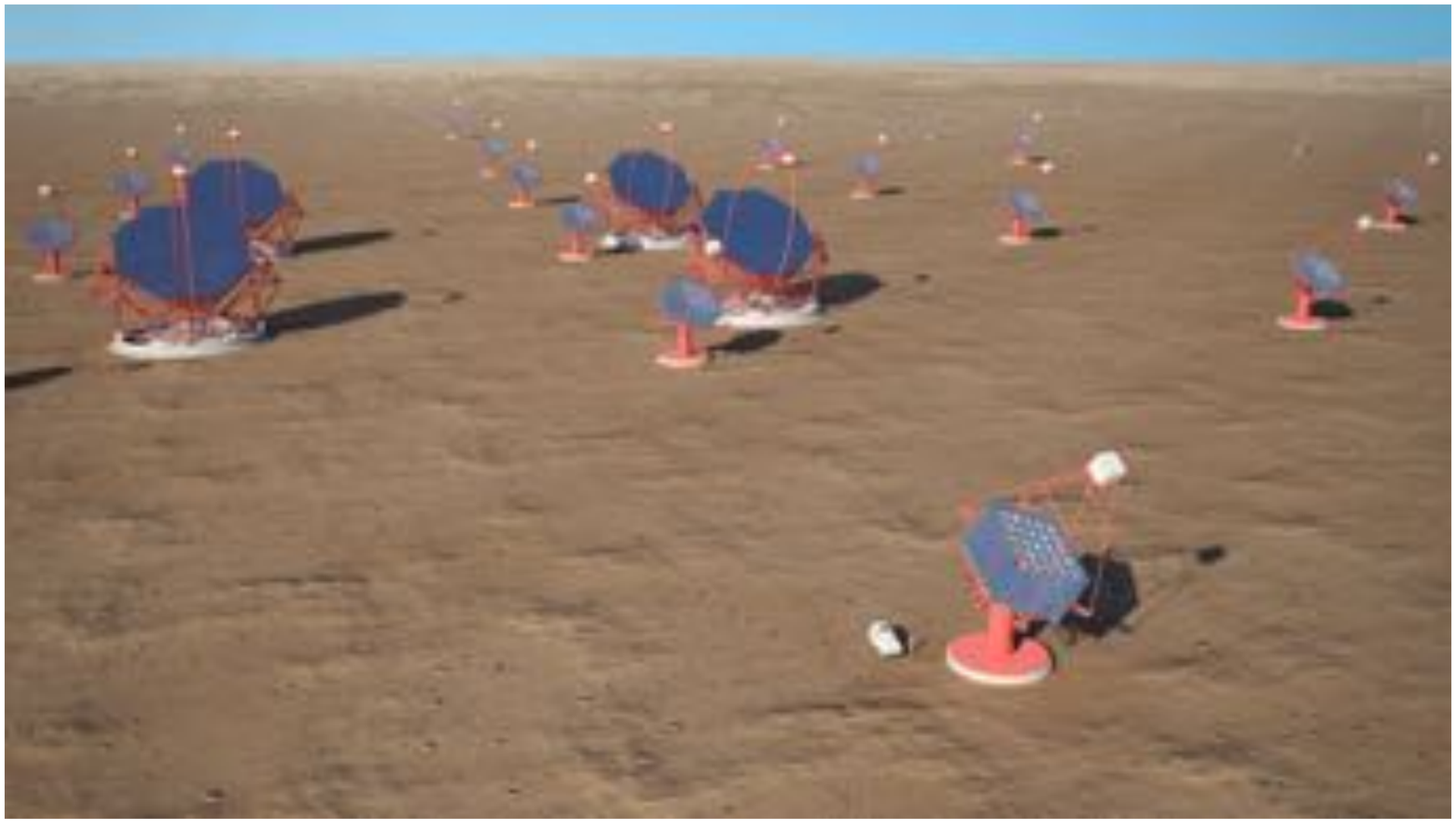
CTA and NectarCAM

CS @ LLR — June 29, 2016

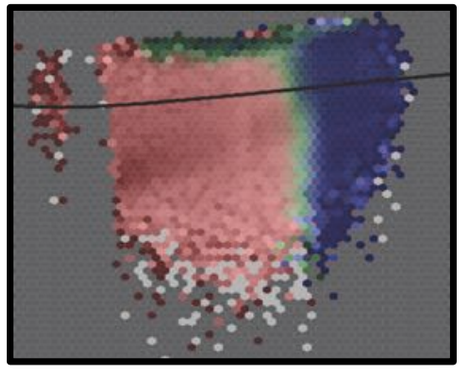
Stephen FEGAN

Cherenkov Telescope Array (CTA)

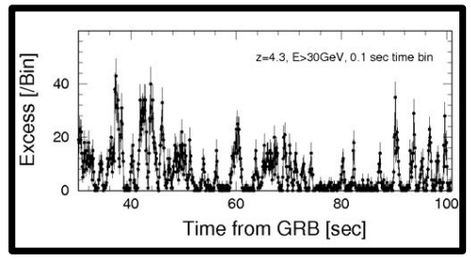


- Observatory for very-high-energy gamma-ray astronomy (20 GeV - 300 TeV) with a desired sensitivity increase of ~10
- Arrays of three classes of telescopes using *imaging atmospheric Cherenkov effect*.
- Two sites : Paranal (Chile) and La Palma (Canary Islands, Spain)

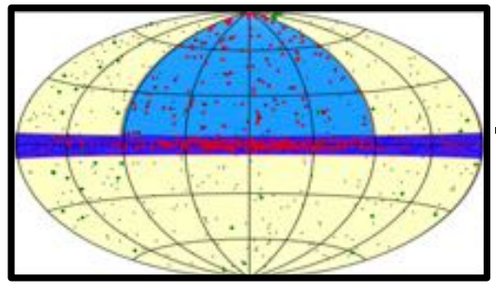
CTA key science projects



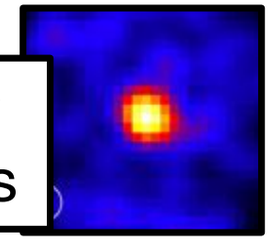
#0 Dark Matter Programme



#5 Transients



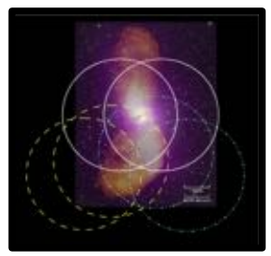
#4 ExGal Survey



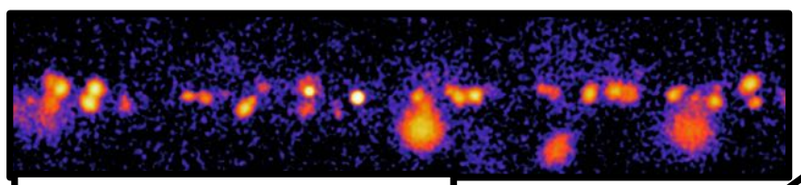
#9 Galaxy Clusters

Extragalactic

#7 Star Forming Systems

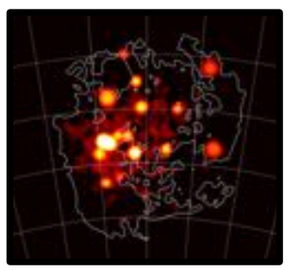


#8 AGN



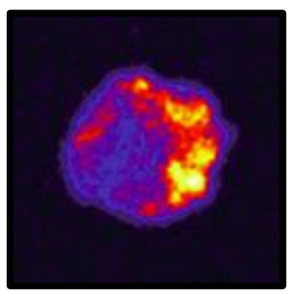
#2 Galactic Plane Survey

#3 LMC Survey

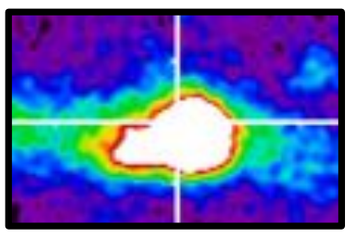


Galactic

#6 PeVatrons



#1 Galactic Centre

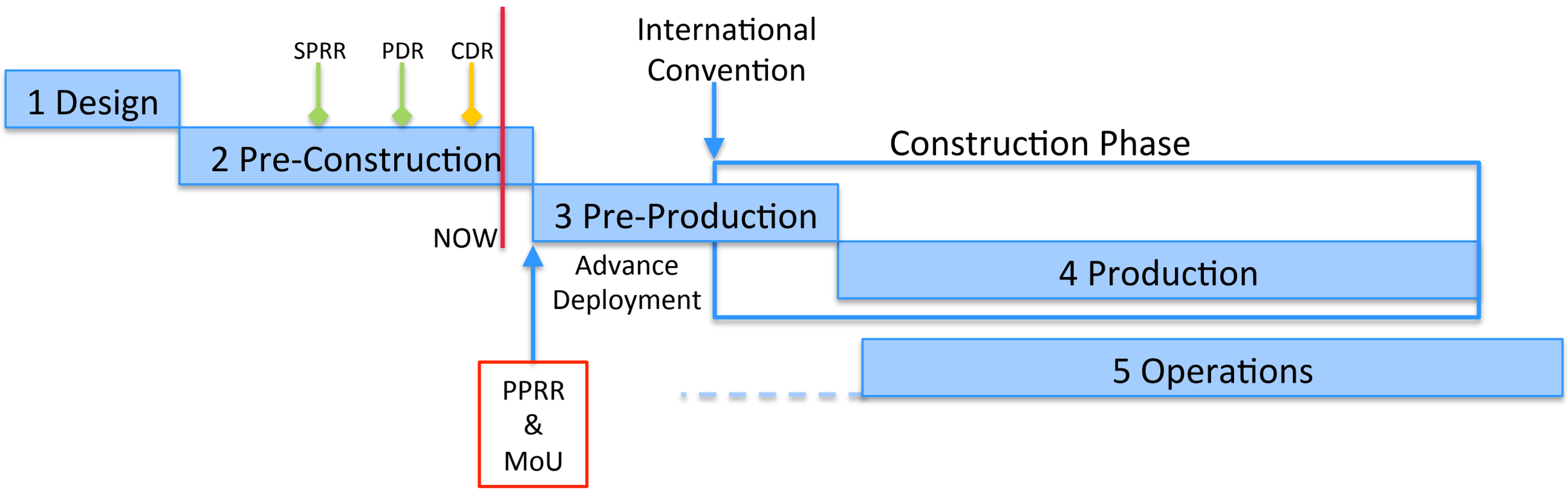


(Credit: Rene Ong)

CTA construction threshold

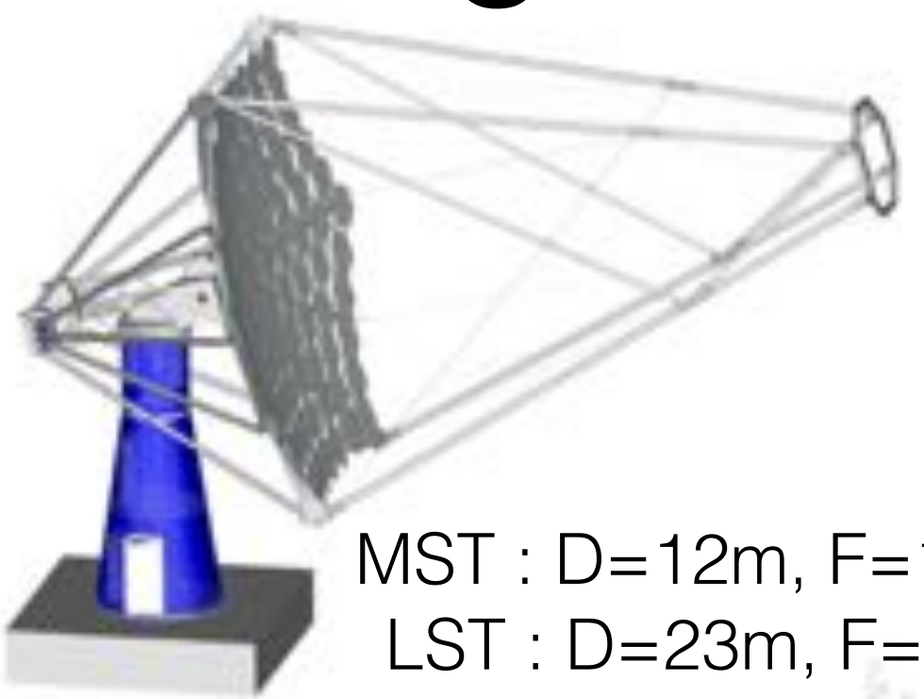
- EoI : 450M€ cost of full array envisioned by consortium; 250M€ in funding identified
- Threshold for construction - initial phase to to implement minimum “threshold” of array costing 250M€:
  - North : 4 LST, >5 MST
  - South : >15 MST, 50 SST
- Unclear today how this will affect French funding from TGIR (50M€)

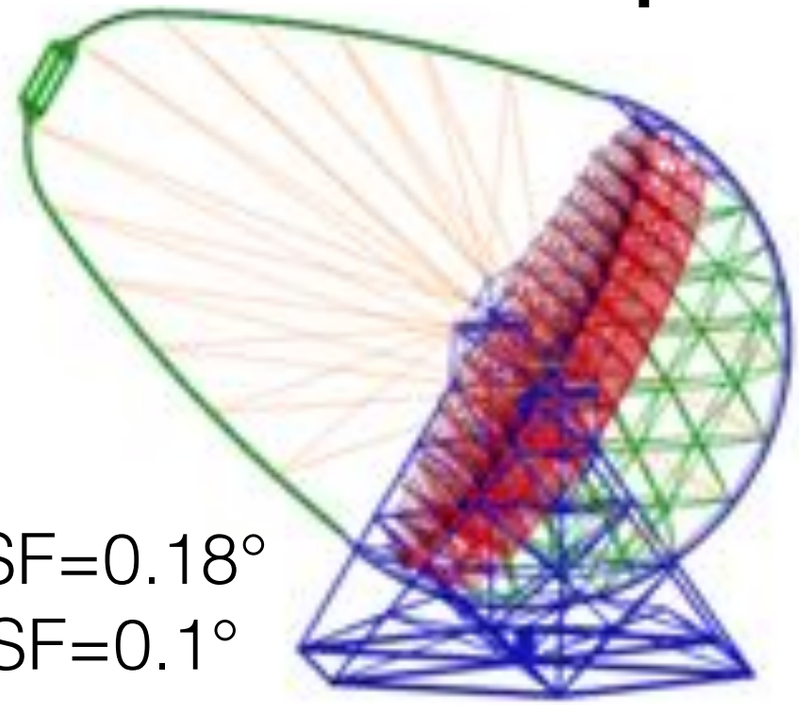
CTA construction timeline



- CTA is (still) in Pre-construction phase, priorities are:
  - ➡ Getting pre-production telescopes on site (PPRR)
  - ➡ Getting site(s) ready for pre-production telescopes
- Discussions for Southern site more difficult that for North.
- Prototypes for different telescopes / cameras at somewhat different points (depending on funding)

CTA single-mirror telescopes

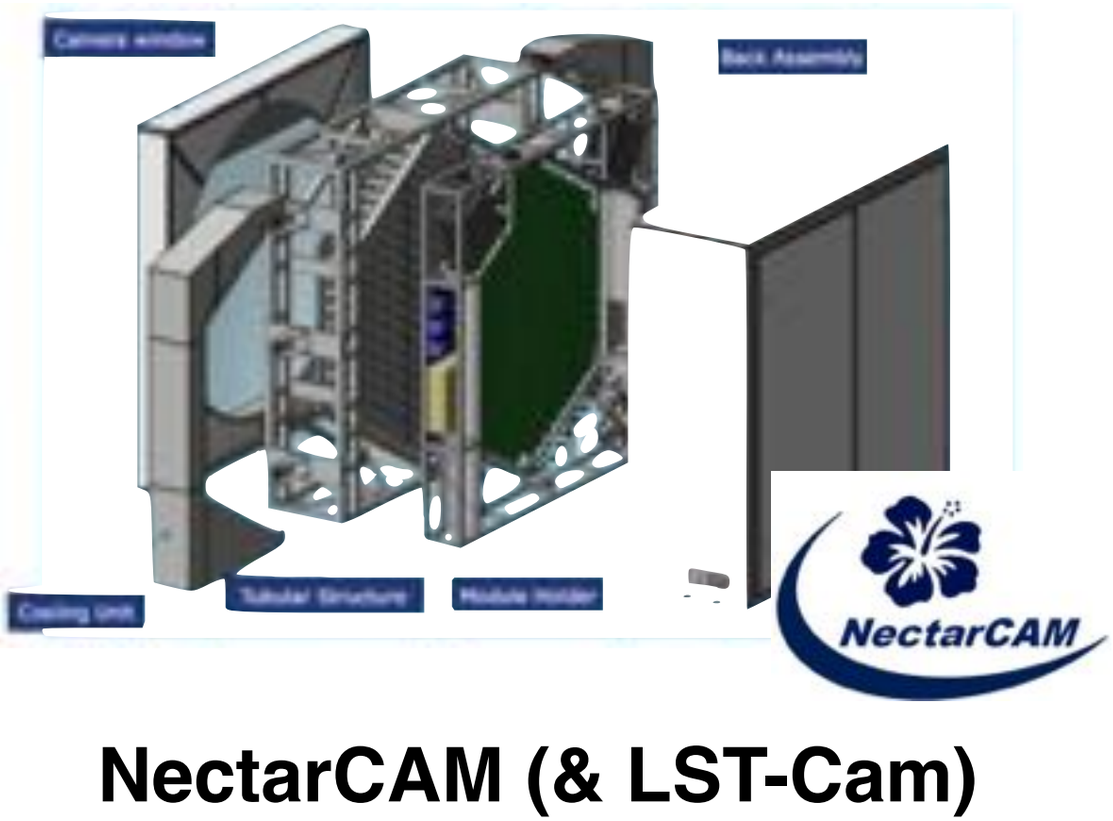


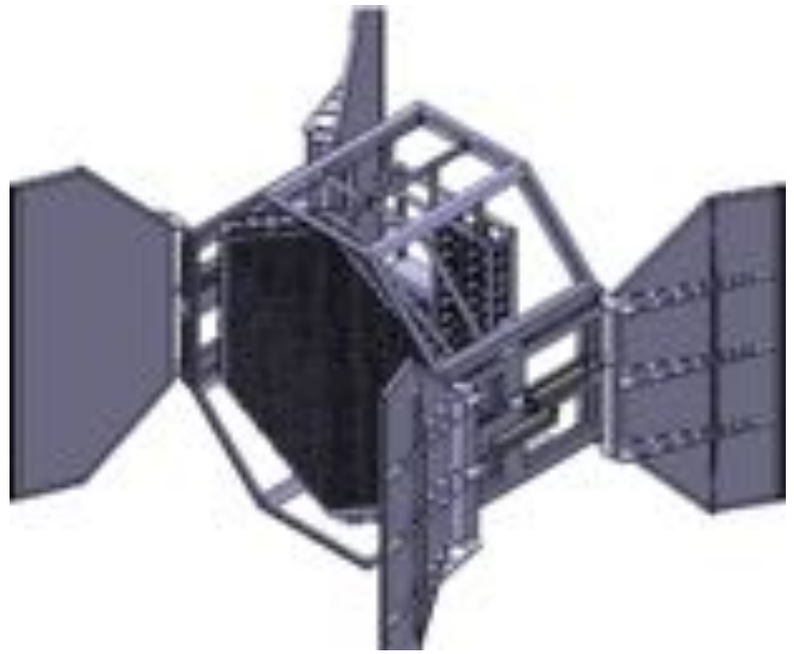


MST : D=12m, F=16m, PSF=0.18°
LST : D=23m, F=28m, PSF=0.1°

- Single-mirror telescope : PSF and plate scale compatible with classical camera of PMTs (MST : 5cm = 0.18°)
- Three cameras proposed : **NectarCAM (MST Nectar ASIC)**, FlashCam (MST, FPGA) and LST-Cam (LST, Dragon ASIC)
- Similar mechanically & optically : 2,000 channels, 2-3m diameter, <2,000 kg in weight
- Different designs : reflect different requirements & philosophies

CTA PMT cameras





NectarCAM (& LST-Cam)

- HESS-like design philosophy
- “Vertical” modules of 7 channels
  - 7 x Concentrators
  - 7 x PMTs
  - Electronics
- Nectar ASIC : **1 GHz ARS / 14-bit**
- High degree of commonality between NectarCAM and LST-Cam

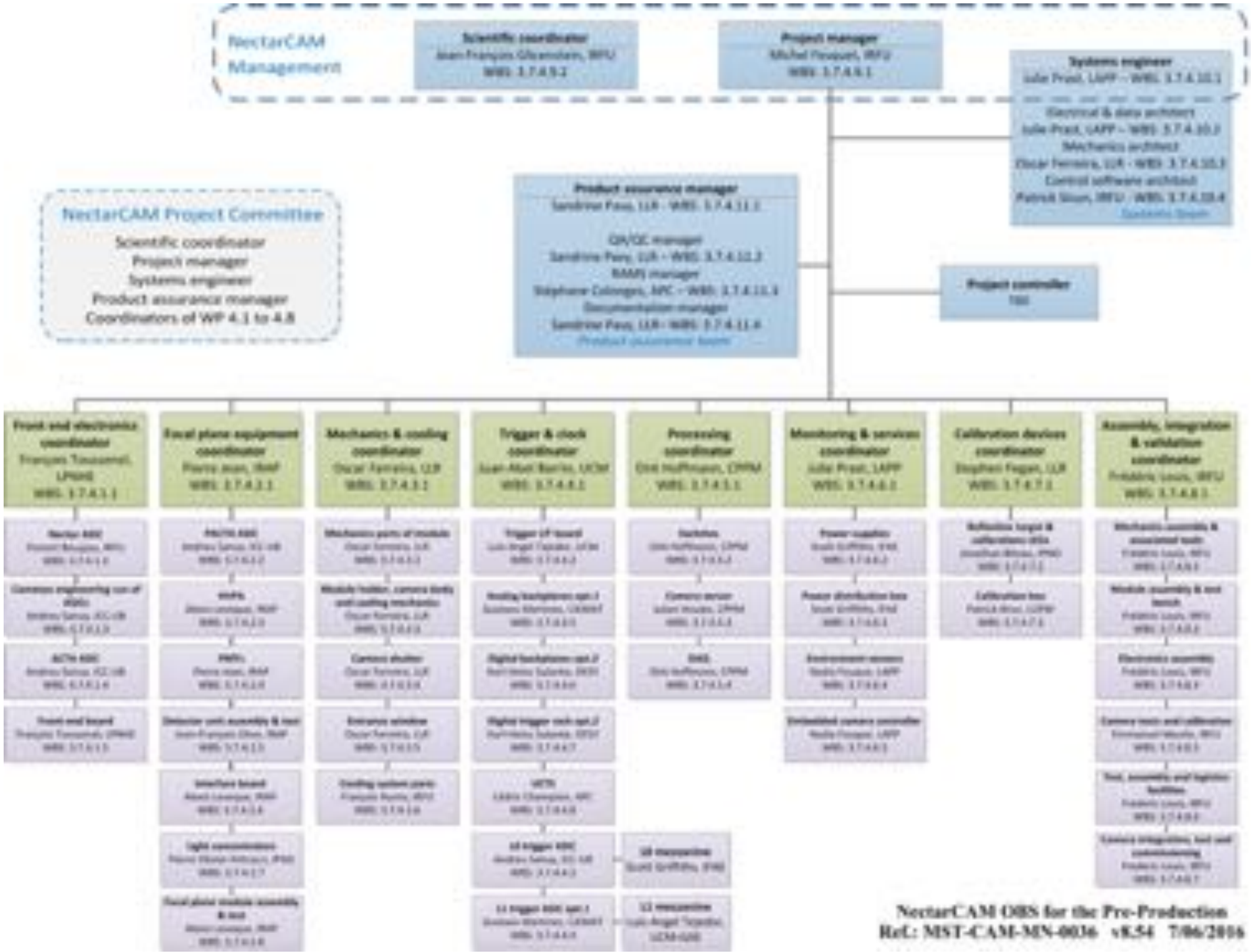
FlashCam

- VERITAS-like design
- “Horizontal” planes:
  - Concentrator plate
  - PMTs and cables
  - Electronics in racks
- Commercial FADCs and FPGAs. Digital trigger.
- **250MHz / 12-bit**

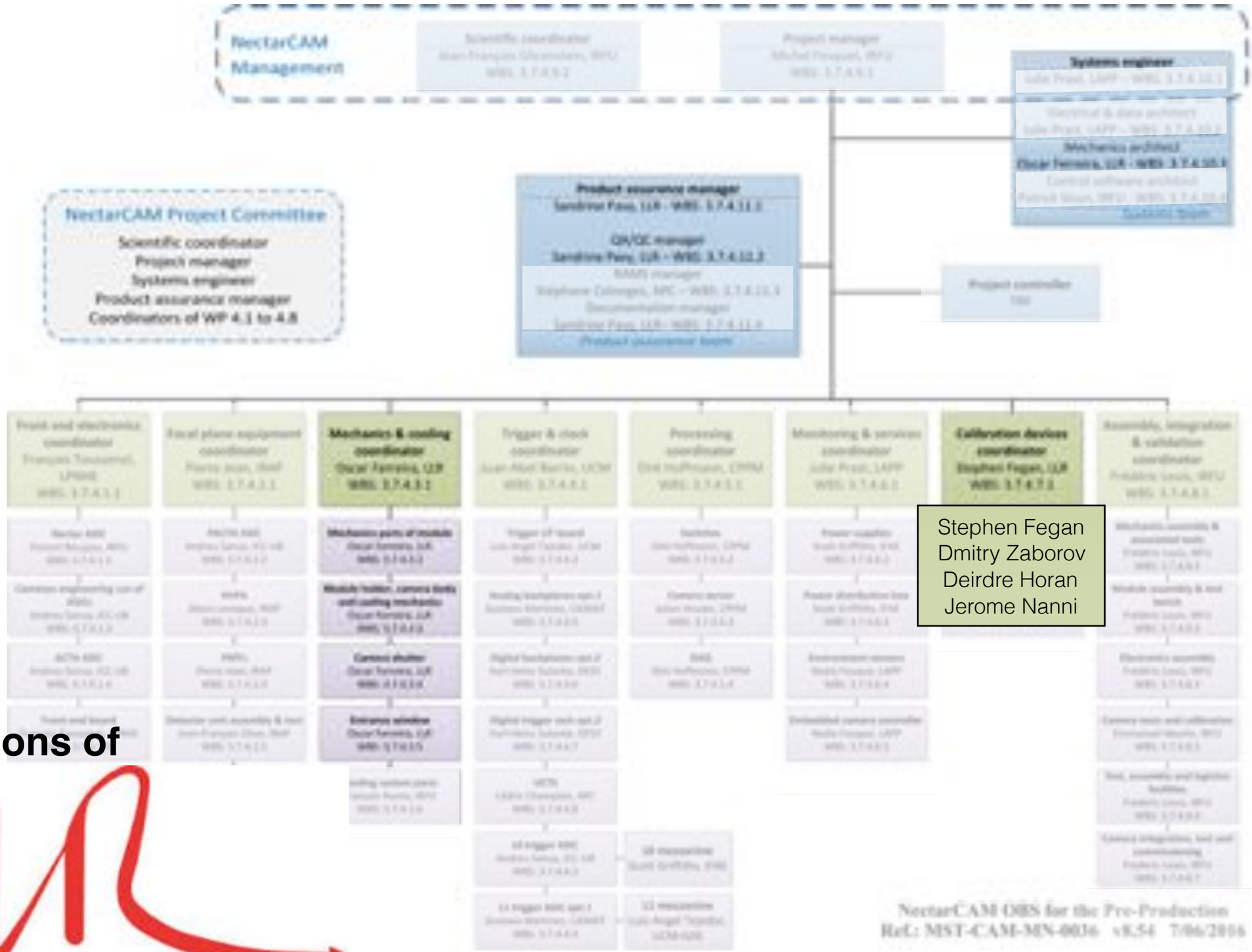
NectarCAM Collaboration

- 14 institutions in France, Spain & Germany
- **Focal plane:** IPAG (Grenoble), IRAP (Toulouse), ICC-UB (Barcelona)
- **Mechanics & cooling:** CIEMAT (Madrid), IRFU (Saclay), **LLR (Palaiseau)**
- **Front-end:** LPNHE (Paris), IRFU (Saclay), ICC-UB (Barcelona)
- **Local trigger:** ICC-UB, IFAE (Barcelona), CIEMAT (Madrid), UCM-GAE (Madrid), DESY (Zeuthen)
- **Global trigger/clock:** UCM-GAE (Madrid), APC (Paris), DESY (Zeuthen)
- **DAQ & event builder:** CPPM (Marseille), LUPM (Montpellier)
- **Control, safety, services:** LAPP (Annecy), IFAE (Barcelona), **LLR (Palaiseau)**
- **Calibration:** **LLR (Palaiseau)**, LUPM (Montpellier), IPNO (Orsay)
- **Management, Systems Engineering, Product Assurance:** IRFU (Saclay), LAPP (Annecy), **LLR (Palaiseau),** APC (Paris)
- **Integration:** IRFU (Saclay)

NectarCAM HR architecture



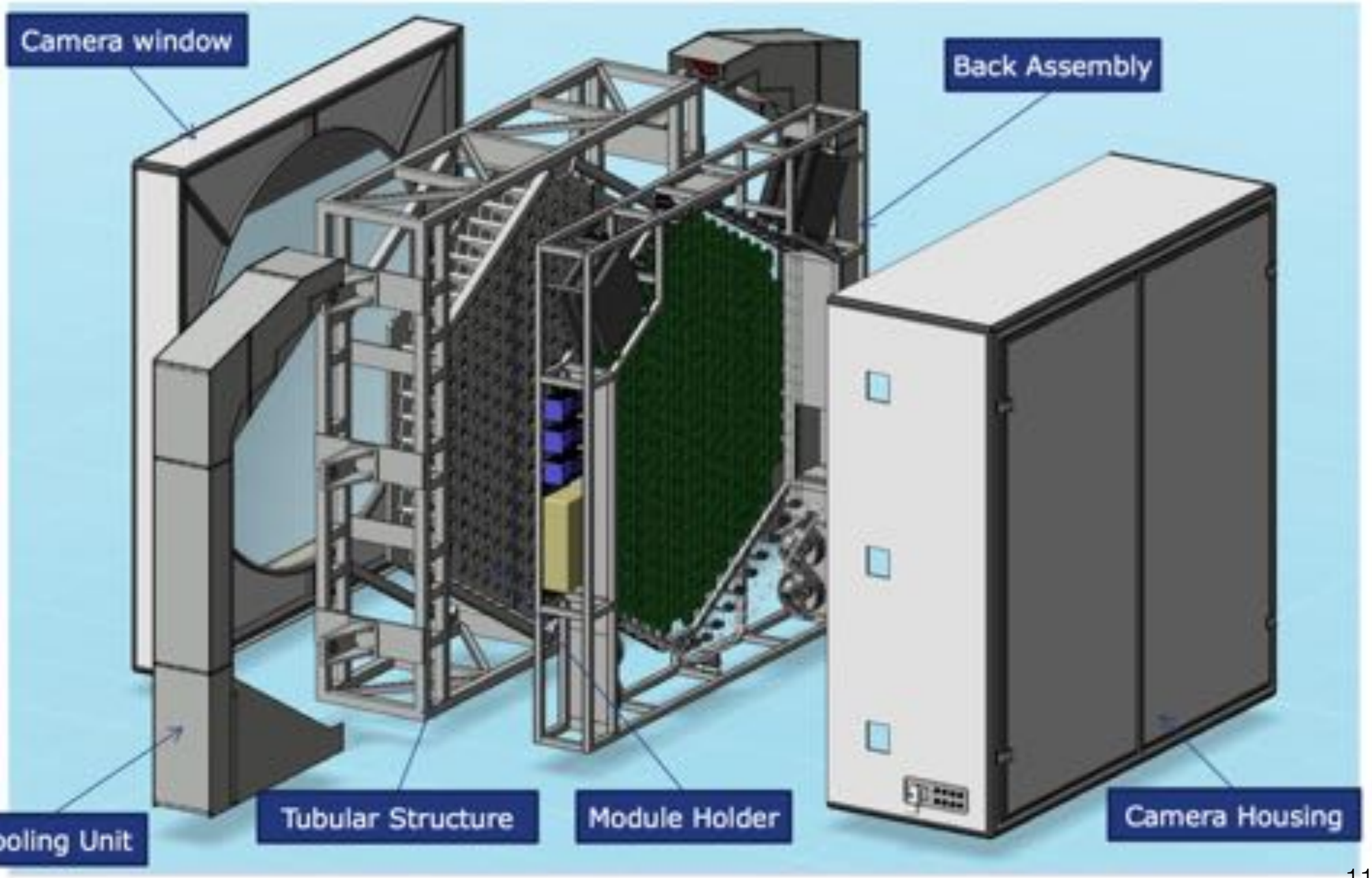
NectarCAM HR architecture



Contributions of

3 members of PC (second only to IRFU who have 4)

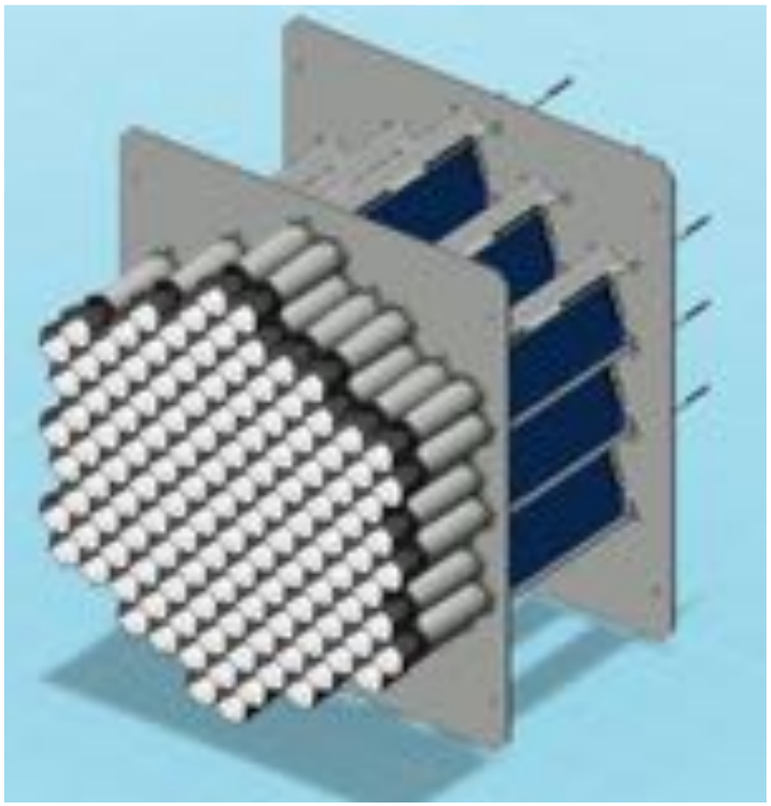
Mechanics & cooling

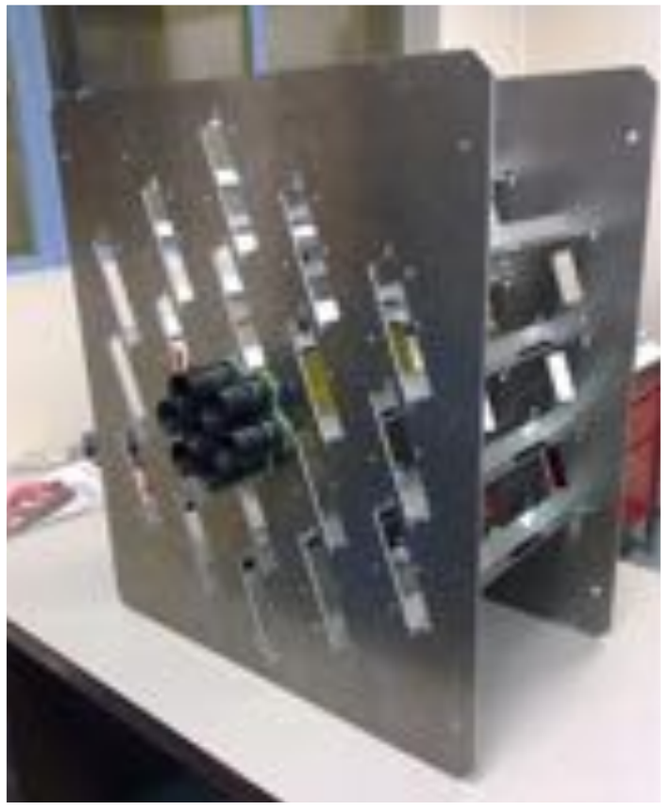


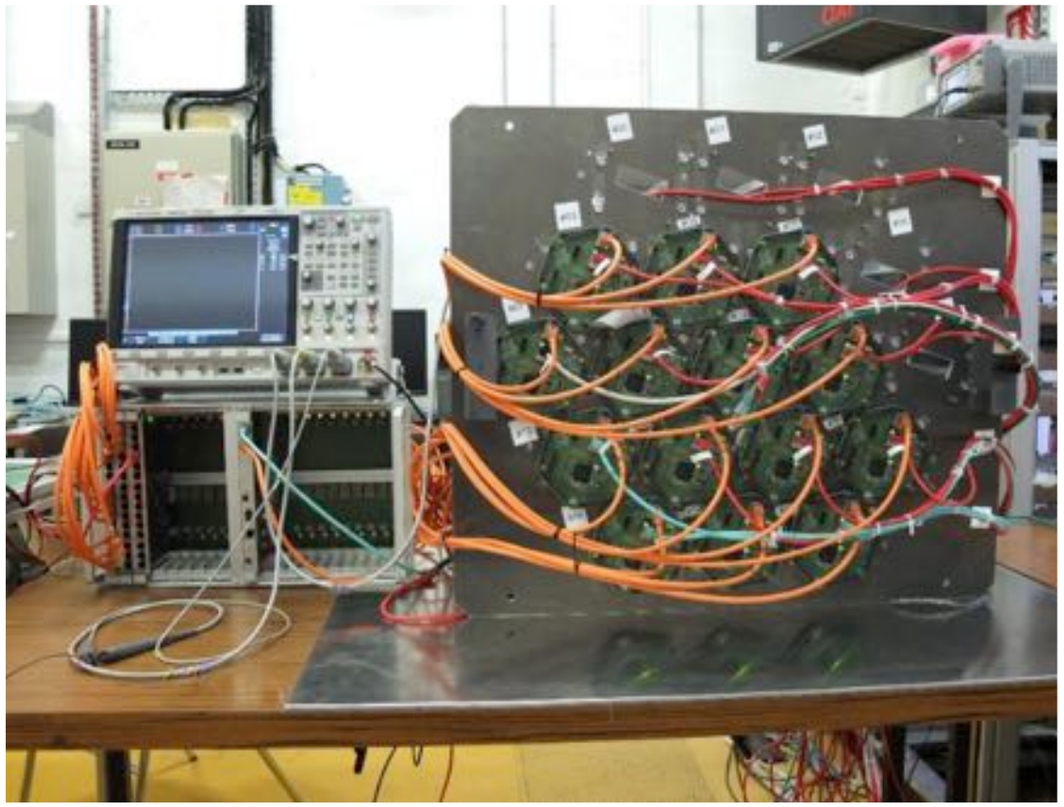
Mechanics WP Organisation

NectarCAM - LLR / LST - CIEMAT	NectarCAM (QM)	LST (1)
Camera Module		Japan
Module Holder		
Tubular Structure		
Cooling System		
Camera Front Part (Window / Shutter)		
Camera Back Part (Cabling / equipment)		
Camera Housing		
Interface with Telescope		

19-module demonstrator

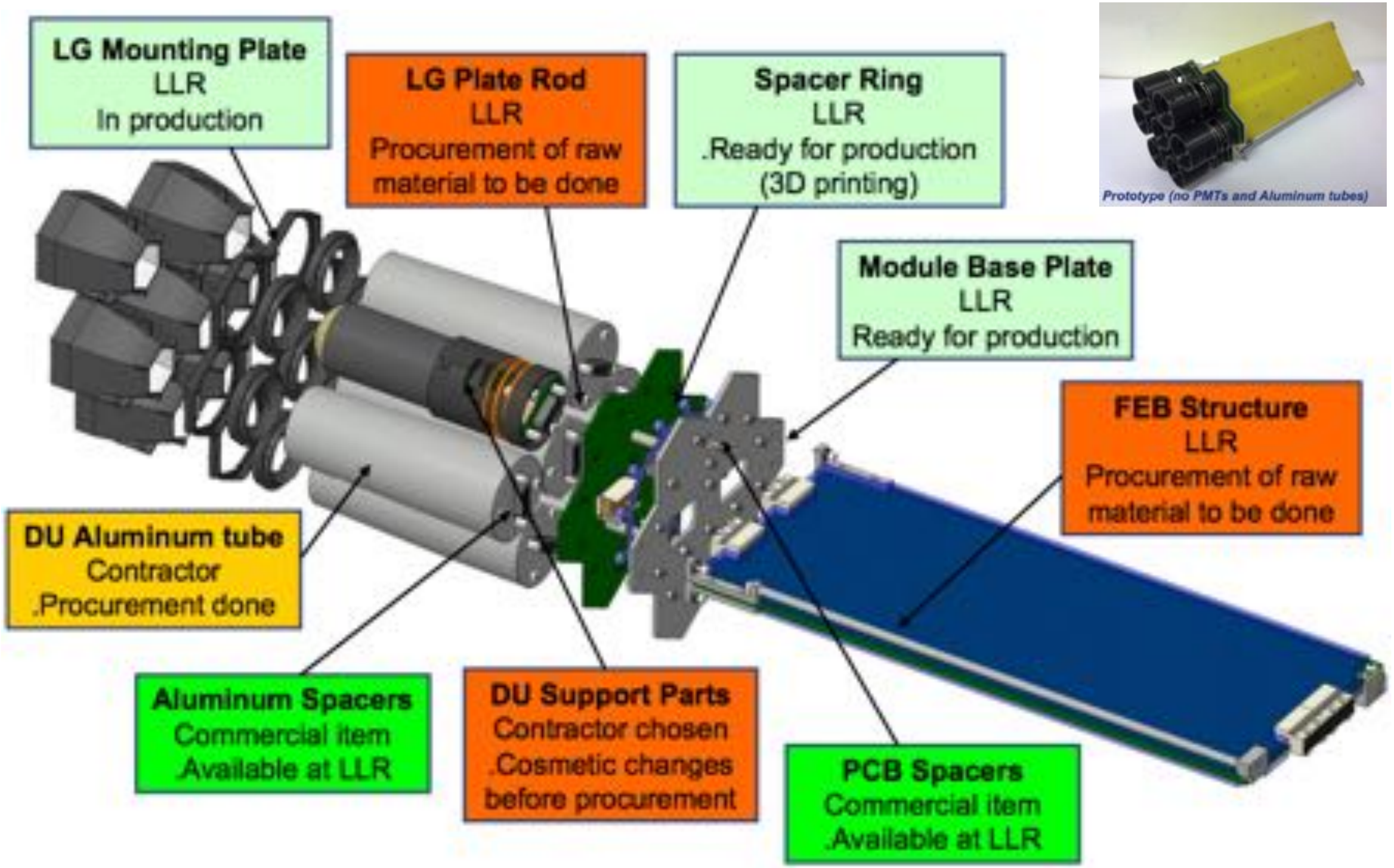






- Bring together most elements of camera for first time for series of robust tests in dark room at IRFU. Major step before full Qualification Model.
- **Detector units** (cones, PMT, HV, preamp), FEBs, L0 and L1 trigger, backplane, clock distribution, DAQ, **mechanical elements**, calibration devices, slow control, OPC-UA interface, data format, **diagnostics and calibration algorithms**.

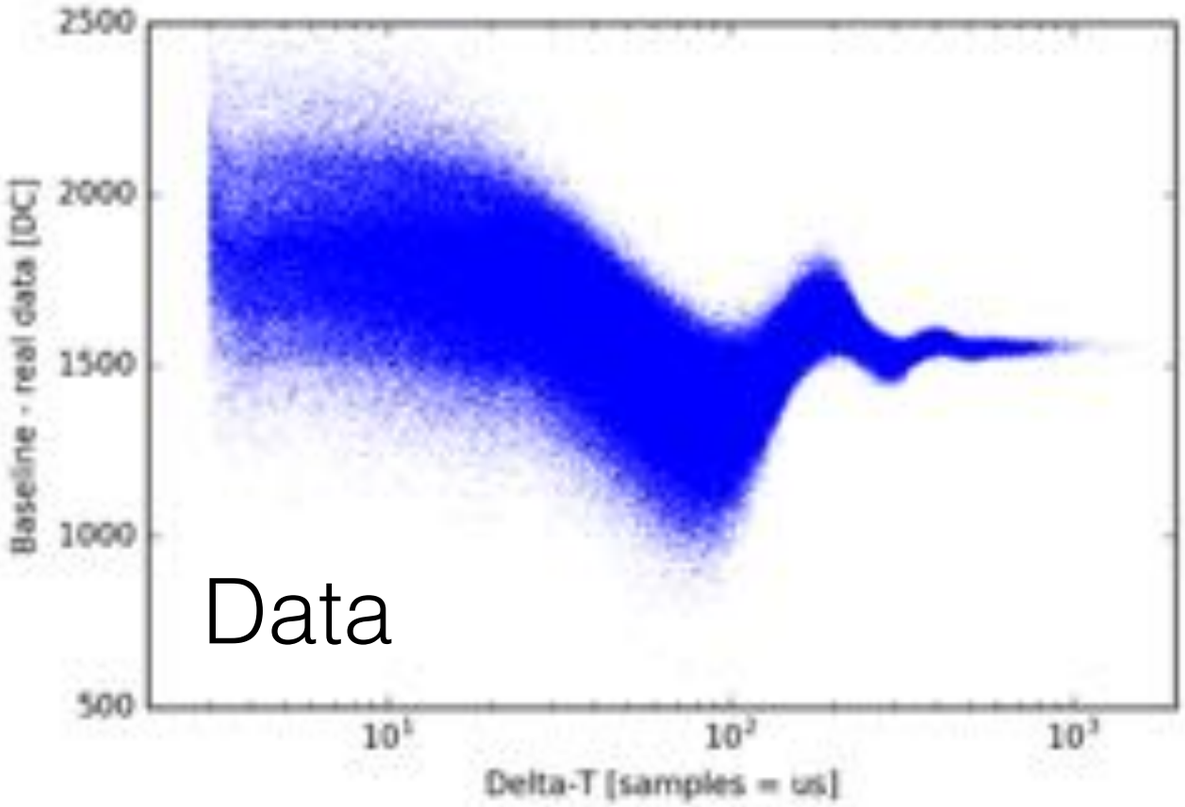
7 channel module

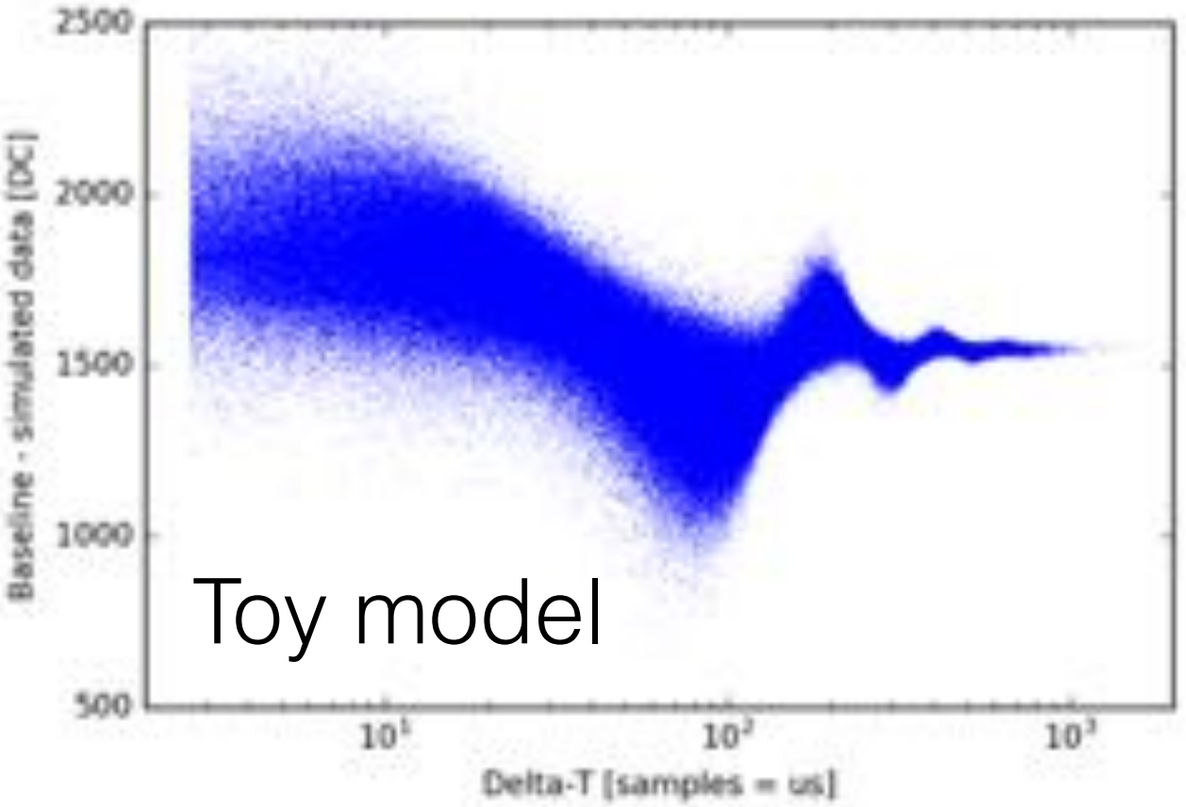


Calibration & validation

- LLR is leader of calibration group for NectarCAM
  - Coordination of calibration devices (internal and external light sources)
  - Interaction with CTA-wide calibration group
  - Development of calibration / validation data analysis code
- Heavily involved in validation of 19-module data

Problems found…

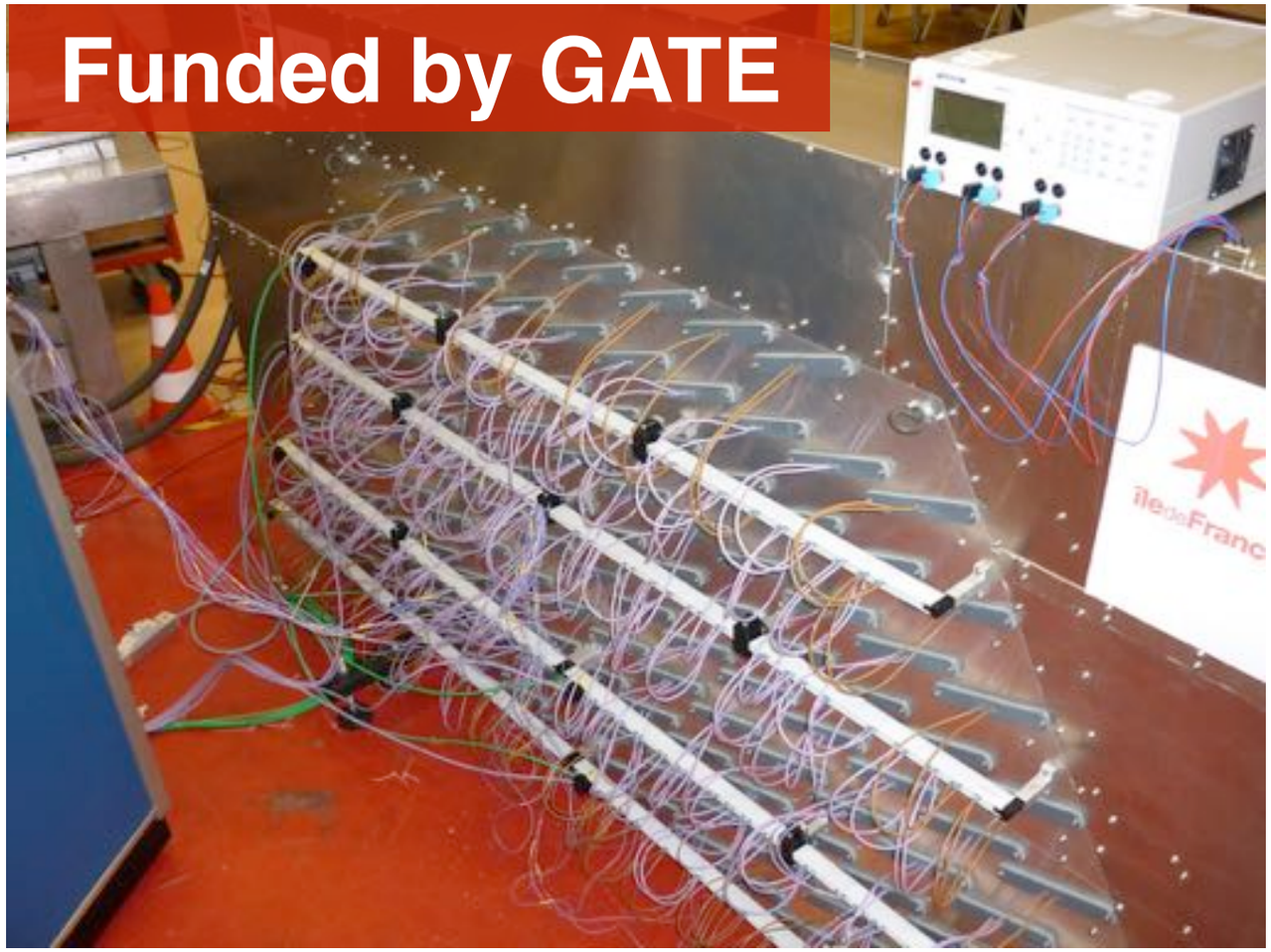


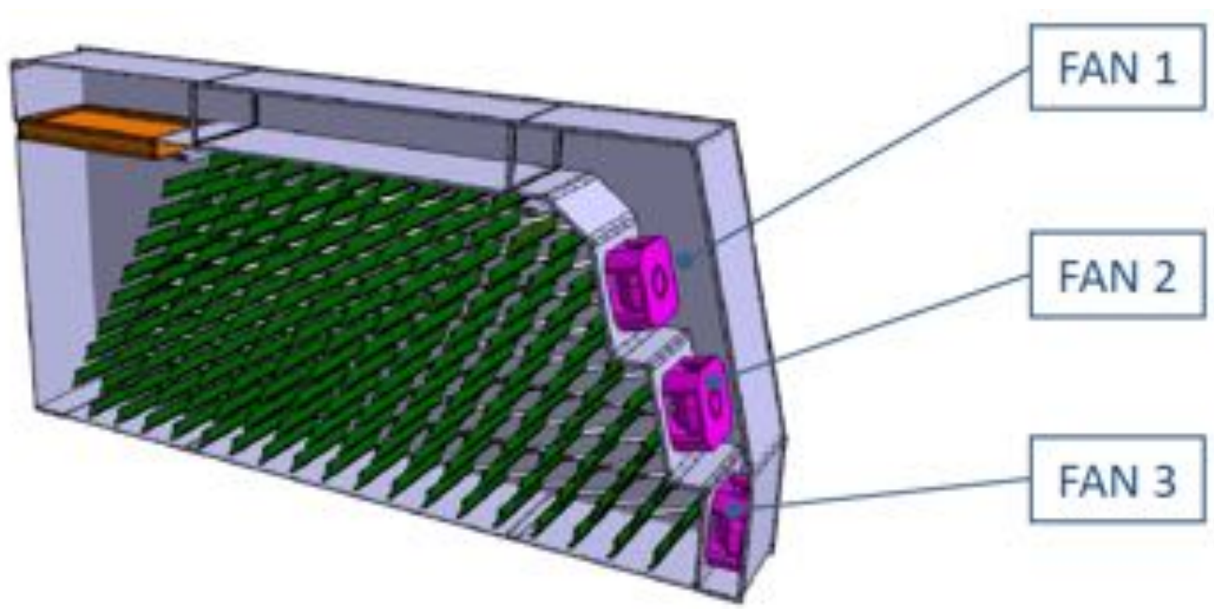


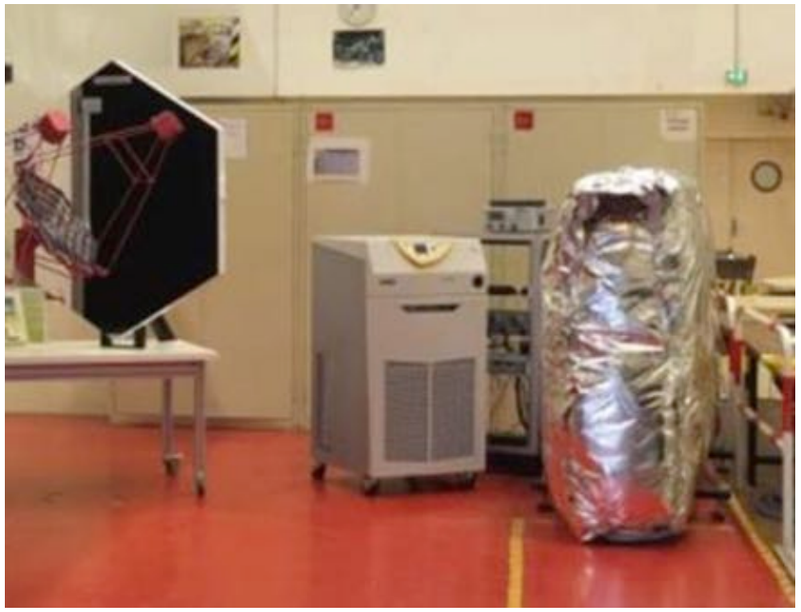
- Triggering of demonstrator using Poisson source for first time. Found that baseline in traces shifts depending on time since last event (& since those previous).
- Possibly caused by Nectar chip switching from “recording” to “reading” mode lit larger power requirements. Power supply not adequately stiff and rejection not good enough.
- Toy model of this scenario matches reasonably well with data.

Thermal demonstrator

Funded by GATE

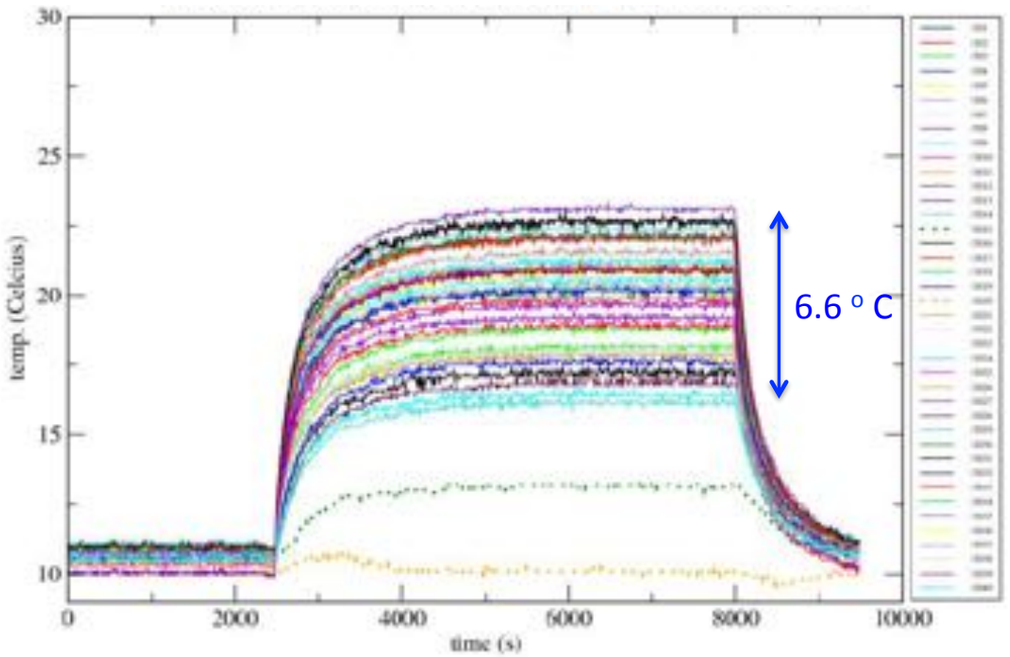




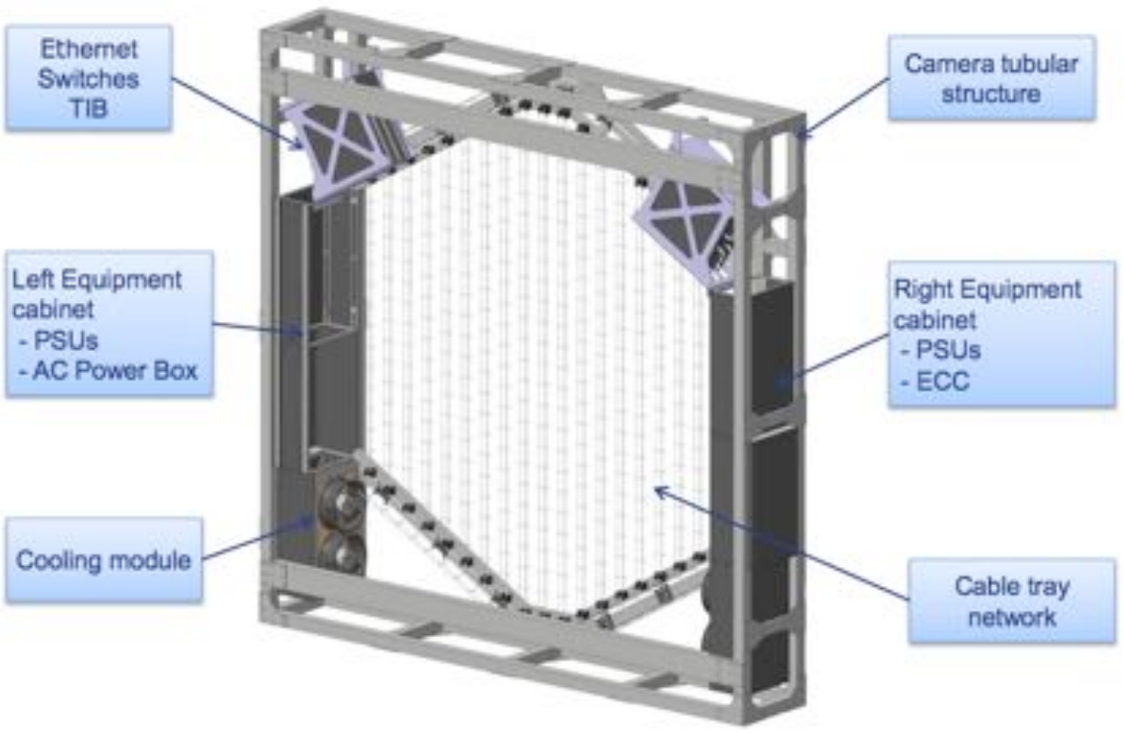


Results:

Gradient in camera less <10° as required. Outside temperature has little effect.



Cabling demonstrator



Product Assurance

- LLR is responsible for product assurance for NectarCAM (Sandrine Pavy)
  - ➡ Coordination of product assurance activities
  - ➡ Product assurance plan : design and write
  - ➡ Control of product management activities across all NectarCAM labs (with local person)
  - ➡ Risk management
  - ➡ Change-request management
  - ➡ Non-conformities management
  - ➡ Newcomer and access rights management for full project
  - ➡ Website and documentation management

P2IO and the QM

- Financing to-date has been very piecemeal - yearly operations support from IN2P3 (INSU, IRFU, ANR) to labs - has permitted (slow) development of most elements to point where 19 module tests possible.

- But next major step is Qualification Model - “full” camera to verify and refine industrialisation plan - required by CTA.

- Major financing commitment required - but TGIR not before 2018.

- P2IO[1] *provided first major financing for NectarCAM* : funds will permit construction of partial QM during 2016-2018.

[1] with DIM-ACAV, OCEVU, OSUG@2020

P2IO and the QM

- CANEVAS : project to build partially instrumented NectarCAM camera that will become QM
- Asked for 894k€, received 710k€ including contribution of 50k€ from IN2P3 for 1-year postdoc.
- LLR : 100k€ for postdoc, 155k€ for hardware:
  2016: 23k€, **2017: 117k€**, 2018: 15k€
- Personnel : 2-year postdoc to help offset loss of manpower in group over last few years (Berrie & Bruno)
- Equipment : build core of camera (structure, modules, cooling, racks, window)
- **But** some components can’t be financed given budget reduction - e.g. shutter. IN2P3 to complete in 2017.

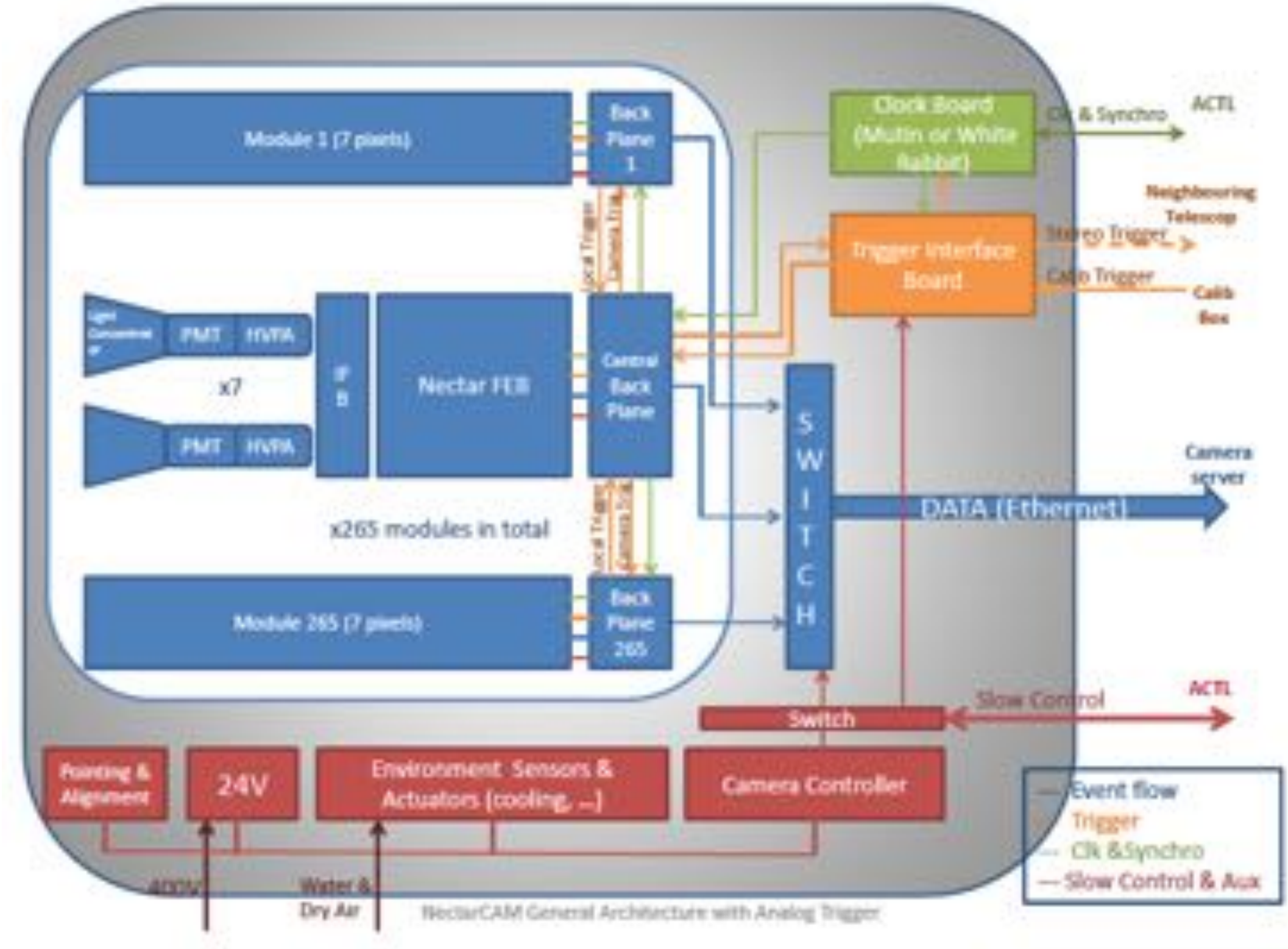
Backup

NectarCAM specs

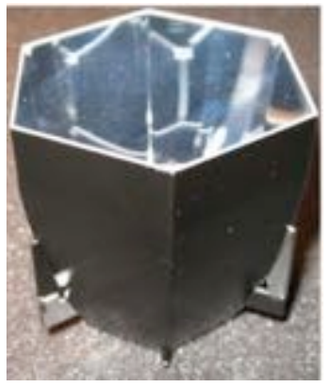
Parameter	Value
Camera Field of View (FoV)	8°
Number of photodetectors	1855 PMT
Number of modules	265 modules
FoV of each photodetector	0.18°
Weight	<2000kg
Width	2.8m
Height	2.9m
Depth	1.15m
Power consumption	<7kW embedded part <3kW ground part

The NECTAr chip has the dual functionality of switched capacitor array and analog-to-digital convertor. The switched capacitor array, which acts as a circular buffer, has a depth of 1024 samples and can be operated between 500 MHz and 3.2 GHz. The NECTAr chip has a bandwidth of more than 400 MHz and a dynamic range of 11.3 bits. The power consumption is 210 mW. The dead time is 2 μs for the readout of 16 cells.

NectarCAM HW architecture

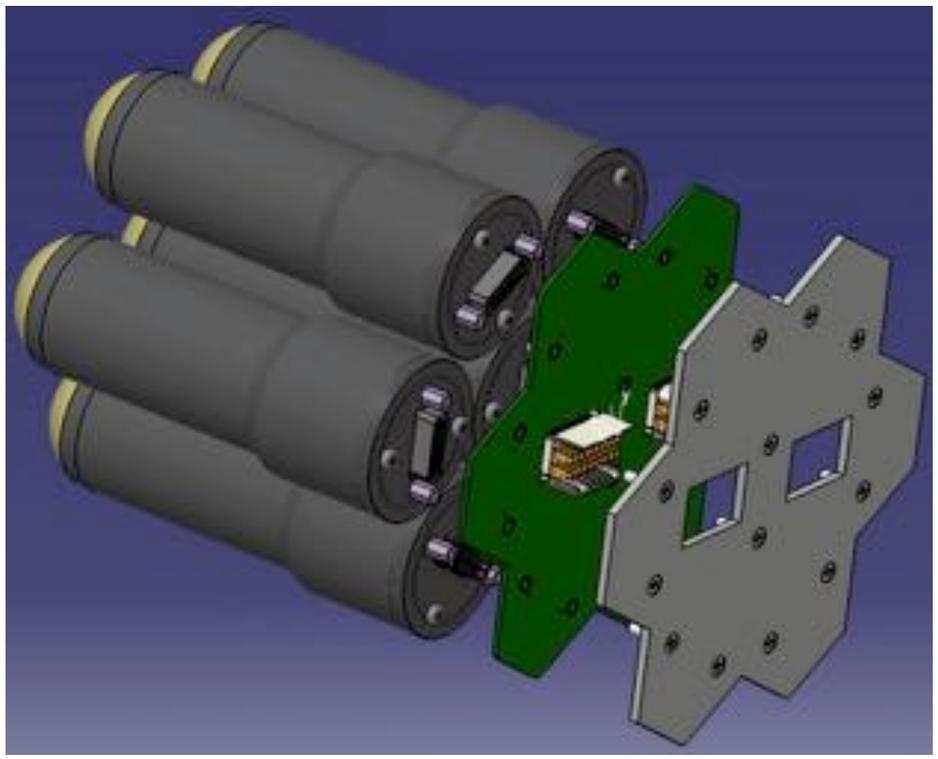


Focal plane



Light concentrator
Winston cone with 86% efficiency. Three parts clip together.

Photo-detector
Default is new high QE Hamamatsu PMT specially designed for CTA. Nominal gain of 4E4 with 7 dynodes. Efficiency integrated with Cherenkov spectrum is 35%.



PMT cluster and interface board
Slow-control interface allows setting of HV, over-current protection, etc., and routes amplified signals to front-end board. Mechanical structure **designed at LLR** includes metallic PMT shield, mounting for HV board and compression spring to hold PMT tightly against front plate.

HV and Preamp board
Cockroft-Walton power supply and PACTA preamplifier ASIC with control interface.

Front-end board

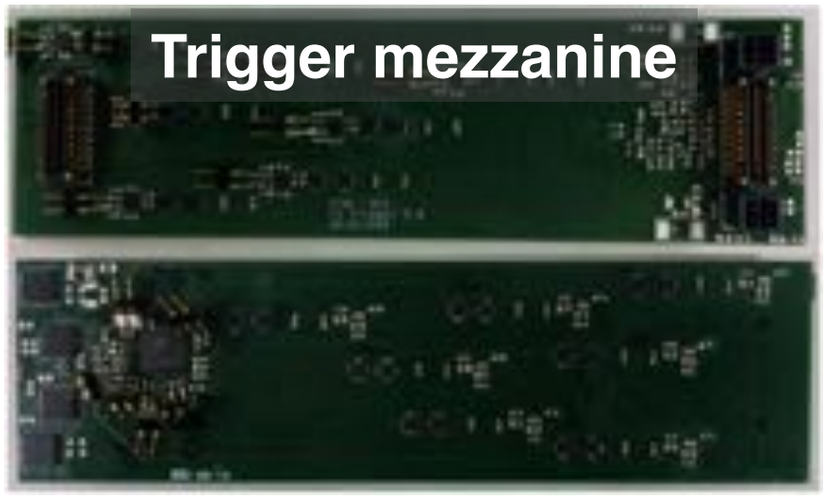
Signal amplification, storage and digitization

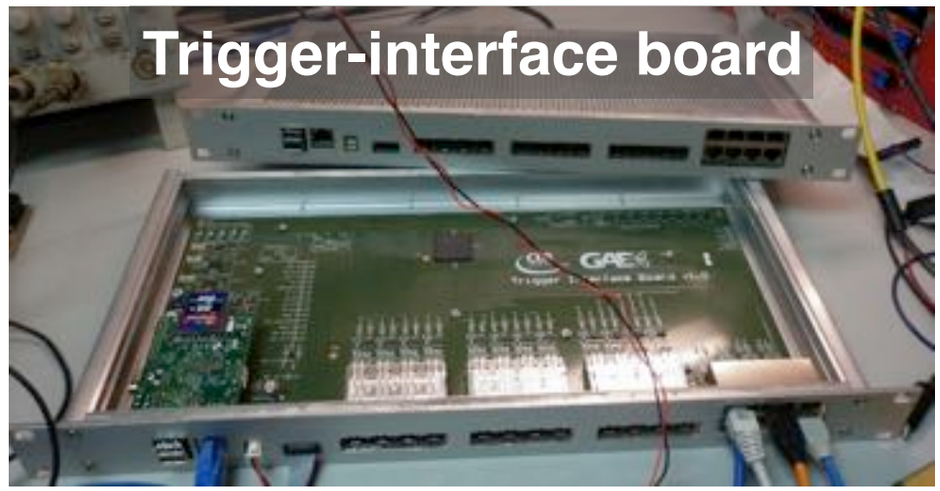
- Amplification in ACTA ASIC - common between NectarCAM & LST-Cam
- Eight Nectar chips with 1024 sample ARS and 12-bit ADC.
- Can sample at >3GHz but will operate at 1GHz for CTA.
- High and low gain channels have ~90DC/PE and ~7DC/PE at PMT gain of 4E4.
- Dynamic range from 0.2 to >3000 PE.
- Sampling mode or integration mode (to reduce data size) on FPGA.

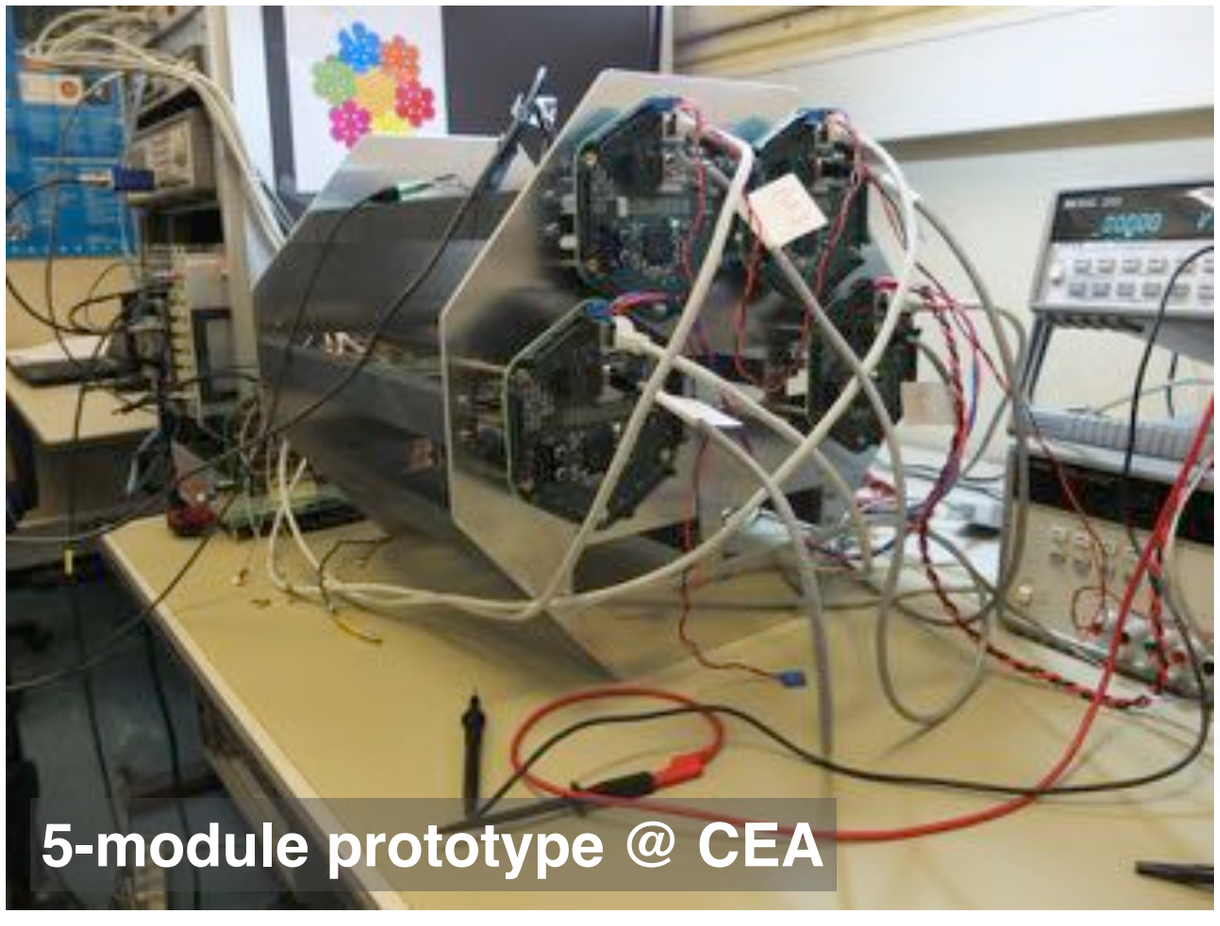
Trigger

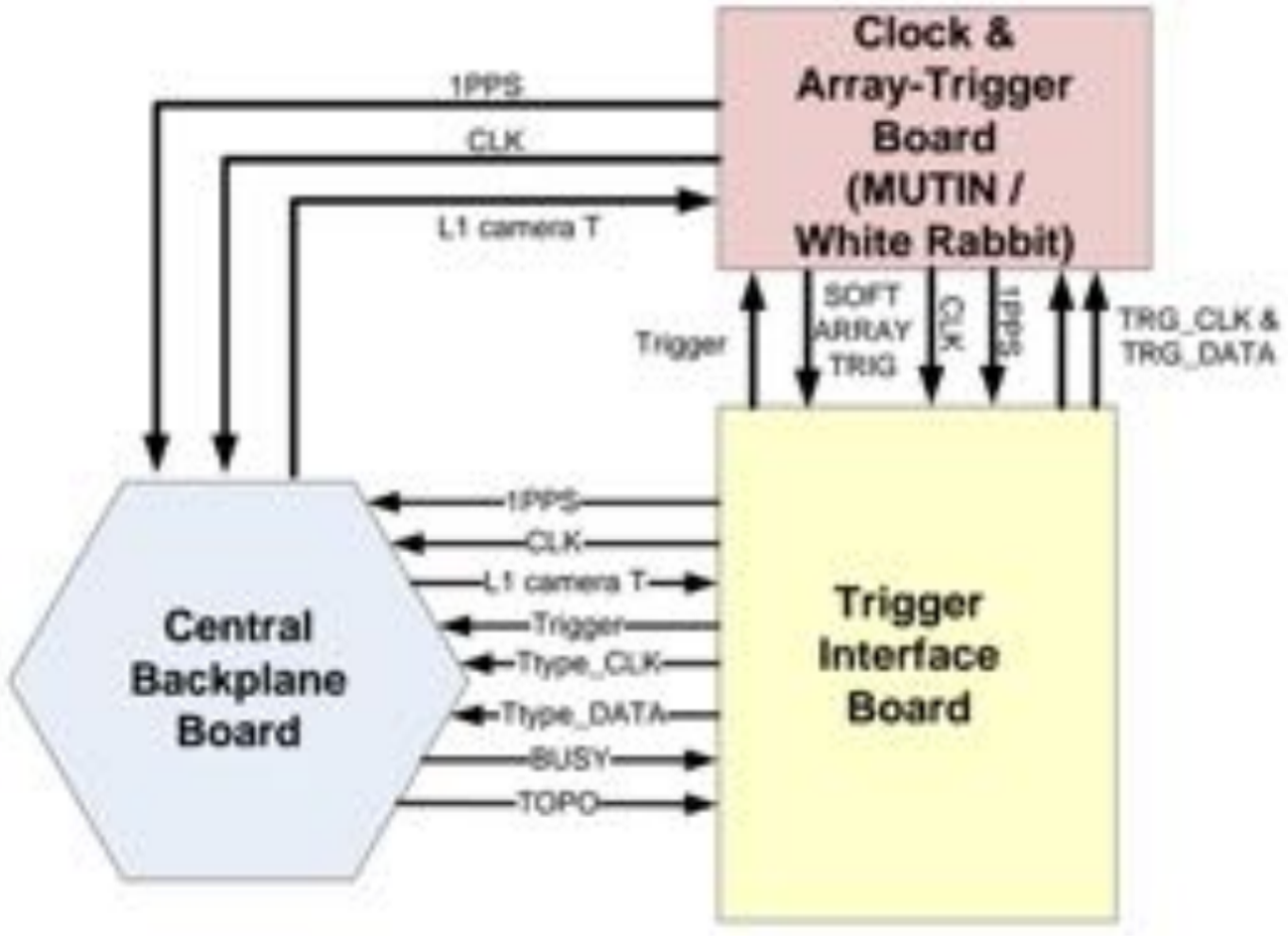
- Two trigger options in development - analogue and digital
- Both are common between NectarCAM & LST-Cam
- Implemented as mezzanine cards in prototype

Trigger









Complexity : must handle different requirements of LST-Cam & NectarCAM