CTA & NectarCAM

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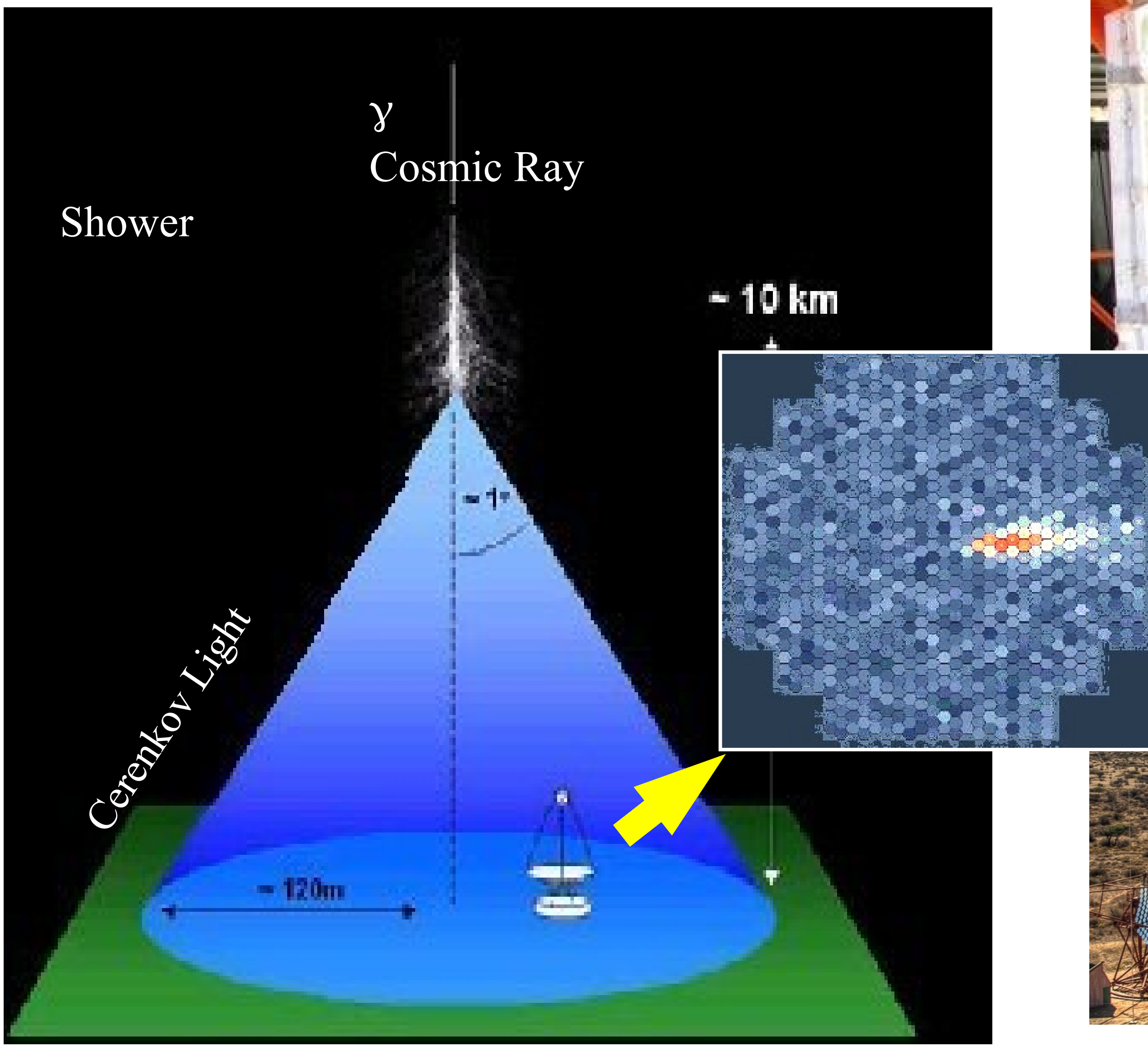
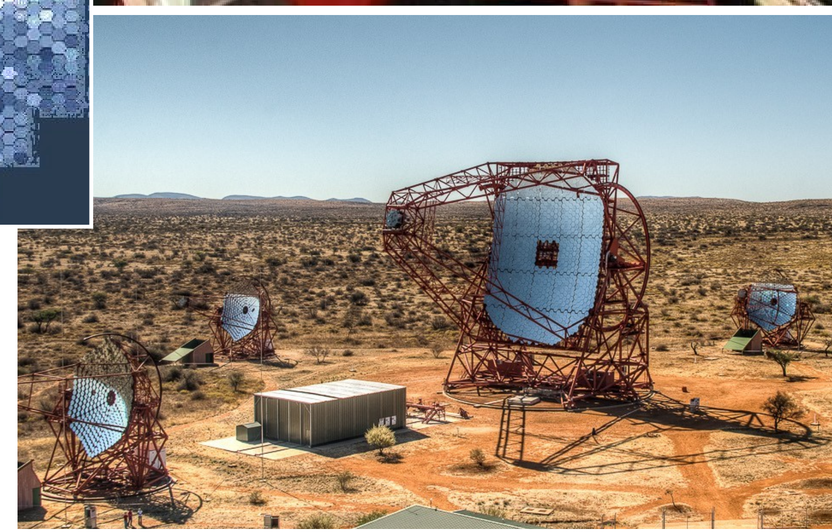
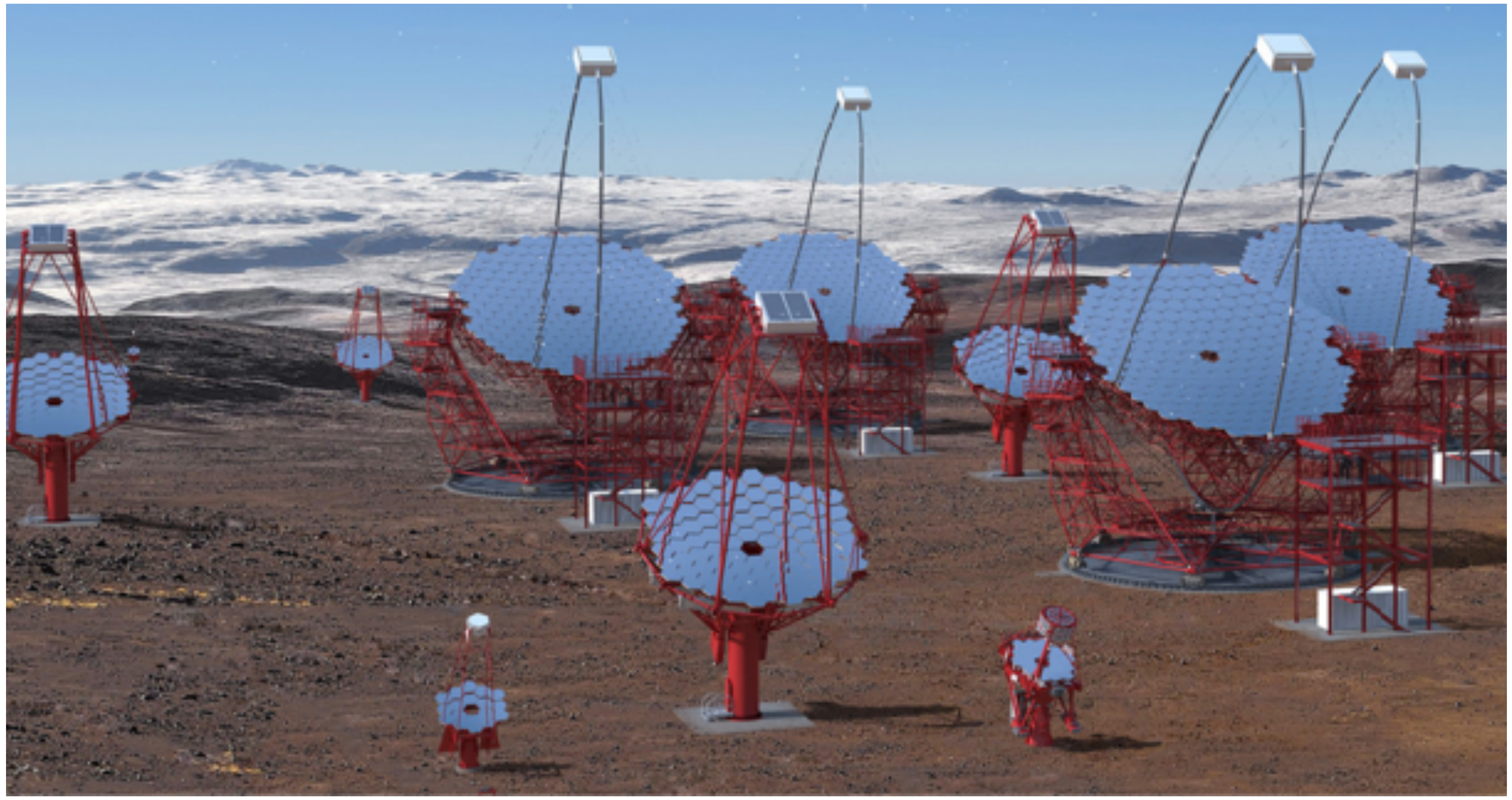
Congrès du LLR 2017-10-19

Technique Cherenkov Atmosphérique



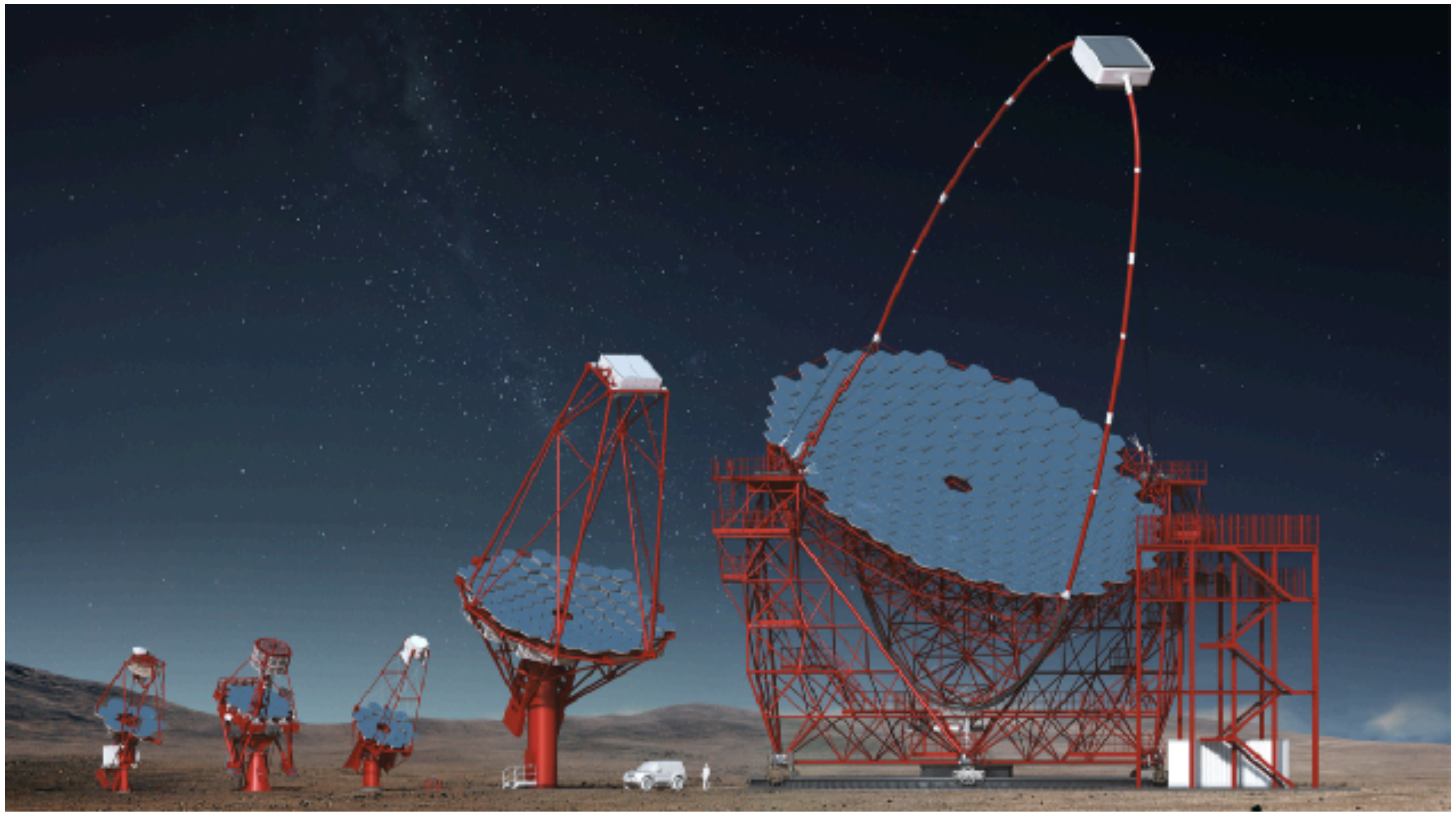


Cherenkov Telescope Array (CTA)



- Observatory for very-high-energy gamma-ray astronomy (20 GeV - 300 TeV) with ultimate sensitivity increase of ~10 over H.E.S.S.
- Arrays of three classes of telescopes using *imaging atmospheric Cherenkov effect*.
- Two sites : Paranal (Chile) and La Palma (Canary Islands, Spain)
- Proposal-driven, open-access facility (new paradigm for VHE astro!)

Cherenkov Telescope Array (CTA)



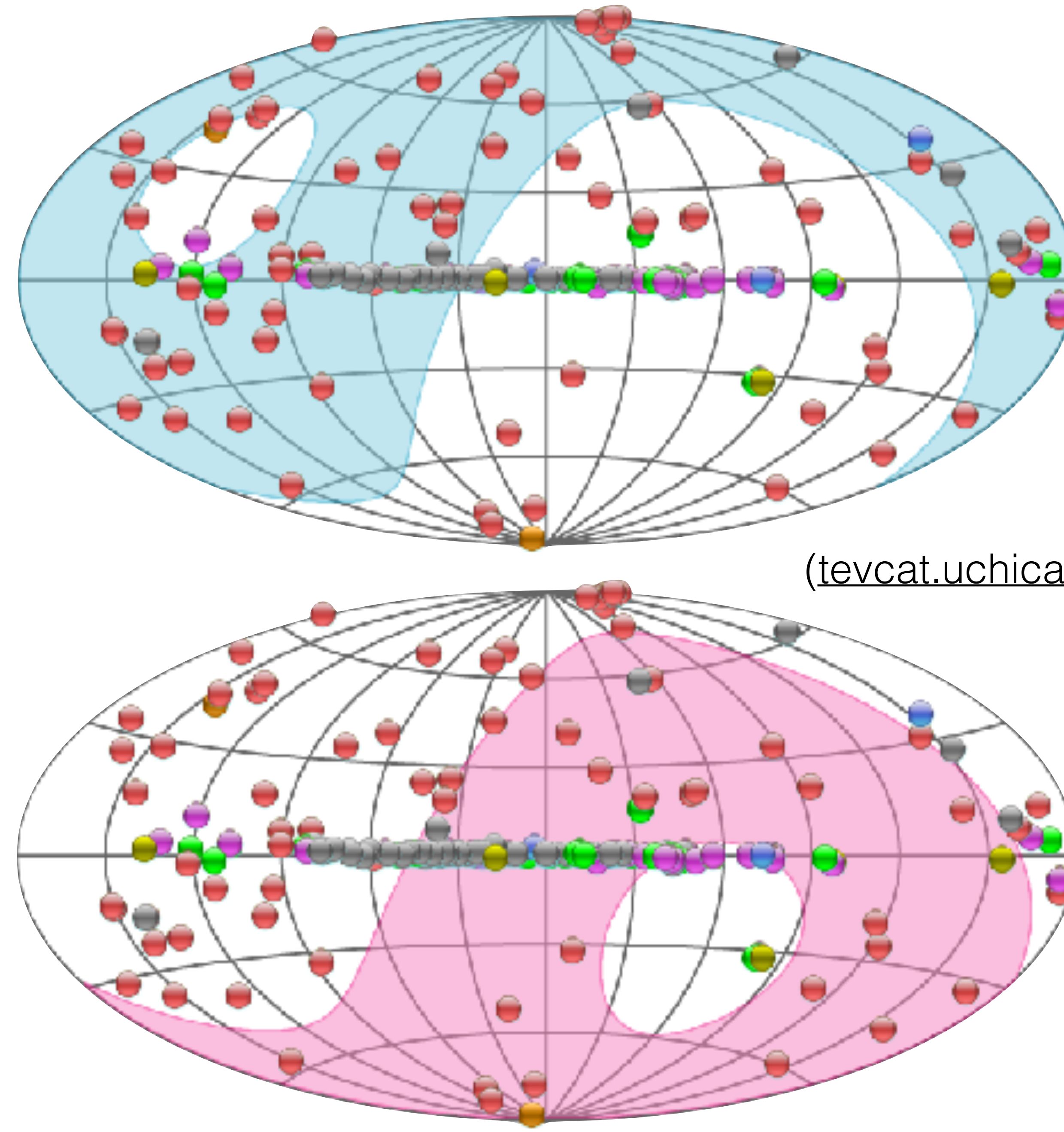
- Three classes of telescope:
  - large (LST), ϕ=23m, north (& south?);
  - medium (**MST**), ϕ=12m, north & south, and
  - small SST, ϕ=1–2m, south.
- **NectarCAM** - one of the camera designs for the MST telescope: France, Spain, Germany. Prototype planned for northern site at La Palma

Principal advances of CTA

- **Two sites** — full sky visible, double available science. First extra-galactic survey (1/4 sky) will complement deep Galactic survey.
- **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.
- **Faster electronics, data processing, rapid pointing…**

One observatory, two sites

CTA-N : 4 LST, 5–15 MST
Effective area @10TeV : 8×10^5 m^2
Focus on extra-galactic sources

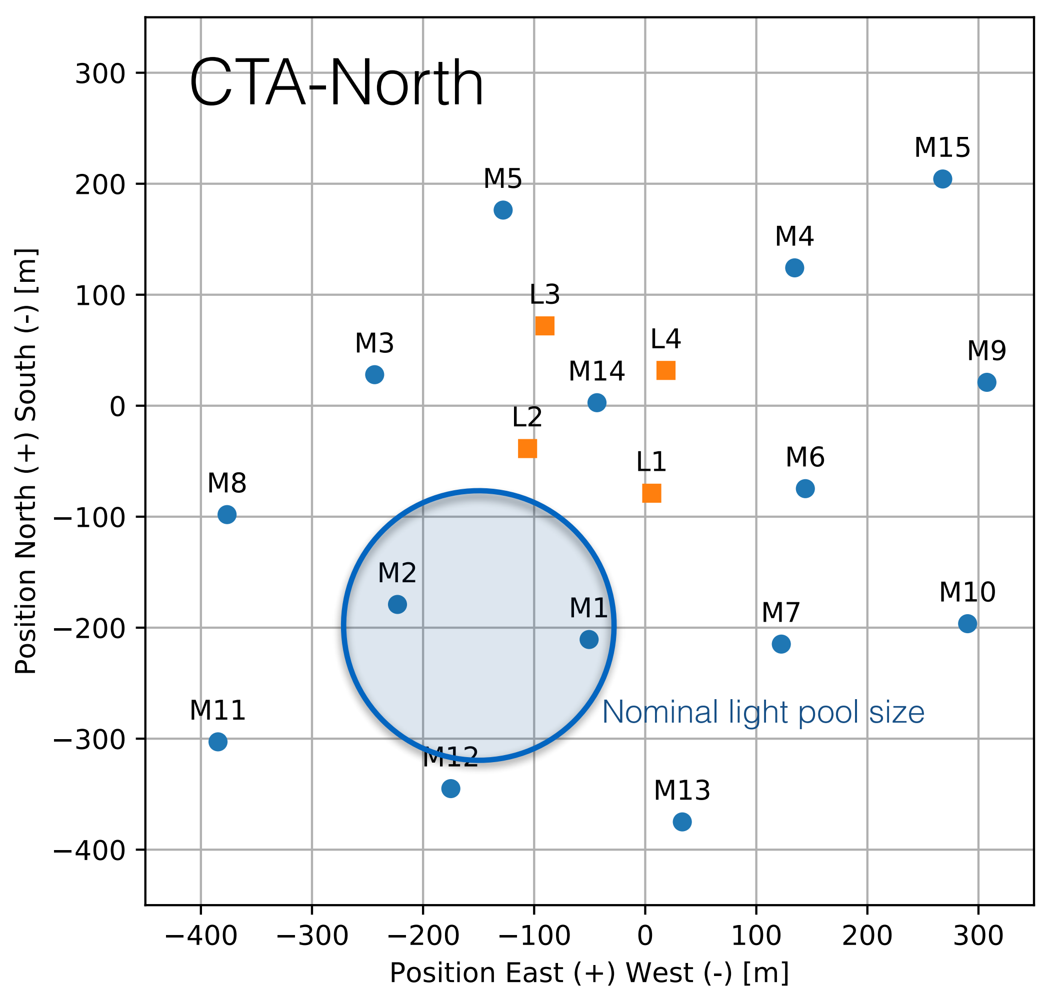


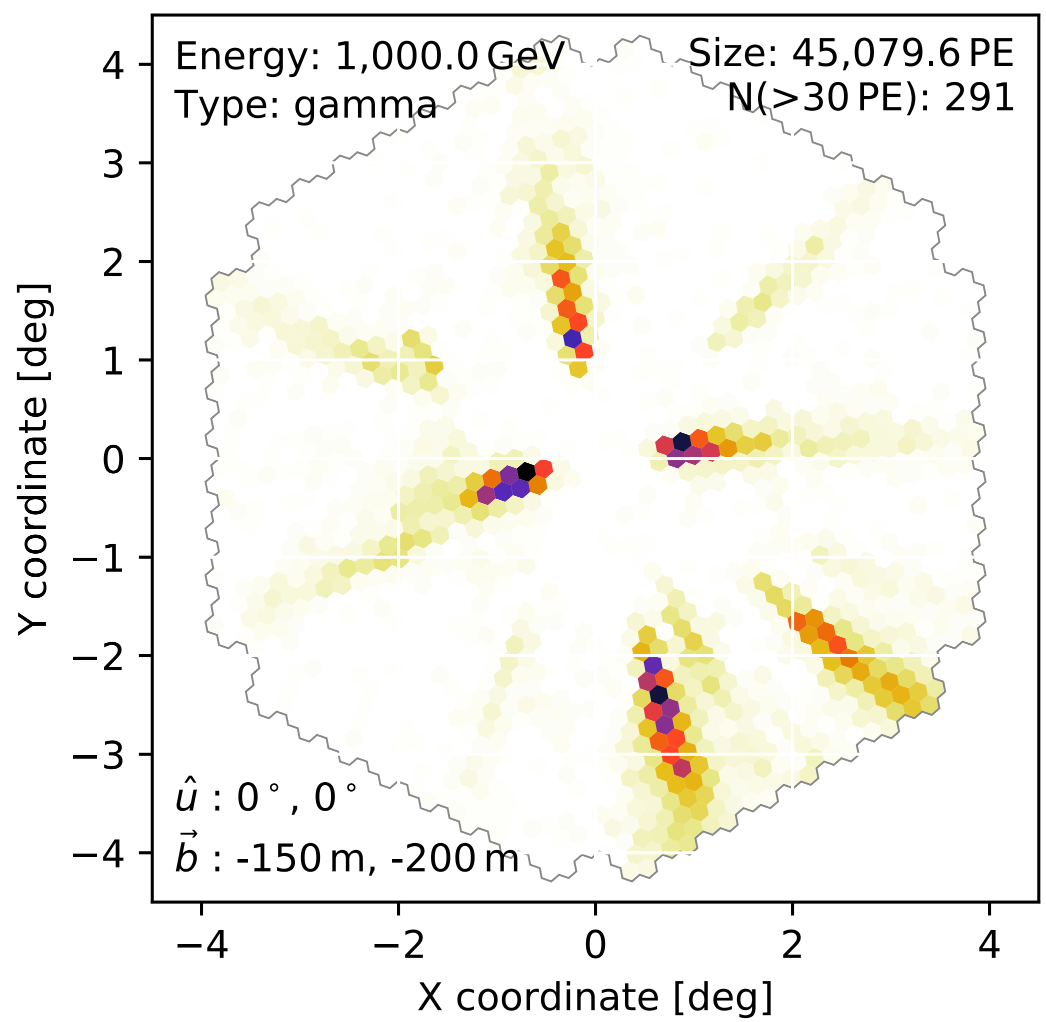
(tevcat.uchicago.edu)

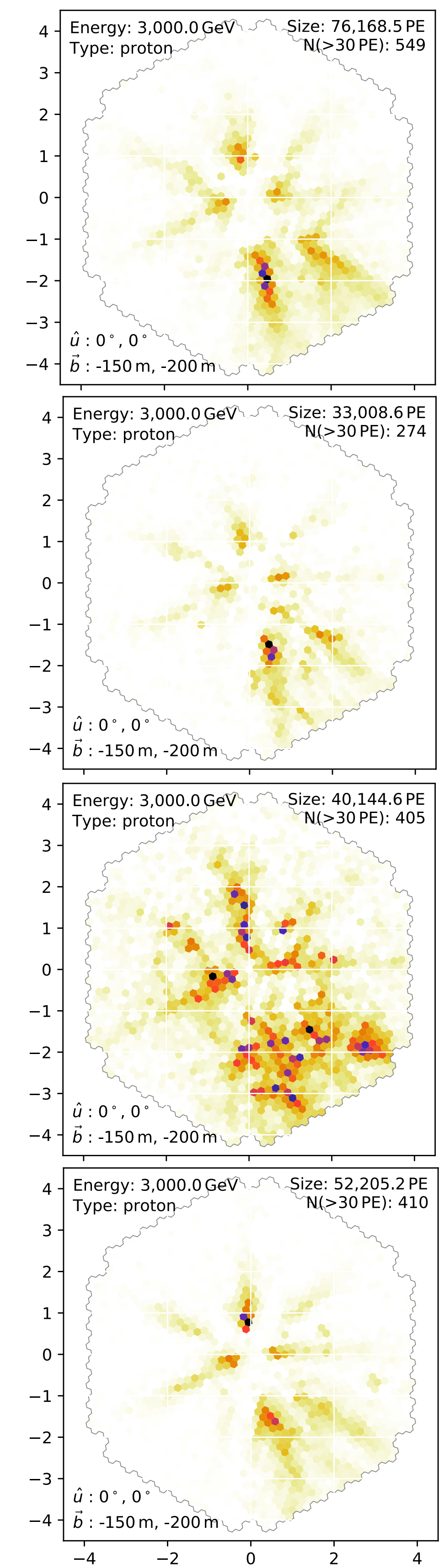
CTA-S : 0–4 LST, 15+ MST, 50 SST
Effective area @10TeV : 3×10^6 m^2
Optimised for observation of Galaxy

- Some sources accessible to both sites - ~4 hour offset in longitude will allow these to be observed for somewhat longer periods if necessary.
- Same analysis & simulations tools for both sites. Ideally some common hardware.

Large number of telescopes

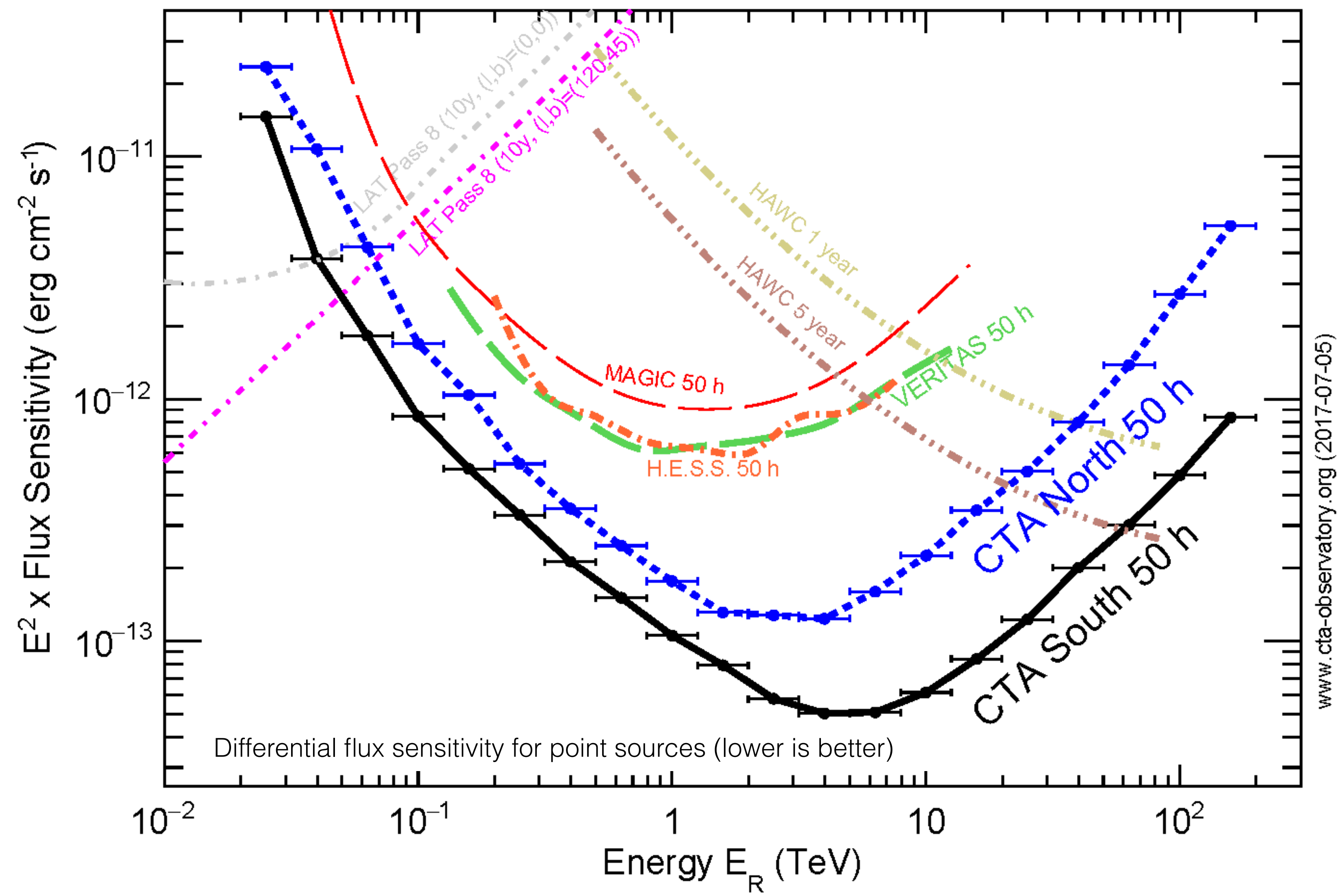






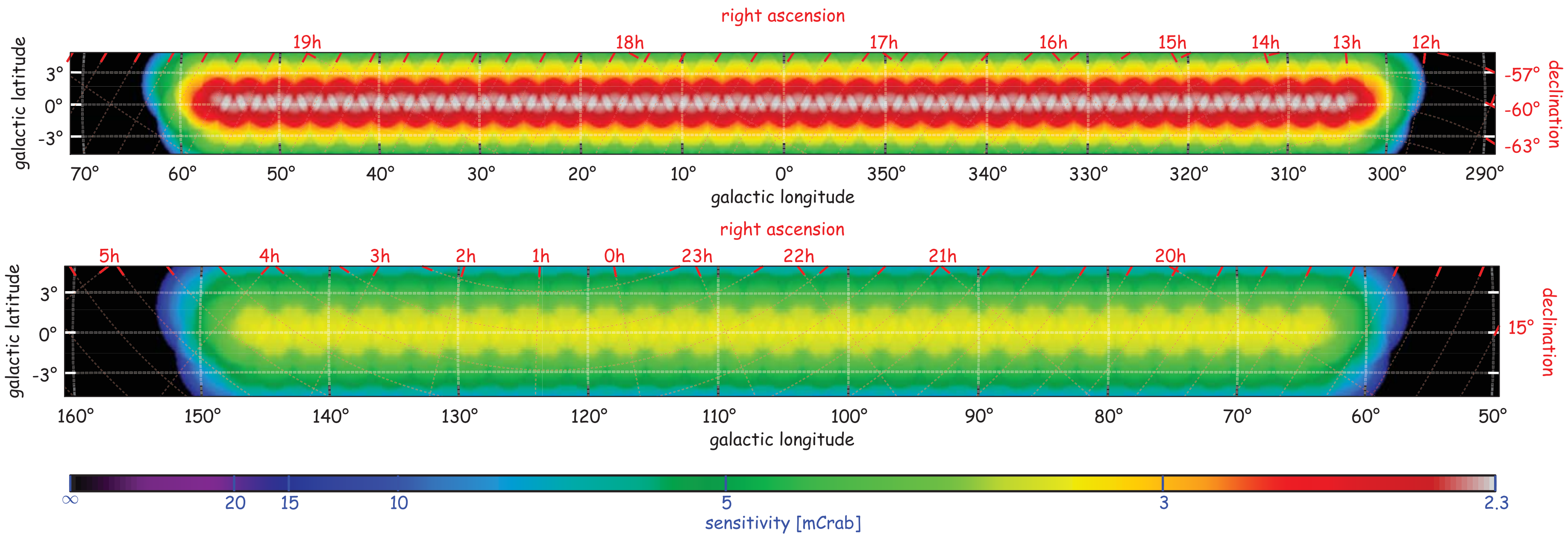
- Area of array is significantly larger than the Cherenkov light pool
- Many telescopes see each event, especially at high energy; "composite" of images from 1TeV gamma rays and 3TeV protons
- Reconstruction of shower parameters (direction, impact point and energy) significantly improved over small instruments like HESS
- Rejection of background protons also vastly improved

Flux sensitivity improvement



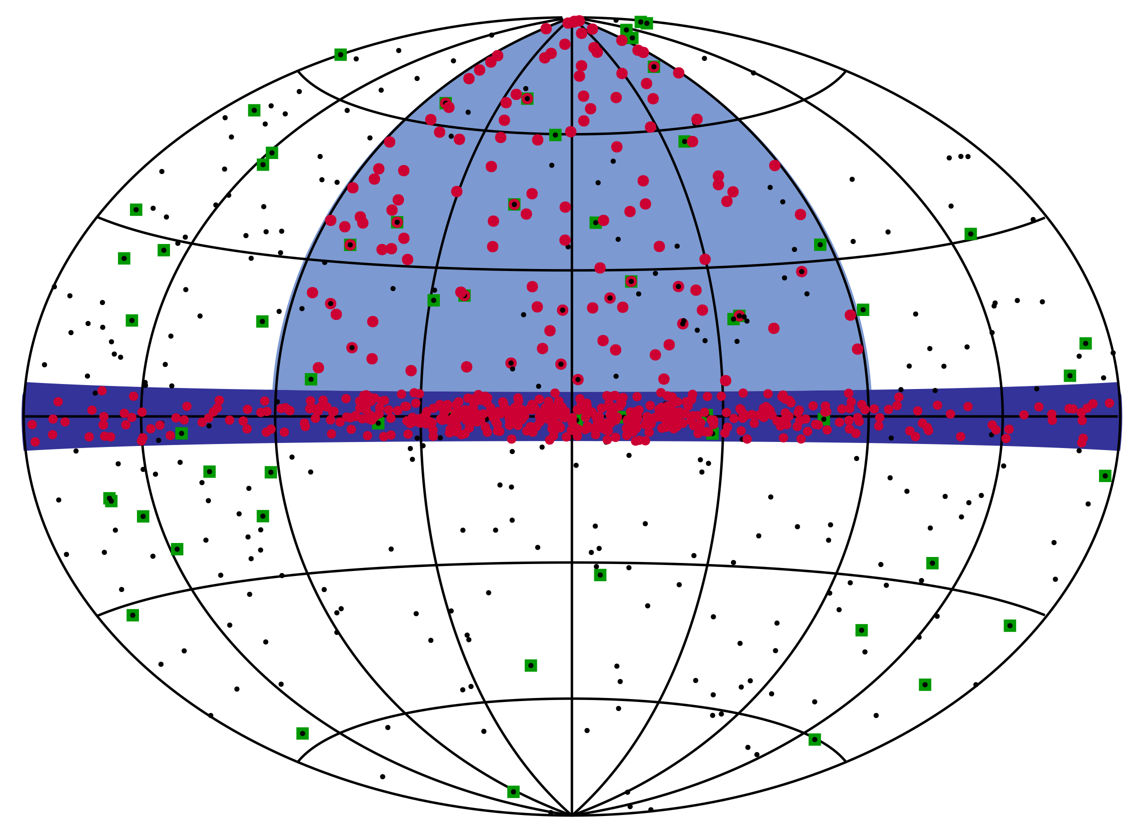
- Major sensitivity improvement over 3rd generation telescope arrays such as H.E.S.S., with CTA-S more than 10 times more sensitive than H.E.S.S. at a few TeV
- Sensitivity better than that of Fermi for steady sources (10 years of observation) for energies greater than approximately 60 GeV
- But sensitivity 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

Large field of view



Point-source sensitivities (colour scale, in mCrab) achieved in the short-term programme (STP; Years 1 – 2) of the CTA Galactic Plane Survey by the north (top) and south (bottom) observatories.

- Era of big cameras : NectarCAM, 1855 pixels, 8 degree FoV, 3m physical diameter
- Deeper galactic survey than was practicable with H.E.S.S., detect lower flux sources in reasonable observation time
- First extra-galactic VHE survey covering 1/4 of the sky (10,000 deg^2). First measures of:
  - unbiased sample of extragalactic sources
  - log N - log S for VHE AGN
  - “diffuse” VHE background from unresolved AGN - test assumptions about jet beaming



Proposed region of the extragalactic survey in Galactic coordinates: $b > 5$; $90 < l < 90$, 25% of the sky, marked in a light blue. The Galactic Plane Survey is indicated by a darker blue. Red points show a hypothetical example of the sources to be detected in the extragalactic and Galactic CTA surveys. Extragalactic and unidentified Fermi-LAT hard-spectrum sources (2FHL catalogue) are displayed as black dots whereas green points show the AGN that have been detected so far by IACTs.

CTA science themes

Release of booklet on CTA science **this week!**

★ 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 and jets

— Neutron stars & relativistic outflows

— Exploring cosmic voids

★ Exploring Frontiers in Physics

— Dark matter : nature & distribution

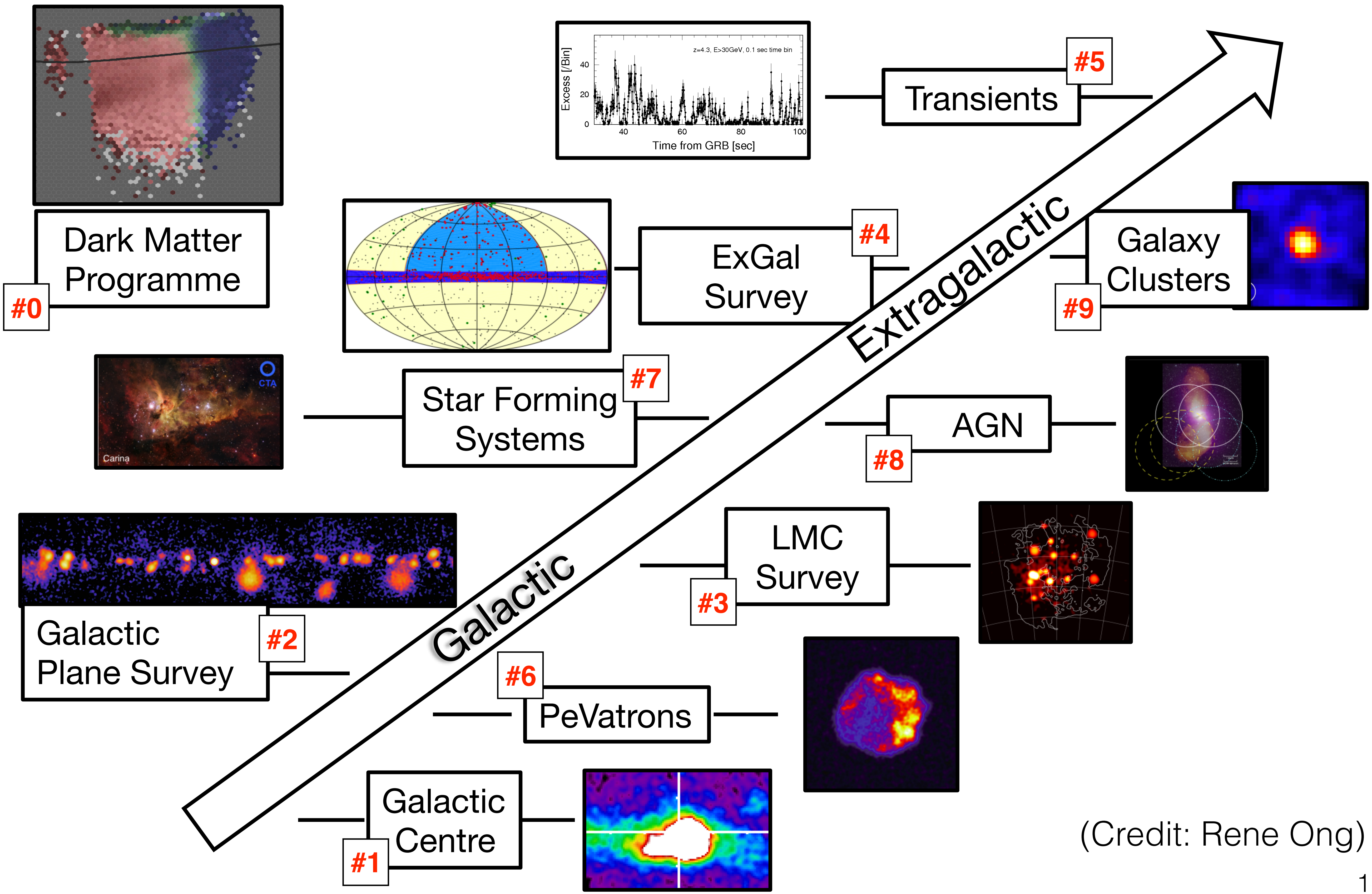
— Quantum gravity : Lorentz symmetry near Planck energy

— Do axion-like particles exist?

Science gathering phases

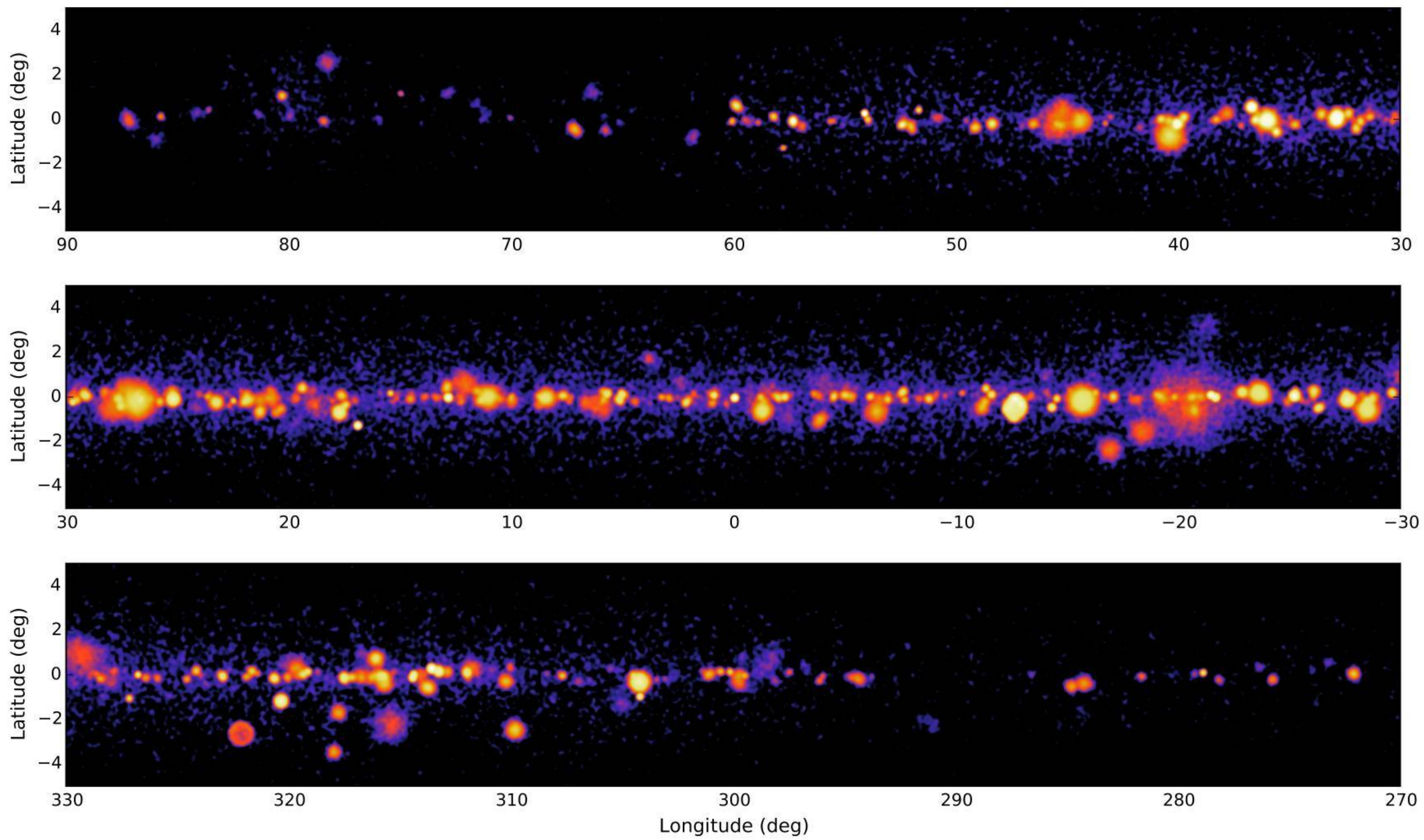
- **Key science projects** — initially observatory time will be dedicated to Key Science Projects as discussed next. In this phase CTA collaboration will direct observations, perform analysis and publish the results - catalogs, science papers etc…
- **Open observatory** — as time goes on, and in particular as the galactic and extra-galactic surveys are completed, CTA will operate as the first open, proposal-driven observatory for VHE astronomy. The observatory-mode operation of CTA is expected to significantly boost scientific output by engaging a research community much wider than the historical ground-based gamma-ray astronomy community. Proposals from the community will be reviewed by a time-allocation committee, observations scheduled at the appropriate site, data collected, reduced, and made available to the proposer, with appropriate tools.

CTA Key Science Projects (KSPs)



(Credit: Rene Ong)

KSP#2 : Galactic plane survey

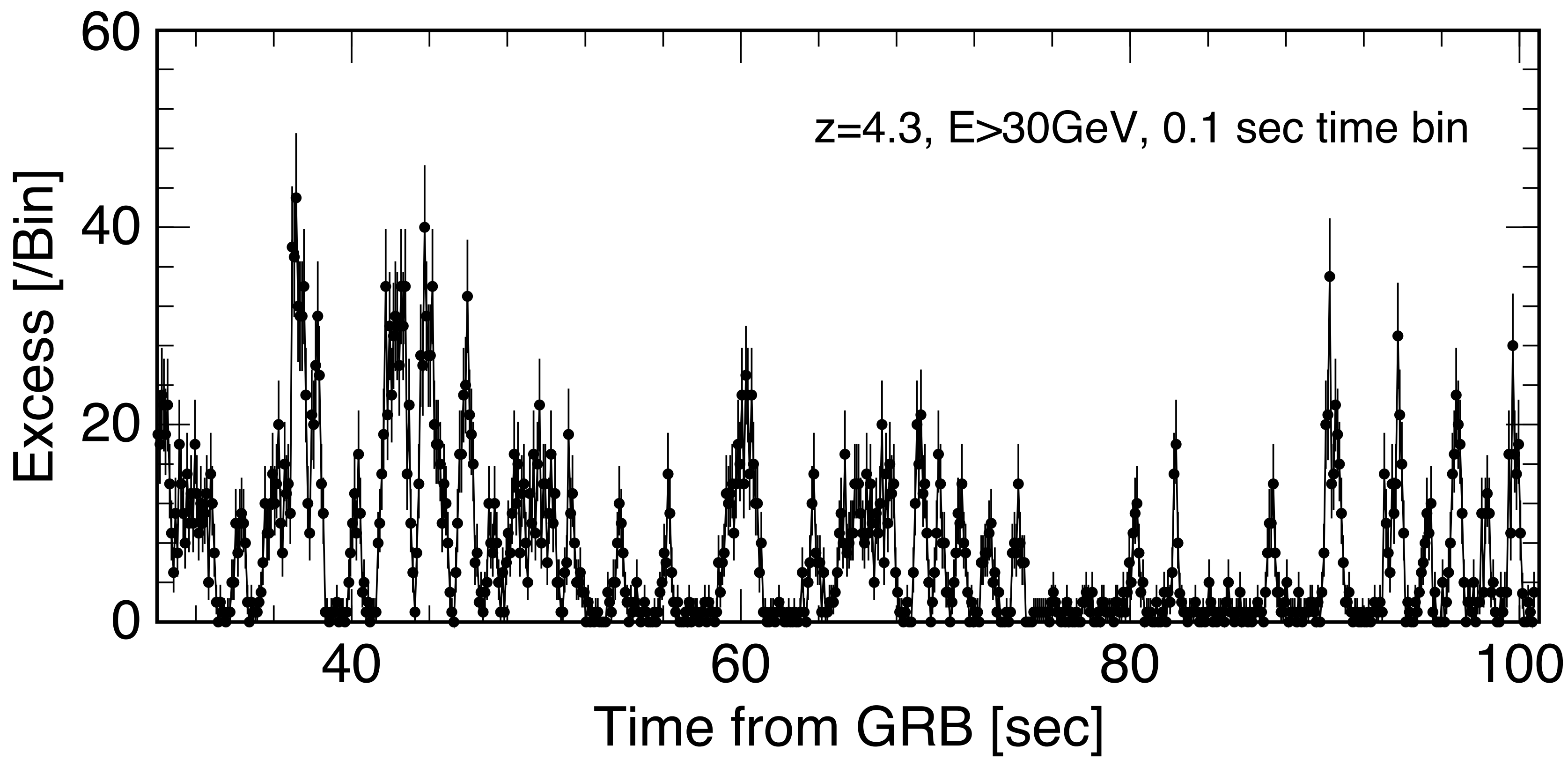


Simulated CTA image of the Galactic plane for the inner region $-90^{\circ} < l < 90^{\circ}$, adopting the actual proposed GPS observation strategy, a source model incorporating both supernova remnant and pulsar wind nebula populations and diffuse emission.

- The major astrophysical legacy* of CTA will probably be its survey of the Galactic plane
- This will cover a larger energy range, with deeper sensitivity, better angular and energy resolution and less source confusion than previously possible
- There will clearly be a large increase in the number and types of detected sources
- But the new capabilities, such as spectra-morphology studies, will provide new insights into the physics behind the acceleration and radiation processes at play.
- It's not just quantity of sources but quality of the observations that is exciting!!

*It seems strange to talk about the legacy of an instrument that has not even been built yet, but that is the terminology that's used !!

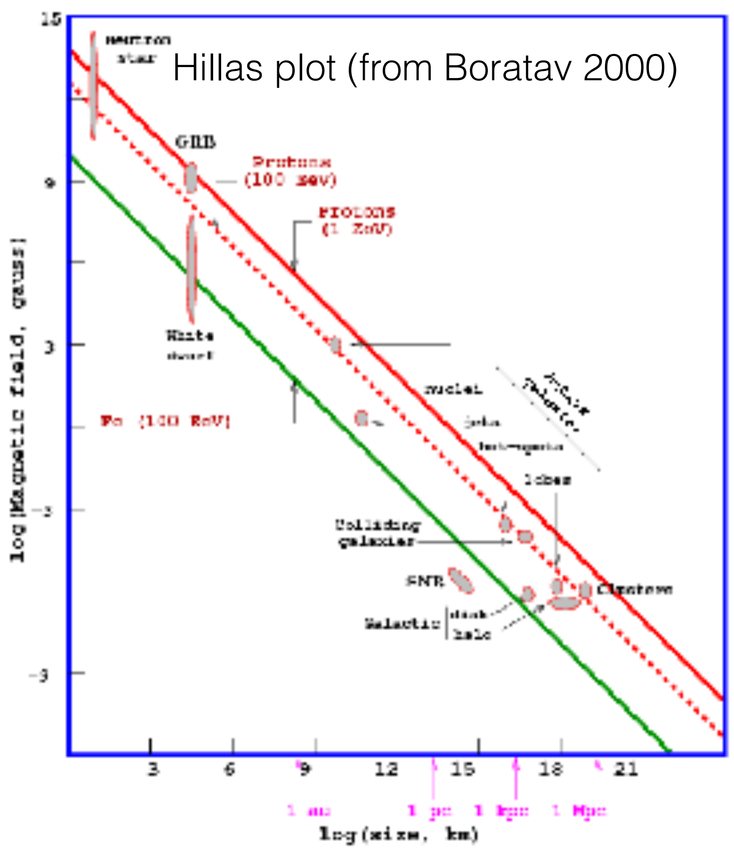
KSP#5 : GRB and GW transients

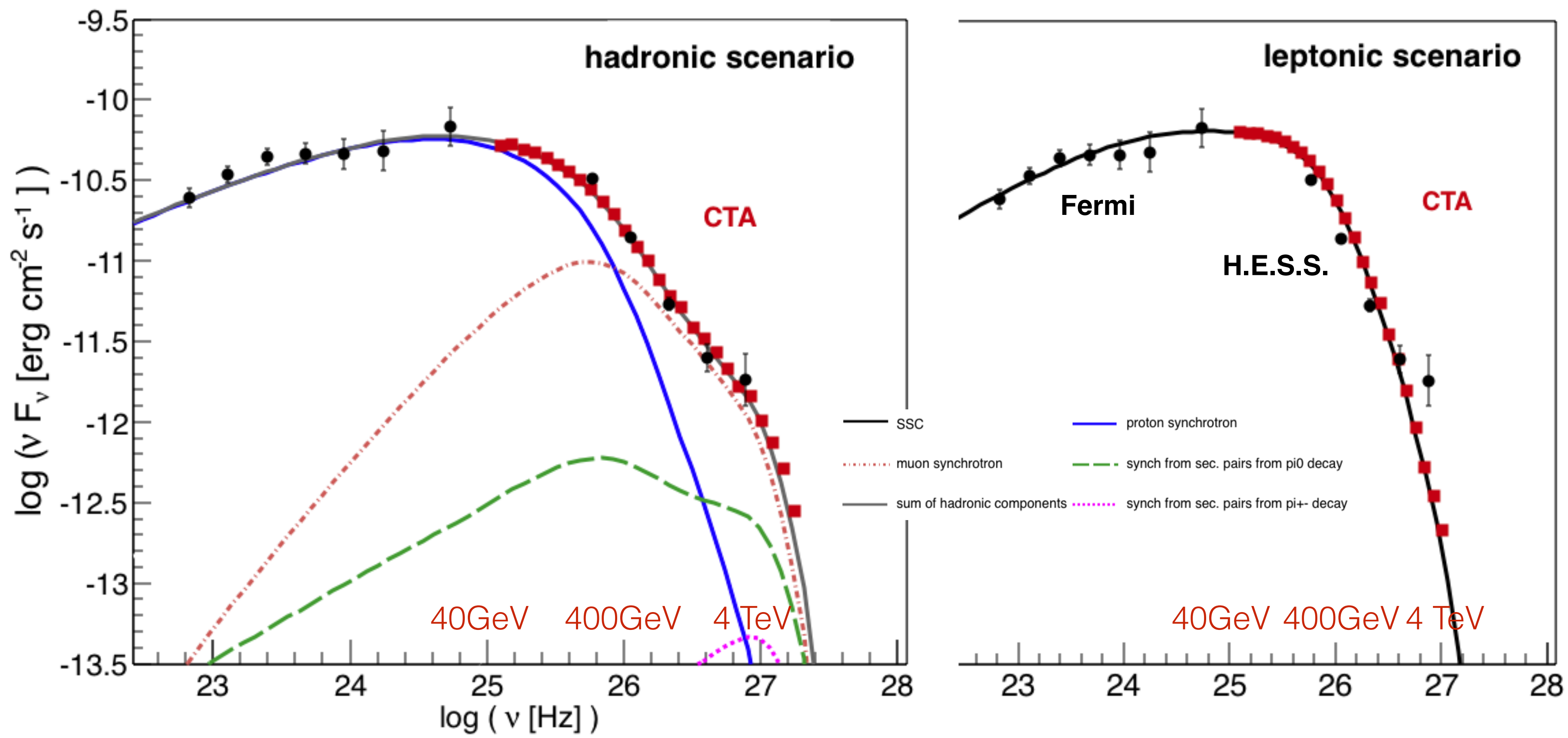


Simulated CTA light curve of GRB 080916C at z=4.3, for observed photon energies above 30 GeV with 0.1 sec time binning and plotted from t_0 = 30 seconds after burst onset. The assumed template is the measured Fermi-LAT light curve above 0.1 GeV for this burst, extrapolating the intrinsic spectra to very high energies with power-law indices as determined by Fermi-LAT in selected time intervals and taking a standard EBL model.

- With its large effective area CTA will provide unprecedented temporal resolution for flaring and transient phenomena where photon statistics is major limiting factor.
- Fast follow-up on GRBs an design requirement of CTA (LST pointing time <30sec!)
- Short duration GRBs, possibly the result of NS-NS mergers, may be associated with GW events in LIGO-VIRGO. NS-NS mergers may be complex events with material being ejected, falling back and/or colliding with surrounding material creating flares (“kilonovae”) for some time after initial explosion.
- CTA may see such GW follow-up events, possibly even in cases where gamma-ray jet is not aligned, i.e. where there is no “traditional” GRB event.

KSP#8 : Active Galactic Nuclei (AGN)





A comparison of the expected CTA spectra for two specific (simple) emission models for the blazar PKS2155-304. A hadronic scenario, where high-energy emission is caused by proton- and muon- synchrotron photons and secondary emission from proton-photon interactions, is shown on the left, and a standard leptonic synchrotron self-Compton (SSC) model on the right. The exposure time assumed for the simulations (33h) is the same as the live time for the H.E.S.S. observations (black data points above 3×10^{25} Hz). The statistical uncertainties in the CTA data points are smaller than the red squares.

- AGN, with super-massive black holes (SMBH; $M>10^8\,M_\odot$), are one of the leading candidates for the production of UHECRs (10^{20} eV). However VHE gamma-ray observations show fast flaring that can best be explained by radiation from leptonic particles that cool quickly.
- But protons must be there somewhere! They may play a role in the “quiescent”, baseline VHE emission. CTA will have the sensitivity to resolve spectrum of the quiescent state, distinguishing hadronic from leptonic scenario.

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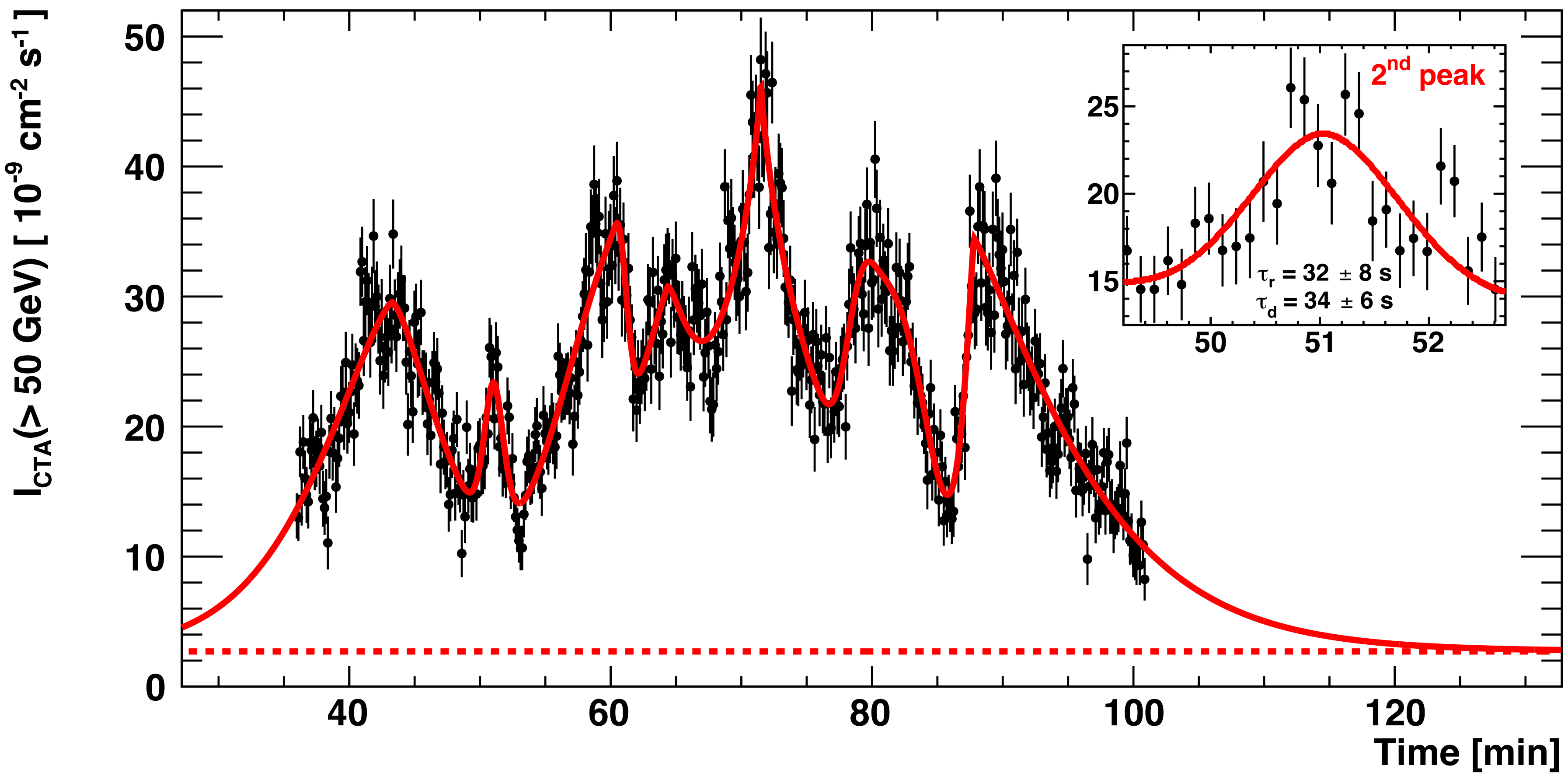


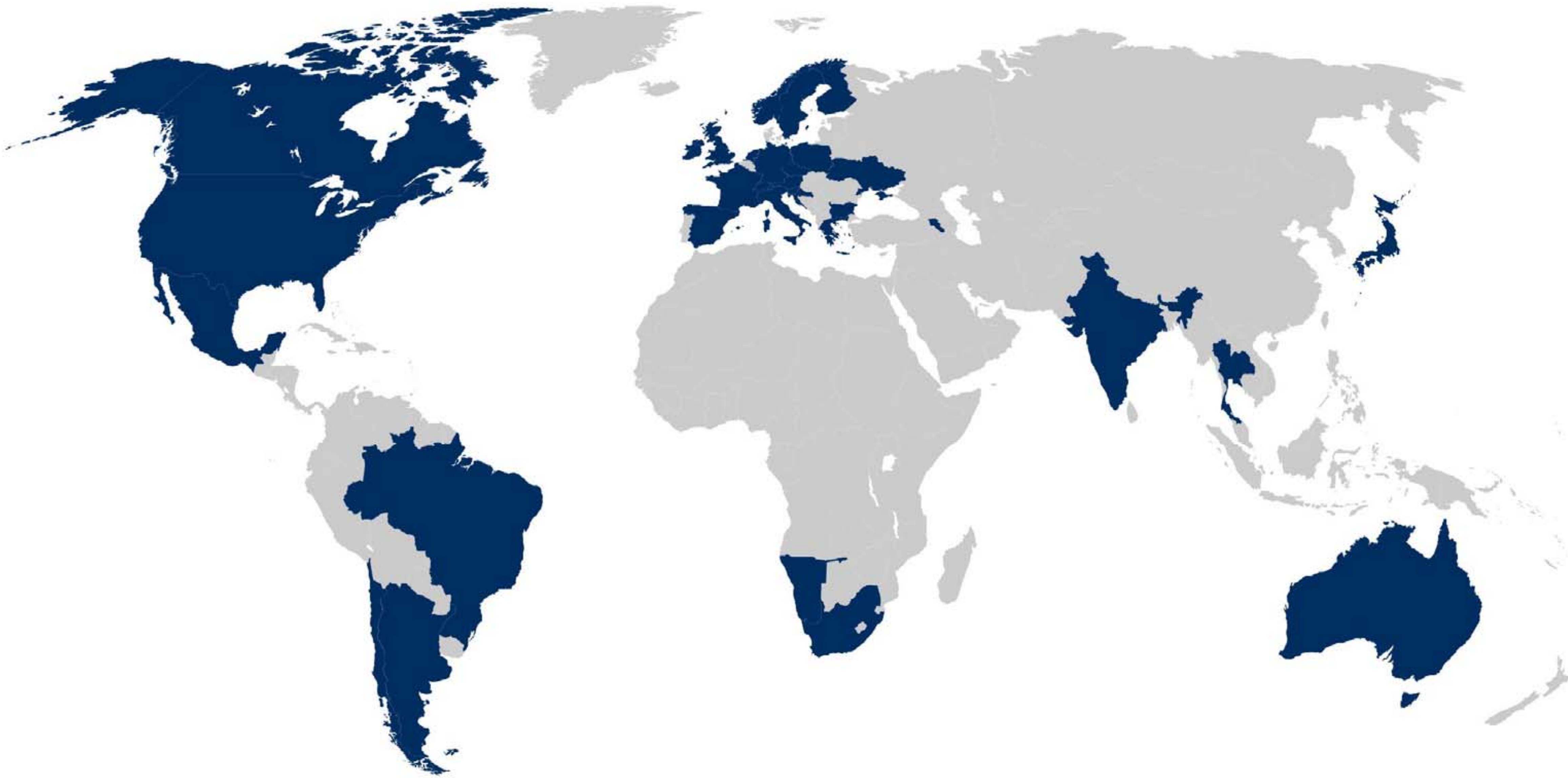
Simulated light curve based on an extrapolation of the power spectrum of the "famous" 2006 H.E.S.S. flare from PKS 2155-304 with an ad hoc flaring model fitted. The doubling rise time and decay time are indicated for the second peak in insert.

- The ability to probe variability timescales shorter than the light-crossing time for the event horizon of the SMBH, T_{BH}=3hr M/10^9 $M_\odot$, has the power to constrain structures and processes responsible for particle acceleration and cooling in the jet.
- Given a flare with the same intensity as the 2006 flare from PKS 2155-304 seen by H.E.S.S., CTA would be able to resolve sub-minute rise and decay timescales. If such fast flares are found they would point to "exotic" processes, such as turbulent, multi-zone emission or magnetic reconnection in the jet, or to EM processes associated with SMBH magnetosphere, i.e. to "physics beyond the standard model" of blazers (SSC).

CTA legal structure

- **CTA Consortium (CTAC)** — agreement between scientists and agencies to participate in construction and operation of CTA. Defines rights and responsibilities of collaborators.
- **CTA Observatory (CTAO)** — legal structure that will own and operate telescopes, project office, negotiate site agreements etc. Stake holders are funding agencies in member countries.
  - Today structure is **CTAO-GmbH** with seat in Germany
  - Future structure to be **CTAO-ERIC** : "European Research Infrastructure Consortium" with seat in Italy (13 ERICs exist, e.g. European Spallation Source in Lund). Application takes 9 months, including translating documents to all EU languages.

CTA Consortium



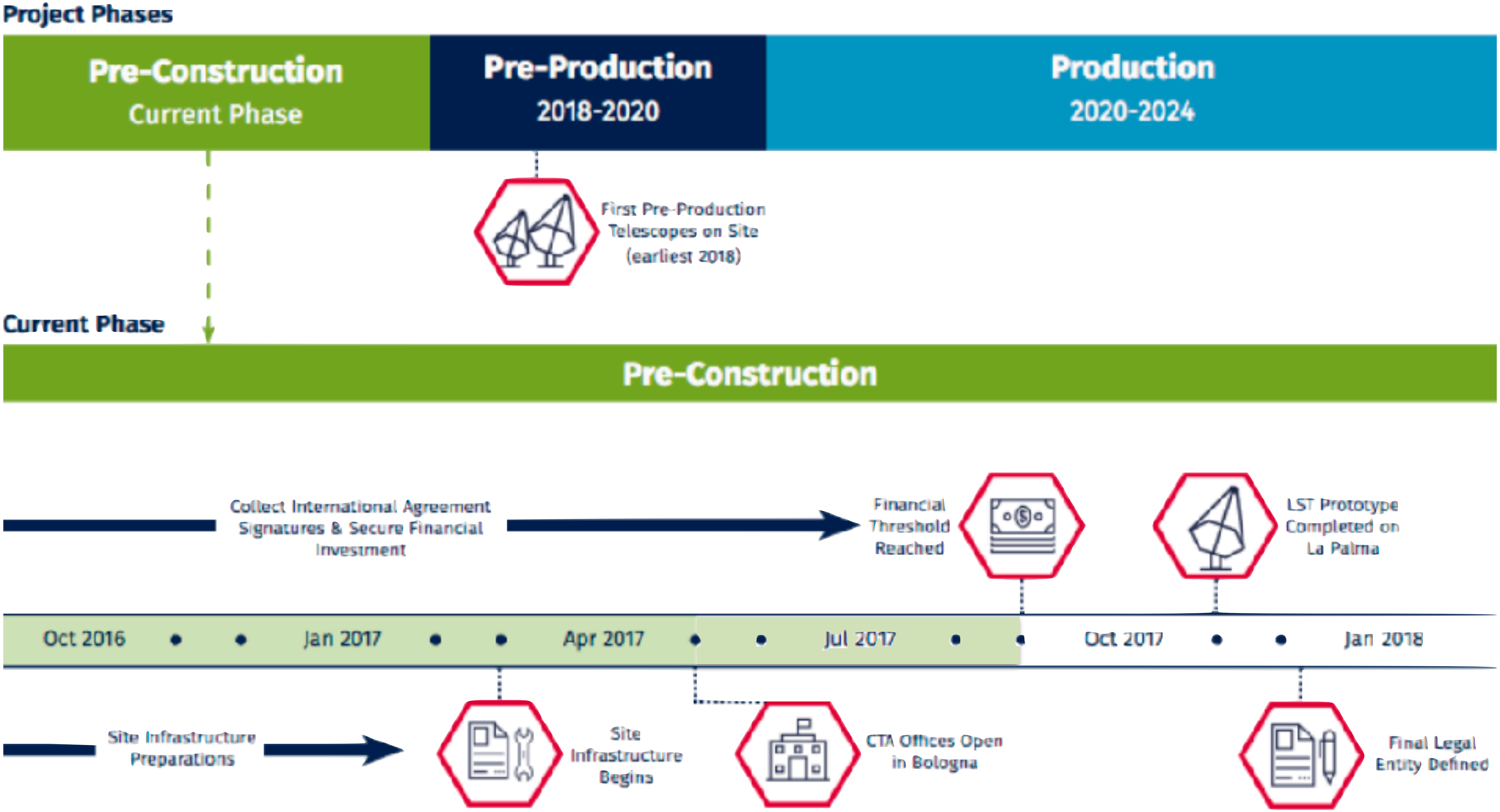
32 countries, ~1402 scientists, ~208 institutes, ~480 FTE

The consortium originated CTA and will contribute to the construction of the arrays.

(Credit: Rene Ong)

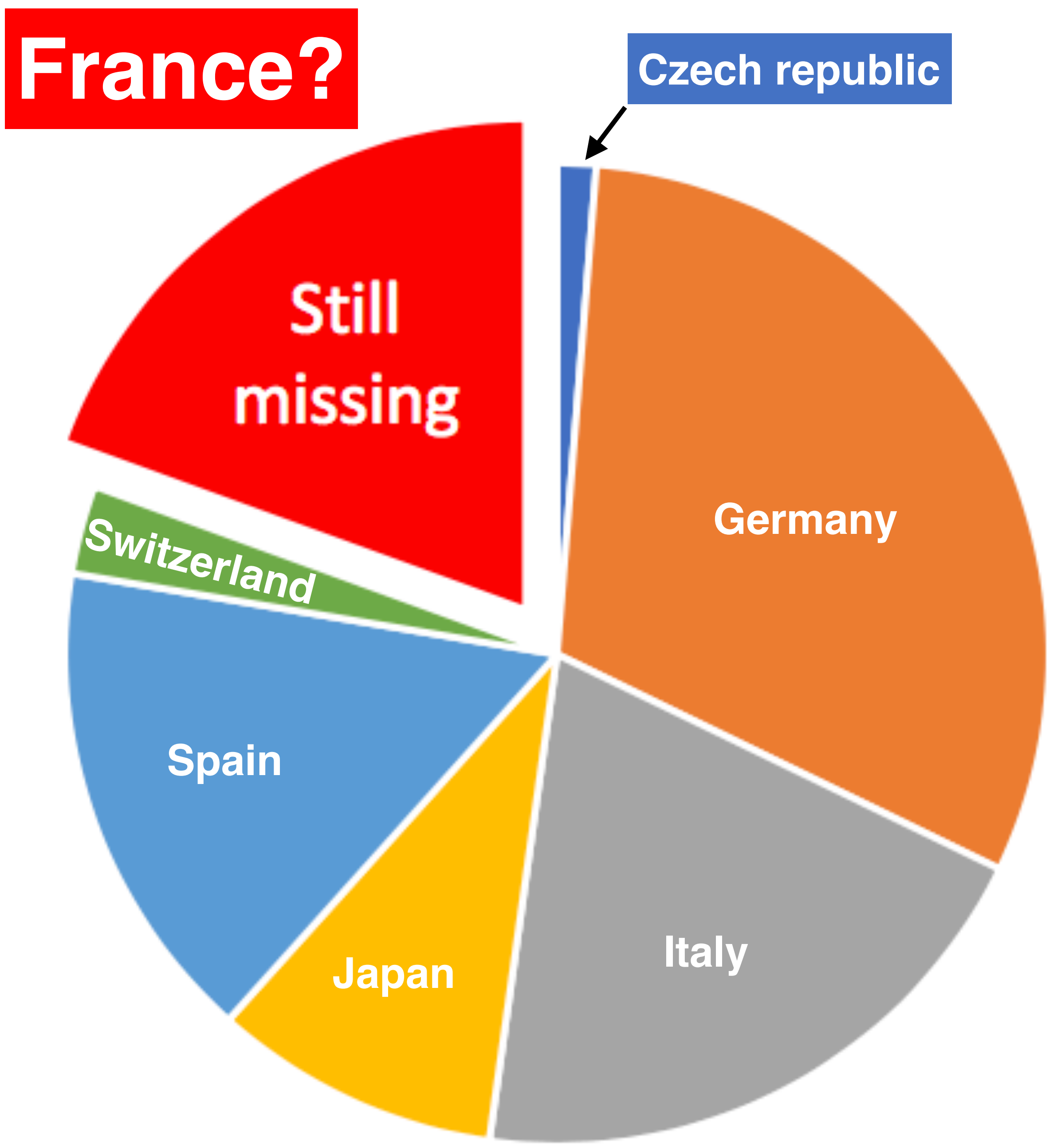
CTA timeline

(at time of 2017 Spring collaboration meeting, May 2017)



Threshold & Funding

- Cost of full proposed observatory is ~450M€
- “Threshold” observatory defined at which point it makes sense to start construction — 250M€
  - N: 4×LST, >5×MST
  - S: >15×MST, 50×SST
- Funding identified for 80% of threshold, still missing is the “French” contribution of 52M€



TGIR funding situation

EAOM 2017-05-29

Evénements attendus en 2017/ Objectifs

Rapport HC TGIR et décisions CD TGIR de Février :

- Participation aux upgrades Phase II LHC : oui –
- Participation française à CTA : oui/non, à quelle hauteur ?

Feu vert (concret = financements !) fortement attendu par les équipes

Objectifs 2017 :

- Démarrer la construction de ces grands équipements (durée 6-8 ans)
- Mise en service de Virgo (2nd semestre 2017).
- Mise en service SPIRAL2 (inauguré en 11/16) et finalisation schémas financement phase 1 (11 M€ à trouver).
- Décisions participations Auger-Prime (CSI 2/17), BELLE-II (cf. CSI 6/17)
- Important travail de mise à jour de la feuille de route IR nationales, de la liste ESFRI, Prospectives nationales -> début 2018

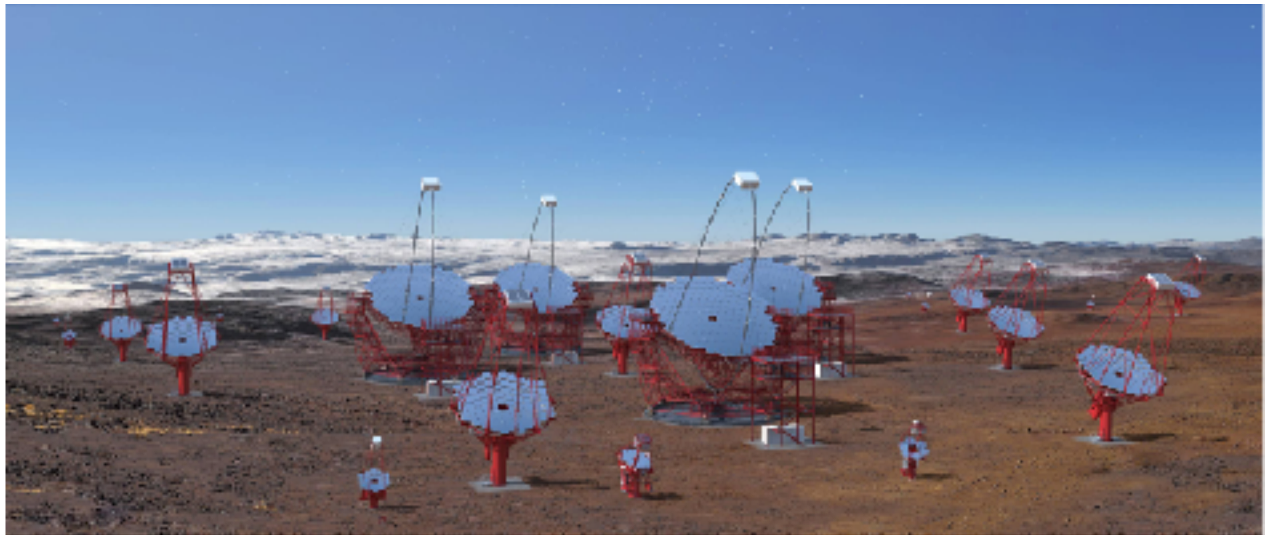
5/5/2017 Visites Laboratoires 2017 12

- Feb 2017: CTA recommended by HC TGIR and approved by CD
- … **but** funding level not yet decided: 0M€ « x < 52M€
- … **nor** is funding profile for coming years decided

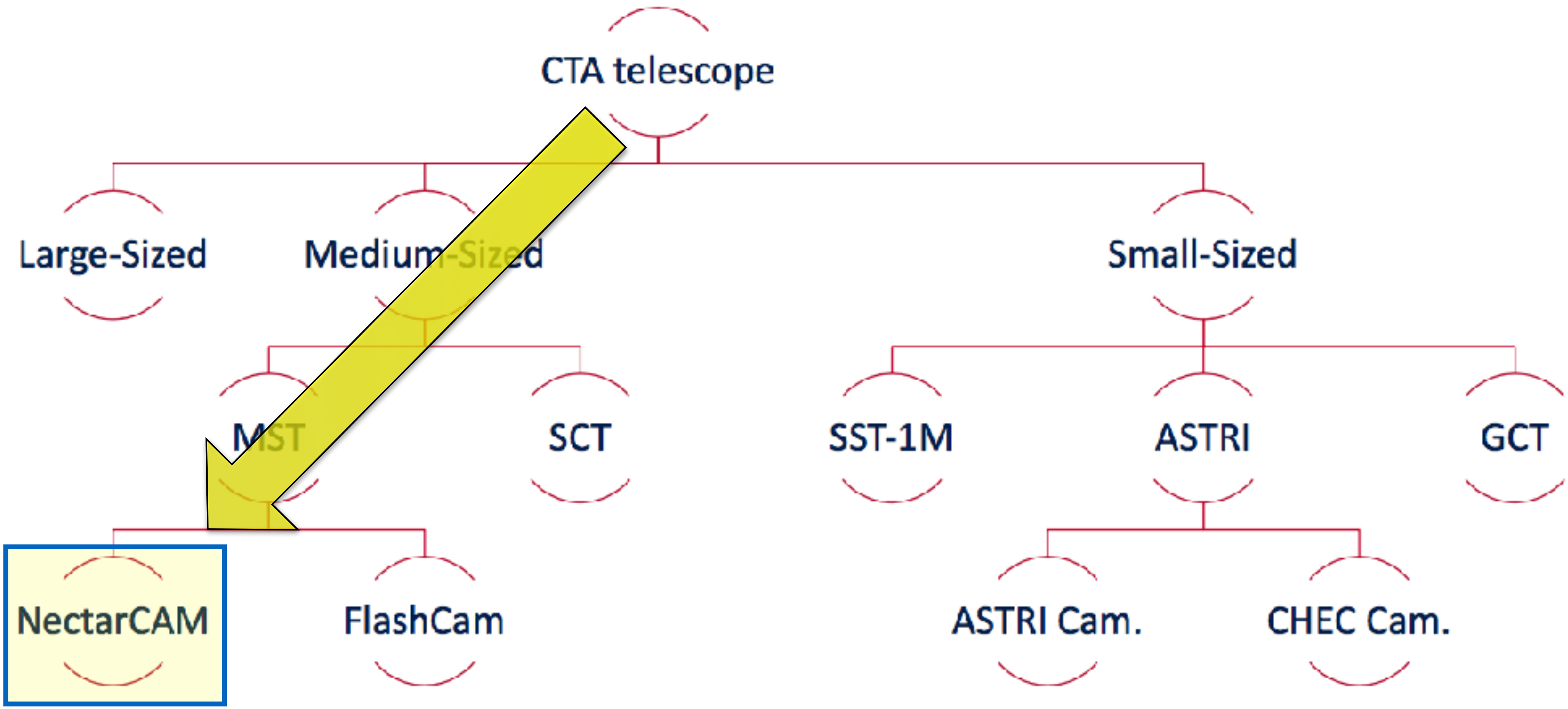
Site hosting agreements

- **IAC on La Palma, Spain** : hosting agreement signed more than a year ago. Work on site has started.

- **ESO in Chile** : ESO council and CTAO council agreed on a hosting agreement in December 2016
  - CTAO on land of ESO
  - CTAO defines construction and operation
  - CTAO may use services from ESO, if available
  - CTA material will be owned by ESO (-> VAT exemption) ESO will operate on behalf of CTAO
  - However, still not signed.



NectarCAM : A camera for MST



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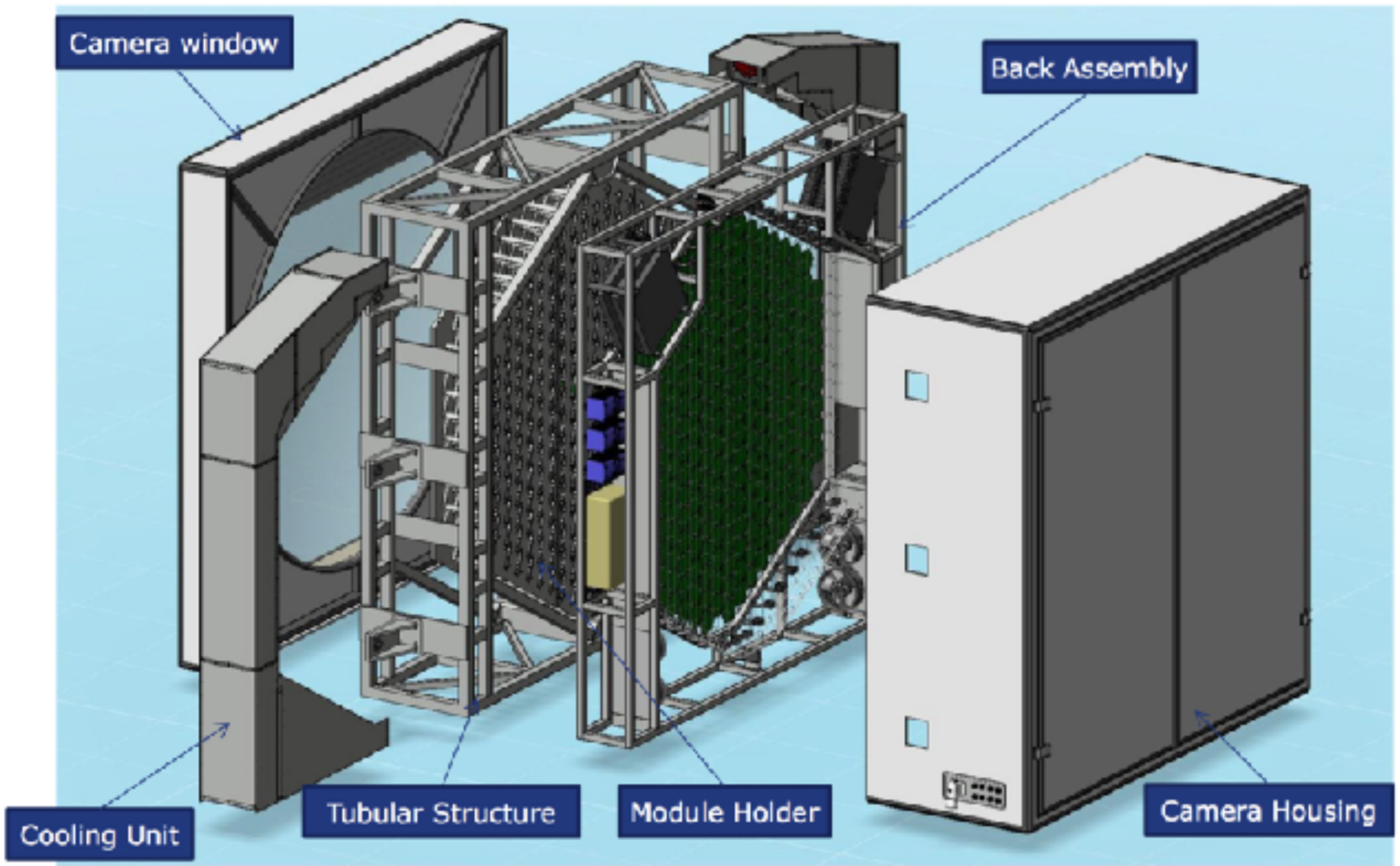
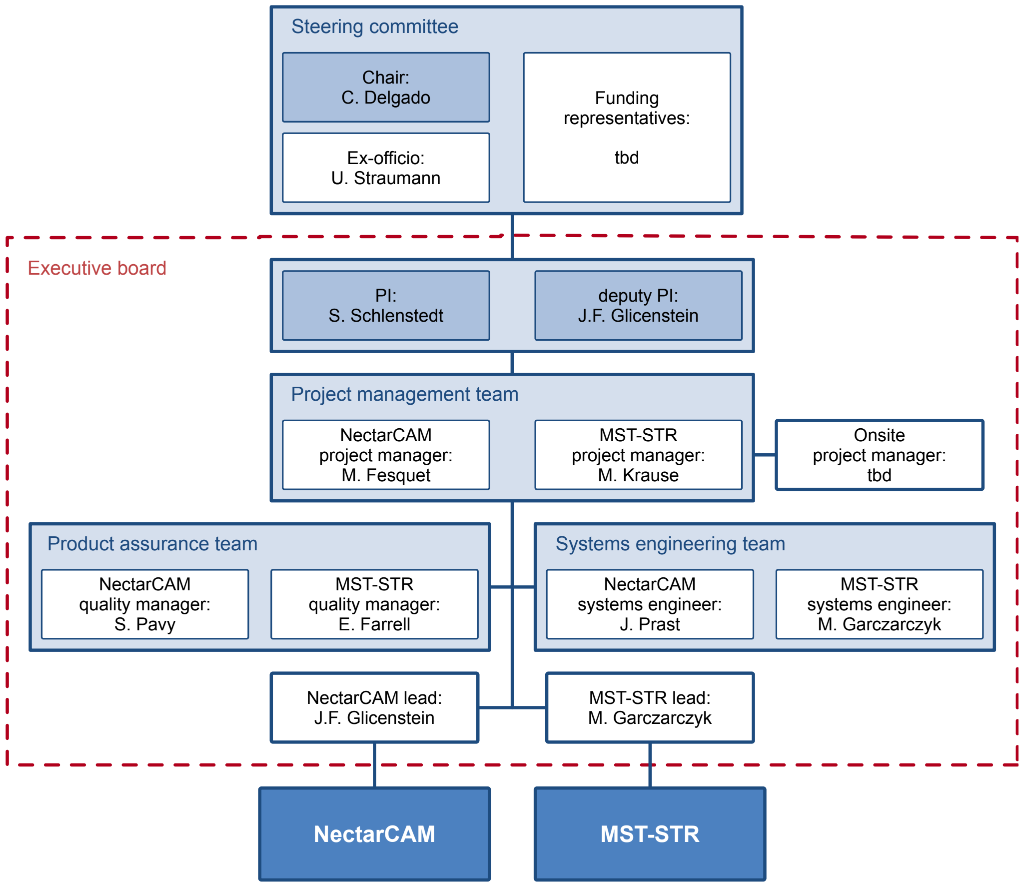


- Large 3m x 3m camera with 1,855 channels, covering 8 deg FoV.
- 265 highly integrated modules of 7 channels (PMT, light concentrator, HV board), digitisation, trigger distribution, and Ethernet downlink
- Analog memory and digitisation with Nectar ASIC : **1 GHz / 2 x 12-bit**
- High degree of commonality between NectarCAM and LST-Cam

NectarCAM collaboration

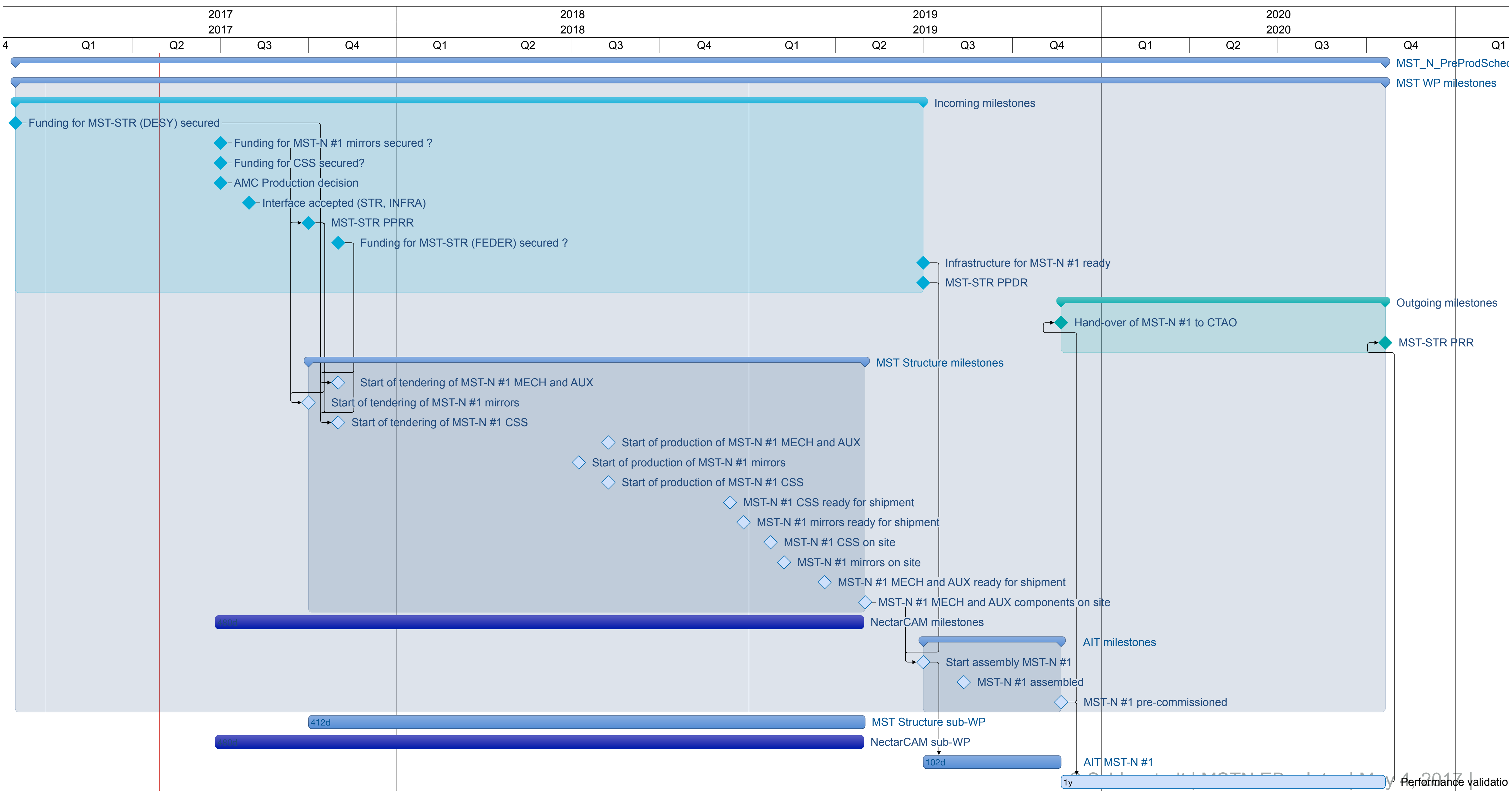
- 14 institutions in France, Spain & Germany
- **Focal plane:** IPAG (Grenoble), IRAP (Toulouse), ICC-UB (Barcelona)
- **Mechanics & cooling:** CIEMAT (Madrid), IRFU (Saclay), **LLR (Palaiseau)**
- **Front-end:** LPNHE (Paris), IRFU (Saclay), ICC-UB (Barcelona)
- **Local trigger:** ICC-UB, IFAE (Barcelona), 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)

MST-NectarCAM (MSTN) sub-consortium



- Sub-consortium to build and operate one MST telescope with NectarCAM qualification model at Observatorio del Roque de los Muchachos (ORM) on La Palma
- MoU between responsible parties :
  - Instituto de Astrofísica de Canarias (IAC, Site),
  - DESY, U. de Sao Paolo (MST), and
  - CIEMAT, DESY, **IN2P3**, INSU, IRFU (NectarCAM)
- Defines scope, governance, responsibilities, contributions, equipment, commissioning, liability…
- Funding : FEDER funds, DESY, **P2IO**, other LABEXs, **TGIR**

MSTN timeline (aligned to NectarCAM)



P2IO and CANEVAS

- CANEVAS : project to build partially instrumented NectarCAM camera that will become Qualification Model
- 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)
- **This allows NectarCAM timeline to continue before TGIR decision is made.**
- TGIR will be needed to finish fully equipped camera.

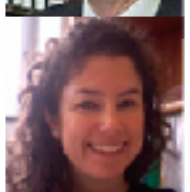
CTA group @ LLR

- Sami CAROFF (P2IO postdoc)
  - Calibration test bench for NectarCAM

- Stephen FEGAN (CR)
  - LLR CTA group leader
  - **Calibration coordinator for NectarCAM**

- Oscar FERREIRA (IR)
  - **Overall responsibility for mechanical design of NectarCAM**

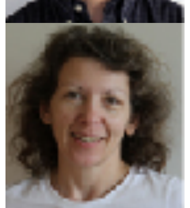
- Gérard FONTAINE (DR, émérite)
  - CTA board member



- Deirdre HORAN (CR)
  - CTA catalog planning

- Gerome NANNI (R)
  - Calibration test bench for NectarCAM

- Mathieu de NAUROIS (DR)
  - Analysis & reconstruction, software



- Sandrine PAVY (IE)
  - **Product assurance coordinator for MST-N**
  - **Quality assurance for NectarCAM**

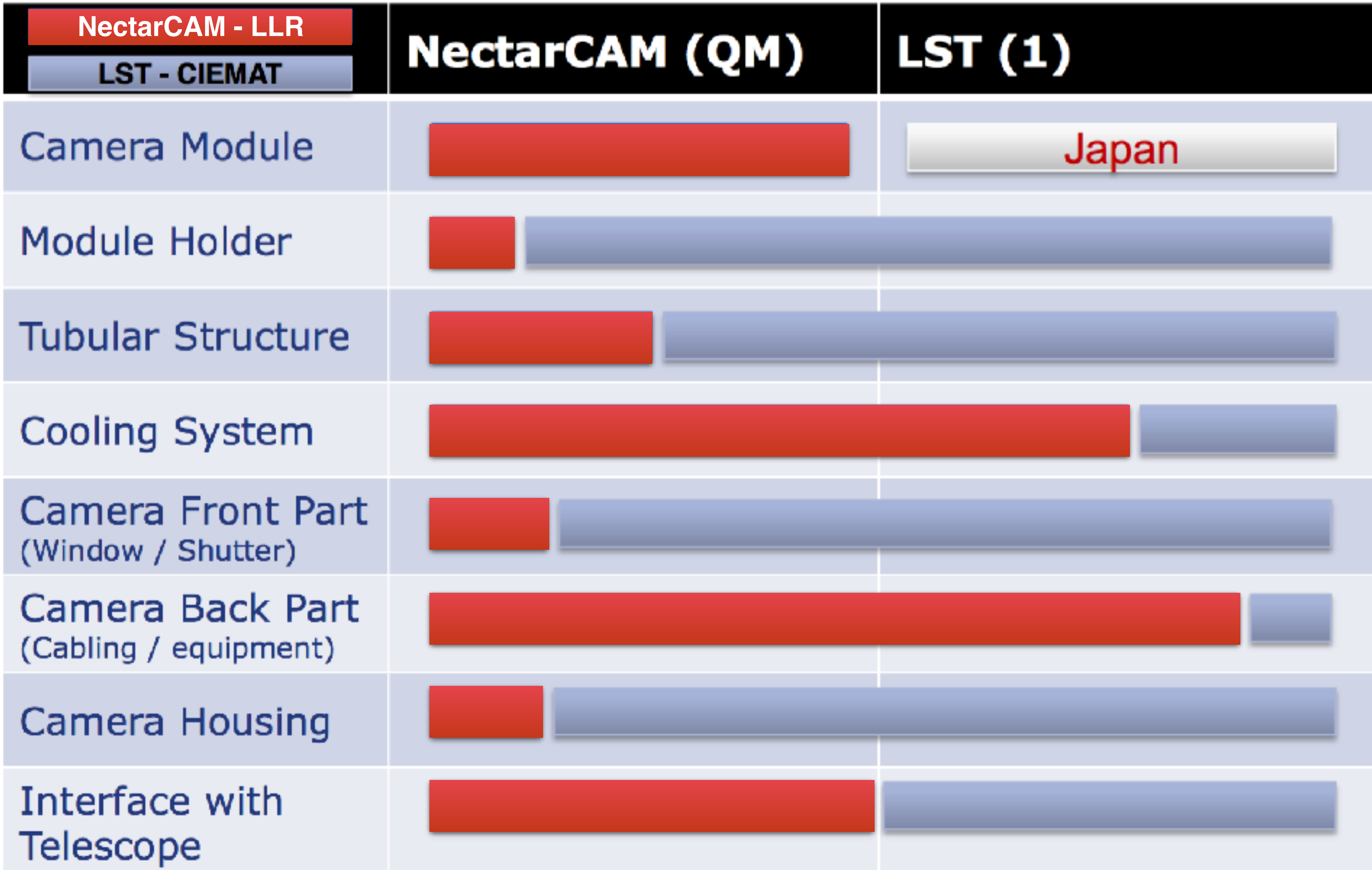
LLR CTA Responsibilities

Mechanics for NectarCAM

Product assurance for MST-N & NectarCAM

Calibration for NectarCAM

Organisation of mechanics WP



Organisation of mechanics WP

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

Benefits of shared design

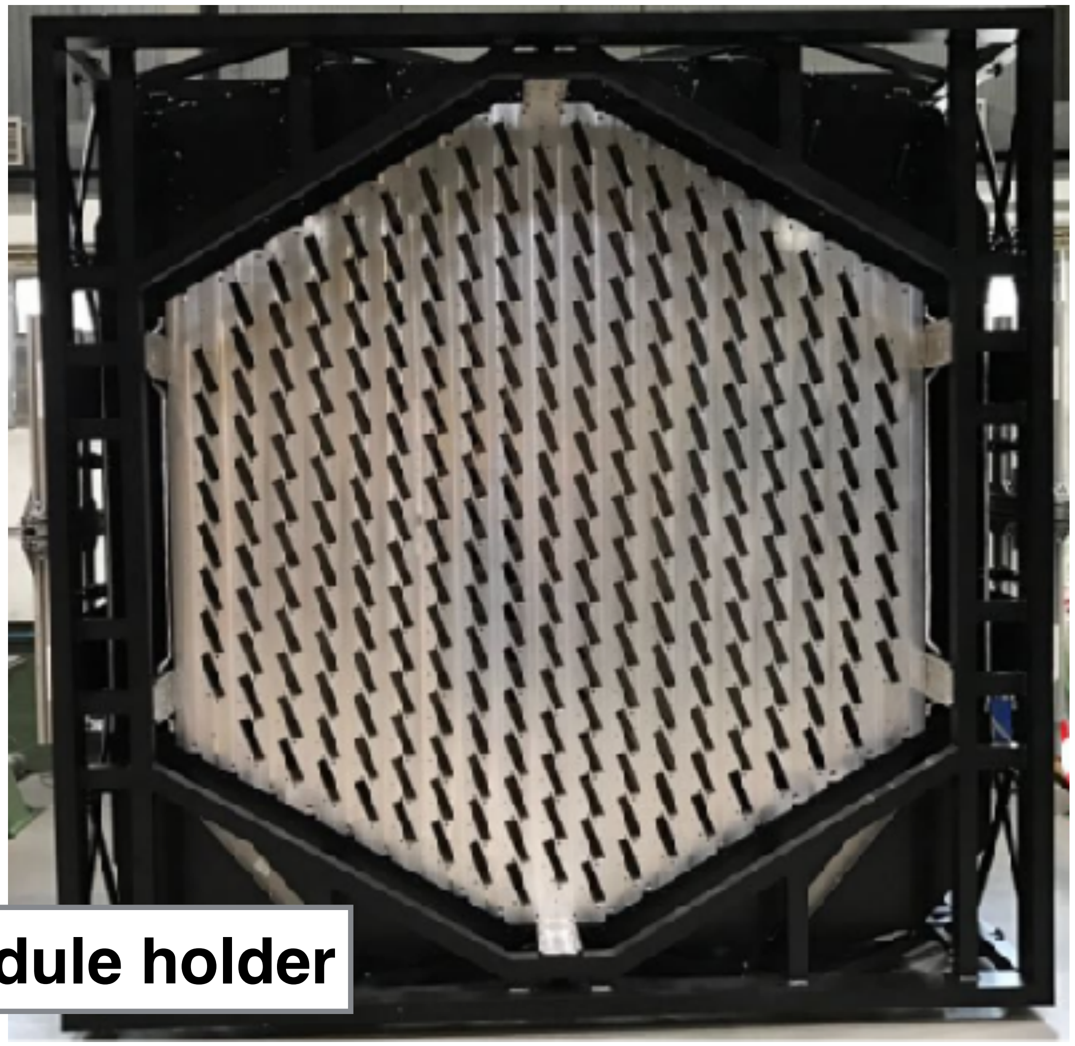
Reduced overall design workload thanks to reuse of common design elements

Early retirement of NectarCAM QM mechanical design risks from testing of common design elements on LST prototype.

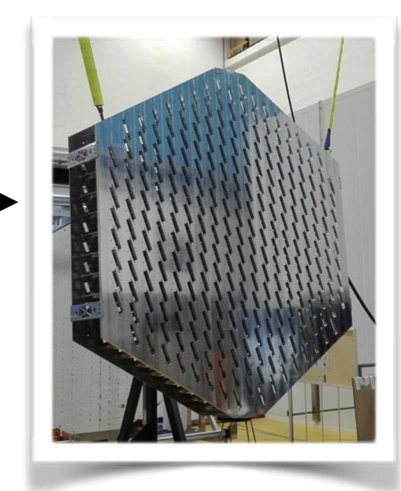
Reduction of design, manufacturing and maintenance costs for common components.

Major mechanical elements for QM

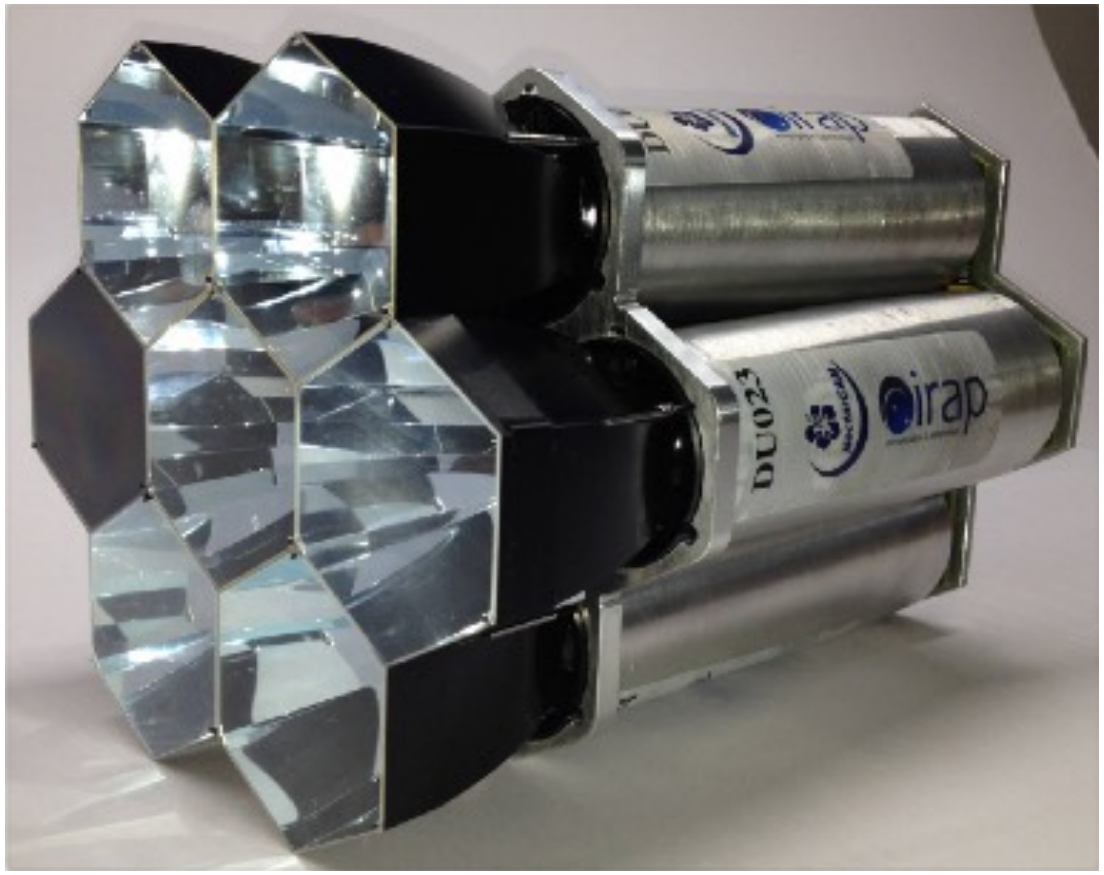
(O. Ferreira, LLR)



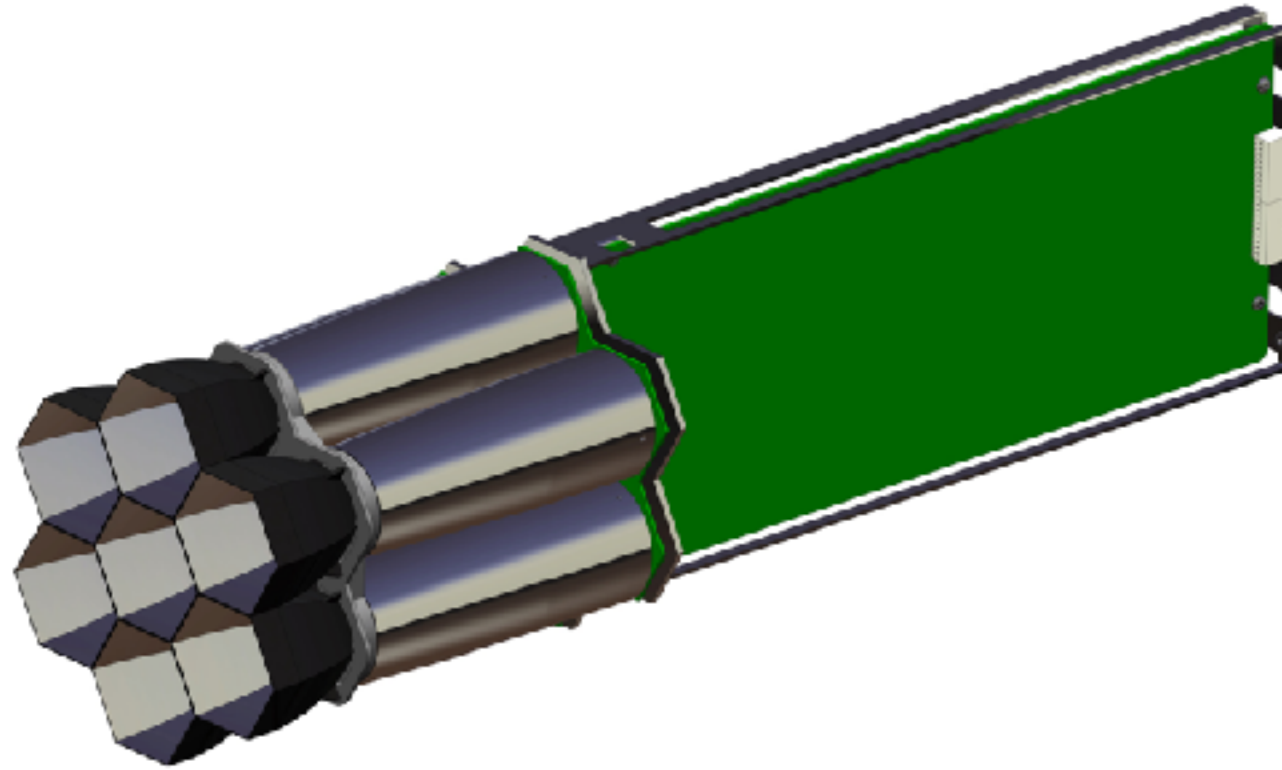
- LST mechanical components similar to those of NectarCAM.
- NectarCAM module holder for QM now assembled @IRFU →
- NectarCAM enclosure is major **CANEVAS** responsibility of LLR. Procurement before end of 2017 for delivery to IRFU.



NectarCAM module mechanics



(O. Ferreira, LLR)



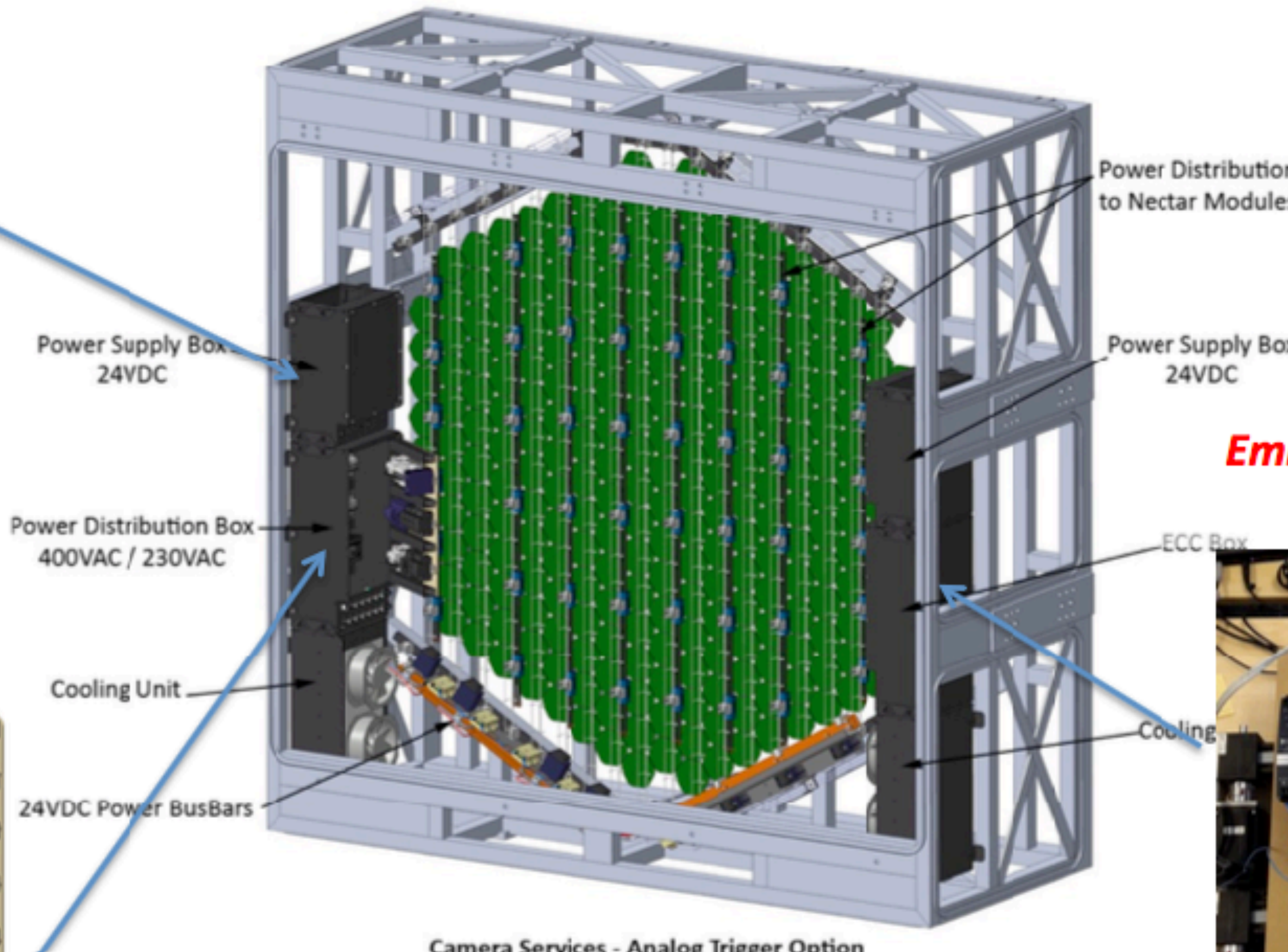
- Design and testing of module mechanics completed — design evolved through testing at 19 module test bench at IRFU.
- Procurement of module mechanical components for CANEVAS will start very soon (~70 modules).
- Procurement of FEBs (IRFU/LPNHE) and detector units (IRAP) to also start soon and all components will come together with module holder (already at IRFU) for testing of partially instrument NectarCAM QM (CANEAS)

Mechanics at rear of camera

(O. Ferreira, LLR)

Power Supply Box

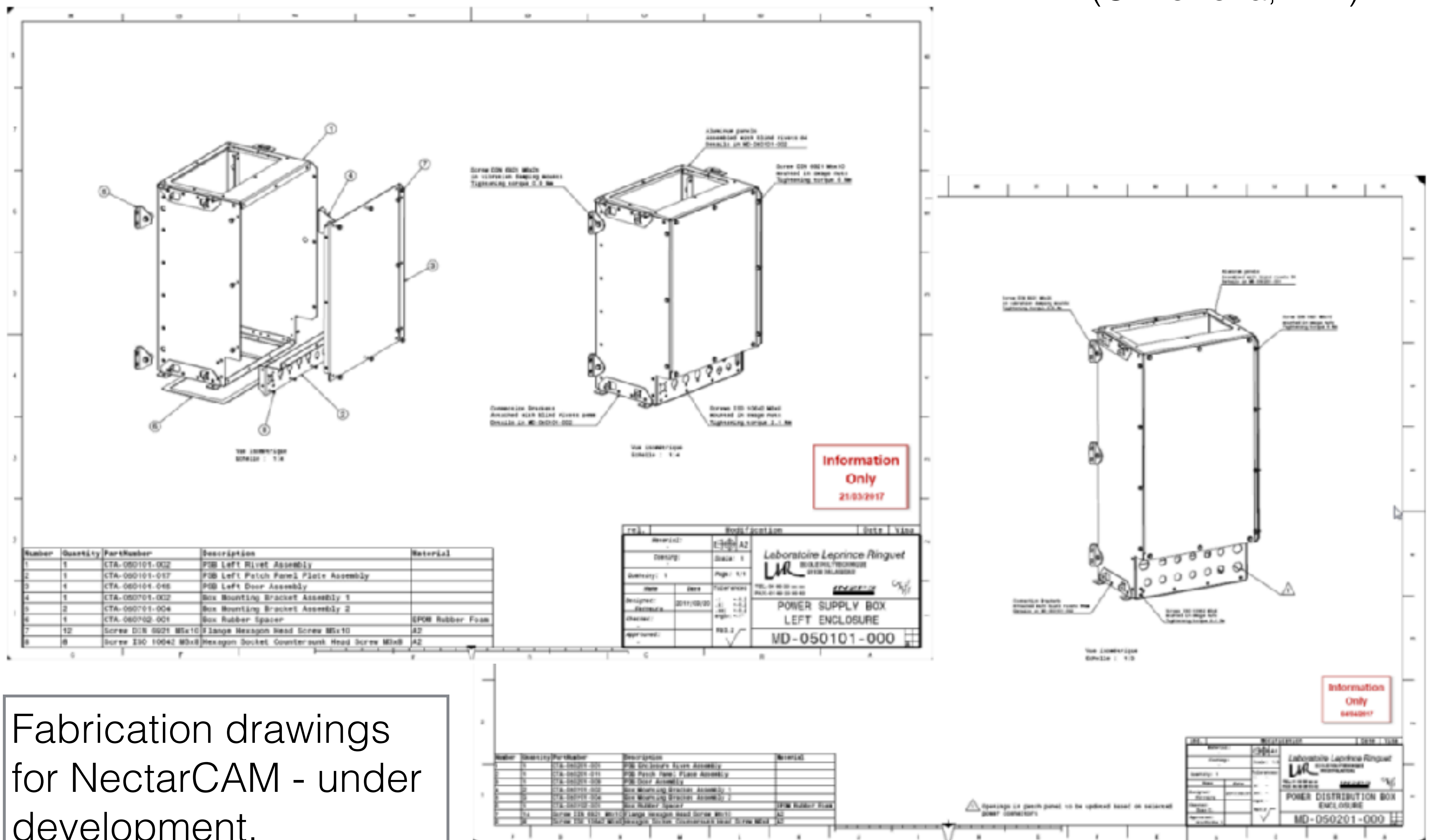
Power Distribution Box



Embedded Camera Controller

Mechanics at rear of camera

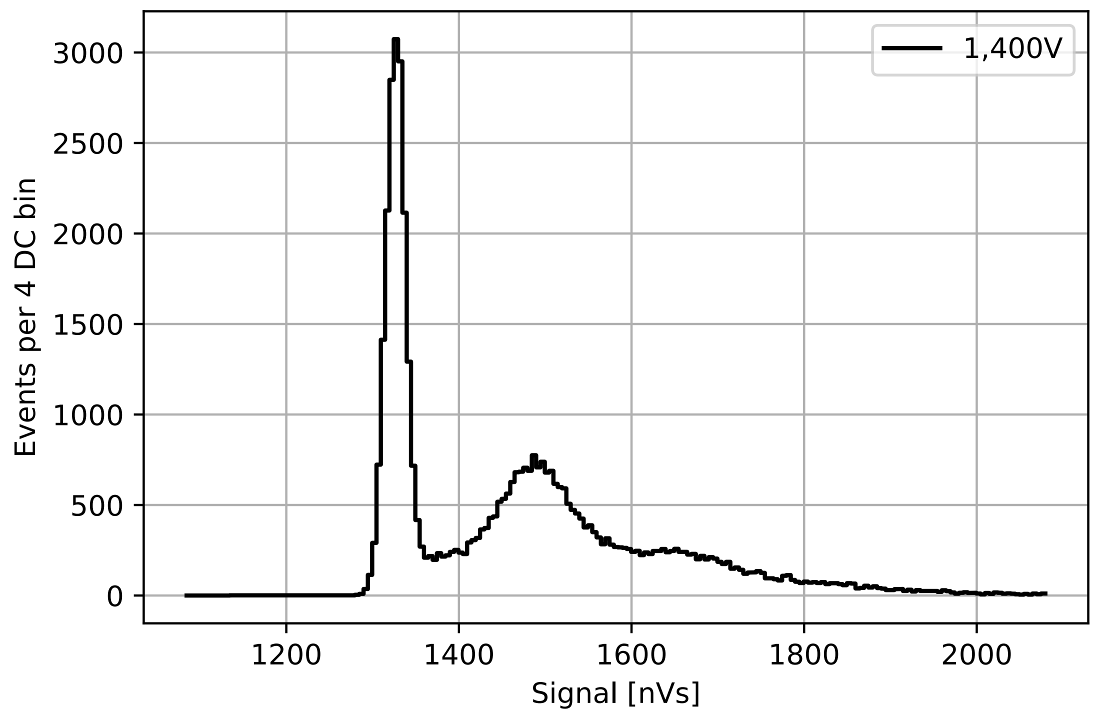
(O. Ferreira, LLR)

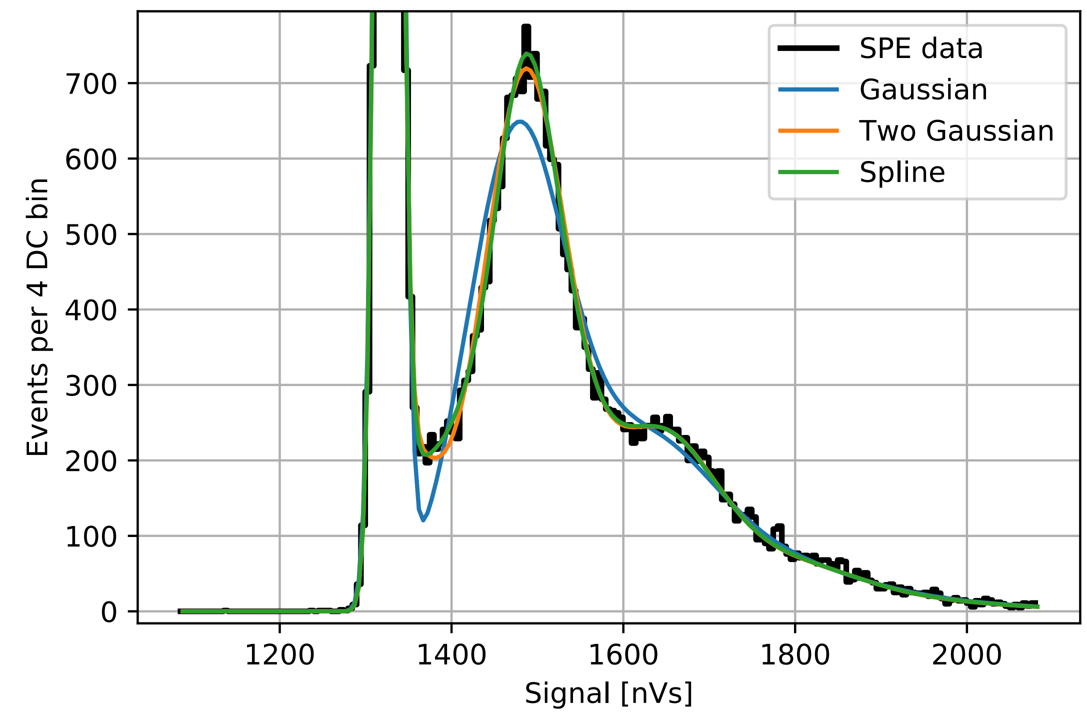


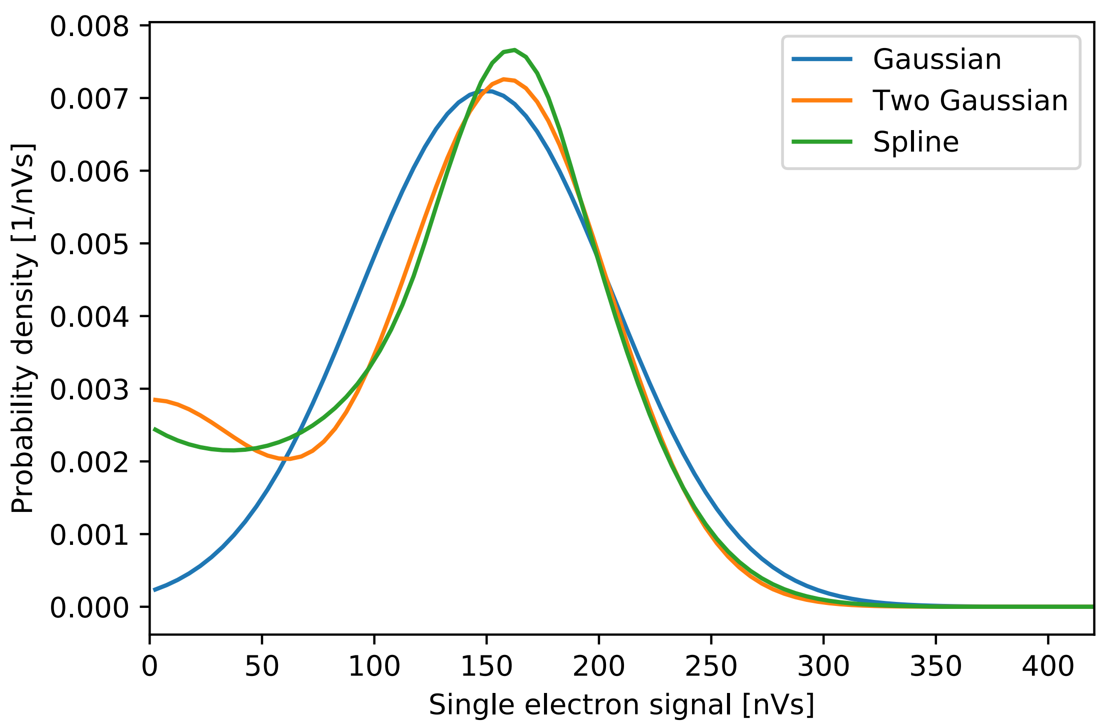
Fabrication drawings for NectarCAM - under development.

Calibration

(S. Fegan, S. Caroff, J. Nanni, LLR)







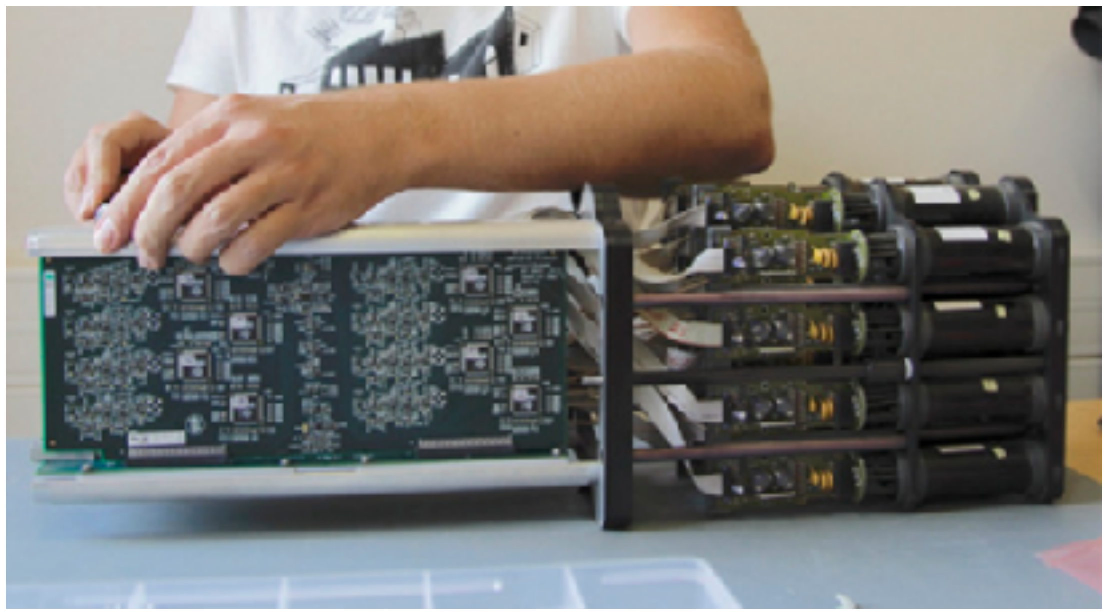
- LLR responsible for coordination of calibration tasks for NectarCAM
- Develop and test new algorithms for calibration : PMTs, muons etc…
- This positions us to be able to quickly exploit science data from first telescope.

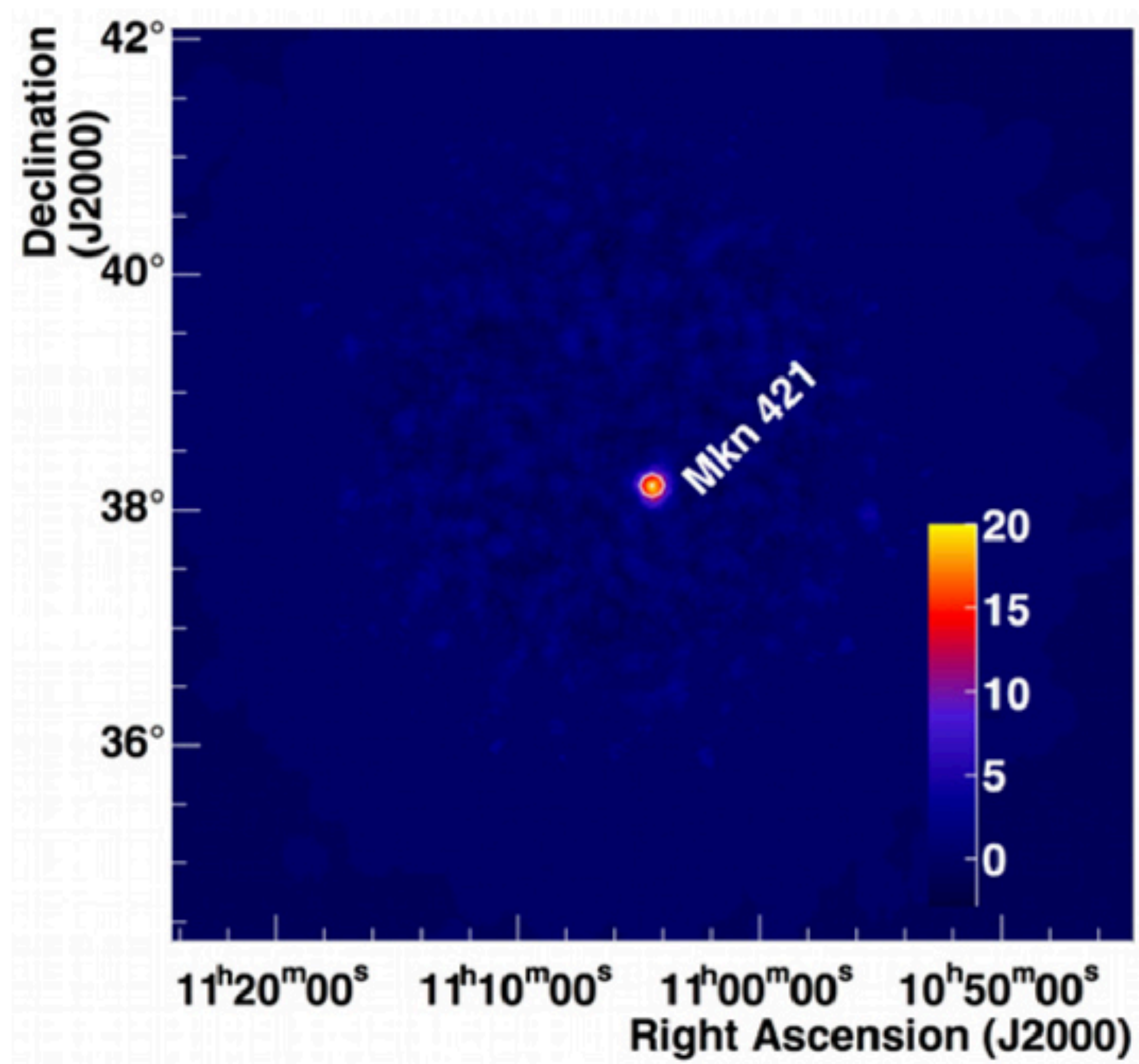
Product Assurance

(S. Pavy, LLR)

- Coordination of product assurance package for MSTN consortium
- NectarCAM manufacturing readiness reviews :
  - Light concentrator MRR completed with large LLR contribution
  - FEB MRR completed between June and September 2017
- Documentation for NectarCAM
- Management of non-conformance procedures

First gamma-ray source detection by Nectar-based camera (HESS-U)





Credit : HESS / DESY, March 2017

https://www.mpi-hd.mpg.de/hfm/HESS/pages/home/som/2017/03/