# HIP Project Presentation

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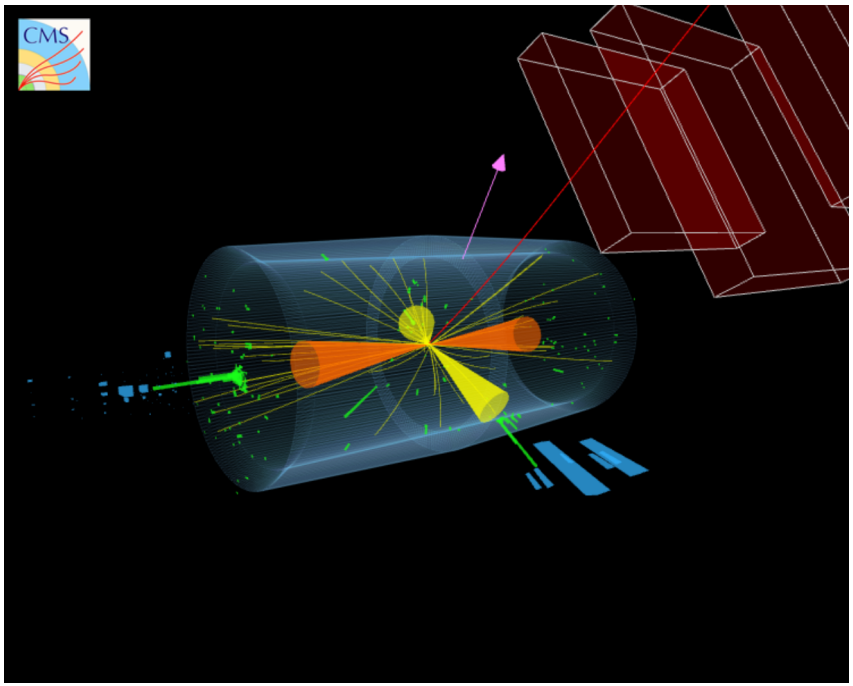


# Introduction

- study of vector boson scattering (VBS)
- can signal presence of anomalous EW couplings & new physics at higher energies
- potential of the all-hadronic final state, where bosons decay to quarks forming hadronic jets not fully exploited.
- isolating the scattering of longitudinally polarized vector bosons could be used as a direct test of electroweak symmetry breaking.
- Goal: $\Rightarrow$ Determine the polarization of hadronic jets originating from W-Bosons

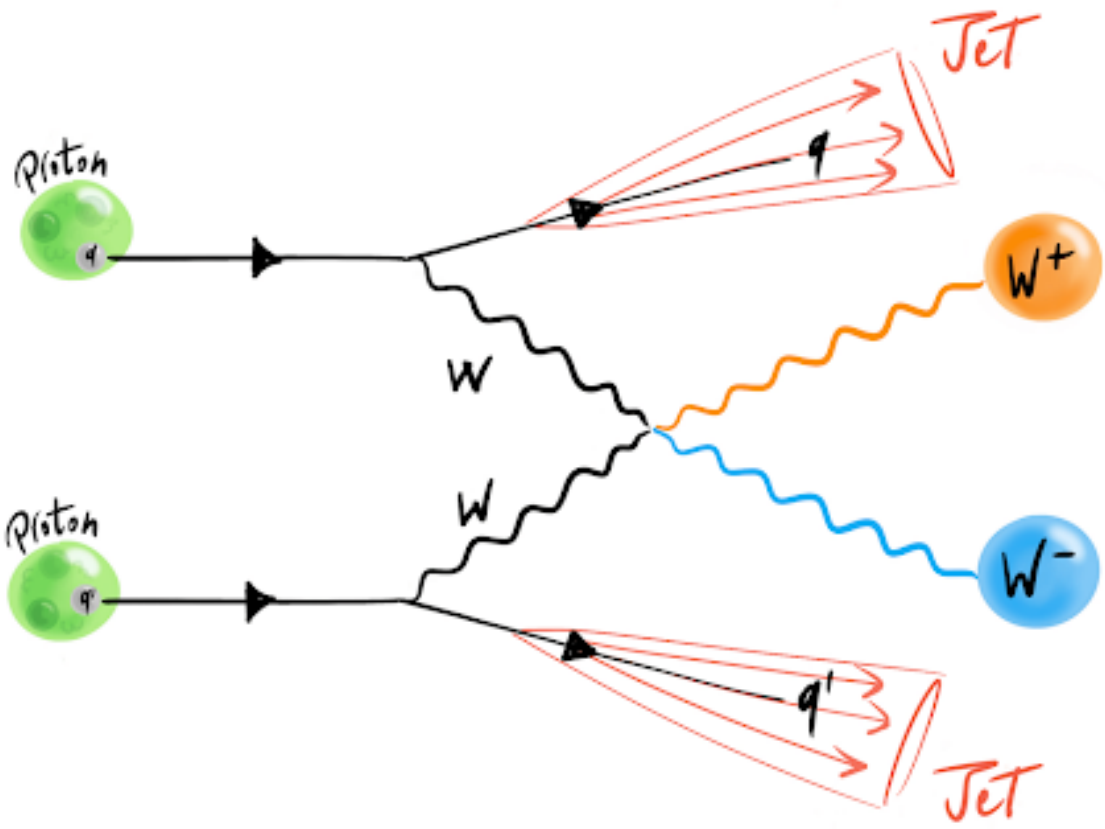



Figure: Example VBS [3]

# Previous Research

- Classification using Proxy variable $p_0$ [4]
- Classification using image representation [1]

# Research Objective

- Can you apply modern models for B-Jet-Tagging to the problem?
- ParT: Transfomer model [2]
- ParticleNet: Graph Neural Network
- PCNN: 1d Convolutional Network
- PCNN: ParticleFlowNetwork

# Features

- Kinematics : $\eta, \phi, E, p_t, ...$
- Particle Identification: $e^-, \mu^-$,(un-)charged hadron, $\gamma$
- Trajectory Displacement: $d_0, d_z, ...$
- 4-Vectors

# Preprocessing

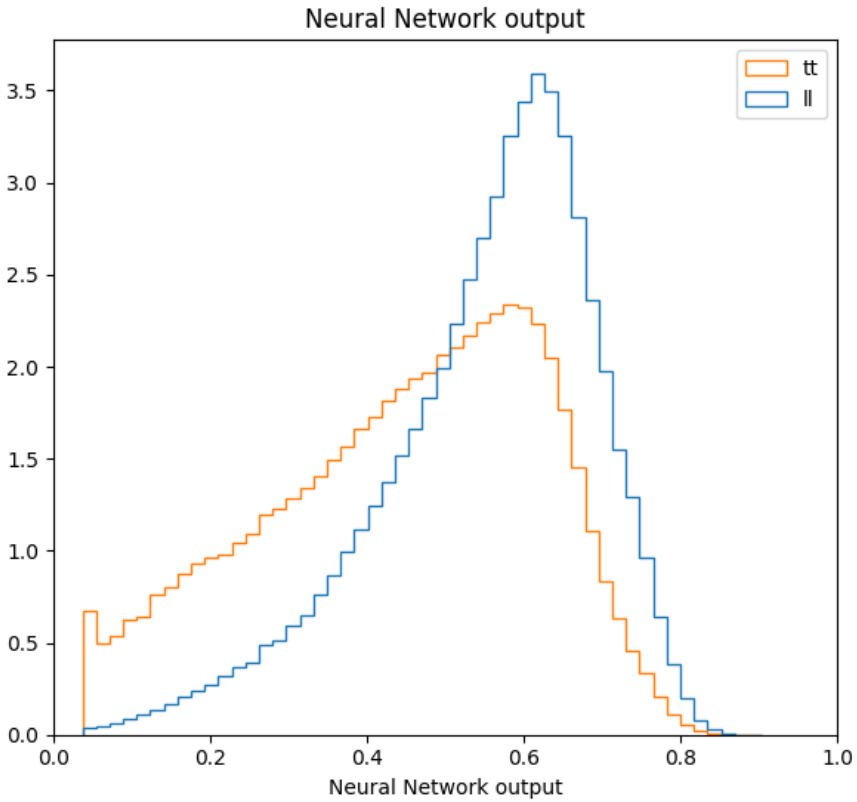
- strip irrelevant attributes from Root-files to allow faster processing
- transform coordinates from Detector-Frame to 4-Vectors
- divide data according to pt
- divide data to test and training data

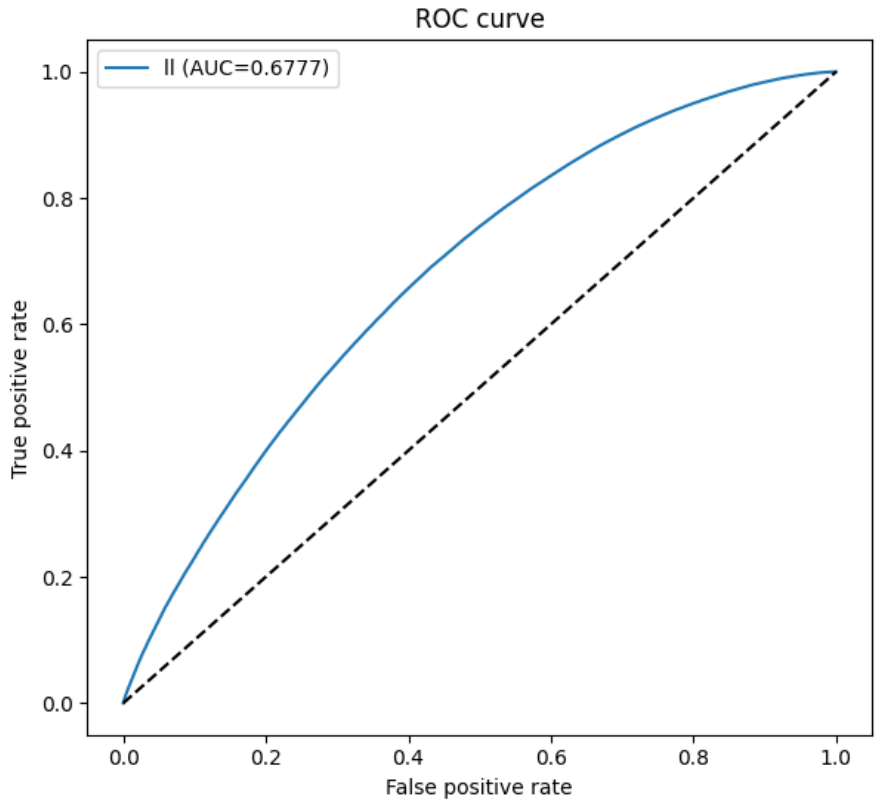
# Model Configuration

- find best learning rate, batch-size
- find the best number of epochs while avoiding overfitting
- adjust models for transfer-learning mode

# Metrics

ParT



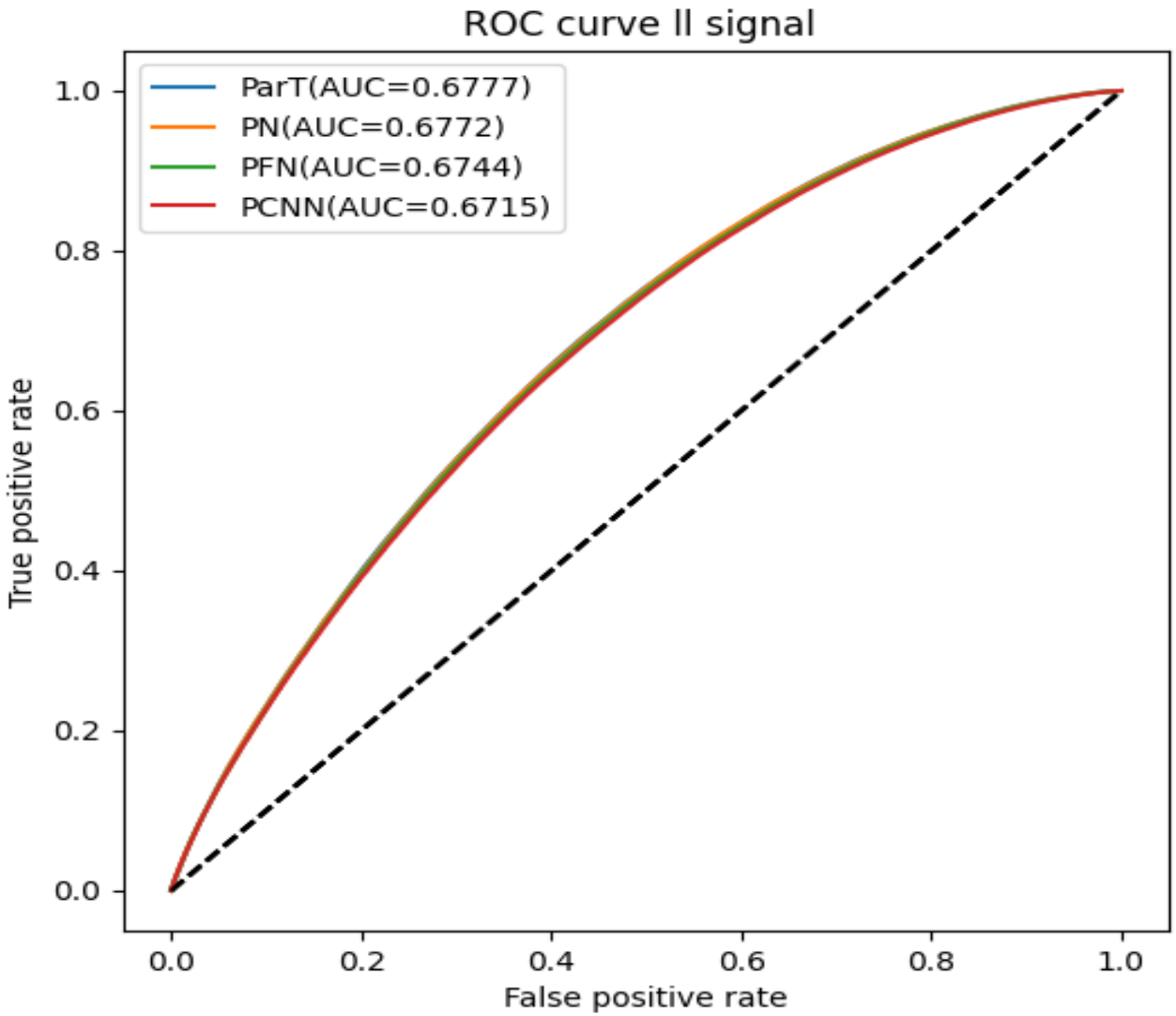



# Results

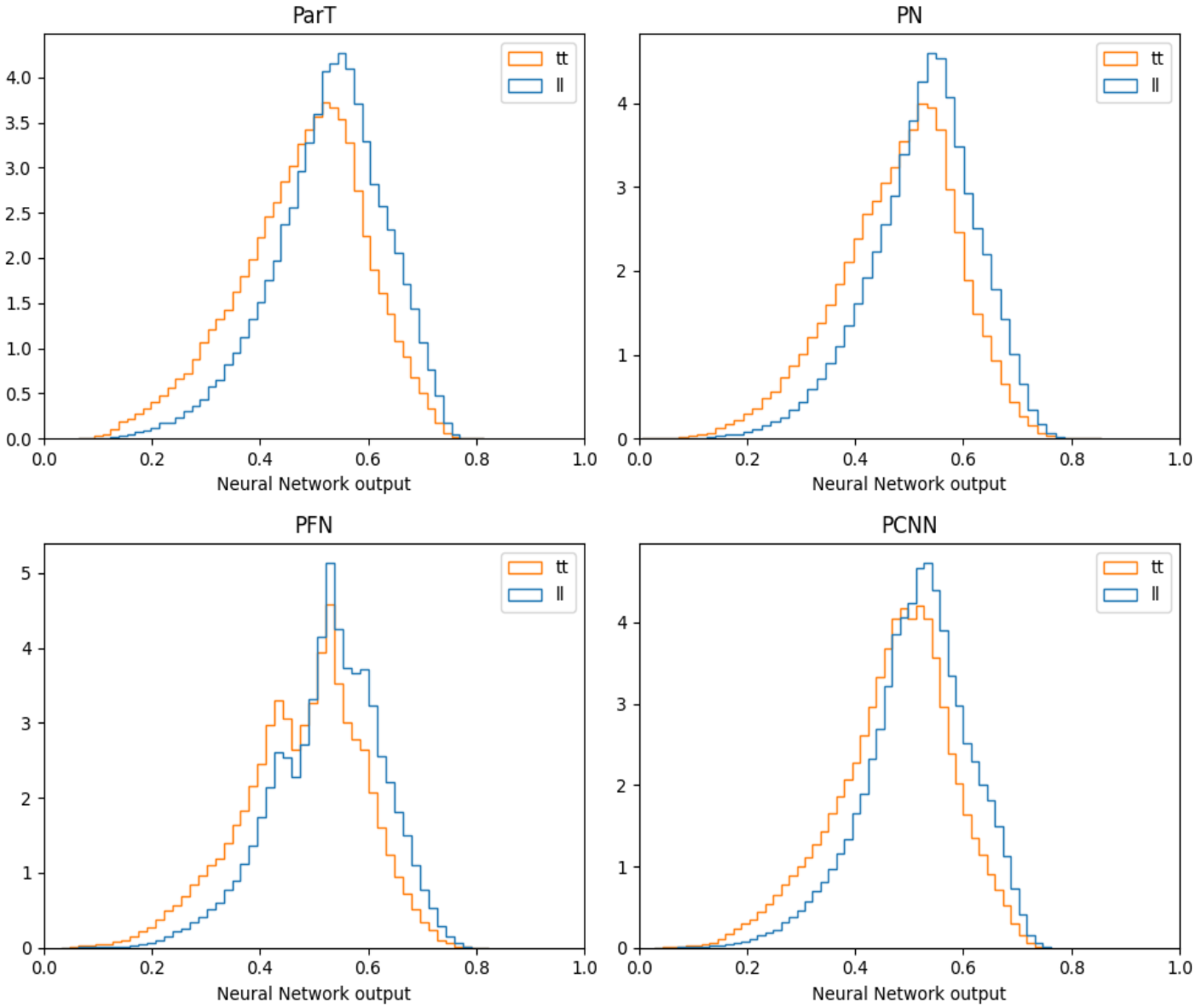
| Model | Metrics | | |
|---|---|---|---|
| | Accuracy | ROC-AUC | Train time(h) |
| ParT | 0.629 | 0.677 | 25.5 |
| ParticleNet | 0.628 | 0.677 | 22 |
| PFN | 0.626 | 0.674 | 2 |
| PCNN | 0.625 | 0.673 | 2 |

Table: Model Comparison with Different Metrics

# ROC-Curve


ROC curve ll signal
ParT(AUC=0.6777)
PN(AUC=0.6772)
PFN(AUC=0.6744)
PCNN(AUC=0.6715)
True positive rate
False positive rate
0.0
0.2
0.4
0.6
0.8
1.0

# Decision Boundaries



# Training-Data-Size

| Size-Trainingset | Accuracy | ROC-AUC |
|---|---|---|
| 200k | 0.6231 | 0.6708 |
| 1M | 0.6281 | 0.6760 |
| 3M | 0.6292 | 0.6777 |

Table: ParT varying Trainingdata

# Comparison Decision Boundaries

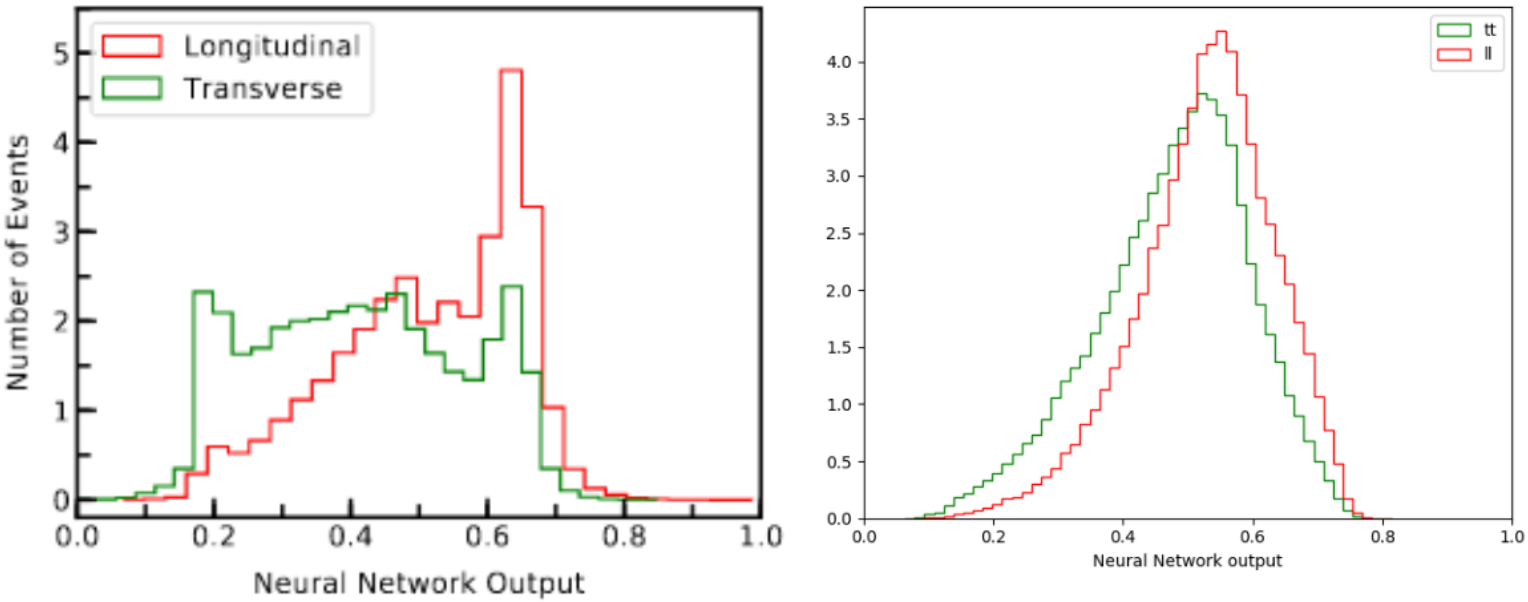



Figure: Image-Representation [1] vs. ParT

# Comparison ROC-Curves

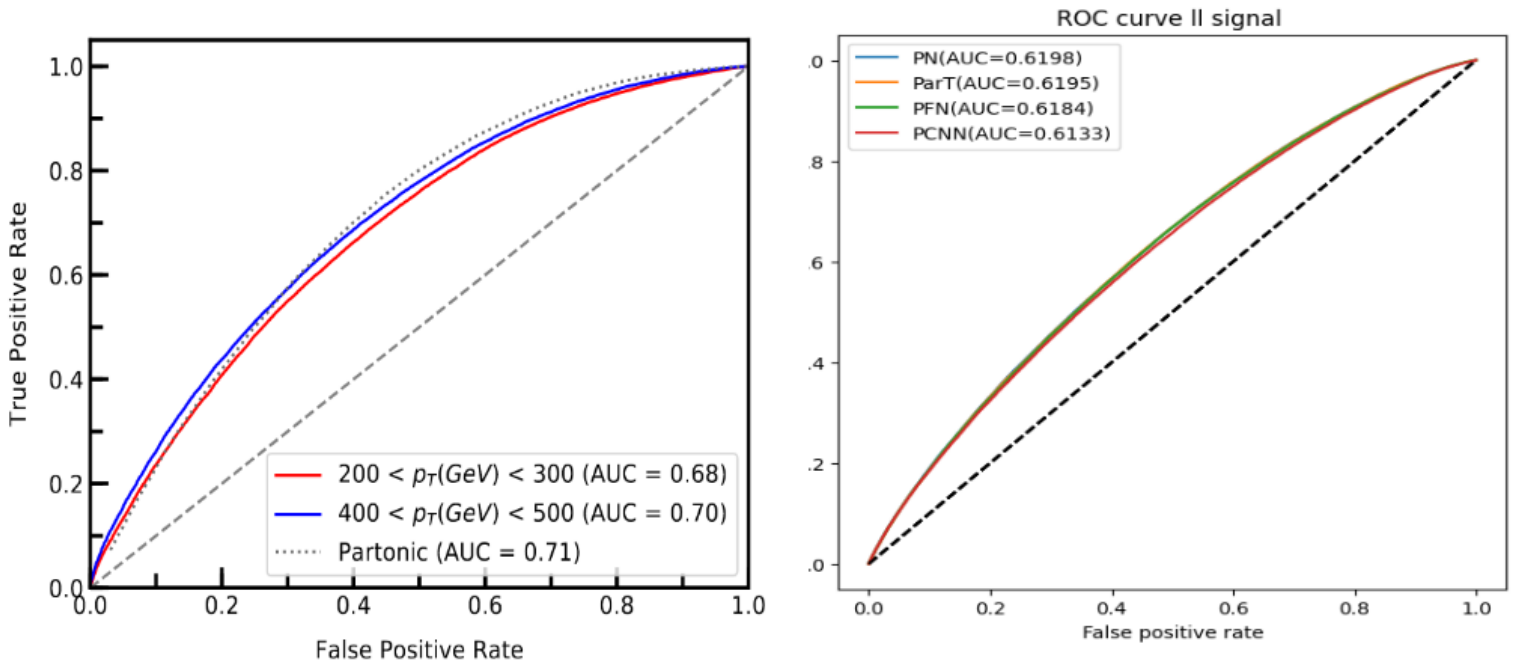



Figure: Image-Representation [1] vs. ParT

# Conclusions

- All models achieve more 50%
- ParT, PN, PFN are all about equivalent
- PCNN has issues with overfitting
- Image-Representation seems a better fit than particle cloud
- higher Jet-Energy $\Rightarrow$ easier classification

# Outlook

- Use models to determine fractions between polarizations
- Implement new model using other observables
- Investigate Transfer-Learning possibilites

# References


[1] T. Kim and A. Martin. "A $W^{\pm}$ polarization analyzer from Deep Neural Networks". In: *ArXiv e-prints* (2021). arXiv: 2102.05124 [hep-ph].

[2] Huilin Qu, Congqiao Li, and Sitian Qian. "Particle Transformer for Jet Tagging". In: *High Energy Physics - Phenomenology* (2022). Submitted on 8 Feb 2022 (v1), last revised 18 Jun 2022 (this version, v2). arXiv: 2202.03772 [hep-ph]. URL: https://doi.org/10.48550/arXiv.2202.03772.

[3] *Search for Rare Production of Vector Boson Pairs*. URL: https://cms.cern/news/search-rare-production-vector-boson-pairs (visited on 06/19/2023).

[4] Jesse Thaler and Ken Van Tilburg. "Identifying Boosted Objects with N-subjettiness". In: *ArXiv e-prints* (2010). arXiv: 1011.2268 [hep-ph]. URL: https://doi.org/10.48550/arXiv.1011.2268.