LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

TÉCNICO LISBOA

Searching for the Z’ boson

David Dias, João Biu, Manuel Ratola

Simulation and Analysis Methods in High Energy Physics

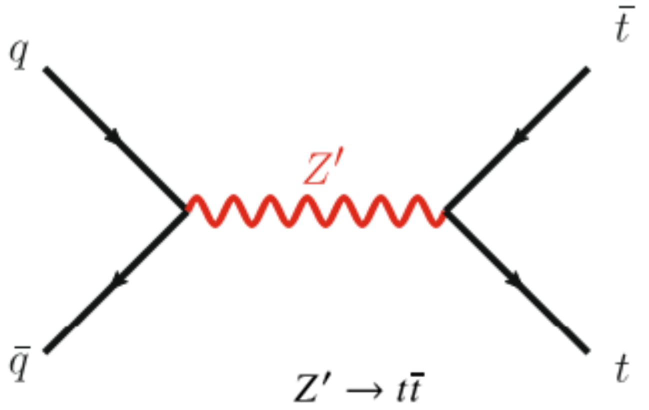
Objectives

- Obtain real data and Monte Carlo generated data using AtlasOpenFramework
- Use this data to train a Neural Network to optimize the signal classifier
- Study which variable is more sensible for the training
- Fit simulation to data
- Obtain the production cross section upper limit

Theoretical Introduction

- Z′ (Z prime) is a hypothetical gauge boson that arises from extensions of the electroweak symmetry of the Standard Model.

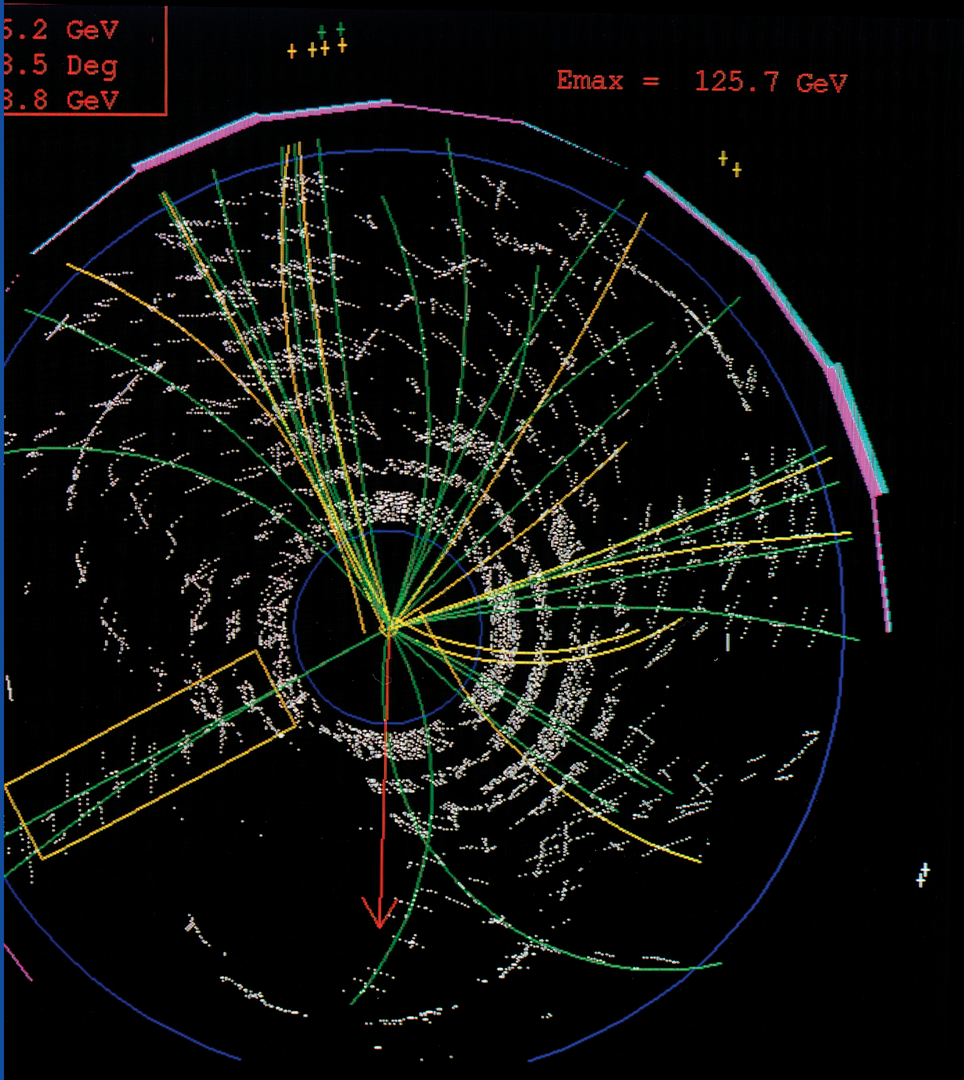
- In this case, the search for the new particle is made in the top-quark pair final state.



Adapted from [1].

Considered Background

- Different SM model Background used in MC samples:
    - W or Z boson in association with additional jets (V+jets)
    - Diboson
    - Single top quark
    - Production of tt



Event Selection

- **Selection channel:** $t\bar{t}$ → WWbb → $l\nu bb$ + jets

- **Selection:**

One W decaying into e- or μ and neutrinos

- Lepton and large missing transverse momentum

→

- pT(lep) > 30 GeV
- MET > 20 GeV
- MET+mTW > 60 GeV

Other W decaying into hadronic jets from quarks

- Large-R jets filtered with top-tagging

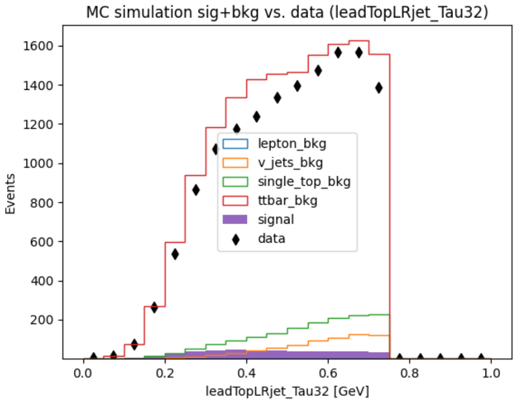
→

- Exactly one good top-tagged LR jet (τ_{32} < 0.75)
- pT > 300 GeV
- $|\eta| < 2$

B-tagged jets

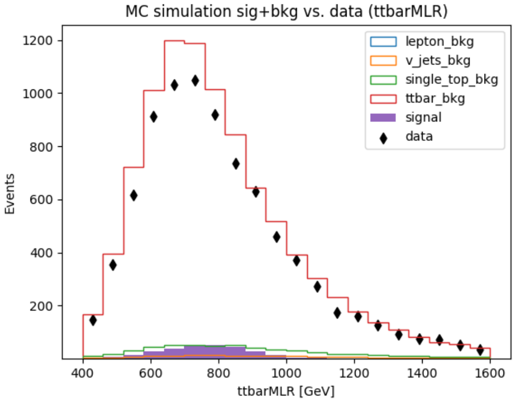
- Small-R jets

Most sensitive variables – simulation and data



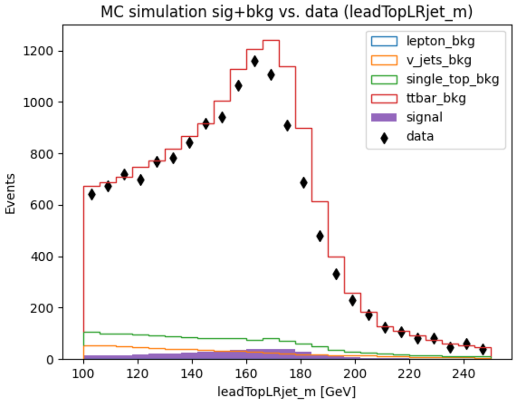
Obs μ upper lim: 0.090

Exp μ upper lim: 0.553



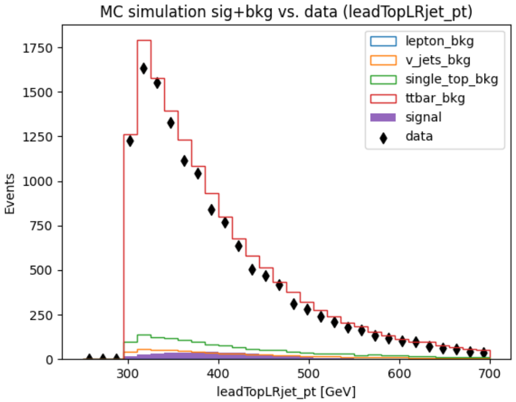
Obs μ upper lim: 0.086

Exp μ upper lim: 0.525



Obs μ upper lim: 0.087

Exp μ upper lim: 0.562



Obs μ upper lim: 0.091

Exp μ upper lim: 0.512

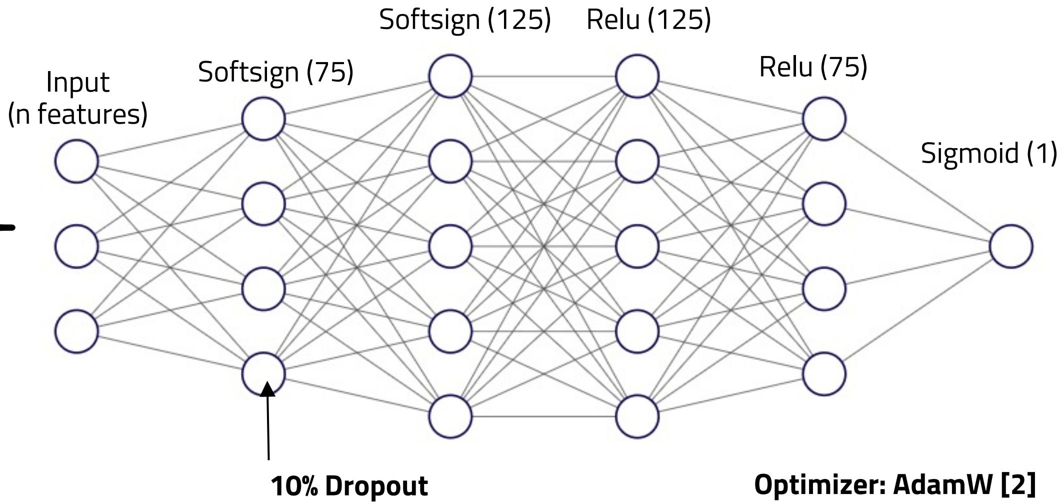
Deep Neural Network

1. Load the dataframe with MC data and their labels .

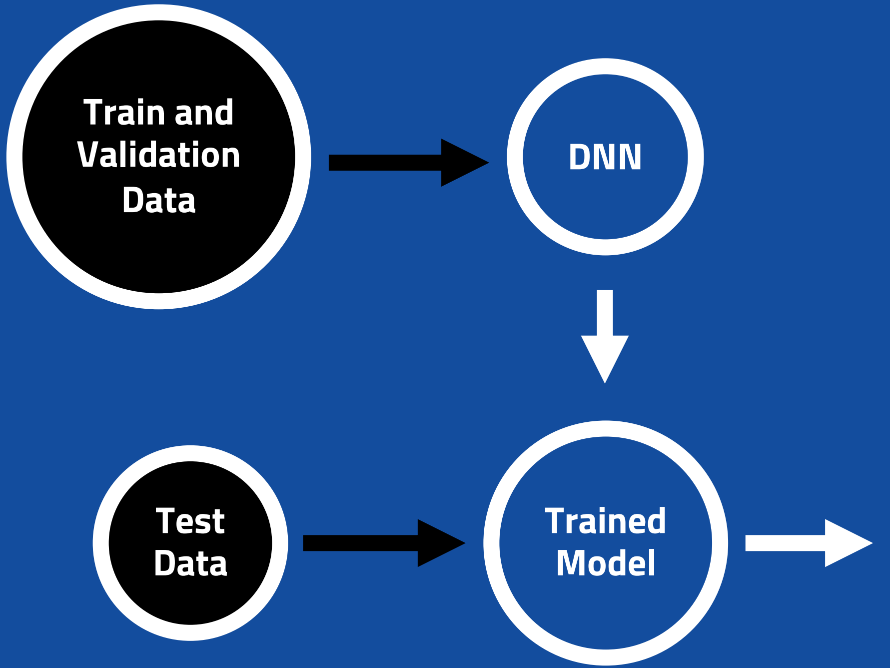
2. Create train weights such that the sum of train weights for signal and background is equal

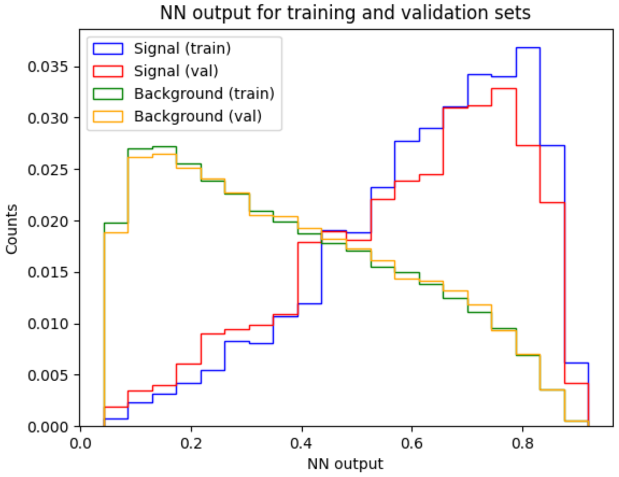
3. Define the train features (ex: missing transverse energy,…)

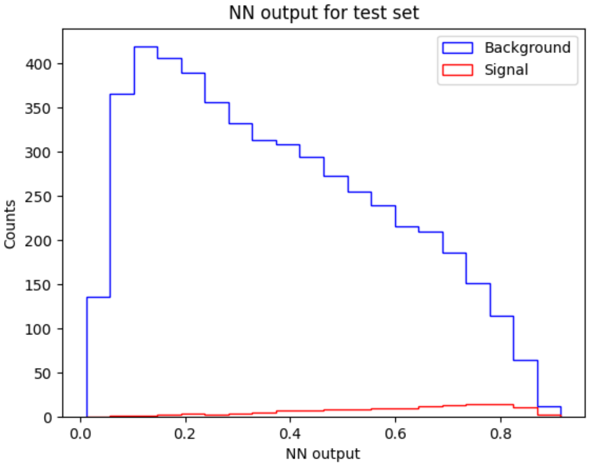
4. Divide the MC samples in 3 groups: train, validation and test



Data Processing and Analysis I



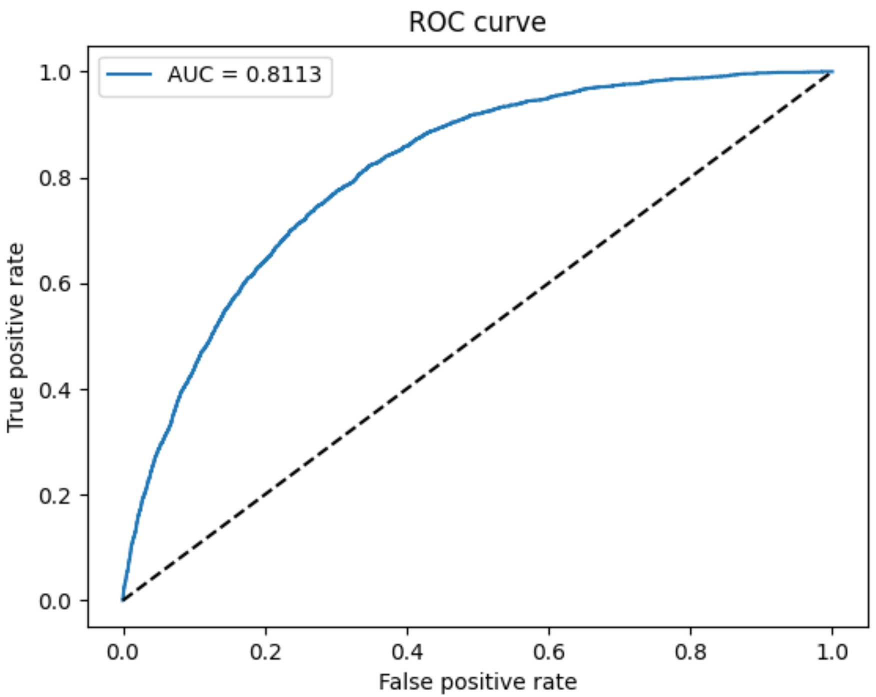




Data Processing and Analysis II

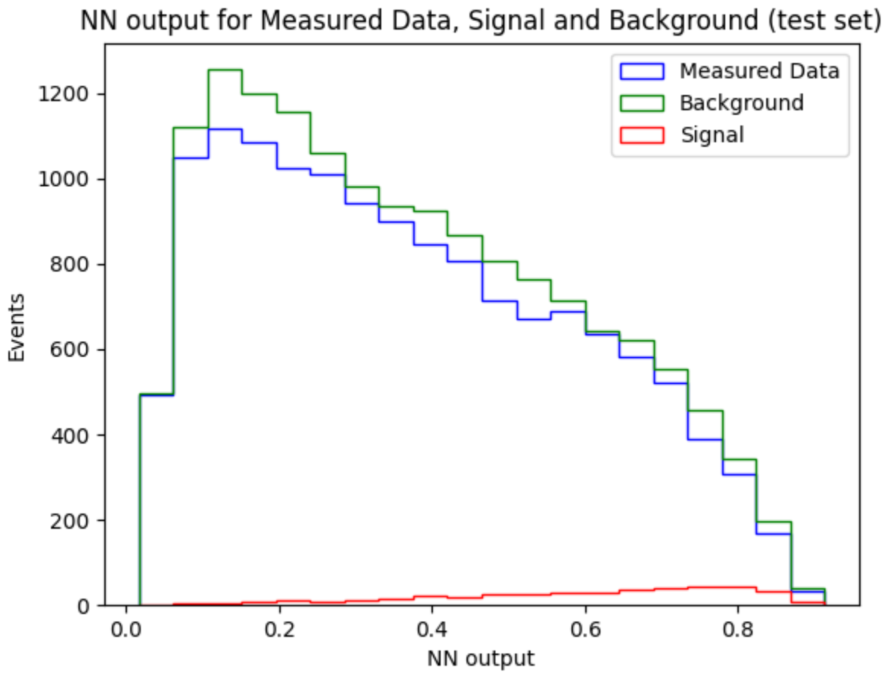
ROC Curve: True Positive vs. False Positive

Area under the curve (AUC): 0.8113



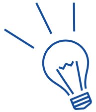
Data Processing and Analysis III – Exclusion Fit

- Observed μ upper limit (obs): 0.080
- Expected μ upper limit 0.376



Data Processing and Analysis IV

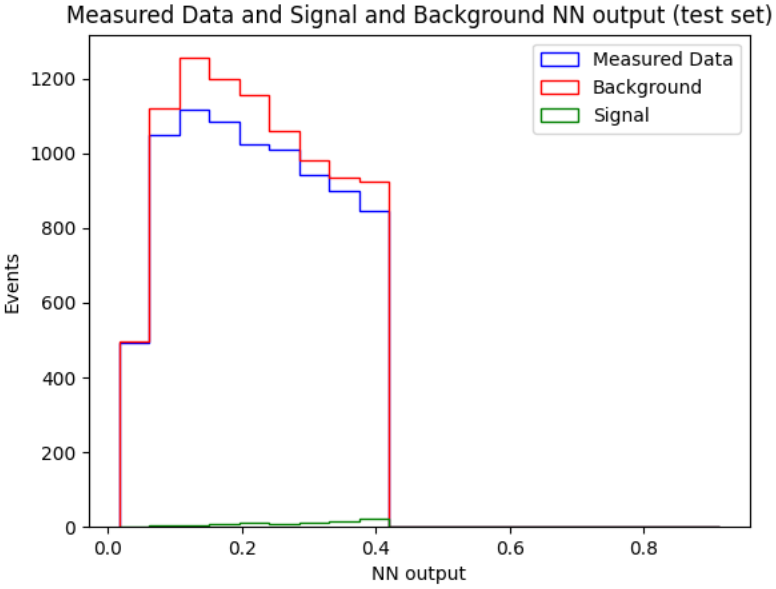
- Normalize the background: Obtain the best value for ε such that: $$\boxed{S + \varepsilon B = N}$$



Discovery Fit

Fitting in the region where the signal is smaller

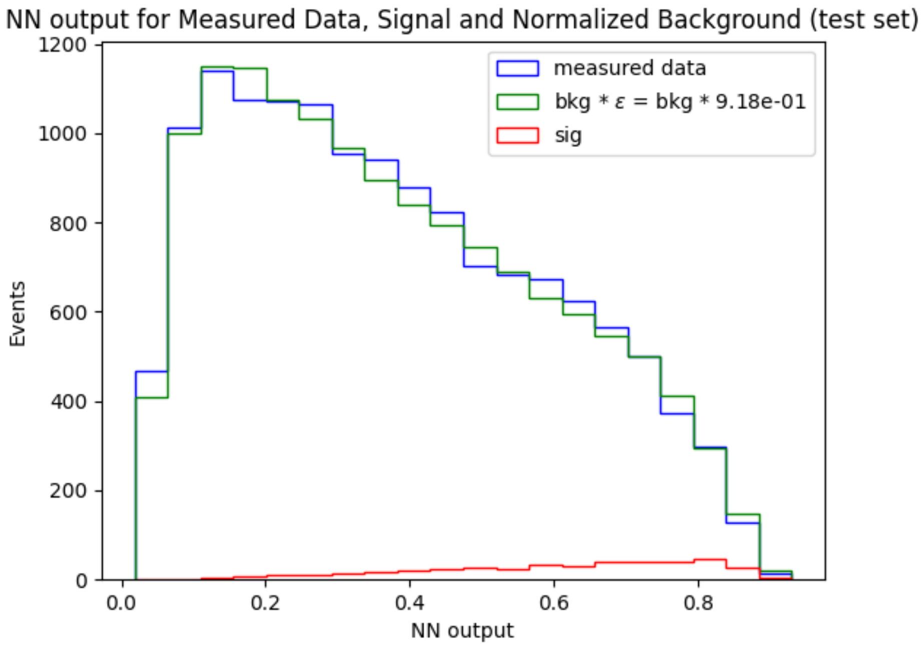
$$\boxed{\varepsilon = 9.18 \times 10^{-1}}$$



Data Processing and Analysis V

Upper limit obtained by doing the exclusion fit with the normalized background:

- Observed μ upper limit (obs): 0.326
- Expected μ upper limit 0.363

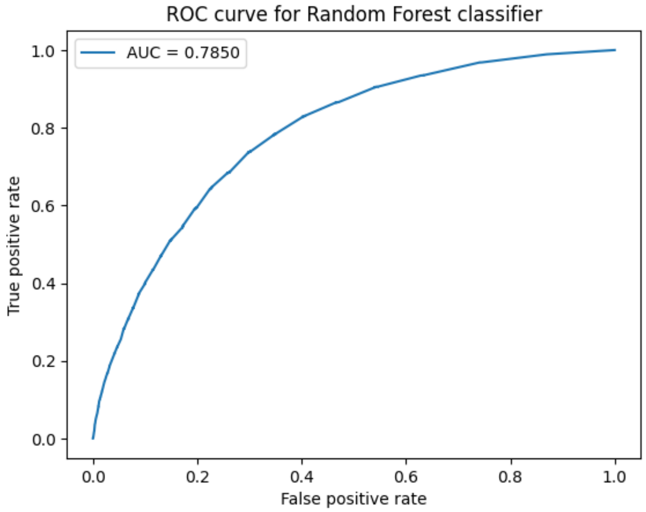


What about Random Forest?

- Random forests or random decision forests is an ensemble learning method for classification, regression and other tasks that operates by constructing a multitude of decision trees at training time.

It can be used as an alternative method to DNN.

Number of estimators: 200



- Observed μ upper limit (obs): 0.443
- Expected μ upper limit: 0.392

Conclusions

- Deep neural network reaches a higher area under the ROC curve than the random forest, achieving better results than other methods.

- Low observed signal strenght closely matching its expected value was found, hinting at the non-existence of the Z' boson, severely limiting its cross-section.

- Signal strenght upper limit observed: 0.326, expected: 0.363

References

[1] Aaboud, M., Aad, G., Abbott, B., Abdinov, O., Abeloos, B., Abidi, S. H., AbouZeid, O. S., Abraham, N. L., Abramowicz, H., Abreu, H., Abulaiti, Y., Acharya, B. S., Adachi, S., Adamczyk, L., Adelman, J., Adersberger, M., Adiguzel, A., Adye, T., Affolder, A. A., … Zwalinski, L. (2018). Search for heavy particles decaying into top-quark pairs using lepton-plus-jets events in proton-proton collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector. *The European Physical Journal C 2018 78:7*, *78*(7), 1–39. https://doi.org/10.1140/EPJC/S10052-018-5995-6

[2] Loshchilov, I., & Hutter, F. (2017). Decoupled Weight Decay Regularization. 7th International Conference on Learning Representations, ICLR 2019. https://arxiv.org/abs/1711.05101v3