Updates to the Circle Hough Trackfinding Algorithm

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P̄ANDA CM58 | HIM, Mainz | Sep 14, 2016

Circle Hough Algorithm

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

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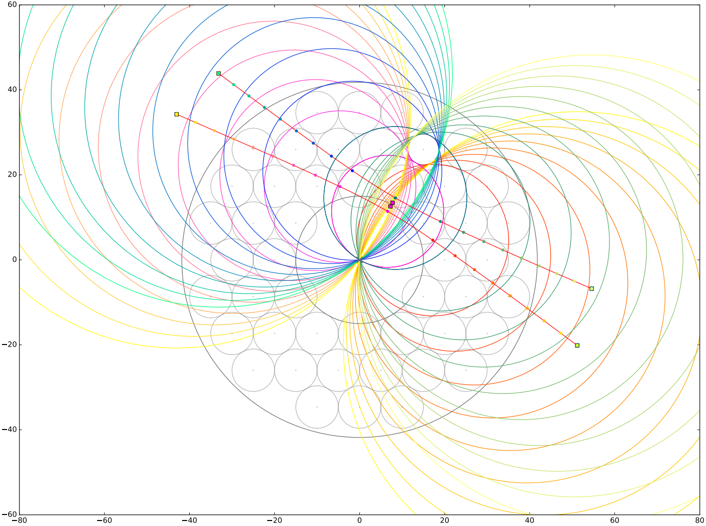
1. Direct calculation
   - For each hit, calculate (x, y) from set of R values
   - Accumulate coordinates in (x, y) Accumulator Array
2. Equation of circle centers known analytically
   - Locus is hyperbola or straight line
   - Accumulate parameters exploiting locus properties (rasterization, analytical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

CH: Principles



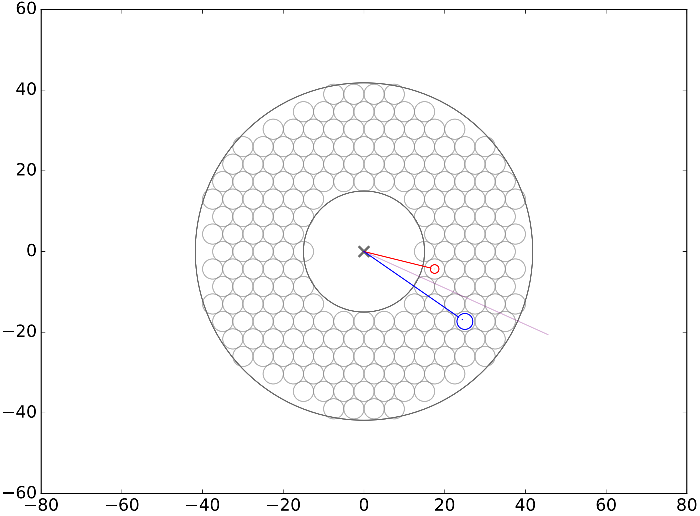
Hit Pair CH

- 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)
- Combinatorial complexity, but 1 fewer degree of freedom

Hit Pairs



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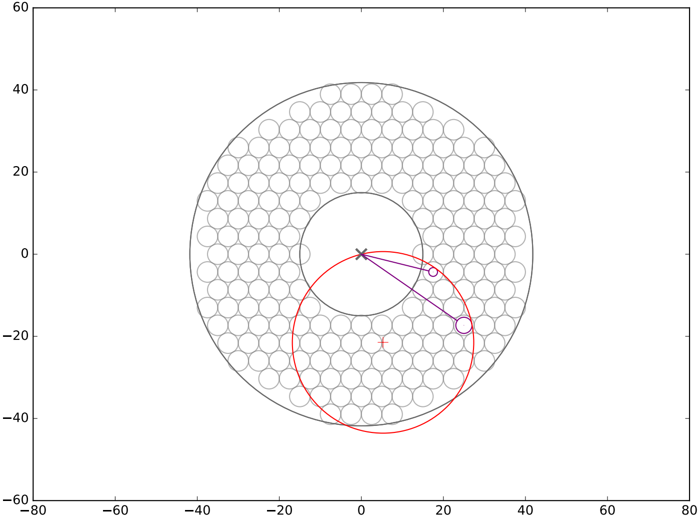

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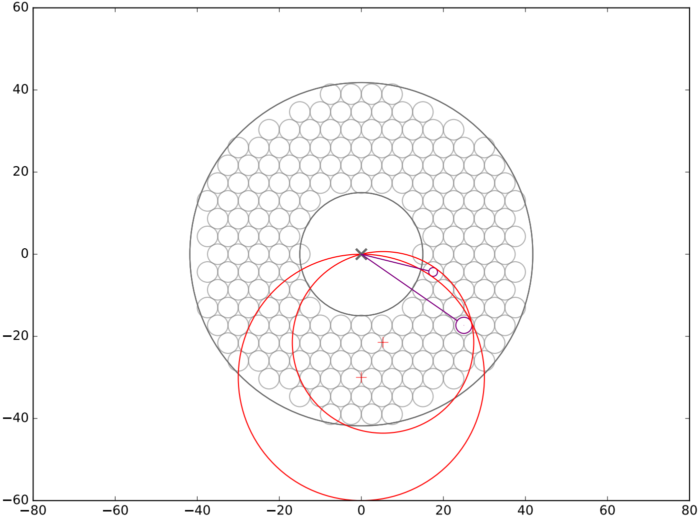

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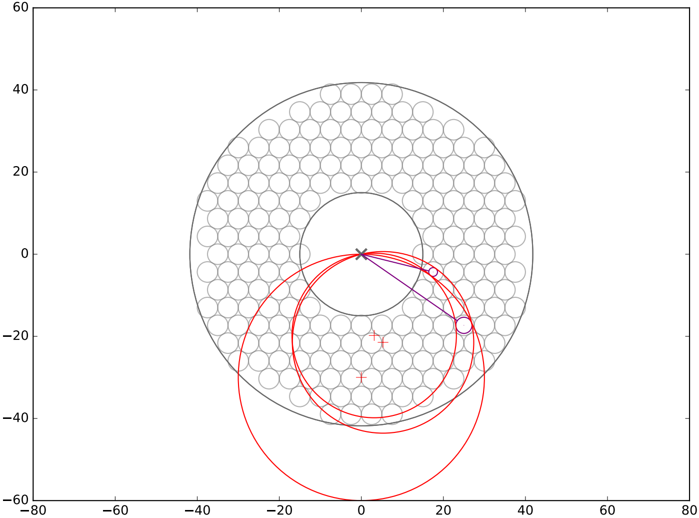

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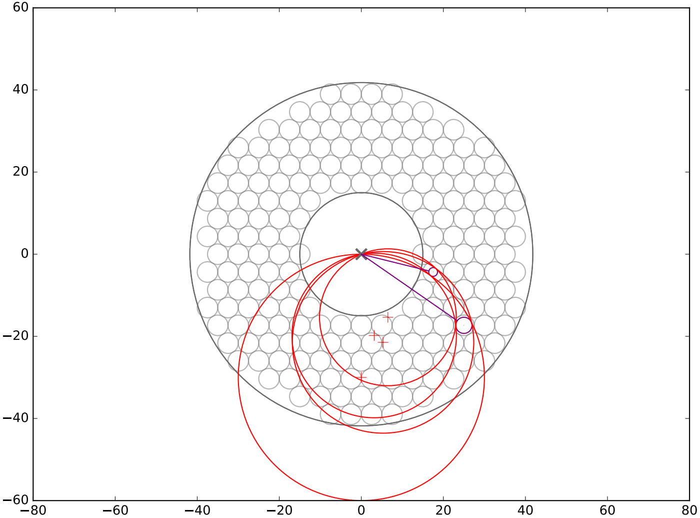

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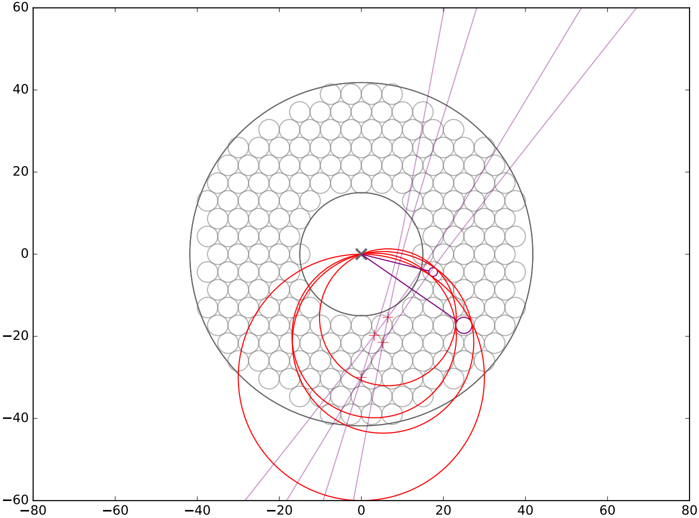
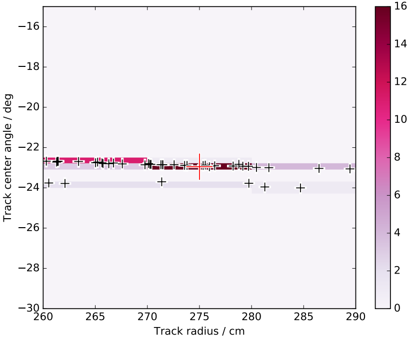


Hit Pair CH: Peakfinding

- Identify most likely track parameters
- Extract hit information from Hough elems in peak region
- Calculate track parameters from coordinates of peak region
- Basic strategy: 2D Accumulator Array (histogram) + peakfinding



Hit Pair CH: Peakfinding

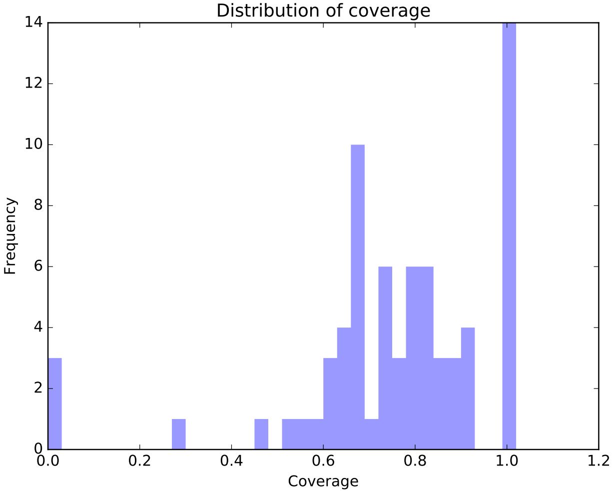
- Features of peakfinding
  - Hough elems aligned in ρ direction
  - "Critical density" close to the real peak
  - (ρ, φ) less coupled for Hit Pair CH
- Strategies
  - 2D peakfinding: rel. threshold + local maximum
  - Also considered: "striped" peakfinding in parallel in one direction + combine with `reduce`/`fold` algorithm
- Caveats
  - Discrete binning causes artifacts and unstable behavior
  - Tune parameters
  - One simple solution:
    1. Use (binned) peakfinding to find location of peak
    2. Select (unbinned) Hough elems in interval centered on peak

Testing the algorithm

- PandaRoot data
- Single tracks generated with `BoxGenerator`
- Useful for:
  - Algorithm exploration/optimization
  - Approximate indication for later, more accurate physics performance tests
- At this point, definitely not useful for:
  - Quoting performance numbers

Performance

Set of ∼ 70 tracks



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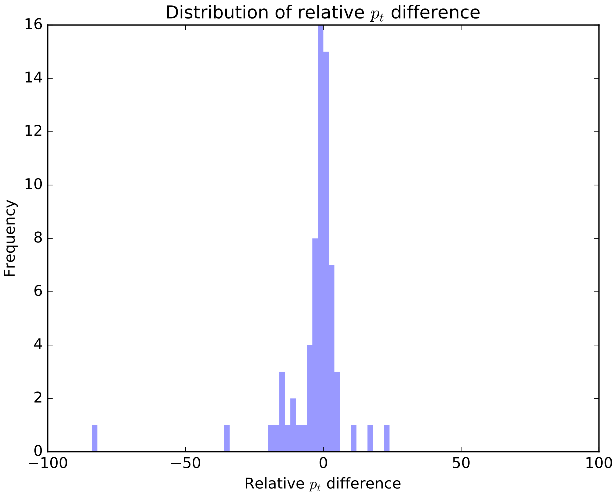
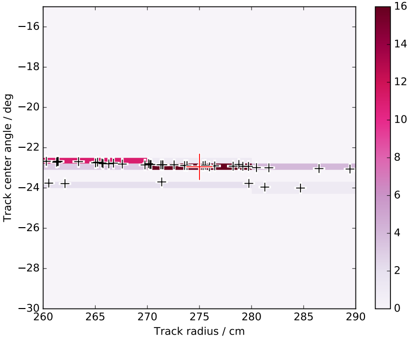


Parameter Study

Width of ρ Interval

- Features of candidate tracks calculated by combining info from Hough elems in interval around peak position
- Main parameter: width of interval in ρ direction
- Tradeoff between: coverage, purity, p_t resolution, …



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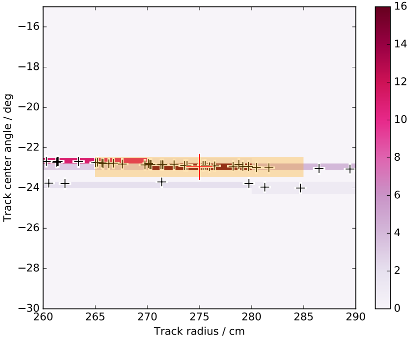

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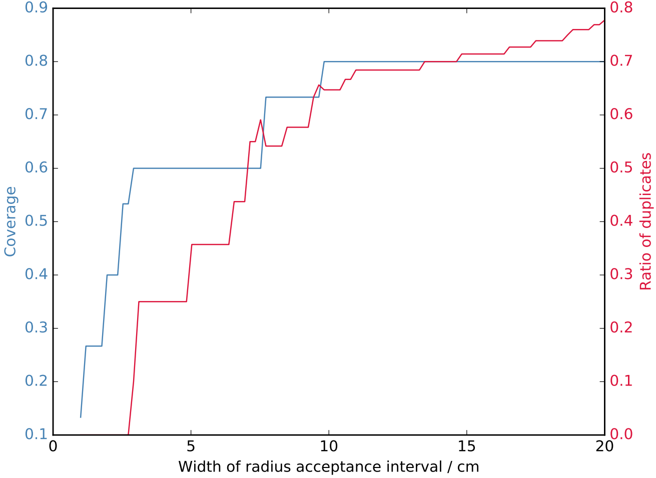

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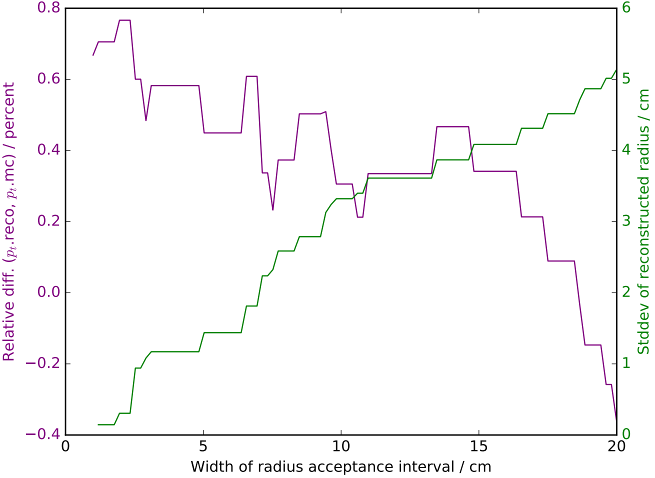
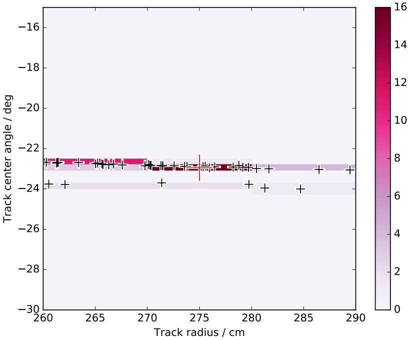


Parameter Study

(ρ, φ) Bin Width

- Performance of peakfinding depends on binning of AA
- Vary N_ρ, N_φ at the same time
- Study inpact of performance metrics on 2D grid



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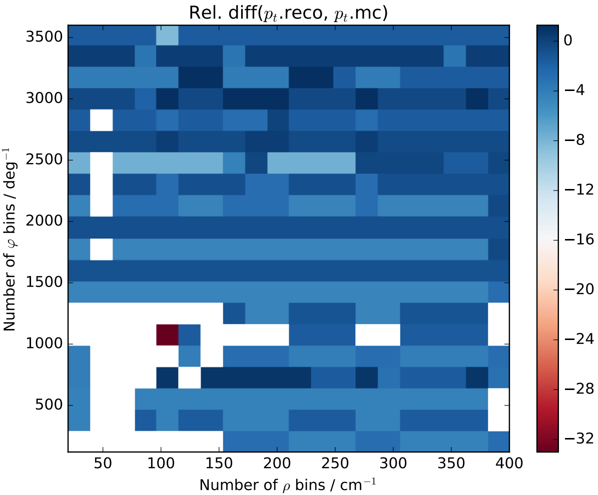

Mitglied der Helmholtz-Gemeinschaft

Parameter Study

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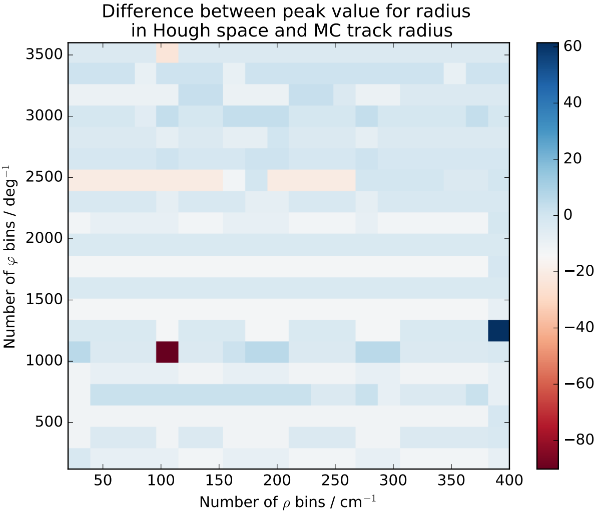
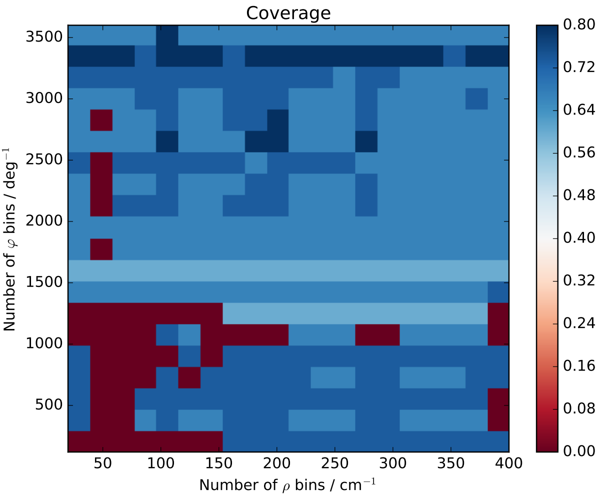


Parameter Study

Binning



Summary & Outlook

- Work in progress
  - Characterization of algorithm
    - Exploration of parameter space
    - Optimization
    - Identify performance tradeoffs
  - Systematic testing with PandaRoot simulated data
    - Single tracks (`BoxGenerator`)
    - Full events (background; physics channels; ...)
- In the immediate future
  - Reference implementation of algorithm in C/C++
    - Identify performance bottlenecks $\Longrightarrow$ Parallelization targets
    - Integration with PandaRoot

Backup—Single Hit CH with ρ/φ Coord.

JÜLICH FORSCHUNGSZENTRUM

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