National Taiwan University

2D Tracker in CDC Trigger

TRG/DAQ workshop in BINP

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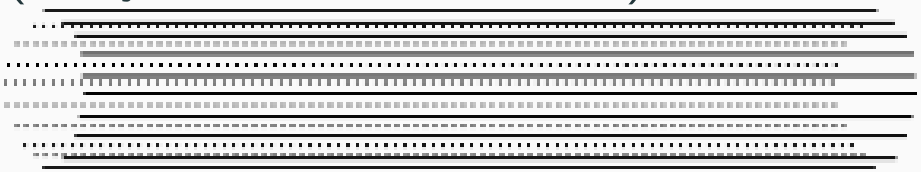
An Overview

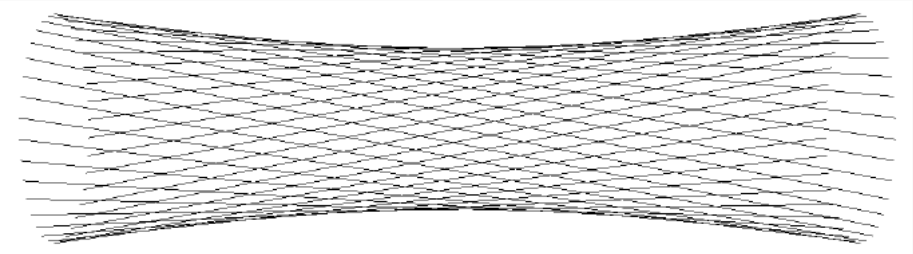
- Mission of 2D tracker: Turn unmarked hits from sense wires in axial super layers into groups caused by same particles.

sense wire geometry

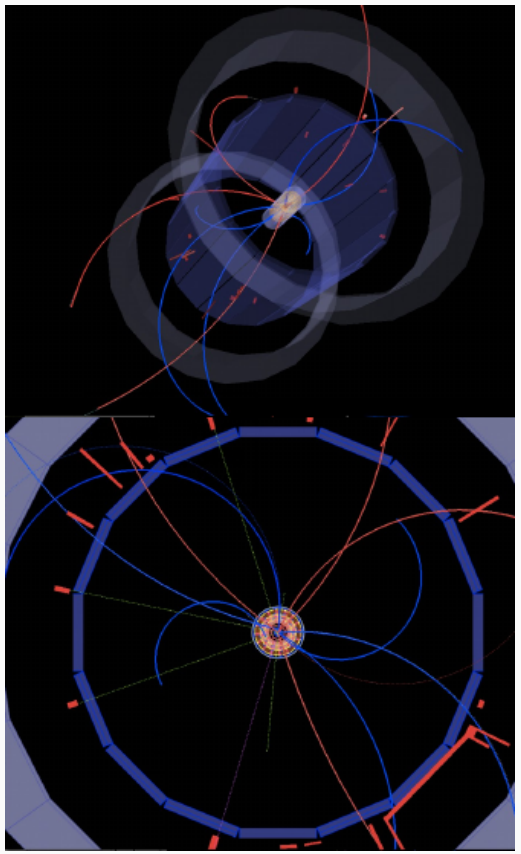
axial super layers (0, 2, 4, 6, 8) for r, ϕ (in cylindrical coordinate)



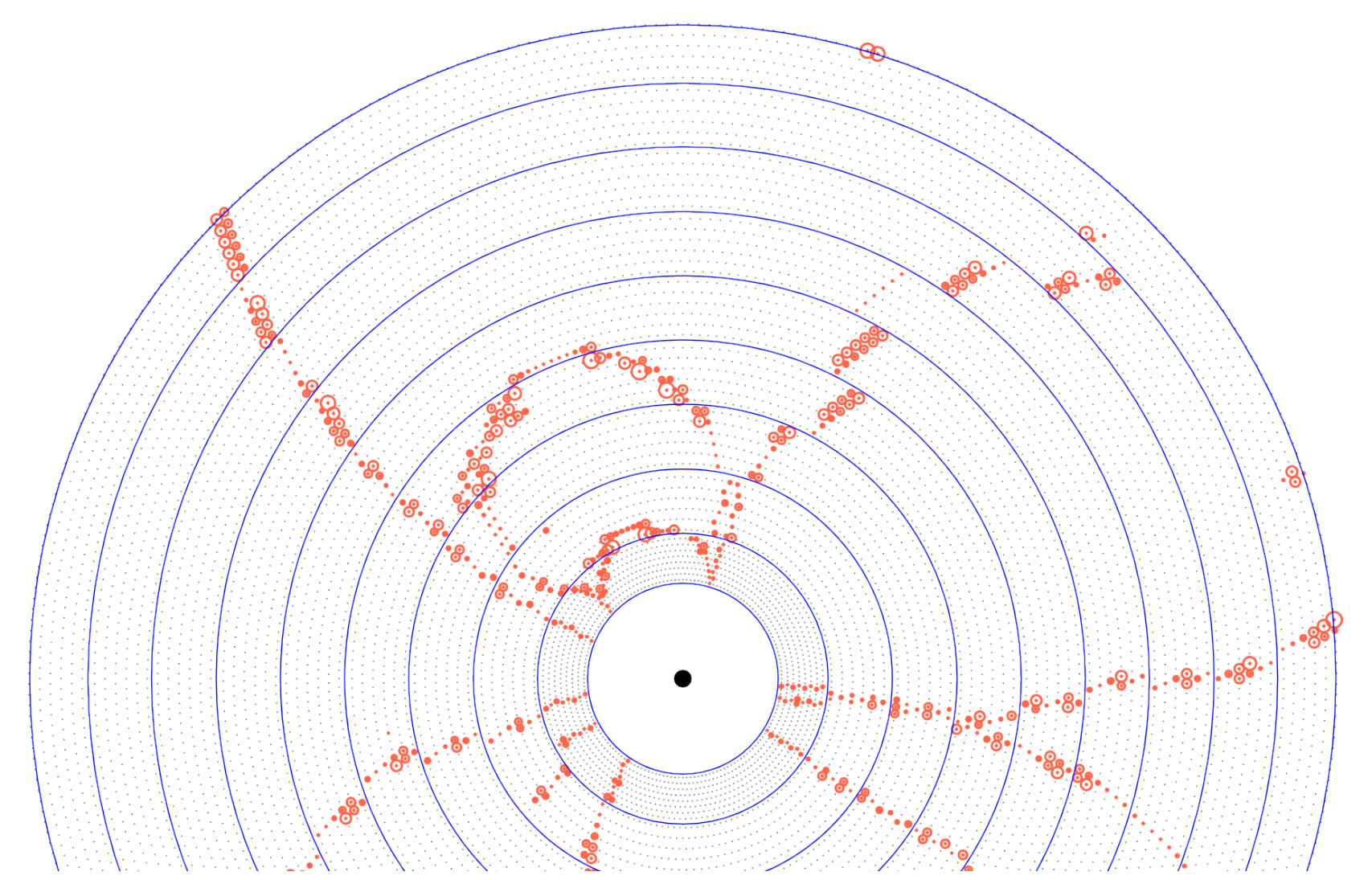
stereo super layers (1, 3, 5, 7) for z extraction



2D projection

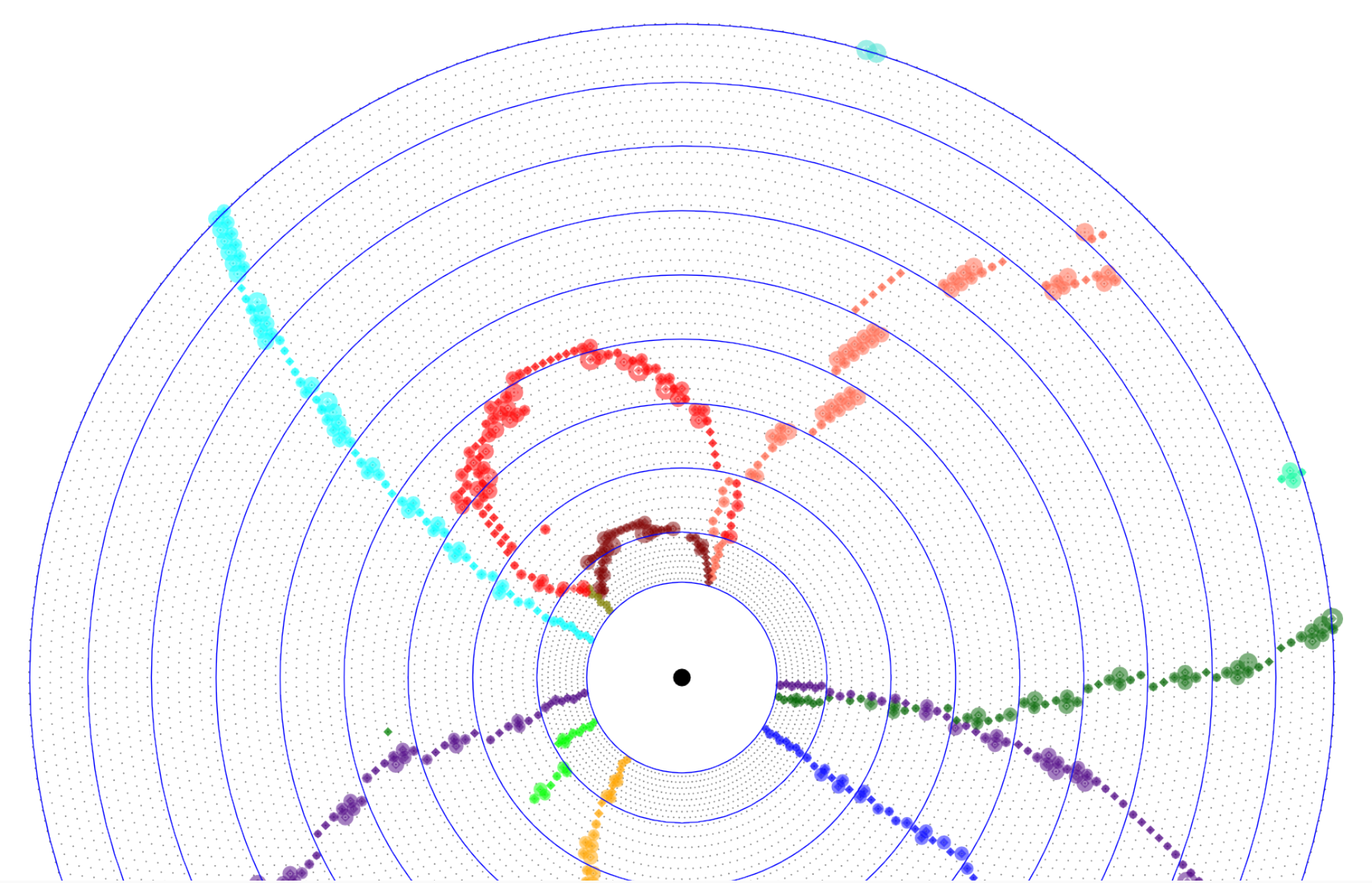


Turn unmarked hits ...



helix $\rightarrow$ circle (arc) on $r - \phi$ plane

into groups caused by same particles

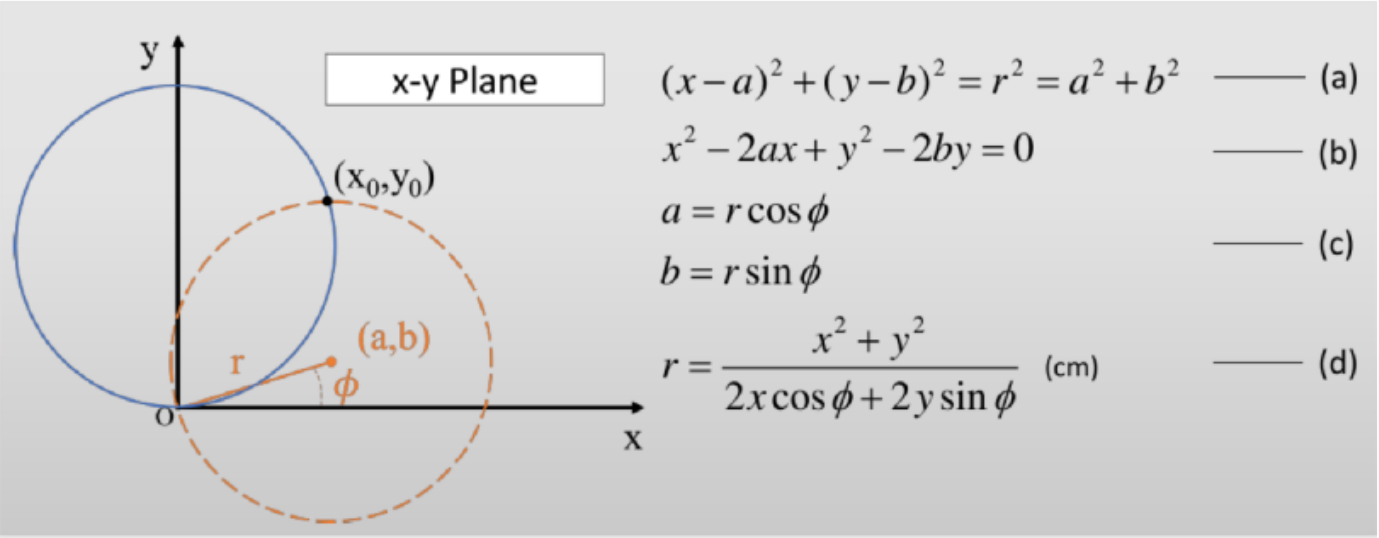


helix $\rightarrow$ circle (arc) on $r - \phi$ plane

Step 1 - Find the circle

- Brute-force algorithm: keep trying various centers and radius until it passes all hits on 5 axial superlayers
  - Why it doesn't work: limited resource in firmware (FPGA)
- An efficient way is through Hough transform

Hough Transform (by FJCU)



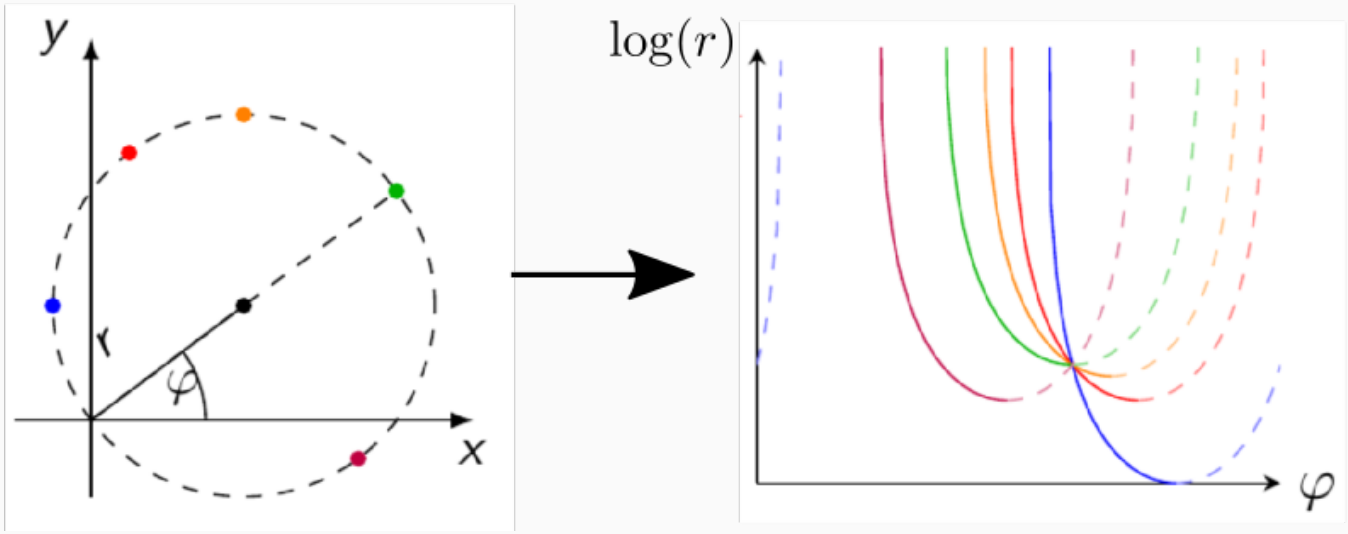
$$(x-a)^2+(y-b)^2=r^2=a^2+b^2 \quad \text{——— (a)}$$

$$x^2-2ax+y^2-2by=0 \quad \text{——— (b)}$$

$$a=r\cos\phi$$

$$b=r\sin\phi \quad \text{——— (c)}$$

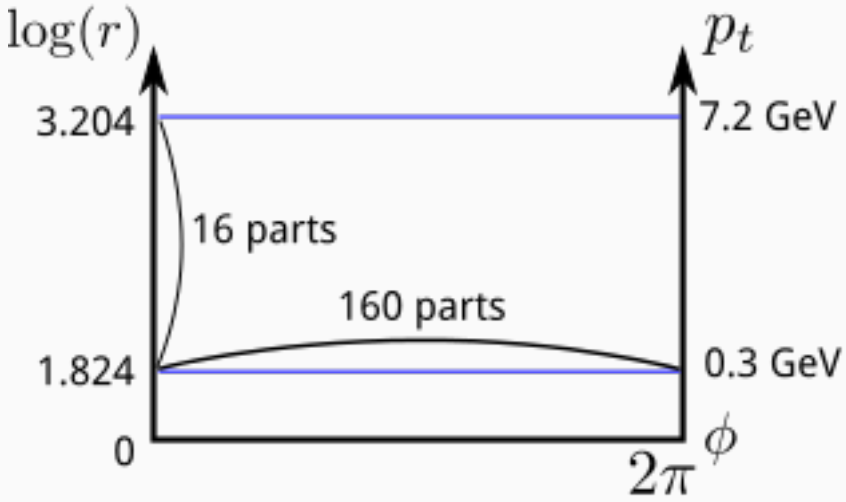
$$r=\frac{x^2+y^2}{2x\cos\phi+2y\sin\phi}\ \text{(cm)} \quad \text{——— (d)}$$

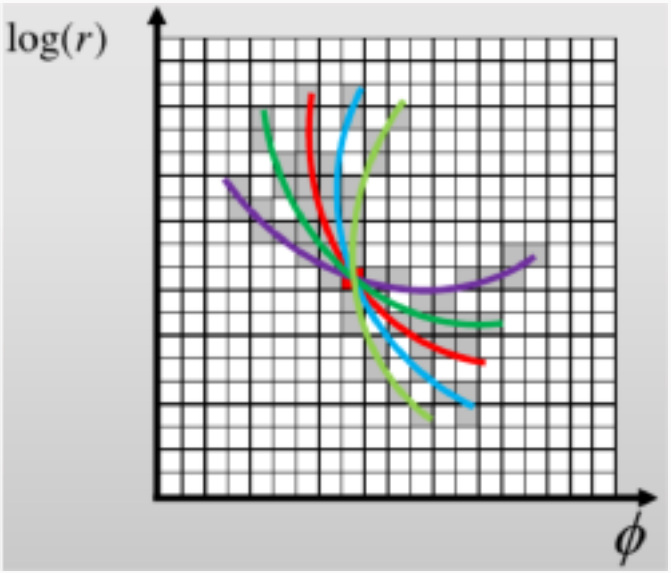


real line: plus track/ dashed line: minus track

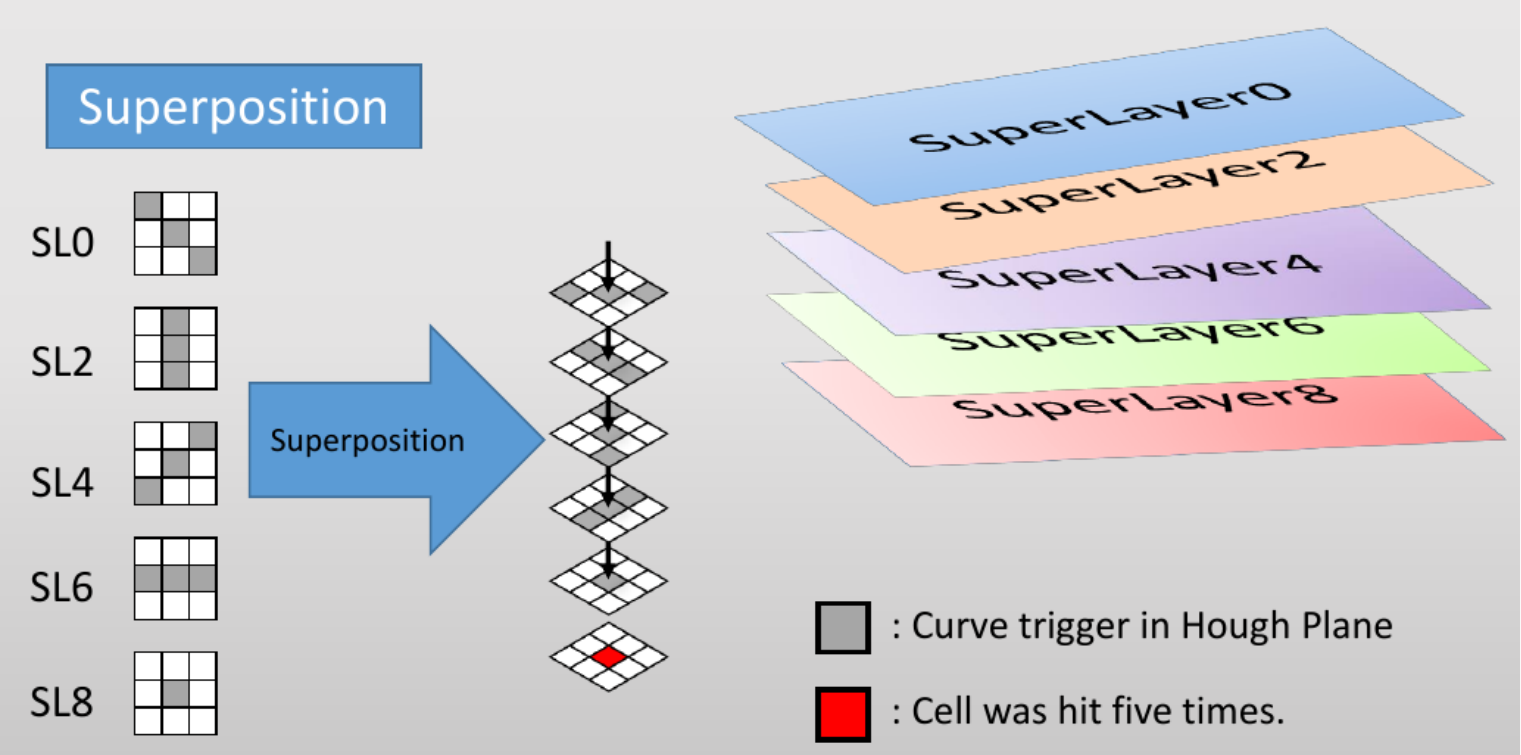
Meshing (by FJCU)

- strike a balance between efficiency and resolution





Hough Voting (by FJCU)

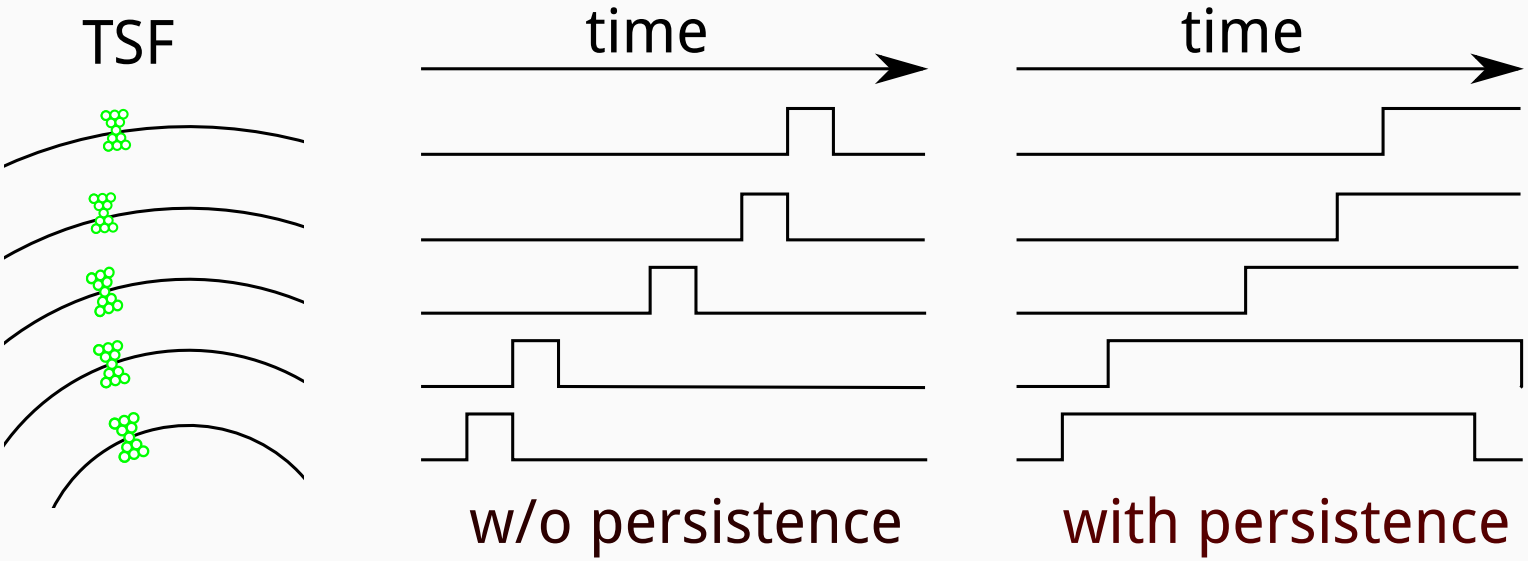


Part0: Persistence of TSF Input

- Voting is done at the same time for 5 superlayers

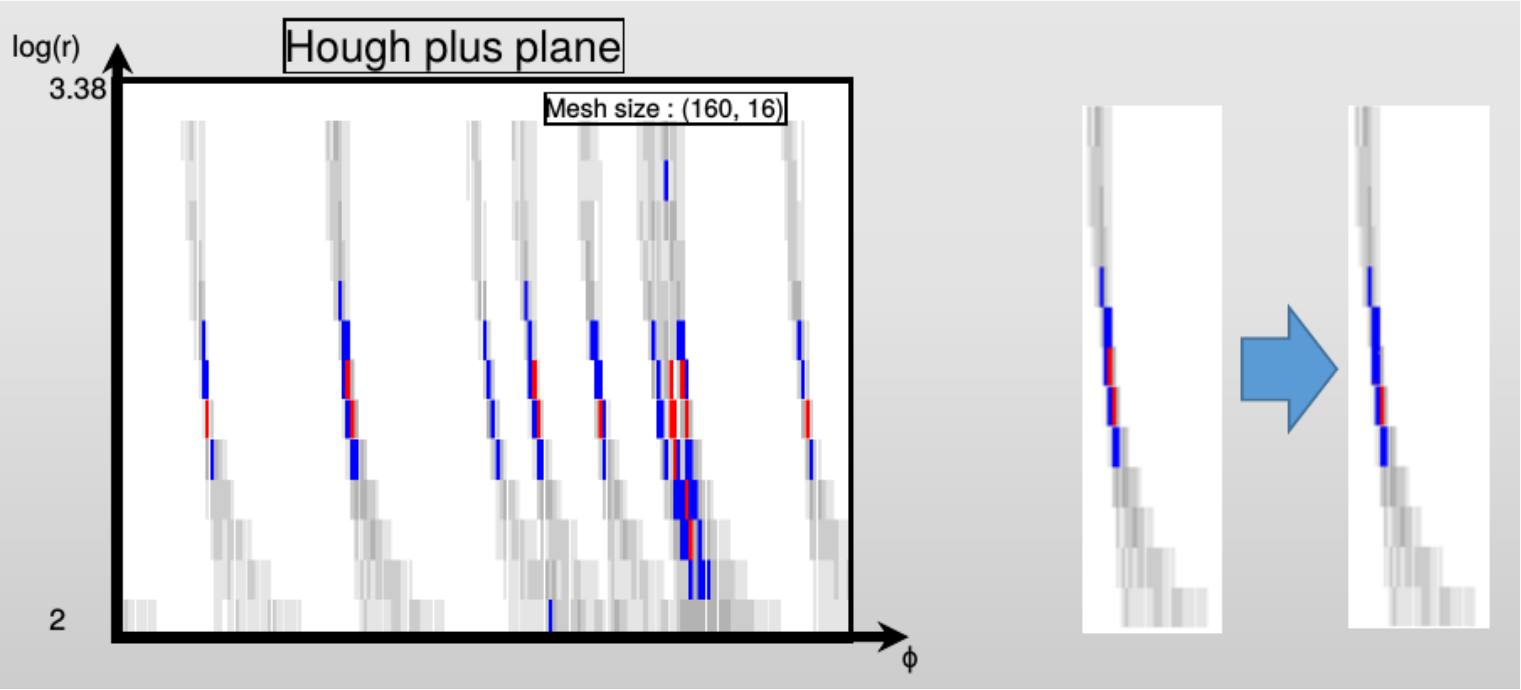
Due to drift time, transmission delay, etc. TSF inputs of different superlayers from the same track arrive at different clocks.

Persisted signal input can rescue such events.

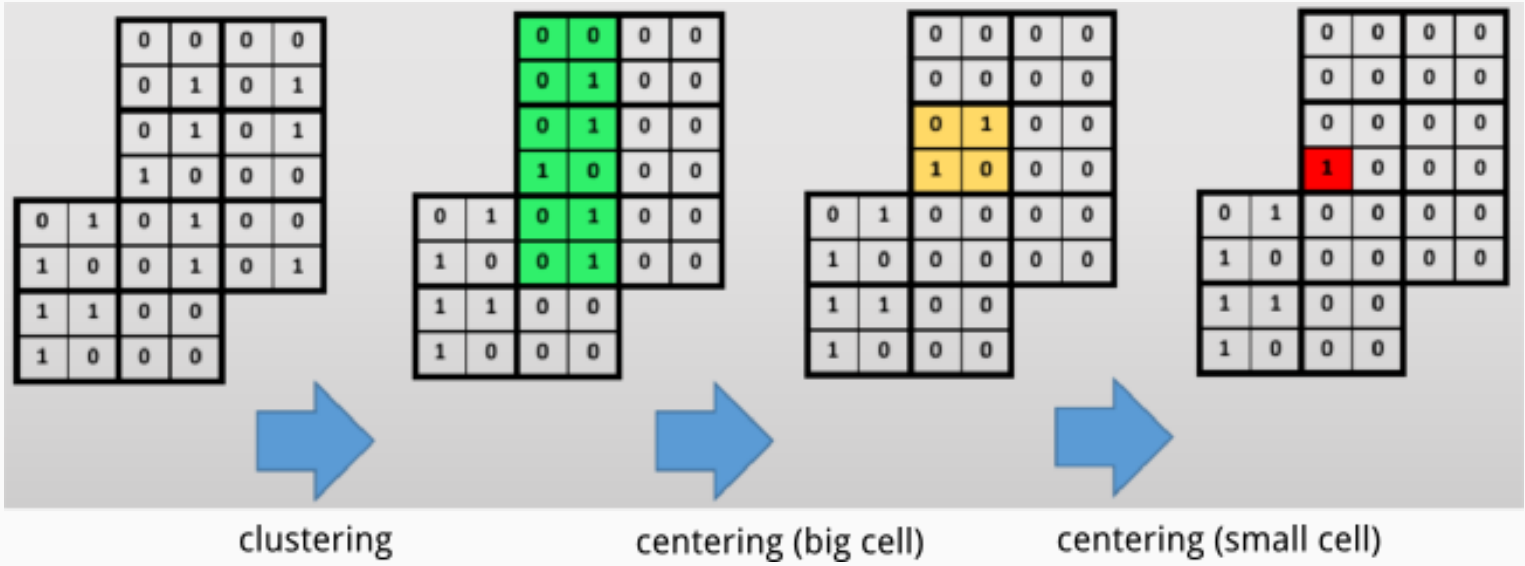


Clustering (by FJCU)

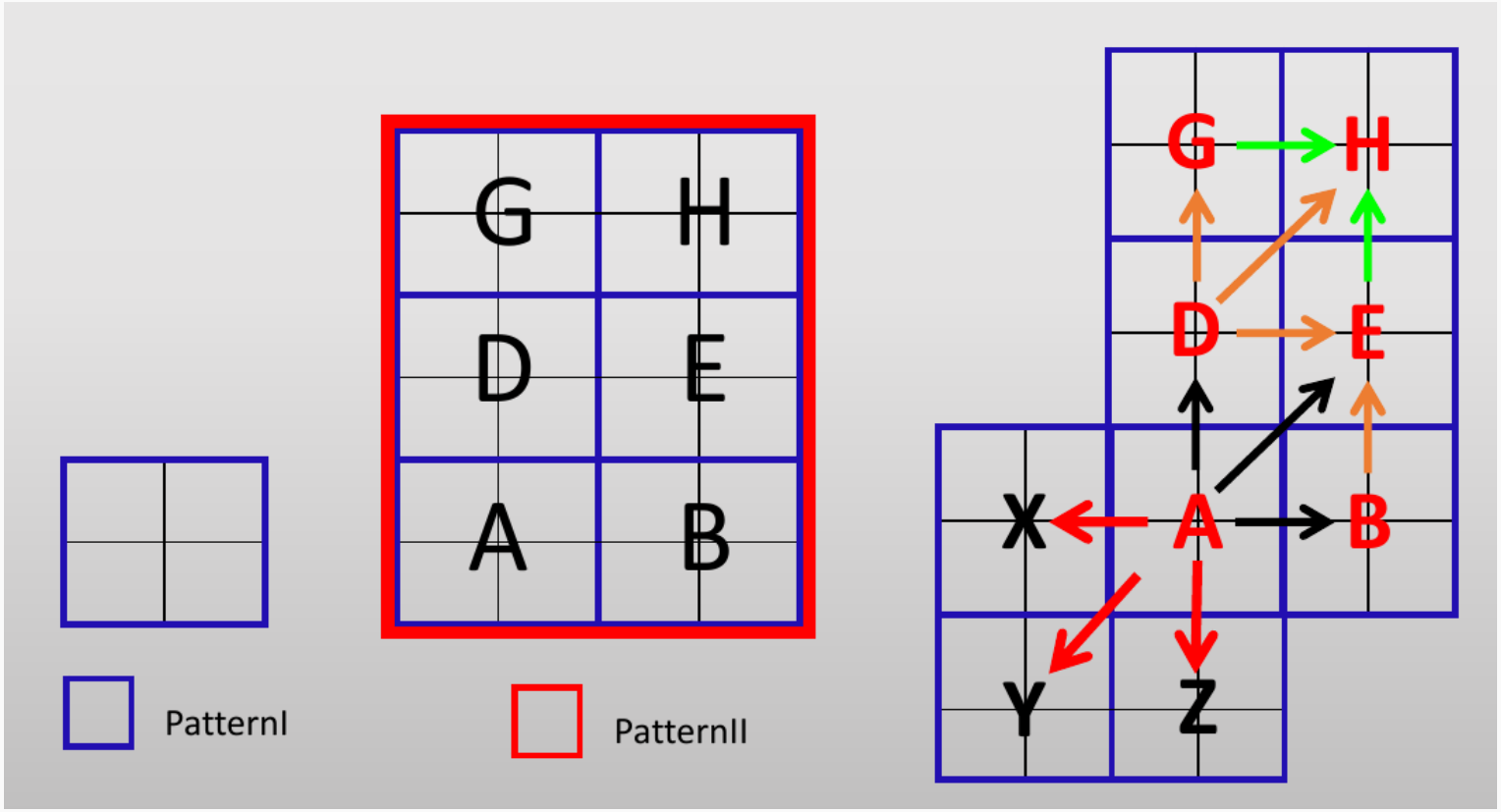
What if more than 1 cell get 5 hits?



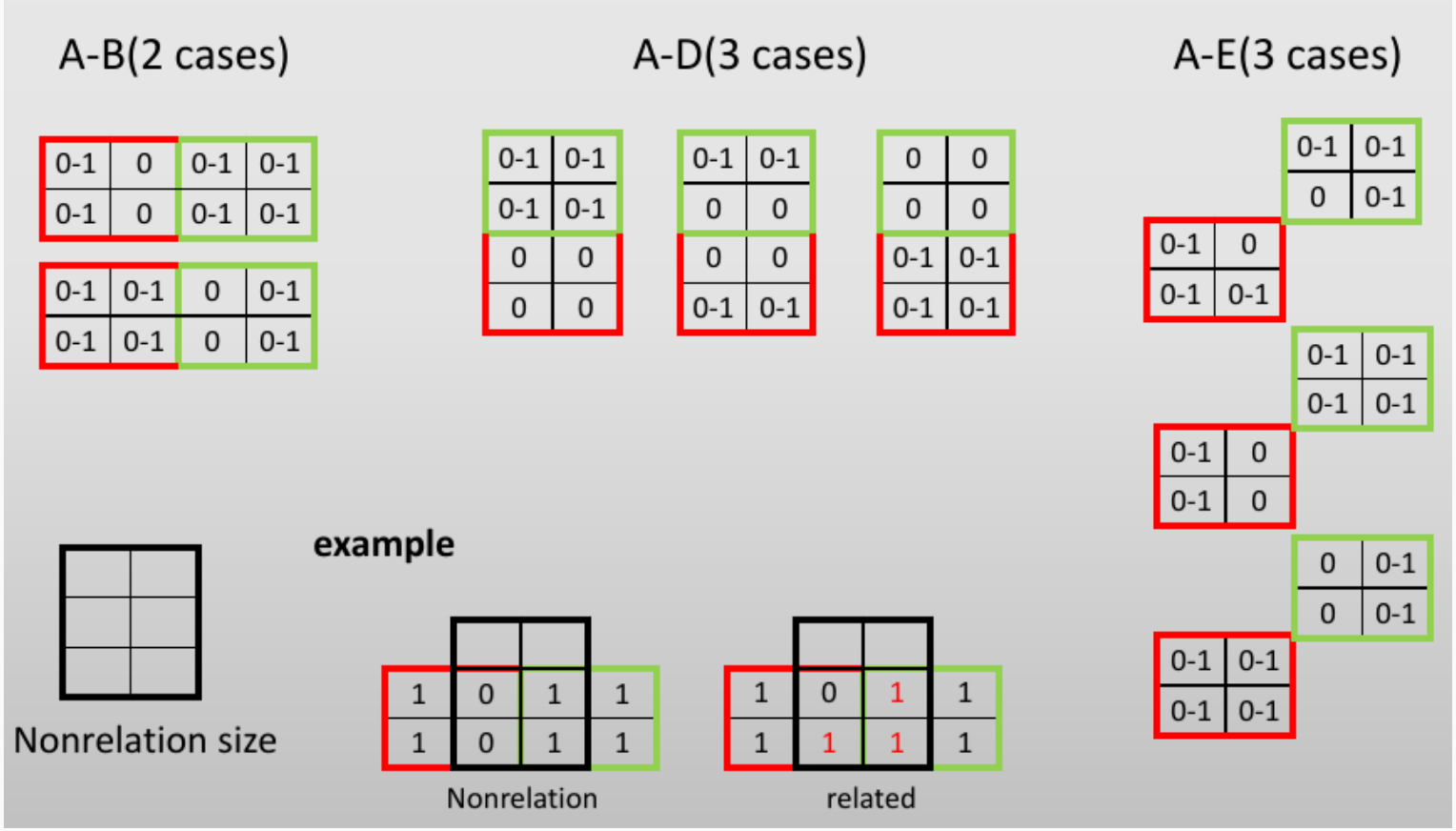
Clustering and Centering (by FJCU)



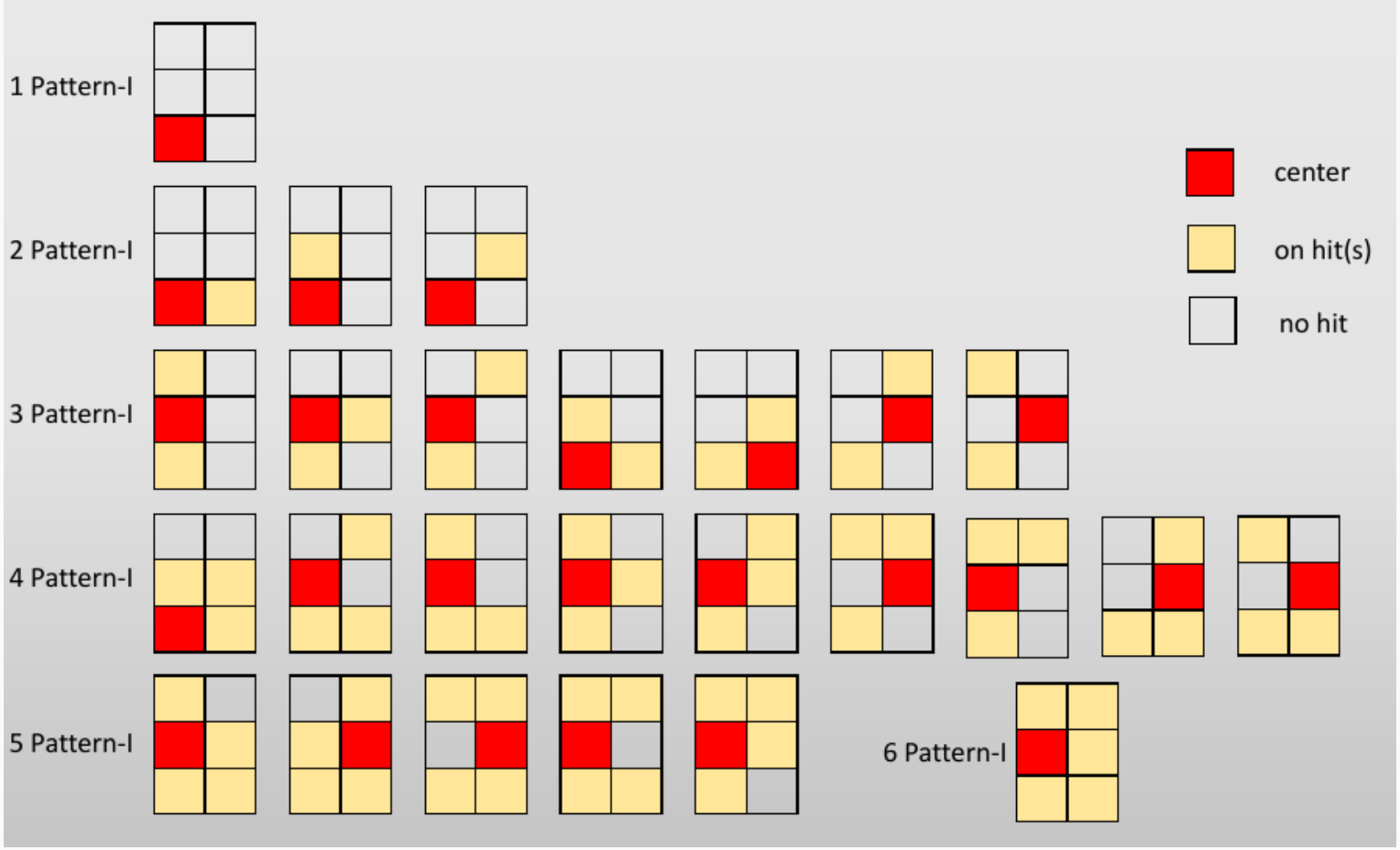
Pattern unit size (by FJCU)



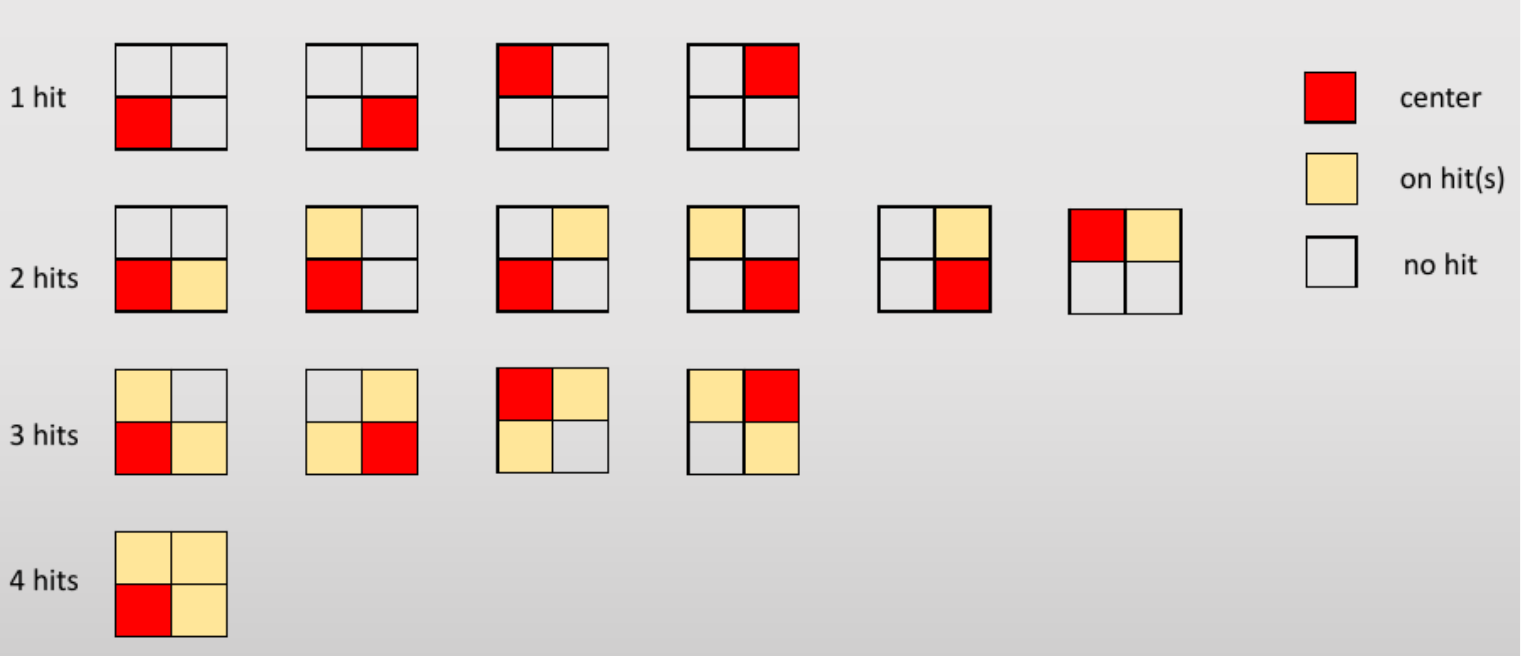
Clustering (by FJCU)



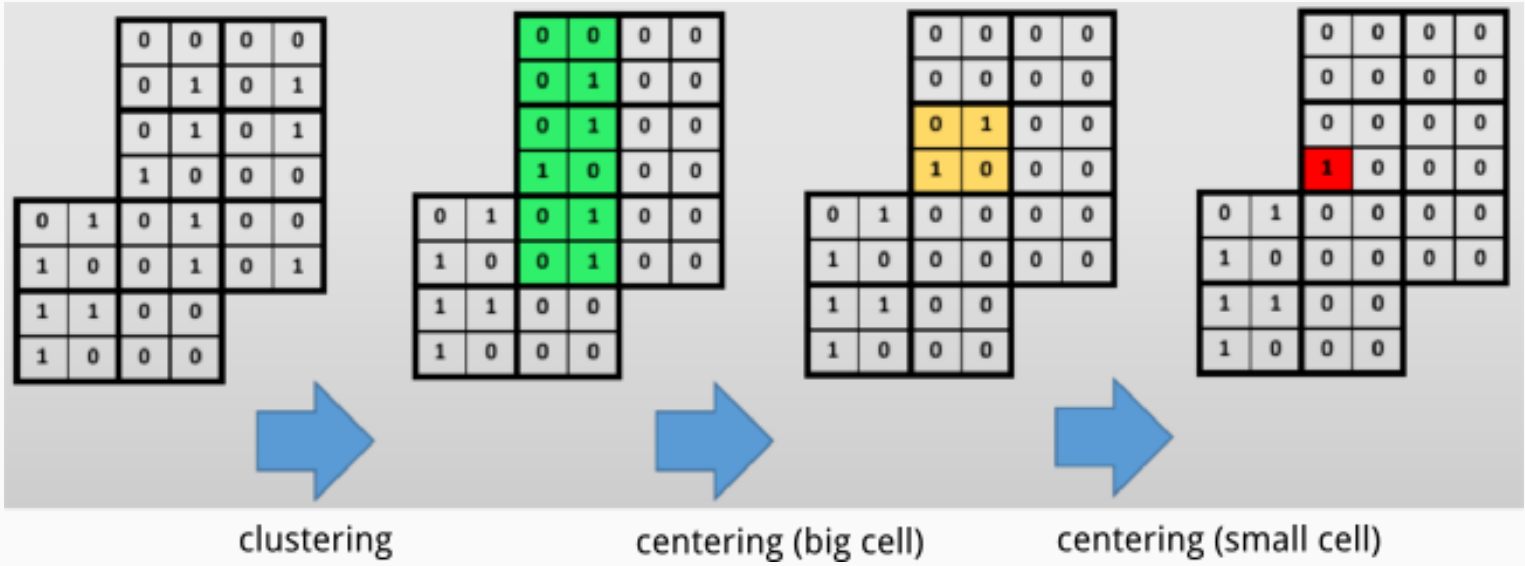
Centering Bigger Pattern (by FJCU)



Centering Smaller Pattern (by FJCU)



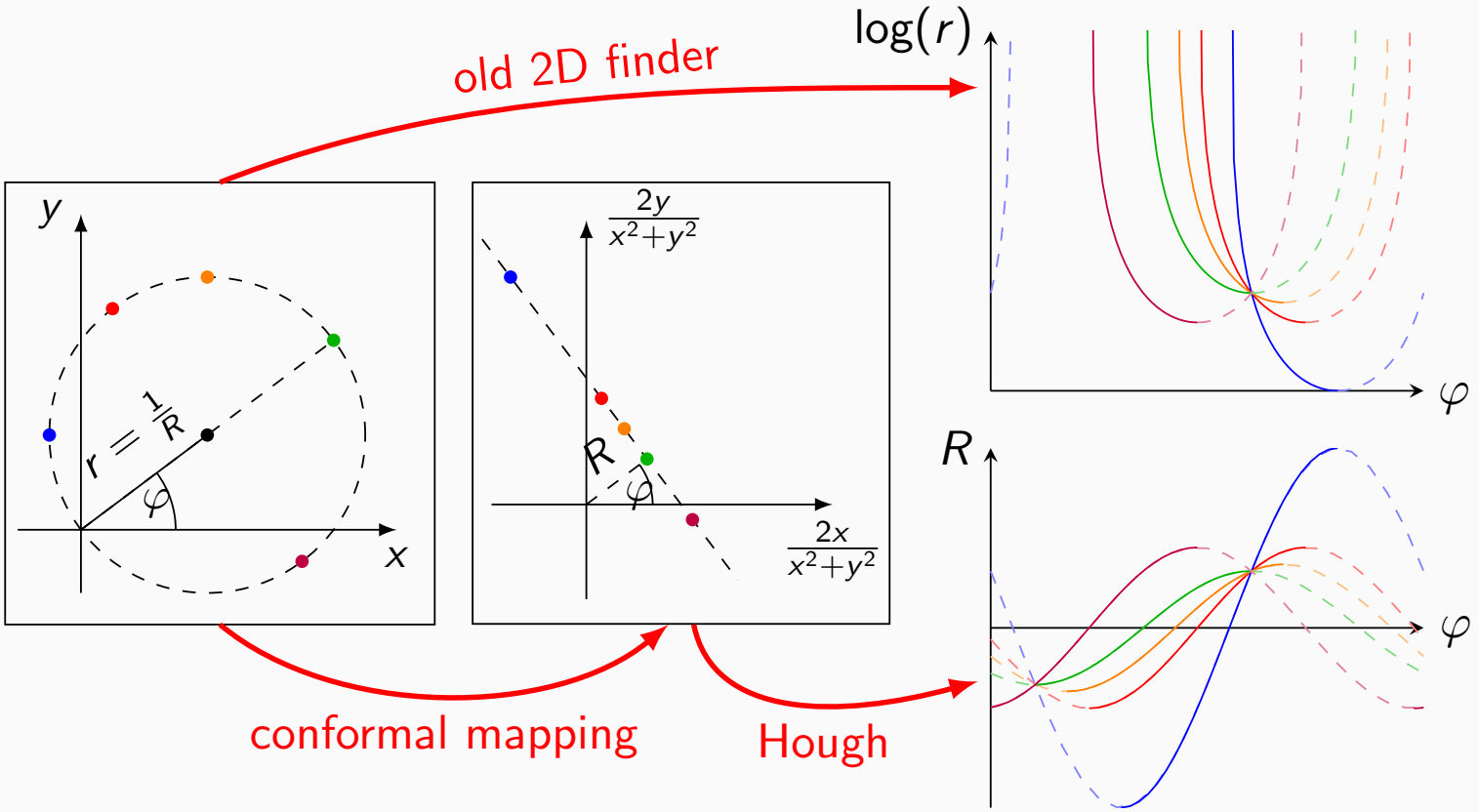
Clustering and Centering (by FJCU)



Remaining issue

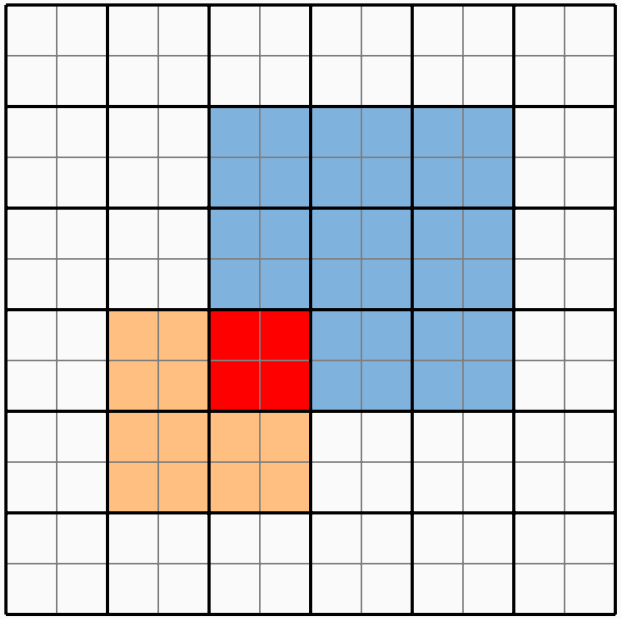
- 10% double counting for high p_T on both plus and minus Hough plane
- Efficiency of tracks triggering all 5 axial SLs not ideal
- biased center position

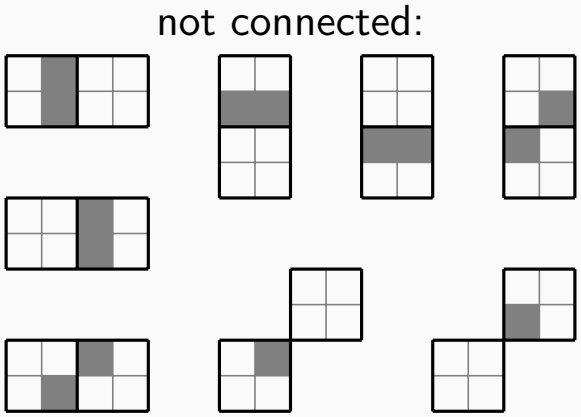
Alternative Transformation (by S. Neuhaus)

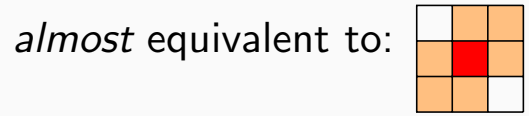


- same Hough plane for charge plus and charge minus
- no double counting for high p_T

Alternative Clustering and Centering (by S. Neuhaus)







- grid of 2×2 squares
- start clustering from red square (not connected to orange squares)
- add connected squares within x $\times$ y block (blue)
- center: average of top right and bottom left corners of cluster

Required changes

- new precalculated patterns for building the Hough plane
- charge plus and charge minus in same plane
  $\rightarrow$ no double counting
- new clustering rules for connected cells
- cluster center: average over corners
  $\rightarrow$ more precise parameter estimate
- hit requirement: 4 of 5 super layers
  $\rightarrow$ higher efficiency
- work in progress:
  optimize number of cells and size of clustering block

Part2: Choosing related track segments

Reminder of the goal: categorize hits

Now that we found the center of the track circle ...

- For each clock, choose the 3 tracks with highest transverse momentum
- Do inverse Hough transform to find out related hits
- Pick up desired TS based on quality of the hit

Part3: Fitting the result (algorithm by J. Kim)

- In 3D tracker board
- very similar to 3D fitter
- Use drift time and L/R information to calculate fine ϕ
- minimize χ^2 of the circle and 5 ϕ 's
- pre-calculated results made into look-up table and stored in block ram

Summary

Components in 2D tracker

- Persisting the input signal
  For input from the same track coming at different time
- Finding the circle
  - Hough transform
  - clustering
  - centering
  - new algorithm under development
- Choosing related track segments
- Fitting the result
  for optimal resolution in firmware

Status

- 2D tracker (old algorithm)
  Firmware completed. Now testing with Belle2Link.
- 2D fitter
  Firmware 90% completed.

Reference (where I stole the images)

- Oliver Frost, Cellular Automaton based Track Finding for the Central Drift Chamber of Belle II.
- Martin Heck, Belle II-Tracking: Status of Preparation, including Pixel Readout and Data Reduction