The Large-Sized Telescope of CTA

Status, first science results and future prospects

Alice Donini (INAF-OAR) on behalf of the CTA-LST project

RICAP-22, 6–9 Sep 2022

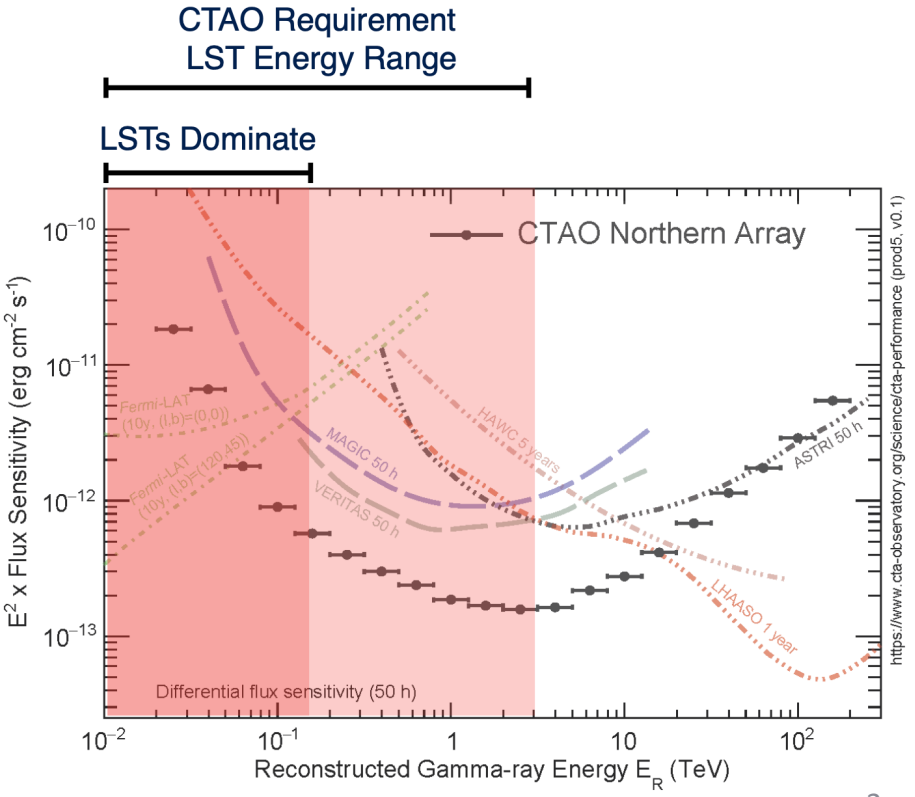
The LST collaboration

https://indico.cta-observatory.org/event/4040/

~250 scientists from different countries

Cherenkov Telescope Array Observatory

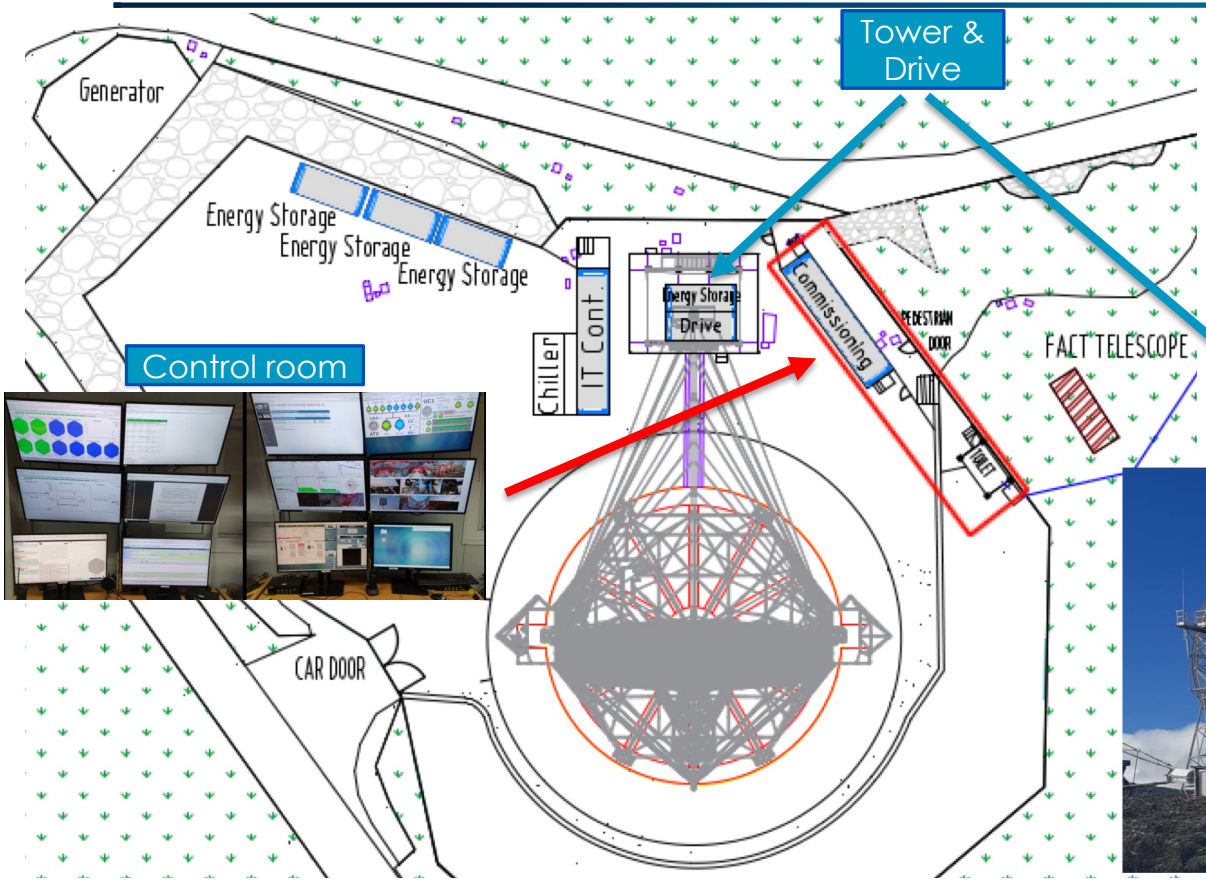
- CTA will consist of 2 sites:
  - La Palma, Spain and Paranal, Chile.
- And 3 telescope types:
  - SST: Small-Sized Telescope
  - MST: Medium-Sized Telescope
  - LST: Large-Sized Telescope
- The LSTs are designed to dominate CTAO sensitivity at the lowest energies (<150GeV).
  - Ideal for fast transients and soft sources.
  - No LSTs included at the South site in the Alpha configuration.



LST-1 design

- Parabolic mirror: 400 m^2 and ⦸23m.
- Camera: 1855 PMTs, FoV ~ 4.3°.
- Energy range > 20 GeV.
- Good overlap with satellites but with the collection areas >10^4 times larger.
- Carbon fiber / steel structure:
  - Total moving weight: ~120 tons.
  - Repositioning speed: 10 deg/s.
- Rapid slewing to transients: < 20s.

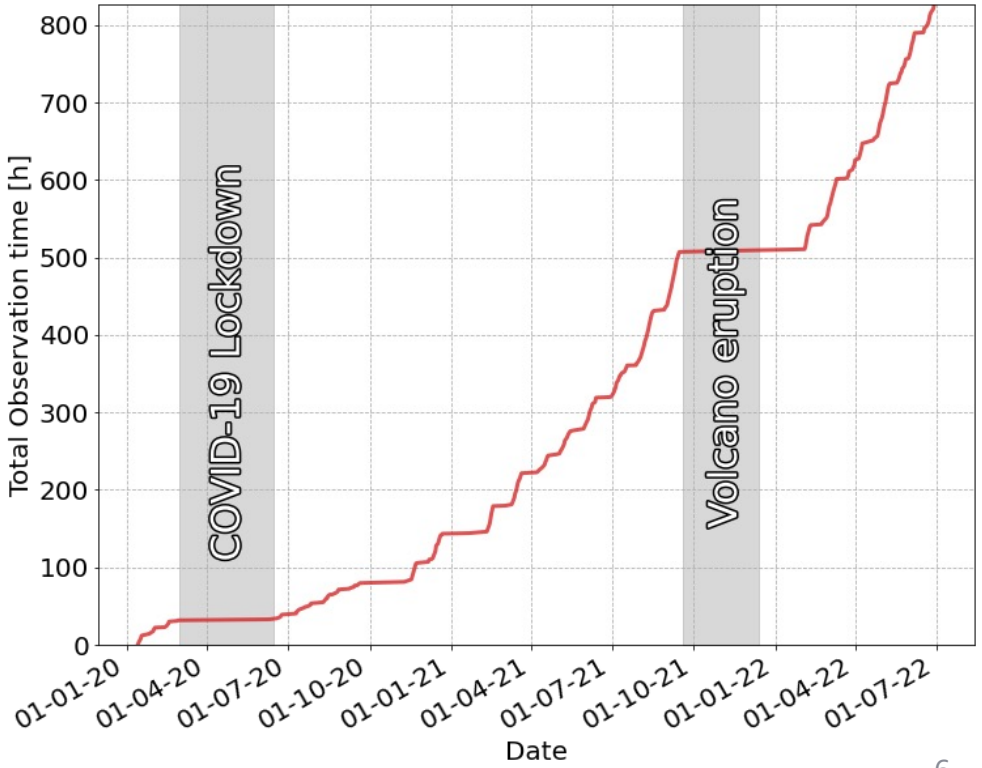
LST-1 site



- Profit from available infrastructure at Roque de los Muchachos Observatory (ORM).
- Added:
  - Power line
  - Diesel generator
  - Onsite IT center
  - Commissioning container

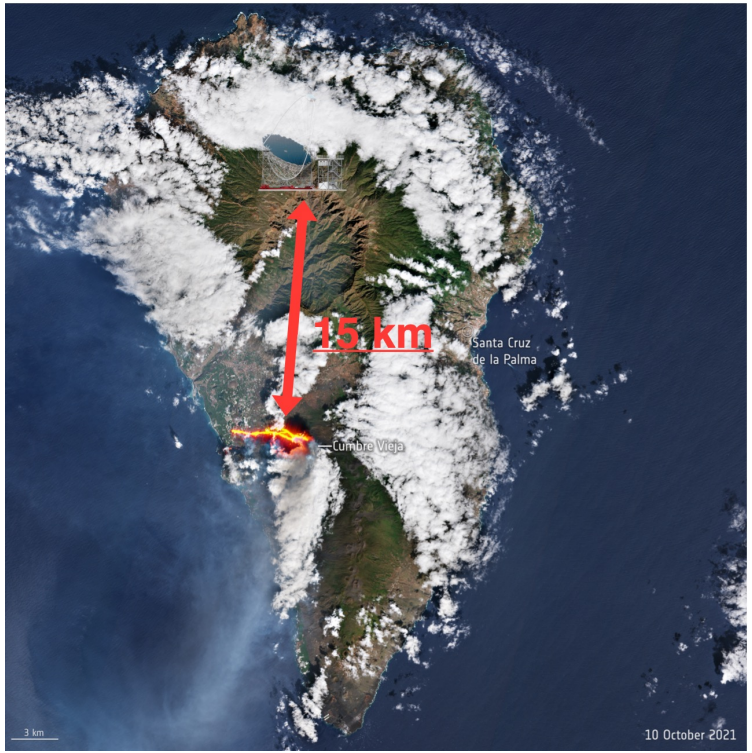
LST-1 status

- LST-1 inaugurated at the CTA-North site (La Palma, Spain) at the end of 2018.
- Taking scientific data since January 2020: > 820 hours.
- Commissioning through pandemic, volcanic eruption, electronic components and shipment crises...



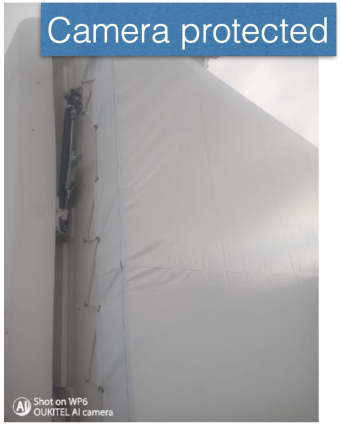
Volcano

- Volcano eruption on Cumbre Vieja from September 2021 up to January 2022.
  - Severe travel restrictions due to frequent airport closures.
  - Massive damage (houses, plantations, tourism, ...).
- Telescope operations stopped, sensitive areas covered, frequent maintenance action on site, clean up of ash.
- Performance did not change over the volcano period.
- No strong effect on any of the systems.



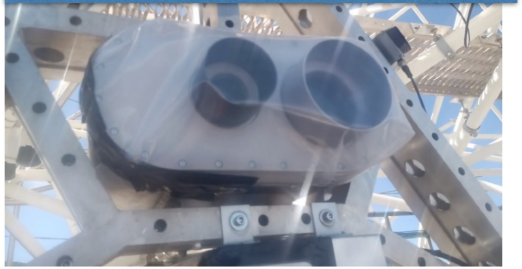
Volcano

Camera protected



Rail protected

devices in dish center protected



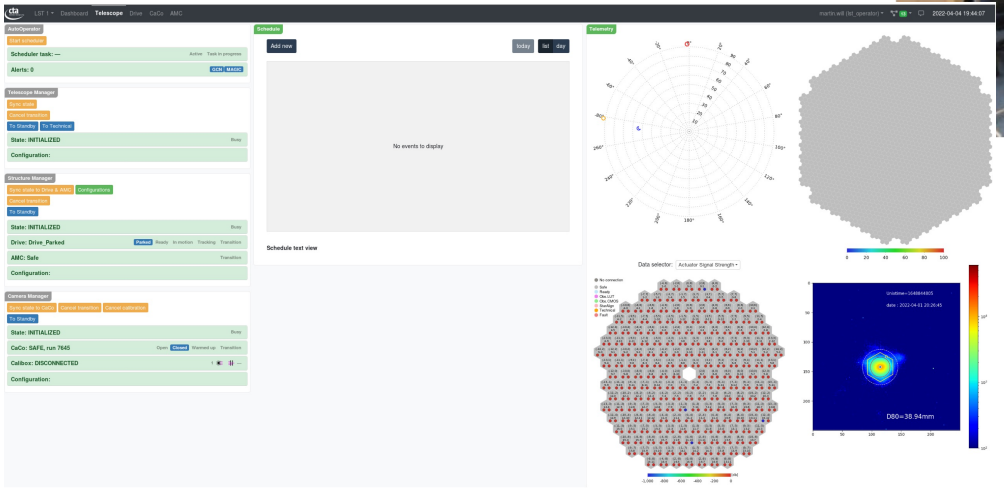
A/C and IT working

A lot of ash

Regular Cleaning by CaSana

COVID Impact

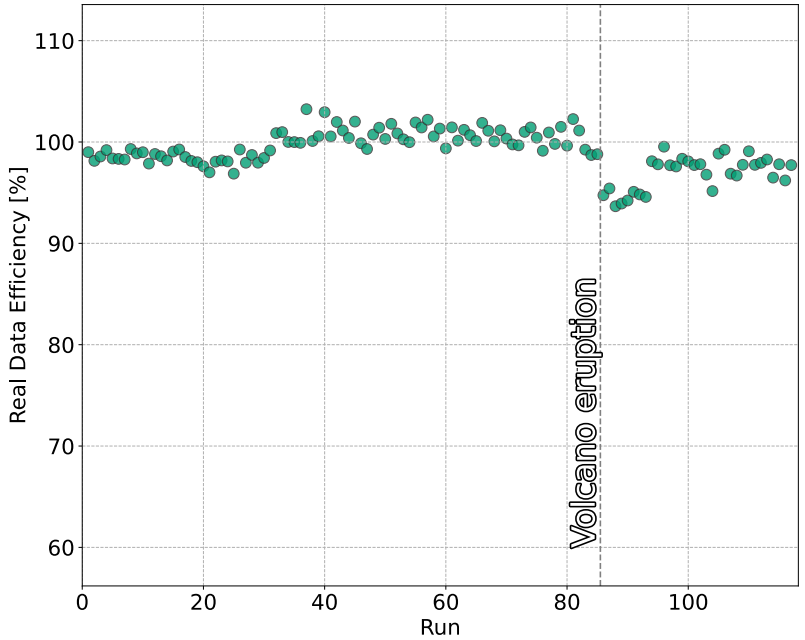
- Improvement of remote control and automatic systems.
  - Locking systems (azimuth, elevation, camera).
  - Park-out, park-in procedures.
- Implementation of semi-remote operations.



- Increment in the software development.
  - ➢ Browser-based telescope control.

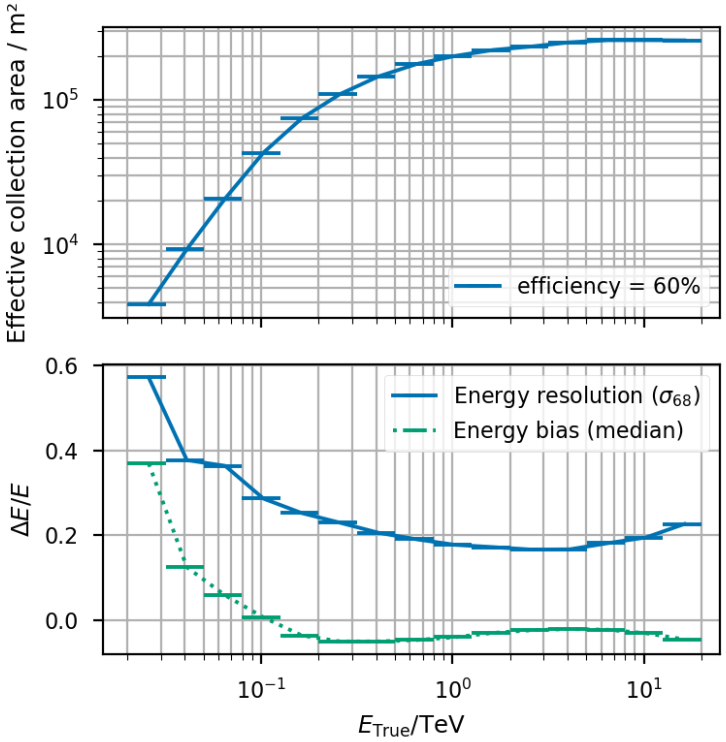
LST-1 performance: optical efficiency

- "Optical efficiency" includes both mirror reflectivity and mirror focusing.
- Stable from November 2020 to March 2022.
  - Maximum spread of 8%.
  - Mostly due to measurement uncertainty and episodes of dust deposition.
- No long-term effect of volcano.
  - Mirrors were cleaned of volcanic ash from the rain.

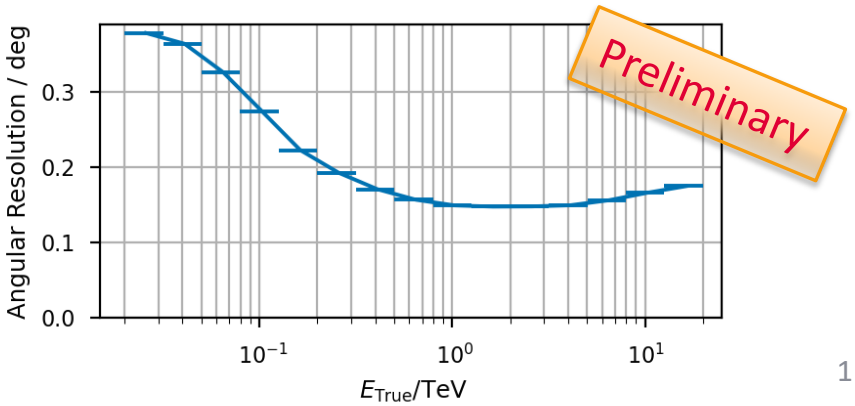


Performance paper out soon!

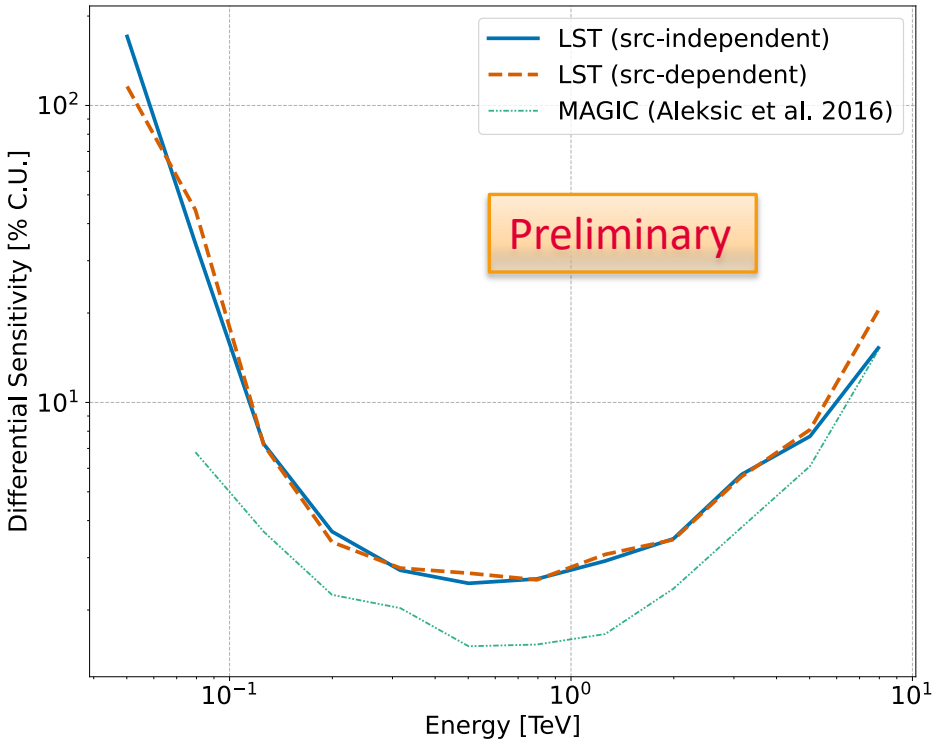
LST-1 performance: effective area, angular and spectral resolution



- Zenith angle = 10 deg, γ-ray efficiency = 60% (due to gammaness cut).
- Effective area >10^3 m^2 down to ~20 GeV.
- LST-1 is a single telescope, so one cannot expect a great angular or spectral resolution. Still they are competitive down to 100 GeV.



LST-1 performance: sensitivity



- Consistent sensitivity for source-dependent and source-independent analyses.
- Roughly 1.5x less sensitivity than MAGIC stereo array.
  - Single telescope system has higher backgrounds.
- Extending down to ~50 GeV.

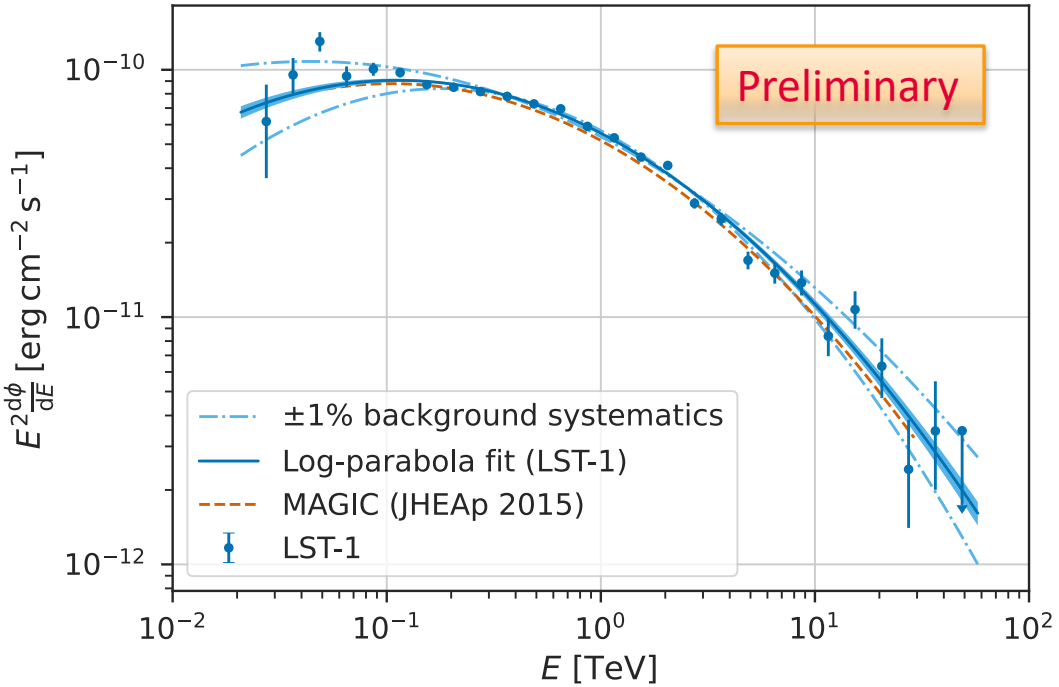
Science with LST-1

- Performance paper to be published soon.
- ~800 hours of data taken since 2020 on many sources:
  - RS Ophiuchi
  - LHAASO J2108+515
  - AGNs: BL Lac (including a strong flare in 2021!), Mrk 421 and 501, 1ES 1959+650, PG 1553+113 and many others
  - Transients
- More papers to come with the data of the last years.
- A preview follows.

LST-1 is already producing science!

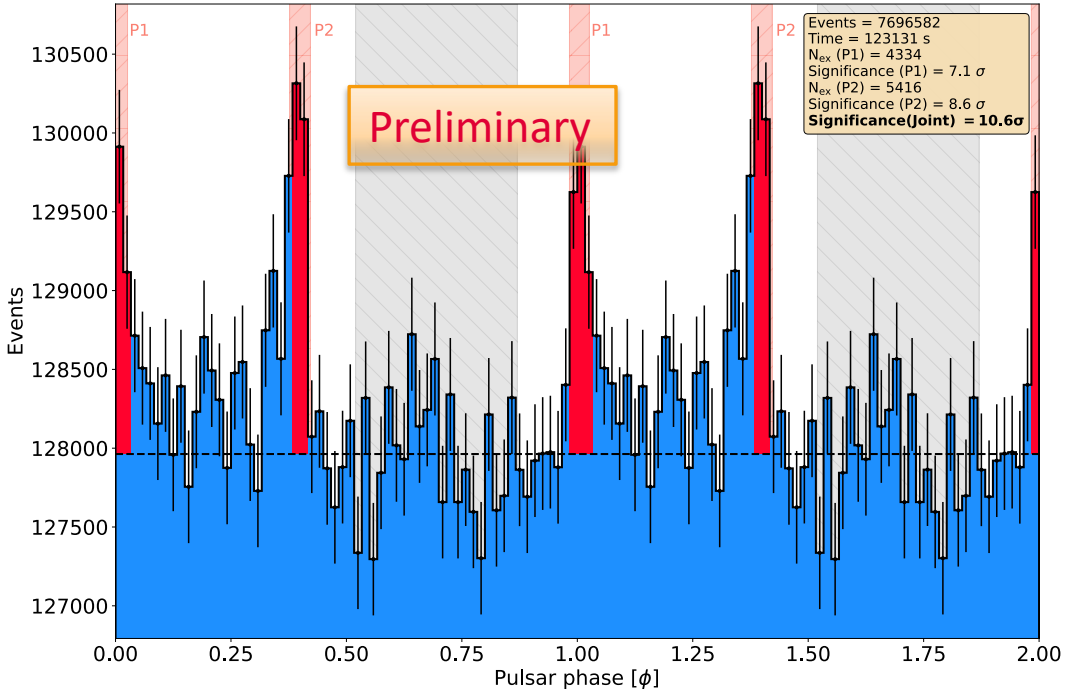
Crab Nebula spectrum

- Observation time: 34 h.
- Gamma-ray efficiency: 70% from gammaness cut and 70% from θ2 cut.
- Error bars are only statistical.
- Systematic errors: blue lines correspond to the effect of ±1% background.
- Consistent with MAGIC and Fermi-LAT.
- Lowest data point at 25 GeV!



Performance paper out soon!

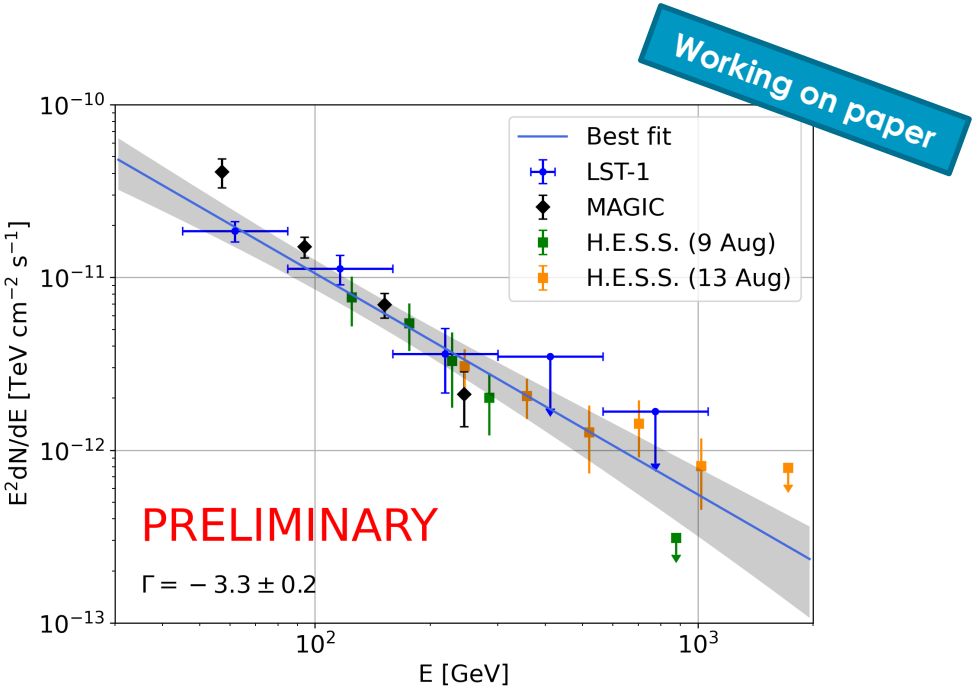
Crab pulsar (PSR J0534+220)



- A rotating neutron star with a period of 33ms.
- Period: Nov 2020 - March 2022.
- Data selection:
  - cut in rate;
  - no technical issues (more strict than previous analyses).
- Highly significant detection down to few tens of GeV.
- P1/P2 ratio tends to 1 at low energies.

Performance paper out soon!

First VHE-detected nova: RS Ophiuchi



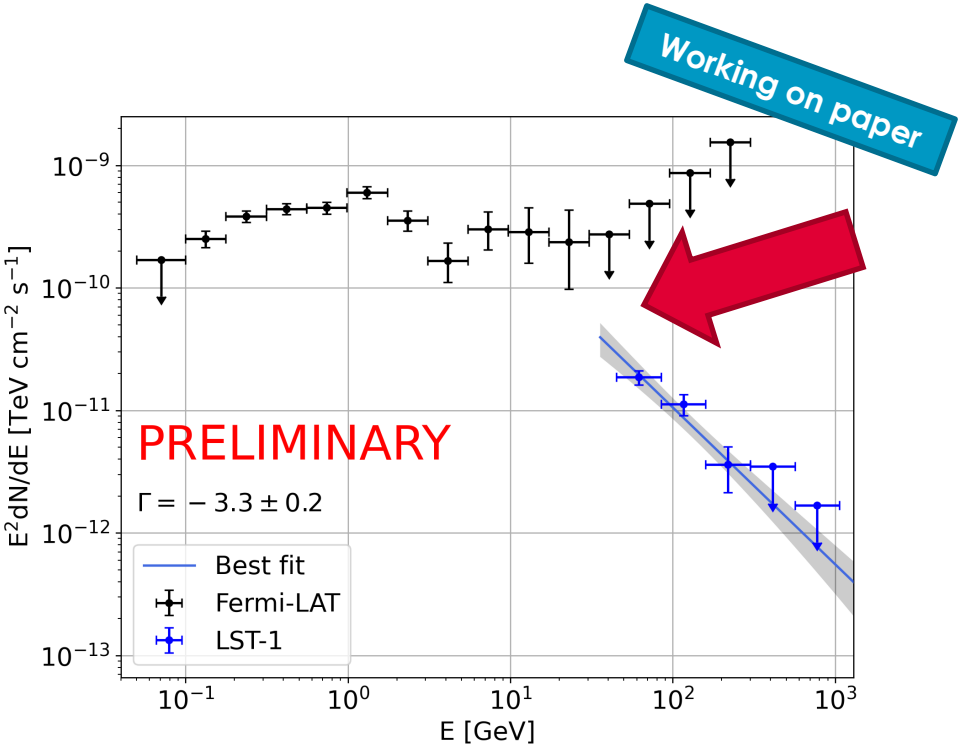
LST-1, MAGIC and H.E.S.S.
Spectral Energy Distribution (SED)

- Symbiotic binary of white dwarf and red giant.
- Recurrent nova, but first detection of a Novae at VHE in 2021.
- LST-1, 3-day average.
- MAGIC, 4-day joint data (from Acciari et al. 2022).
- H.E.S.S. August 9th +13th SEDs (from H.E.S.S. Collaboration 2022).

➢ Compatible SEDs.

See D. Green & A. Mitchell talks on Thursday

First VHE-detected nova: RS Ophiuchi



- LST-1 & Fermi-LAT 4-days average RS Ophiuchi SED.
- No gap between Fermi and LST-1.
- LST-1 data smoothly connect with Fermi-LAT data.

BL Lacertae

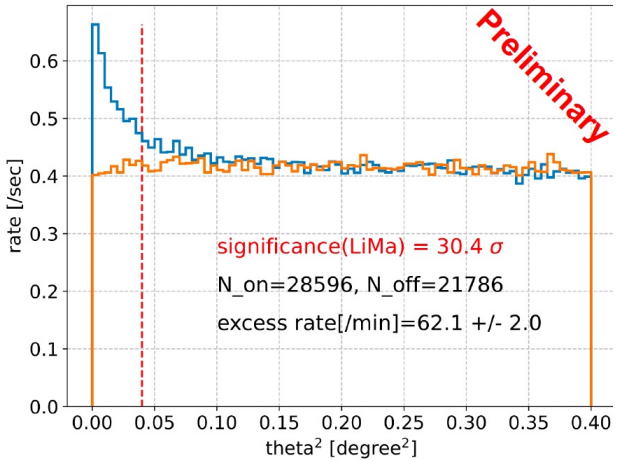
- BL Lac is an active galaxy associated with a strong radiosource.
- Flare in 2021: first ATEL submitted by CTA.
- Demonstrating LST's capabilities for quick analysis and validation of transient results.
- Soft spectrum allows to extract spectral point at 30 GeV in < 2 hour observation.

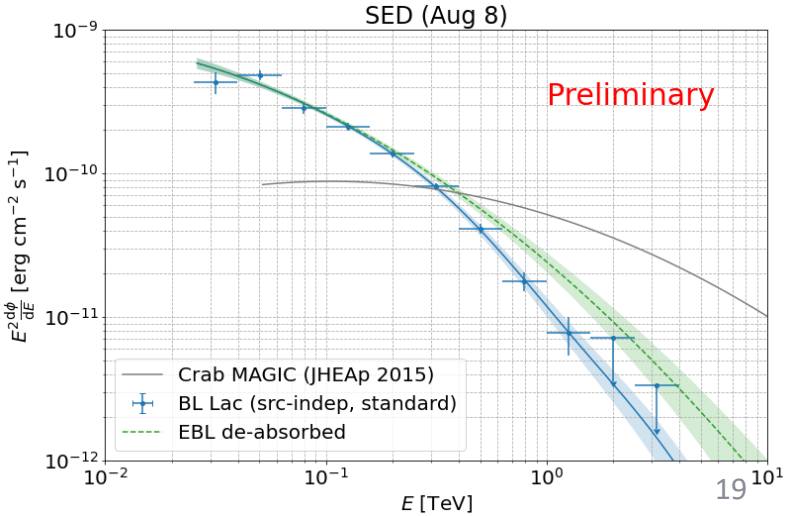
Detection of very-high-energy gamma-ray emission from BL Lac with the LST-1

ATel #14783; *Juan Cortina for the CTA LST collaboration*
on 13 Jul 2021; 21:03 UT
Credential Certification: Juan Cortina (Juan.Cortina@ciemat.es)

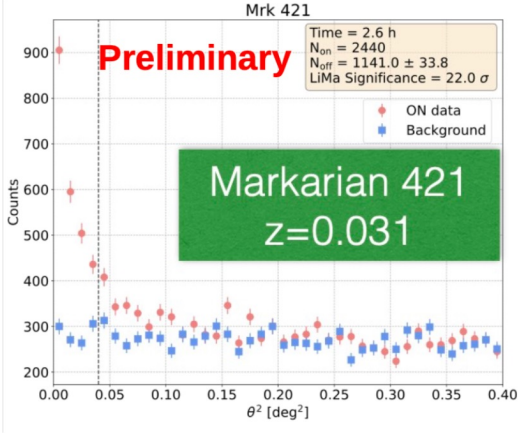
Subjects: TeV, VHE, Request for Observations, AGN, Blazar, Transient

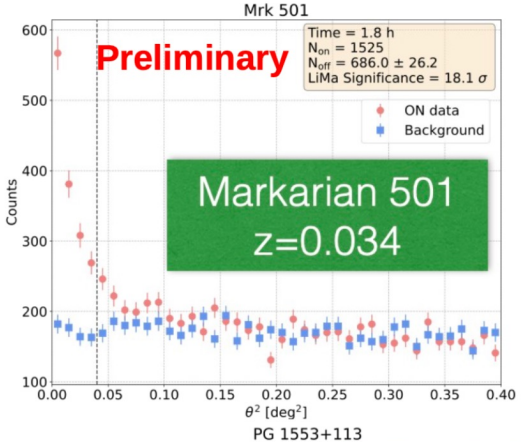
Referred to by ATel #: 14820, 14826, 14839

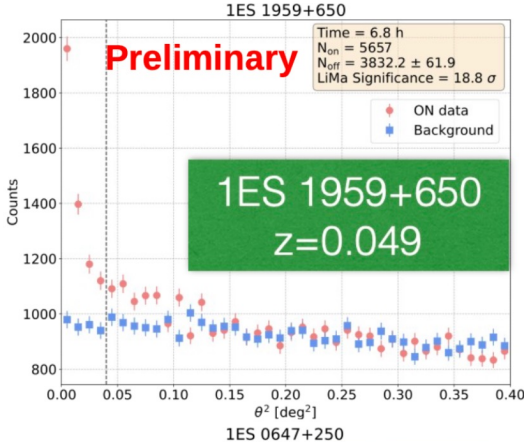




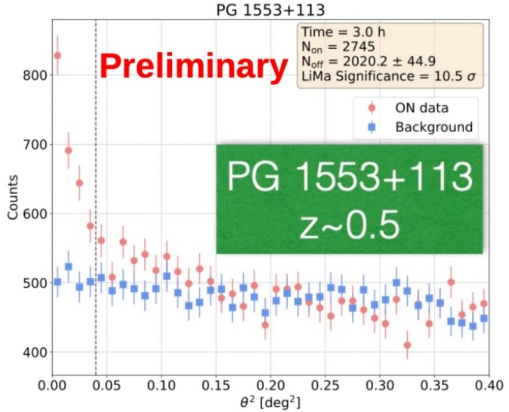
TeV Blazars

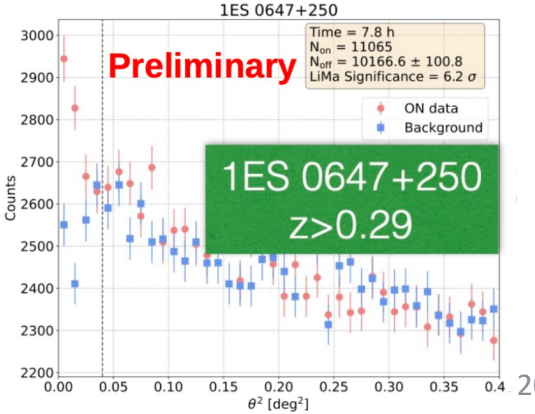






- Observed several other TeV Blazars while flaring.
- All known TeV blazars, but up to z~0.5.

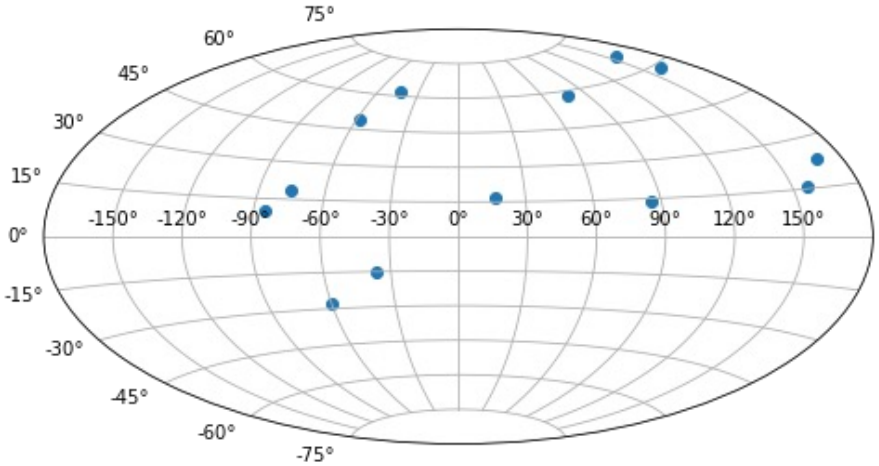




Transients follow-up

GRB #	Zenith angle (deg)	$T_{observation} - T_0$ (minutes)
1	40	1320
2	45	970
3	51	119
4	59	39
5	56	1072
6	61	1302
7	6	57
8	41	588
9	65	60
10	62	35
11	62	1138
12	49	33

Skymap of the GRBs followed by LST-1

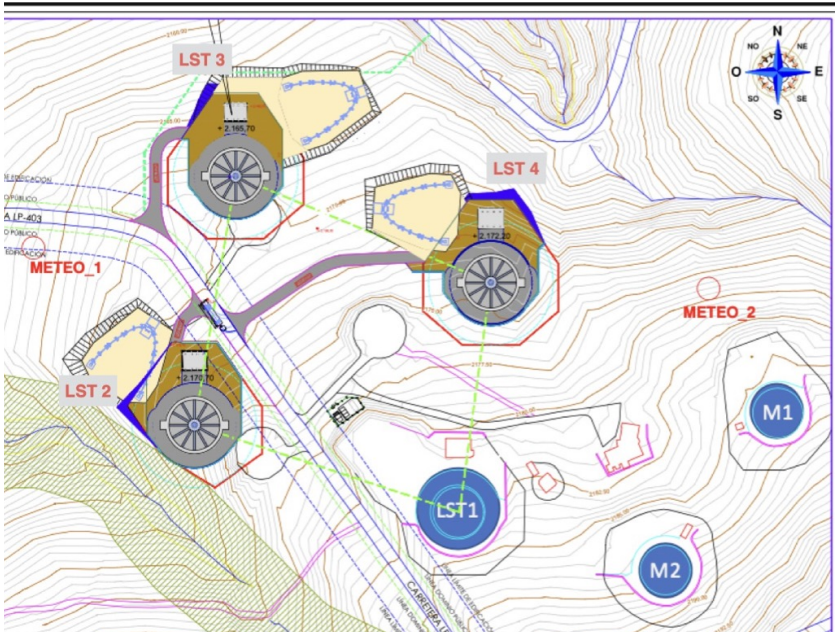


Follow-up of neutrino events, galactic transients, FRBs too.
Soon automatic repointing!

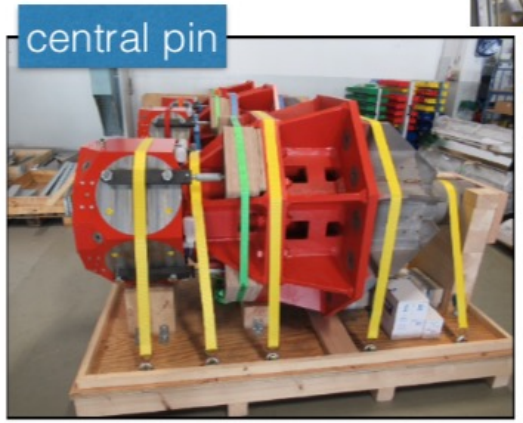
CTA-North: future LST2-4

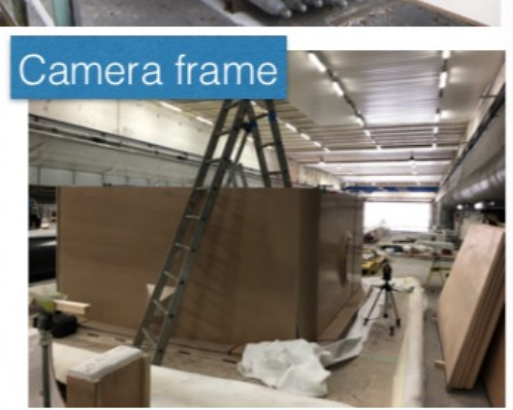
- 98% of the components manufactured and stored, ready for installation on site.
  - Most of them already in La Palma or on the way.
  - Few parts missing (mirror actuators).
  - LST-2 camera already being tested, LST-3 and LST-4 cameras to follow at the end of 2022/beginning of 2023.

- Next steps:
  - Environmental study approved at the end of June.
  - Permit for construction coming soon.
  - Civil works about to start.



LST2-4 components production





LST2-4 components production


camera access tower


Elevation drive

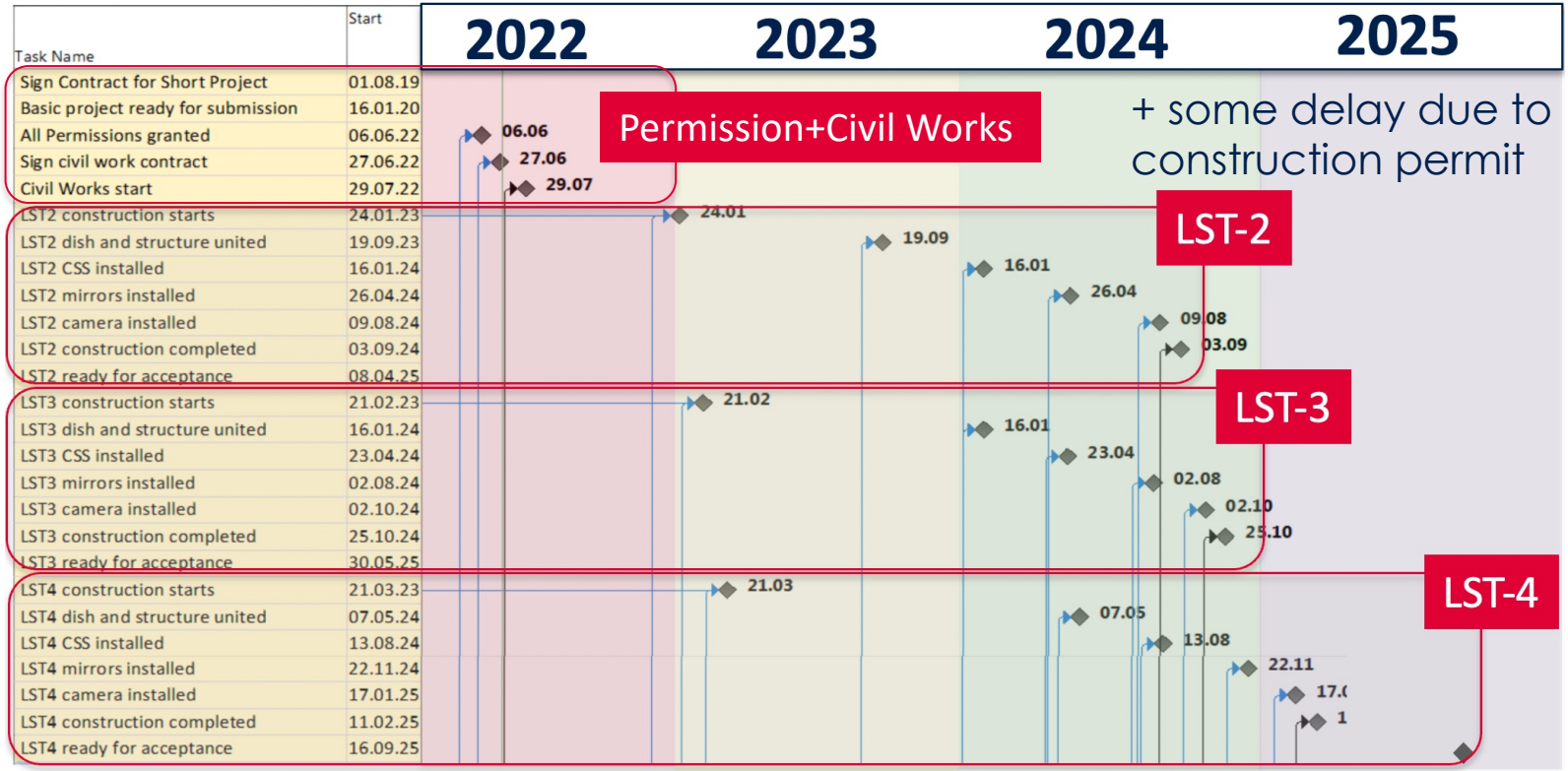

cameras

LST2 camera arrived to the Canaries for final tests in July


tensioning cable parts


camera arch

LST2-4 schedule

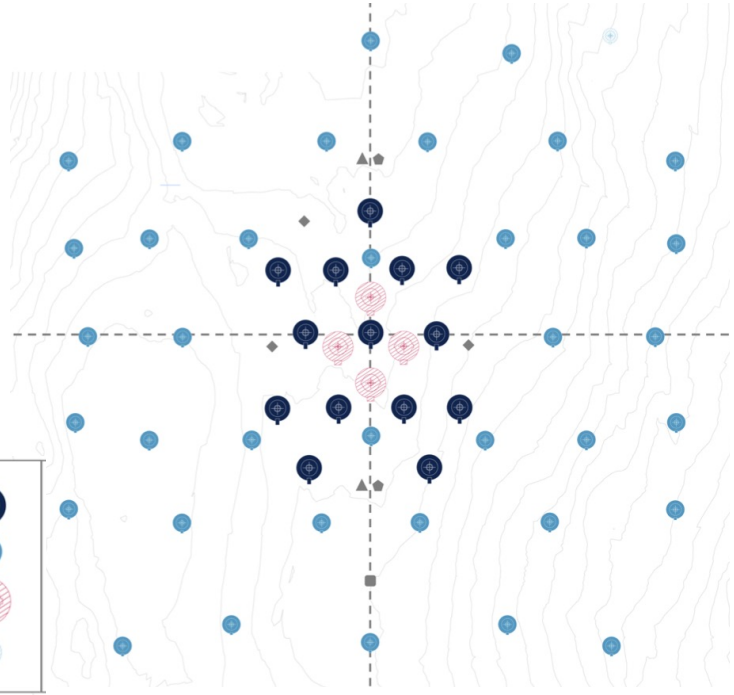


Task Name	Start
Sign Contract for Short Project	01.08.19
Basic project ready for submission	16.01.20
All Permissions granted	06.06.22
Sign civil work contract	27.06.22
Civil Works start	29.07.22
LST2 construction starts	24.01.23
LST2 dish and structure united	19.09.23
LST2 CSS installed	16.01.24
LST2 mirrors installed	26.04.24
LST2 camera installed	09.08.24
LST2 construction completed	03.09.24
LST2 ready for acceptance	08.04.25
LST3 construction starts	21.02.23
LST3 dish and structure united	16.01.24
LST3 CSS installed	23.04.24
LST3 mirrors installed	02.08.24
LST3 camera installed	02.10.24
LST3 construction completed	25.10.24
LST3 ready for acceptance	30.05.25
LST4 construction starts	21.03.23
LST4 dish and structure united	07.05.24
LST4 CSS installed	13.08.24
LST4 mirrors installed	22.11.24
LST4 camera installed	17.01.25
LST4 construction completed	11.02.25
LST4 ready for acceptance	16.09.25

LSTs in CTA-South

- No LSTs included in the Southern Site Alpha Configuration

- LSTs allow the detection of the lowest energies, in CTA-South especially relevant for:
  - GRBs, AGN flares, transients.
  - Dark Matter searches.



Italian colleagues (INAF+INFN) have secured funding for 2 LSTs.
Manufacturing of the telescope parts must happen before the end of 2025!

Conclusions: status of the project

- Prototype telescope LST-1 installed at the CTA-North site in 2018.
  - Performances of the telescope within requirements.
  - ~800h scientific data since Jan 2020.
  - First papers to be published soon.
  - All despite the great obstacles: covid-19, volcano, …
- Construction and commissioning of LST2-4 will start in La Palma these days and should be complete by 2025.
  - 98% of all parts almost produced, assembly of all the cameras to be completed by the beginning of 2023.
  - Civil works to be started soon.
- Funding secured for 2 LSTs in CTA-South.
  - ➢ Still targeting 4 LSTs!