technische universität
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e5 experimentelle physik 5
astroteilchenphysik

Extending ctapipe image reconstruction using FACT methods

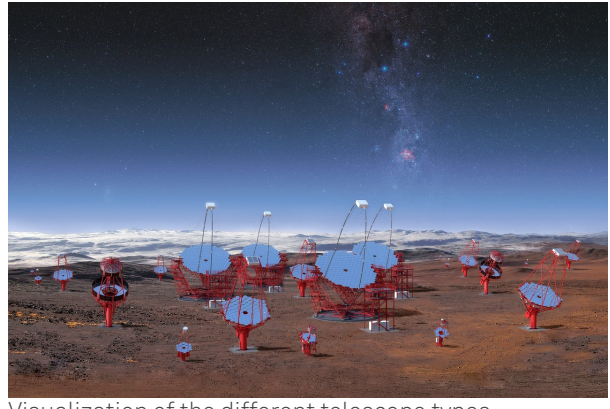
Lukas Nickel and Maximilian Nöthe

28. März 2019

E5b

The Cherenkov Telescope Array

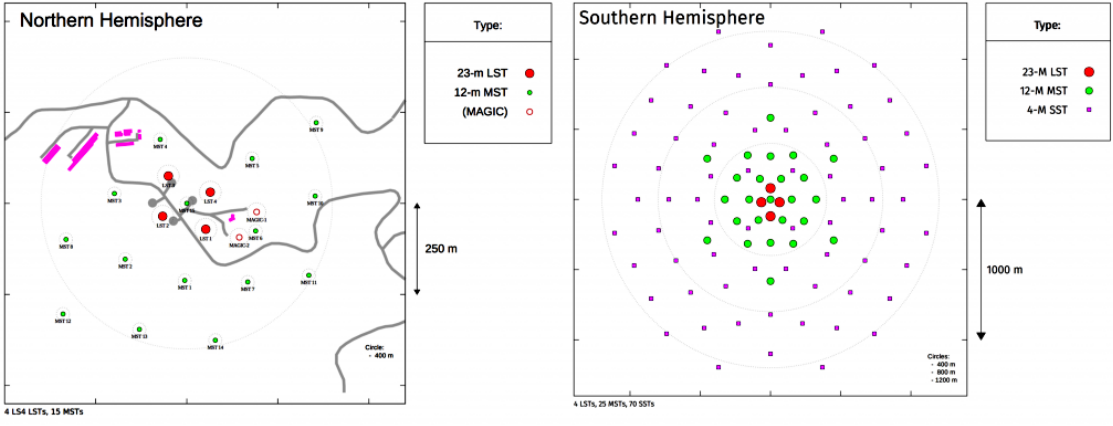
- "Cherenkov Telescope Array"
- Proposed in 2005
- Currently in pre-production
- Status: First light on LST1
- Two arrays of multiple telescopes
- Three types of telescopes: LST, MST, SST
- Goals: Extend observable energy range, improve sensitivity, huge field of view



Visualization of the different telescope types.
CTA/M-A. Besel/IAC (G.P. Diaz)/ESO. 2018. URL:
https://www.eso.org/public/germany/images/eso1841a/

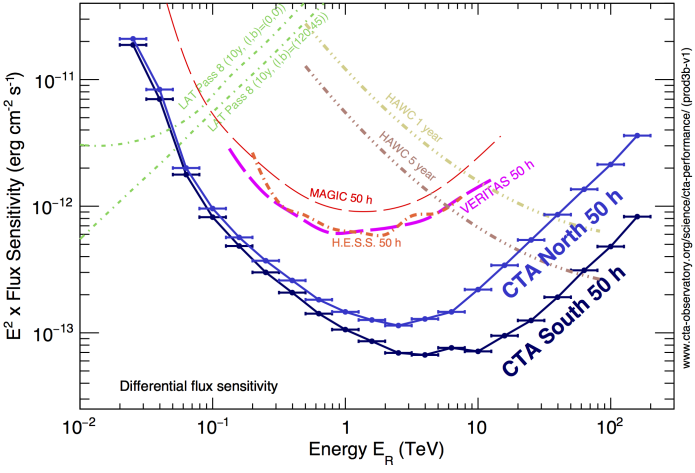
Planned Layout

The CTA Consortium. CTA's expected baseline performance. URL: `https://www.cta-observatory.org/science/cta-performance`



Expected Sensitivity

The CTA Consortium, CTA's expected baseline performance



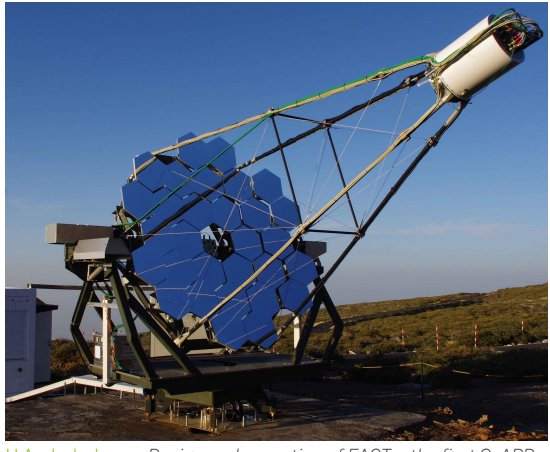
ctapipe

URL: `https://github.com/cta-observatory/ctapipe`

- Pipeline for low-level cta data
- Performs transformations, calibration, cleaning, hillas parameters, 3D-reconstruction, visualization
- Still in active development
- Mainly **python** based

The FACT Experiment

- "First G-APD Cherenkov Telescope"
- Single telescope
- → Monoscopic reconstruction only
- Operating on La Palma since 2011
- → Advanced analysis pipeline
- What did we take a look at?
  - More advanced cleaning methods
  - Distinction of "islands" in shower images
  - → Possible improvements for ctapipe



H Anderhub u. a. *Design and operation of FACT – the first G-APD Cherenkov telescope*. DOI: 10.1088/1748-0221/8/06/p06008

Image cleaning in FACT

Cleaning Methods

Tailcuts cleaning

- “Two treshold procedure”
- Pixels above upper threshold survive
- Signal with less N neighbors get discarded
- Neighboring pixels above the lower threshold get added

”FACT image cleaning”

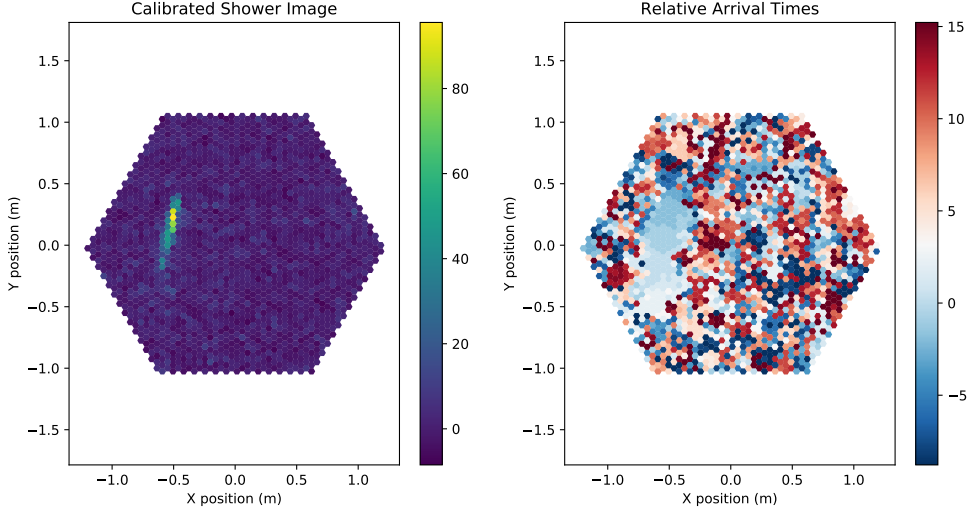
- Similar behaviour, but also uses information about the arrival times

→ Pixels need to have a similar arrival time as their neighbors

- Multiple steps removing ”lonely” pixels

→ Probably removes more pixels with the same intensity thresholds

Sample MC Event



Cleaning Results

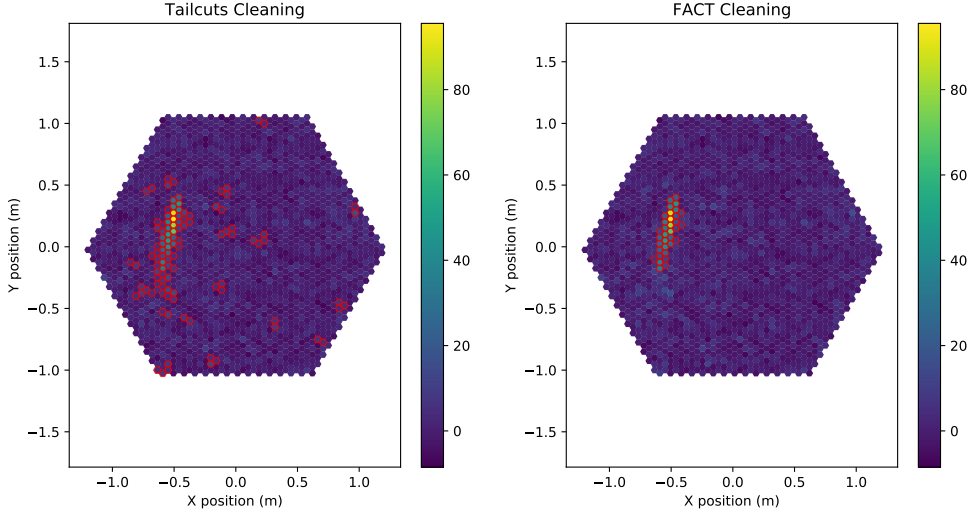
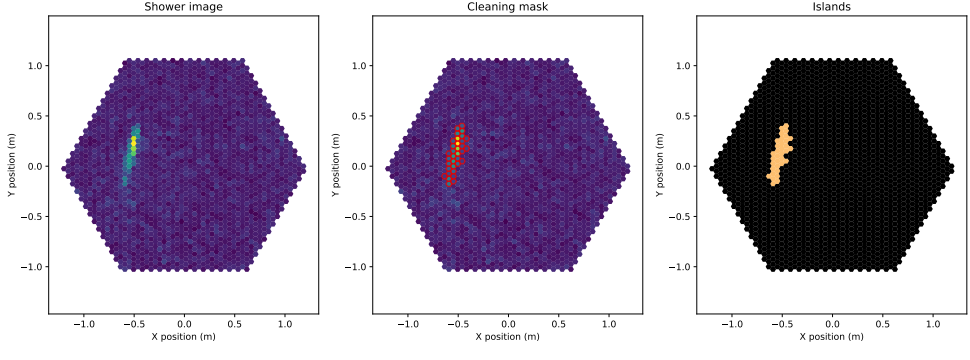


Image cleaning: Tailcuts vs. FACT

Finding islands

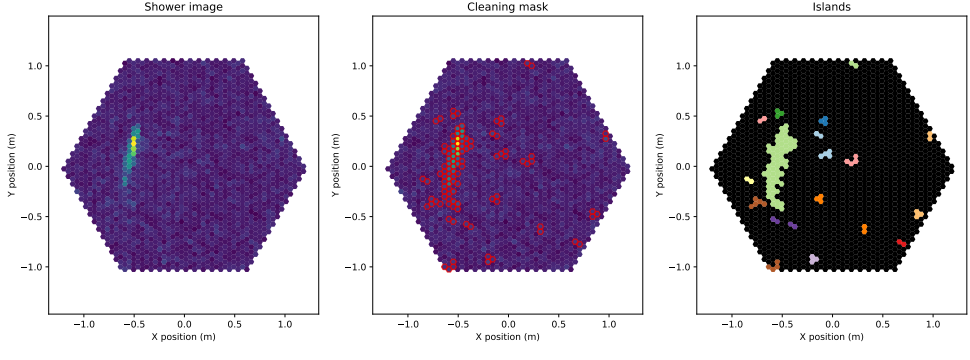
- Cleaning removed all but one cluster of pixels

→ Number of islands: 1



- Cleaning kept too many pixels

→ Number of islands: > 1



Machine learning impacts

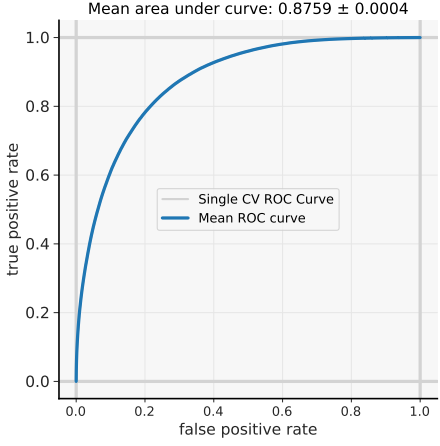
Setup and expectations

- A few 100 000 diffuse gamma and proton MC events
- Preprocessed with ctapipe, machine learning with aict-tools
  URL: `https://github.com/fact-project/aict-tools`

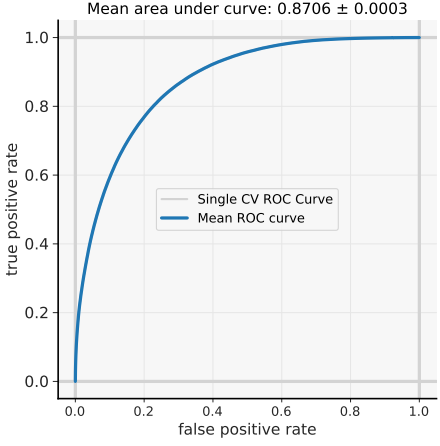
- Tailcuts cleaning should perform pretty well with the chosen parameters
- Cleaning might affect separator performance
- Number of islands hopefully contribute to separator performance
- Number of islands will probably not constribute to gamma energy regression

Gamma/Hadron Separation - AUC

Tailcuts cleaning:

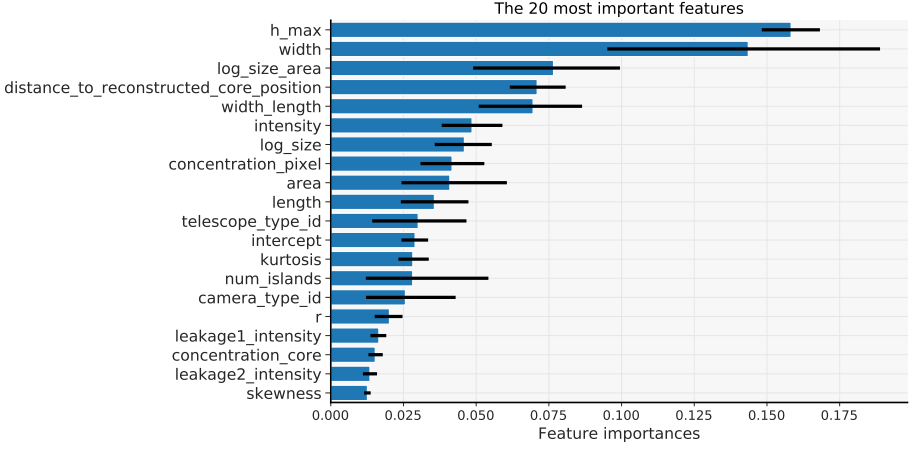


FACT cleaning:



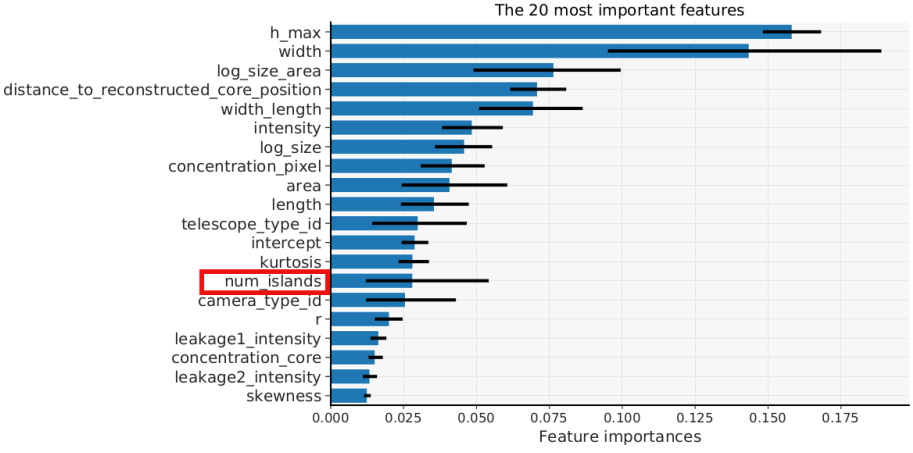
Gamma/Hadron Separation - Features

Tailcuts cleaning:



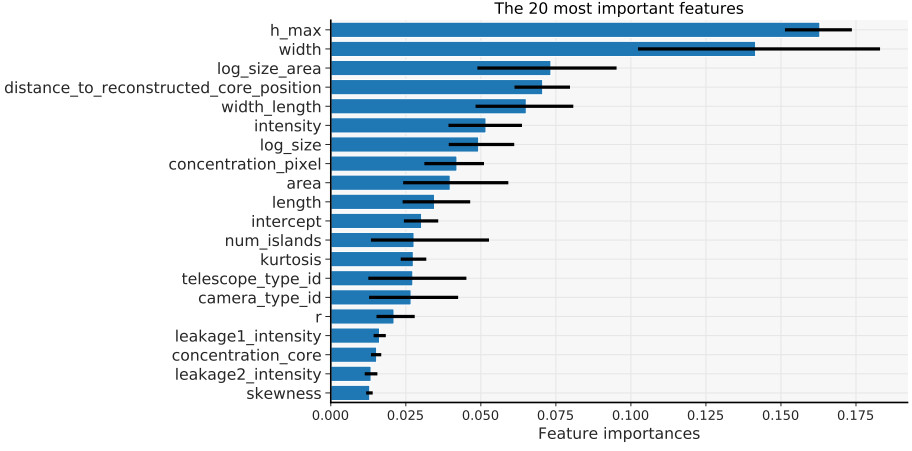
Gamma/Hadron Separation - Features

Tailcuts cleaning:



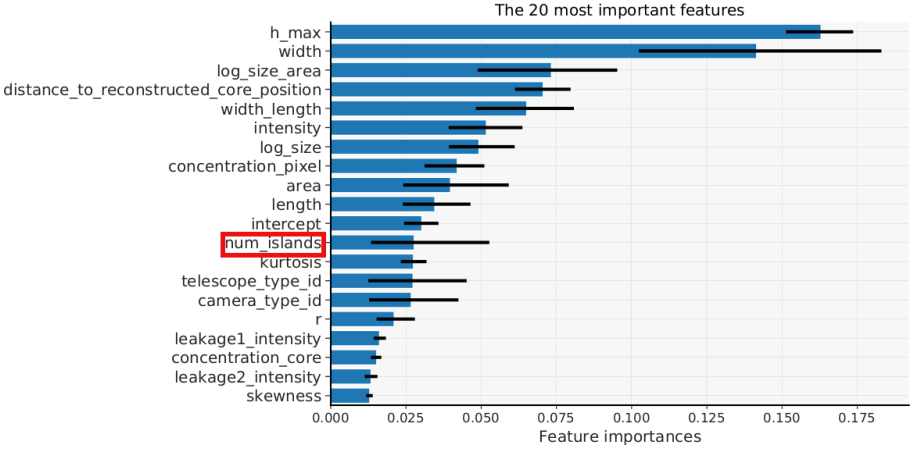
Gamma/Hadron Separation - Features

FACT cleaning :



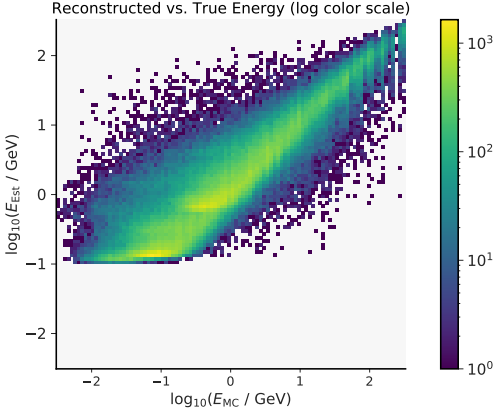
Gamma/Hadron Separation - Features

FACT cleaning :

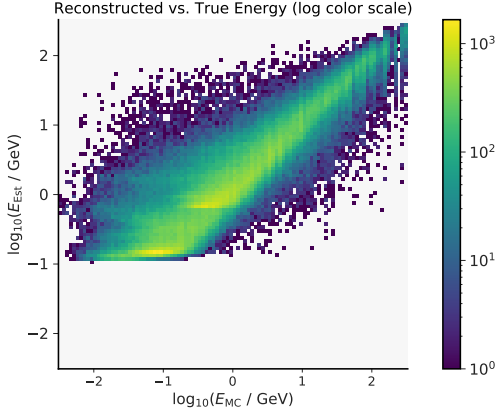


Energy Regression

Tailcuts cleaning:

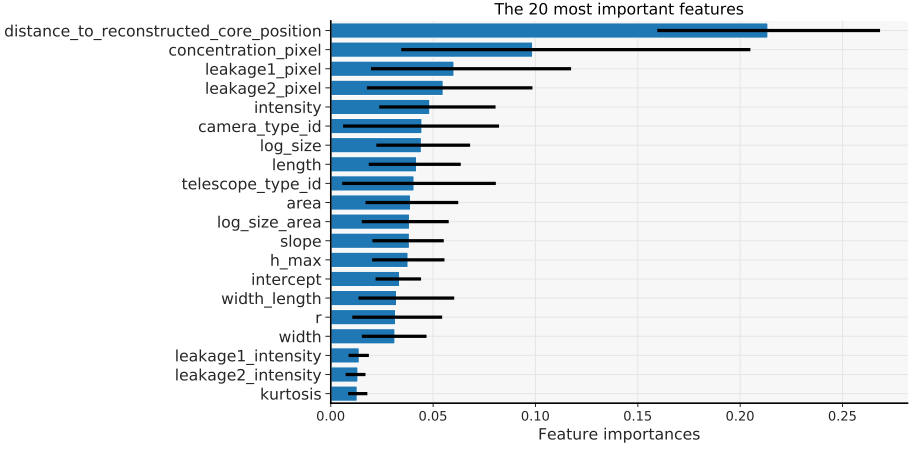


FACT cleaning:



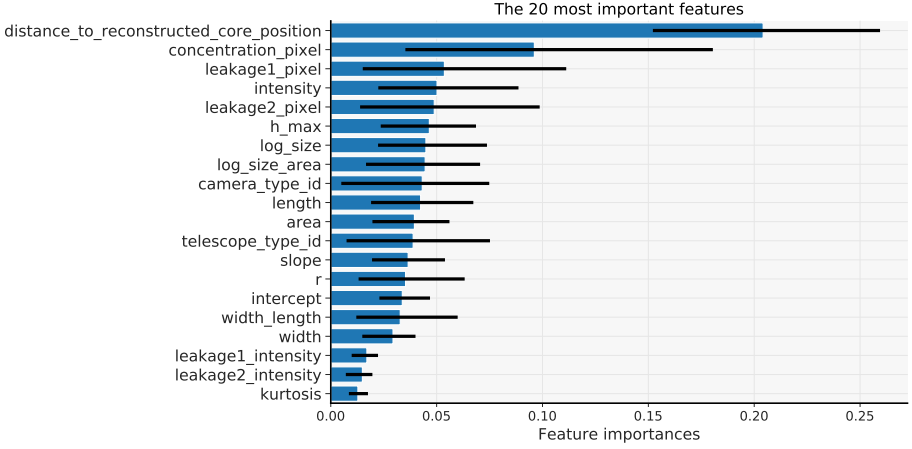
Energy Regression - Features

Tailcuts cleaning :



Energy Regression - Features

FACT cleaning :



Summary

- The Cherenkov Telescope Array is coming
- The pipeline ctapipe is being developed, big changes every once in a while
- We worked on adding features that worked well for FACT
- Number of islands improves gamma/hadron-separation
- FACT-cleaning works reasonably well but can't outperform the established method yet
- Potential improvements for cleaning: proper arrival times, finding optimal parameters

Thank you for your attention!

URL: https://github.com/cta-observatory/ctapipe.

URL: https://github.com/fact-project/aict-tools.

Anderhub, H u. a. *Design and operation of FACT – the first G-APD Cherenkov telescope*. DOI: 10.1088/1748-0221/8/06/p06008.

Consortium, The CTA. *CTA's expected baseline performance*. URL: https://www.cta-observatory.org/science/cta-performance.

Diaz)/ESO, CTA/M-A. Besel/IAC (G.P. 2018. URL: https://www.eso.org/public/germany/images/eso1841a/.