INTT cluster(s) in silicon seeds

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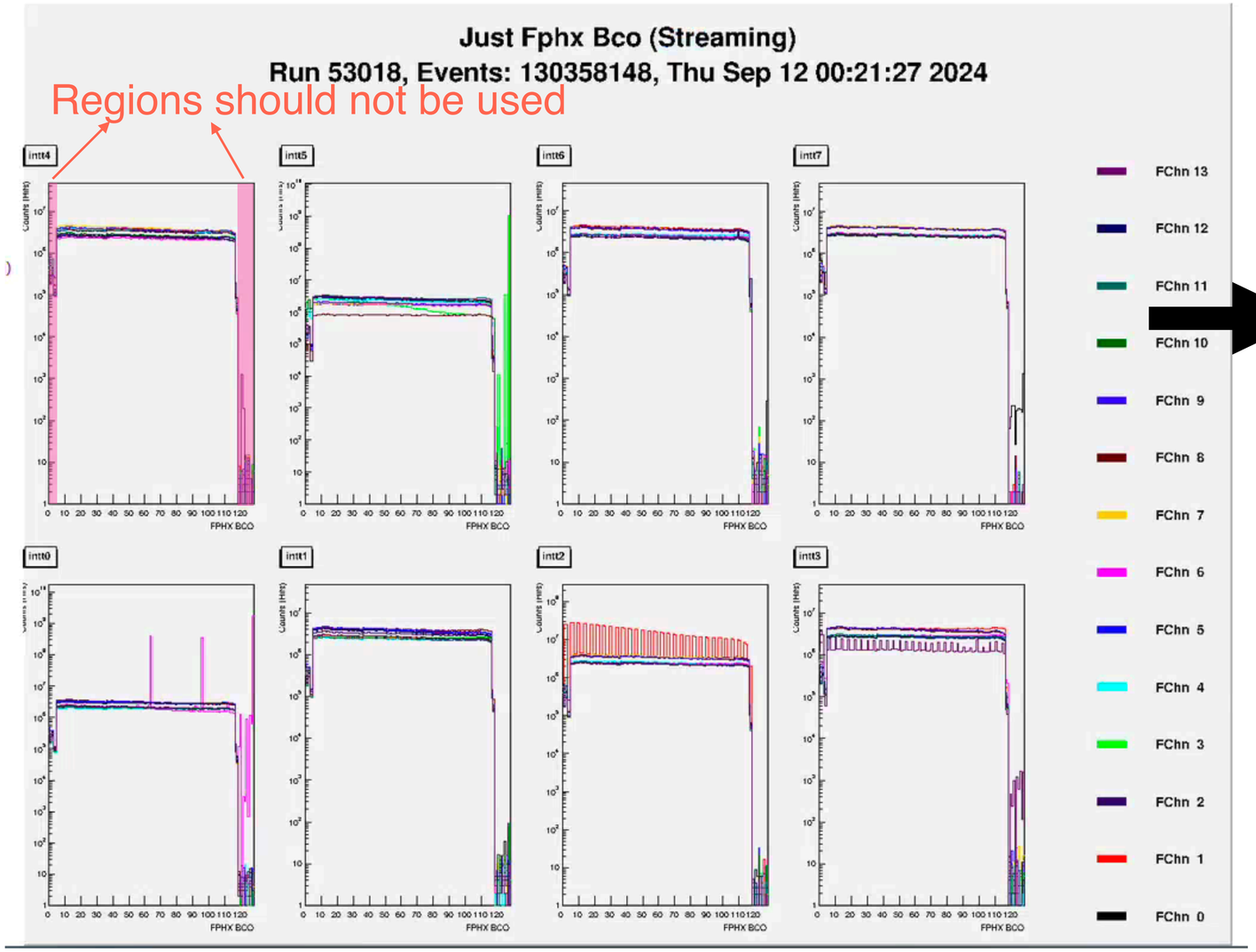
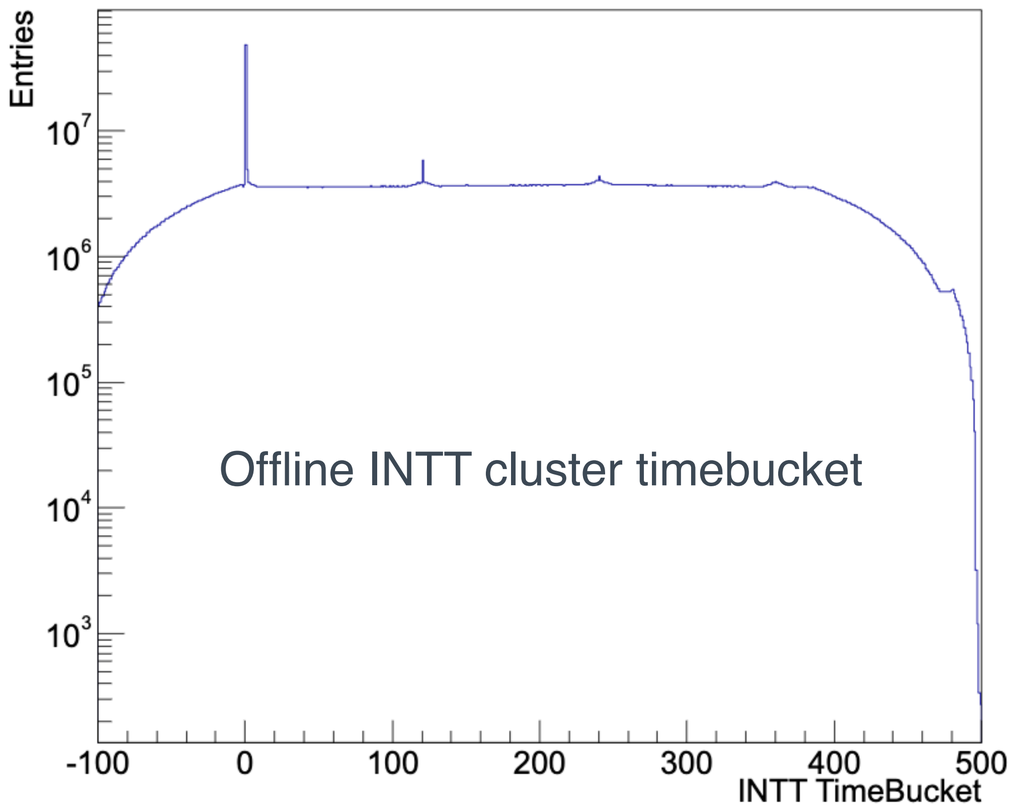
INTT Timebucket





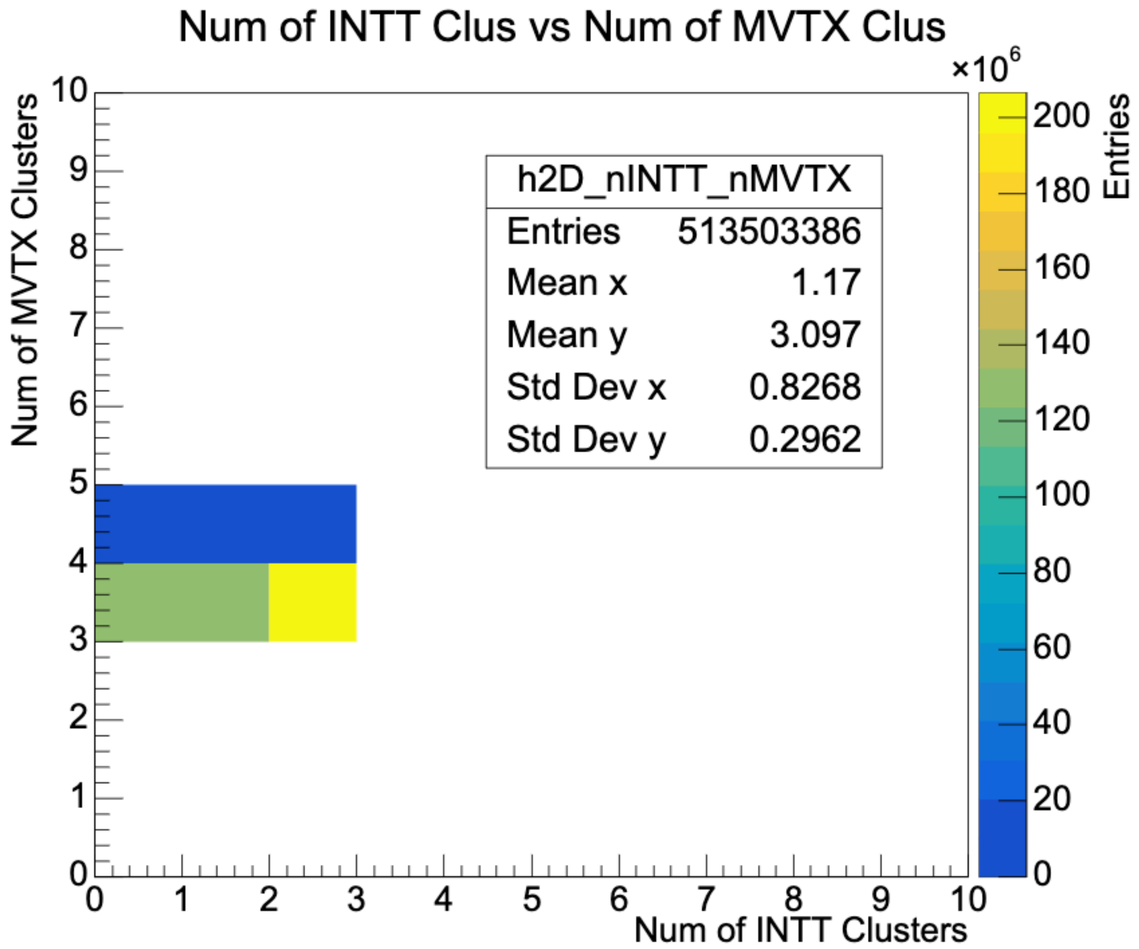
Q1: How from left to right?
Q2: Why three more bumps?
Q3: are the forbidden region included?

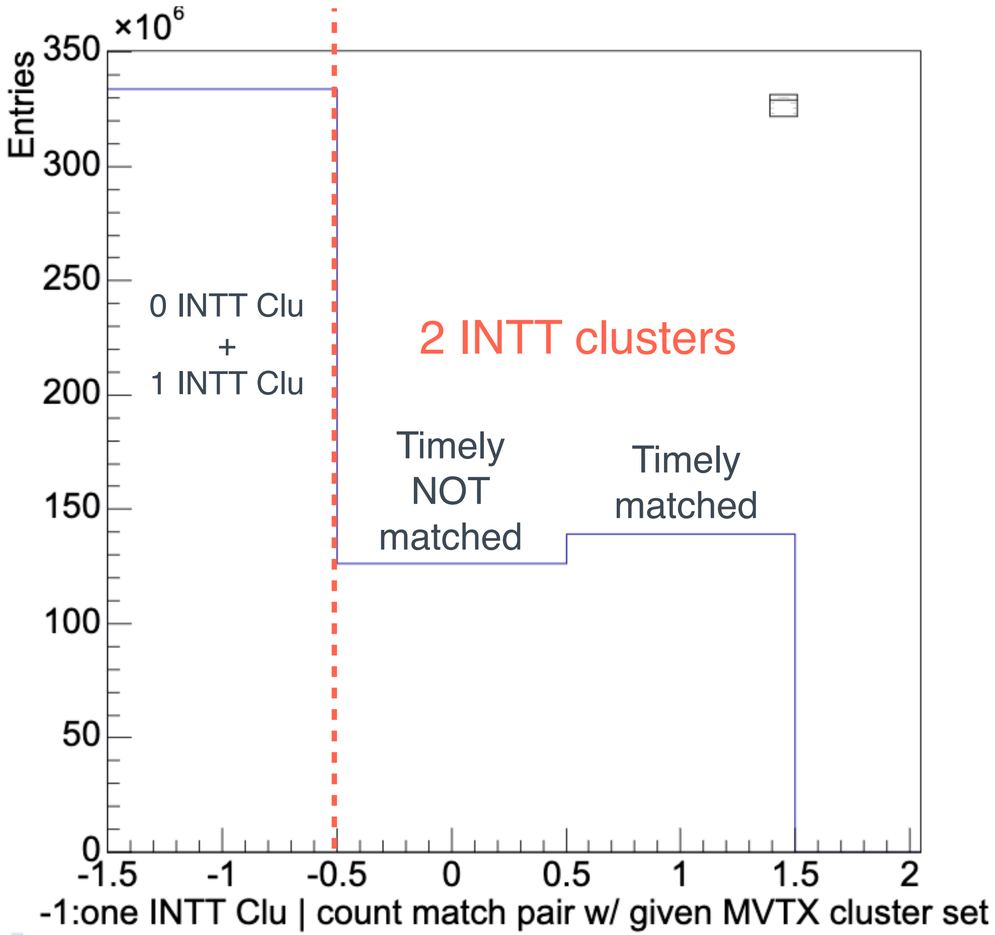
Selections

- Event selections:
  - None

- Track selections:
  - nMVTX Cluster == 3
  - nINTT Cluster == 2
  - !(Track charge != 0)
  - Track pT >= 0.2 GeV && Track pT <= 10 GeV
  - Track Eta <= 1.0
  - (No cut on DCA, DCAXY, track crossing value, and track-vertex association)

N INTT clusters in a silicon seed





In all silicon seeds,
27% no INTT cluster
29% 1 INTT cluster
44% 2 INTT clusters

→

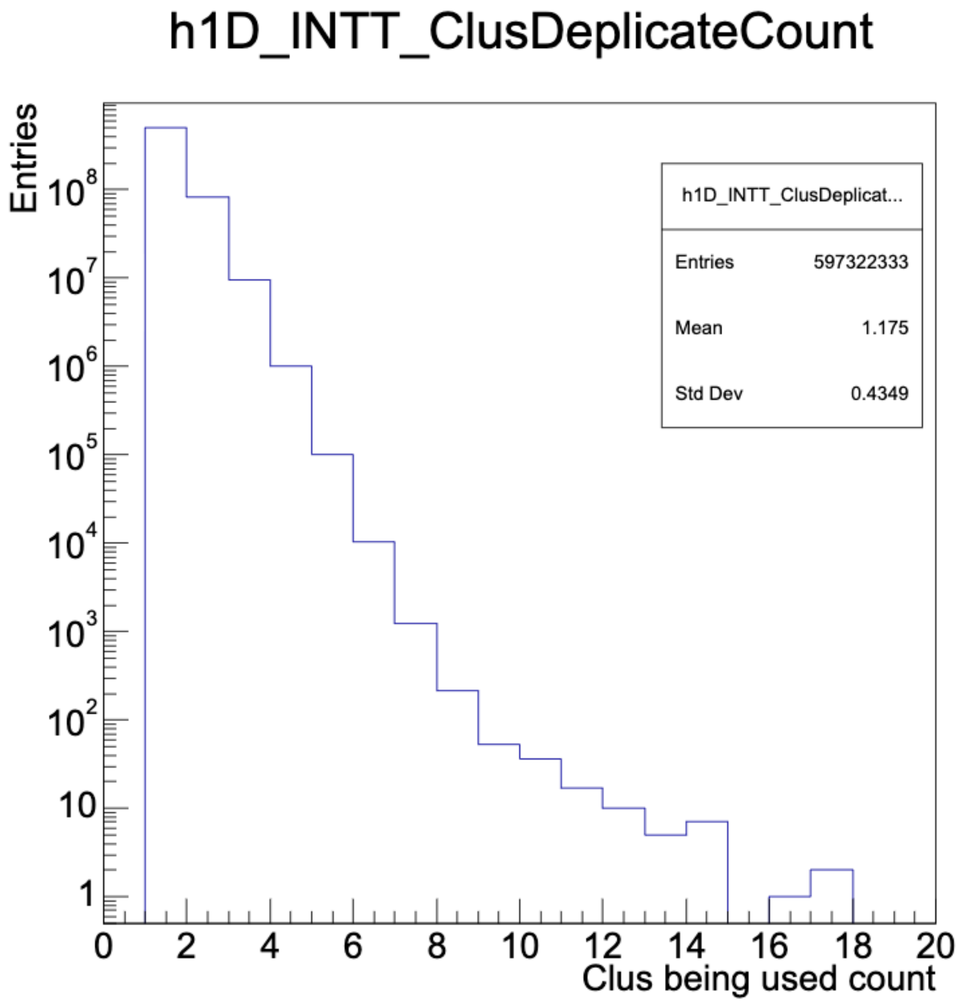
In all 2-INTT-cluster silicon seed,
~45% of seeds have INTT cluster-timebucket difference != 0

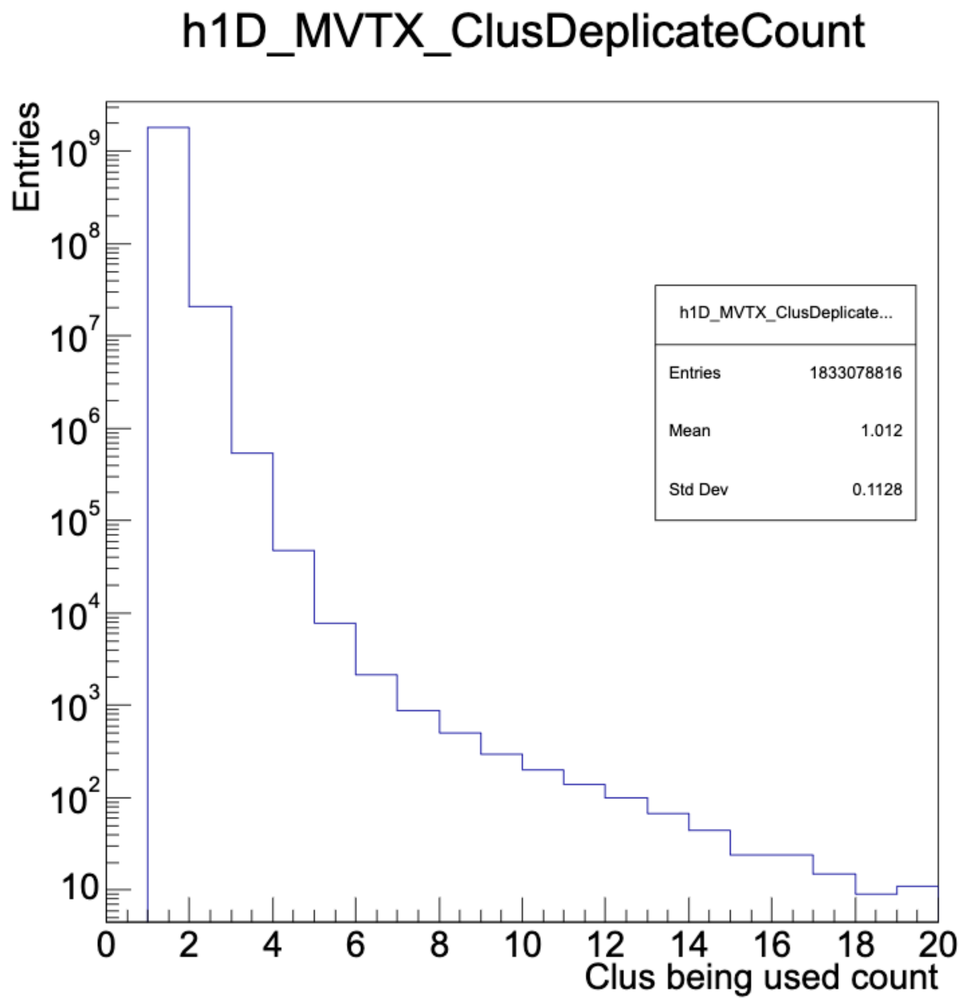
→

A natural question:
how can it be possible?

Cluster duplication distributions

- Number of silicon seeds that a cluster is associated with, for both INTT and MVTX, respectively

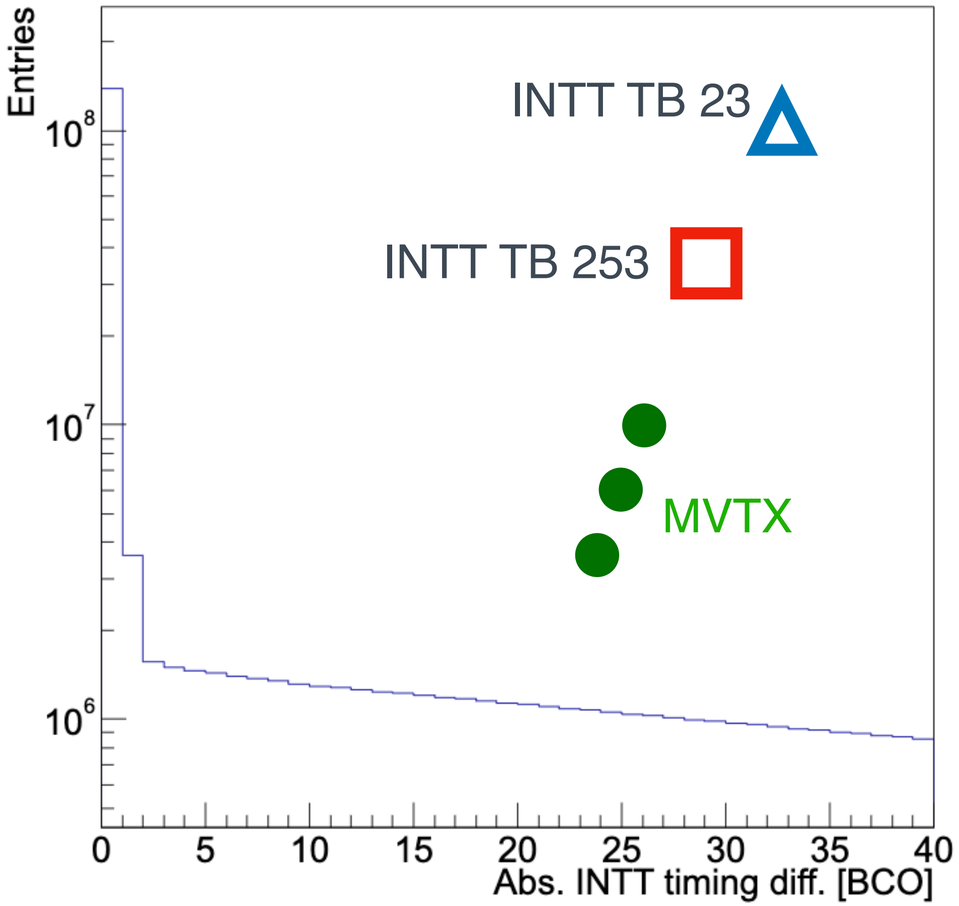


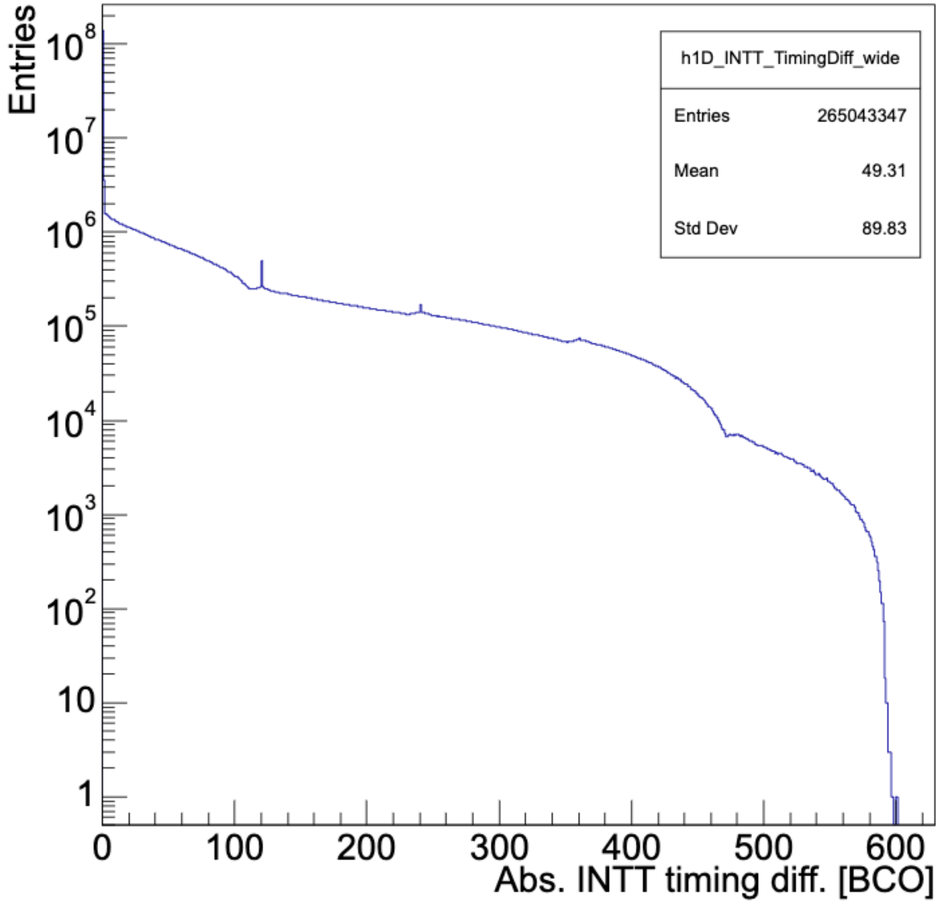


Both INTT and MVTX clusters are allowed to be associated with multiple tracks

Timebucket difference of the INTT clusters in a silicon seed

The timebucket difference of the INTT clusters in a silicon seed, with different histogram ranges



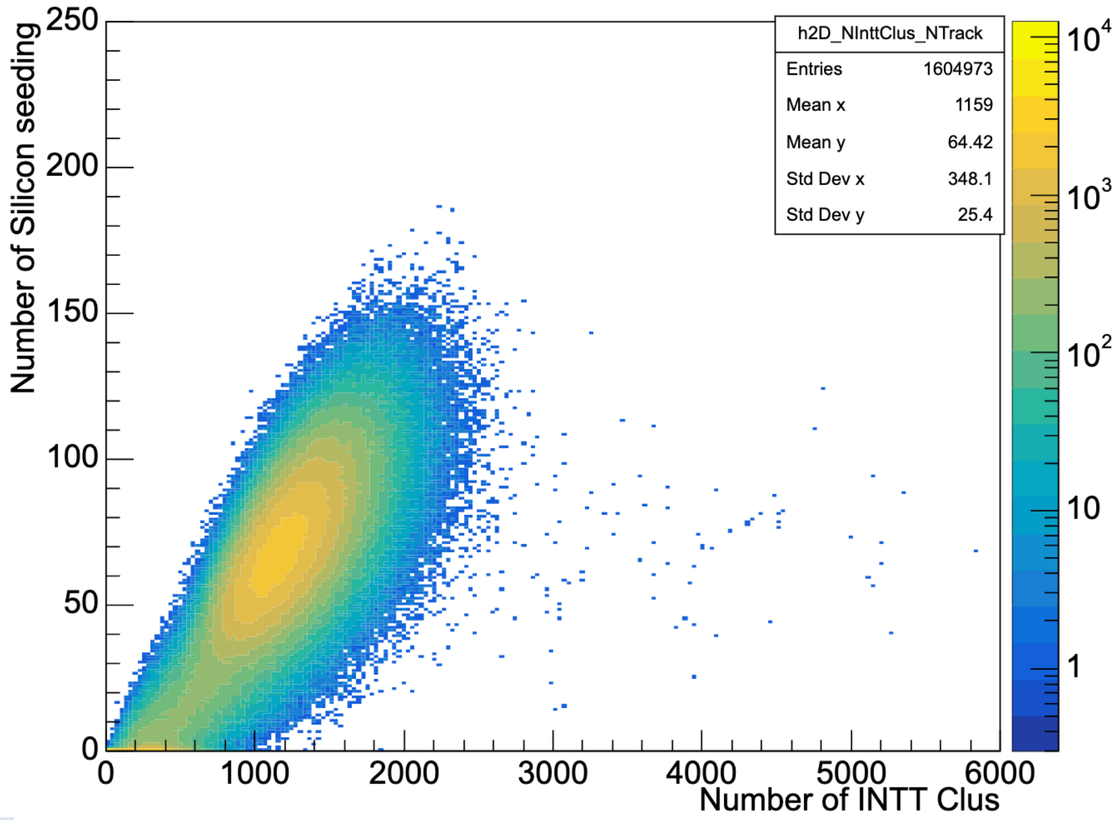


~45% of silicon seeds have INTT cluster-TimeBucket difference != 0

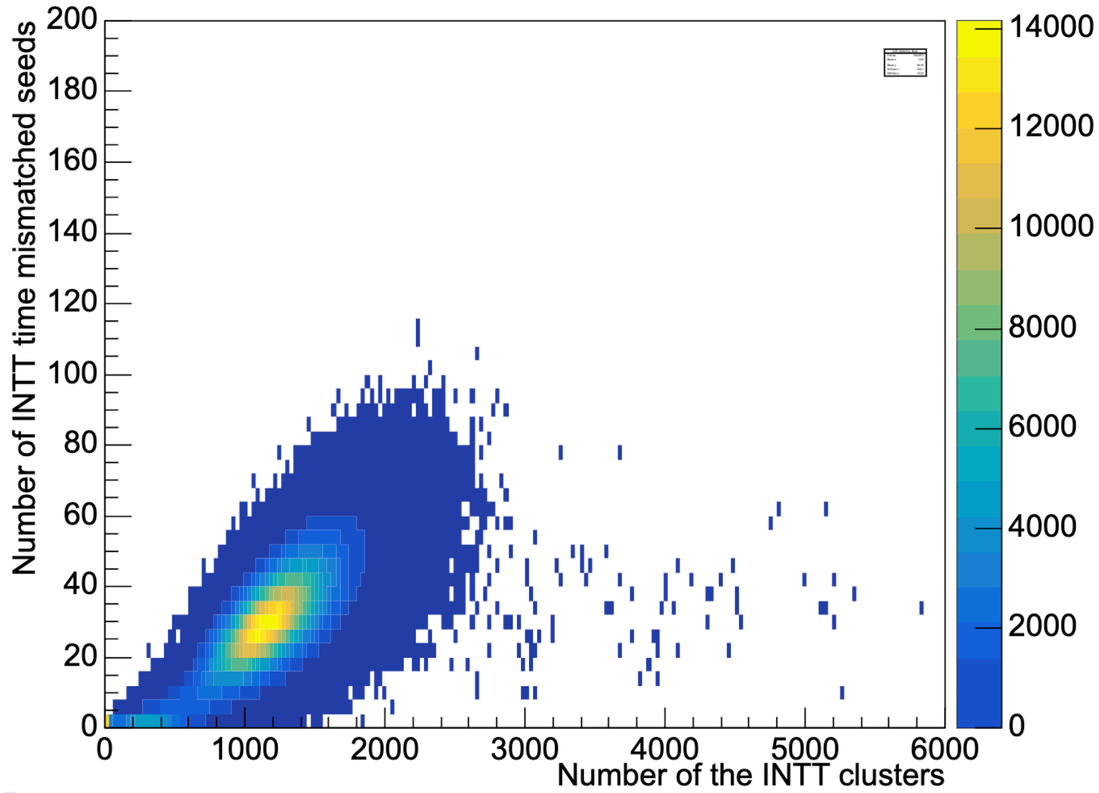
Focus of this slide: try to understand those silicon seeds

Correlations

N INTT clusters vs. N silicon seeds



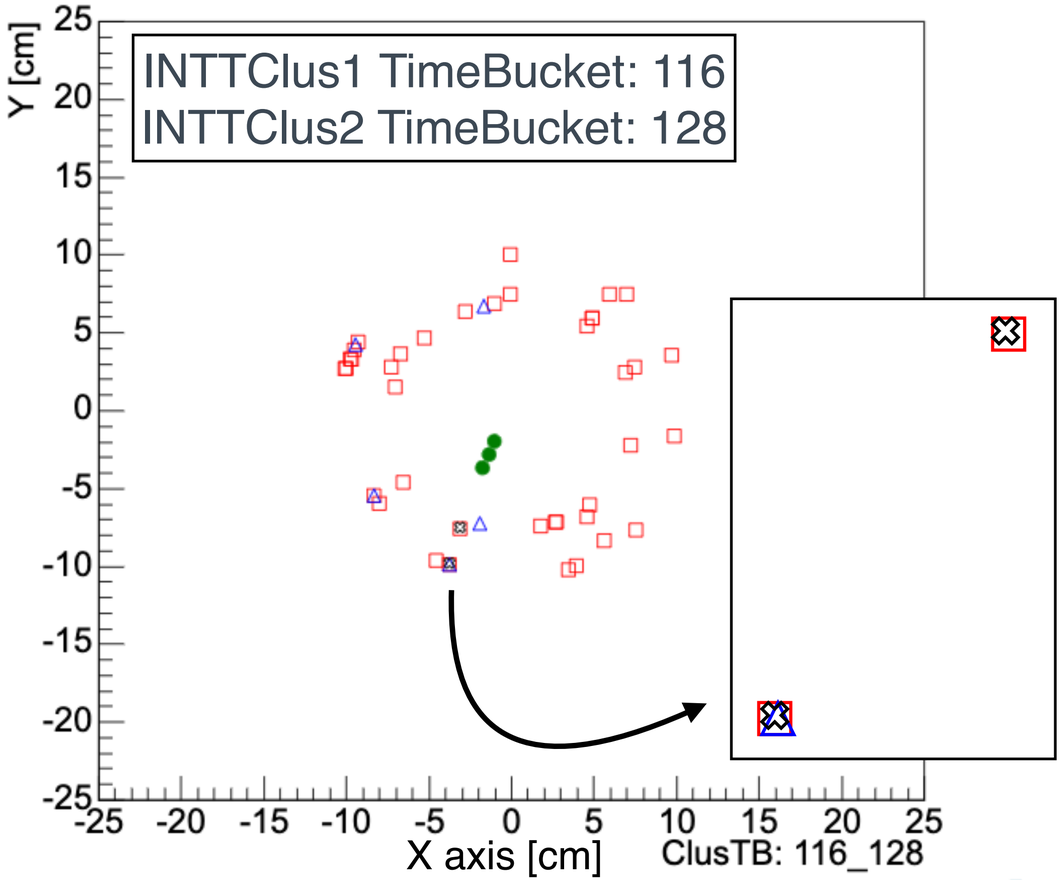
N INTT clusters vs. N INTT-timebucket-mismatched seeds

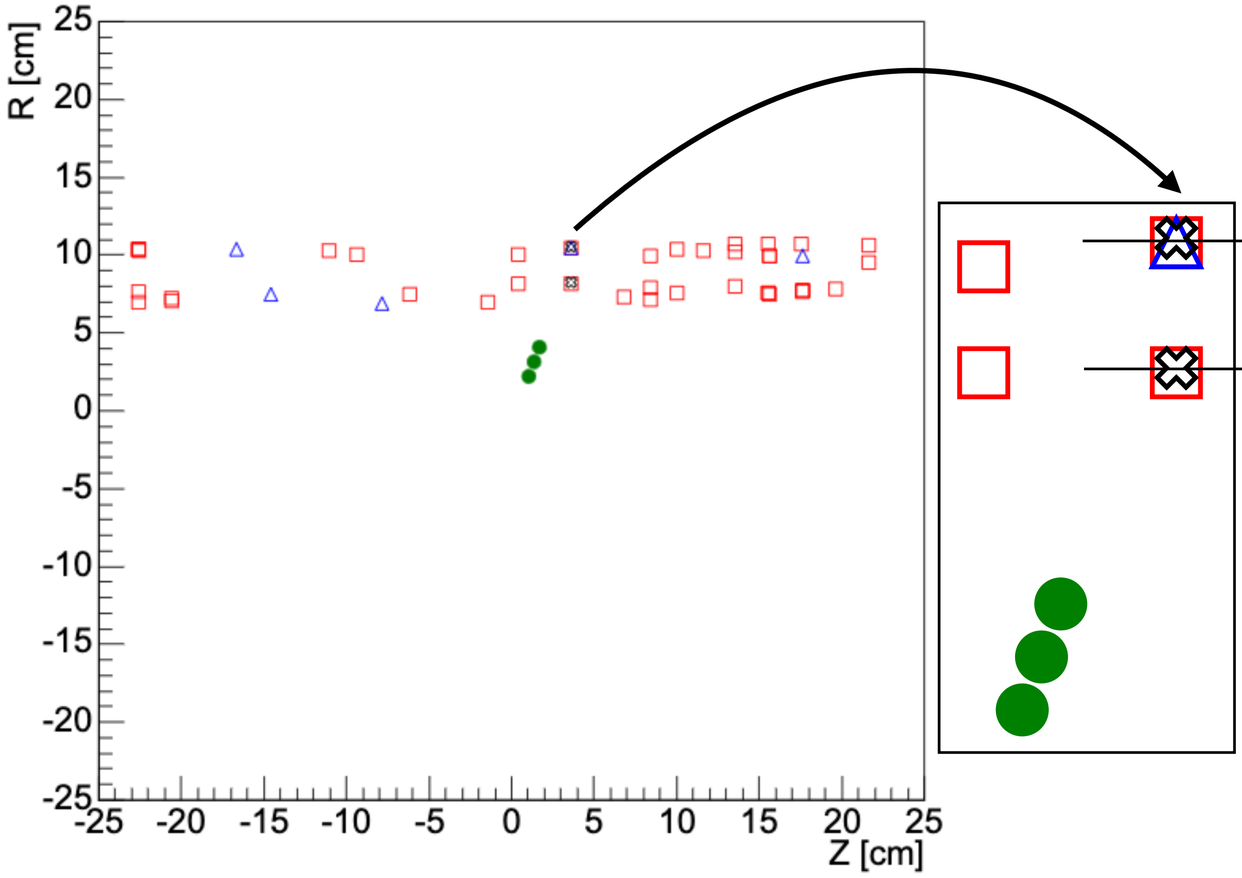


Example of INTT cluster timing mismatch in a silicon seed

One event in Run 53018

In this silicon seed: INTT TimeBucket diff.: 116-128 = 12





All INTT clusters w/ TimeBucket of 116

All INTT clusters w/ TimeBucket of 128

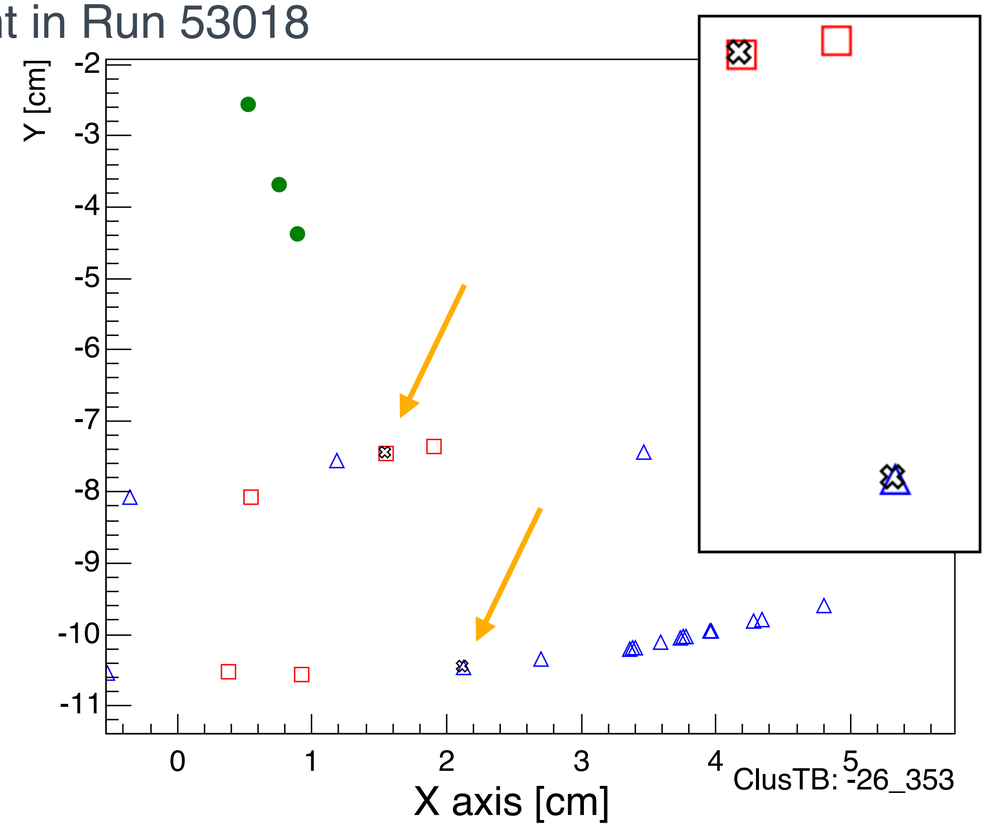
3 MVTX clusters in this silicon seed

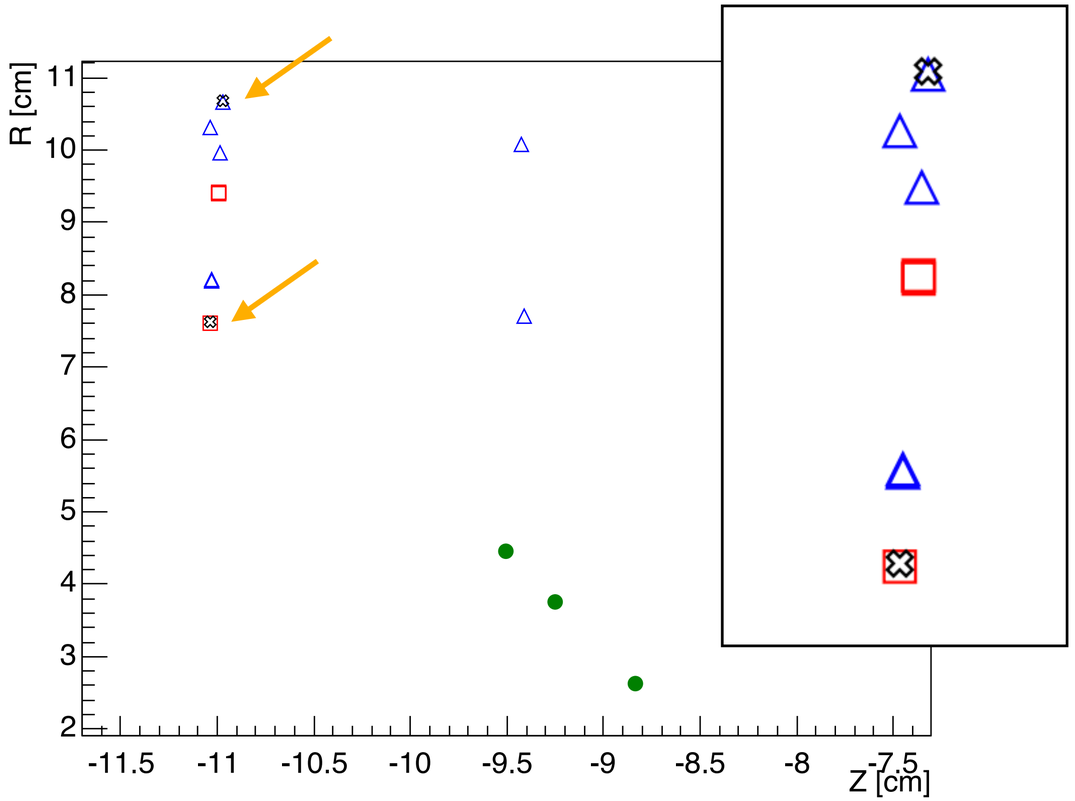
2 INTT clusters in this silicon seed that has timing masmatch (s are the subset of plus)

Two INTT clusters with the same TimeBucket are available for the seed finder to pair them with the MVTX triplet. But somehow it didn't happen

Example of INTT cluster timing mismatch in a silicon seed

One event in Run 53018





All INTT clusters w/ TimeBucket of -26

All INTT clusters w/ TimeBucket of 353

3 MVTX clusters in this silicon seed

2 INTT clusters in this silicon seed that has timing masmatch (s are the subset of plus)

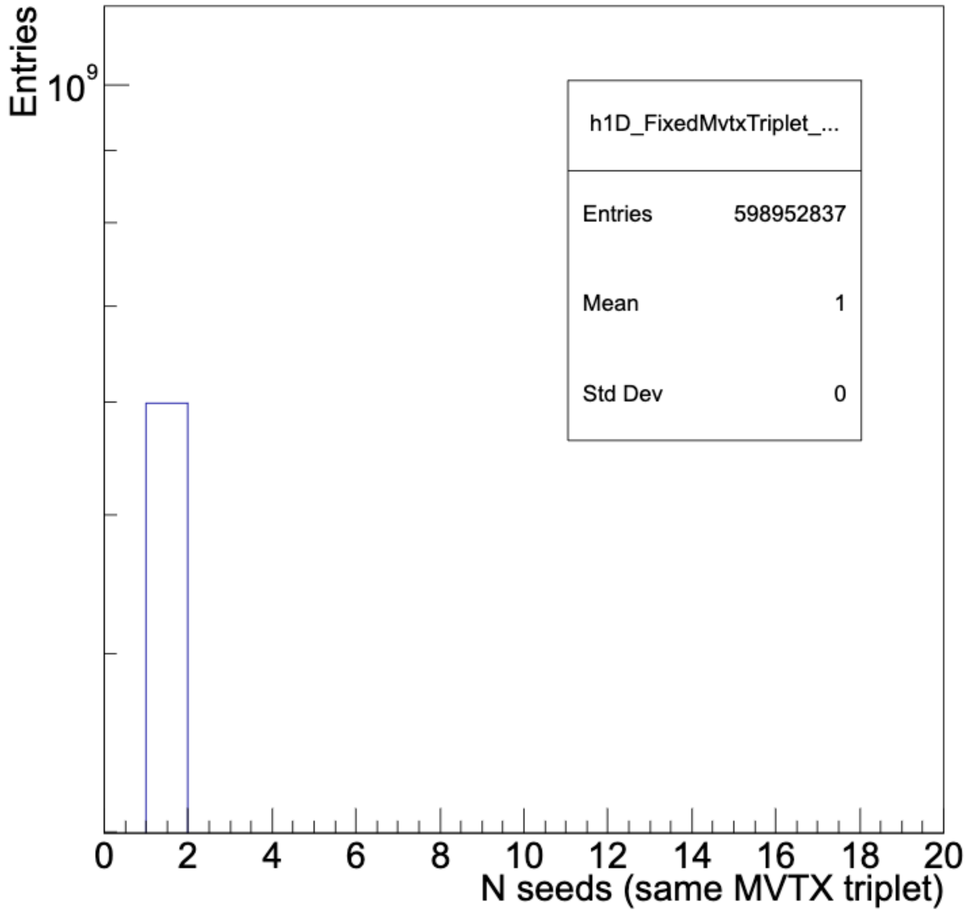
In this case, there are just no clusters available

(no and overlap)

(Both clusters incorrectly associated with the MVTX triplet?)

Seed variety

- Distribution of the number of silicon seeds with a given MVTX triplet (quadruplet)
  - Using cluster_key to fix the clusters of the MVTX-triplet (quadruplet), regardless the order



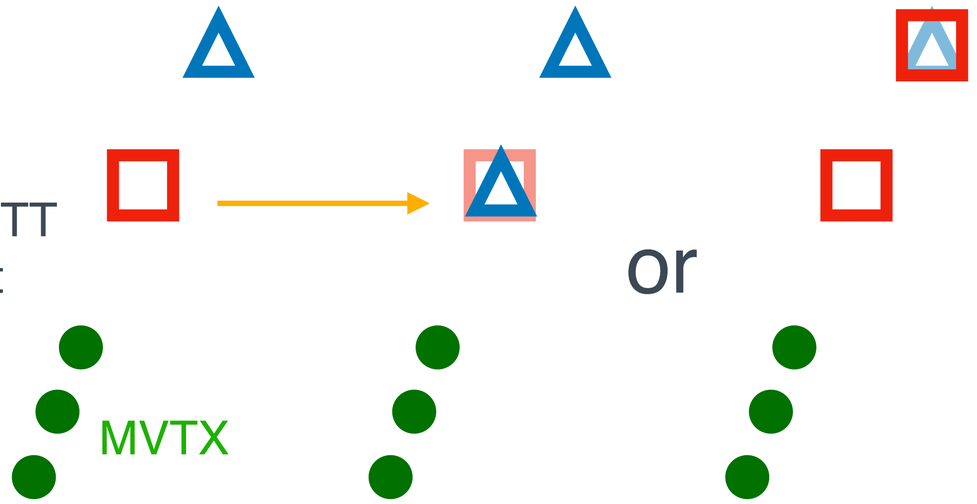
For one set of MVTX clusters, currently it only corresponds to one silicon seed

Try to find a replacement cluster

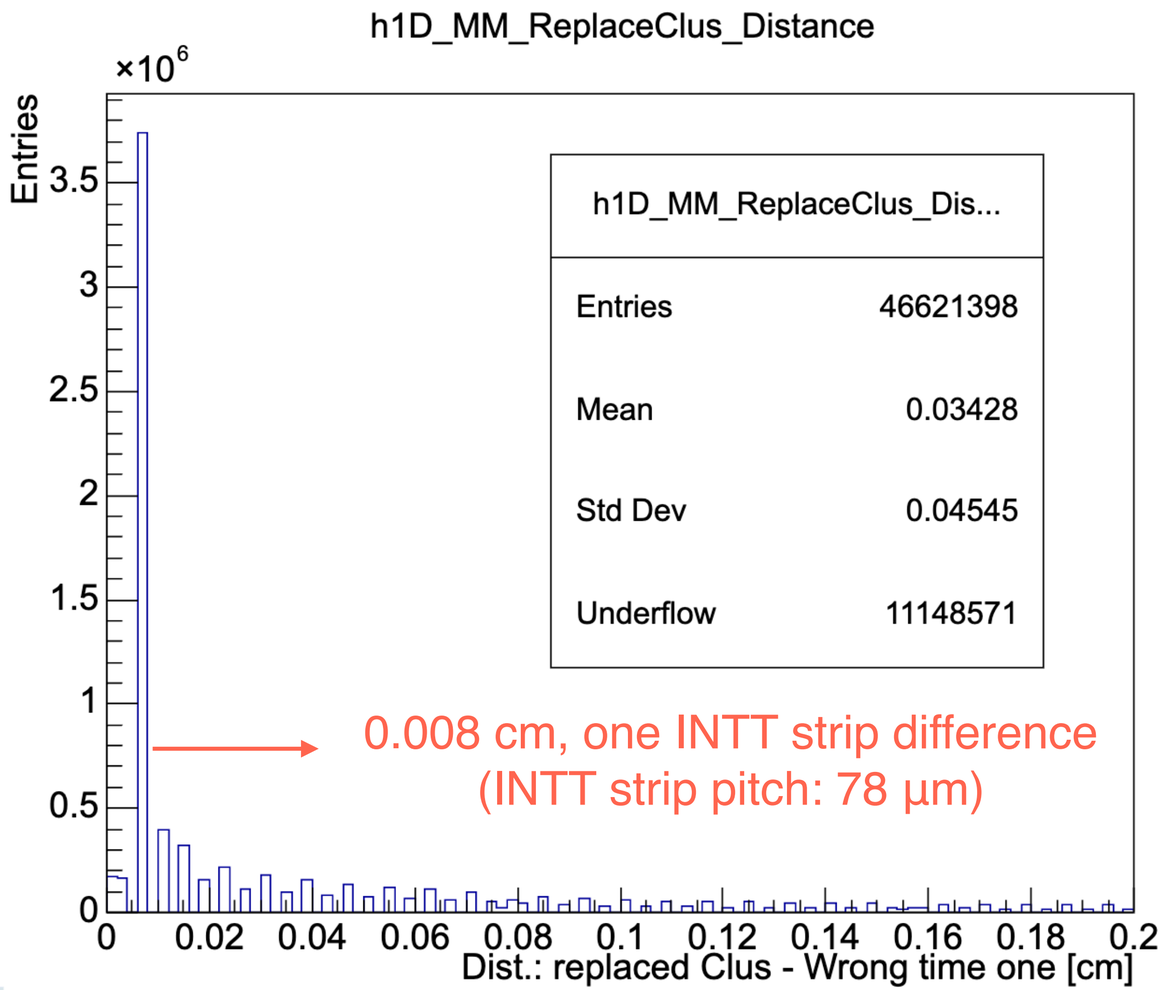
- Define the two INTT clusters in a seed as **InttClus1** and **InttClus2**
- Assuming the timebucket of **InttClus1** (**InttClus2**) is incorrect, then try to find a replacement cluster in the **InttClus2** (**InttClus1**)-timebucket cluster pool

- Pre-selections on the replacement cluster
  - Same layer ID as the wrong-timing cluster
  - In the radius-z plane, the INTT cluster strip intersects with the MVTX-triplet extrapolation

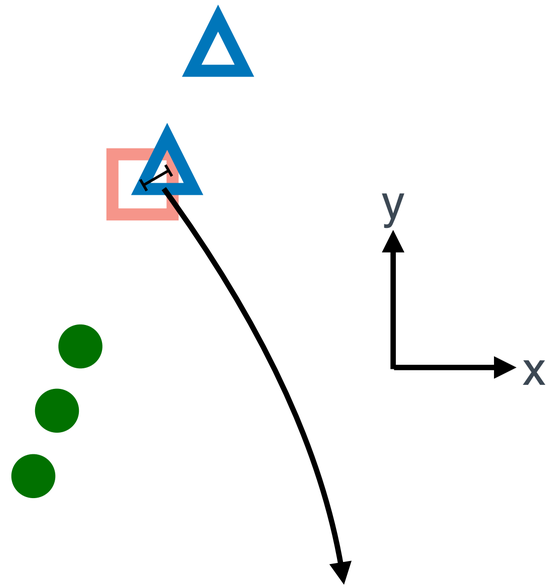
Triangle and square indicate the INTT clusters with different timebucket



Try to find a replacement cluster



Triangle and square indicate the INTT clusters with different timebucket



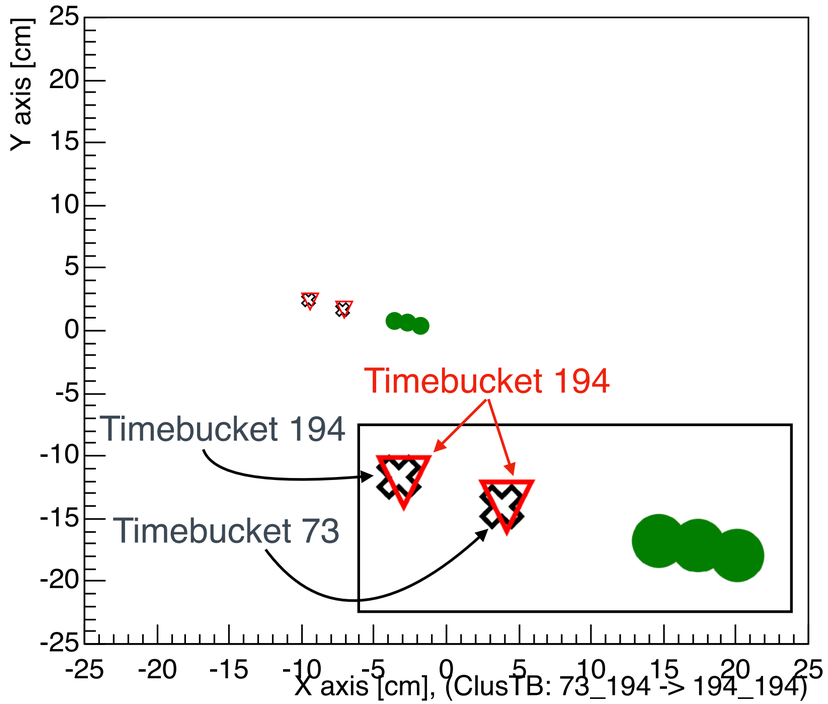
Distance in x-y plane between the replacement cluster and the original one with wrong timebucket

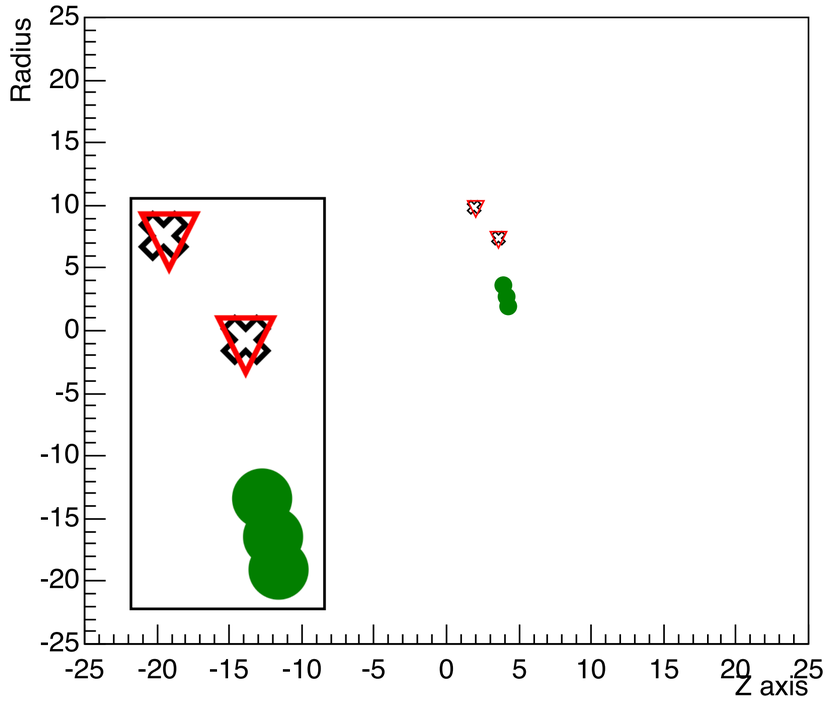
With the distance tolerance of 80 µm, 8.7% of seeds could have the replacement cluster with the same timebucket as that of the remaining one (the cluster assumed to have the correct timebucket)

Try to find a replacement cluster

Replacement cluster requirements:

- Same layer ID as the wrong-timing cluster
- In the radius-z plane, the INTT cluster strip intersects with the MVTX-triplet extrapolation
- Distance deviation <= 80 μm





: Original INTT clusters from the silicon seed, with timebucket of 73 and 194

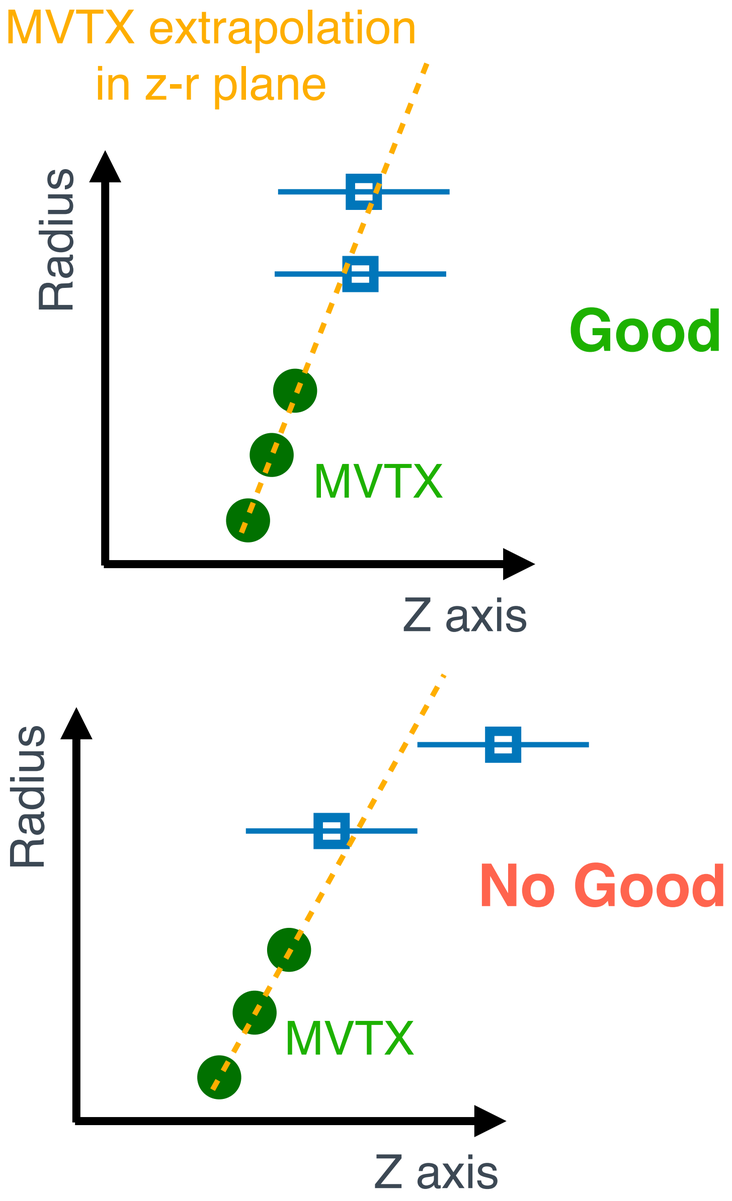
: New pair of INTT clusters with the same timebucket 194 that can match the original pattern

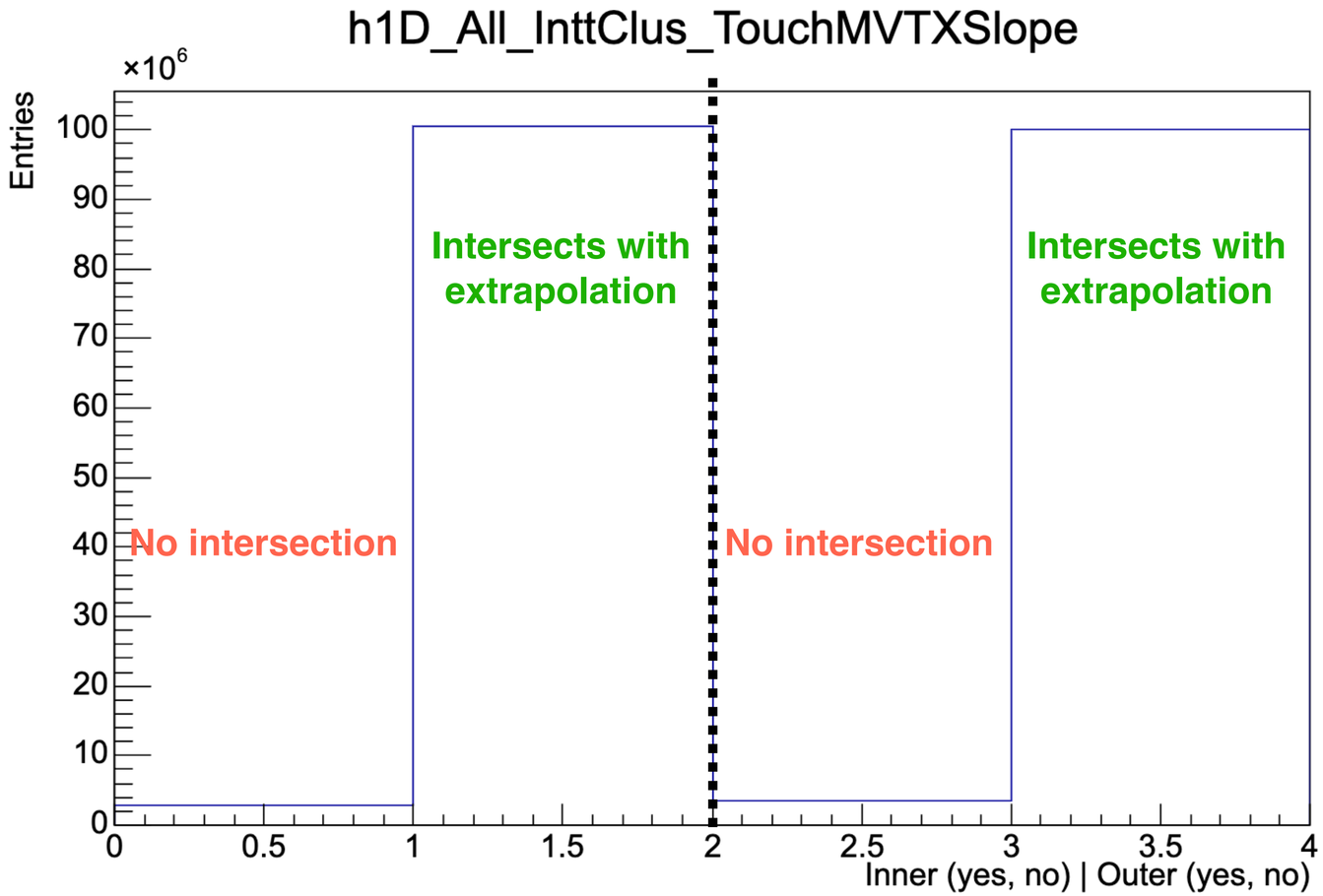
Some thoughts

- Yes, you might be able to just neglect them by requiring the timebucket difference to be <= 1. But a question naturally arose is:
  - if we trust the MVTX triplet, assuming this MVTX triplet is really from a charged particle, how come INTT doesn’t see it?
    - As we know, the INTT hit detection efficiency is very high
    - As we know, the INTT bad area is just around 5%

- If you just neglected them, I'm not sure whether this only has an impact on the tracking efficiency, or there are some systematic problems in the offline analysis chain?

INTT strip intersection check



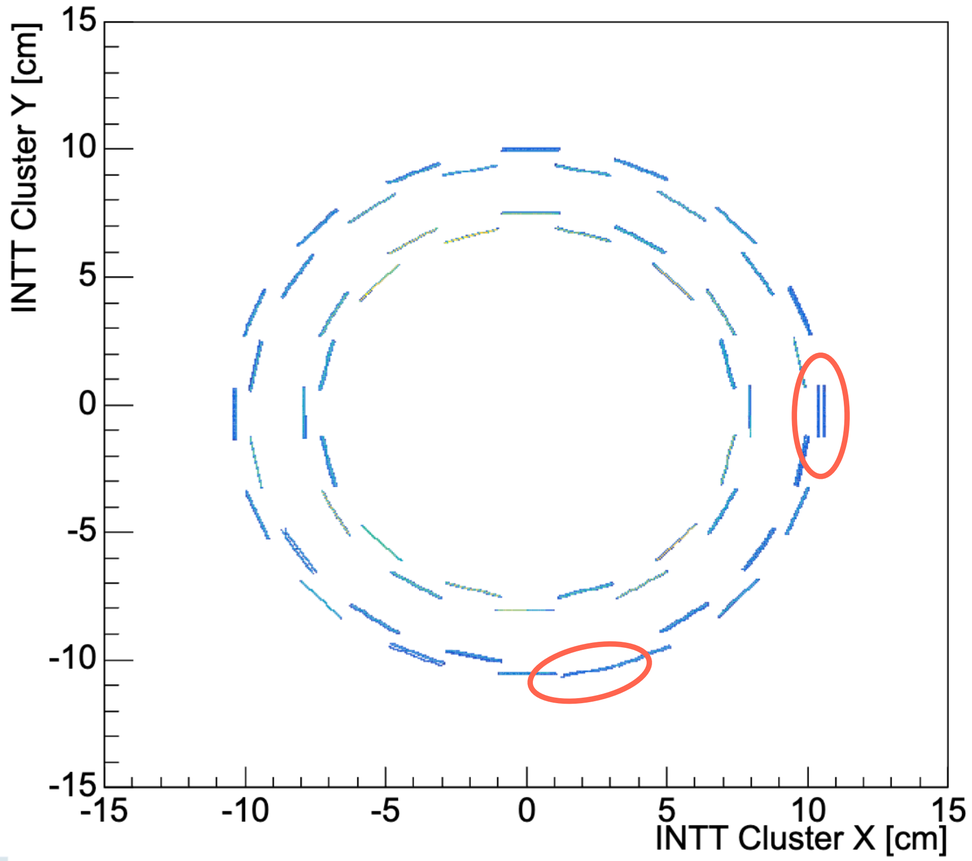


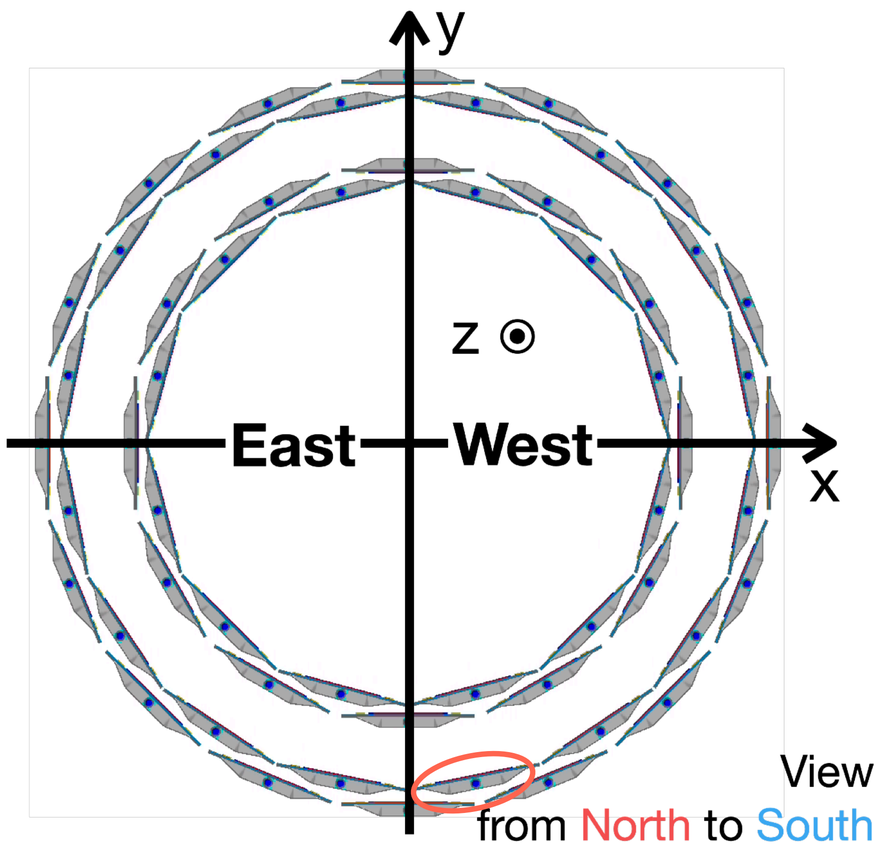
INTT cluster in inner layer **INTT cluster in outer layer**

~3% of silicon seeds have at least one INTT cluster
not intersecting with MVTX-triplet extrapolation
(with tolerance of 0.05 cm in both sides of strip)

INTT alignment paramter

- INTT geometry is a bit disconnected from the real geometry
  - Some sensors are away from their own barrels after applying the alignment parameters
  - Could be due to no constraints in the radial direction in the misalignment study





Conclusion

- In the current silicon seeding algorithm,
  - 27% have no INTT cluster
  - 29% have 1 INTT cluster
  - 44% have 2 INTT clusters

- In those silicon seeds with 2 INTT clusters (44%), 45% have a non-zero INTT cluster-timebucket difference
  - The purity: 44% x 55% = 24.2%
  - This is so low!
  - A natural question, how can it be possible!?

- In the current silicon seeding algorithm,
  - One cluster can be associated with multiple silicon seeds
  - But currently, one set of MVTX triplet (quadruplet) only associates with one seed

- For silicon seeds with INTT cluster timebucket difference that differs from zero, around 9% of them could find a replacement cluster with the same timebucket (assuming one of the INTT clusters is correctly matched to the MVTX triplet)
  - Studying the rest 90% seeds is in progress

- ~3% of silicon seeds have at least one INTT cluster not intersecting with the MVTX-triplet extrapolation

The remaining INTT relevant tasks

As of September 30, 2025

INTT Barrel NIM paper
Chip timing instability
Hit-carried-over issue in pp, in streaming and triggered modes
Hit-carried-over issue in Au+Au, triggered mode
Good run list (Run 24 and Run25)
Cluster splitting (one cluster showed up in multiple adjacent BCOs)
Fraction of hits moved to next BCO bin
INTT MC fine tuning (Geometry, ClusAdc, ClusPhiSize)
INTT geometry distorted by the alignment parameters

These studies could also improve the matching efficiency!!!!

Back up

MVTX cluster split?

The MVTX cluster, 7486127996929, is used in 7 tracks.
In this track, nINTT: 1, nMVTX: 4
The MVTX cluster, 7486127996929, position is: -0.333307 2.15619 4.71476
The MVTX cluster, 291160127963144, position is: -0.669343 2.81597 5.85756
The MVTX cluster, 291160127963145, position is: -0.665772 2.81783 5.86341
The MVTX cluster, 577170590138369, position is: -1.10697 3.72623 7.42418
The INTT cluster, position and timebucket is: 5.06989 -5.66479 13.5827 175
track pt, eta, phi, charge: 0.161452 1.24265 2.10414 -1

In this track, nINTT: 0, nMVTX: 4
The MVTX cluster, 7486127996929, position is: -0.333307 2.15619 4.71476
The MVTX cluster, 7486127996931, position is: -0.346497 2.14951 4.74088
The MVTX cluster, 291160127963145, position is: -0.665772 2.81783 5.86341
The MVTX cluster, 577170590138369, position is: -1.10697 3.72623 7.42418
track pt, eta, phi, charge: 0.568693 1.23272 1.99822 -1

In this track, nINTT: 0, nMVTX: 4
The MVTX cluster, 7486127996929, position is: -0.333307 2.15619 4.71476
The MVTX cluster, 7486127996931, position is: -0.346497 2.14951 4.74088
The MVTX cluster, 291160127963143, position is: -0.544075 2.88132 5.46288
The MVTX cluster, 577033151184897, position is: -0.824223 3.99064 6.57742
track pt, eta, phi, charge: 0.244602 0.858887 1.87799 -1

In this track, nINTT: 0, nMVTX: 4
The MVTX cluster, 7486127996929, position is: -0.333307 2.15619 4.71476
The MVTX cluster, 7486127996931, position is: -0.346497 2.14951 4.74088
The MVTX cluster, 291160127963141, position is: -0.544071 2.88132 5.45411
The MVTX cluster, 577033151184897, position is: -0.824223 3.99064 6.57742
track pt, eta, phi, charge: 0.244731 0.859363 1.87796 -1

In this track, nINTT: 0, nMVTX: 4
The MVTX cluster, 7486127996928, position is: -0.326816 2.15952 4.67584
The MVTX cluster, 7486127996929, position is: -0.333307 2.15619 4.71476
The MVTX cluster, 293359151218692, position is: -1.14153 2.78294 6.77136
The MVTX cluster, 577170590138372, position is: -1.67062 3.20034 8.14877
track pt, eta, phi, charge: 0.427114 1.61344 2.5023 -1

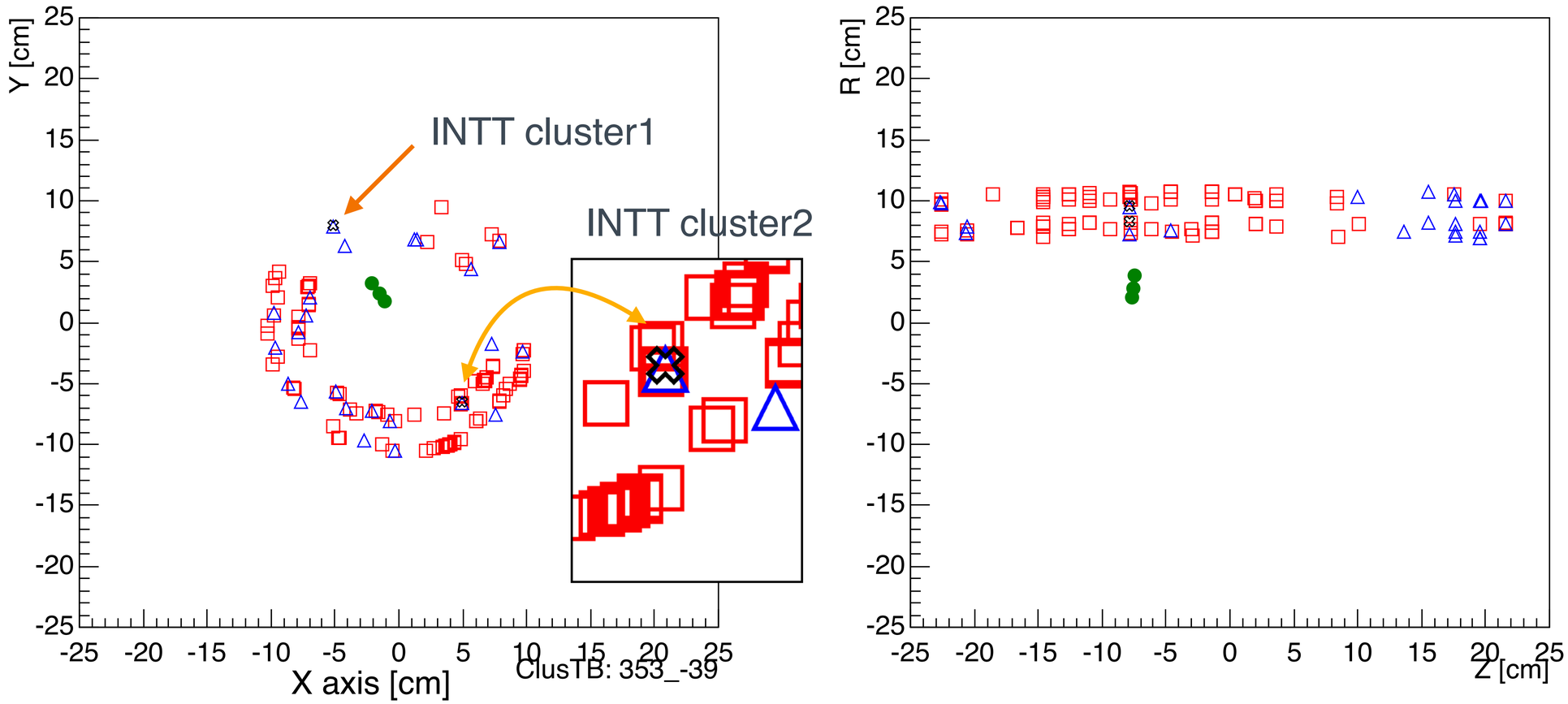
In this track, nINTT: 1, nMVTX: 4
The MVTX cluster, 7486127996929, position is: -0.333307 2.15619 4.71476
The MVTX cluster, 7486127996931, position is: -0.346497 2.14951 4.74088
The MVTX cluster, 293359151218693, position is: -1.14067 2.78396 6.77867
The MVTX cluster, 577170590138372, position is: -1.67062 3.20034 8.14877
The INTT cluster, position and timebucket is: 6.94057 -4.21435 19.5731 268
track pt, eta, phi, charge: 0.507529 1.60314 2.4502 -1

In this track, nINTT: 1, nMVTX: 4
The MVTX cluster, 7486127996929, position is: -0.333307 2.15619 4.71476
The MVTX cluster, 7486127996931, position is: -0.346497 2.14951 4.74088
The MVTX cluster, 293359151218691, position is: -1.13679 2.78861 6.77282
The MVTX cluster, 577170590138372, position is: -1.67062 3.20034 8.14877
The INTT cluster, position and timebucket is: -4.76934 5.26658 15.5794 278
track pt, eta, phi, charge: 0.138008 1.60269 2.39293 -1

_928, _929, _931 are very close to each other

Example of INTT cluster timing mismatch in a silicon seed

Run 53018



All INTT clusters w/ TimeBucket of 353

All INTT clusters w/ TimeBucket of -39

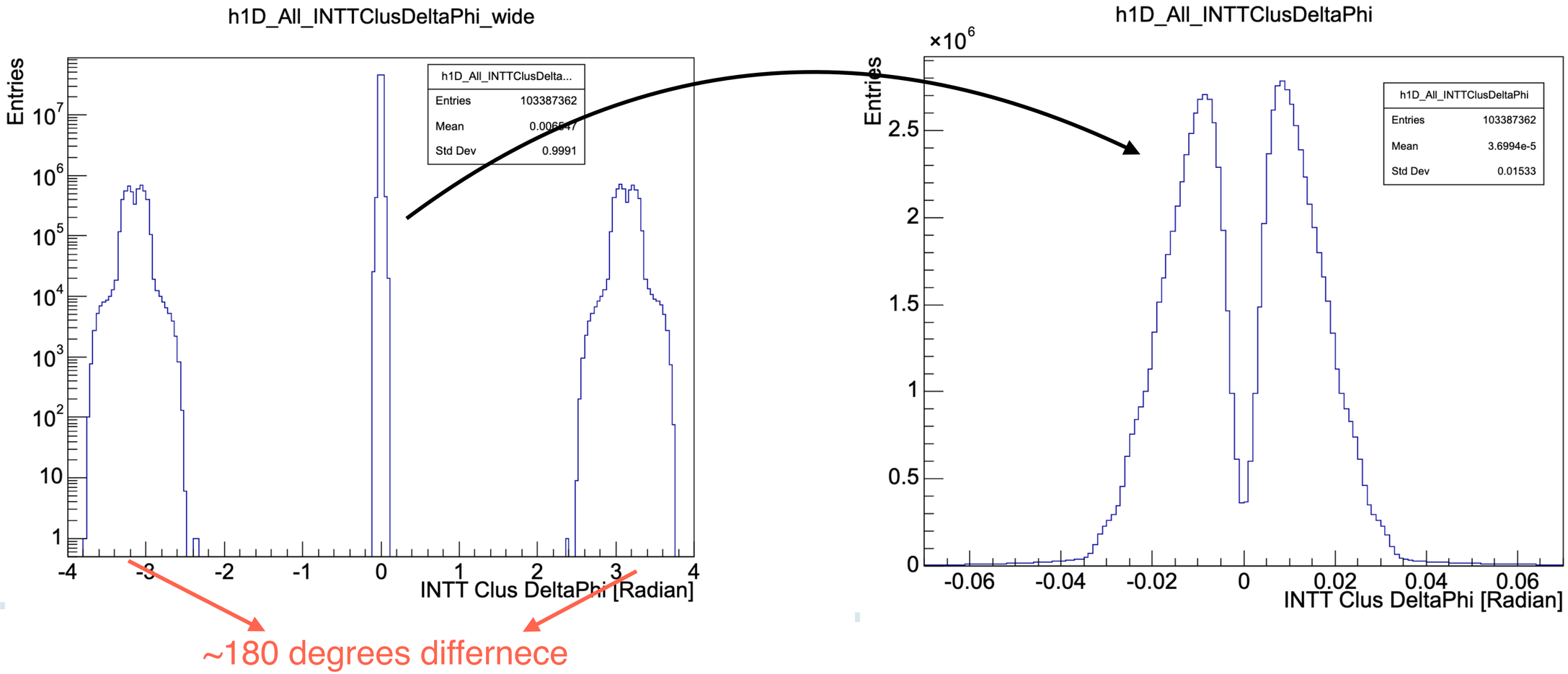
3 MVTX clusters in this silicon seed

2 INTT clusters in this silicon seed that has timing masmatch (✕s are the subset of □ plus △)

A weird seed, where the Δϕ of INTT clusters is ~ 180 degrees

INTT seed-cluster Δϕ

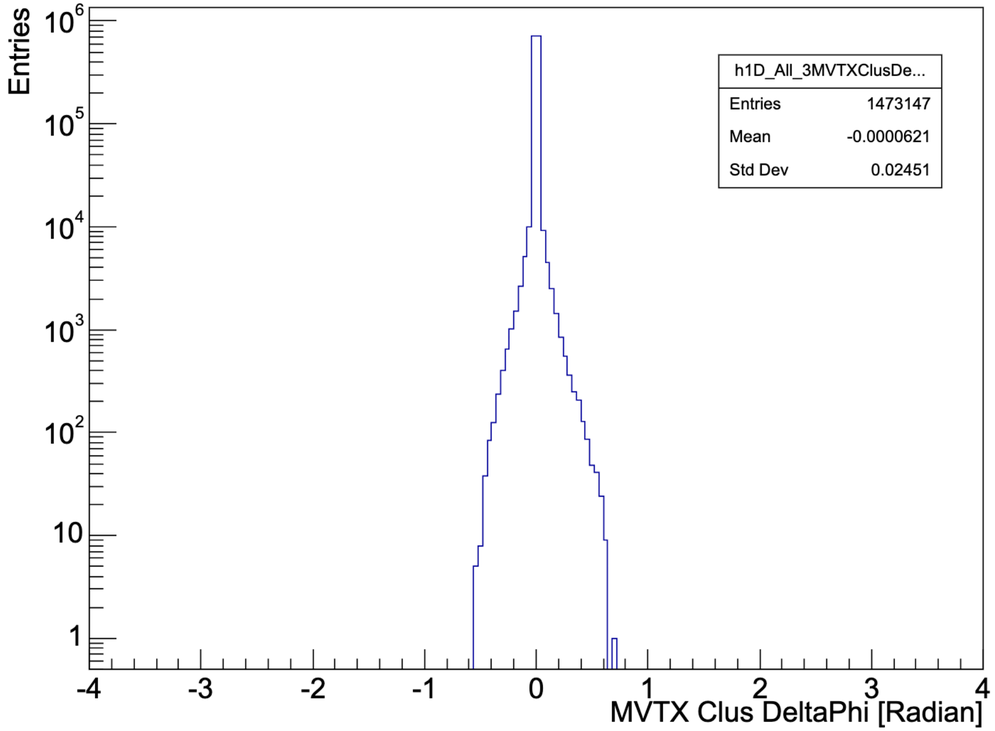
Δϕ distributions of INTT clusters in silicon seeds, with differnet histogram ranges



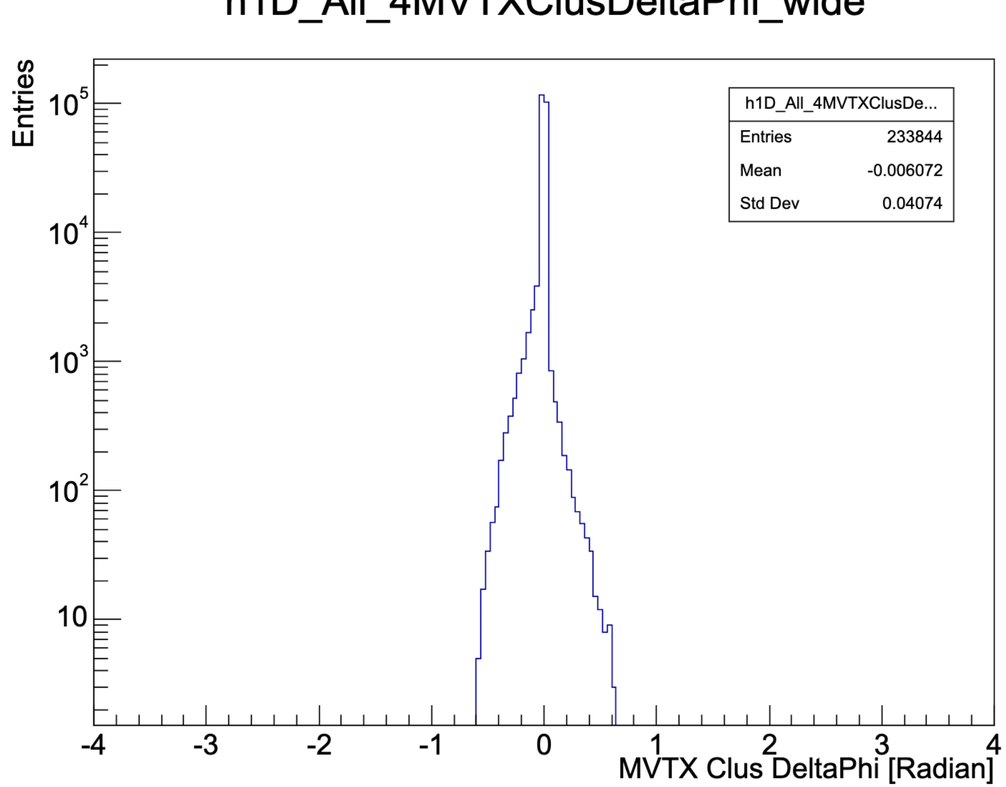
This happened regardless of the value of the INTT cluster-timebucket difference

MVTX seed-cluster Δϕ

n MVTX clusters == 3
(Δϕ of each distinct combination is filled, 3 for each)



n MVTX clusters == 4
(Δϕ of each distinct combination is filled, 6 for each)



No large Δϕ found in MVTX

Configuration

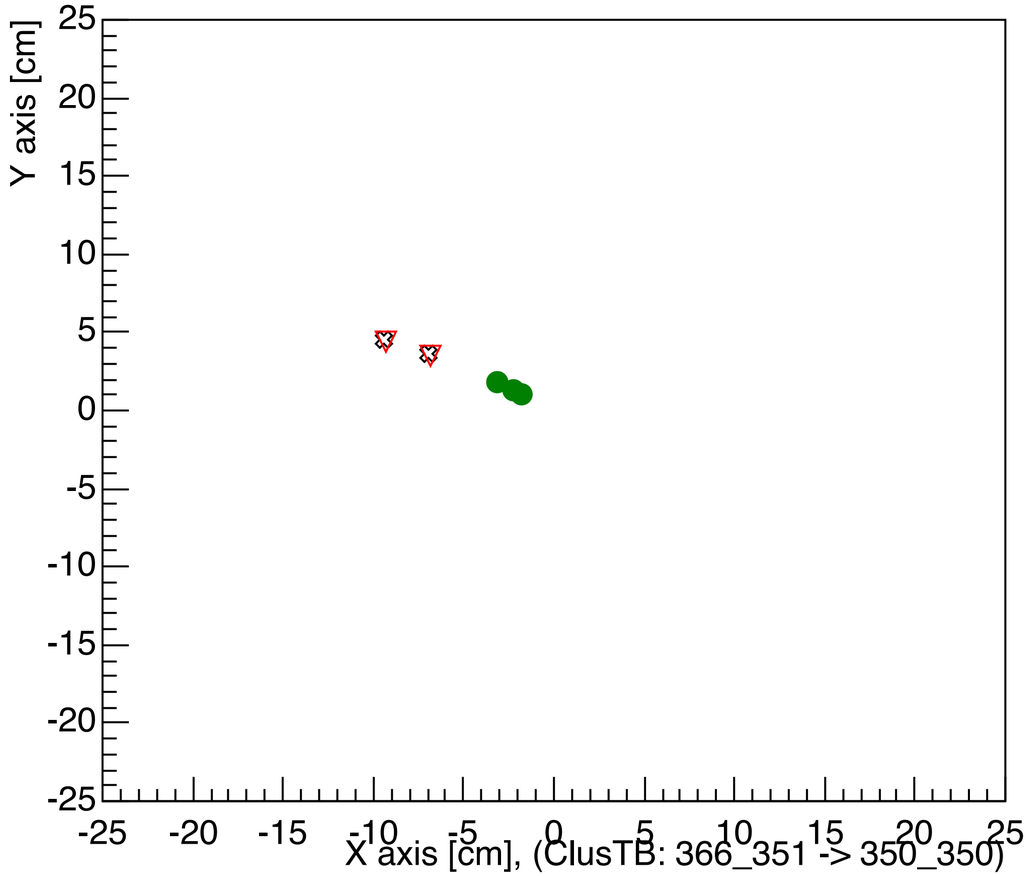
- Analysis build: 503
  - using local trackreco package cloned from GitHub on Sep 25, 2025
- Run number: 53018 (Run24 pp run, one of the runs in the good run list)
- Cluster DST file:
  - /sphenix/lustre01/sphnxpro/production/run2pp/physics/ana504_2024p023_v001/DST_TRKR_CLUSTER/run_00053000_00053100/dst/DST_TRKR_CLUSTER_run2pp_ana504_2024p023_v001-00053018-*.root
- CDB flag: “ProdA_2024”

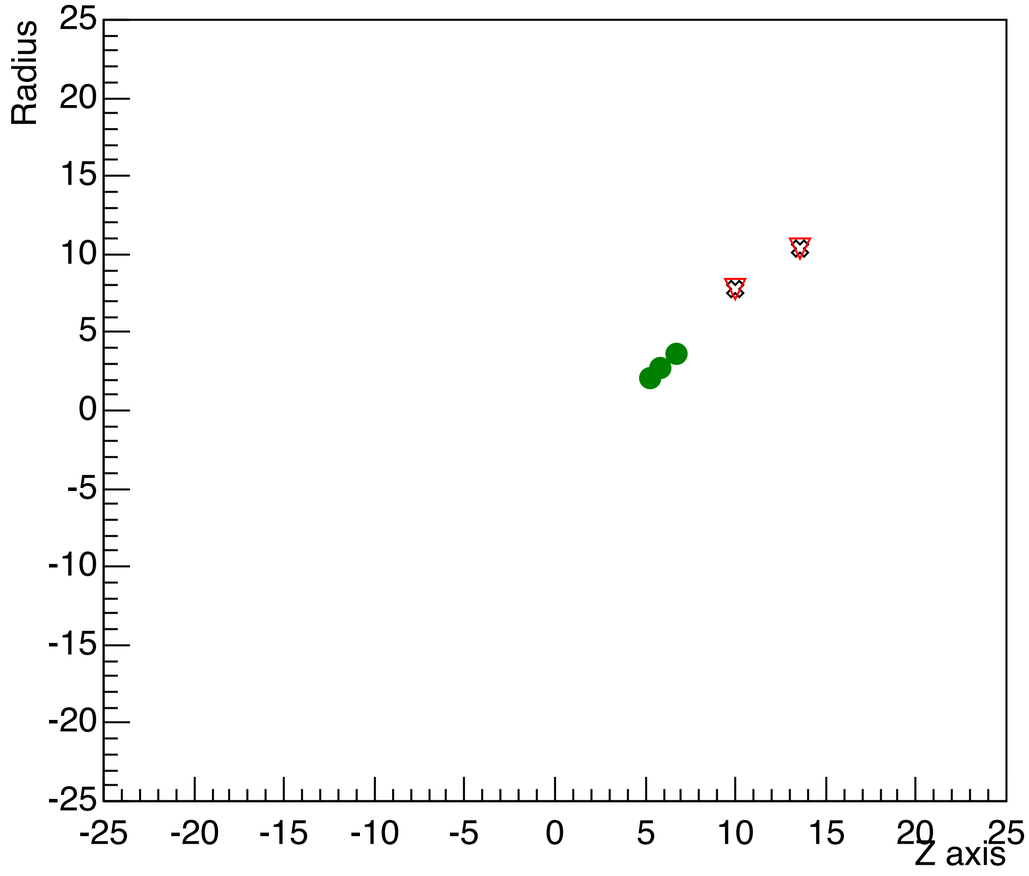
```
auto silicon_Seeding = new PHActsSiliconSeeding;
//silicon_Seeding->Verbosity(1);
silicon_Seeding->Verbosity(ActsSeeding_Verbosity);
silicon_Seeding->setStrobeRange(-5,5);
silicon_Seeding->setinttRPhiSearchWindow(0.2);
silicon_Seeding->setinttZSearchWindow(1.0);
silicon_Seeding->seedAnalysis(false);
```

m_searchInIntt == false

Approach2: Would it be possible that both clusters are wrong?

- Another possibility, both INTT clusters are wrong





in progress