

The Large-Sized Telescope of the Cherenkov Telescope Array

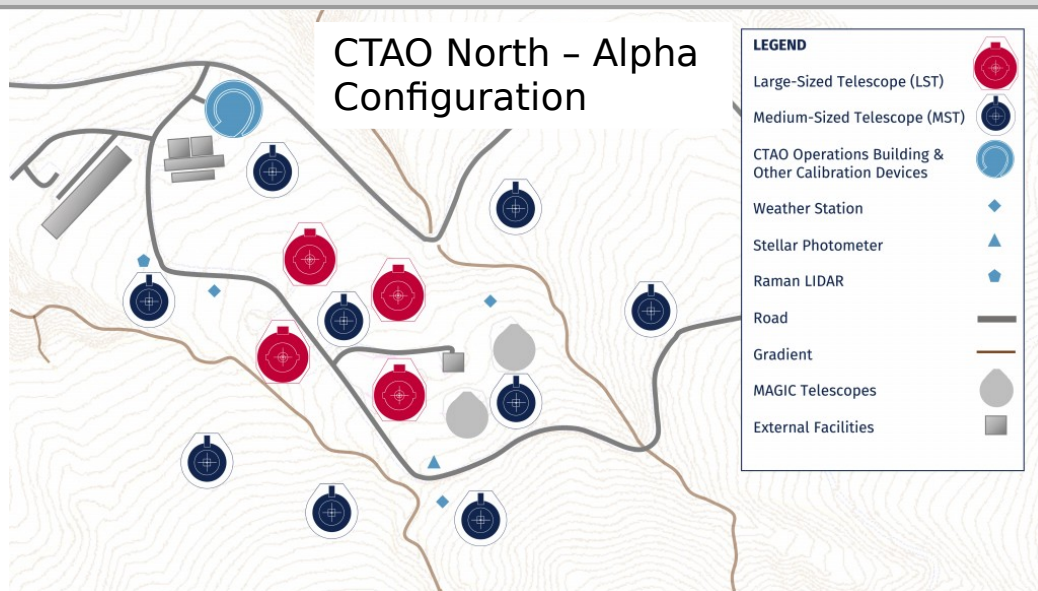
Status, first science and perspectives

F. Di Pierro (INFN Torino) on behalf of the CTA-LST Project

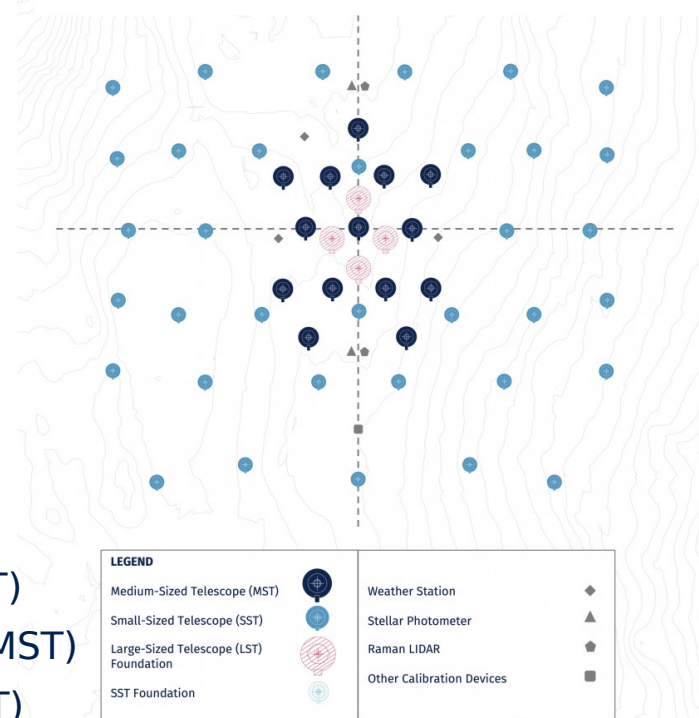


12th Cosmic Ray International Seminar
Naples, Italy, September 12 -16, 2022

The CTA Observatory



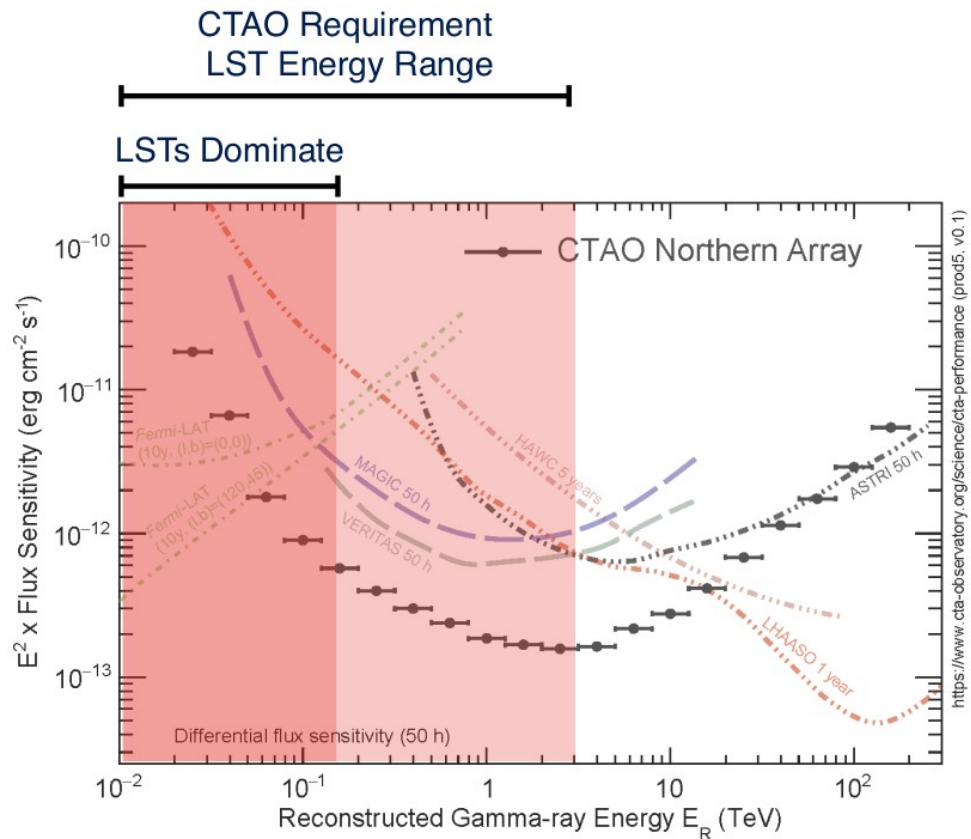
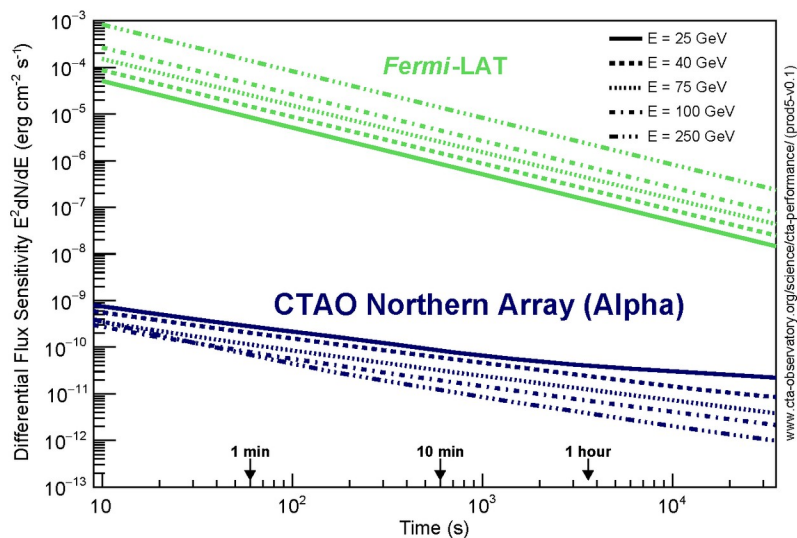
CTAO South – Alpha Configuration



- CTA will consist of 2 arrays
 - Northern, La Palma Spain
 - Southern, Paranal Chile
- Three telescope types
 - Large-Sized Telescopes (LST)
 - Medium-Sized Telescopes (MST)
 - Small-Sized Telescopes (SST)

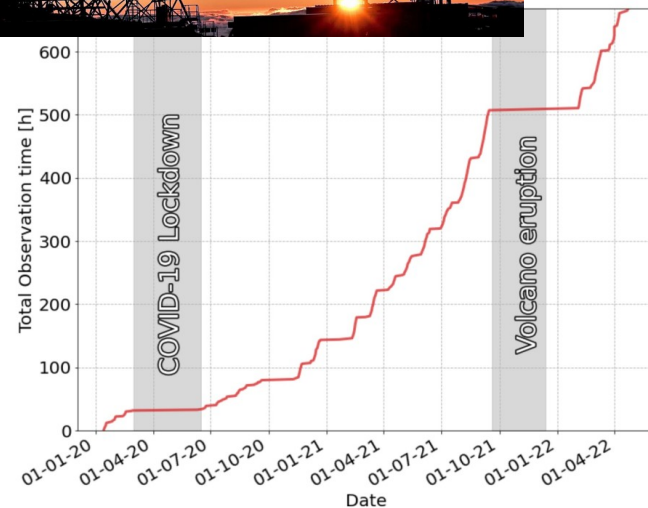
Performance of CTAO North

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



Status of the project

- Construction ahead of CTAO ERIC constitution
- LST-1 first telescope at CTA site:
 - Telescope inaugurated in La Palma in 2018
 - Under commissioning since then: COVID-19, volcano, inflation,...
 - ~800 h taken since Jan 2020
 - Data-taking efficiency 70% in dark time, not yet reaching 95% requirement
- LST-2, LST-3, LST-4: under production, starting civil works in La Palma
- LST South: partially funded



The LST Collaboration



The CTA LST Collaboration consists of 250+ scientists from 12 countries

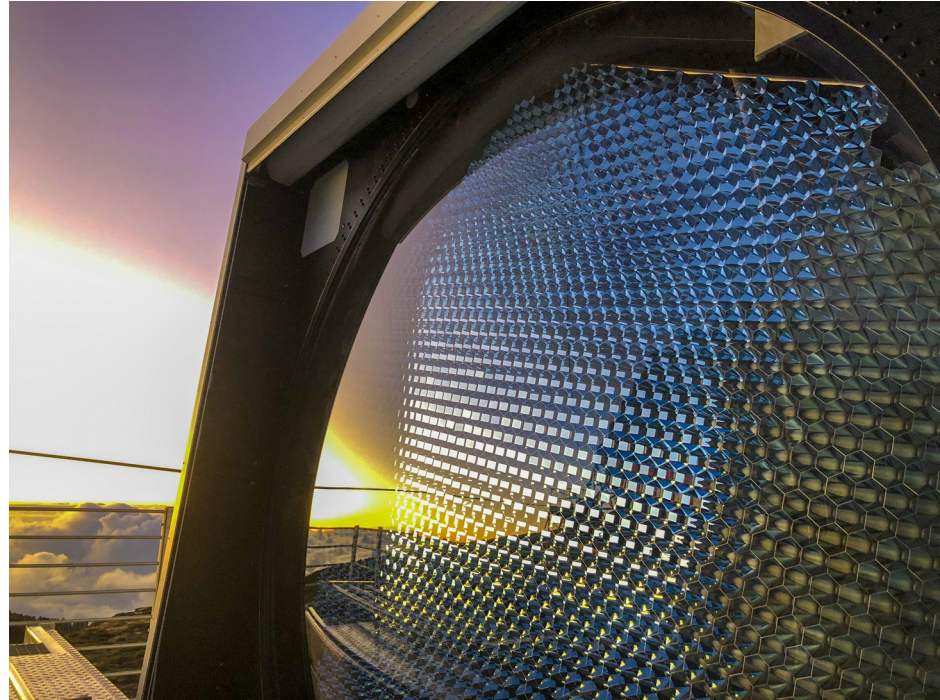
The Large-Sized Telescope

- Structure
 - Alt-Az mount on circular rail
 - Carbon fiber / steel structure
 - Total moving weight ~ 120 tons
 - Repositioning speed: 10 deg/s
 - Repointing any sky direction < 20 s
- Optics
 - Parabolic mirror: ~ 400 m² and $\varnothing 23$ m

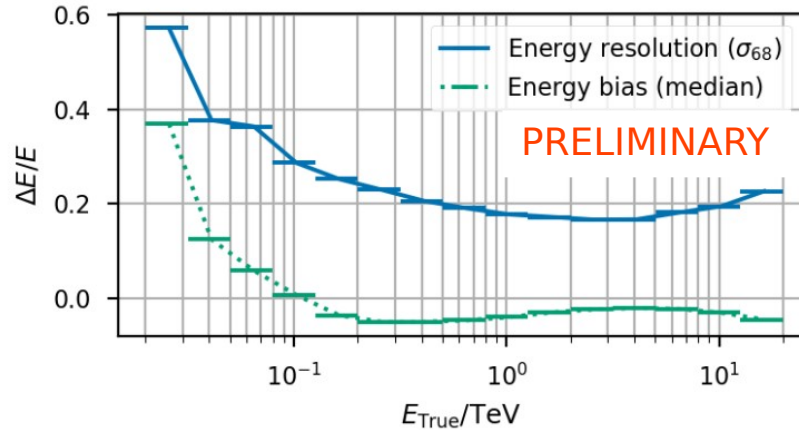
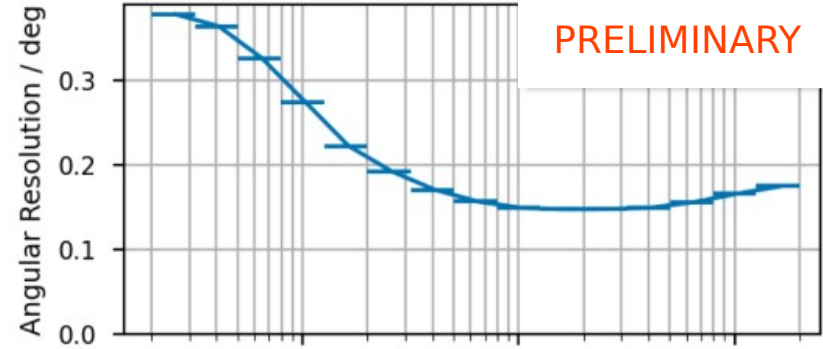
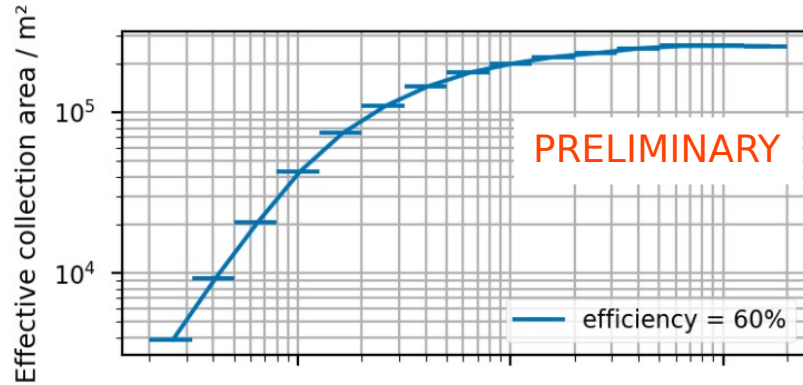


The Large-Sized Telescope

- Camera
 - Number of pixels: 1855 PMTs
 - Field of View: $\sim 4.5^\circ$
 - Pixel size: 0.1°
 - Sampling rate: 1 GHz
- Energy range > 20 GeV
- Overlap with satellites but with collection area $> 10^4$ times larger

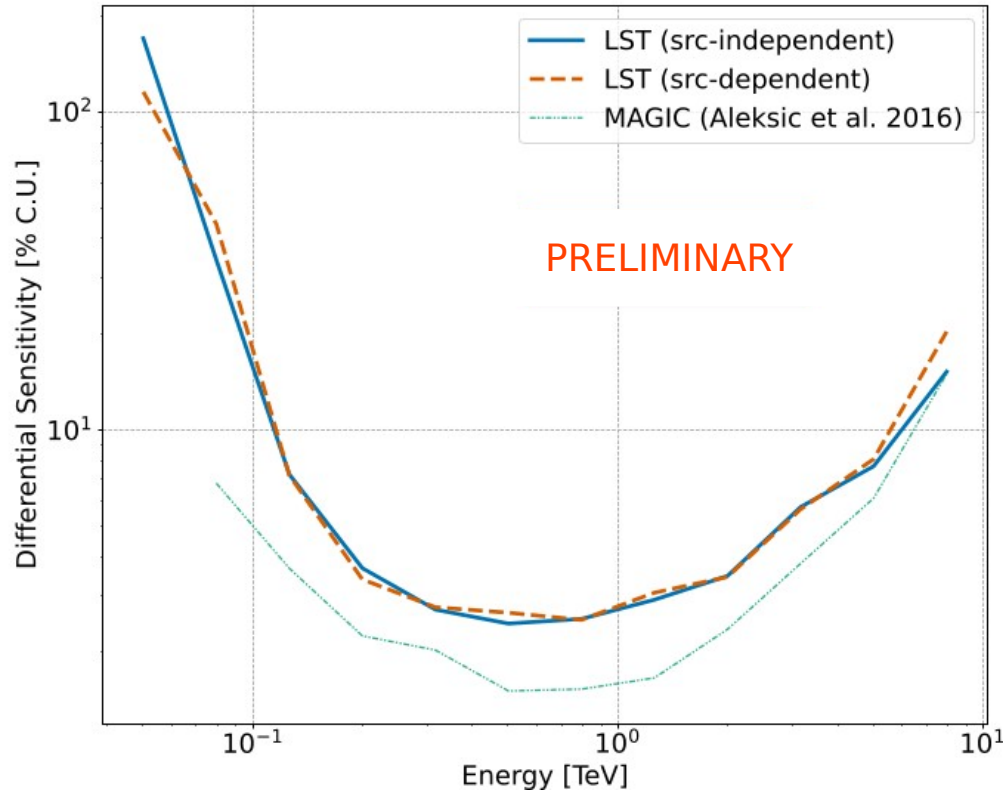


LST-1: effective area, angular and energy resolution



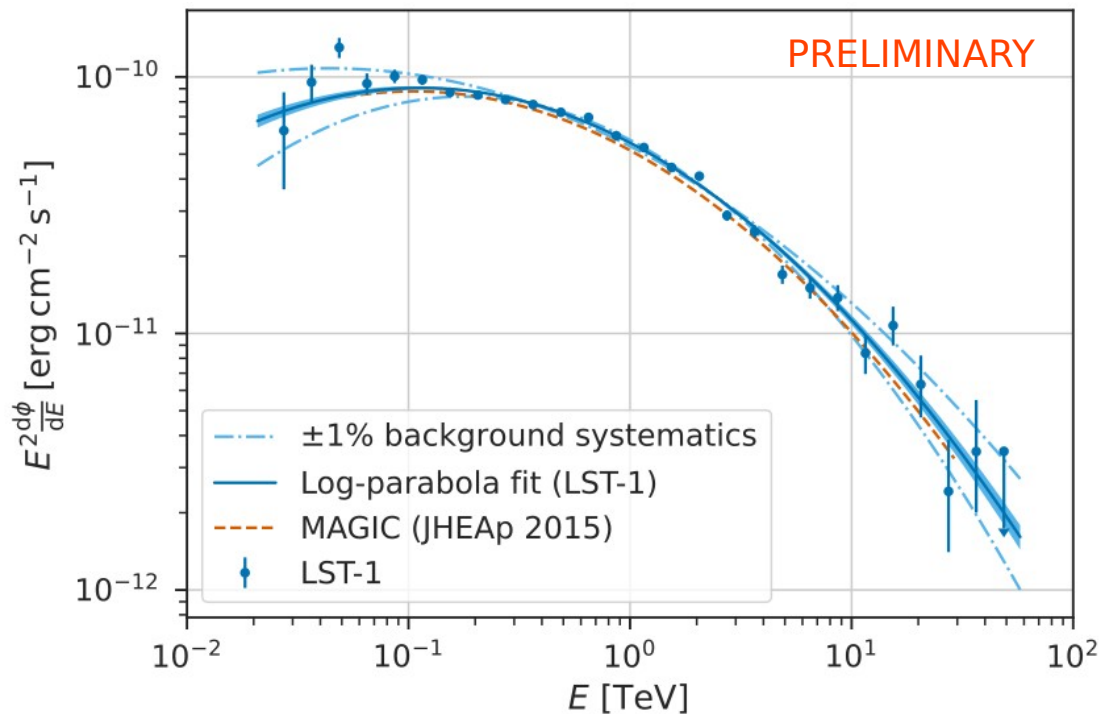
- The telescope is well understood, good Data - MC agreement.
- Zenith angle = 10 deg; γ -ray efficiency = 60%
- Effective area > 10³ m² down to 20 GeV
- LST-1 is a single telescope, expected limited performance w.r.t. stereoscopic systems, still competitive.

Sensitivity of LST-1



- ~1.5 worse than MAGIC (as expected)
- but with a lower Energy threshold (of ~50 GeV)
- at high energies LST-1 benefits of the larger F.o.V.

Performance of LST-1: Crab SED

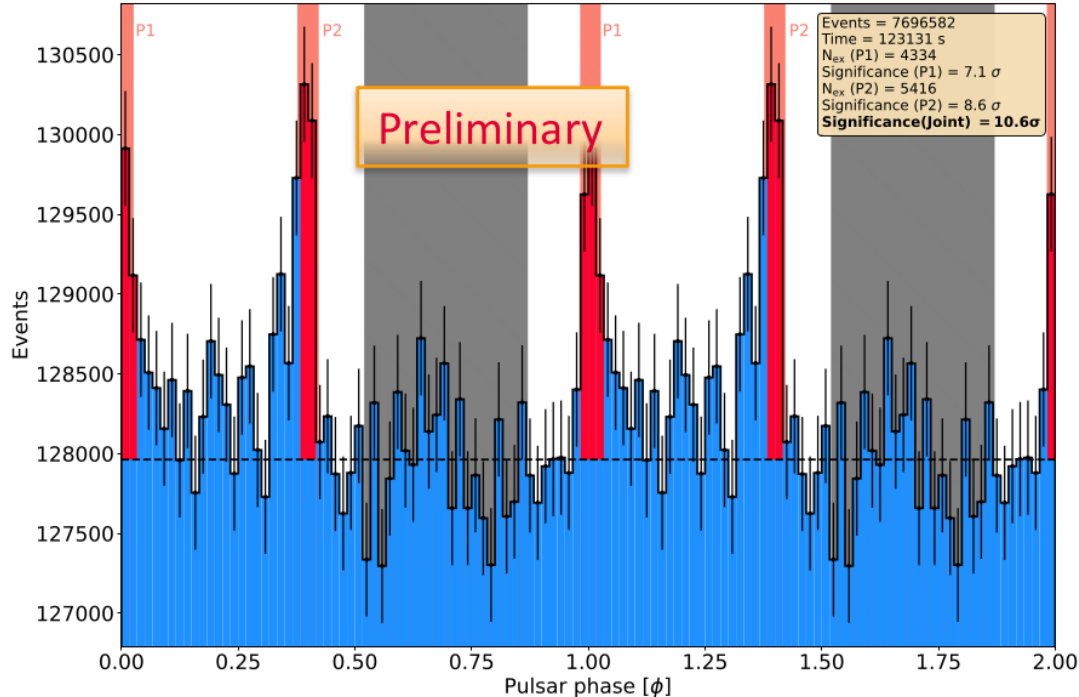


- 34h effective time
 - Nov 2020 - March 2022
 - Good quality data, $Z_d < 35^\circ$
- γ -ray efficiency: 70% from gammaness cut and 70% from θ^2 cut
- Error bars are only statistical
- Systematics: blue lines correspond to effect of $\pm 1\%$ background
- Consistent with MAGIC and Fermi-LAT
- Lowest data point at 25 GeV

First scientific results of LST-1

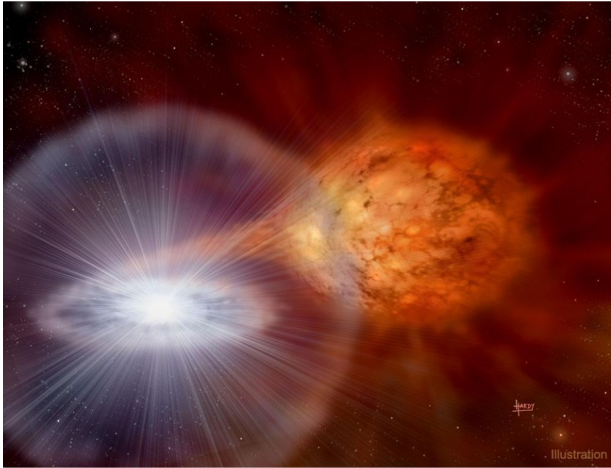
- LST-1 is still in commissioning
- Performance paper to be published soon
- With the first ~800 h of data many sources have been observed
 - Crab Nebula
 - RS Ophiuchi
 - LHAASO J2108+515
 - Several AGNs: BL Lac, Mrk421, Mrk 501, 1ES1959+650, PG1553+113, etc.
 - Transients
- Dedicated papers already in preparation

Crab pulsar phaseogram

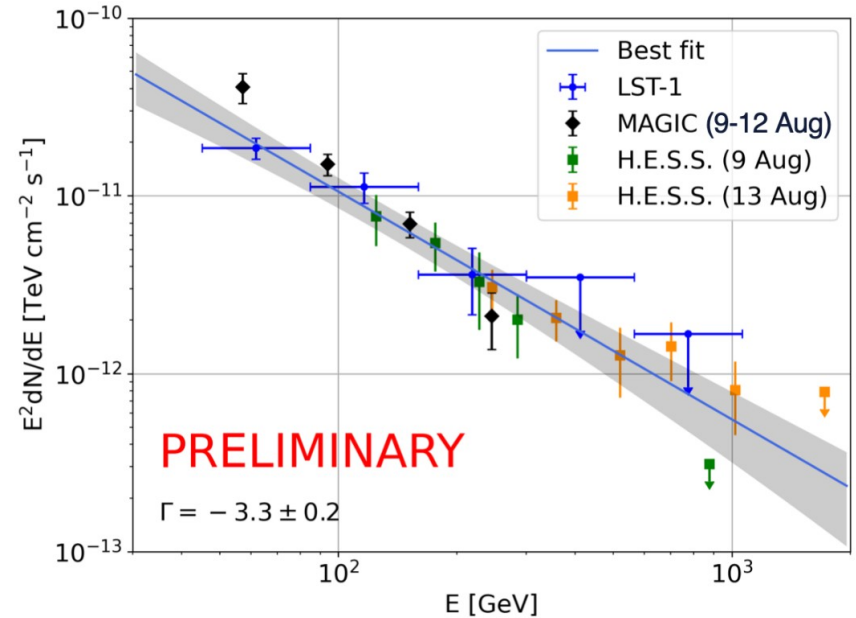


- Crab Pulsar (PSR J0534+220), 33 ms period
- Data Selection: same as Crab Nebula SED
- Significant detection down to few tens of GeV
- P1/P2 ratio tends to 1 at low energies

RS Ophiuchi

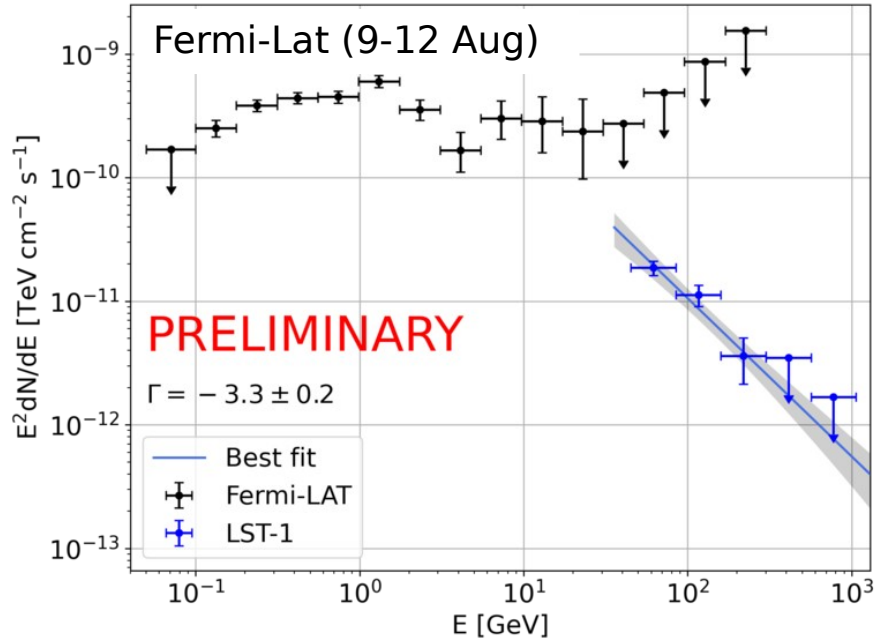


- RS Oph: recurrent symbiotic nova, 15-20 yr
- LST-1, 3 days average
- MAGIC: 4 days joint data (Acciari et al. 2022)
- HESS: 9 Aug and 13 Aug data (H.E.S.S. collaboration 2022)
- SEDs are consistent



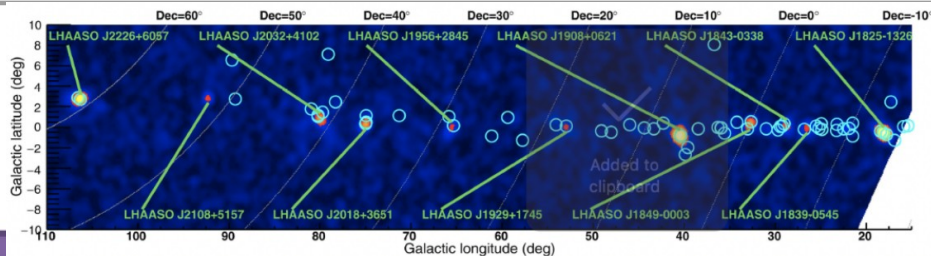
RS Ophiuchi

- Nice connection between LST-1 and Fermi-LAT data
- Energy threshold already competitive with MAGIC (~45 GeV)
- Paper in preparation



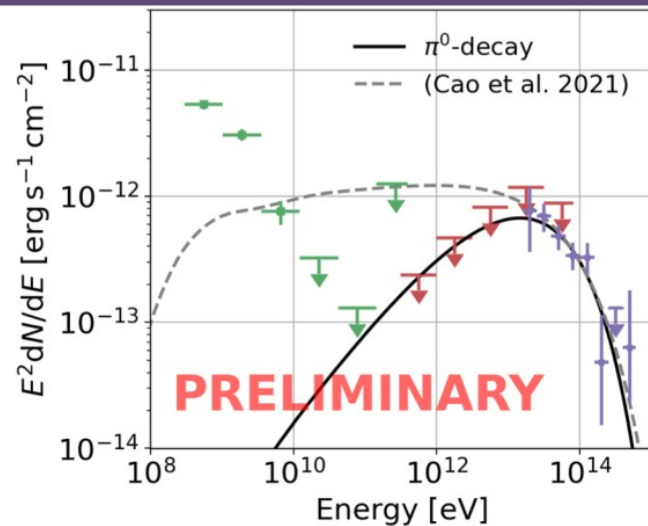
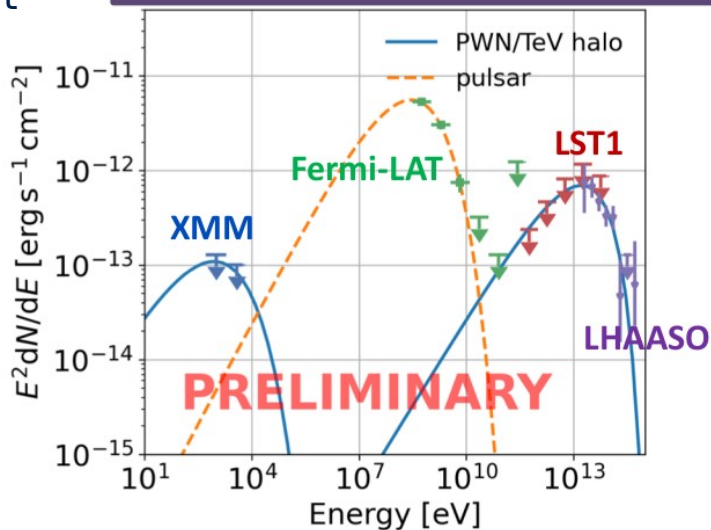
LHAASO J2108+5157

- Cao et al. (2021): PeVatron reported to be point-like, without X-ray and VHE counterpart
- 49.3 h good quality data: no detection, but relevant upper limits
- Not yet possible to definitely exclude one of the 2 scenarios
- Paper in preparation



Leptonic scenario

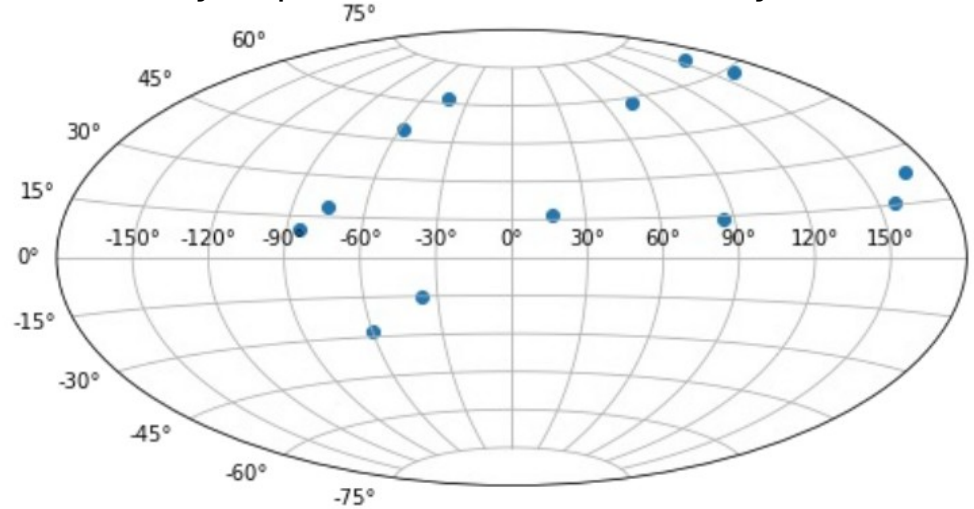
Hadronic scenario



Transients follow-up program

GRB #	Zenith angle (deg)	$T_{\text{observation}} - T_0$ (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

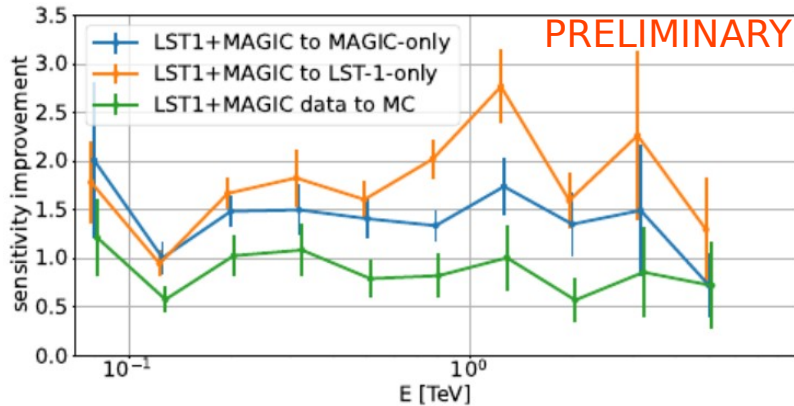
Skymap of the GRBs observed by LST-1



- LST-1 has an active transients follow-up program:
 - GRBs, HE neutrinos, Galactic transients, FRBs
 - Soon automatic repointing and full speed

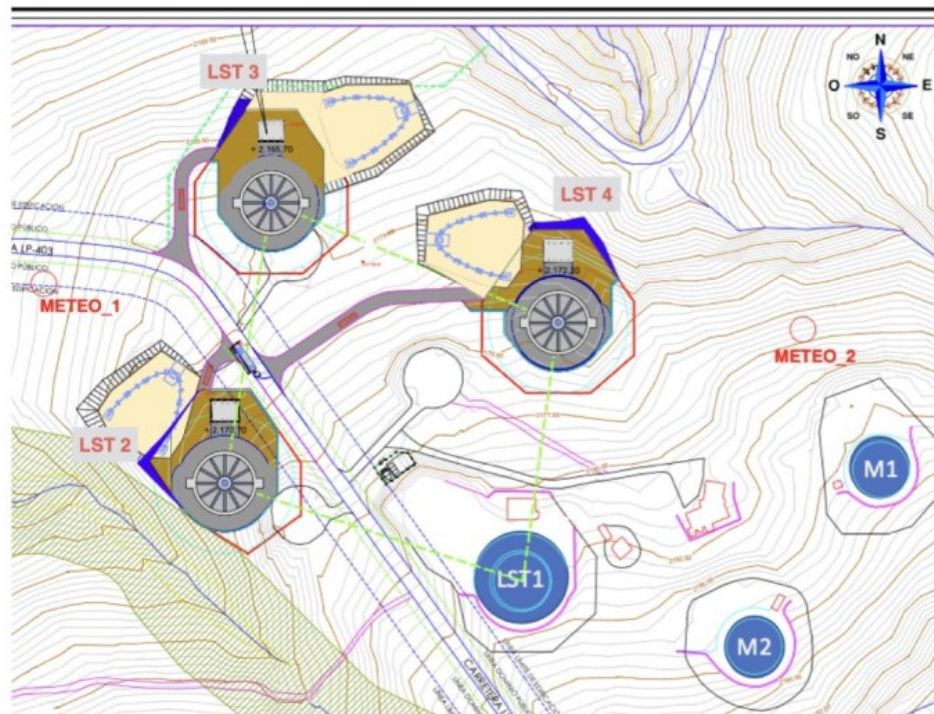
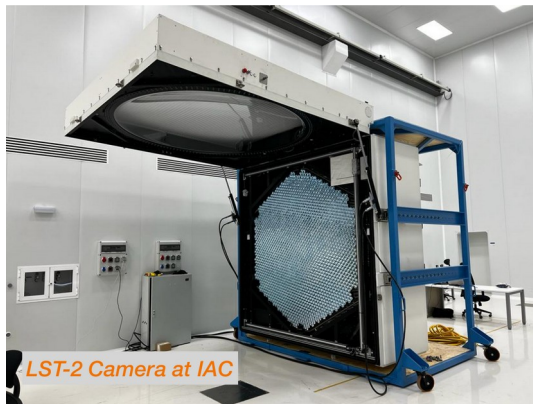
Joint observations with MAGIC

- MoU between MAGIC and LST-1 for joint observations
- Software trigger with event timestamps
- Common data analysis newly developed
 - Preliminary results show an improvement in sensitivity of the 3-tels w.r.t. MAGIC

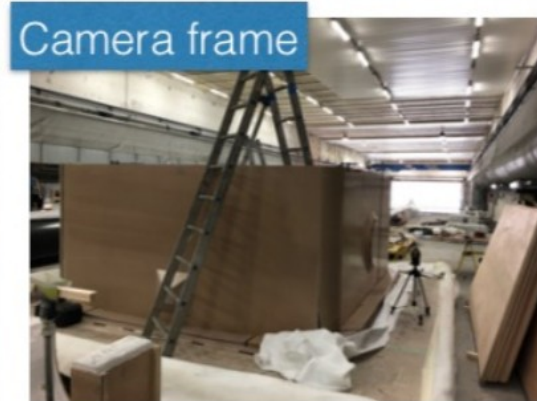
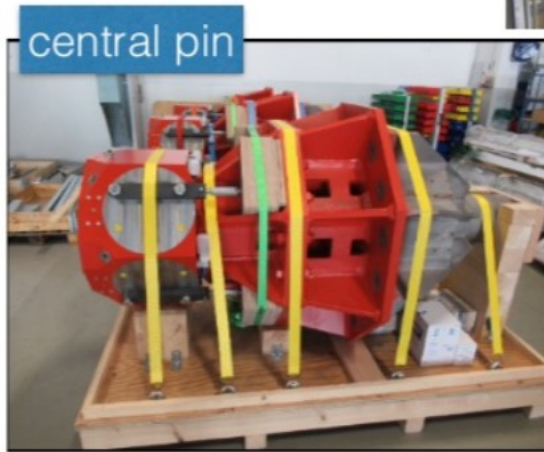


LST North: future LST2-4

- 98% of the components manufactured and stored, ready for installation
 - Most of them already in La Palma
 - LST-2 camera already being tested
 - LST3-4 cameras will follow (end of 2022 and beginning of 2023).



LST2-4 components production



LST2-4 components production

tensioning cable parts



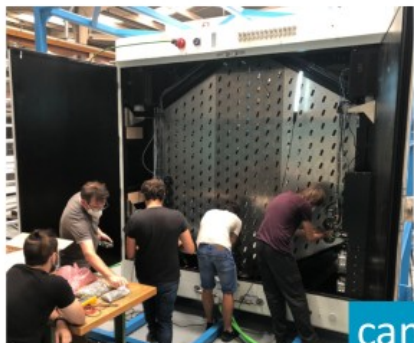
camera access
tower



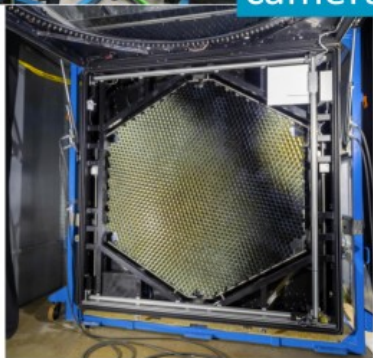
Elevation drive



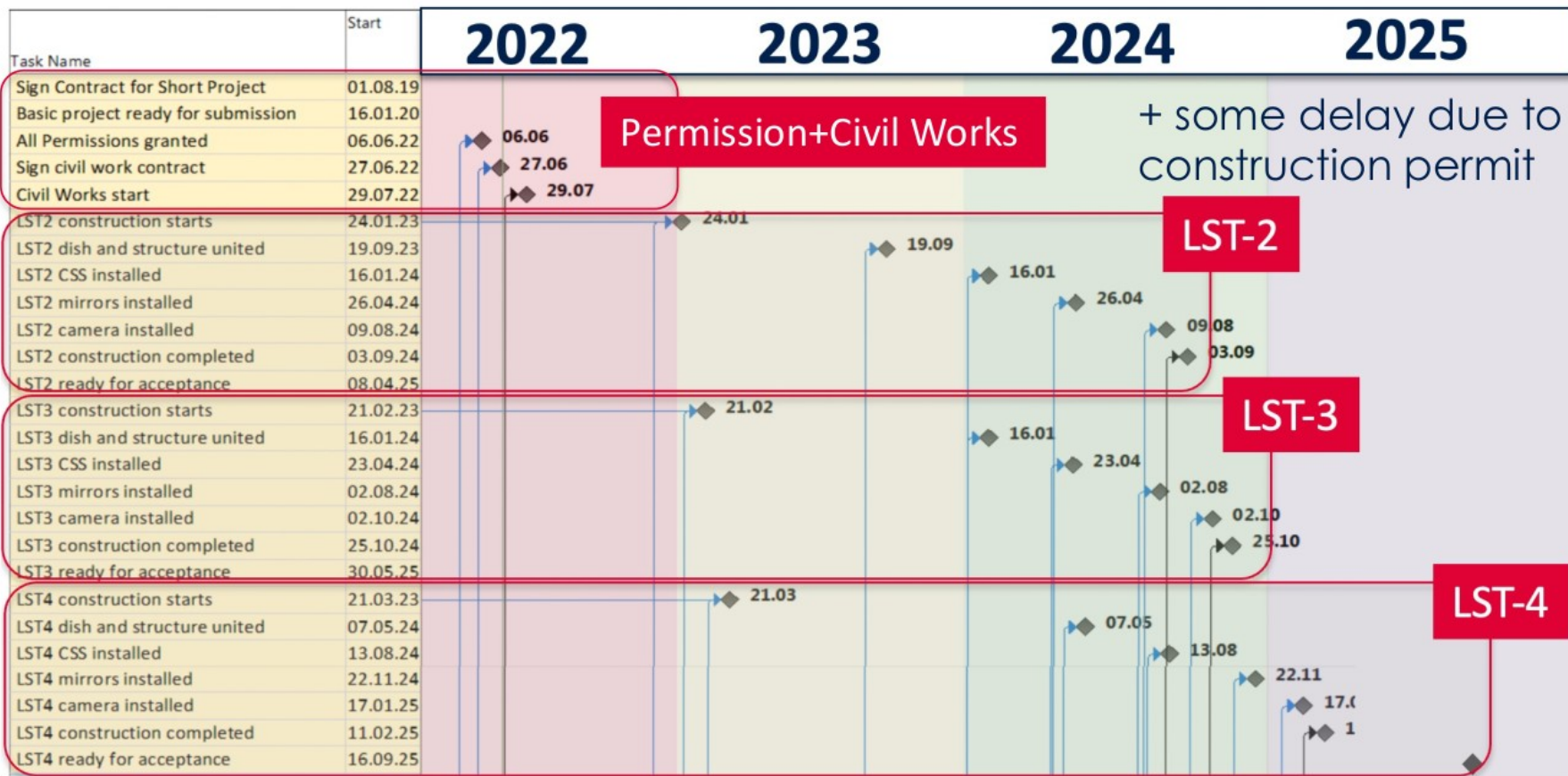
cameras



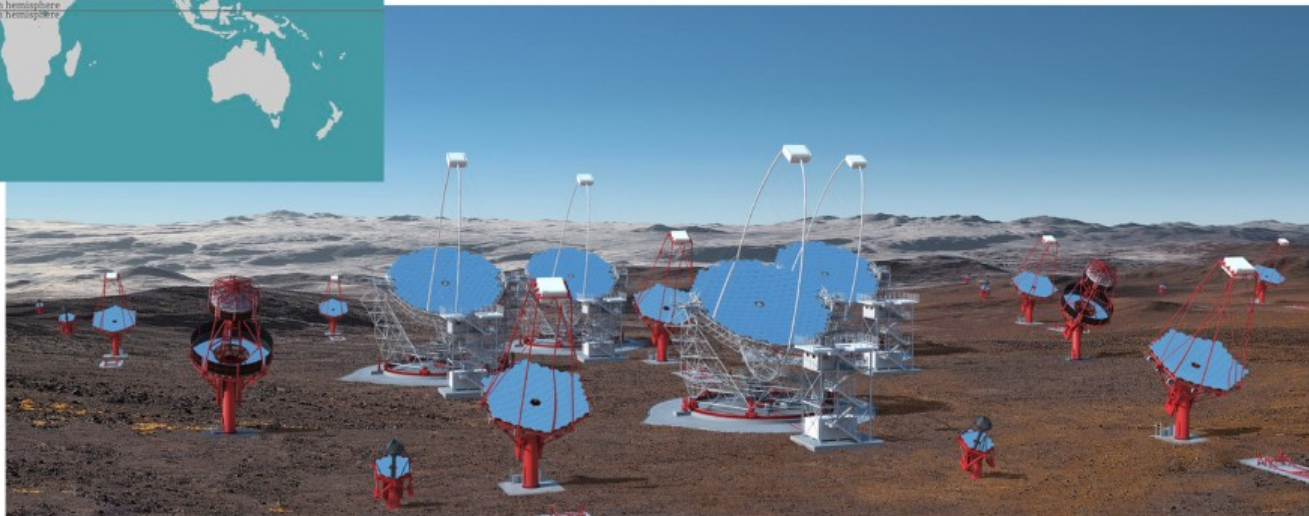
camera arch



LST2-4 schedule

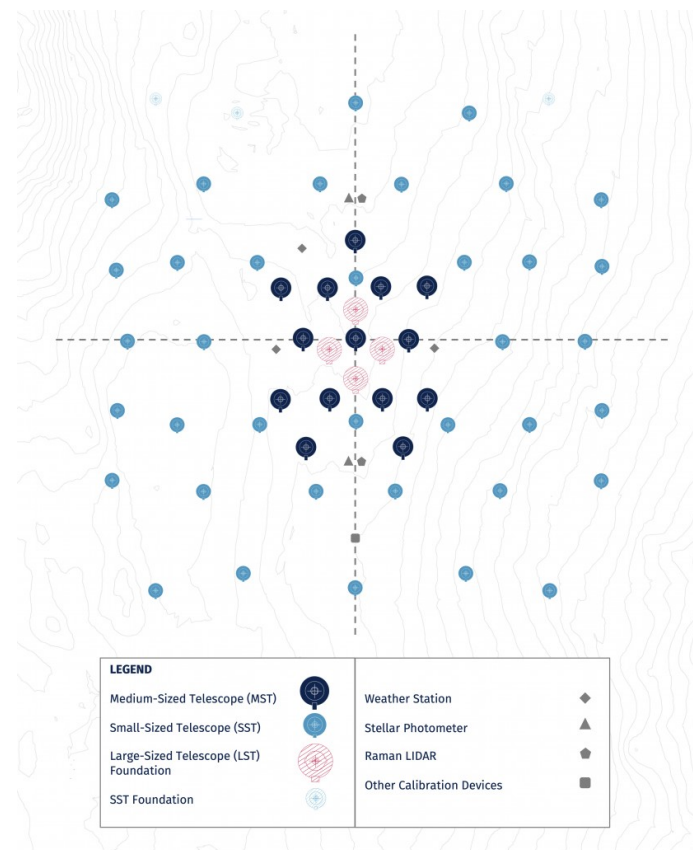


CTA South



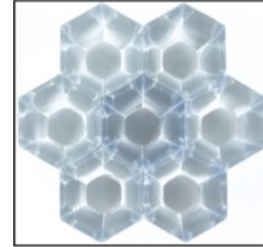
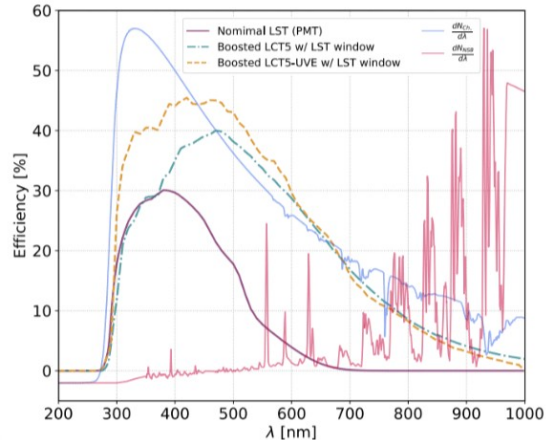
LSTs in CTA South

- No LSTs were foreseen in the CTA alpha configuration. INAF and INFN have secured extra money for 2 LSTs in the south.
 - Still targetting 4 LSTs!
- Manufacturing of the telescopes must happen before the end of 2025
- LSTs also in the south will bring down the energy threshold:
 - Transients, AGN flares, GRBs
 - DM searches

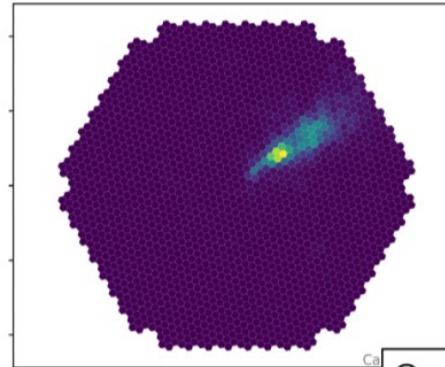


R&D towards an Advanced Camera

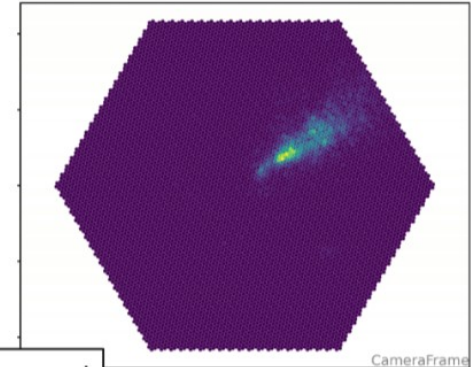
- Improve duty cycle, robustness, stability using SiPMs
- Increase image granularity for better image feature extraction
- Fully digital readout for better upgradability and improved trigger strategies



LST PMT camera (**0.1°**)



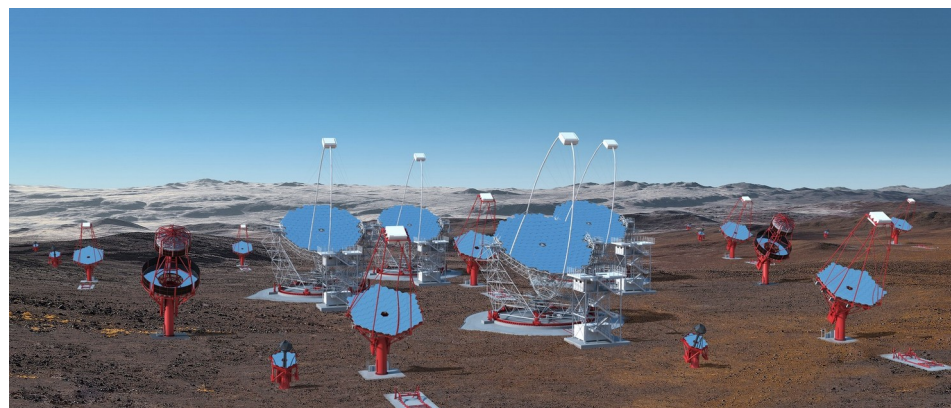
LST SiPM camera (**0.05°**)



Gamma event

Conclusions

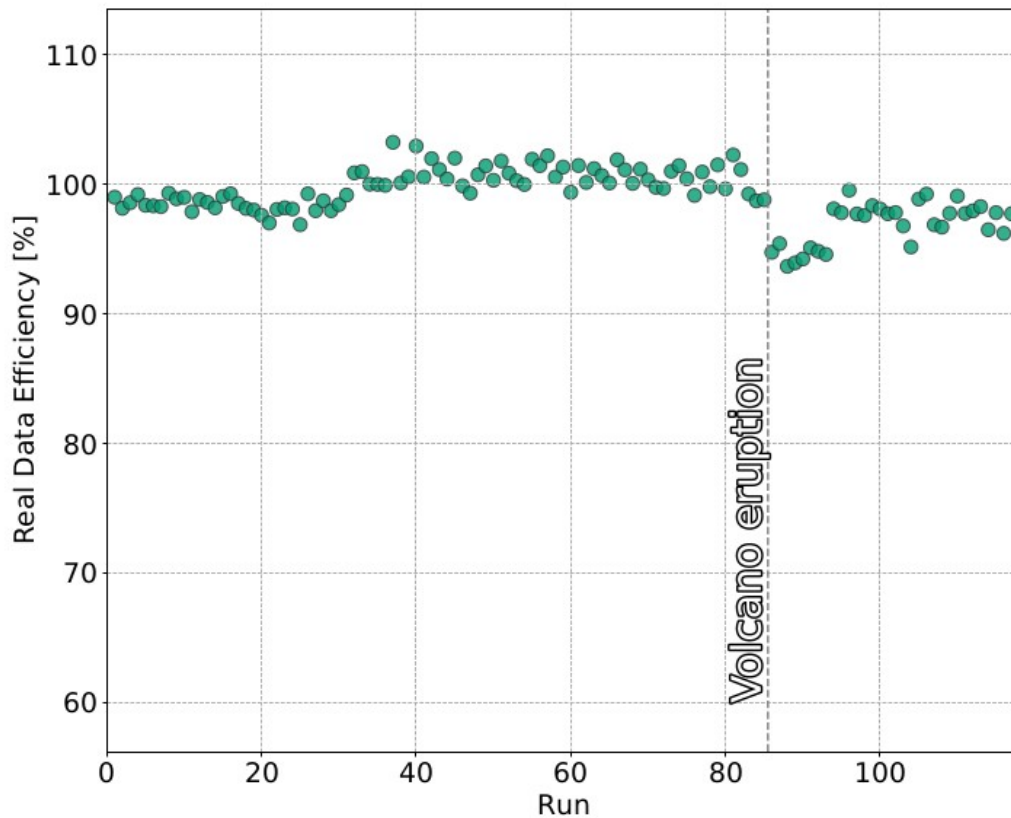
- CTA Project well on track
- LST-1 has been installed in La Palma and its commissioning is ongoing
 - Performance of the telescope within requirements and well understood
 - Taking data since 2020
 - First papers to be published soon
 - Already an active scientific program (e.g.: Crab pulsar, RS Oph, LHAASO J2108, BL Lac, TeV blazars, transients...)
- Construction of LST-2 to LST-4 should be complete by 2025
- Funding secured for 2 LSTs in CTA-South



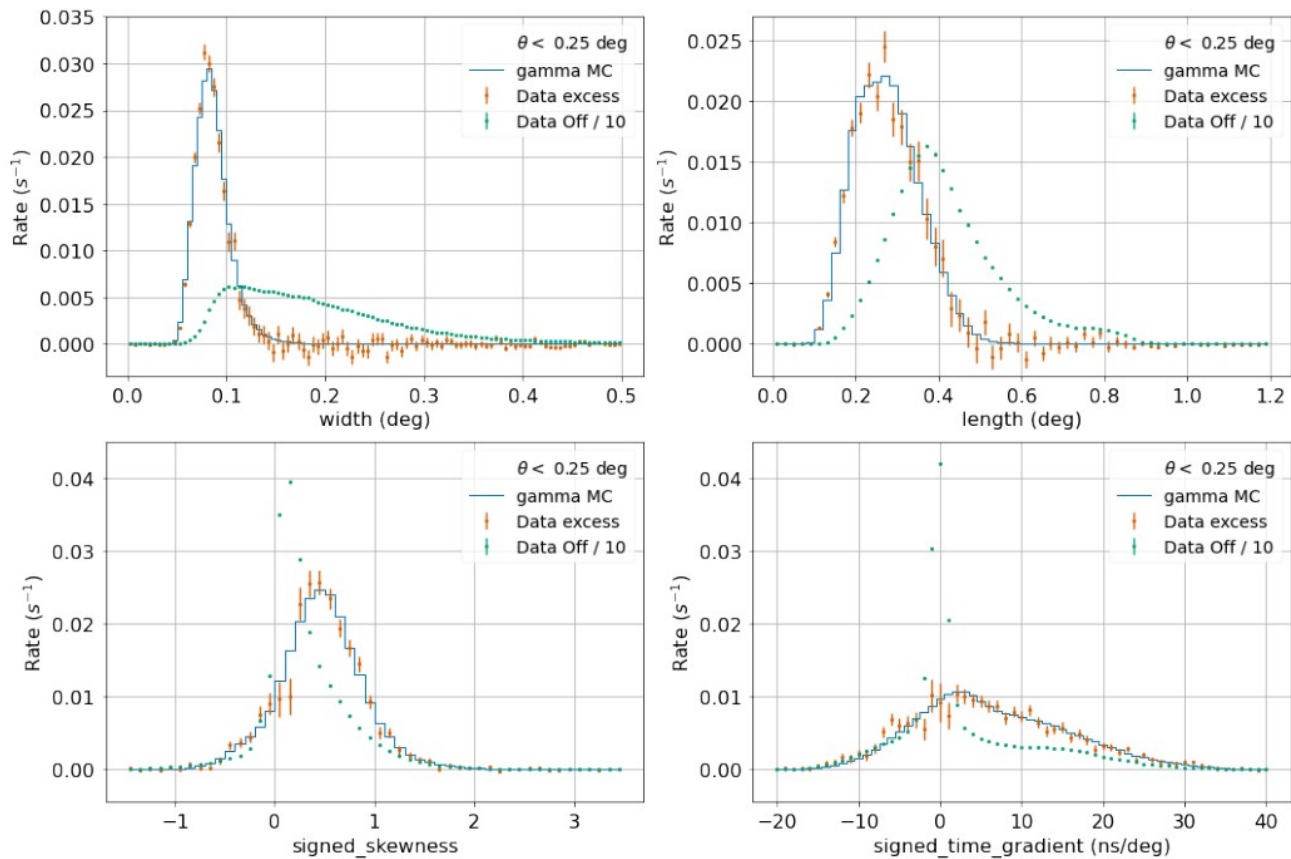
BACKUP



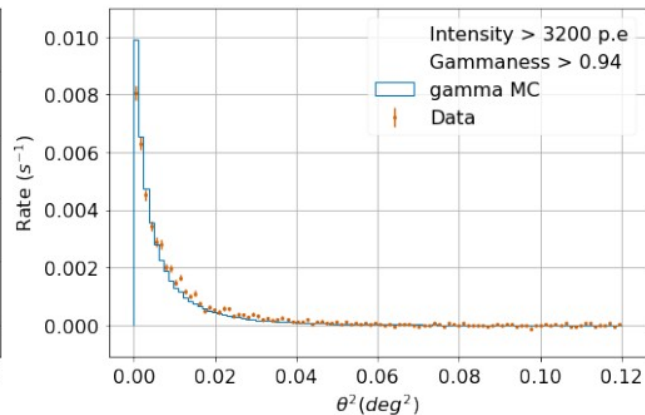
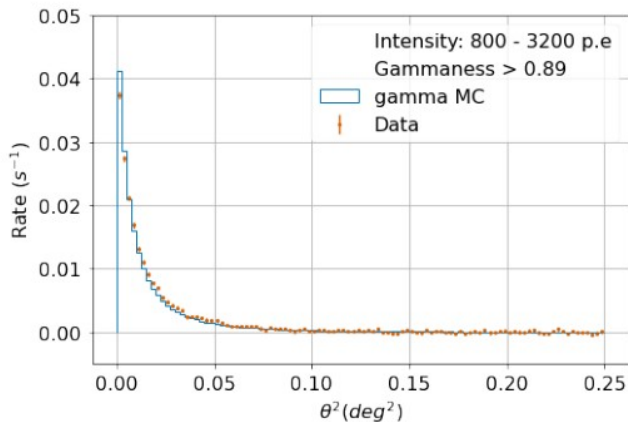
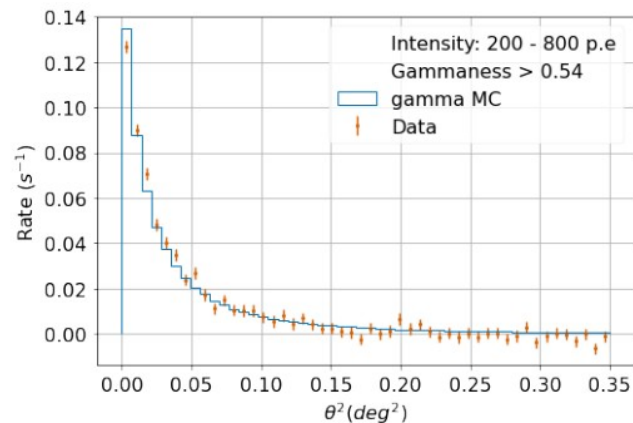
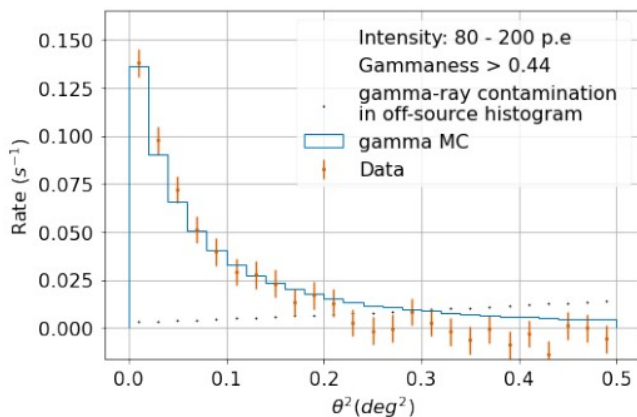
Optical efficiency vs run



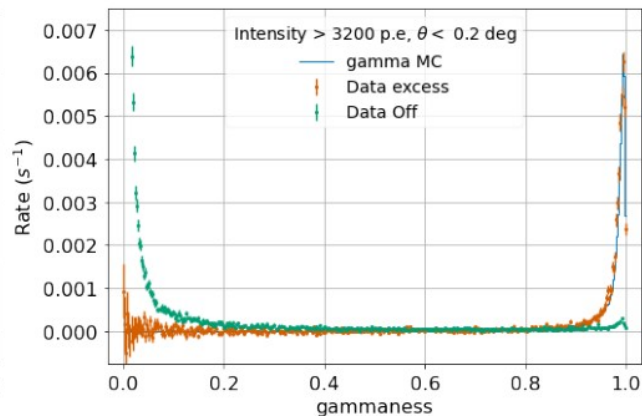
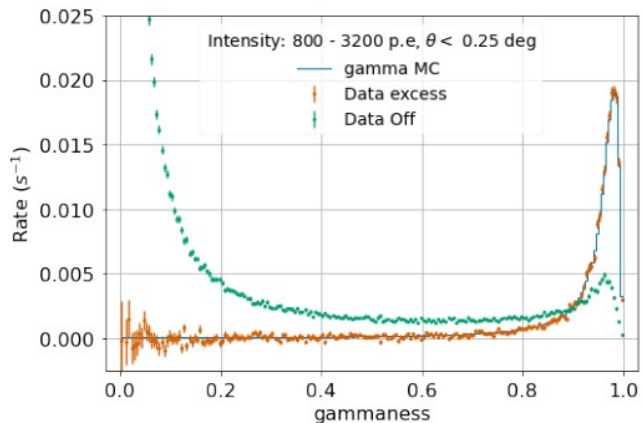
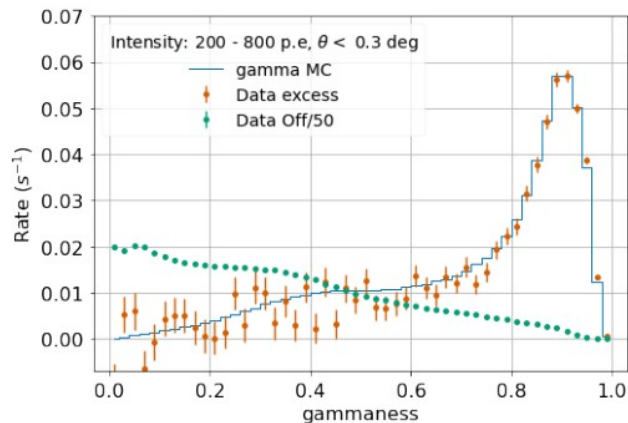
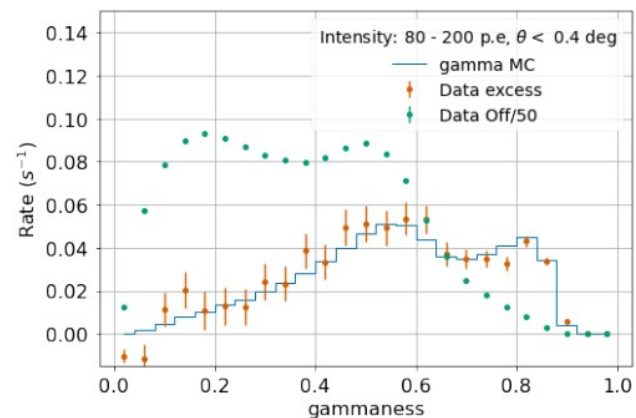
LST-1 Data - MC comparisons



LST-1 Data - MC comparisons



LST-1 Data - MC comparisons



Crab pulsar, P1 and P2 SEDs

