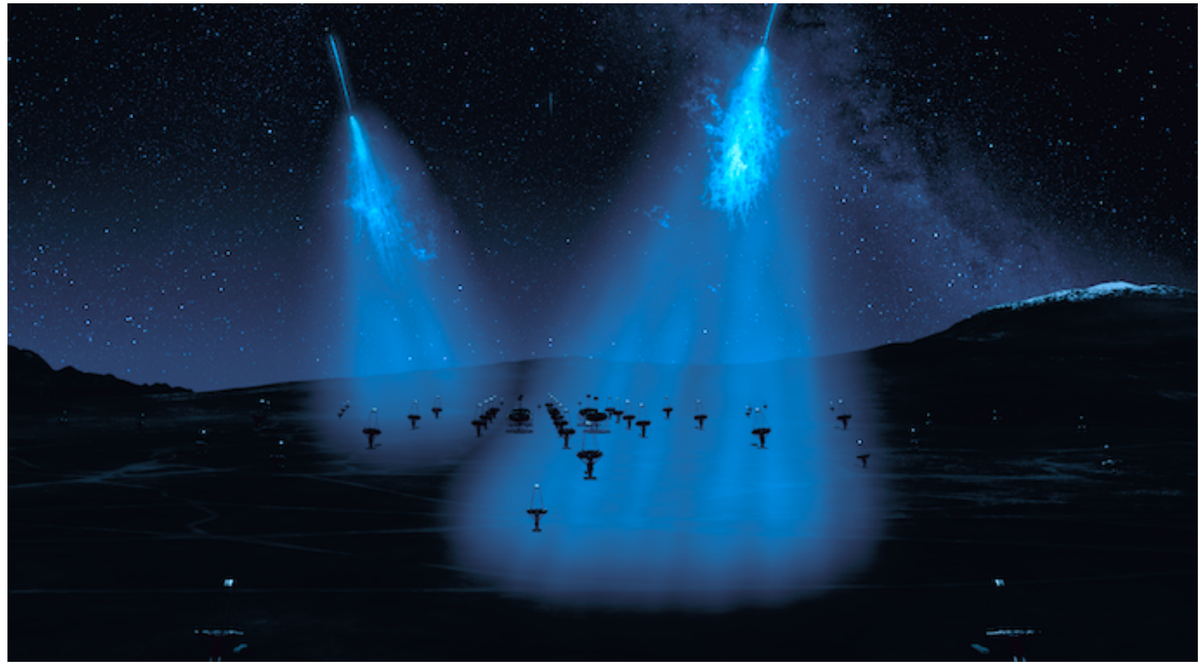
The Large-Sized Telescope prototype of CTA: status and first observations.

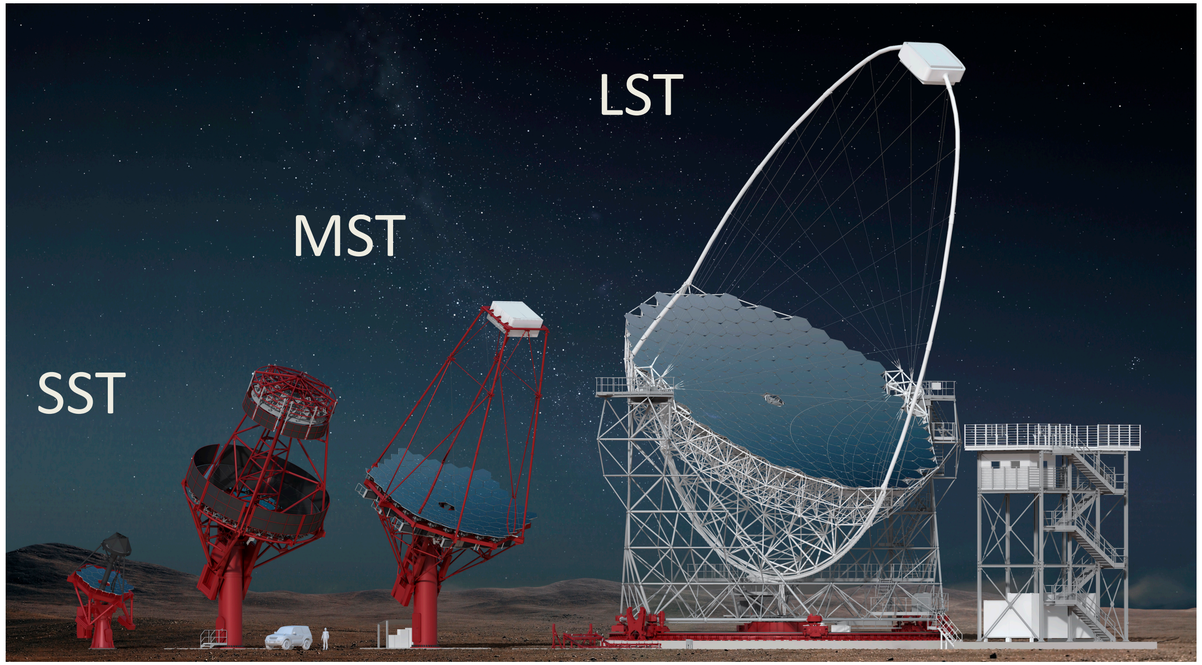
Domenico della Volpe on behalf of the LST collaboration

TeV Particle Astrophysics Conference. October 2021, TeVPA 2021 , Chengdu China

Photo Credits. D. Kerszberg

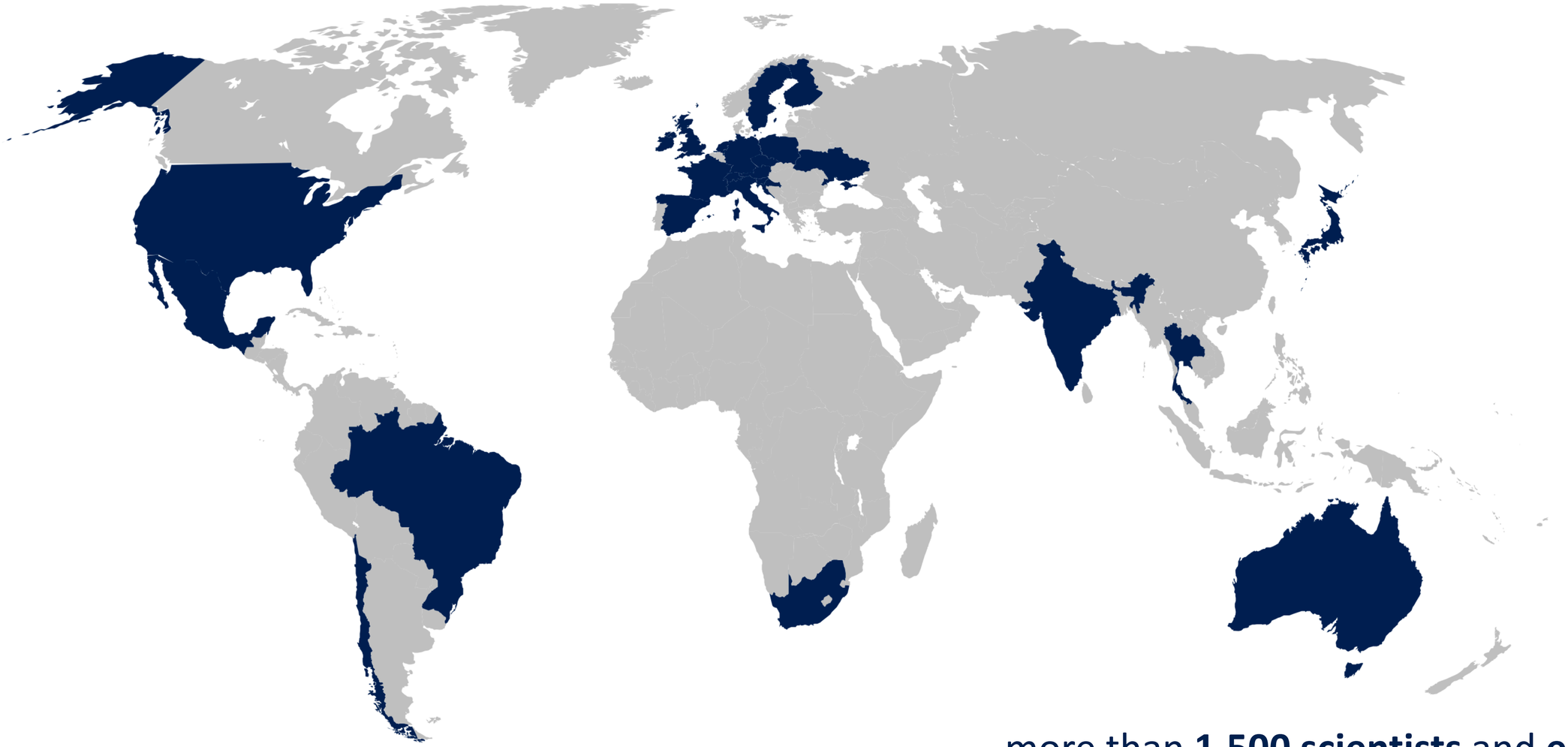
CTA, the Cherenkov Telescope Array





- CTA is the next-generation observatory for gamma-ray astronomy in the **Very-High Energy band (>20 GeV)**
- Concept: **Cherenkov telescopes** of different sizes deployed over an area of O(km^2)
- Order of magnitude better sensitivity than existing facilities
- June 25th 2021: design and cost-book of first CTA phase ("Alpha configuration") approved by the Board of governmental representatives $\Longrightarrow$ green light for construction

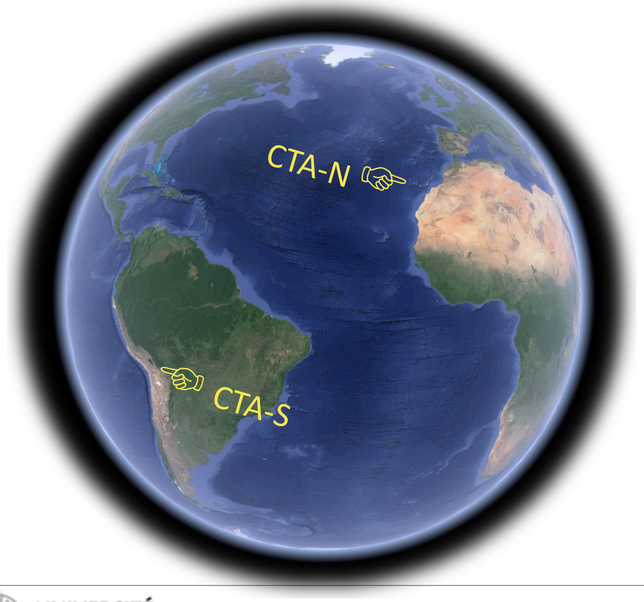
The CTA consortium

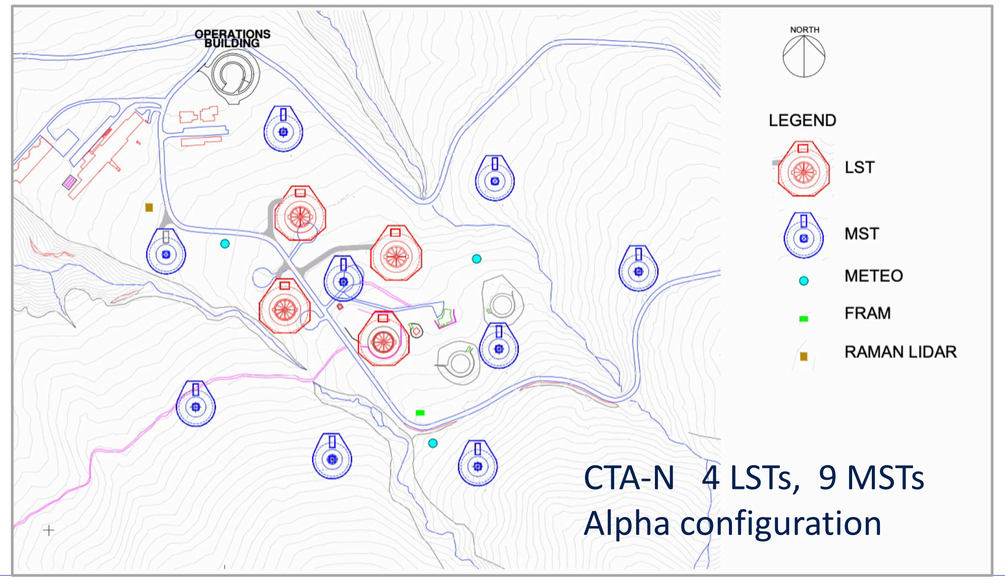


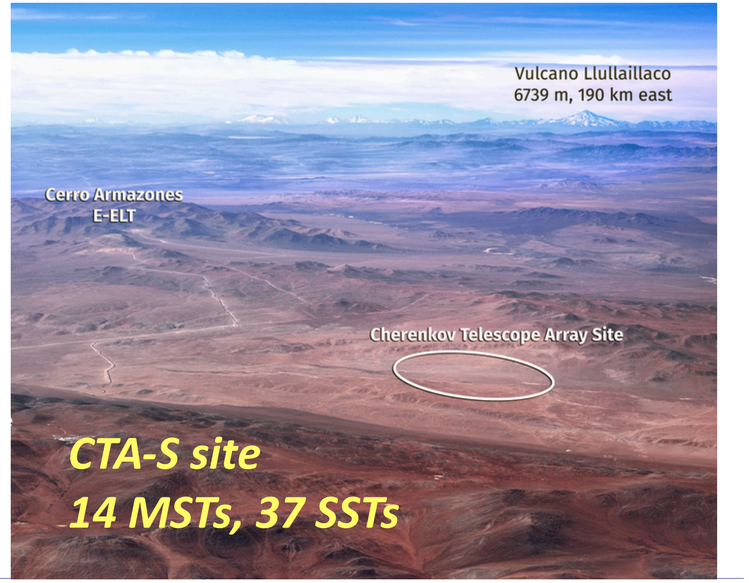
more than **1,500 scientists** and **engineers**
from about **150 institutes** in **25 countries**

Cherenkov Telescope Array (CTA)

Two sites (Atacama desert, Chile, and La Palma, Spain) for full-sky coverage

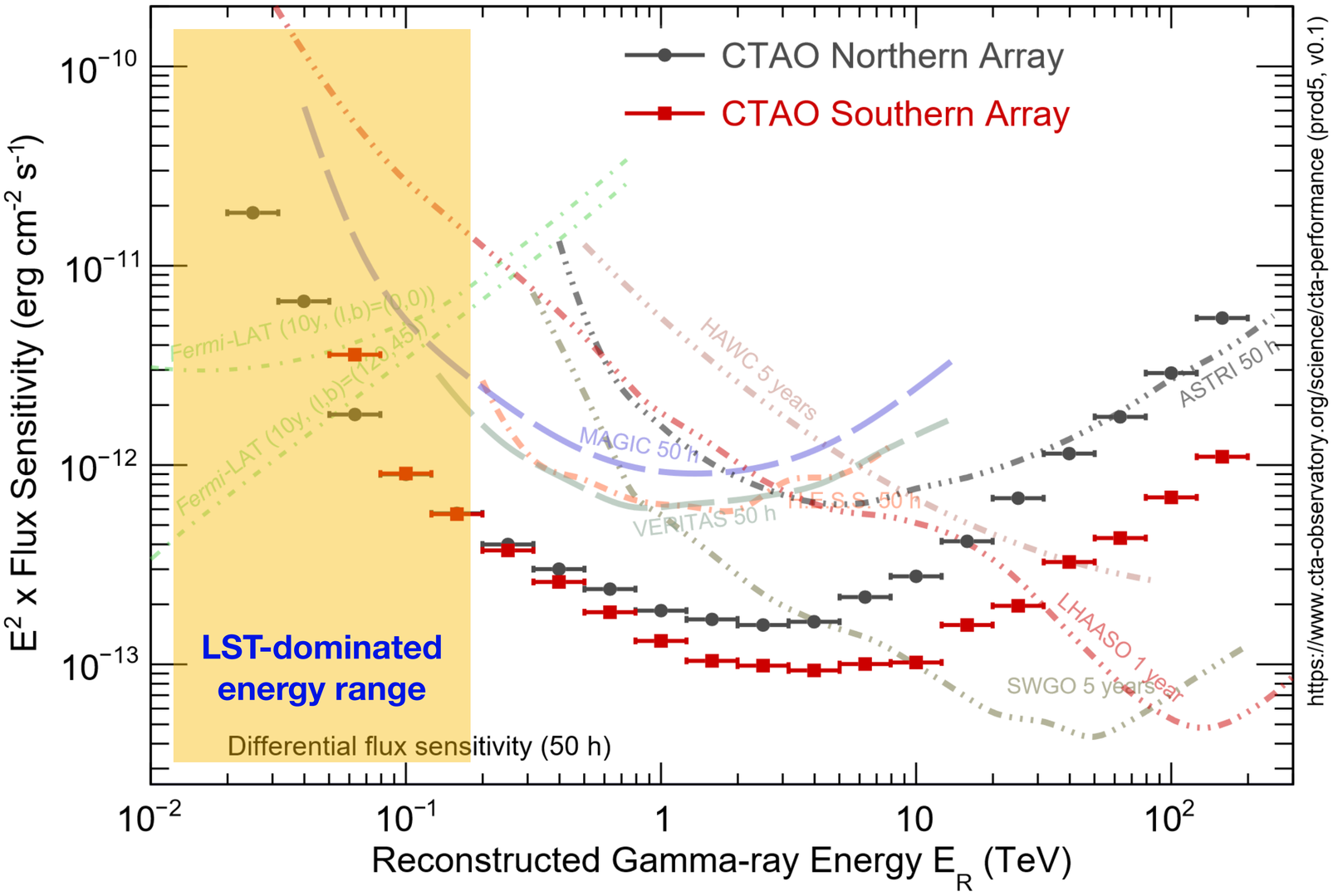






CTA performance (Alpha configuration)

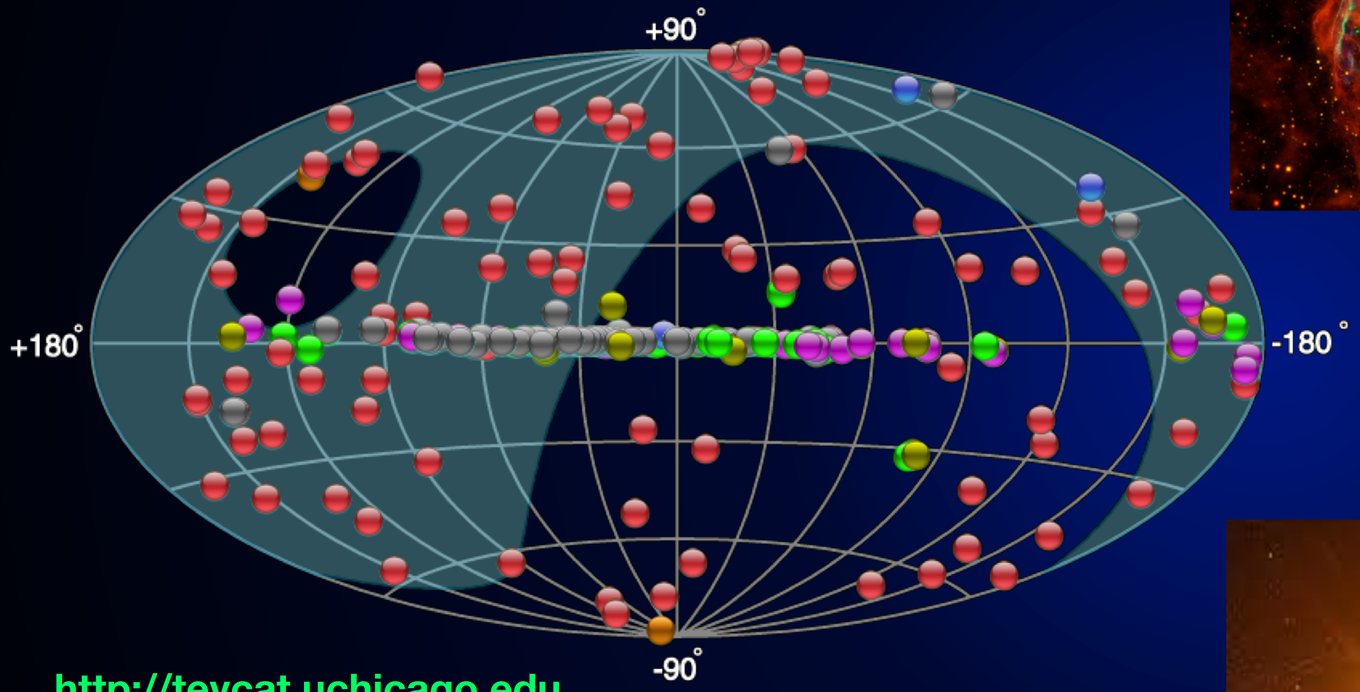
https://www.cta-observatory.org/science/ctao-performance/



- LSTs dominate the performance below 100 GeV
- Largely outperforms space instruments for short-timescale phenomena in the overlapping energy range (downside: modest FOV!)
- Significantly better angular & energy resolution than all other ground-based facilities

LST Science drivers

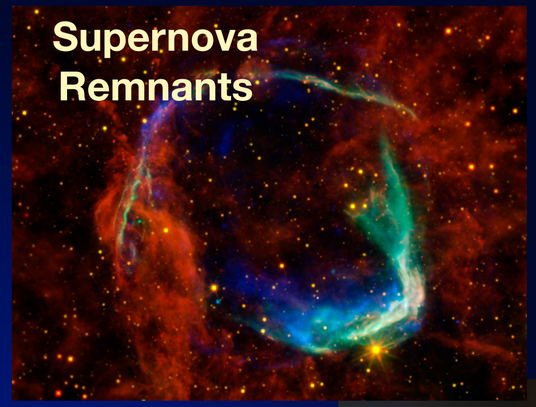
- Origin and Role of Cosmic Rays
- Search for Dark matter and new physics
- Probing extreme environments (AGNs, SNRs...)



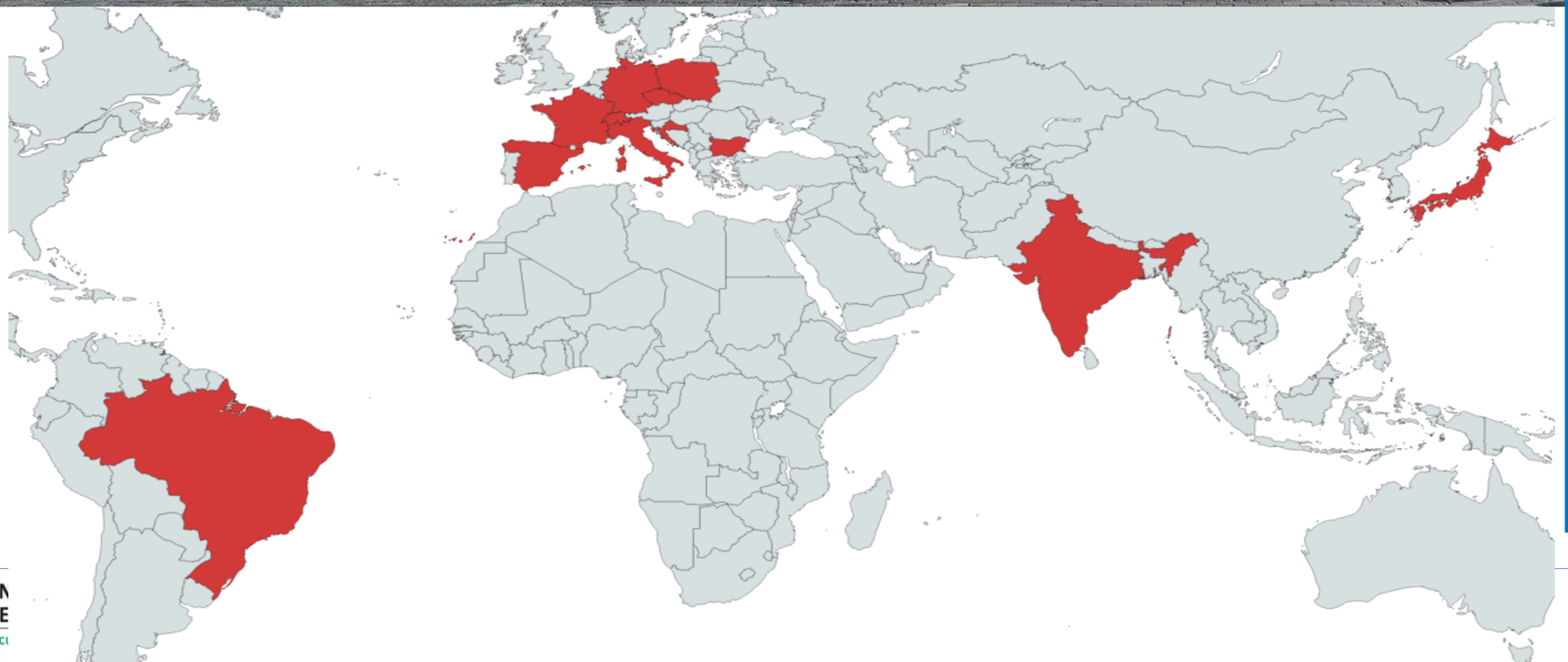
http://tevcat.uchicago.edu

More than 220 HE sources discovered so far

CTA has the potential to discover thousands of sources



LST collaboration



	Members	Scientist	Authors
Bulgaria	3	3	3
Brazil	3	2	2
Croatia	13	13	13
Czech Rep.	15	15	9
France	37	16	18
Germany	34	27	27
India	2	2	2
Italy	55	46	36
Japan	73	69	54
Poland	2	2	2
Spain	77	42	49
Switzerland	13	12	12
Total	327	249	227

Current status

The CTA Large-Sized Telescope (LST)

Stucture	
Alt-Azimuth Mount on a circular rail	
Tubular Structure in CFRP & Steel	
Full Telescope Weight	100 tons
Maximum time for repositioning	20 s
Optics - Parabolic Mirror	
Primary Mirror Diameter	23 m
Focal Length	28 m
Effective area including shadowing	368 m^2
Camera	
Field of View	4.5°
Number of Pixels	1855
Pixel size	0.1°
Photo Sensor	PMT
Signal sampling rate	GHz

- LST-1, the prototype LST, inaugurated in October 2018 at ORM, currently completing its commissioning phase

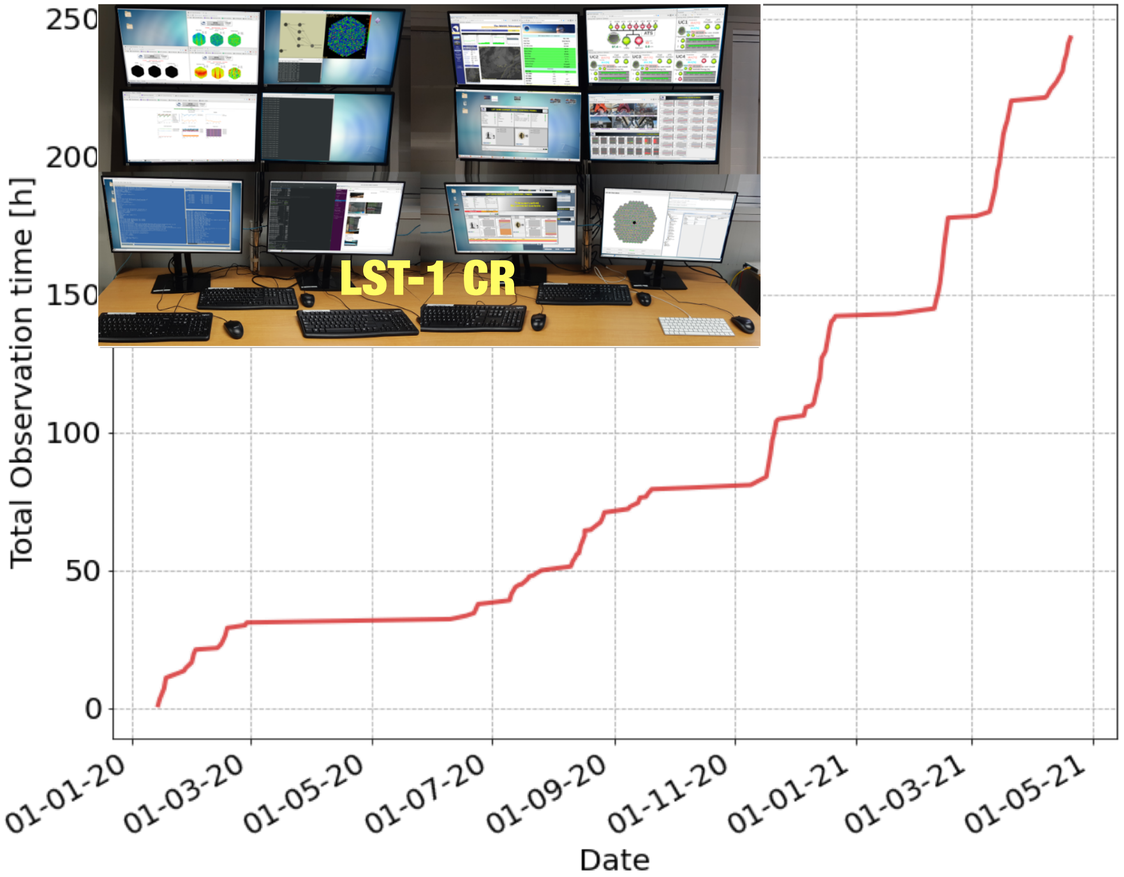
The CTA Large-Sized Telescope (LST)

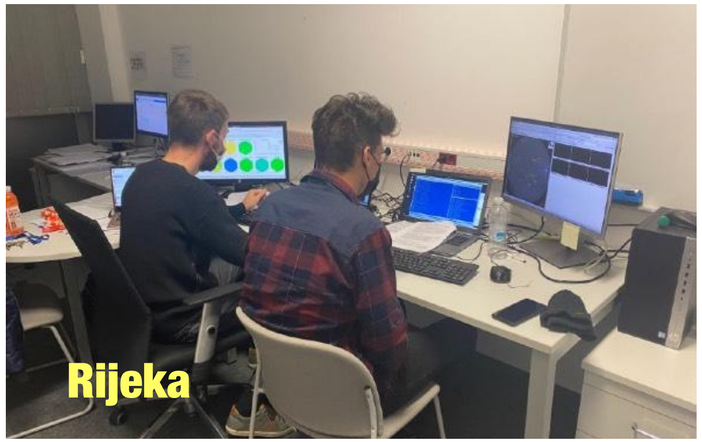
Stucture	
Alt-Azimuth Mount on a circular rail	
Tubular Structure in CFRP & Steel	
Full Telescope Weight	100 tons
Maximum time for repositioning	20 s
Optics - Parabolic Mirror	
Primary Mirror Diameter	23 m
Focal Length	28 m
Effective area including shadowing	368 m^2
Camera	
Field of View	4.5°
Number of Pixels	1855
Pixel size	0.1°
Photo Sensor	PMT
Signal sampling rate	GHz

- LST-1, the prototype LST, inaugurated in October 2018 at ORM, currently completing its commissioning phase

LST-1 commissioning

https://pos.sissa.it/395/872

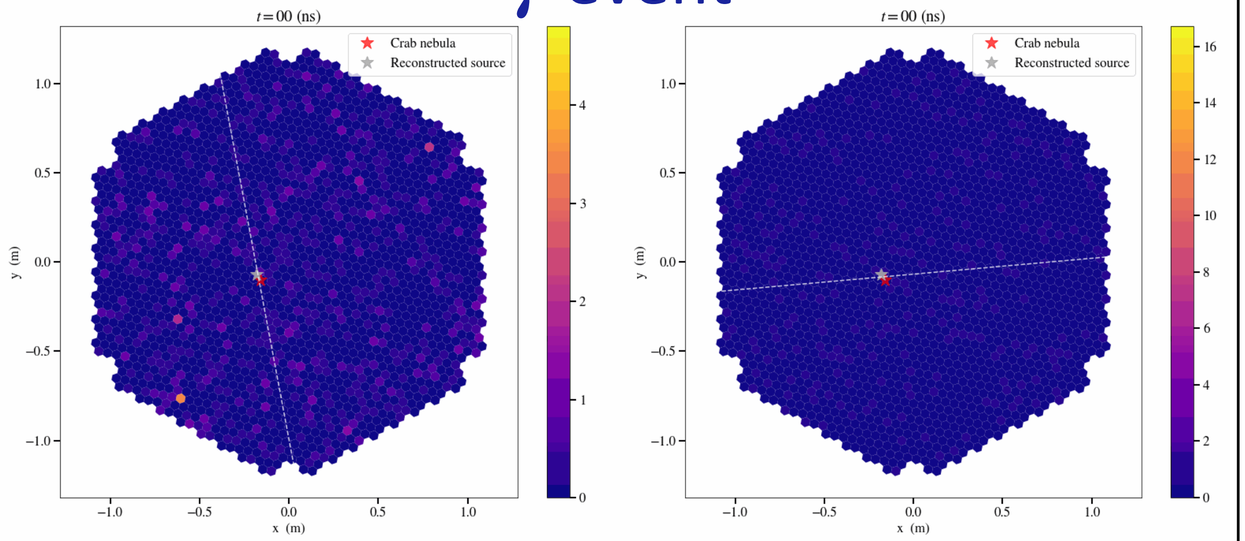




- Implemented semi-remote operations, triggered by Covid-19 pandemic
- Telescope operated remotely, plus at least two people on-site
- Data processed at dedicated on-site IT center contributed by U-Tokyo

LST-1 events reconstruction

γ event



Baseline analysis based on "**Hillas parameters**" and other image features

⇩

Classification & parameter regression algorithms (Random Forest) trained on **MC simulations**

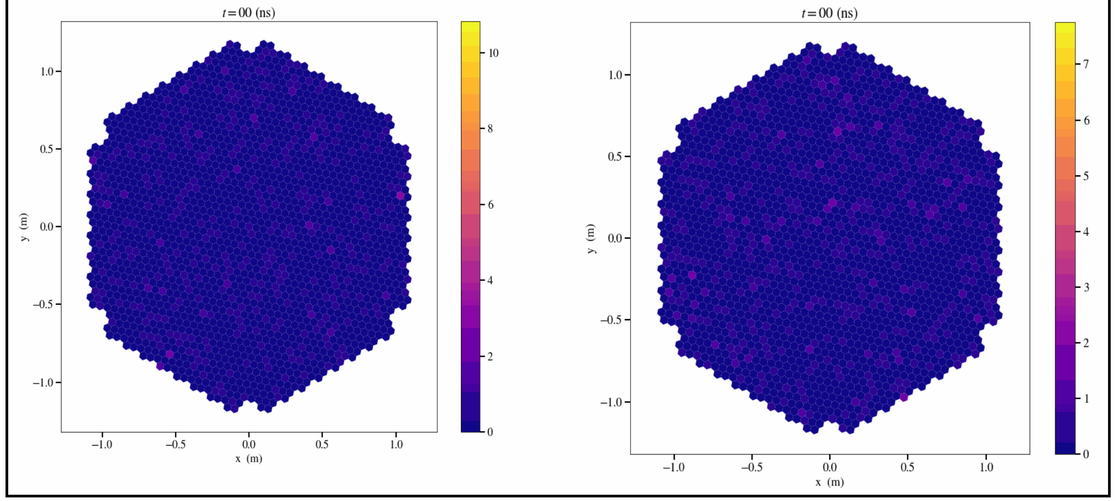
⇩

Reconstructed **direction, energy, and nature** of the primary - "gammaness"

Trigger rate is (6 – 10) × 10^3 events/s
A few example events recorded in one minute on 2020-11-20

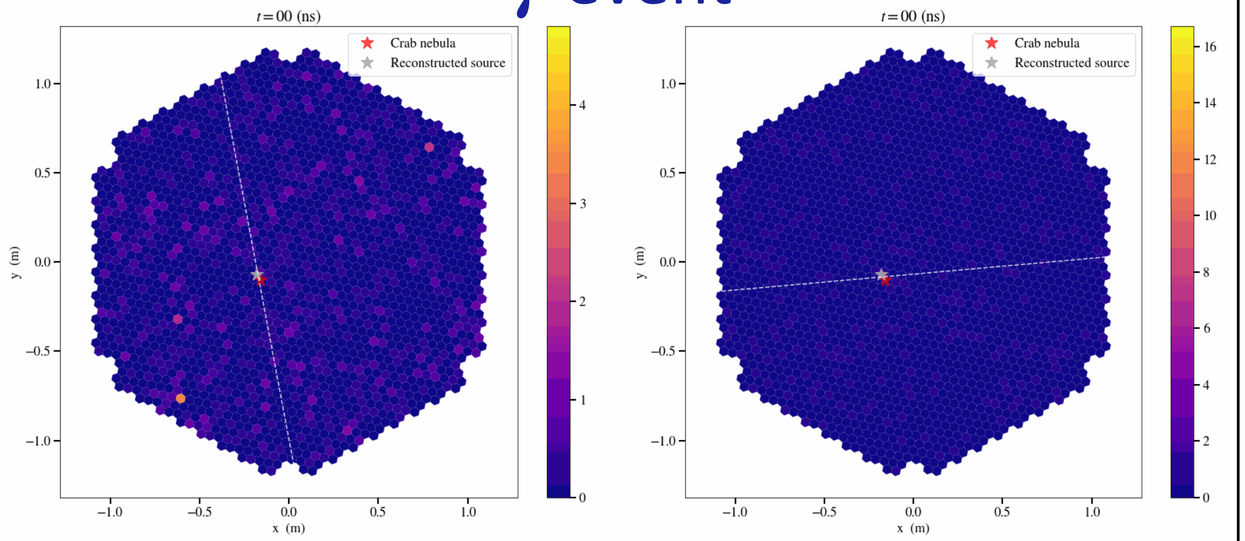
Clean, **isolated μ** are useful for the telescope calibration / MC tuning

⇩ ⇩



LST-1 events reconstruction

γ event



Baseline analysis based on "**Hillas parameters**" and other image features

⇩

Classification & parameter regression algorithms (Random Forest) trained on **MC simulations**

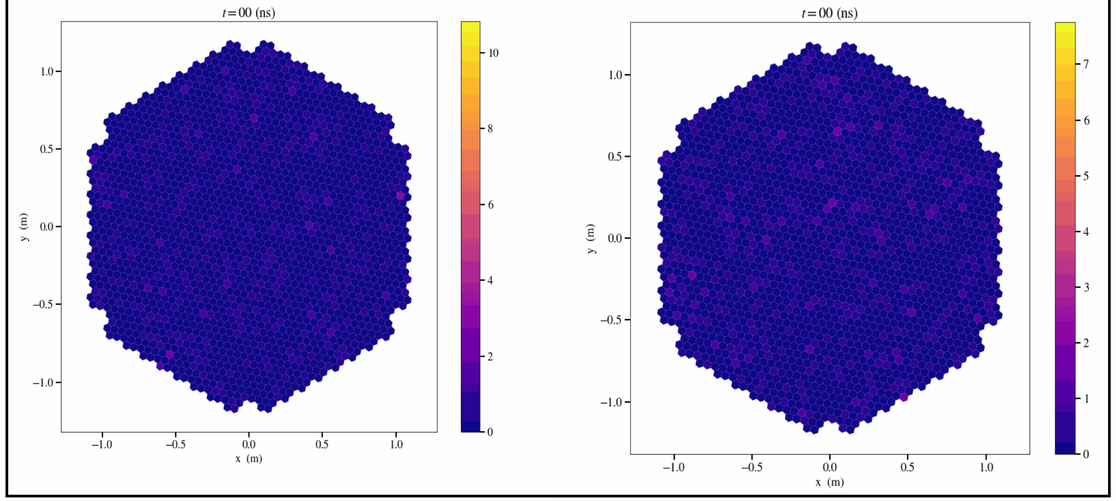
⇩

Reconstructed **direction, energy, and nature** of the primary - "gammaness"

Trigger rate is (6 – 10) × 10^3 events/s
A few example events recorded in one minute on 2020-11-20

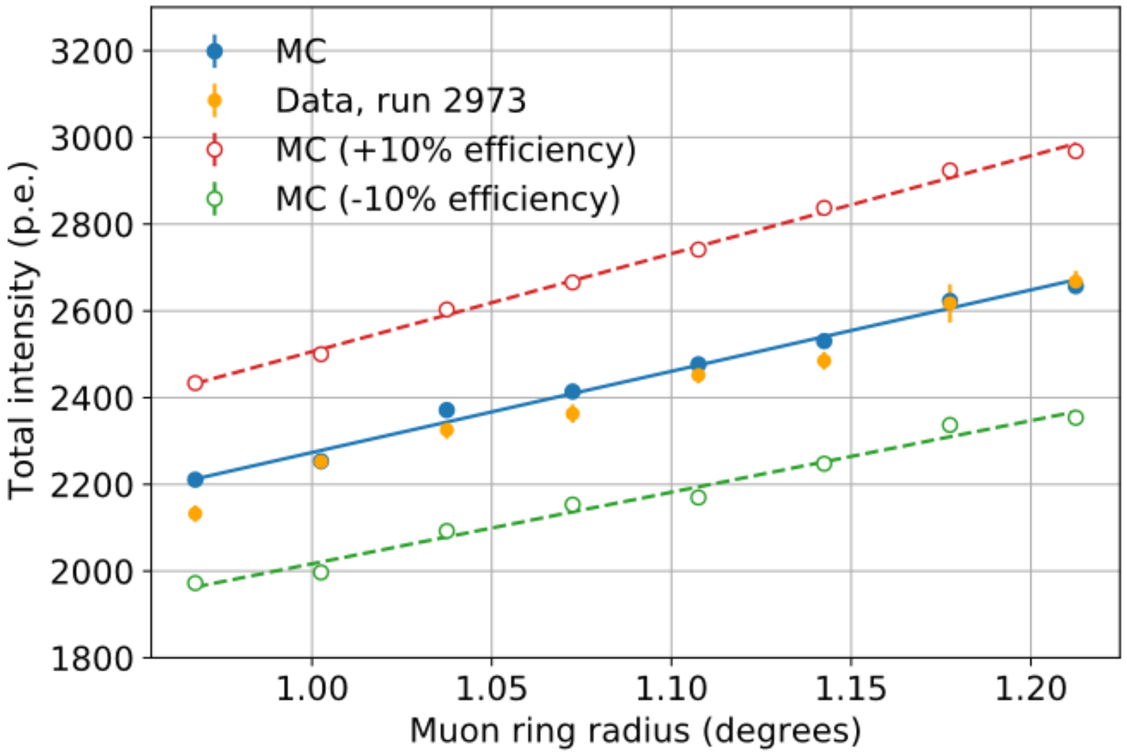
Clean, **isolated μ** are useful for the telescope calibration / MC tuning

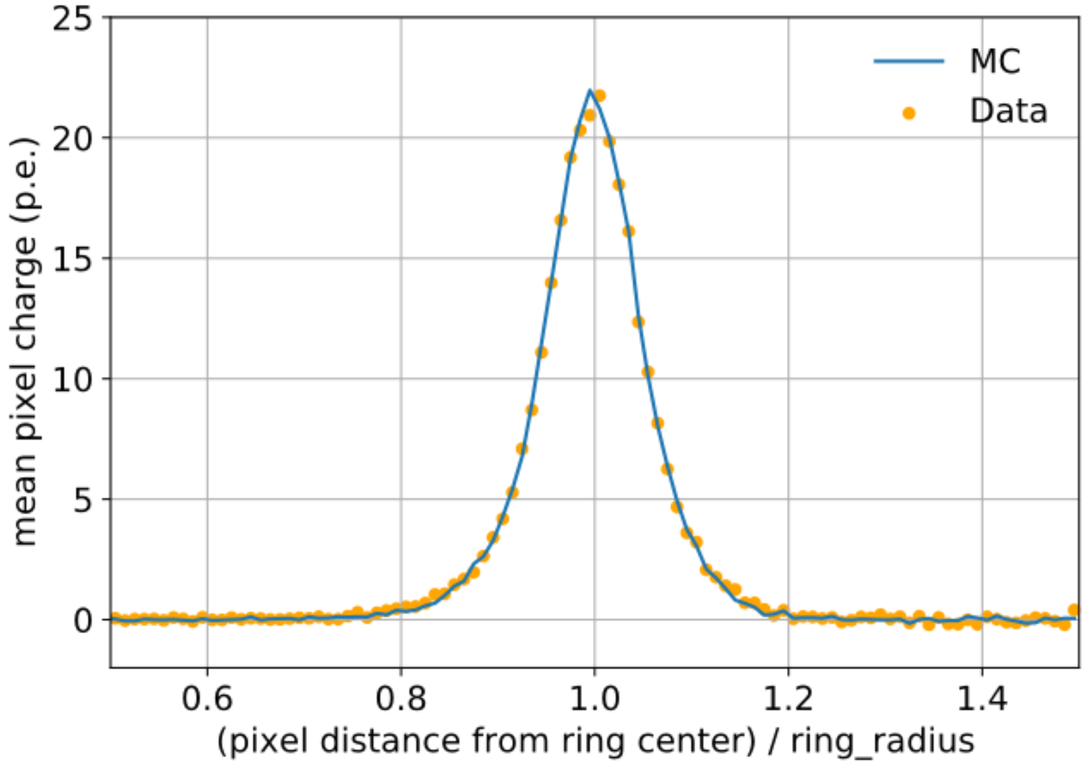
⇩ ⇩



Tuning MC simulations on muon rings

- Monte Carlo simulations are a key tool for atmospheric Cherenkov telescopes
- Isolated muon rings allow to tune the overall light collection efficiency of the system, as well as its optical PSF, via the ring widths ⇩ ⇩



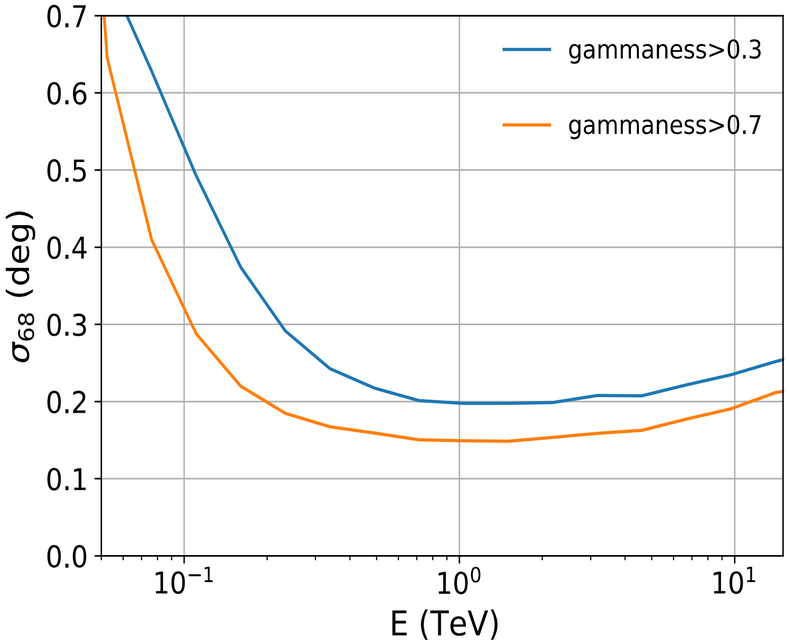


https://pos.sissa.it/395/806

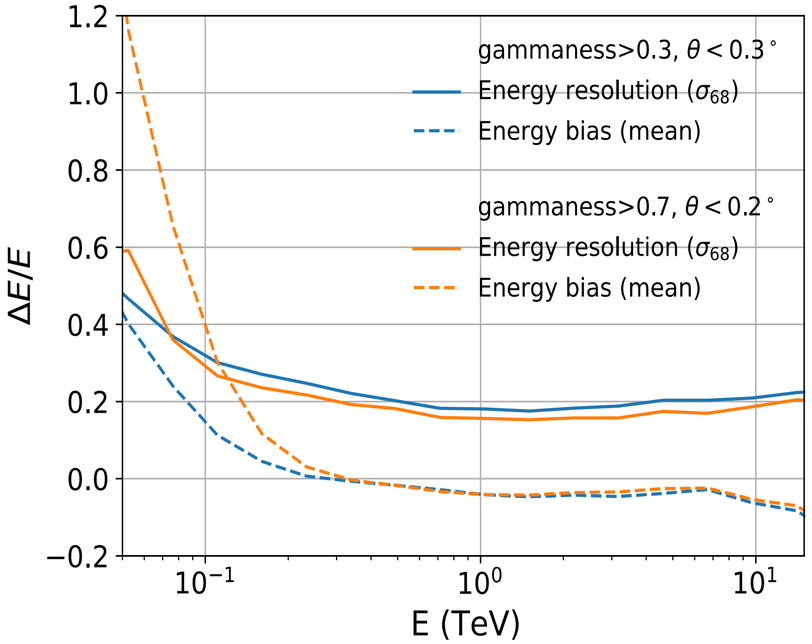
LST-1 standalone performance

https://pos.sissa.it/395/806

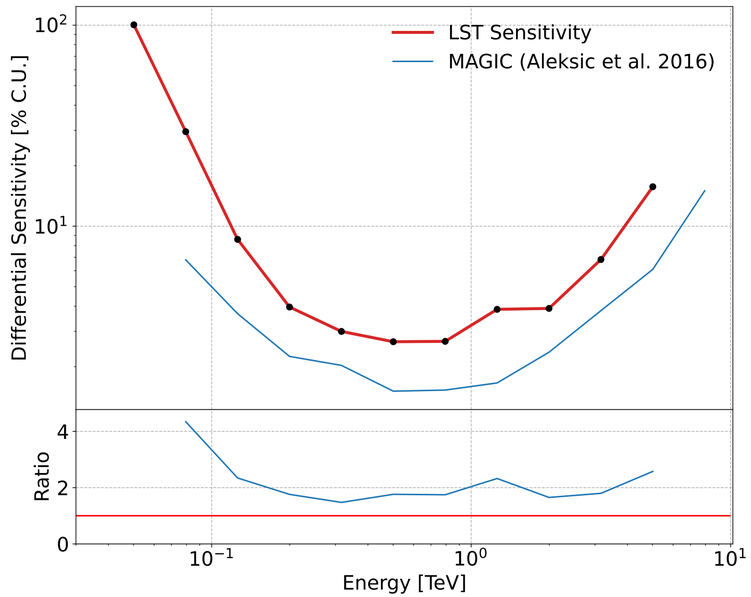
Angular resolution



Energy resolution



Flux sensitivity

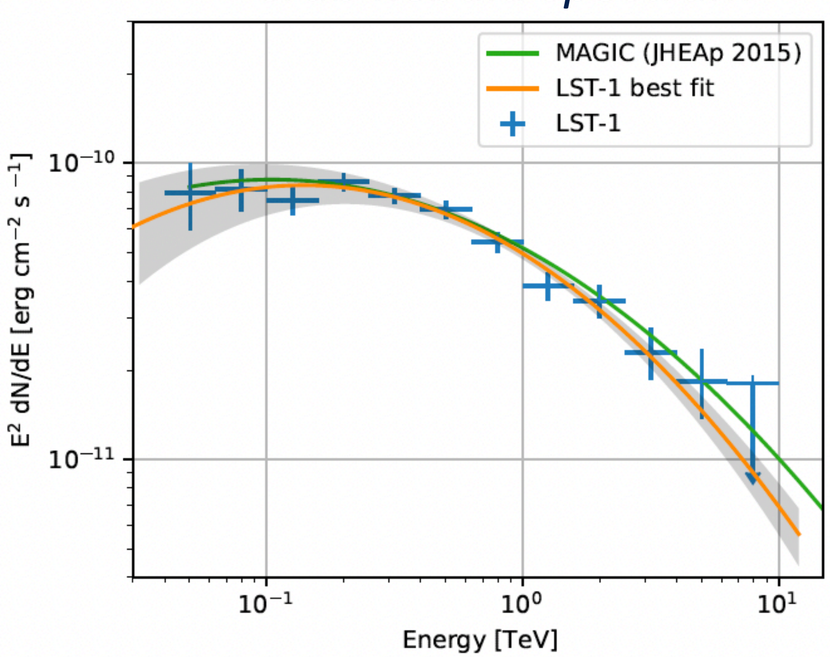


- Performance of a single imaging atmospheric Cherenkov telescope is limited by the lack of 3-D reconstruction of the shower location ($\Longrightarrow$ relatively poor background rejection, especially at low E)
- LST-1 alone does not outperform current facilities in the overlapping energy range, but reaches lower energies ($\Longrightarrow$ already competitive for certain physics cases)

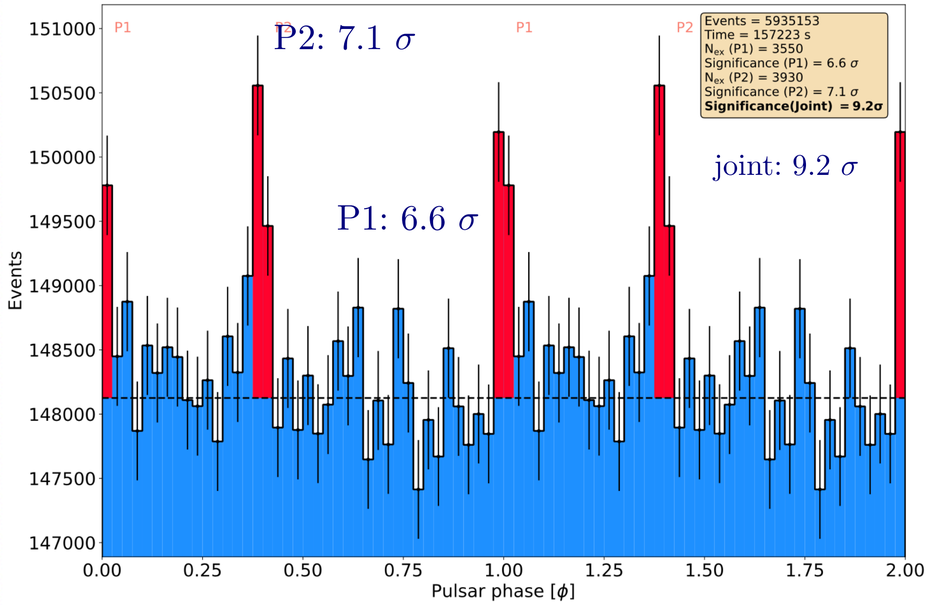
LST-1 early physics results

https://pos.sissa.it/395/806

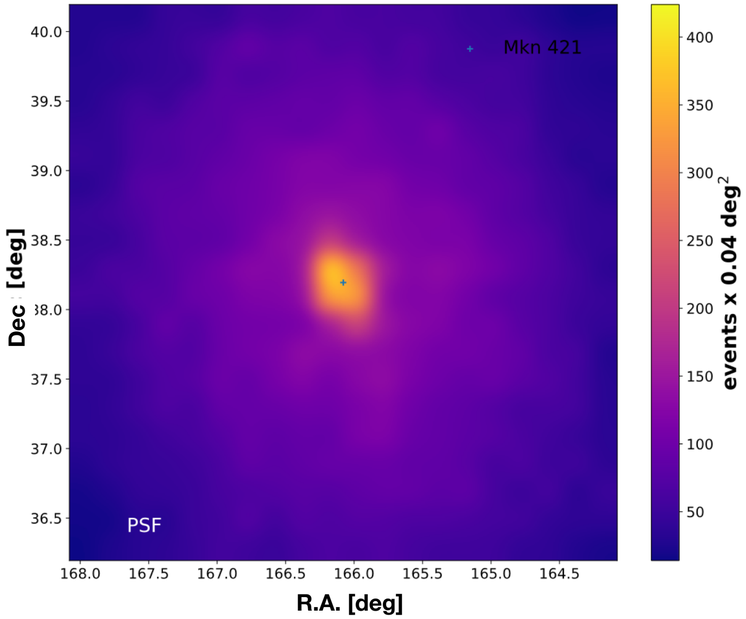
Crab nebula spectrum



Crab pulsar phaseogram



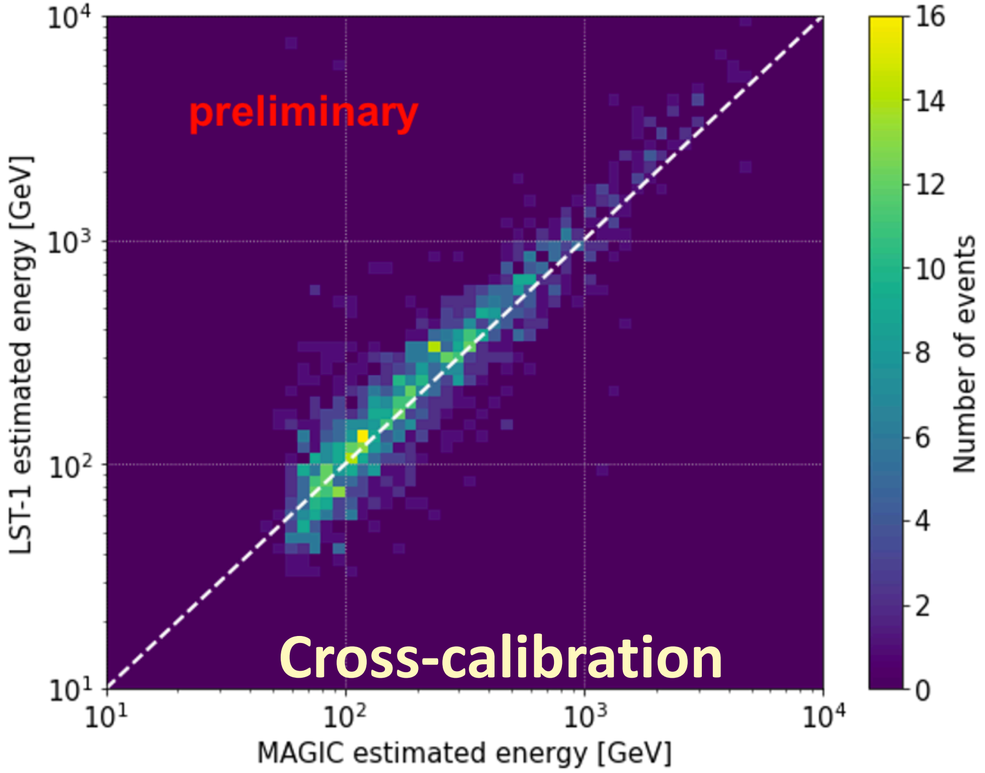
Mrk 421 significance map

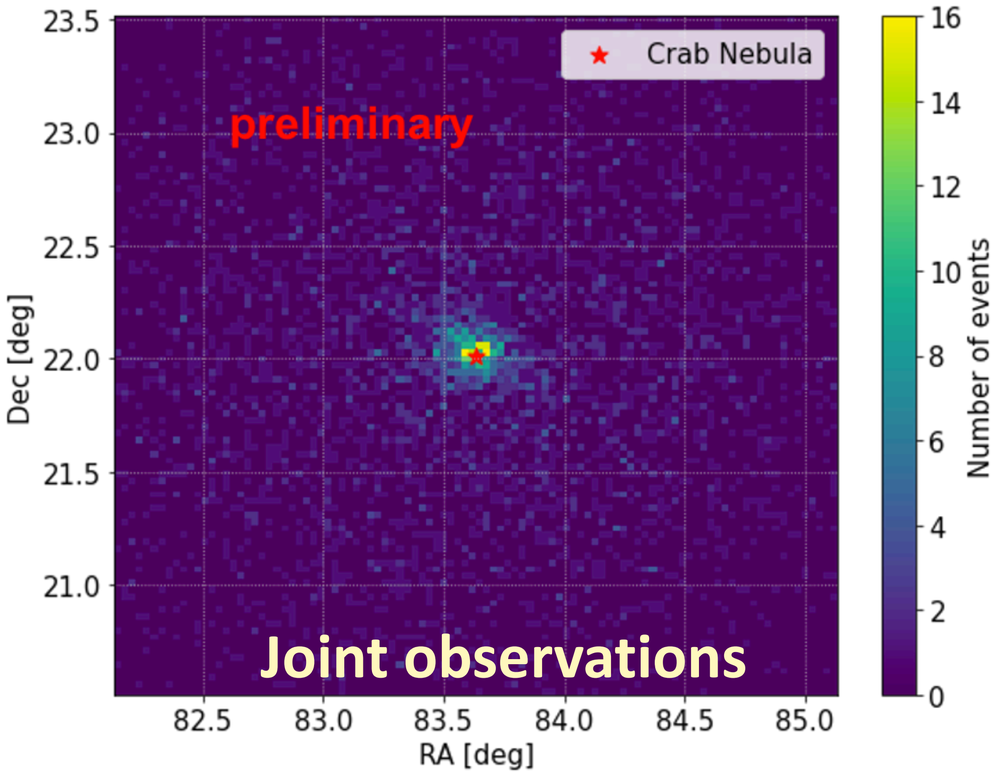


- Detection of Crab nebula, Crab pulsar and several known AGN up to z~0.5 (Mrk 421, Mrk 501, 1ES1959+650, 1ES0647+250, PG1553+113)
- First LST-1 ATel: BL Lac flare on July 11th 2021, ATel #14783
- Higher-level spectral analysis using Gammapy: gammapy.org

A **Python** package for **gamma-ray** astronomy

LST-1 and the MAGIC telescopes





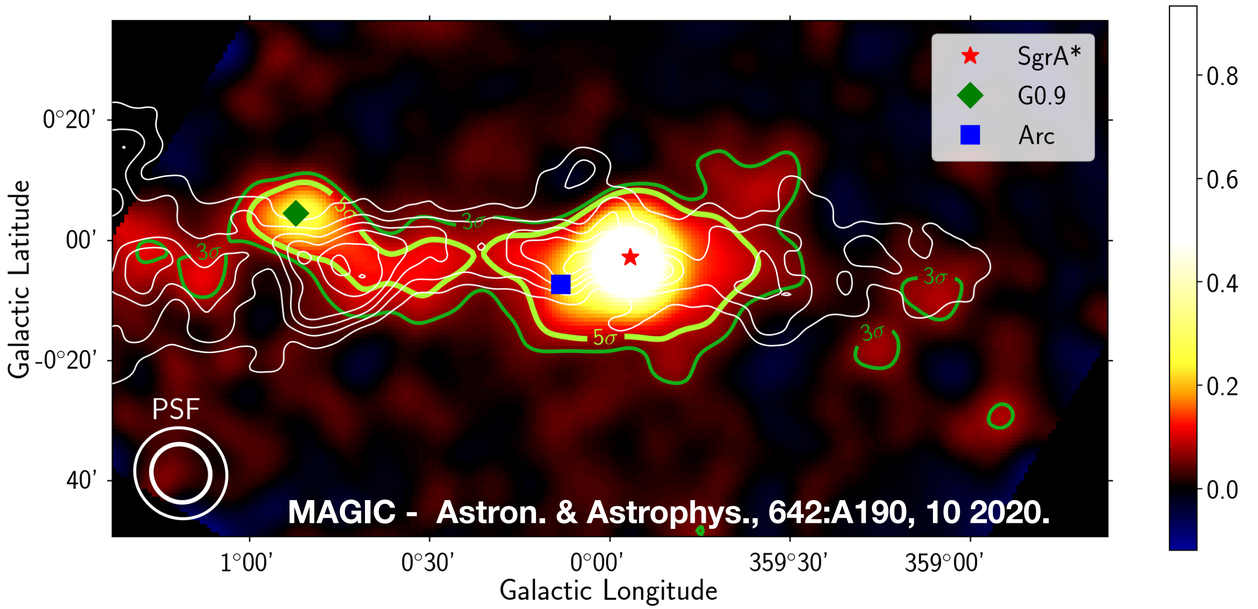
- Cross-calibration based on the observation of the same showers‡
- First joint stereoscopic observations ongoing (better shower reconstruction, but energy threshold driven by MAGIC's)

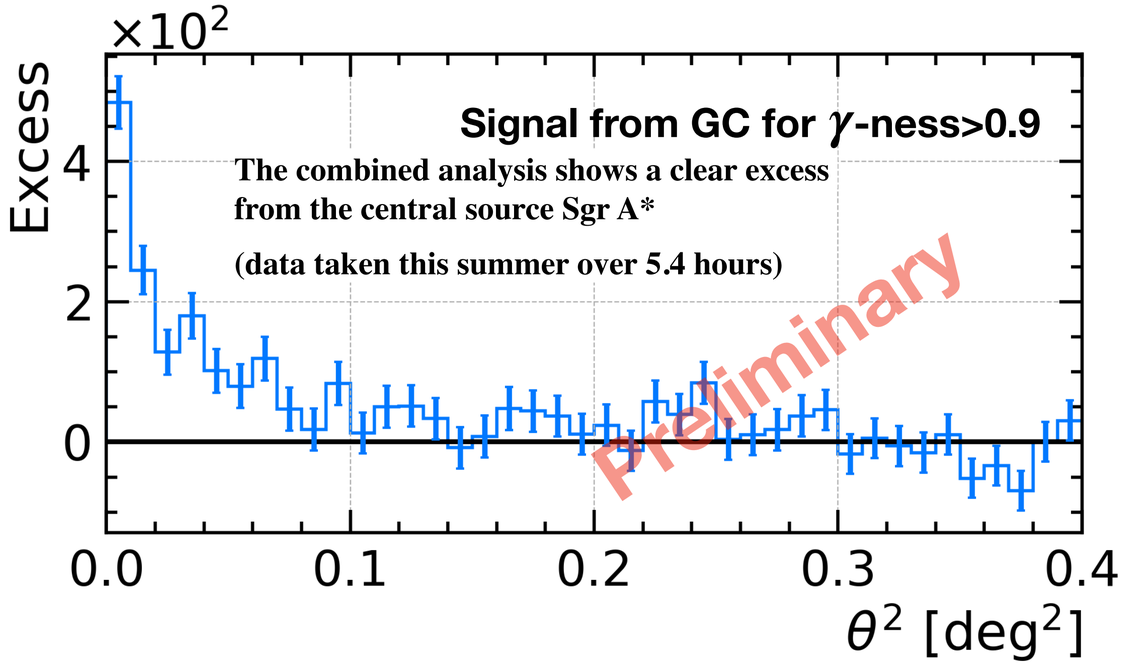
https://pos.sissa.it/395/724

‡*Events coincidence done with a software timing based on timestamps*

Joint observation of Galactic Center

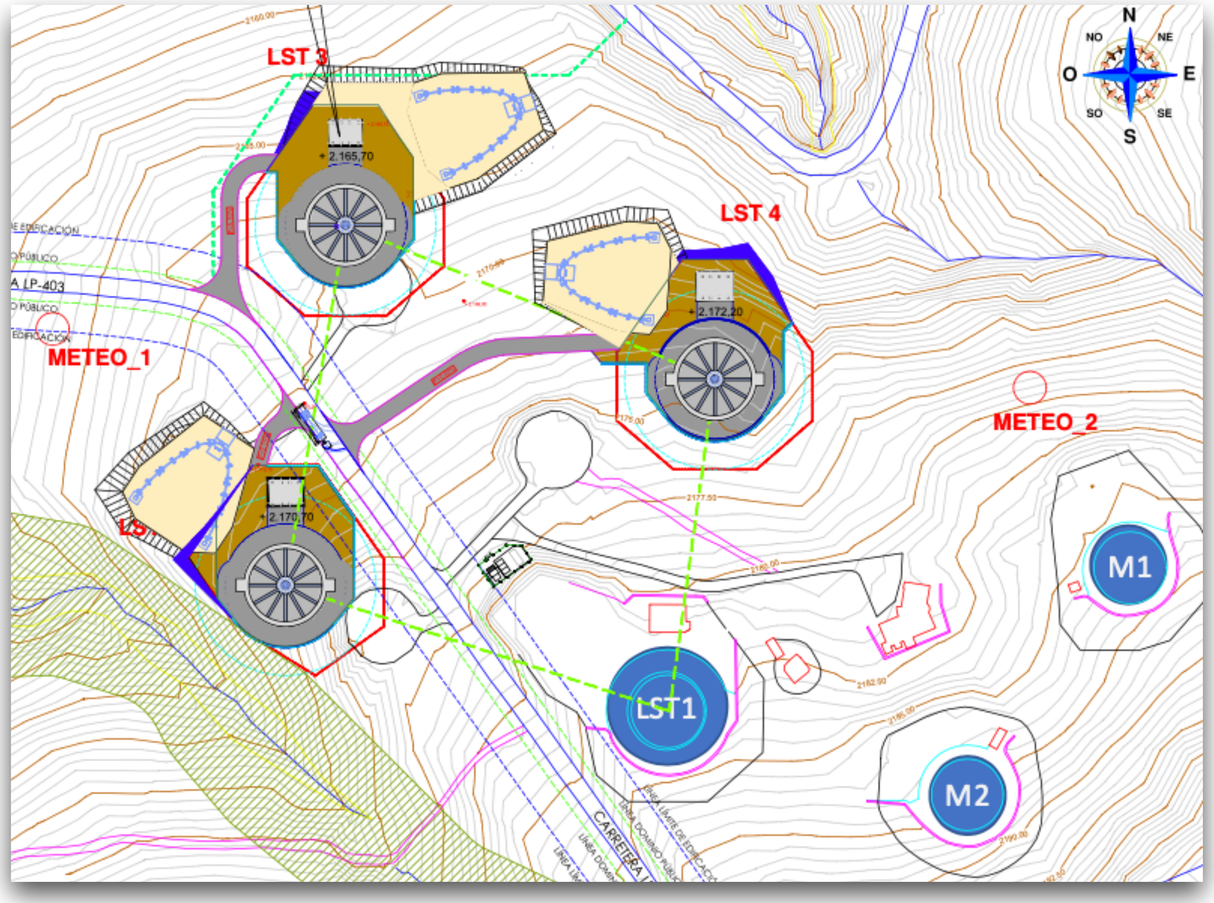
- **The Galactic Center (GC) is one of the target regions for MAGIC + LST-1 observations, given the abundance of science targets (Sgr A*, Gal. diffuse emission and Dark Matter)**
- The GC region culminates at large zenith angle of 58 degree seen at La Palma, thus enlarging the light pool and increasing the efficiency of the stereo triggering of LST array
- At the same time, the complexity of the area, requires improved the angular resolution in order to understand/constrain the origin of the gamma-ray emission





What's next

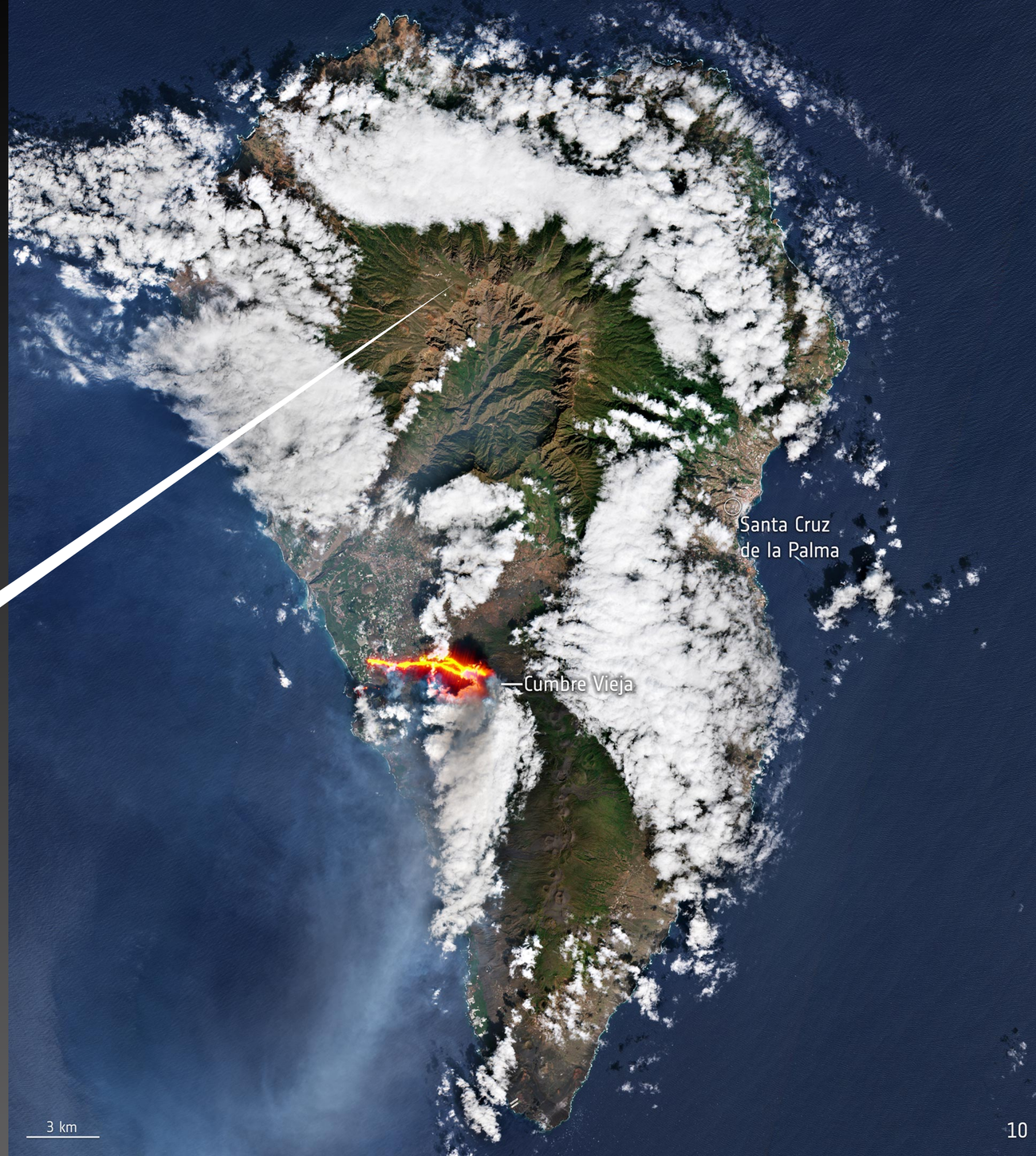
- Thanks to a large effort by the LST team, the project is healthy and progressing.
- From prototype to first CTA LST telescope
  - CDR was passed and will be closed in 2022
  - Strong effort to complete LST1 Commissioning completion to release pressure and gain momentum for the LST2-4 construction.
- LST2-4 construction is about to start.



- Looking forward deliver further physics data soon ……..

When Volcano will allow....

- On the 19th of September the Cumbre Veija erupted
- A major event, luckily no dead people but major impact on the territory
- Volcano is far away from ORM but ashes and gas emission can reach ORM.
- All activity are suspended until the eruption will stop



Cumbre Vieja volcano eruption seen from the Observatory Los Roques de los Muchachos

Thank you for your attention

https://www.cta-observatory.org/status-volcanic-eruption-la-palma/