USING DEEP CONVOLUTIONAL NEURAL NETWORKS TO RECONSTRUCT COSMIC RAY EVENTS

Tyler Sledge and Frank McNally, Ph.D

INTRODUCTION

Cosmic ray particles are high-energy protons and atomic nuclei that travel through space. Upon entering Earth’s atmosphere, these cosmic ray events produce showers of secondary particles that can reach the surface. The IceCube Neutrino Observatory, located at the South Pole, was designed to be a neutrino detector and can detect particles produced in Cosmic Ray showers. IceTop, the surface array of IceCube, provided simulated event data for our study. In the past, determining the accuracy of the cosmic ray event reconstruction has been based on a likelihood function. For this study, we aimed to see if a different reconstruction algorithm could achieve using machine learning.

OBJECTIVES

- Develop a deep convolutional neural network that can reconstruct cosmic ray events using charge as a single input
- Visualize and assess the success of new energy reconstruction
- Fine tune the CNN architecture for more accurate reconstruction

MATERIALS AND METHODS

- Required Packages: Anaconda Python with Tensorflow, Keras, Scipy, Numpy, Matplotlib
- Laptop used: Dell Latitude 7450
- CPU: Intel Core i5-5300U @ 2.30GHz
- Memory: 8.00 GB (7.88 GB of usable RAM)
- Storage: 512 GB SSD
- OS: Windows 10 Pro
- Developed a deep CNN using regression analysis that inputs the recorded charge of particles as one layer of a 10 x 10 matrix

RESULTS

- Figures 4-6 show the subtle differences when using the full composition, iron, and proton compositions in training the model
- Each model was trained on the exact same neural network architecture
- Iron and proton models were trained on iron-only and proton-only datasets
- Both were reconstructed on all events
- Each 2D Visualization shows a smooth reconstructed energy path

CONCLUSIONS

- Deep CNNs that reconstruct cosmic ray events produce results consistent with the likelihood function
- An accurate energy reconstruction can be produced with a relatively simple neural network architecture and only using a single charge input layer
- We plan on improving our model architecture to show a smaller energy spread and less uncertainties
- The full composition with seeds to produce the most accurate reconstruction
- These models can run on a low-end laptop
- Models can be run in succession and can easily be packaged to be sent to other researchers

REFERENCES


ACKNOWLEDGMENTS

Many thanks to Dr. Frank McNally for his amazing guidance. I’d also like to thank the Mercer University Department of Physics for introducing me to this topic and the Wisconsin IceCube Particle Astrophysics Center (WIPAC) for hosting the IceCube Bootcamp during the summer of 2019.