Development of an Imaging Atmospheric Cherenkov Telescope Array for Ultra-High Energy Gamma-ray Astronomy

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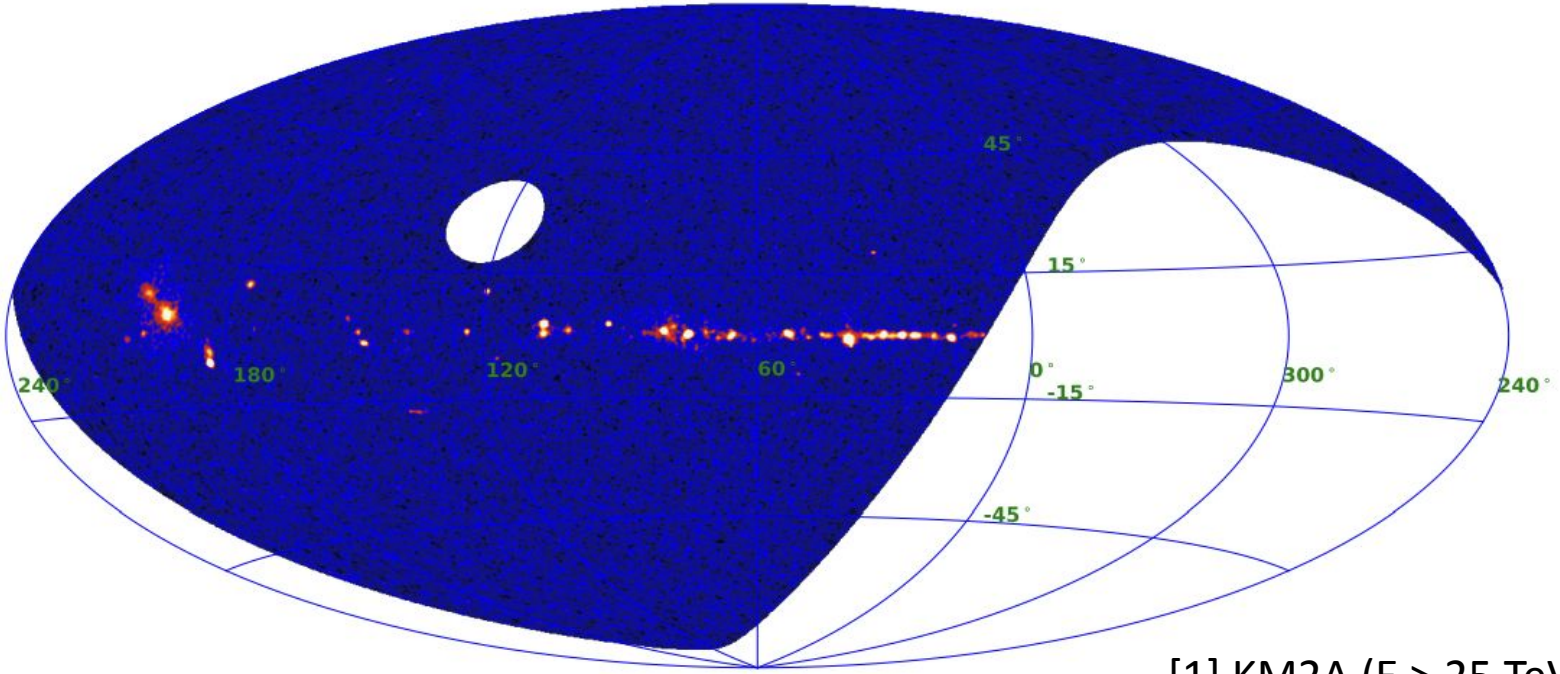
PANO SETI

UNIVERSITY OF DELAWARE

BARTOL RESEARCH INSTITUTE

Ultra High Energy (UHE)



[1] KM2A (E > 25 TeV)

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[1] *The First LHAASO Catalog of Gamma-ray Sources*, Cao et al., 2023

Ultra High Energy (UHE)

- 43 UHE sources (E > 100 TeV) [1]
  - 9 of these have no known TeV association
  - Largely extended to ground detectors
- Imaging atmospheric Cherenkov telescope (IACT) arrays
  - Excellent angular resolution
  - Large effective area per detector
  - **Not** currently optimized for UHE sensitivity
- If observing UHE is the primary goal, the most effective array will consist of many small and affordable telescopes that are sparsely separated

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[1] *The First LHAASO Catalog of Gamma-ray Sources*, Cao et al., 2023

This is that small telescope

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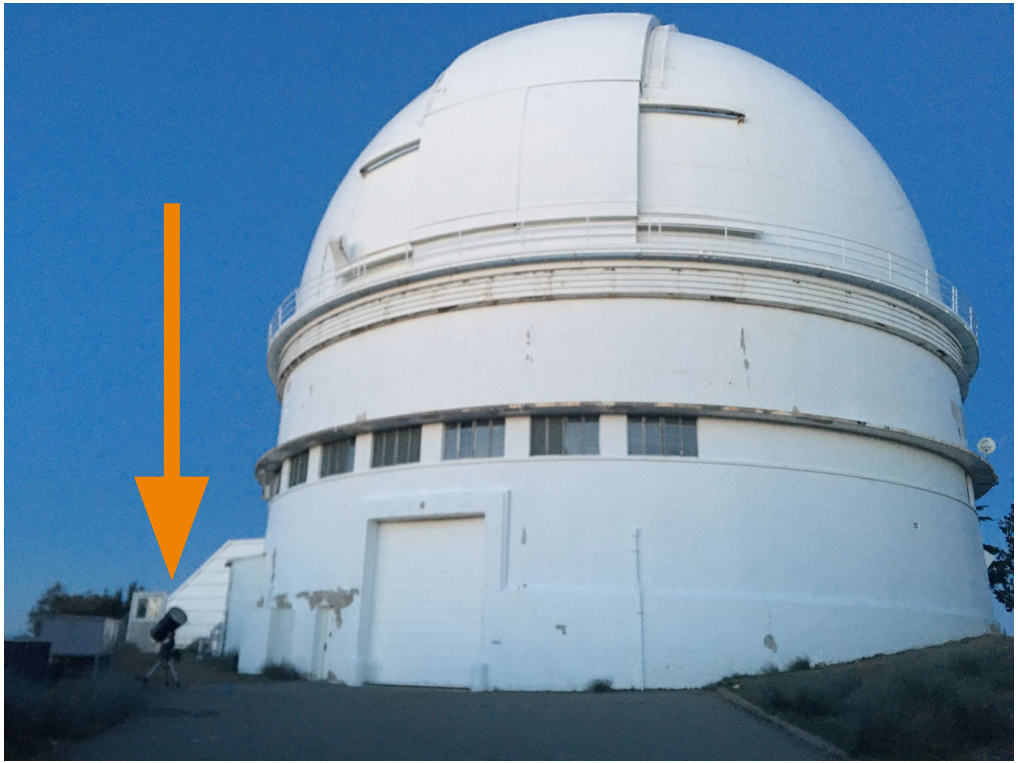
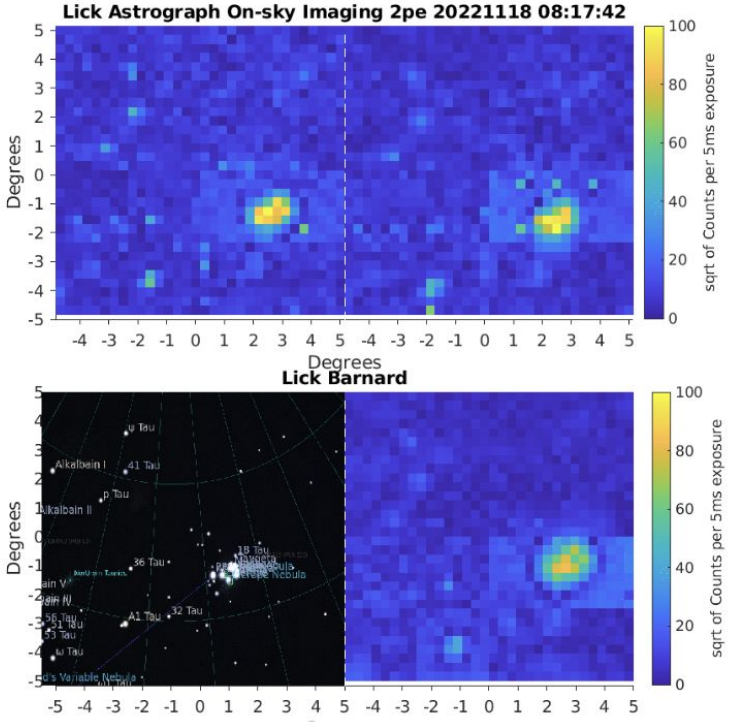
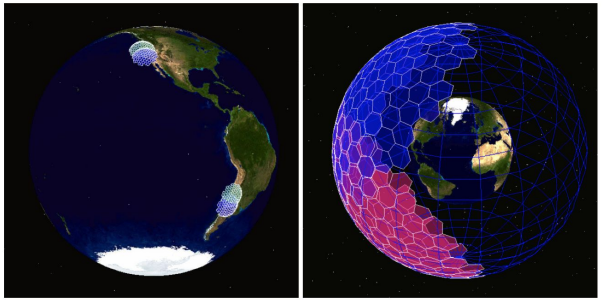


This is PANOSETI

PANOSETI Overview



- Ultrafast optical transients [2]
- Two stations separated by ~ 1 km tessellating the sky in each hemisphere
  - This initial plan has since evolved as a result of this work



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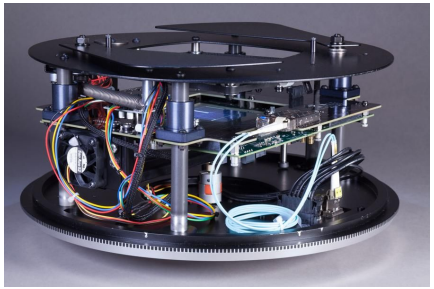
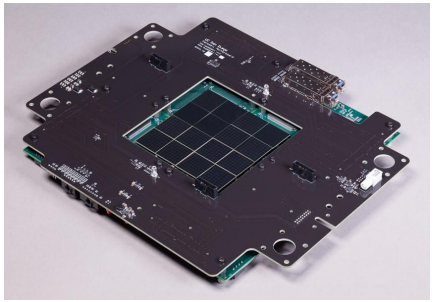
[2] *Panoramic optical and near-infrared SETI instrument: overall specifications and science program*, Wright et al., 2018

Telescope Design

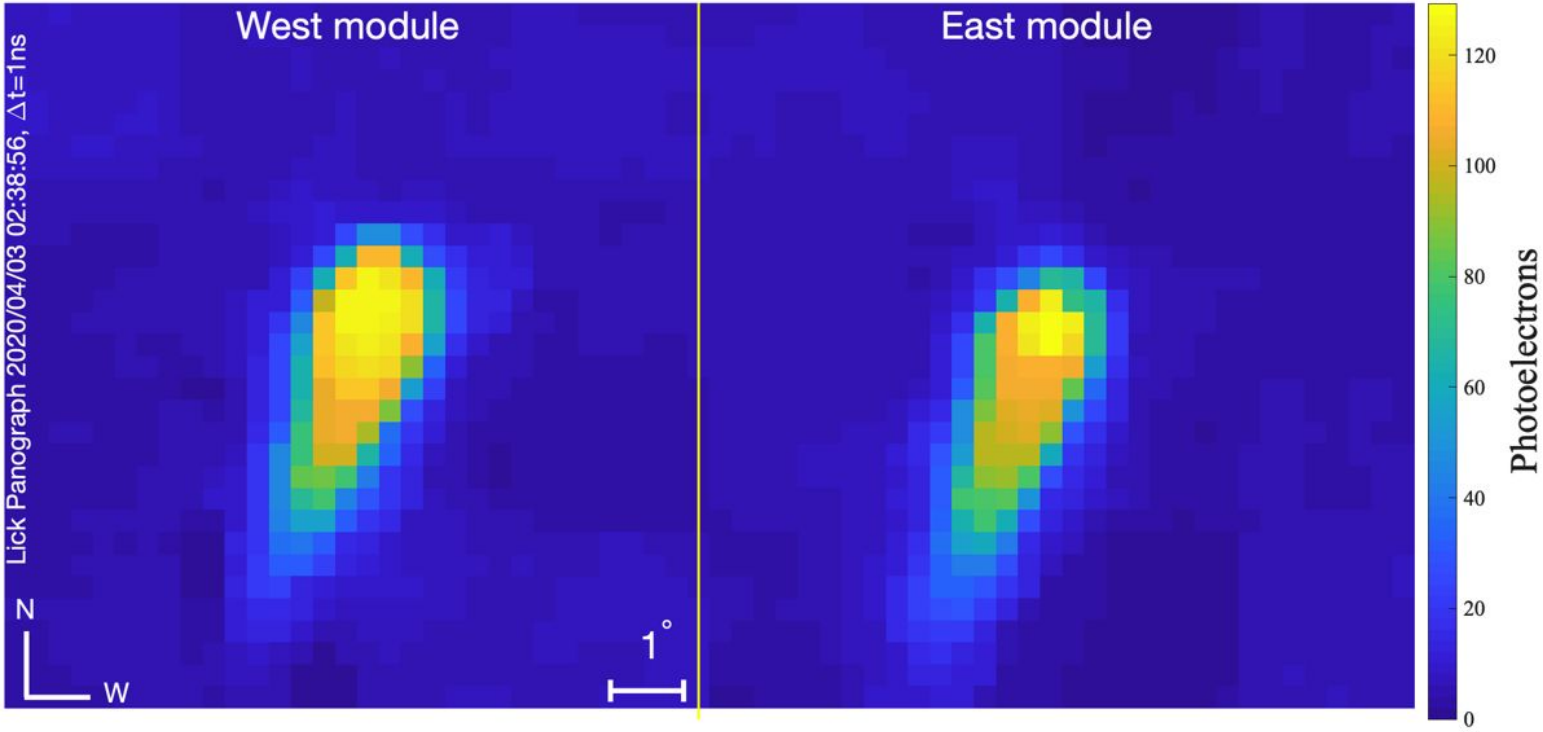
- Modular design [3], [4]
  - 0.5 m Fresnel lens
  - 1024 pixel SiPM camera - 0.31° pixel
  - 10° x 10° field of view
  - Commercially available tracking mount
  - < 10 p.e. Trigger threshold
  - Orders of magnitude cheaper than traditional IACTs
- Different from other detectors
  - FAMOUS, IceAct, HAWC'S Eye, TAIGA-HiScore, ASTRI, SST





[3] *Panoramic optical and near-infrared SETI instrument: optical and structural design concepts*, Cosens et al. 2018
[4] *Panoramic optical and near-infrared SETI instrument: prototype design and testing*, Maire et al., 2018

One scientist's noise is another's signal



Observations Coincident With VERITAS

- Operated at VERITAS for 5 nights in November 2021 [5]
- Observed the Crab Nebula
  - 6 hours
- Gamma-ray initiated showers tagged by VERITAS and time-matched with PANOSETI
- Coincident events at < 1 Hz
- 3 gamma rays detected by both PANOSETI telescopes in coincidence with VERITAS
  - Each with E > 10 TeV

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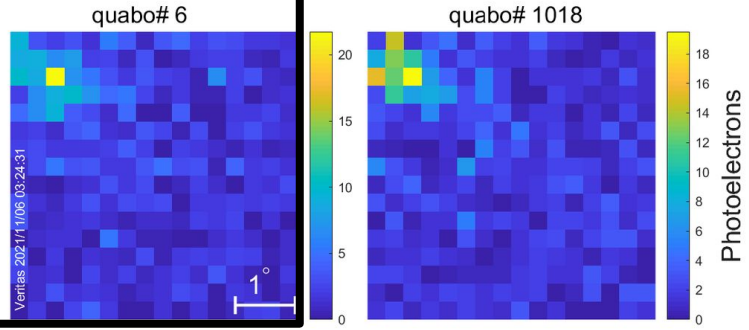
[5] *Panoramic SETI: Program Update and High-Energy Astrophysics Applications*, J. Maire, et al., 2021

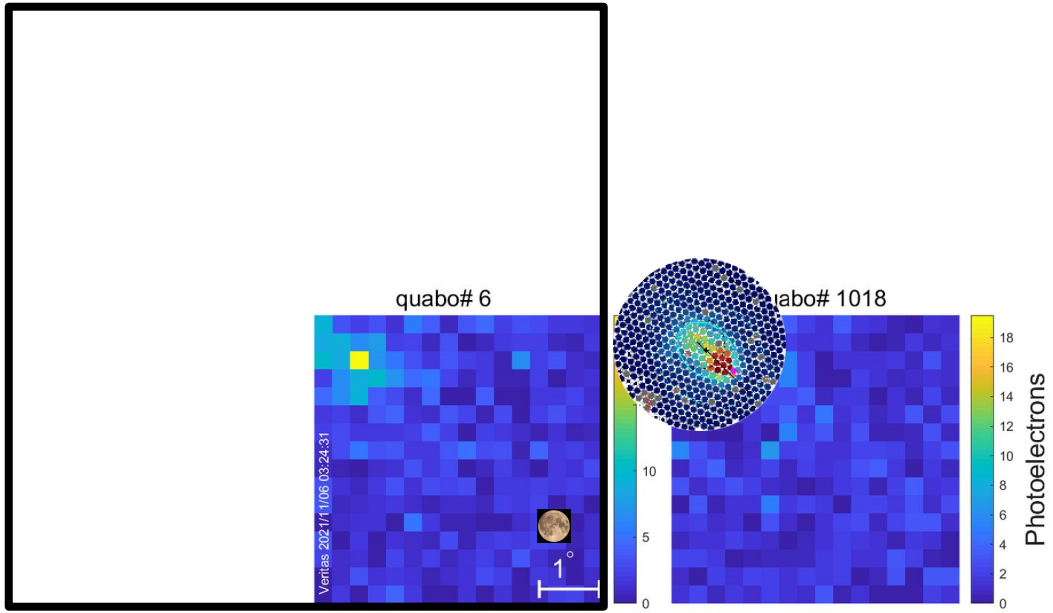
Air Shower Image (Uncalibrated)

Full camera

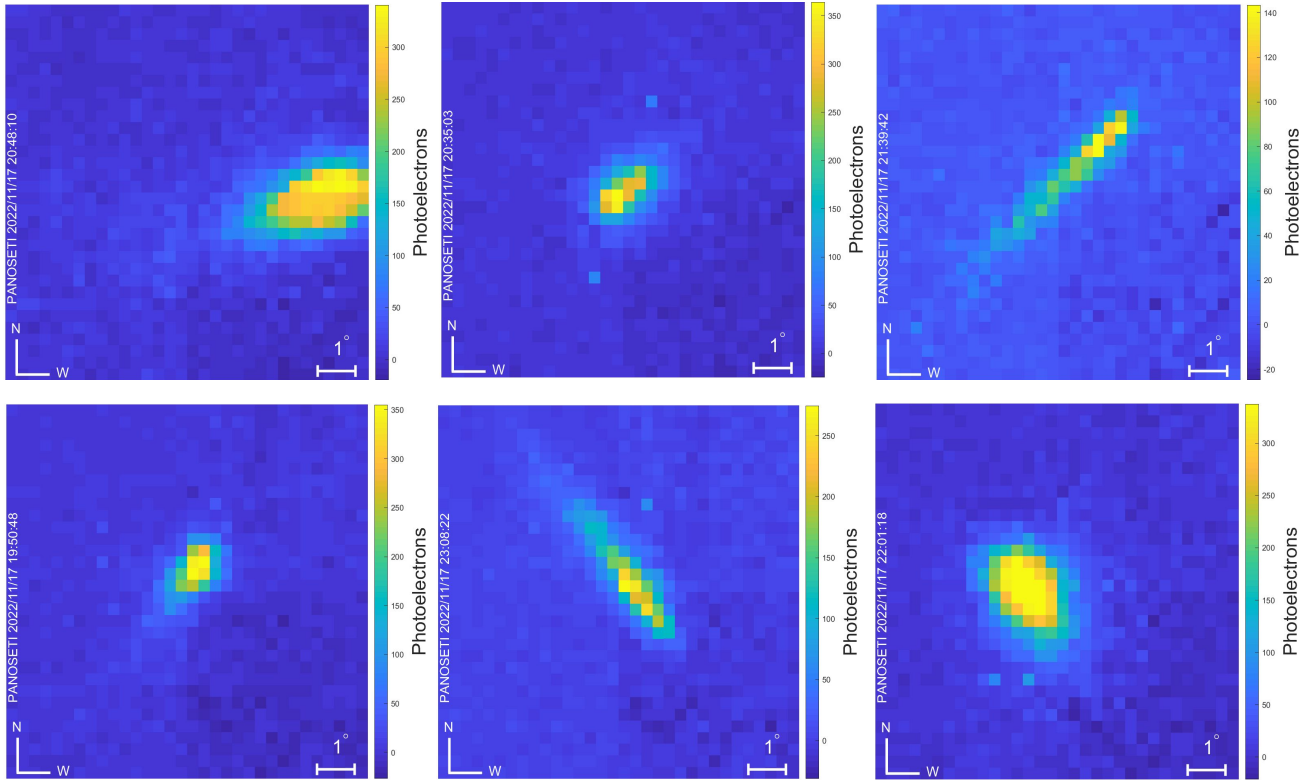


This is a 50 TeV gamma ray

Air Shower Image (Uncalibrated)



More Full-Camera Images



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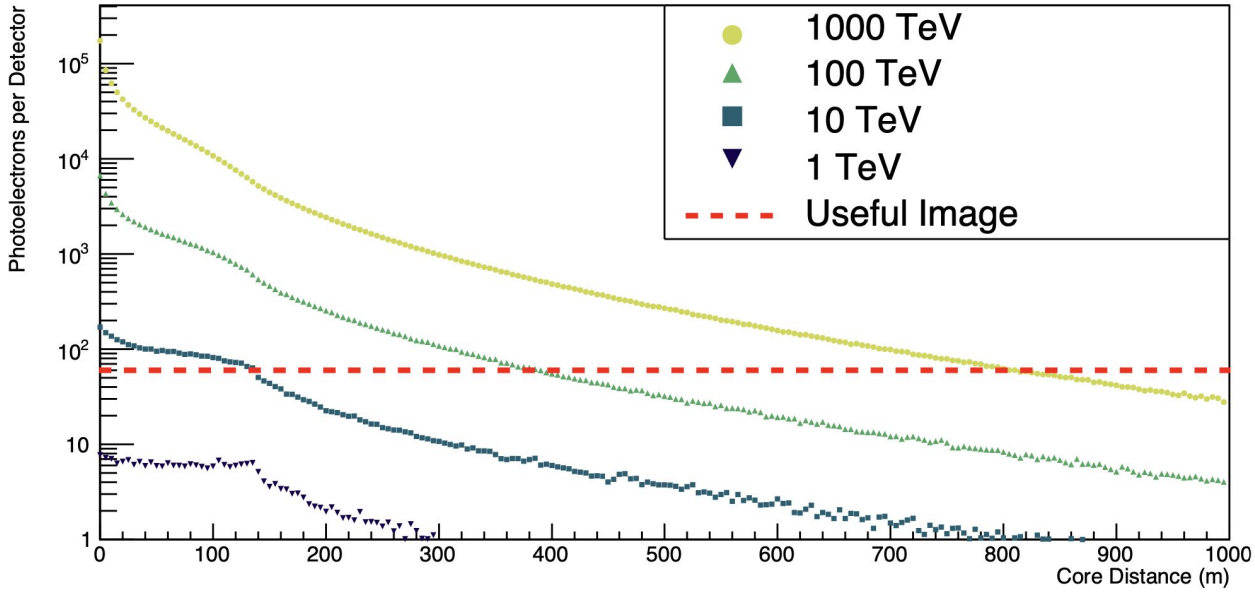
CORSIKA Simulations

- Image cleaning first developed and tested on simulated images [6]
- Simulated air showers are difficult to reconstruct when cleaned images contain fewer than 60 p.e.
- Predicted energy threshold is about 10 TeV with 150 m telescope spacing



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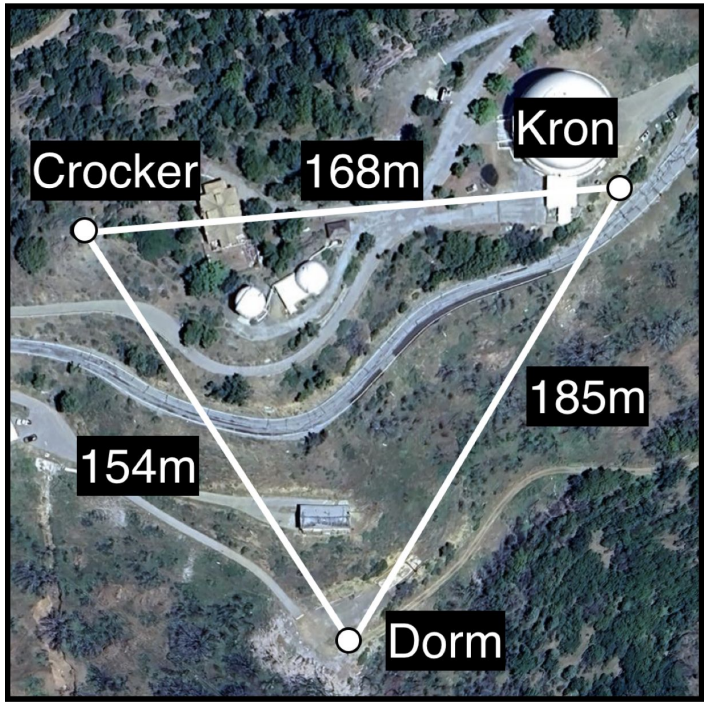
[6] *PeV Gamma-ray Astronomy With Panoramic Optical SETI Telescopes*, Korzoun et al., 2023

March 2024 Array Configuration
Lick Observatory, Mt Hamilton, CA



Crocker

Kron

Dorm

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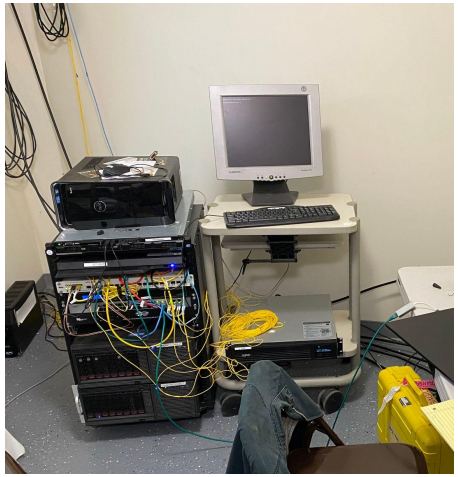
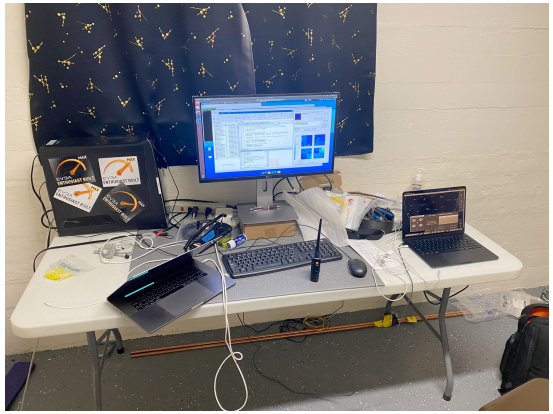
Easy, Efficient Deployment

- Assembly, power, and network configuration of a 3-telescope IACT array took a team of 6 people a few days to deploy
- Two observers packed up everything and left in only one afternoon

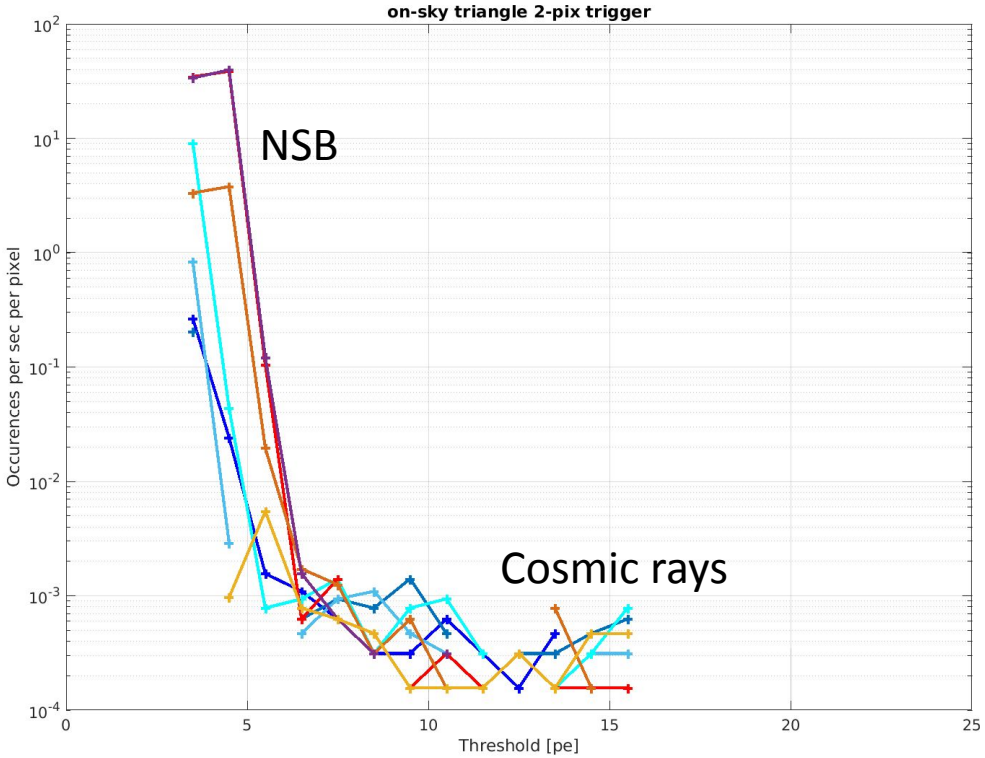
Data Acquisition



Control Room

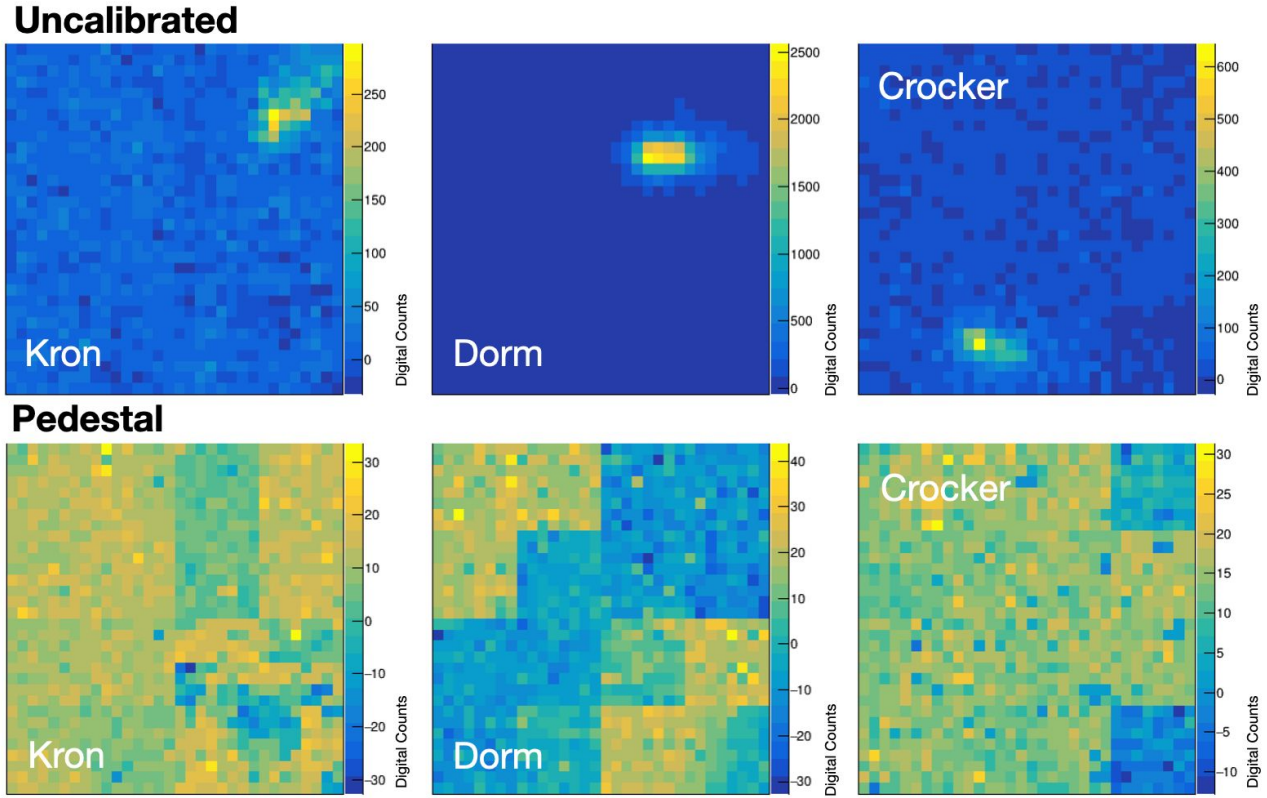


On-Sky Trigger Rate

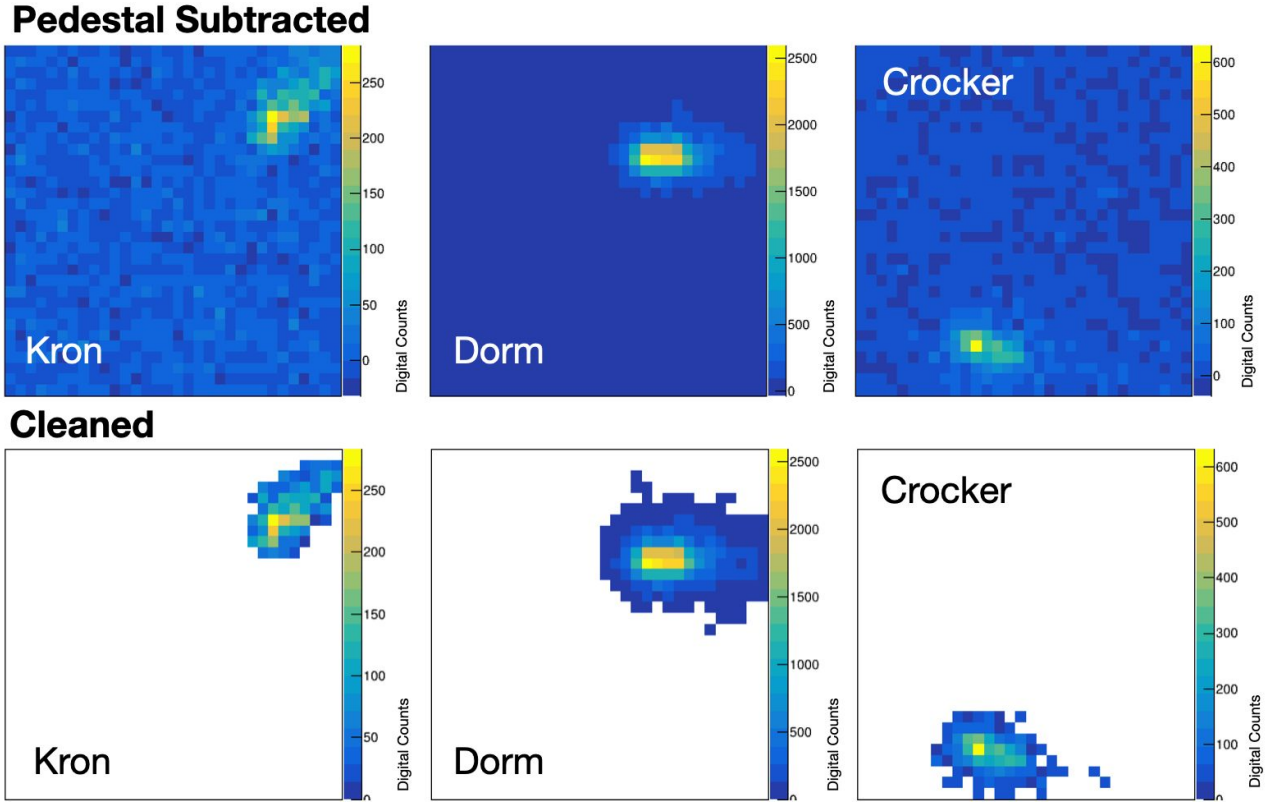


- Each color corresponds to a unique quadrant of one camera of one telescope
- 2 adjacent pixels within the same quadrant of the camera must be above threshold to trigger a readout
- 6.5 p.e. threshold was used for subsequent observations

3-Telescope Coincident Event

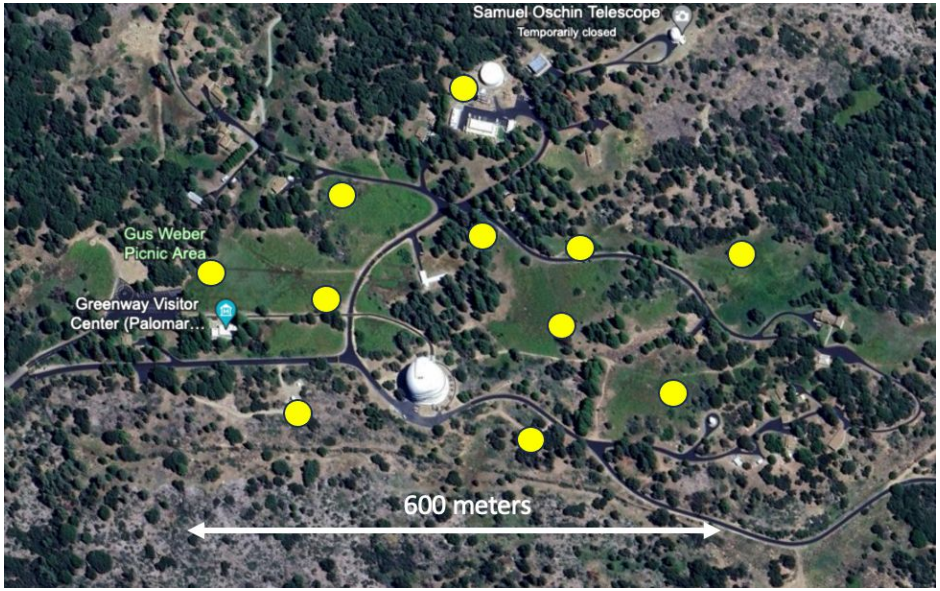


3-Telescope Coincident Event, Cleaned



Ongoing work

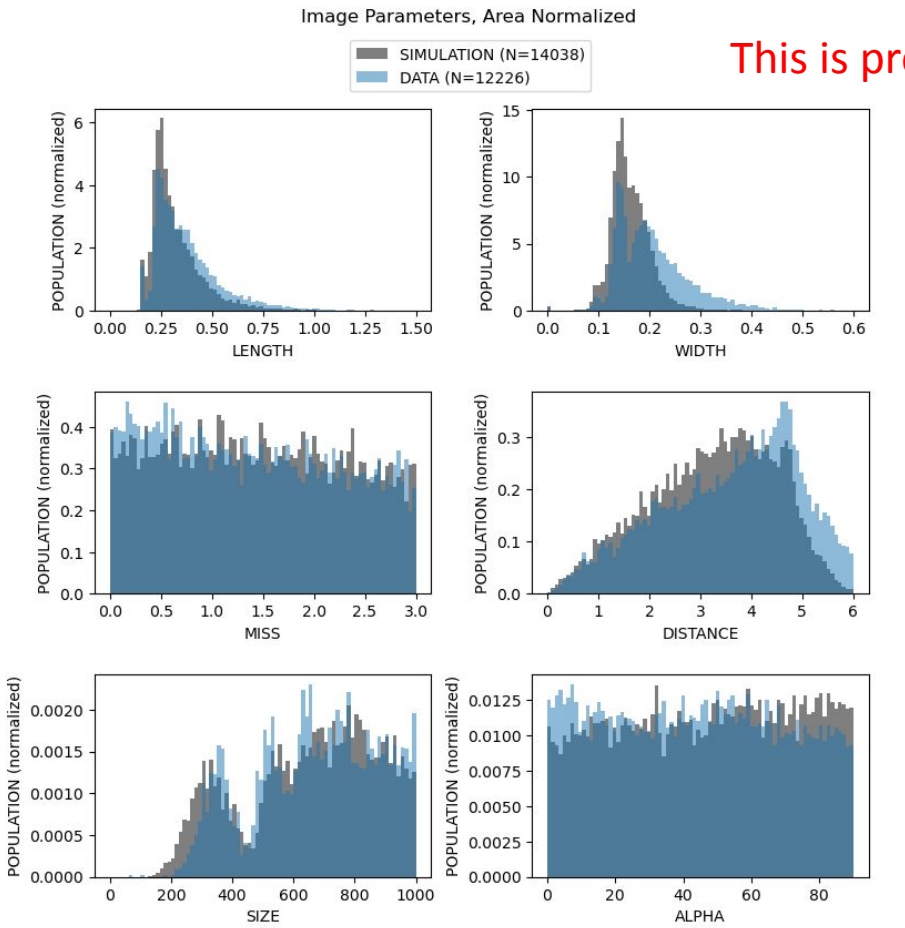
- Planning another observing run at Lick Observatory at the end of this October
  - Crab Nebula
- Comparison of background data with simulations
  - Define selection criteria for gamma/hadron separation
- Procurement for a 10 telescope array is in progress
  - Palomar Observatory (San Diego) under consideration along with Lick Observatory
  - Will allow us to study UHE sources in higher resolution
- Dark100
  - Large array of PANOSETI telescopes probing dark matter > 100 TeV

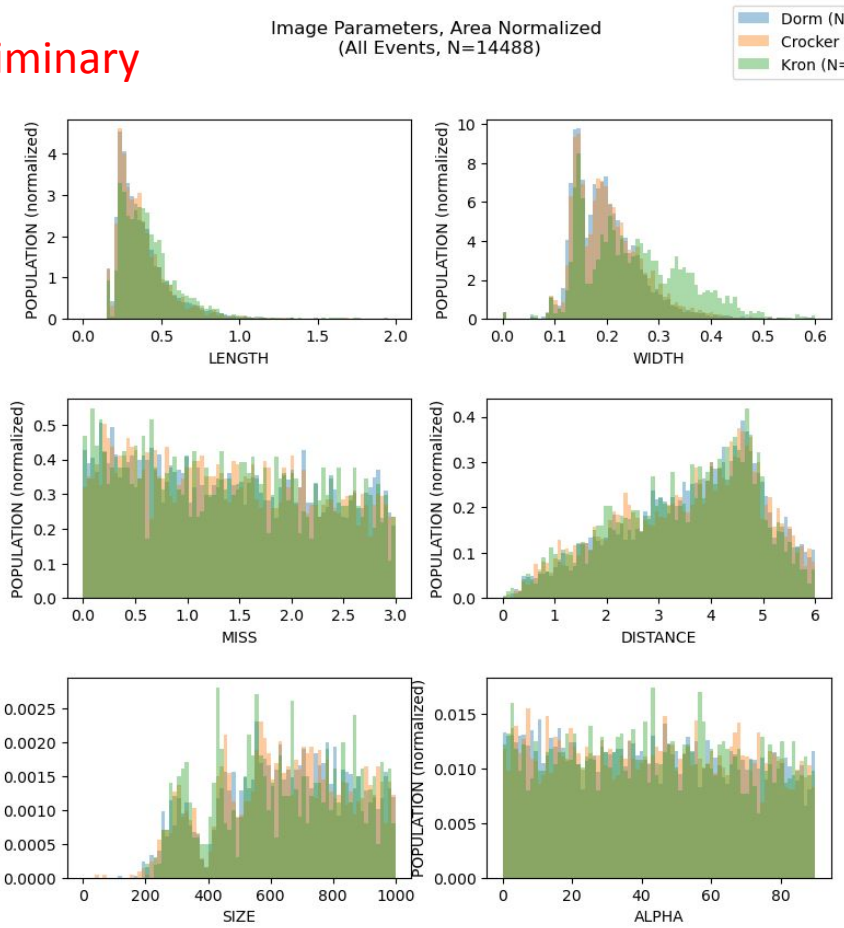


Possible locations for deployment at Palomar Observatory

Backup

This is preliminary

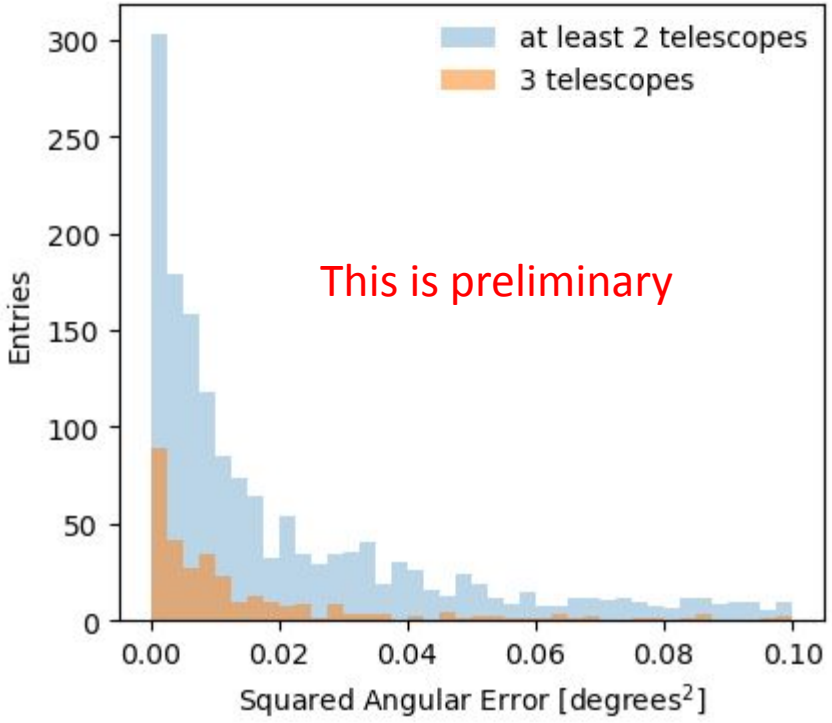




Angular Resolution (10 TeV threshold) *

Angular error 68% containment (2+ tel): **0.23°**

Angular error 68% containment (3 tel): **0.11°**

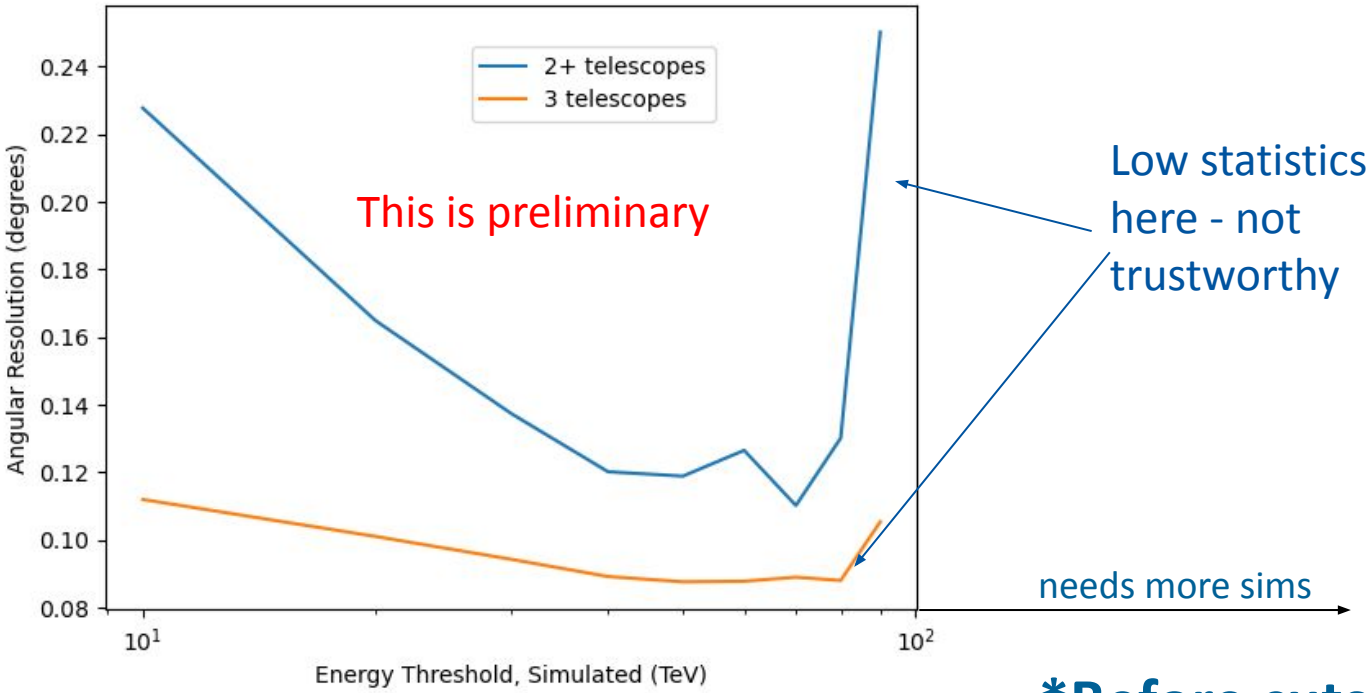


KM2A angular resolution at 20 TeV (Zenith angle < 20°) [1]: **0.50°**

***Before cuts**

[1] *The First LHAASO Catalog of Gamma-ray Sources*, Cao et al., 2023

Angular Resolution*



***Before cuts**

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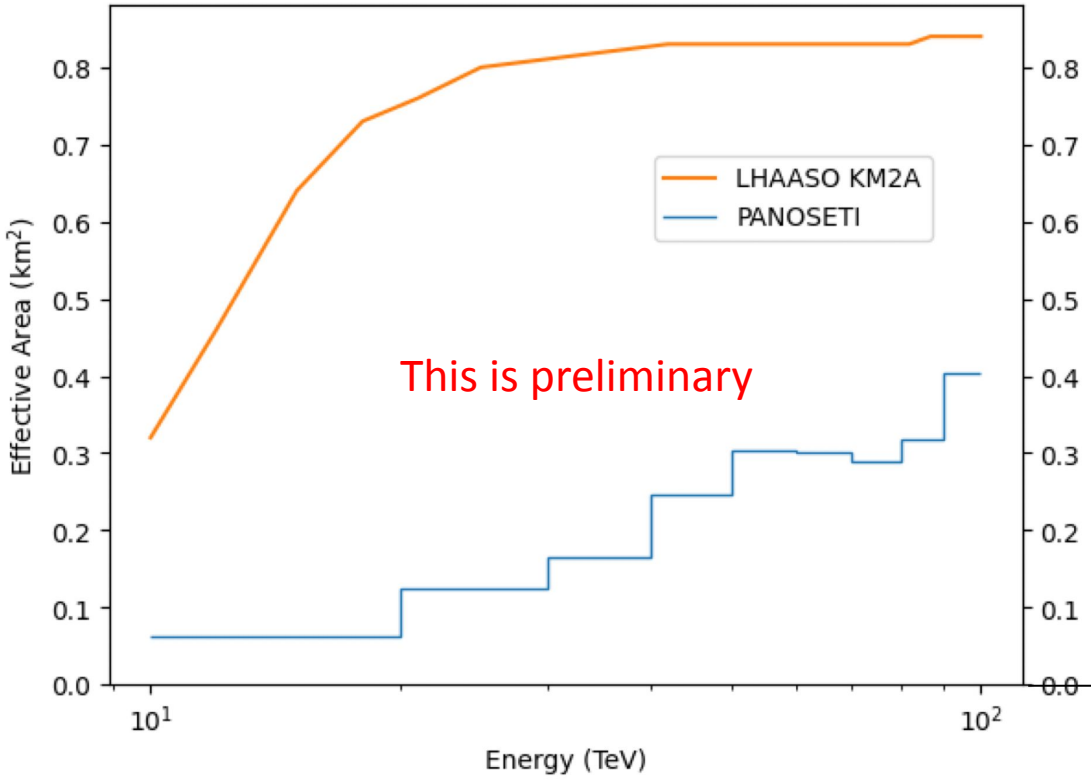
Effective Area*



needs more sims

***Before cuts**

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