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Improving the Belle II Neural Track Trigger with Deep Neural Networks

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Members of the Belle II Trigger Group



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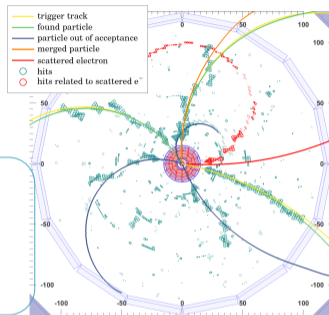
MAX-PLANCK-GESELLSCHAFT

MPI & TUM

- Felix Meggendorfer
- [Elia Schmidt]
- Simon Hiesl
- Timo Forsthofer
- Christian Kiesling
- Alois Knoll

focus of
TUM/MPI groups:

Track Triggers



Preprocessing of Input Variables



- Central Drift Chamber (CDC) at Belle II with 54 layers of wires organized in nine superlayers
- Hour-glass-shaped Track Segments passed from Track Segment Finder (TSF) over Hough-Finder to Neural Network

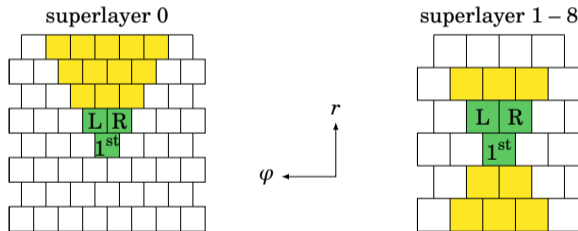
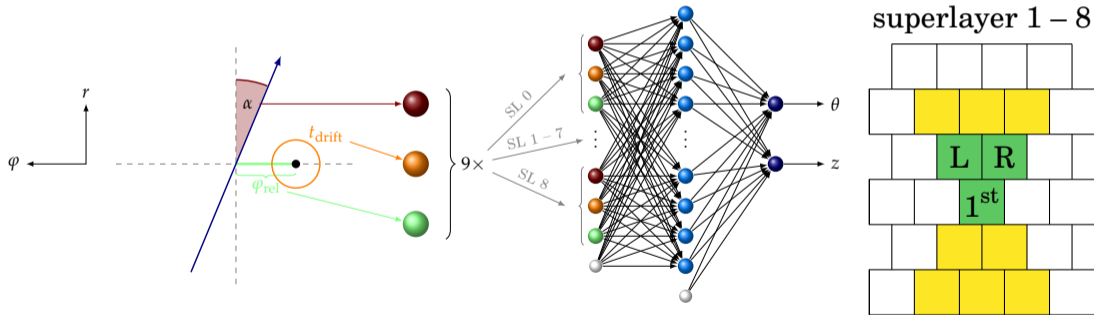


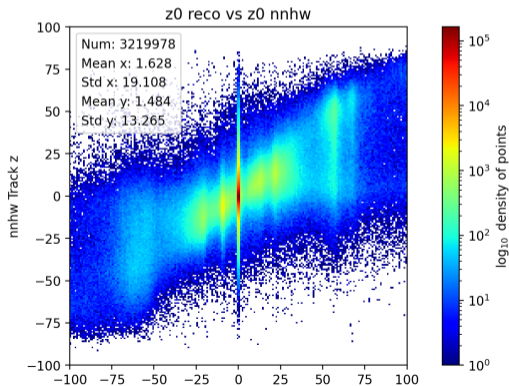
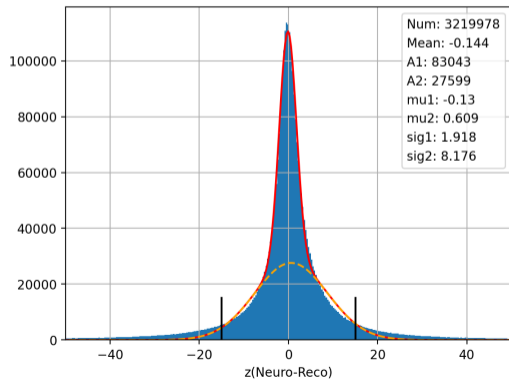
Figure: Structure of a Track Segment

Current Network

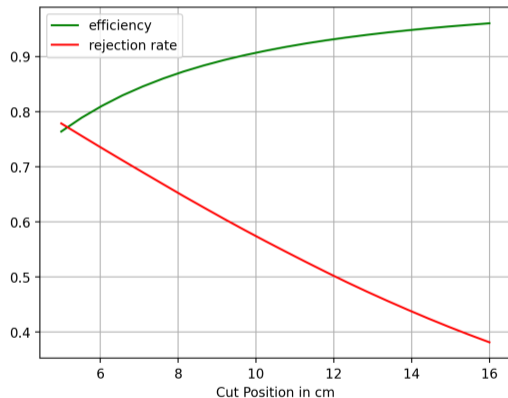
- Three input parameters for each superlayer
- 81 hidden nodes and two output nodes (z and θ)
- Five experts for different configurations of missing Stereo Layers



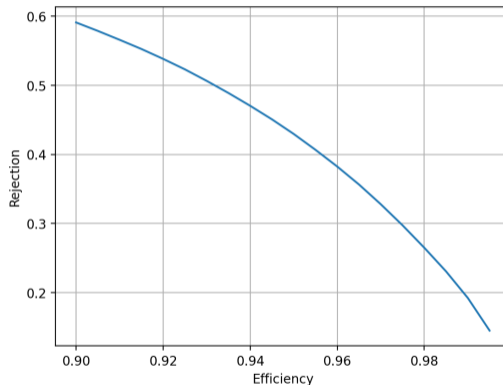
- Data in previous runs had less background
- Retraining on noisy data alone increases the resolution
- Strong bias in input data leads to Feed-Up and Feed-Down



- Present trigger condition: Accept all tracks with $|z_{neuro}| < 15$ cm

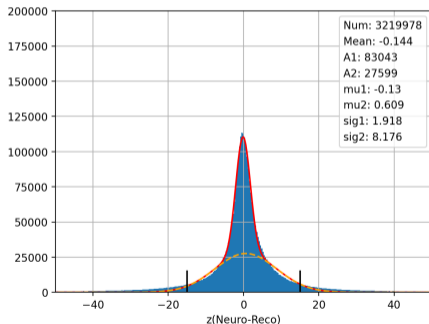


Efficiency and Rejection for Different Cuts

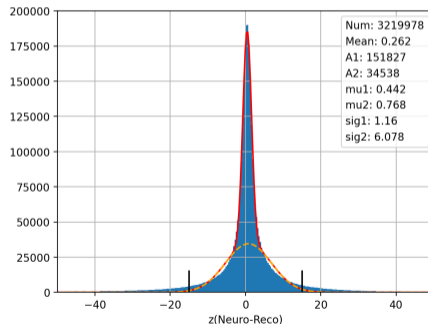


Rejection for Different Efficiencies

- Newer, more powerful FPGAs allow for bigger networks
- Three or four hidden layers beneficial for resolution
- More hidden layers better than more nodes per layer

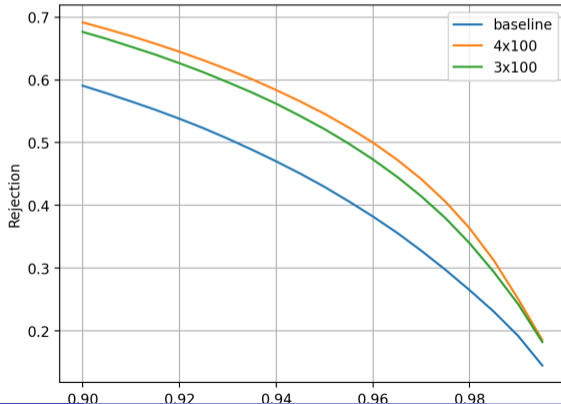


1HL with 81 Nodes

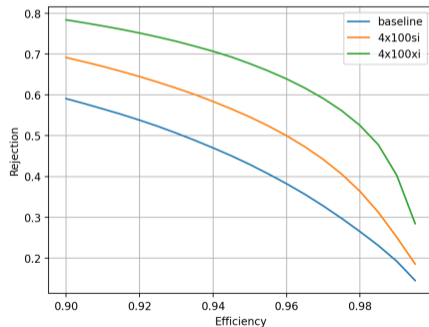
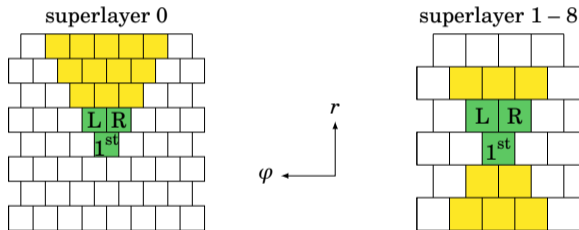


4HL with 100 Nodes per HL

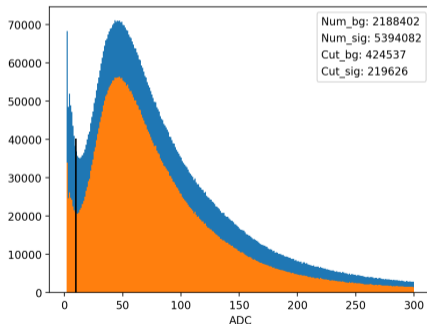
- Rejection rate up to 10 percentage point higher compared to present architecture (baseline) for same efficiency
- Input data already went through L1, so not many background tracks



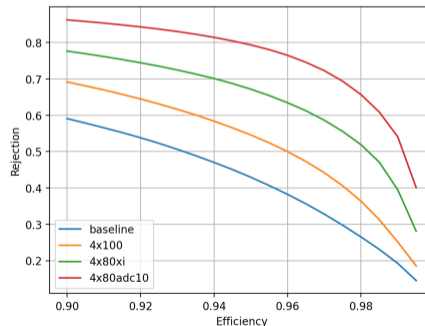
- New hardware can also pass more information to the network
- Drift times for all 11 wires in track segment passed on to network
- Particularly effective for improving the background rejection rate



- ADC-count indicates strength of electric signal
- Potential for further decrease of noise in the CDC wires
- Low counts often not real hits, so it's better to ignore them



ADC-Distribution on Signal and BG

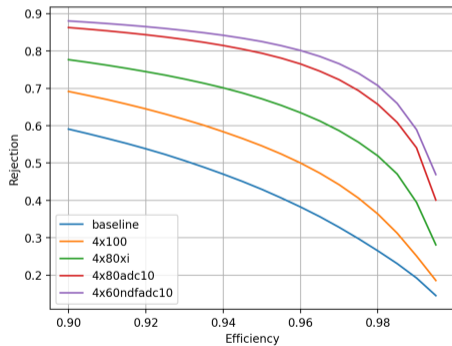


Effect of an ADC-Cut at ten

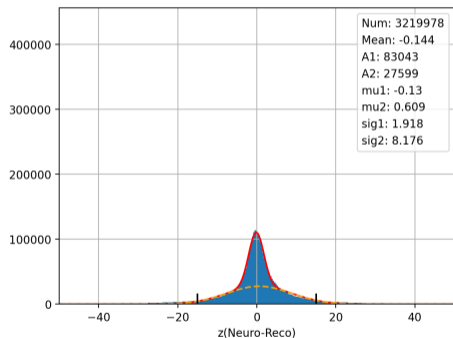
Combining ADC-Cut and 3D-Hough-Finder



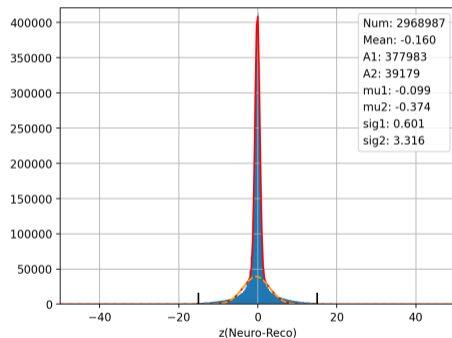
- ADC-Cut works well with 3D-Hough Finder (see presentation by Simon Hiesl)
- 3D-Hough Finder already rejects a lot of background and fake tracks, so the performance is underrepresented here



- Combination of all advances leads to increase in accuracy by almost a factor of three
- z-Cut can be reduced from 15cm to under 10cm

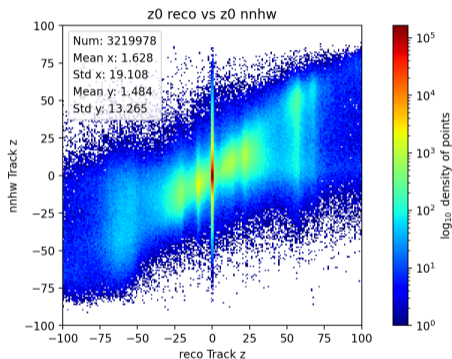


Present Network Architecture

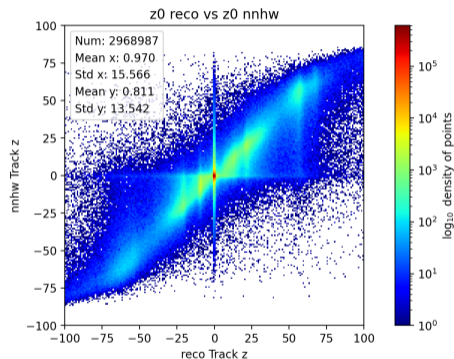


Deep Neural Network with Extended Input, ADC-cut and 3D-Input

- Especially extended input helpful in reducing Feed-Up and Feed-Down



Present Network Architecture



Deep Neural Network with Extended
Input, ADC-cut and 3D-Input



- Deep Neural Networks, Extended Input, ADC-Cut and the 3D-Hough Finder each bring significant improvements and work well together
- Implementation into hardware in cooperation with KIT ITIV
- Future training on unbiased input data
- Displaced Vertex Trigger

