Northern Illinois University

# 2022 PhD Progress Review

Elliot Parrish[†] Dhiman Chakraborty[†] Jahred Adelman[†]

[†]Northern Illinois University, USA

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## Contents

# Timeline

# Timeline to 2022

- **Summer 2017:** @ NIU
  - Started at NIU
  - Started ATLAS qualification task on the hadronic Tile calorimeter
- **Summer 2018:** @ CERN
  - Qualified as author on ATLAS
  - Start training as Tile Calorimeter Data Quality (DQ) Co-Coordinator
  - Tile test beams
  - *Machine Learning for High Energy Physics Summer School*
    - University of Oxford
    - August 6, 2018 - August 12, 2018
- **Fall 2018:** @ NIU
  - Take over full time as DQ Co-Coordinator
  - Finished collecting Run-2 data
- **Summer/Fall 2019:** @ CERN
  - Ramped up work on $H^{\pm} \rightarrow \tau\nu$ analysis
  - ATLAS data quality Run-2 paper
  - Reprocessing campaign of Run-2 data starting
  - Moved to CERN long term

# Timeline to 2022

- **Spring 2020:** @ CERN
  - Polish National Agency for Academic Exchange: *International Scholarship Exchange of PhD Students and Academics*
    - February 17, 2020 - February 2021, 2020
    - Institute of Nuclear Physics Polish Academy of Sciences, Krakow, Poland
- **Summer 2020:** @ CERN
  - On detector readout and control electronics maintenance
  - Started $H^{\pm} \to \tau\nu$ PNN HPO
- **Fall 2020:** @ CERN
  - Reprocessing monitoring tests
- **Spring/Summer 2021:** @ CERN
  - Tile ACES (equipment inventory)
  - Trained replacement DQ Co-Coordinator
  - Finalized Run-2 reprocessing preparations
  - APS DPF 2021
- **Fall 2021:** @ USA
  - Tile test beams
  - Moved from CERN back to US
  - Finished involvement with Tile

# Tile Calorimeter

# ATLAS Hadronic Tile Calorimeter

- ATLAS is a general purpose particle detector on the Large Hadron Collider at CERN
- The Hadronic Tile calorimeter is the outermost sub-detector besides the muon system
  - Designed to measure hadron energy by fully absorbing particle showers
  - Highly important in jet reconstruction
  - Scintillating tile with steel absorber
  - Light readout via optical fibers to PMTs

TileCalDiagramATLAS.png

TileModuleCrossSection.pn

LHC.png

ATLASCrossSectionDiagram.png

# Tile Calorimeter Calibration Systems

- Cesium
  - Hydraulically moved throughout detector
  - Measures response of scintillator
- Laser
  - Measures response of photomultiplier tubes
  - Can be taken during physics data taking and individual calibration runs
- Charge Injection
  - Four capacitors, two low gain, two high gain
  - Measures response of digitizers and readout electronics
- One centralized database to store all calibration constants

Tile_Calibration_Diagram.png

## Centralized ATLAS Conditions Database

- Online and Offline database
- Three main tags within databases
  - UPD1
    - Used to quickly process 10% of events
    - Can only append information
  - UPD4
    - Used after 48 hrs to process full run
    - Can change previous information
  - ONL01

- TileCal Robot Authorship Task
  - Web based interface to update conditions database (Tile internal)
  - Previously, had to update all three tags individually
  - Created automated syncing of tags

TileRobotTrippleUpdateScreenShot.png

# Tile Data Quality Co-Coordinator

- Took over from Puja Saha at the end of Summer 2018 until Fall 2021
- Workload was dependent on ATLAS data taking schedule
- During data taking
  - 48 hours to investigate issues and take action before full processing of runs
  - Coordinate two shifters (Data Quality Validator and Data Quality Leader)
  - Personally sign off every run and tag with appropriate defects
- During Long Shutdown 2
  - Coordinate two shifters (Data Quality Validator and Data Quality Leader)
    - Fill in when needed
  - Reconstruction codebase was restructured to support multithreading
    - Signed off many tests
    - Finished Summer 2021
  - Reprocessing of Run-2 data
    - Revised Tile channel statuses for 2018, applied changes from previous DQ Co-Coord
    - Finalized Fall 2021

# Tile Data Quality Run-2 Performance

- As DQ Co-Coordinator I was responsible for channel and cell status
  - (Un)Masking based on performance
  - Various status flags used in reconstruction

masked_cells_timeline_2018.png

- Tile boasted 100% Data Quality Efficiency for 2018
  - For all of Run-2, we were 99.65% efficient
- Paper detailing ATLAS Run-2 data quality performance published in Journal of Instrumentation
  - DOI: 10.1088/1748-0221/15/04/P04003

DataQualityLosesRun2.png

# Tile Maintenance

- At the start of the pandemic, many experts had to leave the CERN area
  - I volunteered to help with transition of new CIS/Maintenance technicians
  - During Long Shutdown 2, Tile performed maintenance
    - Repaired/replaced electronics, PMTs, added cooling isolation valves, etc.
  - I helped install the demonstrator module that is a proof of concept for future Tile upgrades
    - Will remain inside of Tile for Run-3 data collection

OnLBA14.jpg

TileElectronicsJalal

TileMaintenanceTeamJune2020.png

# ACES Database Update

- ATLAS Central Equipment System (ACES)
  - A central database for all racks, cables, detector parts, and general equipment
- Needed to update with latest information since Long Shutdown 2 was coming to an end
  - Myself and Michaela Mlynáriková were tasked with inputting new information
- Finished in Fall 2021

Hard_At_Work.jpg

- USA15

Y.04-16.A1.jpg

- ACES

Y.04-16.A1_A

# Tile Test Beams

- Participated in two test beams for Tile
  - Summer 2018
  - Fall 2021
- In both, collected data for various electronics upgrades
  - Set beam energy and beam type from an offshoot of the Super Proton Synchrotron (SPS)
  - Moved Tile module to collect spatial response
- Helped setup test beam site in 2021
  - Tracing down cables, connected various

TileTestBeamSetup_Michaela_Wil

# $H^{\pm} \to \tau\nu$ **Analysis**

# Search for $H^{\pm} \rightarrow \tau\nu$ using the ATLAS experiment

- Many extensions to the Higgs sector imply the existence of charged scalars (2HDM, NMSMM, Triplet, etc.)
  - $H^{\pm} \rightarrow \tau^{\pm}\nu_{\tau}$ remains significant for high $\tan\beta$
    - $\tan\beta$ defined as the ratio of the vacuum expectation values of the two doublets
- At the LHC, theoretical production mode of $H^{\pm}$ is mainly in top-quark decays or in association with a top-quark ($t$)
  - $H^{\pm}$ production mode is dependent on $m_{H^{\pm}}$
  - Analysis is sensitive for low mass ($m_{H^{\pm}} < m_t$), intermediate mass ($m_{H^{\pm}} \simeq m_t$), and high mass ($m_{H^{\pm}} > m_t$)
- Two sub-channels based on the decay mode of associated $t$

| $t \rightarrow jets$ | $t \rightarrow \ell$ |
|---|---|
| Sensitive at high mass due to higher $W \rightarrow q\bar{q}$ BR | Sensitive at low mass due to single lepton triggers |

Charged_Higgs_BR.png

HPlus_taunu_tanB.png

# Analysis Overview

- Search for singly charged $H^{\pm}$ decaying to $\tau_{had} + \nu$ over a wide mass range
  - Low mass ($m_{H^{\pm}} < m_t$):
  - Intermediate mass* ($m_{H^{\pm}} \simeq m_t$)
  - High mass ($m_{H^{\pm}} > m_t$)
- Dominant backgrounds

| **Backgrounds w/ prompt hadronic $\tau$** | **Backgrounds w/ fake $\tau$** |
|---|---|
| $t\bar{t}$ estimated with MC | Fake $j \rightarrow \tau$ estimated with data driven fake factor method |
| $V + jets$ estimated with MC | Fake $\ell \rightarrow \tau$ estimated with MC, validated on $Z \rightarrow ee$ |
| VV estimated with MC | |

- MVA score is used as the final discriminant

| **Sub-Channel** | | | | | | | |
|---|---|---|---|---|---|---|---|
| $\tau + jets$ **SR** | $E_T^{miss}$ Trigger | 1 hadronic $\tau$<br>$p_T^{\tau} > 40$ GeV | 0 $\ell$ (e or $\mu$)<br>$p_T^{\ell} > 20$ GeV | $\geq 3$ jets<br>$p_T^{j} > 25$ GeV | $\geq 1$ b-jets<br>$p_T^{b-jet} > 25$ GeV | $E_T^{miss} > 150$ GeV | $m_T(\tau, E_T^{miss}) > 50$ GeV |
| $\tau + \ell$ **SR** | Single Lepton Trigger | 1 hadronic $\tau$<br>$p_T^{\tau} > 30$ GeV | 1 $\ell$ (e or $\mu$)<br>$p_T^{\ell} > 30$ GeV | $\geq 1$ jet<br>$p_T^{j} > 25$ GeV | $\geq 1$ b-jets<br>$p_T^{b-jet} > 25$ GeV | $E_T^{miss} > 50$ GeV | Opposite sign $\tau$ and $\ell$ |

double_resonant_production_low_ma

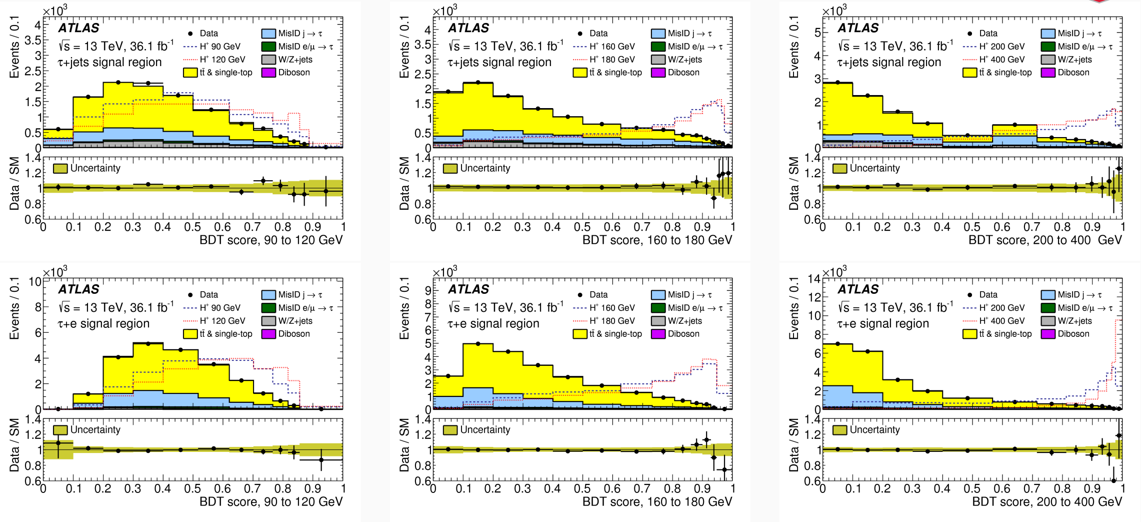
$m_{H^{\pm}} < m_t$

non_resonant_production_intermed

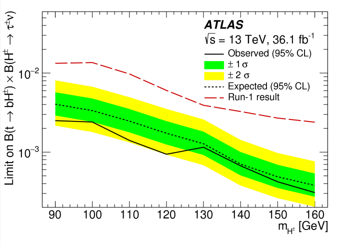
$m_{H^{\pm}} \simeq m_t$

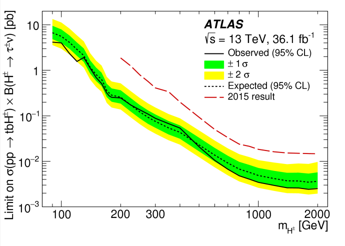
SingleResonant.pdf

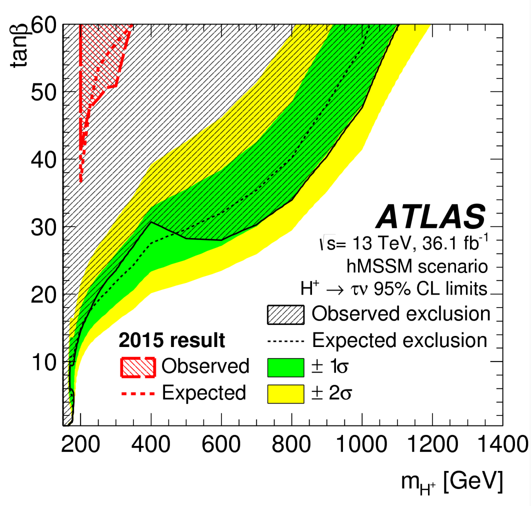
# JHEP 09(2018)139 BDT Scores in Signal Regions



# JHEP 09(2018)139 Limits



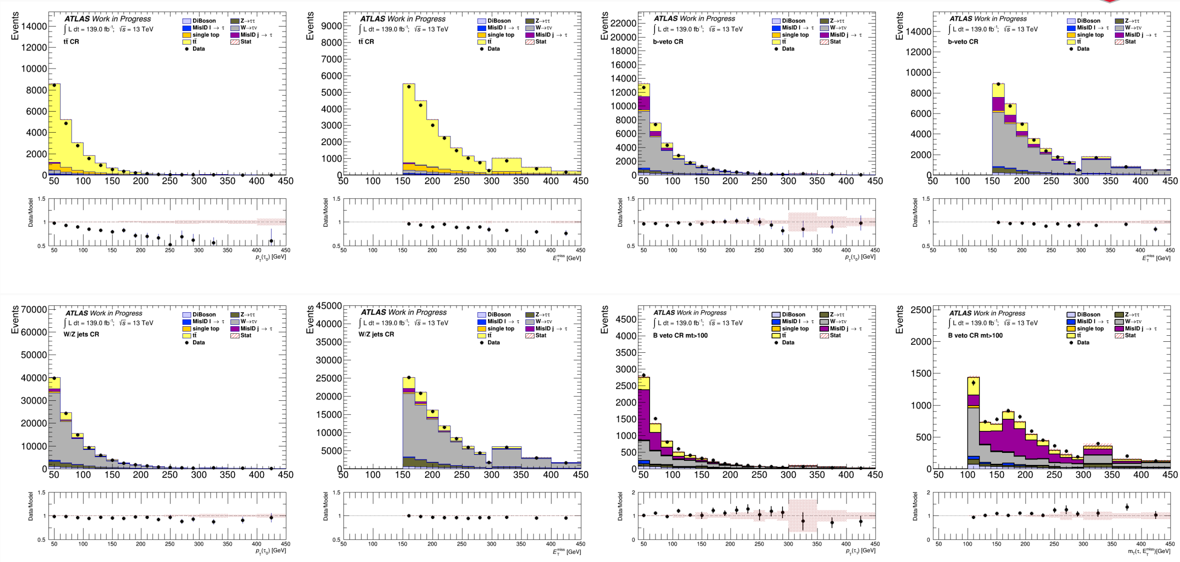



# Updates to analysis since last publication

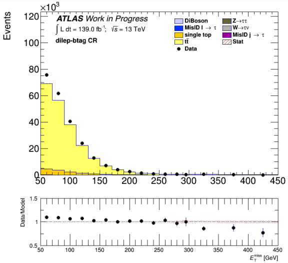
- Signal mass range extended
  - Previous: $90 \leq m_{H^\pm} \leq 2000$ GeV
  - Current: $80 \leq m_{H^\pm} \leq 3000$ GeV
- Signal filtering applied in order to effectively increase the statistics in the signal regions
- New analysis framework centered around using modern Machine Learning tools
- Investigating new multivariate analysis techniques
- Updated derivations
  - RNN $\tau$ ID recommendations
  - Updated b-tagging recommendations
  - PFlow jets
  - Latest Combined Performance recommendations

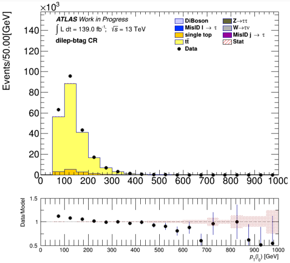
intlumivstimeRun2.png

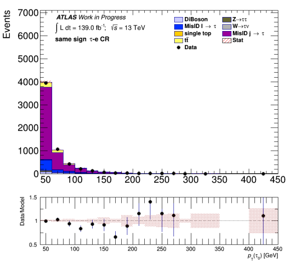
# $\tau + jets$ Background Modeling

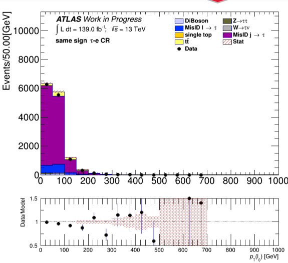


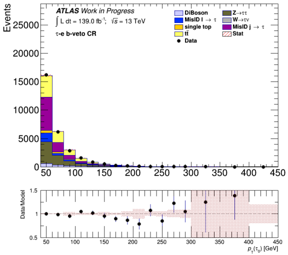
# $\tau + \ell$ Background Modeling

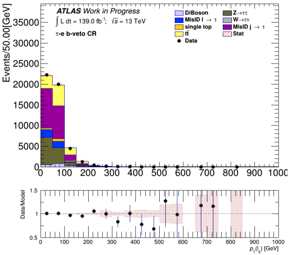


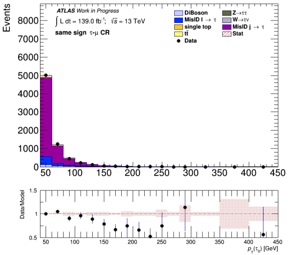



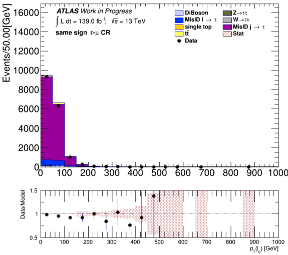



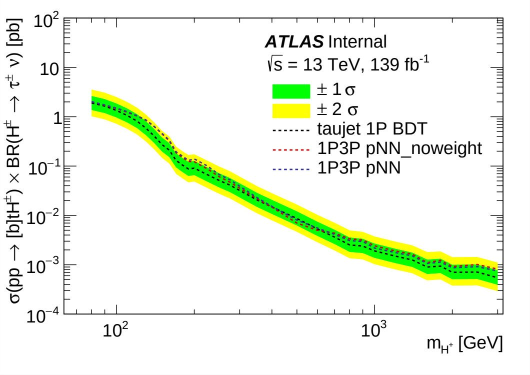
# Parameterized Neural Networks

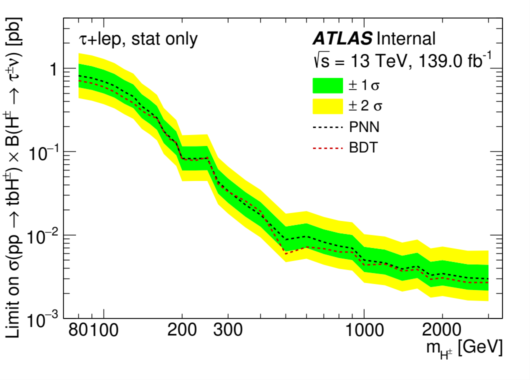
- Parameterized Neural Networks (PNNs) can be trained and evaluated on an entire mass range
  - Detailed information here: arXiv:1601.07913
- Trained using Tensorflow backend for Keras
- $m_{H^\pm}$ is used as an input feature of the model
- Allows one model to be used across entire $m_{H^\pm}$ mass range
- Separate models trained on 1 prong and 3 prong $\tau$
- $\tau + \ell$ channel is trained inclusive for $\tau + e$ and $\tau + \mu$
- Evaluated on single mass points

NN_Diagram.png

# Parameterized Neural Network vs Boosted Decision Tree

- One model for entire mass range makes analysis less computationally expensive
- PNN can be evaluated on mass points that are not simulated
- Limits are preliminary, many fixes and changes have been implemented since



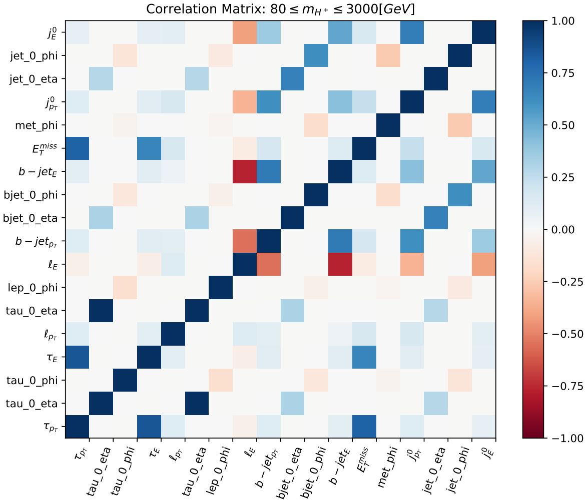



# Feature Ranking

- Linear correlations between input features
  - Neural Networks often do not work very well with linearly correlated variables
- Produced features rankings via Local Interpretable Model-agnostic Explanations (LIME)
  - LIME explains an instance ($\times$) by sampling nearby points with classifier, weighting by distance from $\times$
  - LIME then learns a linear model which explains the decision locally (dashed line)

limeToyExplanation.png

# Input Feature Linear Correlations



# Comparing to Previous Analysis

- Given bkg event

PawelModel_HPlus80_BKG.png

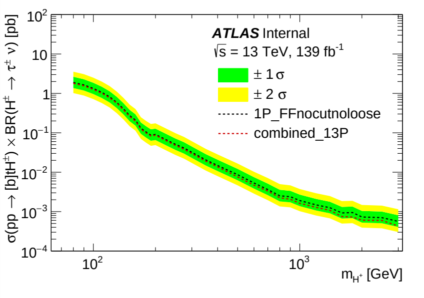
- Given signal event

PawelModel_HPlus80_SIG.png

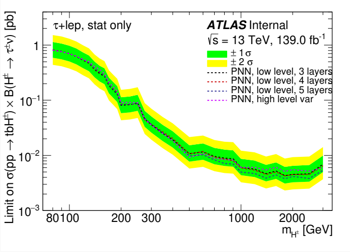
- Last analysis BDT (low mass)

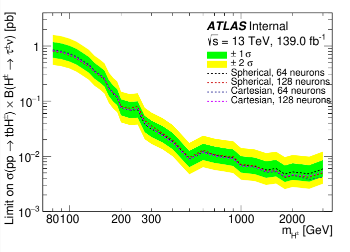
IntNotefeatureRanking.png

# $H^{\pm} \to \tau\nu$ Expected Limits PNN Studies




$\tau + jets$




$\tau + \ell$

# PNN Hyperparameter Optimization

- Performed in the $\tau + \ell$ sub-channel
- Used area under curve (AUC) of scores as figure of merit
  - Averaged over 5 kfolds, standard deviation is taken from kfolds
- Used early stopping for training
  - $\Delta_{min} = 0.00001$ and a patience of 10
  - Best weights were kept
- To make hyperparameter optimization (HPO) go quicker, ran multiple small grids of hparams
  - Scan over activation functions and loss functions
  - Scan over dropout value
  - Scan over activation function
  - Scan over LeakyReLU $\alpha$
  - Fixed alpha over more widths and depths
    - AUC from 80 GeV to 500 GeV to optimize for low mass

# PNN Hyperparameter Optimization

| Parameter | | | |
|---|---|---|---|
| activation function | softsign | relu | LeakyReLU |
| loss function | $\boxed{\text{binary crossentropy}}$ | mean squared error | mean absolute error |
| width | 32 | | |
| depth | 10 | | |

| Parameter | | | |
|---|---|---|---|
| width | 8 | 16 | 32 |
| depth | 3 | 5 | 10 |
| dropout | $\boxed{0.1}$ | 0.3 | |
| activation function | softsign | | |
| loss function | binary crossentropy | | |

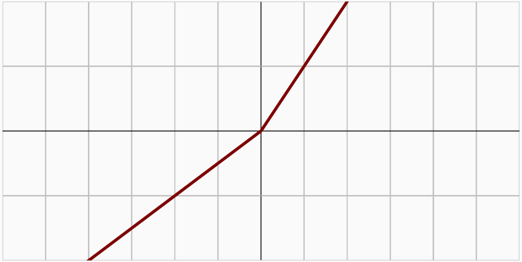
| Parameter | | | |
|---|---|---|---|
| width | 32 | 64 | 128 |
| depth | 2 | 3 | 4 |
| dropout | 0.1 | | |
| activation function | softsign | relu | $\boxed{\text{LeakyReLU}}$ |
| batch size | 1025 | | |
| loss function | binary crossentropy | | |

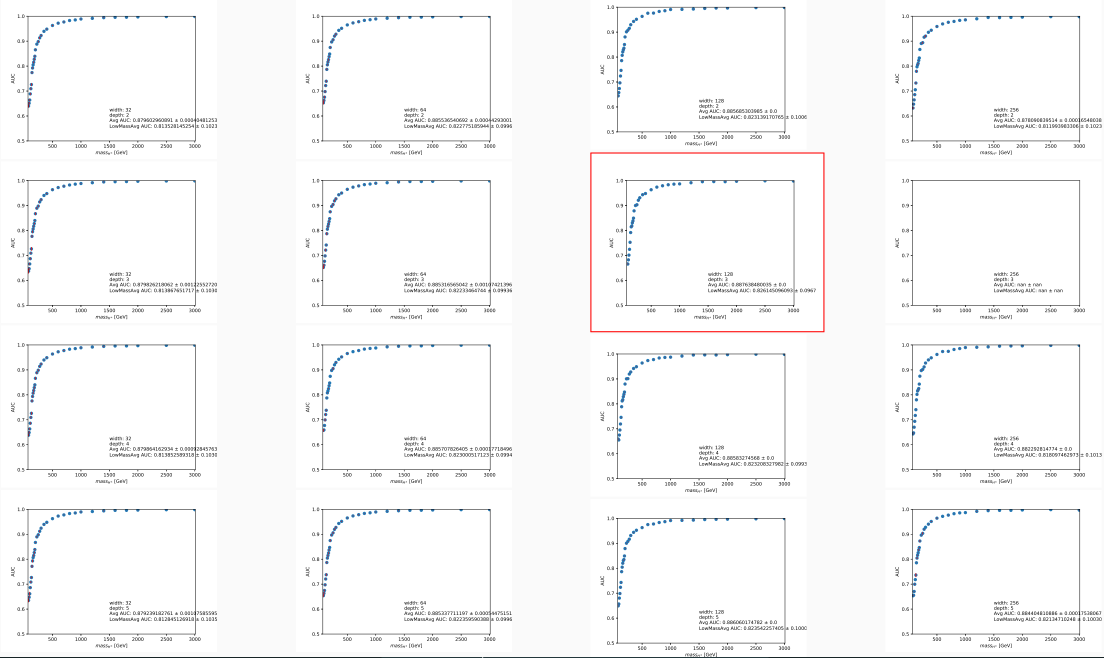
| Parameter | | | | |
|---|---|---|---|---|
| width | 32 | 64 | 128 | |
| depth | 2 | 3 | 4 | |
| $\alpha$ | 0.01 | $\boxed{0.05}$ | 0.001 | 0.005 |
| batch size | 1024 | | | |
| dropout | 0.1 | | | |
| activation function | LeakyReLU | | | |
| loss function | binary crossentropy | | | |

| Parameter | | | | |
|---|---|---|---|---|
| width | 32 | 64 | $\boxed{128}$ | 256 |
| depth | 2 | $\boxed{3}$ | 4 | 5 |
| batch size | 1024 | | | |
| dropout | 0.1 | | | |
| activation function | LeakyReLU | | | |
| $\alpha$ | 0.05 | | | |
| loss function | binary crossentropy | | | |

# PNN Hyperparameter Optimization Search

- LeakyReLU activation function has an $\alpha$ parameter
- Slope of negative portion
  - Prevents neurons from "dying" by allowing negative weight values
- Standard relu is where $\alpha = 0$



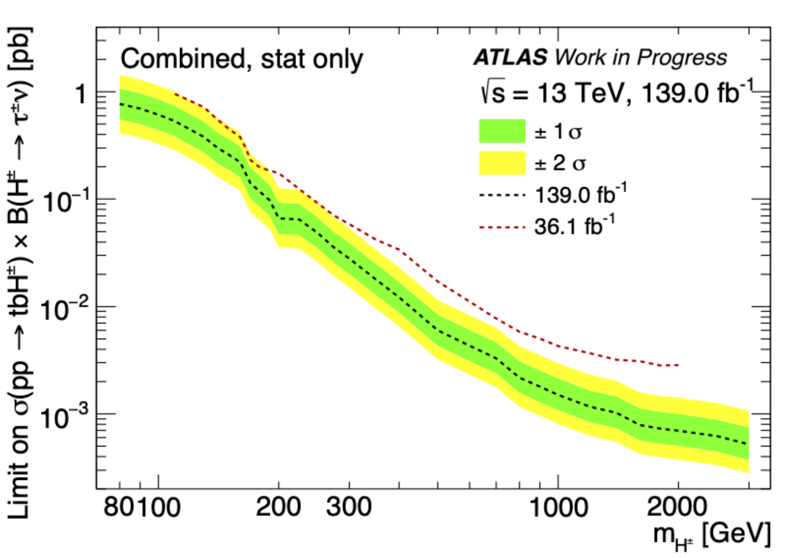


width: 32
depth: 2
Avg AUC: 0.879602960891 ± 0.00040481253
LowMassAvg AUC: 0.813528145254 ± 0.1023
width: 64
depth: 2
Avg AUC: 0.885536540692 ± 0.00044293001
LowMassAvg AUC: 0.822775185944 ± 0.0996
width: 128
depth: 2
Avg AUC: 0.885685303985 ± 0.0
LowMassAvg AUC: 0.823139170765 ± 0.1006
width: 256
depth: 2
Avg AUC: 0.878090839514 ± 0.00016548038
LowMassAvg AUC: 0.811993983306 ± 0.1023
width: 32
depth: 3
Avg AUC: 0.879826218062 ± 0.00122552720
LowMassAvg AUC: 0.813867651717 ± 0.1030
width: 64
depth: 3
Avg AUC: 0.885316565042 ± 0.00107421396
LowMassAvg AUC: 0.82233464744 ± 0.09936
width: 128
depth: 3
Avg AUC: 0.887638480035 ± 0.0
LowMassAvg AUC: 0.826145096093 ± 0.0967
width: 256
depth: 3
Avg AUC: nan ± nan
LowMassAvg AUC: nan ± nan
width: 32
depth: 4
Avg AUC: 0.879864162934 ± 0.00092845763
LowMassAvg AUC: 0.813852589318 ± 0.1030
width: 64
depth: 4
Avg AUC: 0.885707826405 ± 0.00017718496
LowMassAvg AUC: 0.823000517123 ± 0.0994
width: 128
depth: 4
Avg AUC: 0.88583274568 ± 0.0
LowMassAvg AUC: 0.823208327982 ± 0.0993
width: 256
depth: 4
Avg AUC: 0.882292814774 ± 0.0
LowMassAvg AUC: 0.818097462973 ± 0.1013
width: 32
depth: 5
Avg AUC: 0.879239182761 ± 0.00107585595
LowMassAvg AUC: 0.812845126918 ± 0.1035
width: 64
depth: 5
Avg AUC: 0.885337711197 ± 0.00054475151
LowMassAvg AUC: 0.822359590388 ± 0.0996
width: 128
depth: 5
Avg AUC: 0.886060174782 ± 0.0
LowMassAvg AUC: 0.823542257405 ± 0.1000
width: 256
depth: 5
Avg AUC: 0.884404810886 ± 0.00017538067
LowMassAvg AUC: 0.82134710248 ± 0.10030
AUC
$mass_{H^{\pm}}$ [GeV]

# PNN Hyperparameter Optimization Results

| width | depth | 80 | 80Std | 150 | 150Std | 250 | 250Std | 500 | 500Std | Avg | AvgStd | LowMassAvg | LowMassAvgStd |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 128 | 3 | 0.666137 | 0.000000 | 0.814508 | 0.000000 | 0.903123 | 0.000000 | 0.963256 | 0.000000 | 0.887638 | 0.000000 | 0.826145 | 0.096754 |
| 128 | 5 | 0.649154 | 0.000000 | 0.804344 | 0.000000 | 0.907763 | 0.000000 | 0.962846 | 0.000000 | 0.886060 | 0.000000 | 0.823542 | 0.100037 |
| 128 | 4 | 0.659330 | 0.000000 | 0.811707 | 0.000000 | 0.901186 | 0.000000 | 0.963811 | 0.000000 | 0.885833 | 0.000000 | 0.823208 | 0.099379 |
| 128 | 2 | 0.644392 | 0.000000 | 0.807016 | 0.000000 | 0.907517 | 0.000000 | 0.963076 | 0.000000 | 0.885685 | 0.000000 | 0.823139 | 0.100649 |
| 64 | 4 | 0.657593 | 0.005023 | 0.807977 | 0.001327 | 0.905193 | 0.004490 | 0.965553 | 0.001622 | 0.885708 | 0.000177 | 0.823001 | 0.099420 |
| 64 | 2 | 0.652767 | 0.006639 | 0.805184 | 0.002345 | 0.905695 | 0.003172 | 0.965077 | 0.000726 | 0.885537 | 0.000443 | 0.822775 | 0.099628 |
| 64 | 5 | 0.653787 | 0.005006 | 0.804417 | 0.001933 | 0.905833 | 0.003671 | 0.965293 | 0.001398 | 0.885338 | 0.000545 | 0.822360 | 0.099660 |
| 64 | 3 | 0.652007 | 0.006721 | 0.805076 | 0.001760 | 0.904237 | 0.004398 | 0.964922 | 0.001898 | 0.885317 | 0.001074 | 0.822335 | 0.099360 |
| 256 | 5 | 0.653576 | 0.000963 | 0.804396 | 0.003342 | 0.903638 | 0.004193 | 0.964415 | 0.002172 | 0.884405 | 0.000175 | 0.821347 | 0.100307 |
| 256 | 4 | 0.643401 | 0.000000 | 0.801775 | 0.000000 | 0.901747 | 0.000000 | 0.961914 | 0.000000 | 0.882293 | 0.000000 | 0.818097 | 0.101322 |
| 32 | 3 | 0.636902 | 0.009356 | 0.794963 | 0.004126 | 0.897744 | 0.003173 | 0.963498 | 0.002178 | 0.879826 | 0.001226 | 0.813868 | 0.103095 |
| 32 | 4 | 0.638362 | 0.003653 | 0.793516 | 0.003269 | 0.898635 | 0.003664 | 0.963582 | 0.001635 | 0.879864 | 0.000928 | 0.813853 | 0.103071 |
| 32 | 2 | 0.639871 | 0.005791 | 0.792428 | 0.002366 | 0.898305 | 0.003283 | 0.962854 | 0.002313 | 0.879603 | 0.000405 | 0.813528 | 0.102342 |
| 32 | 5 | 0.634979 | 0.007666 | 0.793076 | 0.005599 | 0.898086 | 0.002238 | 0.962539 | 0.000514 | 0.879239 | 0.001076 | 0.812845 | 0.103520 |
| 256 | 2 | 0.632035 | 0.004384 | 0.797129 | 0.000014 | 0.893944 | 0.003417 | 0.958731 | 0.001777 | 0.878091 | 0.000165 | 0.811994 | 0.102326 |
| 256 | 3 | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN |

# Preliminary $H^{\pm} \to \tau\nu$ Expected Limits



# Negative Monte Carlo Weights

- Limits seem to have spikes and dips at and above the top mass
- Noticed some weird values for our pileup weights
    - NOMINAL_pileup_combined_weight
- Only occurs in signal samples
    - No selections made, pulled directly from signal ntuples

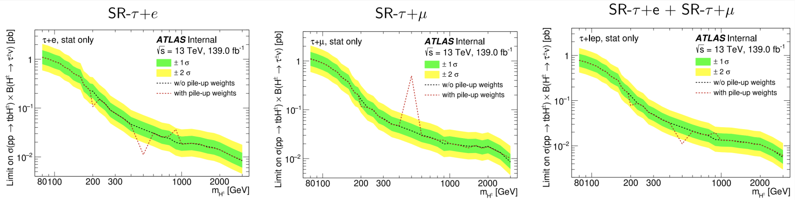
pileup_distributions.png

abs_pileup_weights_distributions_log.png

pileup_histogram.png

# Weight Strategy

- Large absolute values come from very small mc weights
  - $PUW = \frac{X}{mcweight}$
  - Incorrect signal mc weights were applied in high mass region when originally generated
  - Bad weights interact very negatively with pileup reweighting tool
- Pileup Weight (PUW) strategy finalized
  - Applying a cut that encompasses full lower mass PUW distributions
    - $0 \geq PUW \leq 2.5$
  - Setting all values outside of threshold to 1



## Continuing Work

- MC/Background agreement studies and reweighting are undergoing finalizing
  - Reweighting $t\bar{t}$ backgrounds due to generator mismodelling of high jet multiplicity
  - Fake factor studies
  - Including systematic uncertainties
- Systematic studies
  - PNN evaluation on systematic files
- Partial unblinding of low PNN score areas
  - Iterating with Editorial Board on strategy and preliminary results
- Finish Internal Note
  - Iterating with Editorial Board
- Make Public Note
- Paper publication
  - Targeted for July, 2022

# Conclusion

# Thank You

CERN_globe.jpeg

# PS: I was also an underground ATLAS tour guide!

WillAndMeAtATLAS.jpg

ATLAS_Tour.jpg

# Backup

# Tile

# ATLAS Data Flow

ATLASDataFlowChart.png

# Signals

# $H^{\pm}$ Signals

| $H^{\pm}$ Mass | Production Mechanism | Decay | Main Background |
|---|---|---|---|
| $m_{H^{\pm}} < m_t$ | double-resonant $t \rightarrow H^{\pm}b$ (LO)<br>double_resonant_production_l | $H^{\pm} \rightarrow \tau\nu$<br>(low $tan(\beta) \implies H^{\pm} \rightarrow cs$ or $H^{\pm} \rightarrow cb$ ) | $t\bar{t}$, single-top |
| $m_{H^{\pm}} \simeq m_t$ | non-resonant $t \rightarrow H^{\pm}b$ (LO)<br>non_resonant_production_intermediate_mass.png<br>interferences taken into account | $H^{\pm} \rightarrow \tau\nu$ | $t\bar{t}$ ,single-top |
| $m_{H^{\pm}} > m_t$ | single-resonant $gg \rightarrow tbH^{\pm}$ (NLO)<br>single_resonant_production_l | $H^{\pm} \rightarrow tb$<br>($cos(\beta - \alpha) \simeq 0$ and large $tan(\beta) \implies H^{\pm} \rightarrow \tau\nu$<br>$BR(H^{\pm} \rightarrow \tau\nu) \simeq 10 - 15\%$ ) | multi-jet |

# Branching Ratio of $H^{\pm}$

Charged_Higgs_BR.png

# Object Definitions

# $\tau$ ID Working Point Definitions

TauIDWP.png

# Object Selection

# Object Selection

| Object | $\tau + jets$ | $\tau + \ell$ |
|---|---|---|
| $\tau$ | Leading reconstructed $\tau$ (regardless of its ID), mediumID$^*$, $p_T > 40$ GeV, $\lvert\eta\rvert^{***} < 2.3$, $e$ OLR | Leading reconstructed $\tau$ (regardless of its ID), mediumID$^*$, $p_T > 30$ GeV, $\lvert\eta\rvert^{***} < 2.3$, $e$ OLR |
| $e$ | LoseLLH, $p_T > 20$ GeV, $\lvert\eta\rvert^{***} < 2.47$, Loose isolation, IP cuts | TightLLH, $p_T > 30$ GeV, $\lvert\eta\rvert^{***} < 2.47$, Tight isolation, IP cuts |
| $\mu$ | LooseID, $p_T > 20$ GeV, $\lvert\eta\rvert < 2.5$, Loose isolation, IP cuts | TightID, $p_T > 30$ GeV, $\lvert\eta\rvert < 2.5$, Tight isolation, IP cuts |
| jet | AntiKt4EMPFlow, $p_T > 25$, GeV $\lvert\eta\rvert < 2.5$, JVT$^{**} > 0.59$, Btag=70%, DL1r | AntiKt4EMPFlow, $p_T > 25$ GeV, $\lvert\eta\rvert < 2.5$, JVT$^{**} > 0.59$ , Btag=70%, DL1r |

- $\tau$ mediumID$^*$
  - 1-prong: 75% ID eff
  - 3-prong: 60% ID eff
- JVT$^{**}$
  - $p_T < 60$ GeV
  - $|\eta| < 2.4$
- $|\eta|^{***}$
  - $1.37 < |eta| < 1.52$ excluded

# Region Definitions

# Signal Region Definitions

| $\tau + jets$ **SR** | $\tau + \ell$ **SR** |
|---|---|
| $E_T^{miss}$ Trigger (mostly HLT_xe110) | Single lepton trigger (e or $\mu$) |
| 1 hadronic $\tau$ | 1 hadronic $\tau$ |
| $p_T^{\tau} > 40$ GeV | $p_T^{\tau} > 30$ GeV |
| 0 $\ell$ (e or $\mu$) | 1 $\ell$ (e or $\mu$) |
| $p_T^{\ell} > 20$ GeV | $p_T^{\ell} > 30$ GeV |
| $\geq 3$ jets | $\geq 1$ jet |
| $p_T^{j} > 25$ GeV | $p_T^{j} > 25$ GeV |
| $\geq 1$ b-jets | $\geq 1$ b-jets |
| $p_T^{b-jet} > 25$ GeV | $p_T^{b-jet} > 25$ GeV |
| $E_{\mathrm{T}}^{\mathrm{miss}} > 150$ GeV | $E_{\mathrm{T}}^{\mathrm{miss}} > 50$ GeV |
| $m_T(\tau, E_T^{miss}) > 50$ GeV | Opposite sign $\tau$ and $\ell$ |

# $\tau + jets$ Region Definitions

| $t\bar{t}$ **CR** ($t\bar{t}$ modeling) |
|---|
| 1 hadronic $\tau$ |
| $p_T^\tau > 40$ GeV |
| $\geq 3$ jets |
| $\geq 2$ b-jets |
| $E_T^{miss} > 150 GeV$ |
| $m_T(\tau, E_T^{miss}) < 100\ GeV$ |

| **W+Jets CR** (W+Jets modeling) |
|---|
| 1 hadronic $\tau$ |
| $p_T^\tau > 40\ GeV$ |
| $\geq 3$ jets |
| $p_T^{jet} > 25\ GeV$ |
| $E_T^{miss} > 150 GeV$ |
| $m_T(\tau, E_T^{miss}) > 100\ GeV$ |
| b veto |
| $\ell$ veto |

| **b-veto CR** (Close to SR) |
|---|
| 1 hadronic $\tau$ |
| $p_T^\tau > 40\ GeV$ |
| $\geq 3$ jets |
| $p_T^{jet} > 25\ GeV$ |
| $E_T^{miss} > 150 GeV$ |
| $m_T(\tau, E_T^{miss}) > 50\ GeV$ |
| b veto |
| $\ell$ veto |

| **b-veto** $m_T \geq 100$ **CR** (Fake enriched region) |
|---|
| 1 hadronic $\tau$ |
| $p_T^\tau > 40\ GeV$ |
| $\geq 3$ jets |
| $p_T^{jet} > 25\ GeV$ |
| $E_T^{miss} > 150 GeV$ |
| $m_T(\tau, E_T^{miss}) > 100\ GeV$ |
| b veto |
| $\ell$ veto |

# $\tau + \ell$ Region Definitions

| **Dilepton-btag CR** ($t\bar{t}$ modeling, used in fit) |
|---|
| $\tau$ veto |
| $n \geq 1$ jets |
| $p_T^{jet} > 25 GeV$ |
| $\geq 1$ b-jets |
| $E_{\mathrm{T}}^{\mathrm{miss}} > 50 GeV$ |
| 1 $e$ |
| 1 $\mu$ |

| **b-veto CR** (Close to SR) |
|---|
| 1 hadronic $\tau$ |
| $p_T^{\tau} > 30$ $GeV$ |
| 1 $e(\mu)$ |
| Veto $\mu$ ($e$) |
| Opposite sign $\tau$ $e$ ($\mu$) |
| $\geq 1$ jets |
| $p_T^{jet} > 25 GeV$ |
| $E_{\mathrm{T}}^{\mathrm{miss}} > 50 GeV$ |
| 1 tight $e$ ($\mu$) |

| **Zee CR** (Fake enriched region) |
|---|
| 1 hadronic $\tau$ |
| $p_T^{\tau} > 30$ $GeV$ |
| veto $\mu$ |
| Opposite sign $\tau$ $e$ |
| $\geq 1$ jets |
| $p_T^{jet} > 25 GeV$ |
| bjet veto |
| $E_{\mathrm{T}}^{\mathrm{miss}} > 50 GeV$ |
| 1 $e$ |
| $40 < mass(\tau, e) < 140 GeV$ |

| **Same Sign CR** (Fake enriched region) |
|---|
| 1 hadronic $\tau$ |
| $p_T^{\tau} > 30$ $GeV$ |
| Same sign $\tau$ $e(\mu)$ |
| Veto $\mu$ ($e$) |
| $n\_jets \geq 1$ |
| $p_T(jet) > 25 GeV$ |
| $E_{\mathrm{T}}^{\mathrm{miss}} > 50 GeV$ |
| 1 tight $e$ ($\mu$) |

# PNN

# kFold Method

kFoldDiagram.pdf

# Comparing kFolds (80 GeV, given BKG)

80GeV_Fold0.png 80GeV_Fold1.png 80GeV_Fold2.png 80GeV_Fold3.png 80GeV_Fold4.png

# Comparing kFolds (80 GeV, given SIG)

80GeV_Fold0_SIG.png

80GeV_Fold1_SIG.png

80GeV_Fold2_SIG.png

80GeV_Fold3_SIG.png

80GeV_Fold4_SIG

# Comparing kFolds (3000 GeV, given SIG)

3000GeV_Fold0_SIG.png 3000GeV_Fold1_SIG.png 3000GeV_Fold2_SIG.png 3000GeV_Fold3_SIG.png 3000GeV_Fold4_S

- May have gotten bkg/sig labels backwards :)

# Preliminary PNN Results $\tau + e$ SR

# Preliminary PNN Results $\tau + \mu$ SR

Scores/taulep/myOutDirClf

Scores/taulep/myOutDirClf

Scores/taulep/myOutDirClf

Scores/taulep/myOutDirClf

Scores/taulep/myOutDirClf

Scores/taulep/myOutDirClf

# Pileup Weights

# Pileup Weights Distributions

pileup_histo.png

pileup_histo_zoomed.png

# Pileup Weights Statistics

| | 80 | 90 | 100 | 110 | 120 | 130 | 140 | 150 | 160 | 170 | 180 | 190 | 200 | 225 | 250 | 275 | 300 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| count | 80844.000000 | 81658.000000 | 83016.000000 | 84173.000000 | 86004.000000 | 86958.000000 | 85136.000000 | 84247.000000 | 82619.000000 | 84875.000000 | 86097.000000 | 86257.000000 | 40284.000000 | 40886.000000 | 41792.000000 | 42556.000000 | 42978.000000 |
| mean | 1.001054 | 1.001780 | 1.000126 | 1.001323 | 1.000811 | 1.002053 | 0.999559 | 0.998034 | 0.996655 | 0.999633 | 0.999488 | 0.999026 | 0.508634 | 1.010265 | 1.099422 | 1.014135 | 1.014974 |
| std | 0.253943 | 0.253156 | 0.254526 | 0.253217 | 0.252664 | 0.251347 | 0.255629 | 0.257582 | 0.258068 | 0.254013 | 0.255667 | 0.255854 | 17.490118 | 0.288834 | 6.412658 | 0.339309 | 0.356573 |
| min | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | -610.129272 | -0.445639 | -1.273962 | -1.206831 | -1.760294 |
| 25% | 0.920860 | 0.921549 | 0.921623 | 0.921557 | 0.921378 | 0.921159 | 0.921536 | 0.920747 | 0.921333 | 0.923230 | 0.920085 | 0.920768 | 0.900776 | 0.885019 | 0.934779 | 0.922488 | 0.943855 |
| 50% | 1.079184 | 1.081243 | 1.079326 | 1.079540 | 1.080067 | 1.080879 | 1.079532 | 1.079685 | 1.080971 | 1.079383 | 1.080233 | 1.080472 | 1.060562 | 1.064517 | 1.041212 | 1.063800 | 1.046314 |
| 75% | 1.148908 | 1.155570 | 1.150078 | 1.156189 | 1.149427 | 1.150257 | 1.149785 | 1.149956 | 1.150023 | 1.149662 | 1.151101 | 1.150765 | 1.165013 | 1.178183 | 1.187810 | 1.207834 | 1.167239 |
| 95% | 1.205099 | 1.203470 | 1.204149 | 1.204069 | 1.203694 | 1.203698 | 1.205689 | 1.203701 | 1.204432 | 1.204153 | 1.202932 | 1.205496 | 1.315114 | 1.390322 | 1.320100 | 1.326961 | 1.355505 |
| max | 2.409515 | 2.389924 | 2.411615 | 2.404698 | 2.393531 | 2.405815 | 2.386079 | 2.406105 | 2.400672 | 2.398967 | 2.392730 | 2.376339 | 28.892088 | 3.133942 | 464.072968 | 8.240099 | 17.410671 |

| | 350 | 400 | 500 | 600 | 700 | 800 | 900 | 1000 | 1200 | 1400 | 1600 | 1800 | 2000 | 2500 | 3000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| count | 43798.000000 | 44565.000000 | 45412.000000 | 45469.000000 | 45321.000000 | 45464.000000 | 45156.000000 | 43913.000000 | 44639.000000 | 43592.000000 | 43273.000000 | 42691.000000 | 42769.000000 | 41885.000000 | 40783.000000 |
| mean | 1.006303 | 1.023722 | 0.591891 | 1.020003 | 1.006465 | 1.008190 | 0.926411 | 1.016459 | 1.021096 | 1.018929 | 1.011275 | 1.021495 | 1.006681 | 1.027024 | 1.054152 |
| std | 0.325241 | 0.590001 | 28.165703 | 0.393464 | 0.305804 | 1.520343 | 4.324449 | 0.346823 | 0.410831 | 0.771618 | 0.514045 | 0.328171 | 0.453343 | 0.314811 | 2.333855 |
| min | -7.745956 | -0.068810 | -1897.117554 | -3.842706 | -3.495028 | -127.155434 | -209.416672 | -5.508759 | -0.557234 | -40.070904 | -15.846775 | -1.963920 | -11.616090 | -1.816558 | -2.588256 |
| 25% | 0.880324 | 0.922226 | 0.900143 | 0.933184 | 0.905355 | 0.907488 | 0.940907 | 0.900577 | 0.924895 | 0.932238 | 0.891818 | 0.927121 | 0.909429 | 0.928094 | 0.920930 |
| 50% | 1.067698 | 1.043523 | 1.057348 | 1.062986 | 1.040850 | 1.022655 | 1.068709 | 1.080882 | 1.039005 | 1.053244 | 1.050301 | 1.053411 | 1.040414 | 1.068602 | 1.037835 |
| 75% | 1.176714 | 1.174688 | 1.188619 | 1.166802 | 1.191314 | 1.184892 | 1.165839 | 1.181656 | 1.163044 | 1.164395 | 1.189937 | 1.157566 | 1.193018 | 1.166120 | 1.161961 |
| 95% | 1.360068 | 1.336481 | 1.326447 | 1.296390 | 1.347952 | 1.450452 | 1.356199 | 1.408593 | 1.391922 | 1.416487 | 1.371108 | 1.371884 | 1.398844 | 1.420707 | 1.432250 |
| max | 3.044234 | 19.576925 | 1.687775 | 8.729278 | 3.958143 | 9.343400 | 2.870858 | 5.665573 | 17.634136 | 26.660934 | 20.727751 | 5.528868 | 3.841987 | 4.248174 | 175.623535 |

# Preliminary PNN Results with No Pileup Weights

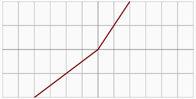
# Preliminary PNN Results with No Pileup Weights

Scores/taujet/rnnTest_1p_3

Scores/taulep/myOutDirClfE

# PNN Hyperparameter Search

# Activation and Loss Functions



LeakyReLu

Hinge_LossFunction.png
Hinge Loss

Hinge_Squared_lossFunctio
Squared Hinge Loss

Binary_Crossentropy_LossF
Binary Cross
Entropy Loss

# PNN Hyperparameter Search Results

| dense_layer_size | activation_function | dropout | batch_size | epochs | depth | loss_function | alpha | 100 | 1000 | 1000Std | 100Std | 110 | 110Std | … | 900 | 900Std | 90Std | Avg | AvgStd |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 128 | LeakyRelu | 0.1 | 1024 | 1000 | 2 | binary_crossentropy | 0.050 | 0.675354 | 0.988841 | 0.001601 | 0.003291 | 0.699657 | 0.004528 | … | 0.985760 | 0.000463 | 0.004433 | 0.886284 | 0.000155 |
| 128 | LeakyRelu | 0.1 | 1024 | 1000 | 3 | binary_crossentropy | 0.050 | 0.679473 | 0.989161 | 0.001413 | 0.005557 | 0.702593 | 0.003978 | … | 0.985901 | 0.000787 | 0.003013 | 0.886223 | 0.000477 |
| 128 | LeakyRelu | 0.1 | 1024 | 1000 | 4 | binary_crossentropy | 0.050 | 0.675702 | 0.989347 | 0.001652 | 0.005289 | 0.700170 | 0.003286 | … | 0.985907 | 0.000815 | 0.005959 | 0.885751 | 0.000413 |
| 128 | LeakyRelu | 0.1 | 1024 | 1000 | 2 | binary_crossentropy | 0.010 | 0.674119 | 0.988726 | 0.001530 | 0.005967 | 0.699226 | 0.003525 | … | 0.985769 | 0.000535 | 0.004433 | 0.885717 | 0.000366 |
| 128 | LeakyRelu | 0.1 | 1024 | 1000 | 4 | binary_crossentropy | 0.001 | 0.677169 | 0.989606 | 0.001393 | 0.007265 | 0.700208 | 0.003482 | … | 0.986028 | 0.000687 | 0.003813 | 0.885651 | 0.000664 |
| 128 | LeakyRelu | 0.1 | 1024 | 1000 | 3 | binary_crossentropy | 0.010 | 0.677337 | 0.989180 | 0.001447 | 0.006111 | 0.699528 | 0.004680 | … | 0.986043 | 0.000469 | 0.006227 | 0.885645 | 0.000430 |
| 128 | LeakyRelu | 0.1 | 1024 | 1000 | 2 | binary_crossentropy | 0.005 | 0.672798 | 0.988891 | 0.001416 | 0.007853 | 0.698829 | 0.004816 | … | 0.985858 | 0.000548 | 0.003968 | 0.885438 | 0.000724 |
| 128 | LeakyRelu | 0.1 | 1024 | 1000 | 2 | binary_crossentropy | 0.001 | 0.676020 | 0.988712 | 0.001508 | 0.005354 | 0.698812 | 0.003865 | … | 0.985851 | 0.000984 | 0.002317 | 0.885428 | 0.000231 |
| 64 | LeakyRelu | 0.1 | 1024 | 1000 | 3 | binary_crossentropy | 0.005 | 0.676475 | 0.989748 | 0.001420 | 0.006405 | 0.699184 | 0.004397 | … | 0.985872 | 0.000448 | 0.005710 | 0.885304 | 0.000129 |
| 64 | LeakyRelu | 0.1 | 1024 | 1000 | 4 | binary_crossentropy | 0.050 | 0.679112 | 0.989307 | 0.001660 | 0.006506 | 0.699347 | 0.003593 | … | 0.985807 | 0.000537 | 0.006672 | 0.885302 | 0.000910 |
| 64 | LeakyRelu | 0.1 | 1024 | 1000 | 3 | binary_crossentropy | 0.010 | 0.678008 | 0.989513 | 0.001472 | 0.005217 | 0.698716 | 0.002866 | … | 0.985915 | 0.000479 | 0.004274 | 0.885230 | 0.000433 |
| 64 | LeakyRelu | 0.1 | 1024 | 1000 | 2 | binary_crossentropy | 0.050 | 0.676305 | 0.989213 | 0.001529 | 0.007167 | 0.699310 | 0.003670 | … | 0.985754 | 0.000662 | 0.003771 | 0.885399 | 0.000474 |
| 128 | LeakyRelu | 0.1 | 1024 | 1000 | 4 | binary_crossentropy | 0.005 | 0.674899 | 0.988656 | 0.001406 | 0.005074 | 0.699264 | 0.004034 | … | 0.985863 | 0.000228 | 0.002997 | 0.885009 | 0.000735 |
| 64 | LeakyRelu | 0.1 | 1024 | 1000 | 2 | binary_crossentropy | 0.005 | 0.675374 | 0.989078 | 0.001514 | 0.007579 | 0.697086 | 0.004142 | … | 0.986063 | 0.000653 | 0.002944 | 0.884990 | 0.000519 |
| 64 | LeakyRelu | 0.1 | 1024 | 1000 | 3 | binary_crossentropy | 0.050 | 0.675319 | 0.989642 | 0.001483 | 0.007403 | 0.697994 | 0.004439 | … | 0.985773 | 0.000614 | 0.002778 | 0.884990 | 0.000253 |
| 128 | LeakyRelu | 0.1 | 1024 | 1000 | 3 | binary_crossentropy | 0.001 | 0.675327 | 0.989316 | 0.001412 | 0.007454 | 0.697732 | 0.003169 | … | 0.985852 | 0.000657 | 0.003712 | 0.884939 | 0.000325 |
| 128 | LeakyRelu | 0.1 | 1024 | 1000 | 4 | binary_crossentropy | 0.010 | 0.670972 | 0.988877 | 0.001351 | 0.006667 | 0.698059 | 0.002821 | … | 0.985853 | 0.000569 | 0.002058 | 0.884749 | 0.000367 |
| 64 | LeakyRelu | 0.1 | 1024 | 1000 | 4 | binary_crossentropy | 0.010 | 0.673943 | 0.989374 | 0.001368 | 0.005307 | 0.697785 | 0.004704 | … | 0.985878 | 0.000751 | 0.005562 | 0.884734 | 0.000430 |
| 64 | LeakyRelu | 0.1 | 1024 | 1000 | 4 | binary_crossentropy | 0.005 | 0.675513 | 0.989584 | 0.001486 | 0.008425 | 0.698441 | 0.003499 | … | 0.985725 | 0.000806 | 0.003204 | 0.884685 | 0.000728 |
| 64 | LeakyRelu | 0.1 | 1024 | 1000 | 2 | binary_crossentropy | 0.010 | 0.676252 | 0.989619 | 0.001260 | 0.007249 | 0.697642 | 0.001884 | … | 0.985871 | 0.000759 | 0.004734 | 0.884640 | 0.000509 |
| 64 | LeakyRelu | 0.1 | 1024 | 1000 | 3 | binary_crossentropy | 0.001 | 0.675812 | 0.989723 | 0.001210 | 0.006366 | 0.697156 | 0.003174 | … | 0.985927 | 0.000792 | 0.005927 | 0.884570 | 0.000278 |
| 64 | LeakyRelu | 0.1 | 1024 | 1000 | 2 | binary_crossentropy | 0.001 | 0.674691 | 0.989216 | 0.001673 | 0.007183 | 0.696982 | 0.003235 | … | 0.985630 | 0.000592 | 0.003090 | 0.884540 | 0.000561 |
| 128 | LeakyRelu | 0.1 | 1024 | 1000 | 3 | binary_crossentropy | 0.005 | 0.672696 | 0.988897 | 0.001547 | 0.004248 | 0.696299 | 0.002851 | … | 0.985969 | 0.000442 | 0.007895 | 0.884512 | 0.001005 |
| 64 | LeakyRelu | 0.1 | 1024 | 1000 | 4 | binary_crossentropy | 0.001 | 0.673248 | 0.989397 | 0.001482 | 0.006594 | 0.695754 | 0.004270 | … | 0.985548 | 0.000420 | 0.003493 | 0.883645 | 0.001434 |
| 32 | LeakyRelu | 0.1 | 1024 | 1000 | 3 | binary_crossentropy | 0.050 | 0.668895 | 0.989221 | 0.001369 | 0.005375 | 0.689845 | 0.002351 | … | 0.985728 | 0.000359 | 0.003486 | 0.882044 | 0.000412 |
| 32 | LeakyRelu | 0.1 | 1024 | 1000 | 4 | binary_crossentropy | 0.050 | 0.667735 | 0.988979 | 0.001478 | 0.004895 | 0.688598 | 0.002426 | … | 0.985511 | 0.000536 | 0.004979 | 0.881824 | 0.000294 |
| 32 | LeakyRelu | 0.1 | 1024 | 1000 | 2 | binary_crossentropy | 0.005 | 0.671241 | 0.989198 | 0.001356 | 0.007668 | 0.690885 | 0.003381 | … | 0.985370 | 0.000427 | 0.001915 | 0.881778 | 0.001118 |
| 32 | LeakyRelu | 0.1 | 1024 | 1000 | 4 | binary_crossentropy | 0.010 | 0.666860 | 0.988451 | 0.001466 | 0.003635 | 0.690436 | 0.003976 | … | 0.985354 | 0.000695 | 0.003577 | 0.881668 | 0.000278 |
| 32 | LeakyRelu | 0.1 | 1024 | 1000 | 4 | binary_crossentropy | 0.005 | 0.668348 | 0.989281 | 0.001490 | 0.007594 | 0.690928 | 0.003102 | … | 0.985910 | 0.000466 | 0.005629 | 0.881666 | 0.000616 |
| 32 | LeakyRelu | 0.1 | 1024 | 1000 | 3 | binary_crossentropy | 0.001 | 0.667010 | 0.989757 | 0.001410 | 0.006797 | 0.688926 | 0.005730 | … | 0.985699 | 0.000714 | 0.005208 | 0.881618 | 0.000815 |
| 32 | LeakyRelu | 0.1 | 1024 | 1000 | 2 | binary_crossentropy | 0.001 | 0.668533 | 0.988926 | 0.001580 | 0.005990 | 0.690975 | 0.003715 | … | 0.985274 | 0.000715 | 0.004177 | 0.881581 | 0.000641 |
| 32 | LeakyRelu | 0.1 | 1024 | 1000 | 2 | binary_crossentropy | 0.010 | 0.668831 | 0.989272 | 0.001580 | 0.007441 | 0.690039 | 0.002666 | … | 0.985466 | 0.000794 | 0.006708 | 0.881545 | 0.001193 |
| 32 | LeakyRelu | 0.1 | 1024 | 1000 | 2 | binary_crossentropy | 0.050 | 0.666606 | 0.988768 | 0.001560 | 0.005963 | 0.690456 | 0.002258 | … | 0.985498 | 0.000919 | 0.005389 | 0.881527 | 0.000290 |
| 32 | LeakyRelu | 0.1 | 1024 | 1000 | 3 | binary_crossentropy | 0.010 | 0.670208 | 0.989975 | 0.001153 | 0.006664 | 0.688434 | 0.004370 | … | 0.985734 | 0.000487 | 0.002686 | 0.881467 | 0.000913 |
| 32 | LeakyRelu | 0.1 | 1024 | 1000 | 3 | binary_crossentropy | 0.005 | 0.666117 | 0.989592 | 0.001748 | 0.006474 | 0.689812 | 0.004397 | … | 0.985814 | 0.000594 | 0.004067 | 0.881372 | 0.000452 |
| 32 | LeakyRelu | 0.1 | 1024 | 1000 | 4 | binary_crossentropy | 0.001 | 0.662353 | 0.989750 | 0.001149 | 0.007869 | 0.682127 | 0.000018 | … | 0.985387 | 0.000284 | 0.000284 | 0.879930 | 0.000408 |

# PNN Hyperparameter Search Results

| dense_layer_size | activation_function | dropout | batch_size | epochs | depth | loss_function | 100 | 1000 | 1000Std | 100Std | 110 | 110Std | 120 | 1200 | 1200Std | 120Std | 130 | 130Std | 140 | 1400 | 1400Std | 140Std | 150 | 150Std | 160 | 1600 | 1600Std | 160Std | 170 | 170Std | 180 | 1800 | 1800Std | 180Std | 190 | 190Std | 200 | 2000 | 2000Std | 200Std | 225 | 225Std | 250 | 2500 | 2500Std | 250Std | 275 | 275Std | 300 | 3000 | 3000Std | 300Std | 350 | 350Std | 400 | 400Std | 500 | 500Std | 600 | 600Std | 700 | 700Std | 80 | 800 | 800Std | 80Std | 90 | 900 | 900Std | 90Std | Avg | AvgStd |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | softsign | 0.1 | 1024 | 1000 | 3 | binary_crossentropy | 0.668442 | 0.988357 | 0.001511 | 0.006622 | 0.690576 | 0.004482 | 0.718379 | 0.991058 | 0.001112 | 0.005303 | 0.740013 | 0.004053 | 0.784814 | 0.993403 | 0.001679 | 0.004966 | 0.803365 | 0.001858 | 0.812240 | 0.995645 | 0.000777 | 0.002880 | 0.816757 | 0.003086 | 0.828559 | 0.995721 | 0.000426 | 0.004517 | 0.838446 | 0.001325 | 0.863275 | 0.996492 | 0.000458 | 0.003562 | 0.886628 | 0.003376 | 0.897851 | 0.998251 | 0.000378 | 0.003856 | 0.913150 | 0.002921 | 0.921732 | 0.998515 | 0.000495 | 0.002362 | 0.937733 | 0.000715 | 0.947028 | 0.001373 | 0.962236 | 0.001992 | 0.971575 | 0.001038 | 0.976836 | 0.001990 | 0.641818 | 0.982109 | 0.003389 | 0.006826 | 0.655557 | 0.985016 | 0.000608 | 0.003989 | 0.881299 | 0.000716 |
| 32 | softsign | 0.3 | 1024 | 1000 | 3 | binary_crossentropy | 0.653746 | 0.988558 | 0.001361 | 0.004163 | 0.679953 | 0.003337 | 0.707064 | 0.990733 | 0.000454 | 0.001268 | 0.730226 | 0.001862 | 0.774637 | 0.993838 | 0.001774 | 0.003781 | 0.793437 | 0.001823 | 0.804621 | 0.995546 | 0.000624 | 0.004416 | 0.807830 | 0.003220 | 0.818365 | 0.995474 | 0.000393 | 0.004944 | 0.830249 | 0.002090 | 0.855010 | 0.996453 | 0.000471 | 0.002390 | 0.878366 | 0.003441 | 0.890352 | 0.998039 | 0.000329 | 0.003512 | 0.907321 | 0.002933 | 0.916719 | 0.998095 | 0.000315 | 0.003062 | 0.934864 | 0.001072 | 0.944070 | 0.001621 | 0.960376 | 0.001966 | 0.971445 | 0.000933 | 0.977188 | 0.001573 | 0.621125 | 0.982132 | 0.000488 | 0.005800 | 0.638292 | 0.985106 | 0.000430 | 0.007701 | 0.875601 | 0.000659 |
| 16 | softsign | 0.1 | 1024 | 1000 | 3 | binary_crossentropy | 0.655997 | 0.987596 | 0.001229 | 0.002745 | 0.680095 | 0.004247 | 0.705529 | 0.990967 | 0.000895 | 0.002583 | 0.725768 | 0.002949 | 0.772331 | 0.994043 | 0.001418 | 0.003612 | 0.792100 | 0.003056 | 0.802440 | 0.995247 | 0.000294 | 0.003066 | 0.806811 | 0.004242 | 0.816051 | 0.995783 | 0.000514 | 0.002932 | 0.828268 | 0.001865 | 0.856238 | 0.996659 | 0.000441 | 0.004203 | 0.878907 | 0.002681 | 0.890819 | 0.998333 | 0.000320 | 0.002865 | 0.907295 | 0.002587 | 0.917254 | 0.998525 | 0.000494 | 0.002319 | 0.935111 | 0.000738 | 0.944825 | 0.001623 | 0.960553 | 0.001933 | 0.970633 | 0.001365 | 0.975891 | 0.001978 | 0.623440 | 0.981435 | 0.000792 | 0.004699 | 0.636652 | 0.984664 | 0.000850 | 0.003593 | 0.875188 | 0.000456 |
| 16 | softsign | 0.3 | 1024 | 1000 | 5 | binary_crossentropy | 0.647180 | 0.986892 | 0.001186 | 0.004798 | 0.671307 | 0.004396 | 0.695754 | 0.990380 | 0.000880 | 0.004176 | 0.715194 | 0.007183 | 0.762777 | 0.993642 | 0.001581 | 0.005121 | 0.781373 | 0.004100 | 0.794602 | 0.994854 | 0.000447 | 0.004169 | 0.798966 | 0.002506 | 0.808438 | 0.995314 | 0.000516 | 0.004209 | 0.822063 | 0.002473 | 0.846855 | 0.996484 | 0.000435 | 0.002675 | 0.870000 | 0.004009 | 0.883128 | 0.997757 | 0.000417 | 0.003875 | 0.901425 | 0.003365 | 0.912662 | 0.998150 | 0.000604 | 0.003252 | 0.930468 | 0.000683 | 0.941385 | 0.002855 | 0.958130 | 0.001977 | 0.968829 | 0.001755 | 0.974710 | 0.001802 | 0.618814 | 0.980018 | 0.001271 | 0.010135 | 0.630757 | 0.983897 | 0.001113 | 0.001761 | 0.870381 | 0.000998 |
| 16 | softsign | 0.3 | 1024 | 1000 | 3 | binary_crossentropy | 0.644435 | 0.986483 | 0.001150 | 0.007903 | 0.671590 | 0.004579 | 0.696296 | 0.990789 | 0.000836 | 0.003696 | 0.716796 | 0.004453 | 0.759628 | 0.993163 | 0.001130 | 0.002494 | 0.781767 | 0.001288 | 0.794978 | 0.994829 | 0.000609 | 0.002712 | 0.799068 | 0.001334 | 0.807917 | 0.995861 | 0.000344 | 0.004596 | 0.821835 | 0.001136 | 0.845840 | 0.996653 | 0.000256 | 0.004087 | 0.870877 | 0.003974 | 0.883798 | 0.997824 | 0.000469 | 0.004131 | 0.900029 | 0.003596 | 0.913155 | 0.998561 | 0.000457 | 0.001637 | 0.930484 | 0.001404 | 0.941495 | 0.003439 | 0.957174 | 0.002916 | 0.968854 | 0.001304 | 0.973618 | 0.001222 | 0.621499 | 0.980468 | 0.003087 | 0.003911 | 0.628716 | 0.983340 | 0.001128 | 0.002161 | 0.870244 | 0.000979 |
| 16 | softsign | 0.1 | 1024 | 1000 | 5 | binary_crossentropy | 0.645694 | 0.985481 | 0.001816 | 0.002152 | 0.668081 | 0.003315 | 0.691447 | 0.989579 | 0.001084 | 0.004148 | 0.713557 | 0.004289 | 0.761942 | 0.993057 | 0.001876 | 0.006806 | 0.782681 | 0.002684 | 0.793885 | 0.994547 | 0.000586 | 0.001630 | 0.798806 | 0.002056 | 0.808965 | 0.995003 | 0.000561 | 0.005010 | 0.821742 | 0.003023 | 0.846200 | 0.995827 | 0.000220 | 0.001971 | 0.870132 | 0.002069 | 0.882750 | 0.997172 | 0.000323 | 0.003973 | 0.900452 | 0.004536 | 0.911960 | 0.997684 | 0.000720 | 0.002012 | 0.930176 | 0.001703 | 0.941307 | 0.002336 | 0.956925 | 0.001926 | 0.968440 | 0.001278 | 0.973711 | 0.002412 | 0.610807 | 0.979737 | 0.000909 | 0.004377 | 0.625291 | 0.983371 | 0.001307 | 0.007418 | 0.869263 | 0.001224 |
| 32 | softsign | 0.1 | 1024 | 1000 | 5 | binary_crossentropy | 0.643437 | 0.985523 | 0.001776 | 0.008956 | 0.666397 | 0.005757 | 0.694091 | 0.987247 | 0.000820 | 0.004827 | 0.717189 | 0.001264 | 0.760713 | 0.990947 | 0.001688 | 0.006486 | 0.781625 | 0.002411 | 0.793207 | 0.992956 | 0.001581 | 0.006175 | 0.795608 | 0.004721 | 0.806643 | 0.993699 | 0.000560 | 0.004429 | 0.817200 | 0.002973 | 0.844899 | 0.994820 | 0.000761 | 0.006898 | 0.867366 | 0.005296 | 0.881593 | 0.996631 | 0.000366 | 0.007704 | 0.897332 | 0.004825 | 0.906771 | 0.997048 | 0.000843 | 0.005495 | 0.925577 | 0.003667 | 0.935592 | 0.003610 | 0.952903 | 0.001789 | 0.965583 | 0.001838 | 0.972026 | 0.002905 | 0.608977 | 0.977801 | 0.001960 | 0.009666 | 0.624162 | 0.981233 | 0.001225 | 0.005321 | 0.867400 | 0.001973 |
| 8 | softsign | 0.1 | 1024 | 1000 | 3 | binary_crossentropy | 0.636834 | 0.986776 | 0.001677 | 0.005238 | 0.660658 | 0.002078 | 0.685136 | 0.990081 | 0.001133 | 0.004324 | 0.703508 | 0.005078 | 0.749116 | 0.993143 | 0.001387 | 0.007341 | 0.767433 | 0.002338 | 0.782062 | 0.994639 | 0.001027 | 0.004296 | 0.787192 | 0.006804 | 0.799003 | 0.995031 | 0.000834 | 0.006376 | 0.810510 | 0.006020 | 0.834586 | 0.996162 | 0.000631 | 0.001746 | 0.858749 | 0.003769 | 0.874413 | 0.997749 | 0.000651 | 0.003324 | 0.891675 | 0.003761 | 0.904144 | 0.998190 | 0.000914 | 0.001643 | 0.924848 | 0.002365 | 0.936351 | 0.002769 | 0.955801 | 0.002330 | 0.967295 | 0.001600 | 0.973956 | 0.002085 | 0.605839 | 0.979153 | 0.000772 | 0.004200 | 0.620809 | 0.982558 | 0.000933 | 0.008140 | 0.863856 | 0.001603 |
| 8 | softsign | 0.1 | 1024 | 1000 | 5 | binary_crossentropy | 0.638056 | 0.985707 | 0.001570 | 0.002179 | 0.661535 | 0.003128 | 0.683558 | 0.989670 | 0.001586 | 0.004386 | 0.702467 | 0.003950 | 0.750677 | 0.993269 | 0.001141 | 0.003686 | 0.768782 | 0.003841 | 0.780544 | 0.994468 | 0.000707 | 0.004815 | 0.785154 | 0.003559 | 0.796358 | 0.995209 | 0.000887 | 0.007071 | 0.809411 | 0.002981 | 0.833977 | 0.996439 | 0.000260 | 0.003351 | 0.857470 | 0.004177 | 0.873840 | 0.997583 | 0.000423 | 0.006136 | 0.890663 | 0.004876 | 0.902427 | 0.997970 | 0.000775 | 0.003805 | 0.923032 | 0.002685 | 0.934834 | 0.004802 | 0.954359 | 0.002943 | 0.965977 | 0.002136 | 0.972637 | 0.002438 | 0.604247 | 0.979054 | 0.000726 | 0.003257 | 0.618368 | 0.982740 | 0.000555 | 0.007027 | 0.863140 | 0.001629 |
| 8 | softsign | 0.3 | 1024 | 1000 | 3 | binary_crossentropy | 0.637388 | 0.986078 | 0.001470 | 0.002269 | 0.659872 | 0.004968 | 0.686025 | 0.989864 | 0.000951 | 0.002644 | 0.704439 | 0.003342 | 0.747343 | 0.993171 | 0.001774 | 0.005299 | 0.764948 | 0.004139 | 0.777480 | 0.994310 | 0.000783 | 0.001315 | 0.784106 | 0.003640 | 0.793221 | 0.994924 | 0.000625 | 0.005311 | 0.808002 | 0.001627 | 0.831467 | 0.996373 | 0.000599 | 0.002688 | 0.856036 | 0.001588 | 0.870232 | 0.997607 | 0.000618 | 0.001563 | 0.890324 | 0.004802 | 0.902235 | 0.998193 | 0.000701 | 0.001297 | 0.923321 | 0.000535 | 0.935512 | 0.002472 | 0.955093 | 0.003036 | 0.966195 | 0.001462 | 0.972950 | 0.002374 | 0.597386 | 0.979016 | 0.000569 | 0.013485 | 0.615102 | 0.982881 | 0.000949 | 0.003057 | 0.862222 | 0.000899 |
| 8 | softsign | 0.3 | 1024 | 1000 | 5 | binary_crossentropy | 0.635723 | 0.986647 | 0.001527 | 0.004333 | 0.658350 | 0.002147 | 0.682954 | 0.989402 | 0.000366 | 0.004772 | 0.702854 | 0.002904 | 0.748693 | 0.993145 | 0.001606 | 0.004326 | 0.764413 | 0.000887 | 0.777973 | 0.994639 | 0.000718 | 0.002286 | 0.781926 | 0.002537 | 0.793760 | 0.994728 | 0.000299 | 0.005216 | 0.805696 | 0.002848 | 0.830678 | 0.996068 | 0.000395 | 0.000970 | 0.854820 | 0.003767 | 0.869737 | 0.997663 | 0.000358 | 0.003241 | 0.889661 | 0.003830 | 0.901265 | 0.997860 | 0.000267 | 0.002789 | 0.922425 | 0.001094 | 0.934329 | 0.001913 | 0.954167 | 0.002341 | 0.967288 | 0.001248 | 0.973531 | 0.002004 | 0.605126 | 0.979367 | 0.000291 | 0.013554 | 0.621692 | 0.982879 | 0.000606 | 0.005559 | 0.862170 | 0.000173 |
| 32 | softsign | 0.3 | 1024 | 1000 | 5 | binary_crossentropy | 0.550333 | 0.953535 | 0.007299 | 0.017364 | 0.569416 | 0.021784 | 0.585717 | 0.962867 | 0.002592 | 0.020883 | 0.606464 | 0.022962 | 0.642706 | 0.967763 | 0.008970 | 0.022667 | 0.664346 | 0.024167 | 0.681104 | 0.973256 | 0.005186 | 0.026816 | 0.689708 | 0.023193 | 0.703617 | 0.977399 | 0.004432 | 0.029557 | 0.715346 | 0.027201 | 0.733878 | 0.977035 | 0.004265 | 0.025979 | 0.760046 | 0.028779 | 0.786209 | 0.982152 | 0.005361 | 0.024992 | 0.809506 | 0.021327 | 0.826407 | 0.983117 | 0.005024 | 0.020196 | 0.855419 | 0.015718 | 0.873175 | 0.008859 | 0.905889 | 0.005989 | 0.922750 | 0.003634 | 0.932514 | 0.005889 | 0.519045 | 0.939806 | 0.005439 | 0.011913 | 0.528606 | 0.947252 | 0.005271 | 0.015567 | 0.797700 | 0.011103 |
| 16 | softsign | 0.1 | 1024 | 1000 | 10 | binary_crossentropy | 0.500710 | 0.899289 | 0.009438 | 0.000553 | 0.501079 | 0.000399 | 0.502028 | 0.919352 | 0.002344 | 0.001721 | 0.503177 | 0.002713 | 0.505745 | 0.939880 | 0.003638 | 0.004409 | 0.508345 | 0.007144 | 0.511865 | 0.946513 | 0.005491 | 0.009714 | 0.514104 | 0.011389 | 0.518080 | 0.952531 | 0.001821 | 0.013222 | 0.521589 | 0.015227 | 0.525436 | 0.958214 | 0.002462 | 0.013412 | 0.542301 | 0.023692 | 0.558651 | 0.968208 | 0.004356 | 0.030383 | 0.585169 | 0.027092 | 0.604810 | 0.969850 | 0.002119 | 0.031812 | 0.650533 | 0.035174 | 0.688135 | 0.025851 | 0.758067 | 0.029904 | 0.805677 | 0.011061 | 0.844160 | 0.013887 | 0.500571 | 0.870996 | 0.011435 | 0.000584 | 0.501353 | 0.891590 | 0.010466 | 0.000112 | 0.686500 | 0.011191 |
| 8 | softsign | 0.1 | 1024 | 1000 | 10 | binary_crossentropy | 0.499407 | 0.904687 | 0.023260 | 0.000245 | 0.499833 | 0.000189 | 0.500084 | 0.917482 | 0.019572 | 0.001168 | 0.501294 | 0.002373 | 0.502922 | 0.936485 | 0.012625 | 0.004518 | 0.506044 | 0.007493 | 0.508484 | 0.943842 | 0.011366 | 0.010642 | 0.512435 | 0.012082 | 0.516712 | 0.949079 | 0.010173 | 0.015923 | 0.520746 | 0.020533 | 0.527292 | 0.954185 | 0.009346 | 0.027219 | 0.541653 | 0.034321 | 0.557857 | 0.966369 | 0.003605 | 0.041301 | 0.584694 | 0.049772 | 0.611068 | 0.968576 | 0.005231 | 0.048907 | 0.653721 | 0.055009 | 0.686397 | 0.049723 | 0.754327 | 0.045709 | 0.806712 | 0.052930 | 0.844700 | 0.036994 | 0.499510 | 0.872060 | 0.033446 | 0.000601 | 0.498517 | 0.895364 | 0.027494 | 0.001034 | 0.685704 | 0.020231 |
| 16 | softsign | 0.3 | 1024 | 1000 | 10 | binary_crossentropy | 0.500159 | 0.891440 | 0.017541 | 0.000839 | 0.500139 | 0.000814 | 0.500557 | 0.909662 | 0.033348 | 0.001467 | 0.501395 | 0.002158 | 0.503759 | 0.928202 | 0.010305 | 0.006221 | 0.505218 | 0.008521 | 0.508293 | 0.938625 | 0.007089 | 0.011619 | 0.511493 | 0.015253 | 0.513227 | 0.946602 | 0.004946 | 0.016931 | 0.515332 | 0.018482 | 0.519967 | 0.953012 | 0.003366 | 0.023645 | 0.535218 | 0.031615 | 0.551634 | 0.964811 | 0.005402 | 0.039491 | 0.567522 | 0.041036 | 0.586797 | 0.969737 | 0.003304 | 0.046972 | 0.630646 | 0.052947 | 0.664084 | 0.043949 | 0.734410 | 0.049371 | 0.785089 | 0.033888 | 0.820707 | 0.032726 | 0.499856 | 0.852898 | 0.022985 | 0.000345 | 0.499370 | 0.874562 | 0.019652 | 0.000640 | 0.677638 | 0.017595 |
| 8 | softsign | 0.3 | 1024 | 1000 | 10 | binary_crossentropy | 0.500247 | 0.887080 | 0.006448 | 0.000430 | 0.499955 | 0.000488 | 0.500751 | 0.906857 | 0.009243 | 0.000925 | 0.501173 | 0.001198 | 0.502064 | 0.929459 | 0.004895 | 0.002406 | 0.501988 | 0.002520 | 0.503715 | 0.935967 | 0.005510 | 0.002911 | 0.507333 | 0.005185 | 0.508334 | 0.946850 | 0.006866 | 0.005733 | 0.511246 | 0.006070 | 0.513822 | 0.952773 | 0.007173 | 0.004473 | 0.529829 | 0.006560 | 0.545125 | 0.964350 | 0.001978 | 0.007438 | 0.568606 | 0.000153 | 0.588148 | 0.970475 | 0.003361 | 0.002179 | 0.633810 | 0.004627 | 0.665205 | 0.000711 | 0.735476 | 0.001984 | 0.785666 | 0.014098 | 0.825775 | 0.007730 | 0.500030 | 0.853289 | 0.005852 | 0.000039 | 0.499937 | 0.875574 | 0.003560 | 0.001203 | 0.676591 | 0.000618 |
| 32 | softsign | 0.1 | 1024 | 1000 | 10 | binary_crossentropy | 0.500099 | 0.875658 | 0.008126 | 0.000495 | 0.500533 | 0.000576 | 0.500907 | 0.897182 | 0.006114 | 0.002158 | 0.501723 | 0.002161 | 0.503229 | 0.918119 | 0.004950 | 0.003723 | 0.505085 | 0.005190 | 0.506858 | 0.929384 | 0.003730 | 0.006290 | 0.509700 | 0.008979 | 0.512728 | 0.938053 | 0.002171 | 0.011106 | 0.516003 | 0.011545 | 0.519218 | 0.945189 | 0.001933 | 0.011748 | 0.533720 | 0.017981 | 0.550586 | 0.957723 | 0.005034 | 0.020972 | 0.567387 | 0.020843 | 0.586905 | 0.963376 | 0.004859 | 0.024146 | 0.627690 | 0.027206 | 0.659875 | 0.027344 | 0.725385 | 0.023150 | 0.773705 | 0.011636 | 0.807936 | 0.013042 | 0.499924 | 0.837948 | 0.009621 | 0.000610 | 0.500284 | 0.858961 | 0.009546 | 0.001092 | 0.672846 | 0.008651 |
| 32 | softsign | 0.3 | 1024 | 1000 | 10 | binary_crossentropy | 0.499915 | 0.884289 | 0.004585 | 0.000562 | 0.500302 | 0.000452 | 0.500234 | 0.902473 | 0.010377 | 0.001147 | 0.499932 | 0.000814 | 0.500679 | 0.923356 | 0.006102 | 0.000961 | 0.501086 | 0.001713 | 0.501378 | 0.933607 | 0.006567 | 0.001642 | 0.502344 | 0.002709 | 0.503971 | 0.940052 | 0.006594 | 0.003966 | 0.506139 | 0.005853 | 0.510672 | 0.948207 | 0.005829 | 0.008227 | 0.519507 | 0.013935 | 0.530269 | 0.958530 | 0.004712 | 0.015577 | 0.543106 | 0.014026 | 0.566272 | 0.962230 | 0.004746 | 0.014244 | 0.610161 | 0.014416 | 0.652529 | 0.014065 | 0.722238 | 0.011246 | 0.779489 | 0.026072 | 0.816398 | 0.015670 | 0.500161 | 0.846418 | 0.013327 | 0.000370 | 0.500444 | 0.869373 | 0.007786 | 0.000968 | 0.669805 | 0.004022 |

# PNN Hyperparameter Search Results

| dense_layer_size | activation_function | dropout | batch_size | epochs | depth | loss_function | 100 | 1000 | 1000Std | 100Std | 110 | 110Std | 120 | 1200 | 1200Std | 120Std | 130 | 130Std | 140 | 1400 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 64 | LeakyRelu | 0.1 | 1024 | 1000 | 4 | binary_crossentropy | 0.677521 | 0.988416 | 0.000662 | 0.007174 | 0.701809 | 0.003805 | 0.725118 | 0.992476 | 0.000836 | 0.001037 | 0.748735 | 0.004077 | 0.796065 | 0.994973 |
| 128 | LeakyRelu | 0.1 | 1024 | 1000 | 3 | binary_crossentropy | 0.674556 | 0.988487 | 0.001416 | 0.004746 | 0.702141 | 0.000819 | 0.728154 | 0.992268 | 0.000389 | 0.004069 | 0.750726 | 0.004498 | 0.790560 | 0.993866 |
| 64 | LeakyRelu | 0.1 | 1024 | 1000 | 2 | binary_crossentropy | 0.675605 | 0.988263 | 0.000440 | 0.003663 | 0.698793 | 0.004947 | 0.724603 | 0.991867 | 0.000666 | 0.003256 | 0.747136 | 0.003492 | 0.792448 | 0.995246 |
| 128 | LeakyRelu | 0.1 | 1024 | 1000 | 2 | binary_crossentropy | 0.668722 | 0.986774 | 0.000000 | 0.000000 | 0.699693 | 0.000000 | 0.727764 | 0.991279 | 0.000000 | 0.000000 | 0.756428 | 0.000000 | 0.791954 | 0.995745 |
| 64 | LeakyRelu | 0.1 | 1024 | 1000 | 3 | binary_crossentropy | 0.683887 | 0.989140 | 0.001506 | 0.001212 | 0.701313 | 0.001275 | 0.727966 | 0.991212 | 0.000351 | 0.005343 | 0.750449 | 0.000409 | 0.791983 | 0.994214 |
| 64 | softsign | 0.1 | 1024 | 1000 | 2 | binary_crossentropy | 0.671475 | 0.988896 | 0.001523 | 0.005876 | 0.691981 | 0.005253 | 0.724987 | 0.991022 | 0.000207 | 0.002596 | 0.747296 | 0.002657 | 0.789133 | 0.994122 |
| 128 | softsign | 0.1 | 1024 | 1000 | 2 | binary_crossentropy | 0.672647 | 0.988938 | 0.001350 | 0.006158 | 0.693770 | 0.004839 | 0.725080 | 0.991572 | 0.000814 | 0.003251 | 0.746055 | 0.003590 | 0.789355 | 0.993551 |
| 32 | LeakyRelu | 0.1 | 1024 | 1000 | 4 | binary_crossentropy | 0.671147 | 0.989373 | 0.001588 | 0.007416 | 0.693125 | 0.003185 | 0.720316 | 0.991579 | 0.000101 | 0.003375 | 0.742936 | 0.001739 | 0.785641 | 0.994436 |
| 32 | relu | 0.1 | 1024 | 1000 | 2 | binary_crossentropy | 0.670880 | 0.989042 | 0.001490 | 0.004481 | 0.692506 | 0.003933 | 0.720998 | 0.991612 | 0.000562 | 0.003868 | 0.741906 | 0.005099 | 0.784844 | 0.993814 |
| 32 | LeakyRelu | 0.1 | 1024 | 1000 | 3 | binary_crossentropy | 0.668703 | 0.989938 | 0.001065 | 0.006886 | 0.690111 | 0.004028 | 0.719965 | 0.991541 | 0.000309 | 0.003580 | 0.742484 | 0.003110 | 0.787247 | 0.994138 |
| 32 | LeakyRelu | 0.1 | 1024 | 1000 | 2 | binary_crossentropy | 0.673233 | 0.988611 | 0.001148 | 0.005732 | 0.692316 | 0.003762 | 0.719450 | 0.991426 | 0.000431 | 0.004201 | 0.745035 | 0.002059 | 0.783942 | 0.994964 |
| 64 | softsign | 0.1 | 1024 | 1000 | 3 | binary_crossentropy | 0.671985 | 0.987755 | 0.001556 | 0.001447 | 0.687905 | 0.004335 | 0.720050 | 0.990638 | 0.000435 | 0.006023 | 0.744400 | 0.000230 | 0.786148 | 0.994222 |
| 32 | softsign | 0.1 | 1024 | 1000 | 2 | binary_crossentropy | 0.667970 | 0.989020 | 0.001456 | 0.004902 | 0.689346 | 0.004242 | 0.718315 | 0.991475 | 0.000705 | 0.004503 | 0.740745 | 0.004524 | 0.786192 | 0.993566 |
| 32 | softsign | 0.1 | 1024 | 1000 | 3 | binary_crossentropy | 0.666459 | 0.988882 | 0.001357 | 0.005090 | 0.687644 | 0.009054 | 0.717023 | 0.991171 | 0.000914 | 0.006151 | 0.738213 | 0.005832 | 0.784146 | 0.993137 |
| 32 | relu | 0.1 | 1024 | 1000 | 3 | binary_crossentropy | 0.664157 | 0.988893 | 0.001542 | 0.008538 | 0.687474 | 0.005207 | 0.715402 | 0.991784 | 0.000735 | 0.004353 | 0.732592 | 0.005087 | 0.779052 | 0.993533 |
| 64 | relu | 0.1 | 1024 | 1000 | 2 | binary_crossentropy | 0.658715 | 0.987686 | 0.000324 | 0.002788 | 0.681916 | 0.001330 | 0.710536 | 0.991478 | 0.000875 | 0.001312 | 0.731240 | 0.006072 | 0.780012 | 0.994993 |
| 32 | softsign | 0.1 | 1024 | 1000 | 4 | binary_crossentropy | 0.660352 | 0.988098 | 0.001291 | 0.006714 | 0.683052 | 0.005875 | 0.710369 | 0.990792 | 0.001107 | 0.005164 | 0.732767 | 0.005376 | 0.777375 | 0.993312 |
| 128 | softsign | 0.1 | 1024 | 1000 | 3 | binary_crossentropy | 0.665143 | 0.986872 | 0.000130 | 0.003903 | 0.684295 | 0.002392 | 0.711042 | 0.991334 | 0.001425 | 0.001058 | 0.731565 | 0.006789 | 0.780003 | 0.993788 |
| 128 | relu | 0.1 | 1024 | 1000 | 2 | binary_crossentropy | 0.651161 | 0.988377 | 0.001719 | 0.001925 | 0.678960 | 0.002296 | 0.704859 | 0.991753 | 0.000729 | 0.002349 | 0.725903 | 0.004270 | 0.773554 | 0.993384 |
| 32 | relu | 0.1 | 1024 | 1000 | 4 | binary_crossentropy | 0.662100 | 0.987239 | 0.001448 | 0.008820 | 0.684655 | 0.006620 | 0.708145 | 0.990880 | 0.000993 | 0.007265 | 0.727530 | 0.004931 | 0.771774 | 0.993914 |
| 64 | relu | 0.1 | 1024 | 1000 | 3 | binary_crossentropy | 0.644517 | 0.986812 | 0.000000 | 0.000000 | 0.672497 | 0.000000 | 0.703675 | 0.990522 | 0.000000 | 0.000000 | 0.726712 | 0.000000 | 0.765310 | 0.994941 |
| 64 | softsign | 0.1 | 1024 | 1000 | 4 | binary_crossentropy | 0.645901 | 0.986161 | 0.002215 | 0.004392 | 0.669048 | 0.004888 | 0.696229 | 0.988499 | 0.001027 | 0.003994 | 0.719361 | 0.003143 | 0.765858 | 0.993180 |
| 64 | relu | 0.1 | 1024 | 1000 | 4 | binary_crossentropy | 0.499147 | 0.685886 | 0.000000 | 0.000000 | 0.499683 | 0.000000 | 0.498885 | 0.723038 | 0.000000 | 0.000000 | 0.498919 | 0.000000 | 0.499416 | 0.768229 |
| 128 | softsign | 0.1 | 1024 | 1000 | 4 | binary_crossentropy | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN |
| 128 | relu | 0.1 | 1024 | 1000 | 3 | binary_crossentropy | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN |
| 128 | relu | 0.1 | 1024 | 1000 | 4 | binary_crossentropy | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN |
| 128 | LeakyRelu | 0.1 | 1024 | 1000 | 4 | binary_crossentropy | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN |

| dense_layer_size | activation_function | depth | 1400Std | 140Std | 150 | 150Std | 160 | 1600 | 1600Std | 160Std | 170 | 170Std | 180 | 1800 | 1800Std | 180Std | 190 | 190Std |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 64 | LeakyRelu | 4 | 0.001457 | 0.005204 | 0.812749 | 0.001048 | 0.817373 | 0.996216 | 0.000188 | 0.001360 | 0.819276 | 0.001908 | 0.833115 | 0.996587 | 0.000431 | 0.001855 | 0.843425 | 0.000901 |
| 128 | LeakyRelu | 3 | 0.001285 | 0.002071 | 0.812295 | 0.001096 | 0.820529 | 0.995683 | 0.000242 | 0.002401 | 0.823822 | 0.004206 | 0.831855 | 0.996472 | 0.000470 | 0.001677 | 0.845043 | 0.001271 |
| 64 | LeakyRelu | 2 | 0.001331 | 0.003838 | 0.811003 | 0.000626 | 0.816761 | 0.996207 | 0.000269 | 0.002170 | 0.822058 | 0.003435 | 0.832788 | 0.996552 | 0.000384 | 0.004429 | 0.844233 | 0.001783 |
| 128 | LeakyRelu | 2 | 0.000000 | 0.000000 | 0.813197 | 0.000000 | 0.819948 | 0.995866 | 0.000000 | 0.000000 | 0.825498 | 0.000000 | 0.831790 | 0.996152 | 0.000000 | 0.000000 | 0.845364 | 0.000000 |
| 64 | LeakyRelu | 3 | 0.001478 | 0.005954 | 0.811680 | 0.000311 | 0.815903 | 0.995770 | 0.000555 | 0.004540 | 0.823061 | 0.006551 | 0.829468 | 0.995985 | 0.000312 | 0.002143 | 0.842947 | 0.004409 |
| 64 | softsign | 2 | 0.001788 | 0.005108 | 0.807690 | 0.002311 | 0.817314 | 0.995653 | 0.000681 | 0.003141 | 0.821484 | 0.003576 | 0.828795 | 0.995955 | 0.000353 | 0.001544 | 0.840776 | 0.002759 |
| 128 | softsign | 2 | 0.001445 | 0.005590 | 0.807029 | 0.001446 | 0.815526 | 0.995484 | 0.000391 | 0.002173 | 0.817288 | 0.004040 | 0.829476 | 0.996253 | 0.000375 | 0.002205 | 0.839592 | 0.001686 |
| 32 | LeakyRelu | 4 | 0.001692 | 0.005330 | 0.805166 | 0.001548 | 0.814899 | 0.996053 | 0.000622 | 0.002899 | 0.818842 | 0.003522 | 0.828232 | 0.996008 | 0.000438 | 0.003695 | 0.840008 | 0.001890 |
| 32 | relu | 2 | 0.001767 | 0.006811 | 0.803058 | 0.002372 | 0.812301 | 0.995791 | 0.000543 | 0.002819 | 0.817628 | 0.005126 | 0.828169 | 0.996209 | 0.000372 | 0.003376 | 0.839186 | 0.001968 |
| 32 | LeakyRelu | 3 | 0.001666 | 0.004266 | 0.803748 | 0.000950 | 0.815684 | 0.995744 | 0.000736 | 0.002695 | 0.818549 | 0.003219 | 0.829112 | 0.996262 | 0.000145 | 0.003146 | 0.840104 | 0.002051 |
| 32 | LeakyRelu | 2 | 0.001480 | 0.004403 | 0.804882 | 0.002372 | 0.812138 | 0.995950 | 0.000450 | 0.003826 | 0.817445 | 0.003071 | 0.824614 | 0.995799 | 0.000247 | 0.000654 | 0.838559 | 0.001362 |
| 64 | softsign | 3 | 0.001547 | 0.005108 | 0.804759 | 0.002507 | 0.811459 | 0.995531 | 0.000582 | 0.004309 | 0.817577 | 0.002043 | 0.825849 | 0.995678 | 0.000495 | 0.000375 | 0.839743 | 0.000932 |
| 32 | softsign | 2 | 0.001505 | 0.004442 | 0.803805 | 0.001731 | 0.814166 | 0.995712 | 0.000699 | 0.003047 | 0.815633 | 0.003478 | 0.829147 | 0.996162 | 0.000431 | 0.004523 | 0.838413 | 0.002291 |
| 32 | softsign | 3 | 0.001725 | 0.004469 | 0.802244 | 0.002188 | 0.812453 | 0.995305 | 0.000860 | 0.002627 | 0.815007 | 0.003236 | 0.827063 | 0.995885 | 0.000370 | 0.005925 | 0.836833 | 0.002530 |
| 32 | relu | 3 | 0.001202 | 0.001953 | 0.798592 | 0.003732 | 0.811468 | 0.995919 | 0.000623 | 0.002550 | 0.813581 | 0.004126 | 0.825138 | 0.996288 | 0.000409 | 0.005283 | 0.835547 | 0.003225 |
| 64 | relu | 2 | 0.001335 | 0.003284 | 0.799920 | 0.003157 | 0.807598 | 0.996021 | 0.000092 | 0.001269 | 0.812162 | 0.002670 | 0.824832 | 0.995998 | 0.000297 | 0.003054 | 0.836051 | 0.001687 |
| 32 | softsign | 4 | 0.001719 | 0.002769 | 0.796474 | 0.001665 | 0.806899 | 0.995116 | 0.000501 | 0.002270 | 0.810611 | 0.003660 | 0.822828 | 0.995707 | 0.000678 | 0.002728 | 0.834382 | 0.001467 |
| 128 | softsign | 3 | 0.002335 | 0.004426 | 0.799535 | 0.002140 | 0.805867 | 0.995077 | 0.000257 | 0.002467 | 0.806804 | 0.002875 | 0.823396 | 0.994486 | 0.000539 | 0.001989 | 0.831546 | 0.001469 |
| 128 | relu | 2 | 0.001293 | 0.004225 | 0.794375 | 0.000510 | 0.807823 | 0.995976 | 0.000307 | 0.003846 | 0.811641 | 0.001182 | 0.825554 | 0.995975 | 0.000628 | 0.005082 | 0.833759 | 0.000437 |
| 32 | relu | 4 | 0.001347 | 0.007343 | 0.791497 | 0.004057 | 0.801358 | 0.995161 | 0.000807 | 0.005890 | 0.808425 | 0.005629 | 0.818073 | 0.995523 | 0.000710 | 0.004840 | 0.830722 | 0.004987 |
| 64 | relu | 3 | 0.000000 | 0.000000 | 0.786469 | 0.000000 | 0.794307 | 0.995521 | 0.000000 | 0.000000 | 0.799849 | 0.000000 | 0.805718 | 0.995079 | 0.000000 | 0.000000 | 0.821180 | 0.000000 |
| 64 | softsign | 4 | 0.001221 | 0.000141 | 0.784708 | 0.003497 | 0.794821 | 0.994626 | 0.000638 | 0.003335 | 0.797036 | 0.001431 | 0.812444 | 0.994603 | 0.000735 | 0.004250 | 0.820596 | 0.000607 |
| 64 | relu | 4 | 0.000000 | 0.000000 | 0.499257 | 0.000000 | 0.499405 | 0.795463 | 0.000000 | 0.000000 | 0.499237 | 0.000000 | 0.499262 | 0.813411 | 0.000000 | 0.000000 | 0.499540 | 0.000000 |
| 128 | softsign | 4 | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN |
| 128 | relu | 3 | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN |
| 128 | relu | 4 | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN |
| 128 | LeakyRelu | 4 | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN |

| dense_layer_size | activation_function | depth | 200 | 2000 | 2000Std | 200Std | 225 | 225Std | 250 | 2500 | 2500Std | 250Std | 275 | 275Std |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 64 | LeakyRelu | 4 | 0.868499 | 0.997494 | 0.000017 | 0.001526 | 0.891543 | 0.002487 | 0.902782 | 0.998554 | 0.000041 | 0.003367 | 0.919880 | 0.000968 |
| 128 | LeakyRelu | 3 | 0.872644 | 0.997237 | 0.000219 | 0.001210 | 0.893361 | 0.002023 | 0.903432 | 0.998294 | 0.000316 | 0.003755 | 0.916440 | 0.003031 |
| 64 | LeakyRelu | 2 | 0.867701 | 0.997154 | 0.000041 | 0.002913 | 0.891272 | 0.000751 | 0.902216 | 0.998590 | 0.000199 | 0.003551 | 0.919136 | 0.001489 |
| 128 | LeakyRelu | 2 | 0.872428 | 0.997130 | 0.000000 | 0.000000 | 0.894353 | 0.000000 | 0.899828 | 0.998730 | 0.000000 | 0.000000 | 0.919487 | 0.000000 |
| 64 | LeakyRelu | 3 | 0.867613 | 0.997013 | 0.000272 | 0.005067 | 0.889141 | 0.005202 | 0.898923 | 0.998064 | 0.000246 | 0.005300 | 0.914097 | 0.002202 |
| 64 | softsign | 2 | 0.867158 | 0.996482 | 0.000536 | 0.002523 | 0.890016 | 0.002952 | 0.900116 | 0.998254 | 0.000211 | 0.003954 | 0.914539 | 0.003912 |
| 128 | softsign | 2 | 0.866355 | 0.996643 | 0.000314 | 0.003011 | 0.890145 | 0.001830 | 0.901818 | 0.998205 | 0.000527 | 0.002897 | 0.915111 | 0.002523 |
| 32 | LeakyRelu | 4 | 0.865913 | 0.996834 | 0.000259 | 0.002001 | 0.888436 | 0.002677 | 0.898677 | 0.998408 | 0.000373 | 0.002845 | 0.914690 | 0.003308 |
| 32 | relu | 2 | 0.863415 | 0.996888 | 0.000272 | 0.002396 | 0.886976 | 0.002364 | 0.898475 | 0.998382 | 0.000278 | 0.003532 | 0.913676 | 0.003277 |
| 32 | LeakyRelu | 3 | 0.866917 | 0.996930 | 0.000370 | 0.001309 | 0.887468 | 0.001549 | 0.900117 | 0.998315 | 0.000269 | 0.003598 | 0.914389 | 0.004295 |
| 32 | LeakyRelu | 2 | 0.865090 | 0.996963 | 0.000180 | 0.002996 | 0.887845 | 0.002512 | 0.897493 | 0.998444 | 0.000452 | 0.002302 | 0.913647 | 0.003747 |
| 64 | softsign | 3 | 0.865305 | 0.996330 | 0.000316 | 0.002423 | 0.888469 | 0.002881 | 0.897773 | 0.998049 | 0.000378 | 0.003017 | 0.912546 | 0.003973 |
| 32 | softsign | 2 | 0.863844 | 0.996417 | 0.000451 | 0.001722 | 0.886260 | 0.003232 | 0.900209 | 0.998230 | 0.000338 | 0.003881 | 0.913192 | 0.003765 |
| 32 | softsign | 3 | 0.863048 | 0.996468 | 0.000455 | 0.002146 | 0.886156 | 0.003267 | 0.899269 | 0.998061 | 0.000251 | 0.003804 | 0.912444 | 0.003604 |
| 32 | relu | 3 | 0.864426 | 0.996665 | 0.000628 | 0.001932 | 0.886836 | 0.002804 | 0.897872 | 0.998387 | 0.000448 | 0.001641 | 0.911368 | 0.002878 |
| 64 | relu | 2 | 0.861256 | 0.997255 | 0.000059 | 0.003828 | 0.883907 | 0.003514 | 0.896943 | 0.998553 | 0.000190 | 0.003048 | 0.913267 | 0.001449 |
| 32 | softsign | 4 | 0.860635 | 0.996490 | 0.000443 | 0.003677 | 0.883730 | 0.002901 | 0.894806 | 0.997540 | 0.000355 | 0.001832 | 0.909856 | 0.004084 |
| 128 | softsign | 3 | 0.857816 | 0.996028 | 0.000007 | 0.000385 | 0.882235 | 0.000702 | 0.894033 | 0.998174 | 0.000117 | 0.003516 | 0.912573 | 0.000582 |
| 128 | relu | 2 | 0.859453 | 0.996855 | 0.000361 | 0.002624 | 0.881258 | 0.002108 | 0.896082 | 0.998341 | 0.000275 | 0.003137 | 0.910938 | 0.001534 |
| 32 | relu | 4 | 0.853898 | 0.996883 | 0.000330 | 0.004820 | 0.878311 | 0.004093 | 0.890817 | 0.997993 | 0.000589 | 0.004531 | 0.906962 | 0.003864 |
| 64 | relu | 3 | 0.848804 | 0.996983 | 0.000000 | 0.000000 | 0.872499 | 0.000000 | 0.886991 | 0.998749 | 0.000000 | 0.000000 | 0.904354 | 0.000000 |
| 64 | softsign | 4 | 0.848409 | 0.995716 | 0.000256 | 0.002785 | 0.871721 | 0.002712 | 0.886323 | 0.997279 | 0.000544 | 0.005388 | 0.903795 | 0.001240 |
| 64 | relu | 4 | 0.499763 | 0.835421 | 0.000000 | 0.000000 | 0.500016 | 0.000000 | 0.498982 | 0.874401 | 0.000000 | 0.000000 | 0.498600 | 0.000000 |
| 128 | softsign | 4 | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN |
| 128 | relu | 3 | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN |
| 128 | relu | 4 | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN |
| 128 | LeakyRelu | 4 | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN |

| dense_layer_size | activation_function | depth | 300 | 3000 | 3000Std | 300Std | 350 | 350Std | 400 | 400Std | 500 | 500Std | 600 | 600Std |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 64 | LeakyRelu | 4 | 0.924161 | 0.998868 | 0.000711 | 0.003045 | 0.941949 | 0.000612 | 0.951276 | 0.000553 | 0.966031 | 0.001065 | 0.972749 | 0.000771 |
| 128 | LeakyRelu | 3 | 0.927422 | 0.998878 | 0.000454 | 0.000575 | 0.940831 | 0.000283 | 0.949257 | 0.001844 | 0.963699 | 0.002224 | 0.973533 | 0.000877 |
| 64 | LeakyRelu | 2 | 0.924209 | 0.999045 | 0.000349 | 0.002089 | 0.941640 | 0.000664 | 0.950017 | 0.002251 | 0.964823 | 0.001695 | 0.972941 | 0.000486 |
| 128 | LeakyRelu | 2 | 0.926860 | 0.998665 | 0.000000 | 0.000000 | 0.940487 | 0.000000 | 0.947433 | 0.000000 | 0.962817 | 0.000000 | 0.973710 | 0.000000 |
| 64 | LeakyRelu | 3 | 0.921722 | 0.998476 | 0.000134 | 0.007035 | 0.939457 | 0.001061 | 0.948577 | 0.000588 | 0.961741 | 0.000760 | 0.972537 | 0.002096 |
| 64 | softsign | 2 | 0.923046 | 0.998475 | 0.000223 | 0.002055 | 0.940035 | 0.000782 | 0.947686 | 0.001328 | 0.962366 | 0.001201 | 0.972512 | 0.000931 |
| 128 | softsign | 2 | 0.923291 | 0.998798 | 0.000253 | 0.002928 | 0.940409 | 0.000548 | 0.949049 | 0.001601 | 0.963288 | 0.001475 | 0.972737 | 0.001195 |
| 32 | LeakyRelu | 4 | 0.923078 | 0.998594 | 0.000292 | 0.002885 | 0.940145 | 0.001362 | 0.948236 | 0.001609 | 0.962619 | 0.001568 | 0.973131 | 0.001252 |
| 32 | relu | 2 | 0.922994 | 0.998821 | 0.000394 | 0.002621 | 0.939050 | 0.001188 | 0.947597 | 0.001387 | 0.962916 | 0.001536 | 0.972493 | 0.001459 |
| 32 | LeakyRelu | 3 | 0.922374 | 0.998727 | 0.000315 | 0.002389 | 0.940593 | 0.001369 | 0.949104 | 0.000704 | 0.962973 | 0.001929 | 0.973492 | 0.000915 |
| 32 | LeakyRelu | 2 | 0.922236 | 0.998460 | 0.000065 | 0.003738 | 0.939250 | 0.000969 | 0.947417 | 0.000660 | 0.962067 | 0.001617 | 0.973230 | 0.000831 |
| 64 | softsign | 3 | 0.921542 | 0.998203 | 0.000368 | 0.003503 | 0.937912 | 0.001048 | 0.947065 | 0.000664 | 0.960174 | 0.001883 | 0.972052 | 0.000924 |
| 32 | softsign | 2 | 0.921800 | 0.998653 | 0.000074 | 0.003273 | 0.939719 | 0.000996 | 0.948463 | 0.001232 | 0.963092 | 0.002045 | 0.972039 | 0.001175 |
| 32 | softsign | 3 | 0.921027 | 0.998572 | 0.000368 | 0.003426 | 0.939522 | 0.000874 | 0.947883 | 0.001534 | 0.961848 | 0.002044 | 0.971753 | 0.001226 |
| 32 | relu | 3 | 0.923065 | 0.998767 | 0.000495 | 0.001558 | 0.938413 | 0.000686 | 0.947777 | 0.002078 | 0.962548 | 0.002479 | 0.972252 | 0.001418 |
| 64 | relu | 2 | 0.920429 | 0.998225 | 0.000889 | 0.003138 | 0.938271 | 0.000726 | 0.946721 | 0.001785 | 0.962876 | 0.002031 | 0.971023 | 0.000958 |
| 32 | softsign | 4 | 0.919981 | 0.998448 | 0.000630 | 0.002088 | 0.936862 | 0.001770 | 0.947059 | 0.000845 | 0.961493 | 0.001944 | 0.971412 | 0.001737 |
| 128 | softsign | 3 | 0.916534 | 0.998507 | 0.000706 | 0.003660 | 0.935804 | 0.001512 | 0.946582 | 0.002032 | 0.961188 | 0.000809 | 0.969540 | 0.000361 |
| 128 | relu | 2 | 0.921624 | 0.998055 | 0.000662 | 0.000932 | 0.936833 | 0.001705 | 0.947322 | 0.002888 | 0.962748 | 0.002096 | 0.971945 | 0.000910 |
| 32 | relu | 4 | 0.917190 | 0.998467 | 0.000565 | 0.003965 | 0.935159 | 0.003032 | 0.944496 | 0.003645 | 0.960435 | 0.002321 | 0.970364 | 0.001595 |
| 64 | relu | 3 | 0.917177 | 0.997944 | 0.000000 | 0.000000 | 0.932844 | 0.000000 | 0.940546 | 0.000000 | 0.957258 | 0.000000 | 0.970667 | 0.000000 |
| 64 | softsign | 4 | 0.911211 | 0.997450 | 0.000517 | 0.004767 | 0.930795 | 0.001897 | 0.940086 | 0.000530 | 0.957153 | 0.000561 | 0.967922 | 0.002355 |
| 64 | relu | 4 | 0.498636 | 0.891192 | 0.000000 | 0.000000 | 0.500236 | 0.000000 | 0.506810 | 0.000000 | 0.531736 | 0.000000 | 0.554979 | 0.000000 |
| 128 | softsign | 4 | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN |
| 128 | relu | 3 | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN |
| 128 | relu | 4 | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN |
| 128 | LeakyRelu | 4 | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN |

| dense_layer_size | activation_function | depth | 700 | 700Std | 80 | 800 | 800Std | 80Std | 90 | 900 | 900Std | 90Std | Avg | AvgStd |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 64 | LeakyRelu | 4 | 0.978019 | 0.002606 | 0.653932 | 0.982387 | 0.000546 | 0.007836 | 0.667042 | 0.985819 | 0.000916 | 0.000648 | 0.885776 | 0.000008 |
| 128 | LeakyRelu | 3 | 0.976726 | 0.001596 | 0.653544 | 0.982779 | 0.000852 | 0.004234 | 0.657229 | 0.985804 | 0.000640 | 0.002212 | 0.885549 | 0.000506 |
| 64 | LeakyRelu | 2 | 0.978316 | 0.001803 | 0.656205 | 0.982581 | 0.001036 | 0.005800 | 0.666143 | 0.985841 | 0.000753 | 0.003523 | 0.885356 | 0.000518 |
| 128 | LeakyRelu | 2 | 0.978324 | 0.000000 | 0.648593 | 0.983651 | 0.000000 | 0.000000 | 0.655234 | 0.986101 | 0.000000 | 0.000000 | 0.885313 | 0.000000 |
| 64 | LeakyRelu | 3 | 0.977964 | 0.001122 | 0.651508 | 0.981913 | 0.000937 | 0.003927 | 0.663707 | 0.985783 | 0.000785 | 0.003351 | 0.884788 | 0.001373 |
| 64 | softsign | 2 | 0.977520 | 0.001210 | 0.646618 | 0.982798 | 0.000593 | 0.006751 | 0.661226 | 0.985699 | 0.000277 | 0.004091 | 0.883473 | 0.000392 |
| 128 | softsign | 2 | 0.977085 | 0.001775 | 0.641739 | 0.982200 | 0.001261 | 0.008441 | 0.656628 | 0.985453 | 0.000944 | 0.005023 | 0.883143 | 0.000661 |
| 32 | LeakyRelu | 4 | 0.978316 | 0.001226 | 0.645279 | 0.983081 | 0.000778 | 0.009183 | 0.657273 | 0.985922 | 0.000556 | 0.003130 | 0.882700 | 0.000701 |
| 32 | relu | 2 | 0.977250 | 0.002159 | 0.648987 | 0.982878 | 0.001203 | 0.006073 | 0.659361 | 0.985626 | 0.000974 | 0.005460 | 0.882304 | 0.000777 |
| 32 | LeakyRelu | 3 | 0.978421 | 0.001837 | 0.636053 | 0.983056 | 0.000922 | 0.007942 | 0.654637 | 0.985678 | 0.000343 | 0.002790 | 0.882268 | 0.000485 |
| 32 | LeakyRelu | 2 | 0.977976 | 0.001737 | 0.643967 | 0.982594 | 0.000083 | 0.004376 | 0.654672 | 0.986001 | 0.000124 | 0.006371 | 0.882054 | 0.000462 |
| 64 | softsign | 3 | 0.976789 | 0.001716 | 0.644491 | 0.982402 | 0.000751 | 0.008444 | 0.656800 | 0.985269 | 0.000059 | 0.003585 | 0.881708 | 0.000572 |
| 32 | softsign | 2 | 0.977286 | 0.001895 | 0.641361 | 0.982148 | 0.001304 | 0.005140 | 0.656169 | 0.984940 | 0.000784 | 0.006559 | 0.881672 | 0.000742 |
| 32 | softsign | 3 | 0.976434 | 0.001676 | 0.638619 | 0.981957 | 0.001210 | 0.005489 | 0.655554 | 0.985396 | 0.000561 | 0.004685 | 0.880796 | 0.001130 |
| 32 | relu | 3 | 0.976786 | 0.001301 | 0.643458 | 0.982594 | 0.003032 | 0.008917 | 0.654995 | 0.985262 | 0.000684 | 0.003067 | 0.880340 | 0.003074 |
| 64 | relu | 2 | 0.977571 | 0.001917 | 0.630196 | 0.981957 | 0.000715 | 0.007516 | 0.643127 | 0.985360 | 0.000982 | 0.002466 | 0.878628 | 0.000671 |
| 32 | softsign | 4 | 0.975862 | 0.001867 | 0.636293 | 0.980722 | 0.000794 | 0.003951 | 0.648195 | 0.984423 | 0.001279 | 0.002353 | 0.878186 | 0.000869 |
| 128 | softsign | 3 | 0.975738 | 0.001939 | 0.630149 | 0.979875 | 0.000802 | 0.007634 | 0.648882 | 0.984133 | 0.000714 | 0.002313 | 0.877766 | 0.000127 |
| 128 | relu | 2 | 0.976702 | 0.001720 | 0.629665 | 0.982374 | 0.000962 | 0.011391 | 0.640688 | 0.984551 | 0.000595 | 0.004035 | 0.877140 | 0.000664 |
| 32 | relu | 4 | 0.976022 | 0.001837 | 0.637420 | 0.981278 | 0.000570 | 0.007558 | 0.646109 | 0.984411 | 0.000786 | 0.009590 | 0.876350 | 0.002863 |
| 64 | relu | 3 | 0.976247 | 0.000000 | 0.616402 | 0.980664 | 0.000000 | 0.000000 | 0.629462 | 0.984446 | 0.000000 | 0.000000 | 0.871714 | 0.000000 |
| 64 | softsign | 4 | 0.975508 | 0.000535 | 0.614187 | 0.979686 | 0.001188 | 0.003483 | 0.633007 | 0.983020 | 0.001208 | 0.008437 | 0.870511 | 0.000836 |
| 64 | relu | 4 | 0.590317 | 0.000000 | 0.499830 | 0.630397 | 0.000000 | 0.000000 | 0.499087 | 0.660553 | 0.000000 | 0.000000 | 0.589054 | 0.000000 |
| 128 | softsign | 4 | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN |
| 128 | relu | 3 | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN |
| 128 | relu | 4 | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN |
| 128 | LeakyRelu | 4 | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN | NaN |

# PNN Hyperparameter Search Results

| dense_layer_size | activation_function | dropout | batch_size | epochs | depth | loss_function | 100 | 1000 | 1000Std | 100Std | 110 | 110Std | 120 | 1200 | 1200Std | 120Std | 130 | 130Std | 140 | 1400 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | LeakyRelu | 0.1 | 1024 | 1000 | 10 | binary_crossentropy | 0.666734 | 0.988966 | 0.001555 | 0.007159 | 0.690433 | 0.004321 | 0.717895 | 0.991724 | 0.000689 | 0.004080 | 0.739001 | 0.004253 | 0.784392 | 0.994206 |
| 32 | relu | 0.1 | 1024 | 1000 | 10 | binary_crossentropy | 0.665035 | 0.988636 | 0.001799 | 0.004969 | 0.689402 | 0.001282 | 0.715214 | 0.991515 | 0.000536 | 0.002281 | 0.736669 | 0.004799 | 0.781549 | 0.993856 |
| 32 | softsign | 0.1 | 1024 | 1000 | 10 | binary_crossentropy | 0.661423 | 0.987540 | 0.001730 | 0.007412 | 0.684818 | 0.005172 | 0.711432 | 0.990624 | 0.001063 | 0.003725 | 0.734787 | 0.004450 | 0.778722 | 0.993362 |
| 32 | LeakyRelu | 0.1 | 1024 | 1000 | 10 | mean_squared_error | 0.653511 | 0.988274 | 0.001561 | 0.005343 | 0.679619 | 0.004910 | 0.705460 | 0.991161 | 0.000790 | 0.002521 | 0.726700 | 0.004092 | 0.776340 | 0.993520 |
| 32 | softsign | 0.1 | 1024 | 1000 | 10 | mean_squared_error | 0.642387 | 0.987083 | 0.001491 | 0.006596 | 0.666971 | 0.003596 | 0.696160 | 0.988155 | 0.000743 | 0.004025 | 0.718474 | 0.002047 | 0.764830 | 0.991430 |
| 32 | relu | 0.1 | 1024 | 1000 | 10 | mean_squared_error | 0.599056 | 0.905517 | 0.130800 | 0.062483 | 0.616646 | 0.071330 | 0.638815 | 0.921517 | 0.108976 | 0.081651 | 0.652937 | 0.089817 | 0.692444 | 0.931699 |
| 32 | softsign | 0.1 | 1024 | 1000 | 10 | mean_absolute_error | 0.499981 | 0.841515 | 0.023875 | 0.000022 | 0.500020 | 0.000049 | 0.500054 | 0.867302 | 0.020318 | 0.000109 | 0.500048 | 0.000065 | 0.500195 | 0.892291 |
| 32 | relu | 0.1 | 1024 | 1000 | 10 | mean_absolute_error | 0.500000 | 0.500000 | 0.000000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 |
| 32 | LeakyRelu | 0.1 | 1024 | 1000 | 10 | mean_absolute_error | 0.500000 | 0.500000 | 0.000000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 |

| activation_function | loss_function | 1400Std | 140Std | 150 | 150Std | 160 | 1600 | 1600Std | 160Std | 170 | 170Std | 180 | 1800 | 1800Std | 180Std | 190 | 190Std |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LeakyRelu | binary_crossentropy | 0.001583 | 0.003415 | 0.803143 | 0.002370 | 0.814072 | 0.995968 | 0.000499 | 0.003089 | 0.816649 | 0.003023 | 0.827920 | 0.996286 | 0.000465 | 0.003673 | 0.838507 | 0.001699 |
| relu | binary_crossentropy | 0.001673 | 0.006125 | 0.800947 | 0.002551 | 0.810811 | 0.995689 | 0.000490 | 0.002361 | 0.814099 | 0.004494 | 0.826049 | 0.996071 | 0.000349 | 0.003306 | 0.836840 | 0.001605 |
| softsign | binary_crossentropy | 0.001498 | 0.006315 | 0.798658 | 0.002577 | 0.808065 | 0.995102 | 0.000566 | 0.002943 | 0.810936 | 0.003889 | 0.822903 | 0.995419 | 0.000267 | 0.003146 | 0.833705 | 0.002523 |
| LeakyRelu | mean_squared_error | 0.001814 | 0.003410 | 0.794713 | 0.000915 | 0.808569 | 0.995449 | 0.000884 | 0.003191 | 0.811834 | 0.003431 | 0.822481 | 0.995663 | 0.000605 | 0.003598 | 0.833626 | 0.002647 |
| softsign | mean_squared_error | 0.002473 | 0.006934 | 0.787153 | 0.000717 | 0.799051 | 0.993515 | 0.002046 | 0.004519 | 0.801357 | 0.004188 | 0.812519 | 0.994544 | 0.000204 | 0.003736 | 0.822445 | 0.003043 |
| relu | mean_squared_error | 0.096236 | 0.111912 | 0.706746 | 0.119638 | 0.715193 | 0.942605 | 0.083289 | 0.124704 | 0.719060 | 0.127758 | 0.731209 | 0.947921 | 0.073105 | 0.134216 | 0.735193 | 0.137194 |
| softsign | mean_absolute_error | 0.016084 | 0.000355 | 0.500448 | 0.000637 | 0.500811 | 0.905543 | 0.018141 | 0.000849 | 0.501351 | 0.001442 | 0.501603 | 0.916466 | 0.013599 | 0.001546 | 0.502153 | 0.001794 |
| relu | mean_absolute_error | 0.000000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 | 0.500000 | 0.000000 |
| LeakyRelu | mean_absolute_error | 0.000000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 | 0.500000 | 0.000000 |

| activation_function | loss_function | 200 | 2000 | 2000Std | 200Std | 225 | 225Std | 250 | 2500 | 2500Std | 250Std | 275 | 275Std | 300 | 3000 | 3000Std | 300Std |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LeakyRelu | binary_crossentropy | 0.866415 | 0.997019 | 0.000344 | 0.002636 | 0.888204 | 0.002424 | 0.899612 | 0.998383 | 0.000317 | 0.002636 | 0.914891 | 0.002913 | 0.923506 | 0.998765 | 0.000431 | 0.002747 |
| relu | binary_crossentropy | 0.864227 | 0.996745 | 0.000380 | 0.002785 | 0.886299 | 0.001629 | 0.897653 | 0.998317 | 0.000222 | 0.002914 | 0.912589 | 0.002911 | 0.921445 | 0.998746 | 0.000374 | 0.001939 |
| softsign | binary_crossentropy | 0.860596 | 0.996735 | 0.000480 | 0.001929 | 0.883186 | 0.003036 | 0.894798 | 0.997658 | 0.000608 | 0.003581 | 0.909611 | 0.002786 | 0.919352 | 0.998147 | 0.000558 | 0.002718 |
| LeakyRelu | mean_squared_error | 0.860318 | 0.996561 | 0.000730 | 0.003083 | 0.882079 | 0.002971 | 0.895404 | 0.998042 | 0.000816 | 0.004173 | 0.910843 | 0.003071 | 0.920199 | 0.998058 | 0.001059 | 0.002542 |
| softsign | mean_squared_error | 0.850108 | 0.995283 | 0.000544 | 0.003986 | 0.863892 | 0.005498 | 0.877465 | 0.996894 | 0.000844 | 0.005396 | 0.891461 | 0.004472 | 0.903528 | 0.997606 | 0.000340 | 0.002916 |
| relu | mean_squared_error | 0.749422 | 0.954629 | 0.066005 | 0.144247 | 0.765298 | 0.153962 | 0.778521 | 0.960681 | 0.059100 | 0.161041 | 0.792381 | 0.170168 | 0.800426 | 0.962118 | 0.057933 | 0.173609 |
| softsign | mean_absolute_error | 0.503094 | 0.925963 | 0.013942 | 0.003173 | 0.505822 | 0.004731 | 0.513012 | 0.946462 | 0.008733 | 0.007569 | 0.519805 | 0.011978 | 0.533802 | 0.950738 | 0.009114 | 0.015728 |
| relu | mean_absolute_error | 0.500000 | 0.500000 | 0.000000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 |
| LeakyRelu | mean_absolute_error | 0.500000 | 0.500000 | 0.000000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 |

| activation_function | loss_function | 350 | 350Std | 400 | 400Std | 500 | 500Std | 600 | 600Std | 700 | 700Std | 80 | 800 | 800Std | 80Std | 90 | 900 | 900Std | 90Std | Avg | AvgStd |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LeakyRelu | binary_crossentropy | 0.939925 | 0.001006 | 0.948864 | 0.001872 | 0.963264 | 0.002139 | 0.972731 | 0.001251 | 0.977734 | 0.001869 | 0.640051 | 0.982854 | 0.001033 | 0.008479 | 0.651946 | 0.985639 | 0.000973 | 0.003962 | 0.881741 | 0.000752 |
| relu | binary_crossentropy | 0.938111 | 0.001459 | 0.947511 | 0.001631 | 0.962450 | 0.001839 | 0.972183 | 0.001332 | 0.977091 | 0.002108 | 0.642311 | 0.982231 | 0.001181 | 0.005392 | 0.654502 | 0.985326 | 0.000842 | 0.007886 | 0.880629 | 0.000652 |
| softsign | binary_crossentropy | 0.936504 | 0.001782 | 0.945172 | 0.001875 | 0.960204 | 0.001708 | 0.970647 | 0.001142 | 0.975722 | 0.001092 | 0.629266 | 0.981374 | 0.000787 | 0.008792 | 0.645953 | 0.984227 | 0.000895 | 0.004321 | 0.878020 | 0.000425 |
| LeakyRelu | mean_squared_error | 0.937513 | 0.001687 | 0.947183 | 0.001917 | 0.961960 | 0.001949 | 0.971879 | 0.001479 | 0.977203 | 0.001915 | 0.622235 | 0.982149 | 0.001012 | 0.007176 | 0.637290 | 0.985222 | 0.000953 | 0.005260 | 0.876908 | 0.000586 |
| softsign | mean_squared_error | 0.925009 | 0.001924 | 0.934683 | 0.001581 | 0.953467 | 0.001839 | 0.965258 | 0.000676 | 0.971703 | 0.003174 | 0.607620 | 0.977634 | 0.000517 | 0.008430 | 0.629922 | 0.981350 | 0.001035 | 0.002164 | 0.868351 | 0.000906 |
| relu | mean_squared_error | 0.816018 | 0.182705 | 0.824128 | 0.187505 | 0.839691 | 0.193532 | 0.856267 | 0.181955 | 0.871936 | 0.167571 | 0.570439 | 0.886049 | 0.156005 | 0.048595 | 0.587326 | 0.894888 | 0.141087 | 0.055547 | 0.792712 | 0.119707 |
| softsign | mean_absolute_error | 0.564012 | 0.018022 | 0.594996 | 0.015051 | 0.662517 | 0.016997 | 0.719878 | 0.023072 | 0.758772 | 0.023450 | 0.500074 | 0.793410 | 0.020573 | 0.000139 | 0.499881 | 0.822472 | 0.022887 | 0.000023 | 0.648269 | 0.009180 |
| relu | mean_absolute_error | 0.500000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 | 0.500000 | 0.000000 |
| LeakyRelu | mean_absolute_error | 0.500000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 | 0.500000 | 0.000000 |

# PNN Hyperparameter Search Results

| dense_layer_size | activation_function | dropout | batch_size | epochs | depth | loss_function | alpha | 100 | 1000 | 1000Std | 100Std | 110 | 110Std | 120 | 1200 | 1200Std | 120Std |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 64 | LeakyRelu | 0.1 | 1024 | 1000 | 4 | binary_crossentropy | 0.1 | 0.674768 | 0.989287 | 1.490102e-03 | 0.007019 | 0.697128 | 0.002957 | 0.726193 | 0.991896 | 6.348060e-04 | 0.004602 |
| 64 | LeakyRelu | 0.1 | 1024 | 1000 | 4 | binary_crossentropy | 0.2 | 0.673343 | 0.989068 | 1.701729e-03 | 0.007006 | 0.697438 | 0.003713 | 0.724947 | 0.991814 | 7.602032e-04 | 0.003951 |
| 64 | LeakyRelu | 0.1 | 1024 | 1000 | 4 | binary_crossentropy | 0.3 | 0.666868 | 0.989298 | 1.544812e-03 | 0.006864 | 0.693911 | 0.004413 | 0.721581 | 0.992144 | 6.517756e-04 | 0.002973 |
| 64 | LeakyRelu | 0.1 | 1024 | 1000 | 4 | hinge | 0.3 | 0.500000 | 0.500000 | 0.000000e+00 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000e+00 | 0.000000 |
| 64 | LeakyRelu | 0.1 | 1024 | 1000 | 4 | squared_hinge | 0.1 | 0.500000 | 0.500000 | 0.000000e+00 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000e+00 | 0.000000 |
| 64 | LeakyRelu | 0.1 | 1024 | 1000 | 4 | squared_hinge | 0.2 | 0.500000 | 0.500000 | 0.000000e+00 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000e+00 | 0.000000 |
| 64 | LeakyRelu | 0.1 | 1024 | 1000 | 4 | squared_hinge | 0.3 | 0.500000 | 0.500000 | 0.000000e+00 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000e+00 | 0.000000 |
| 64 | LeakyRelu | 0.1 | 1024 | 1000 | 4 | hinge | 0.2 | 0.500000 | 0.500000 | 0.000000e+00 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 9.016767e-07 | 0.000000 |
| 64 | LeakyRelu | 0.1 | 1024 | 1000 | 4 | hinge | 0.1 | 0.500000 | 0.500000 | 9.004791e-07 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000e+00 | 0.000000 |

| loss_function | alpha | 130 | 130Std | 140 | 1400 | 1400Std | 140Std | 150 | 150Std | 160 | 1600 | 1600Std | 160Std |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| binary_crossentropy | 0.1 | 0.748736 | 0.005134 | 0.792157 | 0.994052 | 0.001568 | 0.004756 | 0.810157 | 0.002325 | 0.818273 | 0.995997 | 0.000509 | 0.003315 |
| binary_crossentropy | 0.2 | 0.746322 | 0.003948 | 0.789440 | 0.994228 | 0.001547 | 0.005913 | 0.807120 | 0.002717 | 0.816935 | 0.996013 | 0.000437 | 0.002121 |
| binary_crossentropy | 0.3 | 0.741683 | 0.003209 | 0.784923 | 0.993612 | 0.001308 | 0.004464 | 0.804618 | 0.002107 | 0.816000 | 0.995978 | 0.000439 | 0.003752 |
| hinge | 0.3 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 |
| squared_hinge | 0.1 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 |
| squared_hinge | 0.2 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 |
| squared_hinge | 0.3 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 |
| hinge | 0.2 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 |
| hinge | 0.1 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 |

| loss_function | alpha | 170 | 170Std | 180 | 1800 | 1800Std | 180Std | 190 | 190Std | 200 | 2000 | 2000Std | 200Std |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| binary_crossentropy | 0.1 | 0.822094 | 0.004146 | 0.833128 | 0.996305 | 0.000375 | 0.003380 | 0.843657 | 0.001636 | 0.869163 | 0.997067 | 0.000304 | 0.002632 |
| binary_crossentropy | 0.2 | 0.819258 | 0.005453 | 0.830821 | 0.996378 | 0.000318 | 0.001723 | 0.841288 | 0.003356 | 0.868201 | 0.997114 | 0.000434 | 0.001945 |
| binary_crossentropy | 0.3 | 0.818864 | 0.004893 | 0.830142 | 0.996357 | 0.000521 | 0.002115 | 0.840012 | 0.002741 | 0.867091 | 0.996988 | 0.000443 | 0.001186 |
| hinge | 0.3 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 |
| squared_hinge | 0.1 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 |
| squared_hinge | 0.2 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 |
| squared_hinge | 0.3 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 |
| hinge | 0.2 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 |
| hinge | 0.1 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 |

| loss_function | alpha | 225 | 225Std | 250 | 2500 | 2500Std | 250Std | 275 | 275Std | 300 | 3000 | 3000Std | 300Std |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| binary_crossentropy | 0.1 | 0.891413 | 0.002520 | 0.902628 | 0.998440 | 0.000299 | 0.003589 | 0.916909 | 0.003050 | 0.925226 | 0.998881 | 0.000389 | 0.003084 |
| binary_crossentropy | 0.2 | 0.889922 | 0.002698 | 0.902708 | 0.998534 | 0.000304 | 0.002186 | 0.916166 | 0.002767 | 0.925006 | 0.998784 | 0.000402 | 0.002830 |
| binary_crossentropy | 0.3 | 0.889752 | 0.000873 | 0.901129 | 0.998498 | 0.000368 | 0.003376 | 0.913800 | 0.003742 | 0.924261 | 0.999001 | 0.000326 | 0.001113 |
| hinge | 0.3 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 |
| squared_hinge | 0.1 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 |
| squared_hinge | 0.2 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 |
| squared_hinge | 0.3 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 |
| hinge | 0.2 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 |
| hinge | 0.1 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.500000 | 0.000000 | 0.000000 |

| loss_function | alpha | 350 | 350Std | 400 | 400Std | 500 | 500Std | 600 | 600Std | 700 | 700Std |
|---|---|---|---|---|---|---|---|---|---|---|---|
| binary_crossentropy | 0.1 | 0.941682 | 0.000862 | 0.949729 | 0.001841 | 0.963866 | 1.843196e-03 | 0.973312 | 0.000907 | 0.978135 | 0.001556 |
| binary_crossentropy | 0.2 | 0.940902 | 0.000786 | 0.949593 | 0.001477 | 0.963721 | 1.547328e-03 | 0.972993 | 0.001231 | 0.977719 | 0.001506 |
| binary_crossentropy | 0.3 | 0.939819 | 0.001009 | 0.948964 | 0.002022 | 0.963112 | 2.359398e-03 | 0.972881 | 0.001027 | 0.977288 | 0.001256 |
| hinge | 0.3 | 0.500000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.000000e+00 | 0.500000 | 0.000000 | 0.500000 | 0.000000 |
| squared_hinge | 0.1 | 0.500000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.000000e+00 | 0.500000 | 0.000000 | 0.500000 | 0.000000 |
| squared_hinge | 0.2 | 0.500000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.000000e+00 | 0.500000 | 0.000000 | 0.500000 | 0.000000 |
| squared_hinge | 0.3 | 0.500000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.000000e+00 | 0.500000 | 0.000000 | 0.500000 | 0.000000 |
| hinge | 0.2 | 0.500000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 0.000000e+00 | 0.500000 | 0.000000 | 0.500000 | 0.000000 |
| hinge | 0.1 | 0.500000 | 0.000000 | 0.500000 | 0.000000 | 0.500000 | 9.016767e-07 | 0.500000 | 0.000000 | 0.499999 | 0.000002 |

| loss_function | alpha | 80 | 800 | 800Std | 80Std | 90 | 900 | 900Std | 90Std | Avg | AvgStd |
|---|---|---|---|---|---|---|---|---|---|---|---|
| binary_crossentropy | 0.1 | 0.648712 | 0.983037 | 1.071493e-03 | 0.004023 | 0.661817 | 0.986011 | 5.169069e-04 | 0.005434 | 0.884995 | 6.292575e-04 |
| binary_crossentropy | 0.2 | 0.647804 | 0.982758 | 8.262460e-04 | 0.010405 | 0.660747 | 0.985771 | 6.133793e-04 | 0.003781 | 0.884152 | 6.198076e-04 |
| binary_crossentropy | 0.3 | 0.647247 | 0.982971 | 1.019282e-03 | 0.004808 | 0.657216 | 0.985521 | 4.987857e-04 | 0.005683 | 0.882860 | 3.492909e-04 |
| hinge | 0.3 | 0.500000 | 0.500000 | 0.000000e+00 | 0.000000 | 0.500000 | 0.500000 | 0.000000e+00 | 0.000000 | 0.500000 | 0.000000e+00 |
| squared_hinge | 0.1 | 0.500000 | 0.500000 | 0.000000e+00 | 0.000000 | 0.500000 | 0.500000 | 0.000000e+00 | 0.000000 | 0.500000 | 0.000000e+00 |
| squared_hinge | 0.2 | 0.500000 | 0.500000 | 0.000000e+00 | 0.000000 | 0.500000 | 0.500000 | 0.000000e+00 | 0.000000 | 0.500000 | 0.000000e+00 |
| squared_hinge | 0.3 | 0.500000 | 0.500000 | 0.000000e+00 | 0.000000 | 0.500000 | 0.500000 | 9.016767e-07 | 0.000000 | 0.500000 | 2.817740e-08 |
| hinge | 0.2 | 0.500000 | 0.500000 | 9.016767e-07 | 0.000000 | 0.500000 | 0.500000 | 9.016767e-07 | 0.000000 | 0.500000 | 8.453219e-08 |
| hinge | 0.1 | 0.500000 | 0.500000 | 0.000000e+00 | 0.000000 | 0.500000 | 0.500000 | 9.004791e-07 | 0.000000 | 0.500000 | 8.907529e-08 |

# $j \to \tau$ Fakes

# Background Estimation: $j \to \tau$ Fakes

- Extract Fake-Factors $FF = \frac{N^{CR}_{\tau_{had-vis}}}{N^{CR}_{\bar{\tau}_{had-vis}}}$ from two orthogonal control regions:

| Multi-Jet (gluon enriched) | W+Jets (quark enriched) |
|---|---|
| $E_T^{miss}$ or Multi-Jet trigger | Single lepton triggers |
| $\geq 3$ jets | $\geq 1$ jet |
| 0 b-jets | 0 b-jets |
| $0\ \ell$ | $1\ \ell$, $p_T^{\ell} > 30$ GeV |
| $E_T^{miss} < 80$ GeV | $1\ \tau$ |
| $m_T(\tau, E_T^{miss}) > 50$ GeV | $60 < m_T(\ell, E_T^{miss}) < 160$ GeV |

- Combine the two Fake-Factors via the template fit method:
  - Find two separate templates for anti-$\tau$ in each CR
  - Fit both templates to the shape of the anti-$\tau$ in the SR
  - Lowest $\chi^2$ of the fit defines $\alpha_{MJ}$ value and the corresponding error

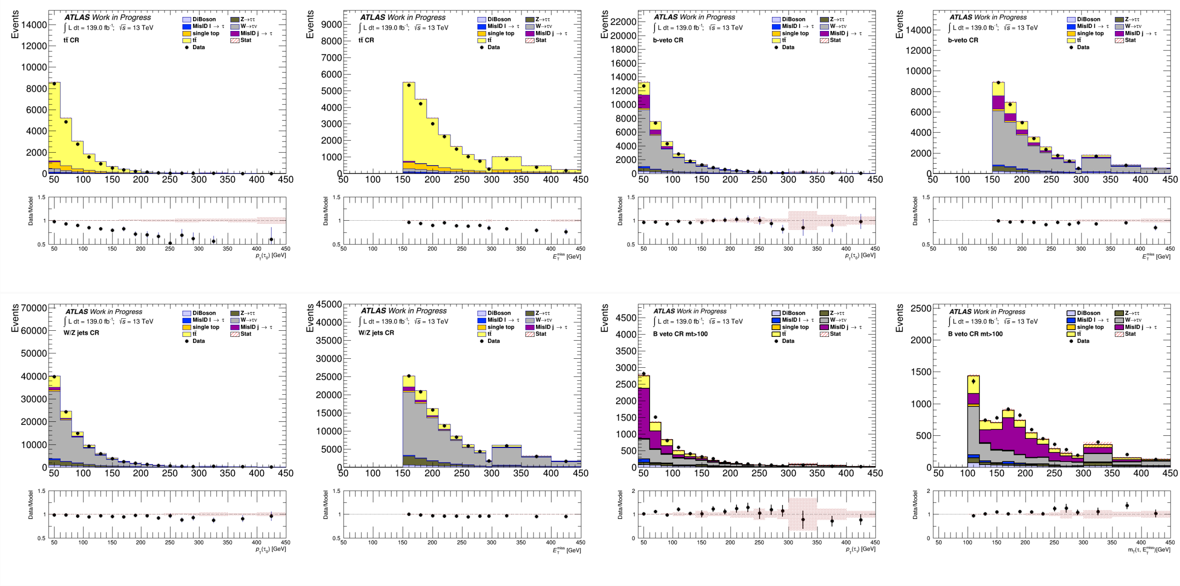
$$FF_i^{comb} = \alpha_i^{MJ} FF_i^{MJ} + [1 - \alpha_i^{MJ}] FF_i^{W+jets}$$

- Number of events with fake $\tau$ in the signal region is given by:

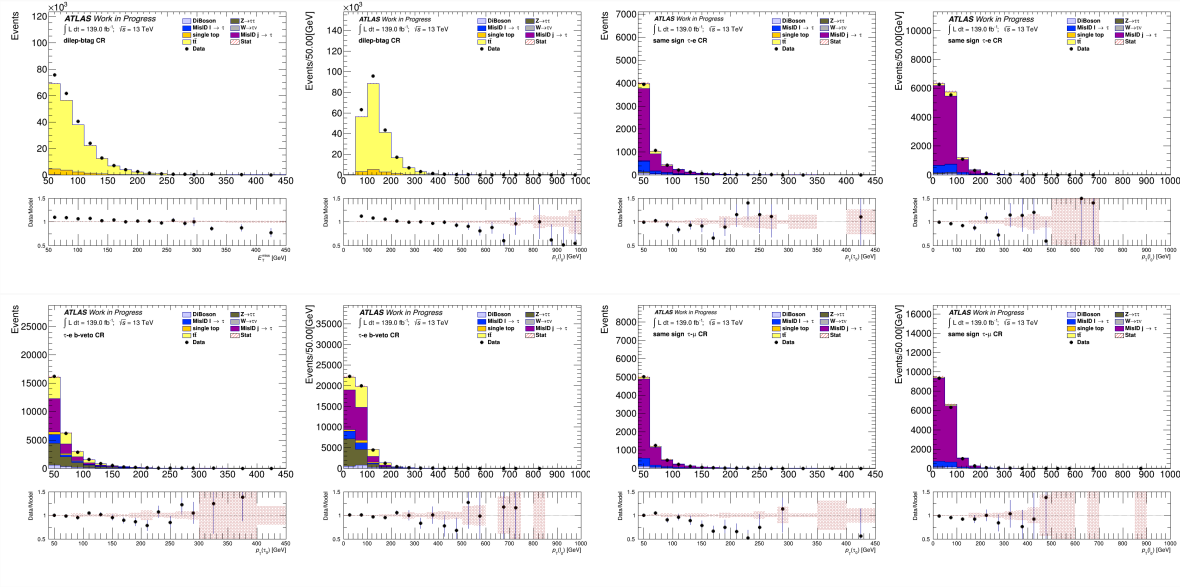
$$N_{fakes}^{\tau_{had-vis}} = \sum_i N^{SR_i}_{\bar{\tau}_{had-vis}} FF_i$$

# Background Modeling

# $\tau + jets$ Background Modeling



# $\tau + \ell$ Background Modeling



# Preliminary PNN Results $\tau + jets$ SR

# Fit

# Fit Model

- Workspaces prepared with WSMaker
- Statistical uncertainty only considered for now
- MVA classifier score used as the discriminating variable
  - Fitting the profile likelihood ratio
- Fitted Regions
  - $\tau + \ell$ Dilepton-btag CR is fit with a single bin (normalization only)

| **Control Region** | **Signal Regions** |
|---|---|
| $t\bar{t}$ | $\tau + jets$ SR |
| | $\tau + e$ SR |
| | $\tau + \mu$ SR |

- Binning is yet to be decided

# Previous Analysis

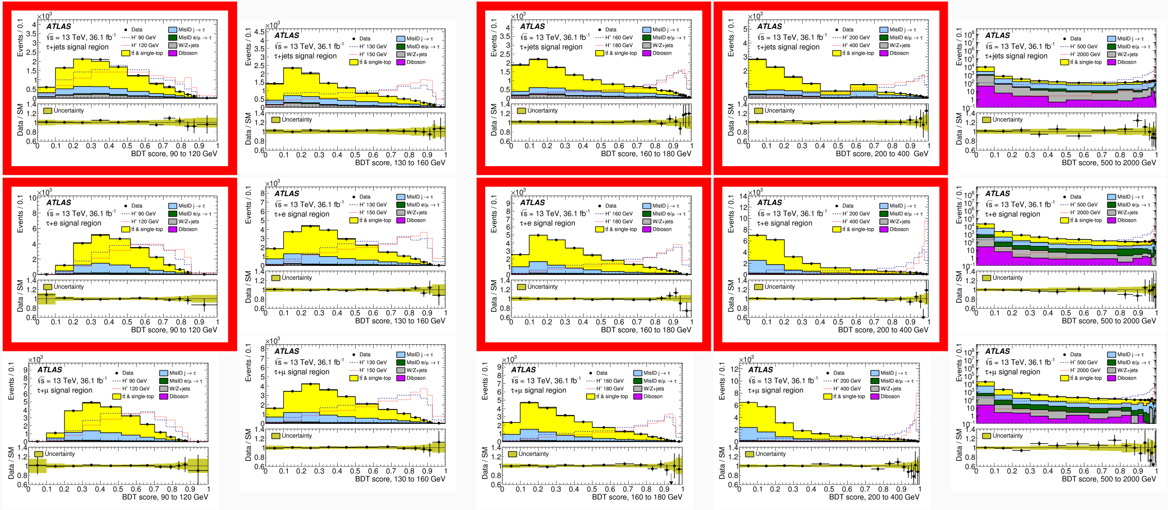
# Previous Multivariate Analysis

- Background modeling and classifier training kept statistically independent via the k-fold method
- BDTs (FastBDT via TMVA) binned in $m_{H^\pm}$
  - 90-120, 130-160, 160-180, 200-400, 500-2000 GeV
  - Trained separately on $\tau + jets$ and $\tau + \ell$
  - Independent trainings for 1 or 3 $\tau$ tracks
  - $\tau + \ell$ trained inclusively, evaluated separately on $\tau + \mathrm{e}$ and $\tau + \mu$
- At low $m_{H^\pm}$, $\tau$ polarization is important
  - $\Upsilon = \frac{E_T^{\pi^\pm} - E_T^{\pi^0}}{E_T^\tau} \approx 2\frac{p_T^{\tau-track}}{p_T^\tau} - 1$
  - Only defined for 1 track $\tau$ candidates
- At high, $m_{H^\pm}$ $\Upsilon$ becomes less important
  - $E_\mathrm{T}^\mathrm{miss}$, $p_\mathrm{T}^\tau$, and $\Delta\phi_{\tau,\mathrm{miss}}$ have higher discriminating power

kFoldDiagram.pdf

| MVA input variable | $\tau + jets$ | $\tau + \ell$ |
|---|---|---|
| $E_\mathrm{T}^\mathrm{miss}$ | ✓ | ✓ |
| $p_T^\tau$ | ✓ | ✓ |
| $p_T^{b-jet}$ | ✓ | ✓ |
| $\Delta\phi(\tau, E_T^{miss})$ | ✓ | ✓ |
| $\Delta\phi(b-jet, E_T^{miss})$ | ✓ | ✓ |
| $\Delta R(b-jet, \tau)$ | ✓ | |
| $p_T^l$ | | ✓ |
| $\Delta\phi(l, E_T^{miss})$ | | ✓ |

# Previous BDT Scores in Signal Regions



# Previous BDT Scores in Signal Regions