Low-Bias Correction Energy

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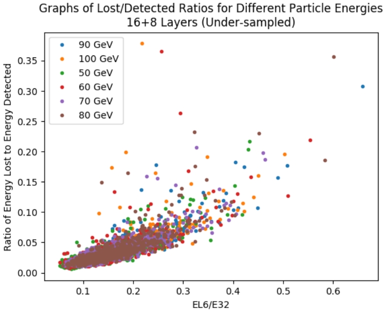
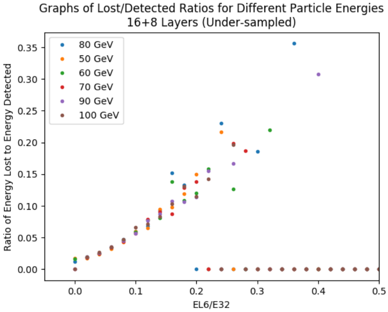
Simple Stack Setup

- Electrons fired perpendicular to calorimeter
- Data generated with 60 thin layers
- Model undersampling of deep layers by ignoring data from alternate silicon layers
  - Thin layer $\approx 0.64X_0$
  - Thick layer $\approx 1.28X_0$
- Correction methods here use only **16 thin layers and 8 thick layers** to measure energy and make correction
  - SiD uses 20 thin and 10 thick layers

Correction Energy from Last Six Layers

- Correlate ratio of energy lost to energy measured
- Function of EL6/E32
- Trend consistent across particle energies
- Model trained on one particle energy can correct other energies





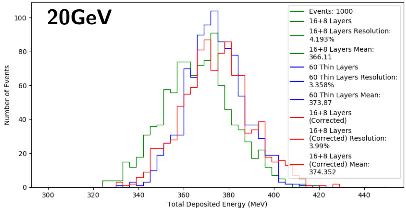
Neural Network using Only Discrete Particle Energies

- One hidden layer
- Batch size = 32
- Epochs = 1000
- Train on each data set separately
- Weight each fit based on how close a given particle's energy deposition is to the average deposited by each training set: $\frac{1}{(E_{avg} - E_{32})^{10}}$
  - E_{avg} is average energy deposited by each training set
  - E_{32} is the energy deposited for the event being corrected

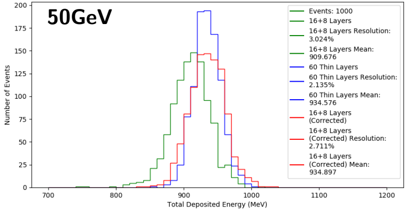
Examples of Neural Network Performance using Discrete Particle Energies

Measured, **Corrected**, **Ideal**

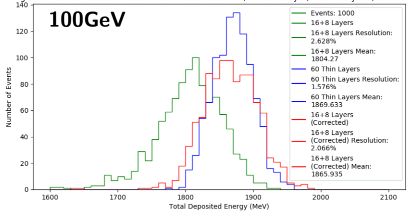
Histogram of 20GeV Events Trained with a Neural Network (1 Hidden Layer) - 16+8 Layers (Under-sampled)



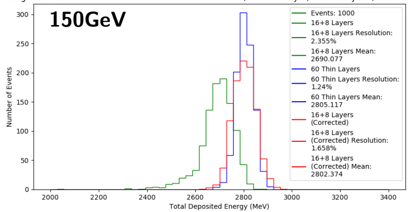
Histogram of 50GeV Events Trained with a Neural Network (1 Hidden Layer) - 16+8 Layers (Under-sampled)



Histogram of 100GeV Events Trained with a Neural Network (1 Hidden Layer) - 16+8 Layers (Under-sampled)

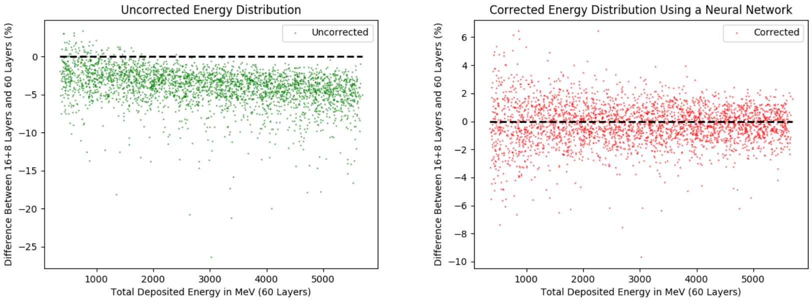


Histogram of 150GeV Events Trained with a Neural Network (1 Hidden Layer) - 16+8 Layers (Under-sampled)



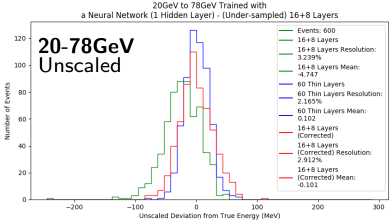
Neural Network Trained on Continuous Distribution of Particle Energies

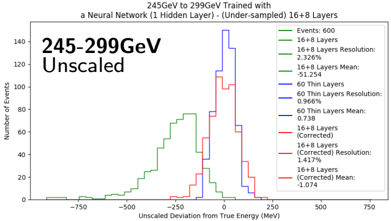
- Neural network trained on entire distribution
- When correcting continuous distribution, resolution calculated by dividing distribution into bins with equal numbers of events

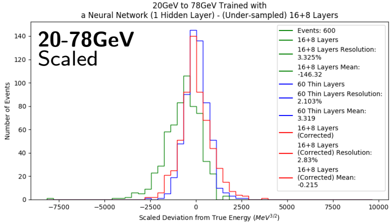


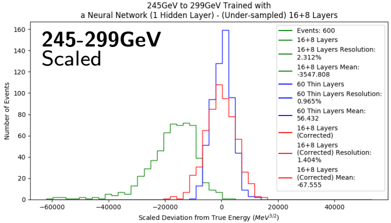
Neural Network Trained on Continuous Distribution of Particle Energies

Each event is scaled by $\sqrt{E_{Truth}}$ and divided by $\sqrt{< E_{Truth} >}$ after binning to improve accuracy of resolution





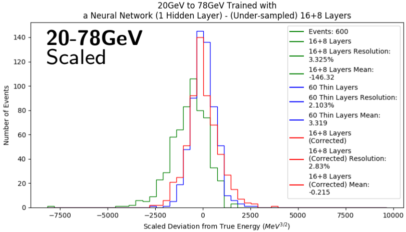


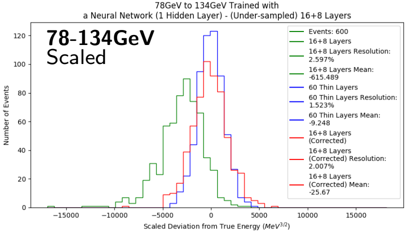


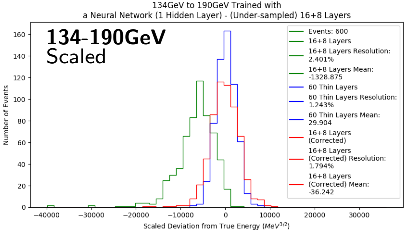
Measured, **Corrected**, **Ideal**

NN Trained on Continuous Distribution Correcting Continuous Particle Energy Distribution

Measured, Corrected, Ideal

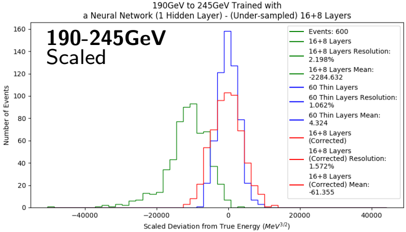


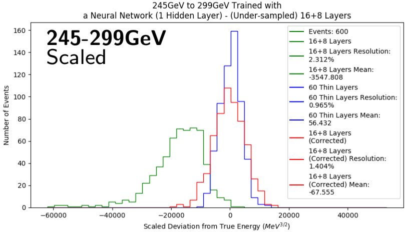




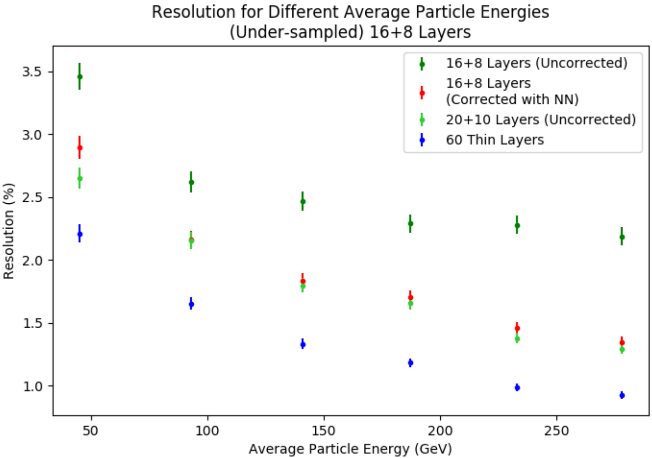
NN Trained on Continuous Distribution Correcting Continuous Particle Energy Distribution

Measured, **Corrected**, **Ideal**

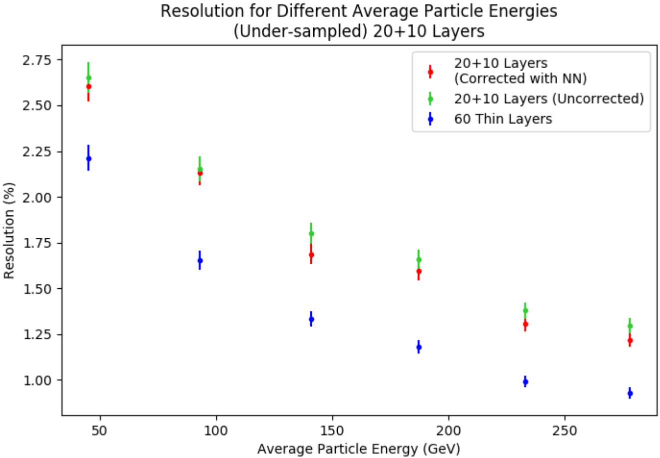




Continuous Distribution Resolution

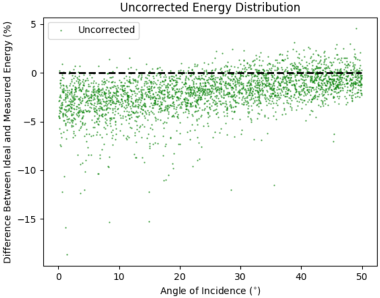


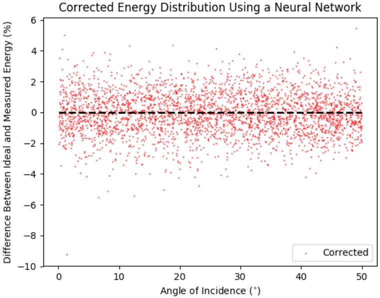
Resolution for 20+10 Layers with NN Correction



NN Trained on Angle Distribution at Constant Energy

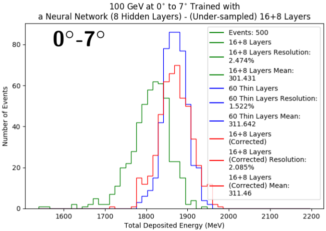
- Electrons incident at random angles between 0° and 50°
- Constant energy: 100GeV

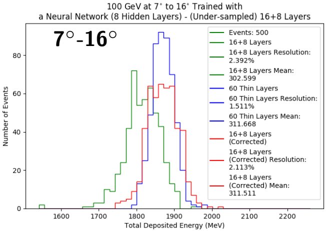


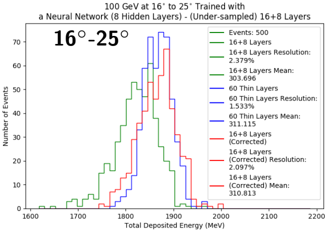


NN Trained on Angle Distribution at Constant Energy

Measured, **Corrected**, **Ideal**

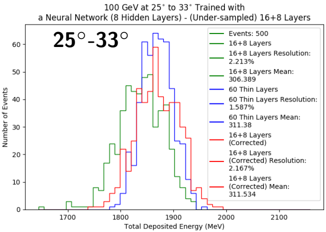


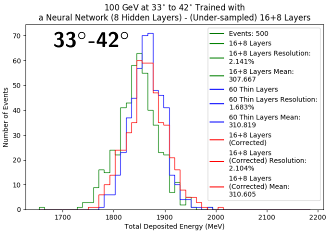


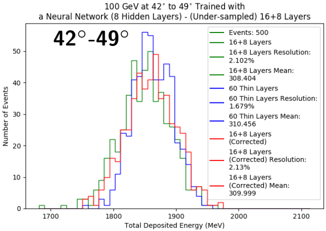


NN Trained on Angle Distribution at Constant Energy

Measured, **Corrected**, **Ideal**

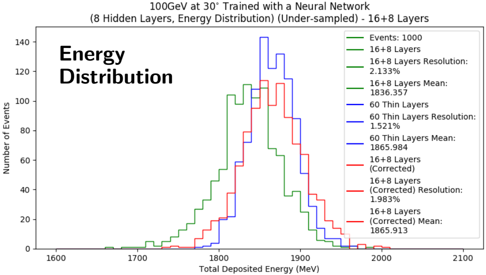


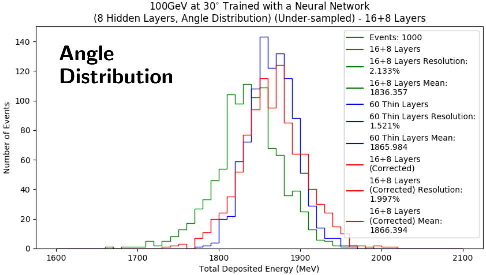




Comparison of Angle Distribution and Energy Distribution Training

- 100GeV events at 30°
- Correction using energy distribution (20-300GeV) at 30° works slightly better than angle distribution (0°-50°) at 100GeV

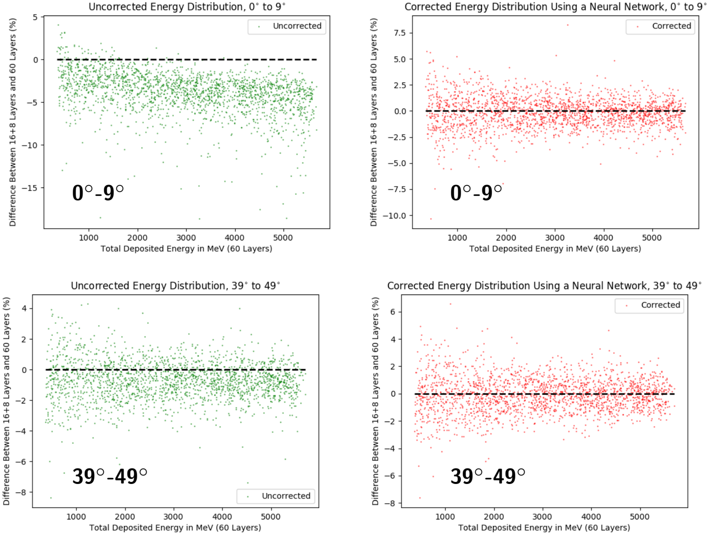




Measured, **Corrected**, **Ideal**

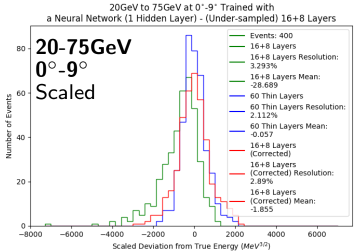
NN Trained on Angle and Energy Distribution

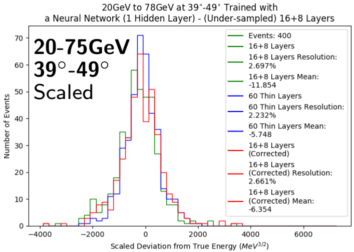
- 10000 events, 20-300GeV, 0°-50°

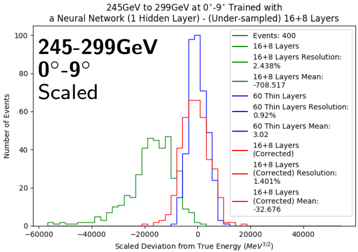


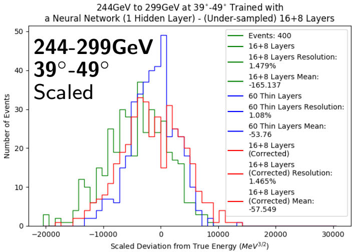
NN Trained on Angle and Energy Distribution

Measured, Corrected, Ideal

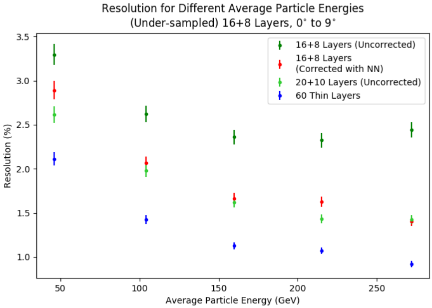


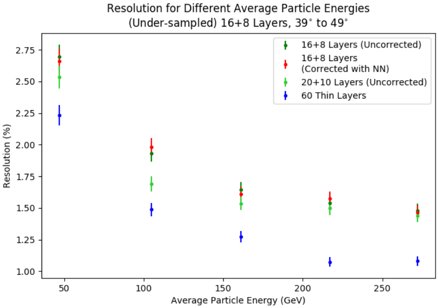






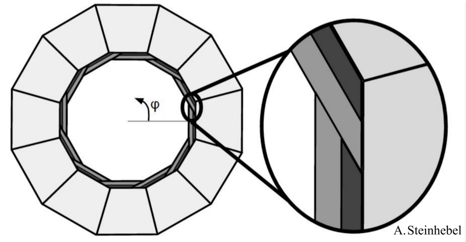
Large resolution improvement at shallow angles
Resolution improvement less important at steep angles



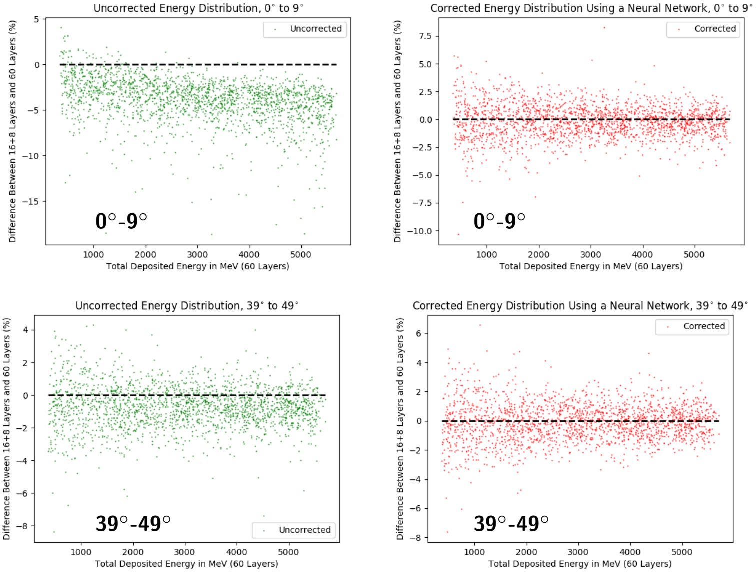


Full SiD Model

- More thorough geometry model
- Modified SiD specifications:
  - No solenoid, $B = 0$
  - No vertex detector, tracker, HCal, or muon system
  - Extended ECal to 60 layers
- Tested NN on distribution of energies (20-300GeV) and angles ($\theta \in (0^\circ, 45^\circ)$, $\phi \in (0^\circ, 360^\circ)$)



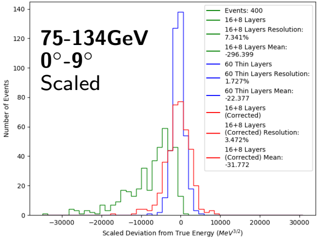
Full SiD Model



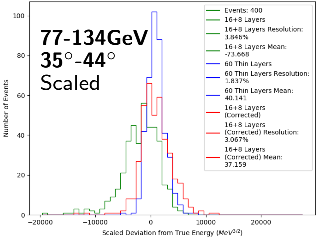
Full SiD Model

Measured, **Corrected**, **Ideal**

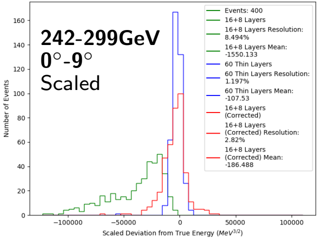
75GeV to 134GeV at 0°-9° Trained with
a Neural Network (1 Hidden Layer), Full SiD Model (All ϕ, B=0)
(Under-sampled) 16+8 Layers



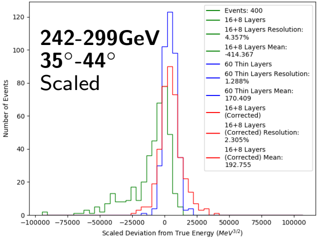
77GeV to 134GeV at 35°-44° Trained with
a Neural Network (1 Hidden Layer), Full SiD Model (All ϕ, B=0)
(Under-sampled) 16+8 Layers



242GeV to 299GeV at 0°-9° Trained with
a Neural Network (1 Hidden Layer), Full SiD Model (All ϕ, B=0)
(Under-sampled) 16+8 Layers



242GeV to 299GeV at 35°-44° Trained with
a Neural Network (1 Hidden Layer), Full SiD Model (All ϕ, B=0)
(Under-sampled) 16+8 Layers



Next Steps

- Account of geometry complications
  - Overlapping regions in ϕ
- Increase amount of data used in NN
  - Number of hits per layer
  - Consider ϕ in analysis as well as θ
- Use ECal hits to calculate angle of incidence (instead of MC truth)