Very Large Zenith Angle Observations with MAGIC

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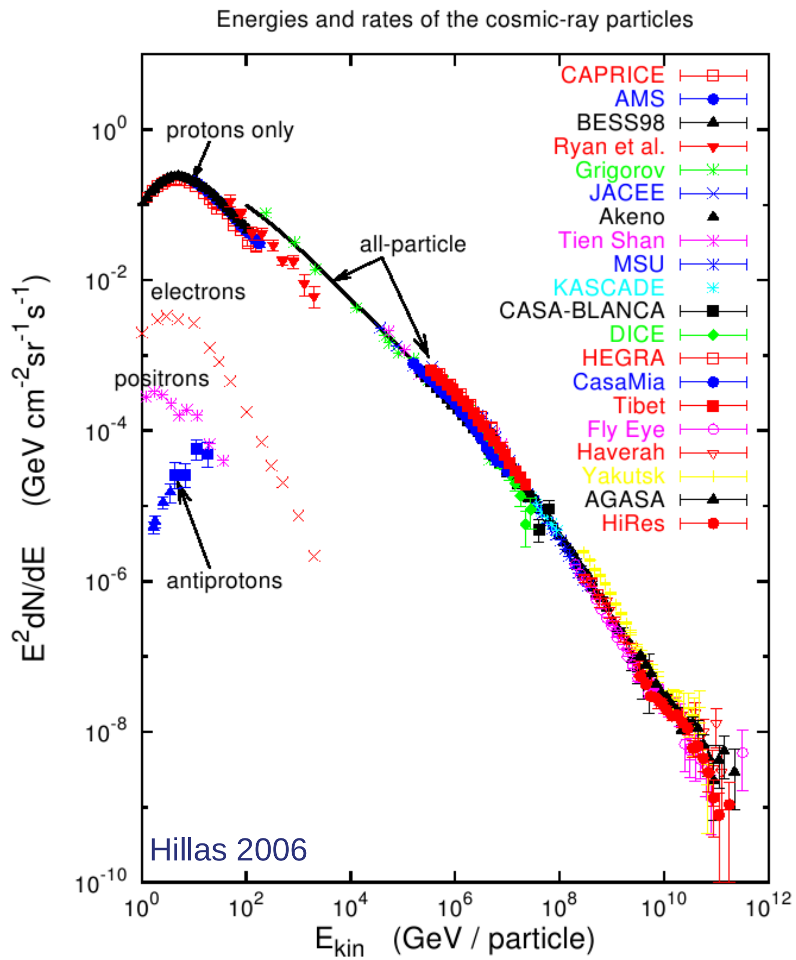
MAGIC

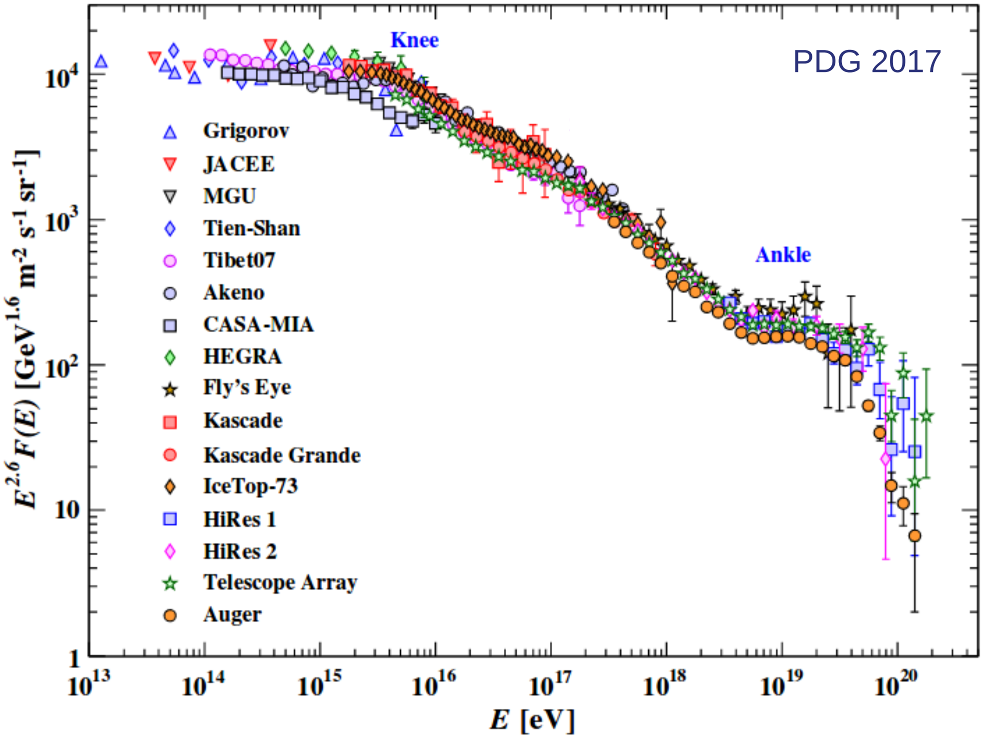
Frühjahrstagung der DPG
Aachen, 26. 03. 2018

Scientific Motivation for VLZA-Observations

The cosmic ray spectrum



Common believe: Cosmic rays below the 'knee' are of galactic origin
Possible source populations: SNRs, pulsars and PWNe, OB-associations, ...



Scientific Motivation for VLZA-Observations

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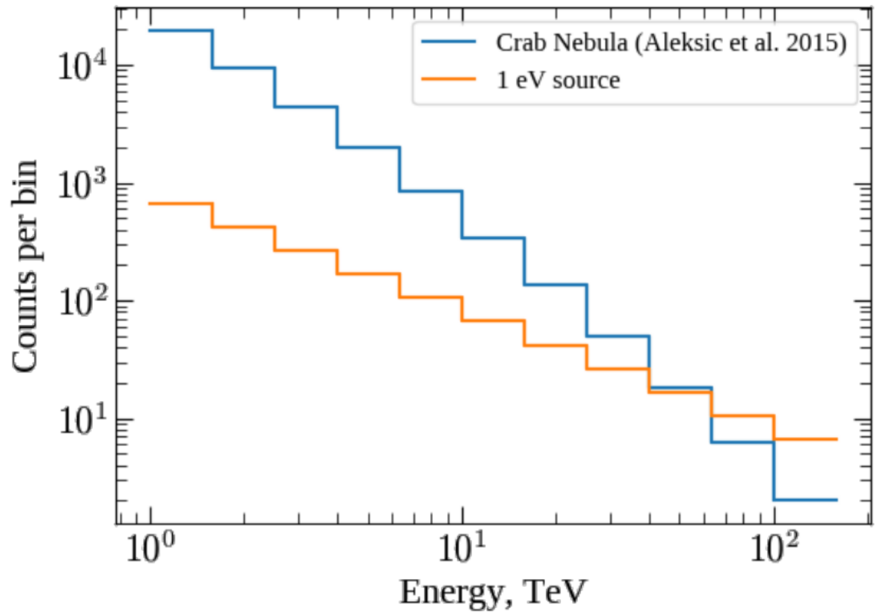
- **Gamma-ray emission processes:**
  Synchrotron radiation, Bremsstrahlung, inverse Compton scattering or hadronic emission
- **Gamma-ray emission above 100 TeV: indicator for presence of PeV cosmic rays in the source**

  Difficulty: expected flux at ~100 TeV is very low

Expected counts for A_{eff} = 1km^2 and T_{obs} = 50 hr



For reasonably short observation times: Increase A_{eff} significantly

→ Cover large area on the ground with many telescopes (future with CTA)

→ observe at very large zenith angles (present with MAGIC)

The MAGIC Telescopes

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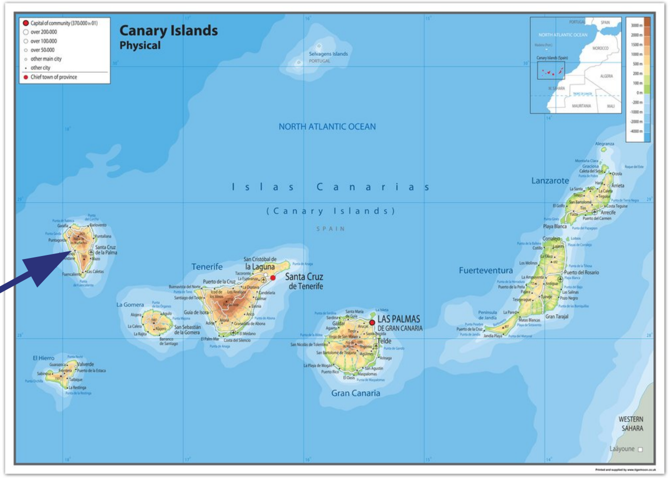
- Two Imaging Air Cherenkov Telescopes (IACTs) working in stereoscopic mode
- Located at Roque de los Muchachos Observatory on La Palma at 2200m a.s.l.



MAGIC 1

Counting House

MAGIC 2

- 17m diameter
- $236m^2$ active mirror surface

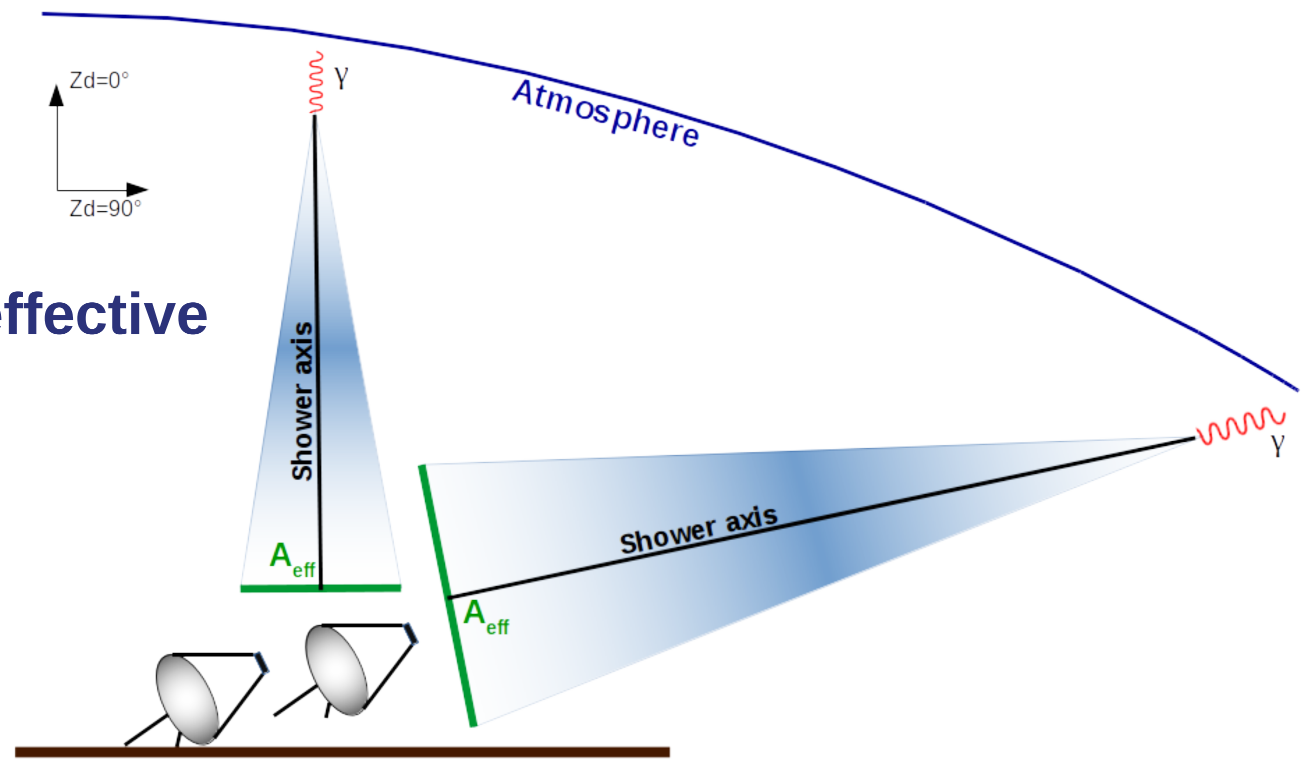
- Energy range from 50 GeV to 50 TeV
- Effective detection area 10^{-3} – $0.1\ km^2$

For standard observations!
(Zenith angles up to 60°)

Very Large Zenith Angle Observations

Observations at zenith angles between 70º and 85º
Compared to standard observations:
air shower created at up to 10 times larger distance from telescopes

Significant increase of effective detection area



Challenges of VLZA-Observations

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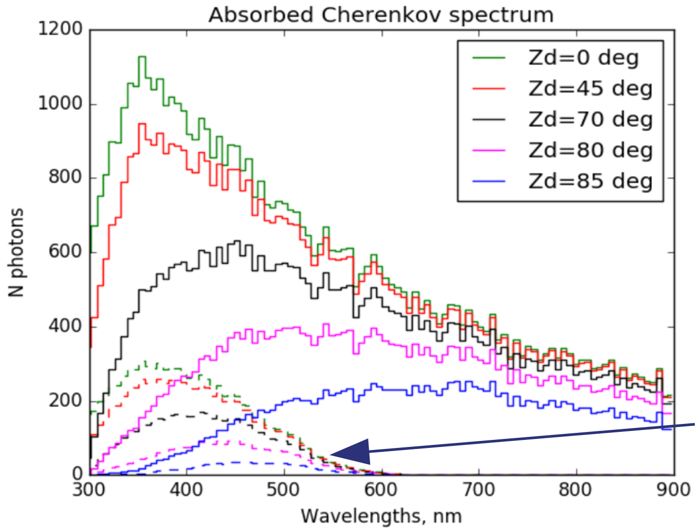
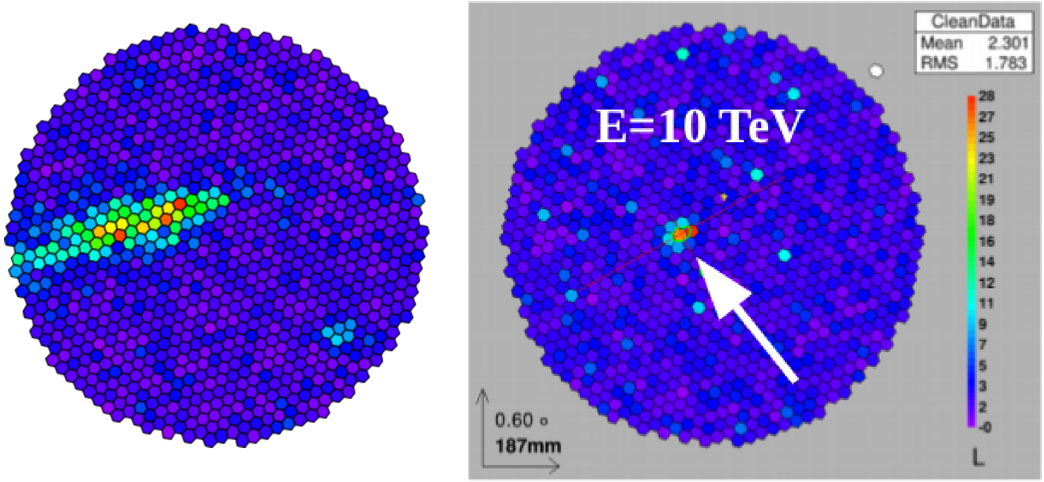


Multiplied with QE of PMT

Typical images of gamma-ray induced air showers

standard VLZA



- Higher atmospheric absorption
- Higher level of night-sky background
- Photon flux strongly decreases towards higher energies
- Cherenkov peak is shifted out of optimal quantum efficiency range of PMT
- ➔ Energy threshold increases

Shower images in camera are smaller

→ pixel size limits image resolution

→ degradation of air shower reconstruction

VLZA Observations of the Crab Nebula

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MAGIC

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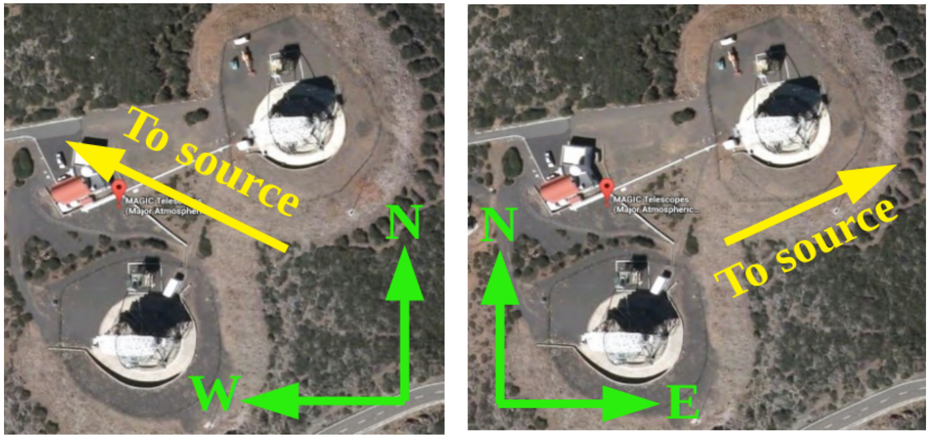
The Crab Nebula

- ‘Calibration source’ for VHE gamma-ray astronomy
- Gamma-ray emission well studied over broad wavelength range
- Spectral shape in general well understood
- In more detail some features not well described by current models

MAGIC VLZA data set

- separation in ‘Rise’ and ‘Set’ depending on telescope configuration
- Zenith angles: 70°-80°
- Observation time (after cuts): ~ 50 hrs

‘Set’ ‘Rise’



VLZA Observations of the Crab Nebula

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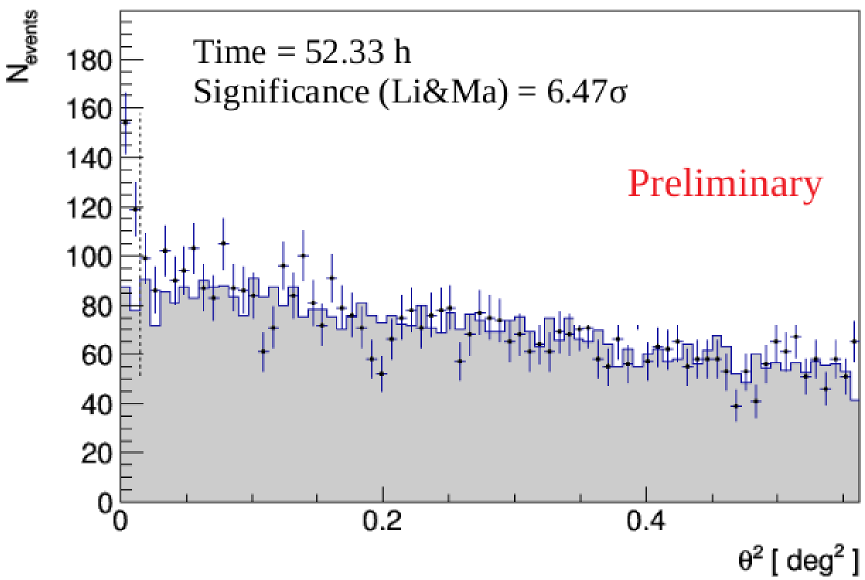
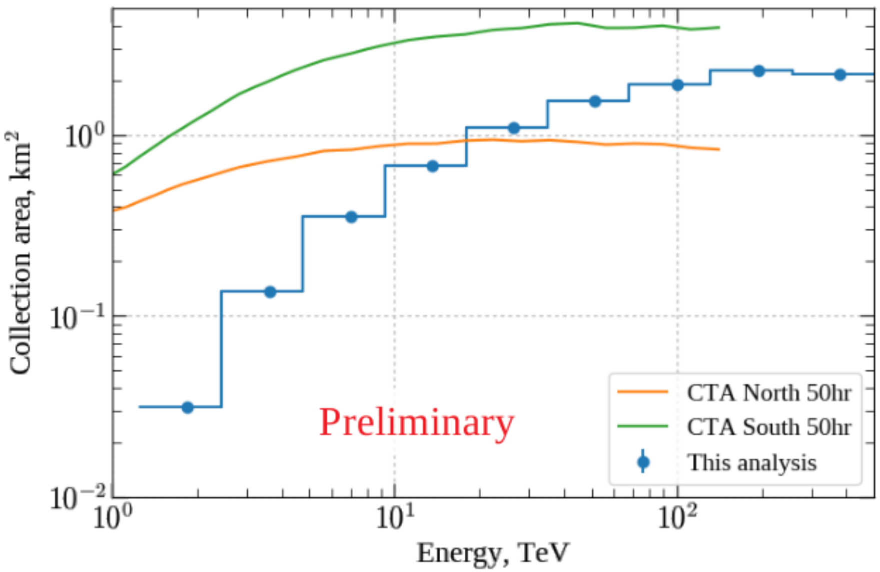
Angular event distribution above 30 TeV estimated energy



Reconstructed collection area



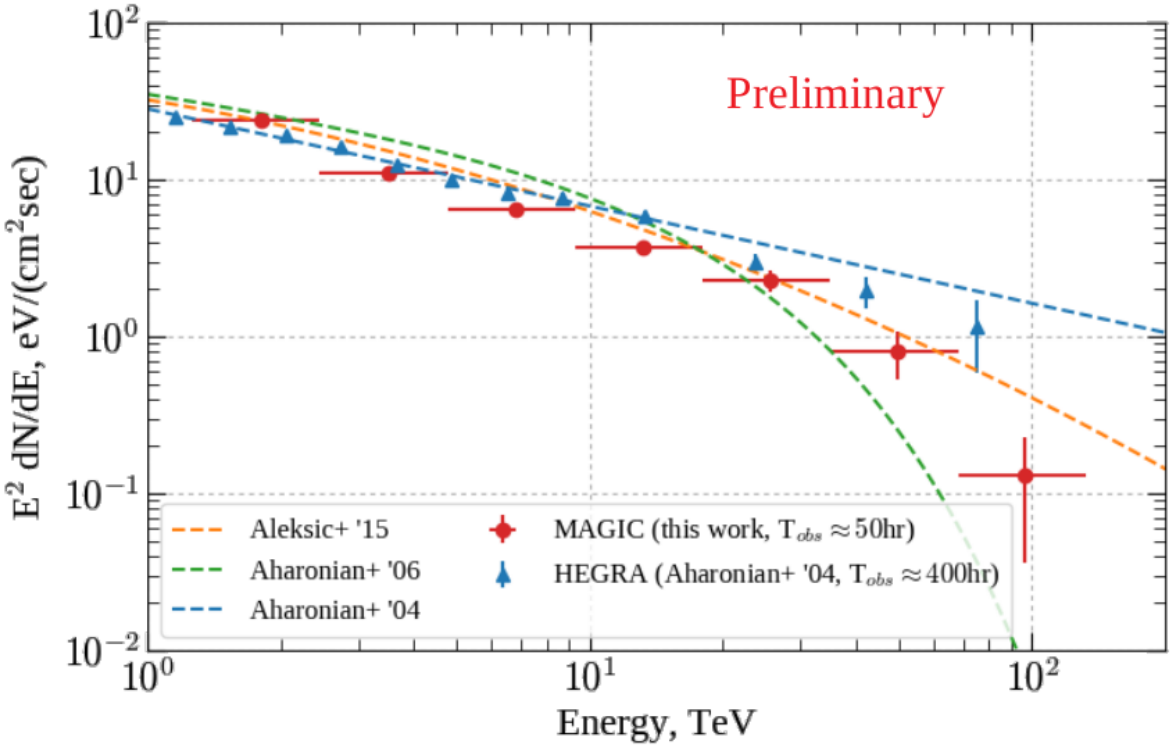
Significant signal above the highest source energy, previously measured by MAGIC (Aleksic+ '15)

VLZA MAGIC collection area @100 TeV is comparable to CTA predictions (at 20° zenith angle).

http://www.cta-observatory.org/science/cta-performance/ (version prod3b-v1)

VLZA Observations of the Crab Nebula

Unfolded Crab Nebula SED



Reconstructed spectrum from VLZA data extends up to ~100TeV

Observation time is 8x less compared to HEGRA measurements

SED is consistent with earlier MAGIC measurements

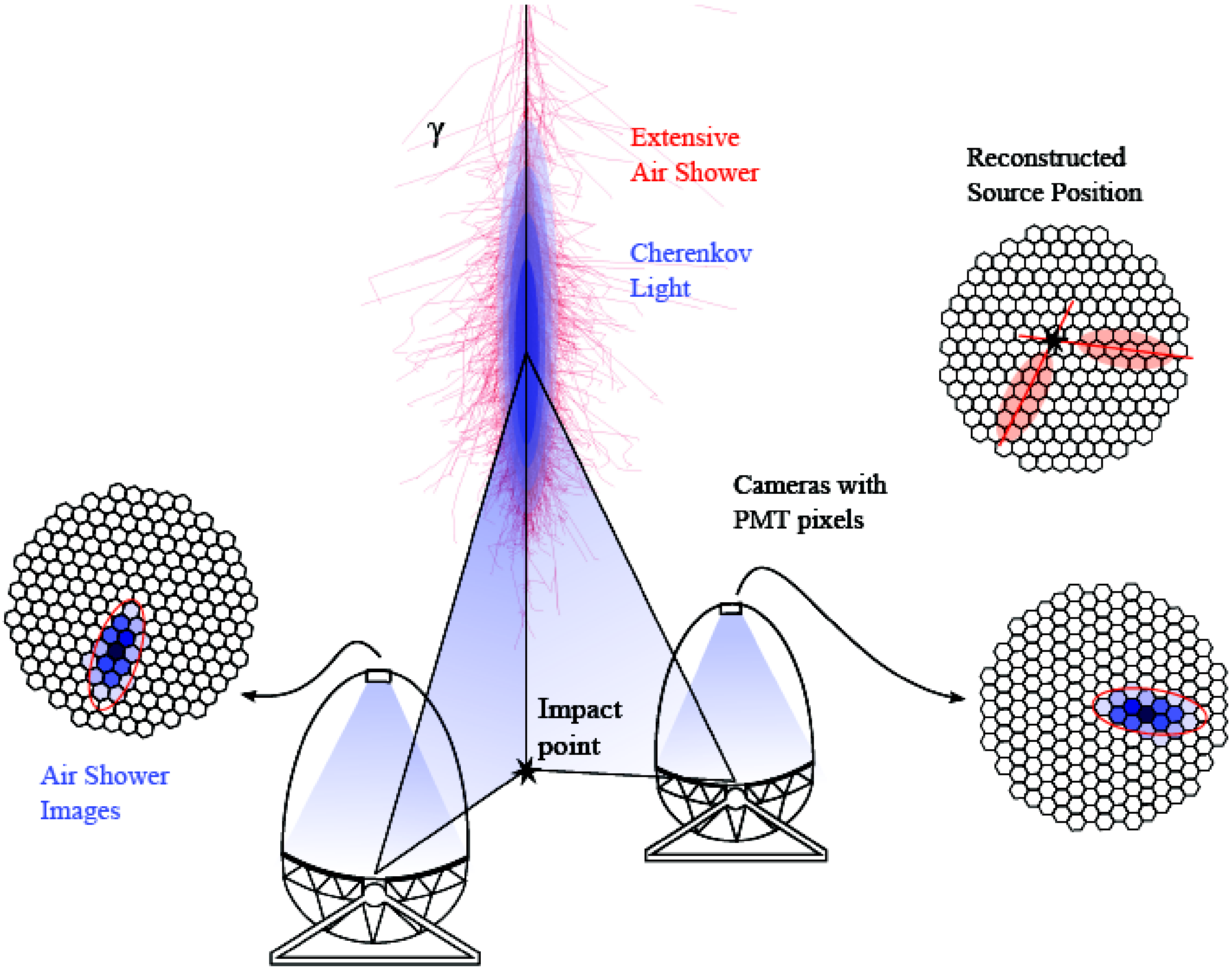
Summary

- **Very large zenith angle observations can extend the high-energy regime of gamma-ray astronomy**
- **MAGIC is suited to perform VLZA observations**
- **VLZA observations extend measurable energy range to above ~100 TeV**
- **First VLZA observations of the Crab Nebula show signal up to 100 TeV in only 50 hrs of observations**

Looking forward to first observations of PeVatrons!

Backup

IACT Observational Technique



Very-Large Zenith-Angle-Observations

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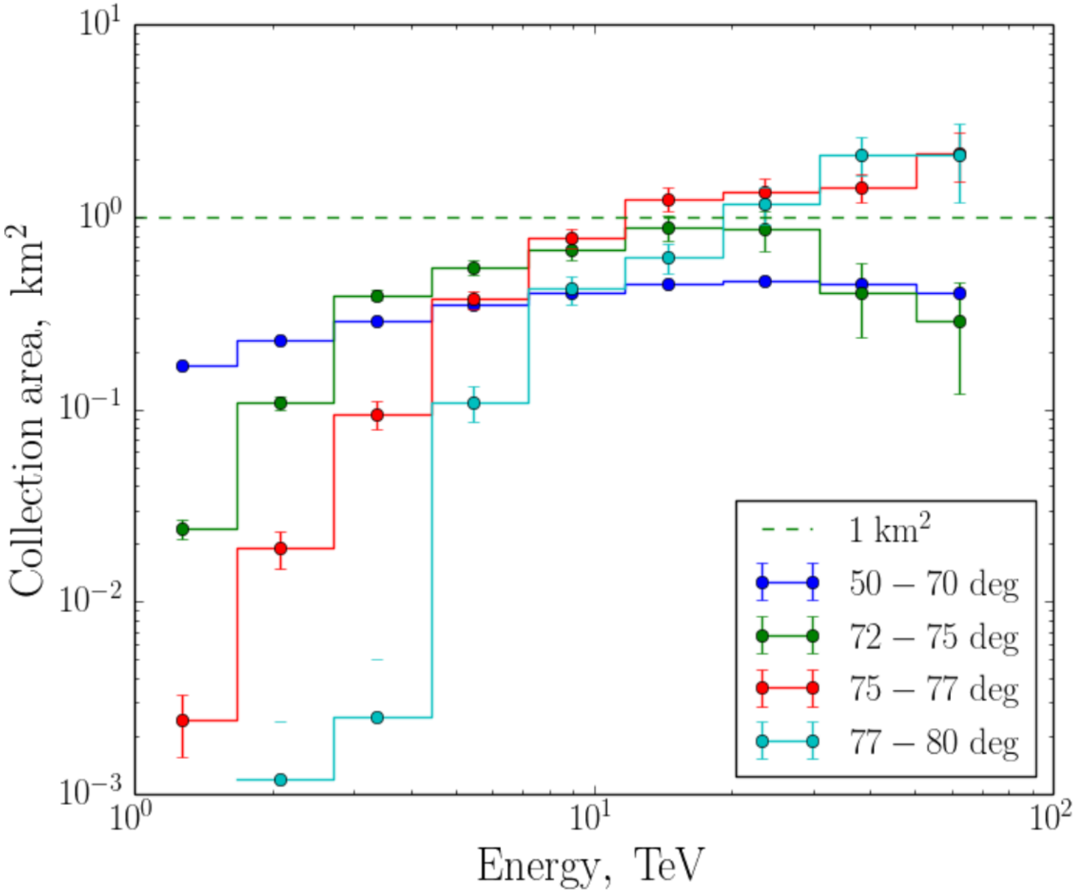
Collection area at different zenith angles at TeV energies – calculated from Monte-Carlo Simulations



Challenges of VLZA-Observations

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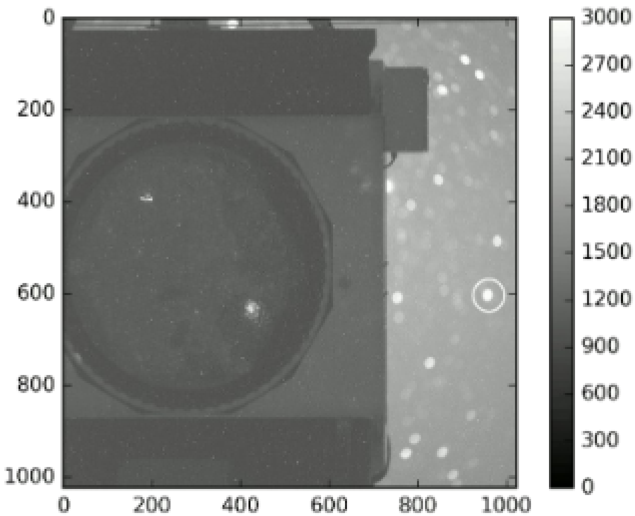
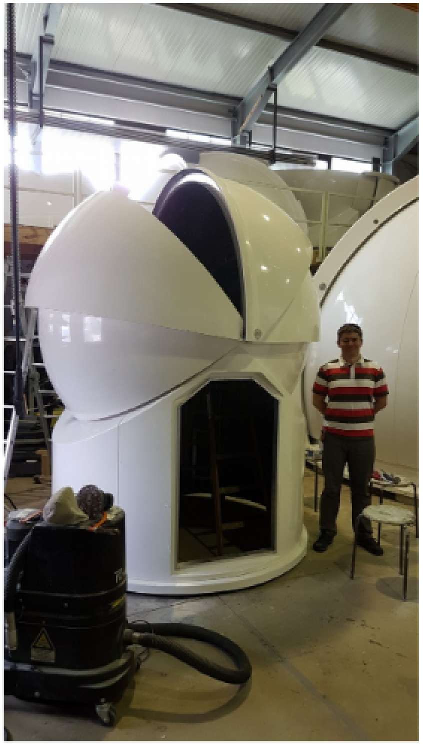
Calibration of atmospheric transmission

In MAGIC usually done by LIDAR - only works up to ~30km distance

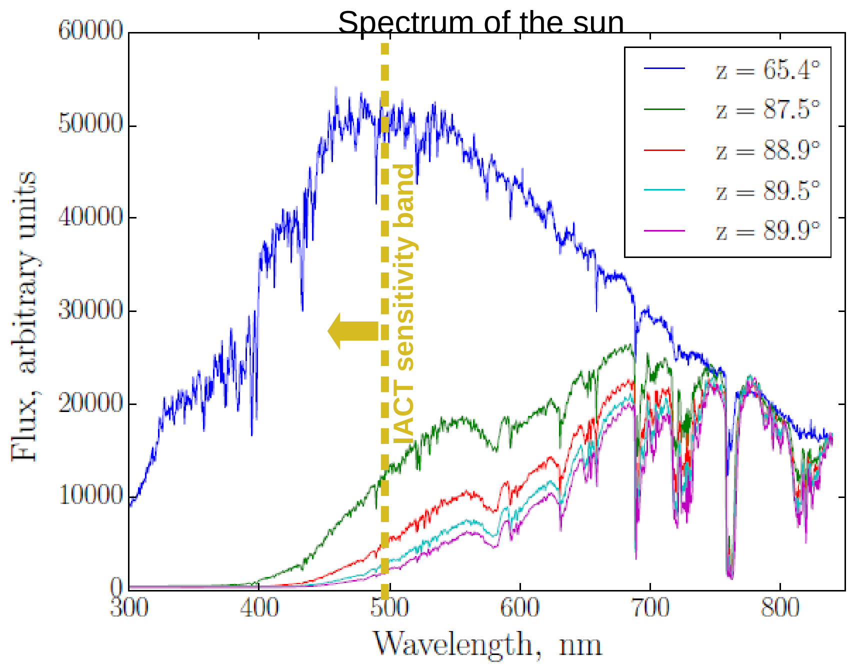
Further atmospheric calibration method is needed



Photometry of bright stars close to the source within FOV



Plan to install 28cm optical telescope with spectrograph at MAGIC site to study atmospheric extinction


Spectrum of the sun
Flux, arbitrary units
Wavelength, nm
IACT sensitivity band
z = 65.4°
z = 87.5°
z = 88.9°
z = 89.5°
z = 89.9°
0
10000
20000
30000
40000
50000
60000
300
400
500
600
700
800