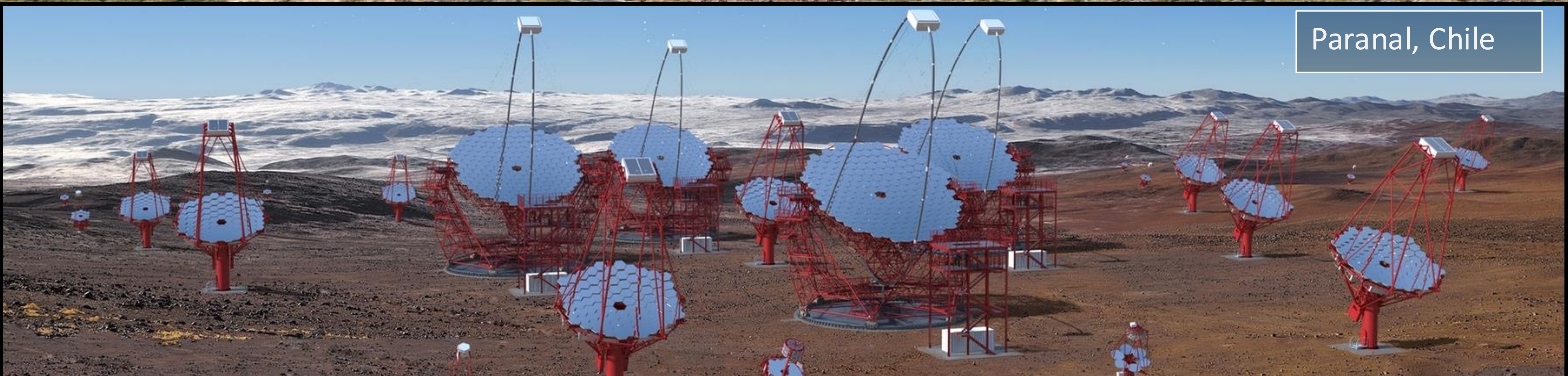
Status of the LST Project

Masahiro Teshima, David Paneque for the LST Collaboration

Max Planck Institute for Physics, Munich, Germany



Alpha Configuration of CTA

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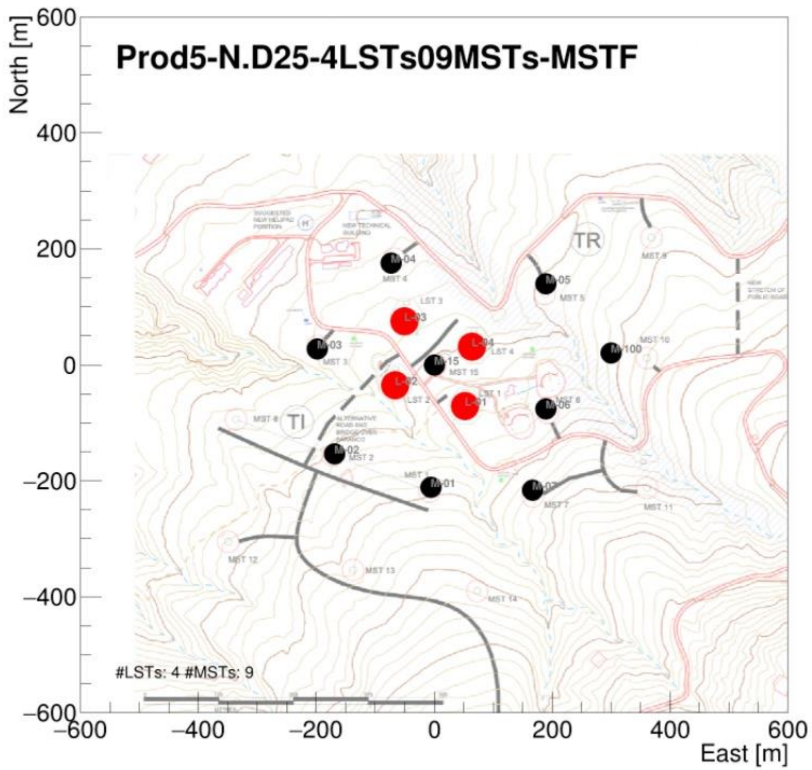
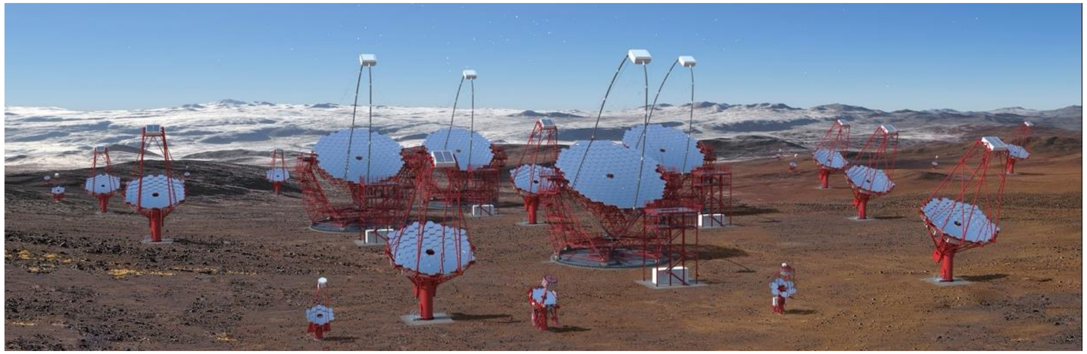
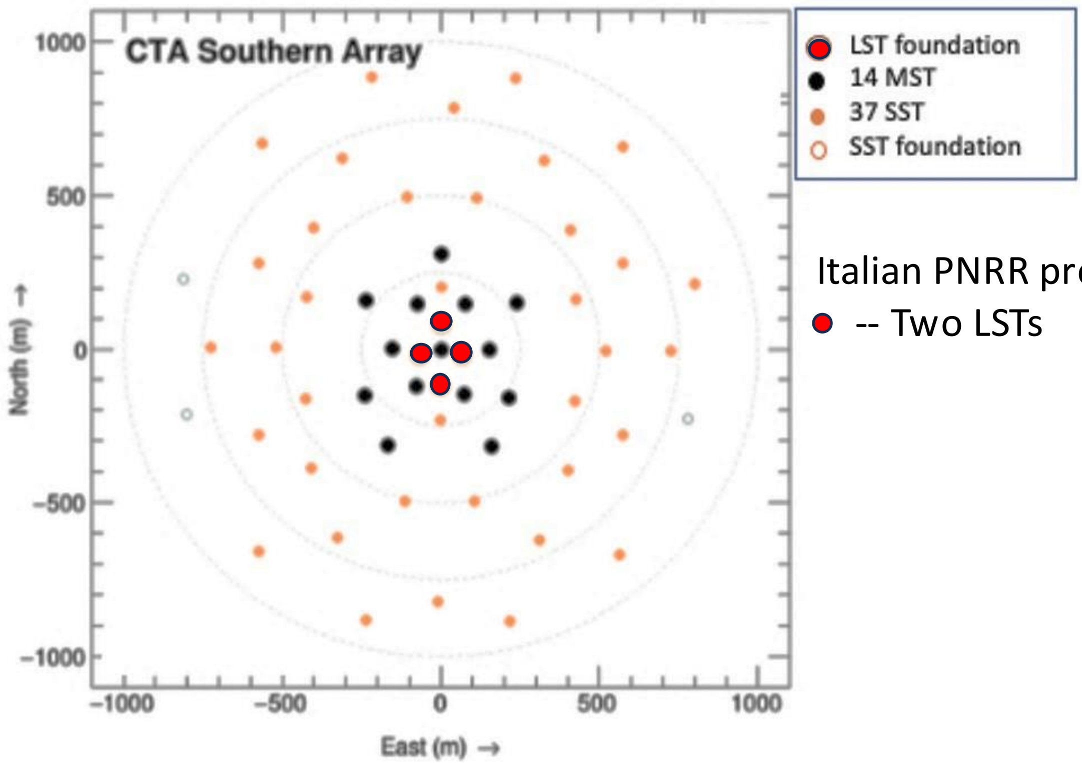
Roque de los Muchachos Observatory
La Palma, Spain



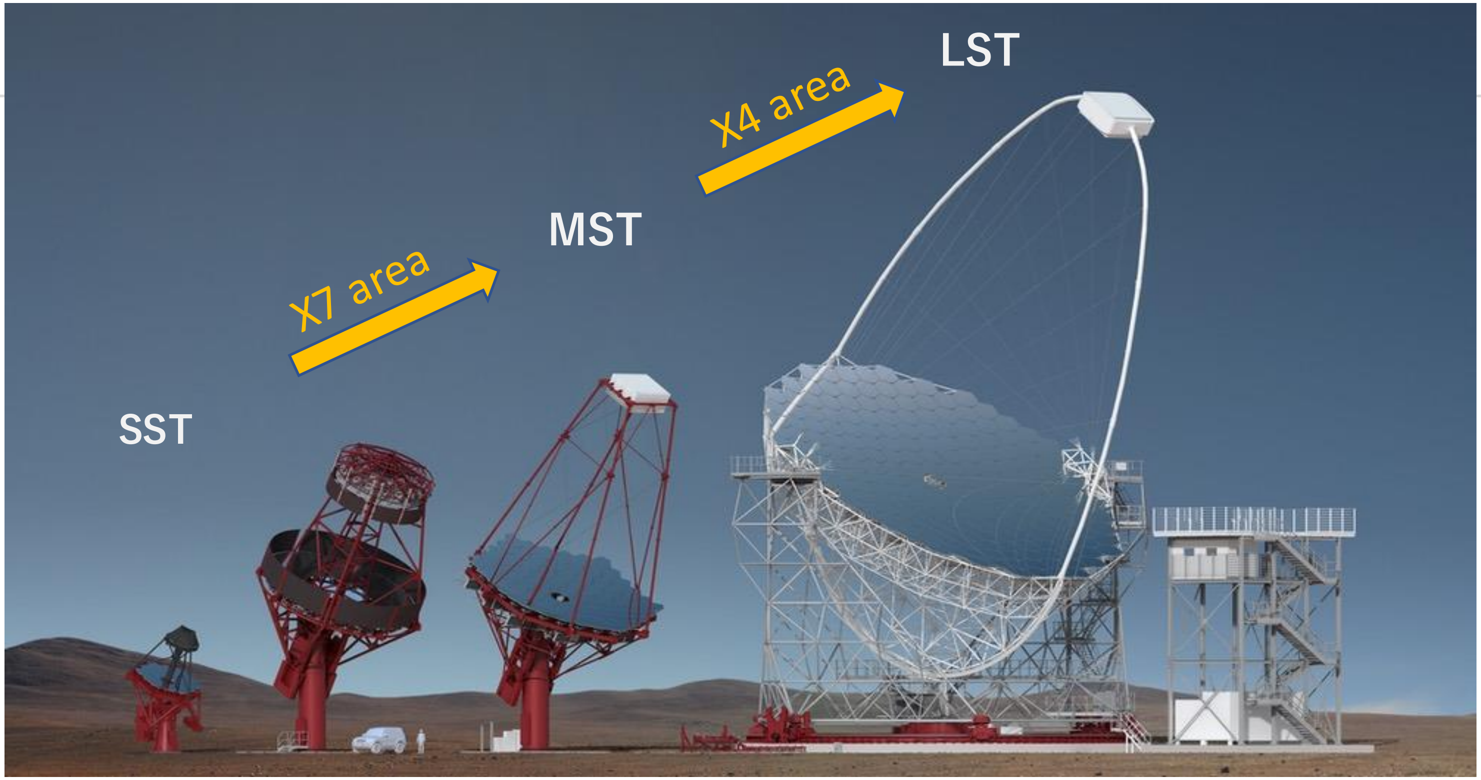
Paranal, Chile





Italian PNRR prog.
-- Two LSTs

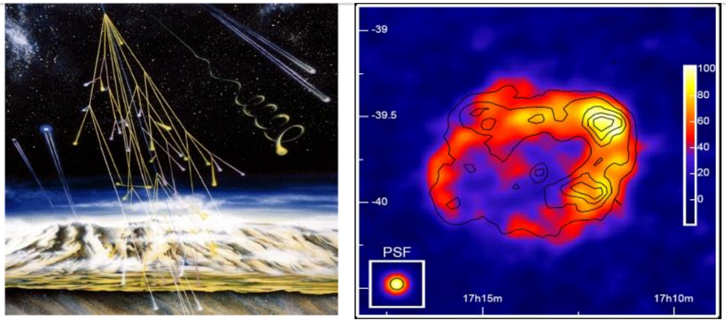
Telescope Design



Telescope Types	SST	MST	LST
Optics	Schwarzschild-Couder	Davies-Cotton	Parabolic (Isochronous)
FoV and Camera	10.5 deg SiPM	7.5 deg PMT	4.3 deg PMT
Mirror Diameter	4.3m	11.5m	23m
Energy Range	3 TeV - 200 TeV	100GeV - 10TeV	20GeV – 2TeV
Science Targets	Galactic Sources PeVatron (UHE CR)	Galactic Sources Nearby AGNs (z<0.5) Dark Matter	Transient Sources AGNs(z<2), GRBs(z <4) Dark Matter

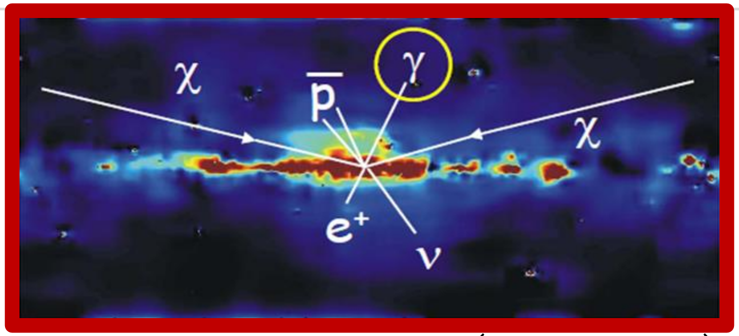
Science of CTA is very wide

CTA-LST will cover S.M.B.H., Dark Matter, AGNs, GRBs



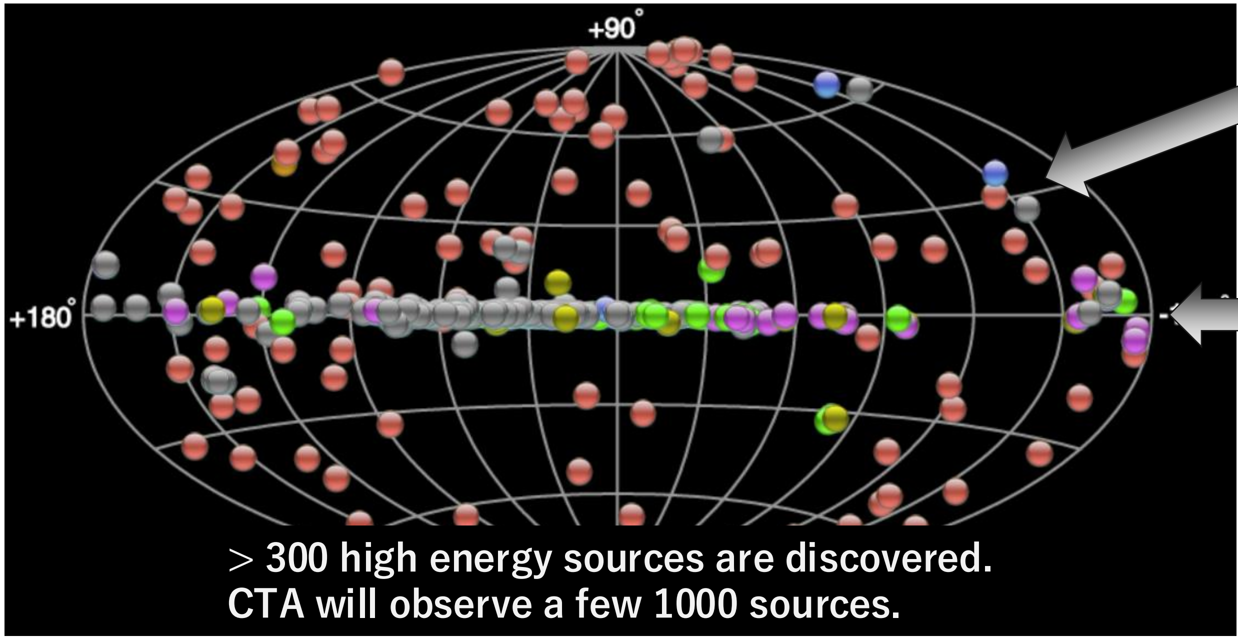
Cosmic Ray Origin


Super Massive Black Holes



Dark Matter Search (Discovery)

- Origin of Cosmic Rays (Big accelerators)
- Black Hole and S.M.B.H.
- Dark Matter Search



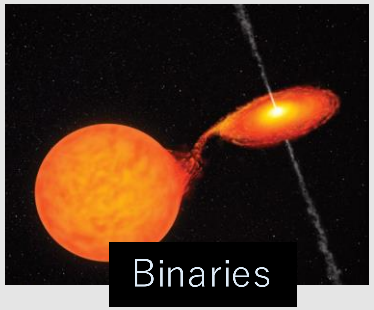
Extragalactic Sources


Active Galactic Nuclei


Gamma Ray Bursts

Galactic Sources


Super Nova Remnants


Binaries

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LST Collaboration

LST statistics			
	Members	Scientists + Students	Authors
Bulgaria	2	2	2
Brazil	3	2	2
Spain	92	61	56
France	42	21	21
Croatia	9	9	9
Czechia	19	19	12
Germany	49	42	39
Switzerland	22	19	16
Italy	129	103	78
Japan	87	82	65
Poland	5	5	5
Total	459	365	305

We have a good number of people

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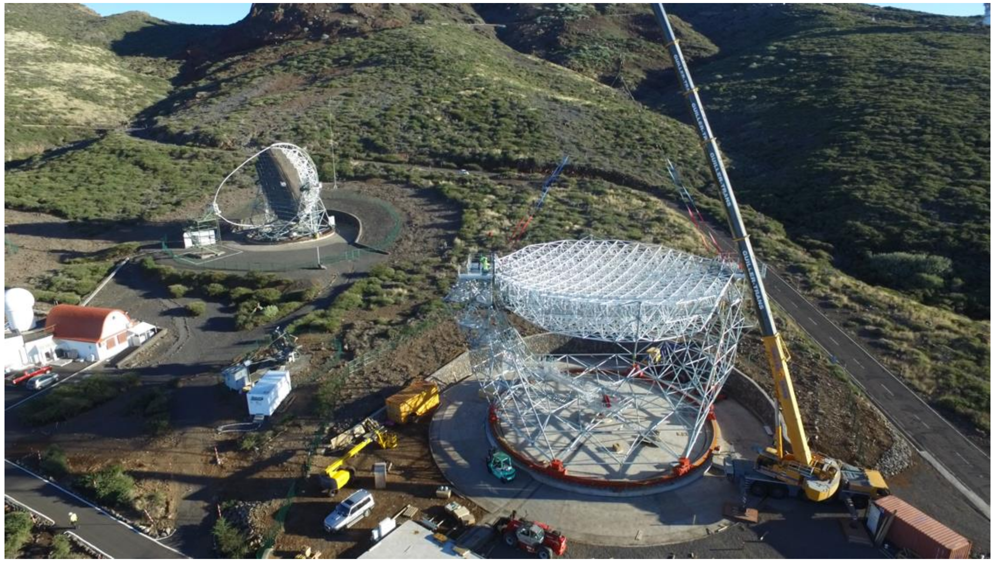
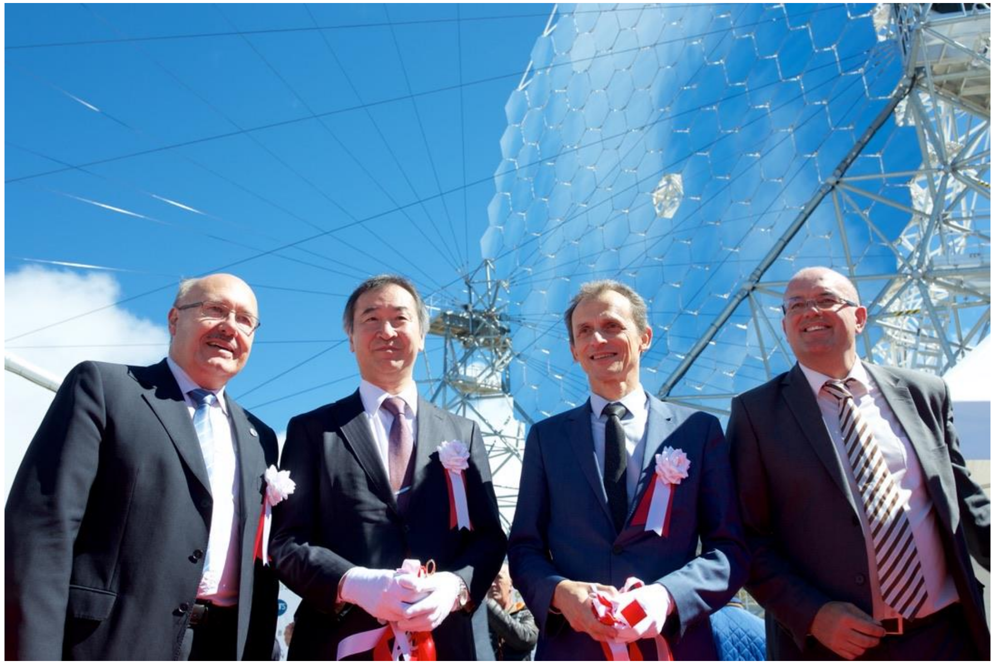
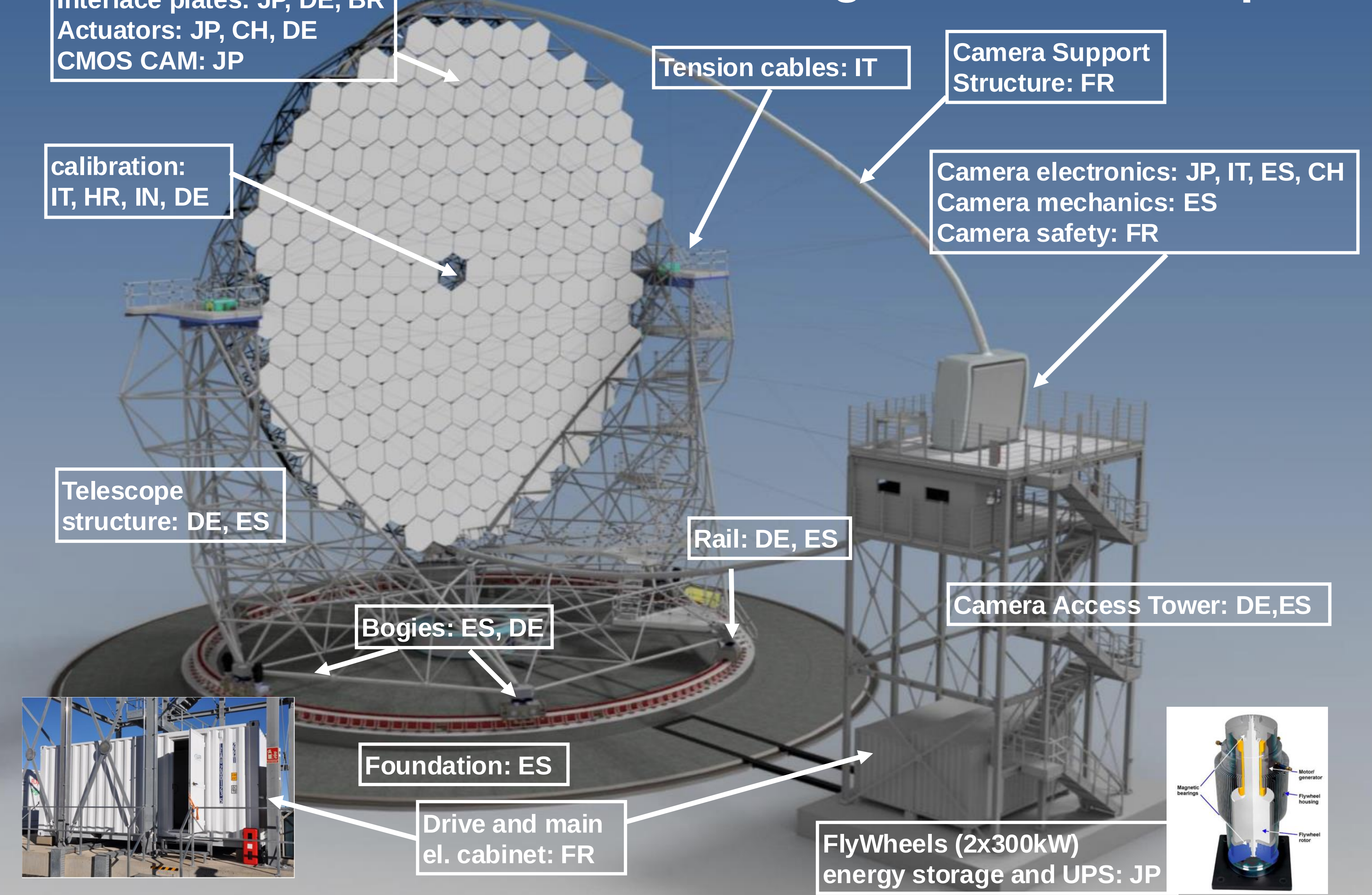
LST1 was inaugurated in Oct.2018

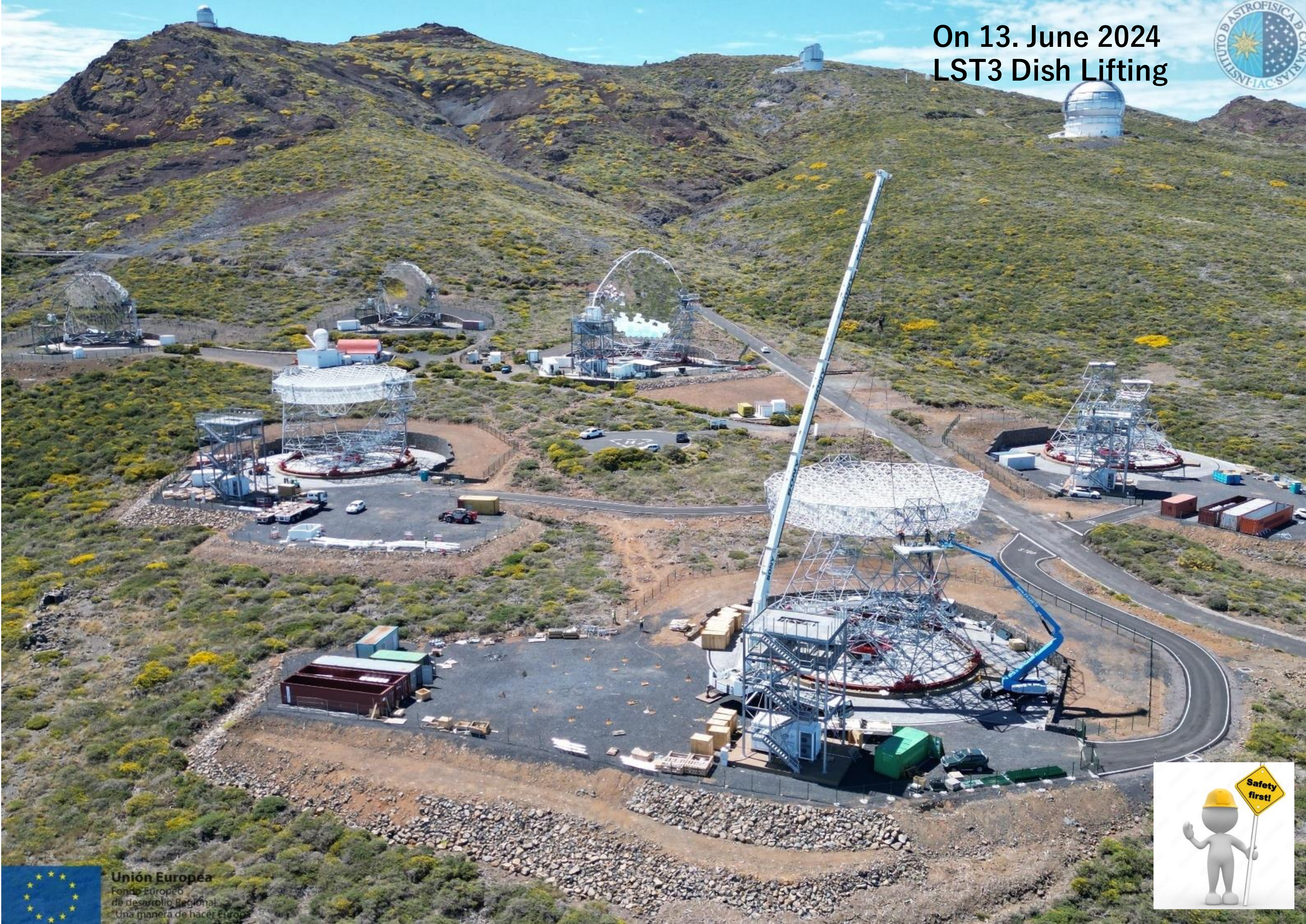




Large-Sized Telescope

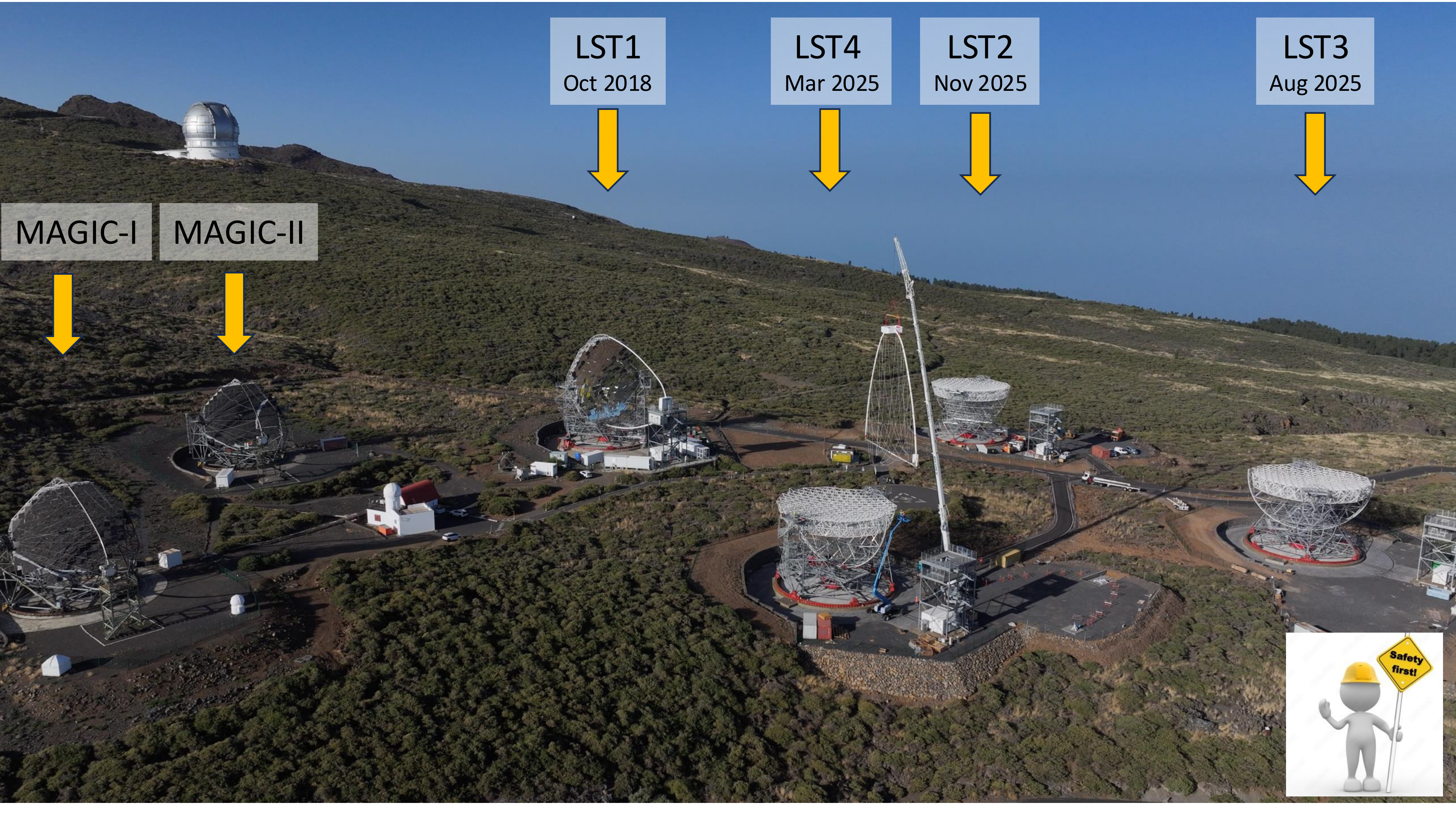


May 2024
Completed in 2025
Operation in 2026
LST4
March 2025
LST1
October 2018
LST2
November 2025
LST3
August 2025
Safety first!

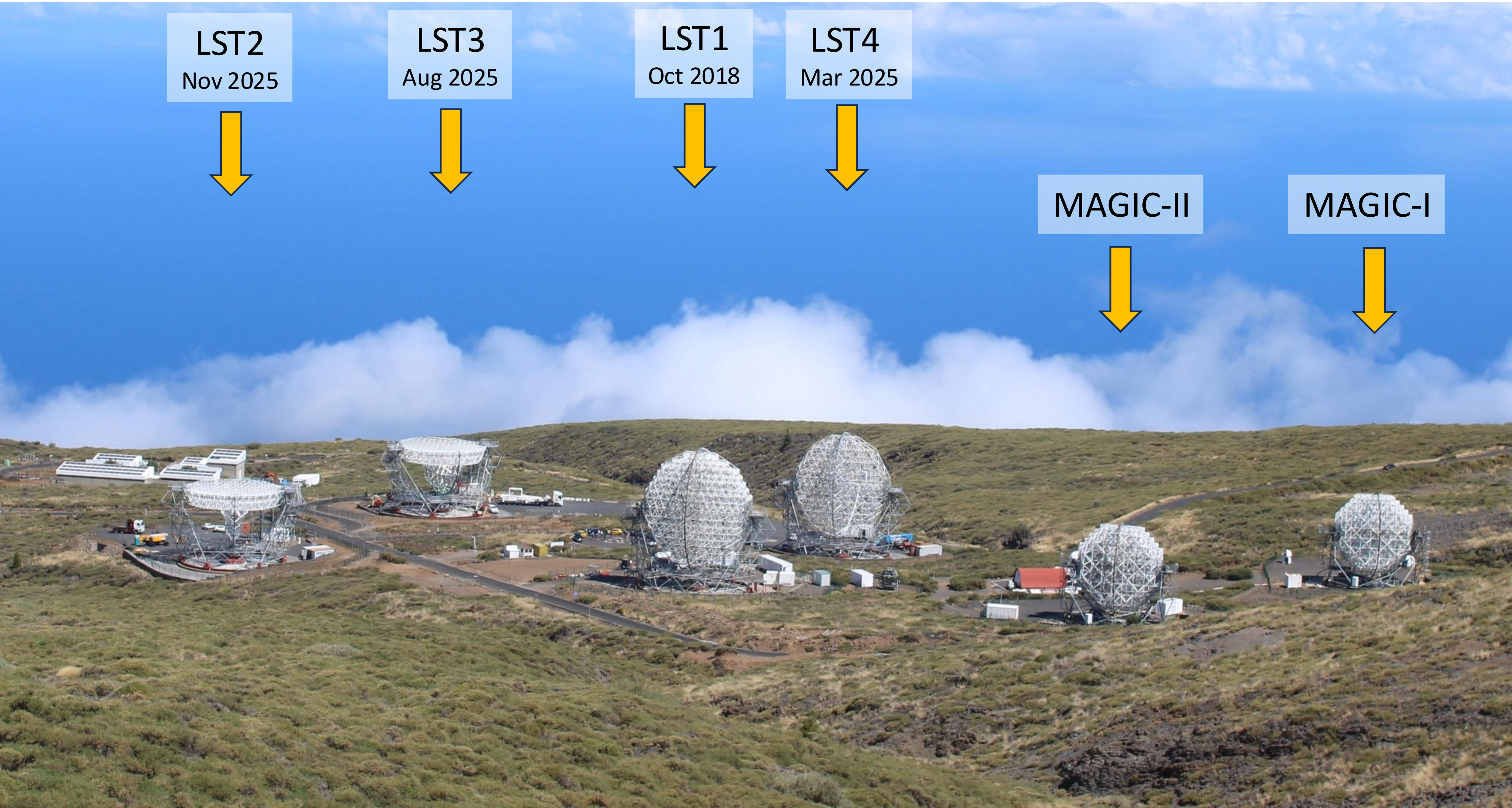

On 13. June 2024
LST3 Dish Lifting
Safety first!
Unión Europea
Fondo Europeo
de desarrollo Regional
Una manera de hacer

LST4 ARCH-CSS installation

on 22.Aug.2024



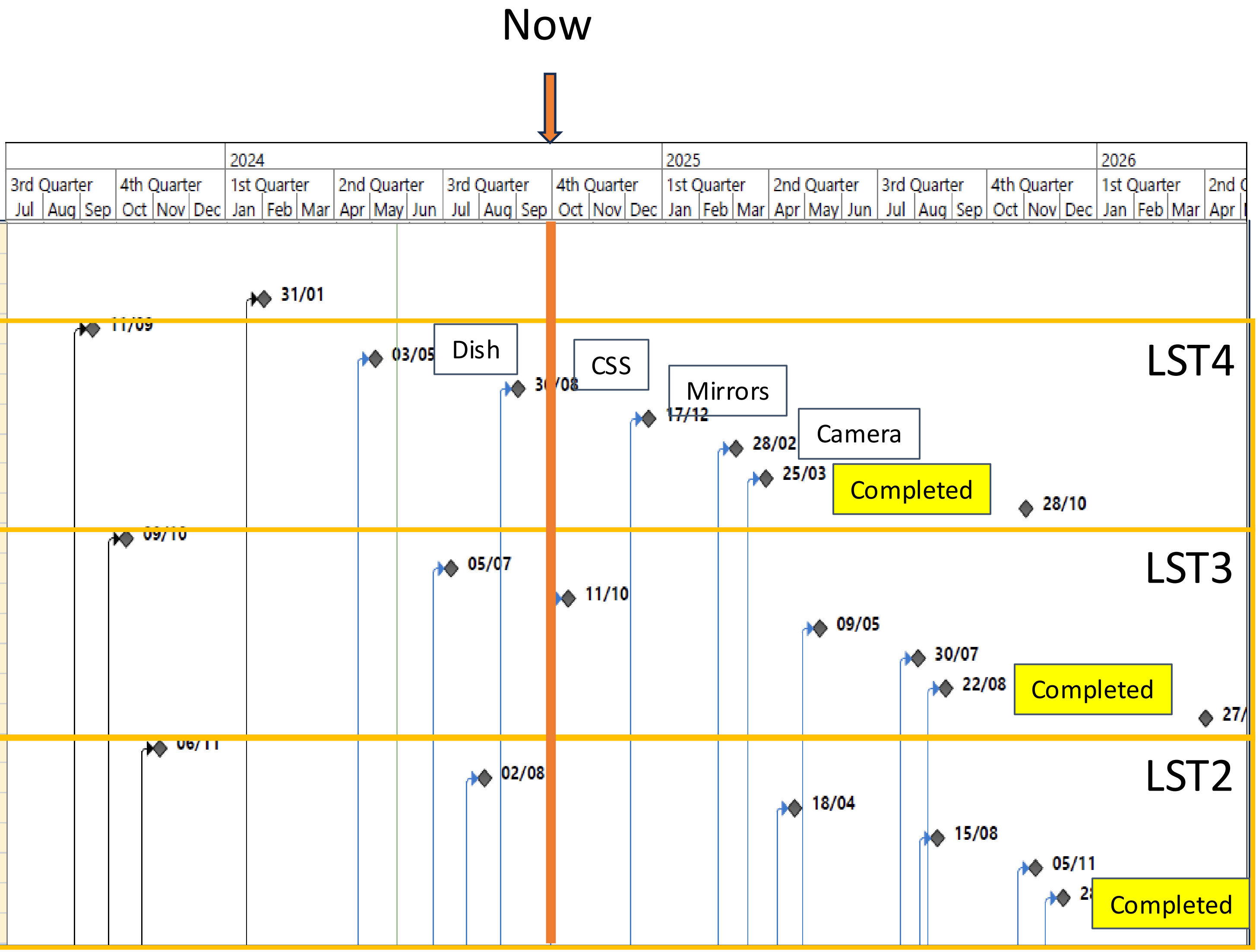
CTAO North sites
on 30.Aug.2024



Schedule for the LST2-4 construction

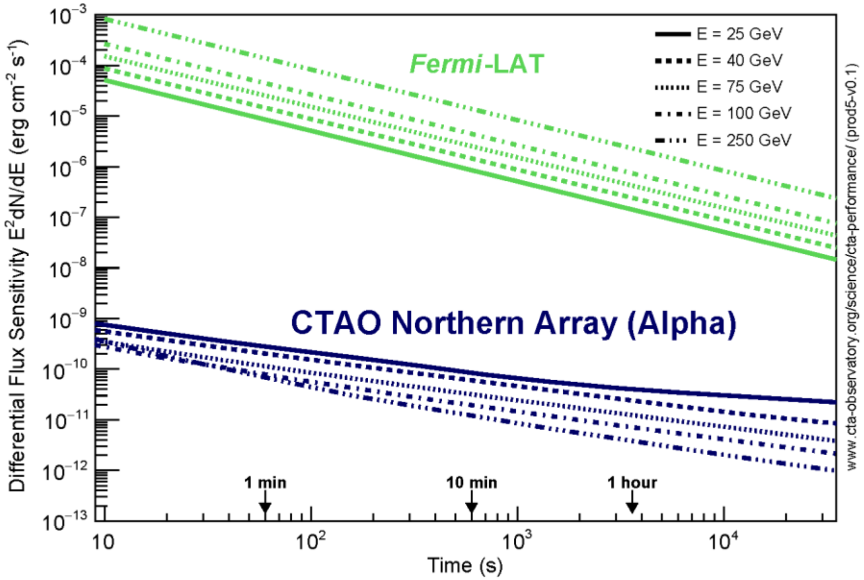
CTAO | LST COLLABORATION

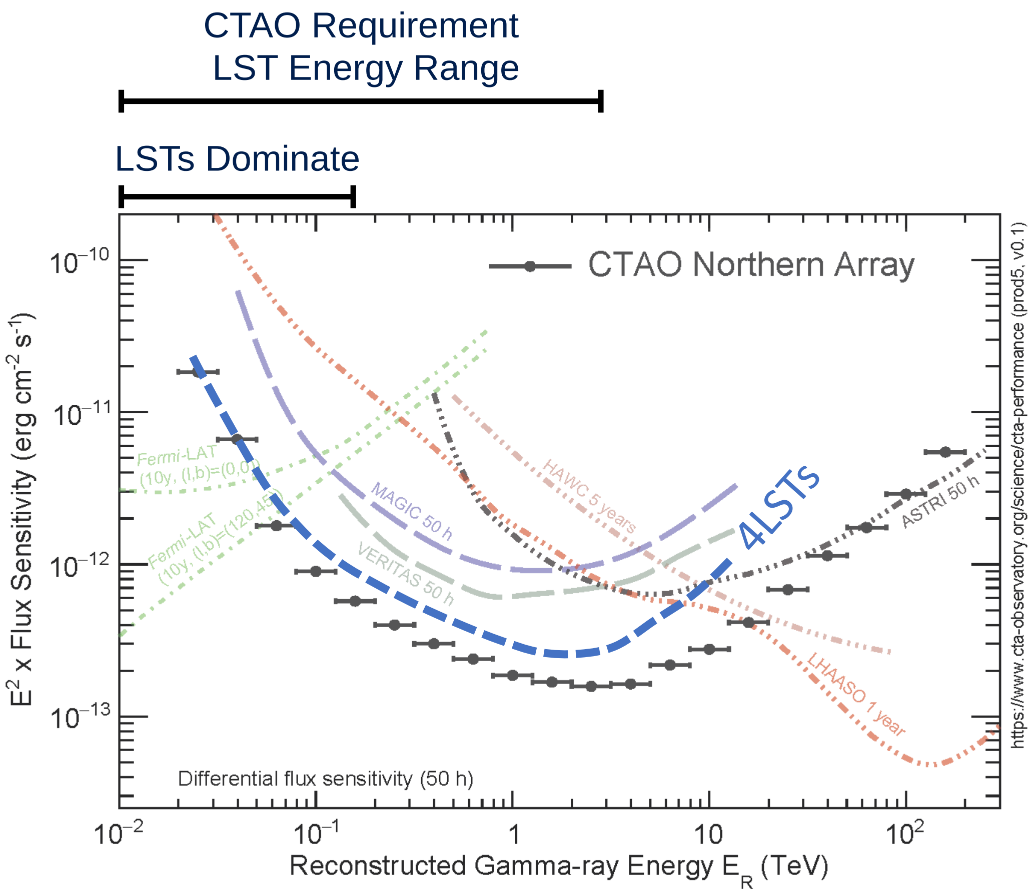
All permits granted	0 days	Tue 18/10/22	Tue 18/10/22
Civil works start	0 days	Mon 24/10/22	Mon 24/10/22
Civil works finish	0 days	Wed 31/01/24	Wed 31/01/24
LST4 construction starts	0 days	Mon 11/09/23	Mon 11/09/23
LST4 dish and structure united	0 days	Fri 03/05/24	Fri 03/05/24
LST4 CSS installed	0 days	Fri 30/08/24	Fri 30/08/24
LST4 mirrors installed	0 days	Tue 17/12/24	Tue 17/12/24
LST4 camera installed	0 days	Fri 28/02/25	Fri 28/02/25
LST4 construction completed	0 days	Tue 25/03/25	Tue 25/03/25
LST4 ready for acceptance	0 days	Tue 28/10/25	Tue 28/10/25
LST3 construction starts	0 days	Mon 09/10/23	Mon 09/10/23
LST3 dish and structure united	0 days	Fri 05/07/24	Fri 05/07/24
LST3 CSS installed	0 days	Fri 11/10/24	Fri 11/10/24
LST3 mirrors installed	0 days	Fri 09/05/25	Fri 09/05/25
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	Fri 27/03/26	Fri 27/03/26
LST2 construction starts	0 days	Mon 06/11/23	Mon 06/11/23
LST2 dish and structure united	0 days	Fri 02/08/24	Fri 02/08/24
LST2 CSS installed	0 days	Fri 18/04/25	Fri 18/04/25
LST2 mirrors installed	0 days	Fri 15/08/25	Fri 15/08/25
LST2 camera installed	0 days	Wed 05/11/25	Wed 05/11/25
LST2 construction completed	0 days	Fri 28/11/25	Fri 28/11/25
LST2 ready for acceptance	0 days	Fri 03/07/26	Fri 03/07/26

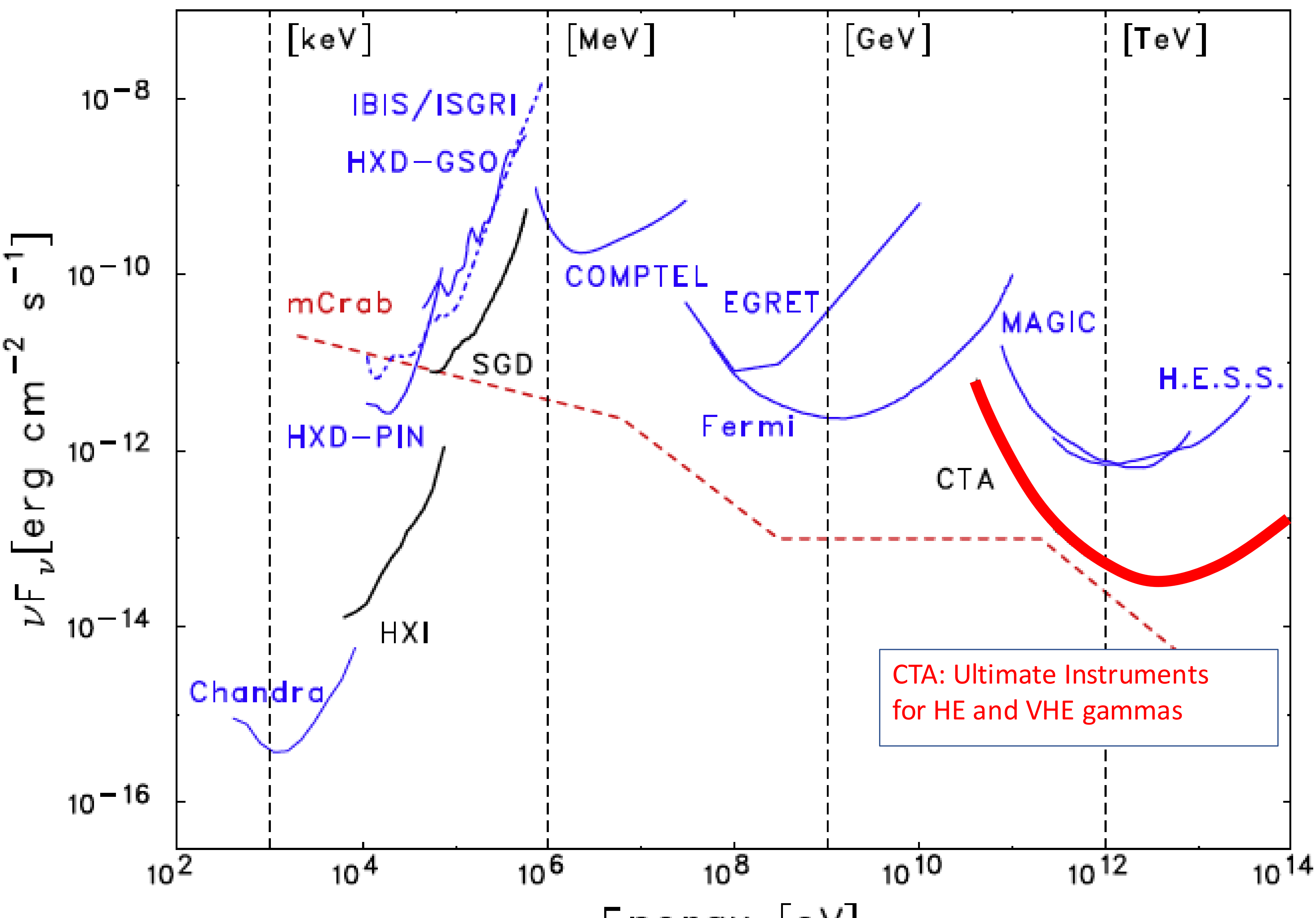


Performance of the CTAO North Array

- LSTs dominate CTAO sensitivity below 150 GeV
- Ideal for fast transients and soft sources



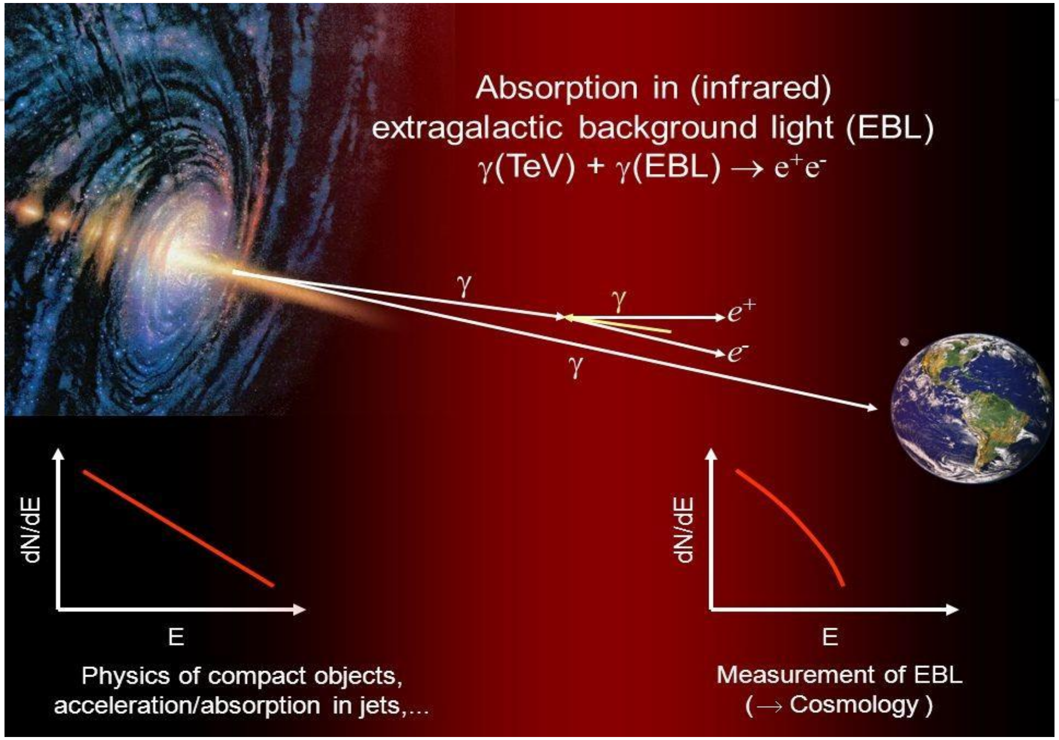


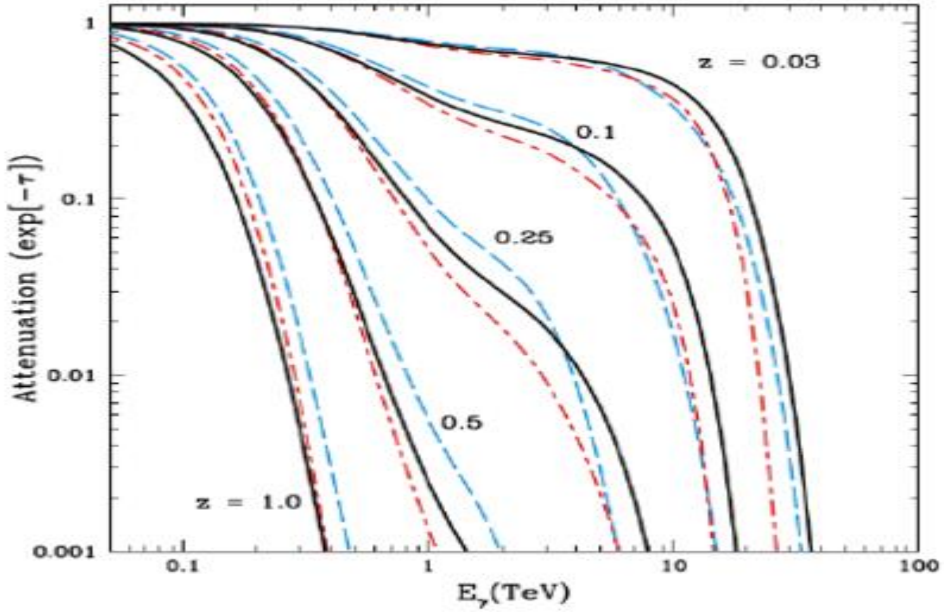


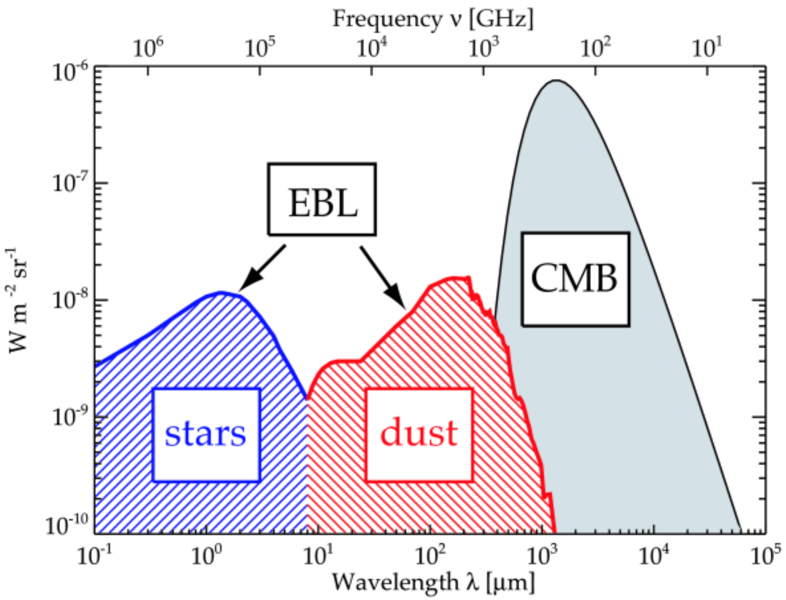
Courtesy of T.Takahashi

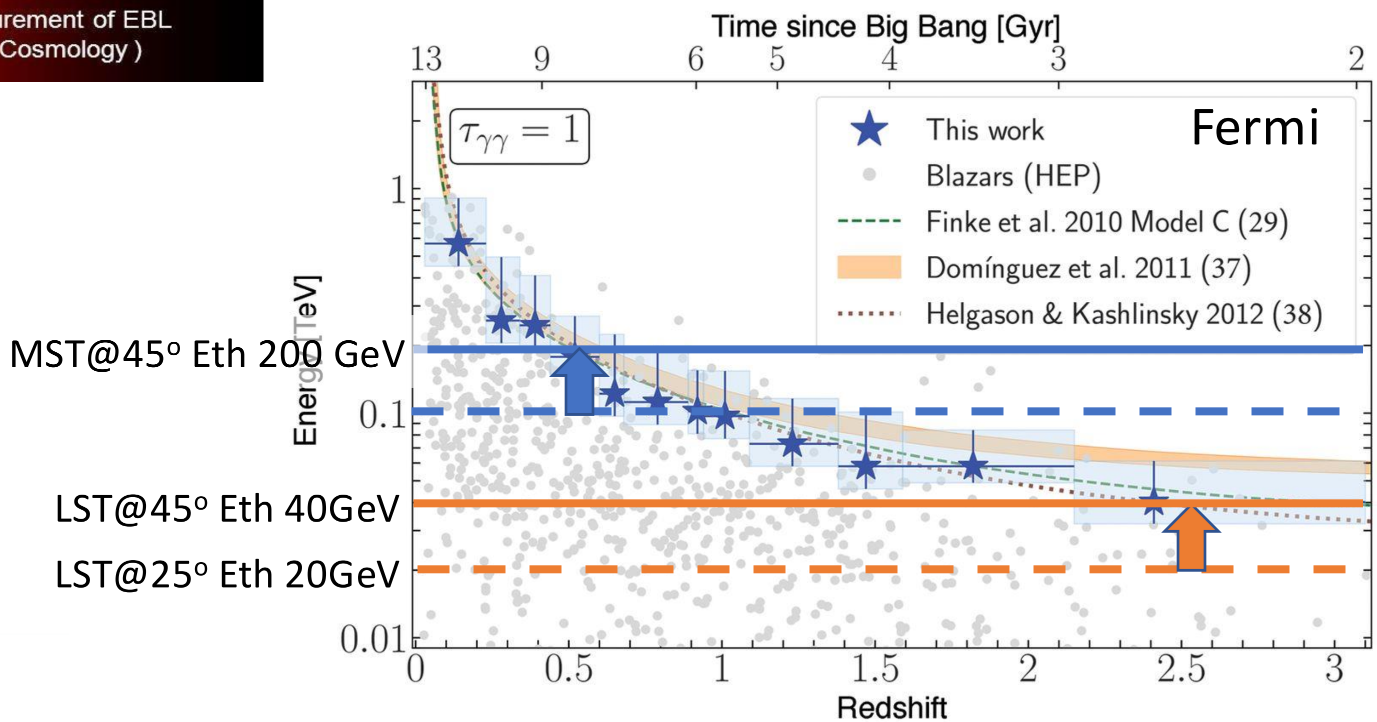
CTAO | LST COLLABORATION

Gamma Ray Horizon
Access the deep Universe with LSTs



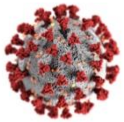


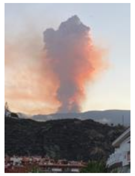


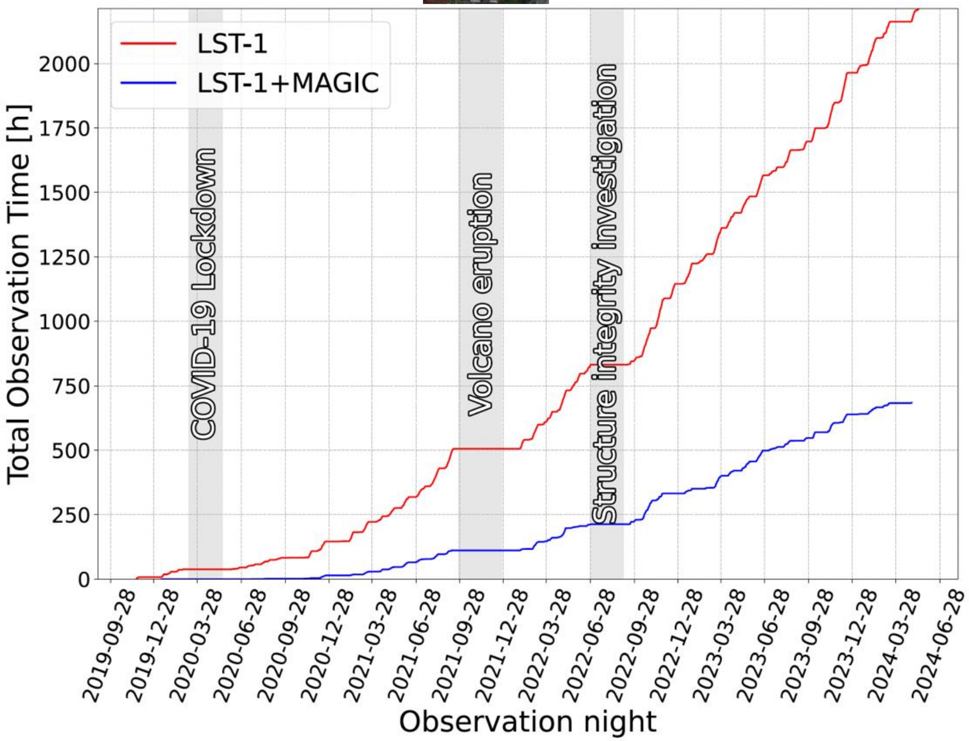


LST1 has been collecting data for more than 2000hrs

Oct 2018: LST1 Inaugurated
Jan 2020: Scientific operation started



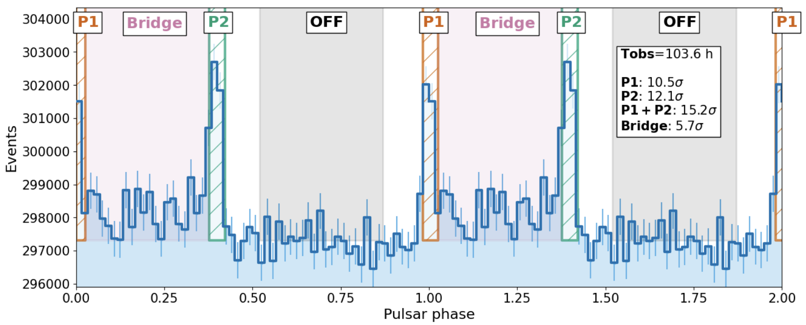




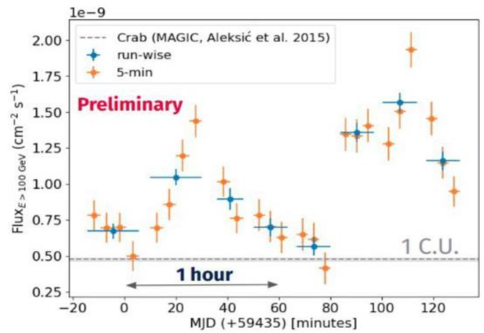
Quick follow-up observation with LST1 for GRBs and other transients.
LST can point any sky direction in 20 seconds

Many scientific results are already delivered

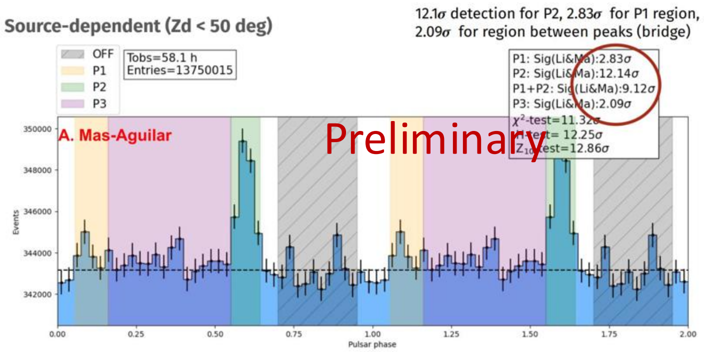
Crab pulsar above 20GeV



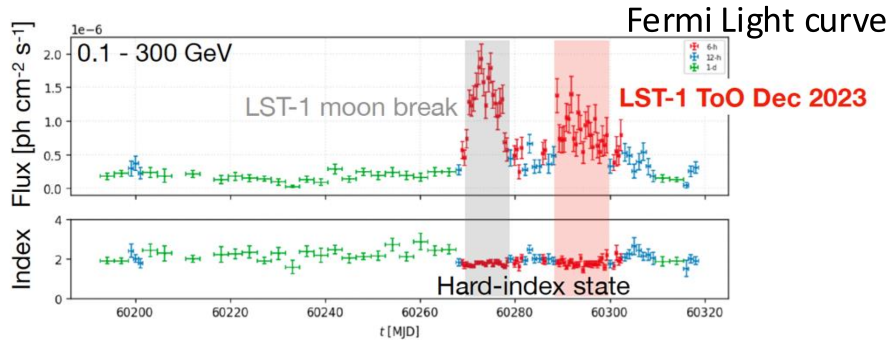
BL Lac intranight fast variability (a few min)



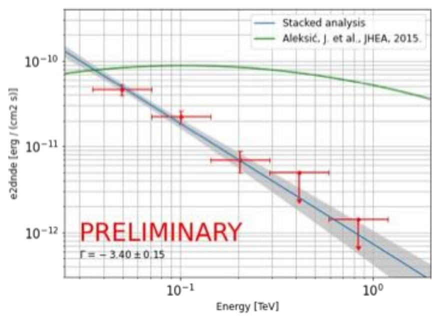
Geminga pulsar above 15GeV



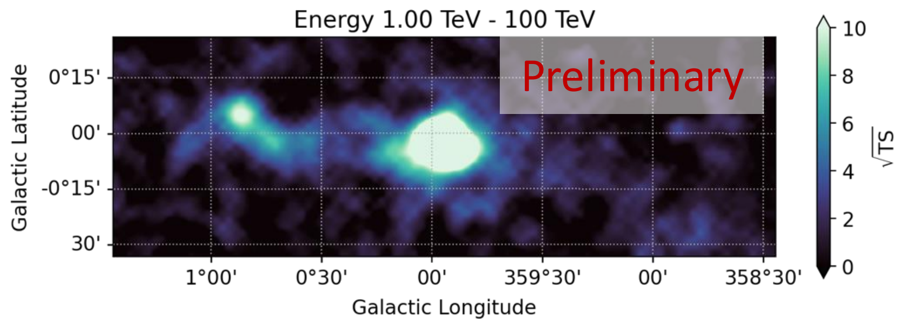
OP313: discovery of the most distant VHE AGN

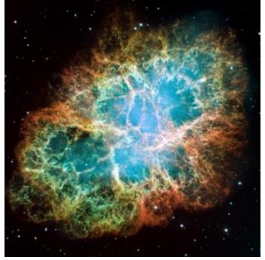


Symbiotic Nova RS Ophiuchi

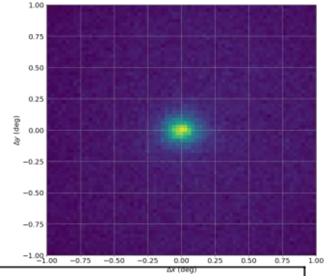


Galactic Center 39hrs (Sgr A*, diffuse)



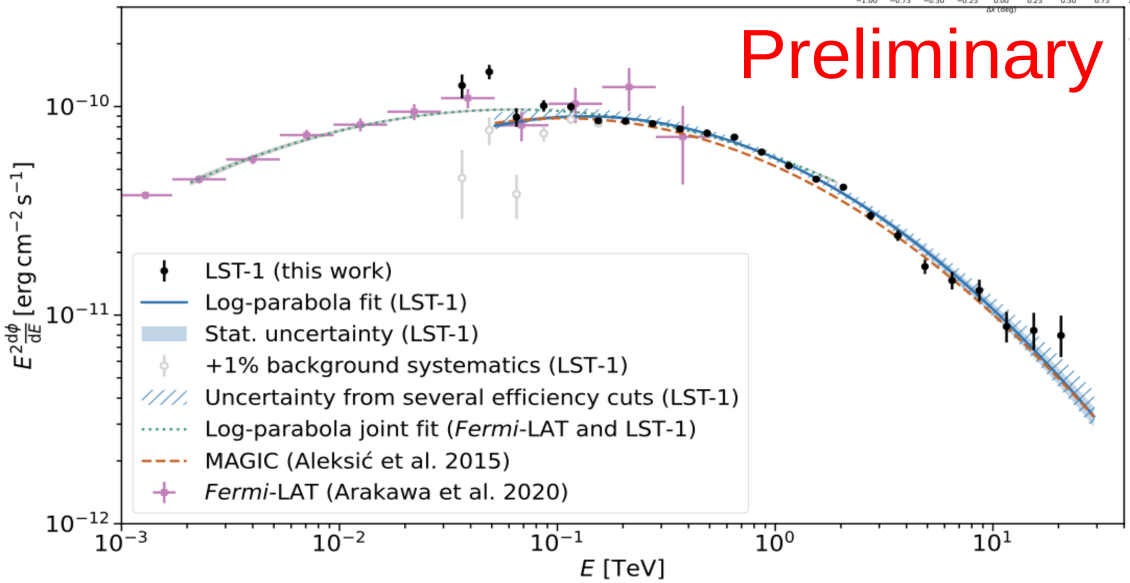


Crab Nebula and Pulsar



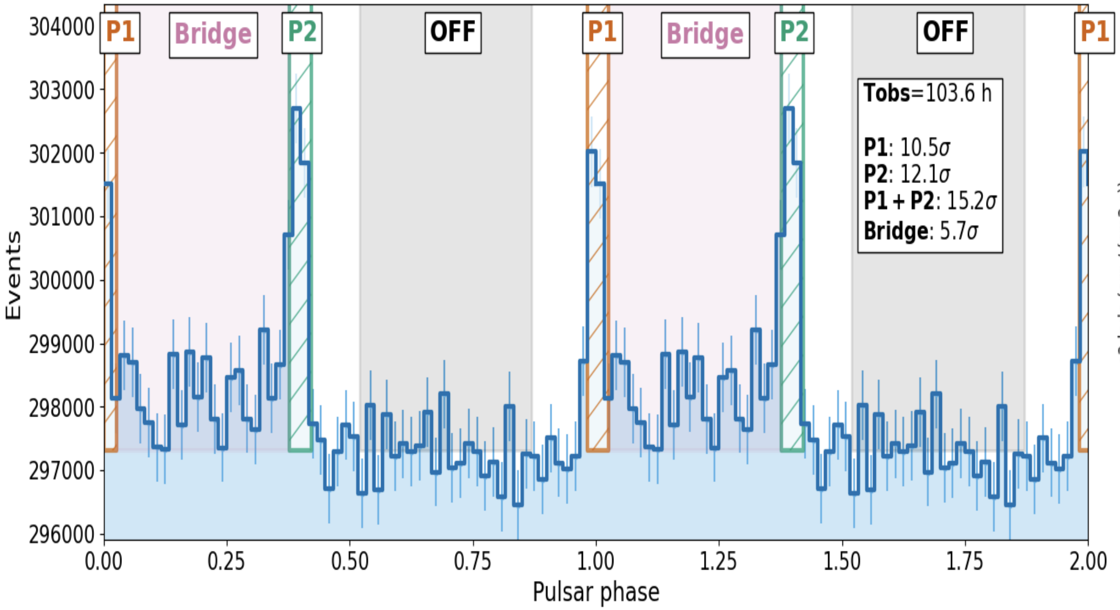
Crab Nebula spectrum

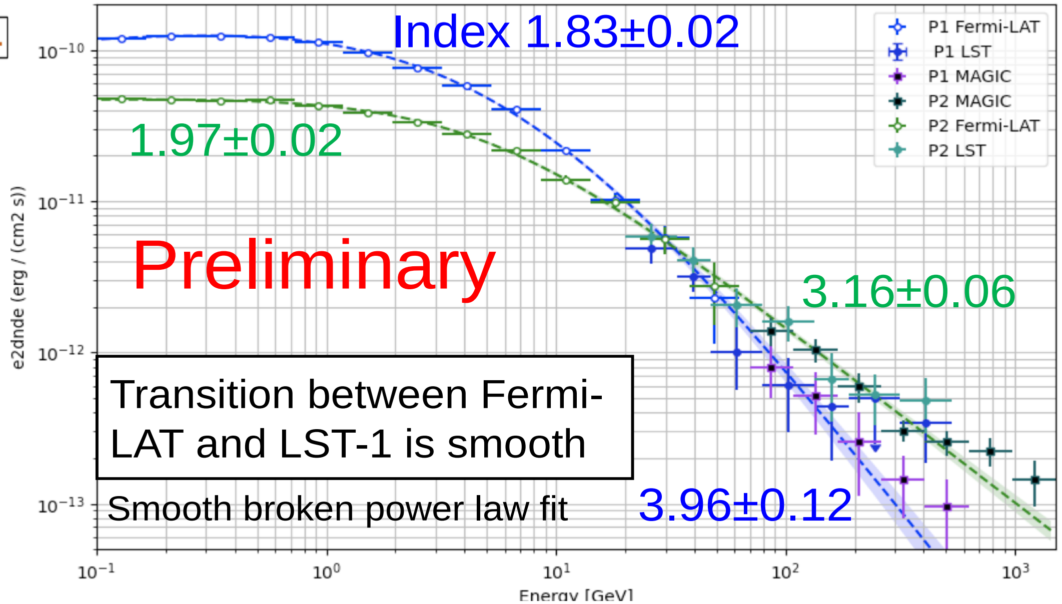
- 34.2 hours of data
- Systematic errors: gray points correspond to the effect of +1% background
- Consistent with MAGIC and Fermi-LAT



Crab pulsar

- Significant detection down to few tens of GeV

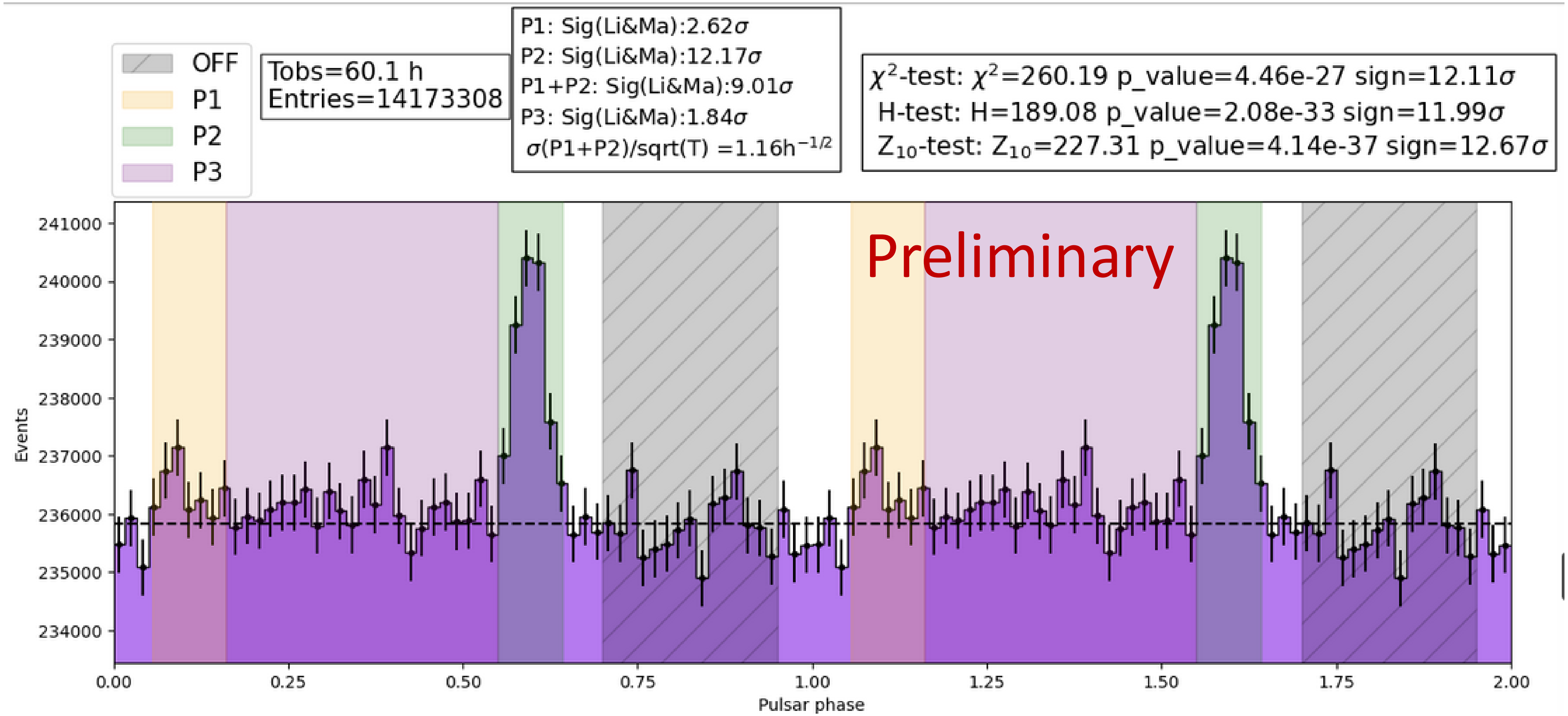




Phase diagram from Geminga Pulsar with LST-1

12 sigma signal is observed with 60hrs observation
The energy threshold is estimated to be 15-20GeV

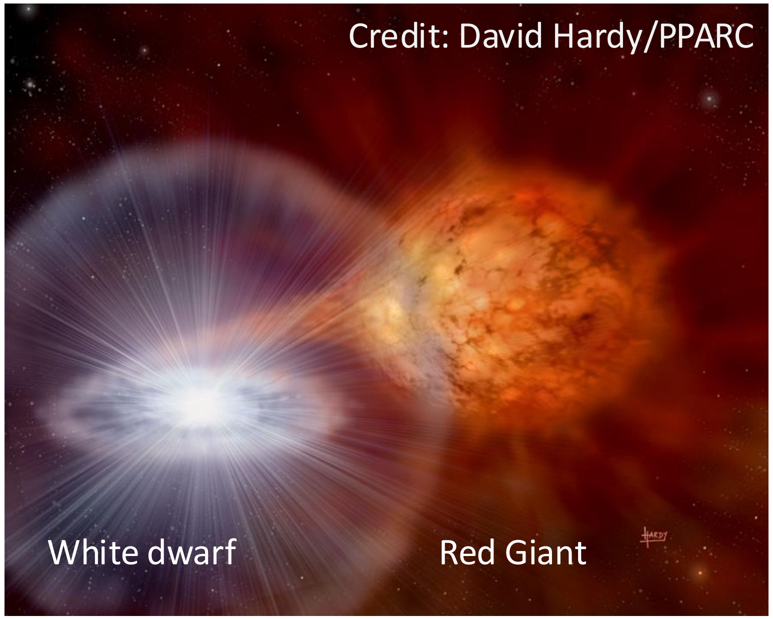
The results are almost ready for publication.

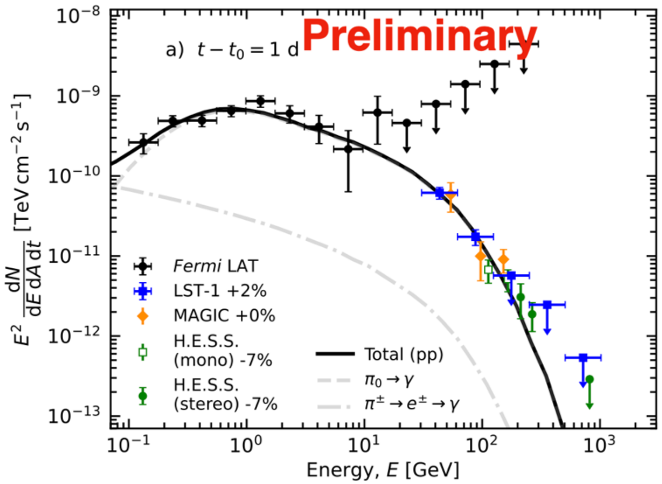


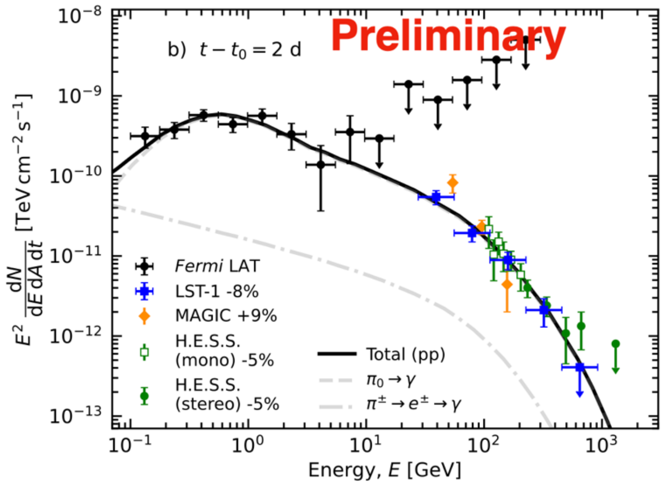
RS Ophiuchi Outburst in August 2021: Evolution of the Energy Spectrum

- RS Ophiuchi is a recurrent Nova.
  - Explosions, 1898, 1933, 1958, 1985, 2006, 2021
  - Mag 12.5 (low state) ➔ Mag 4.7 (~1000 times)
  - Binary System with a White Dwarf and a Red Giant
  - Accumulation of material on the WD and then thermonuclear reaction make recurrent explosions

- The Hadronic model is preferred.
- Cutoff energy increased with time.

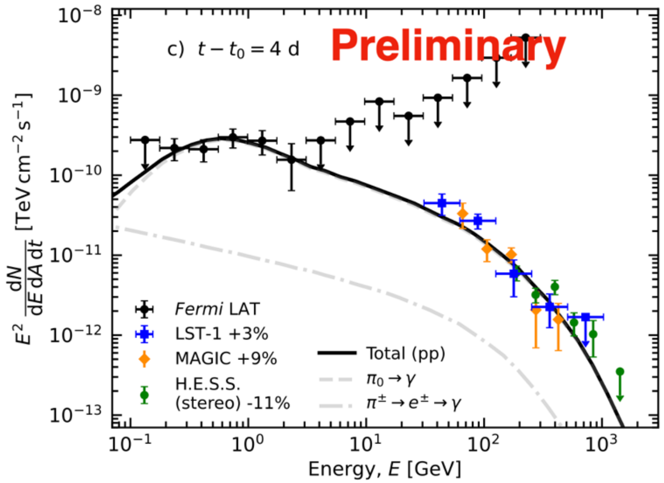






Preliminary

Parameter	Best-fit value on observation day		
	Day 1	Day 2	Day 4
Hadronic ECPL model with systematics			
Slope, Γ_p	$-2.16^{+0.19}_{-0.18}$	$-2.49^{+0.05}_{-0.04}$	$-2.42^{+0.16}_{-0.16}$
$E_{c,p}$ [TeV]	$0.21^{+0.12}_{-0.11}$	$0.9^{+0.2}_{-0.2}$	$1.1^{+0.7}_{-0.7}$
LST-1 syst. [%]	2^{+5}_{-5}	-8^{+8}_{-7}	3^{+6}_{-5}
MAGIC syst. [%]	0^{+7}_{-6}	9^{+6}_{-7}	9^{+6}_{-6}
H.E.S.S. syst. [%]	-7^{+9}_{-7}	-5^{+6}_{-5}	-11^{+4}_{-4}
$\chi^2/N_{d.o.f}$	17.8/12	20.0/19	20.0/13
χ^2_{red}	1.48	1.05	1.54
AIC	29.8	32.0	32.0



The next (expected) Explosive result:

Thermonuclear explosion in T Corona Borealis

T Coronae Borealis (T CrB), is recurrent symbiotic nova.

Erupted in 1866 and 1946 (**80years**), and predicted (AAVSO) to explode in the year 2024 (because of pre-eruption dip in optical LC)

T CrB is 3 times closer to the Earth than RS Oph (0.9kpc vs 2.7kpc)

→ 9 times brighter !

→ once in a lifetime opportunity !

→ Large expectation and commitment to observe from many groups

T CrB also caught attention of Neil deGrasse Tyson

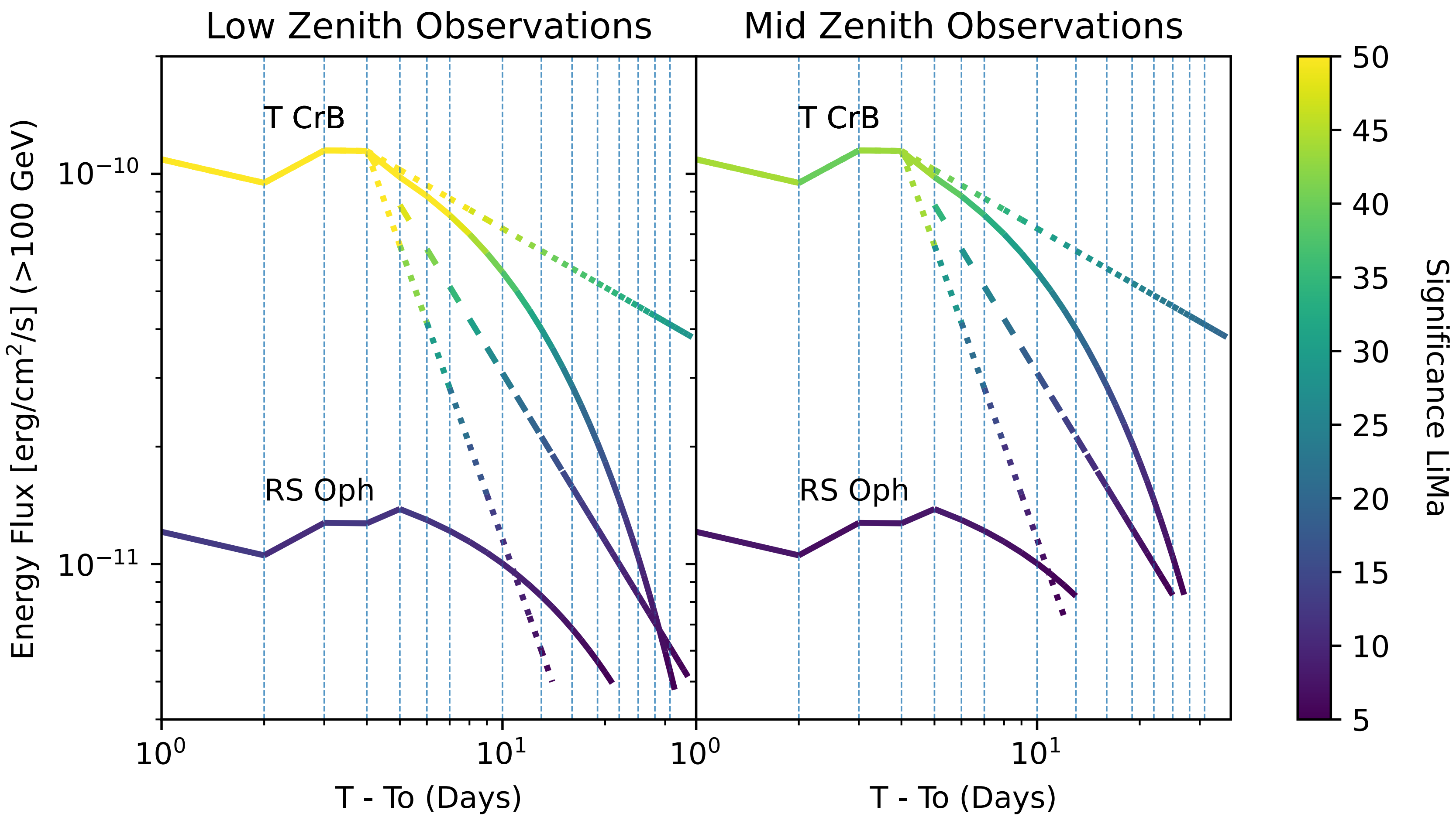
→ youtube video with more than 3M visits in 4 weeks

https://www.youtube.com/watch?v=5i6aEA-RkOQ&list=PLnaXrumrax3Wyn1oMYWYlpcwrc76Nm40Q

Estimated LC for T CrB with LST1-MAGIC

- Scaled RS Oph flux by a factor of 9
- Different estimates assumed for the flux of T CrB after 4^{th} day
- 5-hour observing window used to compute the significance

Result (and observing campaign with LST1-MAGIC) organized by David Green



It can be significantly (>5 sigma) detected 1 month after optical trigger

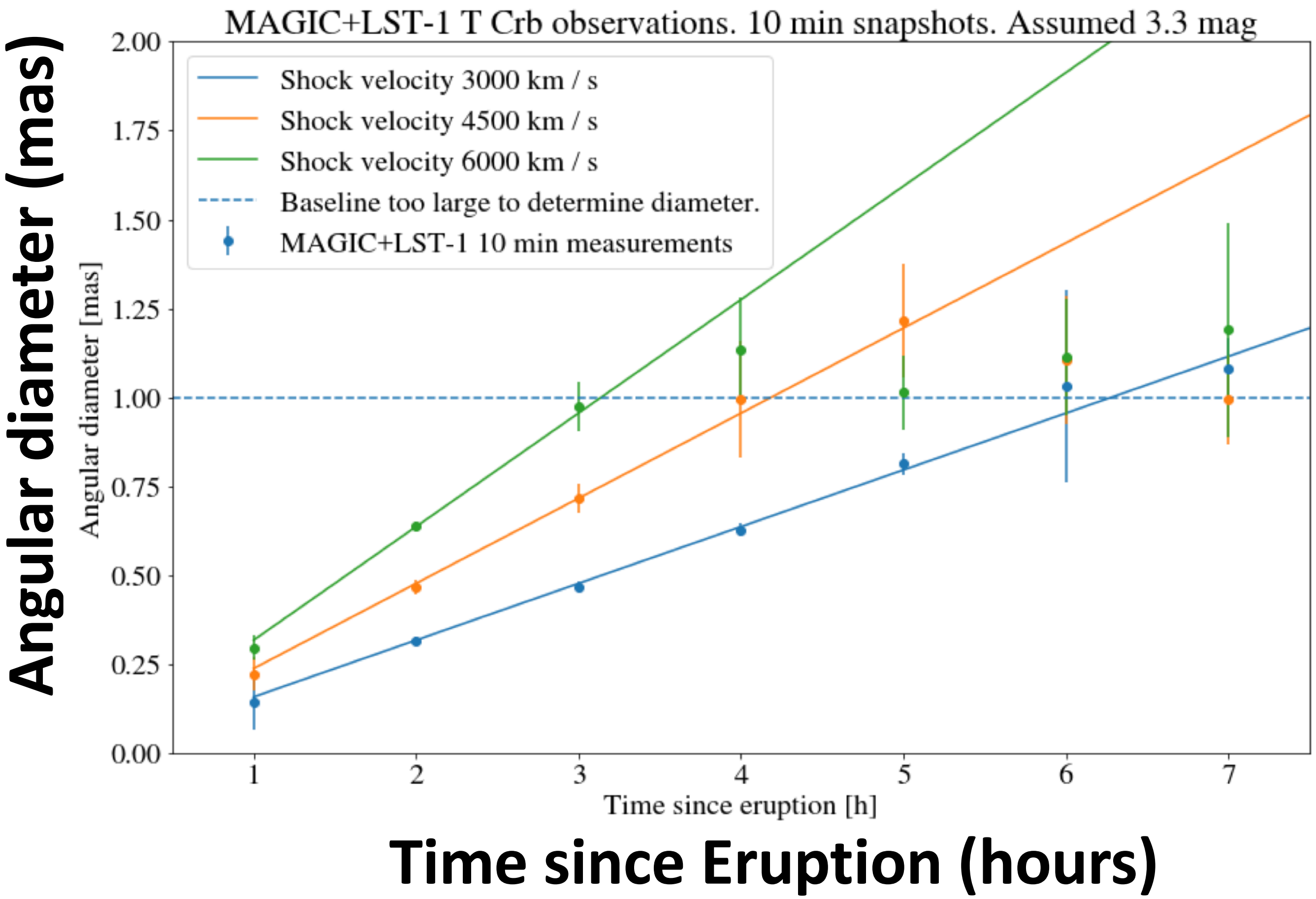
The size of the photosphere with LST1+MAGIC

Intensity Interferometry observations with LST1+MAGIC may measure the size of the expanding photosphere after the explosion

→ Important physical parameter for understating the seed photon density, and compute contribution of leptons to non-thermal emission

→ **MAGIC-II can be performed any time** (no hardware intervention required)

→ **Need >4 mag** (*T Crb is expected to reach V-Band ~2.5*)



- 10 min observation
- 3.3 mag assumed for optical peak

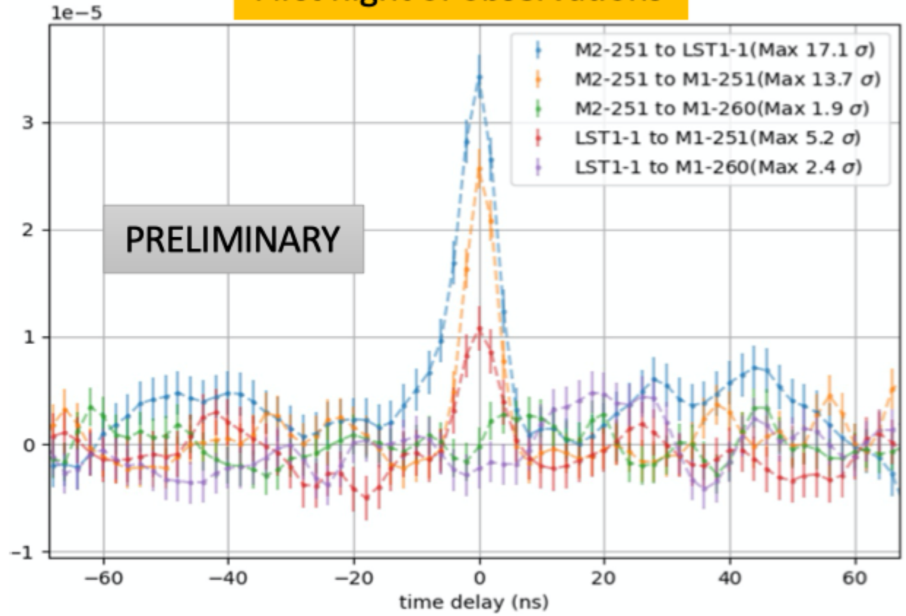
Cortina et al., CTAO symposium 2024

From Juan Cortina, CTAO Symposium, April 2024

First MAGIC+LST1 observations

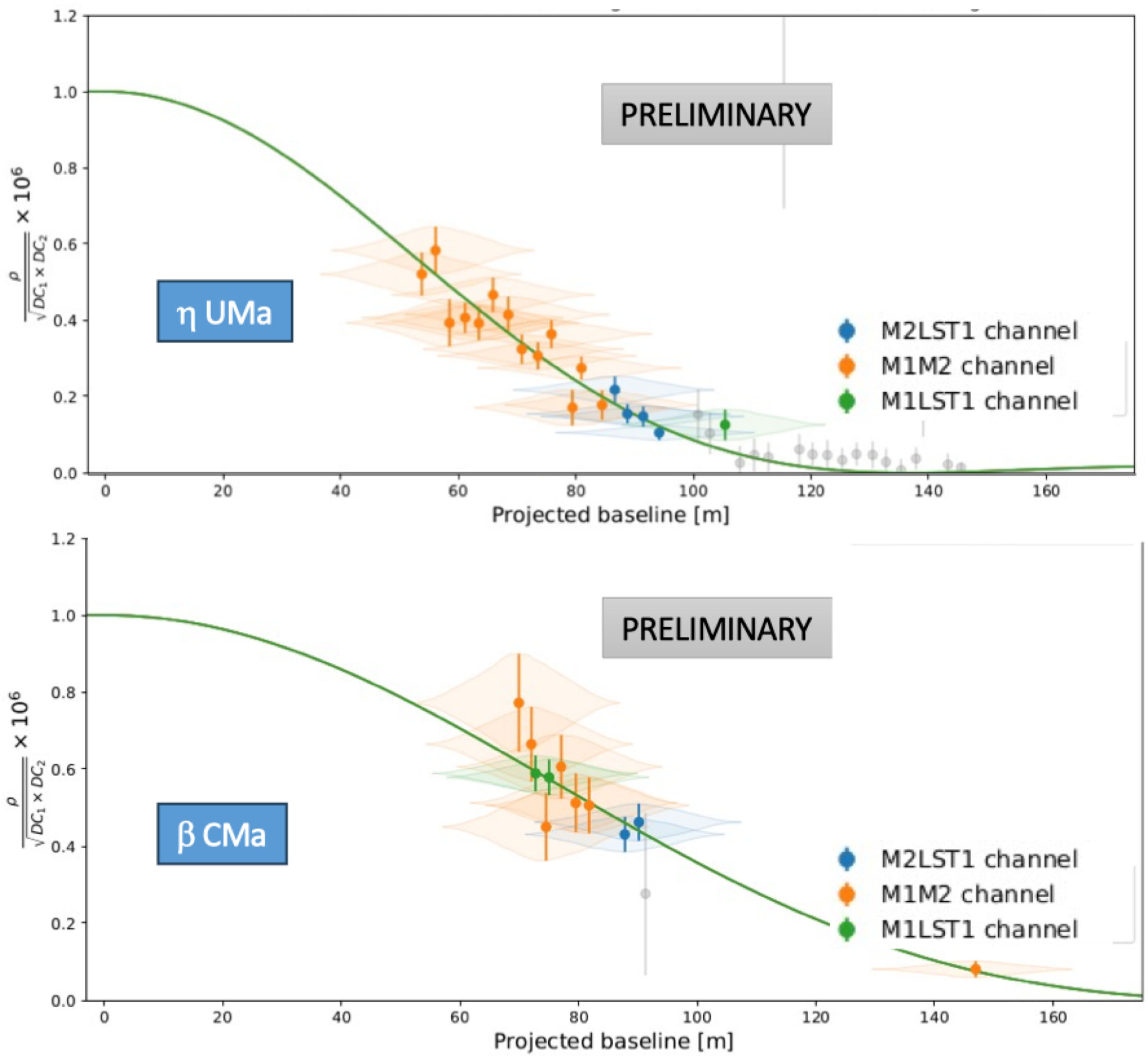
- So far only 25 hours of common MAGIC+LST1 observations:
  - Calibration stars already detected with MAGIC (Mirzam, Adhara, kap Ori…)
  - Weaker and smaller stars, now within reach of MAGIC+LST1: θ<0.4 mas
  - Fast rotators, especially with small diameter.
- Detections are very clear. Sensitivity roughly matching expectations.

First night of observations



From Juan Cortina, CTAO Symposium, April 2024

Broader coverage in the baseline, and higher statistics (smaller errors)

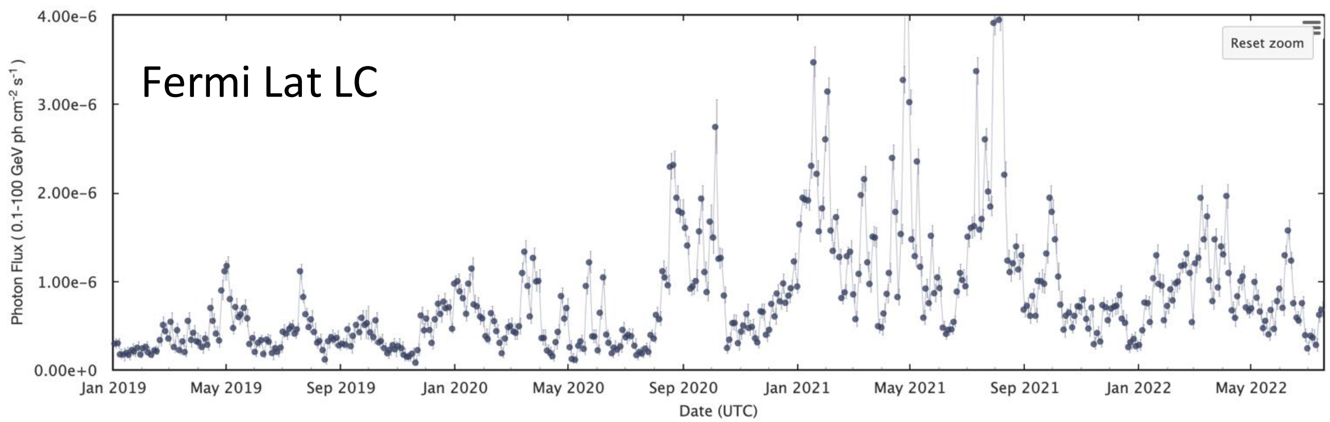


LST COLLABORATION

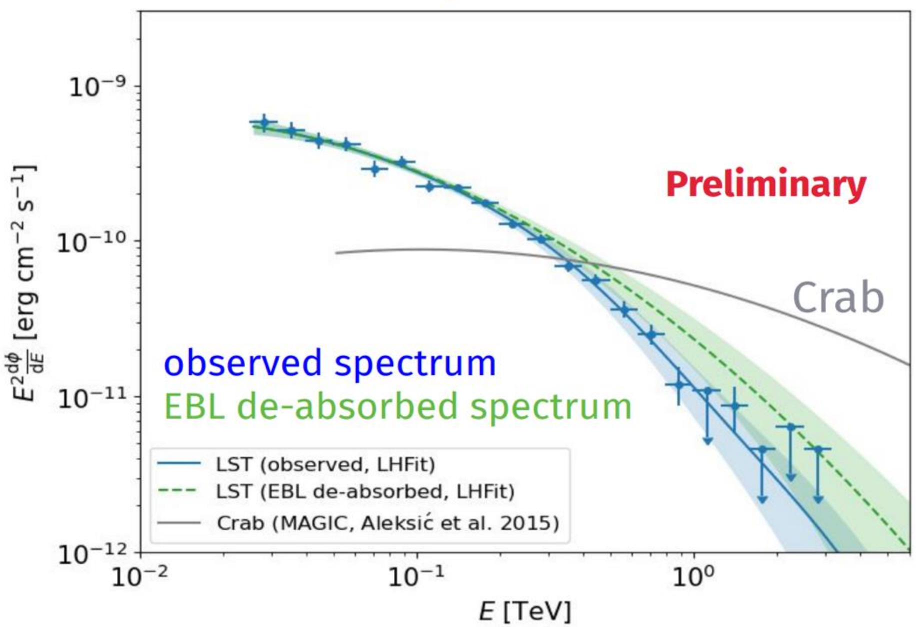
BL Lac Flare 2021

- BL Lac Flare 2021
- BL Lac: IBL, z= 0.069

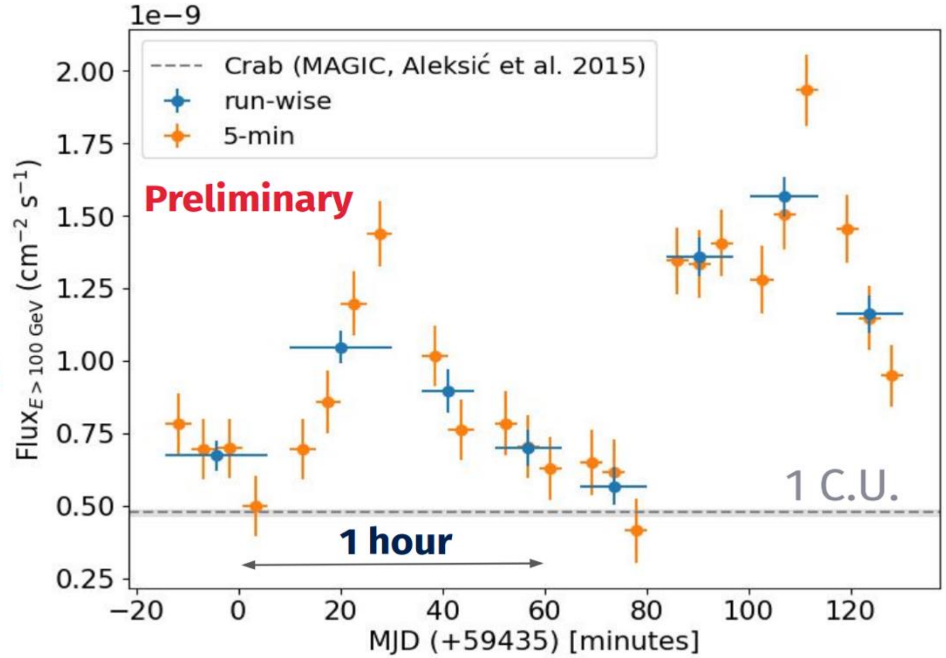
- Spectrum observed > 25GeV
- August 9, about 3-5 Crab Unit at 30-100 GeV
- Very fast variability (<5min)



Aug 9, 2021

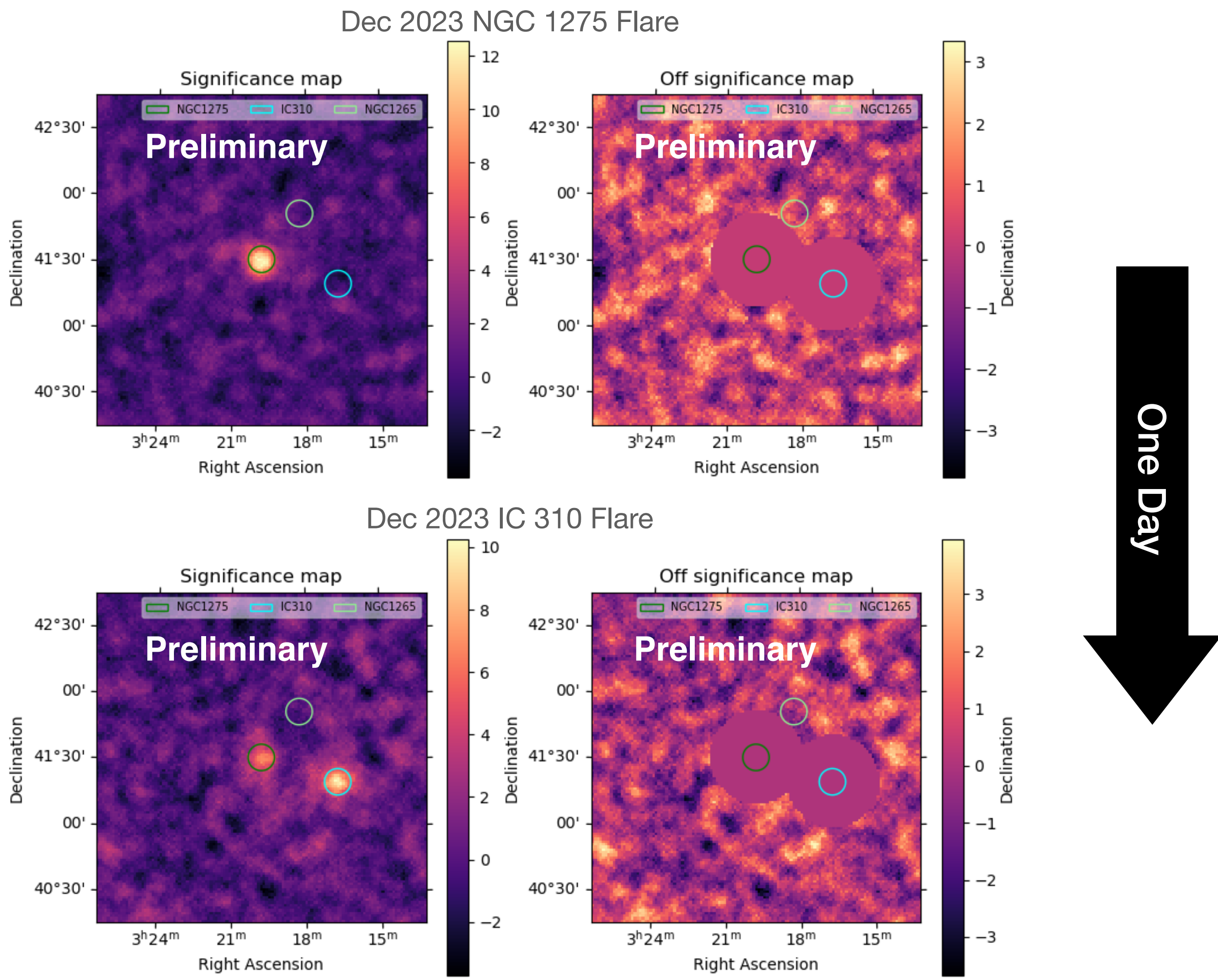


Intranight LC on 9 August, 5 min fast variability



Perseus Cluster
NGC1275 and IC310

- Cluster of radio galaxies in Perseus; ideal targets for LST: NGC 1275 and IC 310
- Timeline of Observations
  - NGC 1275 detected in Dec 2020, and then quiet afterwards
  - NGC 1275 began flaring again in December 2022 - January 2023
  - Again in December 2023, NGC 1275 and IC 310 began flaring together
  - While observing cluster, detected a single night flare of IC 310



Discovery of OP313 (z = 0.997) with LST-1

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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)

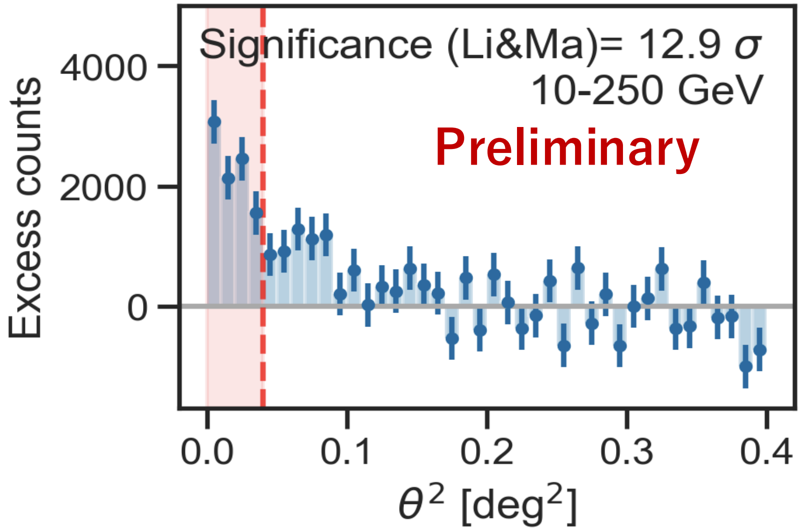
Subjects: Gamma Ray, >GeV, TeV, VHE, Request for Observations, AGN, Blazar, Quasar

MAGIC, LST-1, and MAGIC+LST1 are analyzed.
We are preparing the publication.

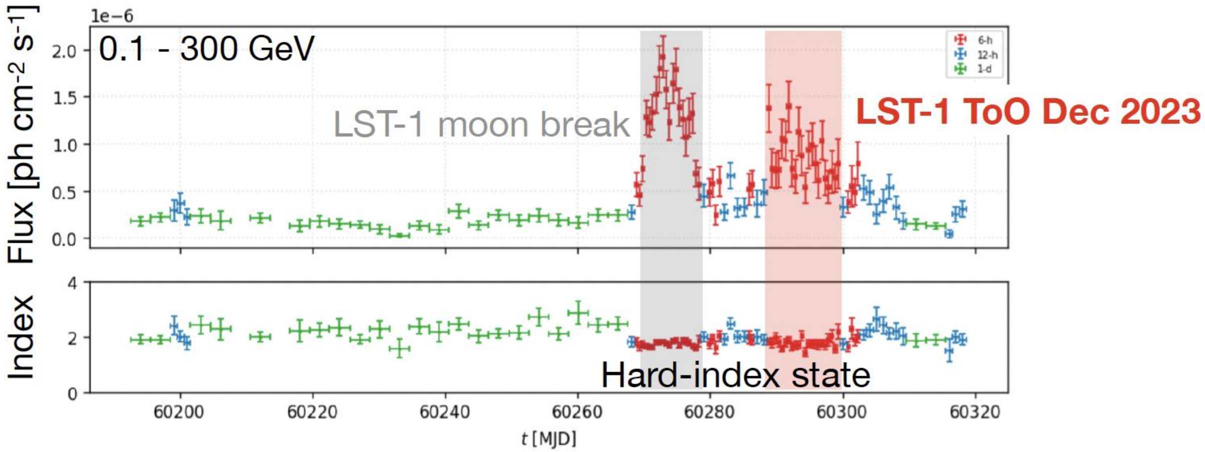
Stacking all December data 2023 data (14.6hrs)

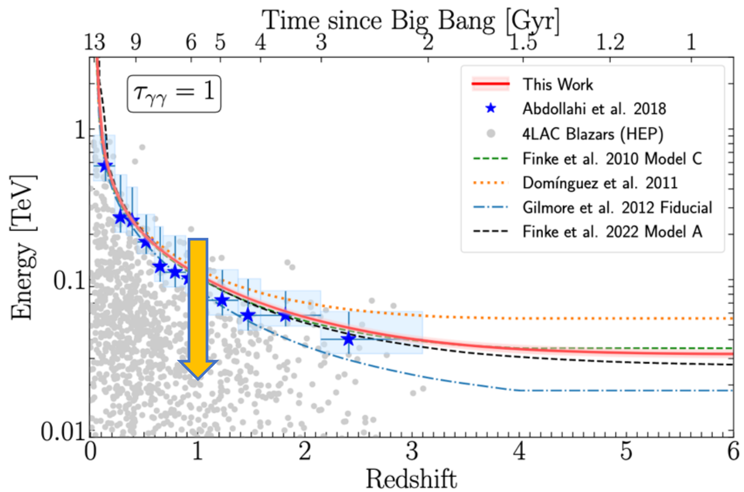
13 sigma excess below 250GeV, No detection above 250GeV

Publication with detailed analysis is expected soon.



Fermi Light Curve of OP313





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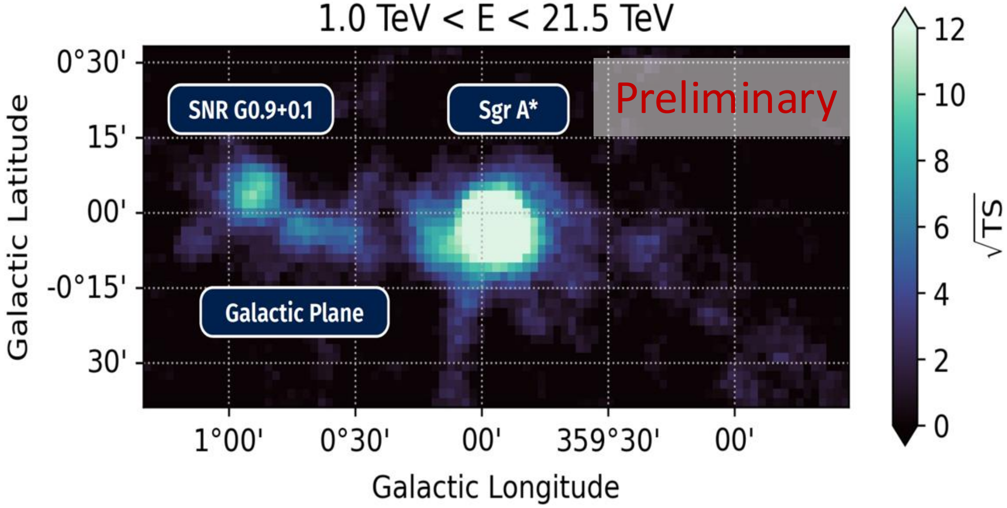
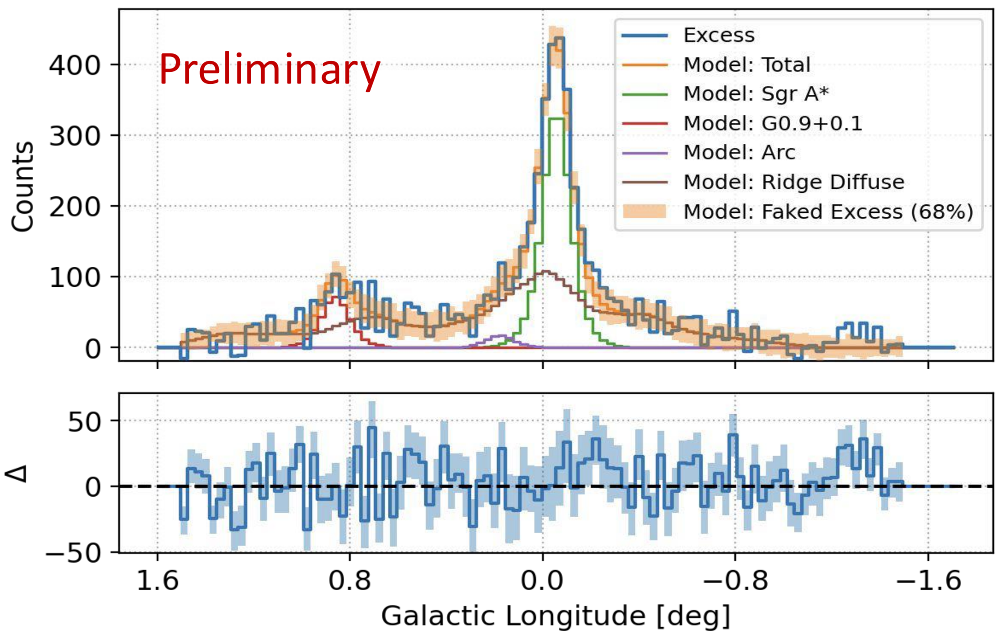
Galactic Center region

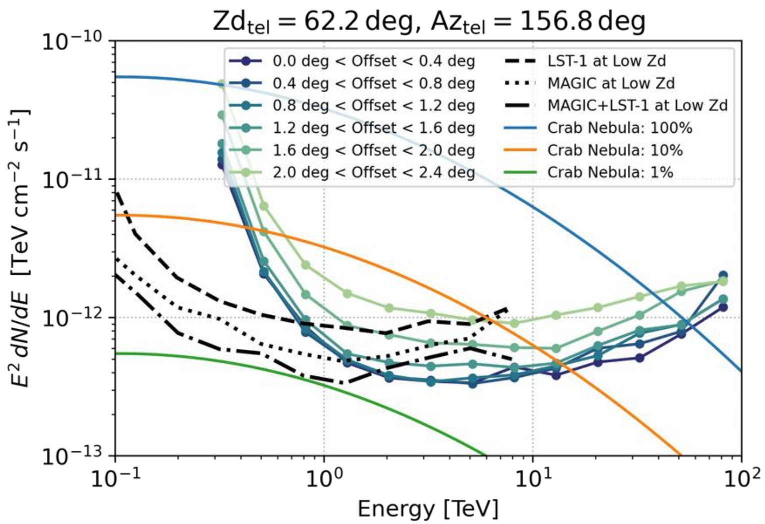


The galactic center is observed for 39hrs with the Large Zenith Angle Technique (ZD 58-68 deg).

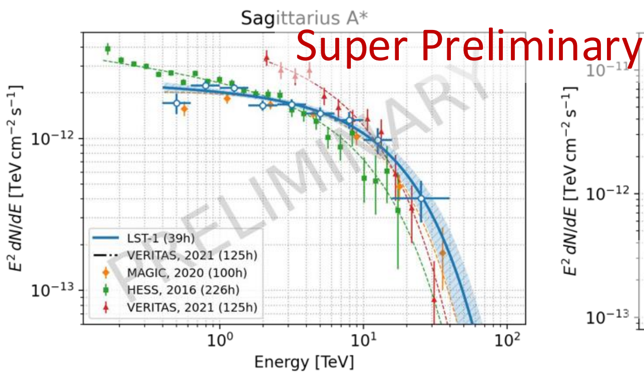
Pros: Getting several times larger collection area

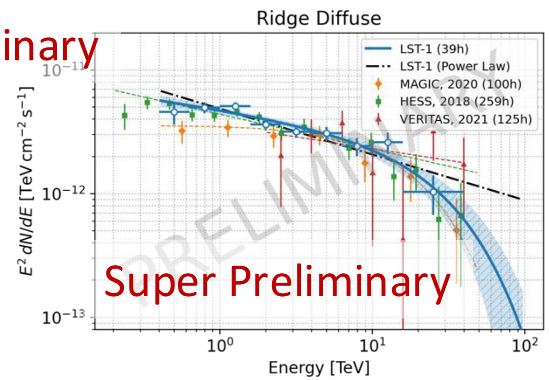
Cons: Higher Threshold Energy (> 300GeV)





Some trials to derive spectra from individuals





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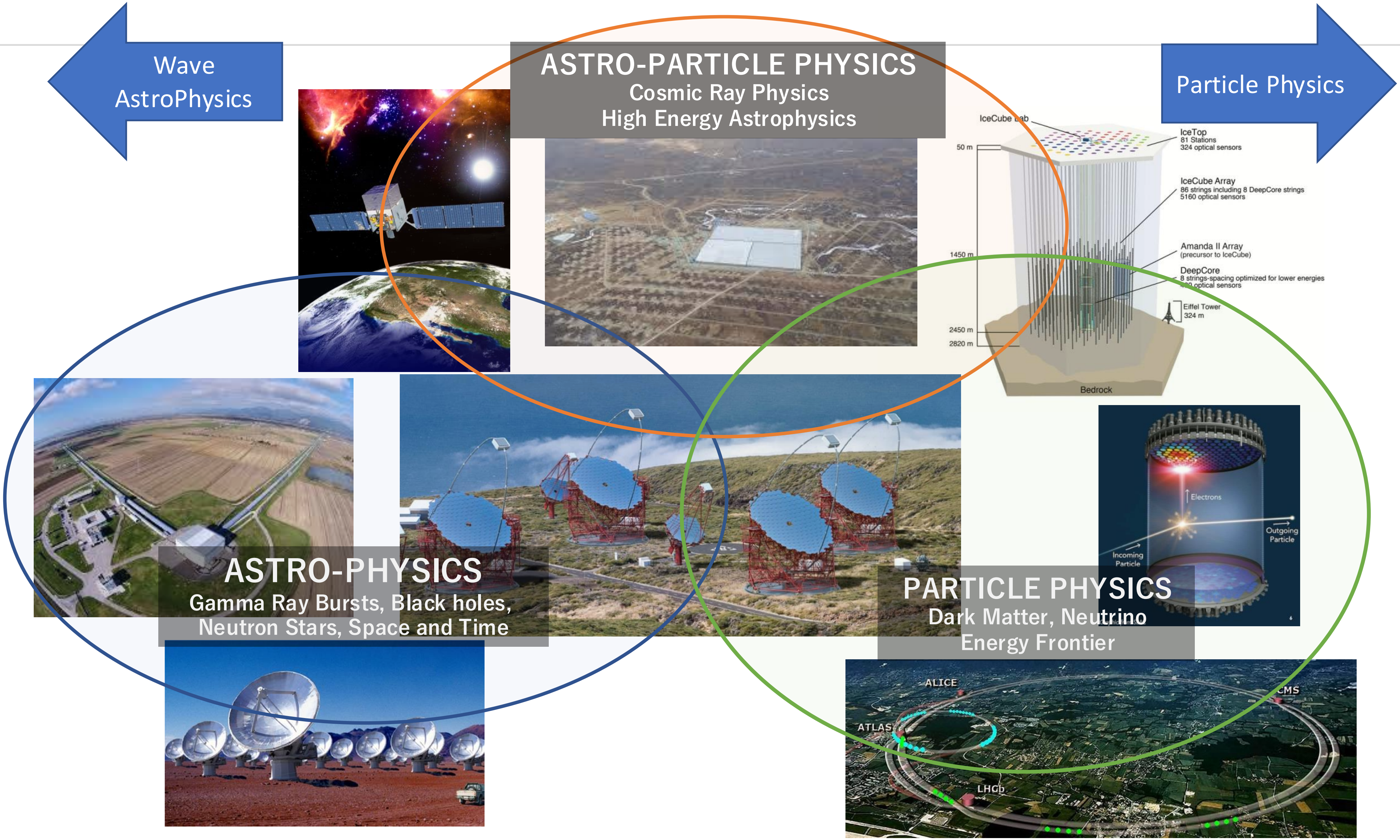
Multi-messenger and Multi-wavelength Astrophysics



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Summary

- The first Large-Sized Telescope LST1 fulfills the requirement and the design performance, including a fast follow-up capability of 20 sec.

- LST2, LST3, and LST4 will be completed by the end of 2025, and then commissioning with four LSTs will start.

- The LST Array will achieve one order of magnitude higher sensitivity than currently running telescopes below 100 GeV and several times around 1TeV.

- The LST Array contributes to the multi-messenger and time-domain astronomy.

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Stay Tuned!