Improving the Belle II Neural Track Trigger with Deep Neural Networks

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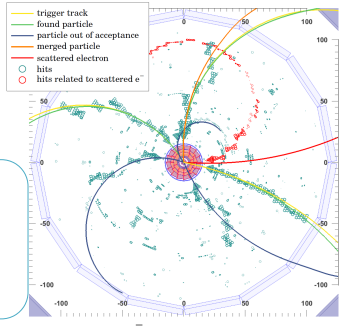
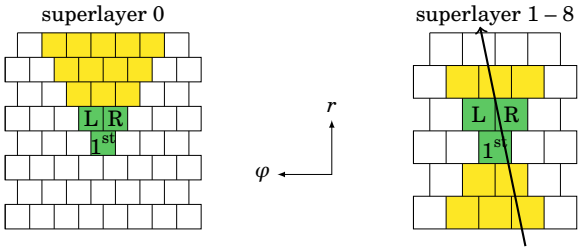


Focus of the MPI/LMU/TUM group:

Track Triggers

Preprocessing of Input Variables

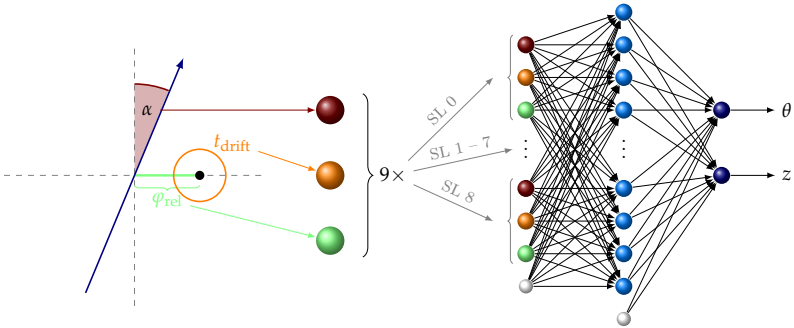
- Central Drift Chamber (CDC) at Belle II with 54 layers of wires organized in nine superlayers
- Hour-glass-shaped Track Segments passed from Track Segment Finder (TSF) over Hough-Finder to Neural Network

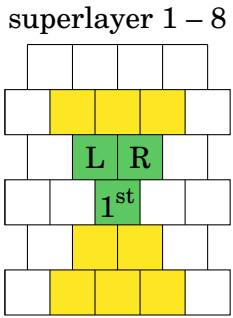


Structure of a Track Segment

Current Network

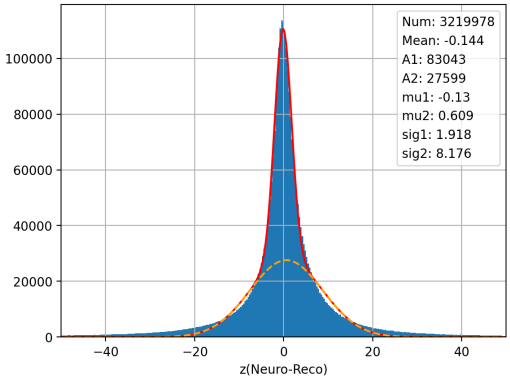
- Three input parameters for each superlayer
- 81 hidden nodes and two output nodes (z and theta)
- Five experts for different configurations of missing Stereo Layers

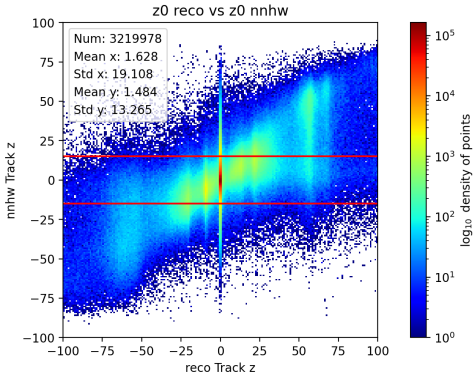




Current Network

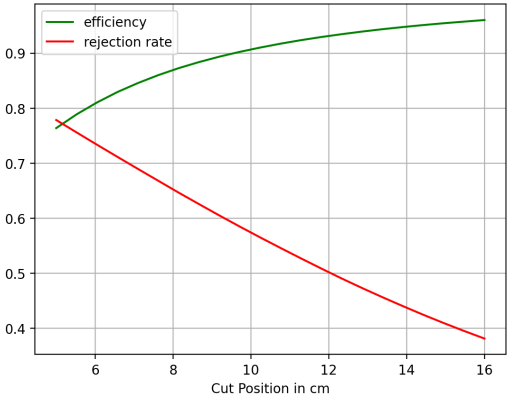
- Data in previous runs had less background
- Retraining on noisy data alone increases the resolution
- Strong bias in input data leads to Feed-Up and Feed-Down



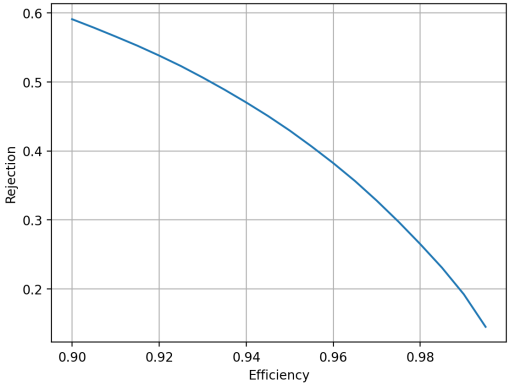


Current Network

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



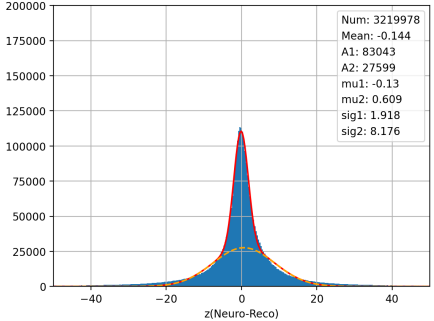
Efficiency and Rejection for Different Cuts



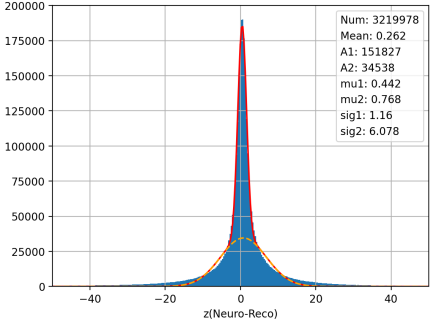
Rejection for Different Efficiencies

Deep Learning Architectures

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



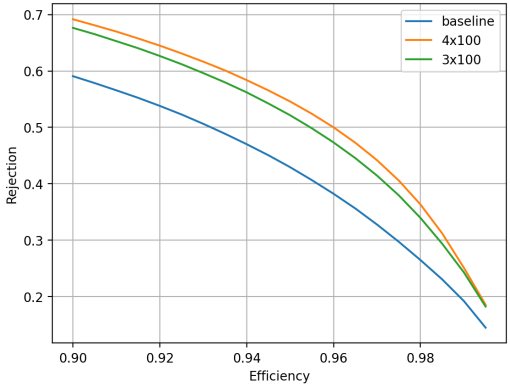
1HL with 81 Nodes



4HL with 100 Nodes per HL

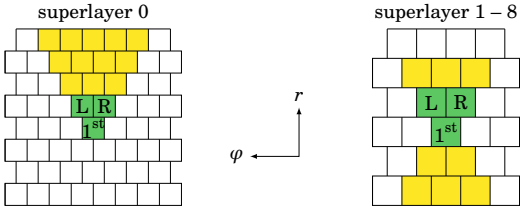
Deep Learning Architectures

- Rejection rate up to 10 percentage point higher compared to present architecture (baseline) for same efficiency
- More hidden layers better than more nodes per layer

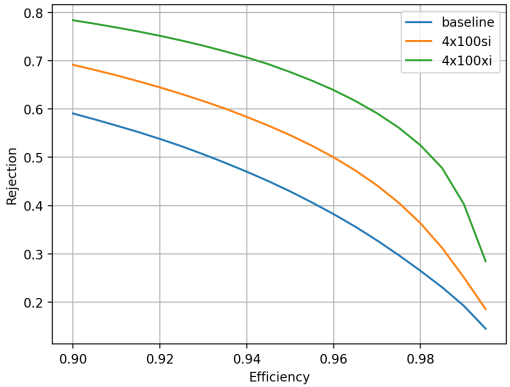


Extended Input

- 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

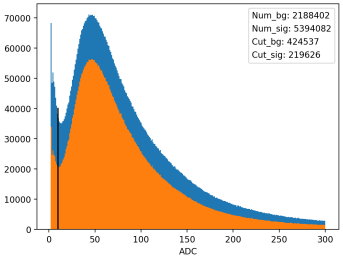


ADC-Distribution on Signal and BG



ADC-Cut

- 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



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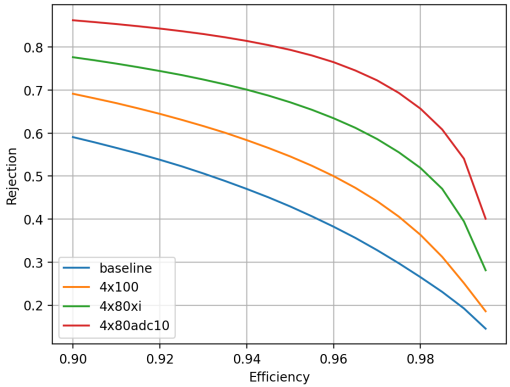
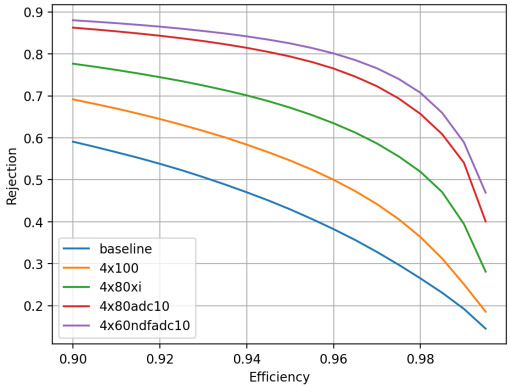


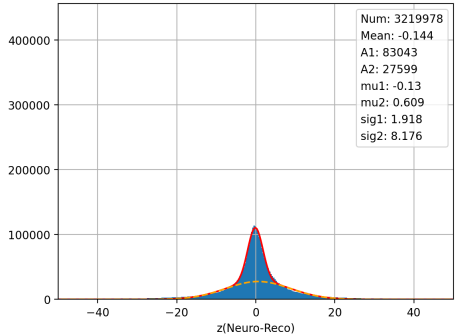
Combining ADC-Cut and 3D-Hough-Finder

- 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

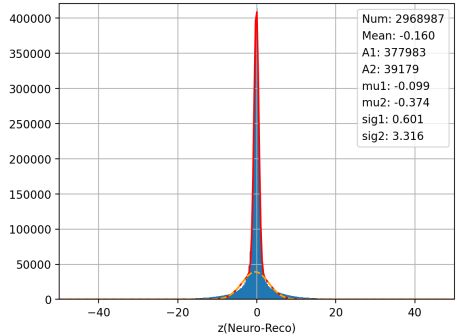


Final Performance Evaluation

- 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



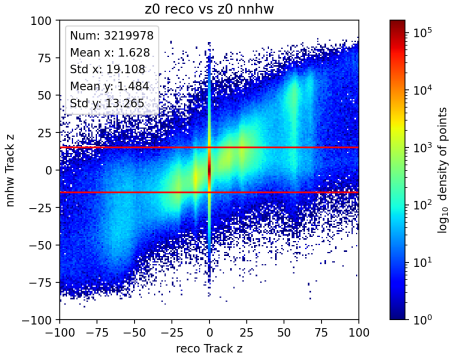
Present Network Architecture



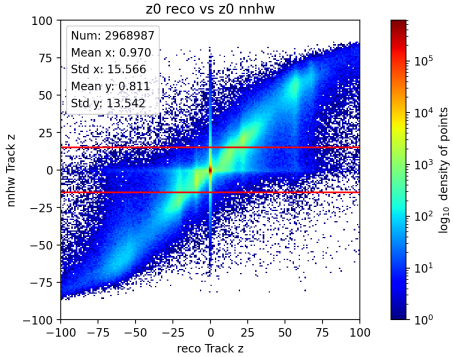
Deep Neural Network with Extended Input, ADC-cut and 3D-Input

Final Performance Evaluation

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



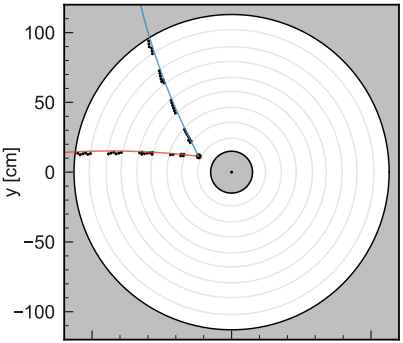
Present Network Architecture



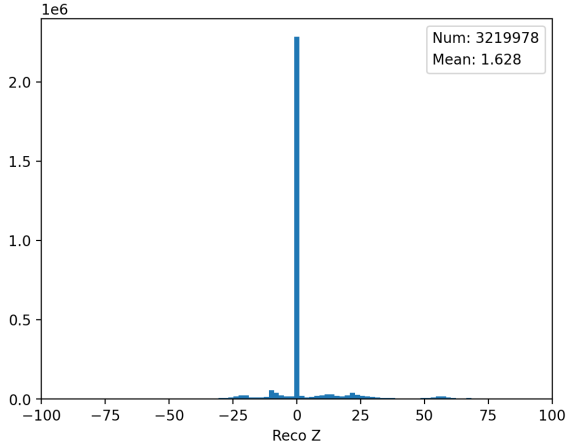
Deep Neural Network with Extended Input, ADC-cut and 3D-Input

Summary and Outlook

- 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



Backup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