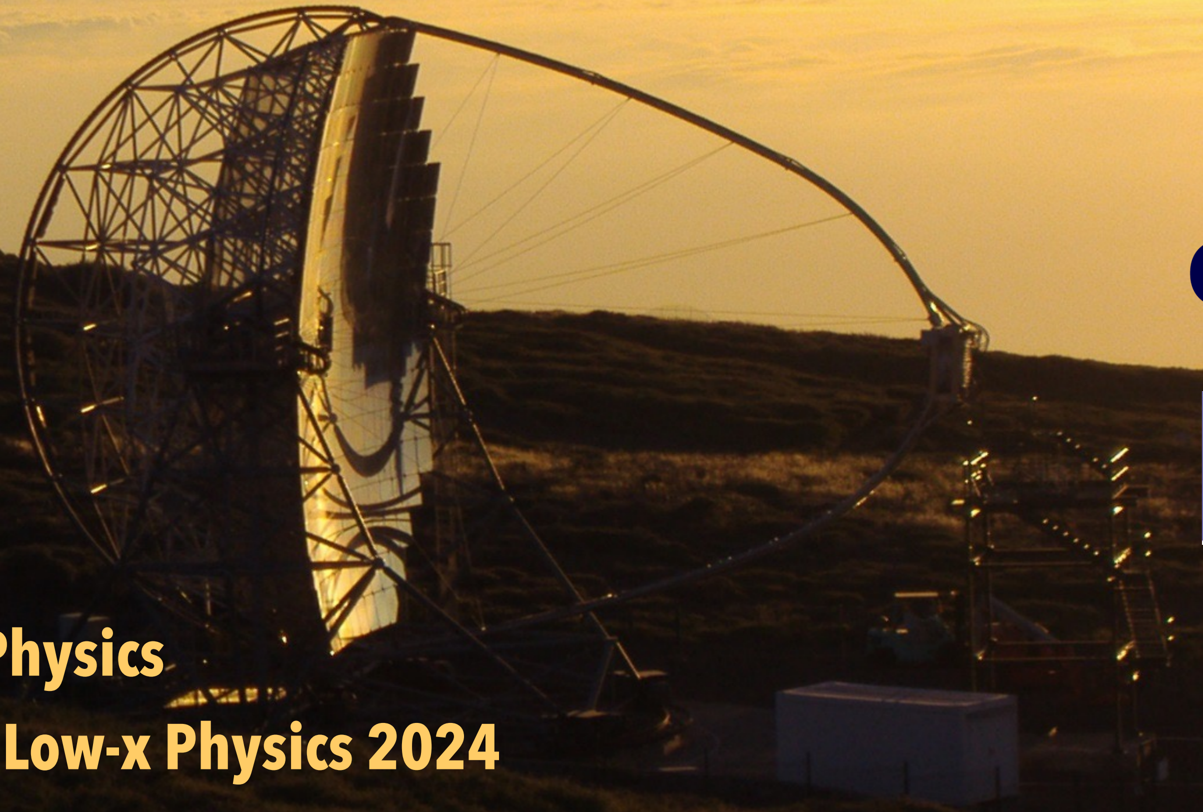
Characterisation of the Atmosphere for Imaging Atmospheric Cherenkov Telescopes



Dijana DOMINIS PRESTER

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New Trends in High-Energy and Low-x Physics 2024

Sfantu Gheorghe, Romania, 2 Sept 2024

CTAO

MAGIC Major Atmospheric Gamma Imaging Cerenkov Telescope

FIZRI

HRZZ Croatian Science Foundation

Outline

- - Imaging Atmospheric Cherenkov Telescopes
- - Adaptive Observation Scheduling for IACTs
- - Atmospheric aerosols transmission profiles (MAGIC LIDAR)
- - Aerosol optical depth maps (CTAO FRAM)

Observatorio del Roque de los Muchachos
(European Northen Observatory)

La Palma, Canary Islands
2400 m a.s.l.

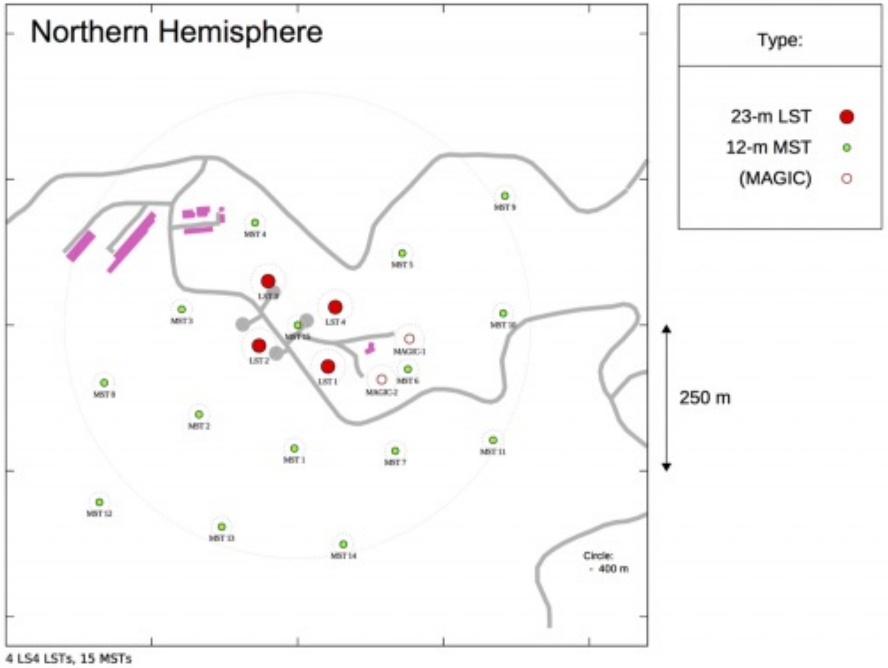
Imaging Atmospheric Cherenkov Telescopes

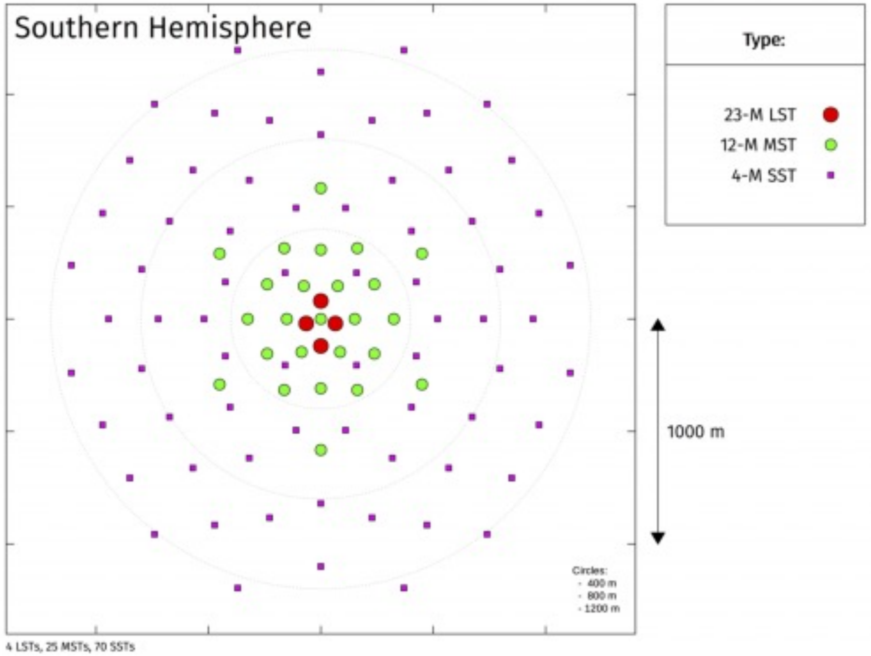
- MAGIC (Major Atmospheric Gamma Imaging Cherenkov telescopes)
- H.E.S.S. (High Energy Stereoscopic System)
- VERITAS (Very Energetic Radiation Imaging Telescope Array System)
- CTAO (Cherenkov Telescope Array Observatory)

MAGIC I and II

LST-1 (CTAO)

Cherenkov Telescope Array Obeservatory (CTAO)





MAGIC Florian Goebel telescopes

April 17th 2009, ORM, La Palma

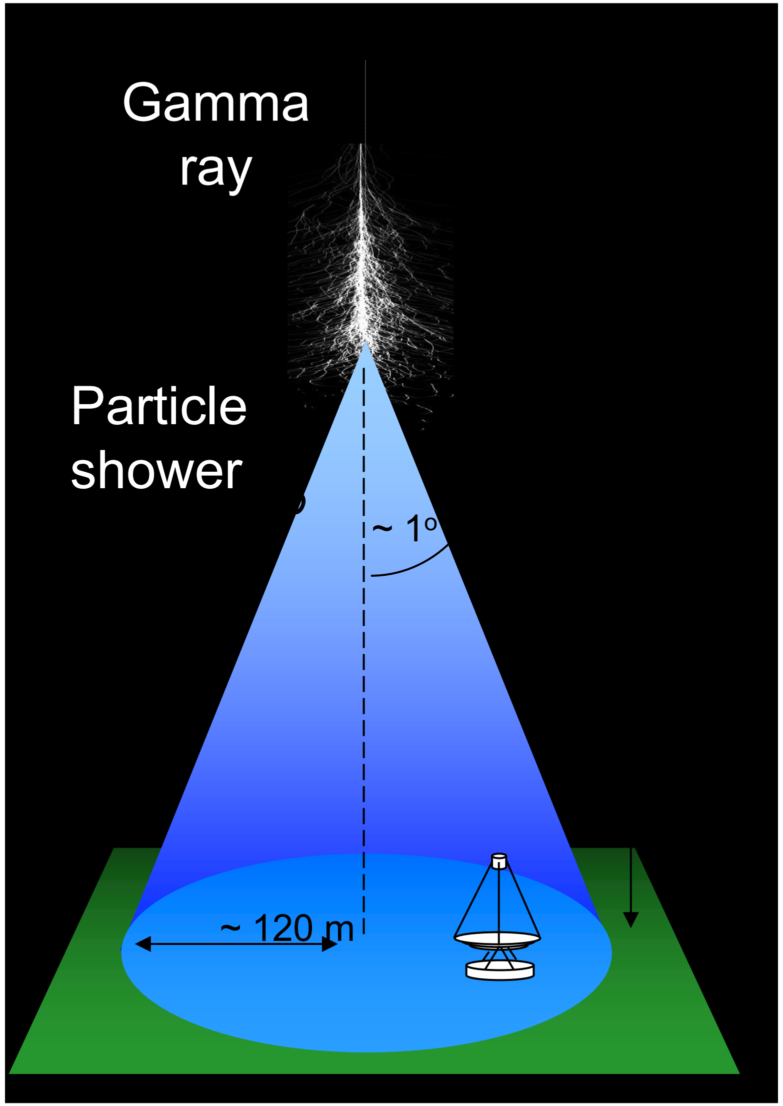
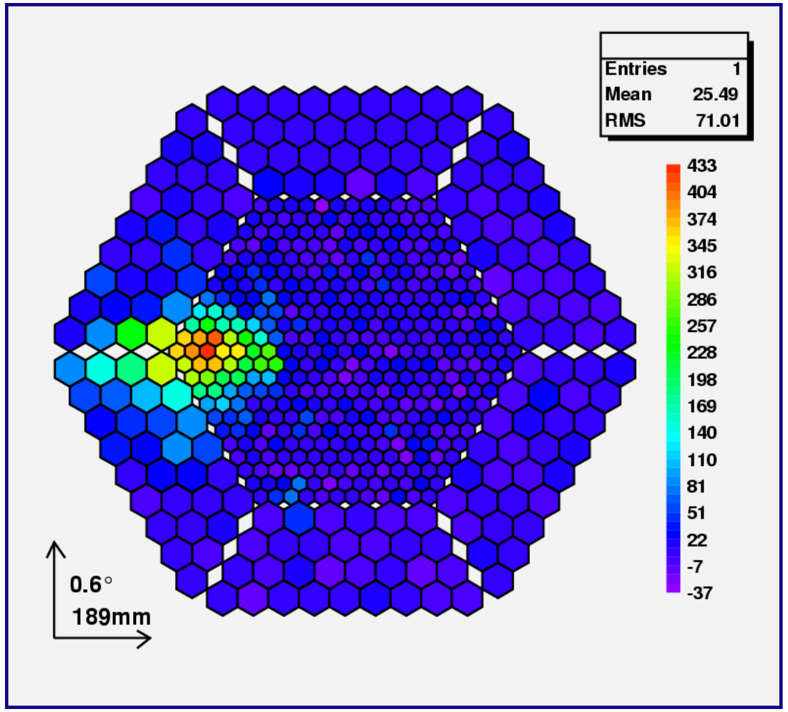
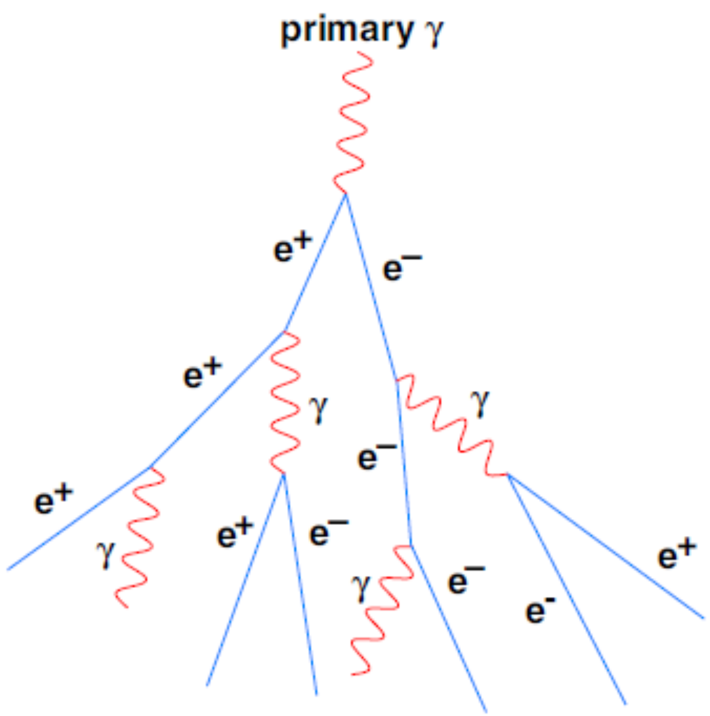


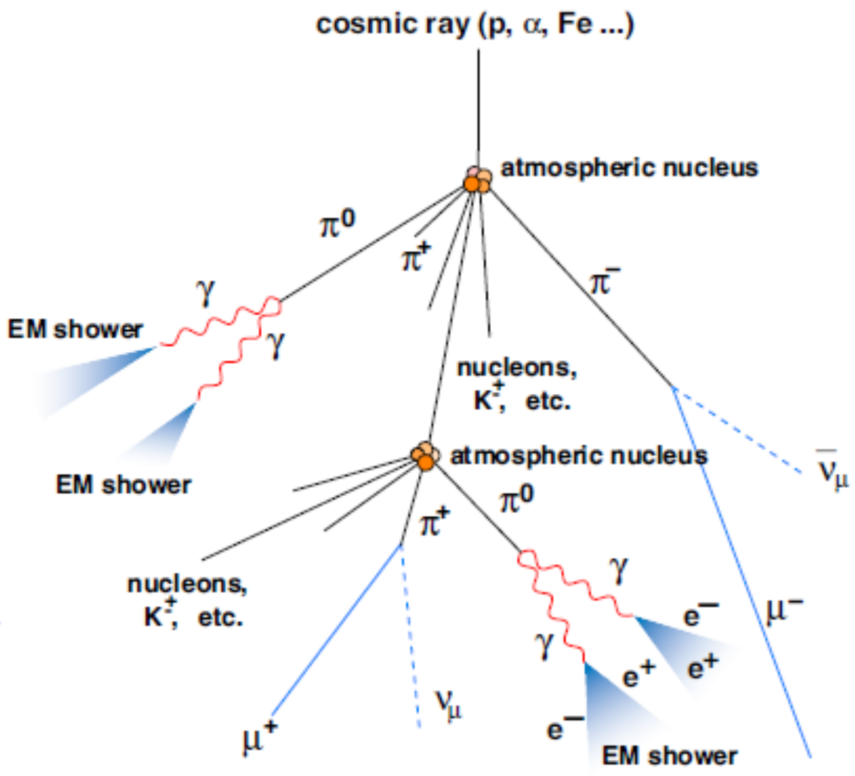
Image in the MAGIC camera



Electromagnetic shower

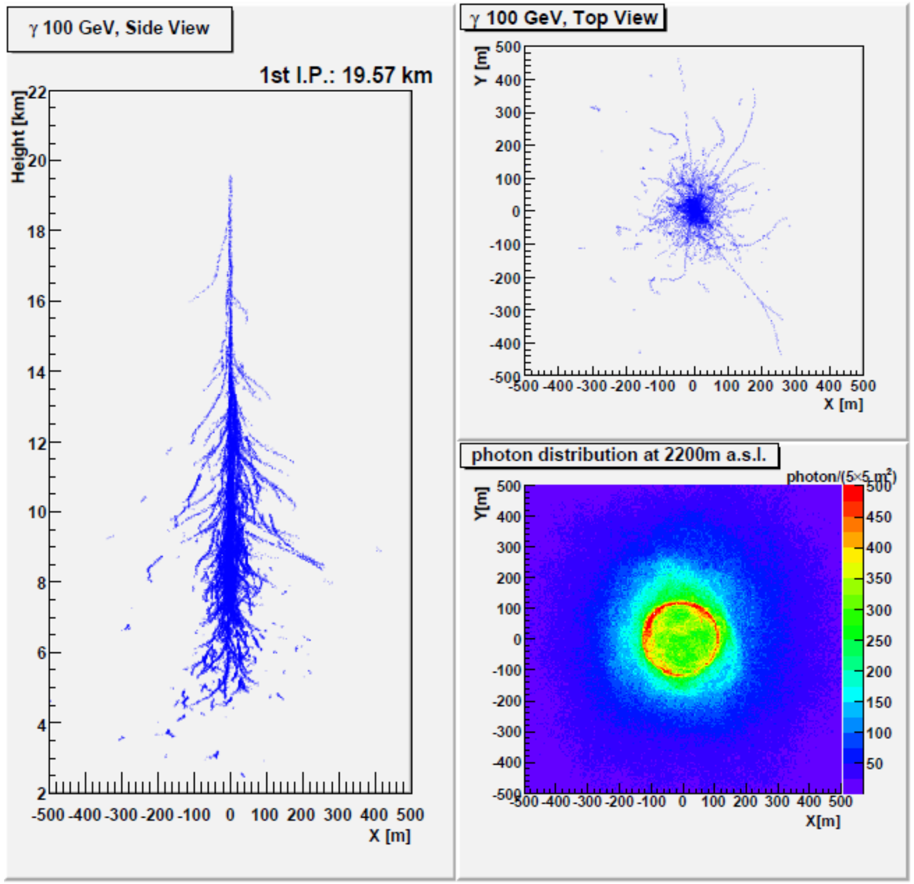


Hadron shower



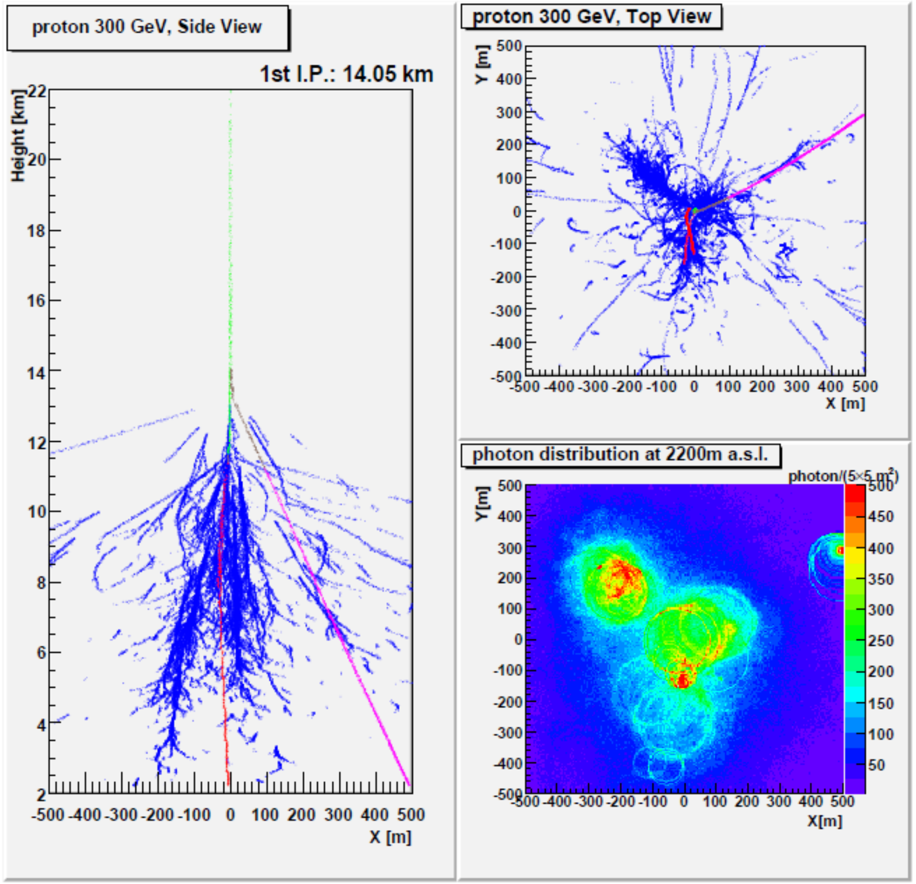
Electromagnetic shower

100GeV gamma photon

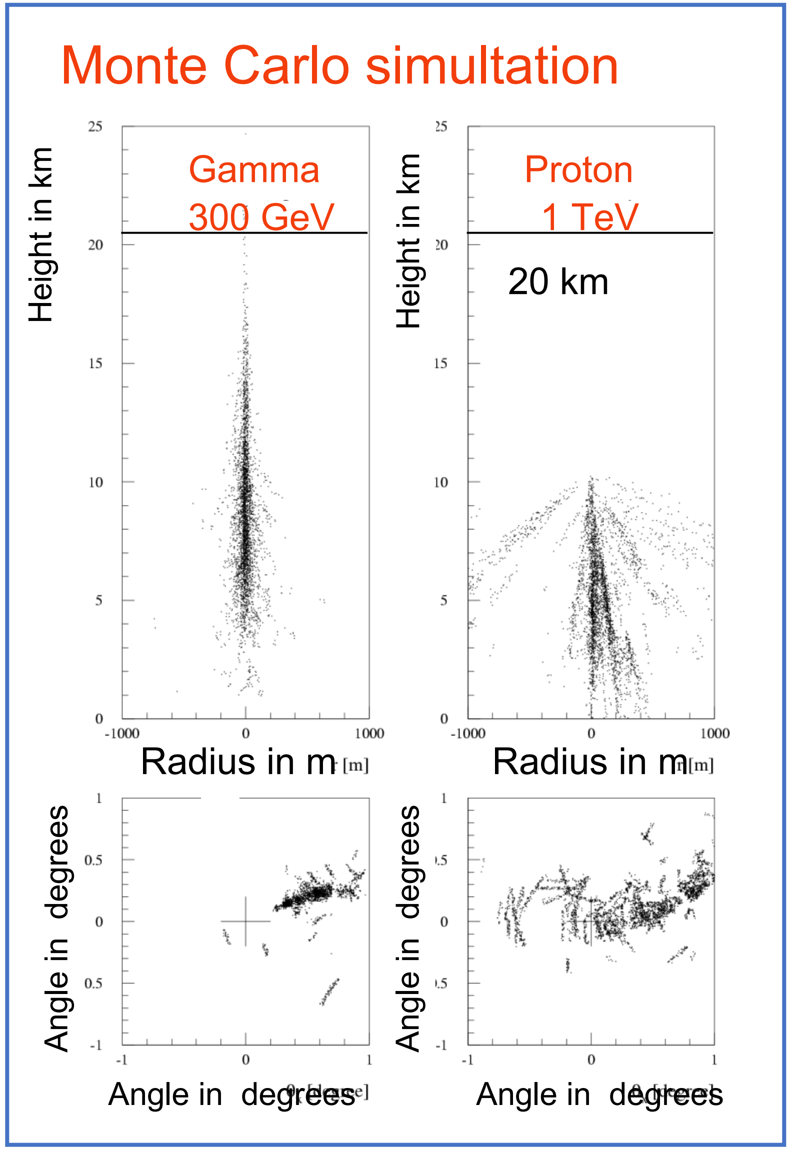


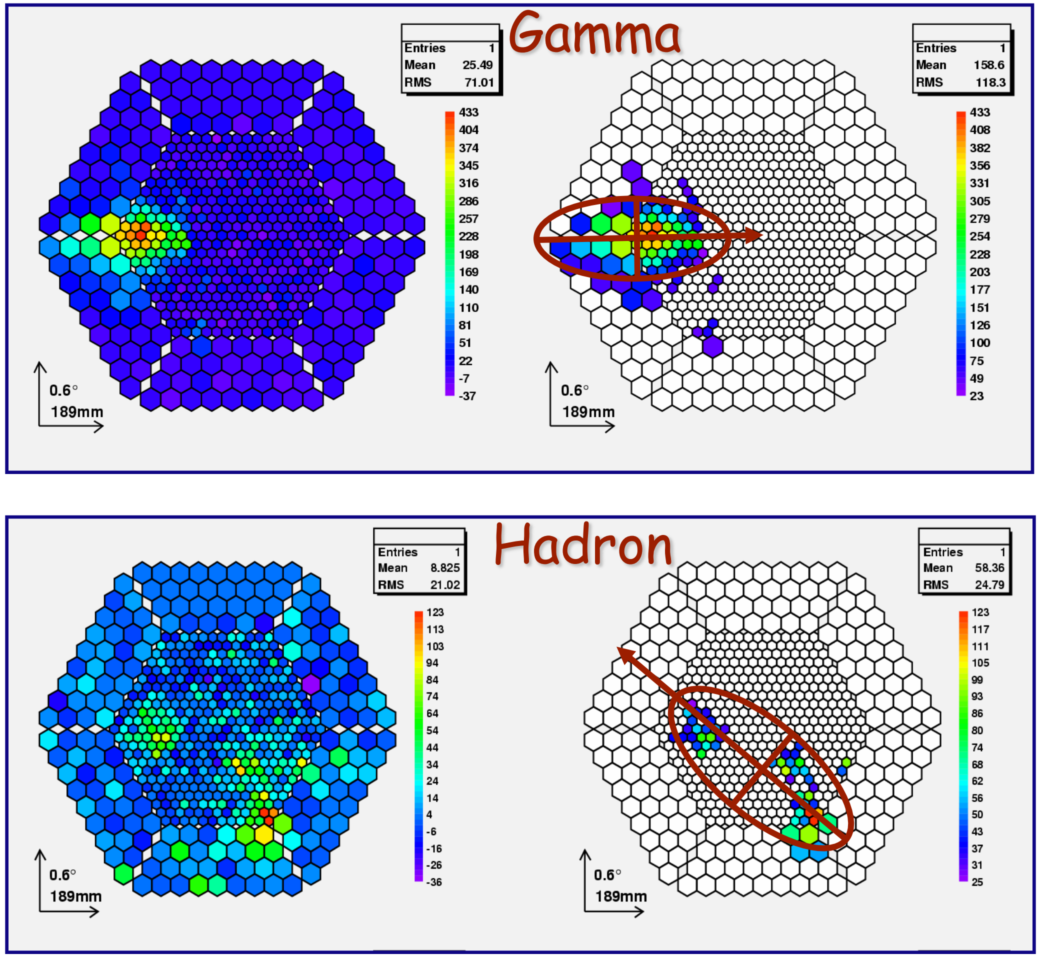
Hadron shower

300GeV proton

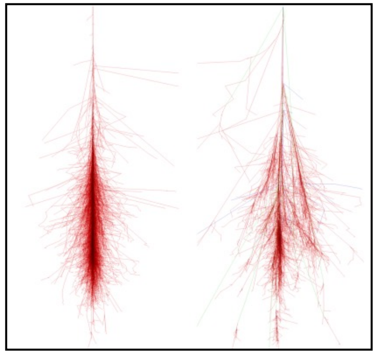


Gamma/Hadron separation



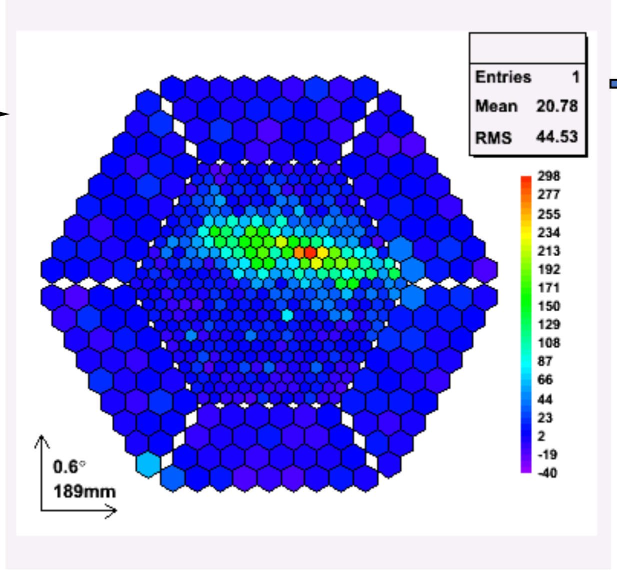


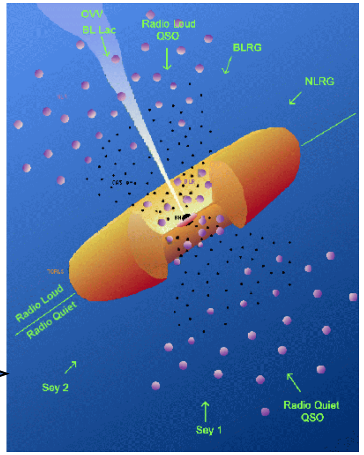
From Observations to Theory



Monte Carlo simulations

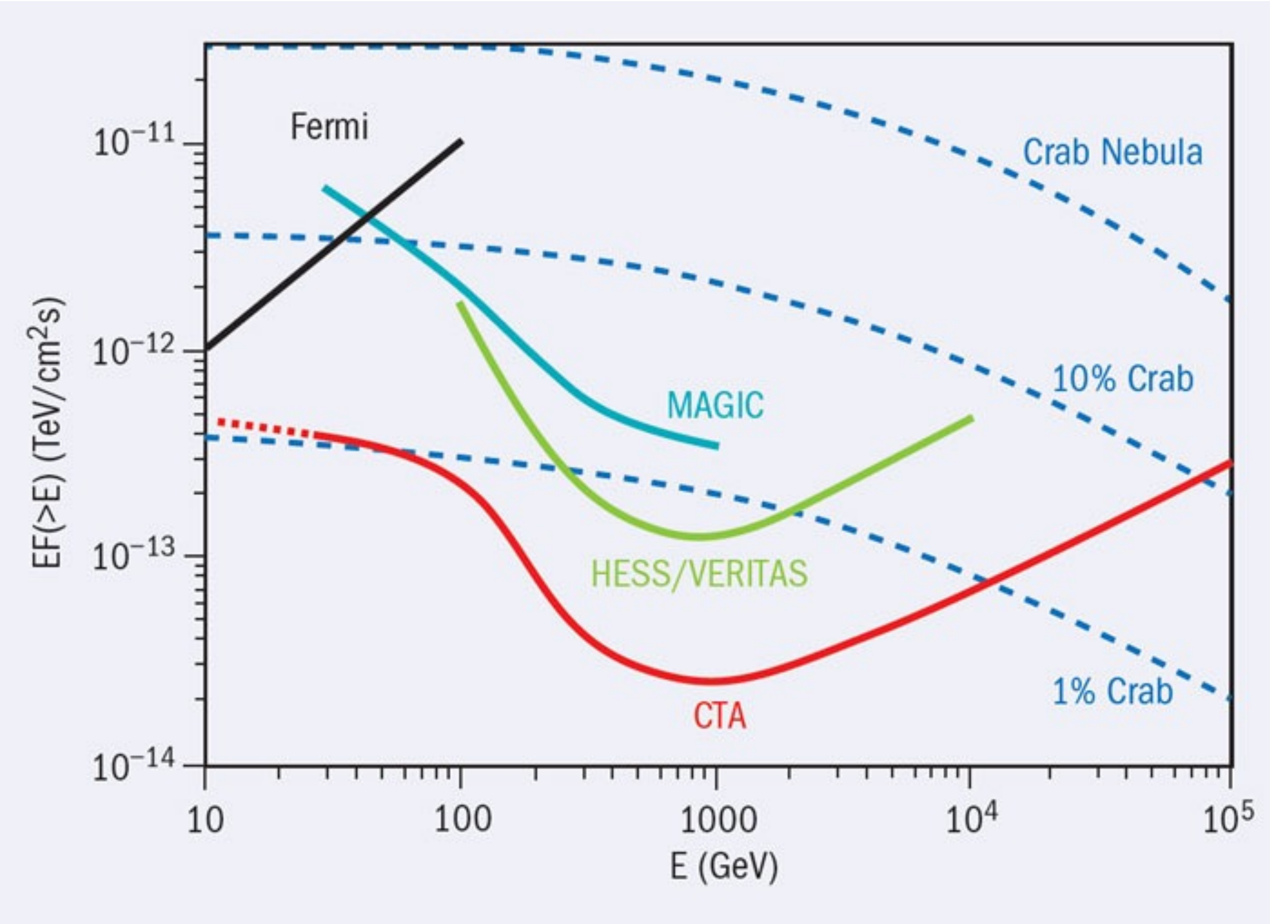
Observation of an Astrophysical source





Theoretical model

Sensitivity of ground-based and space gamma-ray telescopes

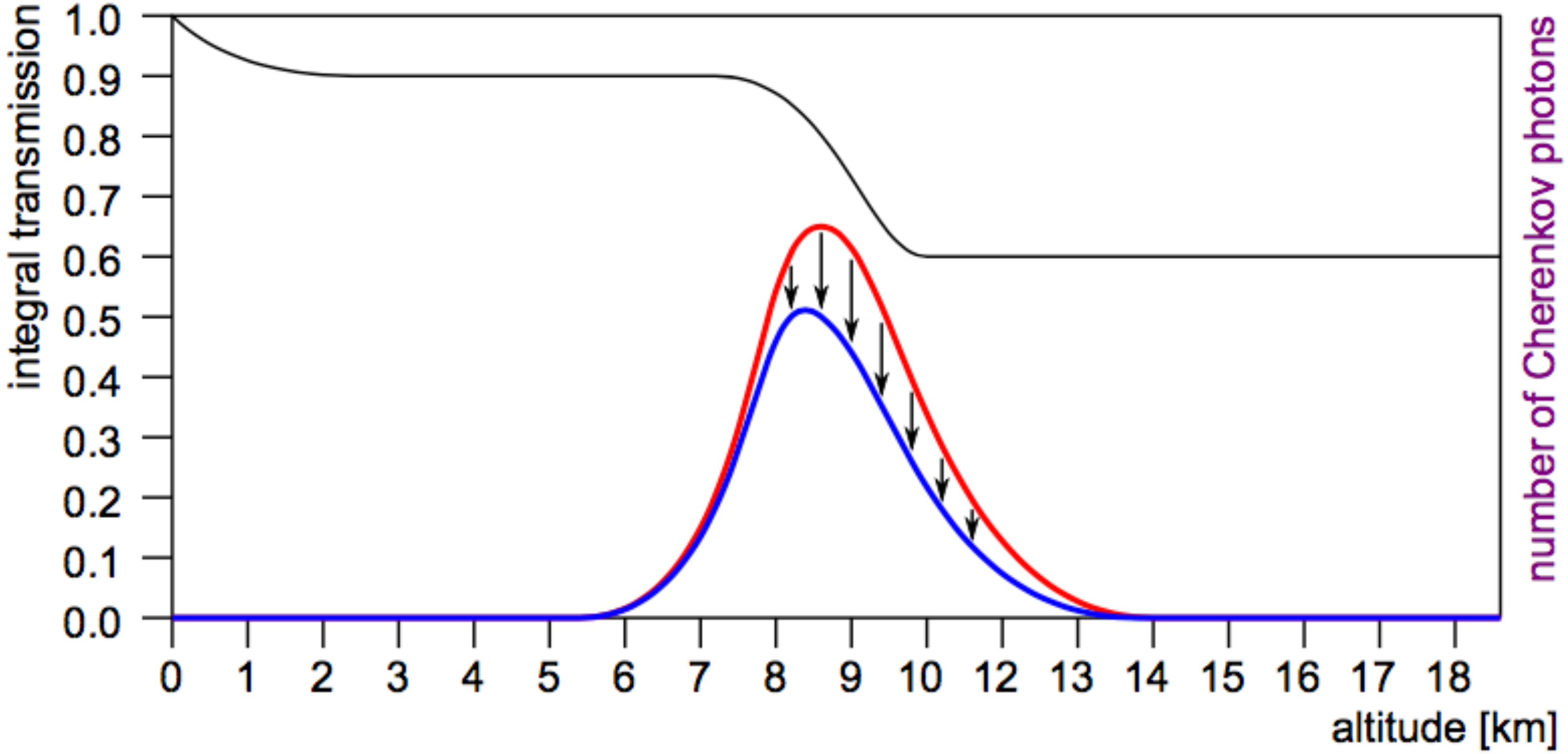


Atmosphere above La Palma

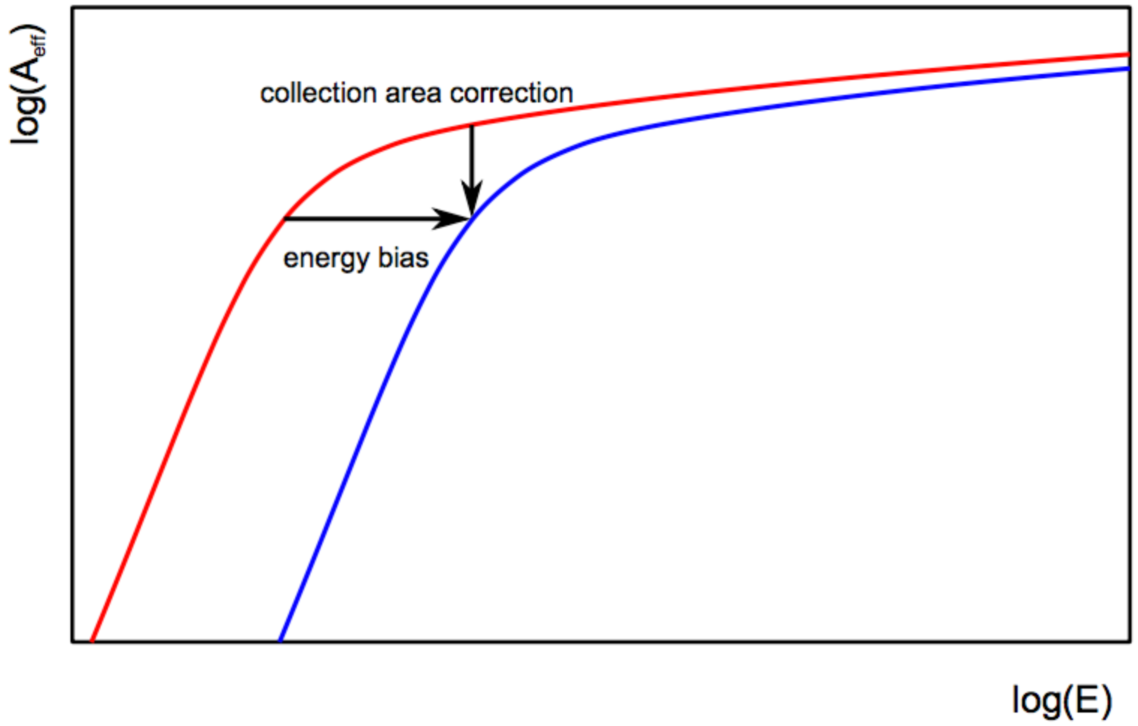
- Cirrus clouds
- Important for understanding the climate
- Altitude 5-20 km

- Calima
- Sahara dust
- Altitude around 3 km

Effect of a cloud on a Cherenkov air shower



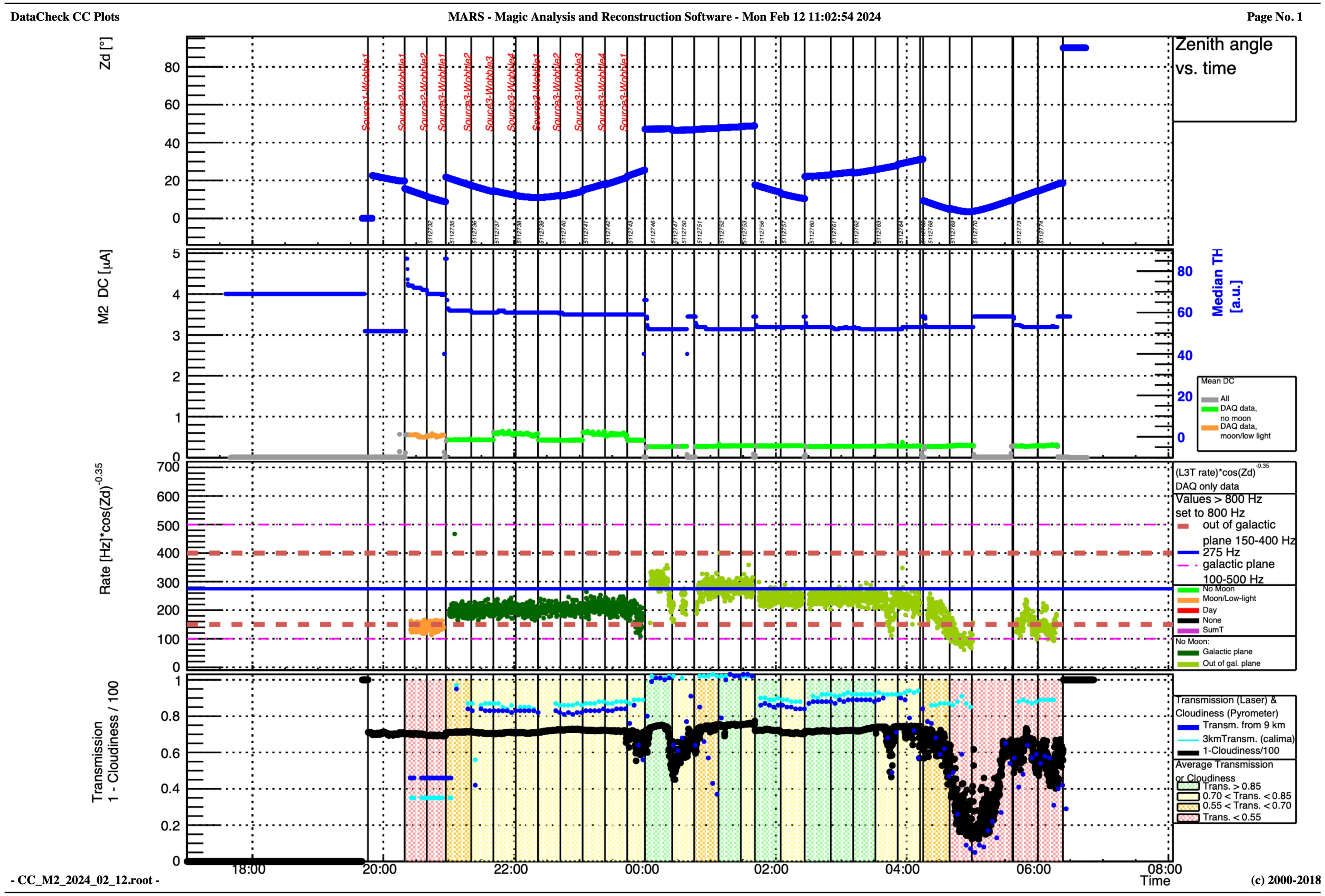
Energy threshold affected by a cloud



MAGIC Optical LIDAR

- LIght Detection And Ranging
- Pulsed optical laser at 532 nm

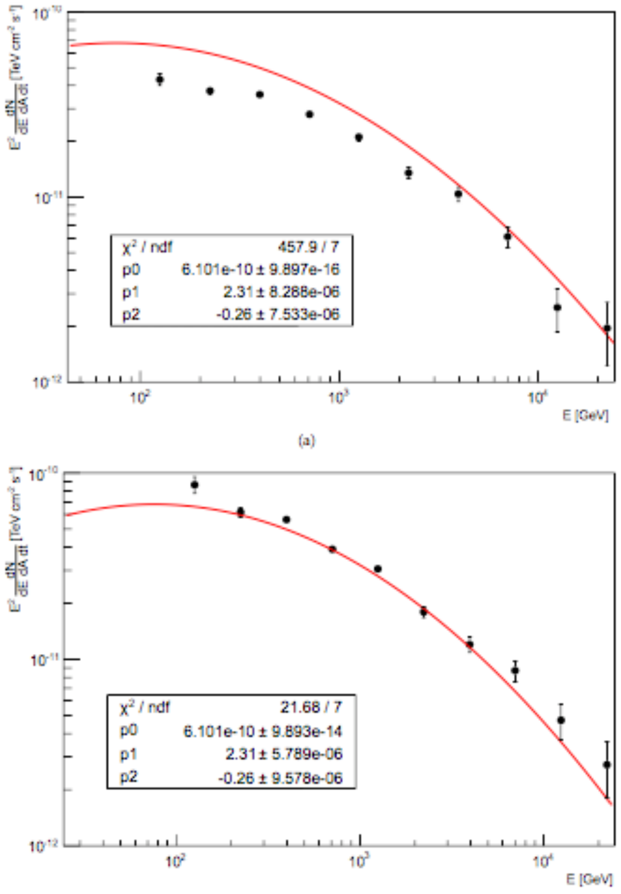
MAGIC: Datacheck for one observing night with variable atmosphere



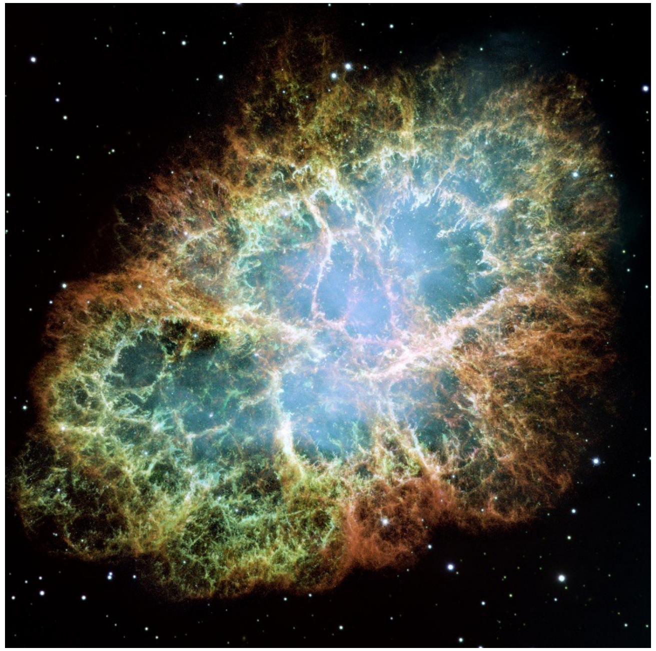
Crab nebula Very High Energy spectrum with and without corrections for atmospheric transmission

Without corrections

With corrections

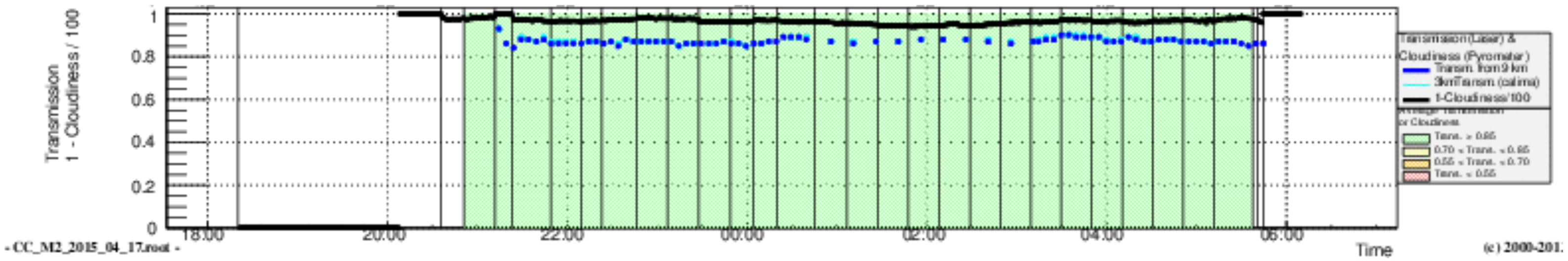


C. Fruck (2015)

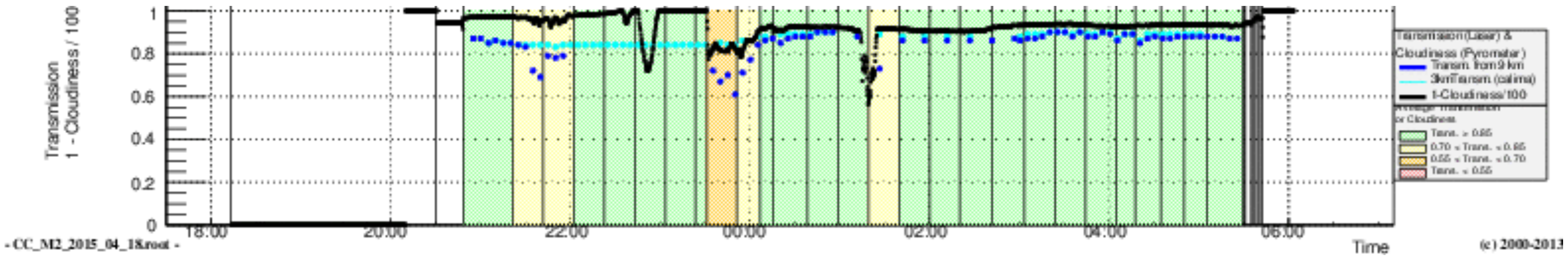


MAGIC: Different atmospheric conditions

Perfect weather: no corrections

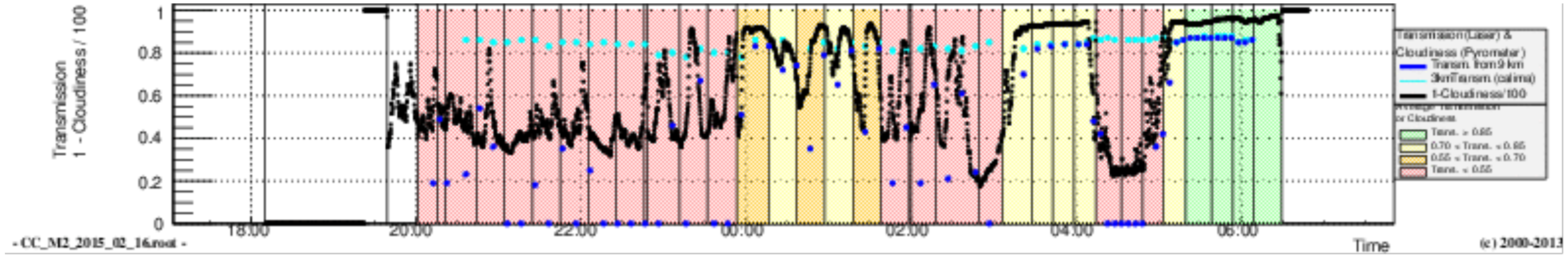


Easy corrections possible



Detection of distant blazar PKS1441+25 (MAGIC Collaboration, 2015)

Very variable atmosphere

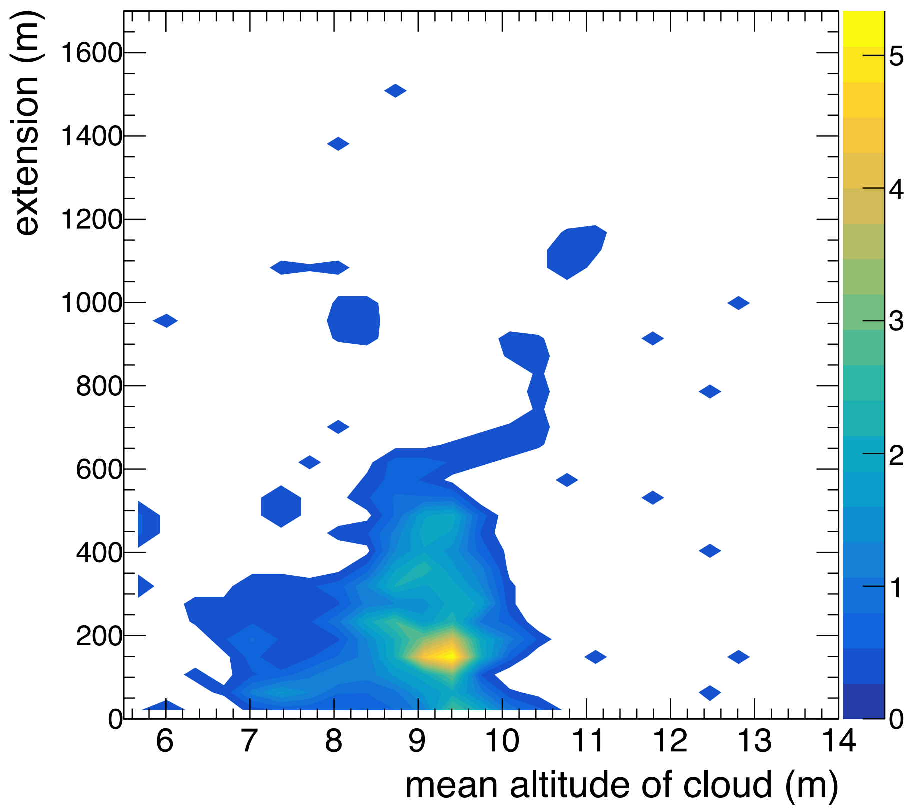


Adaptive Observation Scheduling

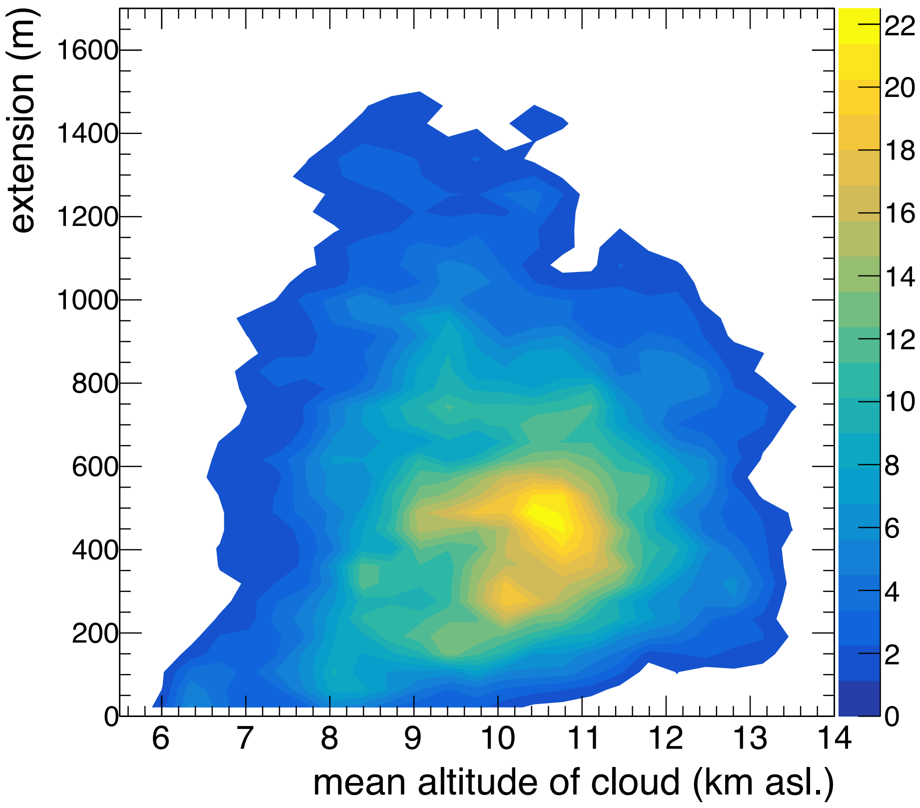
- 20-30% of the observational time at La Palma is affected by moderate atmospheric transmission levels that can be corrected using real-time VAOD measurements
- Observational time with IACTs MAGIC and CTAO is very expensive
- Observations of astrophysical sources and phenomena that emit softer gamma-ray spectra (GeV range energy thresholds) need high atmospheric trasmission (more than 0.85-0.90)
- Sources emitting harder gamma-ray spectra (TeV e.th.), including flaring and nearby AGNs, can be observed also during moderate atmospheric transmission (0.55-0.85) in order to allocate more observing time for sources that need observations with lower energy thresholds

Vertical standard deviation of clouds ("extension") as a function of mean altitude

Summer clouds



Clouds from the rest of the year



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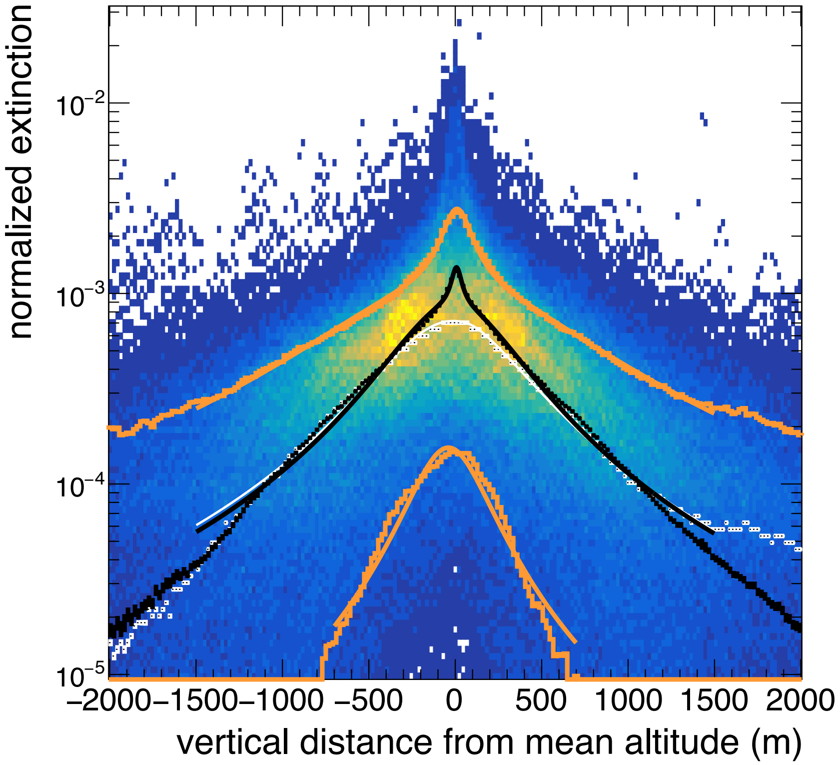
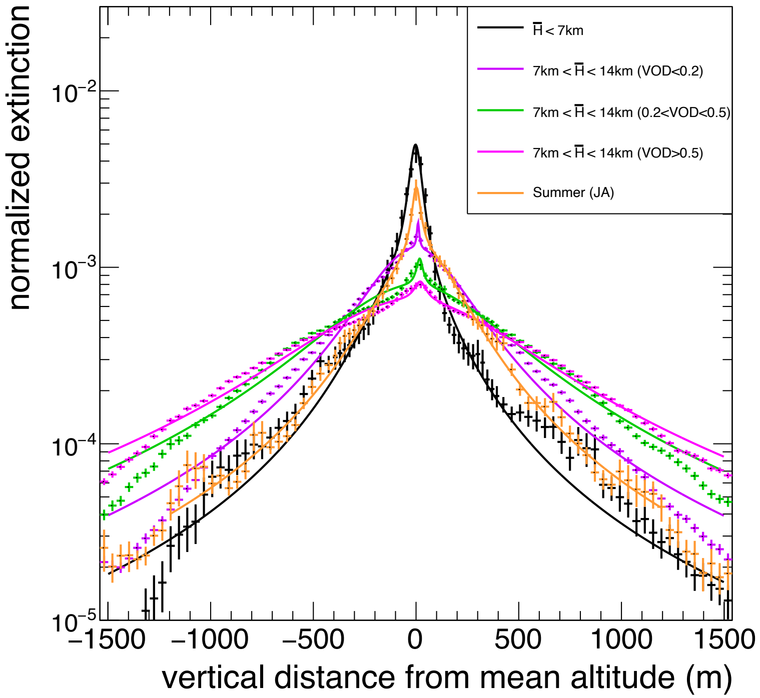
Distributions of normalized extinction vs. vertical distance from mean altitude



All extinction profiles (color map), with the bin-wise means (black), medians (white) and 10% and 90% quantiles (orange).



The mean extinction profiles for different cloud cases: low clouds (H < 7 km asl., black), medium altitude clouds (7 km asl. < H < 14 km asl.) for three different VOD ranges: VOD < 0.2 (lila), 0.2 < VOD < 0.5 (green) and VOD > 0.5 (pink), and Summer clouds (orange).

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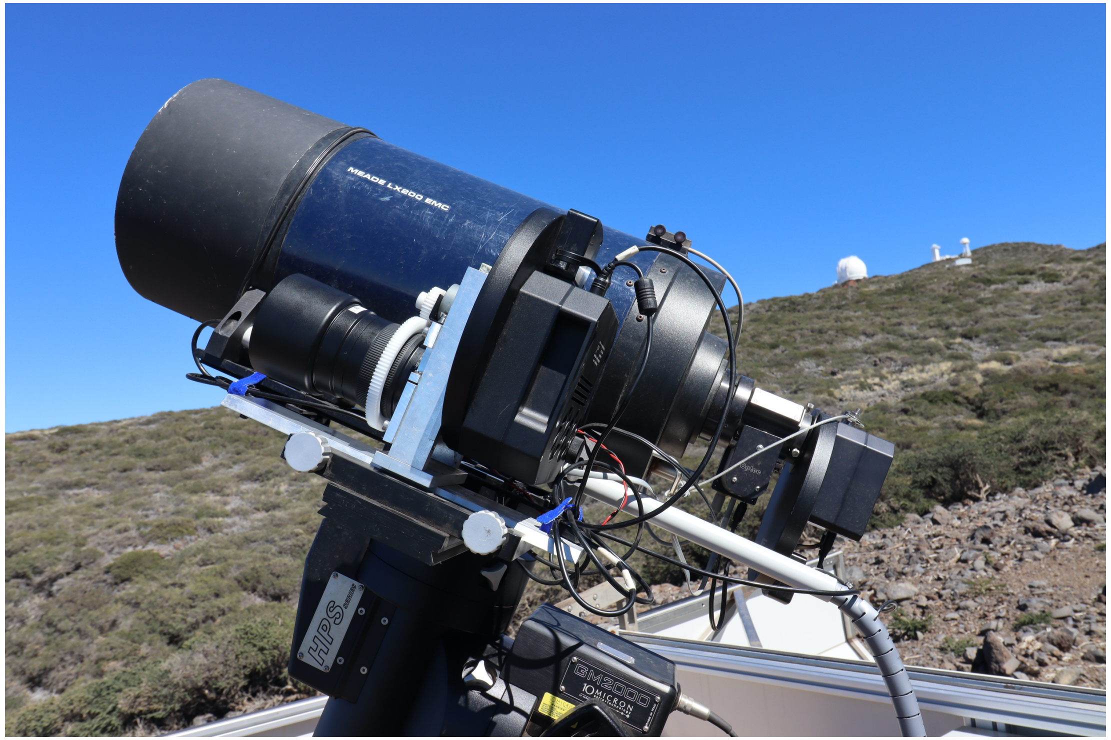
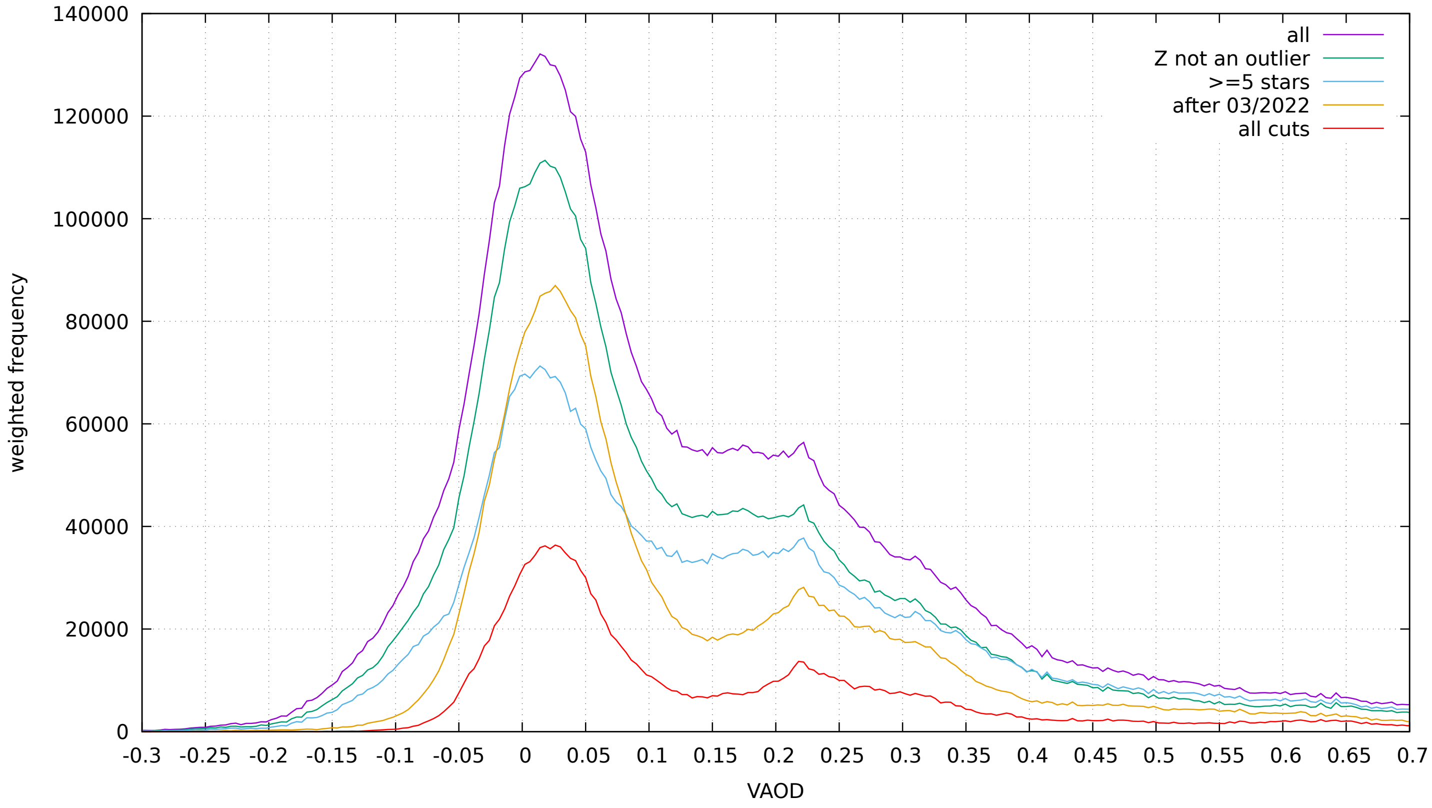
CTAO FRAM



F/Photometric Robotic Telescope

Distribution of Vertical Aerosol Optical Depth (VAOD) values measured by CTAO FRAM in tiles with different cuts applied



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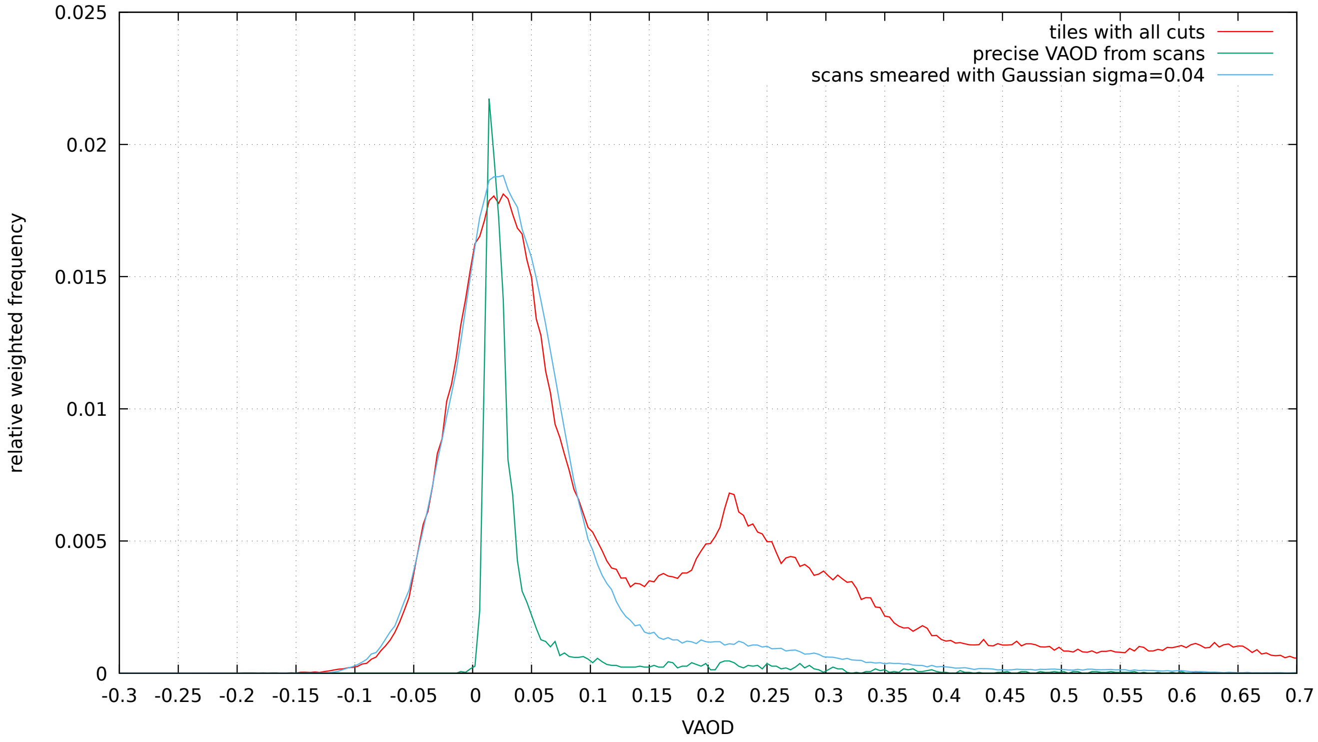
Distribution of VAOD values measured by CTAO FRAM in tiles after all cuts compared with the distribution of the precise VAOD measurements from scans without and with a smearing with a Gaussian with $\sigma = 0.04$



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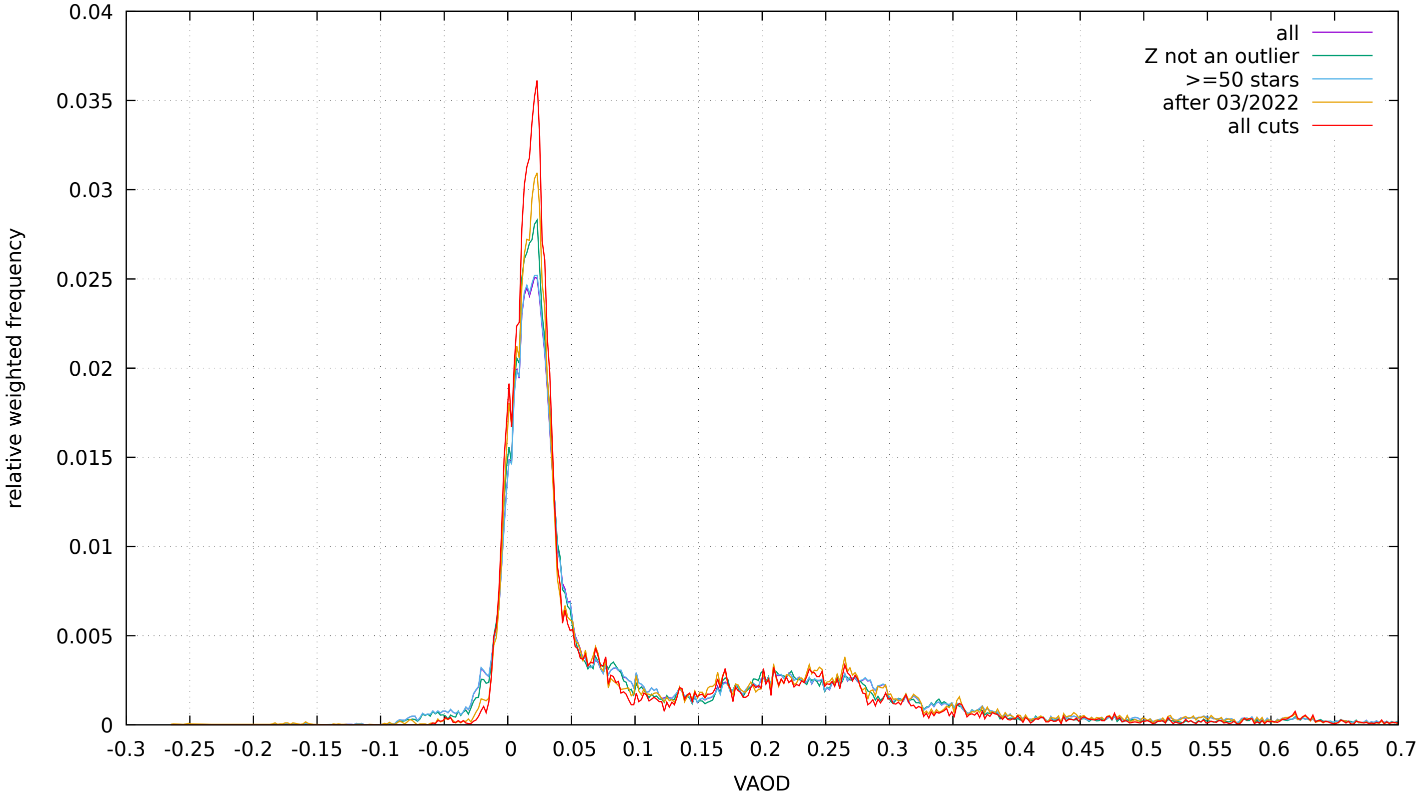
Distribution of VAOD values measured by CTAO FRAM in tiles with different cuts applied (normalised to the number of entires after each cut)



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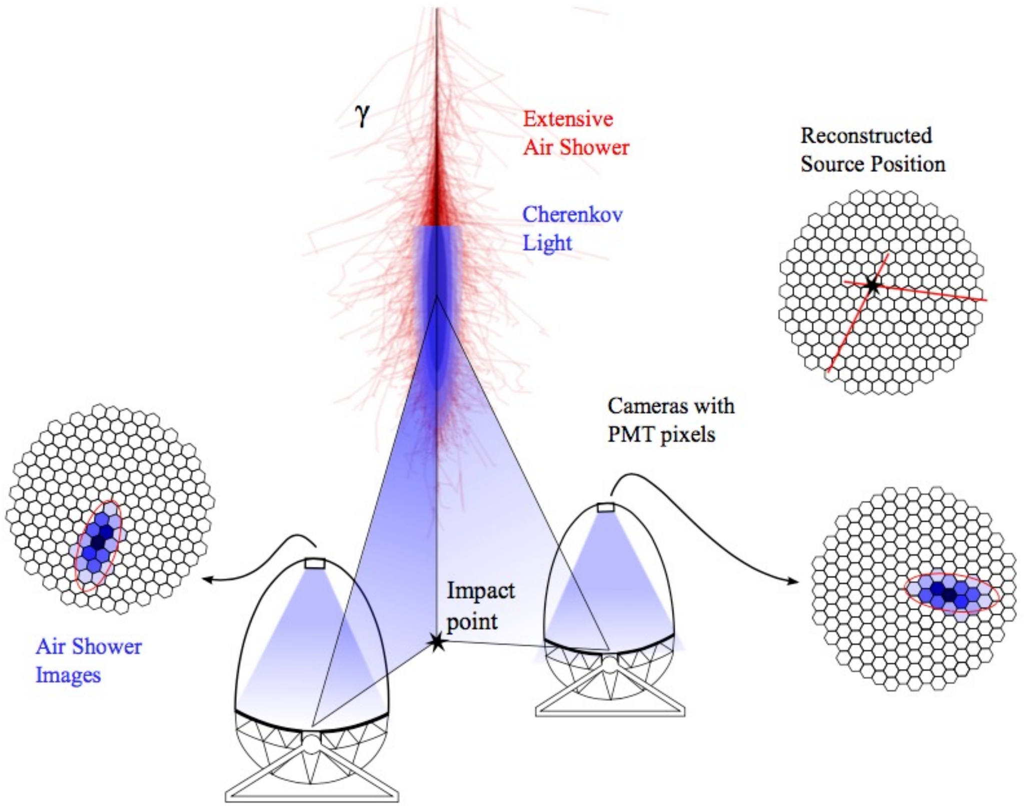
Conclusions and Future Perspectives

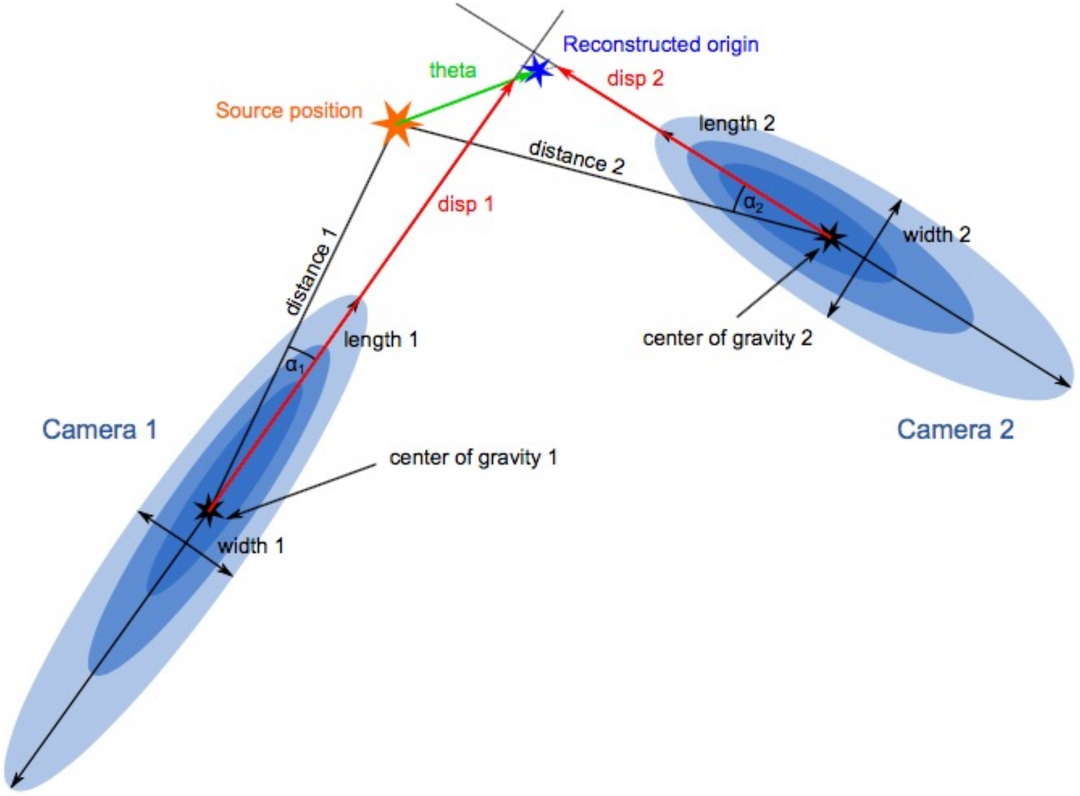
- Aerosols in the atmosphere play an important role for reconstruction of data observed by IACTs
- Adaptive observation scheduling optimises the available observational time of IACTs
- Different independent instruments for atmospheric characterisation used during the same time ensure a better strategy
- Characterisation of the atmosphere for IACTs provides useful data for environmental and climate studies

Backup slides

MAGIC stereoscopic system



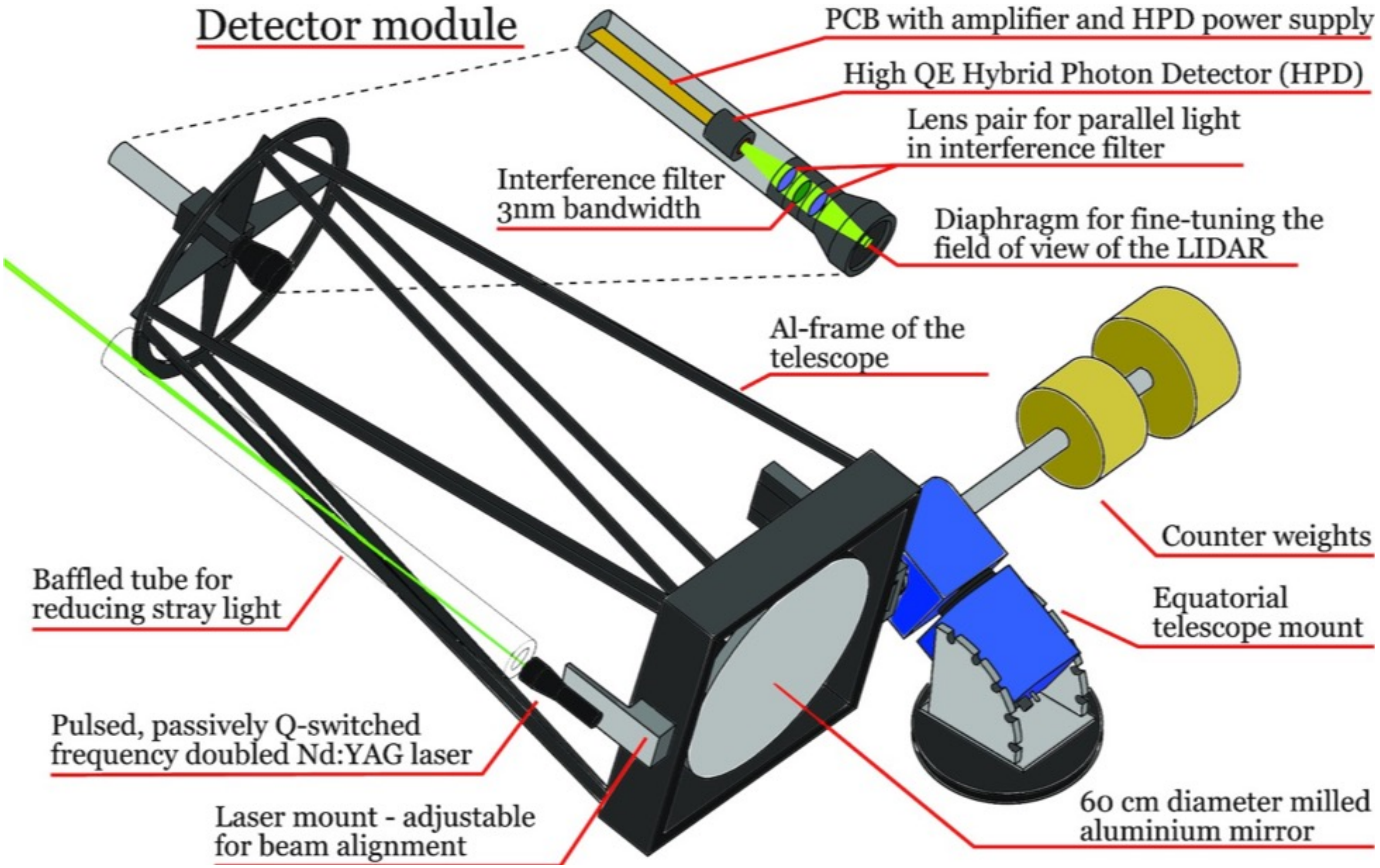
Stereo reconstruction



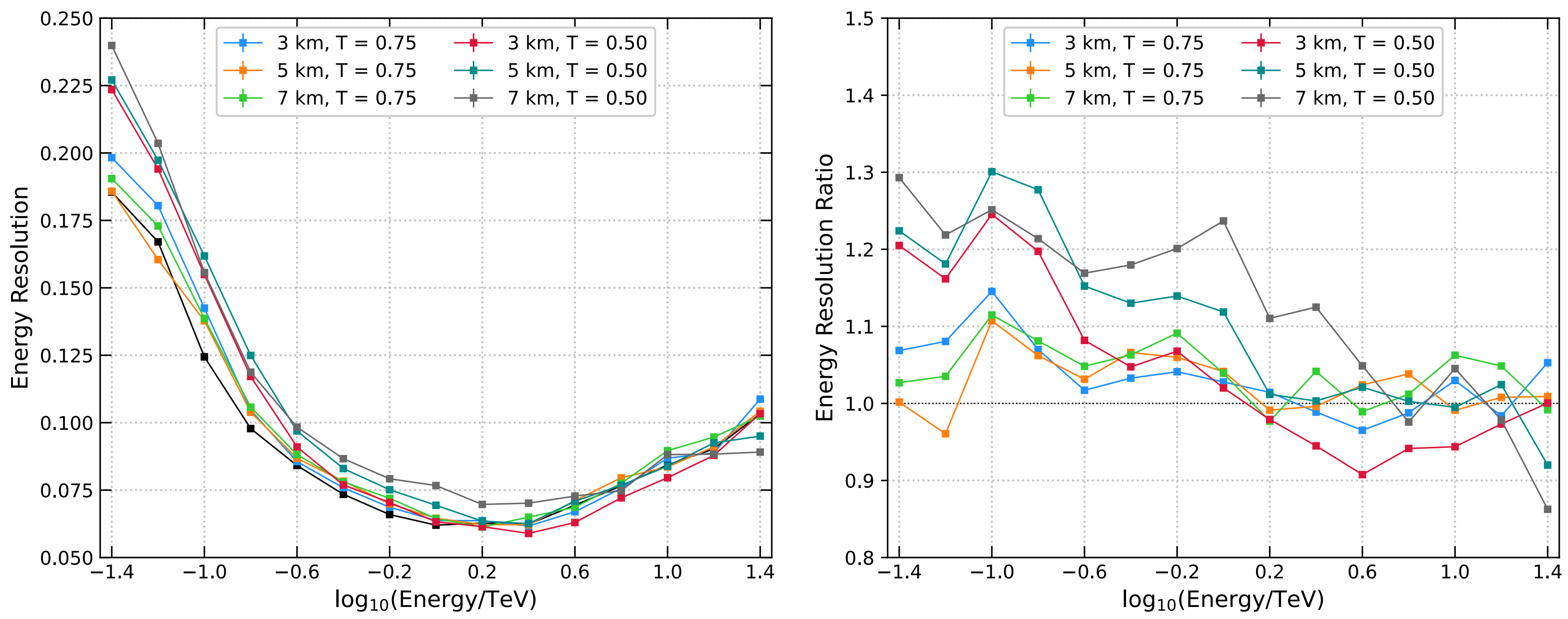
Data quality classes (MAGIC 2 year statistics)

Data quality class	LIDAR T (9 km)	Without calima cut (% of time)	With calima cut
1. (no corrections)	1.00-0.85	69	85
2. (corrections)	0.85-0.70	17	9
3. (corrections)	0.70-0.55	6	2
4. (“garbage”)	0.55-0.00	8	4

MAGIC Optical LIDAR

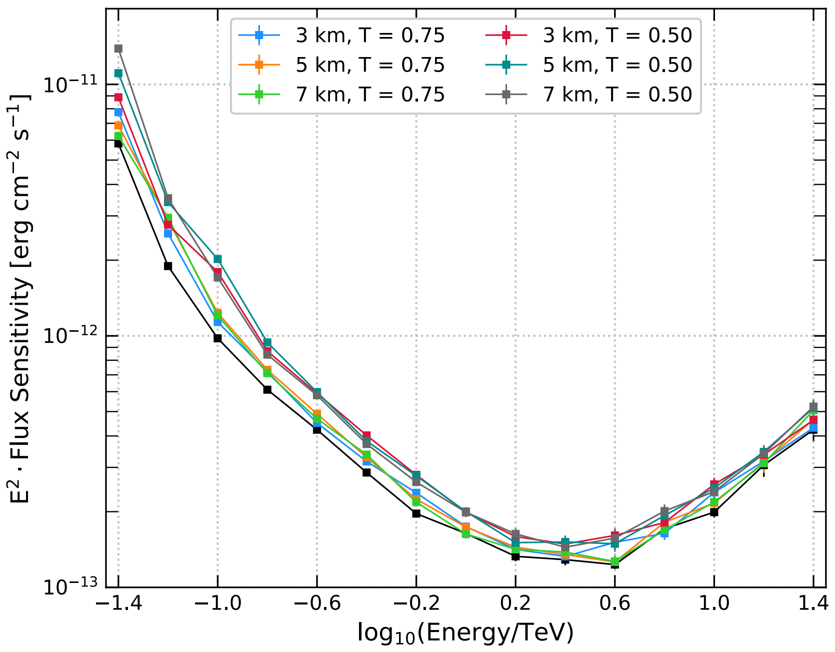


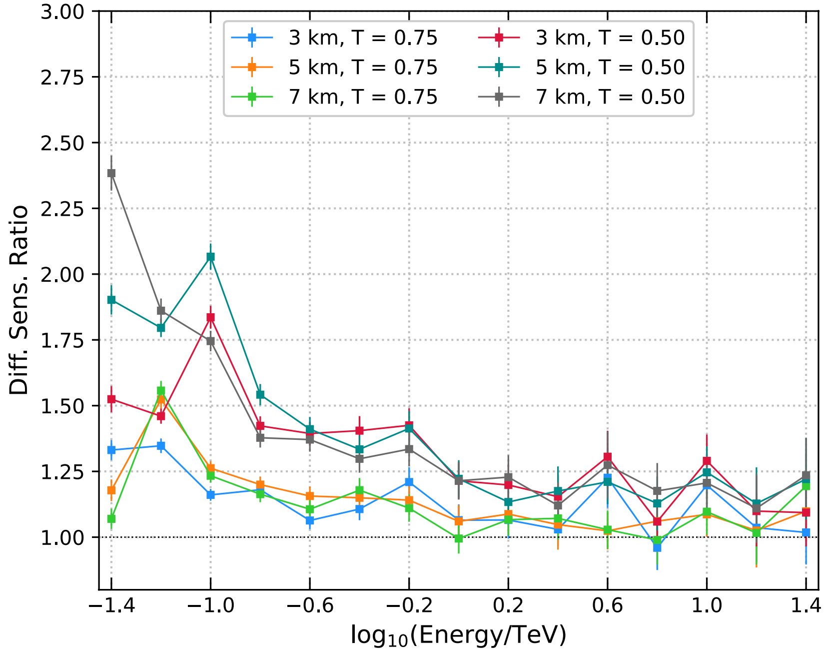
Energy Resolution – CTA North



- varies between 0.18 and 0.24 in the lowest energy bin to ≈ 0.10 at the energy of 15; significantly degraded at energies below 250 GeV, by 30% for $T = 0.50$ and by less then 10% for $T = 0.75$

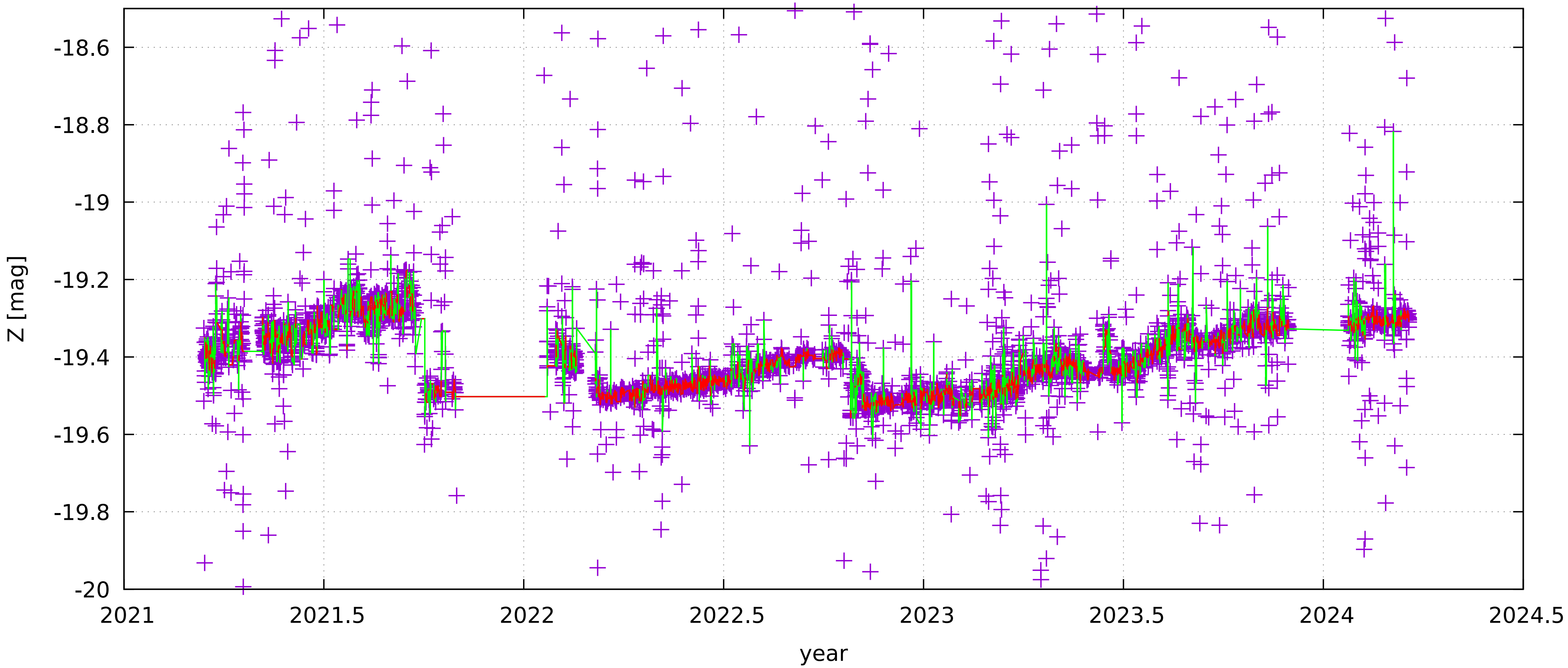
Differential Sensitivity – CTA North





- the most visible effect of clouds is at energies ≤ 150 GeV
- at energies ≥ 1 TeV the stability in reduction is achieved: ≈ 25% for $T = 0.50$, and ≈ 10% in the case of $T = 0.75$

CTAO FRAM time series of zeropoints from scans



Green line - values accepted during real-time processing. Red line - values excluding outliers.

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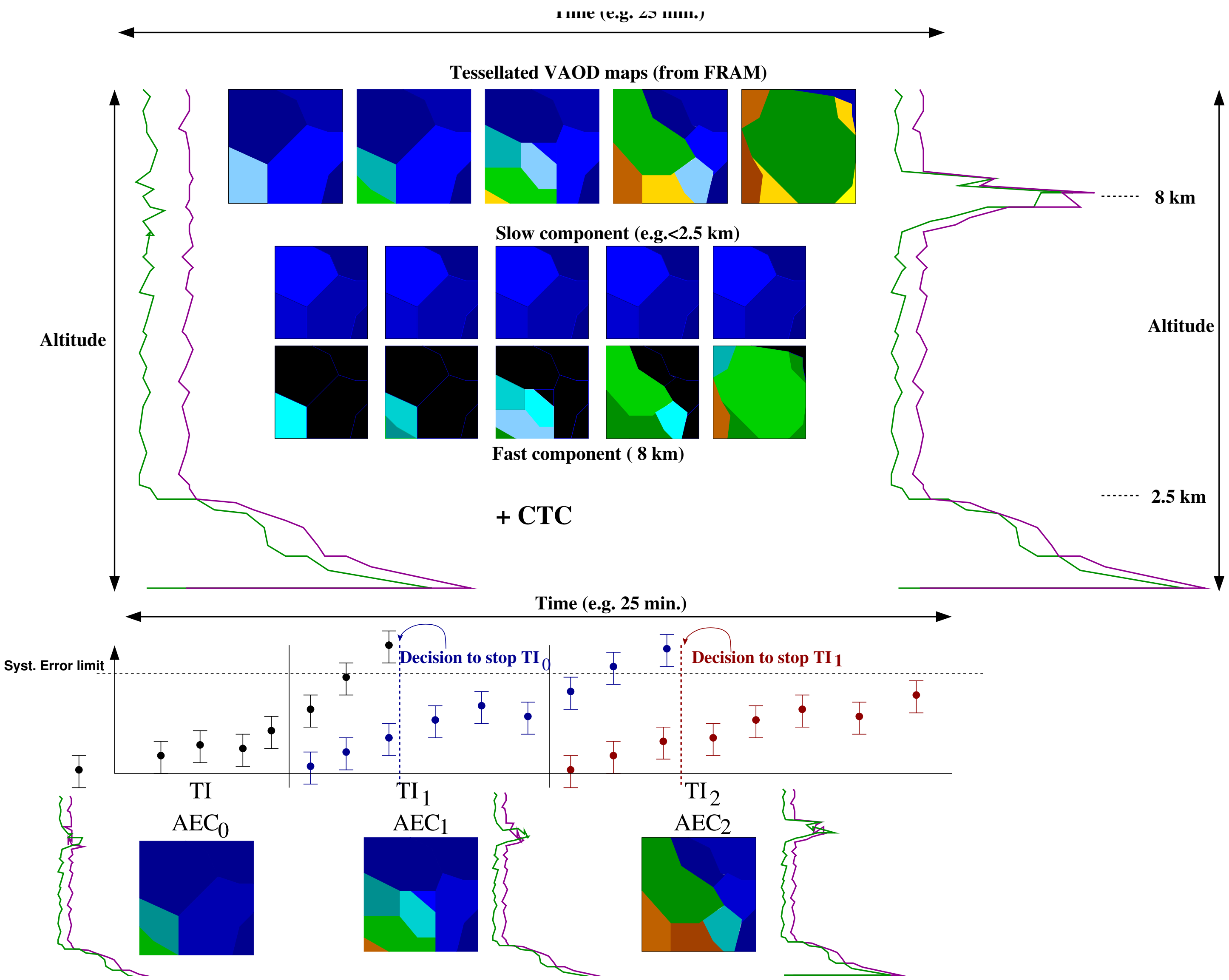
Scheme for the determination of new Stable Time Intervals (STIs) and new Monte Carlo (MC) simulated Instrument Response Functions (IRFs)

Procedure for obtaining average instrument response 114 functions over a time interval within which the systematic error due to simplifications of 115 the profile remains acceptable.



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