technische universität dortmund

INTRODUCTION AND MOTIVATION

The sources of cosmic rays are still an open question in modern astrophysics. With multi-messenger campaigns, scientists are getting closer to solving the puzzle. IACTs, which normally filter charged hadronic events as background from the analysis, provide suitable data sets with high statistics to generate a cosmic-ray spectrum in the TeV range.

THE MAGIC TELESCOPES

In this work, simulations of the MAGIC telescopes are used. MAGIC is a stereo system of IACTs, located at La Palma at an altitude of 2200 m. With a mirror surface of 17 m diameter and a field of view of 3.5 ° it is sensitive for gamma rays between 30 GeV and 100 TeV. The energy range with the highest sensitivity is expected in the same order of magnitude for nucleons.

MONTE CARLO SIMULATIONS

For the analysis, we simulated three particle types in the TeV energy range: protons, helium and iron nuclei. The data is simulated with CORSIKA and processed with the standard MAGIC software including the parameterization of cleaned shower images. The Hillas and stereo parameters are the features for the random forests.

AICT-TOOLS

The random forests for the analysis are modeled with the open-source project aict-tools. It is a reconstruction tool, especially written for IACT data and uses scikit-learn modules. It is was developed at the TU Dortmund and is available at github.

PARTICLE IDENTIFICATION

For the particle separation, two random forests were trained.

1. Separate iron from rest

The first random forest is trained on all three particle types to learn to distinguish iron-like shower image from the images triggered by lighter particle types.

2. Separate helium from rest

The second random forest is trained on proton and helium simulations. It learns to separate helium-like particles from protons. It is applied to all the events surviving the first separation step.

The method of two random forests does not perfectly separate the particles. A migration matrix describes the results and can be used to unfold the spectrum.

PROTON ENERGY REGRESSION

The energy regression in this work is done for the proton events. The random forest is trained on a pure proton simulation set. The energy regression can be easily done for other particle types as well.

The migration matrix of the energy regression of protons shows the quality of the reconstruction and can be used to unfold the spectrum.

SUMMARY

The machine learning approach works well on IACT cosmic-ray data and with an unfolding method, using the migration matrices, a proton spectrum can be produced.