
# Autoencoders for Anomaly Detection in Real-Time at the LHC

Thea Arrestad[1], Katya Govorkova[1], Thomas James[1],
Vladimir Loncar[1], Jennifer Ngadiuba[2], Maurizio Pierini[1],
Adrian Alan Pol[1], Ema Puljak[1], Sioni Summers[1]
[1]CERN [2]Caltech

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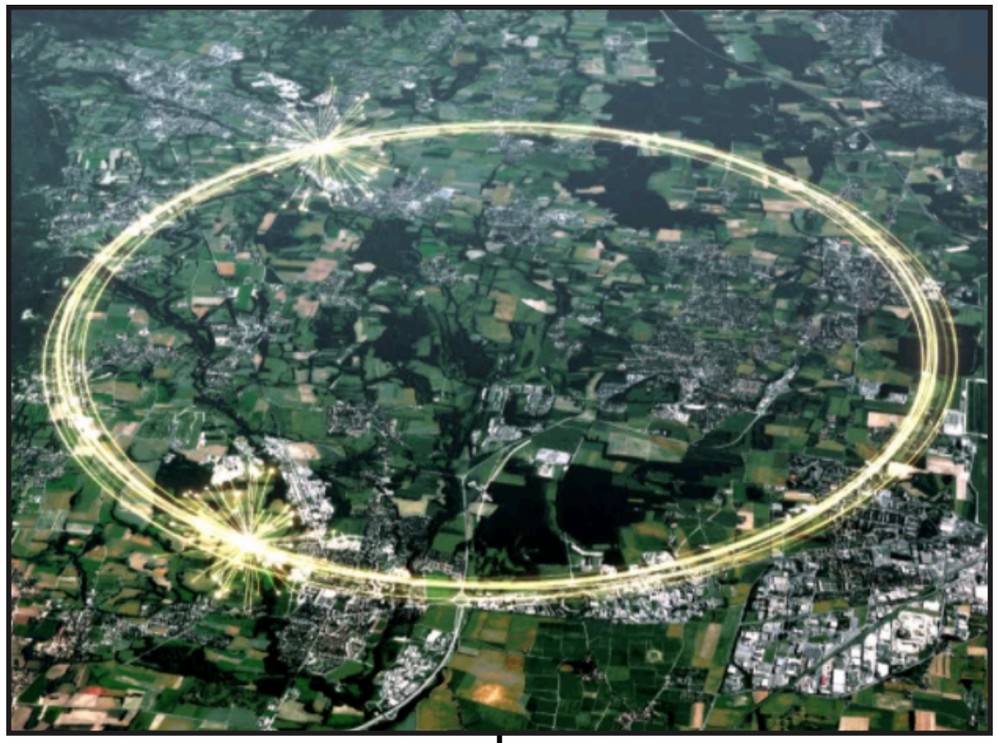
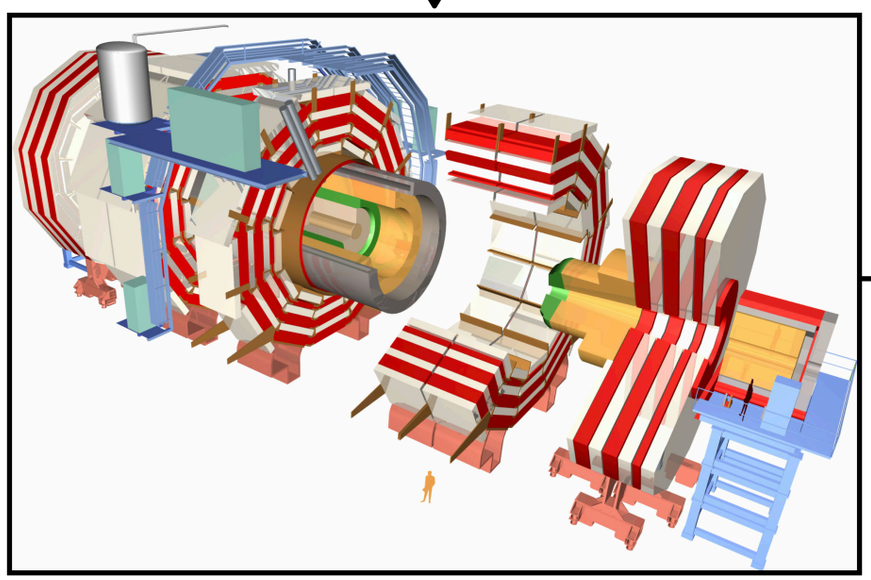


40 MHz



1 kHz

Advanced search for new phenomena — see a dedicated talk by Jennifer

**Reduce** data rates for offline processing from **40 MHz to 1 kHz**

Data selection algorithm must select interesting data in real time within **O(1 $\mu$sec)**

Deploy **Autoencoder** algorithm on **FPGA** using **hls4ml** to search for anomalous events

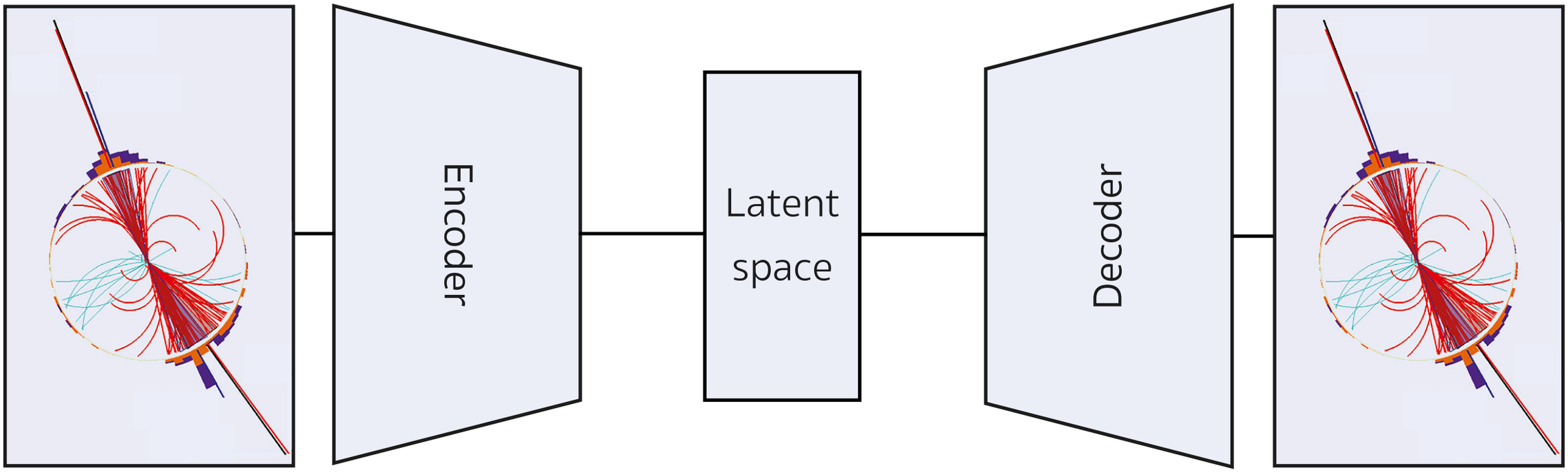
## Autoencoders

Encode input in smaller dimensional space

Train on ‘standard’, background events

Anomalous data will have higher loss

Calculating the loss requires to store the input until the output is computed

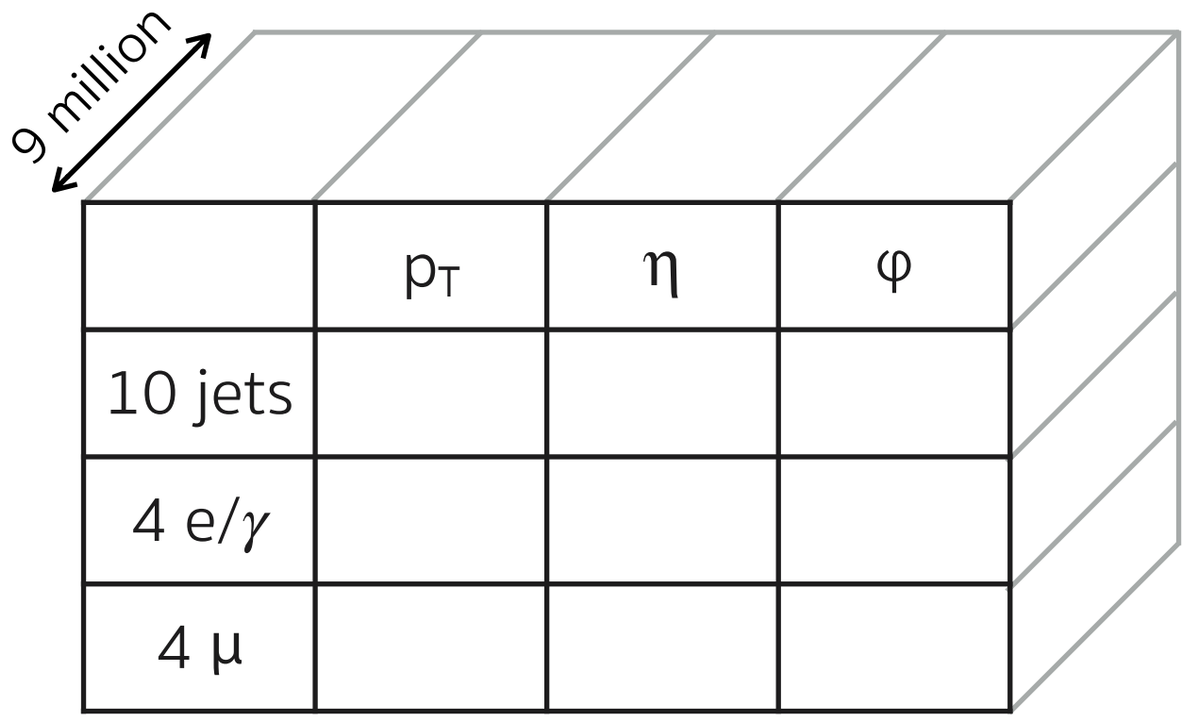


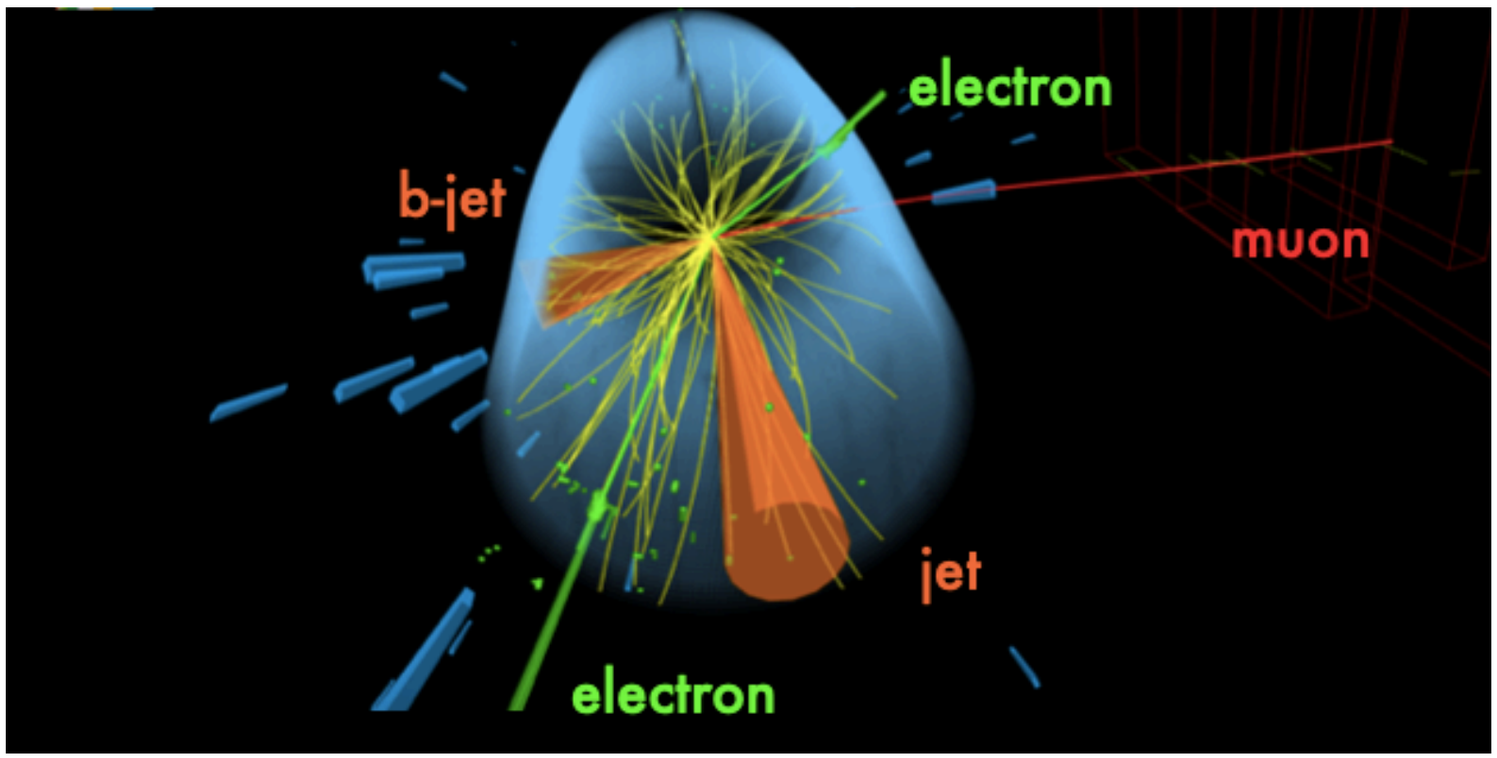
## Data

Train on 9 million events simulated with Delphes, a general detector simulation tool

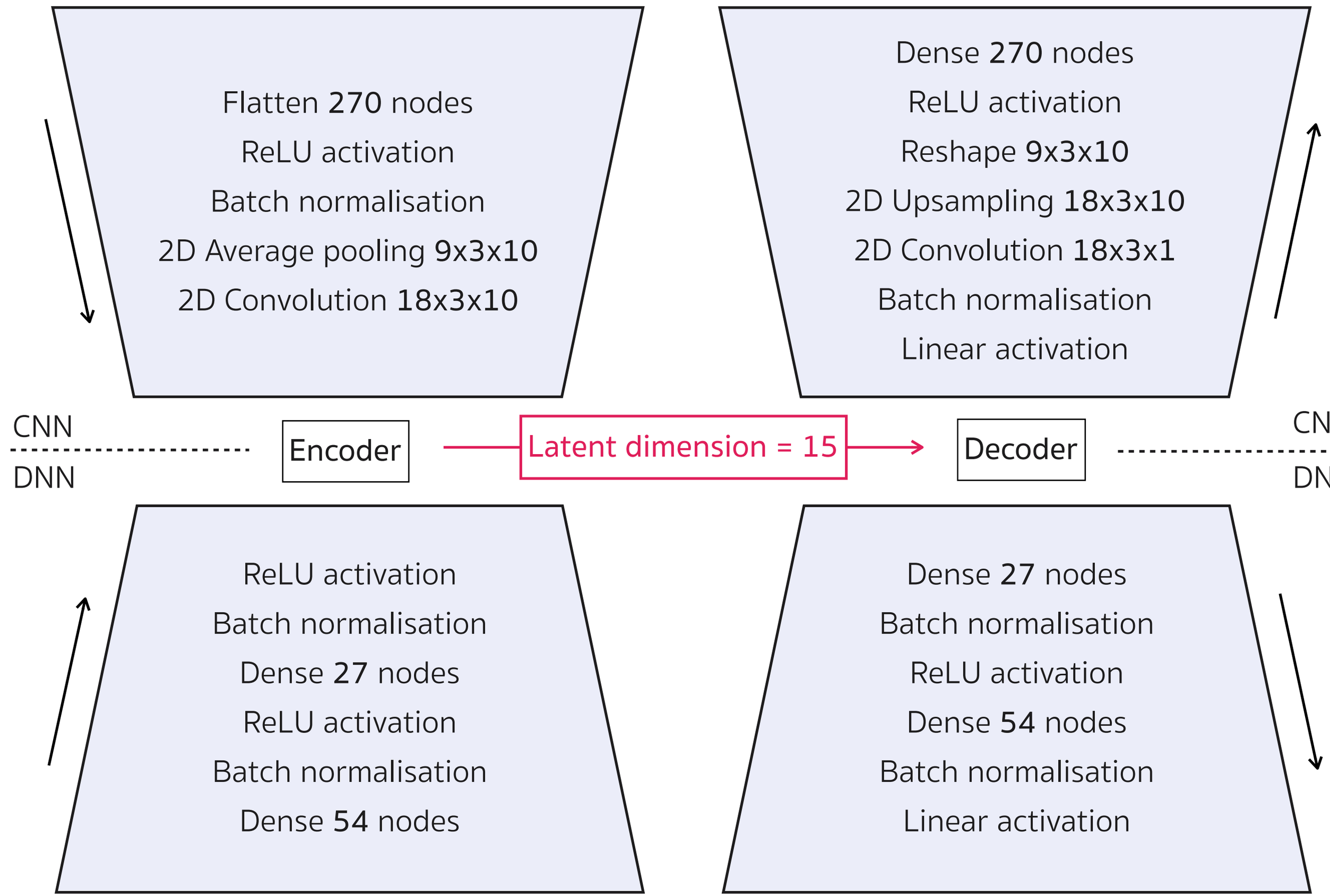
Test performance on several different New Physics simulated samples

Array of particles up to 10 jets, 4 μ and 4 e/$\gamma$



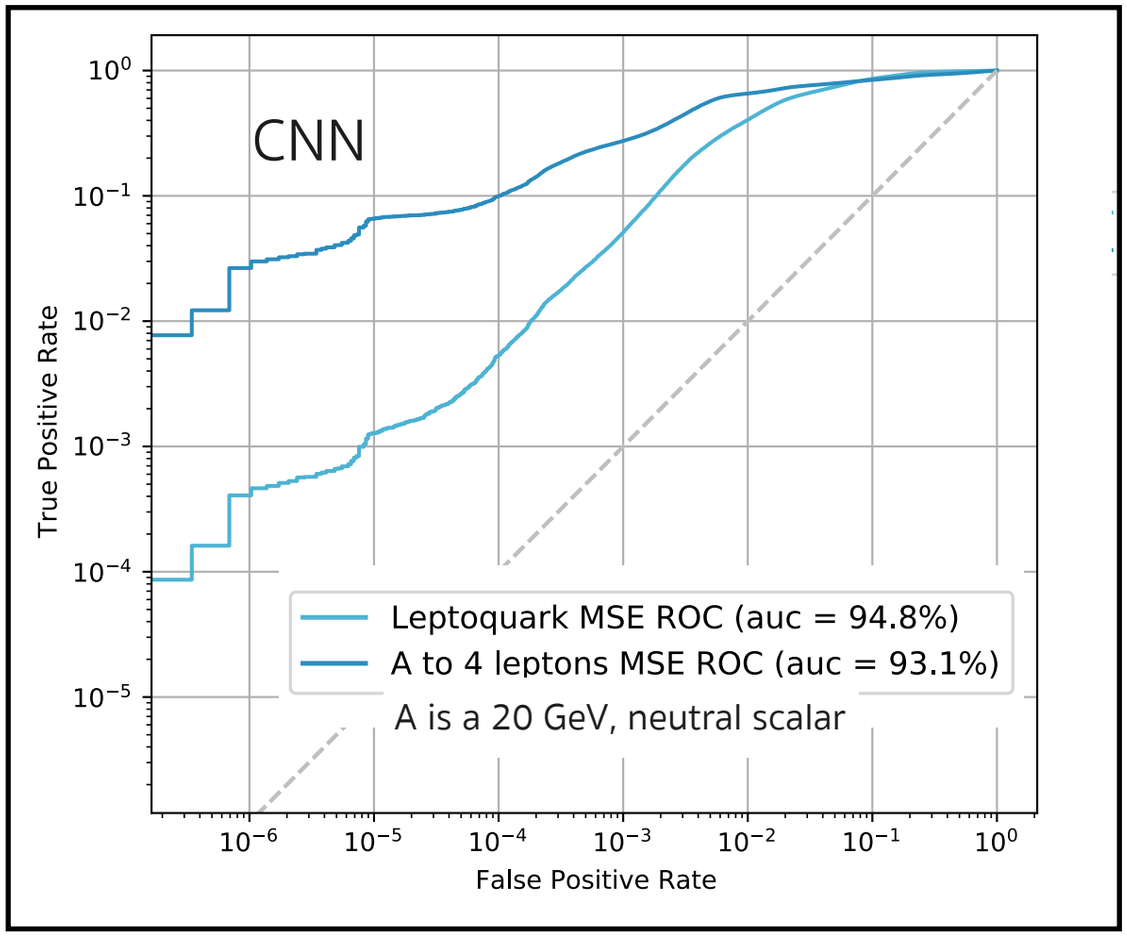



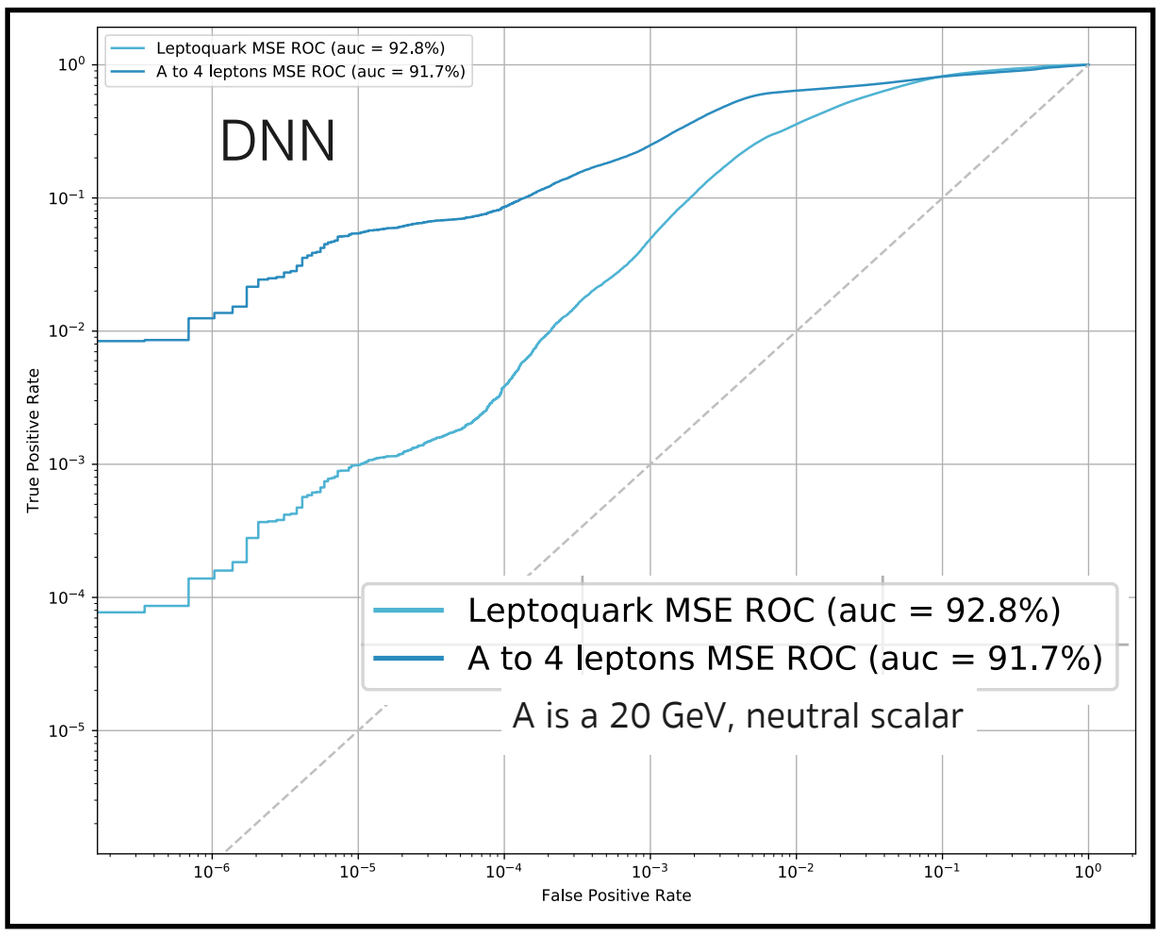
# Convolutional and Dense AE architectures



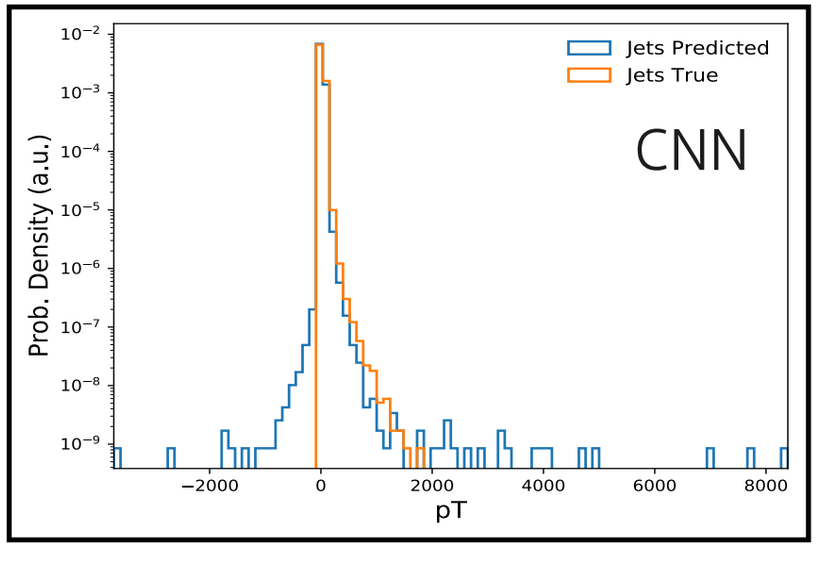
# Performance of the Convolutional AE with MSE loss

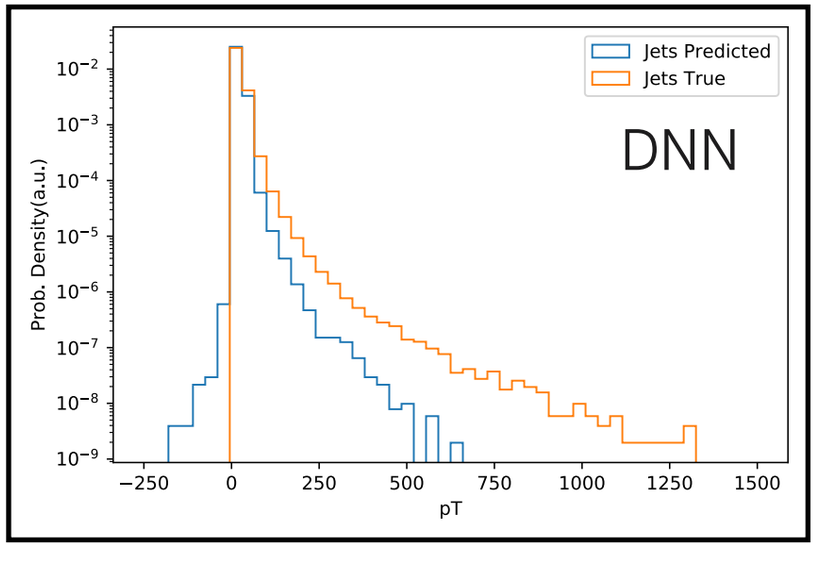
## Anomaly detection




## Reconstruction of the original features



# First results with FPGA

AE has to be implemented on FPGAs

https://fastmachinelearning.org/hls4ml/


Preliminary results for Dense and Convolutional AEs

on **Xilinx VU9P** — Realistic device for the trigger system

**TODO** quantise* and/or prune the model

fix an issue with the last layer dominating the latency**

| | Latency (ns) | DSPs (%) | LUTs (%) | Flip Flops (%) |
|---|---|---|---|---|
| Dense AE | 80 | 21.6 | 3.6 | 0.7 |
| Convolutional AE | 2800** | 42 | 12 | 3 |

* Quantisation can be done with AutoQ/QKeras, see a dedicated talk by Thea

**AE models**

Unsupervised model for anomaly detection is in active development

**FPGA implementation**

First results with hls4ml are promising

**Next steps**

Quantise and/or prune the models to improve the resource usage

Use quantisation aware training* to preserve accuracy while quantising

Perform a physics analysis that proves the utility of this approach

* Quantisation can be done with AutoQ/QKeras, see a dedicated talk by Thea