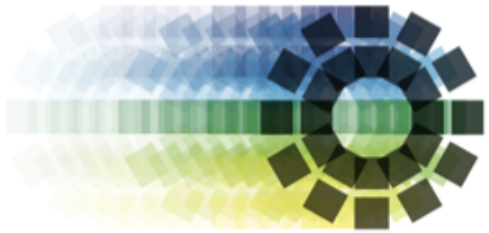


PANORAMIC SETI

Deployment of Imaging Air Cherenkov Telescopes for 10 TeV - PeV Gamma-Ray Astronomy

Yuriy Popovych for the PANOSETI Collaboration

November 3, 2025

TeVPA 2025, Valencia, Spain

BERKELEY SETI
RESEARCH CENTER

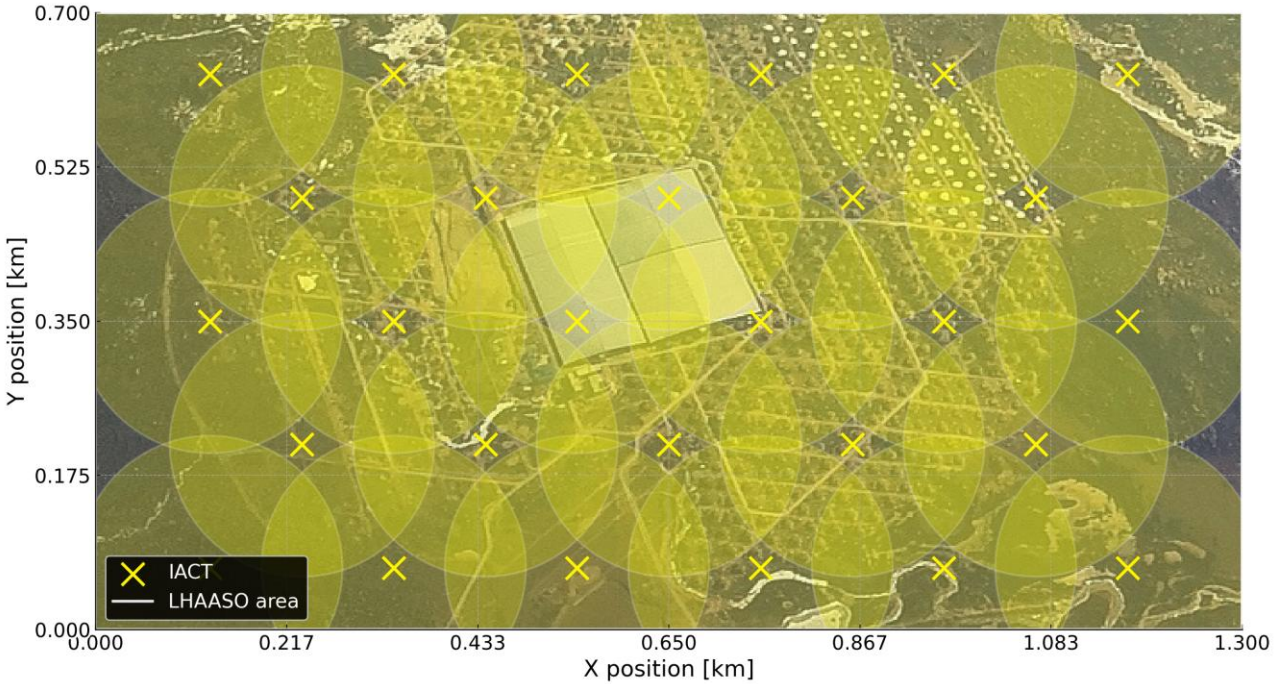
Detection of UHE Gamma-Rays

- State of the art IACTs (VERITAS, HESS, ect.)
  - Good sensitivity with pointed observations, precise spatial and spectral reconstruction
  - Sensitivity for E ~ 100 GeV – 50 TeV
  - **Not optimized for E>100 TeV Events**

- Wide-Field Water Cherenkov Arrays (LHAASO)
  - Sensitivity for E>100 TeV
  - Large Field of View
  - High duty cycle
  - High Cost

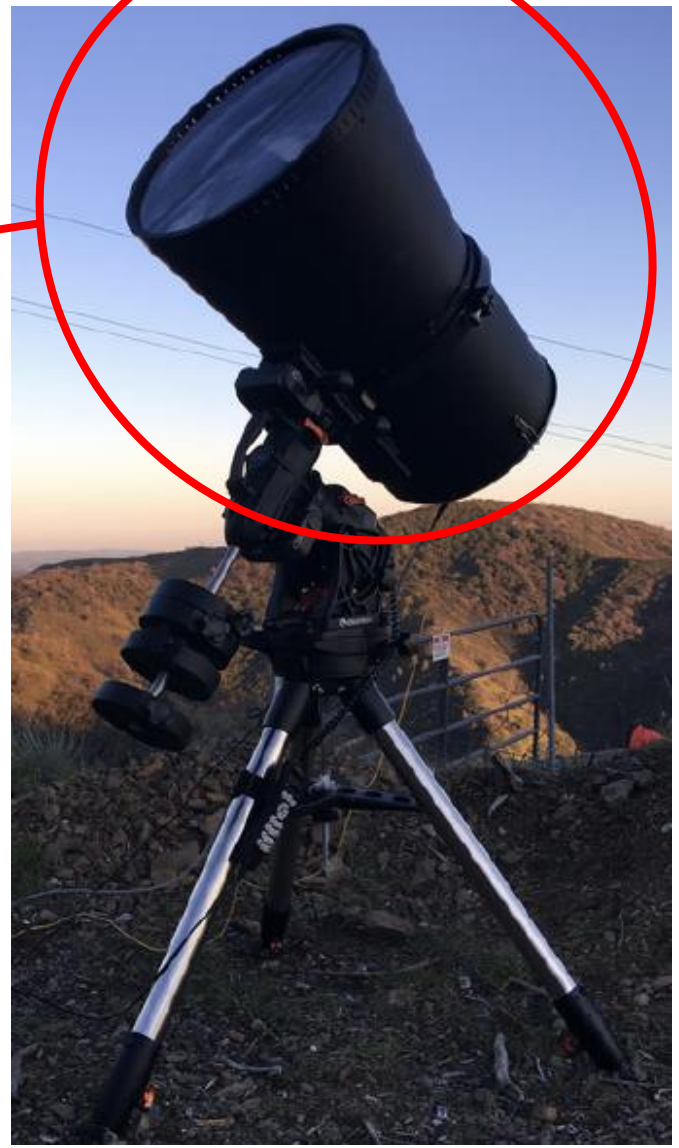
Detection of UHE Gamma-Rays

- Alternative: IACT Arrays (**PANOSETI**)
  - High angular resolution
  - Better Gamma-Hadron Separation
  - Scalable
  - Cost-efficient: ~20-30 IACTs needed to cover area of LHAASO
  - Using small, compact, IACTs for lower cost (compared to e.g. CTA)

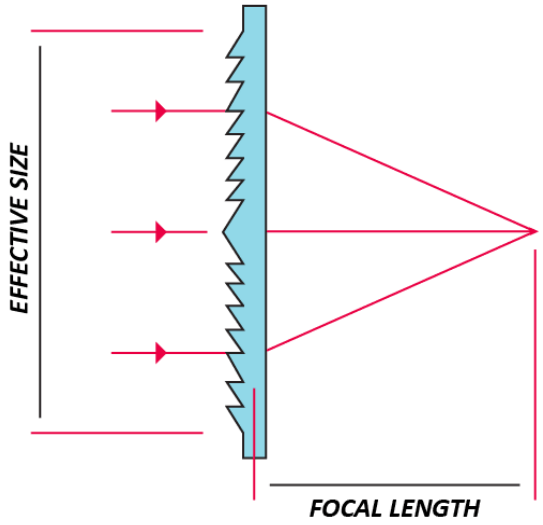


PANOSETI Telescope

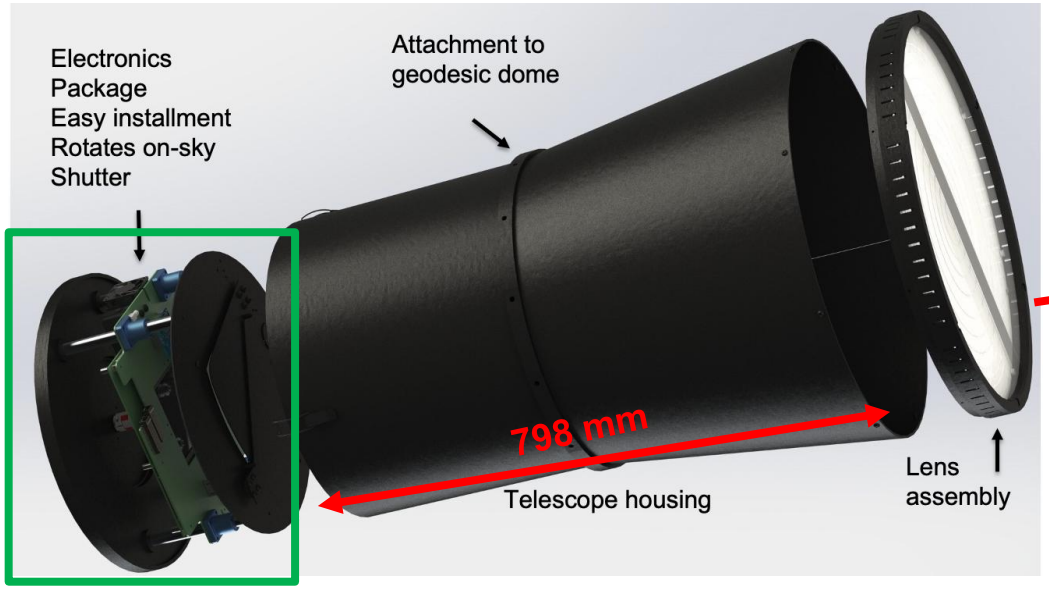
PANOSETI Telescope

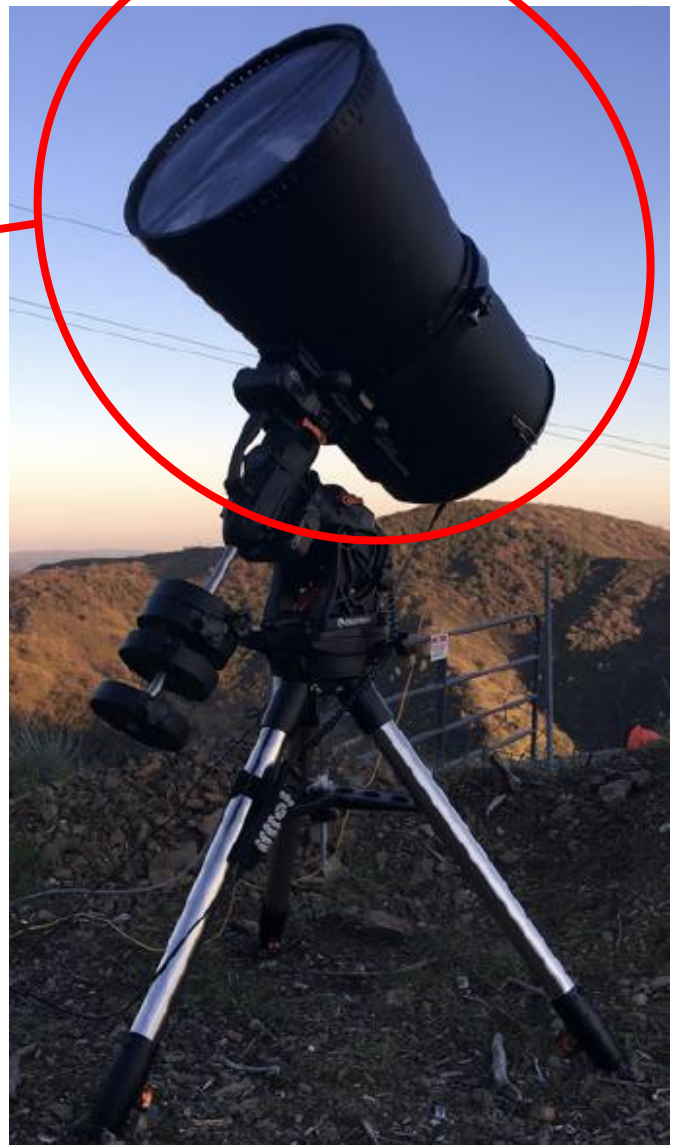


- **Fresnel lens:**
  - 0.42 m diameter
  - 1.8 mm thickness
  - Focusing light on camera based on incident angle
  - Covered by plexiglass

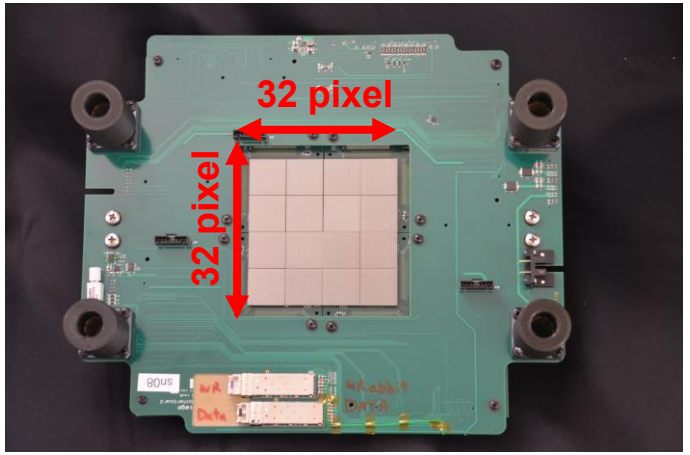


PANOSETI Telescope

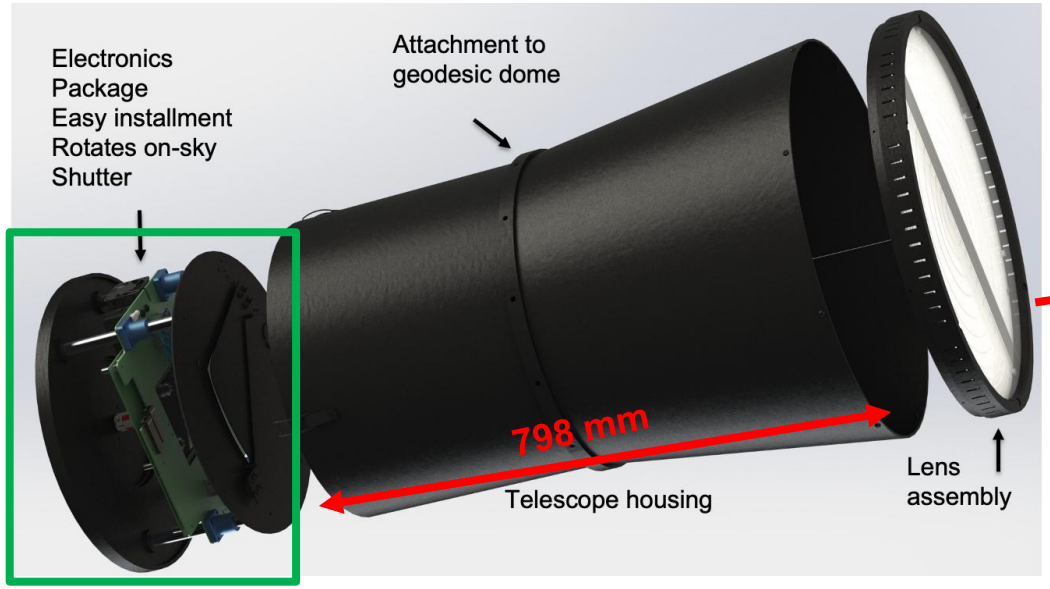


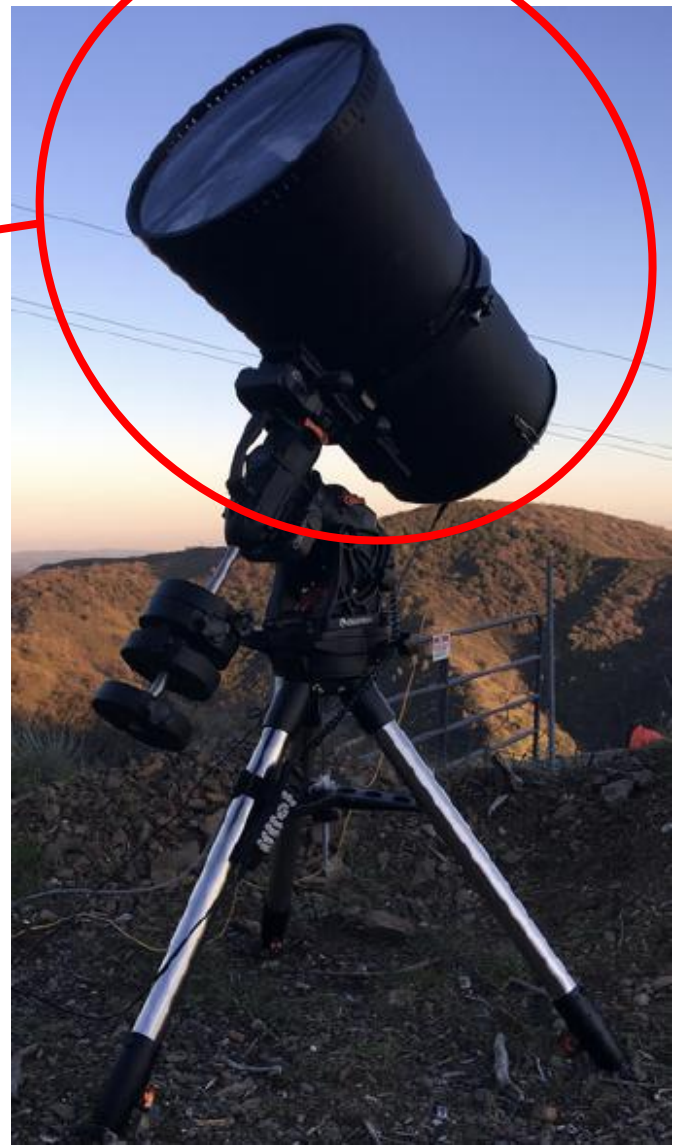


- **Camera:**
  - 4 x 4 SiPM arrays with 8 x 8 pixels each
  - 32 x 32 pixel in total
  - Field of view: 10° x 10°
  - Angular size: 0.31° per pixel

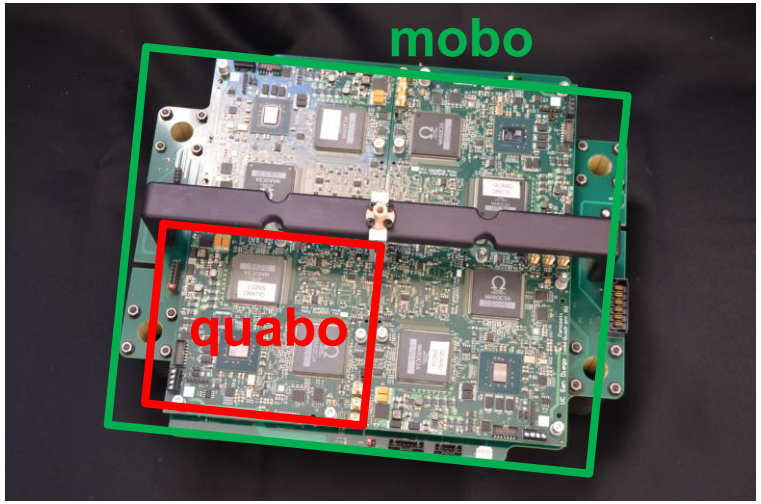


PANOSETI Telescope



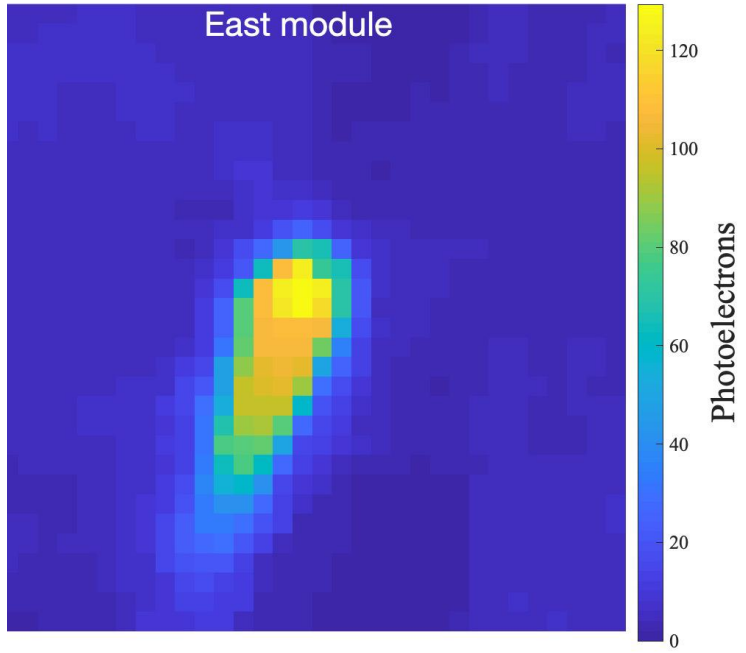


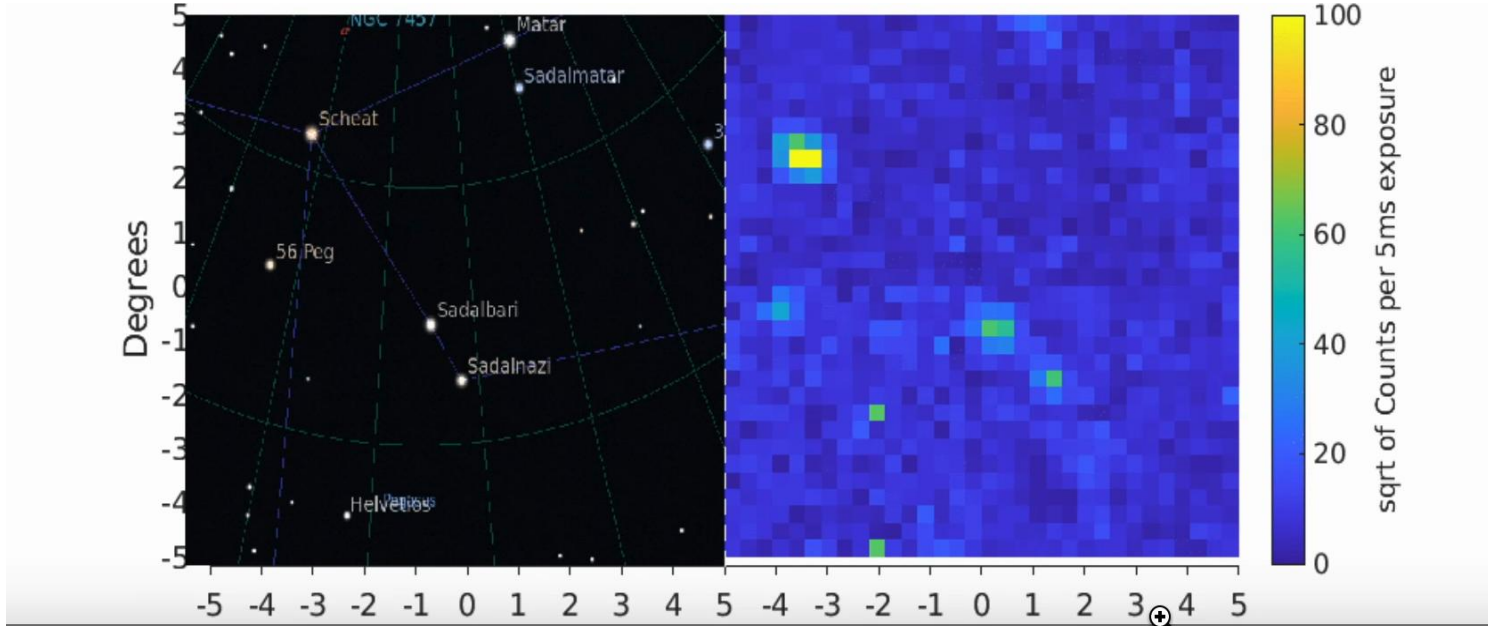
- **Readout:**
  - Group into 4 quadrant boards (**quabos**)
  - Readout and digitization via Maroc3A chips
  - Quabos mounted on Mother Board (**mobo**)



Operation Modes

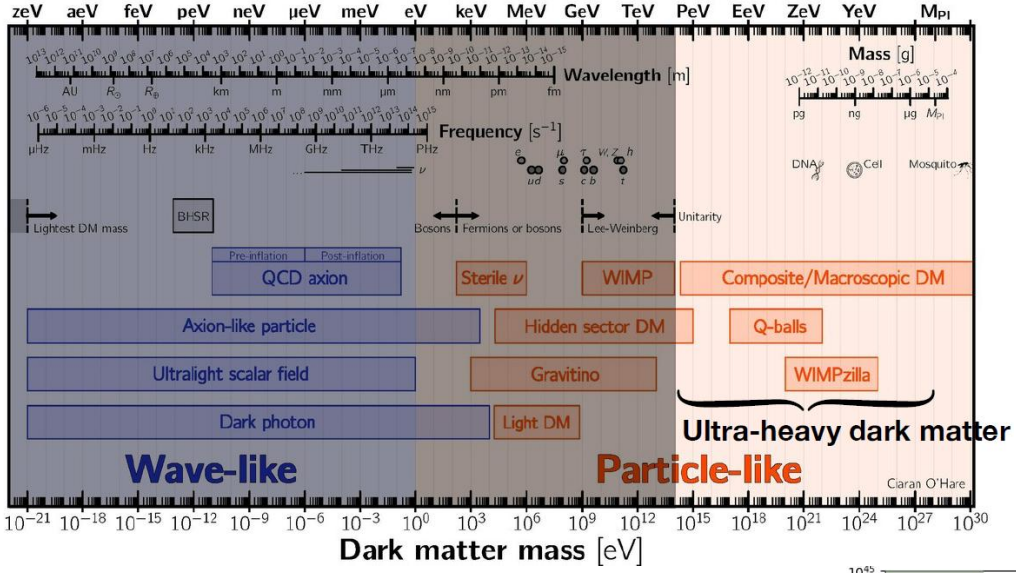
- **PH-Mode**
  - Read out frame of full camera if trigger condition is met (2 pixel on same quabo above set Photo-Electron (PE) threshold)
  - Record single triggered events
  - ns timescale
- **Imaging-Mode**
  - Count number of triggers per pixel over set exposure time
  - Record video of sky with set frame rate (given by set exposure time)
  - µs – s timescale



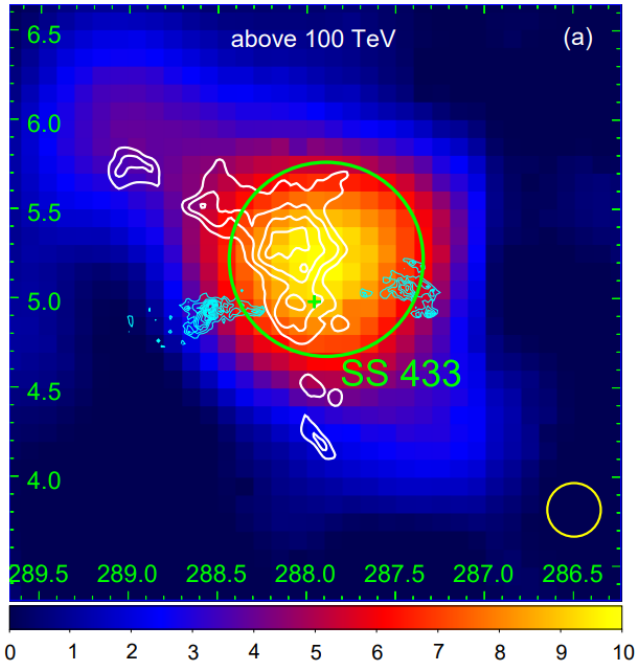


Applications

- **Ultra-heavy dark matter (Dark 100)**

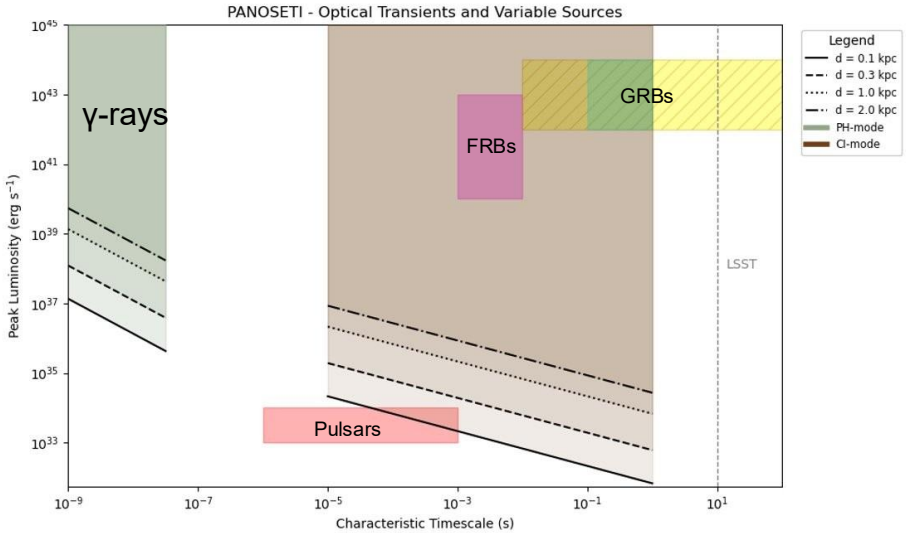


- **Gamma-Ray Observations of PeVatrons**



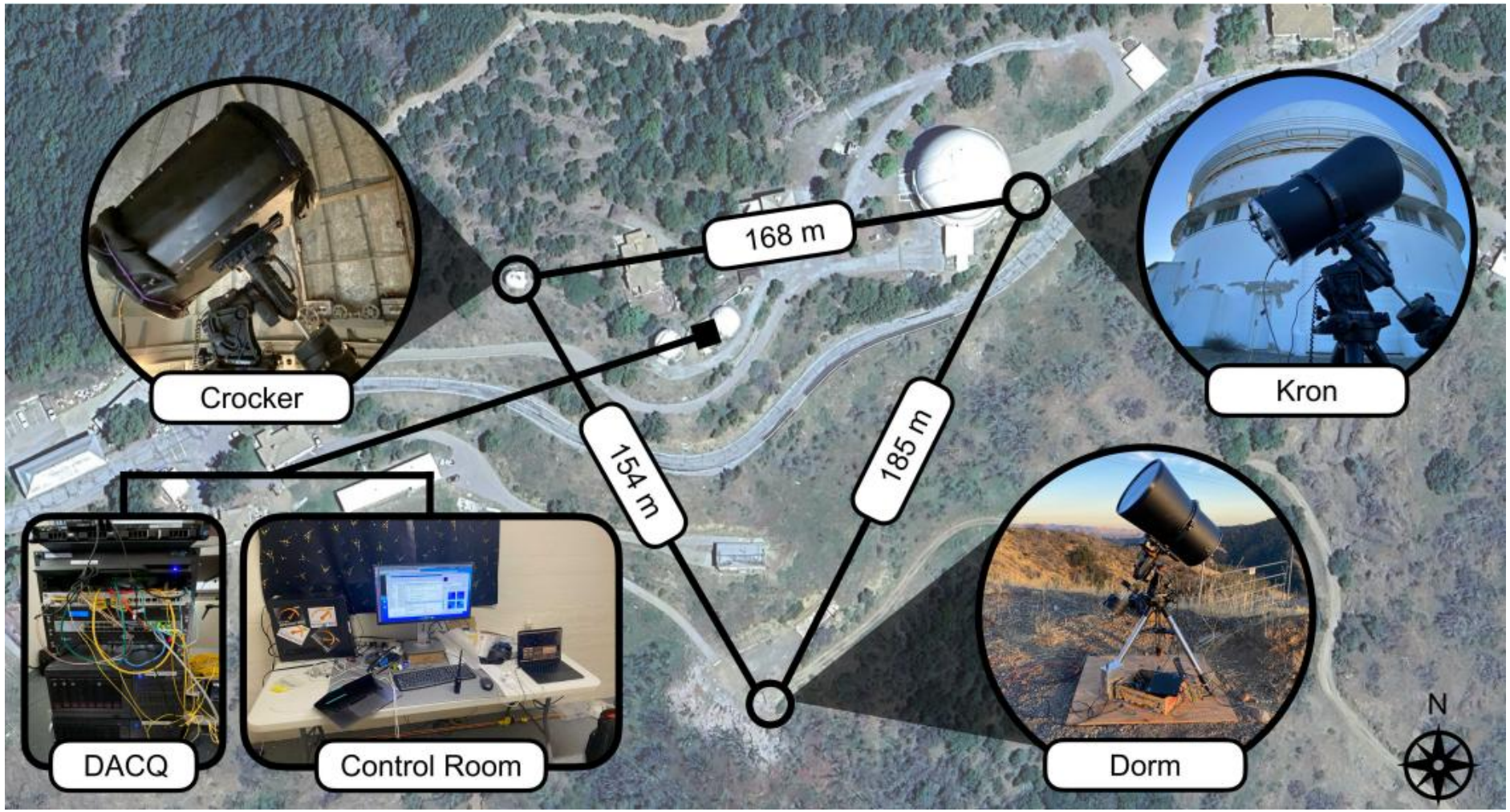
arXiv:2410.08988

- **Optical transients and Variable Sources**



- **Optical SETI**

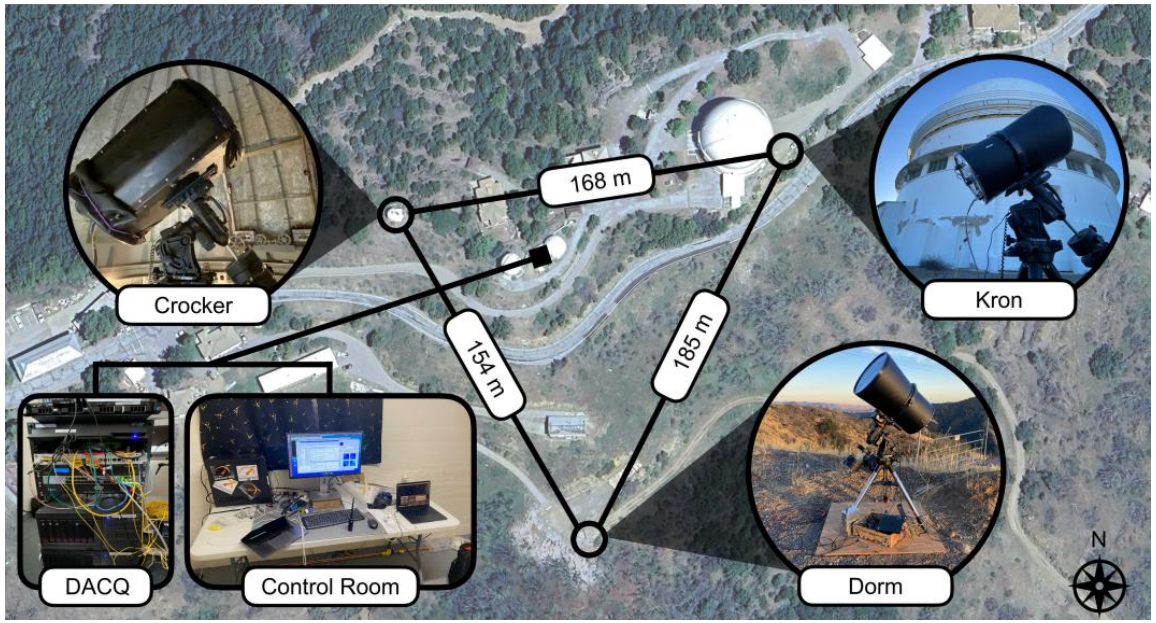
PANOSETI at Lick Observatory

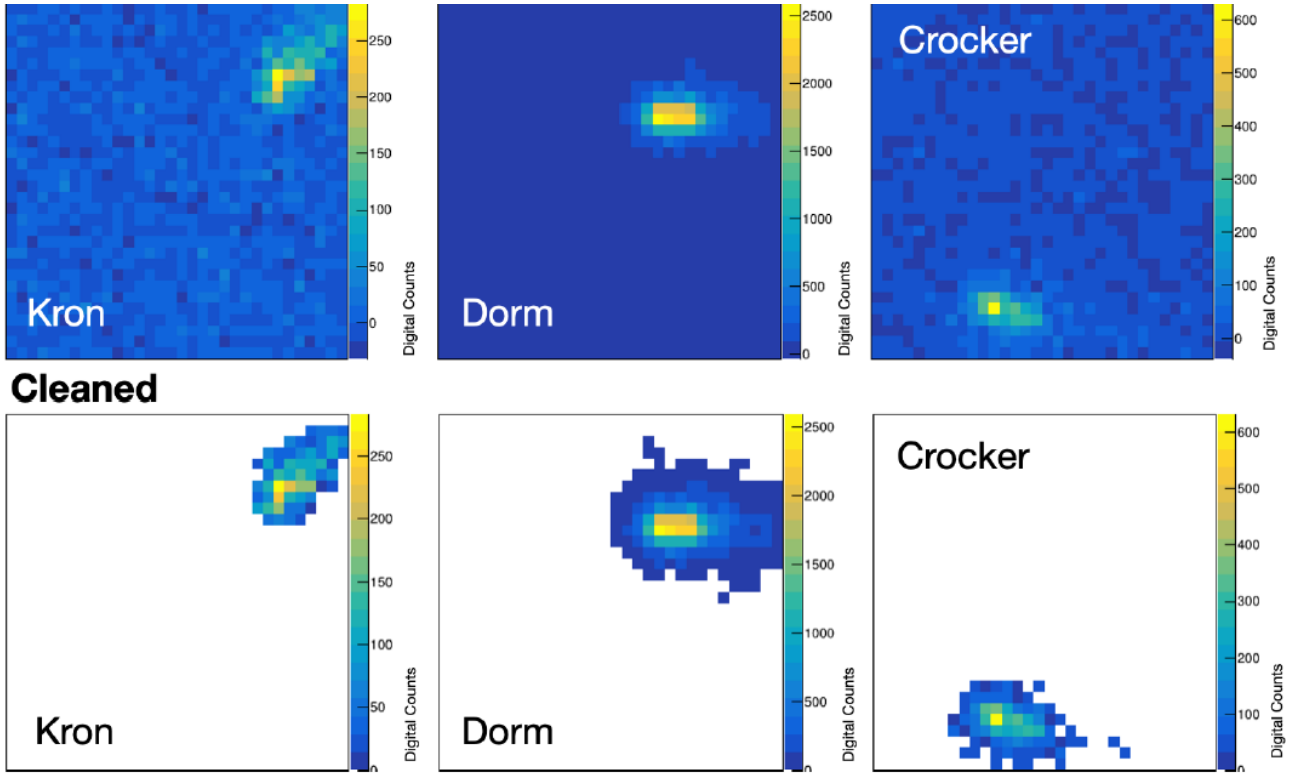


Source: N. Korzoun PoS(ICRC2025)713

PANOSETI at Lick Observatory

Events from Crab Nebula

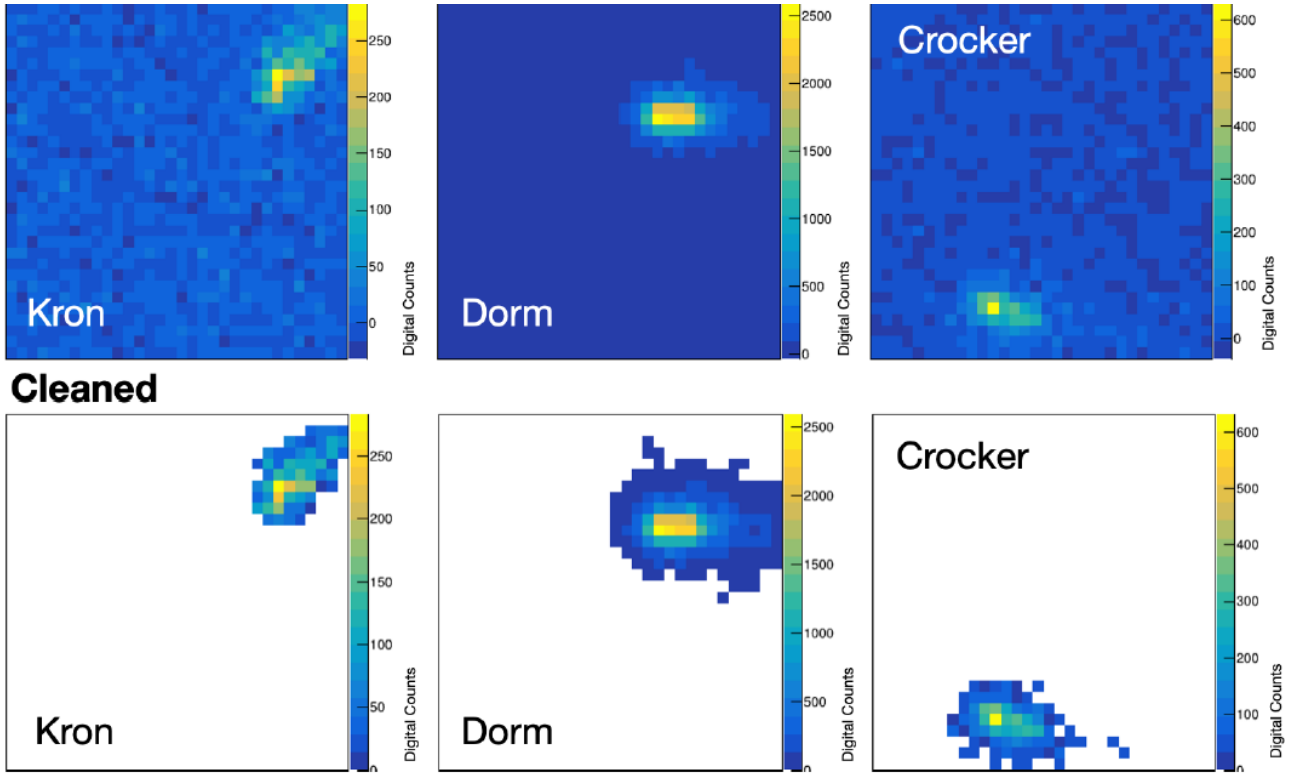




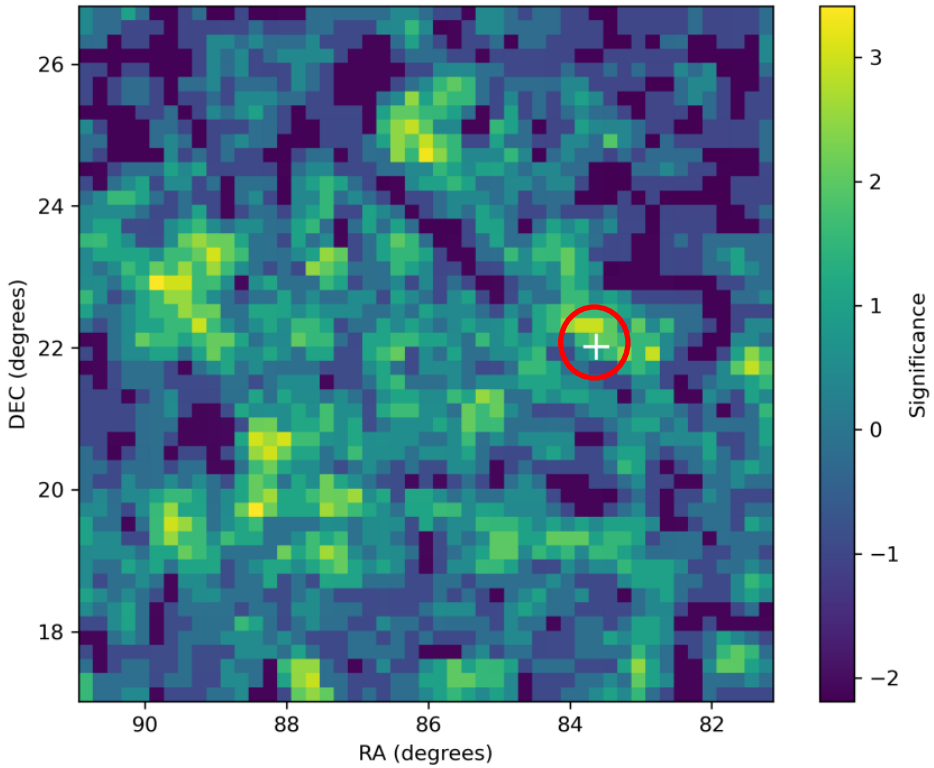
Source: N. Korzoun [PoS(ICRC2025)713]

PANOSETI at Lick Observatory

Events from Crab Nebula



Significance Map

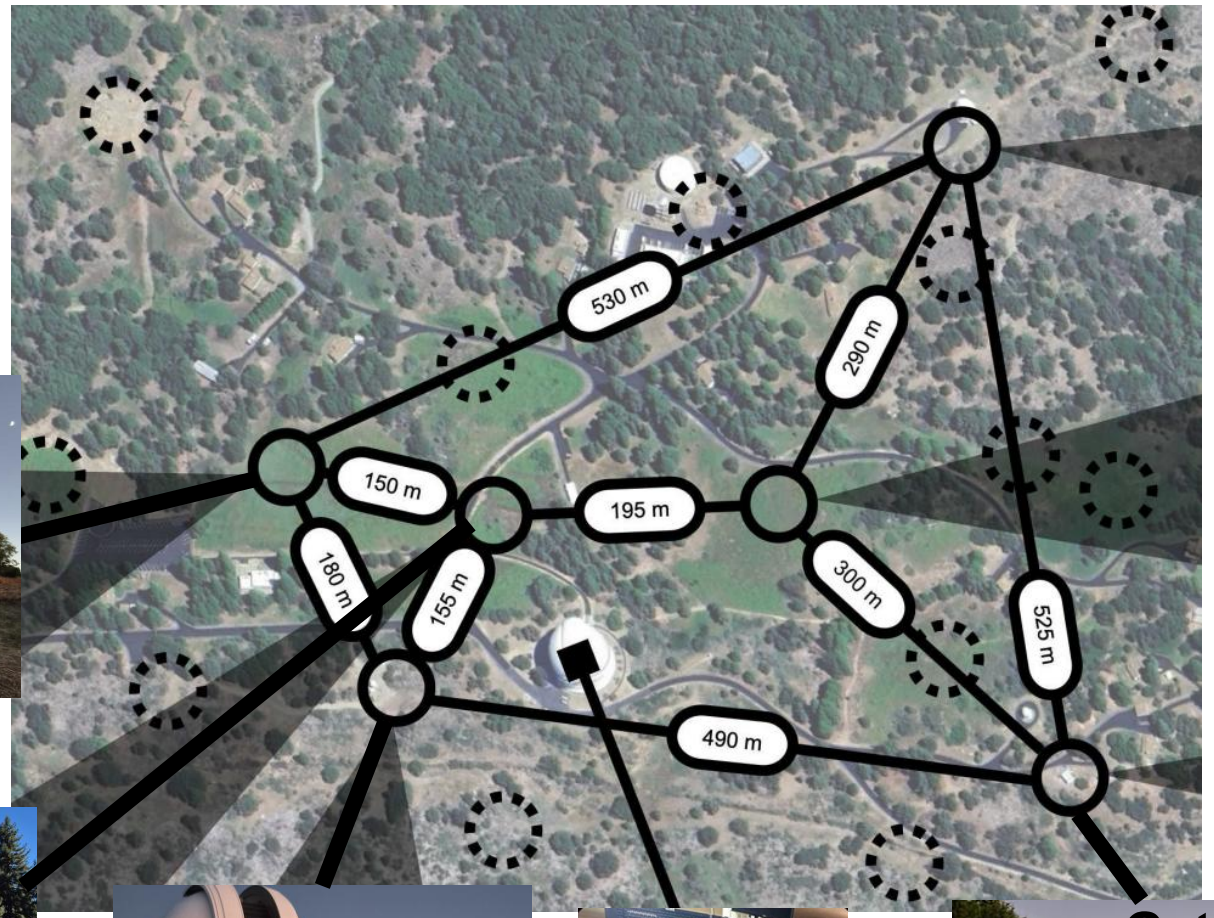


Source: N. Korzoun PoS(ICRC2025)713

- **Gamma-ray excess of 1.55 σ towards Crab Nebula after 5 h of observation time**
- **Established processing and analysis tools for future observations**

PANOSETI at Palomar Observatory

- Installation of 4 sites in 2025
- 2 additional sites in 2026
- Additional up to 30 sites



Fern

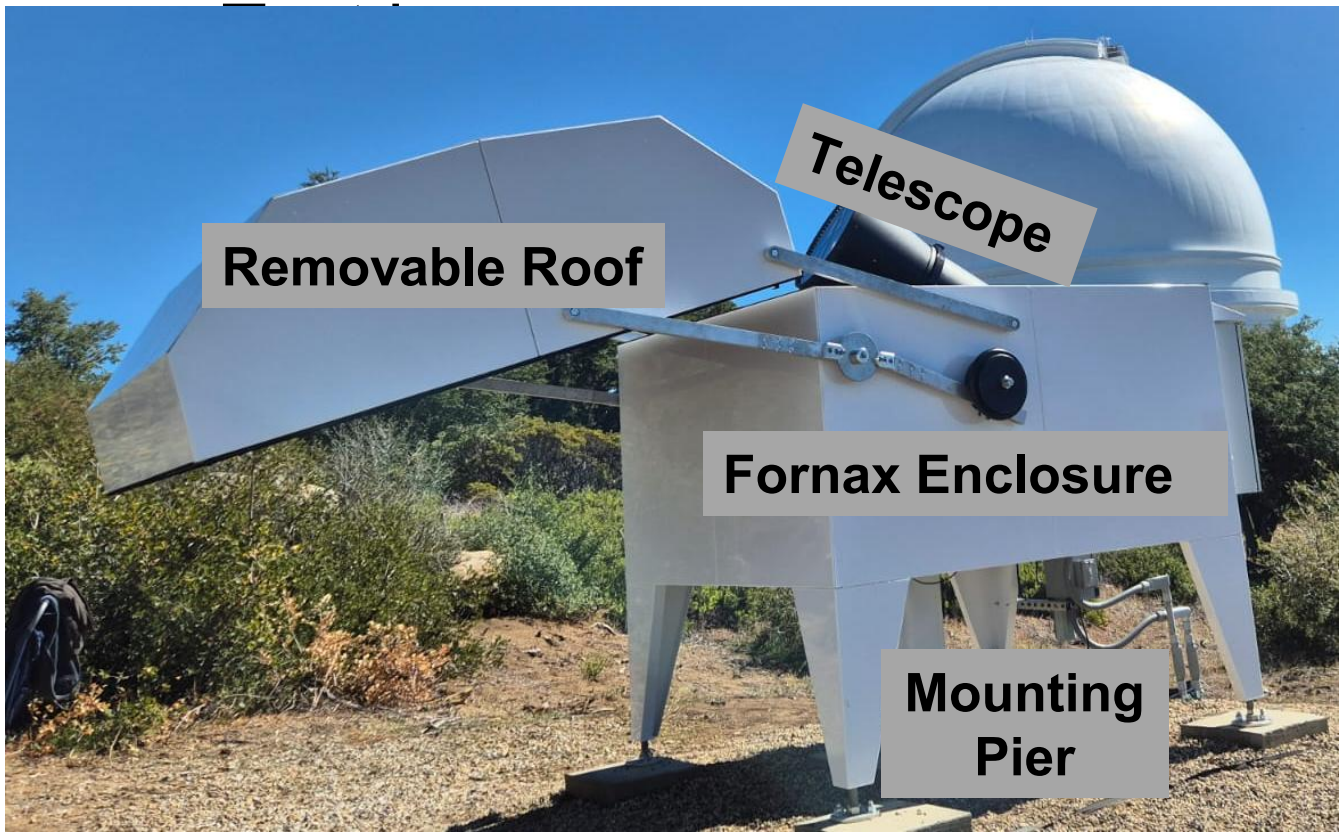
PTI

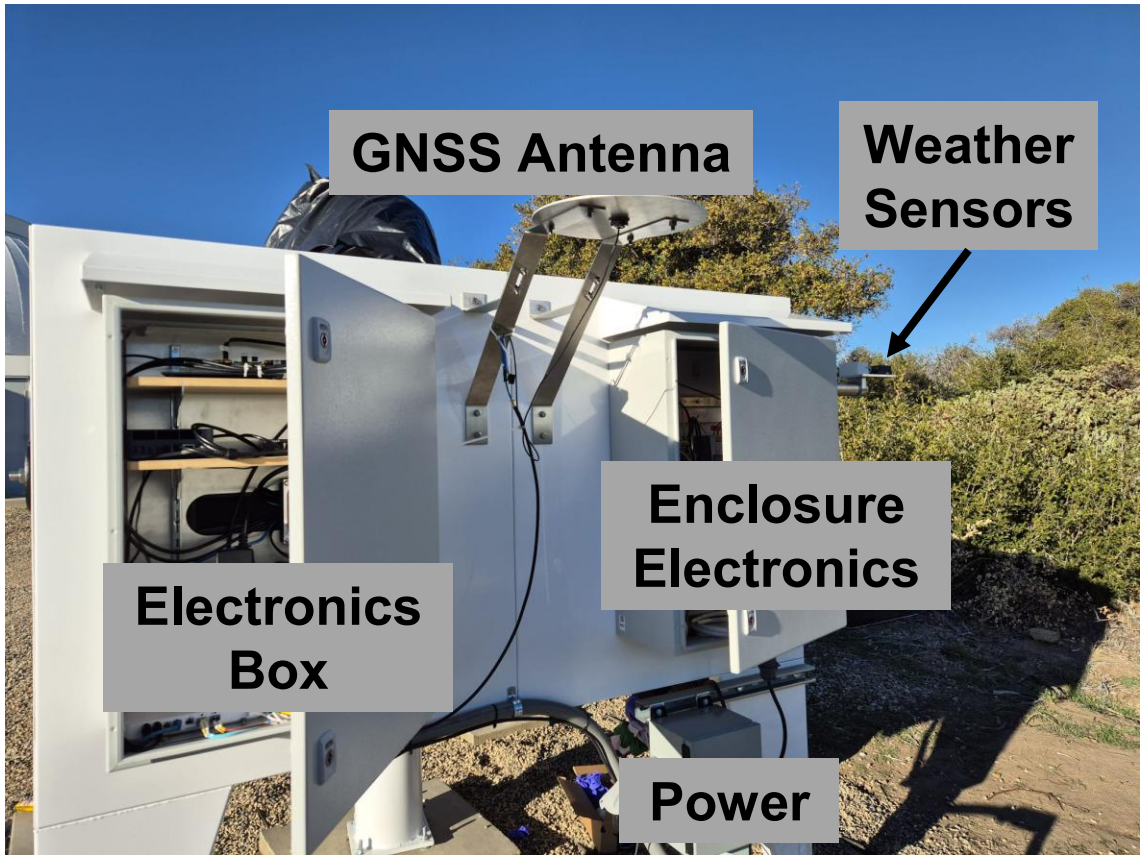
Winter

European Research Council
Established by the European Commission

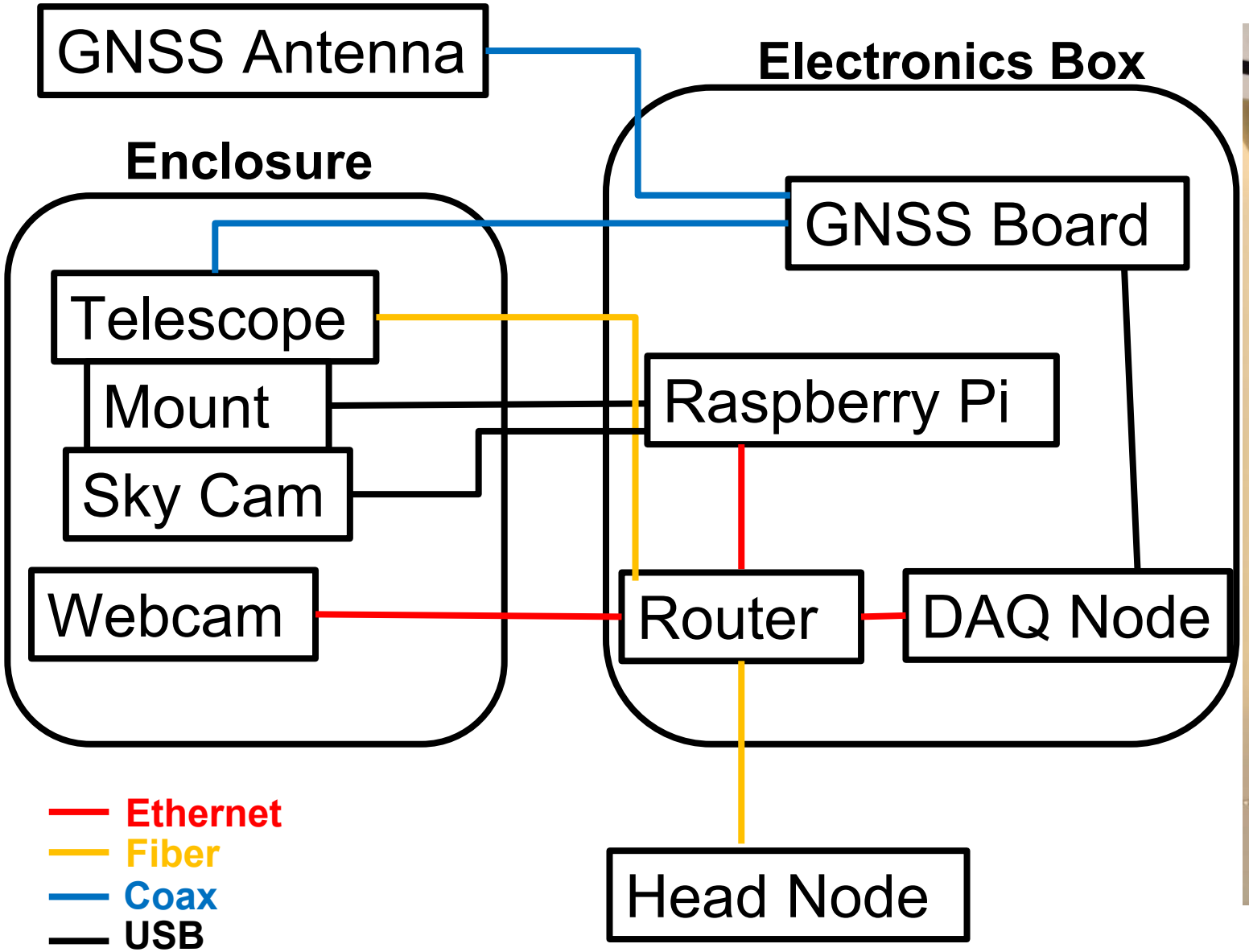
Deployment and operation of the first 6 telescopes are funded by the Dark100 project, financed by the ERC to 2029.

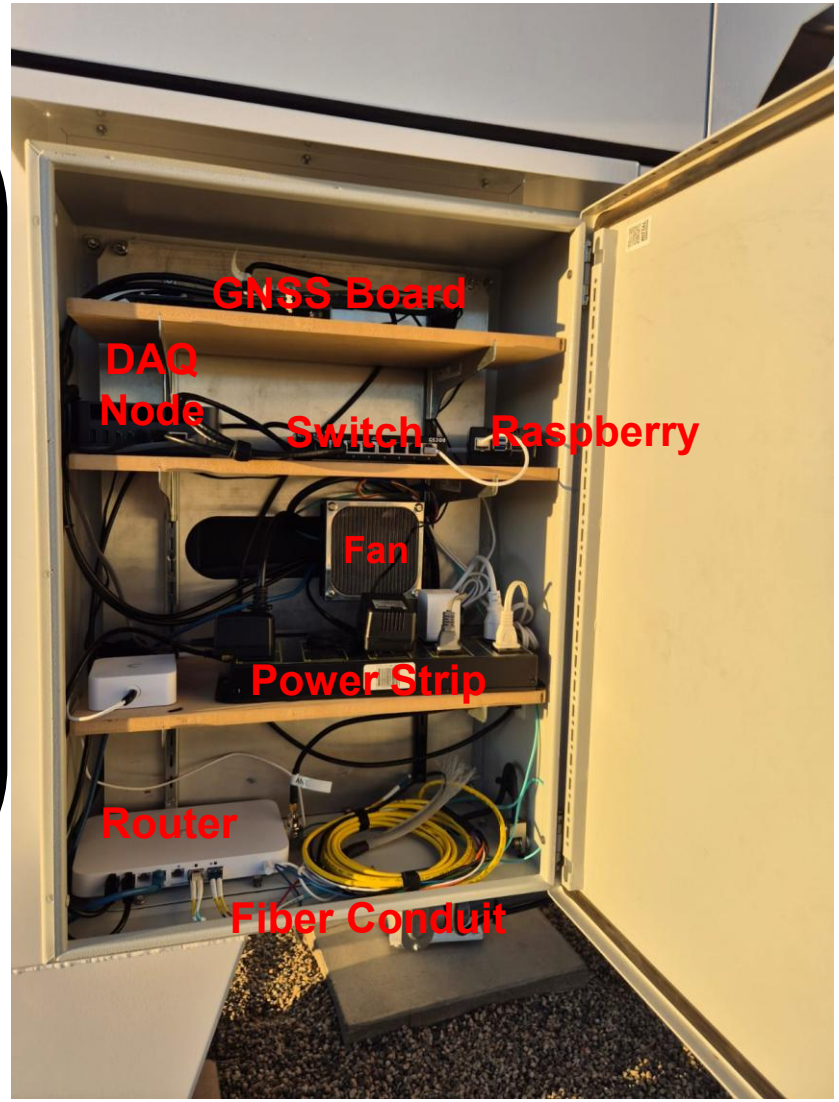
PANOSETI Site





Site Electronics and Network

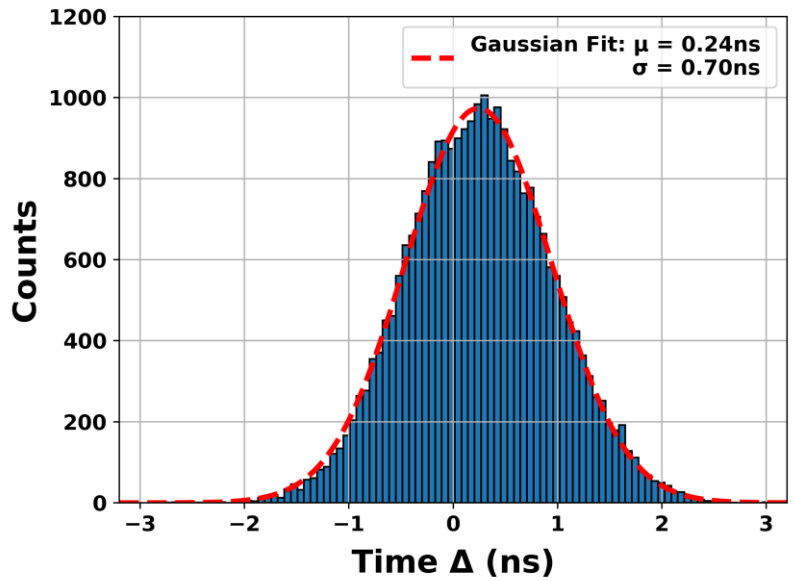




Timing with GNSS

- Localization of GNSS antennas
- Receive high precision timing signals from GNSS satellites
- Runtime differences between sites calibrate absolute clock for all telescopes
- Absolute timing for coincident Cherenkov events

- **Precision of ~0.7 ns**



2 antennas at 800 m distance

Deployment work on Palomar

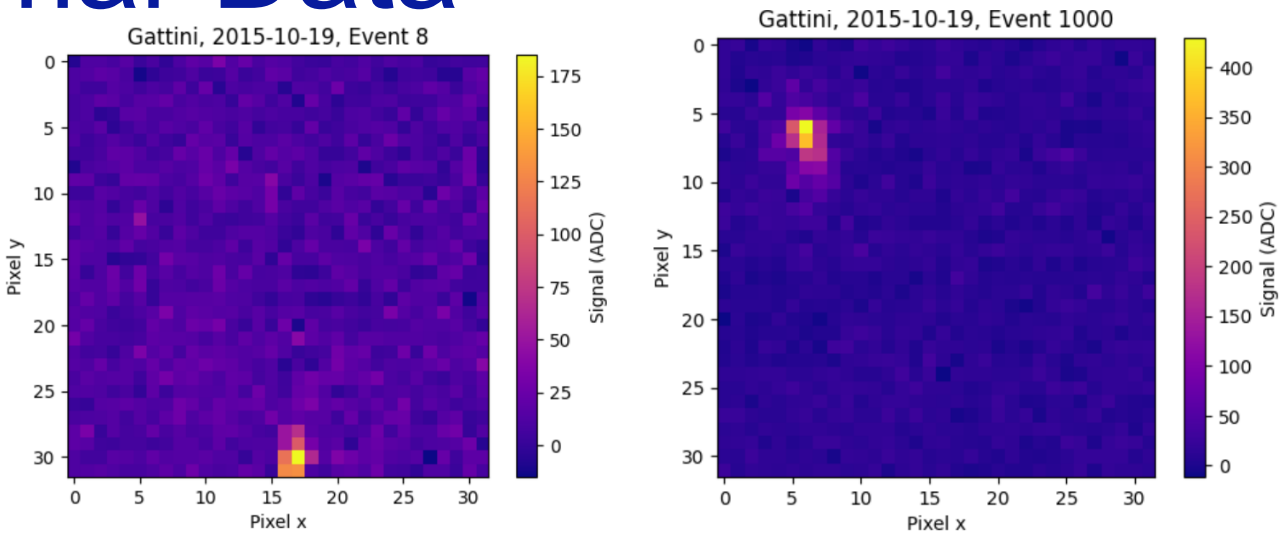
Setting up Enclosure

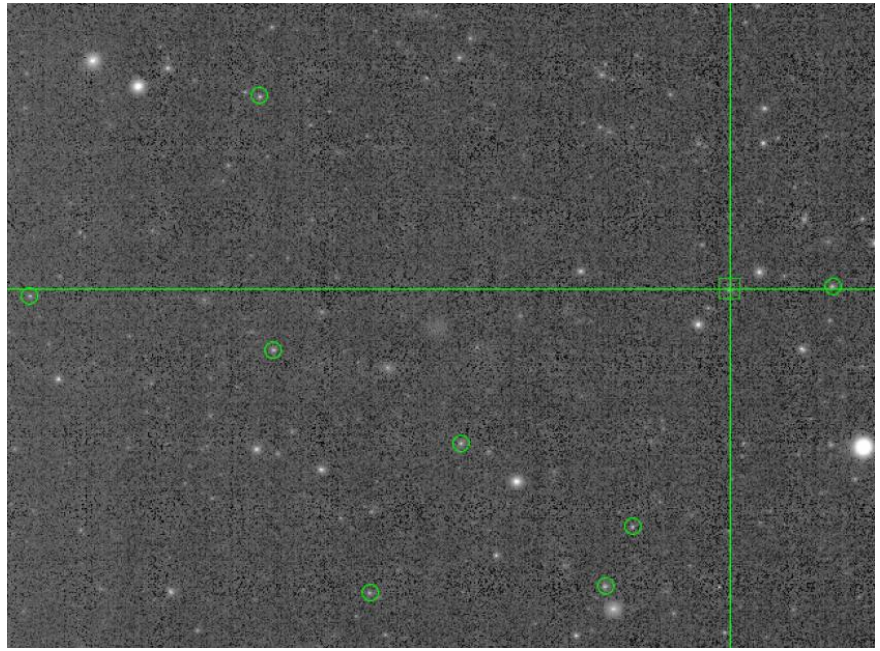
Installing Power

Observations

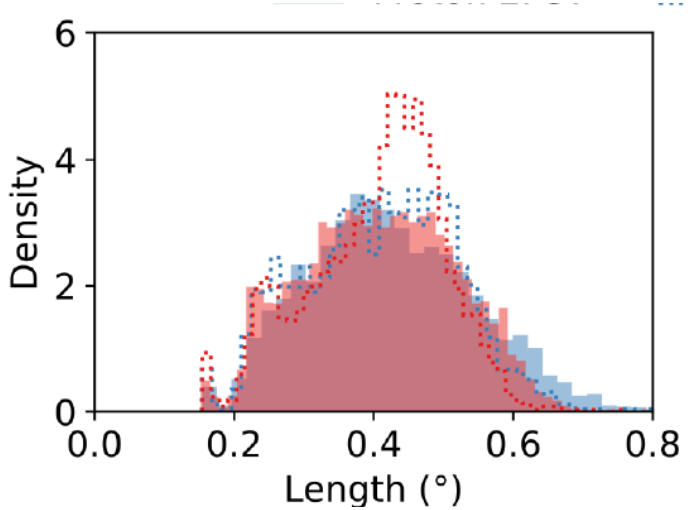
First Palomar Data

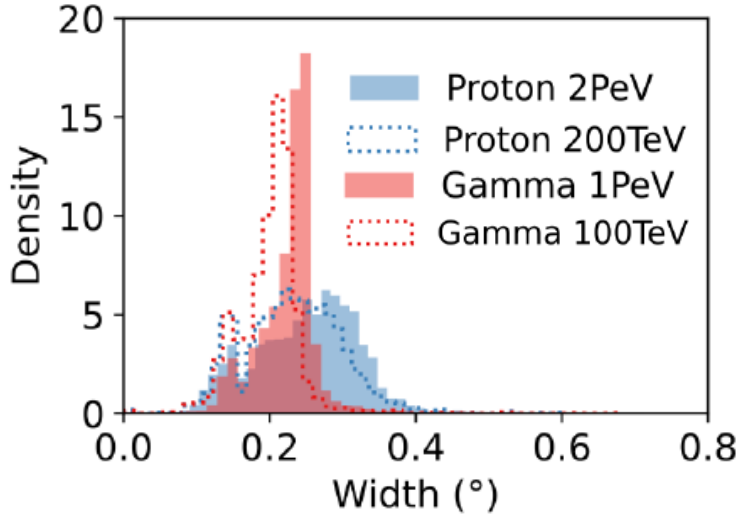
- Observation of Crab Nebula with one telescope
- Detection of first Cherenkov Events
- Using Guider to correct for uncertainties in mount's tracking
- Constant offset, no time drift observed

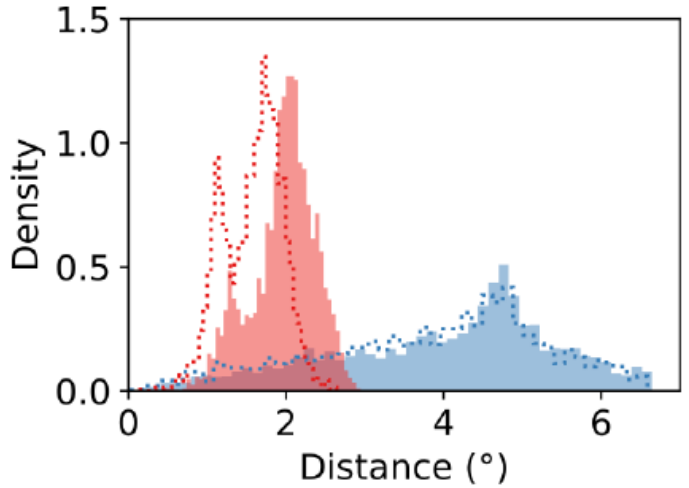




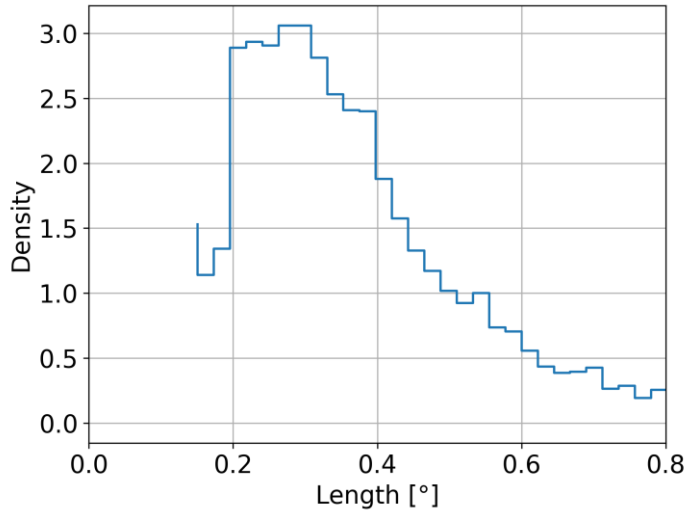
Gamma-Hadron Separation

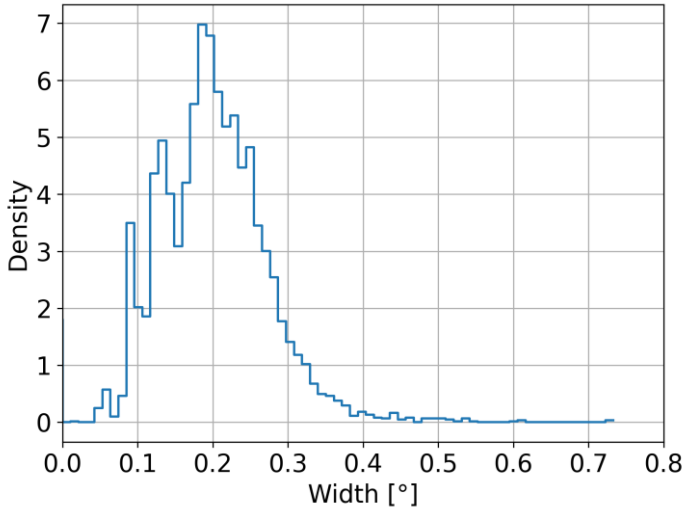


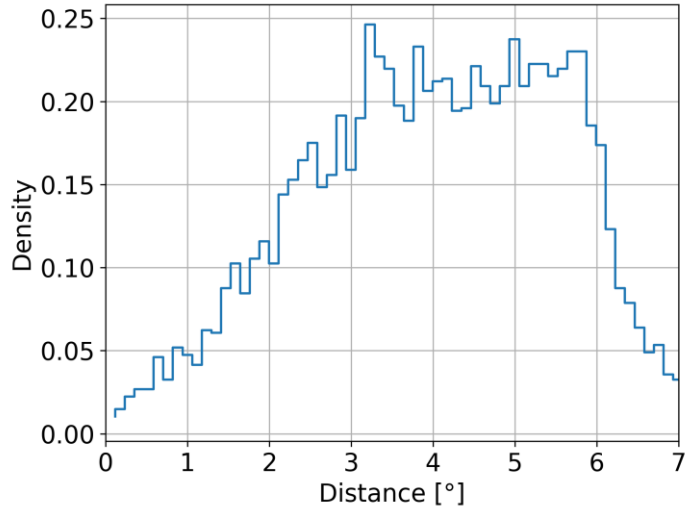




CORSIKA Simulations







Gattini Data from 2025-10-18

Source: S. Ravikularaman PoS(ICRC2025)519

- Work on simulation to data comparison ongoing

Conclusion and Outlook

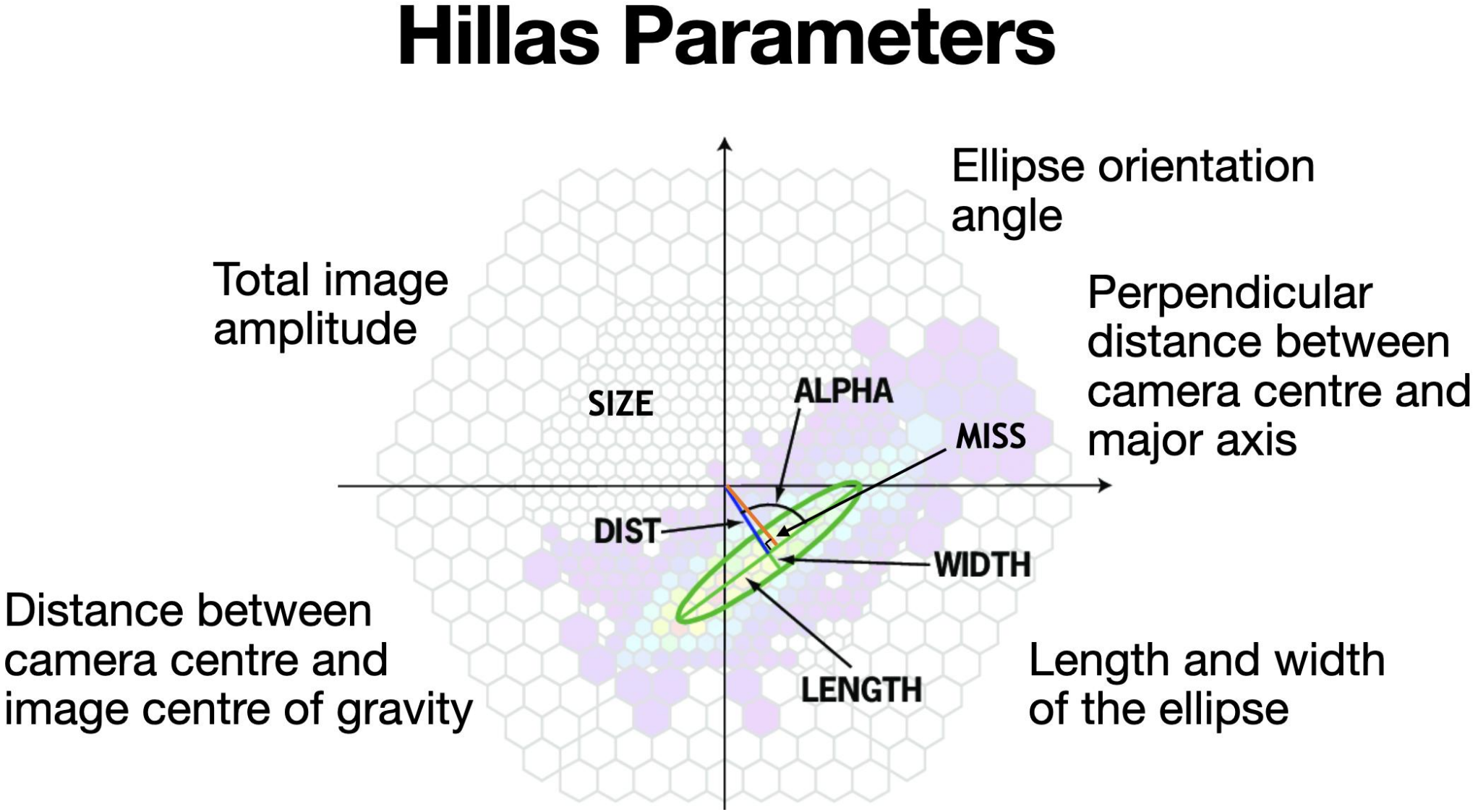
- Deployment and Commissioning of telescopes on Palomar
- Stable observations with one telescope

- **Outlook:**
  - Observations with multiple telescopes with synchronized timing soon
  - Work on data processing and telescope model
  - Crab Nebula Observation until March 2026
  - Establishing analysis pipeline and simulation comparison

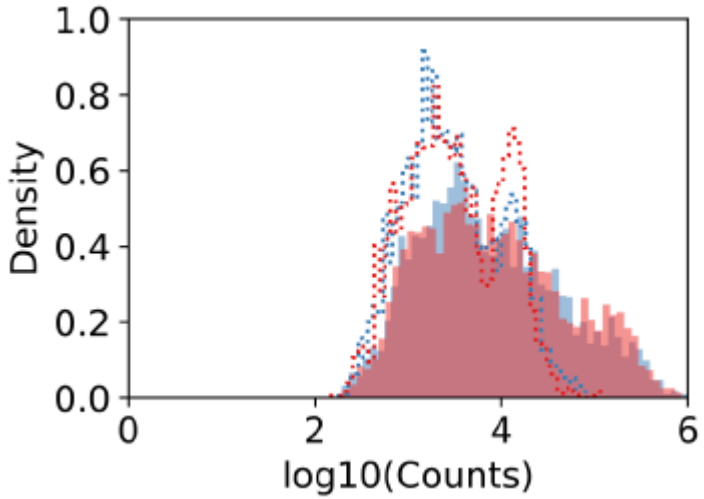
  - Focusing on possible Dark Matter Sources

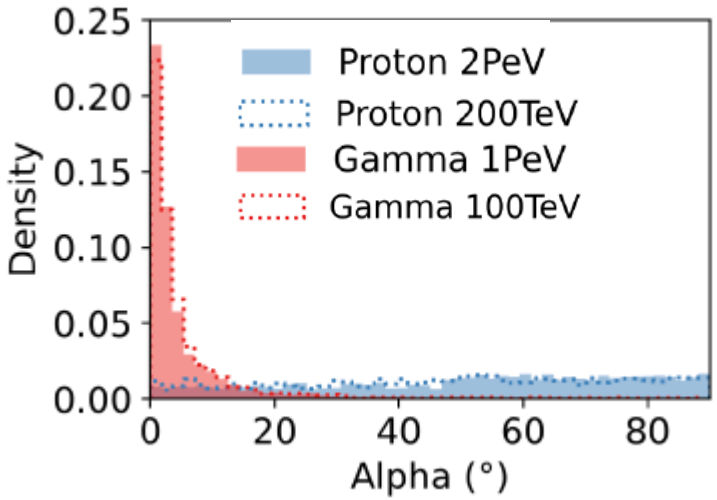
PANOSETI Team at Caltech, August 2025

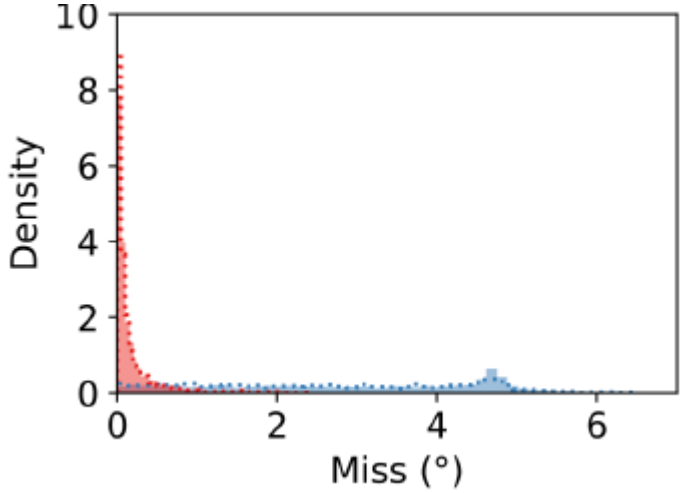
Backup: Hillar Parameter

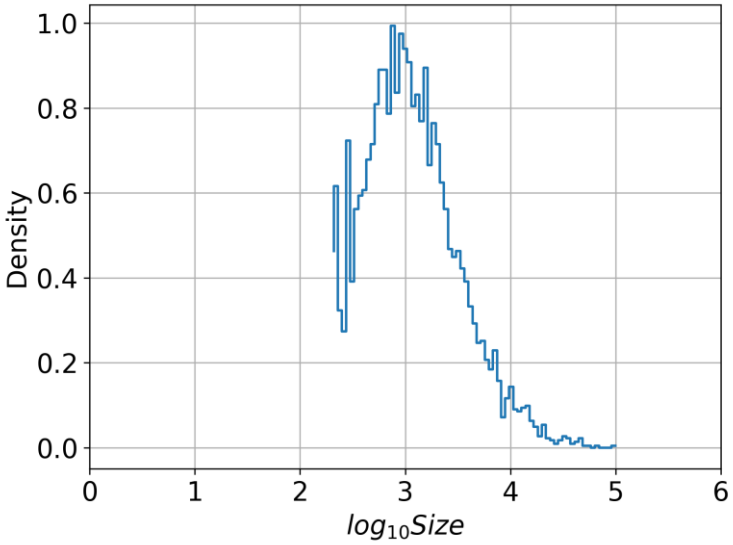


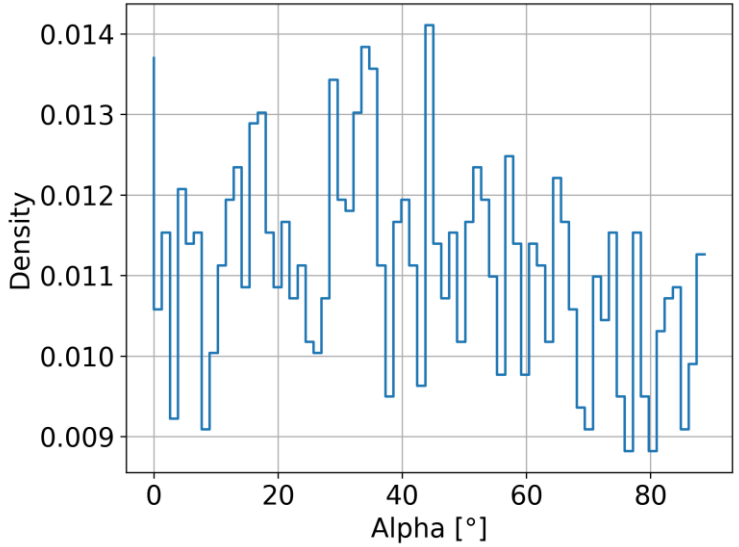
Backup: Gamma-Hadron Separation

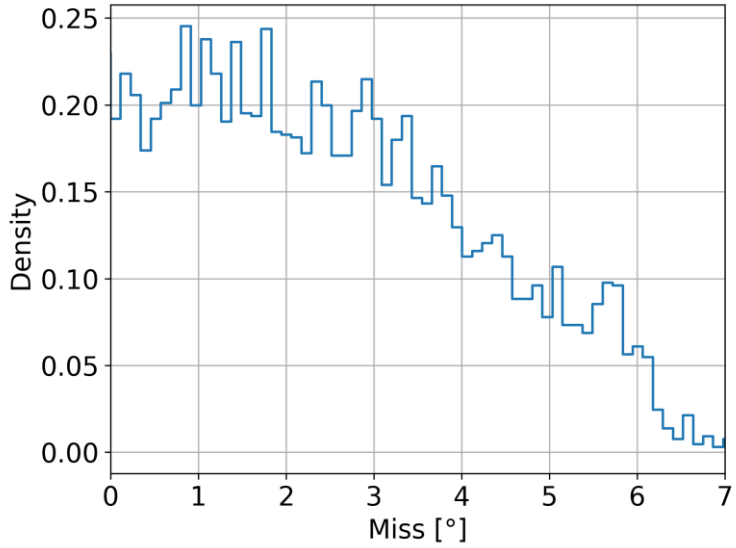












Backup: Pointing Correction

- Using Variation of pedestal values for each pixel
- Bright pixels shows stars in them
- Compare before and after Meridian flip (FoV rotated by 180°)
- Overlay the reference star map from stellarium
- -> Stars match but are slightly offset (~1.8°)