NectarCAM

François Brun

Astroparticle Symposium - 19/11/2025

VHE gamma ray astronomy

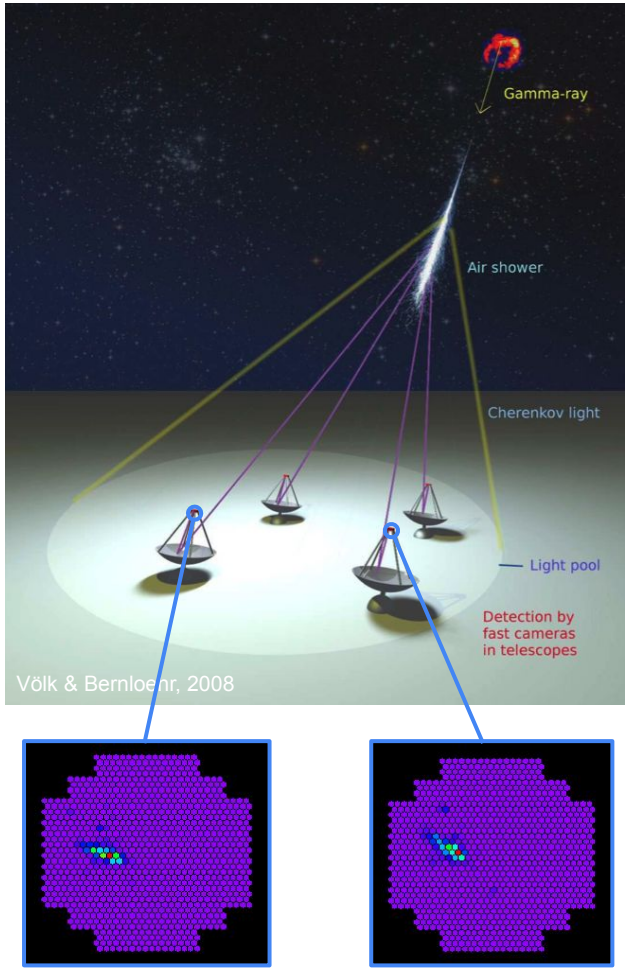
Cosmic photons with E > O(10) GeV

Gamma interacts in the atmosphere

Emission of a brief (~few ns) and weak flash of Cherenkov light

Image of the shower with cameras at the focal plane of telescopes

- ❏ Orientation → Direction
- ❏ Intensity → Energy
- ❏ Shape → Discrimination

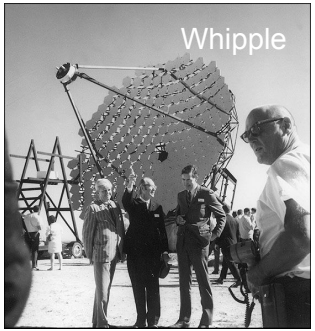


Imaging Atmospheric Cherenkov Technique

The technique works best with :

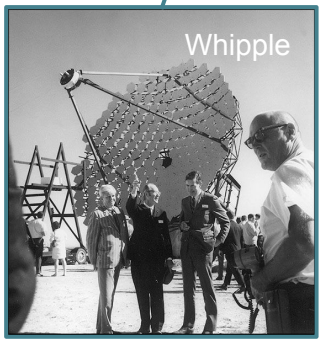
- **Large mirrors**
- **Fast** and **finely pixelated** cameras
- **Stereoscopy**

Current instruments combine these advantages, inherited from the previous generations



Imaging Atmospheric Cherenkov Technique

First detection of a TeV gamma-ray source (1989) : the Crab nebula
5σ detection in 50h



Opening of a new astronomical window !

Imaging Atmospheric Cherenkov Technique

Strong involvement of French/Paris-Saclay teams since the 1990's

- **CAT :** operated at Font-Romeu (IRFU, LLR, LPNHE, APC involved)
- **H.E.S.S. :** cameras designed and built by LPNHE, LLR, APC, in collaboration with IRFU, LAPP and LUPM

Imaging Atmospheric Cherenkov Technique

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- **H.E.S.S. :** camera
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Imaging Atmospheric Cherenkov Technique

First detection of a TeV gamma-ray source (1989) : the Crab nebula
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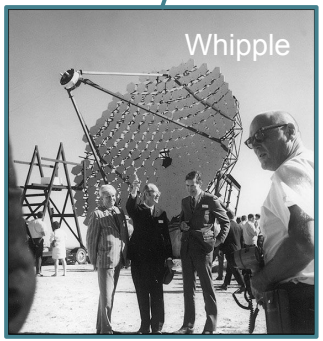
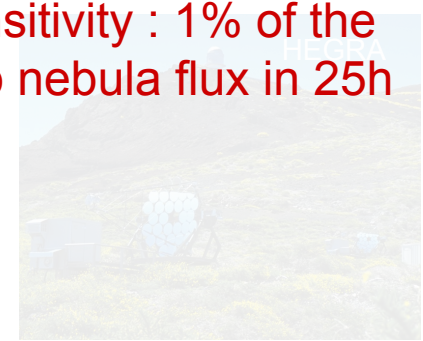


2000's : With H.E.S.S., VERITAS, MAGIC, the field reaches maturity !

Sensitivity : 1% of the Crab nebula flux in 25h



Astronomy at VHE

"Real" astronomy at TeV energies …

- **Sensitive** instrument (1% Crab), on more than 2 orders of magnitude in energy
- **Morphology** studies (sky maps with < 5' resolution)
- **Survey** capabilities
- Detailed **light-curves** – timescales from minutes to years
- **Complementary** to instruments at other wavelength

… as beautifully demonstrated by Berrie's (and students') work !

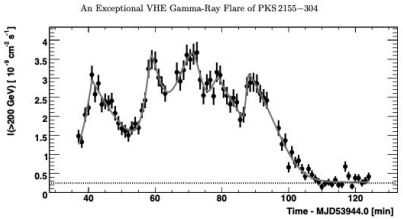


FIG. 1.— The integral flux above 200 GeV observed from PKS 2155−304 on MJD 53944 versus time. The data are binned in 1-minute intervals. The horizontal line represents I(>200 GeV) observed (Aharonian et al. 2006) from the Crab Nebula. The curve is the fit to these data of the superposition of five bursts (see text) and a constant flux.

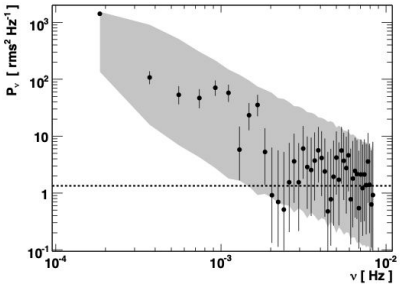


FIG. 2.— The Fourier power spectrum of the light curve and associated measurement error. The grey shaded area corresponds to the 90% confidence interval for a light curve with a power-law Fourier spectrum $P_\nu \propto \nu^{-2}$. The horizontal line is the average noise level (see text).

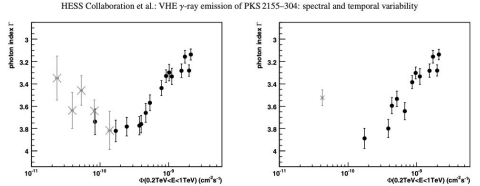


Fig. 7. Evolution of the photon index Γ with increasing flux Φ in the 0.2–1 TeV energy range. *The left panel* shows the results for the July 2006 data (black points, data set $D_{\rm FLY06}$) and for the 2005–2007 period excluding July 2006 (grey points, data set D_{05}). *The right panel* shows the results for the four nights flaring period of July 2006 (black points, data set $D_{\rm FLARE3}$) and one point corresponding to the quiescent state average spectrum (grey point, again data set D_{05}). See text in Sects. 4.1 (*left panel*) and 4.2 (*right panel*) for further details on the method.

PKS 2155-304

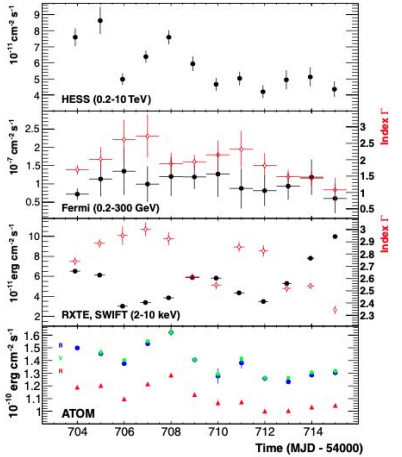
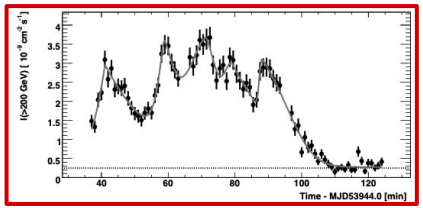
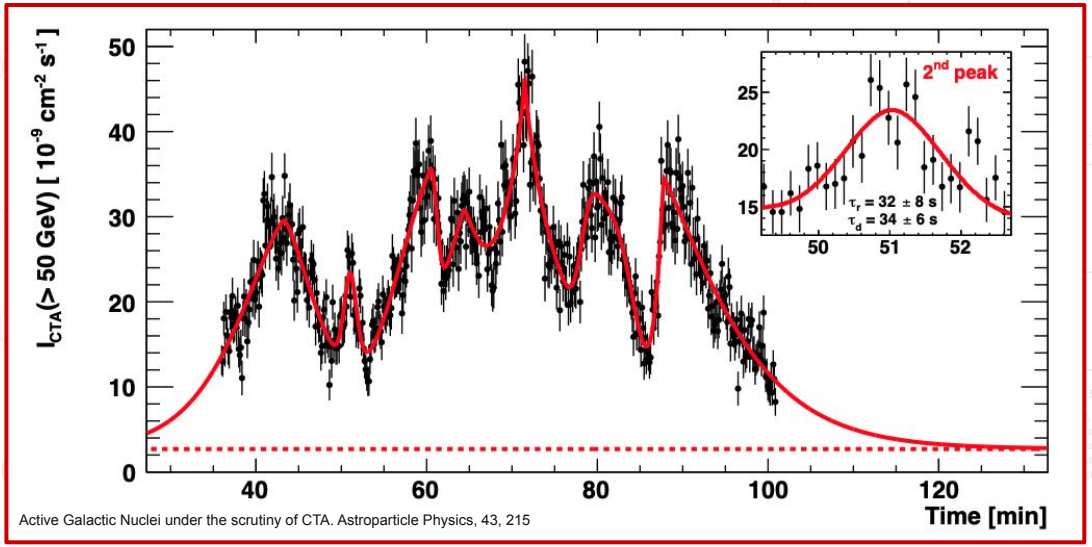


Figure 1. Light curves from (top to bottom): HESS, *Fermi*, *RXTE/Swift*, and ATOM. The *Fermi* and *RXTE/Swift* panels also show the spectral index measurements (red) for each night. Vertical bars show statistical errors only. Horizontal bars represent the integration time and are apparent only for the *RXTE* and *Fermi* data. The ATOM bands are *B* (blue circles), *V* (green squares), and *R* (red squares).

The next generation : CTAO

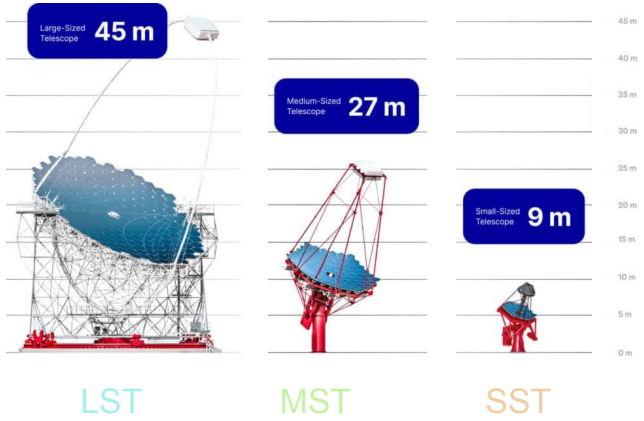


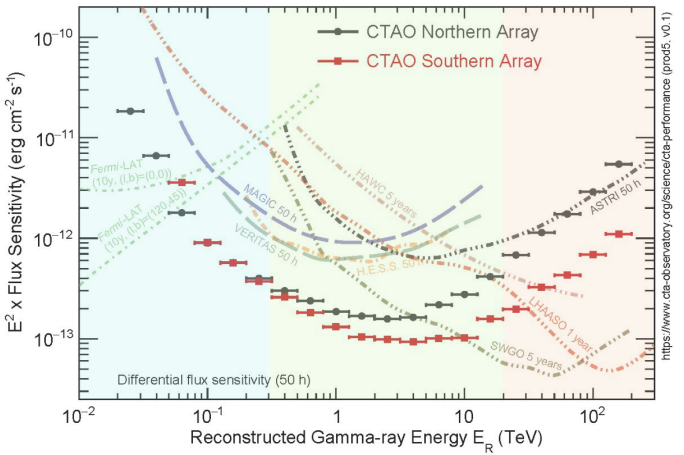


Active Galactic Nuclei under the scrutiny of CTA. Astroparticle Physics, 43, 215

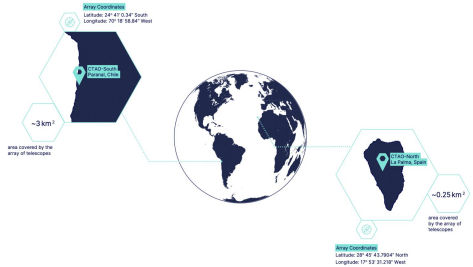
CTAO : overview

- ERIC (European Research and Innovation Consortium) since 01/2025
- First **observatory** dedicated to VHE gamma-rays (20 GeV to 300 TeV)
- Energy range covered by 3 classes of telescopes:
  - Large Sized (LST), 23m reflector, low energies
  - Medium Sized (MST), 12m reflector, intermediate energies
  - Small Sized (SST), dual mirror, primary 4.3m, high energies
- **NectarCAM** : camera for MST telescopes



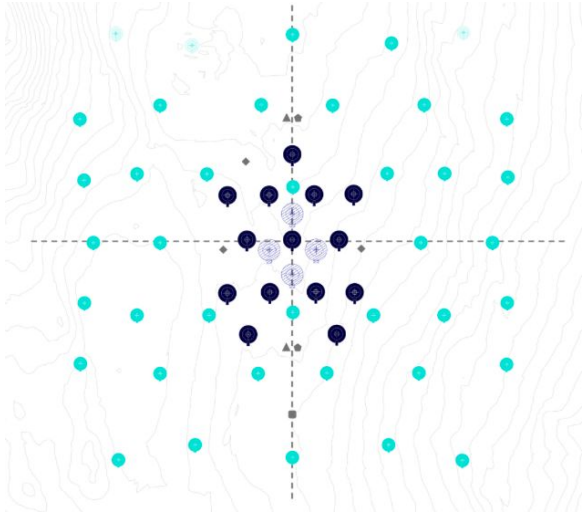


CTAO : overview

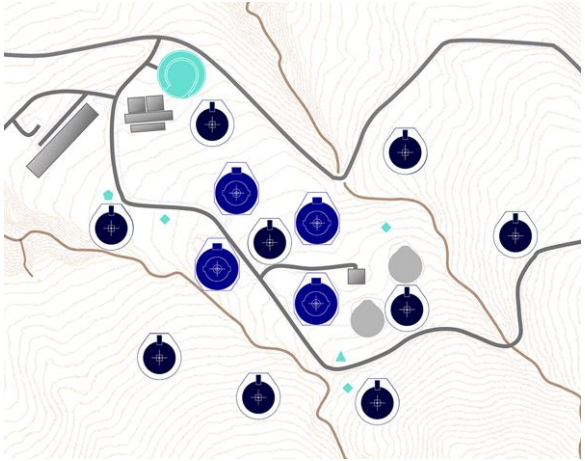


Alpha Configuration
In 6 years

- 2 sites



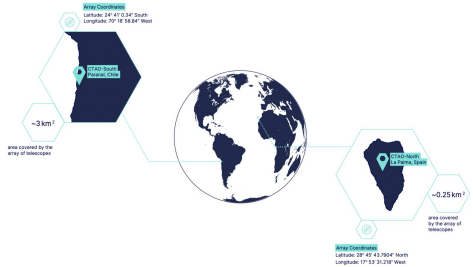
CTAO-South
14 MSTs, 37 SSTs (+2 LSTs)



CTAO-North
4 LSTs, 9 MSTs

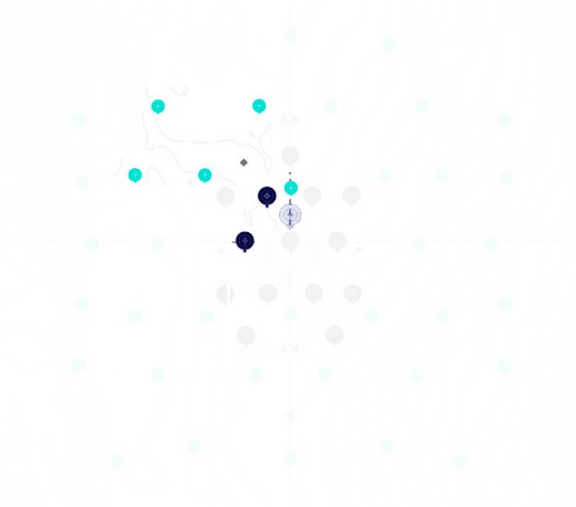
D. Green/CTAO

CTAO : overview

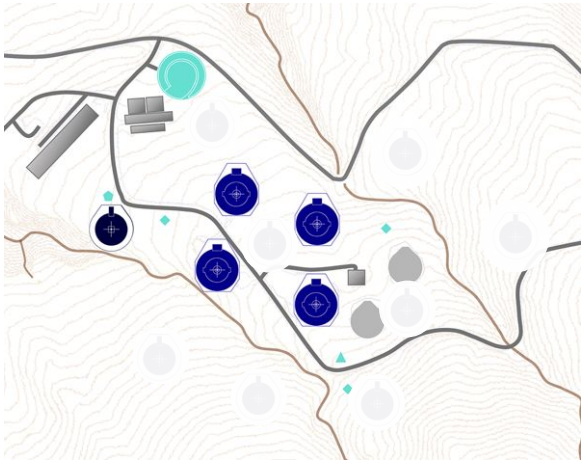


1st Intermediate arrays
~ 2028

- 2 sites



CTAO-South
2 MSTs, 5 SSTs



CTAO-North
4 LSTs, 1 MSTs

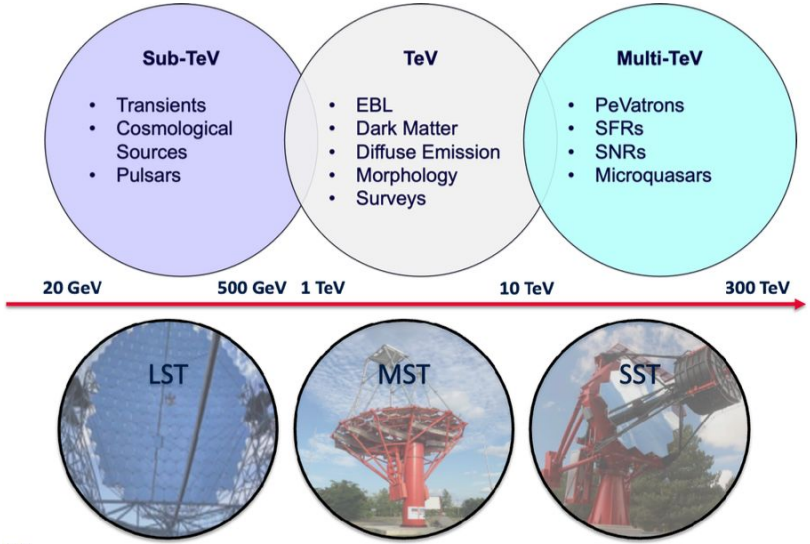
D. Green/CTAO

CTAO Science

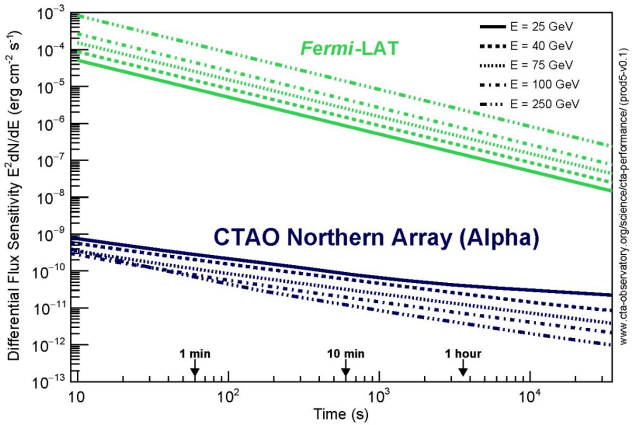
3 main scientific themes :

- Understanding the origin and role of relativistic cosmic particles
- Probing extreme environments
- Exploring frontiers in physics

→ CTAO is the ideal instrument to study **variable sources** and VHE **transient** phenomena



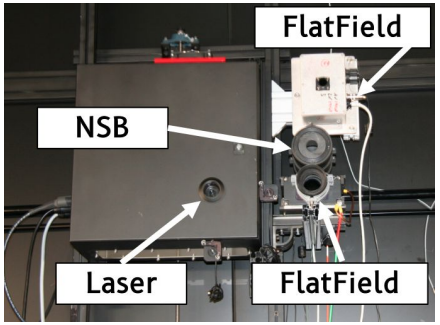
Credit : R. Zanin / D. Green

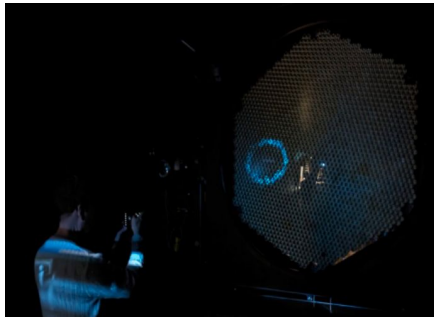


NectarCAM

NectarCAM will equip the **MST** in the **CTAO-North** site (alpha configuration)

- 9 cameras assembled, integrated and verified at CEA-Saclay

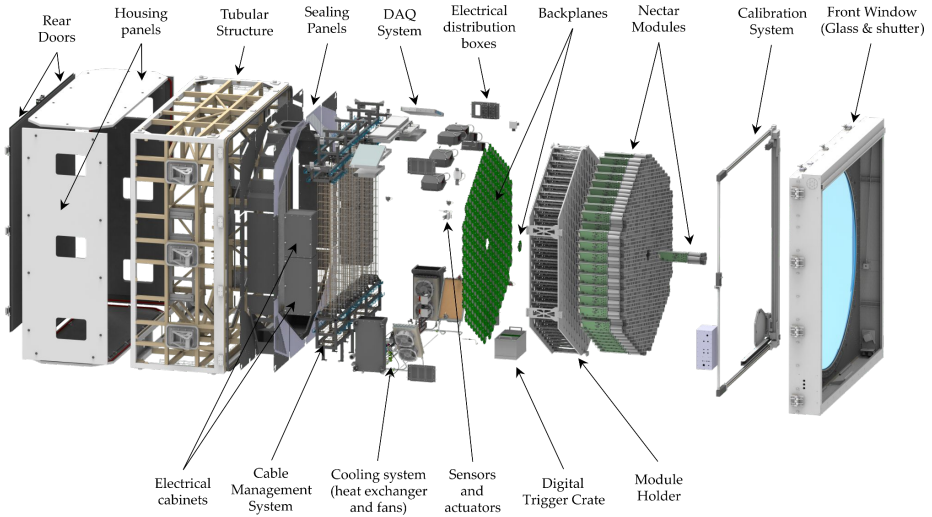


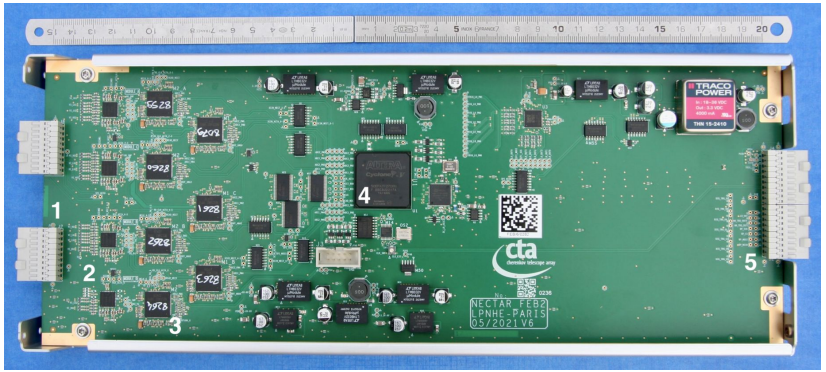


Integration hall &
darkroom (temperature controlled)

Overview of NectarCAM

- **Modular camera** with 265 7-PMTs modules (total 1855 pixels)
- 2.2 tons, dimensions 2.8 x 2.9 x 1.15 m.
- Field of view : 8°
- Basic brick: **Nectar module**
  - based on Nectar chip (upgraded with Nectar3)
  - **1 GHz sampling**. Working in ping-pong mode (deadtime ~ 0.7µs)
  - Integration window : 8 – 60ns
  - 2 gain channels → 0.1 – 2000 pe range
- Time resolution < 300 ps
- Energy range 80 GeV – 30 TeV

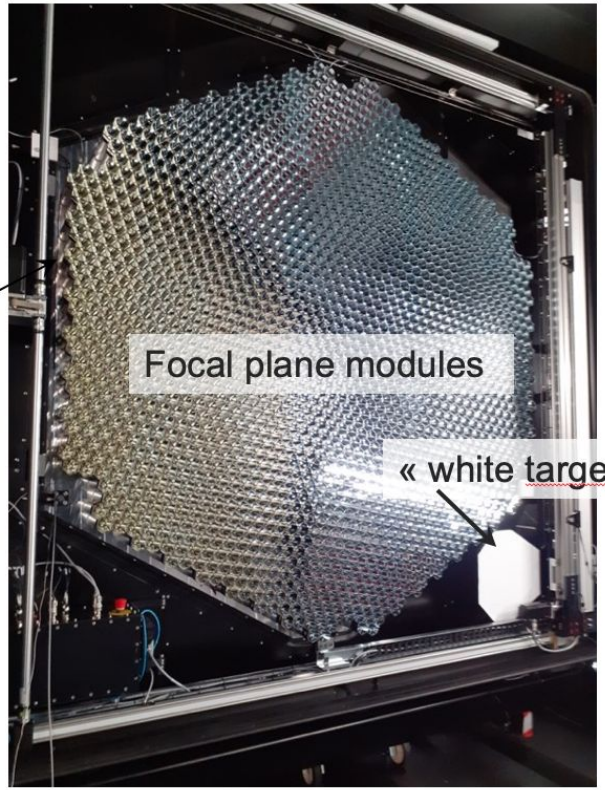




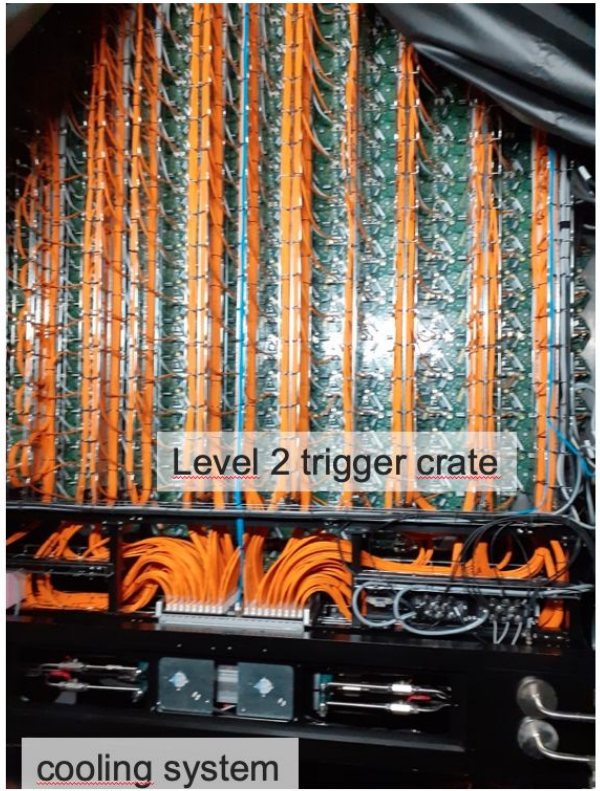
F. Bradascio et al., NIM-A 2024

Overview of NectarCAM

Front view

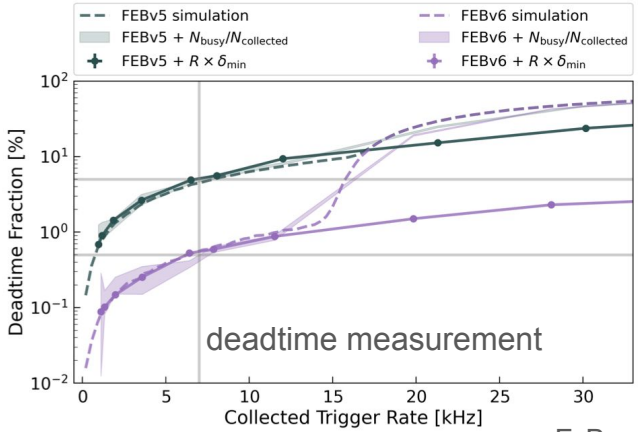


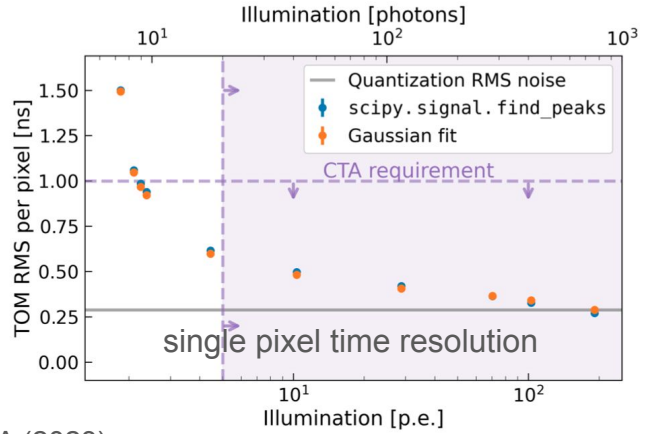
Rear view



NectarCAM : improvements from previous generations

	H.E.S.S.1 cameras	NectarCAM	Goal of improvement
Field of view	5 degrees	8 degrees	extended sources
Signal	integrated charge (16 ns), time of maximum	full waveform (8-60 ns)	Time, charge resolution
Deadtime	$15\mu s$ (H.E.S.S.2)	$< 1\mu s$	Energy threshold (for similar FOV)
Trigger rate (5% deadtime)	3 kHz (H.E.S.S.2)	> 15 kHz	Energy threshold (for similar FOV)
Cooling	air (fans)	forced convection	Calibration, signal stability
Dust, humidity	no protection	plexiglass window	lifetime, quality

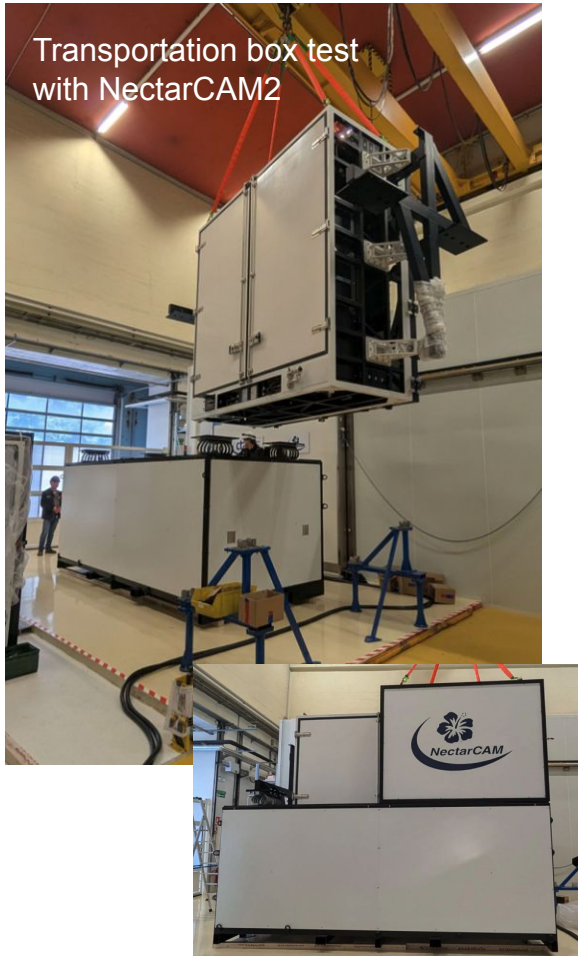




F. Bradascio et al., NIM A (2023)

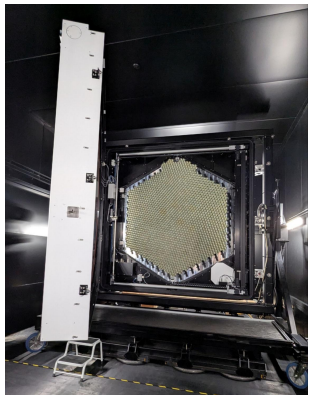
NectarCAM : towards installation

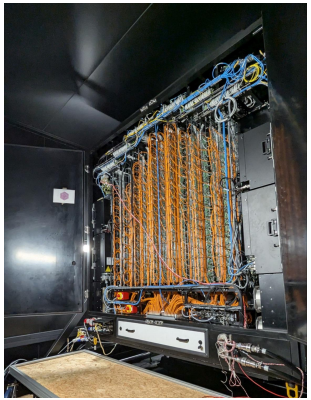
- Up to now : integration of NectarCAM1 (QM)
- NectarCAM2 : first production camera
  - Will be the 1st NectarCAM to be sent
  - **Ready for shipment : summer 2026**
- NectarCAM3 :
  - Will be the 2nd NectarCAM to be sent
  - **Ready for shipment : summer 2027**
- NectarCAM4-9
  - Will be prepared at an increased rate until end of production
  - QM to be sent later, will be refurbished (slight modifications of the mechanical structure)

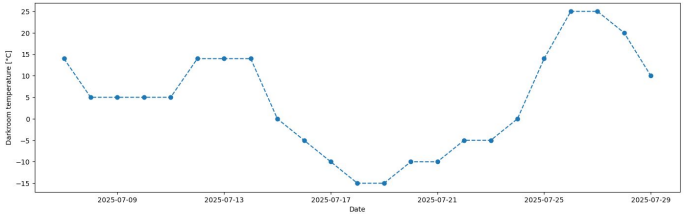


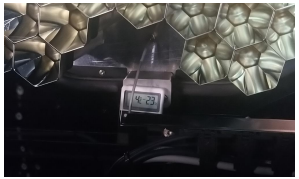
NectarCAM tests with QM

- NectarCAM1 (QM) complete since 12/2024
- Extensively used to :
  - define and test calibration procedure
  - test camera performances
  - develop control + analysis software
- Thermal tests campaign in July 2025
  - Darkroom in CEA - Paris Saclay can be cooled to -15°C
  - Verify pre-shipment test procedures and camera performances



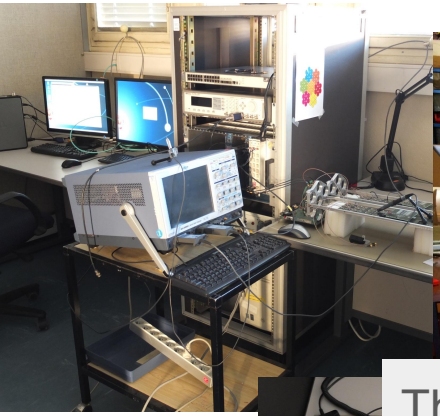


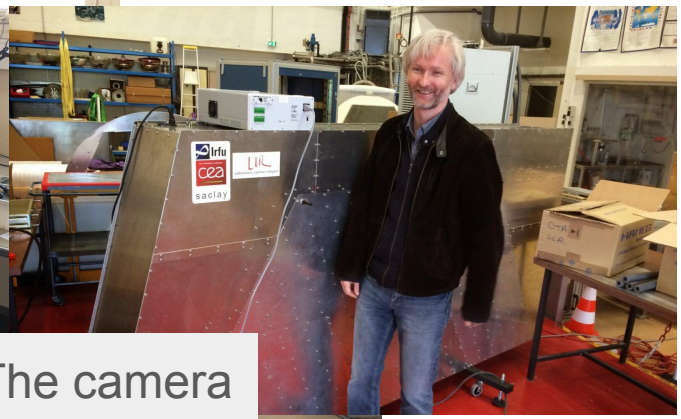


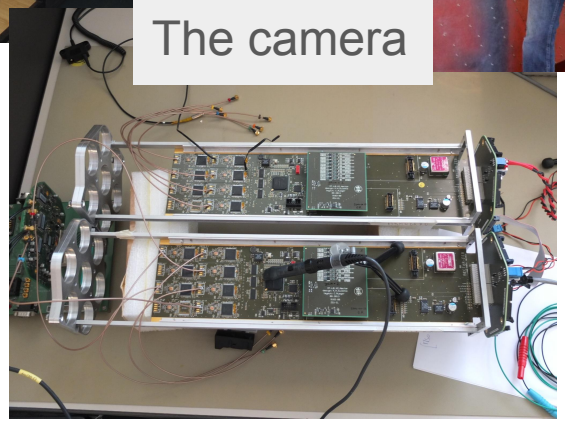


Iced coffee!

NectarCAM in 2014



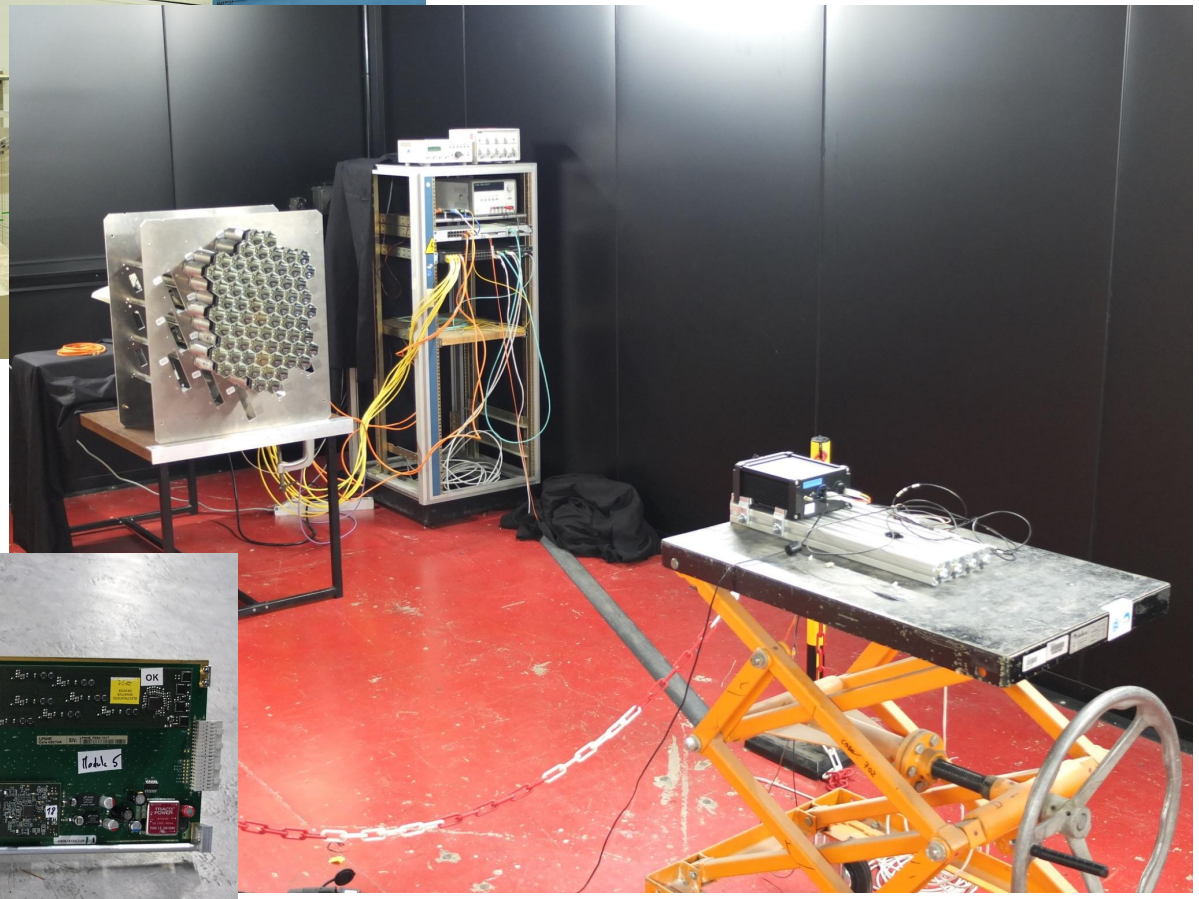




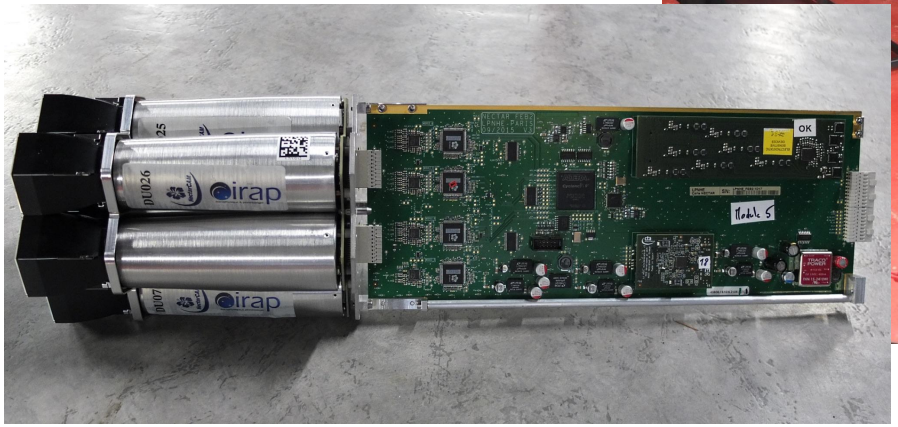
The camera

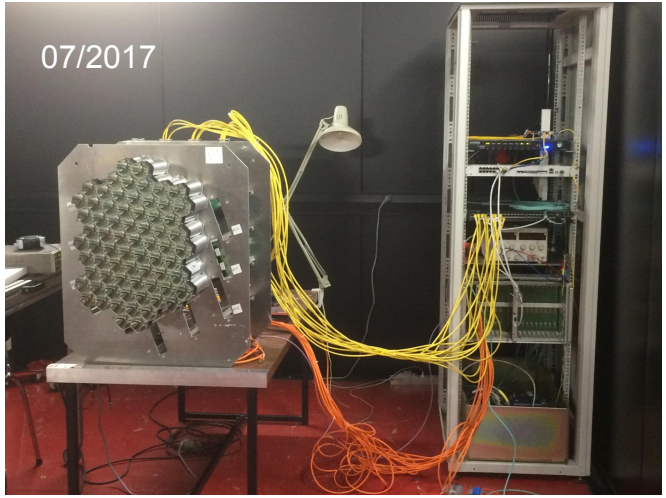
Integration hall

2015 : darkroom installation

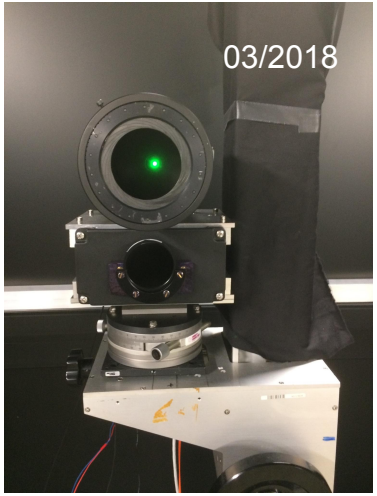


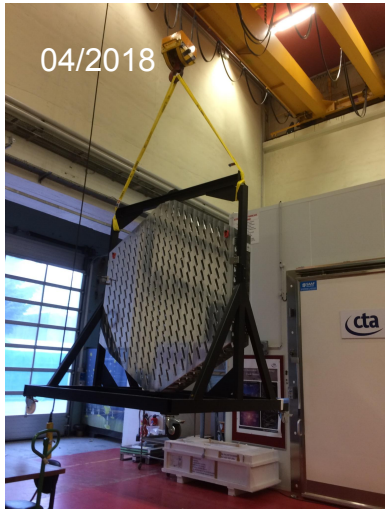
2016

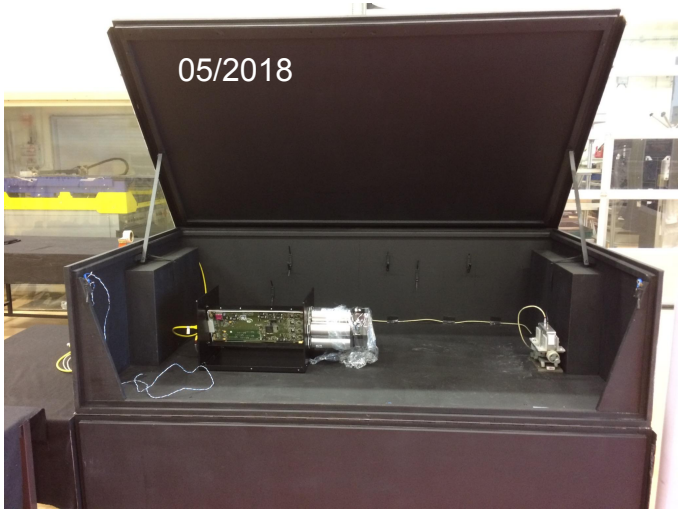


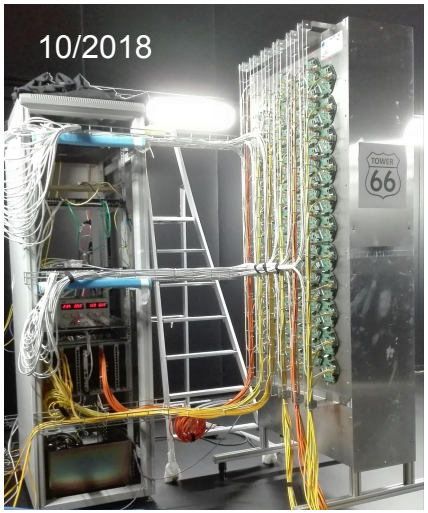

07/2017

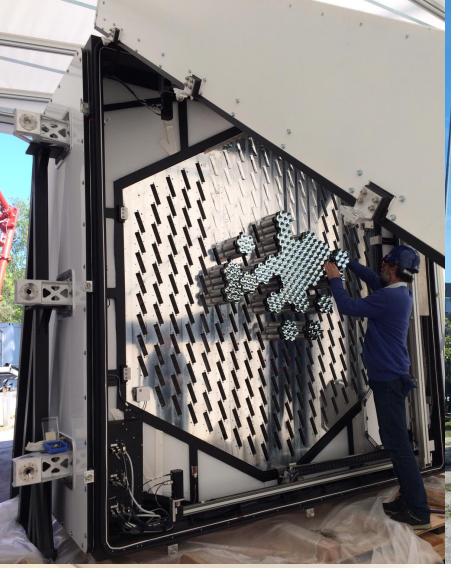

08/2017

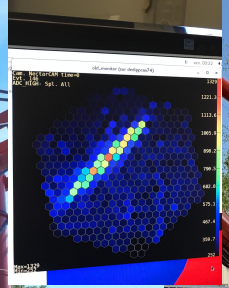

03/2018


04/2018
cta


05/2018


10/2018
TOWER
66





2019 : Adlershof observation campaign



Adlershof May/June 2019 observation campaign

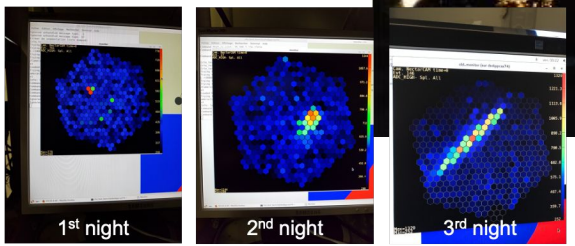
Partially equipped NectarCAM, mounted on a prototype structure

Observations at the “dark spot” : where there is the least parasitic light

- Filters… for a challenging environment !

Allowed for a lot of technical checks:

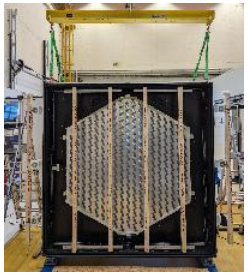
- Vibrations (transport)
- Mounting tools
- Camera on structure and trolley
- Power/optical fibers
- Camera operation in all directions
- Weather conditions (rain, sun, wind)

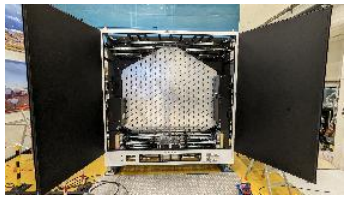
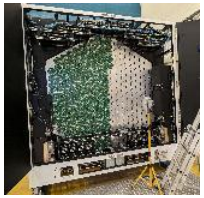


NectarCAM2 status

- 1st NectarCAM to be sent (ready : Q2 2026)
- “Production” mechanical structure (lighter by 100 kg)
- Assembly started Oct. 2024
- FPM modules moved from QM in Aug. 2025
- Few parts still to be integrated but Camera is ready for extensive tests
  - Completion planned Q4 2025
- Test bed for the production cameras
- Document integration & maintenance procedures
- Preparation of shipment





Summary

- CTAO is the next major facility for VHE gamma ray astronomy: early science soon!
- Thermal tests for NectarCAM1 in July 2025
  - Data being analysed
- NectarCAM2 to be completed by the end of the year
  - Ready for shipment by summer 2026
- NectarCAM3 ready by summer 2027
- NectarCAM4-9 right on tracks

Project well on track… thanks to Berrie

Stay tuned !