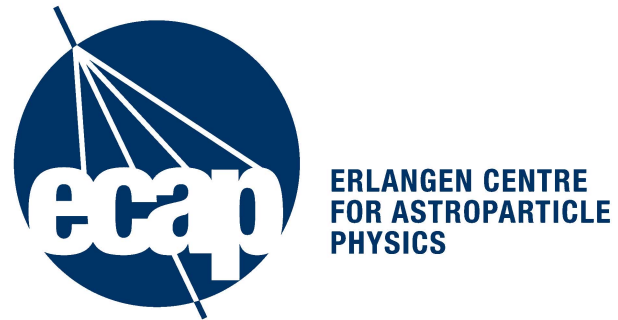


Evaluation of the Gamma-Hadron-Separation performance with HESS-IU using Boosted Decision Trees

Jelena Celic
Women in Data Science Regensburg
05.07.2022

Short Biography



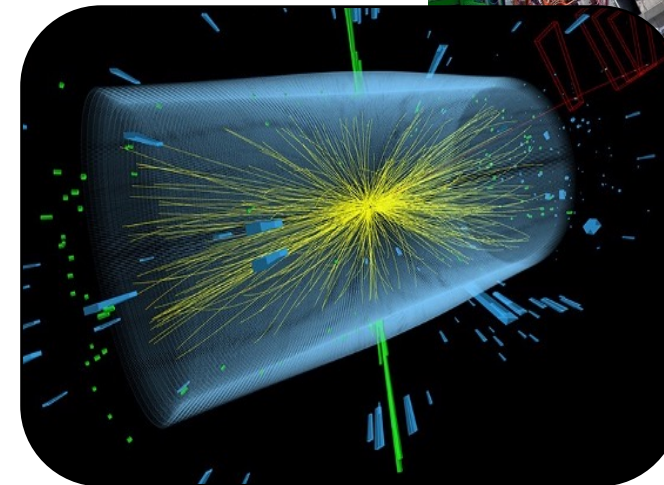
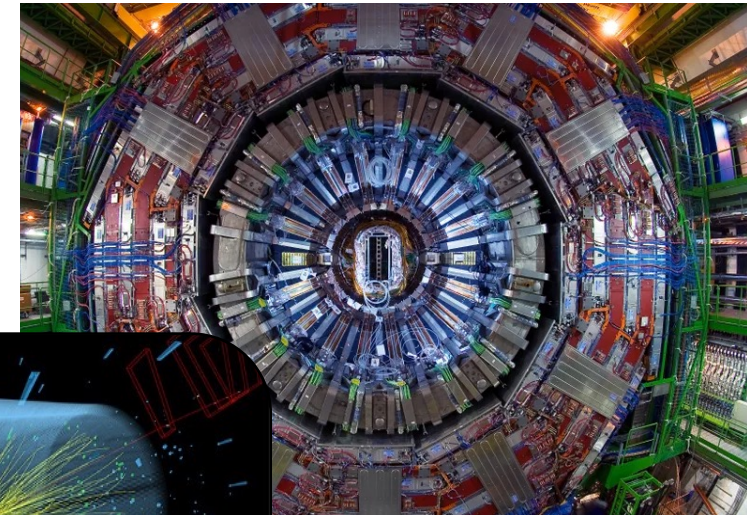
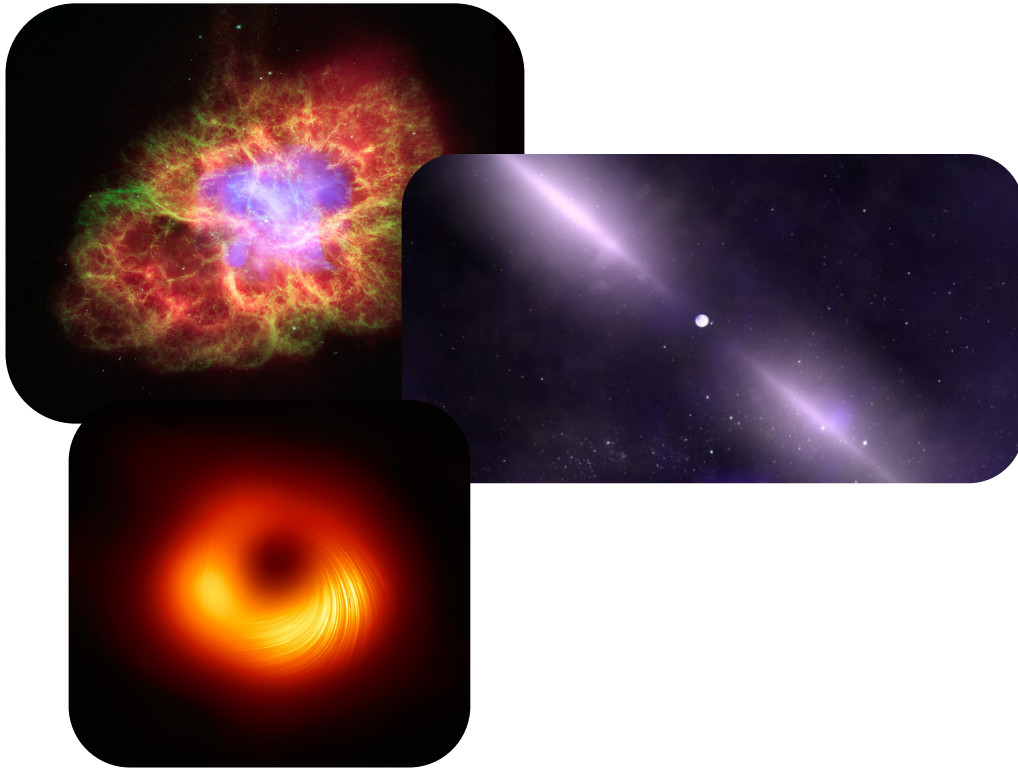
- **Bachelor and Master of Science in Physics** at the Friedrich-Alexander-Universität Erlangen-Nürnberg
- PhD student in the working group of Prof. Dr. Stefan Funk at the **Erlangen Centre of Astroparticle Physics**
- **Member of the H.E.S.S. Collaboration**
- Currently working on:
 - Gamma-ray astronomy
 - Low level: improvement of the low energy response of the experiment
 - High level: study of novae events

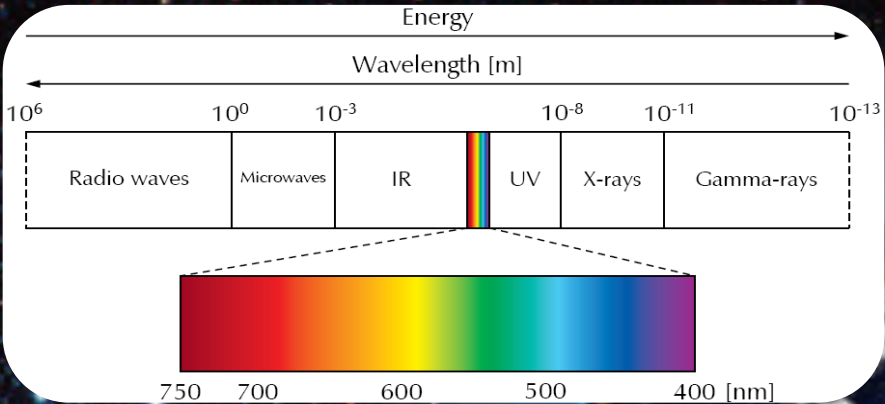
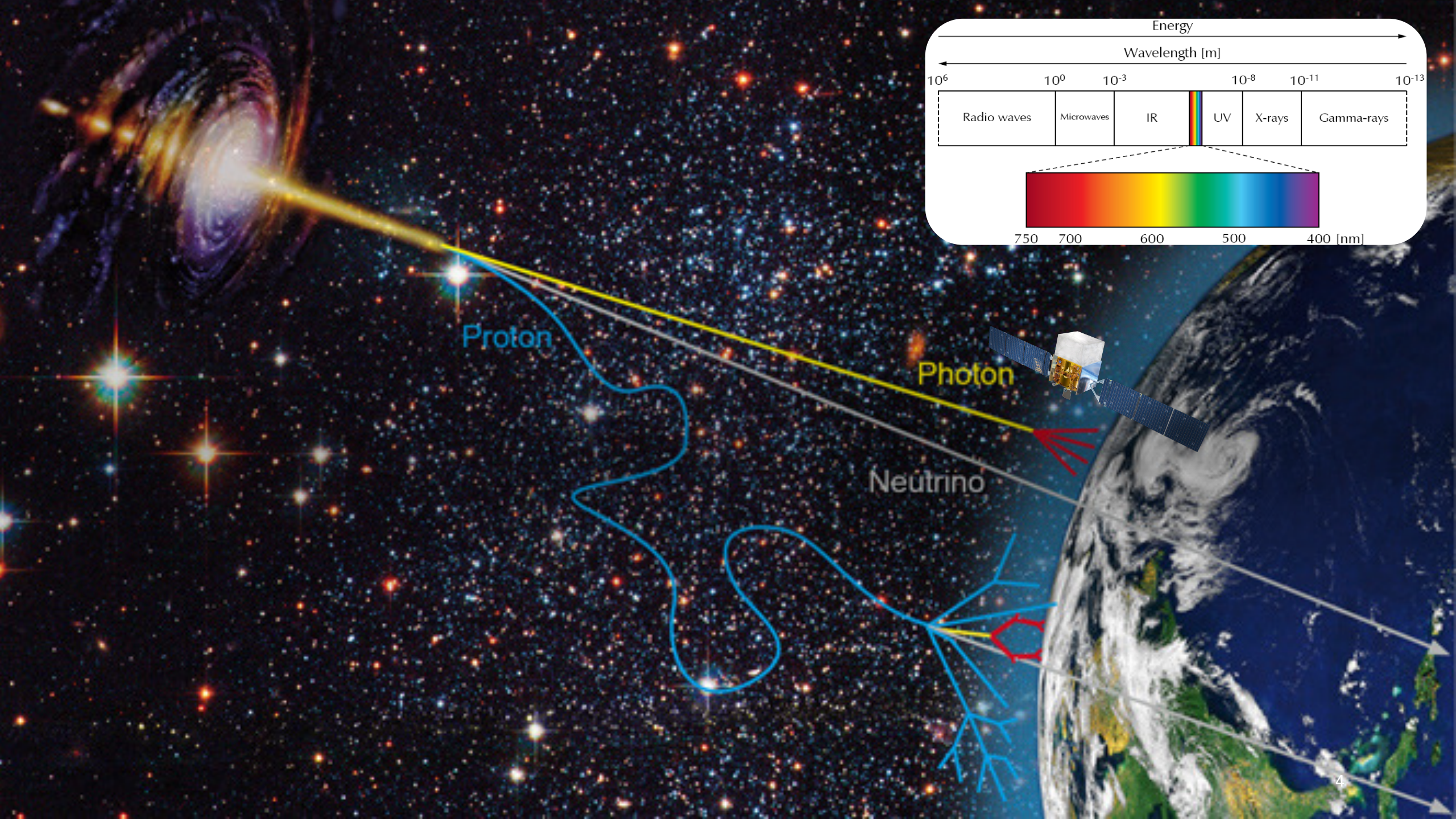
What is astroparticle physics?

Astrophysics,
Astronomy

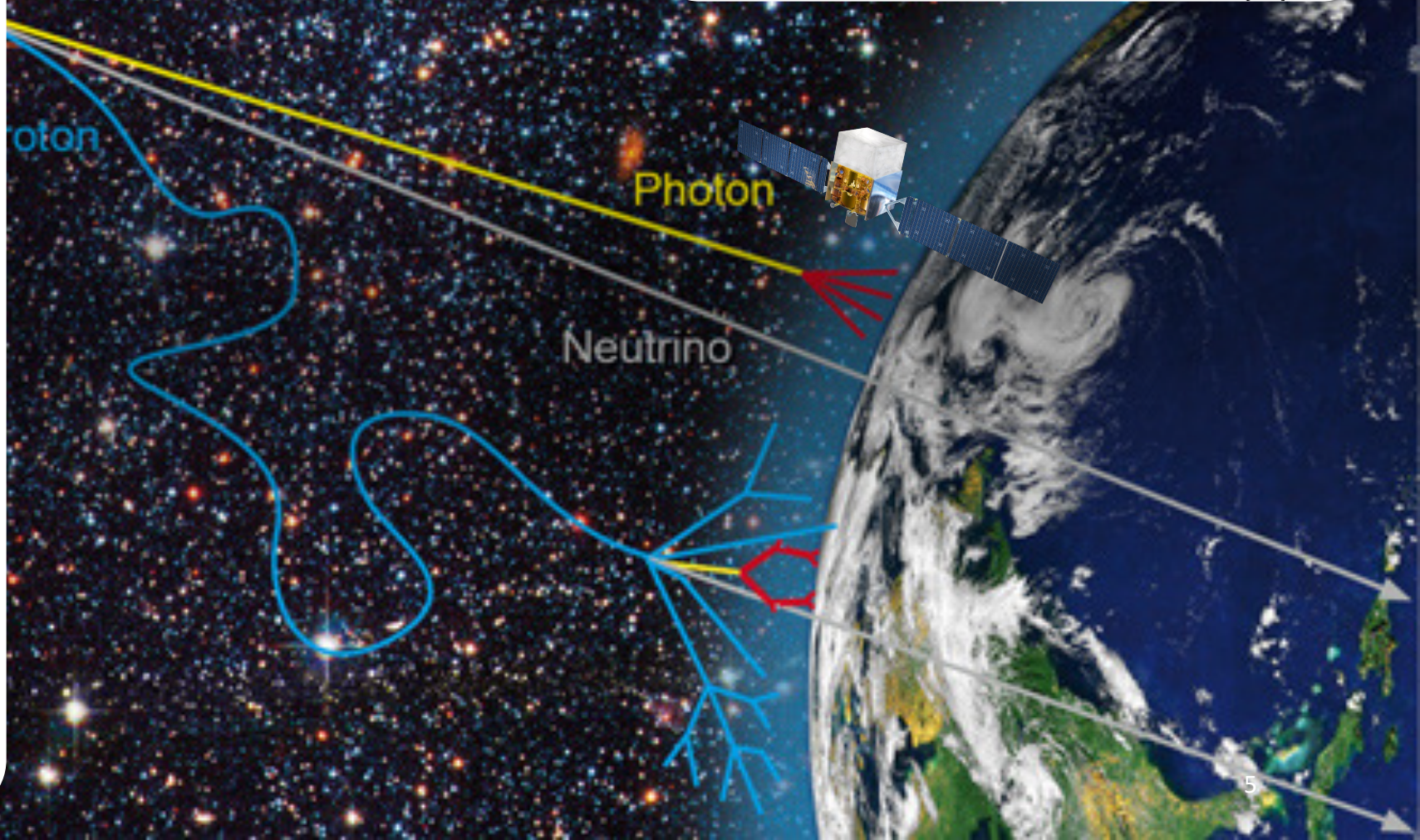
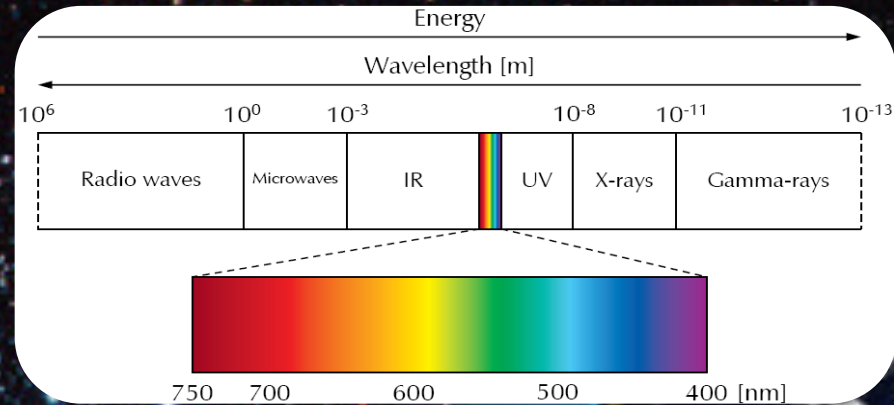
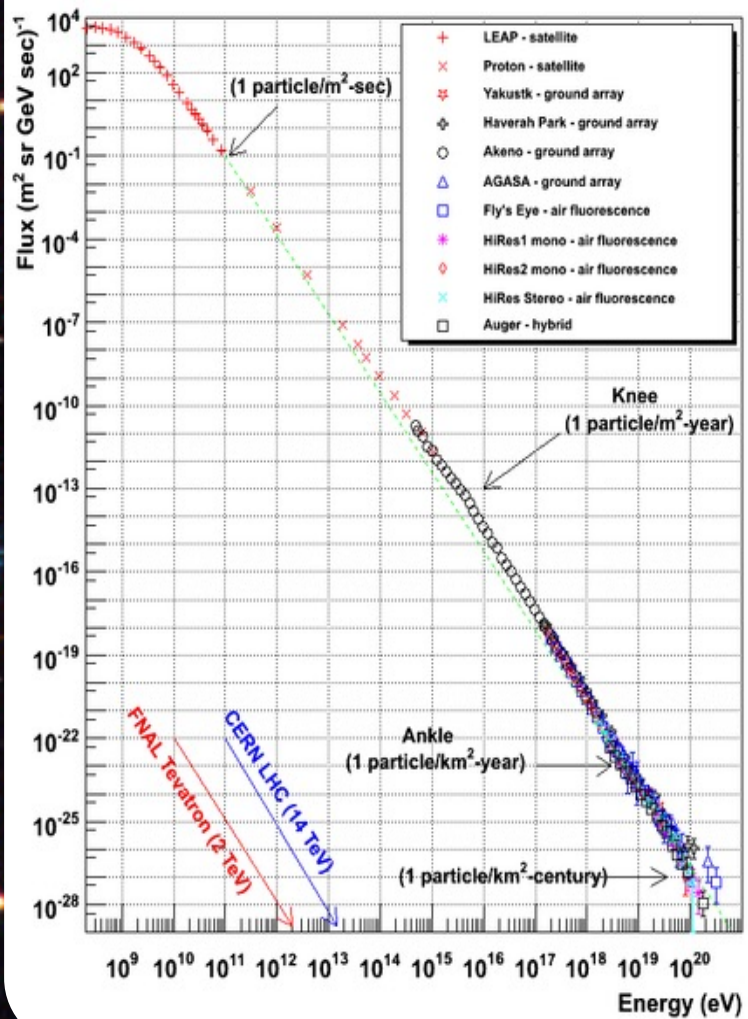
Astroparticle physics

Particle physics





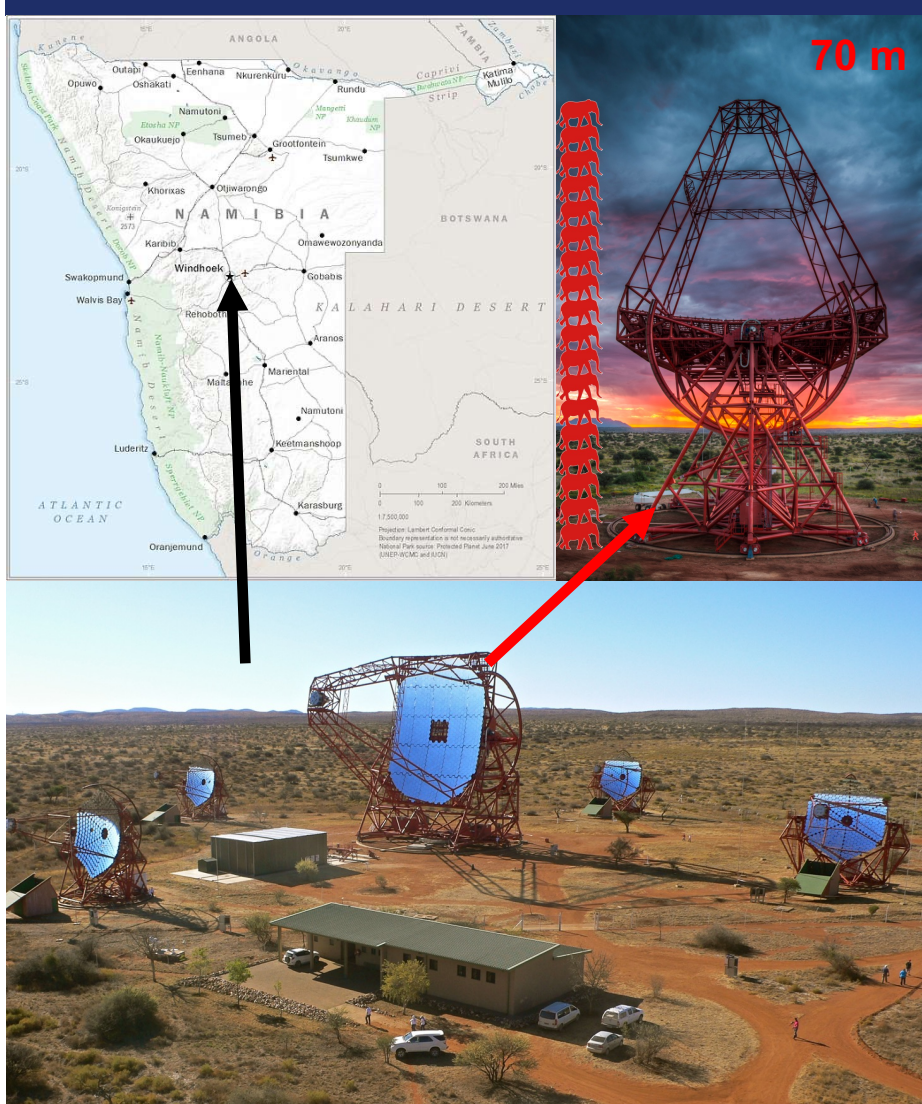
Cosmic Ray Spectra of Various Experiments



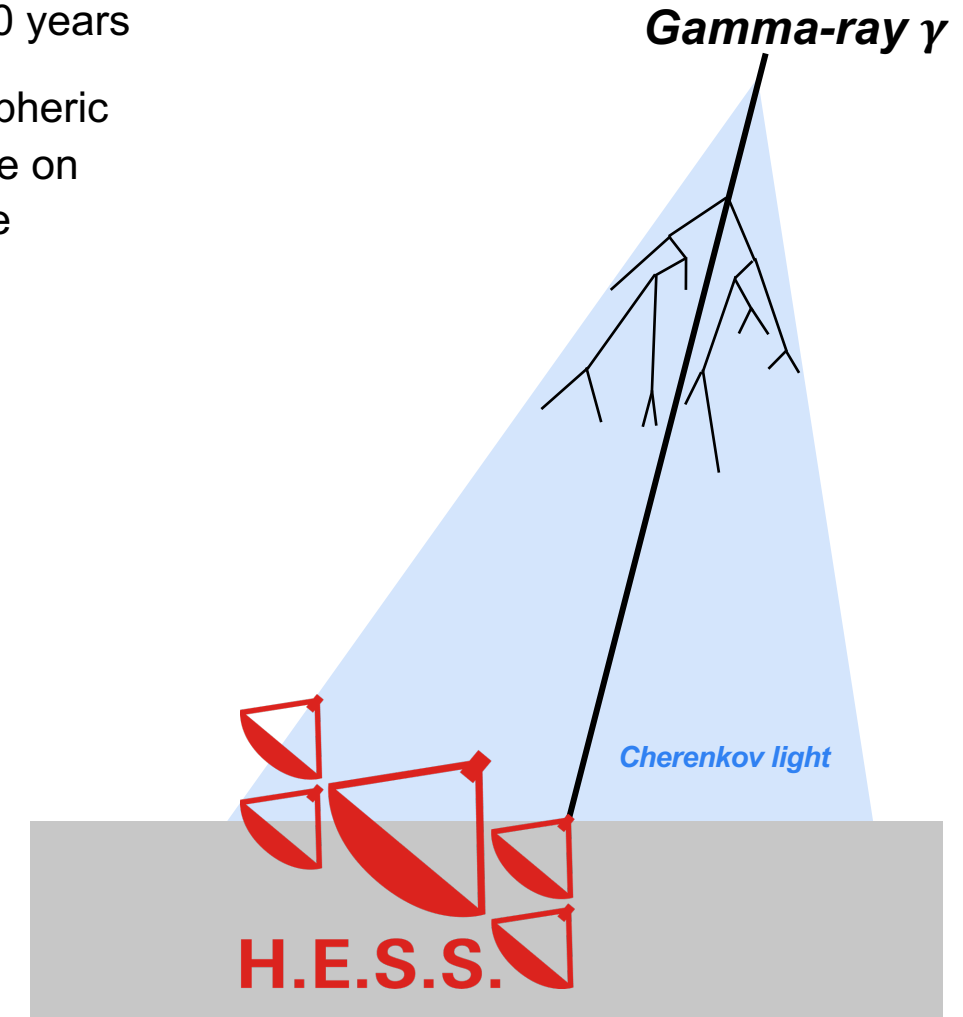
How do we detect cosmic rays with ground-based Cherenkov telescopes?

Detection principle of cosmic rays

With the High Energy Stereoscopic System (H.E.S.S.)

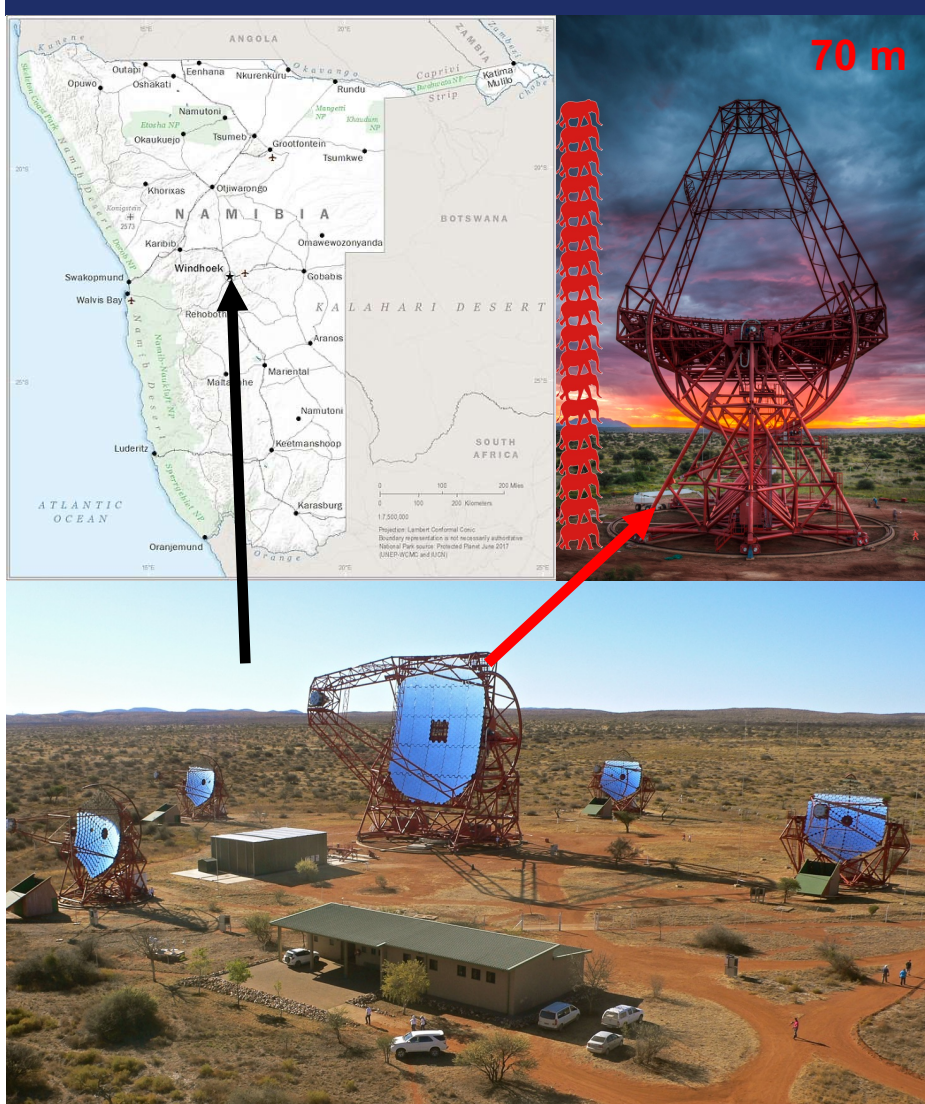


- Operating for over 20 years
- Only Imaging Atmospheric Cherenkov Telescope on southern hemisphere



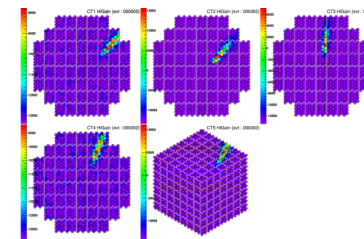
Detection principle of cosmic rays

With the High Energy Stereoscopic System (H.E.S.S.)



- Operating for over 20 years
- Only Imaging Atmospheric Cherenkov Telescope on southern hemisphere

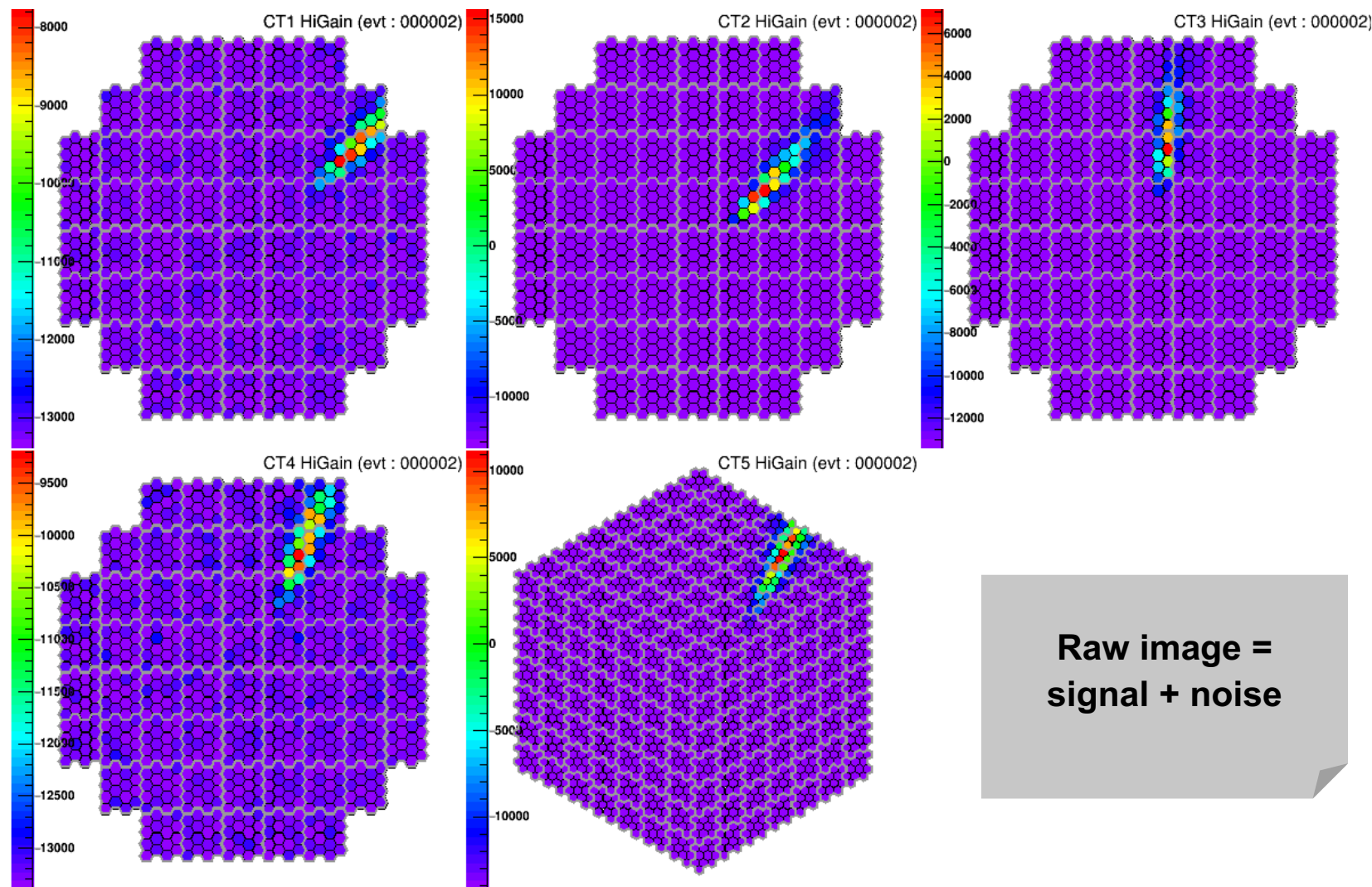
Let's take a closer look on the images



Gamma-ray γ

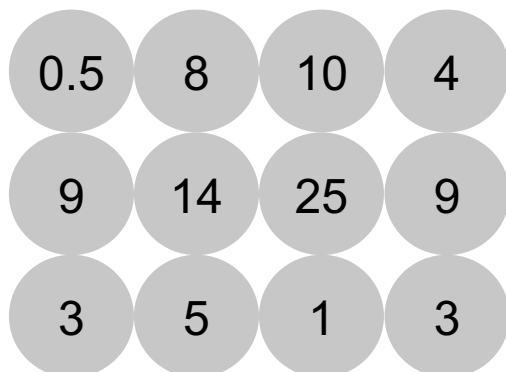
Cherenkov light

- Standard image cleaning method
→ two threshold cleaning
(tailcuts cleaning)

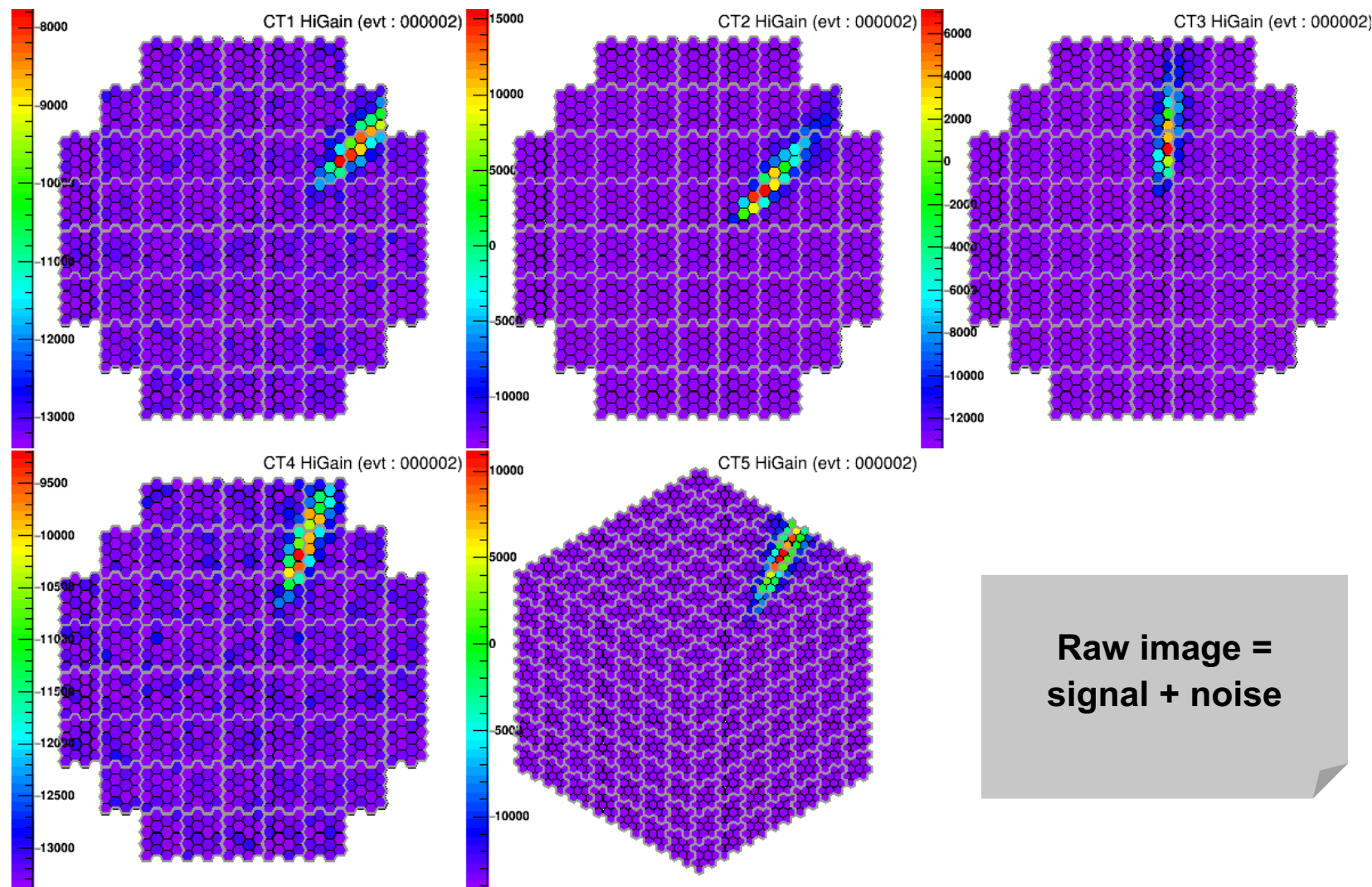


Raw image =
signal + noise

- Standard image cleaning method
→ two threshold cleaning
(tailcuts cleaning)

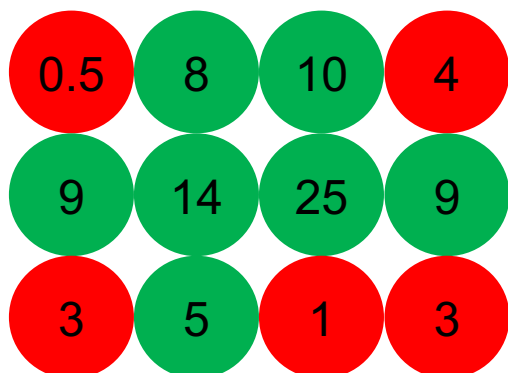


1. Threshold: 10
2. Threshold: 5

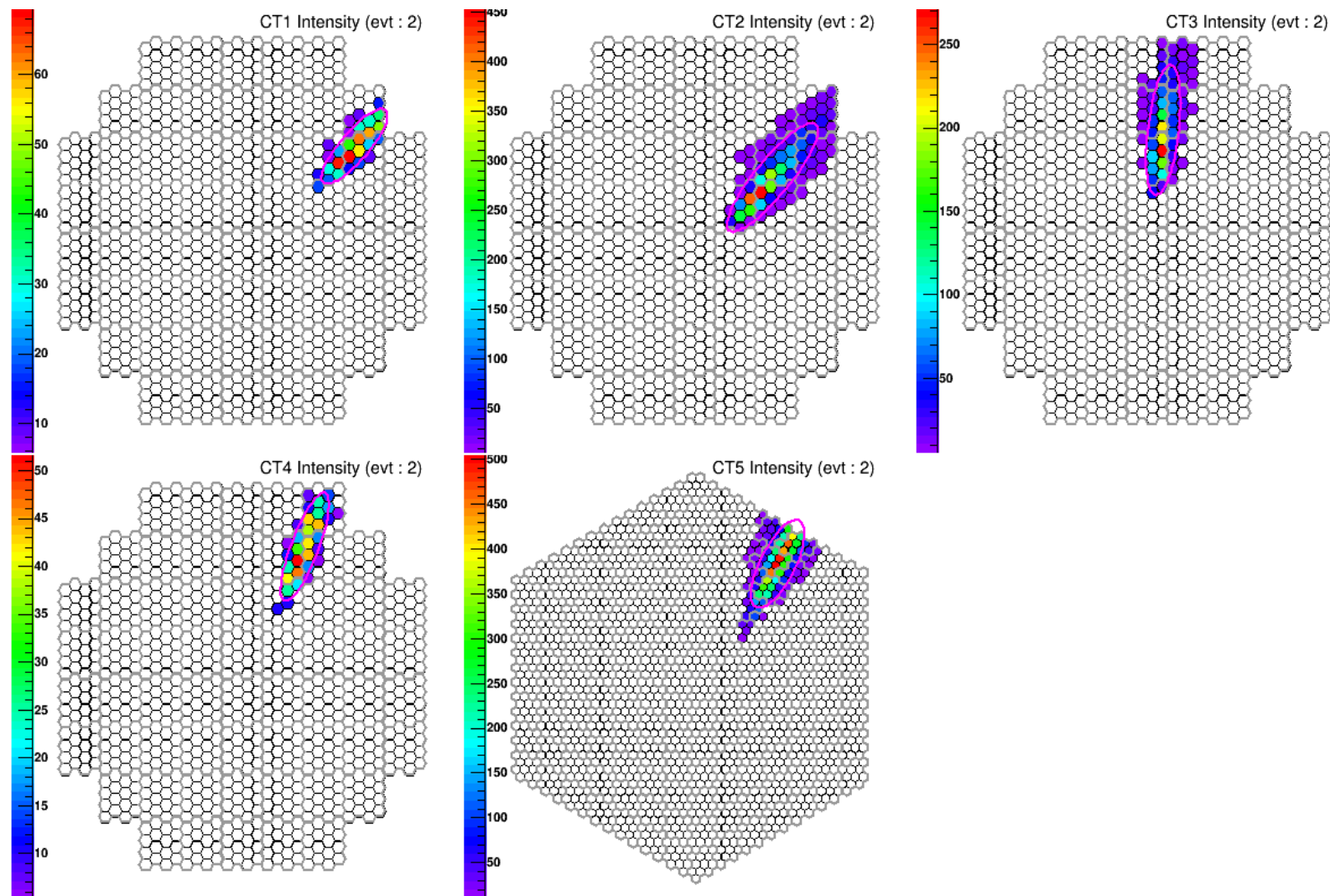


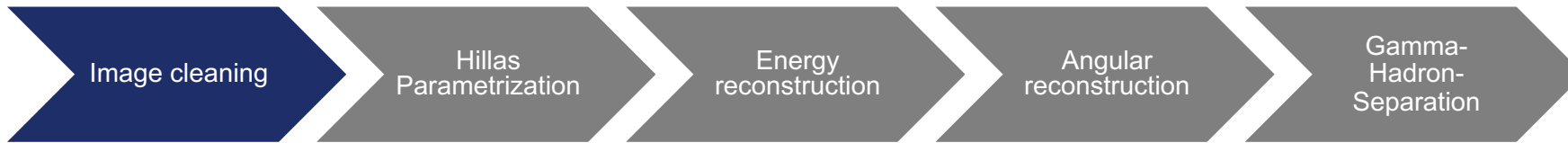
Raw image =
signal + noise

- Standard image cleaning method
→ two threshold cleaning
(tailcuts cleaning)



1. Threshold: 10
2. Threshold: 5





- Standard image cleaning method
→ two threshold cleaning
(tailcuts cleaning)

- New image cleaning method
→ **time based cleaning**

- Our Tool: a **3D DBScan**

- Time-based cleaning =
precleaning + 3D DBScan

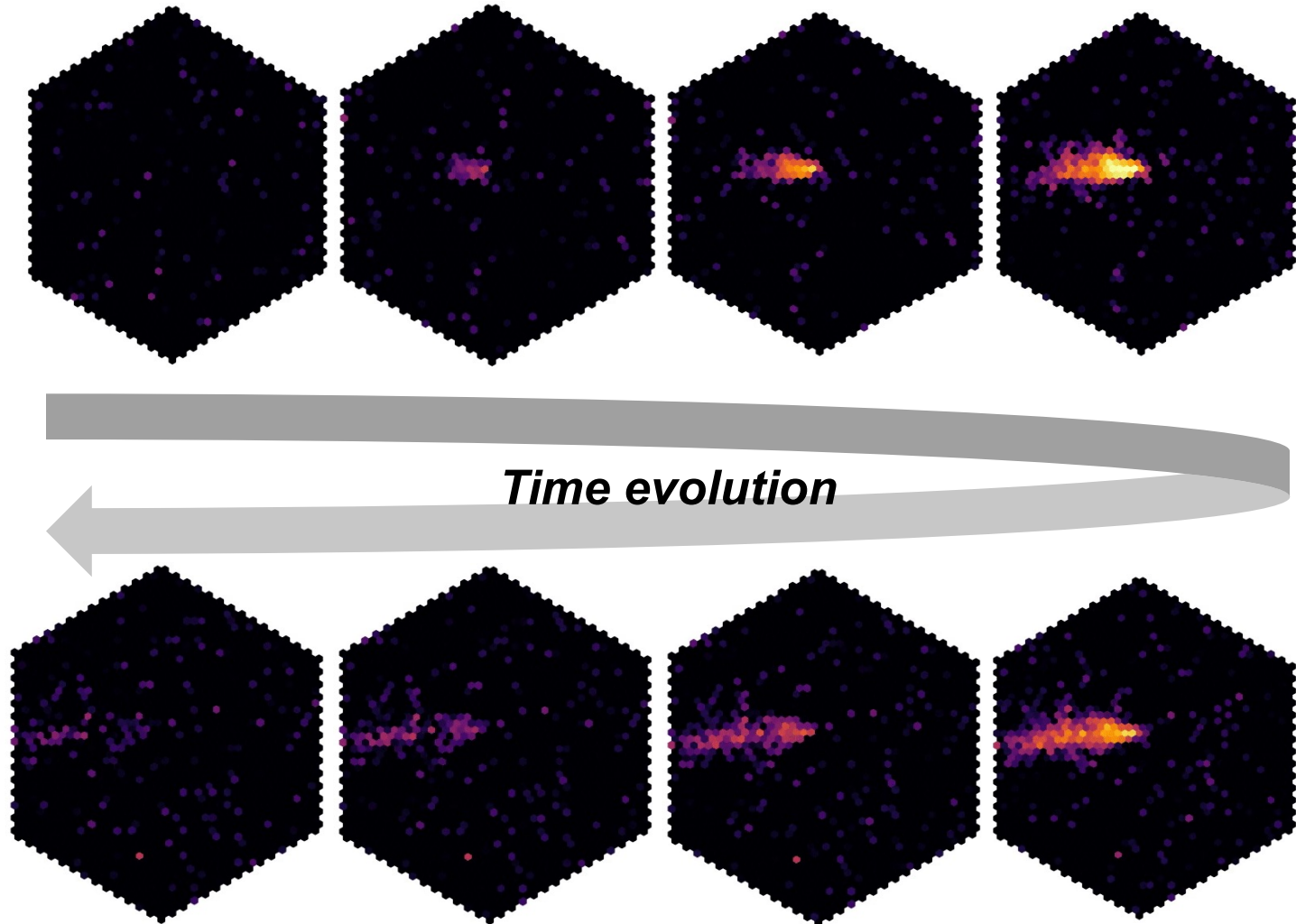


Image cleaning

Hillas
Parametrization

Energy
reconstruction

Angular
reconstruction

Gamma-
Hadron-
Separation



ERLANGEN CENTRE
FOR ASTROPARTICLE
PHYSICS

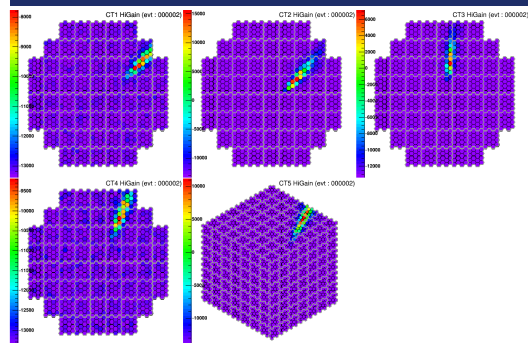
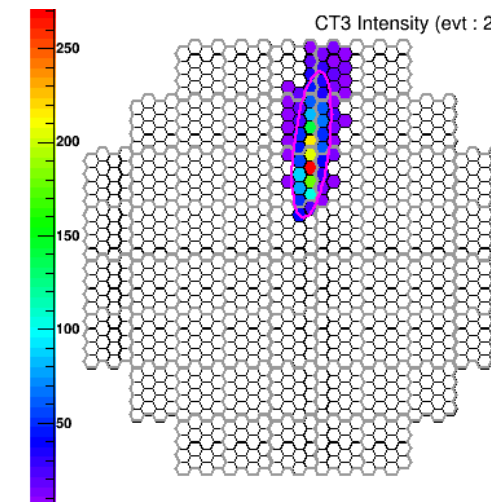
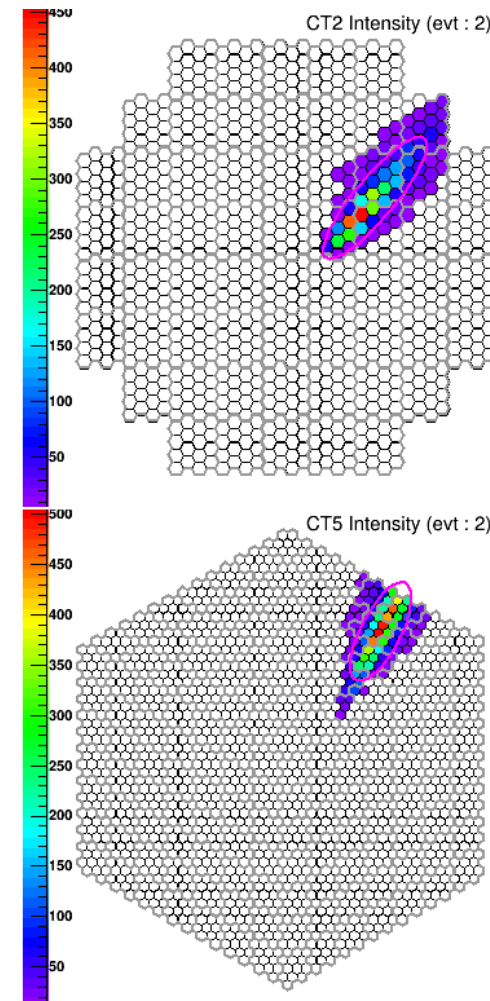
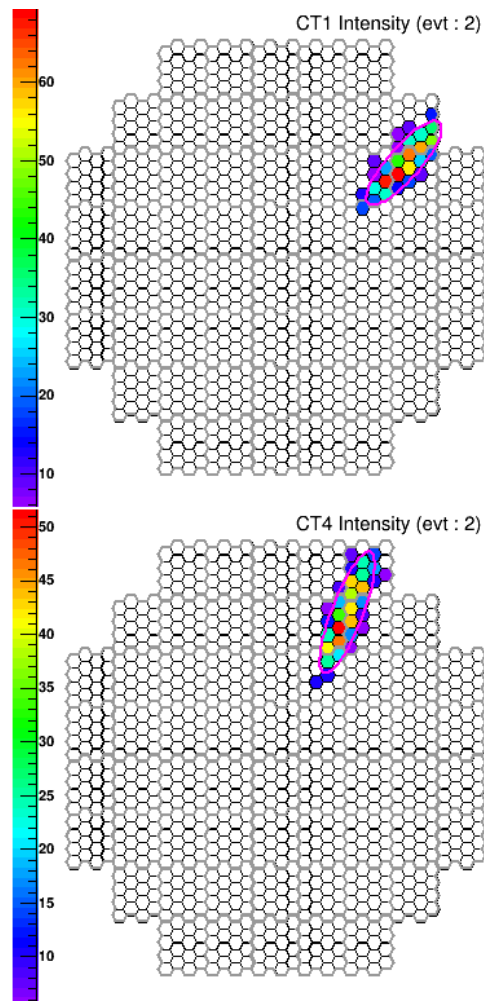
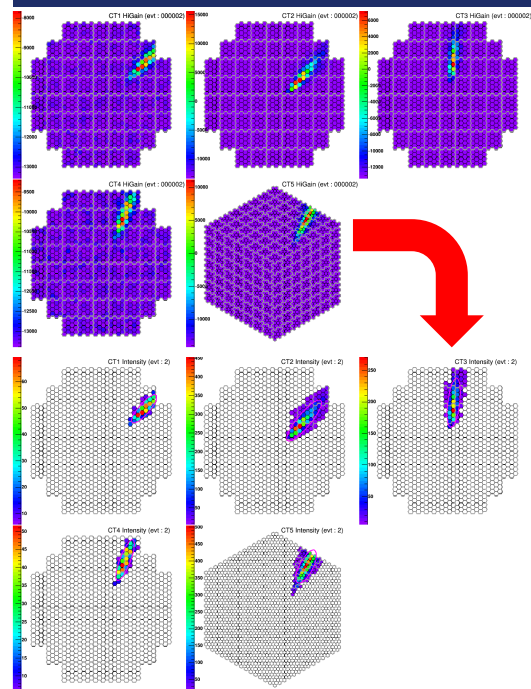


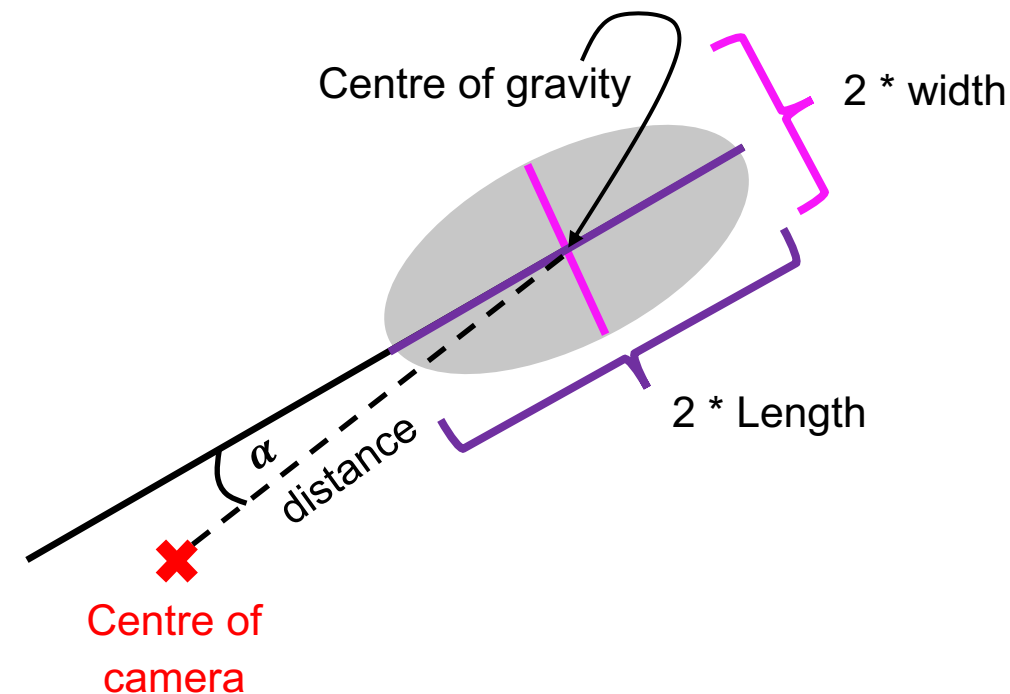
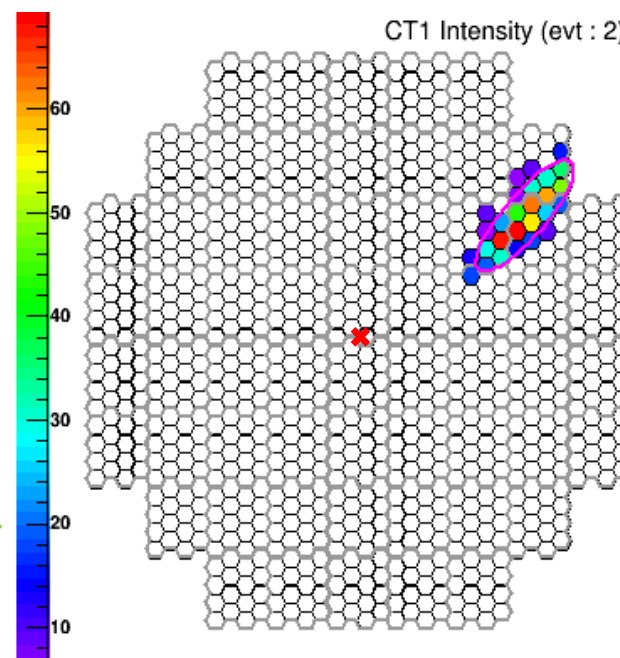
Image cleaning
(e.g. tailcuts cleaning)





Hillas Parametrization

- Parametrization of light density distribution
- Gamma-ray induced signal \sim ellipse \rightarrow position, shape, orientation, brightness of ellipse



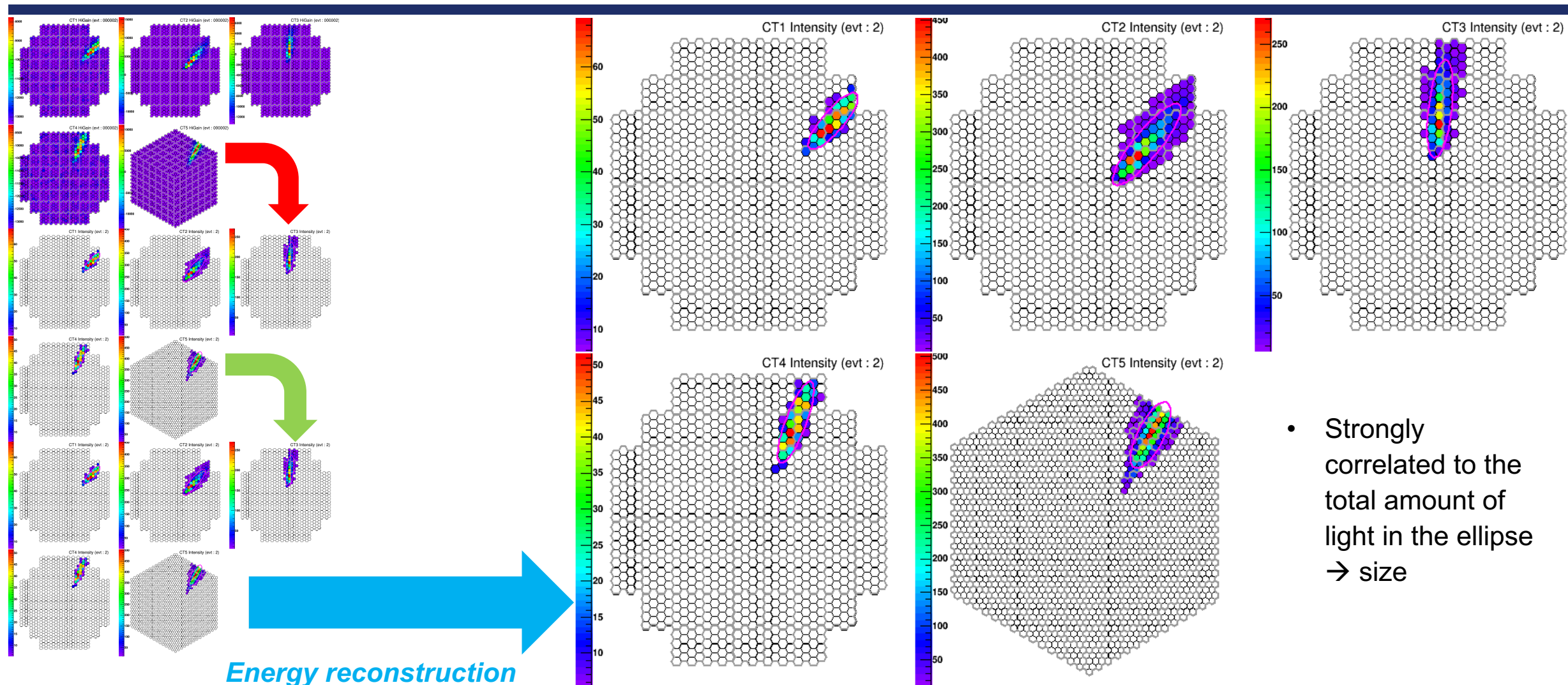


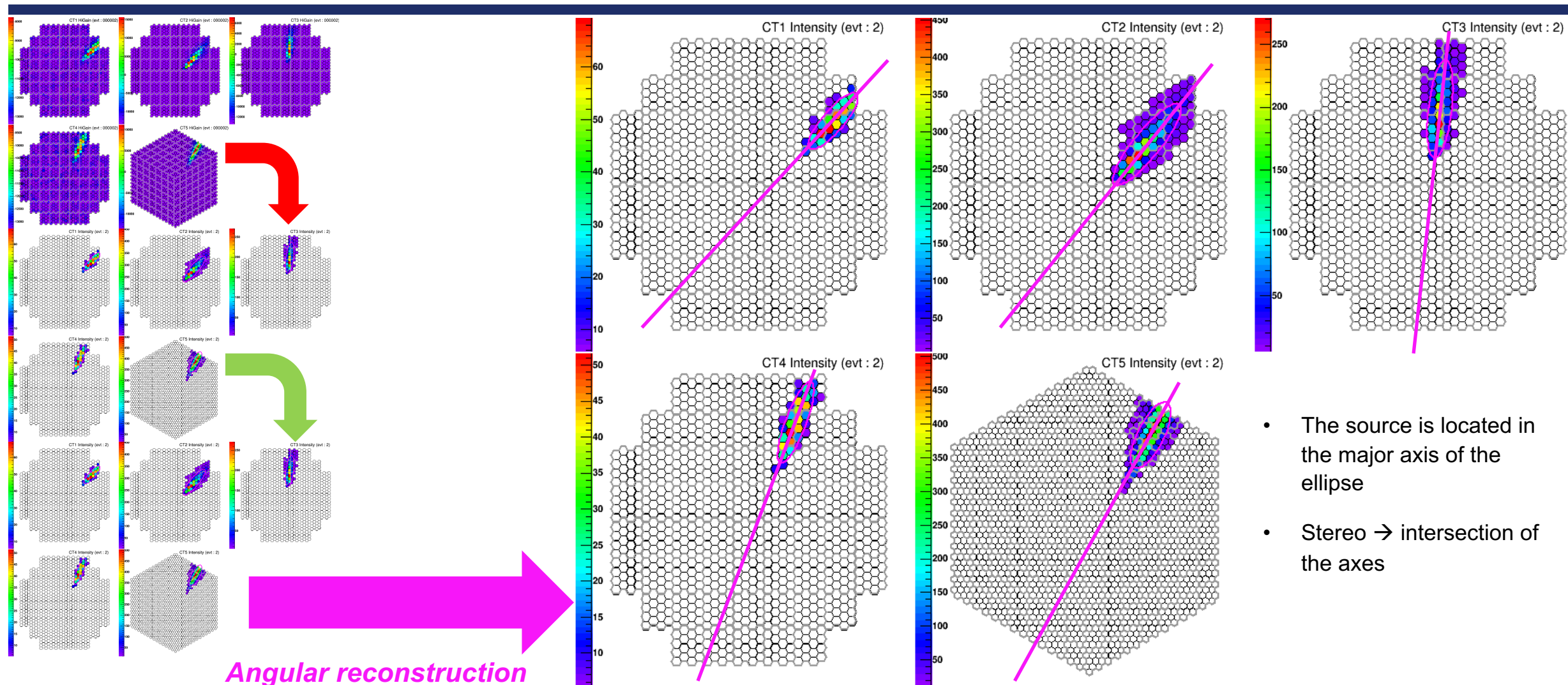
Image cleaning

Hillas
Parametrization

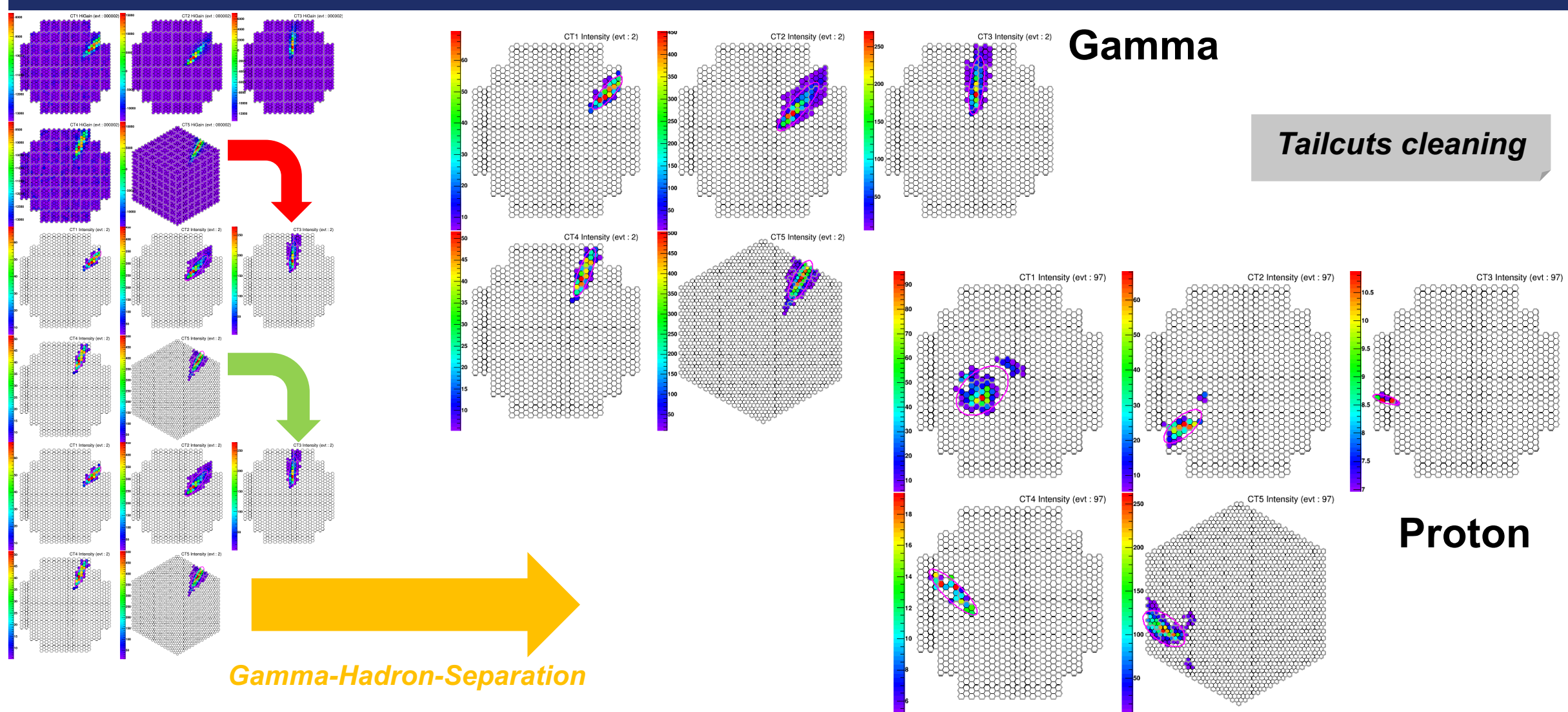
Energy
reconstruction

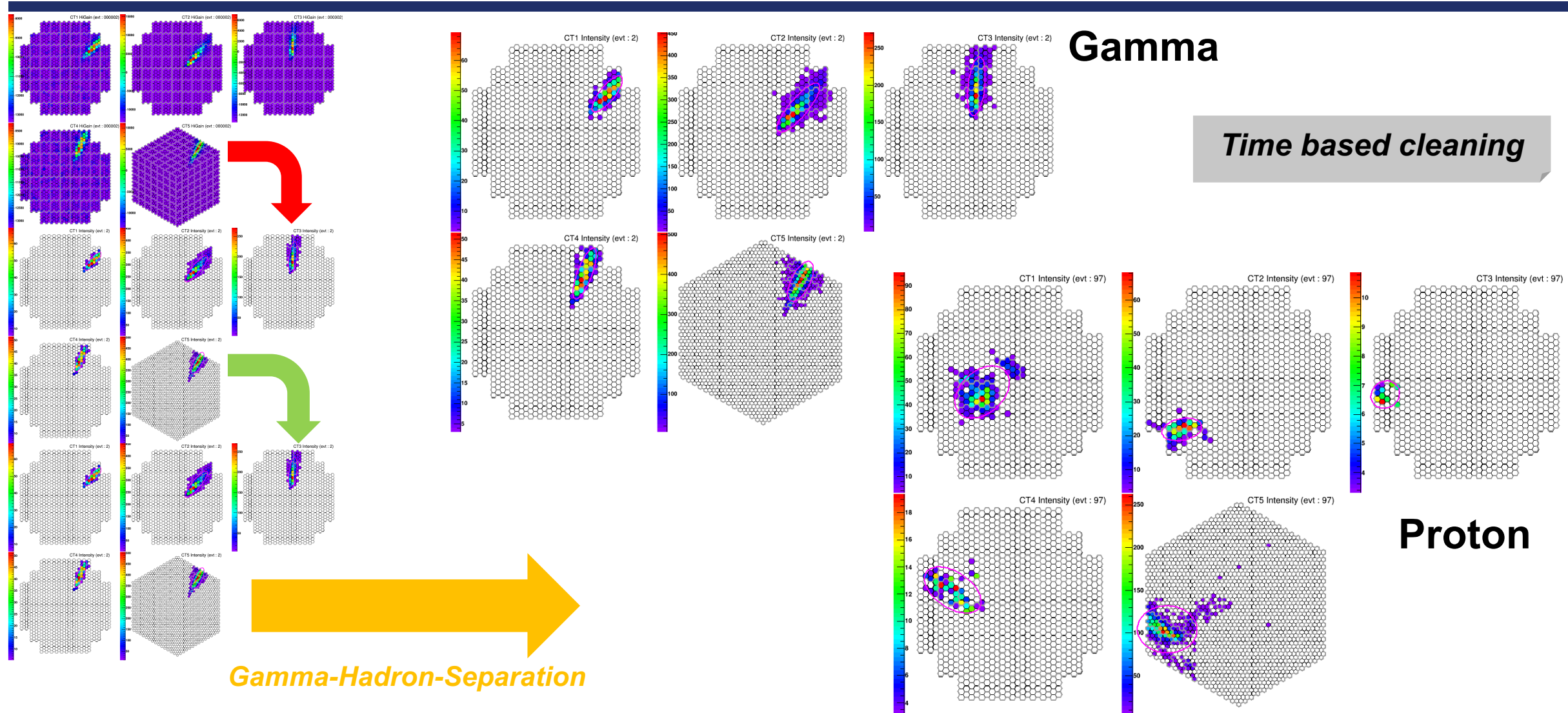
Angular
reconstruction

Gamma-
Hadron-
Separation



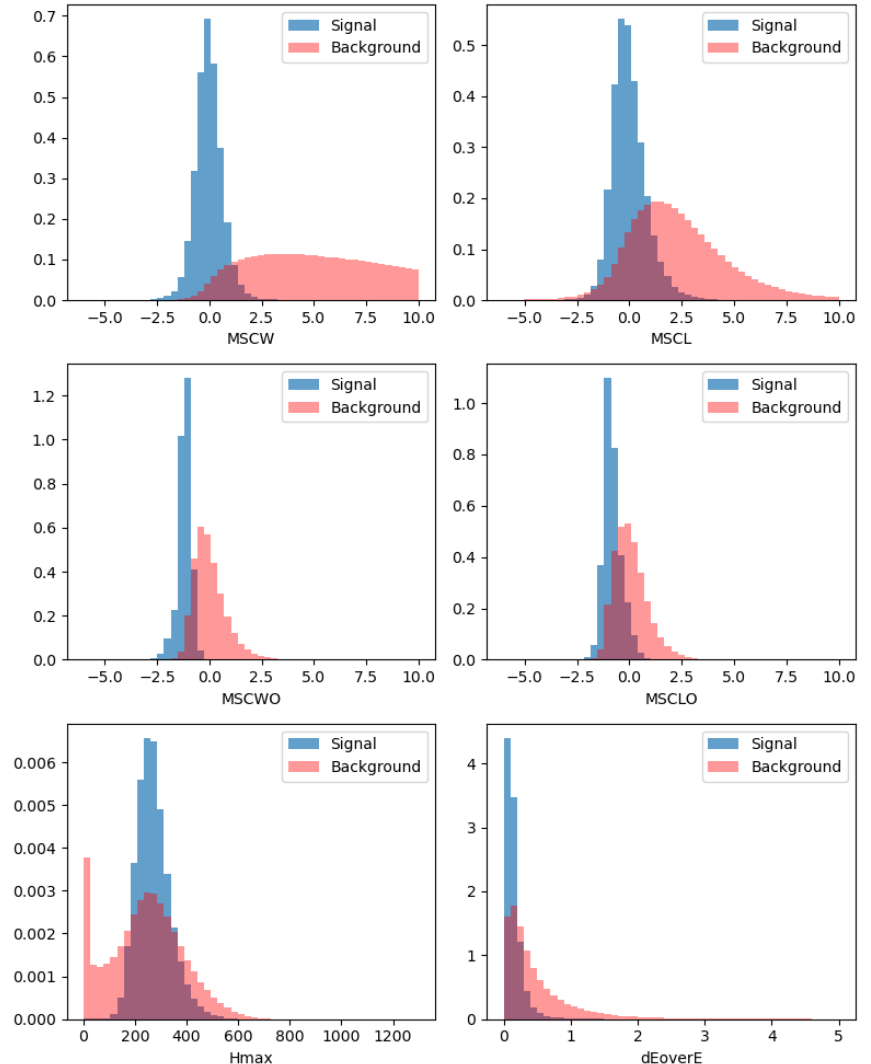
- The source is located in the major axis of the ellipse
- Stereo → intersection of the axes





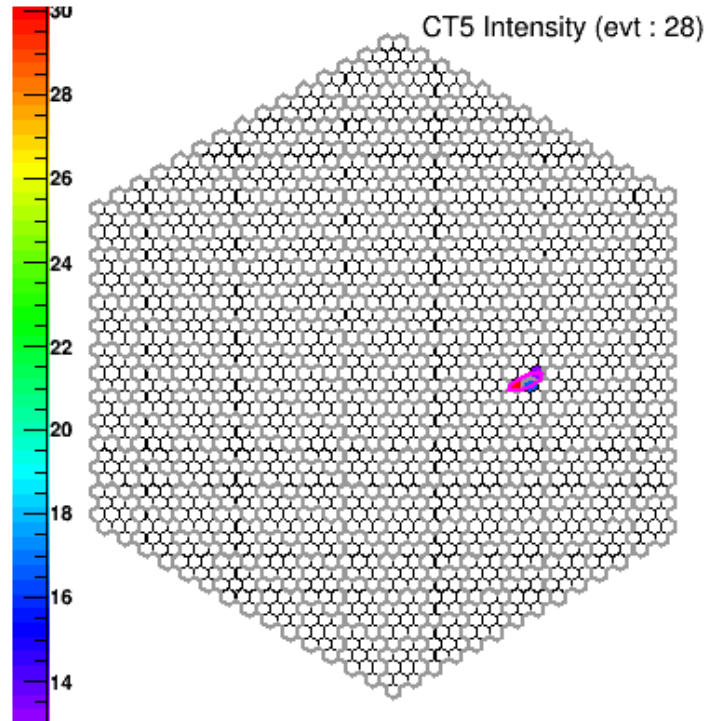
Gamma-Hadron-Separation using Boosted Decision Trees

- BDT-training (xgboost) and information about the shape of the ellipse
- Simulation: 20 deg zenith – 0 deg azimuth – 0.5 offset
- Offruns (mostly protons): 20 deg zenith – 0 deg azimuth
- **Training parameters:**
 - Mean scaled width (MSCW)
 - Mean scaled length (MSCL)
 - Mean scaled width off (MSCWO)
 - Mean scaled length off (MSCLO)
 - depth of the shower maximum H_{\max}
 - averaged spread in energy reconstruction dE/E

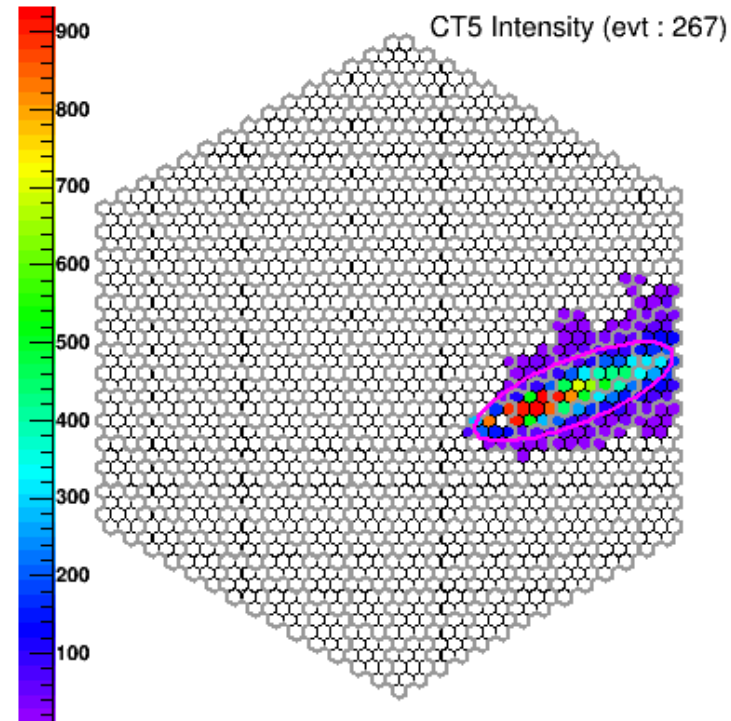


Gamma-Hadron-Separation using Boosted Decision Trees

Low energy event



High energy event

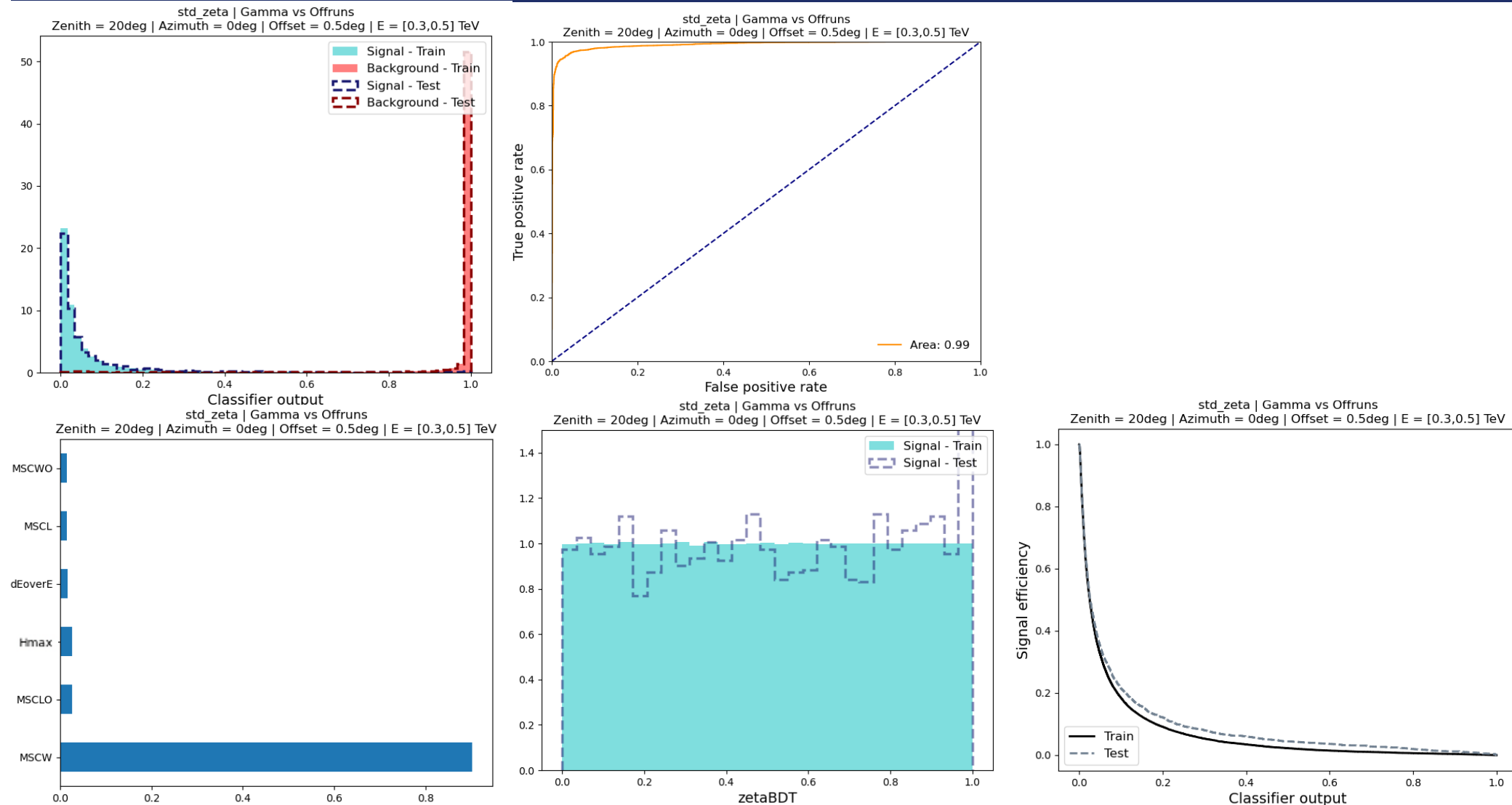


Shape very
dependent on
energy and
distance to impact
point

**Energy dependent
BDT training**

Gamma-Hadron-Separation using Boosted Decision Trees

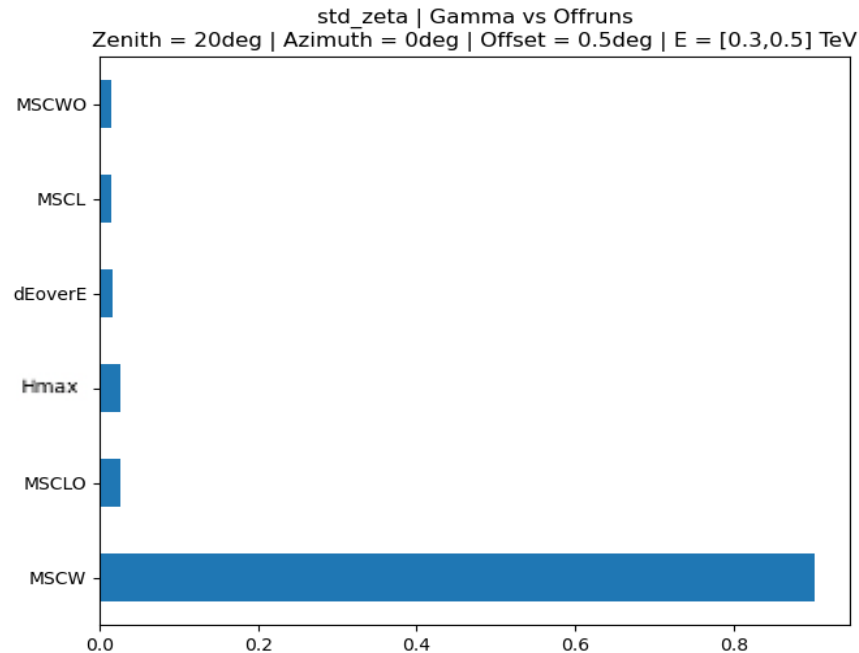
Tailcuts cleaning



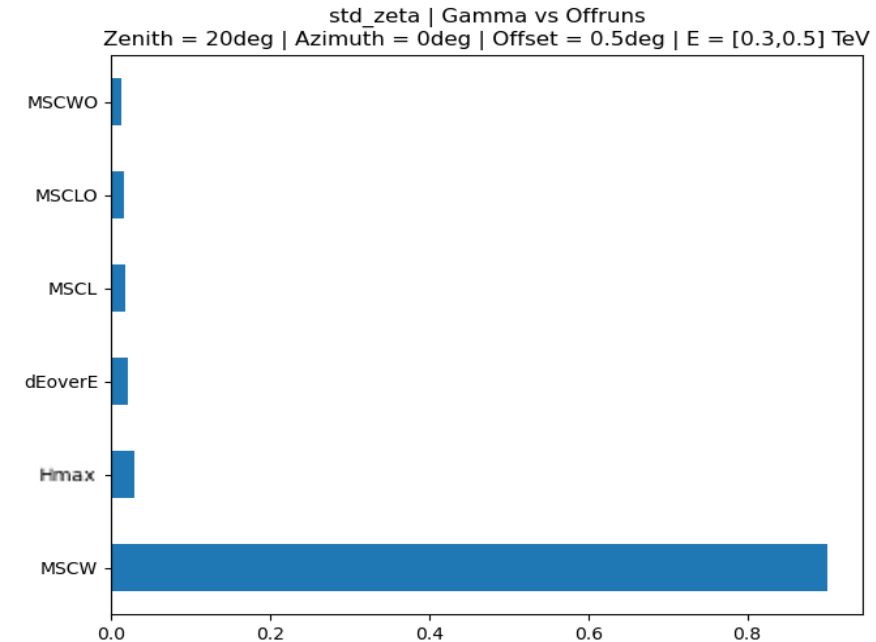
Gamma-Hadron-Separation using Boosted Decision Trees

Comparison of time-based cleaning and tailcuts cleaning (low energy)

Tailcuts cleaning



Time cleaning

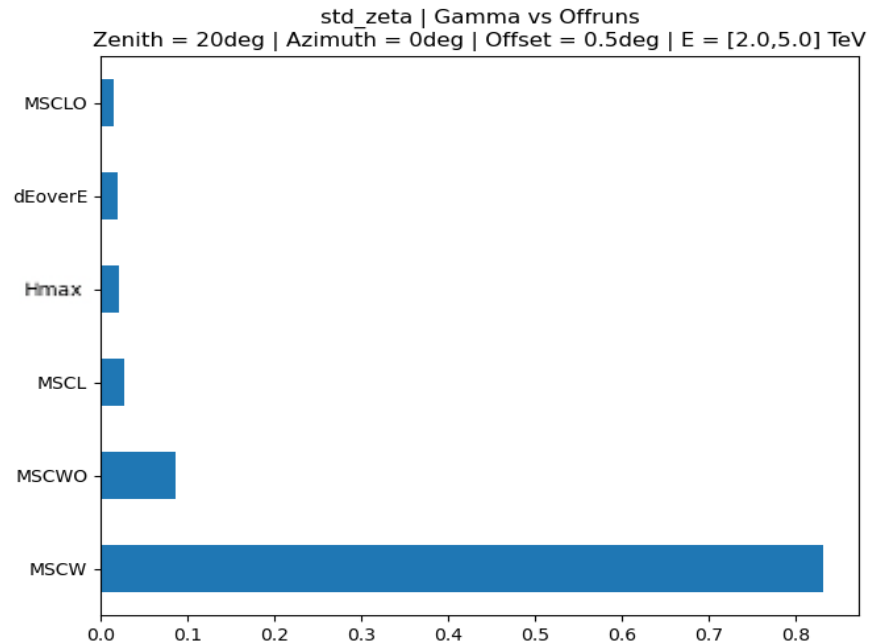


- At low energies: dEoverE and Hmax become more important → **indicator of improvement in event reconstruction**

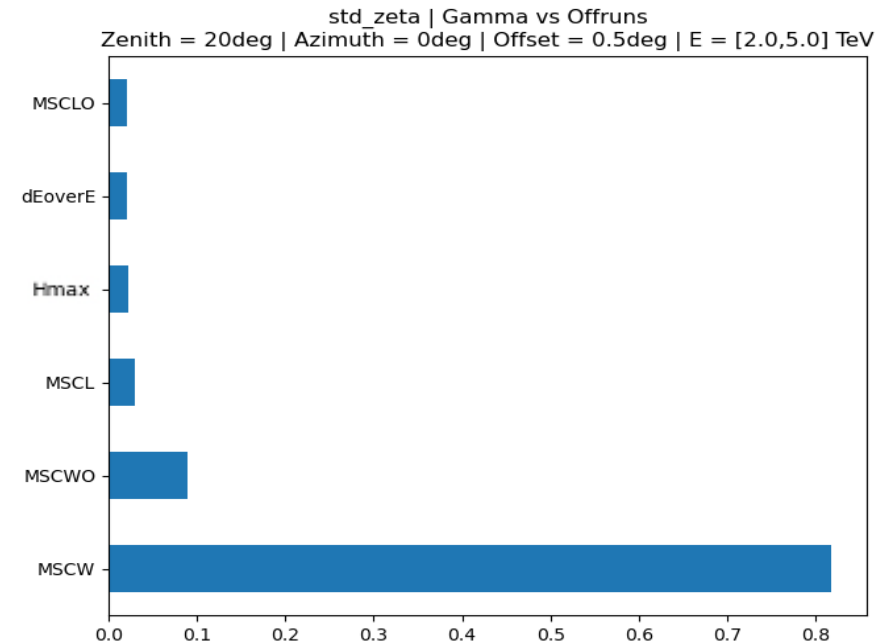
Gamma-Hadron-Separation using Boosted Decision Trees

Comparison of time-based cleaning and tailcuts cleaning (High energy)

Tailcuts cleaning



Time cleaning



- At high energies: order of the parameter's importance doesn't change between tailcuts cleaning and time-based cleaning
→ **no significant difference between the two methods at high energies**

Summary and what's next

- BDT training proven effective in gamma ray astronomy
- New cleaning method introduced to improve the low energy response:
 - needed to retrain and explore the implementation
 - possibility of achieving previously unreachable science goals
 - Studying the influence of different night sky background level:
 - Using ML algorithm to model a realistic NSB model (new upcoming project at ECAP)

Thanks for your attention!
Any questions?

Back-up slides

Time-based cleaning

DB-scan as a tool for time-based cleaning

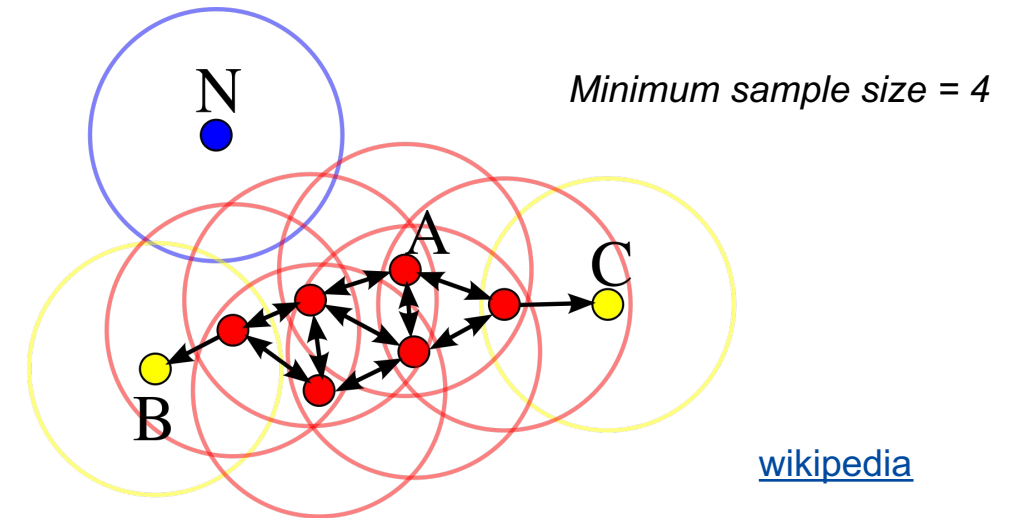
- DBSCAN – Density-Based Spatial Clustering of Applications with Noise

→ 2 parameters: minimum sample size and distance ϵ

- Our case: 3D (X – Y – t)

- NSBTimingCleaner* needs 4 parameters:

- Time scale
 - Spatial scale
 - Cluster size
 - Noise cut (value times RMS pedestal)
- } "normalized" 3D distribution



Optimization of parameters:

- Fake cluster fraction
- Integral shower information probability (MC gamma)
- Integral shower information probability (MC proton)

