Schwarzschild–Couder 型の CTA 小・中口径望遠鏡の開発状況

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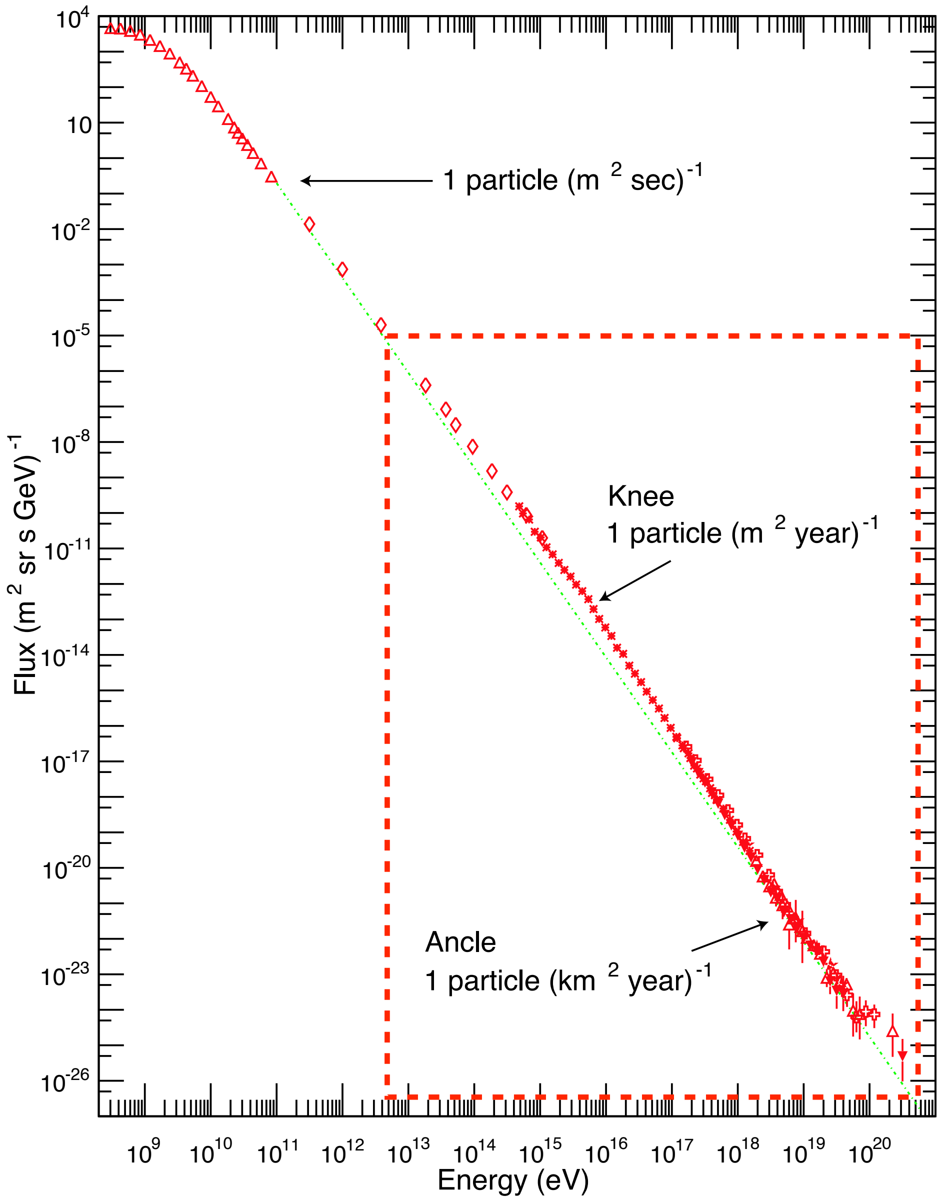
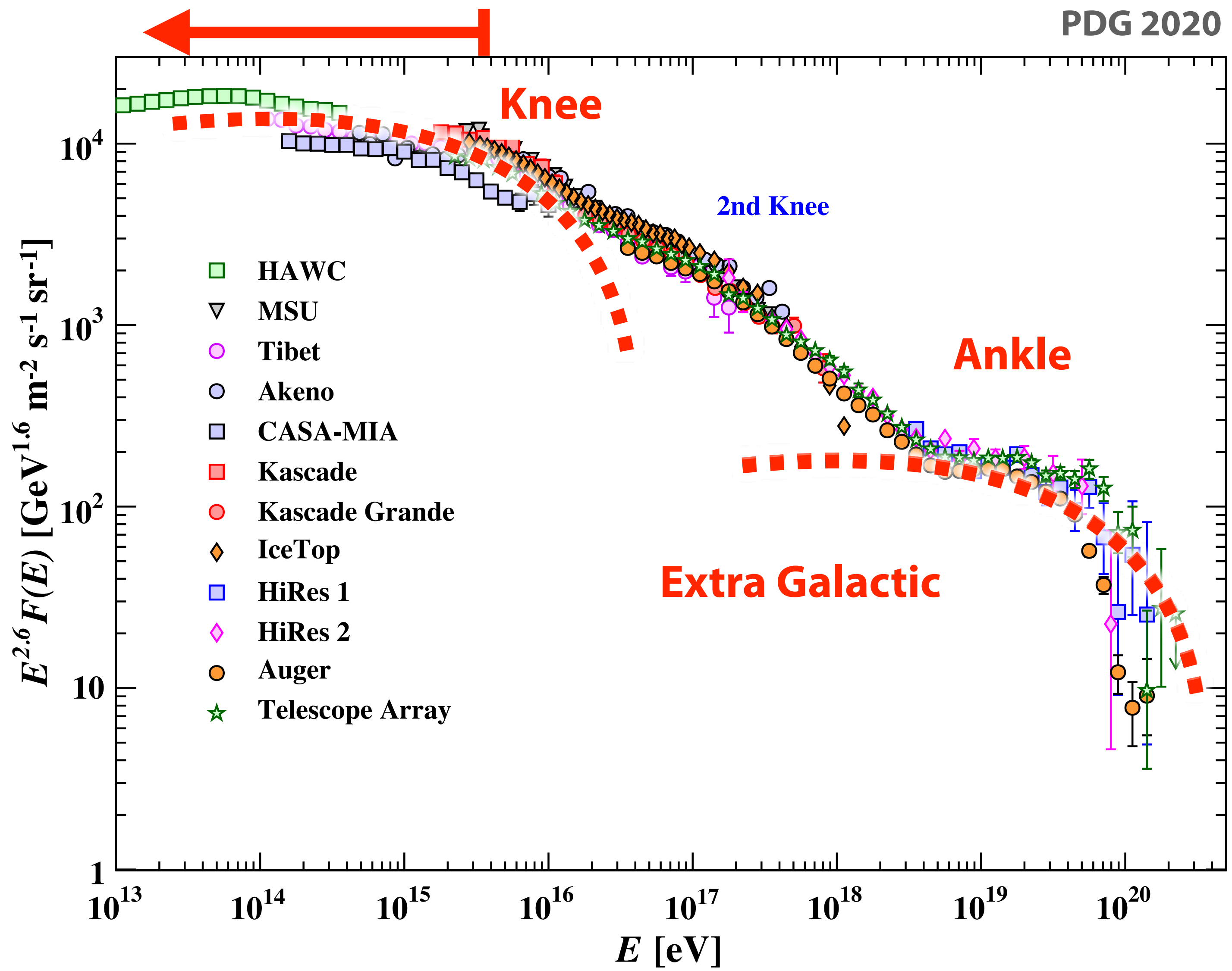
Cosmic-ray Hadron Spectrum

Modified Cronin+ (1997)



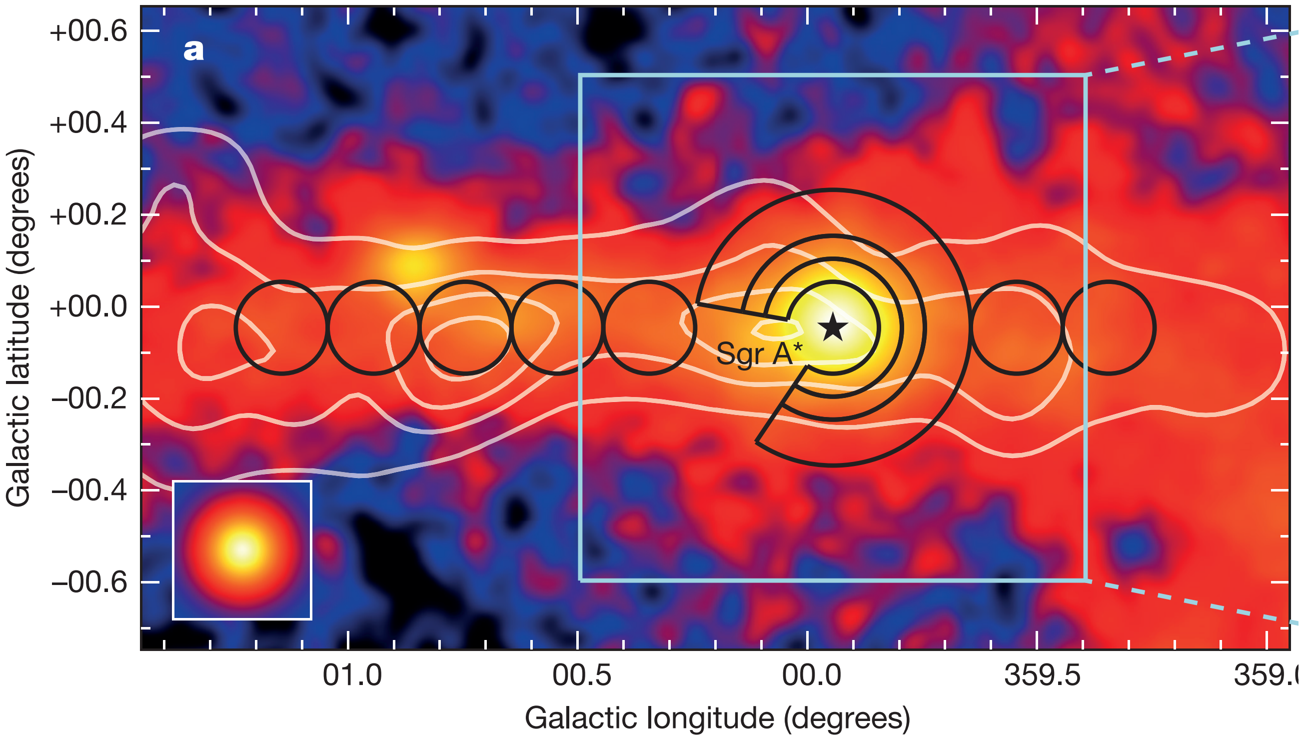
Galactic CRs ~3 × 10[15] eV (3 PeV)

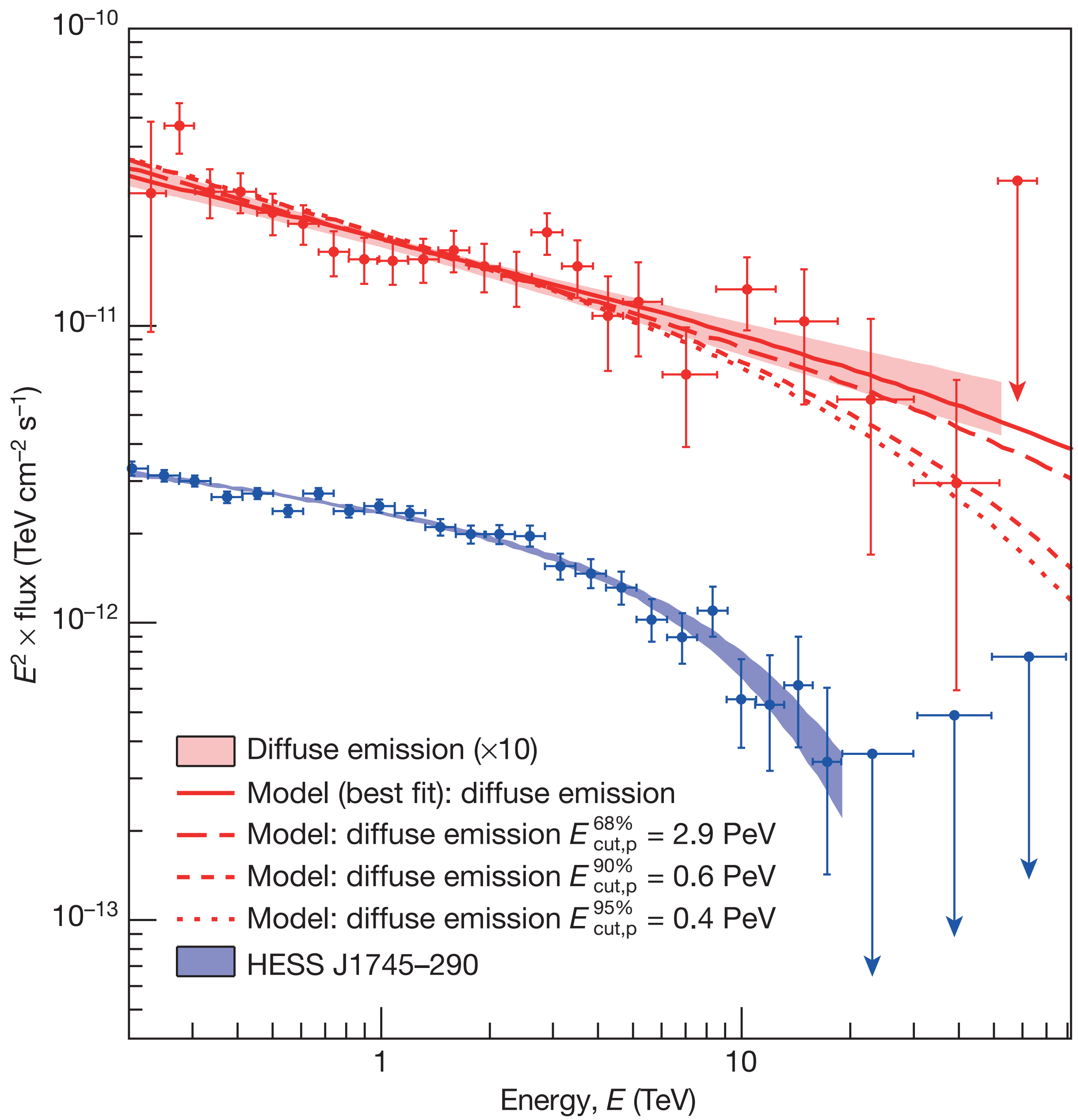


- ~10^8 eV (~100 MeV) to > 10^{20} eV, with a power law of dN/dE = $E^{-2.7}$ to $E^{-3.0}$
- What is the origin (PeVatron) of Galactic CRs (< ~3 PeV)? Supernova remnants? Galactic center?

Galactic Center Region

H.E.S.S. (2016)

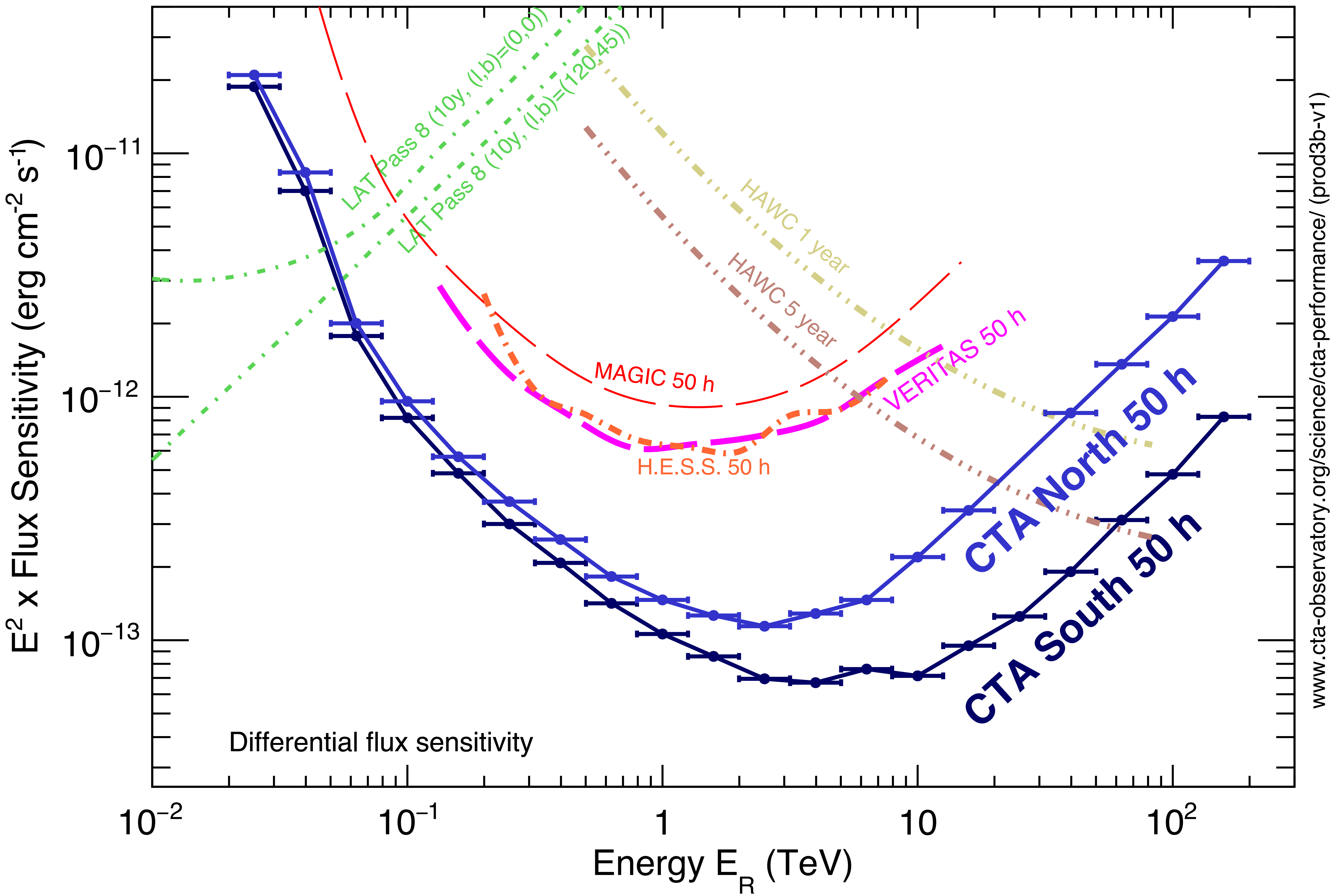




- Massive black hole ($4 \times 10^6\ M_\odot$) at Sgr A* (bright radio source)
- Point source HESS J1745–290 at Str A* and diffuse gamma-ray emission
- Diffuse component has a cutoff energy of 2.9 PeV (68% conf.) → PeVatron?

High-energy Frontier by CTA SSTs

CTA Consortium arXiV:1709.07997



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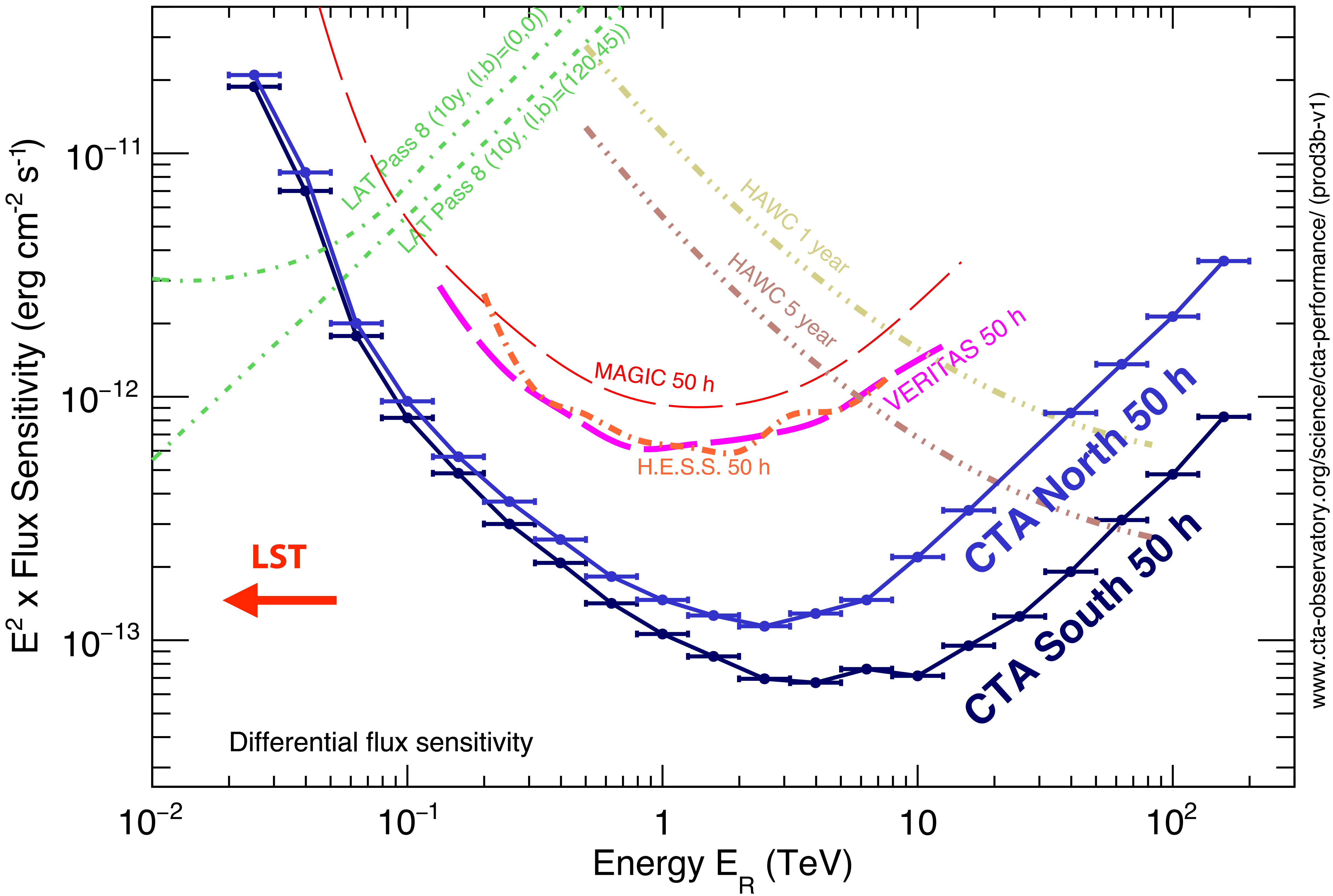

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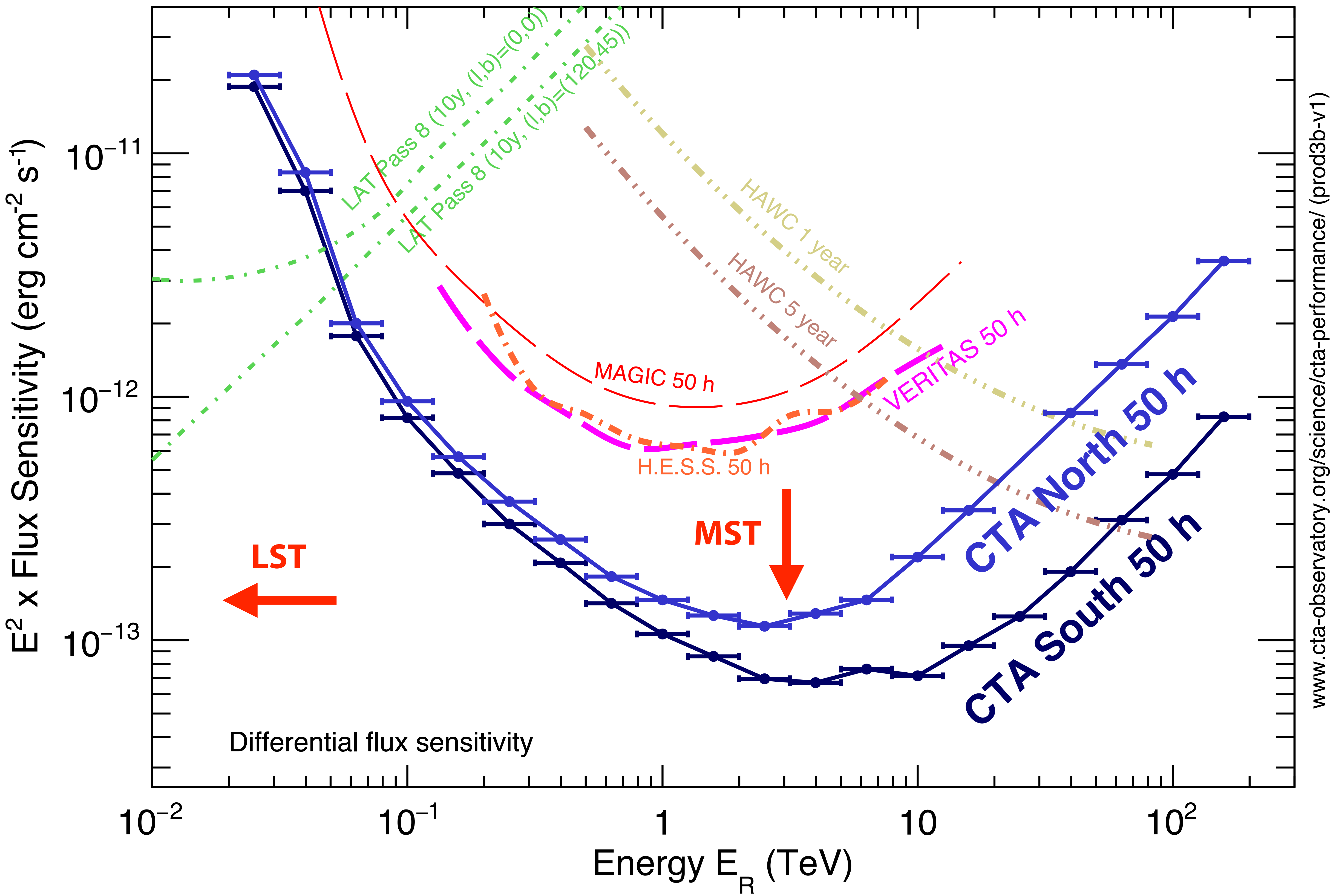

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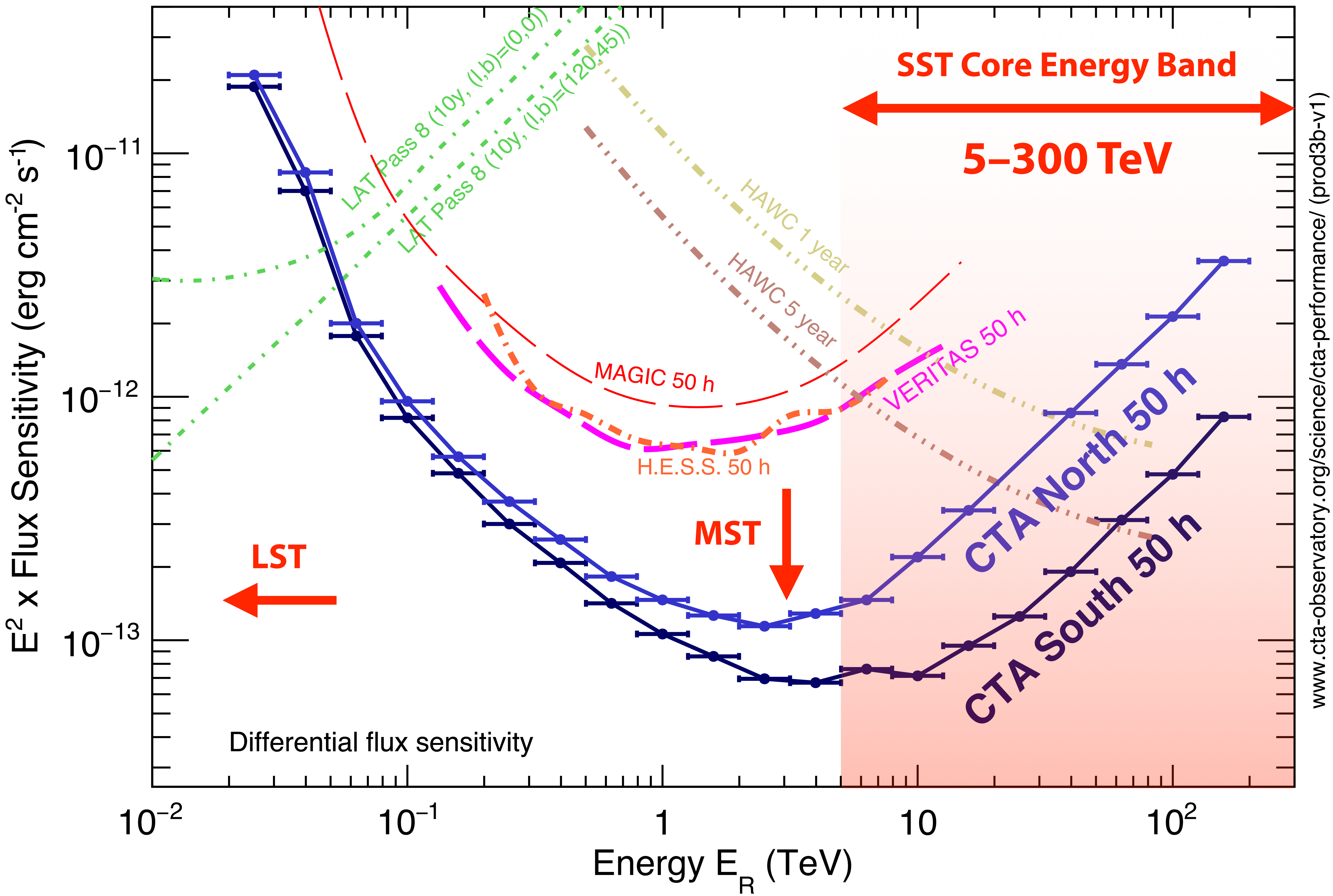

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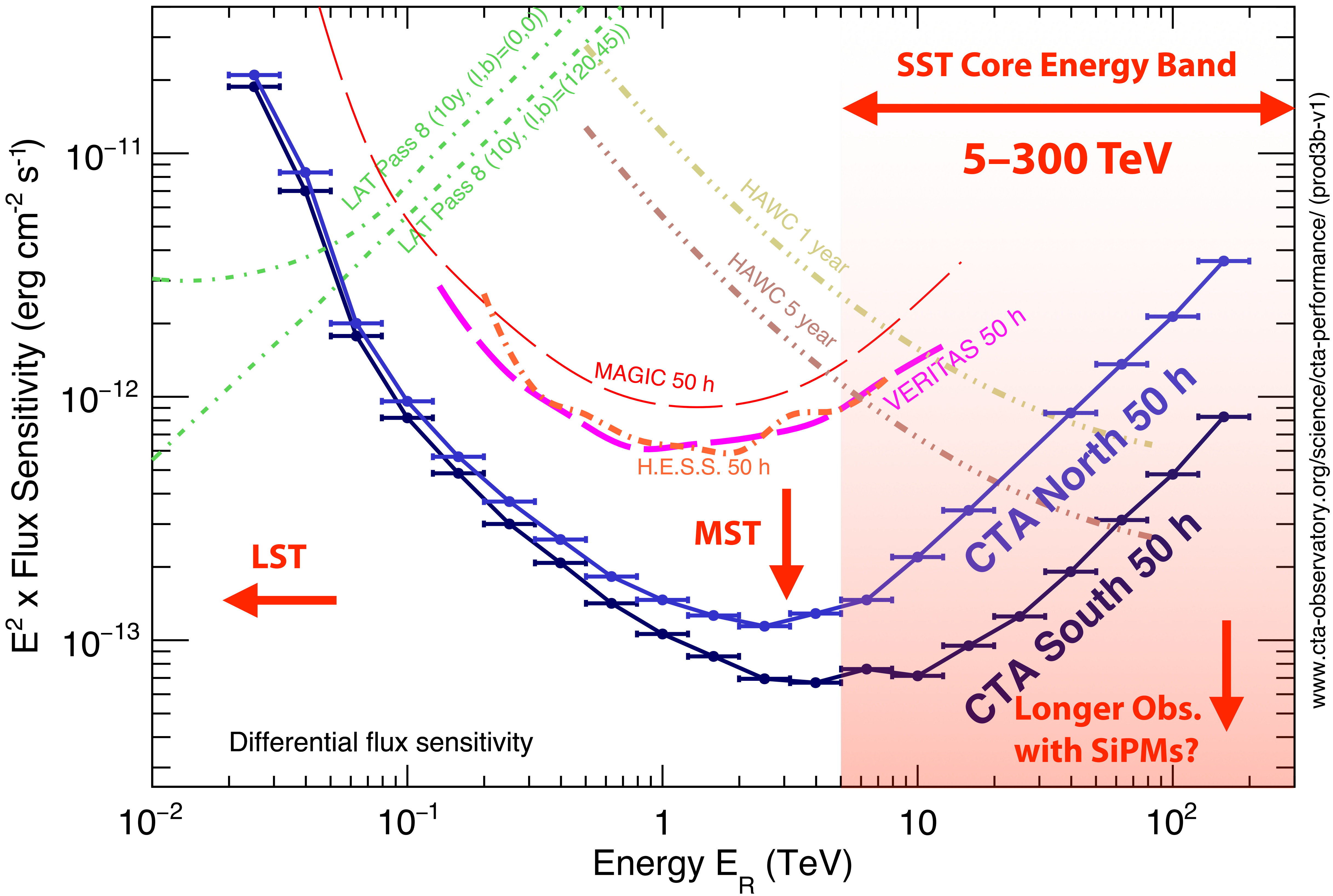


Cherenkov Telescope Array (CTA)

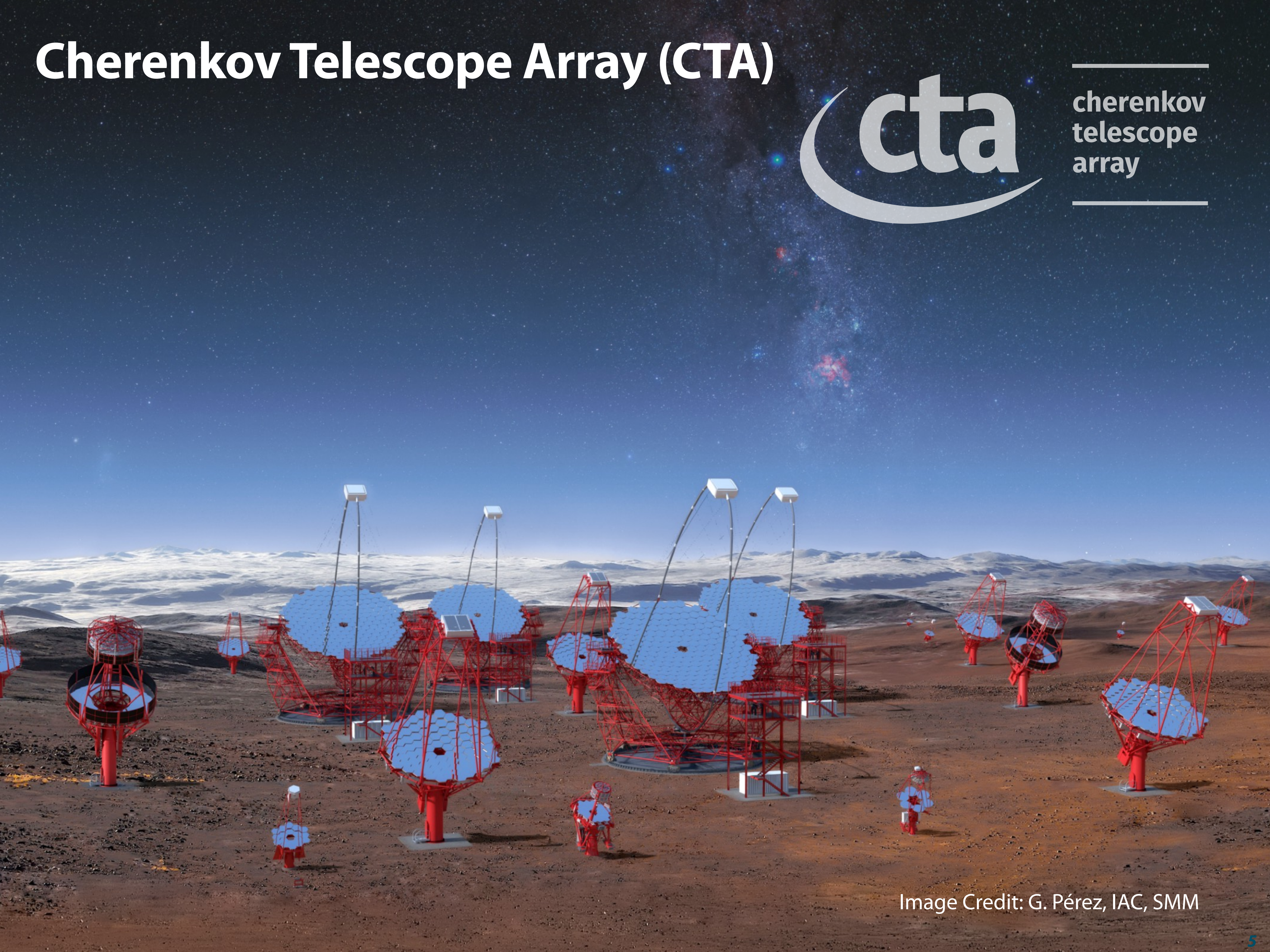
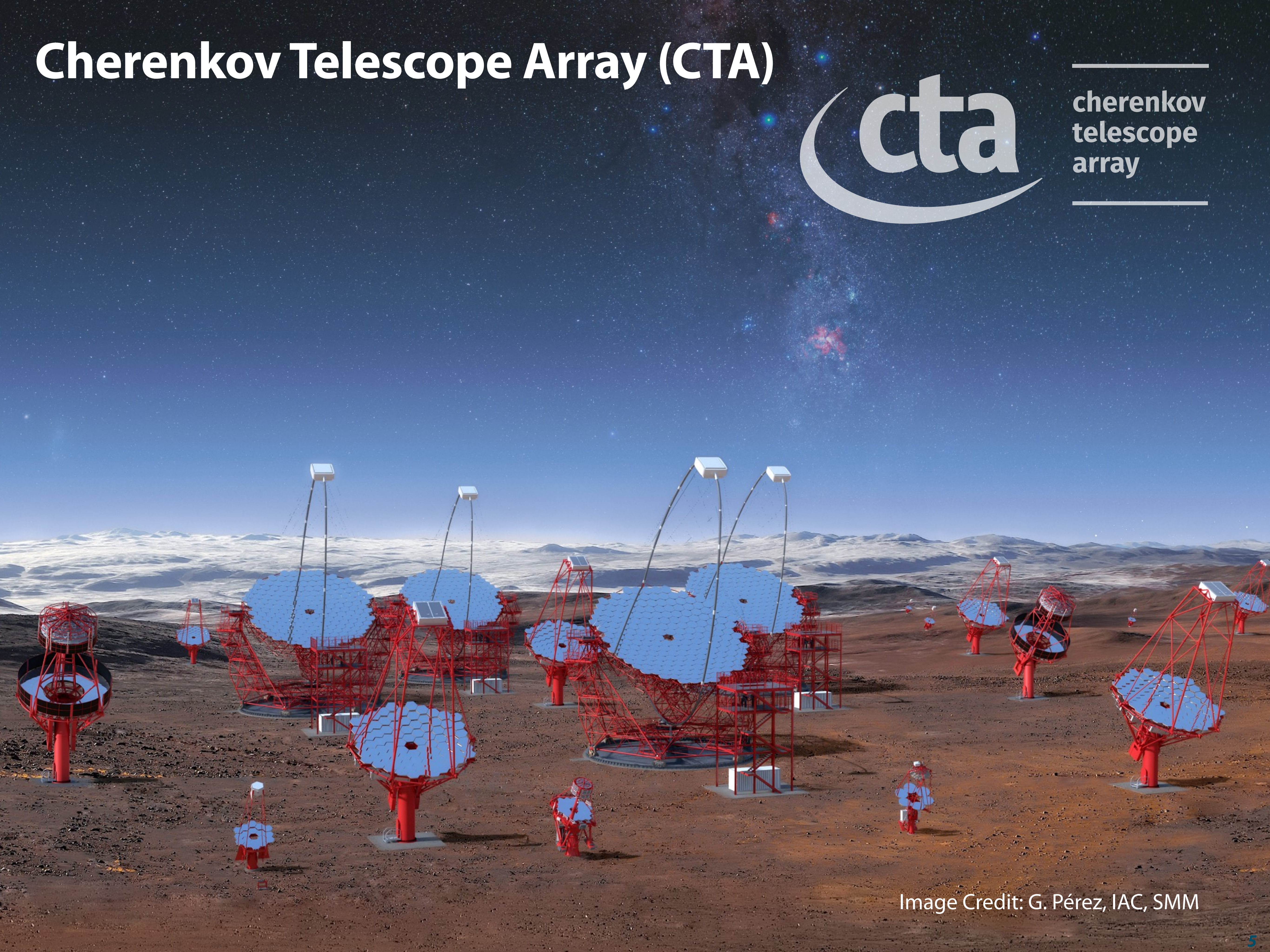


Image Credit: G. Pérez, IAC, SMM

Cherenkov Telescope Array (CTA)



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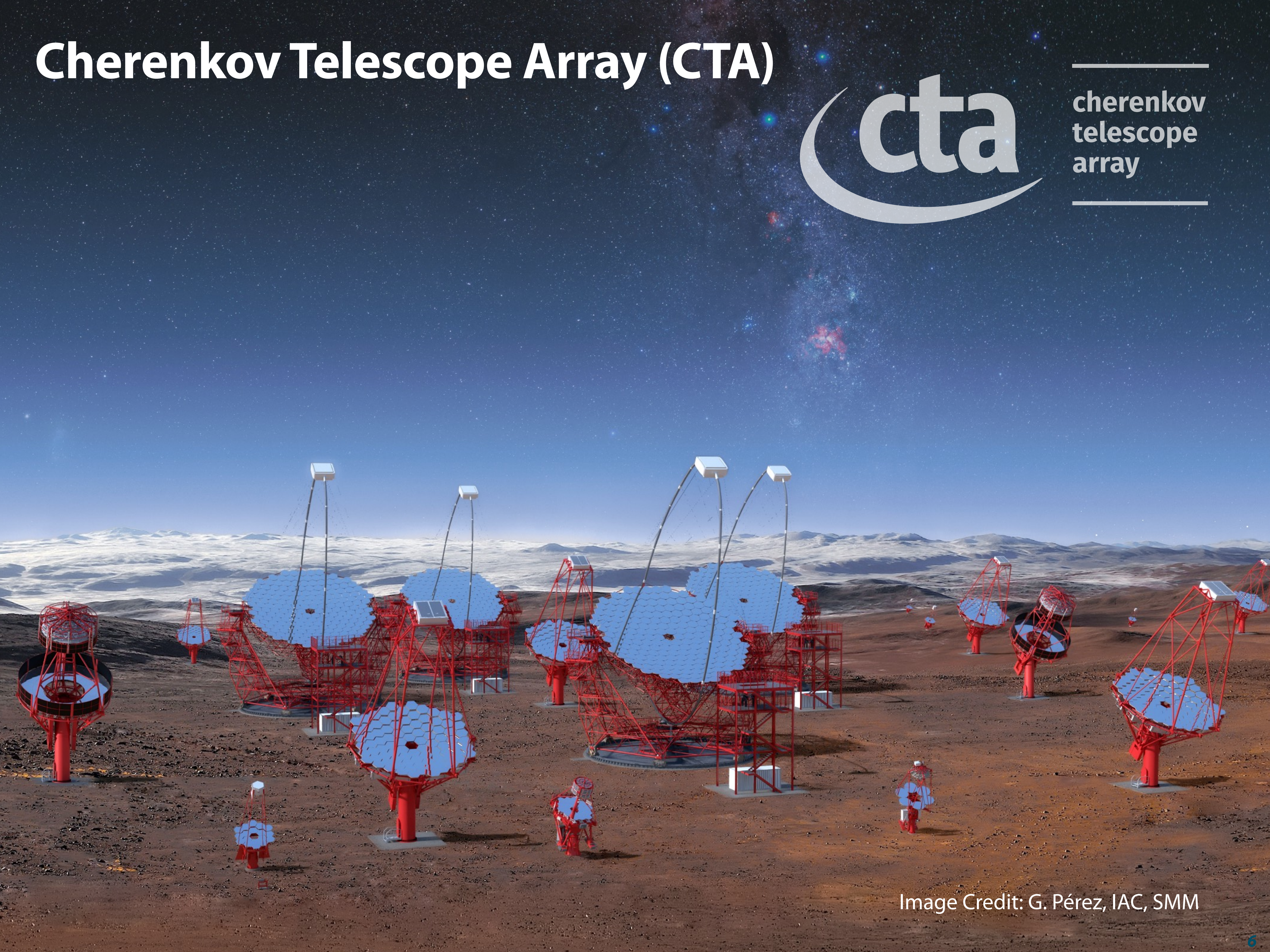


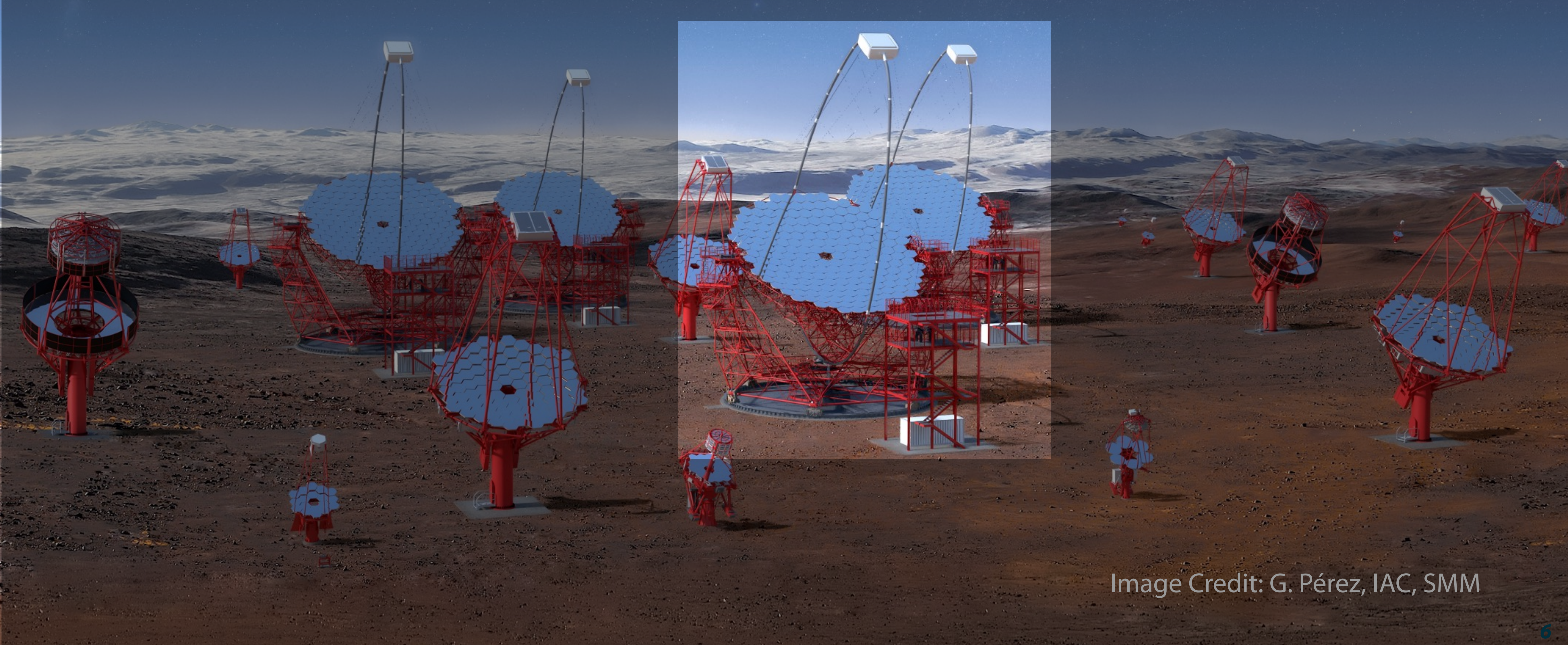
Image Credit: G. Pérez, IAC, SMM

Cherenkov Telescope Array (CTA)

cta
cherenkov
telescope
array

Large-Sized Telescope (LST)

Dia. : 23 m
Energy : 20–150 GeV
N_{Tel} : 4 @ North, 4 @ South



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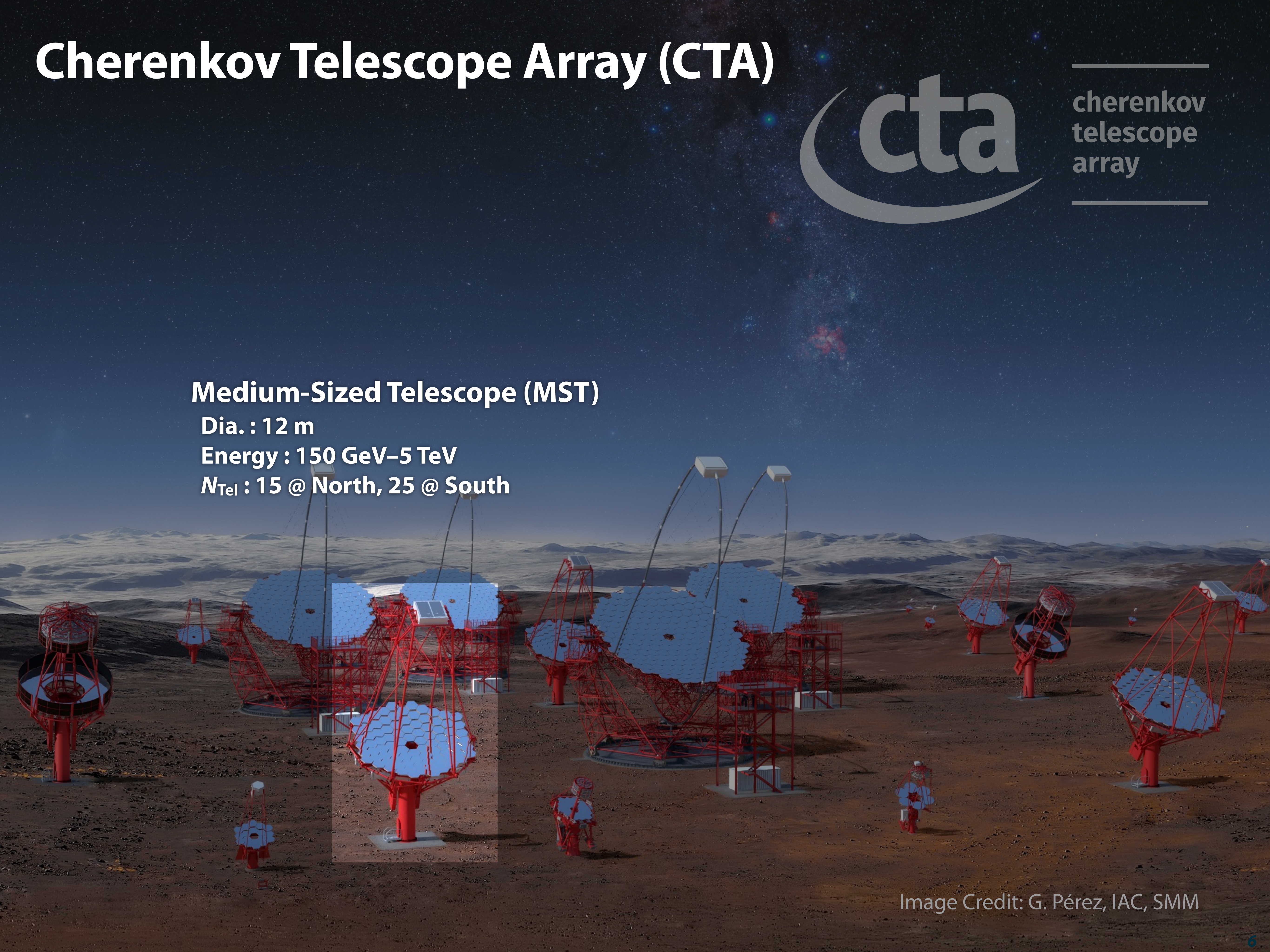


Medium-Sized Telescope (MST)

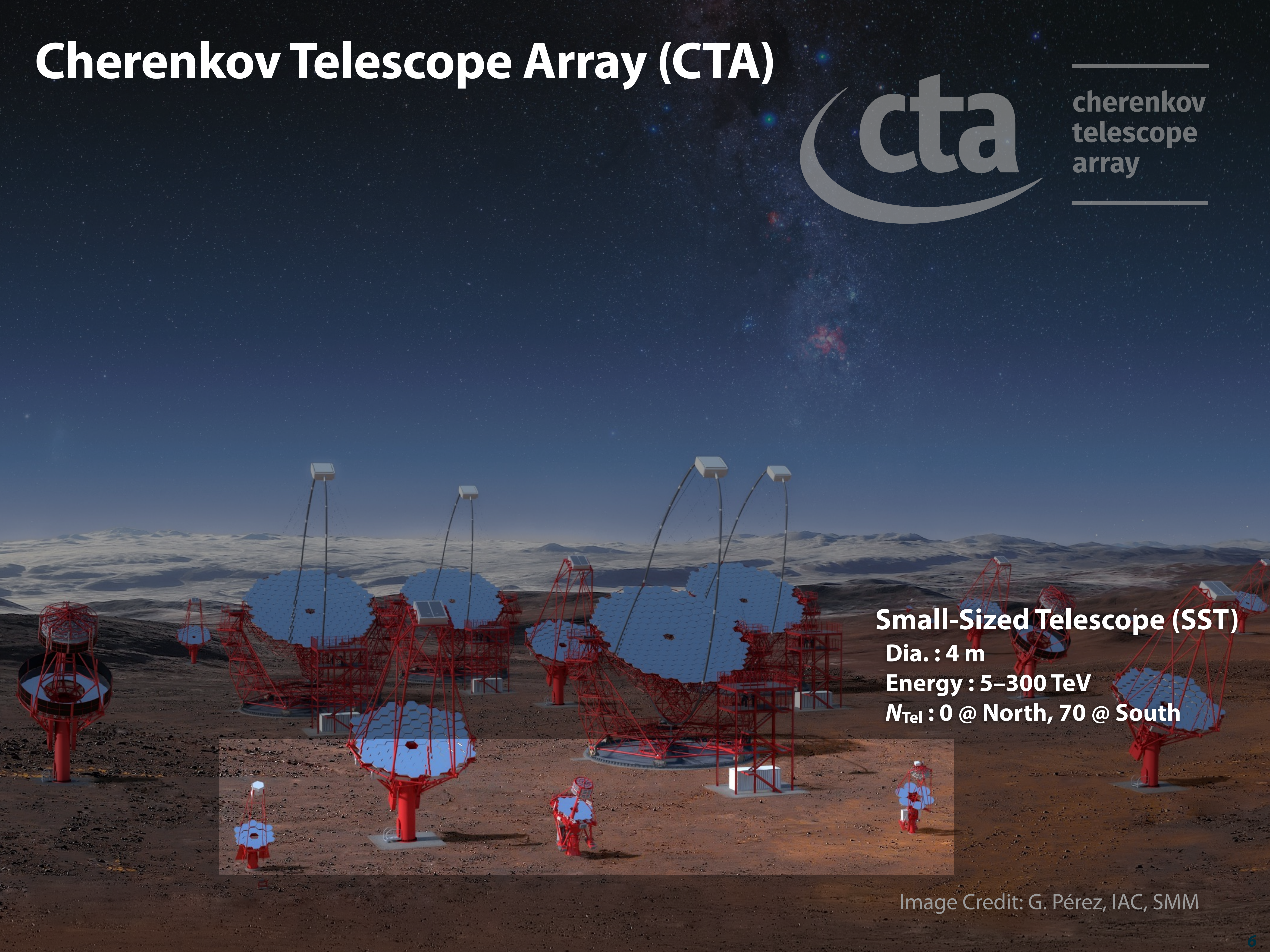
Dia. : 12 m

Energy : 150 GeV–5 TeV

N_{Tel} : 15 @ North, 25 @ South

Image Credit: G. Pérez, IAC, SMM

Cherenkov Telescope Array (CTA)



Small-Sized Telescope (SST)

Dia. : 4 m
Energy : 5–300 TeV
N_{Tel} : 0 @ North, 70 @ South

Image Credit: G. Pérez, IAC, SMM

Cherenkov Telescope Array (CTA)

cherenkov
telescope
array

Schwarzschild–Couder Telescope (SCT)

Dia. : 10 m

Energy : 150 GeV–5 TeV

N_{Tel} : 15 @ North, 25 @ South (incl. MSTs)

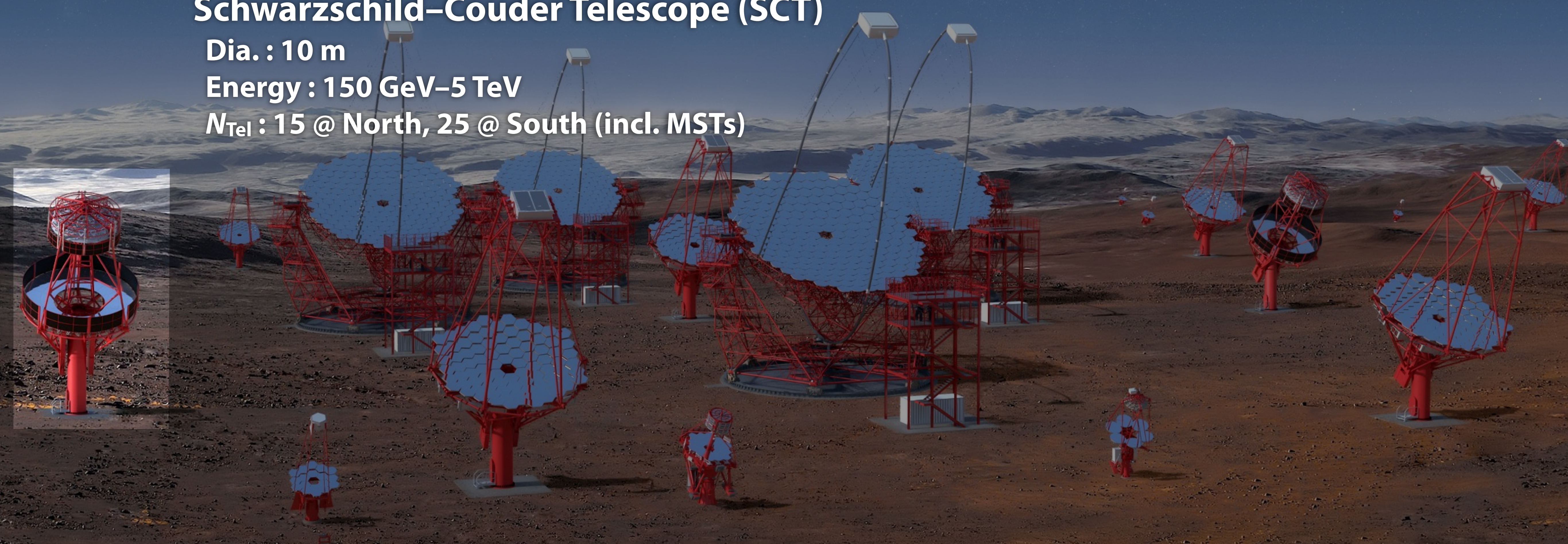
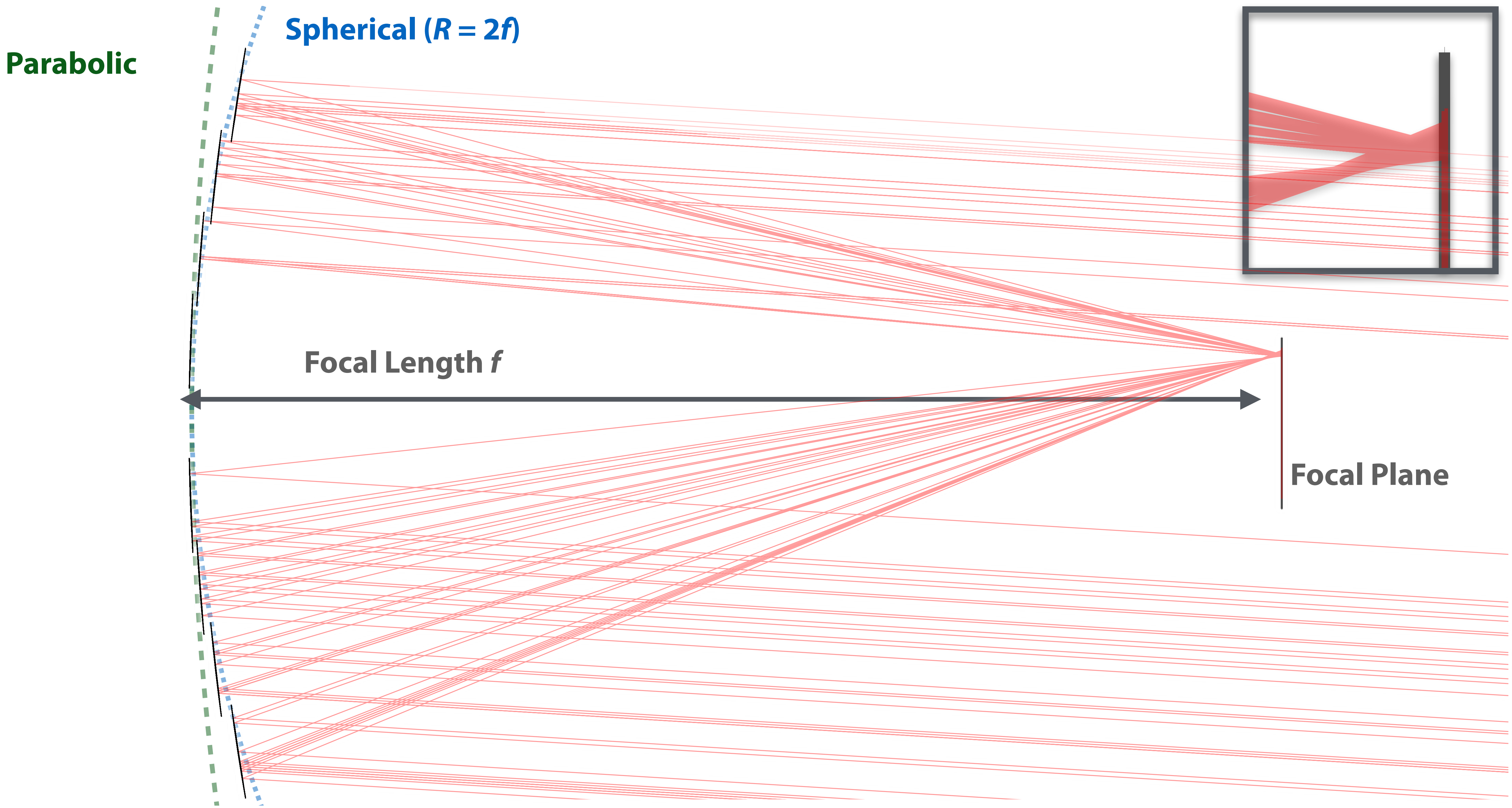


Image Credit: G. Pérez, IAC, SMM

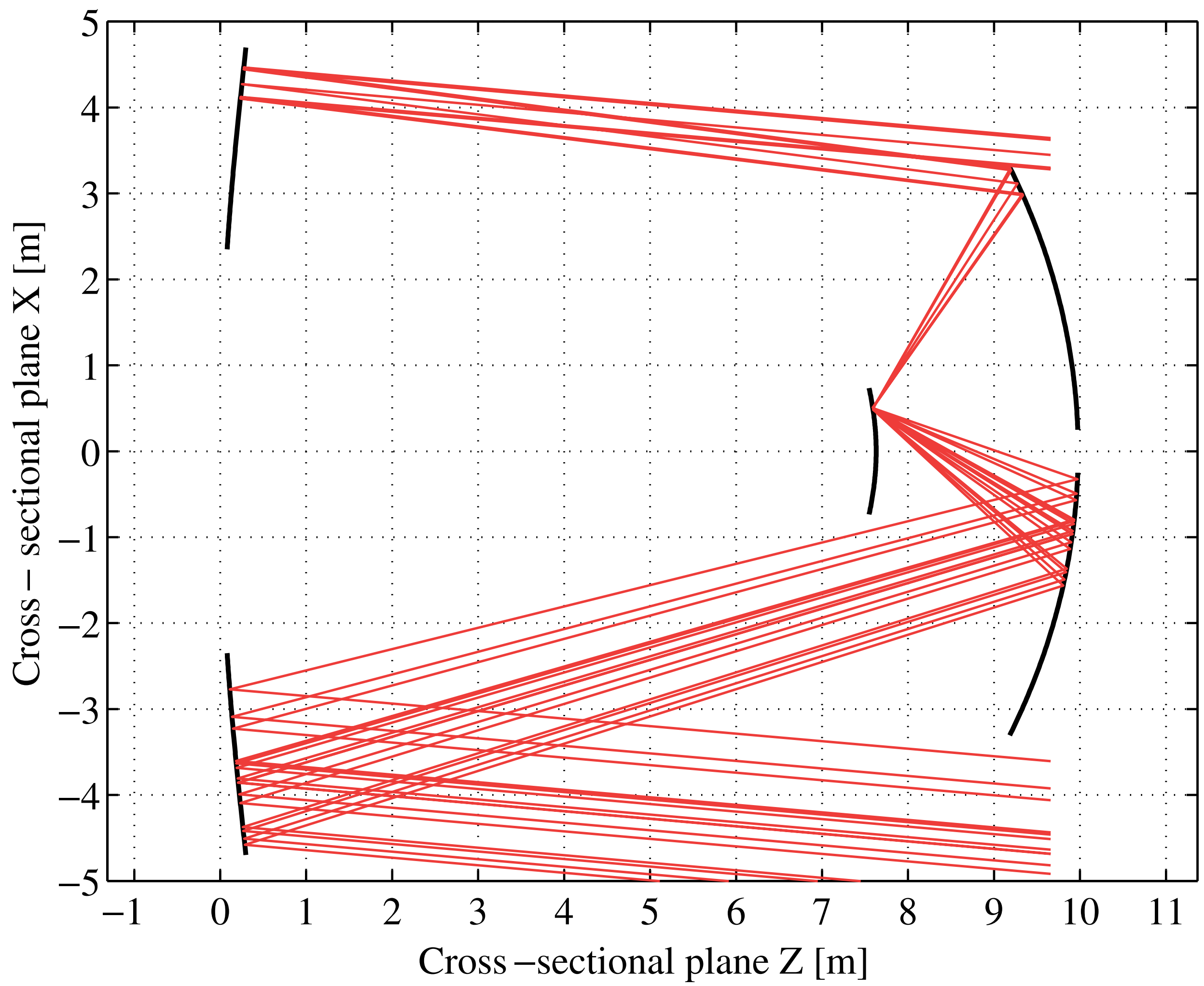
Davies–Cotton Configuration

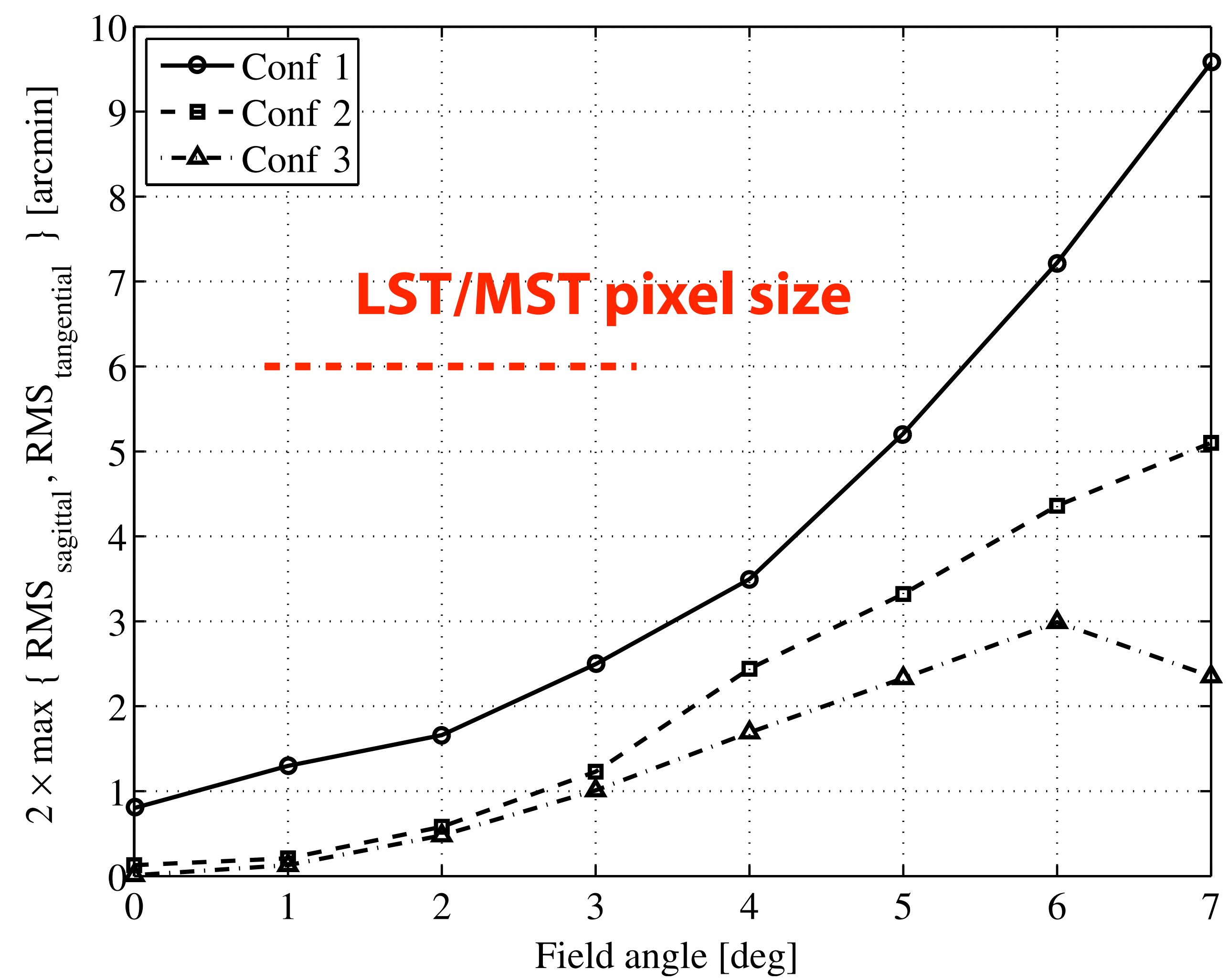


- Another standard optics design in Cherenkov telescopes (Parabola for LSTs)
- Initially proposed for solar power plants
- Wide field-of-view (FOV), but thus low angular resolution

Schwarzschild–Couder Configuration

Vassiliev+ (2007)



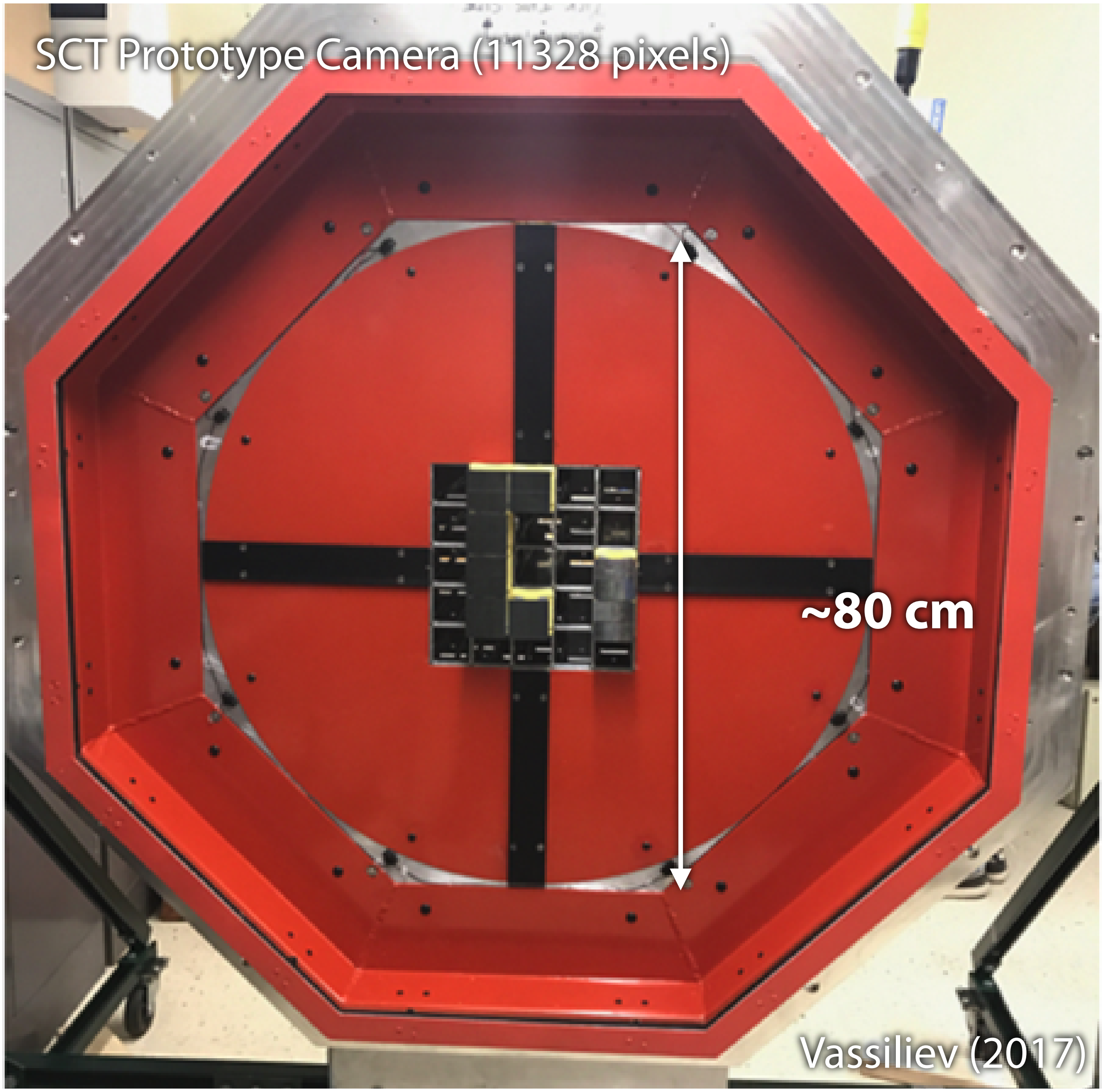


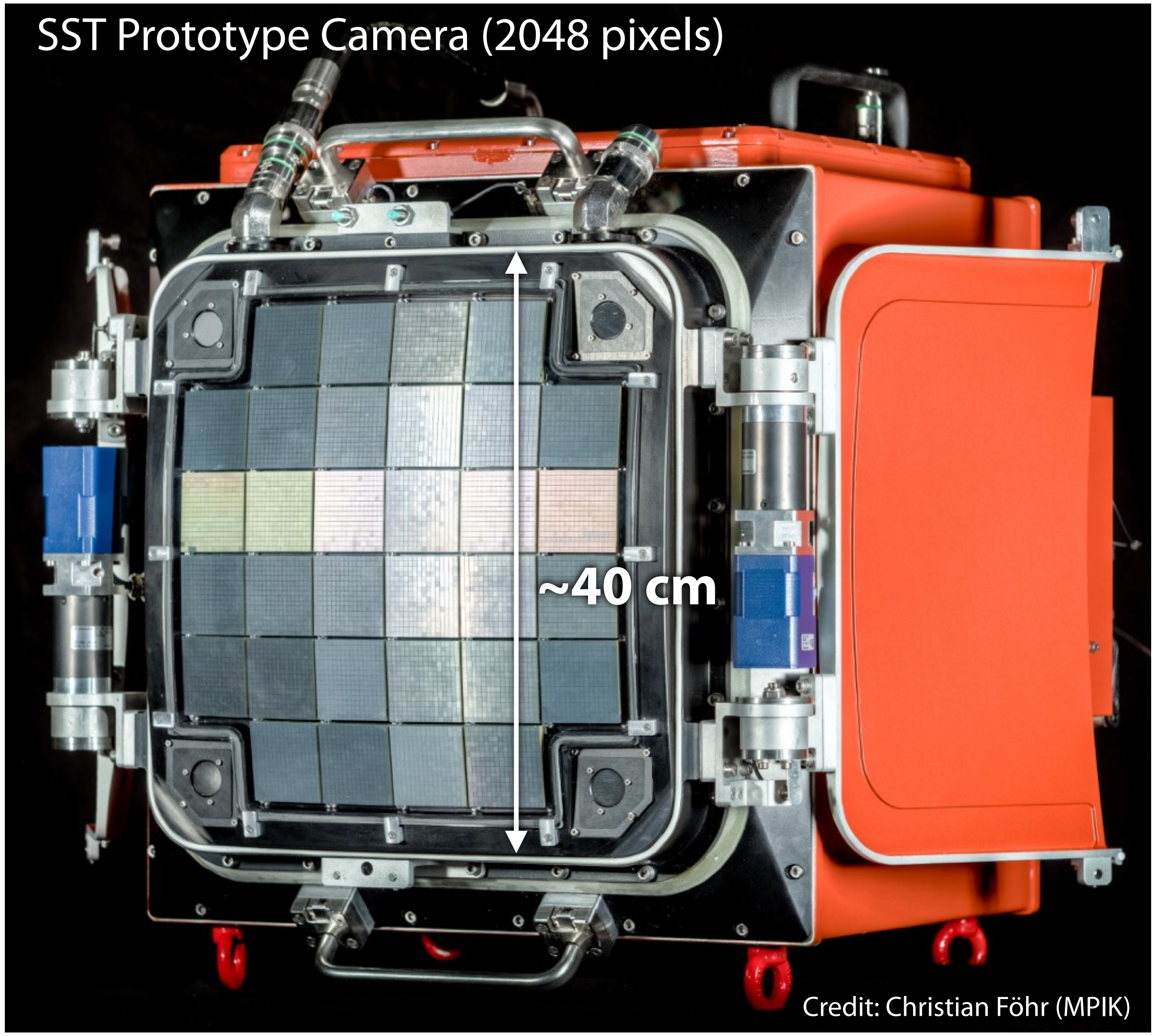
- **Aspherical** primary and **secondary** mirrors to achieve wide FOV and better resolution at the same time
- Wider FOV brings fast survey and wider effective area for higher-energy photons
- Finer shower-image resolution (→ higher sensitivity) and compact camera (→ less expensive) are expected
- Initially proposed by the CTA US group for MSTs

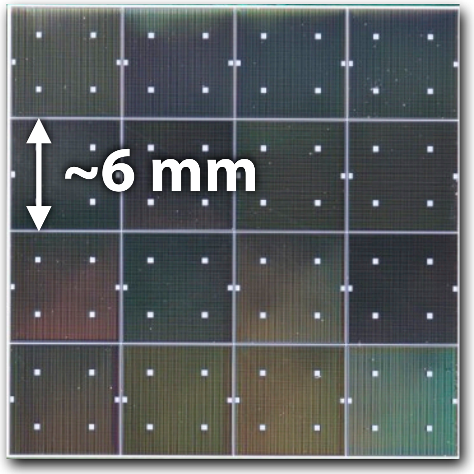
Schwarzschild–Couder Proposals for CTA

- Schwarzschild–Couder MST (SCT) with 10-meter diameter for MST extension
  - US, Italy, Germany, Mexico, and Nagoya
  - Japanese group contributions in SiPM, electronics, MC, and software
- 4-meter SC SST × camera design chosen to be the final SST design from three proposals in June 2019
  - Similar Japanese contributions but more active in SST

Need Compact Cameras with SiPMs



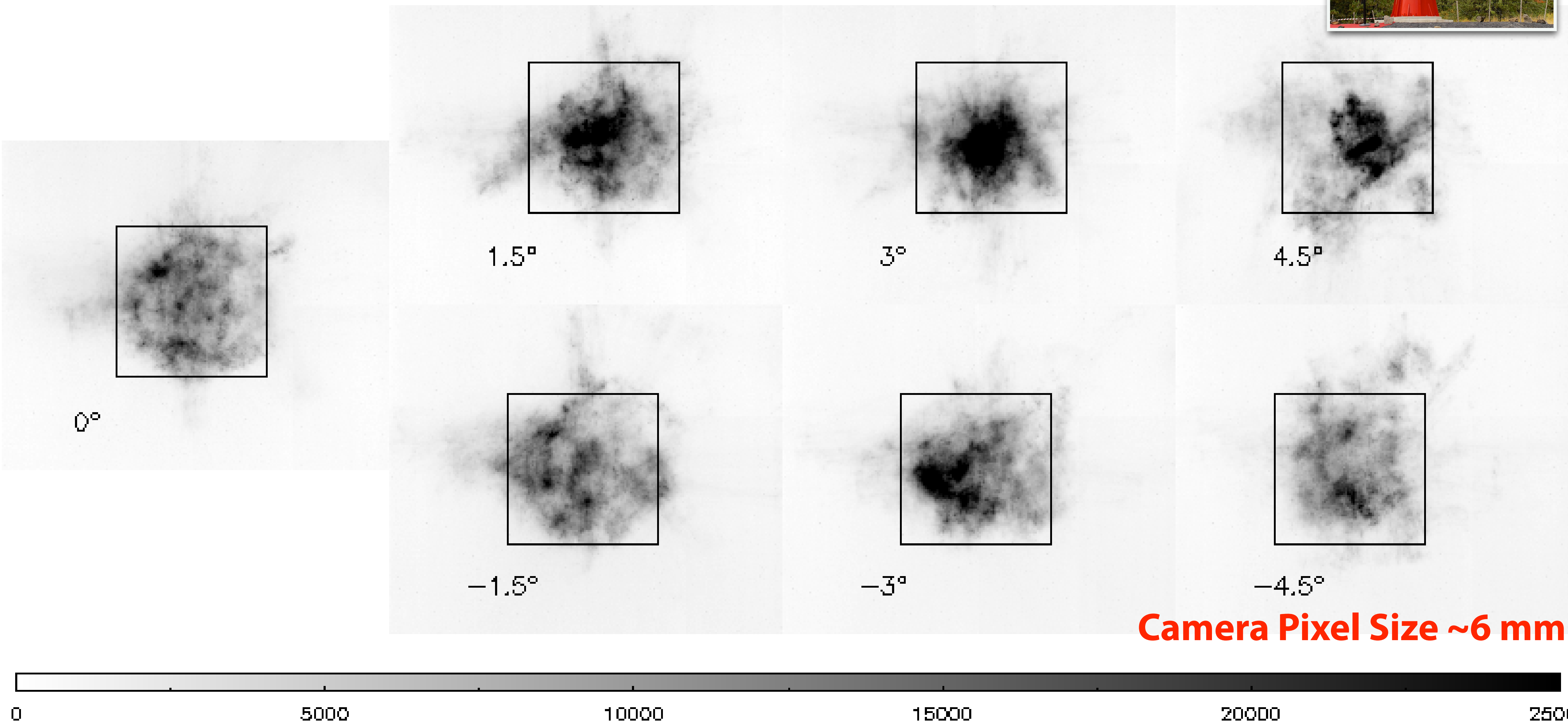




- The concave secondary mirrors make the plate scales (≡ 1/*f*) large and enable us to build compact cameras
- Silicone photomultipliers (SiPMs) are used instead of conventional photomultipliser tubes (PMTs)

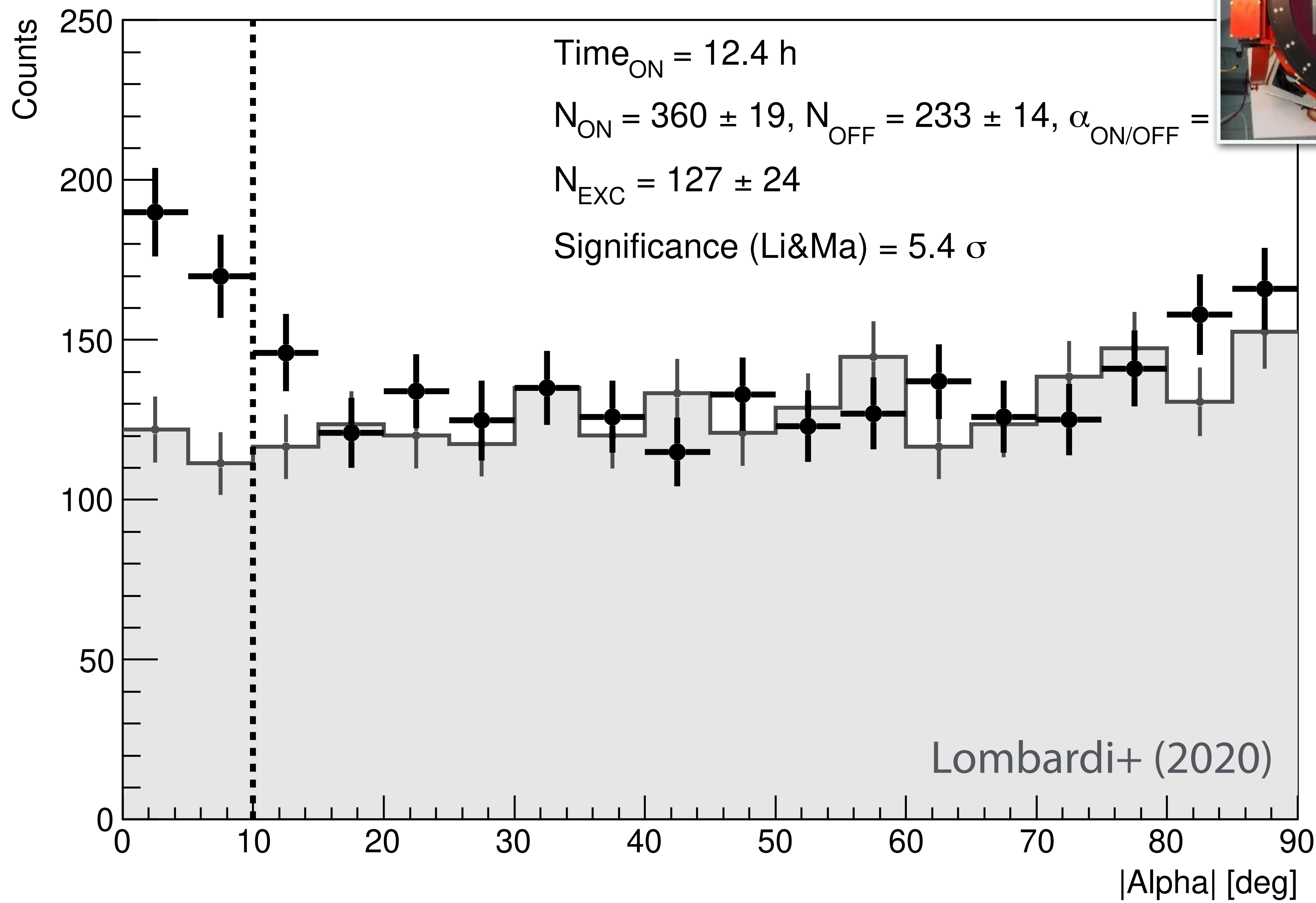
SST Optical System

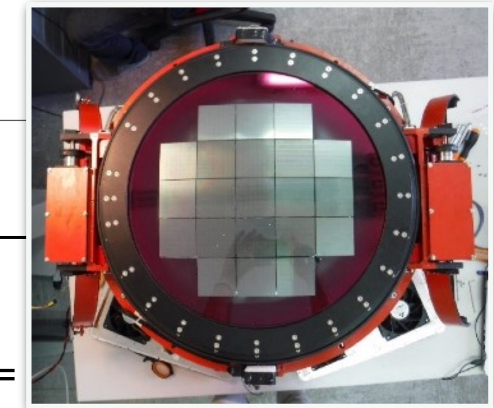
Giro+ (2017)



- Achieved good enough optical resolution matching the SST pixel size
- First realization of the Schwarzschild–Couder configuration ever

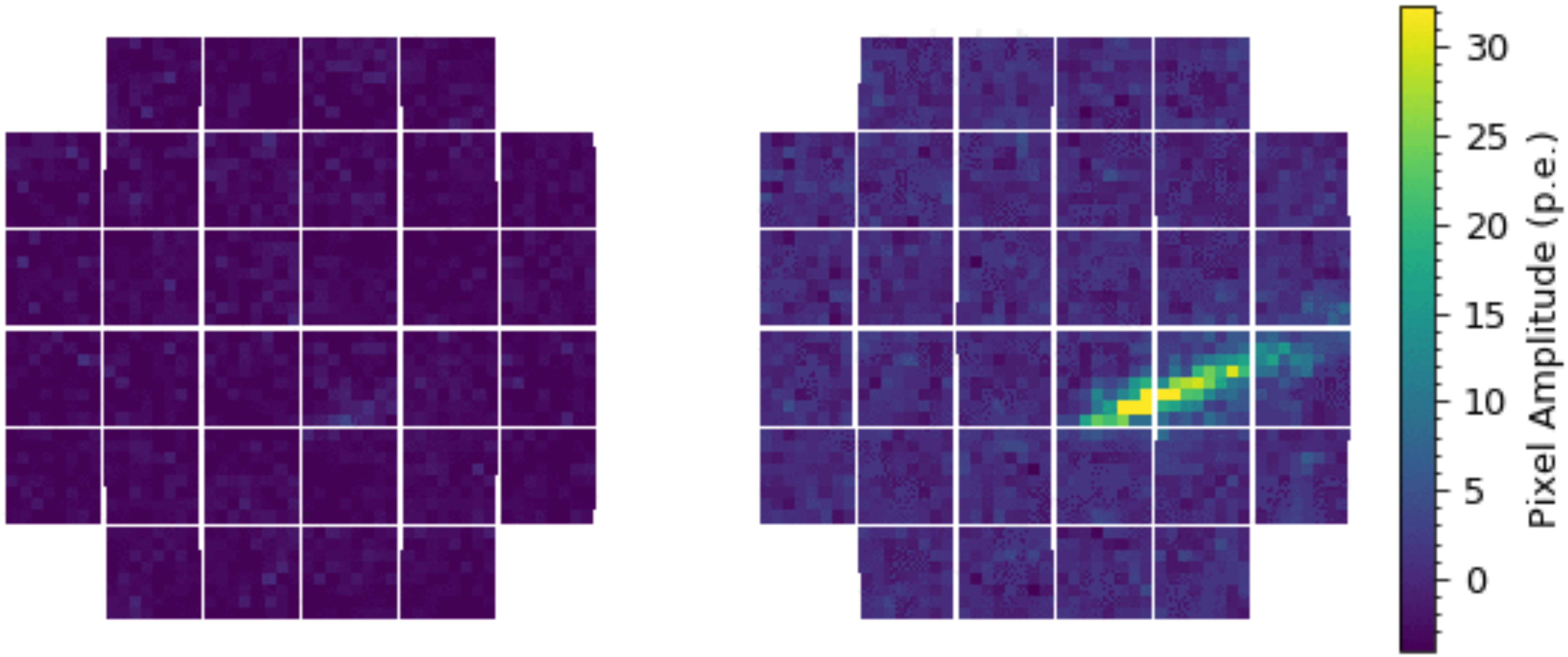
SST Crab Observations: Detection at 5.4 σ





- “ASTRI” camera (lead by Italian groups) successfully detected gamma-ray signal from the Crab Nebula
- Combination of the Schwarzschild–Couder and a SiPM camera verified

Another (Our) SST Camera Test Observations



https://www.cta-observatory.org/chec-achieves-first-light-on-astri/

- "Our" camera also succeeded in air-shower observations on the same prototype telescope (replaceable with the Italian camera)
- Additional test observations canceled due to mirror re-coating and COVID-19

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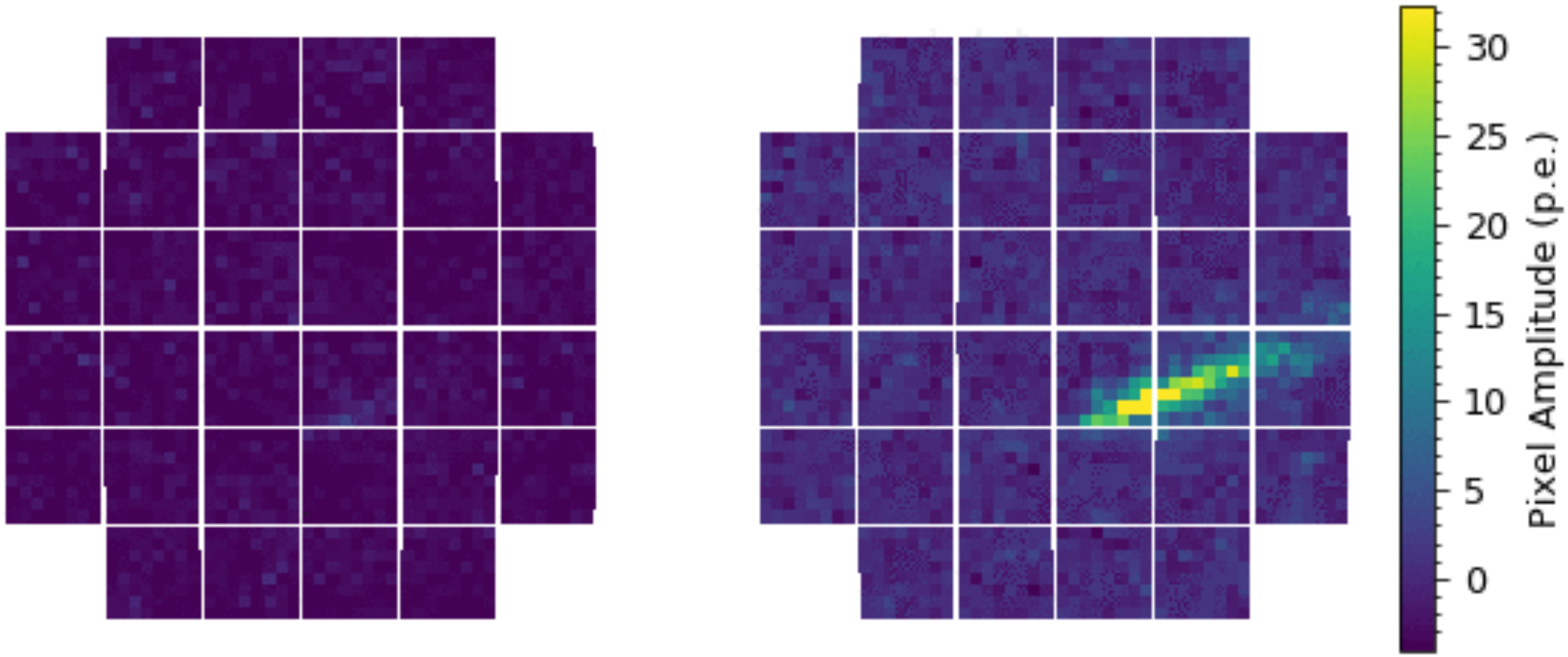

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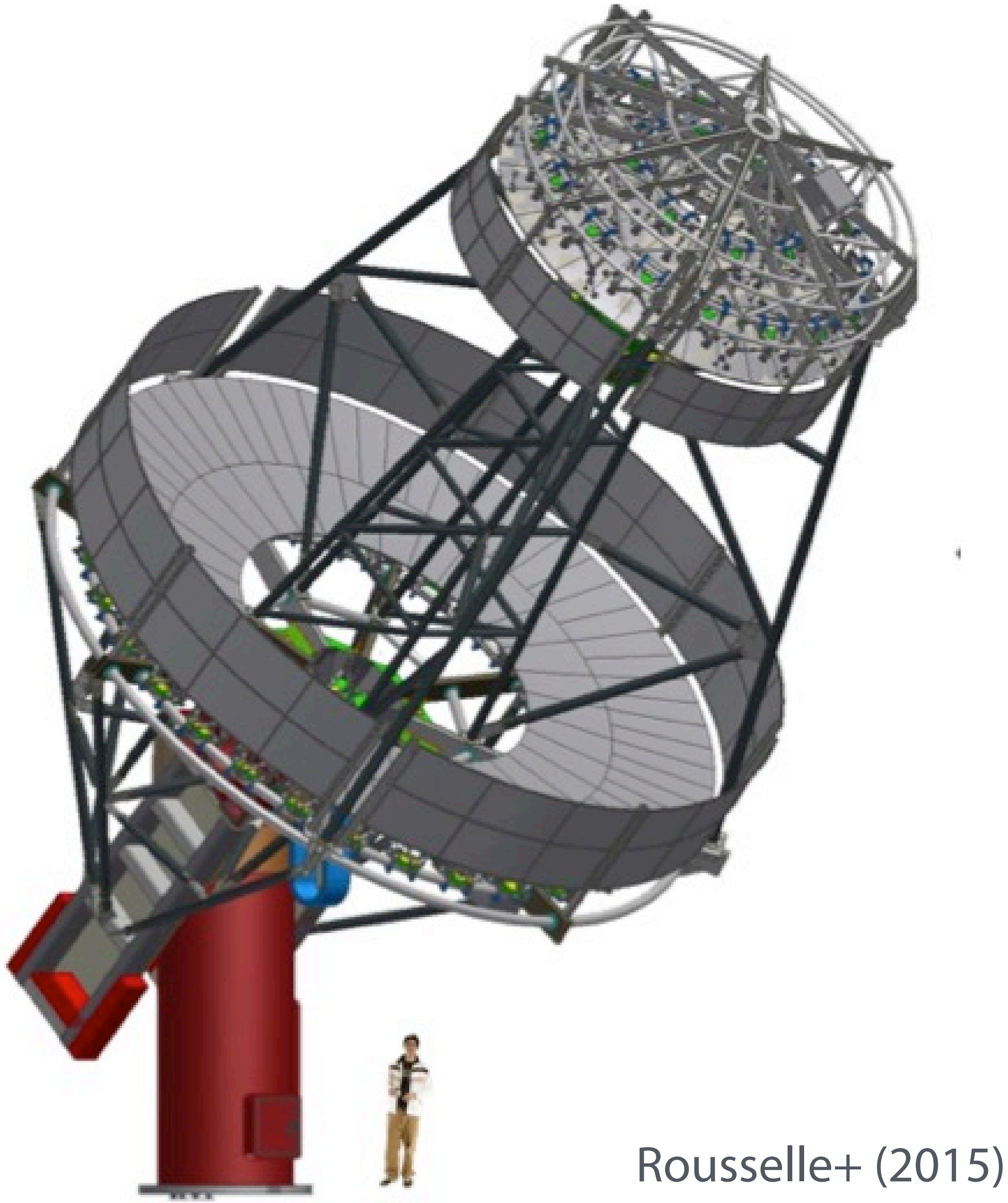
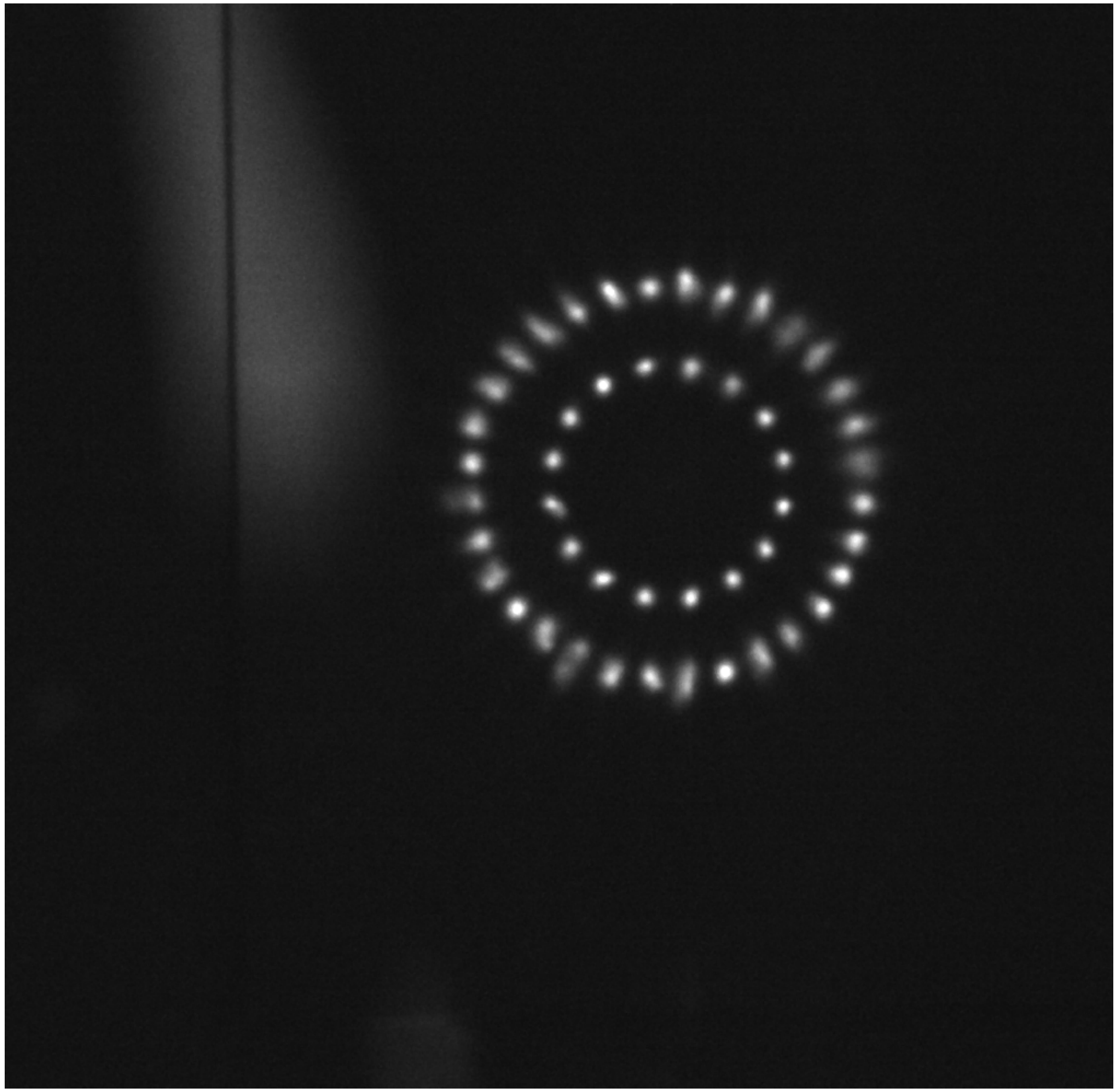
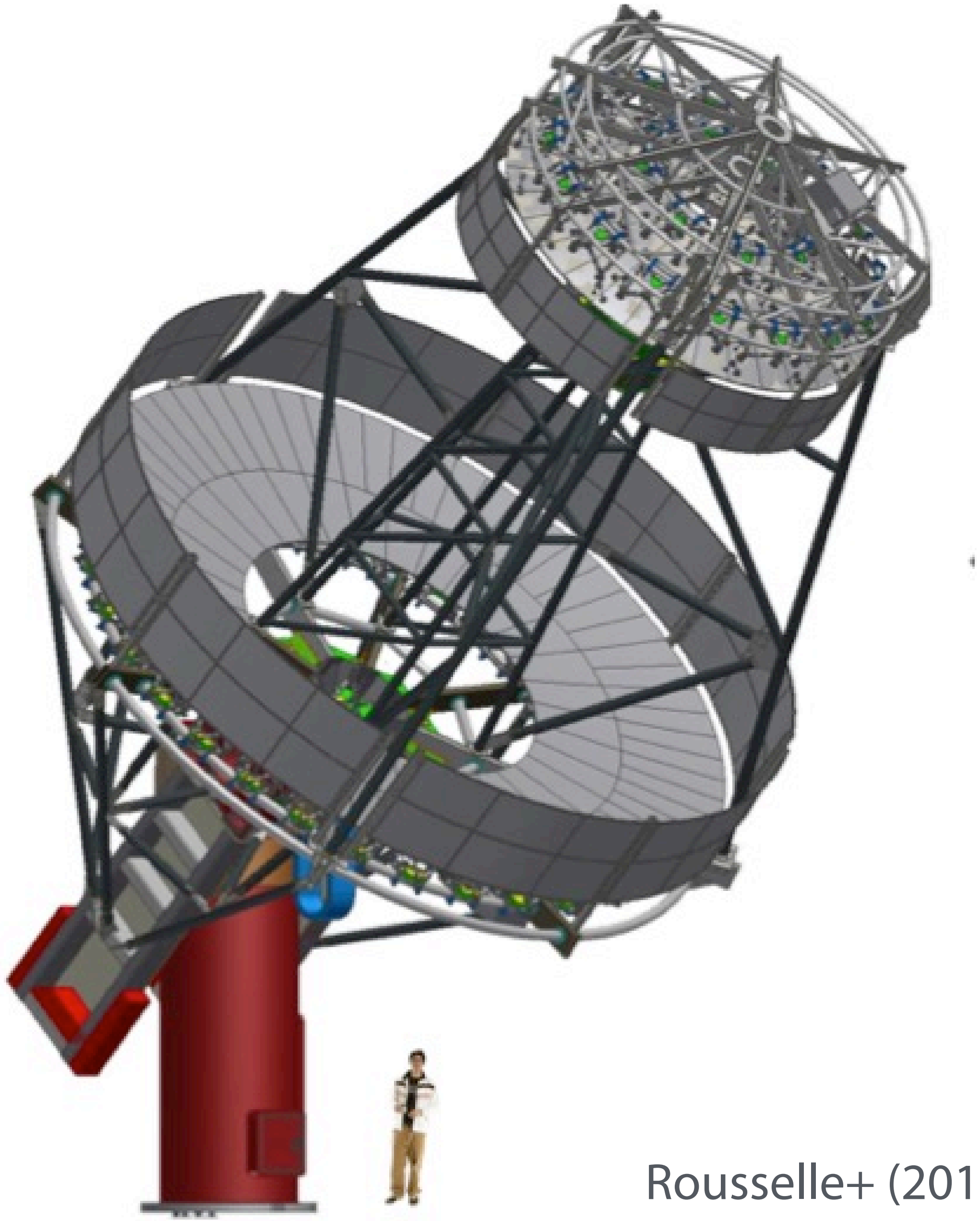
Schwarzschild–Couder MST Optical System



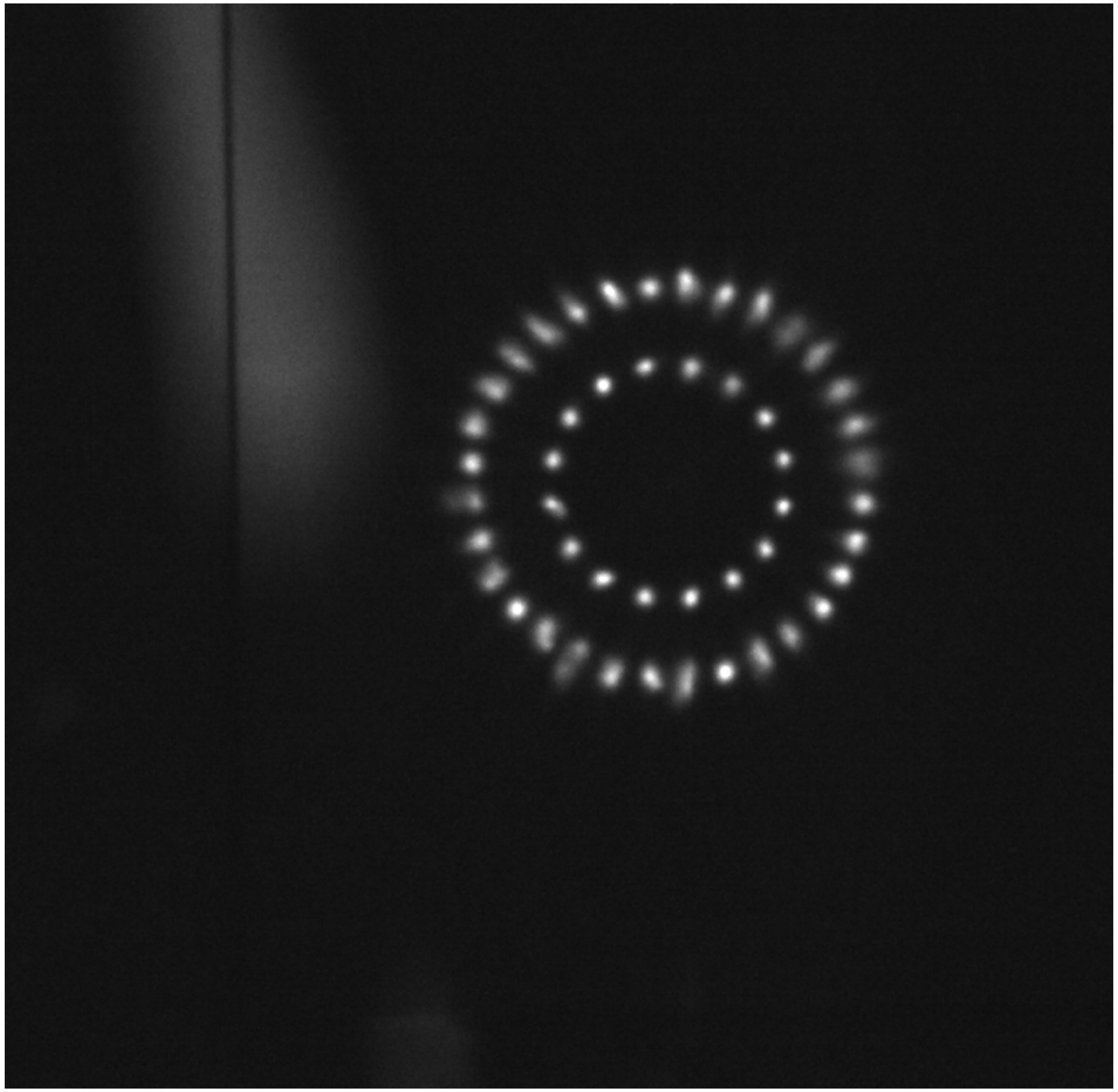


- 2.5 times larger than the SST optical system
- More number of segmented mirrors, thus more complex
- Optical alignment was successfully finished

Schwarzschild–Couder MST Optical System



Rousselle+ (2015)



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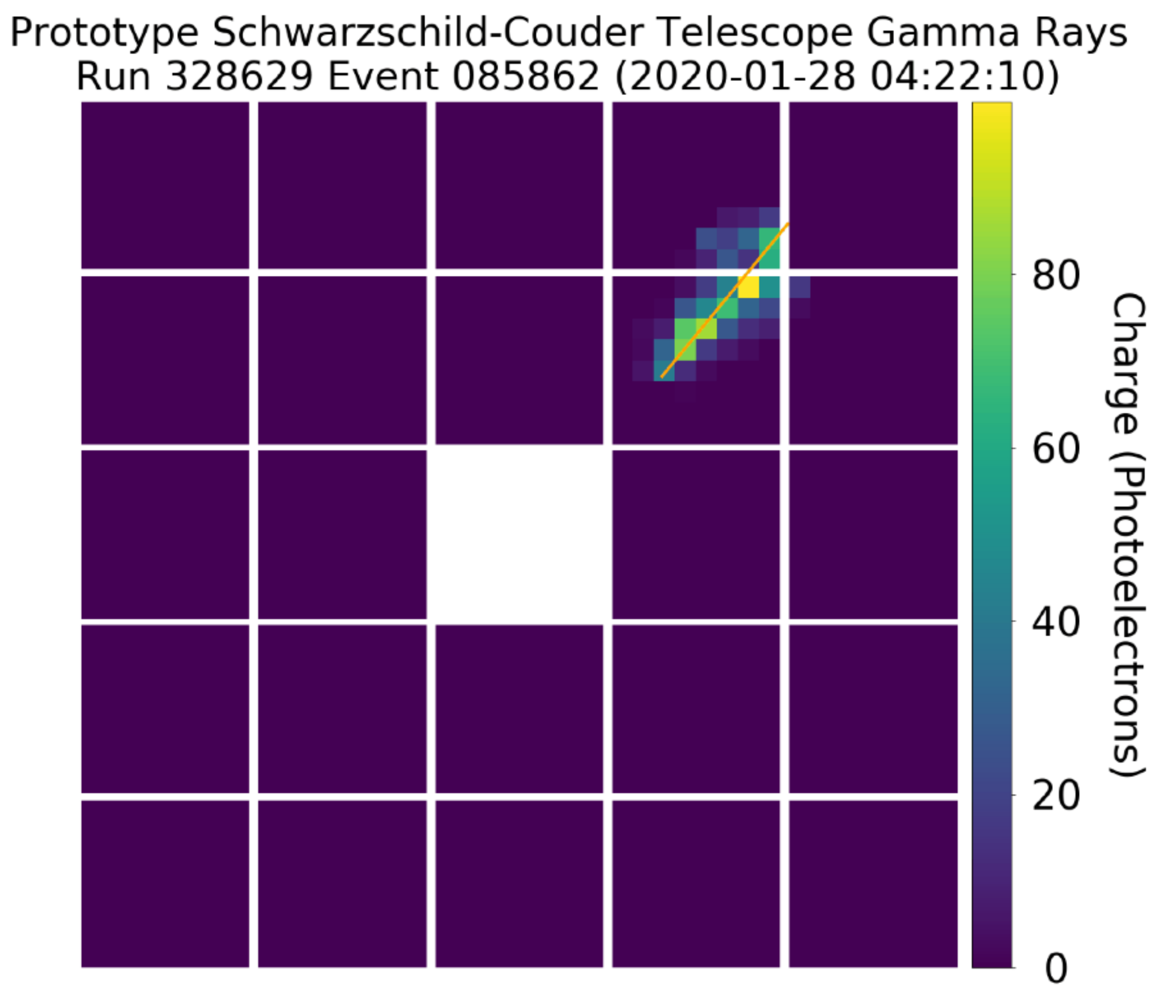
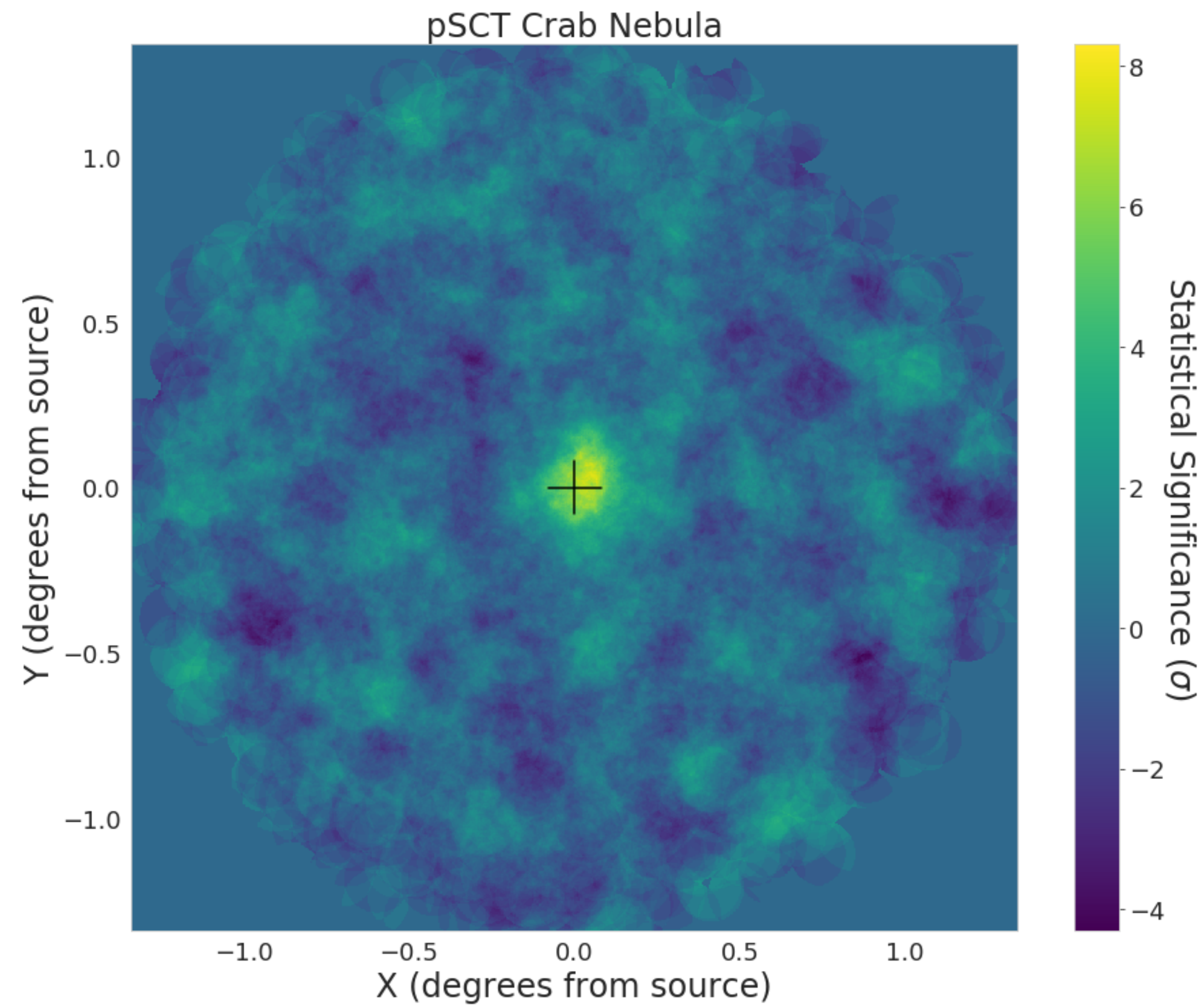
Crab Observations by Prototype Schwarzschild–Couder





- Crab Nebular detection at 8.3σ, while the prototype FOV is still limited

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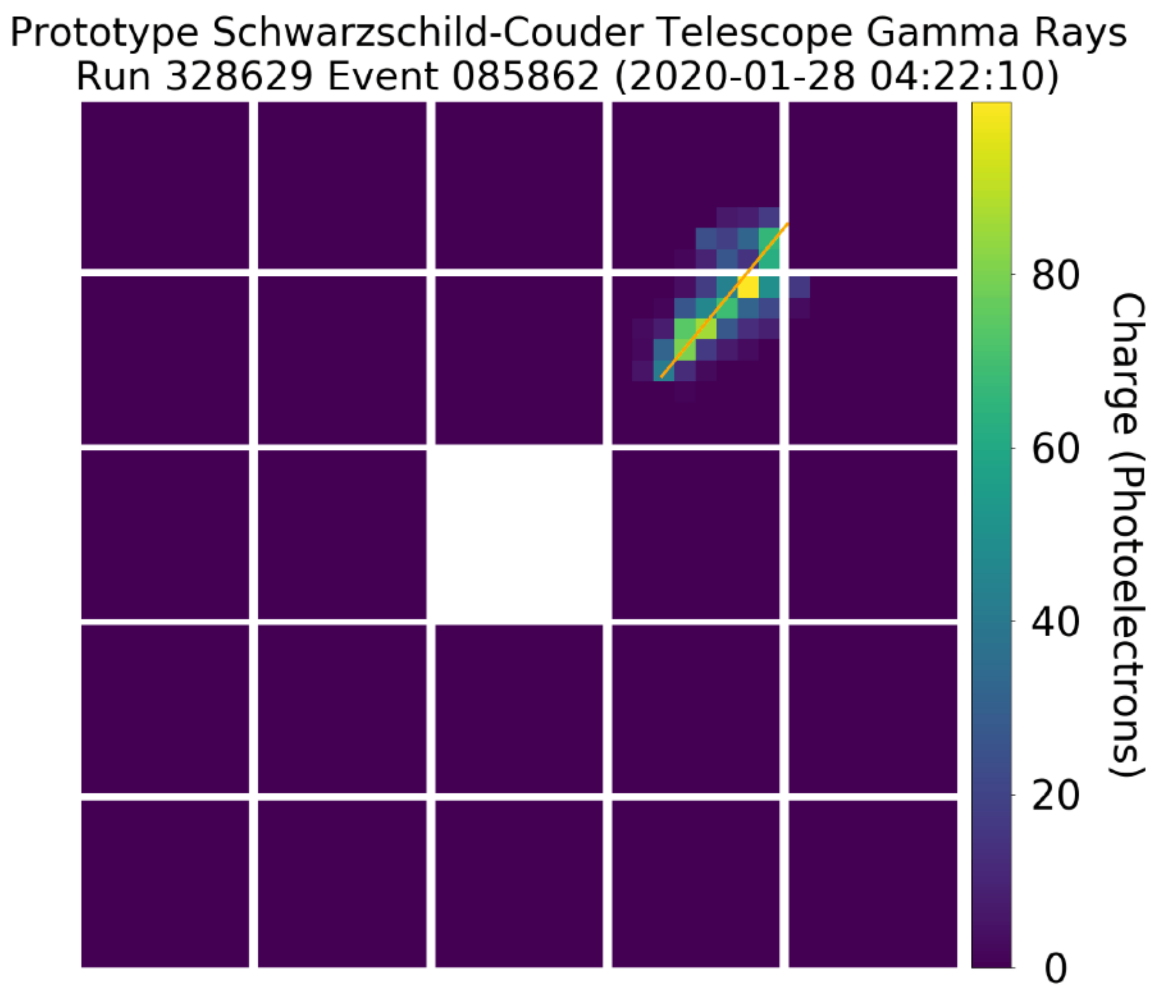

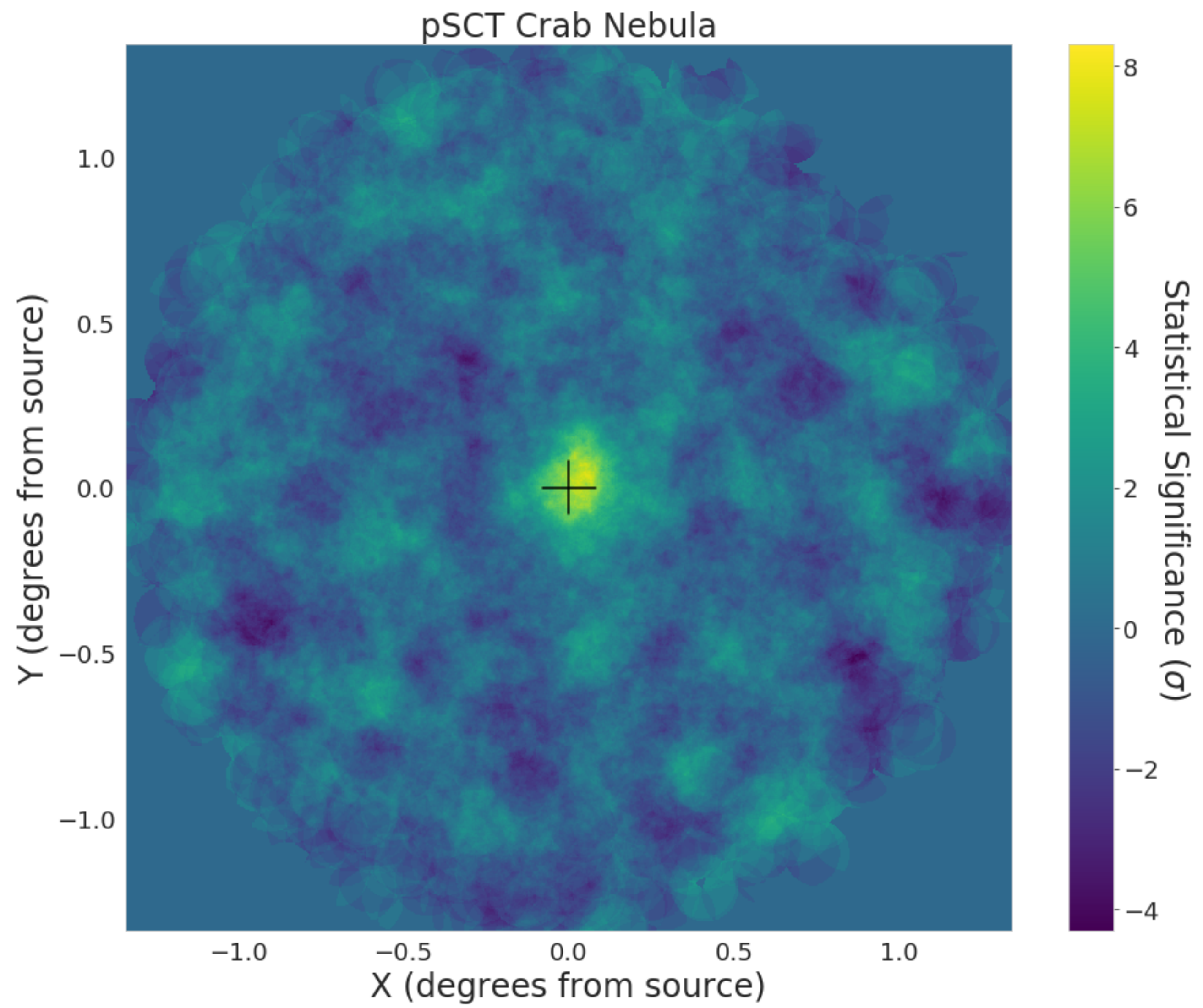

- Crab Nebular detection at 8.3σ, while the prototype FOV is still limited

Summary and Plans

- Prototype Schwarzschild–Couder (SC)telescopes for the CTA Medium- and Small-sized Telescopes constructed
- First realization of the SC configuration
- Both succeeded in air-shower Cherenkov observations and Crab Nebula detection with prototype SiPM cameras

- Prototype SC-MST will be upgraded with full FOV coverage with more SiPM tiles and new electronics
- SST is going to finalize the optics and camera designs
- New SST prototype(s) will be built and tested before the pre-production phase