Machine Learning for Water Cherenkov Detectors of Hyper-Kamiokande

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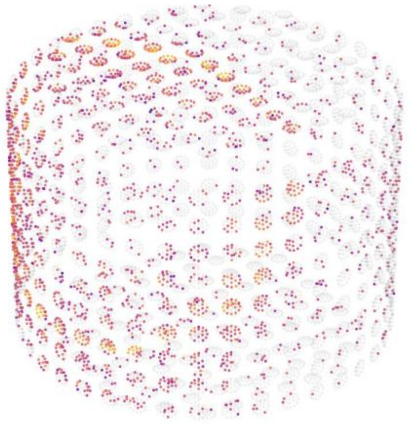
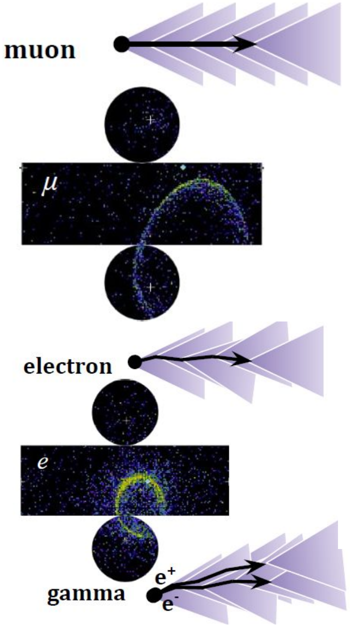
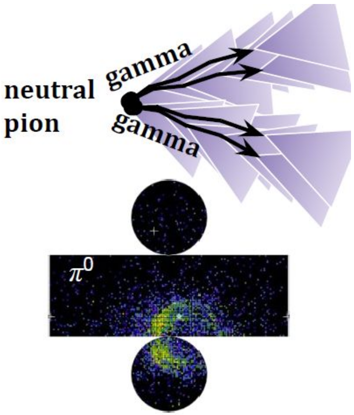


About detector and dataset

- 20 PMTs in one mPMT module (19 PMTs arranged in 2 rings and 1 in the center)
- Simulated nuclear scattering
- Classes e, mu, gamma
- Roughly equal number of events each class
- In dataset: charges of PMTs and time





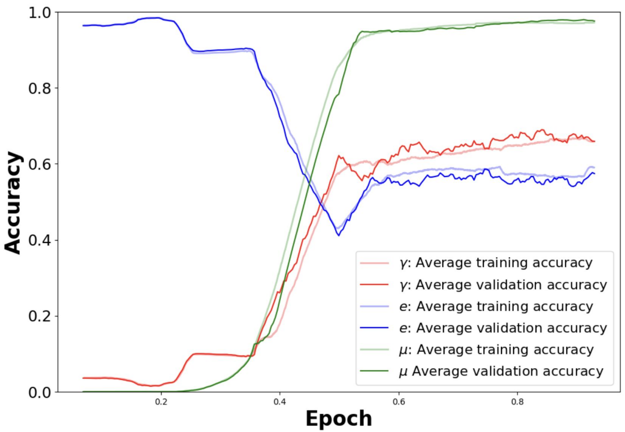
Models

- Multi-layer perceptron (2 ReLU hidden layers, learning rate = 0.00001, SGD optimizer),
- CNN (a natural option, to allow for the encoding of spatial relationship between PMTs),
- ResNet (CNN + residual function): motivated by “degradation problem” with deep NNs.

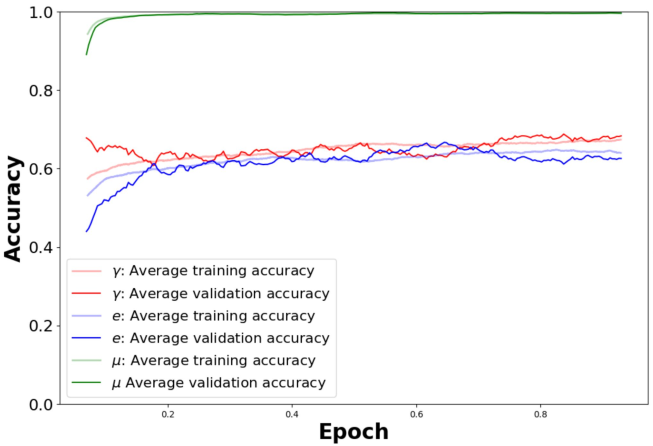
For ResNET different optimizers and number of layers were used - because it’s more interesting.

Results of training and evaluation.
CNN and ResNet

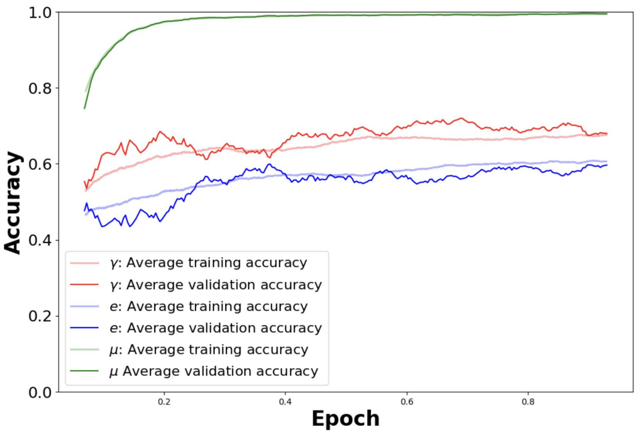
CNN (default)



ResNet18 (default)



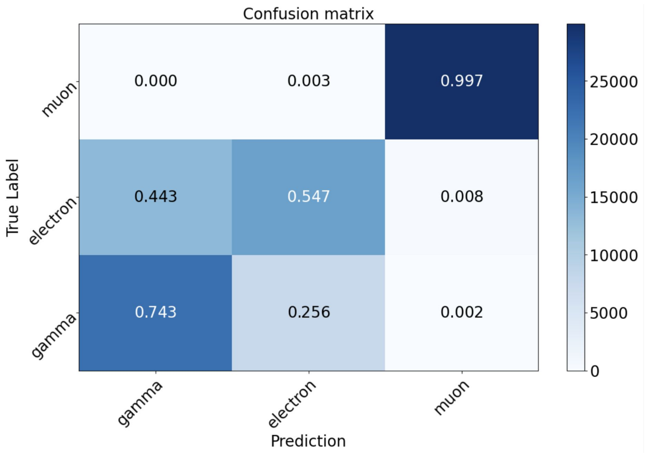
ResNet152 (default)



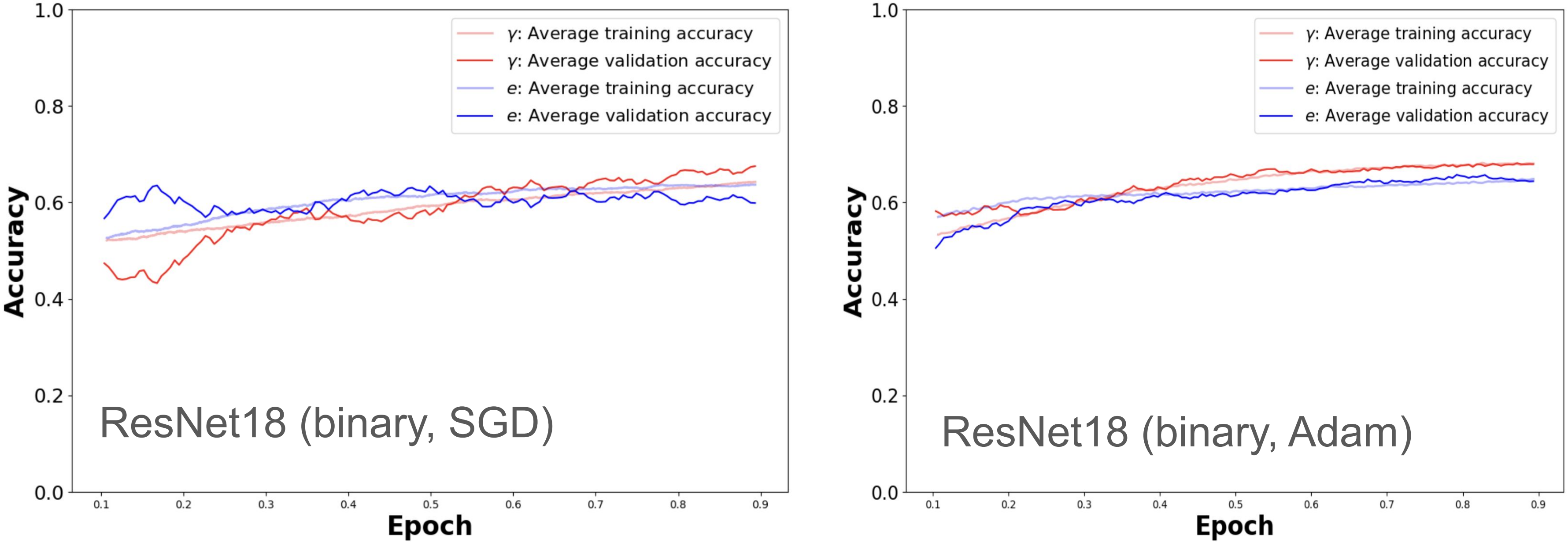
ResNet 18

Do we care about muons?

- Out-of-the-box ML solutions seem to classify muon events extremely well
- Electron/gamma performance masked by high classification accuracy of muons
- May get better classification of “harder to classify events” by dealing with them separately
- Perhaps consider layered binary classification approach
  - 1. e+gamma vs muon
  - 2. e vs. gamma



Try binary classify electron vs gamma



Adam optimiser converges quickly, more stable over iterations, less train/validate difference
No/minimal gain in accuracy switching to binary classifier (over 1 epoch only)