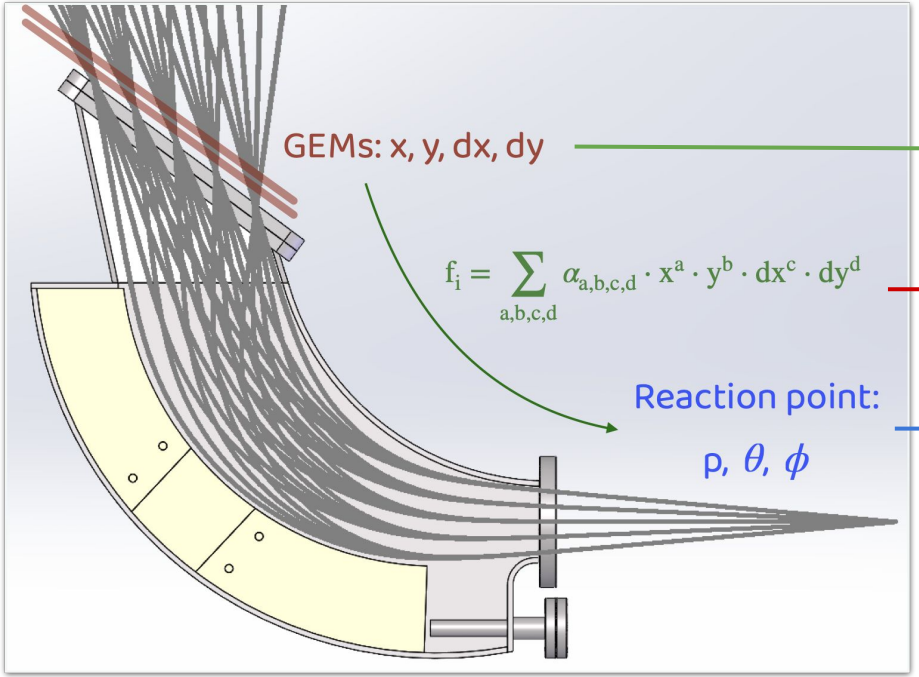
# ML for Mass Reconstruction




Inputs

ML model

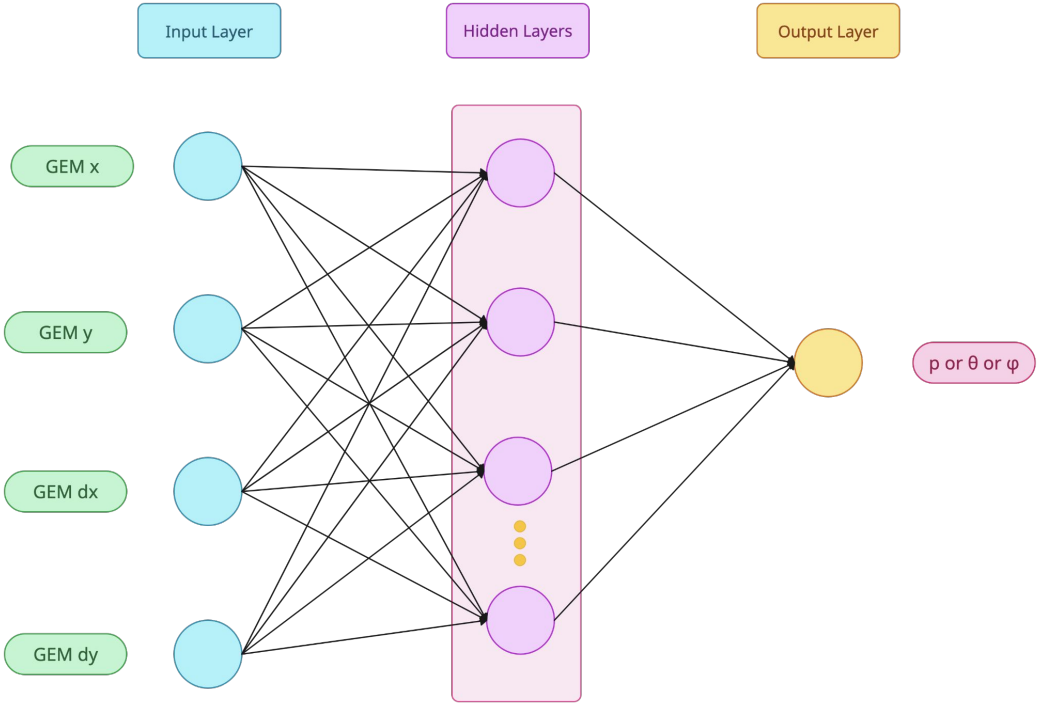
Outputs

- Neural network
- Random forest
- XGBoost

# **Neural network**:

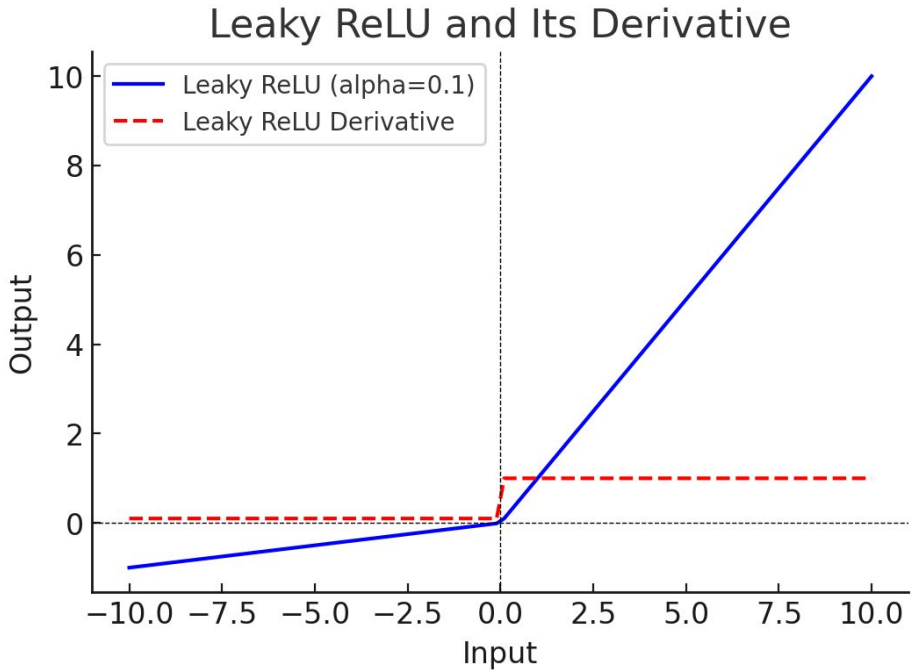
- simple testing model 1

- linear network
- individual model for each output
- Use optimizer to find layers and neurons
- Activation function: Leaky ReLu



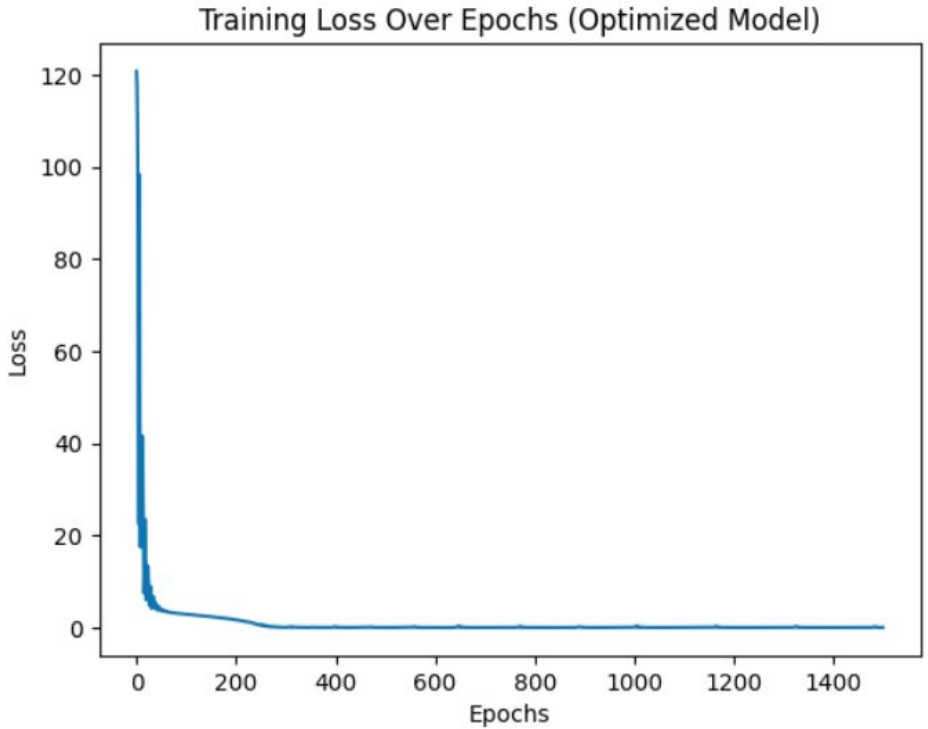
# Leaky ReLU Function

$$\text{LeakyReLU}(x) = \begin{cases} x, & \text{if } x > 0 \\ \alpha x, & \text{if } x \leq 0 \end{cases}$$

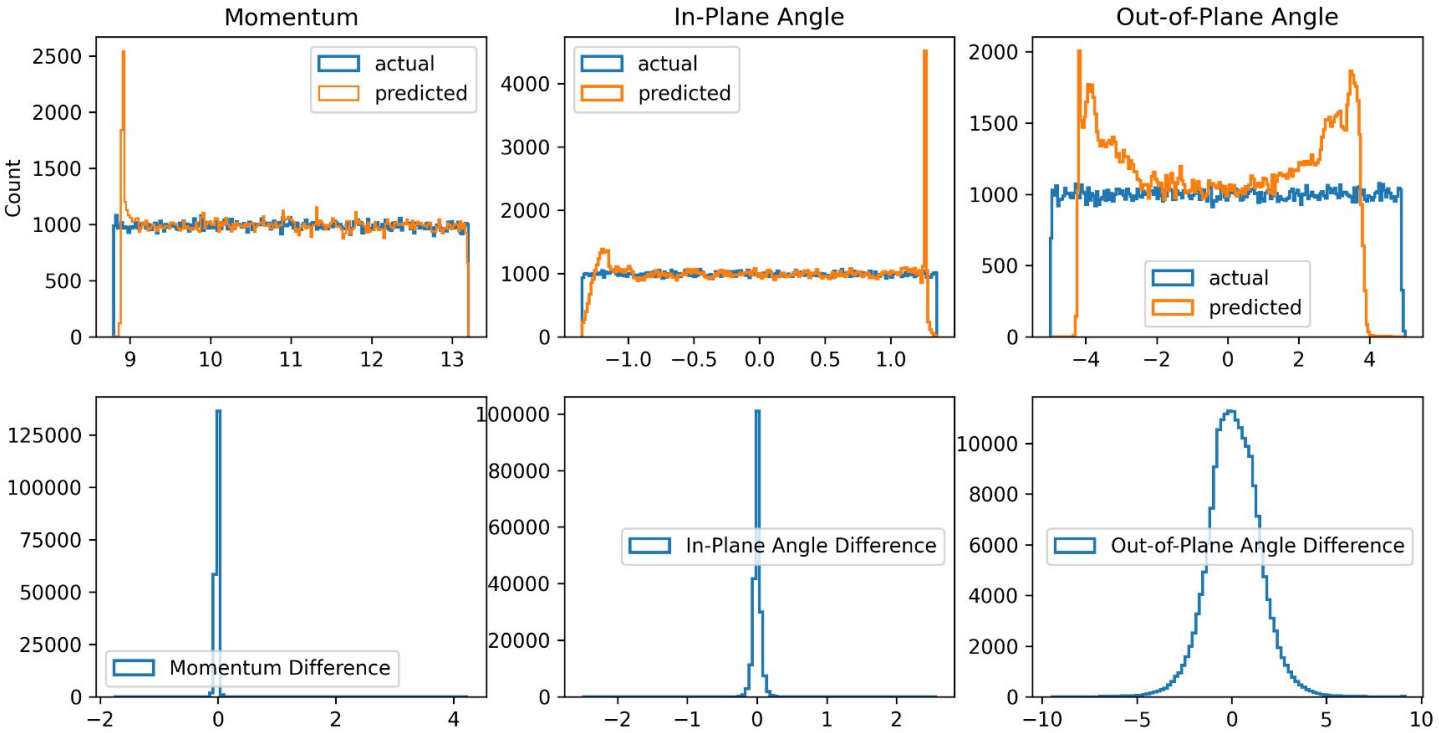


# Network architecture

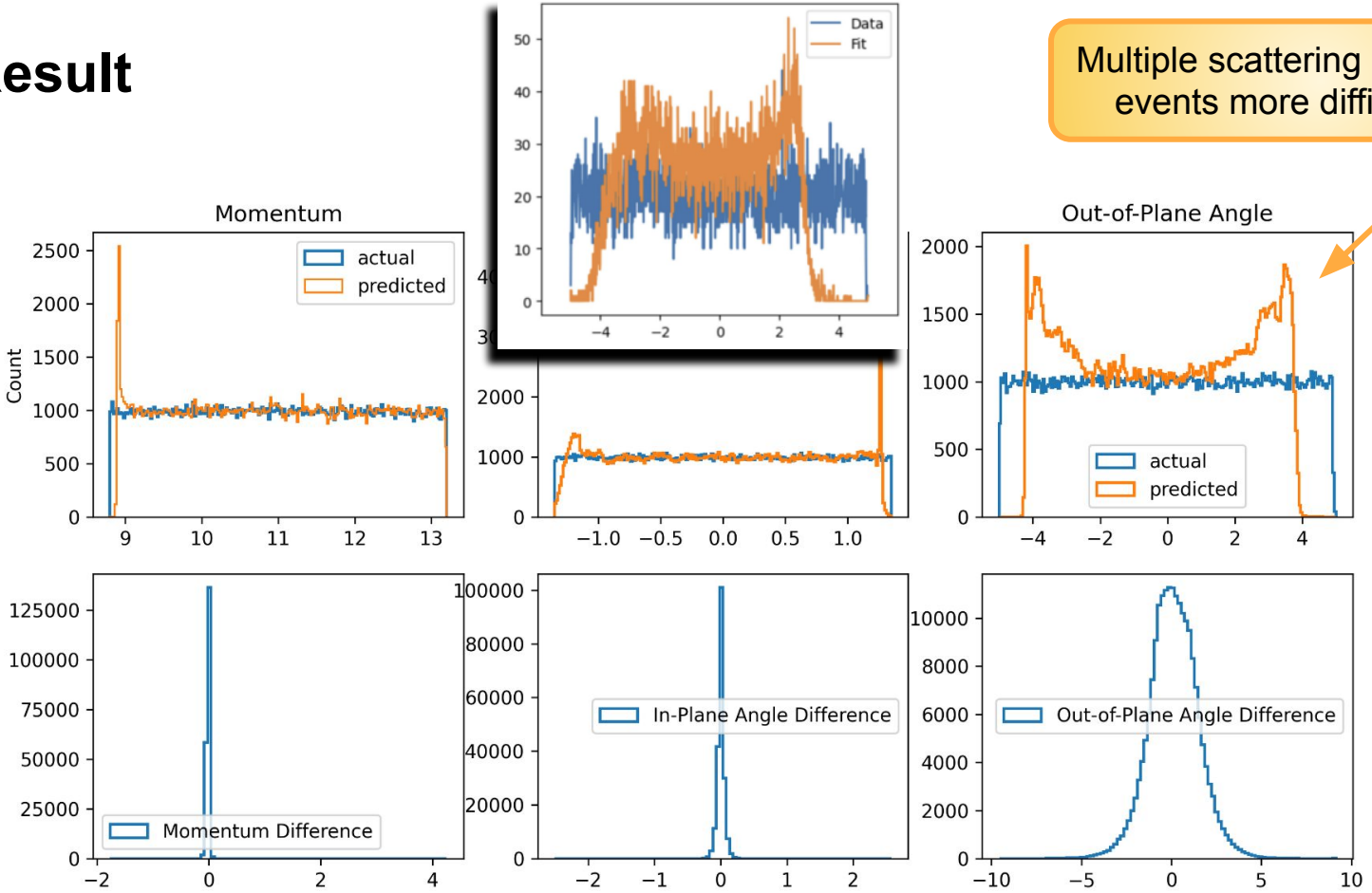
```
OptimizedMomentumNetwork(
  (linear_relu_stack): Sequential(
    (0): Linear(in_features=4, out_features=20, bias=True)
    (1): LeakyReLU(negative_slope=0.01)
    (2): Linear(in_features=20, out_features=20, bias=True)
    (3): LeakyReLU(negative_slope=0.01)
    (4): Linear(in_features=20, out_features=68, bias=True)
    (5): LeakyReLU(negative_slope=0.01)
    (6): Linear(in_features=68, out_features=84, bias=True)
    (7): LeakyReLU(negative_slope=0.01)
    (8): Linear(in_features=84, out_features=84, bias=True)
    (9): LeakyReLU(negative_slope=0.01)
    (10): Linear(in_features=84, out_features=20, bias=True)
    (11): LeakyReLU(negative_slope=0.01)
    (12): Linear(in_features=20, out_features=100, bias=True)
    (13): LeakyReLU(negative_slope=0.01)
    (14): Linear(in_features=100, out_features=1, bias=True)
  )
)
```


Training Loss Over Epochs (Optimized Model)
Loss
Epochs
120
100
80
60
40
20
0
0
200
400
600
800
1000
1200
1400

# NN Result

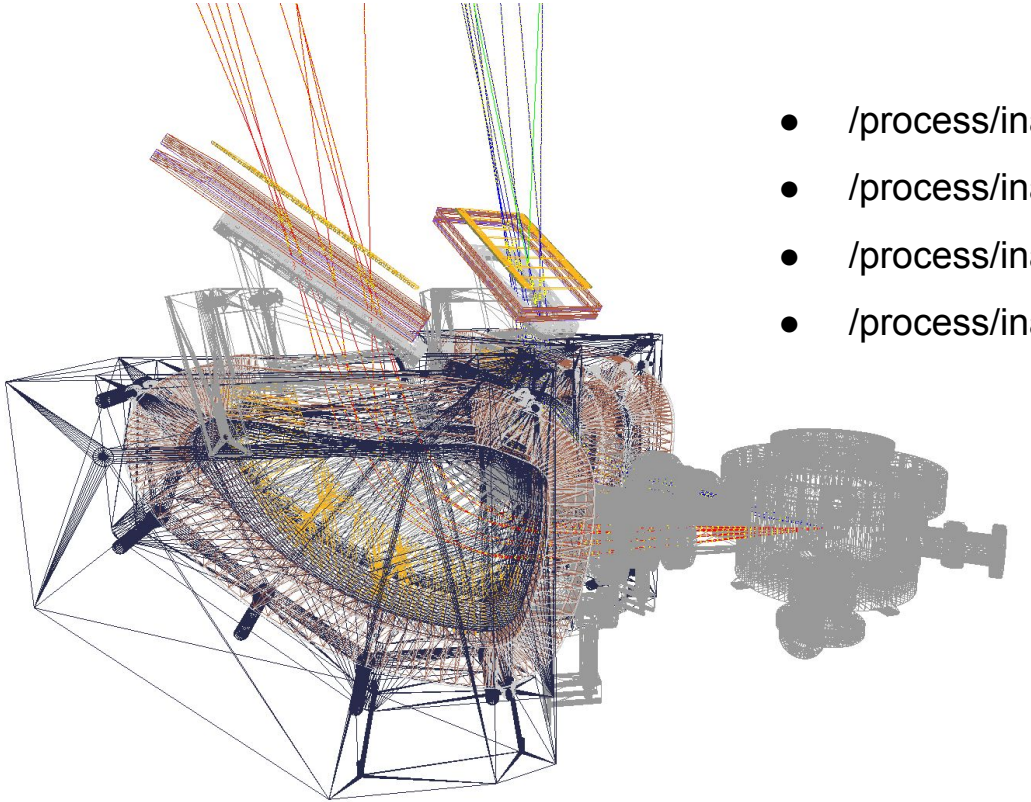

Momentum
In-Plane Angle
Out-of-Plane Angle
Count
actual
predicted
Momentum Difference
In-Plane Angle Difference
Out-of-Plane Angle Difference

# NN Result



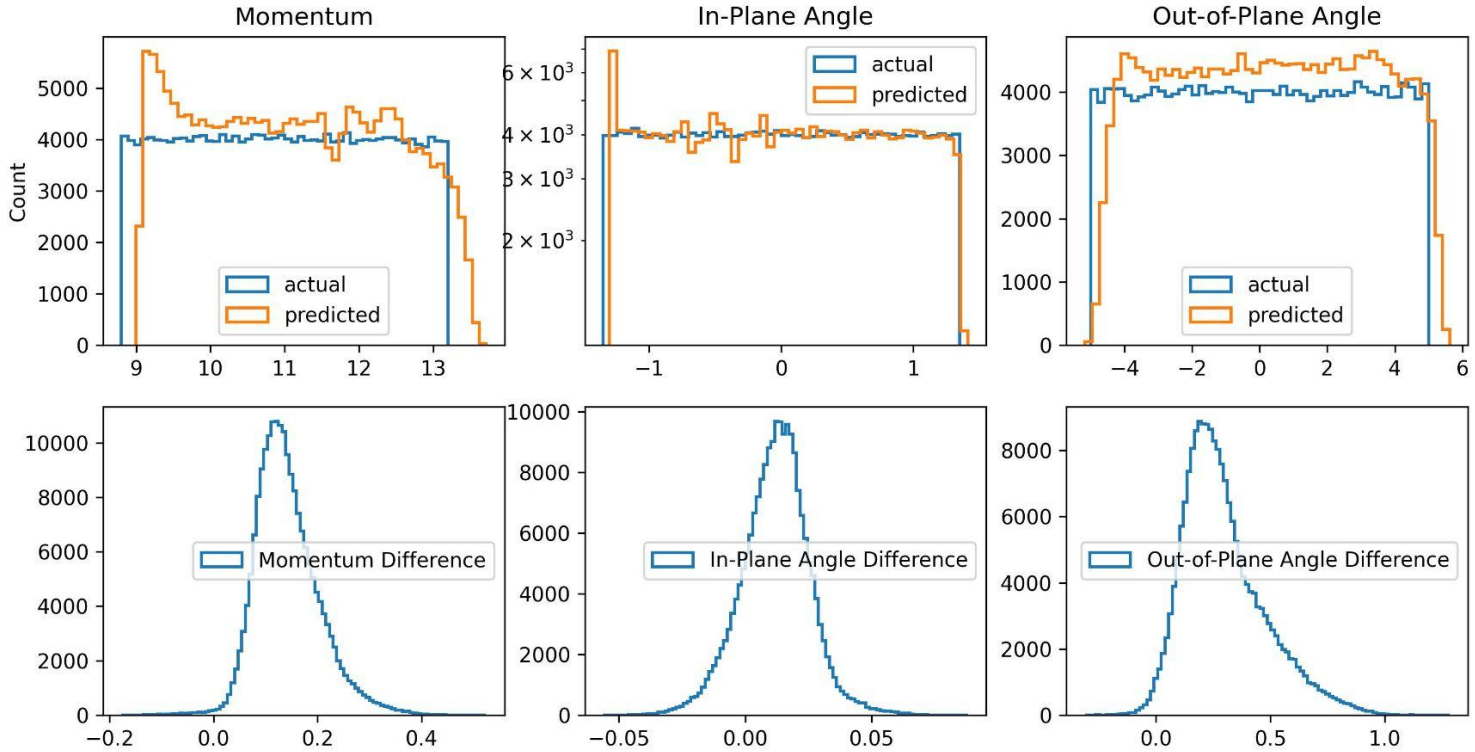

Multiple scattering makes edge events more difficult to fit?

# Tried with less physics effect and smearing



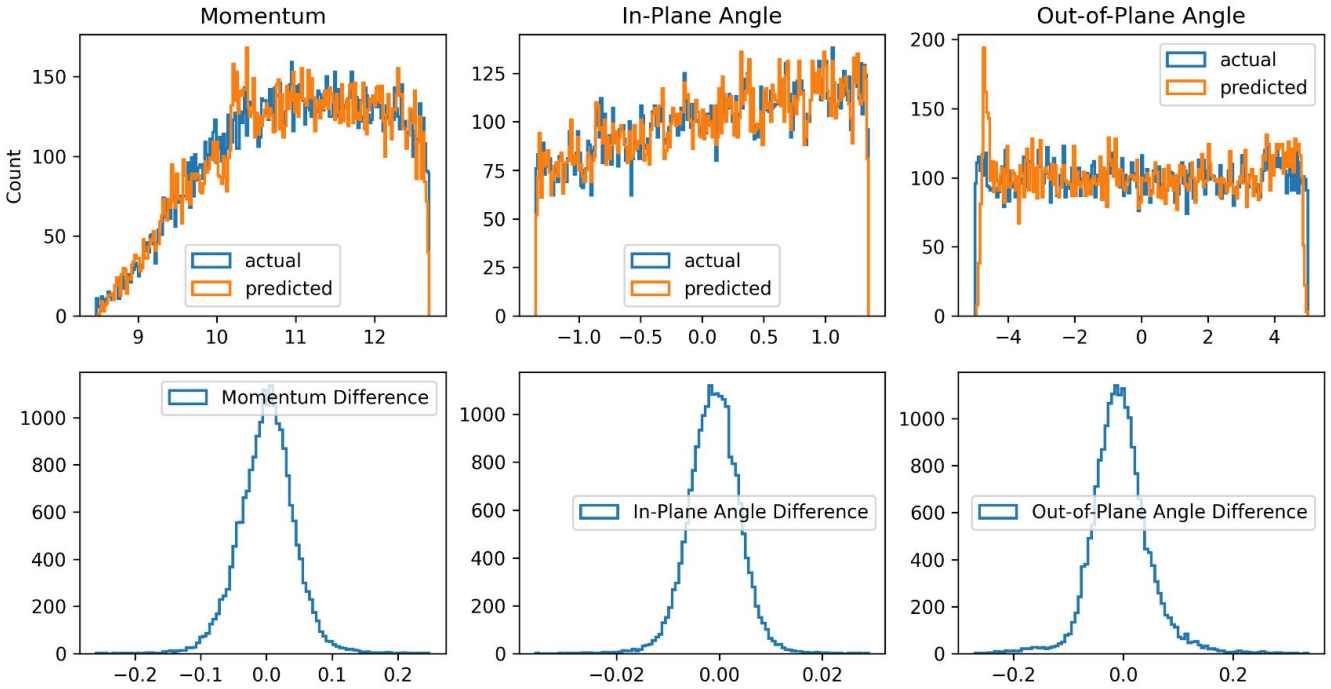
- /process/inactivate msc
- /process/inactivate eIoni
- /process/inactivate eBrem
- /process/inactivate CoulombScat

# Tried with less physics effect and smearing

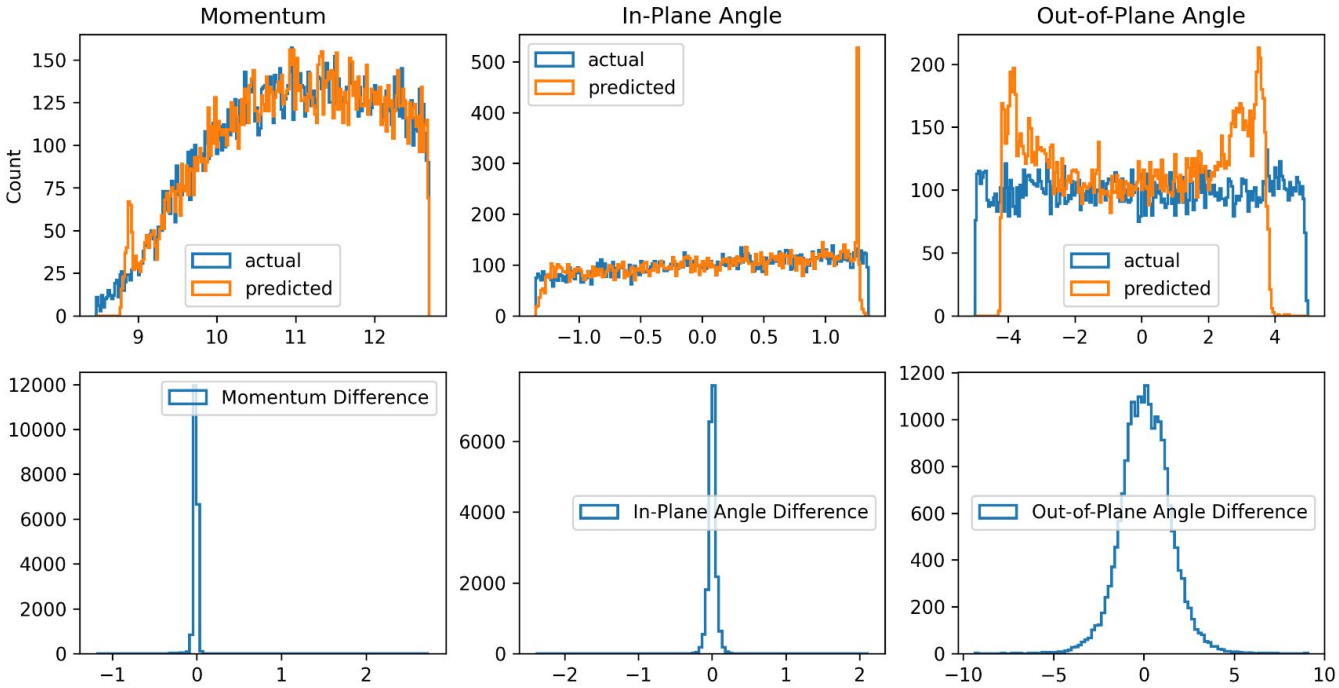



Neural Network

# Neural Networks (No-Scattering + Full Simulation)

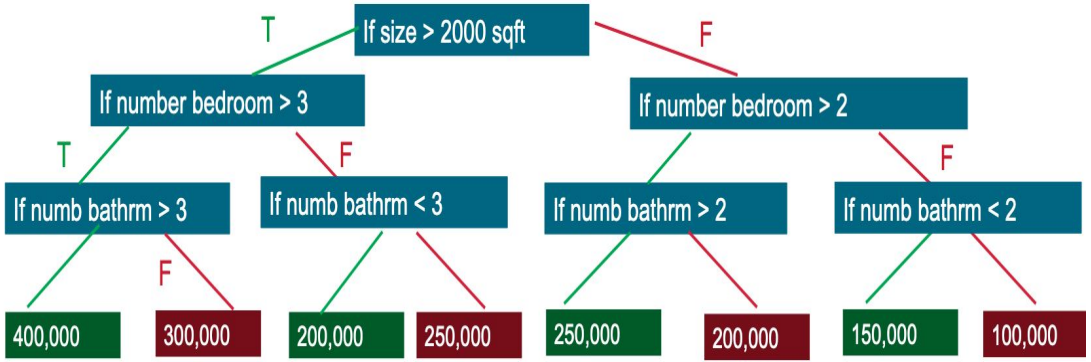


# Neural Networks (Scattering + Full Simulation)

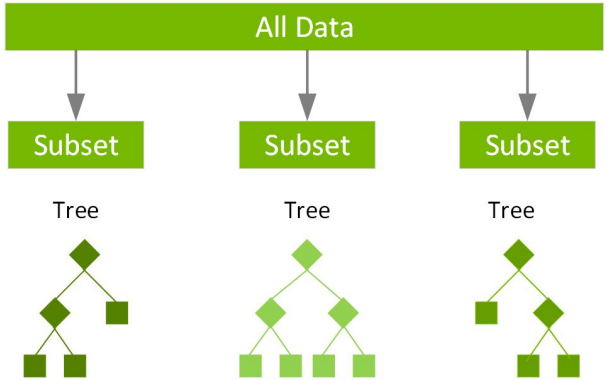


# Model 2: XGBoost (Extreme Gradient Boosting)

Decision trees

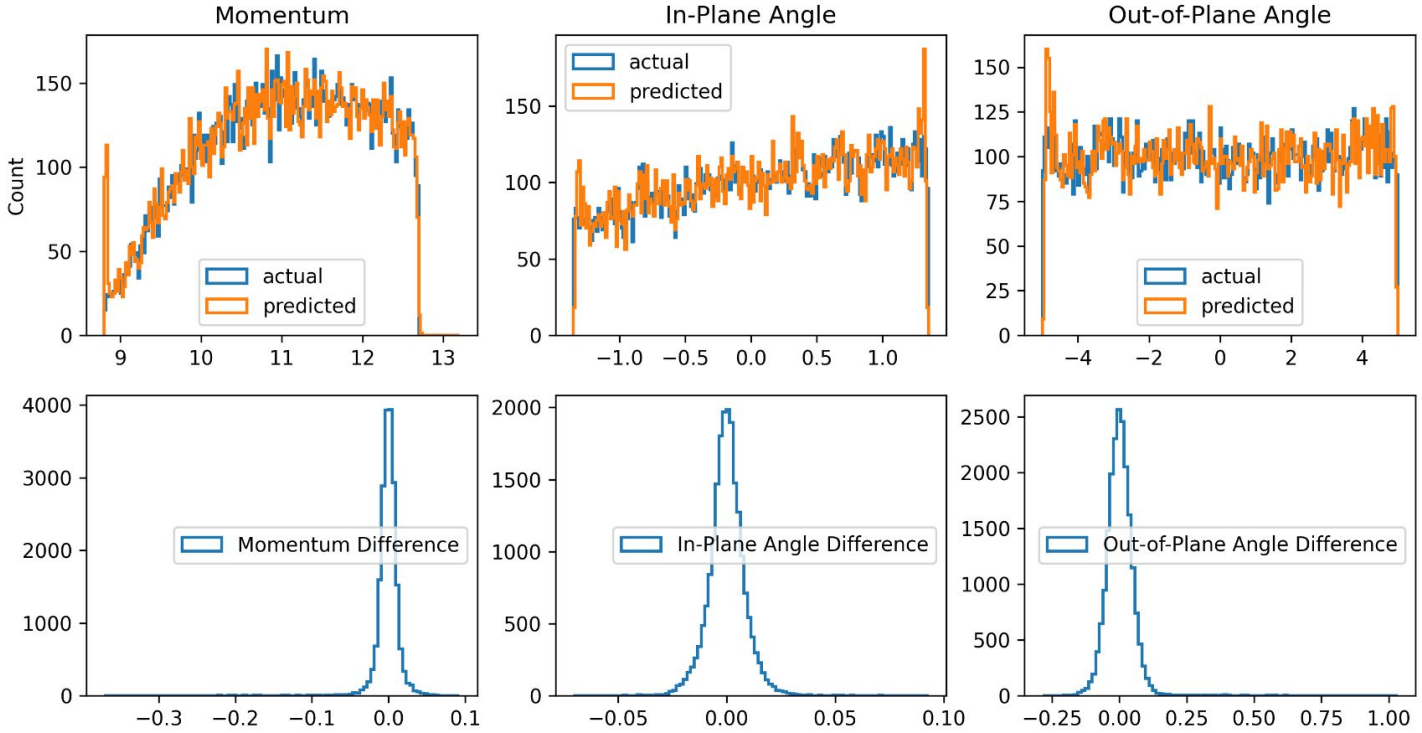



Random forest / Gradient Boosting

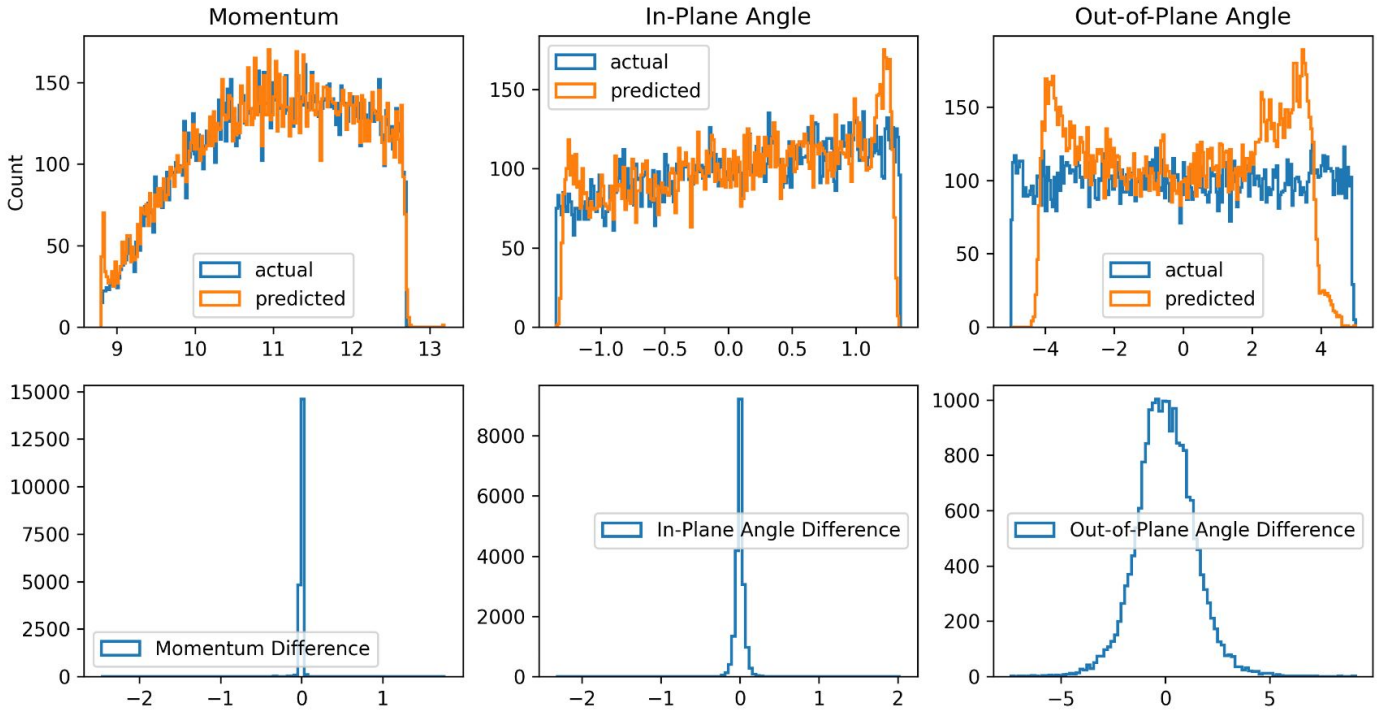



https://www.nvidia.com/en-us/glossary/xgboost/

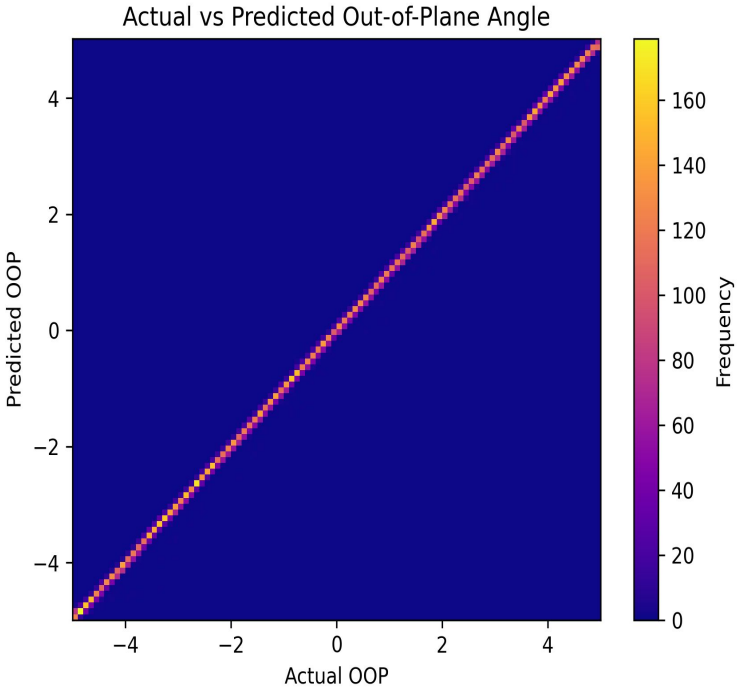
# XGBoost (No-Scattering + Full Simulation)

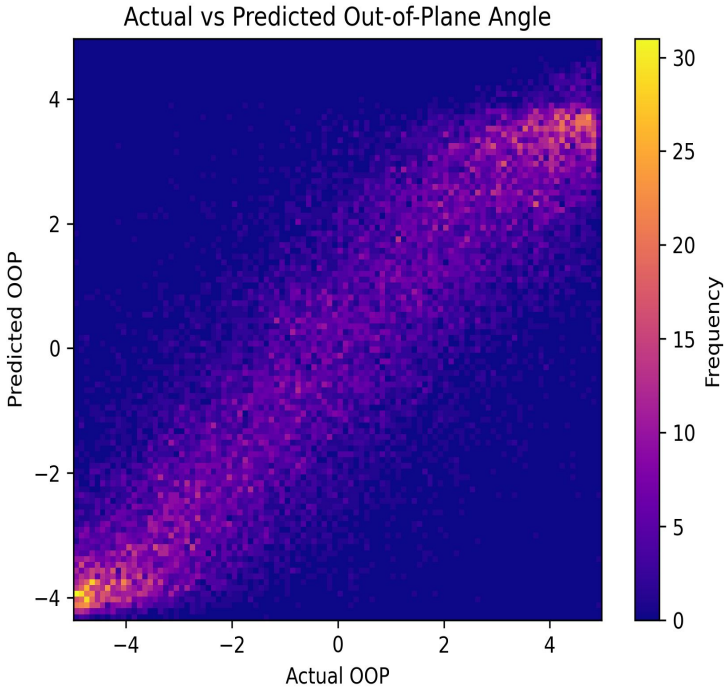


# XGBoost (Scattering + Full Simulation)



# XGBoost Actual vs Predicted Out-of-Plane Angles



XGBoost

| | Time (s) | | Loss (RMSE) | |
|---|---|---|---|---|
| | Optimization | Training | Validation | Test (Signal) |
| No Scattering Data (Electron) | | | | |
| Momentum | 200.12 | 25.7 | 0.0114 | 0.0207 |
| In-Plane Angle | 528.927906 | 19.29 | 0.0087 | 0.00841426 |
| Out-of-Plane Angle | 1534.89 | 23.72504377 | 0.0461 | 0.0207282 |
| | | | | |
| Scattering Data (Electron) | | | | |
| Momentum | 657.94 | 14.11 | 0.0374 | 0.073 |
| In-Plane Angle | 1072.86 | 13.67 | 0.0601 | 0.0694 |
| Out-of-Plane Angle | 1259.41 | 25.23 | 1.29 | 1.369 |

Neural Networks

| | Time (s) | | Loss (RMSE) | |
|---|---|---|---|---|
| | Optimization | Training | Validation | Test (Signal) |
| No Scattering Data (Electron) | | | | |
| Momentum | 162.3624 | 141.3622 | 0.042914 | 0.04217603272 |
| In-Plane Angle | 160.6381 | 157.4693 | 0.01 | 0.005 |
| Out-of-Plane Angle | 188.9062 | 243.3212 | 0.053213 | 0.05369 |
| | | | | |
| Scattering Data (Electron) | | | | |
| Momentum | 208.7046 | 232.819 | 0.047494 | 0.04736 |
| In-Plane Angle | 172.2382 | 170.5199 | 0.061787 | 0.0677 |
| Out-of-Plane Angle | 200.9732 | 191.9274 | 1.387367 | 1.385 |

# Backups

# Polynomial fit