BigDataHEP

LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS

[MACHINE LEARNING *in the* SEARCH FOR NEW PHYSICS PHENOMENA AT THE LHC]

Miguel C. Romão, Nuno Castro, Rute Pedro, Tiago Vale

Deepening the Distance Between Collider Events

Transferability of Deep Learning in Searches for New Physics

DL-assisted Strategies Towards Generic Searches for Exotic Particles

Transferability of Deep Learning in Searches for New Physics

[arXiv:1912.042020, Submitted to *Physical Review D*]

How transferable is a DL model to a new target signal, unknown to the model?

In computer vision, the first layers of DL models are highly transferable to other tasks. They learn about localised pixel variations, textures and patterns and only the last layers distinguish the high-level picture such as *dog or cat*. [1]

We develop Deep Neural Networks (DNN) implemented with Keras using TensorFlow as backend to probe transferability in the HEP domain. DNN Bayesian optimisation from Scikit-Learn is used.

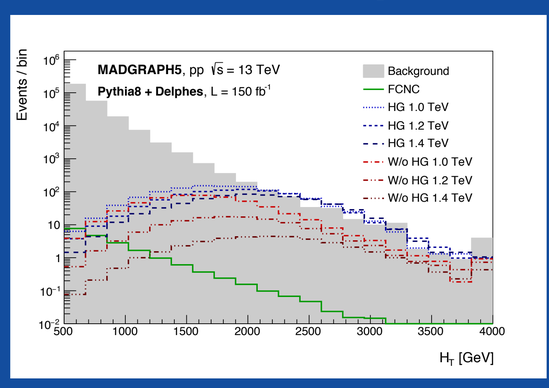
Benchmark signals contain tZ+X final states, and are simulated with MadGraph5+Delphes:

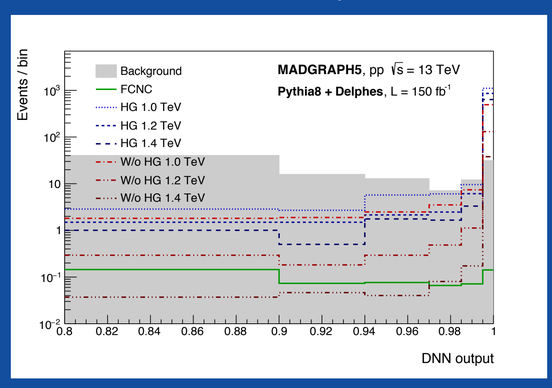
- tZ production via FCNC vertex *utZ*
- Vector-Like Top pair production (TT) via SM gluon or BSM heavy gluon

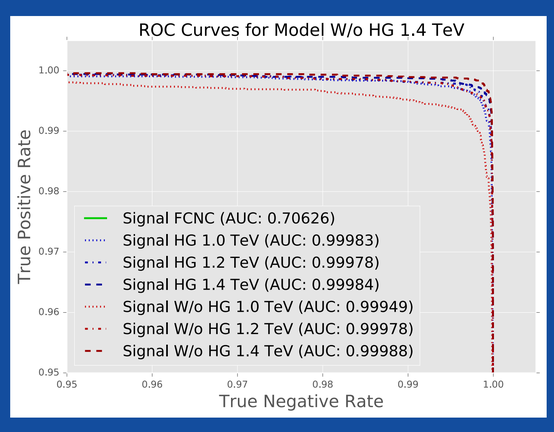
DNN trained to classify each signal type and tested for each signal case:

- Model is able to identify other signal types as non-background
- Exclusion limits computed from DNN discriminant are nearly independent of the train signal

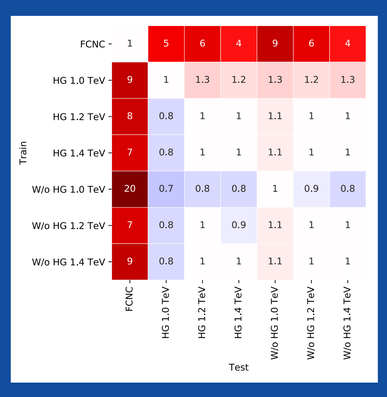
[1] J. Yosinski et al. How Transferable are features in deep neural networks? , 2014

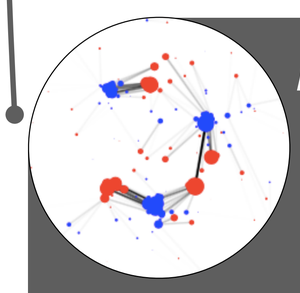






Diagonal matrix with upper limits on the signal strengths





Are rare events distant from more common ones?

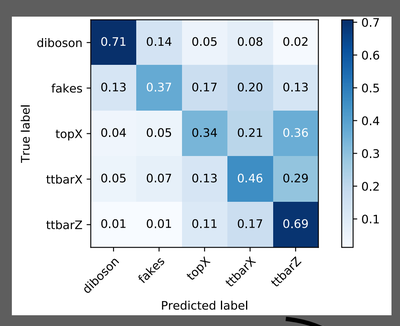
An event metric was recently introduced for the case of jet constituents, assisting in the distinction between boosted top quarks and QCD jets [2].

We deploy the idea of the event metric to fully reconstructed events:

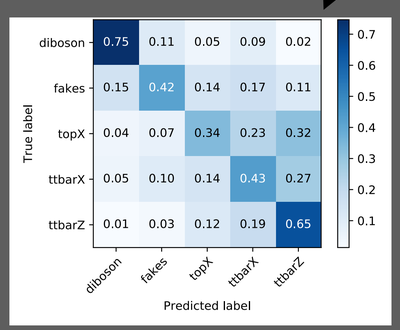
- Distance between events *I* and *J*
  $d(I,J) = \min(\sum_{i,j} \Delta R_{ij} \times |p_{T,i} - p_{T,j}| \times ID(i,j))$
- Minimize the equation with the Earth Mover's Distance algorithm implemented in the Python Optimal Transport library
- Cluster close events and define the central medoid events as references per each process
- Compute the distance to the medoids to access how near/far the event is from the represented process

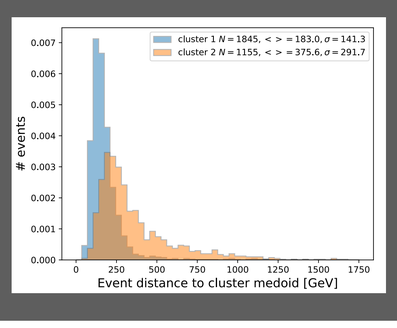
Study rare ttZ production as physics case:

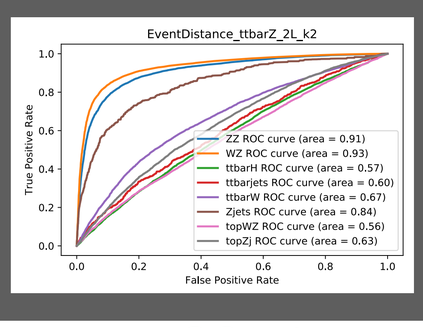
- Distance to ttZ medoids discriminates against diboson and Z+jets
- Performance of a multi-class DNN improved with distance observables



Train with selected features + event metric

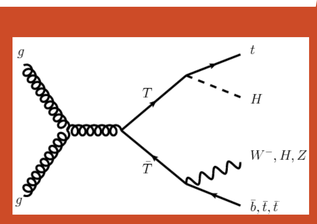






[2] P. T. Komiske et al. The Metric Space of Collider Events, 2019

Which strategy to search generically for Vector-Like Quarks, regardless of the final state topology?



VLQs arise in BSM theories addressing the Naturalness problem with mechanisms cancelling the quadratically-divergent contributions to the Higgs mass.

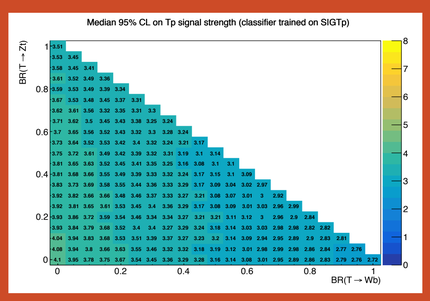
Leading to diverse final states, ATLAS, for instance, needs 17 analyses to reach maximal sensitivity to VLQs [3].

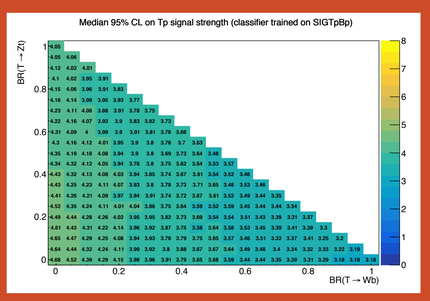
DNN trained with 4-momentum of final state objects:

- Pre-selecting events with at least 1 lepton and large energy deposits excludes most of the background: DNN will focus on difficult cases

Single model trained with signal at fixed branching ratio (BR):

- DNN discriminant has good sensitivity to the full BR plane
- Model trained with BB ~equally sensitive to the TT signal





[3] ATLAS Collaboration, Combination of the searches for pair-produced vector-like partners of the third-generation quarks at sqrt(s)=13 TeV with the ATLAS detector, 2018

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