Differentiating Primary and Secondary Particle Contributions in WTDs Using Clustering Algorithms

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Abstract:
Water Cherenkov Detectors are astroparticle devices based on the Cherenkov effect. They use photomultiplier tubes as the primary sensor to detect the light emitted by ultra-relativistic particles as they move through the water volume. Astroparticles impinging on the Earth cause a flux of secondary particles composed of three main components: electromagnetic, muonic and hadronic. When entering the WCD, these particles produce measurable signals with different features according to the particle type. Resulting charge histograms of the signals, for instance, provide valuable insights into the primary astroparticles' flux and characteristics but do not provide enough information to differentiate each secondary particle contribution. In this work, we applied machine learning techniques to find patterns in the data and subsequently create groups, through clustering, that can be used to provide this differentiation. This unsupervised learning technique is appropriate because we used actual not-labelled data. The processing pipeline we implemented included data wrangling, feature engineering, Principal Component Analysis for dimensionality reduction and feature selection, and finally, clustering techniques to create the machine learning model. Implementation included both linear (k-means) and nonlinear (DBSCAN and OPTICS) clustering algorithms.

LAGO is a ground based observatory that studies transient events (solar or high energy events like gamma-ray bursts) and space weather using a network of Water Cherenkov Detectors as a tool to measure secondary particle flux by astroparticles entering the Earth.

Preliminary results, tested using LAGO data acquired with Water Cherenkov Detectors, showed that density-based clustering algorithms are more appropriate for this context, producing good candidate groups. These results open the possibility to deploy machine-learning-based models in our distributed detection network for onboard data analysis in a semi-operative manner.

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