José Roberto Angeles Camacho, Hermes Leon Vargas and the HAWC collaboration.

Horizontal muon track identification with neural networks in HAWC

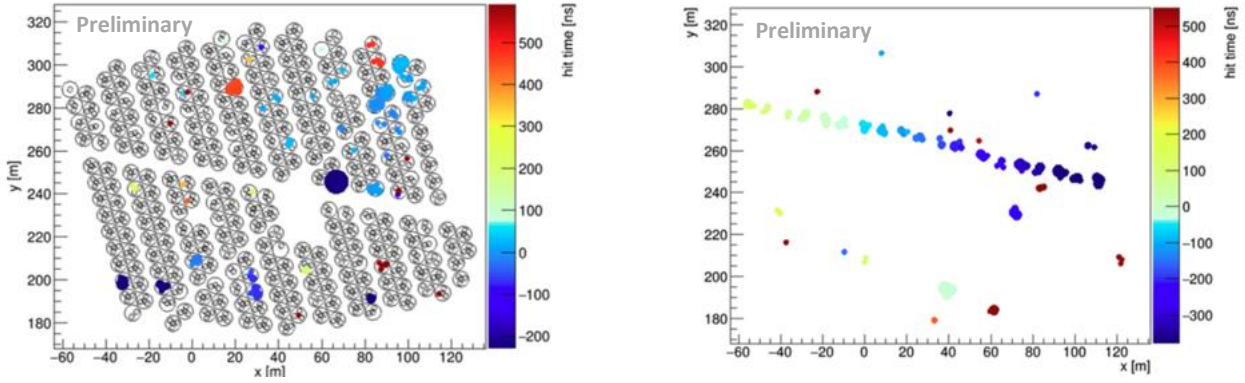
EXECUTIVE SUMMARY

Overview

The HAWC observatory is a water Cherenkov gamma-ray detector that in recent years has implemented algorithms to identify horizontal muon tracks. However, these algorithms are not very efficient. In this work we describe the implementation of three NNs to improve this task.

Motivation

Figure 1 shows a visual comparison between a horizontal track and an air shower. Each colored circle represents a photomultiplier (PMT) that was activated, and its size is proportional to the registered charge. On the other hand, the color scale refers to the activation time. As can be seen, each of these events has a characteristic shape that visually makes it easy to distinguish. We propose an analysis with a convolutional neural network (CNN) to replace the last step to the algorithm mention in [1], with this change we analyze the possibility of increasing the number identified tracks.



(a) Air shower

(b) Horizontal track.

Figure 1. Visual comparison between a horizontal track and an air shower.

Convolutional Neural Network

In this work we test three different models, two based on image classification (model A and B) and one on object detection. For model A we use the normal image given by the official HAWC display (Fig. 1 a) and for model B we remove the tanks and PMT's that were not activated (Fig. 1 b).

Model Comparison

We analyze a real dataset consists of 118476 candidates with our three NNs. The results are shown in table 1. This table also shows the number of tracks identified by the step that we replace (Filtering of candidate tracks) in [1].

Model	Tracks identified	False positives
A	103	3
B	125	5
Object detection	92	0
Filtering of candidate tracks	9	0

Table 1. Comparison of tracks identified by all models for the same dataset.

Conclusion

All our neural networks had an increase of an order of magnitude in the number of tracks identified, compared to the previous algorithm. Also, model B had the highest number of tracks identified, so in this case using a clearer image improves the detection process, but it had the highest number of false positives. However, the object detection network did not have false positives. The results of this study could be used in the future to improve the performance of the Earth-skimming technique for the indirect measurement of neutrinos with HAWC.

Reference

[1] H. León Vargas. Prospects of Earth-skimming neutrino detection with HAWC, in proceedings of 36th International Cosmic Ray Conference. (2019). [arXiv:1908.07622v1].