

# Status of LSTs



**Daniel Mazin for the CTAO LST project**

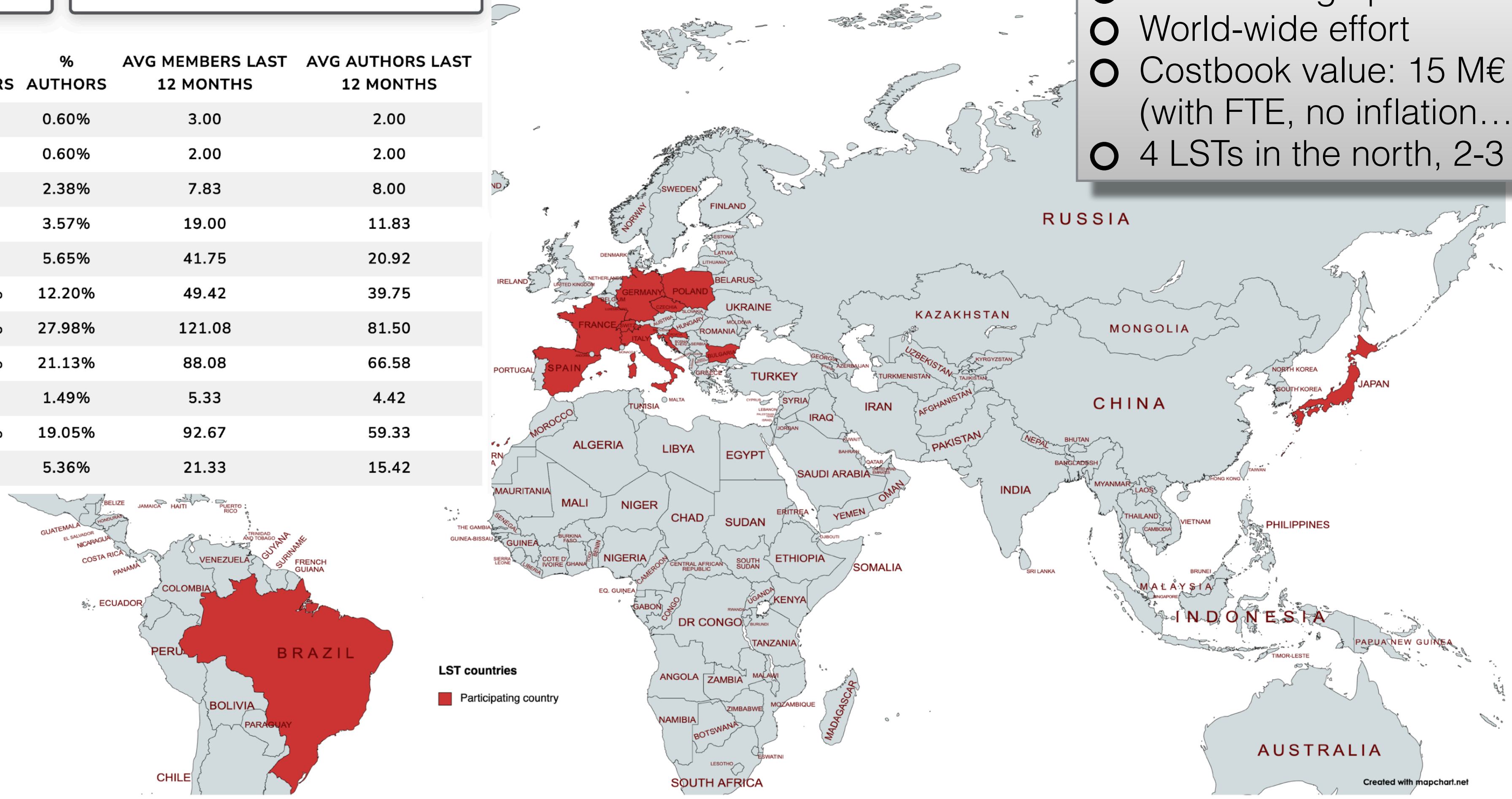
# LST collaboration

TOTAL MEMBERS  
**466**

TOTAL AUTHORS  
**336**

COUNTRY	MEMBERS	AUTHORS	% MEMBERS	% AUTHORS	AVG MEMBERS LAST 12 MONTHS	AVG AUTHORS LAST 12 MONTHS
Brazil	3	2	0.64%	0.60%	3.00	2.00
Bulgaria	2	2	0.43%	0.60%	2.00	2.00
Croatia	7	8	1.50%	2.38%	7.83	8.00
Czechia	19	12	4.08%	3.57%	19.00	11.83
France	44	19	9.44%	5.65%	41.75	20.92
Germany	49	41	10.52%	12.20%	49.42	39.75
Italy	127	94	27.25%	27.98%	121.08	81.50
Japan	89	71	19.10%	21.13%	88.08	66.58
Poland	6	5	1.29%	1.49%	5.33	4.42
Spain	101	64	21.67%	19.05%	92.67	59.33
Switzerland	19	18	4.08%	5.36%	21.33	15.42

- 11 countries, 28 institutions
- LST is a large part of CTAO
- World-wide effort
- Costbook value: 15 M€ / telescopes (with FTE, no inflation...)
- 4 LSTs in the north, 2-3 in the south?



# The LST team

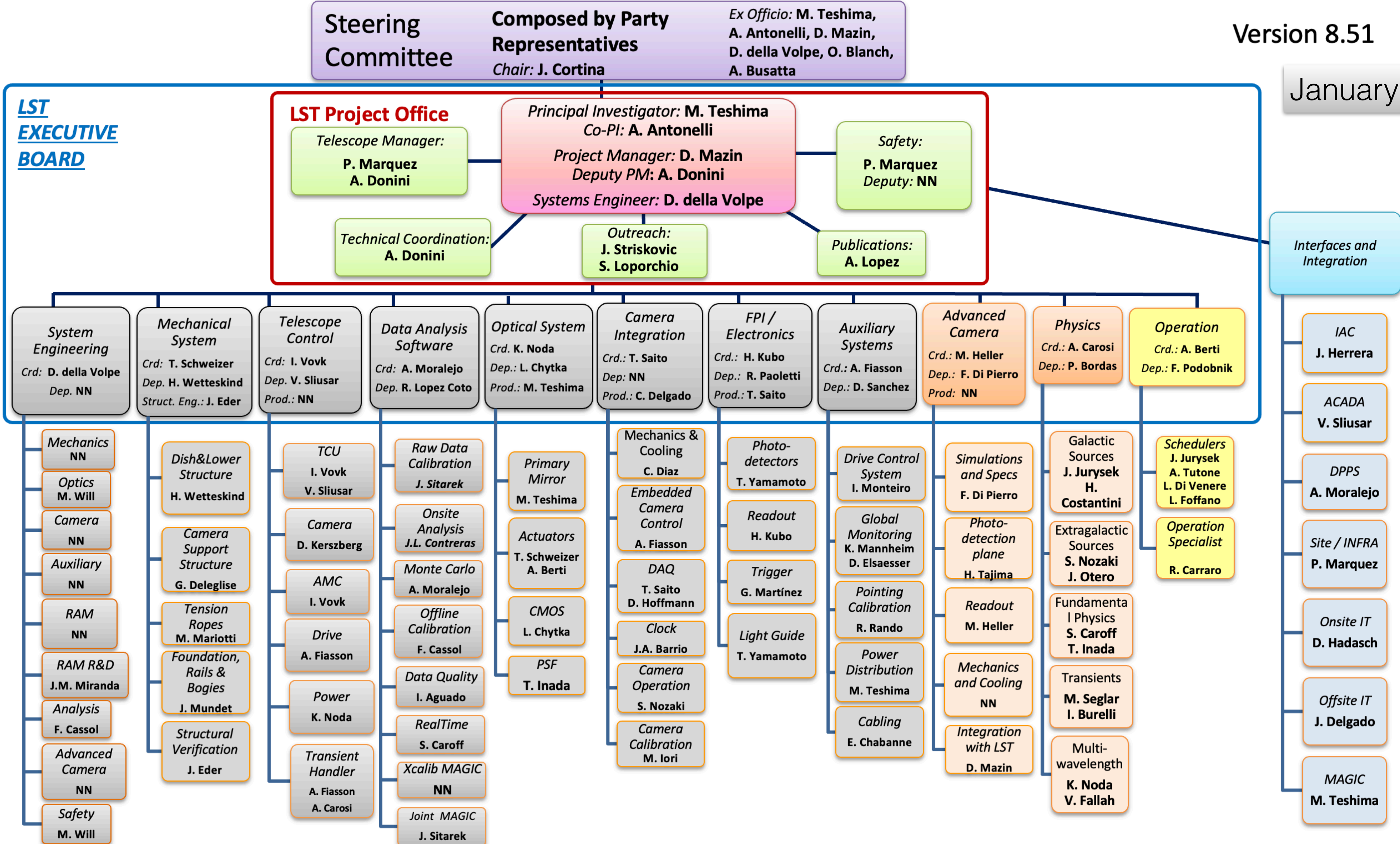
Picture from LST meeting in Prague, May 2024



# LST Coordinators (North)

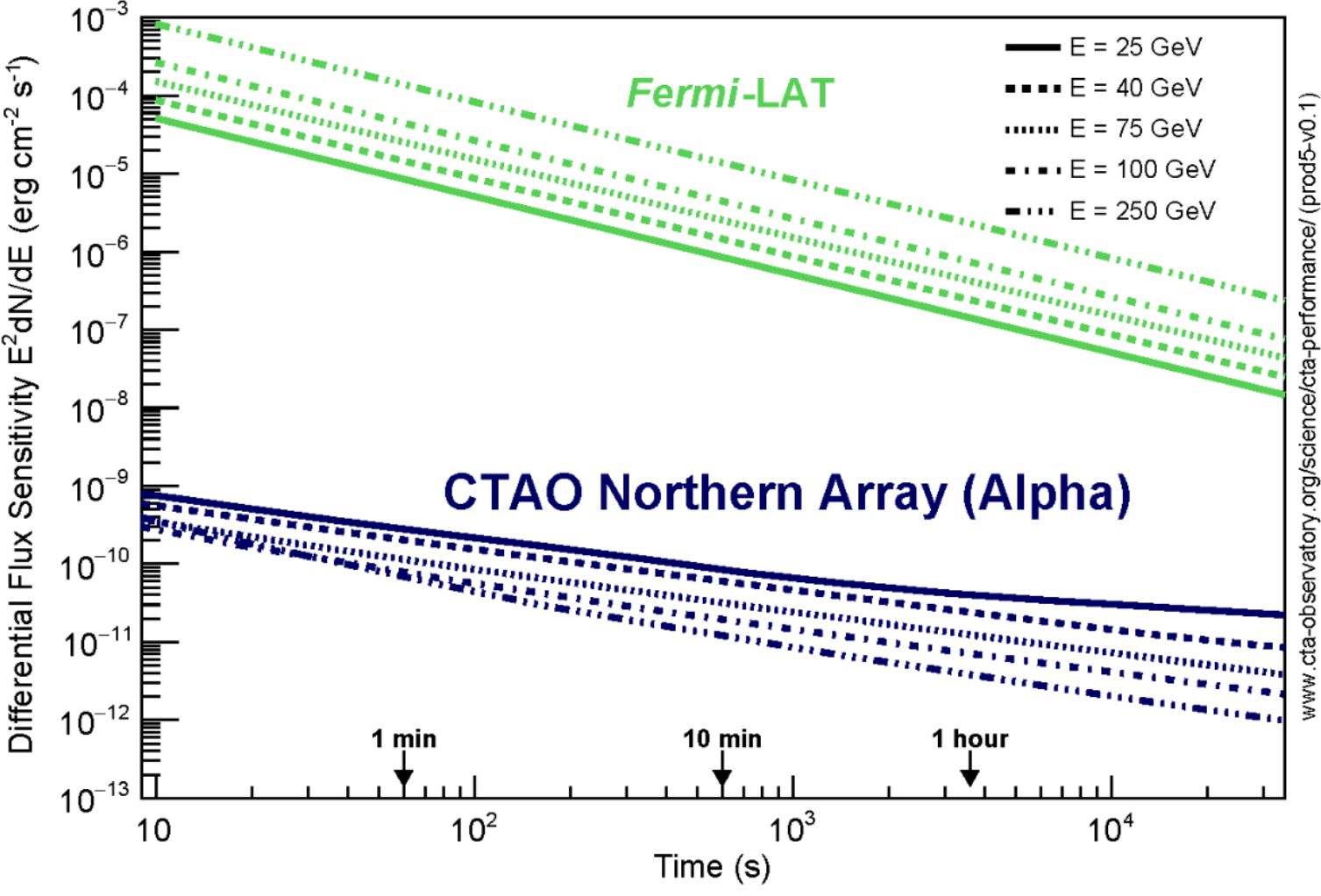
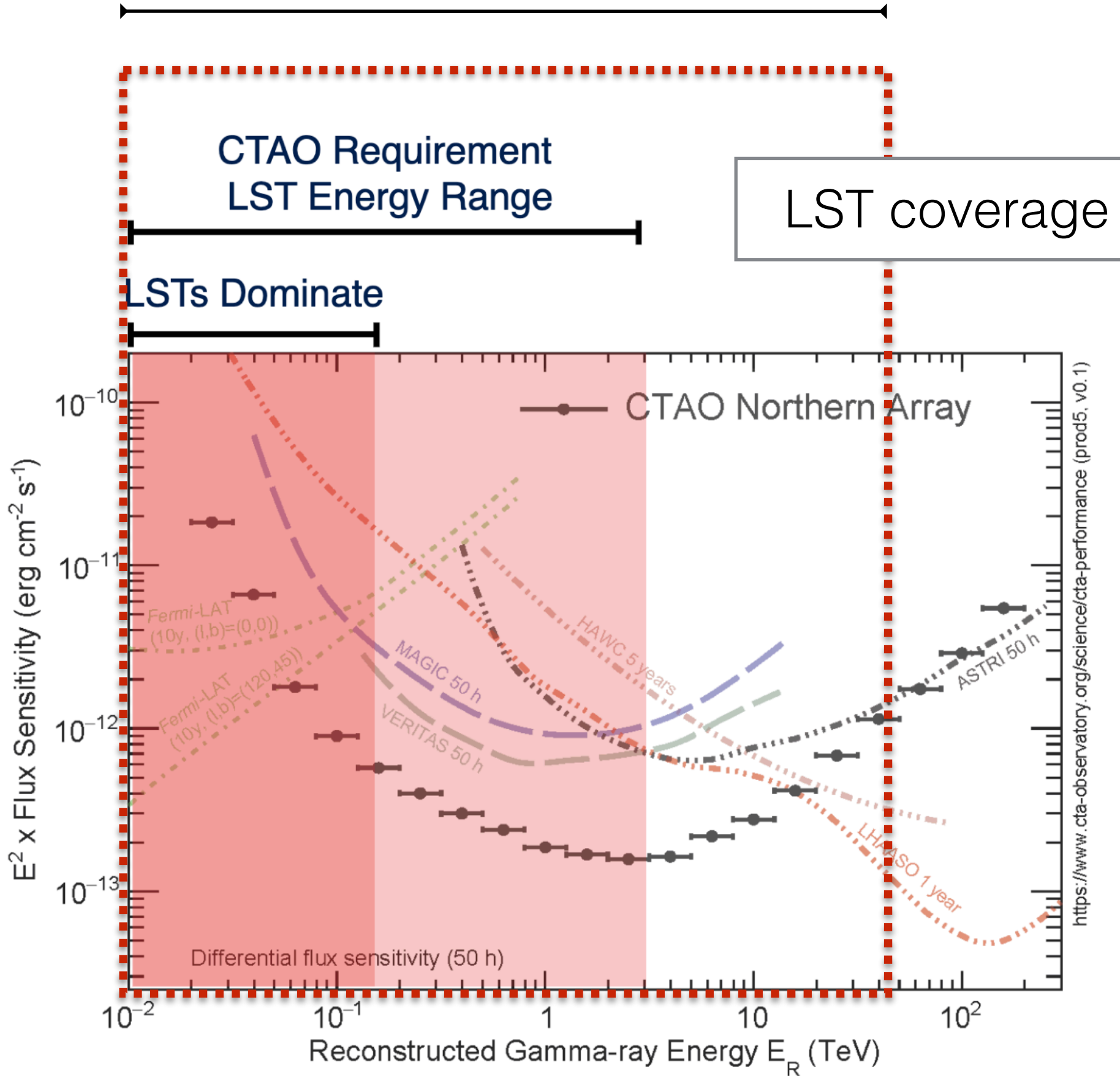
Version 8.51

January 2025



# The telescope specs and expected performance

Large-Sized Telescope (LST)	
Energy range (in which sensitivity is optimized)	20 GeV – 150 GeV
Number of LST telescopes	4 (North)
Optical design	Parabolic
Primary reflector diameter	23.0 m
Effective mirror area (including shadowing)	370 m <sup>2</sup>
Focal length	28 m
Total weight	103 t
Field of view	4.3 deg
Number of pixels	1855
Pixel size (imaging)	0.1 deg
Photodetector type	PMT
Telescope readout event rate after array trigger	>7.0 kHz
Telescope data rates (readout of all pixels; before array trigger)	24 Gb/s
Positioning time to any point in the sky (>30° elevation)	30 s
Pointing precision	<14 arcseconds
Observable sky	Any astrophysical object with elevation > 24 degrees



# The LST telescope

PMT Camera

Camera Support  
Structure

Tension ropes

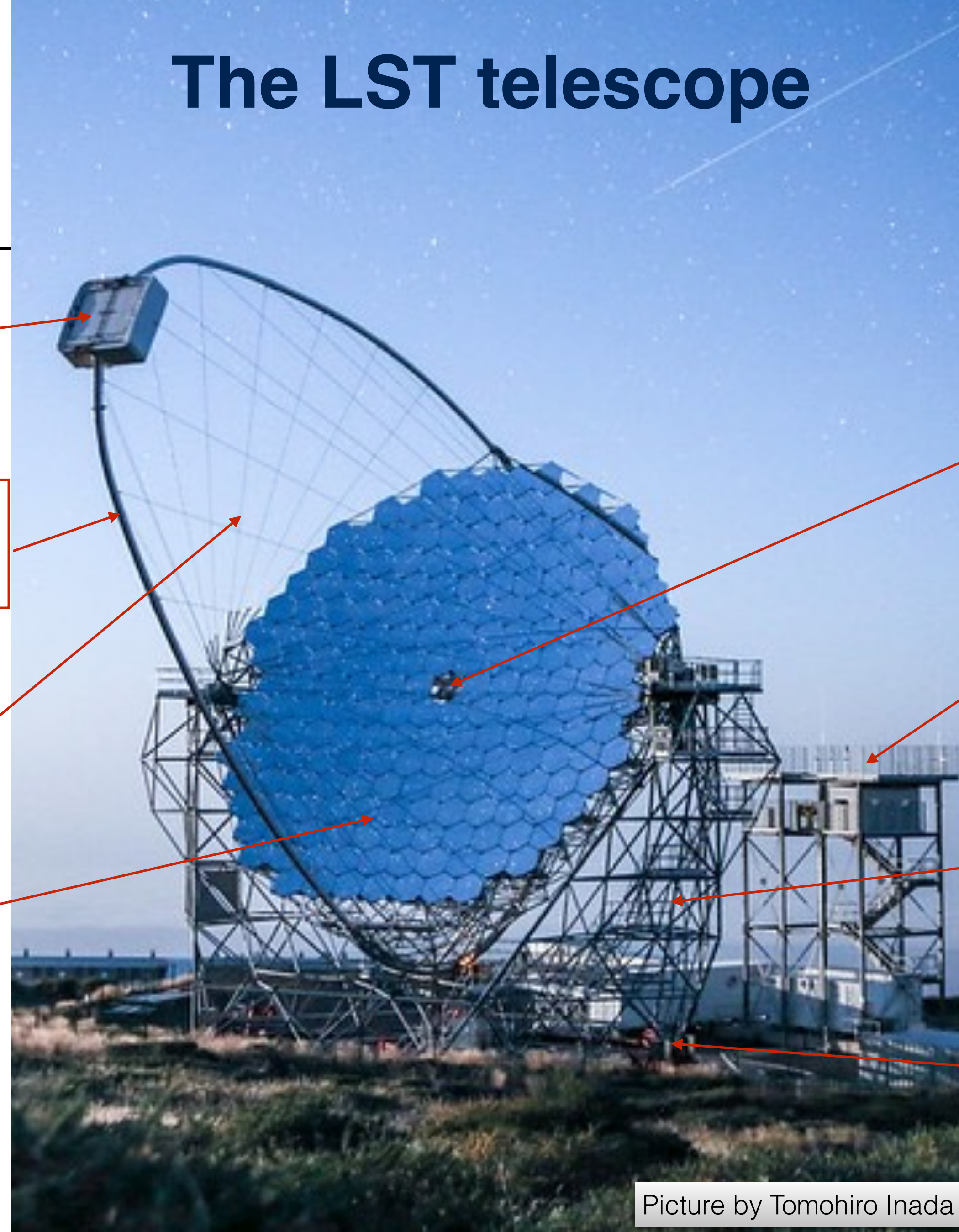
Mirror facets

Calibration  
devices:  
Starguider,  
Calibration Box  
etc

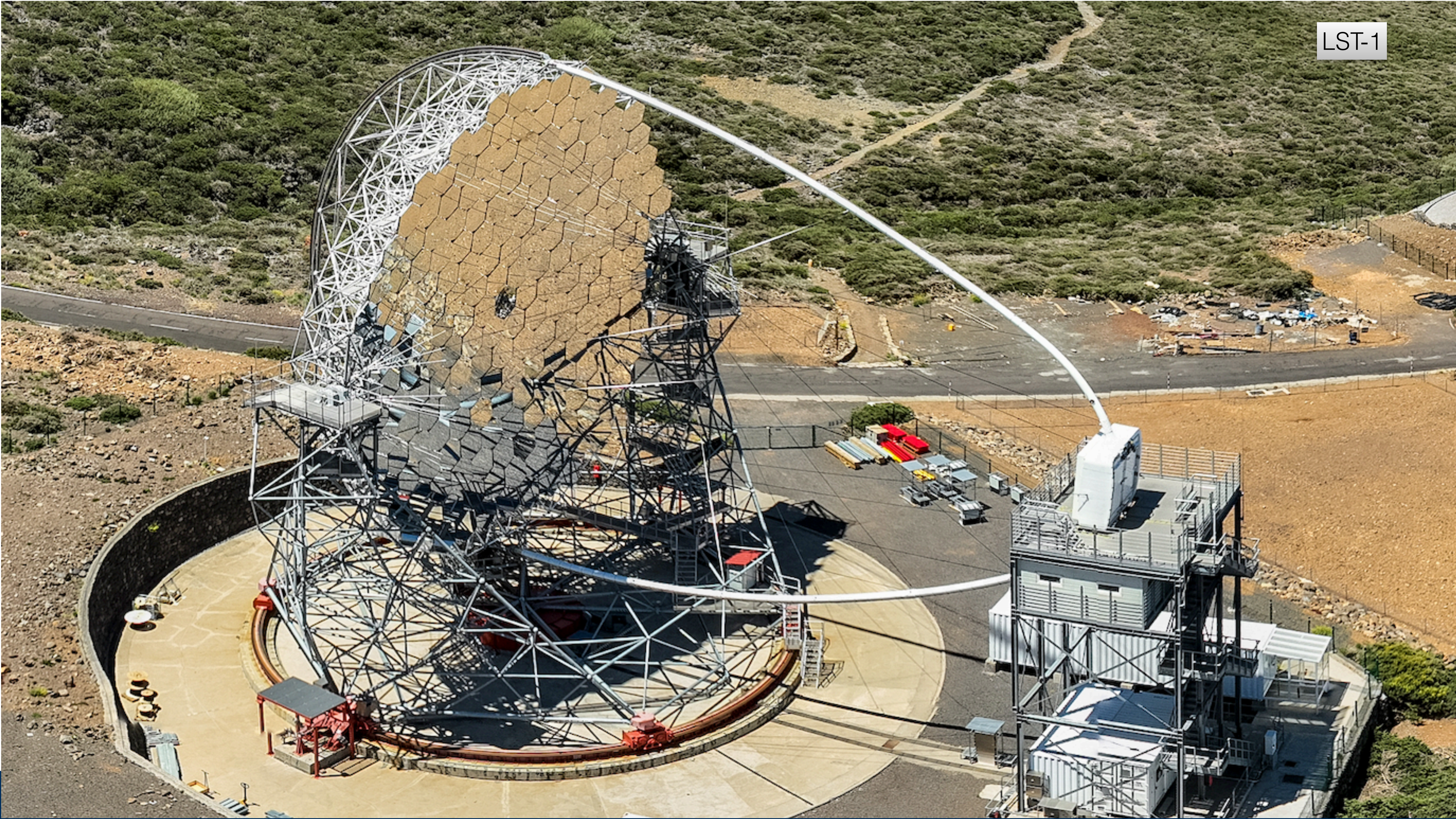
Camera  
access tower

Telescope  
structure

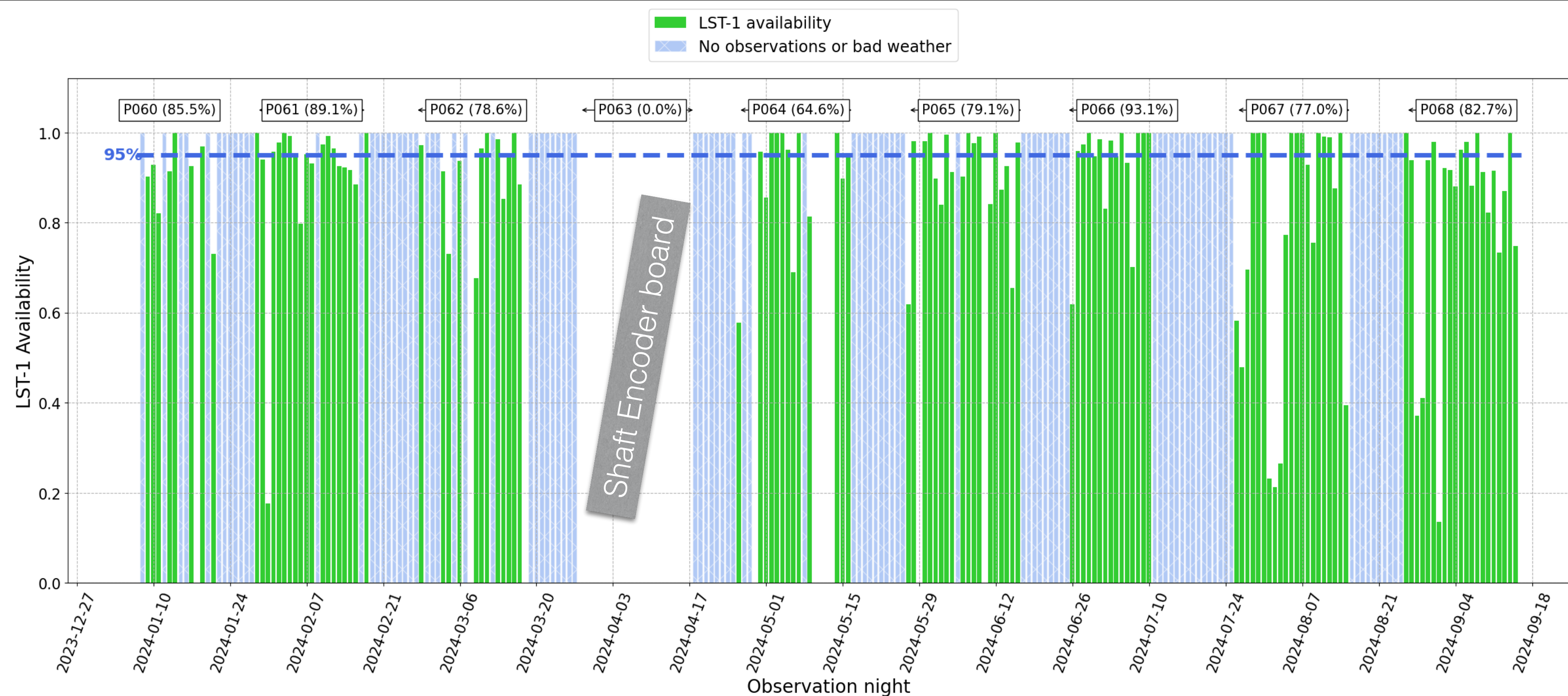
Drive System



Picture by Tomohiro Inada



# Stability of operation



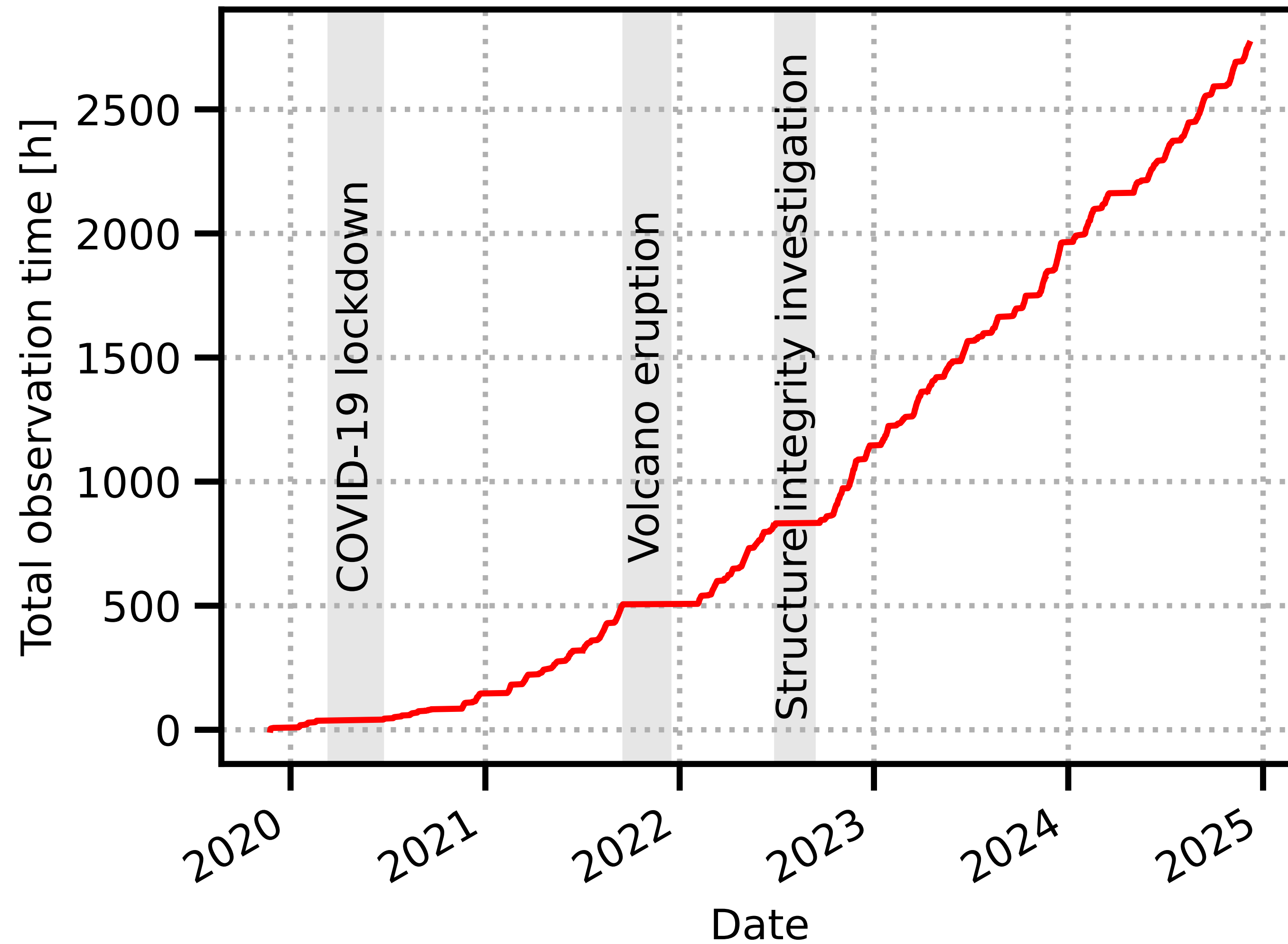
- Reasons are manifold: experience of operators, stability of control software orchestration, software upgrades, need of reboots, network...



# LST-1 is taking data

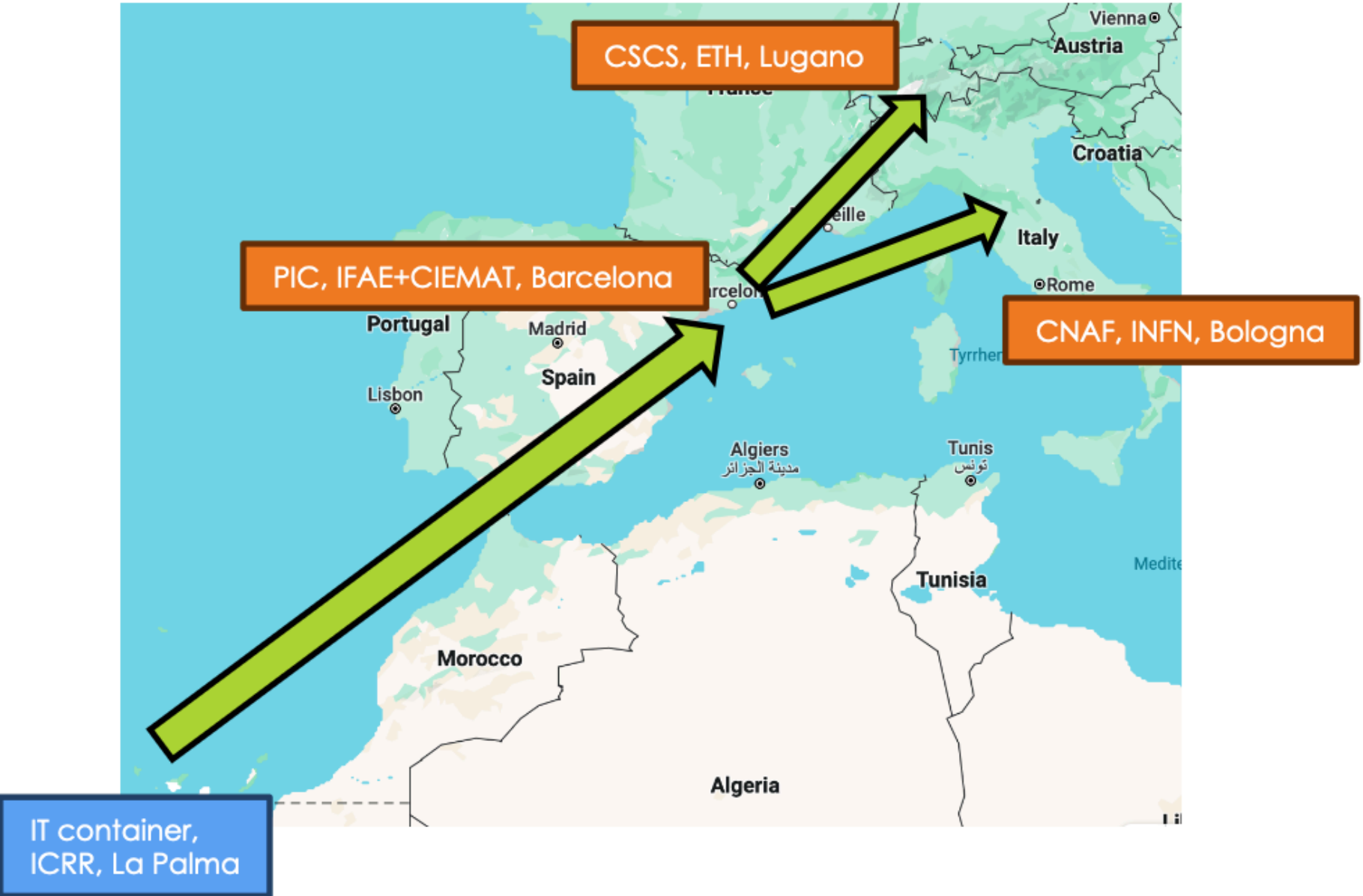
Total obs. time: 2764 h

Last updated: 2024-12-20



- University of Tokyo provided an Onsite IT center for La Palma
- Amount of data is large, and growing, need offsite data centers
- PIC (Spain), CNAF (INFN, Italy) and CSCS (Switzerland) are working together to handle data

Two copies on two different data centers



## DATA MANAGEMENT

- Evolution of the pledges per data center

P I C		2019	2020	2021	2022	2023	2024	2025	← TBC - New cameras and commissioning LST2-4
	Disk		0.26	0.36	0.36PB	0.5PB	0.81PB	1PB	
Tape		0.1PB	0.5PB	1.5PB	3PB	5.5PB	7PB	8.5PB	

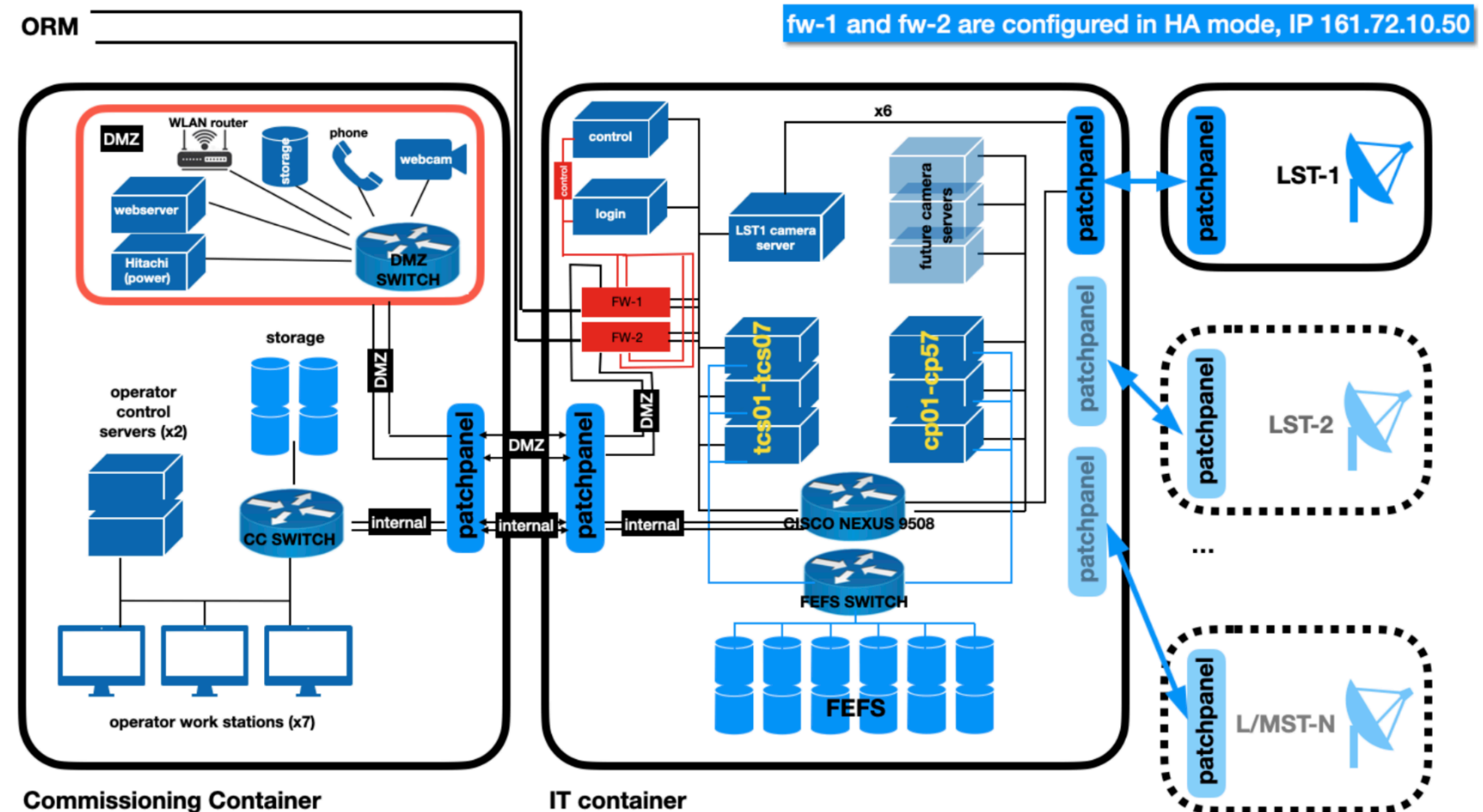
C N A F		2019	2020	2021	2022	2023	2024	2025	→ Updated pledges +300TB to store R0G 2021 datasets
	Disk				0.2PB	0.2PB	0.7PB	1PB	
Tape				0.2PB	0.2PB	1PB	2.7PB	3.7PB	

C S C S		2019	2020	2021	2022	2023	2024	2025
	Disk				2PB	2.2PB	3.7PB	4.7PB
Tape				-	-	-	-	

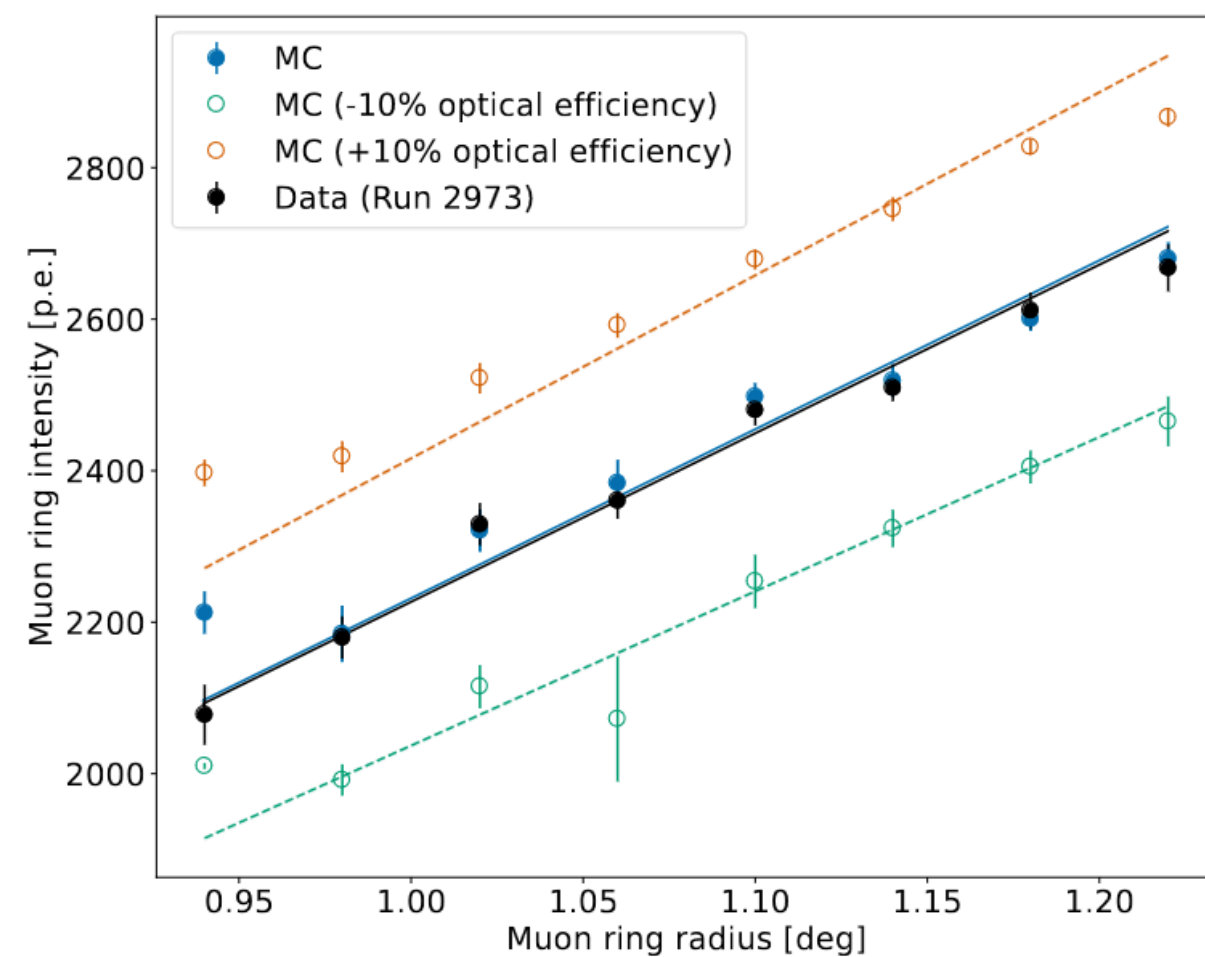
# La Palma Onsite Data Center

- IT container = Fujitsu system procured by the UTokyo
- 5.7 PB disk space
- 2000 cores
- Sufficient for 4 LST + 5 MST
- Commissioning Container = Operation control room, web servers, telephone, radio
- Both are on LST-1 site, temporarily, until the CTAN Operations Building will be ready

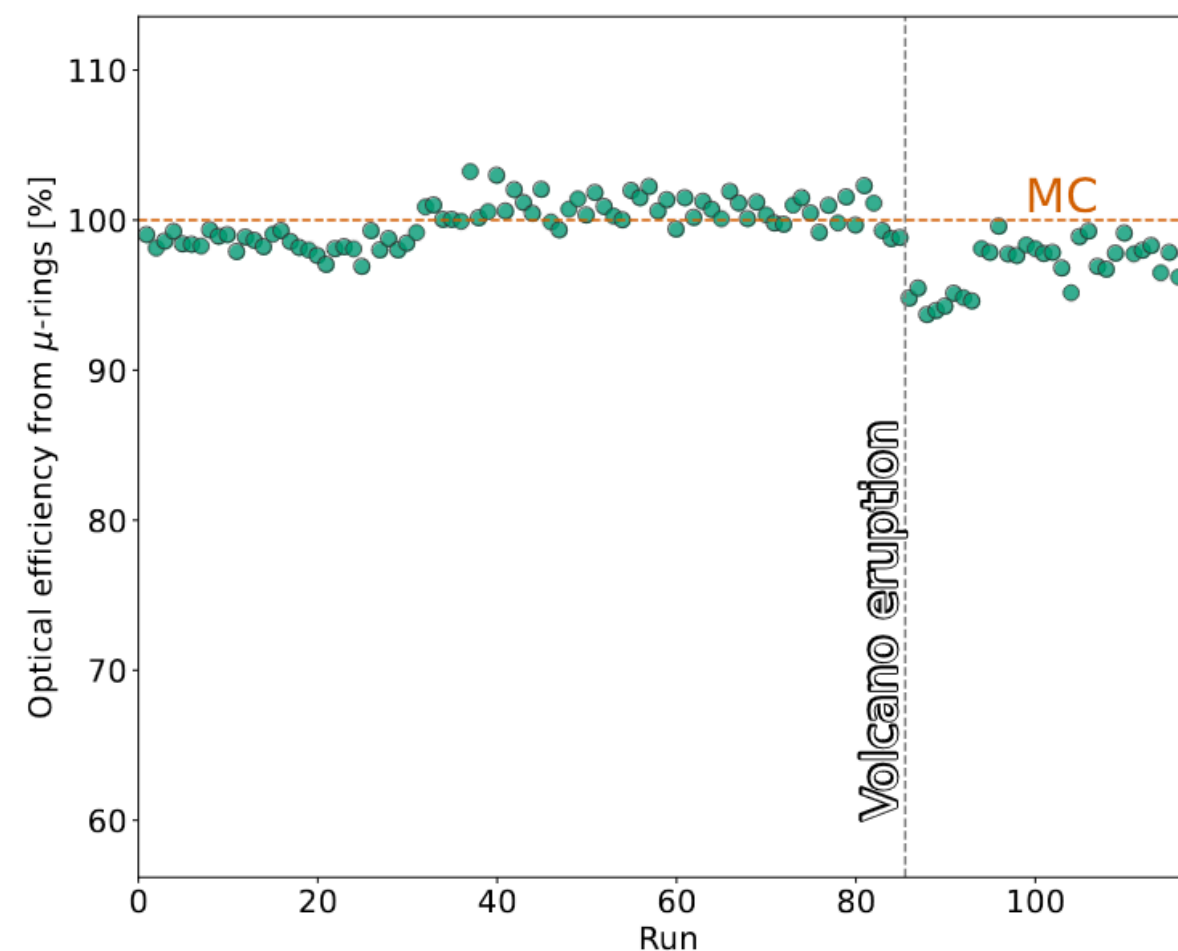


# Telescope Performance

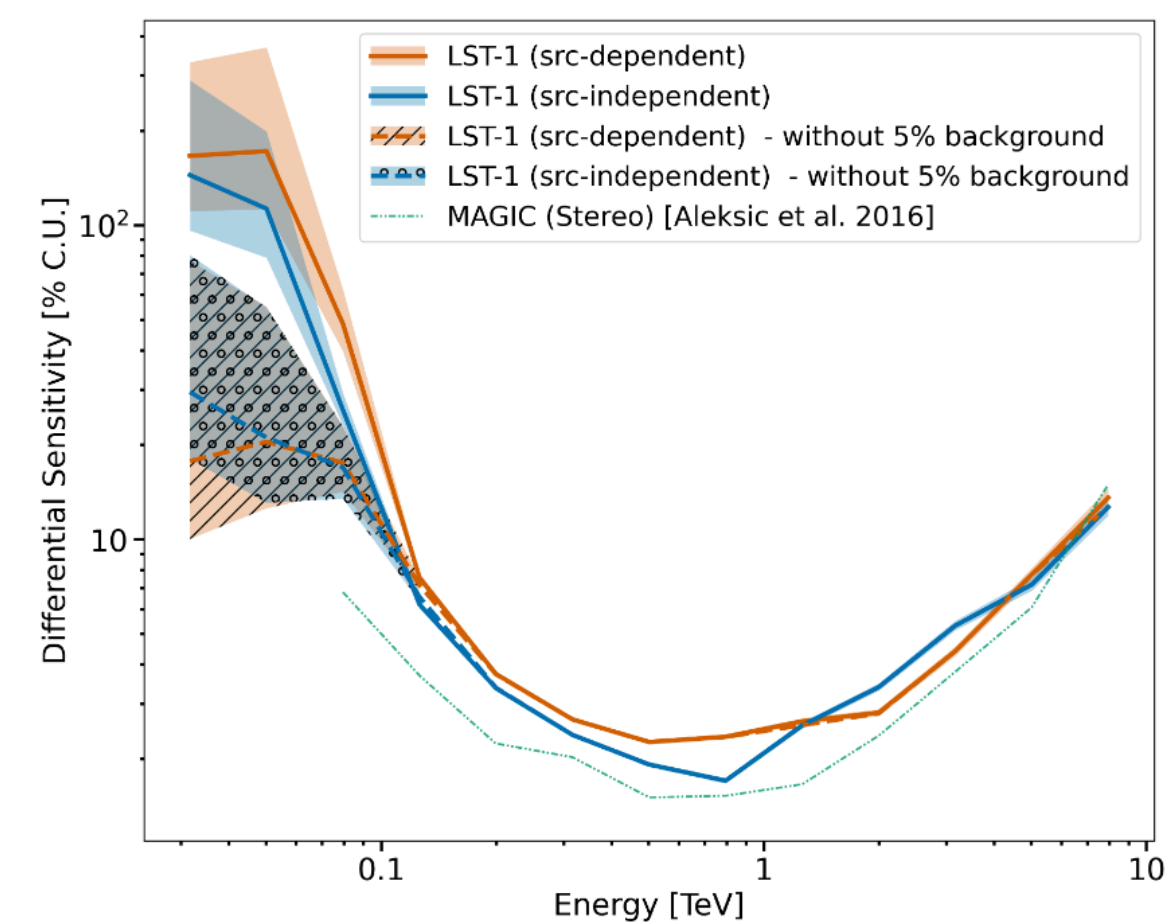
muon ring matching



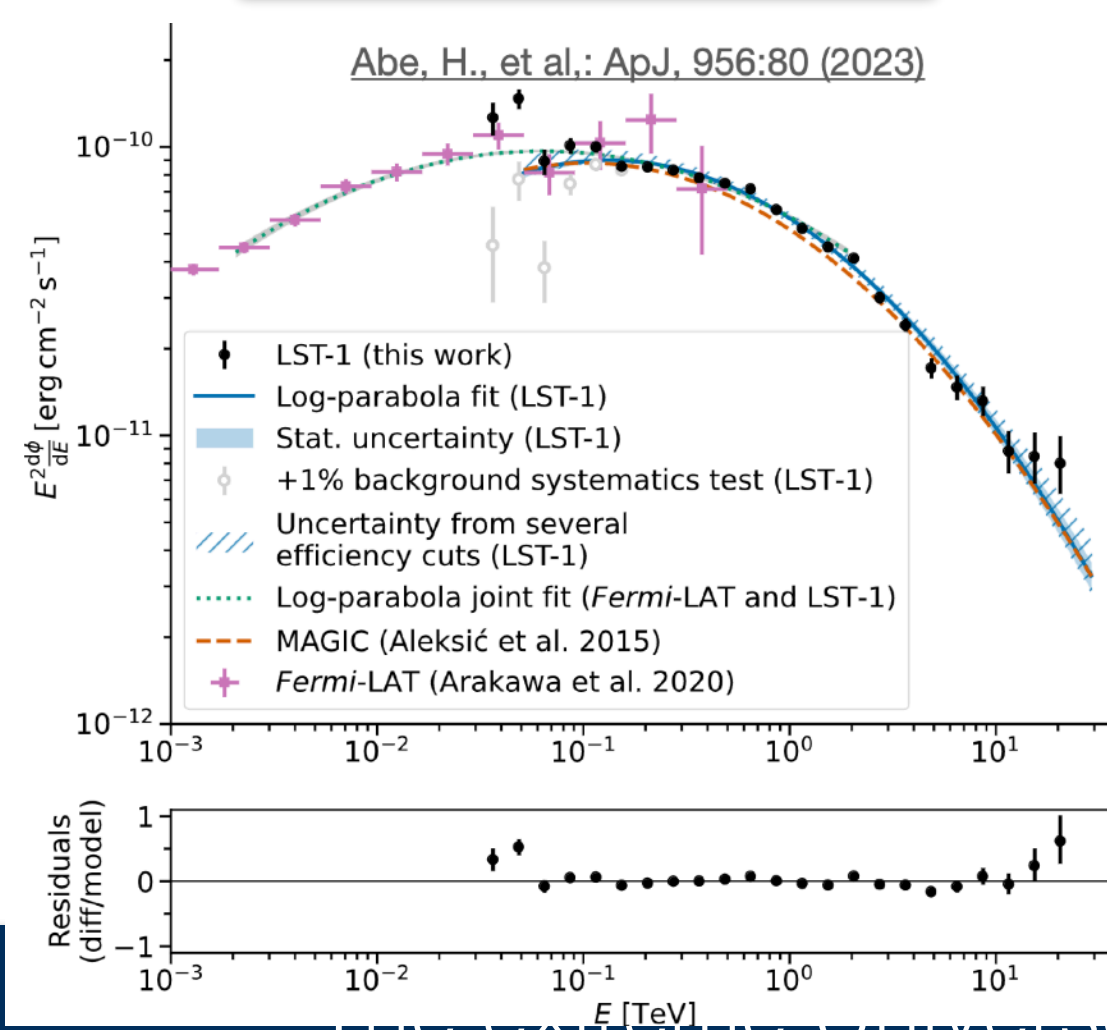
optical throughput



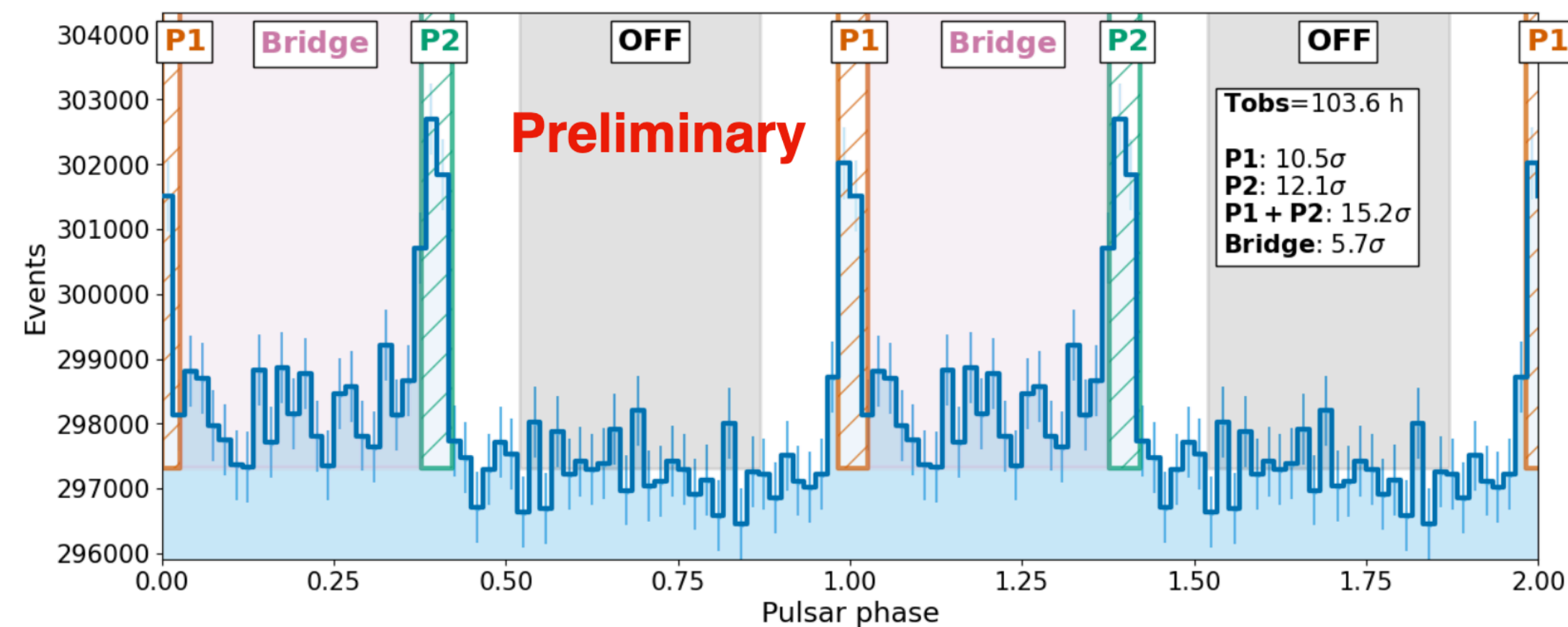
flux sensitivity



Crab nebula SED



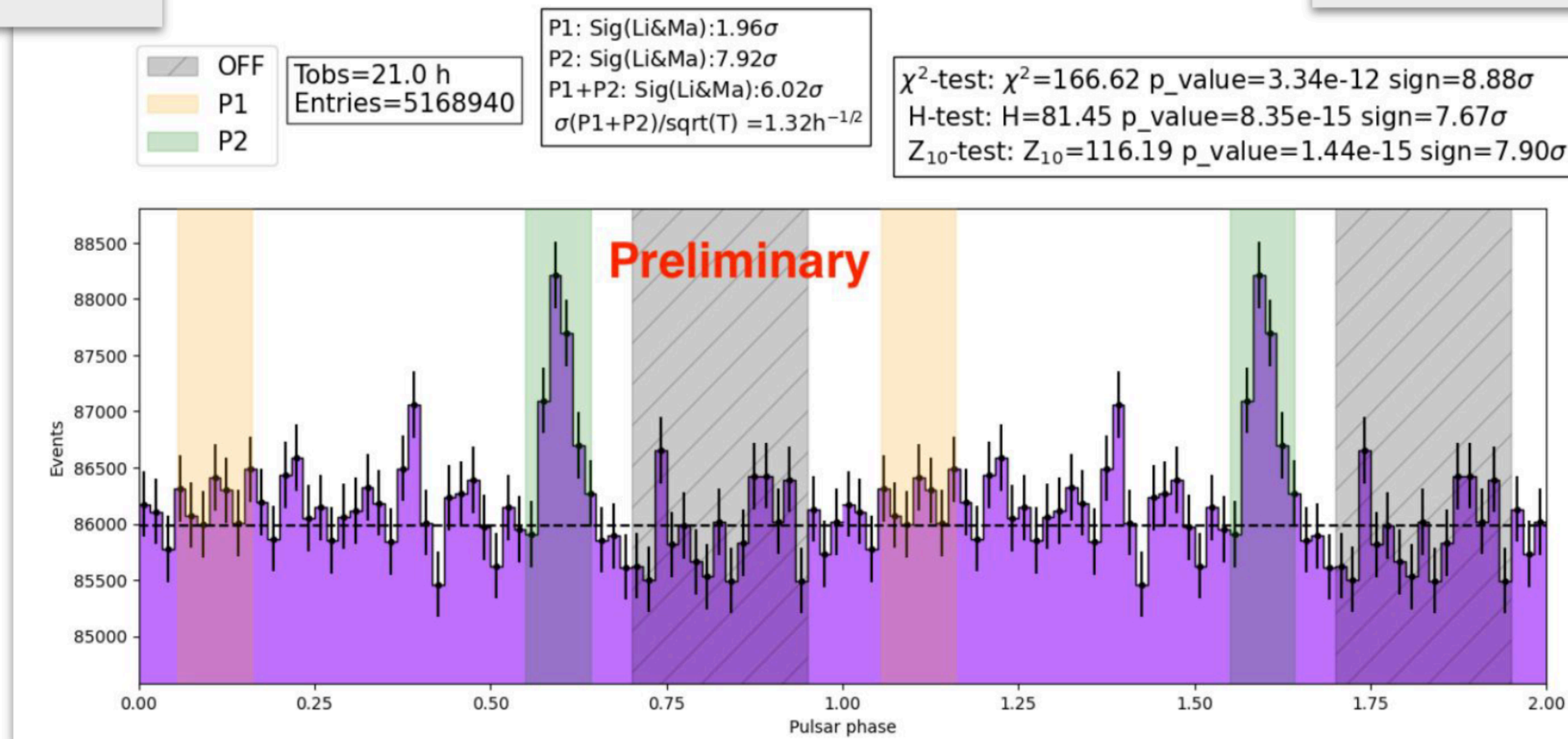
Crab pulsar phaseogram



# First scientific results: Geminga pulsar

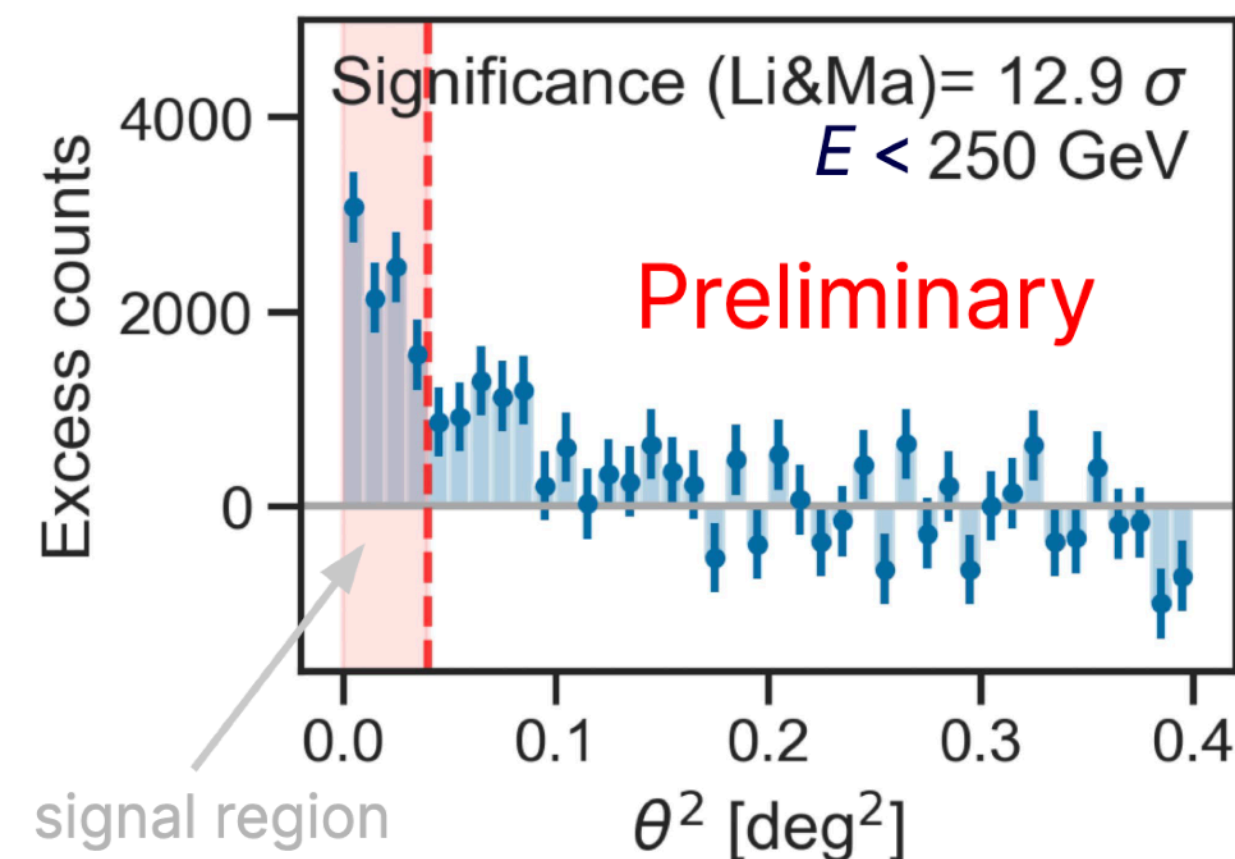
Detected at  $\sim 8\sigma$  in  $\sim 21\text{h}$

PoS ICRC2023 (2023) 569



- P2: 8.9 $\sigma$  after 14 hours. Geminga has a very soft spectrum. The LST-1 result confirms an excellent performance in the 15-30 GeV regime, one of the main scientific drivers of LST
- Compared with MAGIC: 6.3 $\sigma$  for 80 hours for P2 (MAGIC coll., A&A 643 (2020) L14)

- Most distant AGN detected by an IACT,  $z = 0.997$
- Only ten FSRQ ever detected in VHE
- First VHE source discovered by LST-1



## First detection of VHE gamma-ray emission from FSRQ OP 313 with LST-1

ATel #16381; *Juan Cortina (CIEMAT) for the CTAO LST collaboration*  
on 15 Dec 2023; 14:31 UT  
Credential Certification: *Juan Cortina (Juan.Cortina@ciemat.es)*

Subjects: Gamma Ray, >GeV, TeV, VHE, Request for Observations, AGN, Blazar, Quasar

✕ Post

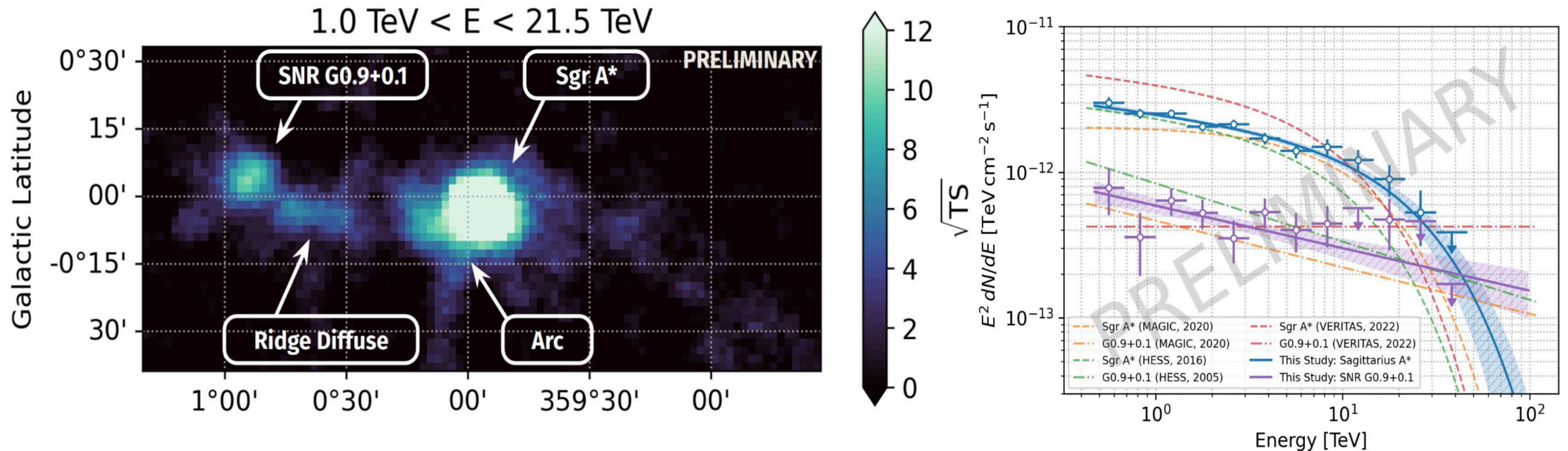
The Large-Sized Telescope (LST-1) on La Palma has been monitoring the very distant Flat Spectrum Radio Quasar (FSRQ) OP 313 ( $z=0.997$ , Schneider et al. 2010, AJ, 139, 2360) since November 2023. Following the announcement of enhanced gamma-ray emission by

Announcement  
2023-December-26

# LST-1 Discovers the Most Distant AGN at Very High Energies

Slide from D. Green

# First scientific results: Galactic center



- Detection of prominent signals, and verification of extended-source observations
- SED results in line with the ones from the current-generation telescopes

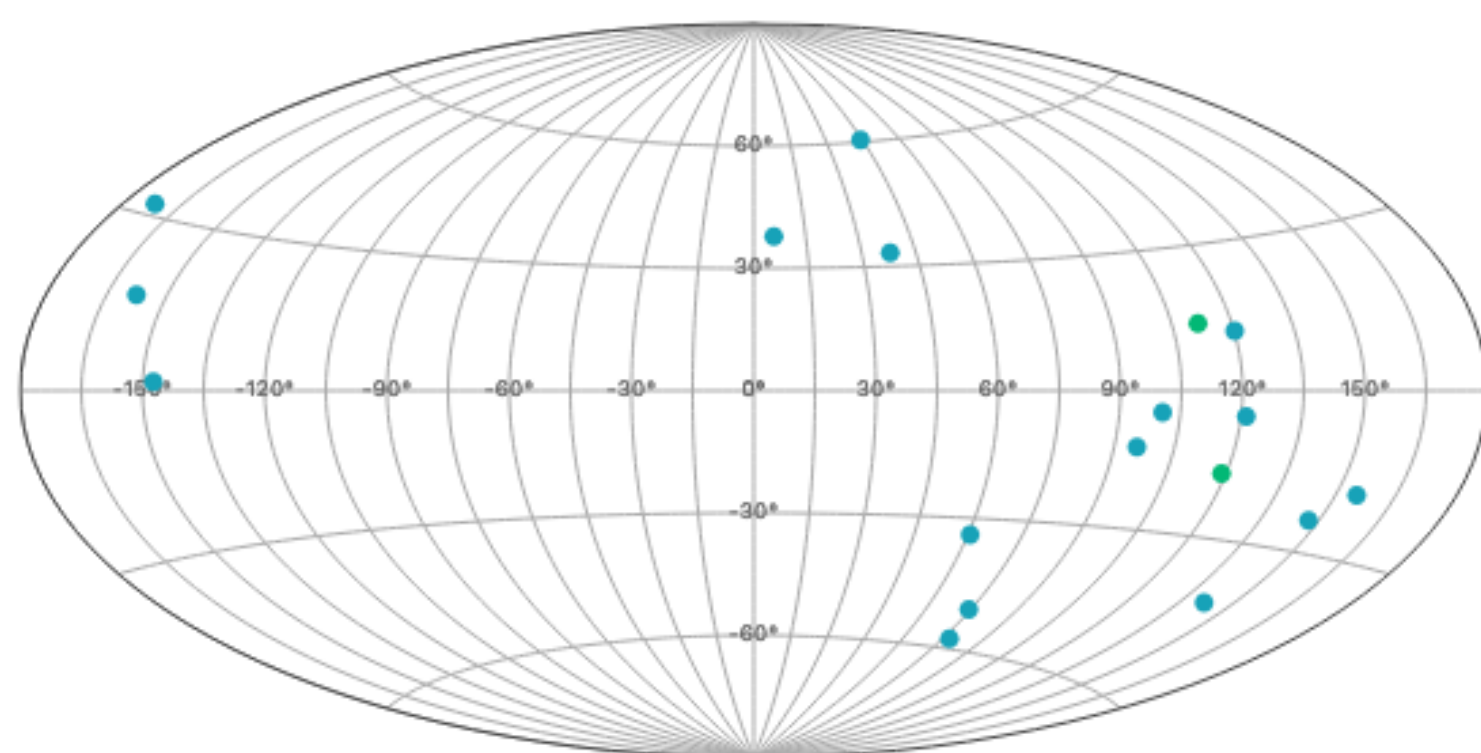
# Transient Observations

Statistics since December 2023

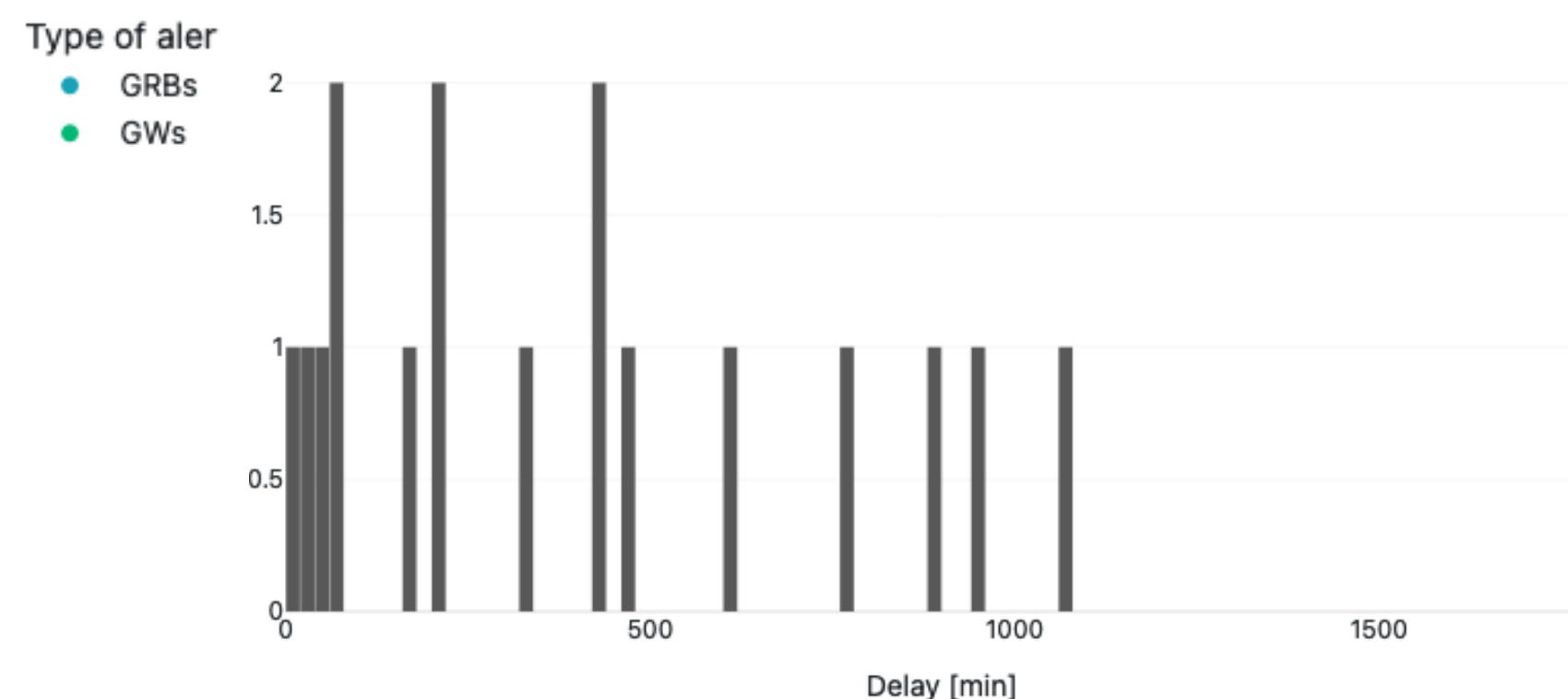
- Low energy threshold is a key for the extragalactic transient source detections
- LST-own transient handler in place
- Automatic reaction (repointing and data taking) to filtered alerts

Total	GRBs	GWs	Neutrinos
73 # total alerts	48 # total alerts	18 # total alerts	7 # total alerts
18 # observed alerts	16 # observed alerts	2 # observed alerts	0 # observed alerts
41.2h observed	37.9h observed	3.3h observed	0.0h observed

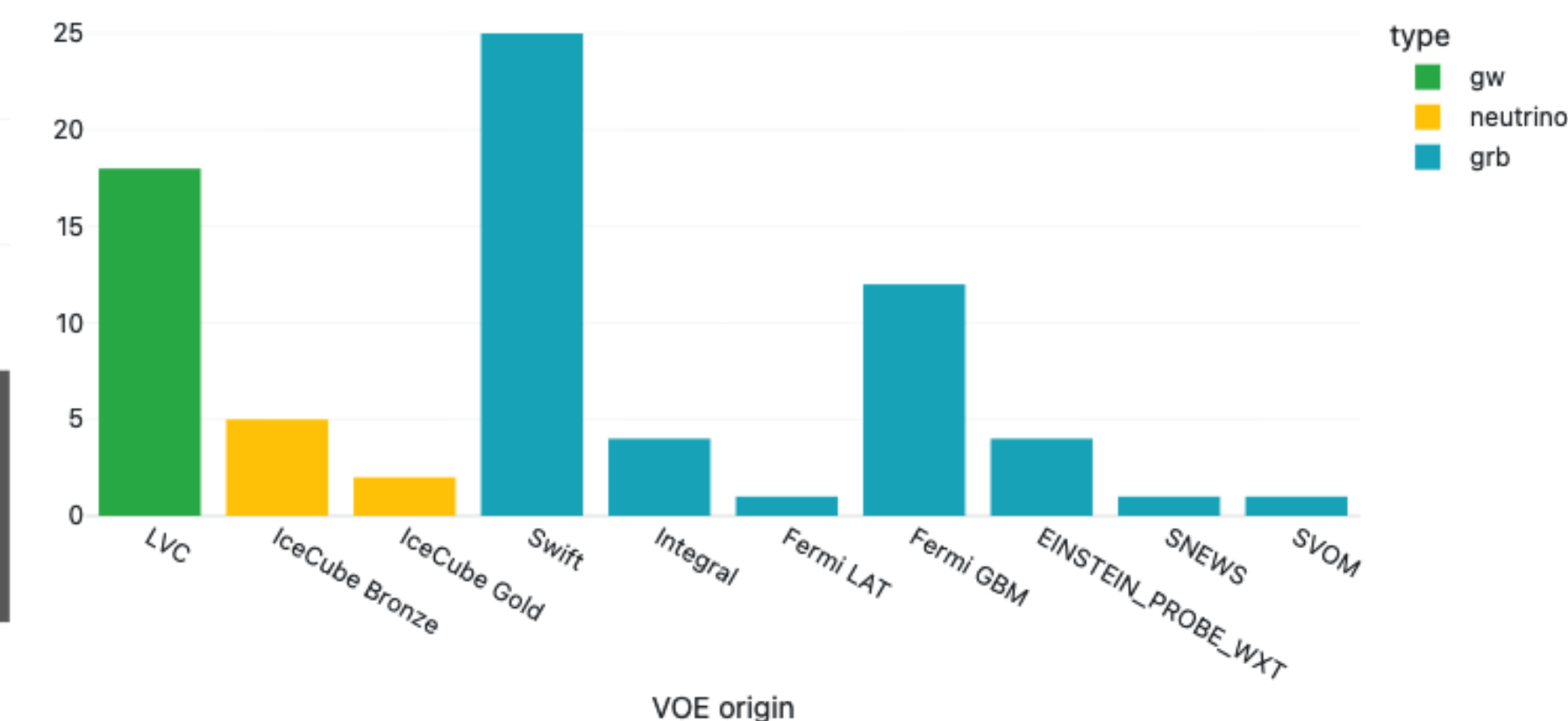
Sky map in Galactic coordinates of all observed alerts



Delay of observations wrt T0



VOE origin of alerts





- Brightest-of-all-times GRB,  $z=0.1505$
- Took place during full moon
- First LST observations (earliest among IACTs) are  $T_0+1.33d$
- Challenging data analysis due to strong NSB
- [ ... ]
- Filling the time gap between HAWC (day before) and H.E.S.S. (day after)
- Emission and upper limits favor structured jet scenario, VHE gamma rays slightly favor outer jet origin

Not released yet

- Published
  - LST-1 performance, [ApJ 956 80 \(2023\)](#)
  - MAGIC + LST1 performance, [A&A, 680, A66 \(2023\)](#)
  - LHAASO J2108+5157, [A&A 673, A75 \(2023\)](#)
  - LST-1 Star Tracking, [A&A 679, A90 \(2023\)](#)
  - Crab Pulsar, [A&A 690, A167 \(2024\)](#)
- Accepted by journal
  - LST-1 Likelihood image analysis, A&A [accepted](#)
- Submitted to journal
  - LST-1 RS Ophiuchi
- In internal review process: 7



# Milestones achieved

Last 12 months

- Critical Design Review (CDR) is closed
- Foundation of LST-1 fixed
- Active Mirror Control (AMC) boxes made European-CE conform
- Unification of AMC boxes between LST-1 and LST-2-4
- Cabinet to release brakes in emergency case installed
- Fast repositioning commissioned (15sec with low wind)
- And many for LST-2-4, see the following slides

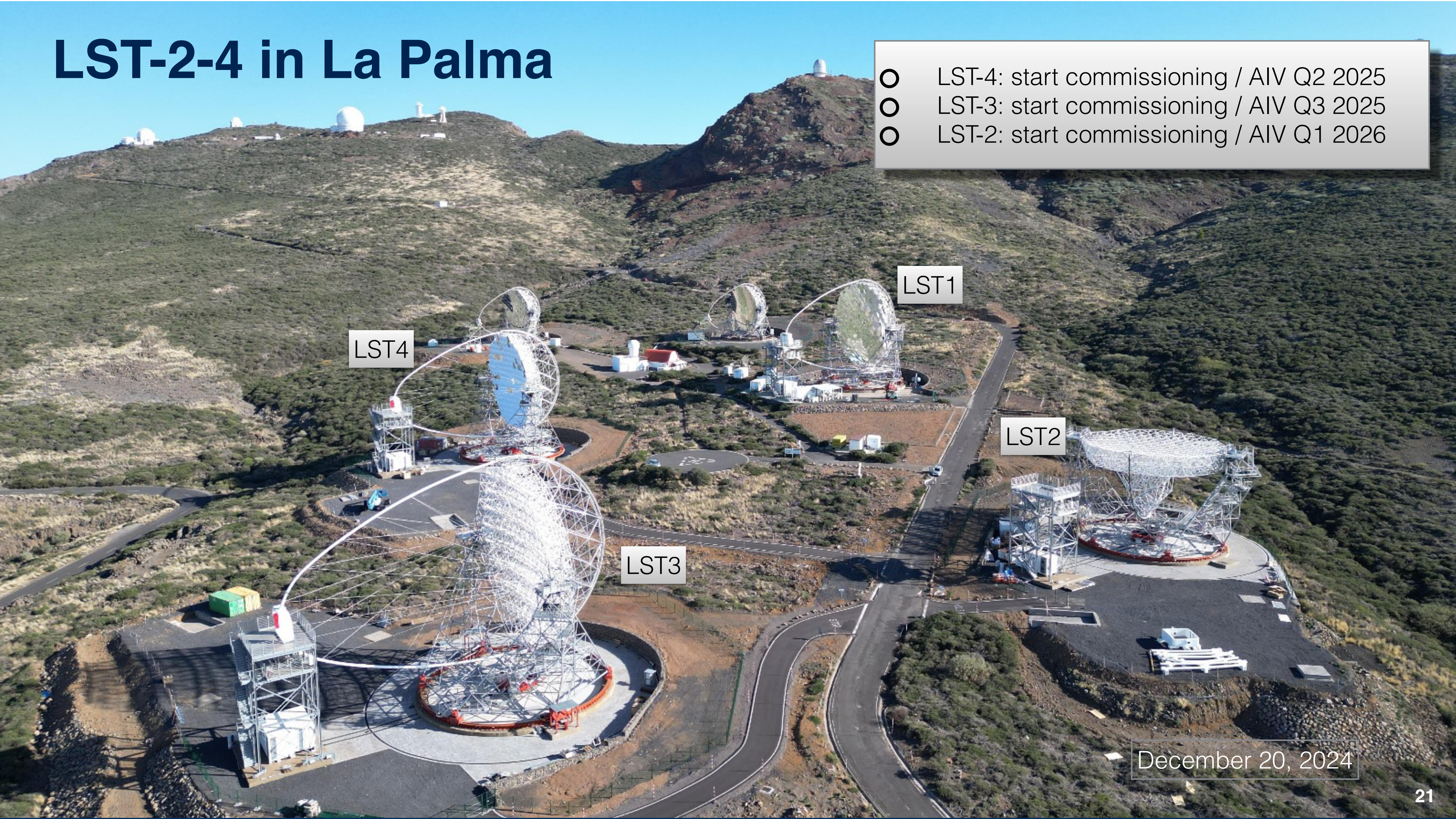
# LST fast repositioning

180deg in 15s (low wind)



# LST-2-4 in La Palma

- LST-4: start commissioning / AIV Q2 2025
- LST-3: start commissioning / AIV Q3 2025
- LST-2: start commissioning / AIV Q1 2026



LST4

LST1

LST2

LST3

December 20, 2024

# LST North Schedule

Version September 2024

Task Name	Duration	Start	Finish	Resource Names	2025															
					Qtr 4, 2024					Qtr 1, 2025			Qtr 2, 2025		Qtr 3, 2025		Qtr 4, 2025			
					Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
All permits granted	0 days	Tue 18/10/22	Tue 18/10/22	✓																
Civil works start	0 days	Mon 24/10/22	Mon 24/10/22	✓																
Civil works finish	0 days	Wed 31/01/24	Wed 31/01/24	✓																
<b>Civil Works</b>																				
LST4 construction starts	0 days	Mon 11/09/23	Mon 11/09/23	✓																
LST4 dish and structure united	0 days	Fri 03/05/24	Fri 03/05/24	✓																
LST4 CSS installed	0 days	Fri 30/08/24	Fri 30/08/24	✓					30/08											
LST4 mirrors installed	0 days	Fri 29/11/24	Fri 29/11/24	↻					29/11											
LST4 camera installed	0 days	Wed 30/04/25	Wed 30/04/25										30/04							
LST4 construction completed	0 days	Fri 23/05/25	Fri 23/05/25											23/05						
LST4 ready for acceptance	0 days	Fri 26/12/25	Fri 26/12/25																	
<b>LST-4</b>																				
LST3 construction starts	0 days	Mon 09/10/23	Mon 09/10/23	✓																
LST3 dish and structure united	0 days	Fri 21/06/24	Fri 21/06/24	✓																
LST3 CSS installed	0 days	Wed 23/10/24	Wed 23/10/24	✓					23/10											
LST3 mirrors installed	0 days	Fri 09/05/25	Fri 09/05/25										09/05							
LST3 camera installed	0 days	Wed 30/07/25	Wed 30/07/25																	
LST3 construction completed	0 days	Fri 22/08/25	Fri 22/08/25																	
LST3 ready for acceptance	0 days	Tue 07/04/26	Tue 07/04/26																	
<b>LST-3</b>																				
LST2 construction starts	0 days	Mon 06/11/23	Mon 06/11/23	✓																
LST2 dish and structure united	0 days	Mon 19/08/24	Mon 19/08/24	✓					19/08											
LST2 CSS installed	0 days	Fri 18/04/25	Fri 18/04/25										18/04							
LST2 mirrors installed	0 days	Tue 05/08/25	Tue 05/08/25																	
LST2 camera installed	0 days	Fri 24/10/25	Fri 24/10/25																	
LST2 construction completed	0 days	Tue 18/11/25	Tue 18/11/25																	
LST2 ready for acceptance	0 days	Tue 23/06/26	Tue 23/06/26																	
<b>LST-2</b>																				

# LST-4 Dish and Lower Structure



# LST-3 Dish and Lower Structure

13 June 2024





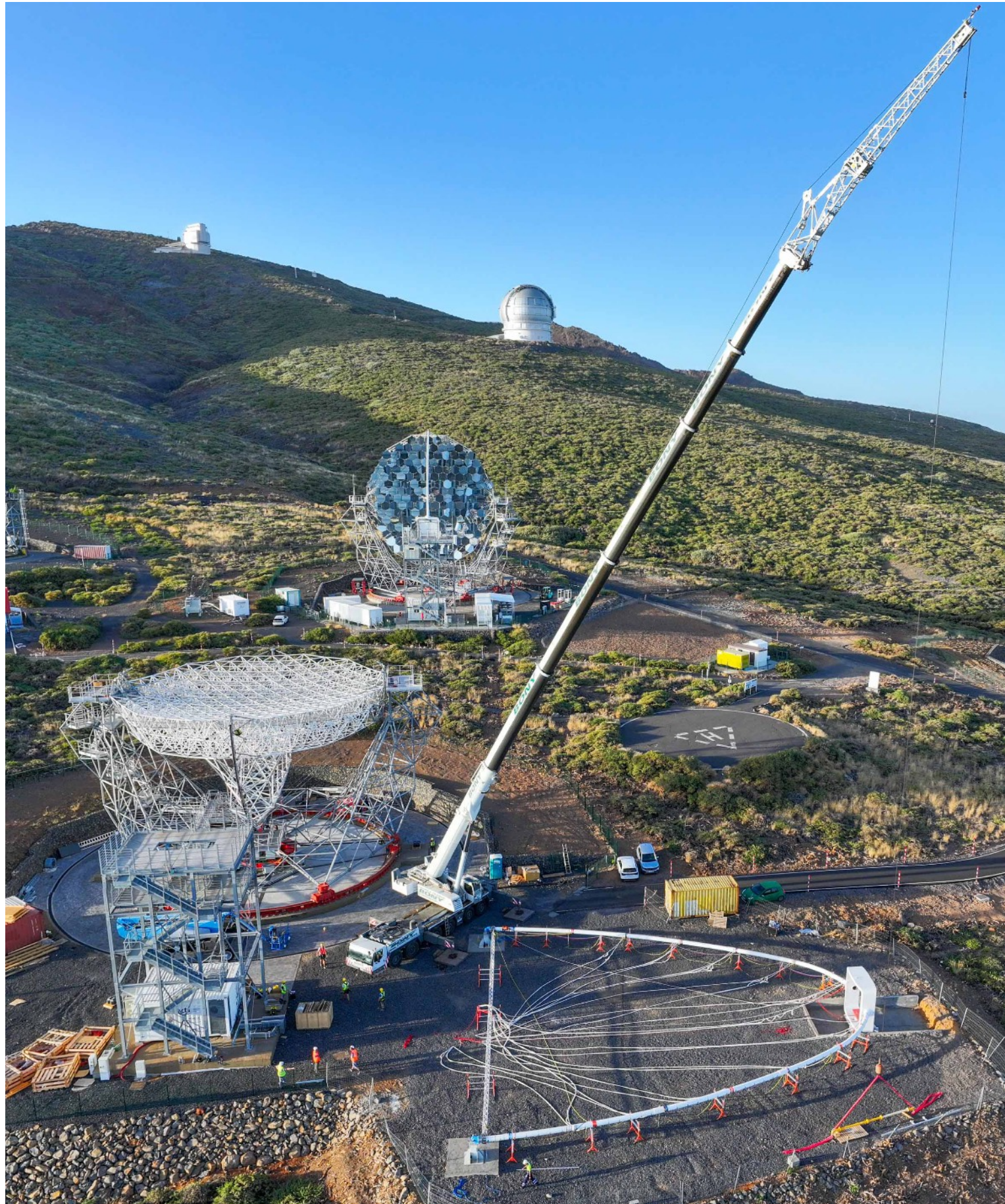
# LST-2 Dish and Lower Structure

12 August 2024



# LST4 Camera Arch Installation

22 August 2024



Camera Support Structure assembled



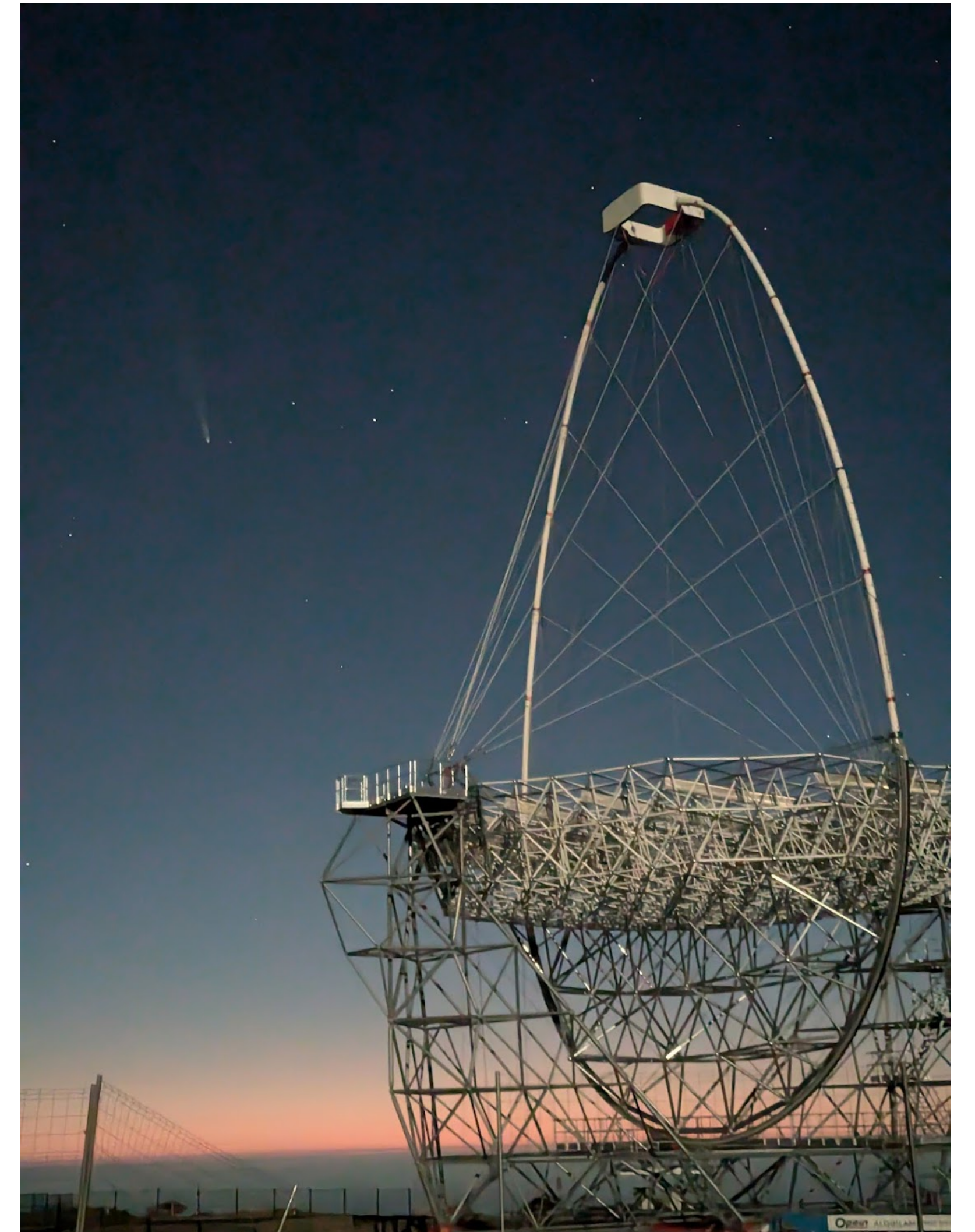
Lifting of Camera Support Structure



Camera Support Structure installed

# LST-3 CSS Installation

17 October 2024

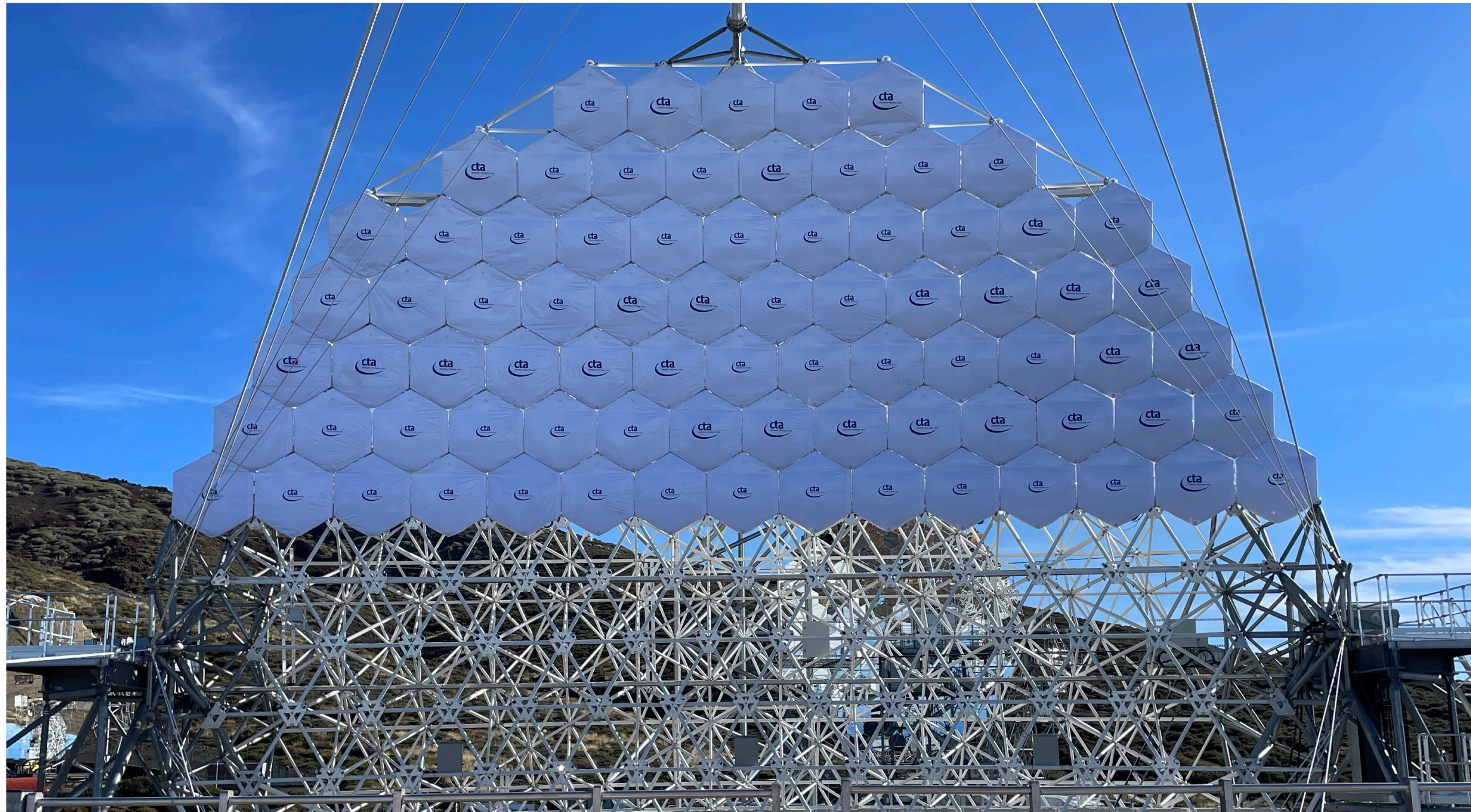


# LST4 start of mirror installation

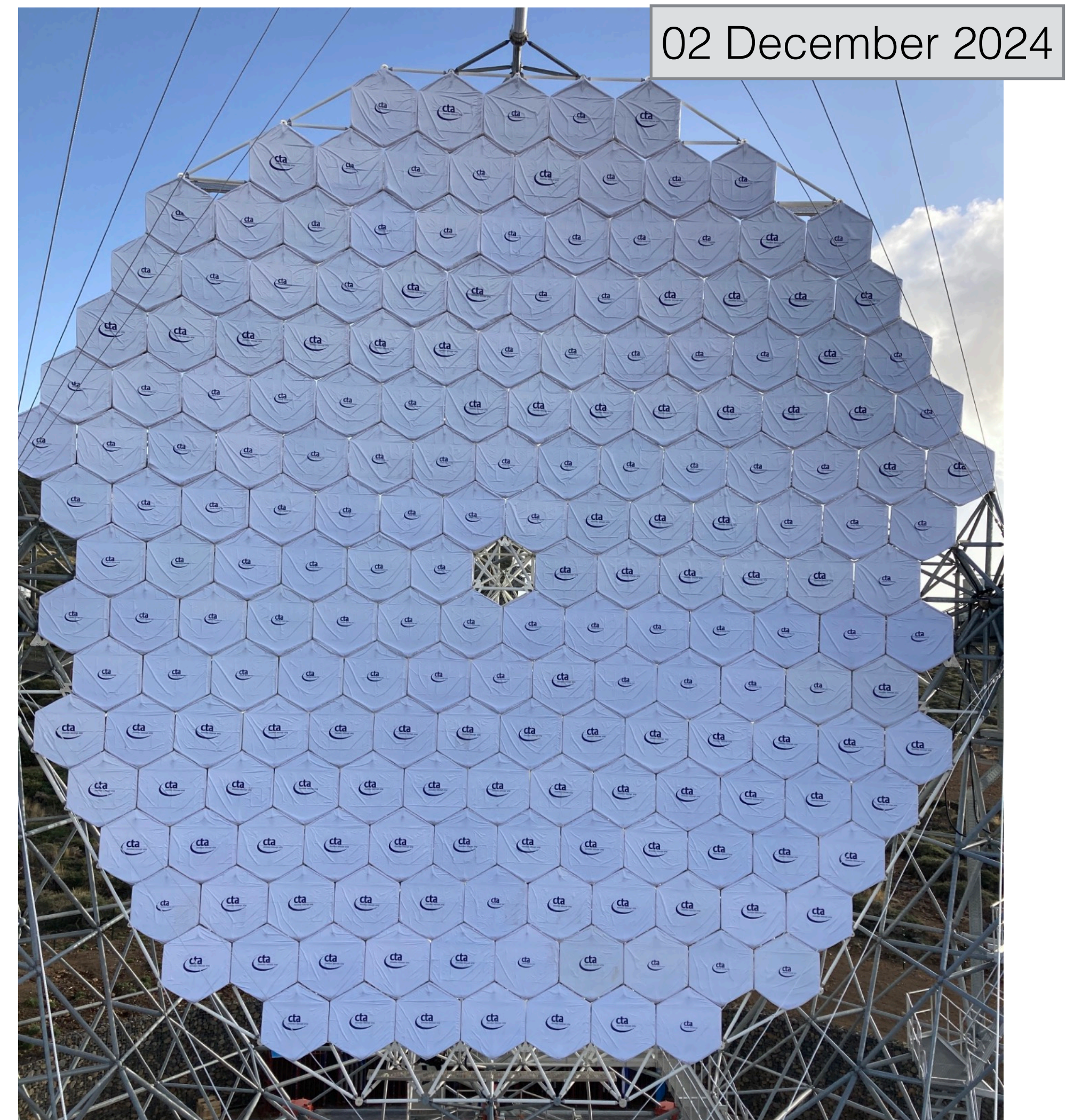
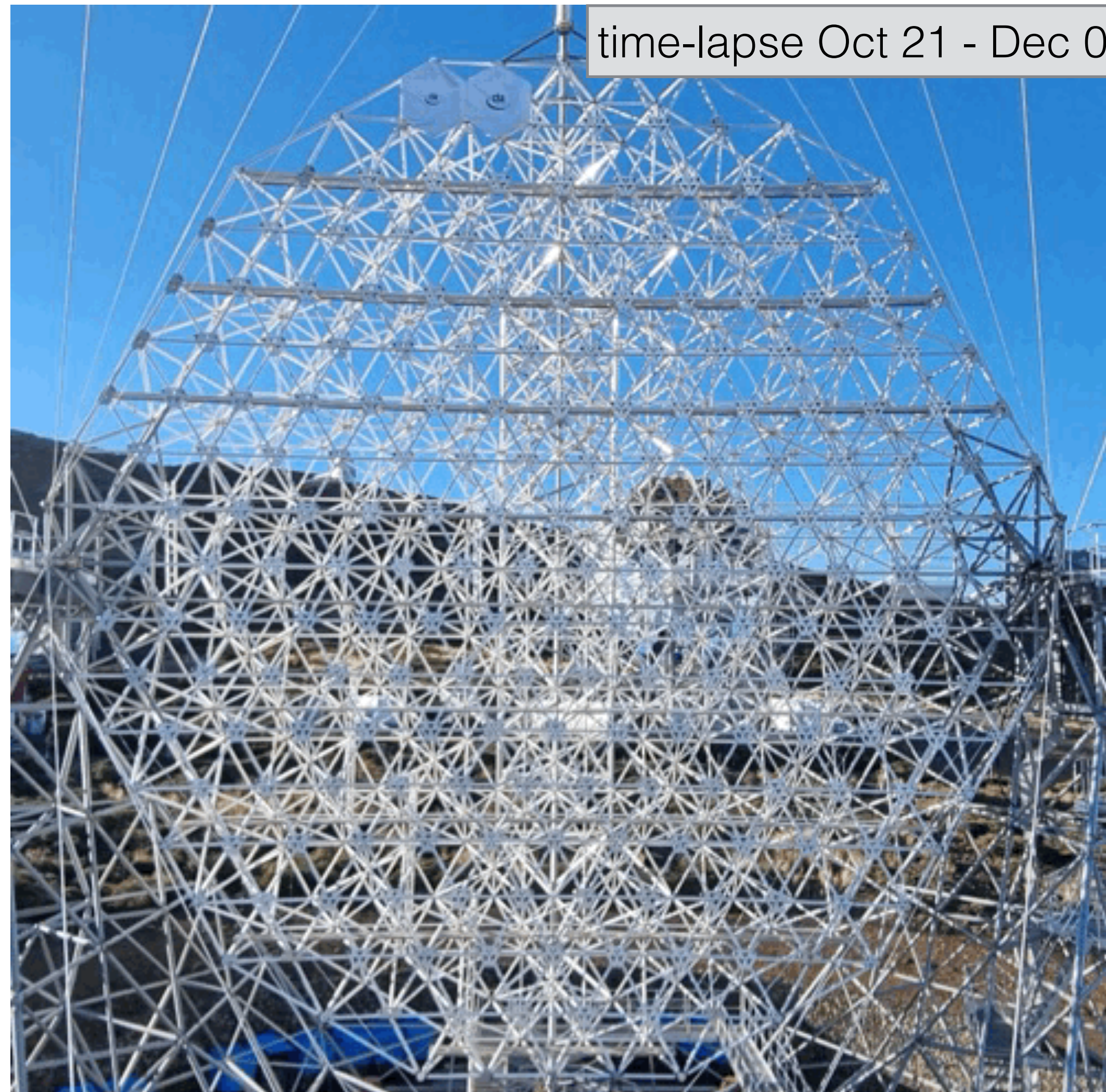
21 October 2024



# LST4 mirror installation: status 1 Nov, 2024



# LST4 mirror installation: finalized



- LST CDR (Critical Design Review) passed in 2020 and closed in 2024. This was a major effort by the team led by the Systems Engineering (Mimmo and Magda)
- Focus now on closing of Open Items (SE + Technical Coordination Board)
- Started seriously discussing Transition Plan from LST to CTAO
  - Verification and Validation of built telescopes
  - QA records, Manuals, HW and SW Configurations, Testing Procedures
  - CTAO starts helping with person power (3 people in La Palma)
- Technical acceptance does not mean Handover, which depends on IKC agreements and budget to Operation and Maintenance from CTAO

# Towards LST acceptance

Hot Topic

- LST CDR (Critical Design Review) passed in 2020 and closed in 2021, a major effort by the team led by the Systems Engineering (Mimmo)
- Focus now on closing of Open Items (SE + T)
- Started seriously discussing Trade-offs
- Verification and Validation
- QA
- Configurations, Testing Procedures
- with person power (2 people in La Palma)
- Technical acceptance budget to Operation

Open Items and System Engineering suffer strongly from lack of human resource

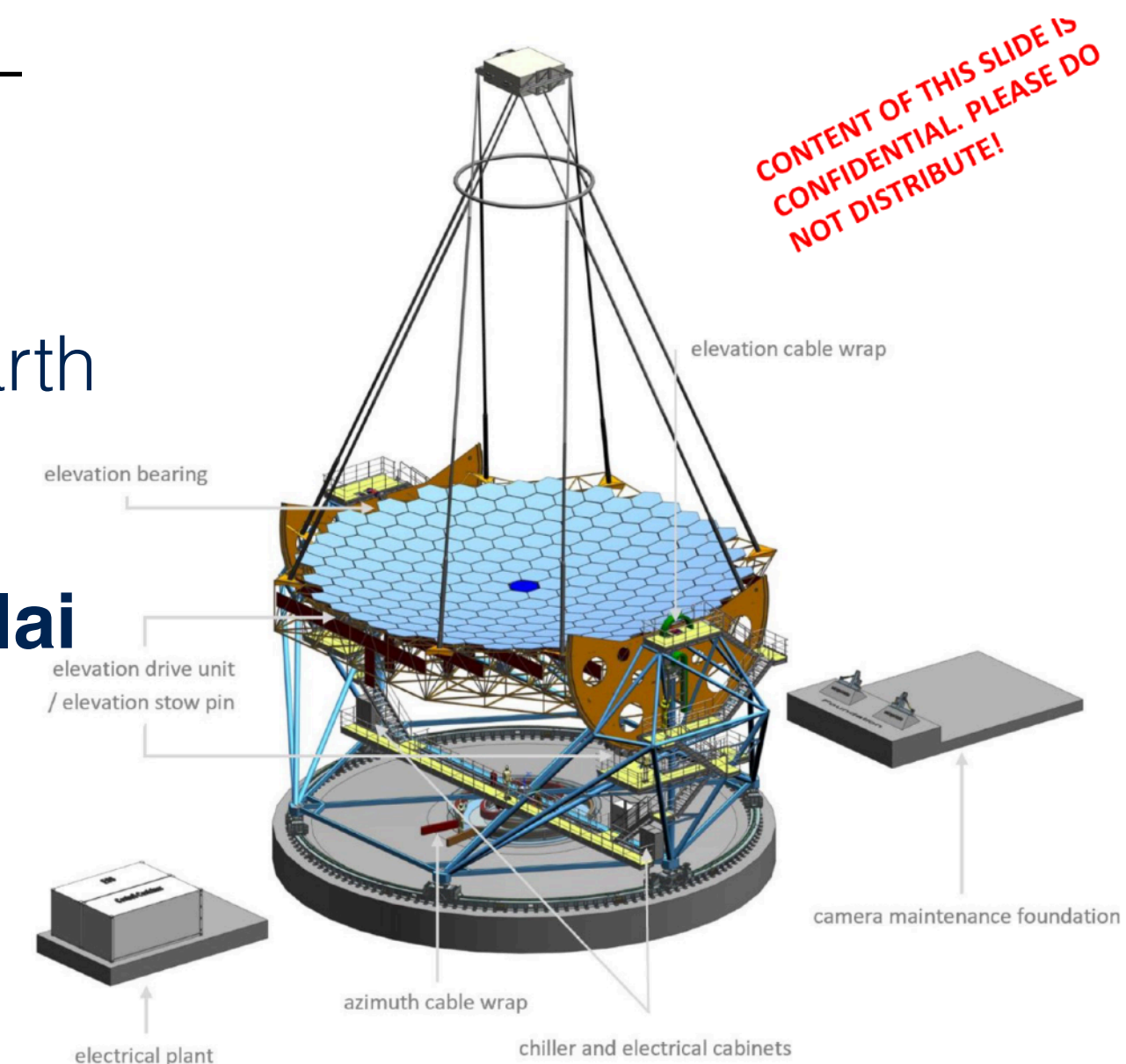
We need to hire professional people dedicated to what is missing



# LST South progress

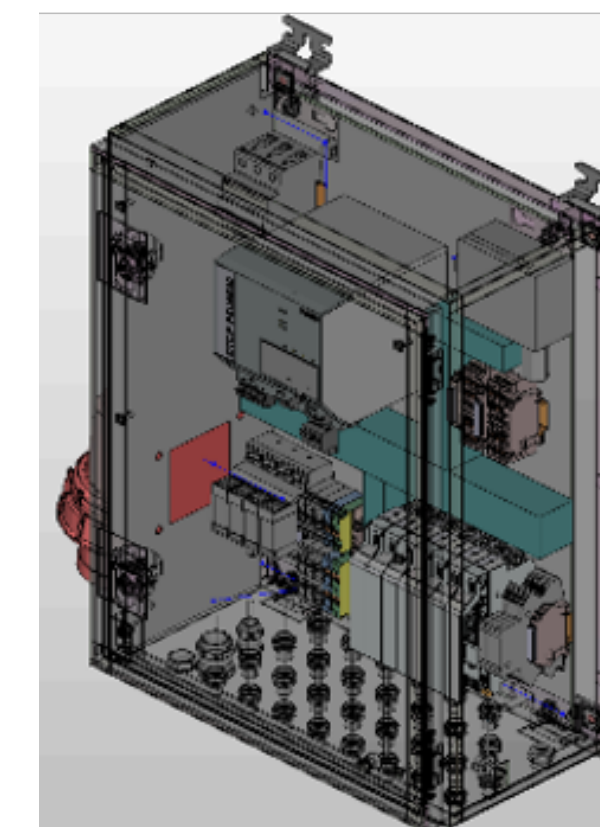
- MOUNT

- Point of many discussions was where to include damping for Earth Quakes in Chile. Probably it will be inside the structure
- Tender assigned to Company Consortium which includes **Cimolai** and **OHB Digital Connect**
- Kick Off at beginning of December done



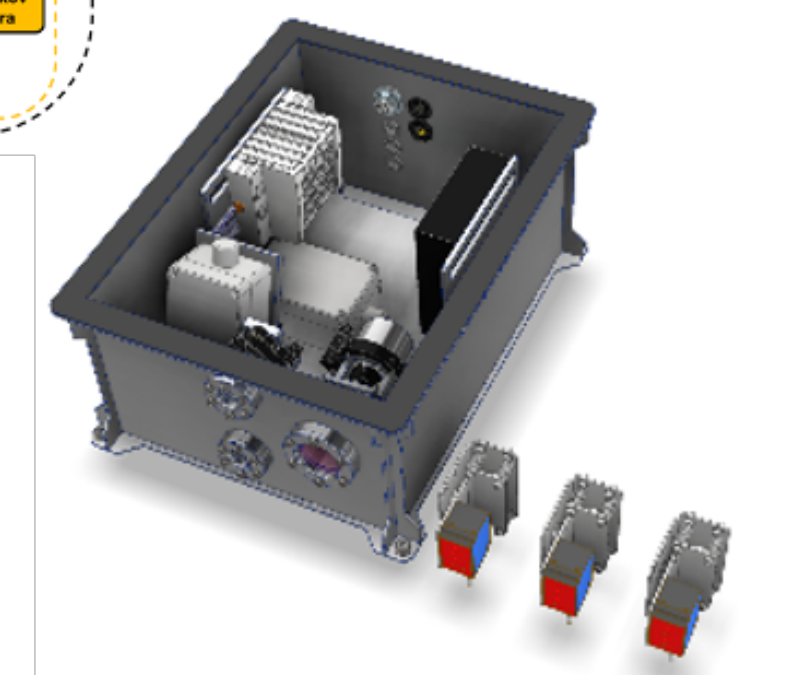
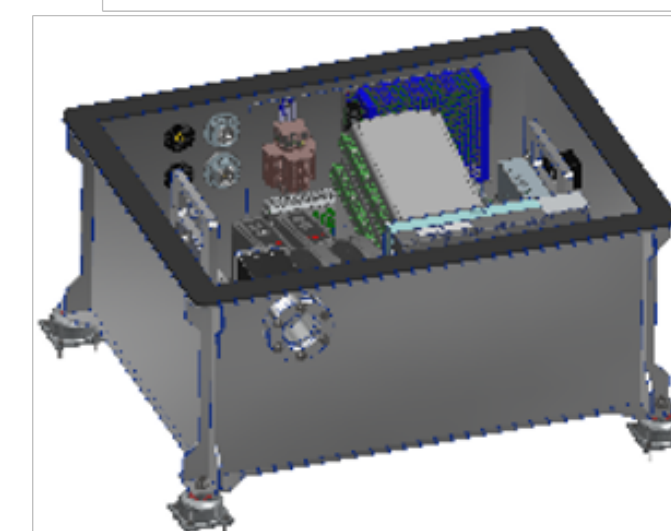
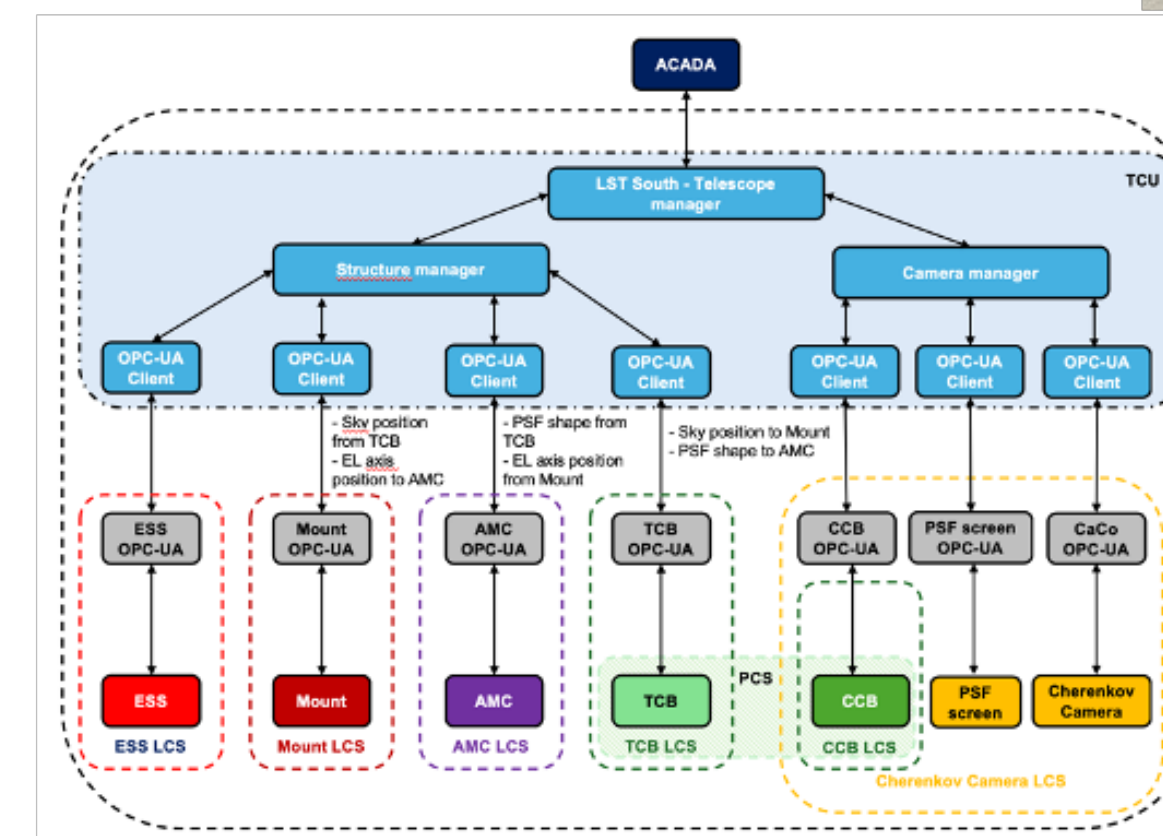
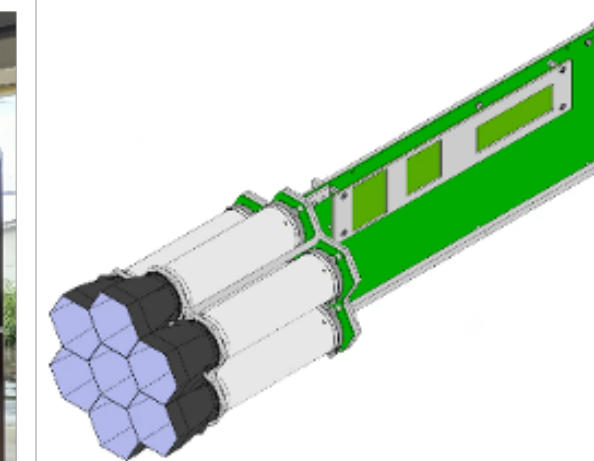
- OPTICS

- Mirrors (open tender) assigned to **Medialario**
- Actuators (open tender) realized in collaboration with UNIGE and DESY
- AMC cabinet and cabling during 2025



# LST South progress

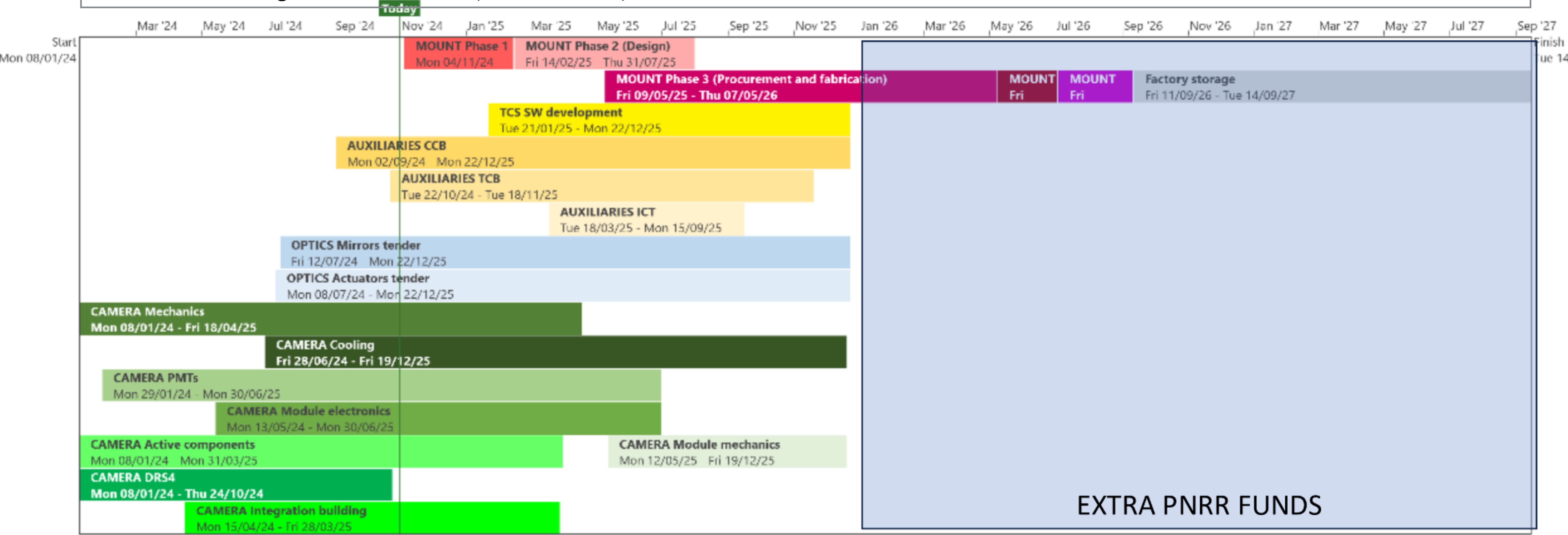
- CAMERA: **exact copy of the LST-North cameras**
  - Structure (open tender)
  - Auxiliary Systems (open tender)
  - PMT (open tender)
  - Board production (open tender)
  - Electronic components (open tender)
  - DRS4 procurement (open tender split in 16 direct assignments)
  - Integration building (open tender)
  - Module mechanical items at beginning 2025
- AUXILIARIES
  - Camera Calibration Box (CCB) and Illuminator structures (direct assignment)
  - CCB components: open tender at beginning 2025
  - Software (higher level): open tender at beginning 2025
  - Telescope Calibration Box direct assignment at beginning 2025



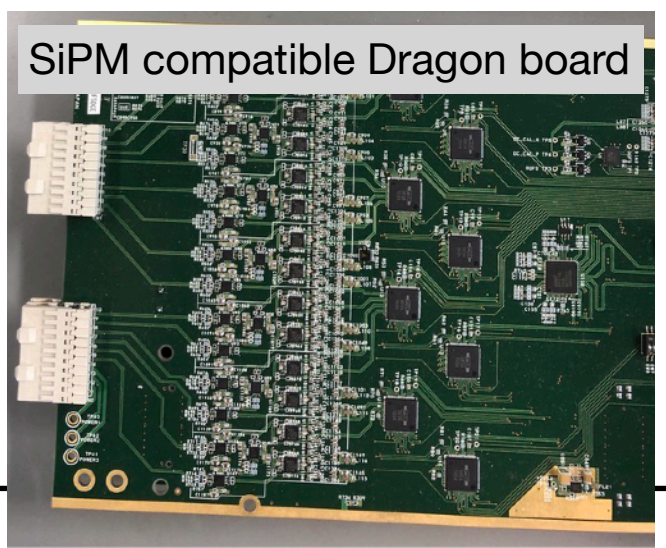
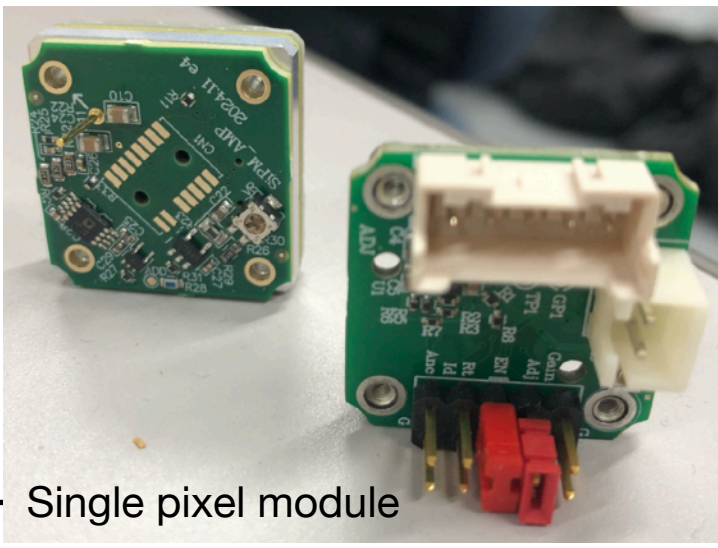
# LST South progress

As of November 2024

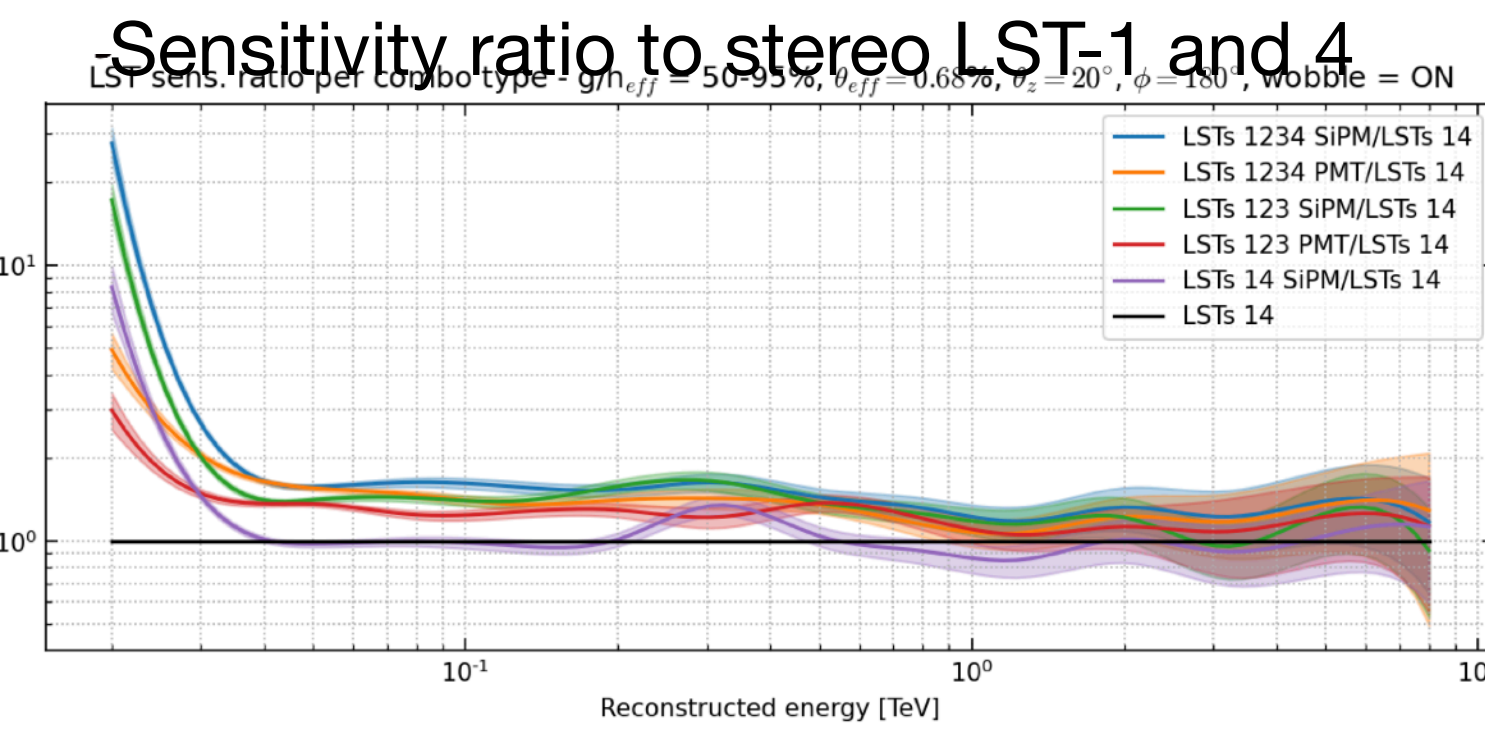
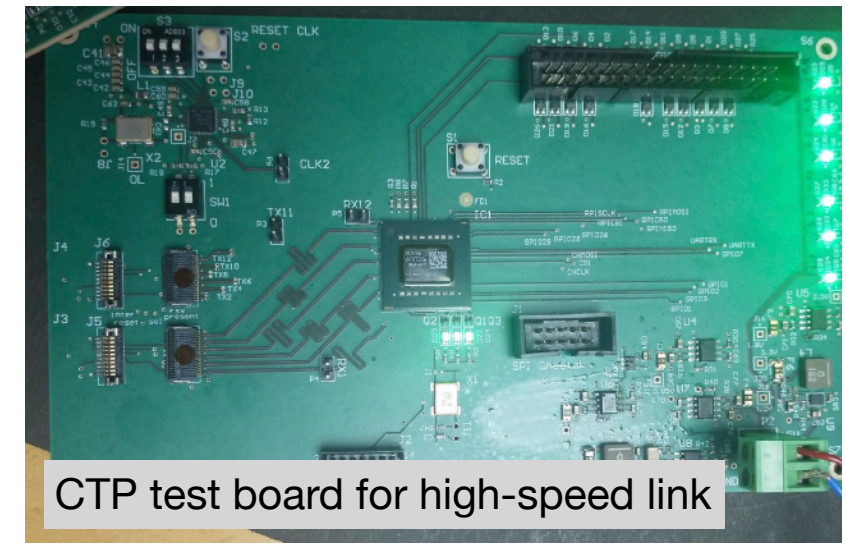
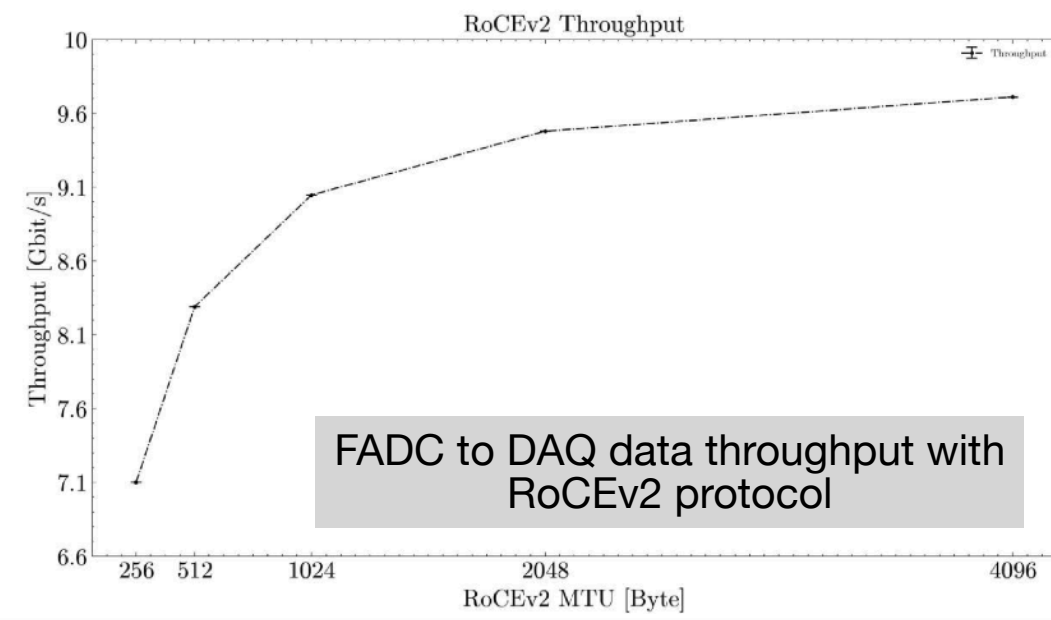
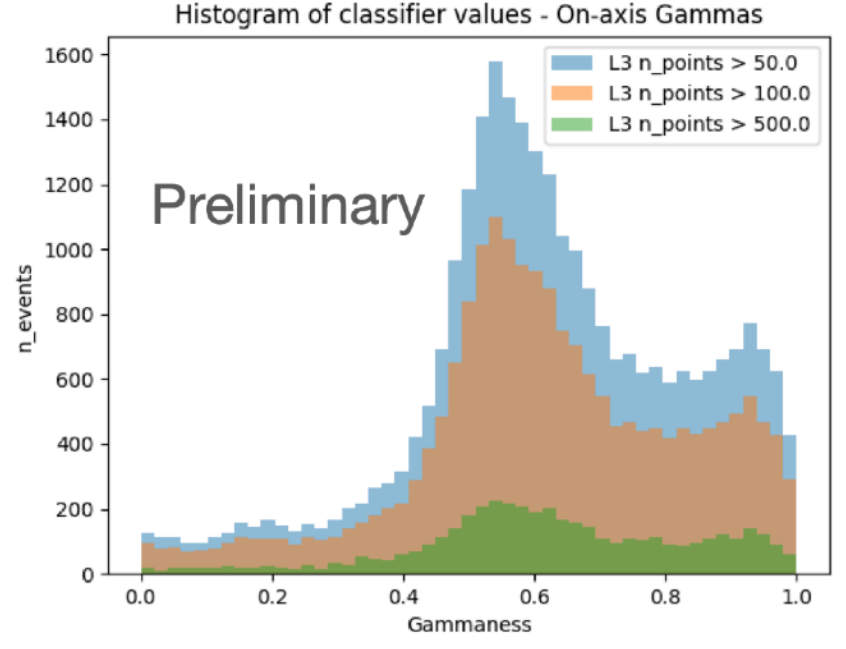
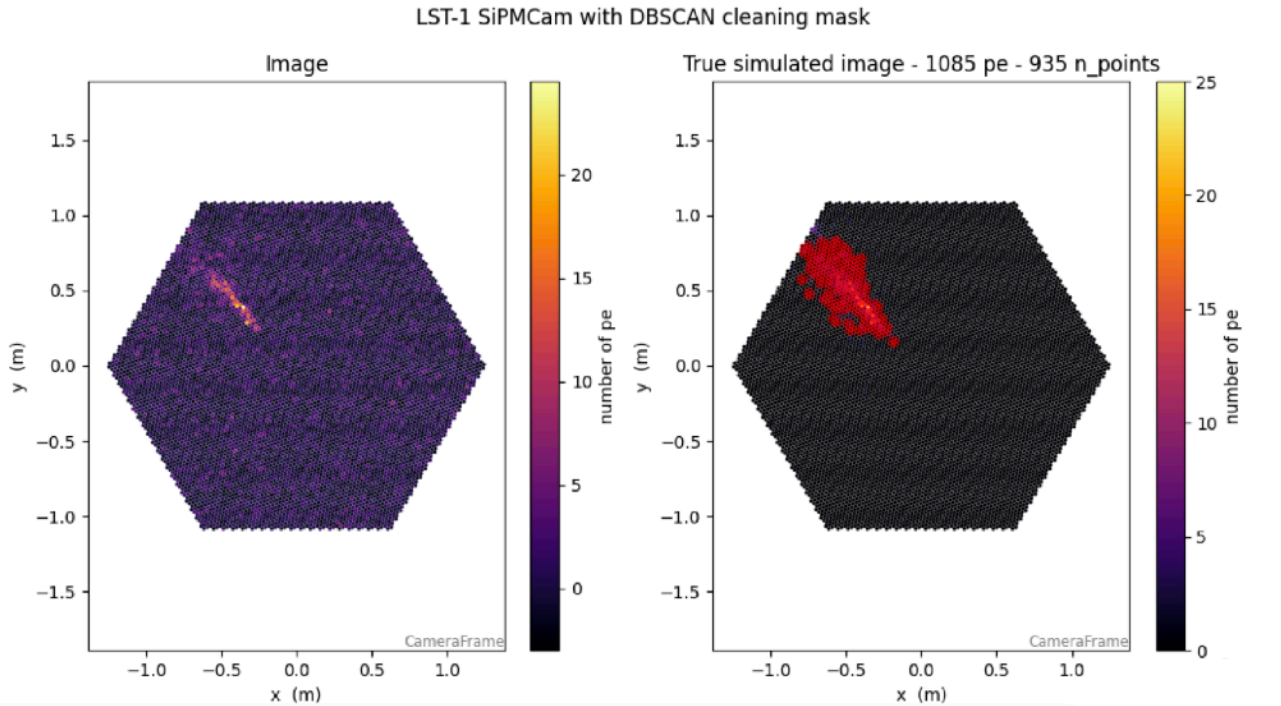
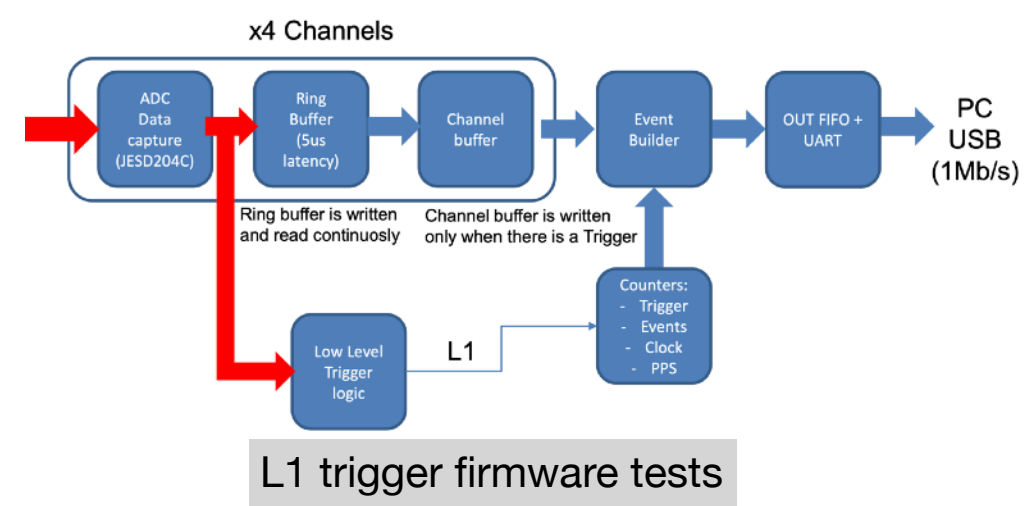
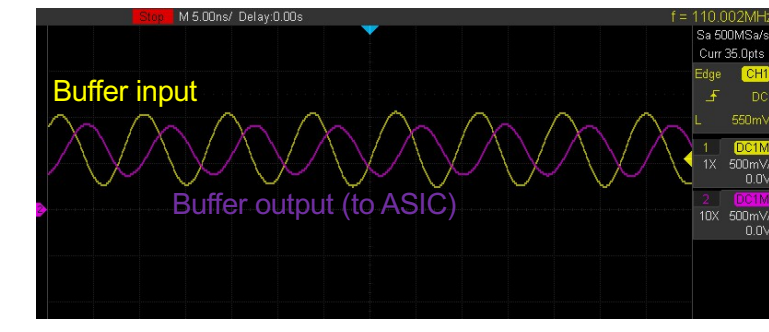
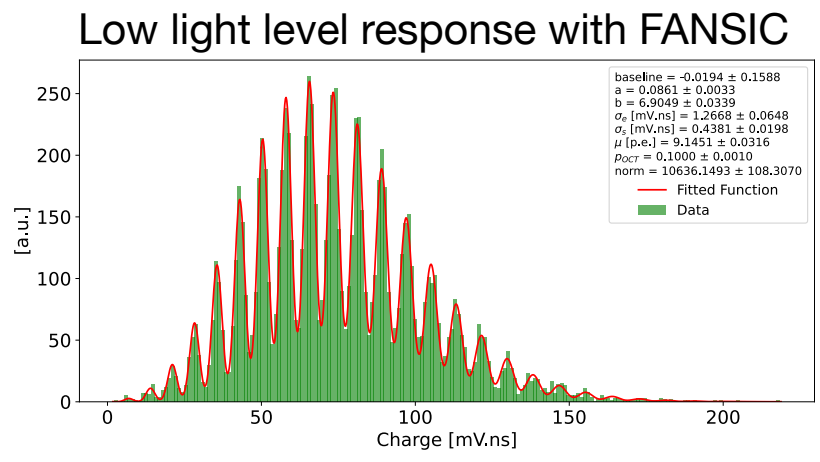
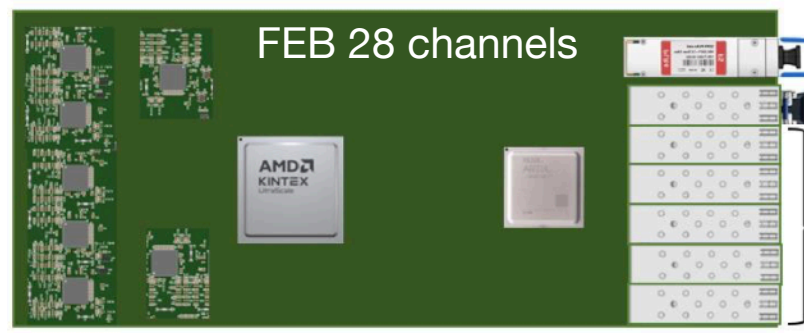
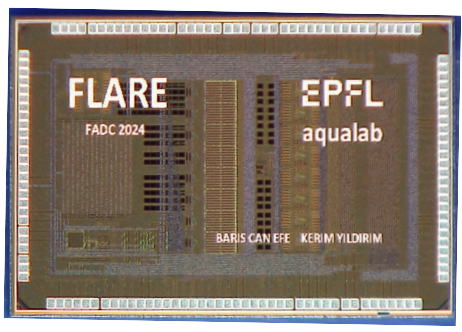
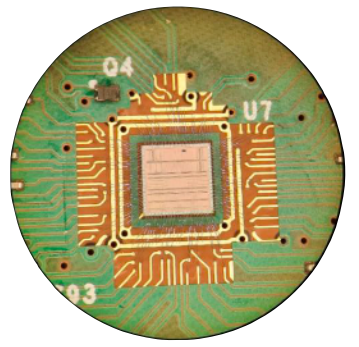
- Project Office nearly complete with essential roles (but it will be increased in 2025)
- Most of the contracts started (at last!)
- Schedule is tight but still valid (see it below)



# Advanced Camera



- One major point of CTA was always that mirrors and **cameras** of the telescopes will **need an upgrade** along the 30 years of observatory's operation time.
- An ambitious work started a few years ago, led by UNIGE, to rethink and improve all aspects of the camera: light sensor, pixelization, trigger, readout.
- After years of preparatory work, **Silicon Photomultiplier camera** for large telescopes **has reached the critical mass** in terms of people power required to go for an R&D program **to realize a full scale prototype camera**
- **Fully digital camera readout has** attracted interest across different research fields offering **synergies with**, e.g., **LHC**
- However, the Swiss institutes cannot do it alone. Team assembled from **Switzerland, Japan, Italy and Spain** from within the LST project **will all need to deliver**



- **LST is a mature** project, driving power of CTAO.
- **LST-1** in La Palma **is performing according to expectations**, early science results are plenty. 6 scientific publications in refereed journals, more in the pipeline
- **People power issues** to finalize the telescope commissioning and provide needed documentation **for CTAO acceptance**
- **LST-2-4** being installed in La Palma **on schedule**, commissioning /AIV starts next year
- **Upgrade of PMT to SiPM camera**: looks very promising, expect boost in performance and duty cycle



THANK YOU