Feasibility Studies on improved Proton Energy Reconstruction with IACTs

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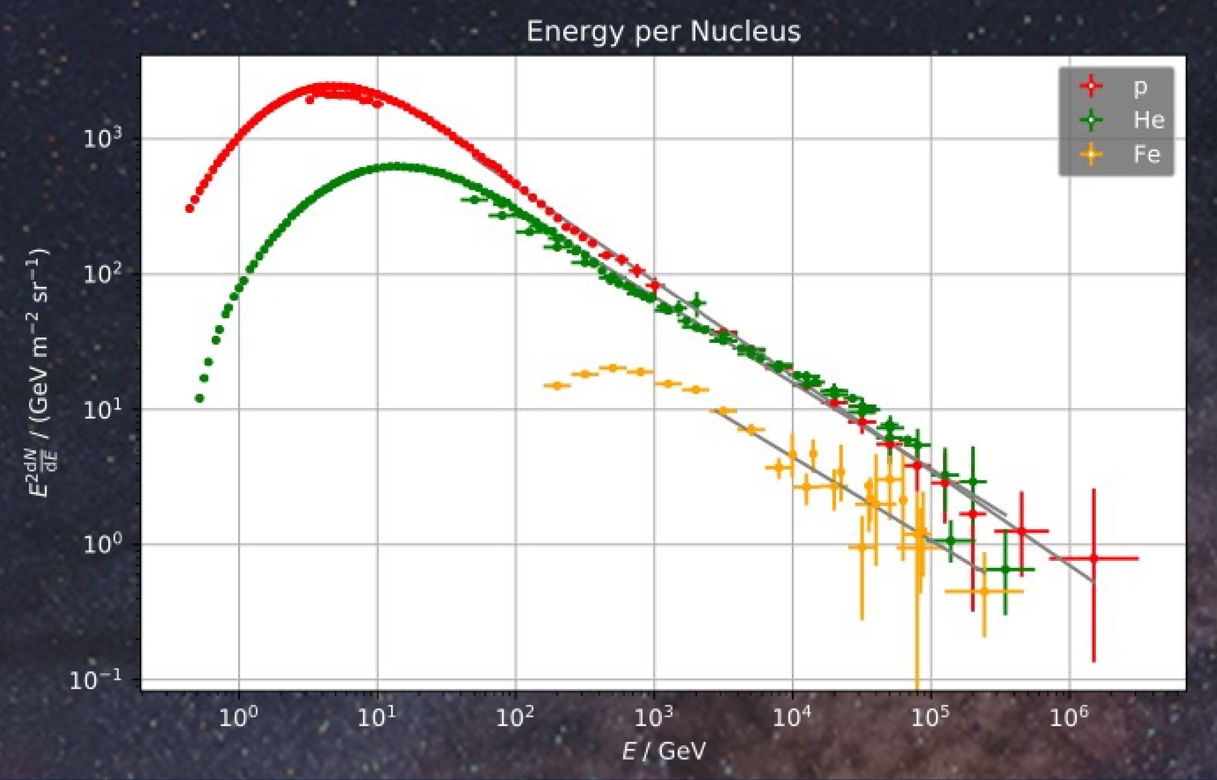
COSMIC RAYS

THE ORIGIN OF COSMIC RAYS

- Deflection of charged cosmic rays by galactic and intergalactic magnetic fields, solar winds and the Earth's magnetic field
- Diffuse cosmic ray flux measured on Earth
- Multi-messenger campaigns to search for cosmic-ray sources
- The GeV energy range is well-explored by balloon experiments [1]
- IACTs can provide measurements with high statistics in the TeV range [2], [3]



AIR SHOWER

AIR SHOWERS IN THE EARTH'S ATMOSPHERE

- Like gamma rays, protons and heavier nuclei interact with atmospheric molecules
- Gamma rays: pair production and bremsstrahlung → electromagnetic shower
- Cosmic nuclei: interactions trigger sub-showers → can be divided into three categories
  - Muonic component
  - Hadronic component
  - Electromagnetic component
- Relativistic charged particles in air showers produce Cherekov Light → measured by IACTs
- Cherenkov signatures of gamma and nuclei induced air showers are challenging to distinguish

IACTs

THE MAGIC TELESCOPES [4]

- Stereo system of IACTs
- Located at La Palma (Canary Islands) at an altitude of 2200 m
- Mirror surface: 17 m diameter
- Field of view: 3.5 °
- Sensitive for gamma rays: 30 GeV to 100 TeV
- Energy range of nucleons in the same order of magnitude
- Gamma-hadron-ratio for weak sources can lead 1:5000

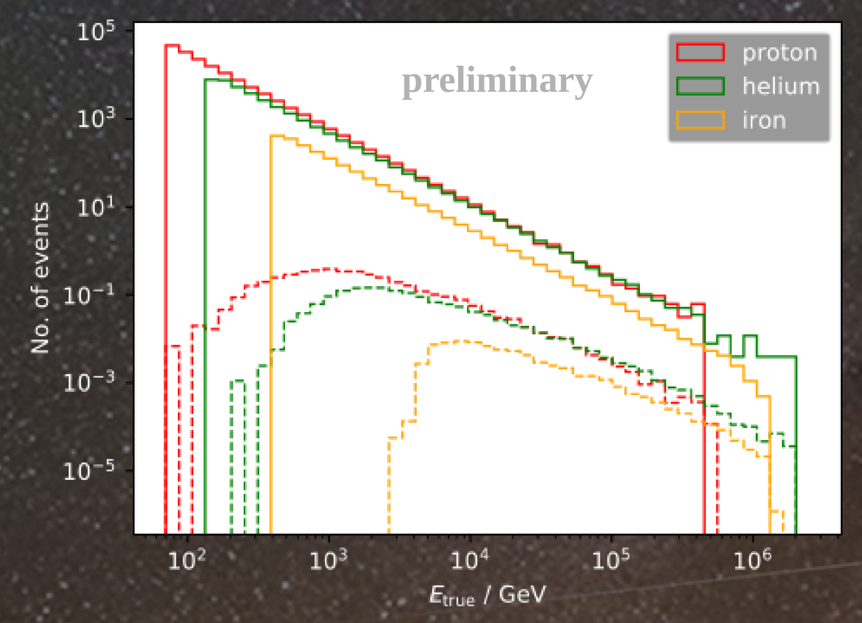
NEW GENERATION OF IACTS: CHERENKOV TELESCOPE ARRAY

- IACTs located at the northern and southern hemisphere
- More sensitive to gamma rays and nuclei than any IACT before

ANALYSIS TOOLS

MONTE CARLO SIMULATIONS

- Three particle types: p, He, Fe
- Attributes: Hillas [5] and stereo parameters



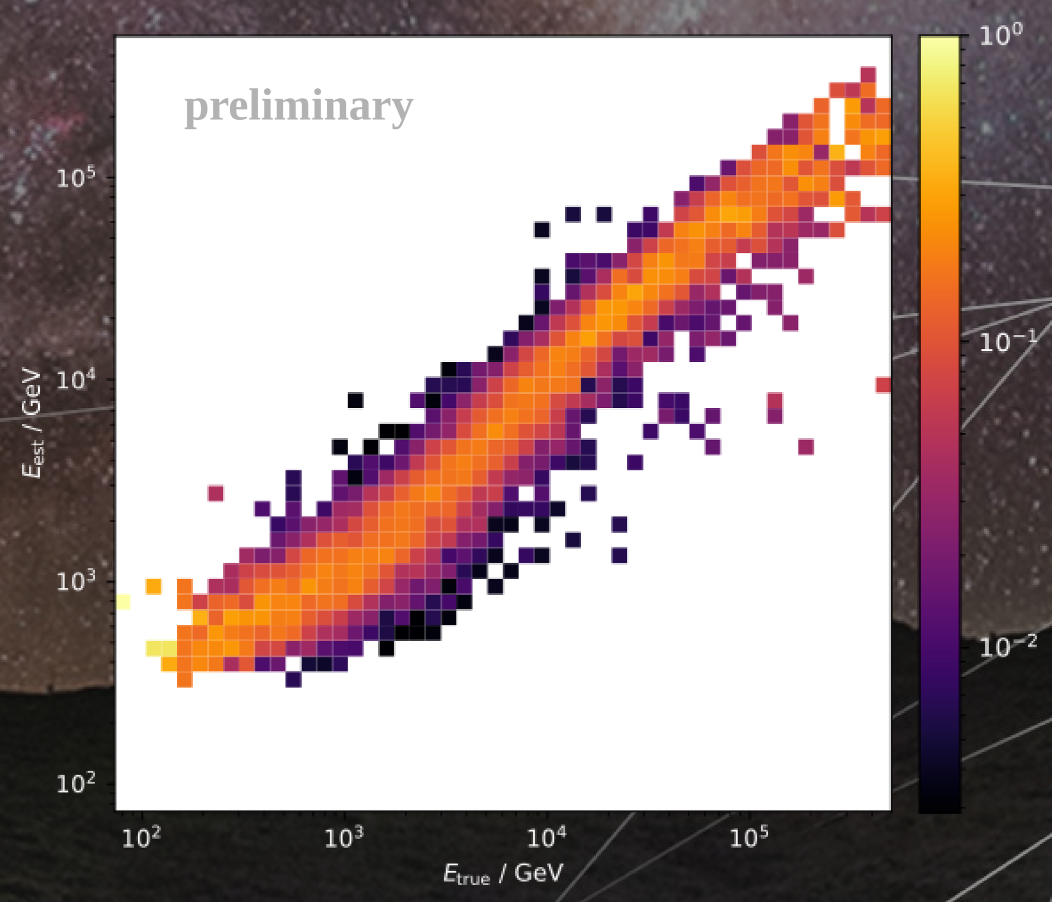
AICT-TOOLS [6]

- Reconstruction tool, especially for IACT-data
- Open-source Python Project
- Based on scikit-learn modules
- Developed at the TU Dortmund

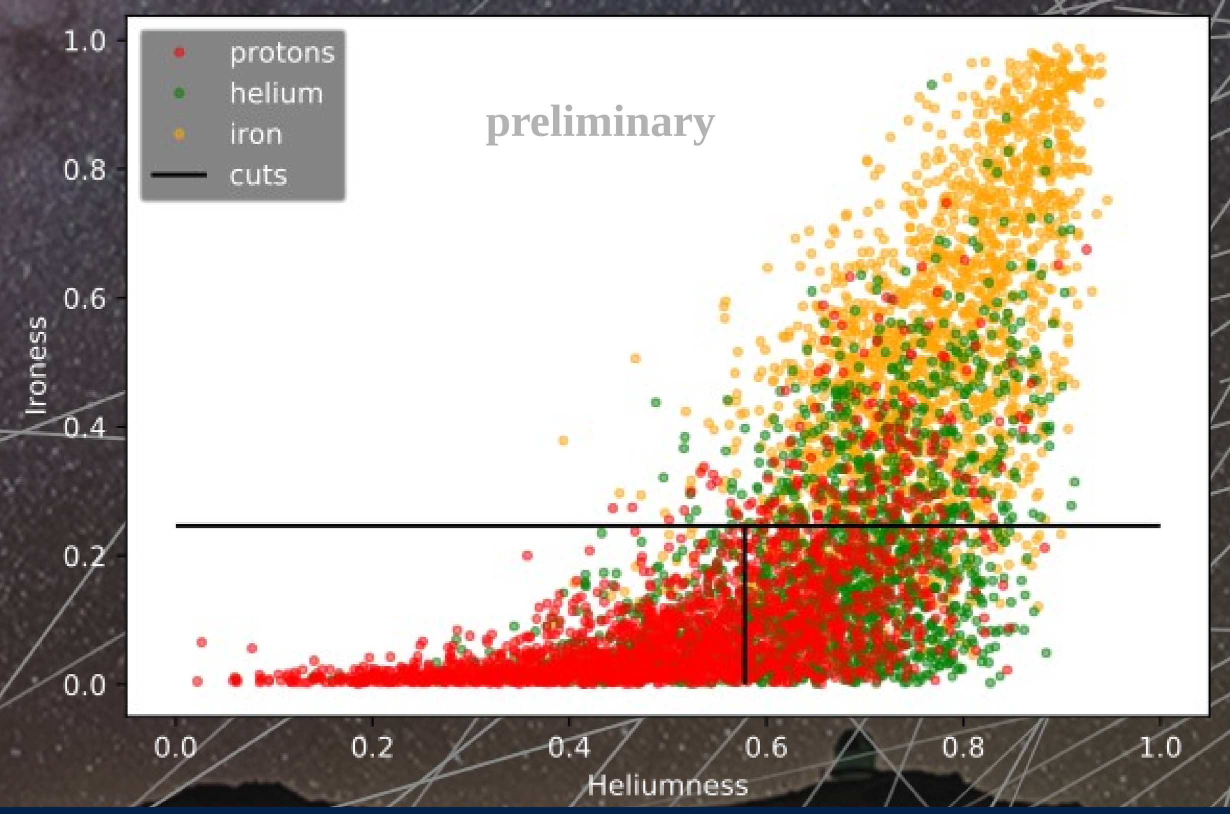
ENERGY REGRESSION

STRATEGY

- Random forest approach
- Trained on a pure proton sample (can be trained for other nuclei as well)
- Energy migration is well-described by MCs

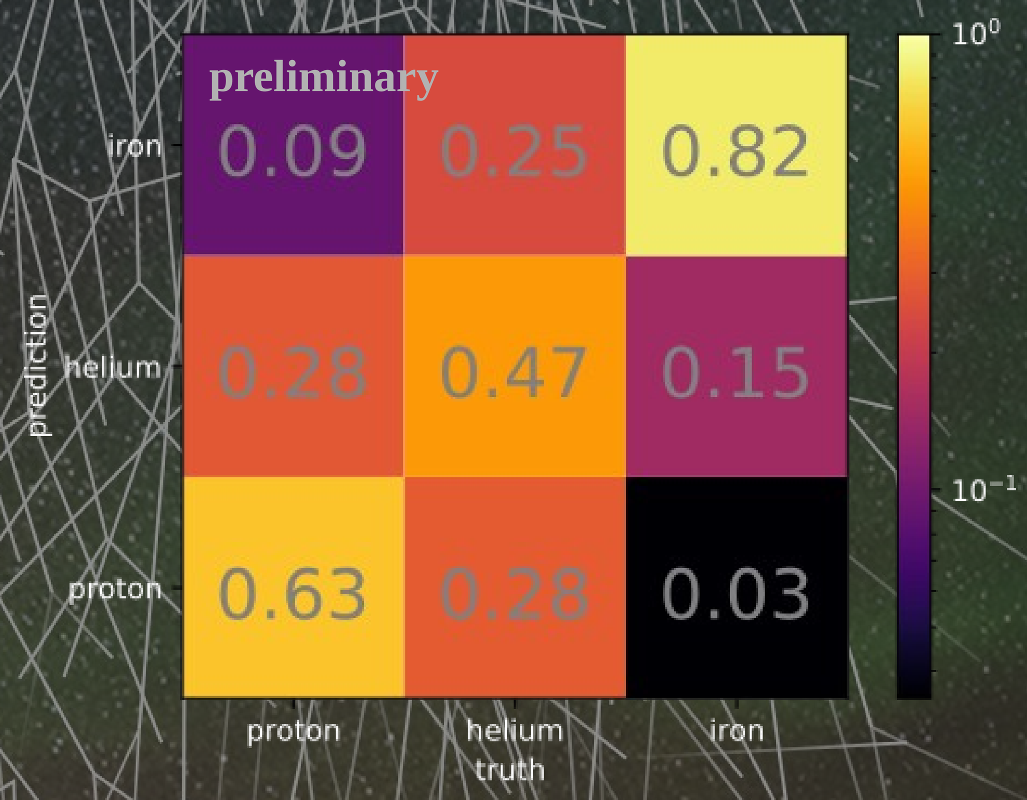


PARTICLE CLASSIFICATION



STRATEGY

- Random forest approach
- Two step classification
  1. Separation of iron nuclei from the lighter particles (Ironess)
  2. Separation of helium nuclei from rest (Heliumness)
- Cuts base on efficiency and purity of the separation
- Different cuts can be chosen for different analysis purposes
- Particle migration is well-described by MCs



SUMMARY

- Aim: investigation of the cosmic-ray spectrum in the TeV energy range
- High statistics of hadronic events in the measurements of IACTs, like MAGIC → good candidates for measure the the cosmic-ray spectrum
- In this work, we have MC simulations of p, He and Fe
- The open-source framework aict-tools is used for training and applying random forests
- Particle identification: two random forests for the particle separation
- Energy regression: a random forest for the protons' energy (but can be trained for He and Fe as well)
- Migration matrices can be used for a subsequent unfolding

CONTACT

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[6] M. Nöthe, K.A. Brügge and J.B. Buß, github.com, 2019.