FACT – the First G-APD Cherenkov Telescope

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

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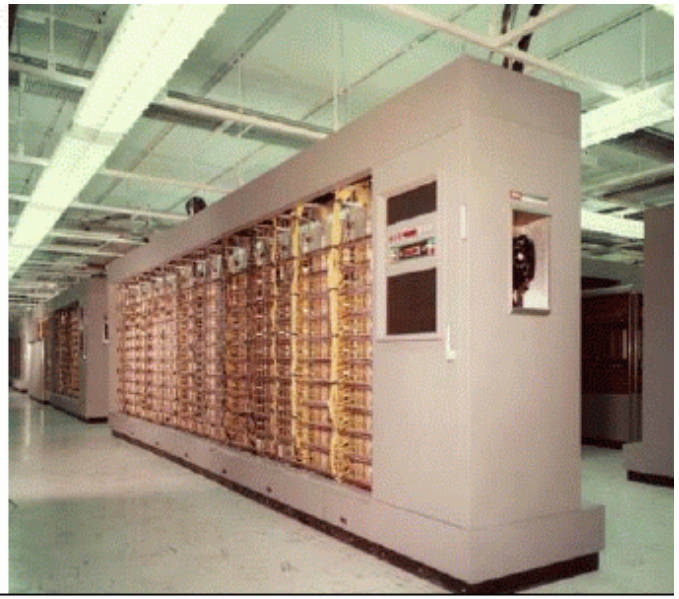
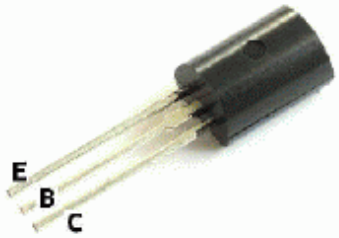
From Tubes to Silicon Devices

tubes →





silicon devices →

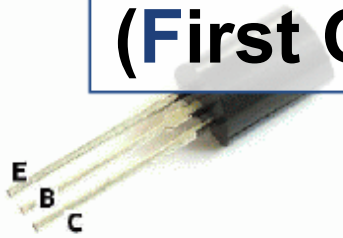
From Tubes to Silicon Devices

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

FACT – History

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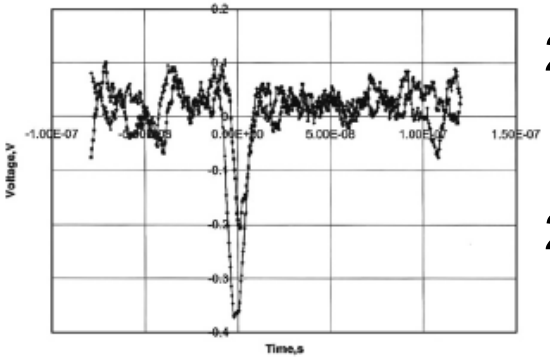
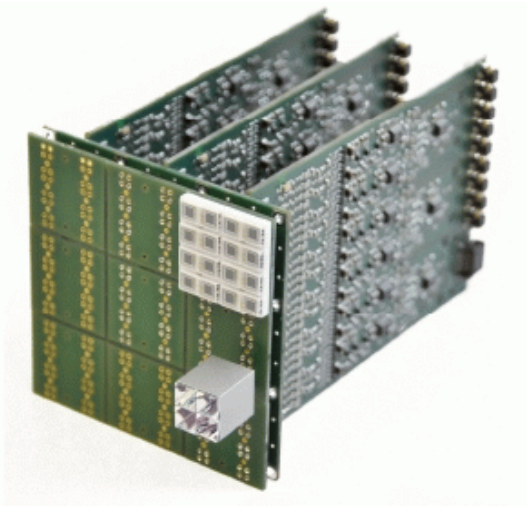
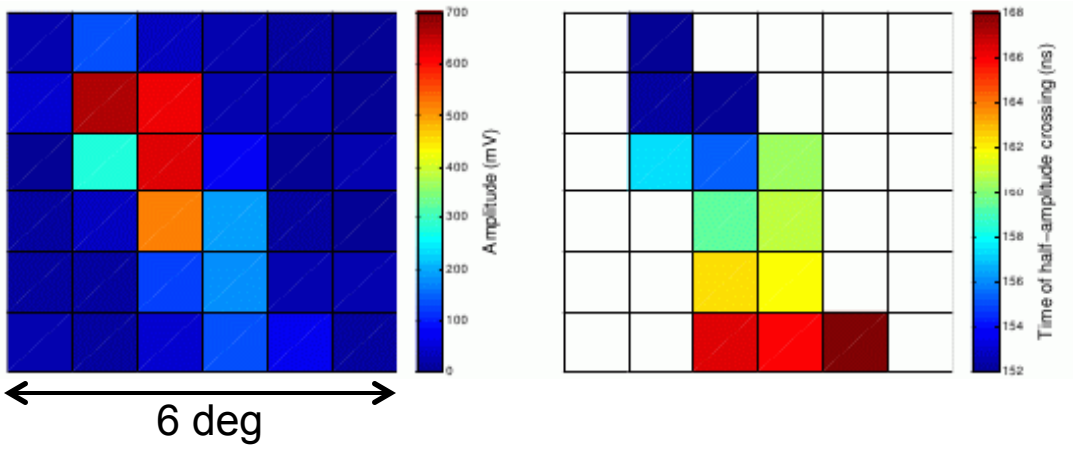


2007: first Cherenkov flashes seen with few G-APDs attached to MAGIC camera [NIM A 581]

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





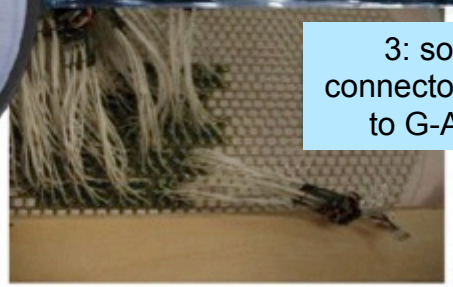
FACT – History

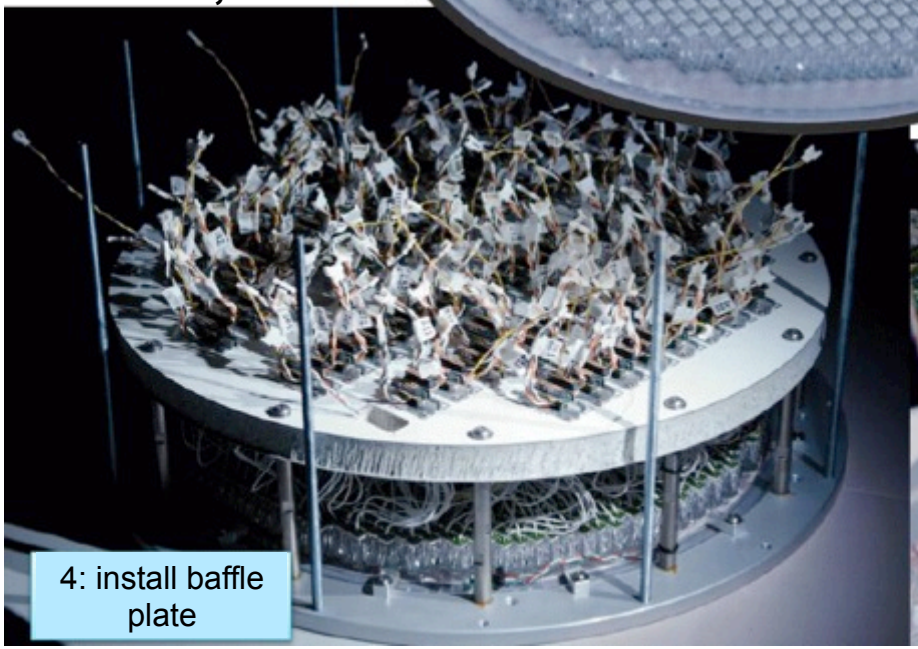
1: glue G-APD to cone

1440 pixels
6 weeks, 3 FTE

2: glue cones to front window

3: solder connector cables to G-APDs



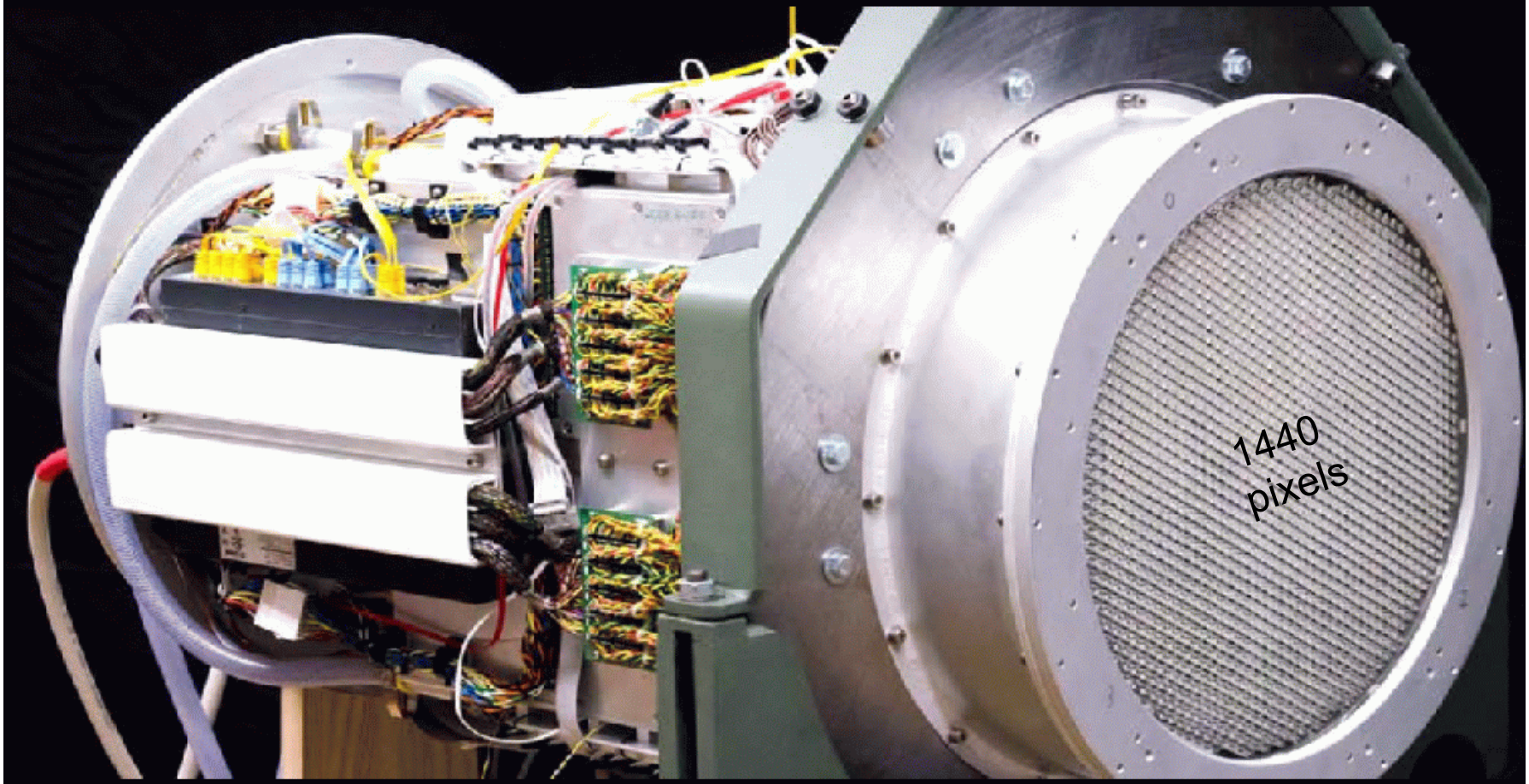


4: install baffle plate

completed sensor plane

Integrated electronics
DRS4 readout

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



Power consumption ≤500W
Readout via Ethernet

160 trigger patches
(sum of 9 channels)

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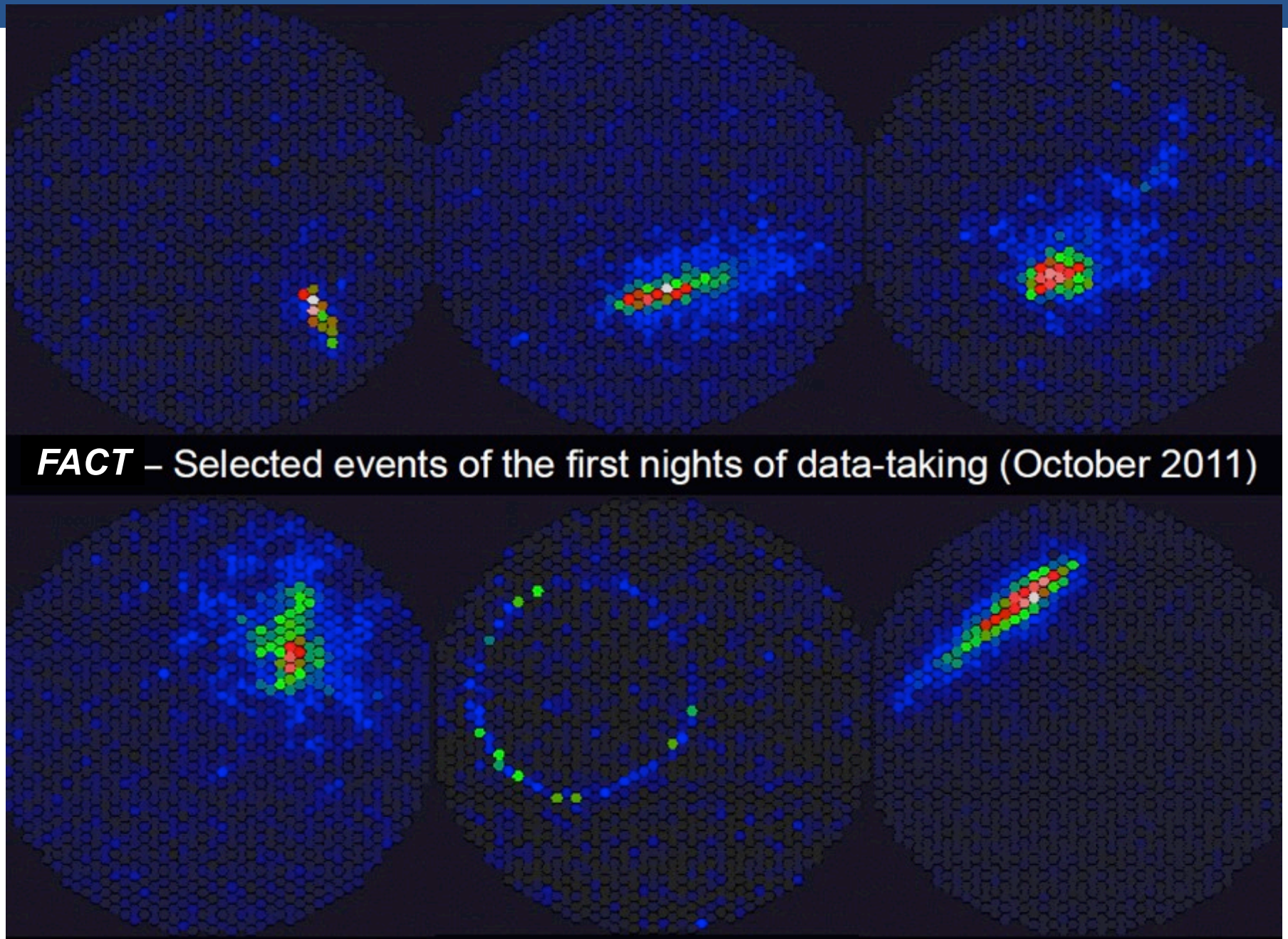
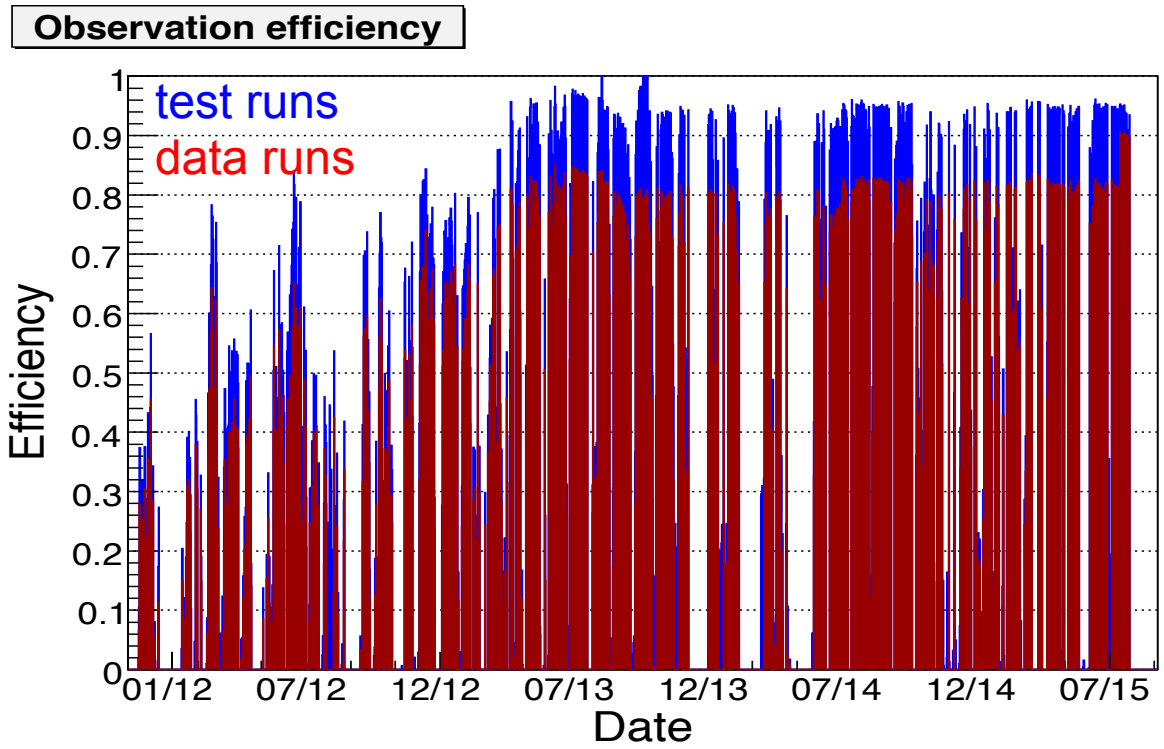


FACT – Selected events of the first nights of data-taking (October 2011)

FACT – Operation

Since late 2012:
remote controlled
automatic operation
➔
very high data
taking efficiency

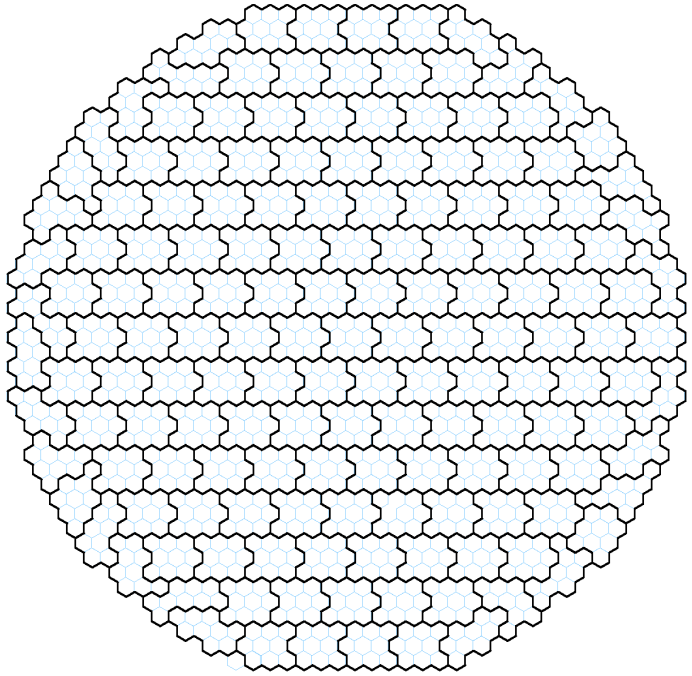


data taking efficiency:
100% = time between astronomical twilights,
including repositioning and non-data tests.

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

FACT – Experience

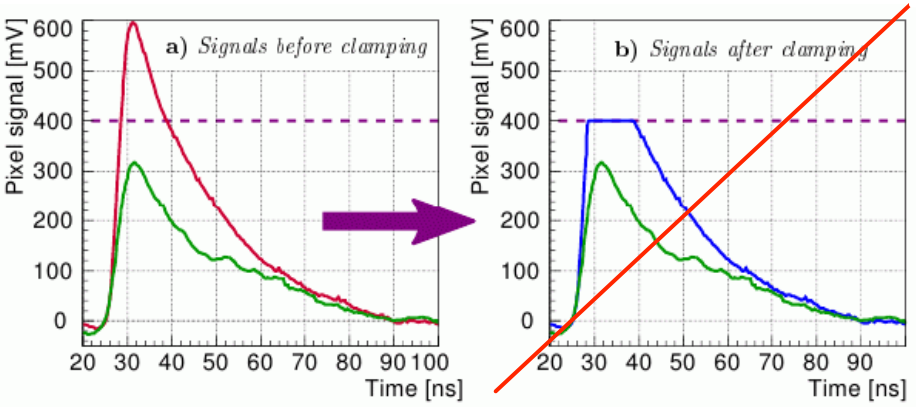
FACT – Sum-Trigger



Readout: nine channels per DRS-4 chip
➔ trigger patch of nine channels

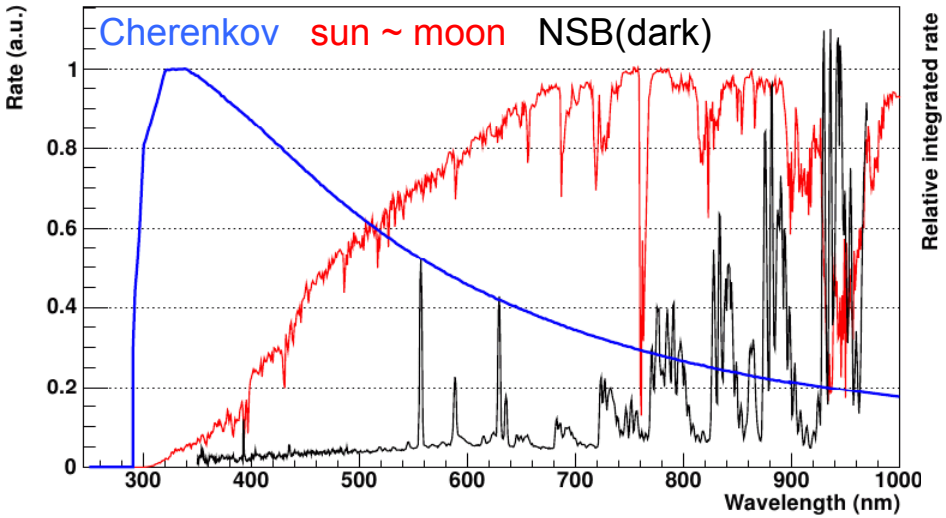
simple sum-trigger (analog sum of 9 pixels)

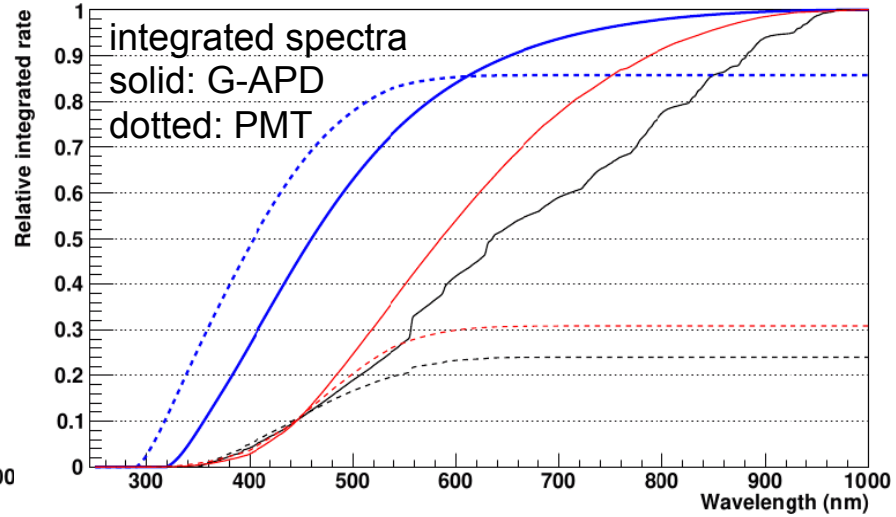
No need for 'clamping':
confirmed by analyzing data ➔
setting 50% clamping limit would
reduce trigger rate by few % .

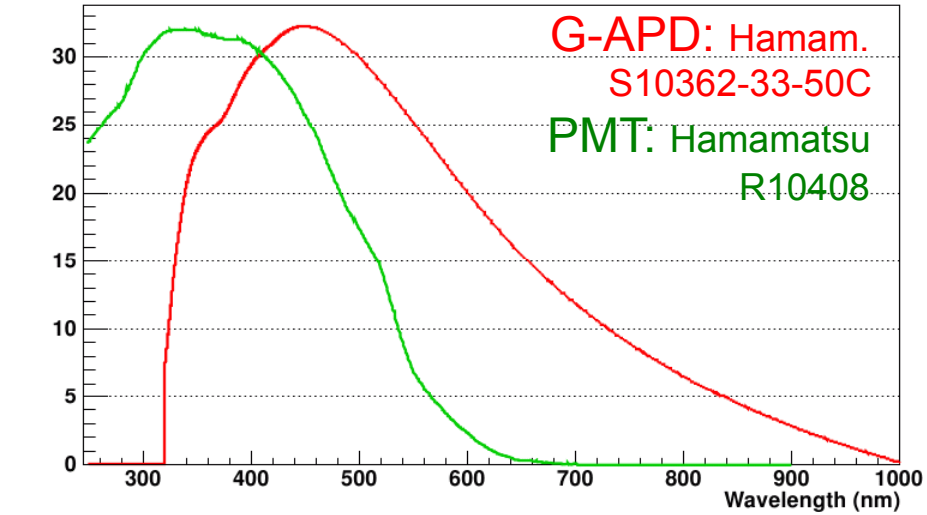


While clamping usually needed for PMTs due to afterpulsing, no need when using G-APD in sum-trigger.
[863 / 1GA(68)]

FACT – Night Sky Background







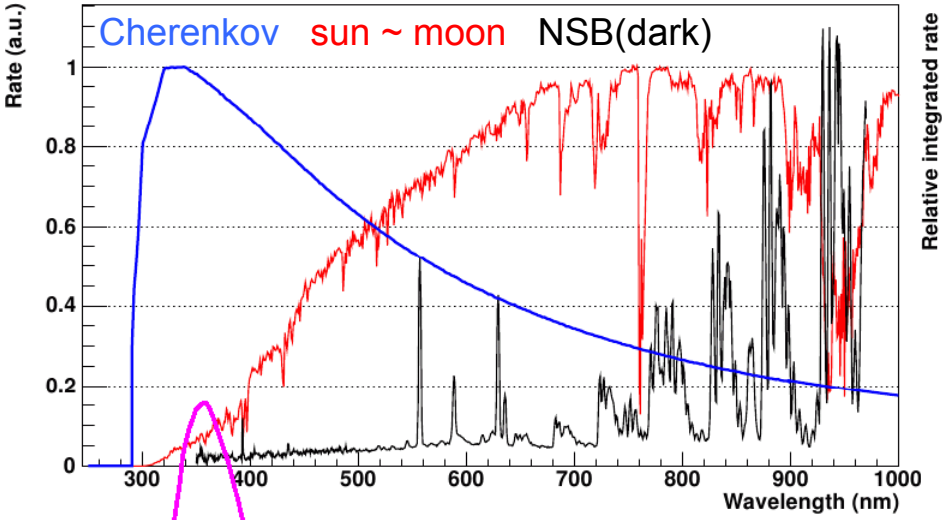
sensitivity curve of the first G-APDs not well adjusted to Cherenkov spect.

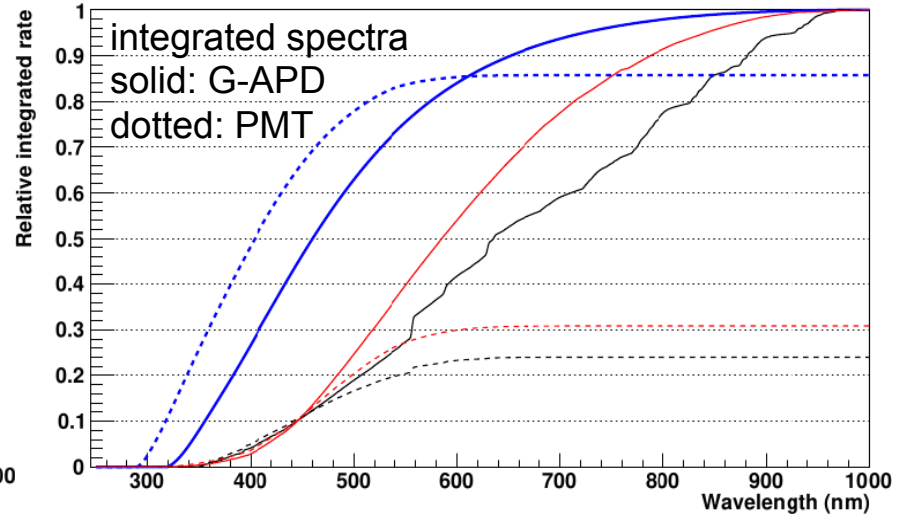
➔

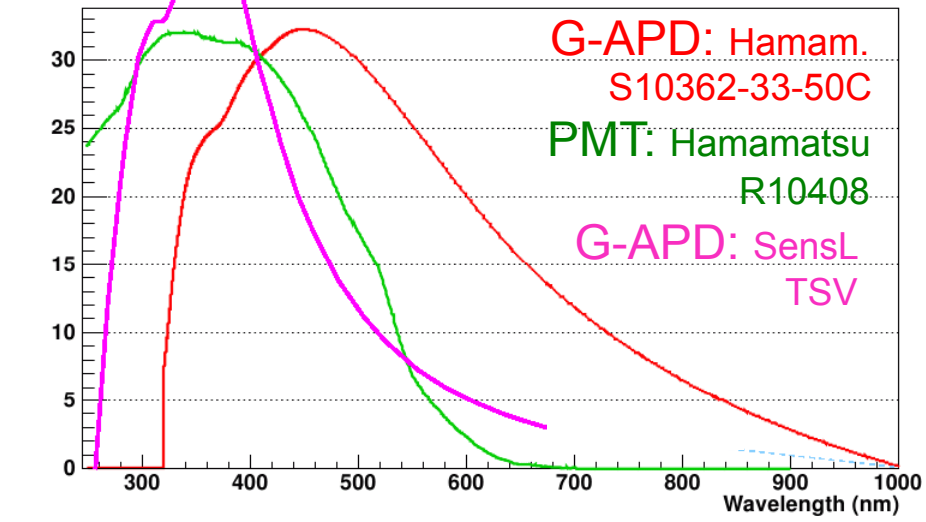
collect much more NSB (and moon) than optimized PMTs (+new G-APD)

Nevertheless, FACT can operate with lot of moonlight without aging

FACT – Night Sky Background



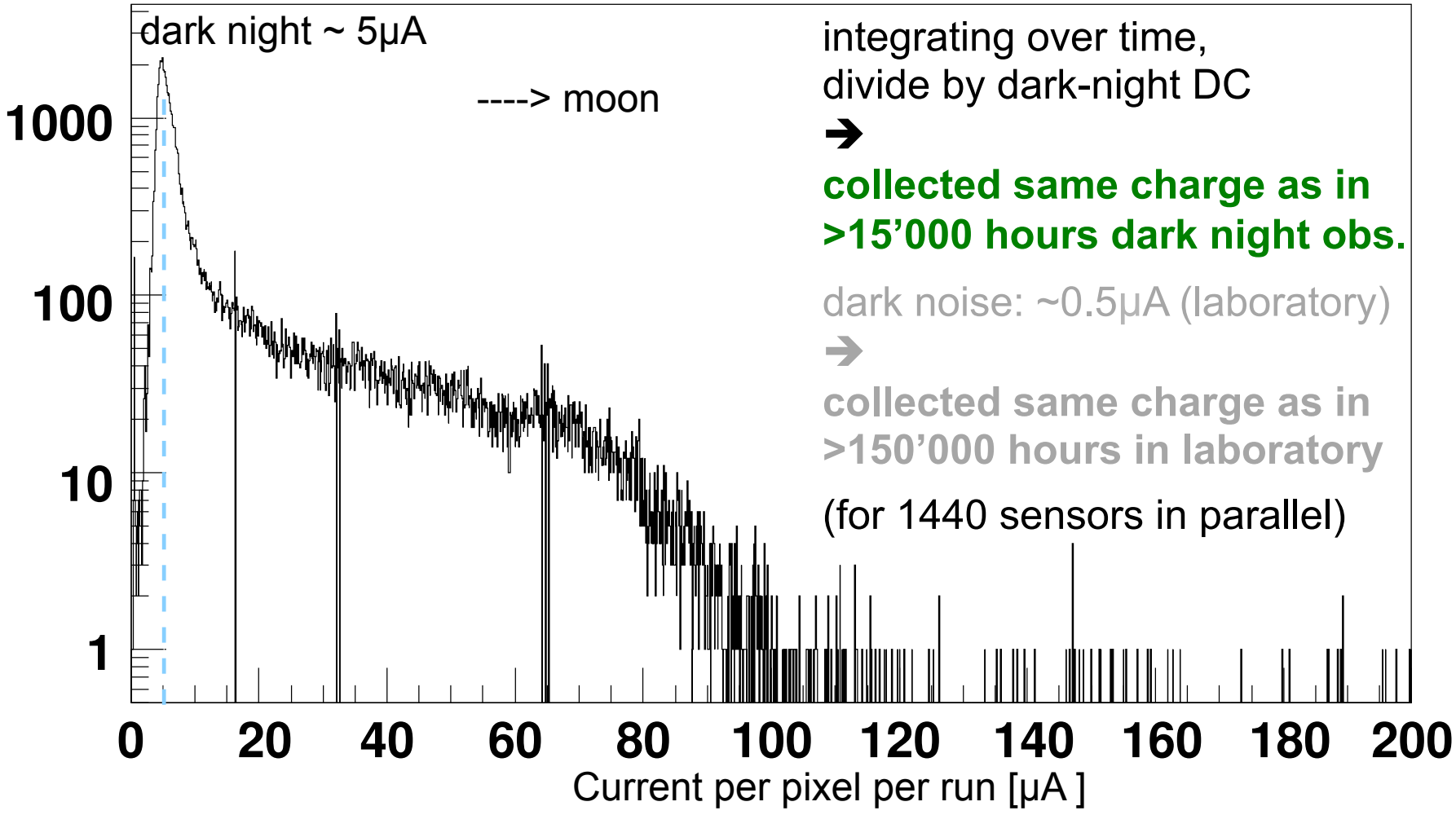


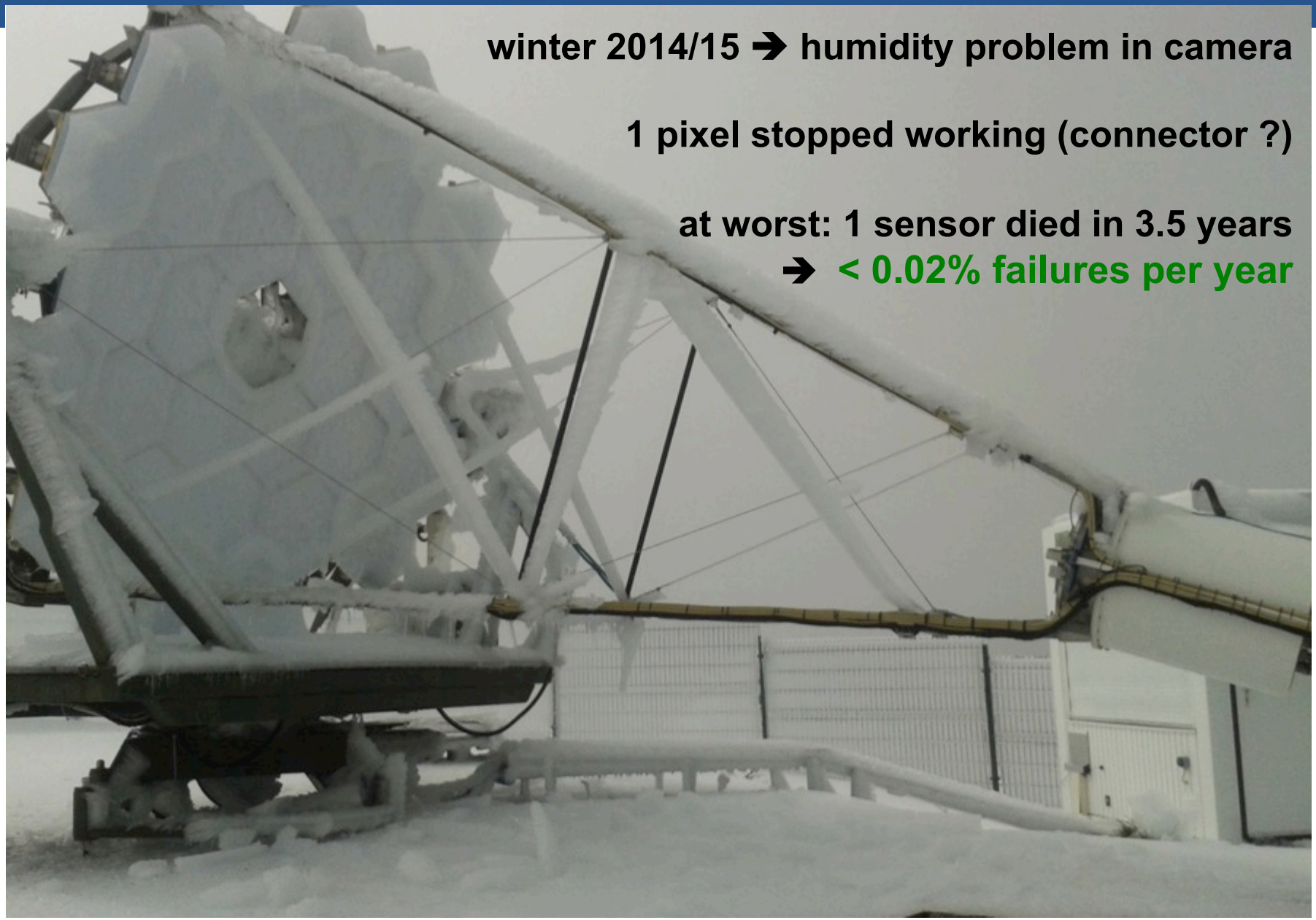


Today's G-APD are much better adapted to the needs of IACTs


June 23rd 2013
brightest
fullmoon
of the year

FACT – Collected Charges





winter 2014/15 ➔ humidity problem in camera

1 pixel stopped working (connector ?)

at worst: 1 sensor died in 3.5 years
➔ < 0.02% failures per year

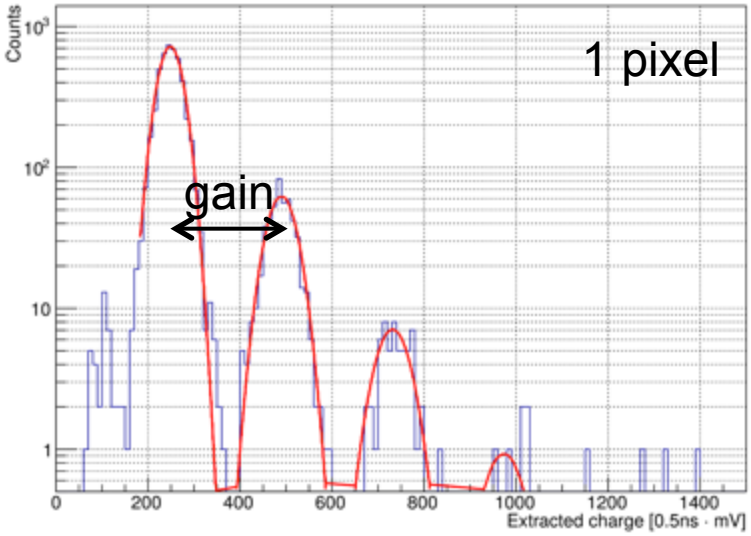
FACT – Uniformity, Stability, Calibration

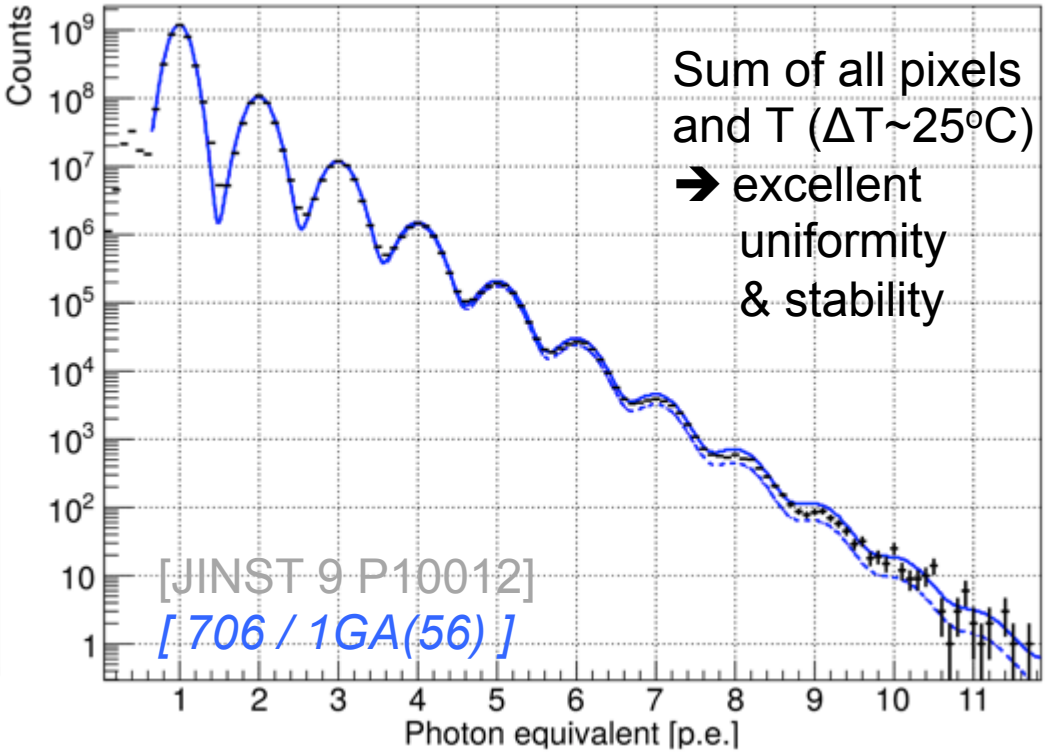
(our) G-APD gain has strong Temperature dependency

➔ feedback system ➔ adjust applied voltage to Temp. (and DC)

check quality with 1pe spectra:

(dark noise + crosstalk are your friends)

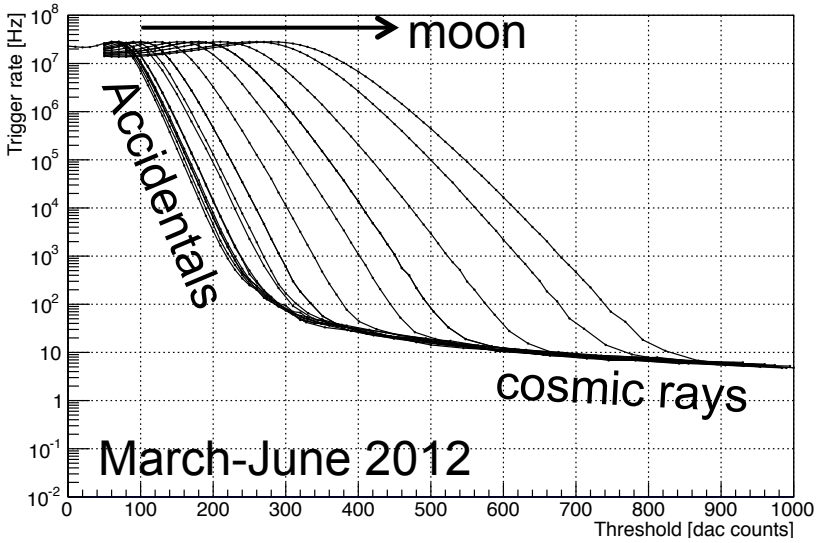


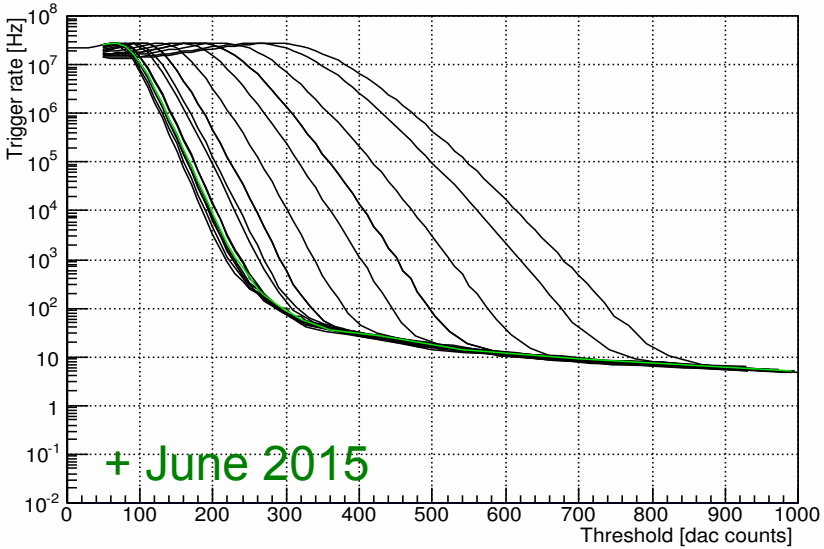


➔**dark noise + crosstalk allow calibration without any external device**

FACT – Uniformity, Stability, Calibration

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





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

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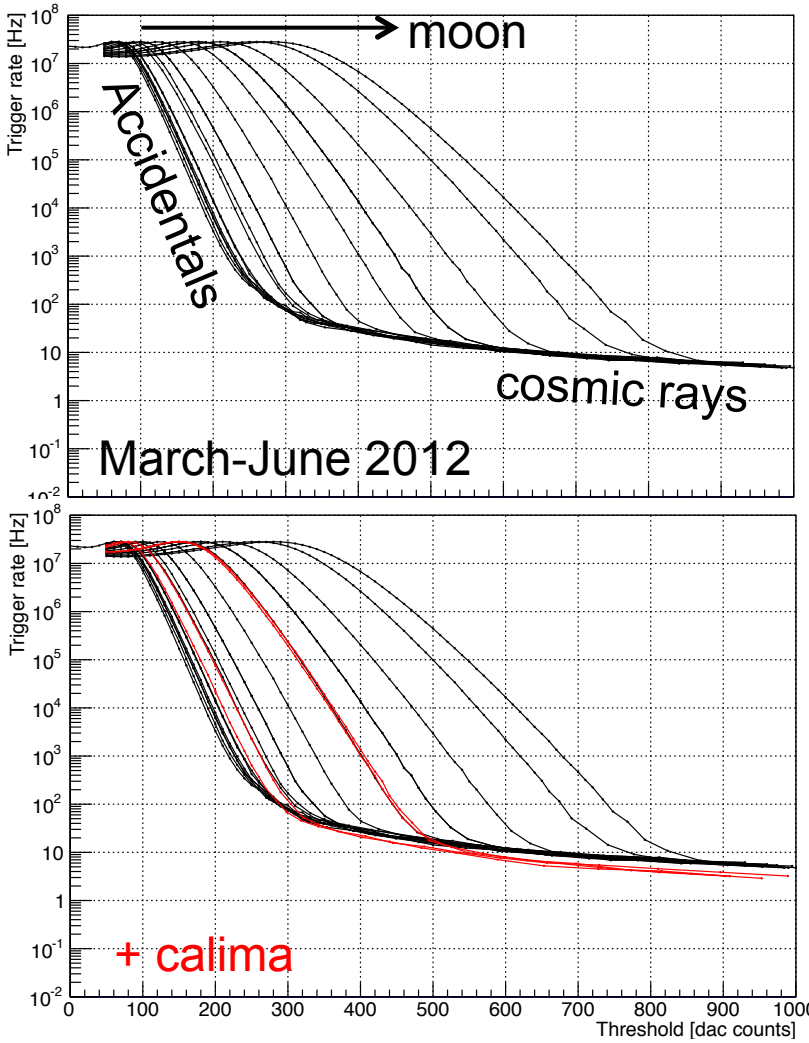

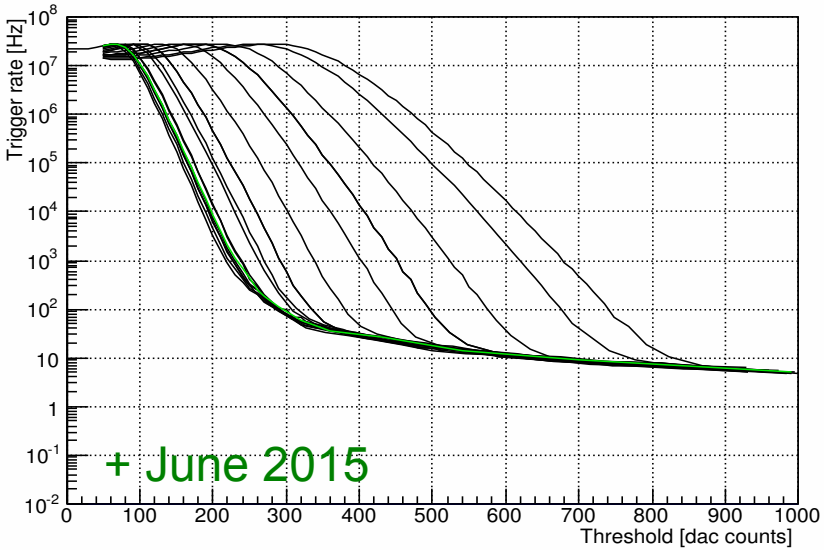

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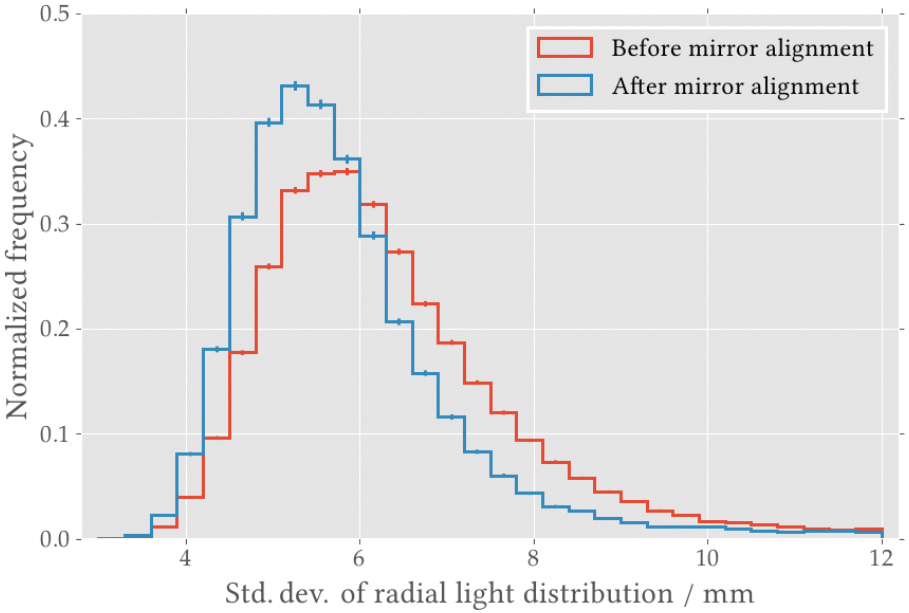
Due to this stability, it is possible to identify bad atmospheric conditions (without external device) [33rd ICRC, 709]

FACT – Uniformity, Stability, Calibration

Muon rings allow to measure

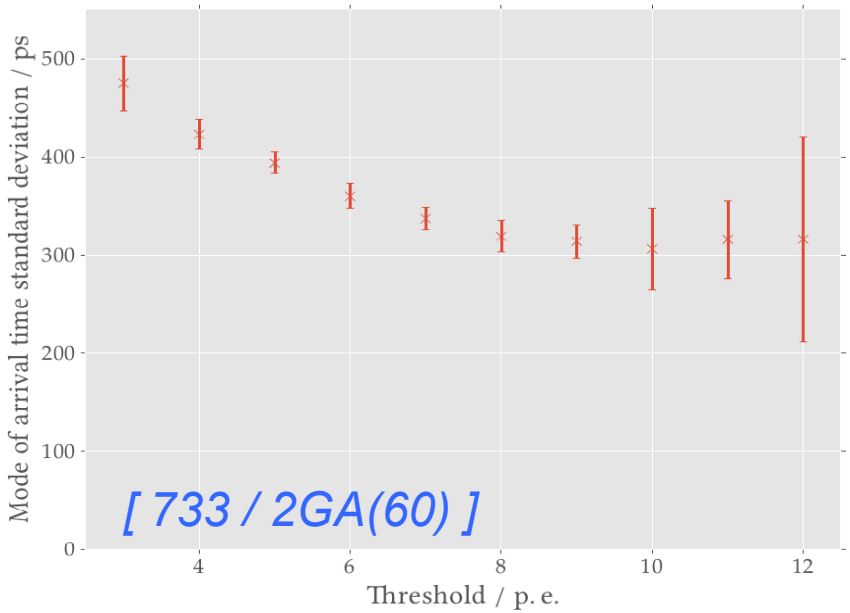
the PSF of the optics and



Novel mirror-alignment method

[776 / 1GA(84)]

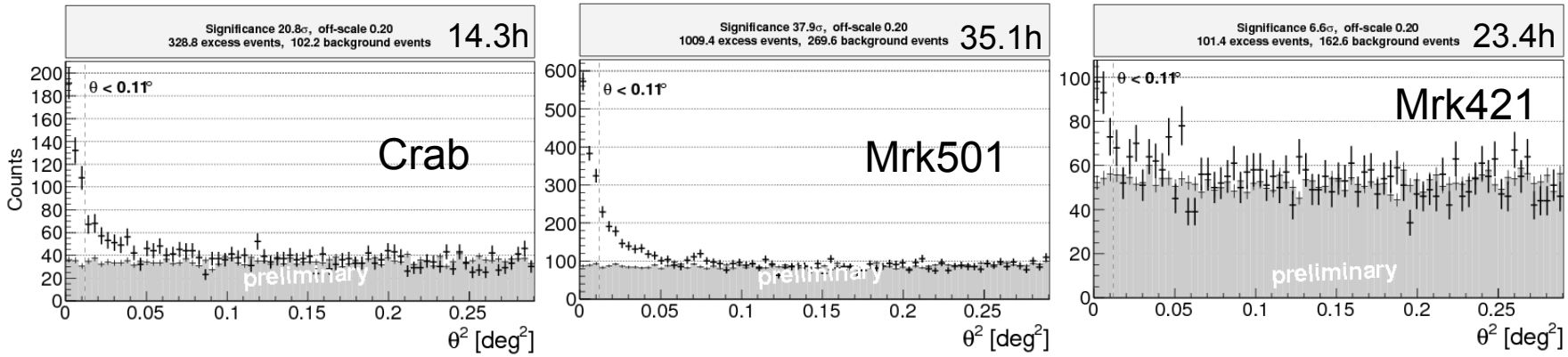
the time resolution of the system.



~320ps for >7pe; including:

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

FACT – Science



First sources presented in July 2012 [Gamma-2012: AIP Conf.Proc.1505]

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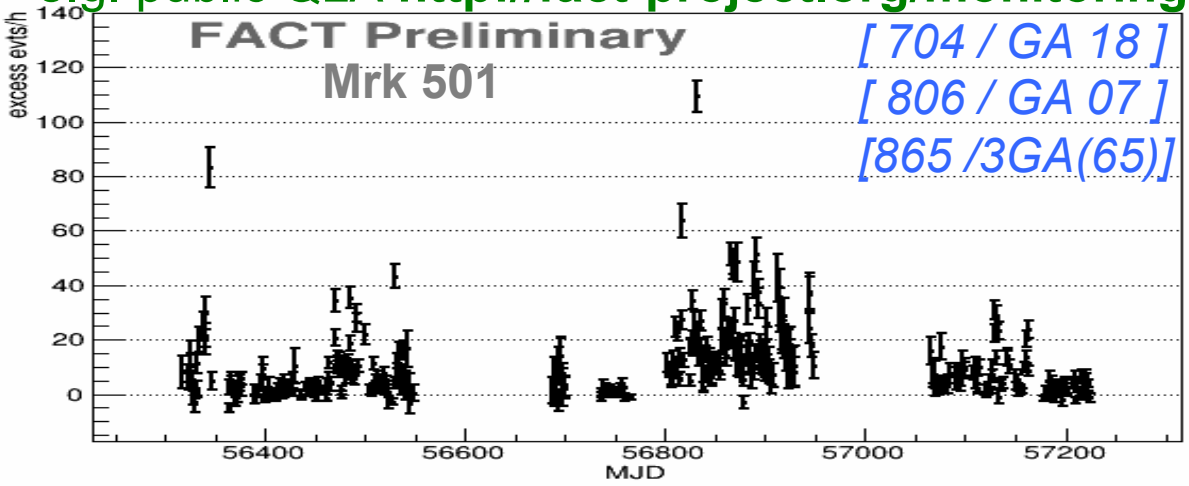
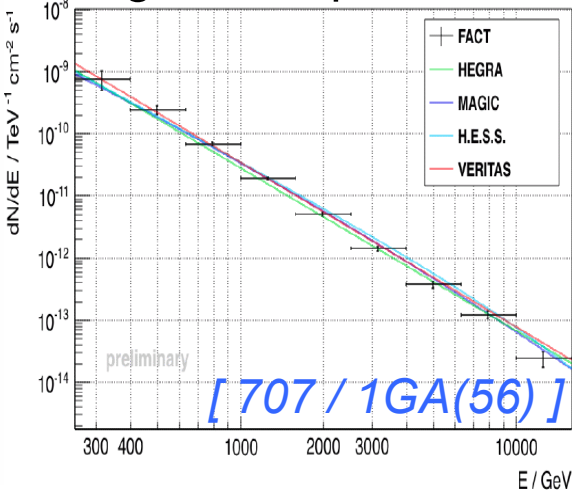
e.g. public QLA **http://fact-project.org/monitoring**



e.g. Crab spectrum



Outlook

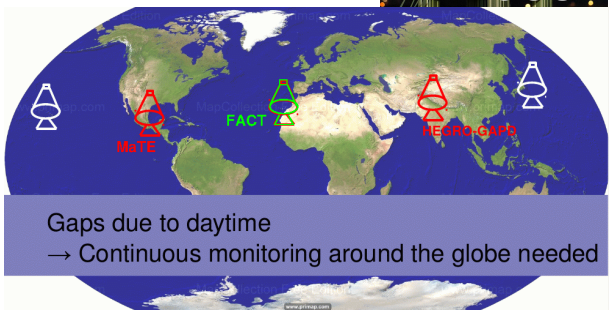
pre-FACT: all CTA designs based on (multianode) PMTs

[Exp.Astr. 32.3(2011)]

plus projects for future MST and LST cameras

post-FACT: many SiPM-based CTA projects.

& CTs outside CTA



Actual SiPM much better than those used in FACT
➔ expect significantly better performances

FACT – Conclusion

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- 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 added to form large pixel

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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)

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