AI IN PARTIAL WAVE ANALYSIS

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Partial Wave Analysis

PyPWA

- A python-based software framework designed to perform Partial Wave and Amplitude Analysis with the goal of extracting resonance information from multi-particle final states.
- In development since 2014 and has been significantly improved with each revision - Version 3.4 just released!
- Efficient amplitude analysis framework including multithreading and CUDA support
- Optimizers include: Minuit, Nestle (or add your own!)

Group Members

Carlos Salgado (NSU/Jlab)
Mark Jones (NSU)
William Phelps (CNU/Jlab)
Michael Harris (NSU)
Andru Quiroga (CNU)

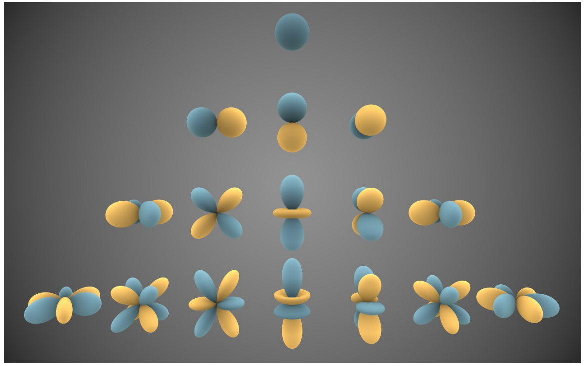
Former Group Members

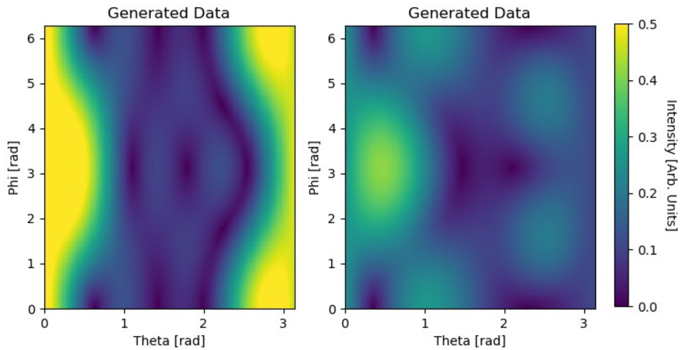
Josh Pond
Stephanie Bramlett
Brandon DeMello

Website: https://pypwa.jlab.org
GitHub: https://github.com/JeffersonLab/PyPWA

Preliminary Studies using Neural Networks

- Generate datasets using decay amplitudes (linear combination of spherical harmonics) with the following quantum numbers
  - L = 1,2,3
  - *m* = 0,1
  - ϵ_R= -1,+1
  - 9 total waves ("fit parameters")





$$I(\Omega) = \sum_k \sum_{\epsilon_R} \sum_{l,|m|,l',|m'|} {}^{\epsilon_R}Y_l^{|m|}(\Omega)\ {}^{\epsilon_R}V_{l,|m|}^{k}\ {}^{\epsilon_R}V_{l',|m'|}^{k*}\ {}^{\epsilon_R}Y_{l'}^{|m'|*}(\Omega)$$

Production Amplitudes

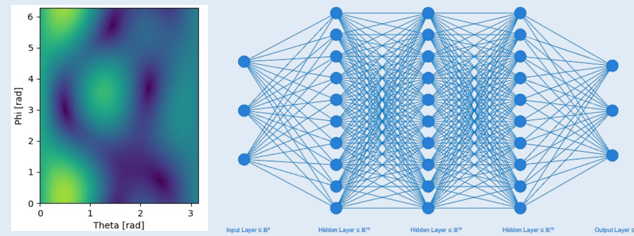
Decay Amplitudes

Early Results

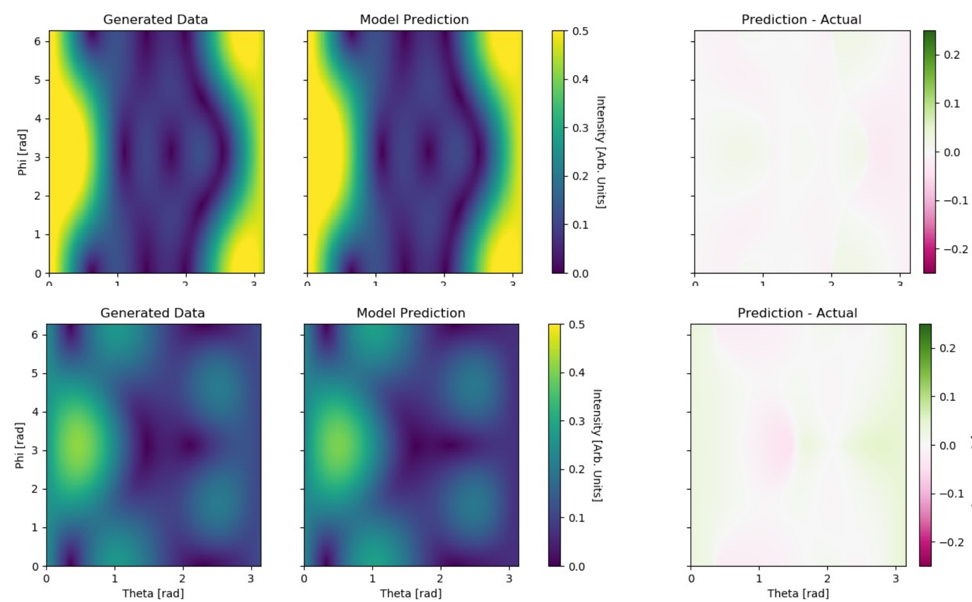
TensorFlow Keras python

- We compare the intensity function and compare it to the model prediction
- Model Architecture:
  - 128x128 2D histogram as input
  - 9x128 Dense Layers – Relu activation
  - 9 production amplitudes as output
- In order to deal with the vast amounts of data we used generators to generate data for each epoch on the fly

Input Histogram



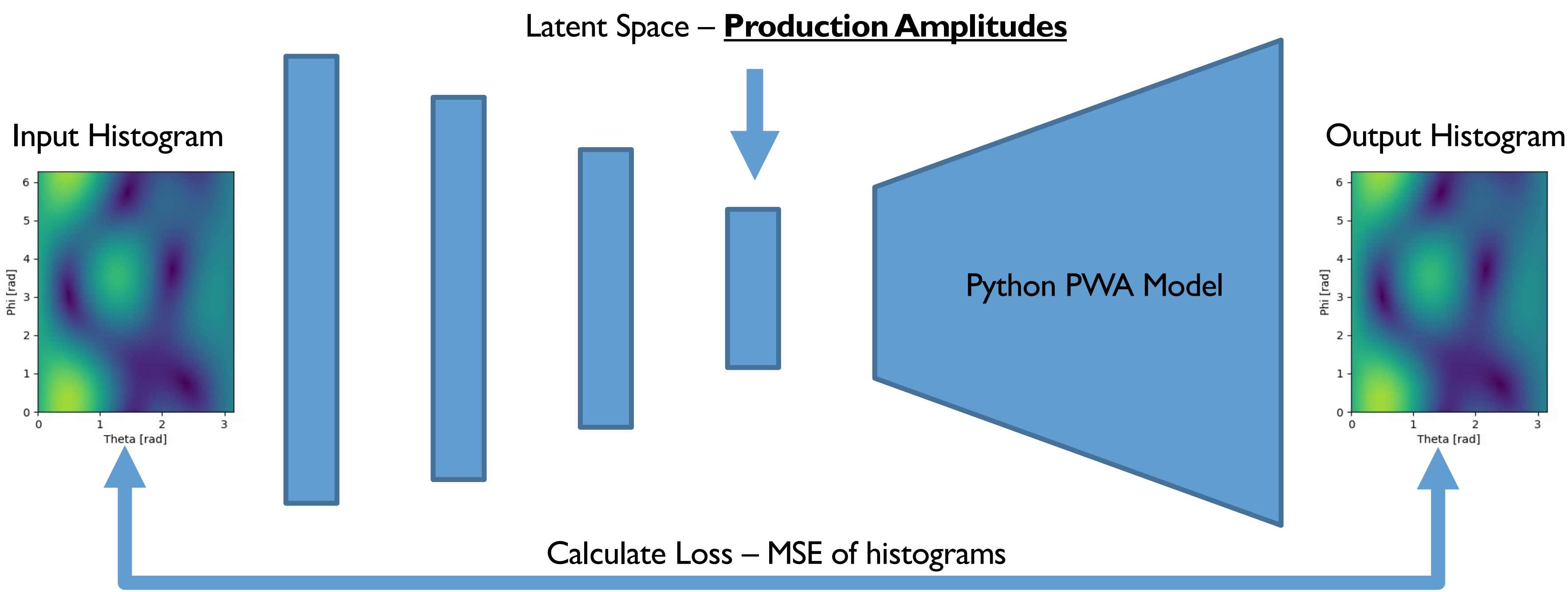
Output - Production Amplitudes



Interesting Tools: Generators, Complex Valued Deep Learning

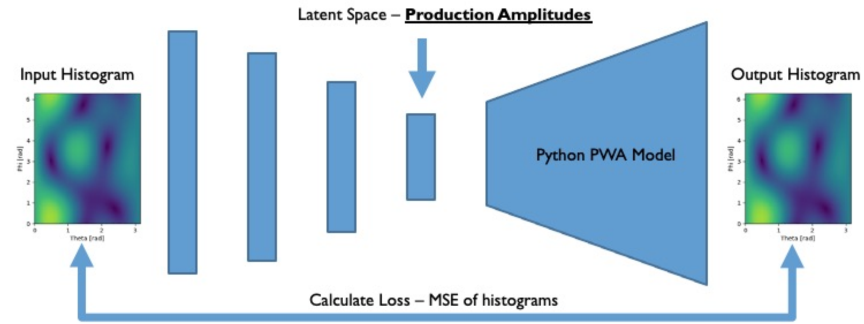
Autoencoder for PWA

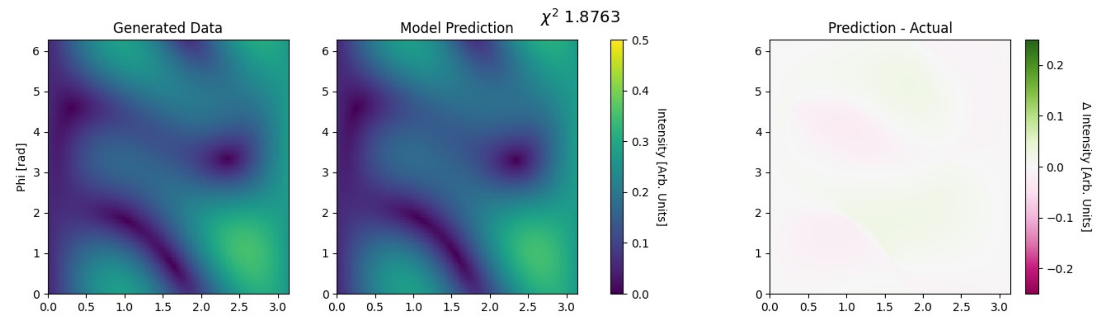
Unsupervised learning!

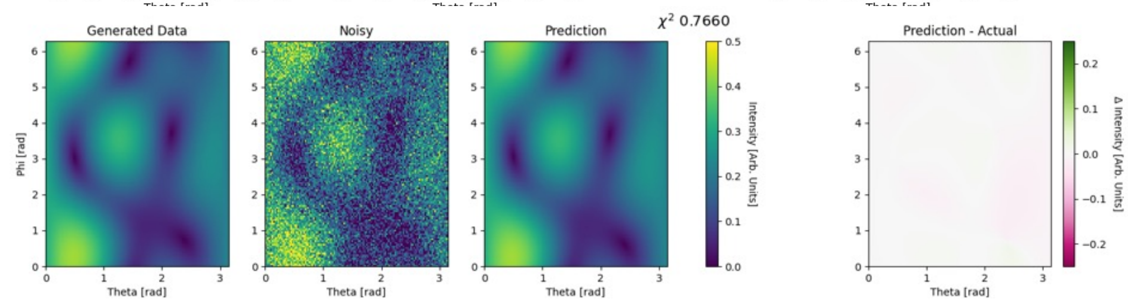


Autoencoders for PyPWA

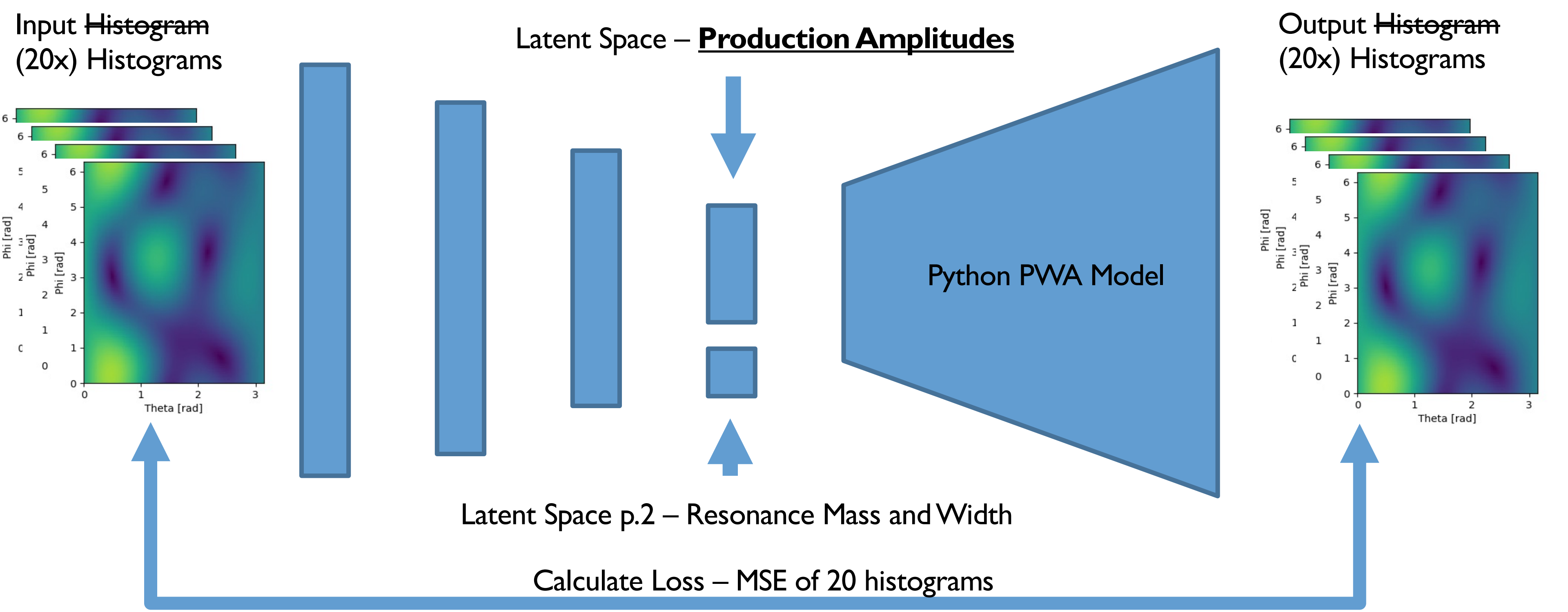
- Encoder portion is a standard MLP, but without labels!
- Decoder is a PyPWA model that takes in production amplitudes and produces a histogram
- Autoencoders *dramatically* improved the accuracy!
- Even works well for noisy data







Future Autoencoder work for PWA



Summary

- We have been able perform PWA "fits" with neural networks
- Autoencoders dramatically improved the performance
- Future work includes adding mass and *t* as parameters to have a global fit

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