Long-term Monitoring of Bright TeV Blazars with FACT

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Würzburg

First G-**A**PD **C**herenkov **T**elescope Major Goals

Proof of principle:

Silicon based photo sensors (G-APDs*) in Cherenkov Telescopes

Long-term monitoring of bright TeV Blazars

* Geiger-mode Avalanche Photodiodes

Photo: Thomas Bretz

First G-**A**PD **C**herenkov **T**elescope
Major Goals

Proof of principle:

Silicon based photo sensors (G-APDs*) in Cherenkov Telescopes

Long-term monitoring of bright TeV Blazars

✓ First successful use in regular operation

* Geiger-mode Avalanche Photodiodes

Photo: Thomas Bretz

First G-**A**PD **C**herenkov **T**elescope
Major Goals

Proof of principle:

Silicon based photo sensors (G-APDs*) in Cherenkov Telescopes

✓ First successful use in regular operation

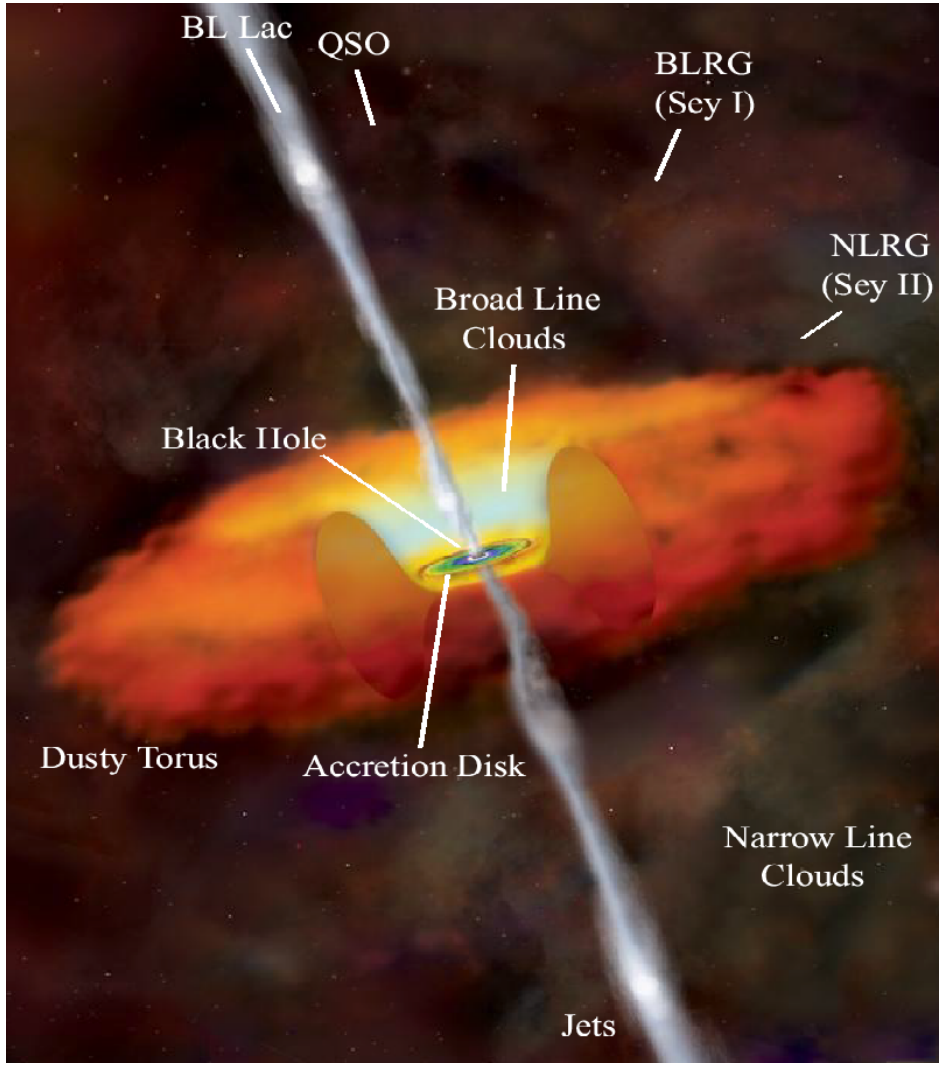
Long-term monitoring of bright TeV Blazars

→ Flare alerts to other instruments
→ Multi-wavelength studies
→ Flare studies of AGN

* Geiger-mode Avalanche Photodiodes

Photo: Thomas Bretz

Active Galactic Nuclei

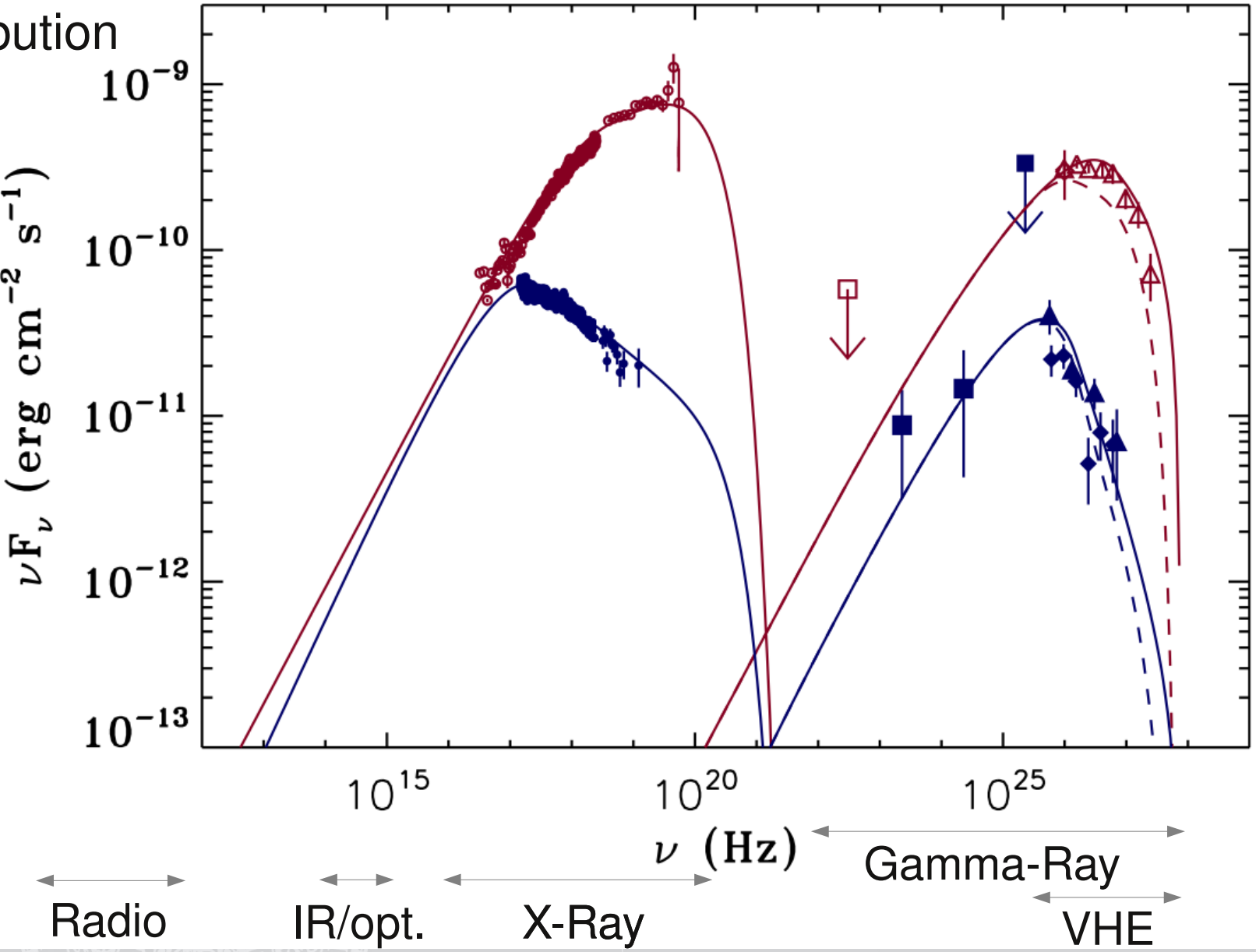


http://chandra.harvard.edu/resources/illustrations/quasar.html

- Central black hole
- Jet: Acceleration to extreme energies
- Classification depending on viewing angle
- Extreme variability on different time scales
- Spectral energy distribution: Two-peak structure

Extreme Variability

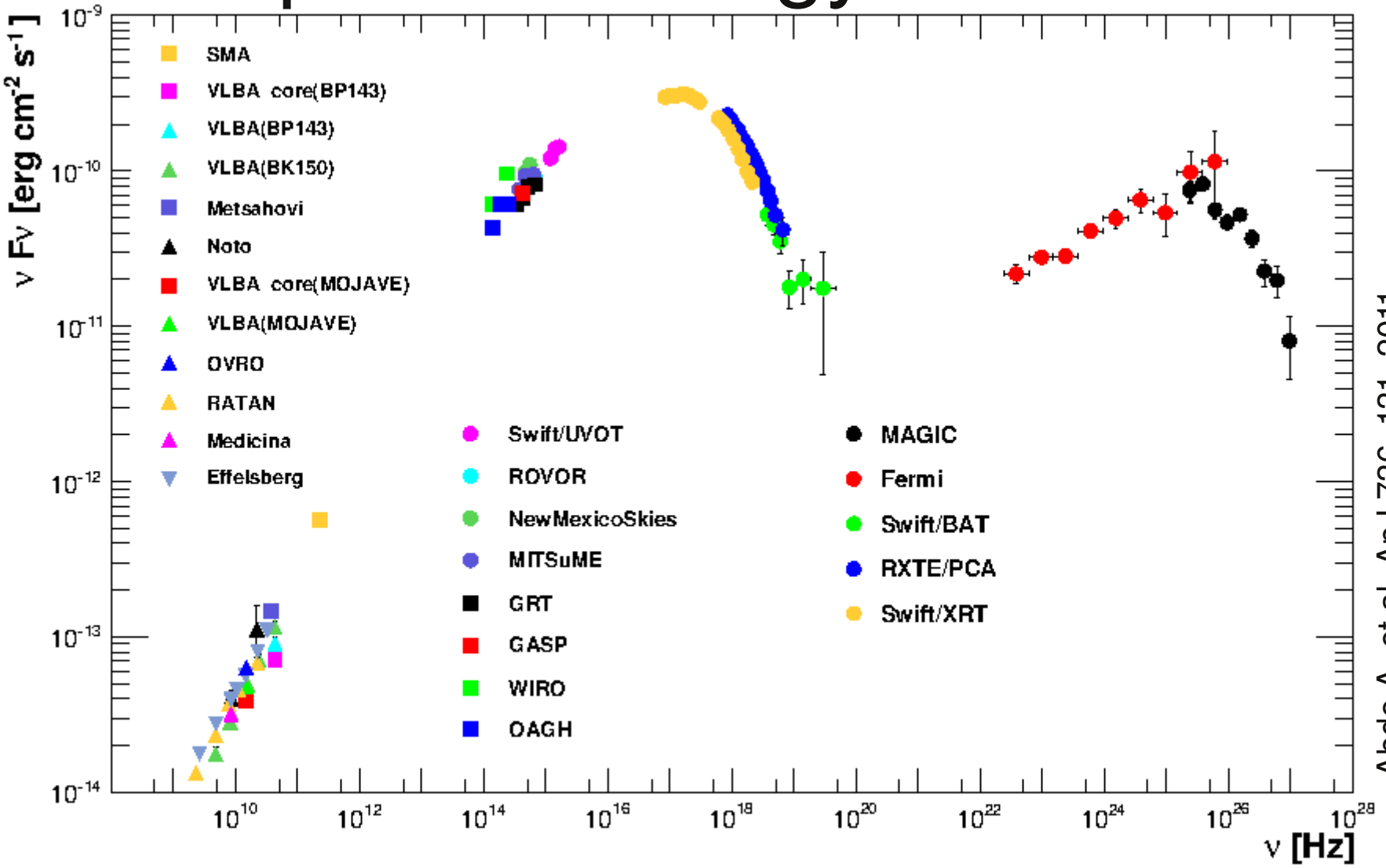
Spectral Energy Distribution



Mrk 501

V. A. Acciari et al. (VERITAS), ApJ 729: 2, 2011

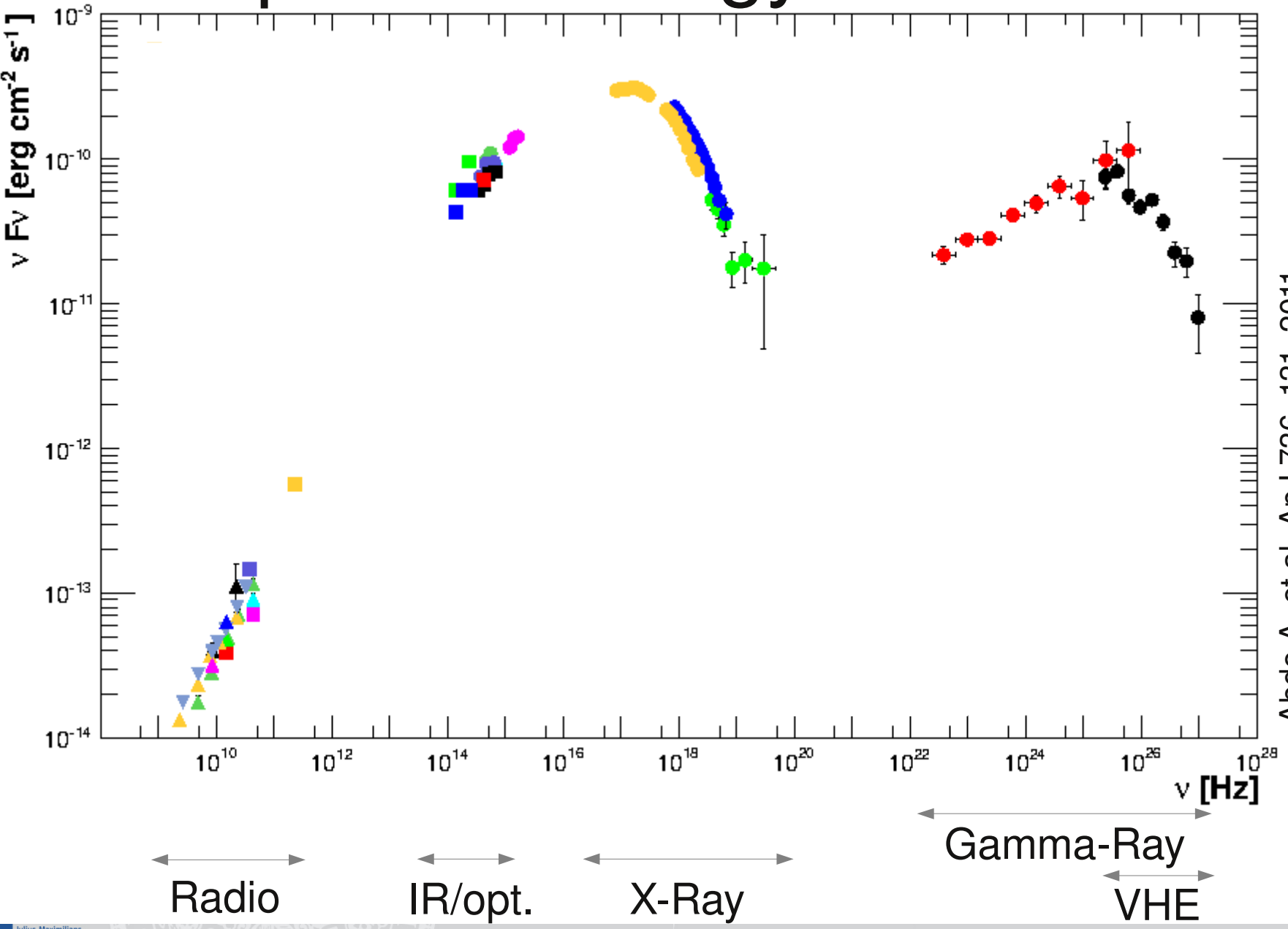
Spectral Energy Distribution



Mrk 421

Abdo A. et al. ApJ 736, 131, 2011

Spectral Energy Distribution



Mrk 421

Abdo A. et al. ApJ 736, 131, 2011

Radio

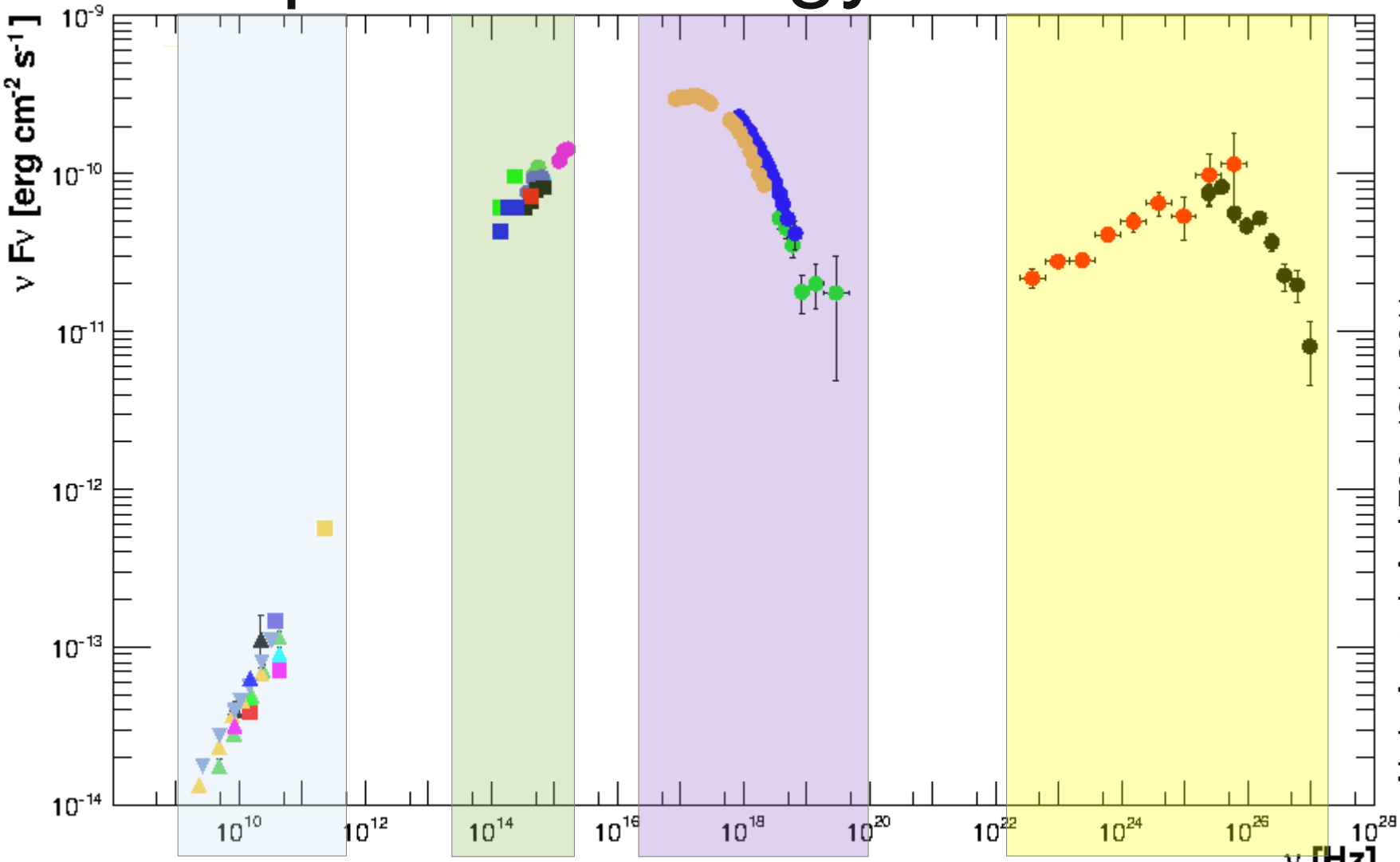
IR/opt.

X-Ray

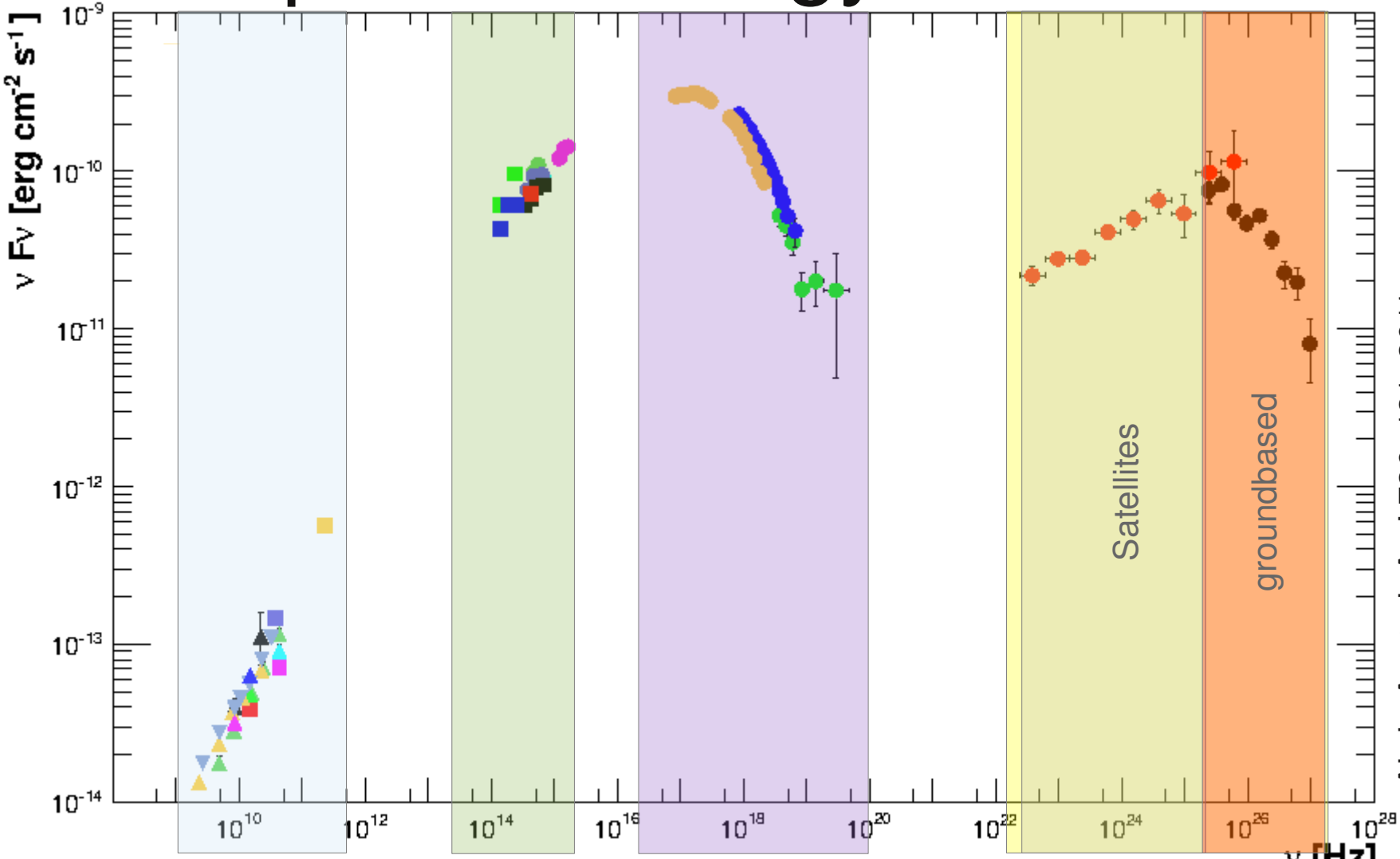
Gamma-Ray

VHE

Spectral Energy Distribution



Spectral Energy Distribution



Mrk 421

Abdo A. et al. ApJ 736, 131, 2011

Radio

IR/opt.

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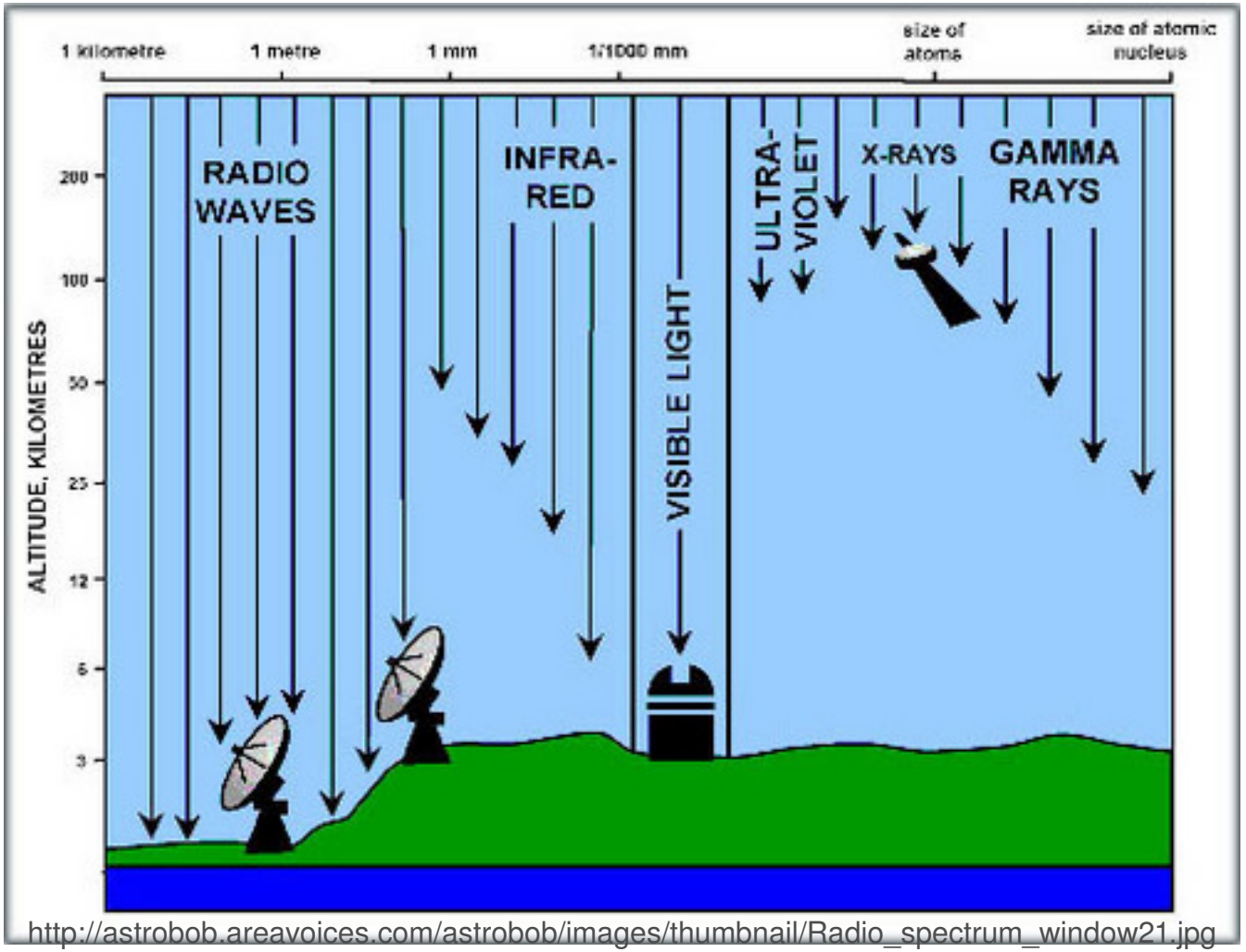
VHE

Gamma-Ray Astronomy

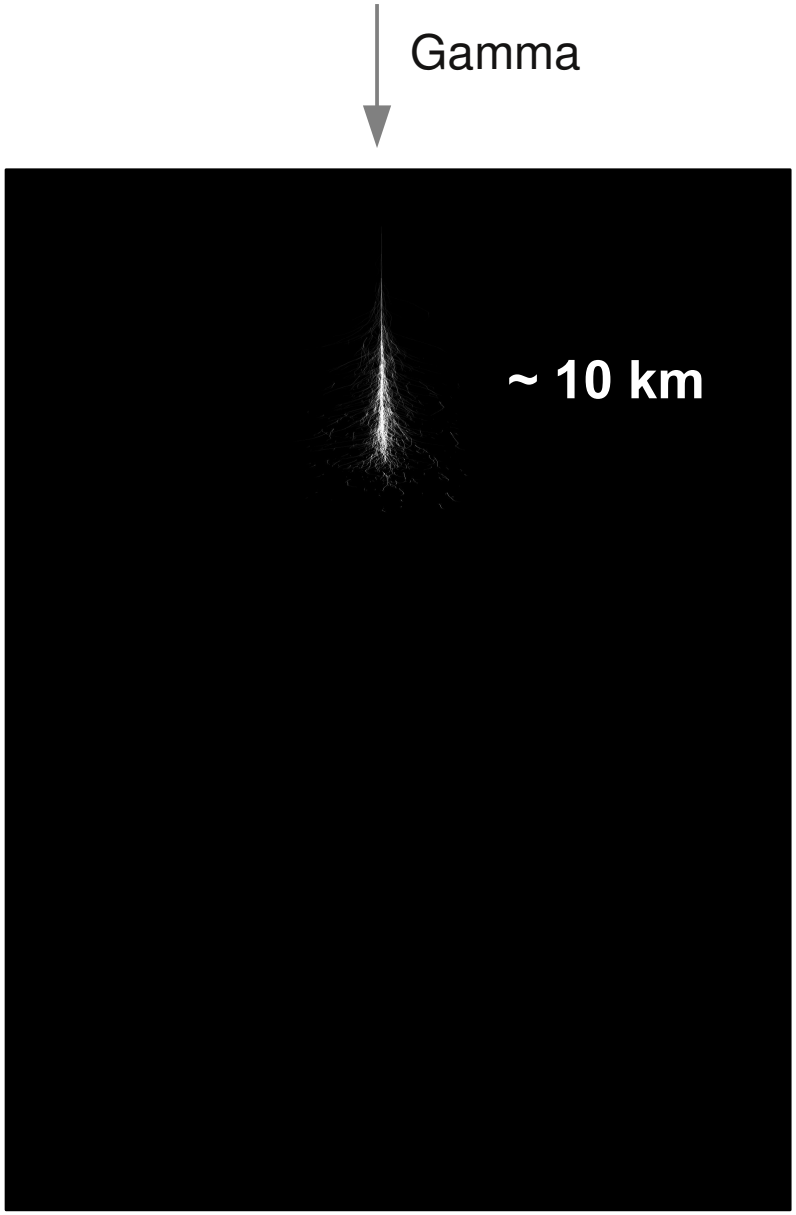


http://astrobob.areavoices.com/astrobob/images/thumbnail/Radio_spectrum_window21.jpg

Atmosphere is not transparent to gamma rays

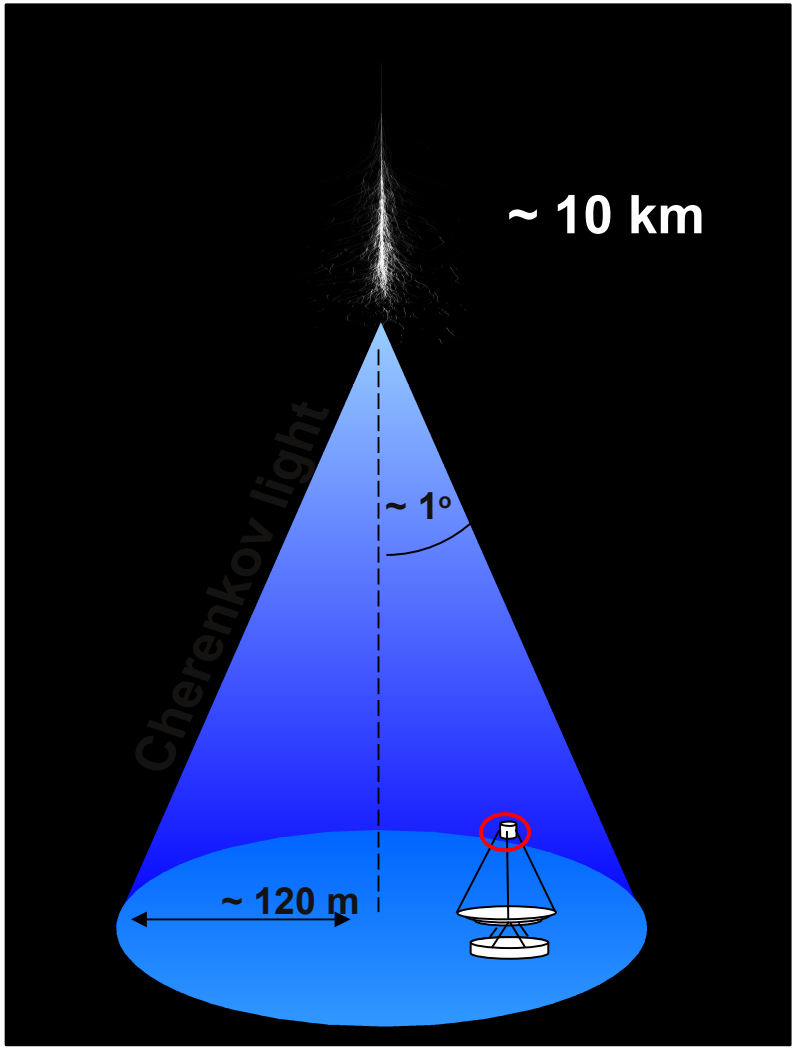
→ indirect detection method from ground

Imaging Air Cherenkov Technique



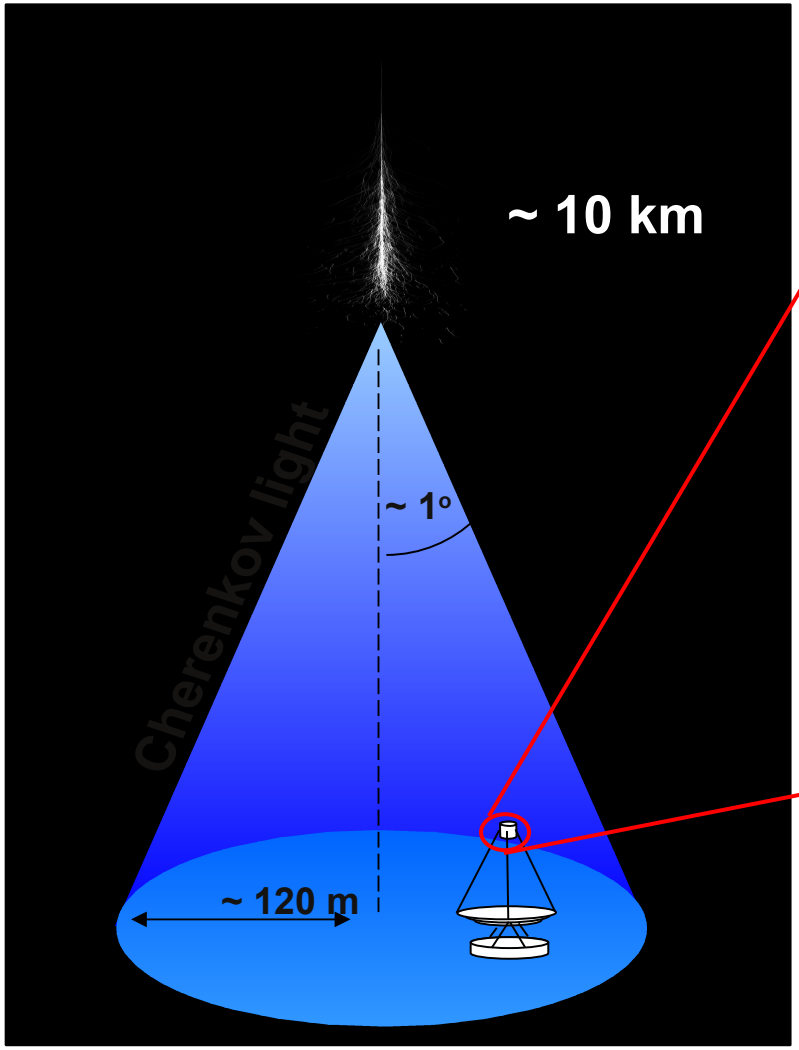
Particle shower

Imaging Air Cherenkov Technique



Emission of
Cherenkov light

Imaging Air Cherenkov Technique



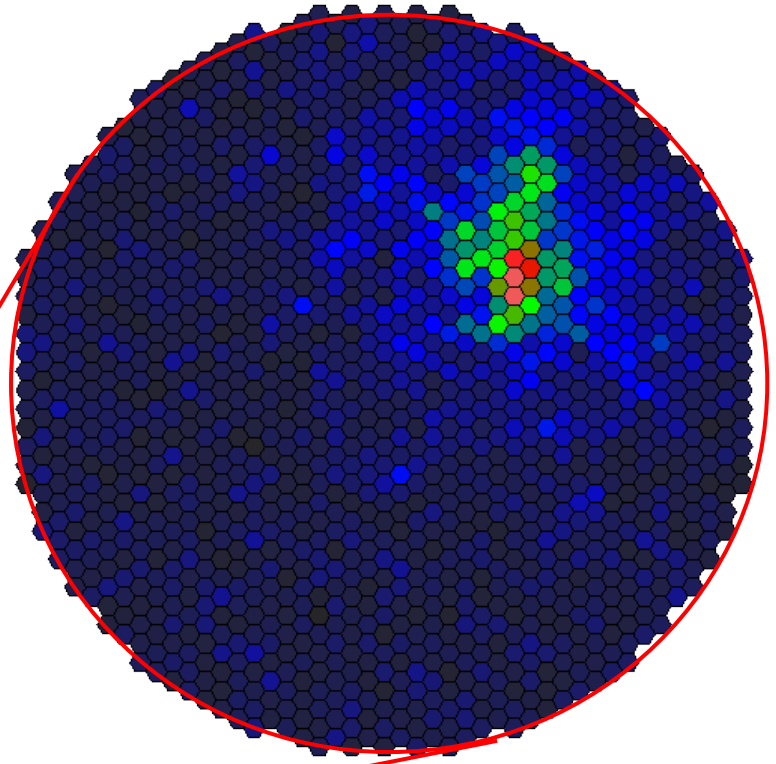
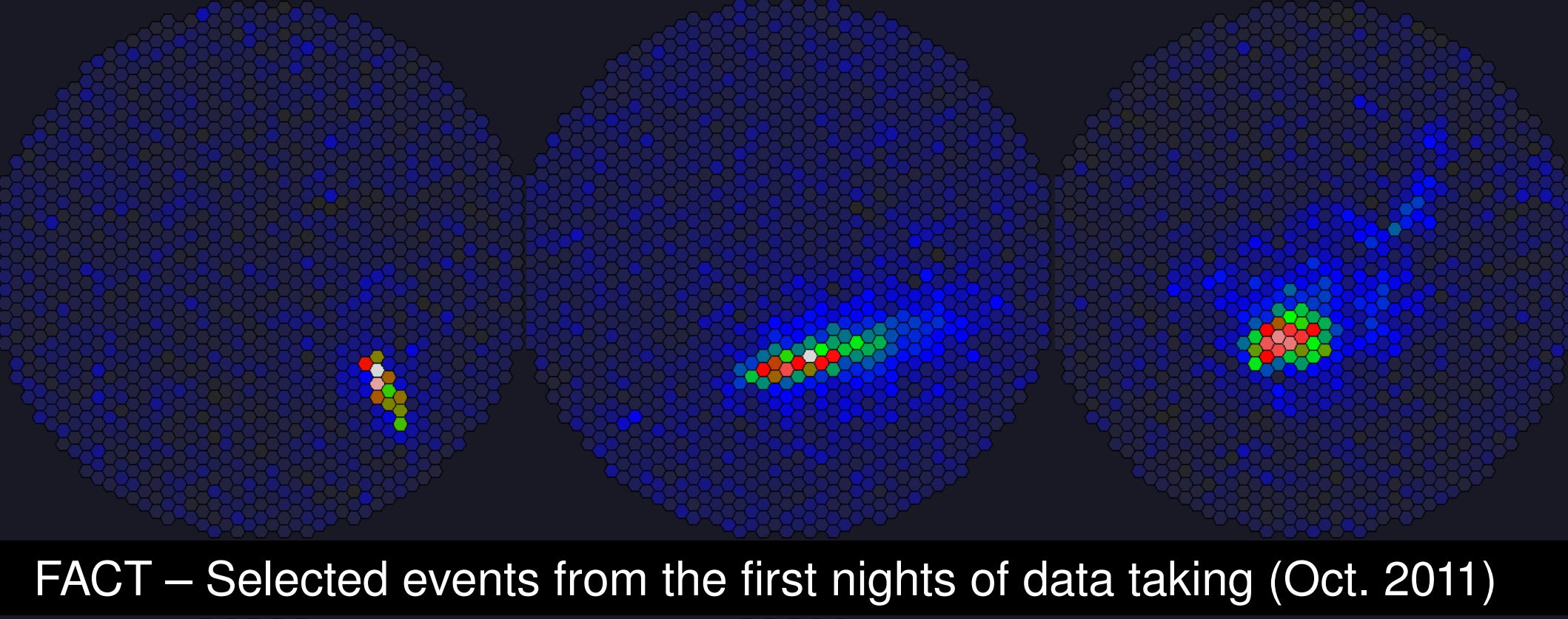
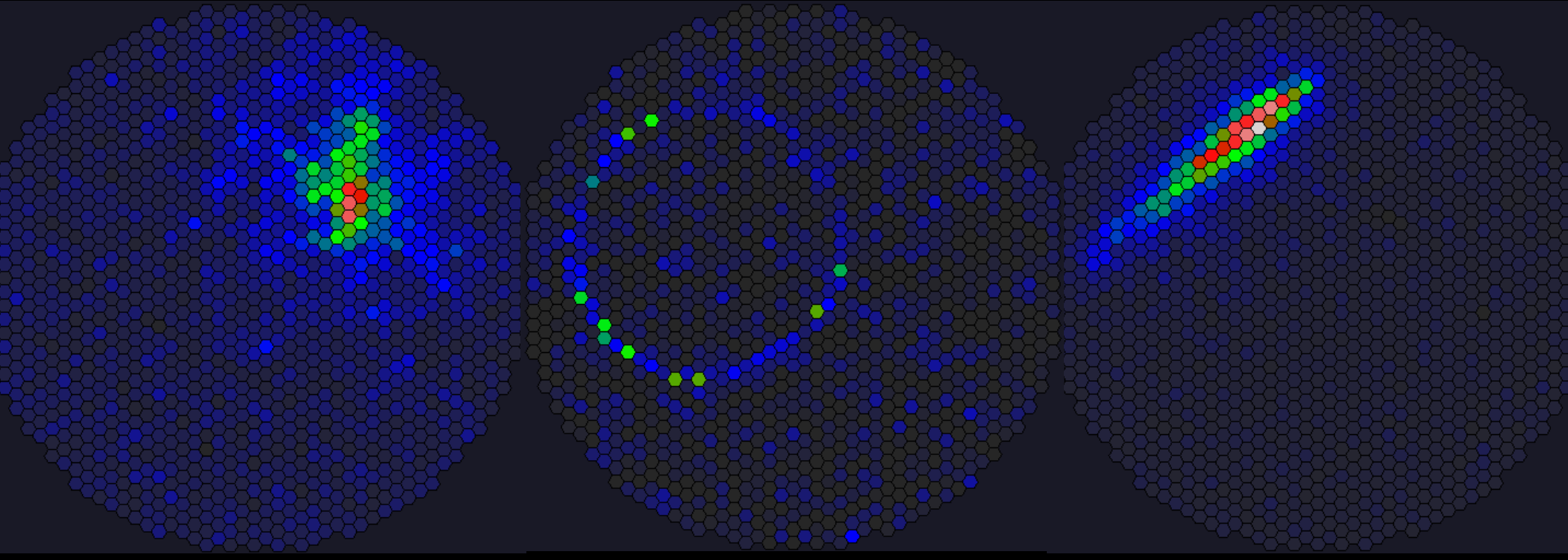


Image in the camera

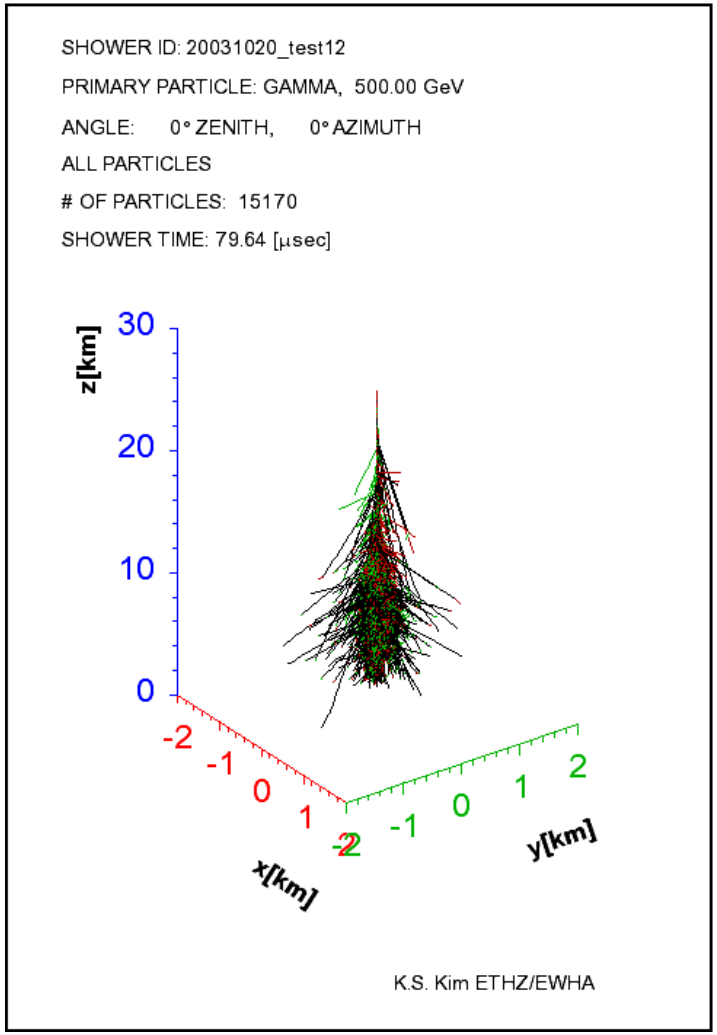


FACT – Selected events from the first nights of data taking (Oct. 2011)

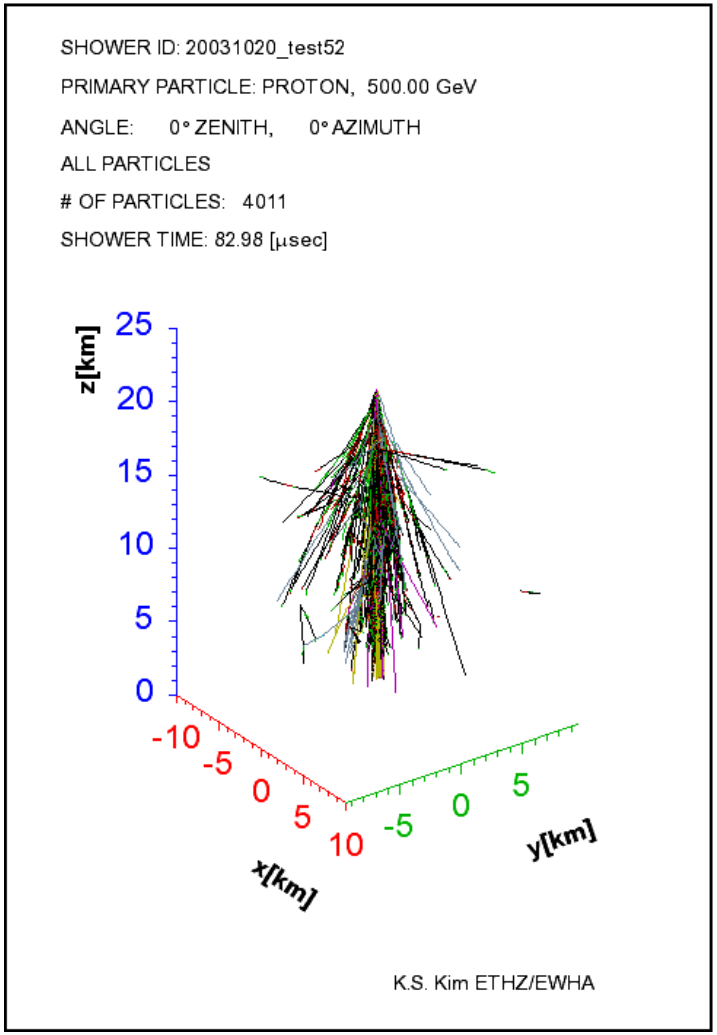


IACT: Background

1 Gamma

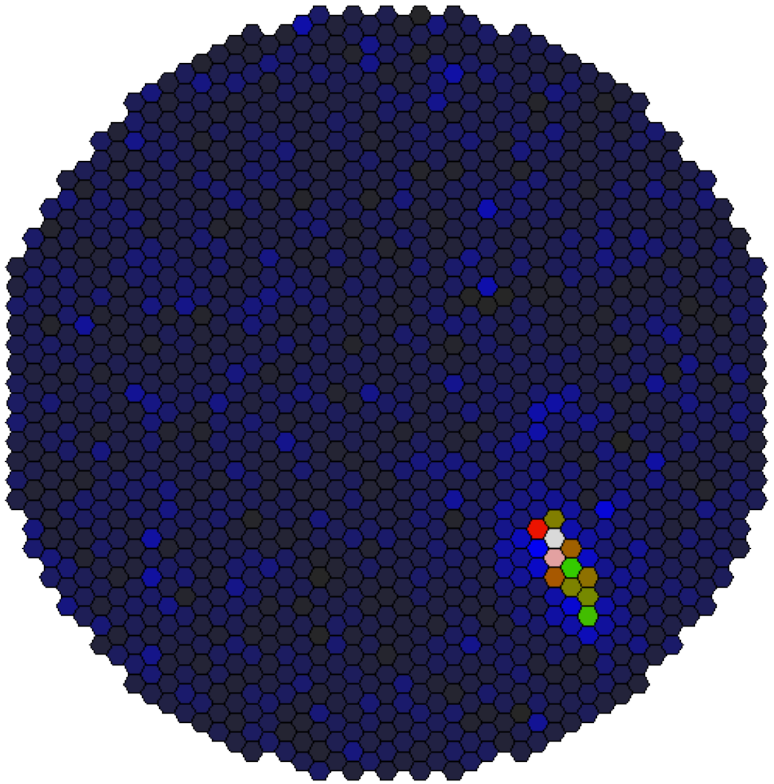


1000 Background

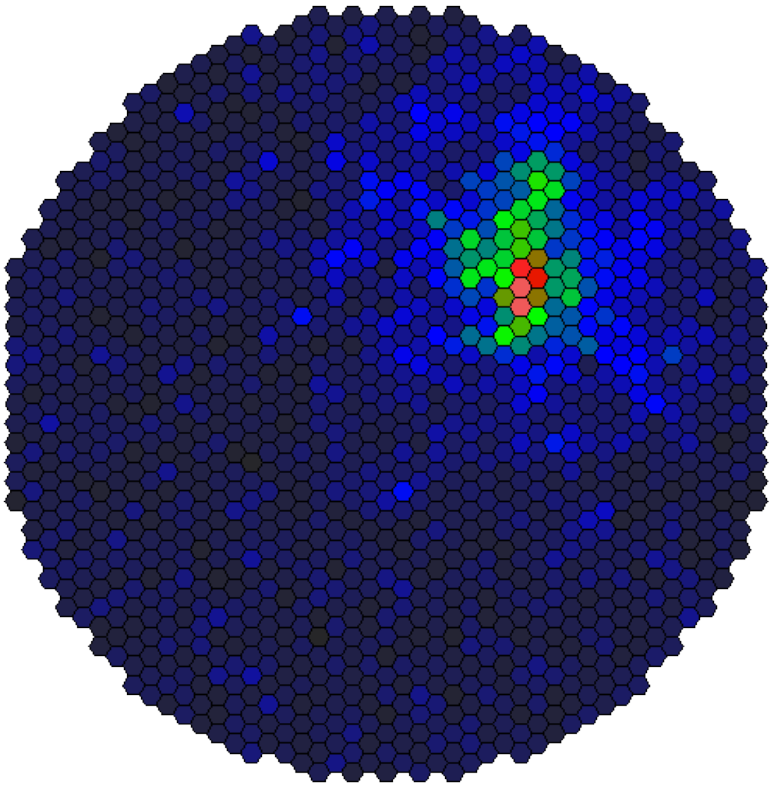


IACT: Background Suppression

1 Gamma



1000 Background



Shower morphology → Reconstruction of particle type

IACT: Shower Origin

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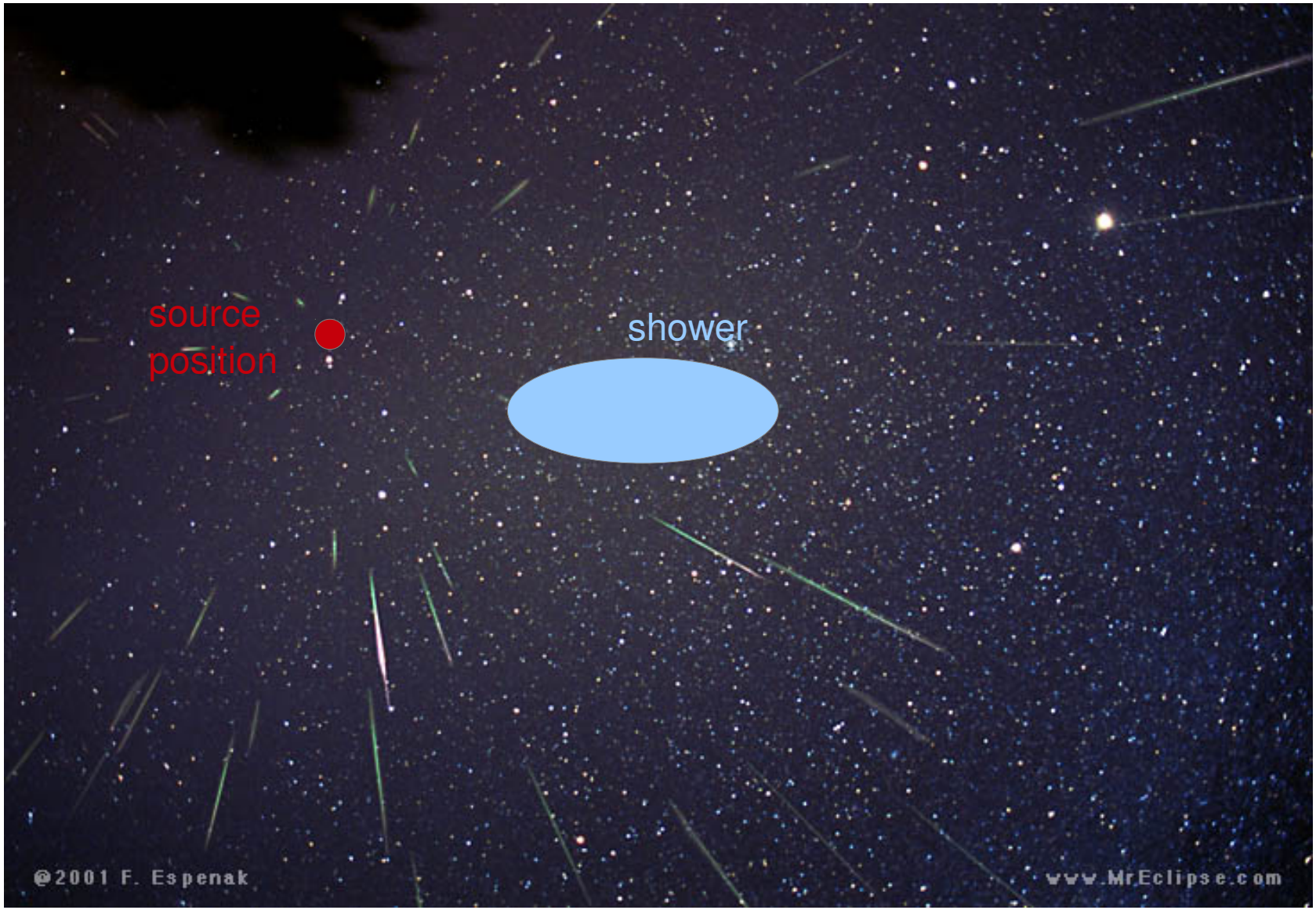
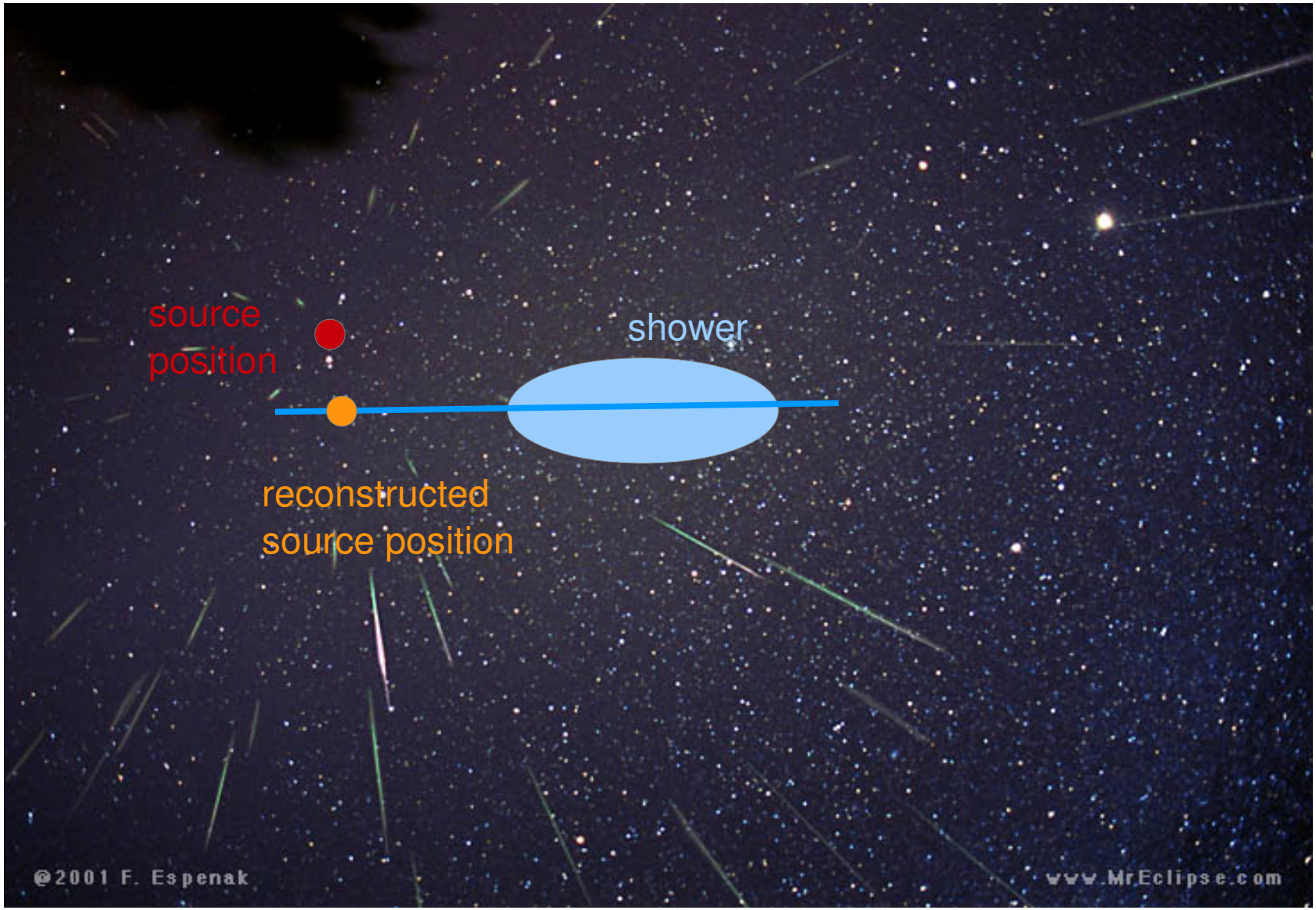
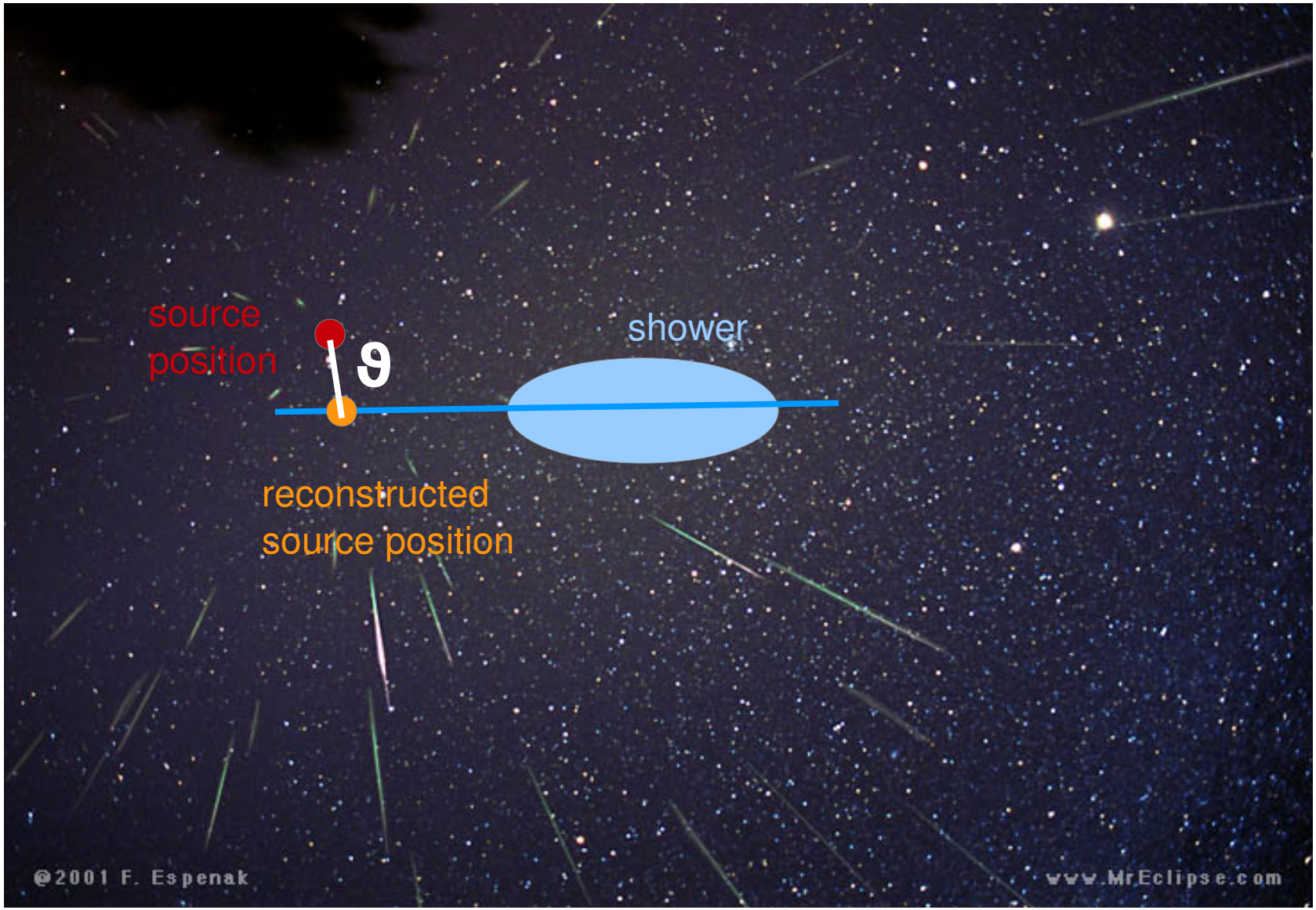


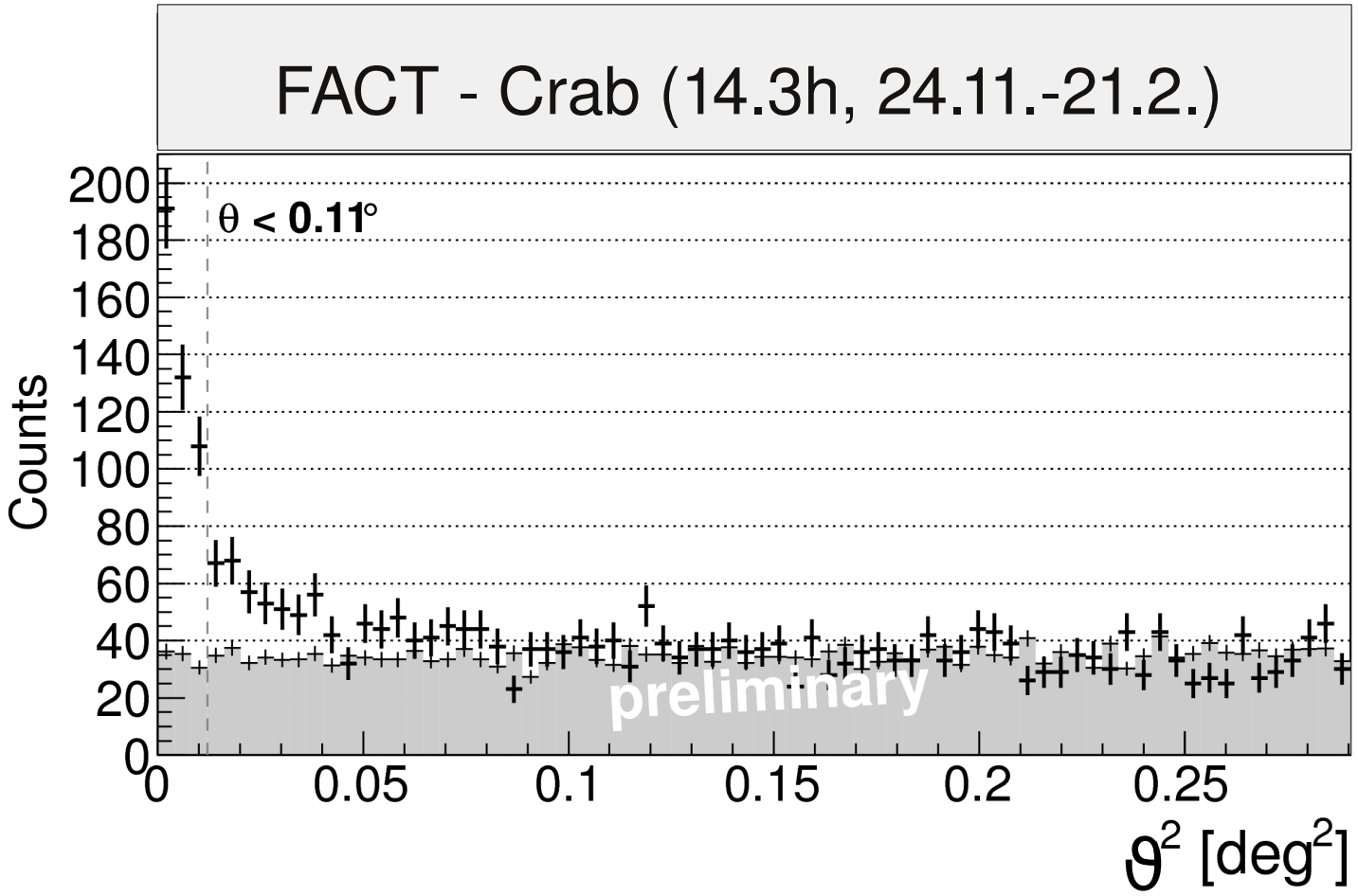
IACT: Shower Origin



IACT: Shower Origin

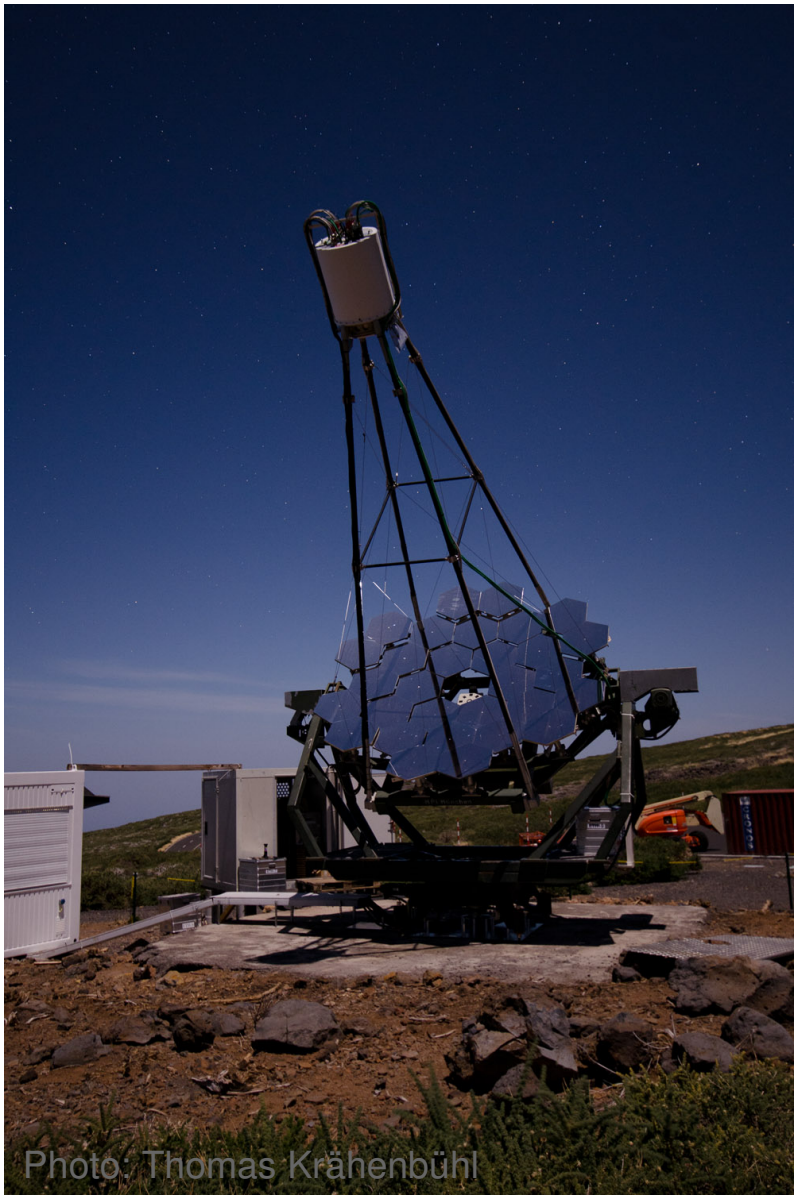


IACT: Signal Detection



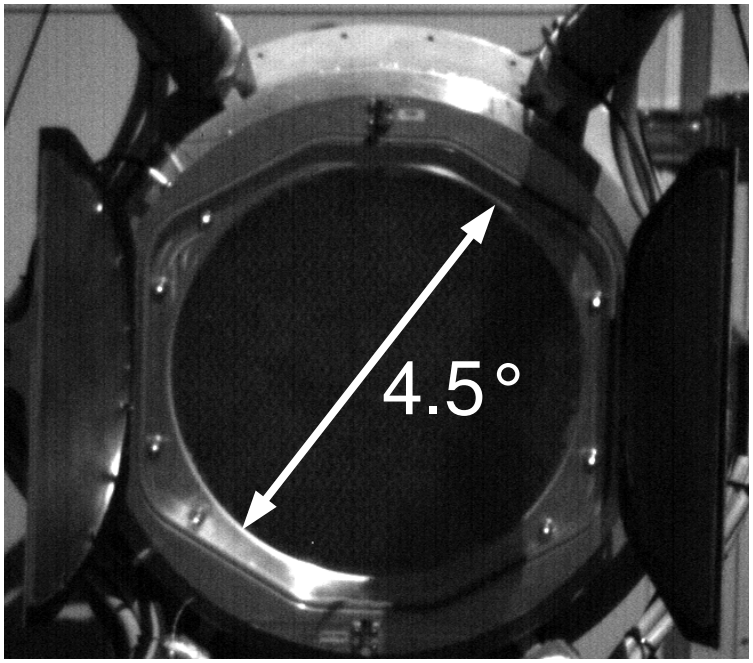
Angle between reconstructed shower origin and target position → Excess in signal region

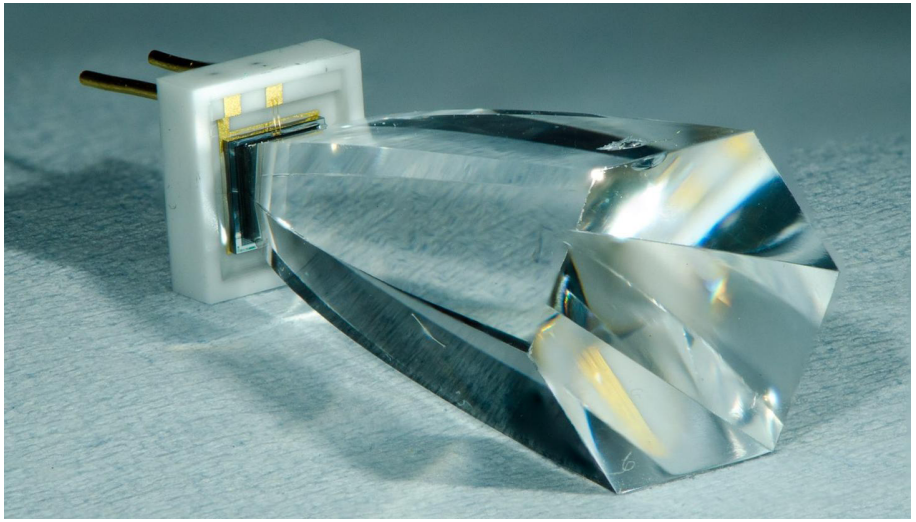
Facts about FACT



- 2200 m a.s.l.
  Observatorio del Roque de los Muchachos, La Palma
- Operational since Oct 2011
- 9.5 m² mirror area
- G-APD camera
- More Details:
  Design and operation of FACT – the first G-APD Cherenkov telescope
  H Anderhub et al 2013 JINST 8 P06008

G-APD Camera





- Silicon based photo sensor: G-APDs aka SiPM
- Solid cones
- 1440 Pixels (0.11° each)
- 4.5° FoV
- More Details:

  Design and operation of FACT – the first G-APD Cherenkov telescope

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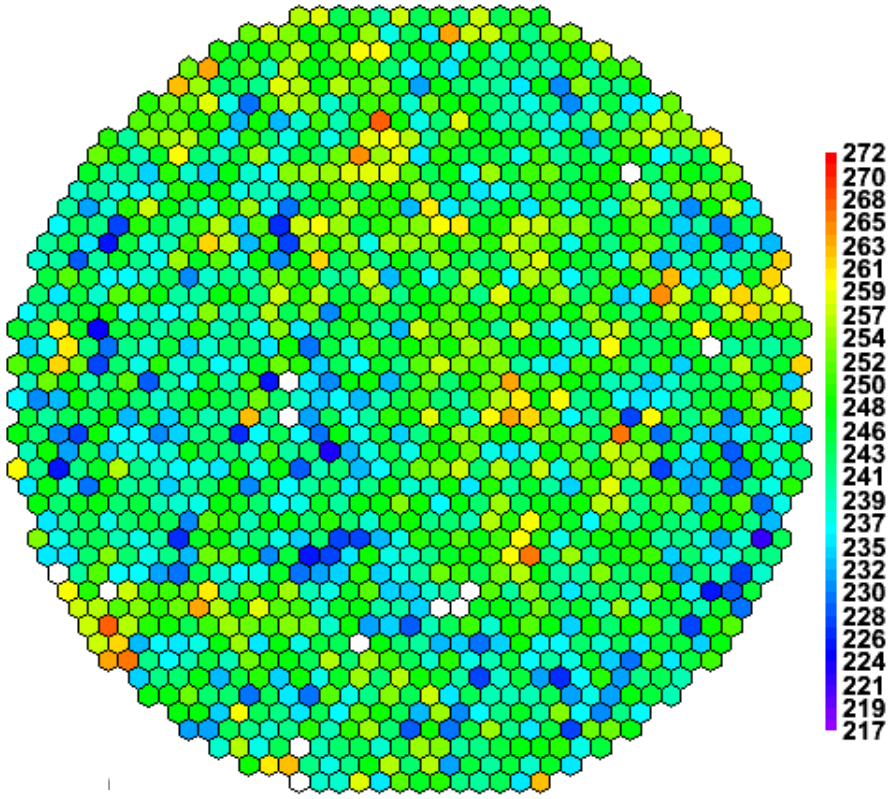
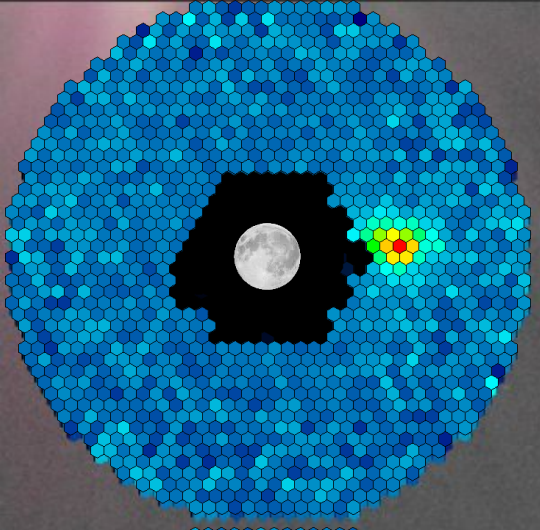
G-APD Camera

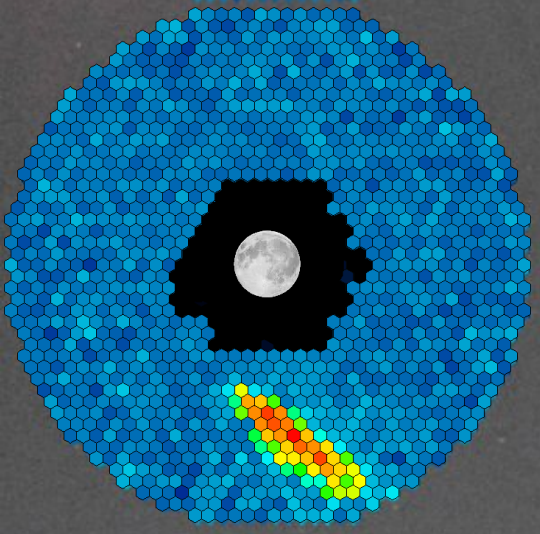
Voltage
correction applied

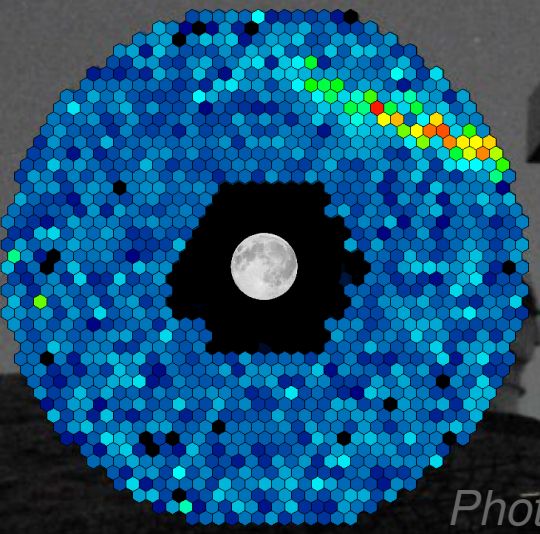


σ ~ 2.3%

- Keep the G-APD gain stable (feedback system)
  → Stable observation conditions
- No aging from strong ambient light
  → Observations during strong moon light possible
- More Details:
  Calibration and performance of the photo sensor response of FACT
  Biland et al. **arXiv:1403.5747**







Shower images recorded pointing to brightest moon of the year.

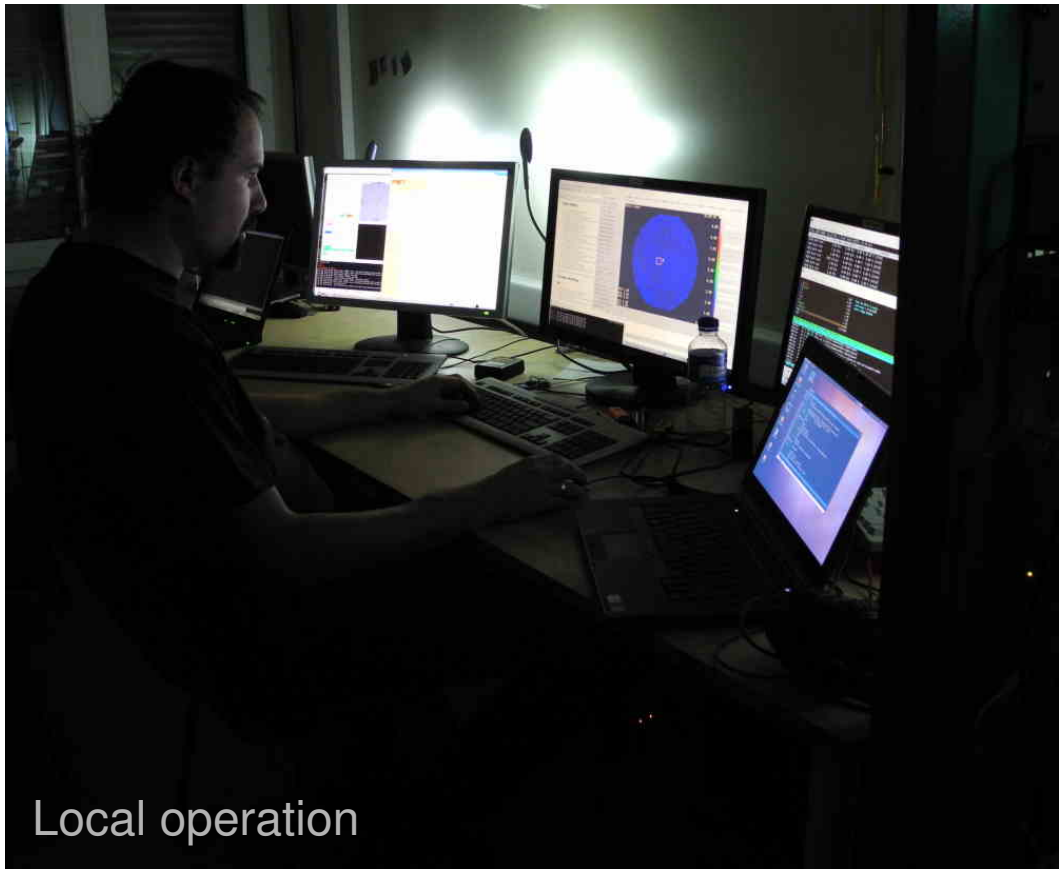
Photos: D. Dorner, T. Krähenbühl

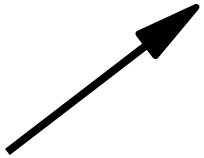
G-APDs – the Revolution in Cherenkov Astronomy

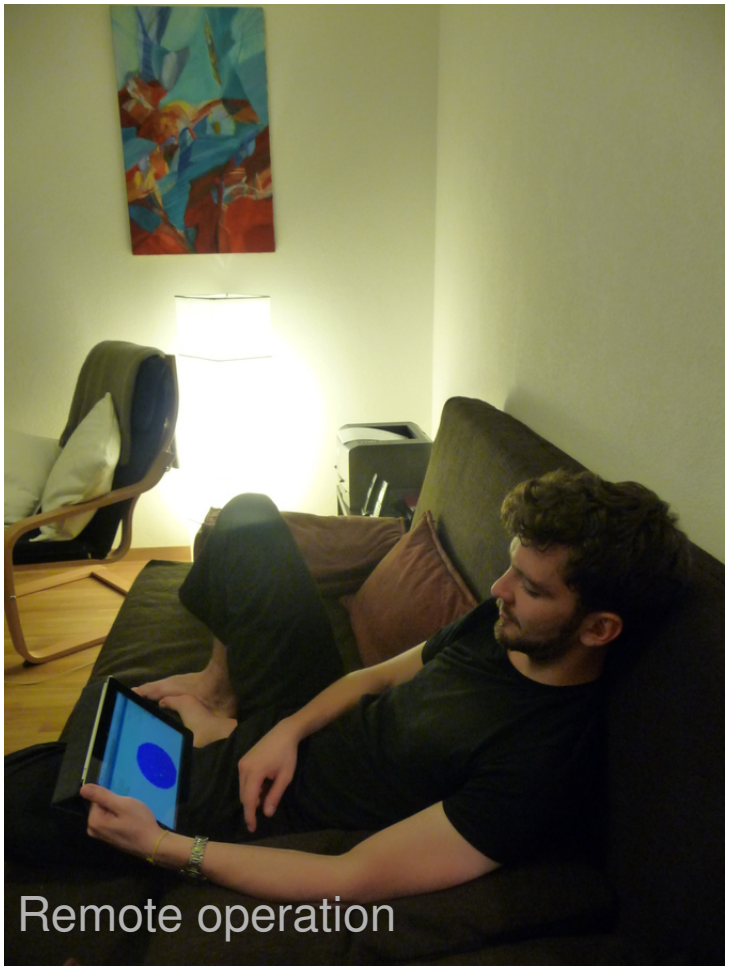

Photo: Daniela Dorner

- Robust and stable
  → Stable telescope performance

Towards Robotic Operation

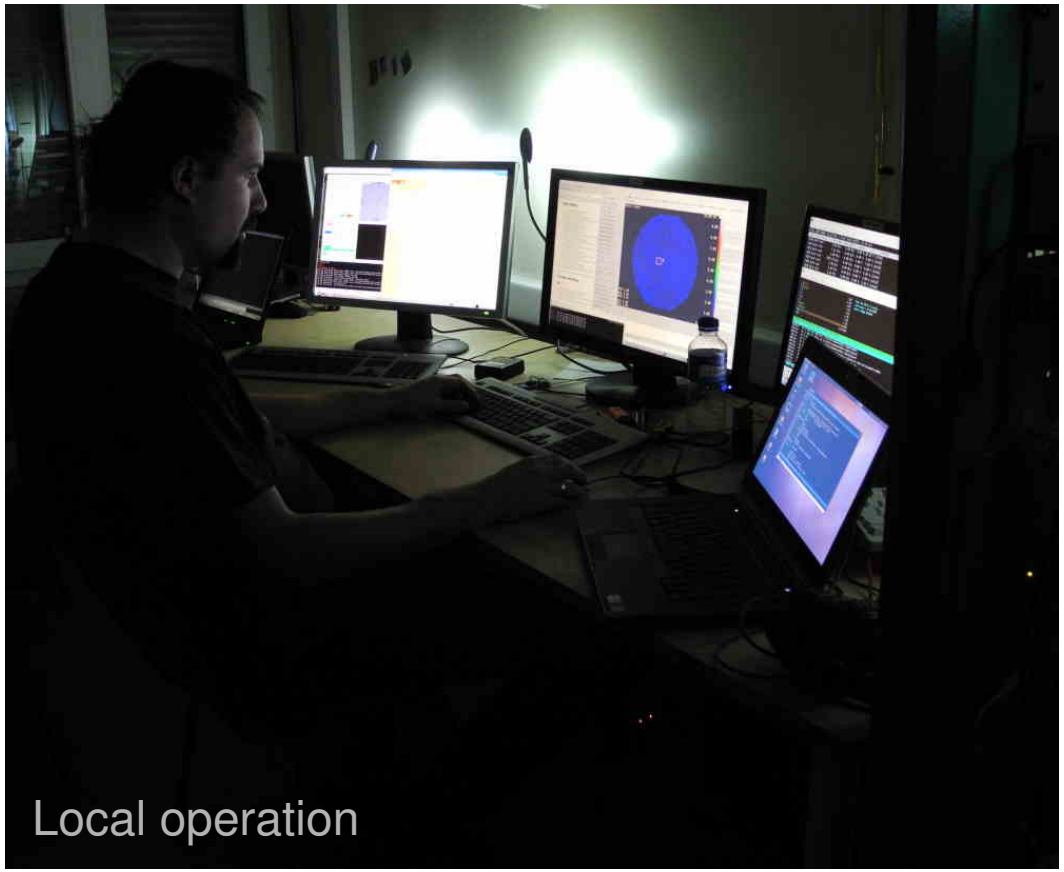


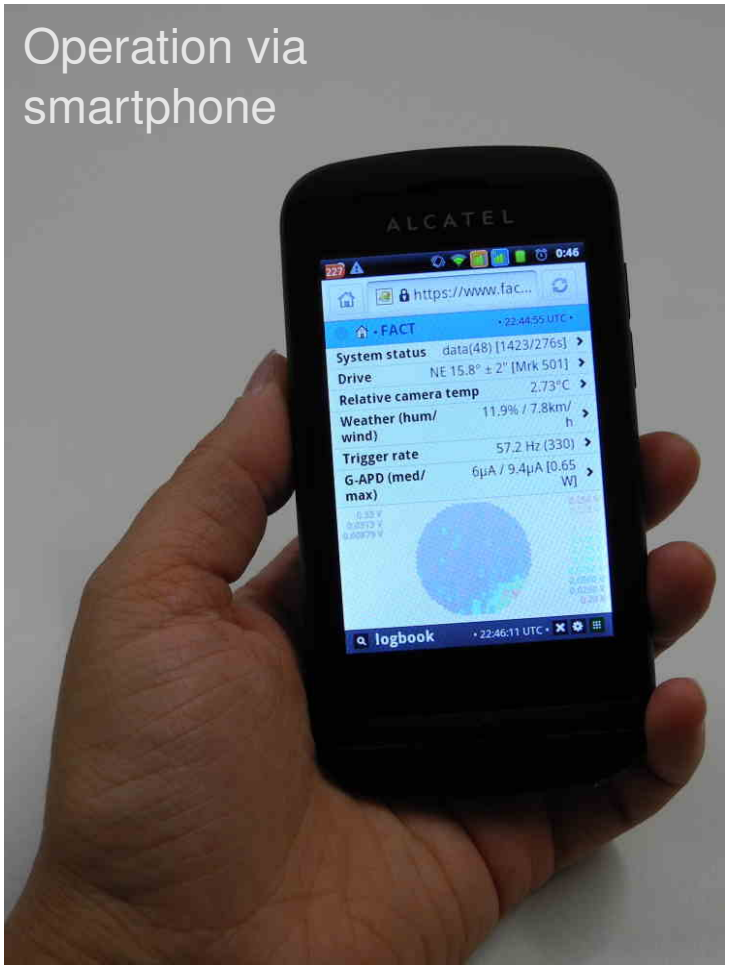




http://www.fact-project.org/smartfact

Towards Robotic Operation





Automatic Operation

http://www.fact-project.org/smartfact

G-APDs – the Revolution in Cherenkov Astronomy


Photo: Daniela Dorner

- Robust and stable
  → Stable telescope performance
  → High data taking efficiency

G-APDs – the Revolution in Cherenkov Astronomy

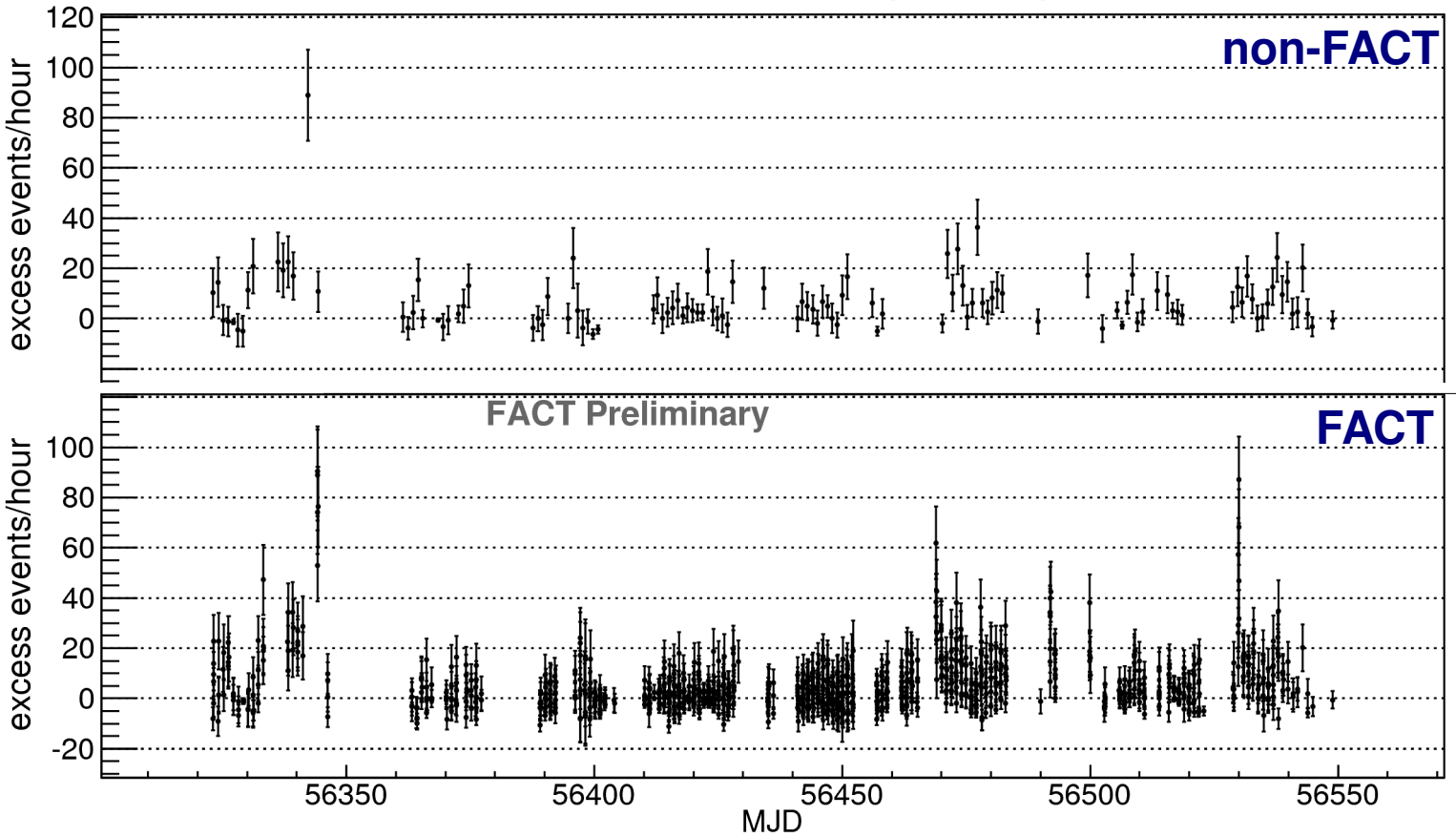

Photo: Daniela Dorner

- Robust and stable
  → Stable telescope performance
  → High data taking efficiency
- Observations during strong moon light
  → Larger duty cycle
  → More complete data sample

Ideal for Monitoring

Long-term Monitoring

Markarian 501 (2013)

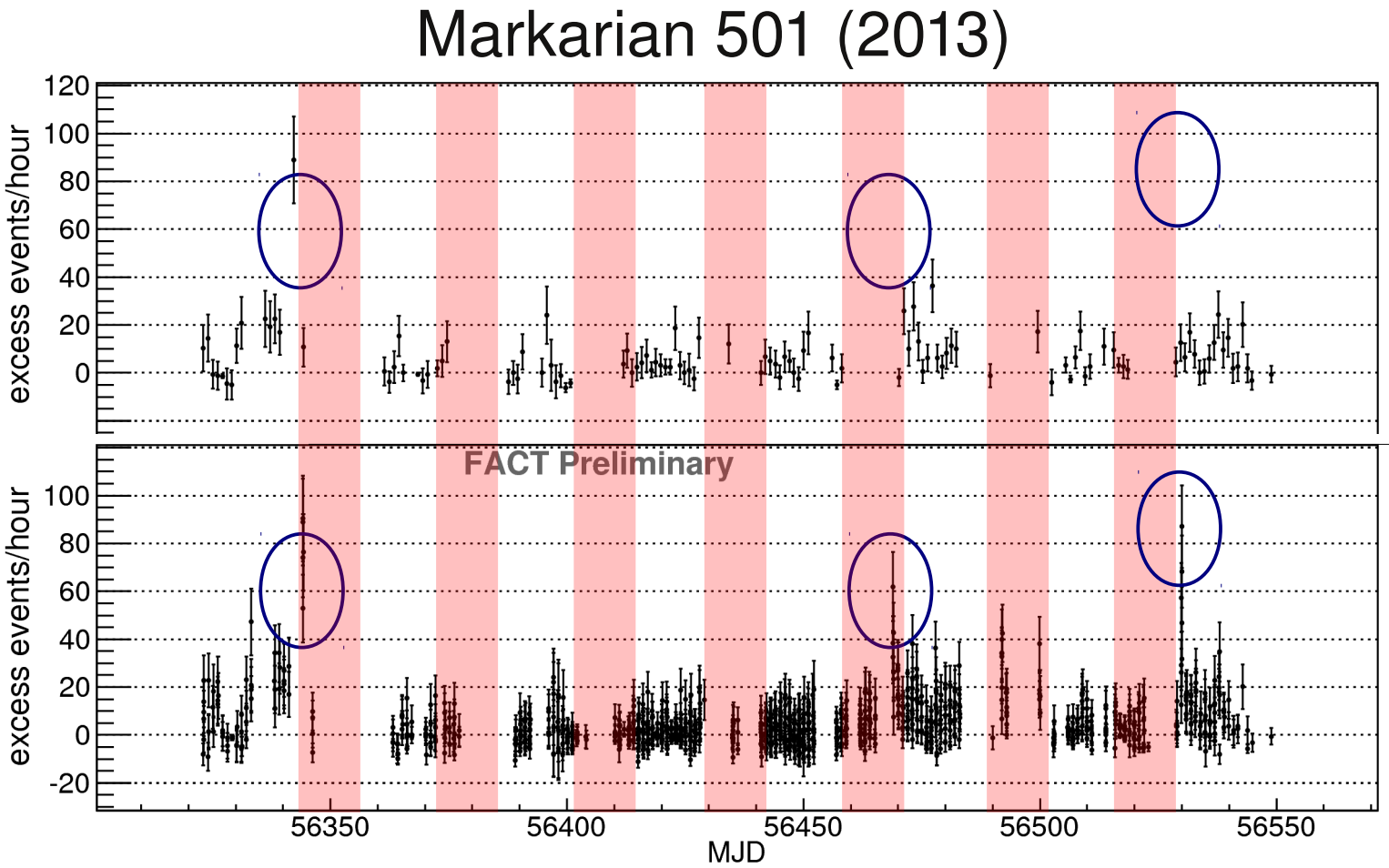


Limited to:

- moon disk < 65%
  ~320h
- 1 · 20min / night
  ~43h

All data ~430h

Long-term Monitoring



Limited to:

- moon disk < 65%
  ~320h
- 1 · 20min / night
  ~43h

All data ~430h

=> Collect enough statistics to study flare probabilities and flare properties

Ideal Case: 24/7 Monitoring

FACT: Observed Sources

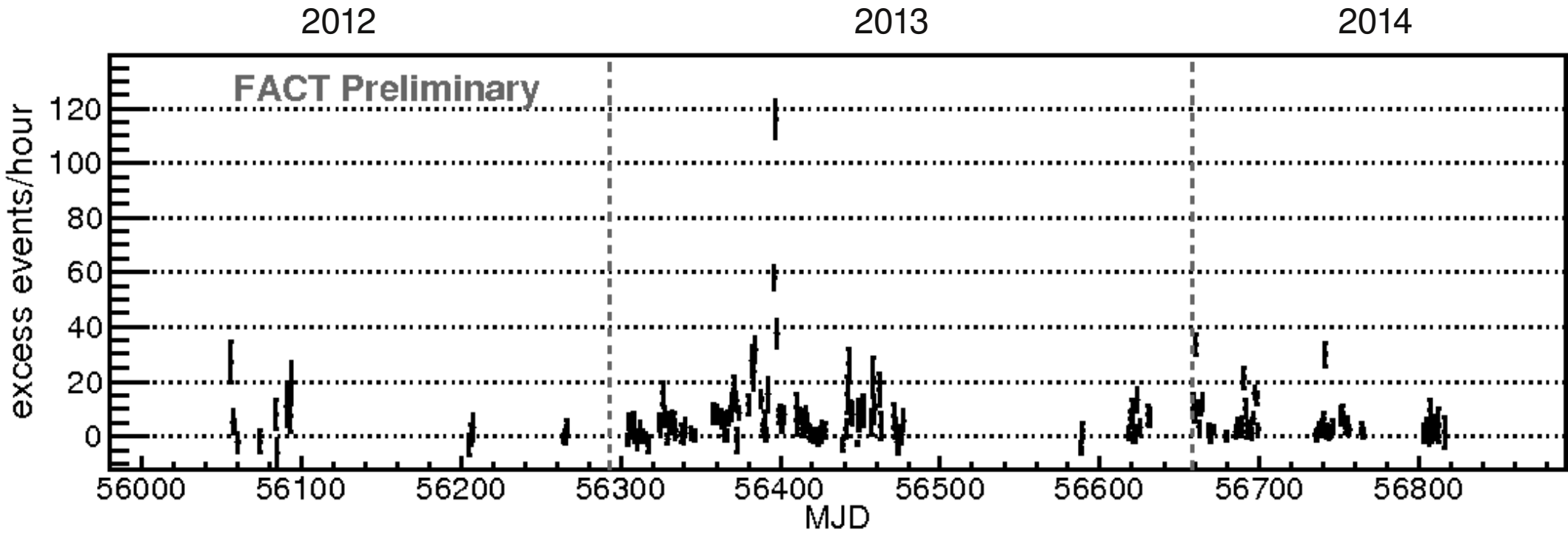
- Sources bright at TeV energies
- Crab Nebula
  → study detector performance
- Bright AGN
  → Flare studies
  → MWL observations

- Current source list
  - Crab Nebula
  - Mrk 421
  - Mrk 501
  - 1ES 1959+650
  - 1ES 2344+51.4
  - 1ES 1218+304
  - IC 310

Results – 2.5 Years of Monitoring →

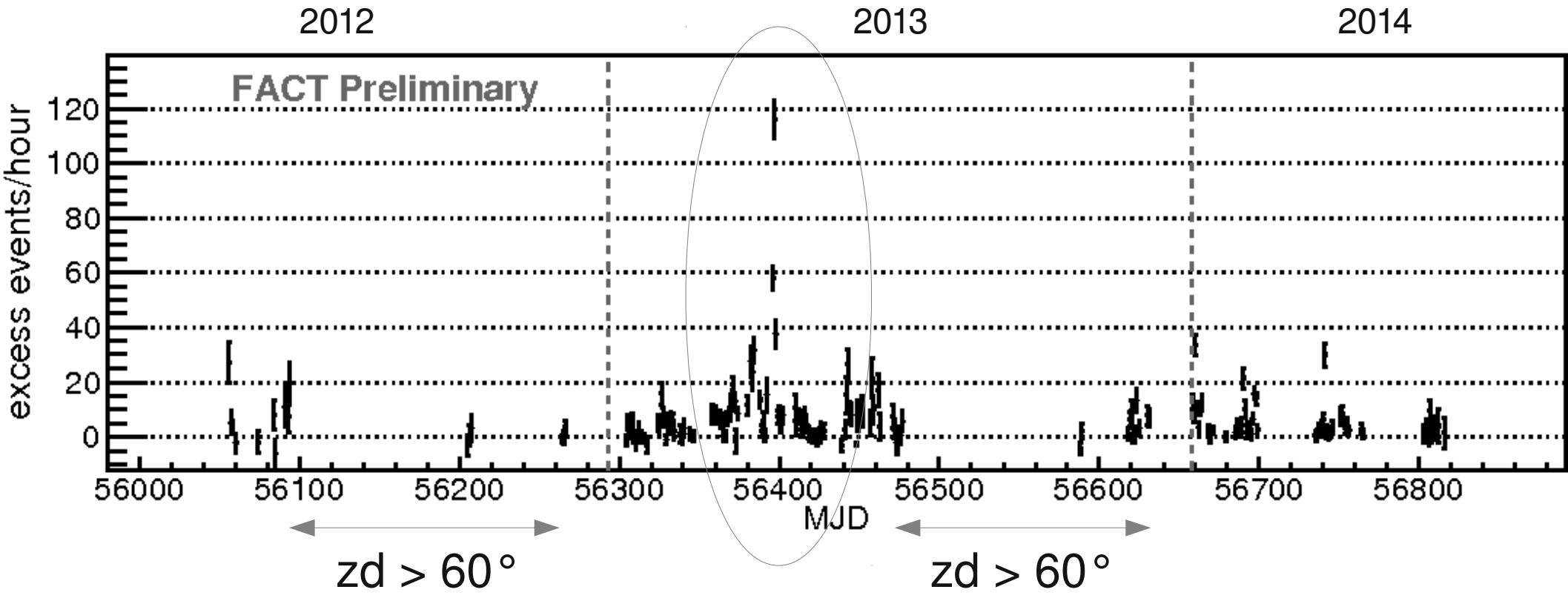
Excess Rate Curve Mrk421

May 2012 – Now



Excess Rate Curve Mrk421

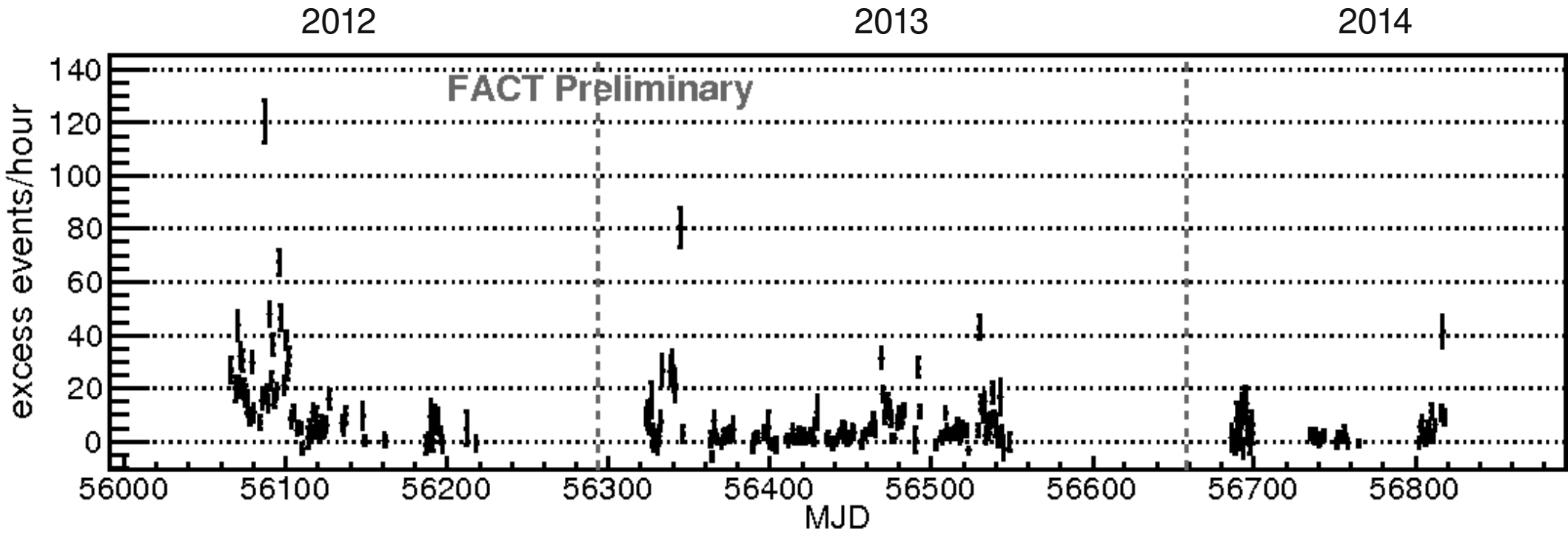
May 2012 – Now



Flare in April 2013

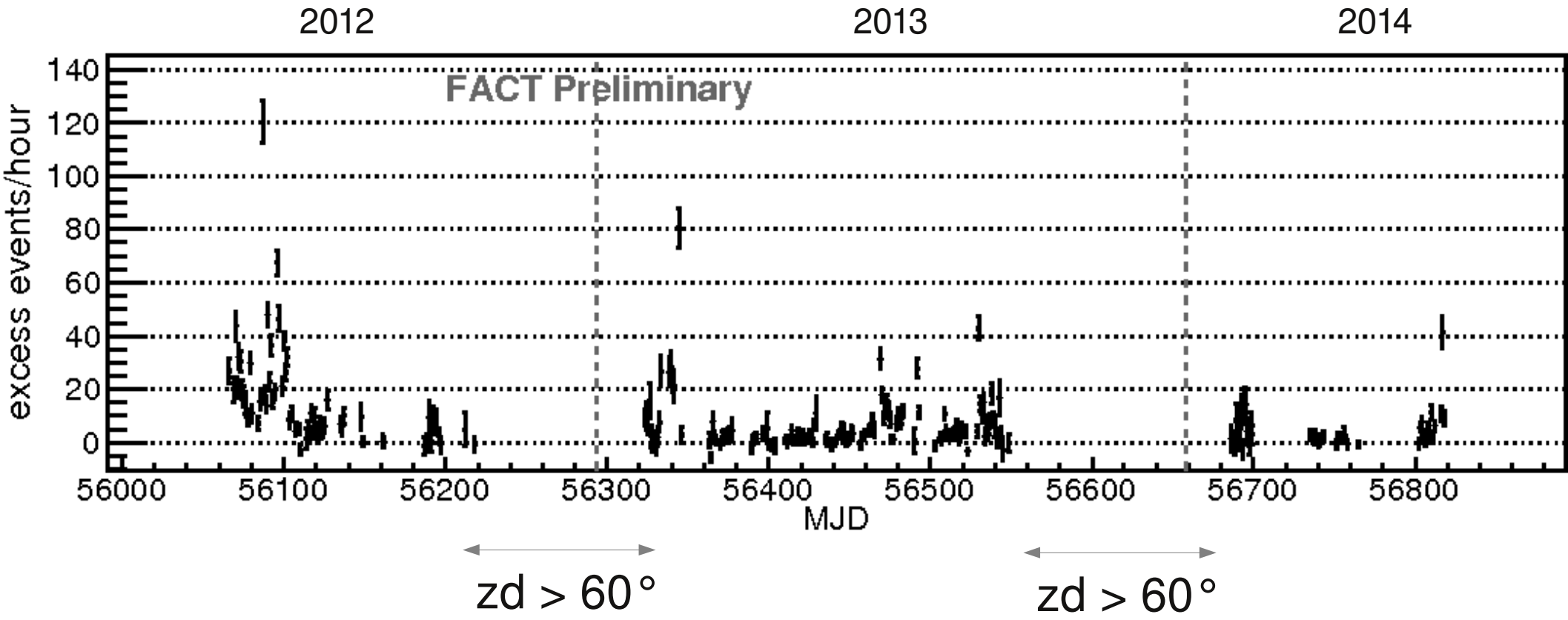
Excess Rate Curve Mrk501

May 2012 – Now



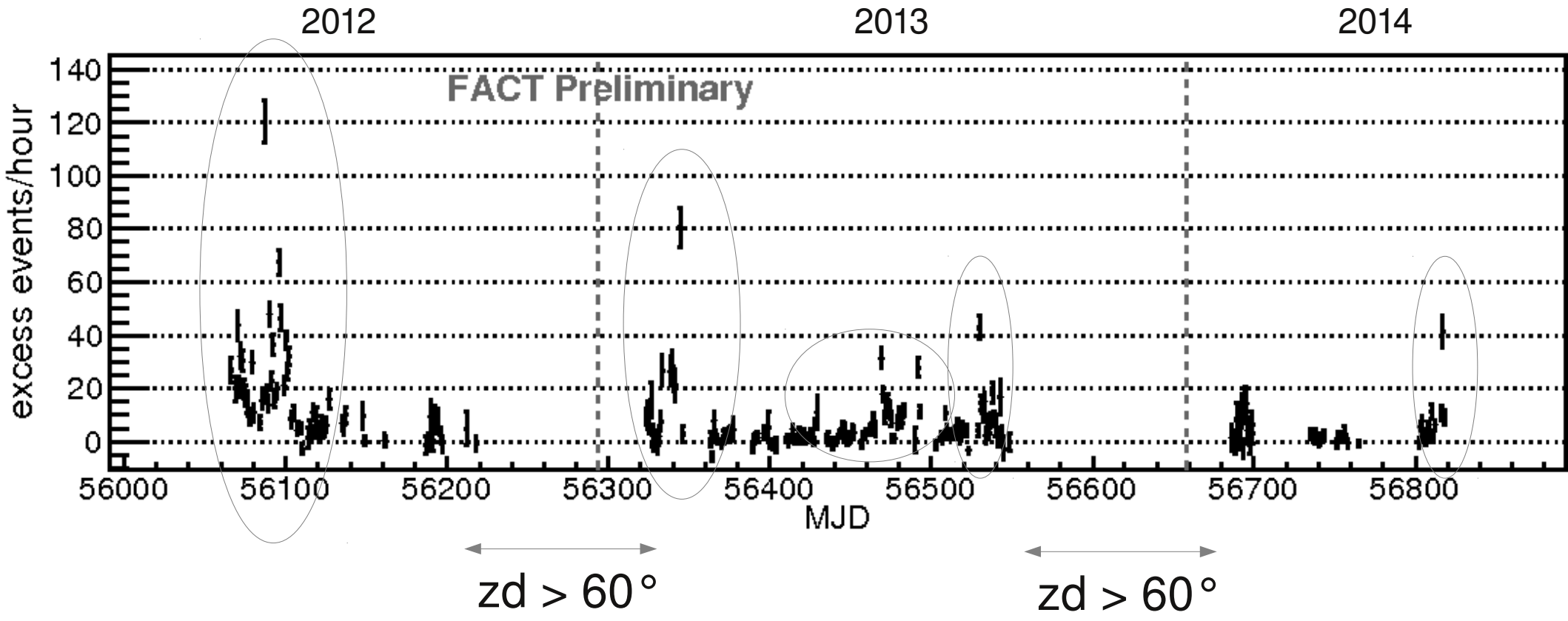
Excess Rate Curve Mrk501

May 2012 – Now



Excess Rate Curve Mrk501

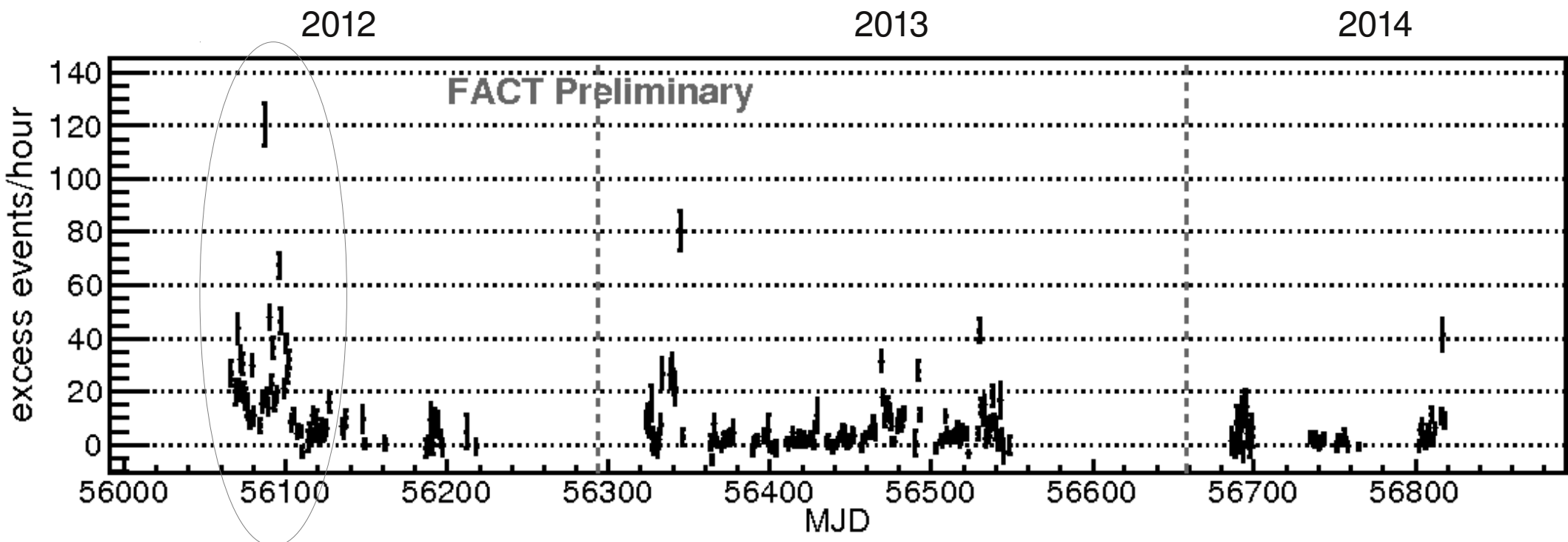
May 2012 – Now



Several flaring activities within 2 years

Excess Rate Curve Mrk501

May 2012 – Now



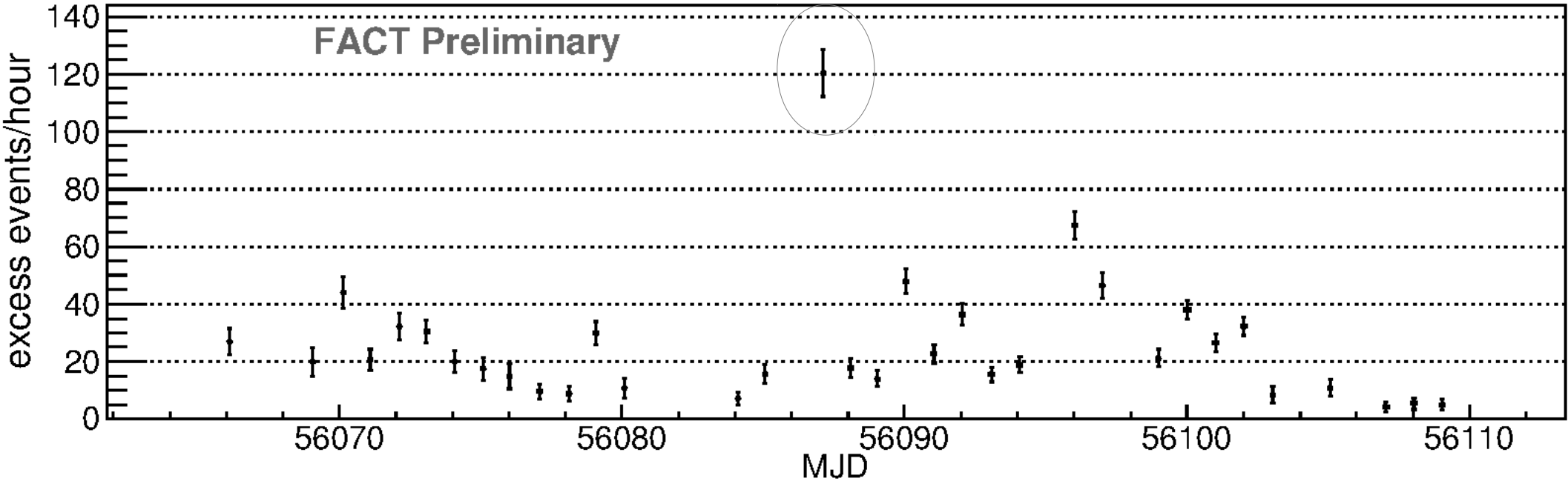
Flare in June 2012

zd > 60°

zd > 60°

Excess Rate Curve Mrk501

18.5.-30.6.2012

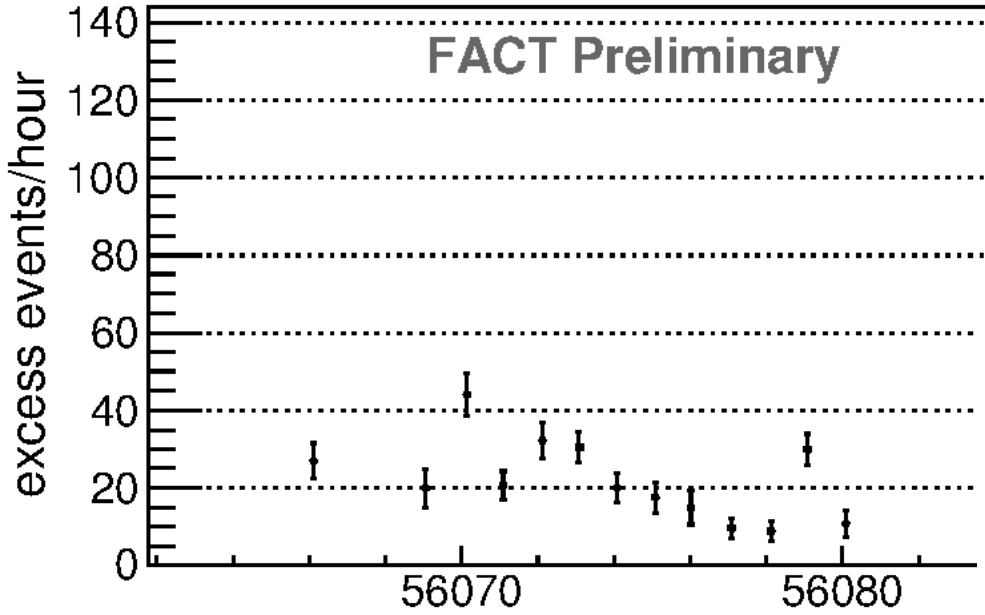


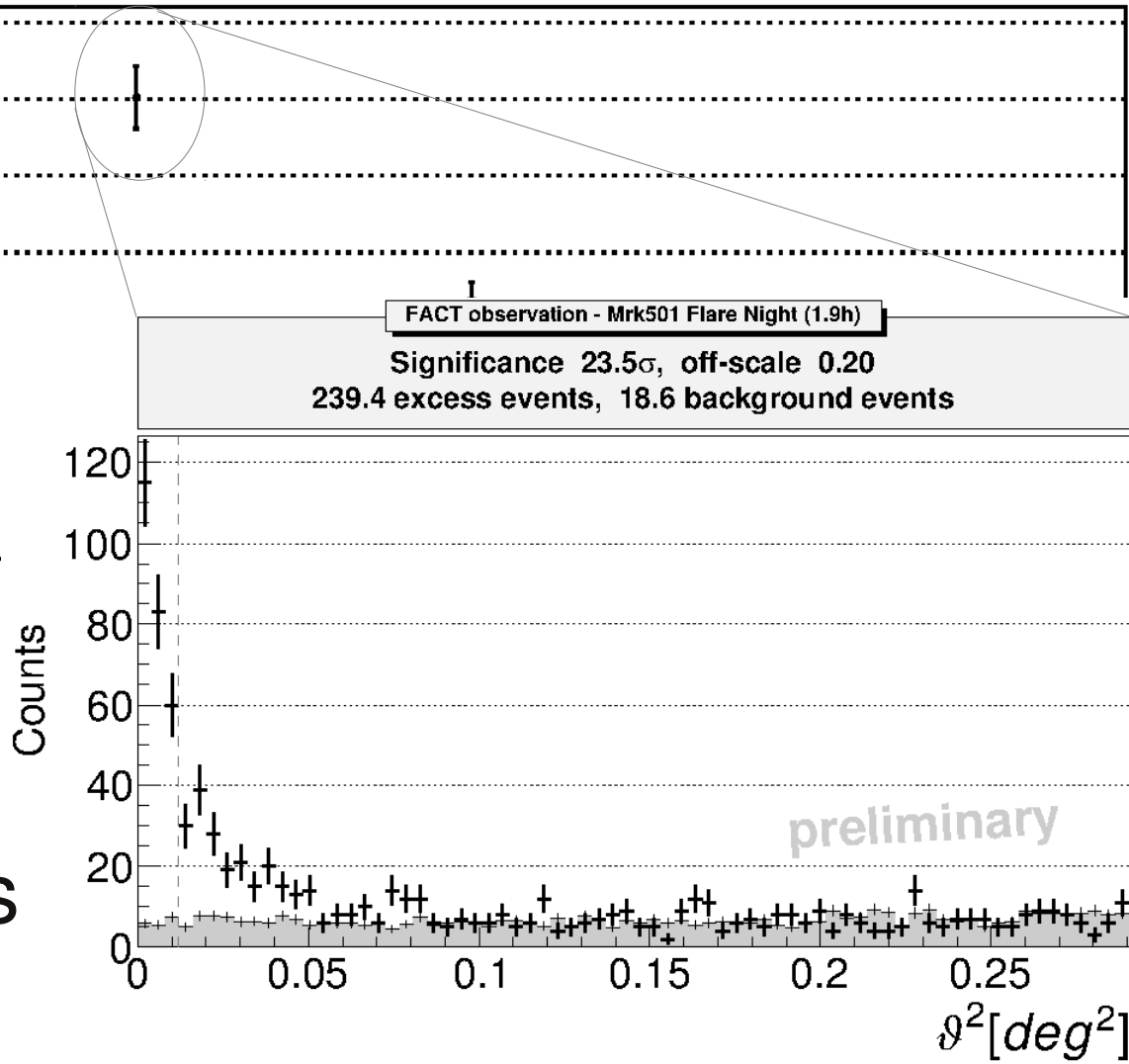
Increase in excess rate by factor 6

> 5 sigma in 5 minutes

Excess Rate Curve Mrk501

18.5.-30.6.2012





> 5 sigma in 5 minutes
→ Flare alerts

Quick Look Analysis: Flare Alerts

- Fast processing on site: Excess rate curves
- Results in almost real time

  => Flare alerts to other telescopes
- Not including:
  - Correction for dependence of threshold on zenith distance and ambient light
  - Detailed data check

http://www.fact-project.org/monitoring

QLA

fact-project.org/monitoring/index.php?y=2014&m=02&d=01&source=1&timebin=3&plot=night

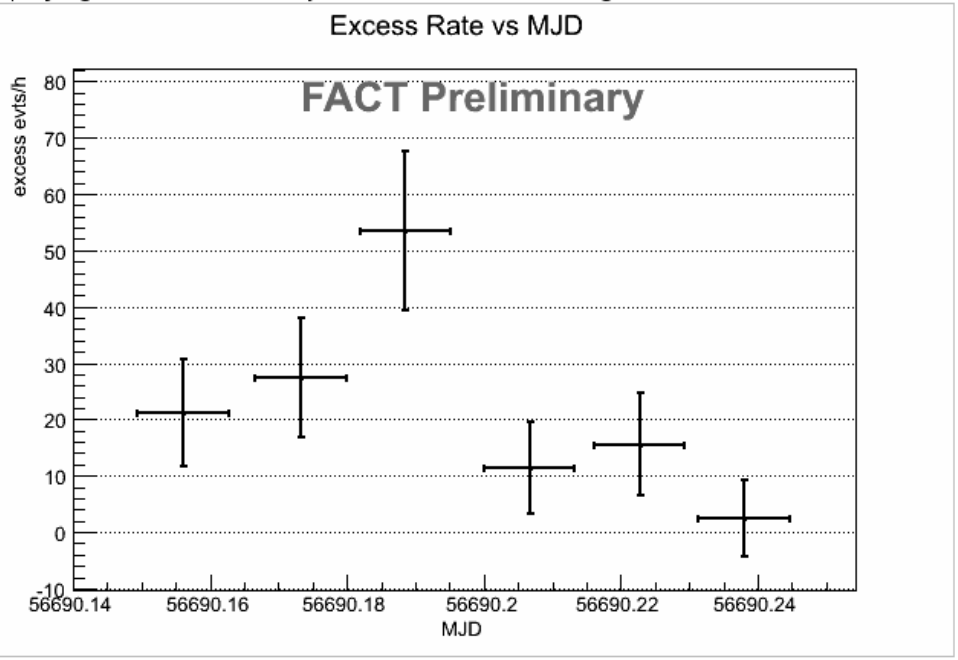
FACT Quick Look Analysis

http://www.fact-project.org/monitoring

Select date 2014 ▾ 02 ▾ 01 ▾ source Mrk 421

Select time binning 20min ▾ and range night ▾ Reset

Displaying 'excess rate vs mjd' for Mrk 421 for the night 2014/02/01.



REMARKS:

- These are the results of a **fast quick look analysis** on site, i.e. they are **preliminary**.
- The quick look analysis includes all data, i.e. no data selection done.
- The shown curves are not fluxes but **excess rates** (number of excess events per effective ontime), i.e. there is a dependence on trigger threshold and zenith distance of the observation (with the current analysis for zenith distance > 40 degree and trigger threshold > 500 DAC counts).
- The curves are provided with 20 min binning and nightly binning.
- In case, you need further details about the data or a different binning, please do not hesitate to contact us.
- Time range 'all' refers to all data since 12.12.2012. For older data, please contact us.

If you intend to use the data or information from this website, please let us know for reference.
Please cite this webpage and the FACT design paper when using information from this webpage or any FACT data.

Reference FACT Design Paper: H. Anderhub et al. JINST 8 P6008 ADS open access

Contact: Daniela Dorner *dorner<at>astro.uni-wuerzburg.de*.

QLA

fact-project.org/monitoring/index.php?y=2014&m=02&d=01&source=1&timebin=3&plot=night

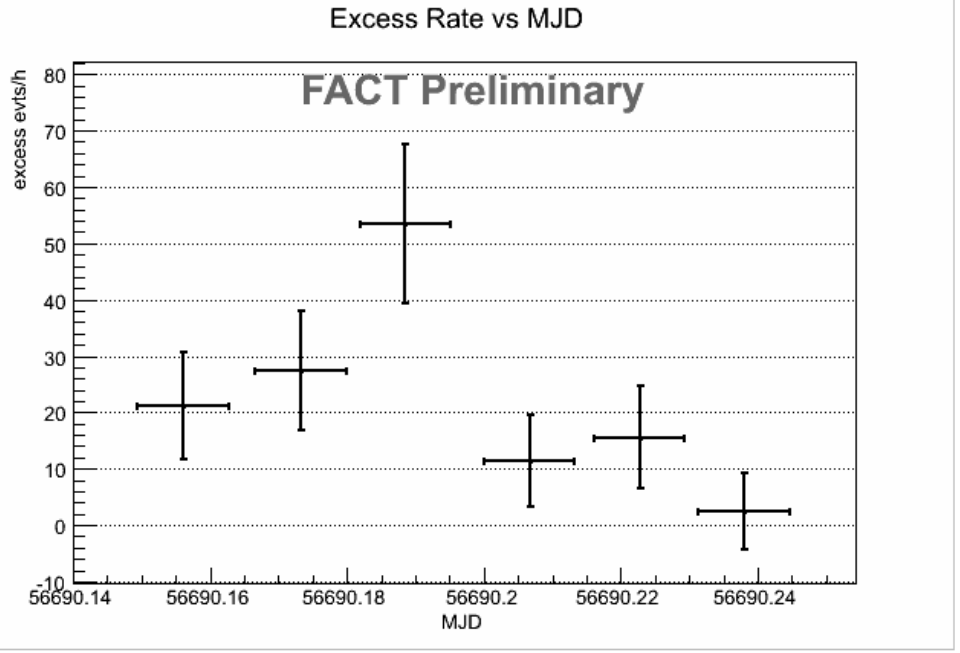
FACT Quick Look Analysis

http://www.fact-project.org/monitoring

Select date 2014 ▾ 02 ▾ 01 ▾ source Mrk 421

Select time binning 20min ▾ and range night ▾ Reset

Displaying 'excess rate vs mjd' for Mrk 421 for the night 2014/02/01.



Select
→ date
→ time range
→ source
→ binning

REMARKS:

- These are the results of a **fast quick look analysis** on site, i.e. they are **preliminary**.
- The quick look analysis includes all data, i.e. no data selection done.
- The shown curves are not fluxes but **excess rates** (number of excess events per effective ontime), i.e. there is a dependence on trigger threshold and zenith distance of the observation (with the current analysis for zenith distance > 40 degree and trigger threshold > 500 DAC counts).
- The curves are provided with 20 min binning and nightly binning.
- In case, you need further details about the data or a different binning, please do not hesitate to contact us.
- Time range 'all' refers to all data since 12.12.2012. For older data, please contact us.

If you intend to use the data or information from this website, please let us know for reference.
Please cite this webpage and the FACT design paper when using information from this webpage or any FACT data.

Reference FACT Design Paper: H. Anderhub et al. JINST 8 P6008 ADS open access

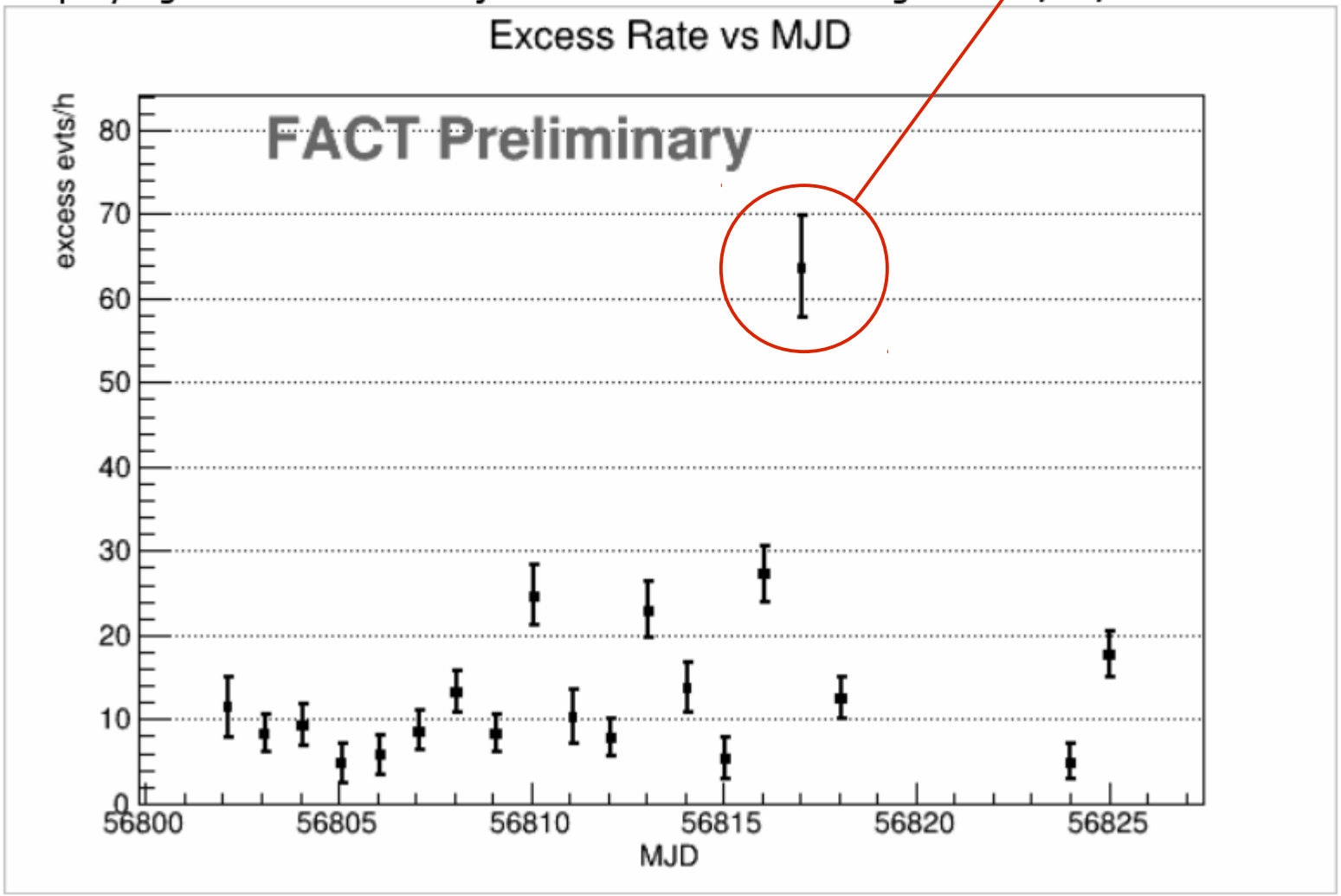
Contact: Daniela Dorner *dorner<at>astro.uni-wuerzburg.de*.

Mrk501:

FACT Quick Look Analysis

Select date 2014 06 16 source Mrk 501
Select time binning 1night and range 28 days Reset

Displaying 'excess rate vs mjd' for Mrk 501 for the night 2014/06/16.



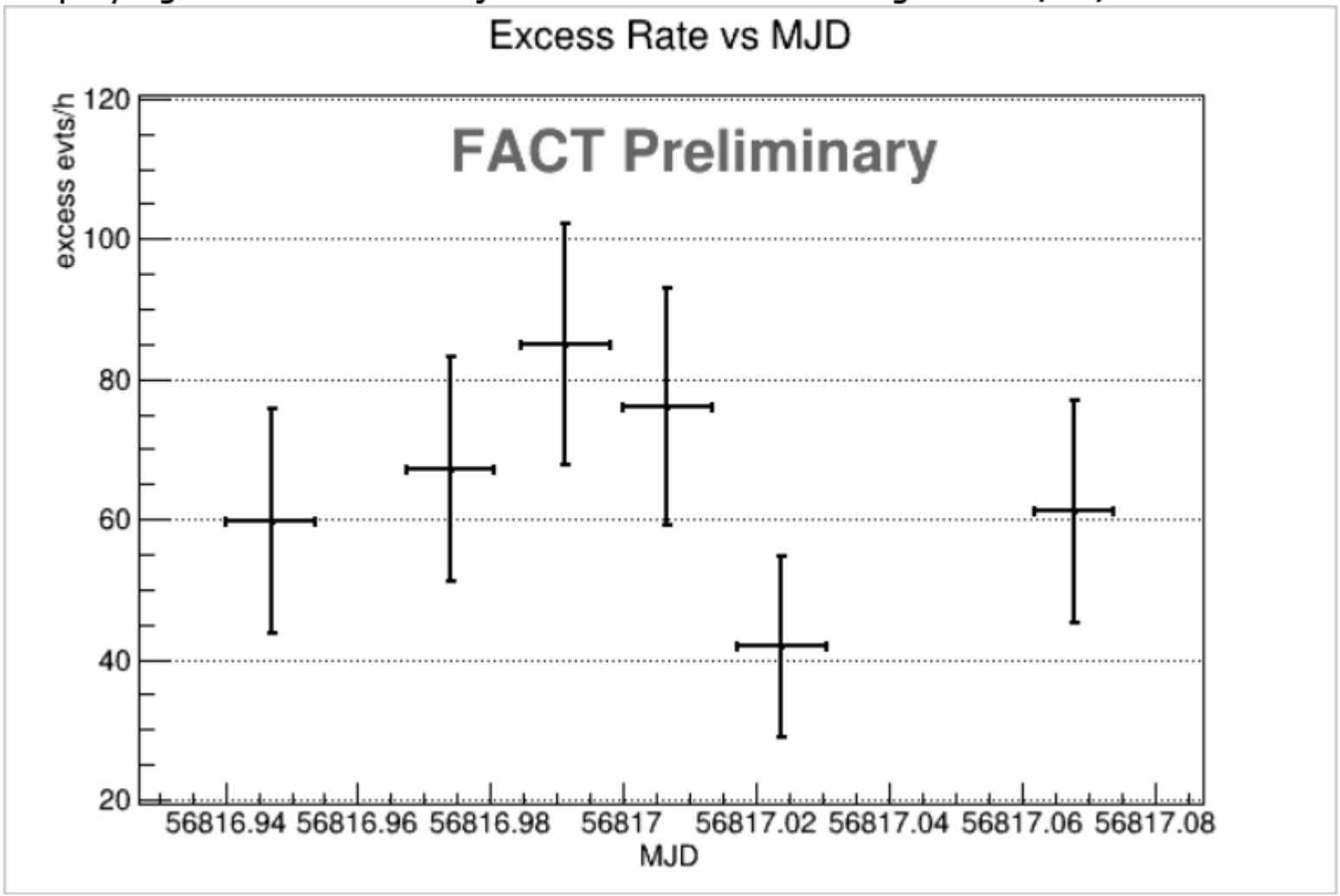
Flare Alert
9 Jun 2014

Mrk501:

FACT Quick Look Analysis

Select date 2014 06 08 source Mrk 501
Select time binning 20min and range night Reset

Displaying 'excess rate vs mjd' for Mrk 501 for the night 2014/06/08.

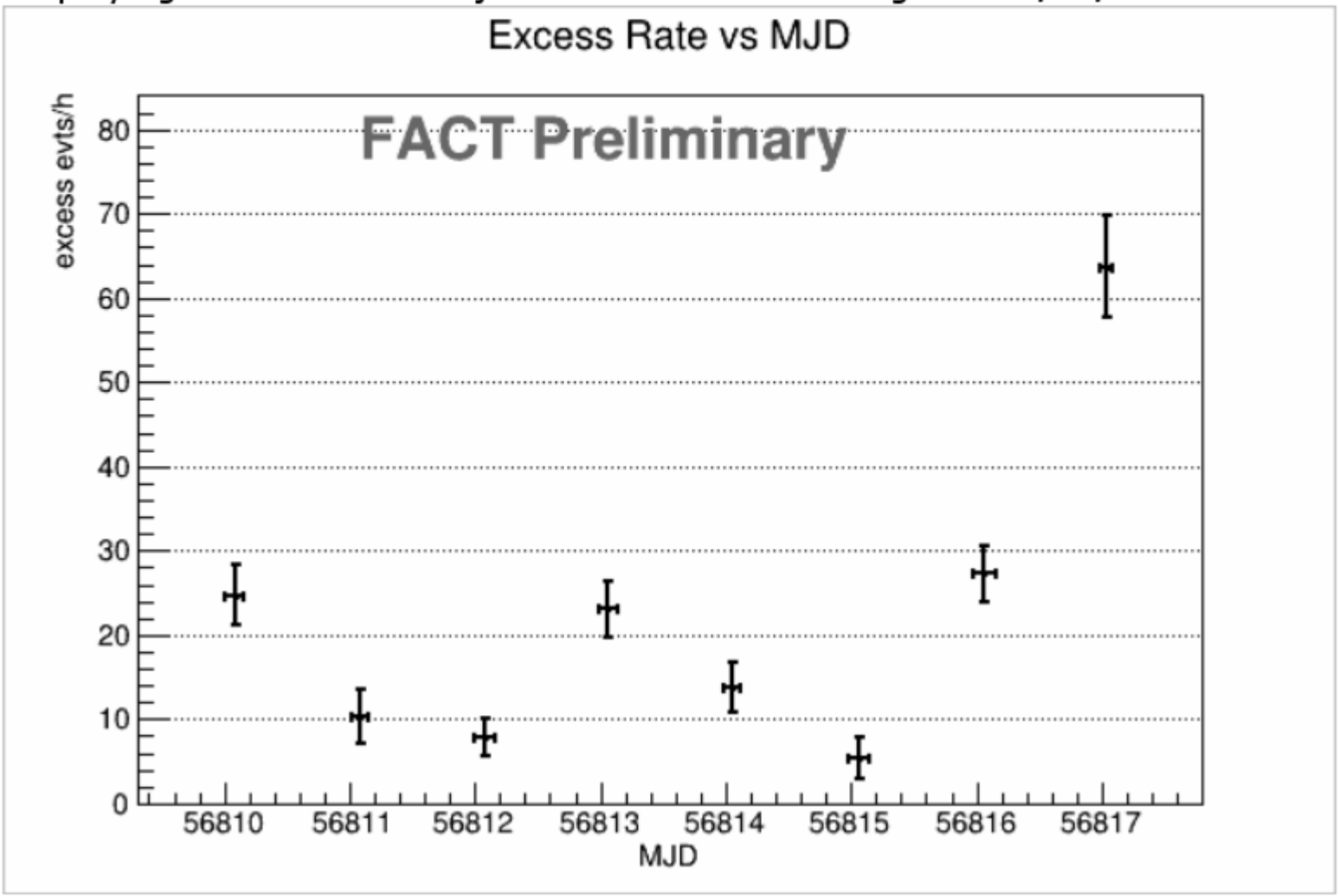


Mrk501:

FACT Quick Look Analysis

Select date 2014 06 08 source Mrk 501
Select time binning 1night and range week Reset

Displaying 'excess rate vs mjd' for Mrk 501 for the night 2014/06/08.

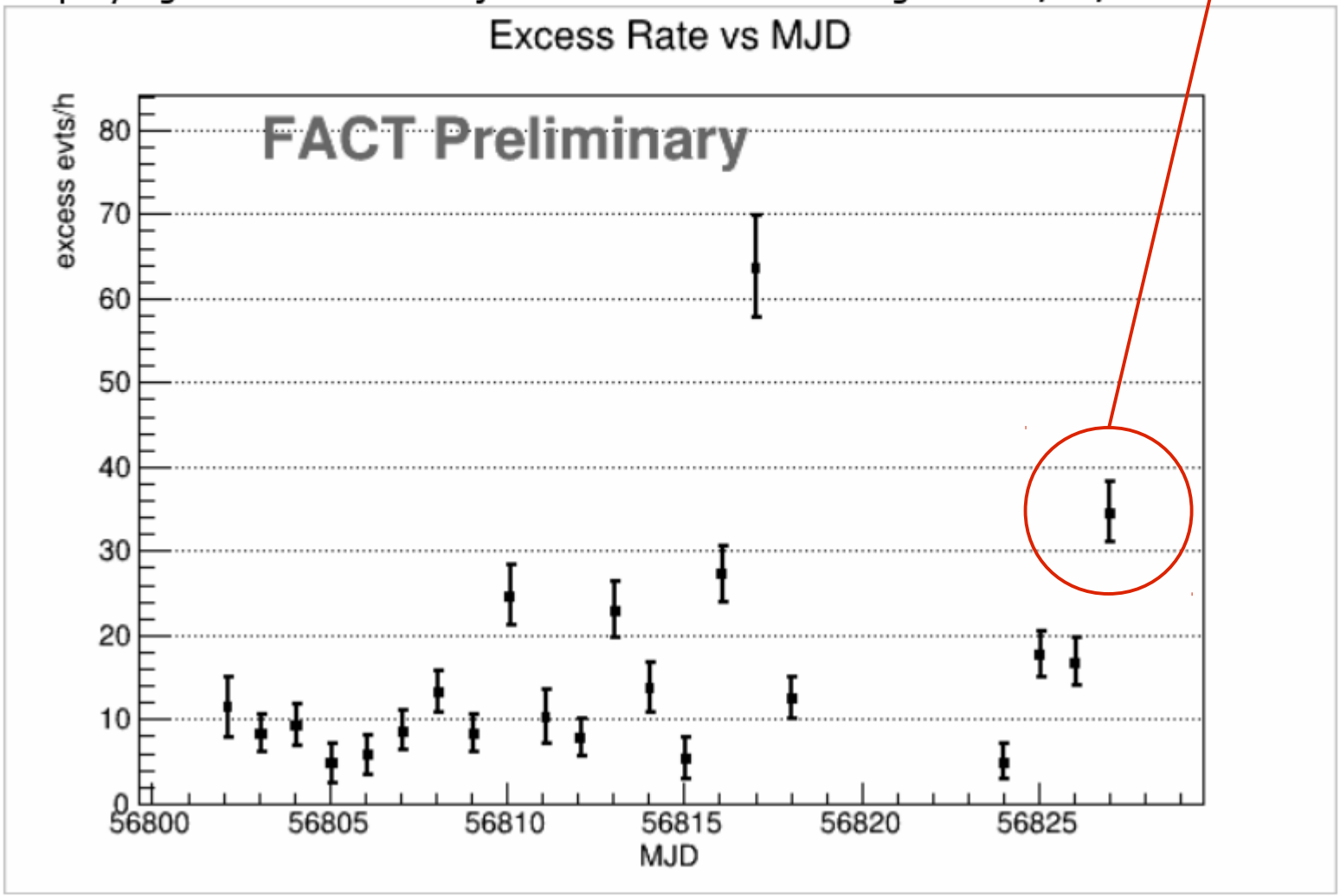


Mrk501:

FACT Quick Look Analysis

Select date 2014 06 18 source Mrk 501
Select time binning 1night and range 28 days Reset

Displaying 'excess rate vs mjd' for Mrk 501 for the night 2014/06/18.



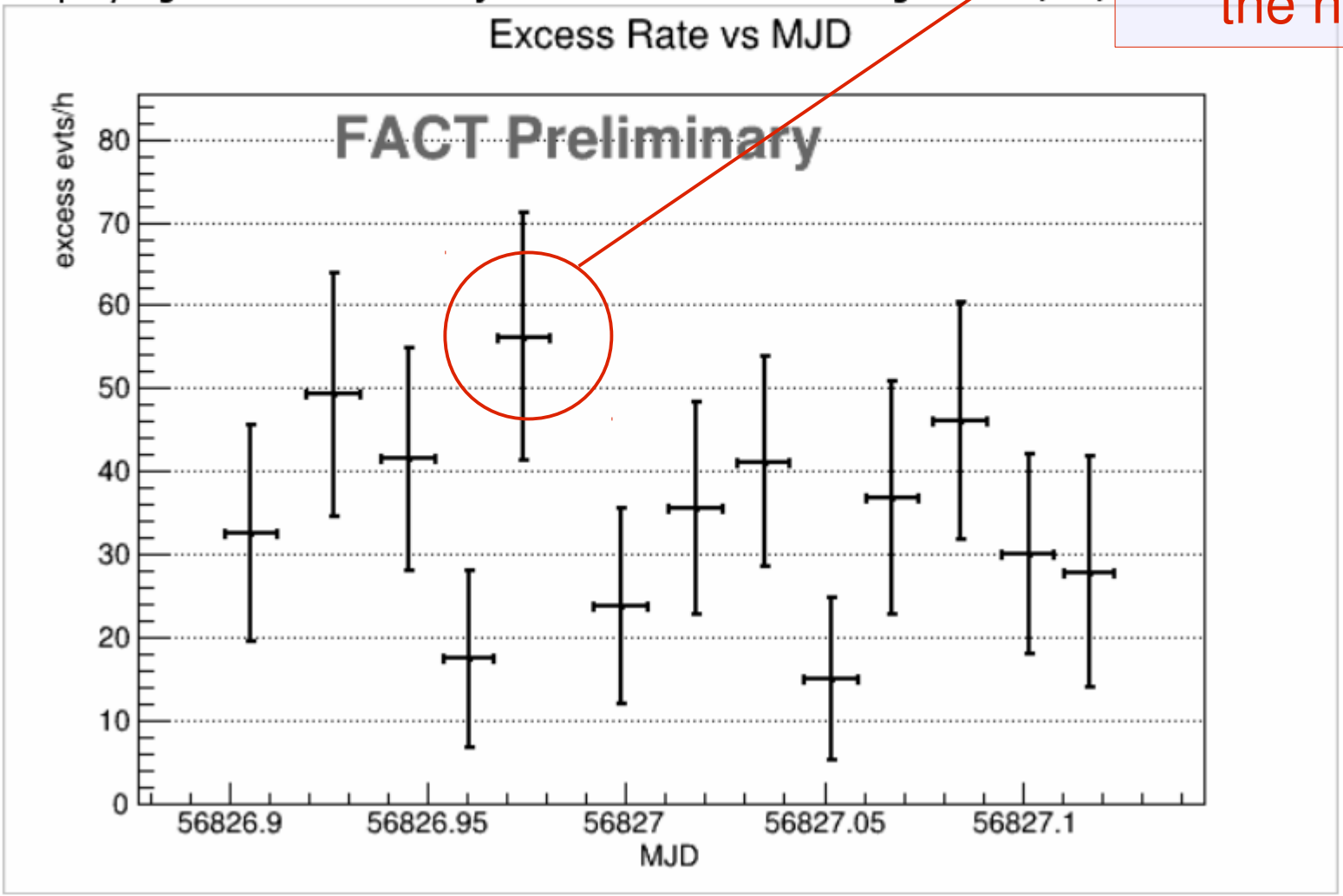
Flare Alert
18 Jun 2014

Mrk501:

FACT Quick Look Analysis

Select date 2014 06 18 source Mrk 501
Select time binning 20min and range night Reset

Displaying 'excess rate vs mjd' for Mrk 501 for the night 2014/06/18.



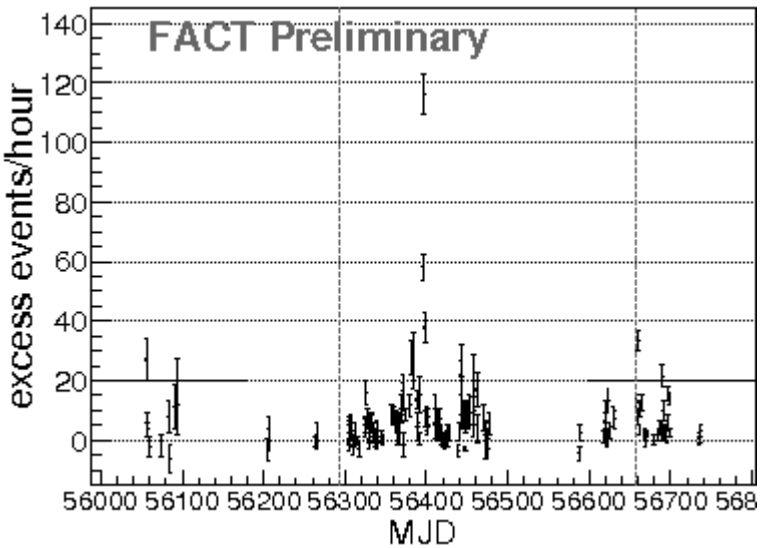
Flare Alert
18 Jun 2014
(sent during the night)

Summary and Outlook

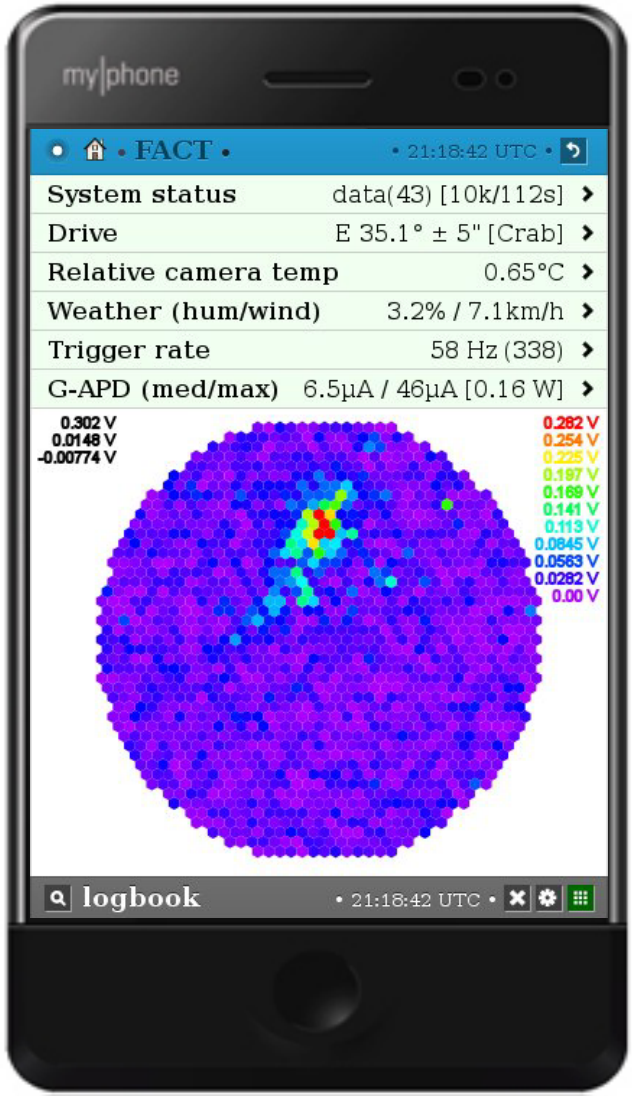
- First G-APD Cherenkov Telescope
  - Stable Performance → Remote and automatic operation
  - No aging → Observations during strong moon light
- Long-term monitoring of bright TeV blazars
  - Quick Look Analysis → Flare alerts (e.g. 9. and 18. June 2014)
  - Several flaring activities → MWL studies
  - Total observation time: ~ 2700 h (> 1600 h in 2013)
  - Complete data sample for variability studies
- Towards robotic operation
- Network of small telescopes: 24/7 monitoring

Check out our monitoring results!

http://www.fact-project.org/monitoring



2.5 years monitoring



[JINST **8**(2013) P06008]
arXiv:1403.5747

~5σ in 5min