Machine Learning Applications for Particle Identification at the SπRIT TPC

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Agenda

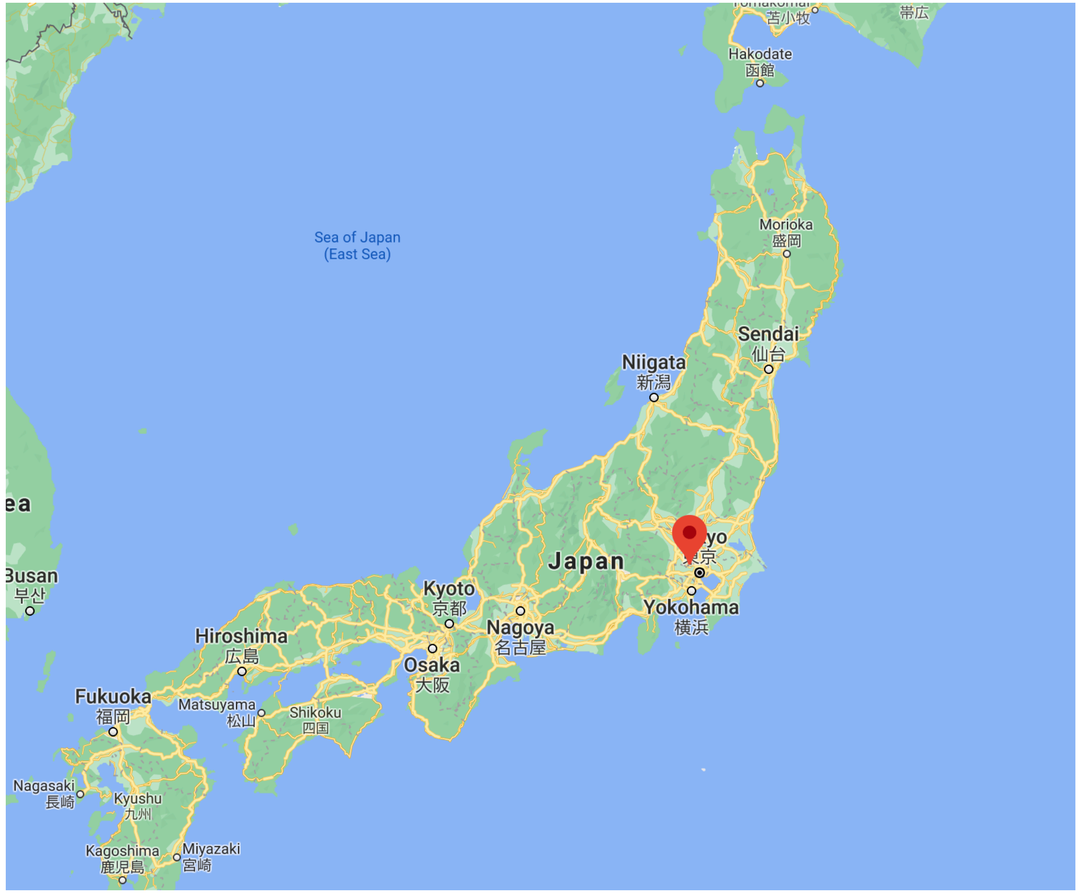
1. Interesting facts about facilities being used remotely for this project
2. Why Particle Identification?
3. What is Machine Learning, and why use it at the SπRIT TPC?
4. Project #1
5. Project #2

How are elements created in the universe?

https://www.riken.jp/en/research/labs/rnc/index.html

RIKEN Nishina Center

Wako, Japan

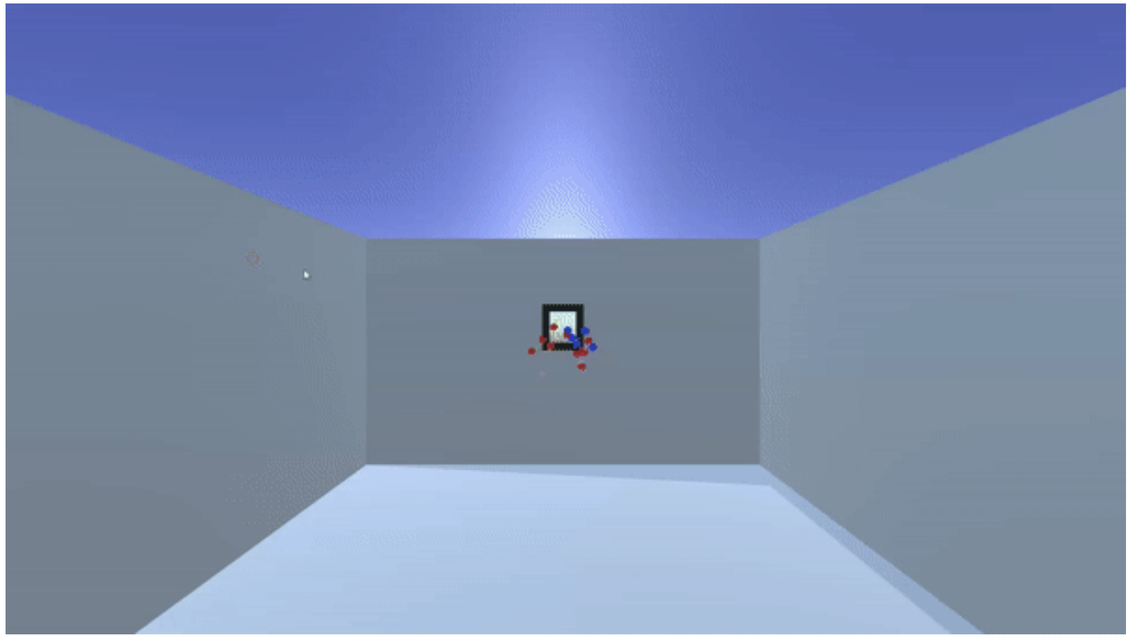


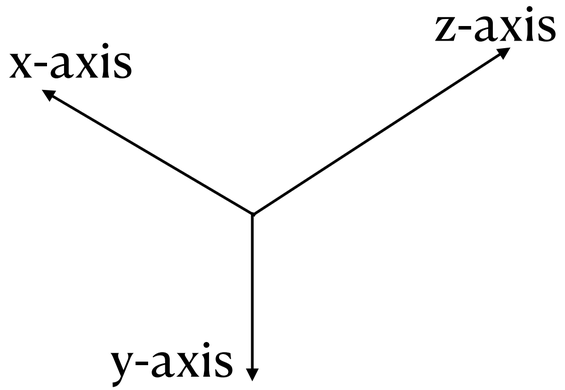
Superconducting Ring Cylcotron- particles go 70% of the speed of light

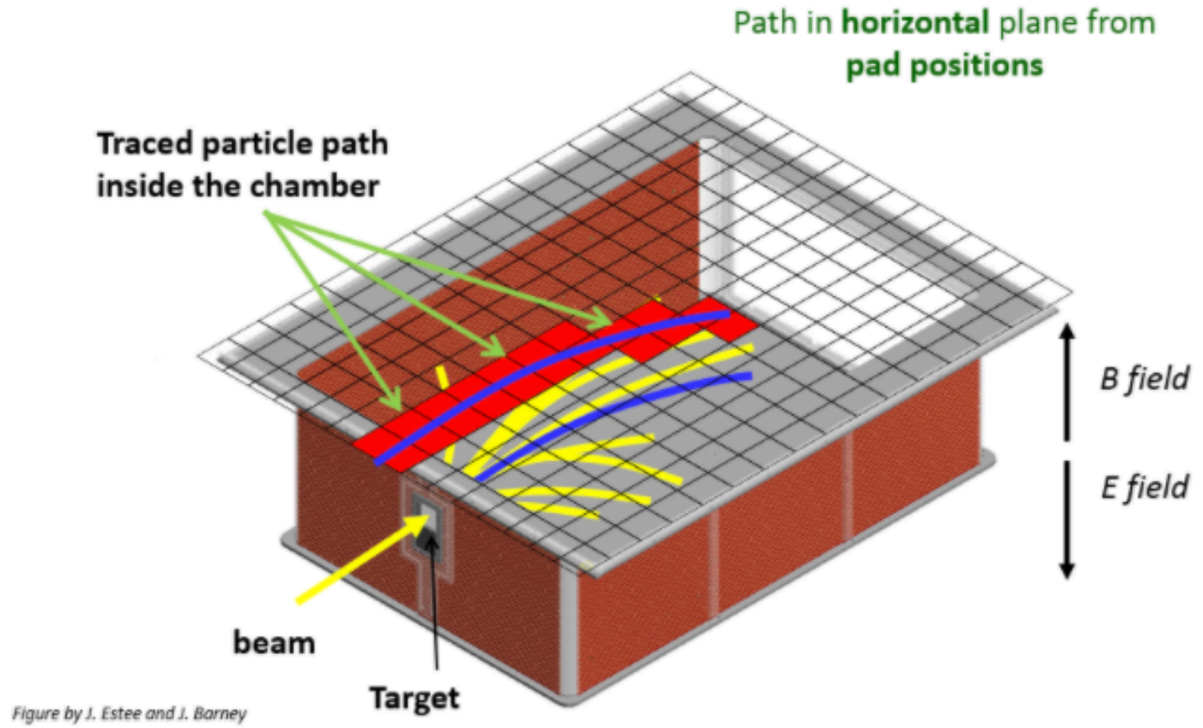
https://commons.wikimedia.org/wiki/File:Riken_src.jpg

What is the SπRIT TPC?

3D image of a nuclear collision





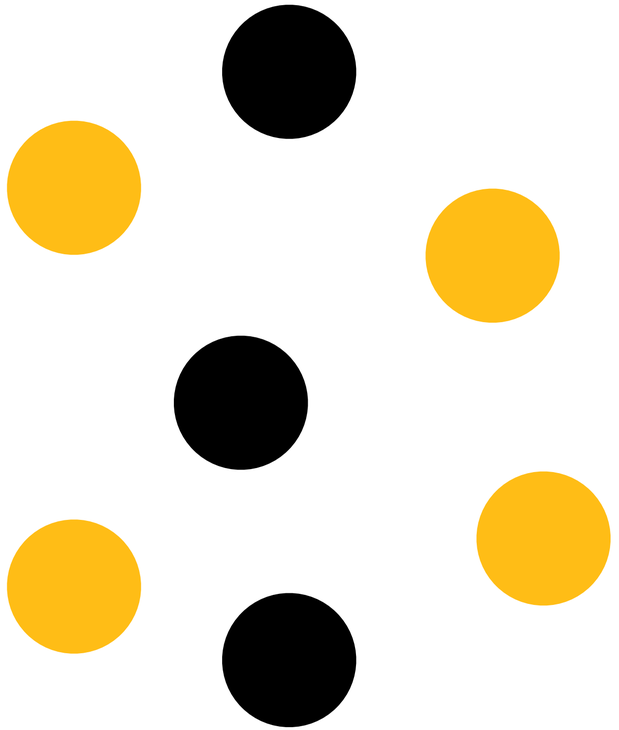


https://groups.nscl.msu.edu/hira/cosmic/SpiritTPC.html

Why Particle Identification ?

Hypothetical Scenario

- A scientist believes that 4 protons and 3 deuterons will come out of a nuclear collision happening inside of a star
- The SπRIT TPC is able to simulate this collision, and they need to be able to detect and identify the reaction



Data Collection at the SπRIT TPC

Identifying Particle Types

Data Collection for the SπRIT TPC

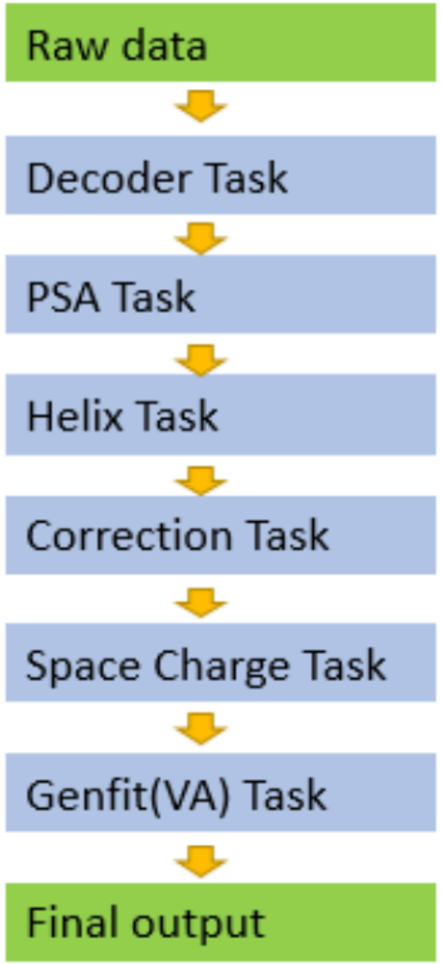
A Brief Overview

- Long pipeline that begins with binary data
- Charge and time data for each pad
- Momentum (P_y, P_x, P_z) and positional change in energy (dEdX)
- Main particle types: pions, protons, deuterons, tritons, He3, He4

Traditional Method

Gaussian Method

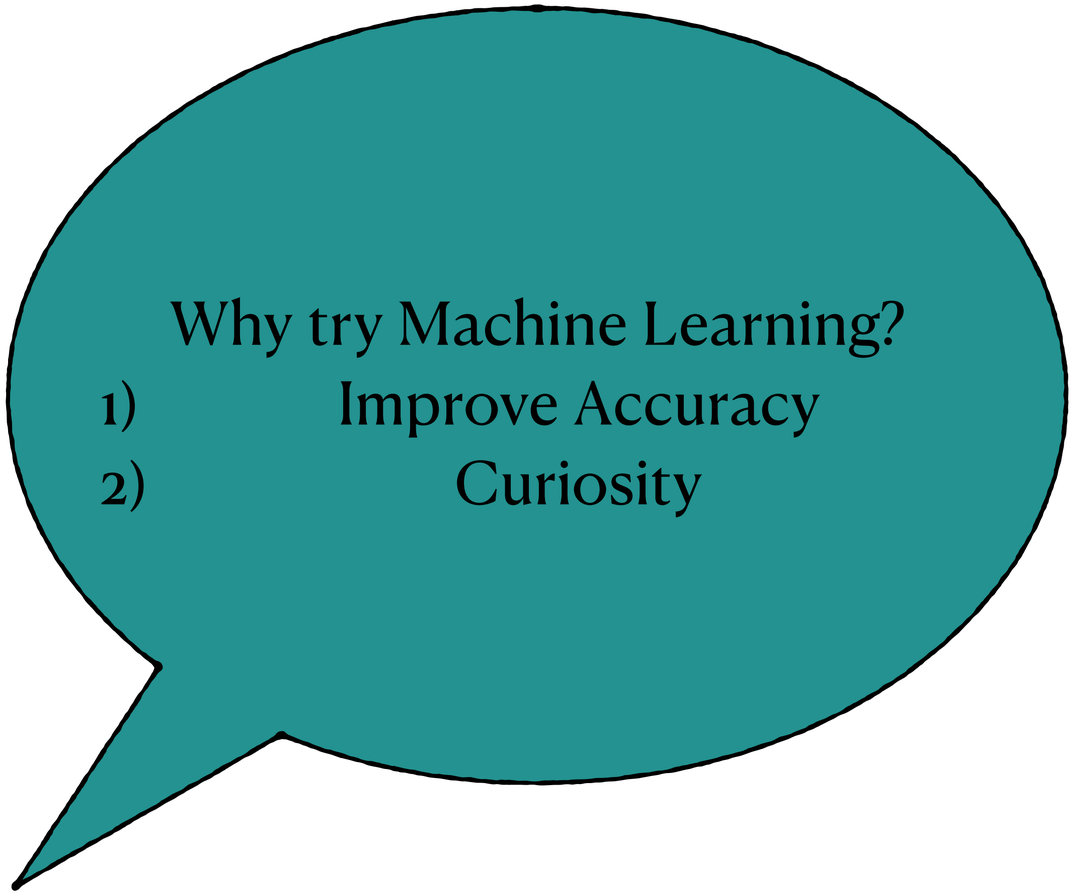
- This method works well, but is there another method that is more accurate?



Credit: Tommy Tsang

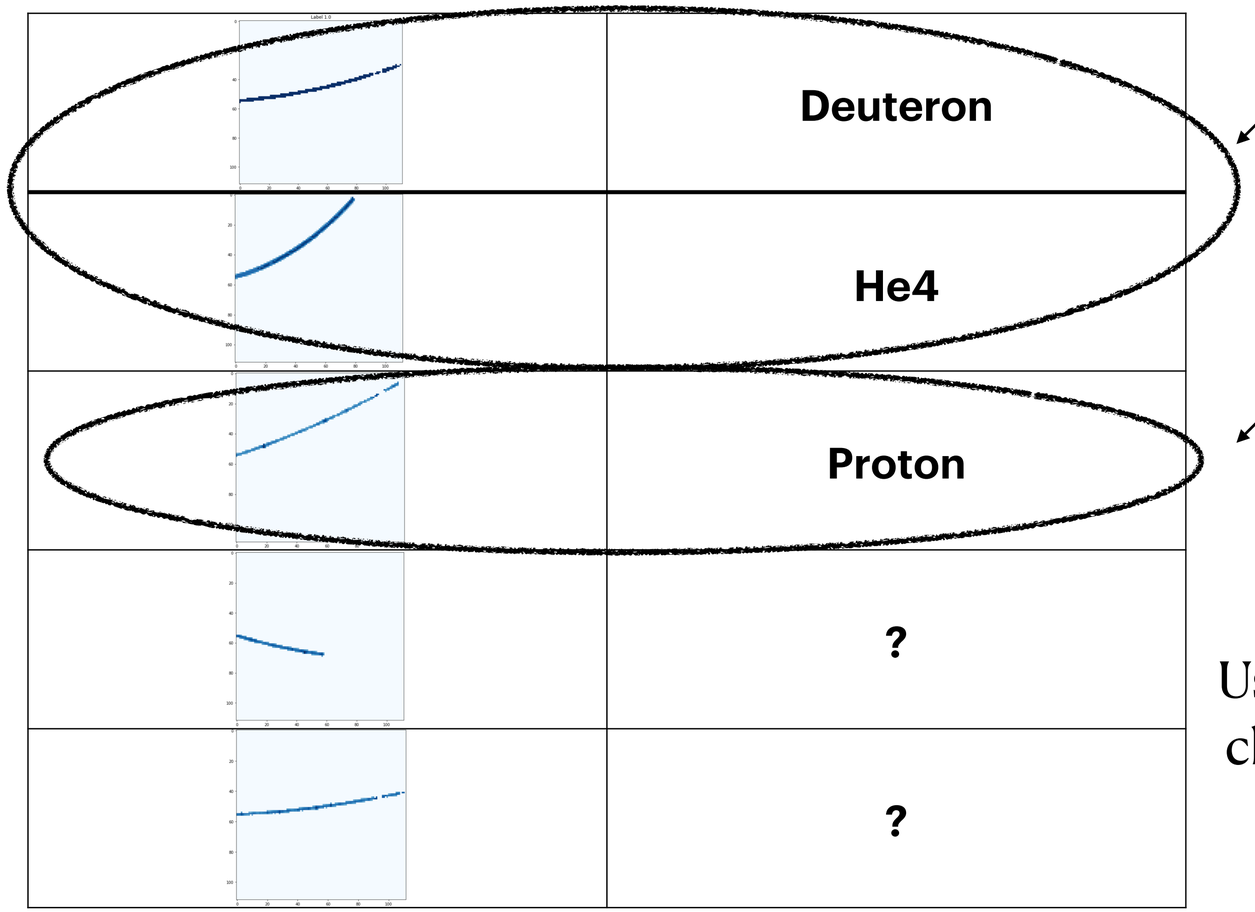
A New Idea:

How about apply Machine Learning?



What is Machine Learning?

- A method for adjusting a mathematical function to be able to predict a correct output for a given input
- Define terminology: **supervised learning**, **labels, training data** and **test data**, **examples**, **features,** and **targets**

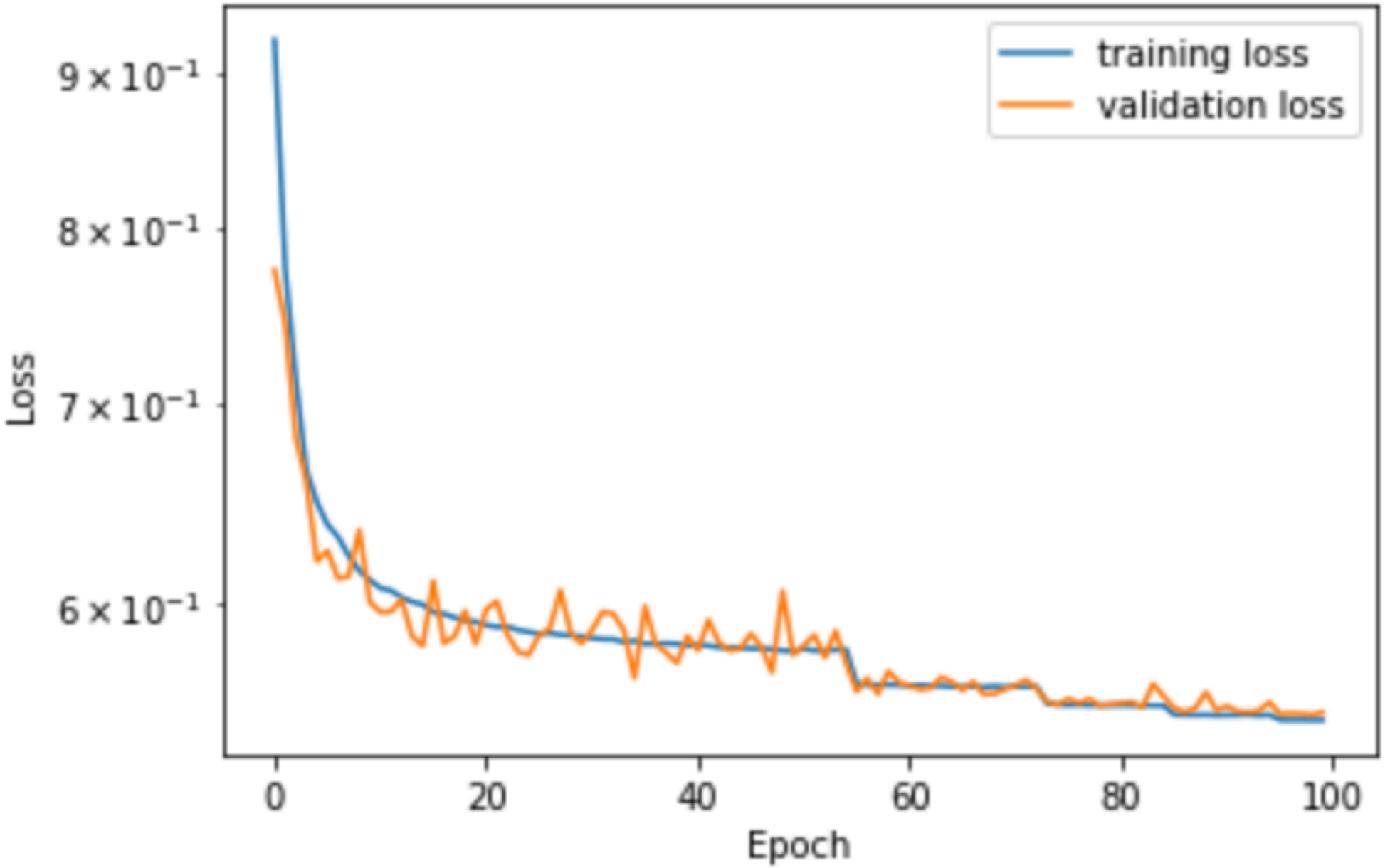


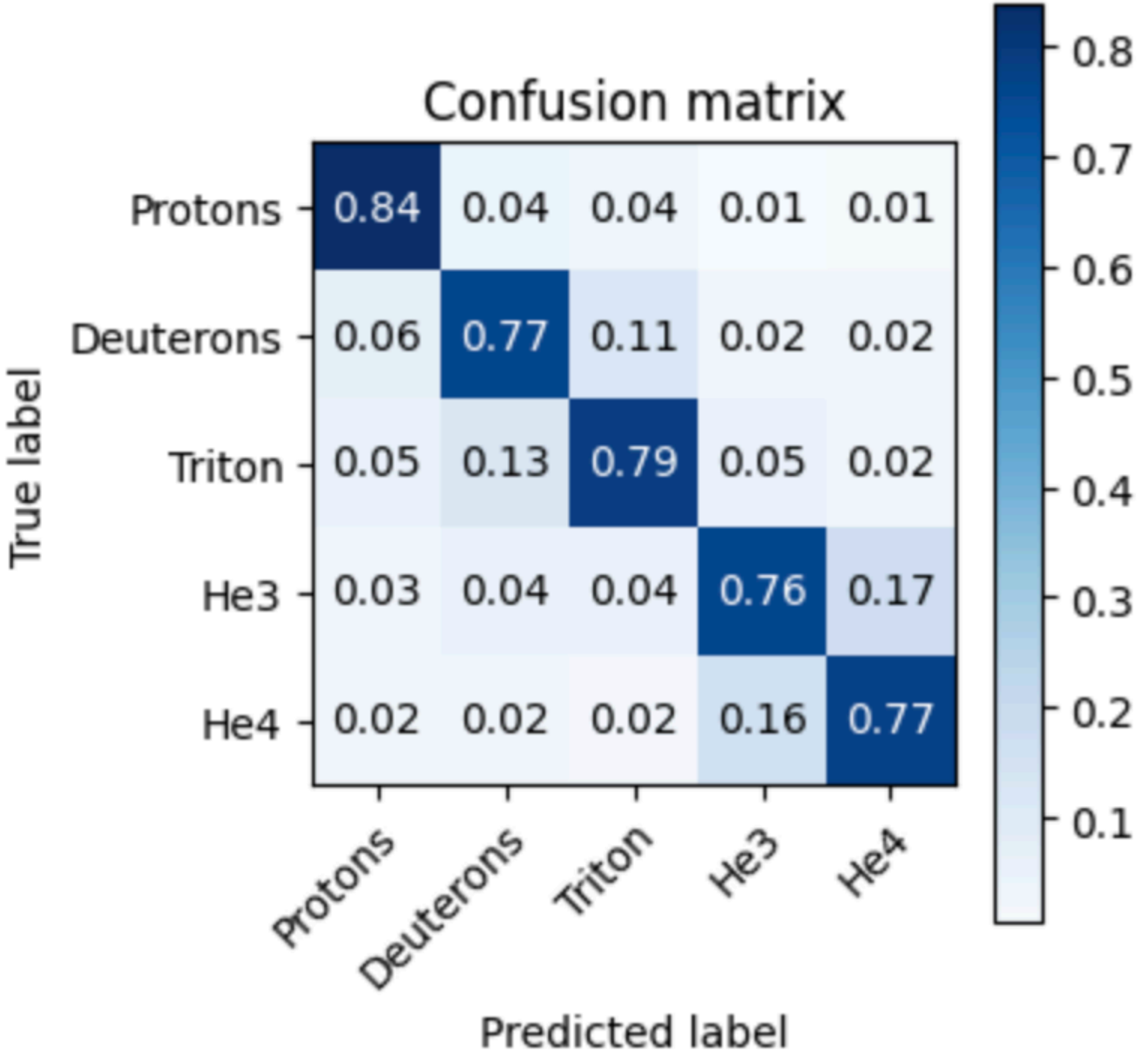
Project #1

Machine Learning For Particle Identification

Project #1

- Project Objective: Identify particle types from a nuclear collision in SπRIT detector when given momentum and energy information from a collision
- Recreated Tom Ladouceur's results
- Features: Px, Py, Pz, and dEdX. Targets: Proton, Triton, Deuteron, He3, He4
- Number of examples in dataset: around 700,000
- Machine learning model: Keras fully connected neural network
  - 3 hidden layers with 30 neurons

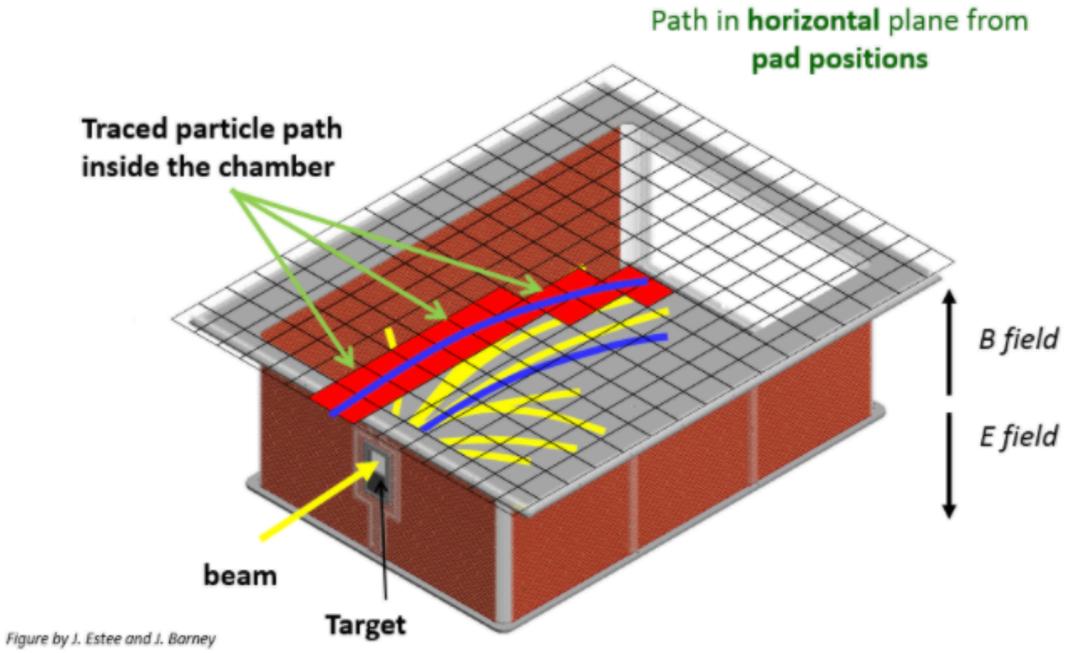

training loss
validation loss
9×10^{-1}
8×10^{-1}
7×10^{-1}
6×10^{-1}
Loss
0
20
40
60
80
100
Epoch


Confusion matrix
Protons
Deuterons
Triton
He3
He4
True label
0.84 0.04 0.04 0.01 0.01
0.06 0.77 0.11 0.02 0.02
0.05 0.13 0.79 0.05 0.02
0.03 0.04 0.04 0.76 0.17
0.02 0.02 0.02 0.16 0.77
Protons
Deuterons
Triton
He3
He4
Predicted label
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

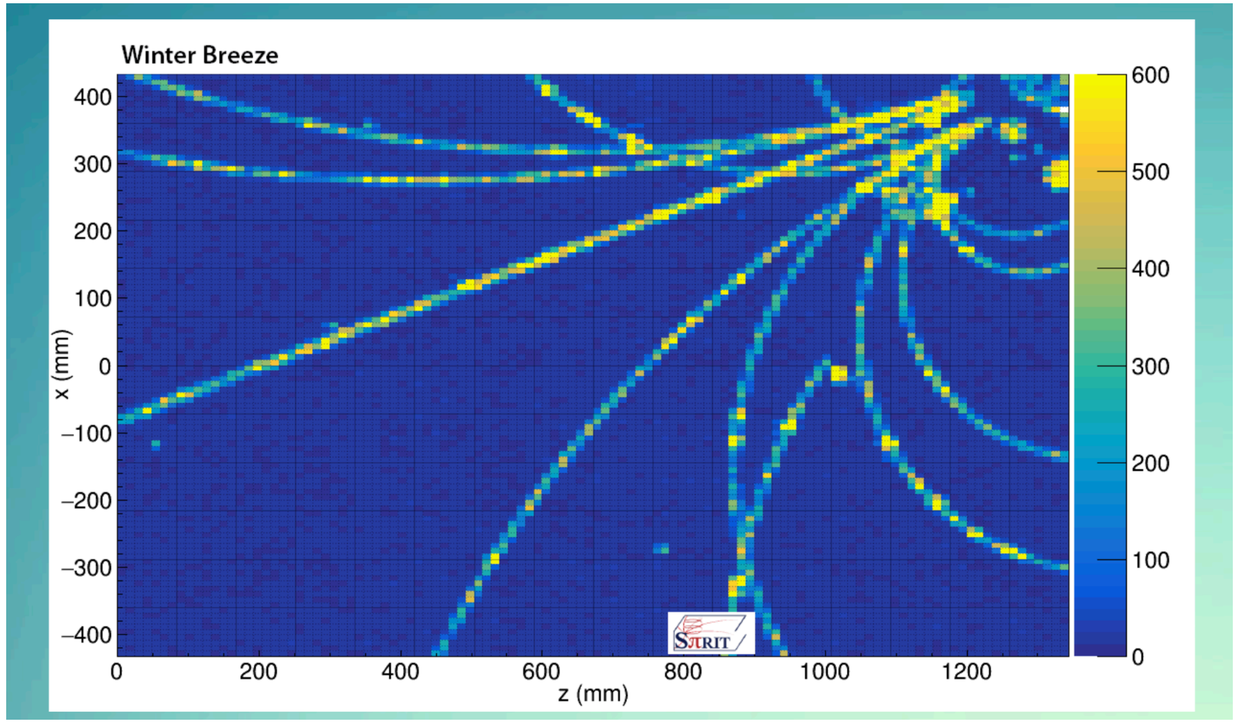
Project #2

SPiRIT TPC Tracks

Pad electricity images



https://groups.nscl.msu.edu/hira/cosmic/SpiritTPC.html

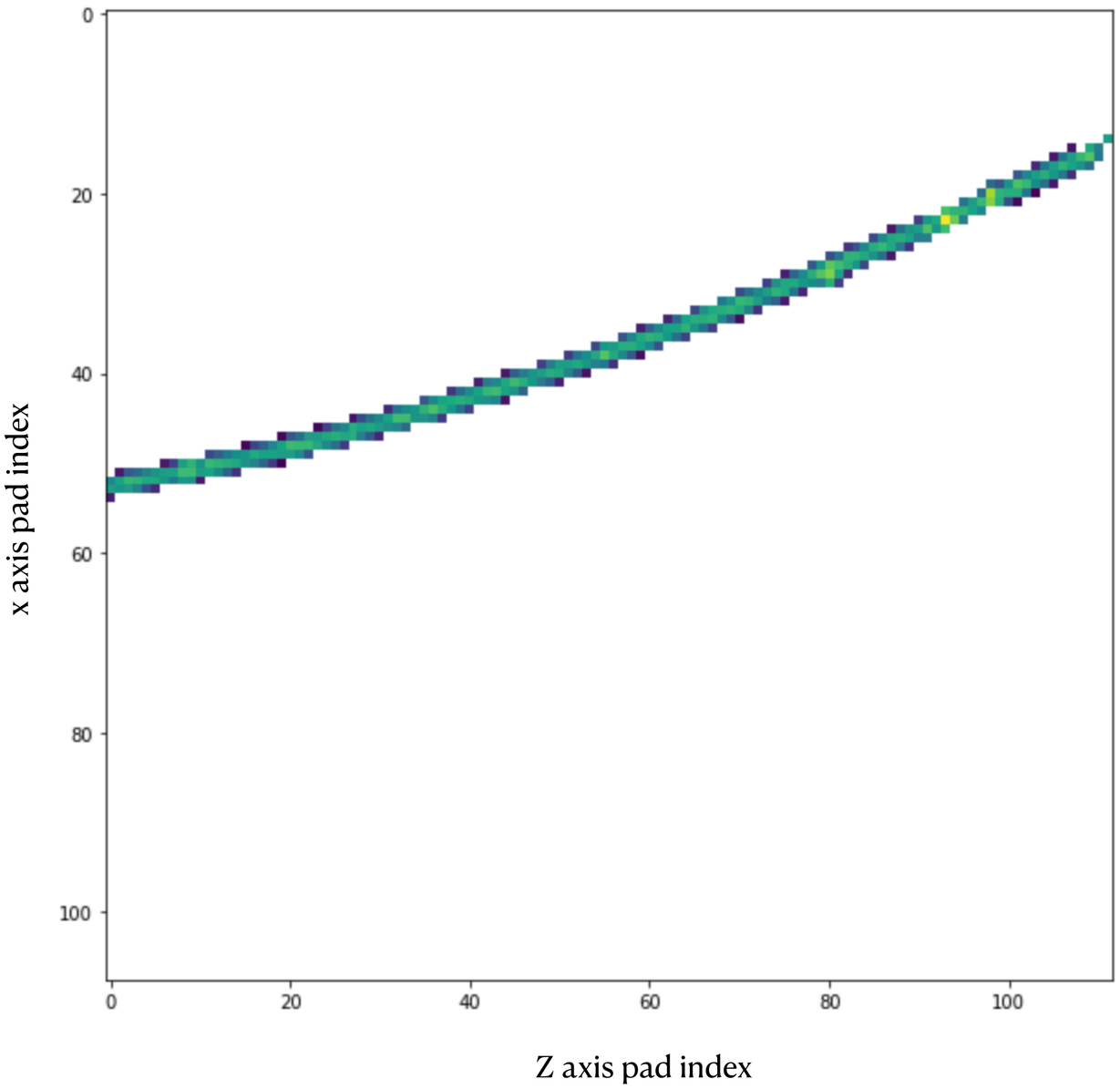


https://groups.nscl.msu.edu/hira/cosmic/CosmicGallery.html

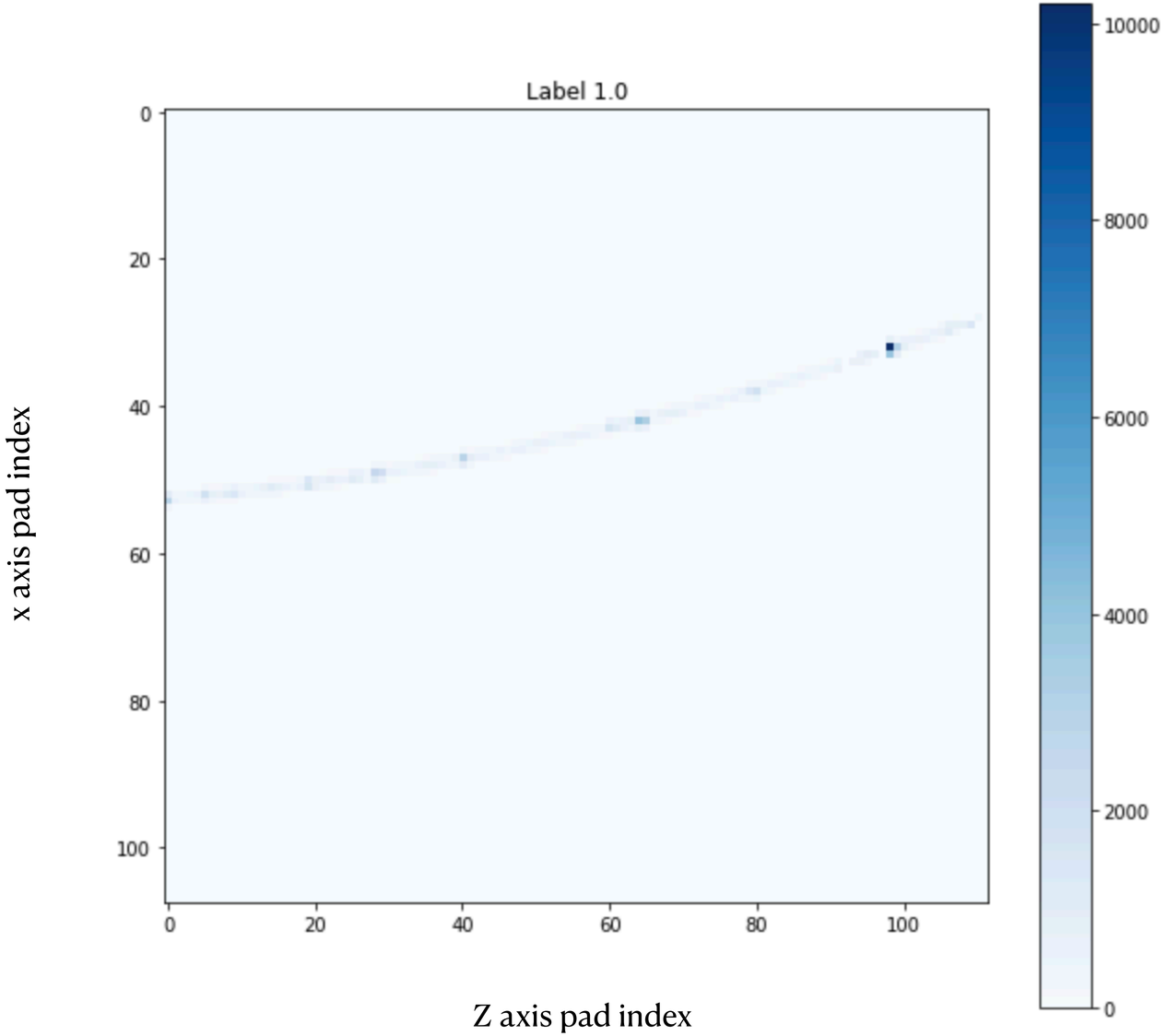
Identifying Single-Track Images

Project #2

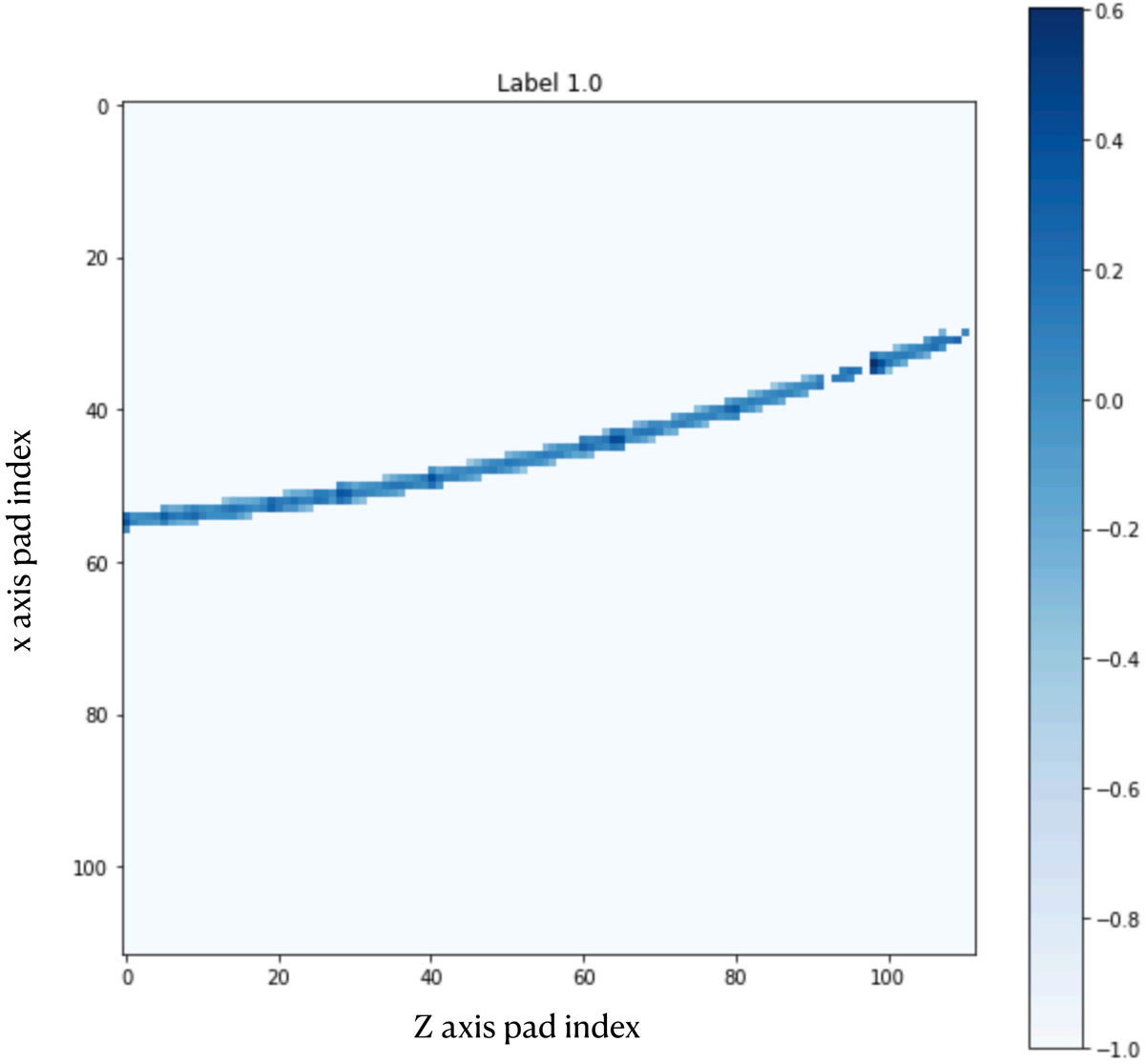
- Objective: Create a machine learning model that can identify a particle solely from an image
- Features: one feature - an image. Targets: P, T, D, He3, & He4
- #of examples: around 7,000
- Strategy: use a pre-trained Convolutional Neural Network (VGG16), and append 2 fully connected layers with 512 neurons each, with a 5 neuron output layer



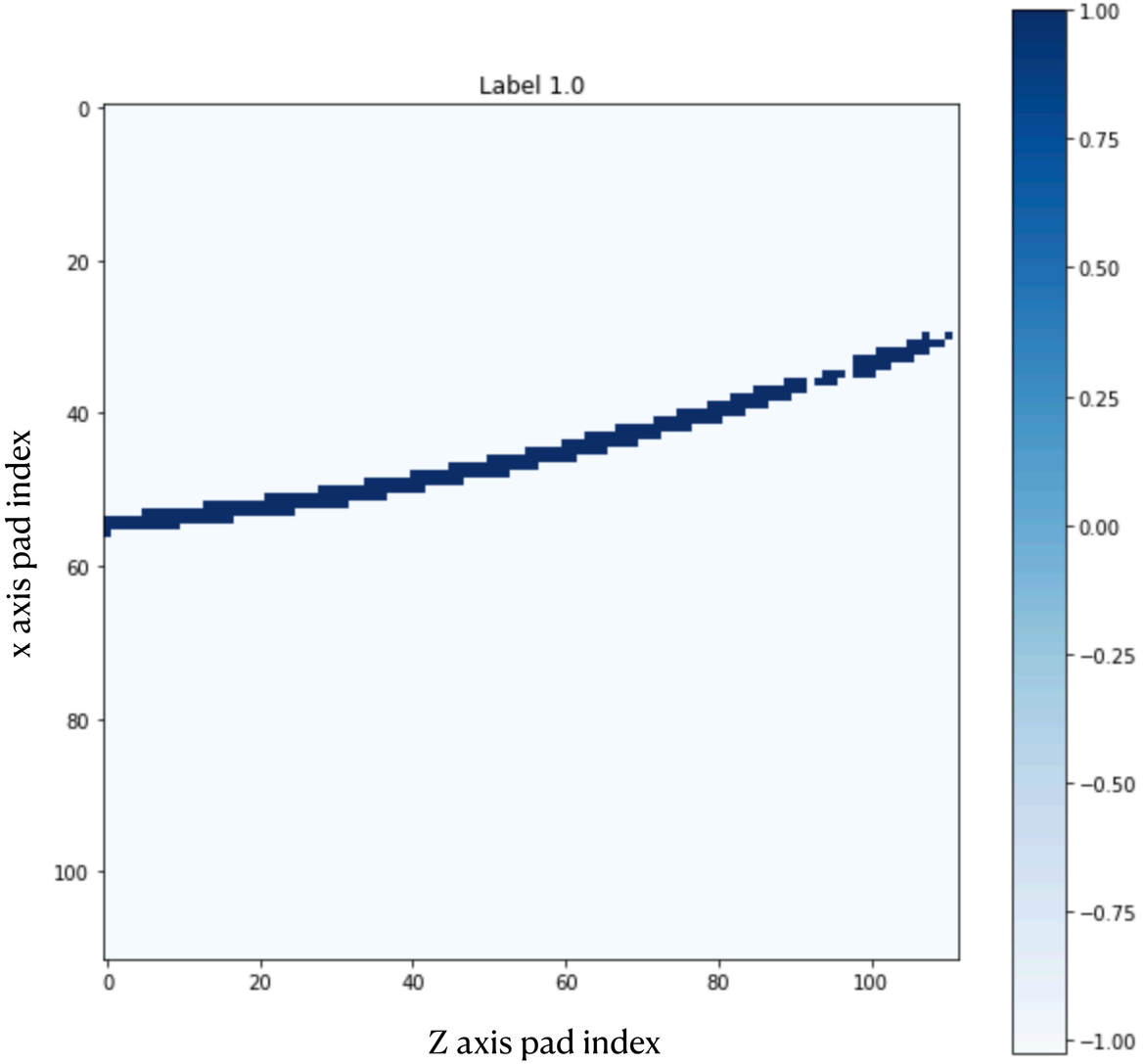
Untouched Input Example



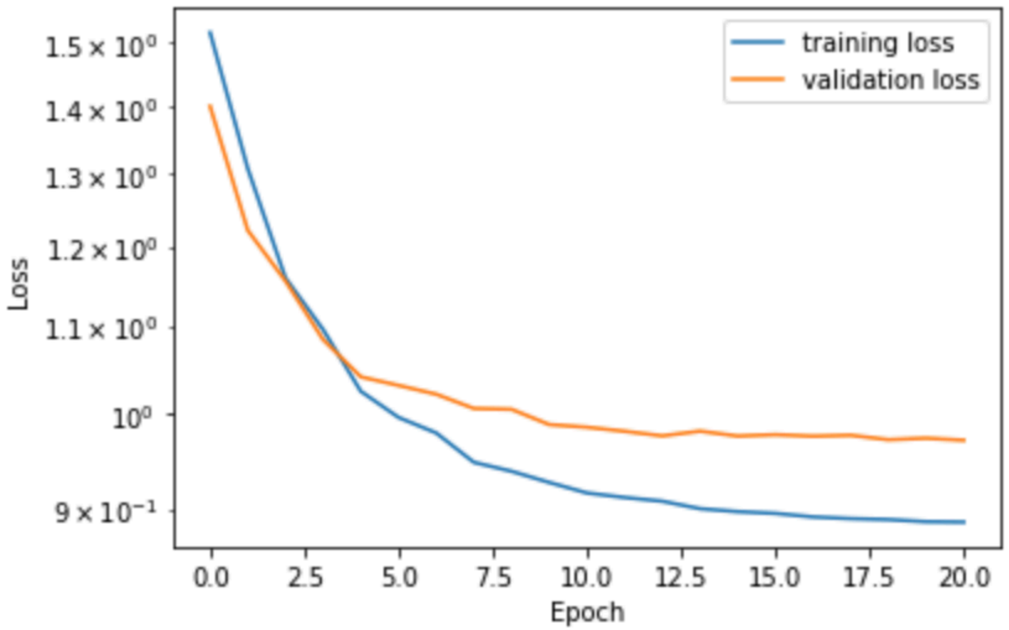
Log Scale- Feature Scaling



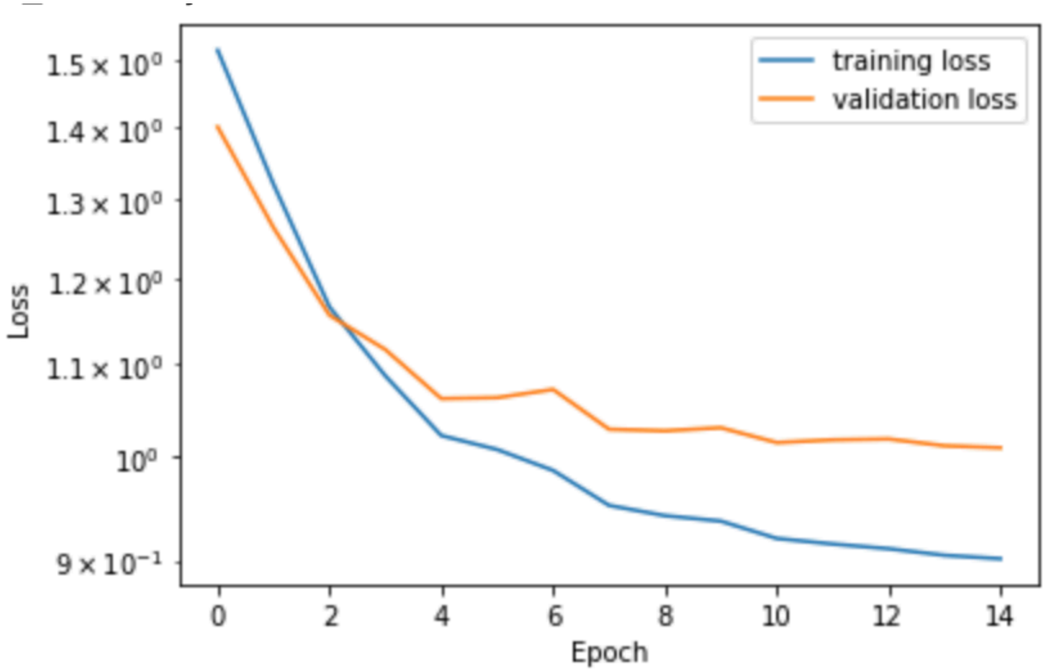
Power Transform Feature Scaling



Log Scale- Feature Scaling Loss Curves

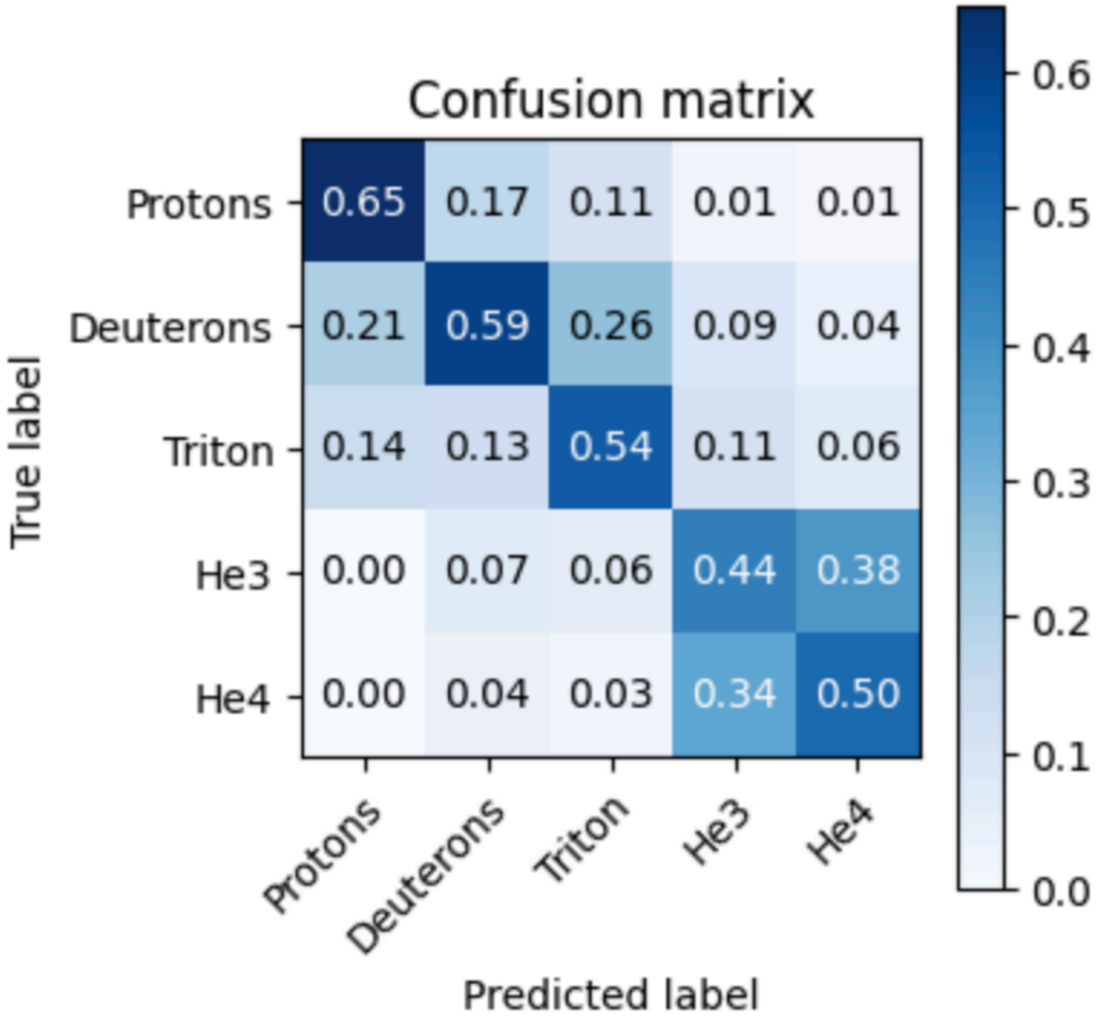


Power Transform- Feature Scaling Loss Curves

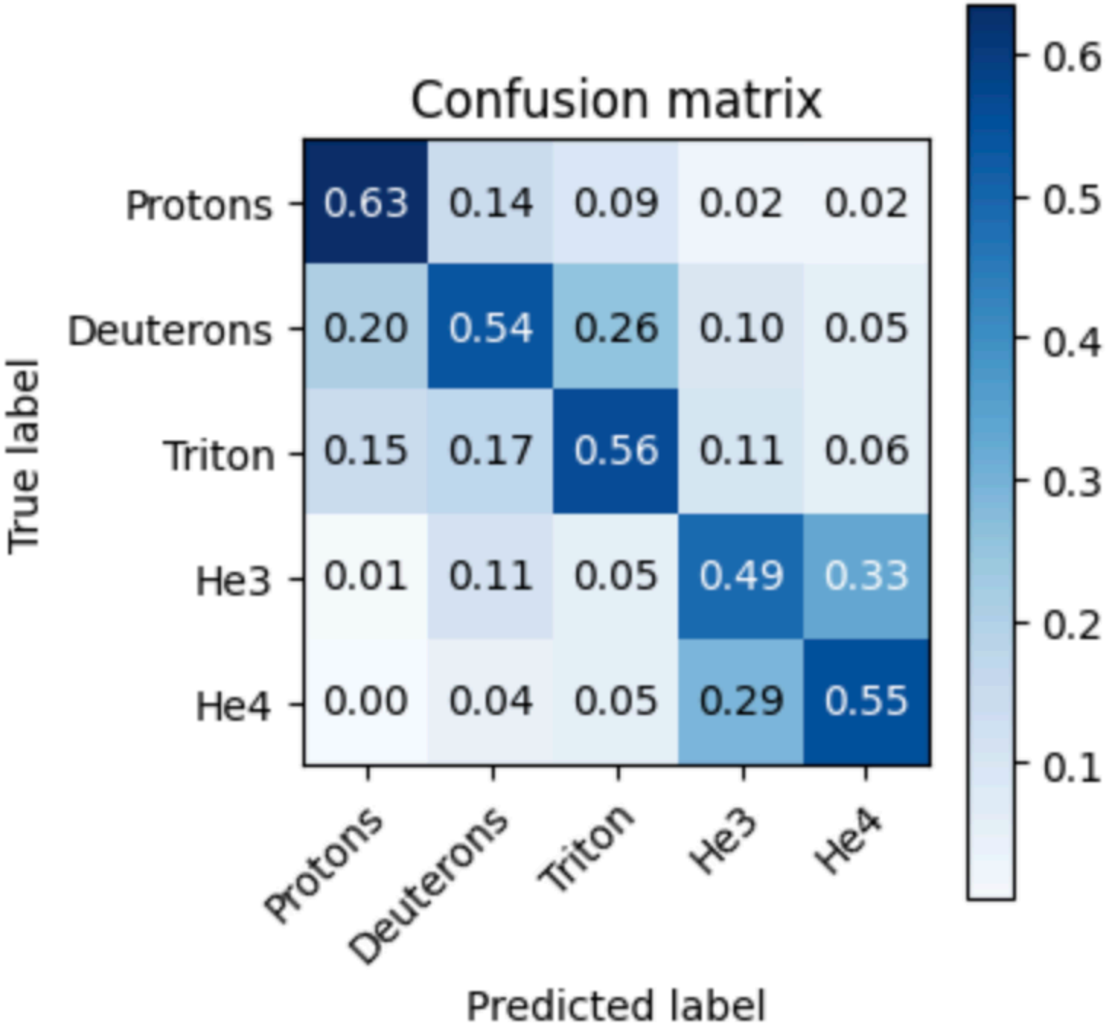


Power Transform

Log Scale- Feature Scaling



Power Transform Feature Scaling



Using Power Transformation-Epoch 15

- What we learned: we can compose machine learning models that identify particles successfully, but there has not been an official comparison between ML methods and traditional methods
- Upcoming work: expanding the machine learning algorithm from Project #2 to identify images with two tracks, of possibly different particle types

Concluded.