TIME PROJECTION CHAMBERS MEET NEURAL NETWORKS
Denoising and Track Recognition in 3D Events Data

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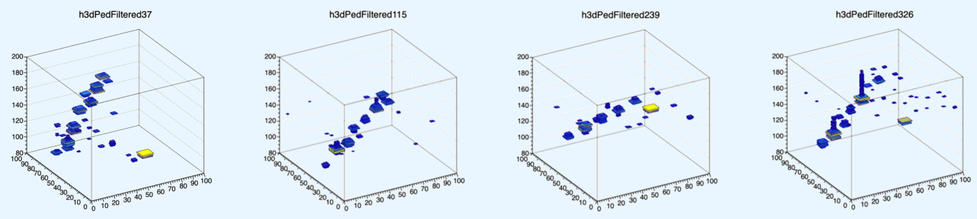
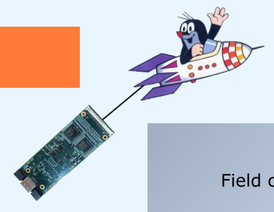
Visit project's GitHub!

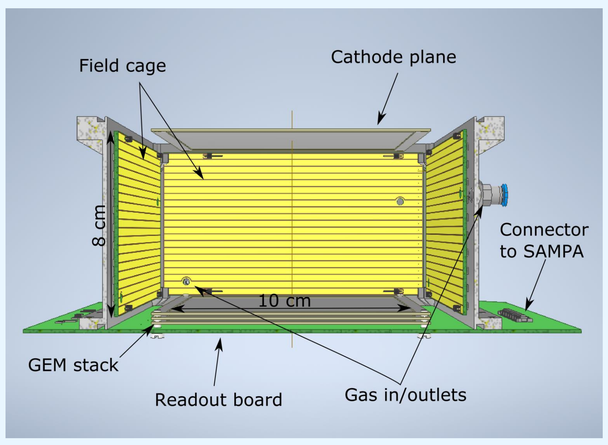
INTRODUCTION

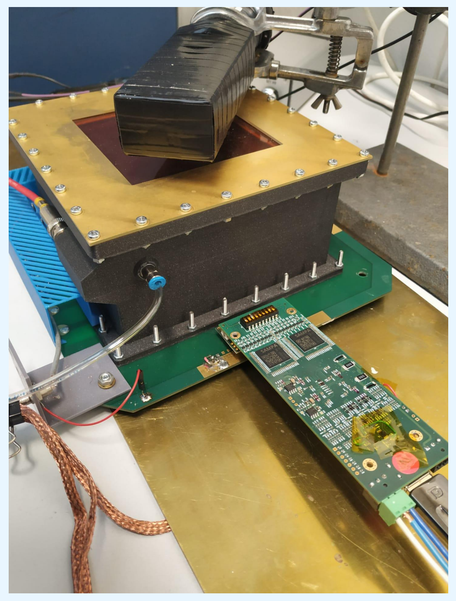
- Microdischarges in TPCs add **noise** to measurements
- Needs to be removed – usually detector-specific, heuristic approach with the need of expert knowledge
- **Our goal:** Use instead **convolutional neural networks** for the denoising
- This was done before only on 2D data, but our events are **3D**
- Part of software for **IEAP X17 experiment** (under development, only TPC prototype measuring cosmic muons now)

EXPERIMENTAL SETUP

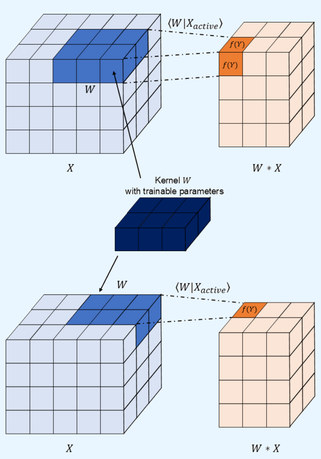




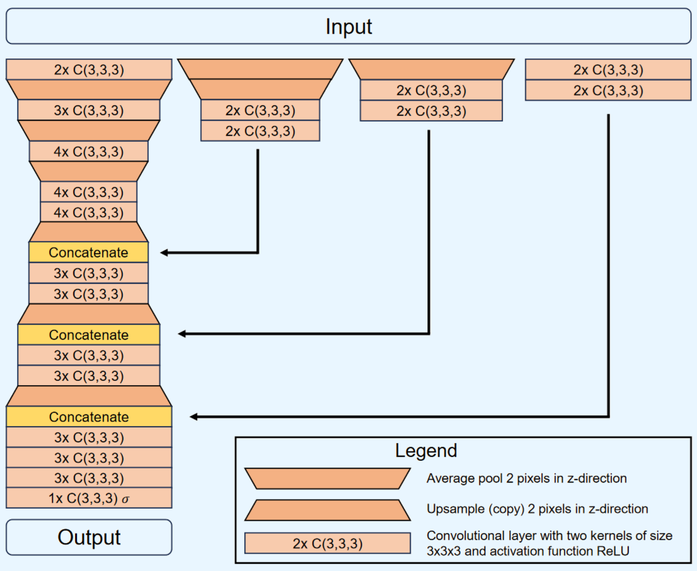




- TPC prototype placed tilted by 30 degrees in a cosmic telescope
- Data acquisition based on the SRS with SAMPA hybrids (the first detector testing the SAMPA/SRS integration)
- At the time there were still many communication issues and a large portion of the data was even noisier than expected in normal operation



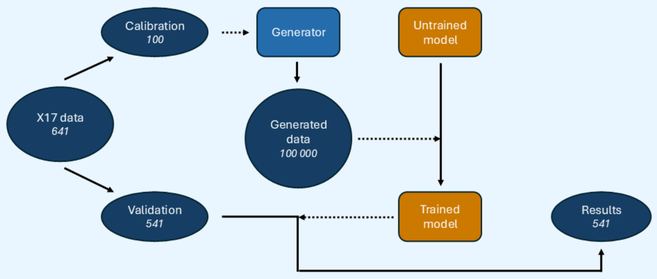
1) Elementwise multiply
2) Sum
3) Apply activation function



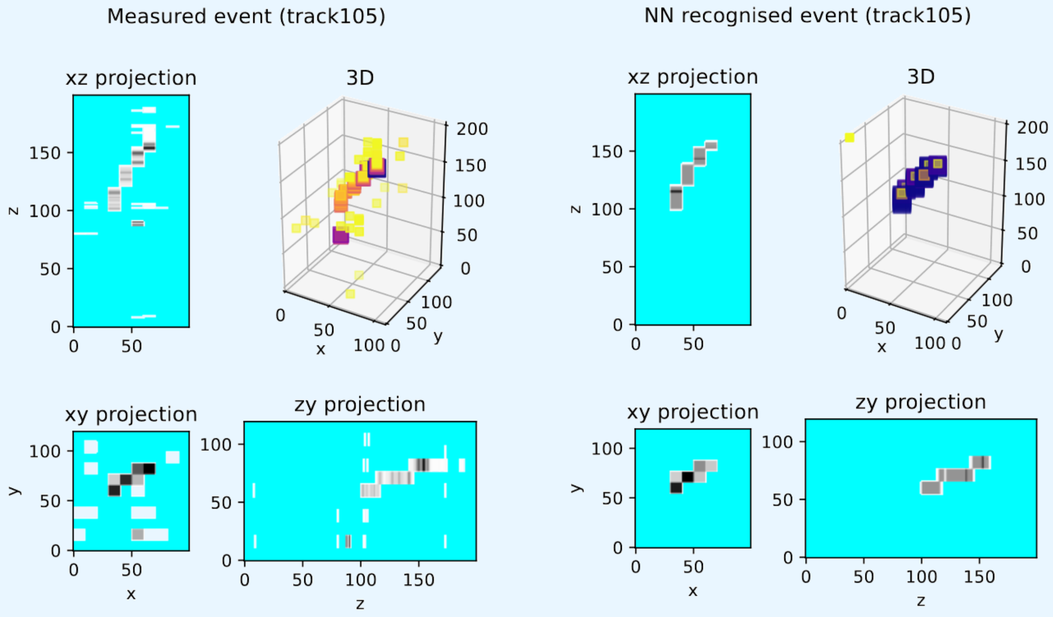
NEURAL NETWORKS

- NNs ≈ highly parametrised mappings (each neuron is parametrised linear combination + nonlinear function, interconnected neurons together compose the network)
- **Training** = parameters are numerically estimated, so that the network fits well training data (= performs well the given task)
- **Convolutional neural networks** are heavily used in image processing
- TPC event can be viewed as a 3D image…
- **Our task for NN:** Classify each event hit as **belonging / not belonging to a track**

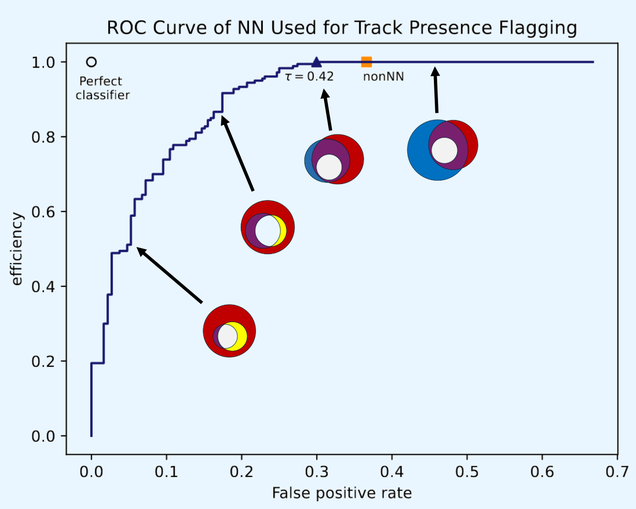
DATA

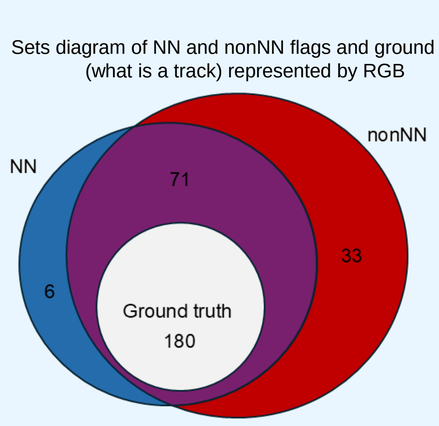


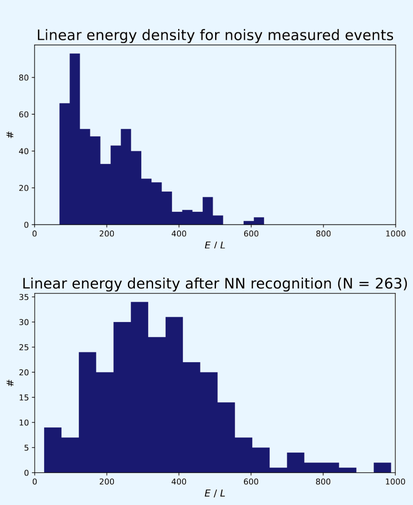
- Event = 3D 12×14×208 tensor containing uncalibrated TPC response amplitudes (corresponding to energies)
- Only 641 linear cosmic events from TPC prototype – insufficient for training, but nice for validation
- Training data are thus **generated** (with the aid of 100 measured events)

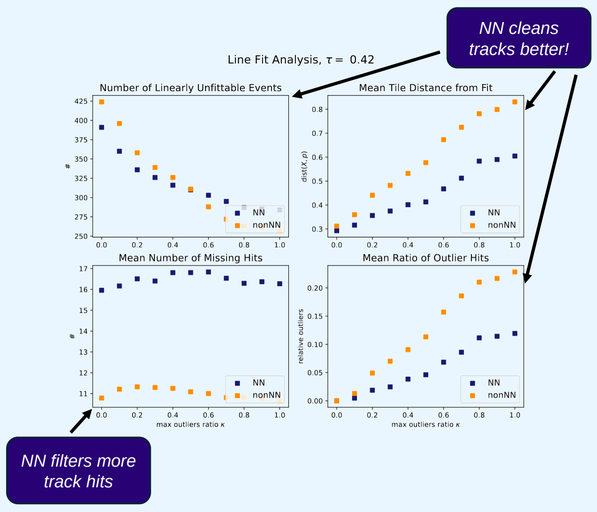


RESULTS & DISCUSSION









EVENT FLAGGING → IS THERE A TRACK?

Consequence of the denoising

Ground truth can be visually determined

FOUND TRACKS IN THE DATASET

Some events without a track are incorrectly flagged (false positives)

NN and nonNN make similar mistakes

REGAINING ENERGY DEPOSITION

Landau distribution of track energy deposition is lost due to the noise

NN recognition cleans this distribution

LINEAR FIT ANALYSIS

Is the recognition meaningful?

Curves closer to zero = better

Recognition performance on individual hits

- Compared with another, non-neural algorithm (*nonNN*)
- Performance measurement nontrivial, more methods needed
- More measurements are planned
- NN gives comparable results to nonNN (in some cases better results!)
- → Potential new low-level denoising algorithms?

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