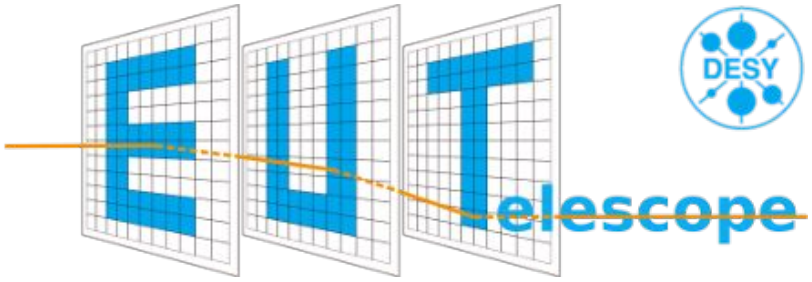
SLAC Testbeam Data Analysis:
High Occupancy Tracking & FE-I4 Cluster Study



Martin Klassen
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Summer Student Talks
Hamburg, 04.09.2014

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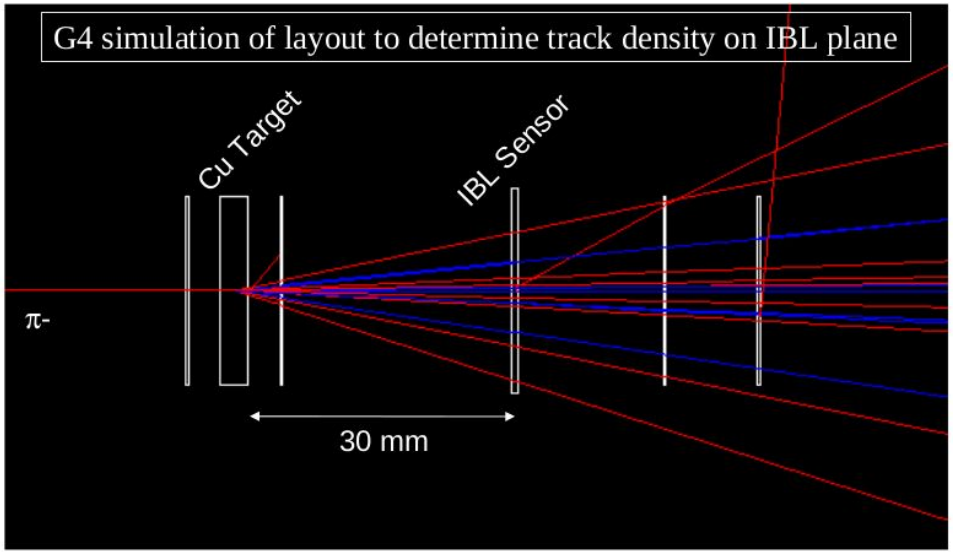
DESY

Outline

- Motivation
  - Why is my Project relevant?
- Short Introduction to EUTelescope
  - Hardware
  - EUTelescope framework
- *Trust, but verify!* - Lenin
  - is the dataset consistent / are there real tracks?
- Results
  - Properties of the Finder-radius
  - What are the resolutions we can resolve 2 different tracks in one cluster?
  - What is their Time over Threshold value (ToT)?

Atlas IBL upgrade – search for b-jets

- Reconstructing tracks of b-jets at high occupancy with IBL at 14 TeV will guide to new difficulties
- Increase in hadron boost and decrease in beam-radius leads to particles being closer together on the IBL layer → two tracks hit on same cluster or even pixel
- Try to separate this two tracks over ToT value

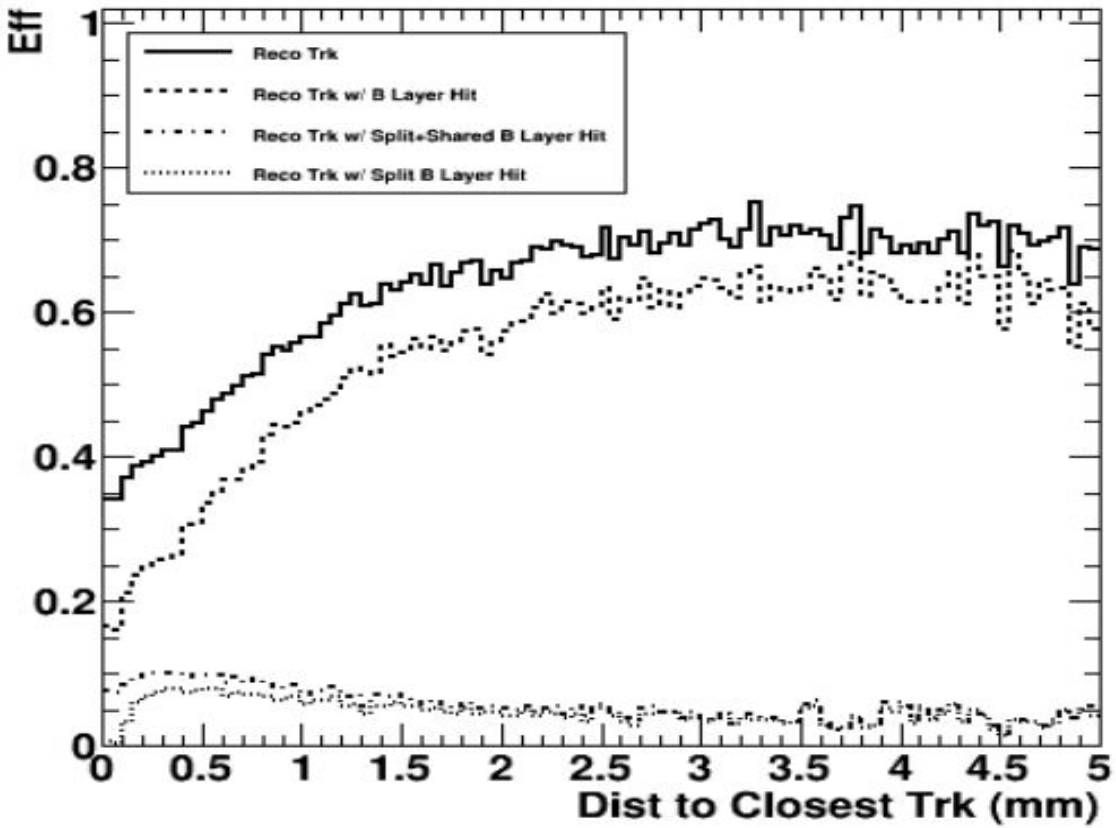


M Battaglia
UCSC and CERN

Atlas IBL upgrade – search for b-jets

ATLAS track reconstruction efficiency

Distance from closest track

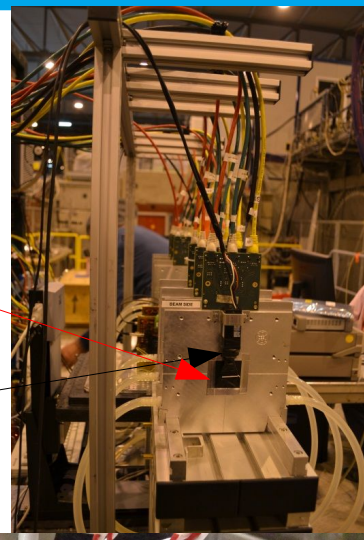


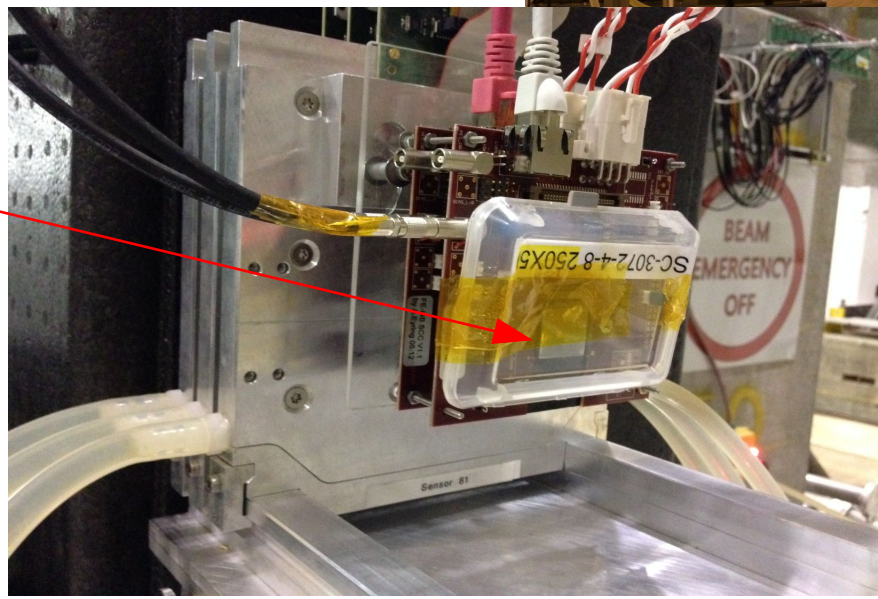
Separation of 2-tracks in long-flying B decays requires detailed studies of IBL clusters for closely spaced (d < 2.5 mm) tracks

DESY

EUTelescope Properties

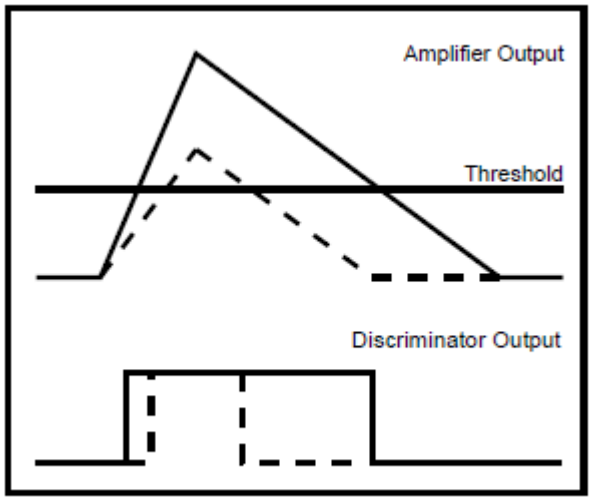
- 6 high precision Mimosa26 planes
  - Pixel pitch 18,4 μm^2
  - 14 µm thickness
  - 1152 x 576 pixels
  - Fast readout → 10^6 particles/cm^2/s
- H5783 PMT with 10 x 20 mm^2 scintillator
- ATLAS-FE-I4
  - Pixel size 50 x 250 μm^2
  - Pixel array 80 x336
  - 50kHz/pixel firing rate → 400 x 10^6 particles/cm^2/s
  - ToT (Due to IBL occupancy 4 bit resolution→ Large range of charges corresponds to one ToT value)





Time over Threshold (ToT)

- ToT Tool for calibration
- Signal shaped by charge amplifier
- Time-over-threshold is proportional to induced charge
- Relation ToT and charge is not linear



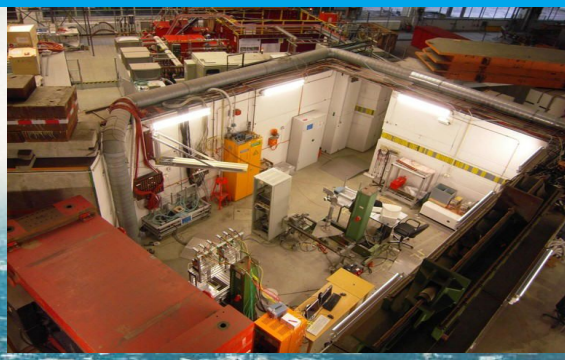
Rieger_PG070714.pdf

ToT Translation

$\mathrm{ToT}_{\mathrm{Code}}$	0-12	13	14	15
ToT [25 ns]	$\mathrm{ToT}_{\mathrm{Code}}+1$	>13	delayed hit	no hit

Why do we use the Data from SLAC? → not DESY?

- Good: e^- Testbeam, Energy up to 6 GeV
- But: To less Tracks per Event recorded to perform reasonable tracking study for separating 2 tracks
  - Event multiplicity only up to 6-7 events



DESY Testbeam area 21

http://www.physics.ohio-state.edu/~ling/group/desy.jpg
http://www-flc.desy.de/polarimetry/sldpol/sldpol.php
http://aida.web.cern.ch/aida/activities/access/DESY/

Why do we use the Data from SLAC? → not LHC/SPS/PS?

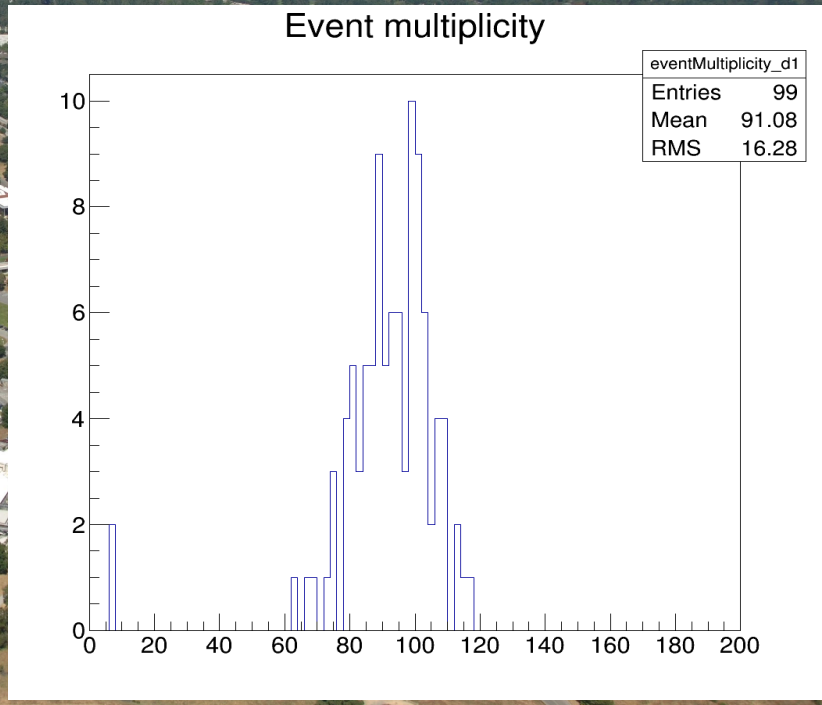
- High luminosity → event multiplicity of 200-800 tracks
- Energies up to 25 Gev in PS
- But: proton machine → produce many secondary particles
- Soon tests at SPS for high occupancy

http://aida.web.cern.ch/aida/index.html

The CERN PS East Area

Why do we use the Data from  ?

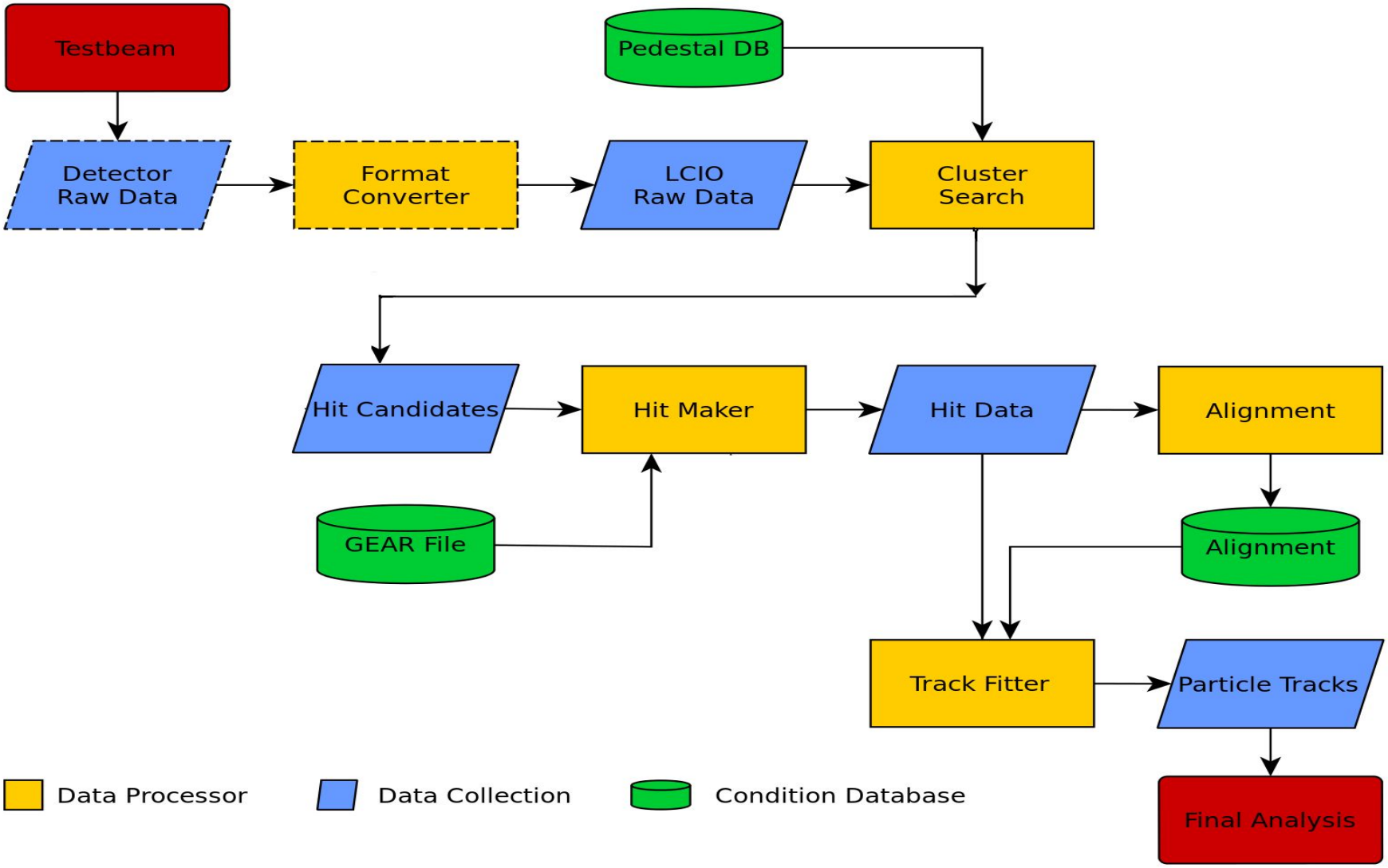
- Good: e^- accelerator, energies up to 16 Gev
- High luminosity → many particles with basically known properties
- Event multiplicity around 90-100



http://4.bp.blogspot.com/-qbtlltGOPMc/T5ZZnwuQmOI/AAAAAAAANPM/ty0mSUwgGAA/s1600/SLAC-graffiti.JPG
https://sciencesprings.files.wordpress.com/2014/07/slac-campus.jpg
https://events.stanford.edu/events/21/2162/280%20at%20night.jpg

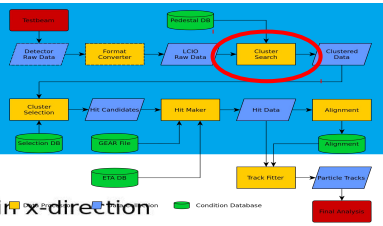
DESY

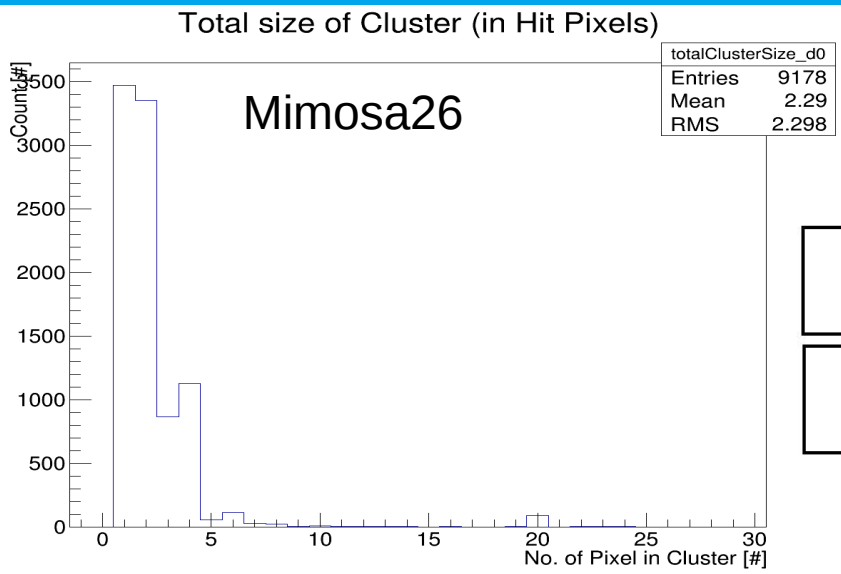
How to do the Data Analysis? - Journey from raw Dataset to some final Results



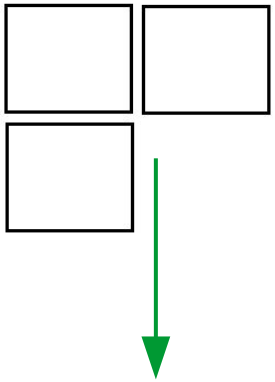
http://eutelescope.web.cern.ch/content/about-eutelescope

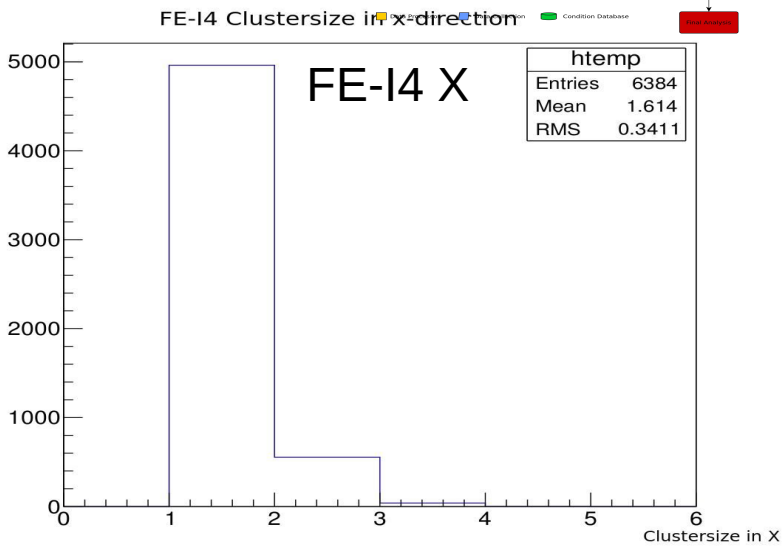
Clustering

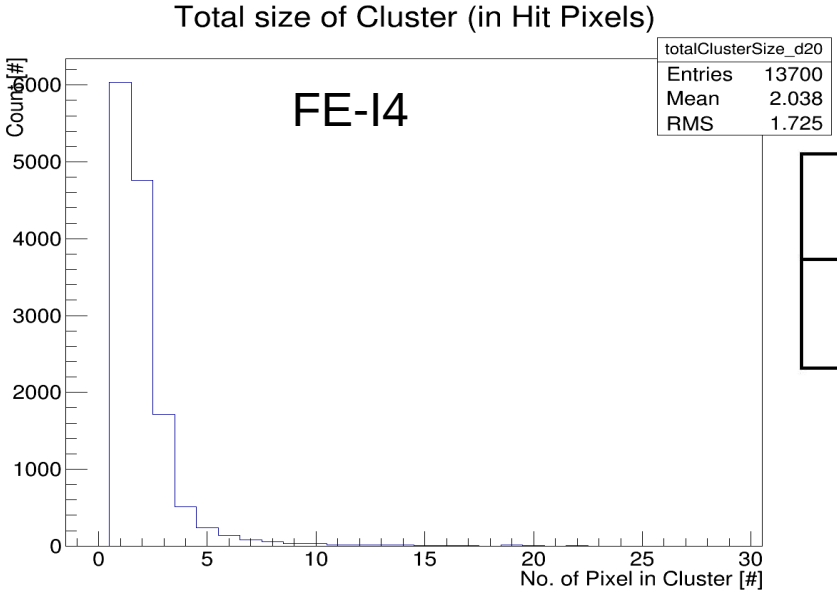




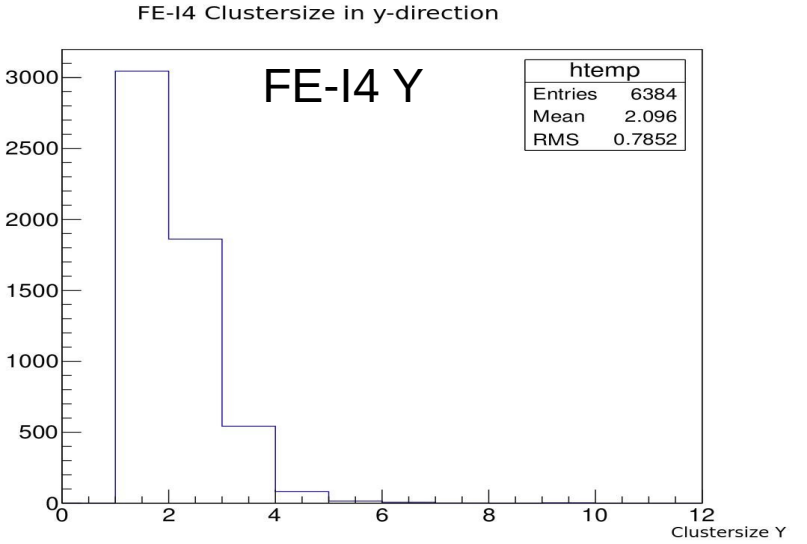
Reminder:
Fired Pixels



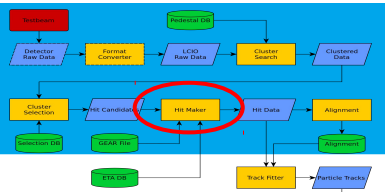




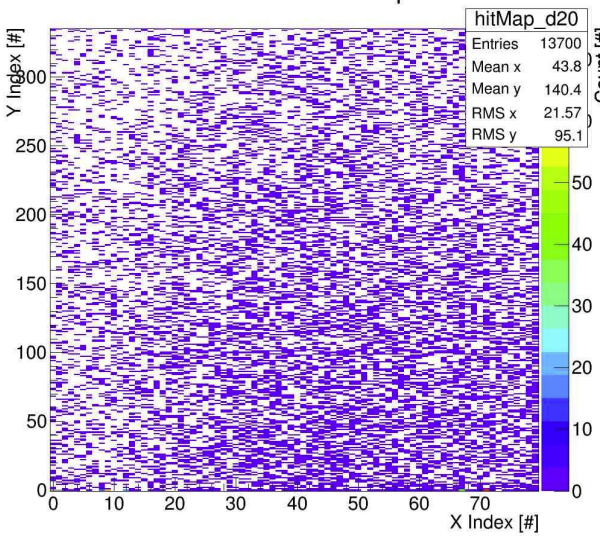
Cluster



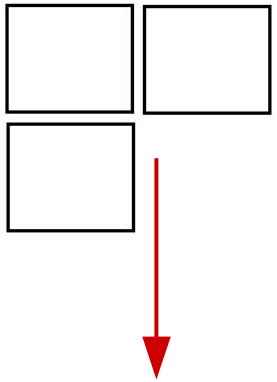
Hitmaker – lets search for correlations!



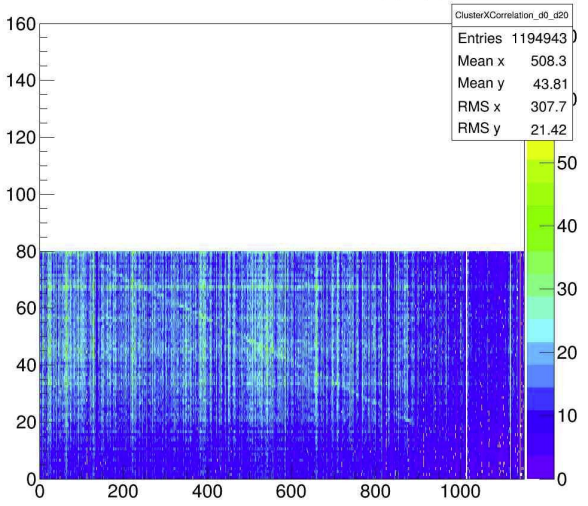
Pixel Index Hit Map



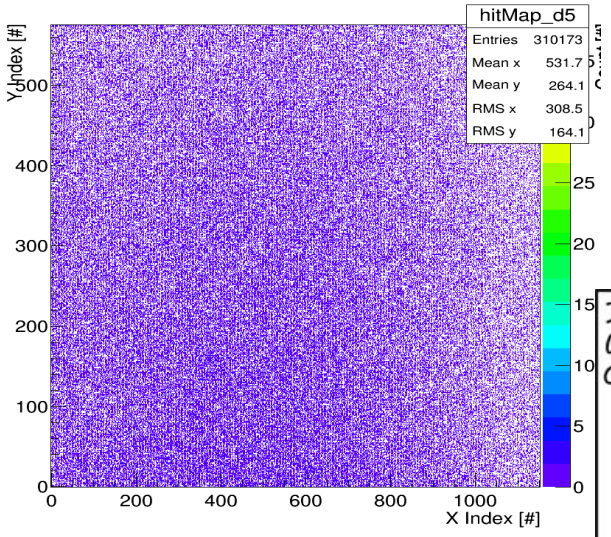
Reminder:
Fired Pixels



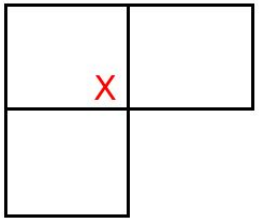
ClusterX/ClusterXCorrelation_d0_d20



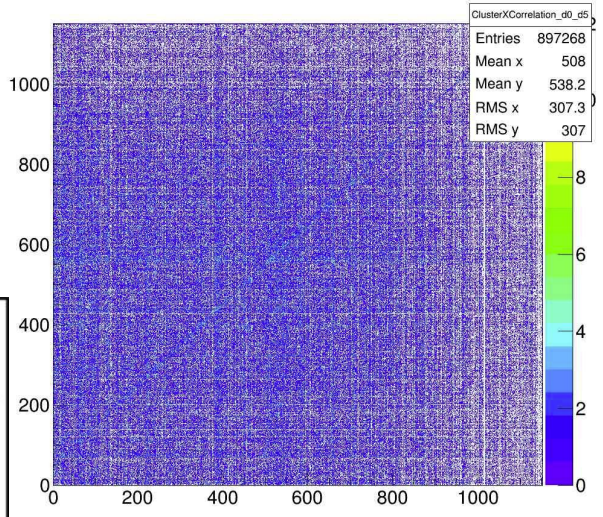
Pixel Index Hit Map

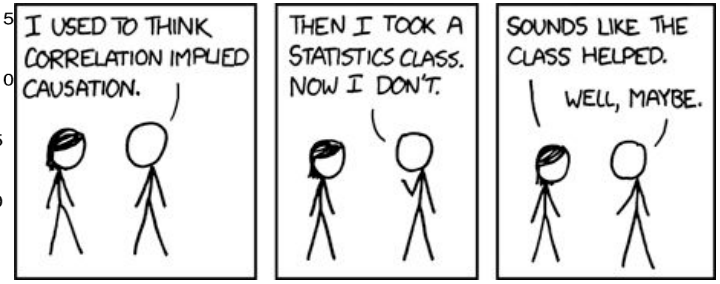


Calculated Hitpoint

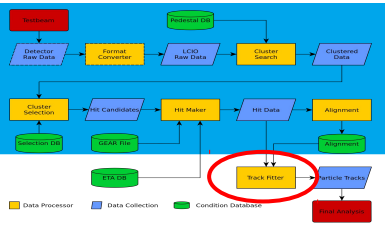


ClusterX/ClusterXCorrelation_d0_d5

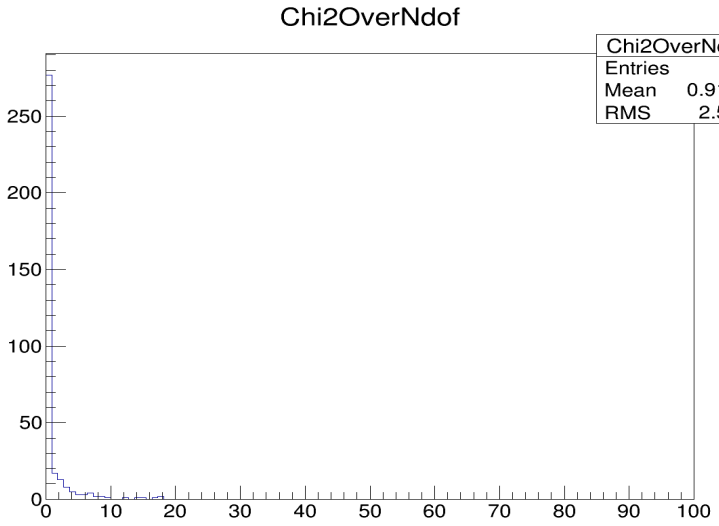


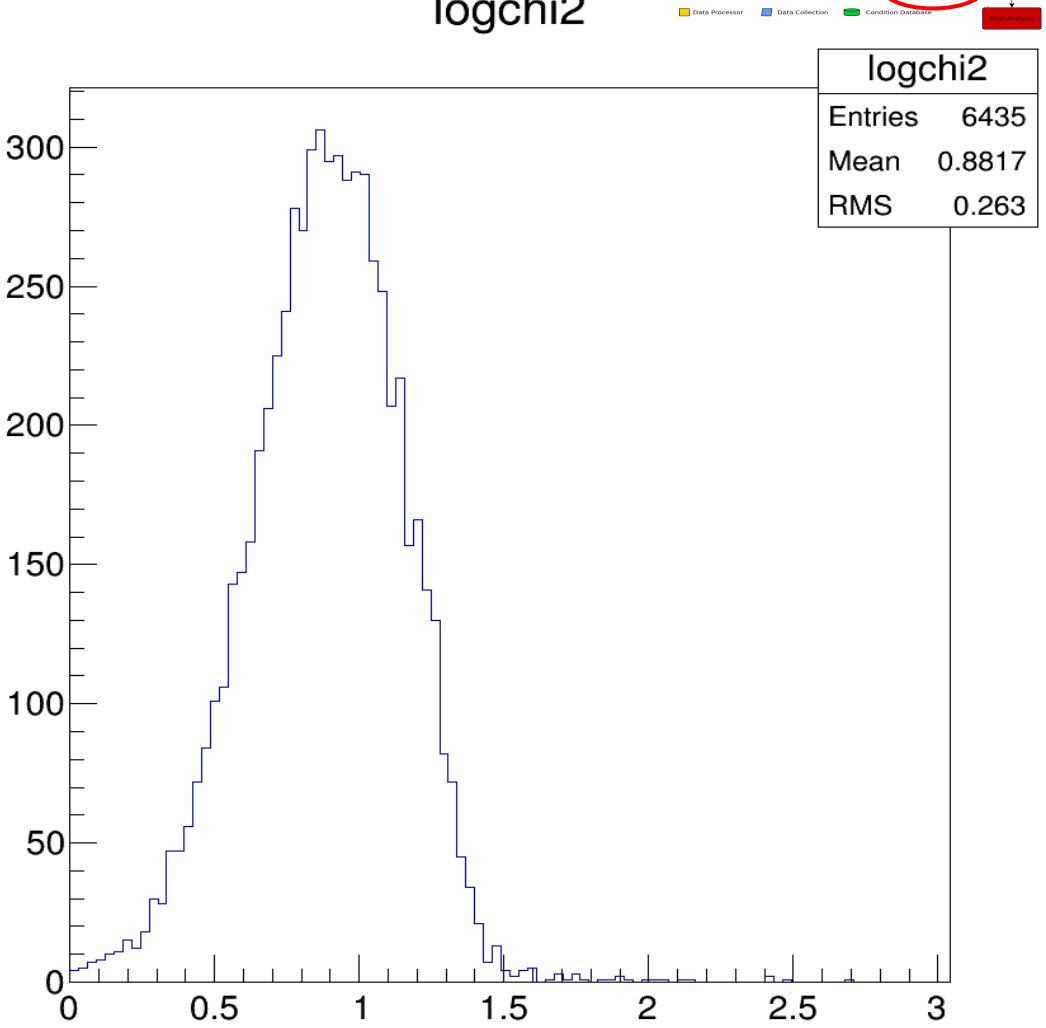


Alignment – lets look at residuals!



- Why is the Chi² so low?:
  - Beam energy was higher then 12 TeV
  - Resolution of Mimosa could be better then 4 µm





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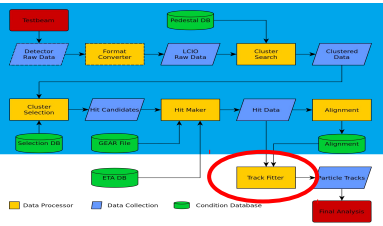
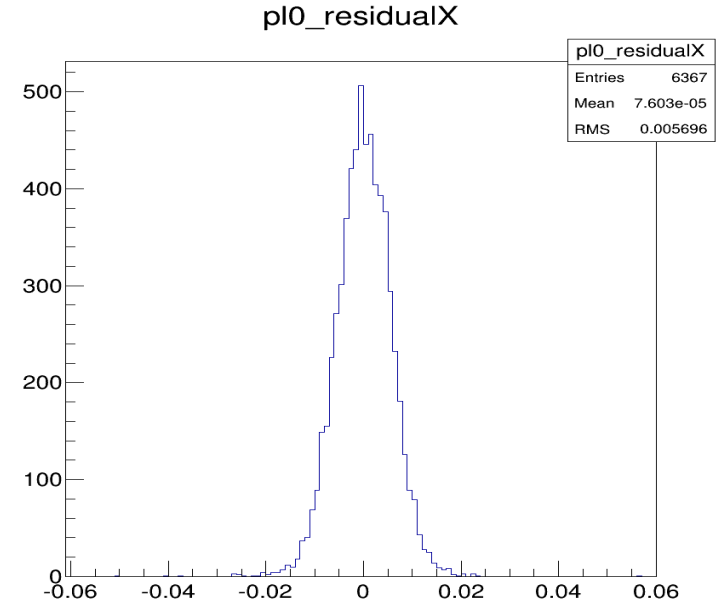
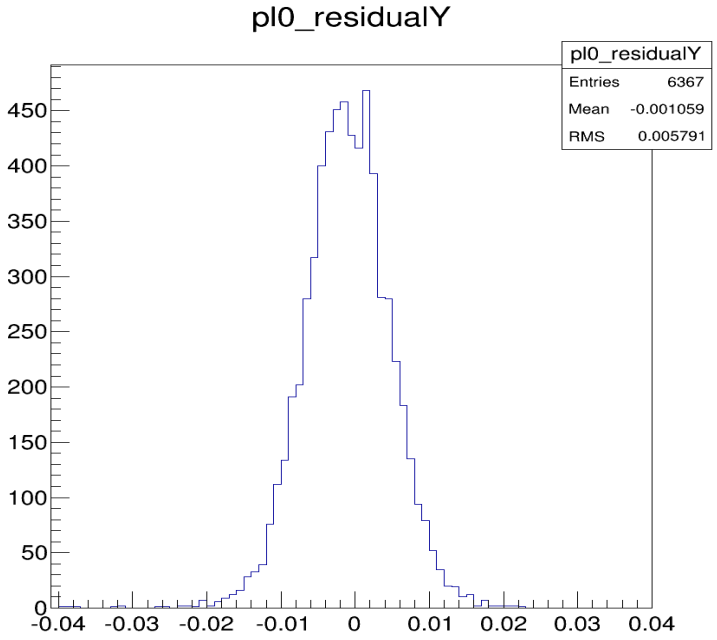
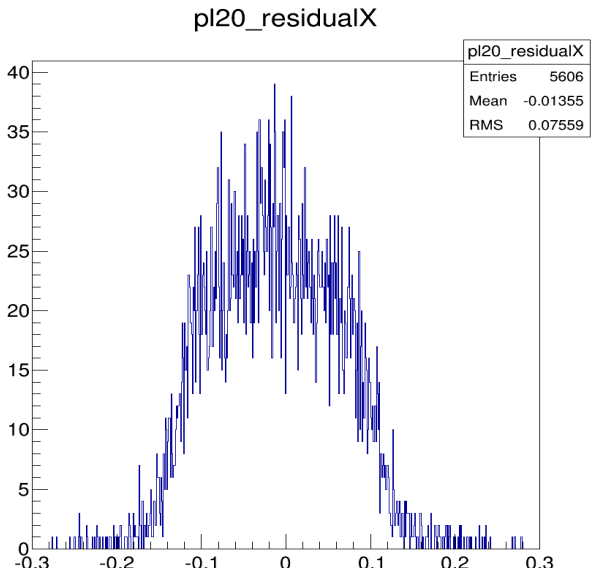
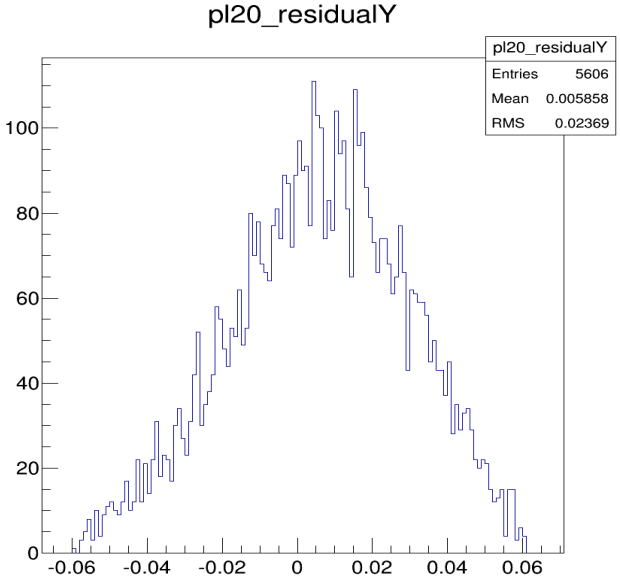


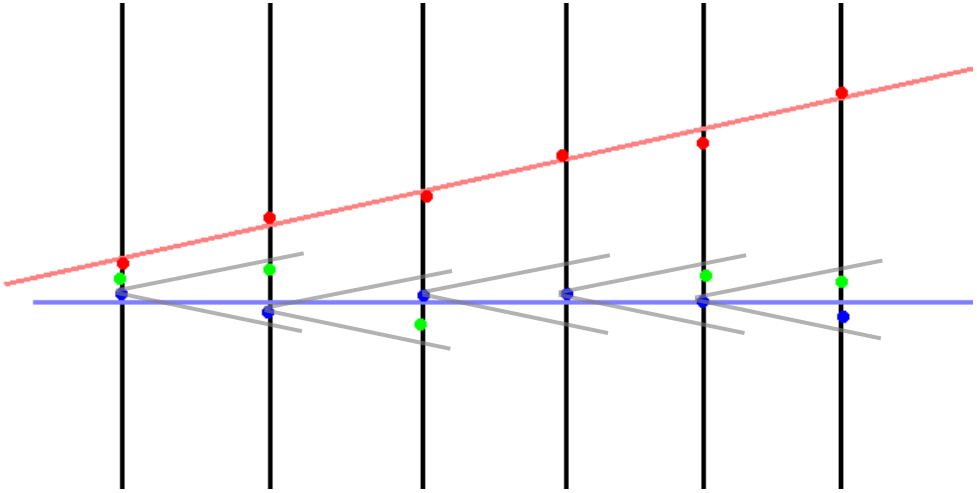




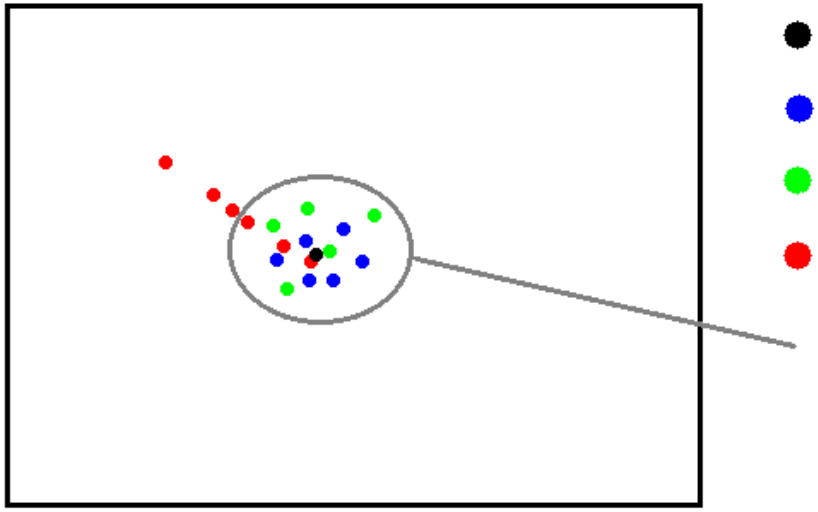




Finder-Radius for fitting tracks



EUTelescope sketch with hits on 6 Planes



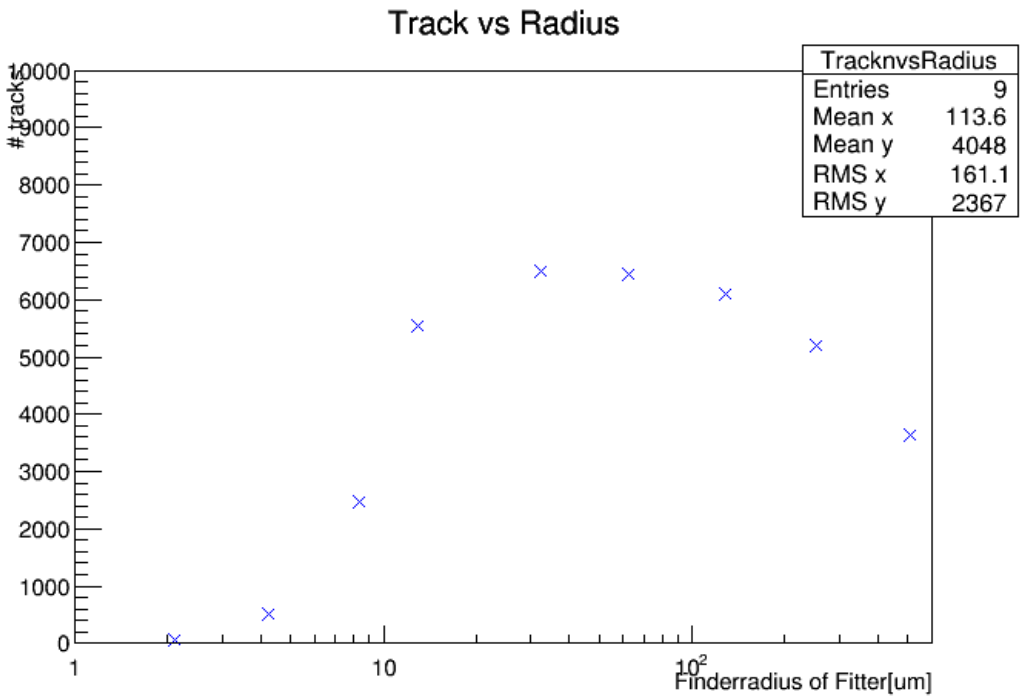
Projection to Mimosa plane 0

- Starting point of a potential track hit
- Hits belonging to reconstructed track
- Hits which belong to secondary interaction
- Hits from track not reconstructed

Finder-radius

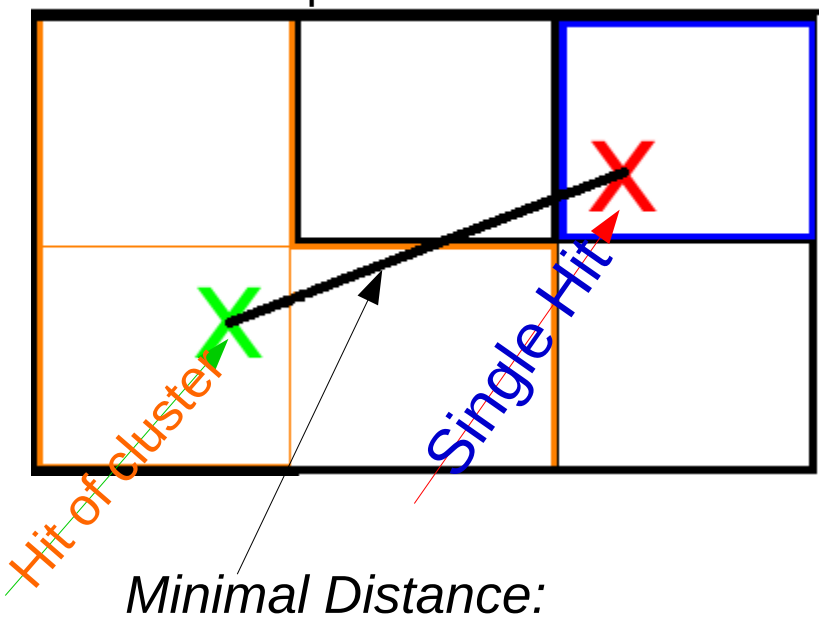
Tracks reconstructed in comparison to Finderradius

- At small Finderradius ~5µm small number of Tracks reconstructed → 10.000 expected, get less then 2.000
- for 640µm around 3.000
- Maximum at Finderradius of 70µm:
  - Found hit clusters 7645
  - Tracks 6961
  - fitted tracks 6435
  - Around 90% reconstructed:
    - Miss aligned planes
    - Missing Hits at planes



Minimal distance between 2 tracks

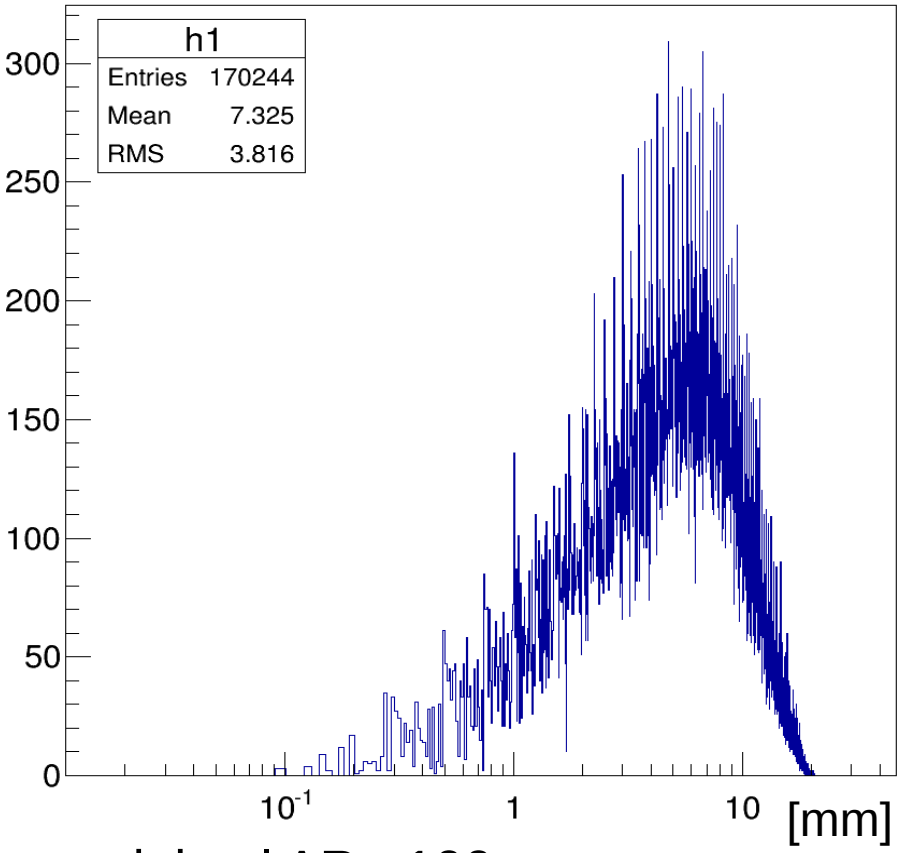
Mimosa26 plane



Minimal Distance:

$$\Delta R = \sqrt{\Delta x^2 + \Delta y^2}$$

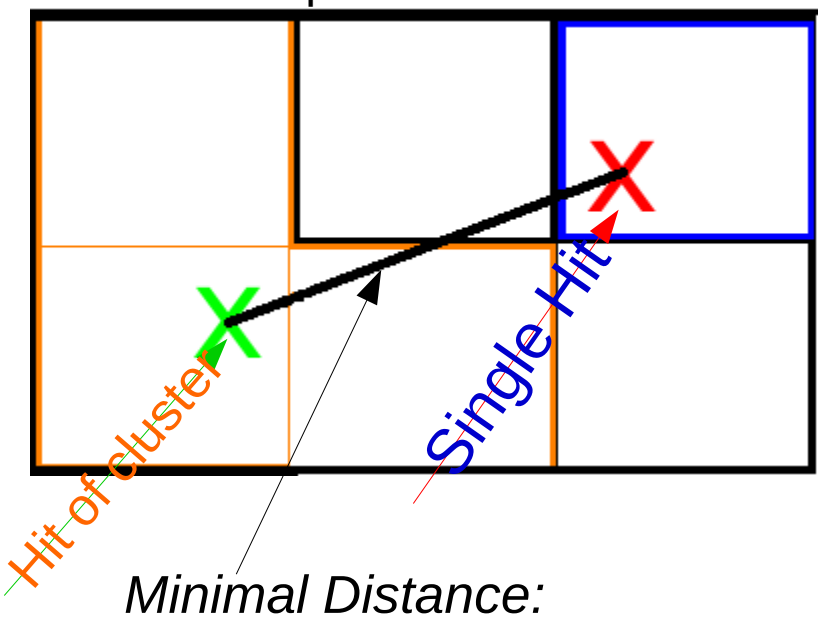
> Plot of ΔR in plane 20



> minimal ΔR ~100µm

Minimal distance between 2 tracks

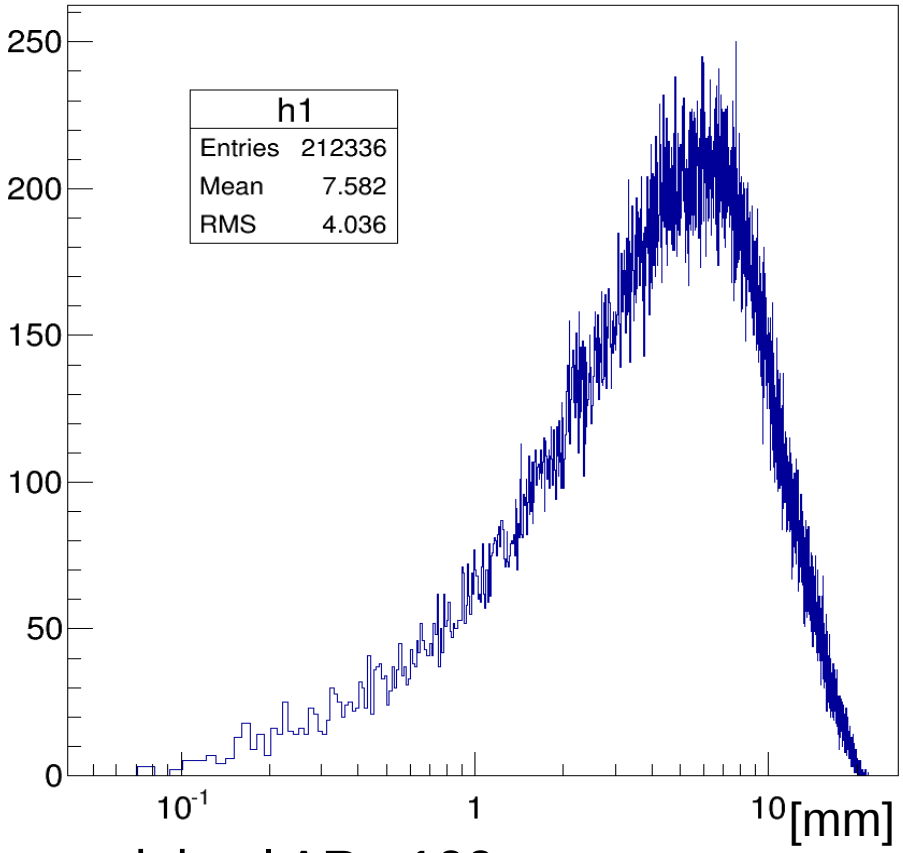
Mimosa26 plane



Minimal Distance:

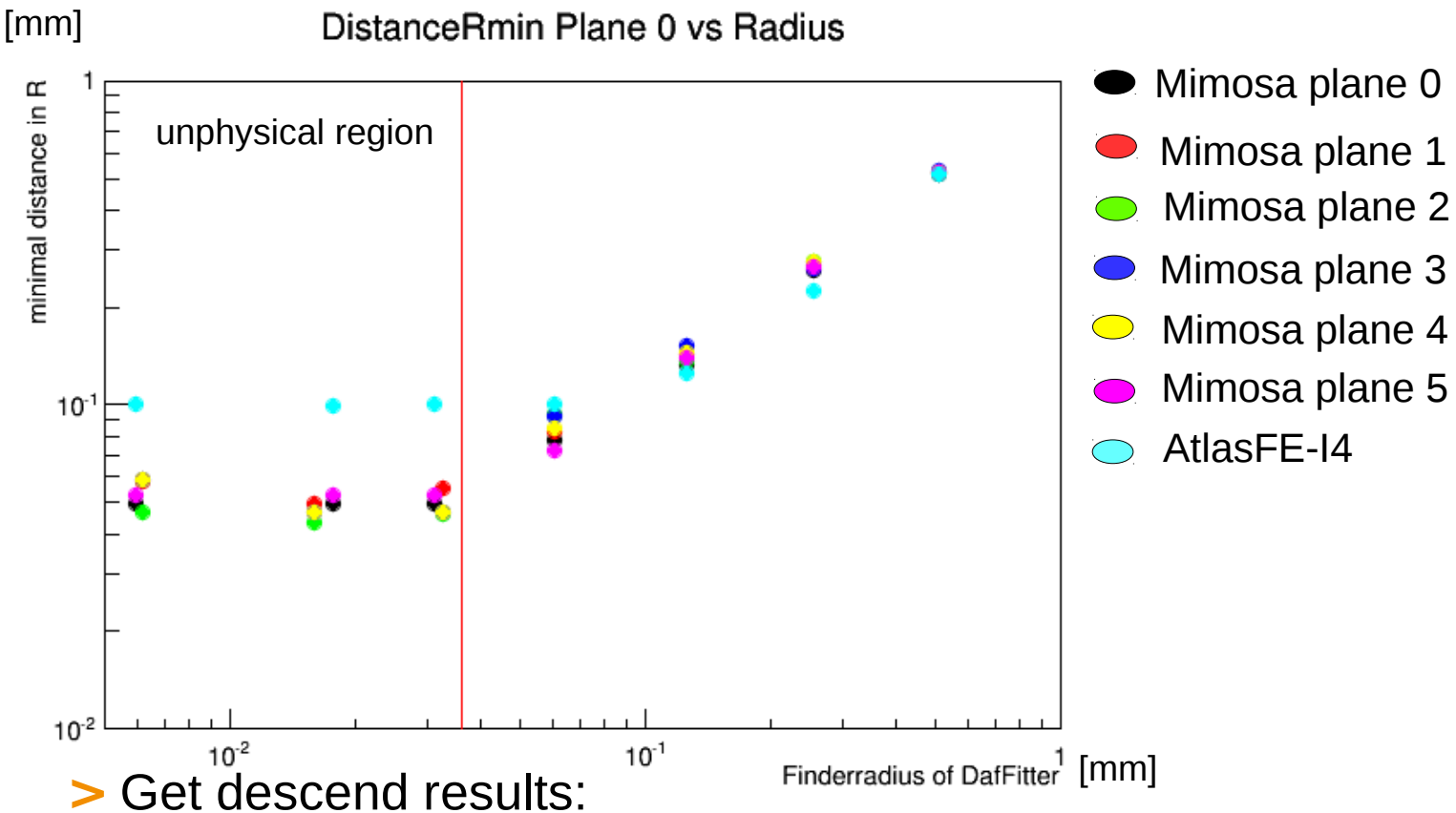
$$\Delta R = \sqrt{\Delta x^2 + \Delta y^2}$$

> Plot of ΔR in plane 5



> minimal ΔR ~100µm

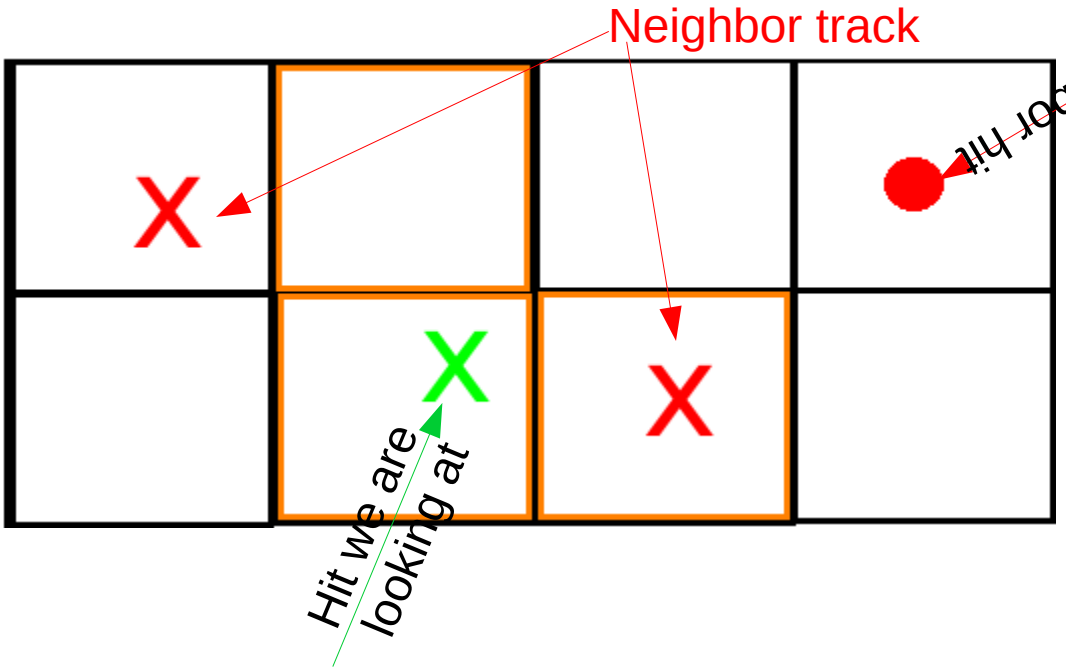
Minimal Distance between 2 separated Tracks vs Finder-radius

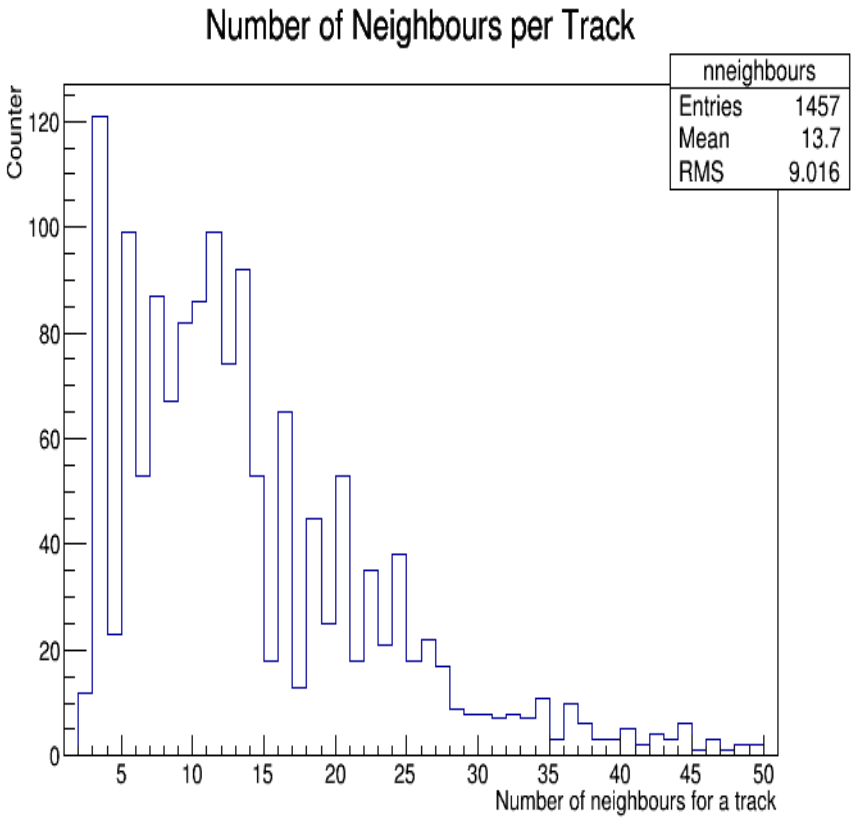


> Get descend results:

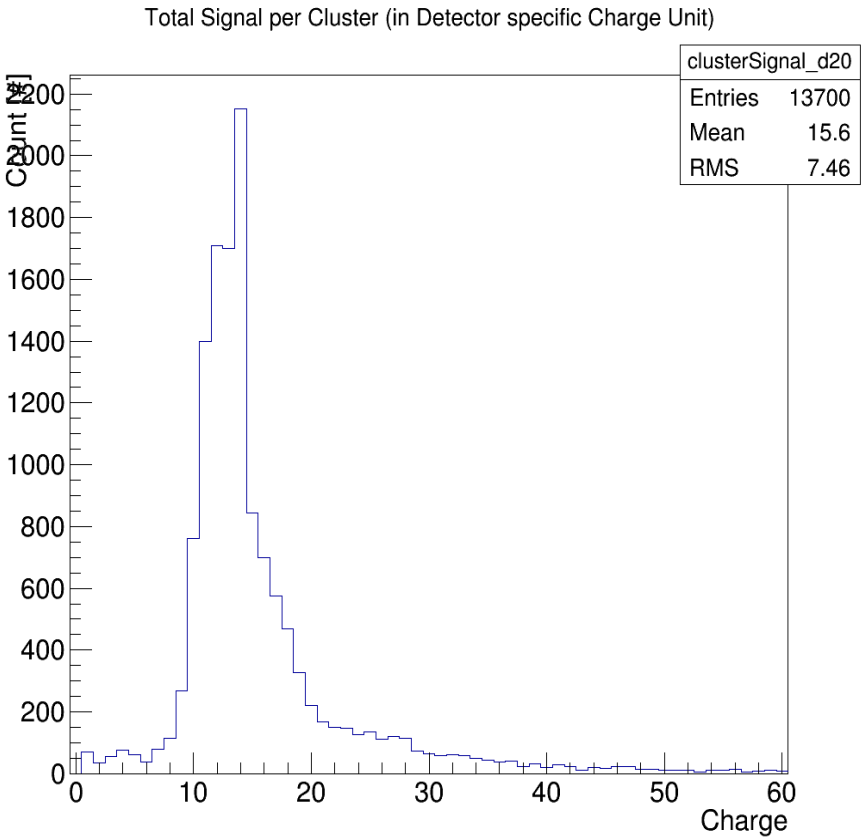
- FE-I4 resolution limited by 100µm
- Mimosa26 resolution of the order of Finder-radius ~ 70µm
- Resolution increases linear as expected for Finder-radius
- Plane 0 behaves unexpected → fixed plane?

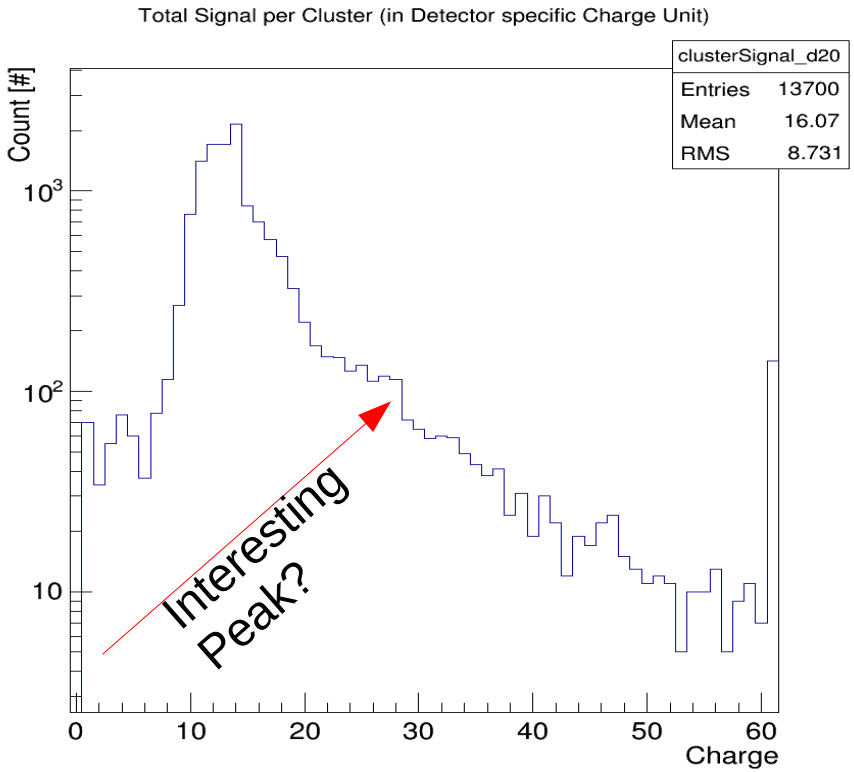
Neighbors of a track



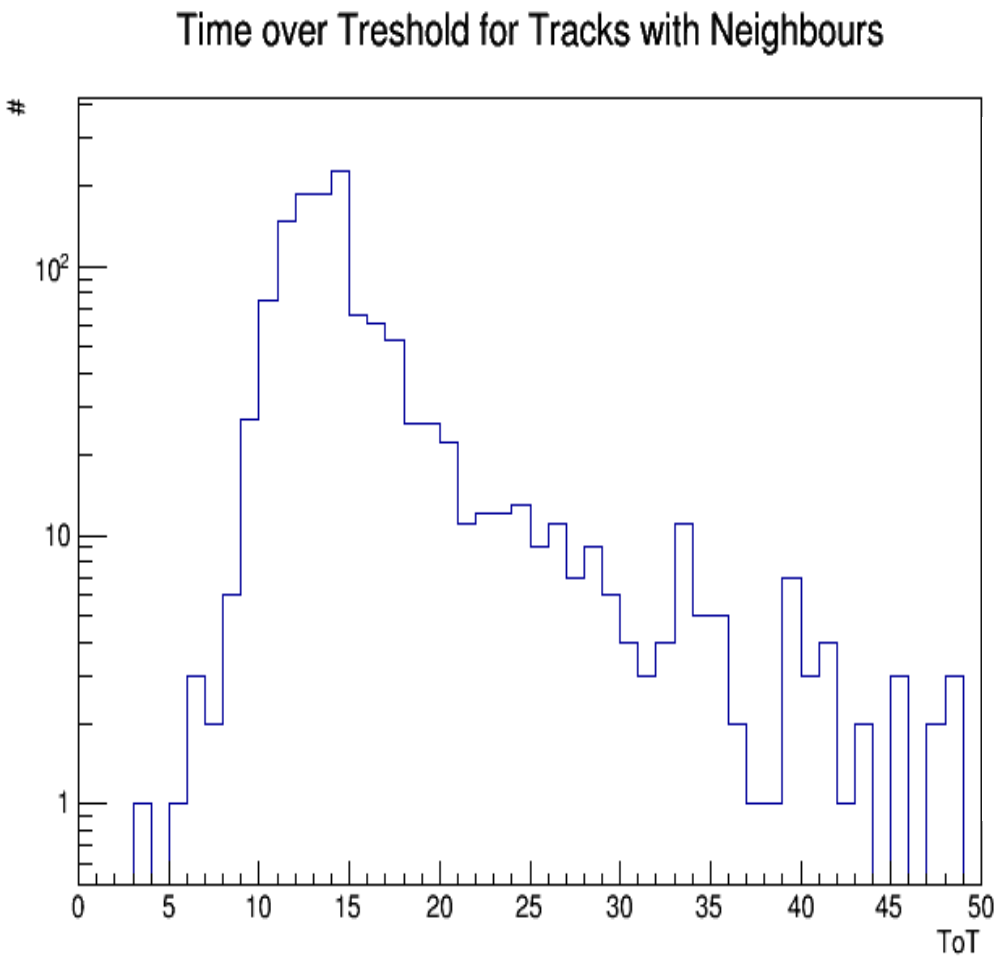


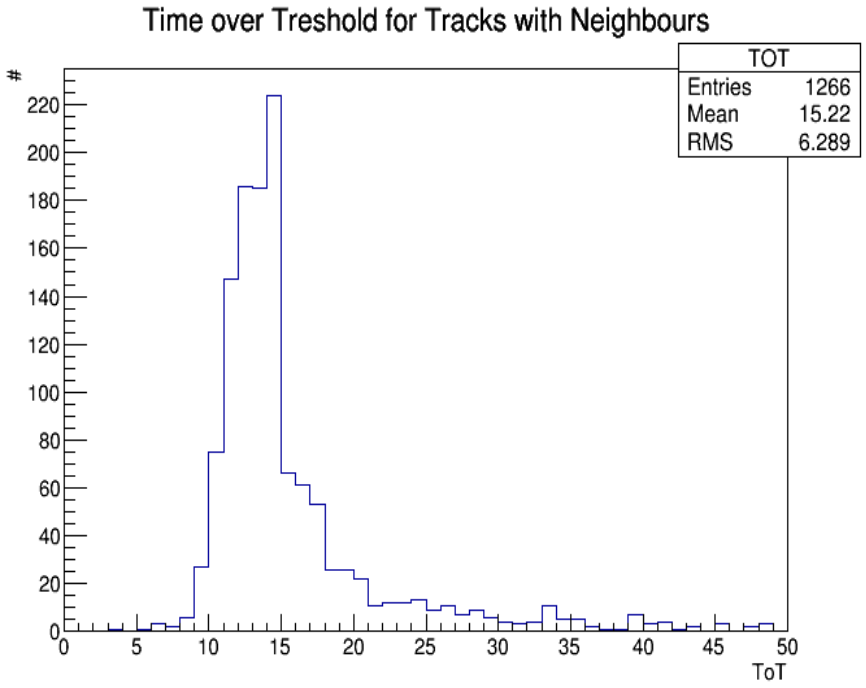
Charge of a cluster – data after clustering



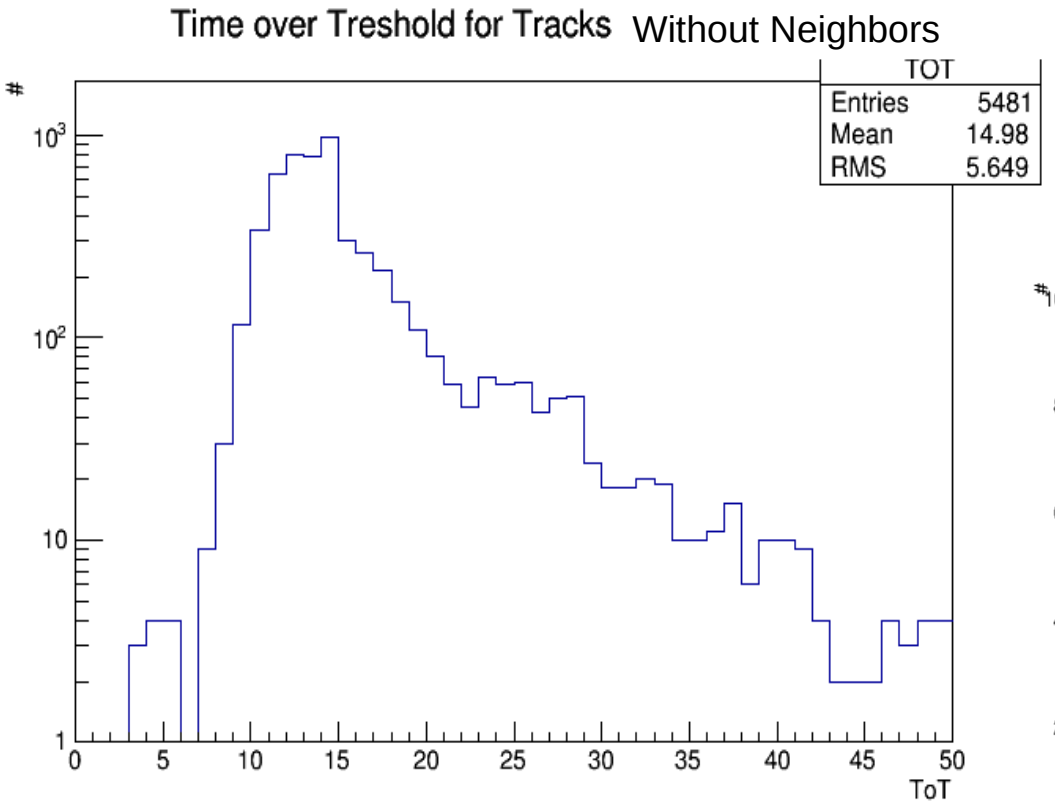


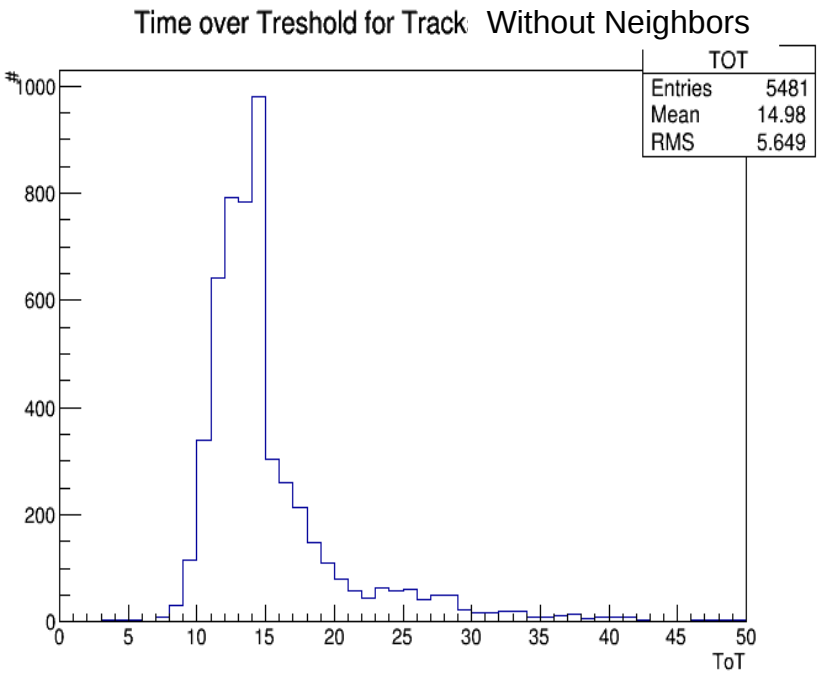
Charge of a cluster with neighbors



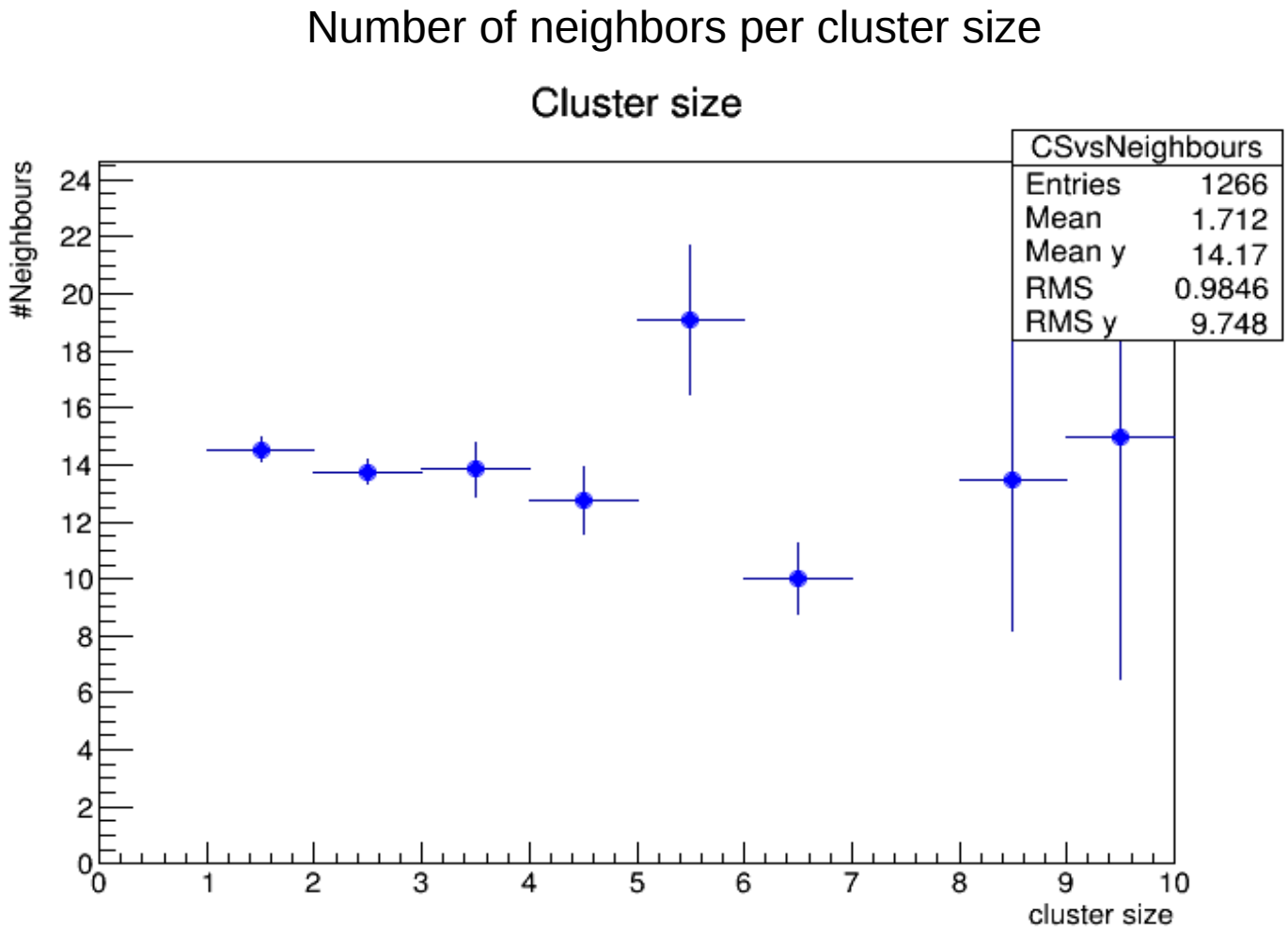


Charge of a cluster without neighbors in 50x250 um



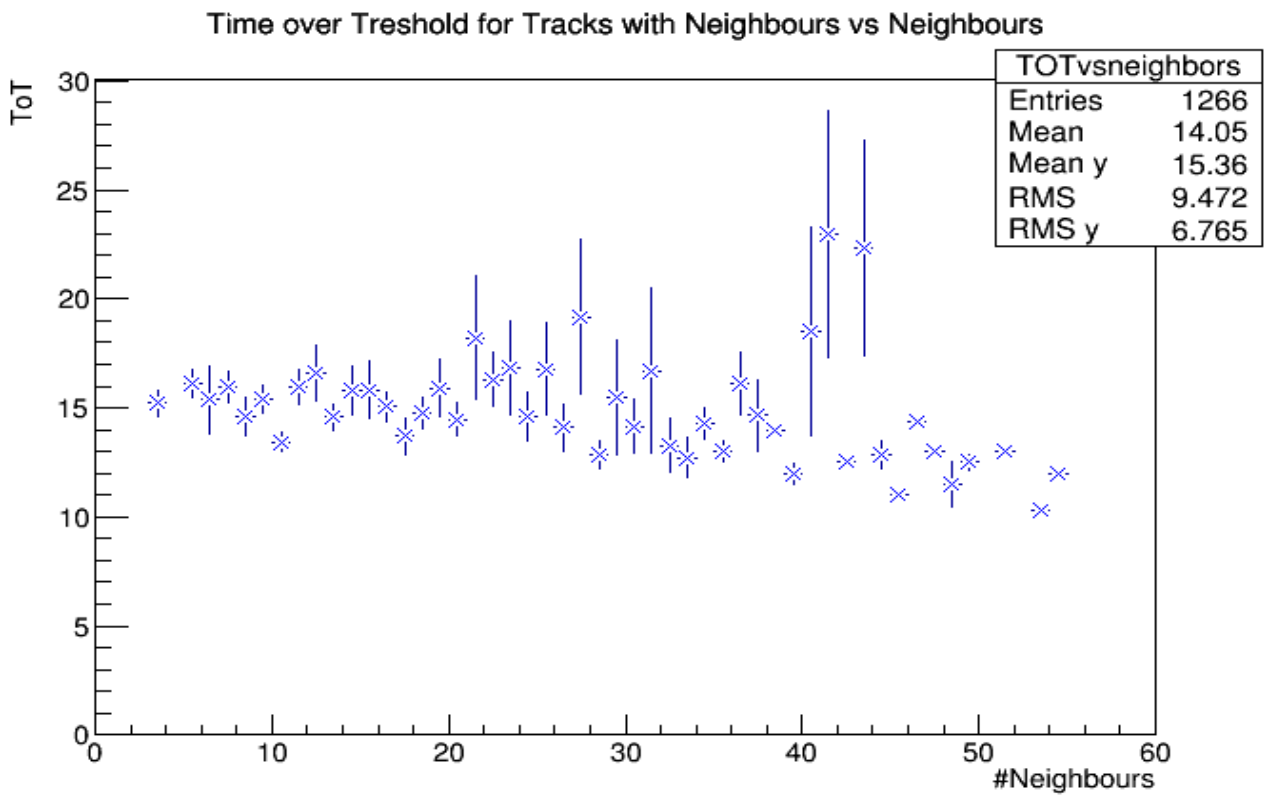


Neighbors per cluster size



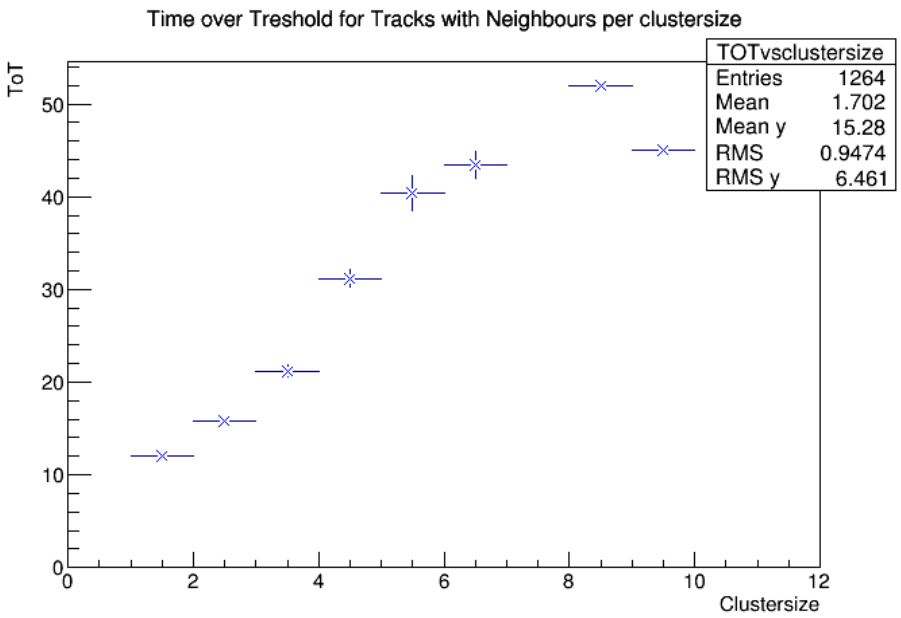
ToT of a cluster with neighbors vs neighbors

ToT per Neighbors

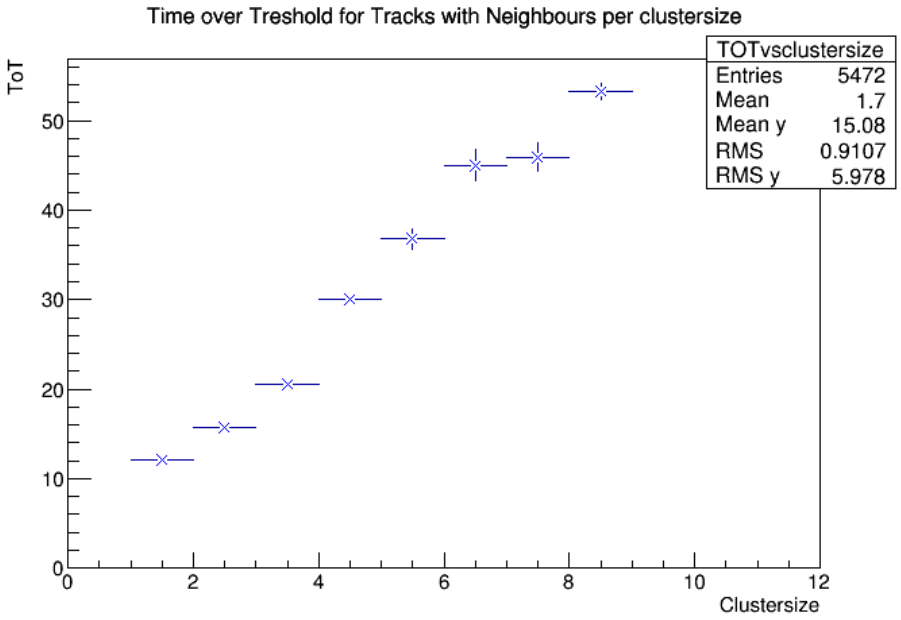


Charge of a cluster vs cluster size

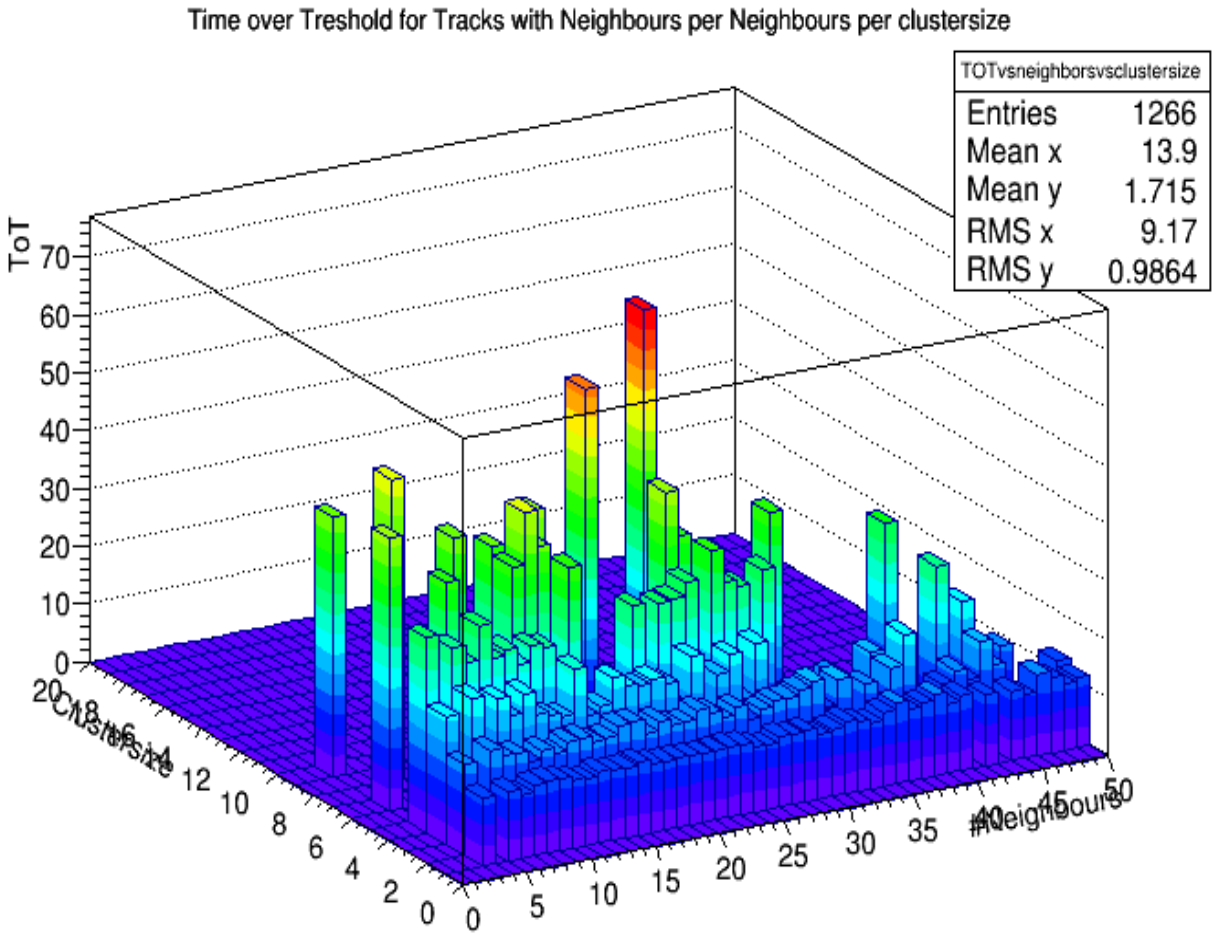
with neighbors



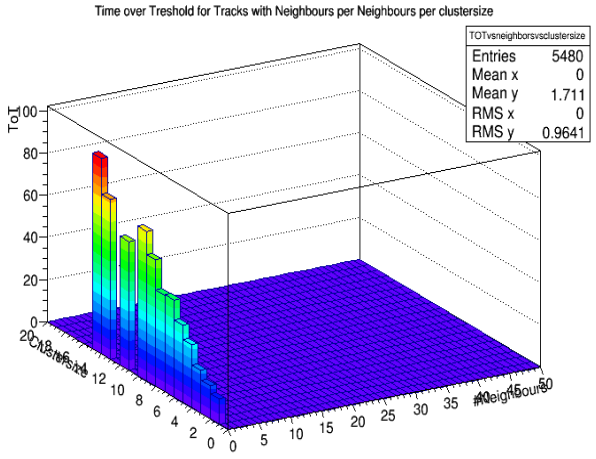
without neighbors



ToT vs Neighbors vs cluster size at low statistics



no neighbors

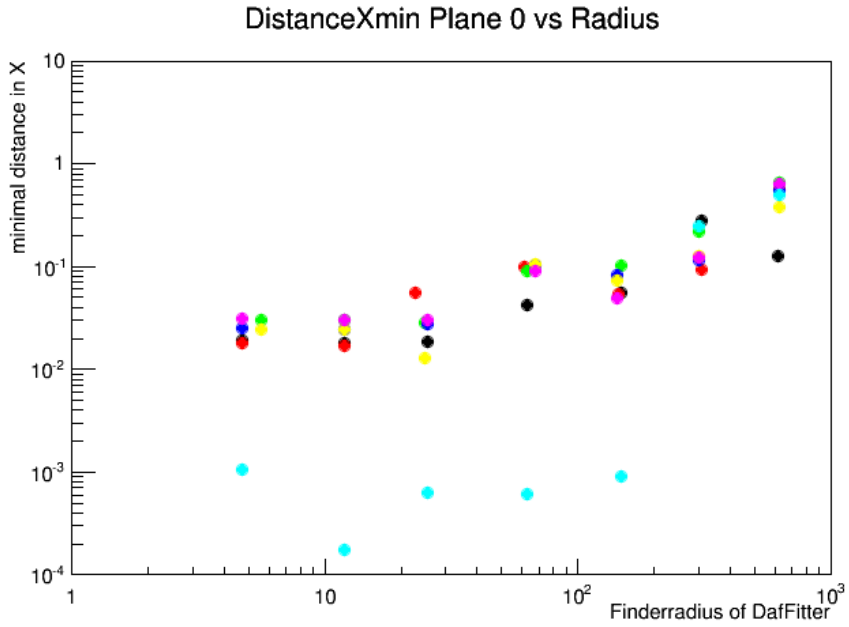


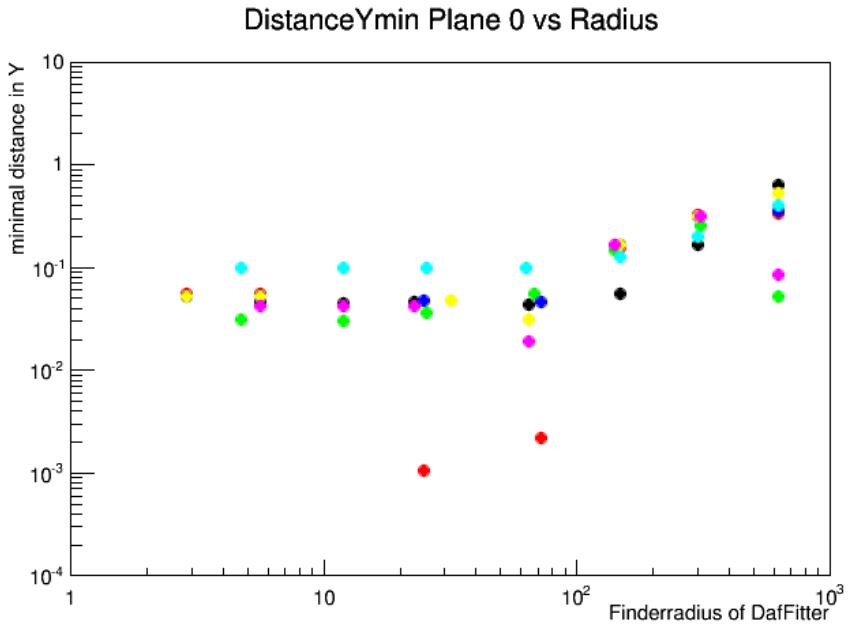
Summary

- High occupancy test beam is best done with parallel beams
- Took test beam data at PS T9 with same setup as SLAC – needs to be analyzed
- Track finding efficiency is ~90%
- Have to add also Neighboring hits into the data analysis program
- First results do not indicate distinct raise of ToT with increasing number of neighboring hits - will be continued

DESY

Backup : Minimal Distance between 2 seperated Tracks vs Finderradius





- Mimosa plane 0
- Mimosa plane 1
- Mimosa plane 2
- Mimosa plane 3
- Mimosa plane 4
- Mimosa plane 5
- AtlasFE-I4

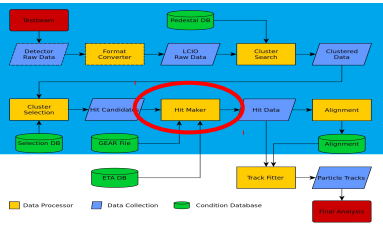
> Atlas FE-I4 expected limit in X:

- Resolution around 50 µm
- With Finderradius 70 µm

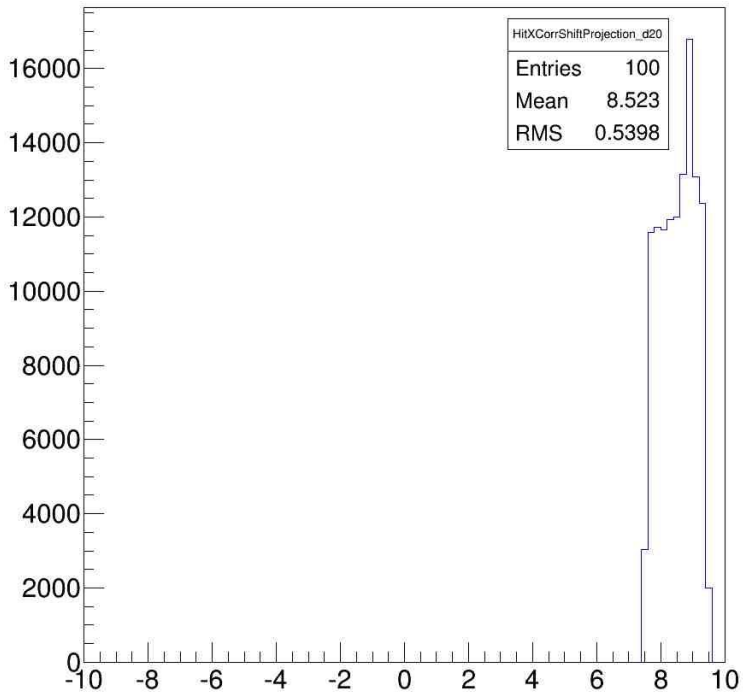
> Mimosa plane 1 in Y expected:

- For 40/80 µm resolution to low

Hitmaker – lets search for correlations!

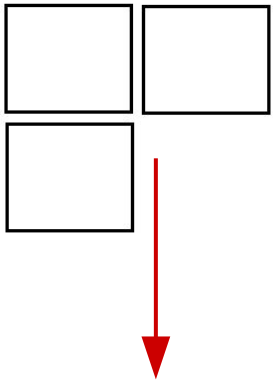


HitXShift/HitXCorrShiftProjection_d20

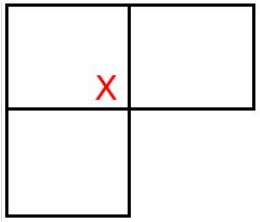


Reminder:

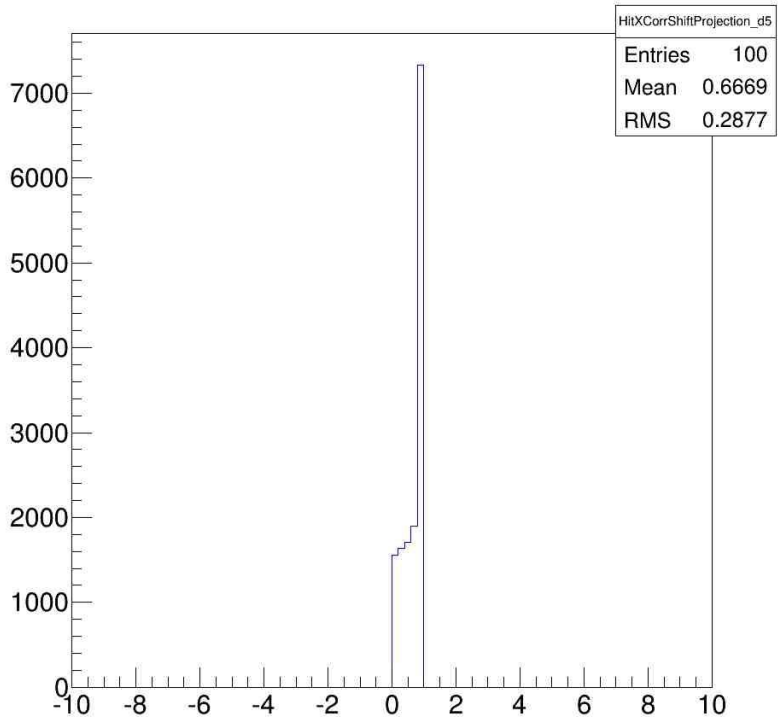
Fired Pixels

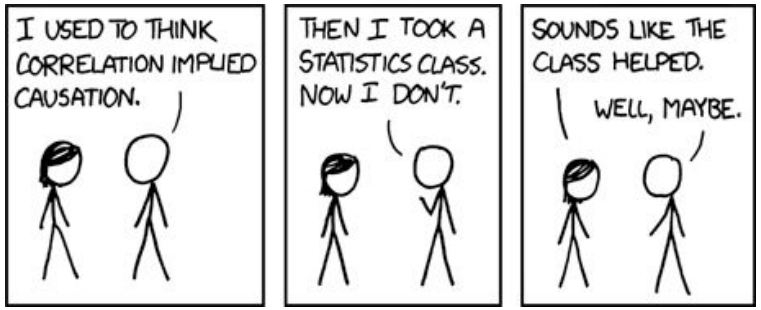


Calculated Hitpoint



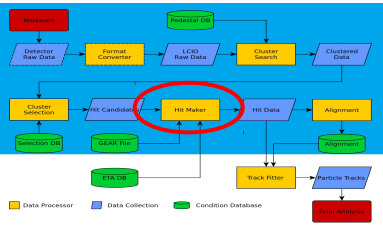
HitXShift/HitXCorrShiftProjection_d5

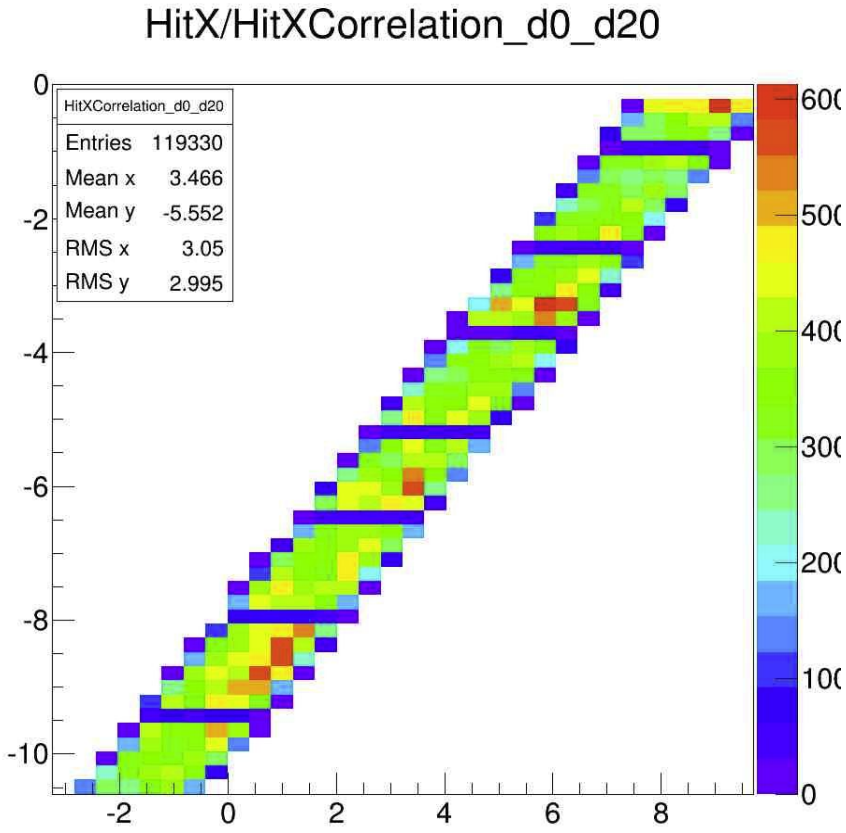


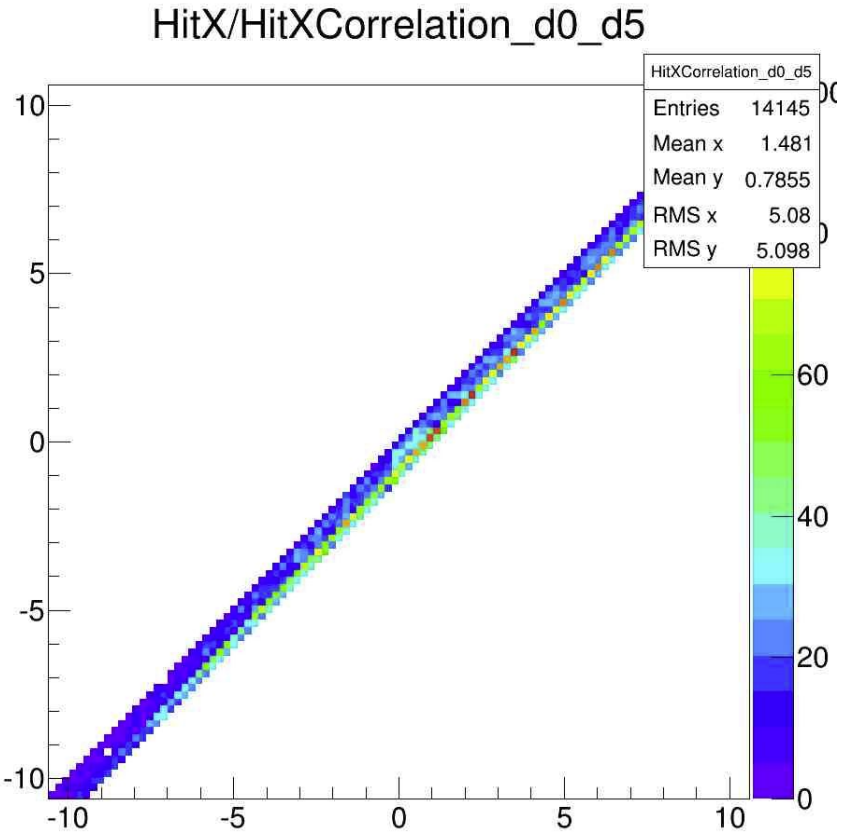


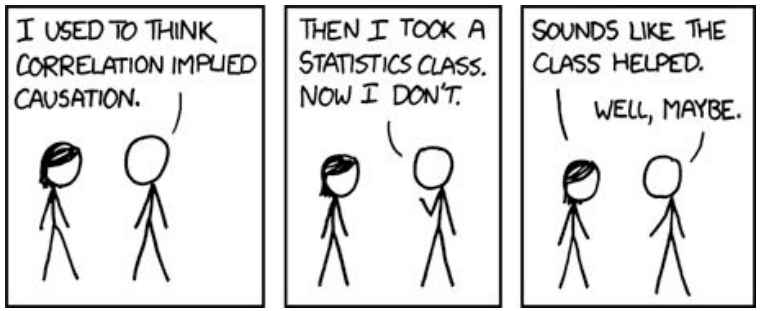
DESY

Hitmaker – lets search for correlations!









EUTelescope Properties