FACT *– the **F**irst G-**A**PD **C**herenkov **T**elescope*

Status and Experience from Seven+ Years Operation of the First SiPM Camera

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ISDC DATA CENTRE FOR ASTROPHYSICS
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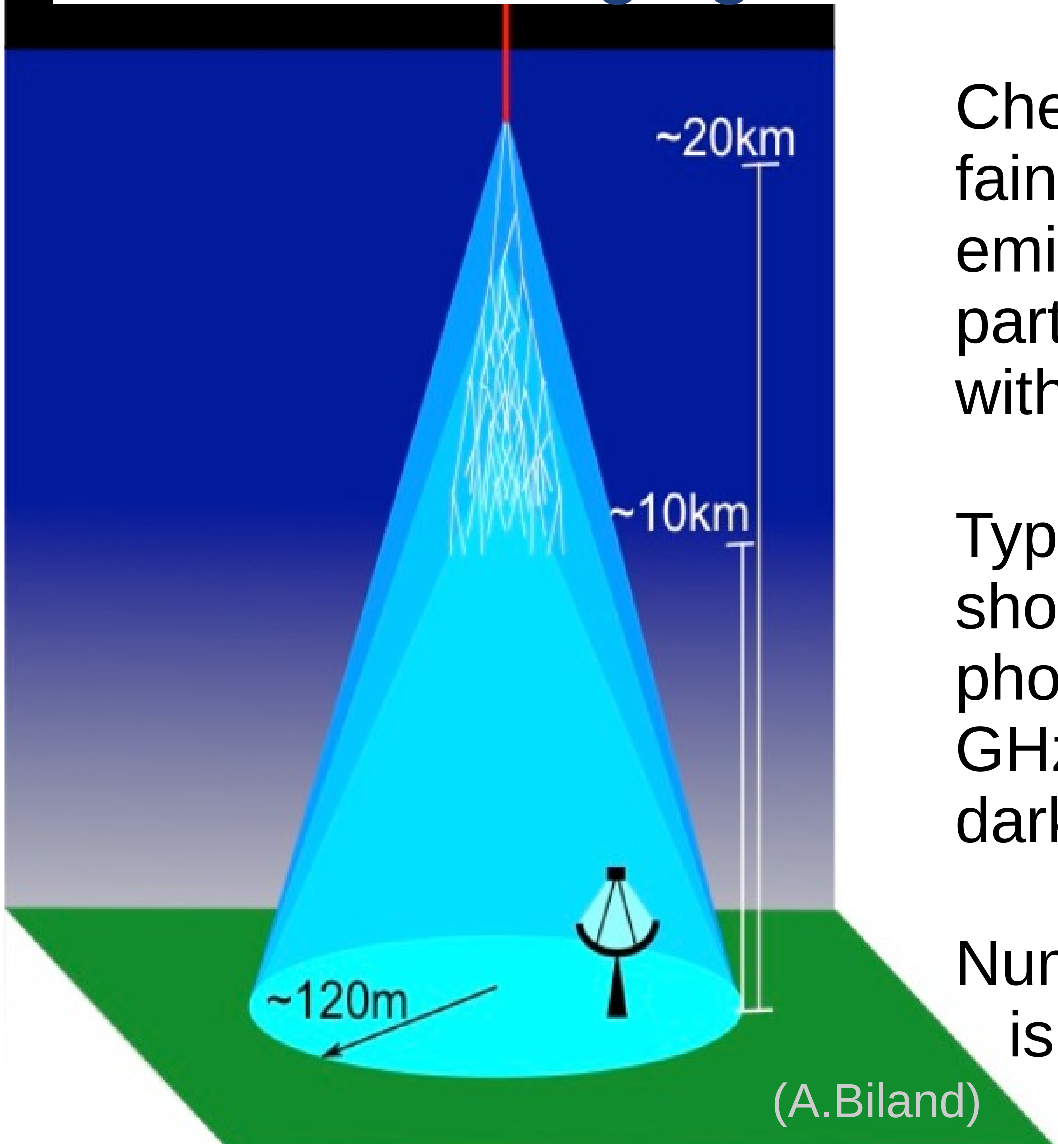
Julius-Maximilians-UNIVERSITÄT WÜRZBURG

IACT - Imaging Air Cherenkov Telescope



Cherenkov telescopes measure faint flashes of Cherenkov light emitted when a cosmic-ray particle or gamma ray interacts with the atmosphere.

Typically one measures showers with 50 Cherenkov-photons within few ns over a 50 GHz night sky background for dark night conditions.

Number of Cherenkov Photons is ~proportional to energy of primary particle.


Very harsh environment intrinsic to IACT
Sensors
Electronics

Detailed List of Problems due to G-APD (SiPM)

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thank you for your attention

FACT – History

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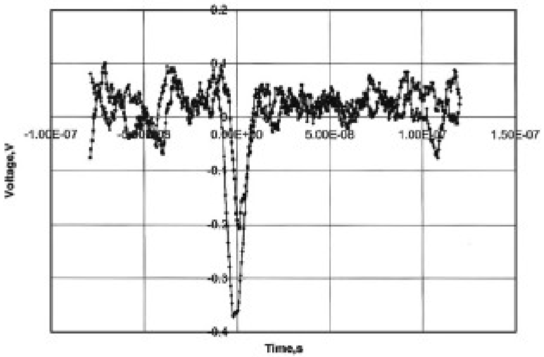
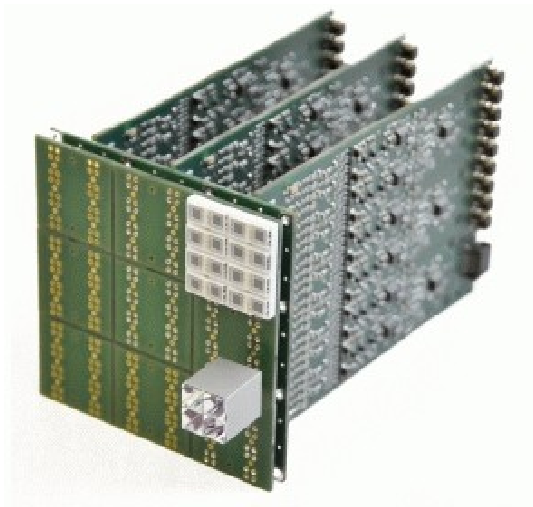
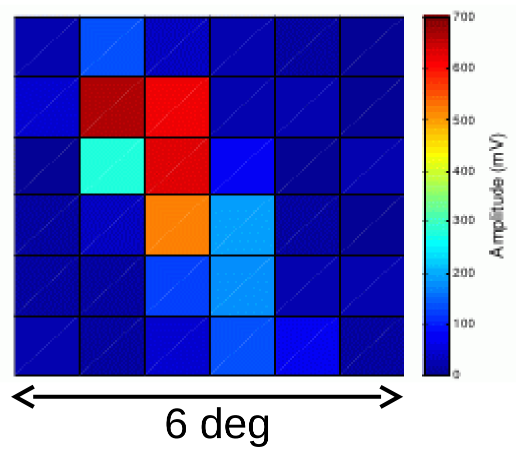


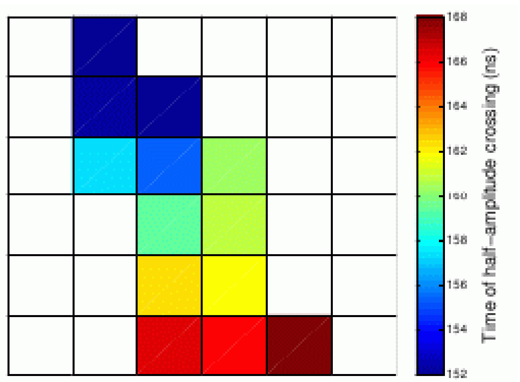
2007: First Cherenkov flashes seen with few G-APDs attached to MAGIC camera [NIM A 581]

2008: Collaboration of ETH Zurich and Universities Dortmund, Geneva, Würzburg (+EPF Lausanne) to build a G-APD based camera for HEGRA CT3

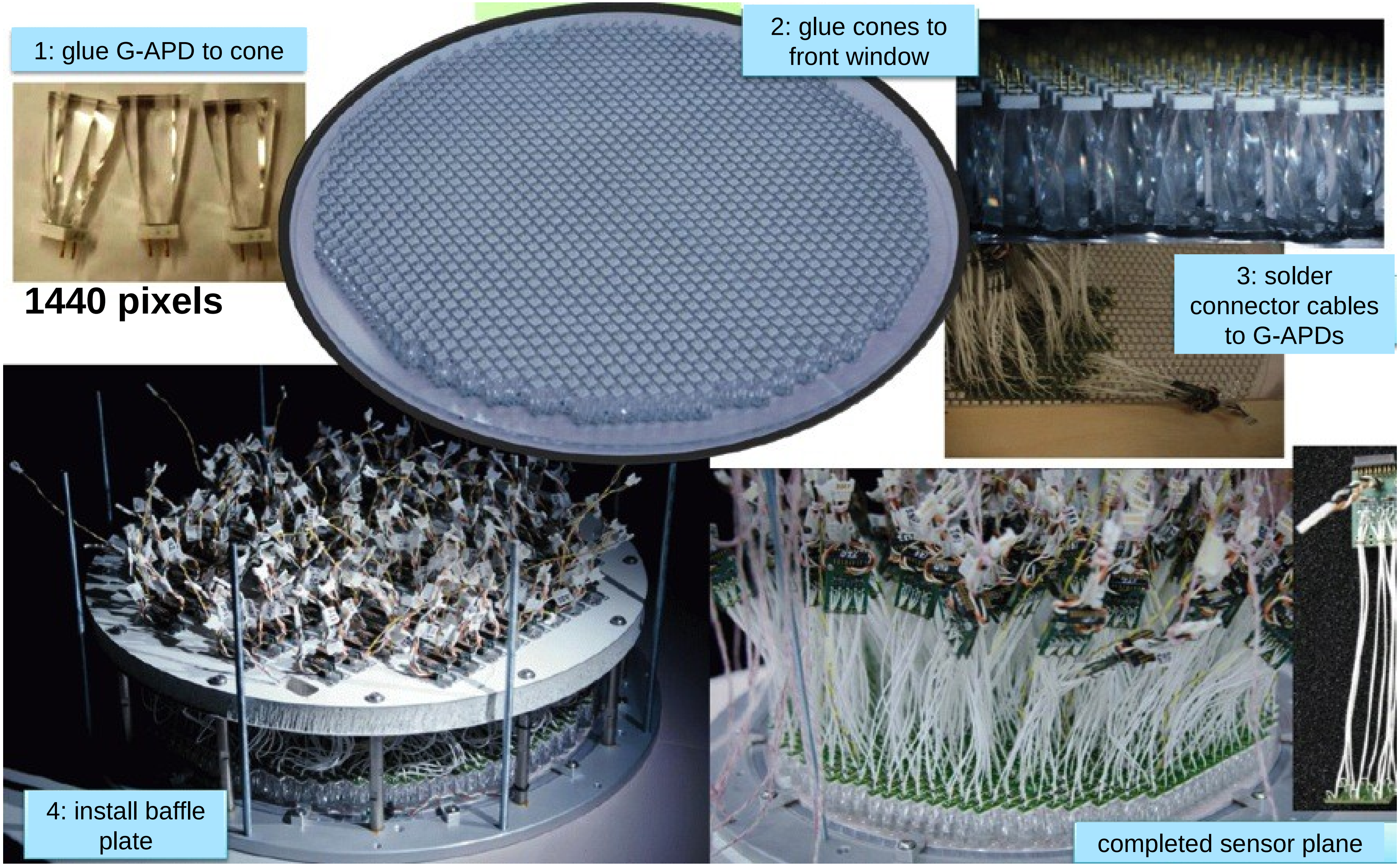
2009: *Module0* (36 pix, 4 G-APD/pix) records self-triggered Cherenkov images from the roof of ETH Zurich [JINST4 P10010] → go for complete camera





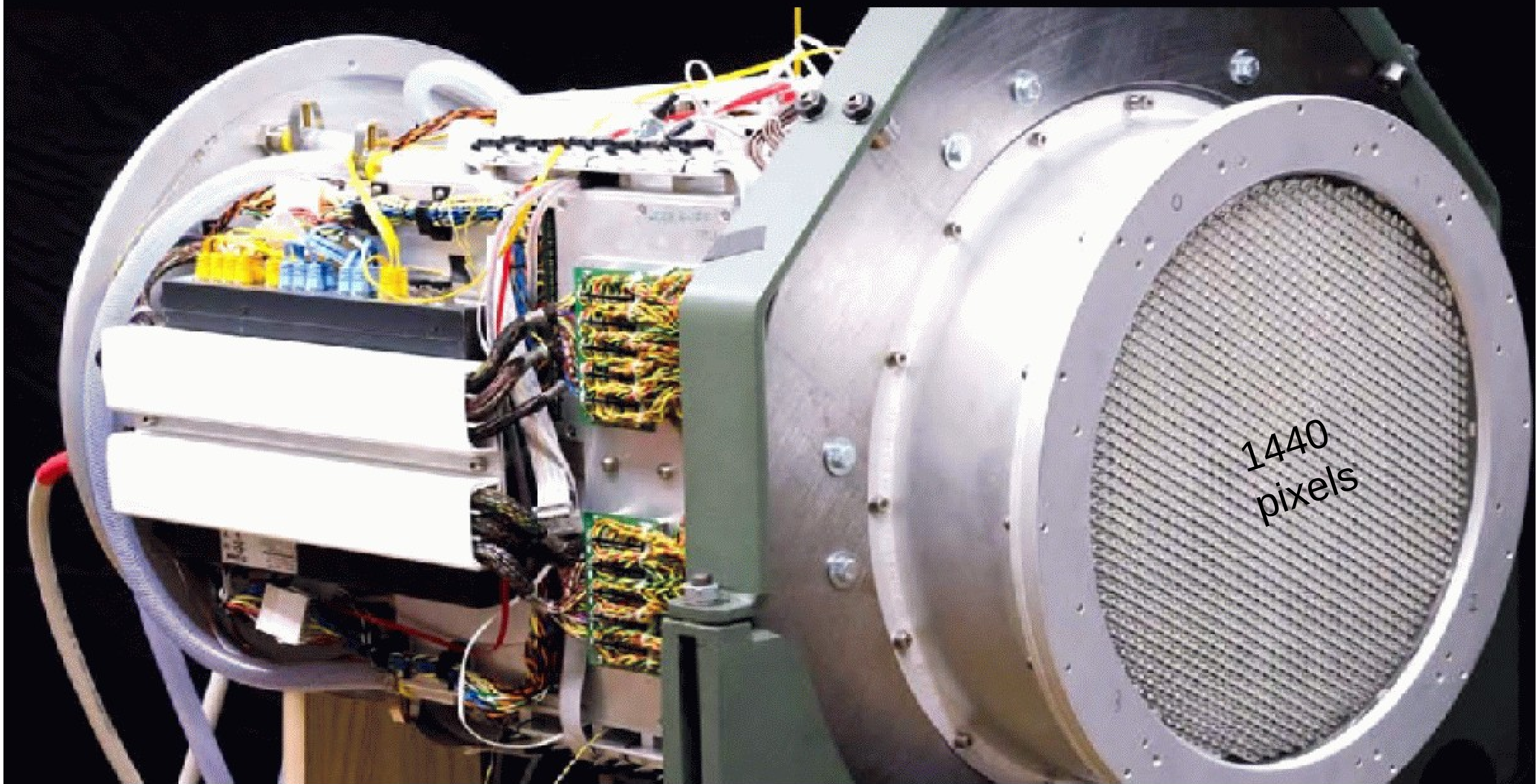


Focal Plane


1: glue G-APD to cone
1440 pixels
2: glue cones to front window
3: solder connector cables to G-APDs
4: install baffle plate
completed sensor plane

Integrated electronics
DRS4 readout

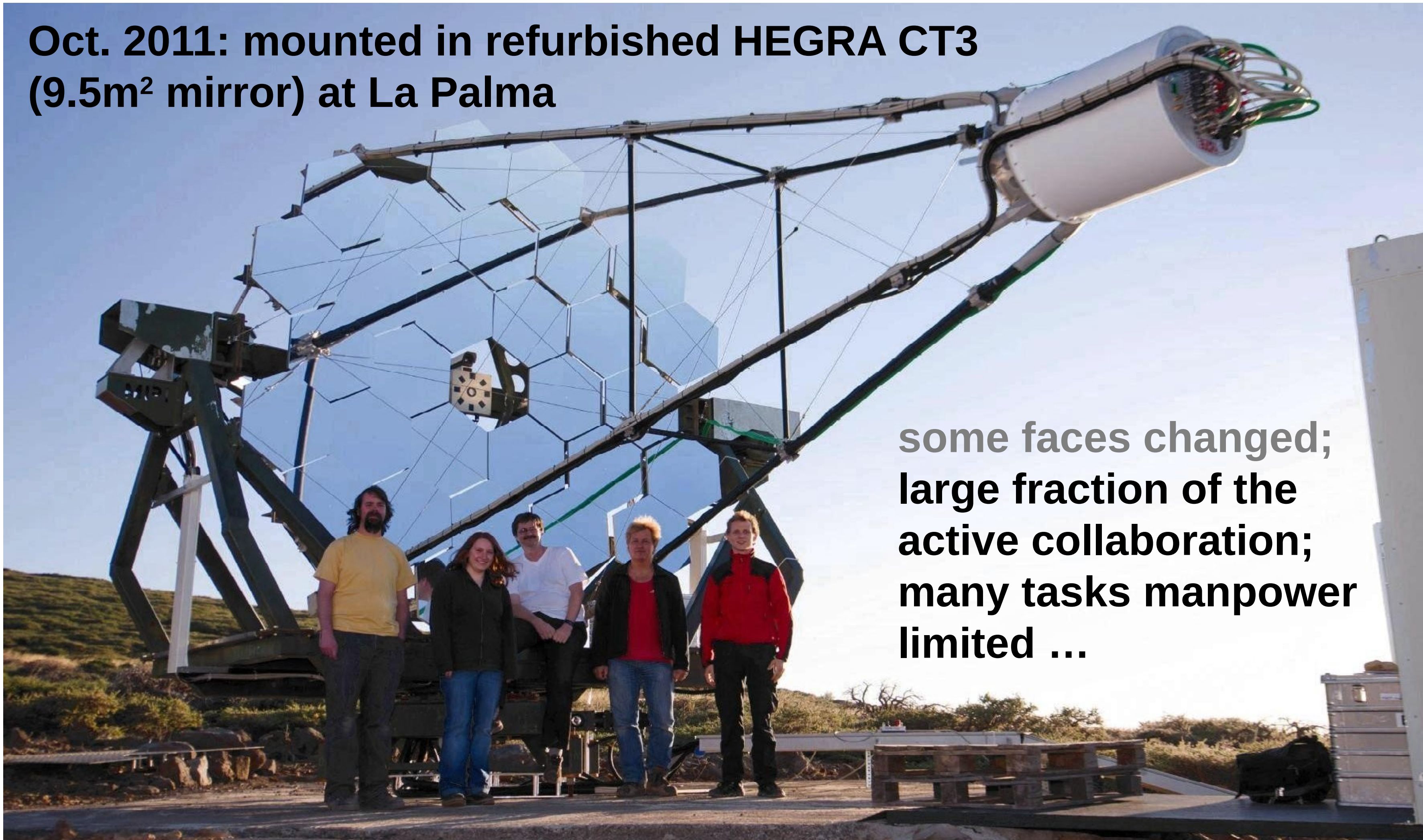
320 bias voltage channels
(1 per 4\5 G-APDs)



Power consumption ≤500W
Readout via Ethernet

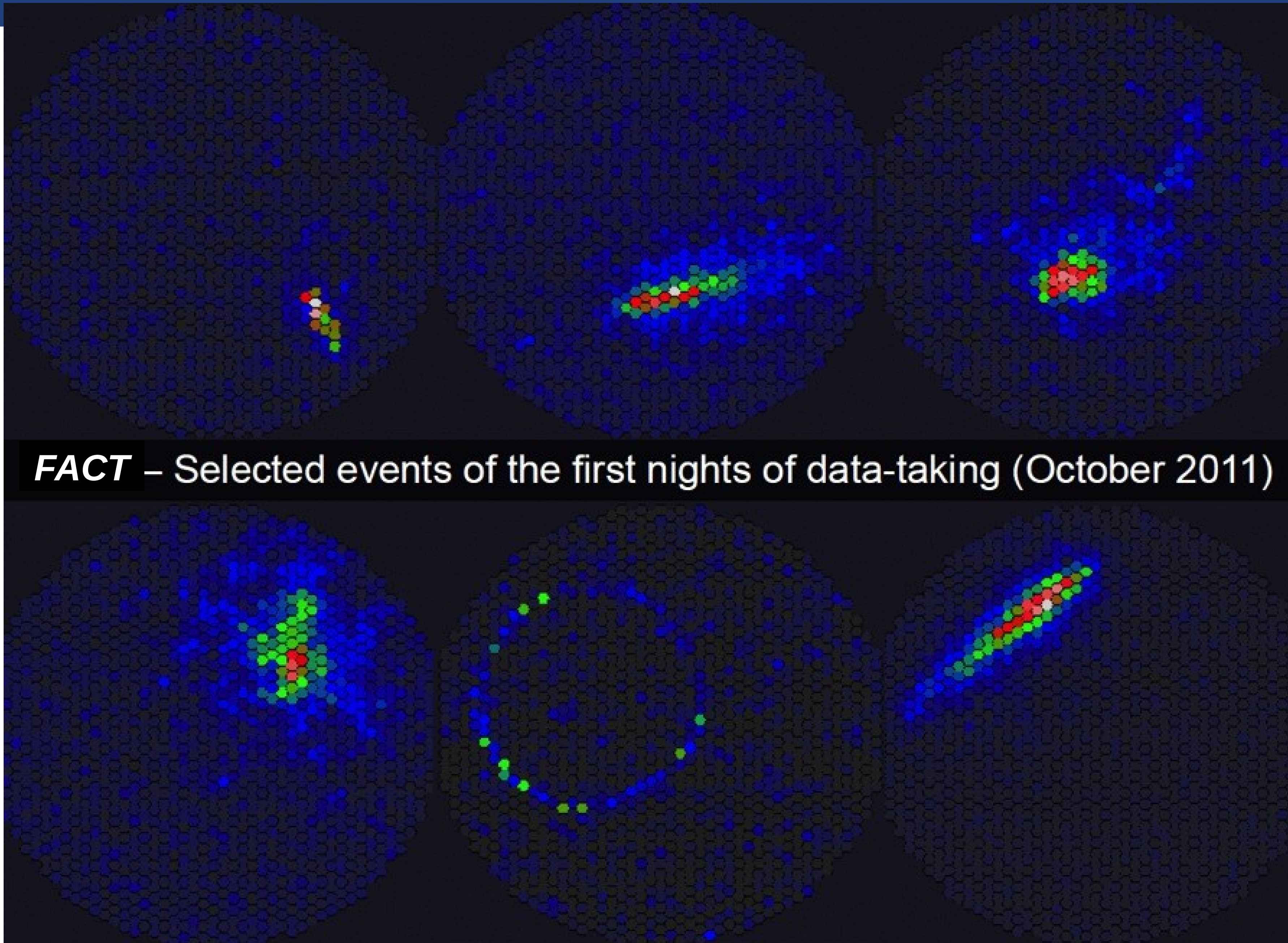
160 trigger patches
(sum of 9 channels)

FACT – the First G-APD Cherenkov Telescope



Oct. 2011: mounted in refurbished HEGRA CT3 (9.5m^2 mirror) at La Palma

some faces changed;
large fraction of the active collaboration;
many tasks manpower limited …


FACT – Selected events of the first nights of data-taking (October 2011)

Uniformity & Stability of Camera – 1 Year of data

(our) G-APD gain has strong temperature dependency (~4%/degree)
→ Feedback system → adjust applied voltage to Temp. (and DC)
Nowadays you can even buy power supplies doing this for you.

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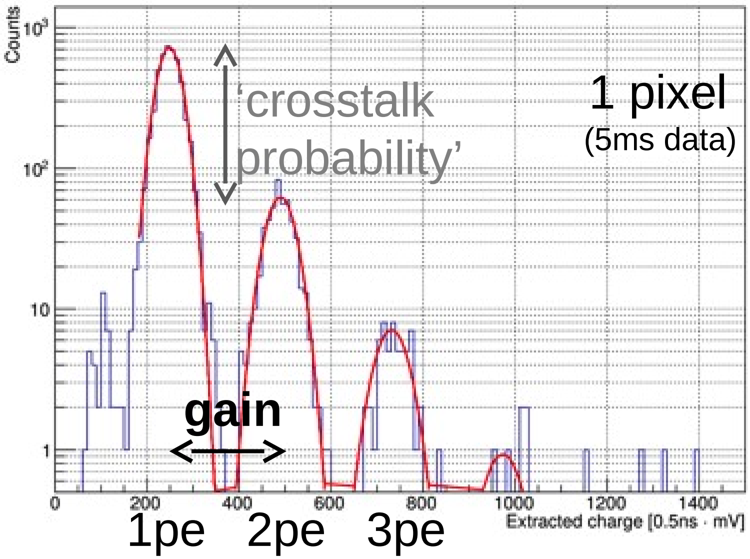
Monitor gain with 1pe spectra:
(dark noise + crosstalk are your friends)



→ dark noise + crosstalk allow calibration without any external device

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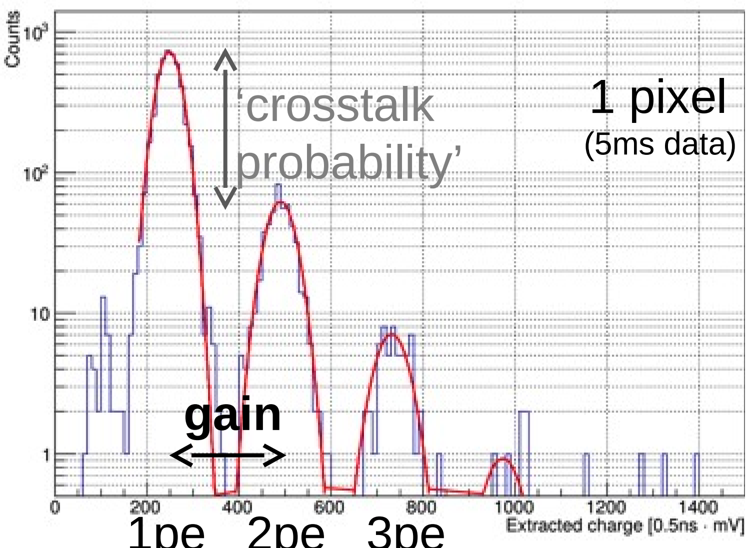

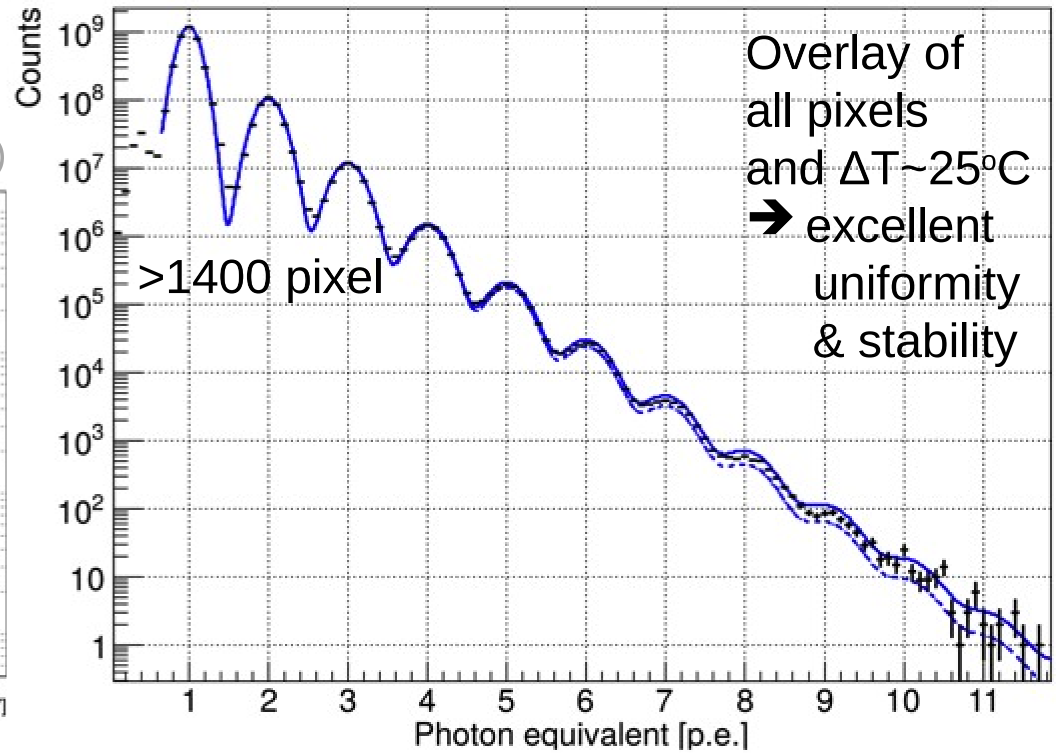

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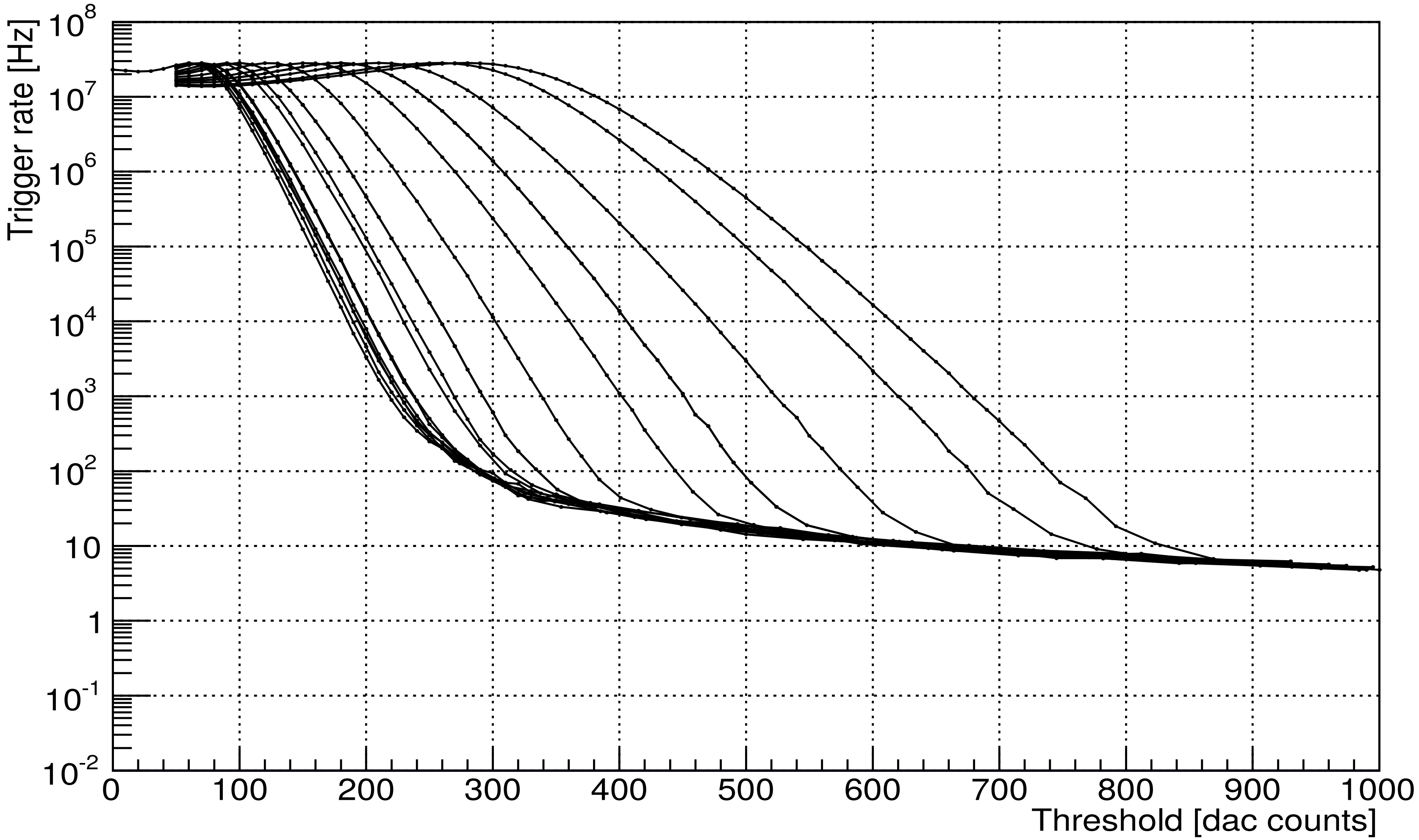
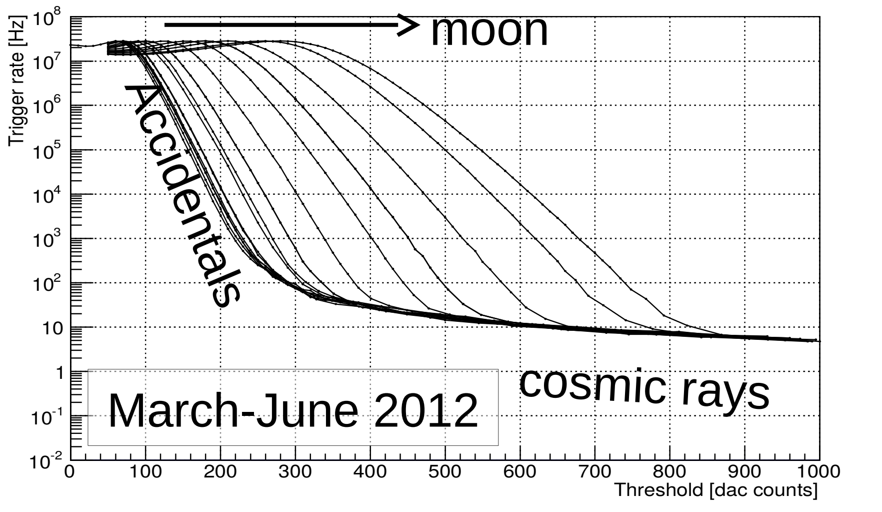
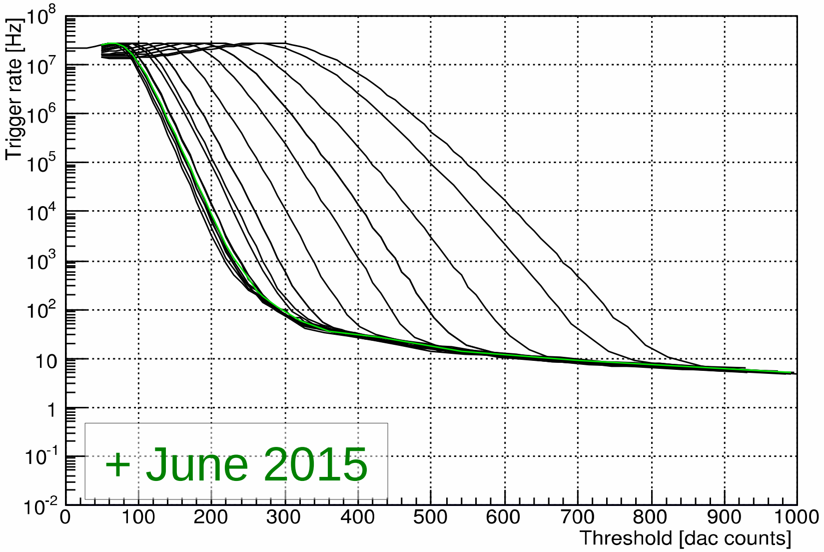
FACT – Stability of System



FACT – Stability of System

For a given pointing, trigger should always see the same rate of cosmic rays.





Ratescans show cosmic ray trigger-rate independent of moon, sensor temperature and age of sensors.

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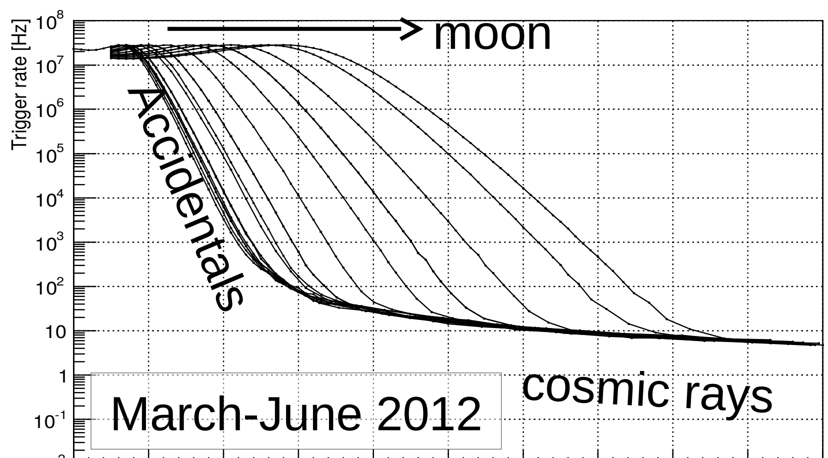
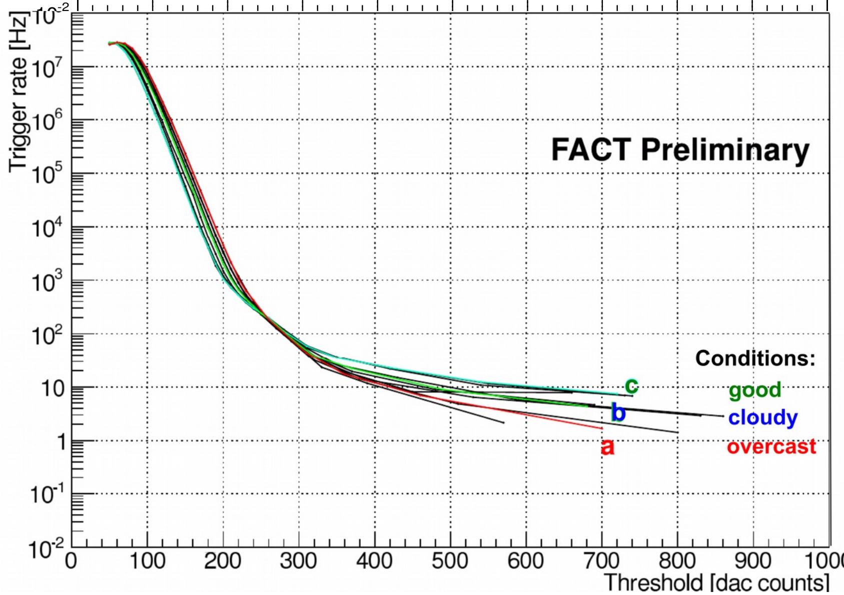
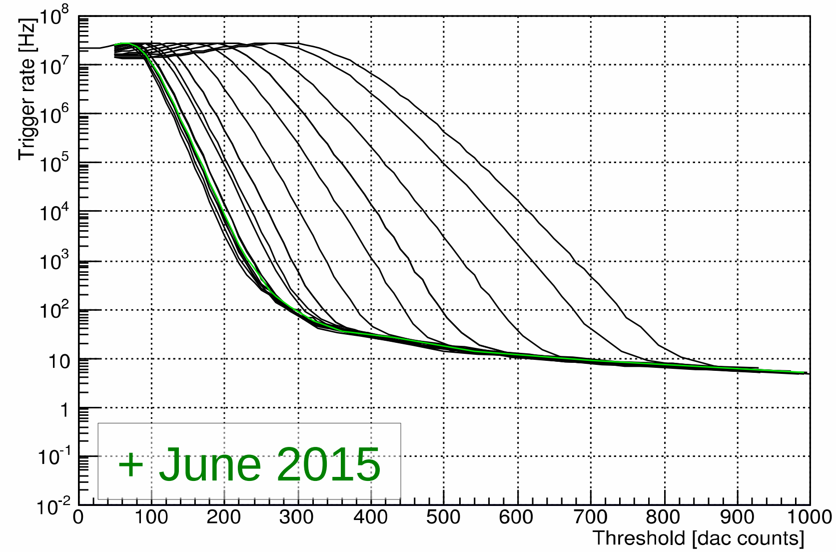


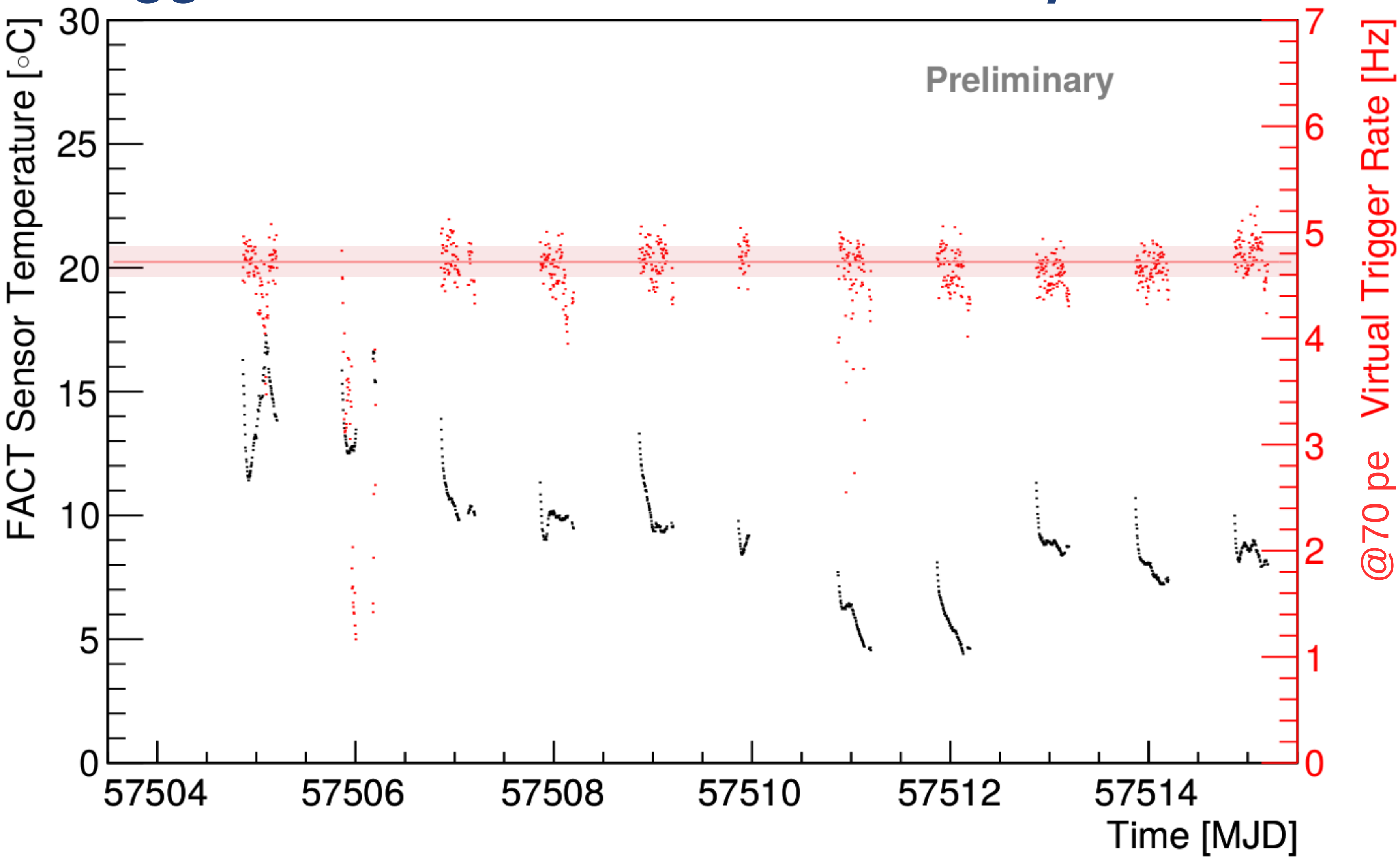




Ratescans show cosmic ray trigger-rate independent of moon, sensor temperature and age of sensors.

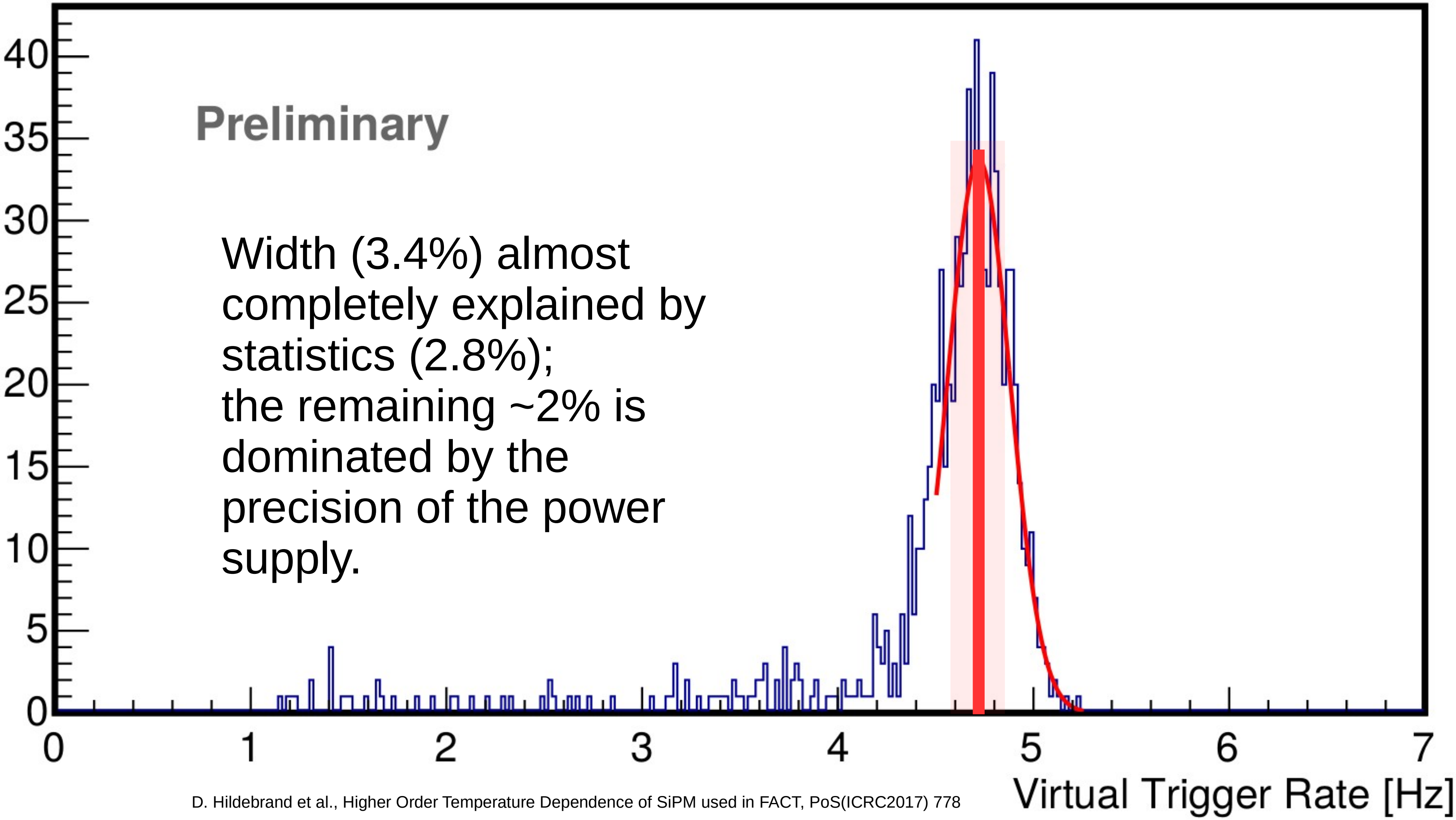
Bad atmospheric conditions give us a handle on 2nd order effects.

Trigger Rate uncorrelated with Temperature



D. Hildebrand et al., Higher Order Temperature Dependence of SiPM used in FACT, PoS(ICRC2017) 778

FACT – Stability of 2nd order temperature effects

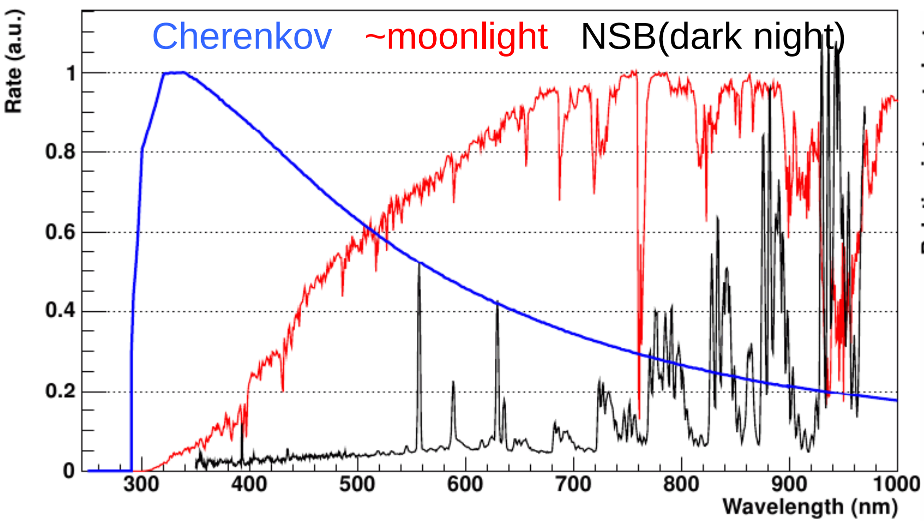


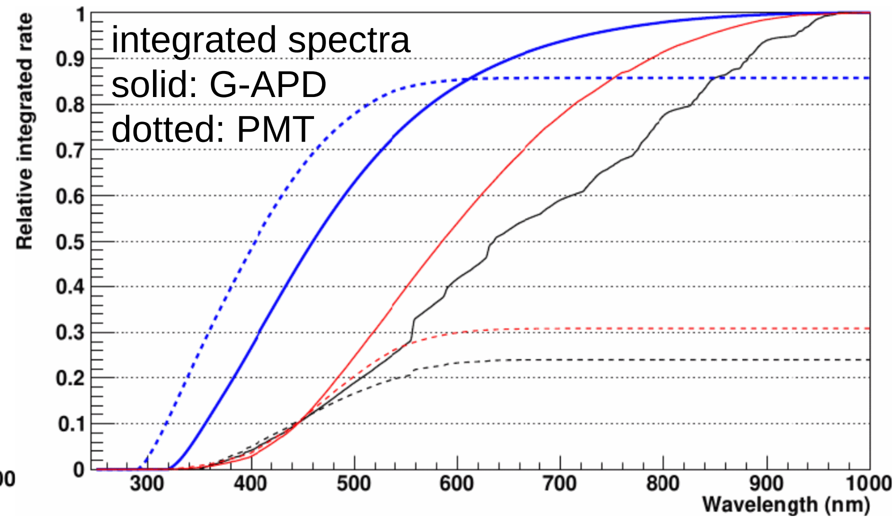
Width (3.4%) almost completely explained by statistics (2.8%); the remaining ~2% is dominated by the precision of the power supply.

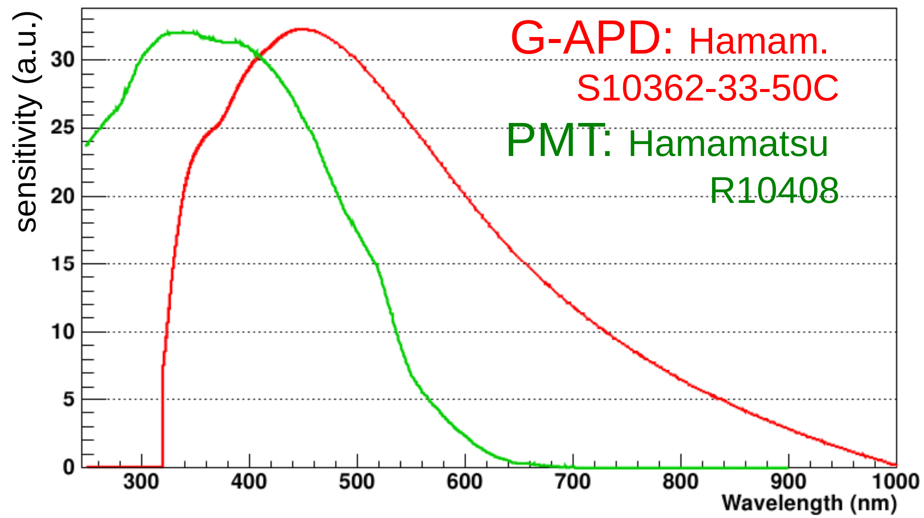
D. Hildebrand et al., Higher Order Temperature Dependence of SiPM used in FACT, PoS(ICRC2017) 778

FACT – Longevity

FACT – Signal & Background





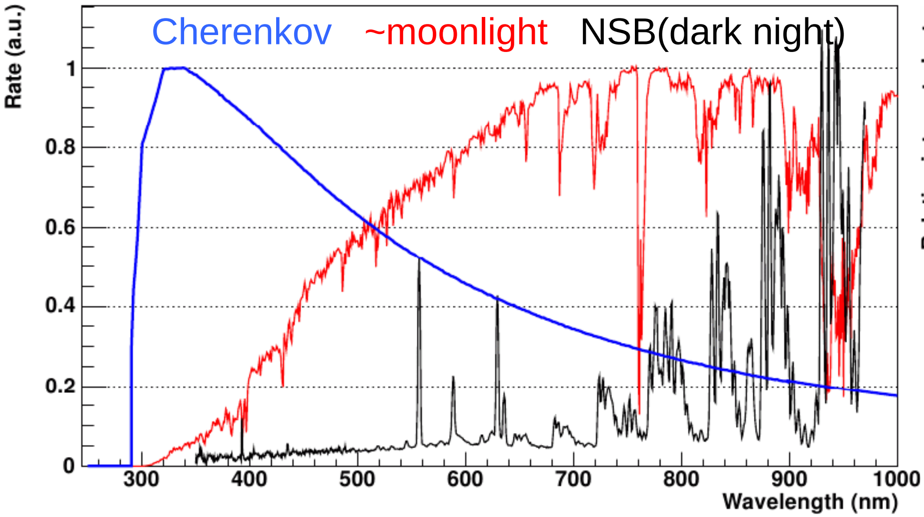


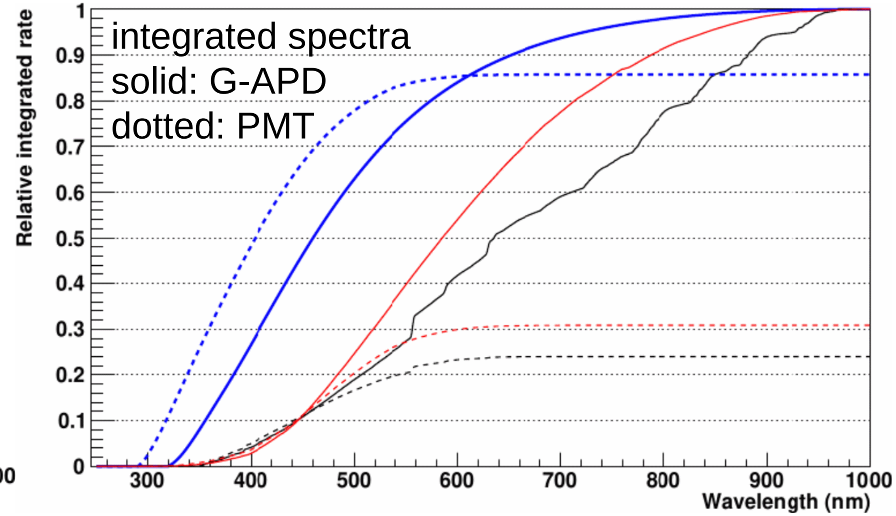
sensitivity curve of the first G-APDs not well adjusted to Cherenkov spect.

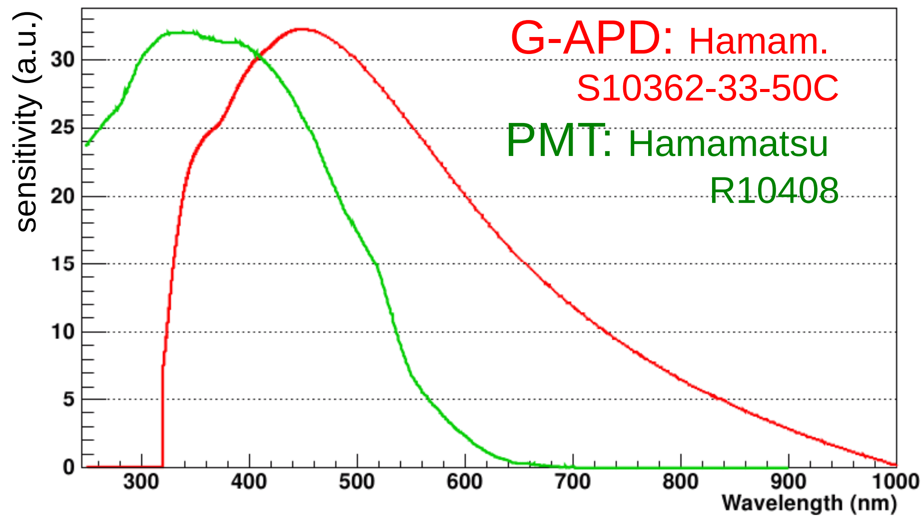
collect much more NSB (and moon) than optimized PMTs

Nevertheless, FACT can operate with lot of moonlight without aging

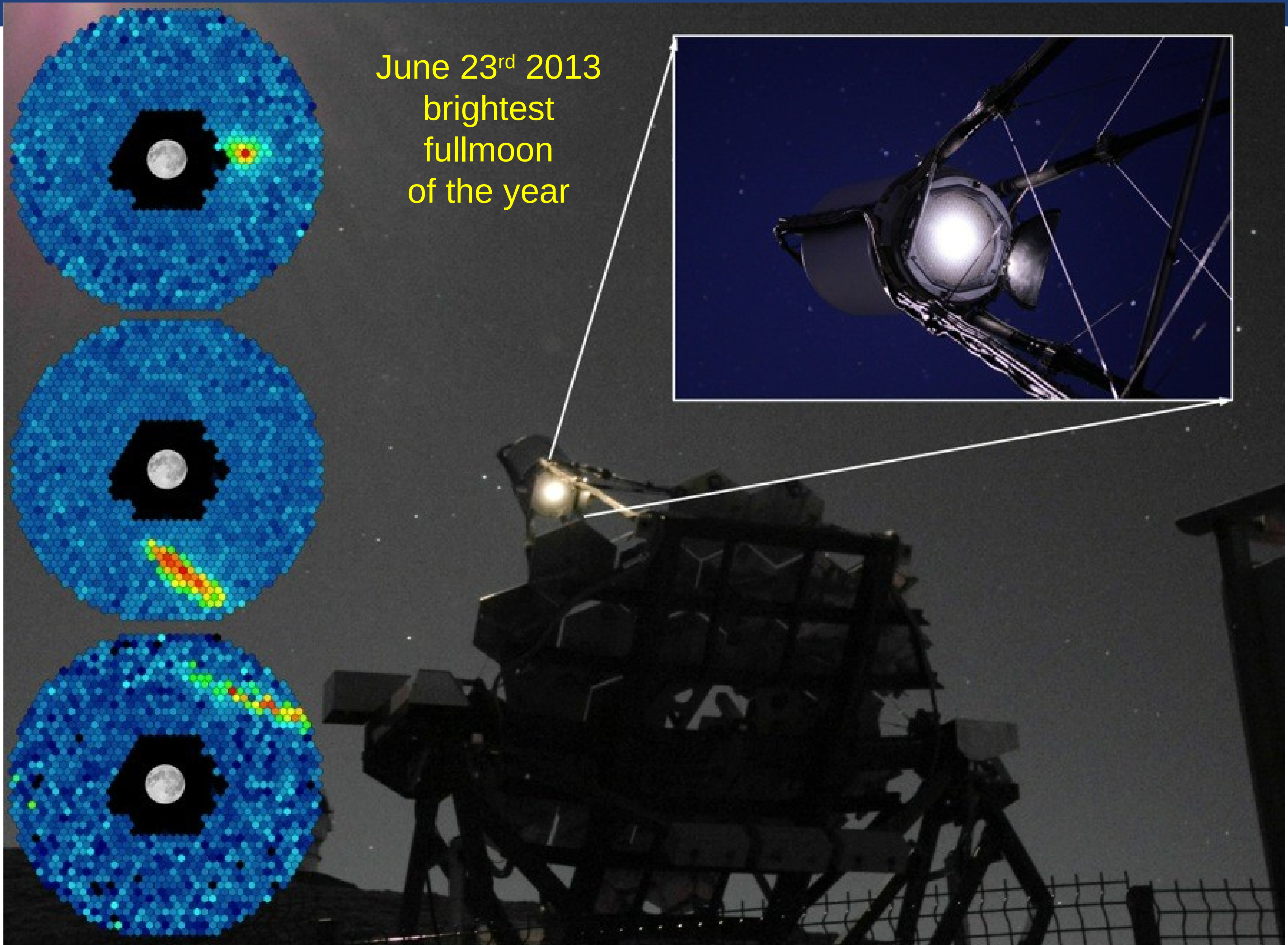
FACT – Signal & Background



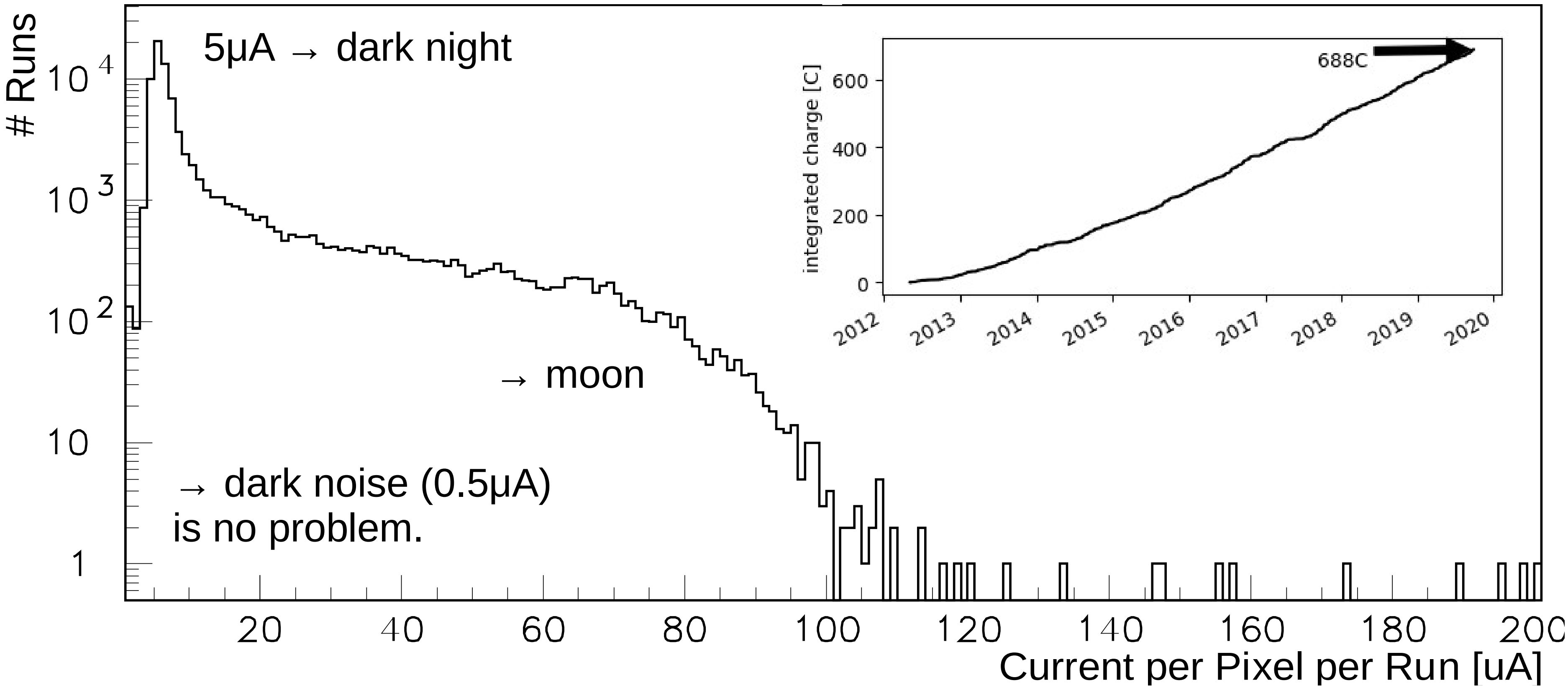




Today exist G-APDs, that are much better adapted to the needs of IACTs.


June 23rd 2013
brightest
fullmoon
of the year

FACT – Collected Charge



integrating over time, divide by dark-night DC (5µA) for each sensor:

collected same charge as in ~1.6k dark night observations

dark noise: ~0.5µA (laboratory)

➔ **collected same charge as in ~43 years continuous op. in laboratory**

FACT – Automation

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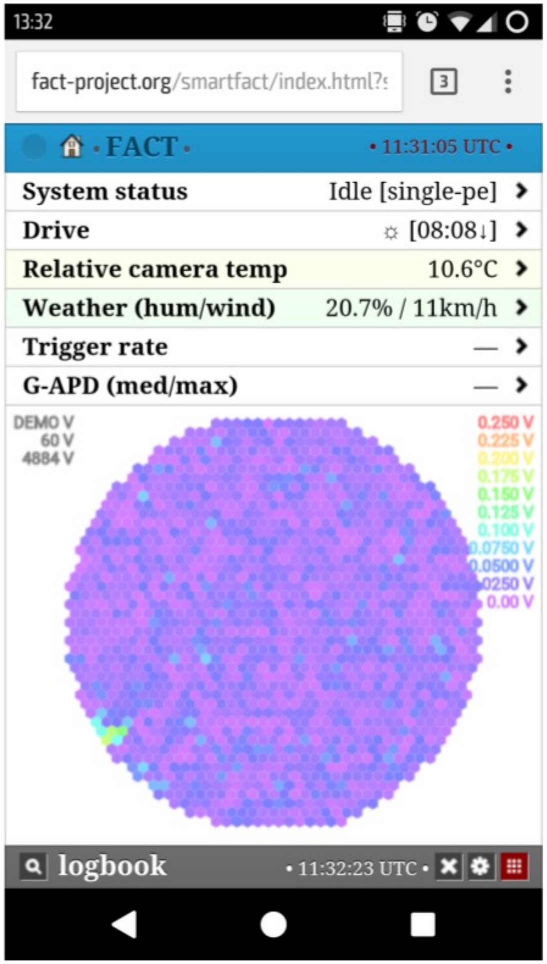
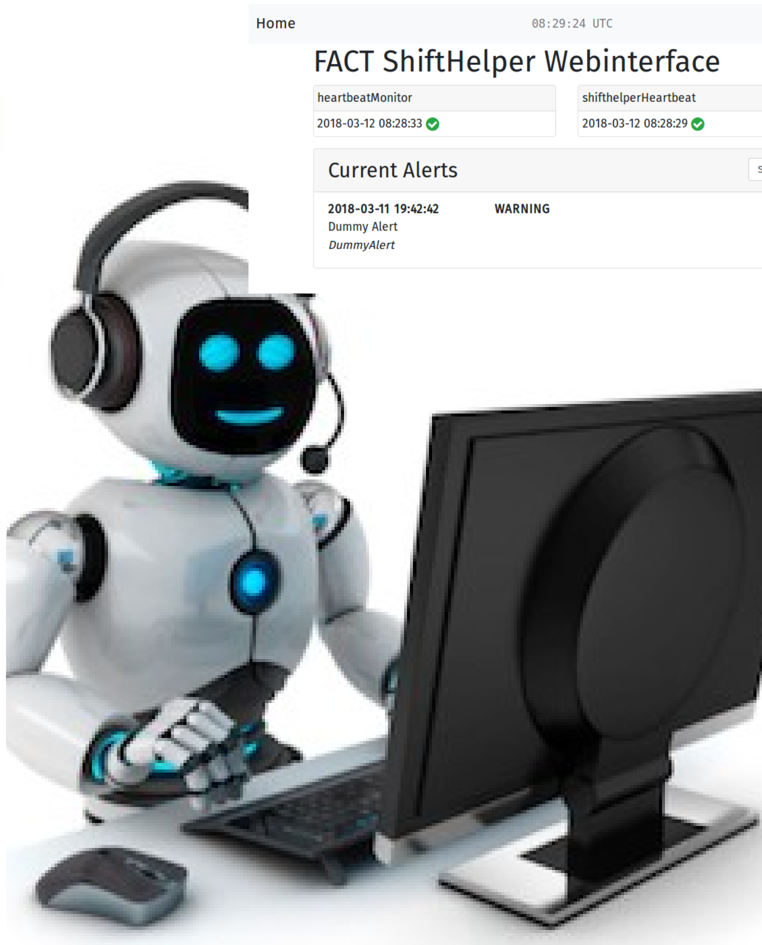
onsite data-taking (2011)

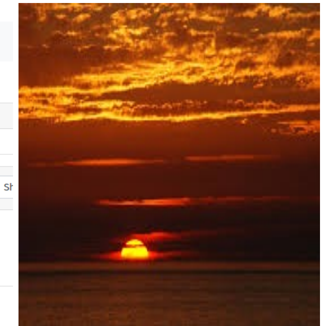
remote data-taking
from anywhere
(since mid 2012)

follow us at http://fact-project.org/smartfact

FACT – Automation

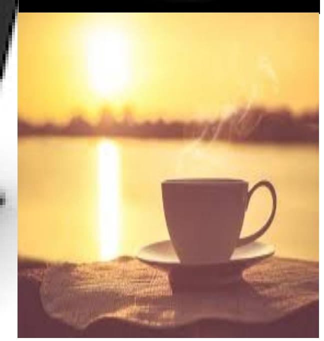






Evening: Arm System

Night: Sleep



Morning: Parked?

Calls shifter if human interaction is needed

FACT – Science

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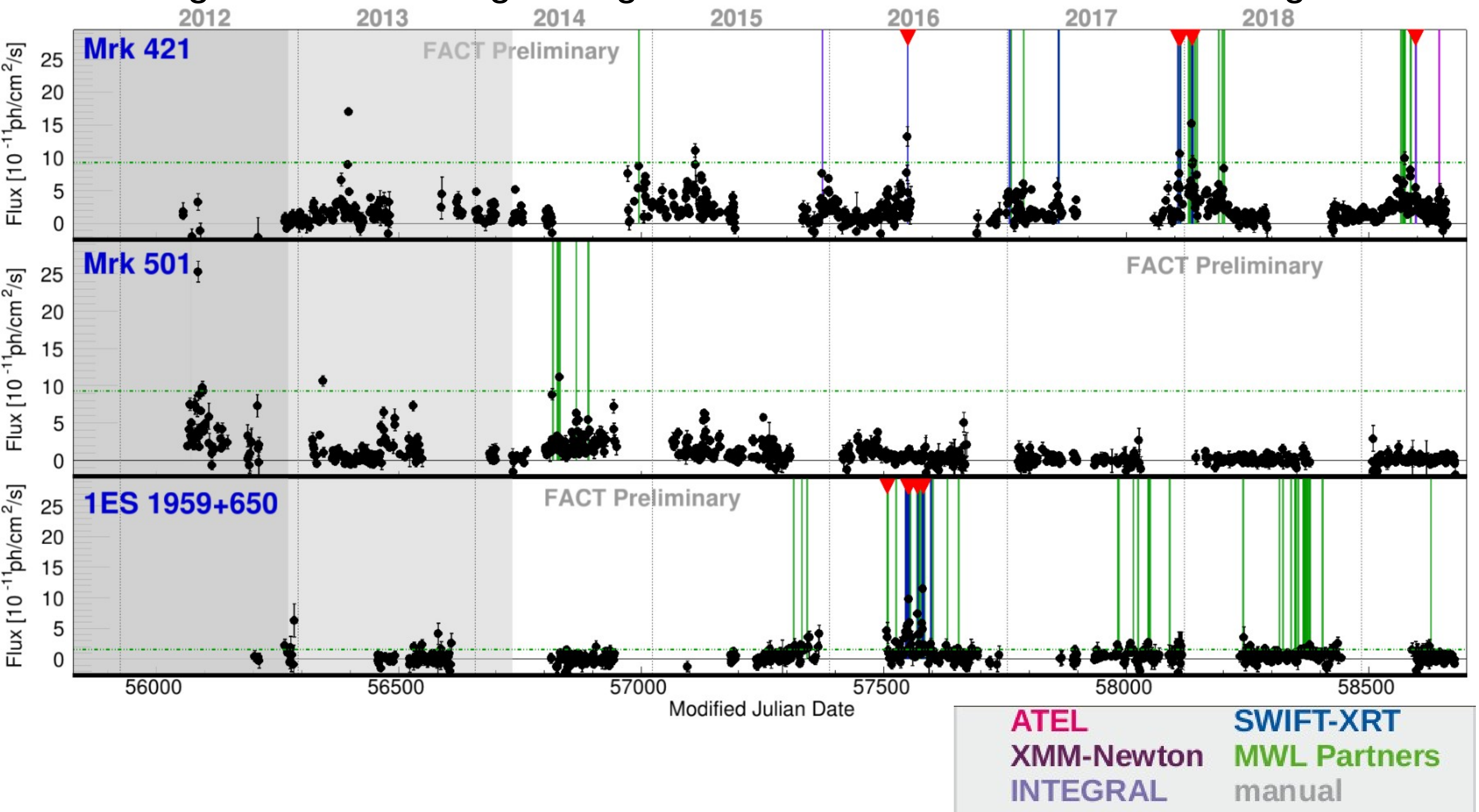
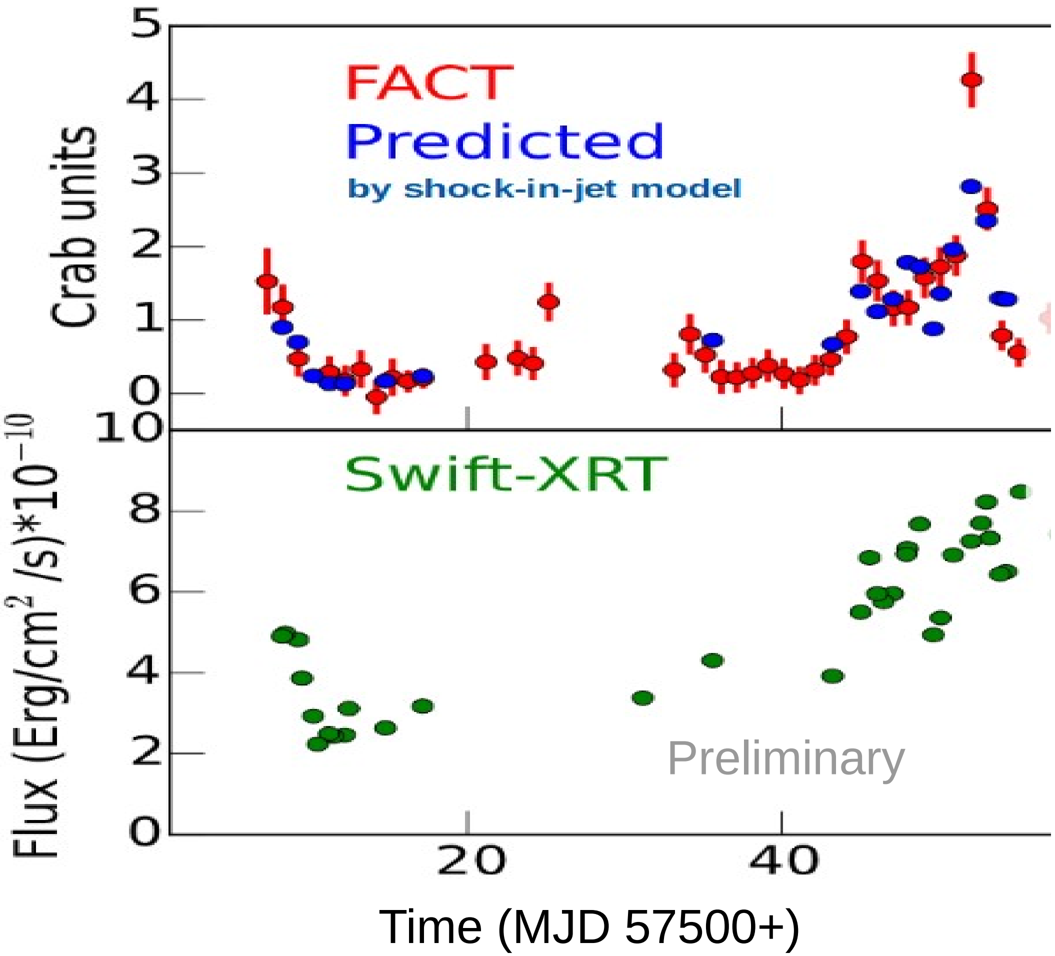
long-term monitoring of bright variable TeV sources and sending alerts:



FACT – Science

1ES 1959+650 – X-ray (keV) / TeV Correlation



One-zone SSC fit
XRT (keV) → FACT (TeV)

Good description,
but fails to describe
short bright flares

PoS (ICRC2017) 608

Conclusion

- G-APDs are excellent sensors for IACTs

- temperature dependence can easily be corrected for

- (moderate) dark noise and crosstalk deliver an excellent calibration device for free (no need for lightpulsers etc.)

- stability allows to predict trigger rates; allows to measure quality of the atmosphere; ideal for long-term monitoring

- long term stability in IACTs much better than PMTs

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We all know:

G-APD are not a 1-to-1 replacement of PMT

thank you for your attention