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Application of Supervised Machine Learning to the Search for New Physics in ATLAS data

A Study of Ordinary Dense, Parameterized and Ensemble Networks and their Application to High Energy Physics

William Hirst   **May 19, 2023**

Outline

Overview

Outline

Why apply machine learning to HEP problems?

How do we search for new physics?

Outline

A summary of the applied methods

Three neural network variants

- Ordinary dense neural network
- Ensemble networks utilizing Local-Winner-Takes-All (LWTA) layers
- Parameterized neural networks (PNN)

One boosted decision tree method

- XGBoost using default settings

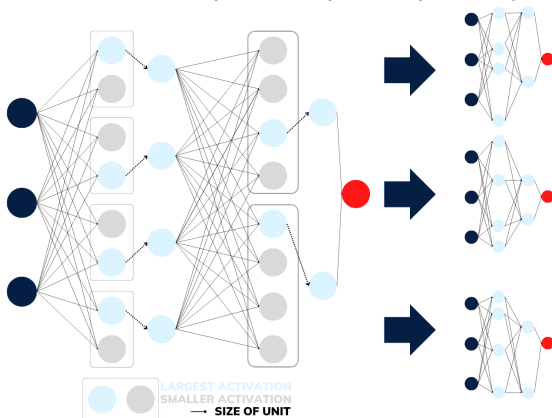# How are the methods compared?

Training strategy

Outline

An introduction and study of each method

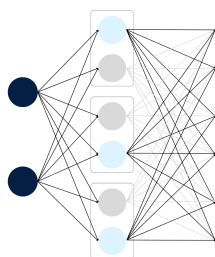# Ordinary dense neural network

Ensemble methods - LWTA

- Dropout
- What is LWTA?
- Competing nodes - Units
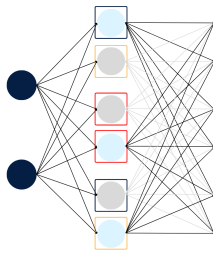- Encode information in pattern specific pathways
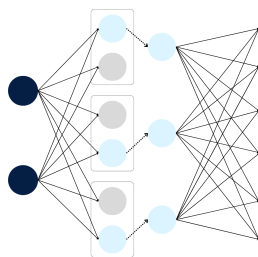
Channel-Out, SCO and Maxout

| Layer	Separate Weights & Biases	Static Units
Channel-Out	*Yes*	*Yes*
SCO	*Yes*	*No*
Maxout	*No*	*Yes*

CHANNEL-OUT   SCO   MAXOUT

Visualization and study of sparse pathways

- A study of the implementation and effect of LWTA layers
- Visualize the activation and paths of 100 randomly sampled events
  - 50 background
  - 50 signal
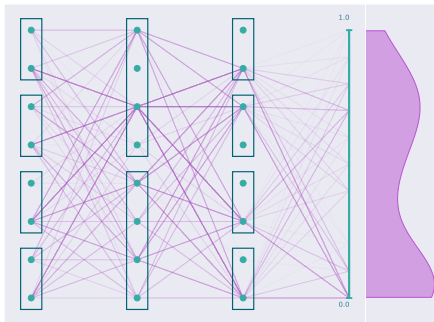- The bolder the line the more frequently the path is used.
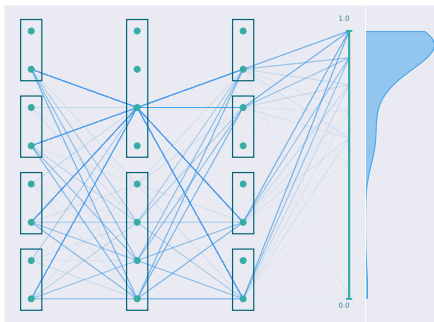
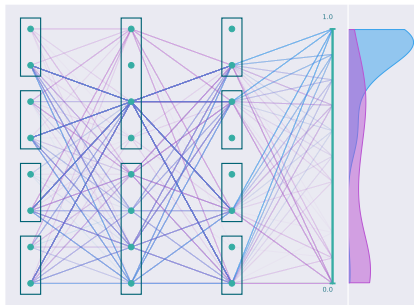**Before training**
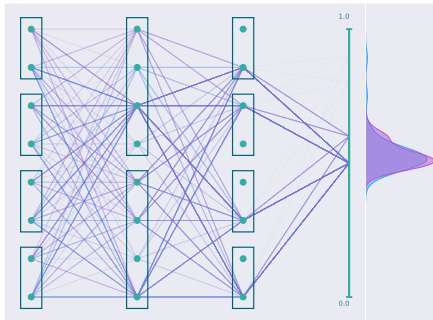
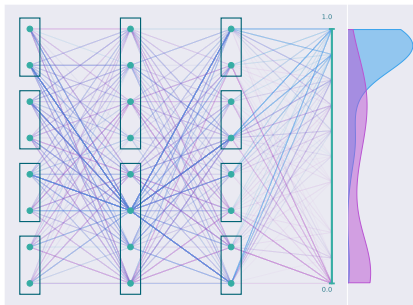**After training**
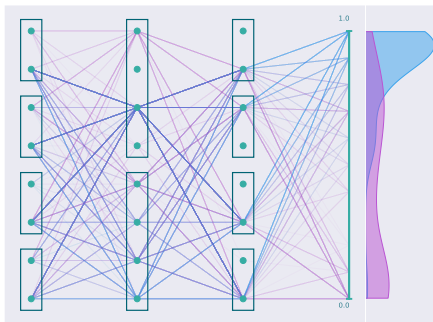
Background

Signal

Comparing activation of Maxout with SCO

Maxout

SCO

Parameterized neural network

- For diverse data set, X, dependent on a parameter, $X(\theta)$
    - Classical approach: One model for each parameter
    - PNN approach: Include θ as feature in feature set
- Signal events using masses $\{A, B\}_{GeV}$ to generate event during simulation will include the parameters A and B in feature set
- Background assigned parameters randomly using same distribution as signal
- Motivation
    - Network will associate parameters with trends in the data
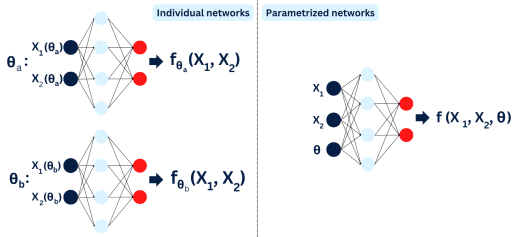
Study the effect of the parameters in the PNN

- Study if the parameters effect the training as intended
- Test: Manually assign all the events, both background and signal, the same parameters (mass combinations) thereby assigning most of the signal the wrong parameters
- Hypothesis: PNN performs better when events are assigned correct parameters

Study the effect of the parameters in the PNN
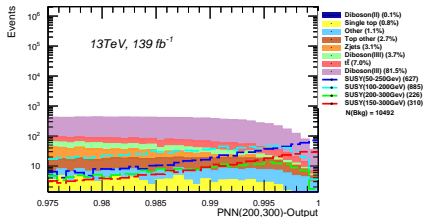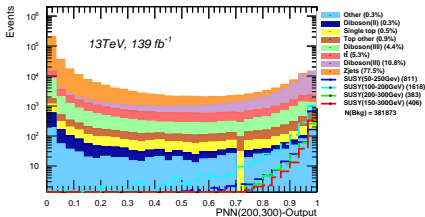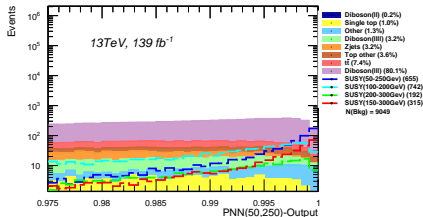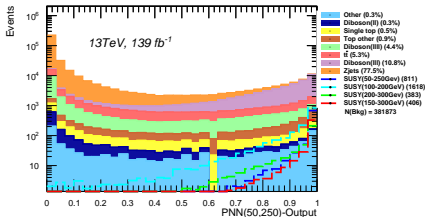
Boosted decision trees - XGBoost

Outline

References I

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📄 Helsø, M.
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🌐 Helsø, M. and Ranestad, K.
Rational quartic spectrahedra, 2018.
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[5] Artin, M.
'On isolated rational singularities of surfaces'.
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