A template method for measuring the iron spectrum in cosmic rays with Cherenkov telescopes.

Henrike Fleischhack

1 henrike.fleischhack@desy.de
2 https://www.veritas.sao.arizona.edu

Introduction

> Cosmic rays known for 100 years.
> Make-up: Mainly protons, nuclei.
> Energy spectrum: ~smooth power law.
> Origin, composition not fully understood.

Direct detection experiments[1]:
> Balloons/space borne detectors.
> Detection area ~1 m².
> Good at small Z, MeV to TeV energies.

Indirect detection — EAS arrays[2] [3]:
> Detect air shower on ground.
> Detection area ~10² m².
> Best at energies of 10¹³ eV and above.

Indirect detection — IACTs[4]:
> Detect Cherenkov light from air showers.
> Detection area ~10³ m².
> Intermediate energies (TeV range).

Imaging Air Showers & Direct Cherenkov Technique

Imaging of Air Showers:
> Charged particles → Cherenkov light.
> Light pool: few 100 m radius at ground.
> Extension in camera: ~1°.
> Reconstruct energy, direction, primary particle from size, shape, orientation.
> Telescope arrays → stereoscopy.
> γ-ray astronomy, large background of CRs.

Direct Cherenkov Technique[5] [6]:
> Charged primary particles: direct Cherenkov (DC) light before first interaction.
> Very concentrated in camera.
> DC Intensity ~ Z² → separation of heavy and light nuclei.
> Combine IACT data on all targets.
> Complementary to EAS, direct detection.

The VERITAS instrument

> Very Energetic Radiation Imaging Telescope Array System [7].
> Array of four imaging atmospheric Cherenkov telescopes at the Fred Lawrence Whipple Observatory (FLWO) in southern Arizona (31 40 N, 110 57 W, 1.3 km a.s.l.).
> Field of view 3.5° per camera, consisting of 499 pixels each.

Template Likelihood Reconstruction

> Likelihood optimization to estimate parameters for a given shower by filling camera images to model [8, 9].
> Goodness of fit: background separation.
> CR analysis: include shower-to-shower fluctuations in likelihood [10].

Performance

> Reconstruction tested on simulated iron showers.
> Select very bright showers only, no cut on goodness of fit.
> Reconstruction works well, safe energy threshold ~10¹² TeV ~30 TeV.
> Energy bias (E_true/E_rec) ~ flat above energy threshold.
> Offset-dependent energy bias, need to correct for that.
> Energy resolution and angular resolution improved compared to geometrical reconstruction.
> Angular resolution still larger than pixel diameter below 100 TeV.

Conclusions

> Have adapted template likelihood reconstruction to reconstruct iron-induced showers.
> Reconstruction works well for iron-induced showers with energies of ~30 TeV – ~300 TeV.
> Future plans: Use goodness-of-fit to separate iron-induced showers from background (showers induced by protons and light nuclei).
> Eventually: Spectrum of cosmic ray iron in the TeV range.

References


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