# **FlashCam**:
# A high-performance camera for IACTs

C. Escañuela Nieves for the FlashCam Team
Max Planck Institute for Nuclear Physics, Heidelberg

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# Outline

- Overview of design and architecture
- Performance in the laboratory
- FlashCam verification and physics operation in HESS
- FlashCam towards the future

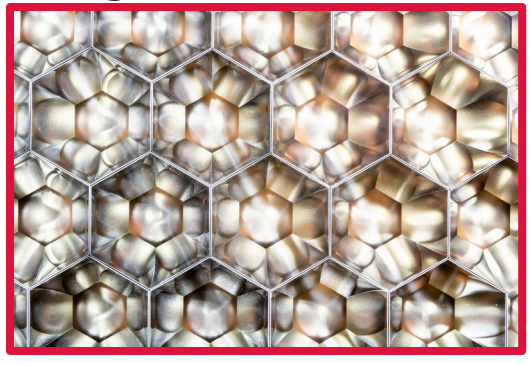
# FlashCam: Architecture

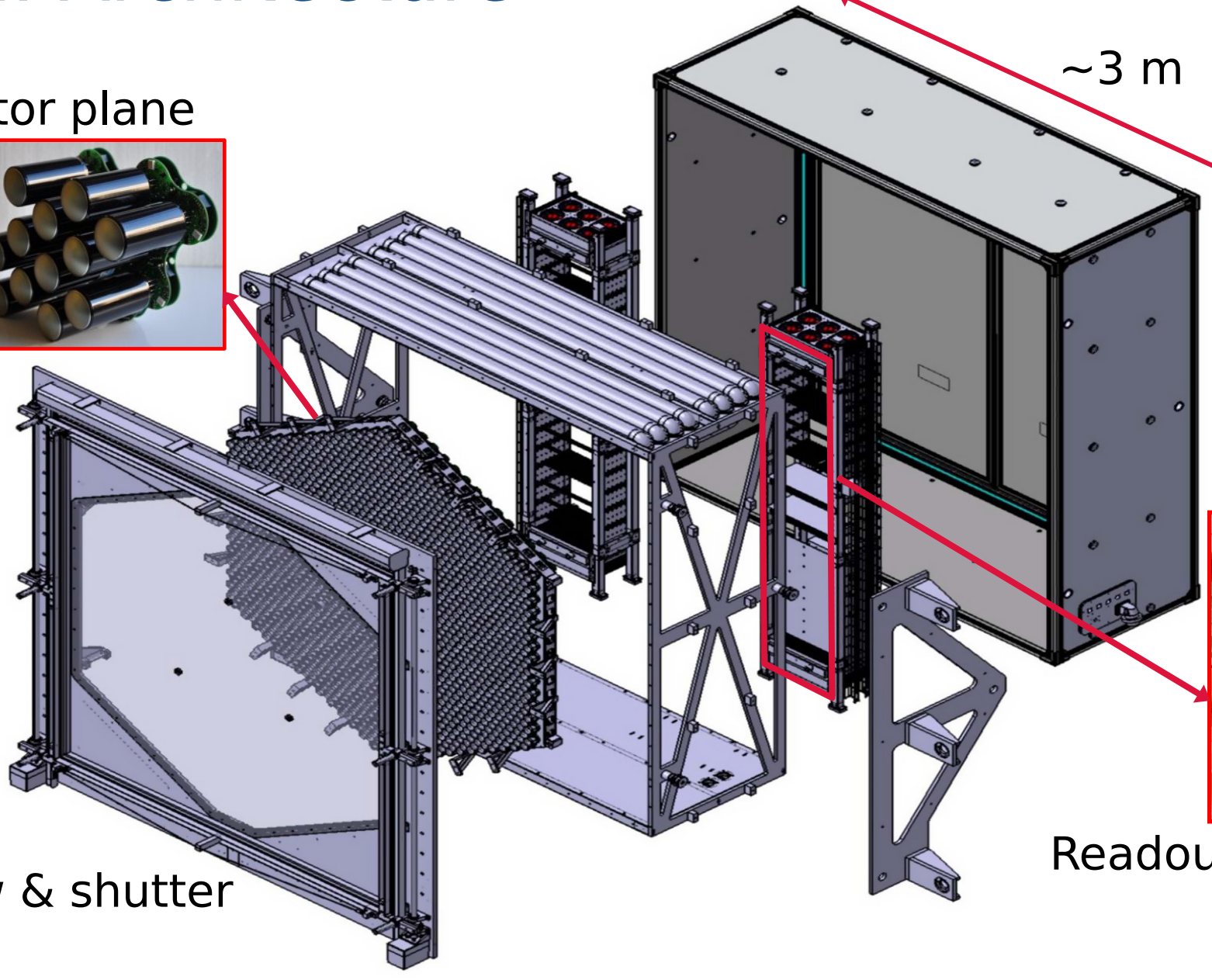
Mechanical structure & thermal insulation

~3 m

Photon detector plane

Light cones



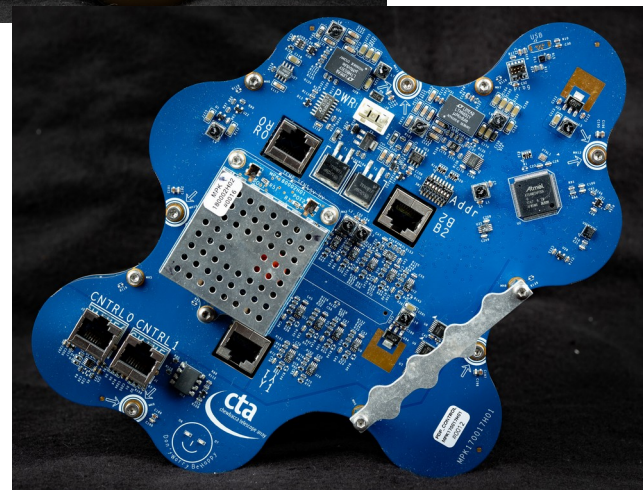


Readout electronics

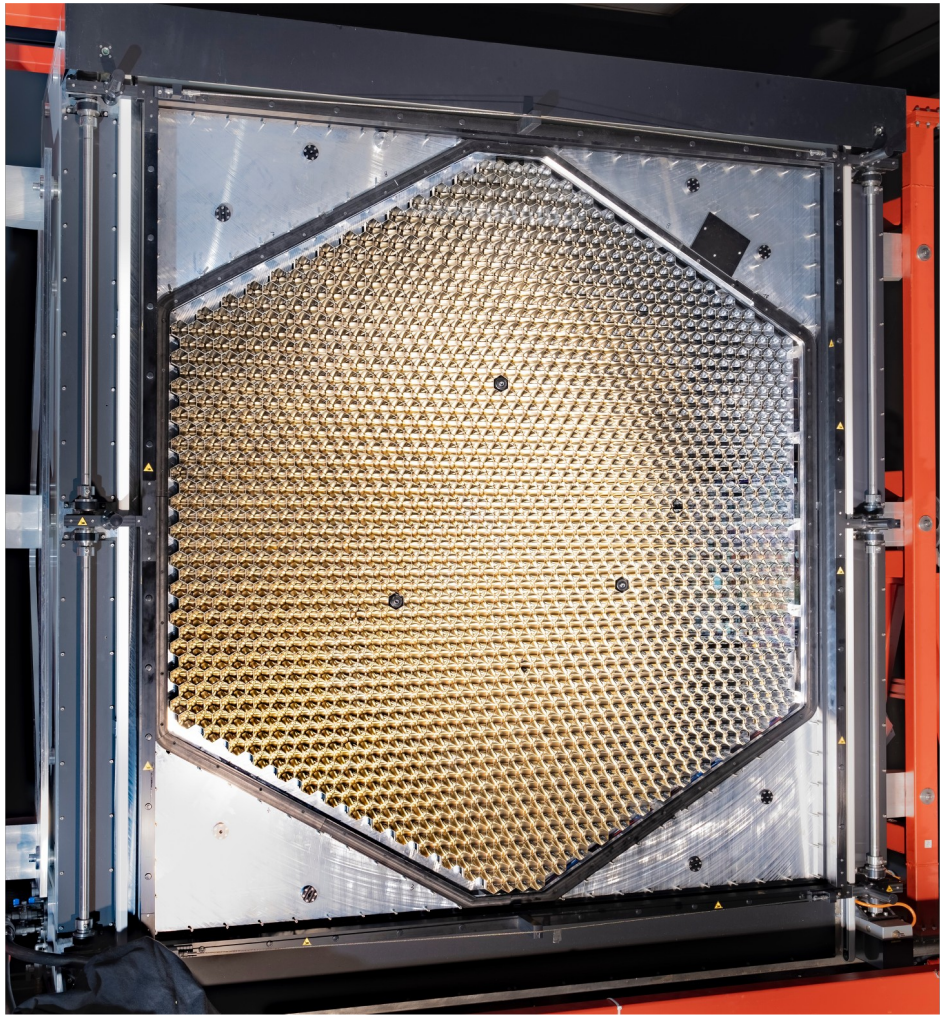
Window & shutter

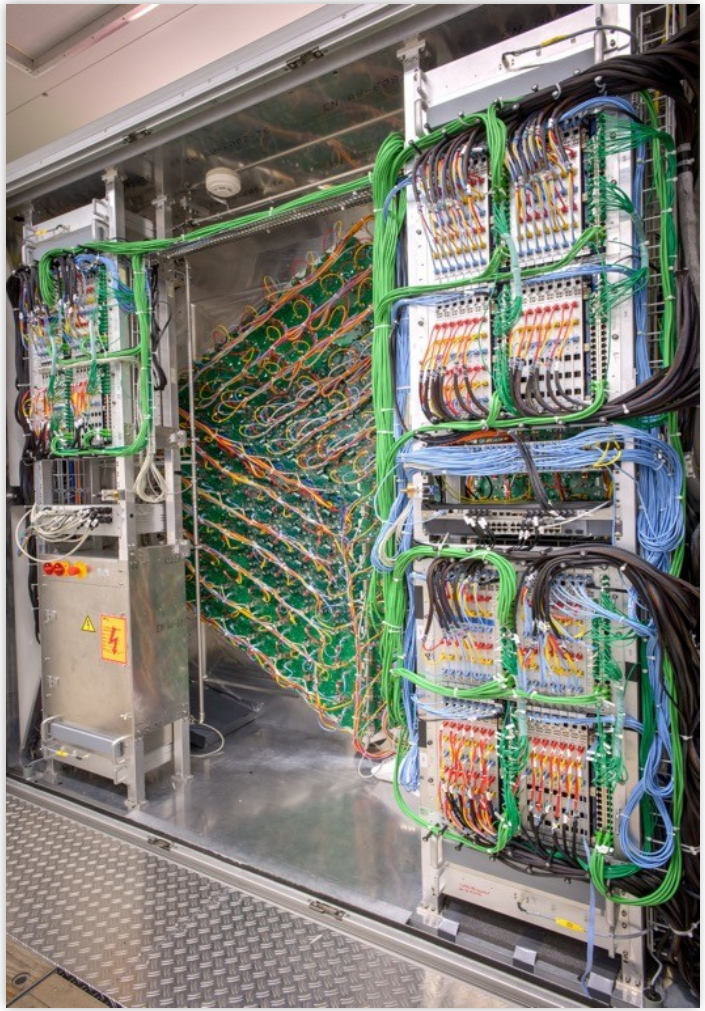
# FlashCam: Characteristics and properties

- 7.7° FoV
- 1764 PMTs in groups of 12, Photon Detector Plane (PDP)
- Dynamic range up to ~3000 p.e.
- Continuous digitisation with 250 MS/s
- Fully digital trigger and readout
- Dead-time free trigger rate >20kHz
- ~4 kW power consumption



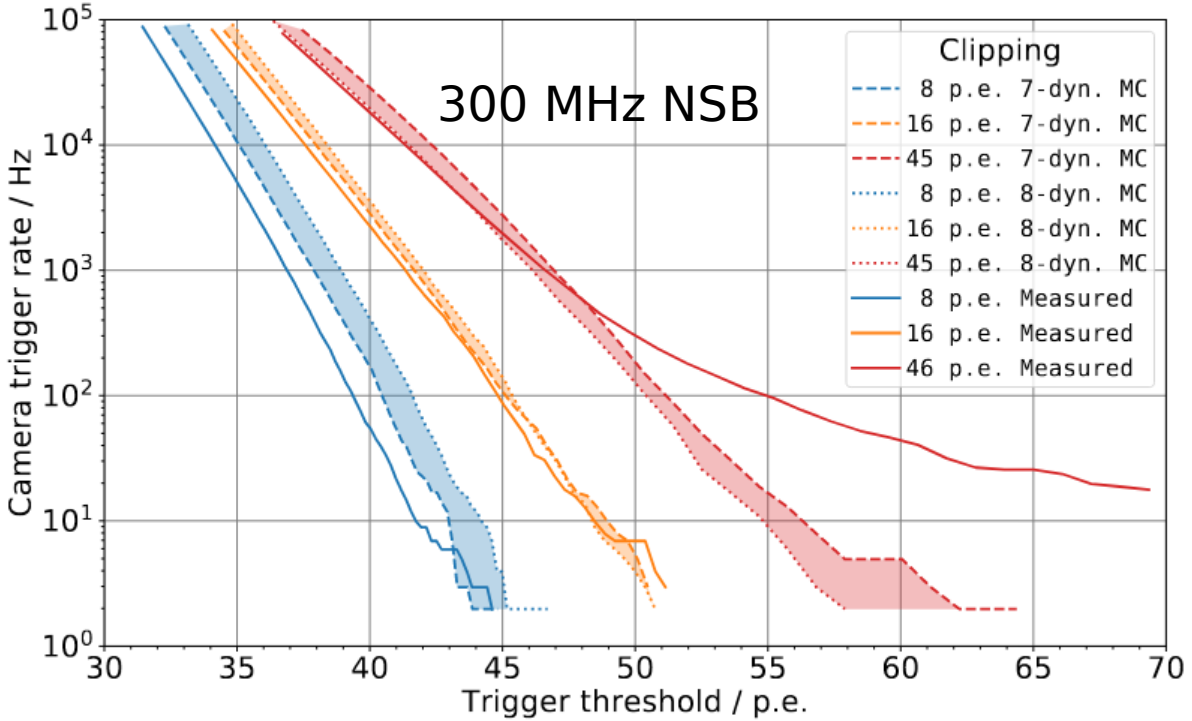
# Fully equipped camera in the lab

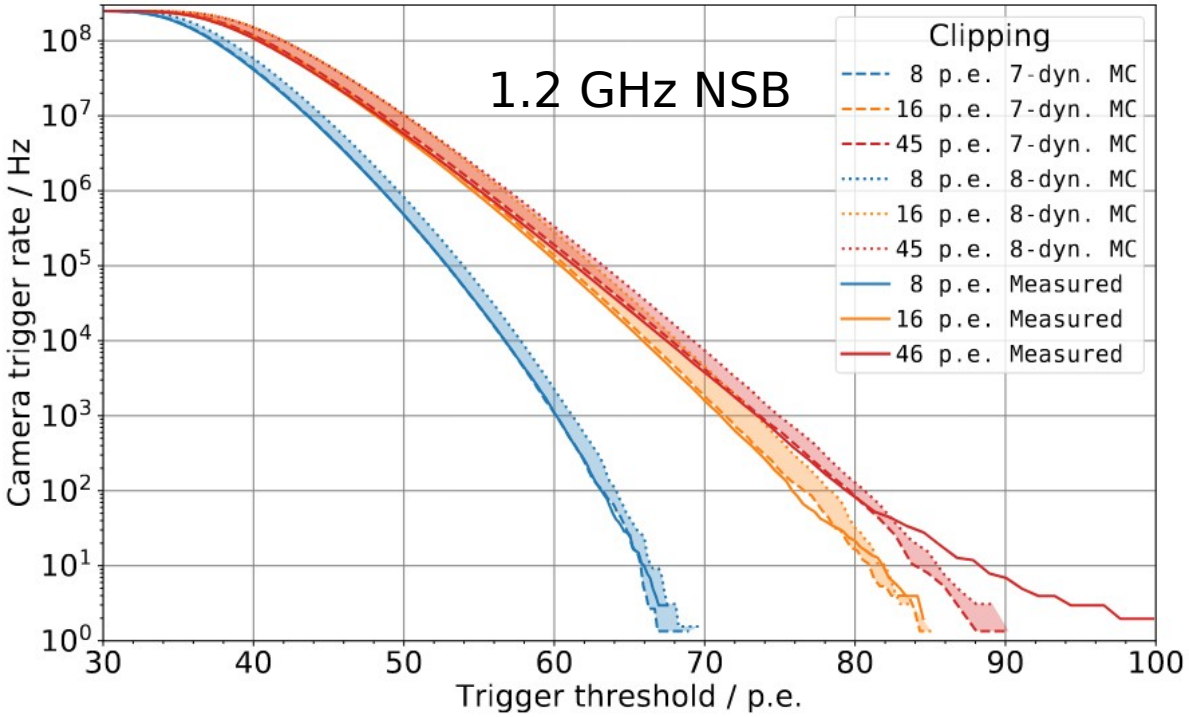




# FlashCam trigger very well understood and consistent with simulations

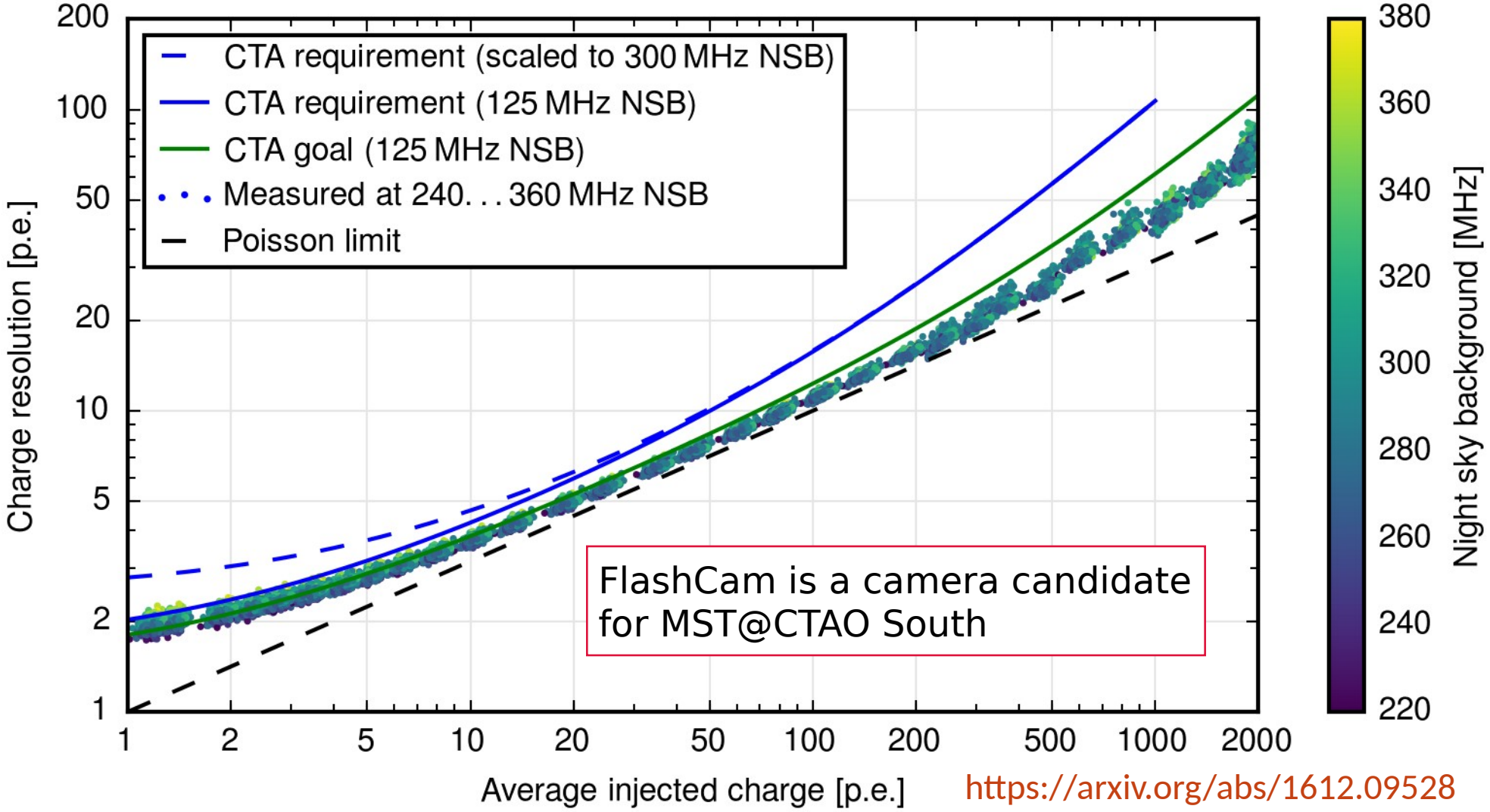
Measurements were conducted in the laboratory using a fully assembled camera with both 7- and 8-dynode PMTs and multiple NSB levels




Simon Sailer, https://arxiv.org/pdf/1907.09220

# Charge resolution better than requirements




https://arxiv.org/abs/1612.09528

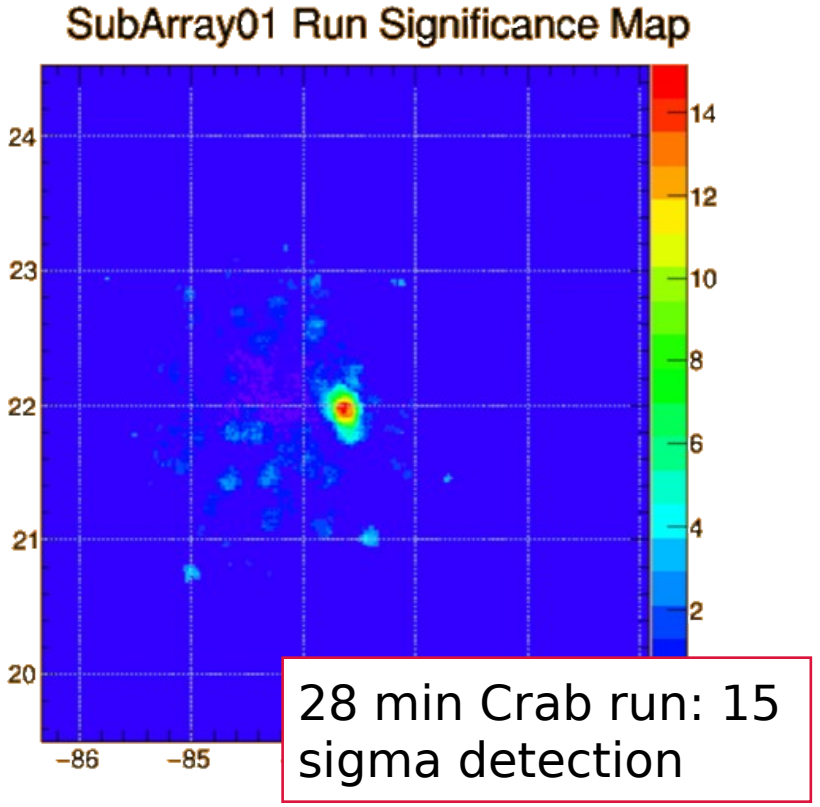
# FlashCam installation in HESS CT5


October 2019 → FlashCam was installed in CT5

# First measurements with FlashCam CT5

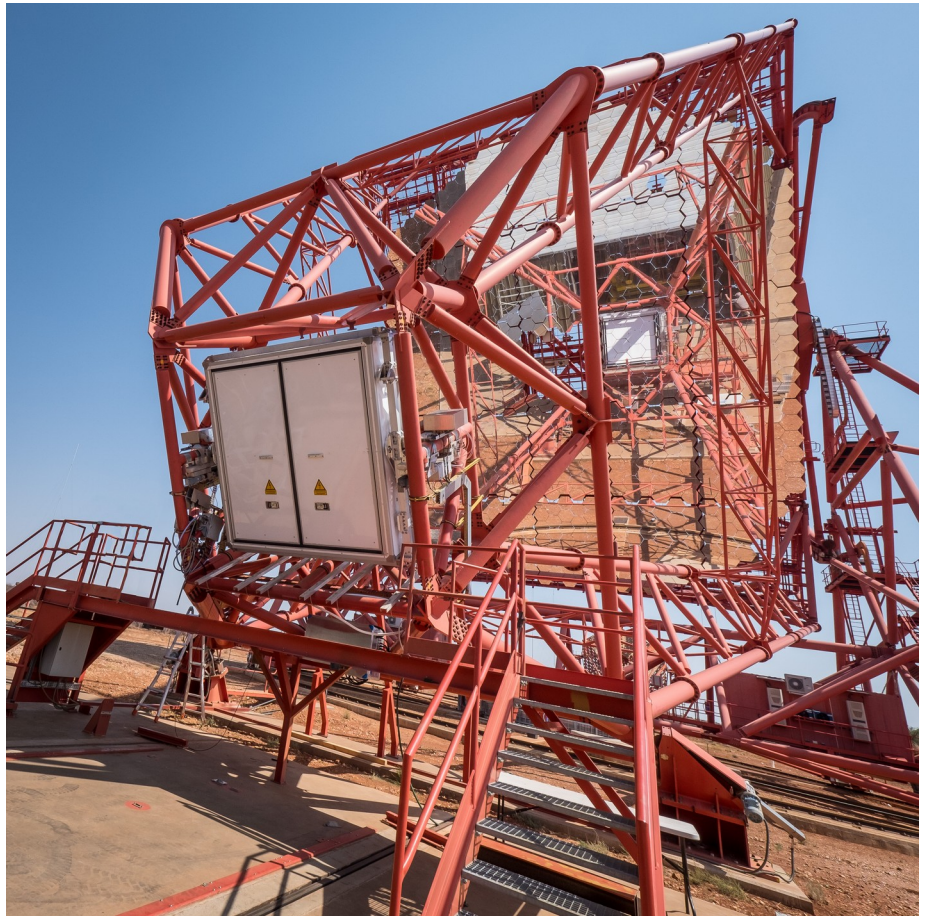
4 October: Camera arrival on site

22-23 October: First gamma-ray sky map




28 min Crab run: 15 sigma detection

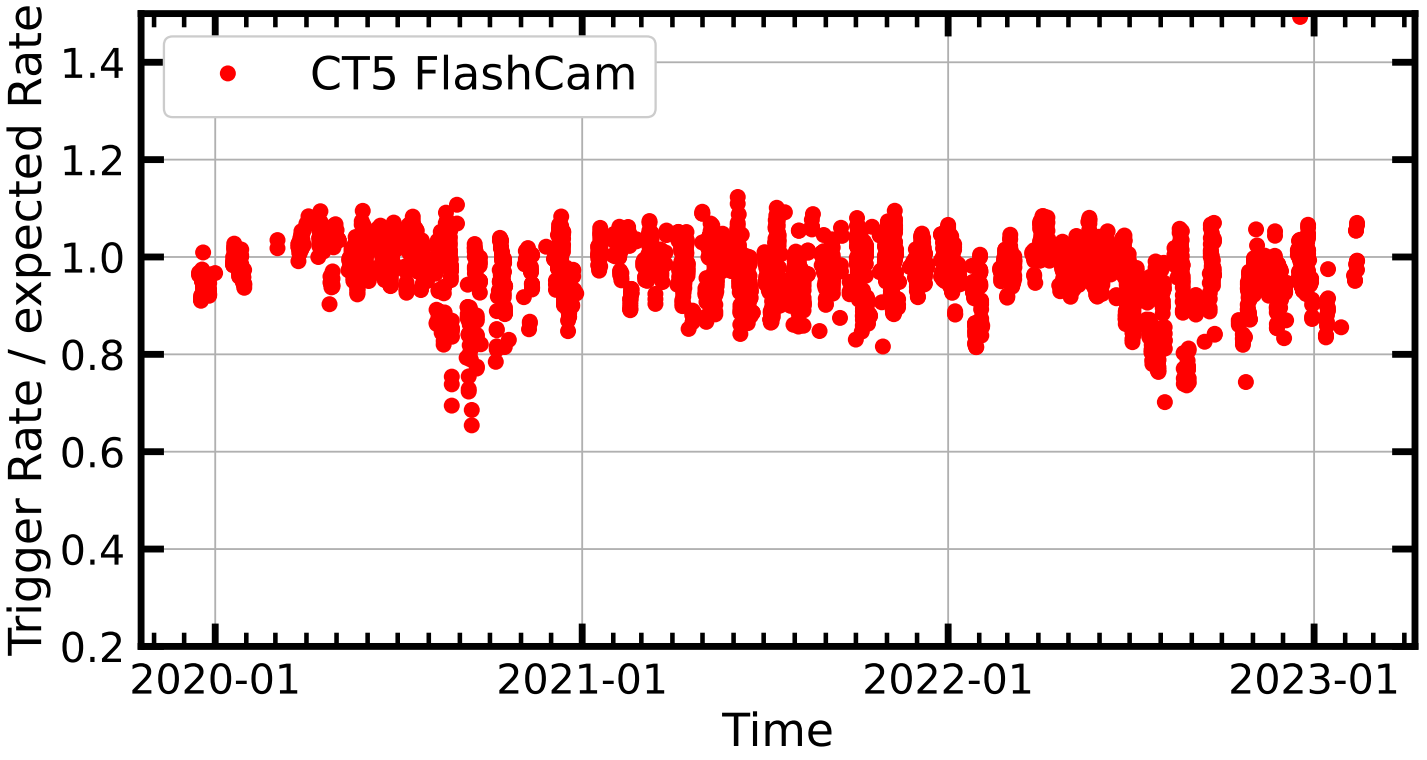
# FlashCam in HESS Namibia: Long-term operation experience and verification

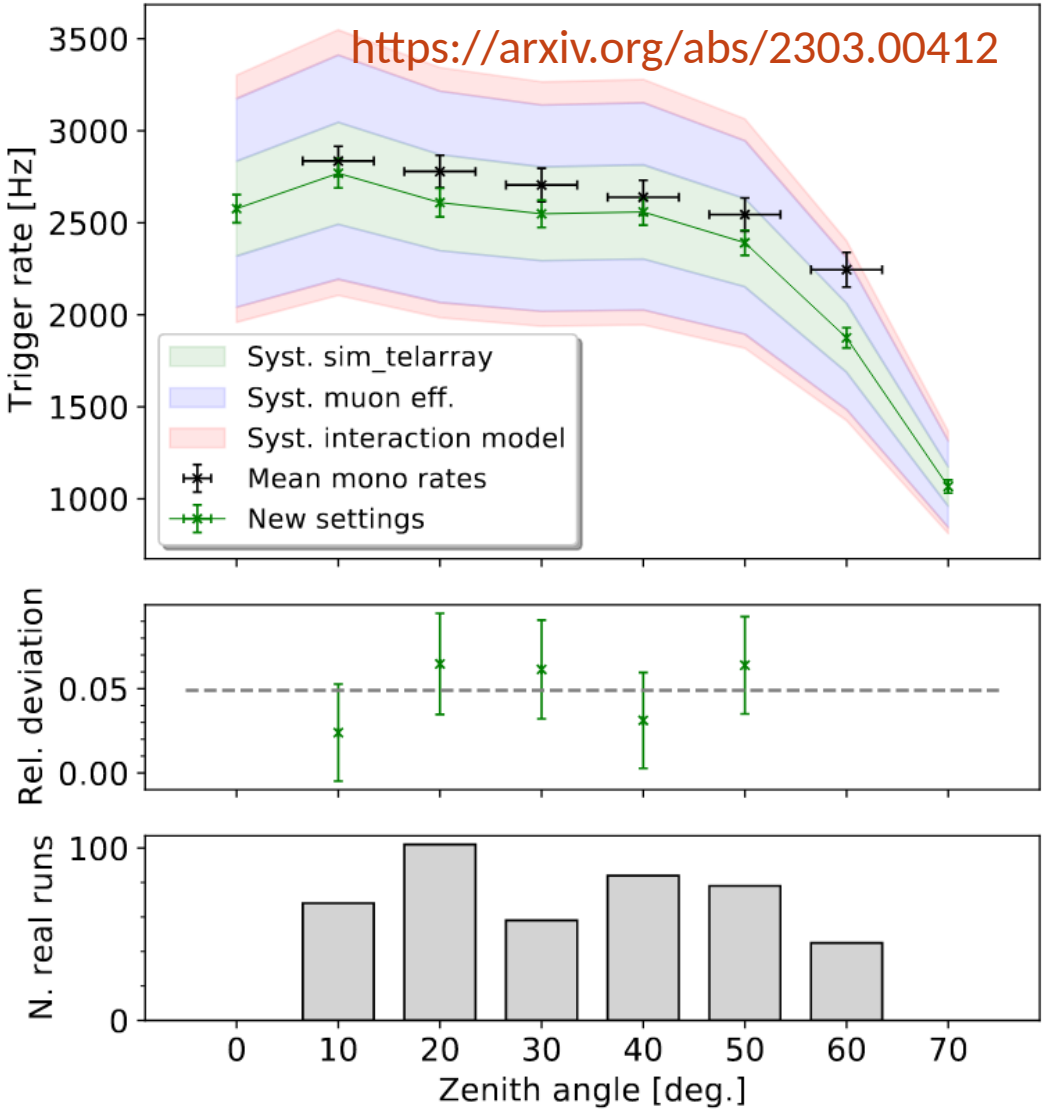


- Smooth physics operation in Namibia since Fall 2019, with > 98 % availability
- Little maintenance and repair effort

  - FlashCam team not needed in Namibia since 2019
- Good and well-understood performance
- Simulation-data consistency checks
- Publications and scientific achievements: e.g. Rs Ophiuchi (Science), Crab (A&A)

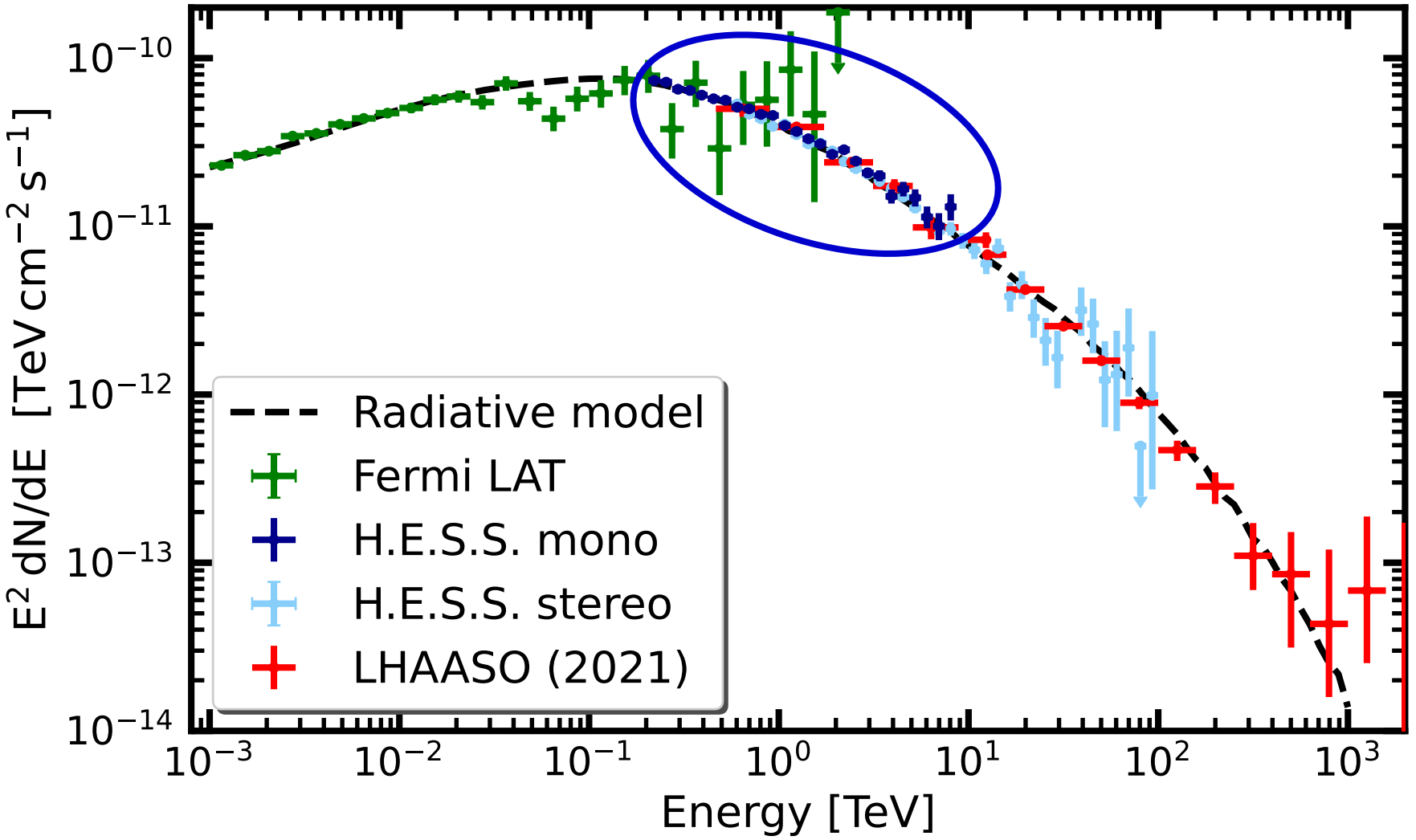
# FlashCam HESS: Simulation-to-data consistency and long-term stability



# Science verification in HESS – Crab Nebula

https://www.aanda.org/articles/aa/pdf/2024/06/aa48651-23.pdf



# FlashCam towards the future

- A second FlashCam is fully equipped at MPIK
- Minor changes to further improve producibility, reproducibility, maintenance, and monitoring

  - Mechanics: Earthquake analysis

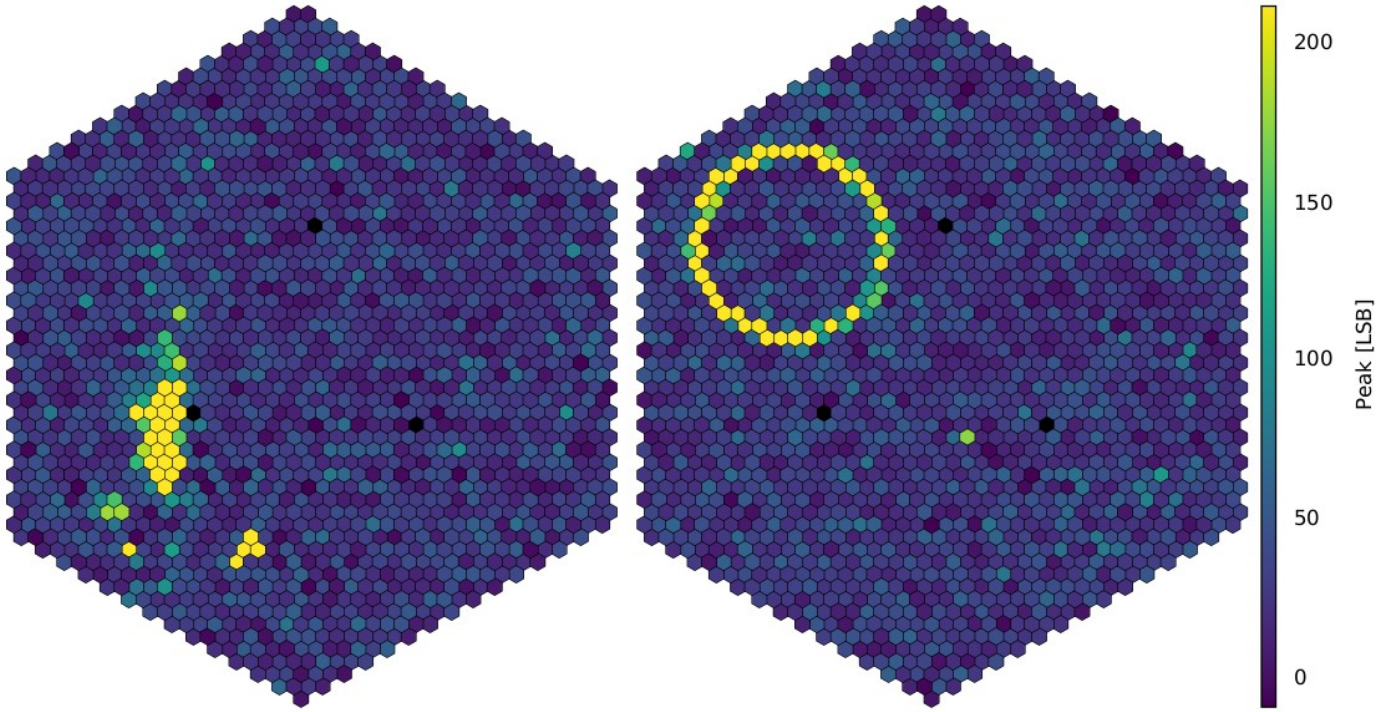
  - PDP modules and power slow control box
- Preparing for a pathfinder in Chile

  - **Muon detection** to calibrate full detector

  - Integration and migration of the analysis chain

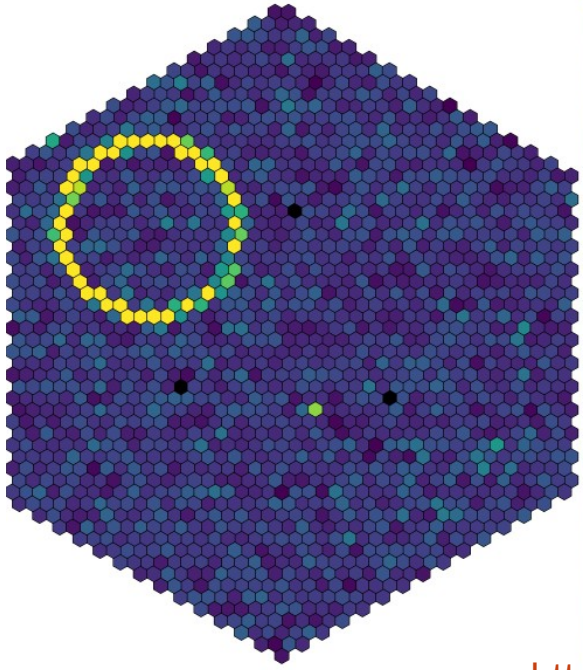
# Muon tagging – Why?

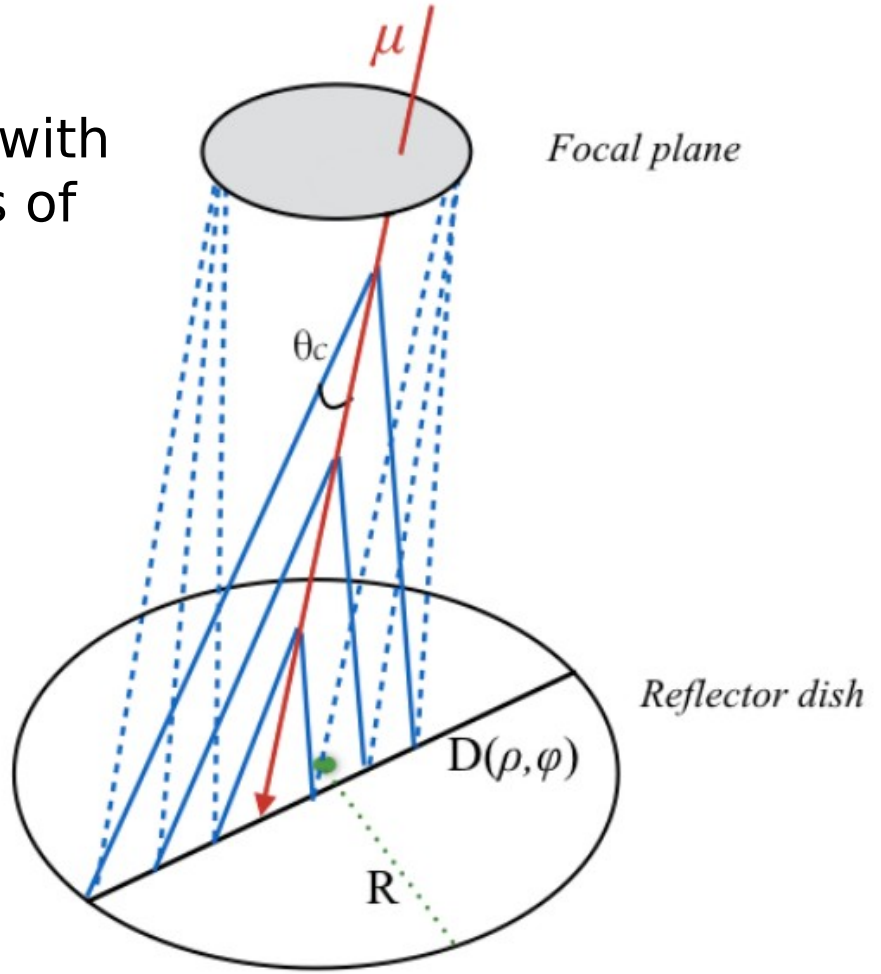
- Muons provide an ideal tool for the continuous calibration of IACTs
- Muons appear as distinct ring-shaped patterns in the camera, spreading over a larger area compared to low-energy showers and triggering more pixels
- Fast online muon detection is essential due to the high event rate



# Muon tagging – How do rings form?

- Only fully contained muon rings are used for calibration
- These rings are formed when a muon strikes the mirror with its direction of travel nearly aligned with the optical axis of the telescope

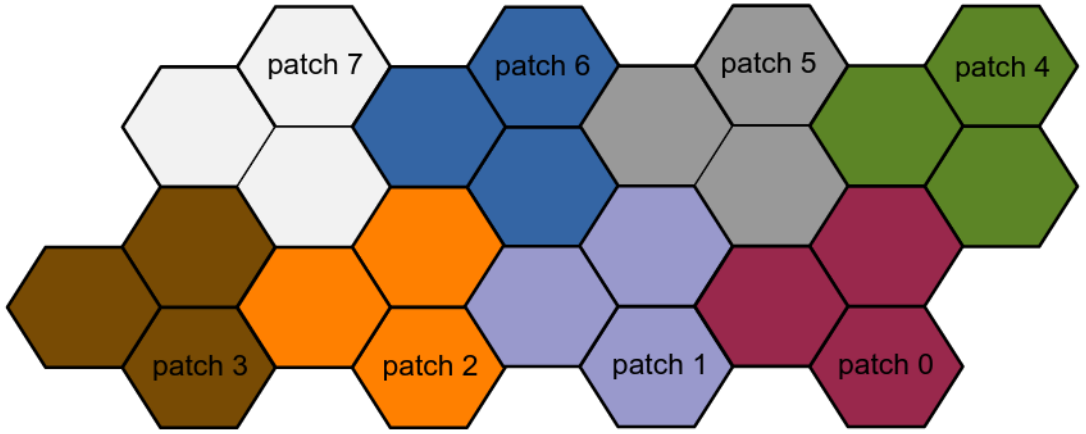


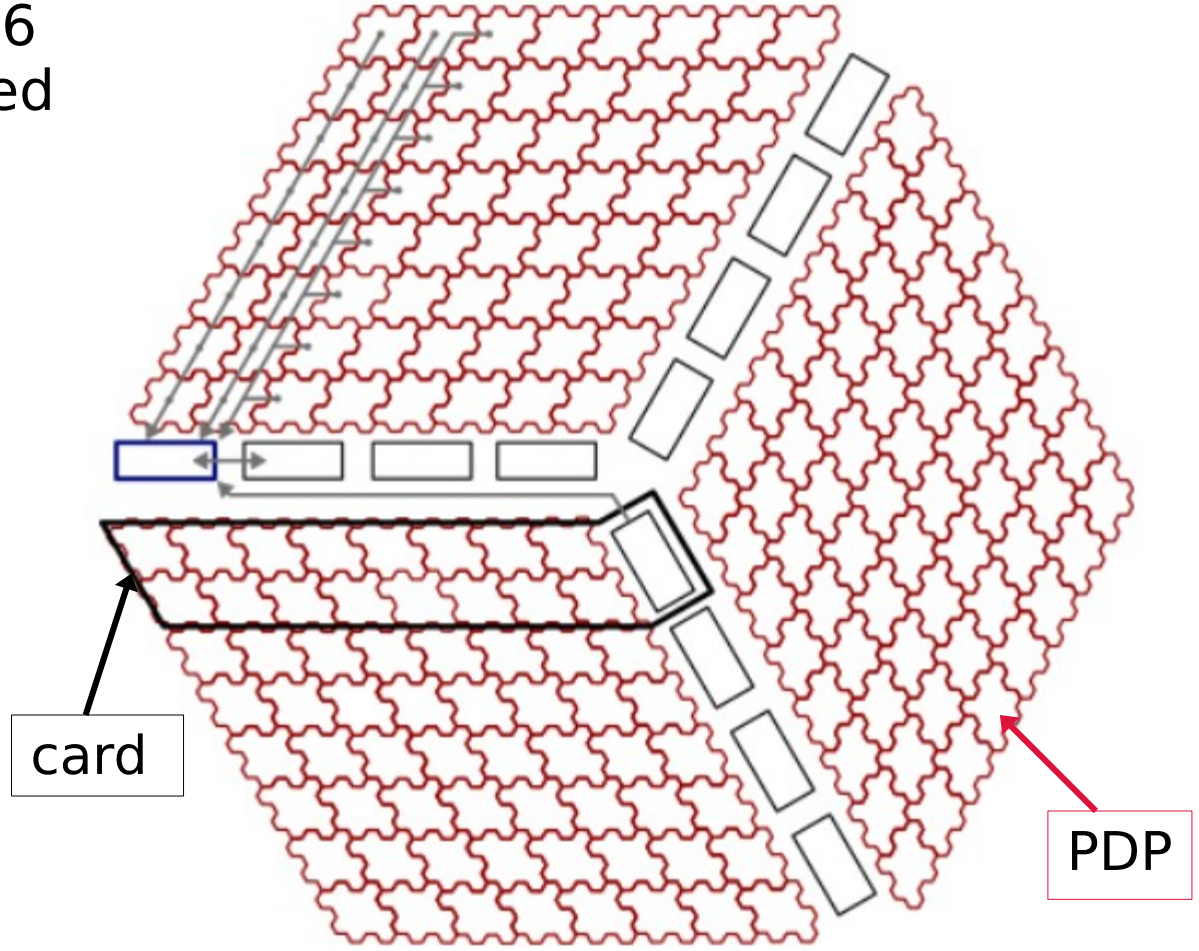



https://www.imprs-hd.mpg.de/113880/thesis_Mitchell.pdf

# Basics of the trigger system

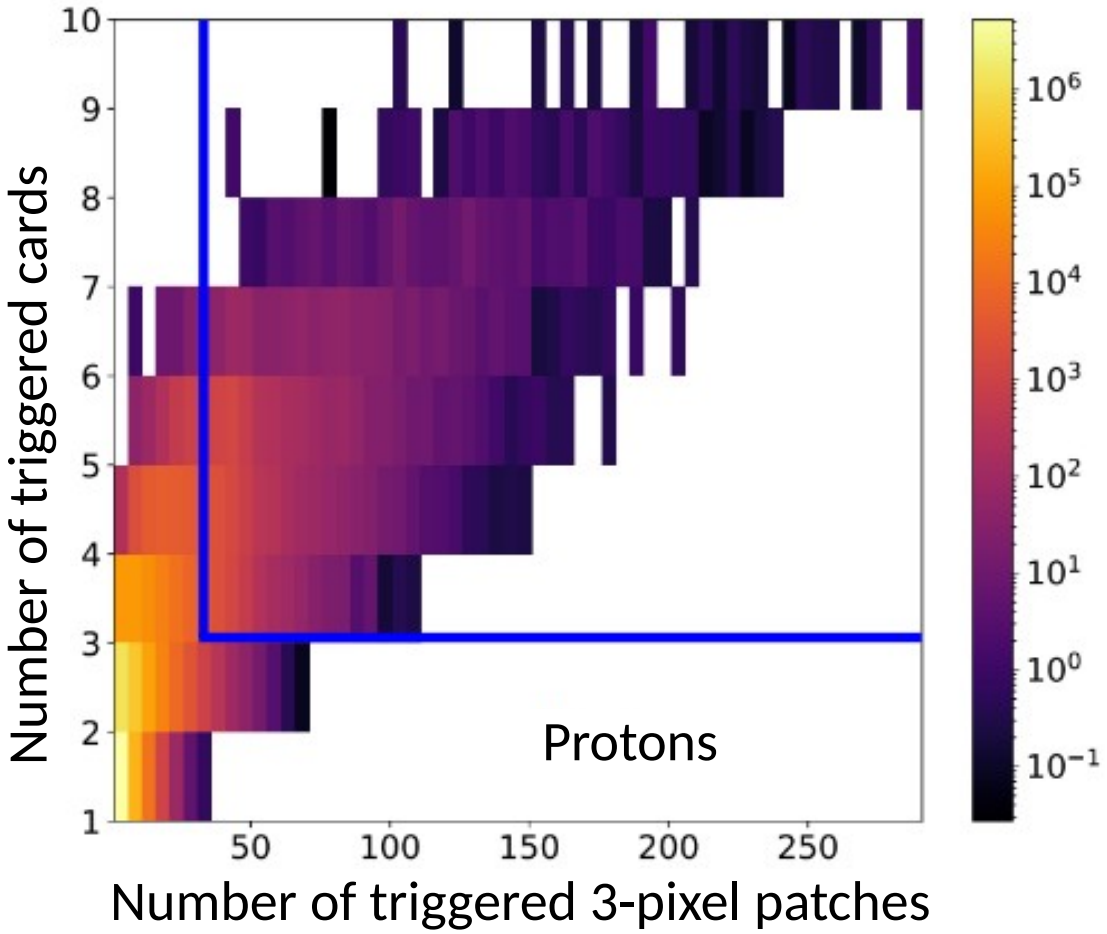
- **Triggered card**: card of 192 pixels (16 PDPs) which contain at least 1 triggered patch (maximum of 12 cards)
- **Triggered patch**: 3-pixel patches digital sum which exceed a threshold (maximum of 588 patches)

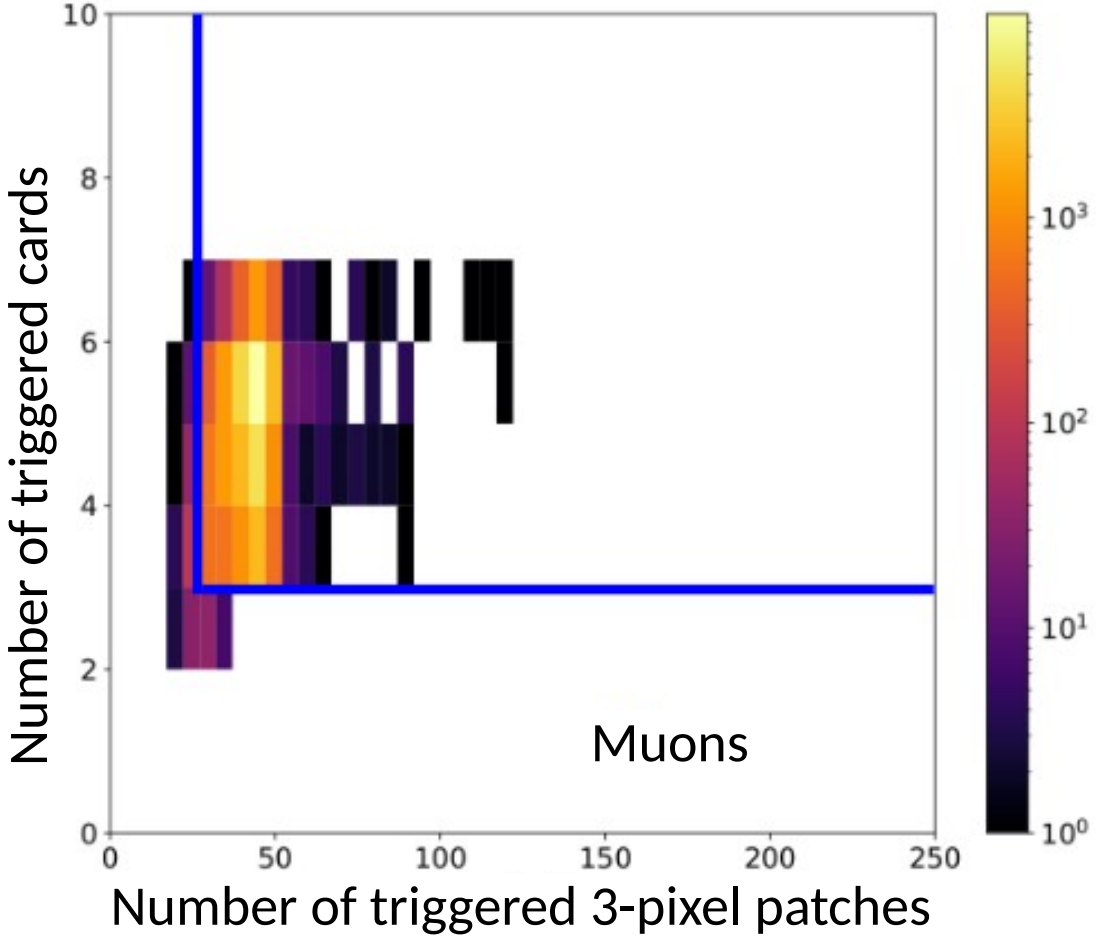


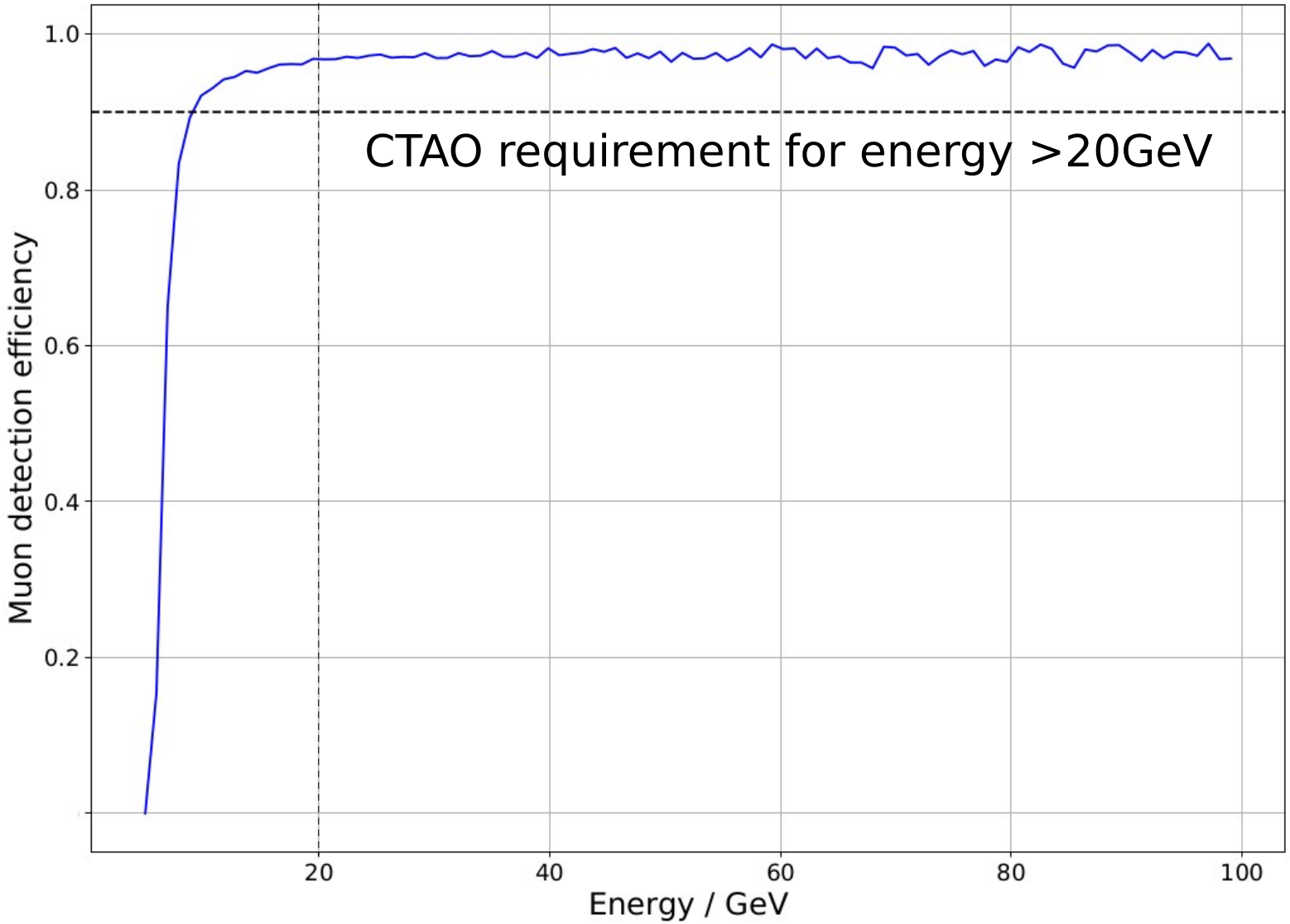

https://archiv.ub.uni-heidelberg.de/volltextserver/29105/1/Sailer_Simon_PhD_printed.pdf

# Muon selection based on trigger information



# High muon detection efficiencies of >95%



# Conclusions

- Two fully equipped cameras: in HESS and in the lab
- Long-term (~5 years) verification in HESS
- Important science contributions to HESS
- Minor changes towards a pathfinder in Chile and optimization of analysis chain