Study of CR selection for 6x6x6 online monitoring and calibration tasks

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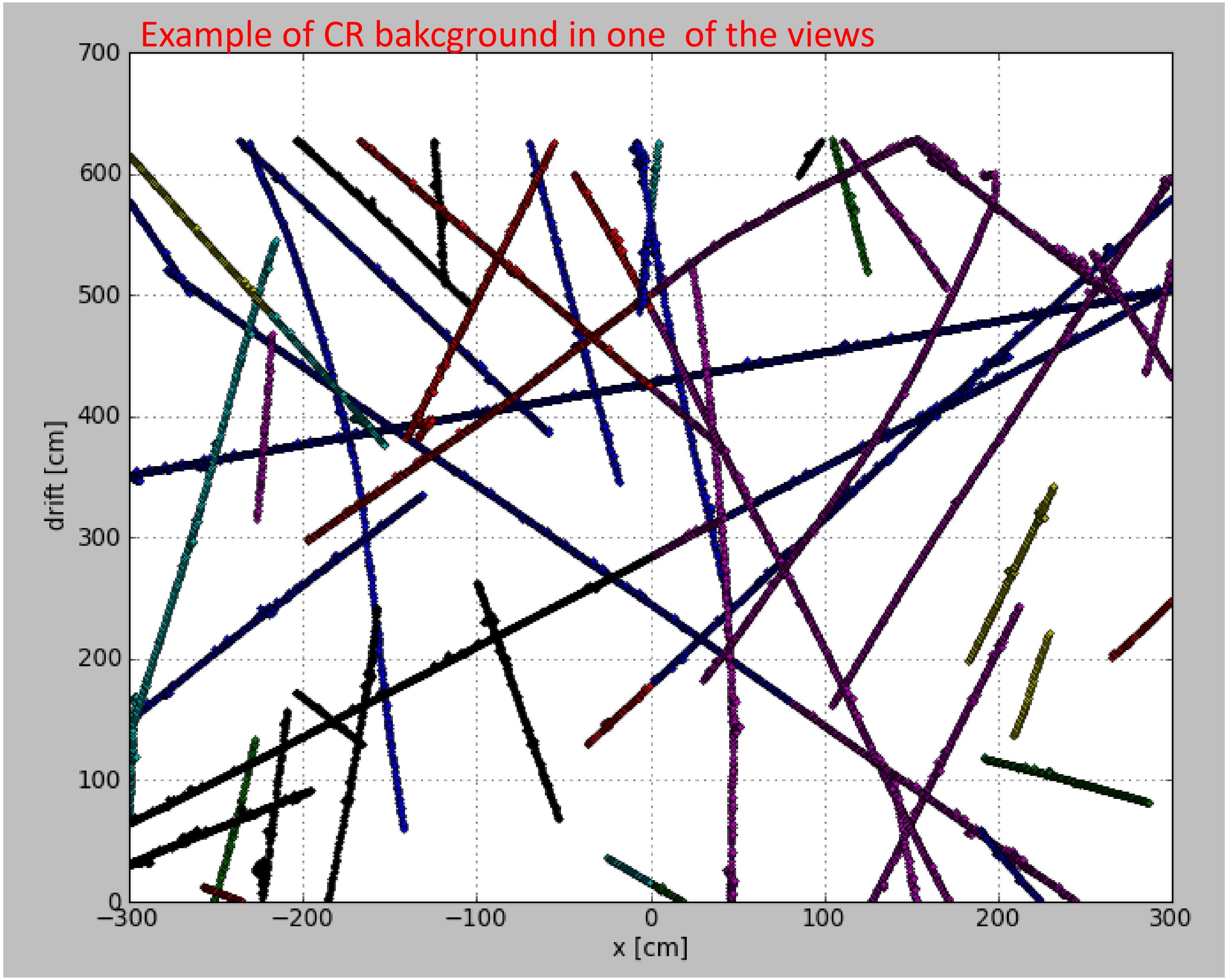
SB Meeting

Introduction

- A first look at the possibility of reconstructing & some cosmic ray tracks in 6x6x6 for online monitoring
- Simplified situation with "empty beam" event: only cosmics for now
  - Allows to get a sense of how much charge is leftover
  - Gives a simpler scenario where all the recorded hits are coming from cosmics

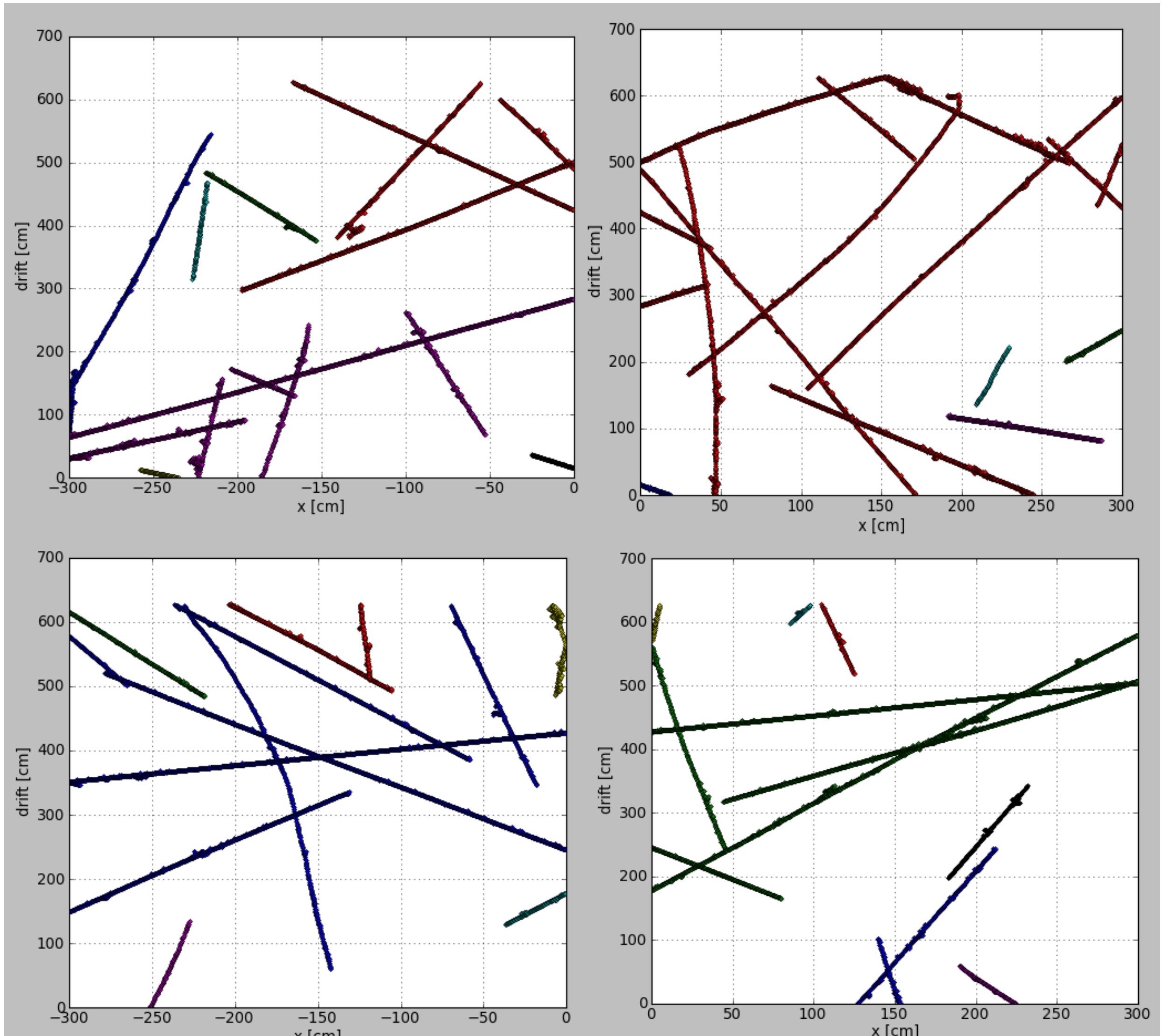
Challenges of CR background

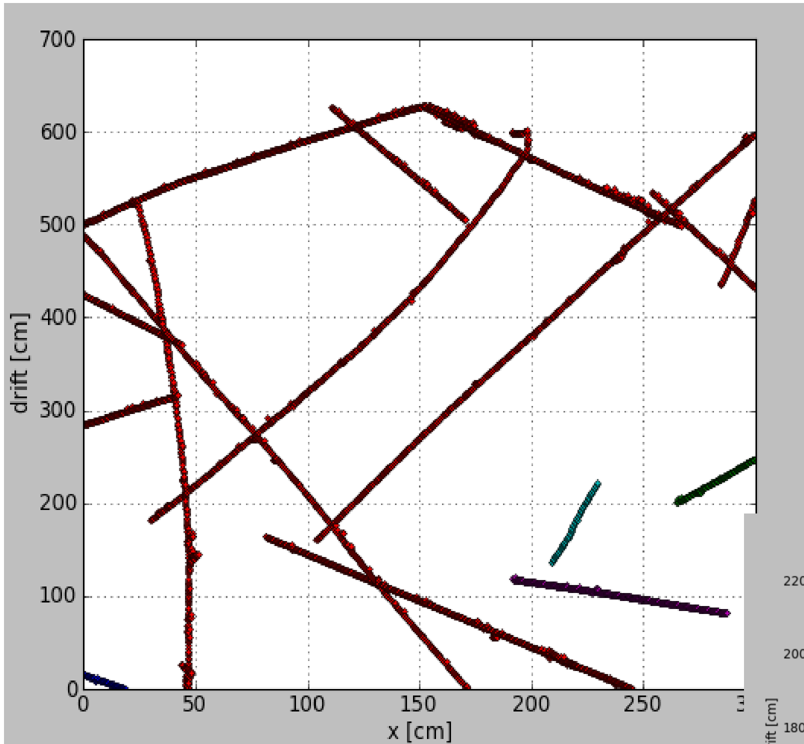
Many tracks of varied length intersecting at different angles



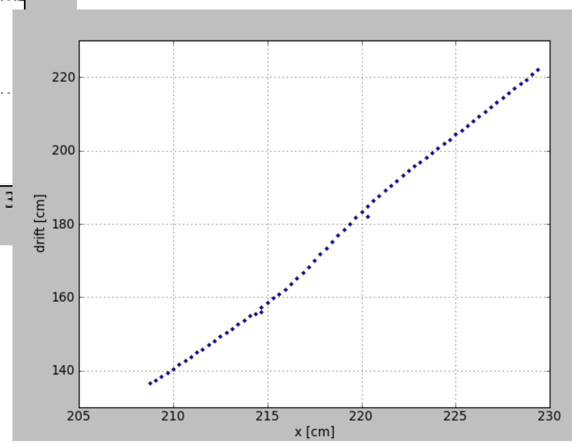
Challenges of CR background in 6x6x6:

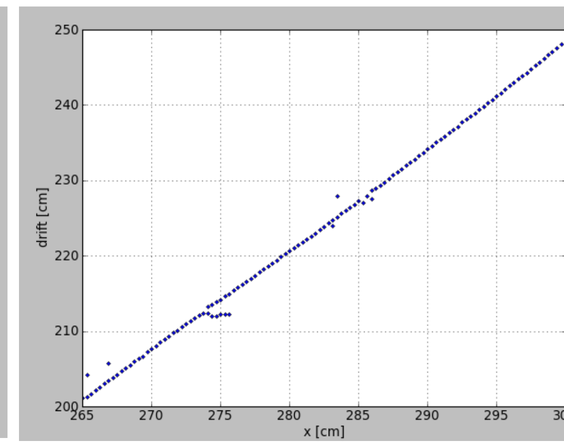
- The situation is better if we work with one 3x3 m^2 CRM at the time
- Then try to merge segments between different CRMs
- And finally merge views to get 3D tracks for gain calibration



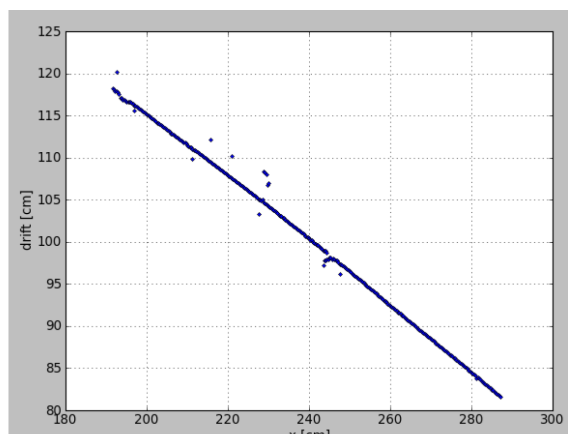


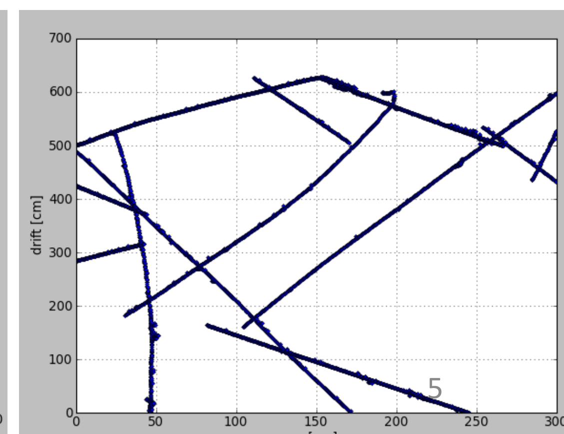
With some clustering we can further breakdown the problem into smaller pieces and can get just clusters of the connected (tracks) objects





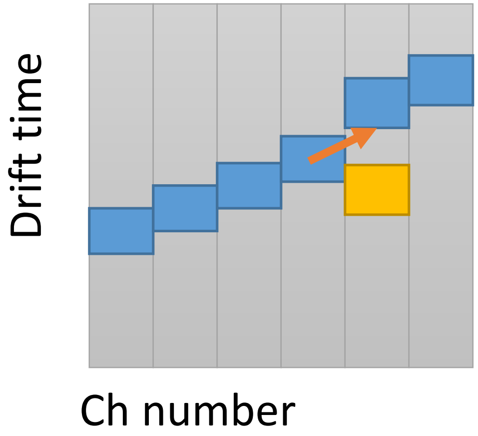
- Sometimes these would be just simple track fragment
  ➔Easy
- Other times more complicated tangle of different segments
  ➔ More challenging





Track trajectory reconstruction

- A trajectory is seeded from unused nearby hits
- It is then followed with a 2D Kalman filter
  - A hit in the next available channel are added / not added with a chi2 cut and then one moves to next channel
  - A parameter for a max number of skipped channels sets determines when the trajectory ends

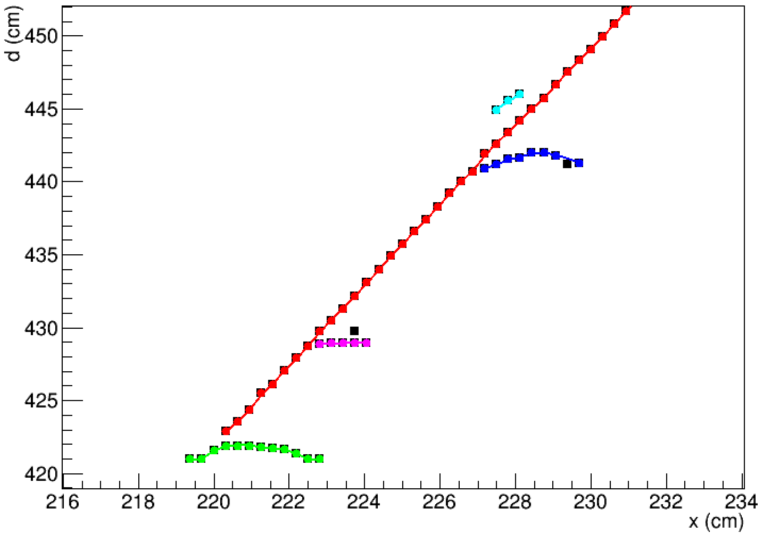


MS covariance matrix

Multiple scattering is added as "process noise"

A rough momentum estimation is made to set the scale of MS, but since we are working with 2D projection normally it is not a correct value (usually smaller to compensate for actually longer path lengths)

Its primary function is to provide some flexibility to the track following → trajectories can even curve for delta-rays



$$Q_{MS} = \theta_0^2 (1 + \tan^2\theta)^{5/2} \begin{bmatrix} 1 & \frac{1}{2}\Delta \\ \frac{1}{2}\Delta & \frac{1}{3}\Delta^2 \end{bmatrix}$$

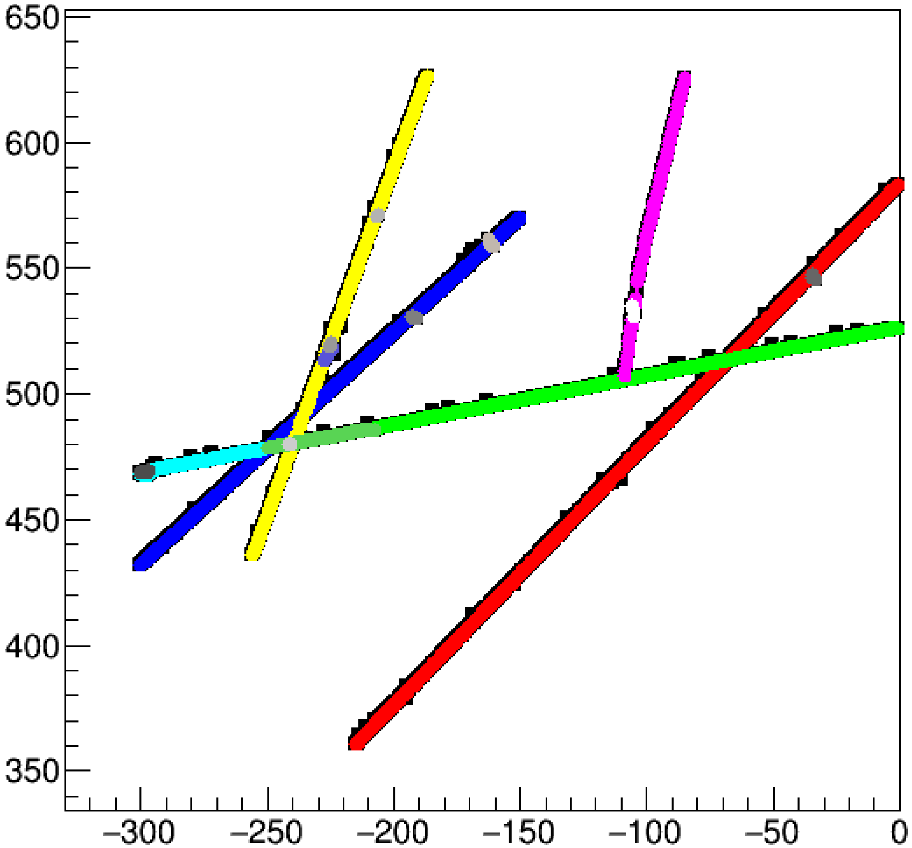
$$\theta_0^2 = \left(\frac{13.6\text{MeV}}{p\beta}\right)^2 \frac{\Delta}{X_0}$$

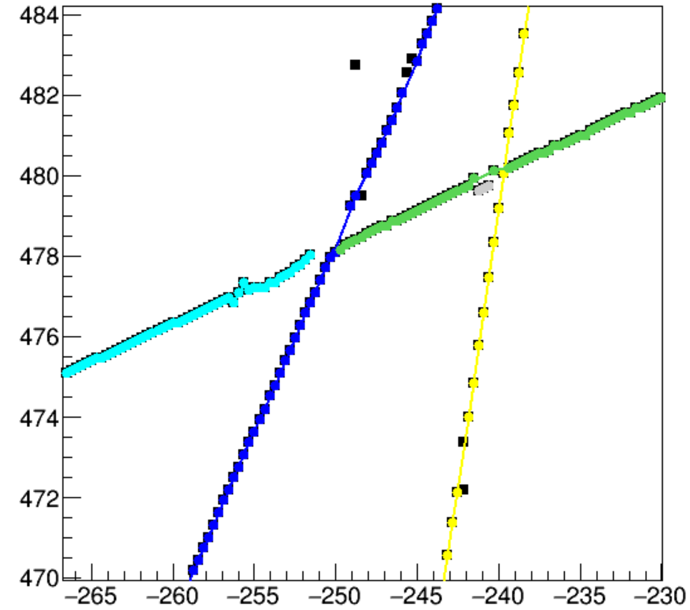
$\tan\theta$ -- slope of the trajectory
Δ – step size (3.125 mm normally)
$X_0 = 14$ cm

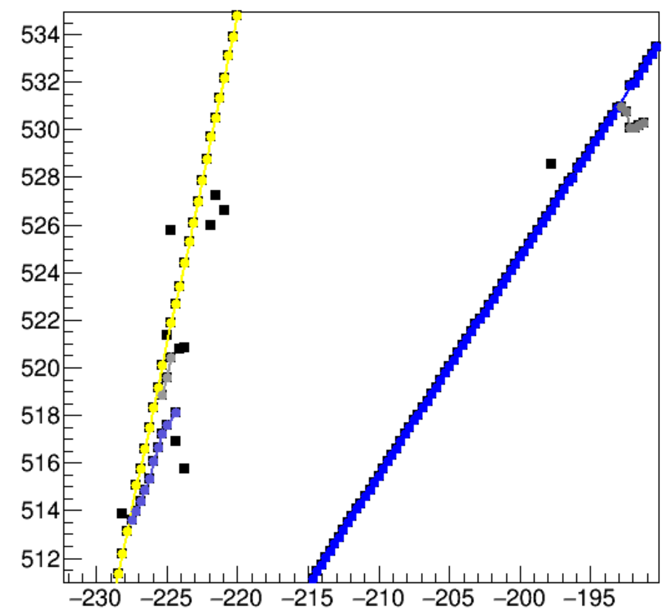
Matrix elements:
Q_{11}- uncertainty on slope due to MS
Q_{22}- uncertainty on displacement due to MS
$Q_{12} = Q_{21}$- correlation term

Some examples

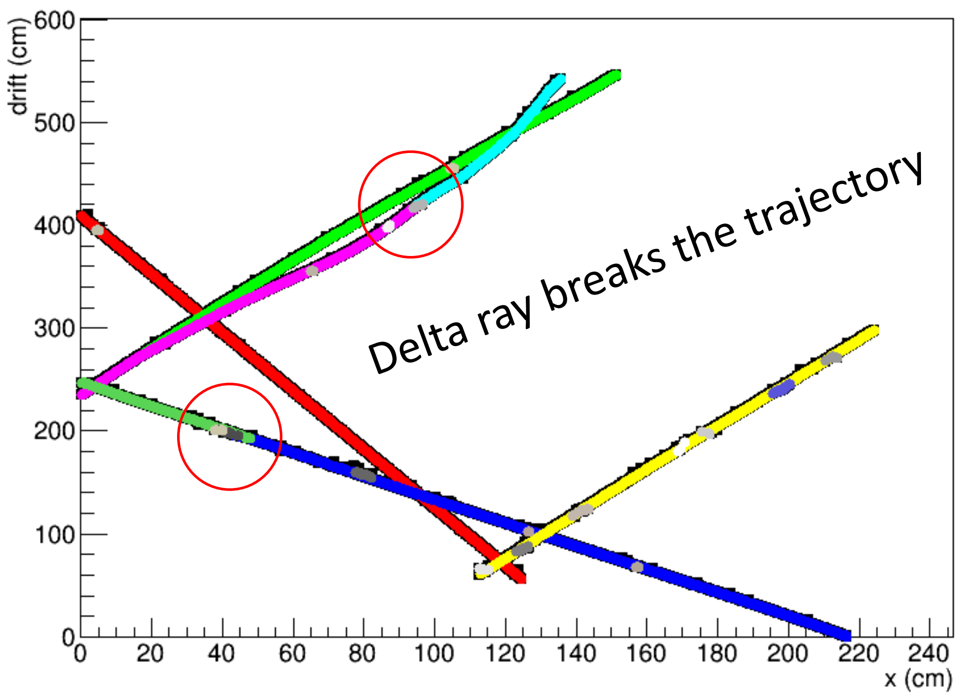
The algorithm can deal well with reasonable clean track
A break in the trajectory can happen in the vicinity of other tracks CR or delta-rays (multi-hit resolution)
Still possible to get a clean delta-ray tracks in many cases

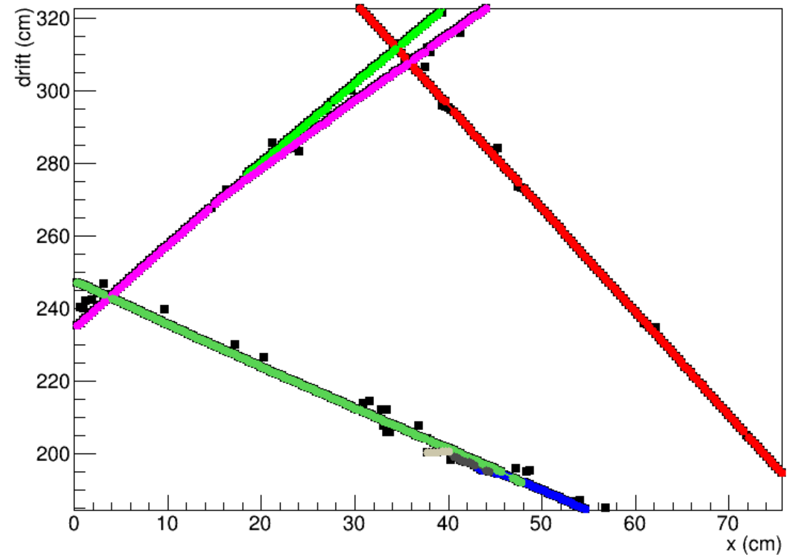


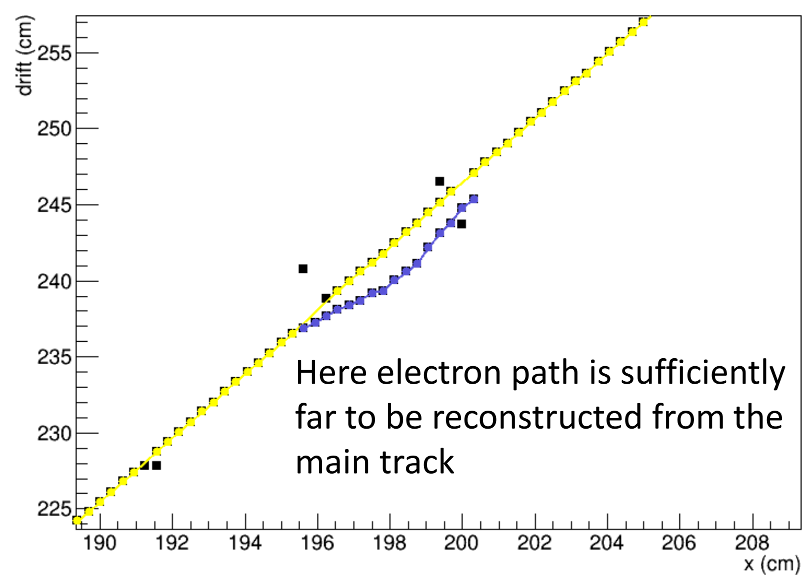




Some examples cont’d



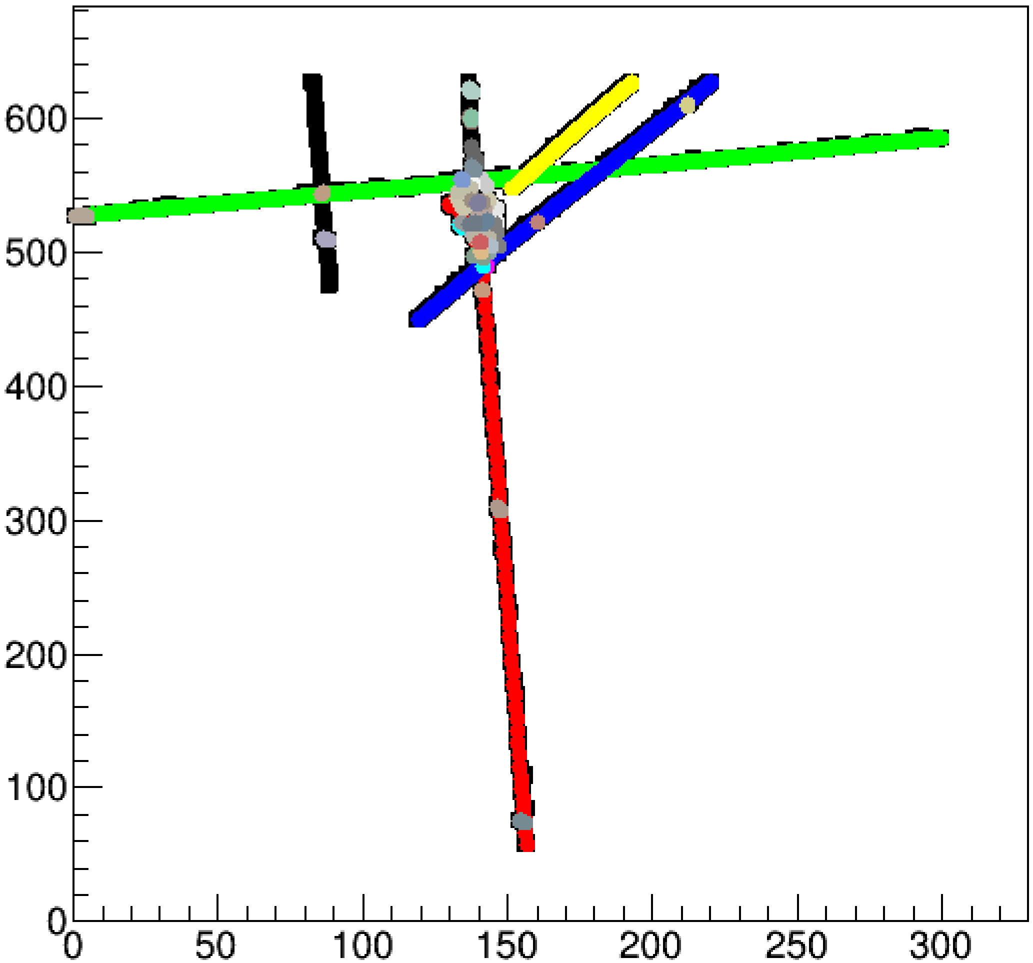


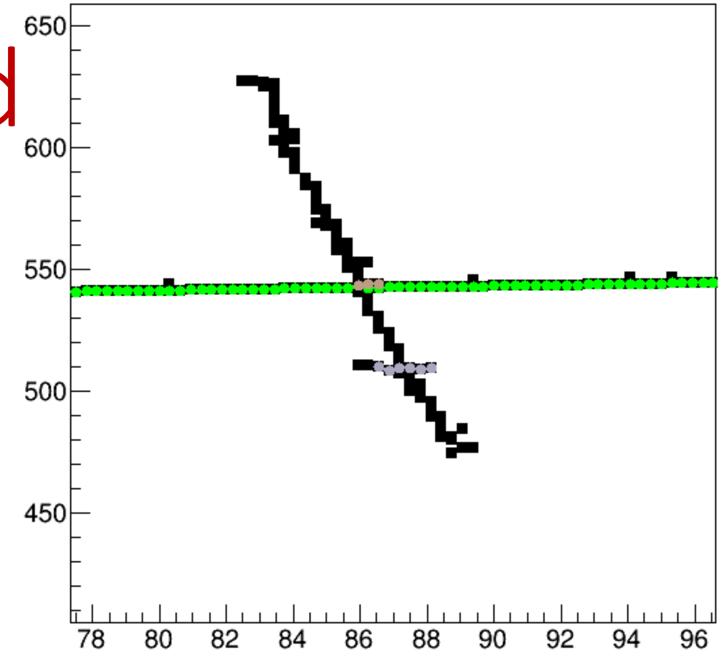


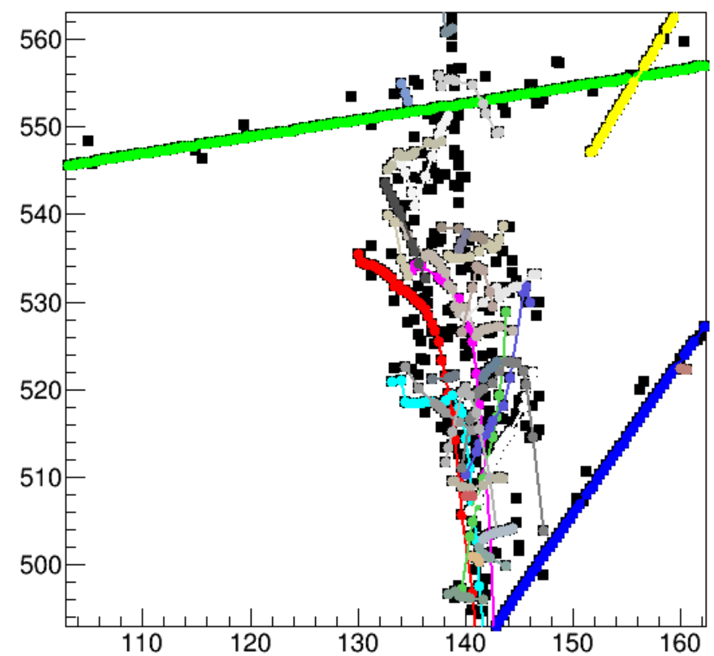
Delta rays emitted close to the particle direction tend to create breaks in the trajectory, but this can be recovered by merging segments afterwards

Some examples cont'd

Iso-channel downward tracks are not well reconstructed
→ looking for a good and quick fix



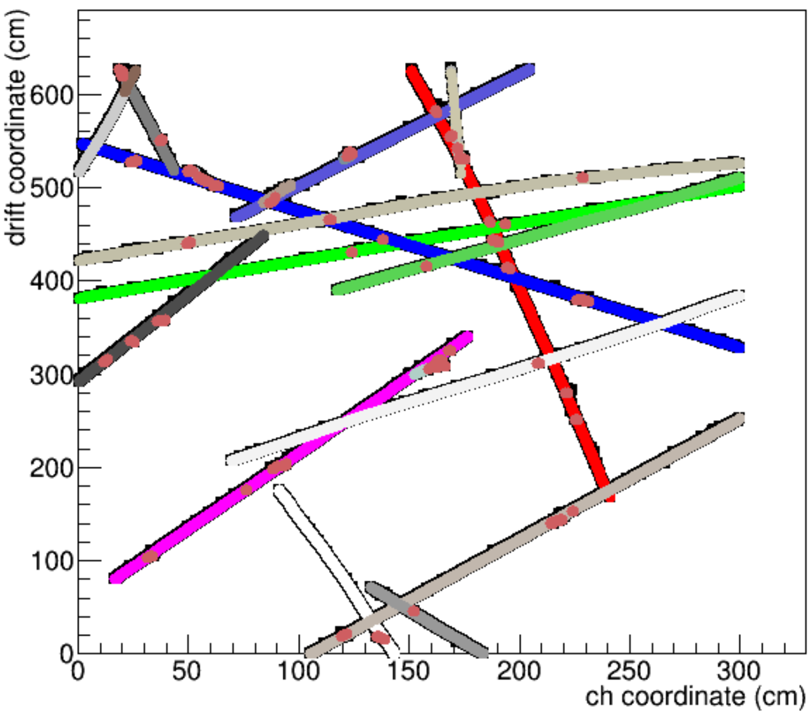


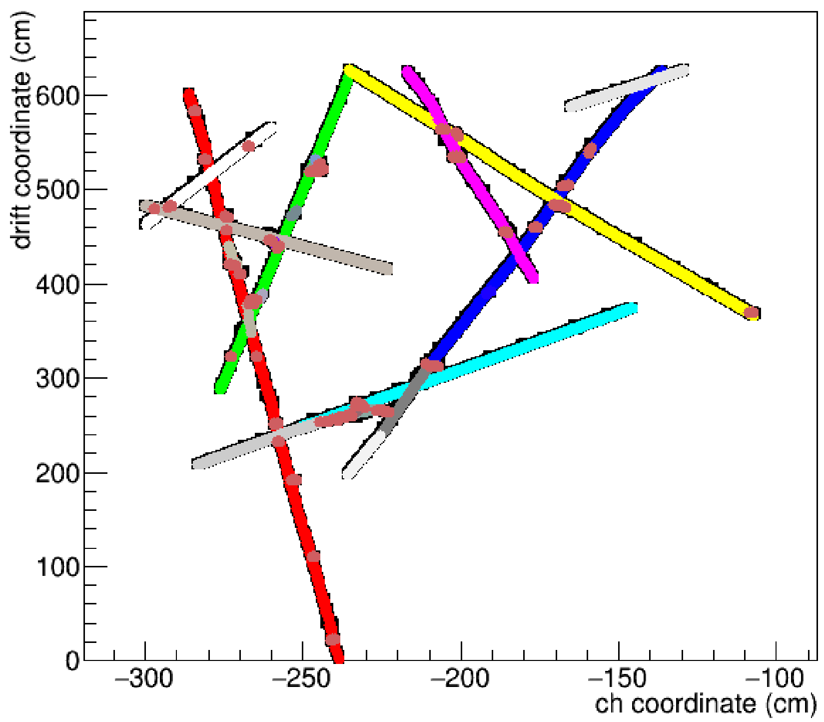


More complicated clusters

Can recover a good fraction of clean tracks even in complicated cluster situations

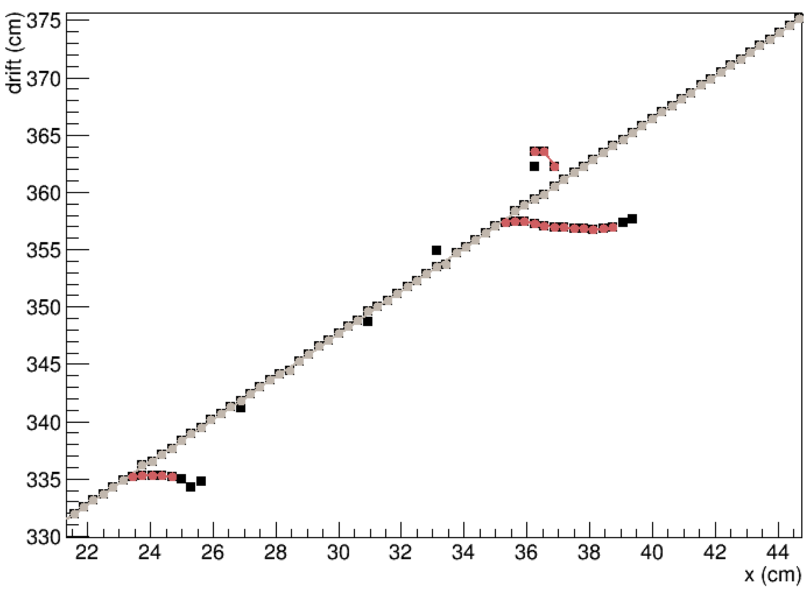
Dark red shows the hits tagged as electrons using rough momentum estimation

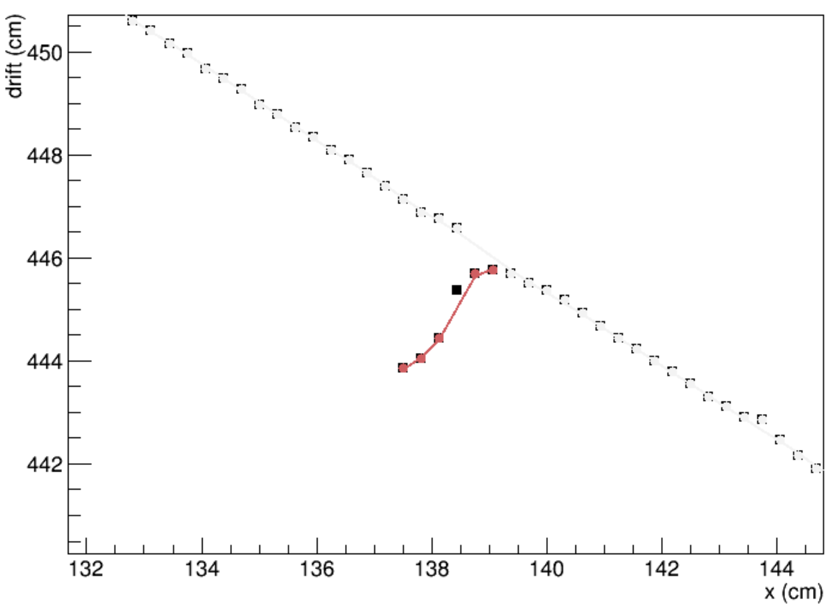




Delta ray track treatment

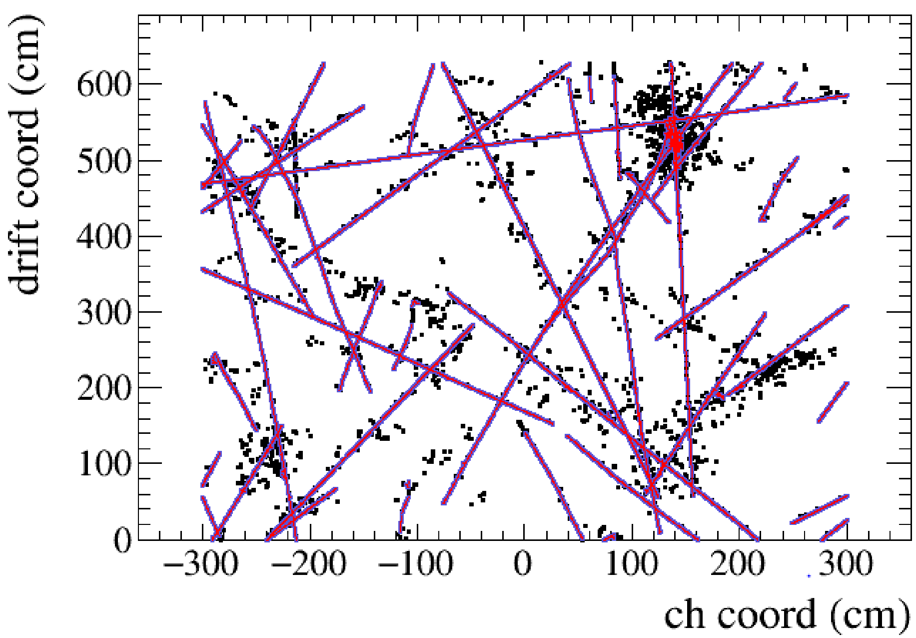
- Reconstructed reasonably well, but often the hits are missed due to larger scattering
- Could be improved. However treating each such track with a great care could be a bit time consuming for online analysis, since there are many of them for each cosmic
- Currently all low momentum (based on rough estimation from MS) tracks are tagged as electron
- They are not associated with the muon track and a simply saved to the output as their own tracks
  - Offline can perform a more complicated analysis

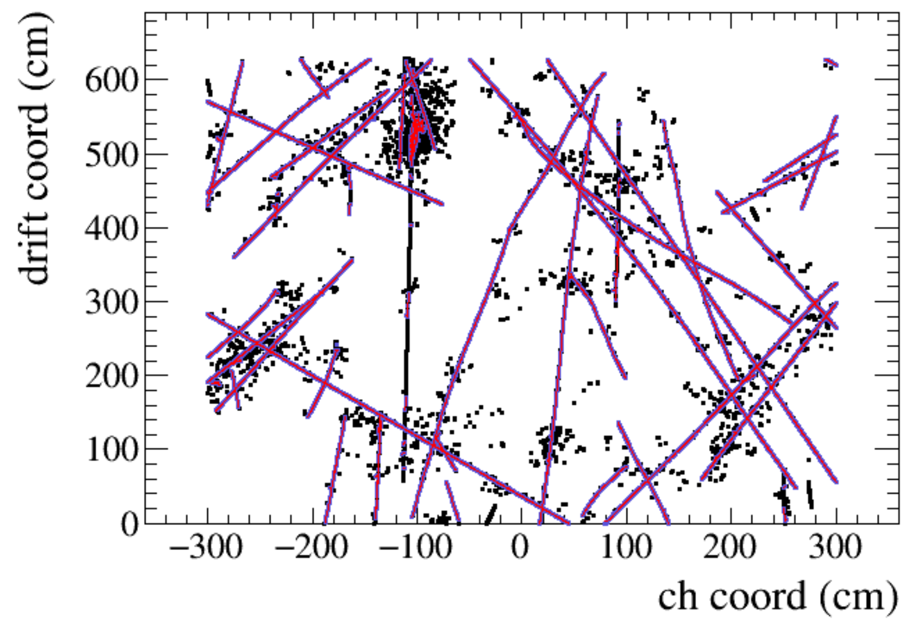




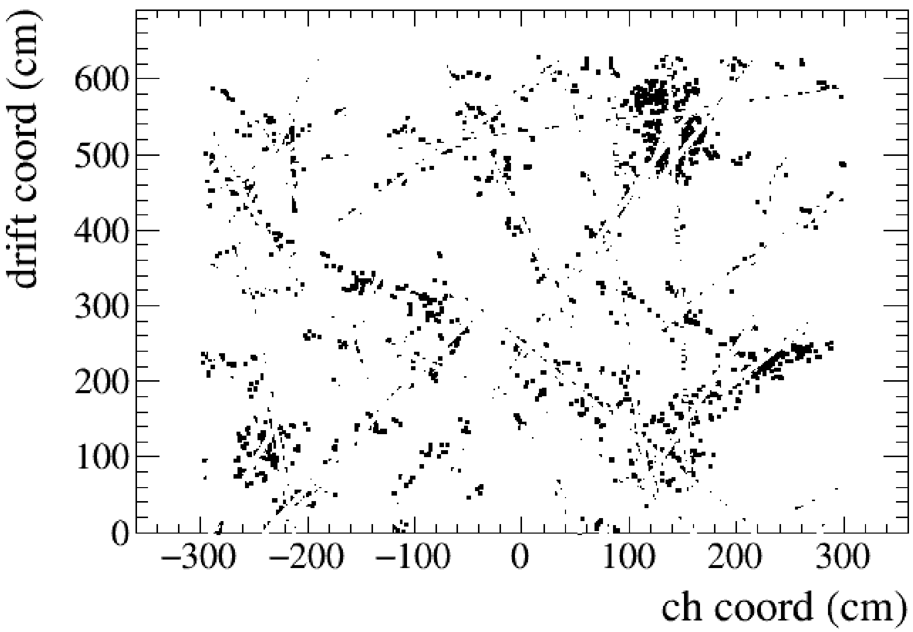
Example event (CR only)

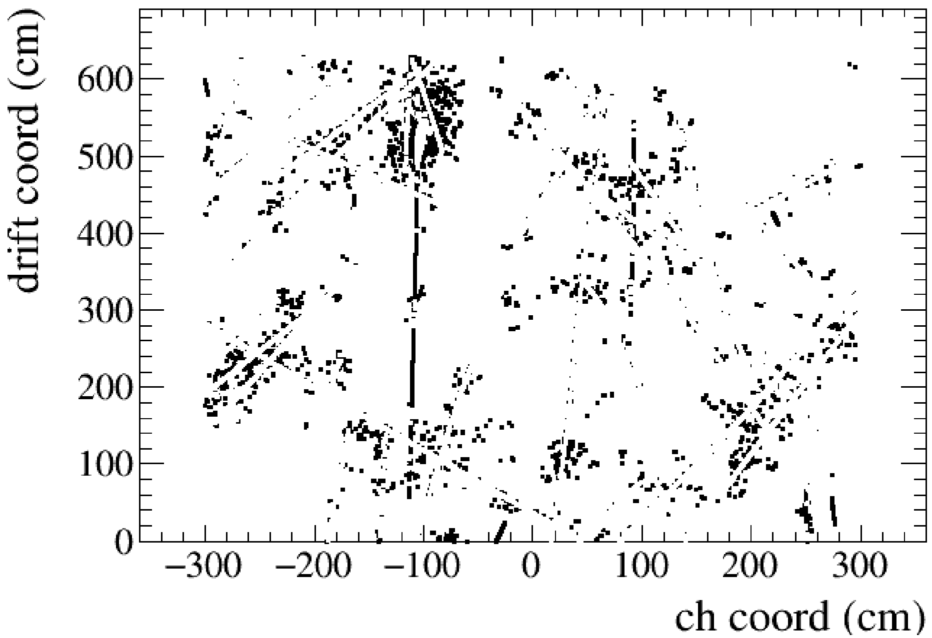
Black points show the reconstructed hits
Blue points show hits associated to some track
Red lines indicate track paths





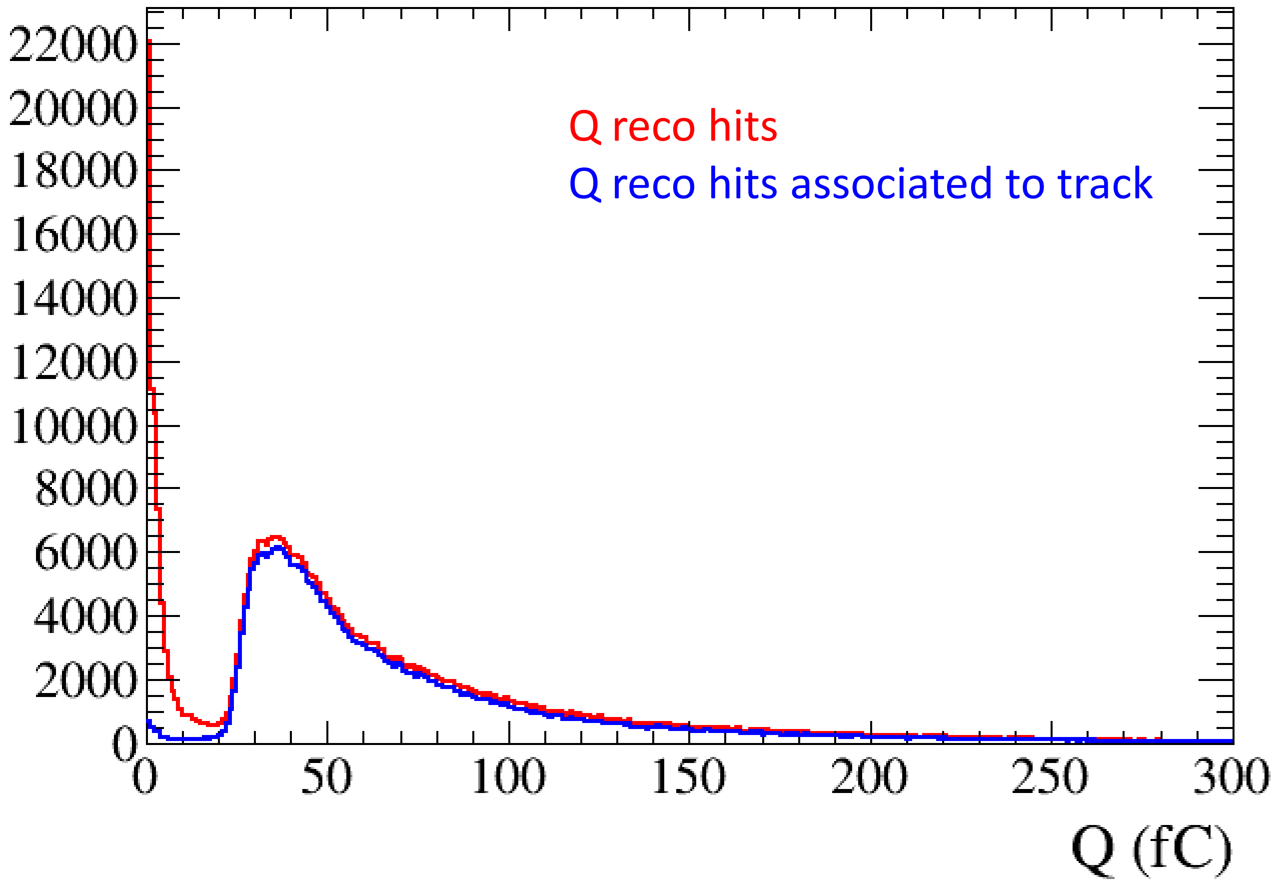
Example event – tracks removed





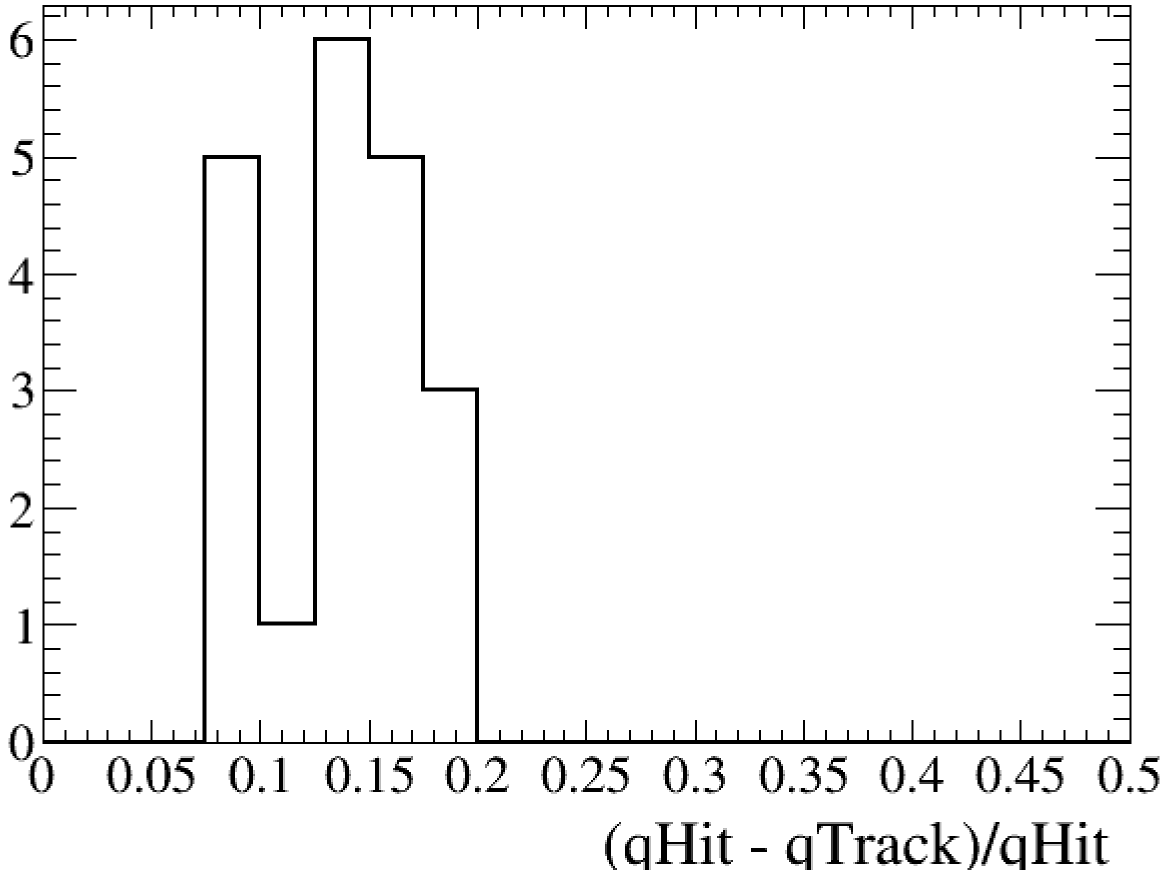
Event with CR only
As mentioned already vertical tracks are not handled as well
Showers are not treated so heavy activity near the tracks remain

Leftover charge



Most of the missing charge comes from in isolated low-q hits (brem photons)

Leftover charge



Assuming all the tracks are identified as cosmic rays perfectly, ~10%
(~1000pC from cosimcs → 100 pC)
➔ More work is needed for CR removal

Online analyses

- Purity:
  - Sufficient to have 2D tracks segments (no need to merge into 3D) ➔ could get O(10) reasonably long tracks per event
  - Measurement of relative attenuation (presentation by Elisabetta at SB) ➔ no need for T0

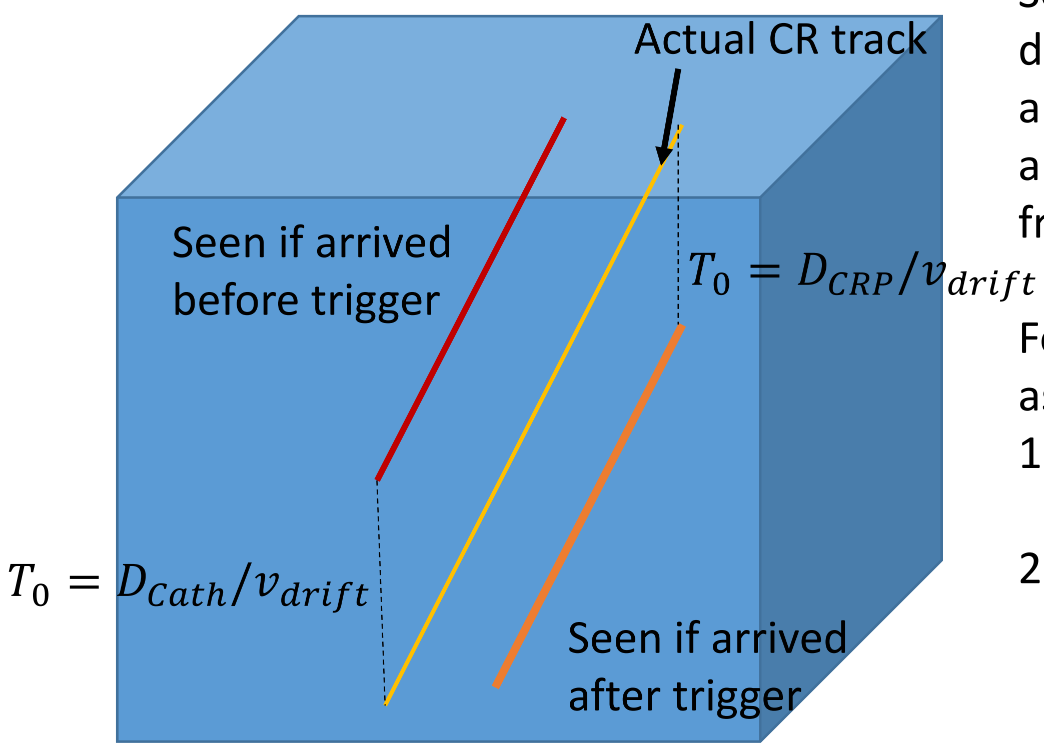
- LEM gain monitoring:
  - Need to reconstruct 3D path to get dE/dx → merging of two views is necessary
  - Need to know T0 to apply charge attenuation correction as a function of the true drift distance
  - Basic idea is to match T0 from LRO with T0 determined from certain track topologies

    ➔ Should be possible to find a few good tracks with such constraints

CR arrival time from 3D tracks

It is possible to calculate T_0:

- For CR arriving before trigger that exit on the cathode side
- For CR arriving after trigger that enter on the CRP side

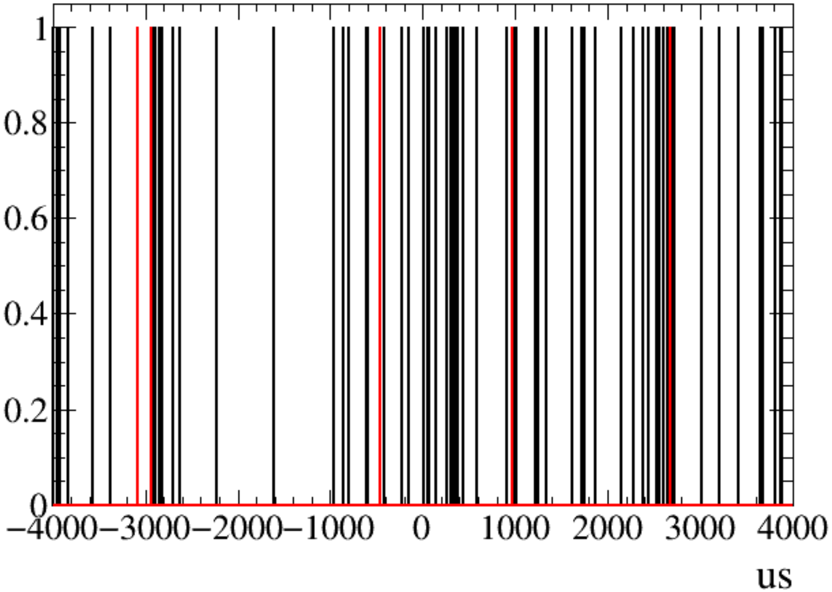


So from endpoints that appear to hang disconnected from either cathode or anode in 3D, we should be able to get T_0 and cross check it against T_0 reconstructed from PMTs

For other situations will not be possible to assign T_0

1. Will not use for gain monitoring (will not know lifetime correction)
2. Can use for purity analysis
   - As was shown, the analysis can be done for relative Q attenuation

T0 from track topologies

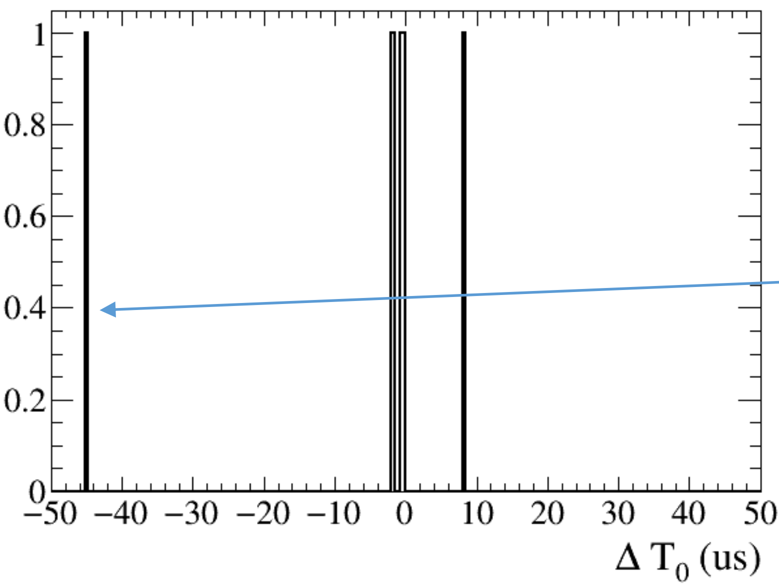


Example to illustrate idea for one event

Black is true T_0 of each CR depositing energy in the active volume in (-4ms, +4ms)
➔In actual measurement this would be results of LightT0Analysis

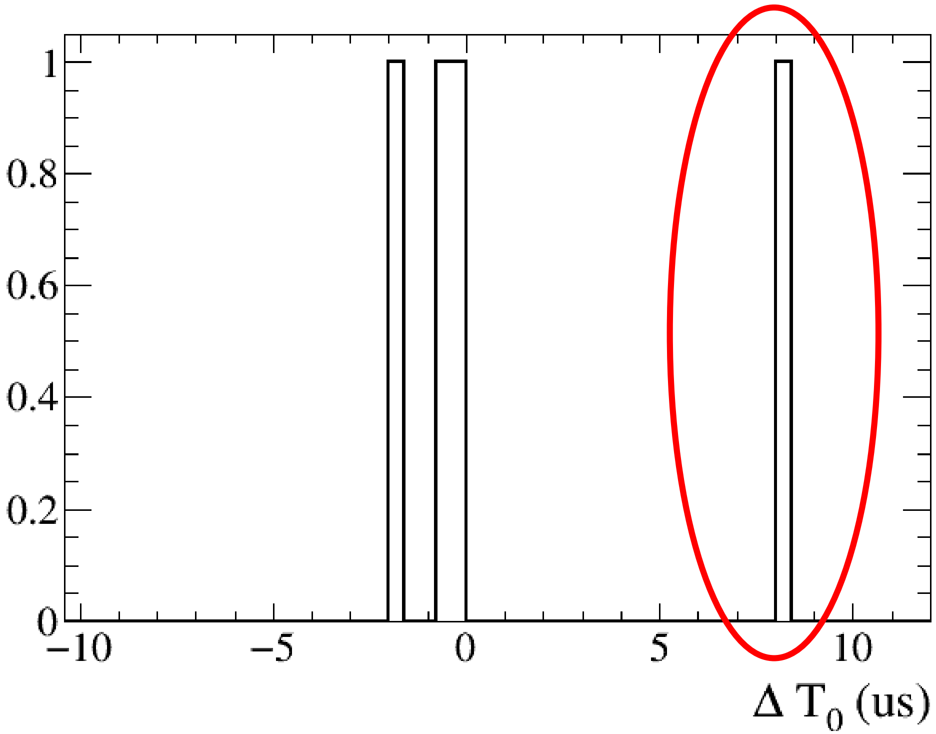
Red is T0 is from track topologies (5 tracks)

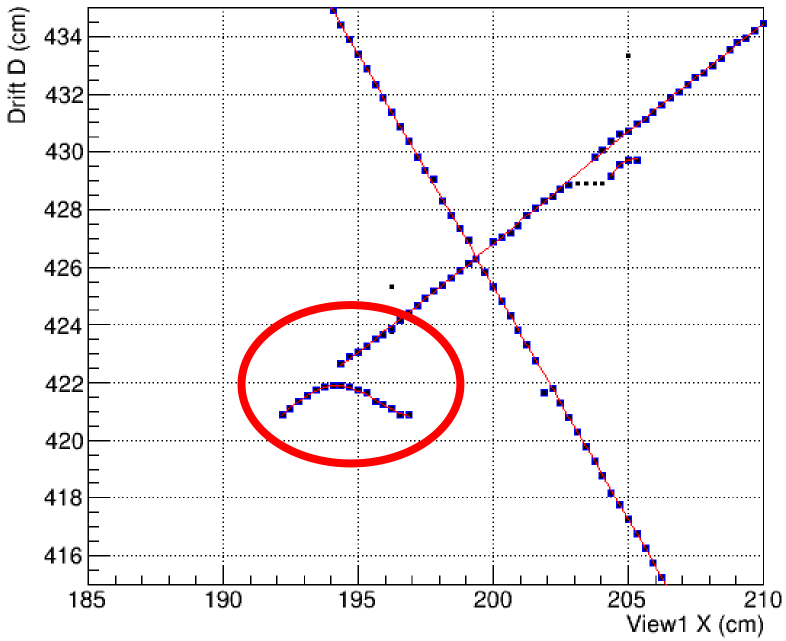
Difference between T0 reco and nearest true T0



Track mismatched between views (due to incomplete merging of segments in one of the views)

T0 from track topologies





The track with $\Delta T_0 \approx 8$us is correctly identified but the start position is biased by ~1 cm due to initial hits attributed to a delta ray

With tight time cut on ΔT_0 can select a few clean tracks per event for gain monitoring
Will need to perform more systematic studies on a larger event sample to understand appropriate cuts on ΔT_0

Summary

- Identification of CR background and its processing is the essential part of online monitoring and vital to ensure we are taking good data
- The first set of tools to get started with some basic track reconstruction of these CRs has been prepared
- Not perfect: important to find balance between processing time vs overall performance
- More systematic studies to be performed

Removal is a more challenging topic

- Look at handling CRs in the presence of the beam event and how to deal with that
- Study of the correlation with reconstructed light information
  - Can get T_0 from track topology and relate that to T_0 from light signals for some cases
  - How well do we understand the number of expected tracks from CRs in the detector given the information from the light data?