Status of the Displaced Vertex Trigger

Elia Schmidt, MPP

Thursday, September 26th 2023

AI trigger group at Belle II

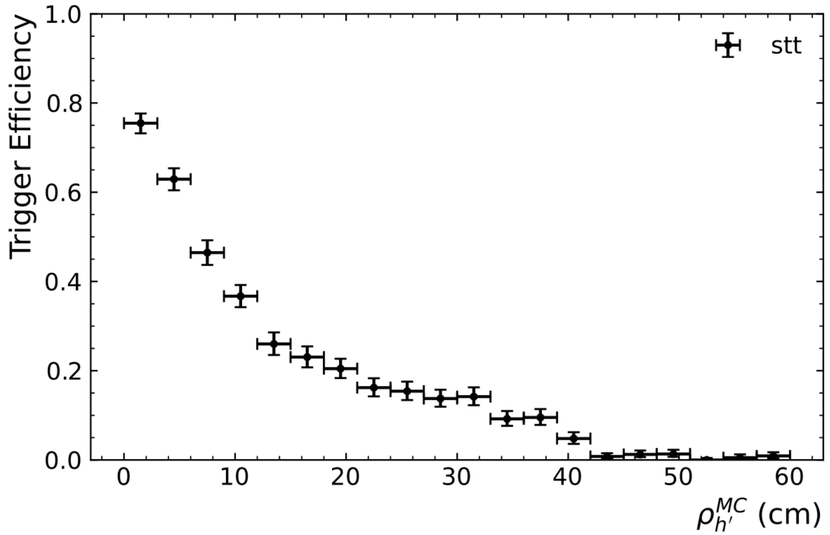
KIT ITIV
- Marc Neu
- Kai Unger
- Jürgen Becker

KIT ETP
- Lea Reuter
- Greta Heine
- Isabel Haide
- Slavomira Stefkova
- Torben Ferber

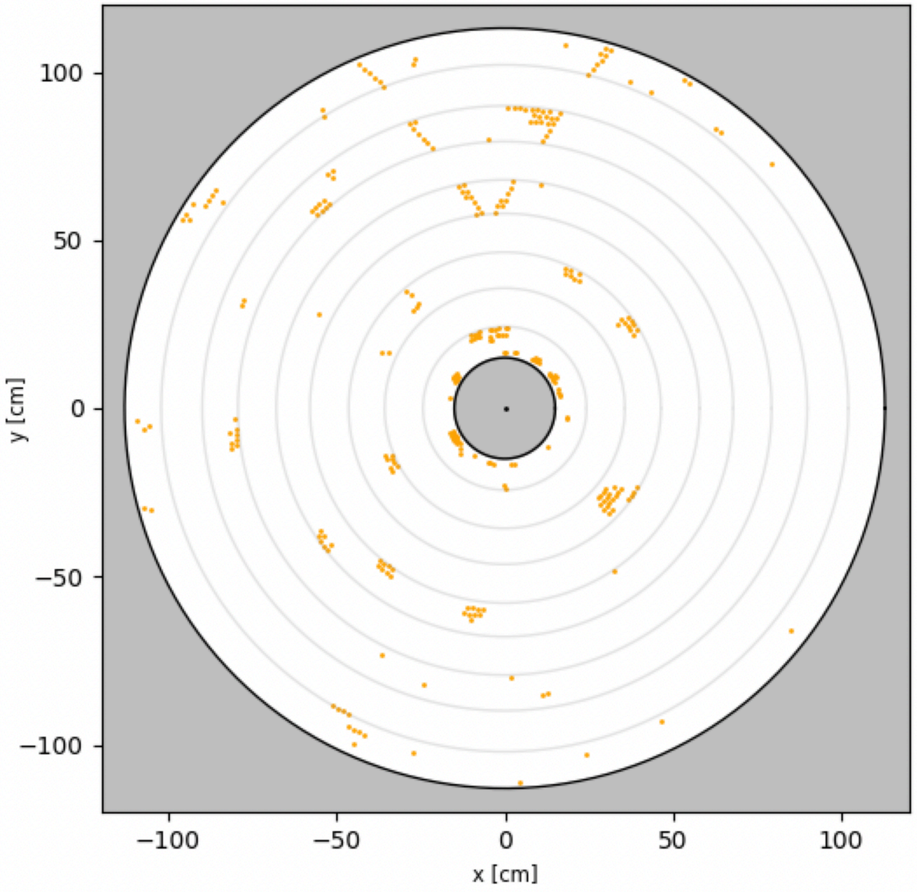
MPI & TUM
- Felix Meggendorfer
- Elia Schmidt
- Christian Kiesling
- Alois Knoll
- Timo Forsthofer
- Simon Hiesl

I: L1 CDC trigger for displaced vertex events

- Development using simulated data (Patrick Ecker, KIT)
- Long lived neutral particle (dark Higgs) [0.5-4.0] GeV
- Decay to muons $e^+e^- \to A'(h' \to \mu^+\mu^-)$



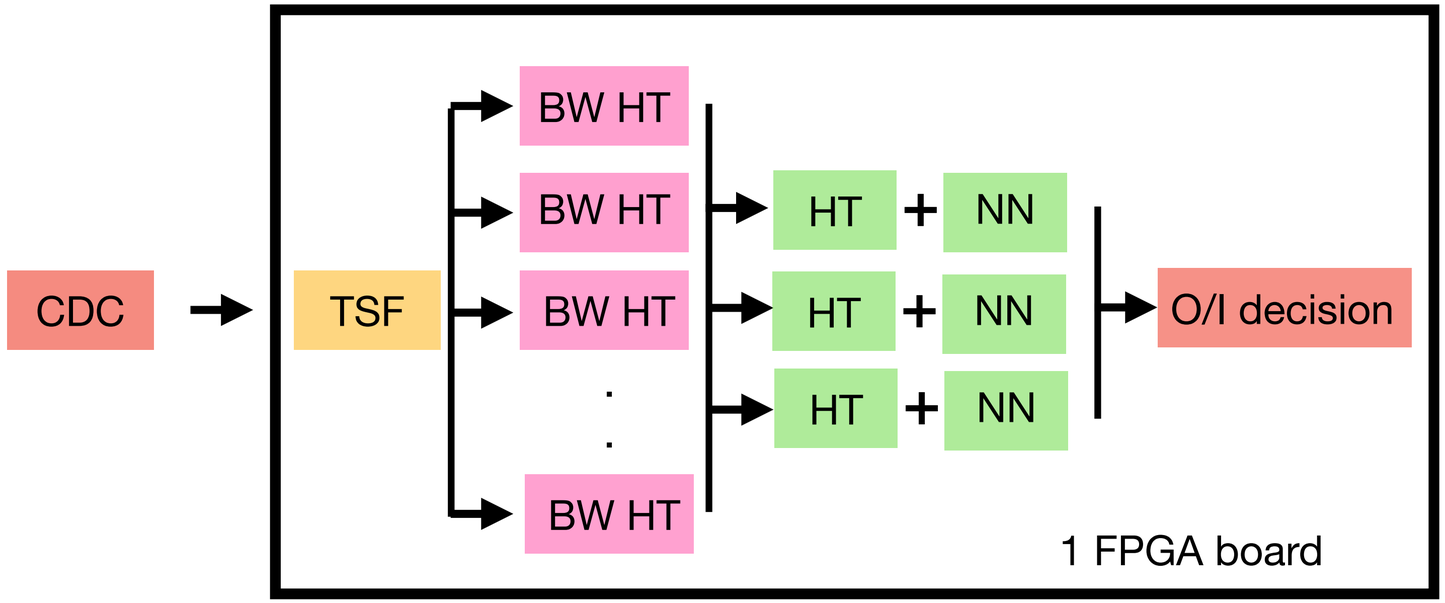
STT efficiency vs. vertex displacement
[credit: Patrick Ecker, KIT]

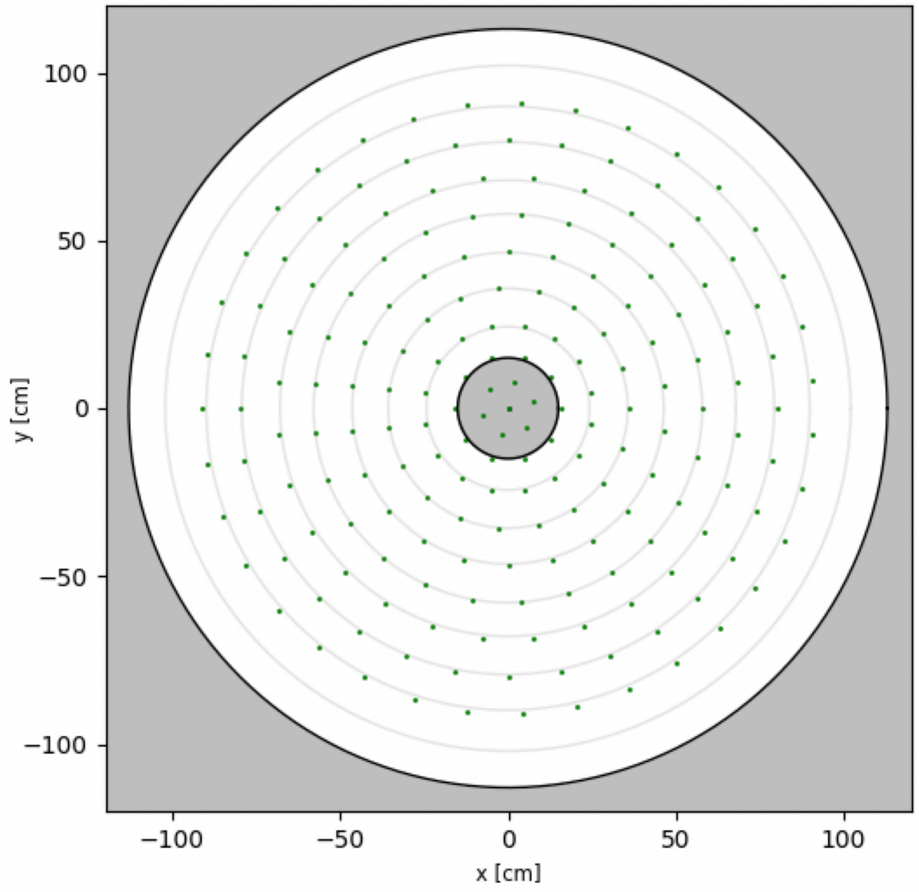


Example event in early phase 3 running conditions

II: Main Idea

- Reference vertices are placed in the CDC (MacroCells)
- Parallel Hough transforms (HT) assuming vertices
- Rough preselection algorithm —> subset of candidates
- Clustering algorithm in the Hough plane
- Neural analysis of cluster variables

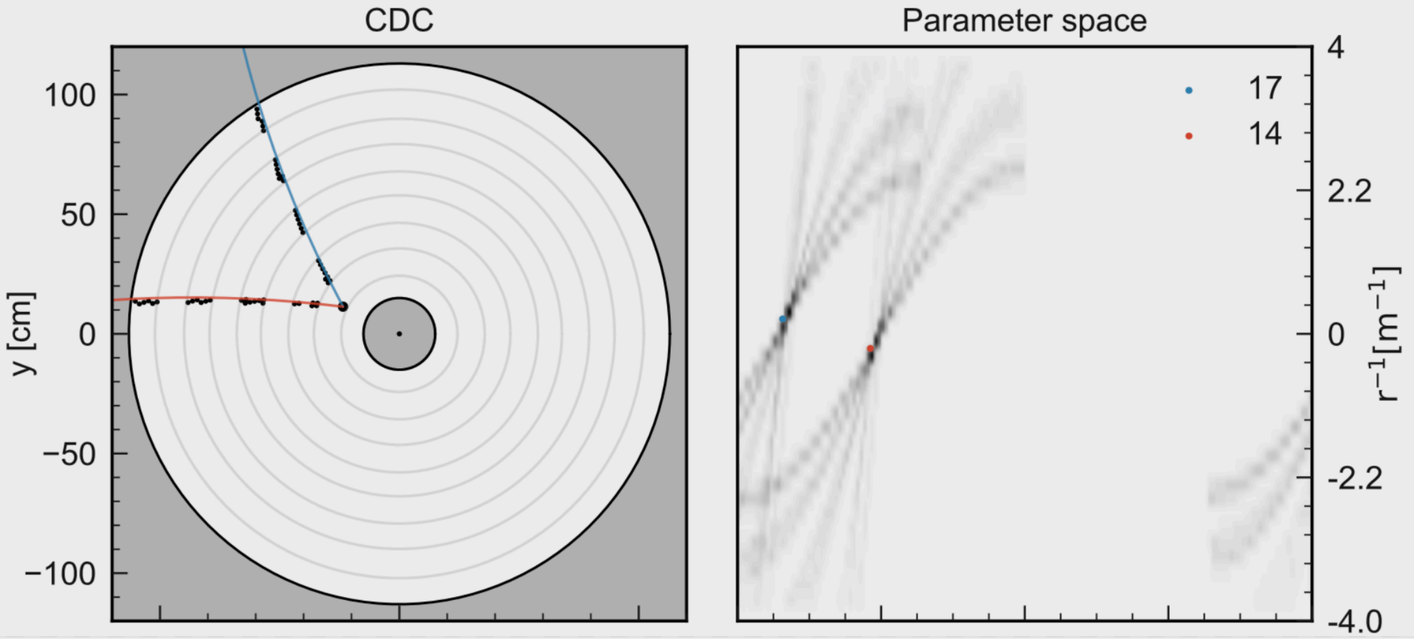




MacroCell structure (194 reference vertices)

Hough transform (HT)

- Hits —> hit curves (assuming ref. vertex)
- Intersections of hit curves —> track parameters
- Clustering in Hough plane



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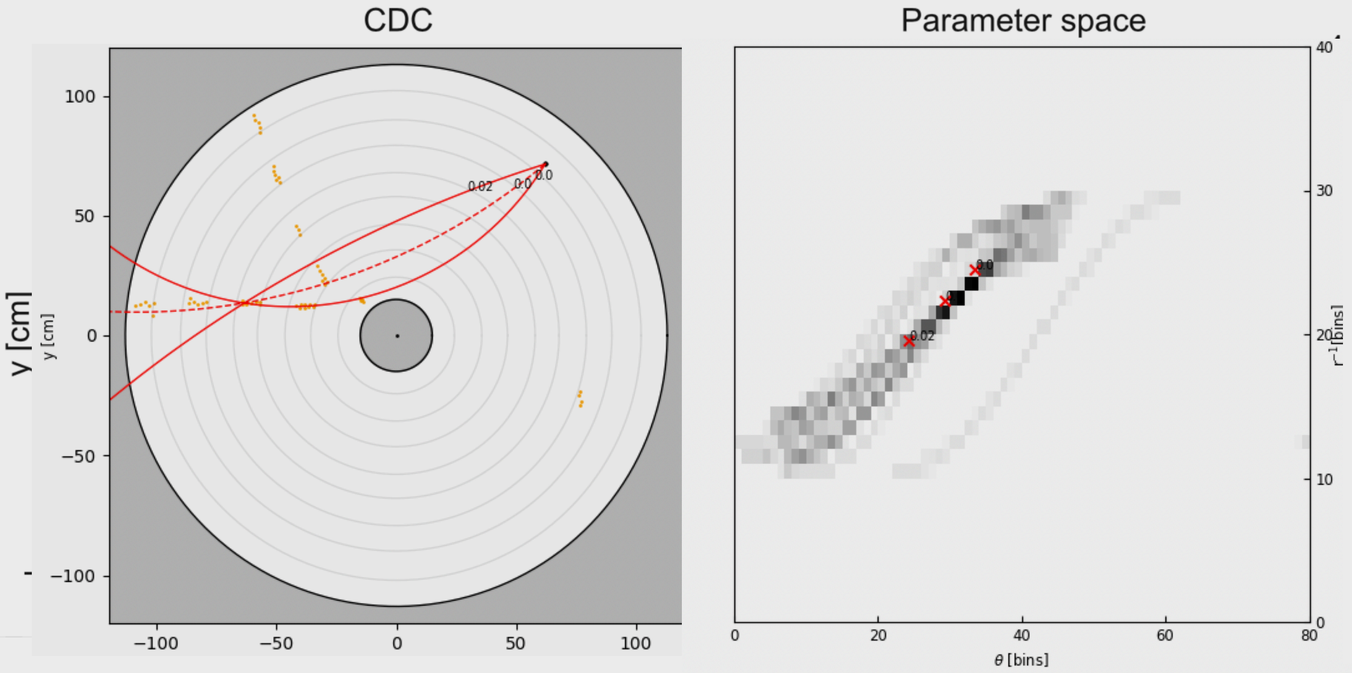
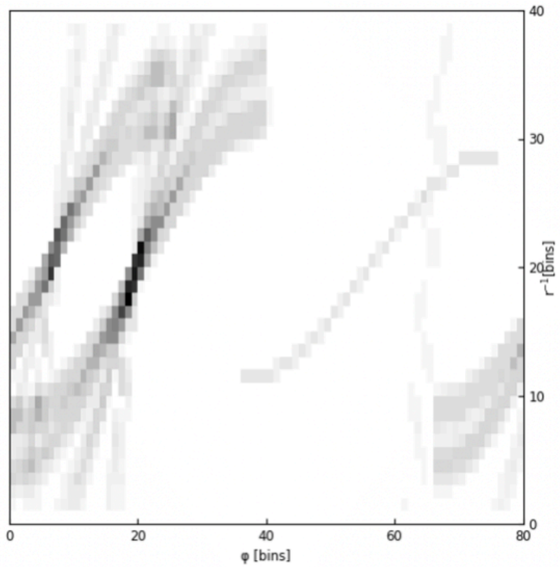
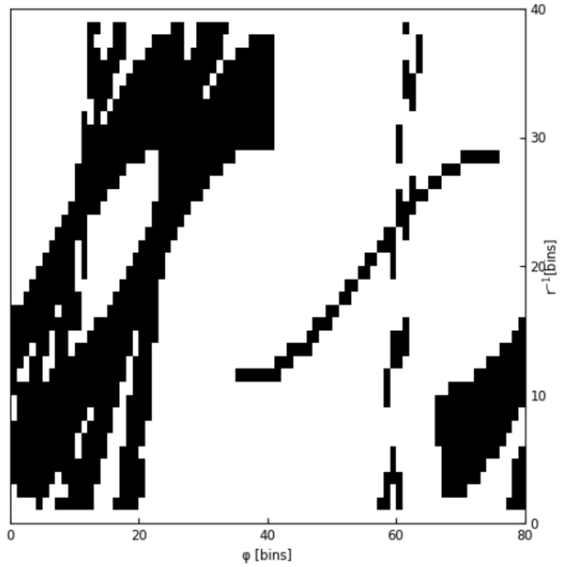


III: Optimization: Black & White HT

	First Implementation	Optimised Version
LUT	1039%	78%
DSP	100%	79%



Normal Hough matrix



b&w matrix

- Initial FPGA implementation for **ONE** vertex
- Bottleneck: Addition of ~80 1-bit Hough matrices
- Solution: „Black-and-White“ Hough transform
- Entire Hough matrix is only one bit

$$\text{score} \equiv \sum_{\omega=5} + \sum_{\omega=35} - \sum_{\omega=19} - \sum_{\omega=20}$$

- Many more MacroCells fit onto UT4 board

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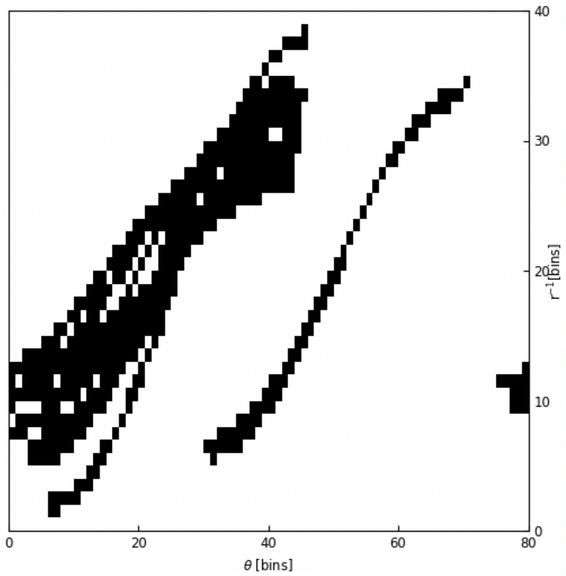
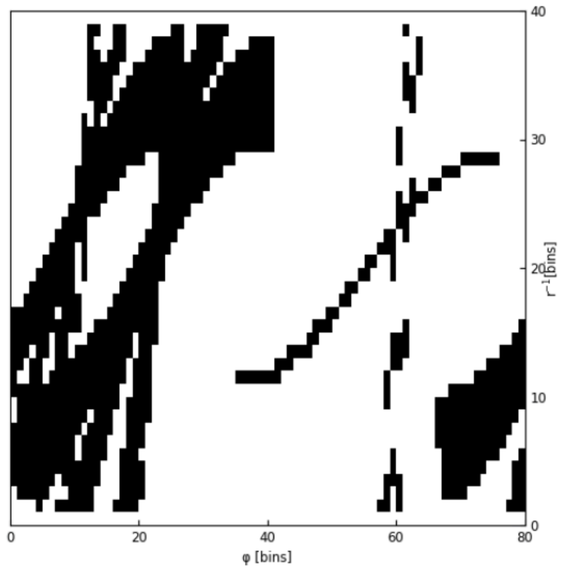


Wrong vertex assumption



Correct vertex assumption

- Initial FPGA implementation for **ONE** vertex
- Bottleneck: Addition of ~80 1-bit Hough matrices
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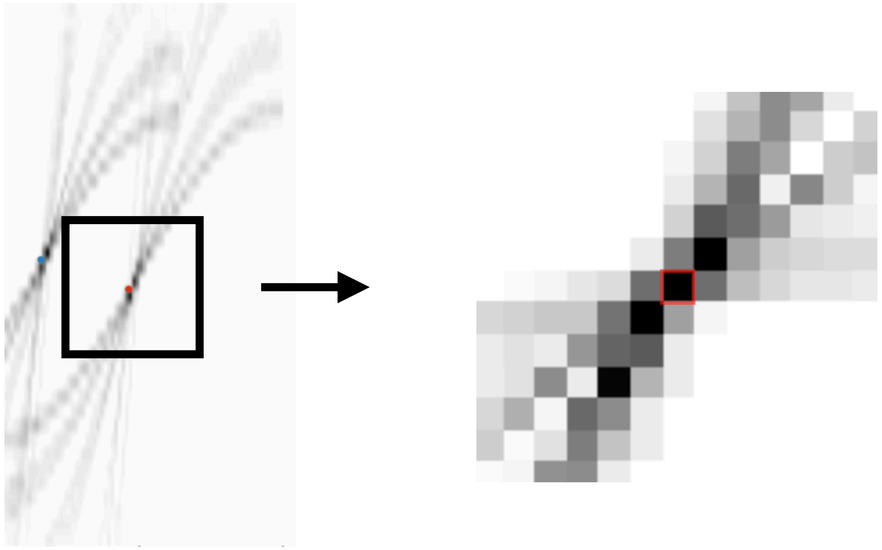
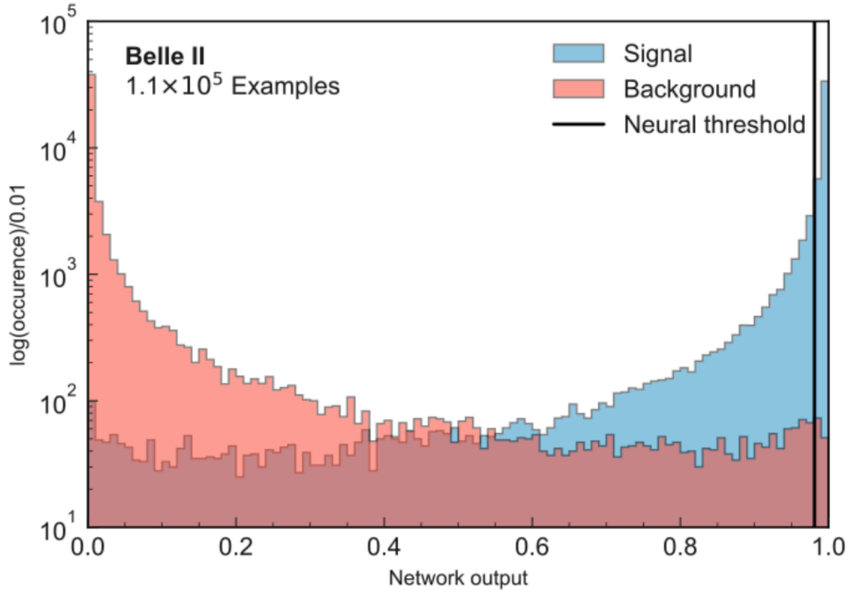
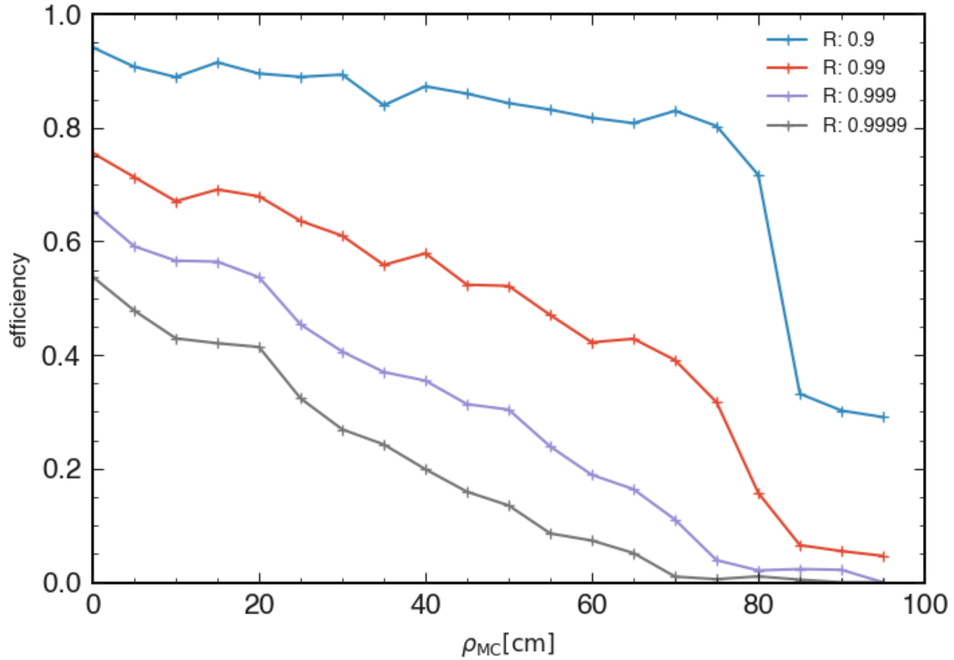
IV: Neural Network

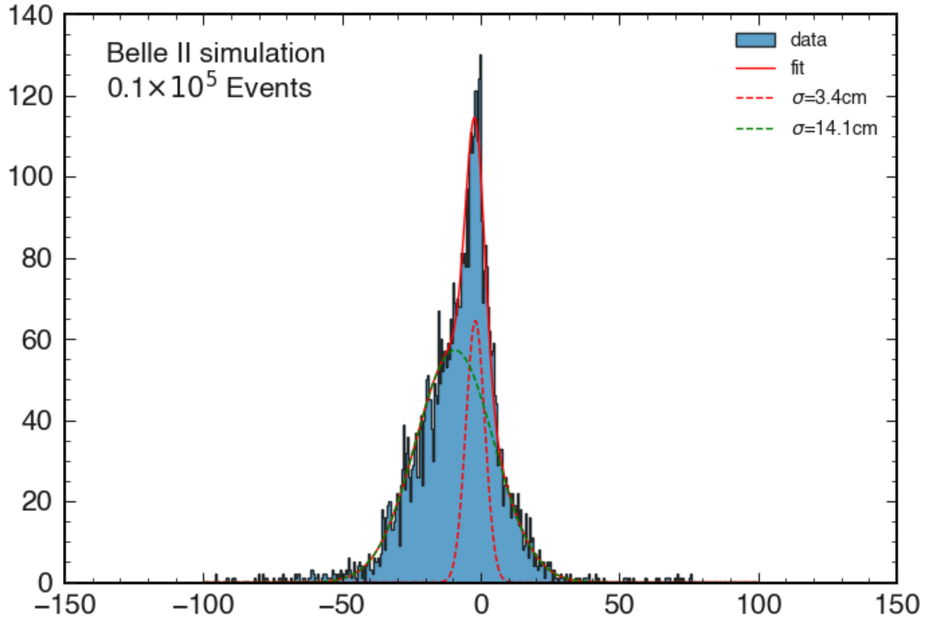




- Analyze regions around Hough matrix maxima
- Extract cluster variables (com, size, sigma …)
- Cluster variables are input to neural network
- Discriminate actual tracks from fakes
- Two good tracks (of opposite charge) from the same vertex—> trigger decision

V: New results





- First network trained (very limited dataset and no optimization at all)
- Stronger in rejection than old algorithm (due to fewer MacroCells)
- Need to determine precise rejection constraint
- Vertex resolution is satisfactory for an L1 trigger

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