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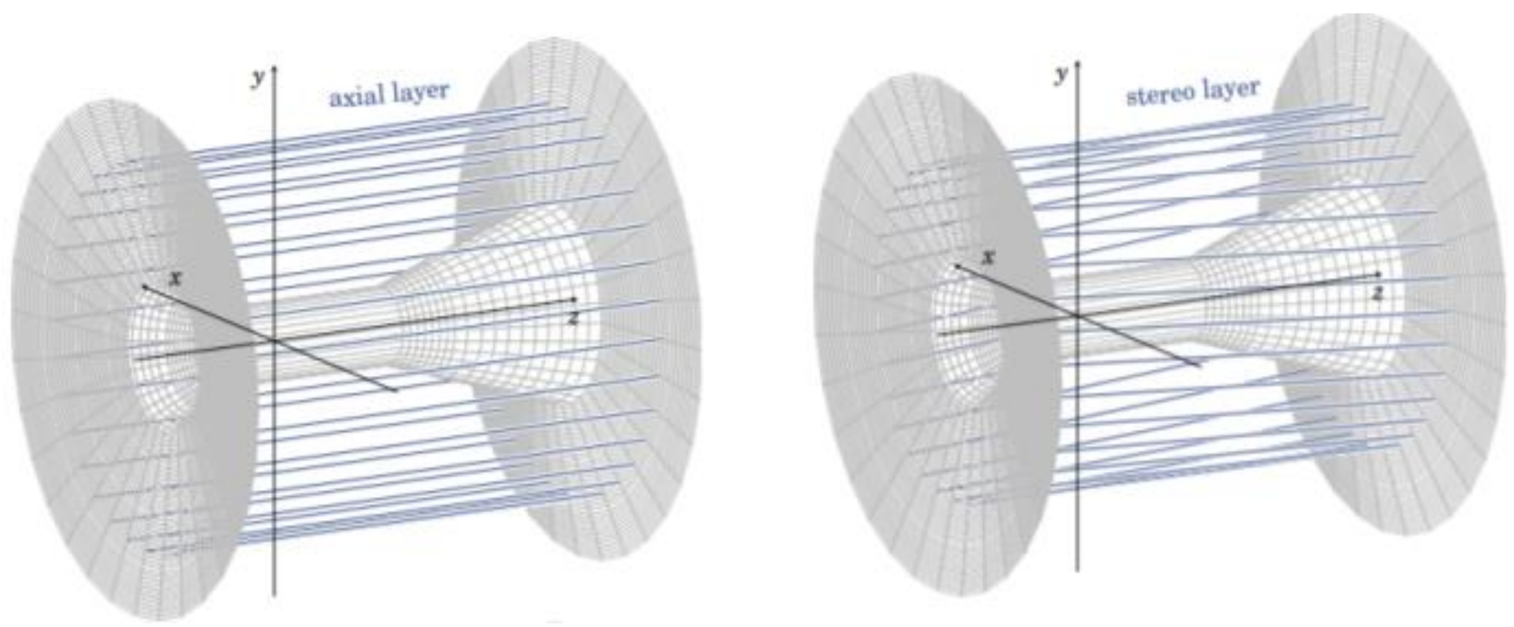
Optimization of a First Level Neural Network z-Trigger for the Drift Chamber at the Belle II Experiment

S.McCarney[1], S. Bähr[2], C. Kiesling[1], F. Meggendorfer[1], S. Skambraks[1], K.L. Unger[2], R. van Tonder[2]

[1] **Max-Planck-Institut für Physik (Werner-Heisenberg-Institut),** Föhringer Ring 6, 80805 Munich, [2] **Karlsruhe Institute of Technology**, Kaiserstraße 12, 76131 Karlsruhe

Belle II Neurotrigger

The Belle II Experiment located in Tsukuba, Japan, must deal with a much higher machine background than it's predecessor Belle. The concept of a First Level Trigger implemented using an Artificial Neural Network (ANN) approach was proposed, which is a factor of 10 better than traditional methods. Using Multi Layer Perceptrons (MLPs), a large fraction of the background can be discarded in real time to reduce the number of events written to disk. This First Level Track Trigger is pipelined and implemented on FPGAs, allowing a total latency of 5 µs and a maximum average trigger rate of 30 kHz.

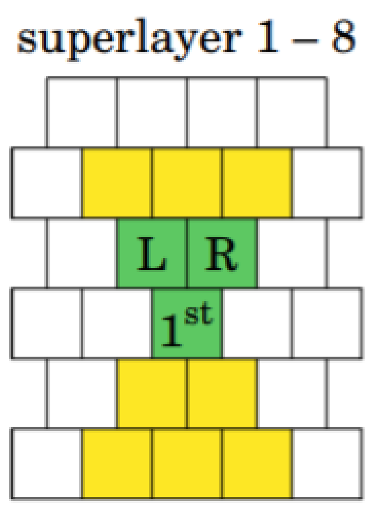


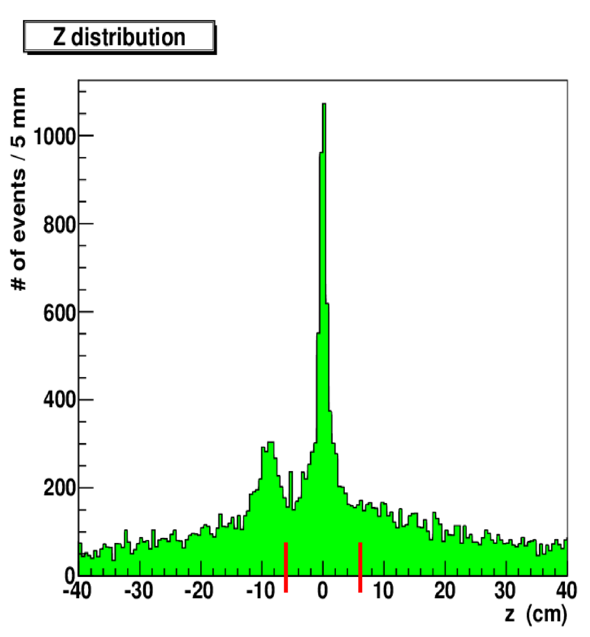
Central Drift Chamber (CDC)

The Belle II Detector surrounds the collision point of the SuperKEKB electron-positron collider. It consists of several sub-detector components, including a Drift Chamber. The CDC is a wire chamber filled with a special gas mixture. A charged particle passing through the chamber creates an electron avalanche which is registered as a hit. There are 56 layers of wires in the CDC which are grouped together into 9 Superlayers. The Superlayers alternate between one of two orientations – axial or stereo - which allows for a 3D reconstruction of tracks.

Track Segment Finder (TSF)

The TSF is the first track finding module in the pipelined implementation. It's output is used as input to the Neurotrigger. Track segments are defined as a particular arrangement of wires from 5 layers within a Superlayer. A hit is produced if there are hits within at least 4 layers of the Track Segment in a certain time window. This compression of hits is necessary for the first level trigger to be within the assigned latency.

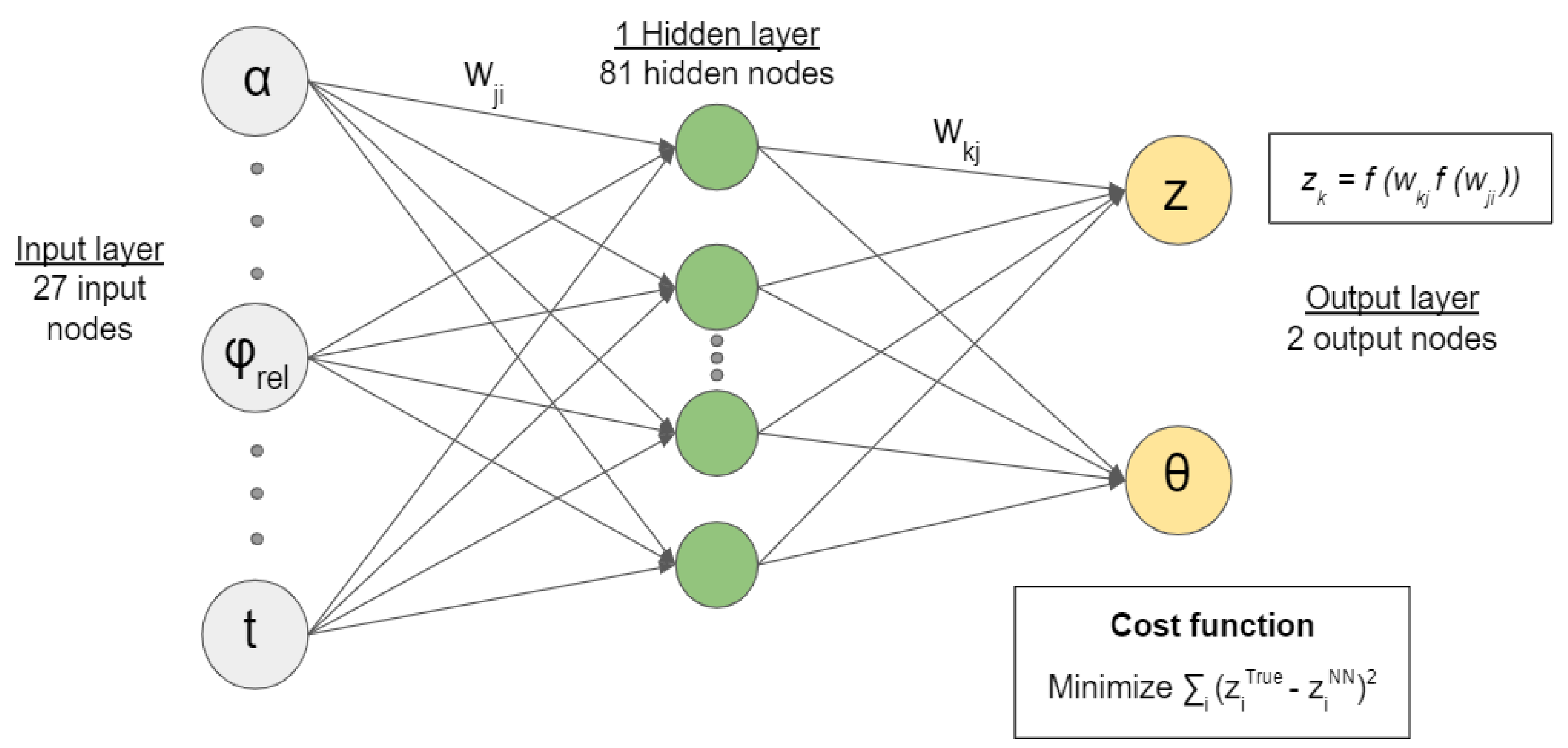




Belle Background

The Belle Experiment did not have a 3D reconstruction at the L1 Trigger. The peak at 0 corresponds to physically interesting events which originate from the Interaction Point (IP). With the higher machine background in Belle II, a precise estimate of the z-vertex position will be necessary to throw away this background, enabling genuine two-track triggers without further conditions. Low multiplicity events are characteristic for Physics beyond the Standard Model.

References
1. Sara Pohl PhD Thesis 2018
2. Belle II Technical Design Report

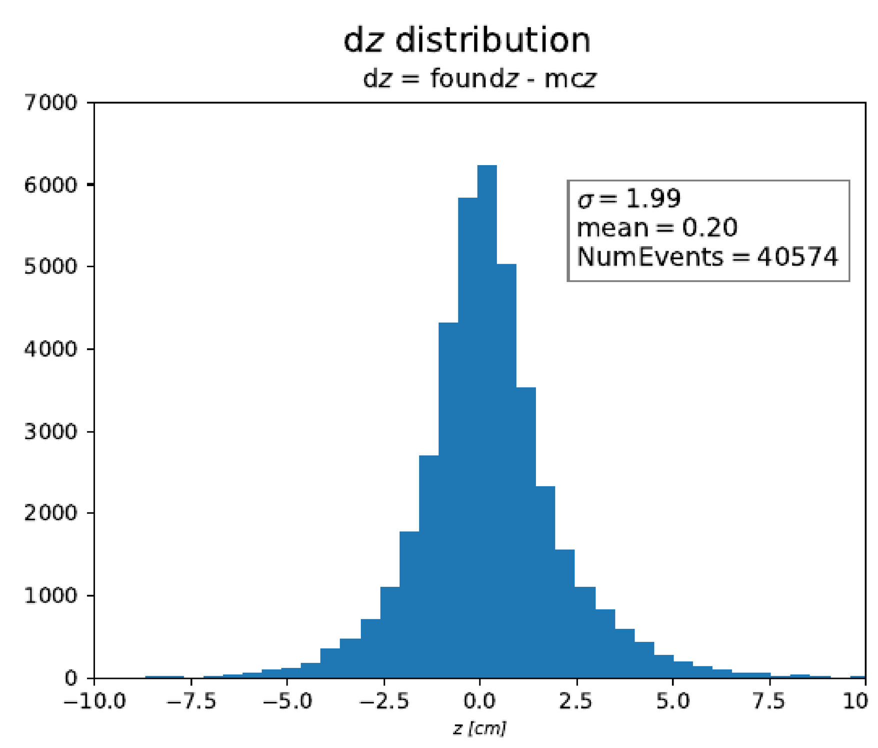


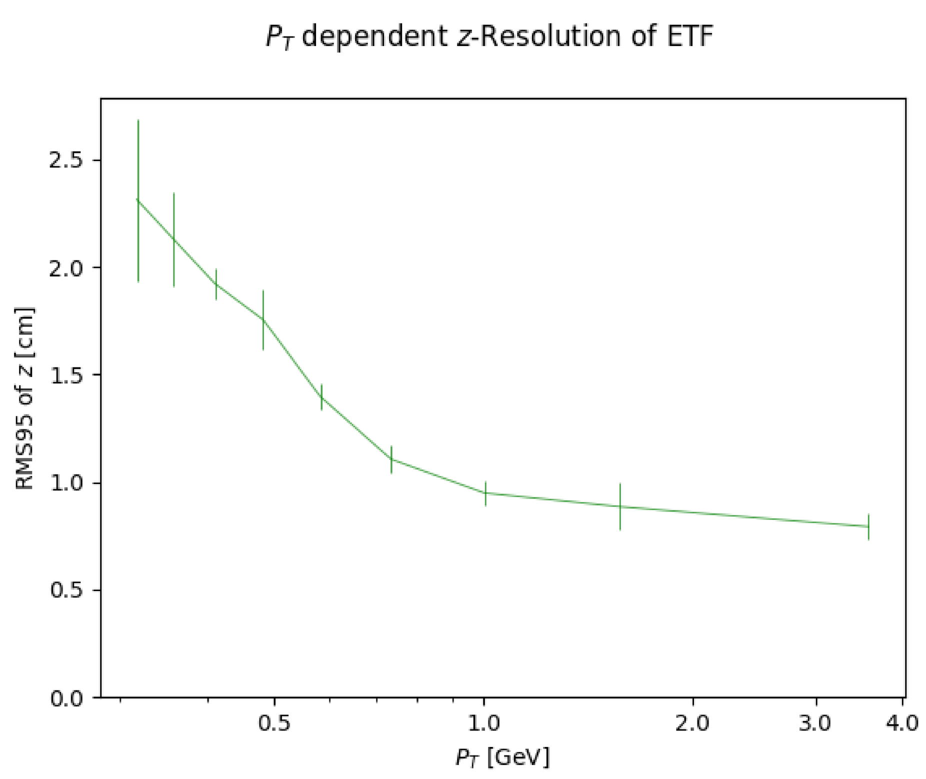
z-Vertex

The z-vertex is the point along the z-axis where a track or event is originating from. Electron-positron collisions originate from the IP where z=0. Any events originating outside of the interaction region are labelled as background and can be discarded. Taking into account resolution studies of our network, we can make a suitable 'z-cut', throwing away events outside of the assigned interaction region. Preliminary studies suggest a z-cut of 6 cm.

Neural Network Approach

The MLP Neural Network employed in the First Level Trigger aims to supress background events by reconstructing the z-vertex and making an appropriate 'z-cut'. The MLP consists of 3 layers; 1 layer of input nodes, 1 layer of output nodes, and one hidden layer. The input layer takes information from suitably preprocessed CDC data, providing information on azimuthal distance, drift time and arc length for each of the 9 Superlayers. This method of supervised learning approximates values for the polar angle and z-vertex (the 2 outputs) by method of Back Propagation; the weights are adjusted during training so that the ANN best matches the training data. Approximate values for the z-vertex and the polar angle are output. All nodes are computed in parallel, making this method ideal for a pipelined implementation and to achieve the desired latency of a few hundred nanoseconds for the ANN component.





Resolution Studies

Software simulation studies are performed using Monte Carlo particle generation. The studies show that the required z resolution of 2 cm can be met over the entire transverse momentum range. The trained weights are stored and can later be uploaded to the FPGAs. Currently a Neural Network is loaded on the firmware, being commissioned with cosmic ray data, and will be ready for the coming luminosity phase.