Anomaly Detection in all-hadronic boosted final states

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Overview

1. Goal of project and why machine learning
2. Dataset and machine learning model
3. Result of models
4. Conclusion and discussion

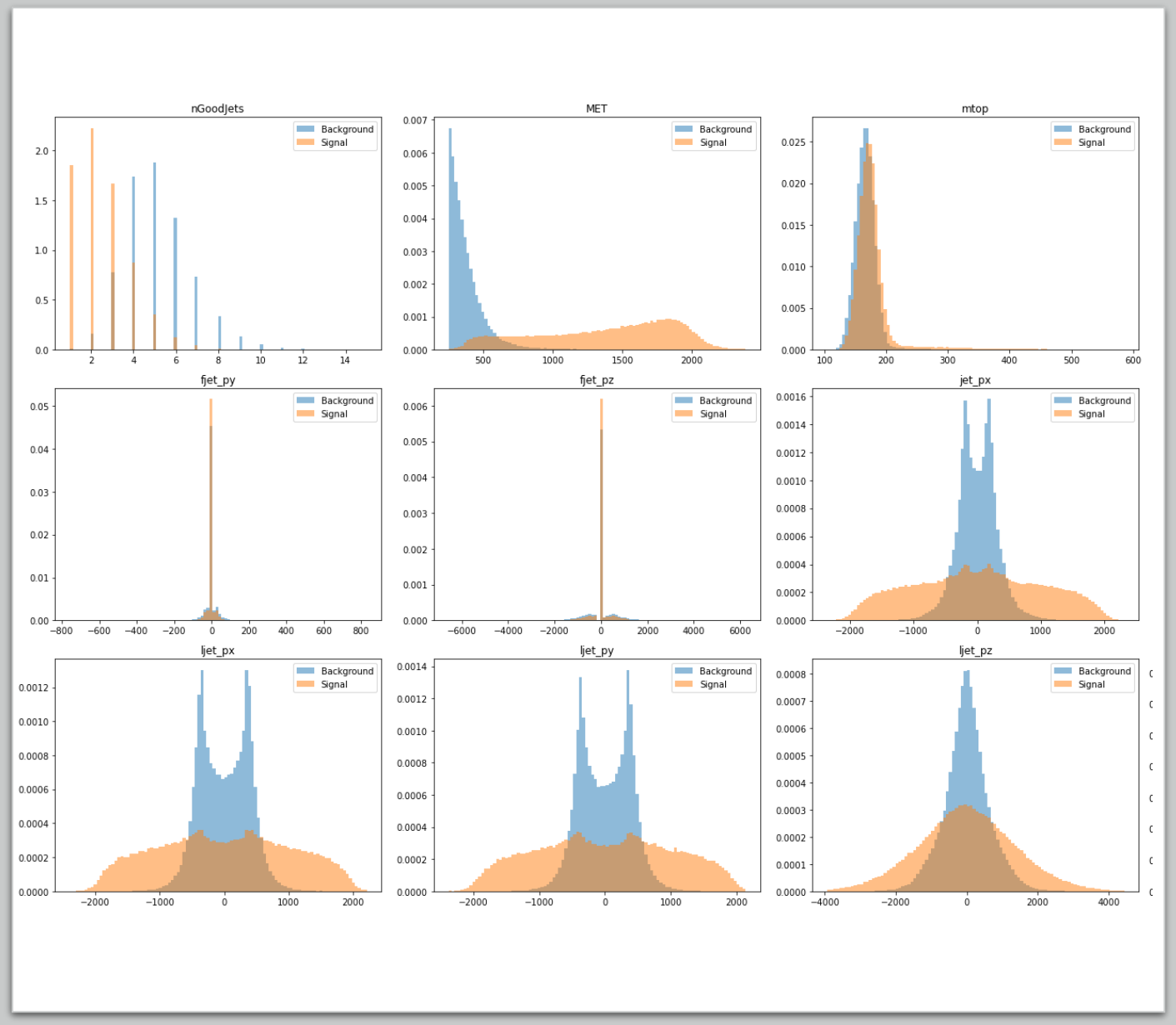
Goal of project and why Machine learning

- Goal:
  - Finding new physics
  - Anomaly detection

- Why machine learning:
  - Large amount data, with multivariable
  - Fast and accurate prediction

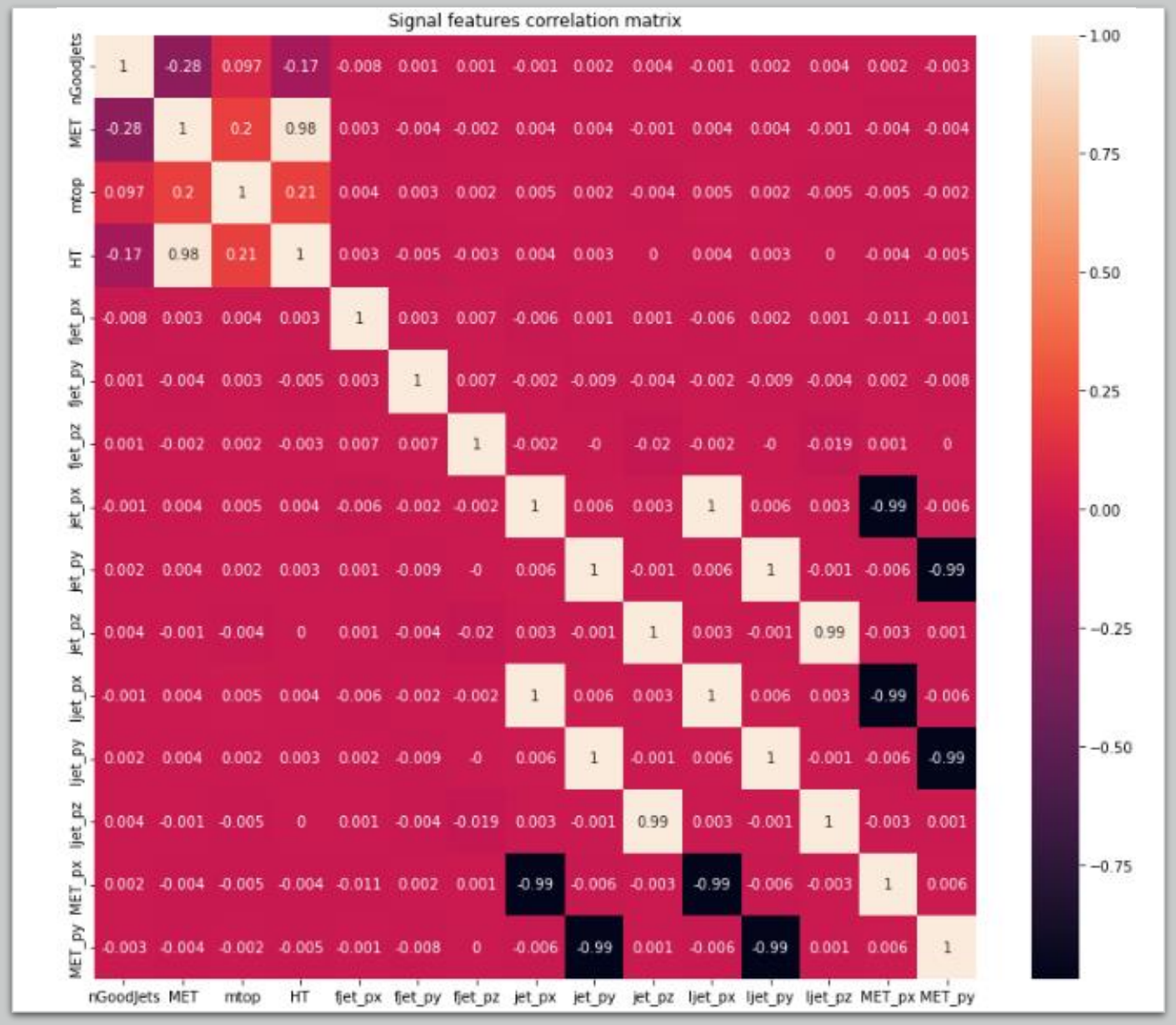
Simulated Dataset

- Simulated data from ATLAS experiment
- Bkg: SM processes leading to hadronic final states with large MET
- Signal: resonant top+MET events
- Missing transverse energy, mass. Momentum, b-tagging algorithm…
- Splited into train, validation and test.



Correlation matrix of selected features

- Features are standardized for the optimized result.
- Most of features are have no correlation between other



Machine learning

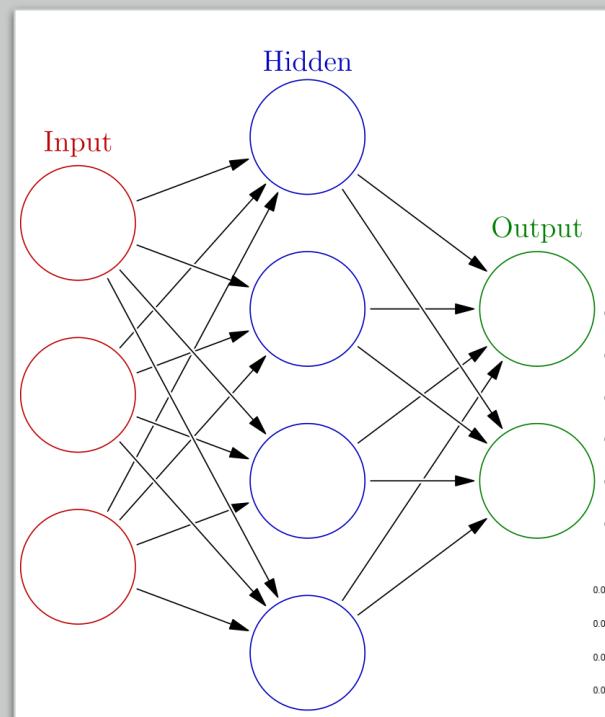
- Supervised learning
  - DNN, GNN
  - More accurate
  - But only works for certain dataset

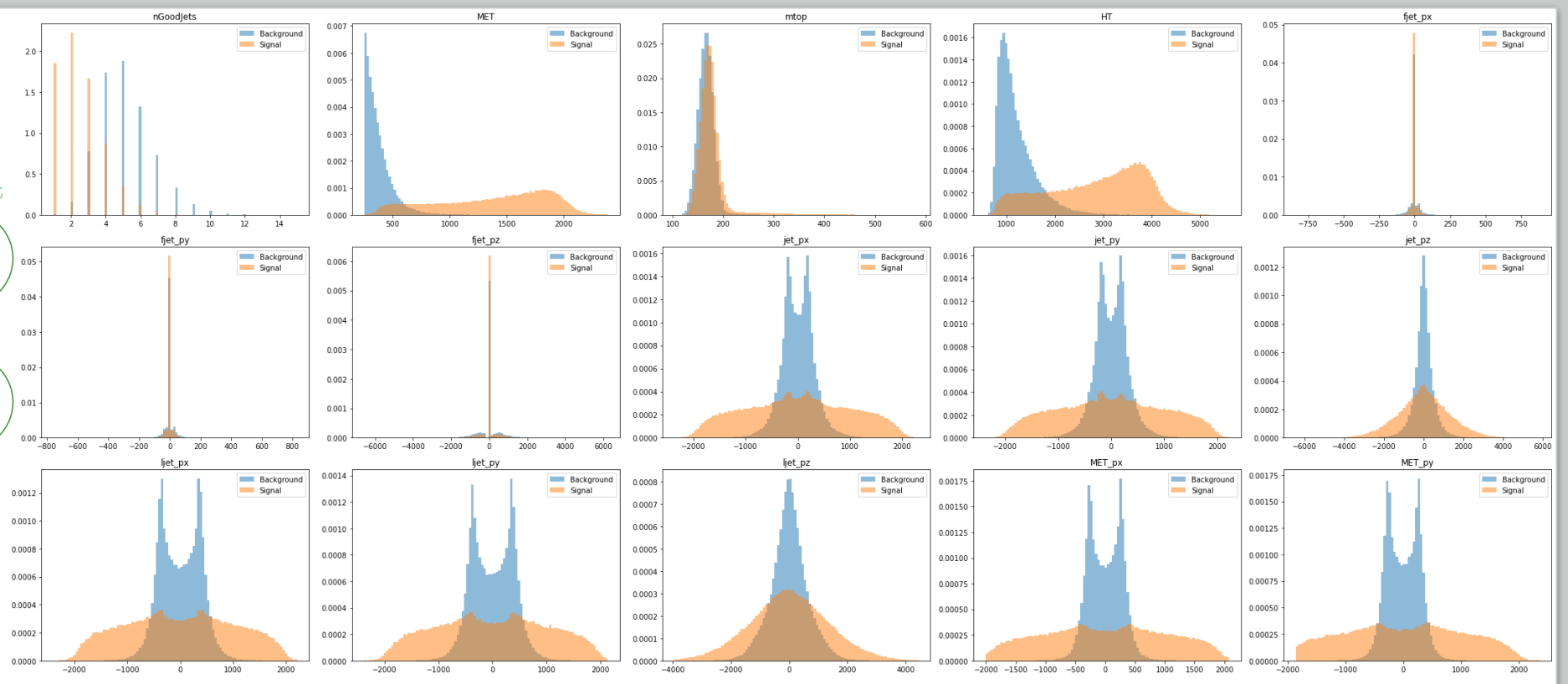
- Semi-supervised learning
  - Autoencoder
  - Less accurate
  - Can be used on other datasets

DNN

- Hyperparameters:
  - Number of layers
  - Number of neurons
  - Activation function
  - Learning rate
  - Optimizer
  - Batch size

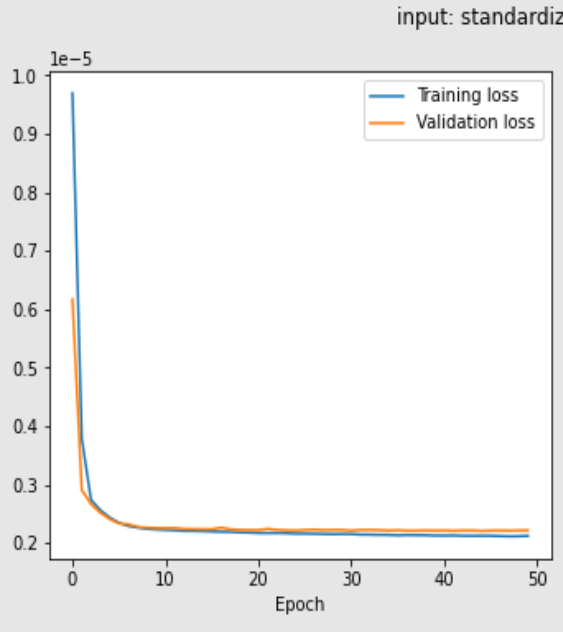
- Trained with selected 15 standardized features.

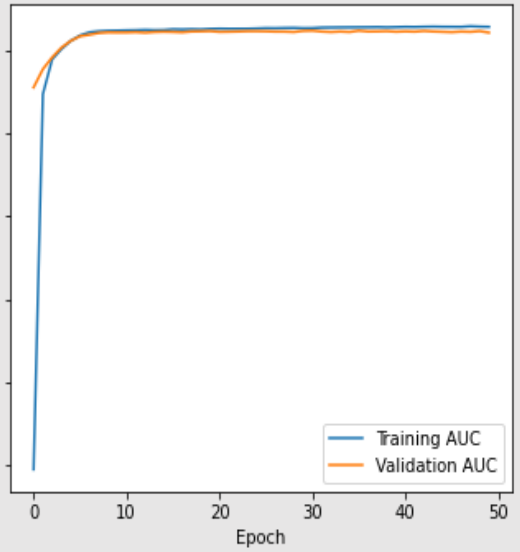


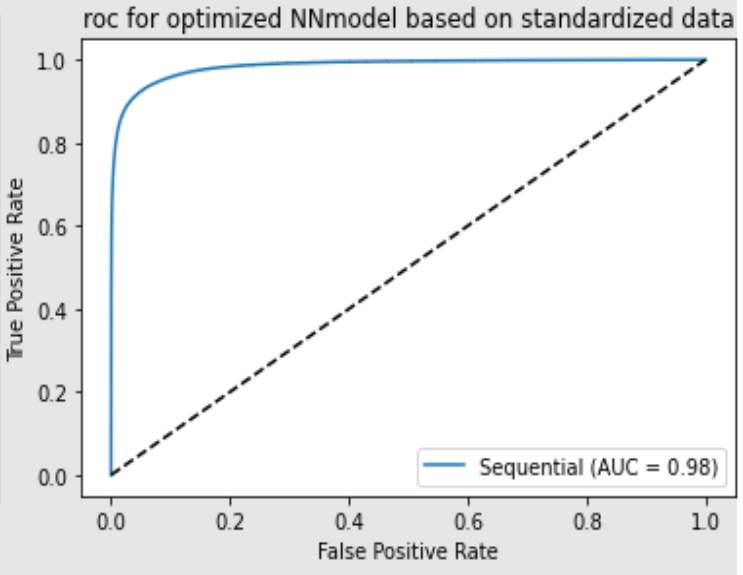


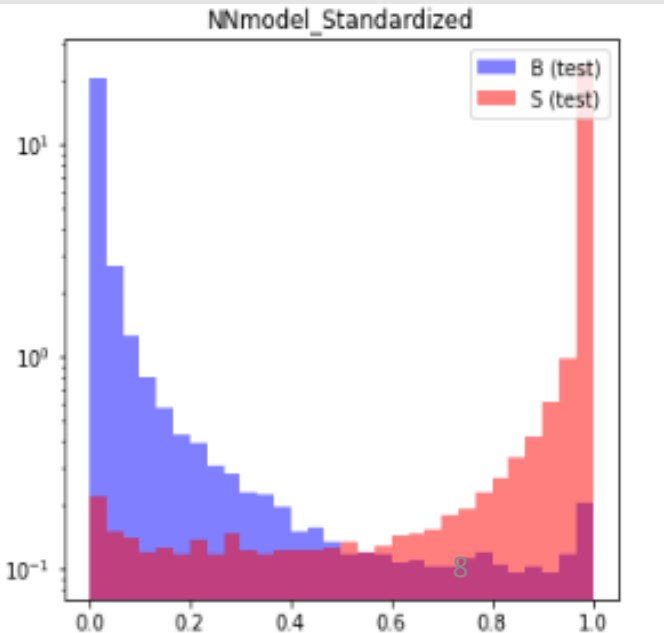
DNN result

- Optimized hyperparameters: Layers 3, Neurons 746, activation ‘selu’, learning rate 0.0003, optimizer ‘RMSprop’, batch size 1024
- Accuracy: 98%



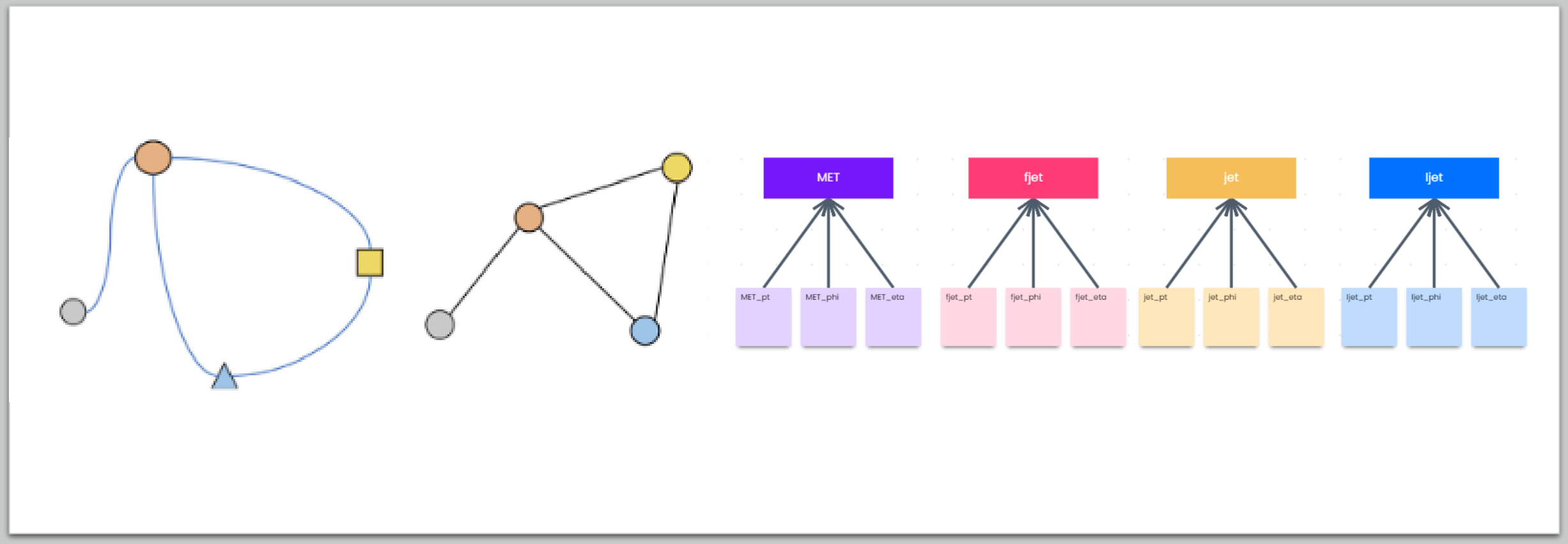






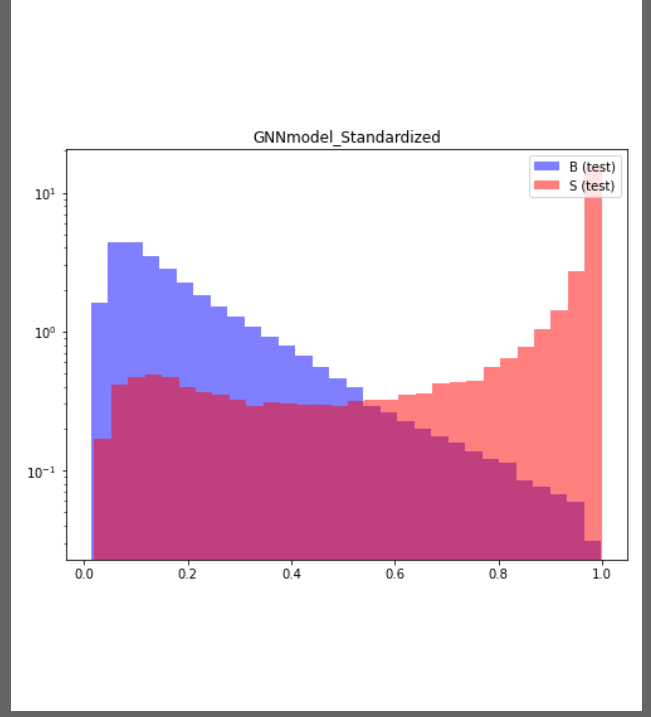
GNN

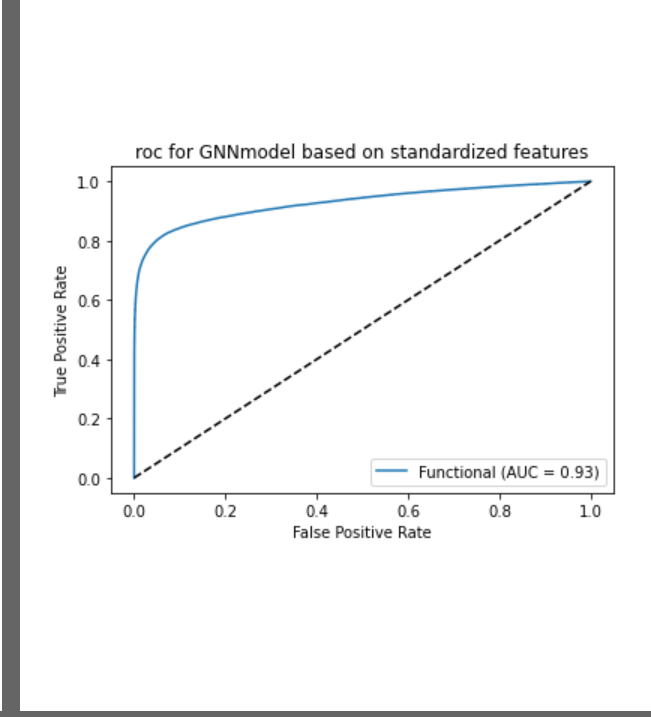
- Neural network operation but on graph
- Each circle represents a node
- 4 nodes, 3 features under each node
- MET_eta is dummy feature for the consistency with other nodes

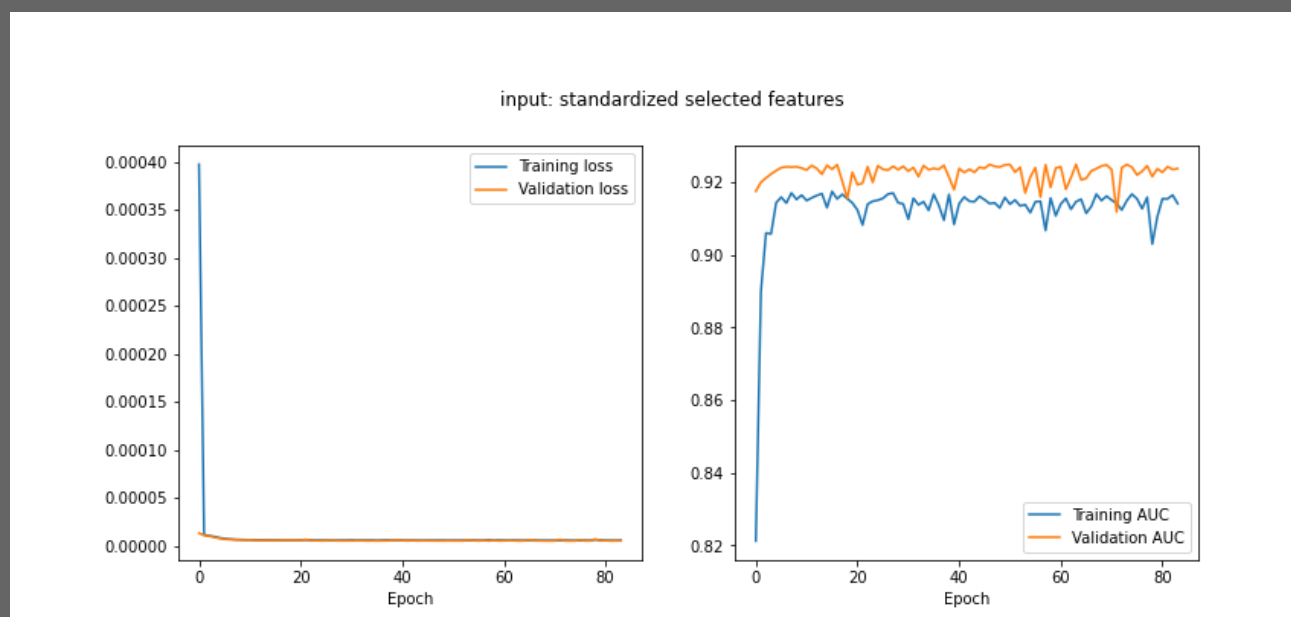


GNN result

- The model haven’t been optimized
- For 1 hidden layer, 20 neurons, the accuracy is 93%

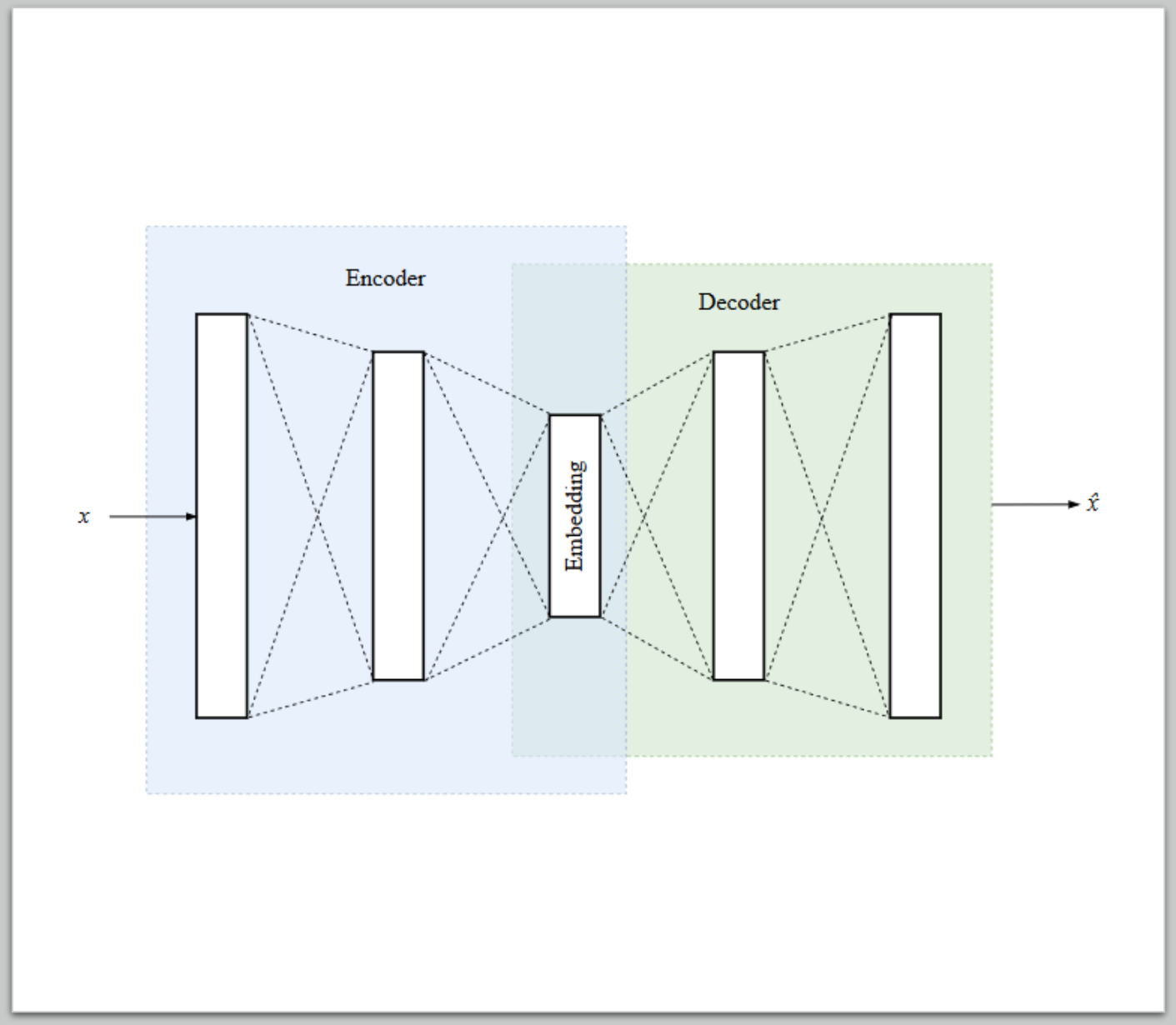






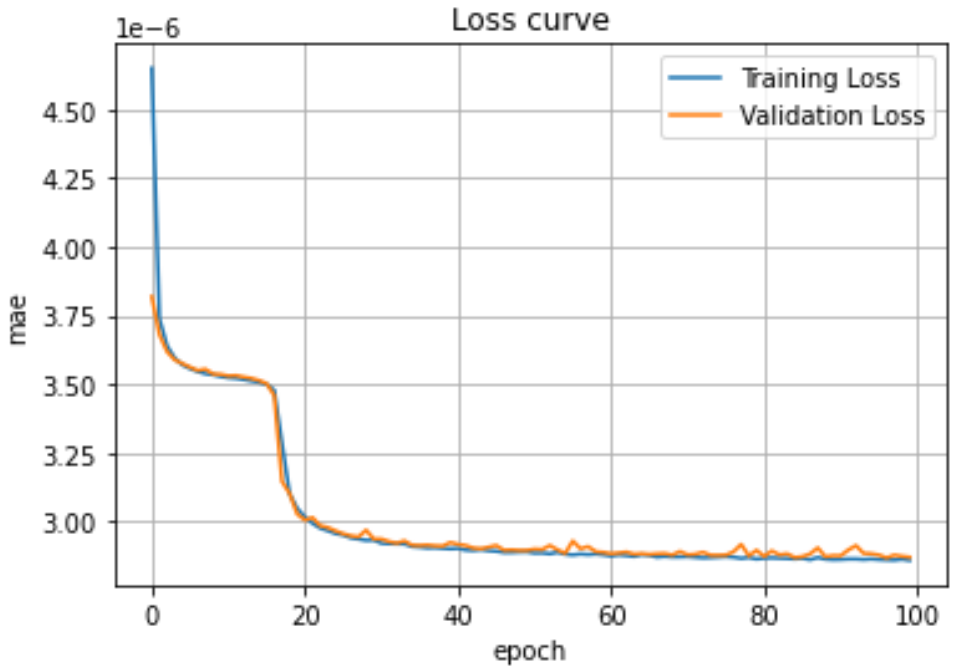
Autoencoder

- Architecture can be split by two: encoder and decoder
- They have symmetric structure



Autoencoder result

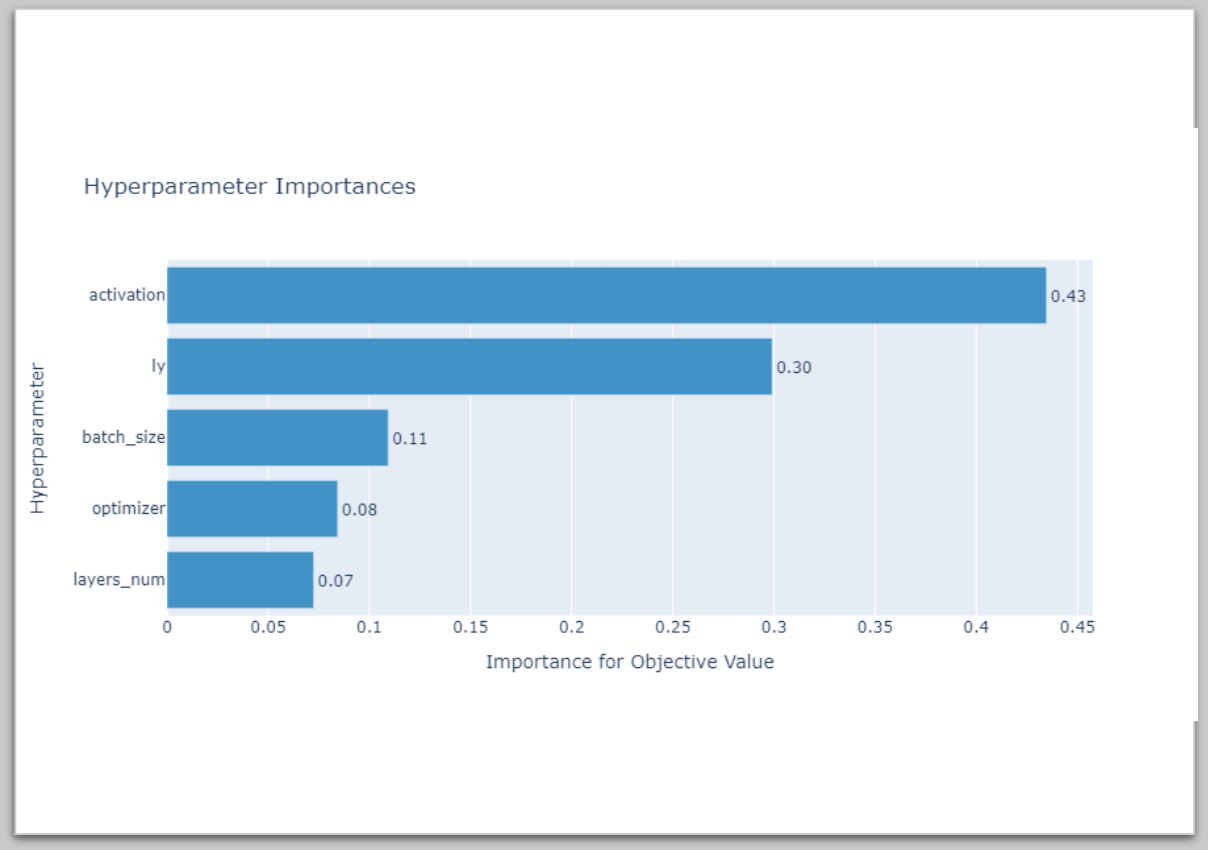
- Input features are same as DNN
- Model have optimized in the same way of DNN
- Average accuracy 72%



	Precision	Recall	F1-score	Support
0	0.6	1	0.75	70498
1	0.88	0.04	0.08	49029
Accuracy			0.61	119527
Macro avg	0.74	0.52	0.42	119527
Weighted avg	0.72	0.61	0.48	119527

Autoencoder result

```
Best hyperparams found by Optuna:
 {'activation': 'selu', 'layers_num': 4, 'batch_size': 256, 'optimizer': 'adam', 'ly': 0.0005827675454643255}
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 encoder0 (Dense)            (None, 240)               3840

 encoder1 (Dense)            (None, 101)               24341

 encoder2 (Dense)            (None, 30)                3060

 encoder3 (Dense)            (None, 3)                 93

 bottleneck4 (Dense)         (None, 4)                 16

 decoder5 (Dense)            (None, 3)                 15

 decoder6 (Dense)            (None, 30)                120

 decoder7 (Dense)            (None, 101)               3131

 decoder8 (Dense)            (None, 240)               24480

 output (Dense)              (None, 15)                3615

=================================================================
Total params: 62,711
Trainable params: 62,711
Non-trainable params: 0
```



Conclusion and discussion

- DNN have much better performance but only works on certain datasets
- Autoencoder less accurate as expected, when compared to supervised learning

Thank you for listening

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Reference

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- Y. Ouali, C. Hudelot, and M. Tami, ‘An Overview of Deep Semi-Supervised Learning’. arXiv, Jul. 06, 2020. Accessed: Jul. 20, 2022. [Online]. Available: http://arxiv.org/abs/2006.05278