The First G-APD Cherenkov Telescope: Status and Results

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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 mm²
FACT Telescope

- 2 km a.s.l La Palma
- Old HEGRA mount
- Mirror area 9.51 m²
- 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
  - $\Delta V \sim 22 \text{ mV}$
  - $\Delta I \sim 1.2 \mu\text{A}$

- Temperature read every 15s
- Current read every second
Feedback: Dark Count Spectra

1428 Pixels, 1 year data, \( \Delta T \sim 25^\circ C \)

Fit: Modified Erlang Dist.

Lid Closed
10K triggers @ 77 Hz
> 2x per night
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

dark night ~ 5µA

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

http://fact-project.org/smartfact
Quick Look Analysis

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

Crab Nebula
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

Mrk 421

Flare alert (ATel #6268)

Mrk 501
Mrk 421 in 2012

Preliminary
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: $<40^\circ$ Zenith and Low threshold (No to moderate Moon)
- Z-colour is the MJD of the correlation
Correlation Mrk 421

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![Graph of Mrk 421 correlation](image)

**Correlation Facts**

- XRT log10( rate [s$^{-1}$])
- FACT log10( excess rate [hr$^{-1}$])

**Graphs:**

- XRT vs. FACT correlation
- DOF vs. Time lag [days]

Preliminary data presented.
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