

# 1 Neural network triggers

## 1.1 Motivation

The station-level triggers in the previous chapter have been shown to perform well enough for the science case of the Pierre Auger Observatory. However, it has also been concluded that a lot of potential data, especially at low energies is ignored. This is by intention in order to keep DAQ readout at feasible levels.

Attempts at improving the overall efficiency of the SD triggers can be made. This is only possible to a certain level. At lowest energies the particle cascade is not big enough to warrant coincident triggers in at least 3 WCD stations. As per ??, the lateral trigger probability a given classification algorithm can maximally achieve is given by the LPP (c.f. ??). The T3 detection probability of such an ideal trigger, and consequently the maximal efficiency for an array with 1.5 km spacing is compared to the efficiency of classical triggers in ??.

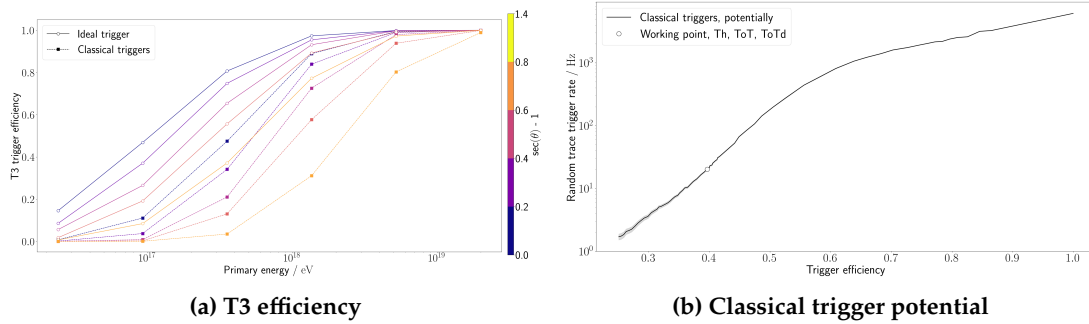
Of course, efficiency can be improved simply by adjusting trigger thresholds of the algorithms in ?? . However, the more lenient these thresholds are, the more background events will be detected. This quickly results in trigger rates that are unmanagable for the infrastructure at the Pierre Auger observatory. The probability with which time traces correctly raise a T2 is shown alongside the resulting random-trace trigger rate for different thresholds of classical algorithms in ??.

Ideally, neural network architectures developed in this chapter should undercut the random-trace trigger rate of classical triggers, while retaining an overall higher accuracy. That is, they lay below and right of the operating point in ??. For any algorithm that achieves this, the corresponding LTP will be greater than that of classical triggers, resulting in higher event detection efficiency, while not exceeding the bandwidth limitations of the underlaying hardware.

## 1.2 Design considerations

### 1.2.1 Network architecture

The hardware specifications at the FPGA level, where trigger conditions are currently checked, are limited. For this reason, NN architectures should be kept as simple as possible. Most importantly, the number of weights, biases and other trainable parameters will need to be hardcoded into station software. Because of minimal available storage space, this number needs to be kept low.



**Figure 1.1:** (a) Comparison of an ideal trigger sensitive to any shower signal from primary energies  $E \geq 10$  PeV to classical triggers. (b) The noise level over calculated efficiency for classical triggers. The tail ends of the potential curve are calculated by adjusting the trigger thresholds from +250% to -95% of the nominal values.

This immediately disqualifies powerful candidates like autoencoders or transformers (compare ??) from consideration, due to their size. Only simple dense-, convolutional-, and recurrent neural networks are viable contenders that could theoretically be implemented in the SD electronics.

## 1.2.2 Training data

## 1.3 ???

1. Have problem
2. Throw math at problem
3. ???
4. Profit

[to do: write this]