Status of the Small-Sized Telescopes of the Cherenkov Telescope Array

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for the CTA Consortium (Thanks to the SST teams)

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The extreme Universe viewed in very-high-energy gamma rays 2018
Oct 12, 2018

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ISEE Institute for Space–Earth Environmental Research
cta cherenkov telescope array
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Small-Sized Telescopes (SSTs)

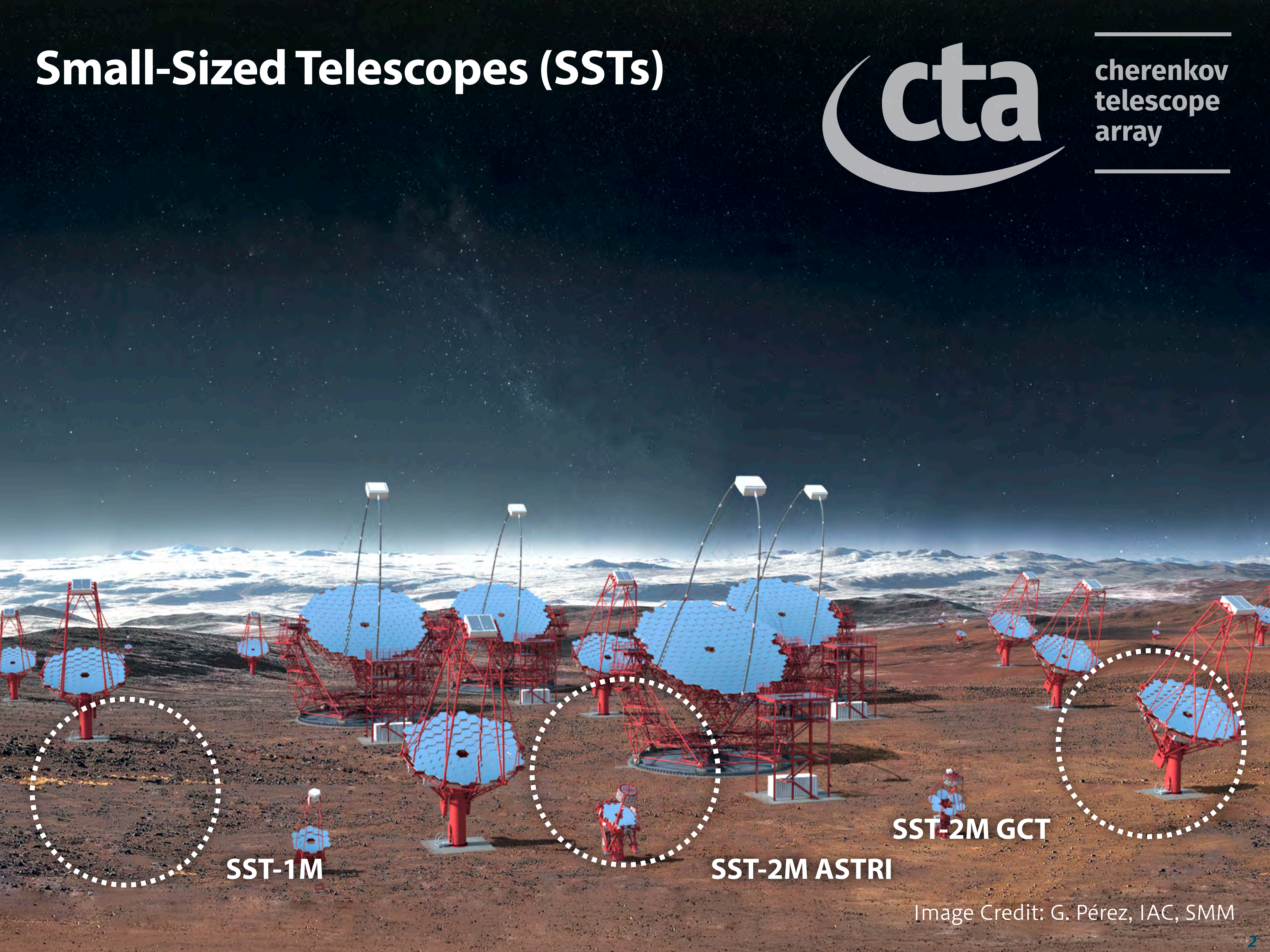
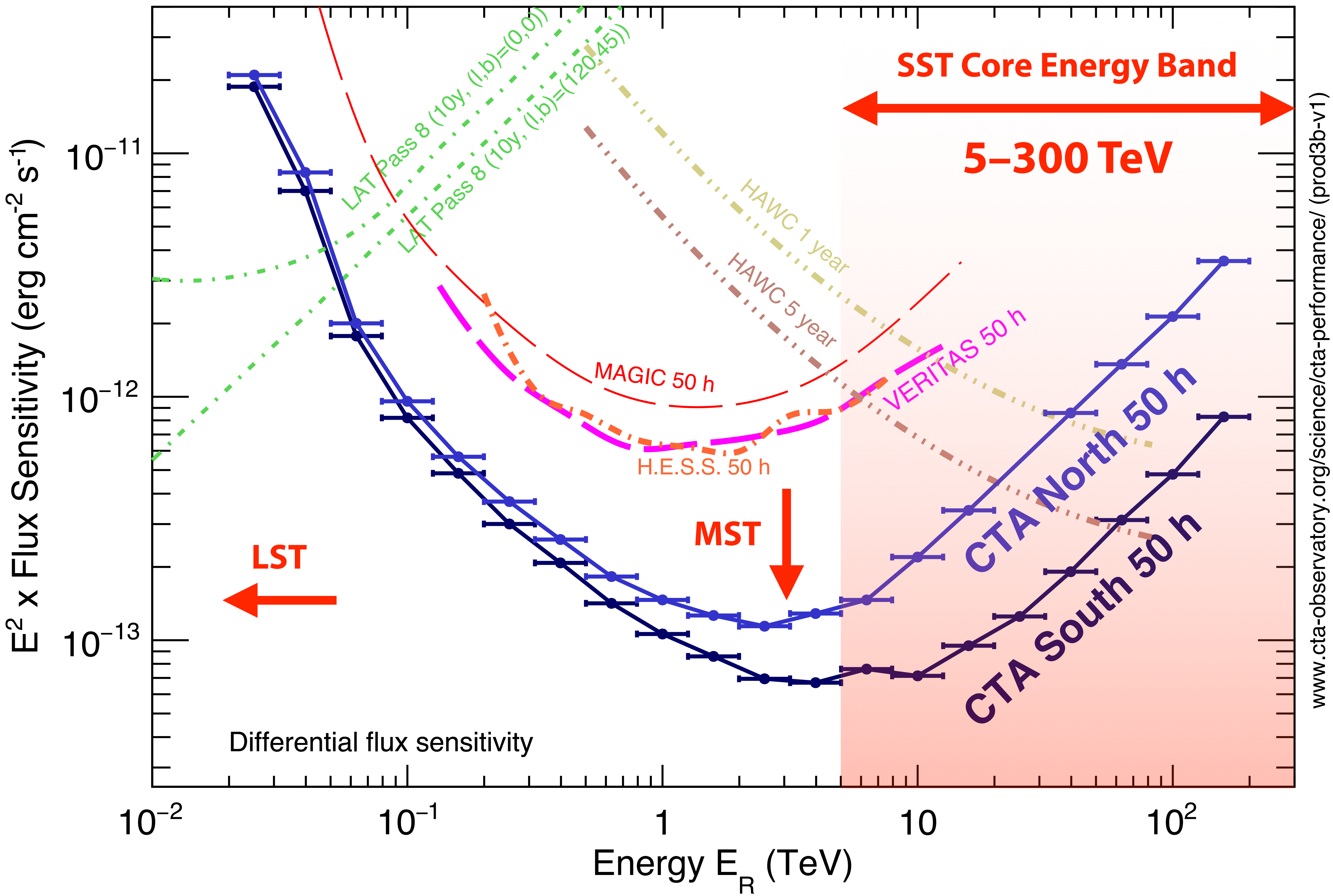


Image Credit: G. Pérez, IAC, SMM

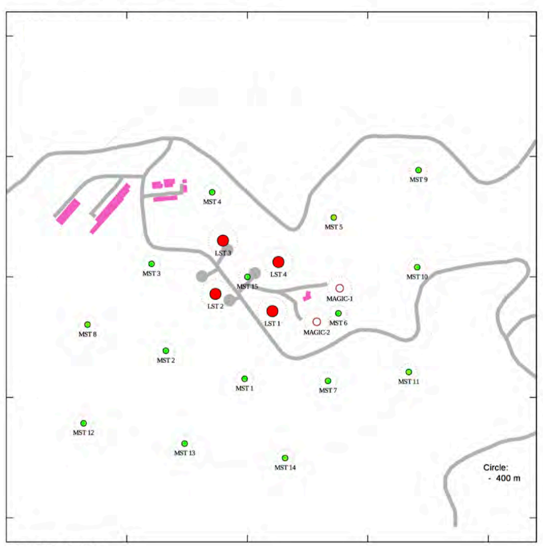
High-energy Frontier by CTA SSTs

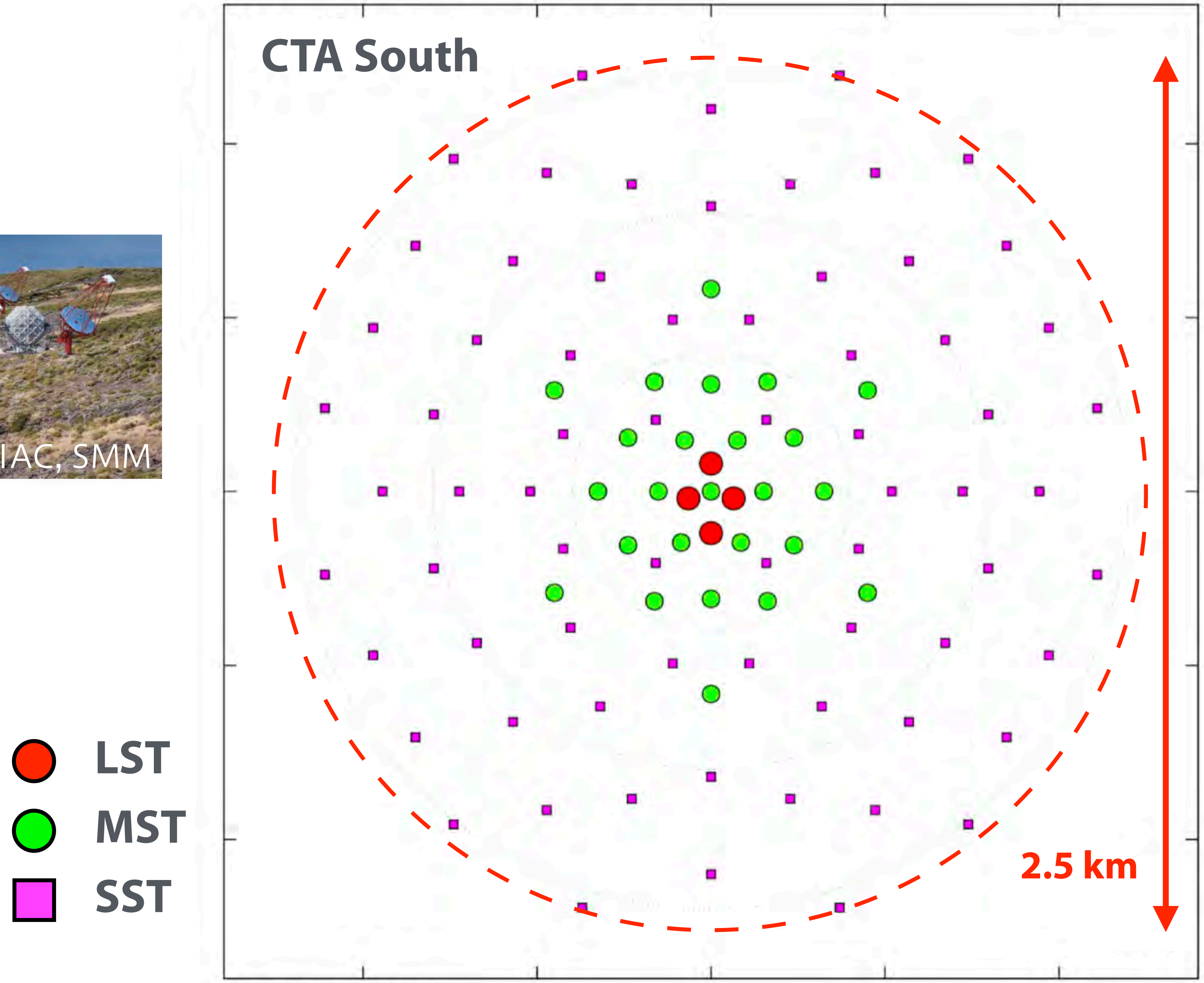
CTA Consortium arXiV:1709.07997



Baseline Layout of CTA with 70 SSTs

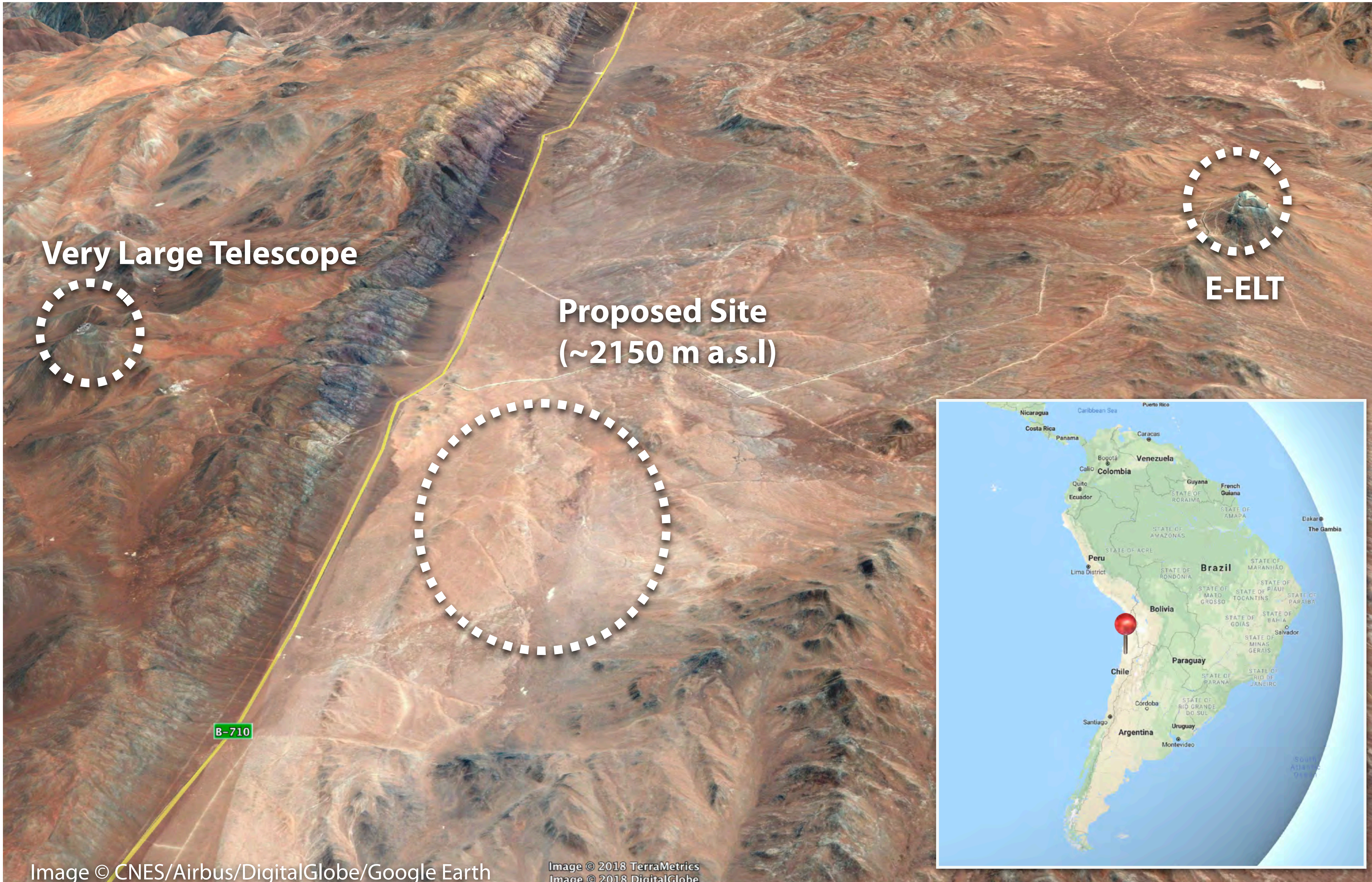
CTA North



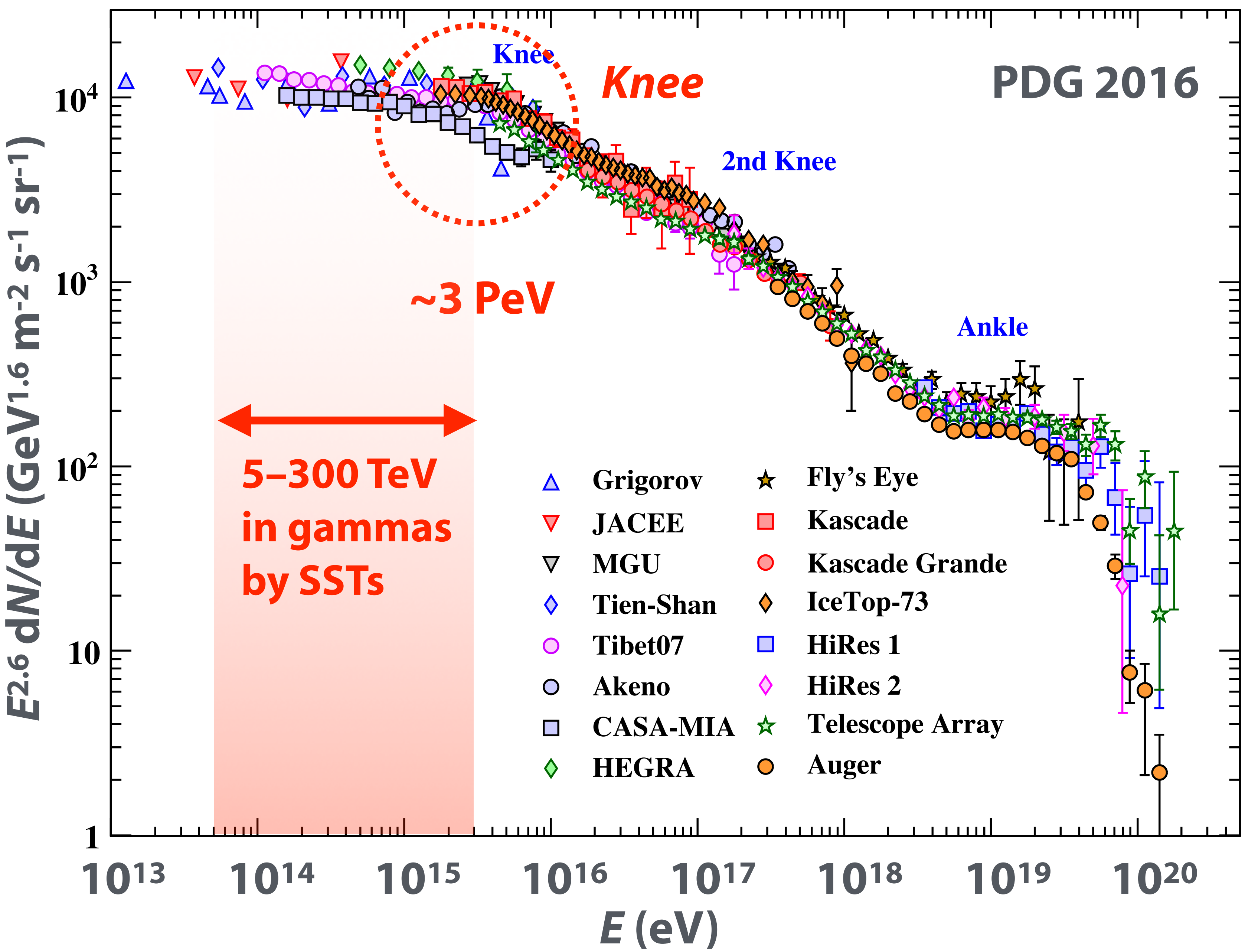


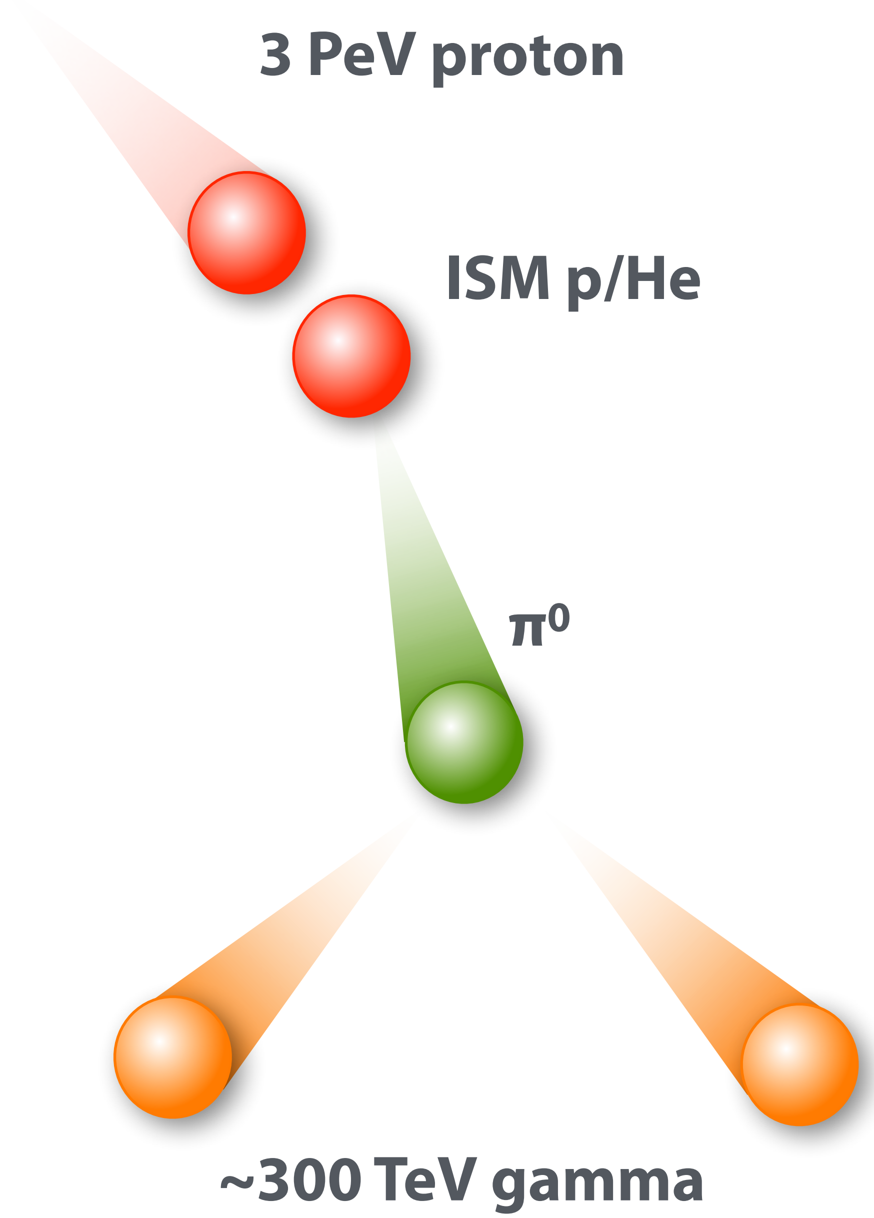
- Achieves a vast effective area of **~5 km²** with **70** SSTs
- Extends the highest-energy frontier to **300 TeV** and beyond

Southern Site – Paranal, Chile



PeVatron: Galactic PeV Cosmic-ray Accelerator

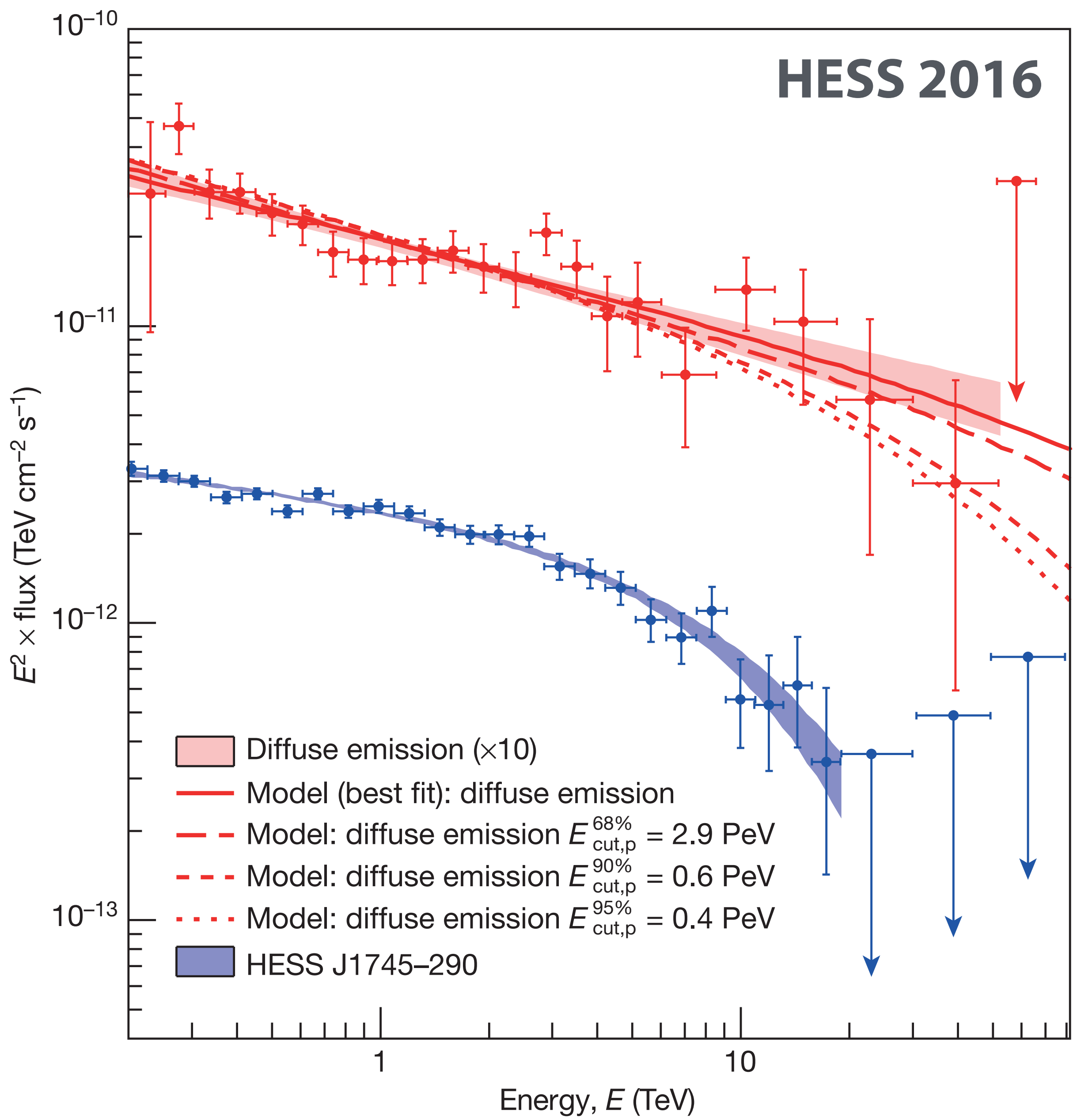


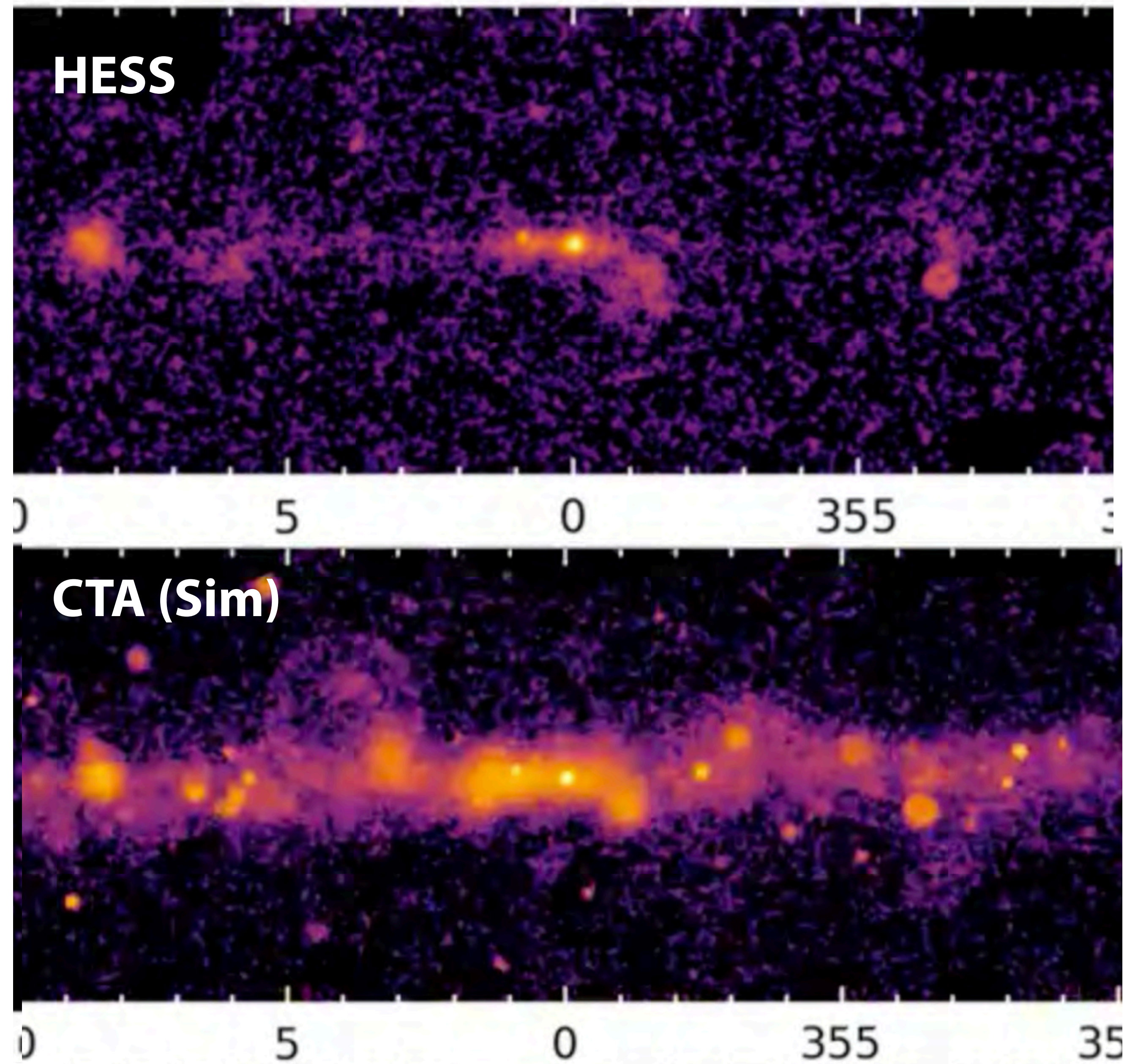


- Where do PeV cosmic rays come from? Do PeVatrons accelerate CRs up to *Knee*?
- ~3 PeV cosmic-ray protons → ~300 TeV gamma rays through π^0 decays

CTA Key Science Projects for PeVatron Search

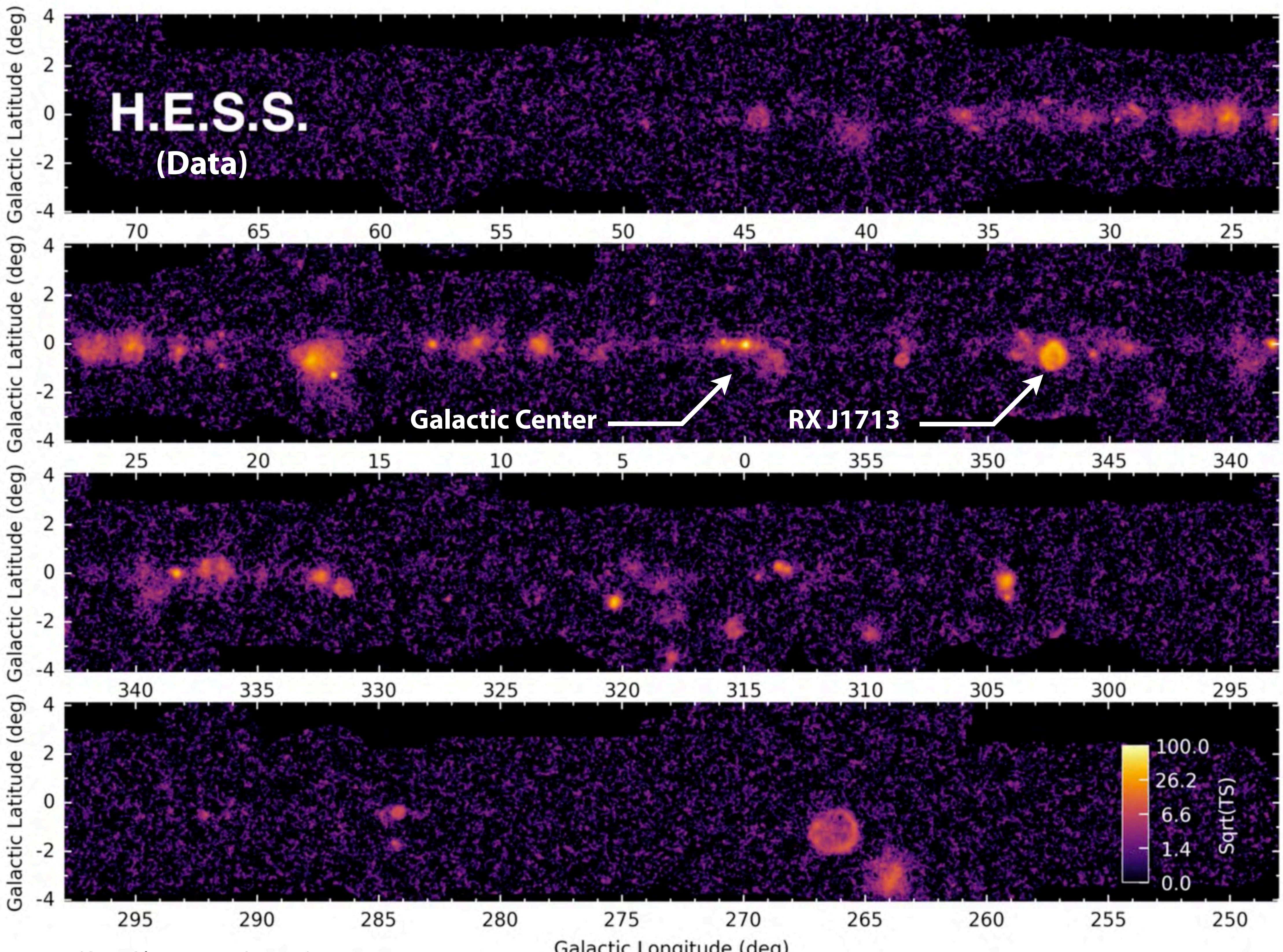
Galactic Center





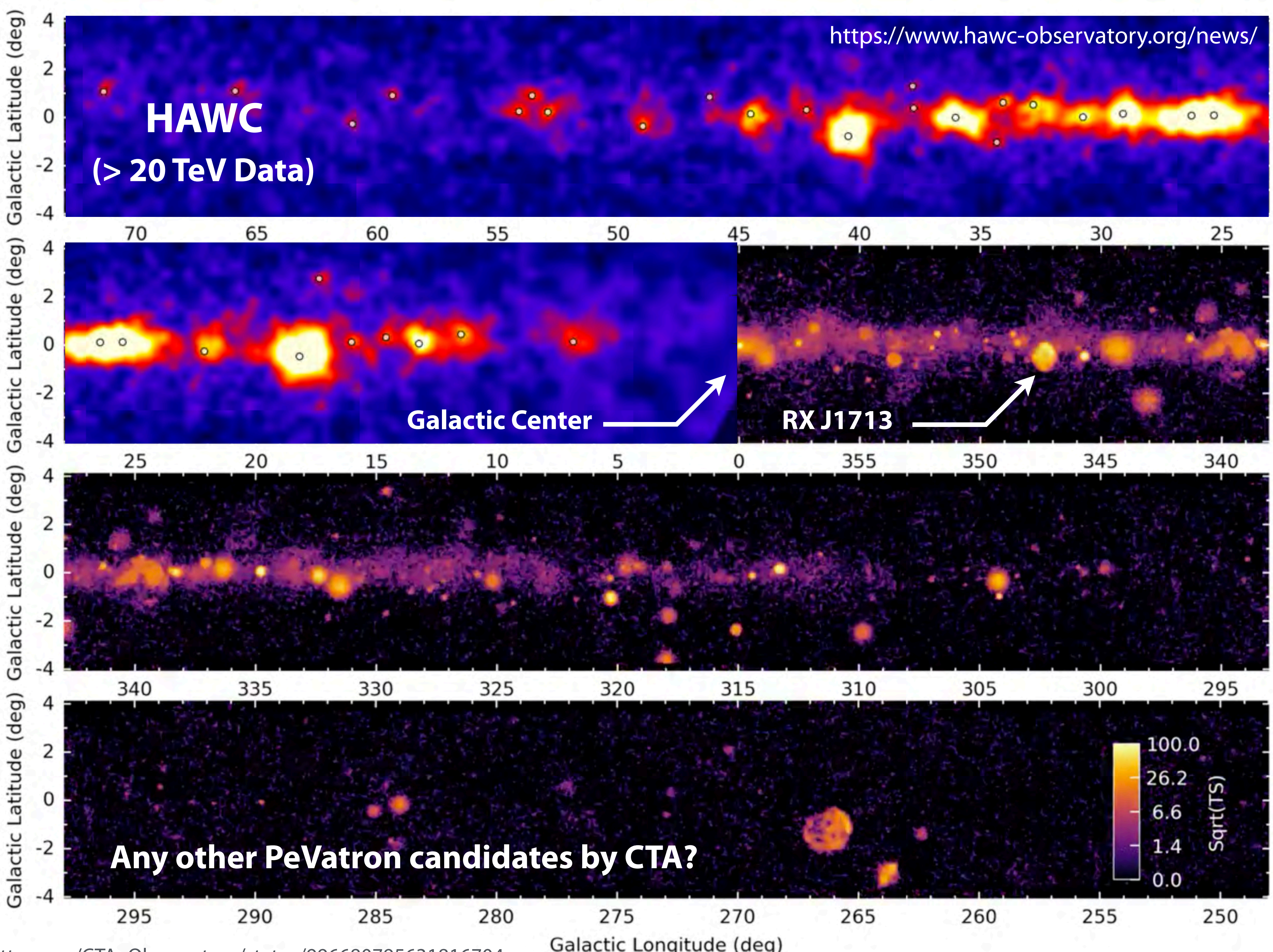
- Galactic center is the best PeVatron candidate so far (possible CR cutoff energy of a few PeV)
- Deep survey of ~800 hours is planned (inc. dark matter search)

Galactic Plane Survey (GPS)



https://twitter.com/CTA_Observatory/status/996680795631816704

Galactic Plane Survey

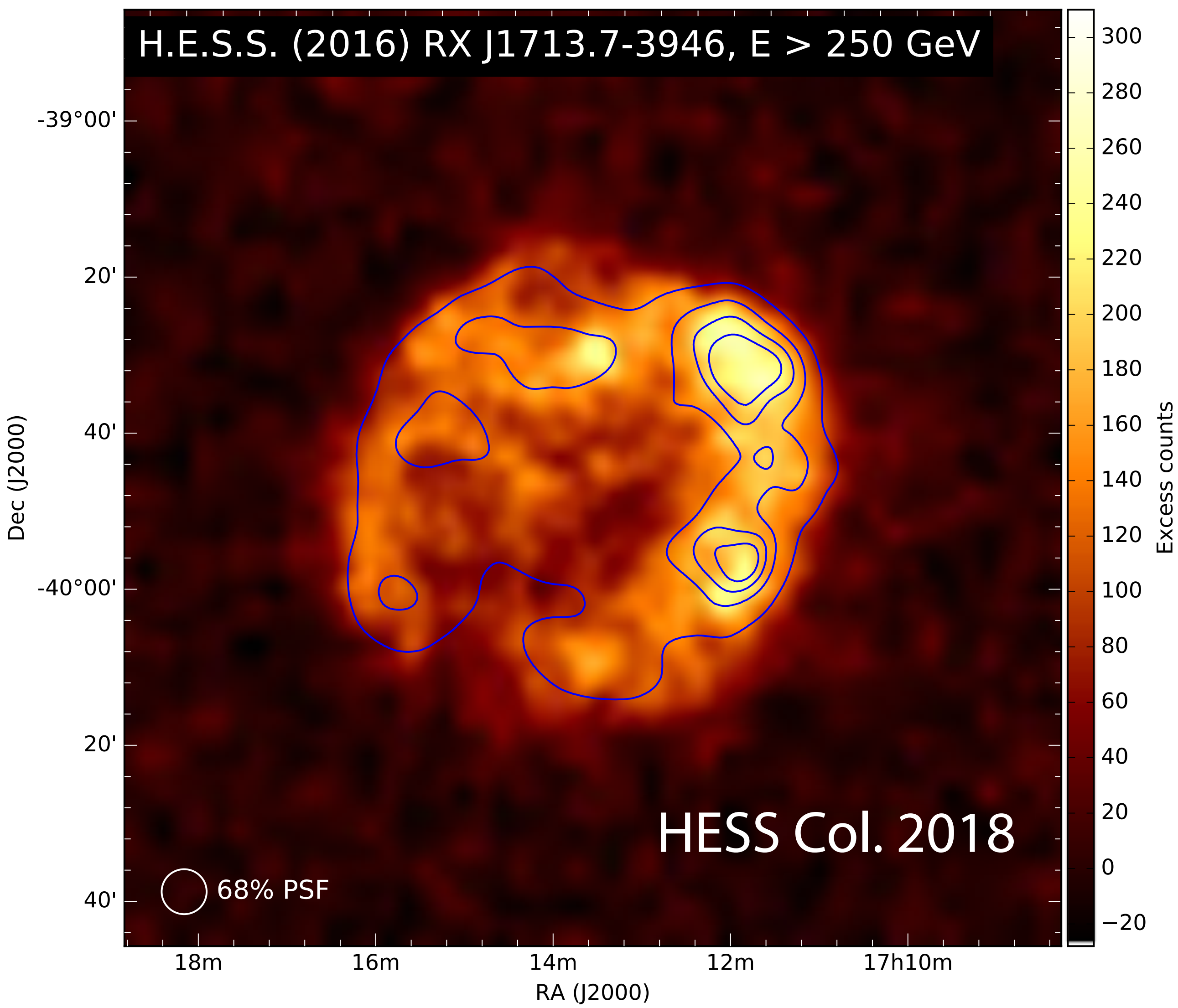


https://twitter.com/CTA_Observatory/status/996680795631816704

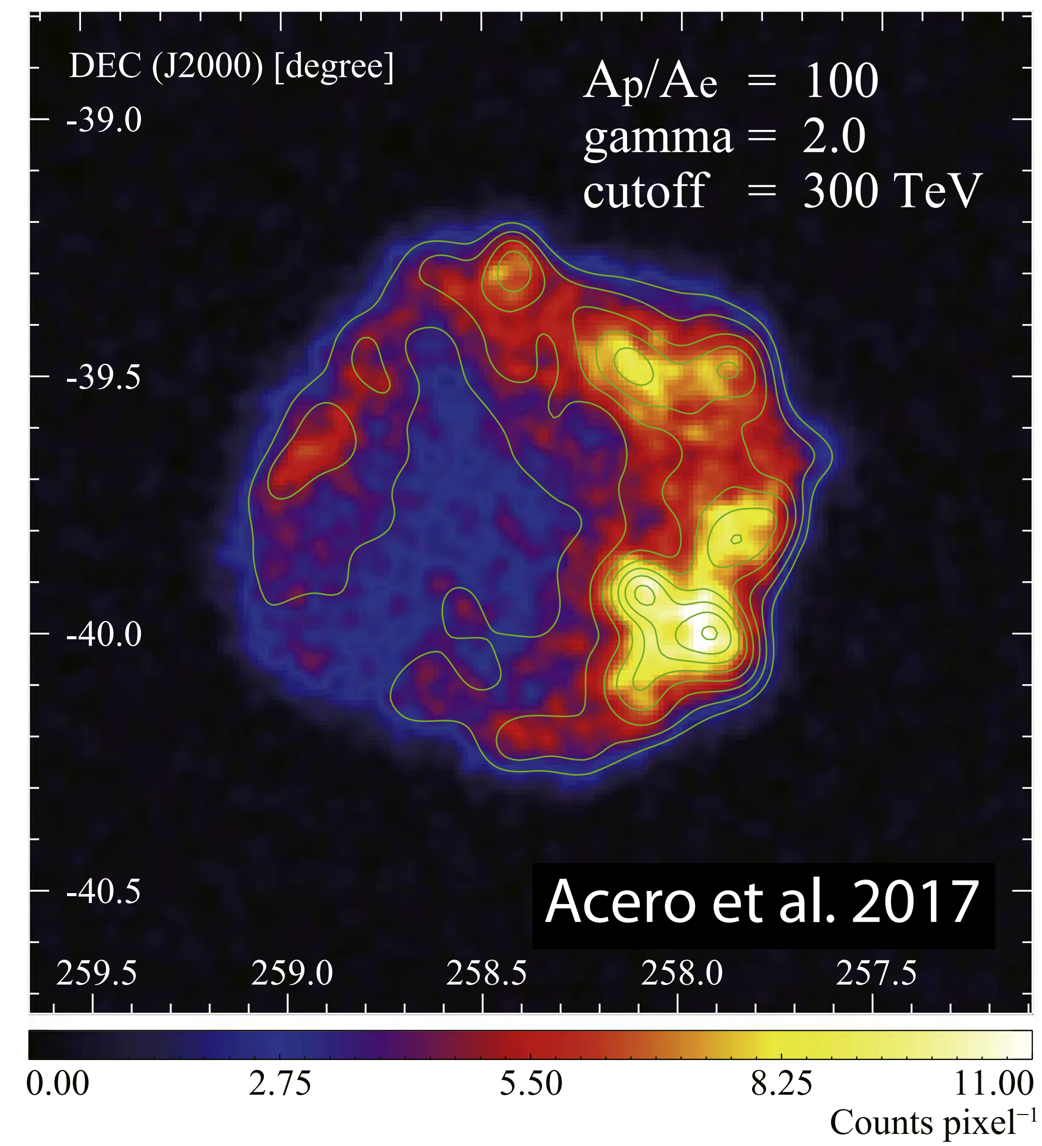
Young Supernova Remnants (SNRs)

See Takeshi's Talk

HESS ~160 hrs



CTA ~50 hrs (sim)

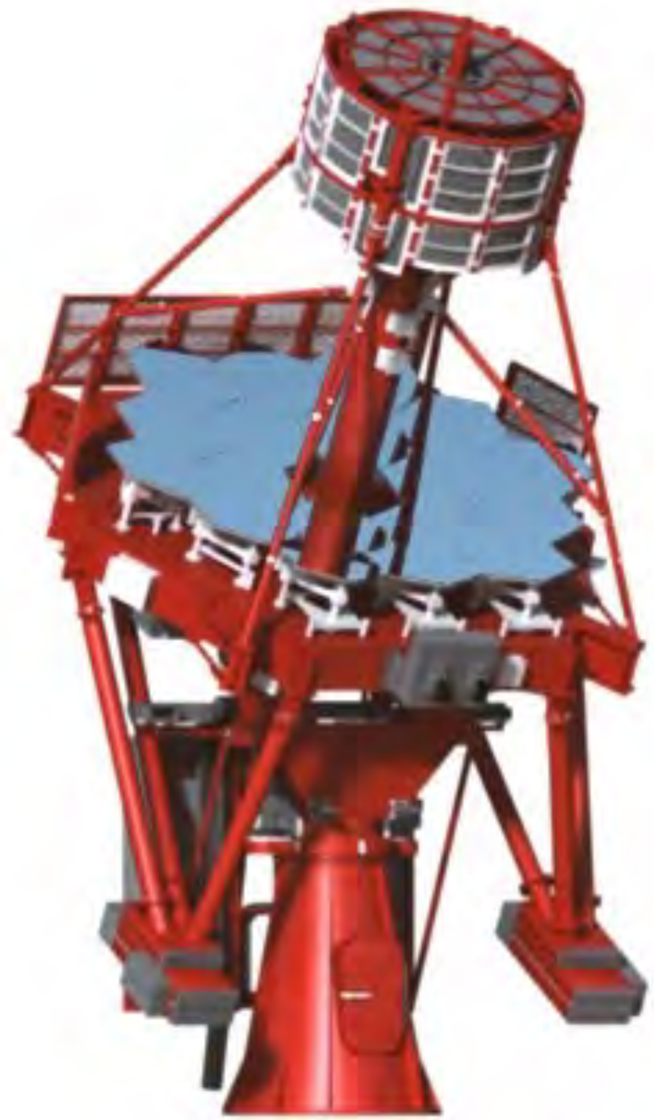


- 50-hrs exposure for RX J1713.7-3946 and other candidates each after GPS
- More photons in > 10 TeV region to study spectral cutoff and hadronic component
- Higher angular resolution and sensitivity may be able to reveal escaping cosmic rays

SST Design Proposals

Image Credit: G. Pérez, IAC, SMM

SST-2M GCT



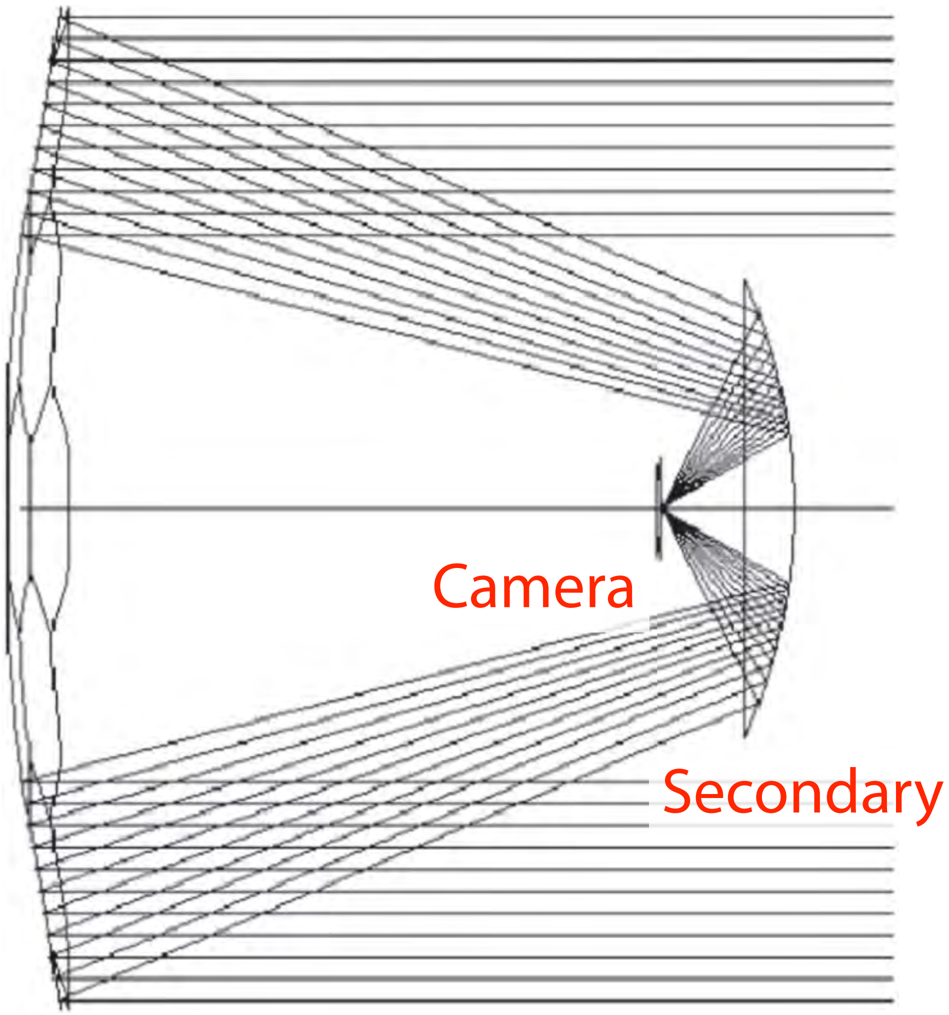
SST-2M ASTRI

SST-1M

- Need 70 SSTs with less expensive technologies (4-m optics & compact camera)
- Large FOV (8–10°) to detect photons with large core distances
- SiPM cameras with 1296–2368 pixels and compact front-end electronics

Optical Systems for >8° FOV

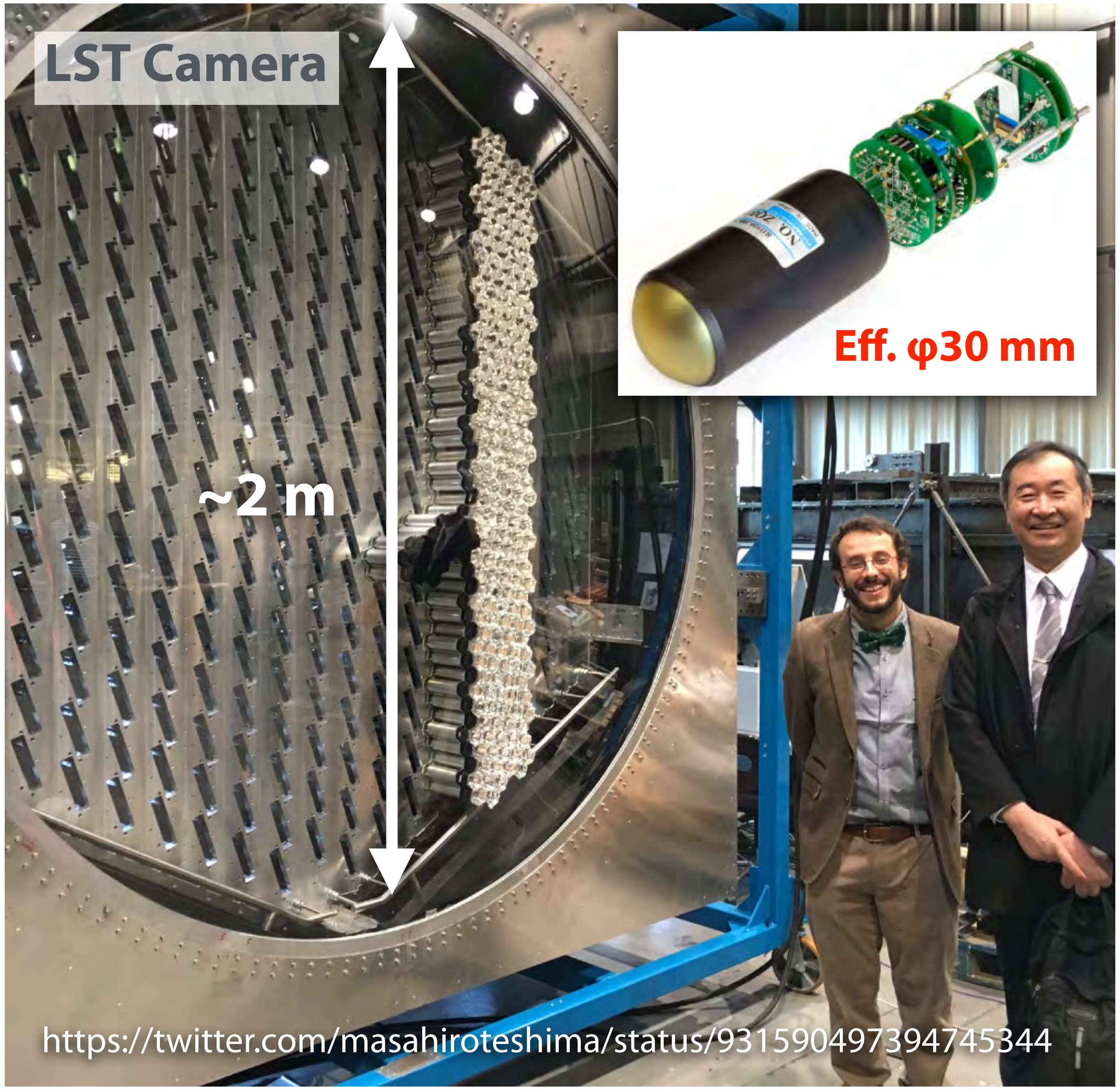
Schwarzschild–Couder (ASTRI and GCT)

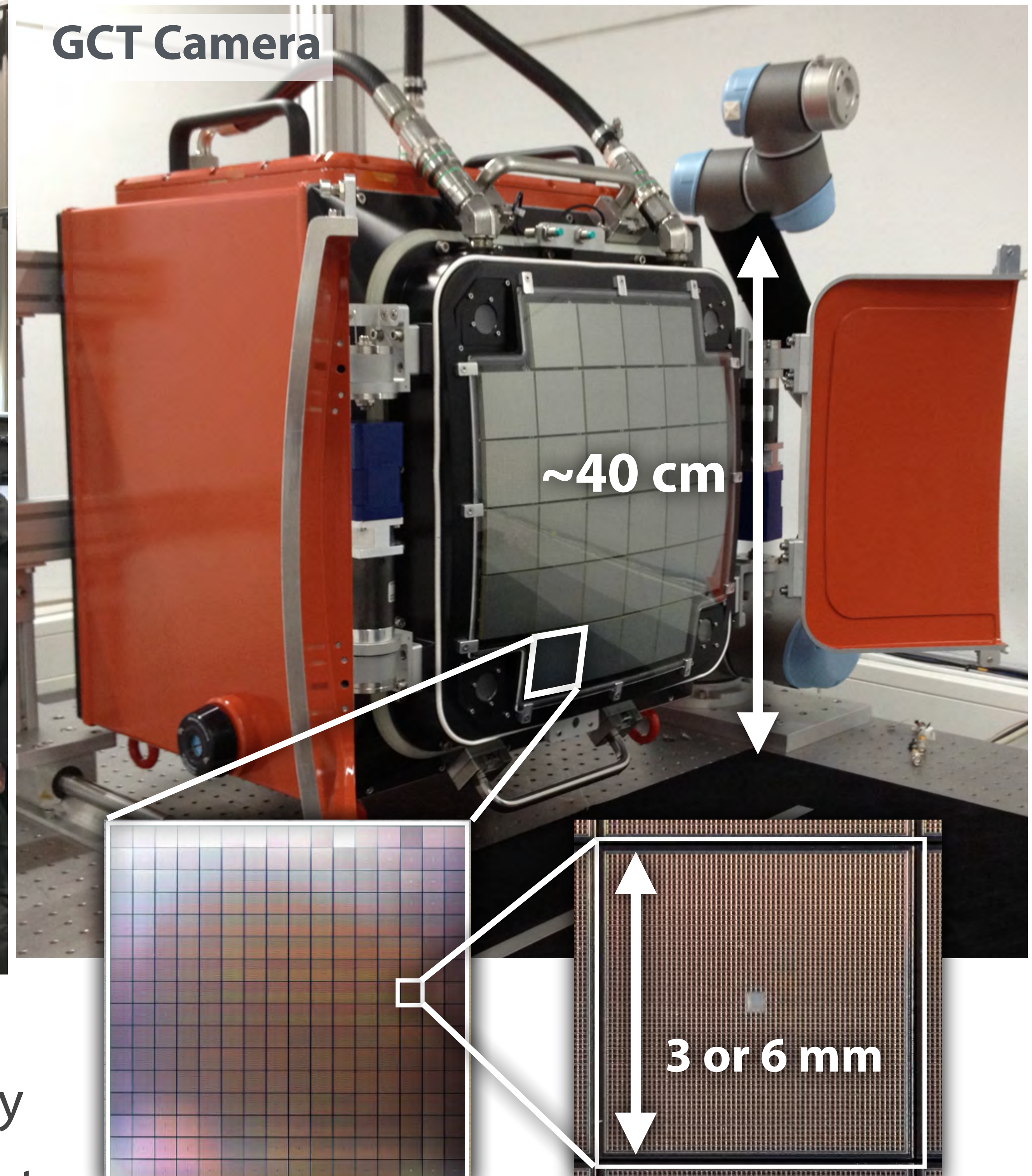


Rodeghiero+ 2016

GCT

SiPM Cameras

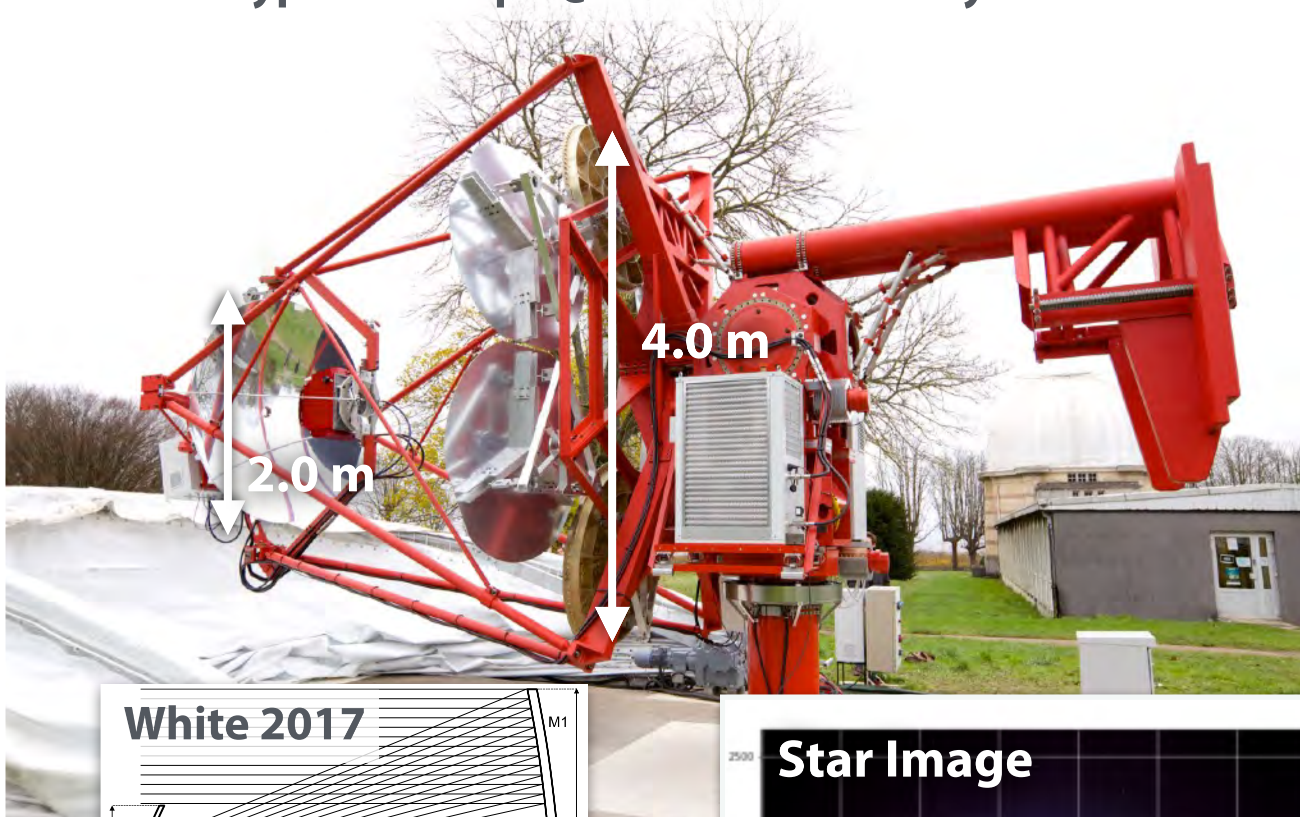


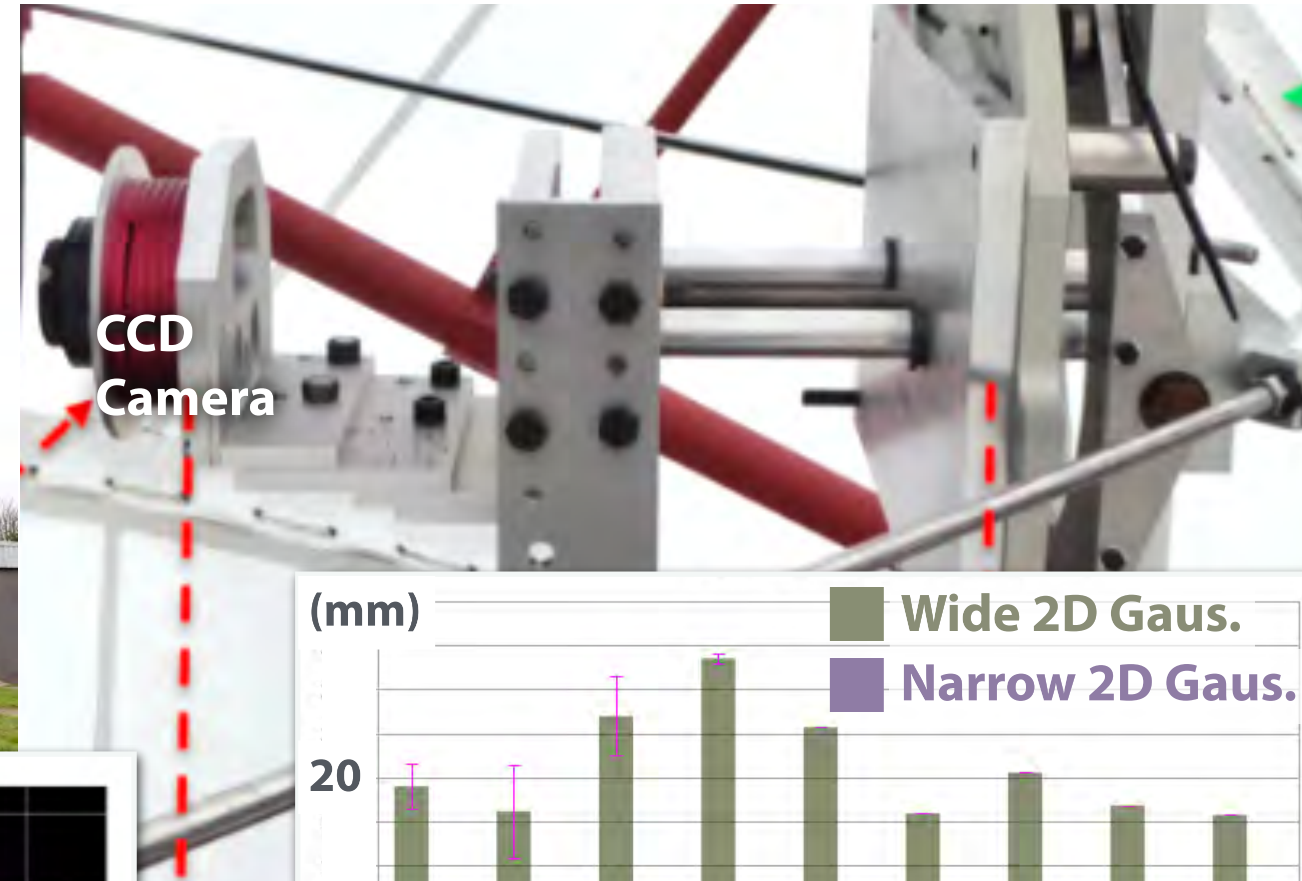


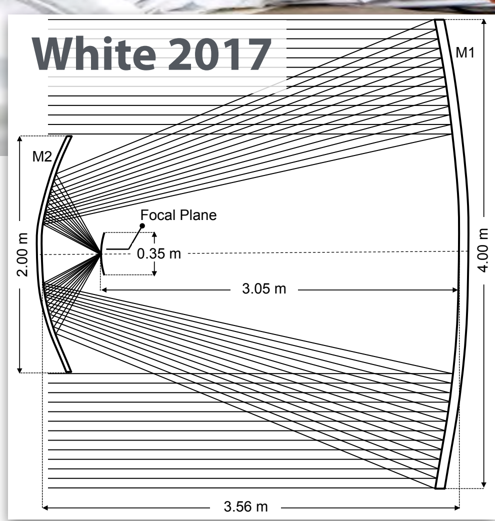
- Use of SiPMs enables us to build compact cameras with high pixel density
- Dedicated compact and modular readout
- Very NSB tolerant and long SST-only observations (> 5 TeV) are possible

SST-2M GCT (Gamma Cherenkov Telescope)

GCT Prototype Telescope @ Paris Observatory

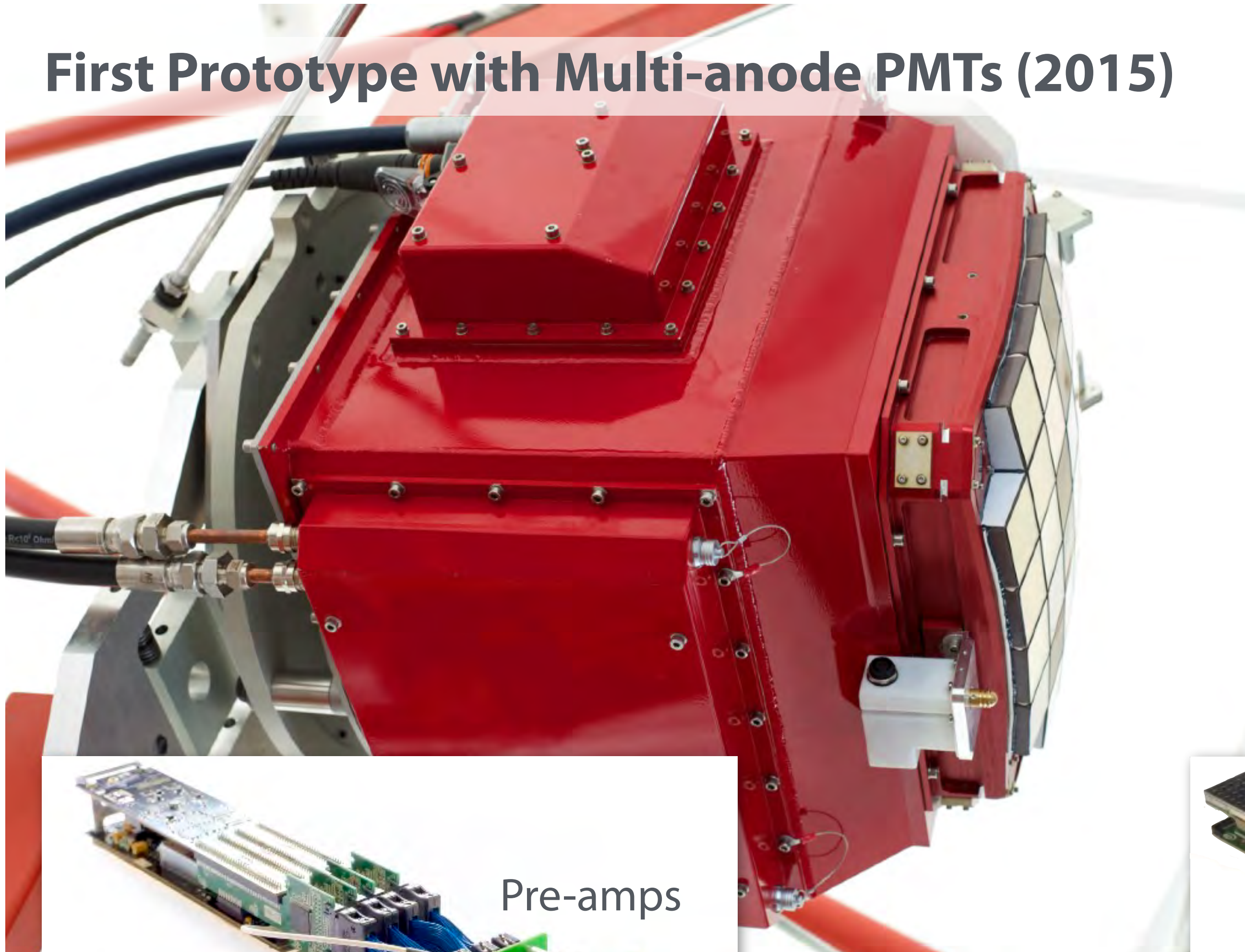


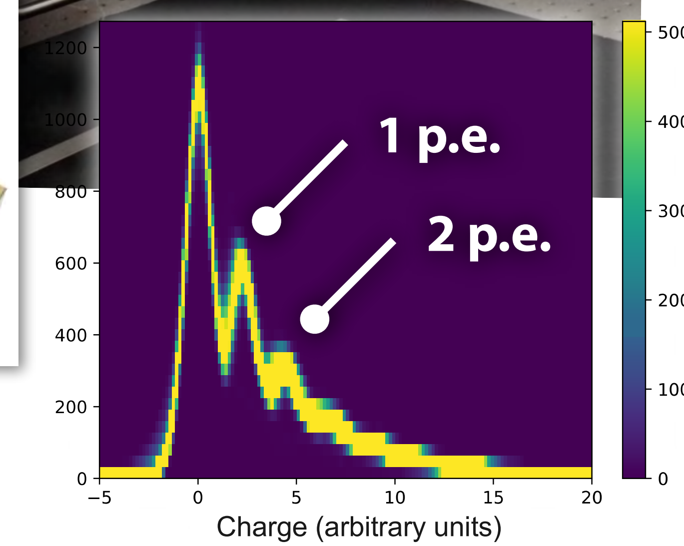




- Built at Meudon site of the Paris Observatory's (very bright sky)
- 6 segmented aspherical primary mirrors and semi-monolithic secondary
- Star images by a CCD camera show 6–7 mm PSF size (narrow component) while wide component (scattering by micro roughness) needs to be improved with new Al mirrors

SST-2M GCT Camera

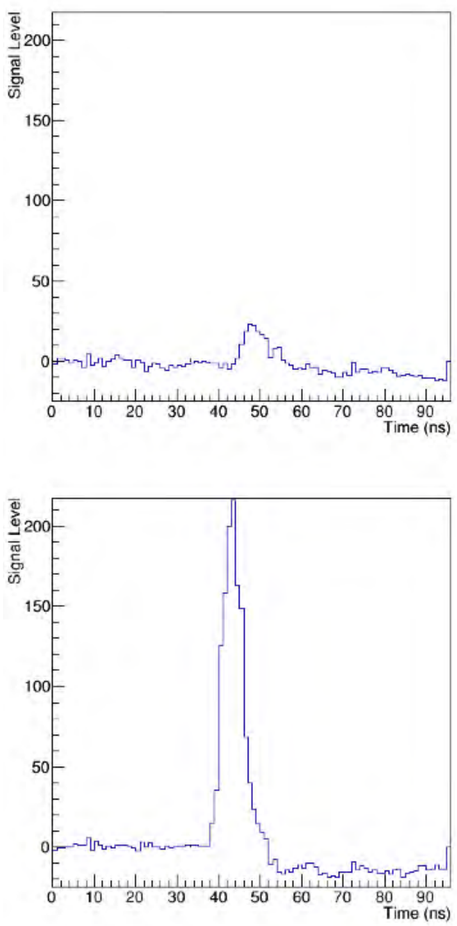


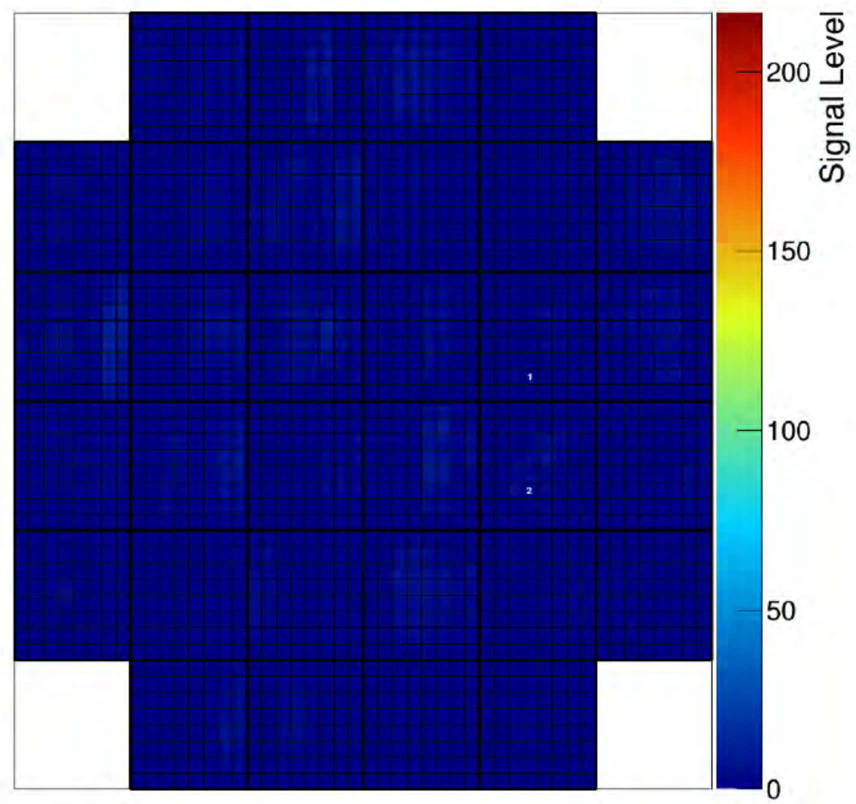


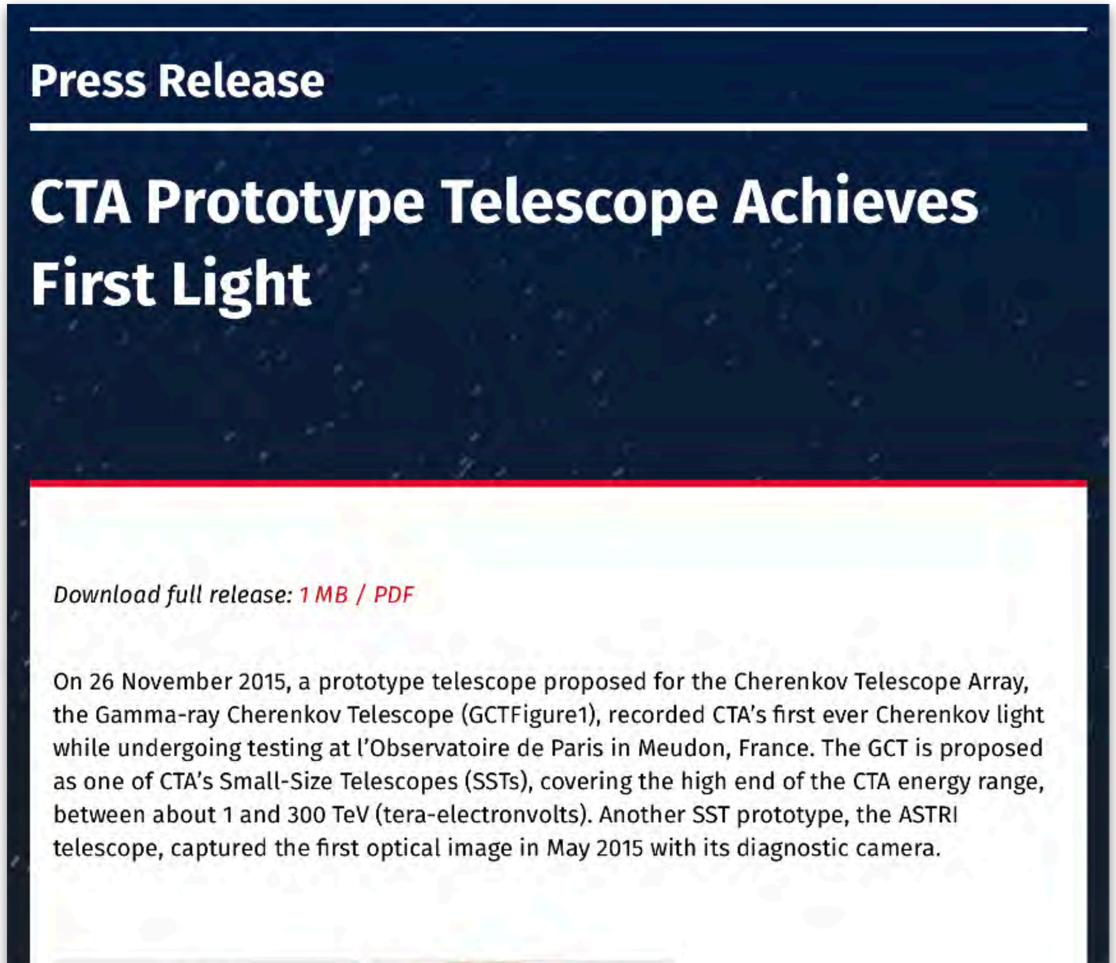
- Updated the first prototype camera with SiPM arrays
  - Better photon detection efficiency, uniform pixel gain, and better charge resolution
  - New sampling and trigger ASICs for better dynamic range, lower noise, improved trigger efficiency, etc
- Lab tests and on-telescope observations

GCT First Light

https://www.cta-observatory.org






Press Release

CTA Prototype Telescope Achieves First Light

Download full release: 1 MB / PDF

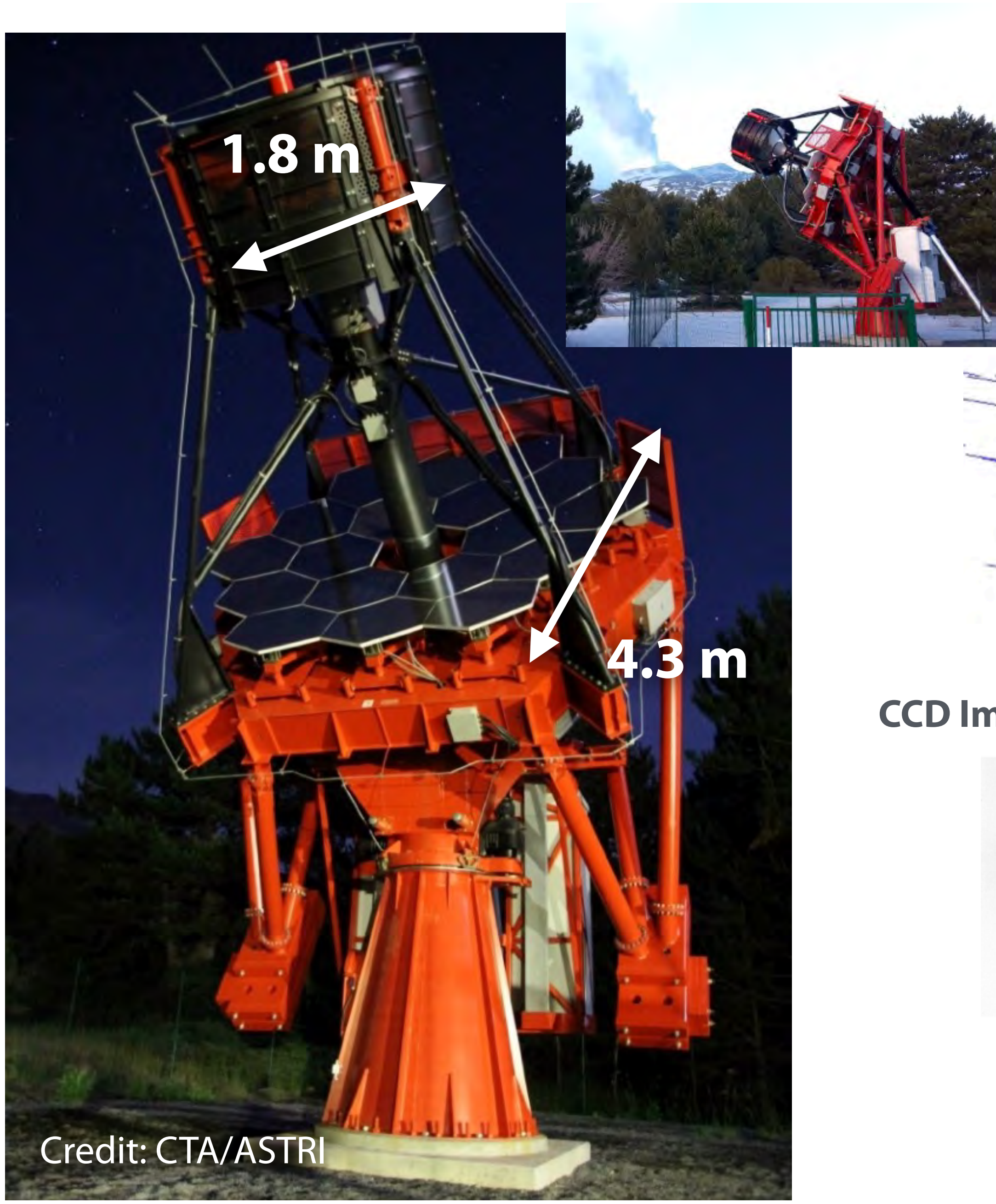
On 26 November 2015, a prototype telescope proposed for the Cherenkov Telescope Array, the Gamma-ray Cherenkov Telescope (GCTFigure1), recorded CTA's first ever Cherenkov light while undergoing testing at l'Observatoire de Paris in Meudon, France. The GCT is proposed as one of CTA's Small-Size Telescopes (SSTs), covering the high end of the CTA energy range, between about 1 and 300 TeV (tera-electronvolts). Another SST prototype, the ASTRI telescope, captured the first optical image in May 2015 with its diagnostic camera.

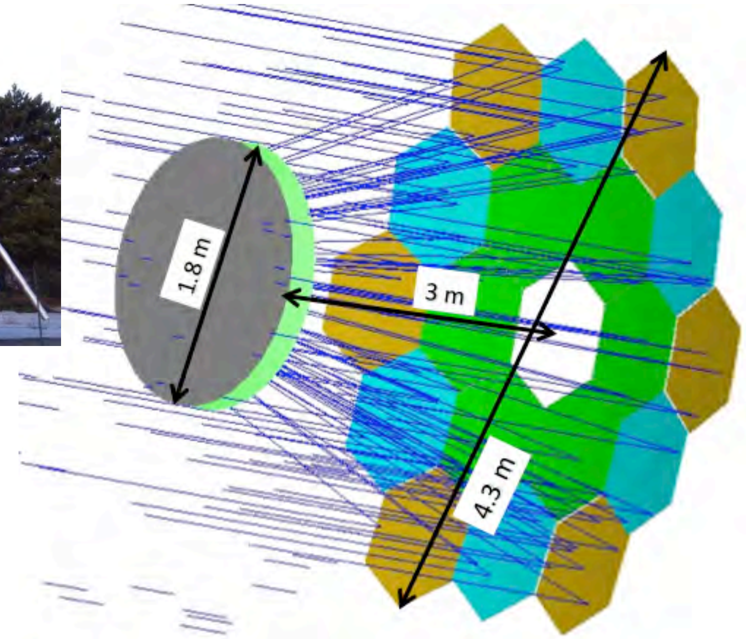
Photo credits: Akira Okumura

- CTA's first ever Cherenkov images taken on Nov 26, 2015
- CR hadron observations with the first camera and telescope prototype at Paris Observatory
- The second camera to be tested on the ASTRI telescope prototype in 2018

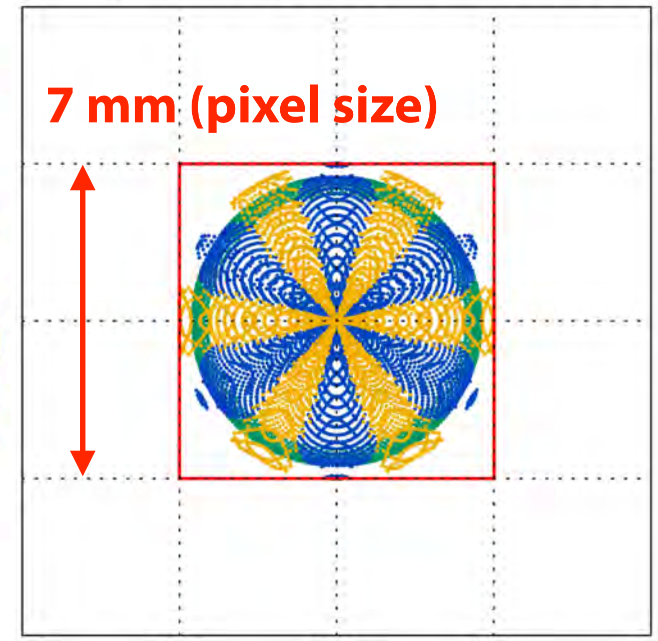
mirror replication technology

SST-2M ASTRI (Astrofisica con Specchi a Tecnologia replicante Italiana)

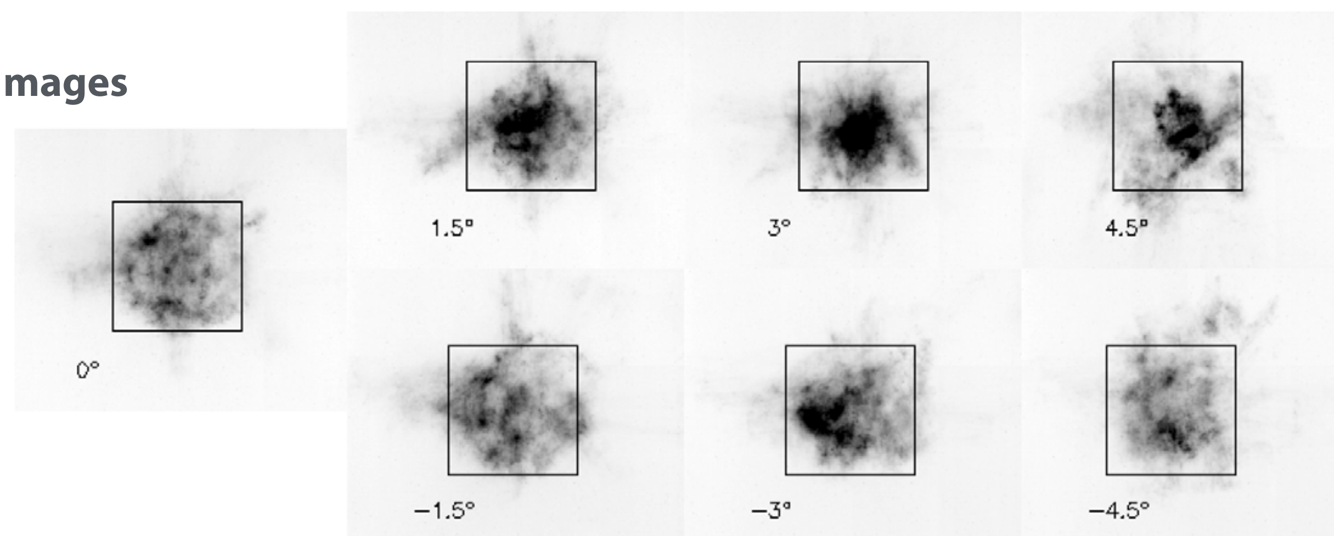




On-axis Simulation



CCD Images

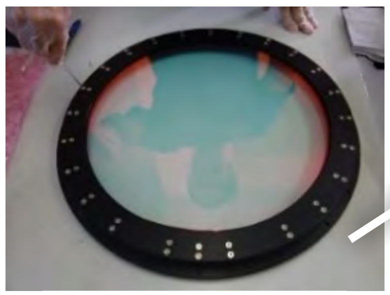


Giro+ 2017

- Built at INAF-Catania mountain station on Mt. Etna (very active volcano)
- 18 segmented aspherical primary mirrors + monolithic aspherical secondary
- ASTRI prototype telescope is the first realization of the Schwarzschild–Couder optics with full mirror configuration

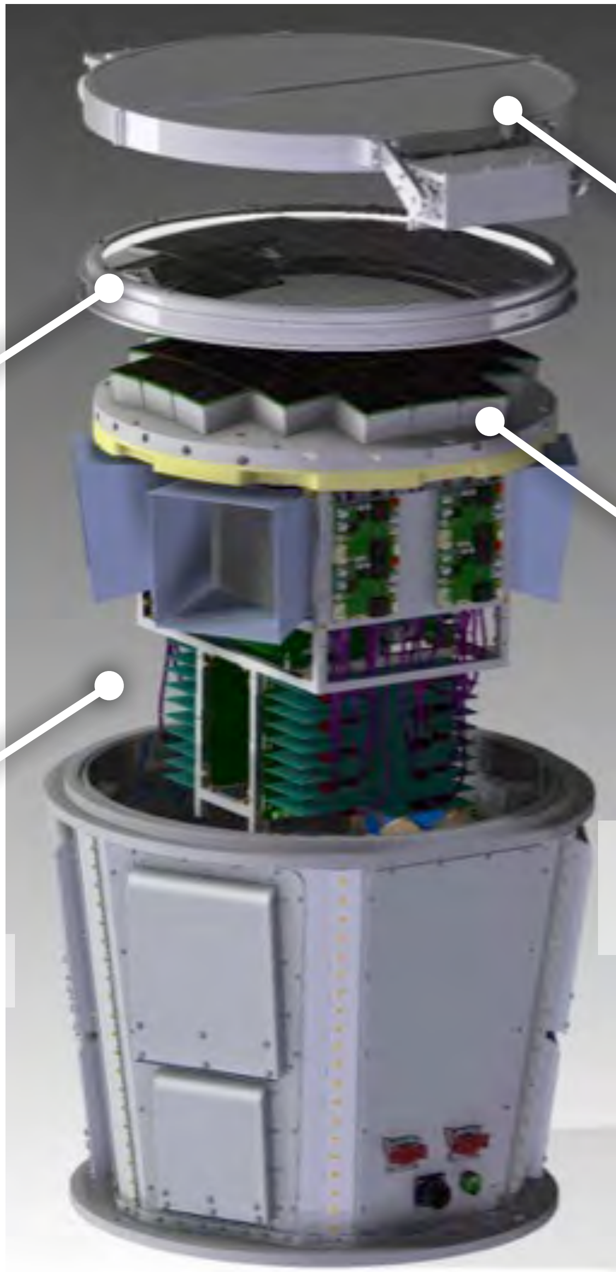
SST-2M ASTRI Camera

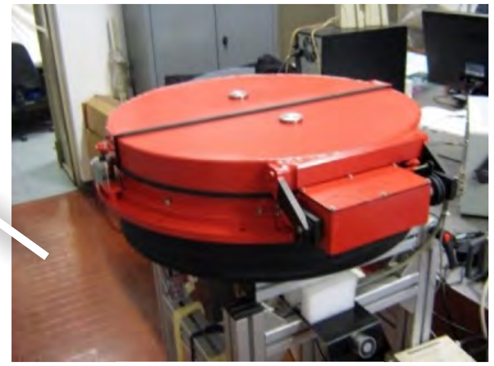
Image credit: CTA/ASTRI



Front Window

Backend Electronics

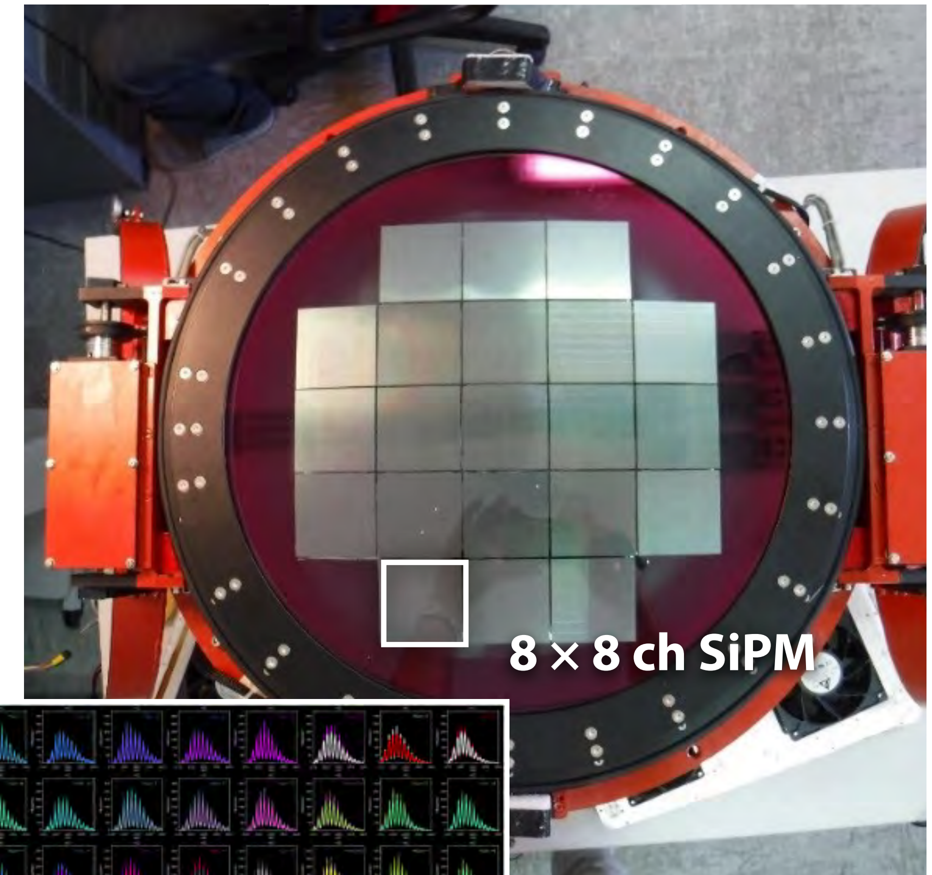


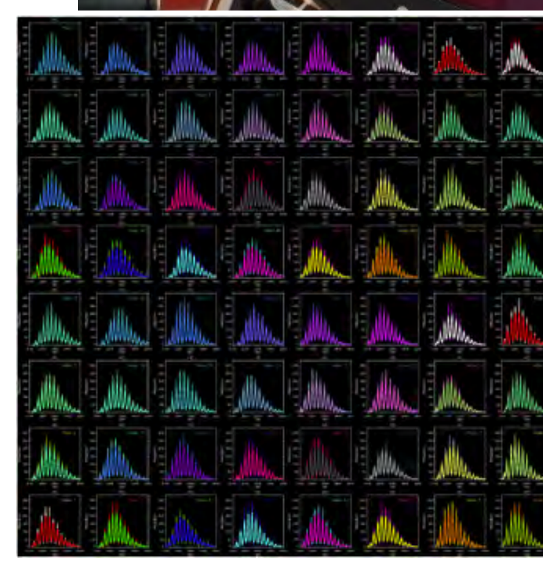


Camera Lids

Photon Detection Module
(SiPM and frontend)

Prototype Camera



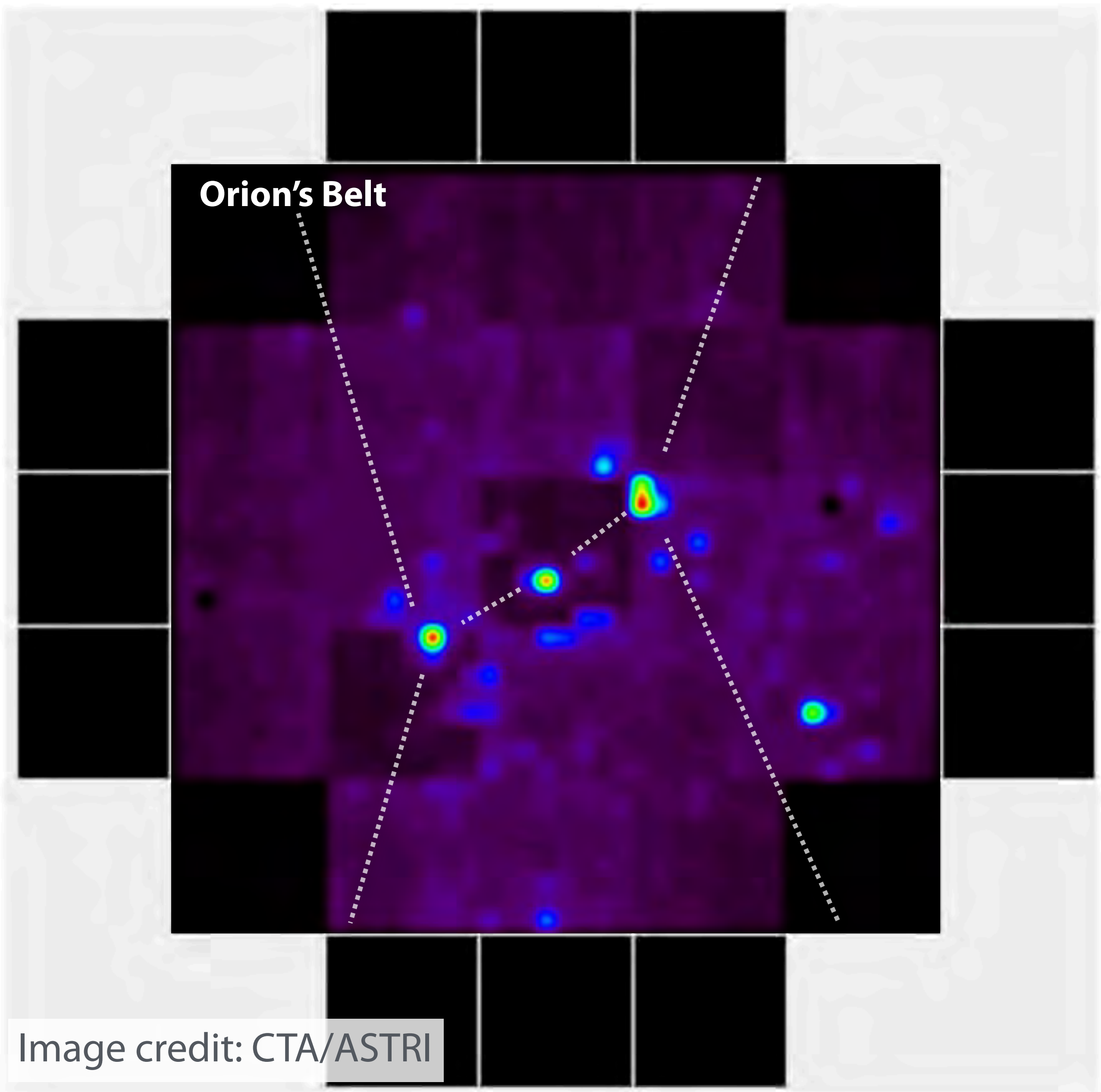


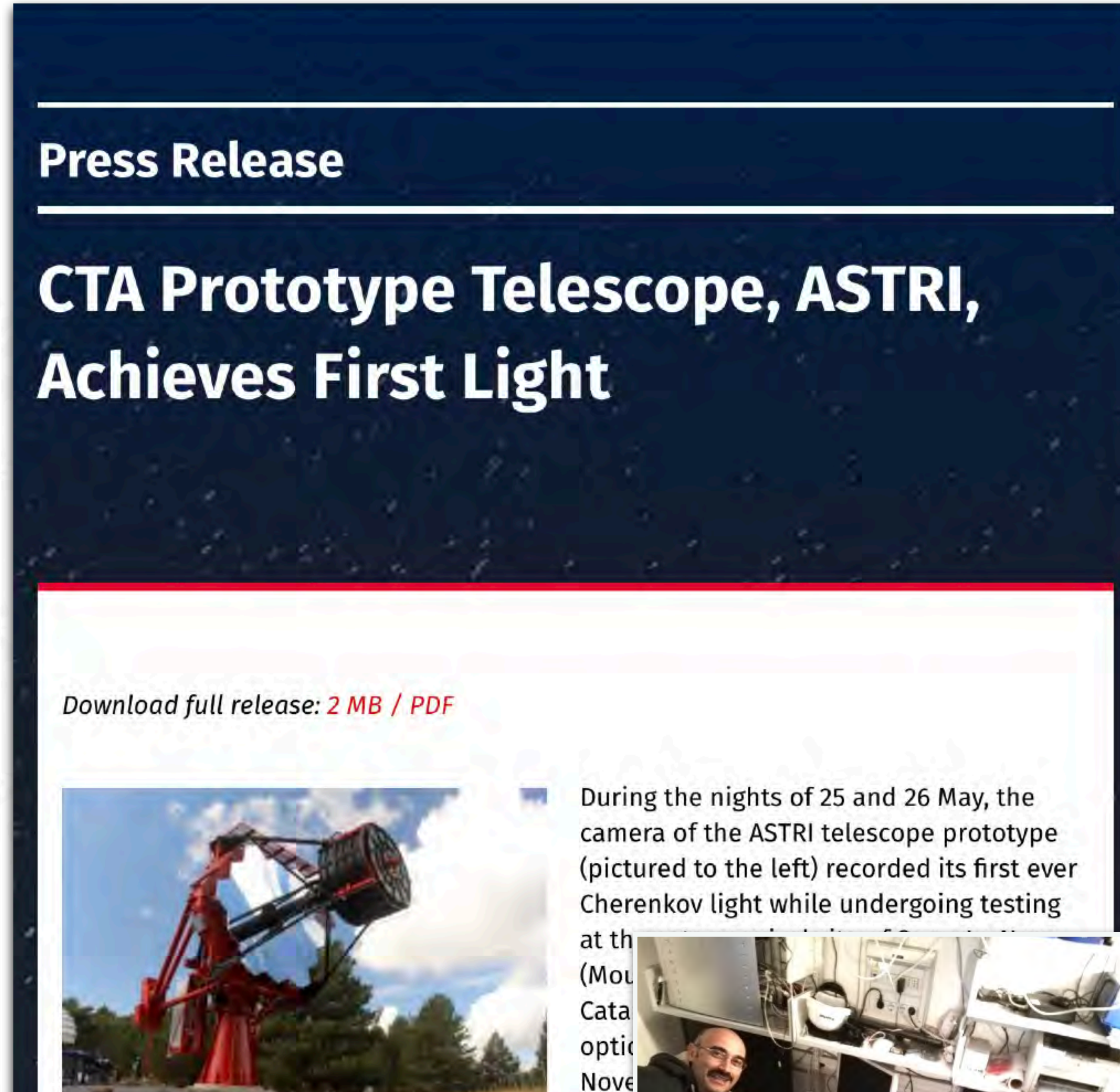
Pulse height distribution
of a single SiPM array

- 8×8 ch MPPC $\times$ 37 = 2368 MPPC pixels at the focal plane
- Dedicated SiPM-readout ASICs (CITIROC) used in front-end electronics
- Compatible design with SST-2M GCT

ASTRI First Light

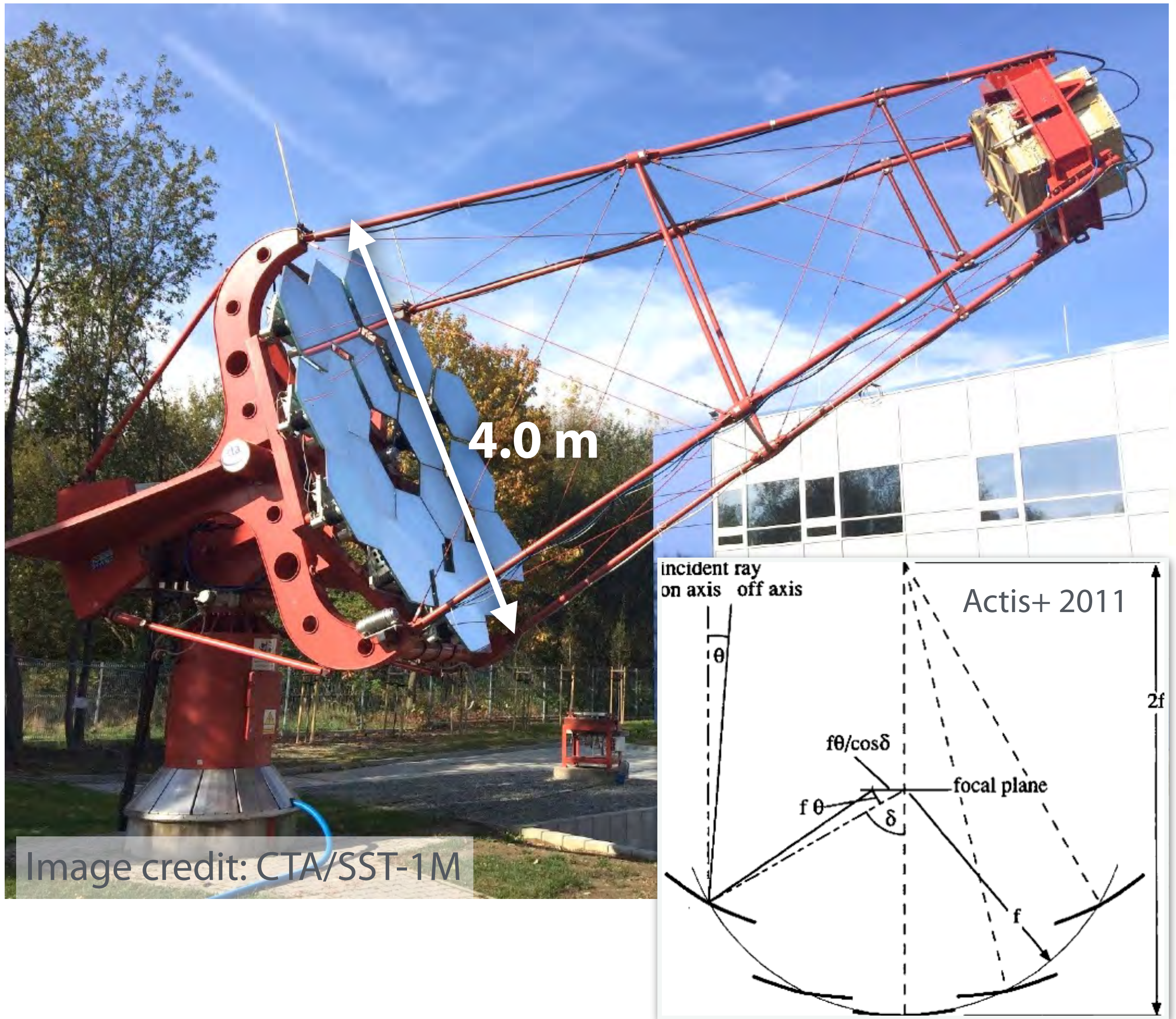
https://www.cta-observatory.org

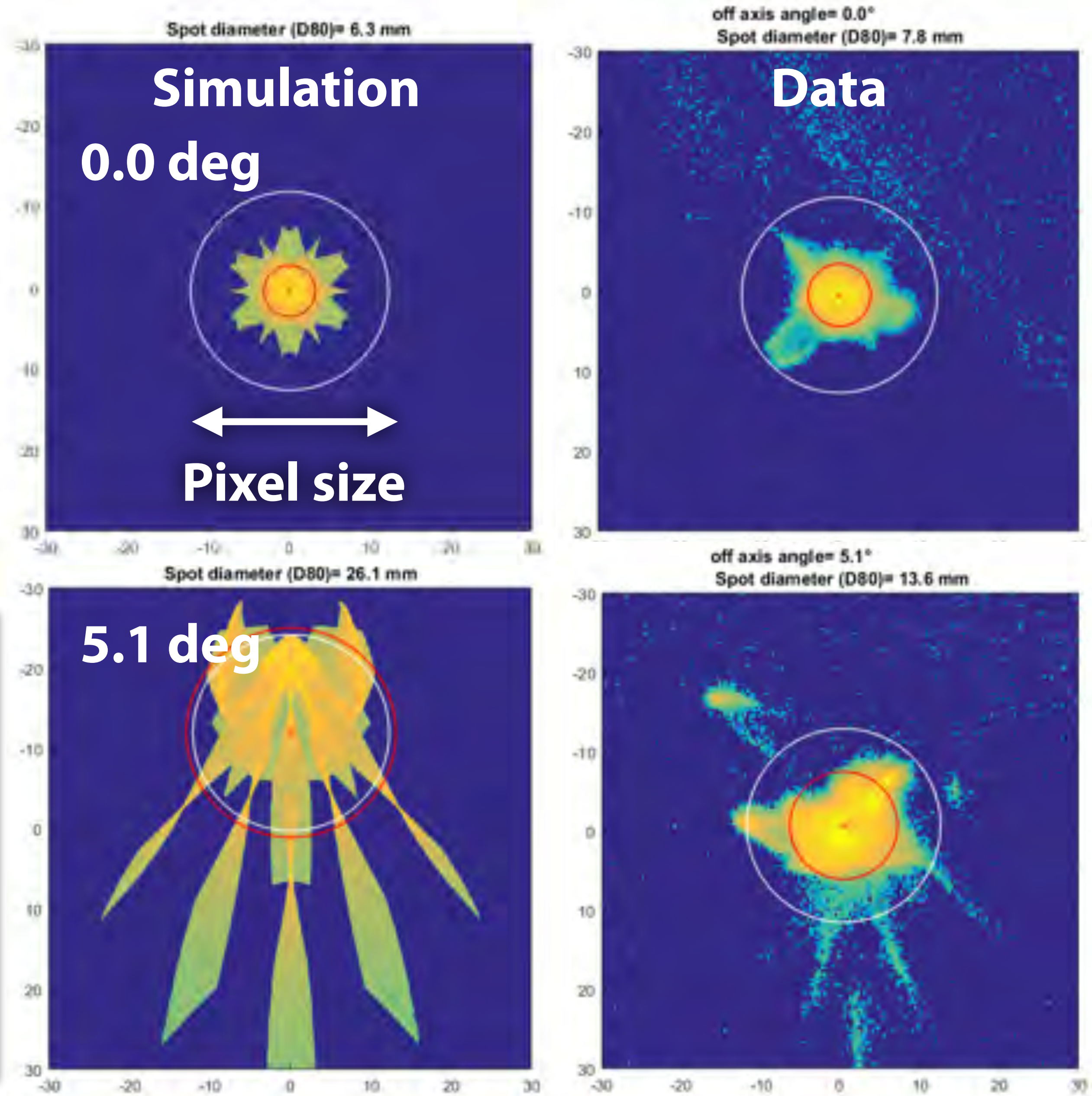




- Achieved first light of air-shower images on May 25, 2017
- Observed Crab and Mrk 501 but not significant yet
- Also able to image stars by measuring pixel amplitude variance (proportional to star flux)

SST-1M

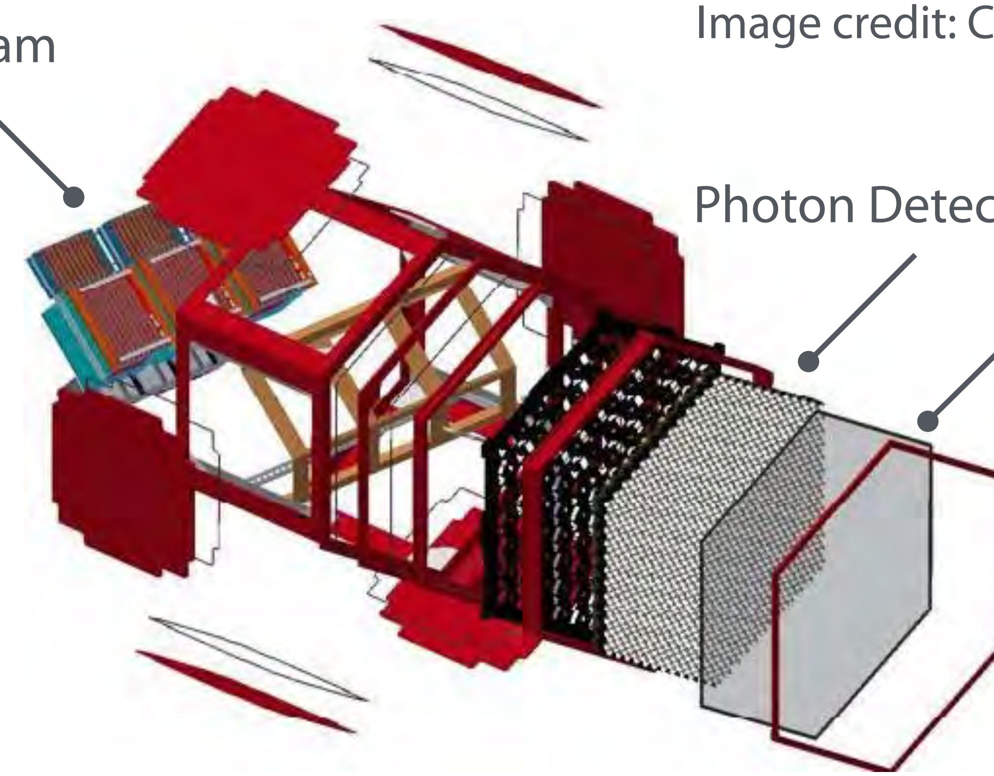




- Conventional Davies–Cotton optics with 18 segmented spherical mirrors (less expensive than Schwarzschild–Couder)
- Fully automated system installed at IFJ, Krakow, Poland
- Optical performance has been verified with star images

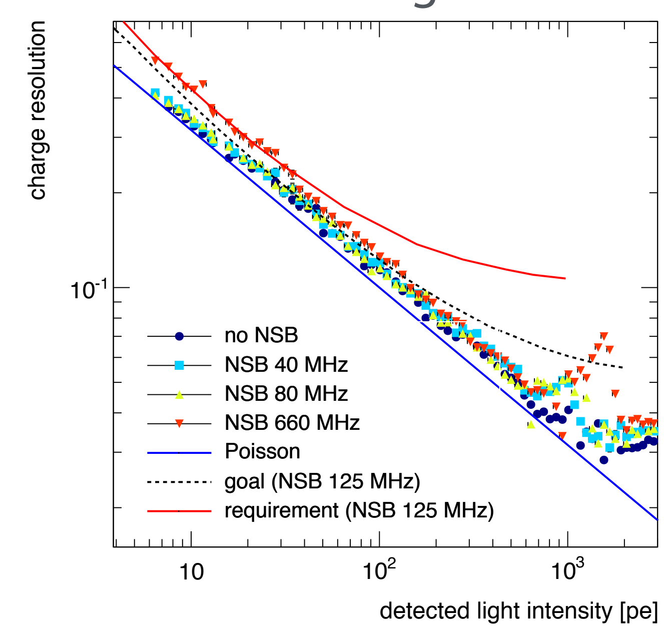
SST-1M Camera

Image credit: CTA/SST-1M



Photon Detection Plane Module

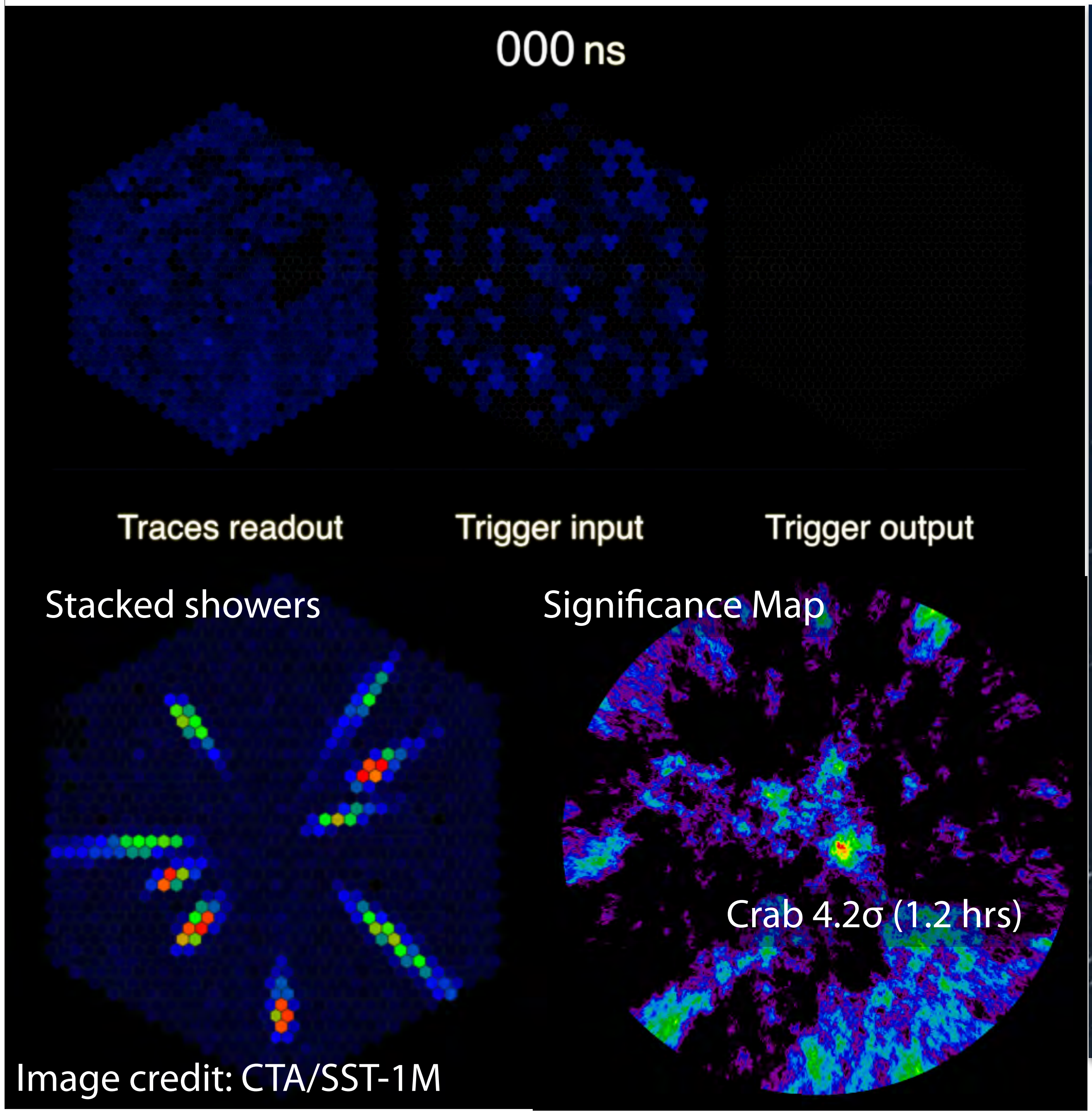
Measured Charge Resolution



- 8.9° FOV with 1296-pixel SiPMs and light concentrators
- Dead-time free fully digital camera (DigiCam)
- Not compatible with SST-2Ms but use similar technologies with MST FlashCam

SST-1M First Light

https://www.cta-observatory.org



Announcement

CTA Prototype Telescope, the SST-1M, Catches its First Glimpse of the Sky

On Thursday, 31 August, 2017, a prototype telescope proposed for the Cherenkov Telescope Array (CTA), the SST-1M, recorded its first events while undergoing testing at the Institute of Nuclear Physics Polish Academy of Sciences (IFJ-PAN) in Krakow, Poland. The SST-1M is proposed as one of CTA's Small-Sized Telescopes (SSTs), which will cover the high end of CTA's energy range, between about 1 and 300 TeV (tera-electronvolts).

A crew in Krakow worked for two days to install the camera on the telescope and spent another two days monitoring it to ensure it could be safely switched on in the high humidity conditions. Watch the camera installation in the video below.

SST-1M Camera Installation

- Achieved first light on Aug 31, 2017
- Prototype detected the Crab nebular with 4.2σ excess in test observations
- New observation campaigns are ongoing in 2018

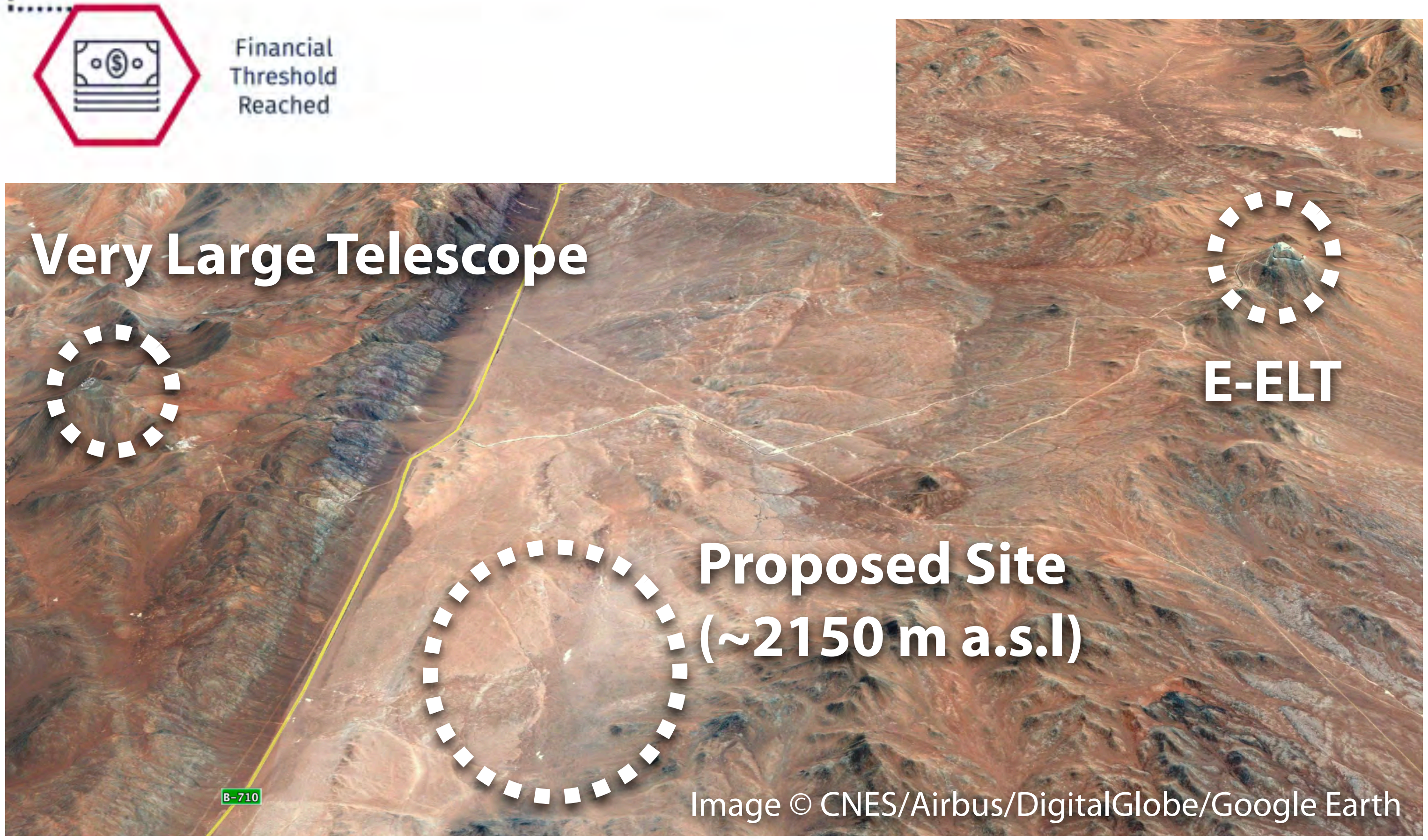
SST Harmonization Started

- Three different approaches are matured and have verified the concept of SSTs
- But it is time to consolidate the optics and camera designs before SST pre-production phase
- “SST harmonization” process started in May 2018 to simplify the southern array with easier maintainability and less construction cost

- Final SST design proposals to be submitted Oct 2018
- Review and evaluation of “the” final SST design will follow in 2019
- Only single acronym, the “SST”, will be used afterwards :-)

Timeline

- Site hosting agreement for CTA south to be signed



ASTRI Mini Array

- 9 ASTRI telescopes to be built as ASTRI Mini Array in parallel to the SST harmonization
- Stereo imaging, array trigger, array control etc. will be thoroughly tested
- ASTRI and GCT cameras can be mounted

Summary

- CTA Small-Sized Telescopes will explore the highest-energy gamma-ray frontier from the ground
  - Core energy coverage of 5–300 TeV
  - 70 telescopes in CTA South
  - Wide-FOV optical system and SiPM camera
  - PeVatrons and cosmic-ray origins
- Three SST designs; GCT, ASTRI, and SST-1M
  - Verified their functionalities in labs and by first light
  - Harmonization process is ongoing
  - Bigger single SST group will be formed and quickly move toward pre-production and completion