

# **CTA at LLR**

**A brief status of the project and outline of activities at LLR**

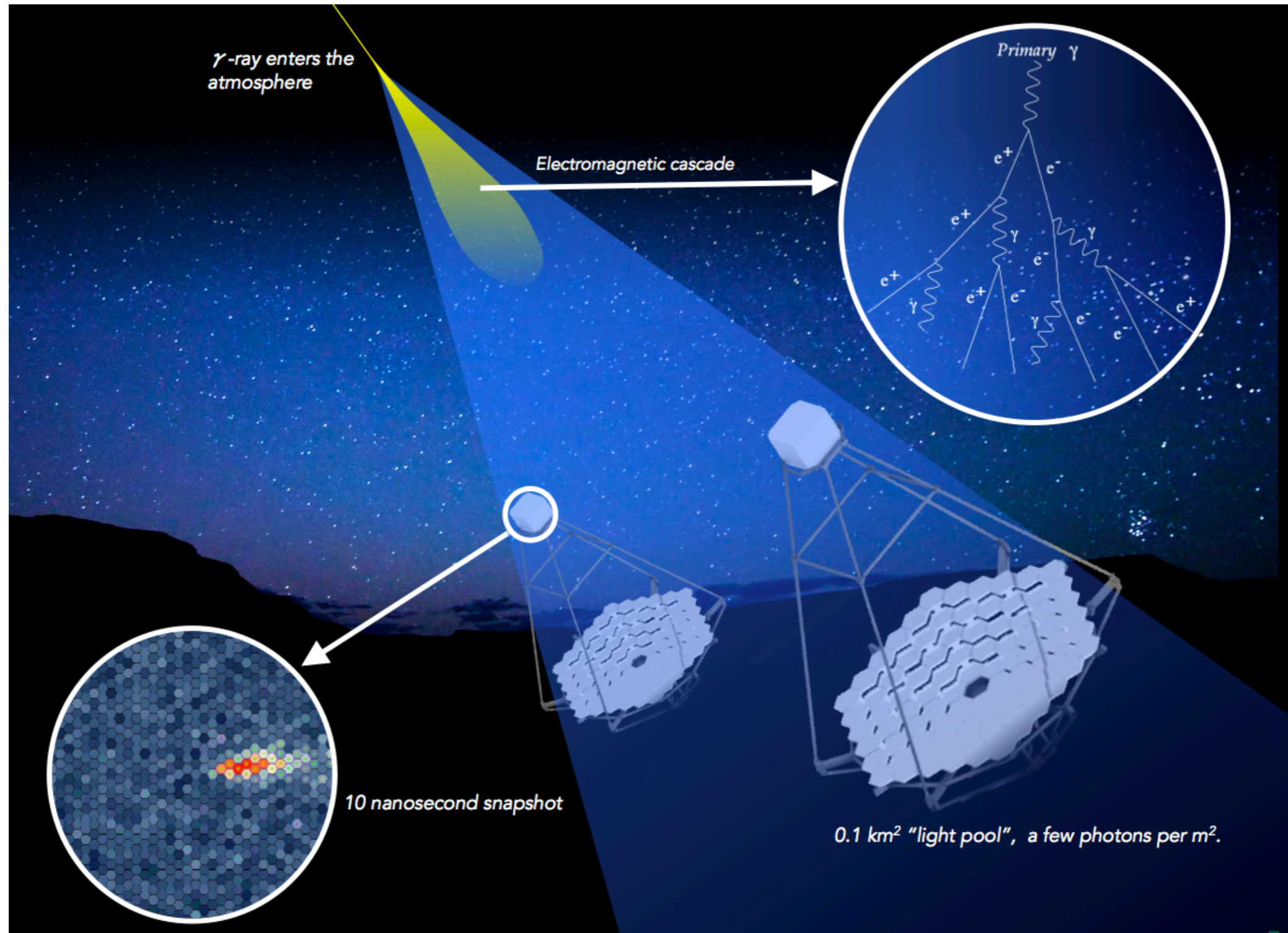
# Principal CTA activities at LLR

## NectarCAM and CTA science preparation

- Design and procurement of NectarCAM mechanical structure (O. Ferreira)
- Local quality assurance (S. Pavy)
- Analysis of NectarCAM data and development of calibration algorithms (S. Fegan, H. Ashkar)
- Preparation of the key-science project on galaxy clusters (R. Adam)
- Transient sources with CTA and NectarCAM (H. Ashkar)
- Speakers and publications office (D. Horan)



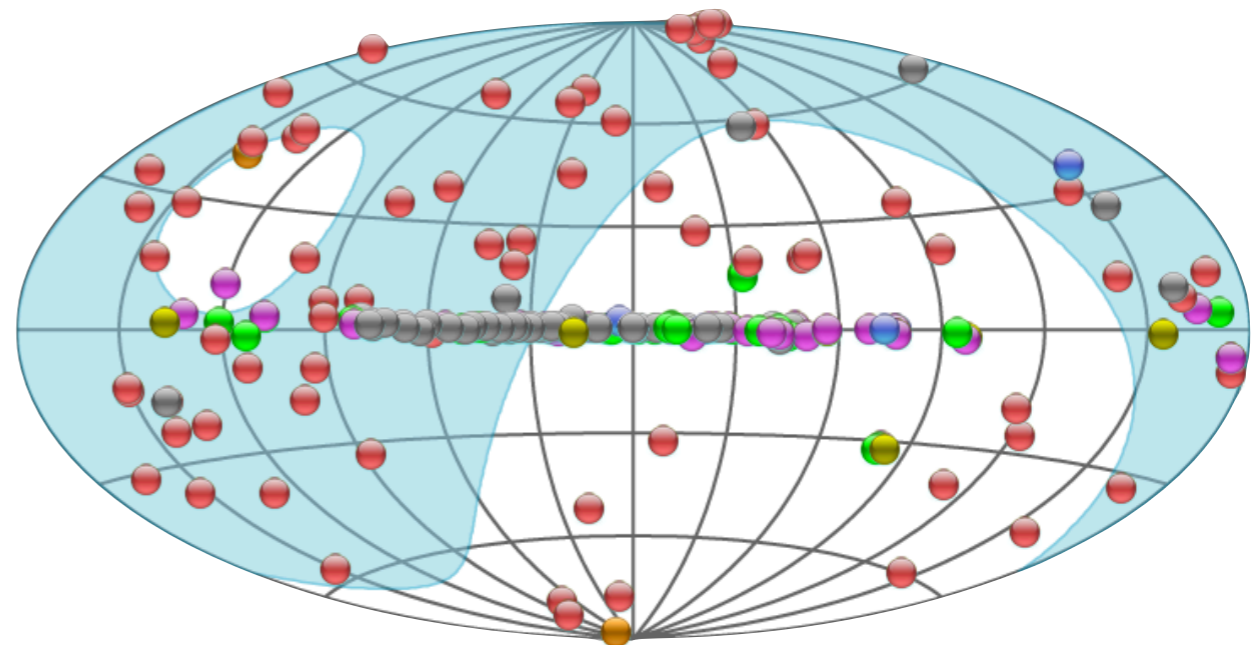
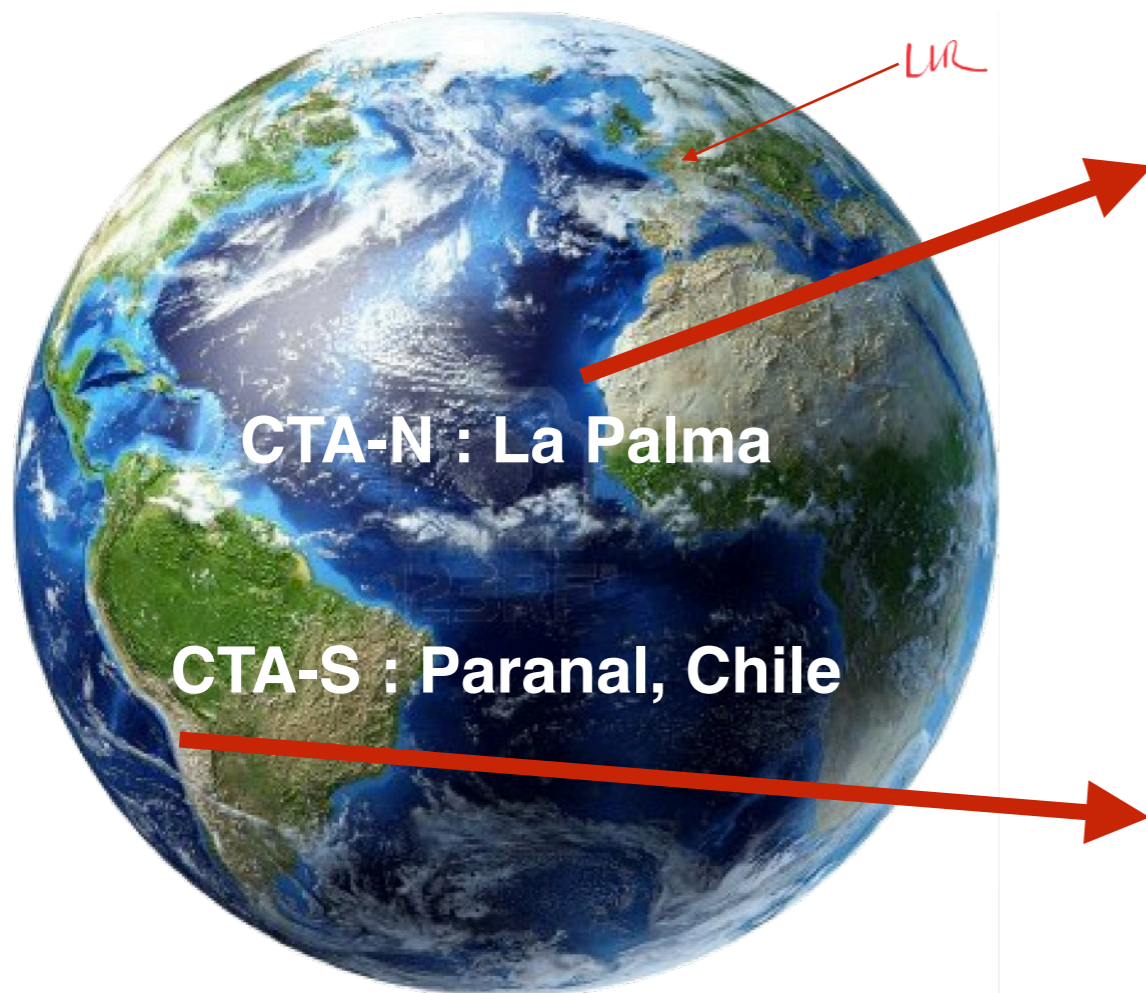
# The Cherenkov Telescope Array



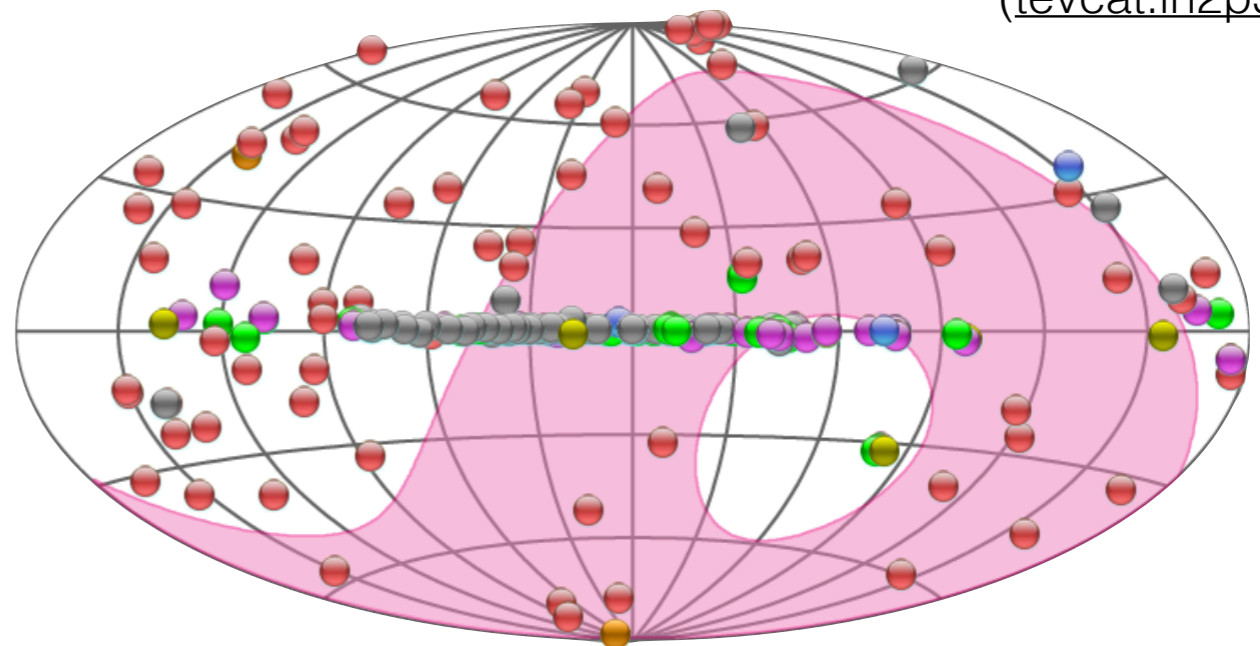
# One observatory, two sites

Full-sky coverage : N extra-galactic, S galactic

CTA-N : 4 LST, 9 MST  
Effective area @10TeV :  $8 \times 10^5 \text{ m}^2$   
Focus on extra-galactic sources



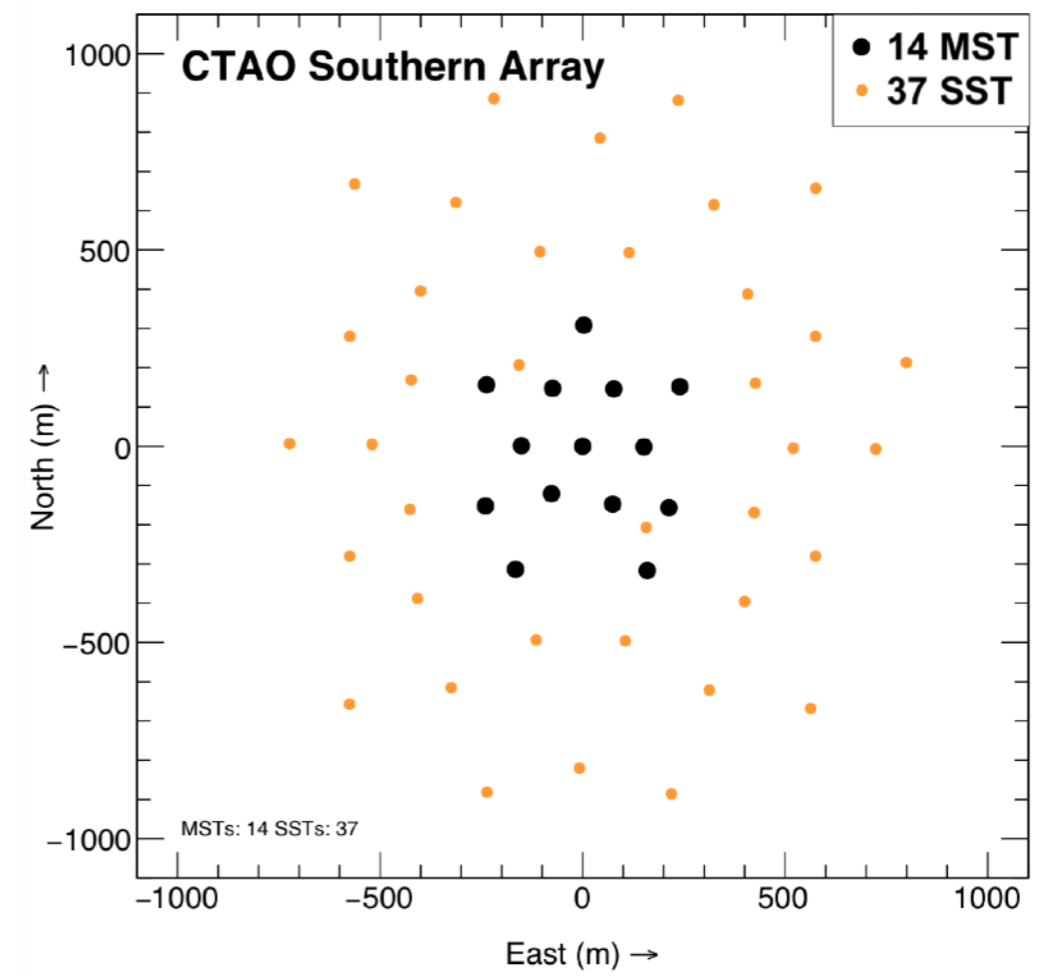
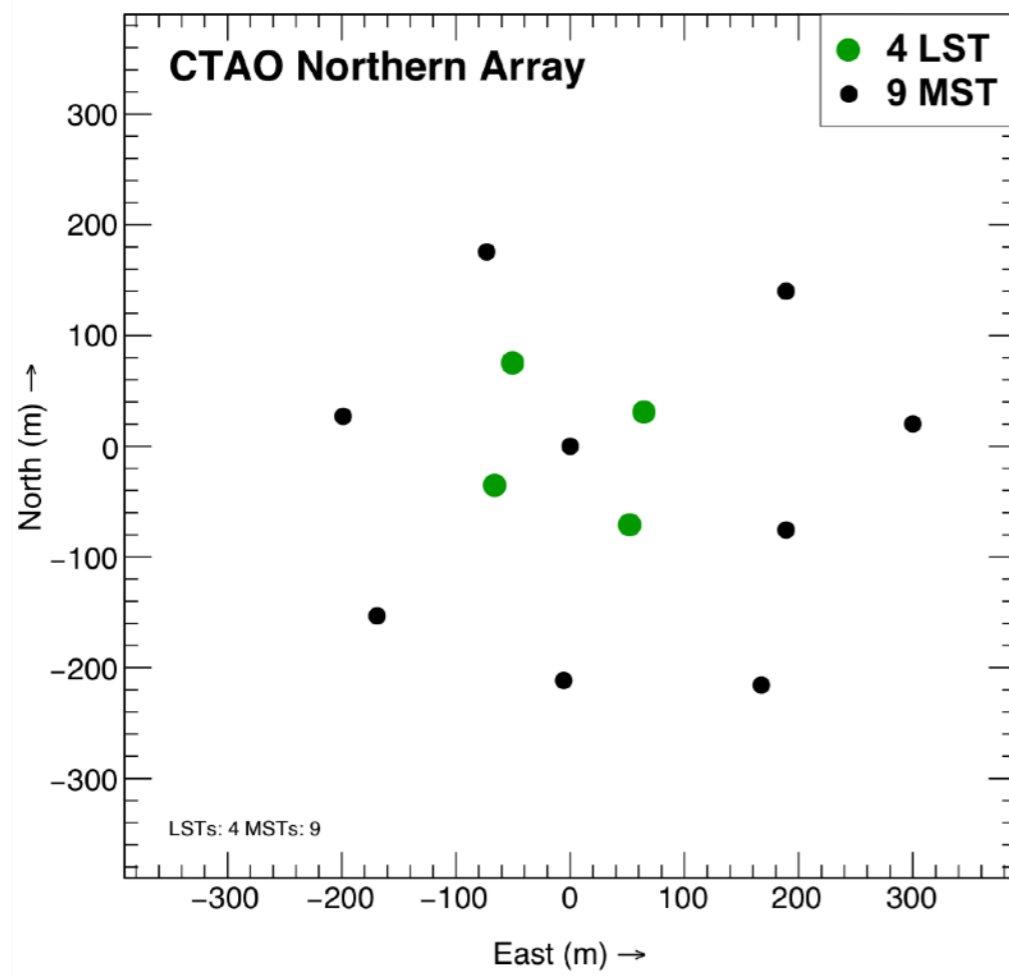
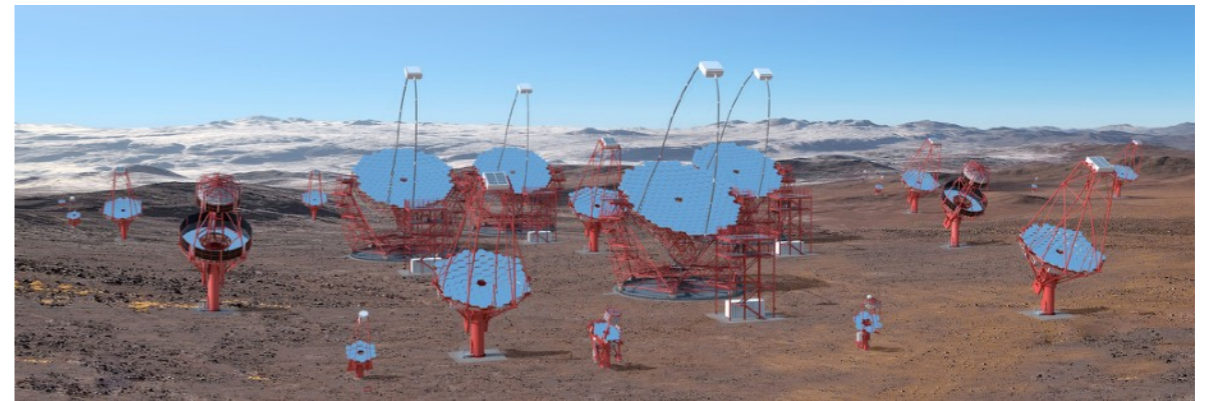
([tevcat.in2p3.fr](http://tevcat.in2p3.fr))



CTA-S : 0–4 LST, 16 MST, 50 SST  
Effective area @10TeV :  $3 \times 10^6 \text{ m}^2$   
Optimised for observation of galactic sources

# One observatory, two sites

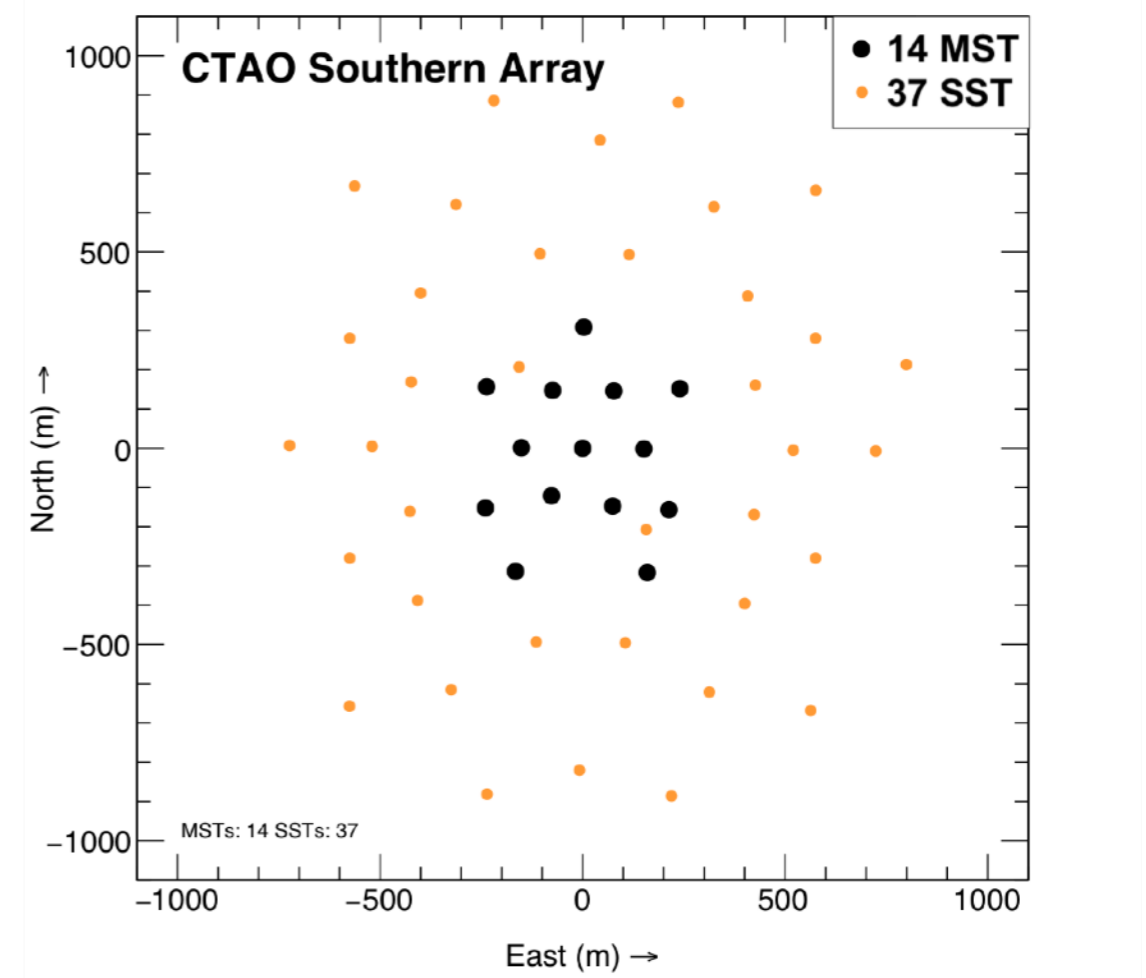
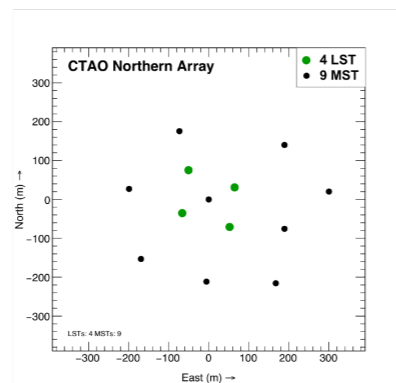
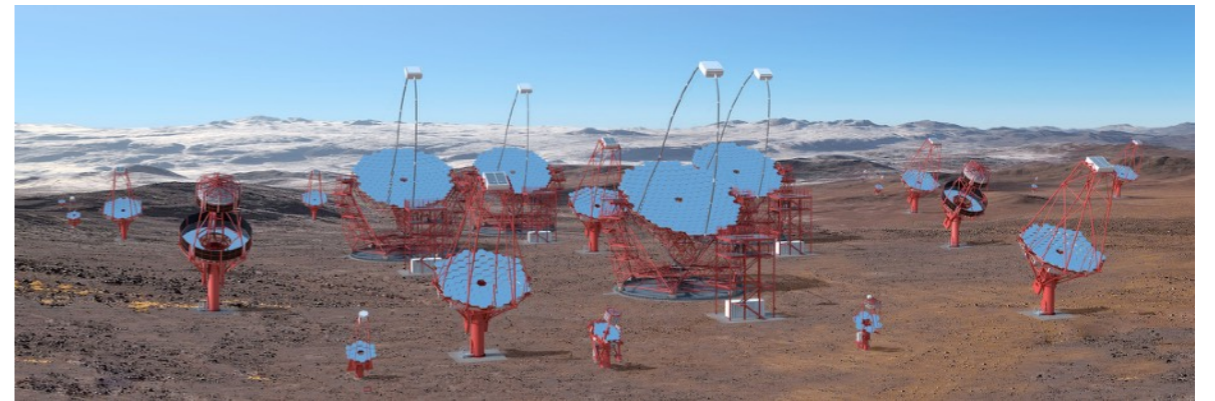
Optimisation of sites for different science cases (\*)



(\*) highest photons absorbed while propagating in extra-galactic space, so optimise Northern site for lower energies (LSTs), and Southern site for high energies (SSTs)

# One observatory, two sites

Optimisation of sites for different science cases (\*)

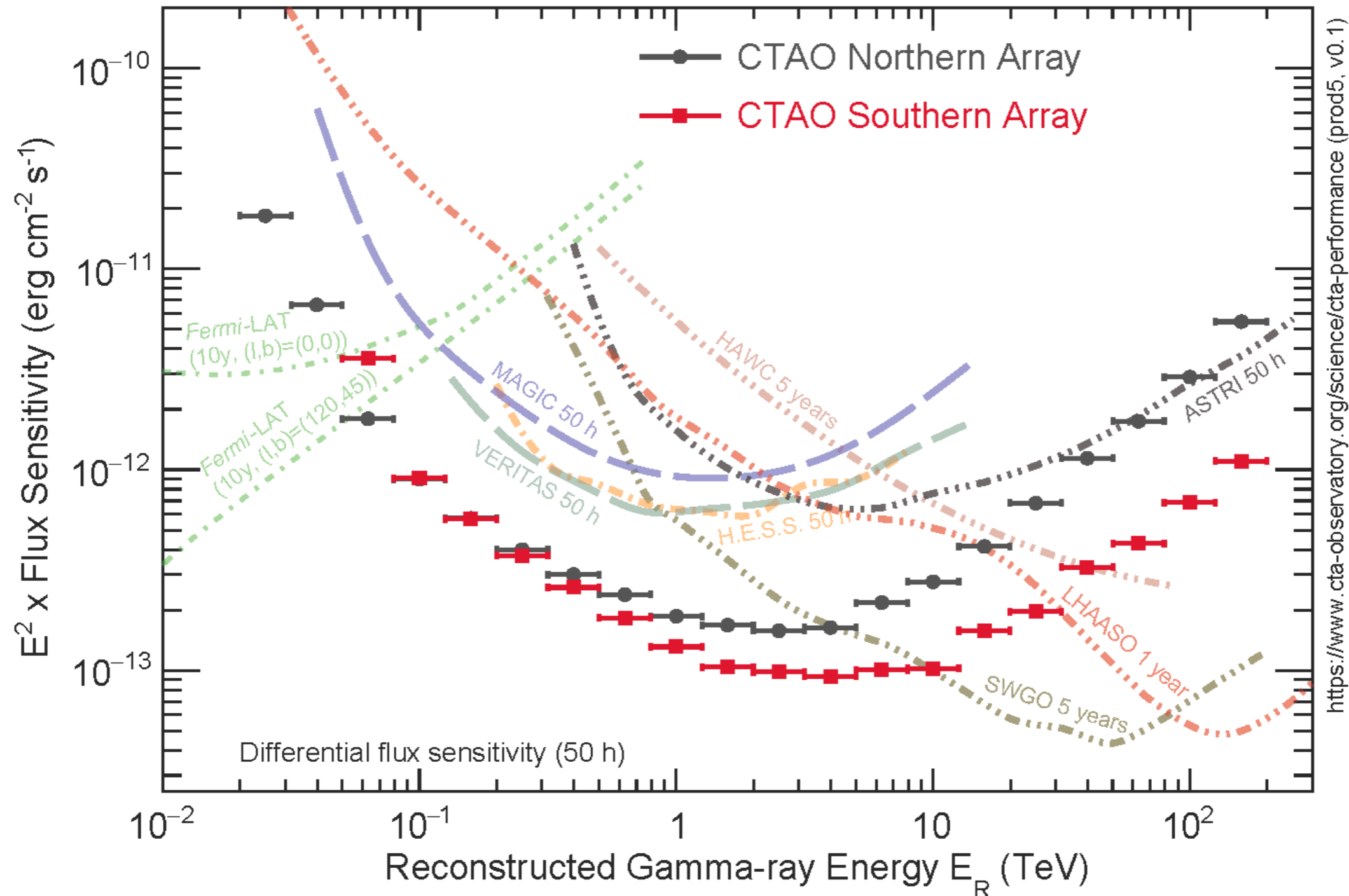


(\*) highest photons absorbed while propagating in extra-galactic space, so optimise Northern site for lower energies (LSTs), and Southern site for high energies (SSTs)

# CTA sensitivity in perspective

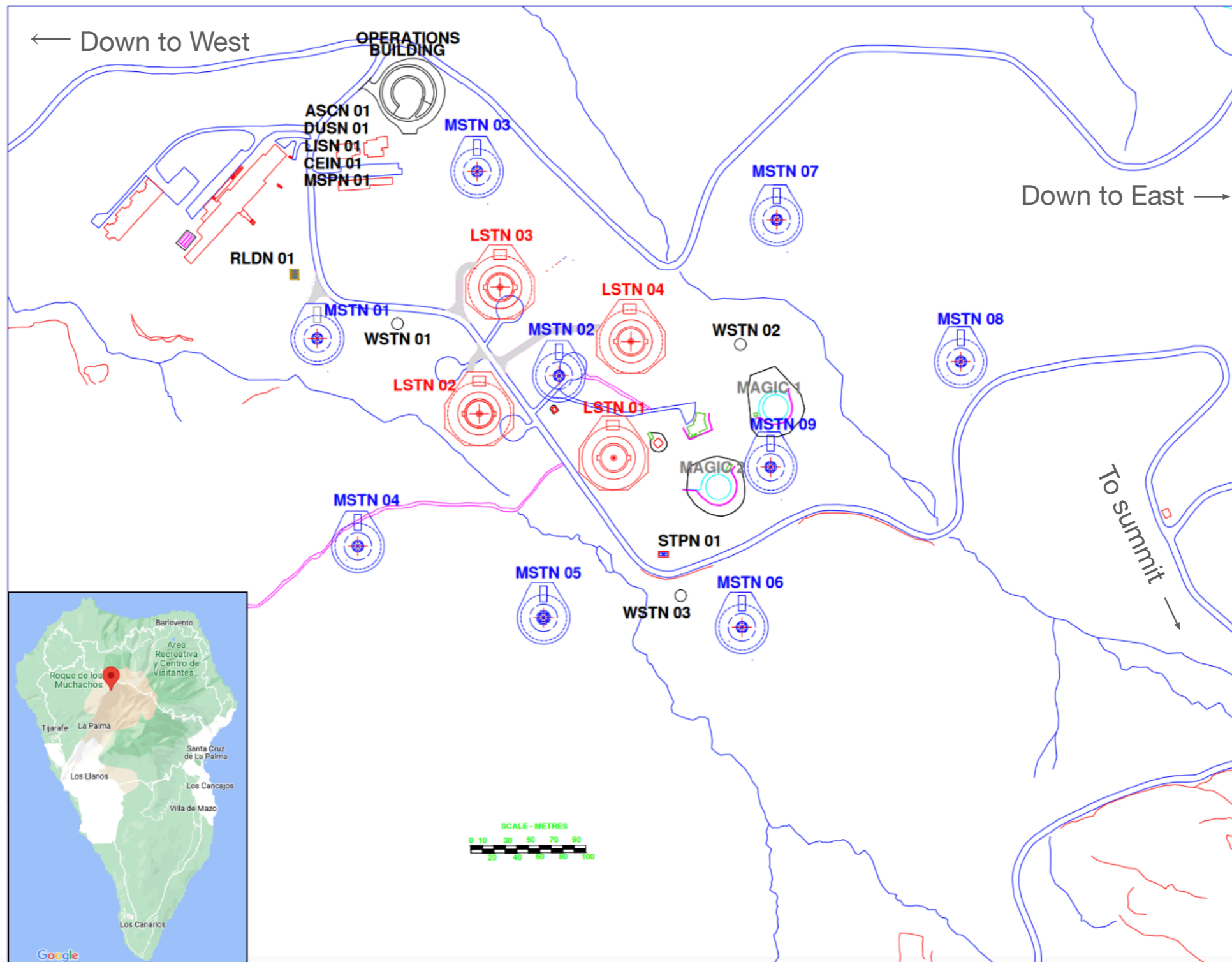
## Brightness of source required to be detected (\*)

(\*) Lower is better



# Northern site

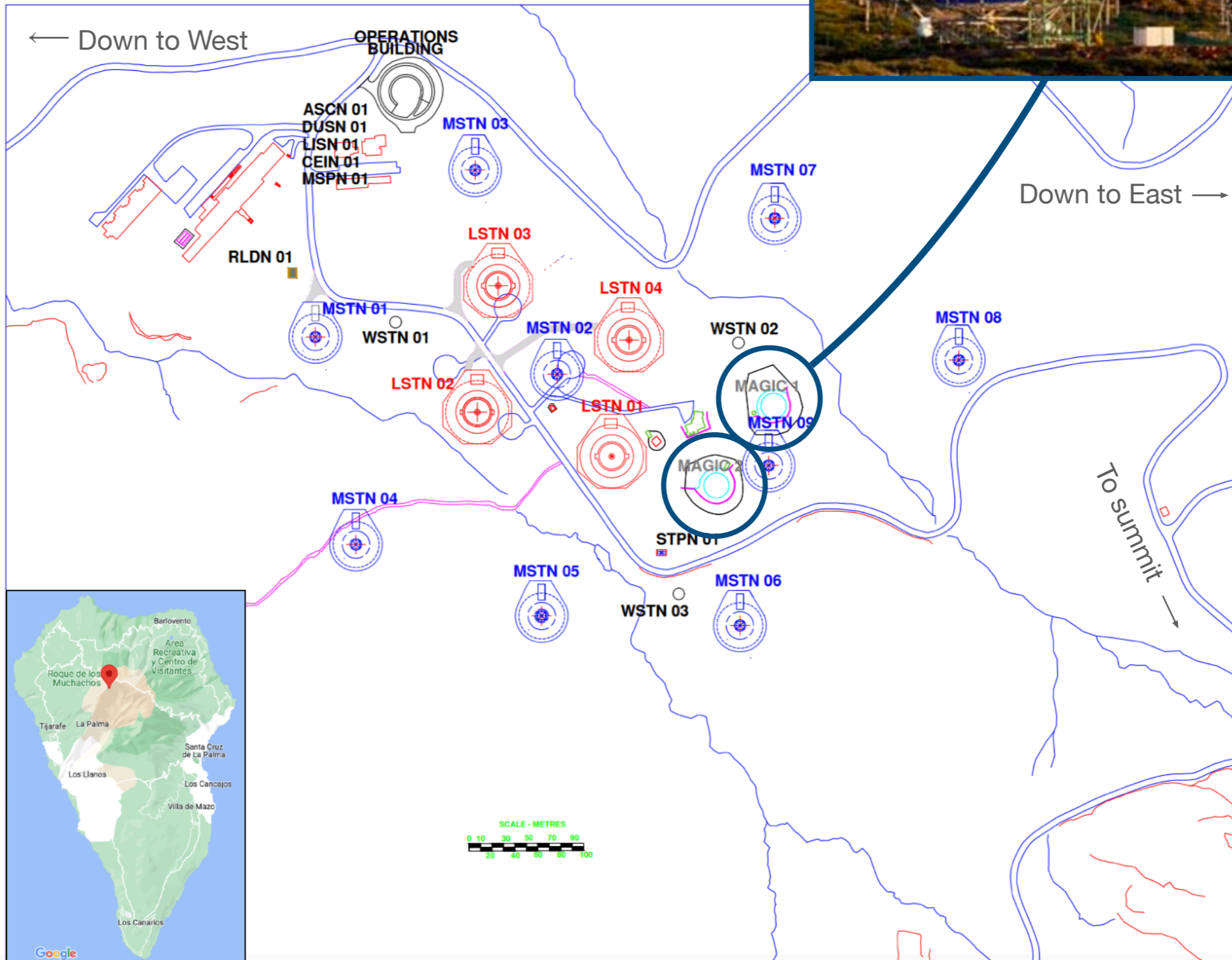
## Layout of the observatory





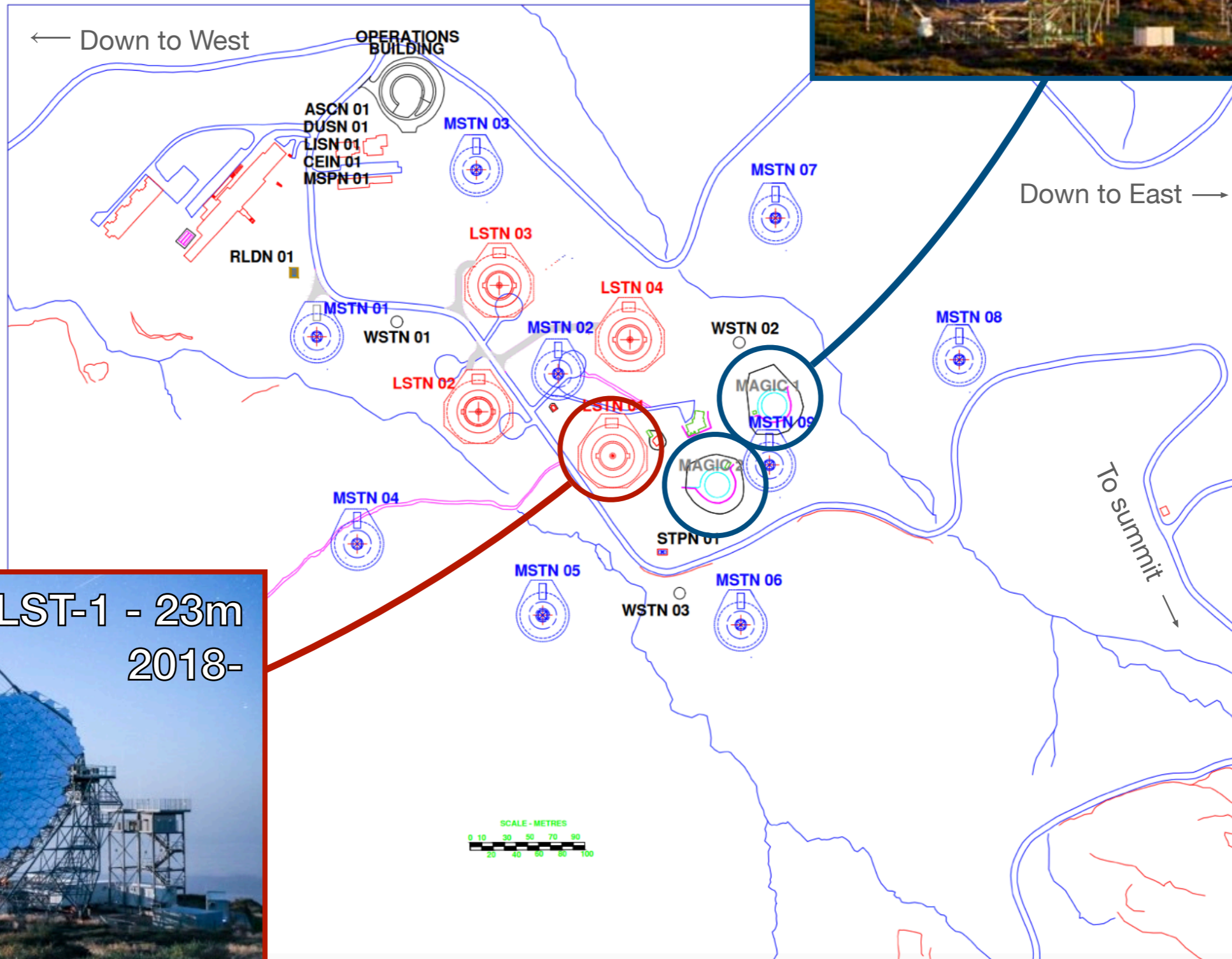
# Northern site

## Layout of the observatory



# Northern site

## Layout of the observatory

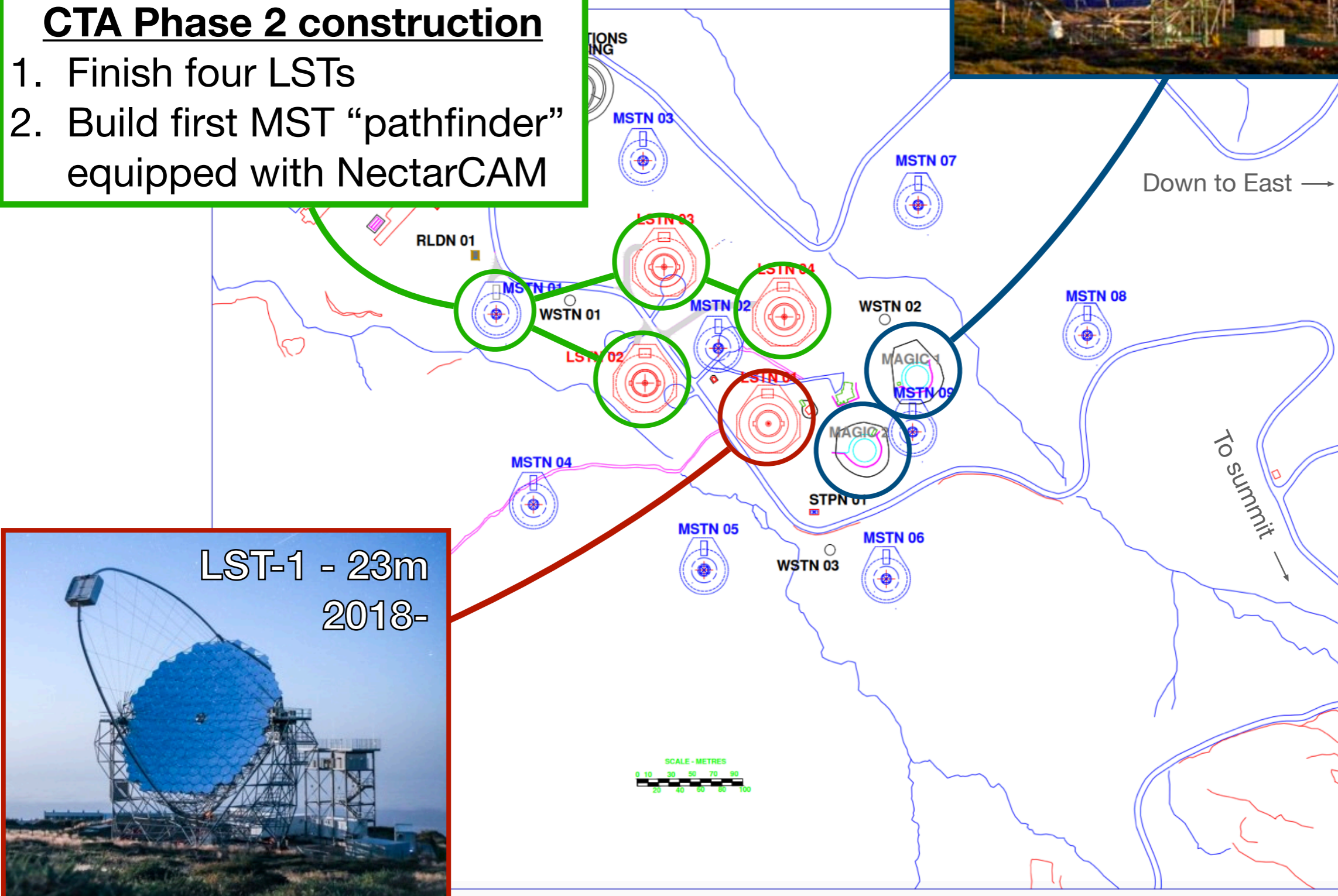


# Northern site

## Layout of the observatory

### CTA Phase 2 construction

1. Finish four LSTs
2. Build first MST "pathfinder" equipped with NectarCAM

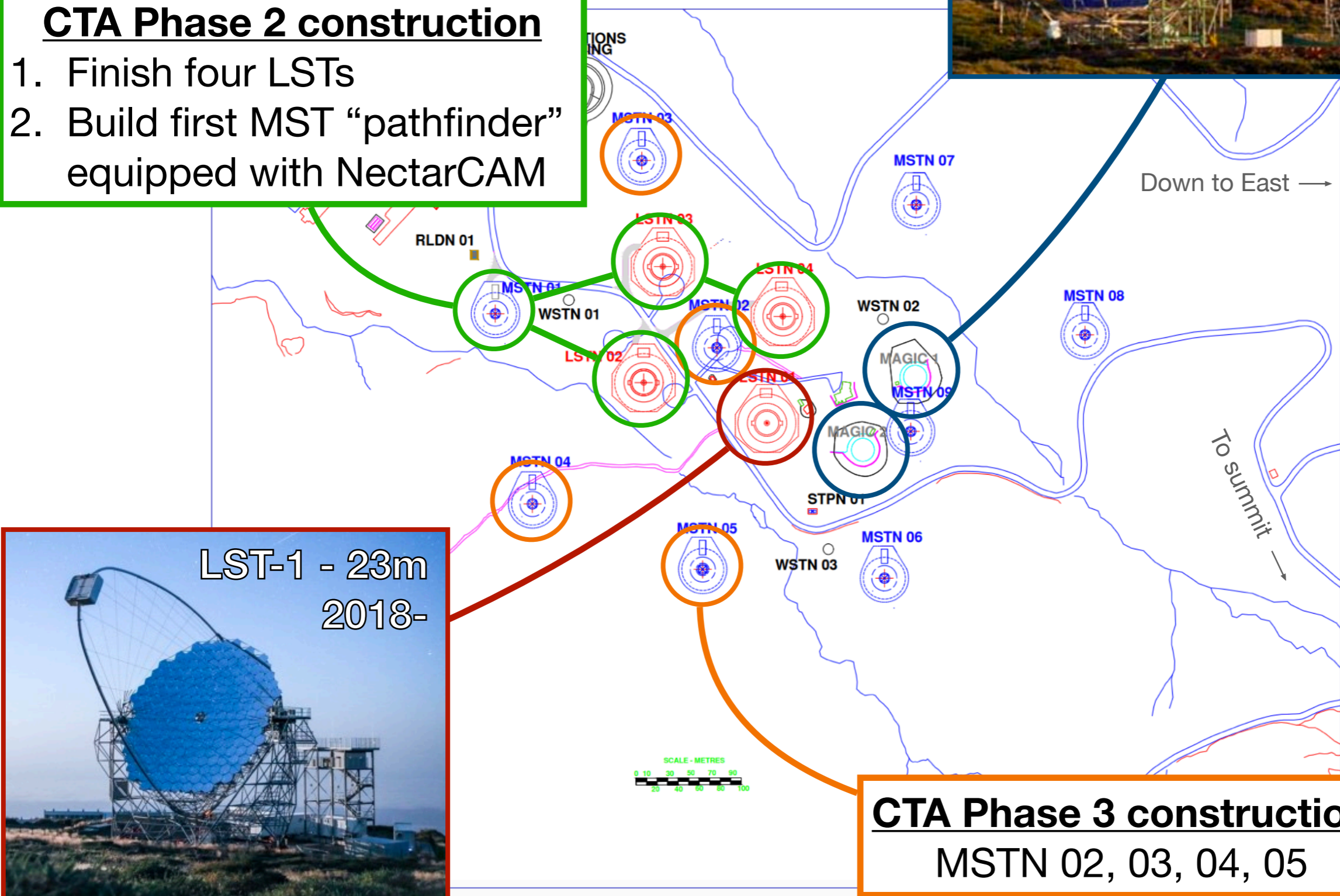


# Northern site

## Layout of the observatory

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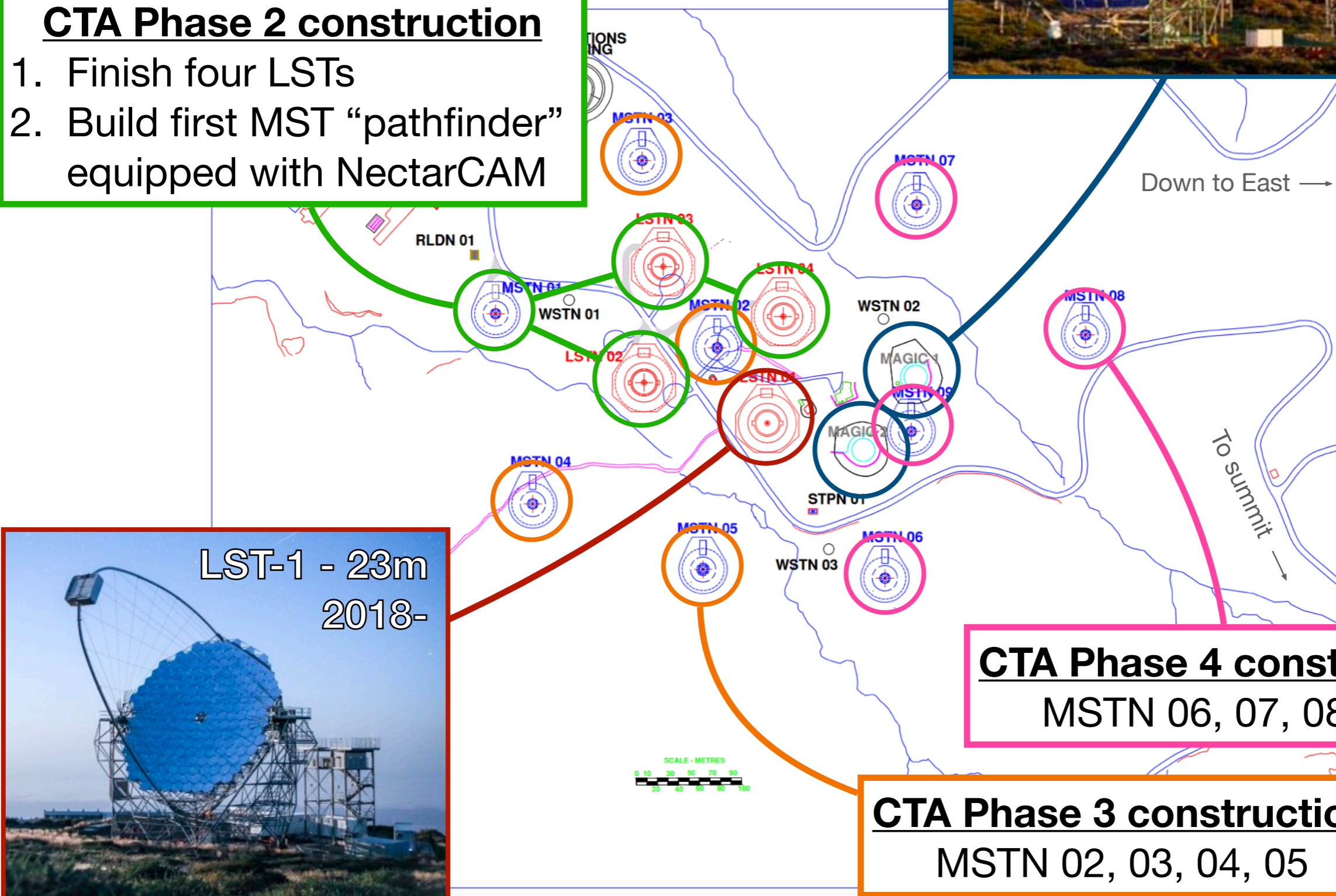
**CTA Phase 3 construction**  
MSTN 02, 03, 04, 05

# Northern site

## Layout of the observatory

### CTA Phase 2 construction

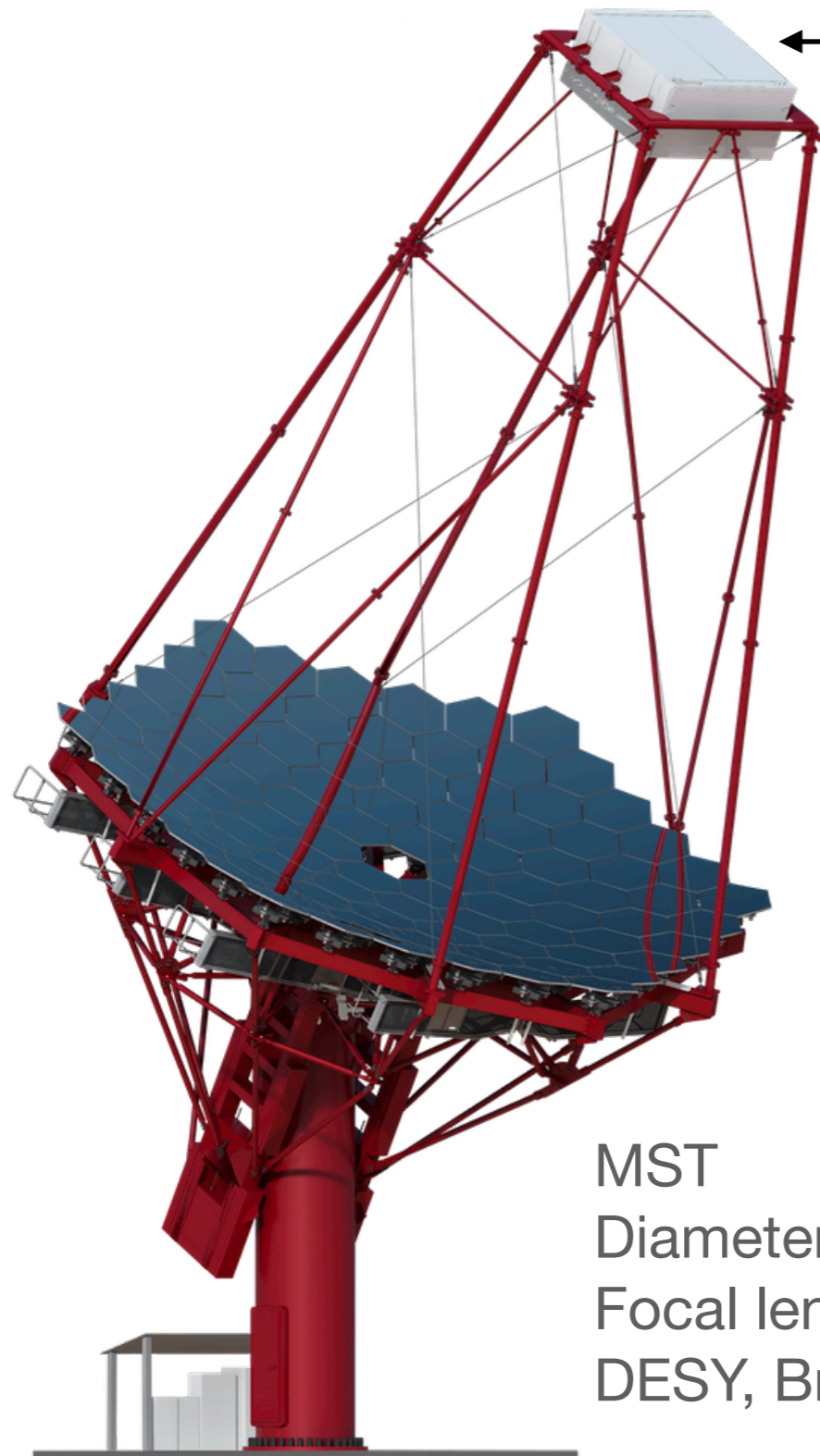
1. Finish four LSTs
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**CTA Phase 4 construction**  
MSTN 06, 07, 08, 09

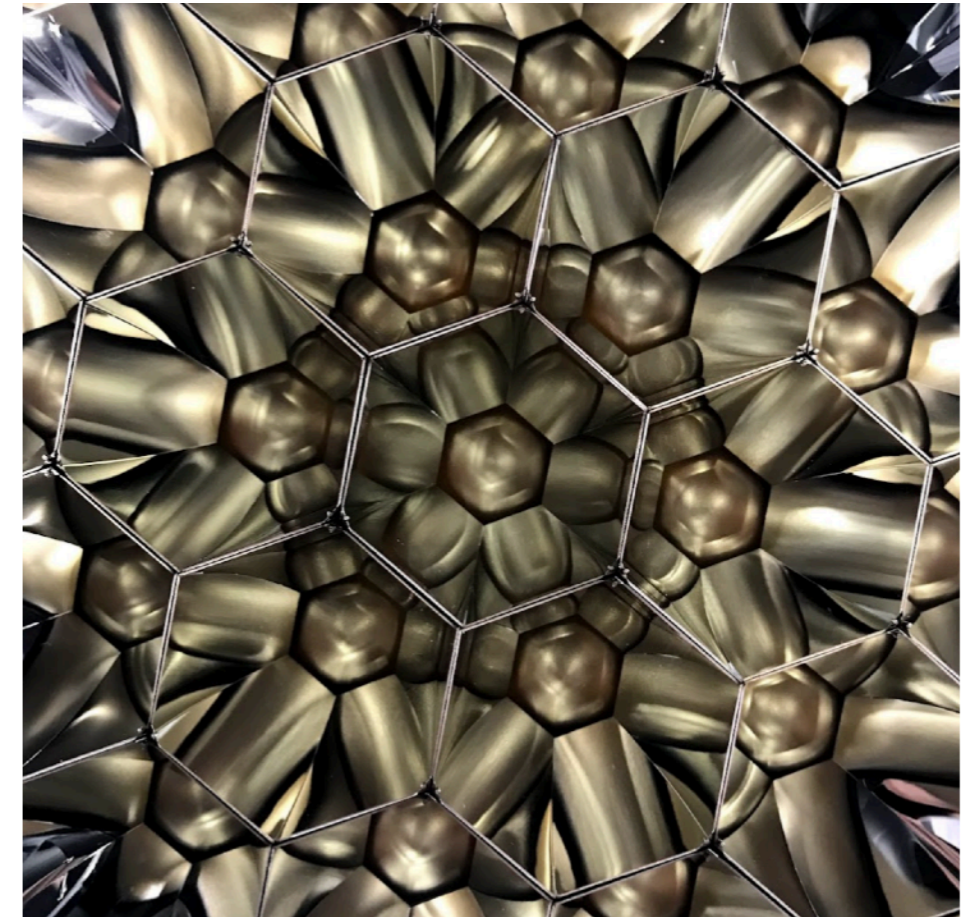
**CTA Phase 3 construction**  
MSTN 02, 03, 04, 05

# MST and NectarCAM



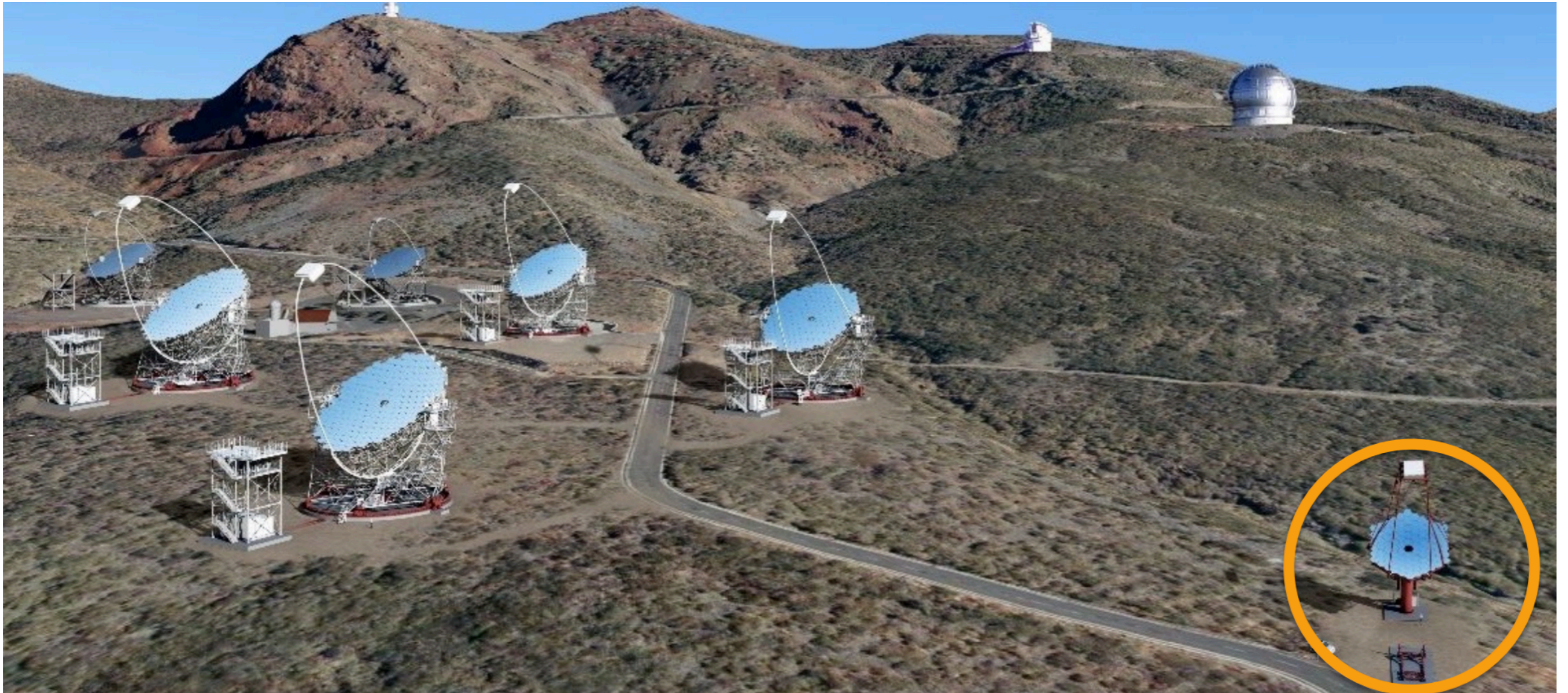
← NectarCAM  
3m x 3m x 1.5m  
1855 PMT pixels  
1GHz sampling  
10kHz event rate  
IN2P3/CEA/INSU

MST  
Diameter : 11.5m  
Focal length : 16m  
DESY, Brazil, Poland, CEA



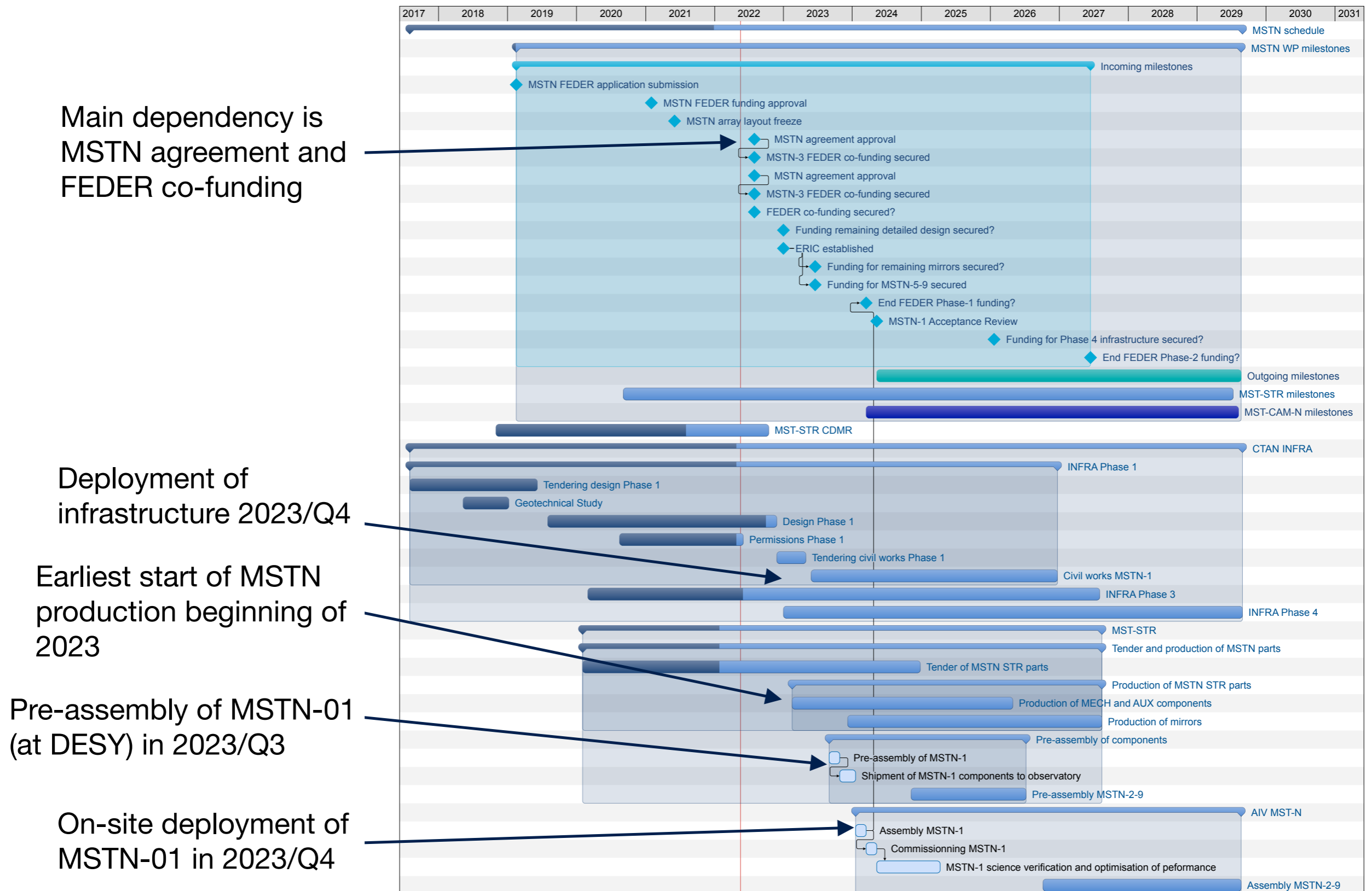
# MSTN pathfinder position

Possible view from a drone in 2023/Q4



Credit M. Garczarczyk, DESY

# MSTN pathfinder schedule





# Northern site

## Status of the construction permits

### Northern Array: construction permits



- At CTAO-North, the as-requested coordinates need to be approved by the local authorities in the form of construction permits

#### CONSTRUCTION PERMIT STATUS

- LSTN-01 built
- LSTN-02, LSTN-03, LSTN-04, MSTN-01 permits requested, approval expected in the next months
- MSTN-02, MSTN-03, MSTN-04, MSTN-05 tender for permit request open but coordinates not submitted yet
- MSTN-06, MSTN-07, MSTN-08, MSTN-09 tender not open yet

Permit request managed by external company under tender.

Call for this tender open but exact position (coordinates) of telescopes not specified in detail as yet.

Ongoing discussion of position of MSTN-09 that is close to MAGIC site.

Possibility to do single application for permits for MSTN-02 to -09.

Credit : Roberta Zanin  
CTA project scientist  
2022-05-19

# Status of NectarCAM-01


## Qualification model (formerly “prototype”)



- Partially-equipped camera tested with MST prototype in Berlin in 2019.
- Modifications made to mechanics based on experience there.
- Use to develop assembly procedure.
- Upgraded camera being tested in dark room in Saclay now.
- Meets all mechanical and electronic requirements of CTA.
- Close out of CDR acceptance with CTAO expected soon.
- Will be installed at La Palma in 2023.

# Procurement of NectarCAM-02 to 09

## European call for tender managed by DR4

	CTA / NectarCAM	Réf. : CTA-LLR-CCTP-039	
	Cahier des Clauses Techniques Particulières (CCTP) Structure Mécanique de la Caméra NectarCAM	Version : 1.3 Date : 03/11/2021 Page : 0/105	

Cahier des Clauses Techniques Particulières (CCTP) – Structure Mécanique de la Caméra NectarCAM

Prepared by	Signature	Accepted by	Signature
Oscar Ferreira, LLR Sandrine Pavy, LLR Vincent Leray, HENSOLDT SPACE CONSULTING		Steve Fegan, LLR	

Approved by	Function	Date	Signature
Steve Fegan	LLR		

Summary	Ce document décrit les clauses techniques exigées pour la réalisation des structures mécaniques et systèmes de refroidissement des caméras du projet NectarCAM.
Annexes	

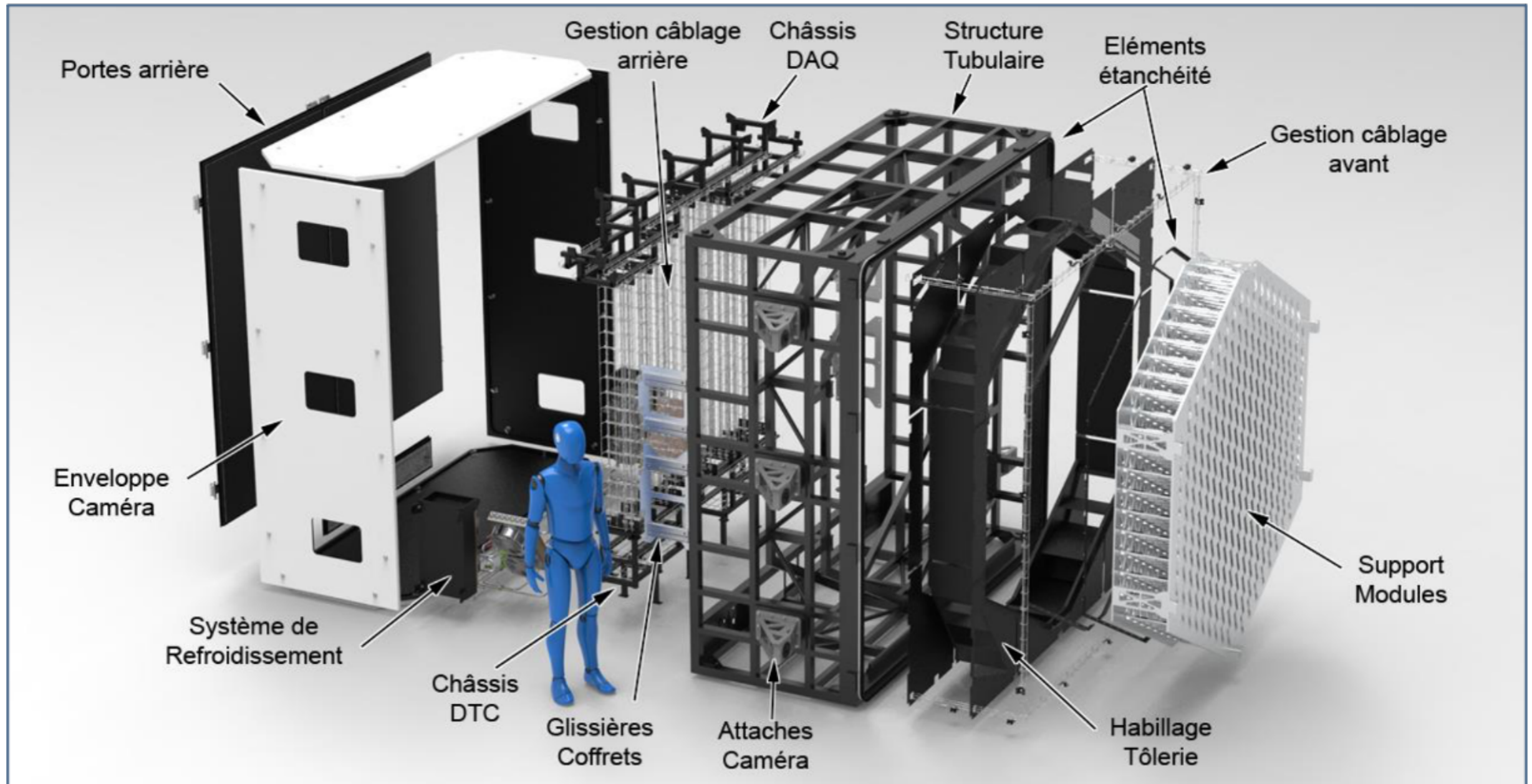
Document Change Record

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- Technical documentation prepared by Oscar, Sandrine & Vincent during 2021/Q4 and 2022/Q1.
- Call for tender for 8 NectarCAMs closed this Tuesday (2022-06-07) after required publication period.
- Fabrication and integration of mechanical elements of camera.
- 4 firm + 4 optional (estimated price of 200k€/camera).
- Analysis of “eligible” offers by DR4 in progress, followed soon by technical analysis by Oscar.

# NectarCAM mechanics

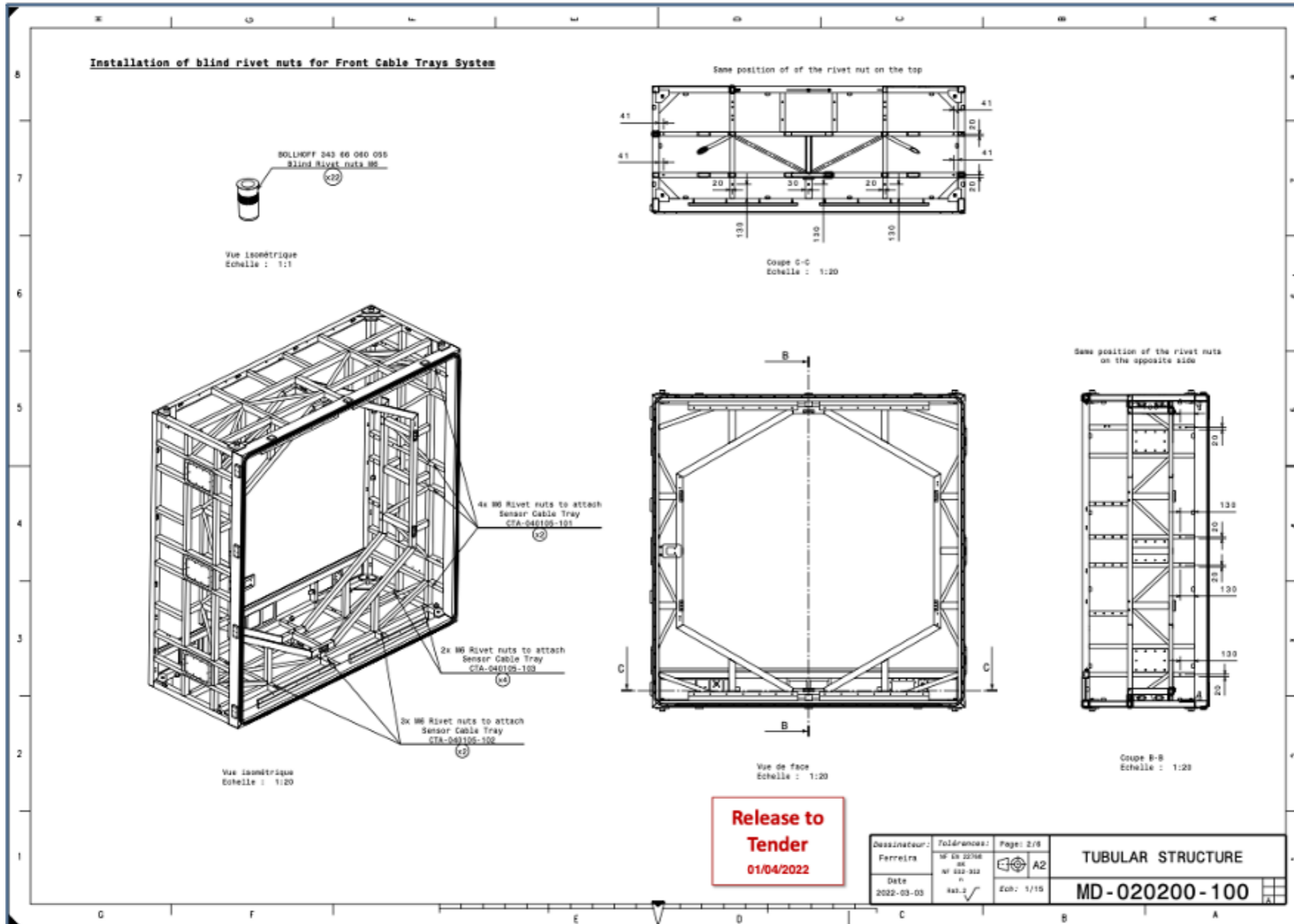
## Mechanical elements included in call for tender



# NectarCAM mechanics

## Fabrication and assembly drawings

267 pages of fabrication and assembly plans



# Procurement schedule

- 2022-06 : analysis of offers and choice of contractor
- 2022-08 (?) : signature of agreement
- 2022/Q4 : procurement of materiel & tooling by contractor
- 2023/Q1 : fabrication of NC-02
- 2023-04 : delivery of NC-02 to Saclay (**at latest : 8 months after signature of agreement**)
- 2023 : fabrication and delivery of of NC-03, -04 & -05 **every 4 months**
- 2023-08 : choice to proceed to optional tranche for NC-06 to -09 (**at latest : on delivery of NC-03**)
- 2024 : fabrication and delivery of NC-06 to -09 to Saclay **every 4 months**
- 2025-08 : final camera delivered to Saclay

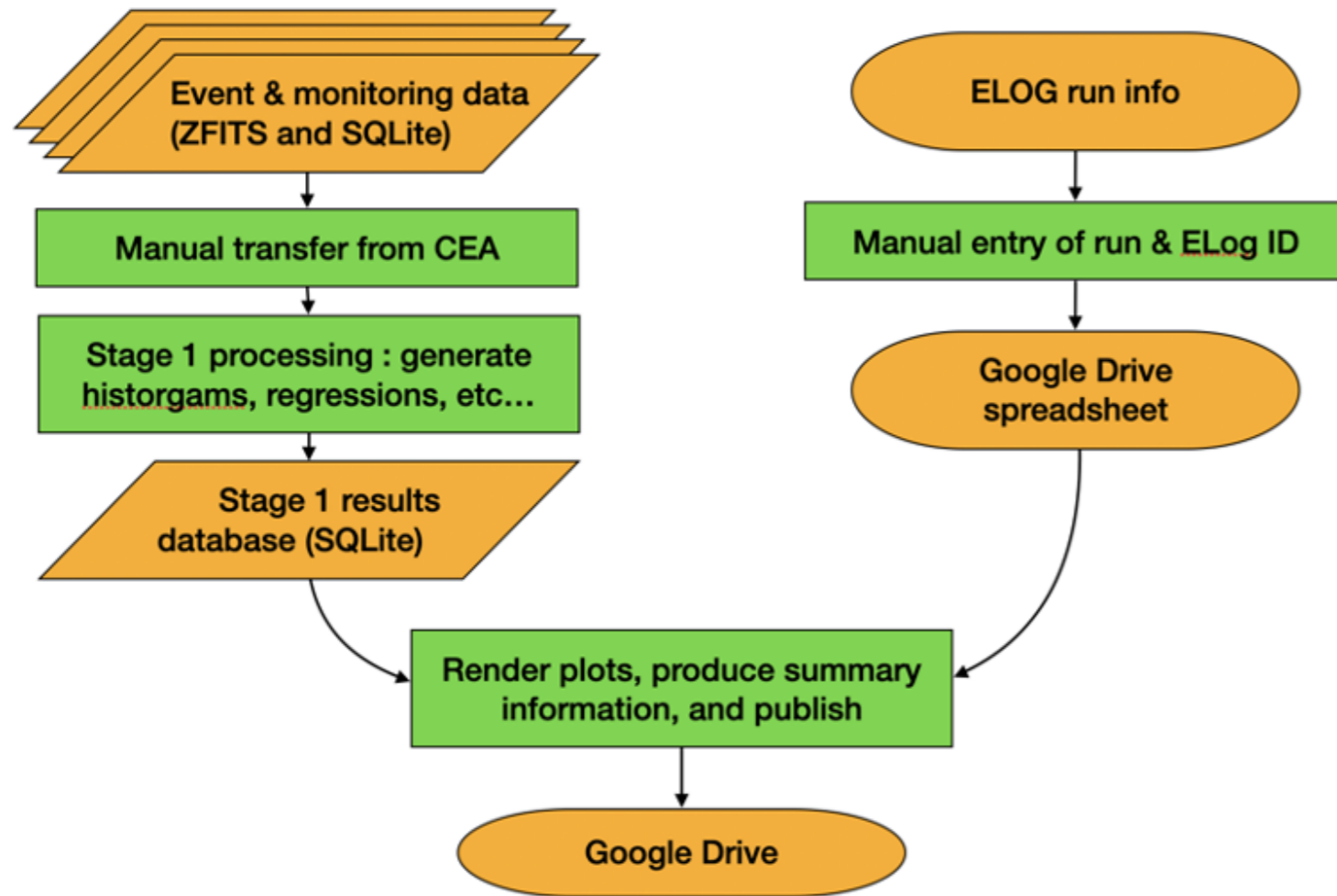
# CTA-N observatory schedule

Should be considered to be (almost) as reliable as the RER-B timetable

- ERIC step 2 : submitted to European commission 2022-06-01, expect about 6 months for consideration of application.
- 2023/Q1 : ERIC in place with all financial commitments secured.
- 2023/Q4 : installation of first MST/NectarCAM at La Palma.
- 2024/Q2 : acceptance of first MST/NectarCAM by CTAO.
- 2026 (2027 ?) : All MST/NectarCAMs accepted by CTAO.
- 2026-2031 : Key-science phase of observatory operation

# NectarCAM data monitoring

## Pipeline for analysis of NectarCAM data



- Development of a data analysis pipeline to monitor data from the NectarCAM test bench and publish results for collaboration to use.
- Produce a standard set of plots that can be easily browsed to identify anomalies.
- Continue development with eye to on-sky commissioning.



# Galaxy clusters as unique laboratories for large scale structure and galaxy formation physics

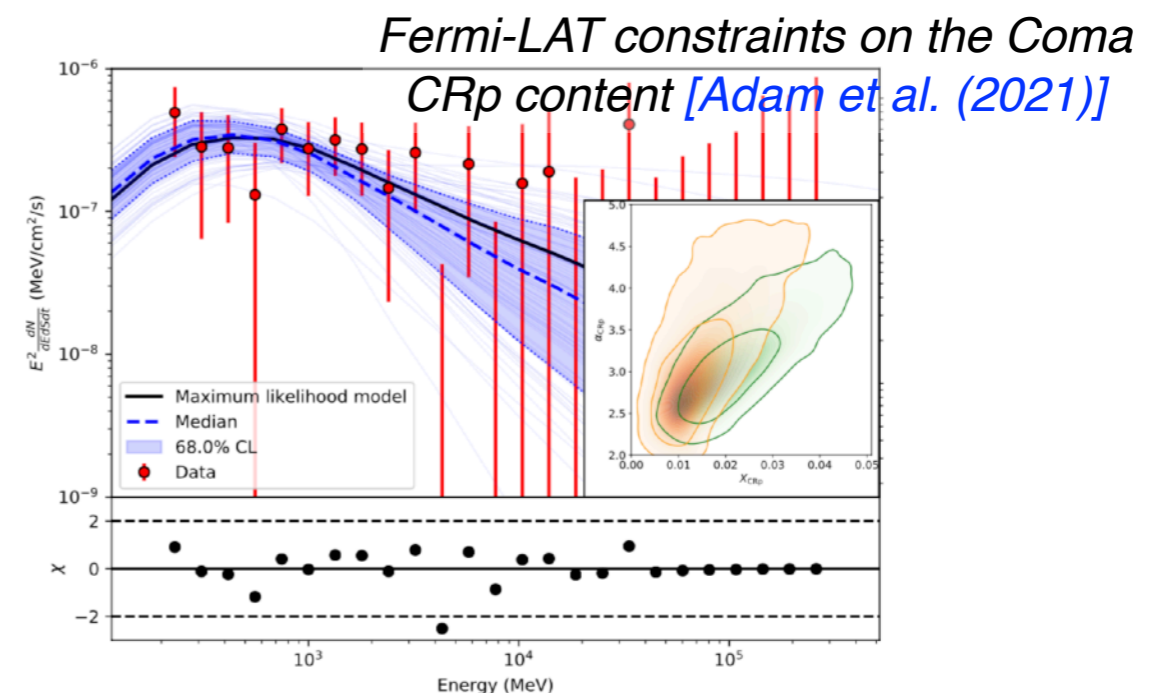
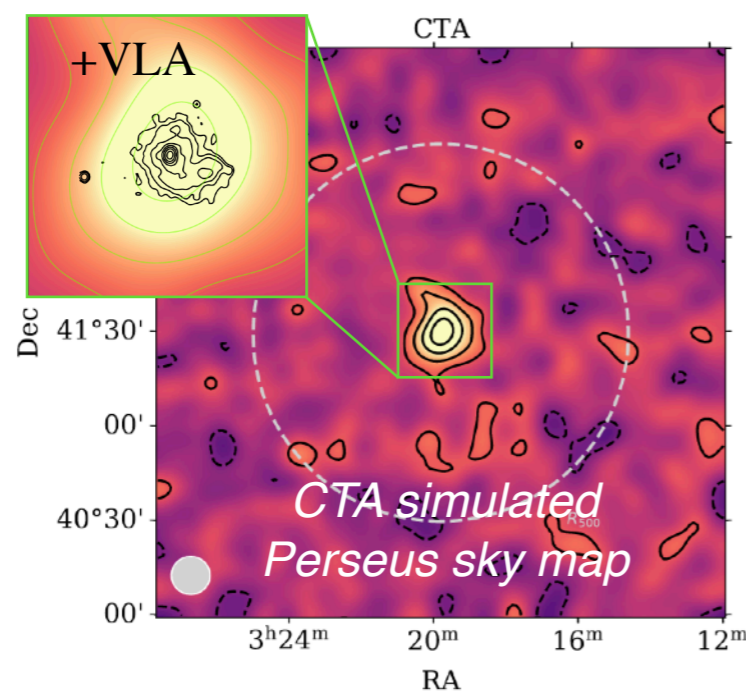
Structure formation energy: heat (~80%) + turbulence + cosmic rays + magnetic field  
 Key for cluster cosmology & large scale structure astrophysics



What is the nature of DM? What is the non-thermal composition? How is it established?

**Strategy:** development of modelling, simulations and analysis tools to prepare CTA observations and scientific exploitation & application to current instruments

➔ **LLR leadership at all stages of CTA cluster CR science & state-of-the-art constraints**



# Transients with CTA & NectarCAM

## Optimise search strategy & analysis for GW alerts

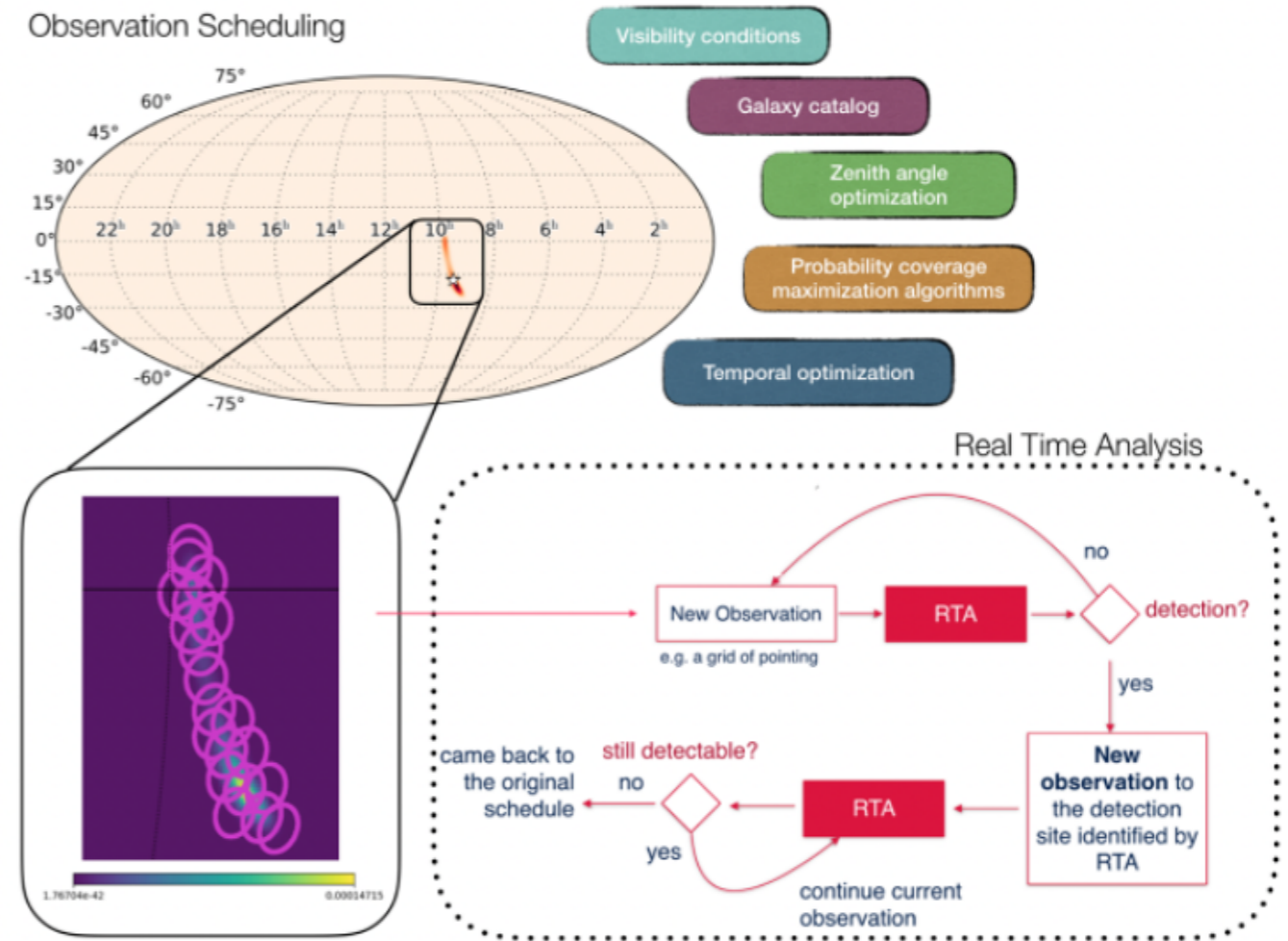
- GW alerts from LIGO/Virgo have large uncertainty areas.
- Optimise search strategy for pointed observations with CTA :

- Galaxy density & distance.
- Observability from 2 sites.
- Field-of-view & energy threshold of instruments.

- Optimise NectarCAM analysis for wide field-of-view.

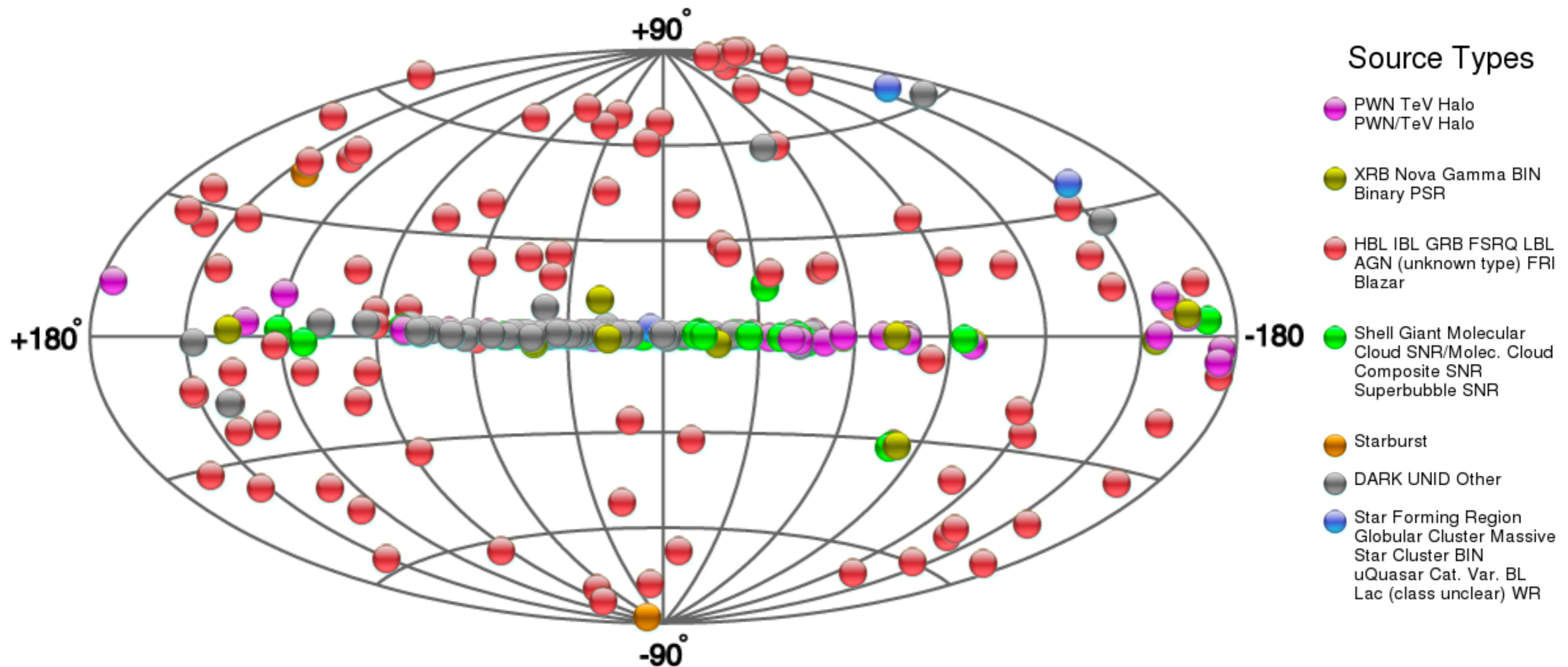
- Broad interest in group to work on physics of transients with CTA.

- ANR with CEA/IJCLab (Co-PI at LLR : D. Horan).



# TeV source catalogue

<http://tevcat.in2p3.fr/>



- TeV catalogue & science portal maintained by D. Horan at LLR.
- Unique resource that will be important to continue into CTA era.

# CTA perspectives for the 2020's

## Commissioning and key-science projects

- Installation date of first MST/NectarCAM becoming more clear
- Intensive period of commissioning & validation of 9 NectarCAMs
  - Validation of instrument with on-sky observations
  - Detailed MC/Data comparisons
  - Optimisation of analysis for different science cases
- Intensive period of early science & key-science projects
  - Agreement with CTA with defined KSP deliverables & dates
- Science on transients, AGN, clusters of primary interest of LLR group

# EAOM 2023

## Requests by the CTA group...

- PhD thesis : on the preparation for observation of transients with NectarCAM and CTA. Optimisation of analysis for wide field-of-view of NectarCAM. Strategy for CTA-N site using LSTs and MSTs. Analysis of HESS transient follow-ups.
- Postdoc : to continue work started by Halim at LLR on transient science with CTA-N after he leaves in Nov 2023, and to participate in commissioning of NectarCAM.
- Preference for PhD ...
- ... but financement of PhD thesis requested as as part of ANR proposal “MOTS” to work on transient / multi-messenger followups with CTA and Fermi.

# **Backup**

**Just in case...**

# NectarCAM DQM results

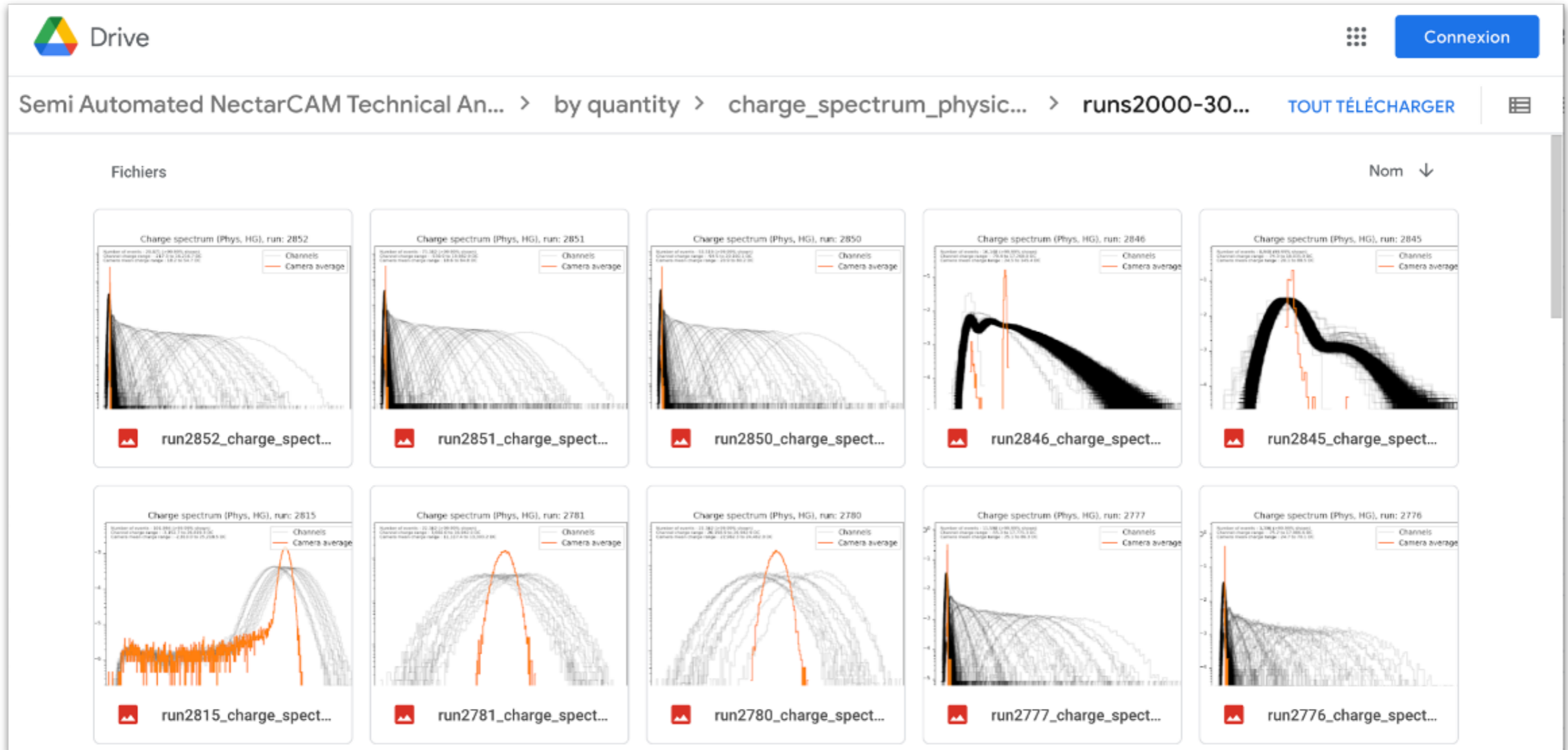
## Run-by-run spreadsheet

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Run	Events	Trigger types found				Problematic events						UCTS-based run dur		
2	num	on disk	L1 trig	Ped trig	Ext flash	Int flash	Duplicate	Missing	No UCTS	No TIB	No T&C	Partial	Duration	Trig rate	Disk rate
3		[event]	[event]	[event]	[event]	[event]	[event]	[event]	[event]	[event]	[event]	[event]	[sec]	[Hz]	[Hz]
286	2837	306,298		27,835	278,463			412					278.87	1,099.84	1,098.36
287	2838	308,462		28,033	280,430			50					280.51	1,099.84	1,099.66
288	2839	218,079		19,817	198,262			414					198.66	1,099.85	1,097.77
289	2840	356,468		32,396	324,072			217					324.31	1,099.84	1,099.17
290	2841	106,881		9,713	97,168			51					97.23	1,099.83	1,099.31
291	2842	24,942		2,267	22,675			142					22.81	1,099.86	1,093.63
292	2843	121,409			121,409			580					17.28	7,061.15	7,027.58
293	2845	8,948	8,948					130				6	25.19	360.40	355.24
294	2846	16,148	16,148					459					16.49	1,007.31	979.46
295	2847	98,555		1,988	96,567			145					20.02	4,929.18	4,921.93
296	2848	105,270		2,125	103,145			47					21.34	4,934.81	4,932.61
297	2850	73,848	53,519	20,328				363		9		6	203.61	364.47	362.69
298	2851	80,704	73,382	7,322				6				2	73.23	1,102.20	1,102.12
299	2852	32,248	28,871	3,077			299	467				300	33.69	971.01	957.15
300	2857	49,374		8,221	41,153			1,135				2	84.29	599.24	585.78
301	2858	50,598		12,630	37,968								126.69	399.38	399.38
302	2860	109,689		2,366	107,323								23.73	4,621.59	4,621.59
303	2861	9,692		9,692				519					102.10	100.01	94.92
304															

[https://docs.google.com/spreadsheets/d/1LeINmO-Cjfcbt87yOBFomoappE610\\_pS5SUNdX6Rp2A/edit?usp=sharing](https://docs.google.com/spreadsheets/d/1LeINmO-Cjfcbt87yOBFomoappE610_pS5SUNdX6Rp2A/edit?usp=sharing)

# NectarCAM DQM results

## Histograms, ordered by quantity or by run



[https://drive.google.com/drive/folders/1cjOwwFVjfVVC86F\\_gqVkJrF-IBC7W7SN?usp=sharing](https://drive.google.com/drive/folders/1cjOwwFVjfVVC86F_gqVkJrF-IBC7W7SN?usp=sharing)