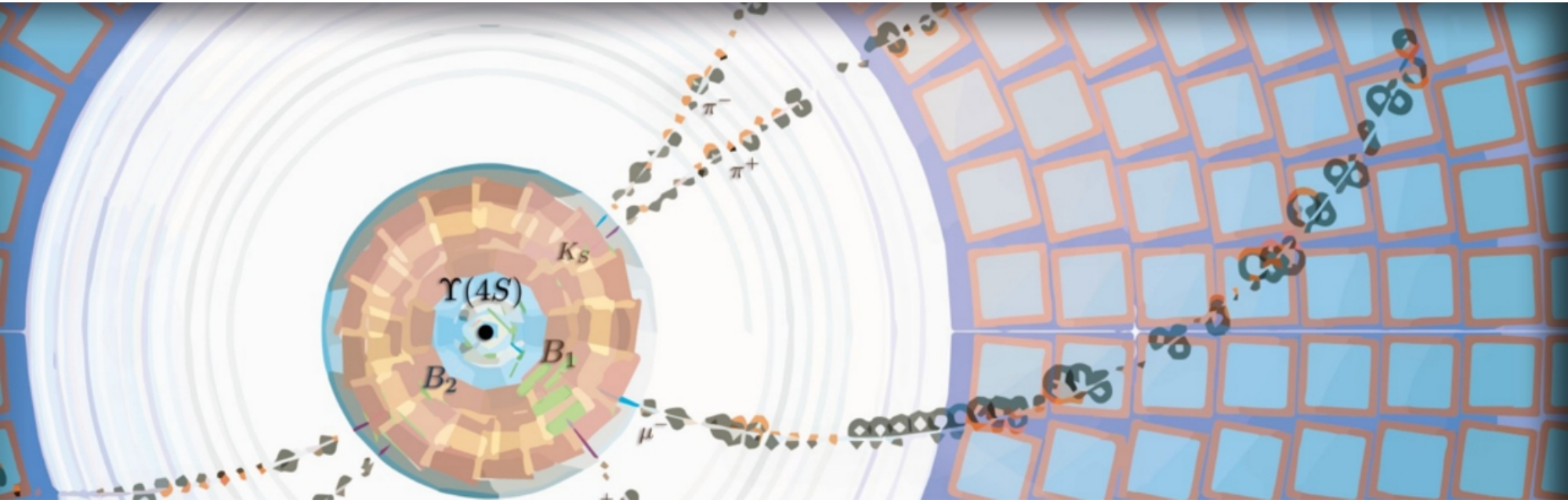
Tracking in the Belle II Drift Chamber.

Hamburg - Face-to-face tracking meeting



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2016-11-23

DESY

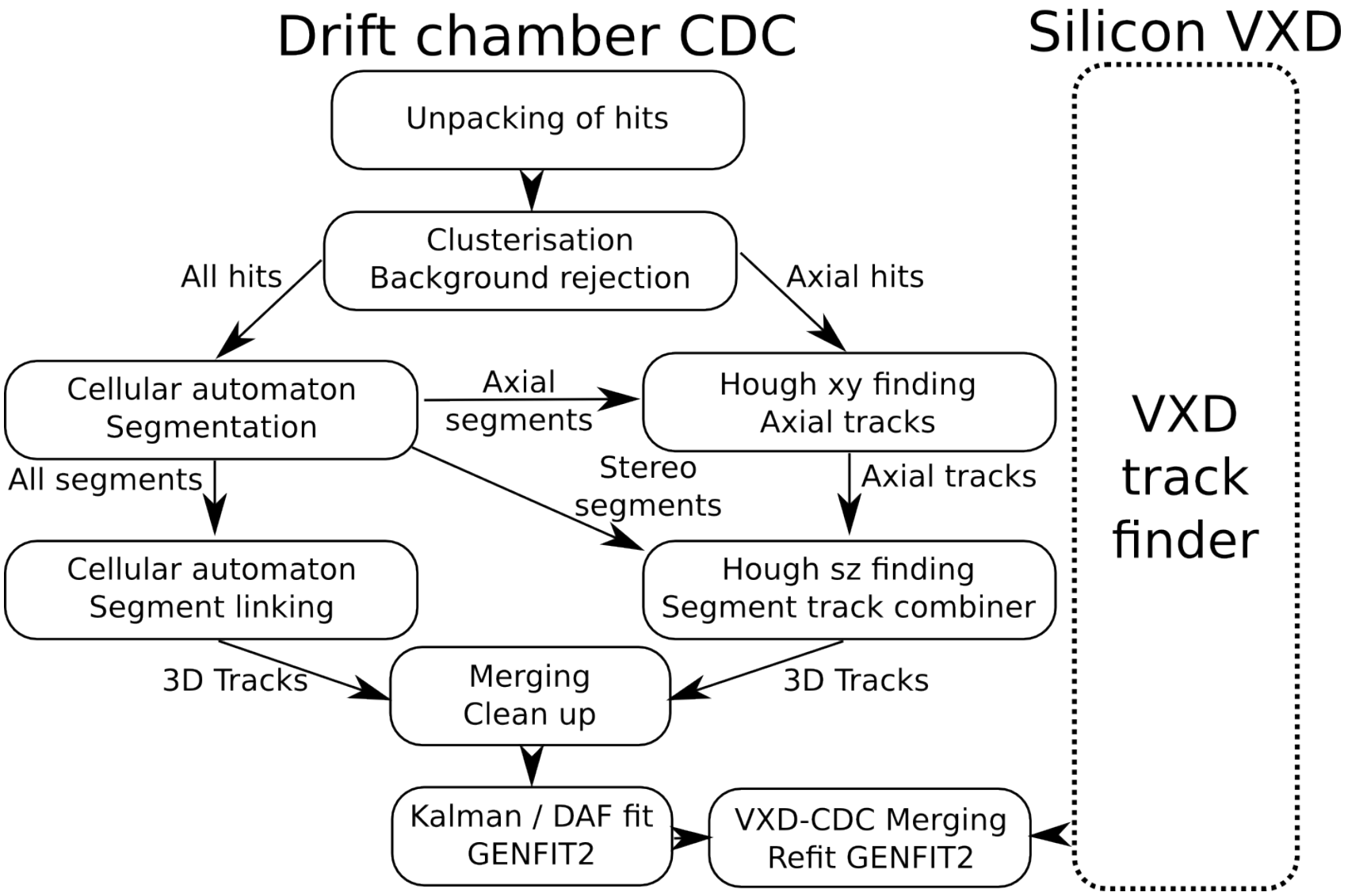
HELMHOLTZ ASSOCIATION

Belle II

Overview

- Track finding in the CDC - recap
- Segment aliasing
- News from the second stage cellular automaton
- Comparision of performance

Track finding overview



Current standard reconstruction

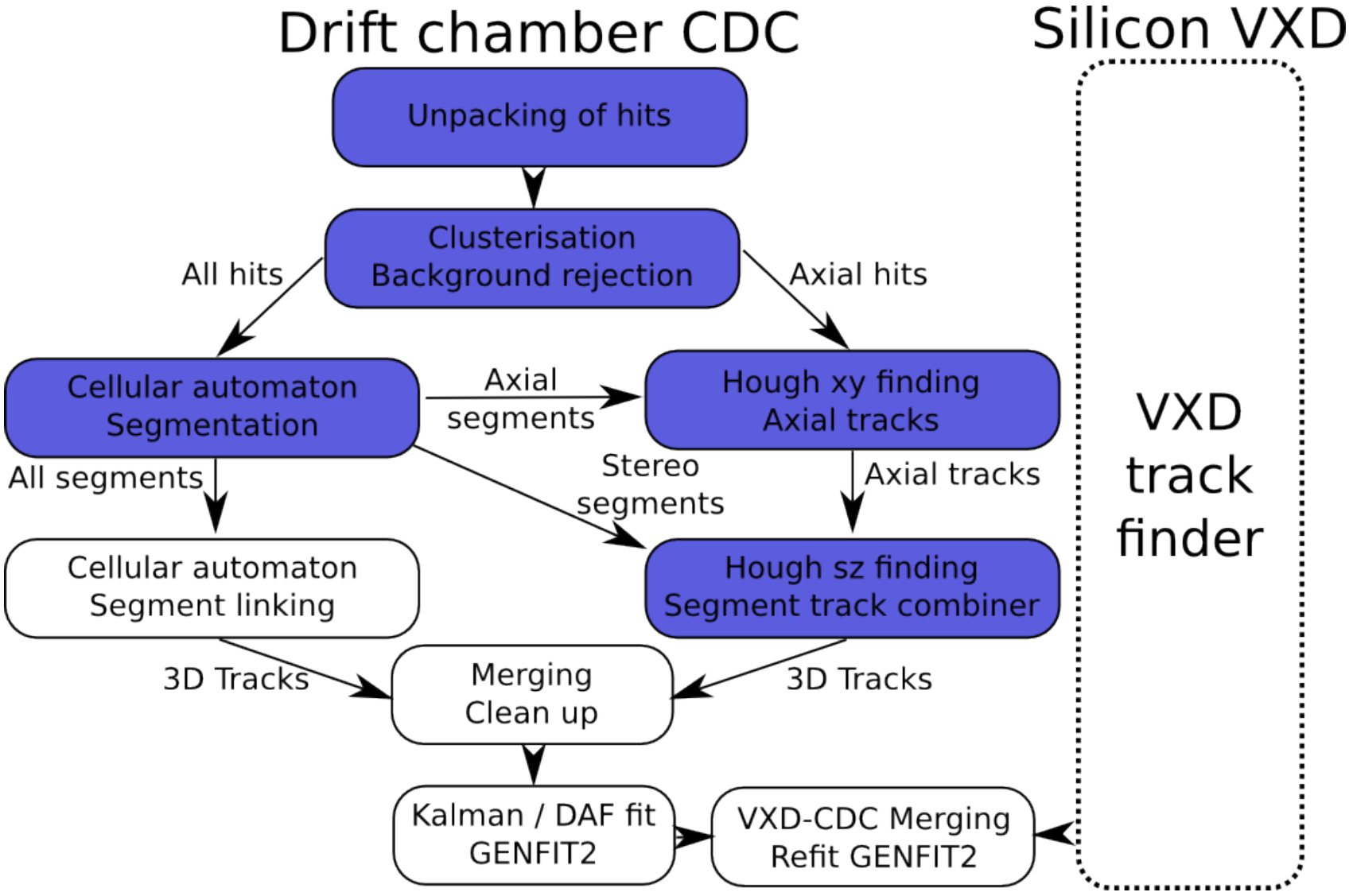


Figure 1: *add_track_finding_cdc*

Newly completed cellular automaton path

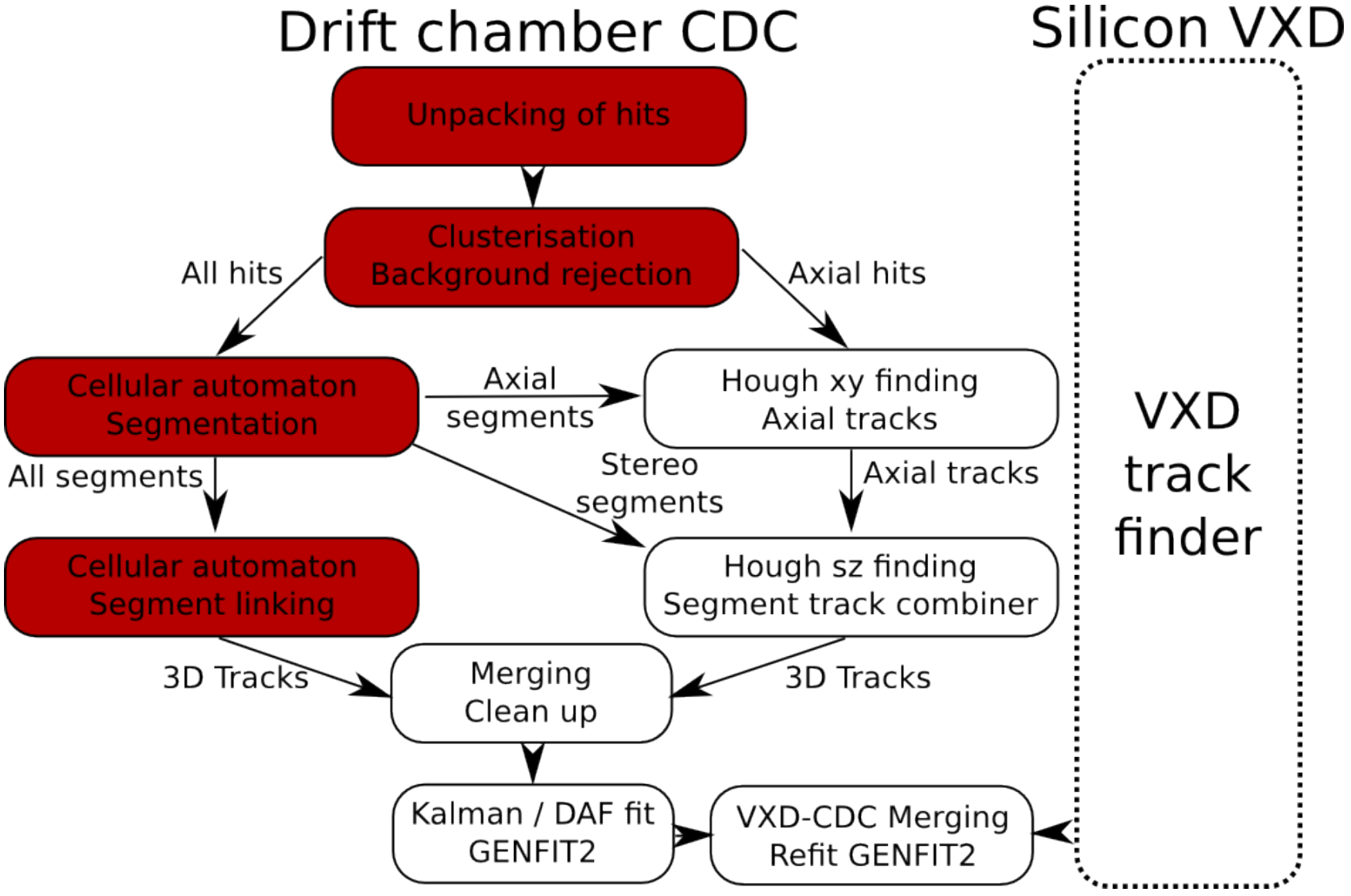


Figure 2: TrackFinderCDCAutomaton

Cellular automaton path

First stage cellular automaton

- Clusterisation creation and background rejection
- Hit triple creation
- Hit triple linking
- Intermediate reestimation of flight times
- Segment fitting

Overhauled second stage cellular automaton

- **Segment alias resolution**
- **Segment linking in cluster**
- Axial-stereo segment pair creation across super layers
- Axial-stereo segment pair relation creation for cellular automaton
- **Track linking**

99 ways to skrew up your segment fit

Drift circles have two symmetries

- Reversal symmetry: forward $\leftrightarrow$ backward

  Local least square fits can never distinguish forward from backward

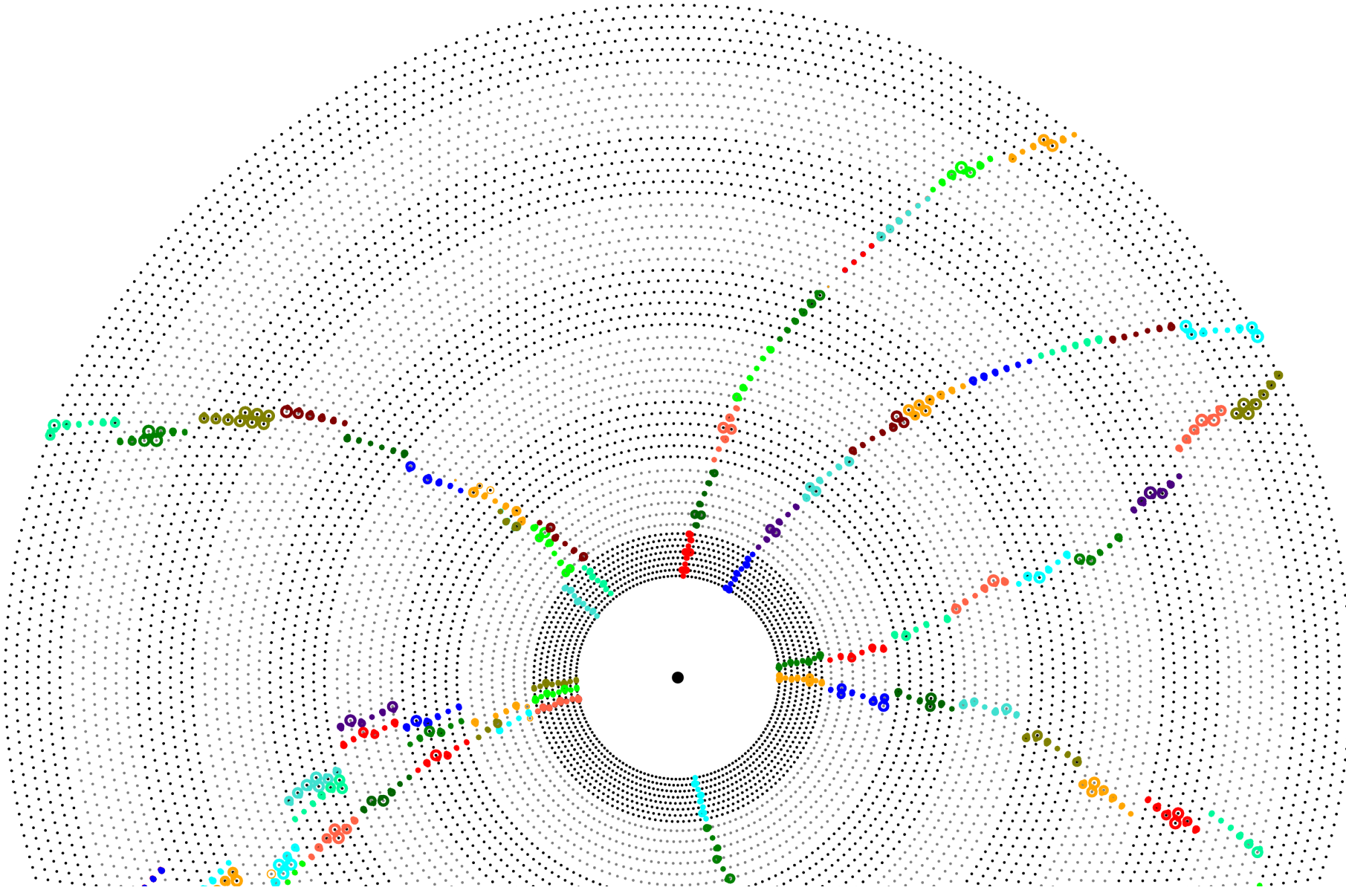
- Aliasing symmetry: right $\leftrightarrow$ left

  Local least square fits may not distinguish right from left in underconstrained situations

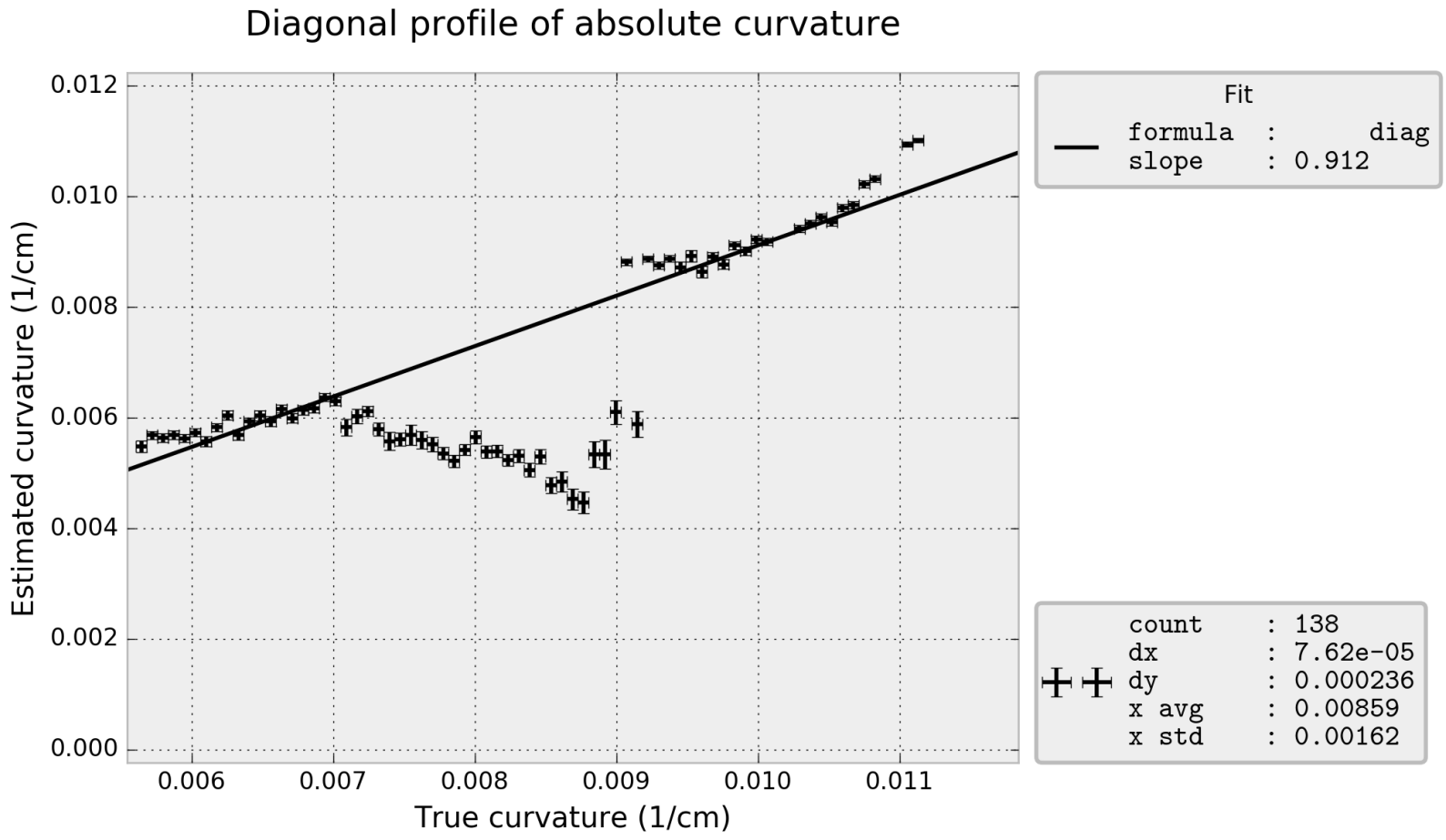
Aliasing observable in mid range momentum sample

- generator alias: low_gun
- 10000 events
- 10-muon events
- Constant magnetic field for simplicity
- Mediocre p_t between 400 MeV and 800 MeV

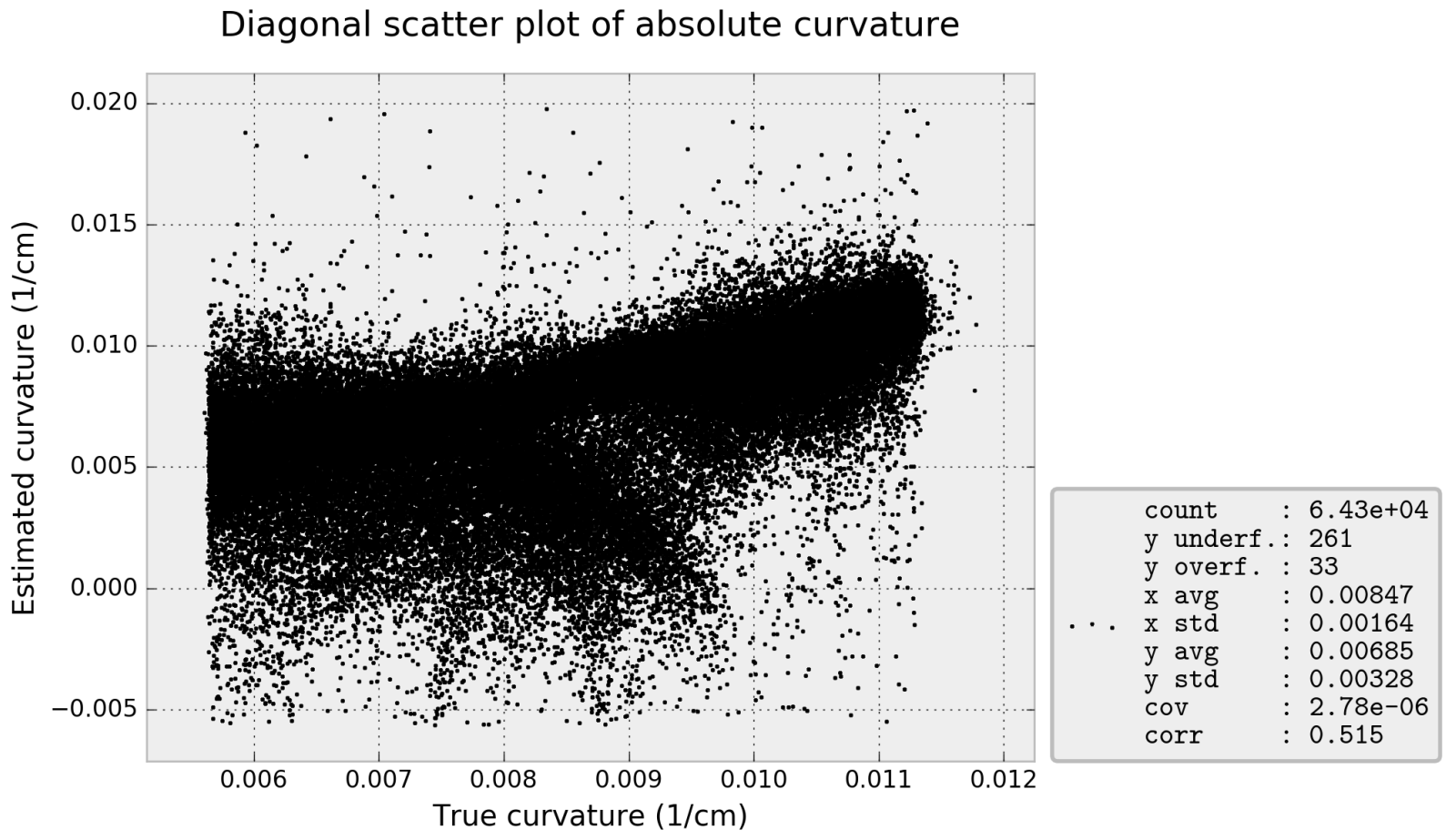
Sample event after the first stage



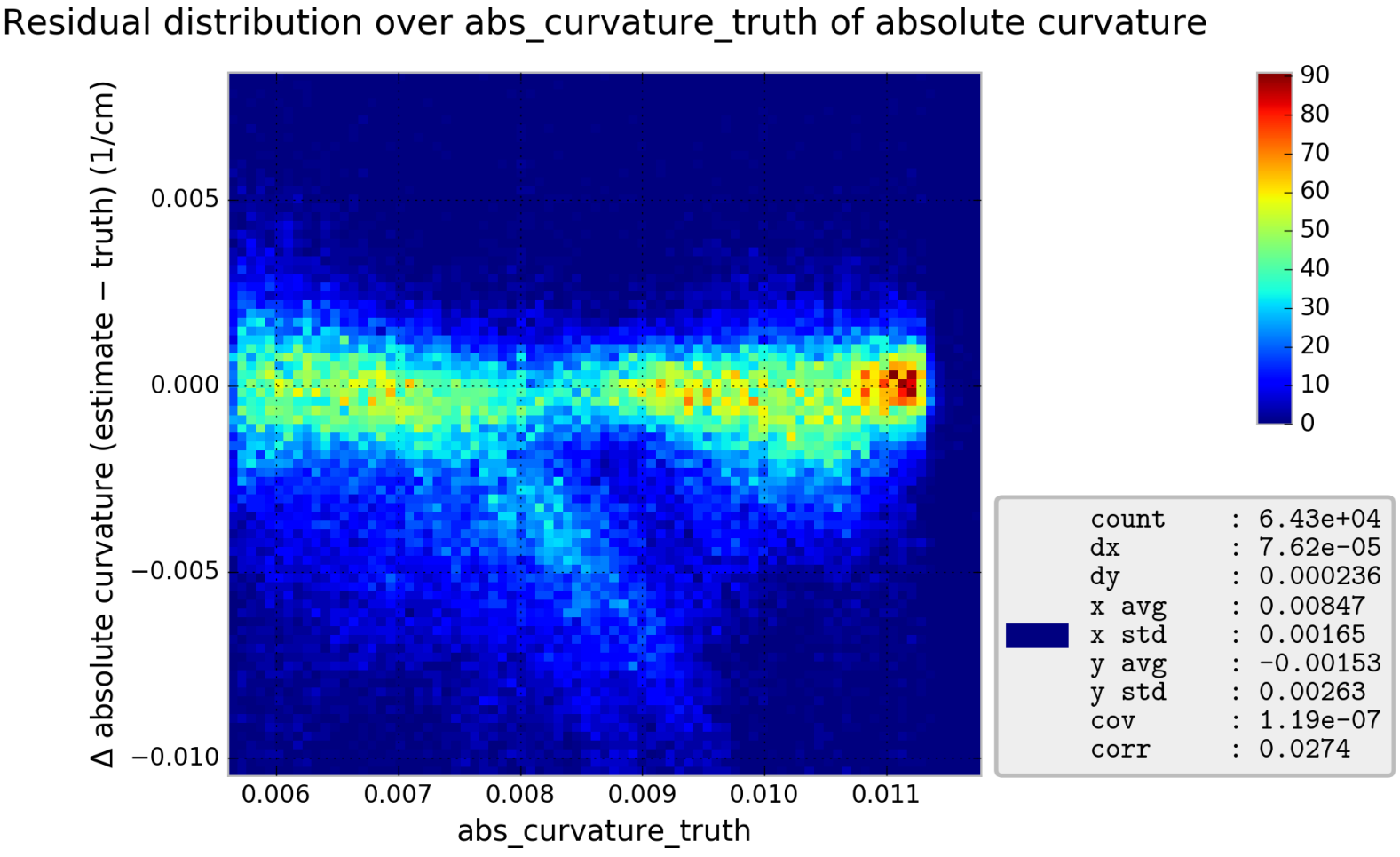
Curvature estimation inconsistency - super layer 8



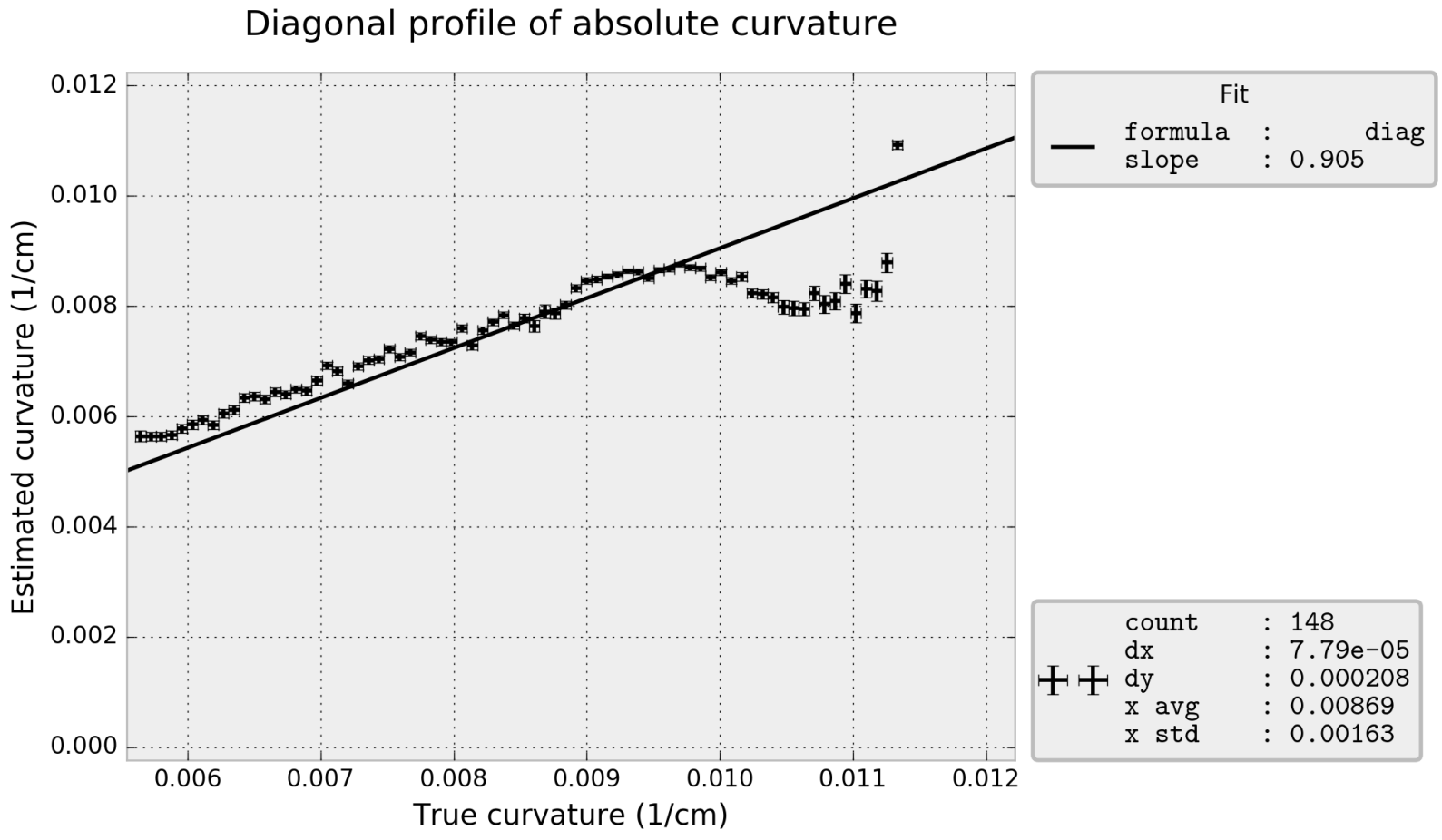
Curvature estimation inconsistency - super layer 8



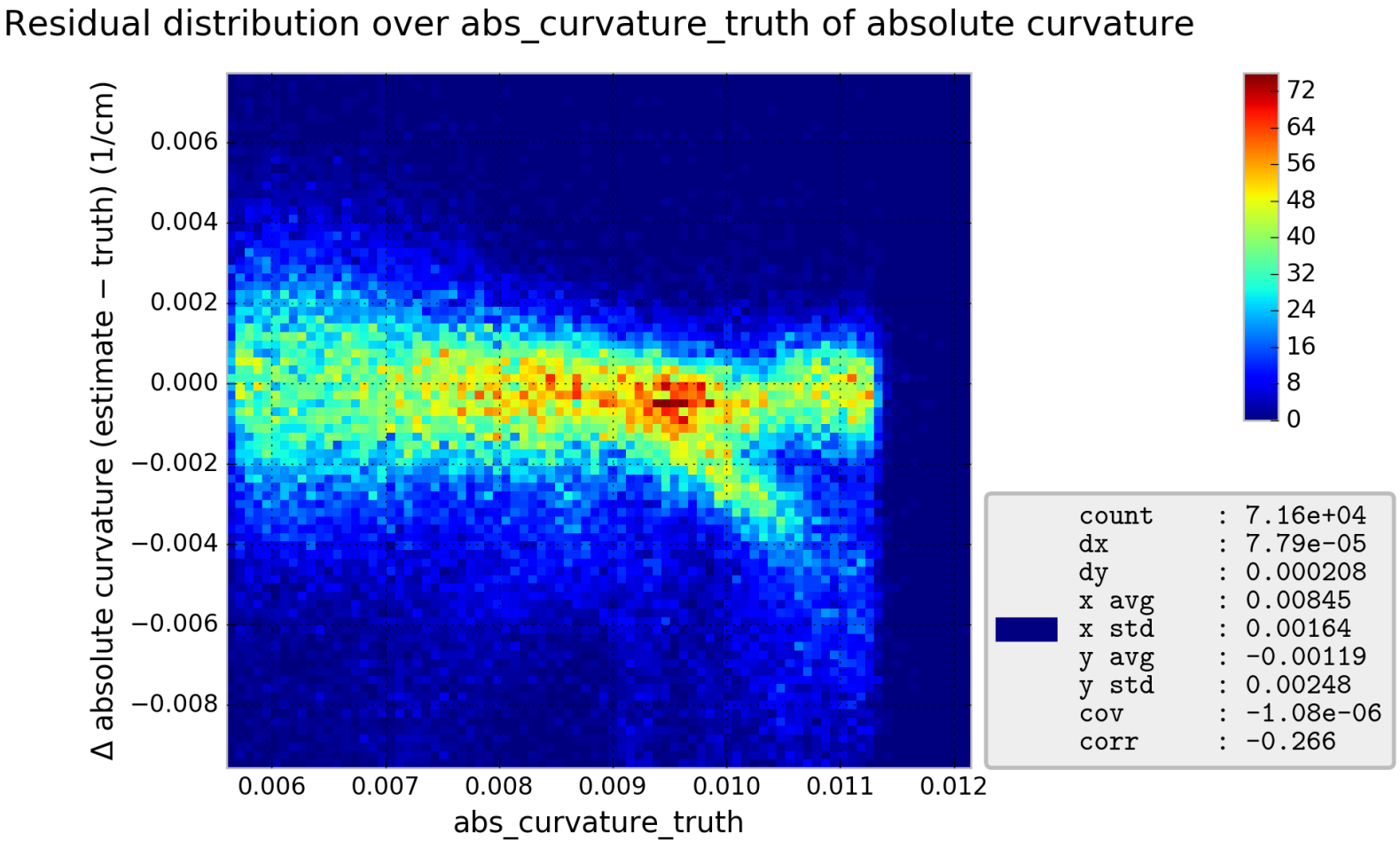
Curvature estimation inconsistency - super layer 8



Curvature estimation inconsistency - super layer 6



Curvature estimation inconsistency - super layer 6

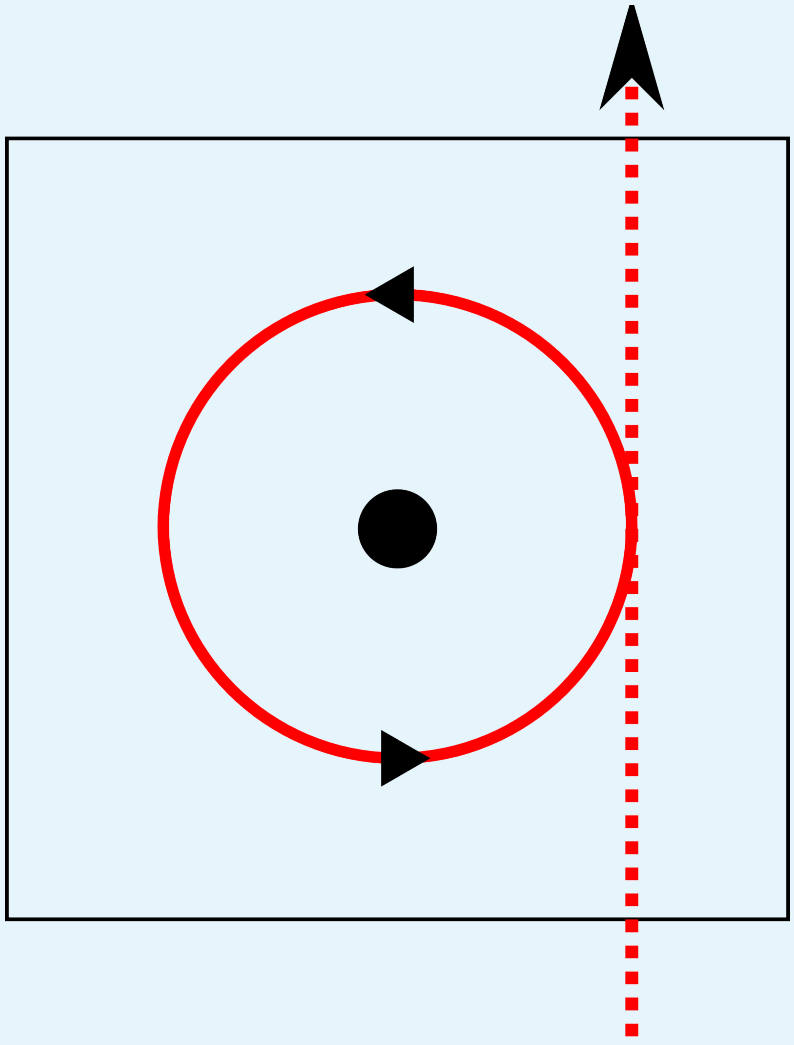


Observations

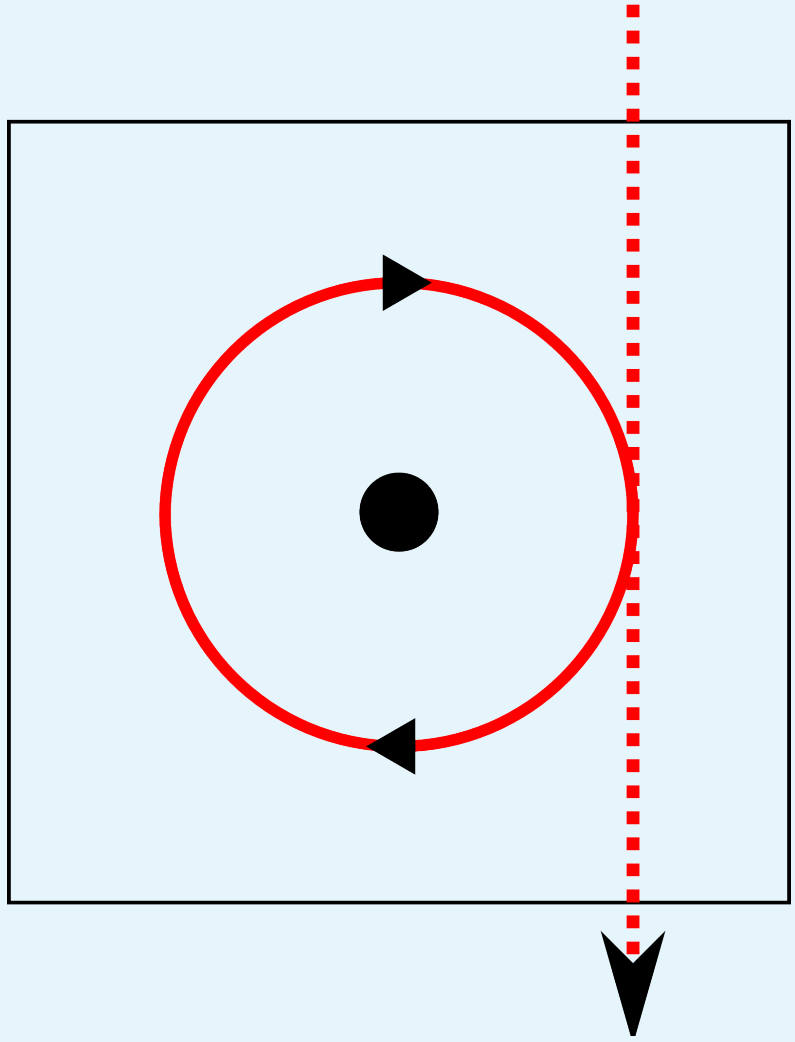
- Some serious underestimation of the segment curvature in some curvature range
- The exact location seems to depend on the super layer
- Generally lower super layer $\leftrightarrow$ higher curvature
- Effect must be geometrical sweet spot for certain transverse momenta

Reversal symmetry of hits

Forward wire hit

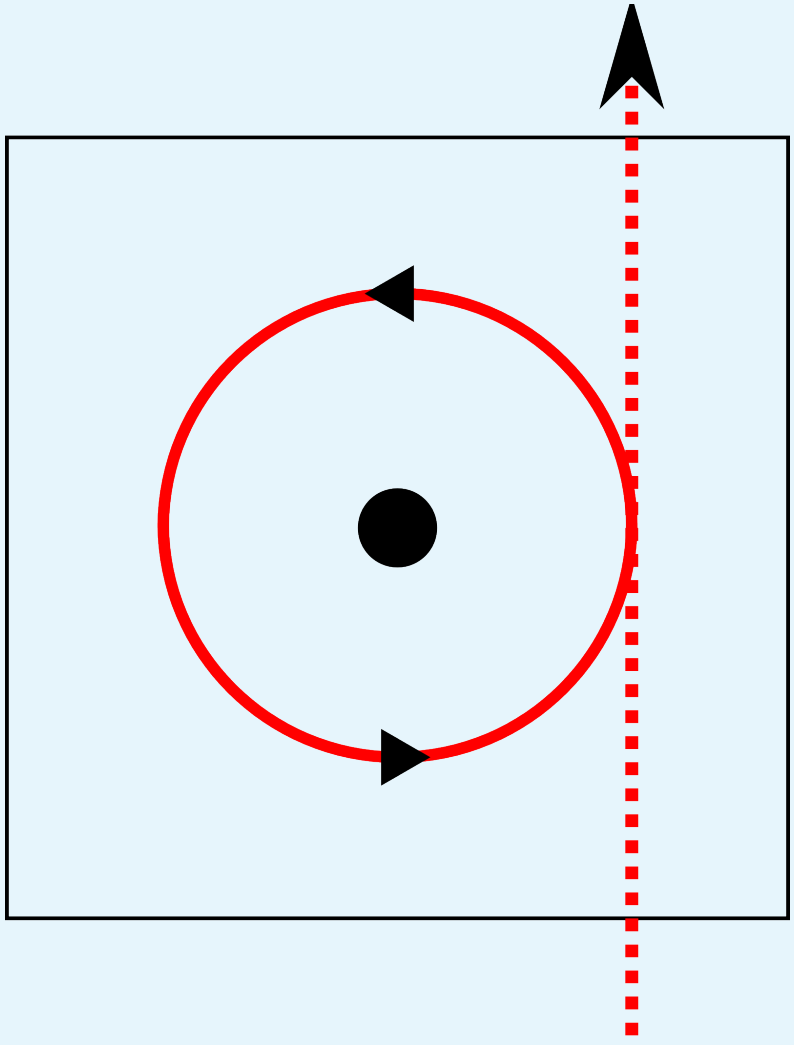


Backward wire hit

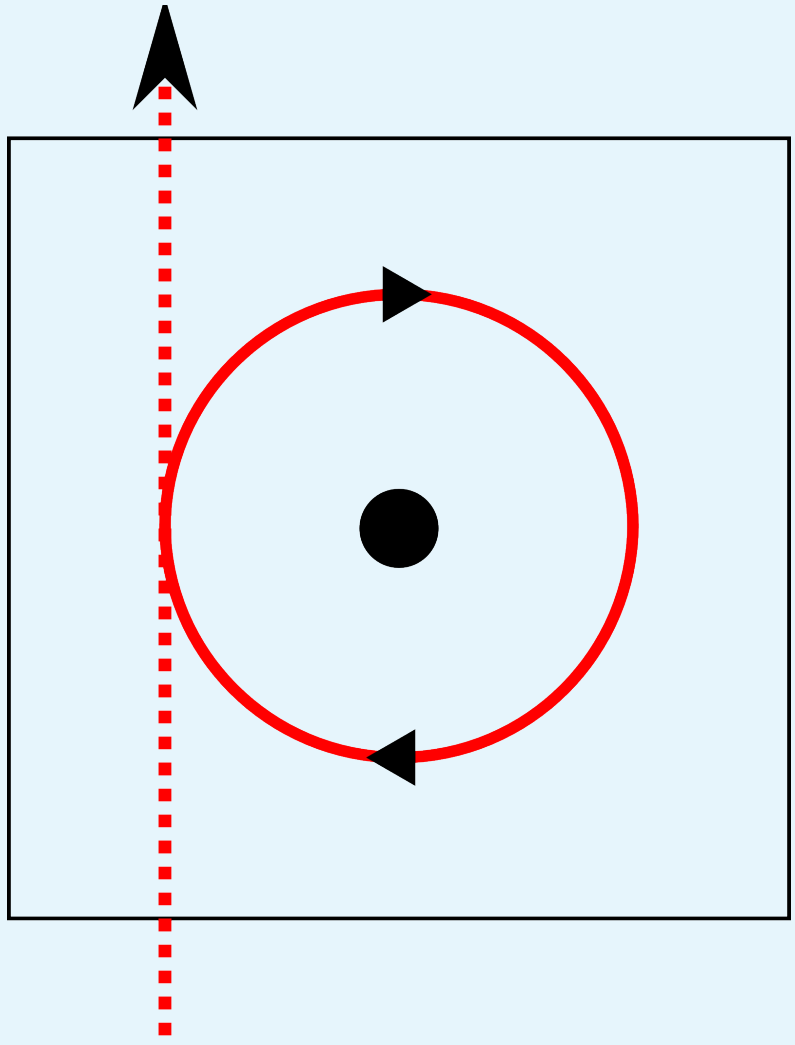


Aliasing symmetry of hits

Forward wire hit (left)



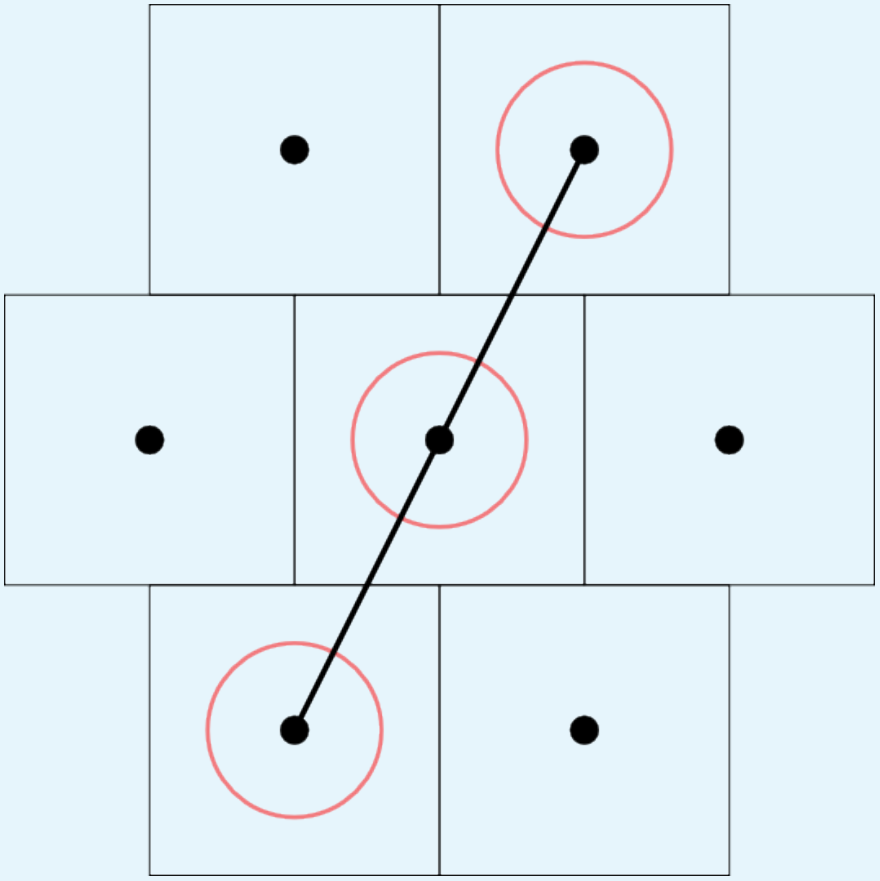
Forward wire hit (right)



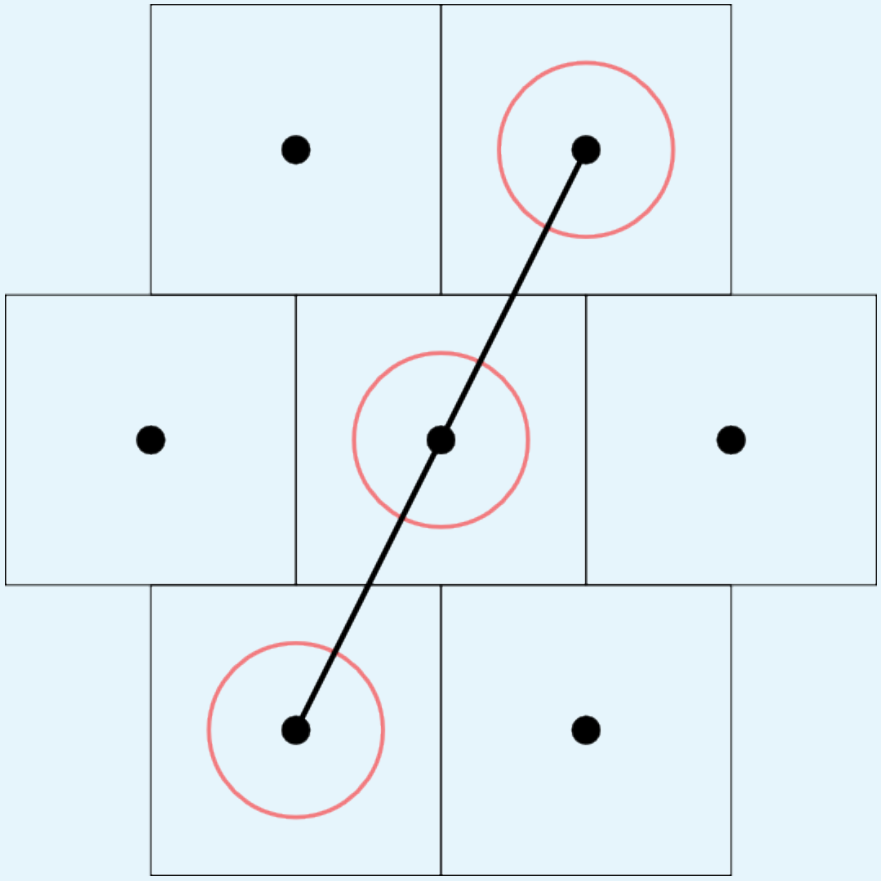
Symmetry of hit triplets

Straight hit triplets (para configuration) have both symmetries

Para facet



Para facet

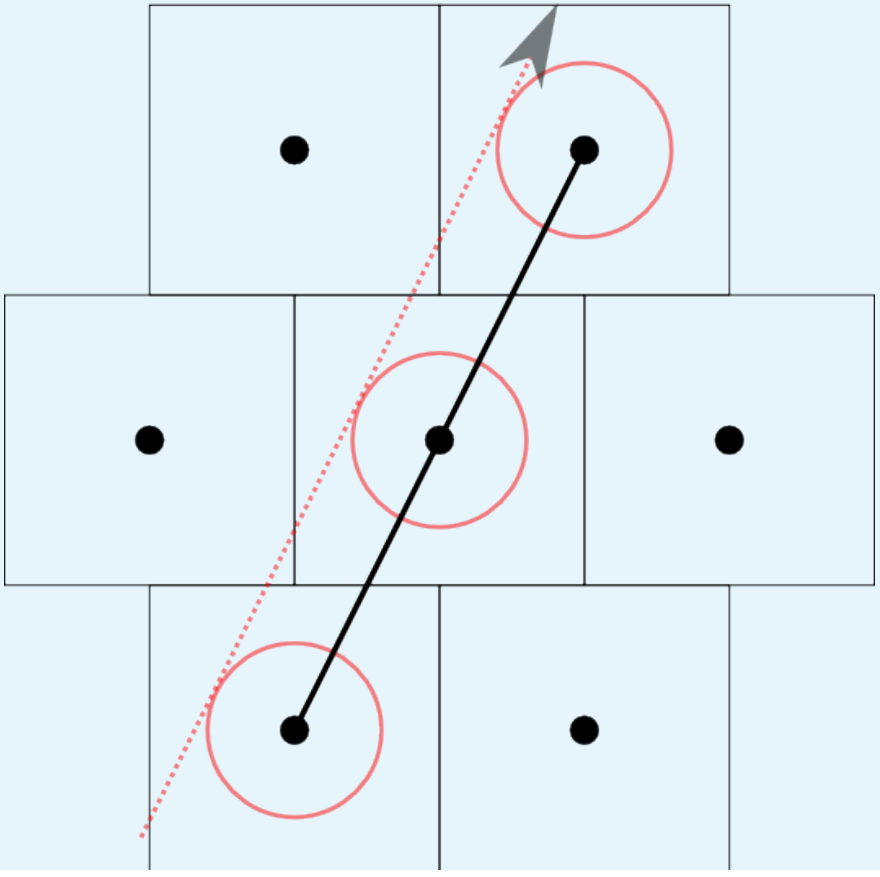


Reversal symmetry of hit triplets

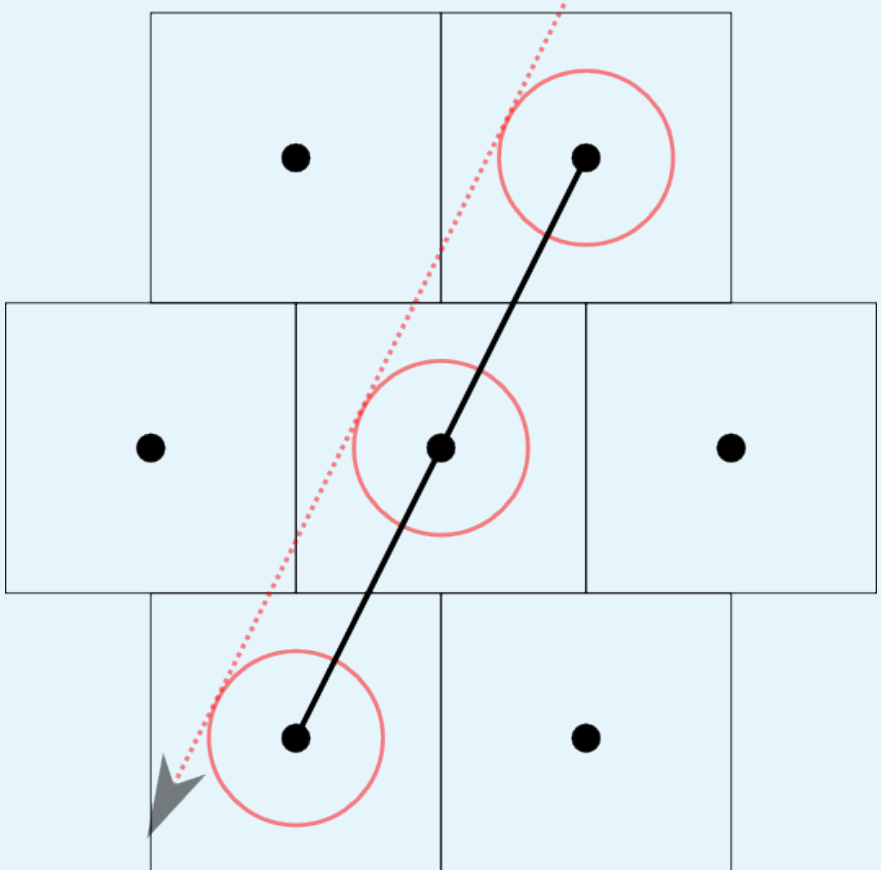
Straight hit triplets (para configuration) have both symmetries

> Resolved as far as preliminary flight time estimates are significantly different.

Para facet - forward



Para facet - backward

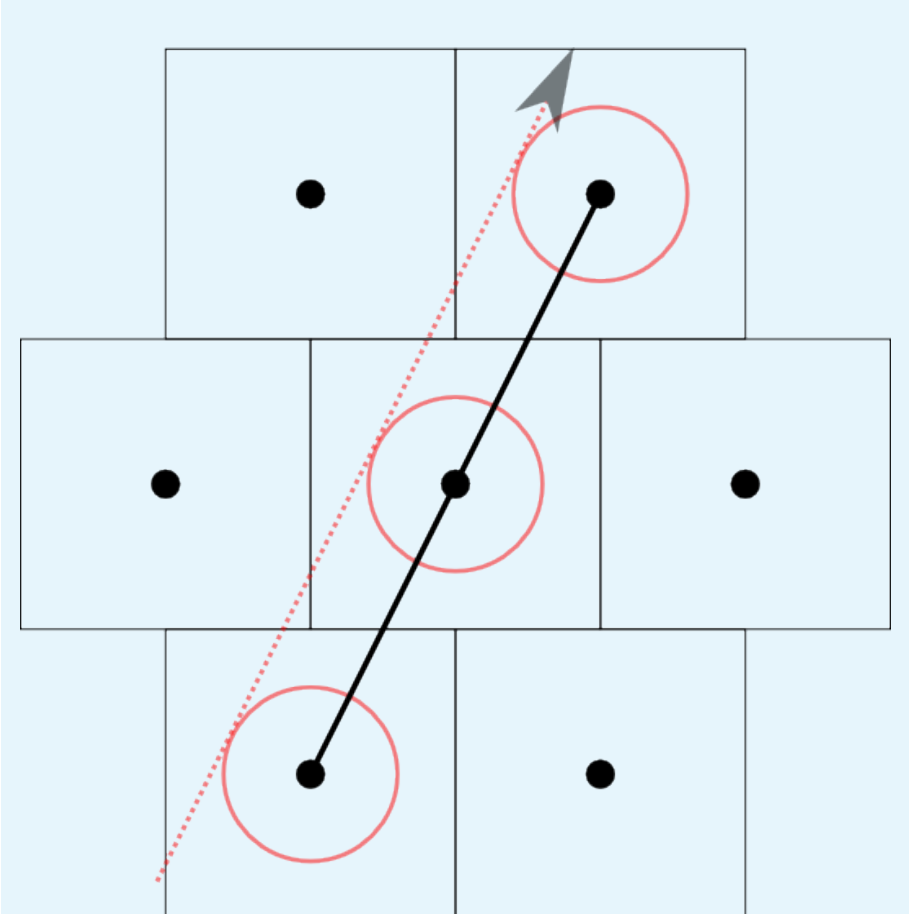


Alias symmetry of hit triplets

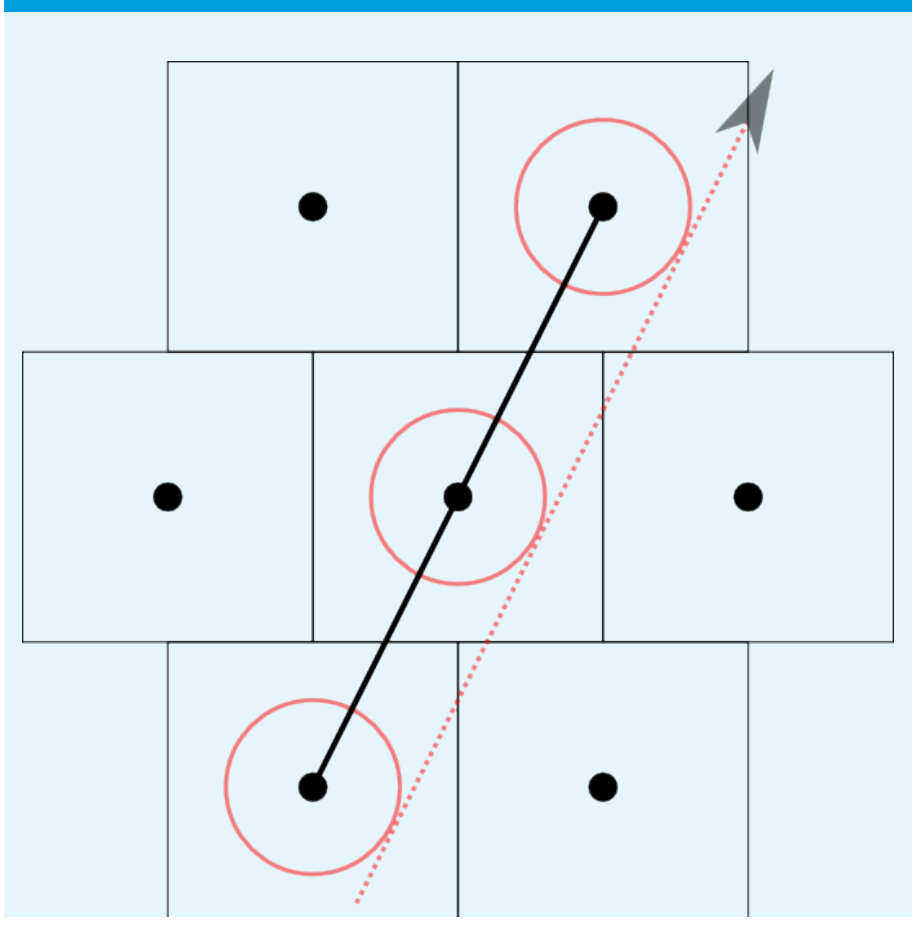
Straight hit triplets (para configuration) have both symmetries

> Aliasing impossible to resolve for one triplet

Para facet - left alias



Para facet - right alias



Alias symmetry of segments

- Some hit triplets may not distiguish aliases
- The cellular automaton may build the wrong segment alias

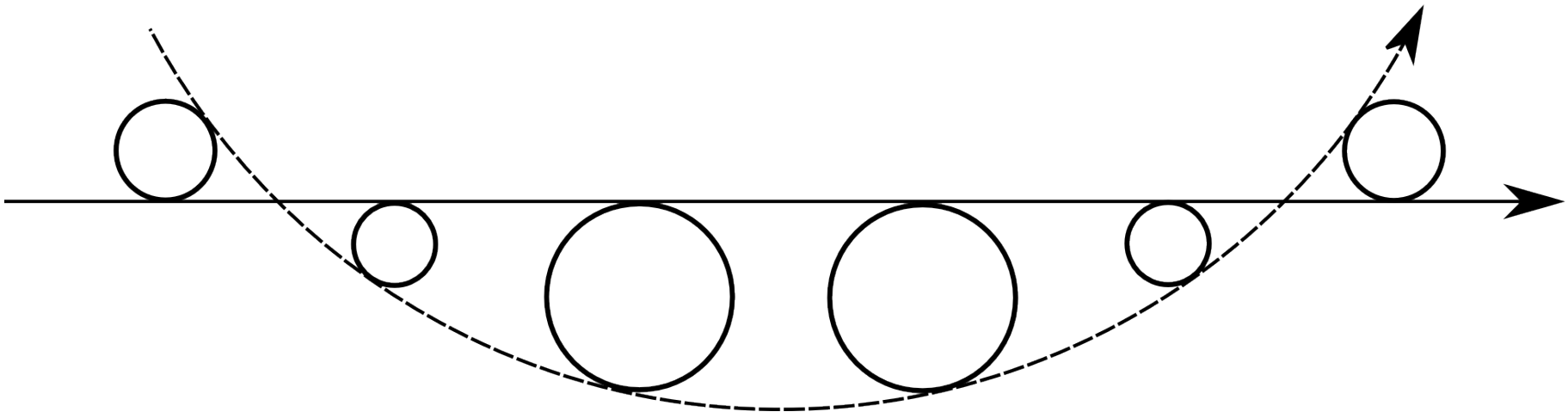
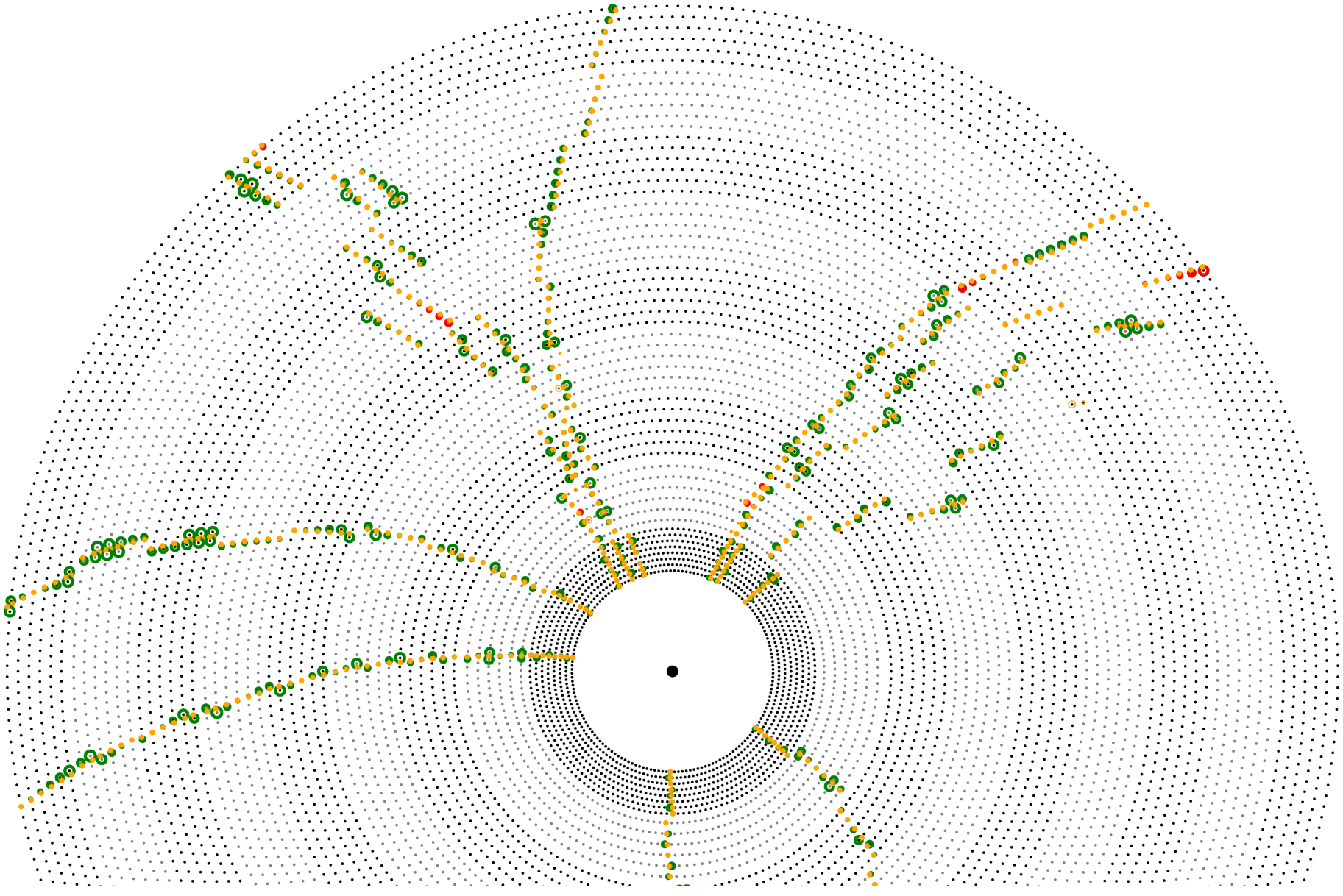


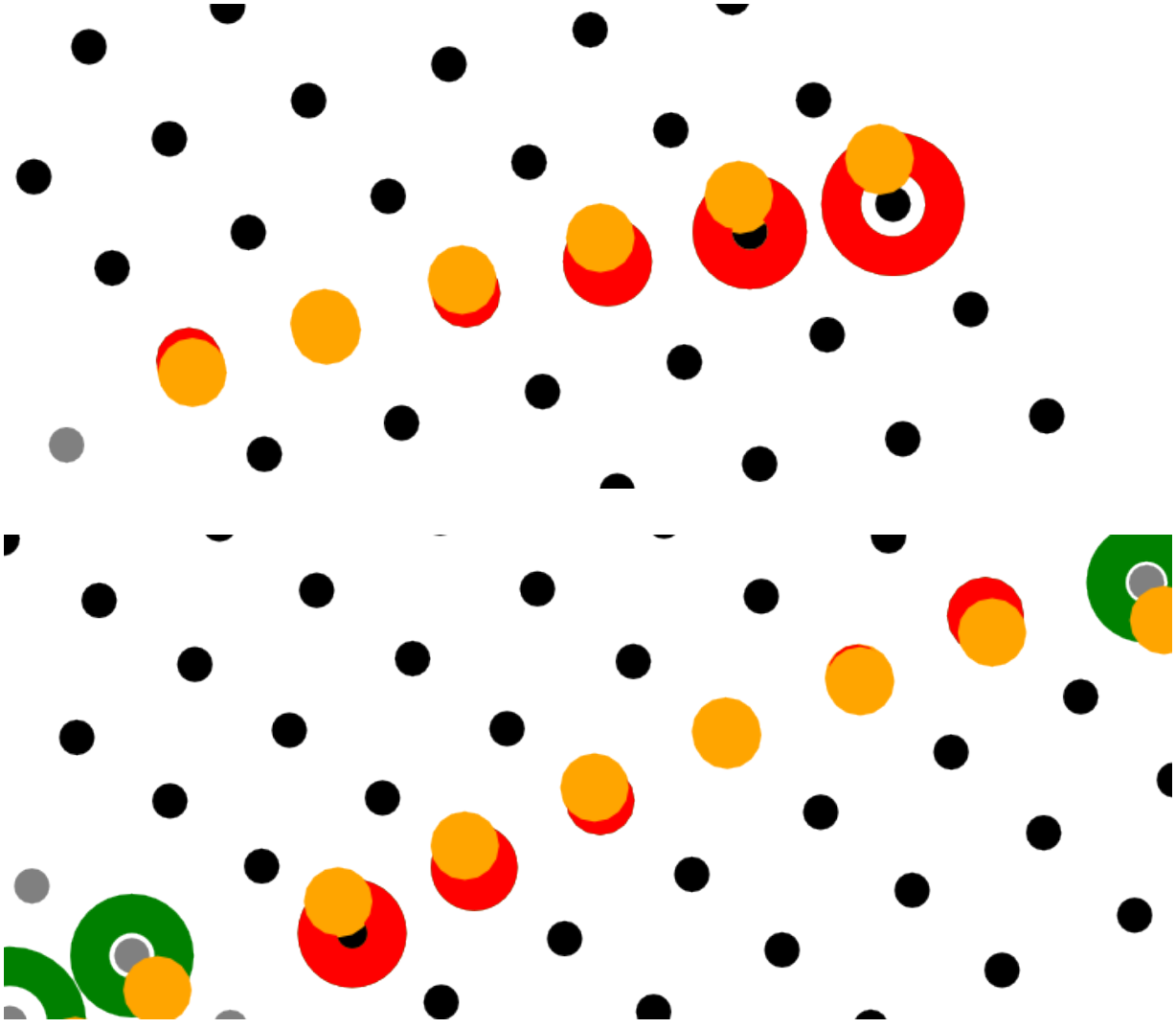
Figure 3: Schematic aliasing situation - not actual CDC geometry

- Cellular automaton usually selects the straighter alias

Examples of alias segments



Examples of alias segments



- Only one switch left $\leftrightarrow$ right
- Leaves room for the alias version to be correct

Distinguishing aliases

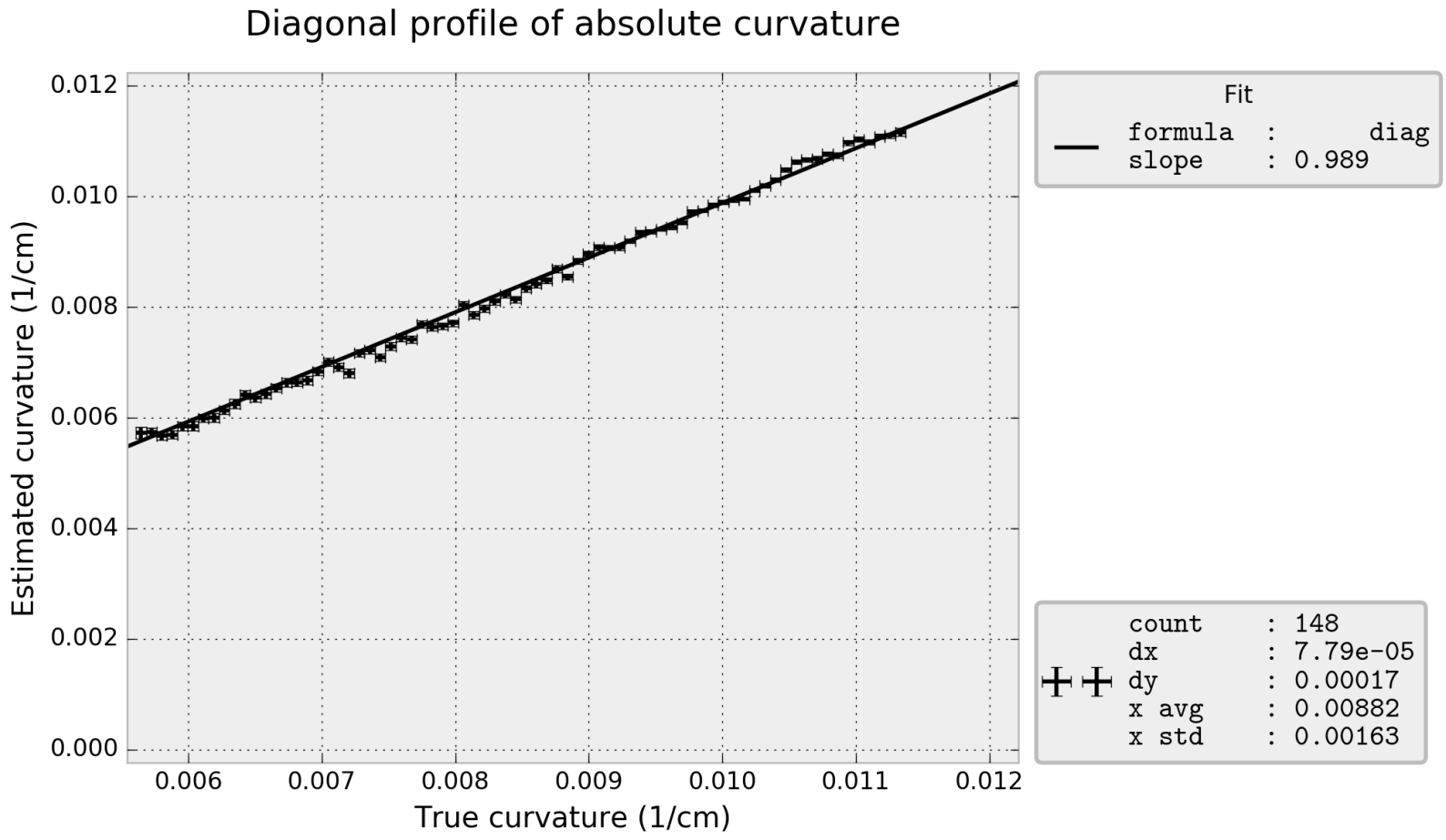
Alias misidentification

- Cellular automaton prefers *straighter* alias leading to lower estimated curvatures
- Each super layer as a momentum sweet spot where aliasing is likely
- Typically such that segments only have one right/left switch
- Three or more right/left switches a long the segments fix the alias definitly.

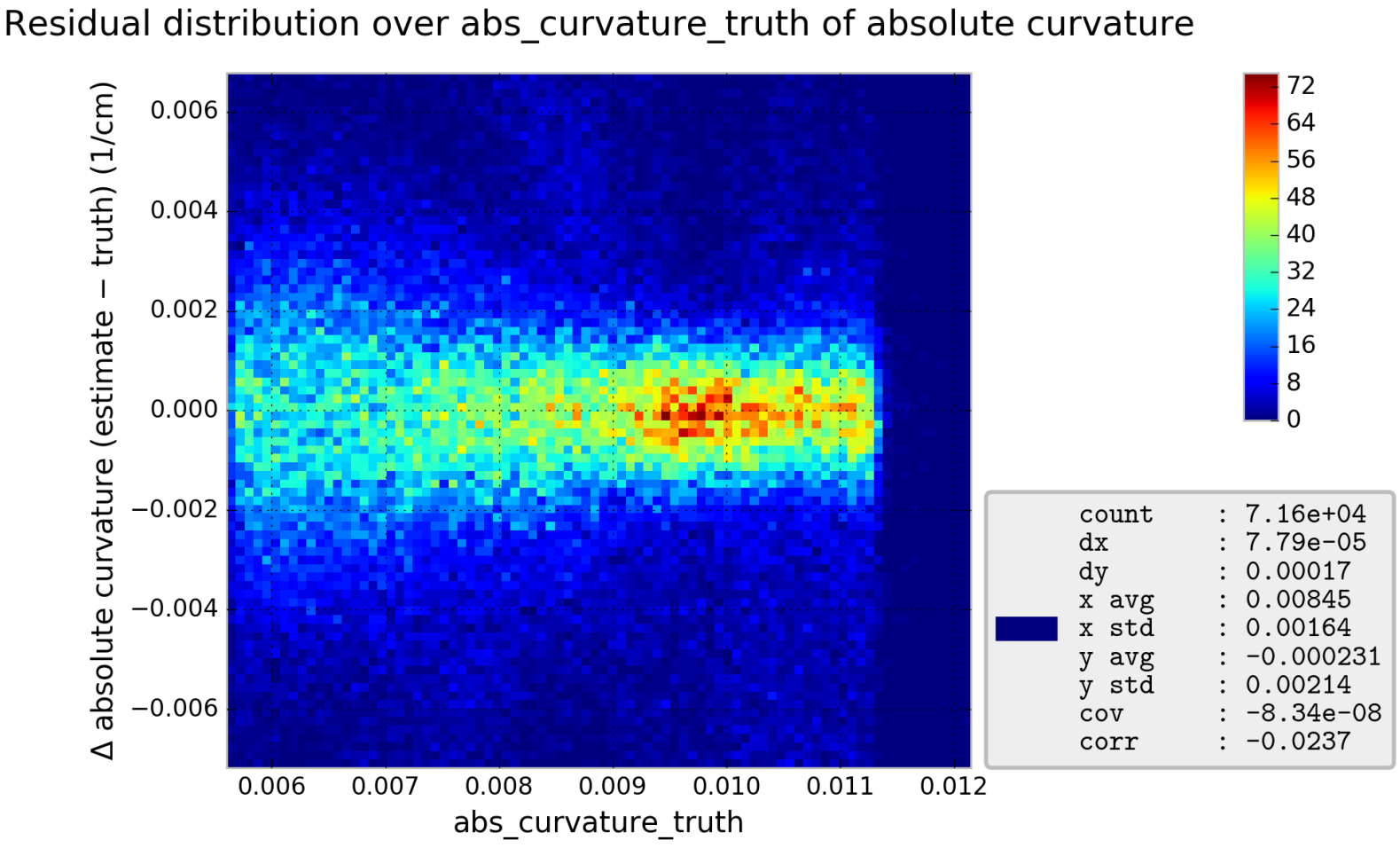
Resolution approaches

- Keep both viable aliases for the next stage
  - Similar to reversal symmetry
  - Harms time performance in combinatorics in next cellular automaton
- Using better χ^2 fit
  - Relatively cheap
  - Used for now
  - In addition: Check for wrong first / last alias hits in segment

Curvature estimation after alias resolution - super layer 6



Curvature estimation after alias resolution - super layer 6



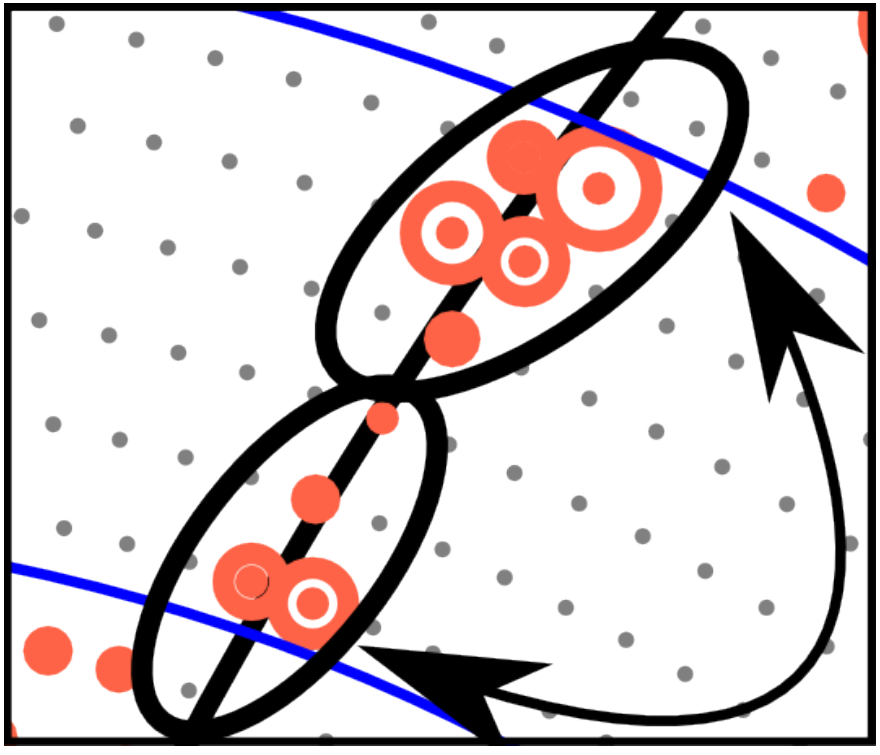
Overhauled second stage cellular automaton

- **Segment alias resolution**
- **Segment linking in cluster**
- Axial-stereo segment pair creation across super layers
- Axial-stereo segment pair relation creation for cellular automaton
- **Track linking**

New approach

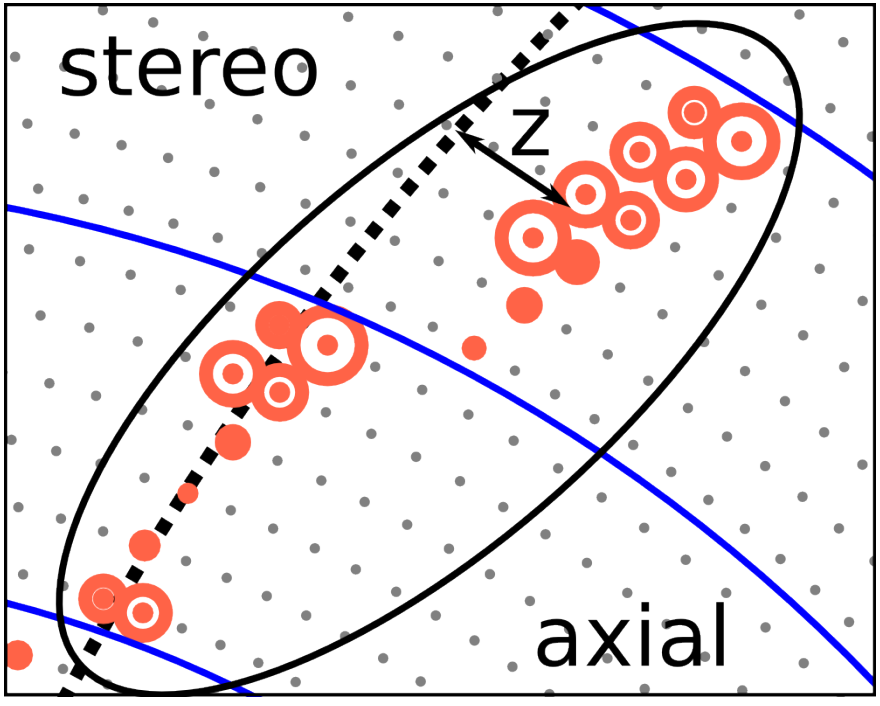
- Earlier attempts to make hand crafted selection did not cut it.
- New attempt leverages efficient / background rejection classifier, i.e. FastBDT
- Use a weight to differenciate more likely connections.
- Concentrate on the combinatorics in the *first loop* only
- Make consecutive cuts to reject work as soon as possible

Segment linking



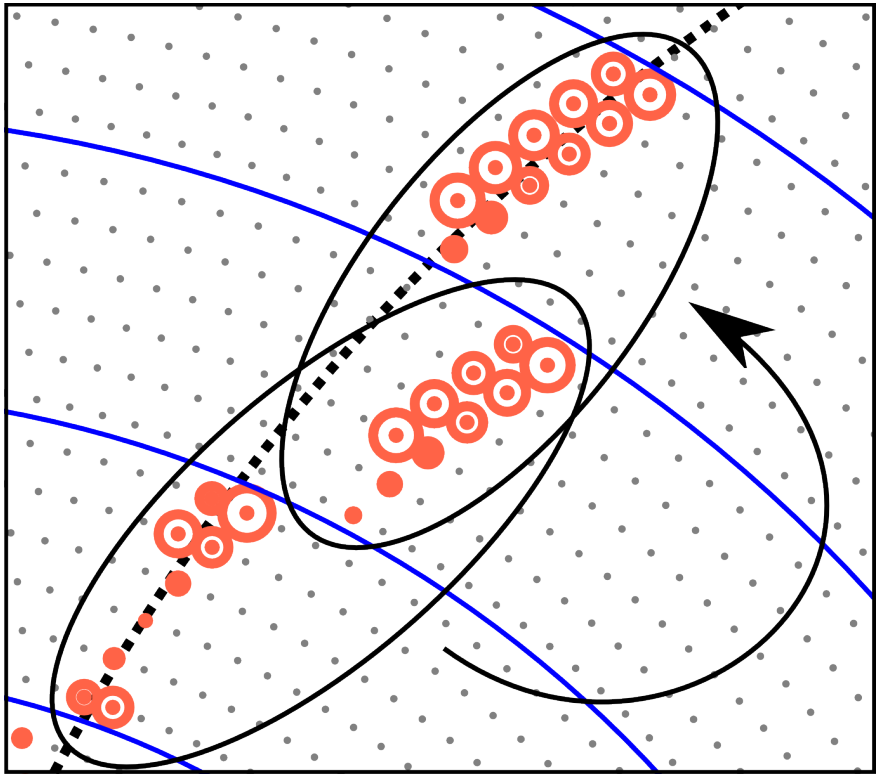
- Joins broken segments with two classifiers
  - Feasibility classifier with simple variable
  - Final weight classifier using common fit
- 99% pur., ~50 % eff.
- Impact on final figures of merits is low

Axial-stereo segment pair creation



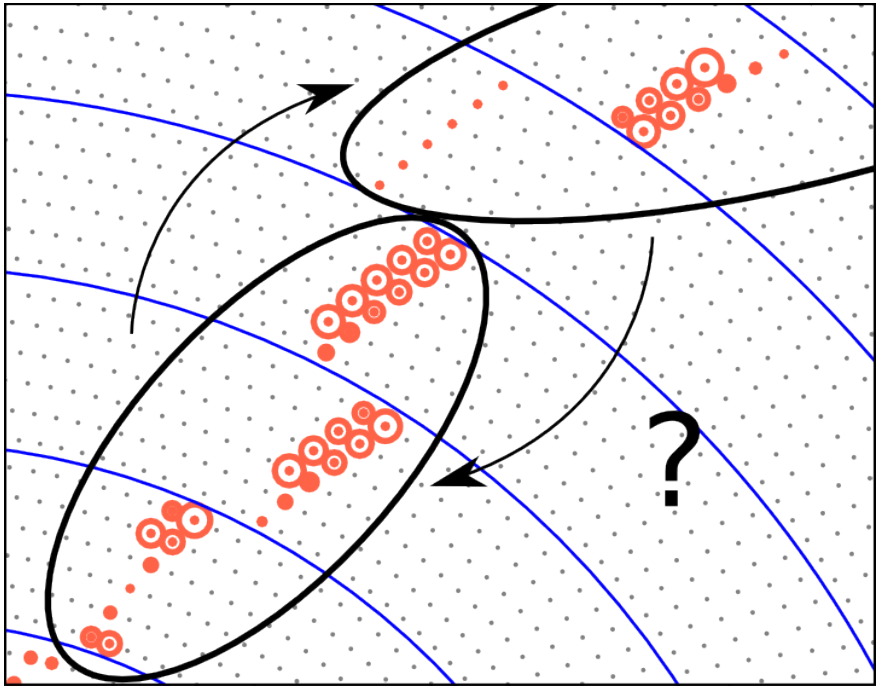
- Three consecutive cuts:
  - Hard coded cut for non-sensical combinations
  - Feasibility classifier with simple variable
  - Final weights incoorporating the combining helix fit
- Accounts for ~ 30% of the runtime of this setup
- Quality critical for this approach
- ~55 % pur., 99 % eff. (on first loop)

Axial-stereo segment pair relation



- Segment pair creation stage is pure enough to skip preselection cut
- One classifier sufficient comparing track parameters and making a common fit
- Allow only best candiate from each segment pair
- ~65 % pur., 99 % eff. (on first loop)

Track linking



- Joins broken tracks with two classifiers
  - Feasibility classifier with simple variable
  - Final weight classifier using common fit
- 99% pur., ~50 % eff.
- Halves the clone rate
- Improvement can be made here

Implementation details

- Fully modularised using the findlet micro modules concept discussed earlier
  - Use as one module **TrackFinderCDCAutomaton** containing all relevant findlets
  - Mix and match from individual findlets
  - Contains a total of 8 FastBDT classifers
- Multivariate classifiers use the mva package instead of the TMVA classifiers directly
  - Performance advantage with upgrade of the FastBDT version ~1.5% in both paths
  - Exact training procedure must still be made more explicit
- Deleted features
  - Removed the CDCWireHitTopology (static object for event data)
  - TMVA interface
  - Lots of cleanup in findlets, filter, variable recording, fitting procedures etc.

Overall performance as of the common validation

add_track_finding_cdc

finding eff.	0.8931
hit eff.	0.8868
clone rate	0.0358
fake rate	0.2505
time	89.01 $\pm$ 78.33 ns

TrackFinderCDCAutomaton

finding eff.	0.9107
hit eff.	0.8386
clone rate	0.1615
fake rate	0.3017
time	59.81 $\pm$ 47.38 ns

Standard tracking coverage for CDC-only track finding

generator	generic
UsePXDHits	False
UseSVDHits	False
UseCDCHits	True
WhichParticles	[‘primary’] $\leftarrow$ choice partially responsible for high fake rate

Overall performance as of the common validation including secondaries

add_track_finding_cdc

finding eff.	0.8082
hit eff.	0.8283
clone rate	0.0725
fake rate	0.0815
time	89.01 $\pm$ 78.33 ns

TrackFinderCDCAutomaton

finding eff.	0.8547
hit eff.	0.7997
clone rate	0.2242
fake rate	0.0794
time	59.81 $\pm$ 47.38 ns

Modified tracking coverage for CDC-only track finding

generator	generic
UsePXDHits	False
UseSVDHits	False
UseCDCHits	True
WhichParticles	['CDC'] $\leftarrow$ match all particles seen in the CDC

Newly completed cellular automaton path

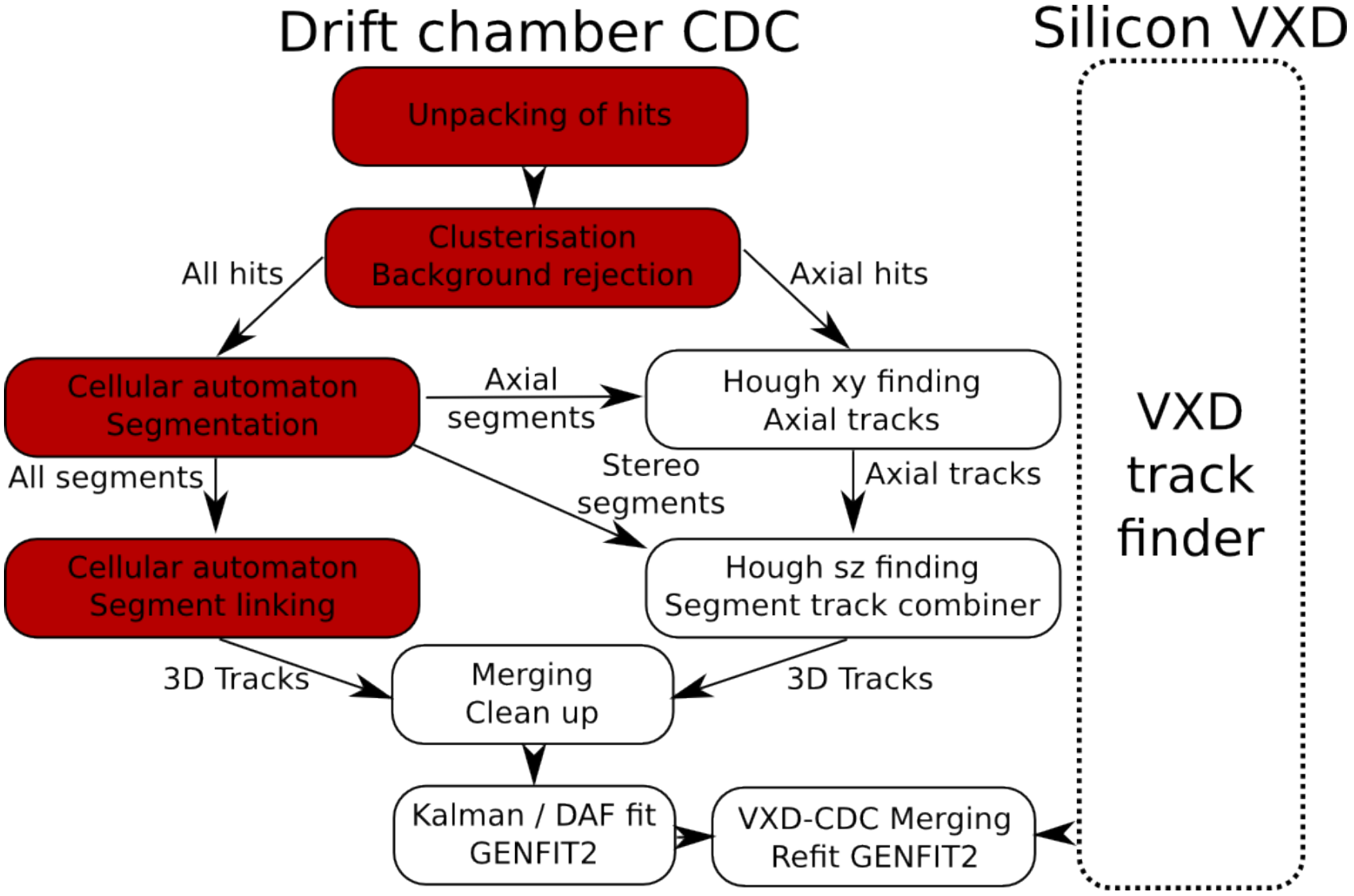


Figure 4: TrackFinderCDCAutomaton

Current standard reconstruction

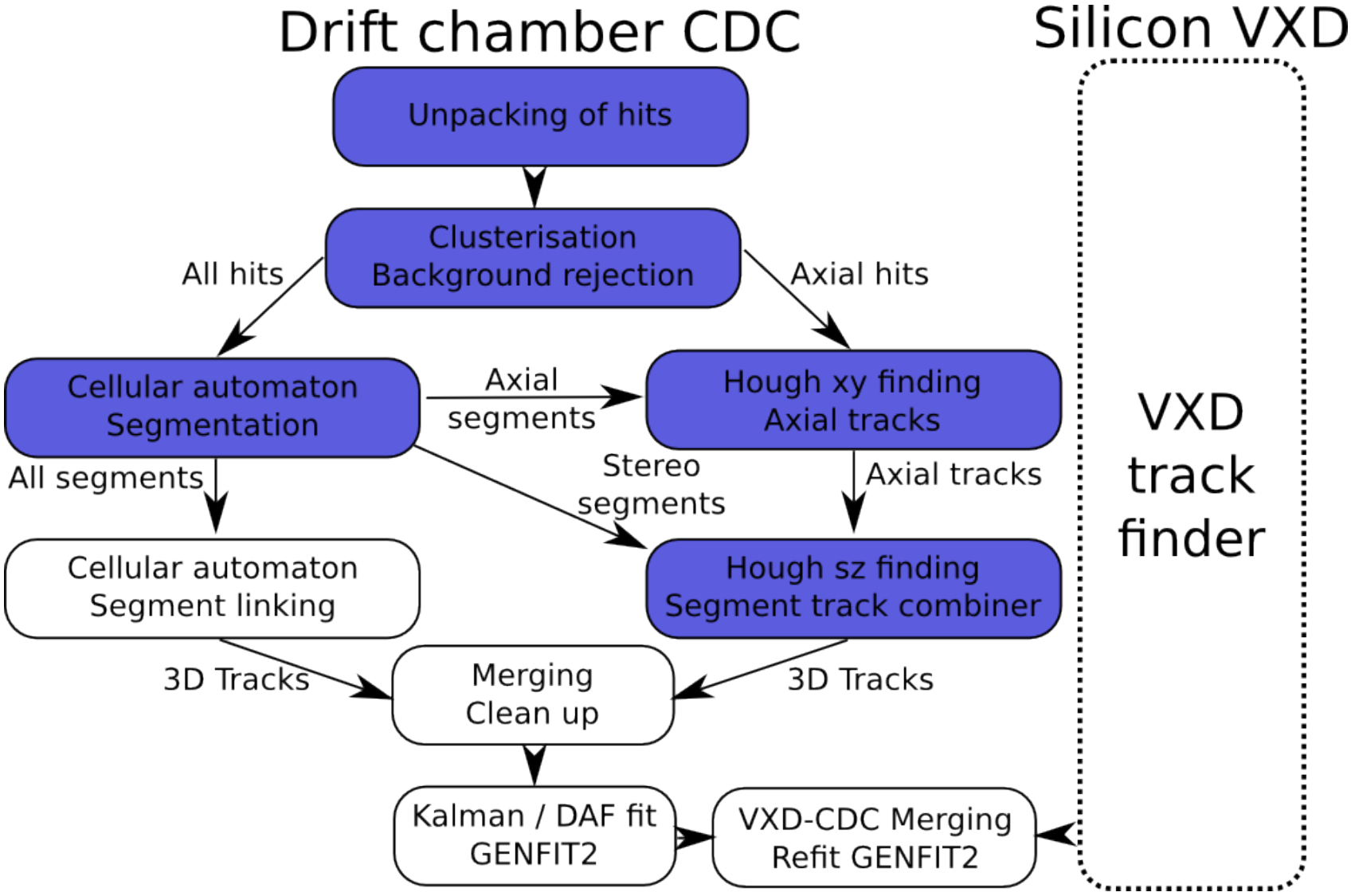


Figure 5: *add_track_finding_cdc*

Combiner stage

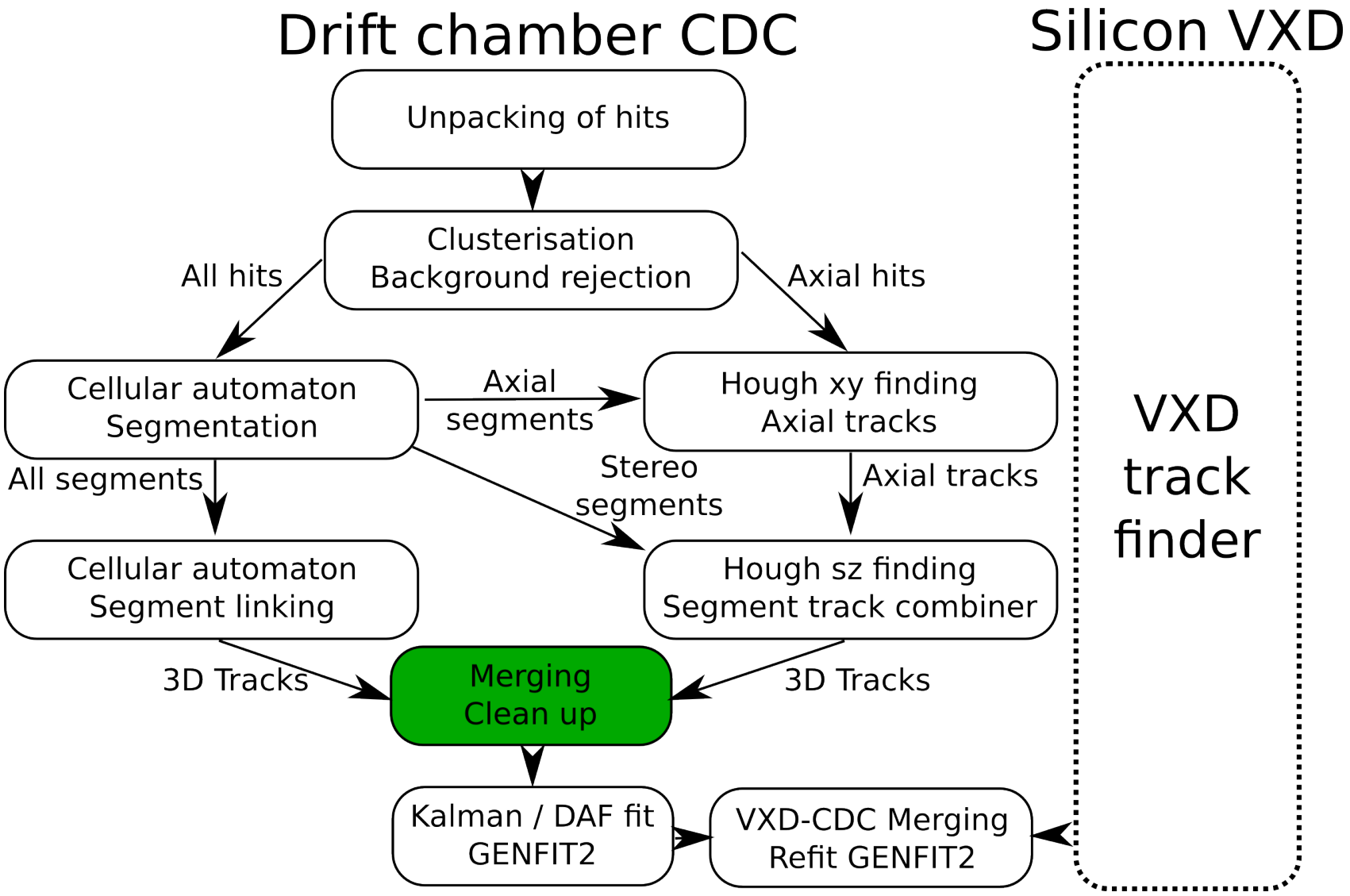


Figure 6: TrackFinderCDCAutomaton

Tasks

- Todo: Combiner stage making best candidate selection
- Group effort: think again what the reference should be.
- Only first loop?
- Include secondaries or not?

Quick and easy event generation and displays

Convenience scripts

- `b2run_generator` - Generator level event generation
- `b2run_simulation` - Belle2 detector simulation, full, only tracking detector, cosmic ray test etc.
- `b2run_tracking` - Run (tracking) reconstruction (complete, CDC-only, VXD-only) on pre-simulated events or simulate on-the-fly
- `b2run_cdc_display` - Two dimensional plotting of CDC tracking results with a lot of color codings

Ideal for newcomers to get something running and something to look at.