The First G-APD Cherenkov Telescope: Status and Results

G Hughes for the **FACT** Collaboration

The FACT Collaboration

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Transition to Silicon

- Can Silicon Photo-Multipliers (Geiger-Mode Avalanche PhotoDiodes / SiPM)
  be used in gamma-ray astronomy?
- They are more robust
- Their size enables the use of new dual mirror designs

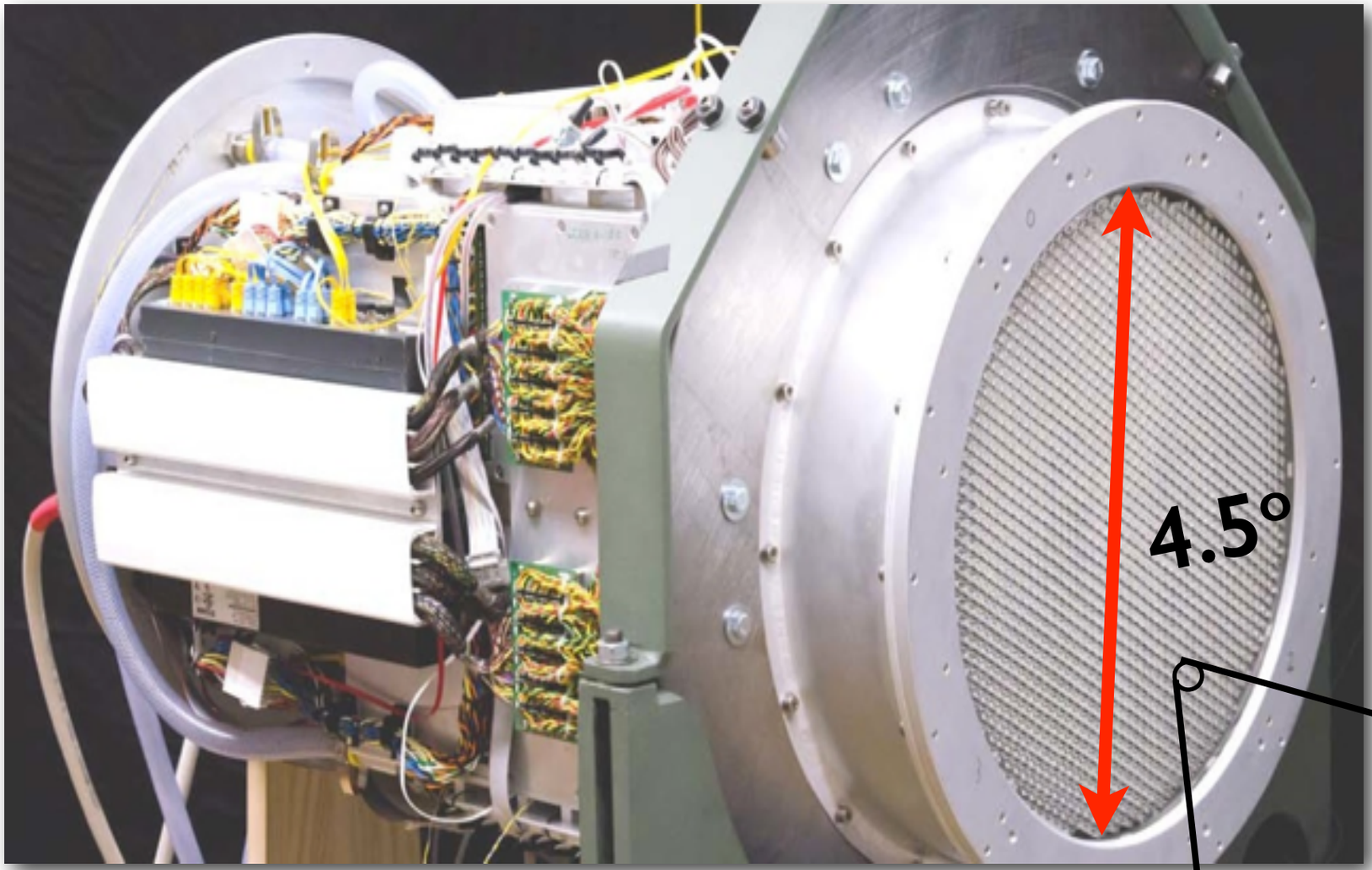
- **First G-APD Cherenkov Telescope**

G-APDs (SiPM)

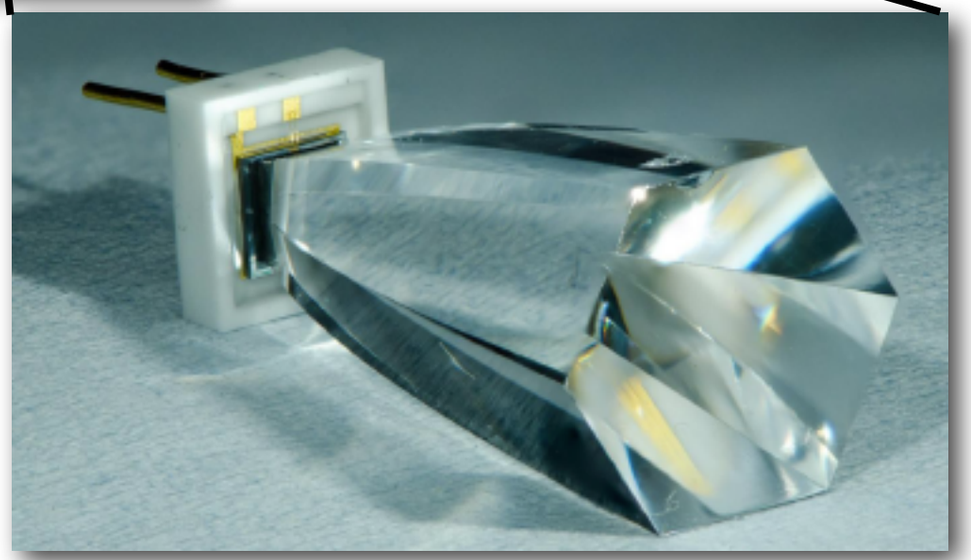
- Hamamatsu MPPC S10362-33-50C
- Comparison with Photo-Multiplier Tubes:
  - Cheaper than PMTs
  - Similar detection efficiencies
  - Do not suffer significant ageing (Moonlight)
  - Can be read out quickly
  - Voltages can be much lower
    (100V compare to 1000V for PMTs)
  - Dark Count < Night Sky Background
- Astroparticle community knows how to handle cross-talk and after pulsing

- However the gain is **temperature dependent** and **ambient light** will result in voltage drop (due to serial resistors)
  ⇒ **Feedback system required**

FACT Camera

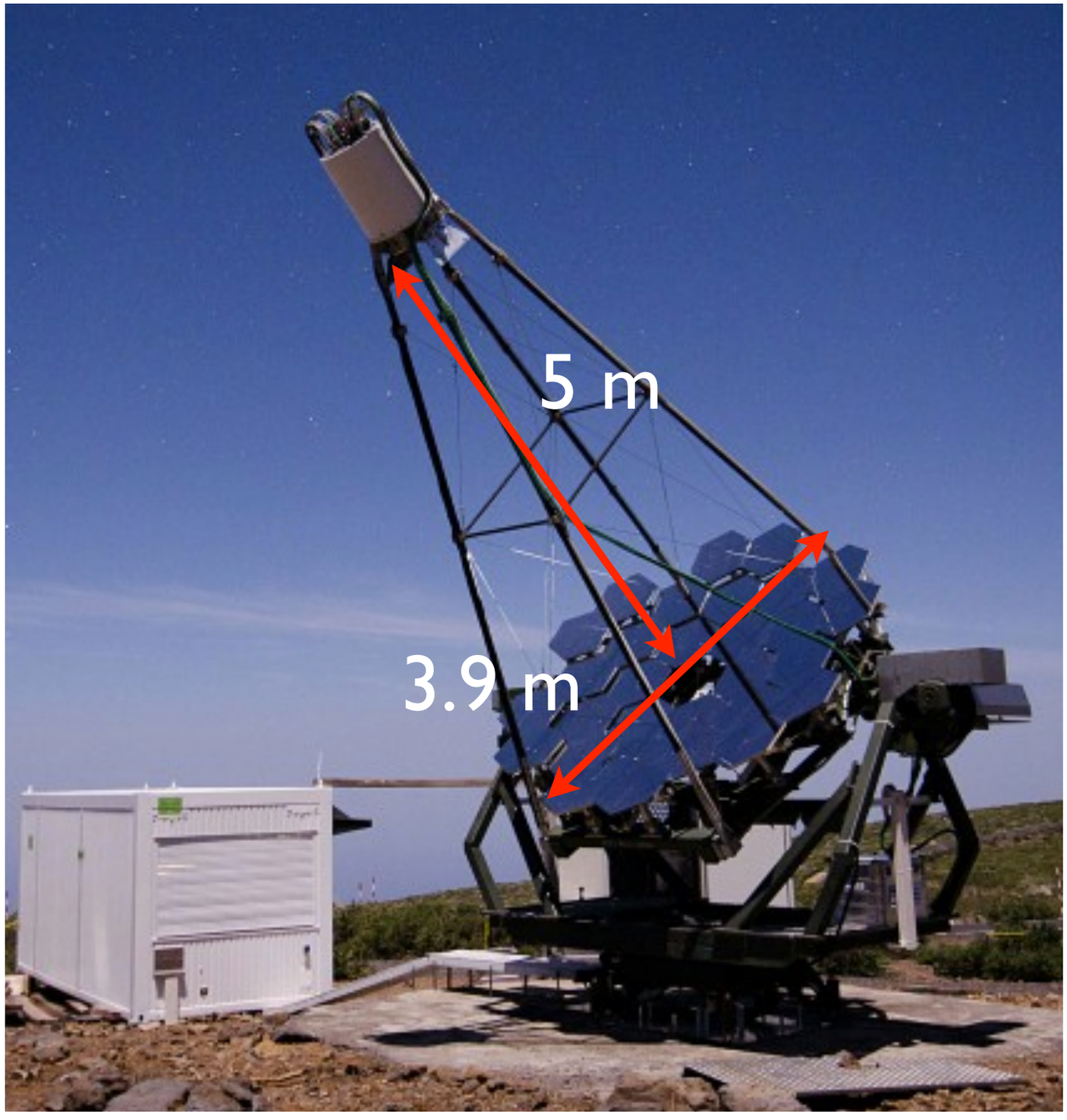


- 1440 G-APDs (SiPM) and readout channels
  Hamamatsu MPPC S10362-33-50C
- Active area of 3×3 mm^2



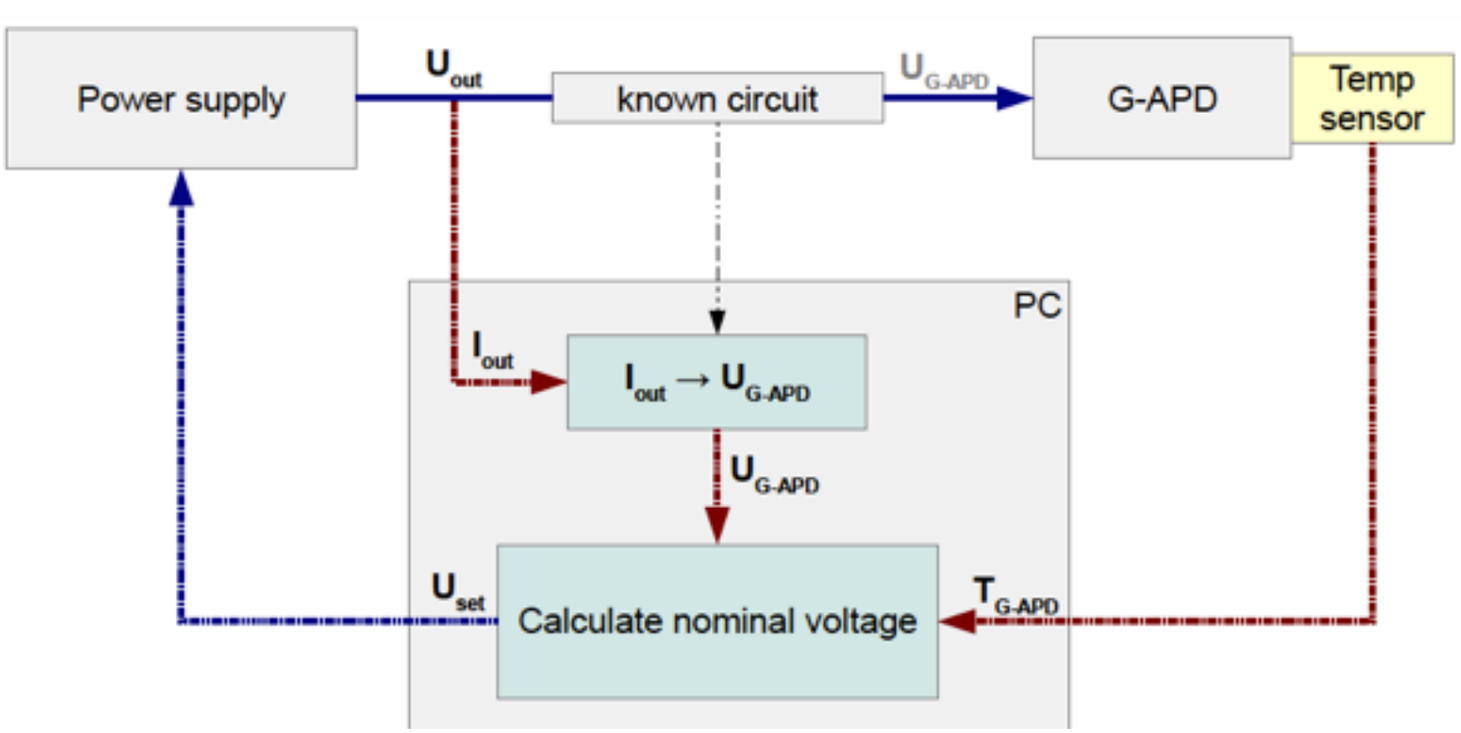
FACT Telescope

- 2 km a.s.l La Palma
- Old HEGRA mount
- Mirror area 9.51 m^2
- 30 Reconditioned facets
- Davies-Cotton optics



Feedback

- Breakdown Voltage depends linearly on temperature
- Cross talk vs PDE: Both depend on Temp/Over-Voltage
- As well as Single PE resolution
- Over-Voltage of 1.4 V used



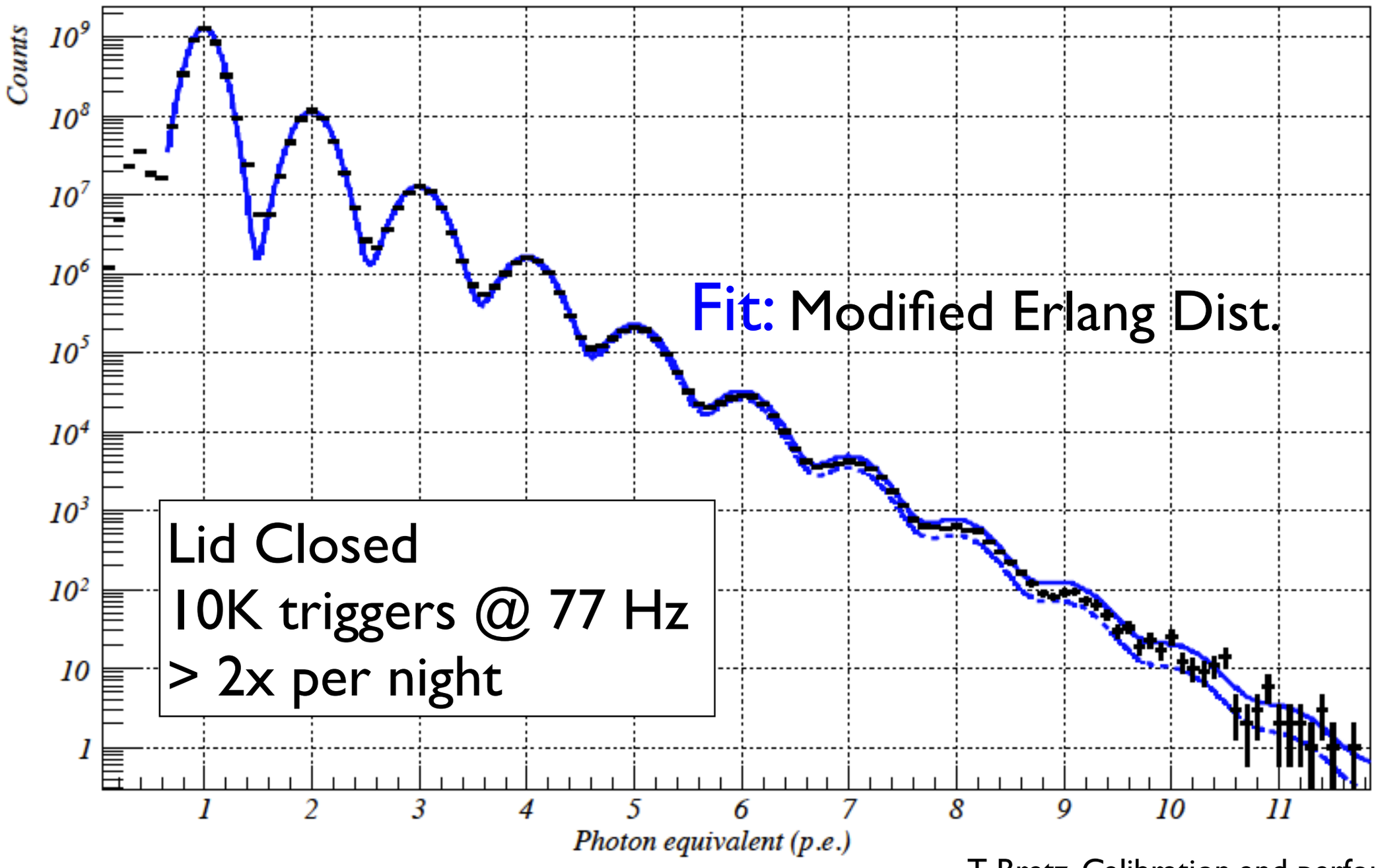
- 320 bias voltage channels

  Max Voltage 90 V
  Max Current 4 mA
  $\Delta V \sim 22$ mV
  $\Delta I \sim 1.2$ µA

- Temperature read every 15s
- Current read every second

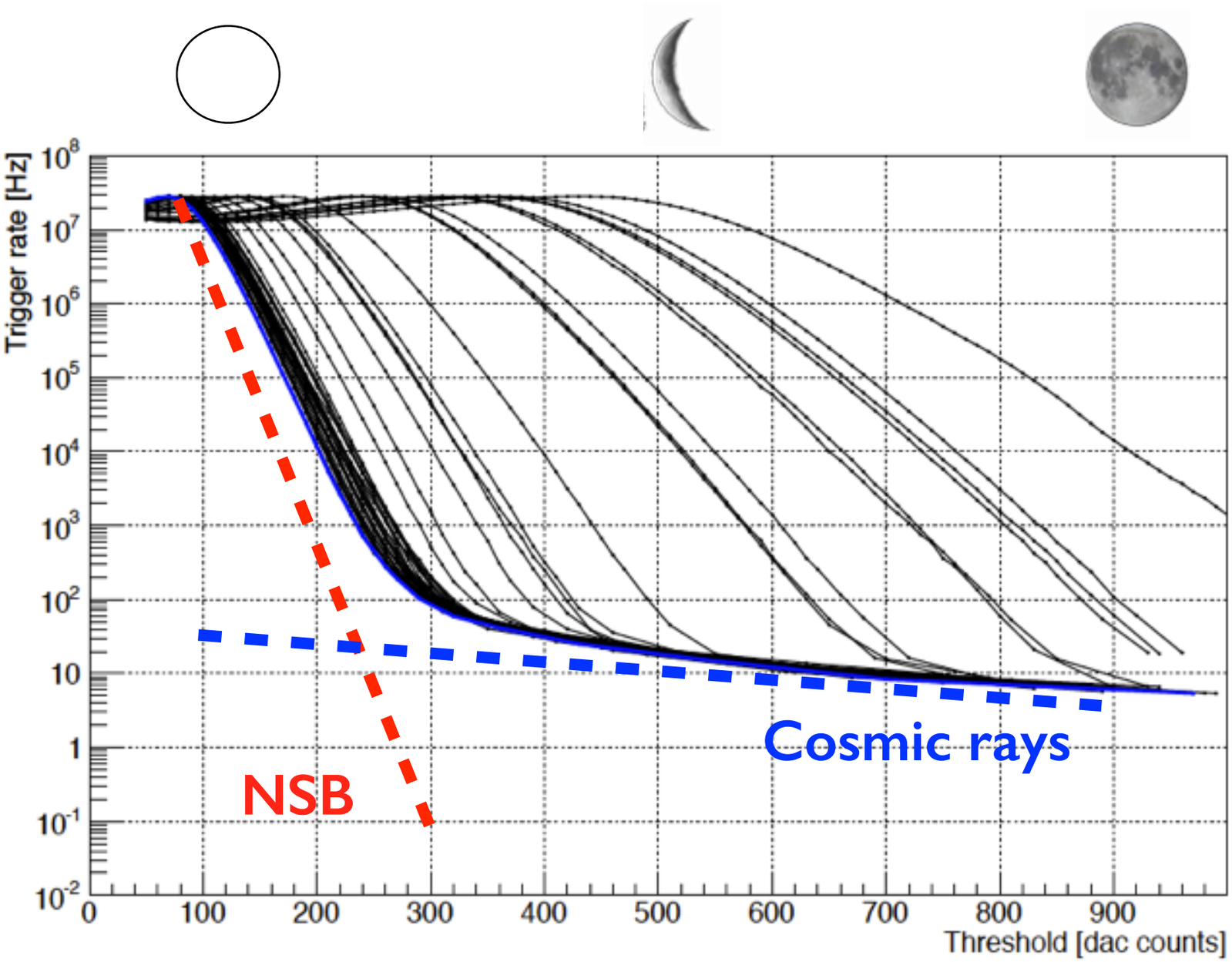
Feedback: Dark Count Spectra

1428 Pixels, 1 year data, ΔT ~ 25°C



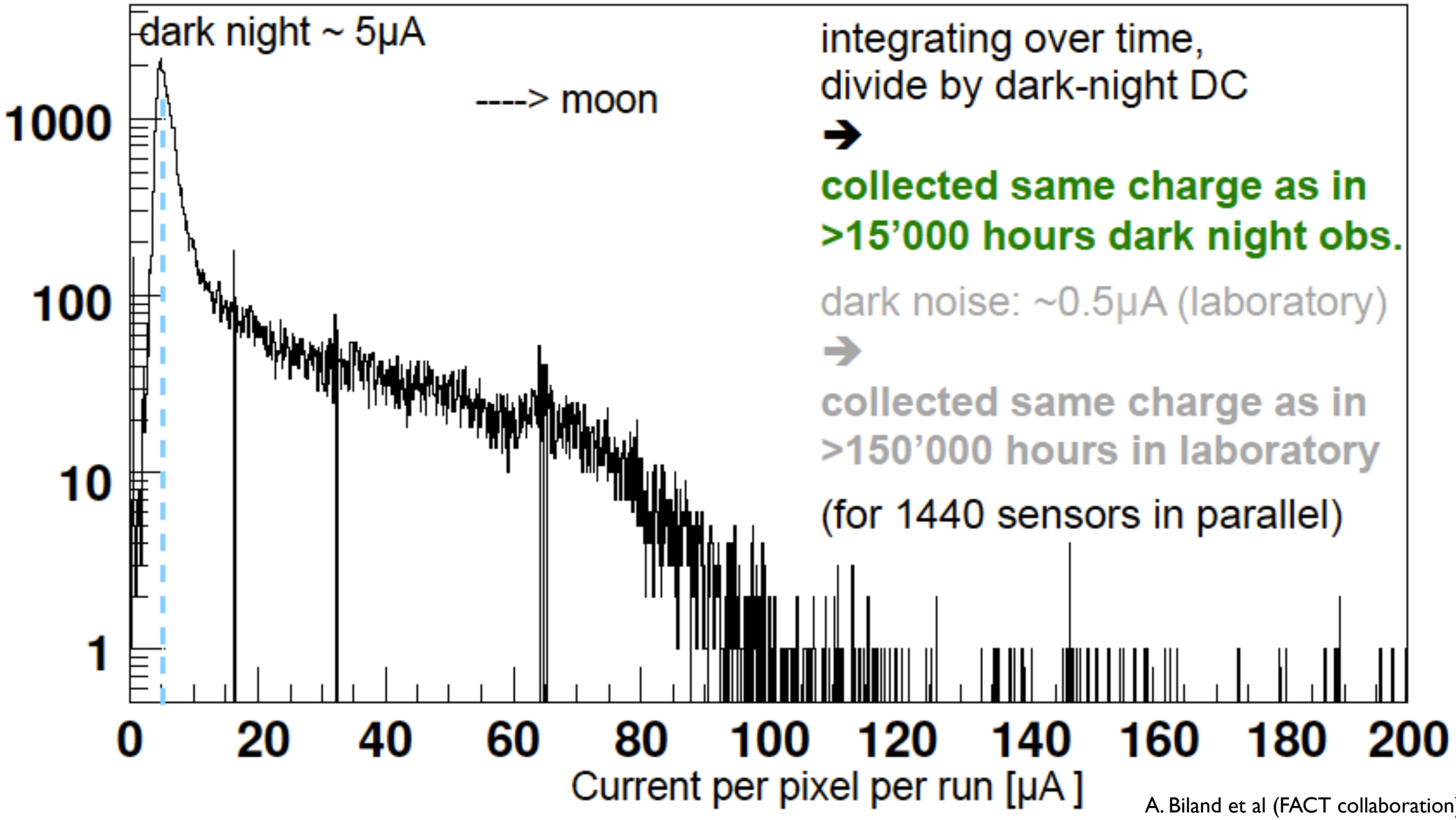
T. Bretz, Calibration and performance of the photon sensor response of FACT, JINST

Stability: Ratescans



- Ratescans are a very useful tool
- Cosmic ray rate shows no dependence on temperature, NSB or sensor age
- Cosmic ray rate does depend on night sky quality

Collected Charges



integrating over time,
divide by dark-night DC

➔

collected same charge as in >15'000 hours dark night obs.

dark noise: ~0.5μA (laboratory)

➔

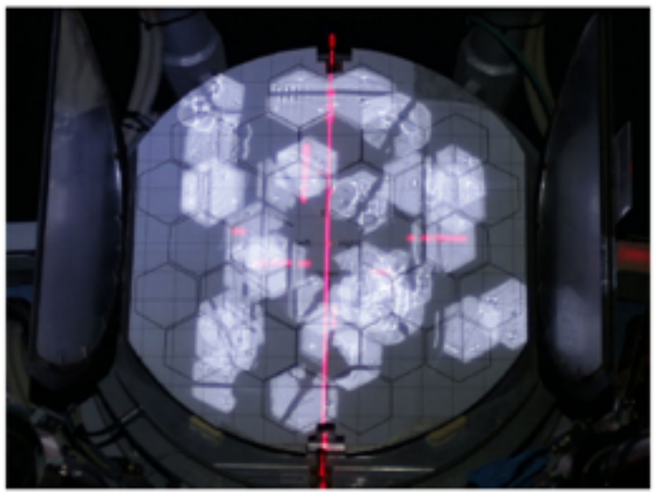
collected same charge as in >150'000 hours in laboratory

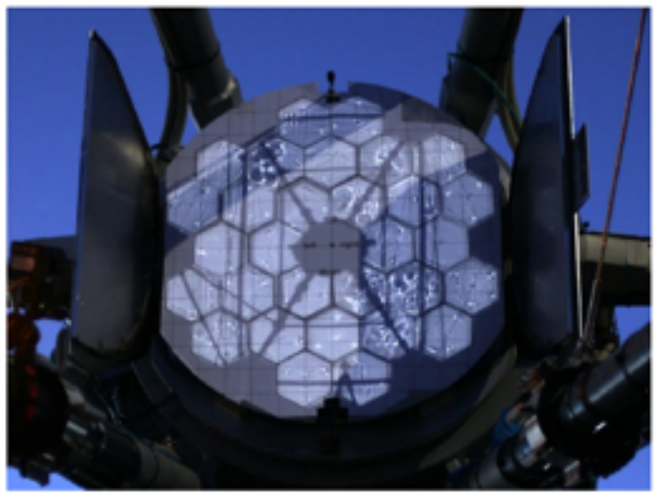
(for 1440 sensors in parallel)

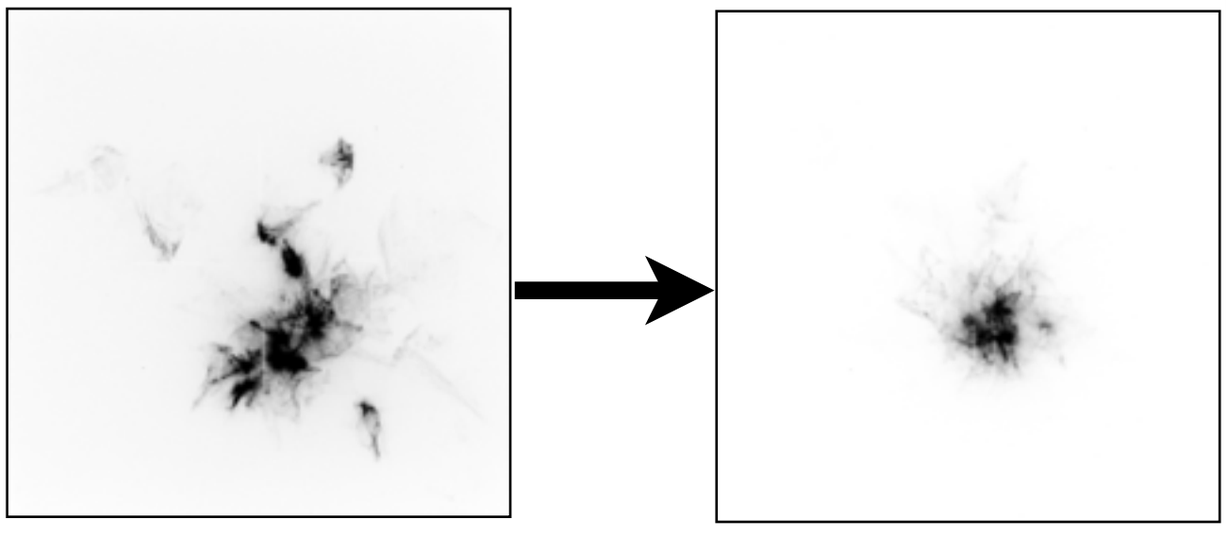
A. Biland et al (FACT collaboration)
Proceedings of 34th ICRC 2015

New Alignment Methods

- Mirror alignment campaign
  May 2014
- Two methods used:
  1. New Bokeh method
  2. Raster Scan Method



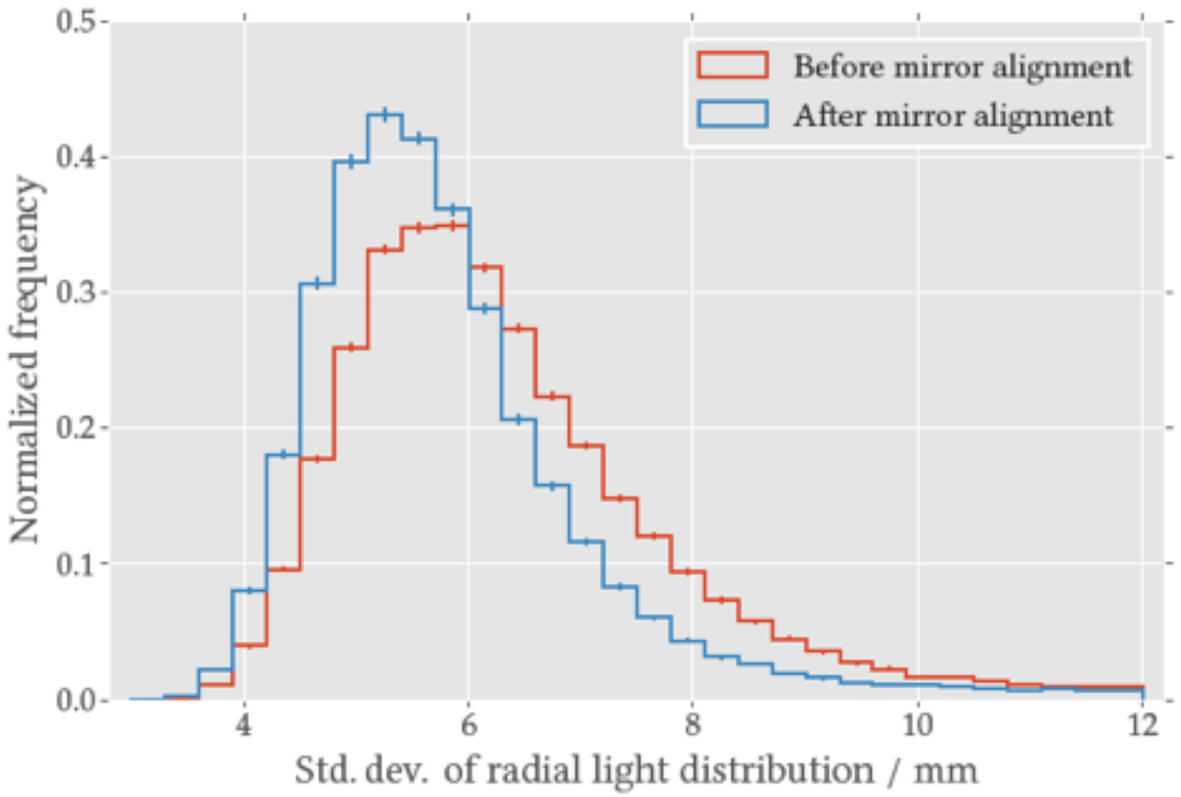


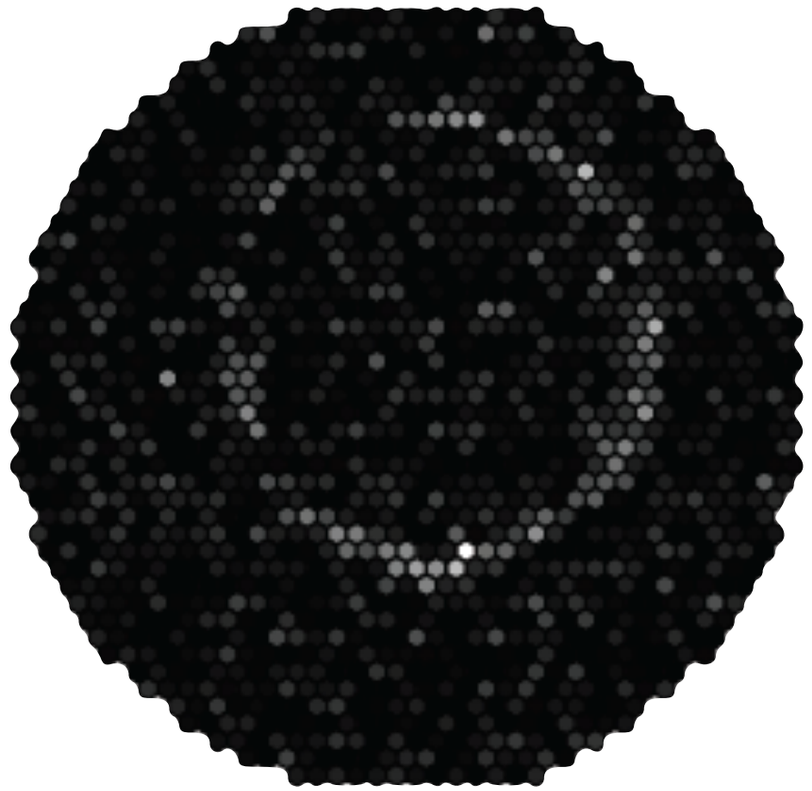


S. Müller et al (FACT collaboration)
Proceedings of 34th ICRC 2015

Stability: Muons

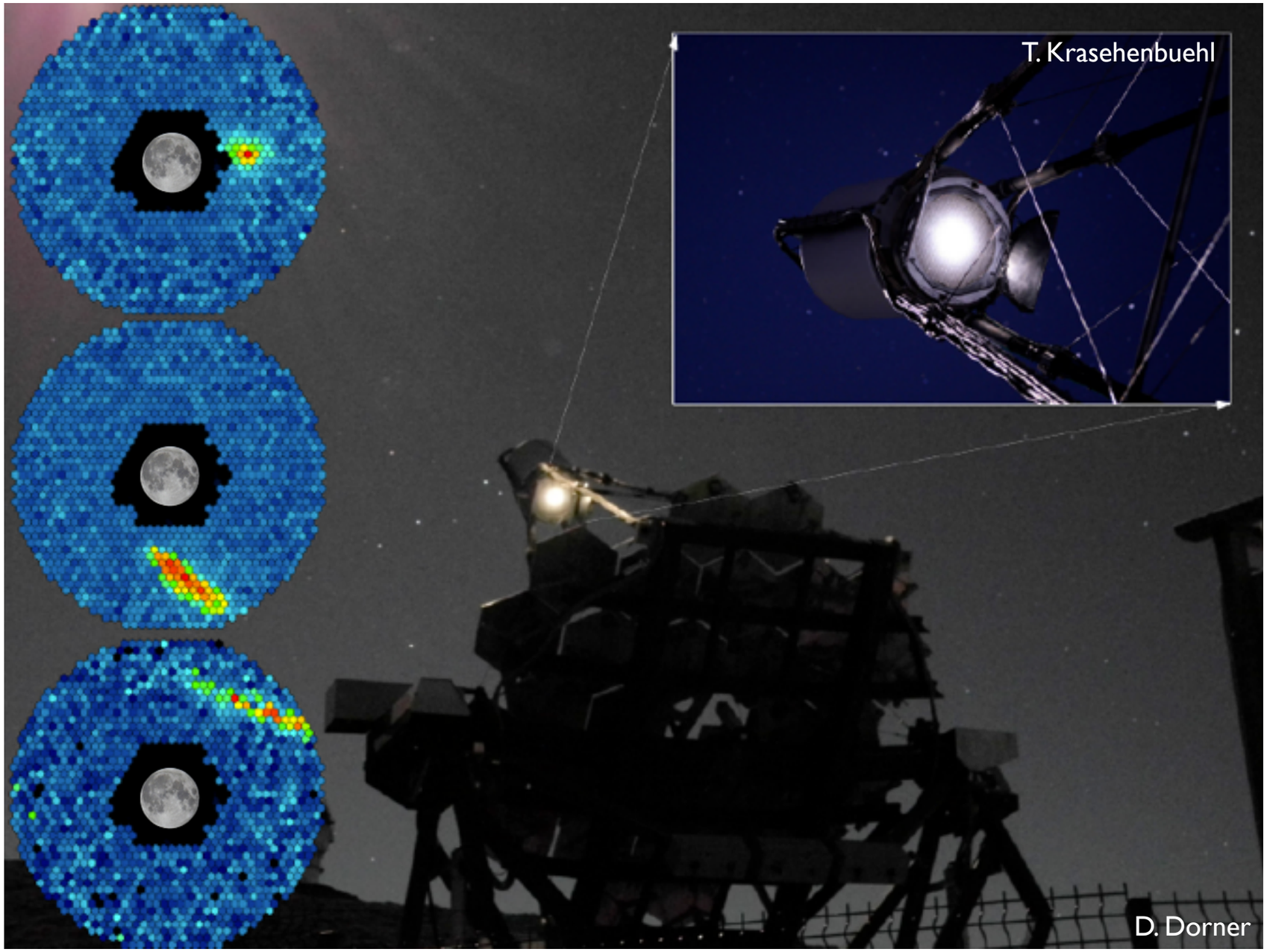
- Single muons from Cosmic ray interactions form rings in the focal plane
- Easy characterised and have a small time spread
- Therefore they can be used to measure
  Point Spread Function
  Time Spread
  Total detector throughput





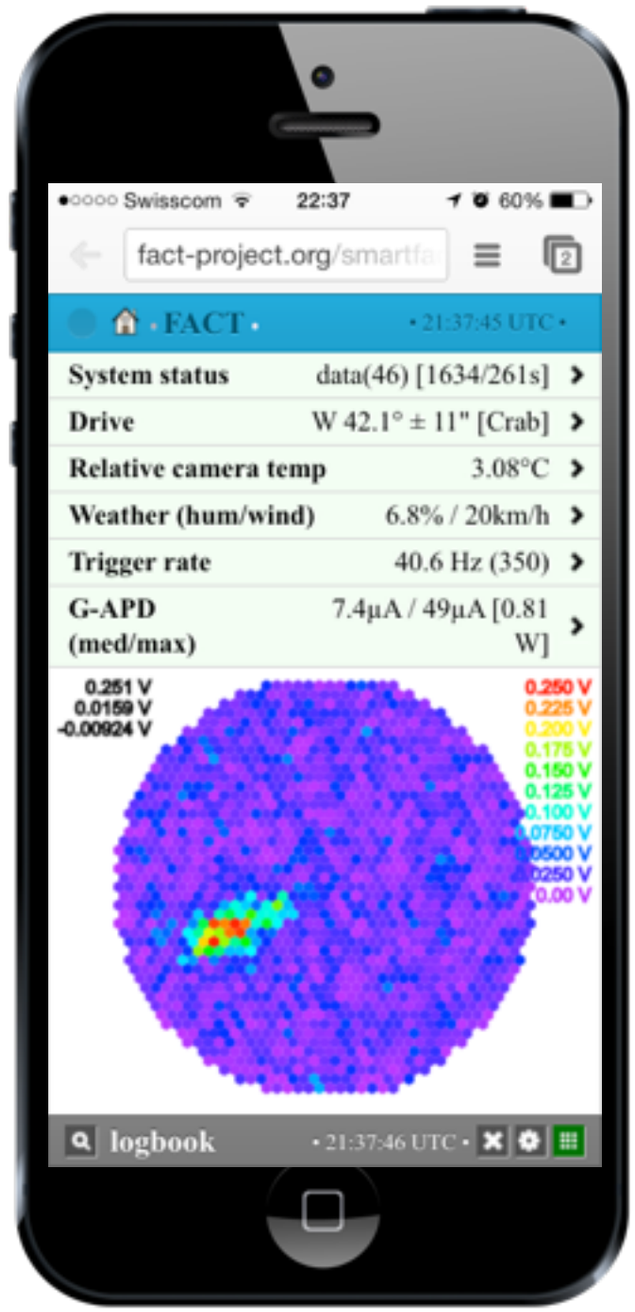
M. Nöthe et al (FACT collaboration)
Proceedings of 34th ICRC 2015

Moonlight Observations



Showers can still be seen whilst point directly at the moon!

Remote Observations

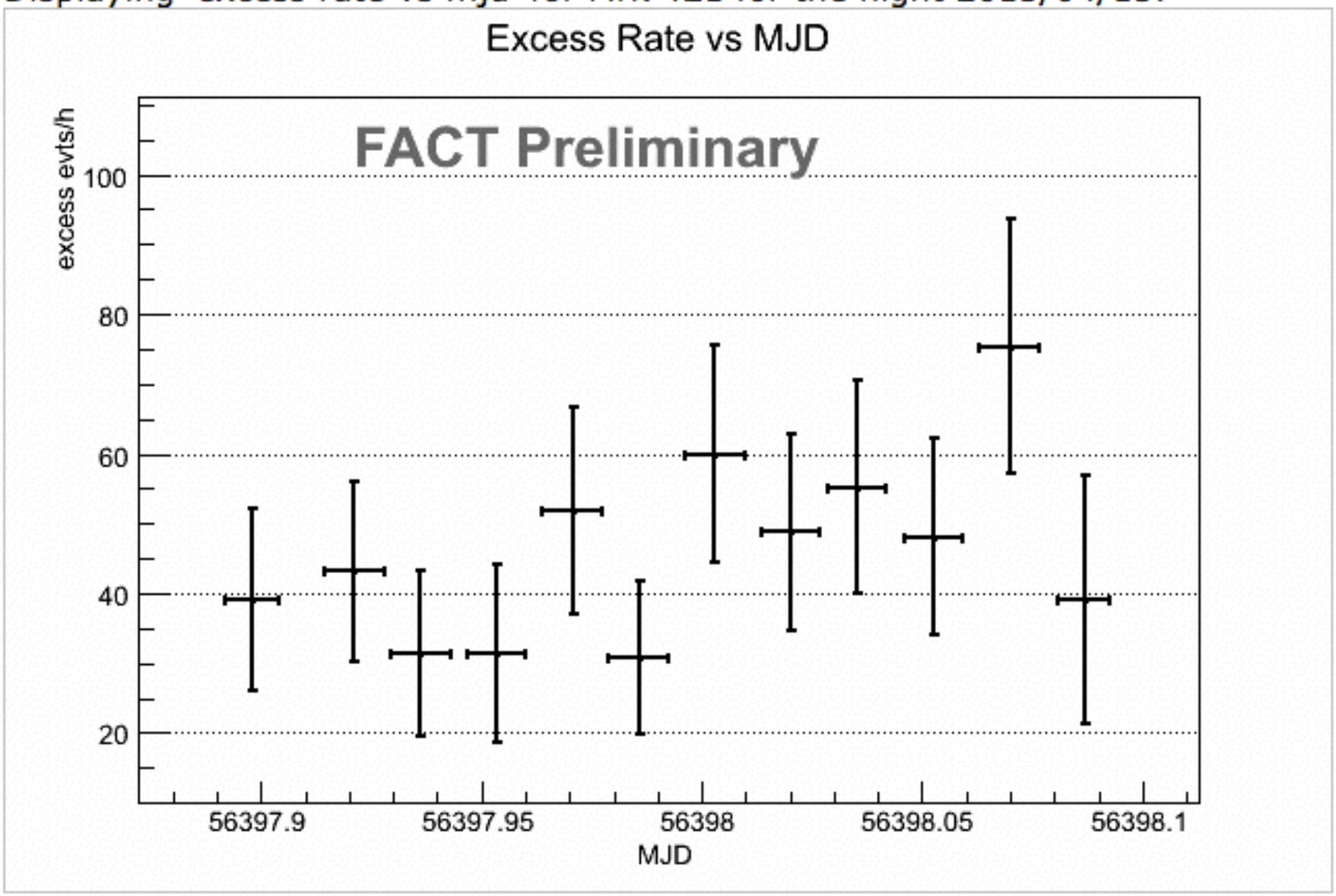


http://fact-project.org/smartfact

Quick Look Analysis

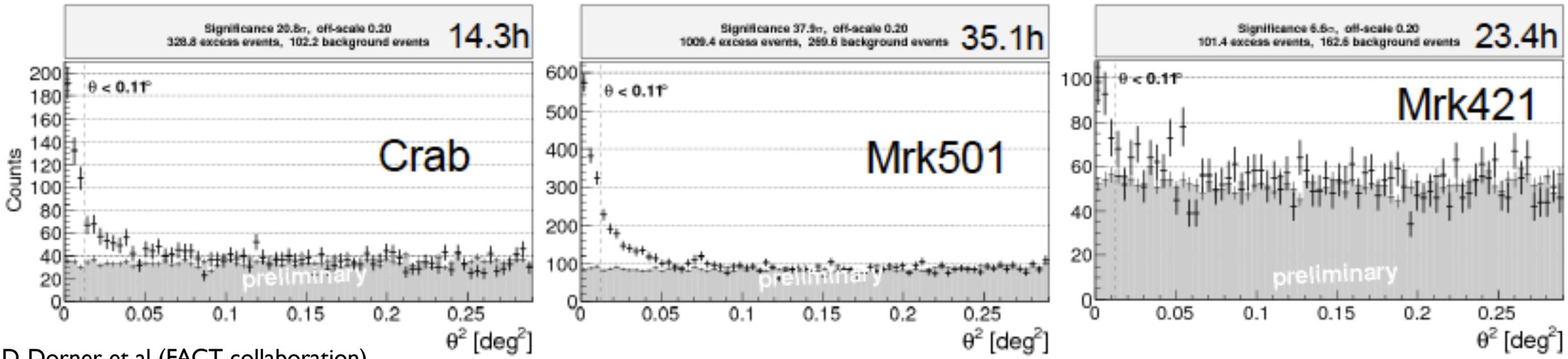
Select date 2013 04 15 source Mrk 421
Select time binning 20min and range night Reset

Displaying 'excess rate vs mjd' for Mrk 421 for the night 2013/04/15.

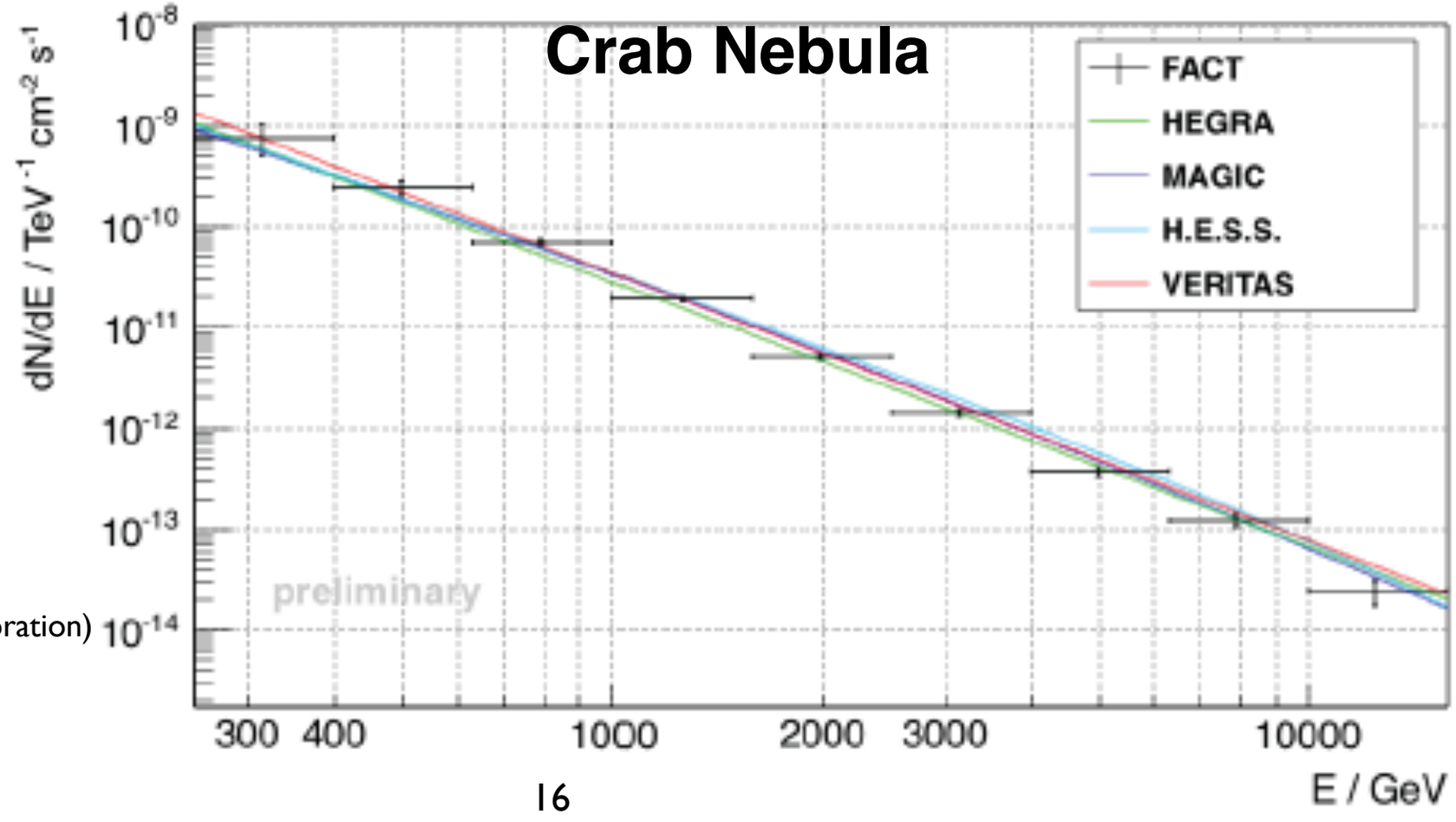


http://fact-project.org/monitoring/

Sources



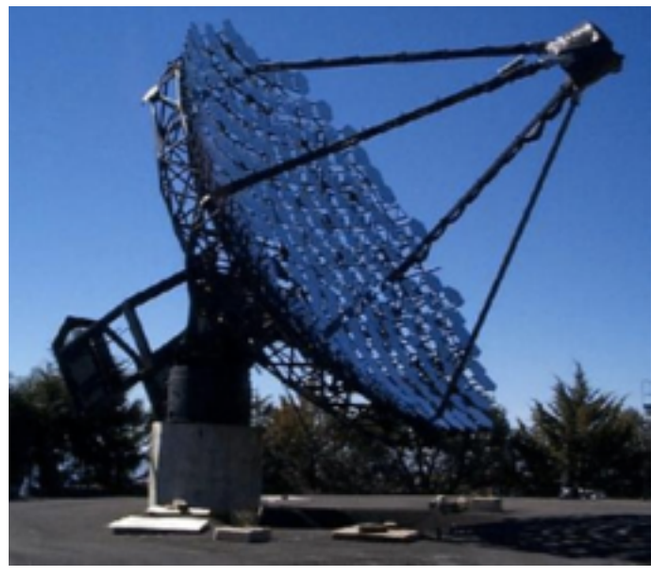
D. Dorner et al (FACT collaboration)
Gamma-2012: AIP Conf.Proc.1505



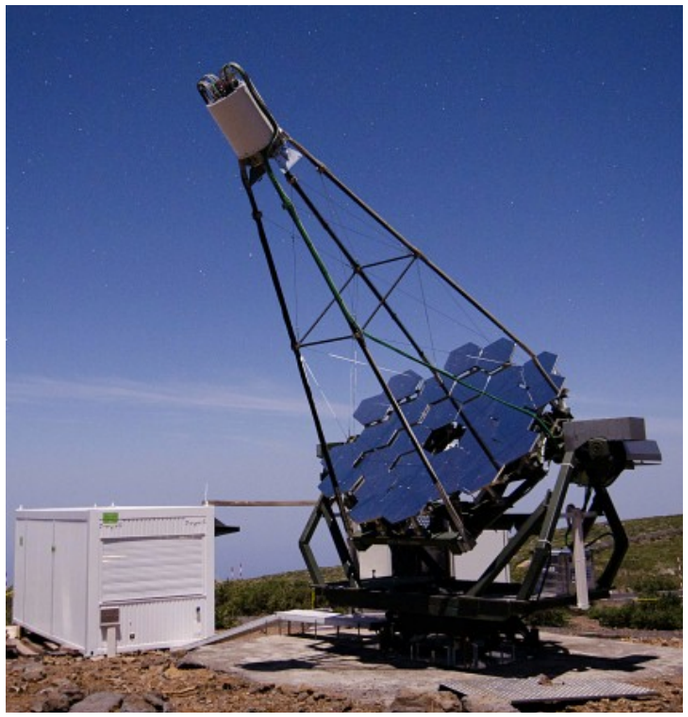
F. Temme, S. Einecke et al (FACT collaboration)
Proceedings of 34th ICRC 2015

Monitoring datasets

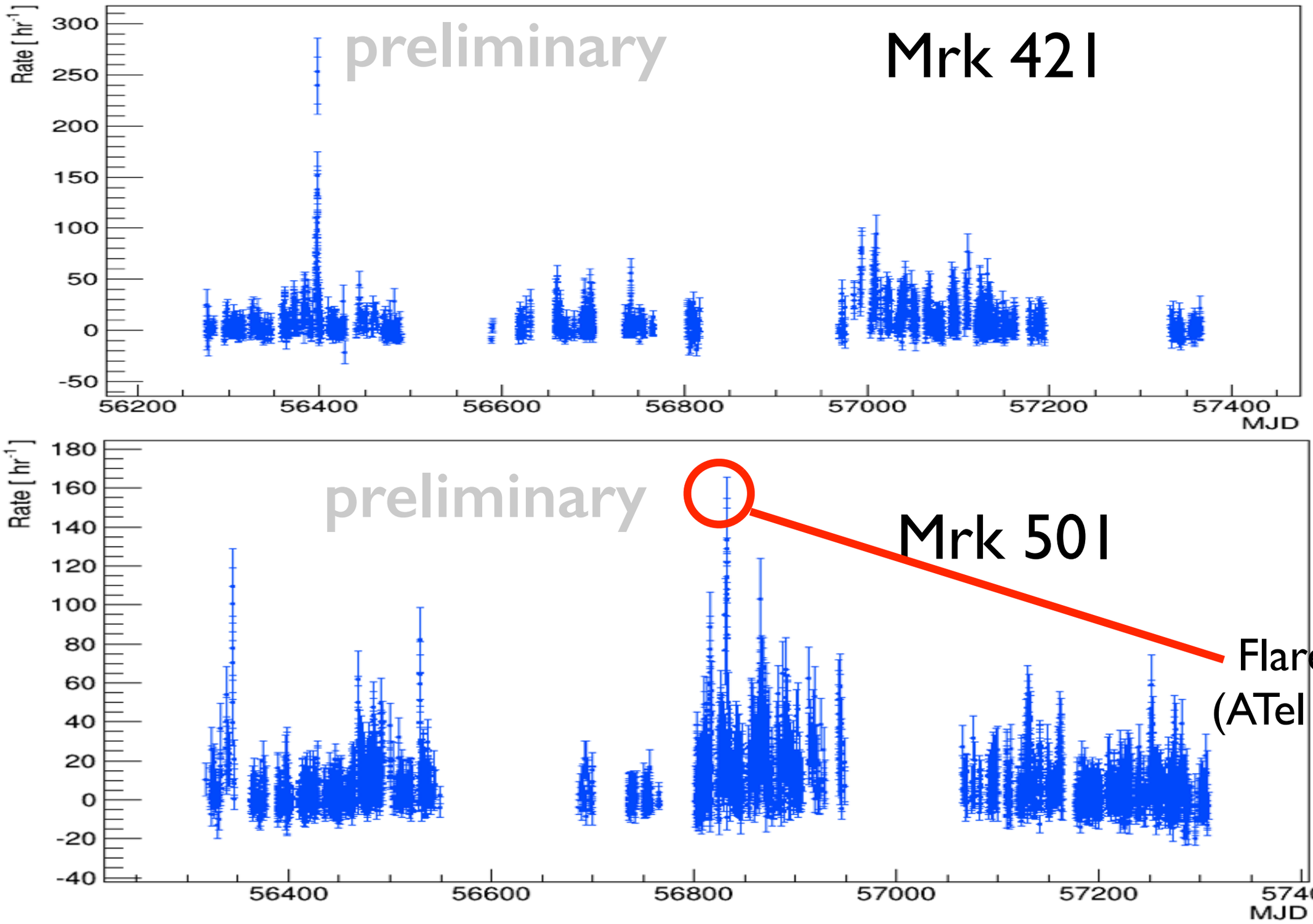
- Comparison Whipple Mrk 421
  - 14 years: 878 hours



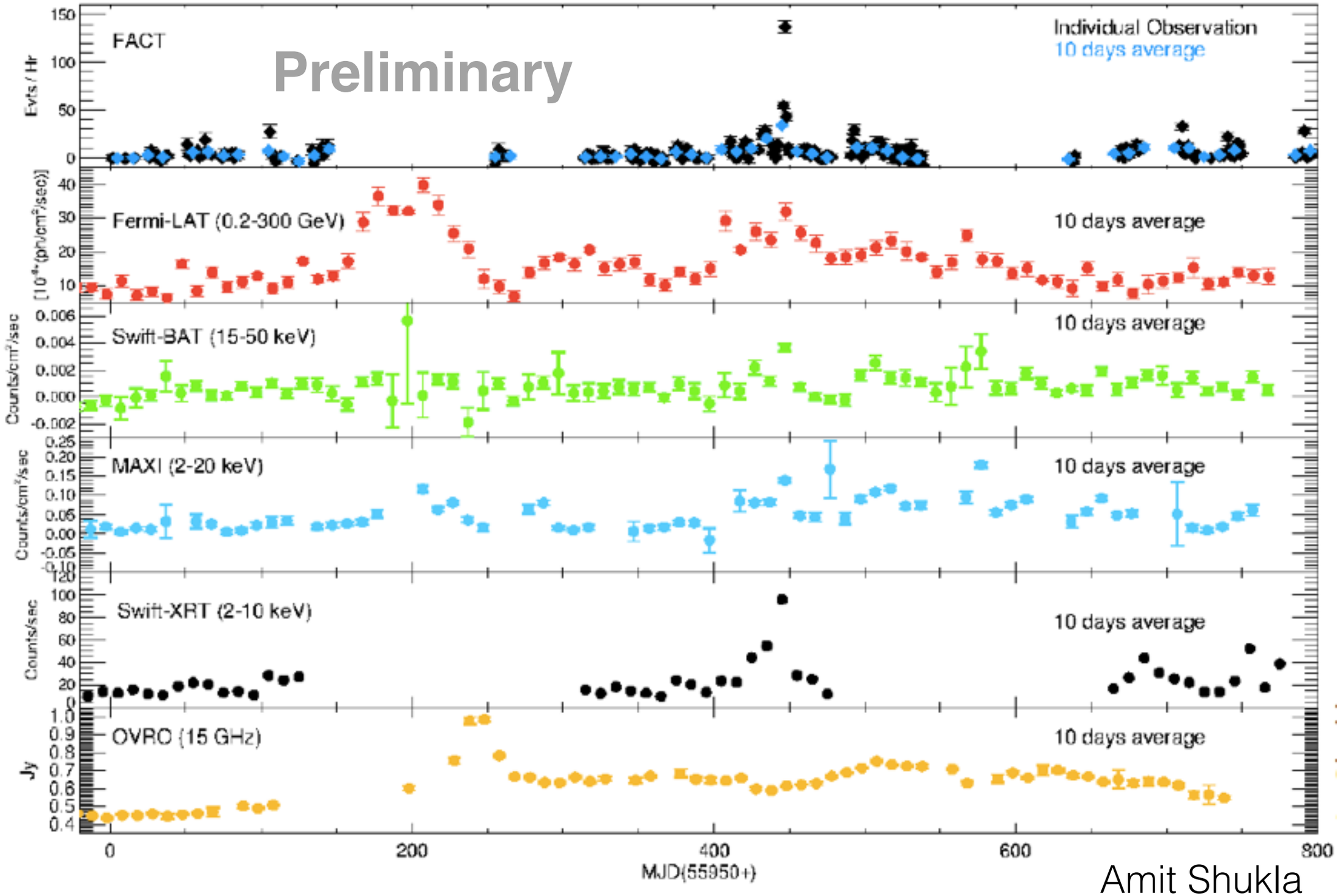
- FACT now has comparable dataset
  - 4 years of operation
  - Mrk 421: 820+ hrs
  - Mrk 501: 1290+ hrs



Monitoring

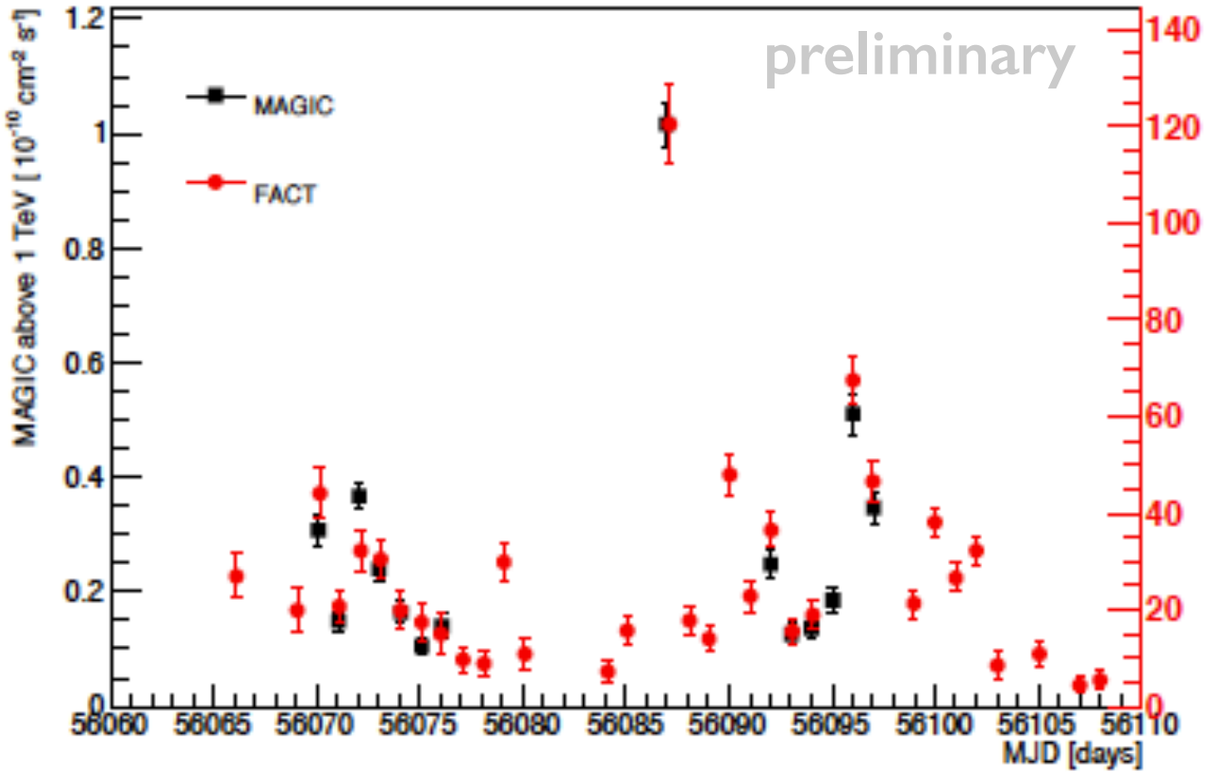

preliminary
Mrk 421
Rate [hr^{-1}]
300
250
200
150
100
50
0
-50
56200
56400
56600
56800
57000
57200
57400
MJD
preliminary
Mrk 501
Flare alert
(ATel #6268)
Rate [hr^{-1}]
180
160
140
120
100
80
60
40
20
0
-20
-40
56400
56600
56800
57000
57200
57400
MJD

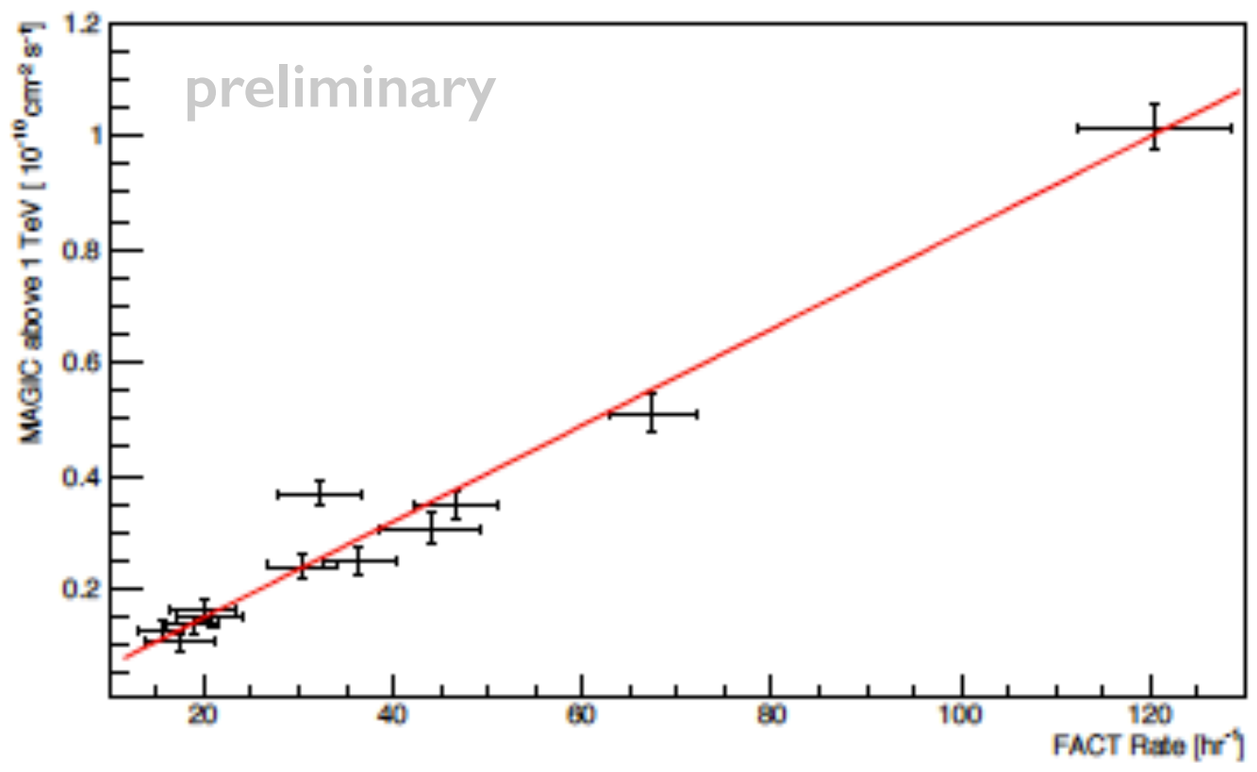
Mrk 421 in 2012



Amit Shukla

Comparison to MAGIC: Mrk 501

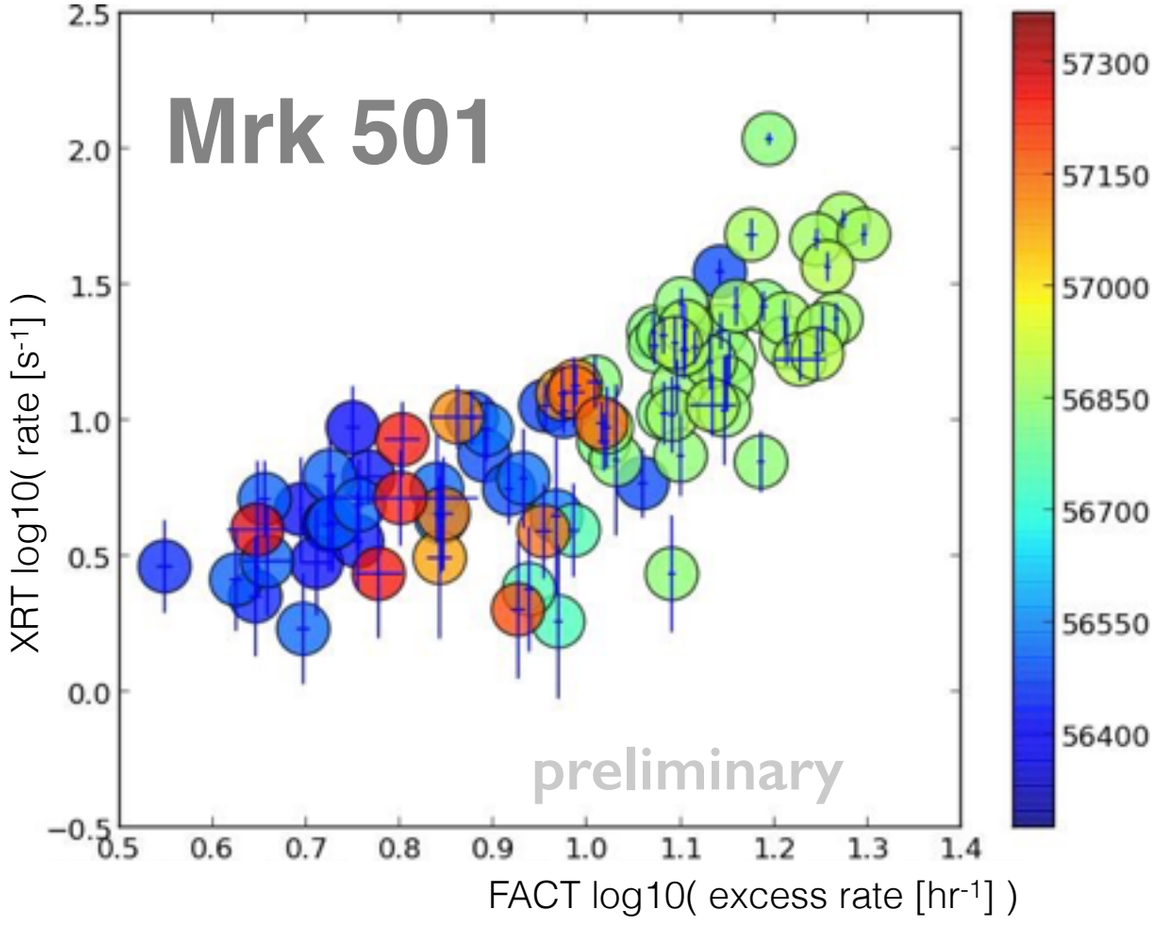


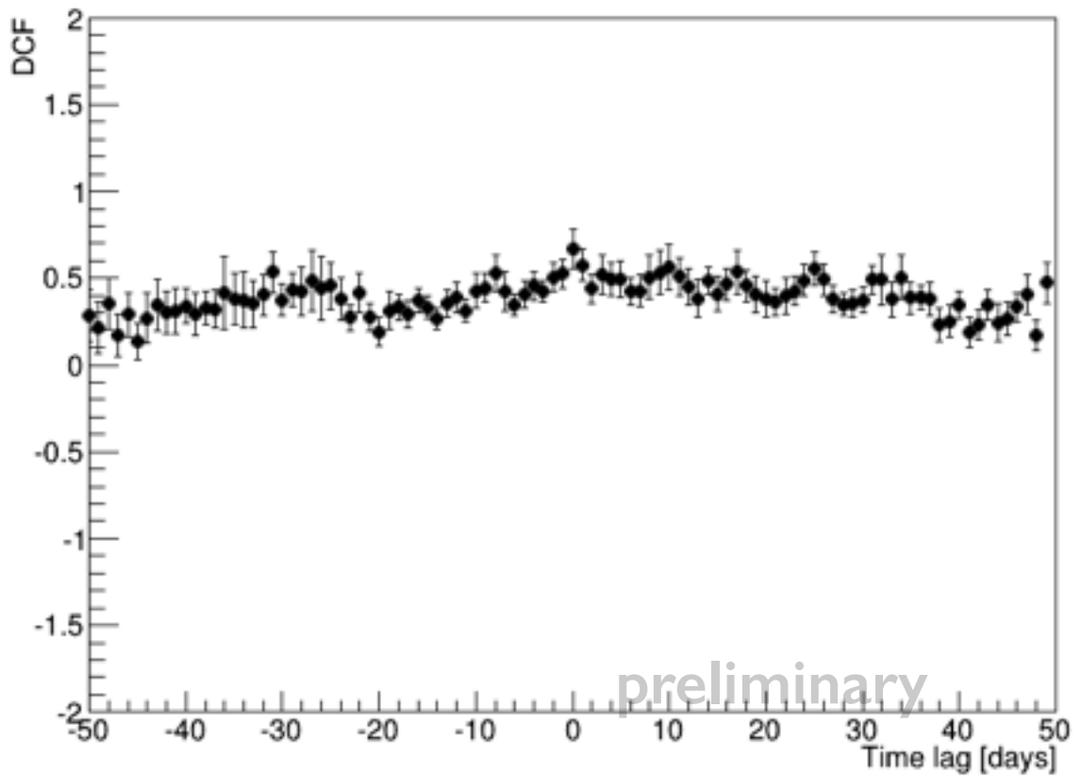


- FACT Mrk 501 data taking started in May 2012
  during MWL campaign
- On the 9th June a 10 Crab Unit flare (>1TeV) was observed
- **Excellent agreement between MAGIC and FACT data**
  Correlation plot linear fit gives $\chi 2$/dof of 10.4/10
- Also in the previous session Mrk 501 2014 data also shown as part of MWL campaign
  J. Becerra

Correlation Mrk 501

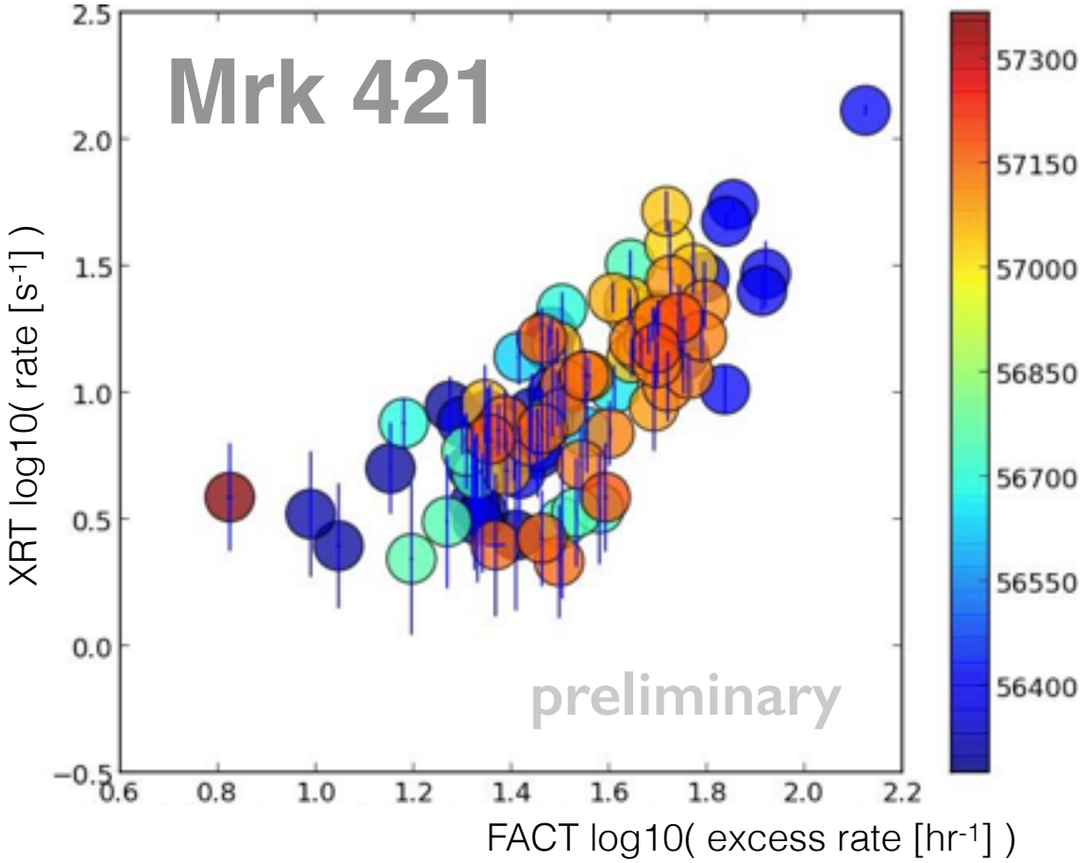
- Correlation FACT nightly rate to the nearest Swift-XRT rate taken within 1 day
- FACT: <40^{o} Zenith and Low threshold (No to moderate Moon)
- Z-colour is the MJD of the correlation

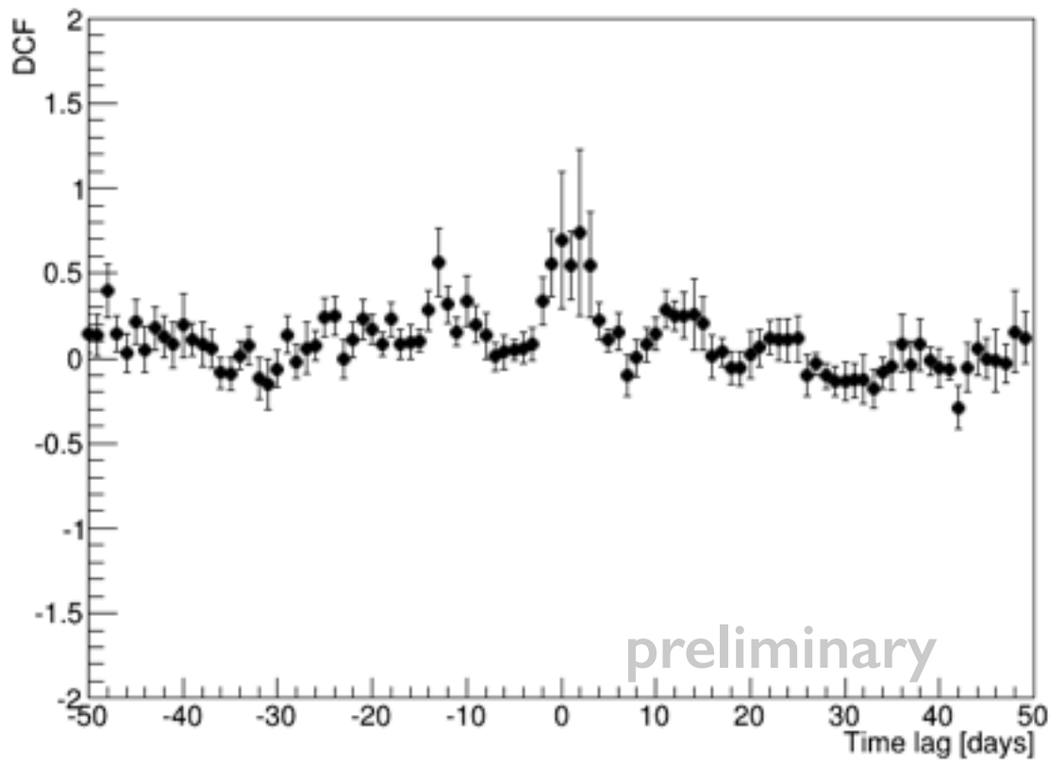




Correlation Mrk 421

- Correlation FACT nightly rate to the nearest Swift-XRT rate taken within 1 day
- FACT: <40° Zenith and Low threshold (No to moderate Moon)
- Z-colour is the MJD of the correlation





Conclusion

- FACT has been operational since October 2011
- Proven to be extremely stable in real life conditions
- Feedback enables uniform data taking
  Ratescans and Muons
- Crab Spectrum
- Large un-biased data sets
  monitoring for the community
- Data shows excellent agreement with MAGIC

- **G-APDs (SiPMs) are a viable option for Cherenkov Telescopes**