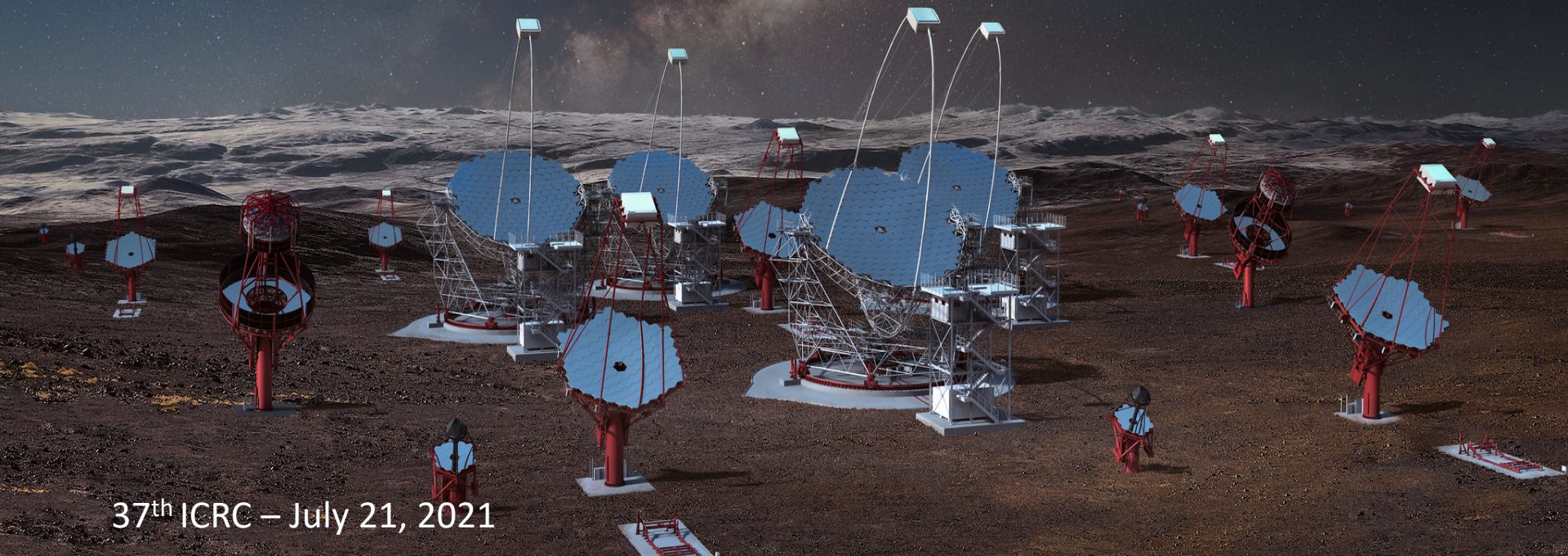


Cherenkov Telescope Array Observatory: the World's largest VHE gamma-ray observatory

Roberta Zanin – CTAO Project Scientist

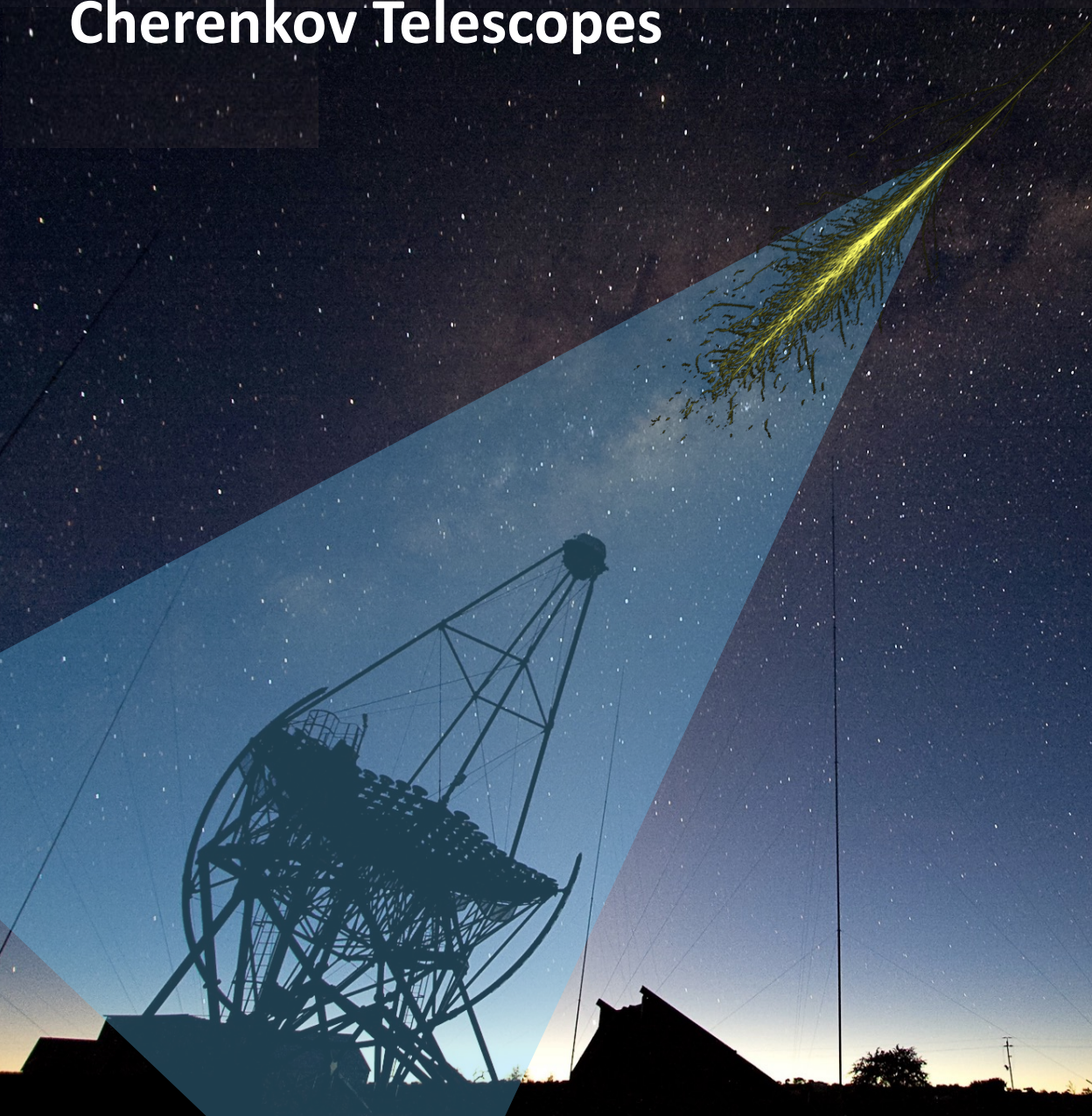
Roberta.Zanin@cta-observatory.org

on behalf of the CTA Observatory, CTA Consortium & the CTA LST Collaboration

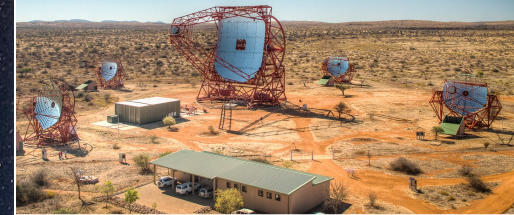


- **Introduction**
 - **Why CTA?**
 - **The CTA design**
- **Few representative science cases**
- **First results from LST-1:
the first CTA telescope under commission**

Imaging Atmospheric Cherenkov Telescopes



H.E.S.S.



MAGIC



VERITAS

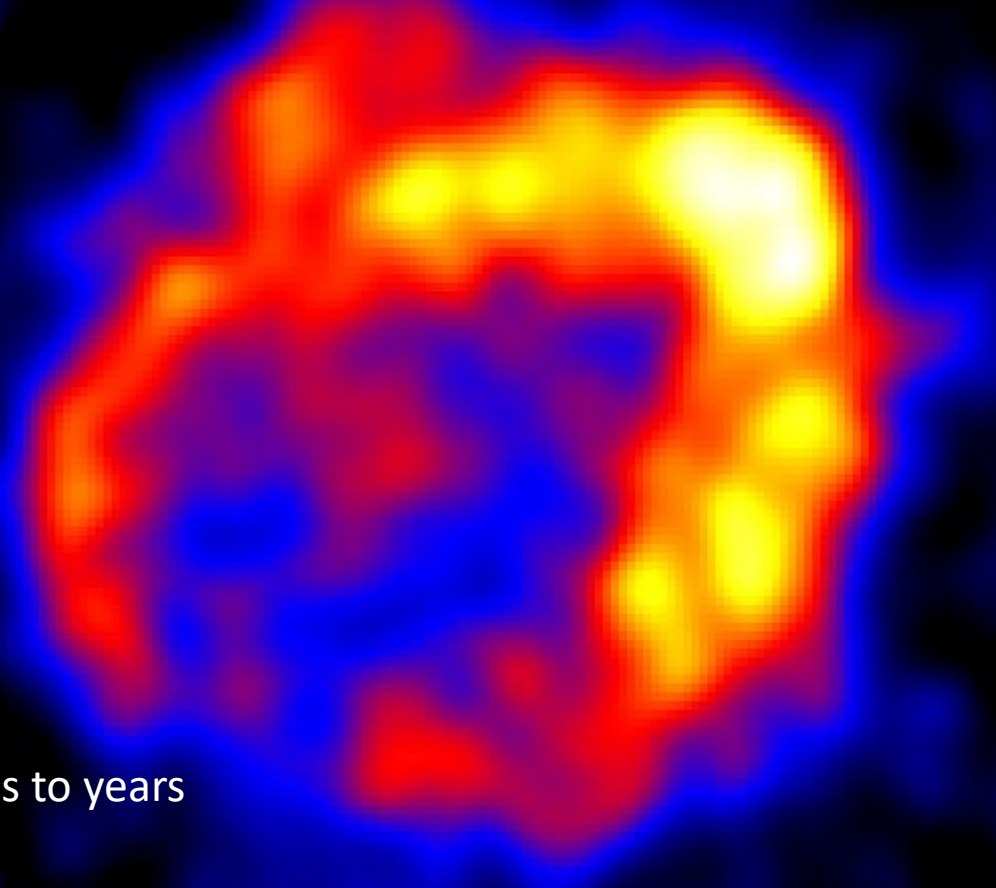


Real astronomy



A successful technique that has joined the astronomy world with precision measurements that provide insights to the physical mechanisms at the basis of the VHE emission

- more than 200 detected sources
- sky maps with 5' resolution
- light curves on all scales from minutes to years
- ~10 different emitting source classes



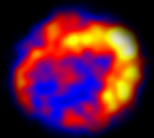
More to come

HESS Point Source

HAWC Point Source

HESS Extended Source (0.4°)

Gamma-ray
Luminosity 10^{34} erg/s



Design drivers for next generation IACT facility

SENSITIVITY $\times 10$

ARCMINUTE ANGULAR
RESOLUTION

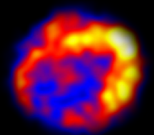
10% ENERGY
RESOLUTION

HESS Point Source

HAWC Point Source

HESS Extended Source (0.4°)

Gamma-ray
Luminosity 10^{34} erg/s



Design drivers for next generation IACT facility



SENSITIVITY x 10

**ARCMINUTE ANGULAR
RESOLUTION**

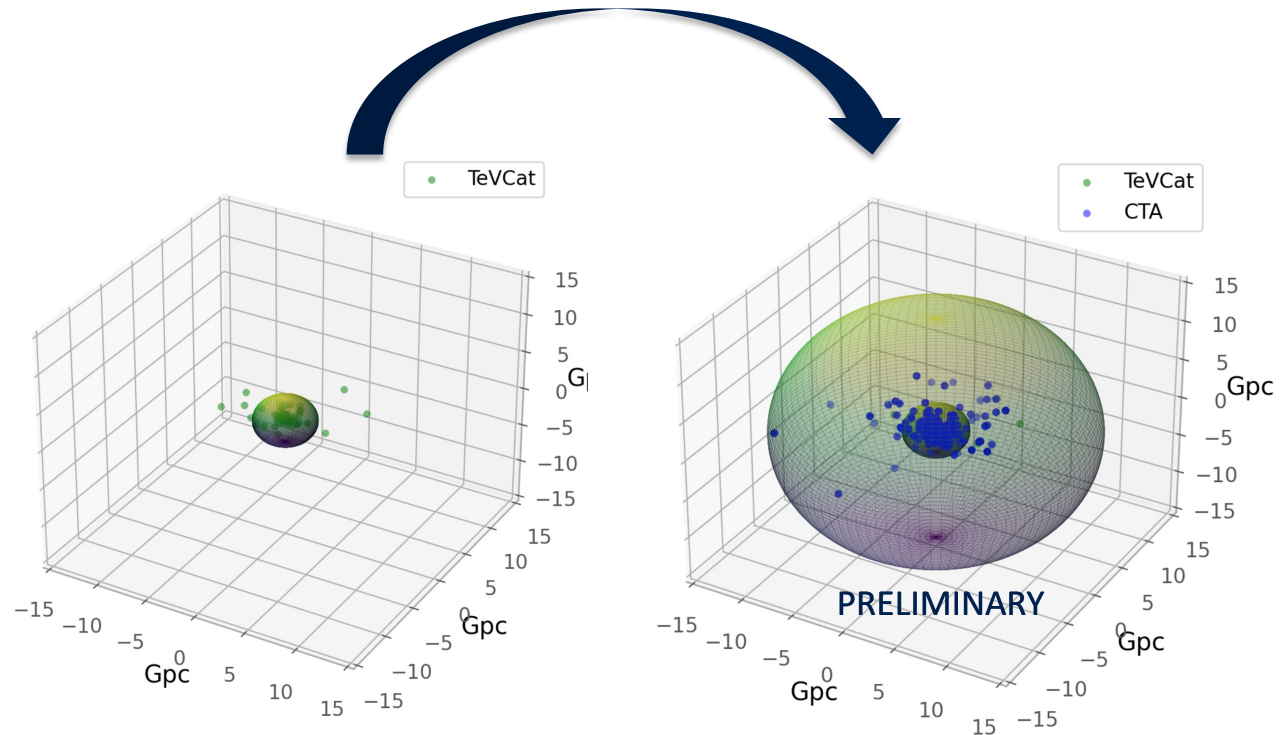
**10% ENERGY
RESOLUTION**

**WIDE ENERGY RANGE
20 GeV – 300 TeV**

FoV x 2

FULL SKY COVERAGE

**30 s RESPONSE TO
EXTERNAL ALERTS**



Credits to J.P. Lenain

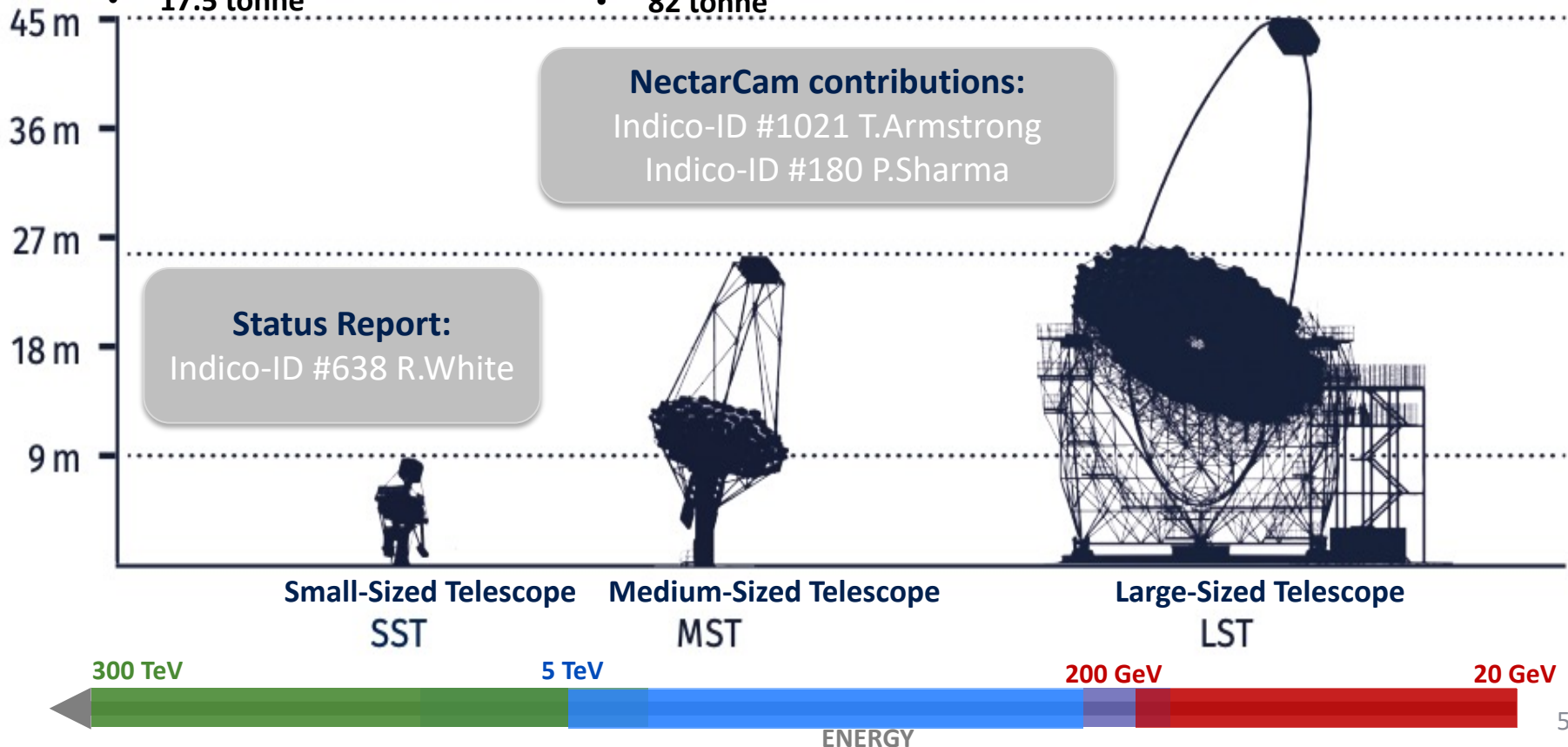
The Cherenkov Telescope Array Observatory



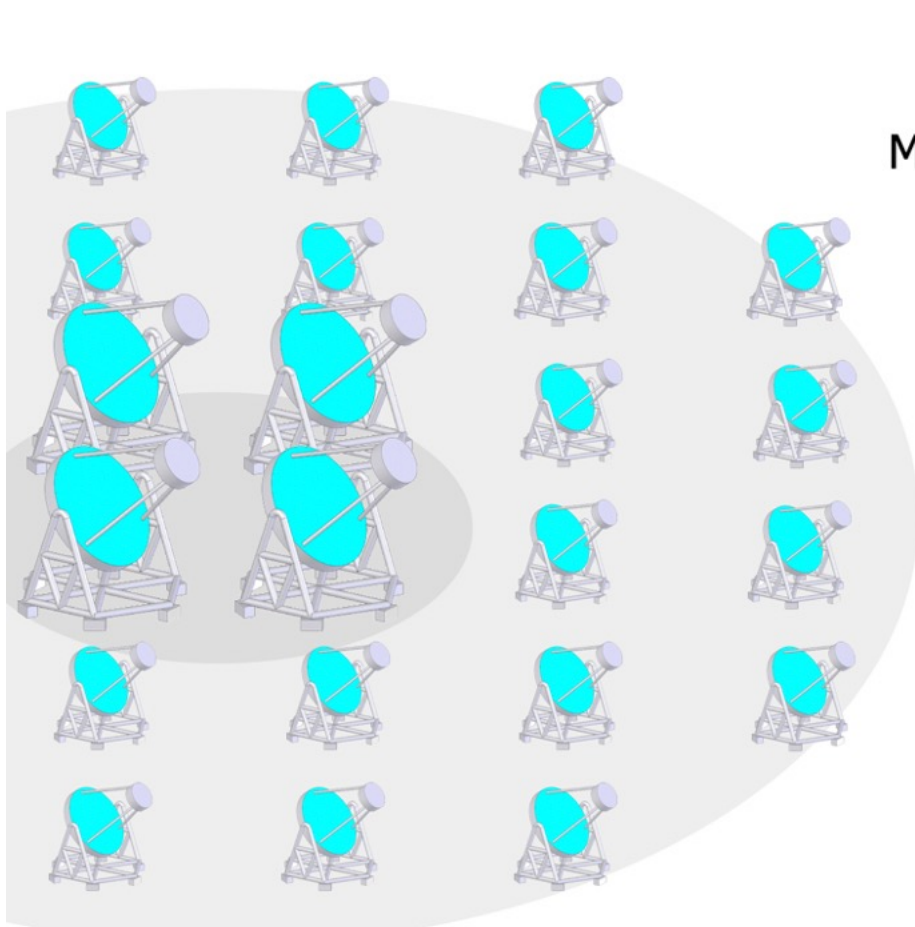
3 telescope designs



- 2-mirror Schwarzschild-Couder optical design
 - 4.3 m \varnothing primary reflective surface
 - SiPM camera: 2048 pixels (0.16°)
 - 8.8° FoV
 - 17.5 tonne
- Davies-Cotton optical design
 - 12 m \varnothing reflective surface
 - PMT camera – 2 designs:
 - NectarCam: 1855 pixels
 - FlashCam: 1764 pixels
 - $\sim 7^\circ$ FoV
 - 82 tonne
- Parabolic optical design
 - 23 m \varnothing reflective surface
 - PMT camera: 1855 pixels (0.1°)
 - 4.3° FoV
 - 100 tonne



Array design



Not to scale !

Mix of telescope types



$E_{th} \sim 20 \text{ GeV}$

100 m

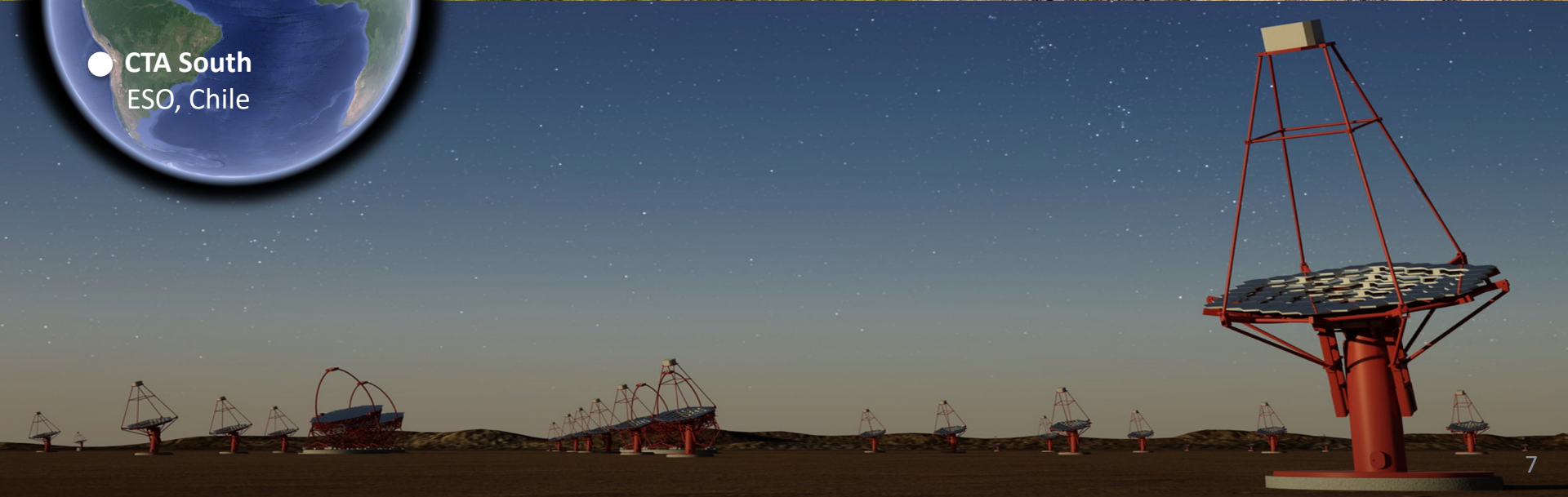
300 m

1 km

$E_{th} \sim 100 \text{ GeV}$

$E_{th} \sim 1 \text{ TeV}$

Full sky coverage

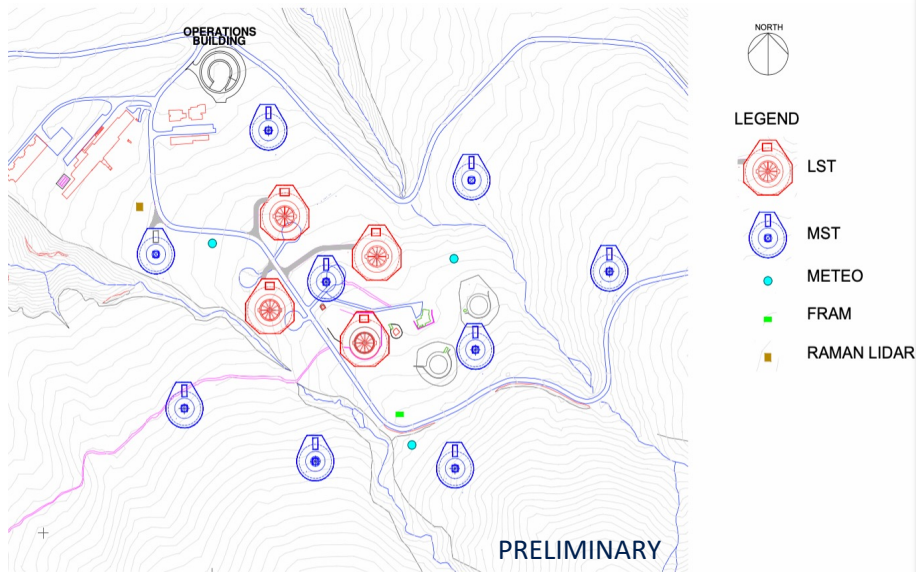


The two initial CTAO arrays: the Alpha Configuration



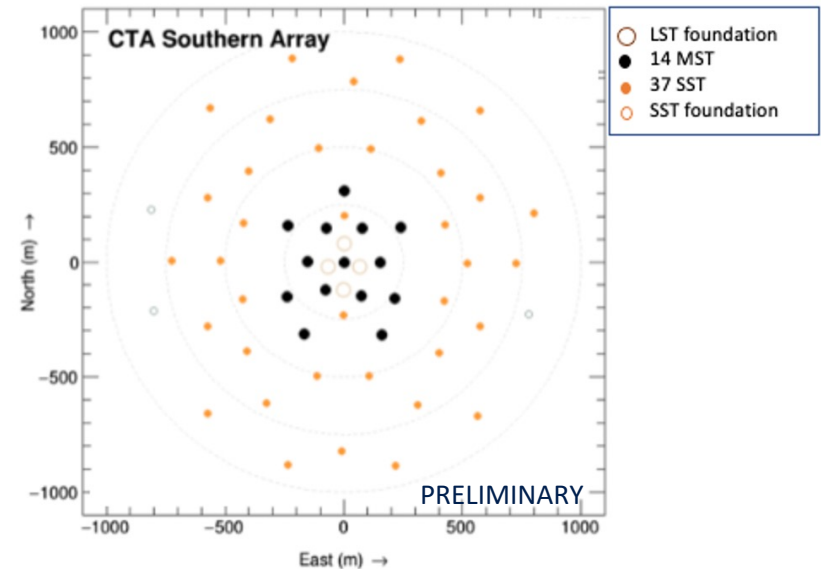
CTAO Northern Array

- 4 LSTs + 9 MSTs
- 0,25 km² footprint
- focus on extra-Galactic science

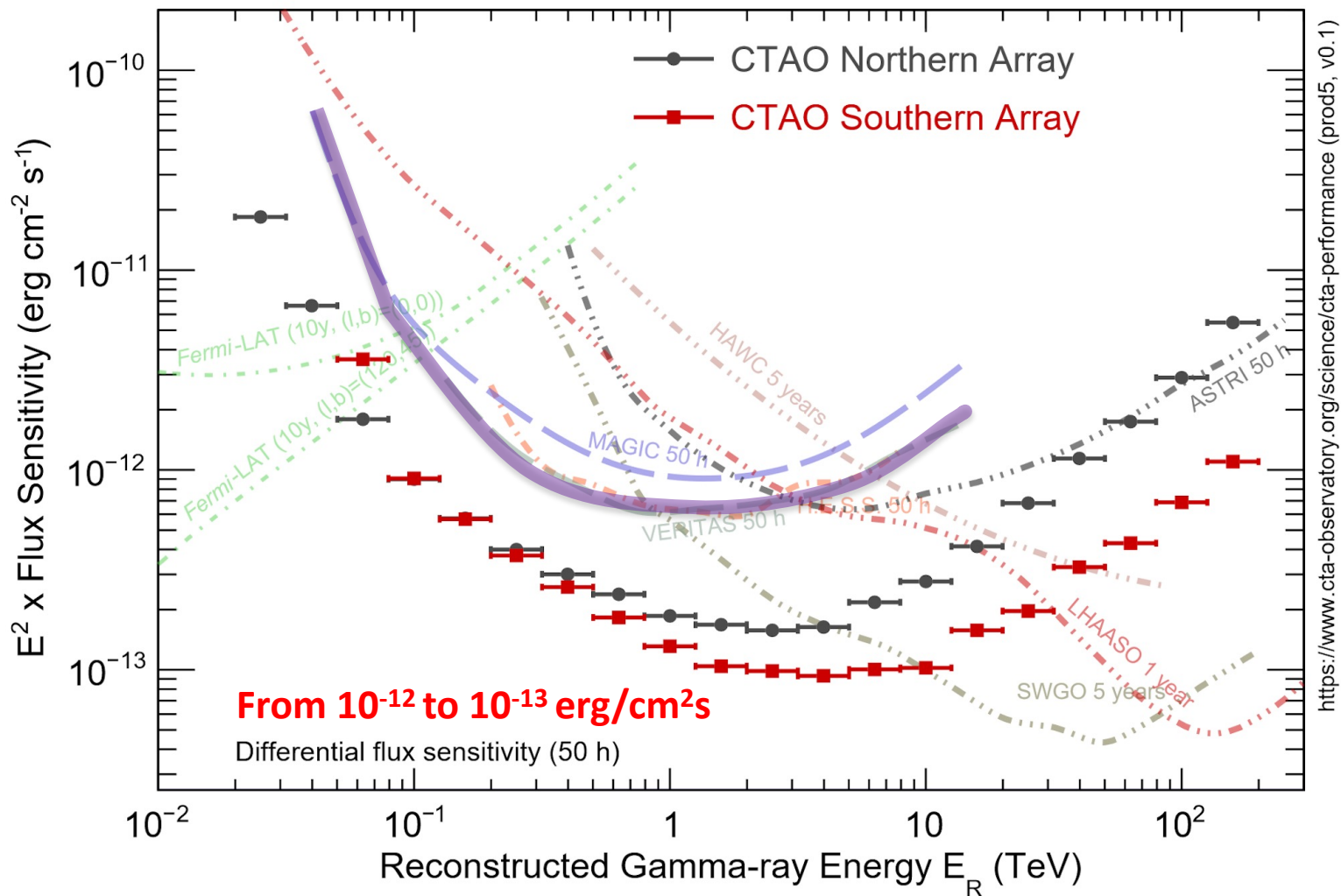


CTAO Southern Array

- 14 MSTs + 37 SSTs
- 3 km² footprint
- focus on Galactic science



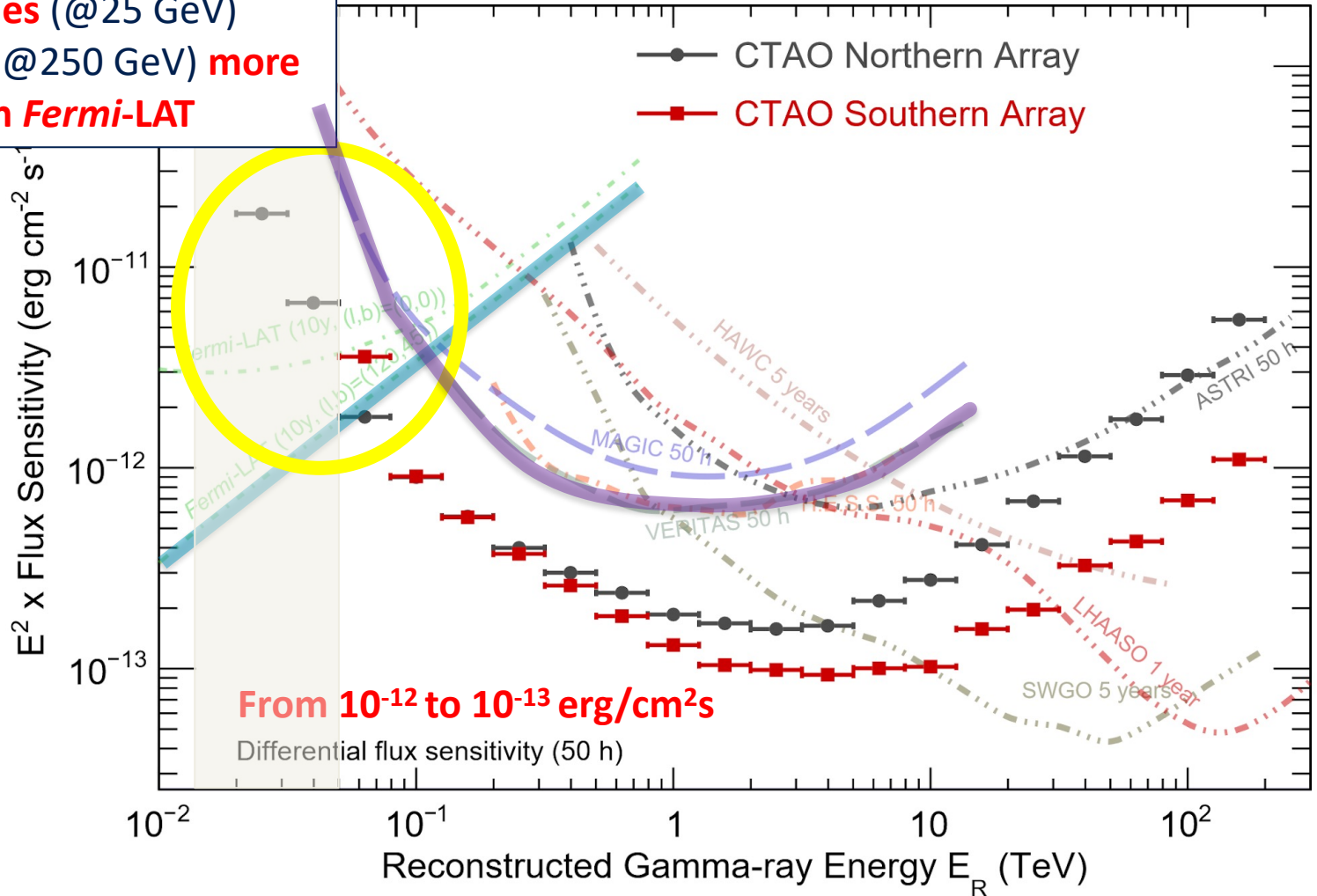
CTAO performance (Alpha Configuration)



CTAO performance (Alpha Configuration)

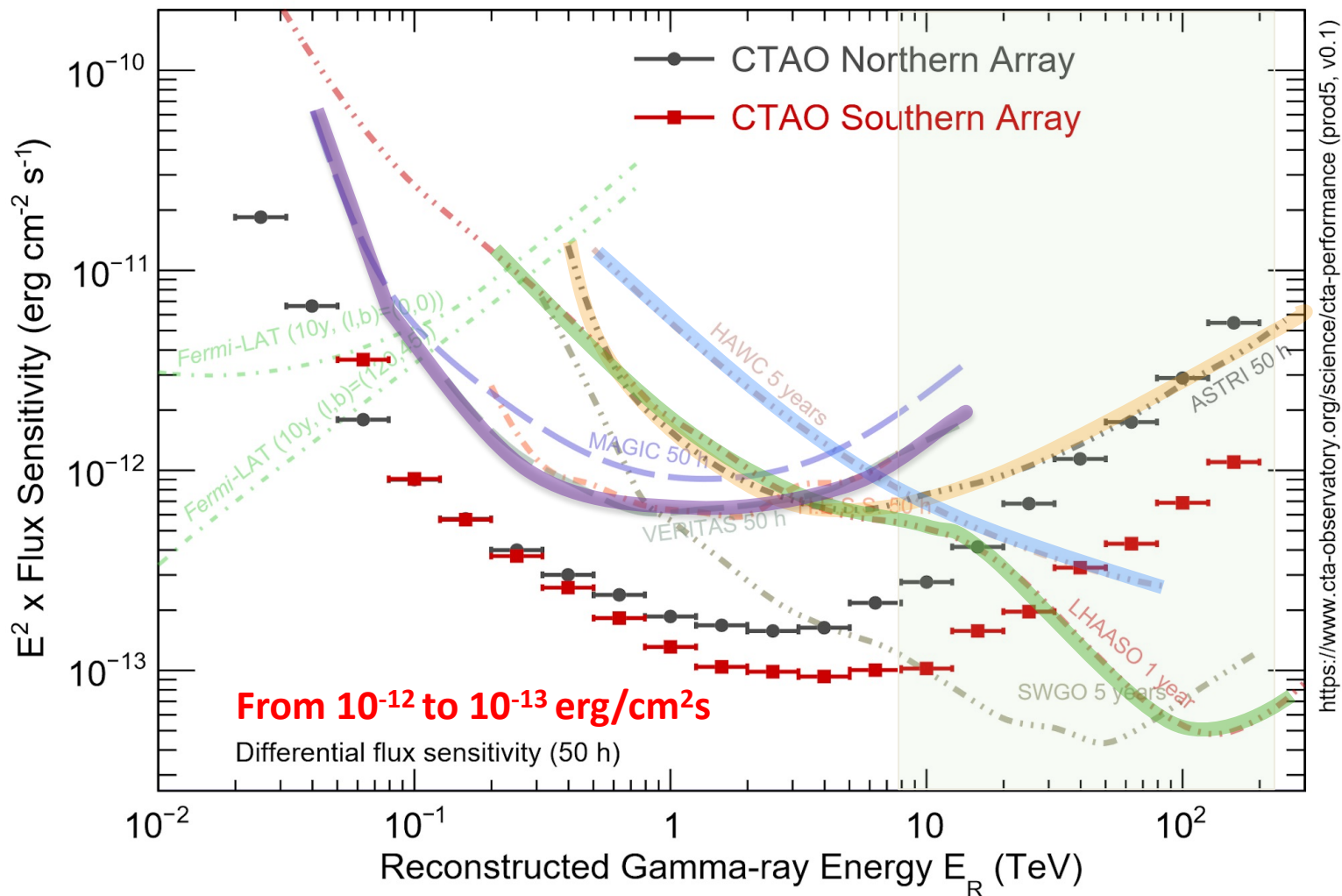


On time scales <1 h
CTA is **10^3 times** (@25 GeV)
to **10^6 times** (@250 GeV) **more**
sensitive than *Fermi-LAT*

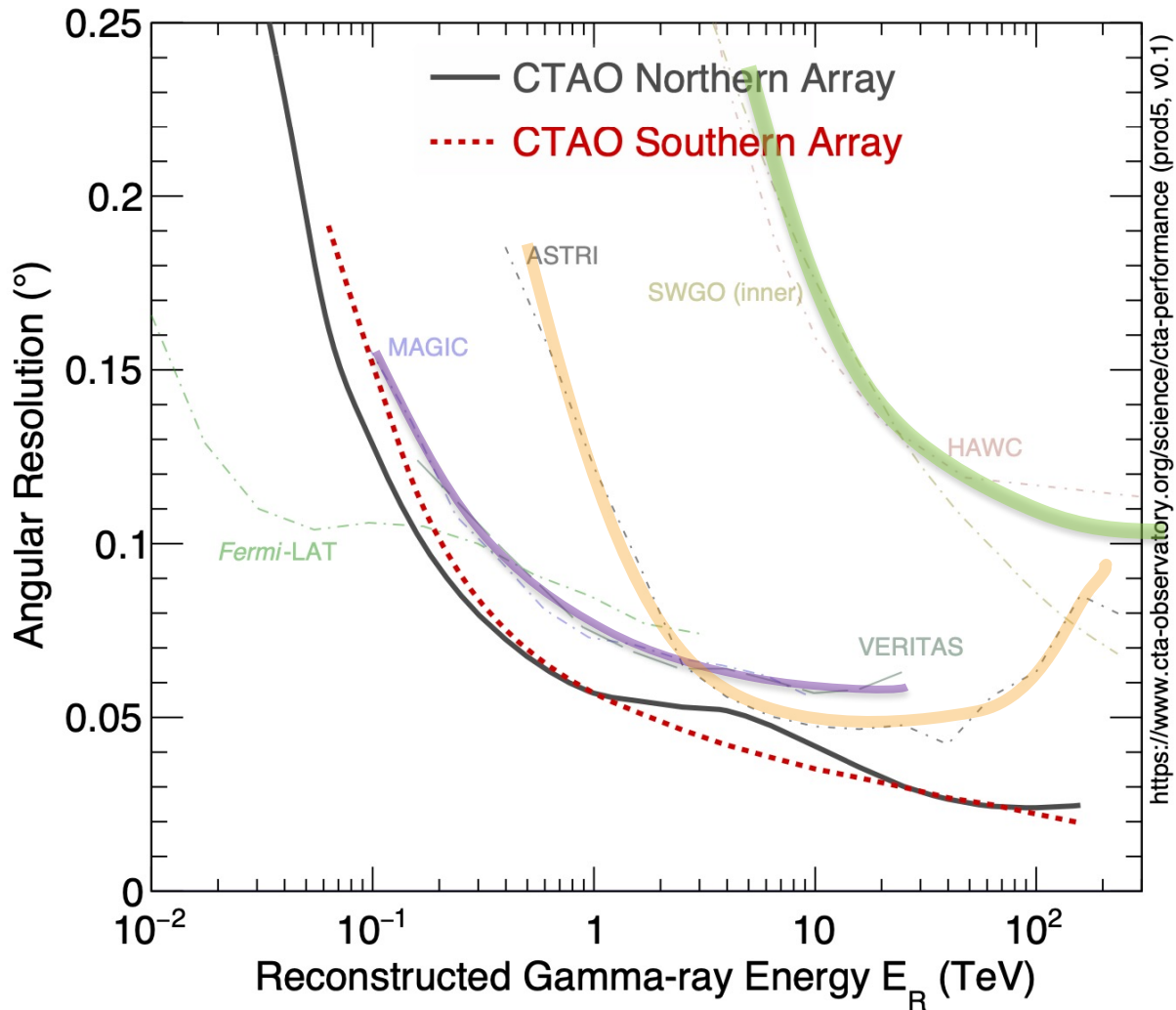


<https://www.cta-observatory.org/science/cta-performance> (prod5, v0.1)

CTAO performance (Alpha Configuration)

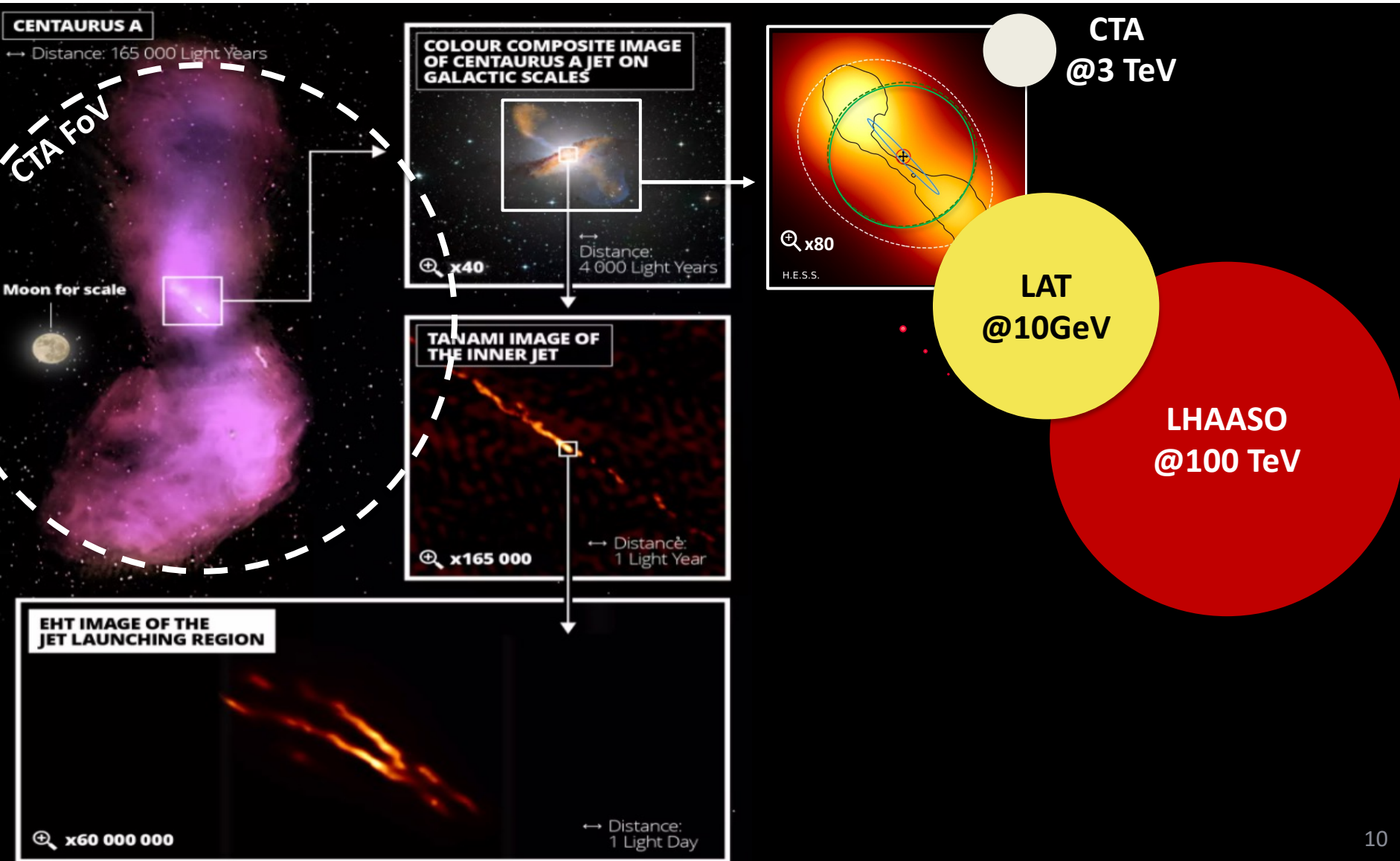


CTAO performance (Alpha Configuration)

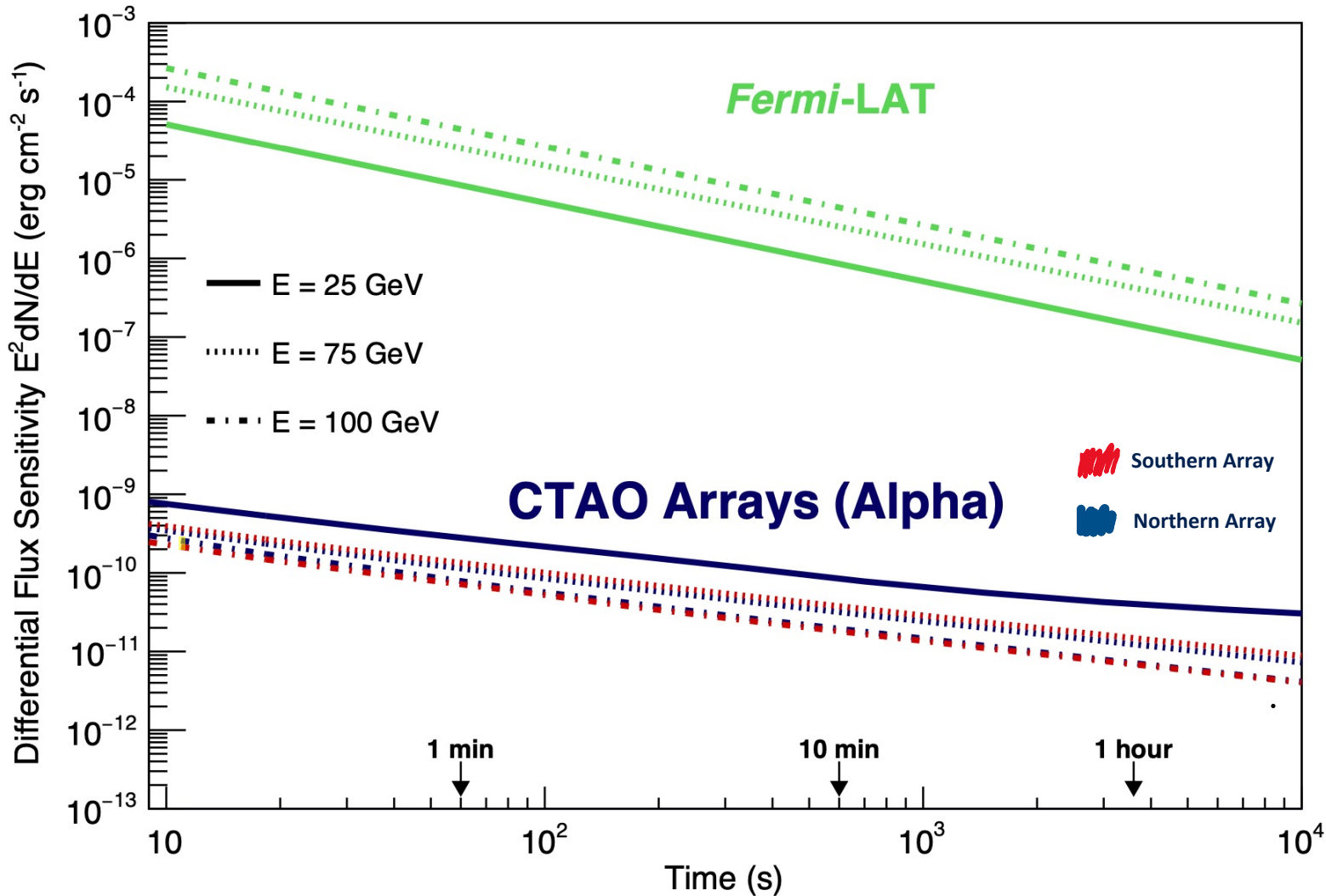


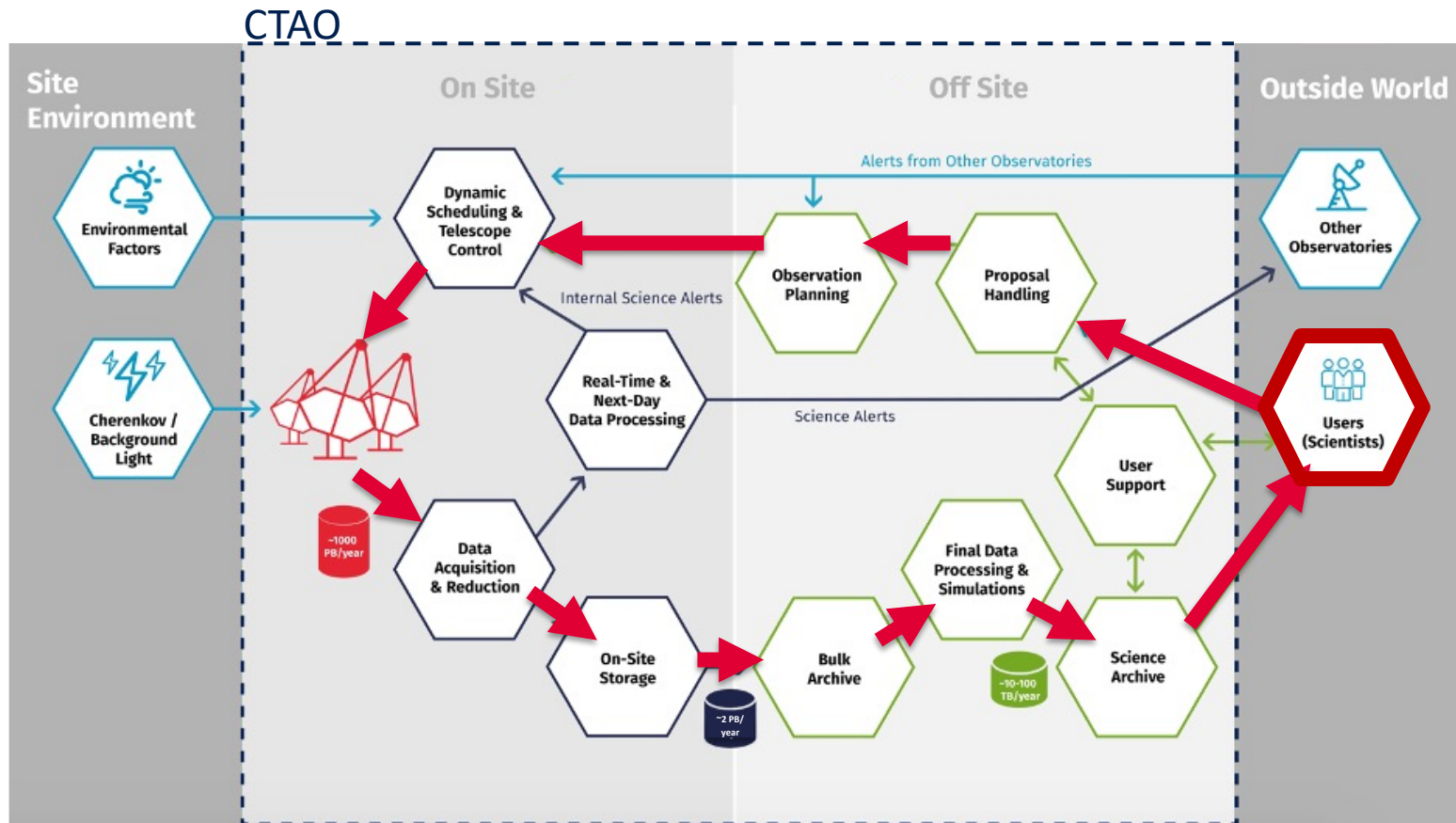
<https://www.cta-observatory.org/science/cta-performance> (prod5, v0.1)

CTAO performance (Alpha Configuration)



The Southern Array: short-term on-axis sensitivity



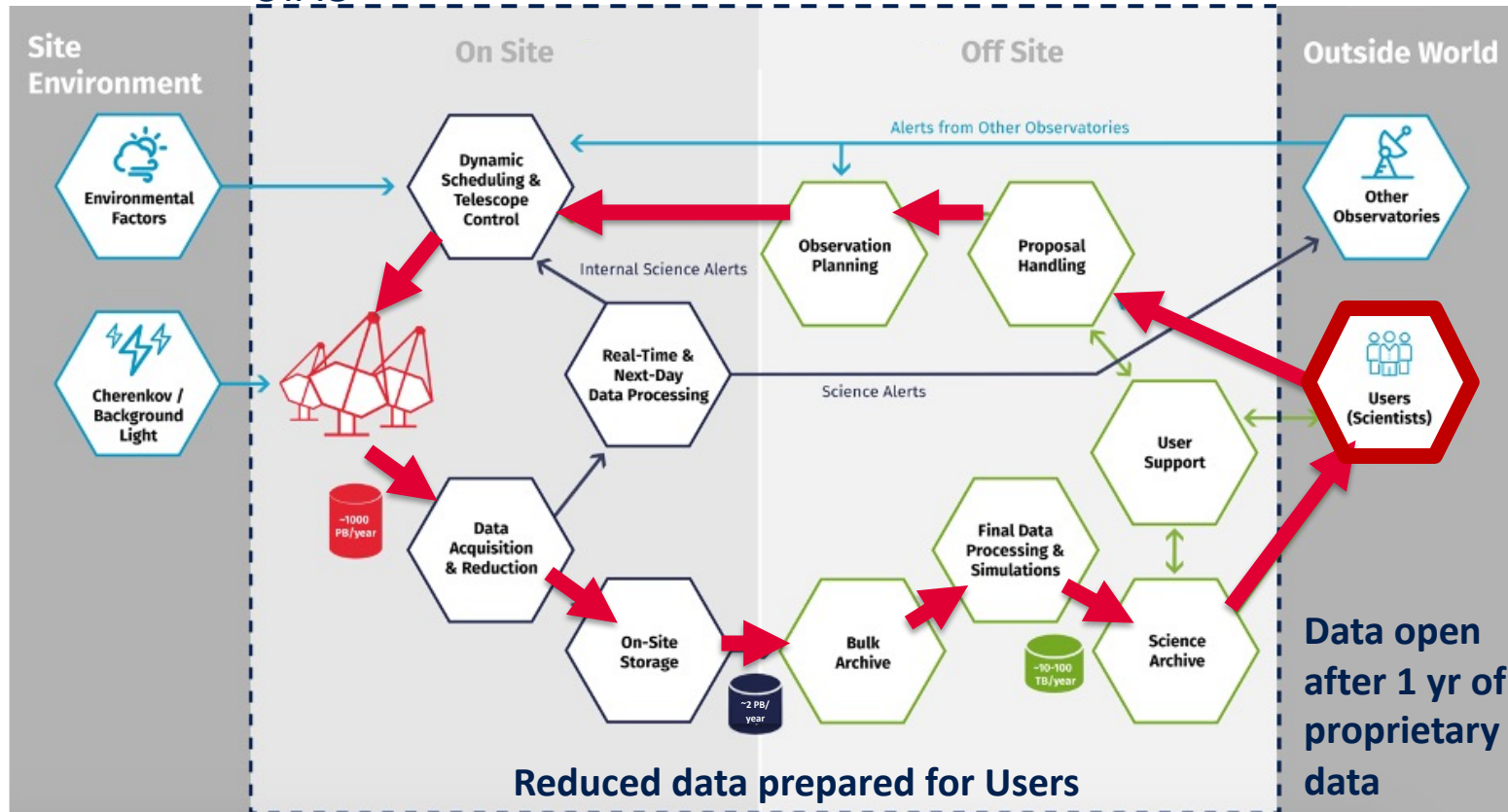


- **Proposal driven observatory:** standard proposals & Key Science Projects
- **Proposals evaluated on scientific merits** by a Time Allocation Committee

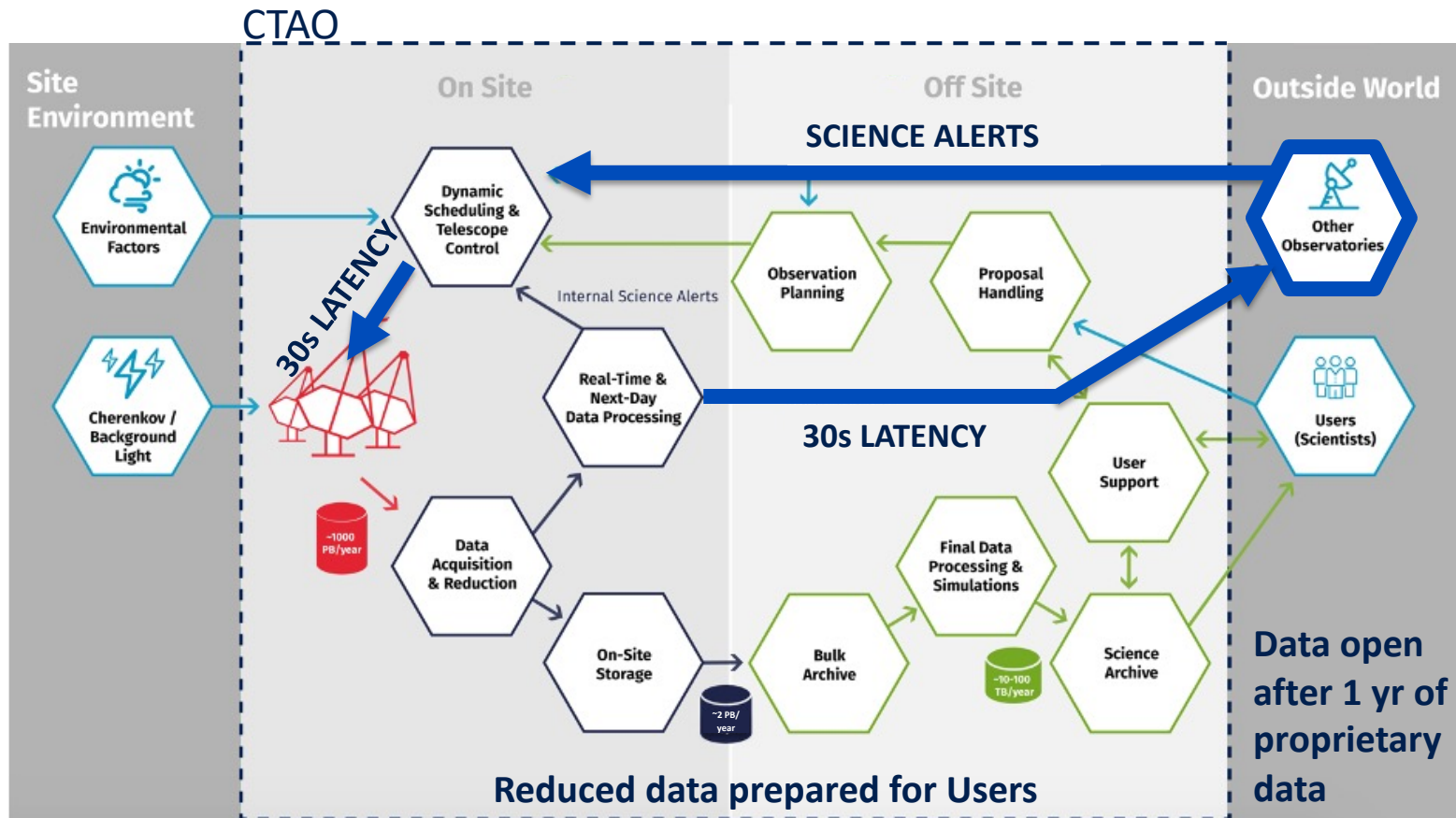
CTA Observatory



CTAO



CTA Observatory



CTA main scientific themes



COSMIC PARTICLE ACCELERATION

- How & where particles are accelerated?
- How do they propagate?
- What is their impact on the environment?



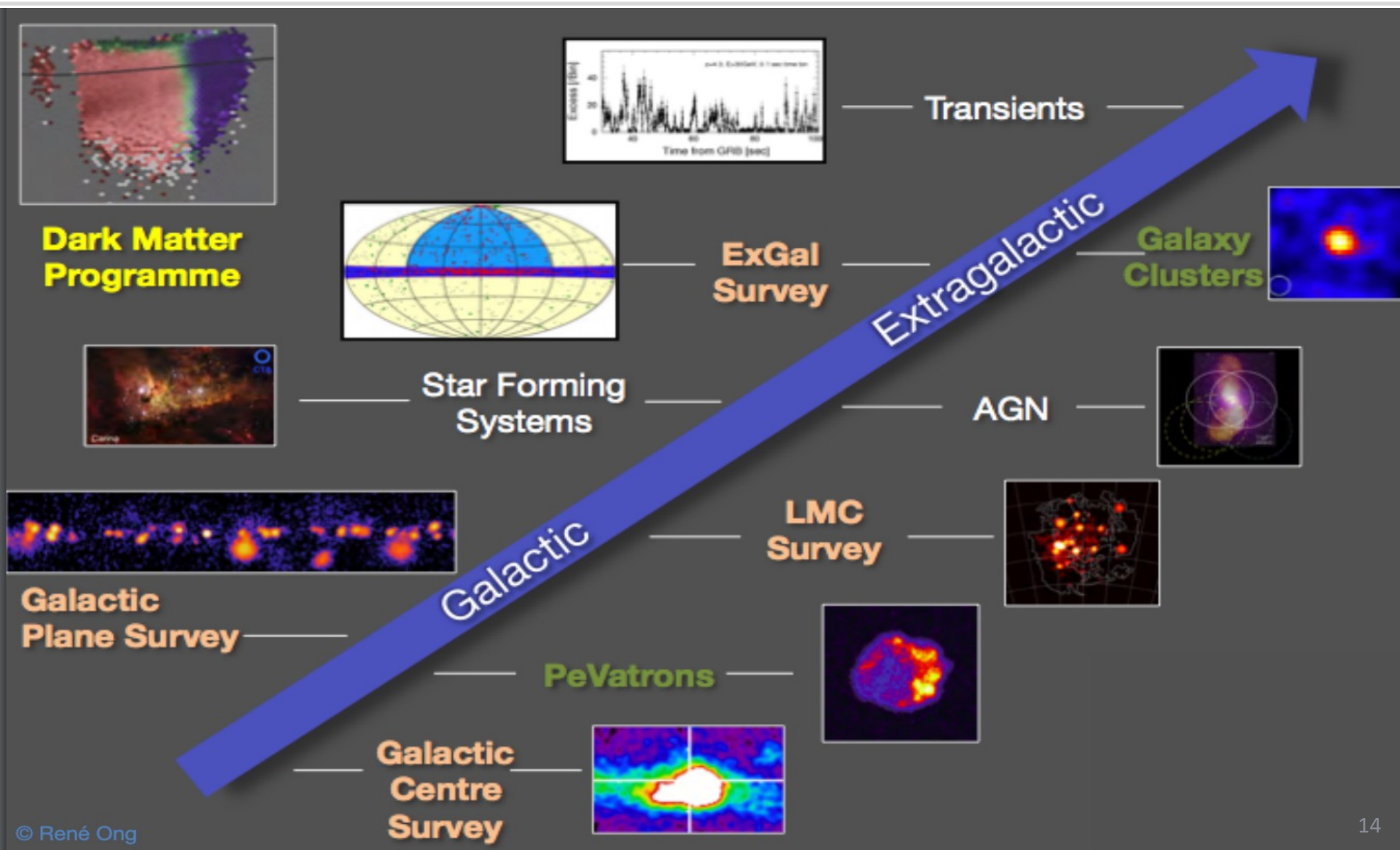
PROBING EXTREME ENVIRONMENTS

- Which are the processes close to neutron stars and black holes?
- Which are the processes in relativistic jets, winds and explosions
- What are the cosmic voids?

PHYSICS FRONTIERS - BEYOND THE STANDARD MODEL

- What's the nature of the dark matter? How is it distributed?
- Do axion-like particles exist?
- Is the speed of light a constant for high-energy photons?

CTA Science Program

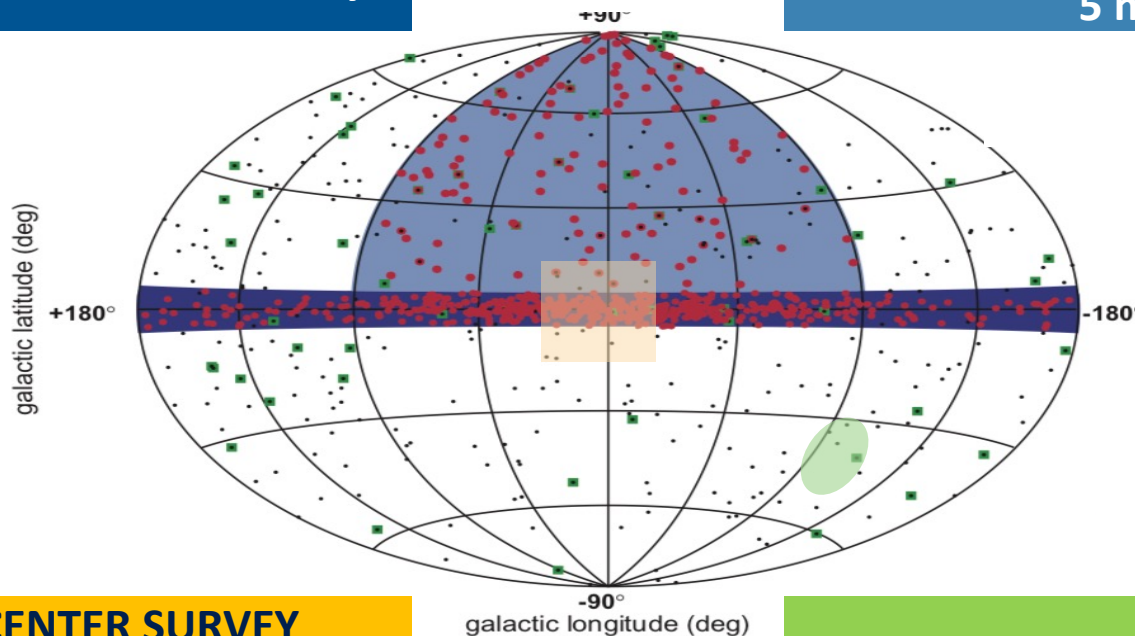


CTA surveys



GALACTIC PLANE SURVEY
not uniform sensitivity across the
plane 2-4 mCrab
pilot survey: first results after ~1 yr

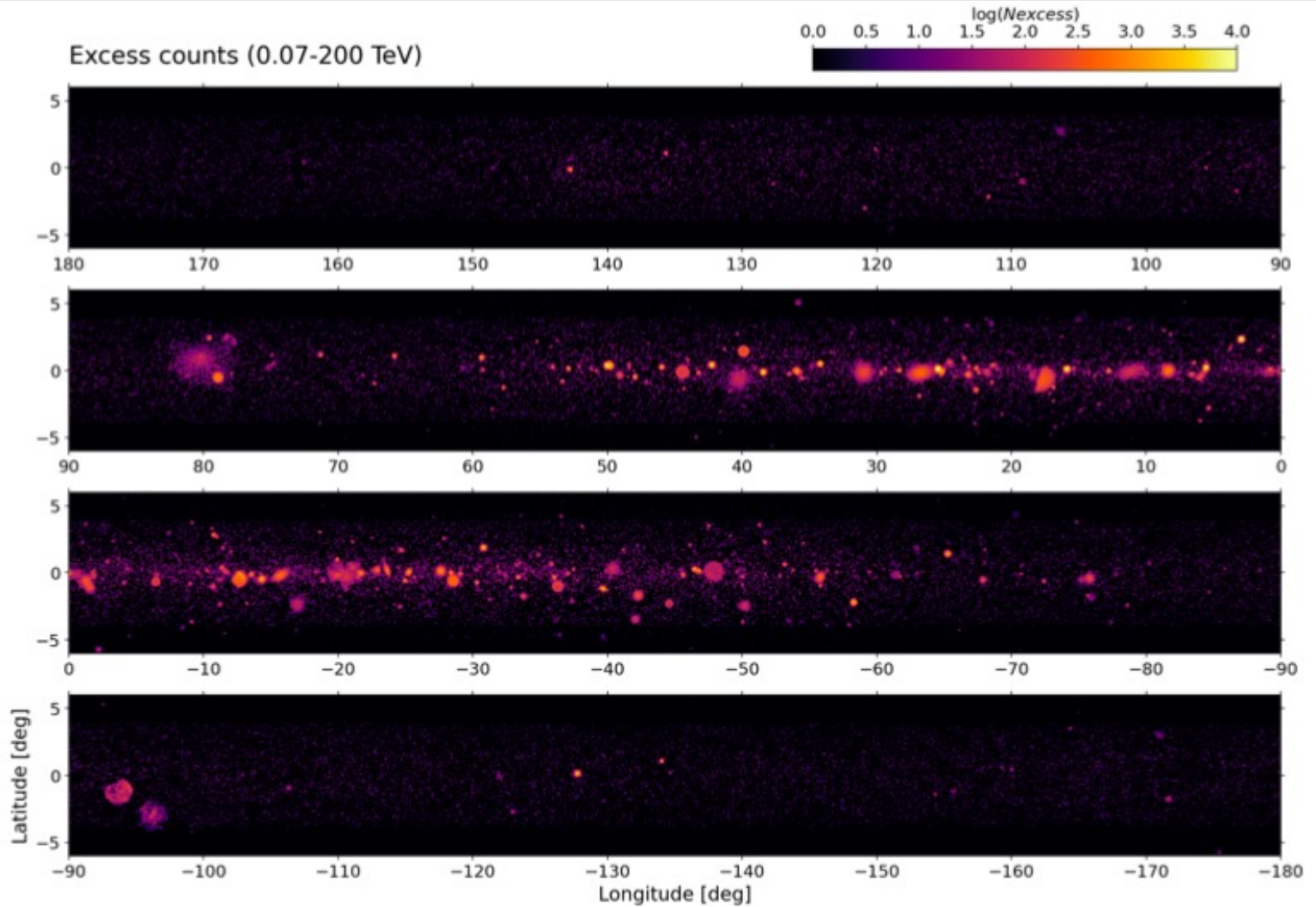
EXTRAGALACTIC SURVEY
unbiased survey of VHE sky → huge
discovery space
25% of the sky
5 mCrab



GALACTIC CENTER SURVEY
deeper observations
around the GC
10° x 10°
2 mCrab

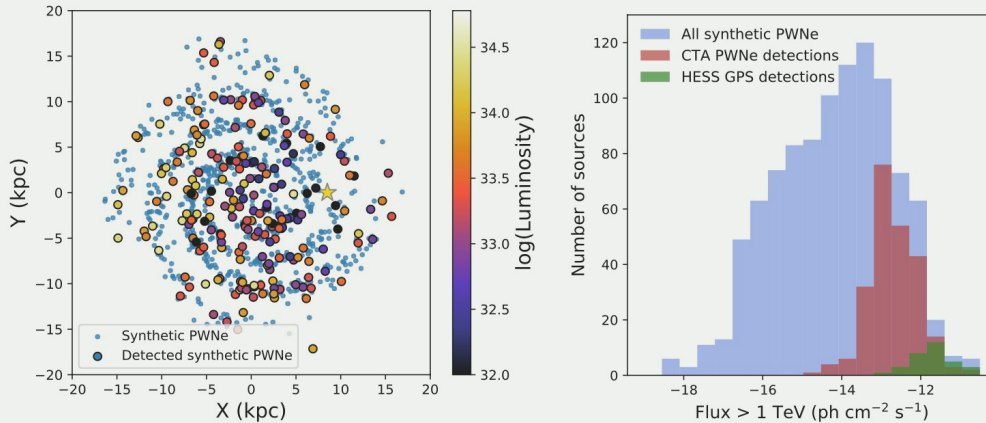
**LARGE MAGELLANIC CLOUD
SURVEY**
1.5-2 mCrab

Galactic Plane Survey



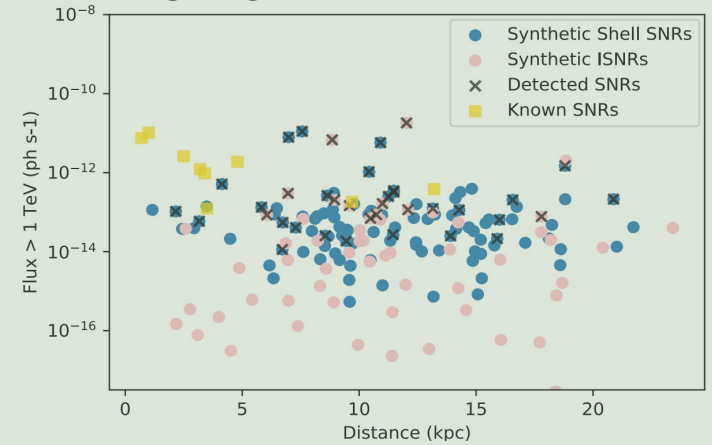
Source population studies

PWNe



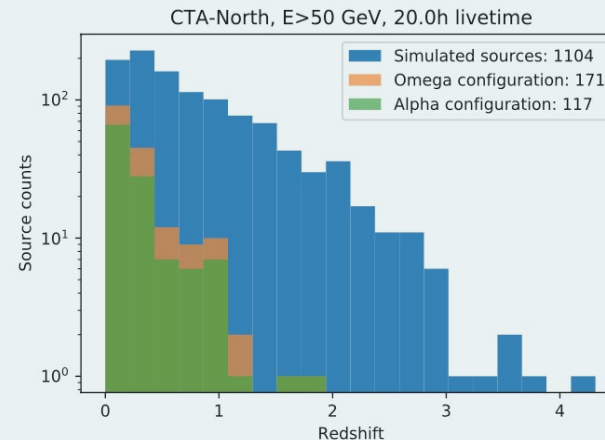
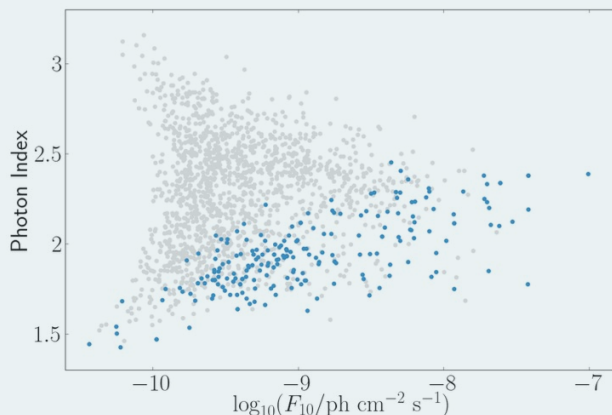
- transformational jump in population size to the PWNe field

SNRs



- SNRs up to other side of the Galaxy
- 5-10 times better flux sensitivity

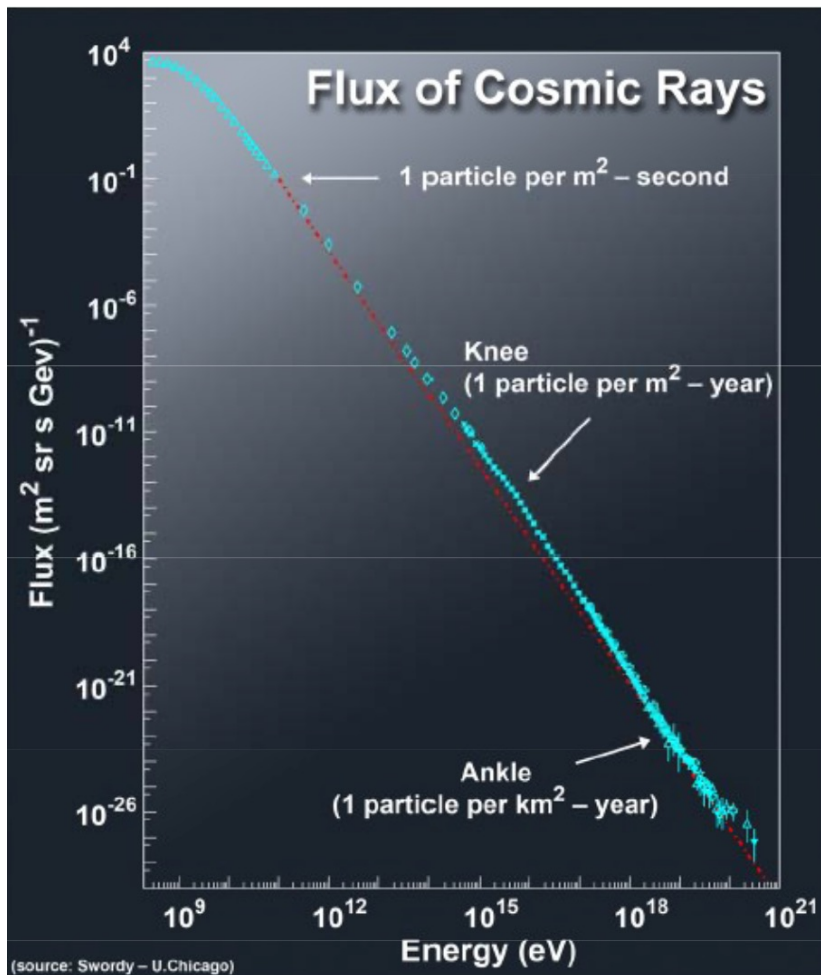
AGNs



- factor > 2 detected non-flaring AGNs
- enlarge the γ -ray horizon up to $z \approx 2$

PeVatrons searches

Q: What sources accelerate hadrons up to the knee?

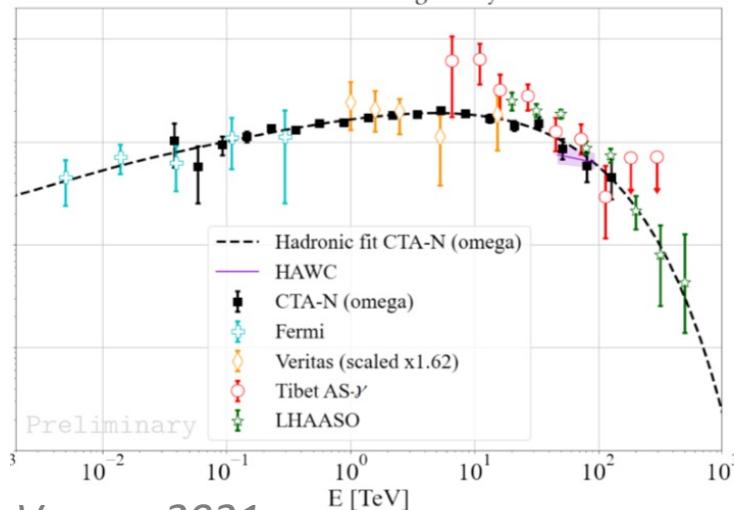


- CR origin: ~ 100 yr mystery!
- Standard picture: shock-acceleration in SNRs – satisfies power & spectrum
- BUT only few SNRs provide good evidence for hadronic acceleration & only up to < 100 TeV

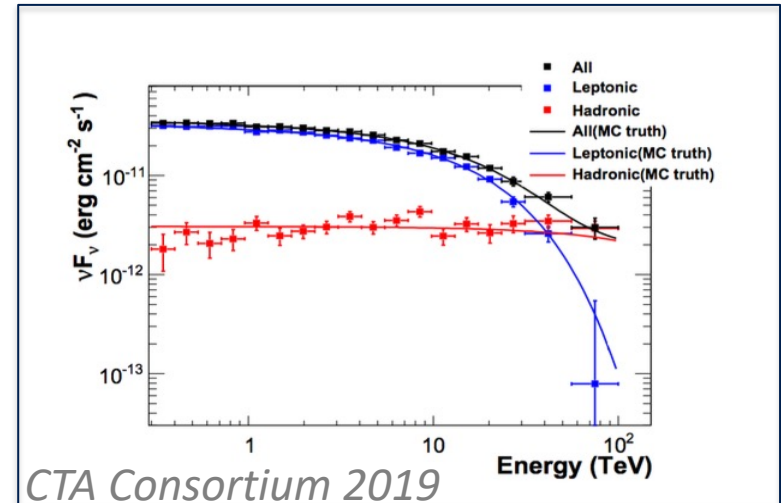
PeVatrons searches

- Search for gamma-ray sources with spectral cutoff of at least 50 GeV
 - Candidate selection on GPS results (10h exposure) based on the lower limit of spectral cutoff

TEST CASE: G106.3+2.7



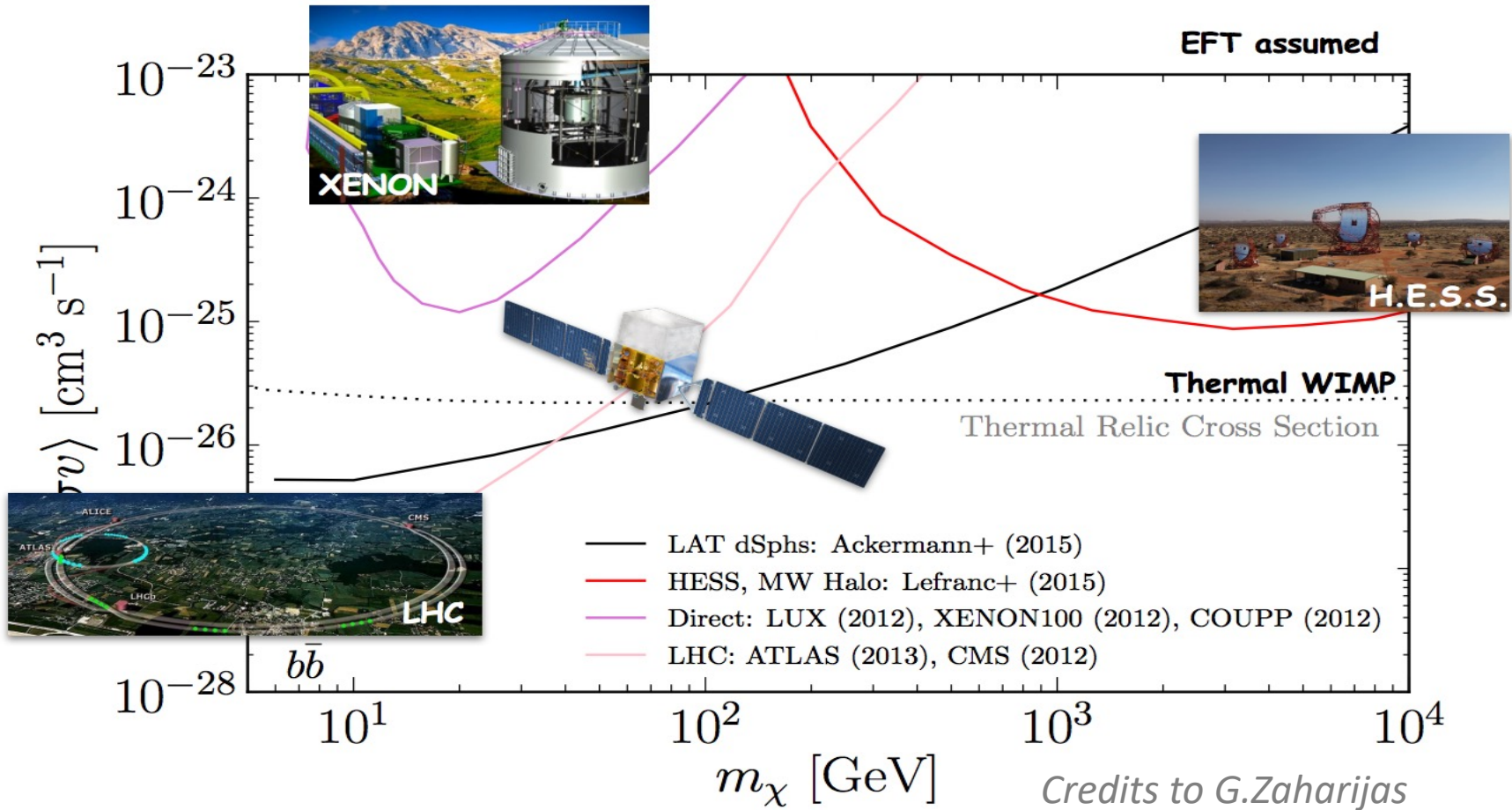
Verna+ 2021



CTA Consortium 2019

- Spectral measurements may not be enough to disentangle between hadronic and leptonic origin
- morphological studies will provide important clues given the CTA's excellent angular resolution

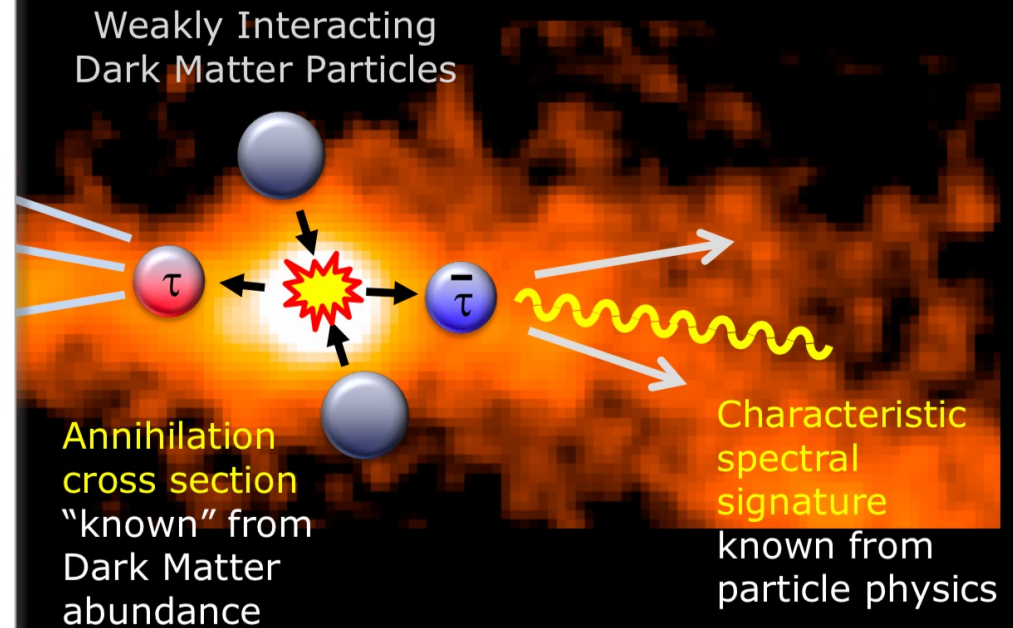
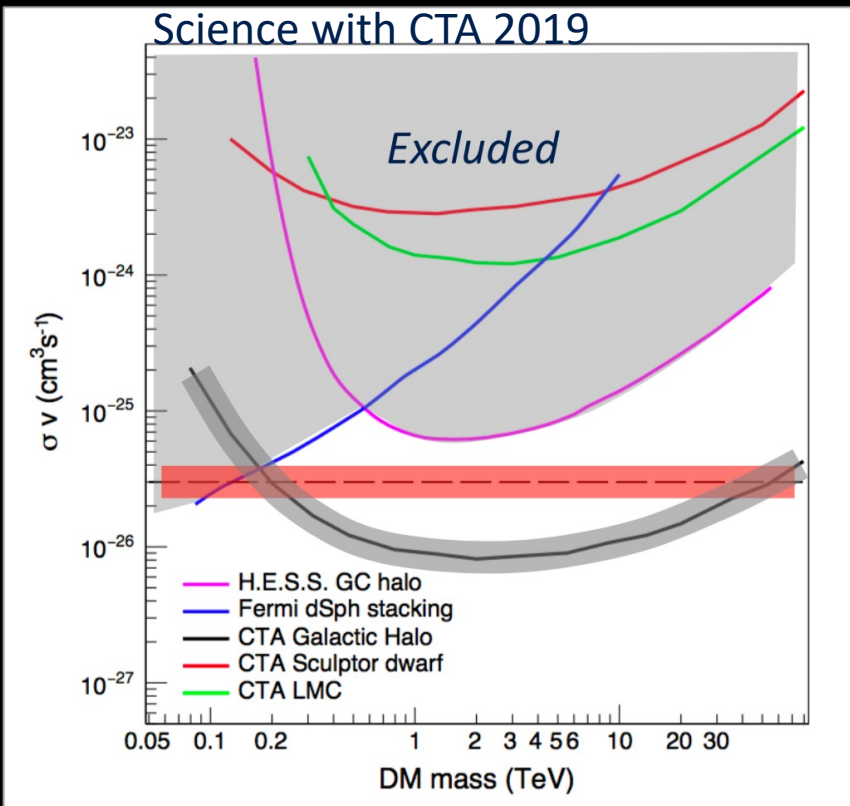
Dark matter search



- WIMP is not ruled out (*Leane+ 2018*)
- The TeV mass domain is unexplored

Dark matter search

- CTA will constrain the WIMP paradigm in case of non-detection



from: Science with CTA
www.worldscientific.com/worldscibooks/10.1142/10986

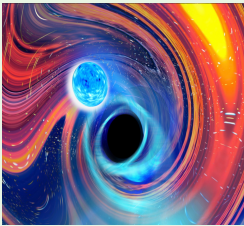
Transients in the multi-messenger era



GRBs



Q: How do the prompt and afterglow dynamics work?



GW COUNTERPARTS

Q: What's the link between the progenitor event and the emerging GRB?



UHE NEUTRINOS COUNTERPARTS

Q: What's the origin of the TeV-PeV cosmic neutrinos?



Tidal Disruption Event - Stein+ 2021



NOVAE

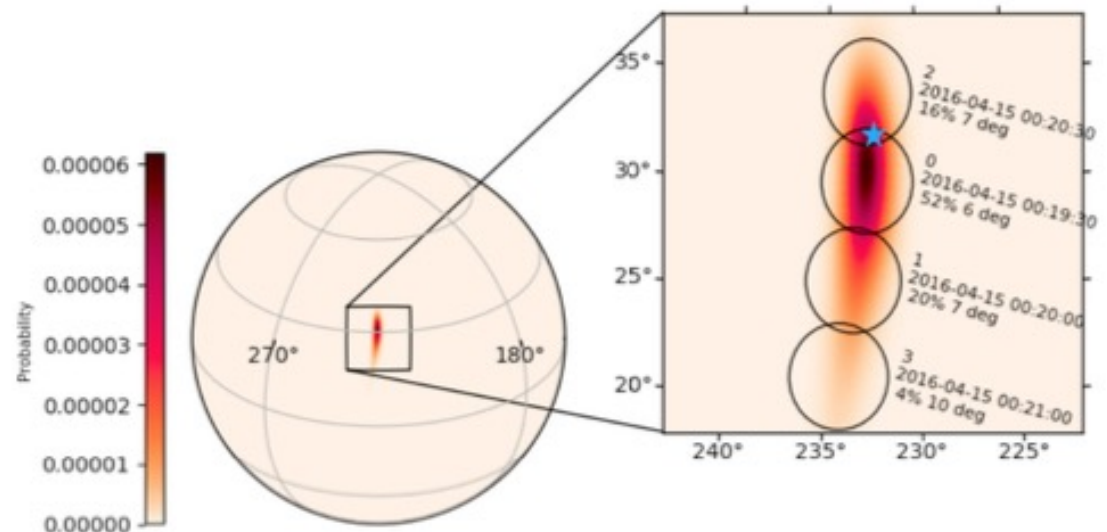
Q: Is there a population of VHE novae?

RS Oph - H.E.S.S. Coll. ATEL #14844

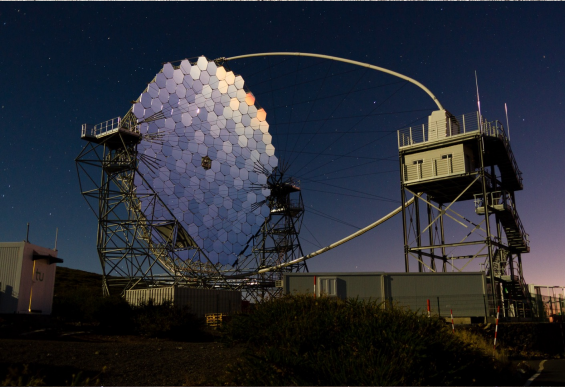
GW - GRB - UHE ν follow-up observations



- **Observational strategies: key element for the success**
 - **Optimal pointing pattern** to cover the largest total alert uncertainty region (10-100 deg²) (*Patricelli+2018, Bartos+2019*)
 - **Optimal pointing cadence**: exposure time selected to achieve 5 σ detection
 - **Site coordination** to prioritize best observational conditions (sky brightness, zenith angle, sky quality) to guarantee lowest energy threshold
 - Phenomenological considerations: galaxy density for GW events
 - **Divergent array pointing mode** to increase the FoV



LST-1 already performing science



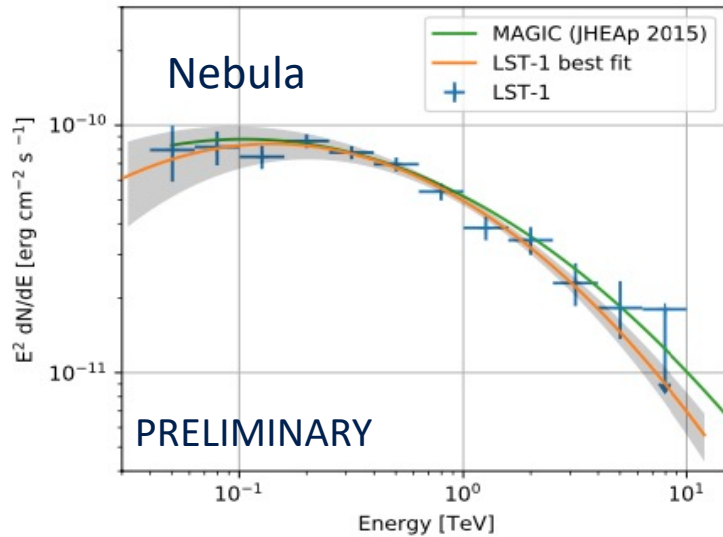
250 hr of GAMMA-RAY OBSERVATIONS ALREADY TAKEN



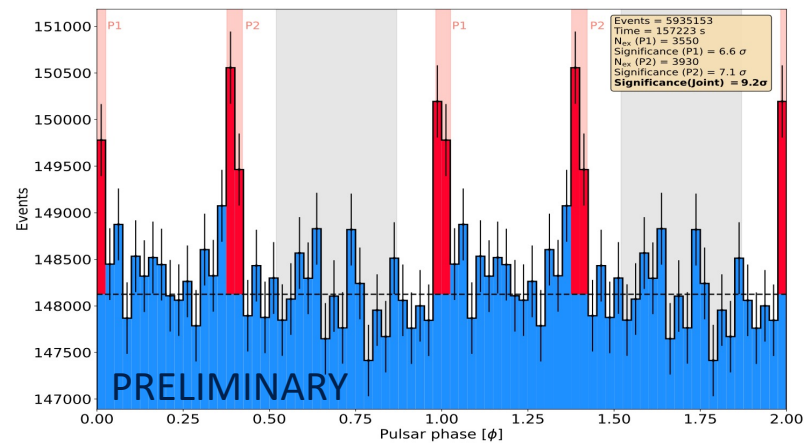
LST-1 already performing science



Always starting from the Crab as reference source to verify the scientific performance



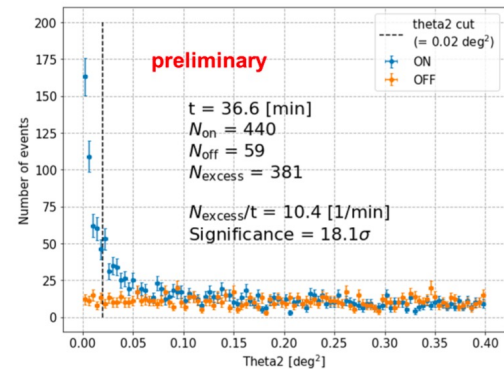
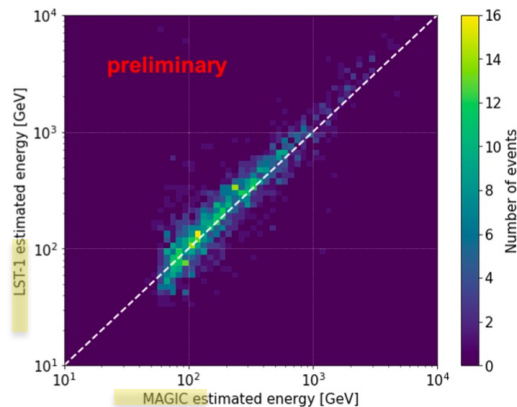
Pulsar: energy threshold ~ 50 GeV



Cross calibration LST-1 with MAGIC

&

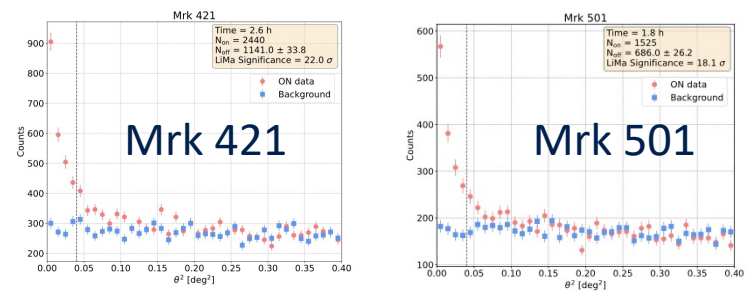
combined LST-1 – MAGIC analysis



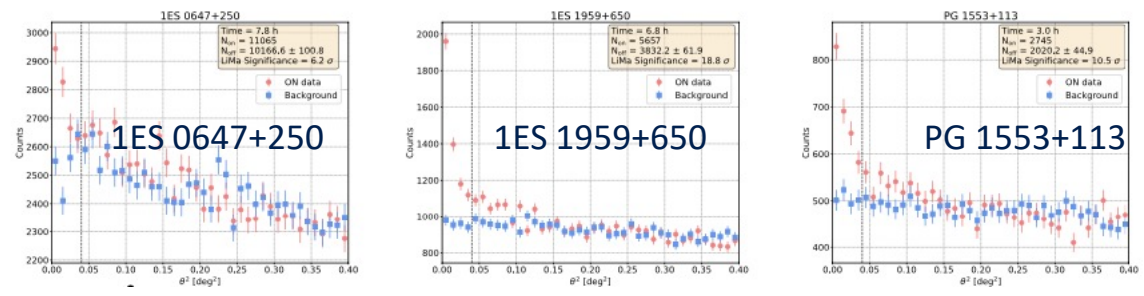
LST-1 already performing science



Several known gamma-ray sources already detected, mainly AGNs



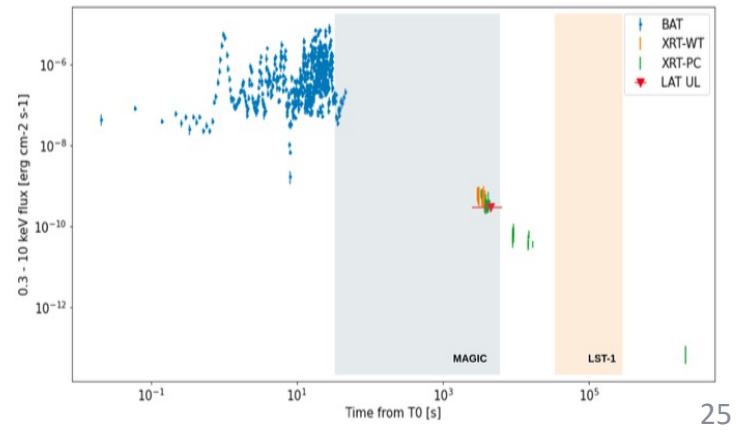
Detection of very-high-energy gamma-ray emission from BL Lac with the LST-1
 ATel #14783; **Juan Cortina for the CTA LST collaboration**
 on 13 Jul 2021; 21:03 UT
 Credential Certification: Juan Cortina (Juan.Cortina@ciemat.es)



First follow-up of GRBs and neutrino golden events

- GRB 201216C
- GRB 210217A
- GRB 210511B
- IC 210210A

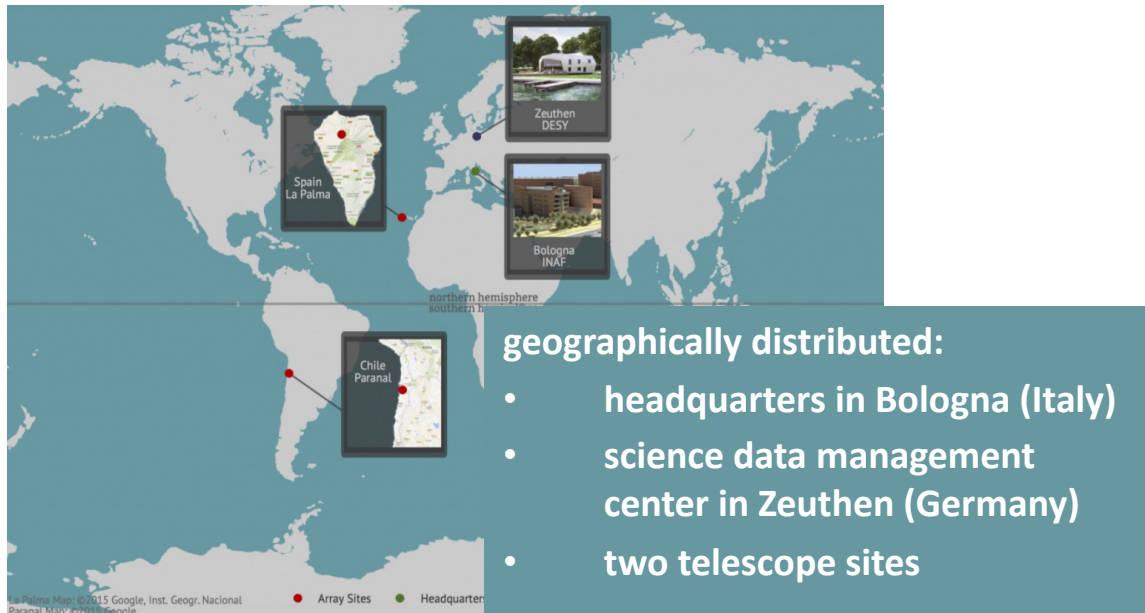
- detected by MAGIC pointing in $< 1'$
- $z = 1.1$
- LST-1 pointed at it 22 hr after the GRB event



CTAO Construction phase is about to start



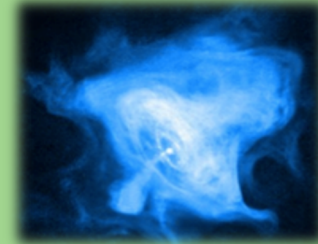
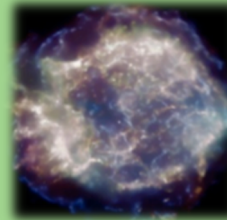
- **CTAO construction scope is agreed**
- The construction phase will start with the establishment of the final legal entity:
CTAO European Research Infrastructure Consortium (ERIC)
 - by Summer 2022?
 - last about 5 yr
- **Early science operations foreseen during the construction phase**



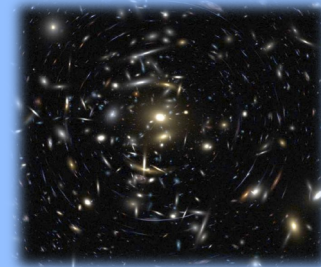
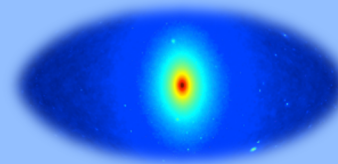
CTA: a phase transition in VHE γ -ray astronomy



In-depth understanding
of known objects and
their mechanisms



Expected discoveries
of new object classes



The fun part:
Things we haven't thought of





cherenkov
telescope
array

Thank you

