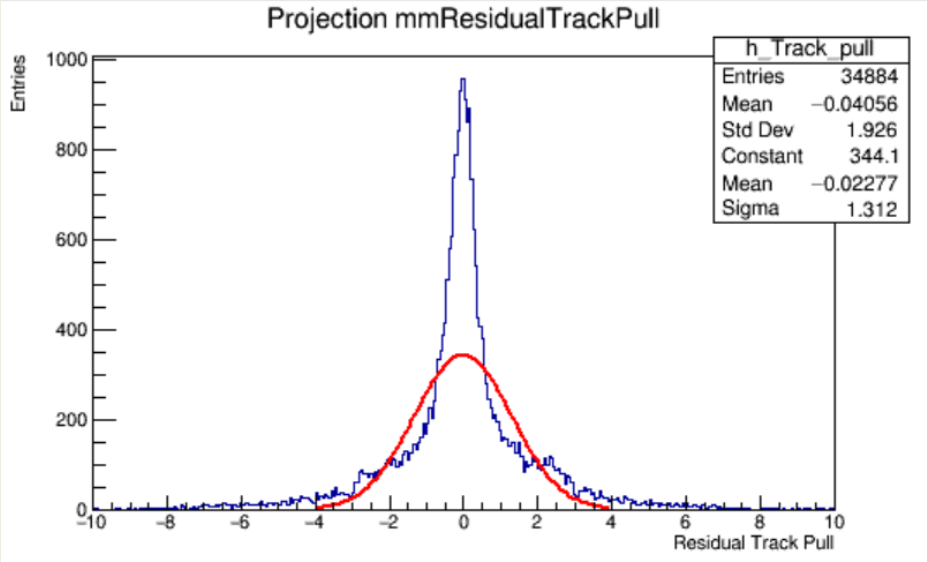

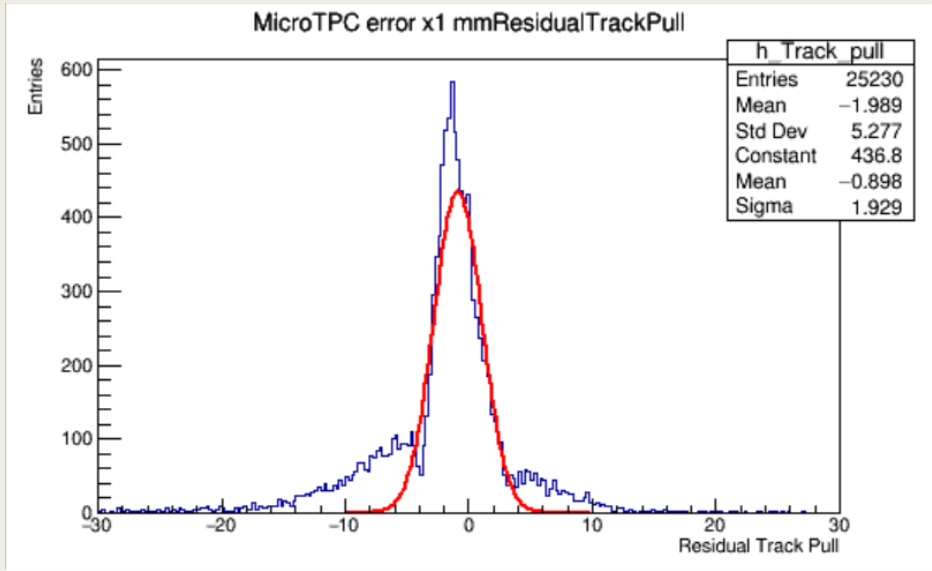

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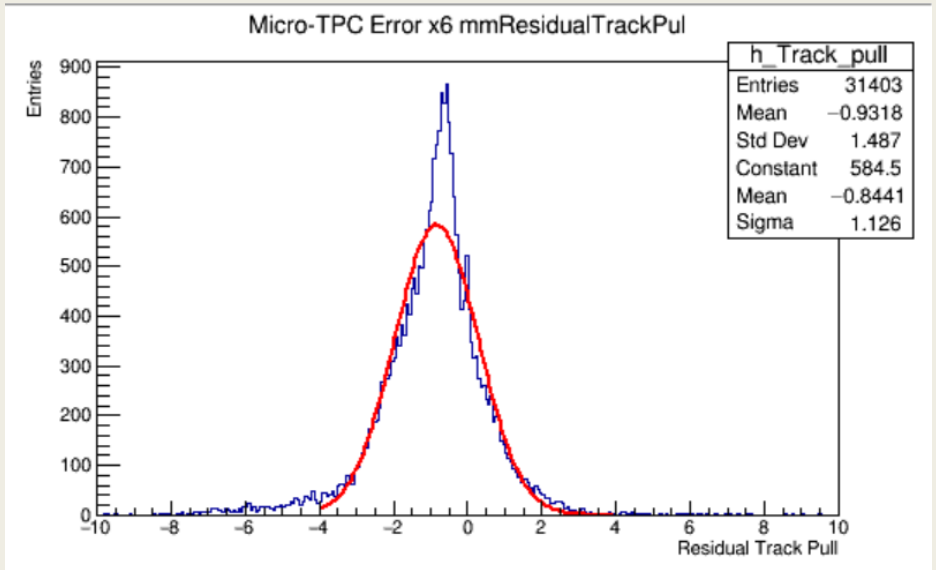

Next Up

- Continue work on the 3 methods of tracking
  - *Theta vs Residual Pulls, etc*
- Determine the strengths and weaknesses of each
- Develop an algorithm that takes those strengths and weaknesses into account when choosing the best method to track a particular muon event based on, but not limited to, the following features:
  - *Theta*
  - *Cluster Size*

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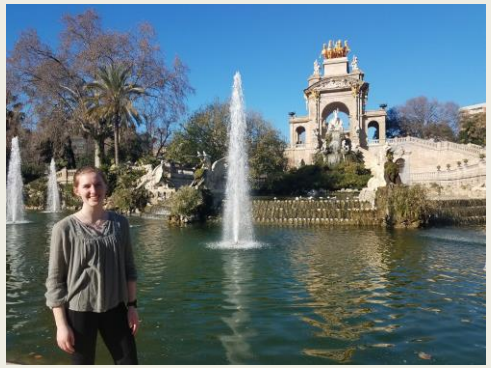

References

1. Scholer, Patrick, 2019, *ATL-MUON-PROC-2019-003*, URL: http://cds.cern.ch/record/2681383?ln=en
2. ATLAS Collaboration, 2013, *CERN-LHCC-2013-006, ATLAS-TDR-020*, URL: http://cds.cern.ch/record/1552862
3. Bhattacharya, Deb Sankar, 2019, *ATLAS-MUON-SLIDE-2019-728,* URL: http://cds.cern.ch/record/2692397?ln=en
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ATLAS EXPERIMENT

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