SoLID GEM Digitization and Tracking

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SoLID Collaboration Meeting

December 2nd

Outline

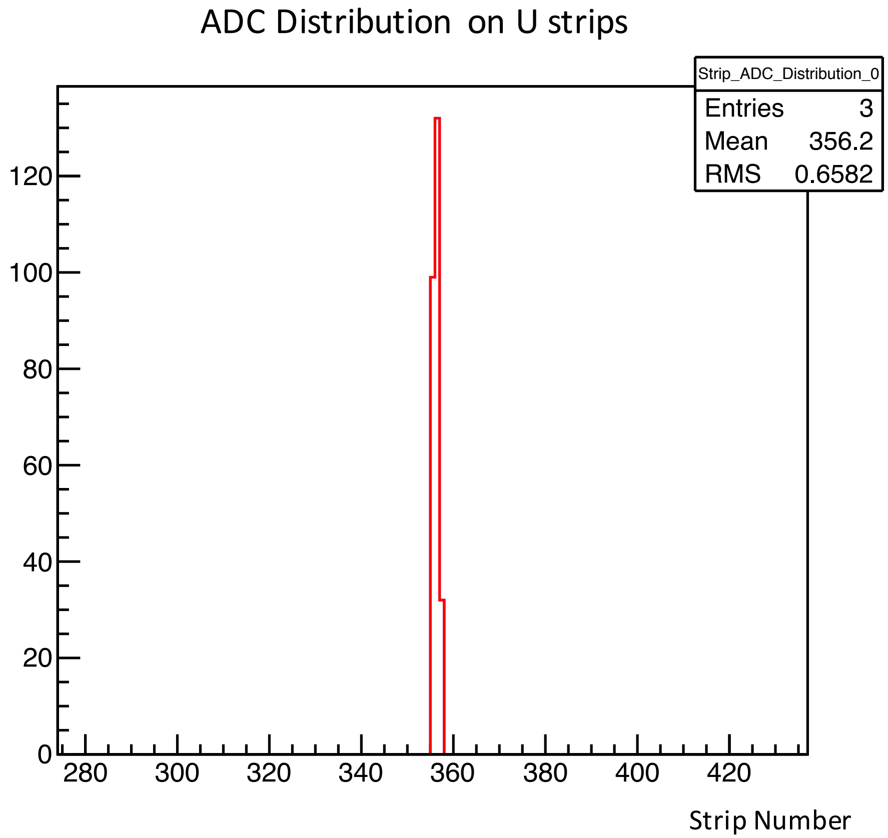
- Part I:
  - New digitization for SoLID GEM
  - Occupancy for the SIDIS-He3 configuration
  - Tracking performance for the SIDIS-He3 configuration

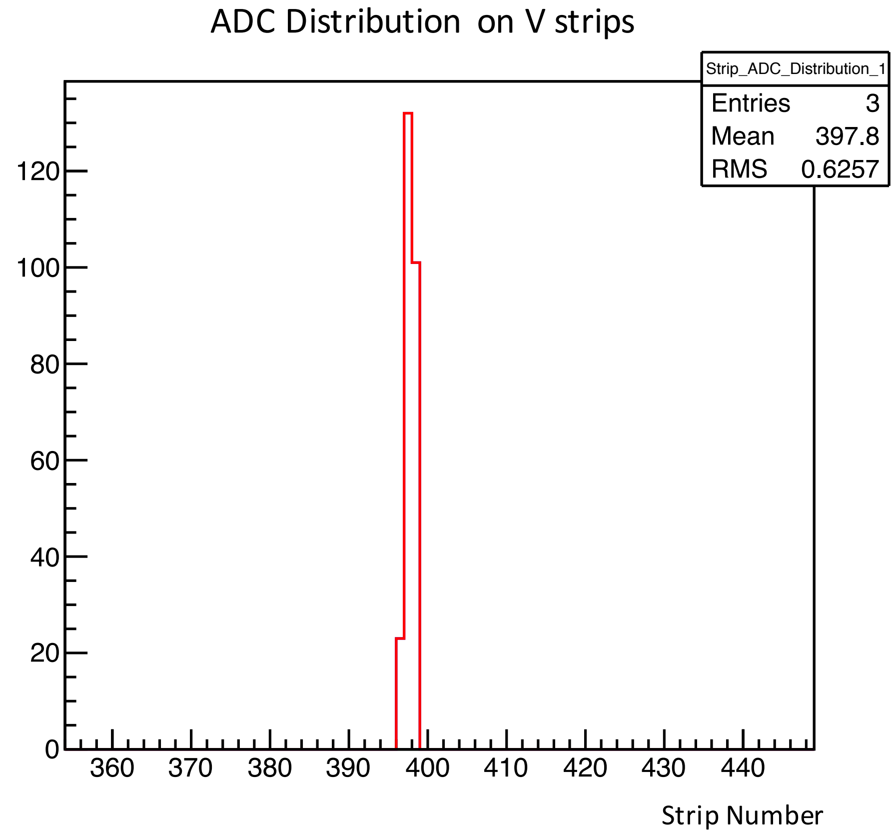
- Part II:
  - Tracking Framework for PVDIS configuration, using Kalman Filter algorithm

What's new in the new digitization

- Three main new features:
  - Avalanche model:
    - Old one: Heaviside model
    - New one: Cauchy-Lorentz model
  - Cross talk signal:
    - Old one: Not implemented
    - New one: add a induced cluster 32 strip away from the main signal. The induced amplitude is about 10% of the main signal
  - Pedestal noise:
    - Old one: simple Gaussian function
    - New one: Gaussian function plus a sinusoidal function with fixed period but varying amplitude

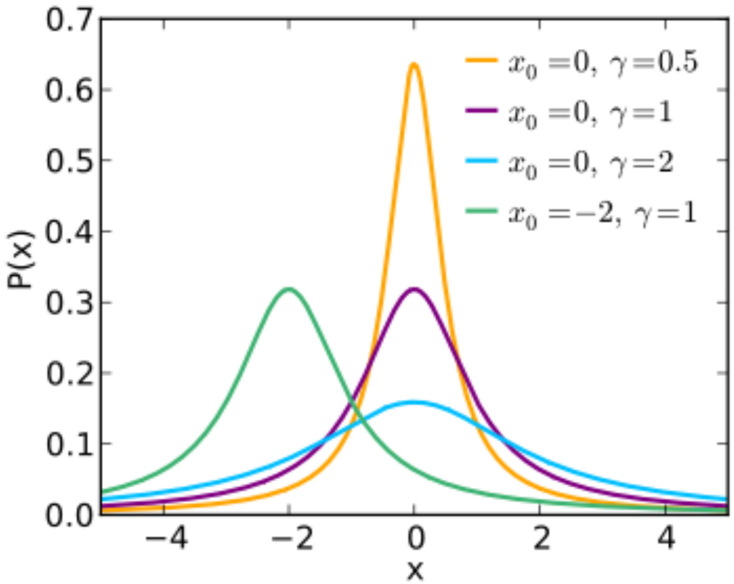
Avalanche Model



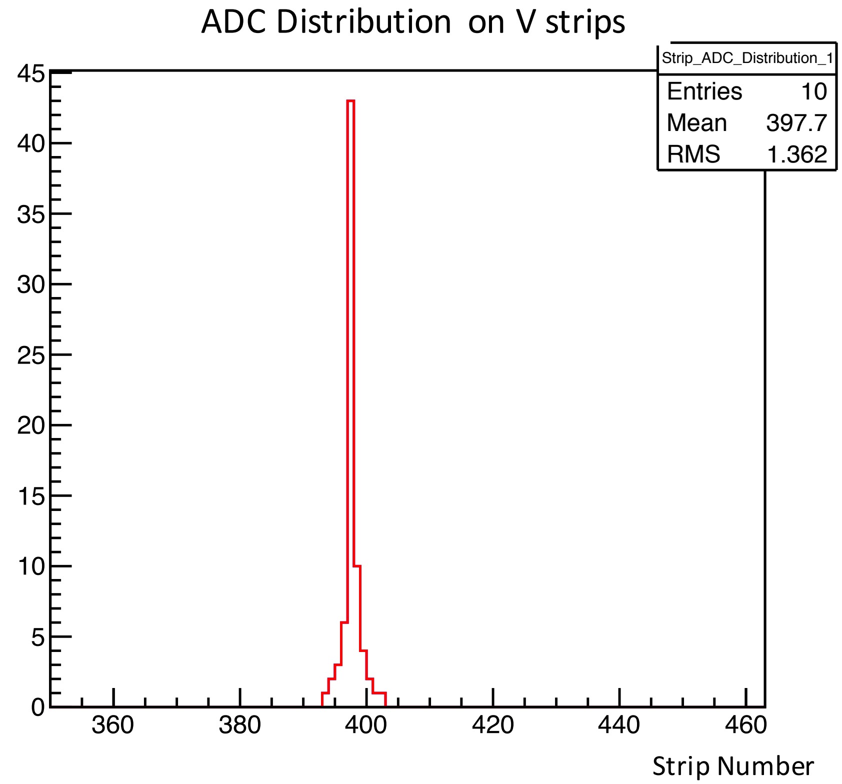


Heaviside avalanche model was the only one in the digitization, give very concentrated signal

Avalanche Model



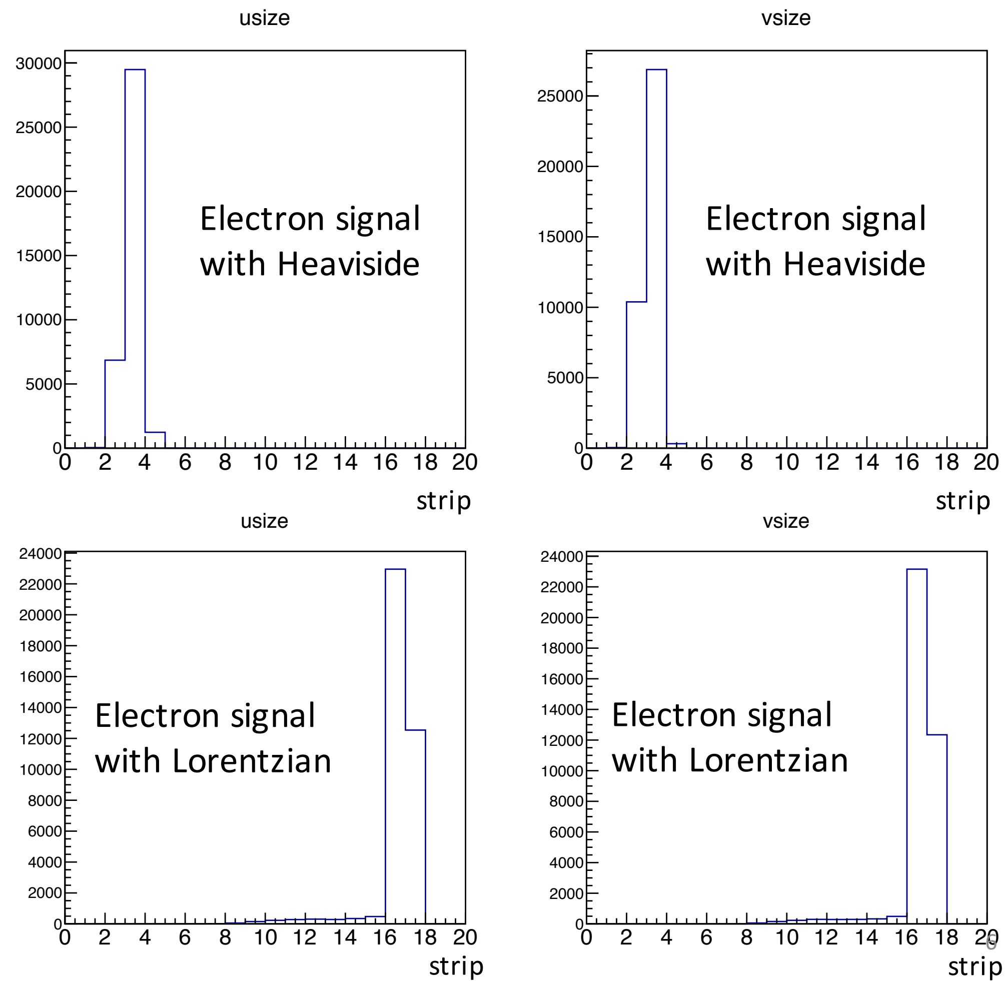
$$f(x; x_0, \gamma) = \frac{1}{\pi\gamma\left[1 + \left(\frac{x - x_0}{\gamma}\right)^2\right]} = \frac{1}{\pi\gamma}\left[\frac{\gamma^2}{(x - x_0)^2 + \gamma^2}\right],$$



Cauchy-Lorentz model is newly developed by Prof. Liyanage

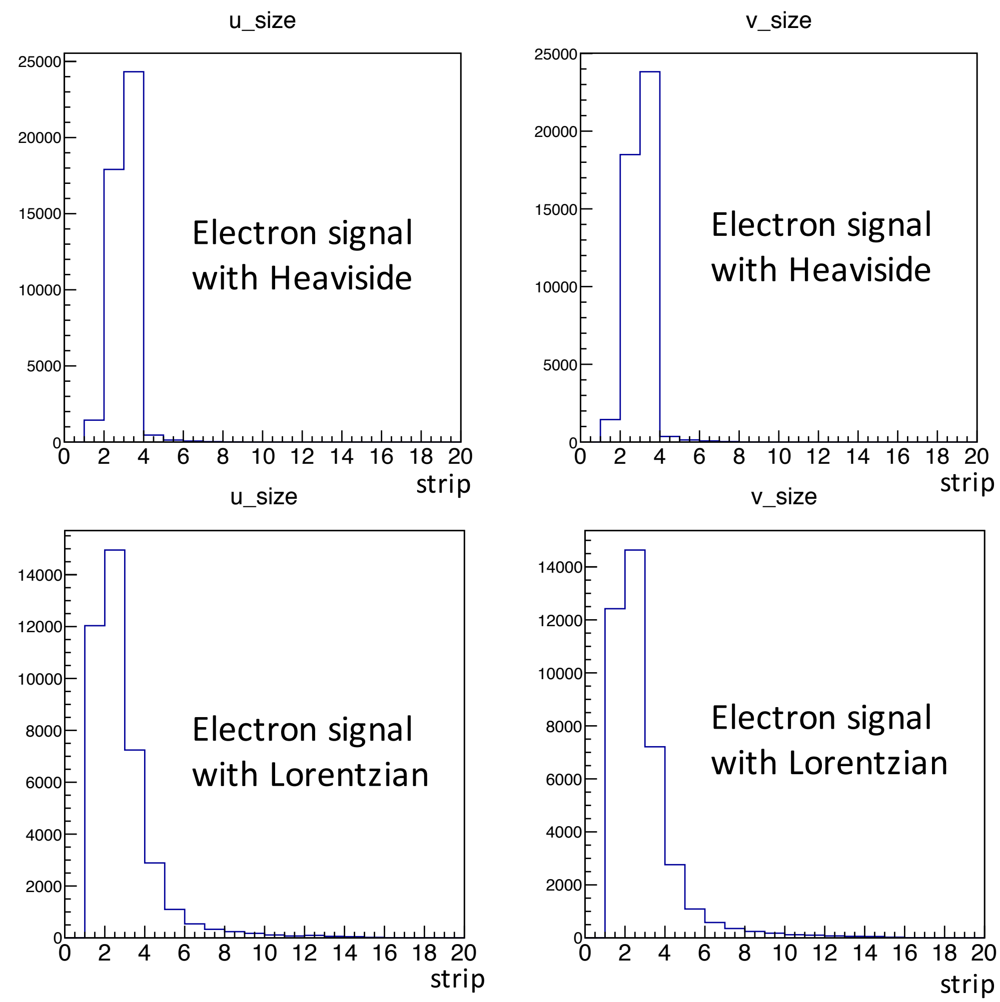
Avalanche Model

- Total size of a cluster using Heaviside and Lorentzian model
- This shows how many strips got “affected” by a cluster
- The actually size of a reconstructed cluster will be smaller than this, based on the threshold that we put
- But in general, larger size lead to higher pile up and occupancy

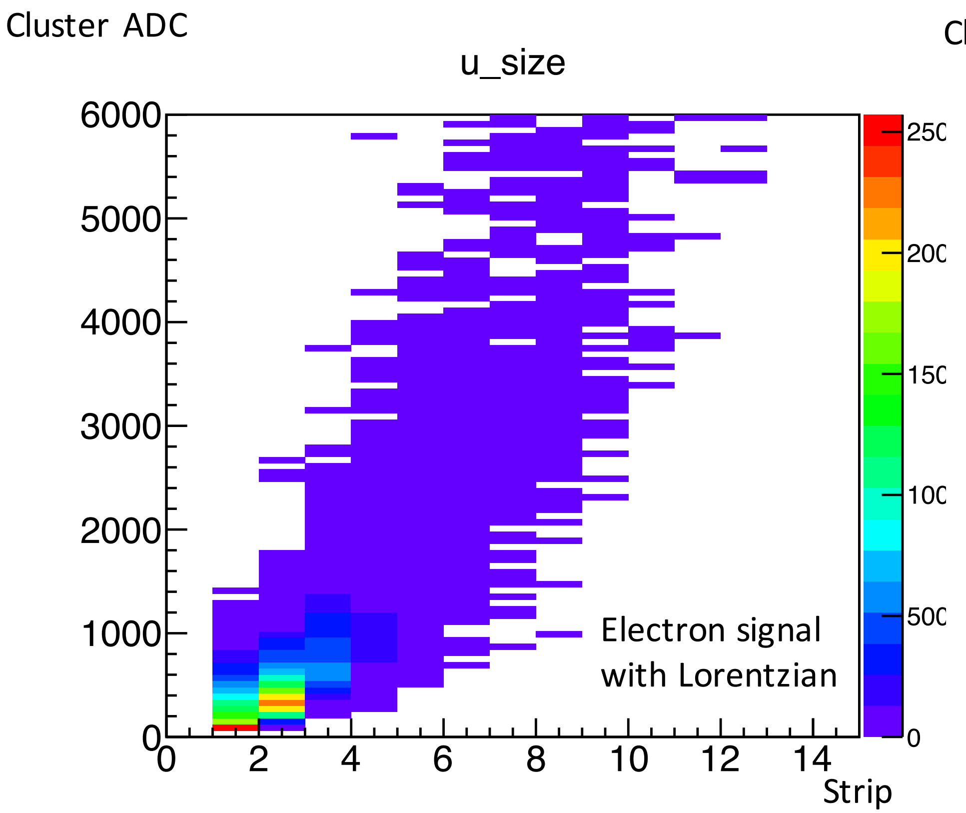


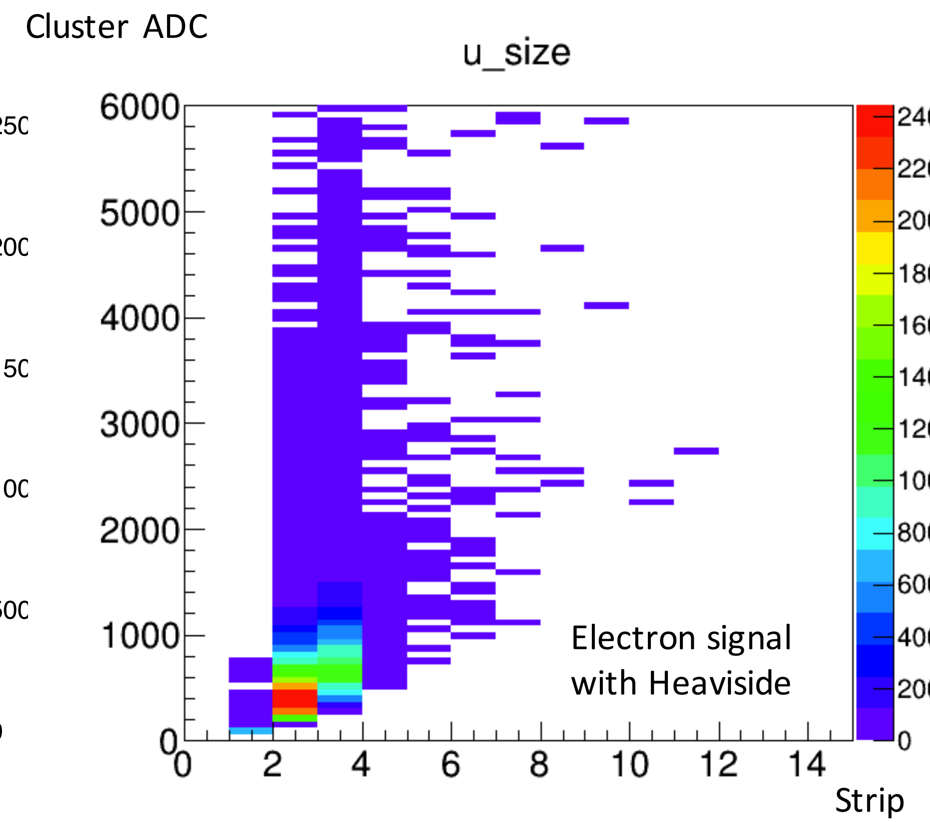
Avalanche Model

- Cluster size after apply a threshold cut at ADC = 80
- Threshold cut doesn’t affect much on the Heaviside model, but has very large impact on Lorentzian
- Lorentzian has a long tail, likely correspond to larger signal (more strips will be appear above the threshold)



Avalanche Model



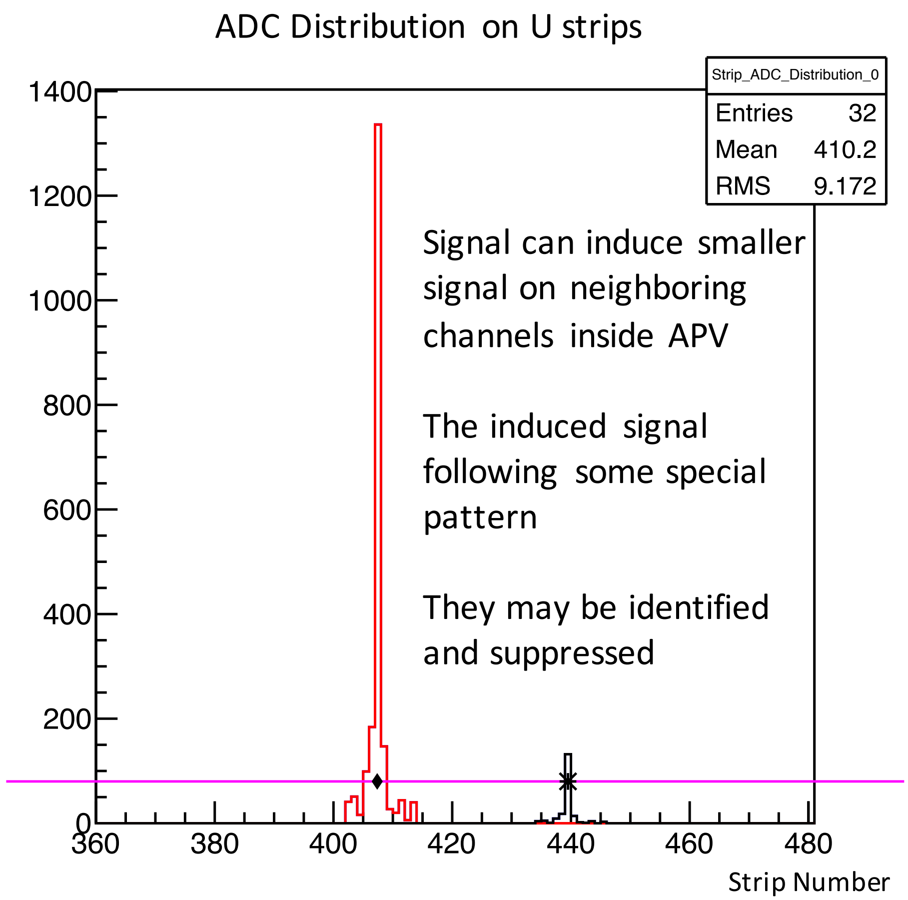


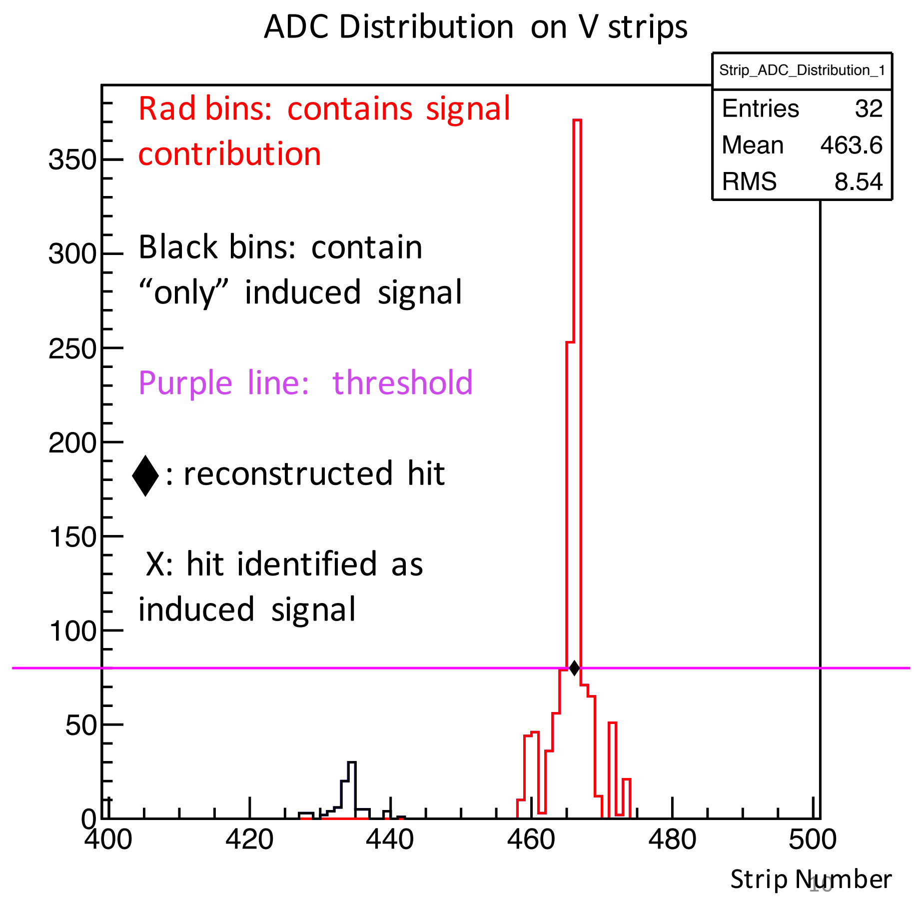
Cluster size after apply a threshold cut at ADC = 80

Cross Talk Signal

- Currently using a very simple and crude simulation for the cross talk
  - After finishing digitizing one cluster, take the cluster and make a smaller copy on either right or left hand side of the cluster (~10% of the main signal)
  - The induced signal is always appear 32 strips apart from the main signal
- To suppress the induced signal
  - After cluster reconstruction, for each hit, see if there is another one that appears 32 strips apart, and with charge < 10% of the main signal
  - Work quite well at 0% background (kill ~70% of induced signal, 0.02% real signal)
  - At 100% background, still need to be refined (pile-up effect makes things worse)

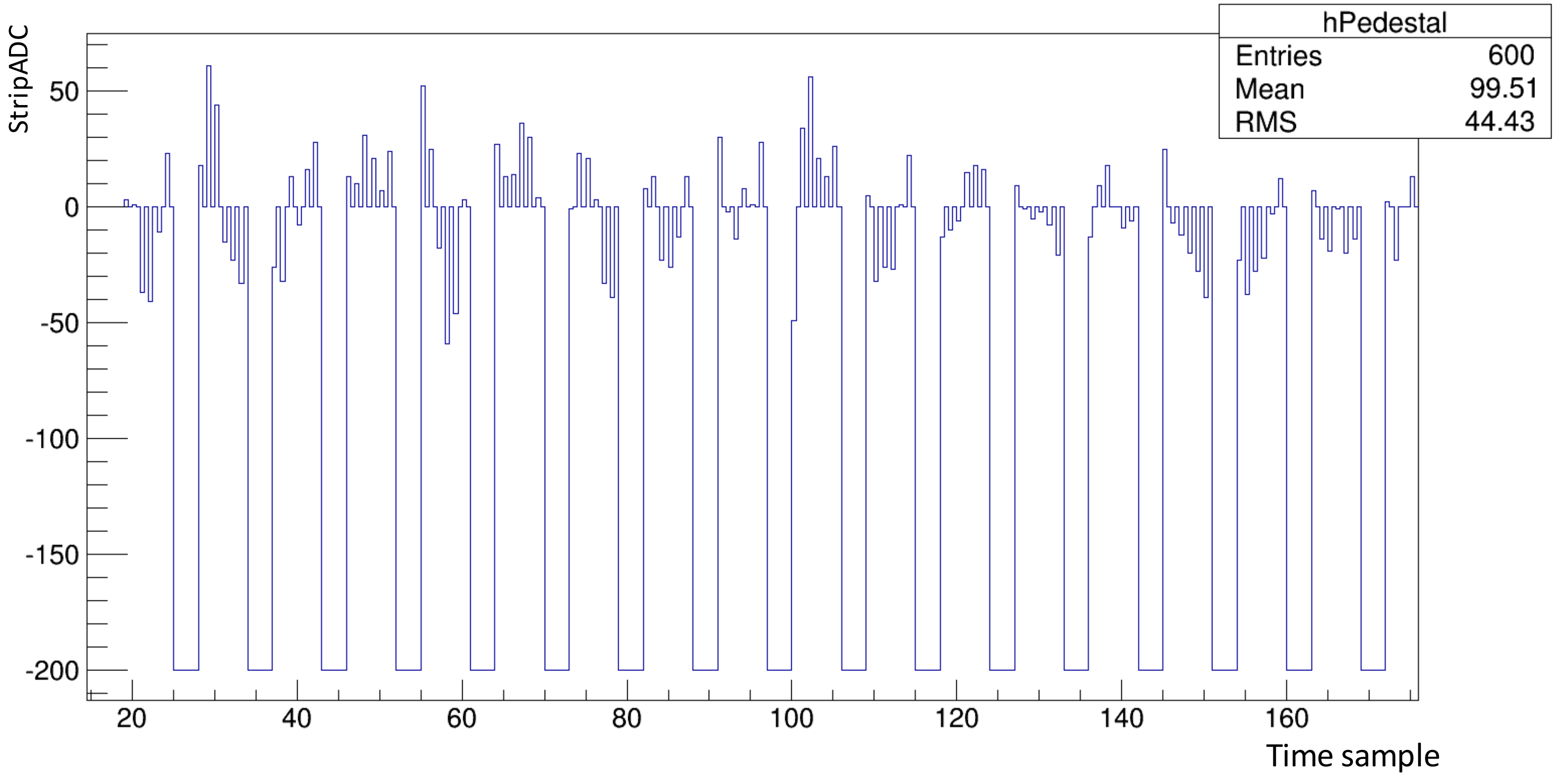
Cross Talk Signal



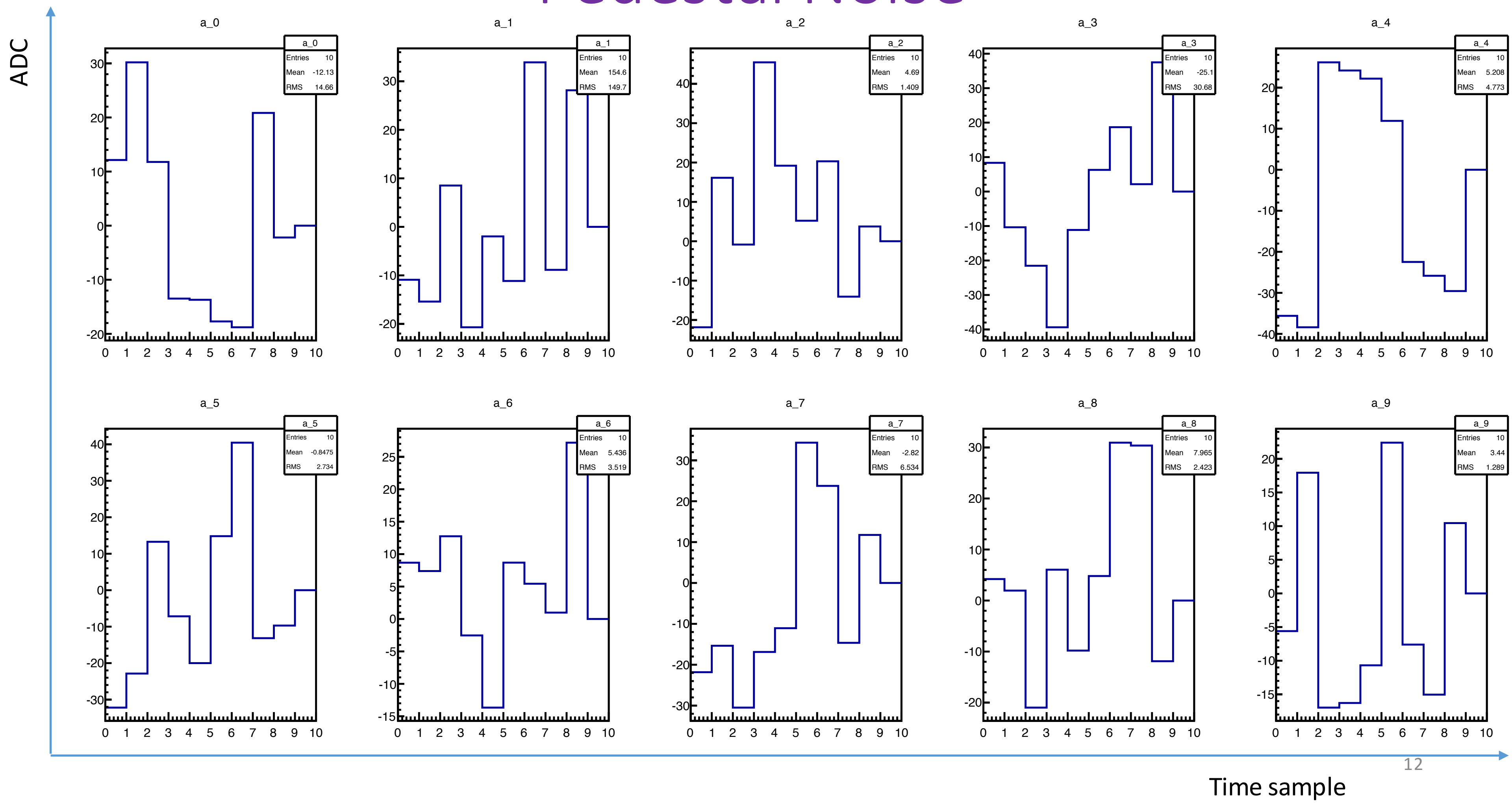


Pedestal Noise (Real Data)

- We assumed uncorrelated Gaussian pedestal noise, but the actual measurement shows a sinusoidal time dependency
- Plot shows GEM pedestal noise measurement, 18 pedestal events with 6 time sample each, separated by big gap (Danning Di)

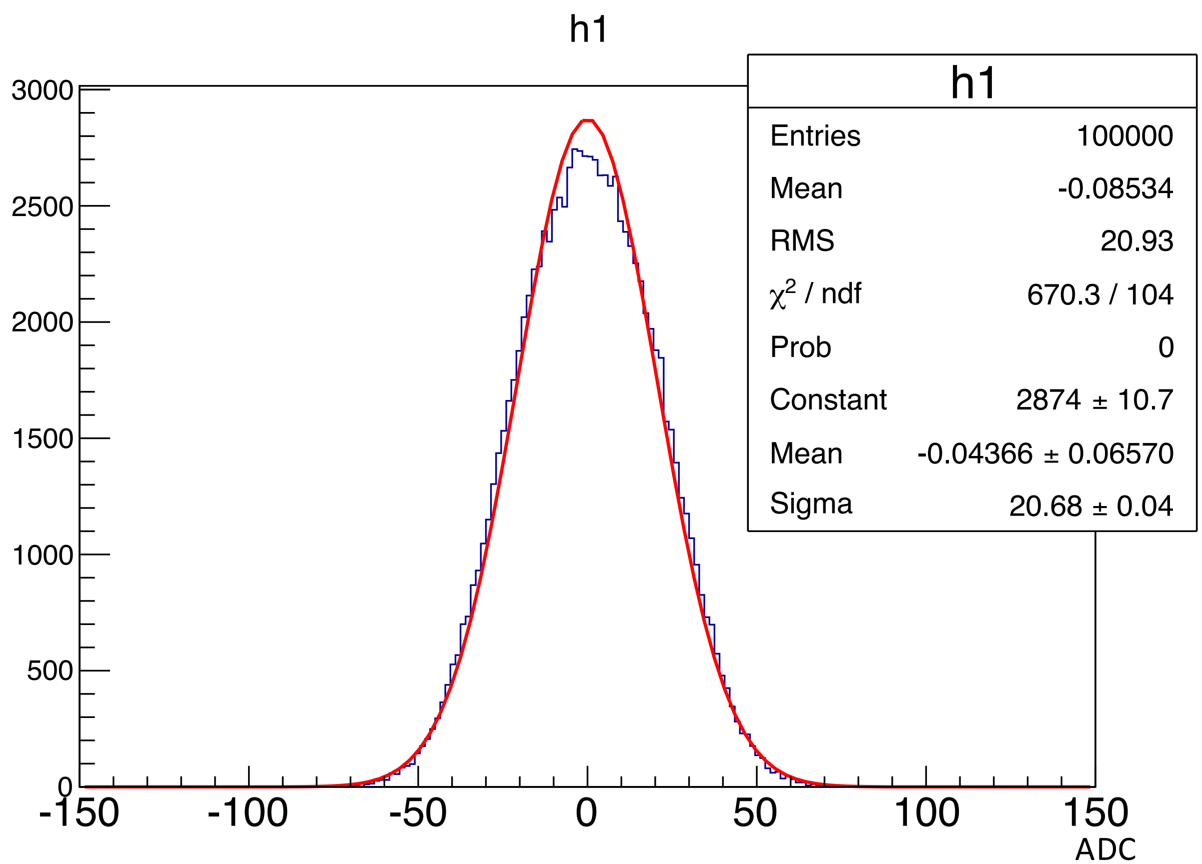


Pedestal Noise



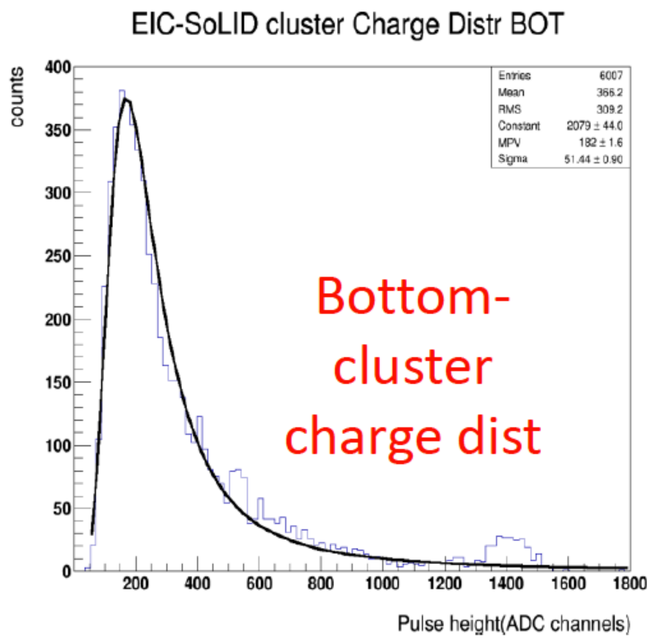
Pedestal Noise

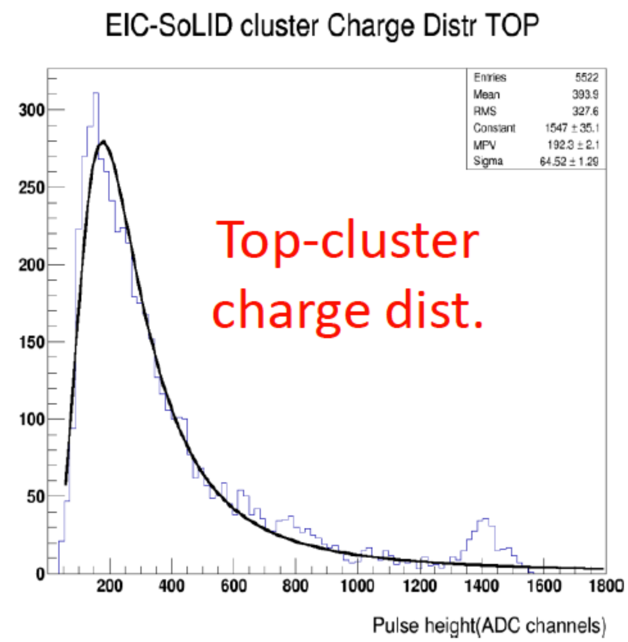
- If we measure pedestal of one sample for multiple times, the distribution is still Gaussian
- Currently using parameters such that the width is about 20.7 ADC



Gain (Real Data)

- Based on cosmic test from UVa (SoLID-EIC cosmic test at FNAL):
  - MPV for Maximum ADC (maximum among all strip and all time samples) of a cluster should appear at around 200 ADC
  - Distribution should follow Landau distribution





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Gain

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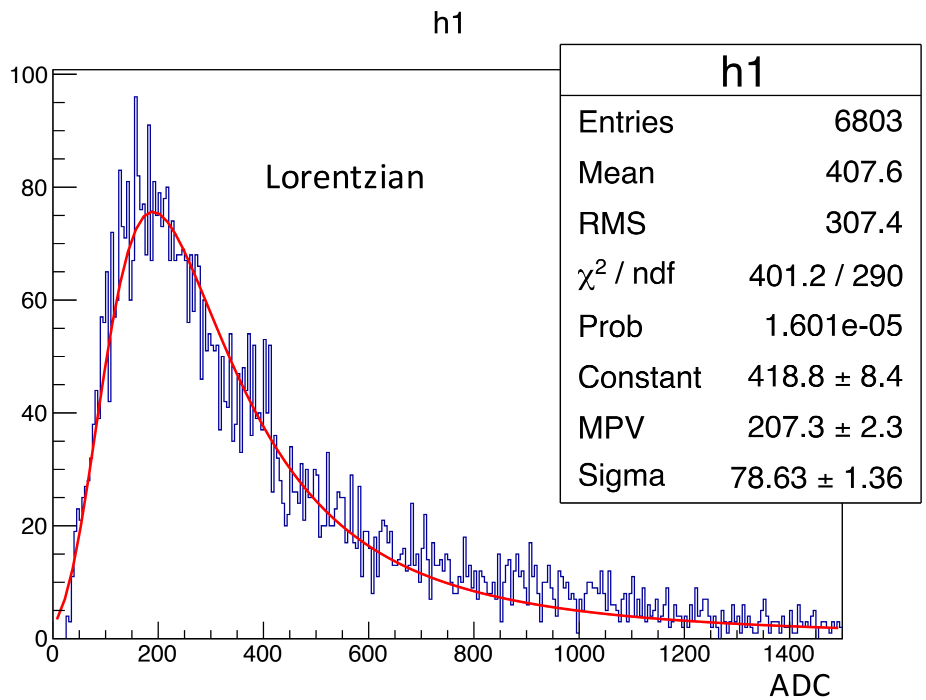
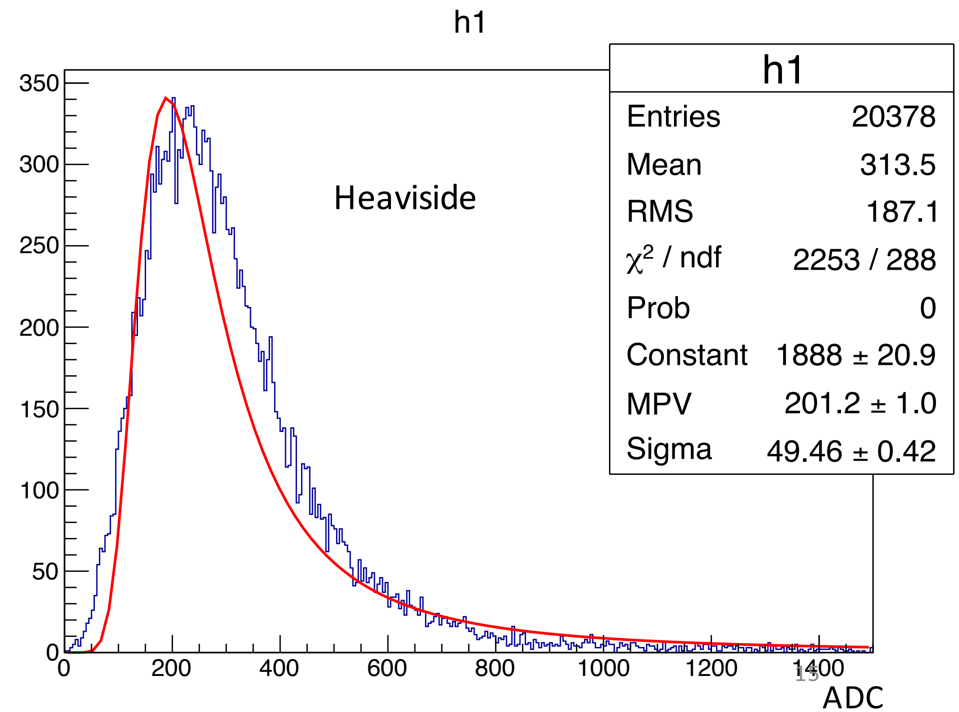
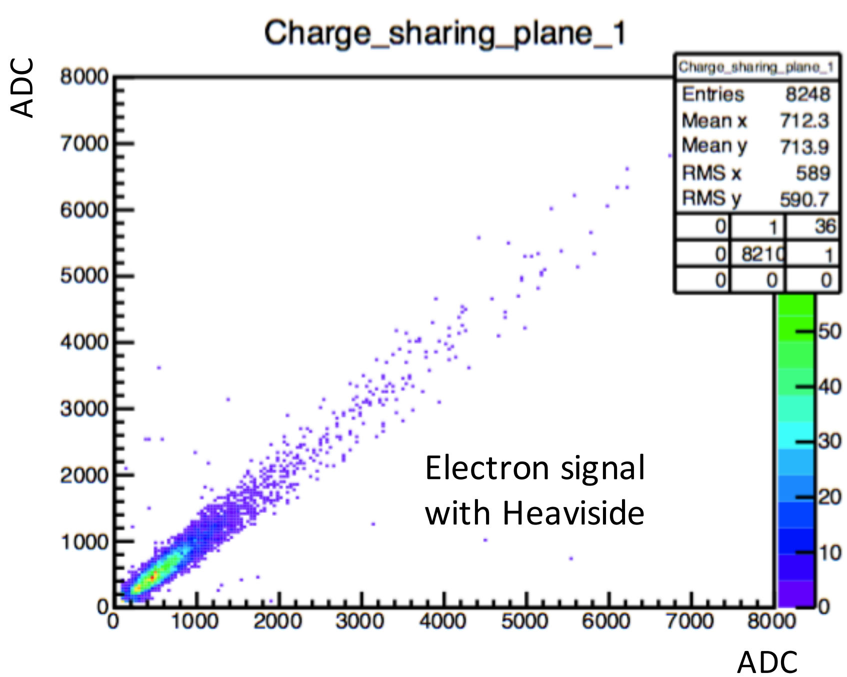
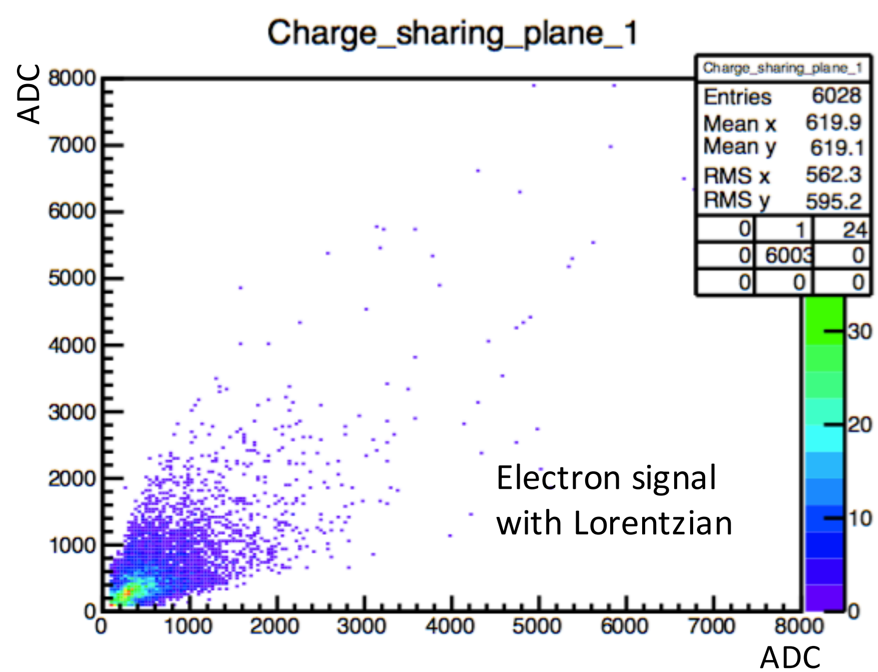




Charge Sharing

- There are still a few remaining issues we are working on right now
  - Charge sharing and GEM resolution





GEM Resolution

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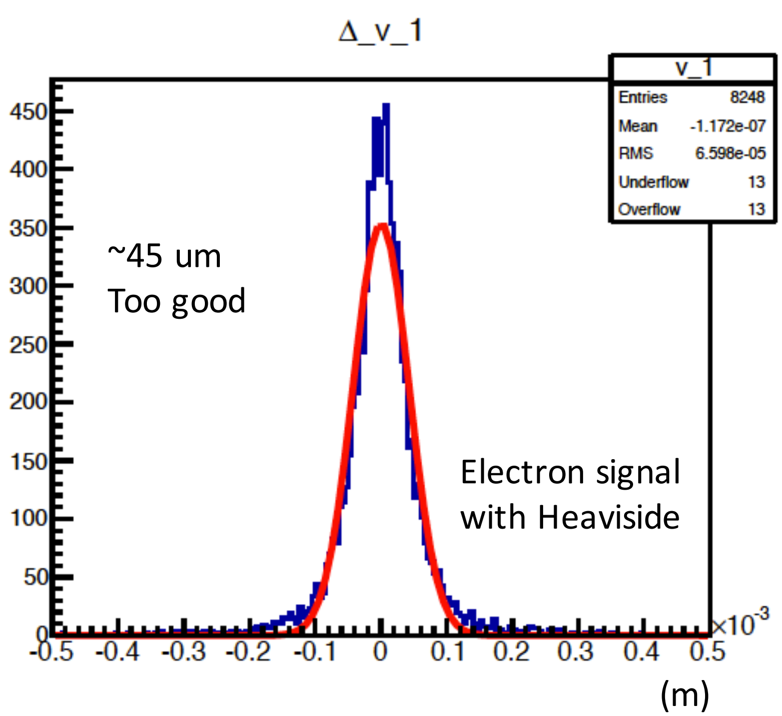
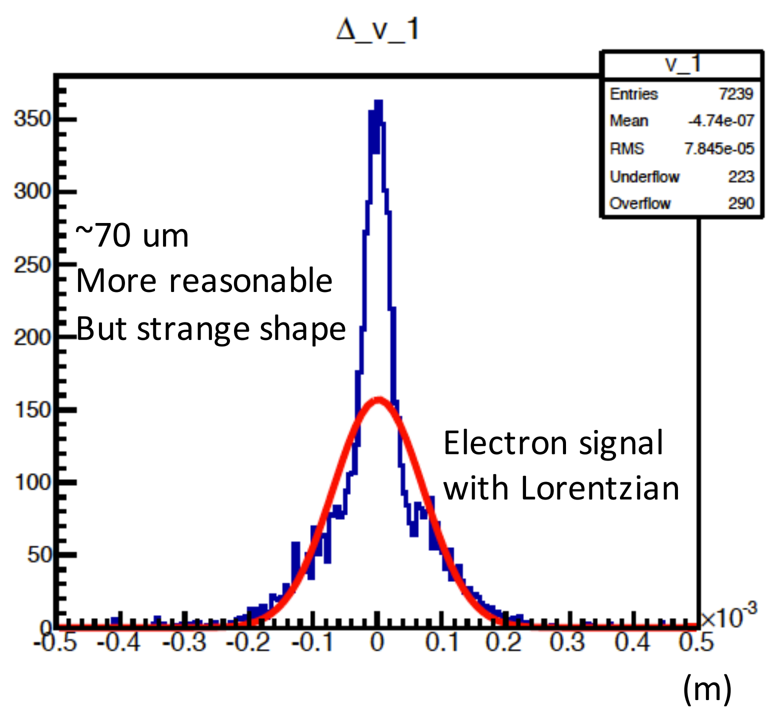
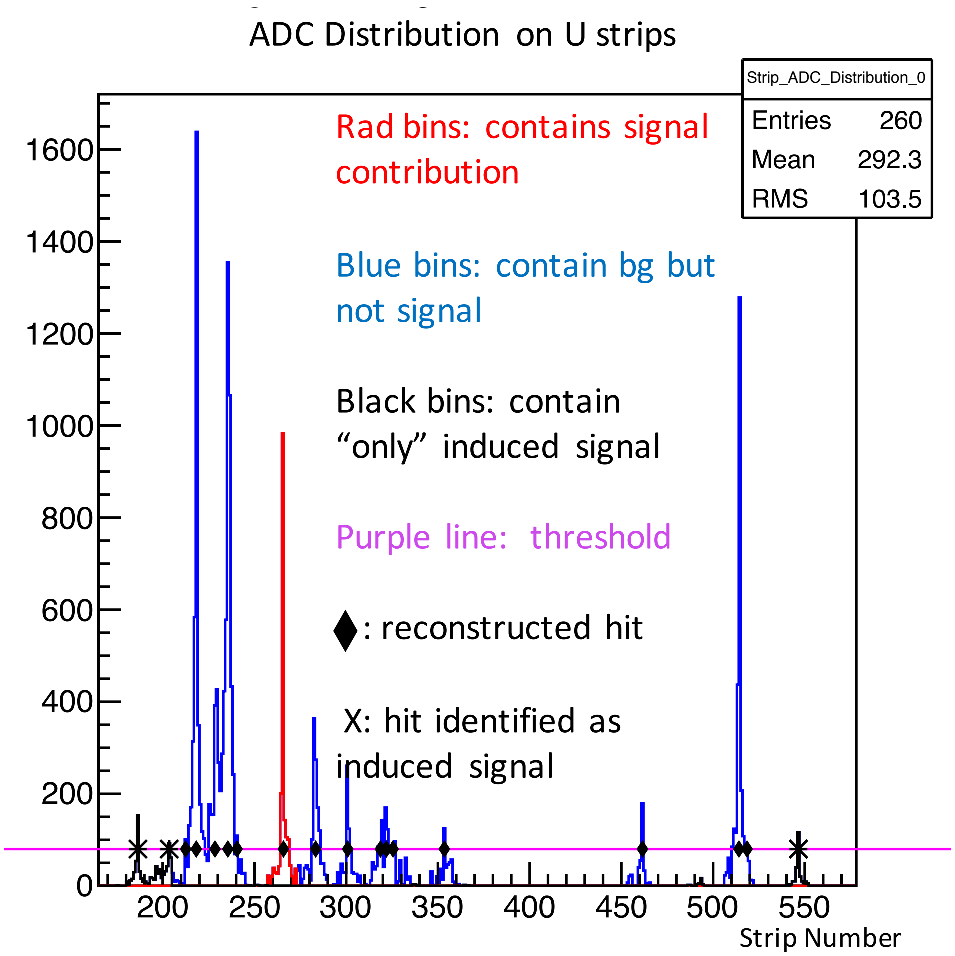
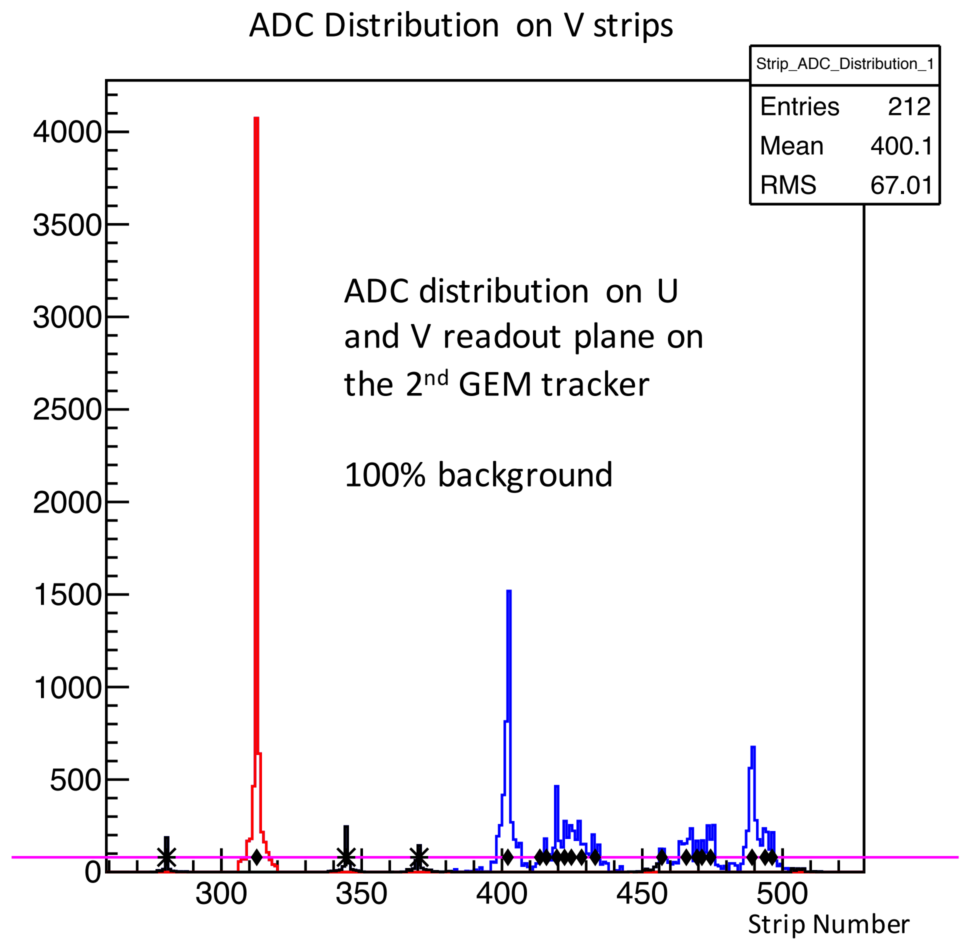
  - Charge sharing and GEM resolution






ADC Distribution on U strips
Strip_ADC_Distribution_0
Entries 260
Mean 292.3
RMS 103.5
Rad bins: contains signal contribution
Blue bins: contain bg but not signal
Black bins: contain “only” induced signal
Purple line: threshold
♦ : reconstructed hit
X: hit identified as induced signal
0
200
400
600
800
1000
1200
1400
1600
200
250
300
350
400
450
500
550
Strip Number


ADC Distribution on V strips
Strip_ADC_Distribution_1
Entries 212
Mean 400.1
RMS 67.01
ADC distribution on U and V readout plane on the 2nd GEM tracker
100% background
0
500
1000
1500
2000
2500
3000
3500
4000
300
350
400
450
500
Strip Number

Initial Estimate On Occupancy and Number of Hits

For SIDIS He3 Configuration, contains cross talk effect

Heaviside

Thres = 80	GEM 1	GEM 2	GEM 3	GEM 4	GEM 5	GEM 6
Occupancy (%)	2.84	9.76	4.23	2.67	2.57	1.92
N Hits	630.6	5577	2129	1334	697	632

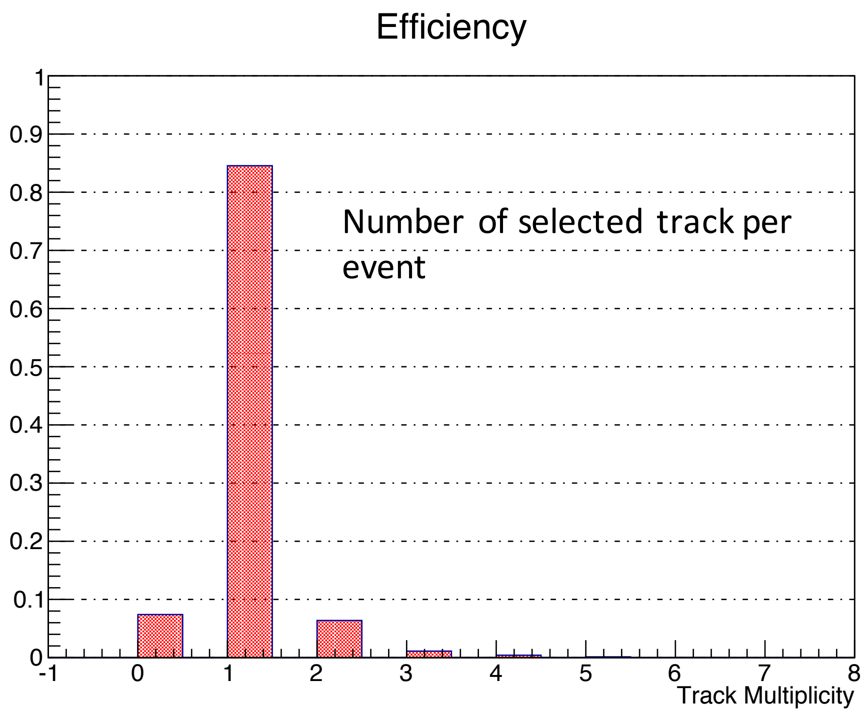
Lorentzian

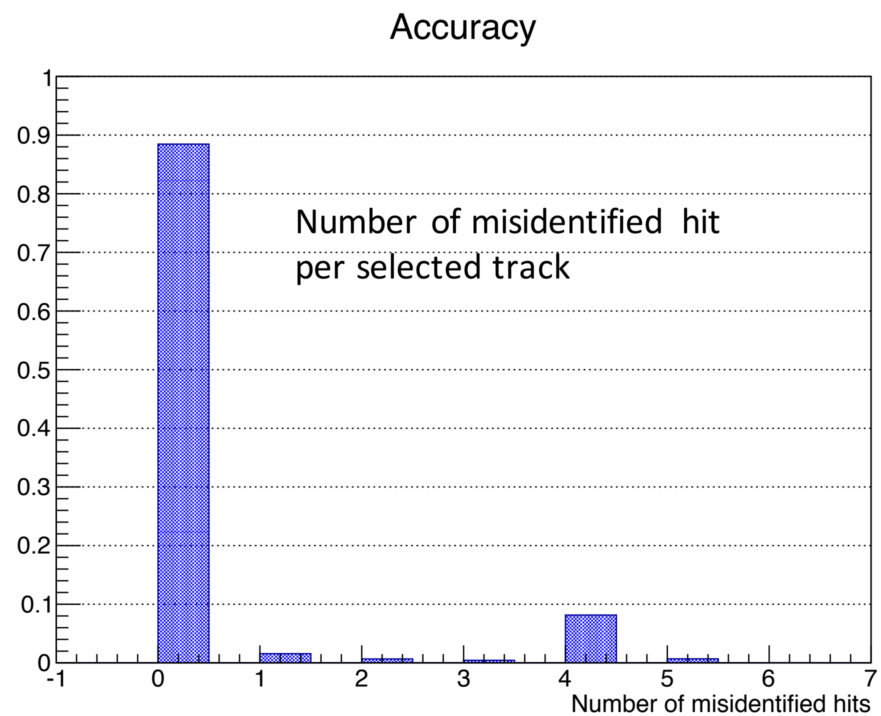
Thres = 80	GEM 1	GEM 2	GEM 3	GEM 4	GEM 5	GEM 6
Occupancy	3.67	12.72	5.41	3.41	3.16	2.33
N Hits	974	9173	3313	1962	1053	956

The result is obtain with 100% background, pedestal noise sigma = 20 ADC, and the effect of cross talk

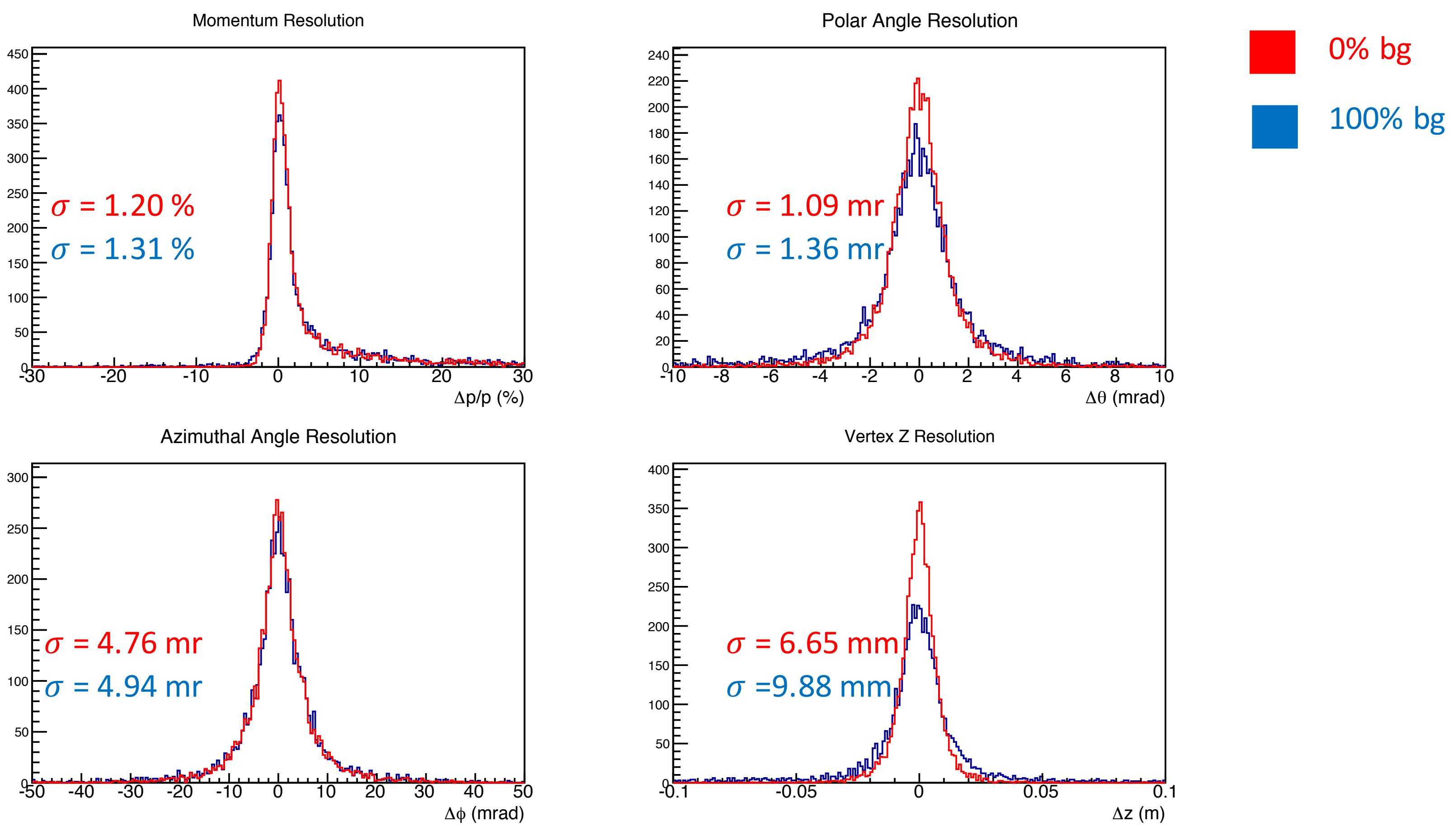
SIDIS Tracking at FA

- Condition: 100% background, single electron track (0.9 ~ 7 GeV), pedestal noise = 20 ADC, Lorentzian avalanche model, cross talk effect on, one sample from APV





Vertex Resolution at SIDIS FA



Conclusion for Part I

- New effects and models have been implemented in the GEM digitization program
  - Lorentzian avalanche model
  - Time dependent pedestal noise
  - Cross talk effect
- Digitization still need some work:
  - Charge asymmetry and GEM position resolution need some more study
- Occupancy increase by a factor of ~30%
- Number of hits increase by over 50%
- Tracking is not breaking apart yet, even though performance is worse and four times slower. Should be able to save it

Kalman Filter Algorithm

Kalman Filter: a recursive fitting algorithm based on χ^2 minimization

1. Prediction: Predict state vector at next measurement site

2. Error Propagation: propagate covariance matrix to the next measurement site and calculate process noise matrix along the way

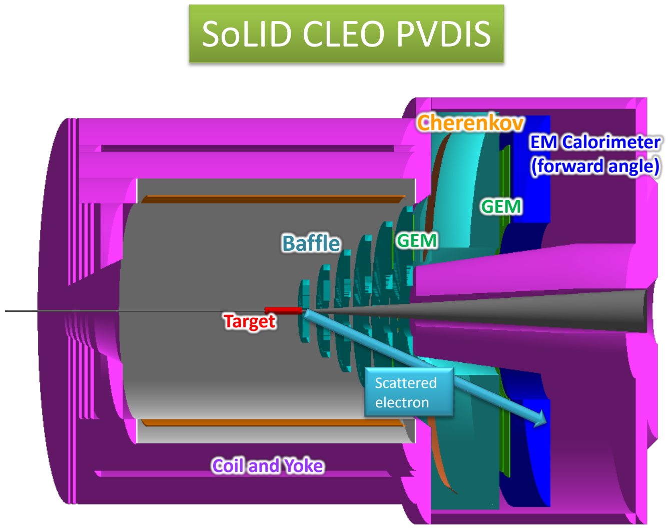
3. Filtering: the weighted mean of the predicted state vector and measurement vector on detector k is calculated

Using Kalman Filter as track finder

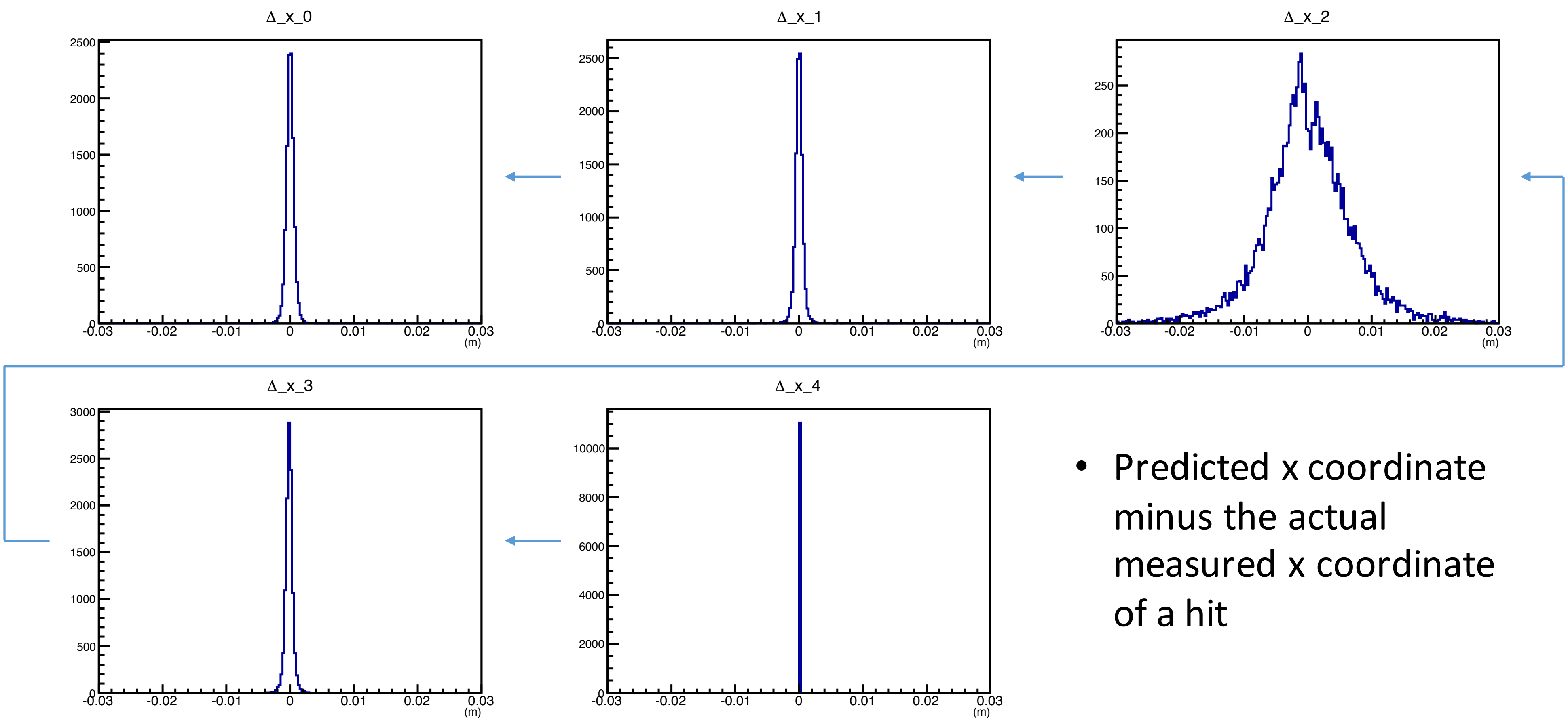
Arbitration: decide whether we want to accept the hit based on the prediction, the propagated covariance matrix and χ^2 increment if accept

Tracking for PVDIS Configuration

- Procedure for applying Kalman Filter (KF) for the PVDIS configuration
  - Select seeds from the last three GEM trackers, assuming the track is straight in 3D space
  - Hits on the last two GEMs (very close to EC) are selected based on the EC hit position
  - Using a straight line to connect hits on the third GEM with hits on the last two GEMs, see if it leads to the EC hit
  - Energy measurement from EC and two hits with straight line model are sufficient to initialize KF
  - The rest is taken cared of by KF automatically

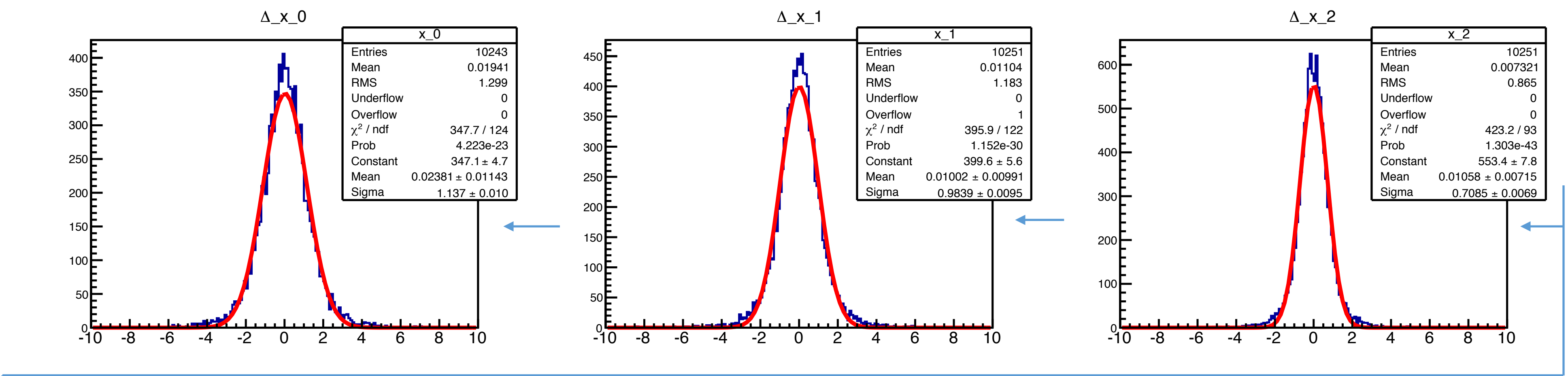


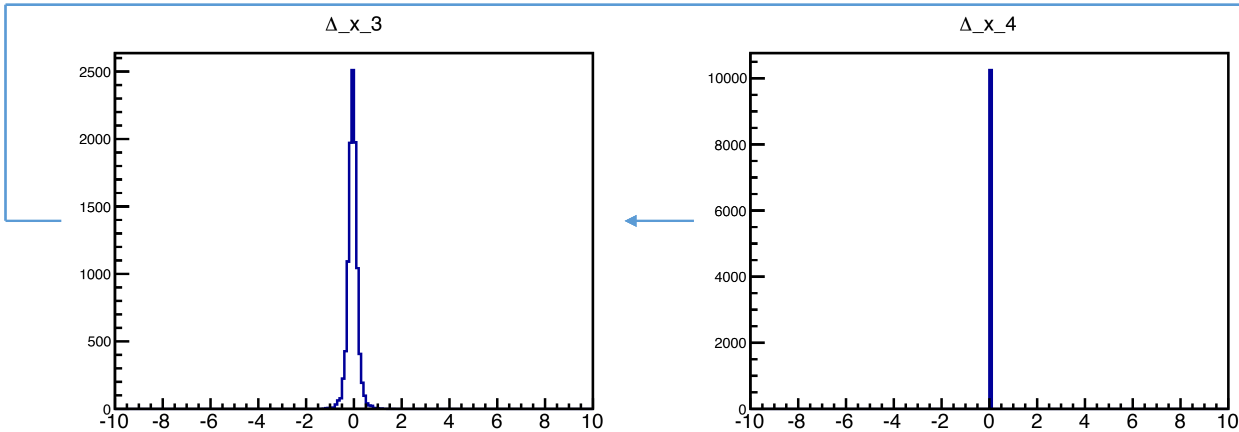
Tracking for PVDIS Configuration



- Predicted x coordinate minus the actual measured x coordinate of a hit

Tracking for PVDIS Configuration

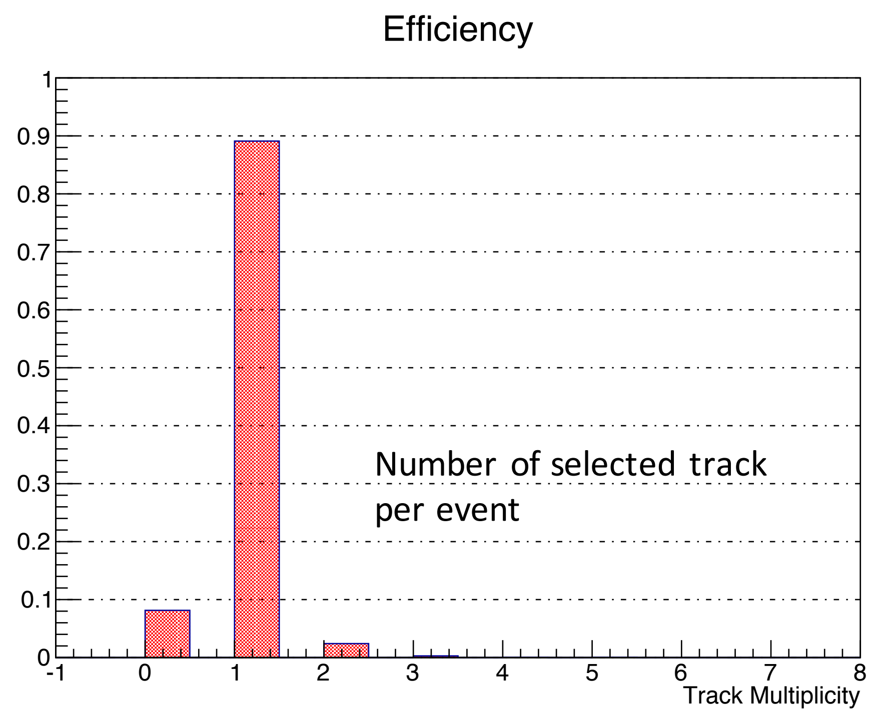


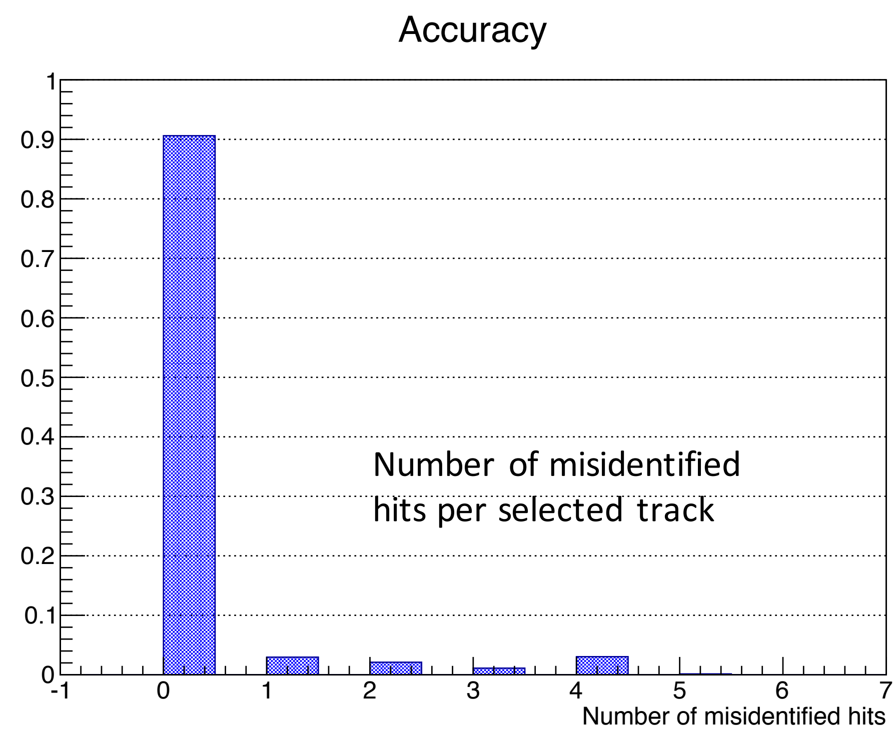


- Error weighted difference between Predicted x coordinate minus the actual measured x coordinate of a hit

Tracking for PVDIS Configuration

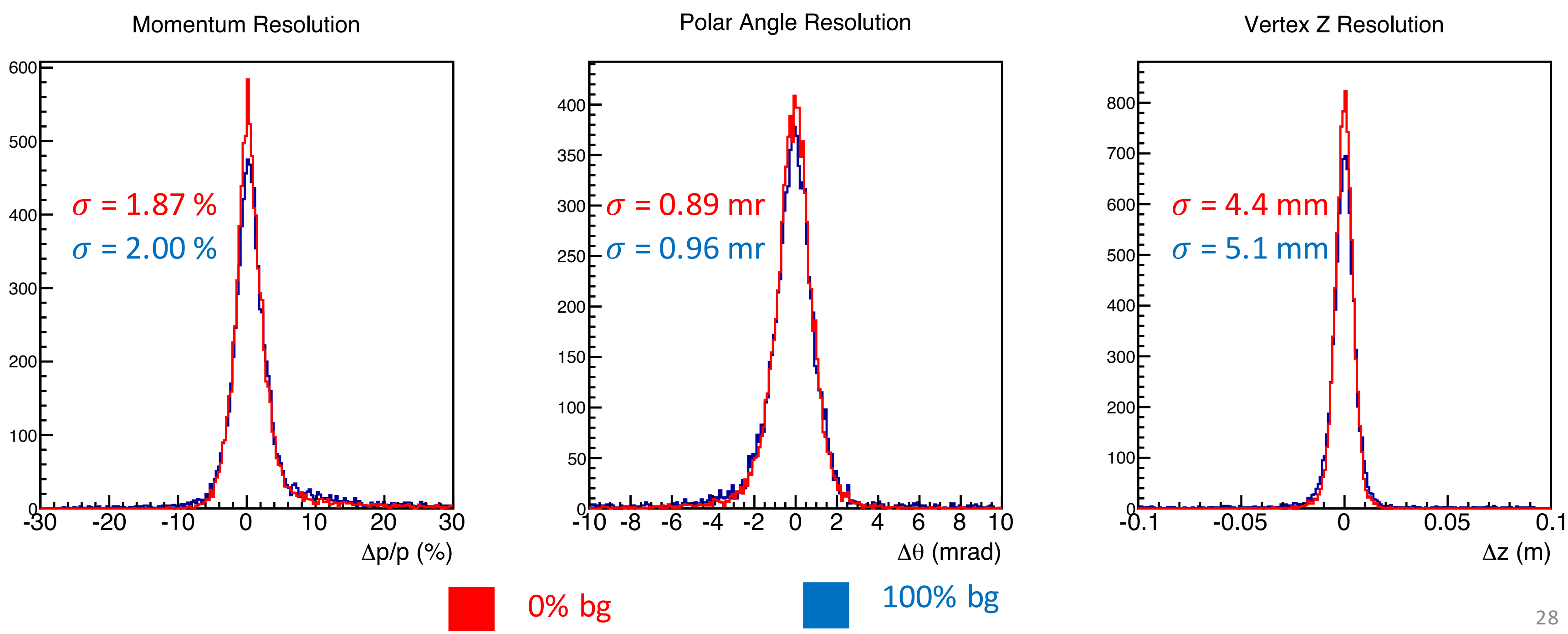
- At 100% background (50uA current), 2 ~ 6 GeV electrons
- Heaviside avalanche model, no cross talk and pedestal noise simulated. 3 samples from GEM





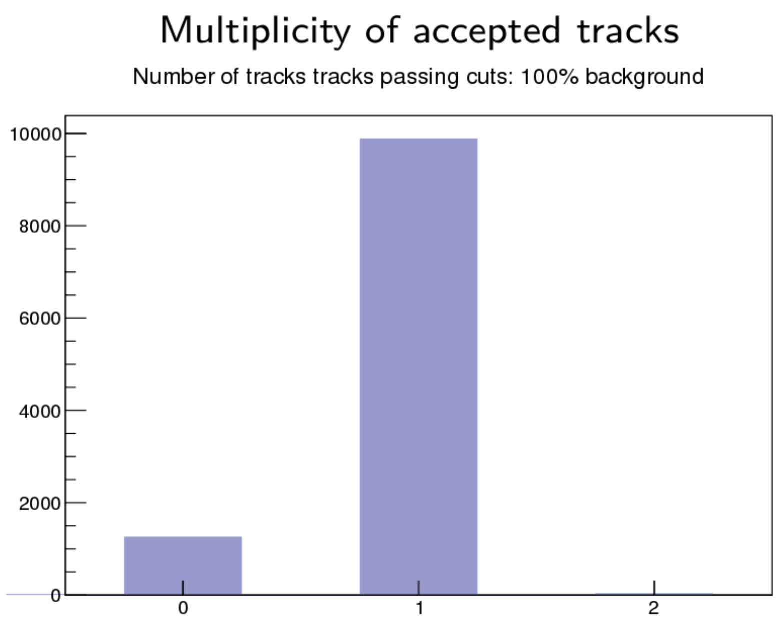
Tracking for PVDIS Configuration

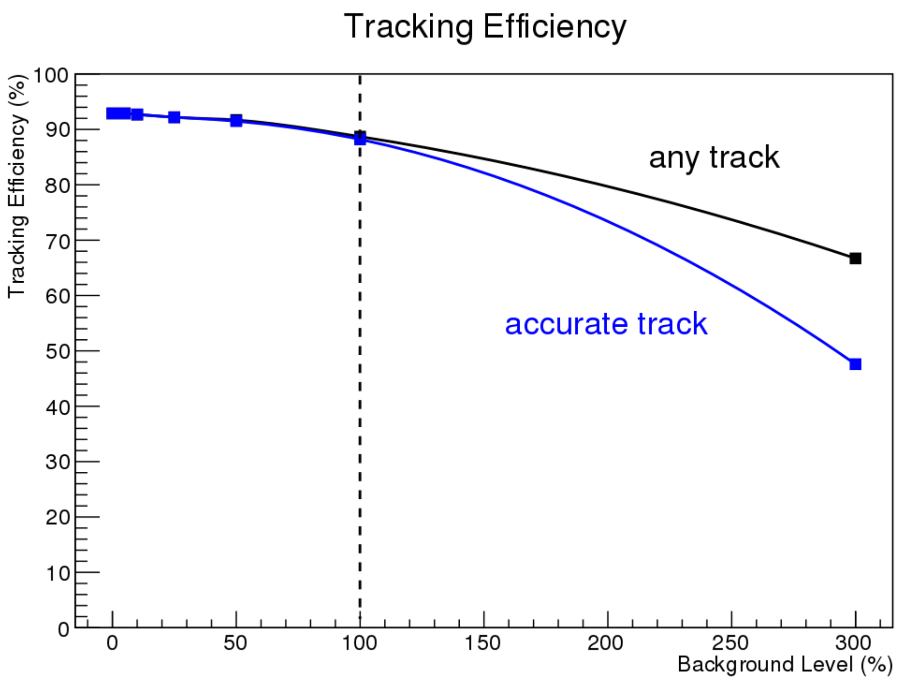
- Resolution not as good as before, possibly because the tracks are fitted only once
- In previous study for PVDIS, I fitted the track twice in order to optimize the resolution
- For tracking finding phase, optimization of vertex variables is not necessary
- We can make it better offline



Tracking for PVDIS Configuration

Ole's result for the director's review, with Tree Search





Results are quite comparable

Conclusion

- Kalman Filter tracking finding framework for the PVDIS configuration has been set up
- Tested the program with 100% background with the old digitization and no electronic noise simulated
- This result is quite comparable with Ole's result with Tree Search algorithm
- Only progress for the moment is the magnetic field is on
- Execution speed is a lot slower compare to Tree Search (3~4 ms per event with KF)
- It is crucial to study tracking with electronic noise simulated, so this is my next step for tracking