CTA 小口径望遠鏡の開発状況

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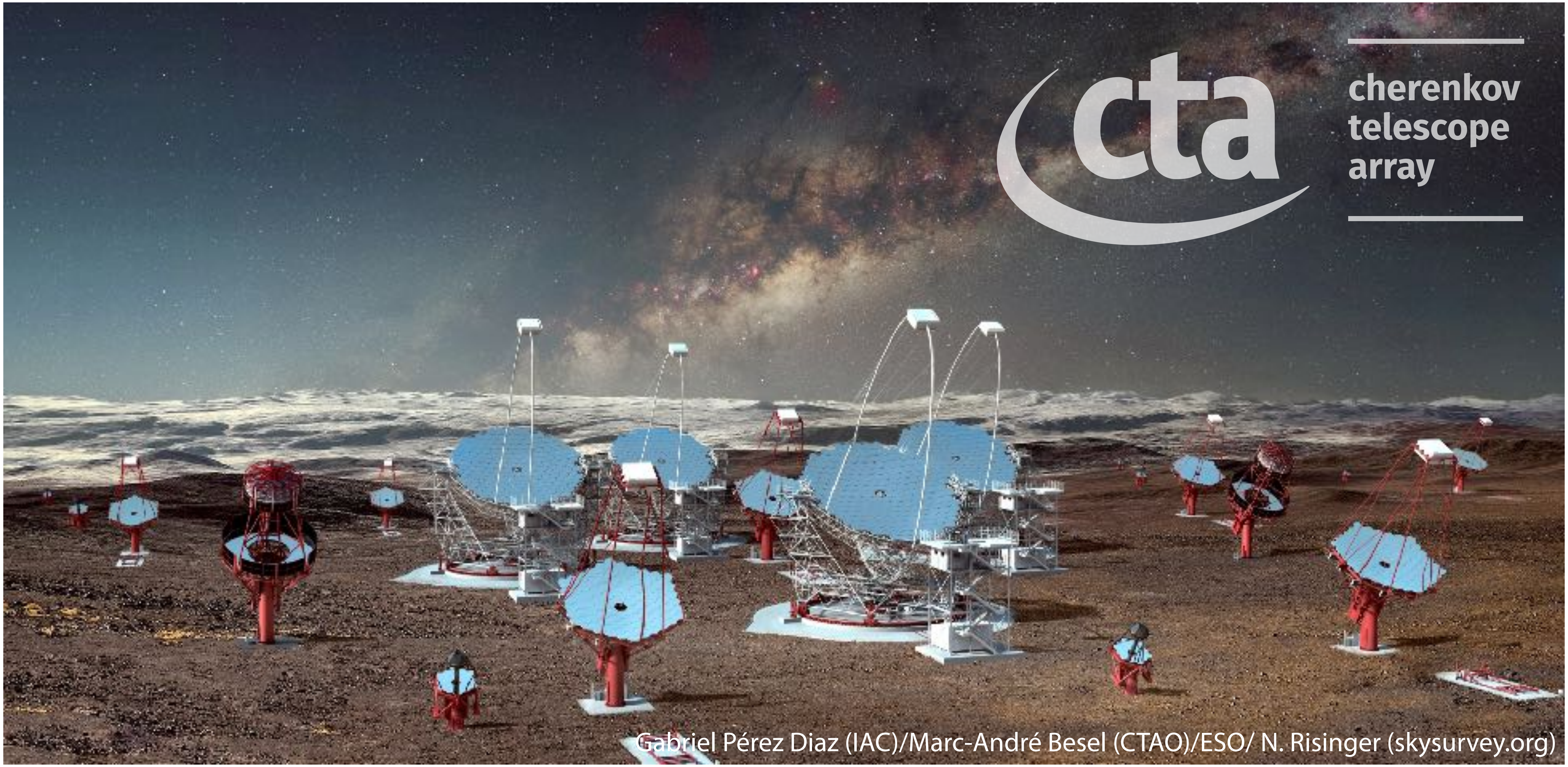
Cherenkov Telescope Array (CTA)



- Next-generation ground-based gamma-ray observatory with ×10 better sensitivity
- Covering 20 GeV–300 TeV with 3 telescope designs
- High angular resolution of 0.02–0.05° above 10 TeV

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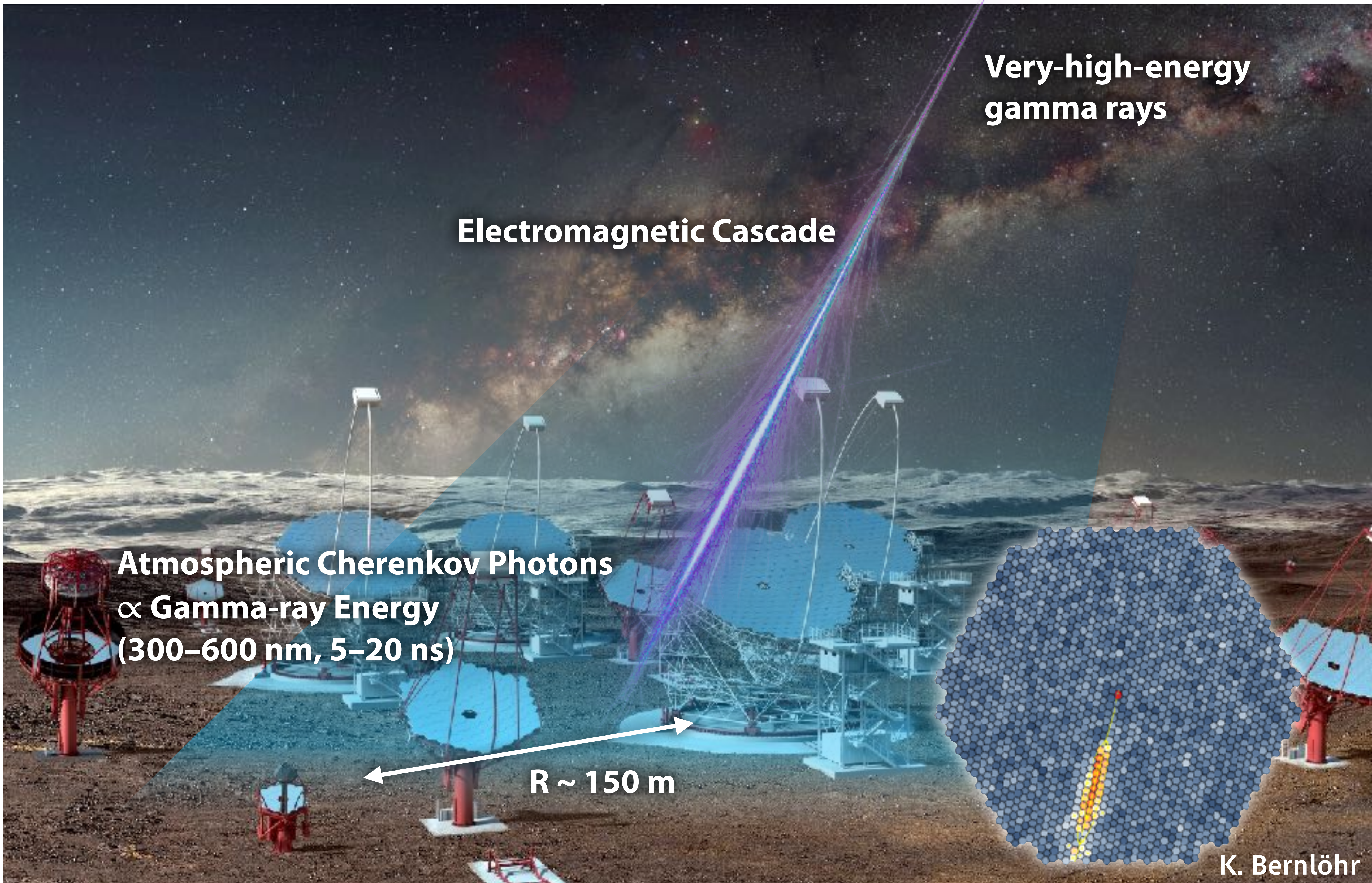

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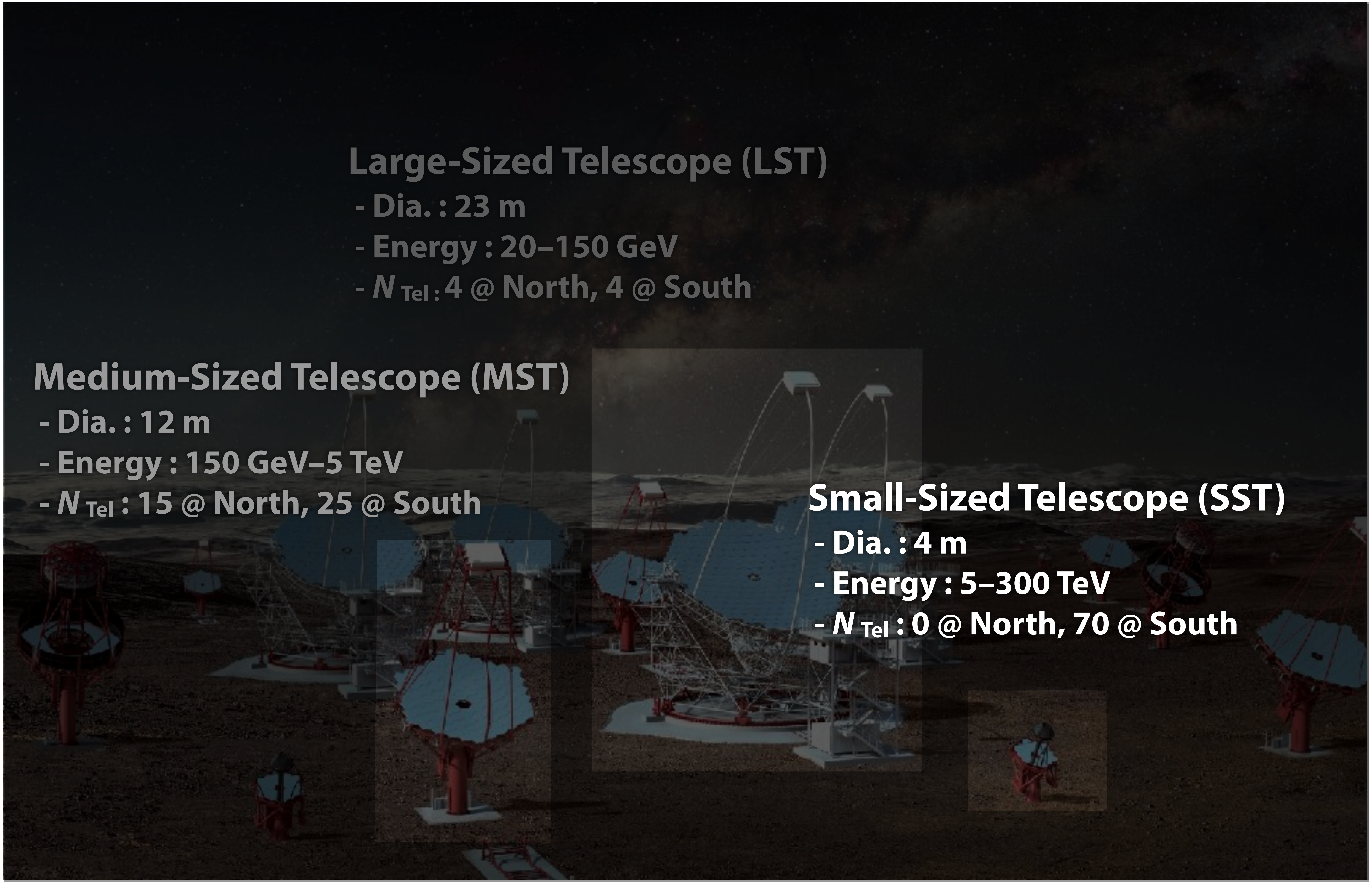
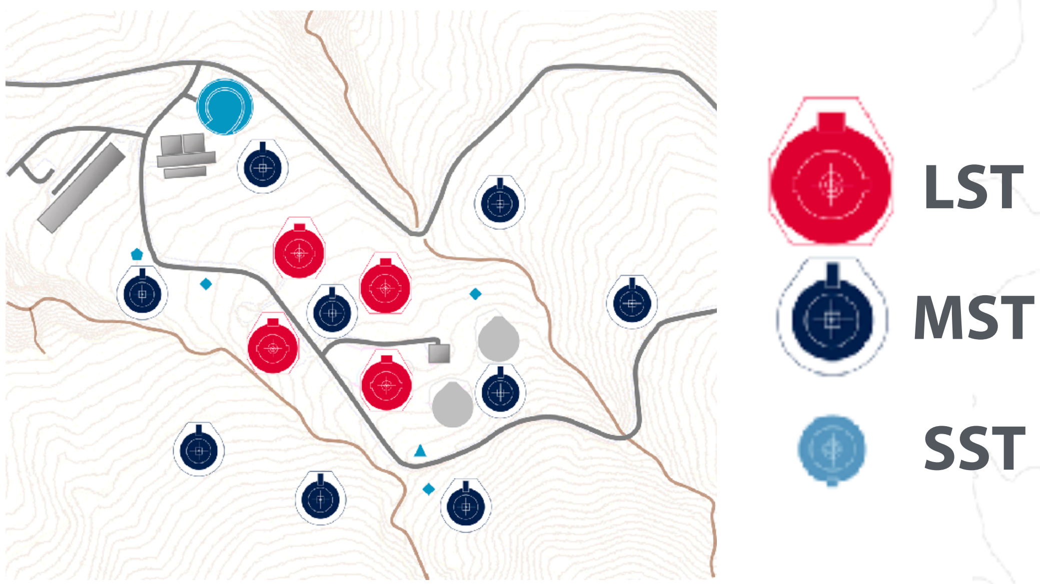
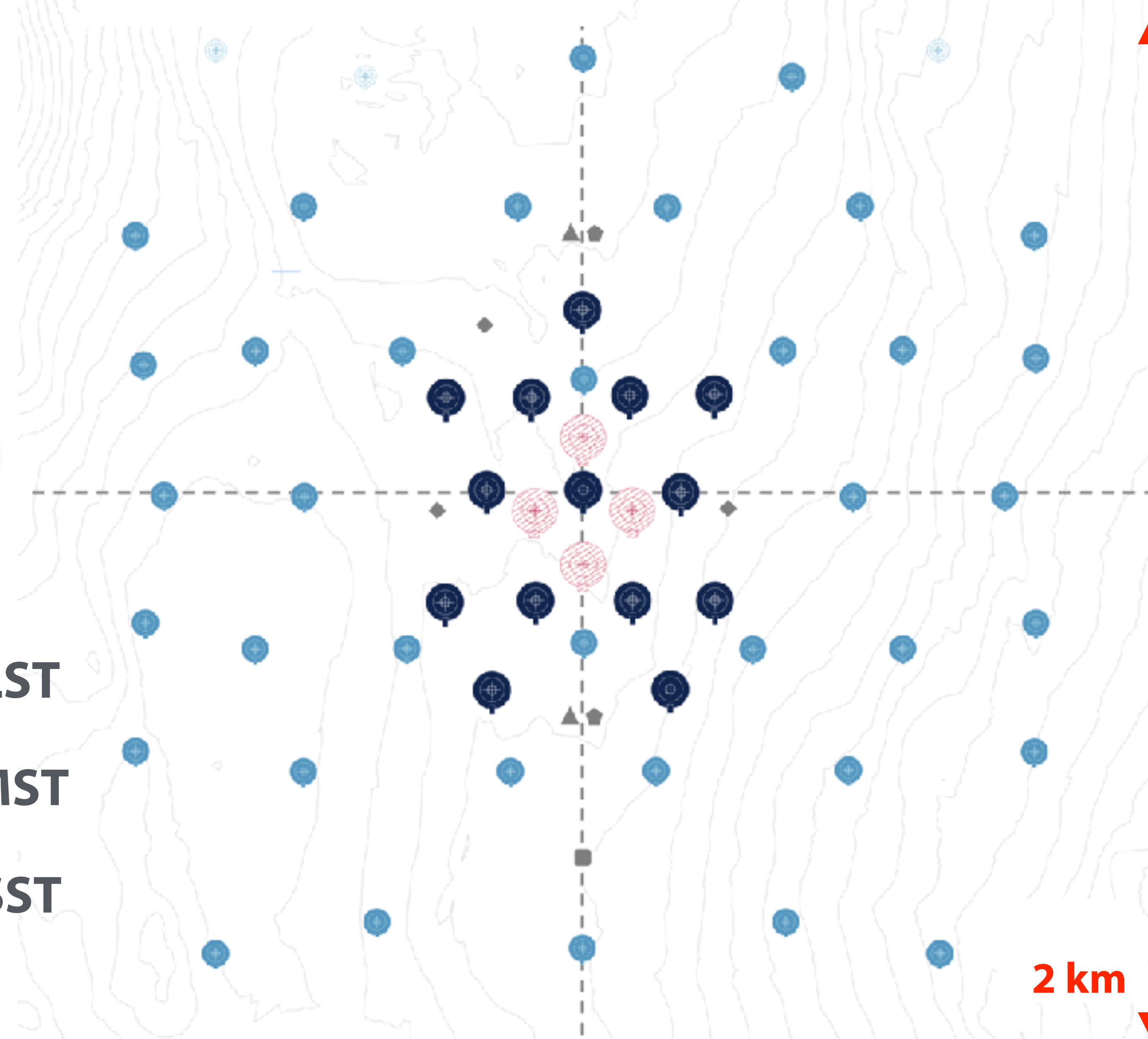


CTA Northern & Southern Sites (Initial Configuration)

CTA North: La Palma, Spain



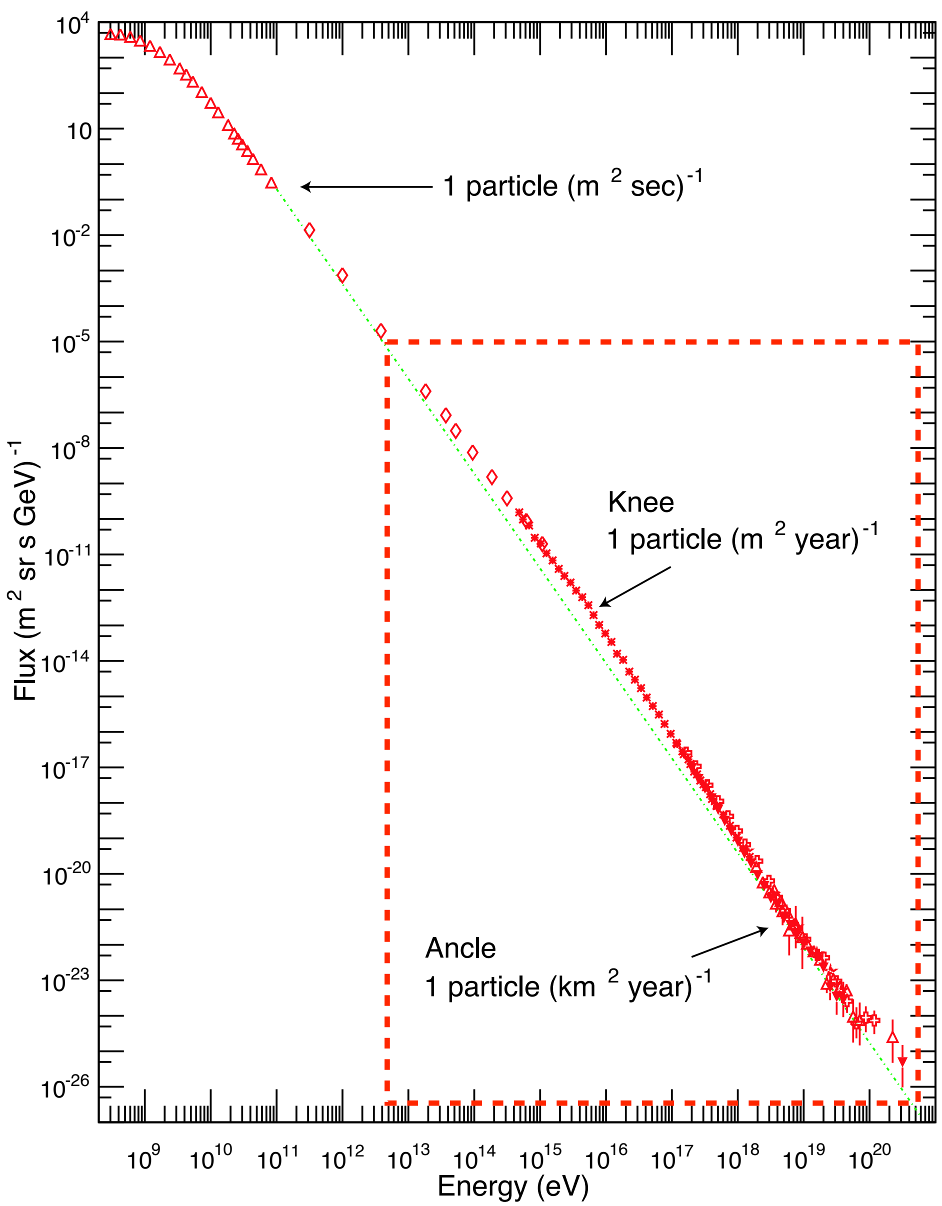
CTA South: Paranal, Chile



- Wide energy coverage of 20 GeV–300 TeV with three telescope sizes
- Spread over ~5 km^2 area to catch Cherenkov photons anywhere in the circle
- Construction phase to start with 4 LSTs + 9 MSTs (north) and 14 MSTs + 37 SSTs (south)

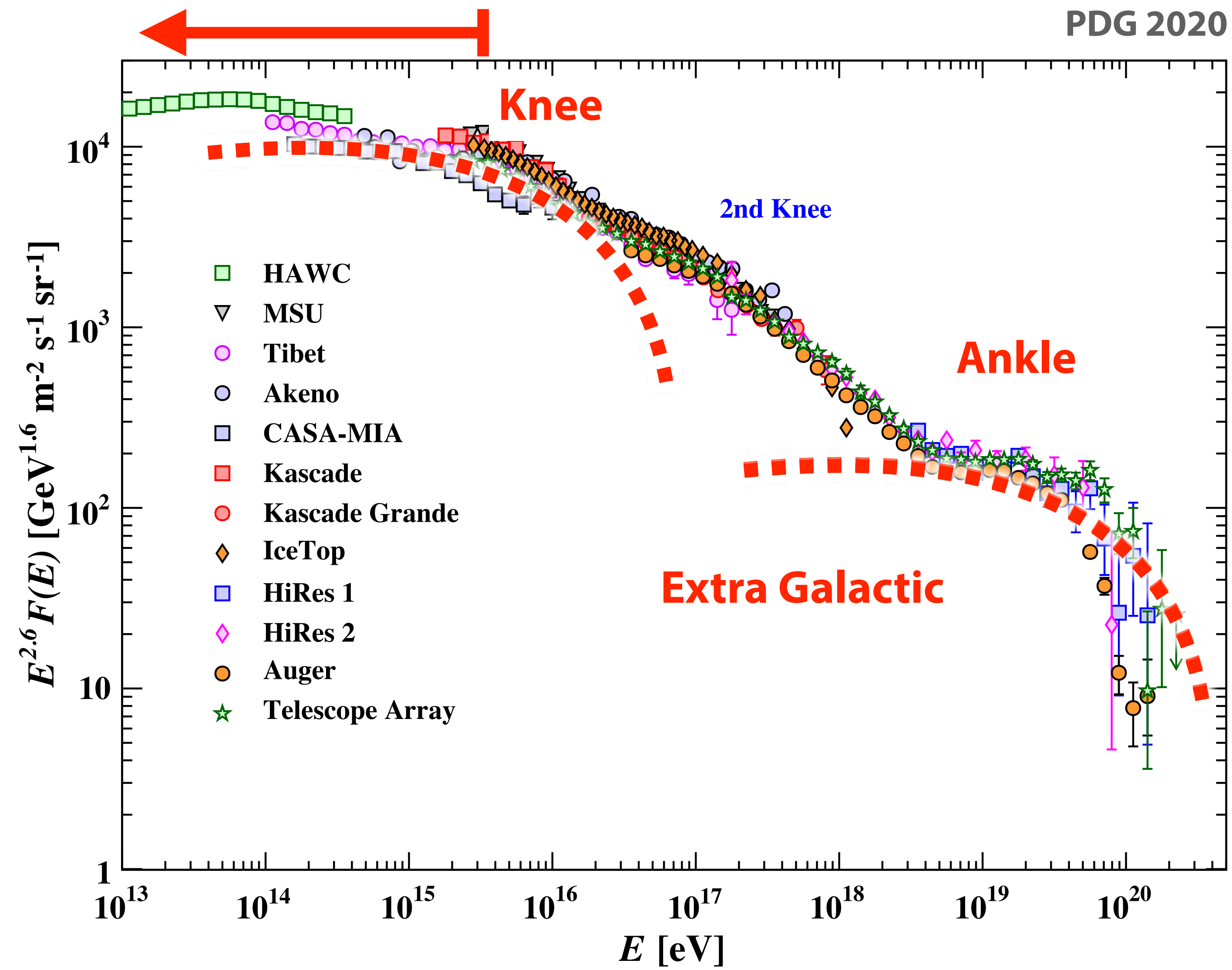
(Hadronic) Cosmic-ray Spectrum at Earth

Modified Cronin+ (1997)



Galactic CRs ~3 × 10[15] eV (3 PeV)

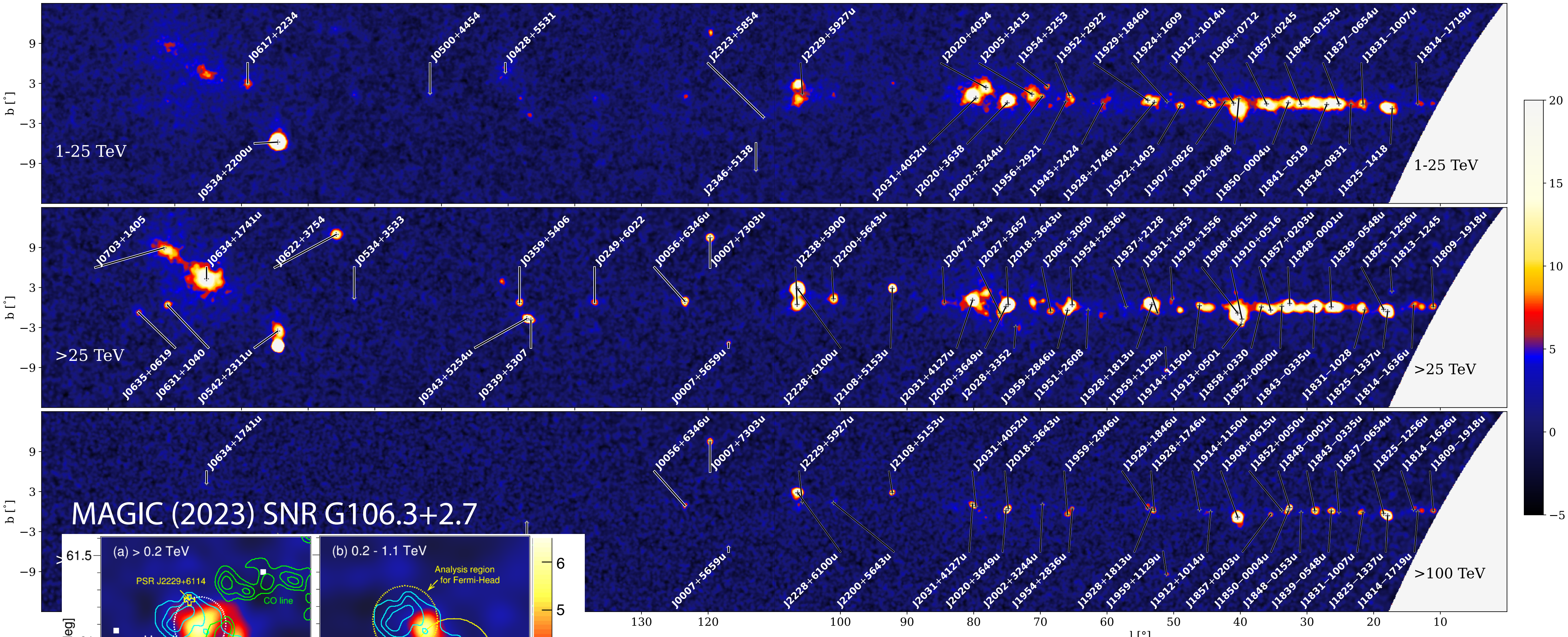
PDG 2020



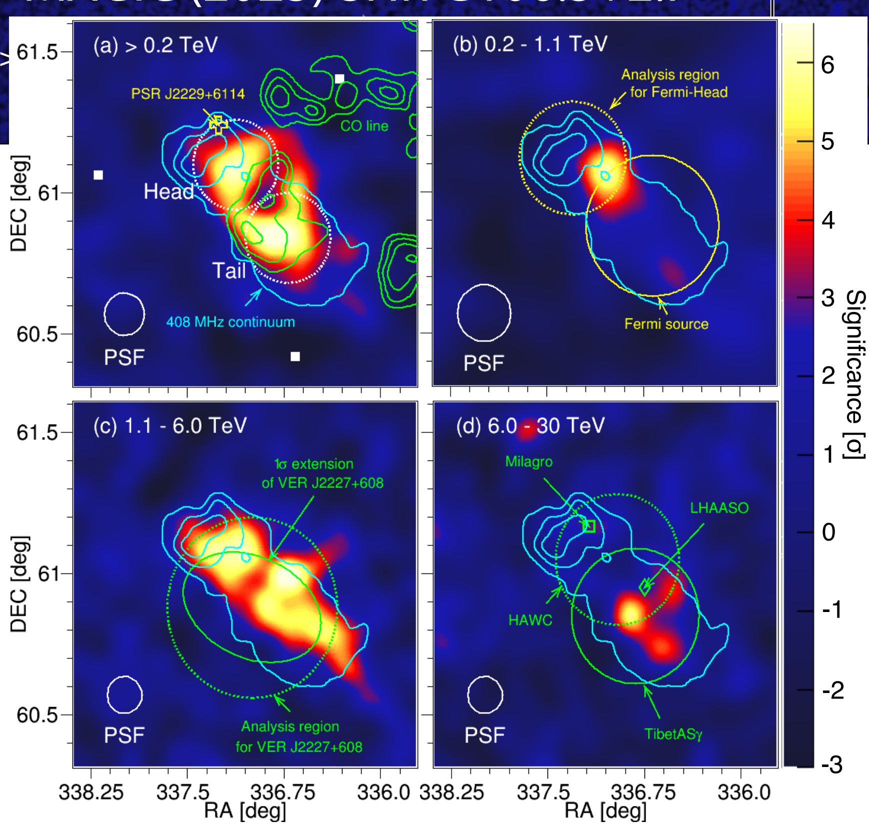
- ~10^8 eV (~100 MeV) to > 10^{20} eV, with a power law of $dN/dE = E^{-2.7}$ to $E^{-3.0}$
- Almost uniformly distribute over the sky (due to the magnetic fields)
- What is the origin (PeVatron) of Galactic CRs (< ~3 PeV)?
  Supernova remnants? Galactic center? $E^{-2.0}$ at the source?

Where are PeVatrons?

LHAASO (2023) 2305.17030

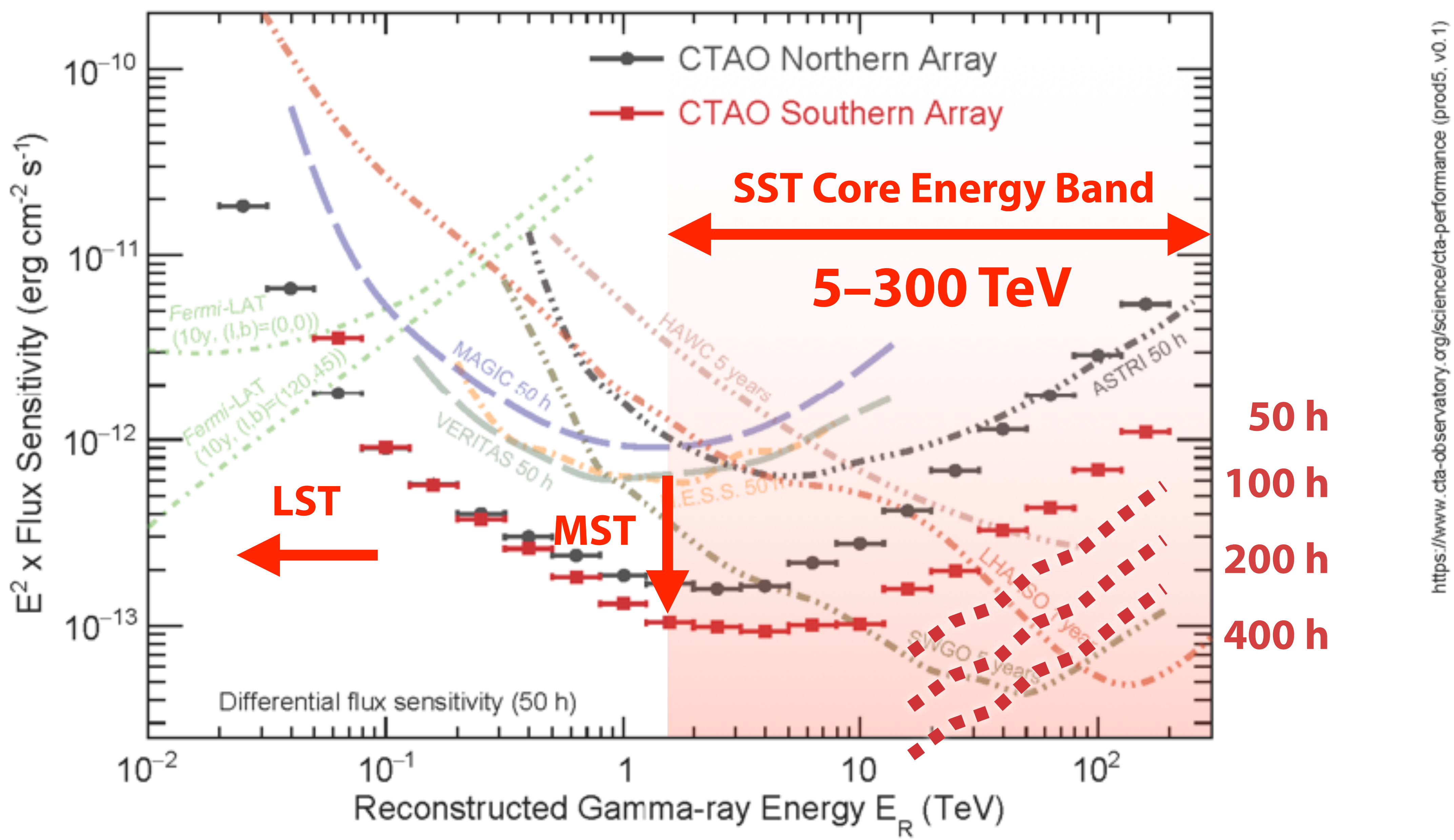


MAGIC (2023) SNR G106.3+2.7



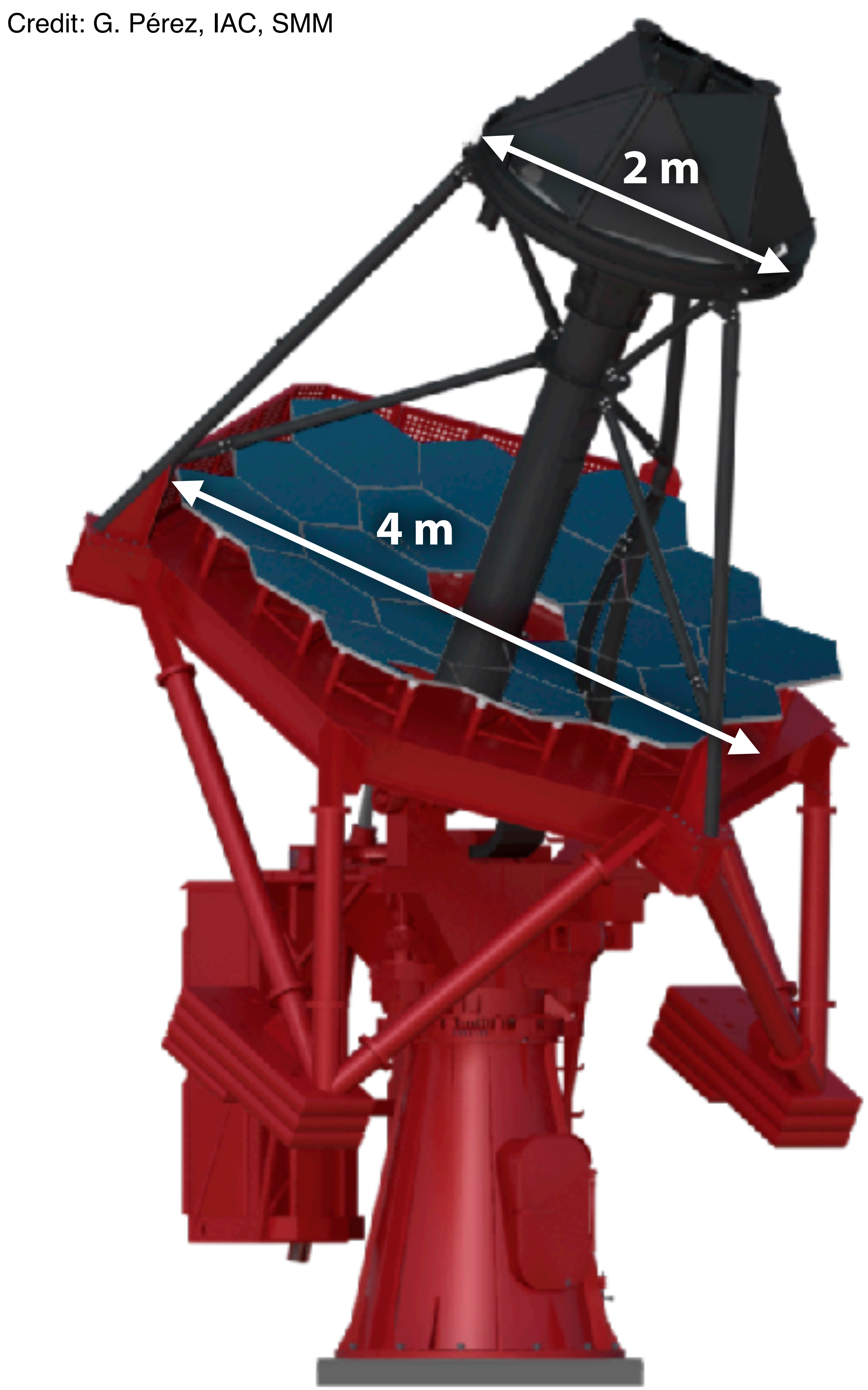
- Northern array-type surface detectors are exploring the PeV band
- LHAASO found 43 sources >100 TeV (> 4σ)
- What can Cherenkov telescopes do?

High-energy Frontier by CTA SSTs (Initial Configuration)



- Covering up to 100–300 TeV is a key for PeVatron search
- Long observations of selected candidates (e.g., Gal. Center) with better ang. reso.
- Observations under bright moon conditions will double the duty cycle

Small-Sized Telescopes (SSTs)



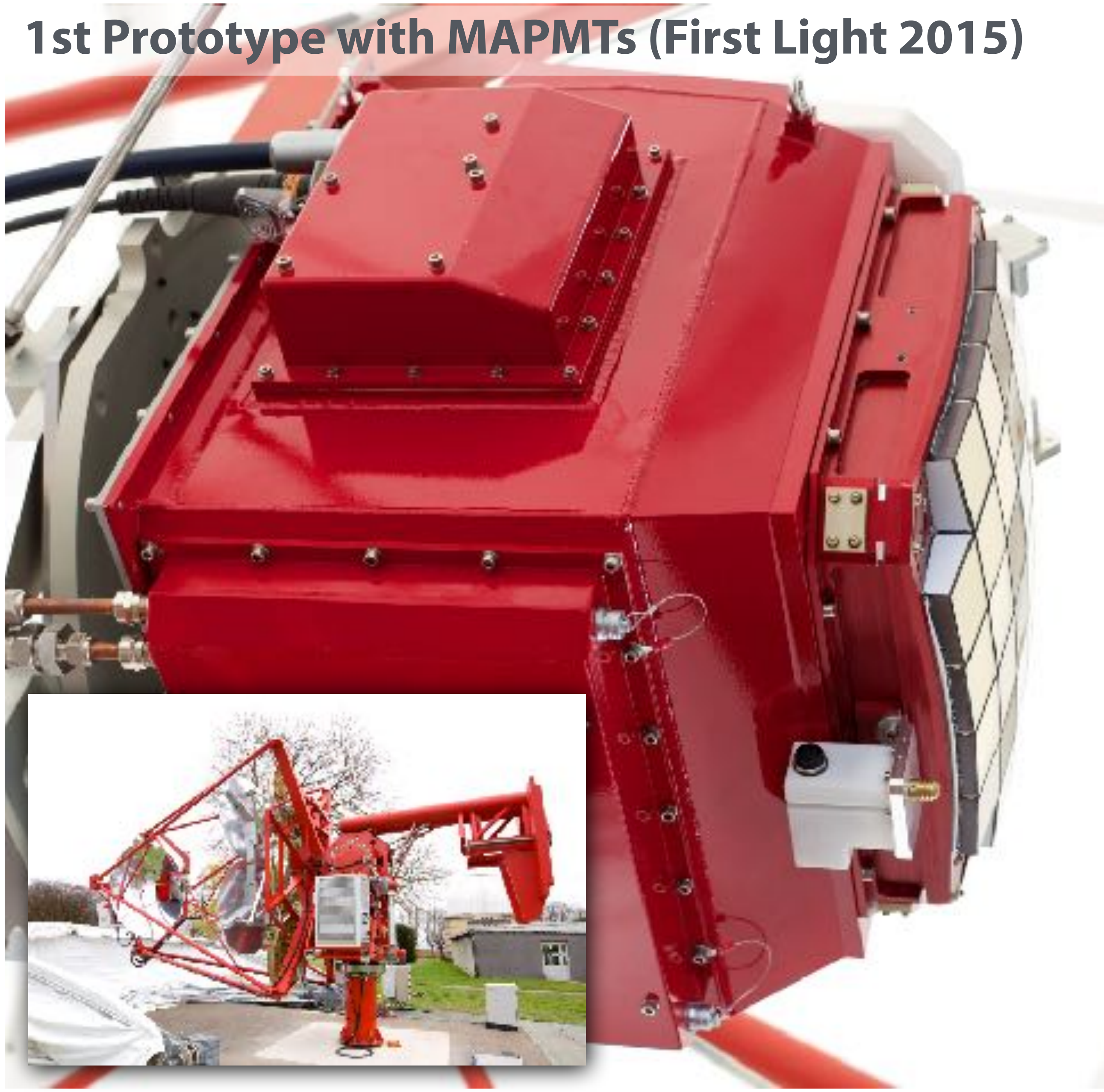
- In 2019, SST "harmonization" process concluded to select this design as the final SST design
- Schwarzschild–Couder optical system
  - 4 m aspherical primary mirrors (segmented)
  - 2 m monolithic secondary mirror (monolithic)
  - ~0.15° PSF diameter over ~9° FOV
- Compact focal-plane camera
  - 2048 SiPM pixels to form 300 mm focal plane
  - 32 × 64-ch camera modules with dedicated ASICs
  - Large contributions from Nagoya University

Status of the SST Optical System

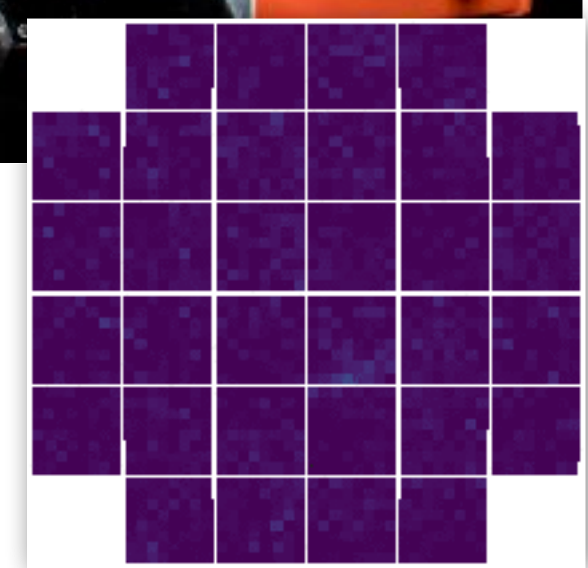
- The optical performance of the Schwarzschild–Couder system validated
- “ASTRI mini-array" (9 SST-like systems) to be built at Teide Observatory
- Optics and array control will be tested and validated before SST construction in ~2026

History of the SST Camera

1st Prototype with MAPMTs (First Light 2015)

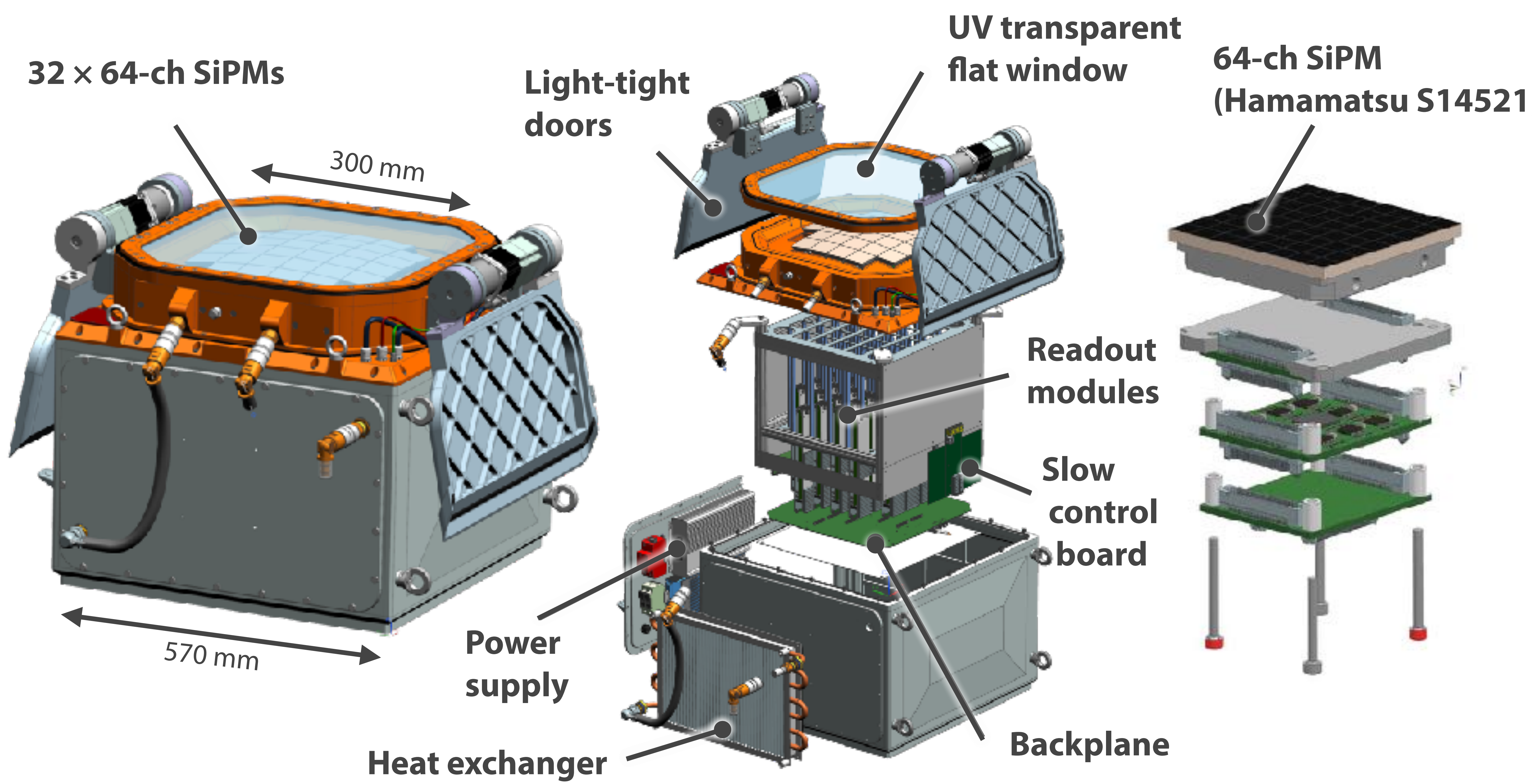


2nd Prototype with SiPMs (First Light 2019)



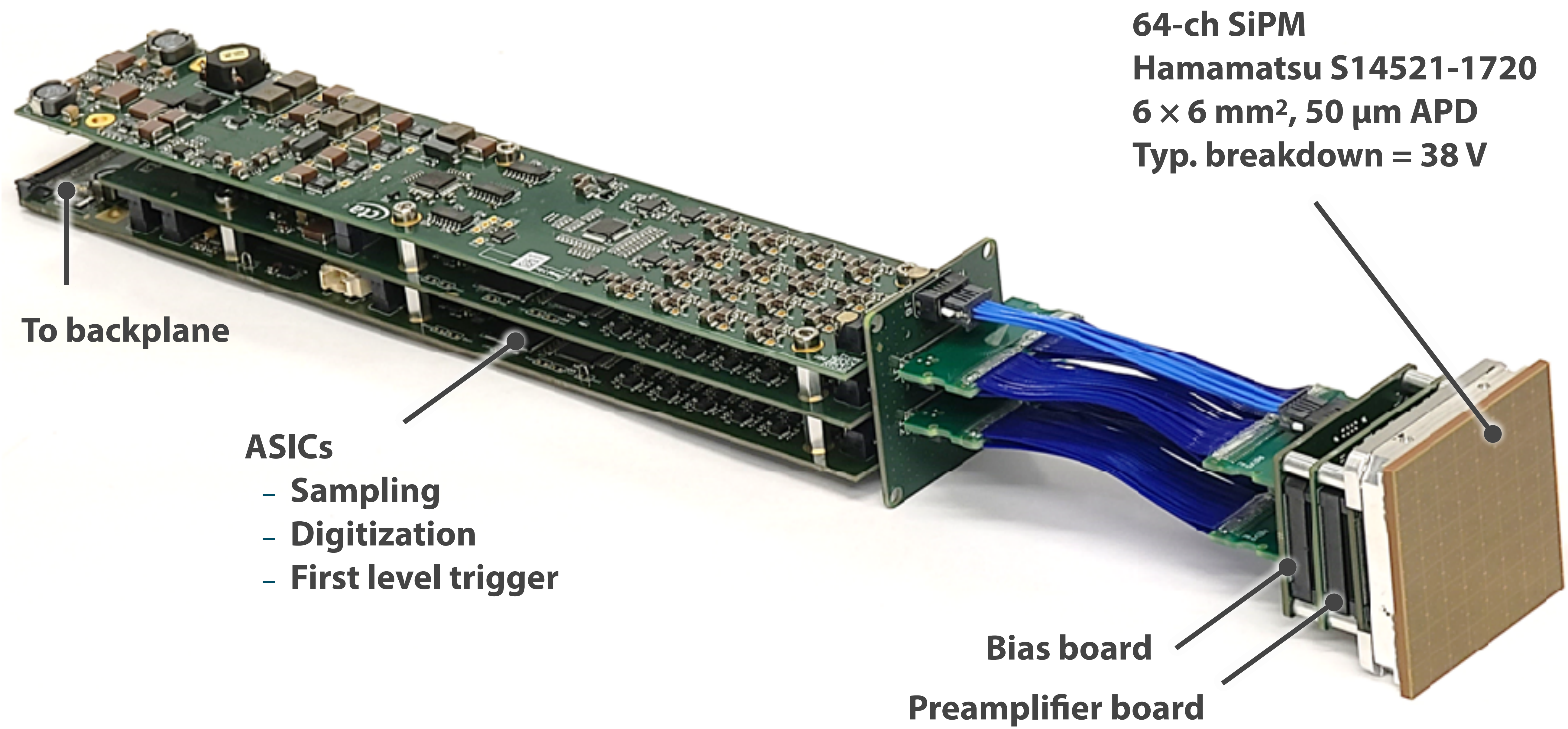
- The current SST camera concept started around 2012
- Two prototypes succeeded in first lights in 2015 and 2019
- SiPMs to be used in the final SST camera design

(Almost) Final Design



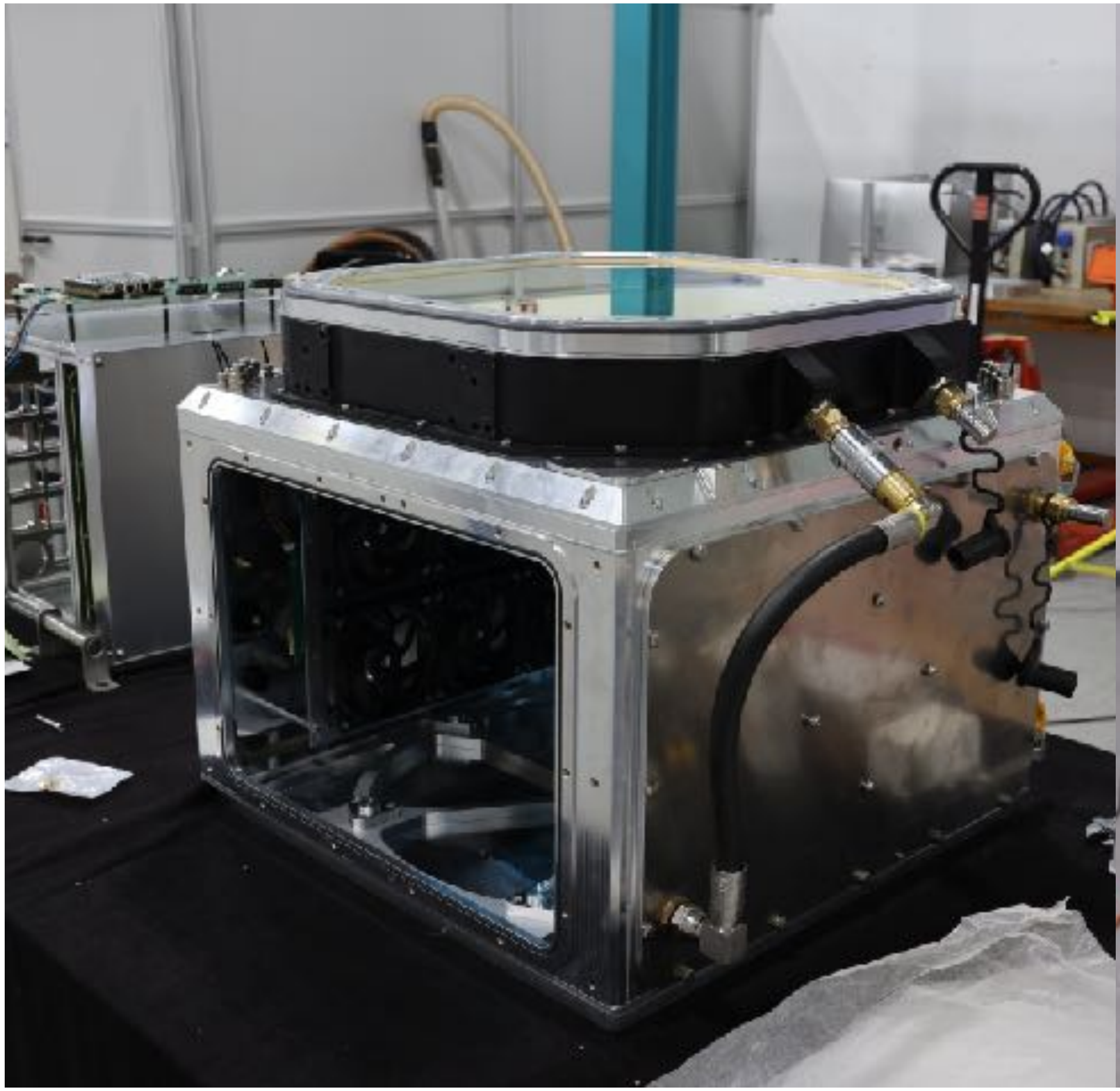
- The same concept: 32 × 64-ch SiPMs to form the spherical focal plane, read and triggered by dedicated ASICs (TARGET series), and controlled by backplane
- After the experience of two prototypes, the design is being finalized now

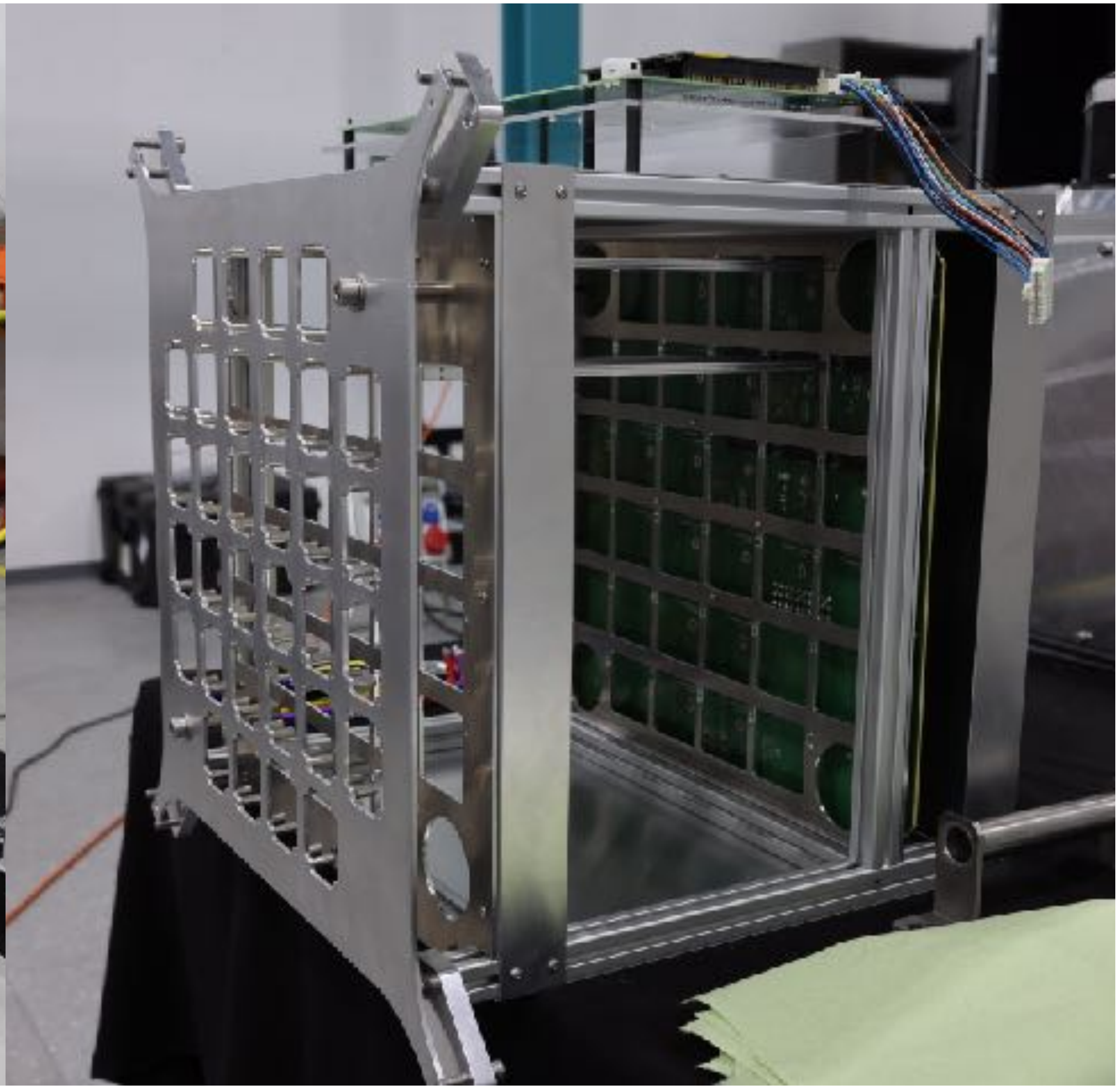
Camera Module



- Started with the first TARGET ASIC (16-ch sampling and trigger), and 64-ch MAPMTs in 2009
- Latest module uses 4 × sampling ASIC (CTC) and 4 × trigger ASIC (CT5TEA)
- UV-sensitive and uncoated low-optical-crosstalk 64-ch SiPMs

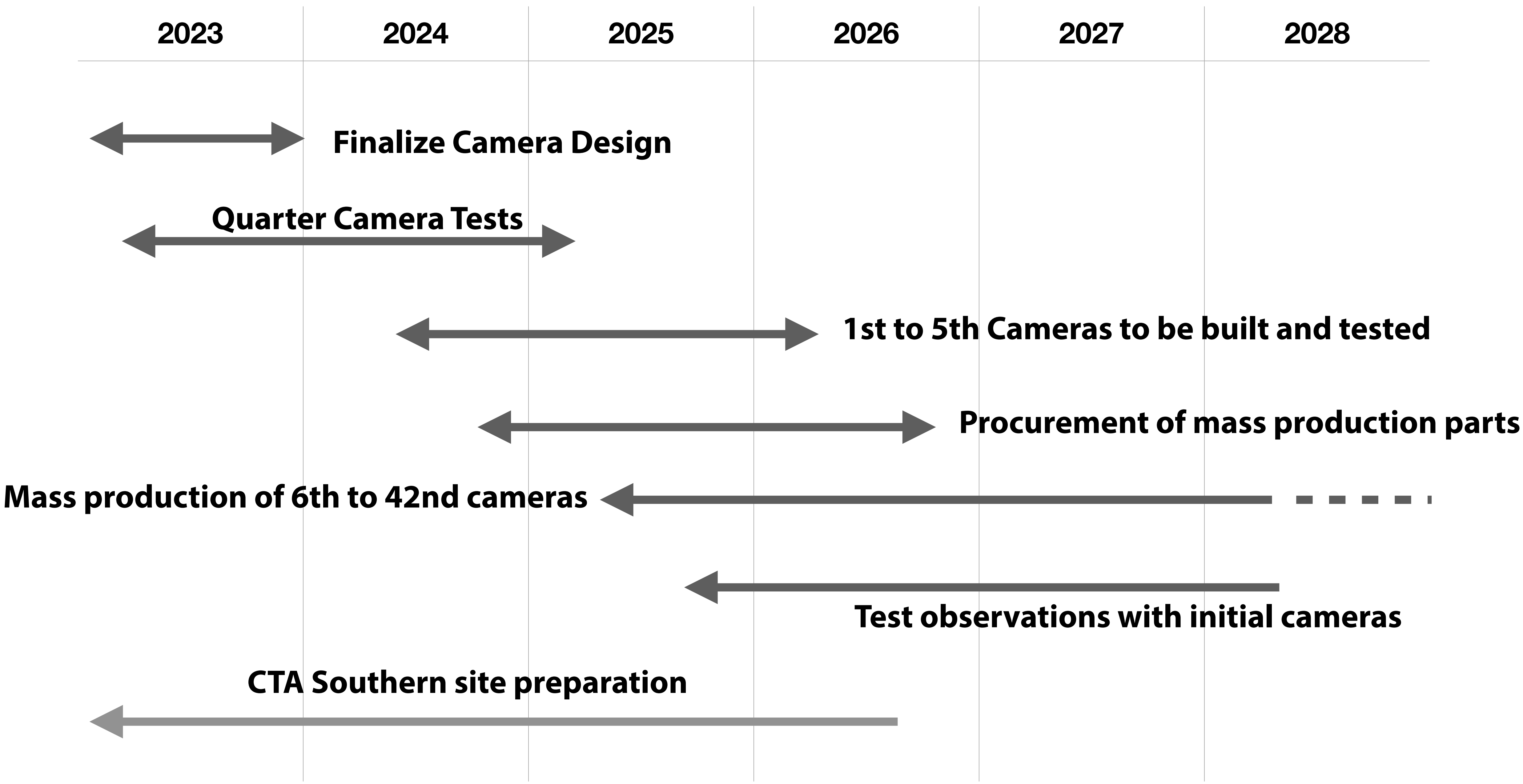
Quarter Camera @ MPIK, Heidelberg





- Quarter camera will have only 8 camera modules (512 of 2048 pixels)
- Mechanical, thermal, and electrical tests started this summer in parallel to stand-alone module tests
- Tests and debugging to finish this year, then a full camera (first camera) will be built in 2024
- Mounting test on a telescope to be done at the Tide Observatory in October

Tentative Schedule



- Quarter camera in 2023–2024, 1st camera in 2024–2025, …
- Once the 1st camera is ready, we will start test observations in 2025
- Must produce and test a new camera a month from 2025

Summary

- CTA Small-sized Telescopes (SSTs) is a key instrument for PeVatron search in 5–300 TeV
- Complementary with array-type surface detectors
  - Better angular and energy resolutions
  - Competing exposure time by pointing and moon-light observations
- The final SST camera and telescope designs are almost finished
- Quarter camera and modules are under tests
- First camera and mass production are expected in the next few years