Status of the Davies-Cotton and Schwarzschild-Couder Medium-Sized Telescopes for the Cherenkov Telescope Array

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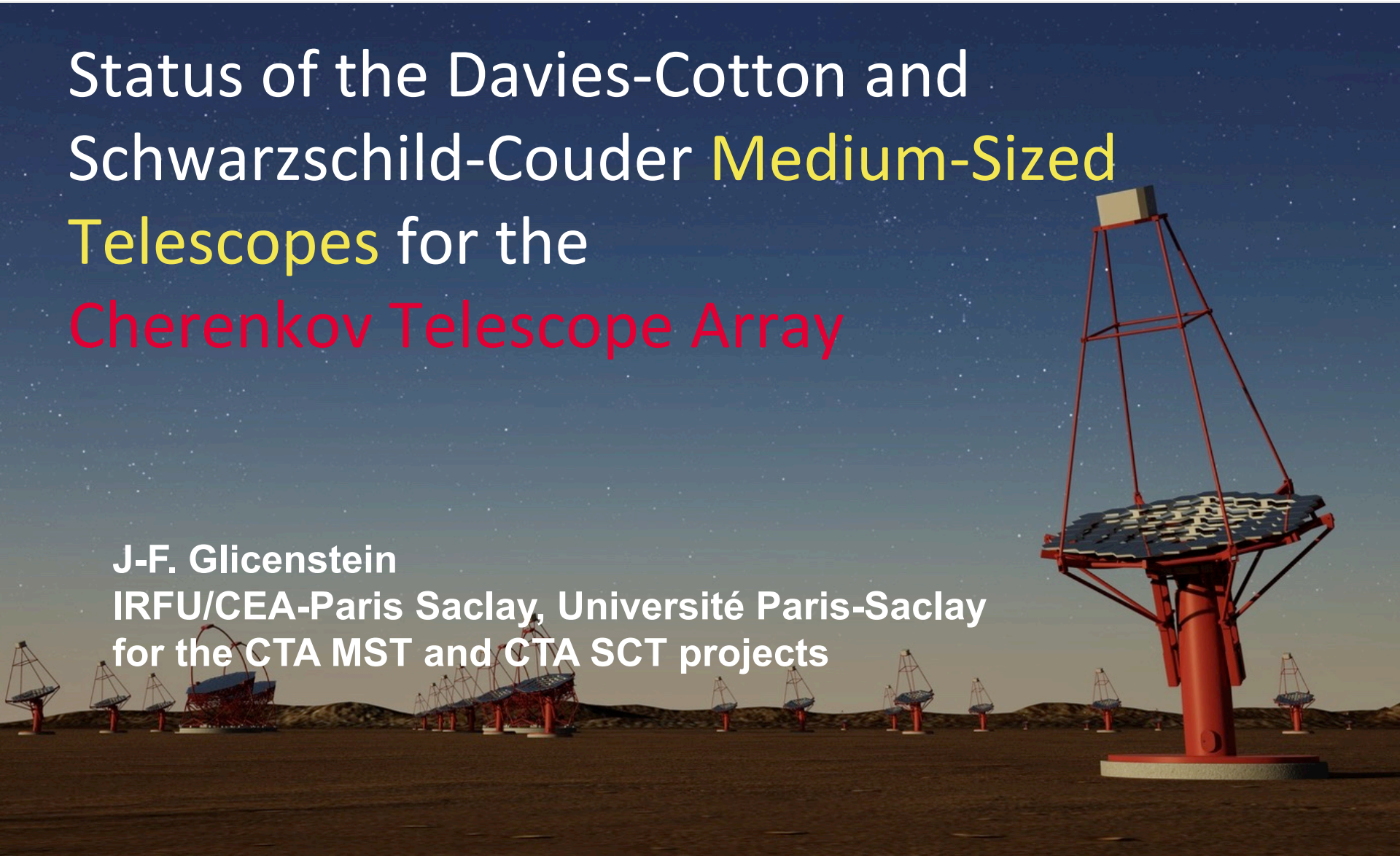
for the CTA MST and CTA SCT projects

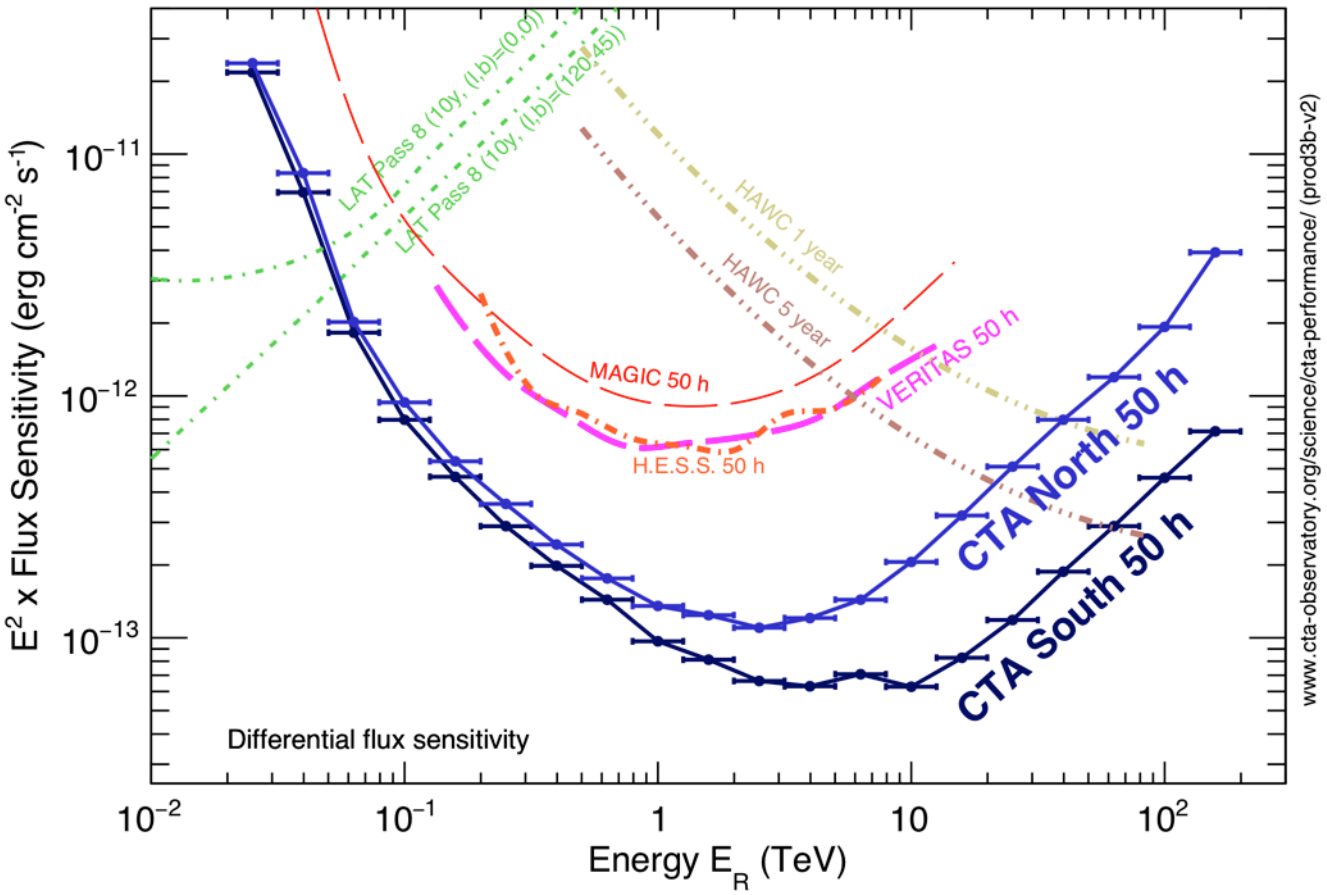


Outline

- Introduction
- Telescope structures for the Medium-Sized Telescopes
  - DC structure
  - SC structure
- Cameras for the Medium-Sized Telescopes
  - Camera for the SCT
  - FlashCam
  - NectarCAM
- Outlook

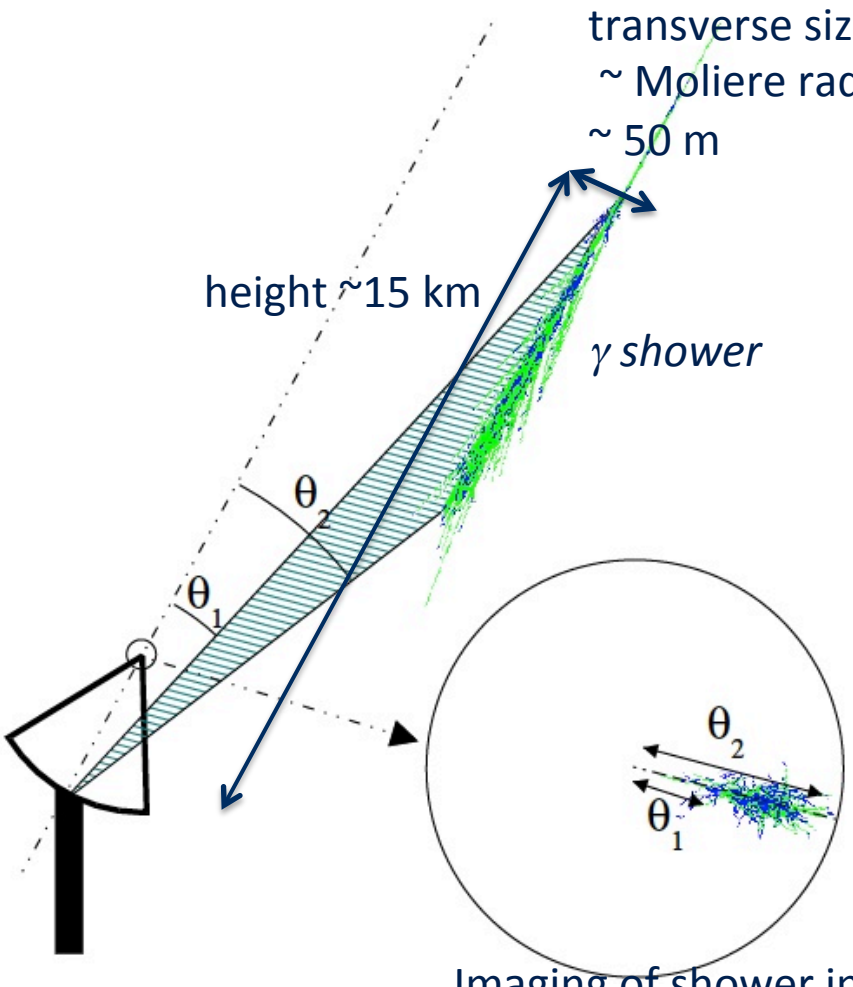
The CTA Medium-Sized telescopes

cherenkov telescope array



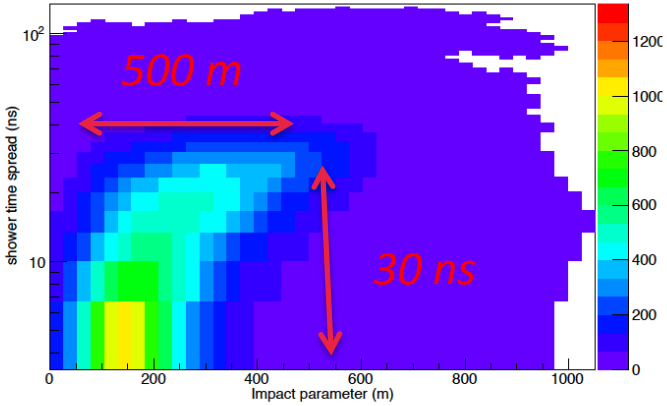
energy range covered

Input from shower physics



courtesy M. de Naurois

Imaging of shower in the focal plane of telescope



signal duration (simulated MST telescope)

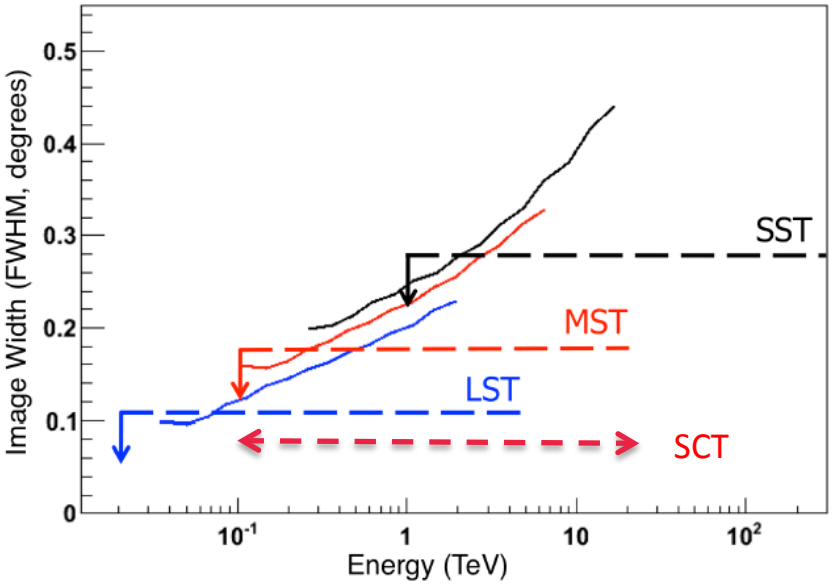
typical angular width
~ 50m/15km = **0.19°**

Field of View ~ 2x500m/15 km
~ 7.5°

CTA requirements for Medium-Sized Structures

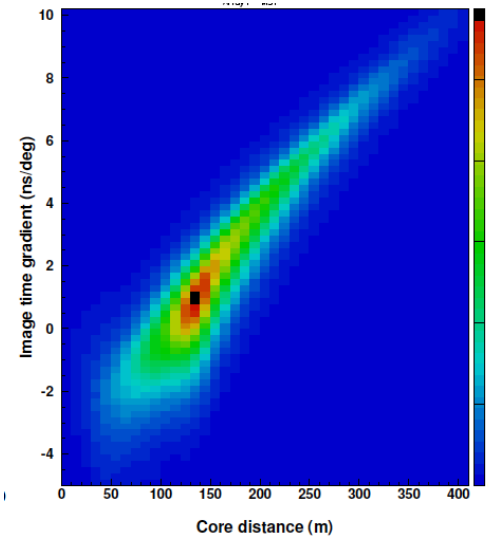
- Field of view > 7º
- Typical angular width of photon showers: 0.18º => pixel size should be < 0.18º
- PSF at the edge of camera < pixel size ~ 0.18º

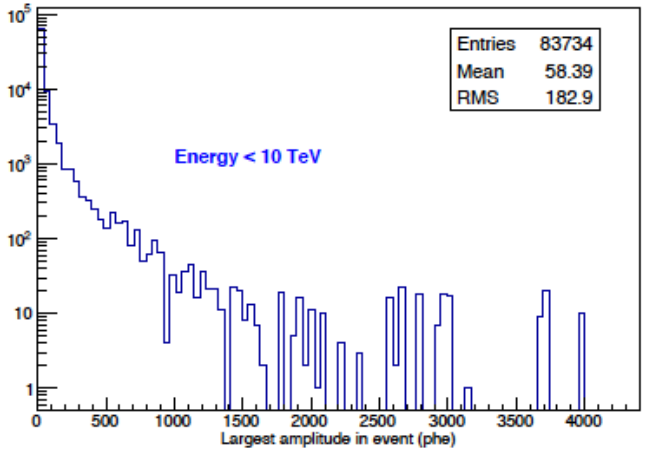
- Pixel size (0.067º) and PSF smaller for SCT type telescopes -> get more details from the shower core to improve hadron rejection.



CTA requirements for Medium-Sized Cameras

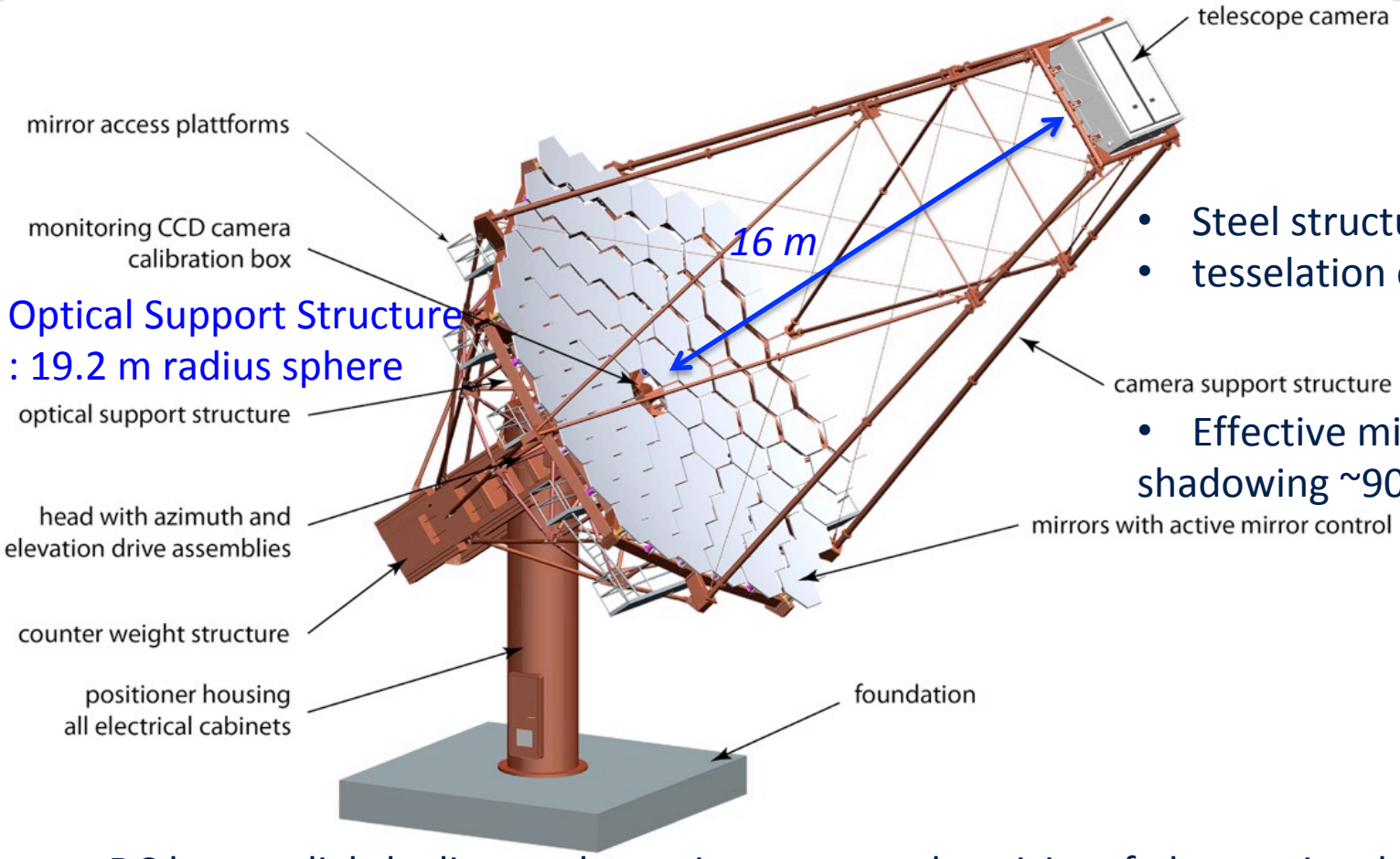
- Should be able to transfer 60ns long waveform
- Precision on relative pixel timing < 2ns (possible reconstruction of shower time development).
- Dynamic range 0-2000 p.e/pixel





- Trigger rate > 7kHz with deadtime <5%

Davies –Cotton structure for MST



Optical Support Structure : 19.2 m radius sphere

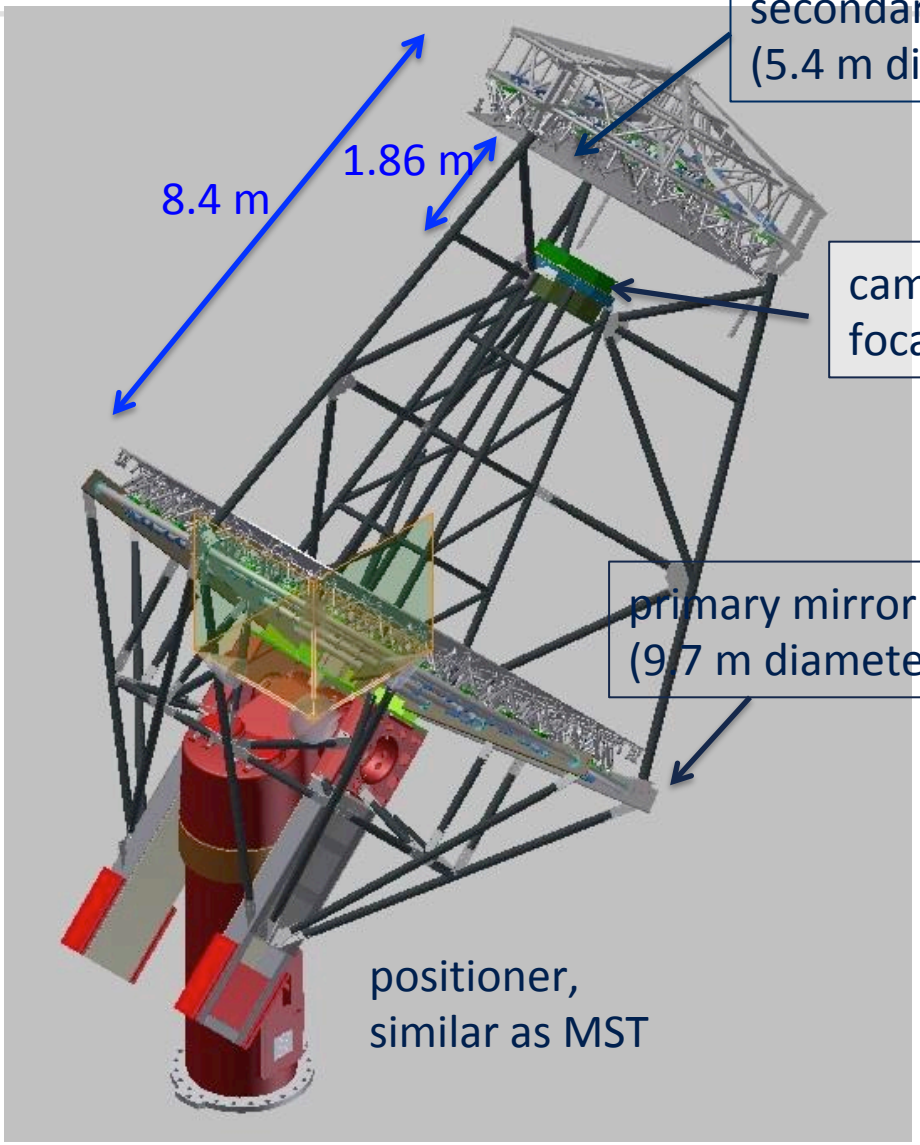
- Steel structure 86 t
- tesselation of 86 mirrors
- Effective mirror area (inc. shadowing ~90 m^2

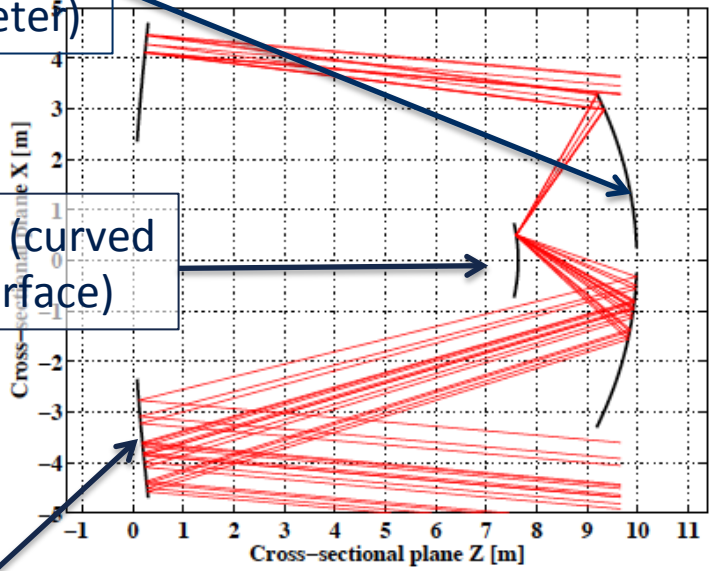
- DC layout slightly distorted to to improve synchronicity of photon signal with minimal aberrations.

Davies –Cotton structure prototype

- Installed at Adlershof (Berlin) since 2012
- Several components upgraded: dish, camera support structure..
- Tests: mirror alignment software, pointing model
- Long term tests of mirror aging
- Campaigns with the FlashCam (2017) and NectarCAM (2019) cameras -> mechanical + water, electricity, data networks tested sucessfully.

Schwarzschild-Couder telescope structure

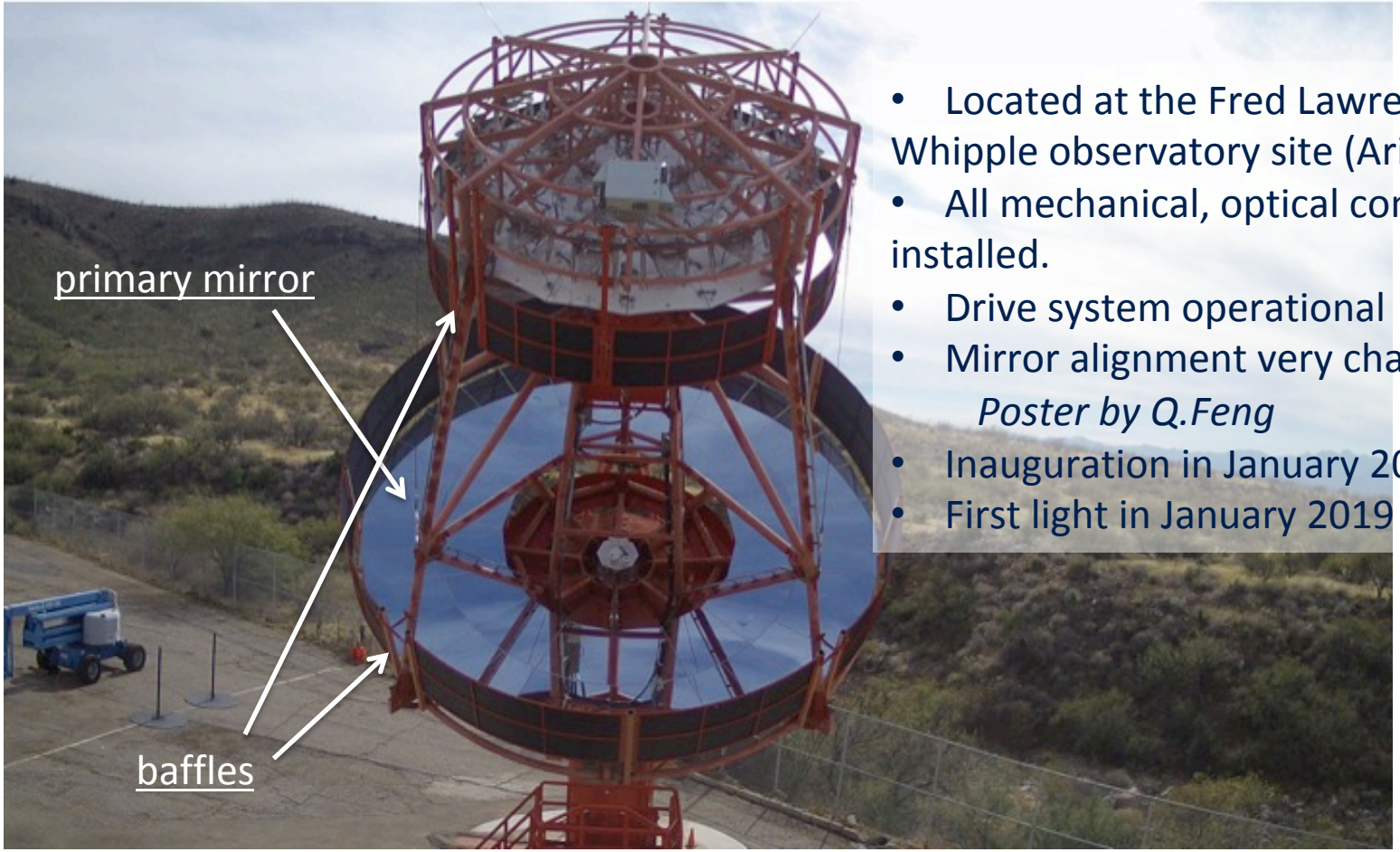




from Vassiliev, Fegan, Brousseau 2006

- Effective mirror area: 50 m^2
- Field of View: 8^o
- Less optical aberrations, PSF at the edge of the FOV: 3.8'
- compact camera

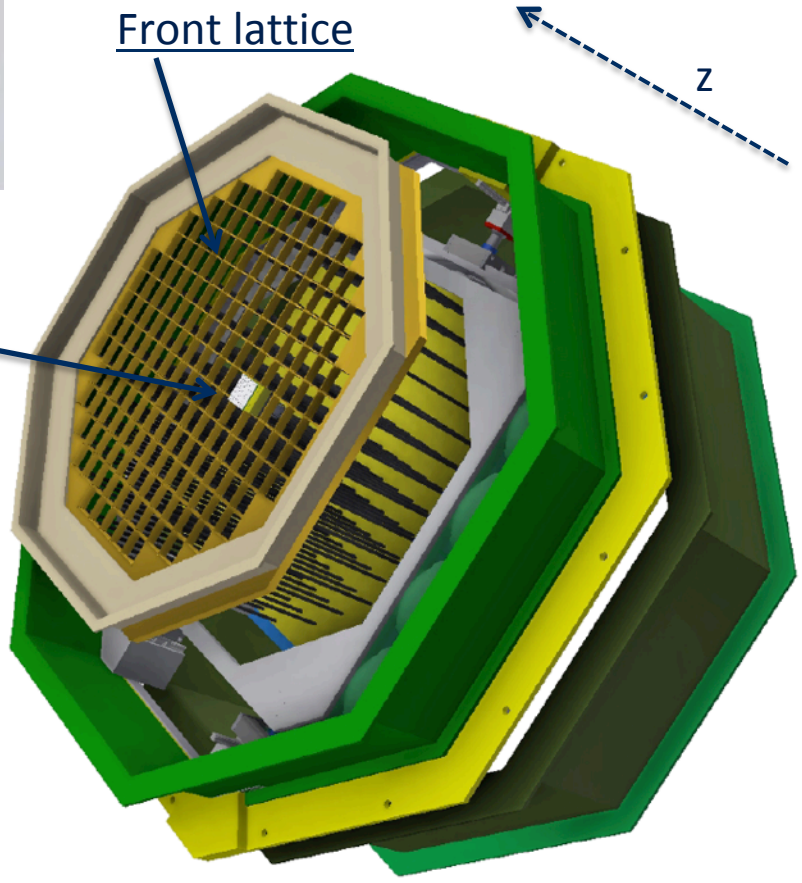
Schwarzschild-Couder structure prototype



- Located at the Fred Lawrence Whipple observatory site (Arizona)
- All mechanical, optical components installed.
- Drive system operational
- Mirror alignment very challenging

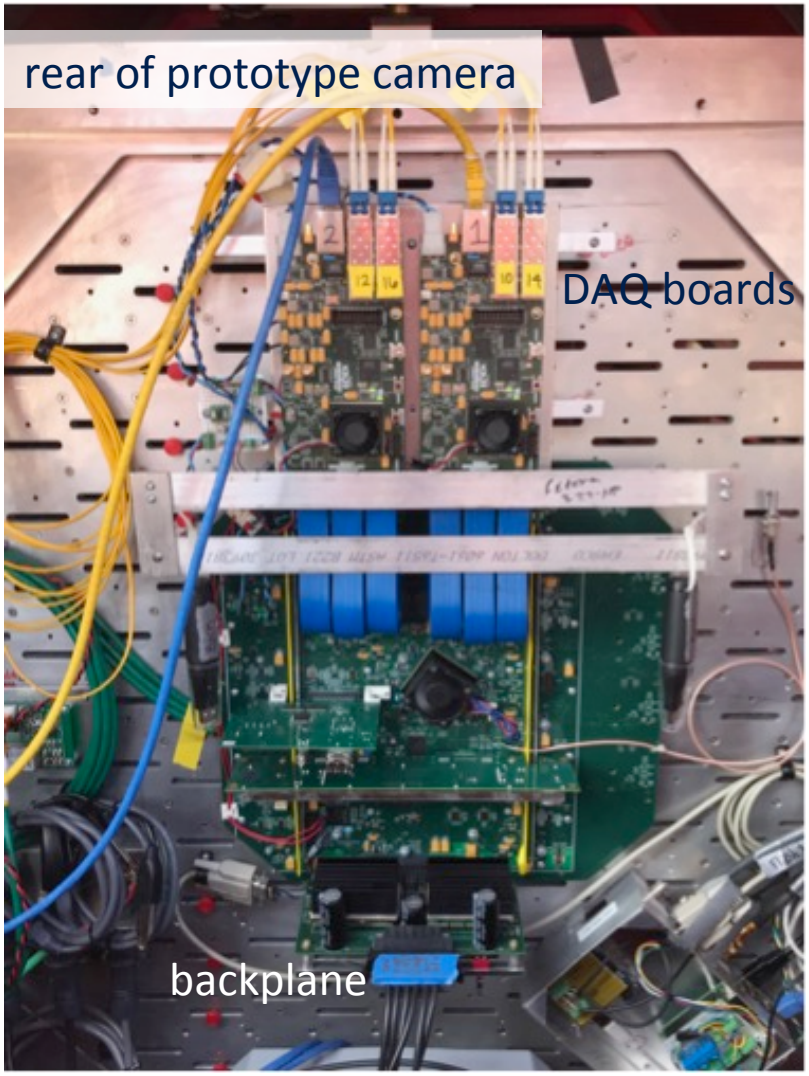
  Poster by Q.Feng
- Inauguration in January 2019
- First light in January 2019

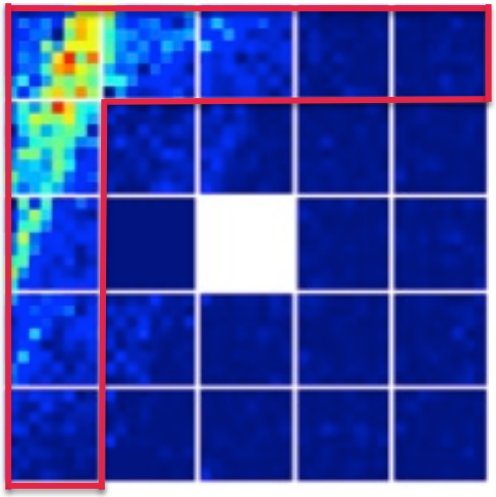
Camera for the SC telescope



- Modular design (177 modules)
- Detection with SiPM
- 8x8 pixels (6mmx6mm)/module
- Module position adjustable in z in the front lattice to emulate the focal surface
- Front end electronics with 2 boards/module
- Auxiliary board dedicated to shaping, amplification
- Primary board with 4 Target7 ASICS
- Target7 have 16 channels with a 16 μs long switched capacitor array (1 GHz sampling).
- Digitization and first level trigger also on Target chip.
- Trigger logic on backplane.

SCT camera prototype





- prototype camera with 24 = 25-1 modules
- use Target7 ASIC based-modules
- 2 different types of SiPM used

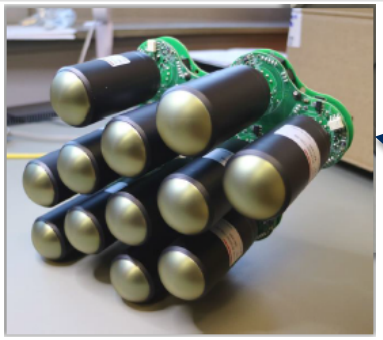
Posters by L. Tosti and L. Taylor

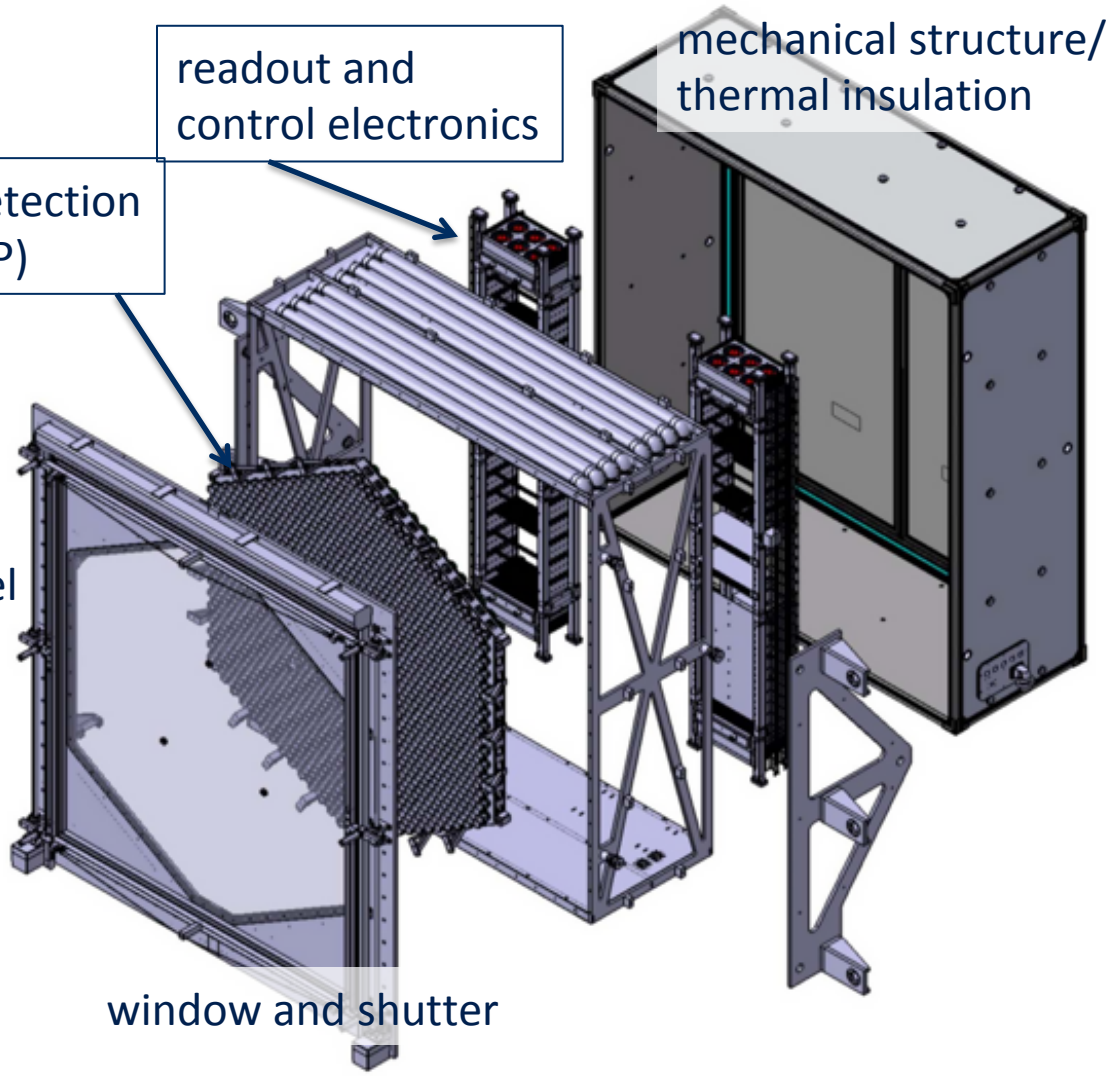
- Future: Upgrade to 177 modules
- New SMART ASIC for SiPM signal shaping+ amplification
- Target 7 replaced by 2 chips:
  - -TargetC for data
  - -T5TEA for triggering

Poster by T. Meures

Camera for the DC structure: FlashCam

cherenkov telescope array





- 1764 pixels (vacuum PMT)
- 7.7^{o} field of view
- Shaping+non-linear amplification

-> 0.2->3000 p.e dynamic range/channel

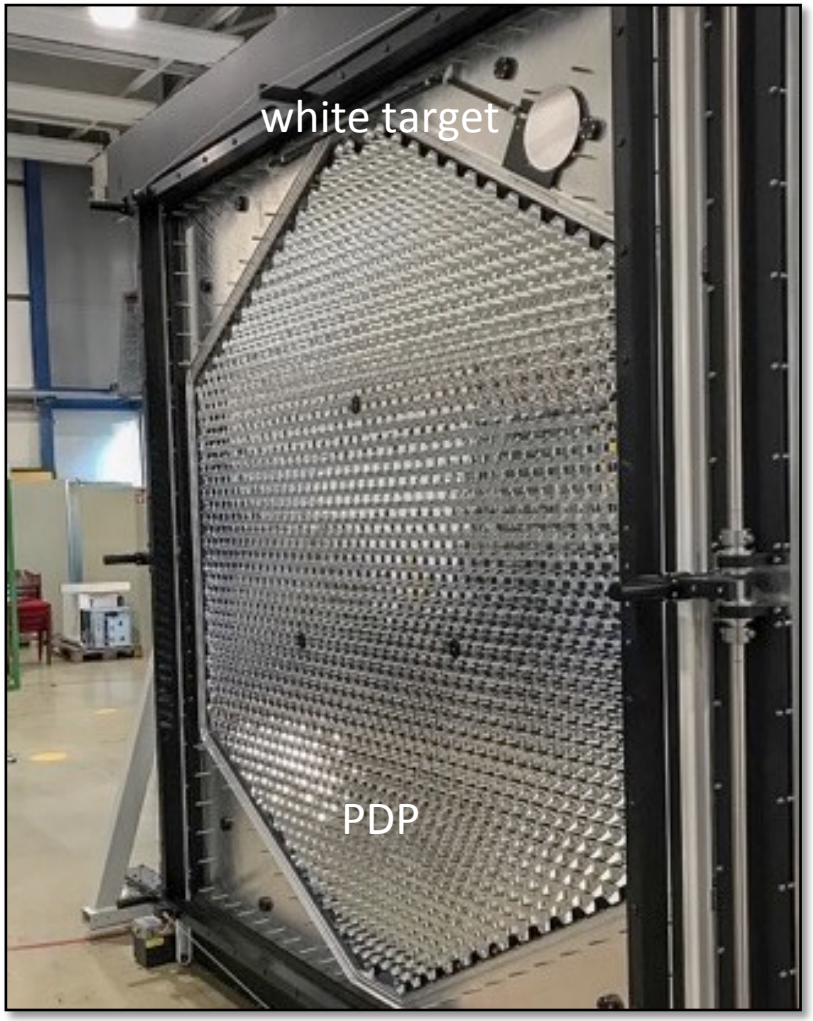
- 12-bit continous digitization at 250 MHz
- Fully digital trigger formation directly on data
- Waveforms: up to 15.6μs
- 30 kHz deadtime-free

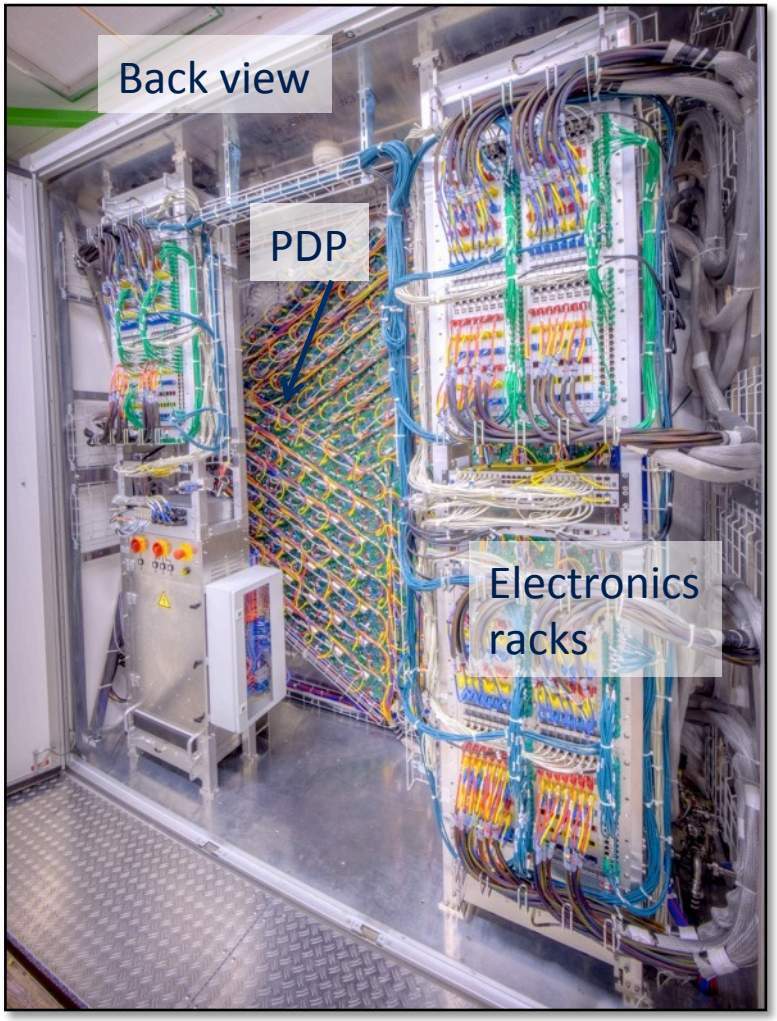
Ethernet-based DAQ

- <4.5 kW power consumption

FlashCam prototype

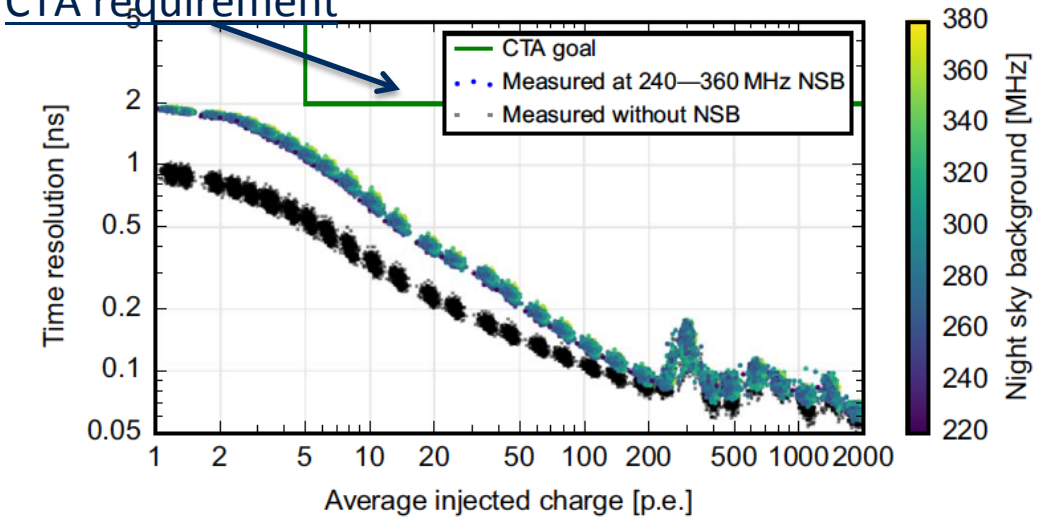
cherenkov telescope array





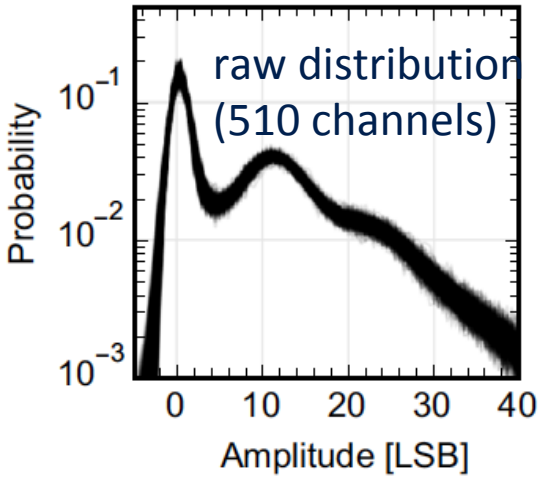
Performances of FlashCam

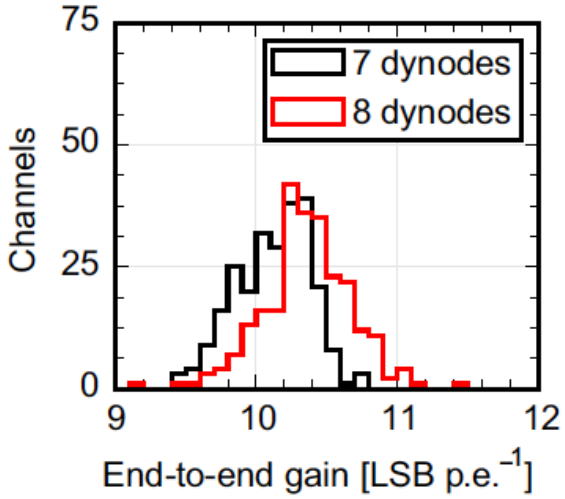
CTA requirement



F.Werner et al, NIM A (2017)

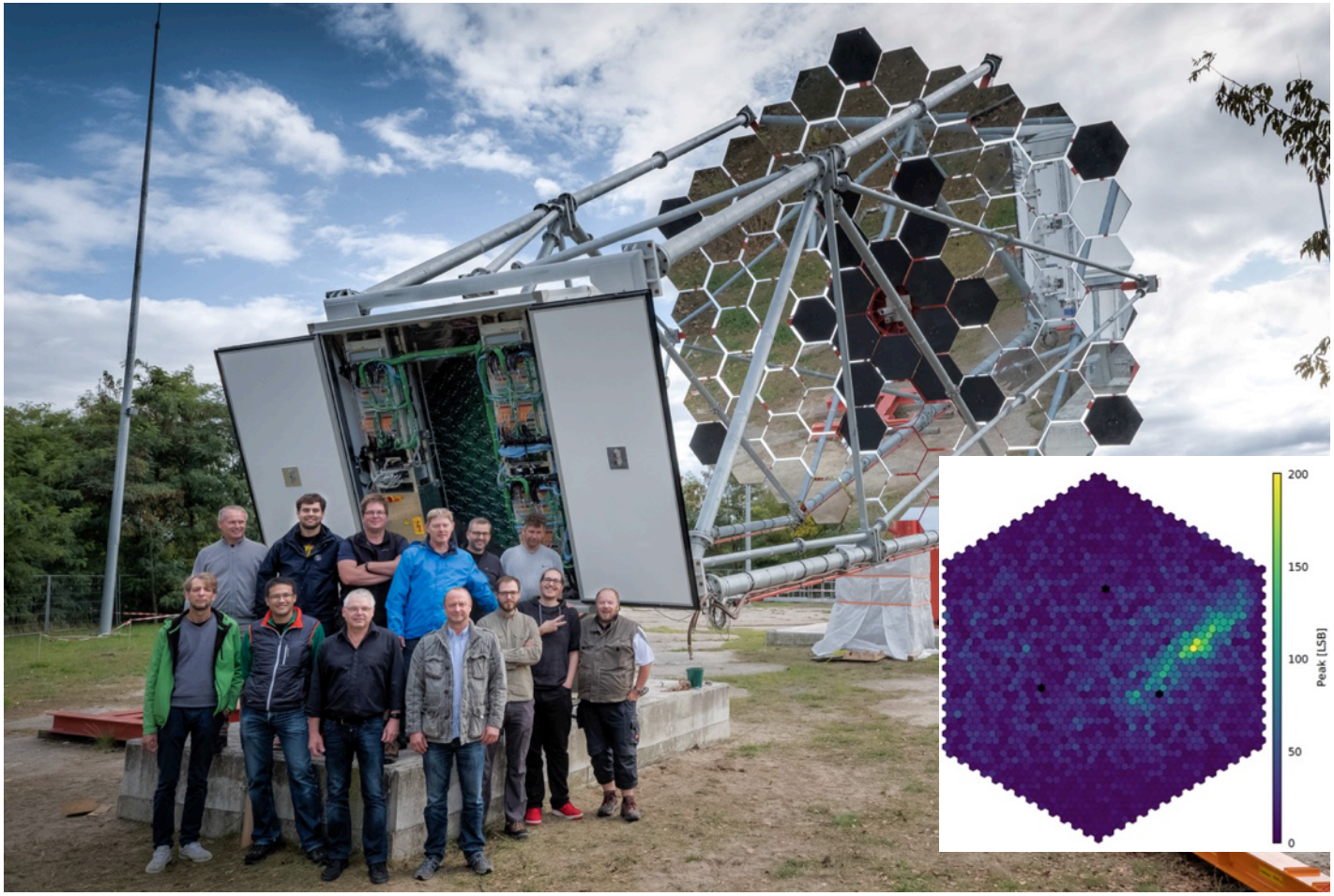
Time resolution





Gain calibration
from a single p.e fit.

FlashCam campaign at Adlershof

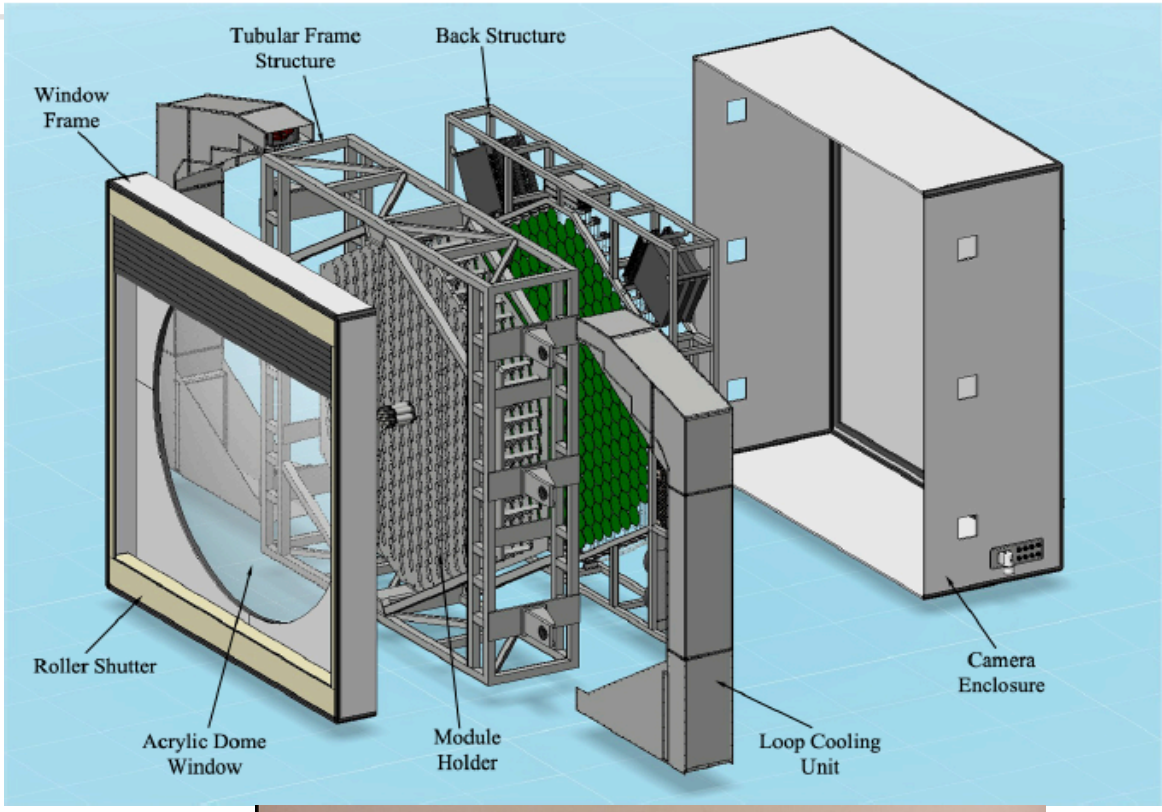


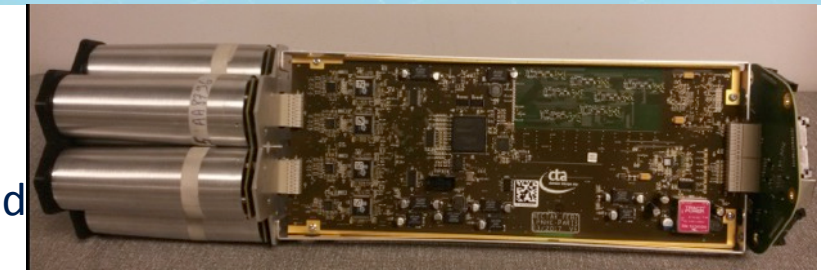
First light in 2017

Camera for the DC structure: NectarCAM

cherenkov telescope array

- Modular structure with 265 7-pixel modules
- Field of view: 8°
- 1 module = 1 focal plane module (PMs, HV, preamplification) + 1 front-end board (amplifiers, Nectar ASICs, level 0 trigger electronics)
- Nectar chip combines a switched capacitor array (1 μs long) (sampling rate 1 GHz) and a 12-bit ADC
- Readout window: 60 ns
- 2 gain channels (combined dynamic range 0.5-> 2000 p.e)
- 1 independent trigger channel
- deadtime ~ 5% at 7kHz trigger rate, dominated by Nectar chip readout.



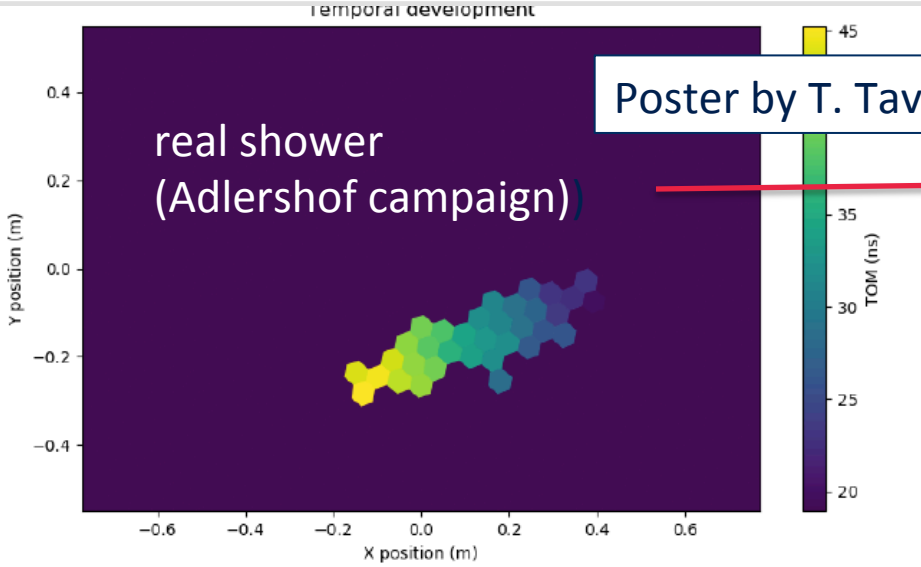


NectarCAM prototype

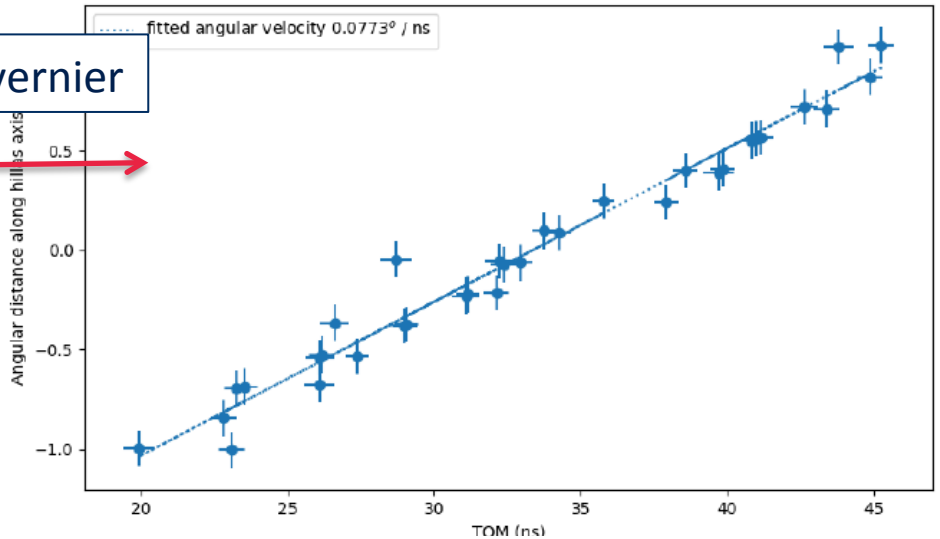
Partially equipped, NectarCAM, front view

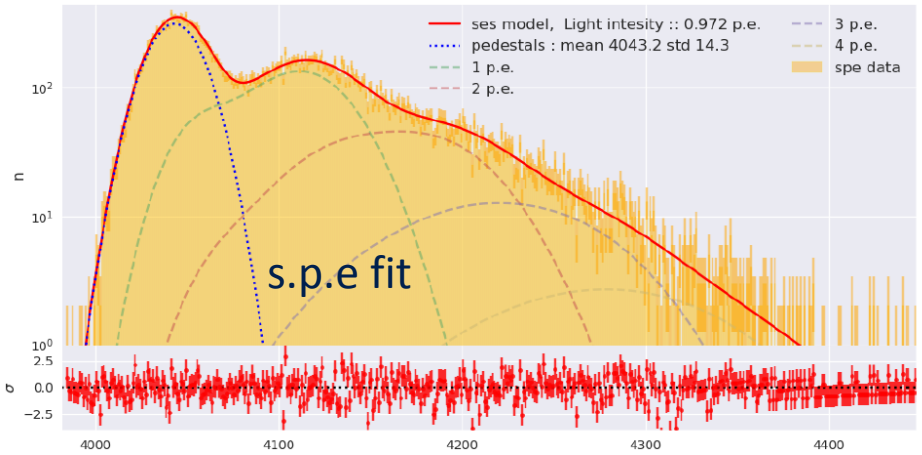
Performances of NectarCAM

cherenkov telescope array

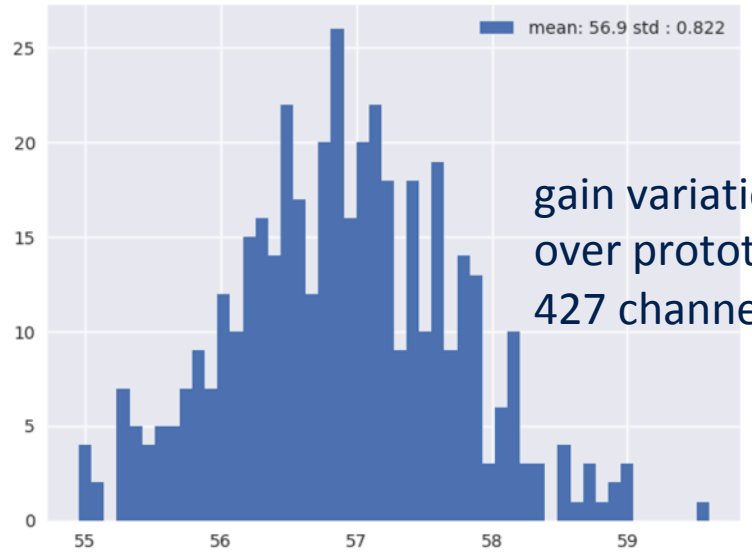


Poster by T. Tavernier





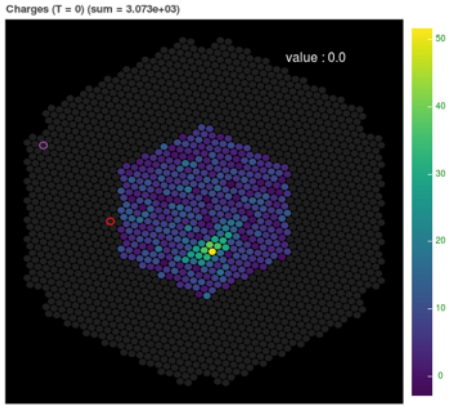
ADC



gain variation
over prototype
427 channels)

NectarCAM campaign at Adlershof

cherenkov telescope array



First light in 2019

Outlook

- 2 telescope structure and 3 cameras have been designed for the CTA medium-energy range

- A prototype of Davies-Cotton structure has been implemented near Berlin in 2012 and extensively tested.
- The FlashCam camera uses off-the-shelf component with a photon detection plane and electronics racks. It had its first light in 2017.
- The NectarCAM camera has a modular structure based on the Nectar ASIC. It has its first light in 2019.

- A prototype of Schwarzschild-Couder structure has been implemented in Arizona. The commissioning of the mirror alignment is ongoing.
- It is equipped with a compact camera based on the TARGET ASIC, and had its first light in 2019.
- New funding from the NSF MRI program in 2018 to upgrade to a full 11000-channel camera