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Updates to the Circle Hough Trackfinding Algorithm

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Circle Hough Algorithm

- Circle Hough algorithm principles
  - Generate all possible tracks
  - Accumulate track parameters
  - Most likely parameters $\Longrightarrow$ real tracks

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- Circle Hough algorithm principles
  - Generate all possible tracks
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  - Most likely parameters $\Longrightarrow$ real tracks
- CH Features
  - High efficiency
  - Flexibility
    - Applicable to all types of hits in the central detector
  - Robustness/stability
  - Intrinsic parallelism
  - Tuneability: computing vs physics performance
    - Online/offine: same algorithms with different working points
  - Hit association and extraction of track parameters at the same time
  - Information from STT isochrone radius taken into accout

CH: Current Approaches

- Hough element: projection of primary track in the transverse plane

  $\Longrightarrow$ Circle passing through IP and hit
- Circle uniquely described by center: 2D parameter space
  - Use one parameter as sampling parameter
  - Calculate center coordinates from hit contact condition

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1 Direct calculation
  - For each hit, calculate (x, y) from set of R values
  - Accumulate coordinates in (x, y) Accumulator Array

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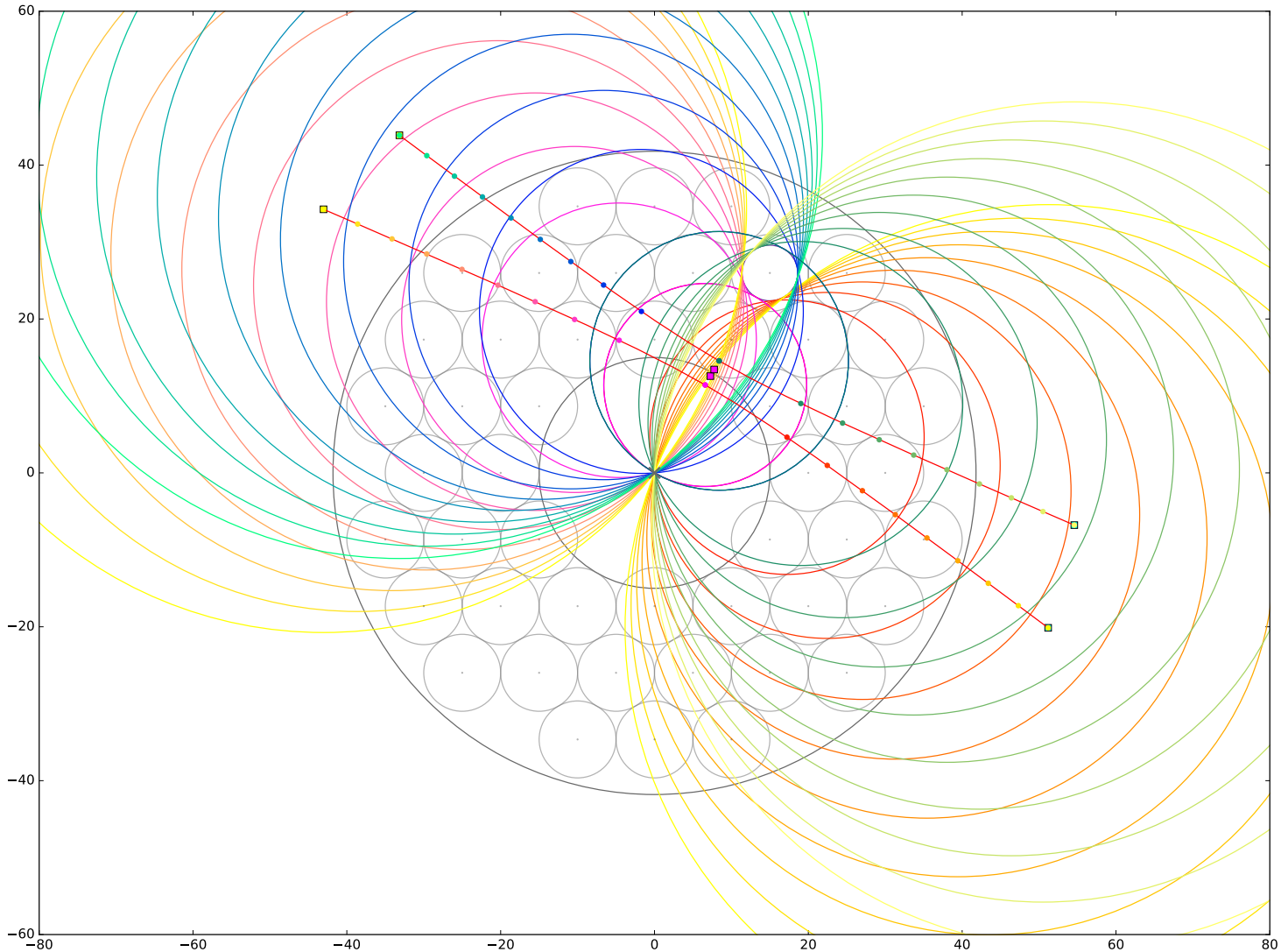
1. Direct calculation
   - For each hit, calculate (x, y) from set of R values
   - Accumulate coordinates in (x, y) Accumulator Array
2. Equation of circle centers known analytically
   - Locus is hyperbola or straight line
   - Accumulate parameters exploiting locus properties (rasterization, analytical intersection)

CH: Current Approaches

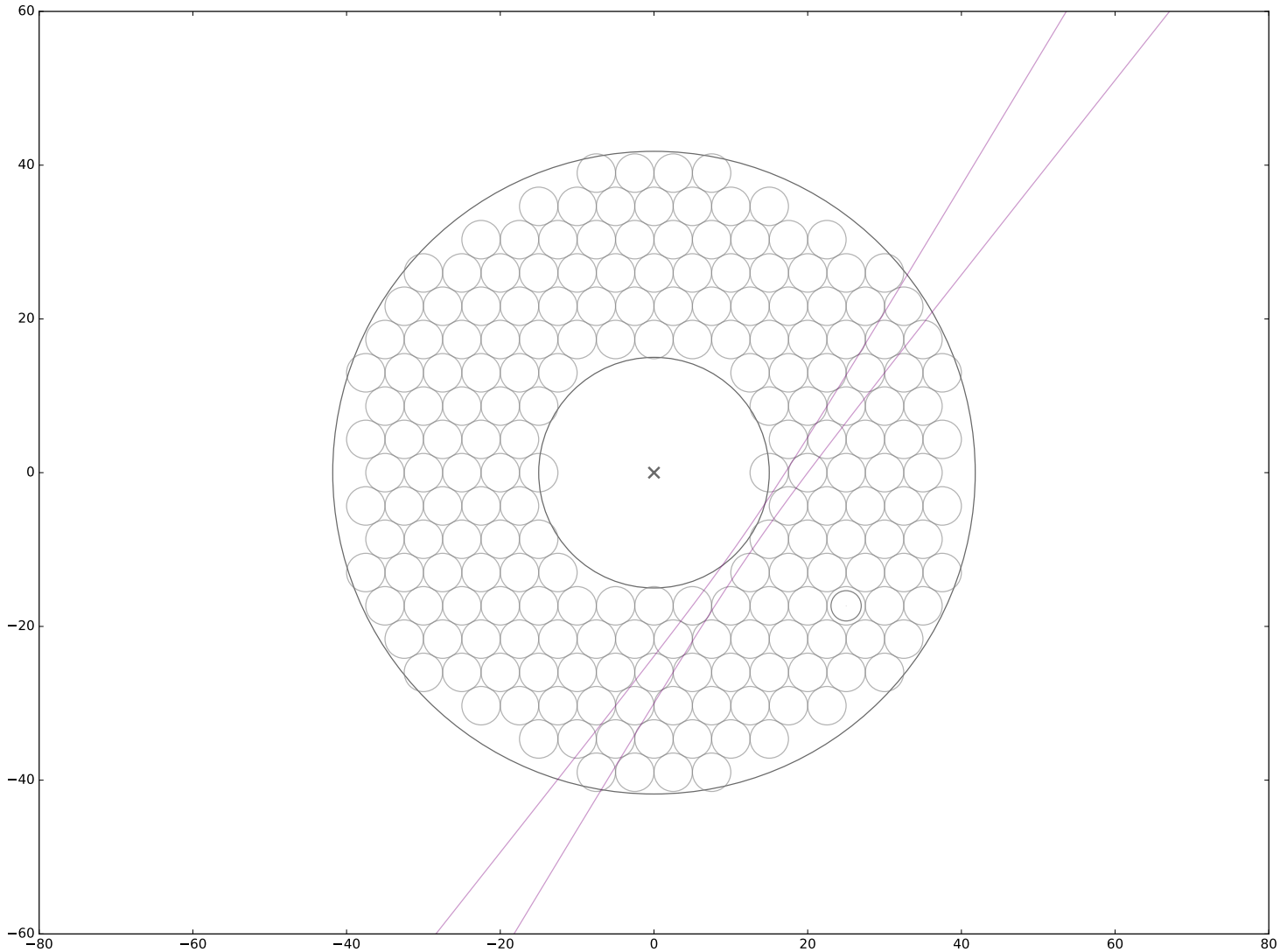


#3: Single Hit CH with ρ/φ Coord.

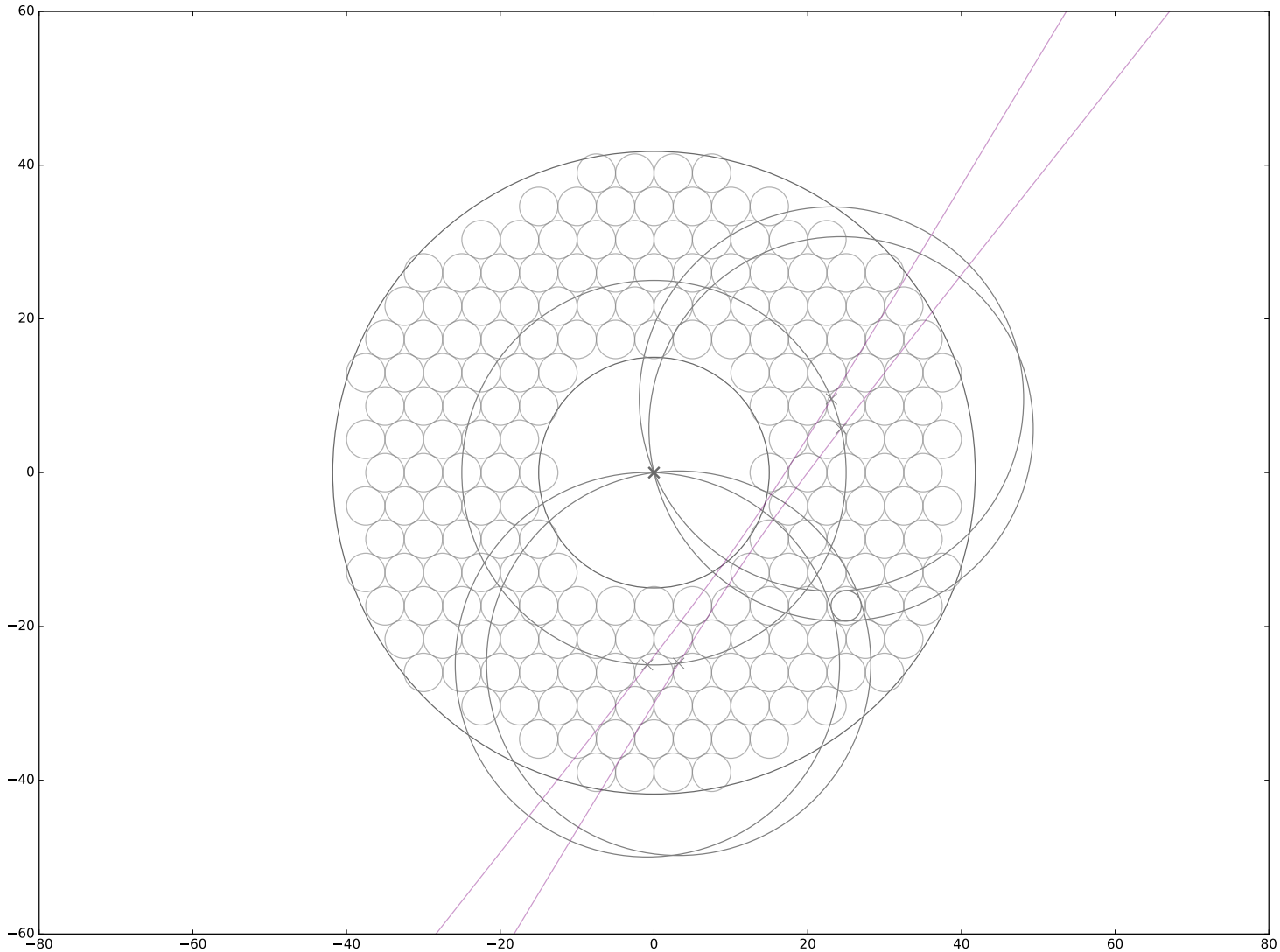
Central idea: use one set of sampling values $(R_0 \ldots R_N)$ for all hits

- Use radial coordinates (ρ, φ) of centers
  - Physically meaningful: $\rho \propto p_t$
- Cells of AA in ρ direction coincide with R values
  - Peakfinding greatly simplified
  - Optimal patterns for filling in parallel (memory writes)
- Improve p_t resolution: "zooming in" recursively
  - Use same points in subregion of AA with finer density in φ direction

CH ρ/φ Coord.



CH ρ/φ Coord.



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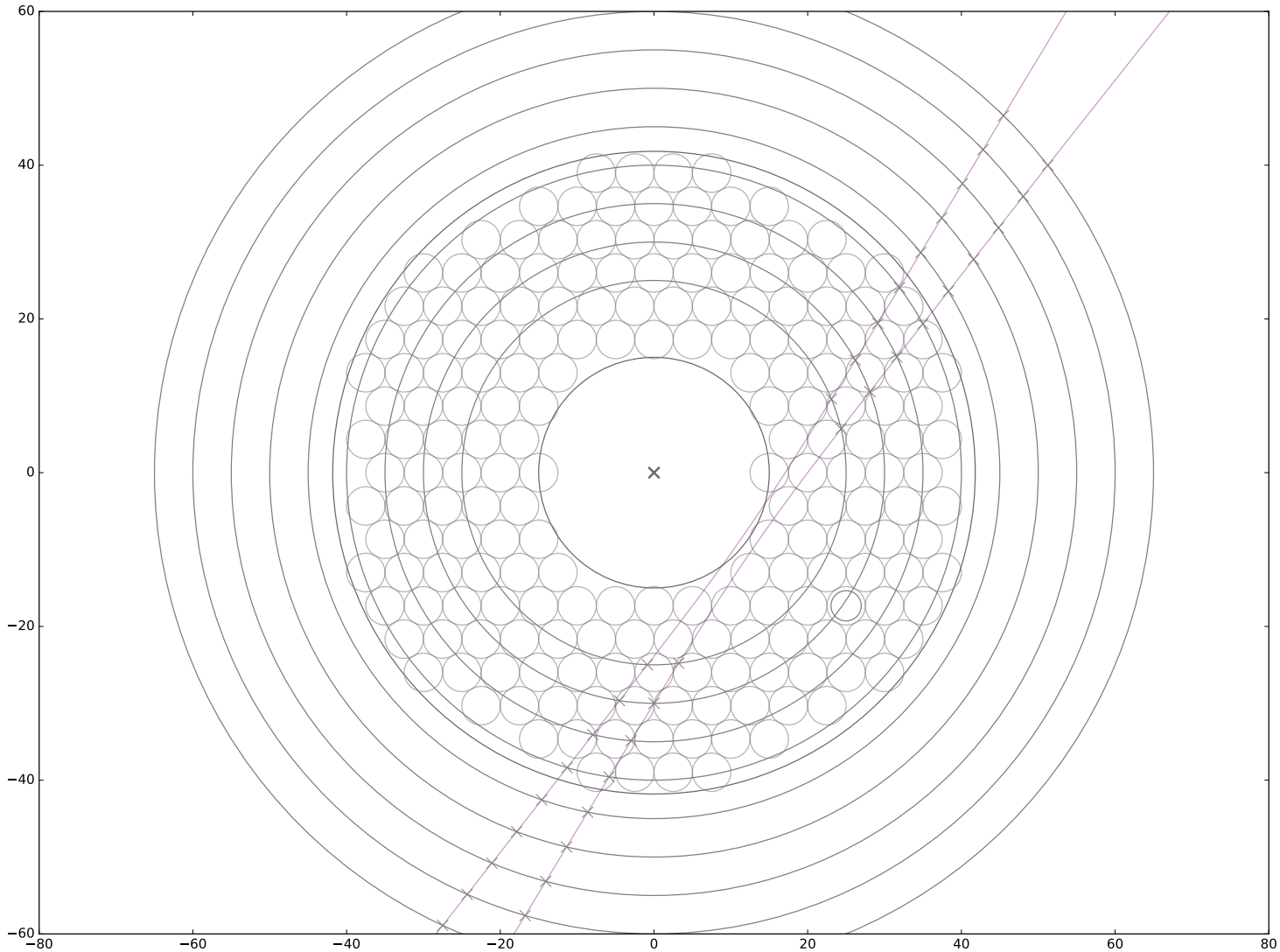

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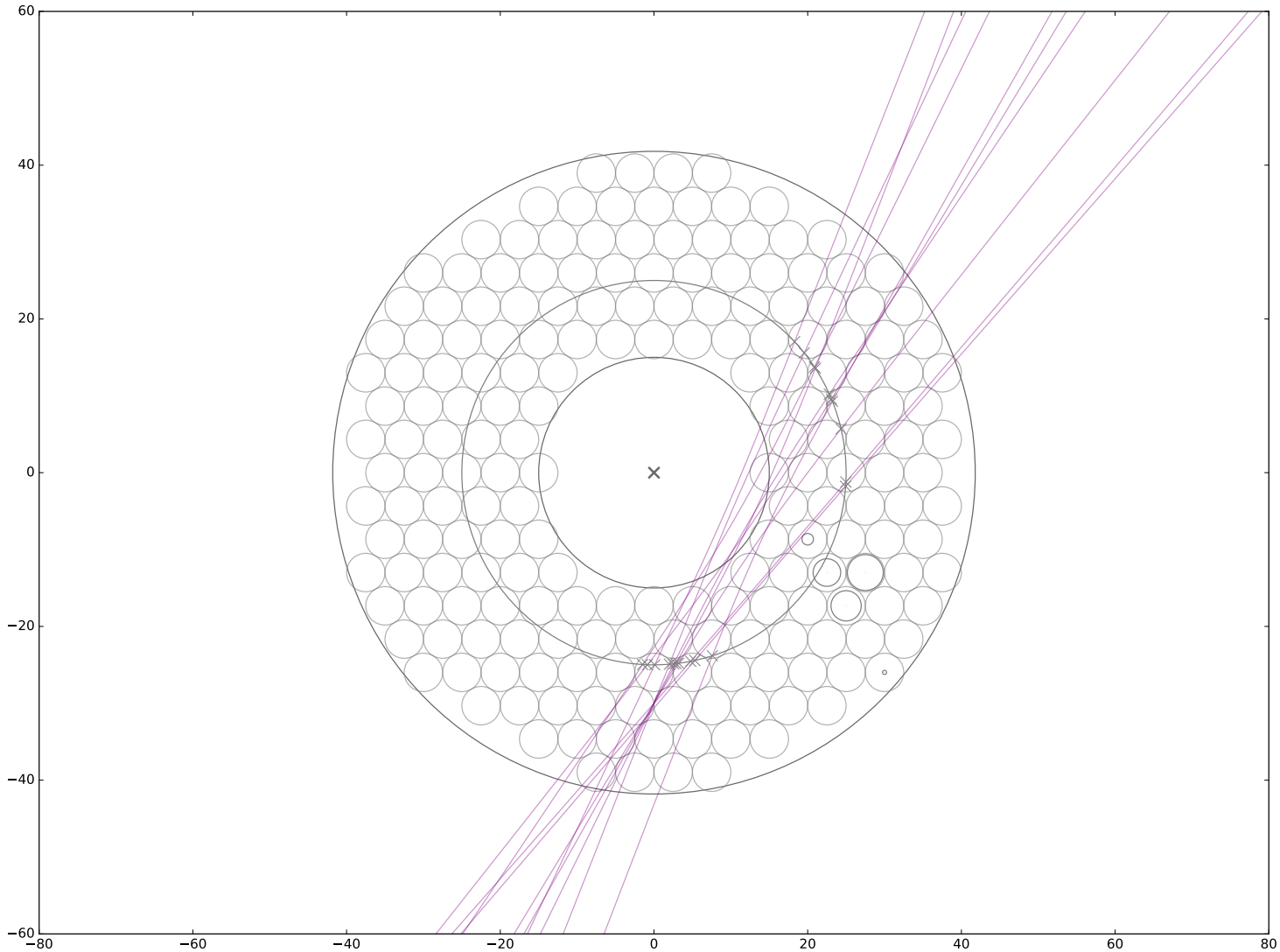

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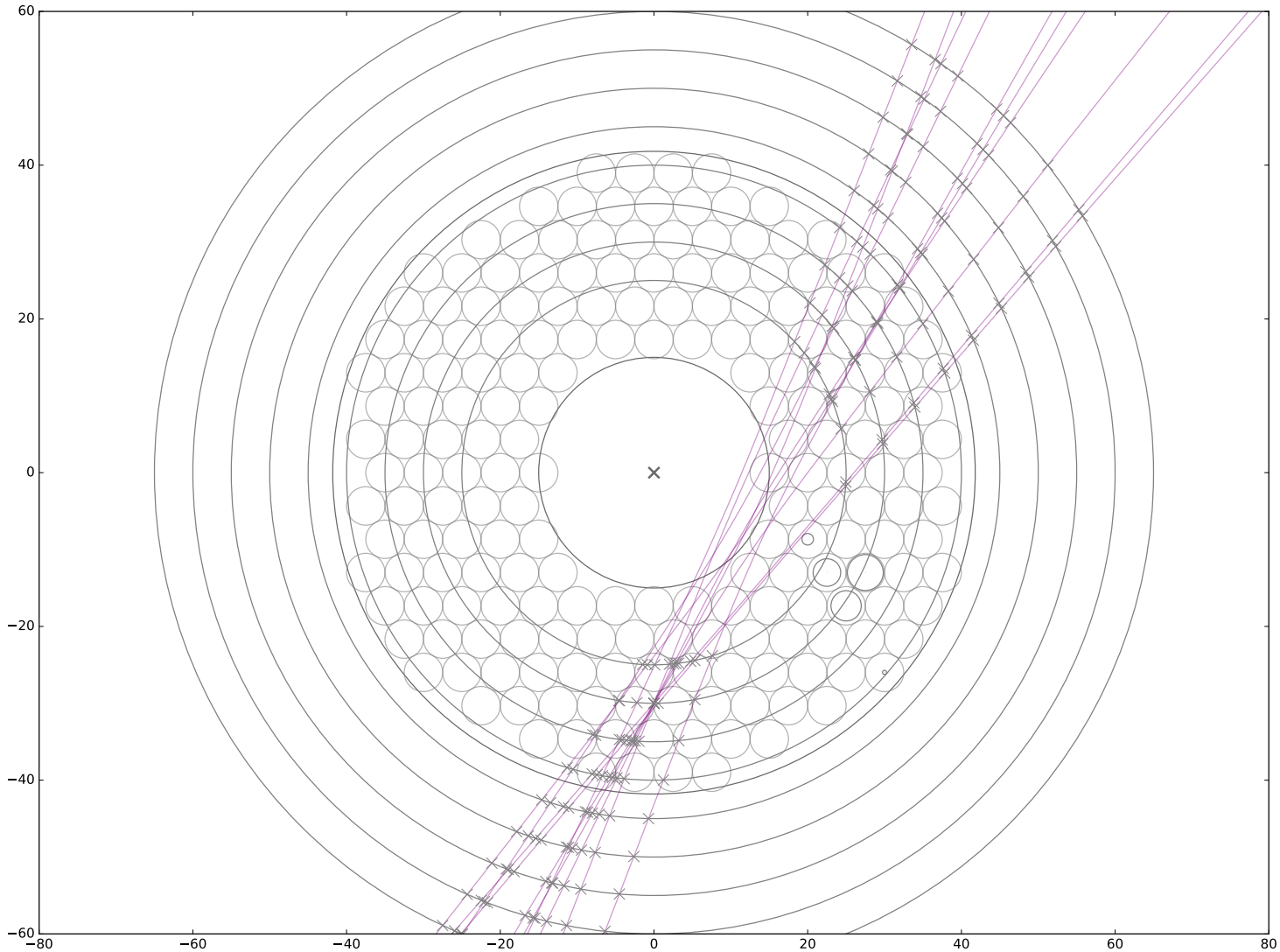
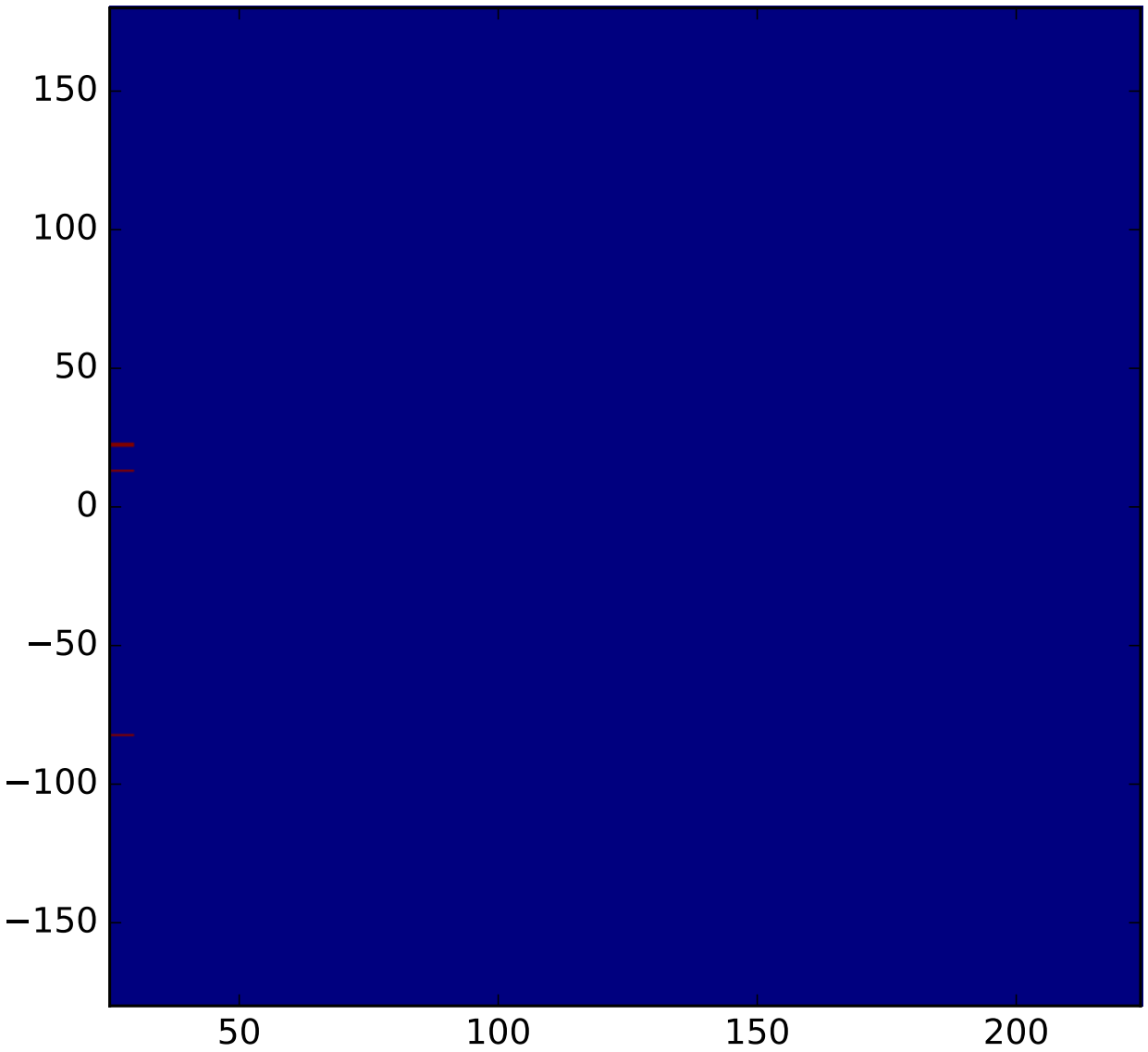


CH ρ/φ Coord.: Accumulator Array



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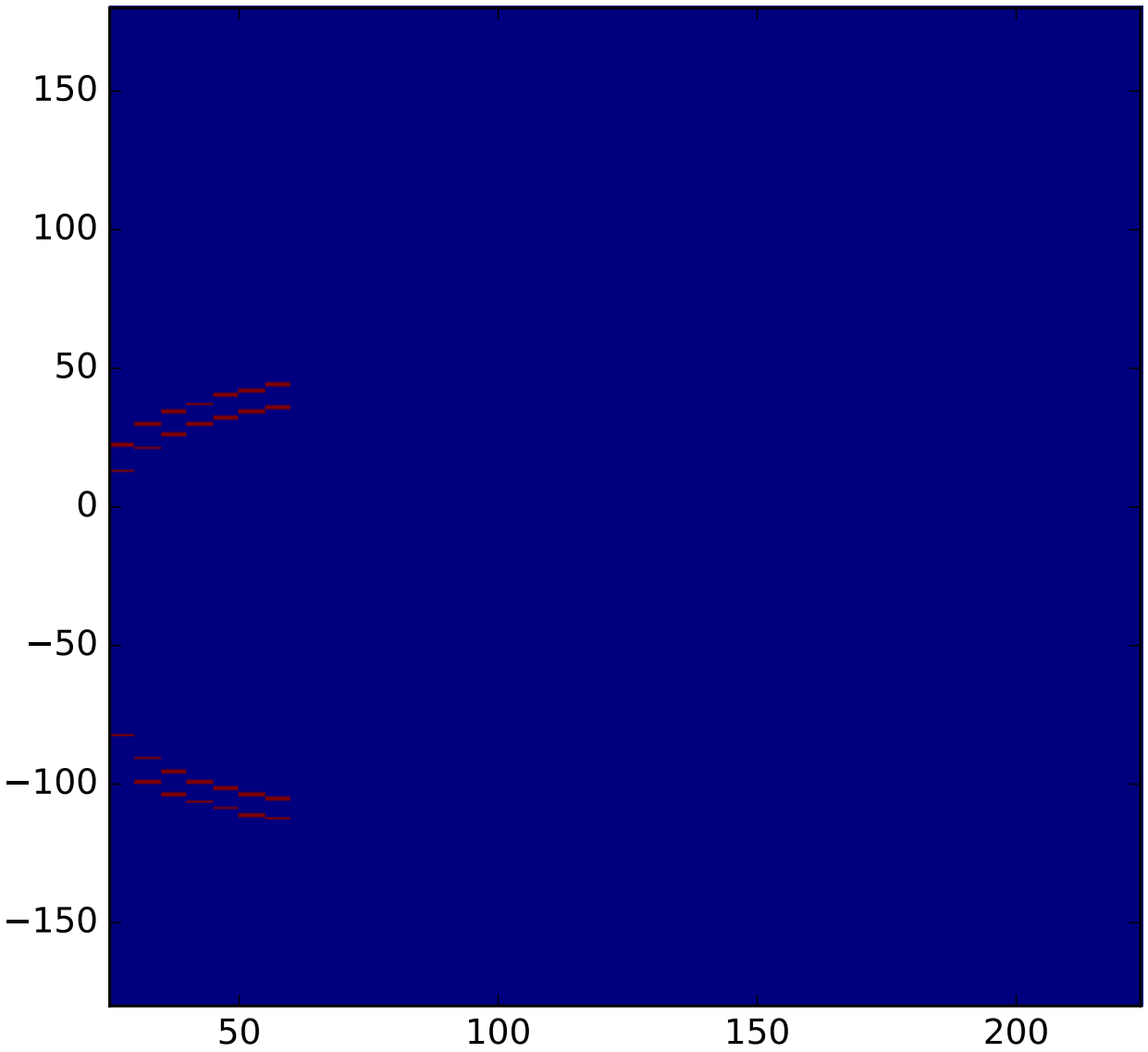

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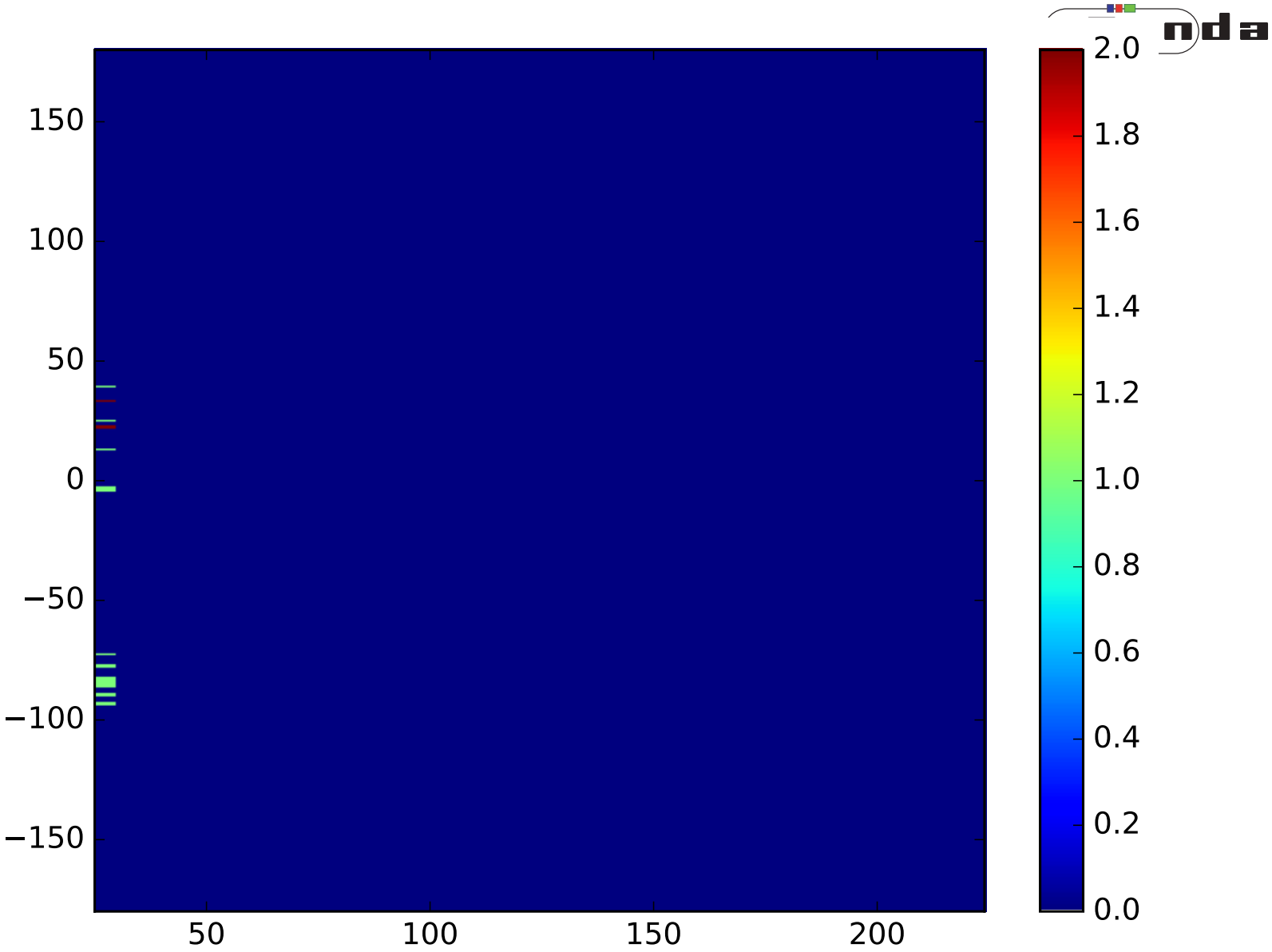

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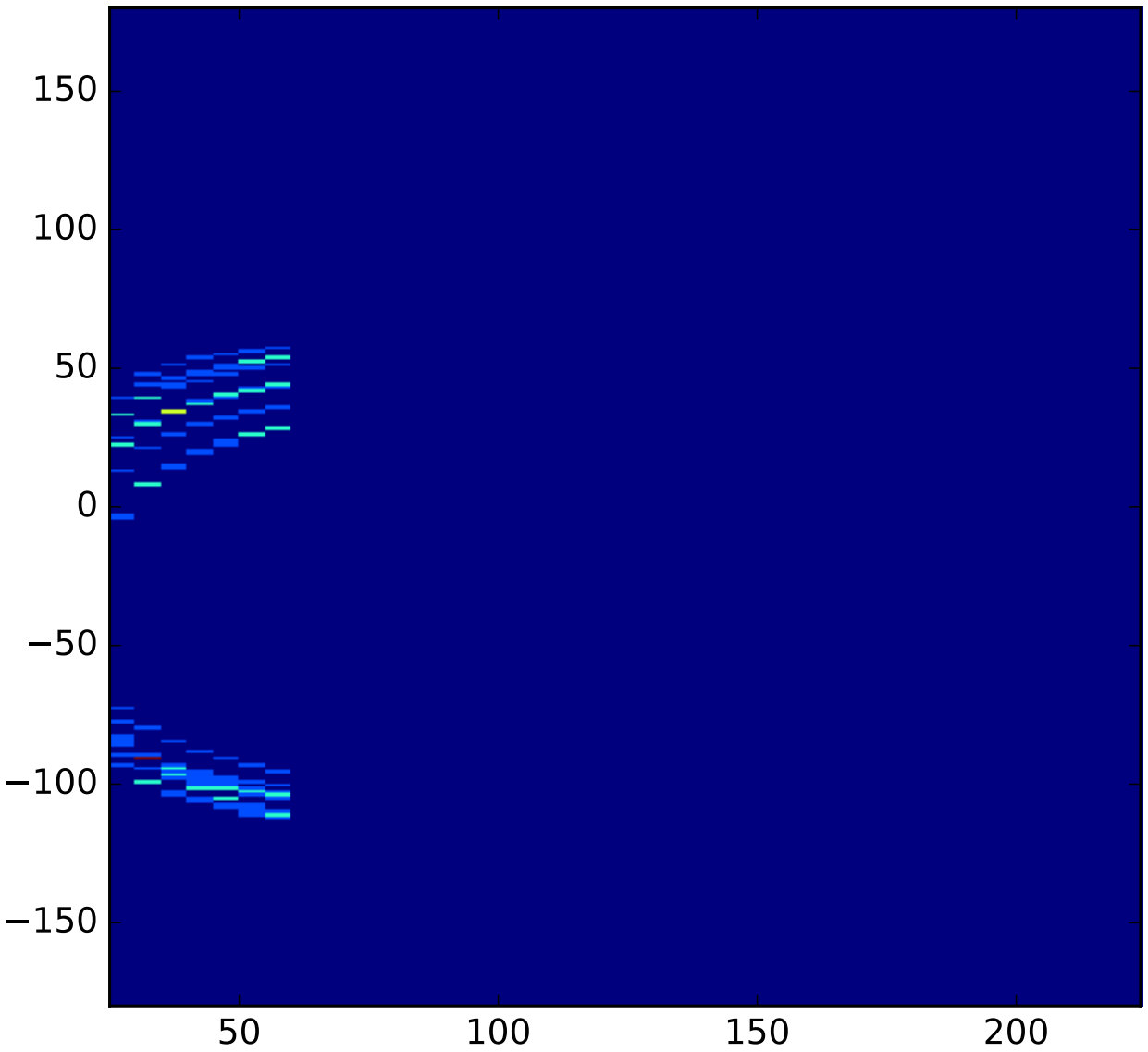

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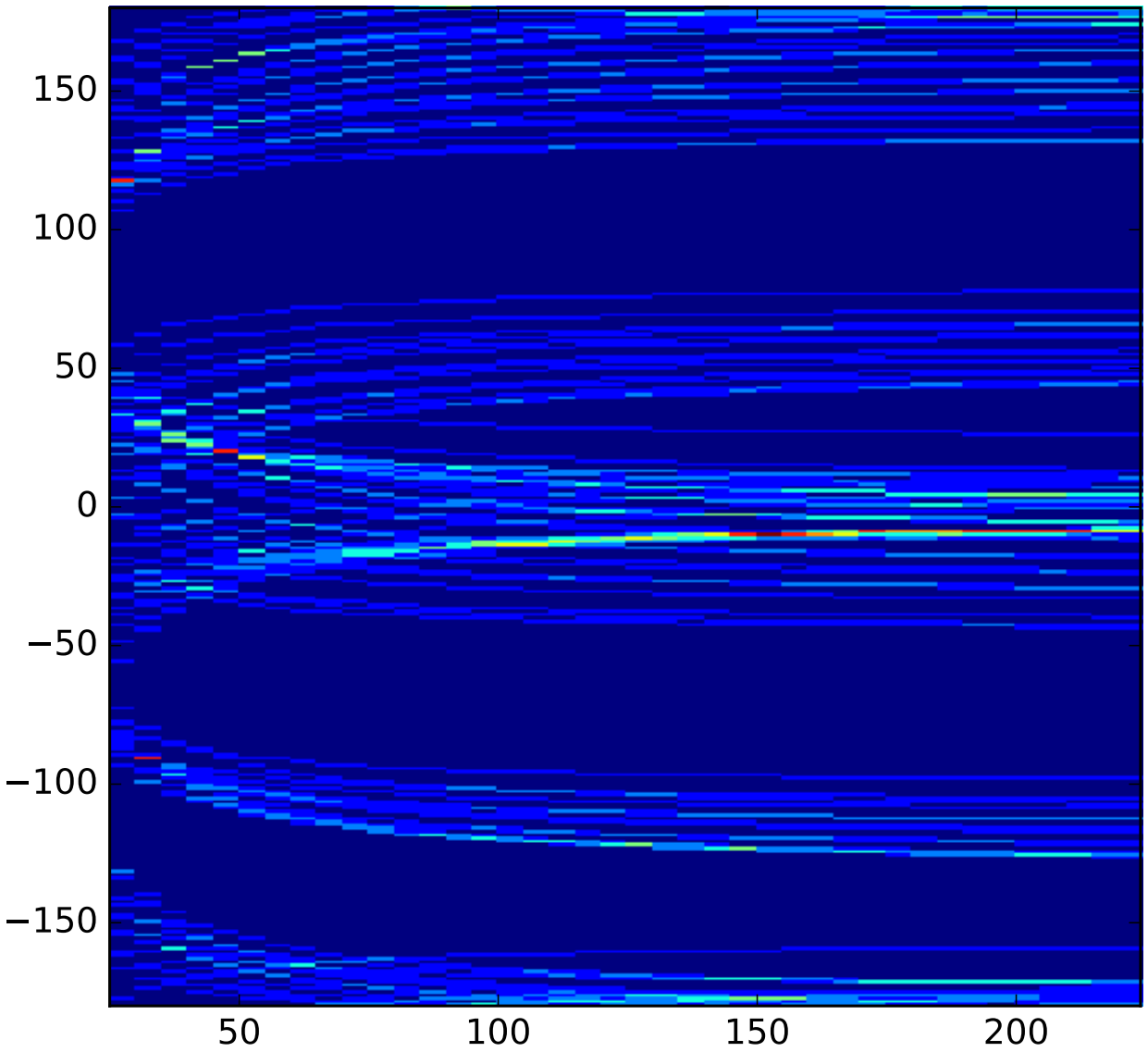

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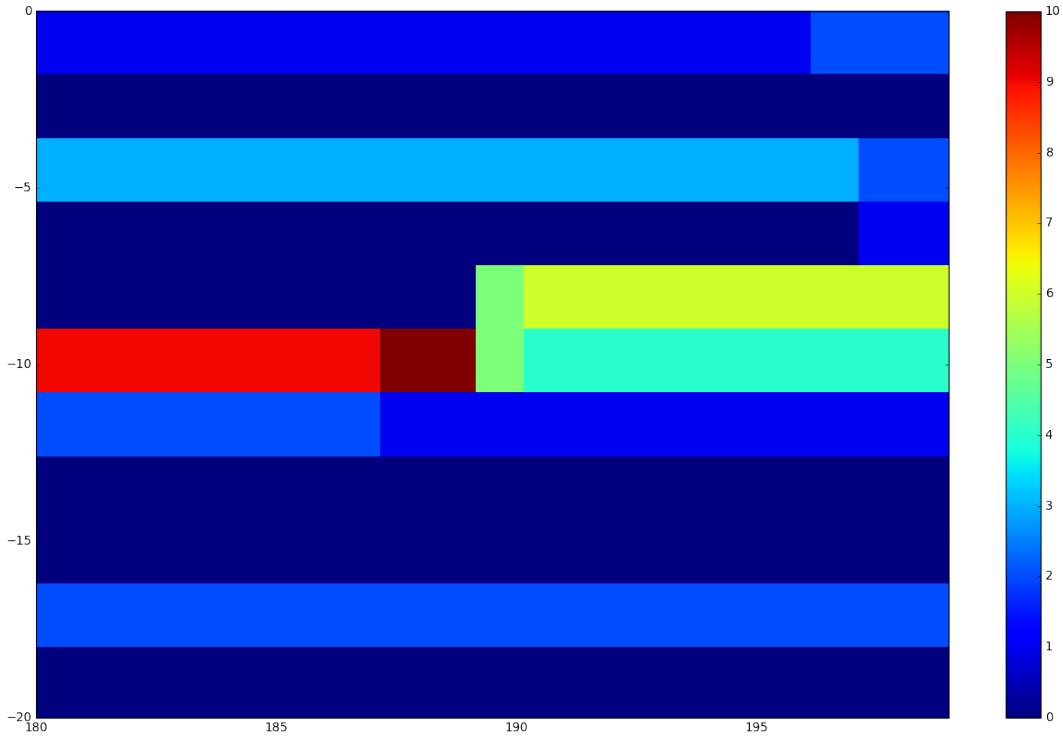

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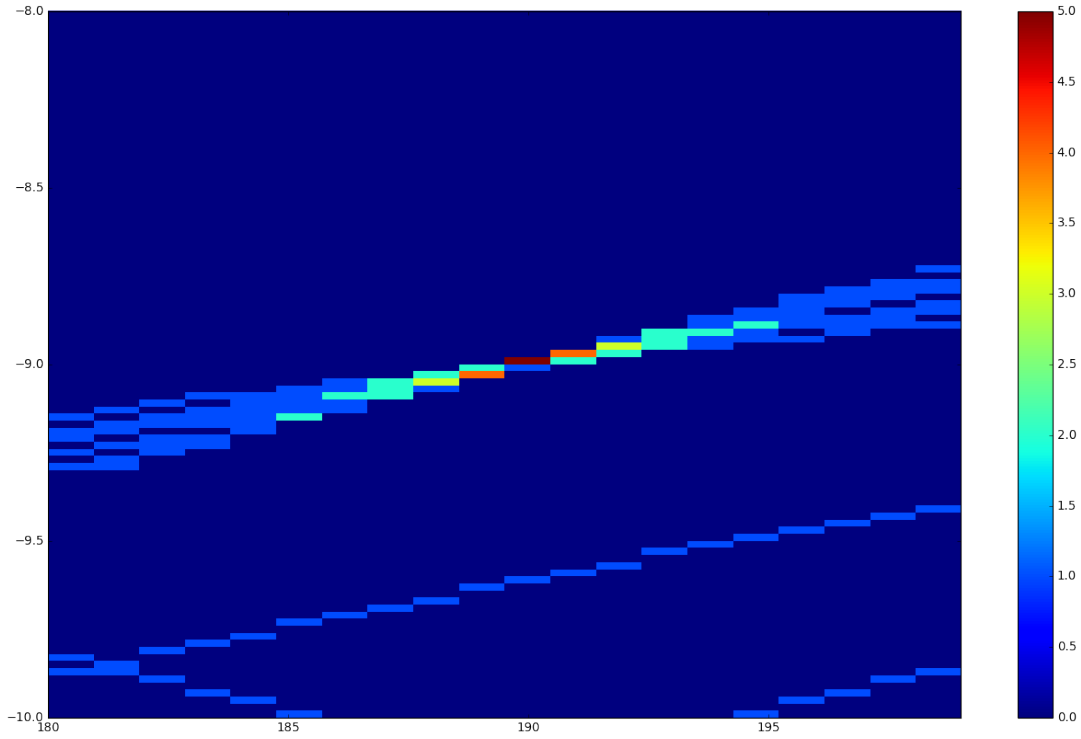


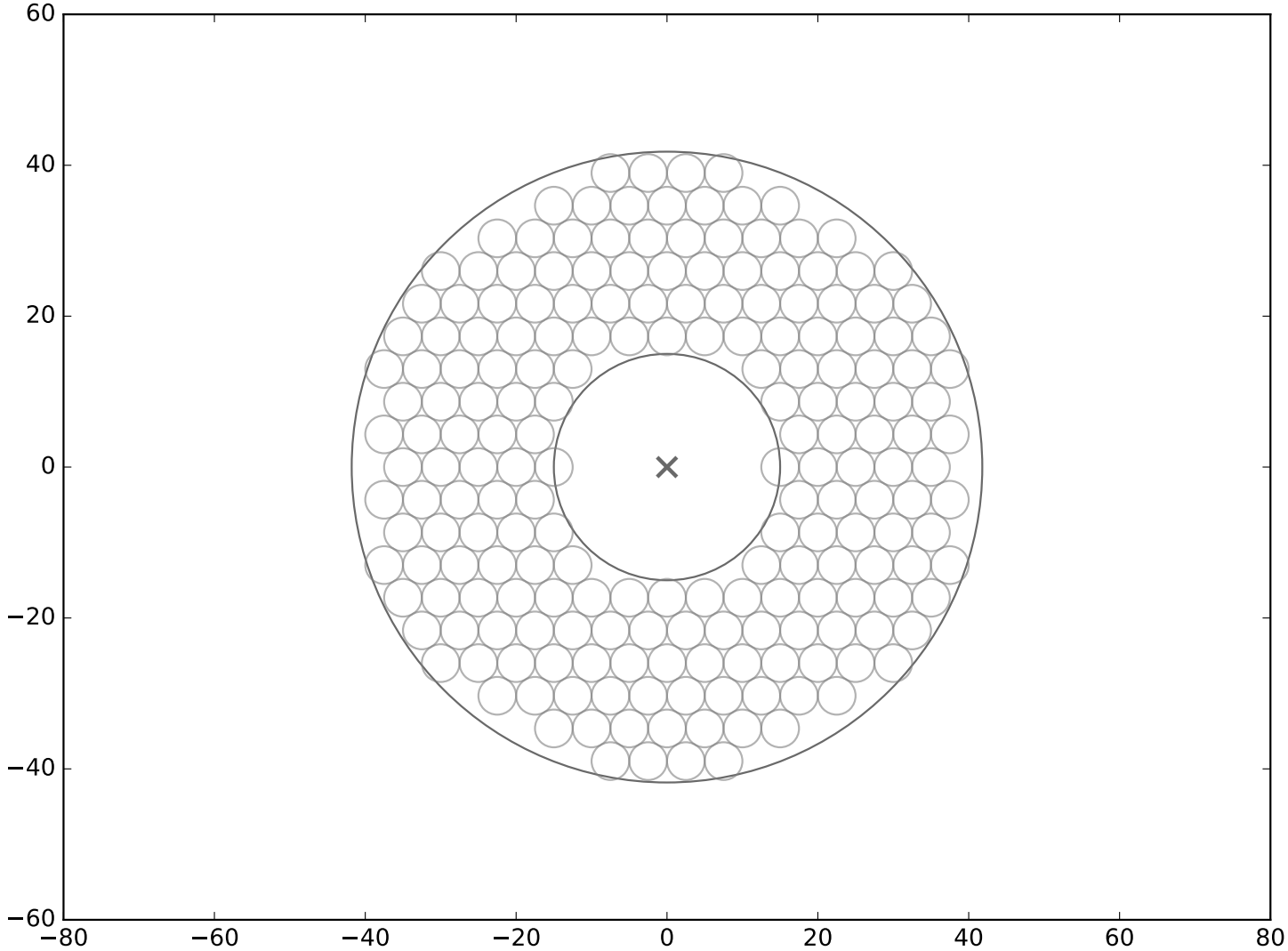
#4: Hit Pair CH

- Find intersections of Hough loci belonging to different hits

$\Longrightarrow$ Consider directly pairs of hits

- Hough element: primary track compatible with two hits
  $\Longrightarrow$ Circle passing through IP, tangent to two hits at the same time
- Explicit analytical solution: problem of Apollonius
  - *"Given three circles, find circles tangent to all of them"*
  - For primary tracks: one of the circles is IP (Apollonius PCC)

Hit Pairs



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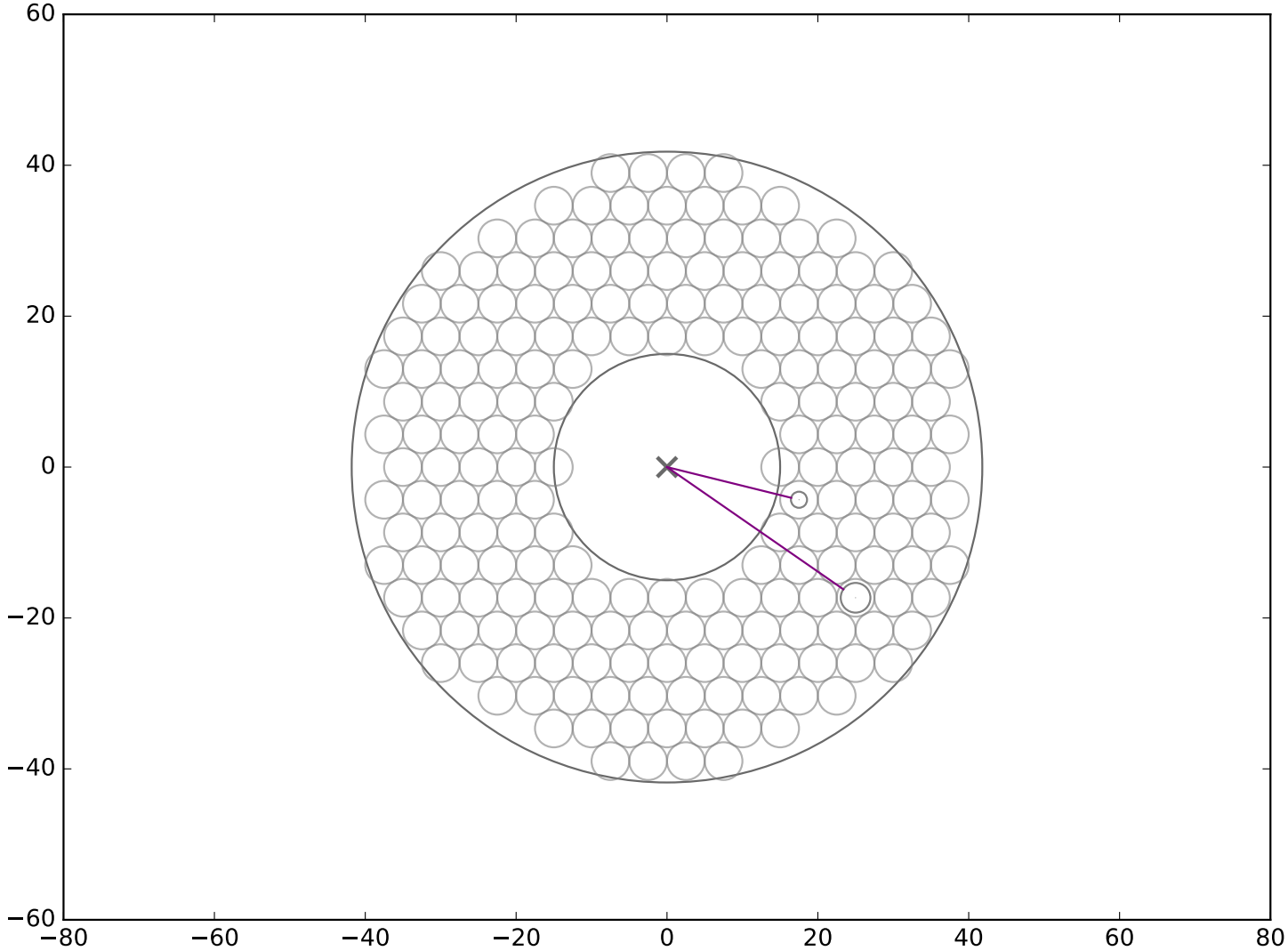

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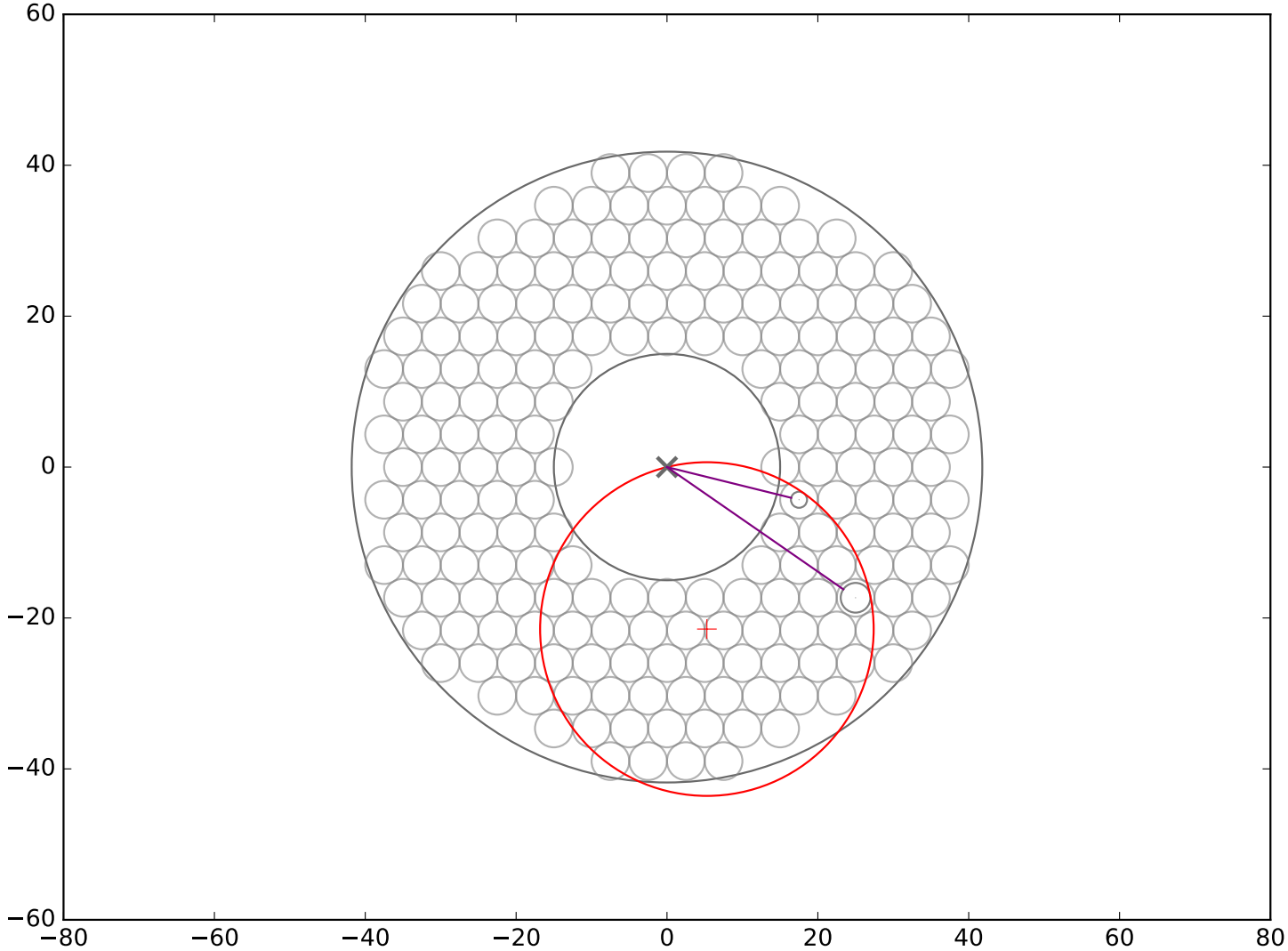

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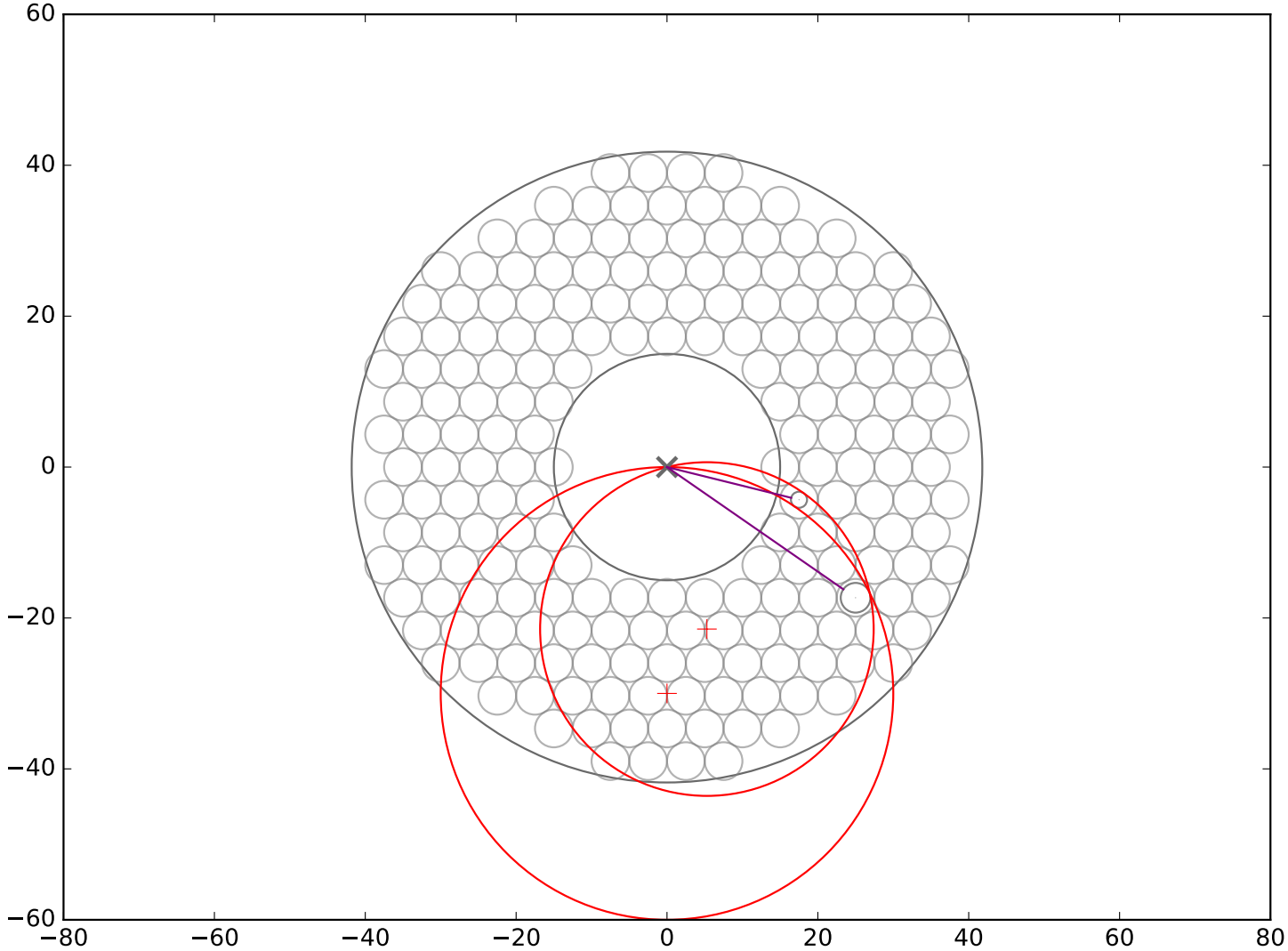

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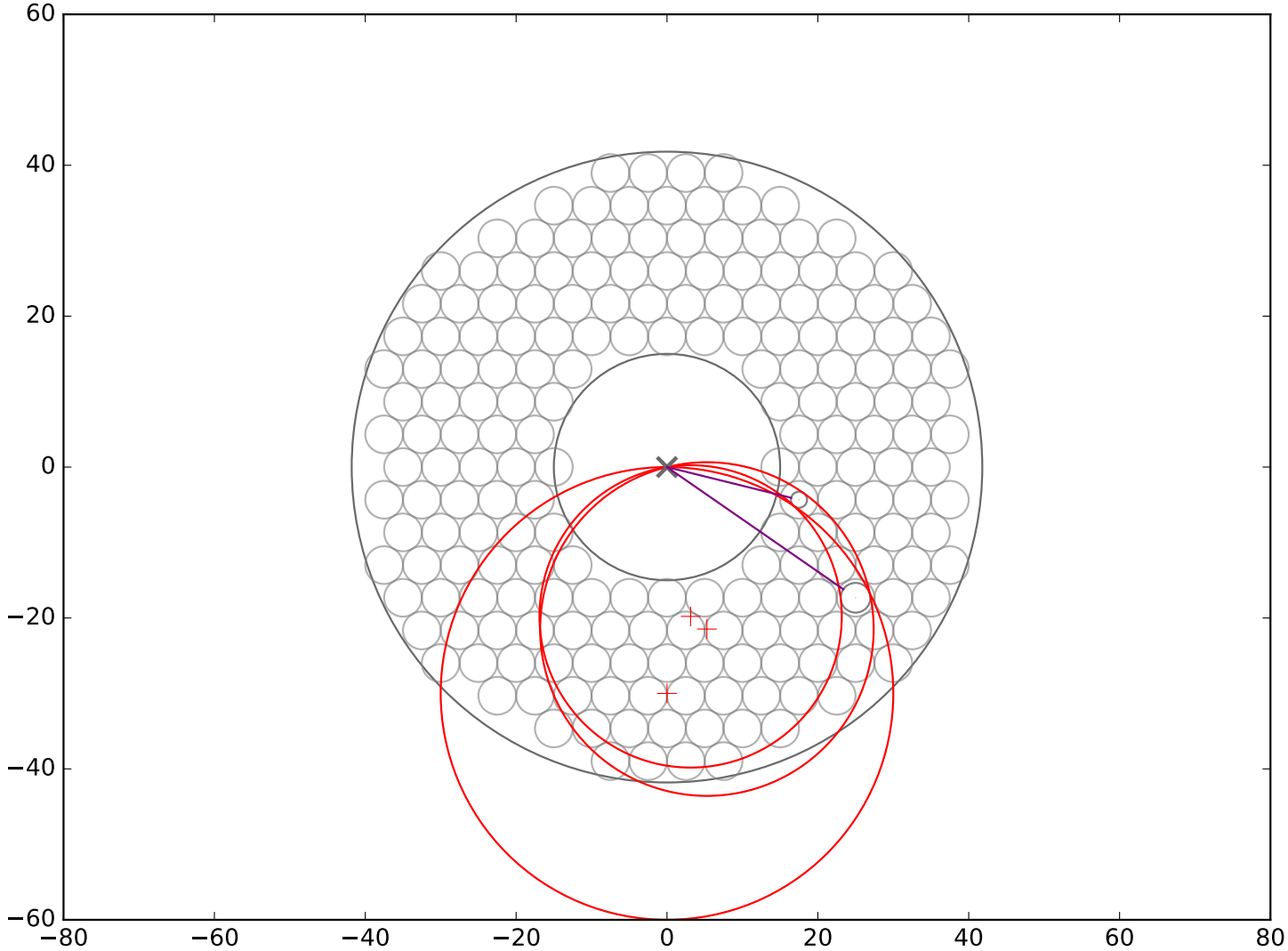

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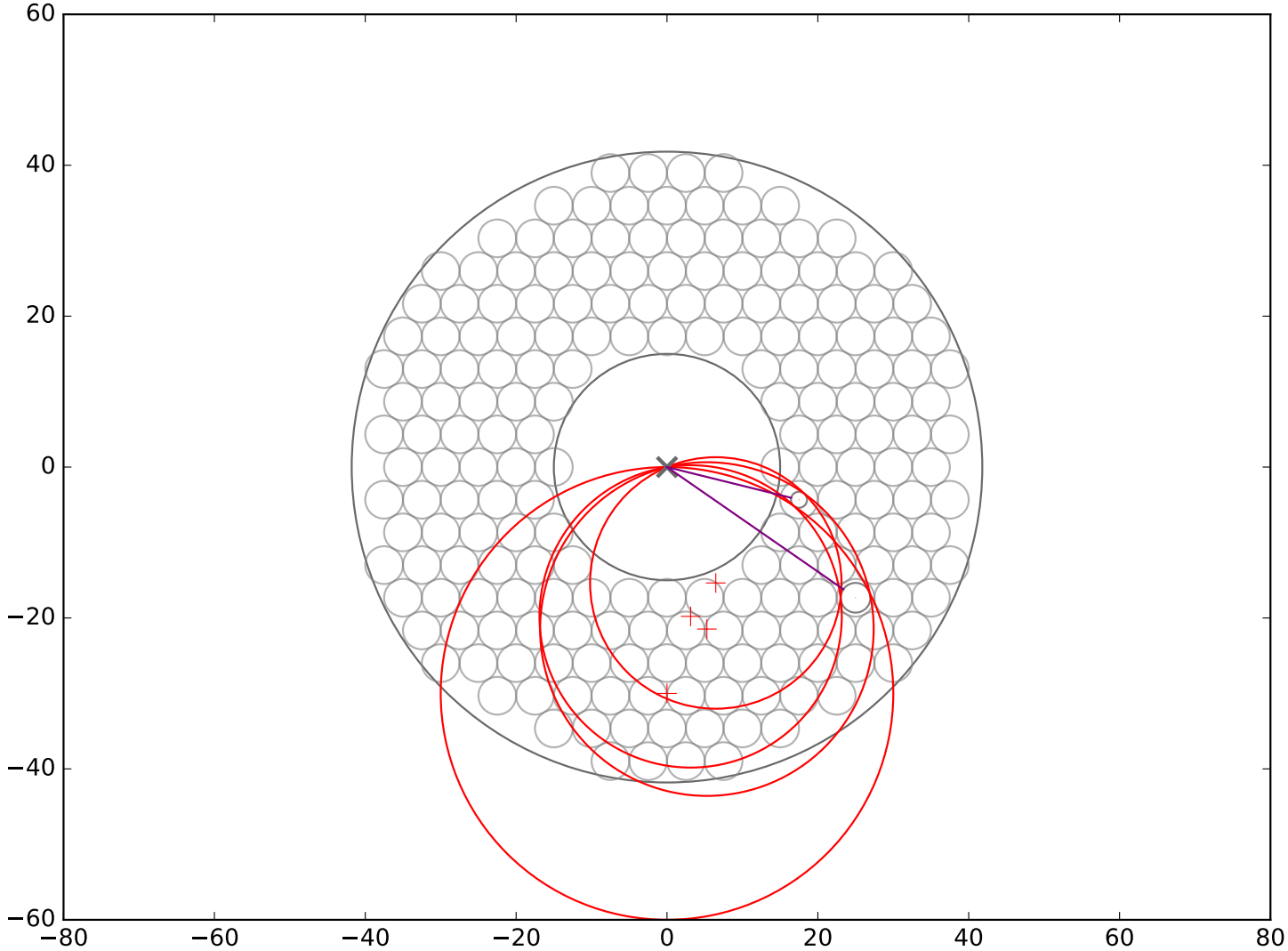

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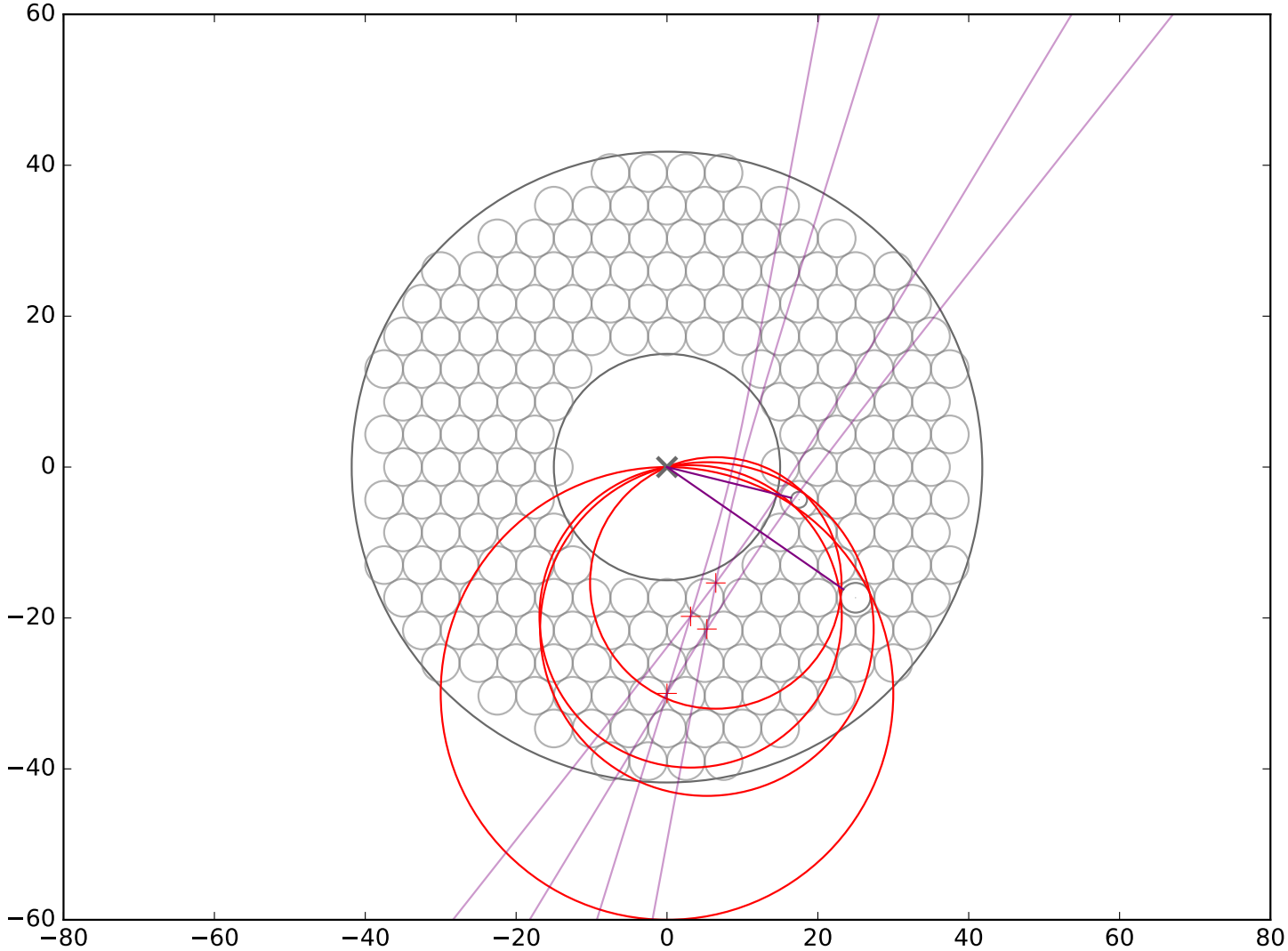

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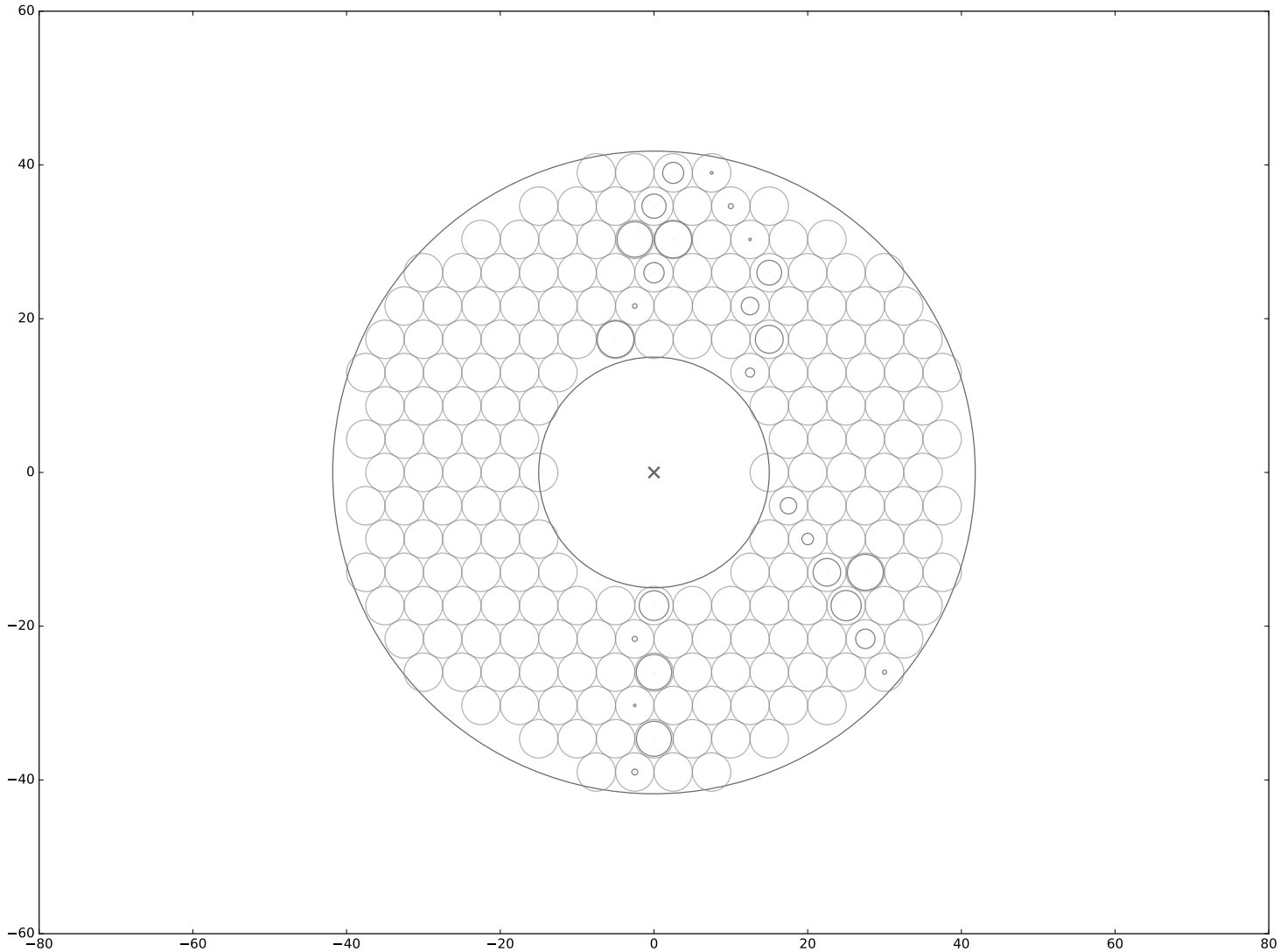

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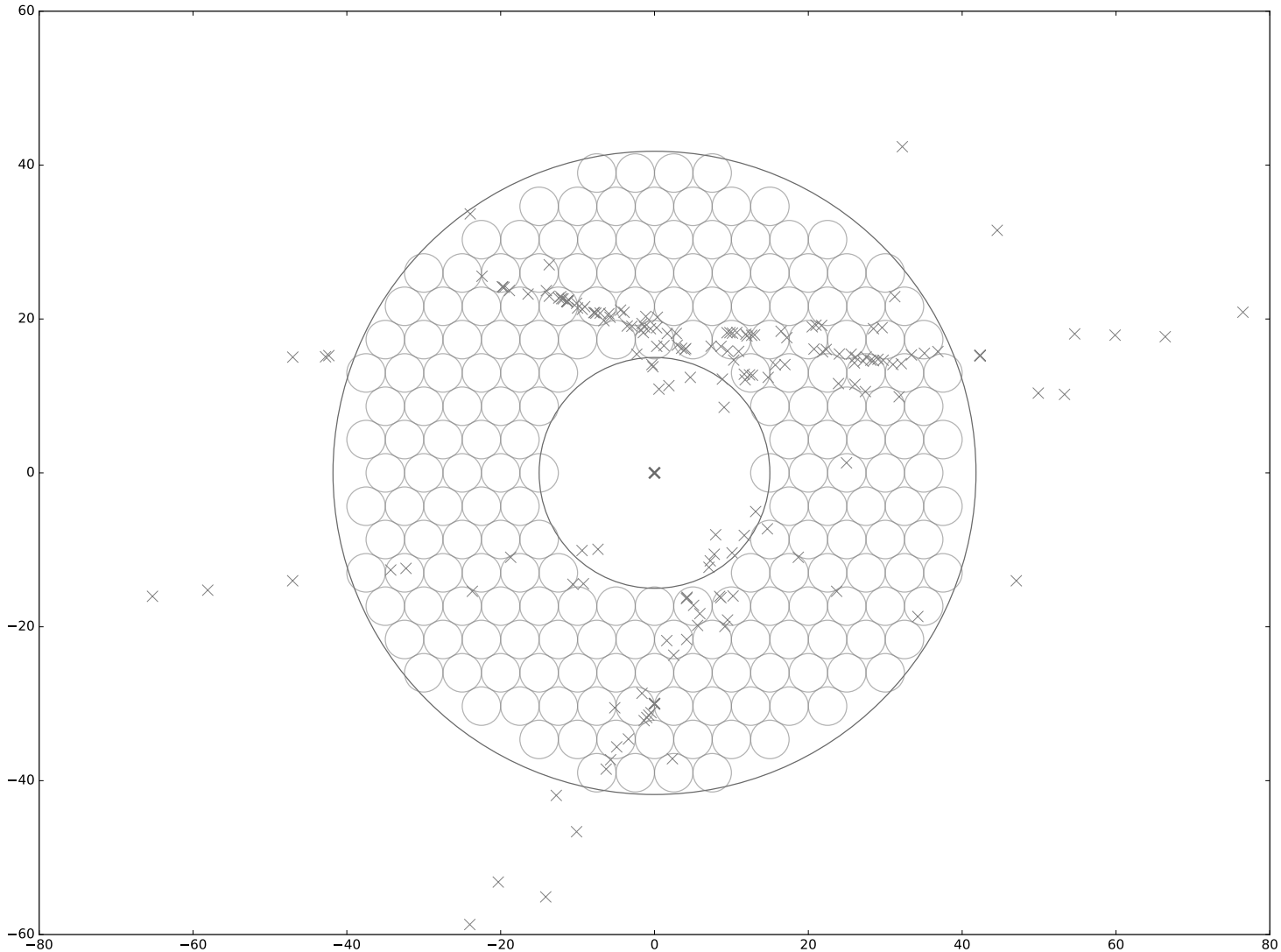

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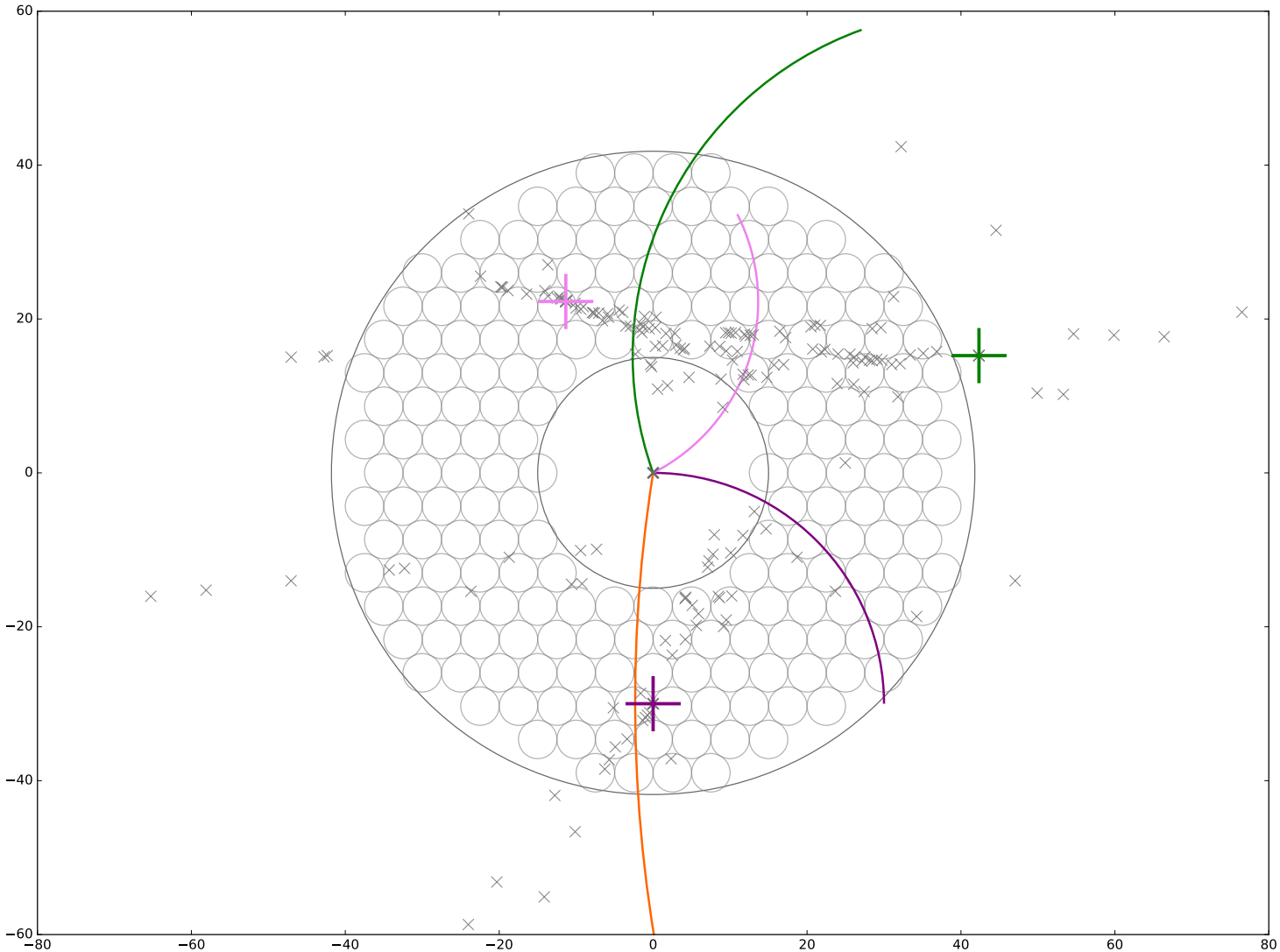
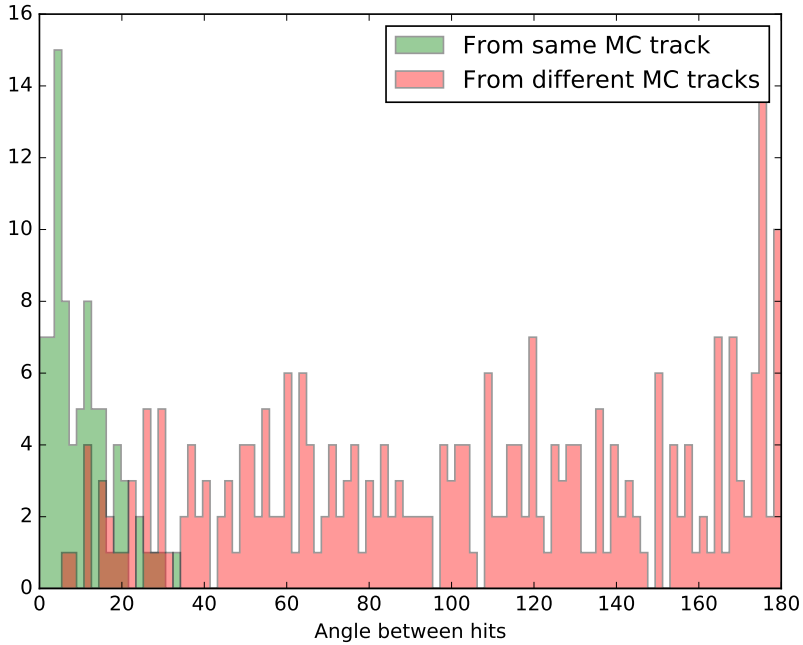


Hit Pair CH: Combinatorics

- n hits $\Longrightarrow$ $n(n-1)/2$ hit pairs: reduce combinatorics
- Simple criterion: $\Delta\varphi$ between hits in a pair
- Threshold cut to remove spurious pairs
  - Optimize wrt track coverage



Hit Pair CH: Peakfinding

- Identify most likely track parameters
- Extract hit information from Hough elements in peak region
- Calculate track parameters from coordinates of peak region
- (ρ, φ) AA: 2D peakfinding simplified
  - Threshold + nearest bins in 2D
- Separate dimensions: consecutive 1D AA + peakfinding
  1. 1D peakfinding (φ)
  2. 1D peakfinding (ρ)
- Fancier data structures + clustering algorithms
  - Clustering of points in 2D space (no AA)
  - 2D space-partitioning binary trees (*k*-d trees, quadtrees)
  - Range search (critical radius/density, DBSCAN, ...)

Summary & Outlook

- Summary
  - 4 main solutions under examination
  - Work in progress: preliminary analysis with PandaRoot hits to compare performance in prototype stage
- Outlook
  - Physics performance: detailed analysis with tracking Q&A in PandaRoot
  - Computing performance: optimized version
    - C++ with OpenACC (CPU/multicore/GPU)
    - CUDA (GPU)
  - Final result: complete parameter analysis in terms of computing requirements vs accuracy