FACT – the First G-APD Cherenkov Telescope

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

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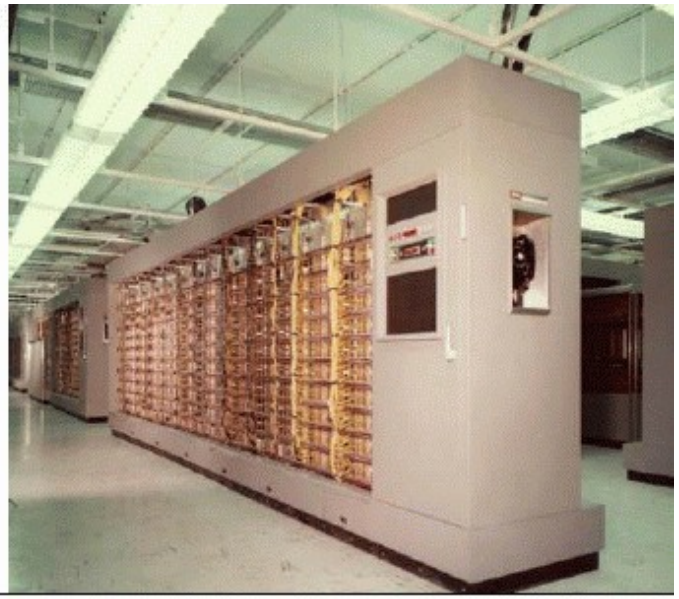
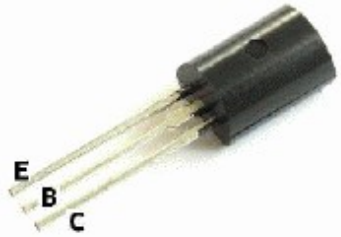
From Tubes to Silicon Devices

tubes →





silicon devices →

From Tubes to Silicon Devices

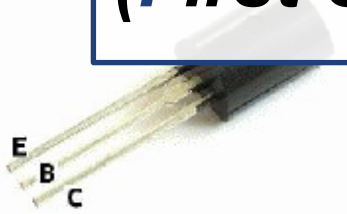
tubes

Are novel Geiger-mode Avalanche Photo Diodes (G-APD aka SiPM) a valid alternative for IACT cameras?

Build a camera and test it → *FACT (First G-APD Cherenkov Telescope)*

silicon

devices



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

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thank you for your attention


despite the very harsh
environment intrinsic
to IACT, no sensor
related problem
encountered
in ~5years

FACT – History

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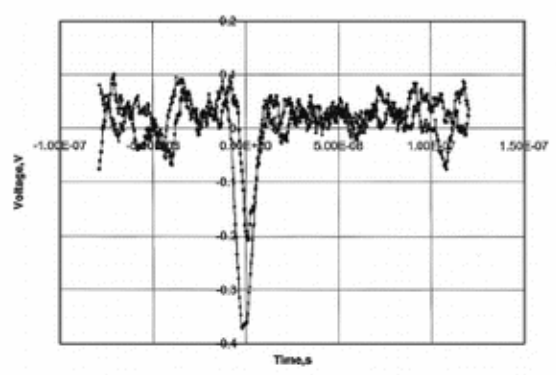
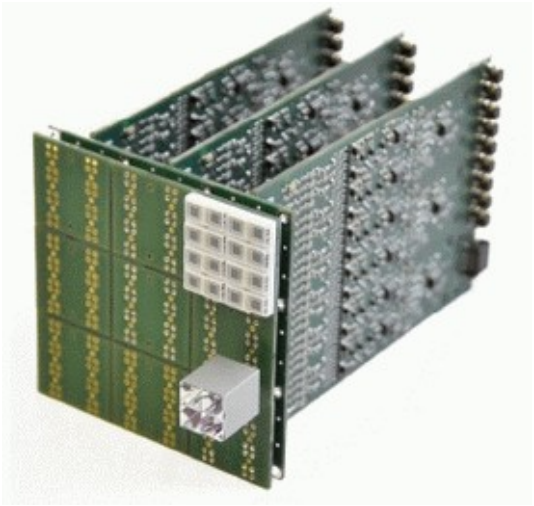
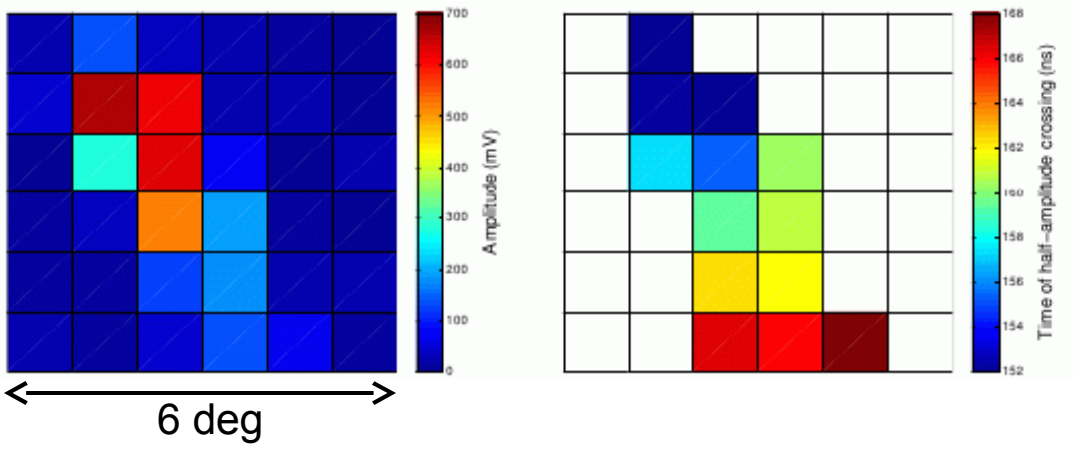


2007: First Cherenkov flashes seen with few G-APDs attached to MAGIC camera [NIM A 581]

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



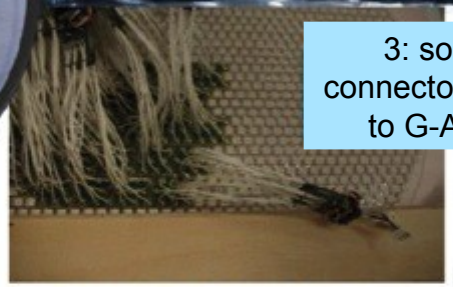


FACT – G-APD Camera

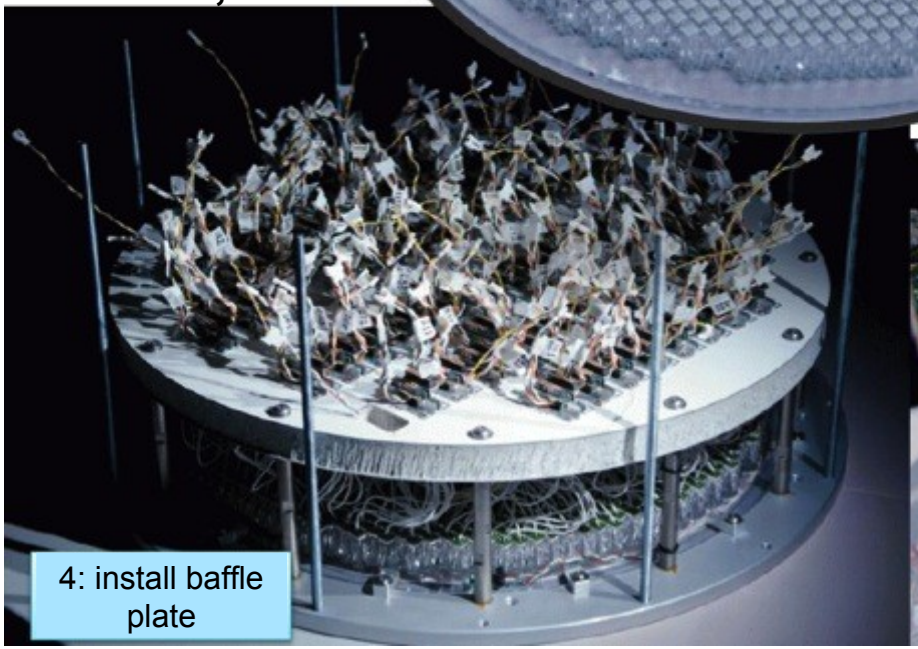
1: glue G-APD to cone

1440 pixels
6 weeks, 3 FTE

2: glue cones to front window

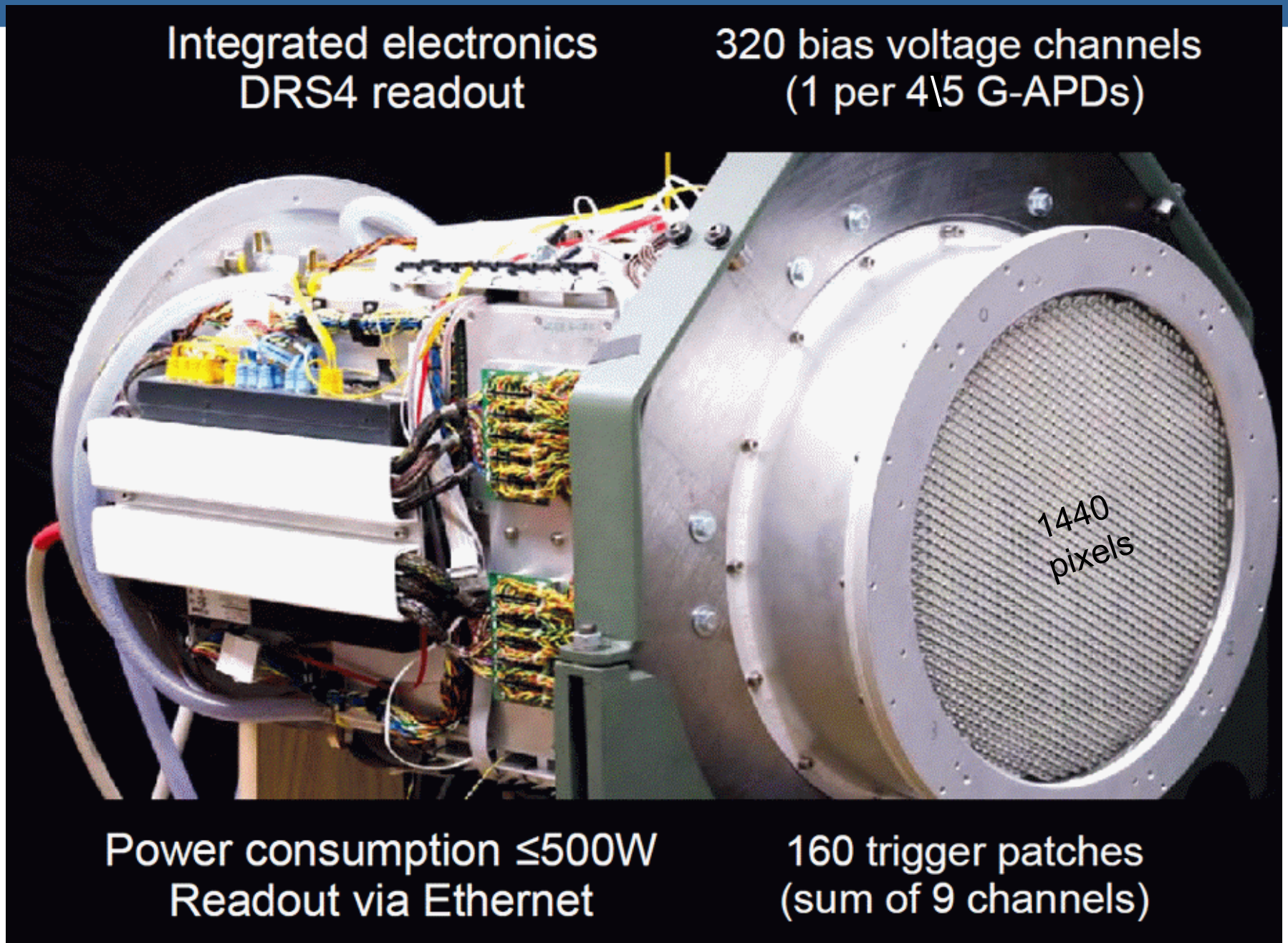


3: solder connector cables to G-APDs

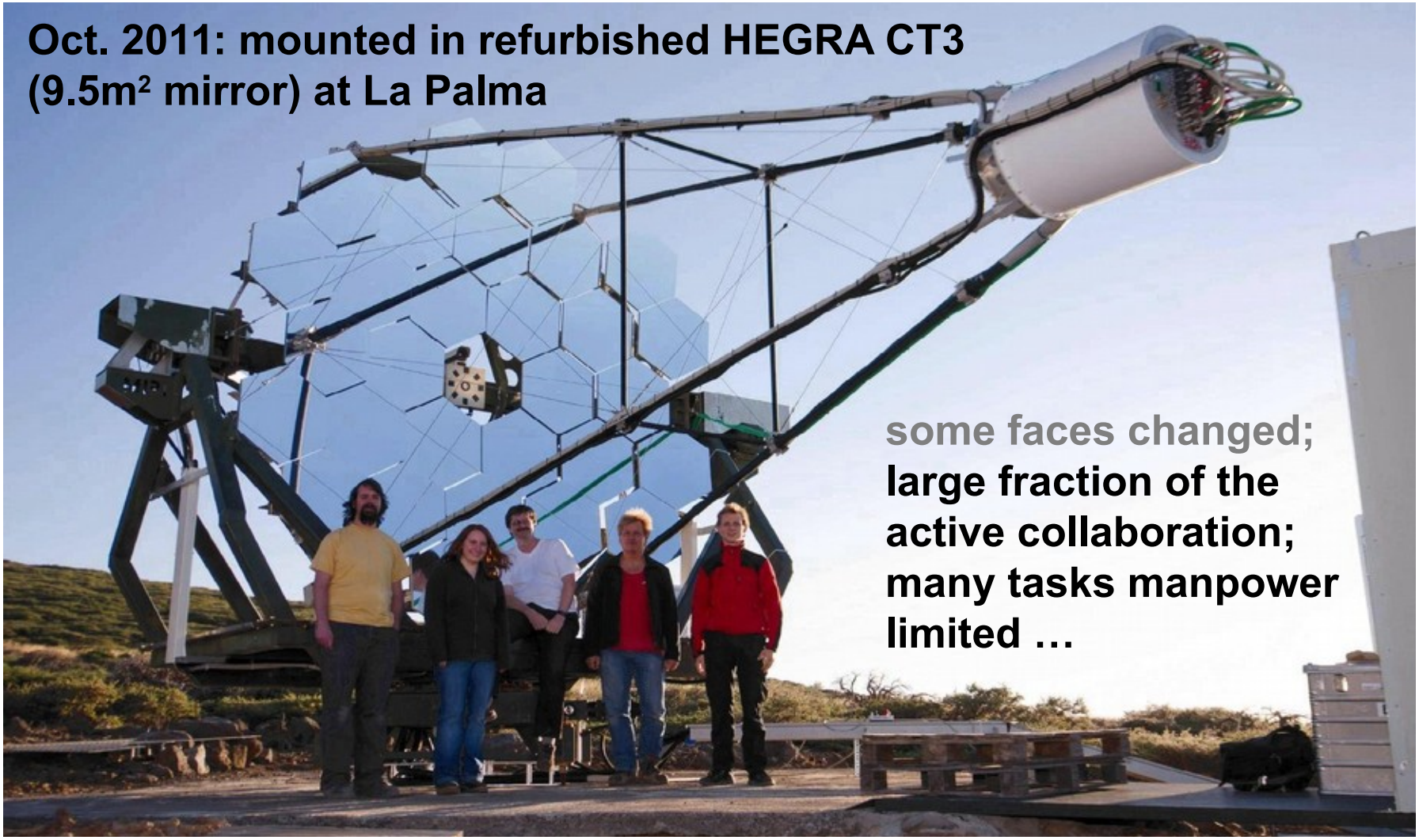


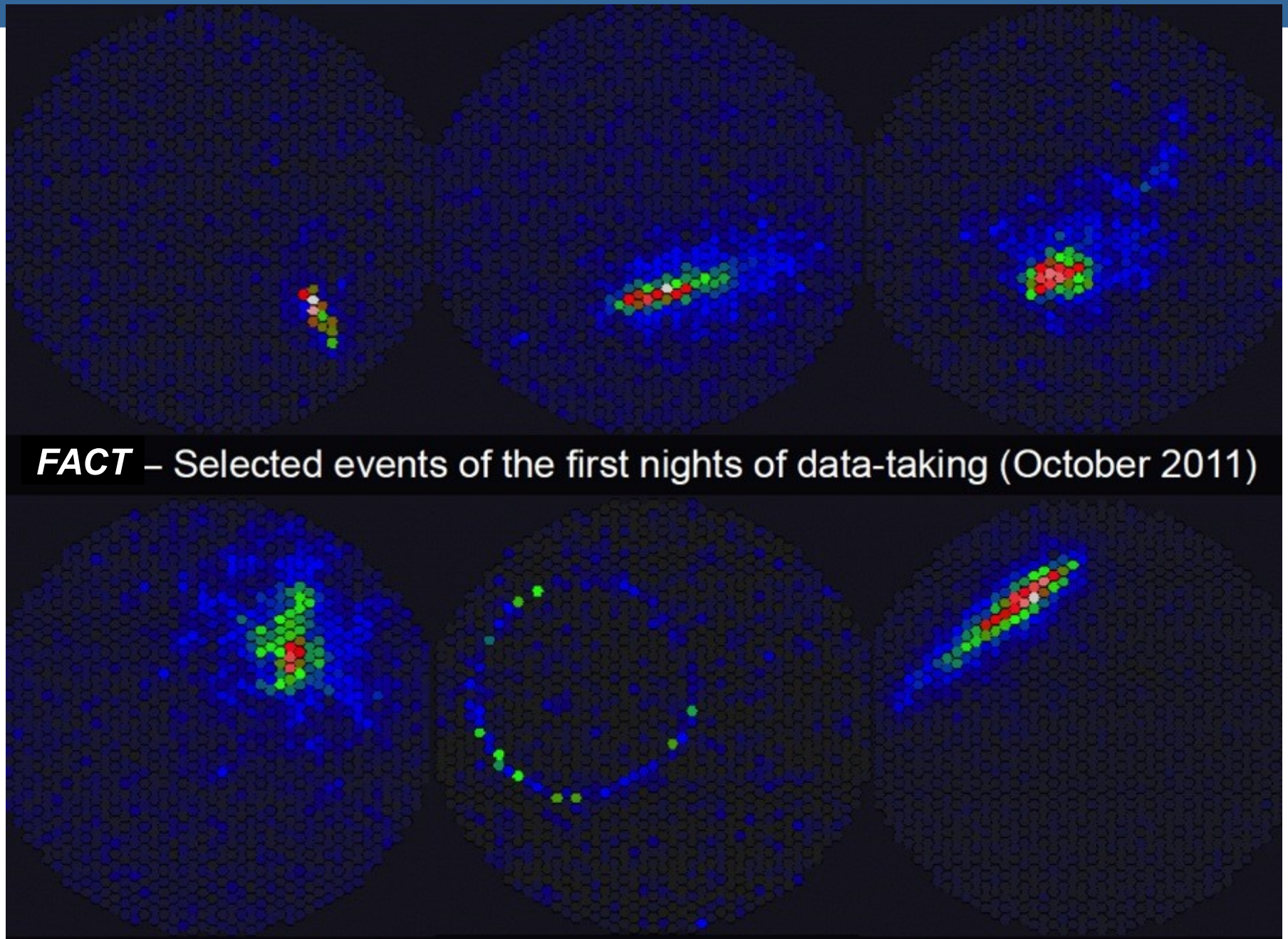
4: install baffle plate

completed sensor plane


Integrated electronics
DRS4 readout
320 bias voltage channels
(1 per 4\5 G-APDs)
1440
pixels
Power consumption ≤500W
Readout via Ethernet
160 trigger patches
(sum of 9 channels)

FACT – the First G-APD Cherenkov Telescope





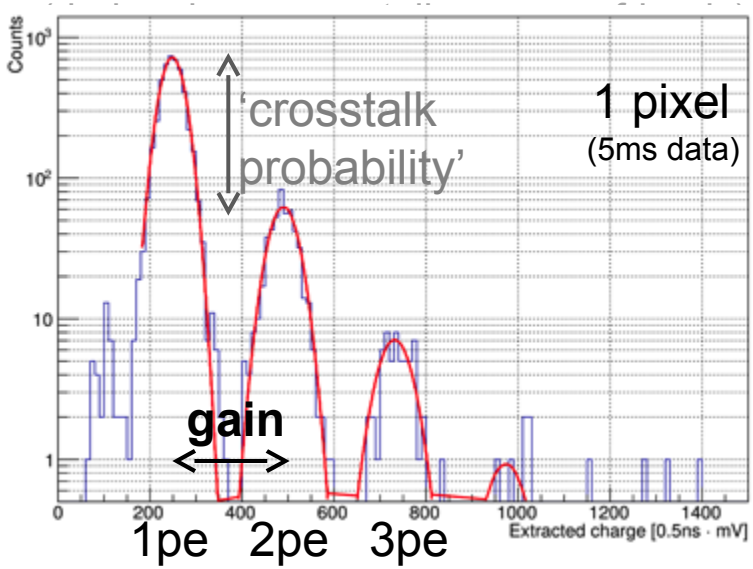
FACT – Selected events of the first nights of data-taking (October 2011)

FACT – Self-calibrating System

FACT – Uniformity & Stability of Camera

(our) G-APD gain has strong Temperature dependency (~4%/degree)
→ Feedback system → adjust applied voltage to Temp. (and DC)

check with 1pe spectra:



→ dark noise + crosstalk allow calibration without any external device

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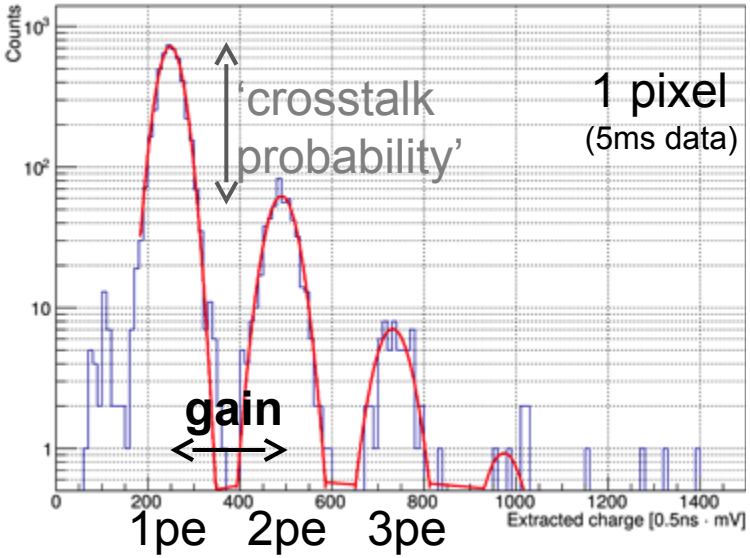

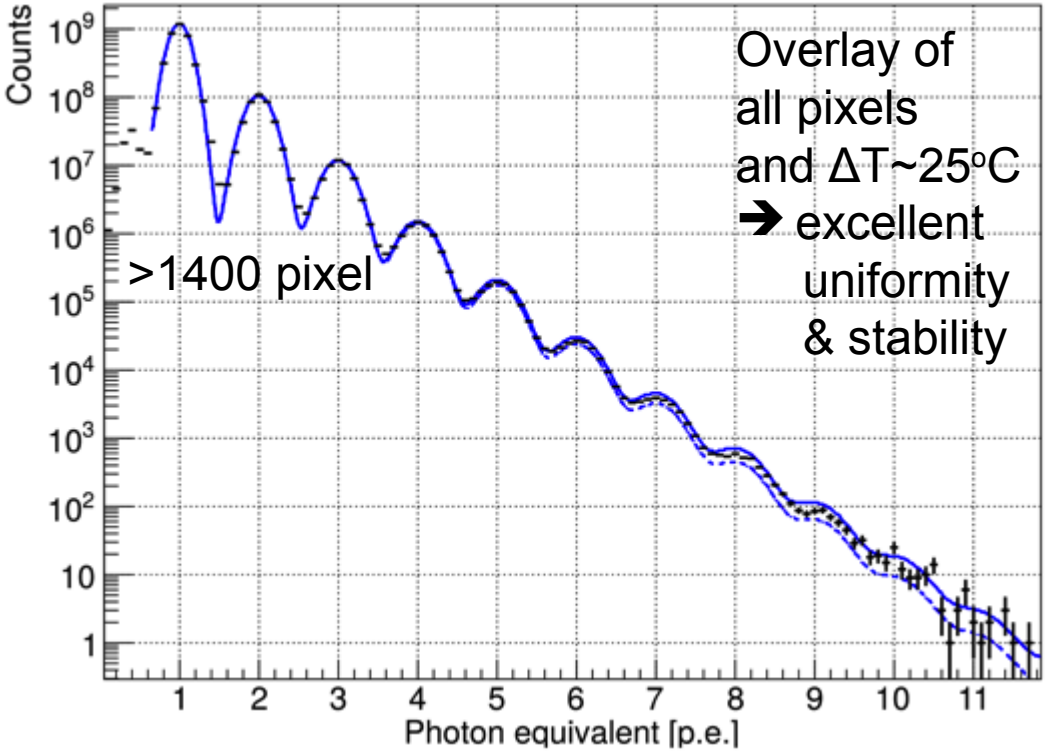

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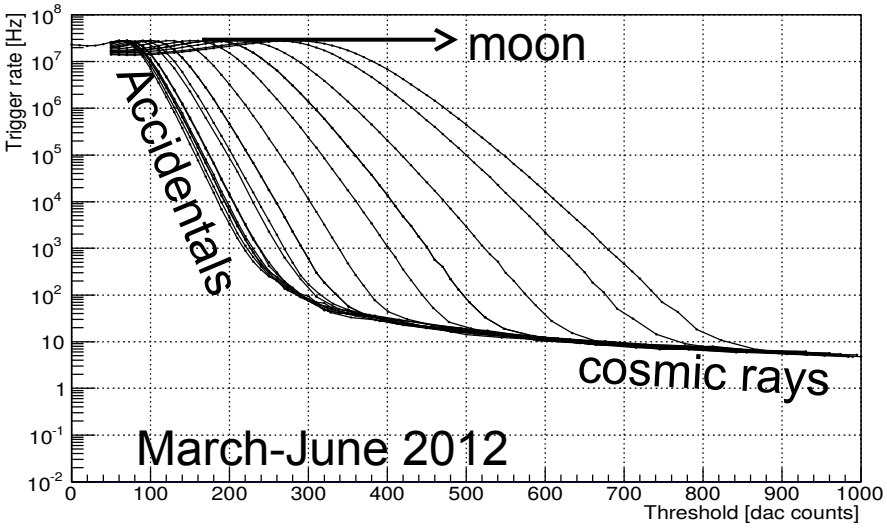
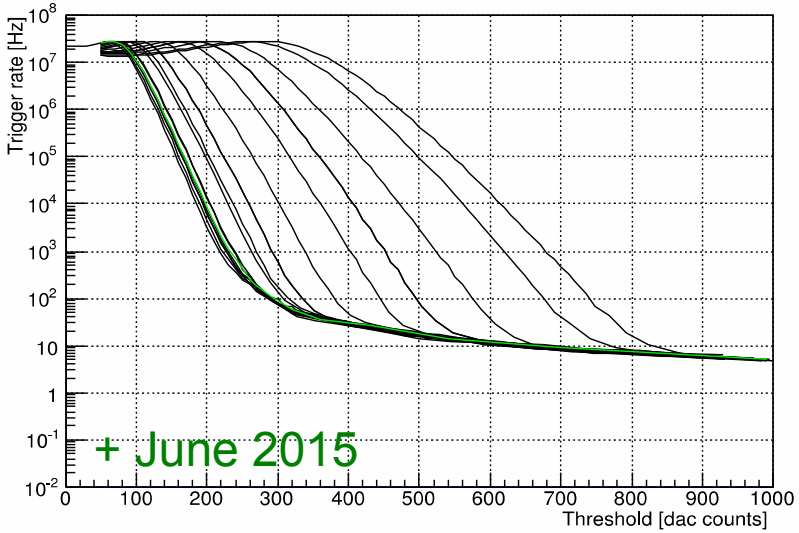
For a given pointing, trigger should always see the same rate of cosmic rays.





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

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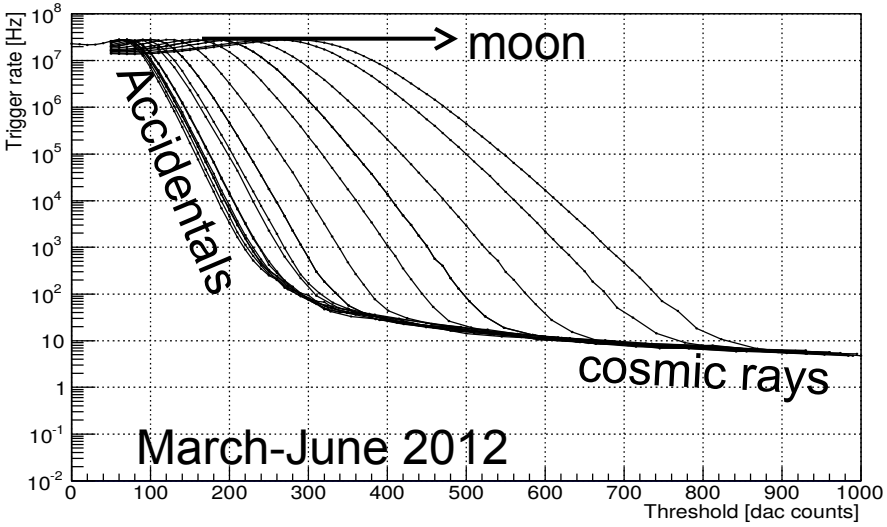
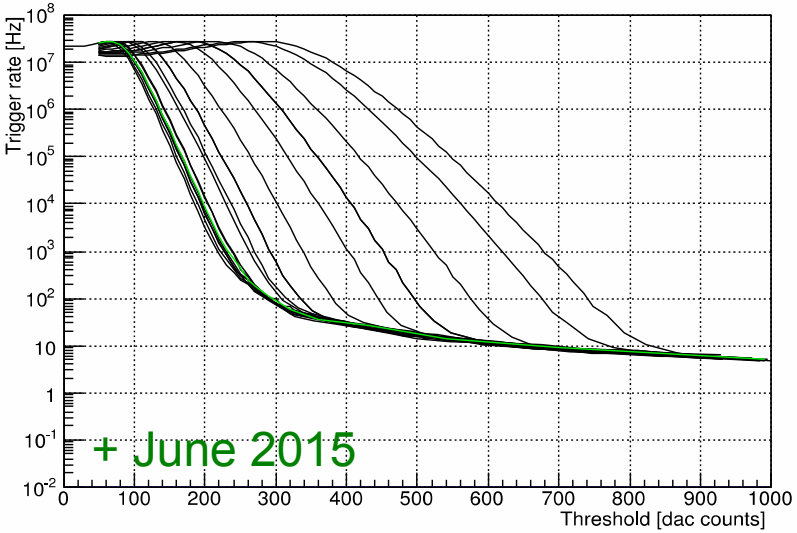
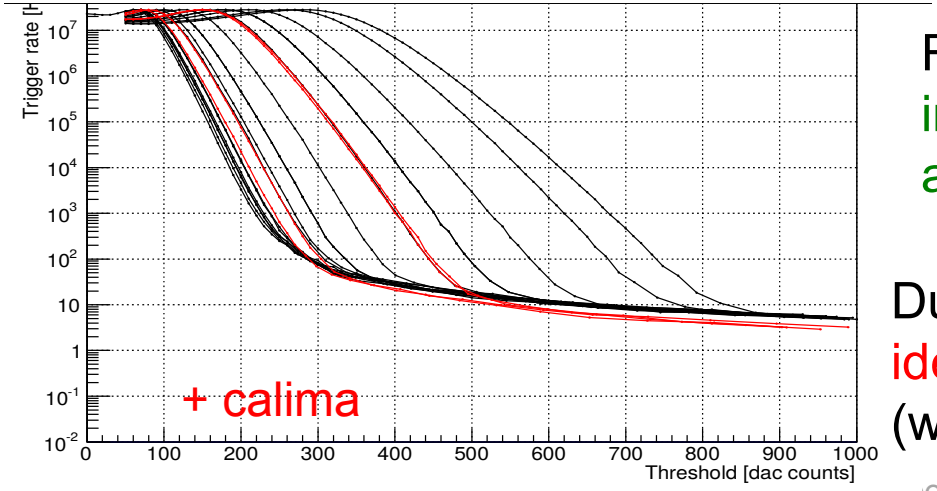






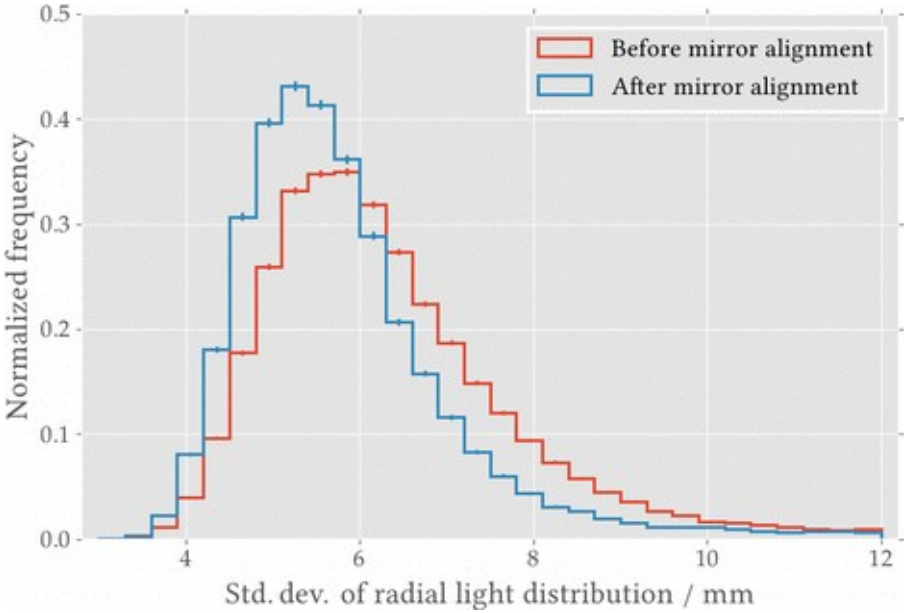
Ratescans show cosmic ray trigger-rate independent of moon, sensor temperature and age of sensors.

Due to this stability, it is possible to identify bad atmospheric conditions (without external device) [33rd ICRC, 709]

FACT – Uniformity & Stability of System

Muon rings allow to measure

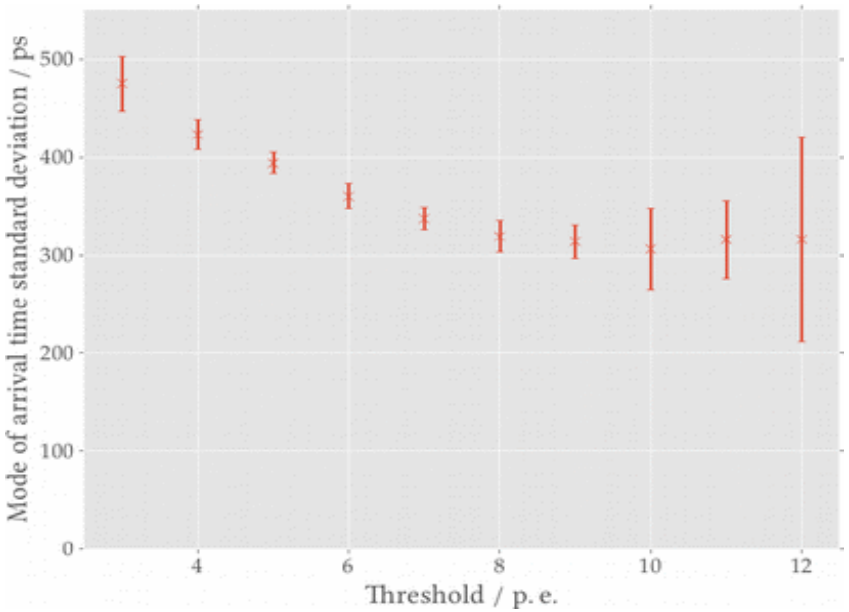
the PSF of the optics and



Novel mirror-alignment method

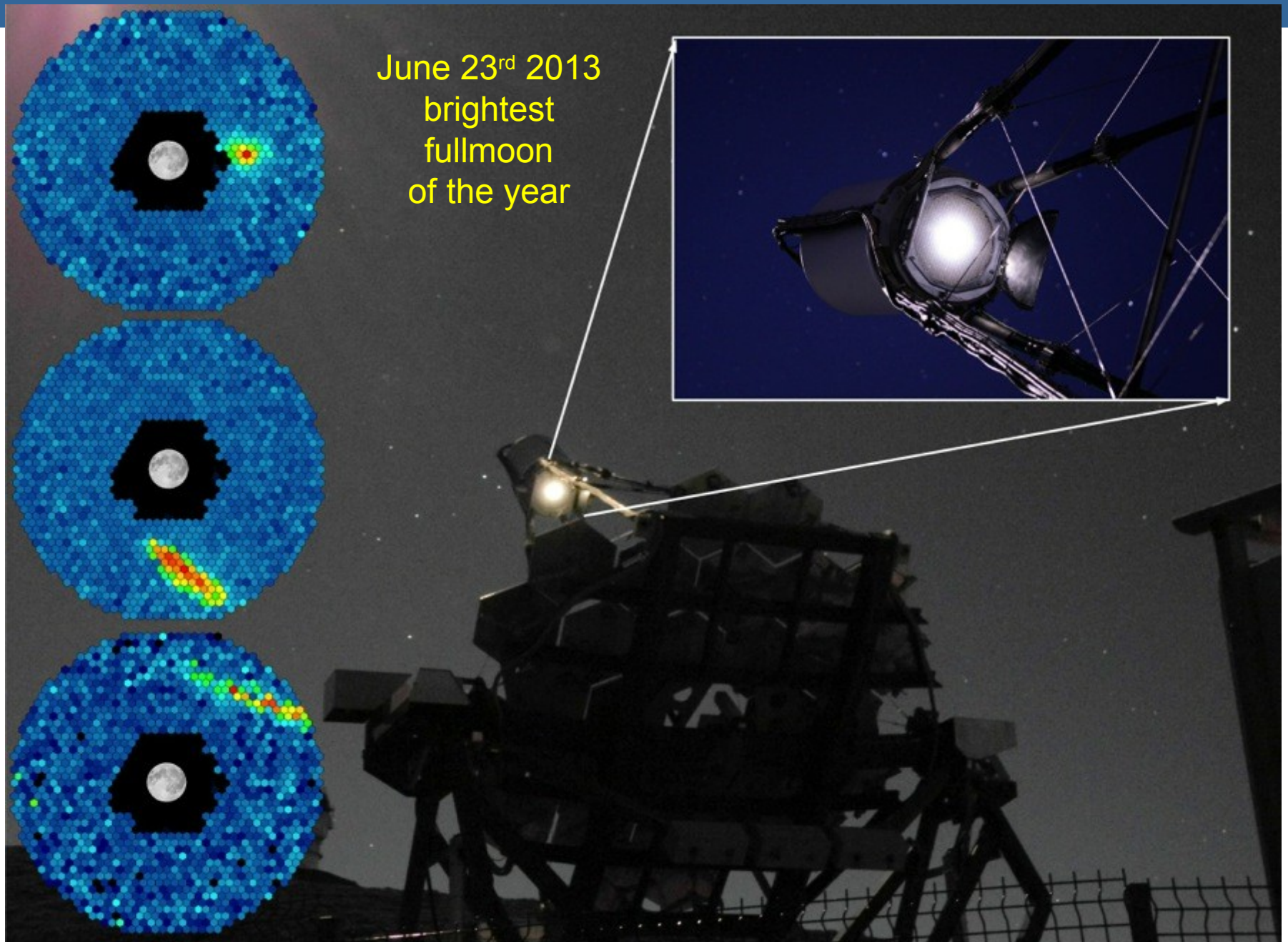
[34rd ICRC, 733]

the time resolution of the system.

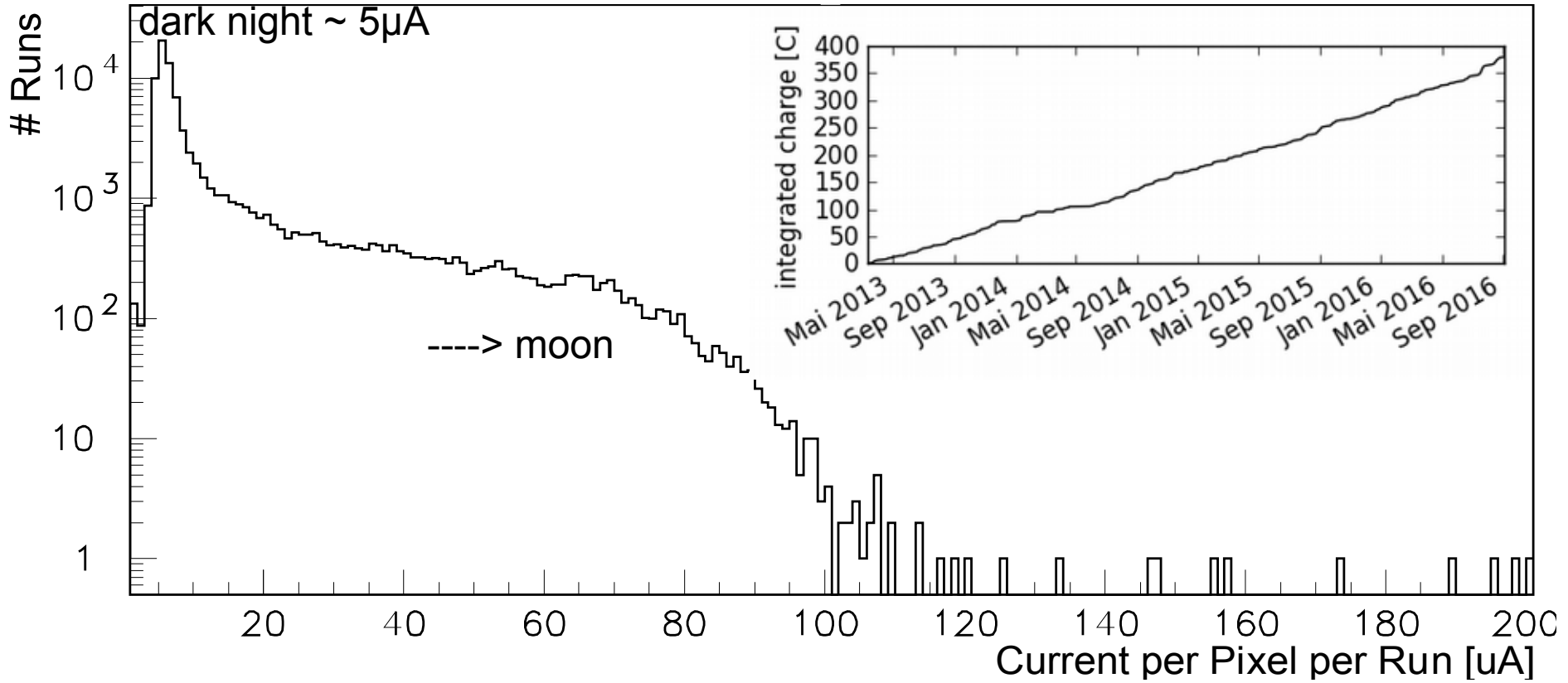


~320ps for >7pe; including:

- physics
- G-APD resolution
- electronics
- signal extraction


June 23rd 2013
brightest
fullmoon
of the year

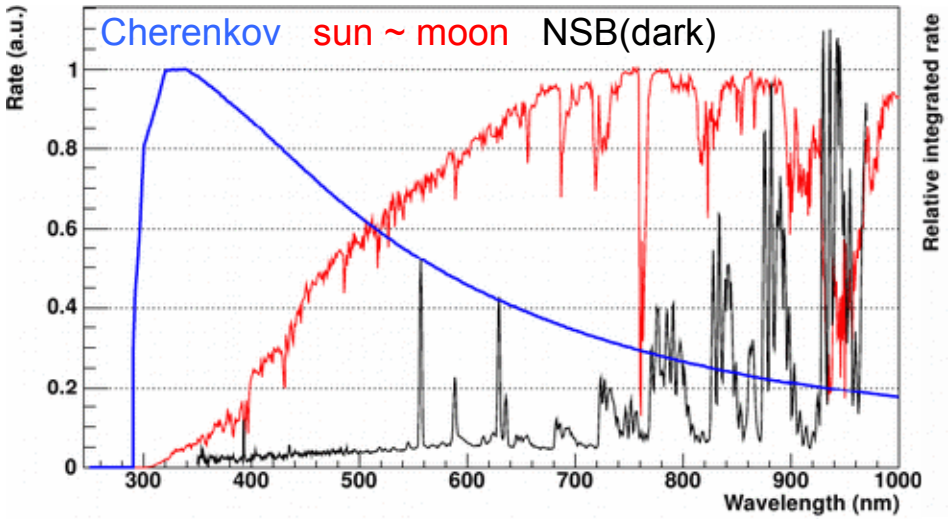
FACT – Collected Charge

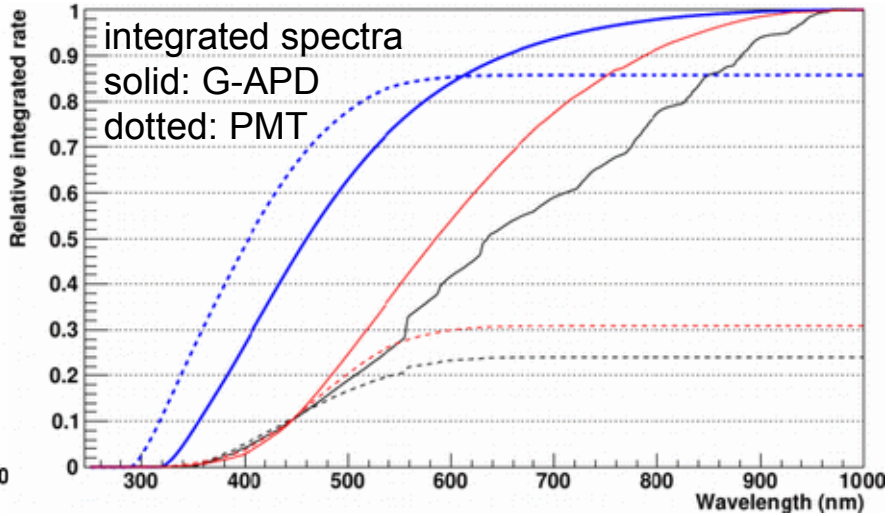


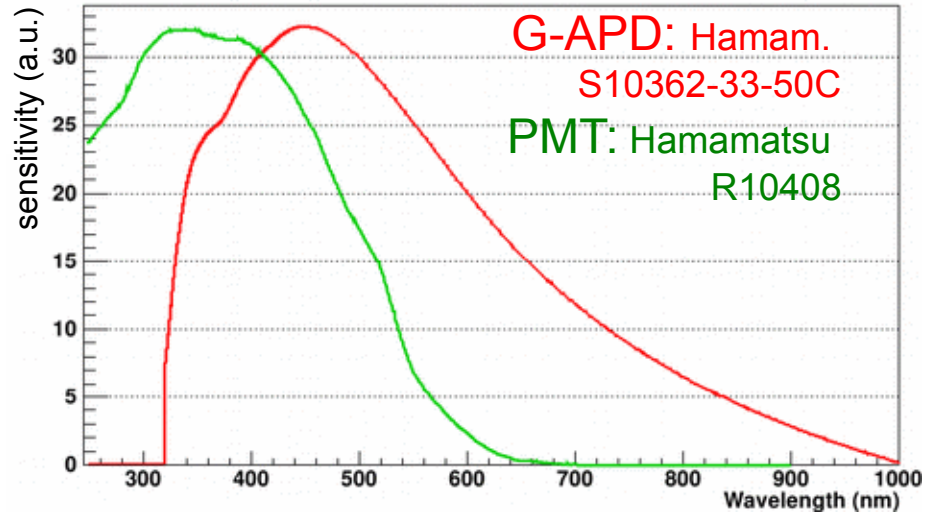
integrating over time, divide by dark-night DC (5µA) for each sensor:
→ **collected same charge as in >17'000 hours dark night observations**

dark noise: ~0.5µA (laboratory)
➔ **collected same charge as in ~20 years continuous op. in laboratory**

FACT – Night Sky Background



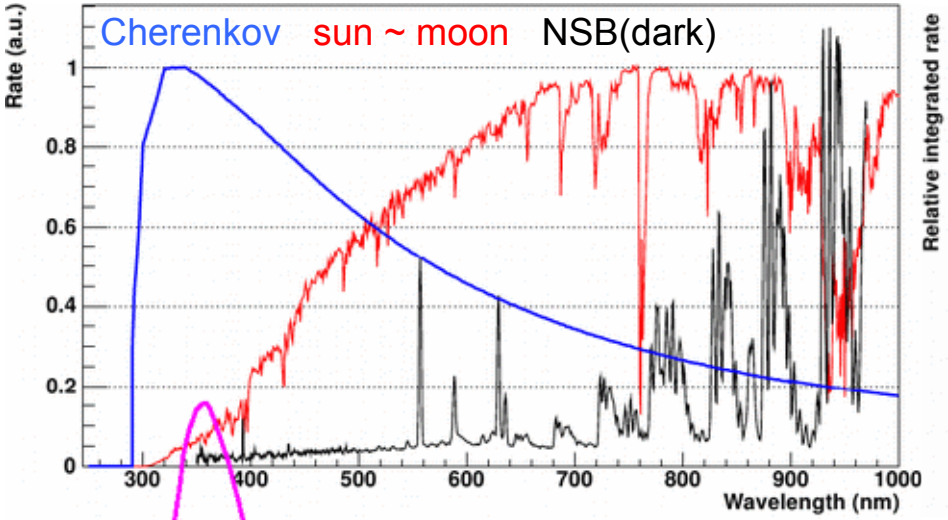


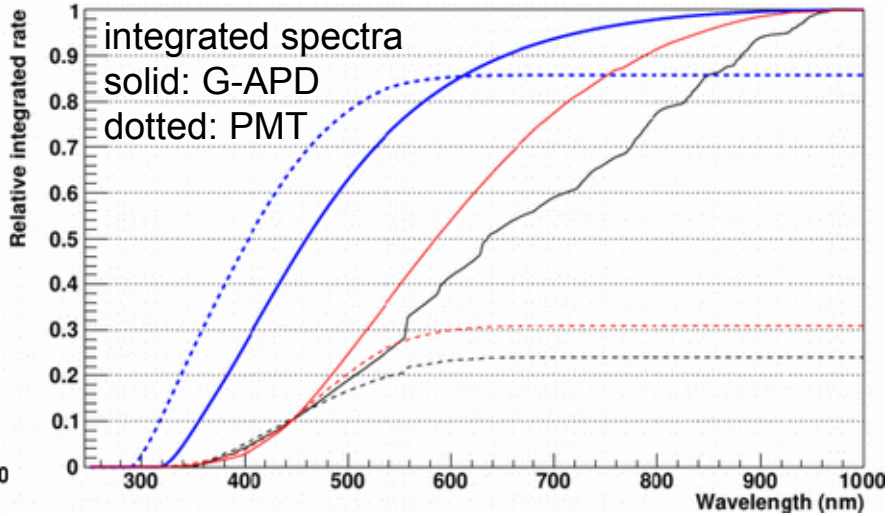


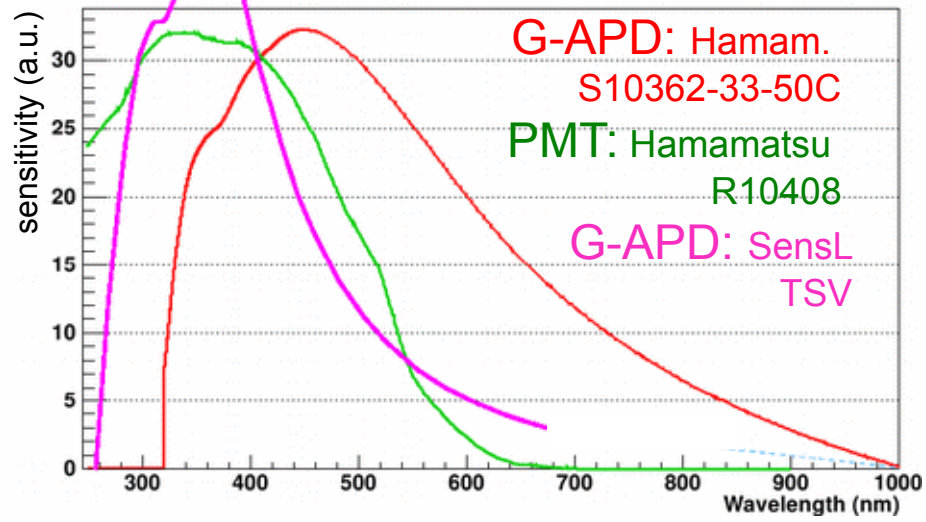
sensitivity curve of the first G-APDs not well adjusted to Cherenkov spect.
→
collect much more NSB (and moon) than optimized PMTs

Nevertheless, FACT can operate with lot of moonlight without aging

FACT – Night Sky Background







Today's G-APD are much better adapted to the needs of IACTs

FACT – Automation

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onsite data-taking (2011)

remote data-taking from anywhere (since late 2012)

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

FACT – Automation

testing:
AI calls
expert if
intervention
is necessary

remote data-taking
from anywhere
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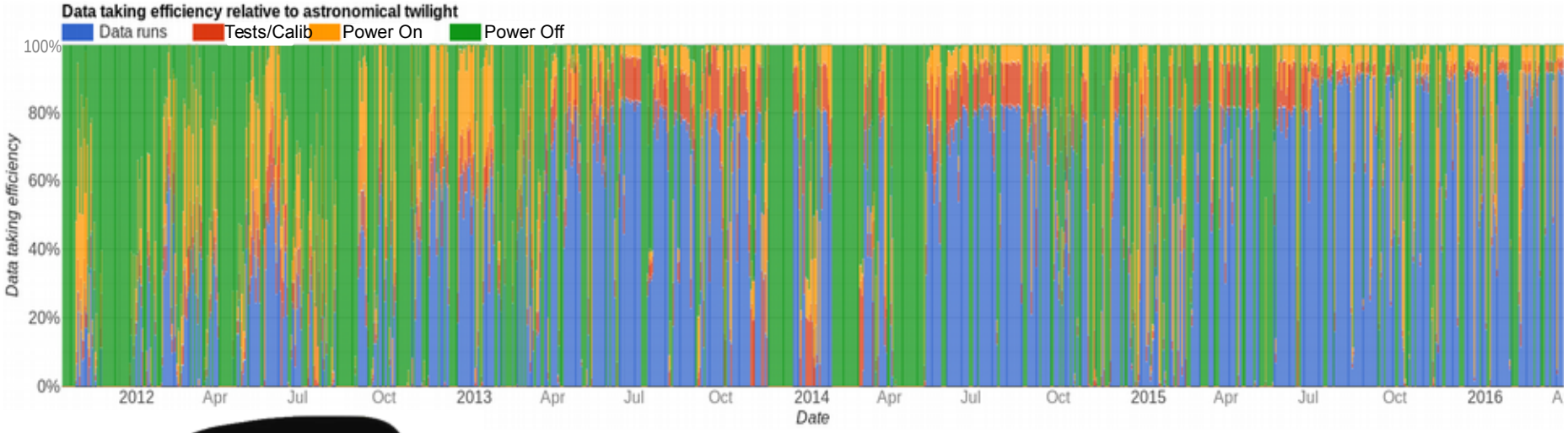
FACT – Automation



data-taking efficiency:
100% = time between astronomical twilights

When weather permits, we reach now a physics data-taking efficiency ~95%, rest mainly for telescope repositioning

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

FACT – Science

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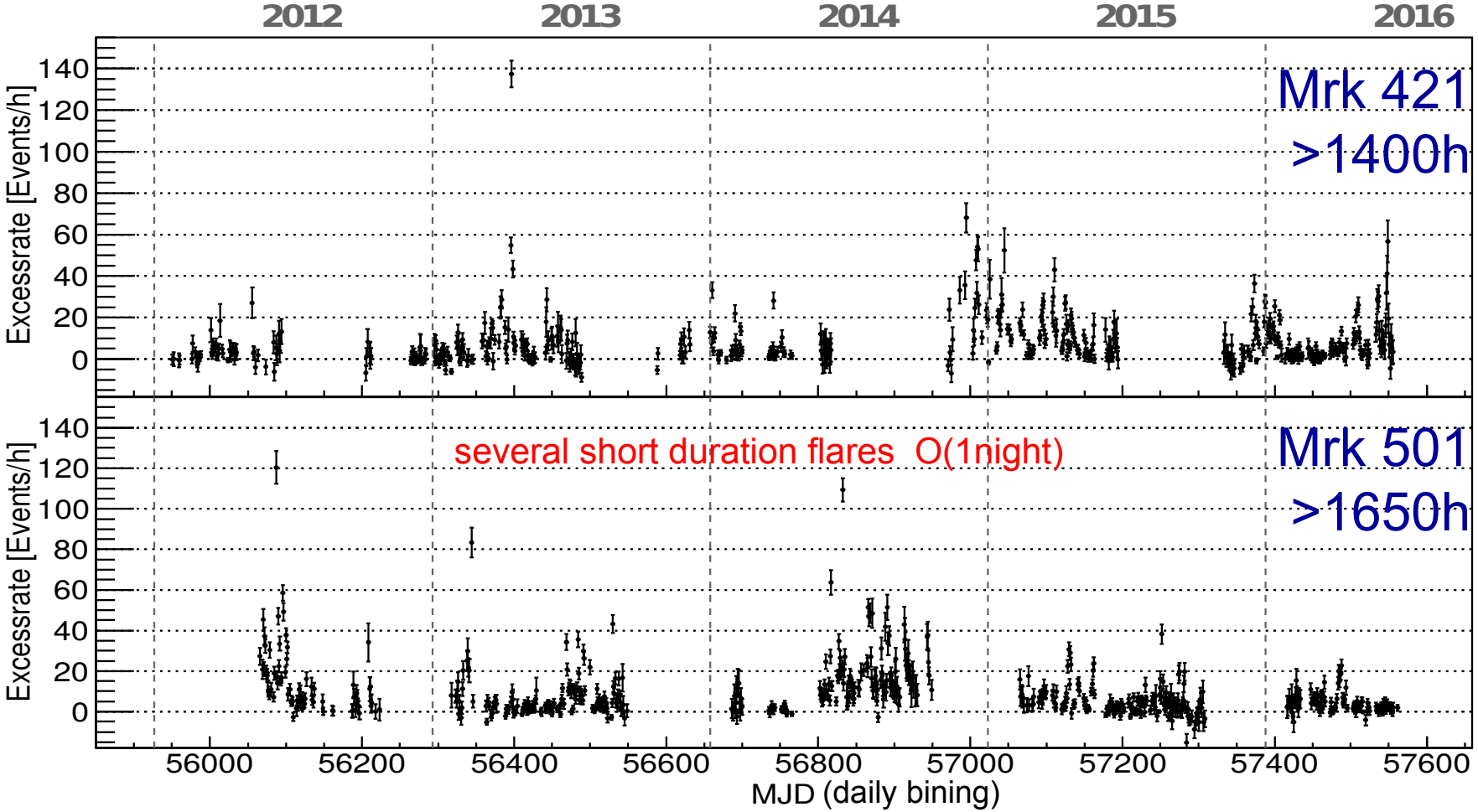
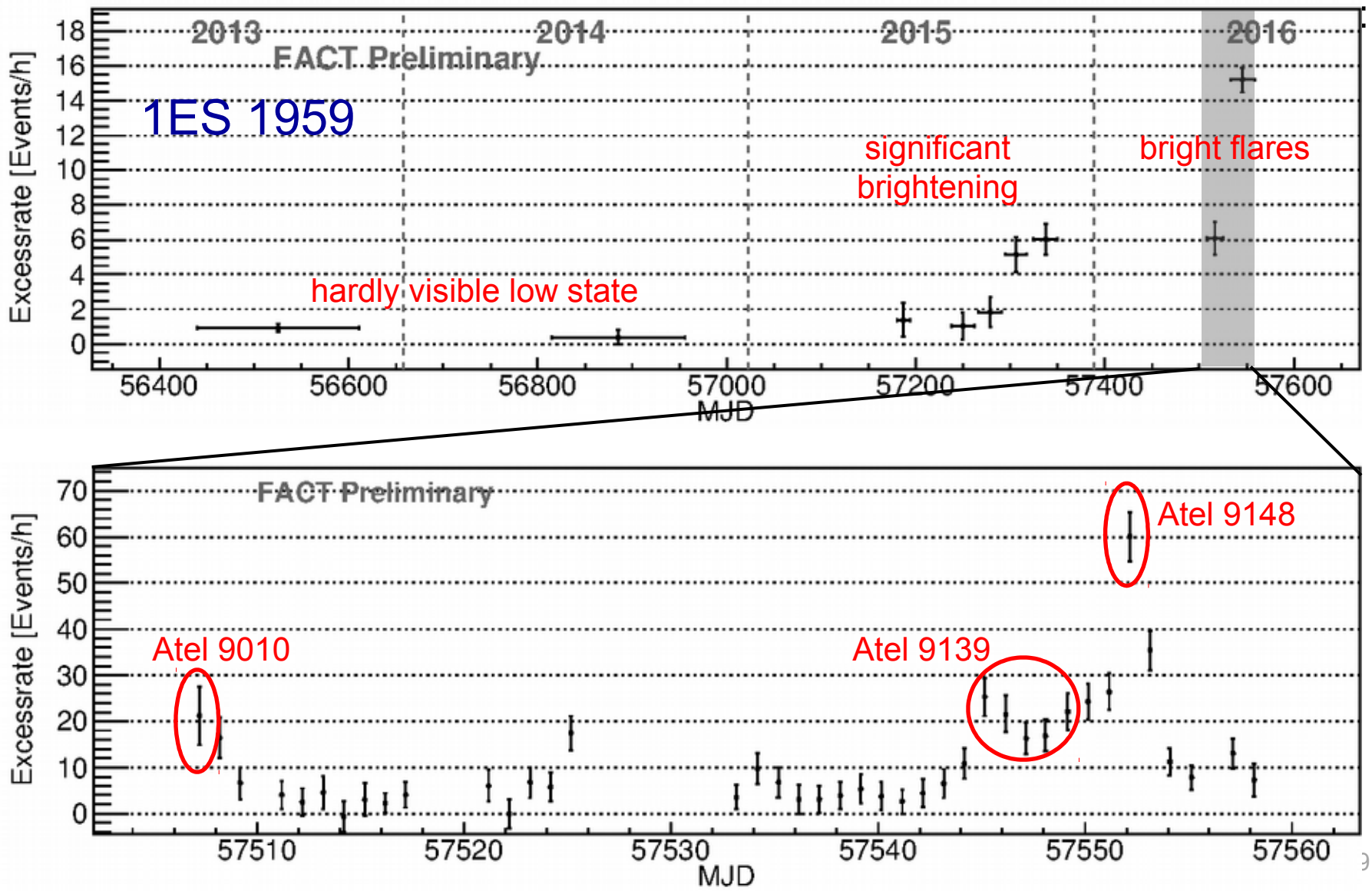
long-term monitoring of bright variable TeV sources and sending alerts:



public access to QLA results: **http://fact-project.org/monitoring**

FACT – Science



FACT – Outlook

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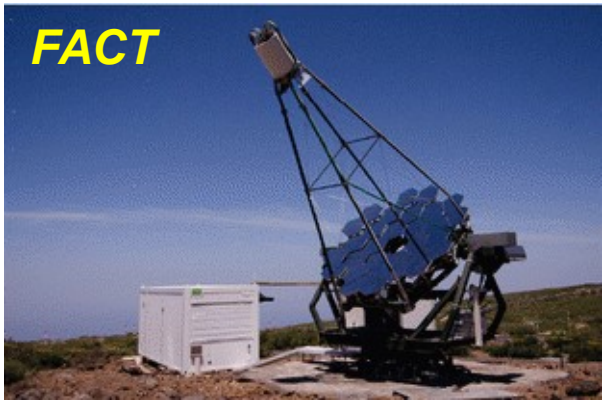
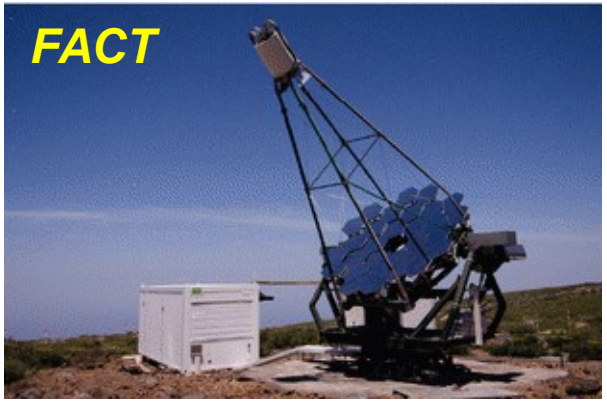
pre-FACT: all CTA designs based on (multianode) PMTs

[Exp.Astr. 32.3(2011)]

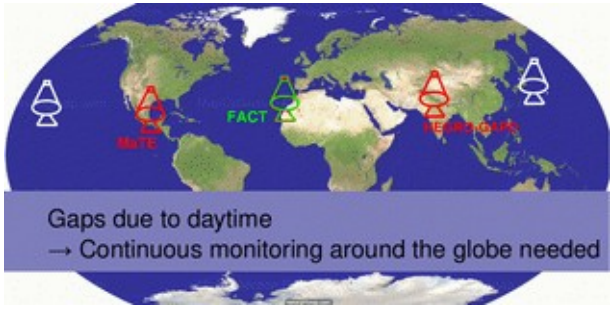


plus projects for future MST and LST cameras



post-FACT: many SiPM-based CTA projects.

and IACT projects outside CTA



Latest SiPM much better than those used in FACT
→ expect significantly better performances

FACT – 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
- G-APDs limited in size; Module0 and Sum-Trigger show that several sensors can easily be summed to form large pixel

Be open minded:

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

(that's why I prefer the name G-APD over SiPM)