EBERHARD KARLS
UNIVERSITÄT
TÜBINGEN

FACULTY OF SCIENCE
Kepler Center for Astro and Particle Physics
Institute for Astronomy und Astrophysics · High Energy Astrophysics

Performance of the New FlashCam-based Camera in the 28 m Telescope of H.E.S.S.

Baiyang Bi, Miquel Barcelo, Christian Bauer, Faical Ait Benkhali, Jacqueline Catalano, Sebastian Diebold, Christian Föhr, Stefan Funk, Gianluca Giavitto, German Hermann, Jim Hinton, Ira Jung-Richardt, Oleg Kalekin, Ruben Kankanyan, Thomas Kihm, Fabian Leuschner, Marc Pfeifer, Gerd Pühlhofer, Olaf Reimer, Simon Sailer, Heiko Salzmann, Andrea Santangelo, Simon Steinmassl, Thomas Schanz, Chris Tenzer and Felix Werner

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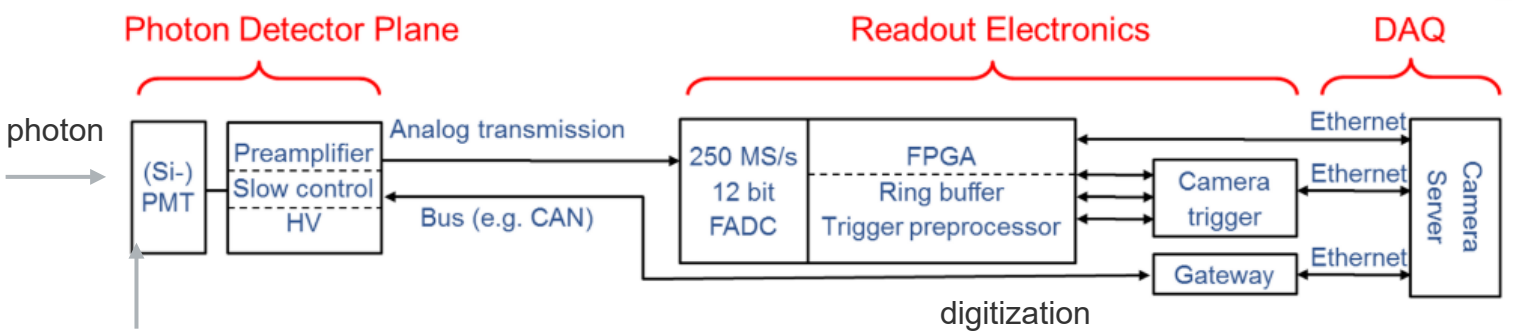
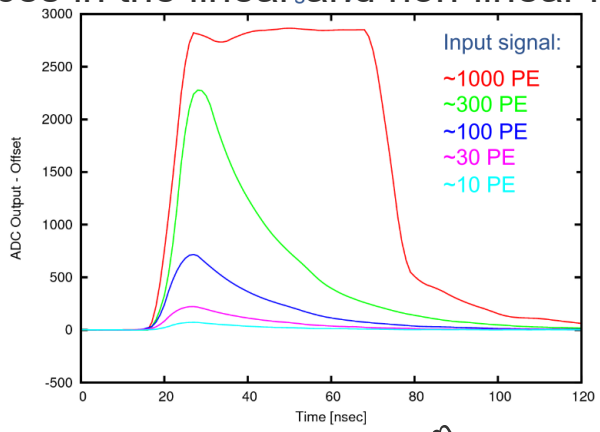
FlashCam Camera

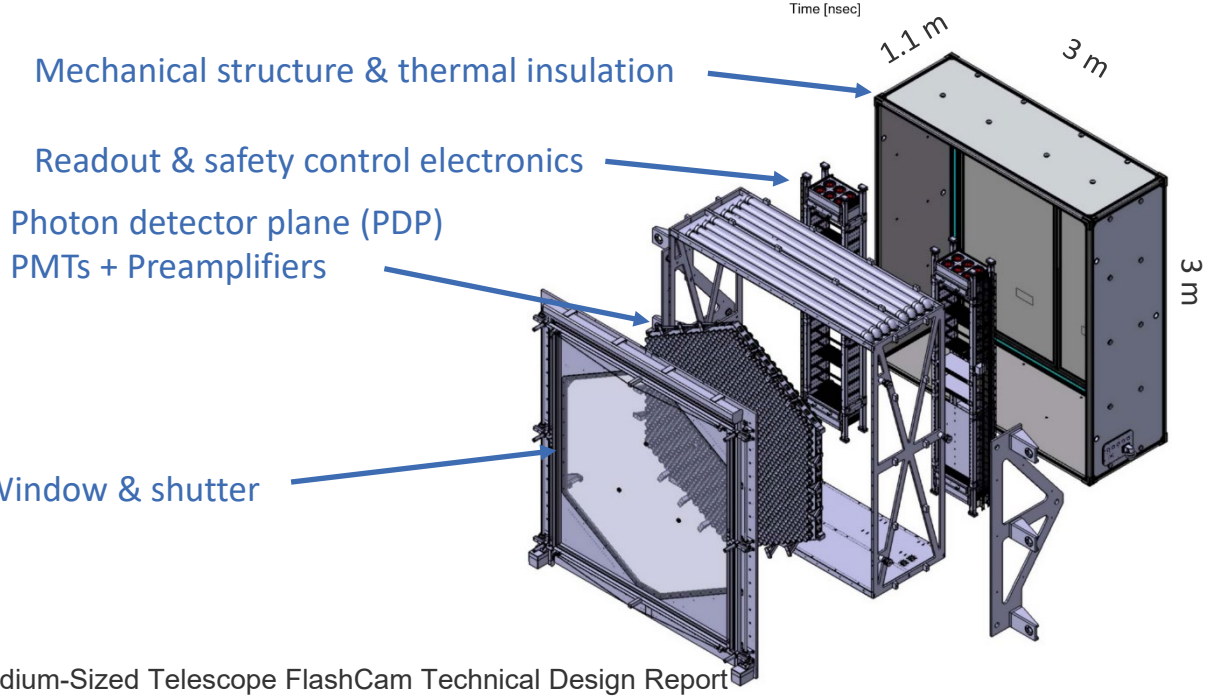


Credit: Medium-Sized Telescope FlashCam Technical Design Report

Traces in the linear and non-linear regime



- Camera candidate for CTA Medium-sized telescope (CTA-MST)
- The Photon Detector Plane (PDP) consists of 1758 active pixels, belonging to 147 PDP modules.
- 7.7° field of view (CTA-MST), 3.5° (H.E.S.S.-CT5)
- Continuous digitization with 250 MHz sample rate
- Fully digital trigger & readout
- >30 kHz deadtime-free Ethernet-based DAQ
- The pre-amplifier saturates in a controlled way when the amplitude exceeds ~ 3000 LSB
- dynamic range up to 3000 p.e.

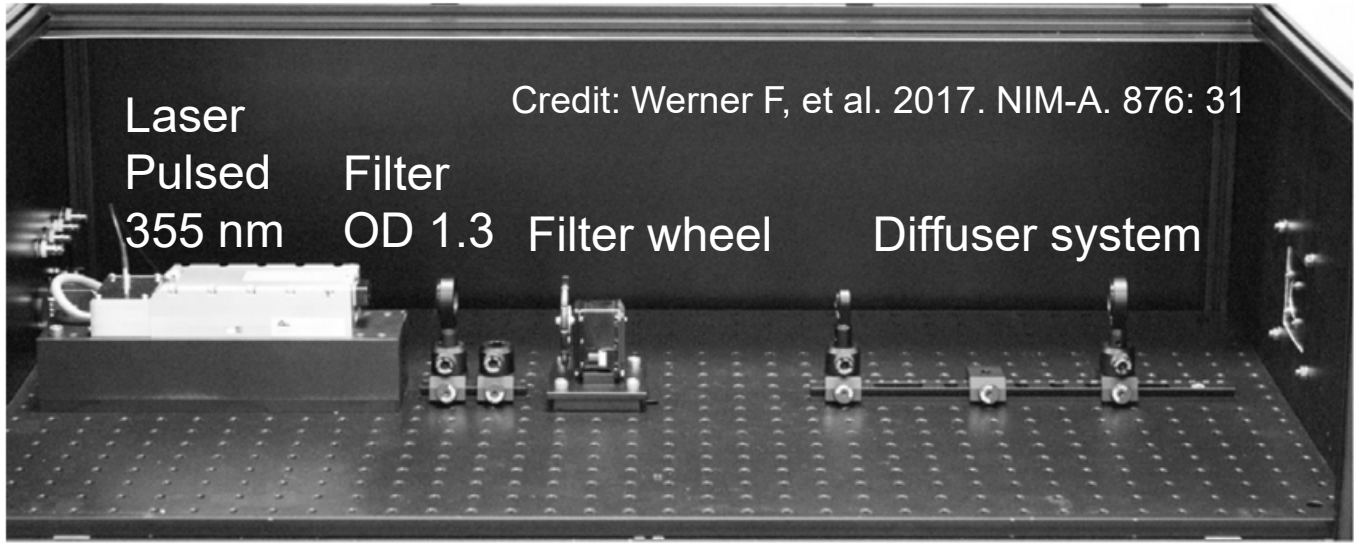


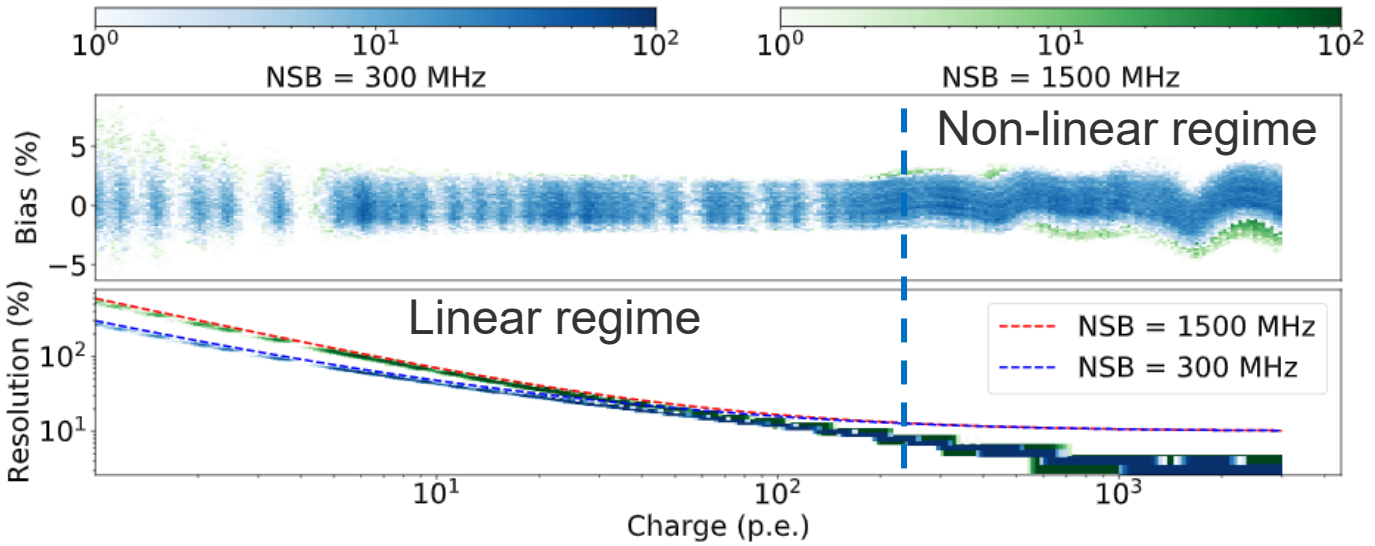
Credit: Medium-Sized Telescope FlashCam Technical Design Report

Calibration in MPIK-lab

- The full-size prototype was calibrated in the lab at Max-Planck-Institut für Kernphysik (MPIK)
- A laser system is used for calibration
- A filter wheel with step motor simulates the light pulse from 0.3 to a few thousand p.e.
- A UV LED is used to simulate the NSB up to 4.8 GHz

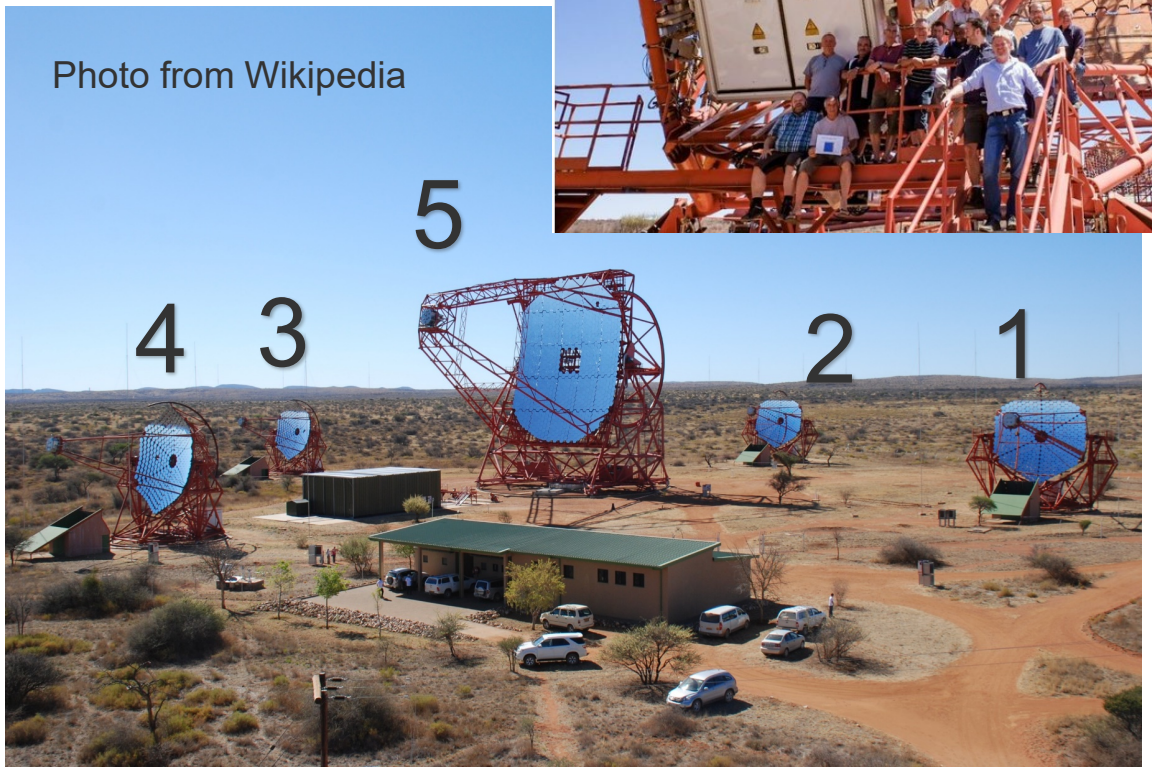
- The maximum bias is roughly 5 %
- The charge resolution complies with the CTA benchmarks (*Werner F, et al. 2017 NIM-A. 876: 31*)





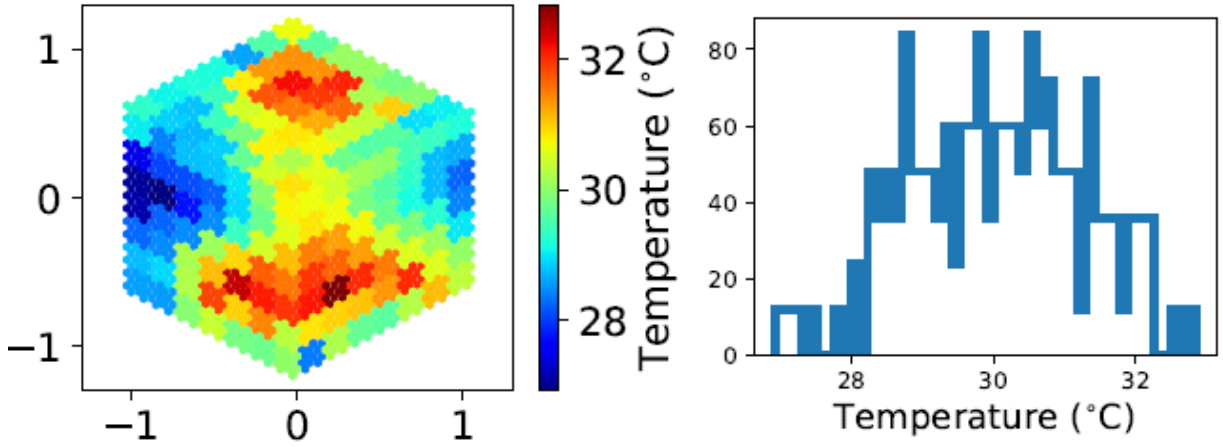
Installation into H.E.S.S. CT5

- The H.E.S.S. array consists of four 12-m telescopes (CT1-4) and one 28-m telescope (CT5)
- In October 2019, an advanced FlashCam prototype was installed into CT5 replacing the previous 7-year-old camera
- Significantly improve the telescope performance and stability
- The net weight was adjusted to keep the load unchanged to minimize the impact on the mechanics of the telescope
- The camera was available for observations more than 98 % of the time



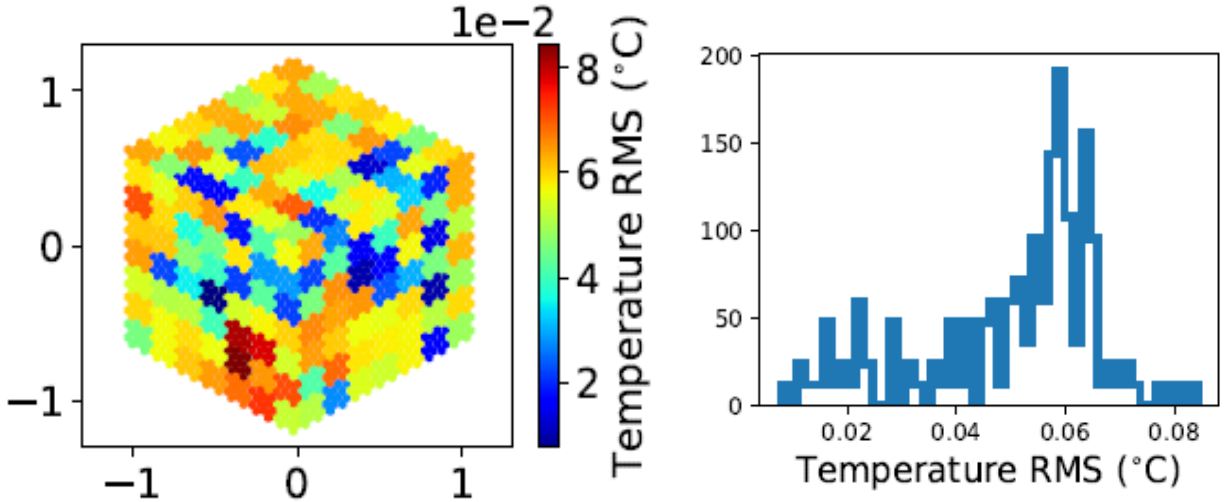
The cooling system

- The active water cooling system keeps a sufficiently constant (~ 30 ℃) camera temperature during observations
- There is one temperature sensor on each PDP module.



(Run 160149, 2020-06-09)

- The optimal medium temperature is 26 to 32 ℃
- An example run shows the median temperature of 30 ℃, with an RMS less than 0.1 ℃



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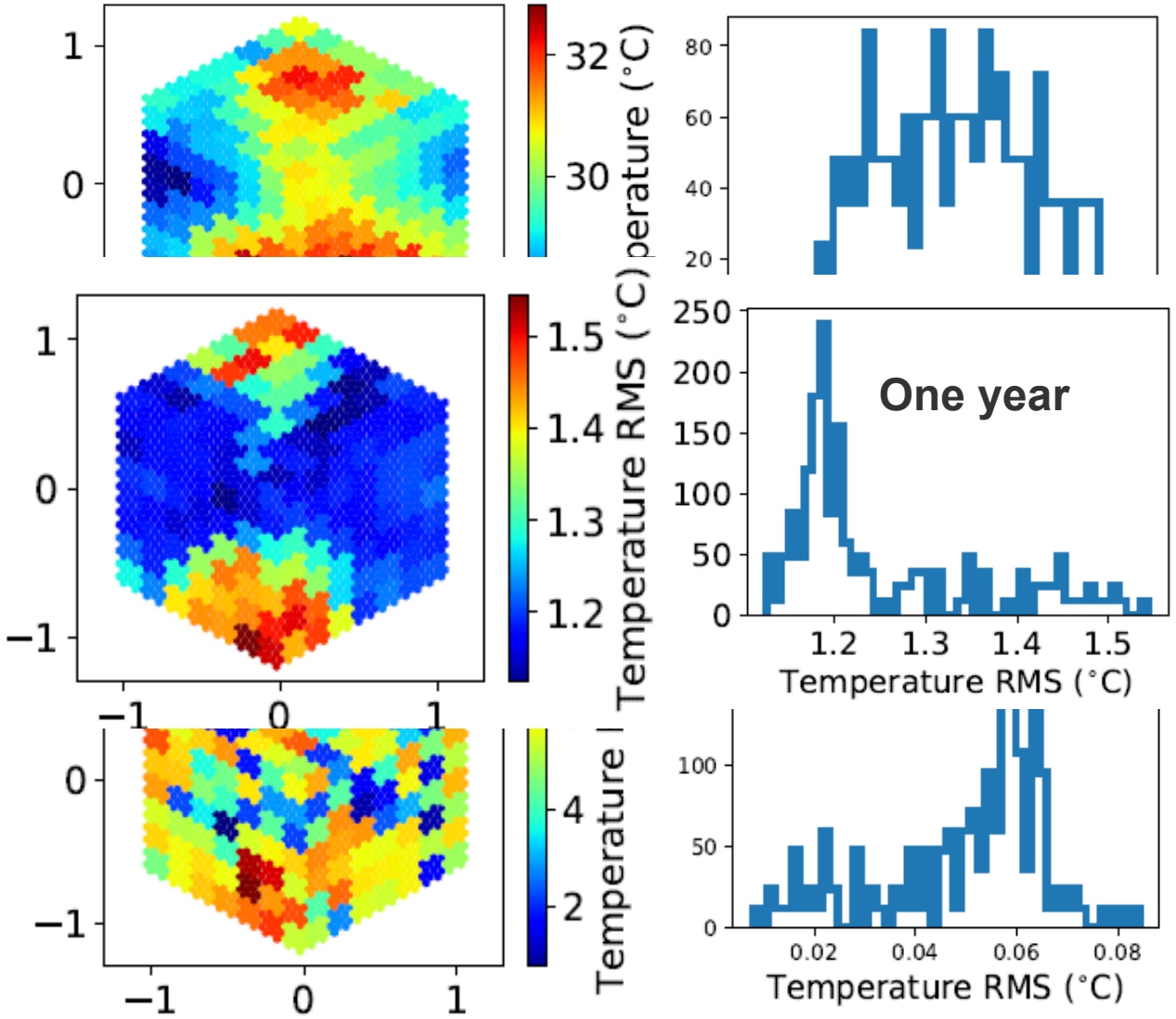
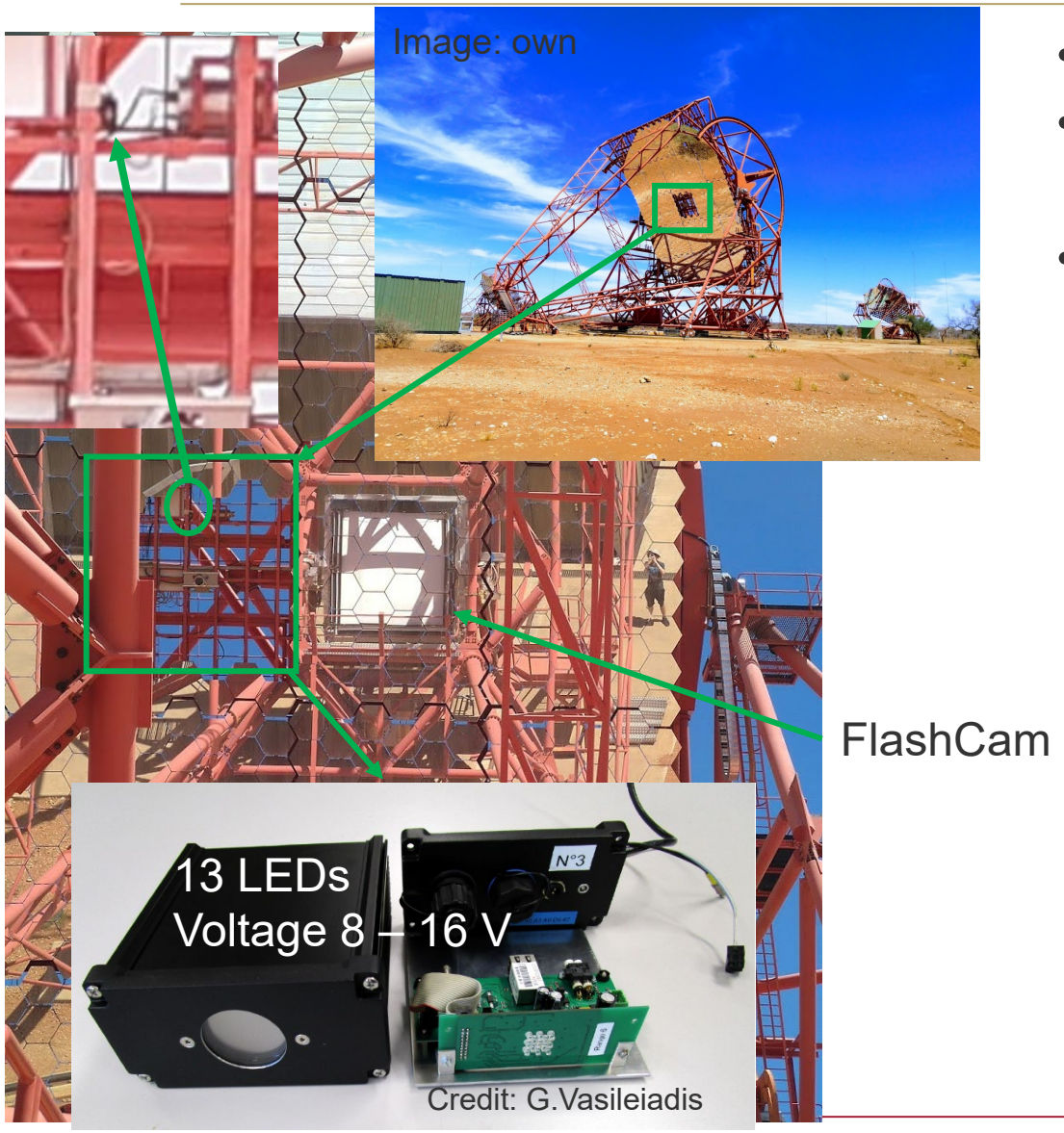
- During operation, the temperature was controlled with a standard deviation of 1.5 ℃

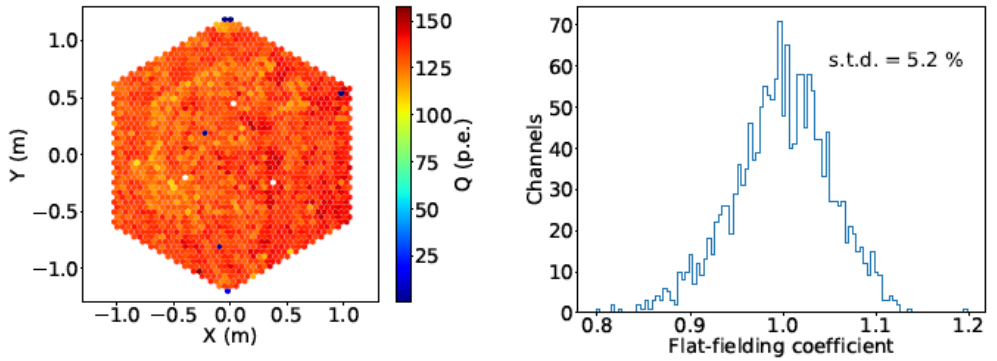


Flat-fielding unit and flat-fielding run

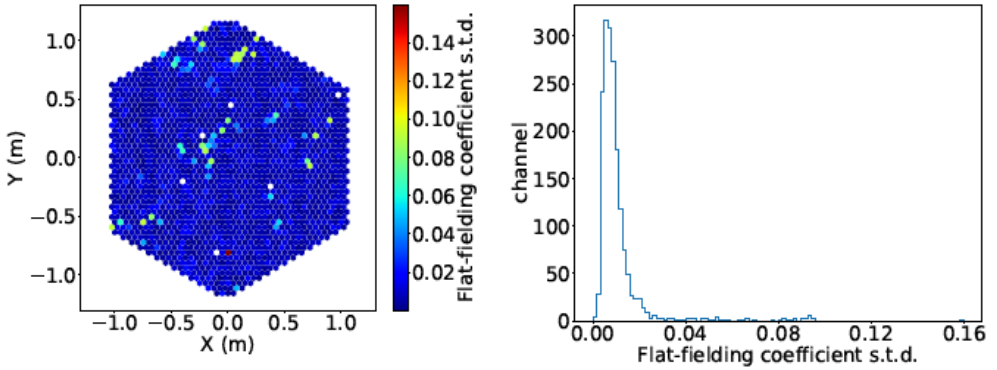


FlashCam

- A flat-fielding unit at the center of the mirror dish
- The st. dev. of flat-fielding coefficients (of the example run) is 5.2%
- The variation of the flat-fielding coefficients (of most pixels) in one year is less than 3%



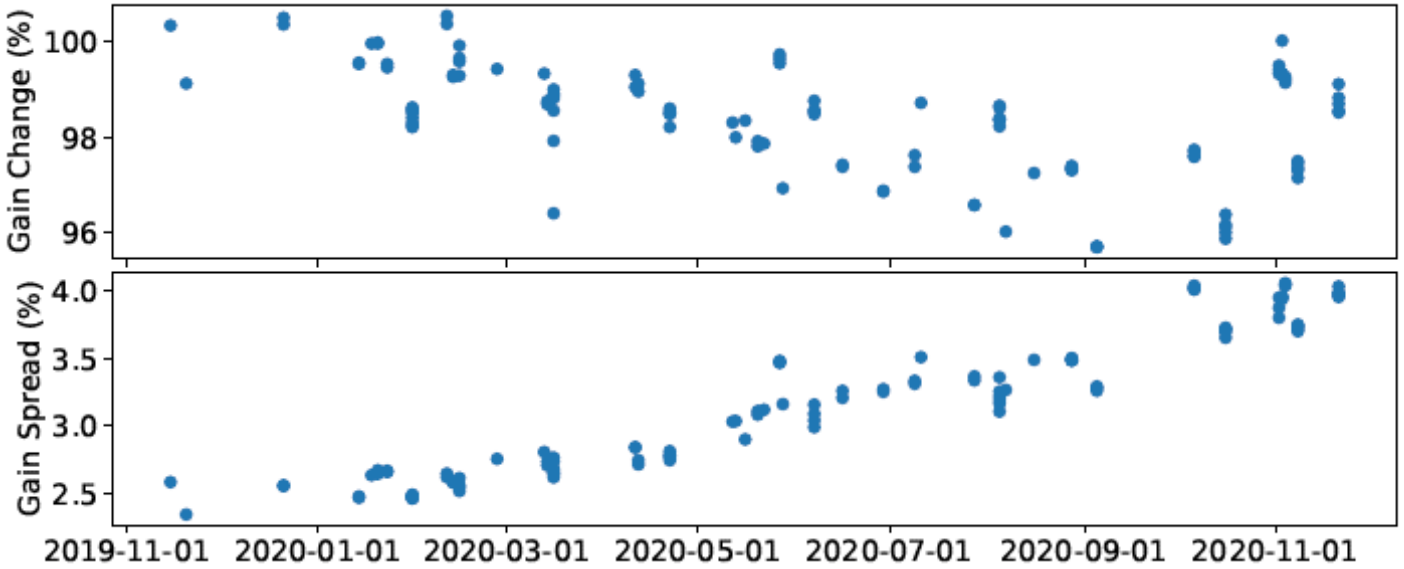
One run



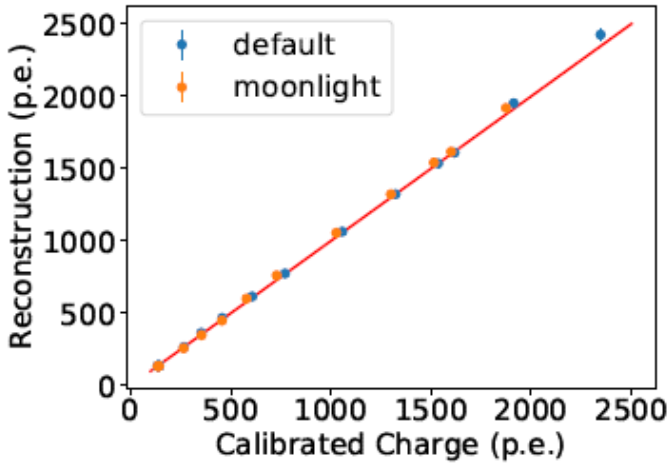
One year

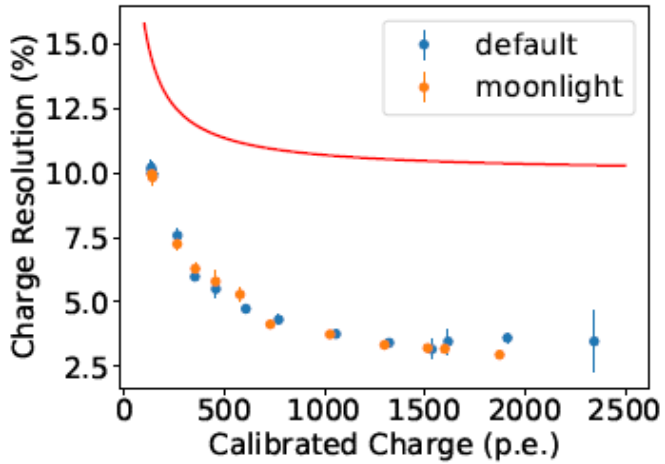
PDP Performance

- The gains of the PMTs are monitored
- In one year (2019-11 to 2020-12), the median gain of the PMTs dropped by ~ 4 %, with the gain spread increasing from 2.5 % to 4 %



- A set of runs, sweeping the intensity of the Flat-fielding unit, were performed in Jan. 2020
- The reconstruction algorithm is verified over the full dynamic range of the camera

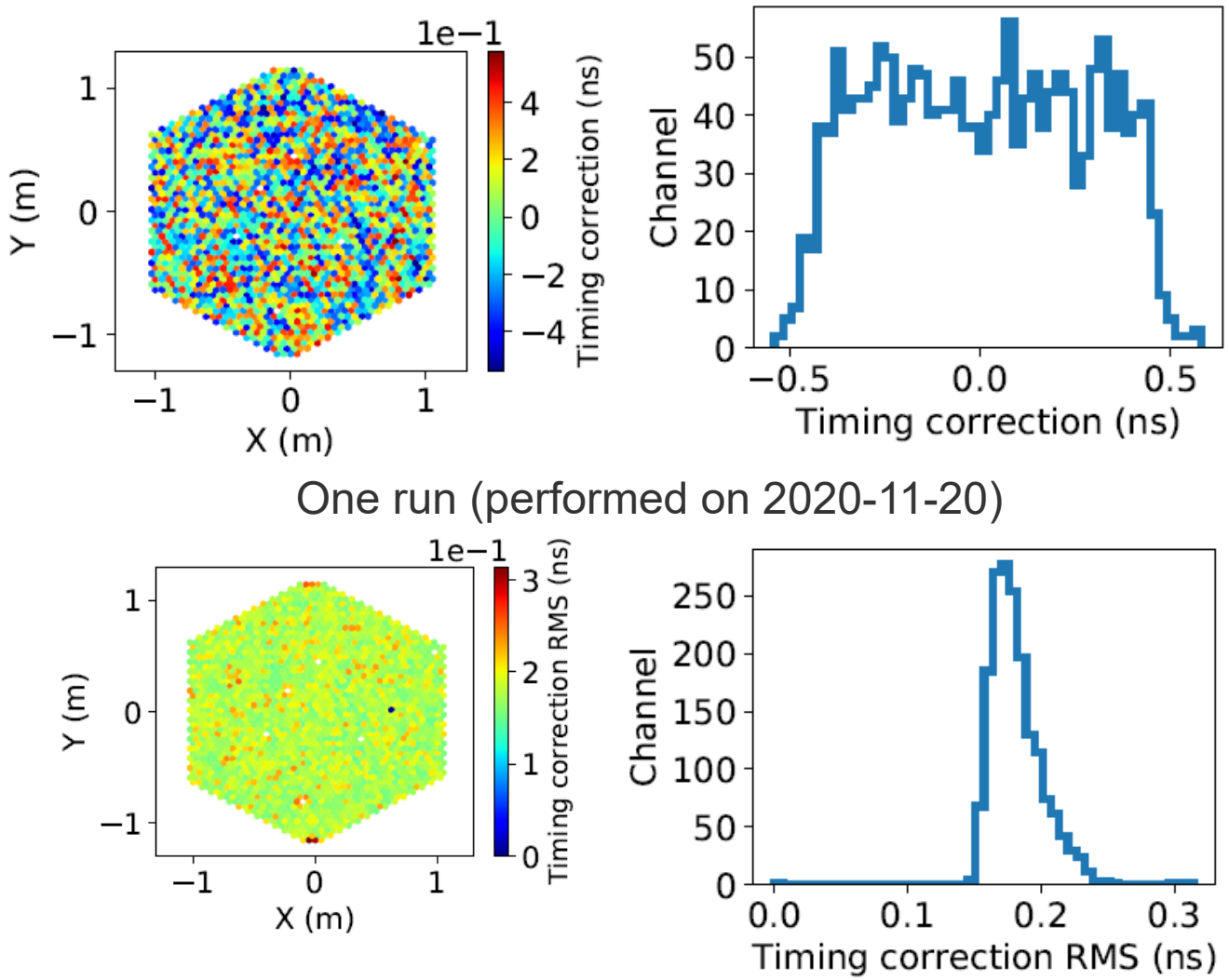




Timing correction

- With the flat-fielding unit, the pixel-wise timing correction coefficients can be measured
- The timing spread is defined as the difference between the trigger time of each pixel and the median trigger time

- In one flat-fielding run (performed on 2020-11-20) the timing spread is in ± 500 ps range, with an RMS (for most of the pixels) no more than 250 ps



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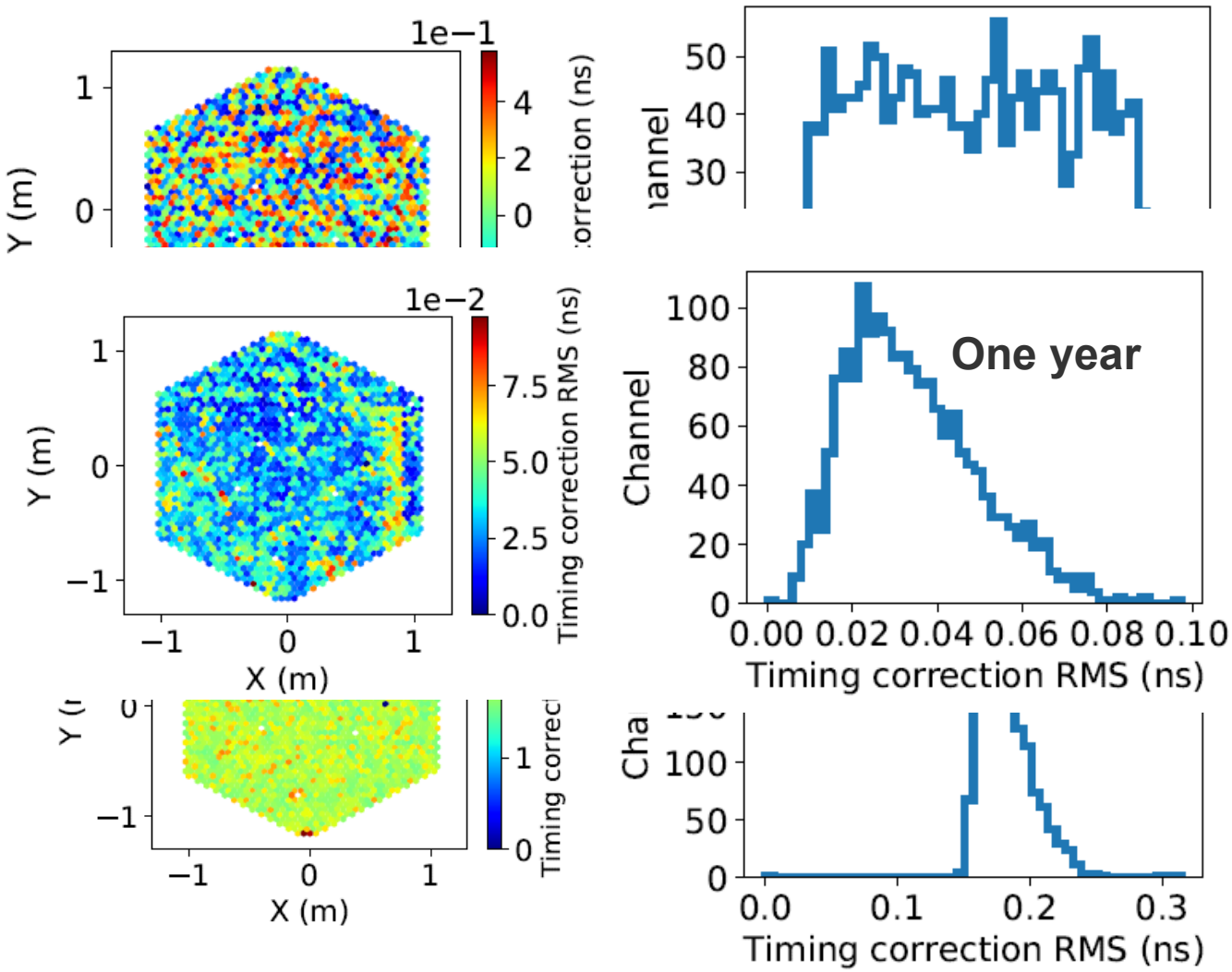
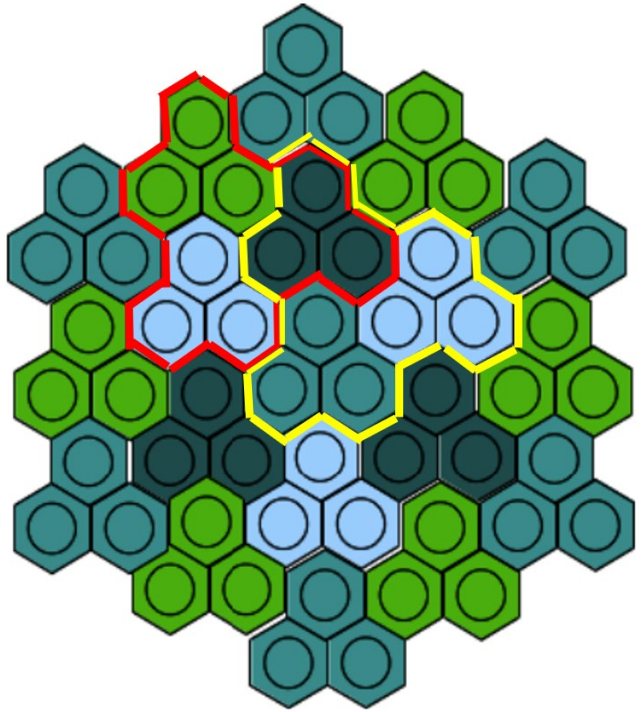
- The timing correction coefficients vary by less than 100 ps in one year



Trigger system

- The PDP is logically mapped onto 588 non-overlapping patches
- Each patch consists of three neighboring pixels
- A trigger patch is formed with three neighboring three-pixel patches
- The sum of each trigger patch, excluding pixels above the NSB limit, is evaluated for the trigger decision
- To study the low energy potential, a lower trigger threshold setting (59 p.e.) is used experimentally for dedicated sources
- The Vela pulsar was successfully observed with this setup



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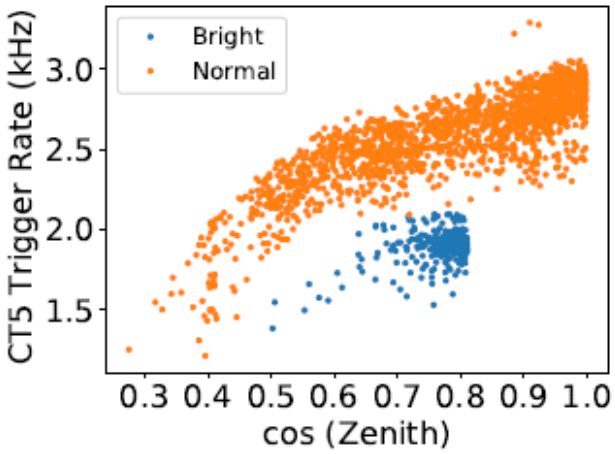
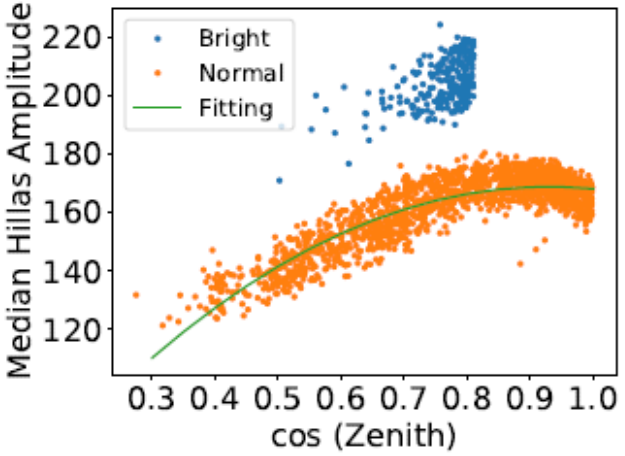
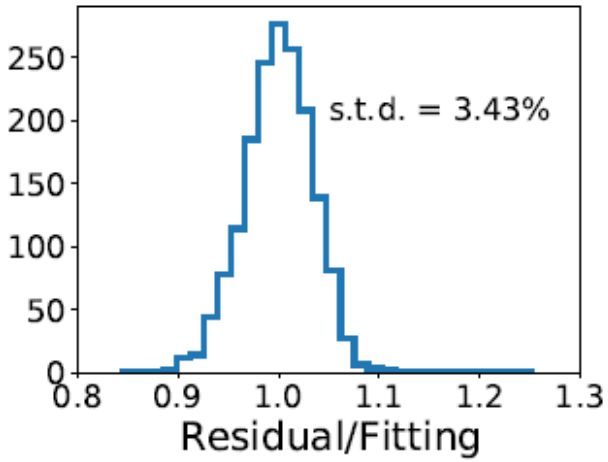
Source region	Run type	Trigger threshold (9-pixel sum)	NSB limit
Normal	ObservationRun	69 p.e.	1.1 GHz
	MoonlightObservationRun	104 p.e.	2.7 GHz
Bright (Eta Carina)	ObservationRun	91 p.e.	2.7 GHz
	MoonlightObservationRun	120 p.e.	2.7 GHz

Trigger system







- Runs with good weather condition (selected by shift logs and CT1-4 rate) are plotted
- The average dead time during observation runs is significantly below 0.1 %
- As expected, the (run-wise average) CT5 trigger rates show a clear tendency with observation altitude
- The median Hillas Amplitude of all triggered events also shows an altitude dependency, and can be fitted to a quadratic function (the green line)
- Taking out this altitude dependency, the st. dev. of the median Hillas amplitude is 3.43 %

Summary

- The calibration of the FlashCam camera at MPIK shows excellent performance:
  - The camera runs dead time free at a trigger rate up to 30 kHz
  - The non-linear regime extends the dynamic range up to 3,000 p.e.
  - The charge resolution complies with the CTA benchmarks
- The FlashCam camera has run smoothly in CT5 for more than one and a half years
- The performance of the camera was stable and excellent:
  - The camera was available for data taking more than 98 % of the time
  - Neither a single channel nor electronics board broke during operation
  - The internal temperature is controlled to be between 26 and 32 ℃ throughout the whole year, with an RMS of less than 0.1 ℃ during a 28-minute run and less than 1.5 ℃ in one year
  - The PMT gains dropped roughly by 4 % in one year, and the gain spread increased from 2.5 % to 4 %
  - The trigger time spreads within a ± 500 ps range
  - The trigger system was stable with a dead time significantly below 0.1 %
- Science verification observations on several targets have been done
- The observation results have been reported in a companion poster presentation (16/07, 18:00)