Machine Learning n/γ discrimination in C^7LYC scintillators

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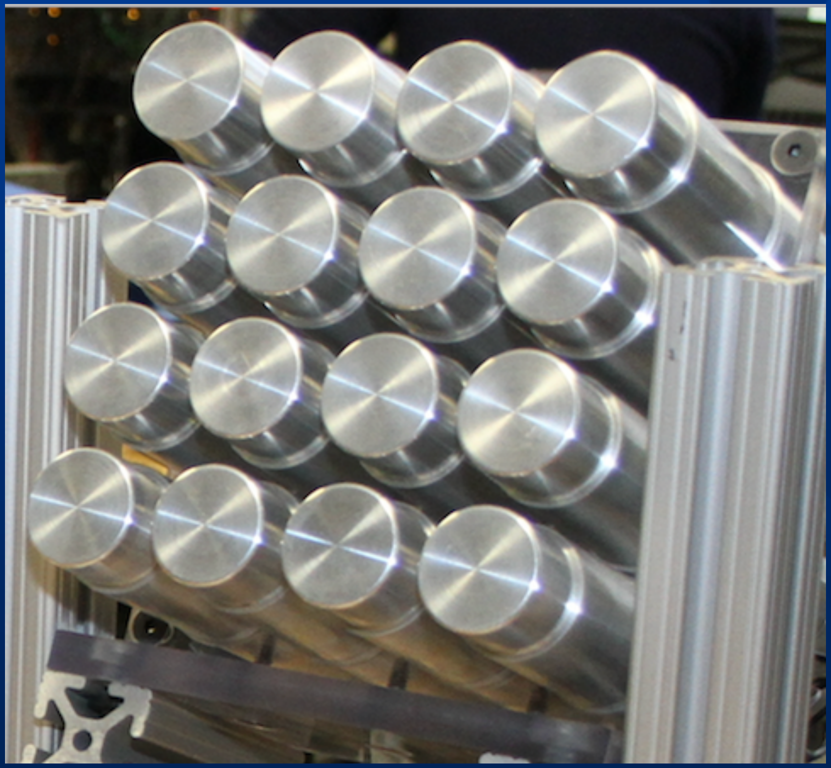
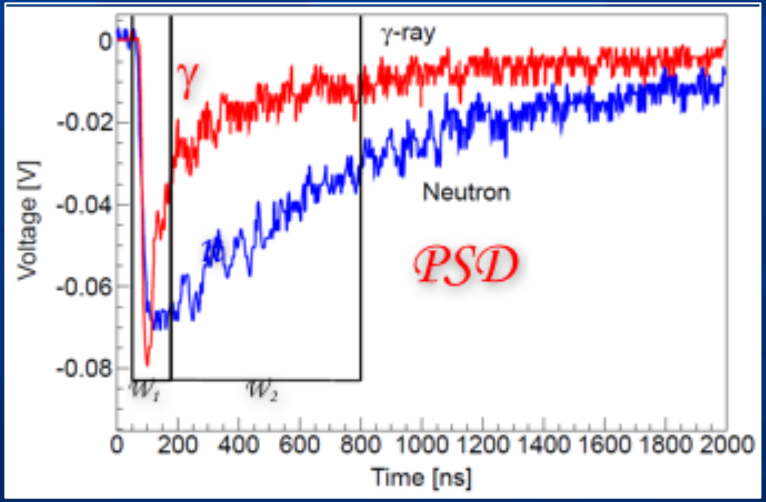
Learning with Purpose

SCANS : Small C^{7}LYC Array for Neutron Spectrocopy

- Eliminate ^{6}Li(n,α) thermal peak via ^{7}Li-enriched C^{7}LYC
- Explore fast neutron spectroscopy potential (NNSA grants)
- Sixteen 1” x 1” C^{7}LYC (largest crystals available at the rime)

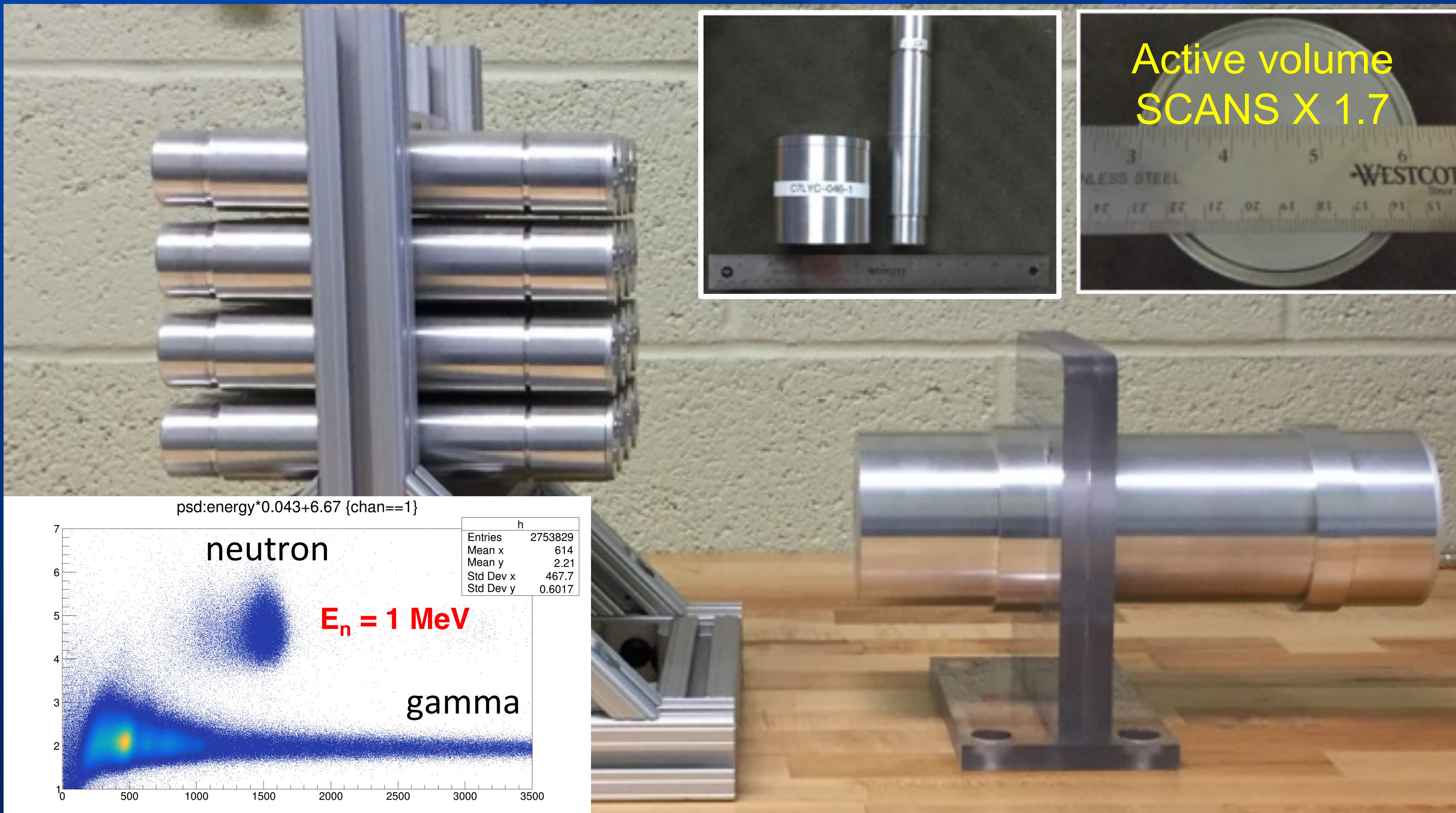




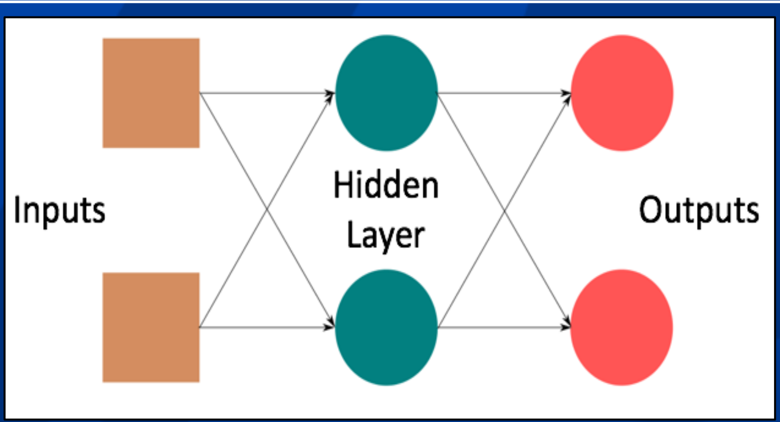
VME Struck Digitizers
- 16 Ch – 250 MS/s
- 14 bit ADC
- n/γ firmware

D’Olympia et al.,
NIM A694, 140 (2012);
NIM A714, 121 (2013);
NIM A763, 433 (2014)

the first 3” x 3” C^7LYC



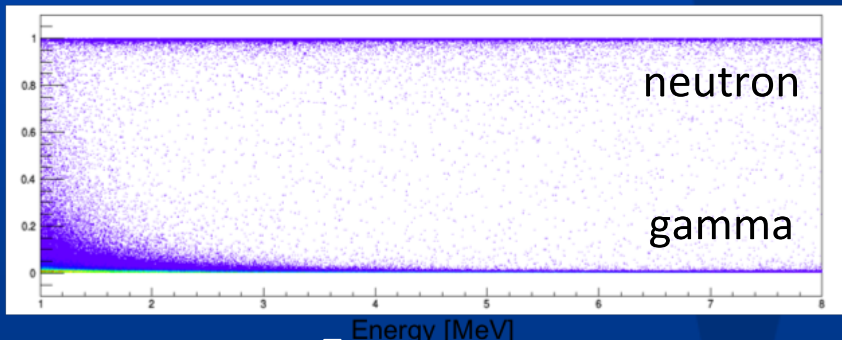
machine learning n-γ discrimination



- n/γ PSD a binary classification problem
- Artificial neural networks (ANNs) have shown promise for n/γ PSD in liquid scintillators
- ANN is "supervised learning" – i.e. requires pre-classified training data
- Feed forward neural network
- Interconnected layers of 'artificial neurons'
- Each neuron has many inputs x_i and one output z
- *z* is a weighted sum of its inputs, passed through an 'activation function'
- The output of the network should be 1 or 0 for a neutron or gamma respectively
- Trace is presented to the network as inputs and passed through a single hidden layer
- Hidden layer uses tanh x as its activation function (forces output between 0 and 1)
- Vary weights and biases of each neuron to maximize accuracy over the training data
- One complete optimization pass over the training data is an 'epoch'
- For the datasets and networks used, each epoch took 3-4s
- Full code is ~500 lines of Python and C++, classifier is in Python, using Keras
- Keras is a wrapper around the Tensorflow machine learning library
- Optimization algorithm is 'stochastic gradient descent'
- Classifier: 544 inputs, 544 neuron hidden layer, 1 neuron output layer
- Training data: 20k gammas and 20k neutrons between 1.5MeV and 5.0MeV

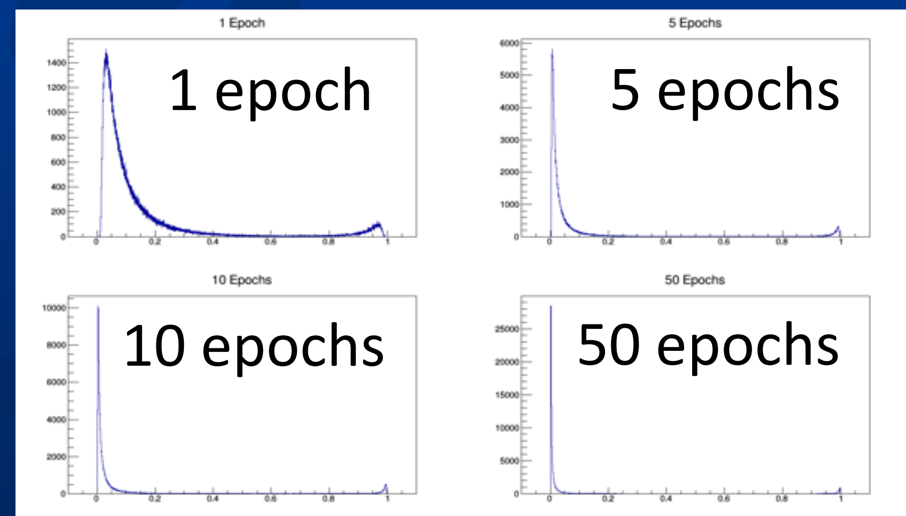
ANN: Supervised Learning

Classification

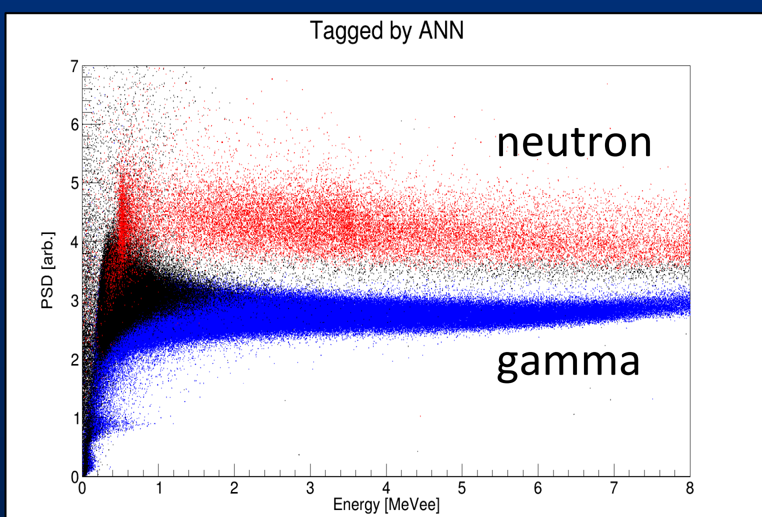


Energy

Separation increases with more training



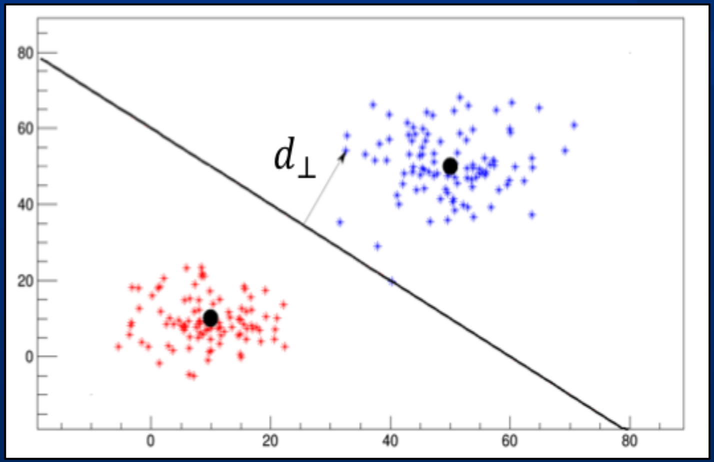
Artificial Neural Network
Supervised learning

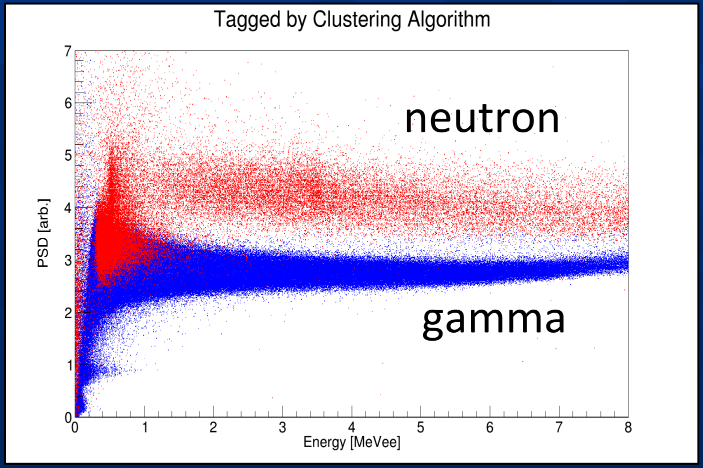


Unsupervised learning: K-means clustering

- Cluster analysis algorithms do not require pre-classified training data
- C^{++} implementation of ***kmeans***$^{++}$ algorithm
- K=2 for n/γ discrimination
- Perpendicular distance from hyperplane between centroids provides separation
- Training data set had ~28K neutrons and ~1.5M gamma rays

K-means Clustering: Unsupervised learning



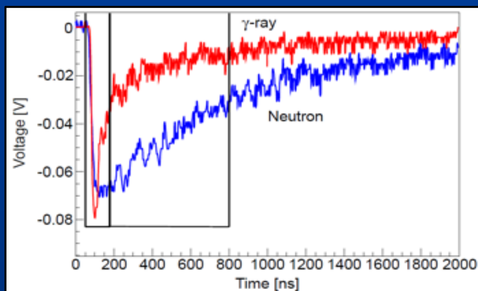


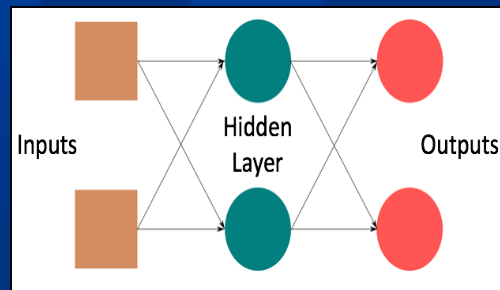
Machine learning algorithms capable of separating neutrons and gamma-rays in CLYC scintillators in the energy range investigated

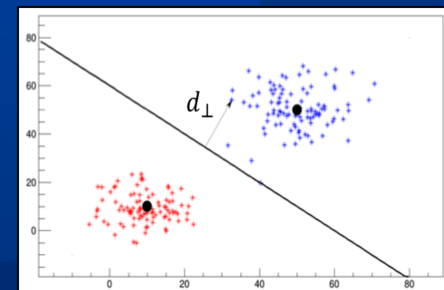
Summary

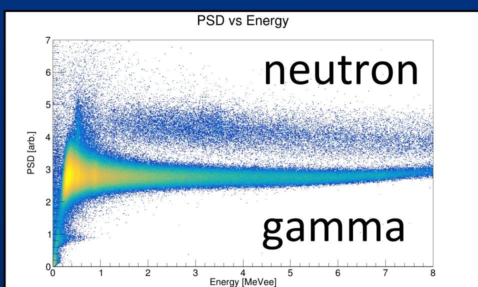
Machine learning n/γ discrimination

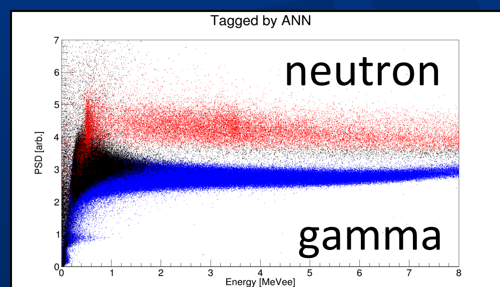
Charge comparison Generates training data	Artificial Neural Network Supervised learning	K-means Clustering Unsupervised learning

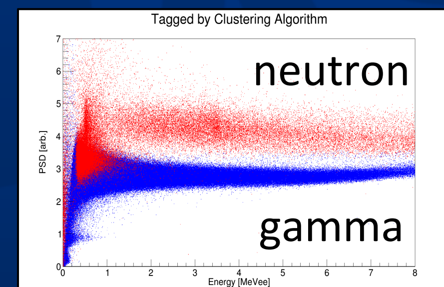












Machine learning algorithms capable of separating neutrons and gamma-rays in CLYC scintillators in the energy range investigated

WORK IN PROGRESS!!

n/γ discrimination at energies < 1 MeV needs improvement