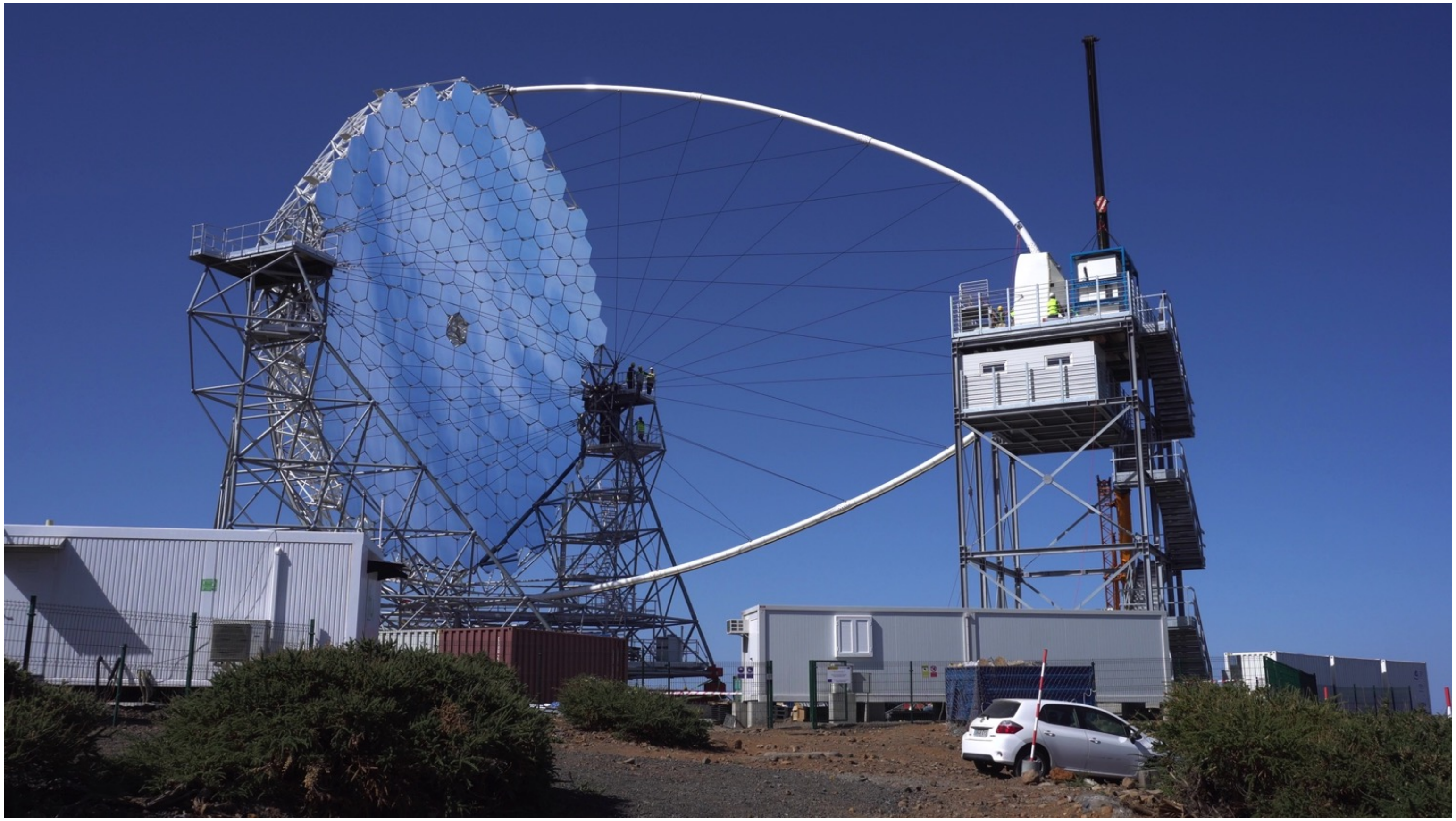
F. Brun (IRFU)
for CANEVAS & NectarCAM



CAmera NEctarcam VAlidation at Paris-Saclay

IPN INSTITUT DE PHYSIQUE NUCLÉAIRE ORSAY
LLR
Irfu
P2IO Physique des 2 Infinis et des Origines

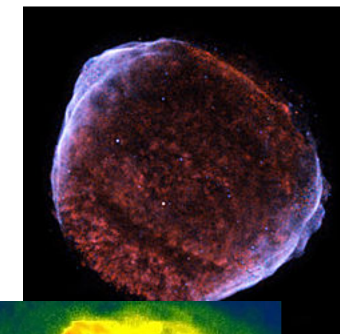
Outline

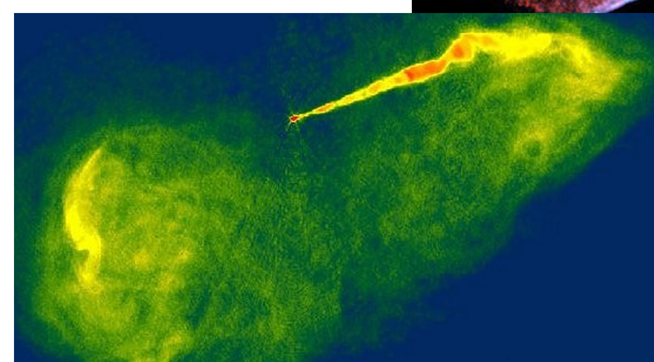
- Very High Energy Gamma ray Astronomy & the Cherenkov Telescope Array Observatory
- NectarCAM and the CANEVAS Project
- CANEVAS tests at Adlershof
- Beyond CANEVAS : First NectarCAM camera

Very High Energy Gamma ray Astronomy

Detect γ-rays produced by interaction of VHE cosmic rays (> 30 GeV)

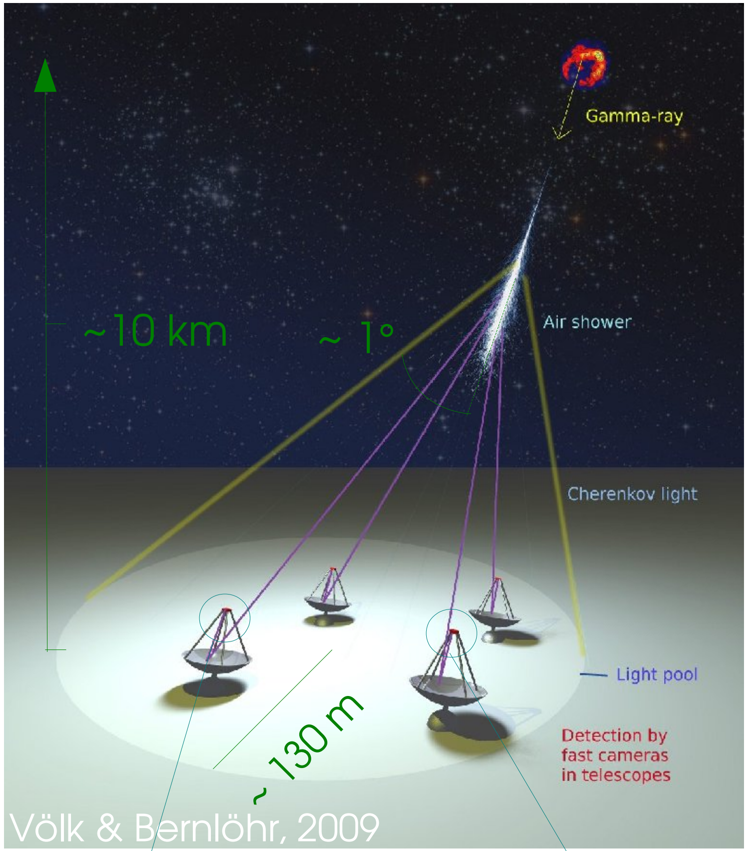
- Understanding the origin and role of relativistic cosmic particles
  - Nature of cosmic accelerators
  - Propagation of accelerated particles
  - Interaction with their environment
- Probing extreme environments
  - Black holes & jets
  - Neutron stars & relativistic outflows
  - Exploring cosmic voids
- Exploring frontier in Physics
  - Dark matter : nature & distribution
  - Quantum gravity : Lorentz symmetry near Planck energy
  - Do axion-like particles exist ?



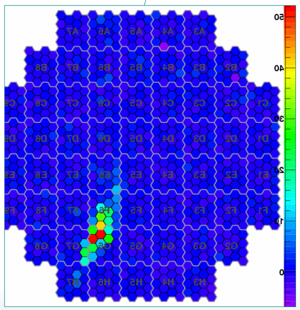


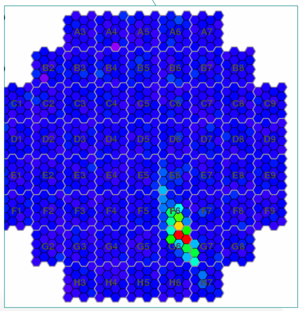
Very High Energy Gamma ray Astronomy

- Cosmic photons with E > O(10) GeV
- γ interacts in the atmosphere
- Development of a particle shower
- Emission of a brief (~ few ns) and weak flash of Cherenkov light
- Image of the shower with cameras at the focal plane of telescopes : stereoscopy



Orientation ➡ Direction
Intensity ➡ Energy
Shape ➡ Discrimination

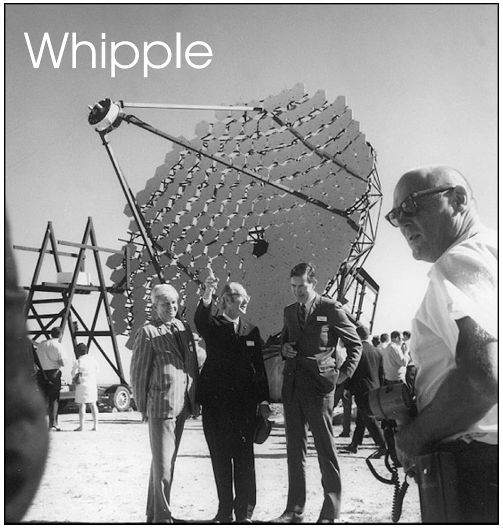


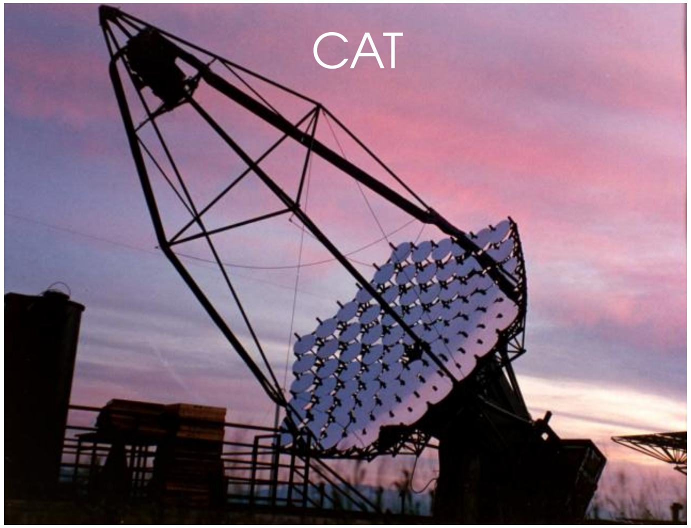


Imaging Atmospheric Cherenkov Technique

- The technique works best with :
  - **Large mirrors**
  - **Fast** and **finely pixelated** cameras
  - **Stereoscopy**

Current instruments like H.E.S.S. combine these advantages, inherited from the previous generations of instruments :



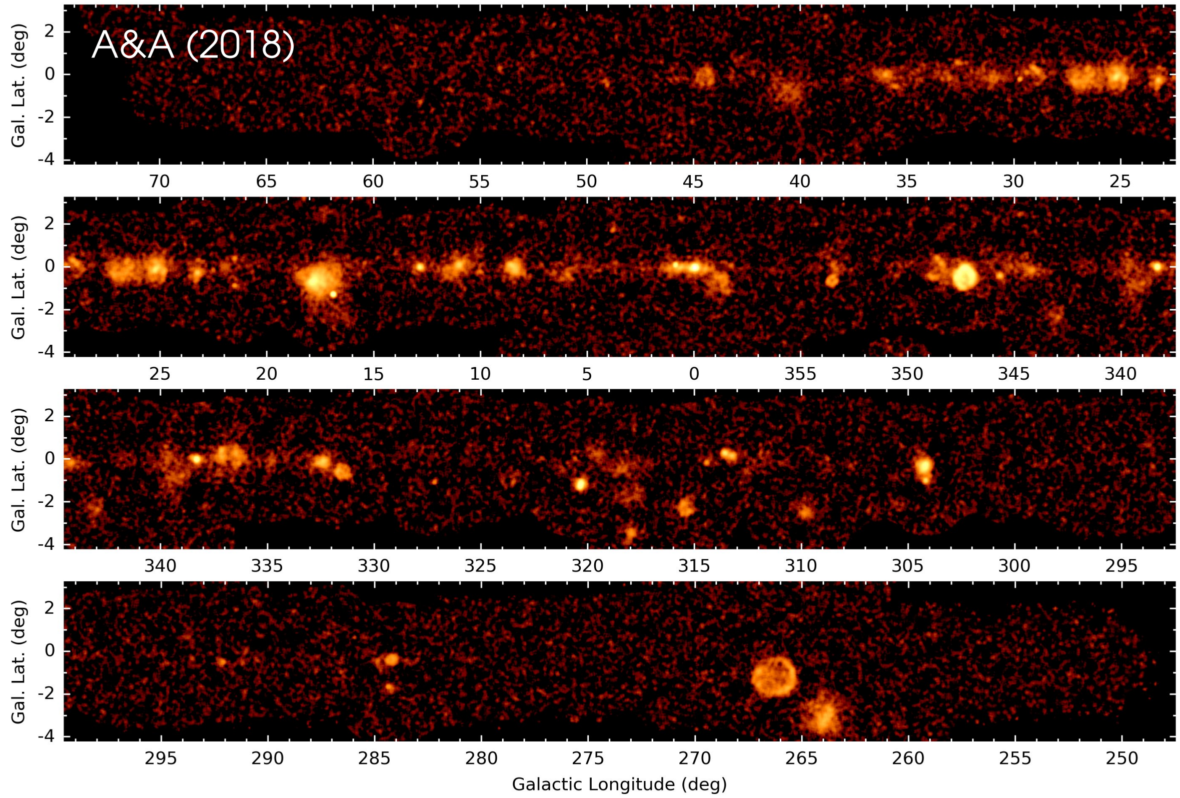


Imaging Atmospheric Cherenkov Technique

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



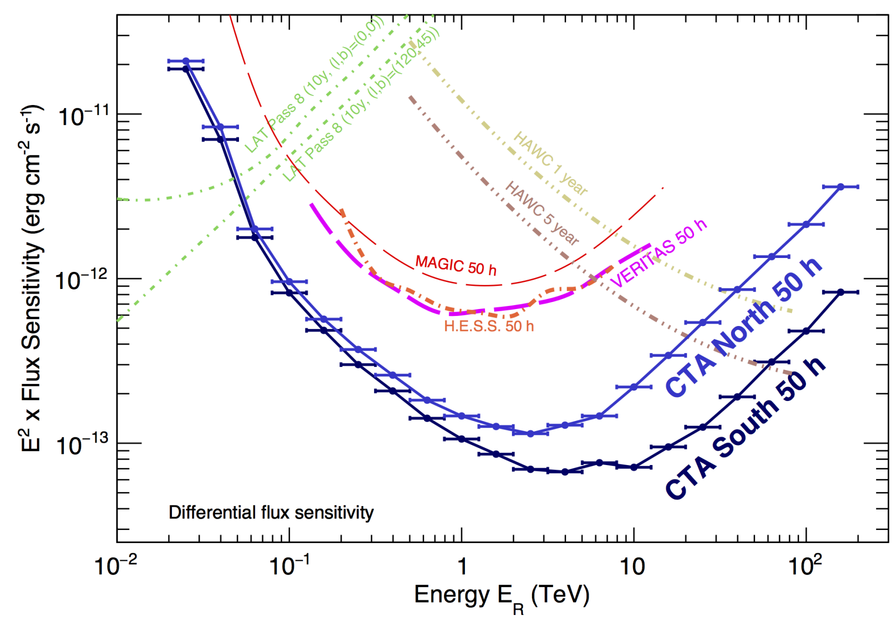
Major achievement in 2018 : H.E.S.S. survey of the Galactic plane :
→ From single source measurement to population studies

2000's : With H.E.S.S., MAGIC & VERITAS, the field reaches maturity !
H.E.S.S. is awarded the Descartes (2006) & Rossi (2010) prizes

The next step : Cherenkov Telescope Array

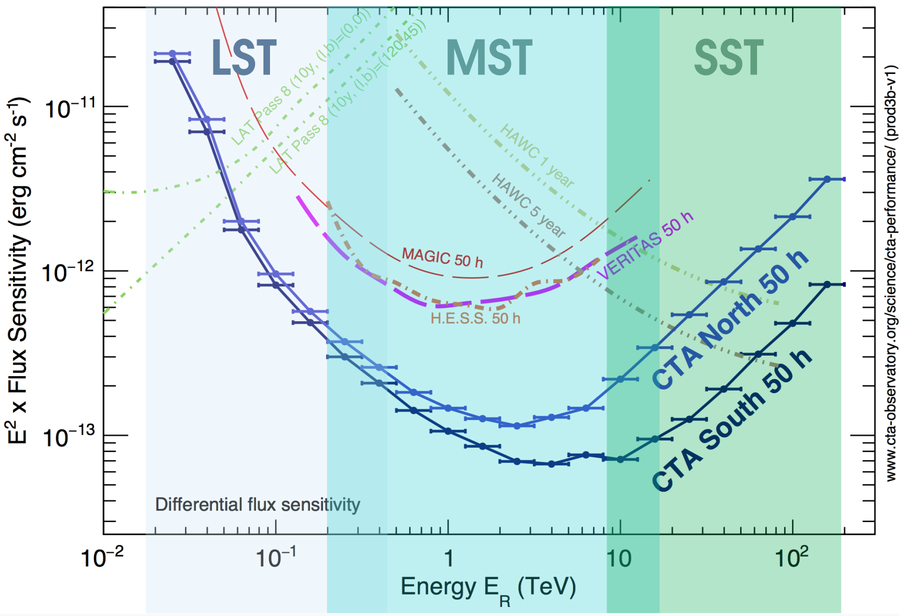
- CTA : several number of telescopes of different sizes
  - 2 sites : northern hemisphere (La Palma/Canary Islands, Spain) & southern hemisphere (Paranal/Chile)
  - 20 GeV – 300 TeV (H.E.S.S. : 50 GeV – 50 TeV)
  - Better sensitivity over the whole energy range (x10 at 1 TeV)
  - Improved angular resolution (5x better)
  - Proposal driven, open-access facility


CTA northern site (artist view)



The next step : Cherenkov Telescope Array

- CTA : several number of telescopes of different sizes
  - Three major classes of telescopes :
    - ➔ Large (LST) : Ø 23m, north : 4 / south : 0-4
    - ➔ **Medium (MST) : Ø 12m, north : 5-15 / south : 15+**
    - ➔ Small (SST) : Ø 1 – 2m, south only : 50
  - Two major designs for MST cameras : **NectarCAM** and FlashCAM



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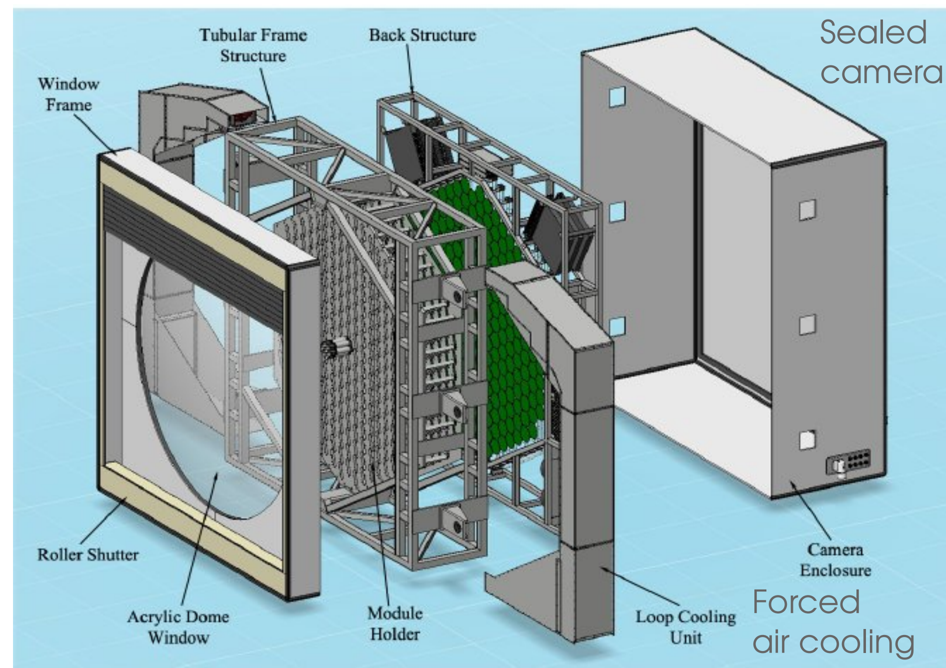
NectarCAM : a camera for MST

- Modular camera : 265 modules of 7 PMTs (total 1855 pixels)
  - 2.8 x 2.9 x 1.15 m / 2 tons
  - Field of view : 8° (H.E.S.S. I : 5°)
  - Analog memory & digitization with Nectar ASIC : 1 GHz sampling
  - Ethernet based readout
- Many elements in common with LST-Cam
- Collaboration of 15 institutions in France, Spain & Germany



The CANEVAS project

Construction of a camera aimed at validating NectarCAM with astronomical data (site : e.g. Roque de los Muchachos – Canary Islands)

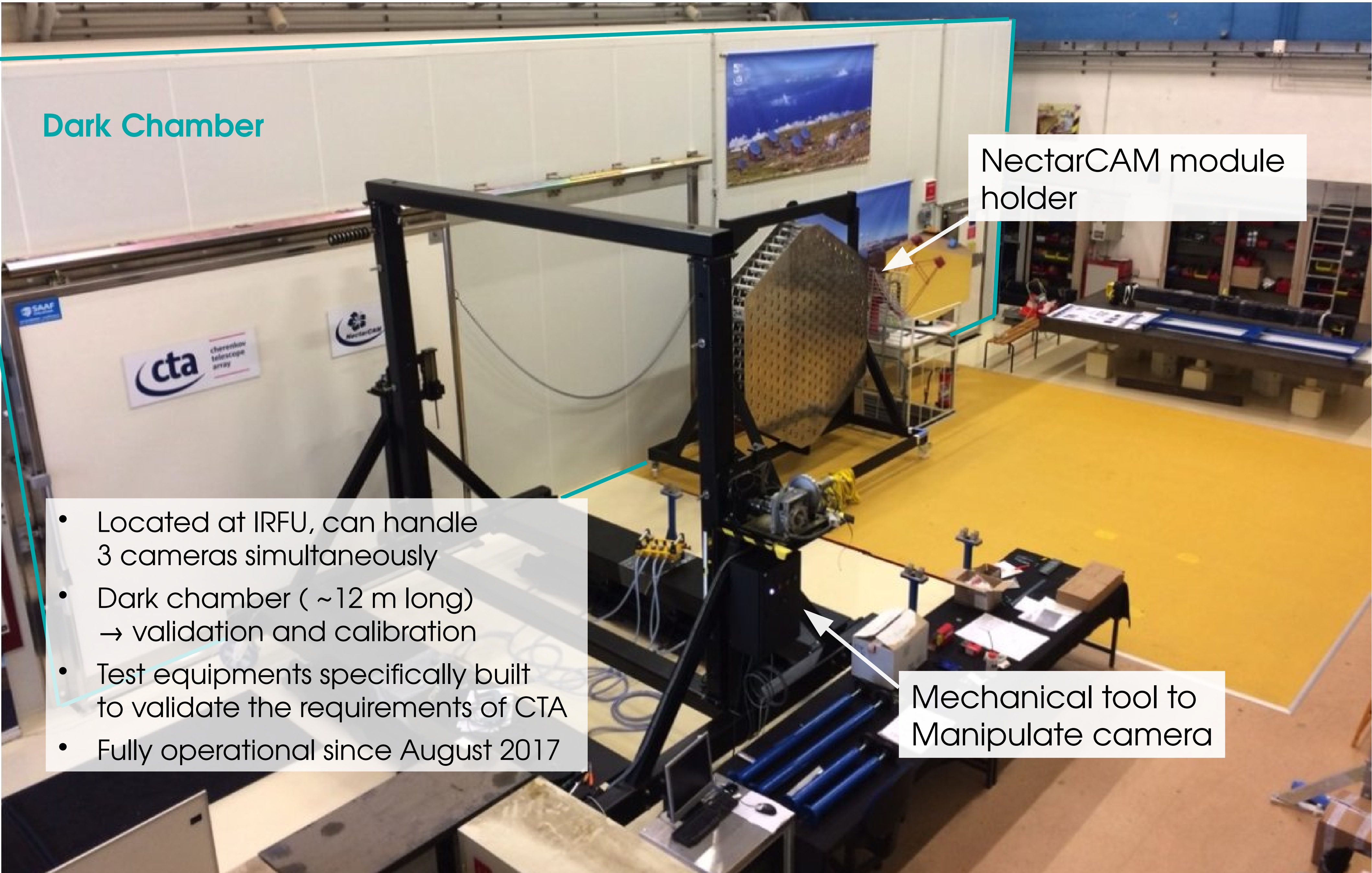
- Build a NectarCAM camera with **1/4 detector units and readout modules**

  → Scale 1 mechanics, cooling system, data acquisition, slow control, power, trigger & clock

- Teaching & outreach component
  - 3 post-doctoral positions at LLR, IRFU and IPNO
  - Outreach for students, engineer and general public

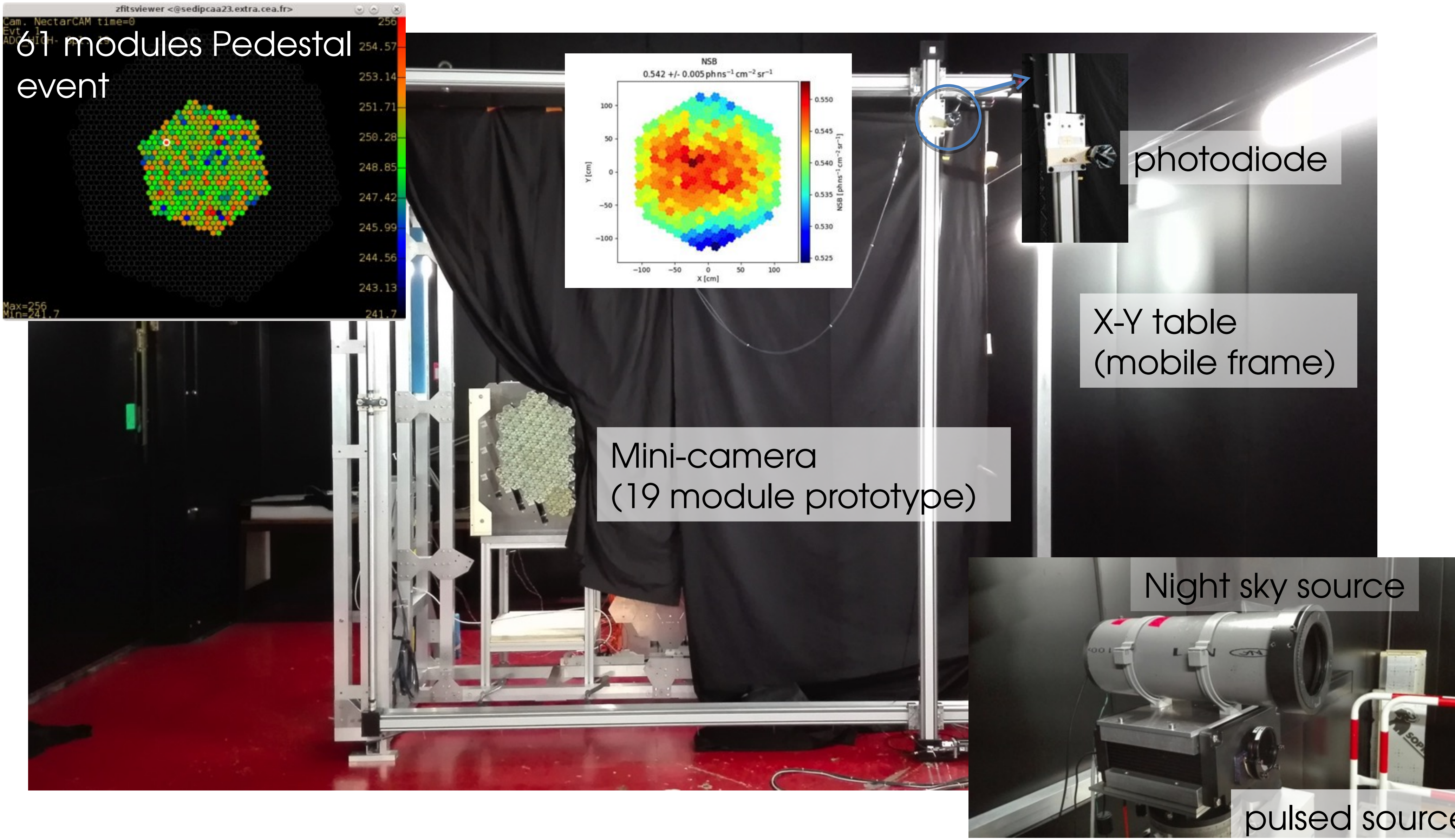
Selected as P2IO « Projet emblématique »
- Total grant from P2IO Labex: 710 k€
- 120 k€ additional grants from OCEVU, OSUG2020 Labexs
- Contributions from IRFU, IN2P3, INSU

Integration hall and dark chamber



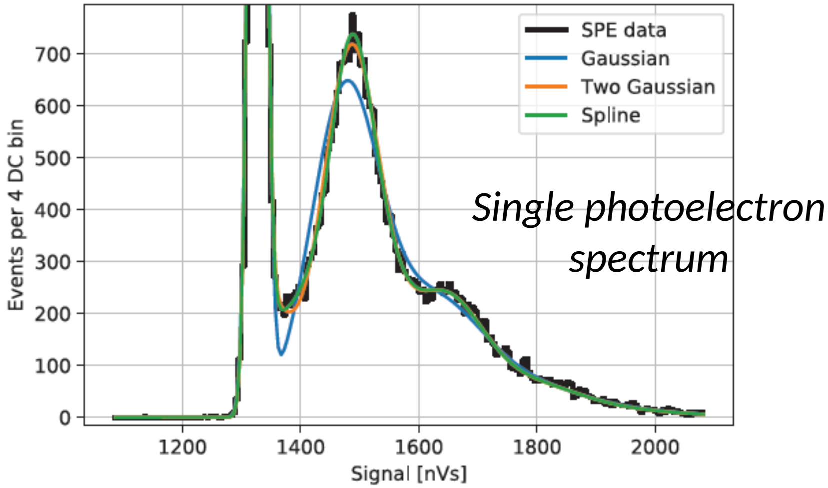
- Located at IRFU, can handle 3 cameras simultaneously
- Dark chamber (~12 m long) → validation and calibration
- Test equipments specifically built to validate the requirements of CTA
- Fully operational since August 2017

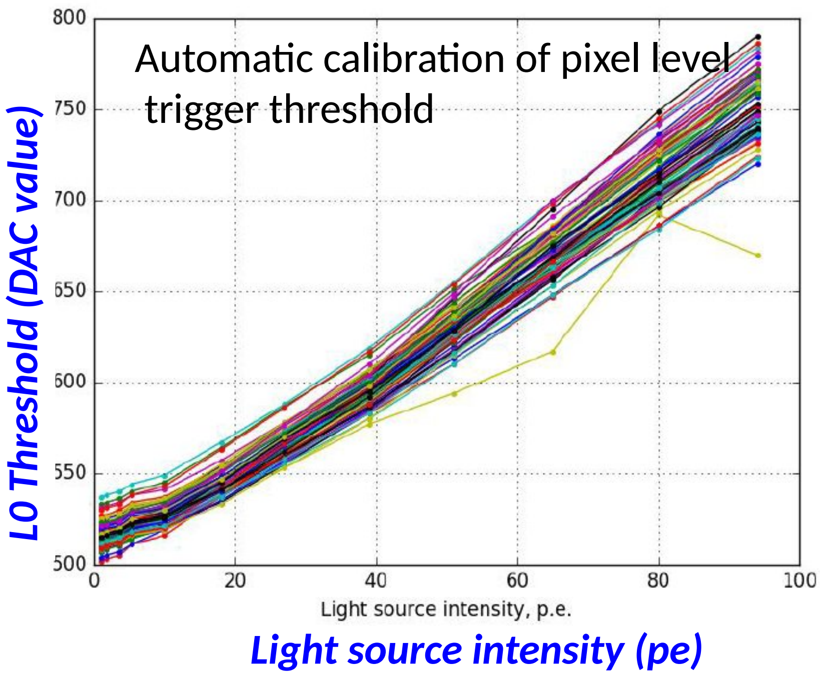
Dark Chamber

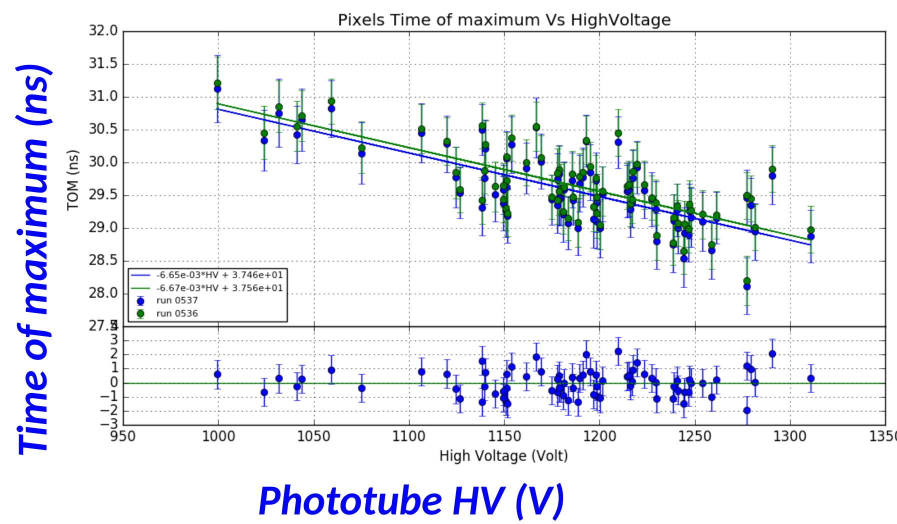


Calibrations

- Develop and test new algorithms for physics calibrations : single photoelectrons, muons, etc
- Automatic calibration procedures implemented

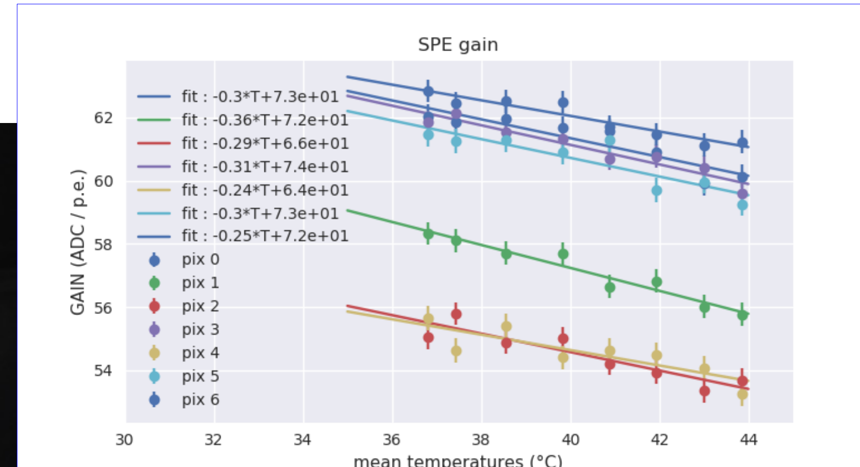


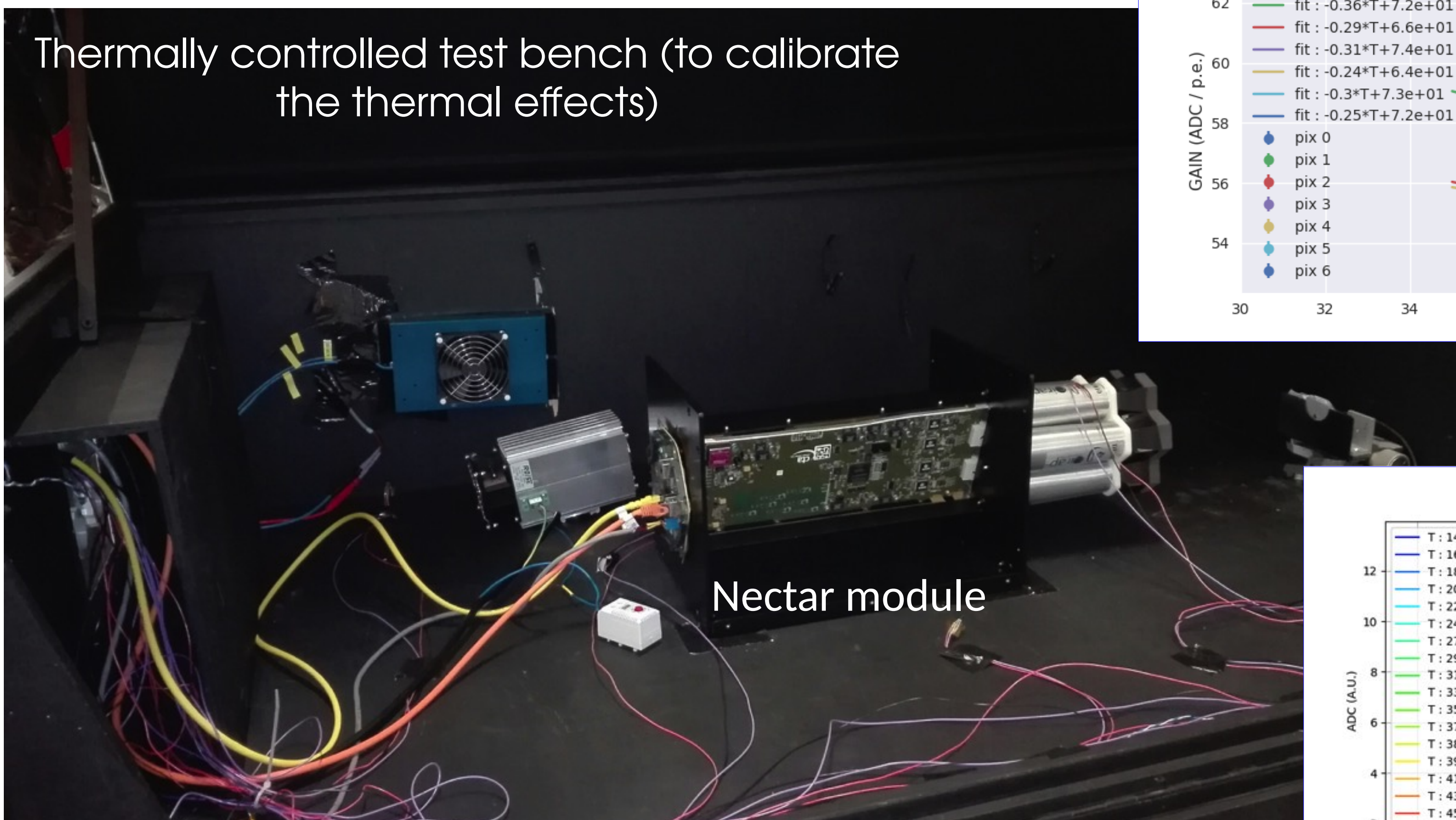


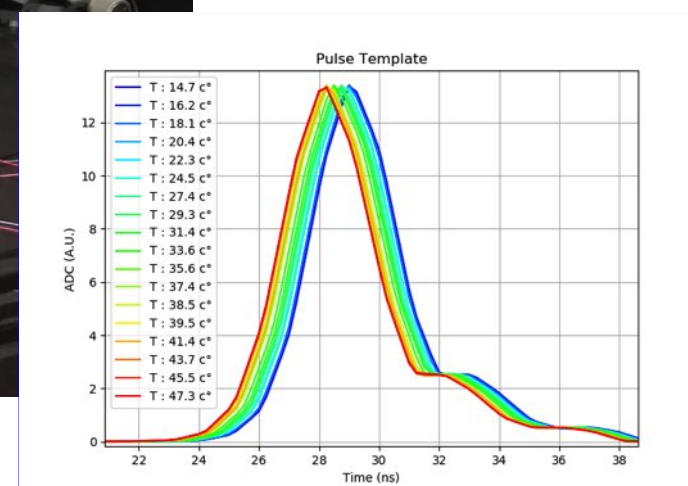


Nectar module test bench

Single pe gain vs. temperature

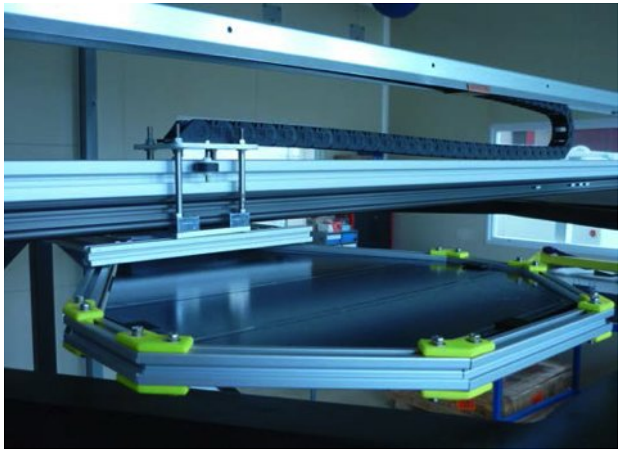




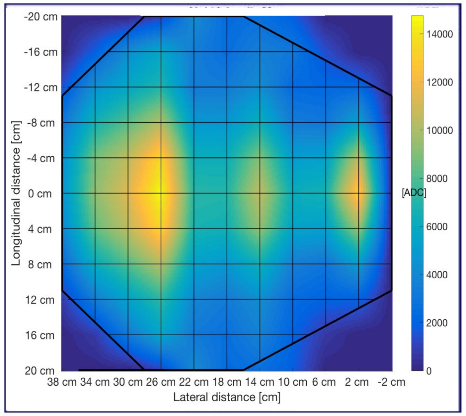


Pulse position vs. temperature

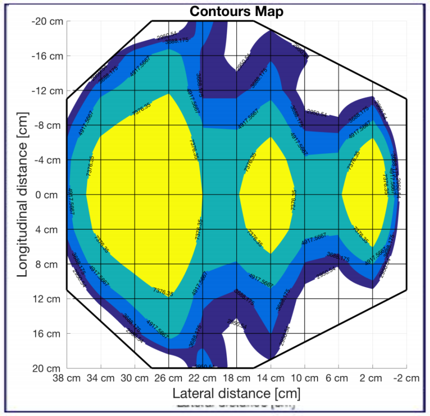
Single PE calibration system



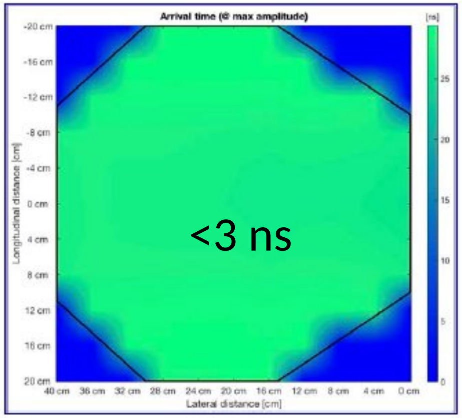
- Internal calibration light source (design & prototyping : IPNO)
  → Rear side: reflective target for mirror alignment
  → Front side: single PE calibration
- X-Y system moves source across camera field with shutter closed
- System for CANEVAS installed Q4 2018.
  → Possibility for use on LST-Cam.



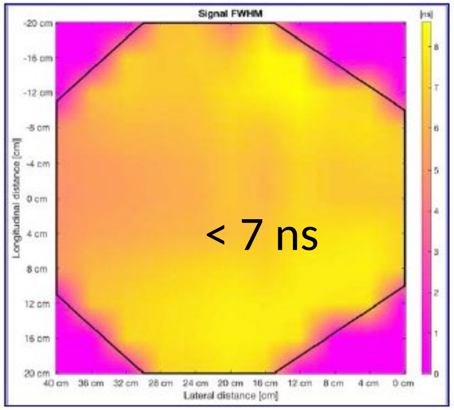
LIGHT INTENSITY MAP



CONTOURS MAP



ARRIVAL TIME



DECAY TIME

Good spatial homogeneity and timing properties

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CANEVAS at Berlin-Adlershof

- Short term schedule : Berlin-Adlershof CANEVAS tests
  - Full mechanical structure equipped with 61 Modules

    → 427 pixels (23% of a fully equipped camera)
  - Goal:

    → Functionnal tests, tests of mechanical interfaces, transport strategy, enviromental constraints, data acquisition, trigger,

    → If possible cosmic-ray/muon reconstruction
  - Duration ~ 1 month
  - Planned for March 2019

CANEVAS at Berlin-Adlershof


66 module tower used to validate the CANEVAS prototype

Technical progress

- 61 Module test = major goal of CANEVAS
- Last elements being manufactured, large mechanical parts delivery at Saclay mid November
- Front end boards : available & being tested at IRFU
- Detailed organisation started
  - Several meetings with the telescope structure team


PMMA window


25/9/18: preparatory meetings at Berlin-Adlershof


Main camera structure

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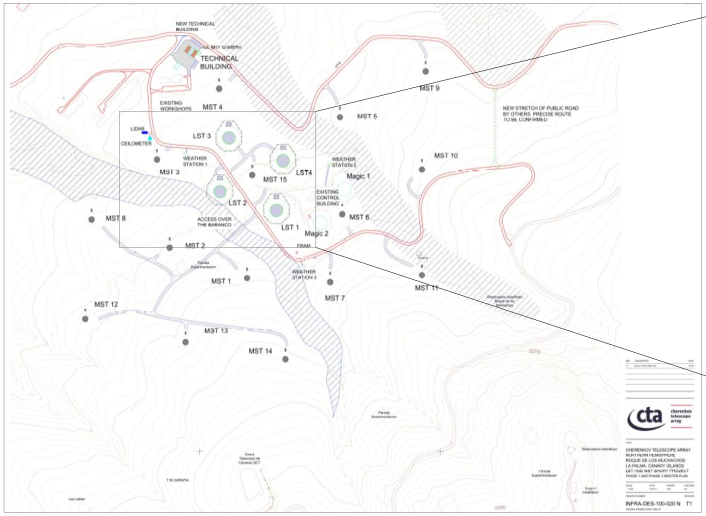
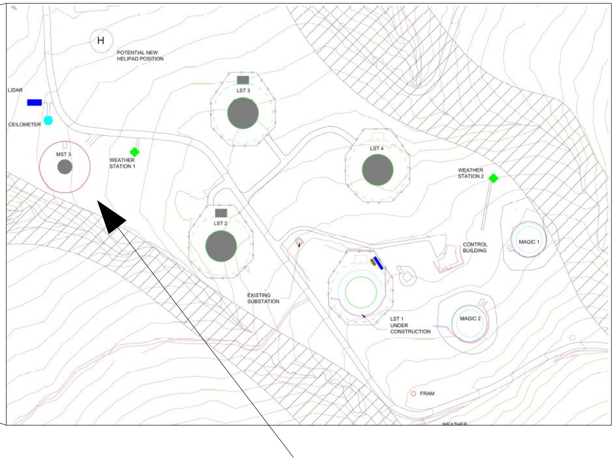
Beyond CANEVAS : A first NectarCAM

- Mid term schedule : NectarCAM at La Palma
  - Dismounting after the Berlin experiment to integrate the final cooling system
  - Full camera Integration planned → 09/2019
  - Full camera tests planned → end of 2019
  - Installation at La Palma when structure is ready → mid 2020

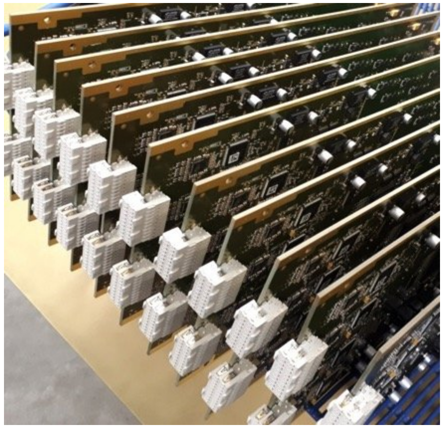




Planned location of CANEVAS/MSTN telescope

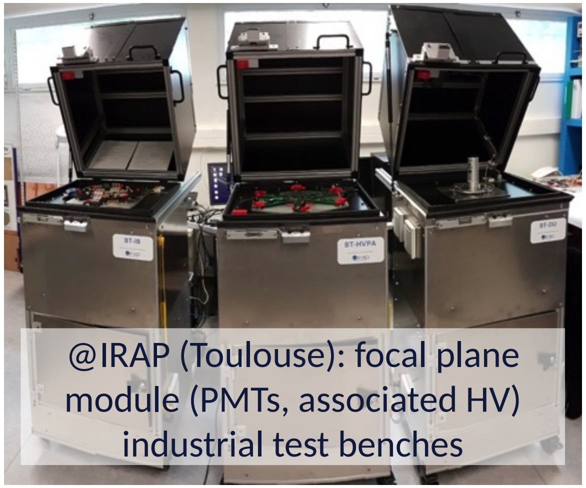
Technical progress : towards a full camera

- Full camera : 265 modules
- Front-end boards :
  - All necessary boards ordered
    → Delivery of the tested boards : 02/2019
- Focal plane modules :
  - Contract being finalised
    → Delivery until 06/2019
- Light guides :
  - Pre-series of 500 already available
  - Ready to launch a series of 2000 if validation in Berlin

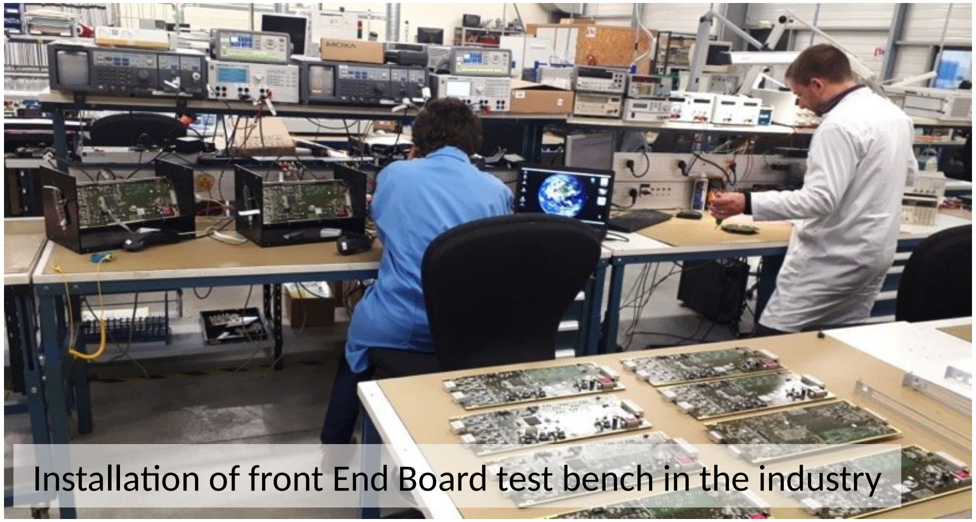


Technical progress : Test benches

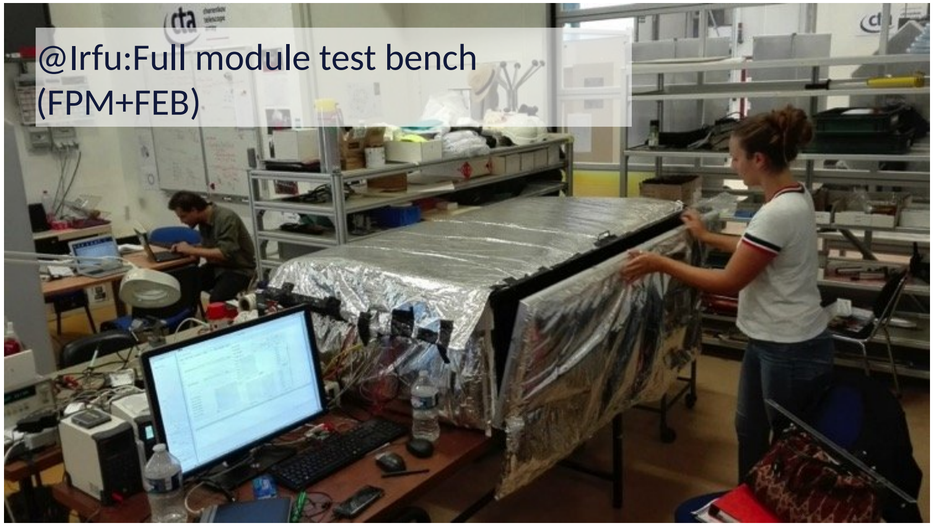
- Industrial test benches have been designed :
  - For camera production in the industry
  - To check the result of industrial production
- Same software libraries at all test benches
- Close to being fully operationnal



@IRAP (Toulouse): focal plane module (PMTs, associated HV) industrial test benches



Installation of front End Board test bench in the industry



@Irfu:Full module test bench (FPM+FEB)

Conclusions

- CANEVAS (and NectarCAM Qualification Model) has advanced well over last year
- The CANEVAS camera equiped with 61 modules will be tested on a structure prototype in Berlin-Adlershof in March next year
- The full NectarCAM camera is now financed by the Très Grands Instruments de Recherche (TGIR).
- Due to site availability, the first NectarCAM will be installed on La Palma site mid-2020.
- Procurement for the first NectarCAM has started. It should be fully integrated mid-2019.

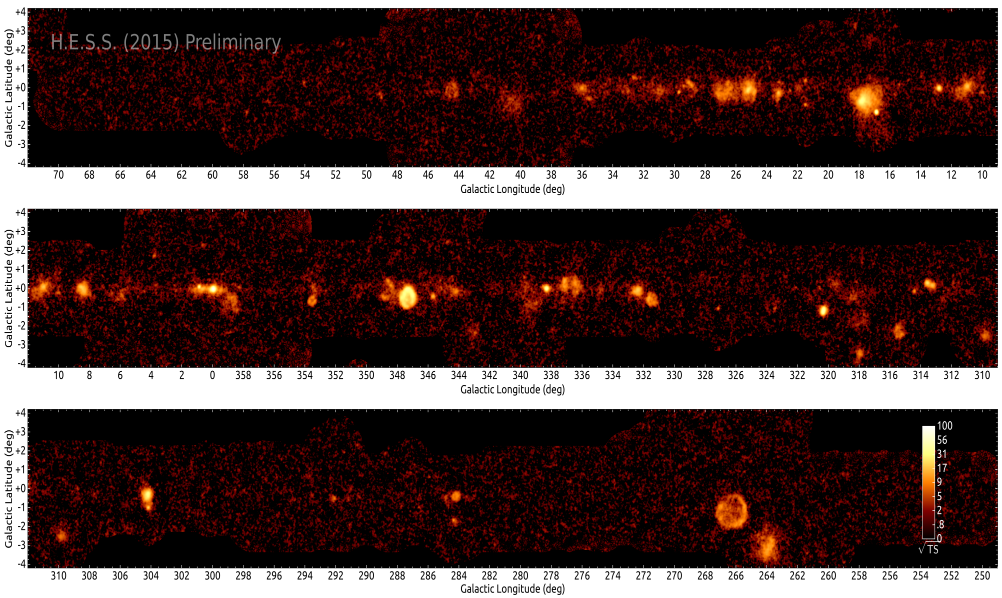
P2IO support was essential to make NectarCAM a viable camera for CTA and to obtain TGIR funding for the whole NectarCAM sub-array.

Backup

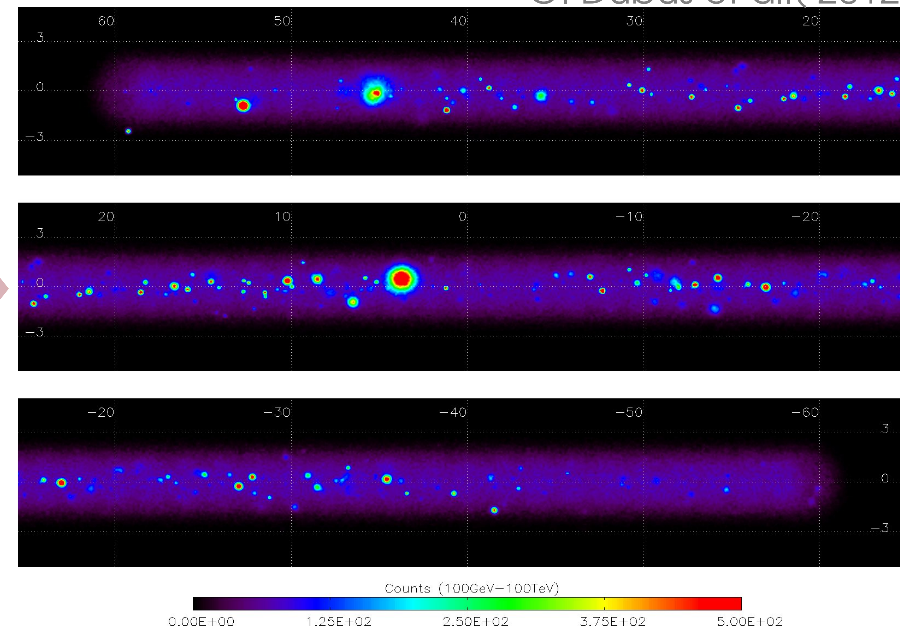
Principal advances of CTA

- Two sites — full sky visible, double available science. First extragalactic survey (1/4 sky) will complement deep Galactic survey (H.E.S.S.)
- Large area — more gamma rays gives improved instantaneous sensitivity; particularly important for transients.
- Many telescopes — improved reconstruction, proton rejection and angular resolution, particularly at high energies.
- Large field of view — increased science efficiency - particularly for survey and for serendipitous detection of transients (GRBs).
- Energy range — three telescope classes extend energy range. Understand spectra & variability at highest energies.
- Lower PMT gain — safely operate in moonlight extending limited number of hours of observation available.
- Focus on "quality" — requirement for larger telescope availability improves science yield and uniformity of data taking. It also reduces the cost of Maintenance.
- Technical advances— faster electronics, data processing, rapid pointing, large quantum efficiency photodetectors.

The Galactic plane as seen with CTA



G. Dubus et al.(2012)



Study sources with (intrinsic) spectral breaks

Population studies, Detailed analysis of interesting sources

Highest energy limit of cosmic accelerators

More/New objects to study !

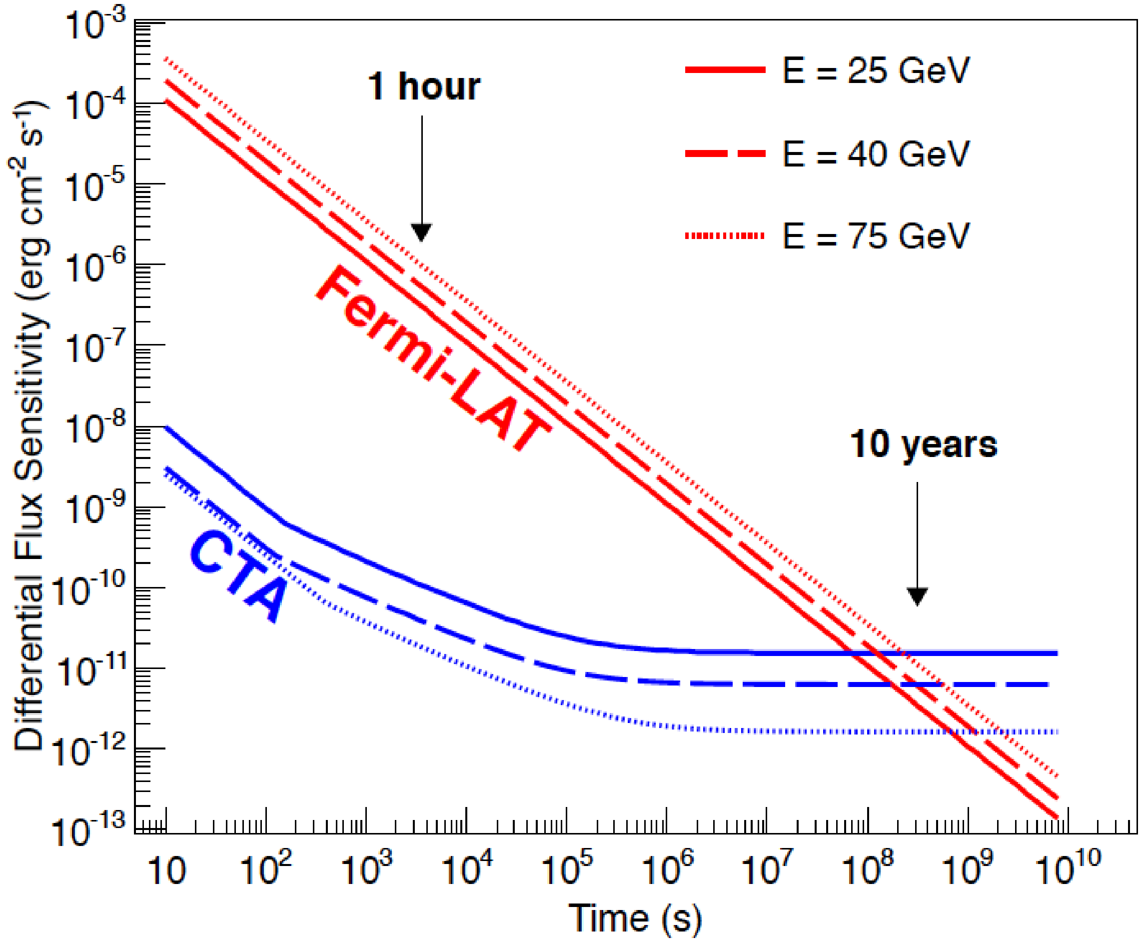
Acceleration efficiency (10 %?)

Search for PeVatron SNRs

Diffusion coefficient studies

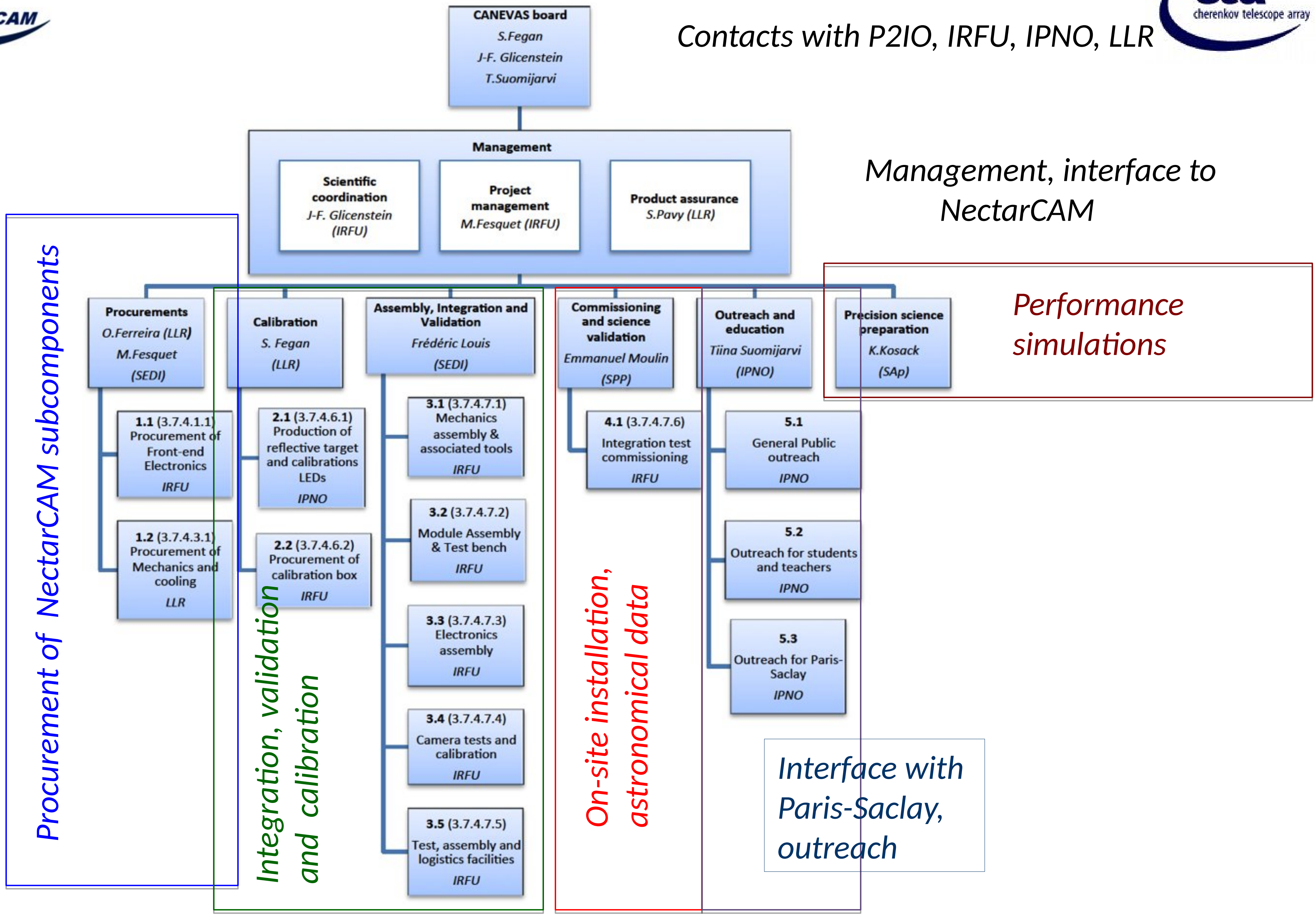
The Knee : 1 peculiar object or a collection of sources ?

Sensitivity to bursts



- Sensitivity to short transients much better than Fermi to significantly lower energies
- CTA will be a superb instrument with which to study variability in the VHE Universe

CANEVAS organisation



Contacts with P2IO, IRFU, IPNO, LLR

MST-NectarCAM (MSTN) consortium

- To validate the NectarCAM/CANEVAS concept : A full size camera has to be installed in an astronomical site
- The best solution is to operate in the CTA framework
  → Infrastructure and networks provided/paid by CTA observatory
  → Proximity of other CTA telescopes (LST) allows data taking with stereoscopy.

MSTN = Consortium to build & operate one MST telescope with NectarCAM qualification model at Observatory de Roque de los Muchachos (La Palma)

- Lead agency : DESY (Germany)
- MoU between responsible parties (signature in next few months) :
  → *Site :* Instituto de Astrofísica de Canarias
  → *MST Structure :* DESY, U. de Sao Paolo
  → *NectarCAM :* CTA Spain, DESY, IN2P3, INSU, IRFU
- Defines scope, governance, responsibilities, contributions, equipment, commissioning…
- May be extended in the future to include more NectarCAMs on CTA-North.
- Funding : FEDER funds (structure), DESY, P2IO, other LABEXs
- End of 2017: the CTA-France consortium has obtained a TGIR funding to build 16 NectarCAM

Participating institutes to MSTN

Structure

Major contributor to Mechanics and AUX, host and infrastructure: IAC (Spain)

Mechanics and AUX design including drive system: DESY (Germany)

Camera support system: Universidade de Sao Paulo (Brasil)

Active Mirror Control QM: University of Tübingen (Germany)

Software: Humboldt University and DESY (Germany)

Single CCD camera: University of Erlangen (Germany)

Mirrors: IRFU (France)

Assembly, Integration, tests: DESY (Germany)

Camera

Focal plane instrumentation: INSU (France), CTA-Spain

Front-End Electronics: IN2P3, IRFU (France), CTA-Spain

Trigger and Clock: DESY (Germany), CTA-Spain, IN2P3 (France)

Mechanics: IN2P3, IRFU (France), CTA-Spain (design)

Processing: IN2P3 (France)

Monitoring and Services: IN2P3 (France), CTA-Spain

Calibration devices: IN2P3 (France)

Assembly, validation: IRFU (France)