A new electron peaks counting algorithm based on a running pulse template

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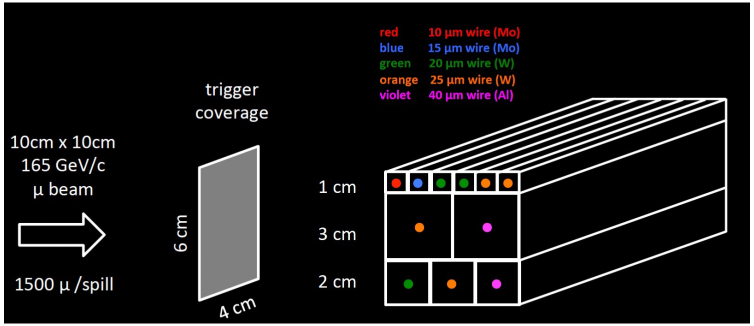
Introduction

- Offline analysis on November test beam data taken with 165 GeV/c muons beams from Nov 2021.
- Different configurations are used (gas mixture, HV, trigger, track incident angle w.r.t. drift tube, sampling frequency).
- Dealing with 11 drift tubes having cell sizes of 1 cm, 2 cm, and 3 cm:



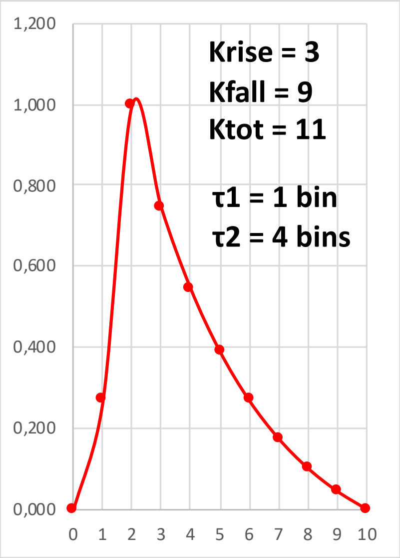
- Channels 0,1,2,3 are Trigger Counters
- Channels 4,5,6,7,8,9 are the 6 Drift Tubes of 1 cm cell size
  - ✓ Channel 4 with a wire diameter of 10 micrometer
  - ✓ Channel 5 with a wire diameter of 15 micrometer
  - ✓ Channel 6 and 7 with a wire diameter of 20 micrometer
  - ✓ Channel 8 and 9 with a wire diameter of 25 micrometer
- Channels 10,11,12 are the 3 Drift Tubes of 2 cm cell size
  - ✓ Channel 10 with a wire diameter of 20 micrometer
  - ✓ Channel 11 with a wire diameter of 25 micrometer
  - ✓ Channel 12 with a wire diameter of 40 micrometer
- Channels 13,14 are the 2 Drift Tubes of 3 cm cell size (Signal acquisition window is out of the signal range)
  - ✓ Channel 13 with a wire diameter of 25 micrometer
  - ✓ Channel 14 with a wire diameter of 40 micrometer

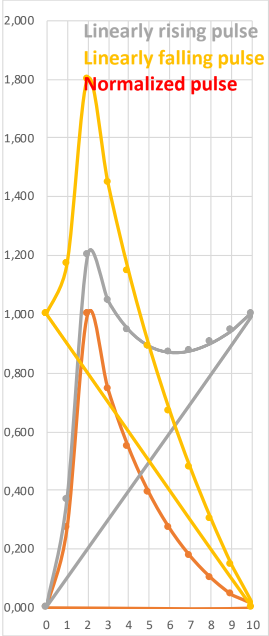
https://github.com/bdanzi/drifttubes_offline_analysis/

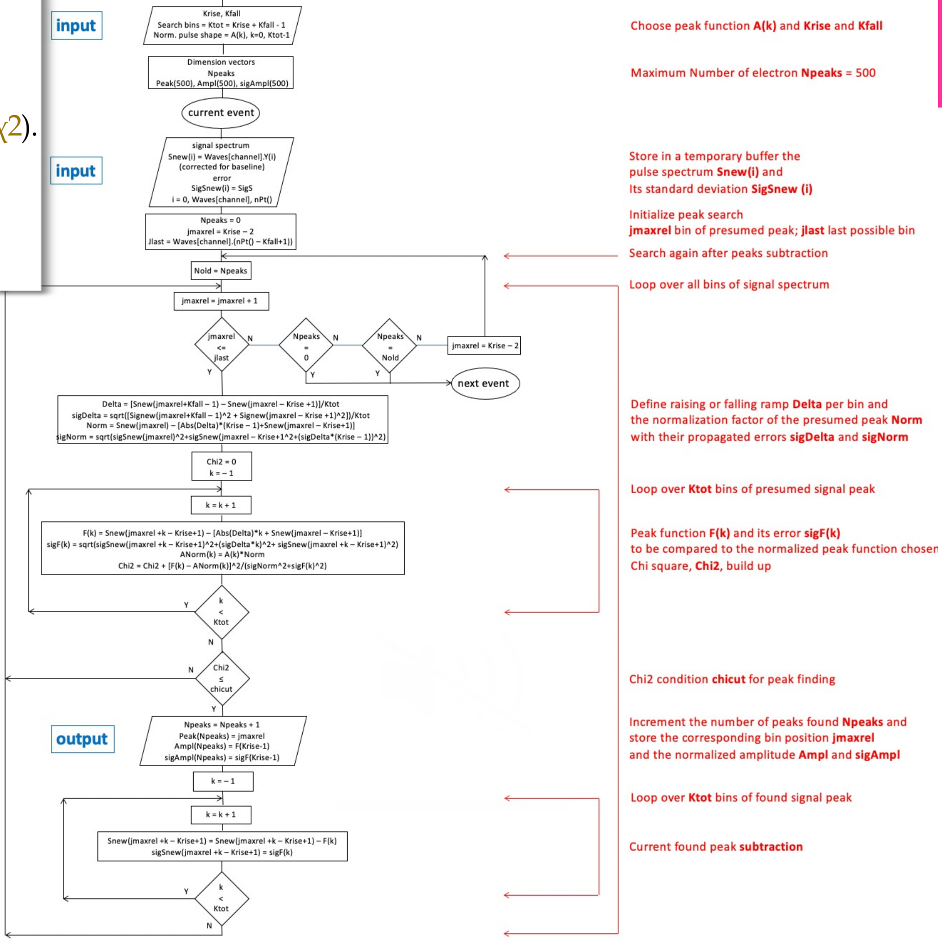
Find Electron Peaks strategy

- Define an electron pulse template based on experimental data.
- Raising and falling exponential over a fixed number of bins (Ktot).
- Digitize it (A(k)) according to the data sampling rate.
- Run over Ktot bins by comparing it to the subtracted and normalized data (build a sort of χ2).
- Define a cut on χ2.
- Subtract the found peak to the signal spectrum.
- Iterate the search.
- Stop when no new peak is found.

k	A(k)
0	0.0
1	0.269
2	1.0
3	0.744
4	0.545
5	0.390
6	0.269
7	0.175
8	0.102
9	0.044
10	0.0







Clusterization counting strategy

The strategy make the clusterization of the electron peaks into ionization clusters:

1) Association of electron peaks in consecutive bins (difference in time == 1 bin) electrons to a single electron.

2) Contiguous electrons peaks which are compatible with the electrons diffusion time (2.5 ns or 3 bins) are considered belonging to the same ionization cluster.

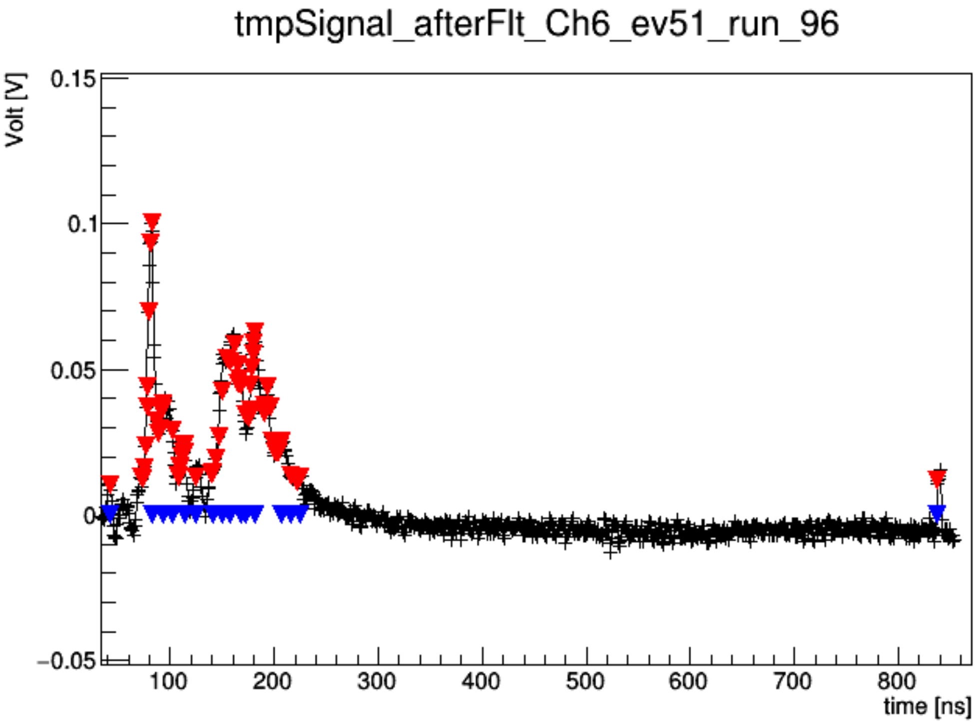
3) Position of the clusters is taken as the position of the last electron in the cluster.

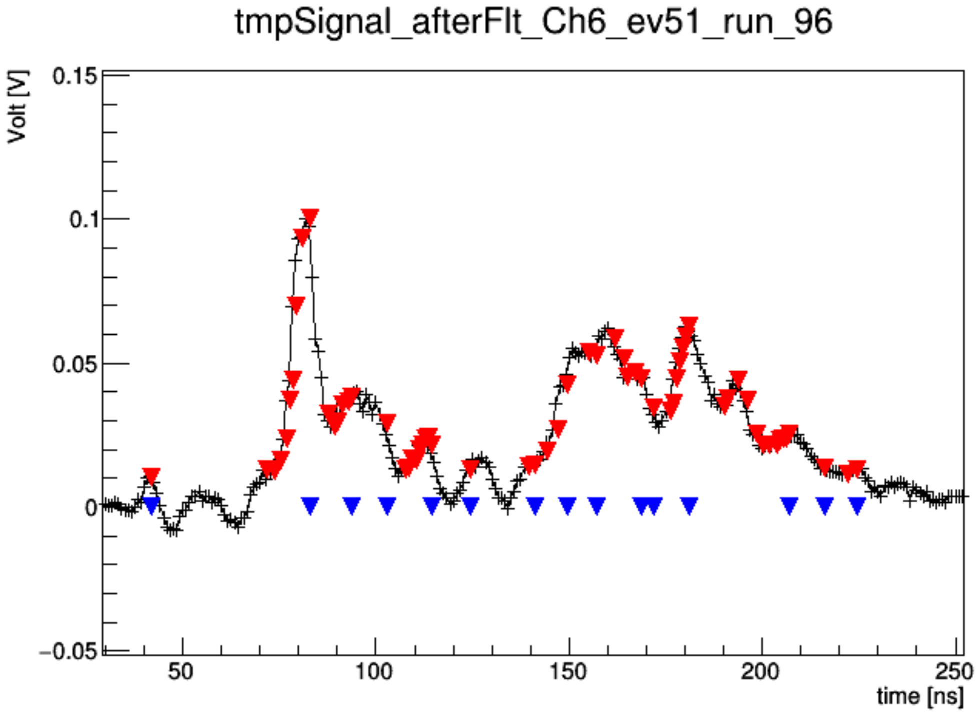
4) The distributions of the number of clusters must follow a Poisson distribution!

Electron peaks counting & clustering

1 cm drift tubes

Run: run_96.root; Track angle:30^0; Gas mixture:90%He10%iC4H10 ; HV = +20

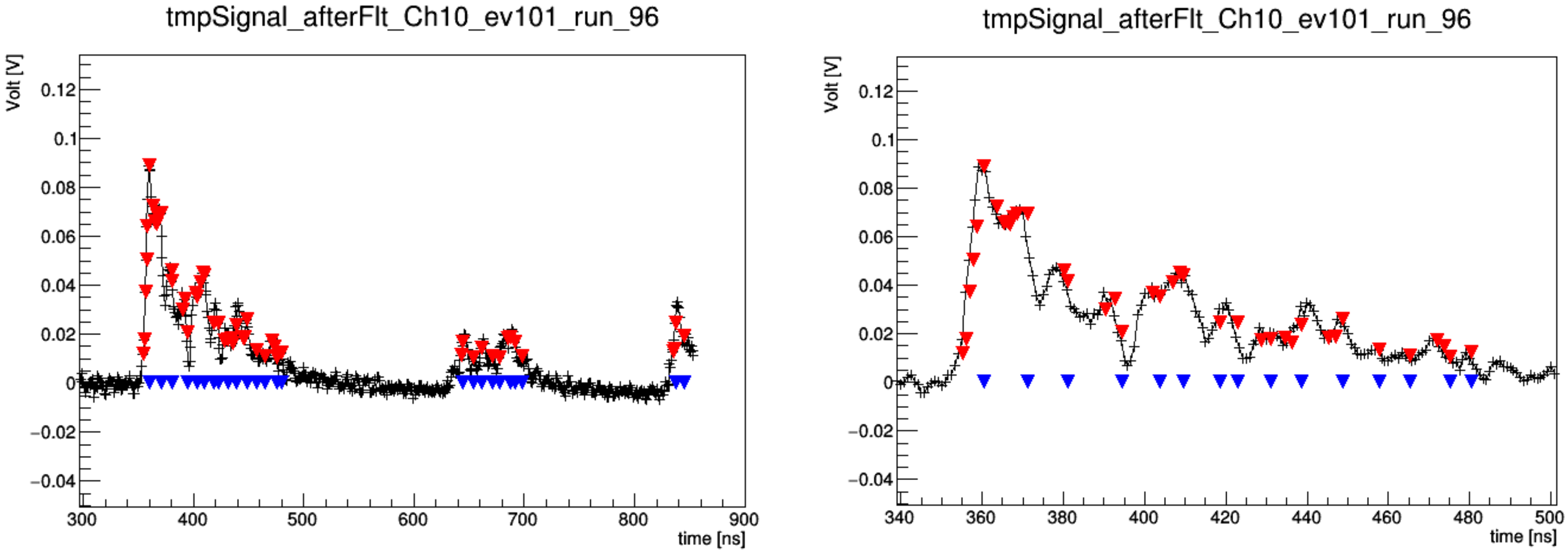




Electron peaks counting & clustering

2 cm drift tubes

Run: run_96.root; Track angle: 30^0; Gas mixture: 90%He10%iC4H10 ; HV = +20



Expected number of Electron Peaks & Clusters

The expected numbers of the electron peaks and clusters are estimated to check our electron peak (cluster) algorithm:

- Expected number of electron peaks =

δ cluster/cm (M.I.P.) * drift tube size [cm] * 1.3 (relativistic rise)* 1.6 electrons/cluster * 1/cos(α)

- Expected number of clusters =

δ cluster/cm (M.I.P.) * drift tube size [cm] * 1.3 (relativistic rise)* 1/cos(α)

α = angle of the muon track w.r.t. normal to sense wire.
δ cluster/cm (mip) = 12 for 90He (18 for 80He) gas mixtures.
drift tube size = 0.8 for 1 cm (1.8 for 2 cm) drift tube.

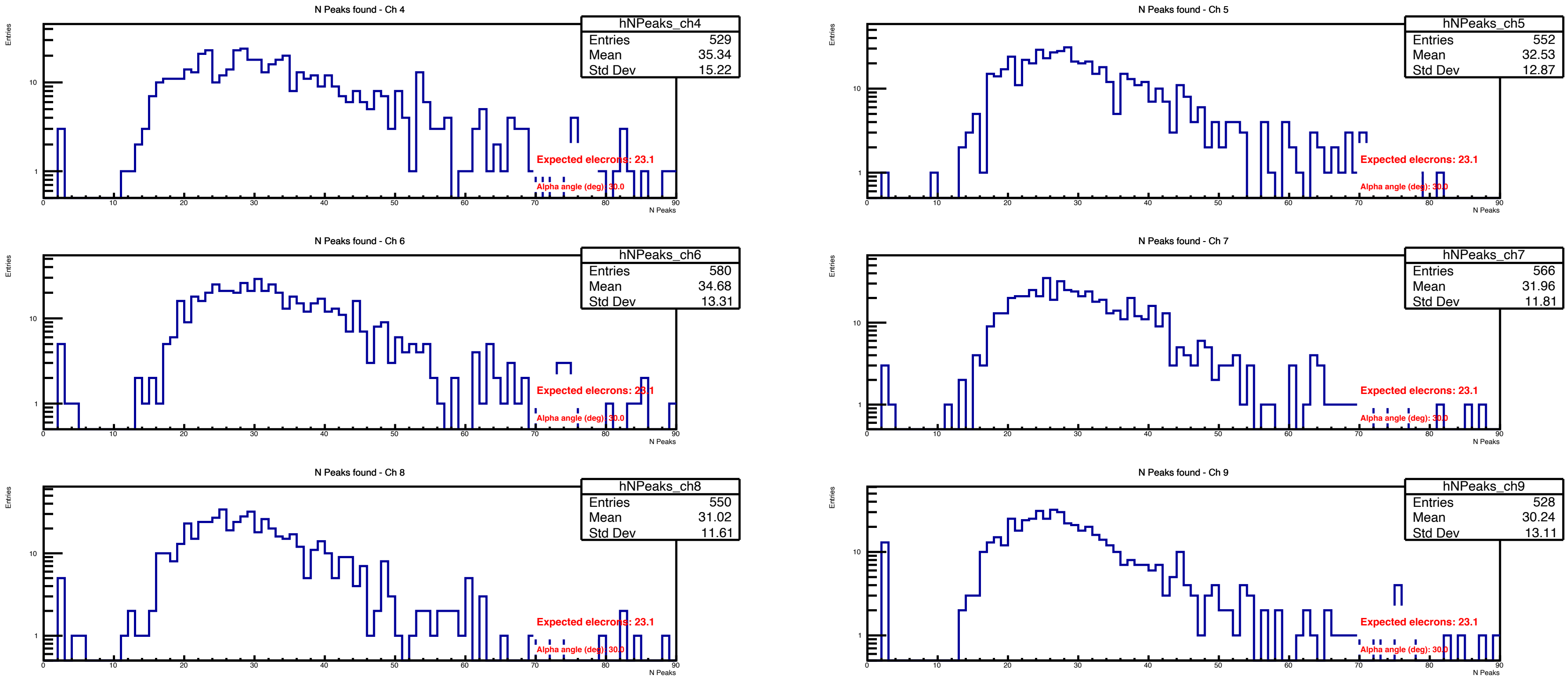
Electron peaks counting

N electrons = 32.4

1 cm drift tubes

Expected = 23.1

Run: run_96.root; Track angle:30^0; Gas mixture:90%He10%iC4H10 ; HV = +20



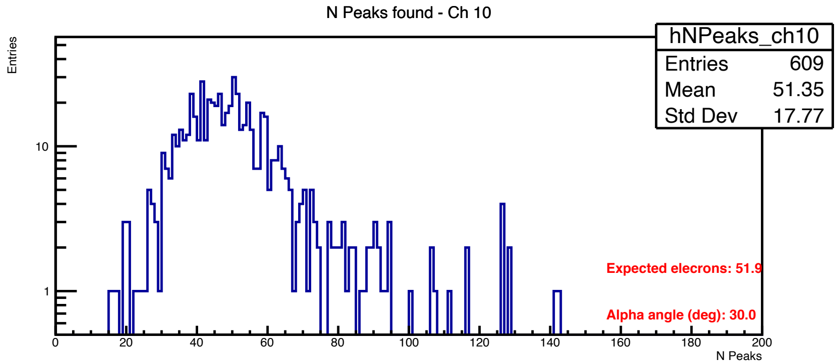
Electron peaks counting

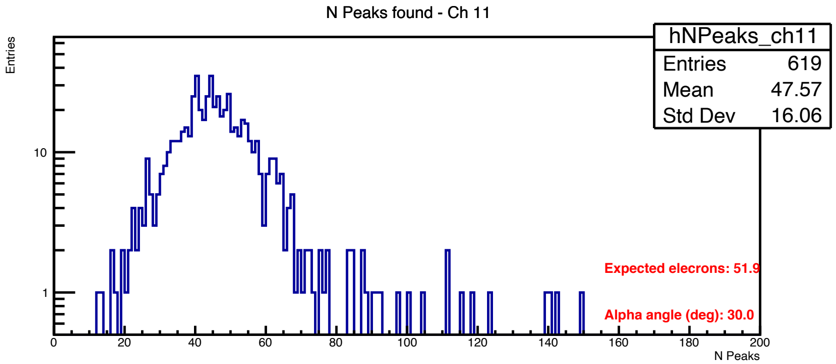
N electrons = 52.8

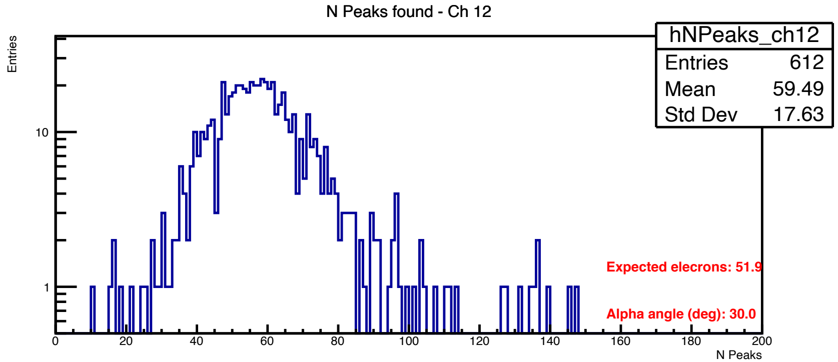
2 cm drift tubes

Expected = 51.9

Run: run_96.root; Track angle: 30^{0}; Gas mixture: 90%He10%iC4H10 ; HV = +20



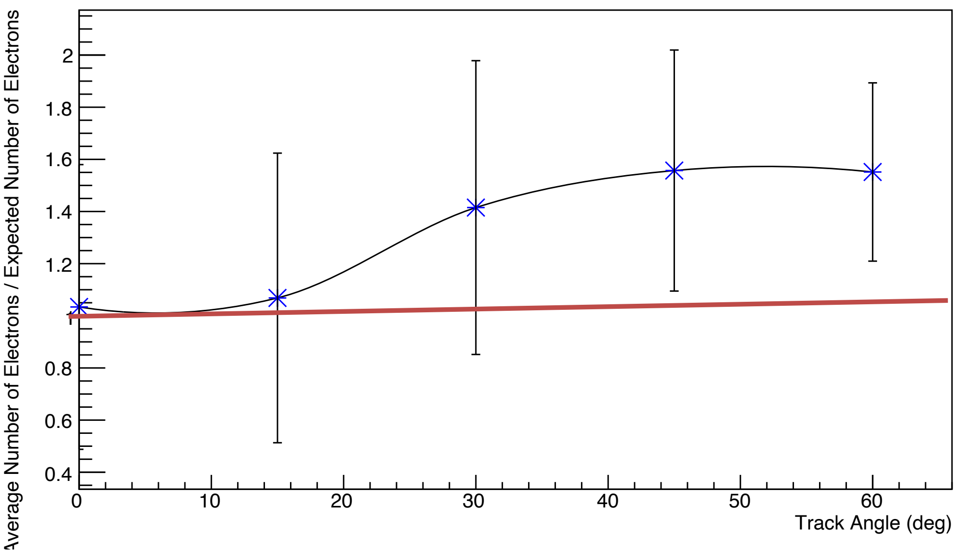




Electron peaks counting

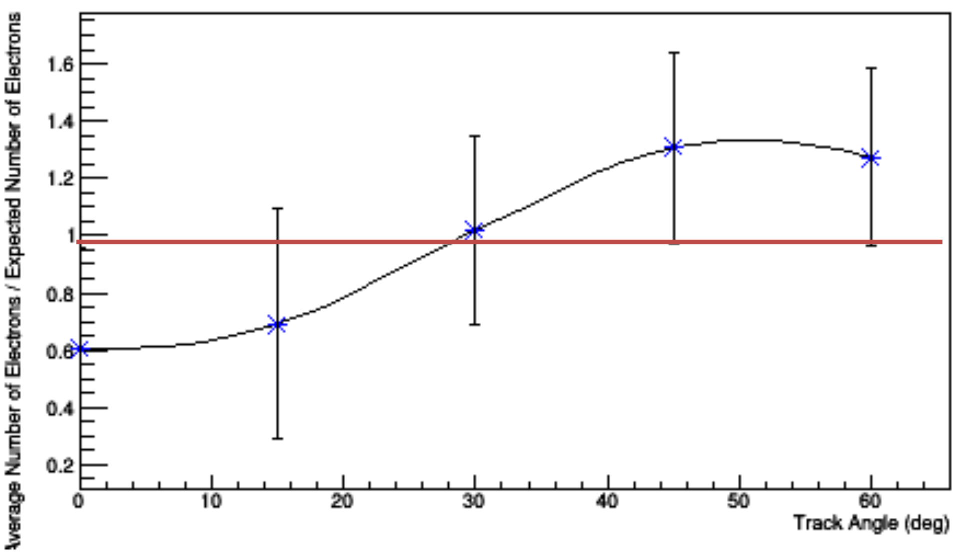
1 cm drift tubes

Electrons Finding Efficiency 1 cm cell size Drift Tubes



2 cm drift tubes

Electrons Finding Efficiency 2 cm cell size Drift Tubes



- Electrons overcounting due to fake electron peaks in adjacent bins.
- (easily corrected in the clusterization algorithm)
- Undercounting for 2 cm $\alpha < 30^0$ due to space charge effects.

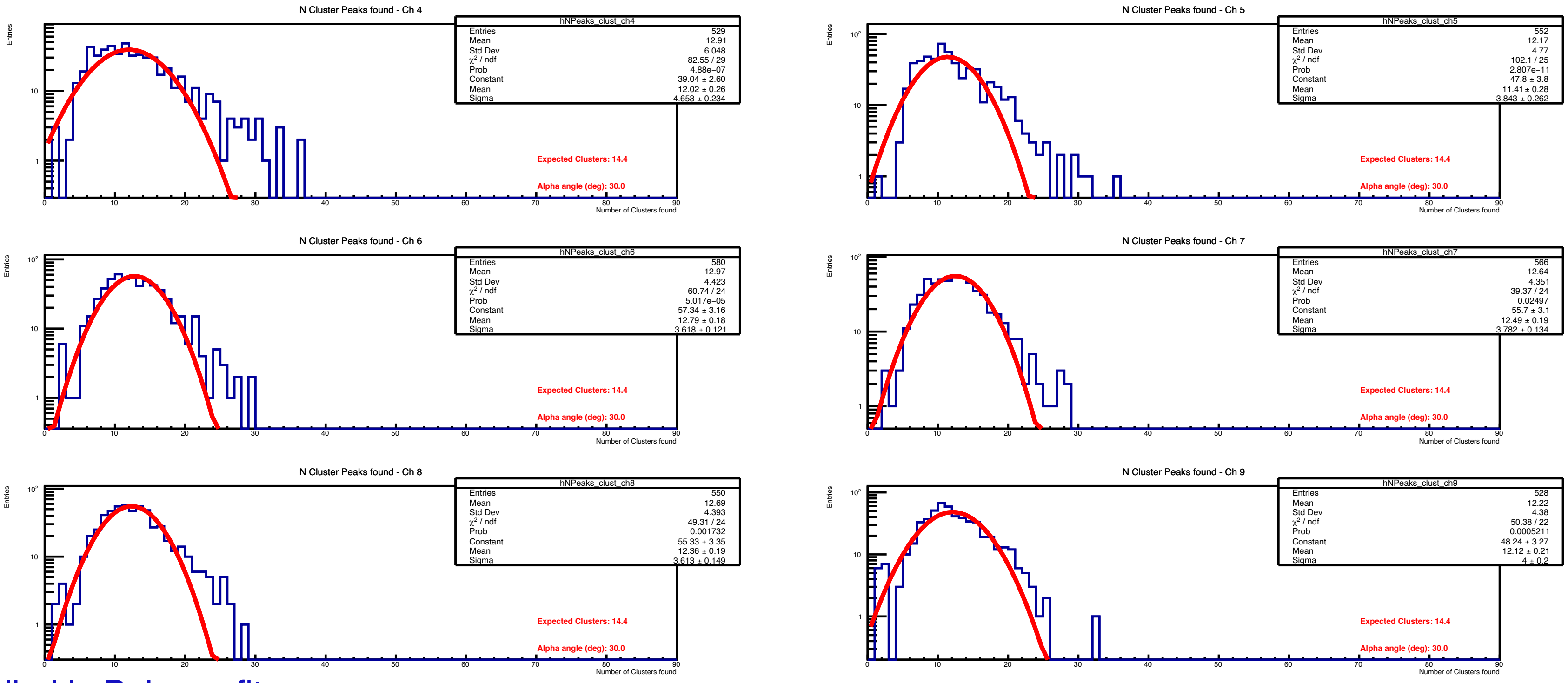
Electron Clustering

N Clusters = 12.6

1 cm drift tubes

Expected = 14.4

Run: run_96.root; Track angle:30^0; Gas mixture:90%He10%iC4H10 ; HV = +20



*The Fit applied is Poisson fit

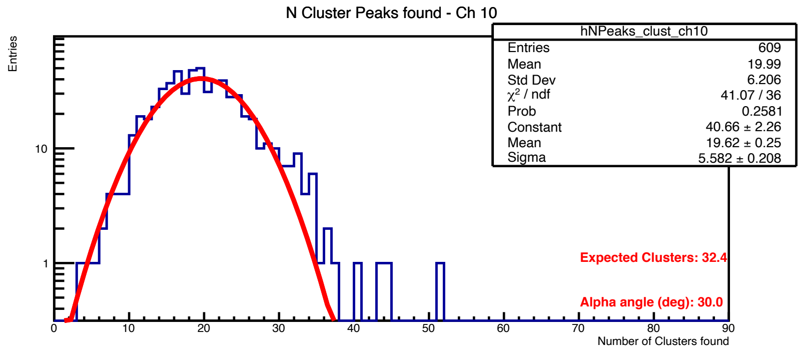
Electron Clustering

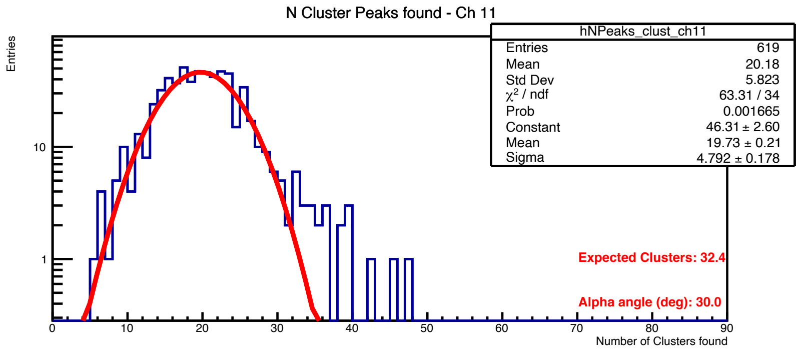
N Clusters = 21.5

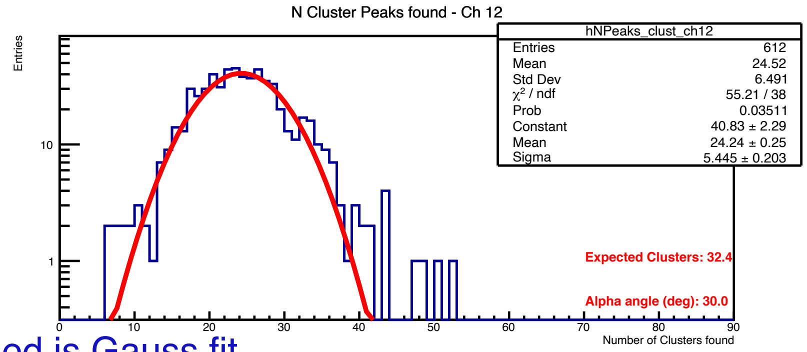
2 cm drift tubes

Expected = 32.4

Run: run_96.root; Track angle:30^0; Gas mixture:90%He10%iC4H10 ; HV = +20



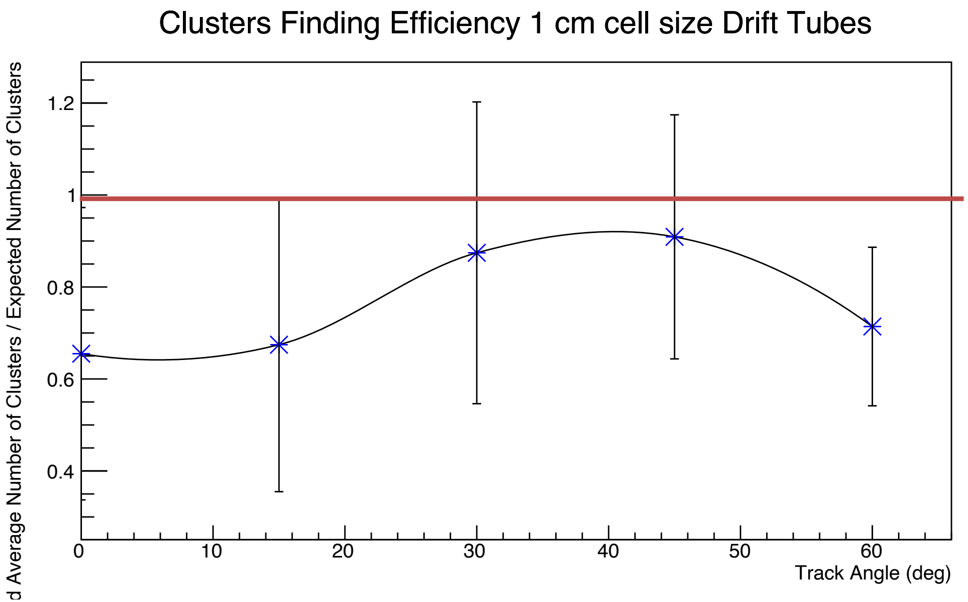




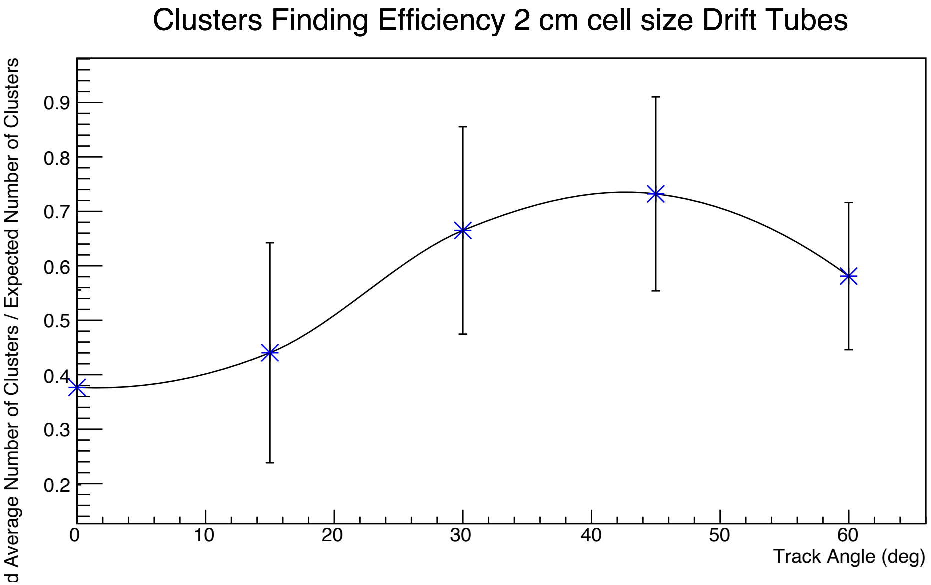
*The Fit applied is Gauss fit

Electron Clustering

1 cm drift tubes



2 cm drift tubes

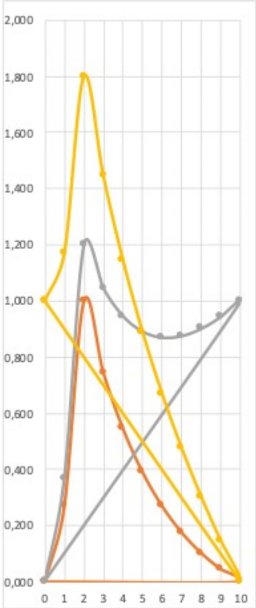


- Undercounting at $\alpha < 30^0$ due to space charge effects.
- Undercounting at $\alpha > 45^0$ due to high electron peaks density.
- 10 % average inefficiency for 1 cm drift tubes ($\alpha < 30^0$ & $\alpha > 45^0$)
- 30% average inefficiency for 2 cm drift tubes (electron inefficiency) ($\alpha < 30^0$ & $\alpha > 45^0$)

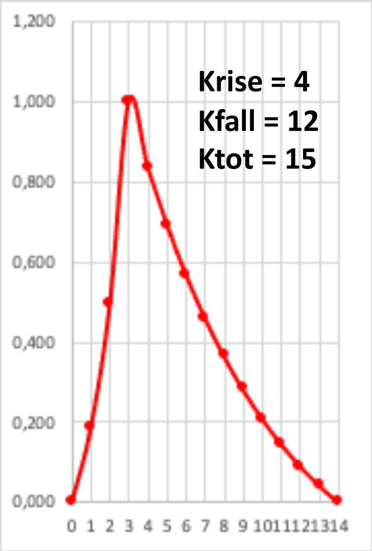
Testing different templates

Template 1

k	A(k)
0	0.0
1	0.269
2	1.0
3	0.744
4	0.545
5	0.390
6	0.269
7	0.175
8	0.102
9	0.044
10	0.0

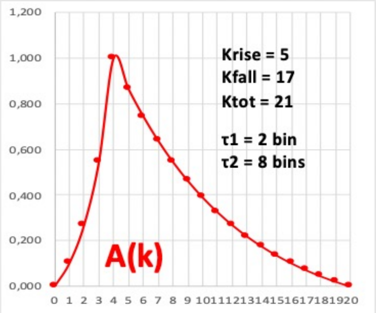


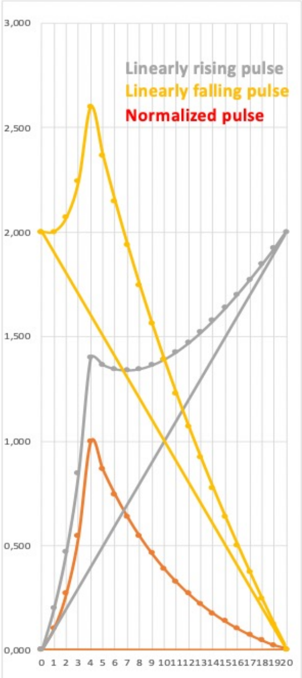
Template 2



Template 3

k	A(k)
0	0,000
1	0,102
2	0,269
3	0,545
4	1,000
5	0,864
6	0,744
7	0,638
8	0,545
9	0,463
10	0,390
11	0,326
12	0,269
13	0,219
14	0,175
15	0,136
16	0,102
17	0,071
18	0,044
19	0,021
20	0,000

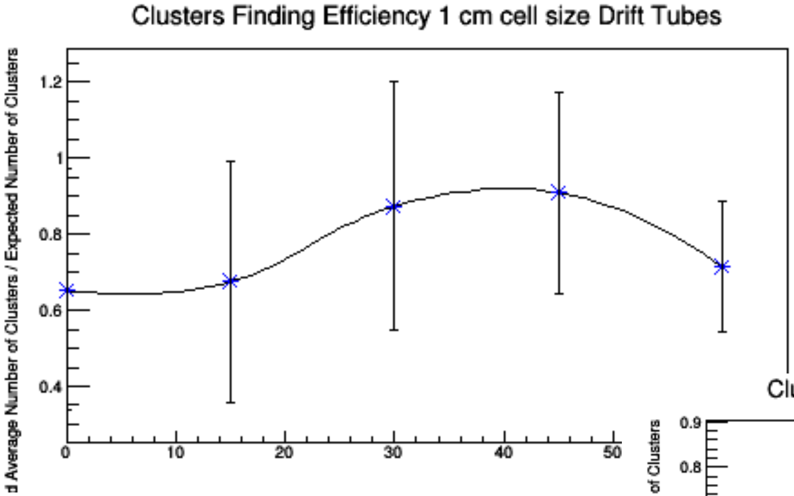




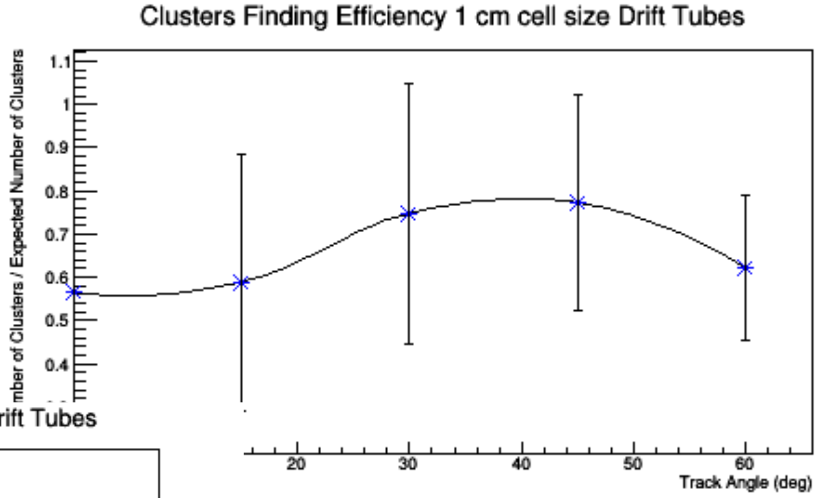
Comparison between the different templates

1 cm drift tubes

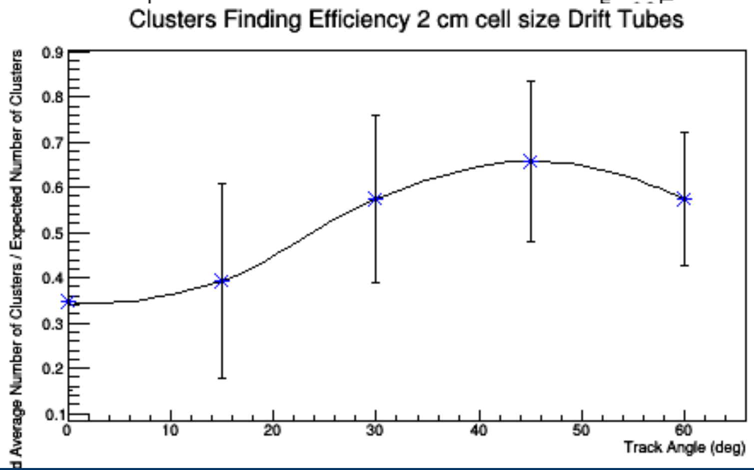
Template 1



Template 3



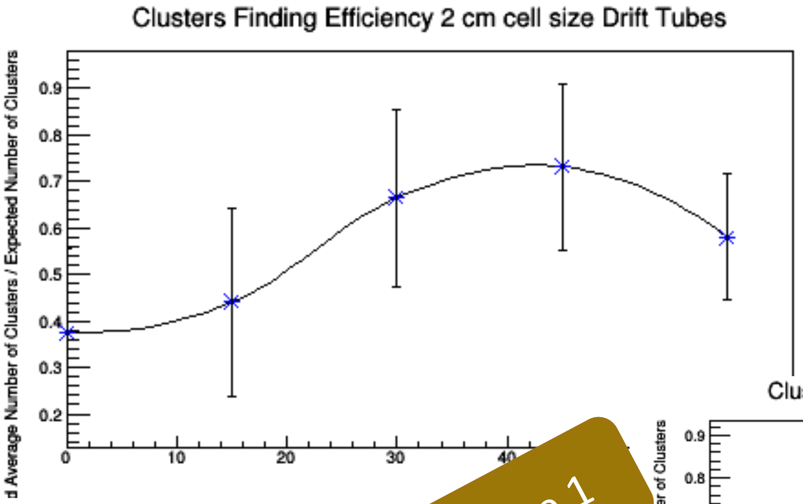
Template 2



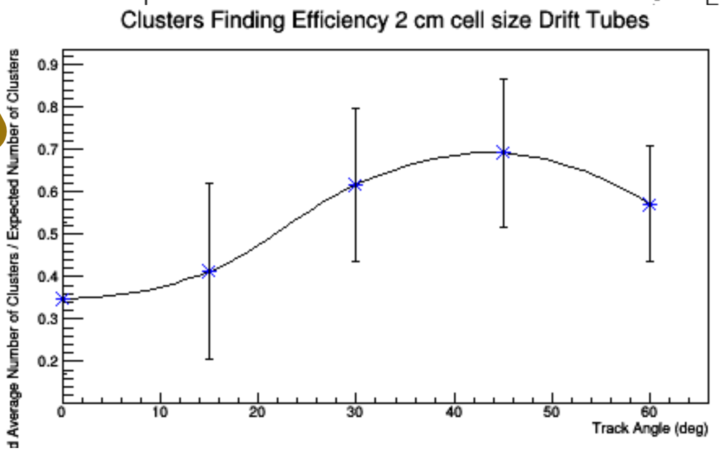
Comparison between the different templates

2 cm drift tubes

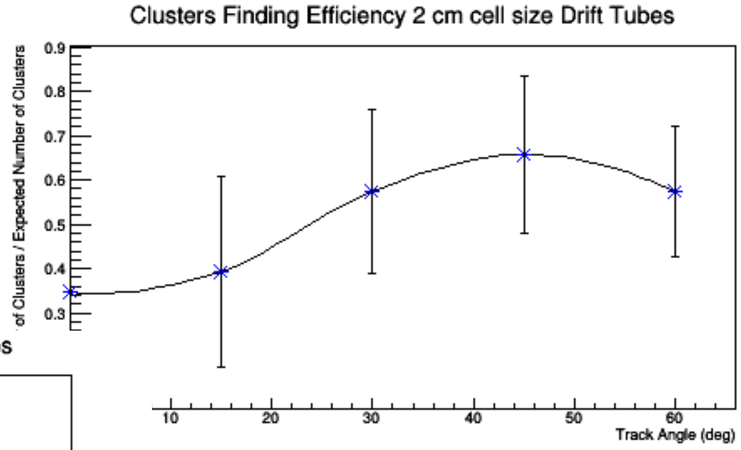
Template 1



Template 2



Template 3



Decided to keep with Template 1

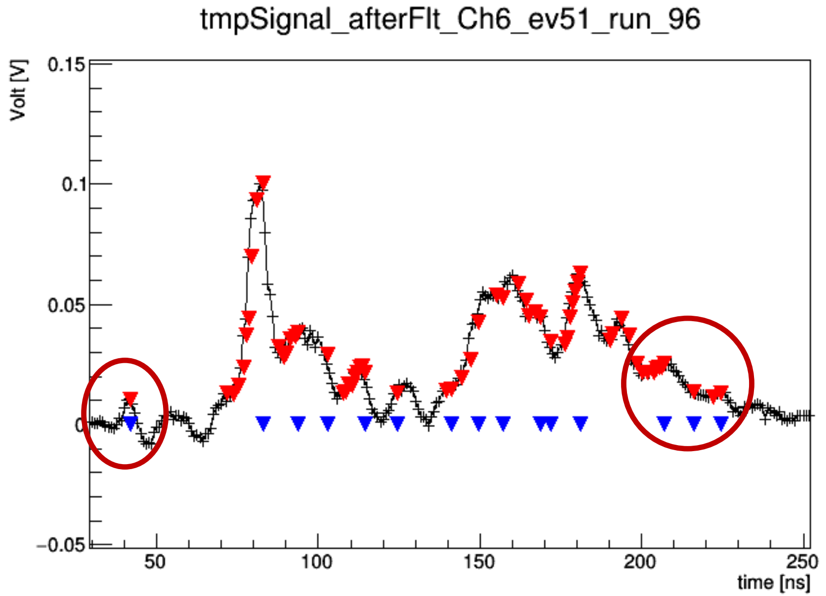
Comparison between DERIV & RTA Algorithms

1 cm drift tubes

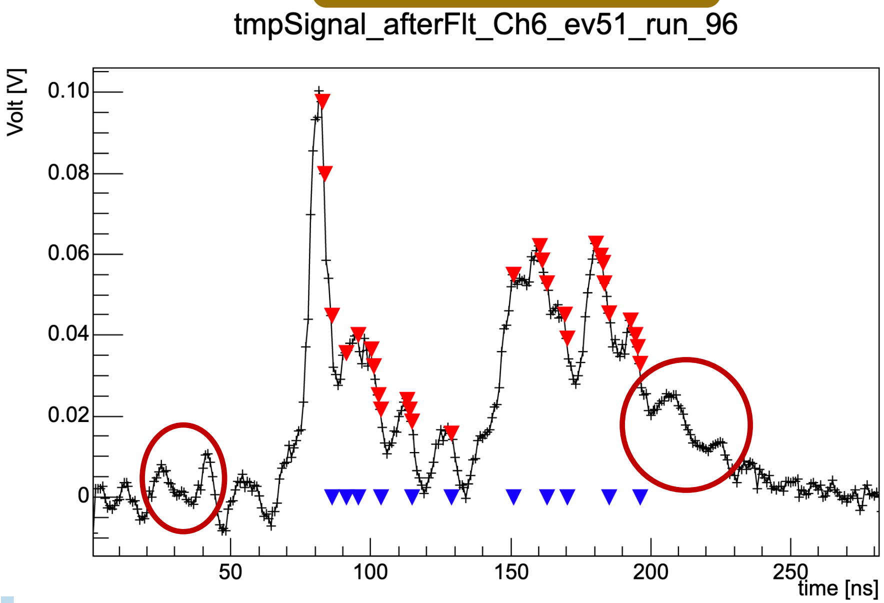
- Comparison between the derivatives (DERIV) and Running Template Algorithm (RTA): "Electron peaks counting & clustering"

Run: run_96.root; Track angle:30^0; Gas mixture:90%He10%iC4H10 ; HV = +20

RTA algorithm



DERIV algorithm



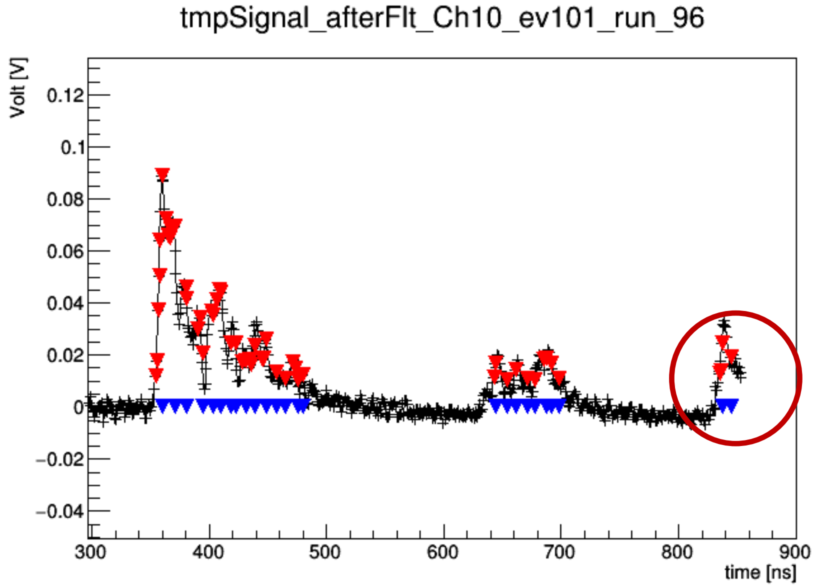
Comparison between DERIV & RTA Algorithms

2 cm drift tubes

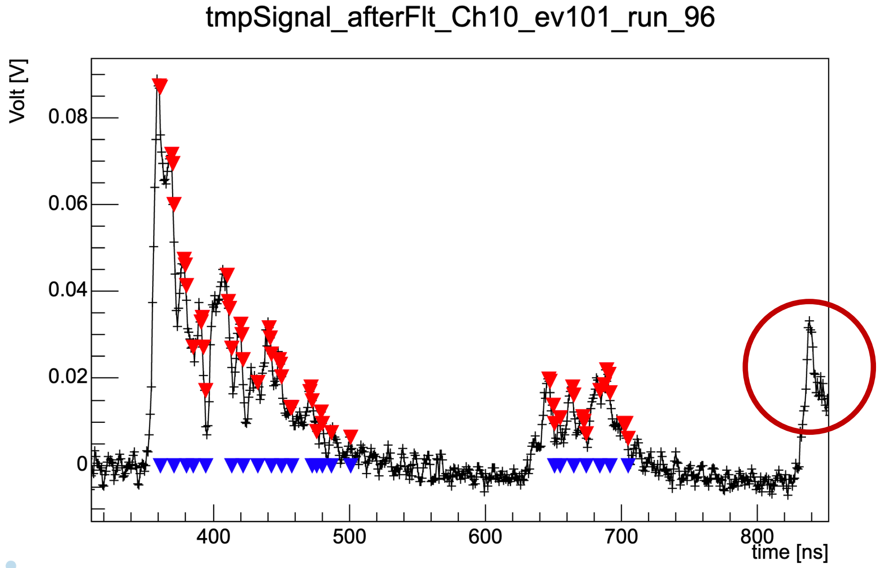
- Comparison between the derivatives (DERIV) and Running Template Algorithm (RTA): "Electron peaks counting & clustering"

Run: run_96.root; Track angle:30⁰; Gas mixture:90%He10%iC4H10 ; HV = +20

RTA algorithm



DERIV algorithm



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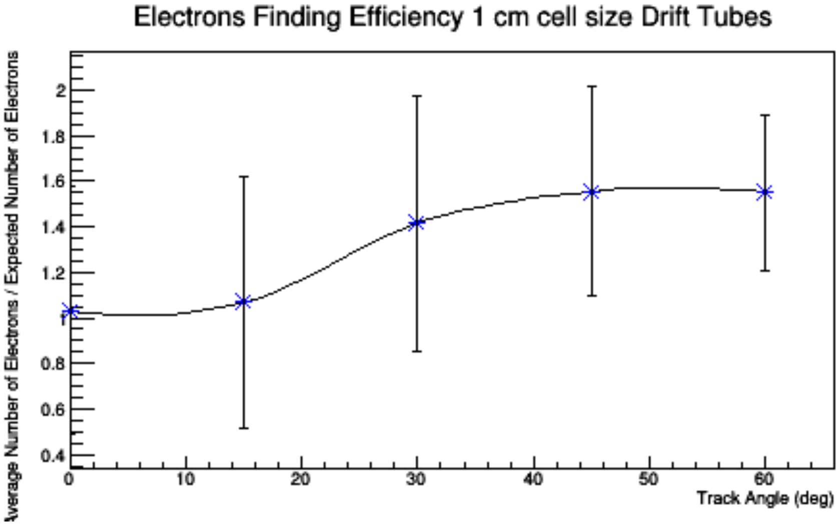
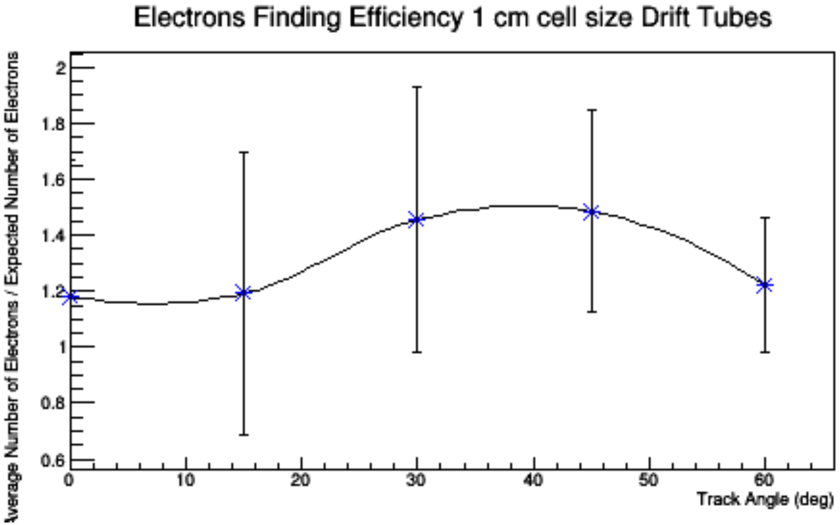


DERIV algorithm



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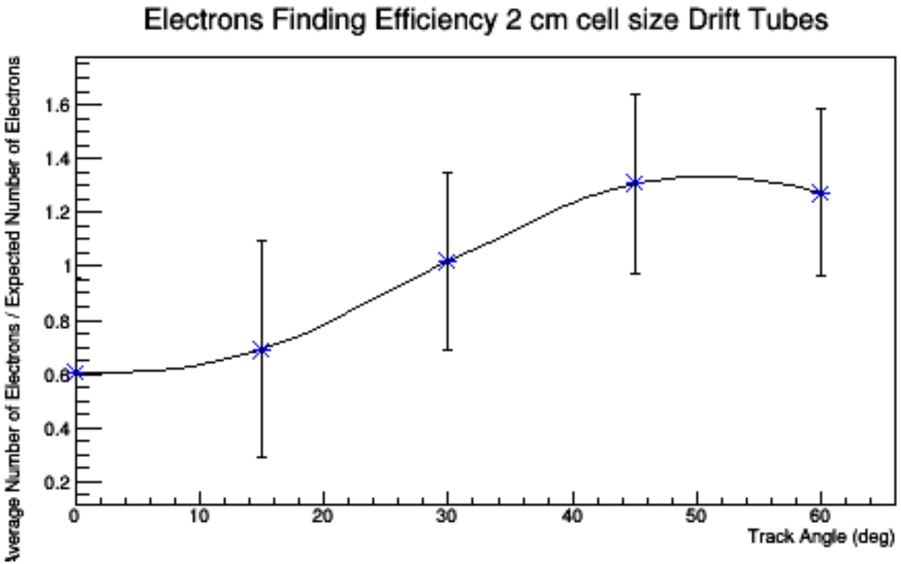
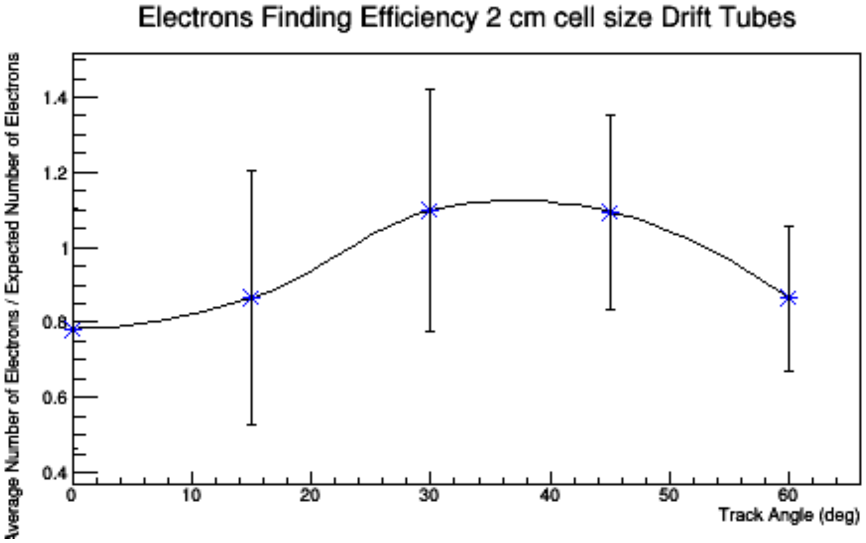


DERIV algorithm



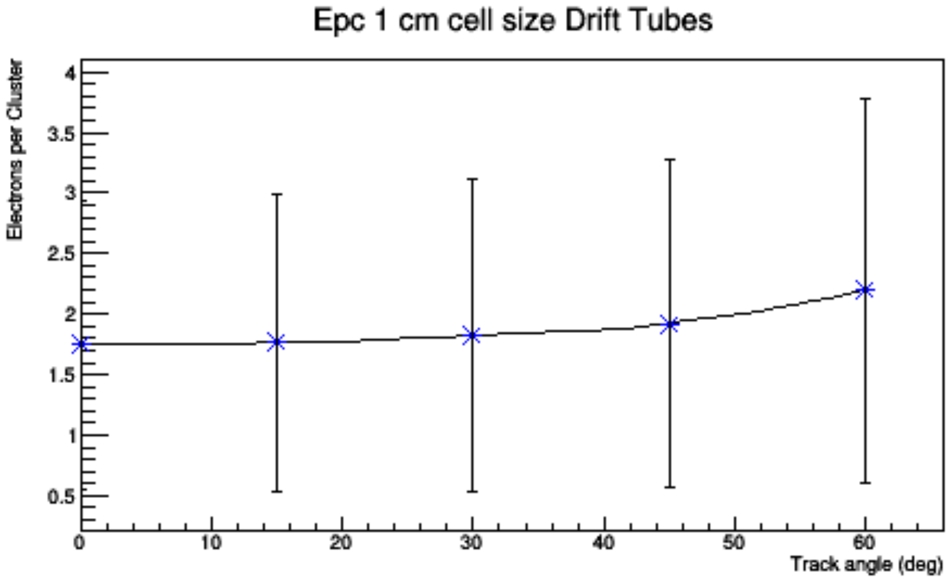
Comparison between DERIV & RTA Algorithms

1 cm drift tubes

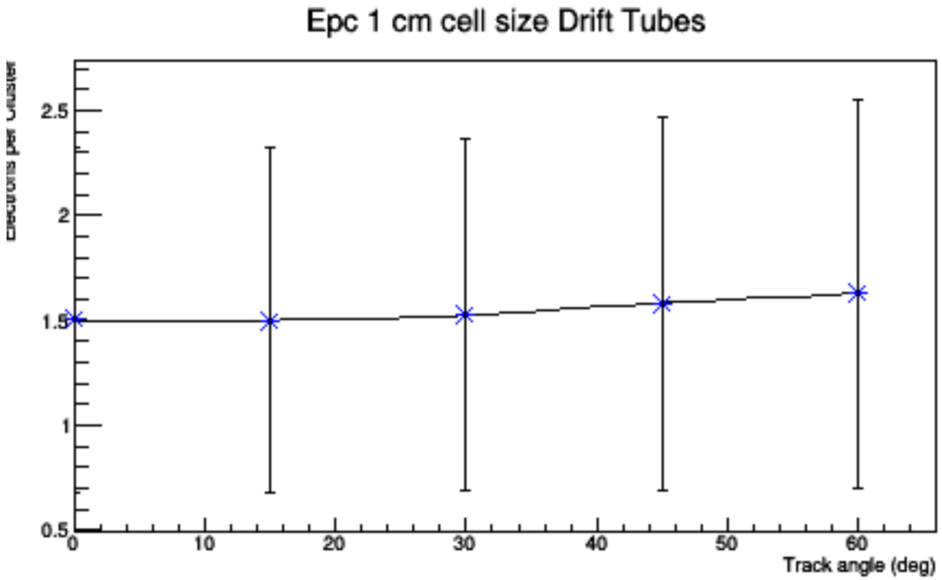
- Comparison between the derivatives (DERIV) and Running Template Algorithm (RTA):

" Electrons cluster density"

RTA algorithm



DERIV algorithm



Comparison between DERIV & RTA Algorithms

2 cm drift tubes

- Comparison between the derivatives (DERIV) and Running Template Algorithm (RTA):

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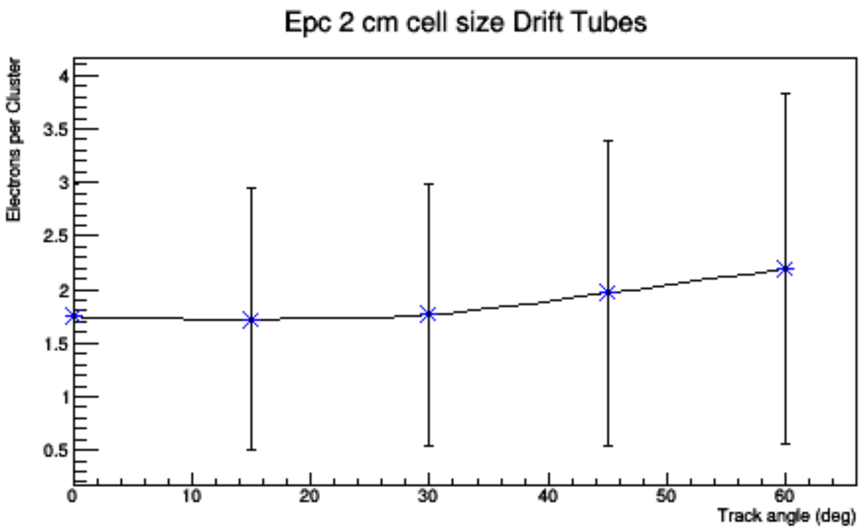
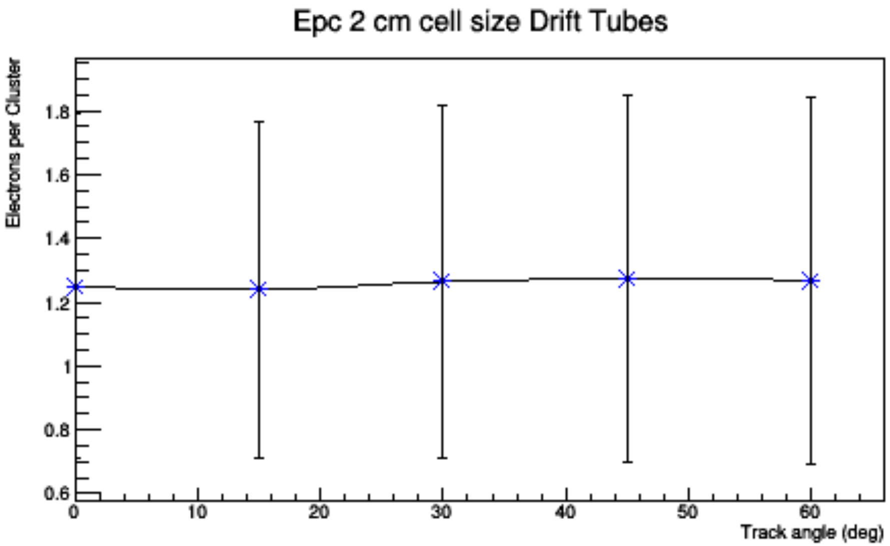
RTA algorithm



DERIV algorithm



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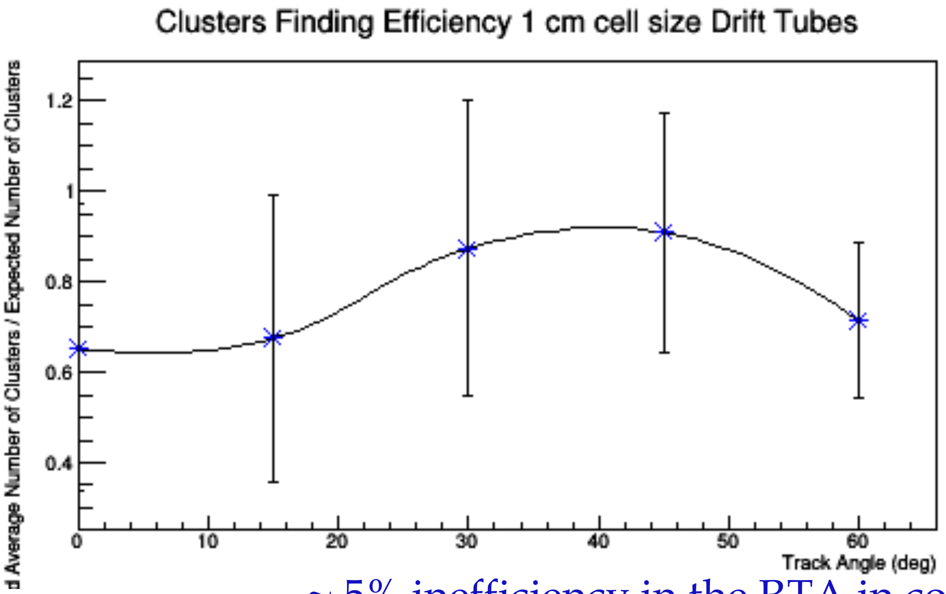
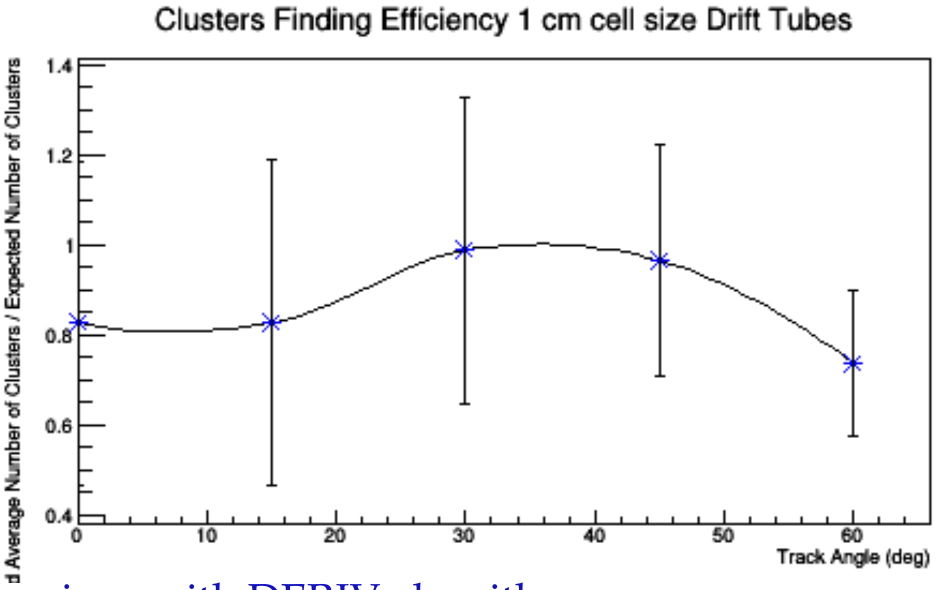


DERIV algorithm



~ 5% inefficiency in the RTA in comparison with DERIV algorithm

Comparison between DERIV & RTA Algorithms

2 cm drift tubes

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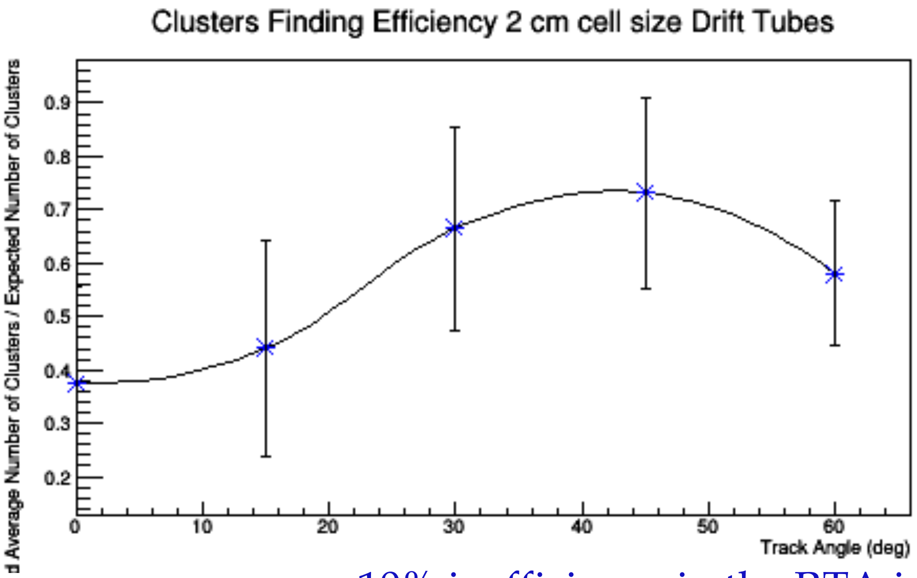
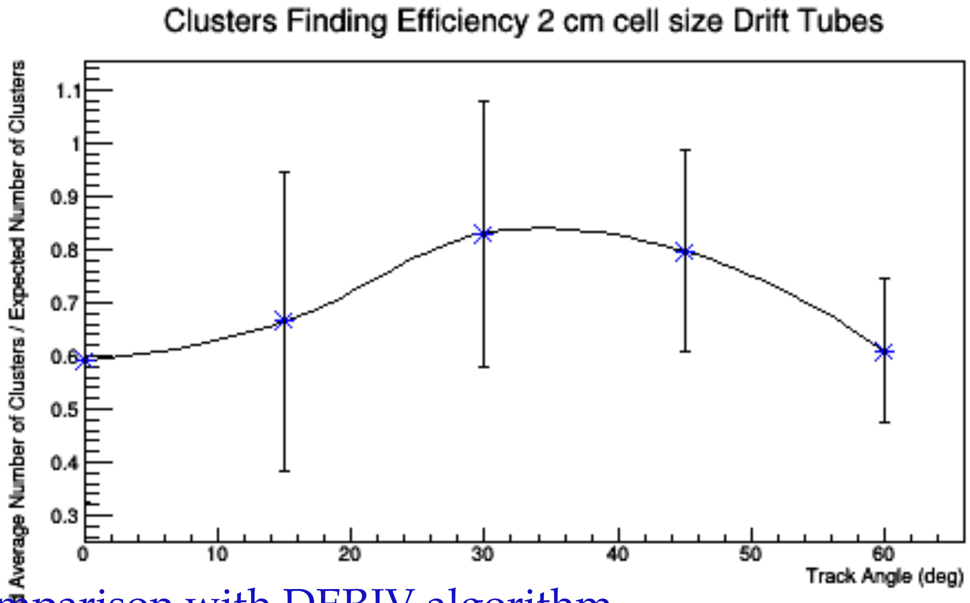
RTA algorithm



DERIV algorithm



~ 10% inefficiency in the RTA in comparison with DERIV algorithm

Conclusions

- Further optimization will be done to the Running Template Algorithm (RTA) in order to recover the inefficiency observed.
- The application of the two different algorithms will be very useful for understanding the pathologies of both algorithms, therefore, it will be extremely useful to have a third algorithm like the one being developed at IHEP with NN.