Position Reconstruction in the CDMS HV100mm Detector

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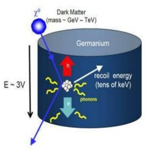
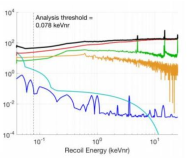
Motivation





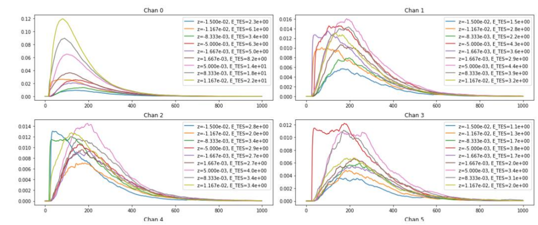
- Detect **dark matter** particle candidates
- Detectors are semiconductor crystals instrumented with **sensors**
- Extract **positional information** reliably from the sensor data
- Improve **background rejection** using fiducial cuts
- An effective fiducial cut **can improve** the **signal-to-background** ratio by up to **20x**!

Dataset & Features

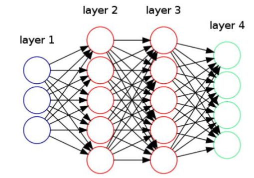
- Output voltage traces of 12 sensors
- Sensor response for energy hits at inputted positions (x, y, z)
- Generated by simulations
- Sensor voltage normalized to range from 0 to 1

- **Input vector:** 12 sensors * 1000 time steps = 12000 row-vector
- **Output/ Label:** 3 row-vector representing x,y,z coordinates

V=0, E=10eV, (x,y)=(0,0)



Model

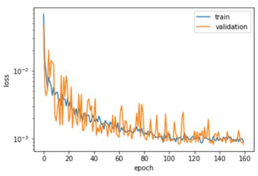


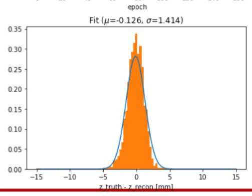
- Supervised Learning
- Fully connected neural network
- #layers, #hidden units as hyperparameters
- Modified MSE cost:

$$L = \sum_i (y_i - \hat{y}_i)^2 + \lambda(\sum_i y_i - \hat{y}_i)^2$$

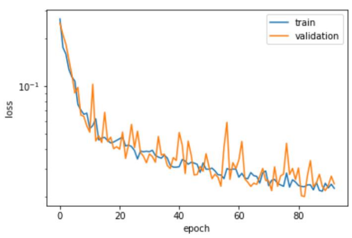
Results

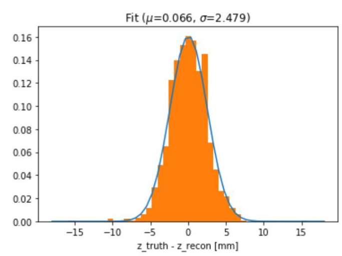
Sub-problem: single coordinate (output = [z])





All coordinates (output = [x,y,z])





- layers: [12000, 16, 20, 16, 18, 3]
- lambda_bias: 1.0

- batch_size: 32
- epoch: 200

Future

- Investigate the **position and voltage dependence** of the resolution
- Try **other neural network models** like convolutional neural network to include effects such as time offsets and pile-ups present in real data
- Train and test the model with **real sensor data**

References

[1] A Deep Learning-based Reconstruction of Cosmic Ray-induced Air Showers, arXiv:1708.00647
[2] Projected sensitivity of the SuperCDMS SNOLAB experiment, PHYSICAL REVIEW D 95, 082002 (2017)