University of Zurich[UZH]

Physik-Institut

cta cherenkov telescope array — the observatory for ground-based gamma-ray astronomy

Very High Energy Gamma-ray Astronomy and the Cherenkov Telescope Array (CTA)

A. M. W. Mitchell[1], A. Gadola[1]

[1]Physik-Institut, University of Zurich

VHE Gamma-ray Astronomy with IACTs

- Astrophysical particle accelerators, potential sources of cosmic rays, produce **Very High Energy (VHE) gamma-rays** as a by-product of the particle interactions.
- Unlike charged cosmic rays, gamma-rays are not deflected by galactic magnetic fields and can be used to study the original sources.
- VHE charged particles and gamma-ray photons entering our atmosphere initiate particle cascades, also known as **extensive air showers (EAS).**
- The atmosphere is effectively used as part of the detector.
- **Imaging Atmospheric Cherenkov Telescopes (IACTs)** detect the nanosecond blue-ish Cherenkov light flashes, generated by these air showers in the atmosphere.
- Using multiple telescopes in arrays enables the original direction and energy to be better determined.
- **VHE gamma-ray astronomy** aims to identify and study the origins of cosmic rays, locations of particle acceleration to the highest energies within the universe.

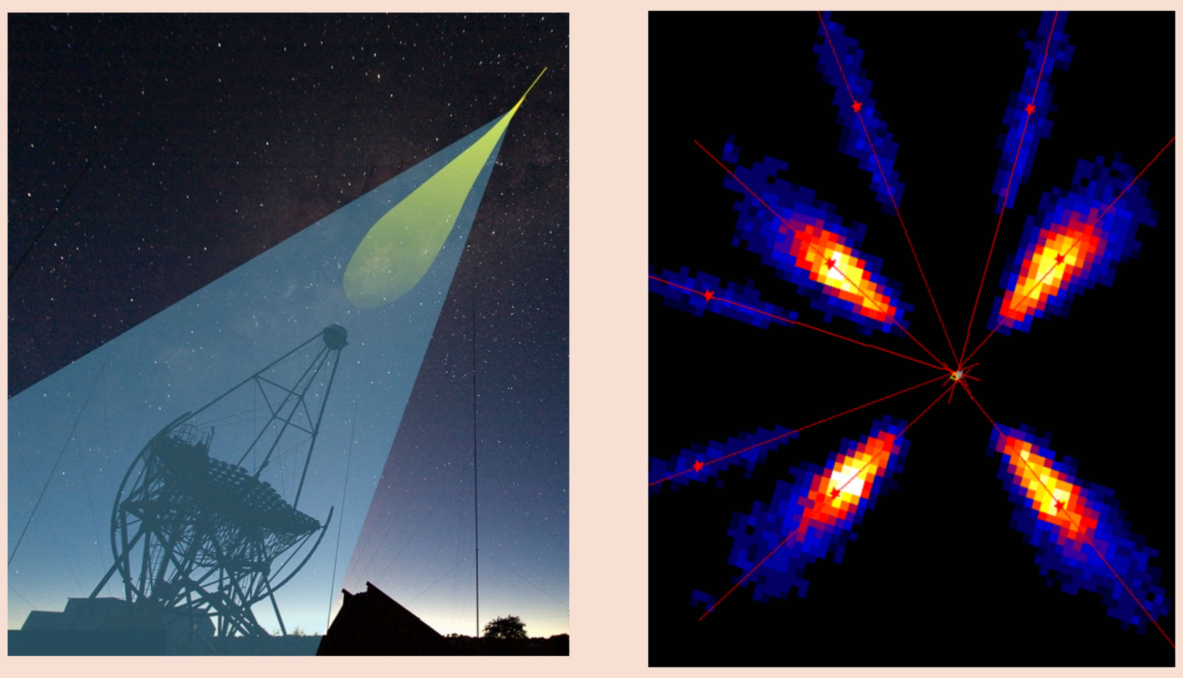

Fig.1: **Left**: IACTs detect blue-ish Cherenkov light from Extensive Air Showers generated within the atmosphere. **Right**: Simulated gamma-ray images superimposed from 8 telescopes – more telescopes improves the reconstruction accuracy.

	CTA South	CTA North
Large Sized Telescopes (LST)	4	4
Medium Sized Telescopes (MST)	25	15
Small Sized Telescopes (SST)	70	0
Location	Paranal, Chile	La Palma, Spain
Altitude (above sea level)	2100 m	2200 m
Array area	~4 km^2	~0.6 km^2

Tab.1: Parameters of the two CTA sites (South and North).

Cherenkov Telescope Array

The Cherenkov Telescope Array (CTA) is a future ground-based observatory for VHE gamma-ray astronomy. [1,2]

- Very High Energy (VHE) ≈ 20 GeV – 300 TeV.
- Comprised of > 100 telescopes of three sizes at two sites.
- Construction will begin around 2020.

Improvements over current facilities:

- by a factor of 5-20 in sensitivity
- by a factor of ~ 1.5 in angular and energy resolution
- reduction from ~60s to 20s reaction time to incoming alerts

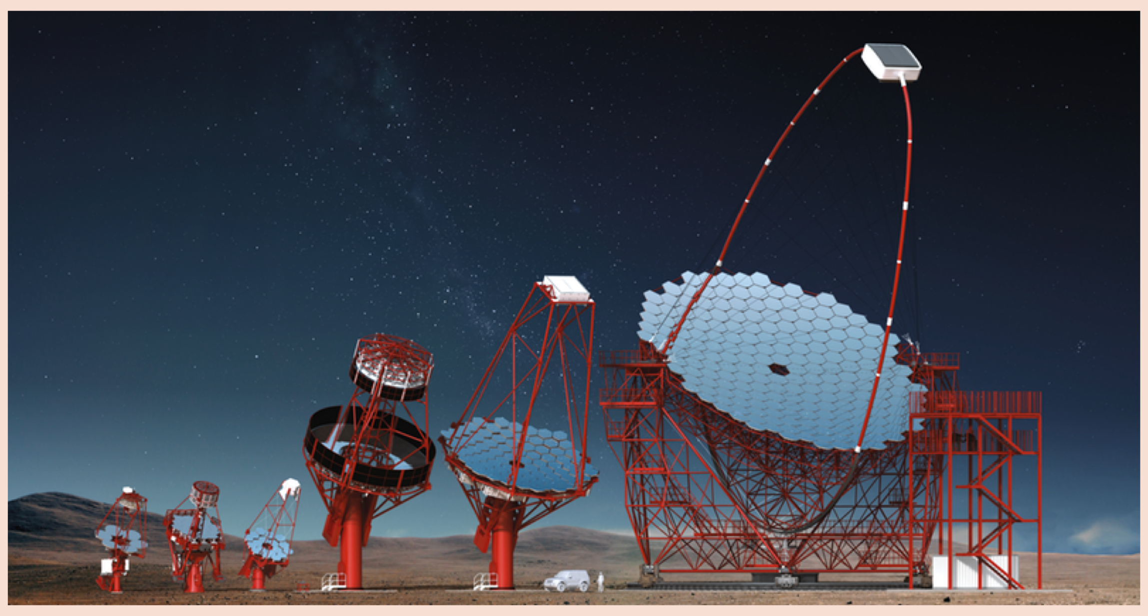

Fig.2: Computer generated image of the prototype CTA telescopes.

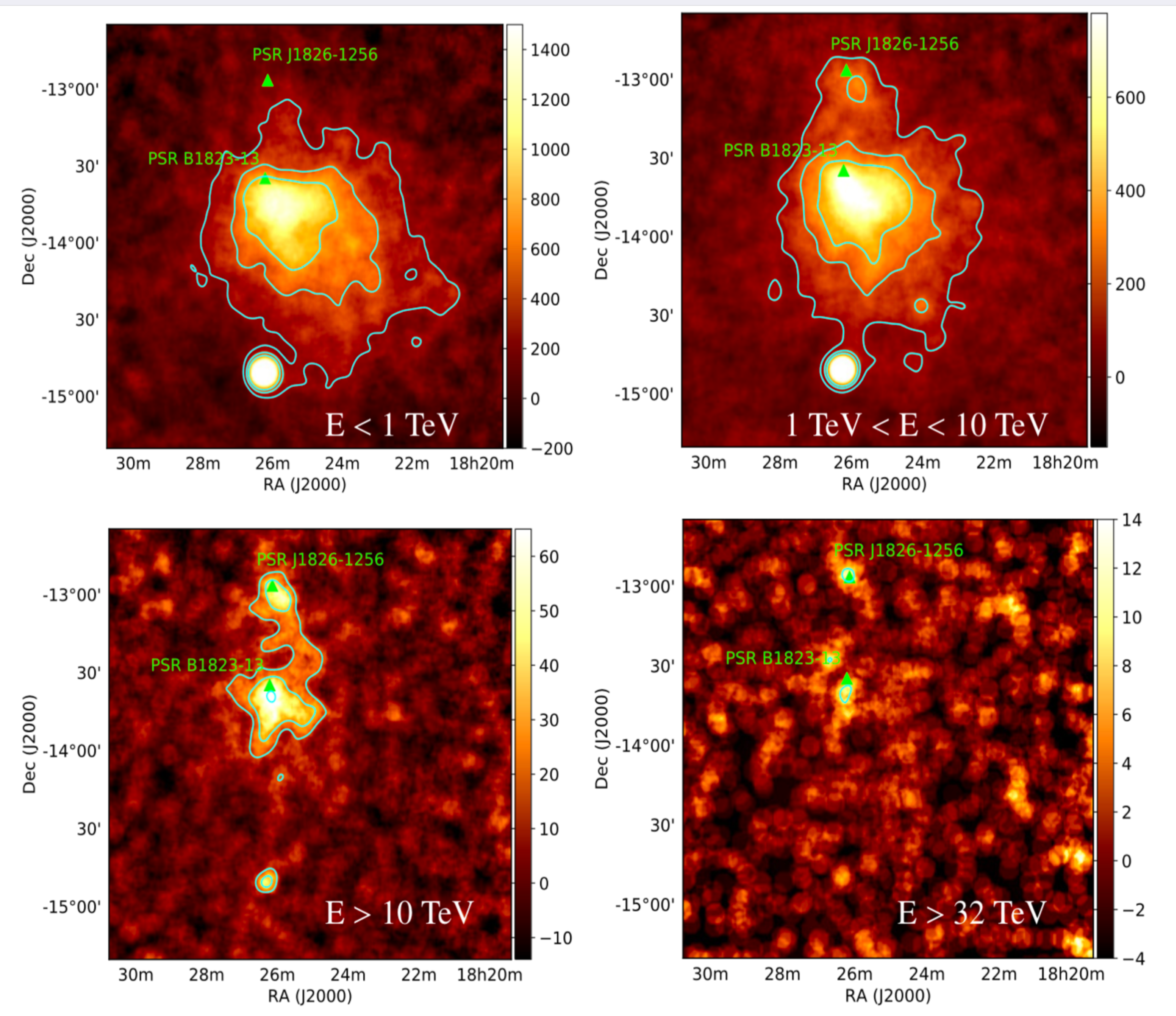

Fig.3: Sky maps of HESS J1825-137 in gamma-ray excess counts: a pulsar wind nebula that reduces dramatically in size with increasing gamma-ray energy.

Data Analysis – gamma-rays

We use data from a current facility (H.E.S.S.) as well as CTA simulations whilst CTA is in preparation.

Gamma-ray sources

Sources of VHE gamma-rays in our galaxy include; supernova remnants and pulsar wind nebulae (PWN).

- HESS J1825-137 is a large, powerful PWN with a strongly energy-dependent size **(Fig.3).**
- Measuring the change in extent with energy enables the particle transport mechanisms within the nebula to be probed **(Fig.4)** [3].

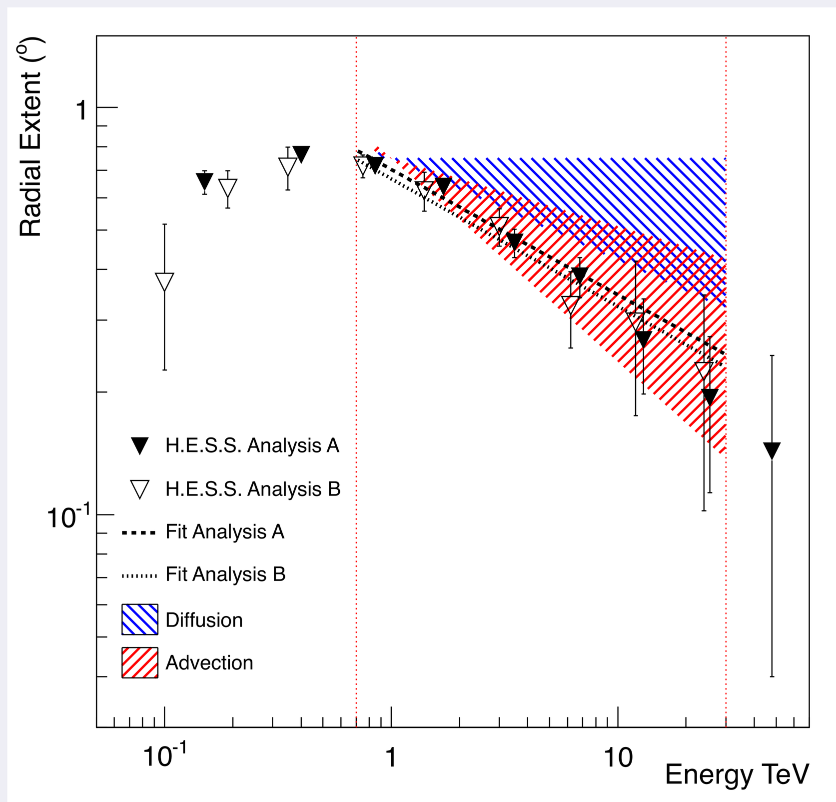

Fig.4: Measured size of HESS J1825-137 with energy. The variation within the relevant energy range disfavours pure diffusion for the particle transport within the nebula, indicating some advection processes must be at work.

Data Analysis – muons

- EAS are generated by both gamma-rays and cosmic rays.
- Muons produced in cosmic ray EAS leave a clear ring-shaped signature in IACTs and can be easily identified **(Fig.6).**
- We use muons as a constant Cherenkov light source to calibrate the optical throughput of IACTs [5].
- We demonstrate for the first time the potential for IACTs to make measurements of the muon distribution within EAS **(Fig.5)** [4].

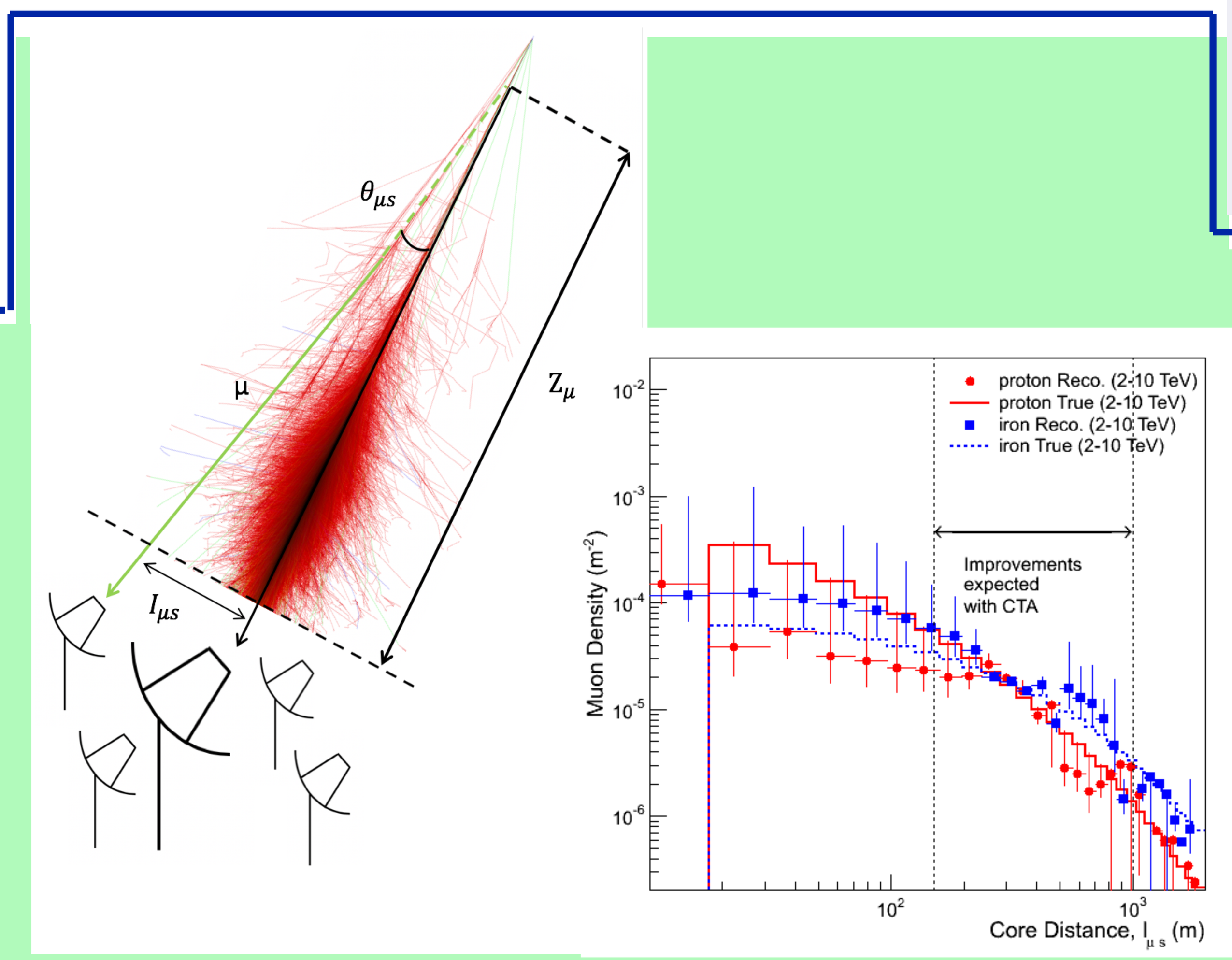

Fig.5: IACTs can simultaneously detect the muon and associated EAS (**left**) enabling the muon lateral distribution function to be derived (**right**). Error bars indicate the most pessimistic uncertainties of the method. [4]

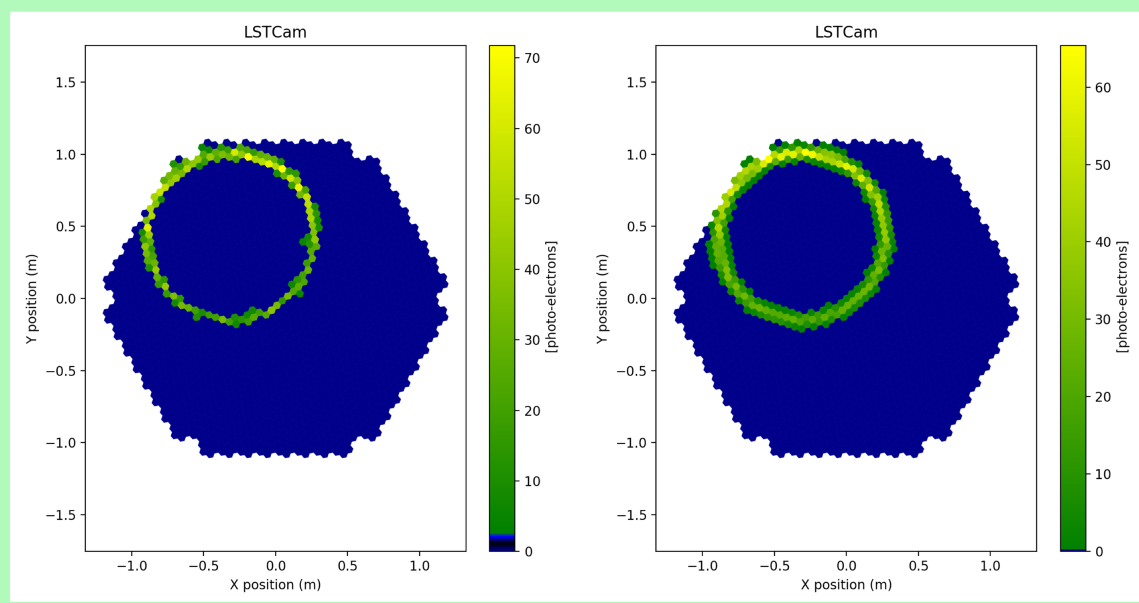

Fig.6: Example simulated muon event in an LST. **Left**: Simulated muon image. **Right**: Predicted muon image. Comparing the amount of light in the prediction to the actual image enables the optical throughput of the telescope to be calibrated. [6]

Key message

CTA

- CTA will be the next generation ground-based gamma-ray observatory with over 100 telescopes.
- CTA will perform a key science program but will also be open to the scientific community.
- Many synergies with other experiments for combined results are expected.

Gamma-ray

- Detailed studies of individual sources are now possible.
- Development of analysis and calibration techniques in preparation for CTA.
- Current facilities preparing for the open data era.

Muon

- Further development of muon identification algorithms.
- Analysis of hadronic showers also possible – plenty of room for improvement.

References

[1] The CTA Consortium, «*Science with the Cherenkov Telescope Array*, arXiv:1709.07997 (2017)

[2] The CTA Consortium, «*Introducing the CTA Concept*», Astroparticle Physics 43, 3-18 (2013)

[3] HESS Collaboration, «*Particle Transport within the Pulsar Wind Nebula HESS J1825-137*», submitted to Astronomy & Astrophysics (2018)

[4] Mitchell et al., «*Measuring muons in TeV air showers with IACTs*» in preparation (2018)

[5] Mitchell et al., «*A Generic Algorithm for IACT Optical Efficiency Calibration using Muons*», in proc. 34th ICRC (2015)

[6] Gaug, Fegan, Mitchell, Maccarone and Mineo, «*Using Muon Rings for the Optical Throughput Calibration of the Cherenkov Telescope Array – Part I*», in preparation (2018)

CTA website: www.cta-observatory.org

HESS website: www.mpi-hd.mpg.de/hfm/HESS

Other CTA Activities at UZH

FlashCam

- Prototype camera for the MSTs of CTA
- UZH involved with hardware and software development

Mirror Actuators

- Development of actuators for the mirror facets of all CTA telescope sizes

Contact (Room Y36-J-94)

Alison Mitchell: alison.mitchell@physik.uzh.ch

Arno Gadola: agadola@physik.uzh.ch