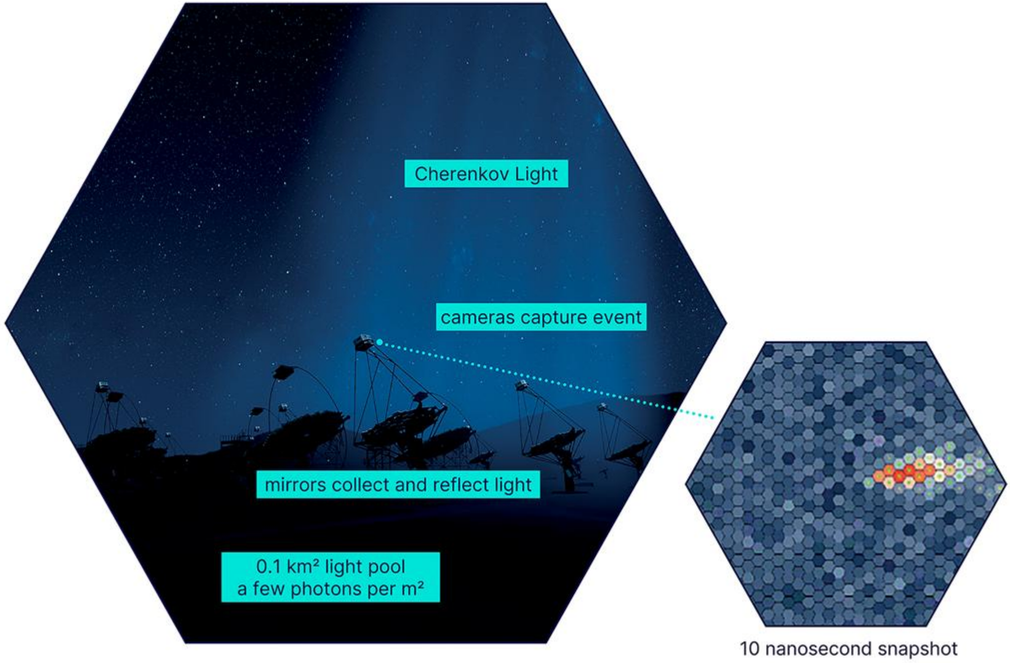
First Light with the Protoype Schwarzschild-Couder Telescope's Upgraded Camera

Zachary Curtis-Ginsberg, UW-Madison
On behalf of the CTAO-SCT Collaboration and the CTAO Consortium
TeVPA 2026, Tendo, Japan
September 2nd, 2026

Imaging Atmospheric Cherenkov Telescopes

- Imaging atmospheric Cherenkov telescopes (IACTs) detect Cherenkov light from extensive air showers
- Those images are used to reconstruct the incident gamma rays (and cosmic rays)

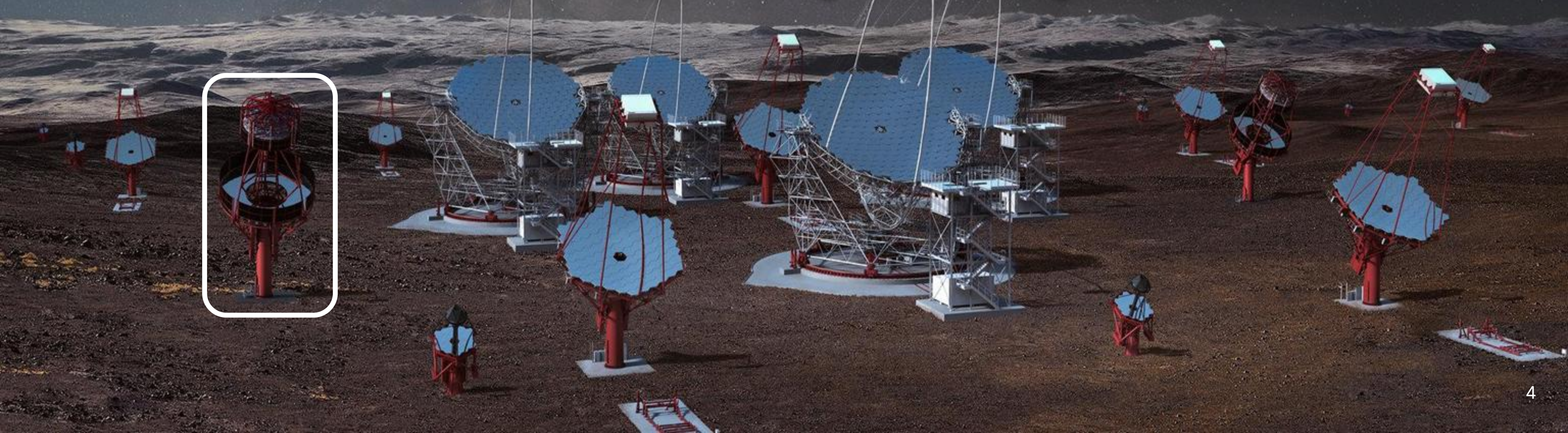


CTAO

- Cherenkov Telescope Array Observatory
  - Next generation gamma-ray observatory
- Full sky coverage
  - Two IACT arrays: La Palma, Spain & Paranal, Chile
- 20 GeV to 300 TeV energy range
  - Large-Sized Telescope (LST): 20 GeV to 3 TeV
  - Medium-Sized Telescope (MST): 80 GeV to 50 TeV
  - Small-Sized Telescope (SST): 2 TeV to 300 TeV
- Both arrays under construction

SCT

- Schwarzschild-Couder Telescope (SCT)
- Medium-sized dual mirror telescope
- Dual-mirror design improves point spread function across the entire field of view, enabling better angular resolution

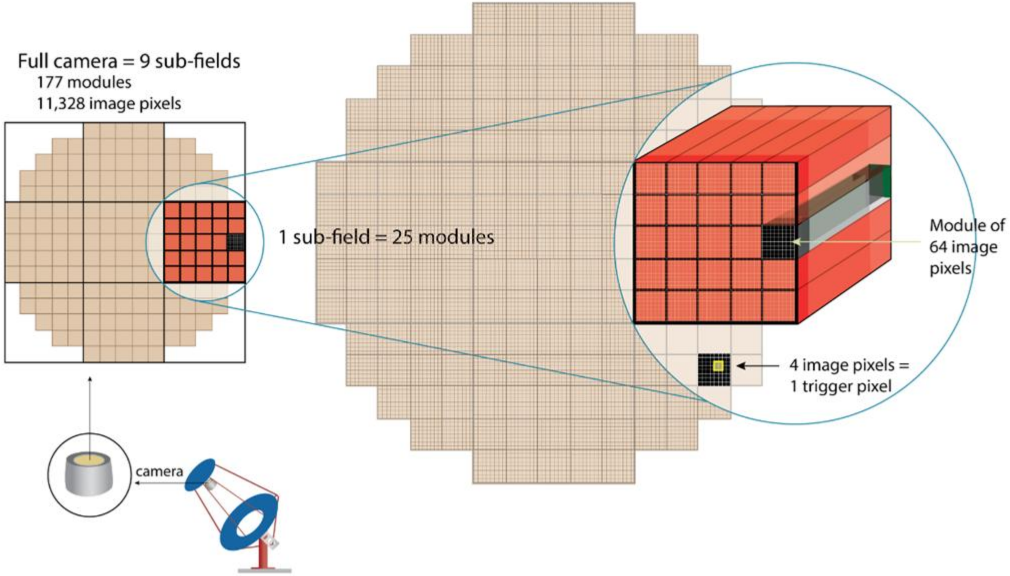


Prototype SCT (pSCT)

- Located at the Fred Lawrence Whipple Observatory in Arizona, USA
  - Co-located with VERITAS
- Dual-mirror optical system
  - Good optical resolution across the entire field of view
  - Fine pixel resolution to match the optical resolution
- 8° field of view with almost constant point spread function (PSF)

pSCT Camera

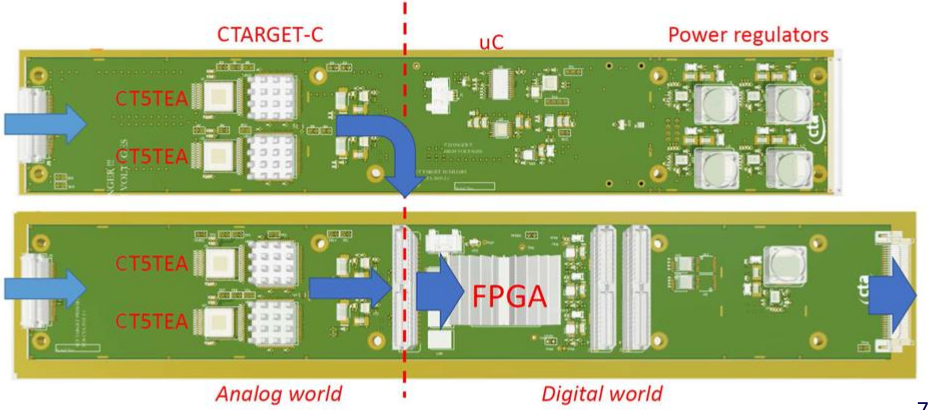
- Modular camera with 9 sectors
- 177x 64-pixel camera modules
- 11,328x 6x6 mm silicon photomultiplier pixels
  - 0.067° per side
- Original camera detected the Crab Nebula in 2020 with only the central sector



pSCT Camera Upgrade

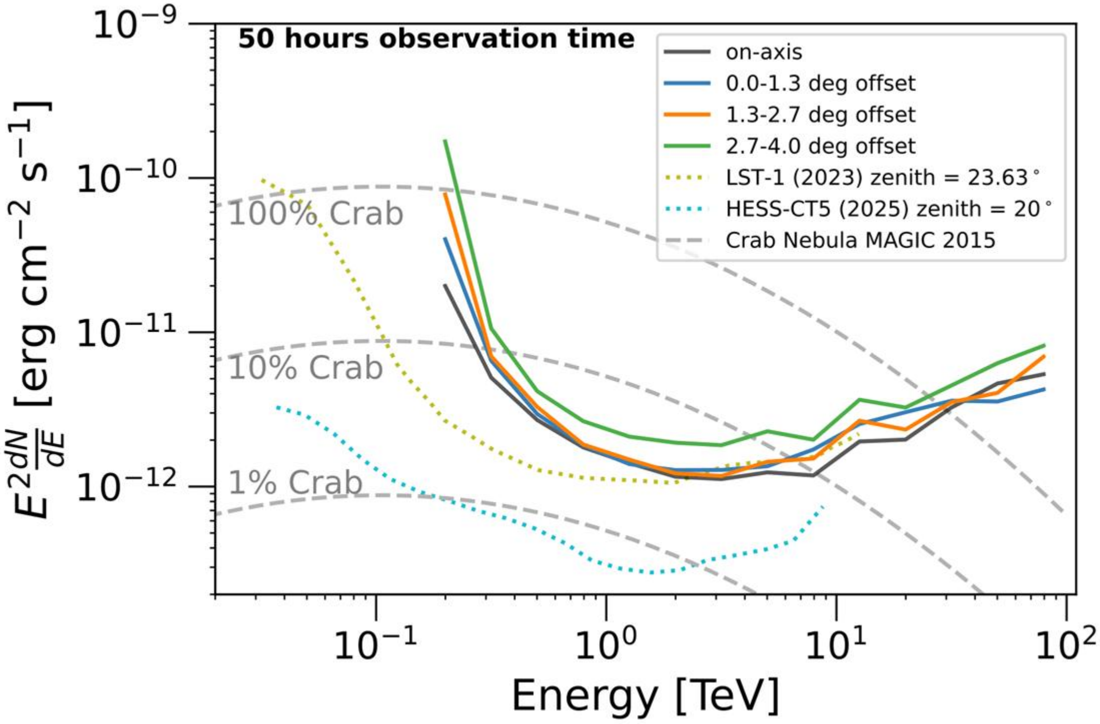
JATIS Volume 12 Issue 3 Article 034001 (2026)

- Ongoing upgrade to improve camera electronics and mechanics
- Will fully populate the camera
- Updated electronics with reduced crosstalk and trigger noise



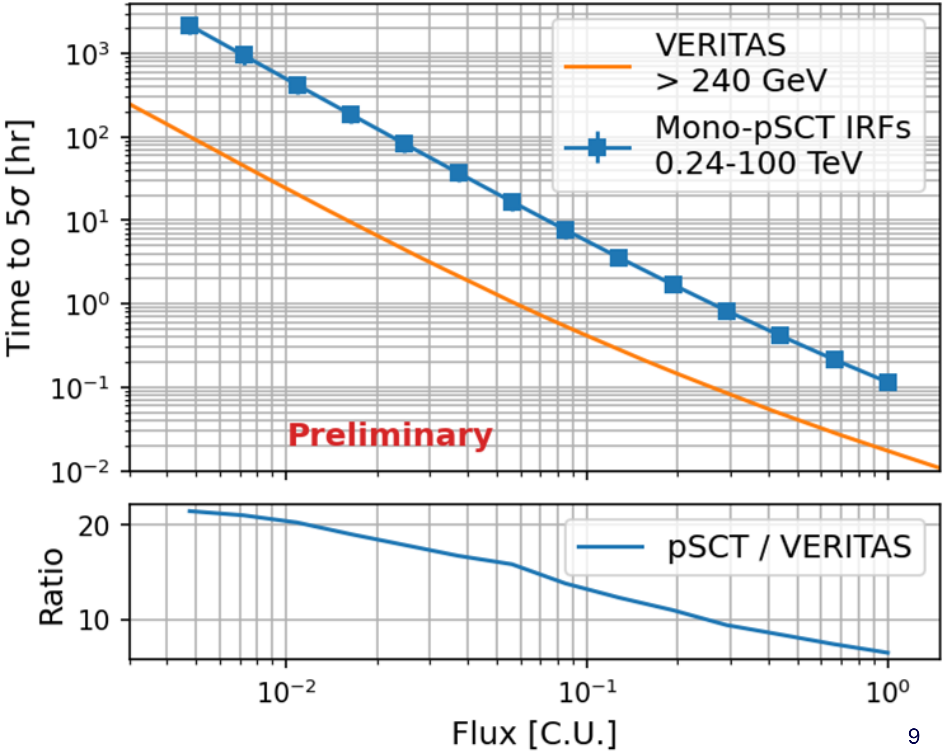
Mono-pSCT Simulations

- Point source sensitivity of the mono-pSCT full camera
- Comparable in its core energy range with other mono telescopes
- Very little loss in sensitivity for off-axis observations



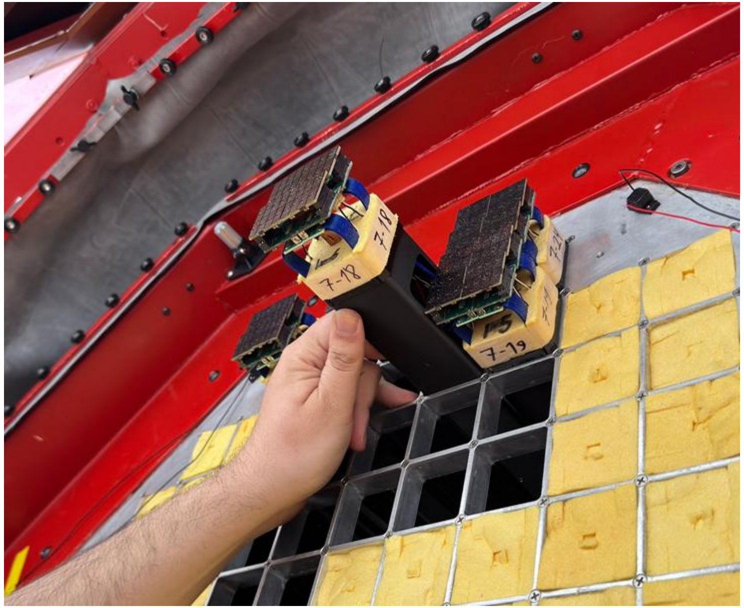
Mono-pSCT Simulations

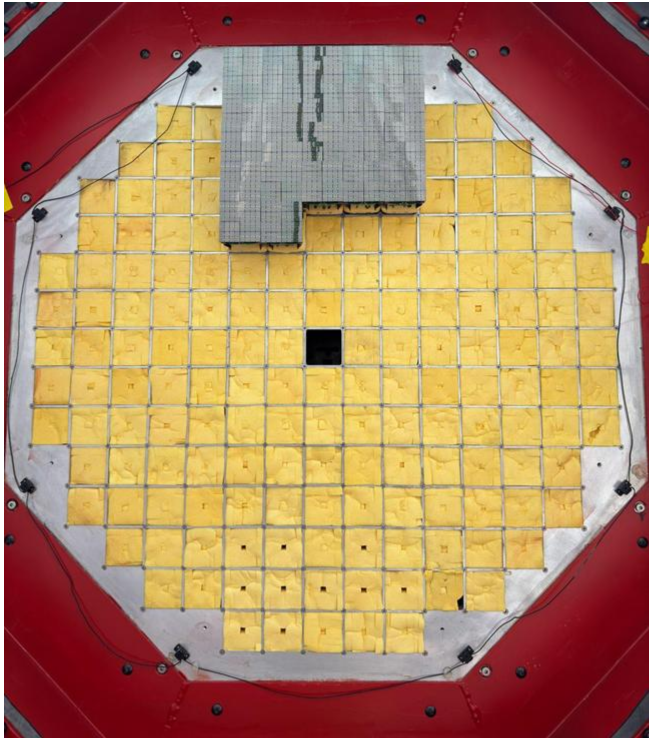
- Observation duration to detect a point source across a broad range of fluxes
- 10% Crab source takes ~5 hours of observations for a 5σ detection
- ~1 order of magnitude less sensitive than VERITAS
    - Under Crab spectrum assumptions



First Sector Installation

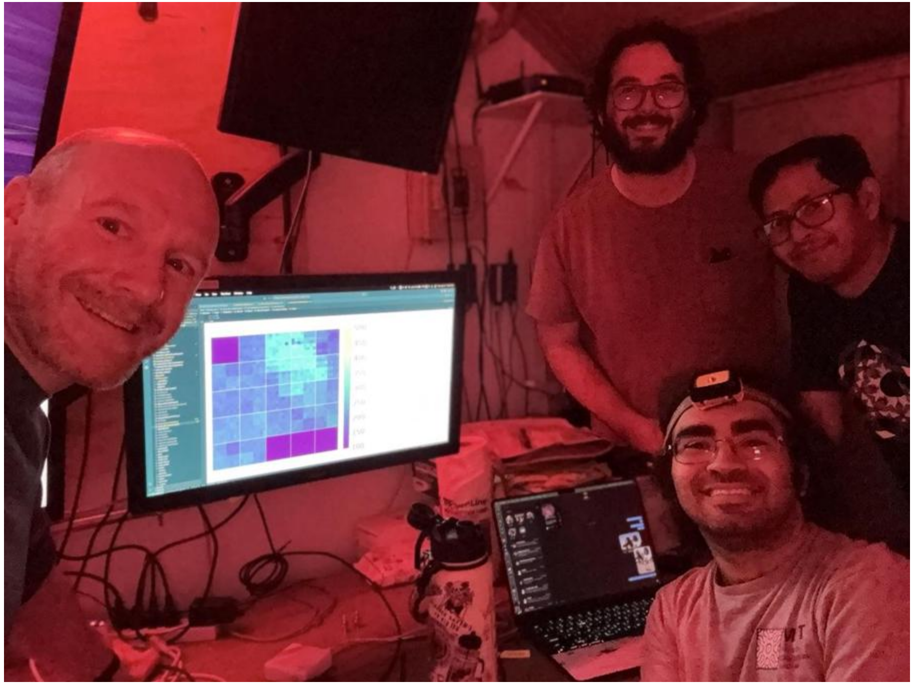
- 22 modules installed April 1st 2026





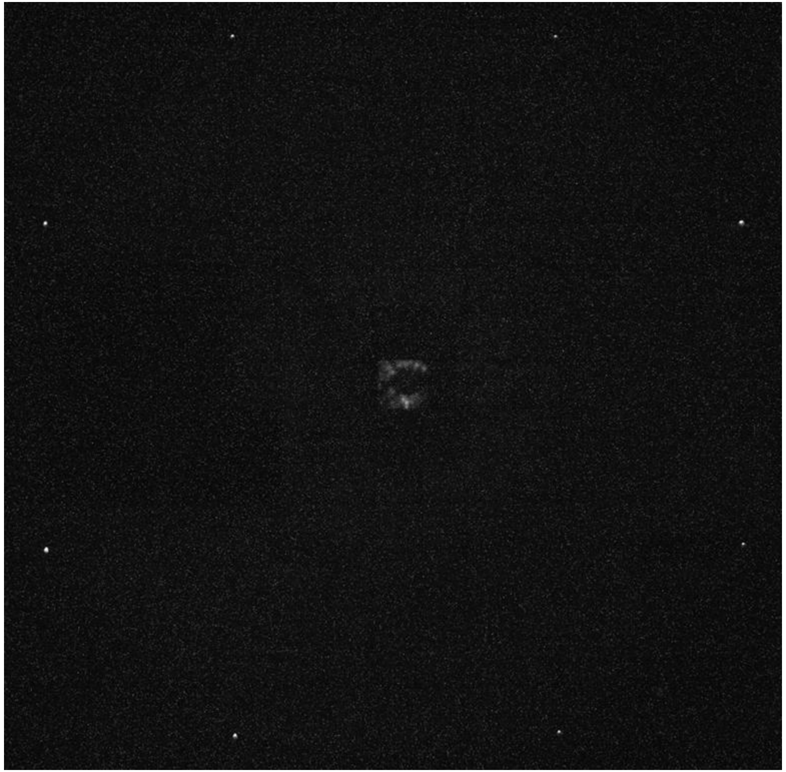
First Light April 2nd ‘26

- First light was achieved with...
  - Camera out of focus
  - Mirrors dirty
  - 98% moonlight
    - Demonstrates the increased robustness and observing time of SiPM cameras
  - No module calibrations applied



PSF Optimization

- Camera has 3D motion control
- Pointing at the bright star Arcturus and moving the camera to/from the focal point to optimize the point spread function
- Further optimization of the optical alignment is planned

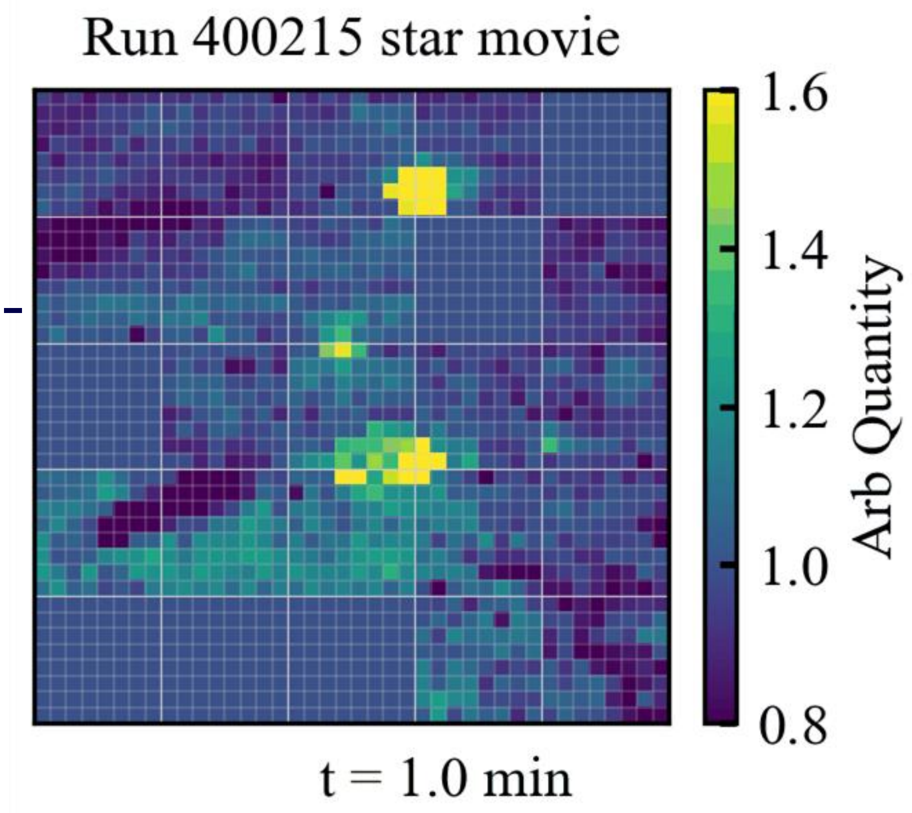


PSF Optimization

- Camera has 3D motion control
- Pointing at the bright star Arcturus and moving the camera to/from the focal point to optimize the point spread function
- Further optimization of the optical alignment is planned

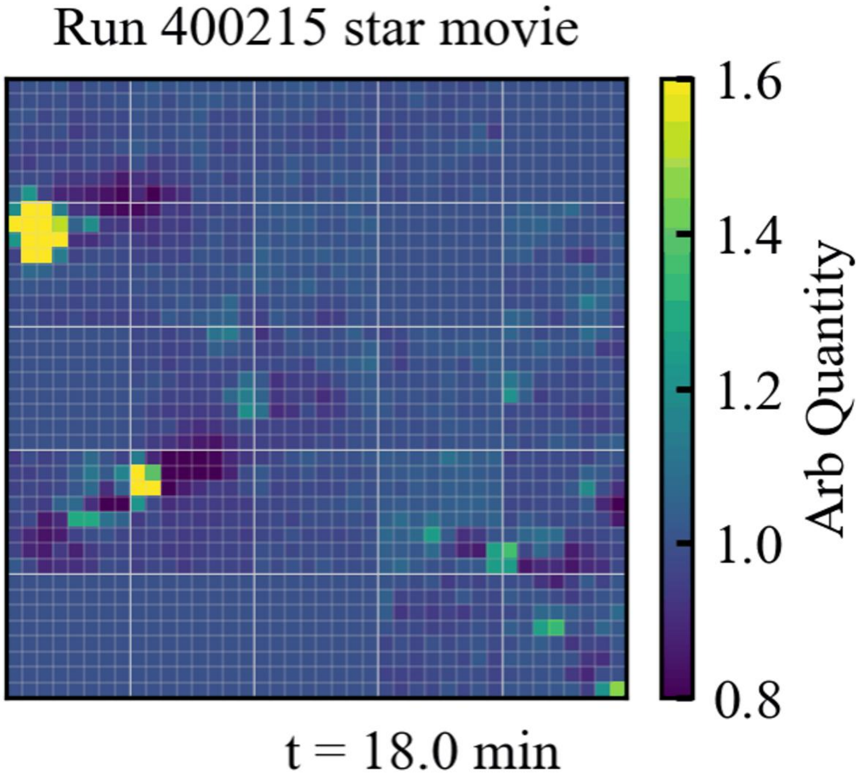
Star Tracking

- Using waveform baseline variance from night sky background events
- Stacking thousands of events to increase signal-to-noise
- Saturated peaks come from colorbar limit



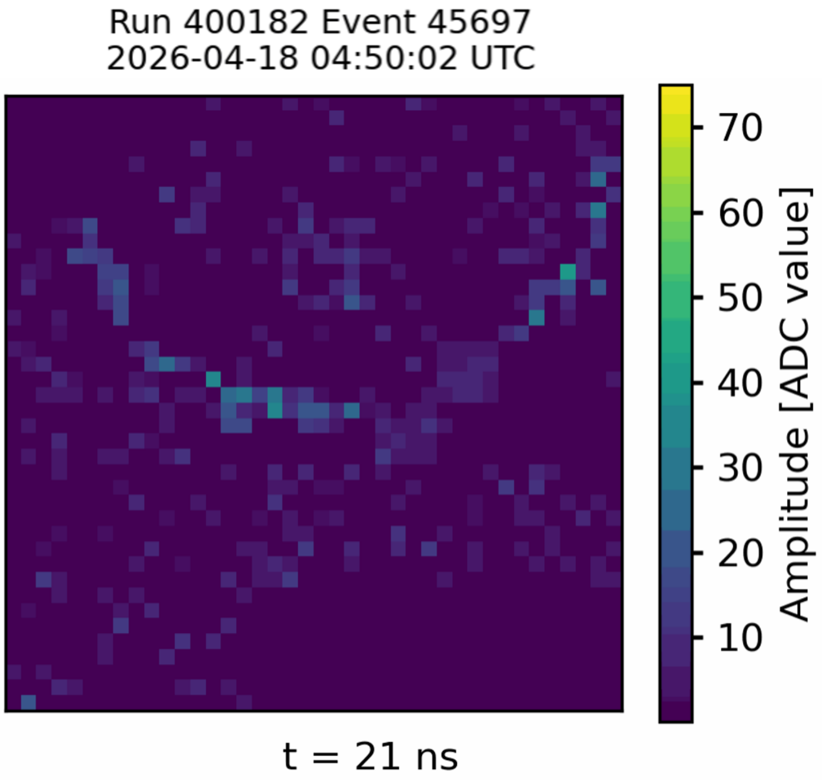
Star Tracking

- Using waveform baseline variance from night sky background events
- Stacking thousands of events to increase signal-to-noise
- Saturated peaks come from colorbar limit



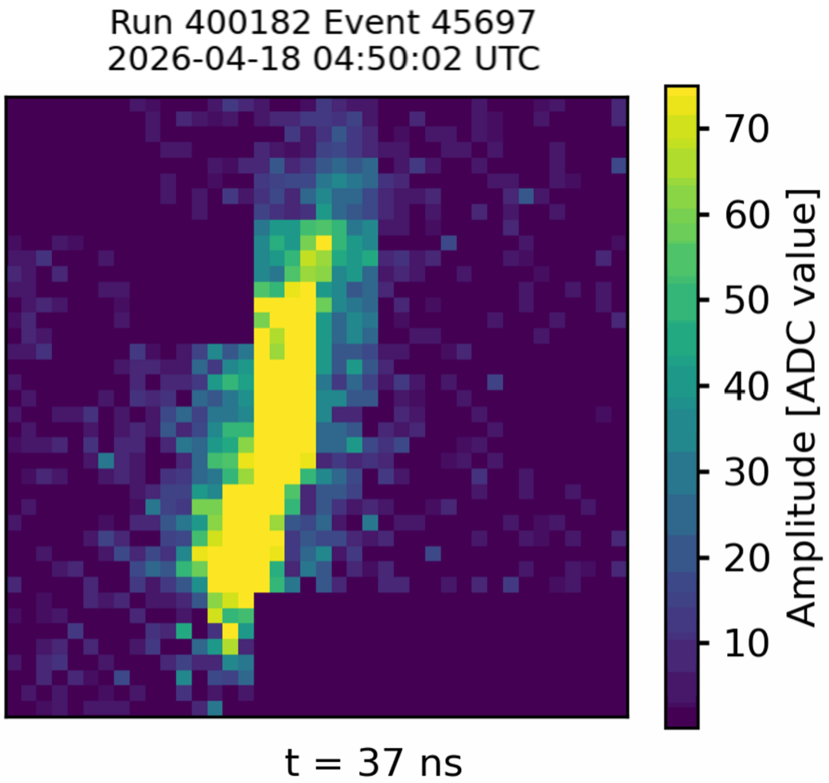
Commissioning Example

- Cherenkov ring from a muon followed ~8ns later by a cosmic-ray shower
- Demonstrates the concept of imaging atmospheric Cherenkov telescopes
  -> muon reaches the ground before the Cherenkov light



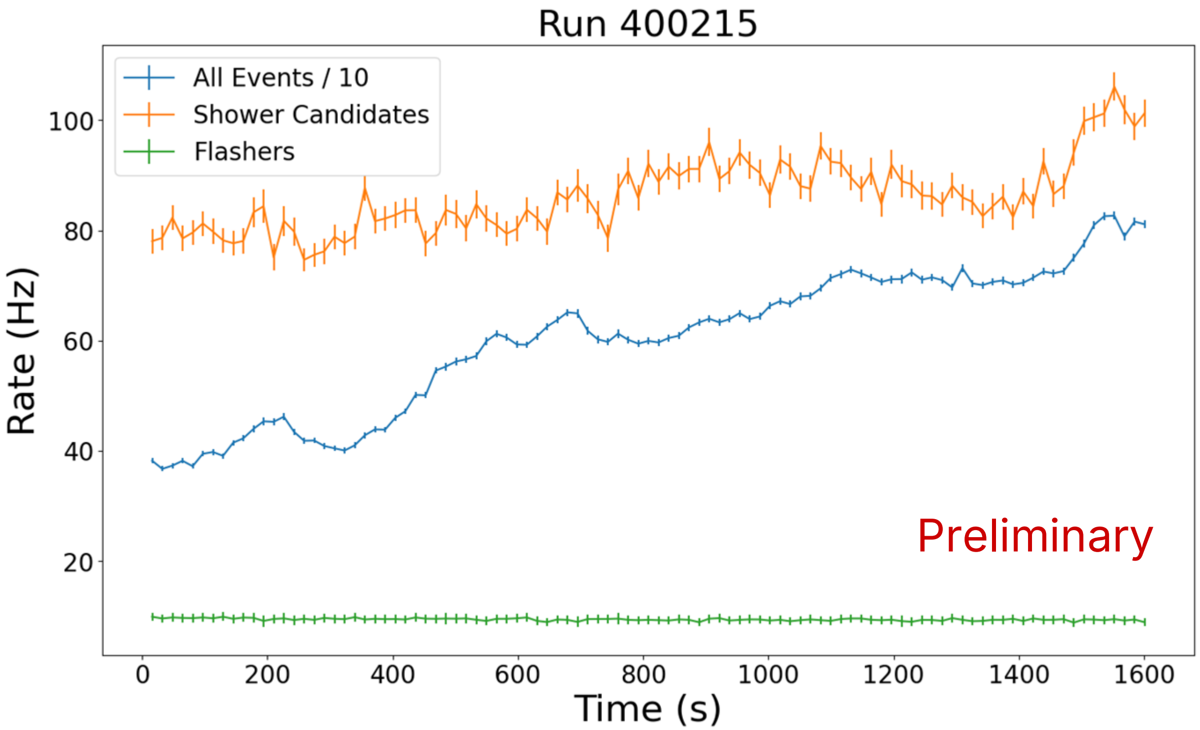
Commissioning Example

- Cherenkov ring from a muon followed ~8ns later by a cosmic-ray shower
- Demonstrates the concept of imaging atmospheric Cherenkov telescopes
  -> muon reaches the ground before the Cherenkov light



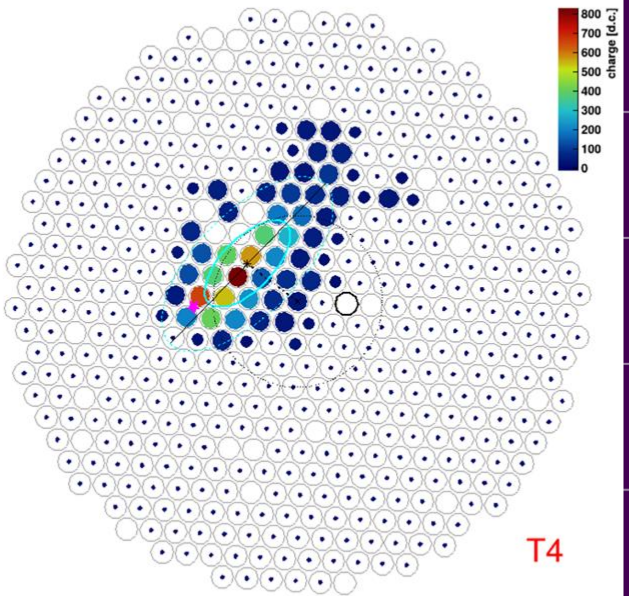
Markarian 421 Observations

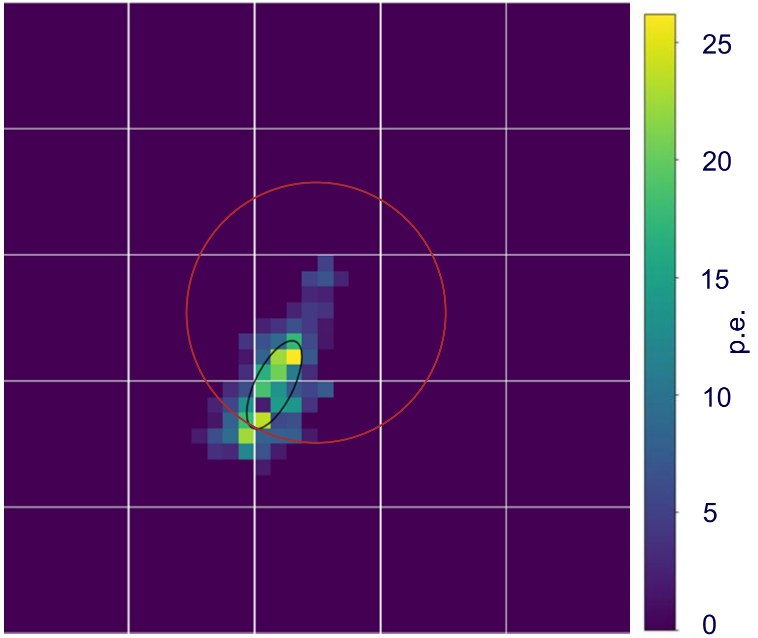
- Example run
- Shower candidate rate is constant at ~80 Hz
  - Events surviving basic cleaning and filtering
  - True shower rate is lower
- Night sky background changes increase all event rate



Markarian 421 Observations

- The pSCT is ~35 meters from VERITAS T4
- Matched cosmic ray

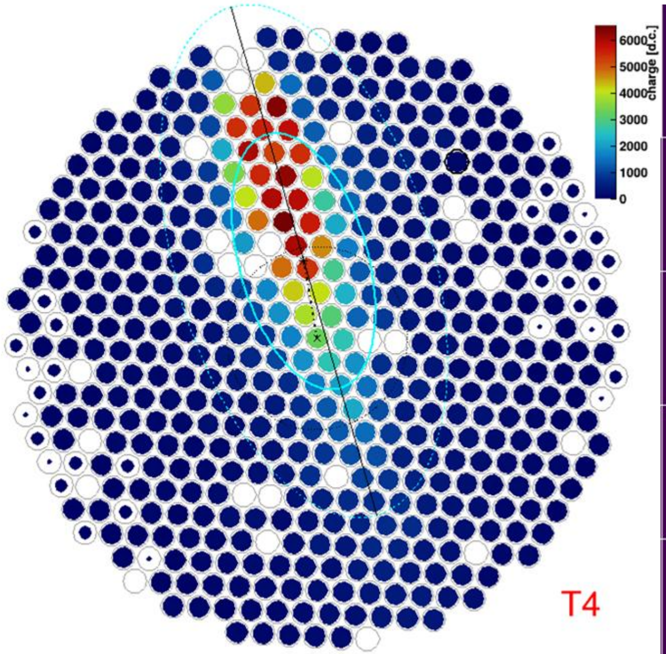


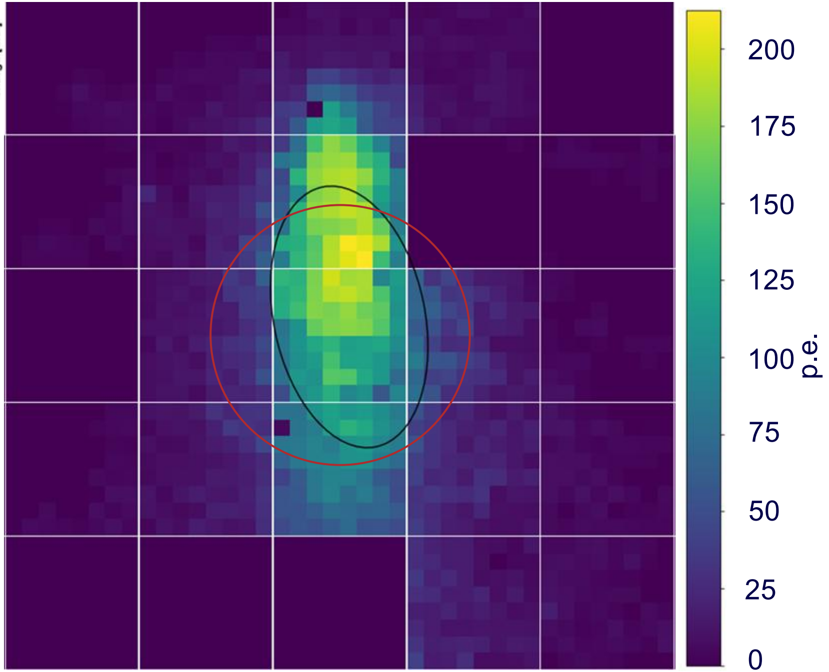


Central circles are 0.5° radius

Markarian 421 Observations

- Matched bright cosmic ray

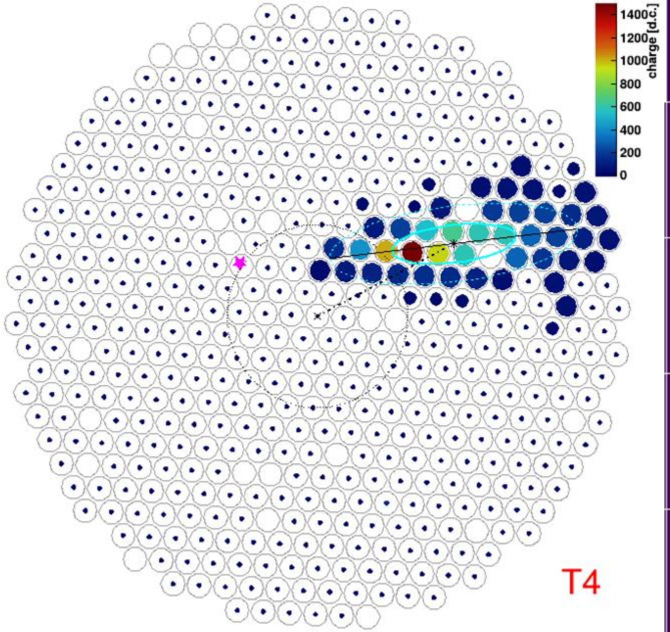


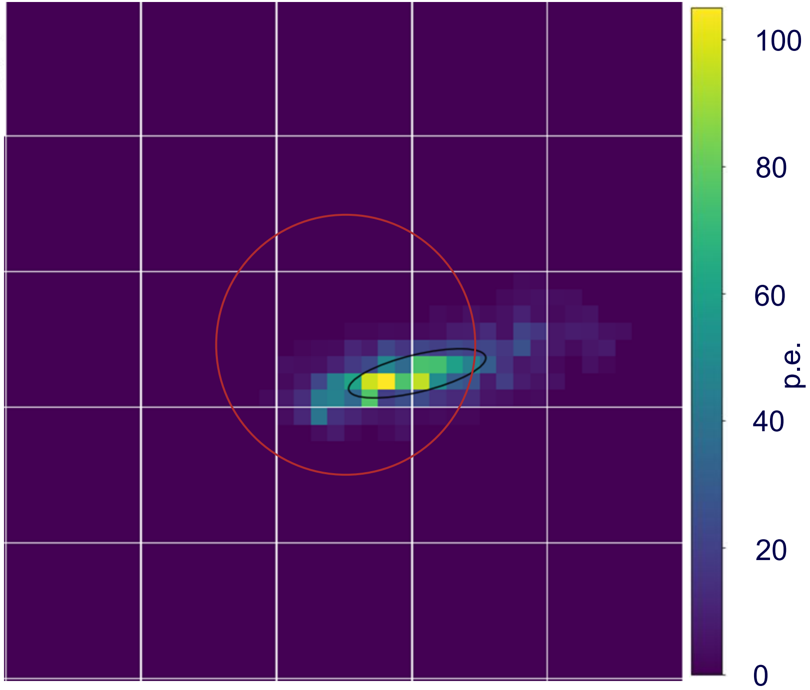


Central circles are 0.5° radius

Markarian 421 Observations

- Matched 3.4 TeV gamma ray

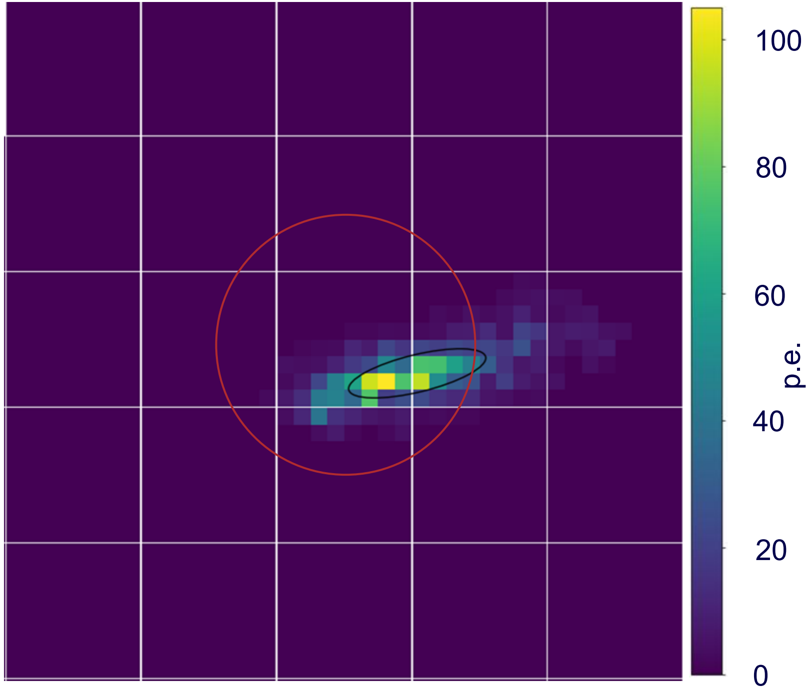




Central circles are 0.5° radius

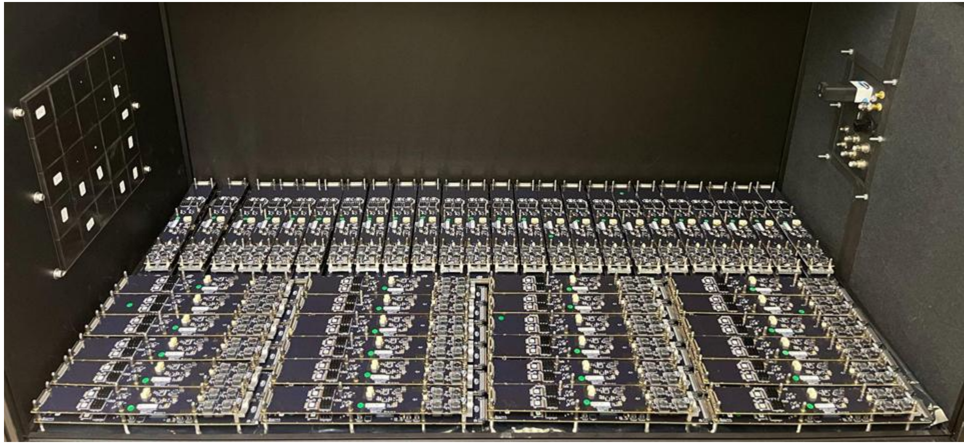
Markarian 421 Observations

- Matched 3.4 TeV gamma ray (162 m from T4)
- Offline matching of cosmic rays and gamma rays is robust
    - ~15 Hz rate of matched showers
- An important step towards possible integration of the pSCT as part of an IACT array



Next Steps

- 52 more camera modules are in Wisconsin for optimization, calibration, assembly, and testing
- They will be installed this fall
- The final 103 modules will follow after that
- Simulations of the mono-pSCT are in development, with further work to improve SCT array simulations



Summary

- The pSCT camera upgrade is underway
- Installation and first light of 22 camera modules
- Gamma-ray coincidence matching with VERITAS during initial Markarian 421 observations
- 52 more modules are expected to be installed this fall
- The last 103 modules are expected to be installed in 2027

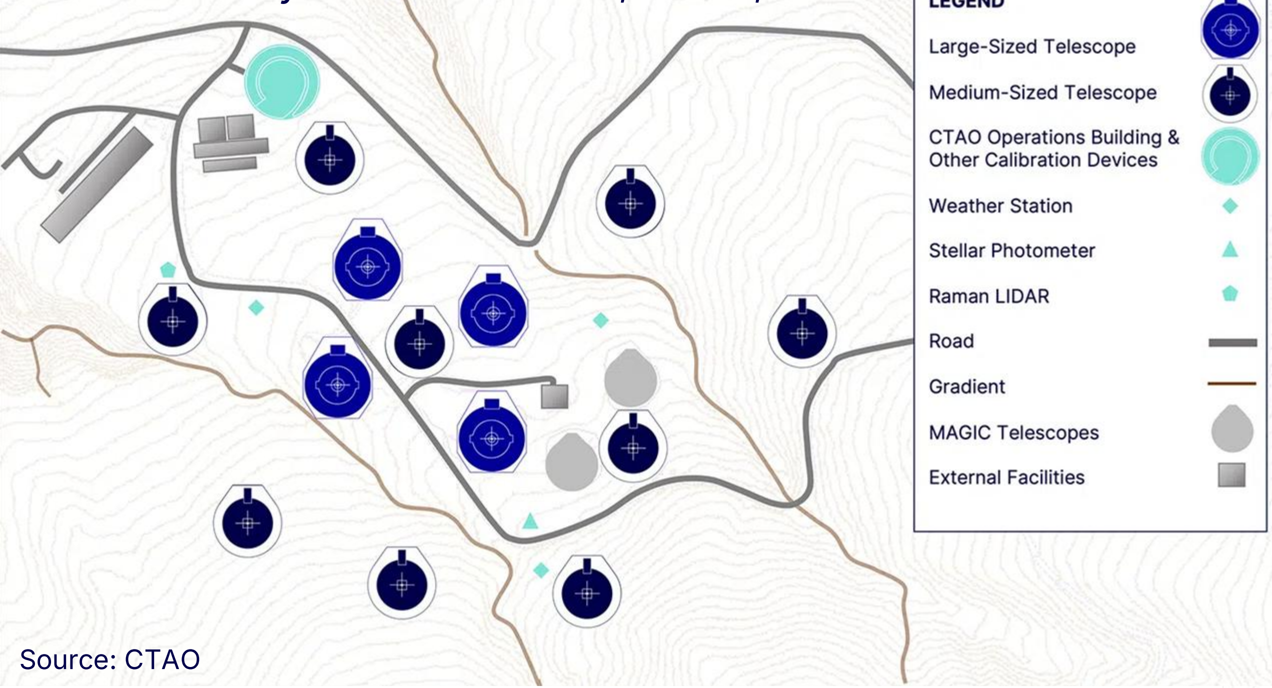
Thank you!

curtisginsbe@wisc.eud

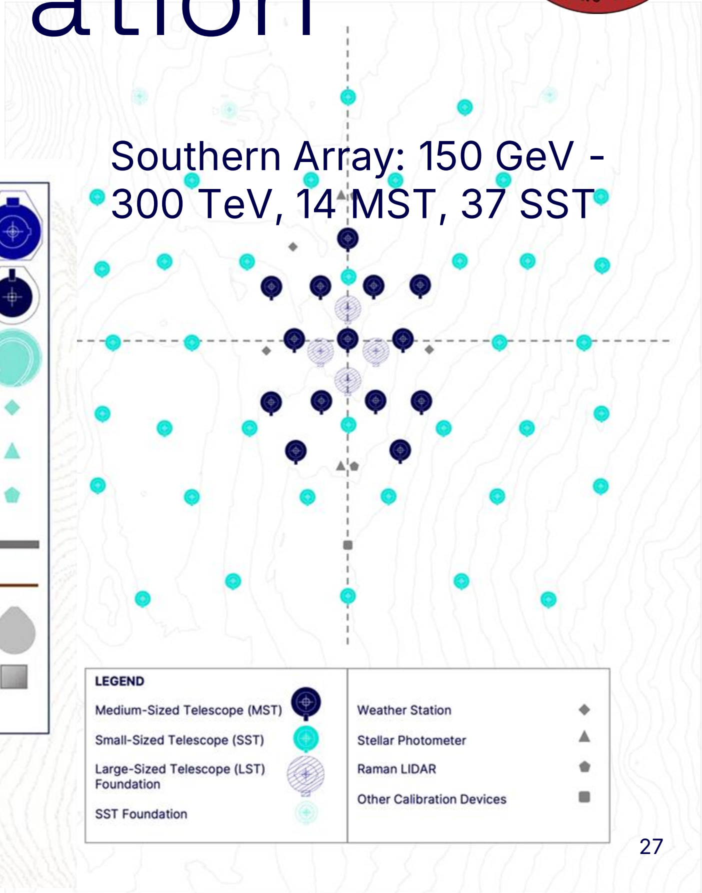
Backup

CTAO Alpha Configuration

Northern Array: 20 GeV - 5 TeV, 4 LST, 9 MST



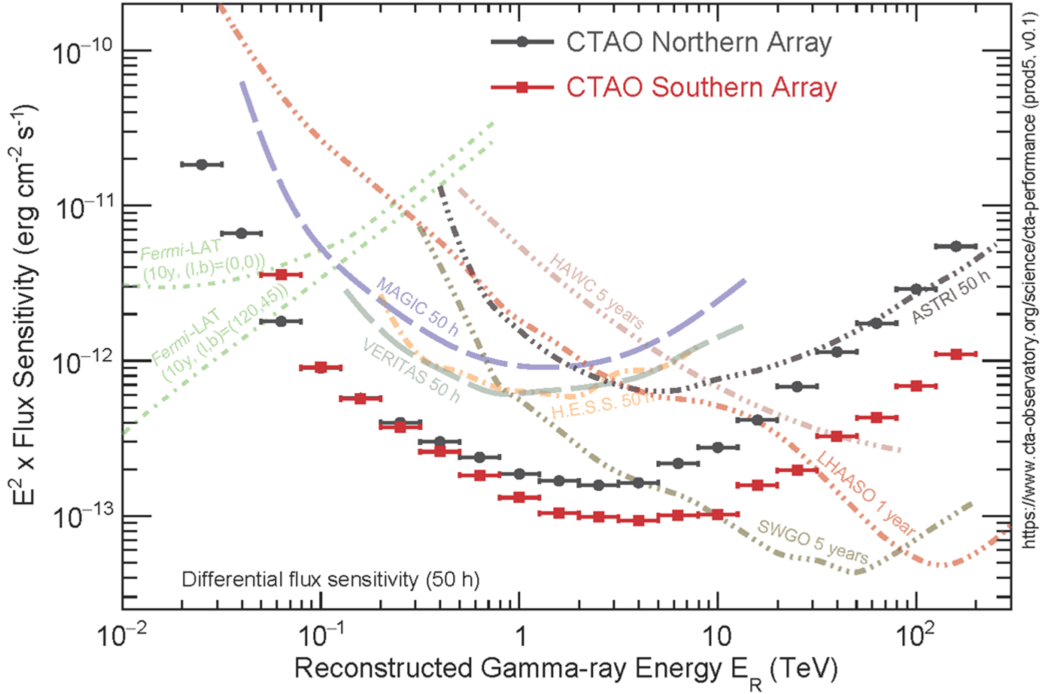
Southern Array: 150 GeV - 300 TeV, 14 MST, 37 SST



Source: CTAO

CTAO Sensitivity

- Minimum flux needed for 5σ detection of a point source with 50 hours of exposure (or instrument equivalent)
    - For the alpha configuration
- Comparing CTAO to other current and upcoming instruments

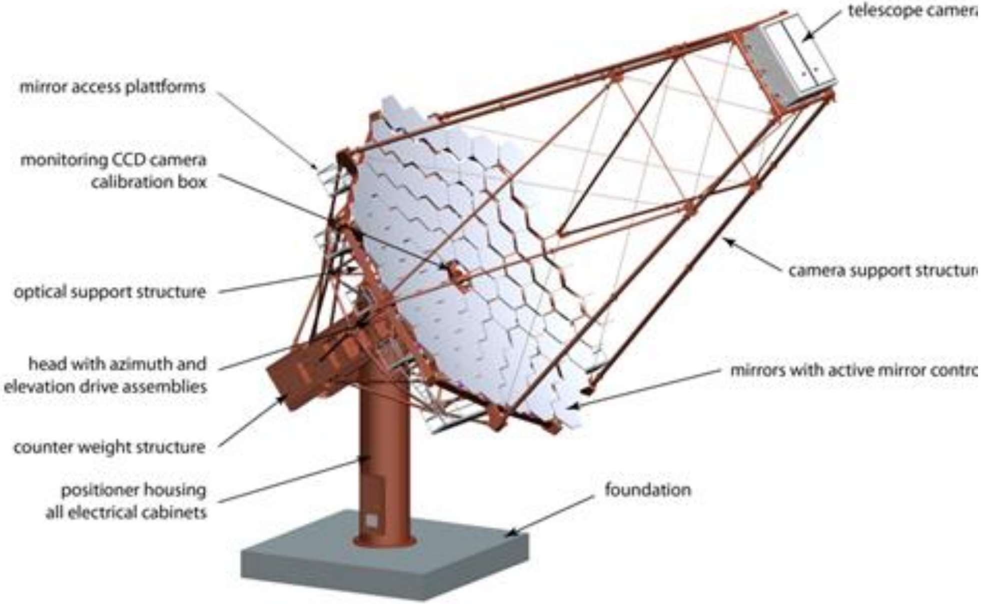


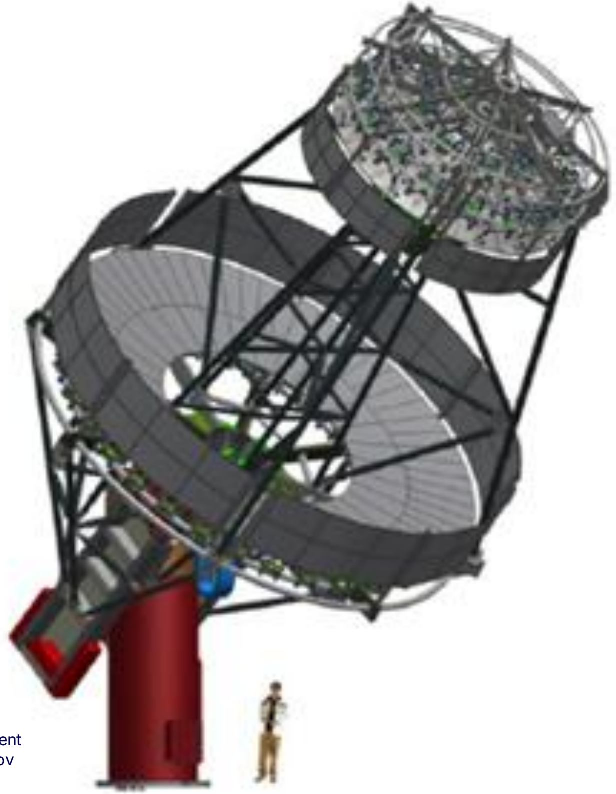
Source: CTAO

CTAO-US

- 17 US institutions, 50+ current members
- Development of the pSCT/SCT instrument
- CTAO leadership contributions
  - Co-spokesperson
  - Science Coordinator
  - Science working group leads
  - SAPO leadership/members
  - Science and technology development
  - White papers leadership

SC Vs. DC Medium Sized Telescope

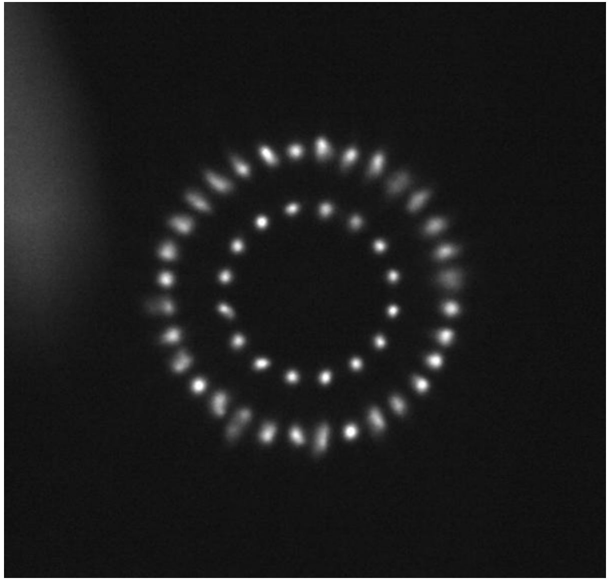


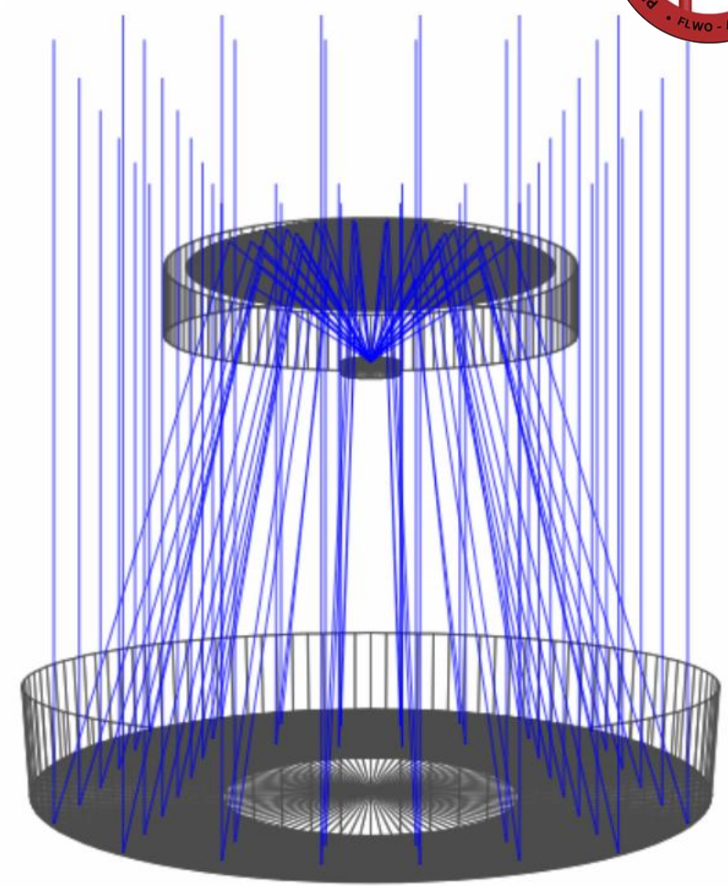


Source: D. Nieto et al. "Construction of a medium-sized Schwarzschild-Couder telescope as a candidate for the Cherenkov Telescope Array: development of the optical alignment system", J-F. Glicenstein. "Status of the Davies-Cotton and Schwarzschild-Couder Medium-Sized Telescopes for the Cherenkov Telescope Array"

SC Optics

- Focal length 5.586m
- Aperture 9.66m

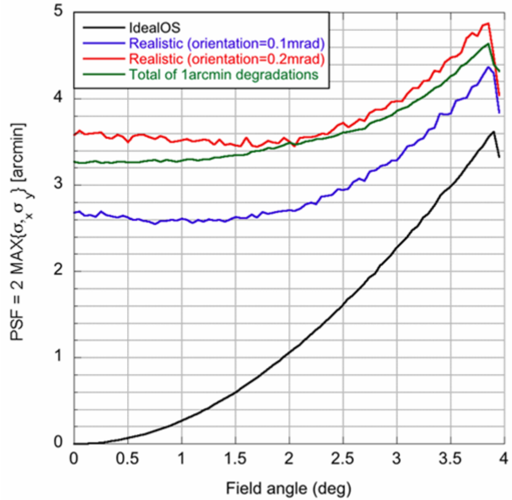


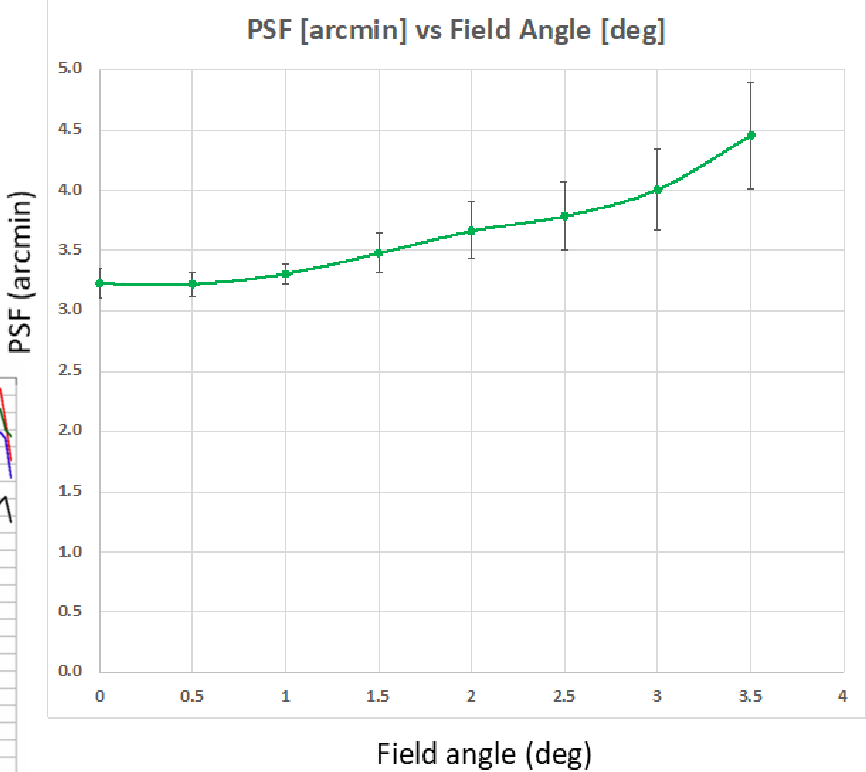


Source: J. Rousselle et al. "Construction of a Schwarzschild-Couder telescope as a candidate for the Cherenkov Telescope Array: status of the optical system"

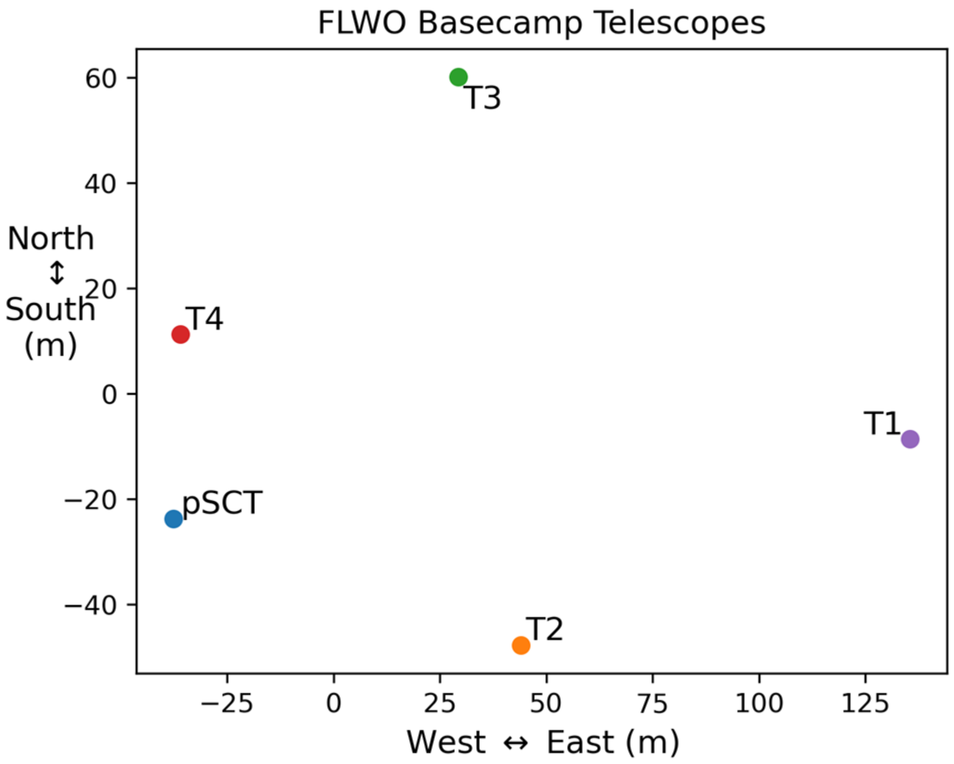
SC Optics

- 9.7m primary, 5.4m secondary
- 48 segments on primary, 24 segments on secondary
- On-axis PSF ~3.2′



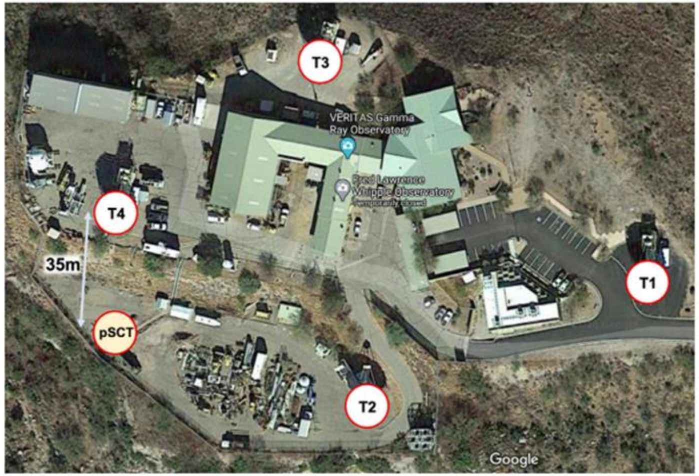


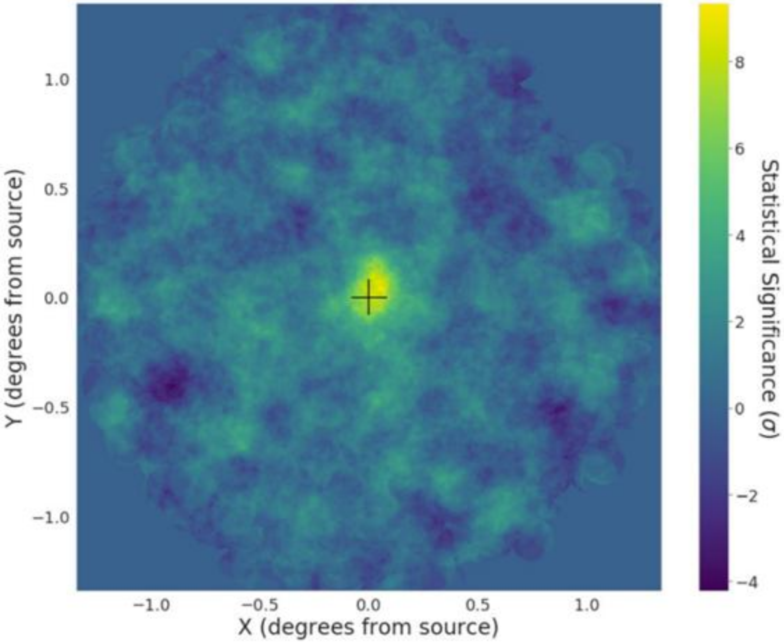
pSCT & VERITAS Locations



pSCT Crab Detection

- Observation campaign of the Crab Nebula in 2020
- 17.6 hours of data
- 8.6σ detection



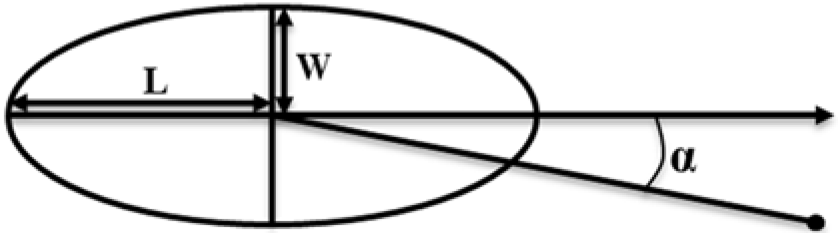


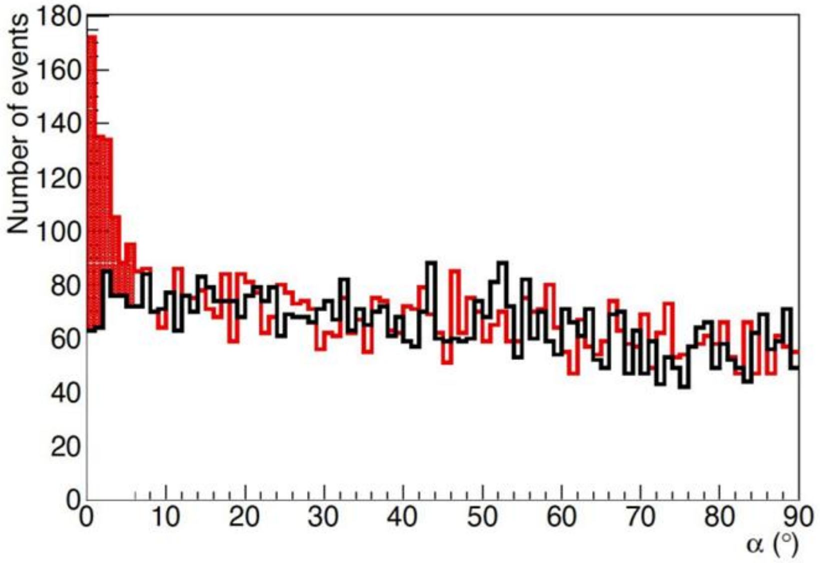
Source: C. Adams et al. “Detection of the Crab Nebula with the 9.7 m Prototype Schwarzschild-Couder Telescope”

pSCT Crab Detection

Table 1: Gamma-ray selection cuts optimized using VERITAS matched events.

Gamma-ray selection cuts
$0.33^\circ < distance < 1.14^\circ$
$250\text{ p.e.} < size < 20000\text{ p.e.}$
$width < -0.070^\circ + 0.047^\circ \log_{10}(size/p.e.)$
$length < -0.369^\circ + 0.201^\circ \log_{10}(size/p.e.)$
$1.139^\circ - 1.742^\circ(width/length) < distance$
$distance < 1.273^\circ - 0.737^\circ(width/length)$
$\alpha < 6^\circ$

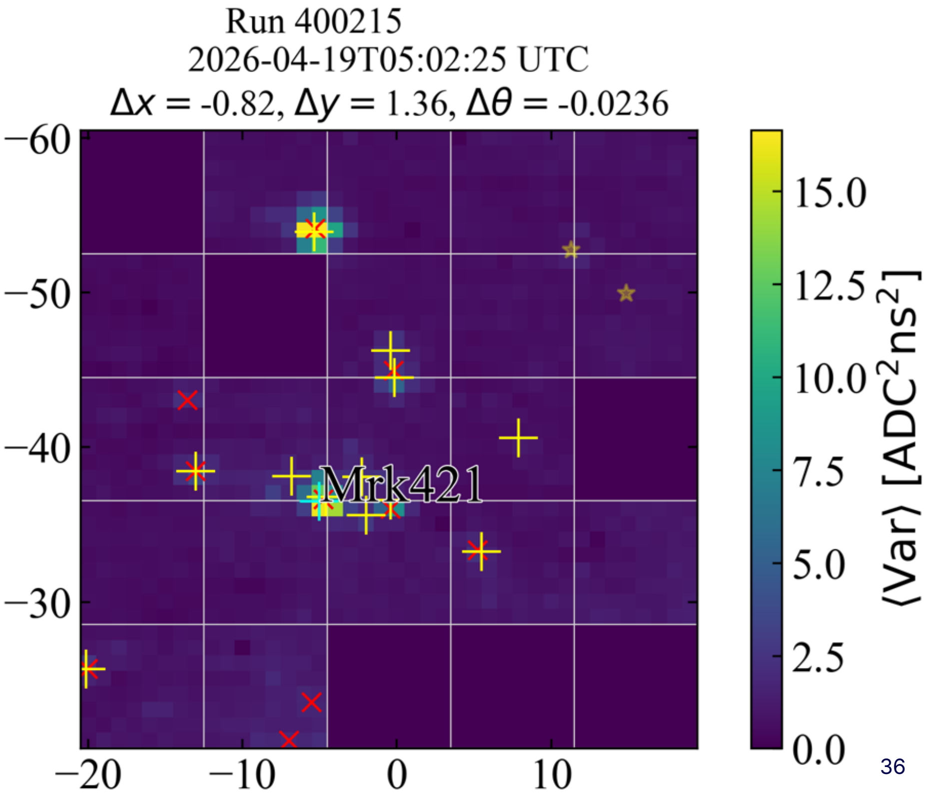




Source: C. Adams et al. "Detection of the Crab Nebula with the 9.7 m Prototype Schwarzschild-Couder Telescope"

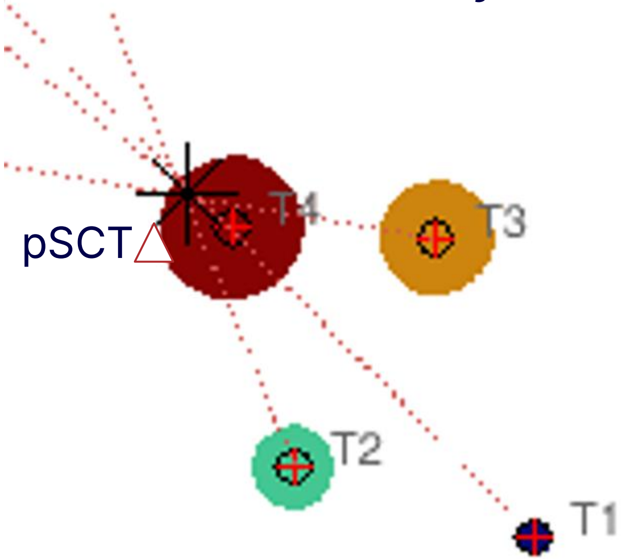
Star Tracking

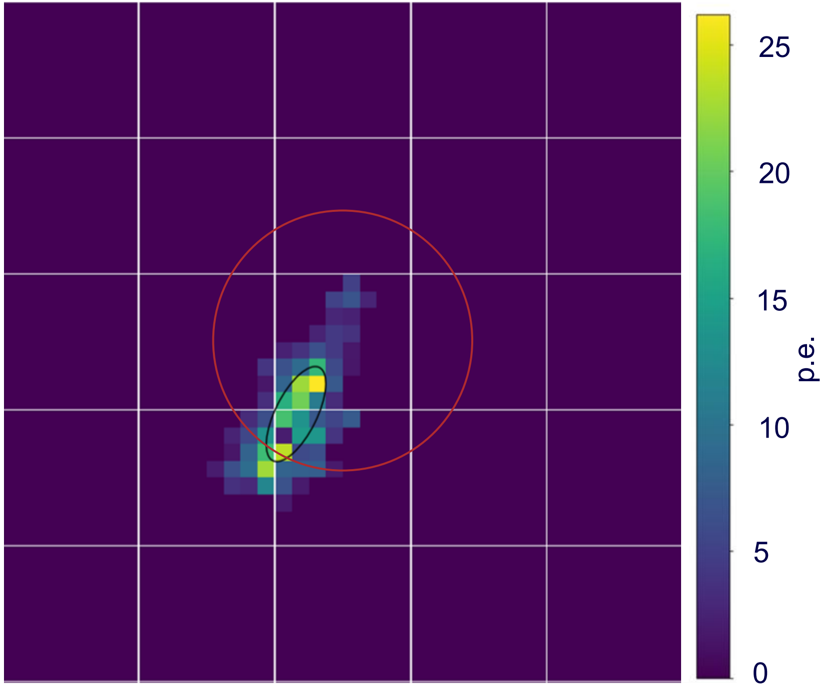
- Red X are peaks in the stacked variance image
- Yellow + are stars expected in the field
- Using solved star field to calculate source position (Markarian 421)



Markarian 421 Observations

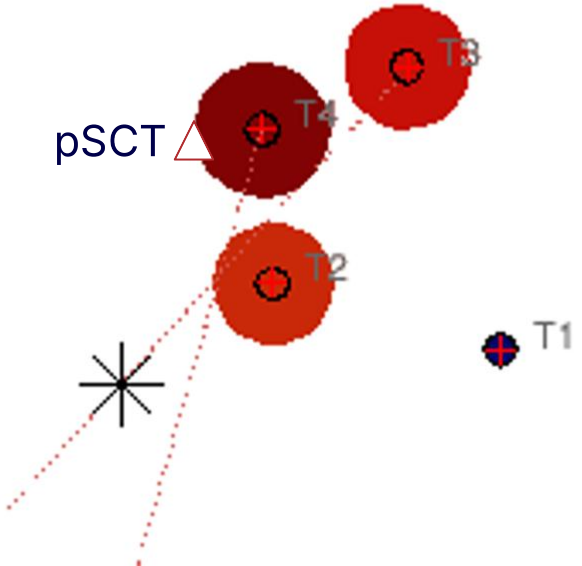
- Matched cosmic ray

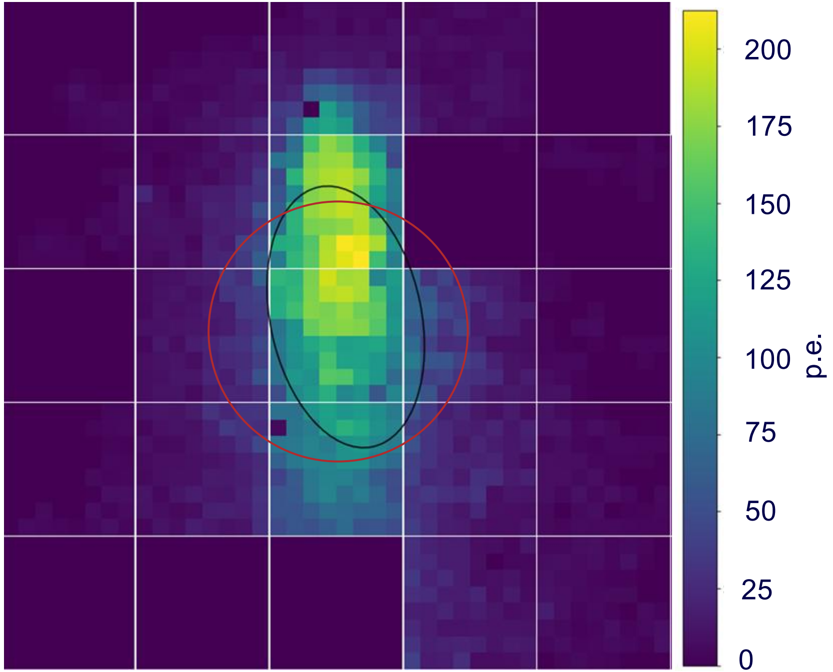




Markarian 421 Observations

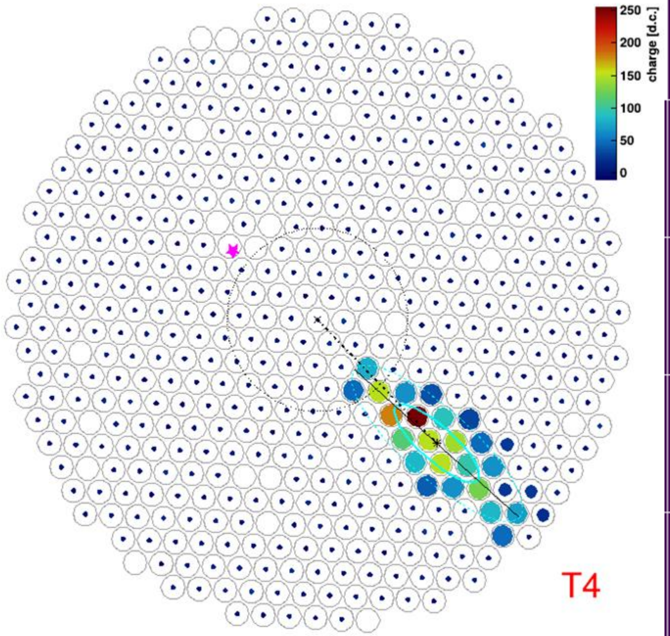
- Matched bright cosmic ray

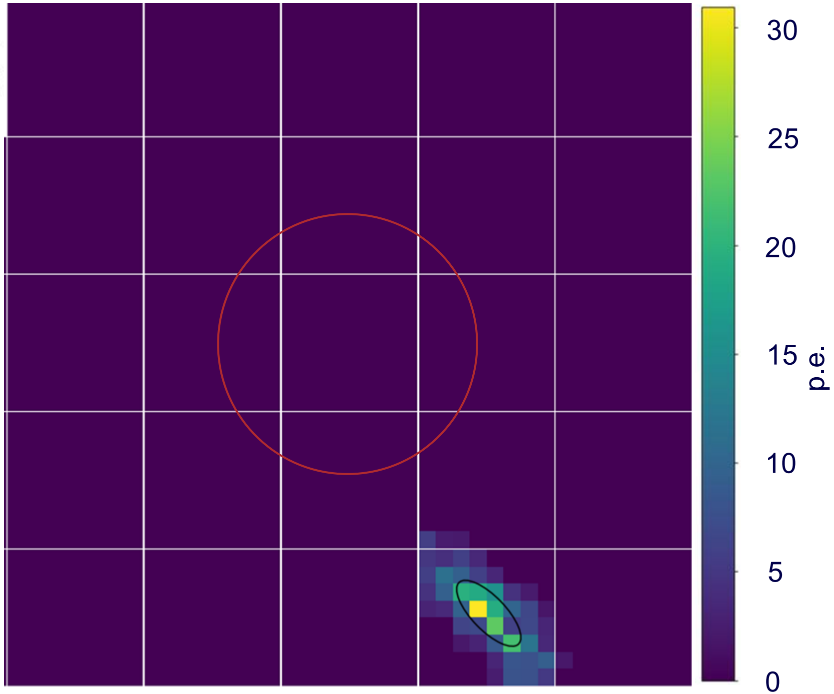




Markarian 421 Observations

- Matched 1.5 TeV gamma ray

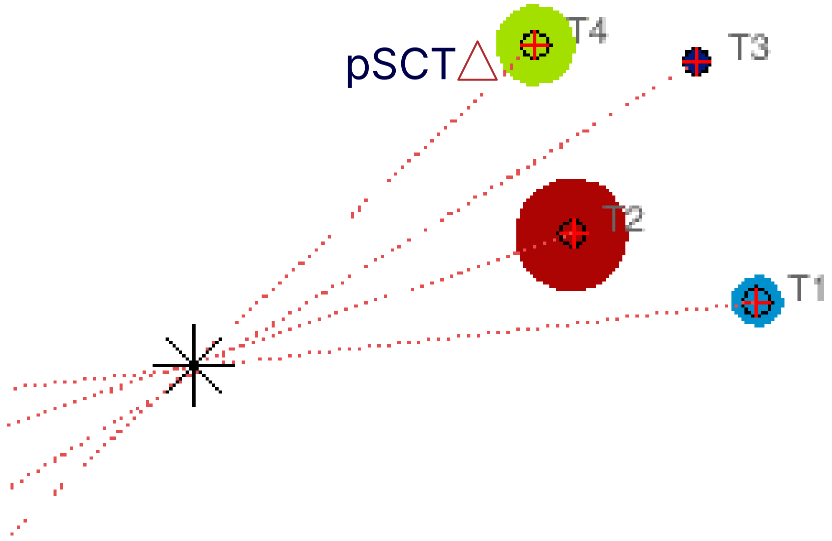


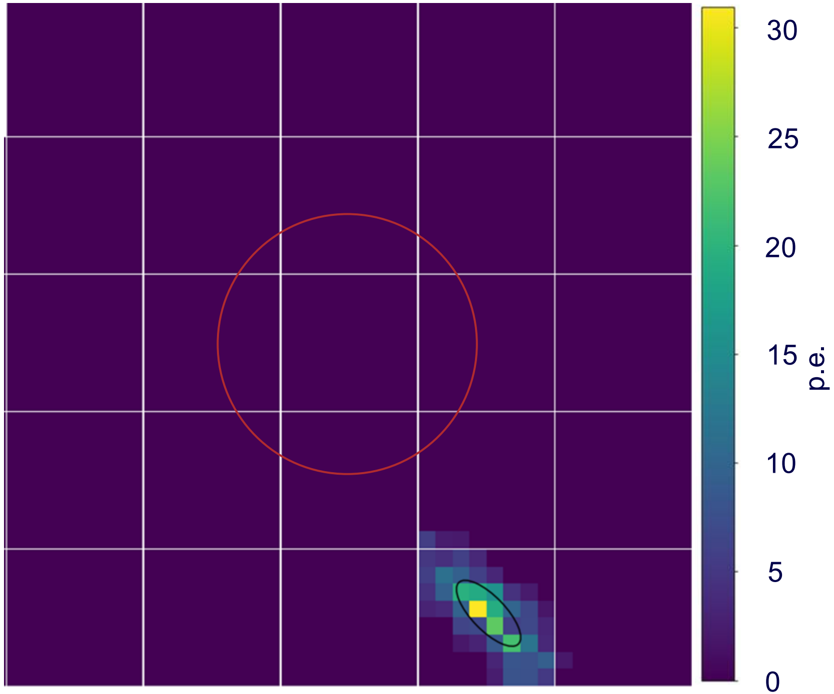


Central circles are 0.5° radius

Markarian 421 Observations

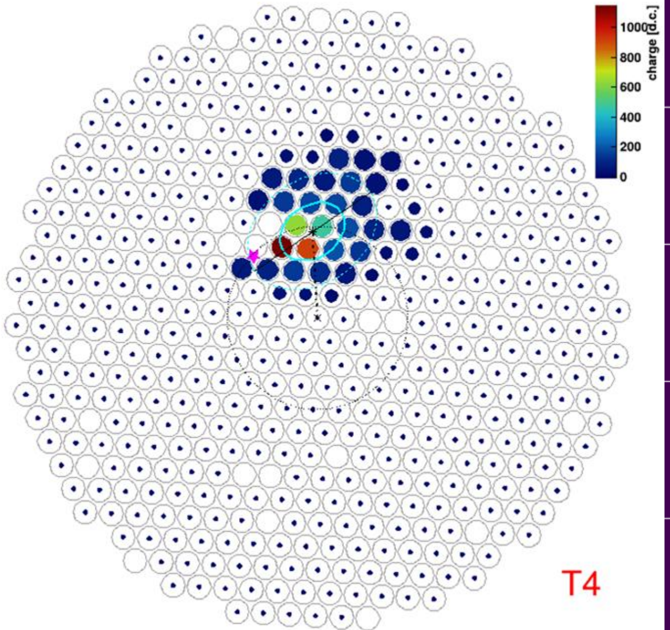
- Matched 1.5 TeV gamma ray (221 m from T4)

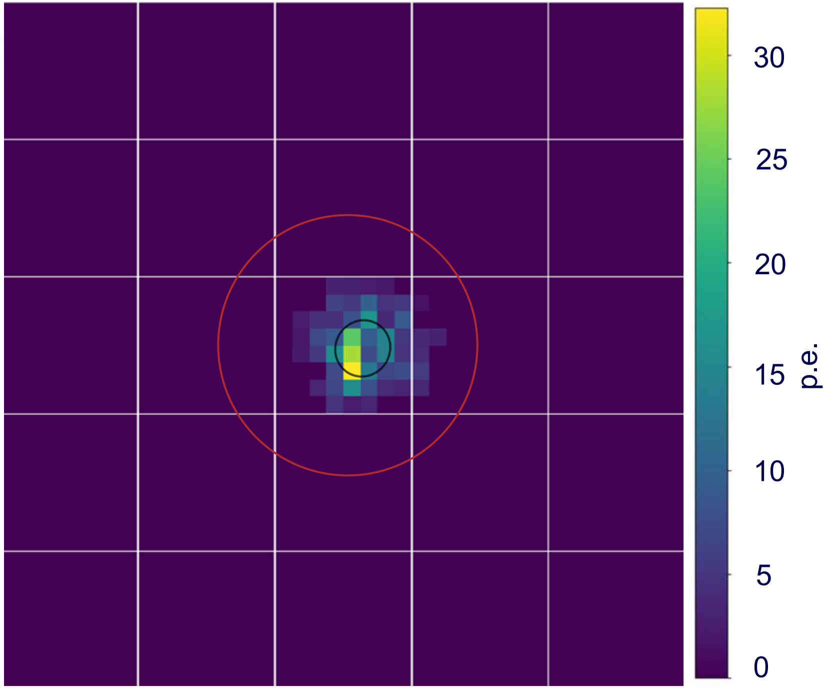




Markarian 421 Observations

- Matched 1 TeV gamma ray (falls almost on top of pSCT)

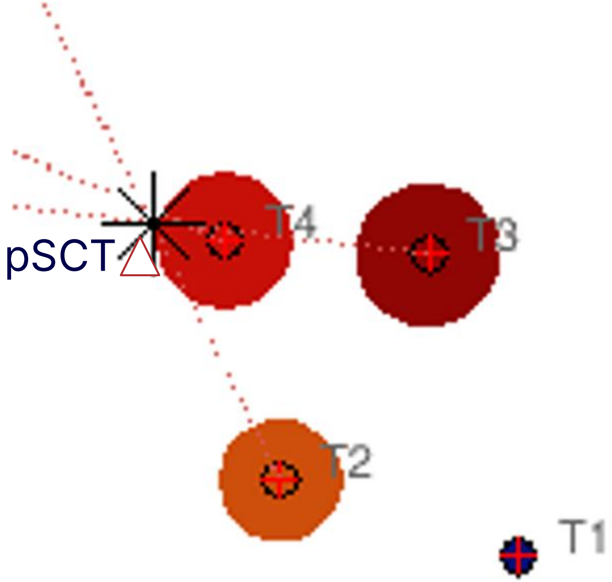


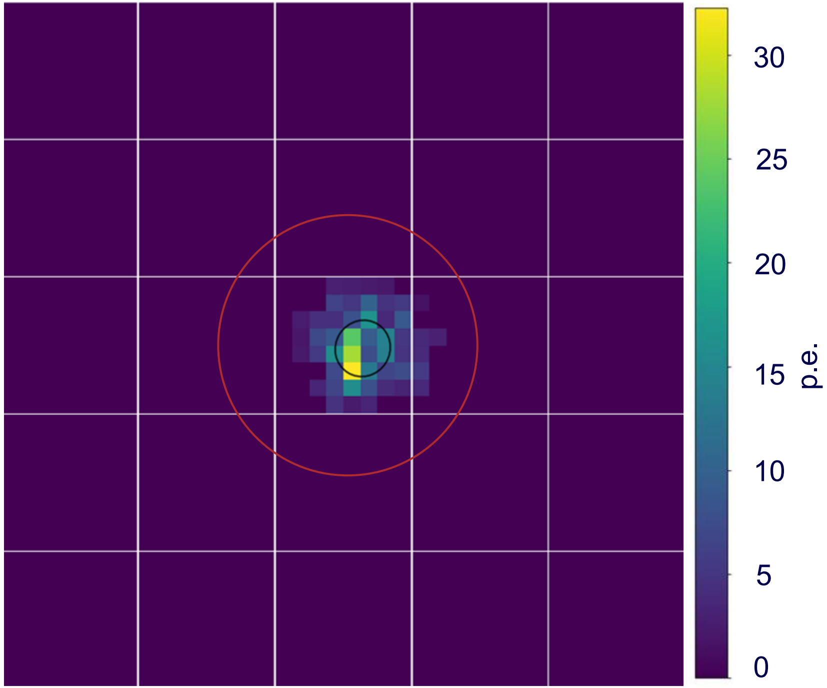


Central circles are 0.5° radius

Markarian 421 Observations

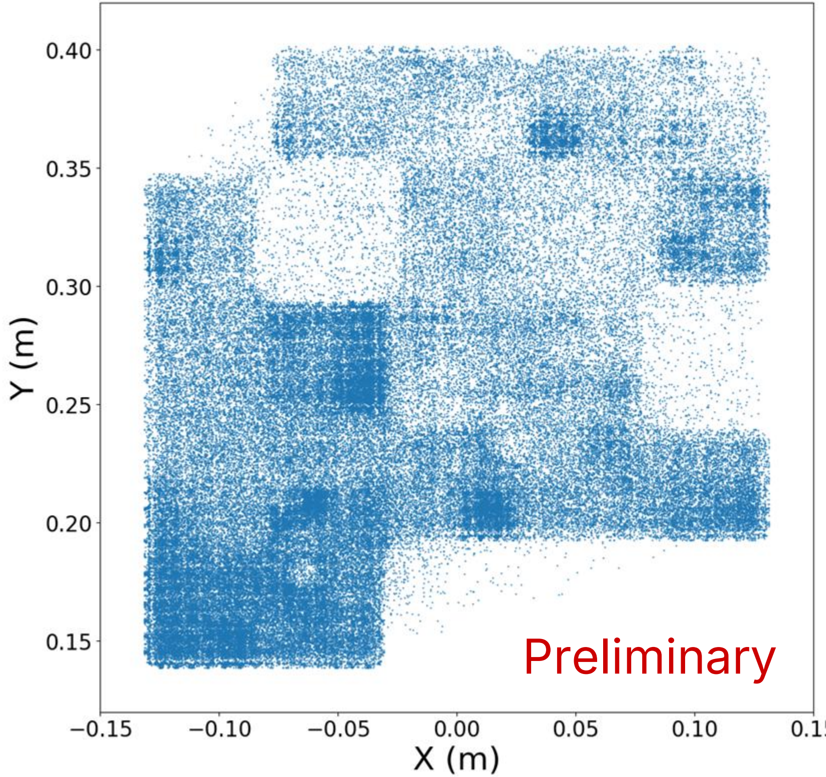
- Matched 1 TeV gamma ray (falls almost on top of pSCT)





Markarian 421 Observations

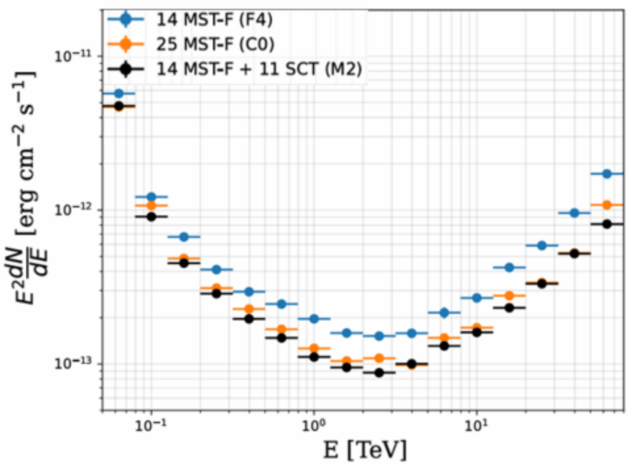
- Spatial location of Hillas centroid for all shower candidates
- 29 minute run



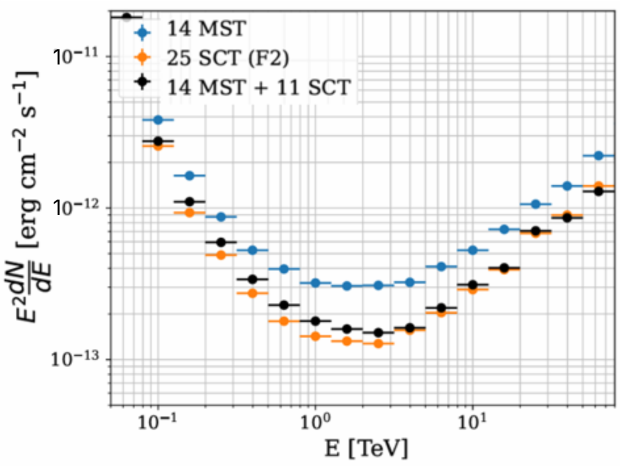
SCT Array

- Adding 11 SCTs improves performance more than 11 DC-MSTs
- The off-axis improvement is even larger
- Updated simulations are in development

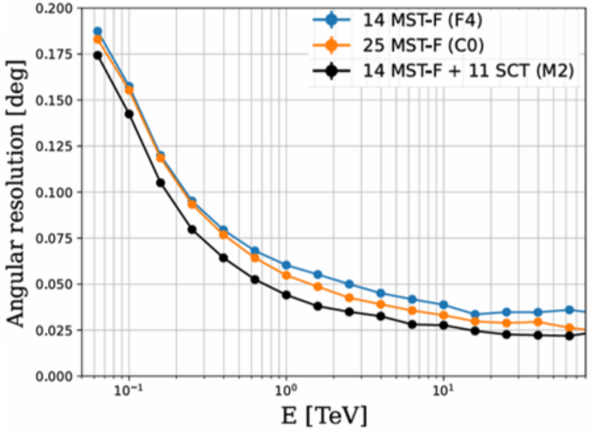
On-Source



3.5 Degrees Off-Axis



On-Source



3.5 Degrees Off-Axis