

Hough Transform Improvements

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How to find a line given a set of data (signal & noise) points

- Take each (x,y) hit and parameterize it into a curve in an (r,θ) Hough Accumulator space.

New!

- Smooth the Hough Accumulator by making cells with heavy neighbors heavier and cells with light/empty neighbors lighter (weighted with a 2D Gaussian).
- Find the heaviest cell.

New!

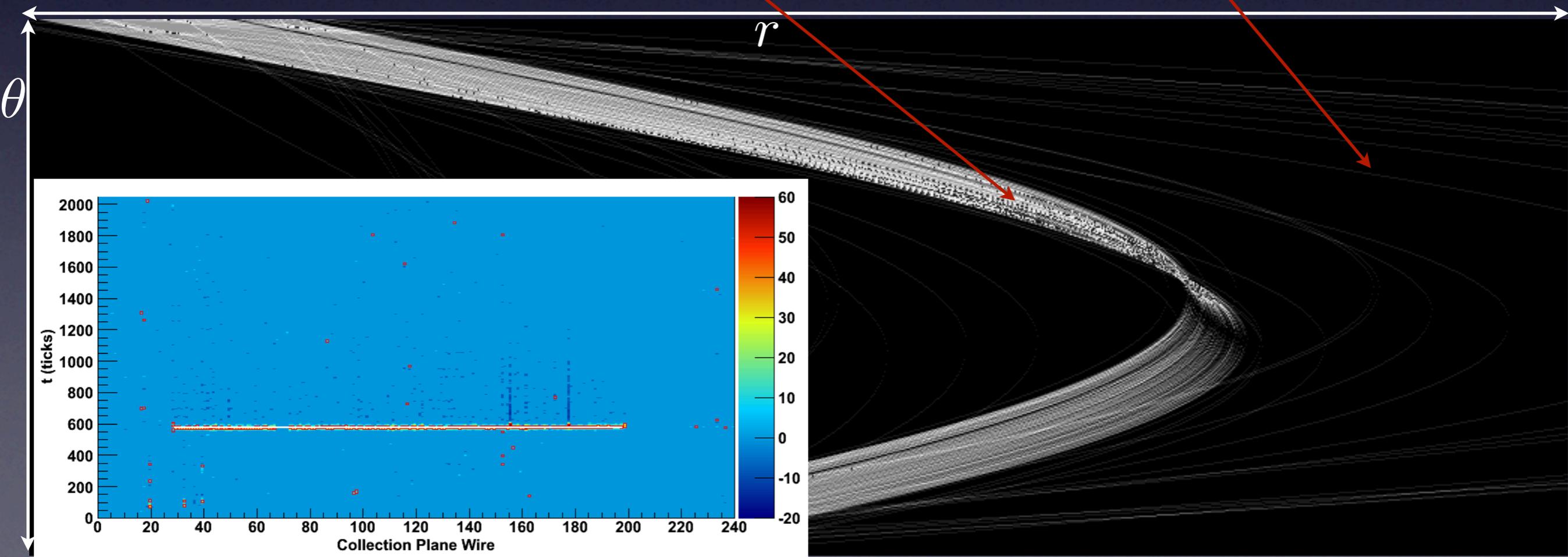
- Find the center-of-mass of the 9 cell system (w/ heaviest cell at the center) to find the true r and θ of the line.
- Repeat, considering only hits that are not yet associated with a line.

Smoothing the Hough Accumulator

Smoothing basically means that cells with heavy nearest neighbors are given more weight and cells with light nearest neighbors are given less weight. Smoothing the Hough Accumulator effectively enhances signal and reduces noise.

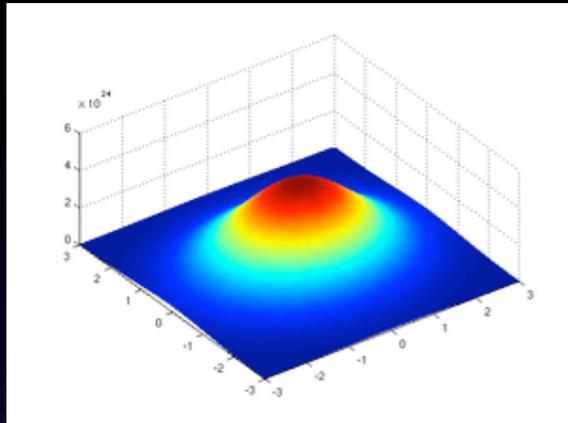
The cells inside these curves (corresponding mostly to signal hits) usually have heavy nearest neighbors. Their weight is increased accordingly.

The cells inside these curves (corresponding mostly to noise hits) usually have light/empty nearest neighbors. Their weight is lowered accordingly.



Smoothing the Hough Accumulator

$$G(x, y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}$$



Each cell in the Hough Accumulator is re-weighted with a 2D Gaussian based on the weights of and distances to its closest neighbors.

Gaussian smoothing (the central cell only) with $\sigma = 0.86$ cells

10	22	11		10	22	11
15	1	10	Smoothing →	15	10.2	10
12	11	10		12	11	10

Example: The central cell gets weighted higher because it is surrounded by larger cells

0	2	1		0	2	1
1	15	0	Smoothing →	1	4.5	0
2	1	0		2	1	0

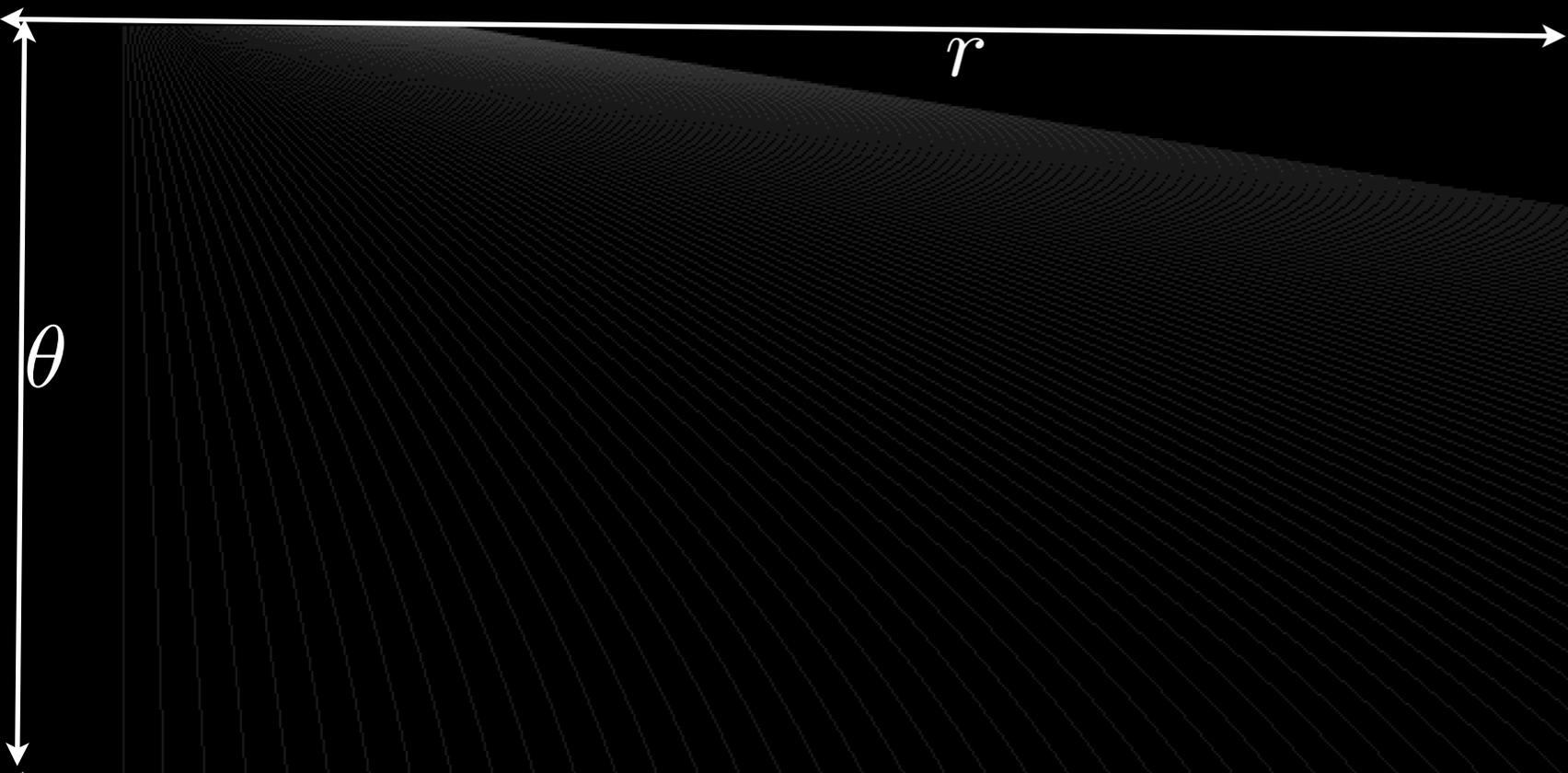
Example: The central cell gets weighted lower because it is surrounded by smaller cells

Note that this is a highly simplified example. In the real Hough Accumulator, all cells are smoothed and neighbors are given a weight up to 3σ away from the central cell.

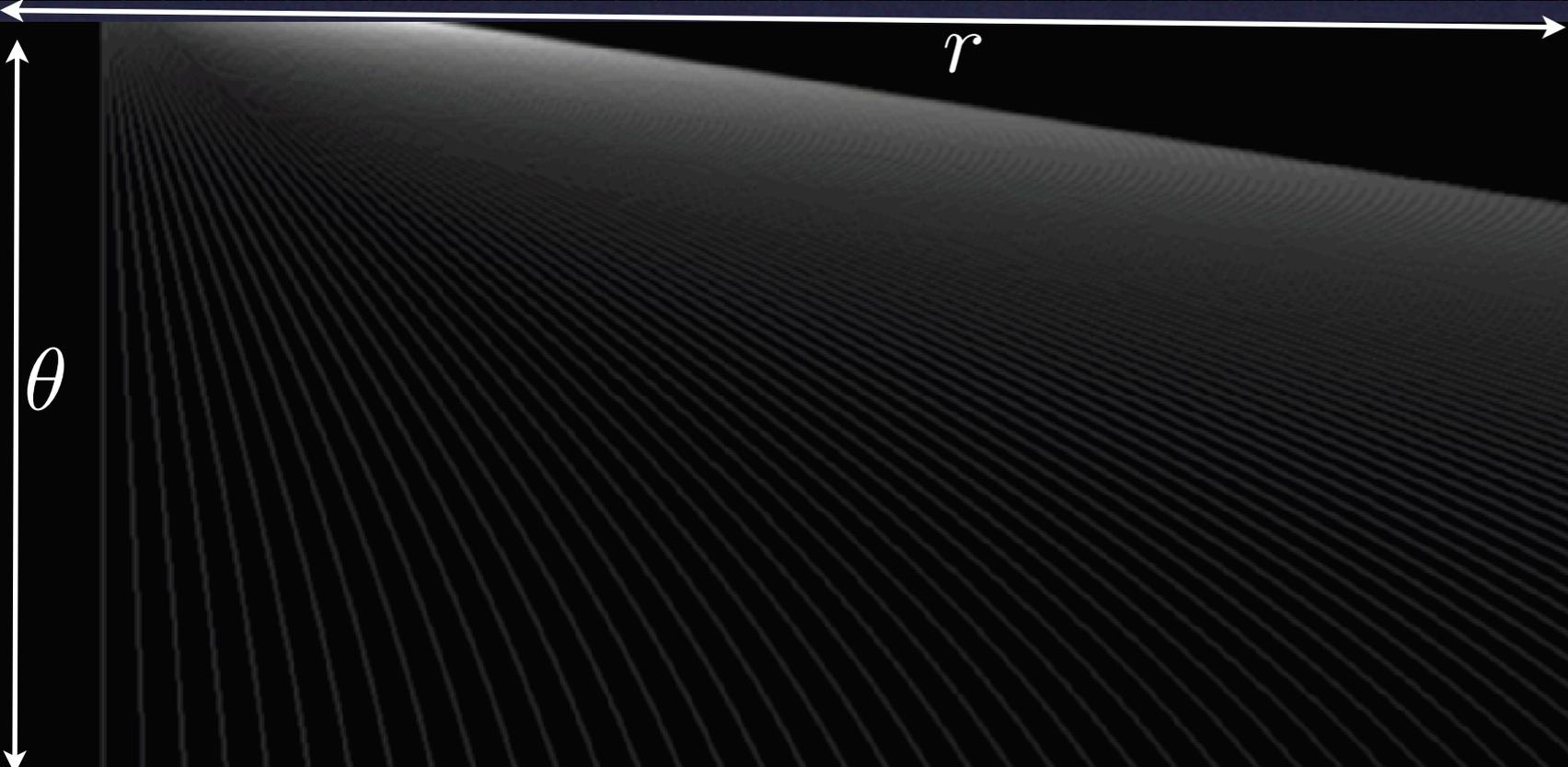


Gaussian smoothing of an image with non-random noise

Smoothing the Hough Accumulator



Hough Accumulator
with no smoothing

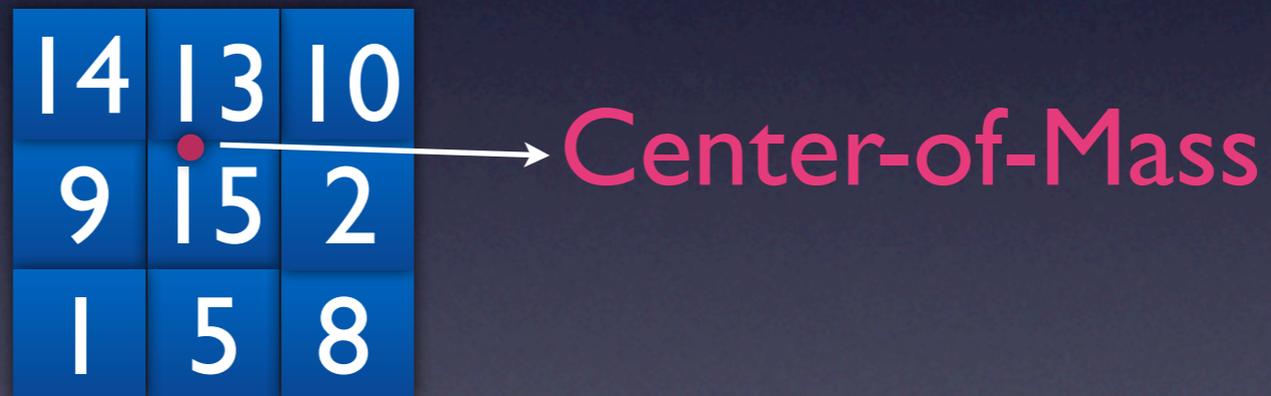


Hough Accumulator w/ 2D
Gaussian smoothing
($\sigma = 1.0$ cell)

Note that the normalization doesn't matter for line-finding and that the contrast and brightness are different in both images

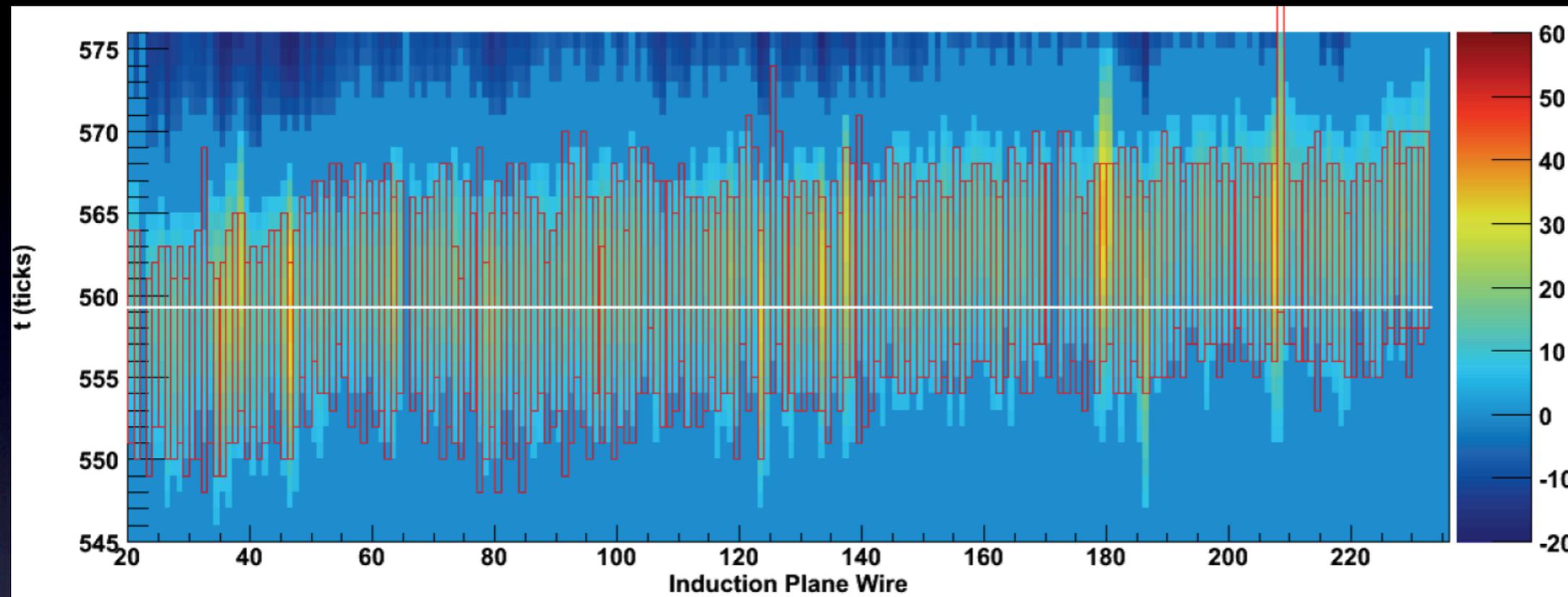
After smoothing

- r and θ are discrete in the Hough Accumulator before and after smoothing. Therefore, it is important to find the center-of-mass of the 9-cell system (w/ the maximum cell in the center) to find the true values of ρ and θ of the line.

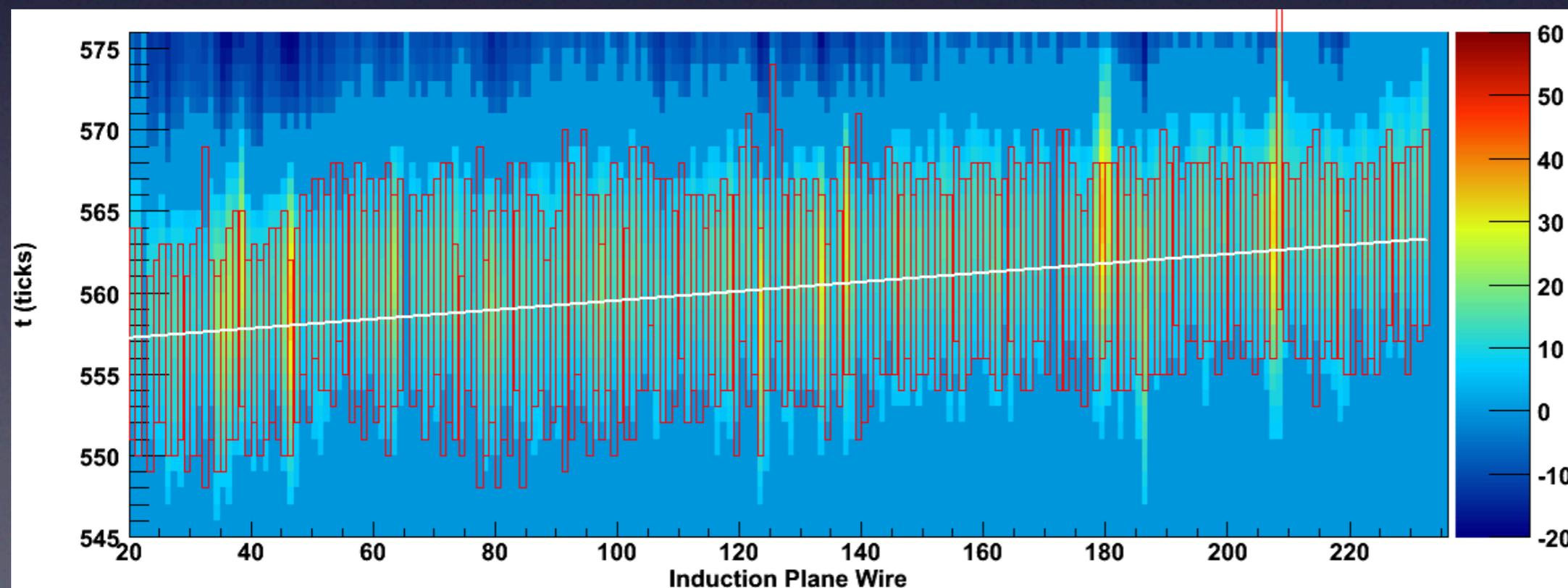


- There are more sophisticated methods for finding the true r and θ of the line from the smoothed Hough Accumulator. For now, this simple method seems fine.

Have the new techniques improved the accuracy of the Hough Transform?



Before



After

Short-term to do

- Improve line endpoint algorithm.
- Quantitatively determine accuracy and efficiency of algorithm.
- Muon kinematic distributions
- Find electron lifetime using through-going muons.

Appendix

Drawing the Hough Accumulator curves in the correct way

The curves in the Hough Accumator are not really lines. Each cell in the accumulator is finite. Each curve needs to be continuous and have a unique r/θ value for each θ/r point.

