Using Graph autoencoders to trigger on new physics at the LHC

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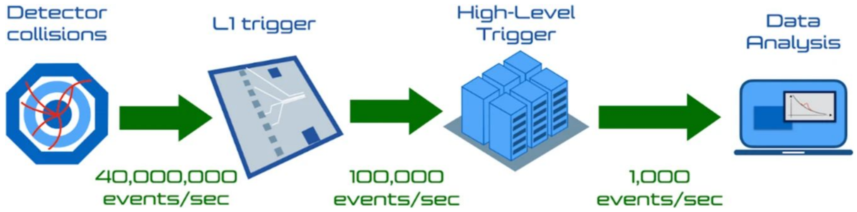
Introduction

- The trigger system at the LHC is designed to select interesting events, most of the events are discarded.
- Theory-motivated approaches have not been successful in finding physics objects beyond the standard model.
- Unsupervised algorithms could be a solution to this problem.
- We investigate the use of the GarNet architecture[1] in an AutoEncoder for anomaly detection at the L1T.



[1] https://doi.org/10.3389/fdata.2020.598927

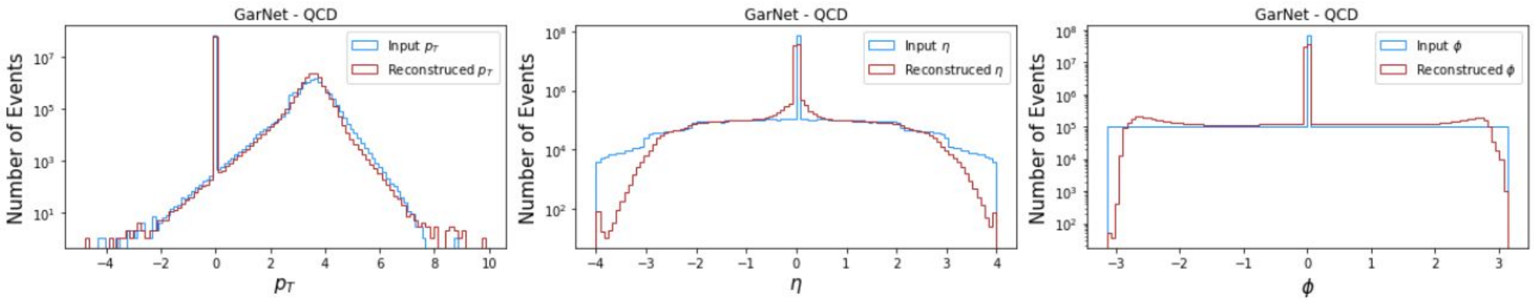
Dataset

- This dataset is mostly representative of the data that is produced by the L1T, however, we applied one-lepton pre-filtering to keep the data to a manageable size for training, due to the limited computing resources we have at hand.
- 4 million background events consisting of:
  - Inclusive W production, with W $\longrightarrow l\nu$ (59.2%)
  - Inclusive Z production, with Z $\longrightarrow$ ll (6.7%)
  - tt production (0.3%)
  - QCD multijet production (33.8%)
- BSM simulated samples:
  - Neutral scalar boson A, 50 GeV $\longrightarrow$ 4 l
  - Leptoquark, 80 GeV $\longrightarrow$ b τ
  - Scalar boson, 60 GeV $\longrightarrow \tau\ \tau$
  - Charged scalar boson, 60 GeV $\longrightarrow \tau\ \nu$

Sample name	Number of events	Type
SM processes[24]	4,000,000	B
$LQ \rightarrow b\tau$[25]	340,544	S
$A \rightarrow 4\ell$[26]	55,969	S
$h^0 \rightarrow \tau\tau$[27]	691,283	S
$h^\pm \rightarrow \tau\nu$[28]	760,272	S

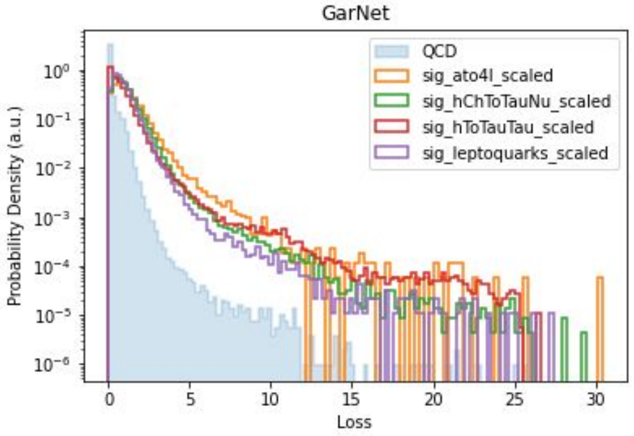
Background Reconstruction

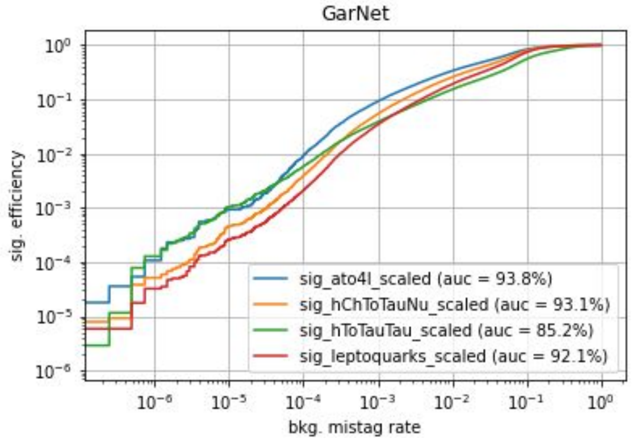
- Model input plotted with the GarNet AE reconstruction for the SM processes.
- We scale pT with natural log.
- Good reconstruction for the 3 features.



Loss & ROC

- The Chamfer Loss distribution shows good separation between the signals and the background.
- We use the AUC of the ROC curve to determine overall model performance with each of the signal samples.
- We see good results across the board, the scalar boson sample produces slightly worse performance, while the Neutral scalar boson produces the best performance.
- A cut is typically made at background mistag rate of 10^{-5}, where we see an order of magnitude or two higher signal efficiency rate.



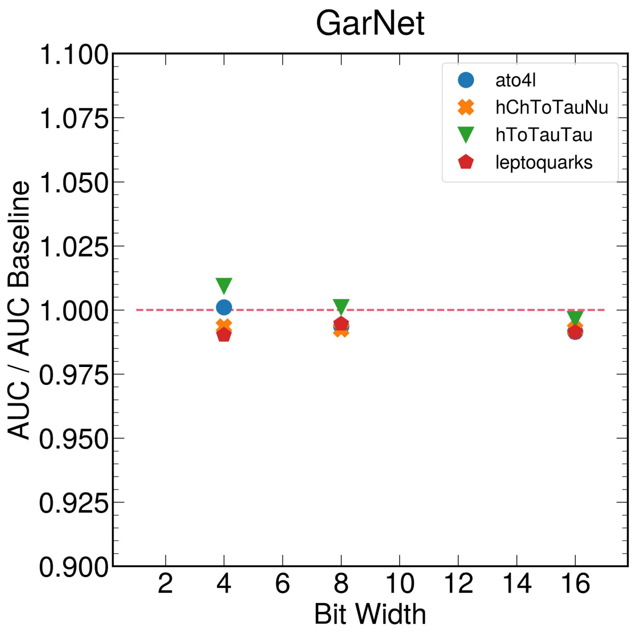


Quantisation

- Quantisation is a way to compress a model so that it runs faster, as in the default state it would not be possible to run this model in under a microsecond in the L1T.

- We use QKeras to perform quantisation aware training (QAT) at different bit widths (4, 8, and 16) and compare their performance to the baseline of 32-bits.

- Overall, we see very little loss in performance when compared to the baseline at all bit widths.



Thanks for listening!

Any Questions?

Backup

Signal Reconstruction

- This is the reconstruction of the signals by the GarNet AE model.
- As expected, we see worse reconstruction for the signals than the background events.