Detection of the Crab Nebula using an innovative gamma-ray telescope

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on behalf of the CTA Consortium

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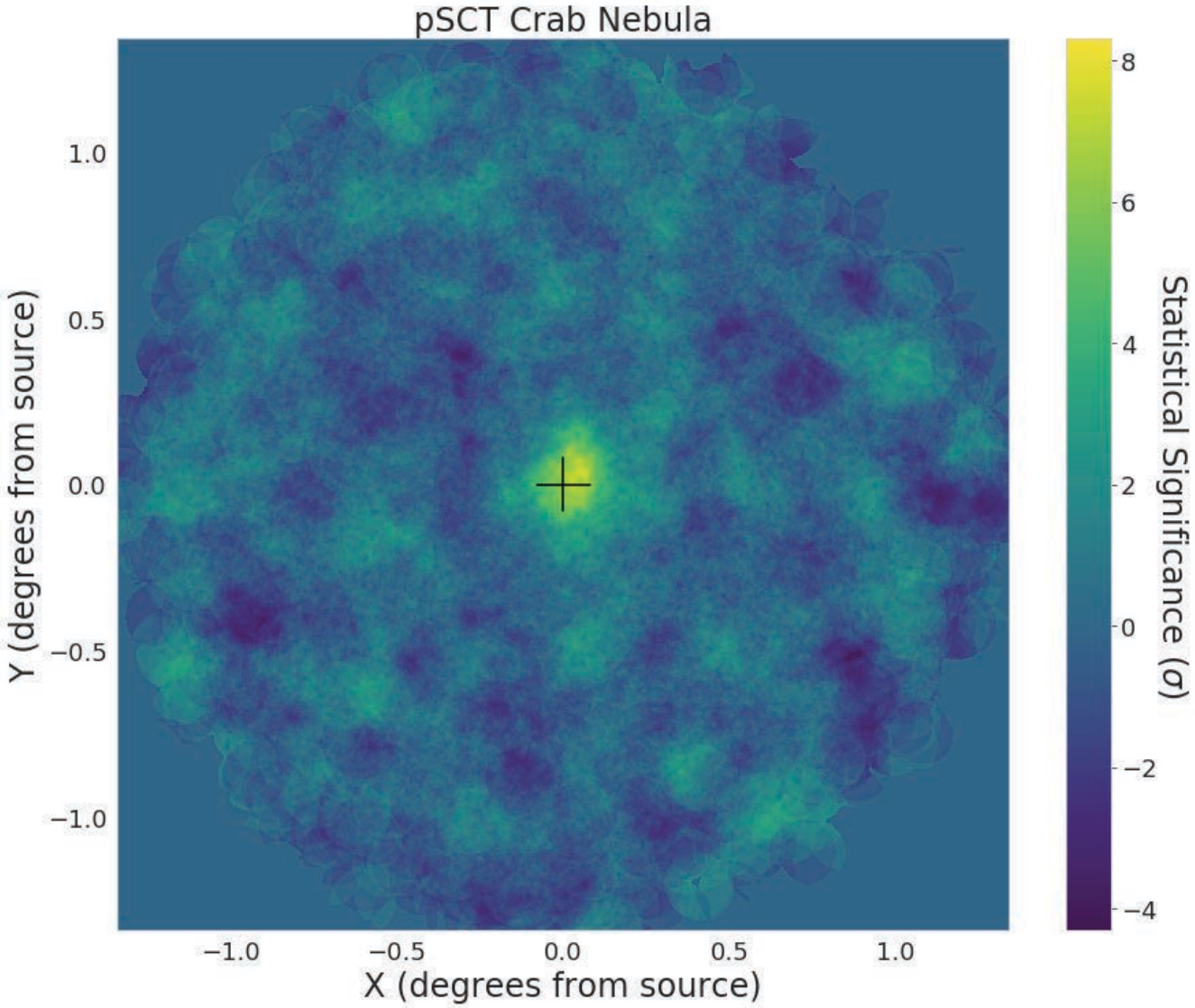
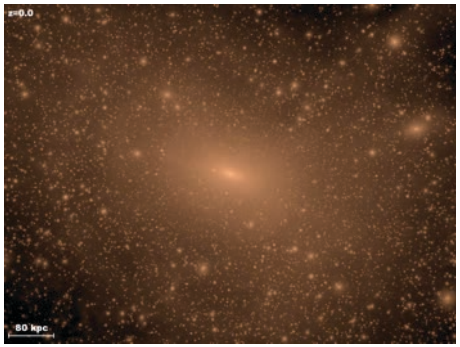
Tera-electron-volt gamma rays from the Crab Nebula



Crab detection establishes innovative telescope technology for gamma-ray astronomy

Science with the highest-energy light in the Universe



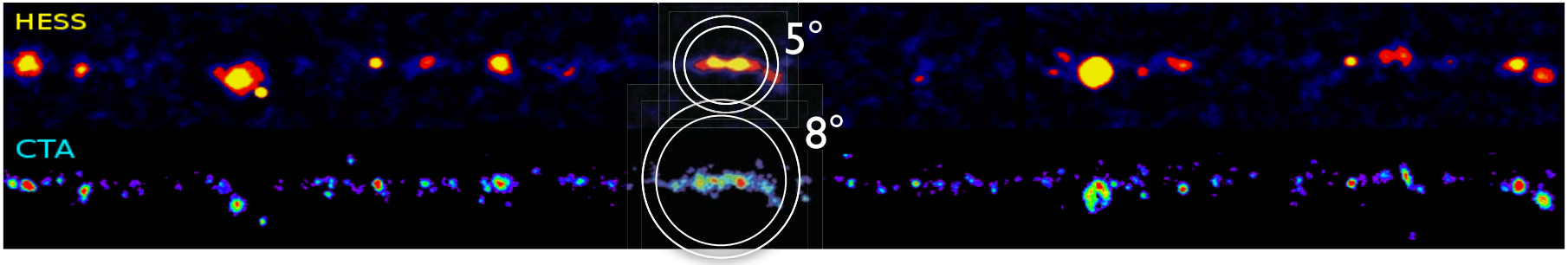
Dark matter

Time-domain / transient astrophysics

Neutrino and gravitational wave (multi-messenger) sources

Black holes and neutron stars as particle accelerators

Simulated Galactic Plane survey

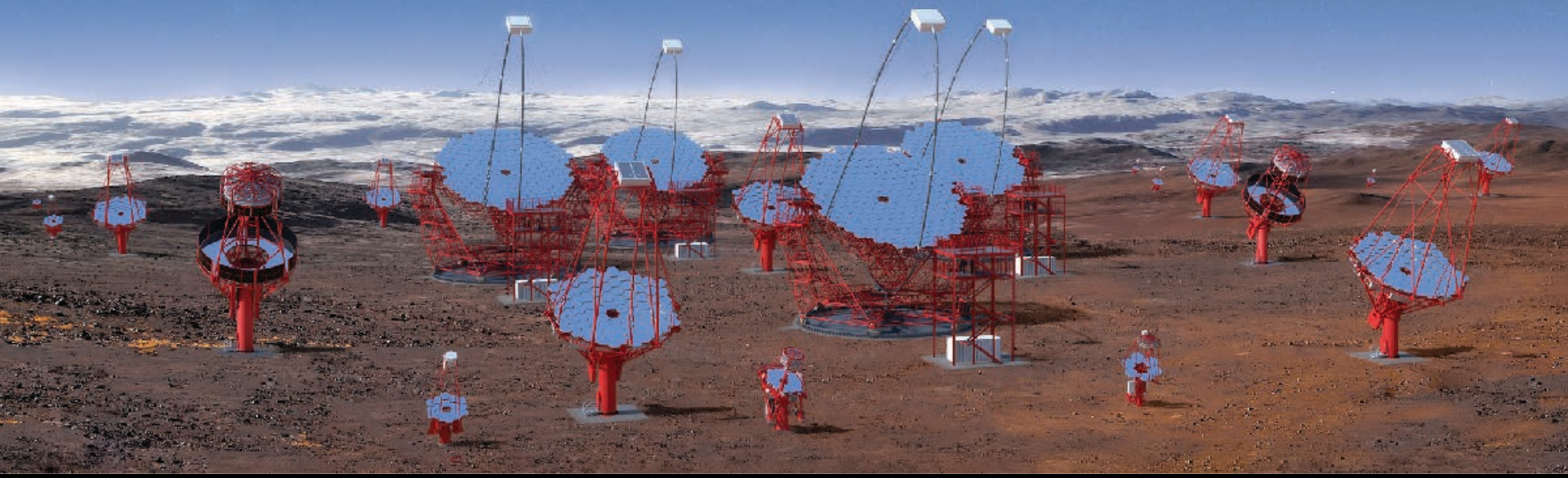


The Cherenkov Telescope Array: the next-generation gamma-ray observatory

Low energies
20 GeV – 150 GeV
23 m diameter
4 telescopes (South)
4 telescopes (North)

Medium energies
150 GeV – 5 TeV
9.5 to 12 m diameter
25 medium-size telescopes (S)
15 medium-size telescopes (N)

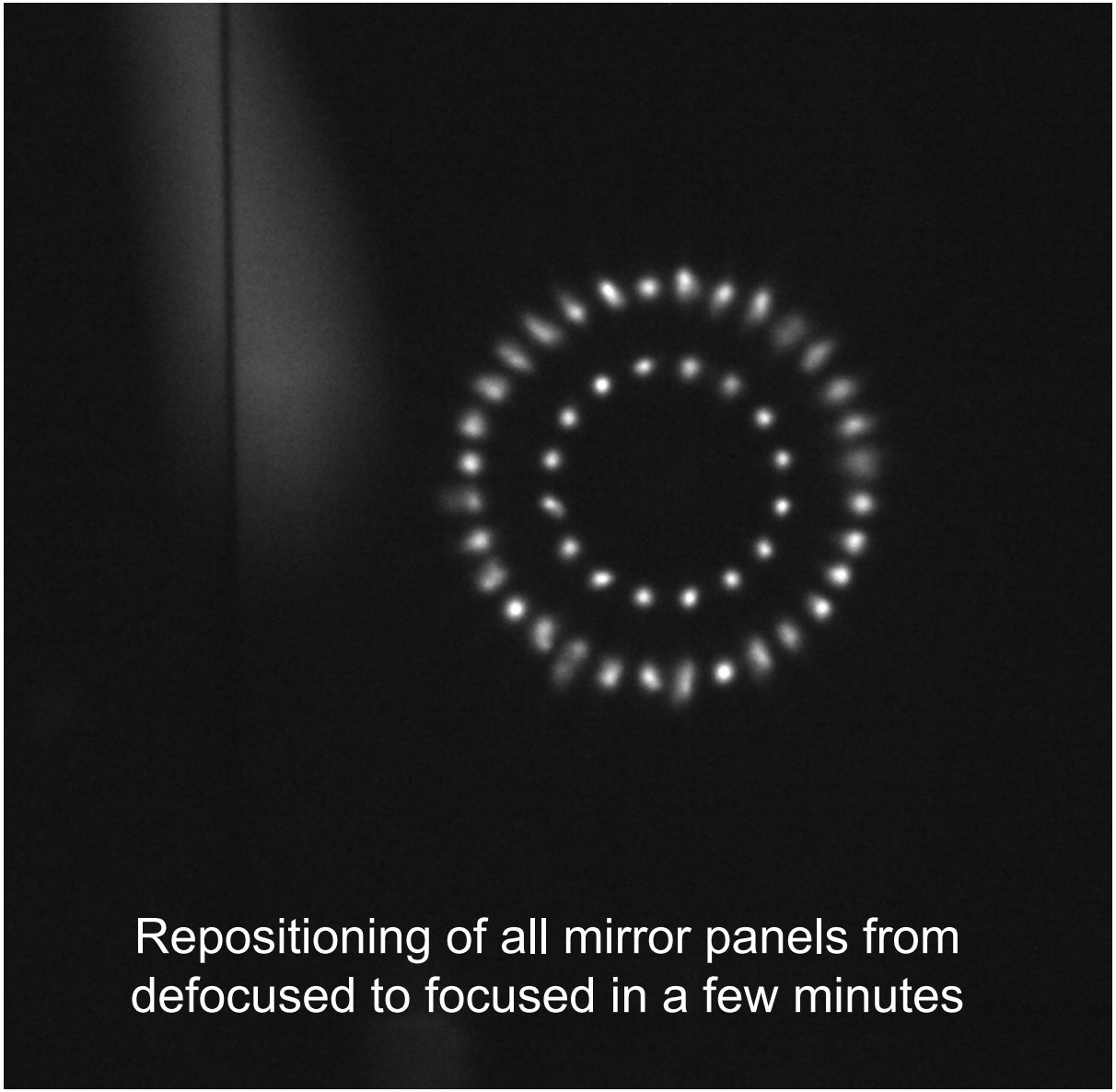
High energies
5 TeV – 300 TeV
4 m diameter
70 small-size telescopes (S only)



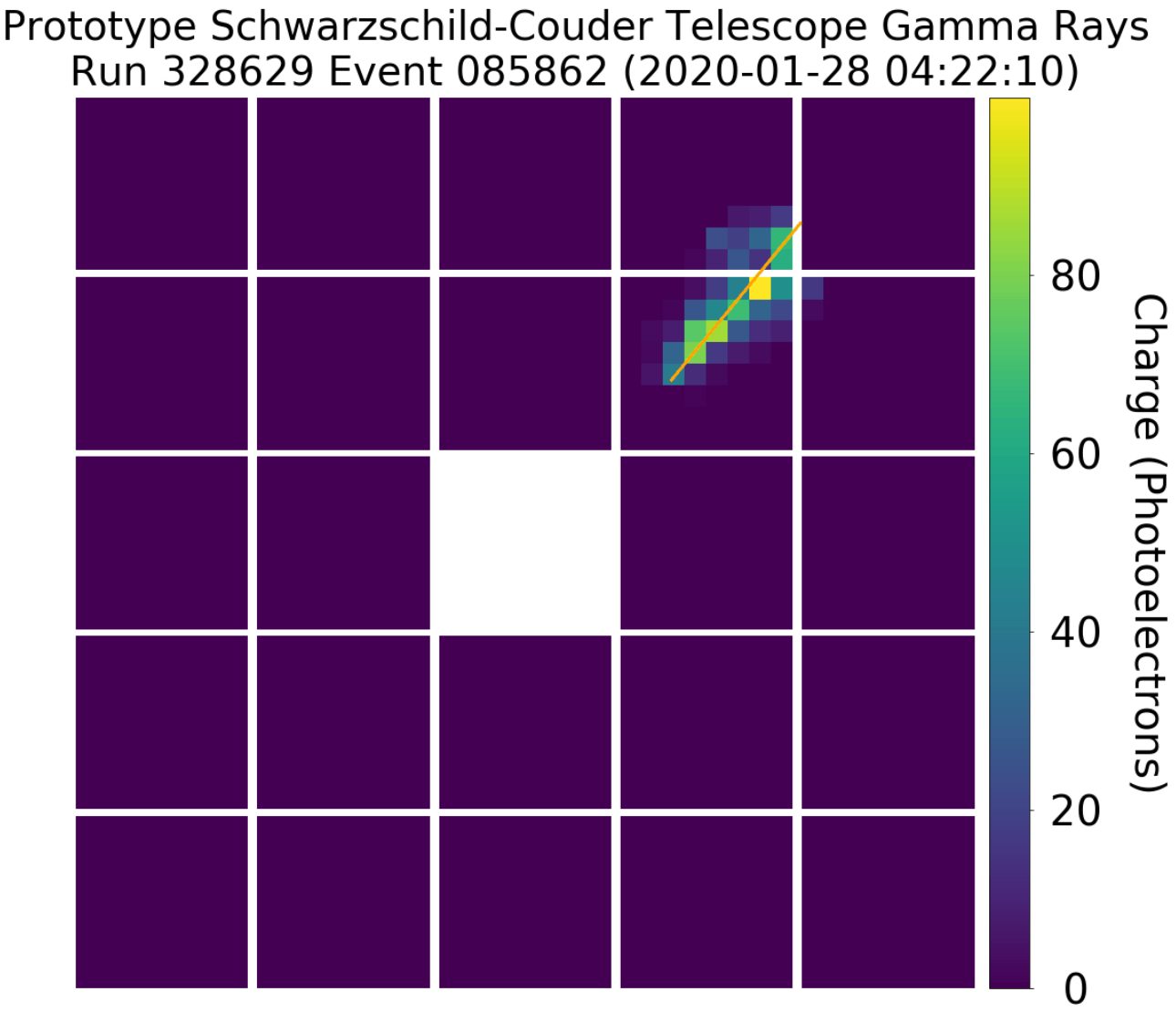
Prototype Schwarzschild-Couder Telescope (pSCT)

- Building on generations of improvements in imaging atmospheric Cherenkov telescopes, starting from first TeV detection of Crab Nebula in 1989 by Whipple telescope
- Using two mirrors instead of one
- Using modern photon sensors and electronics
- These enable improved angular resolution and sensitivity
- Improvements will provide new TeV gamma-ray measurements and discoveries up to two times faster than current telescope technology
- Constructed by members of CTA from US, Germany, Italy, Japan, and Mexico

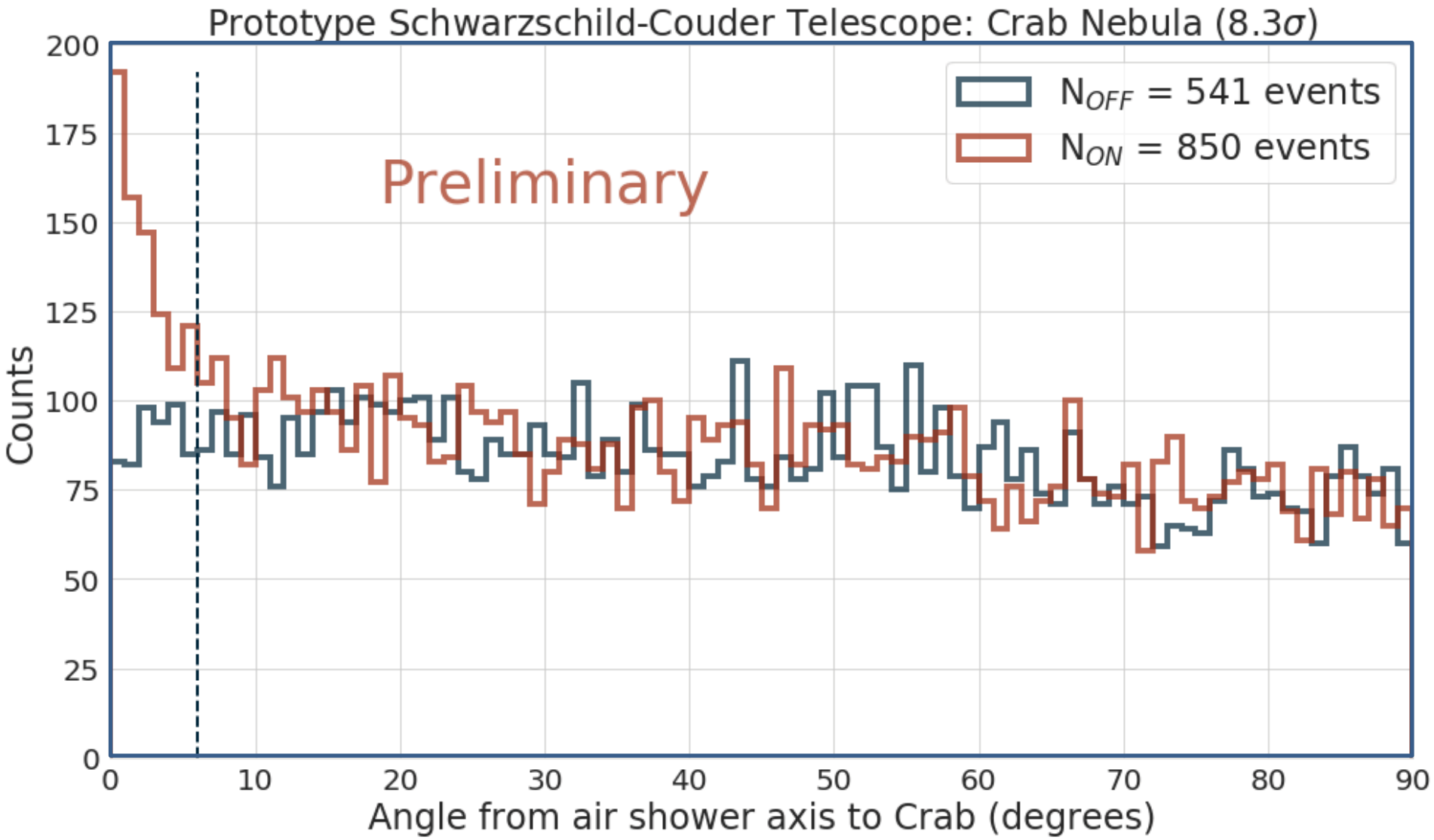
Alignment of Optical System



Images of 18 gamma-ray air showers

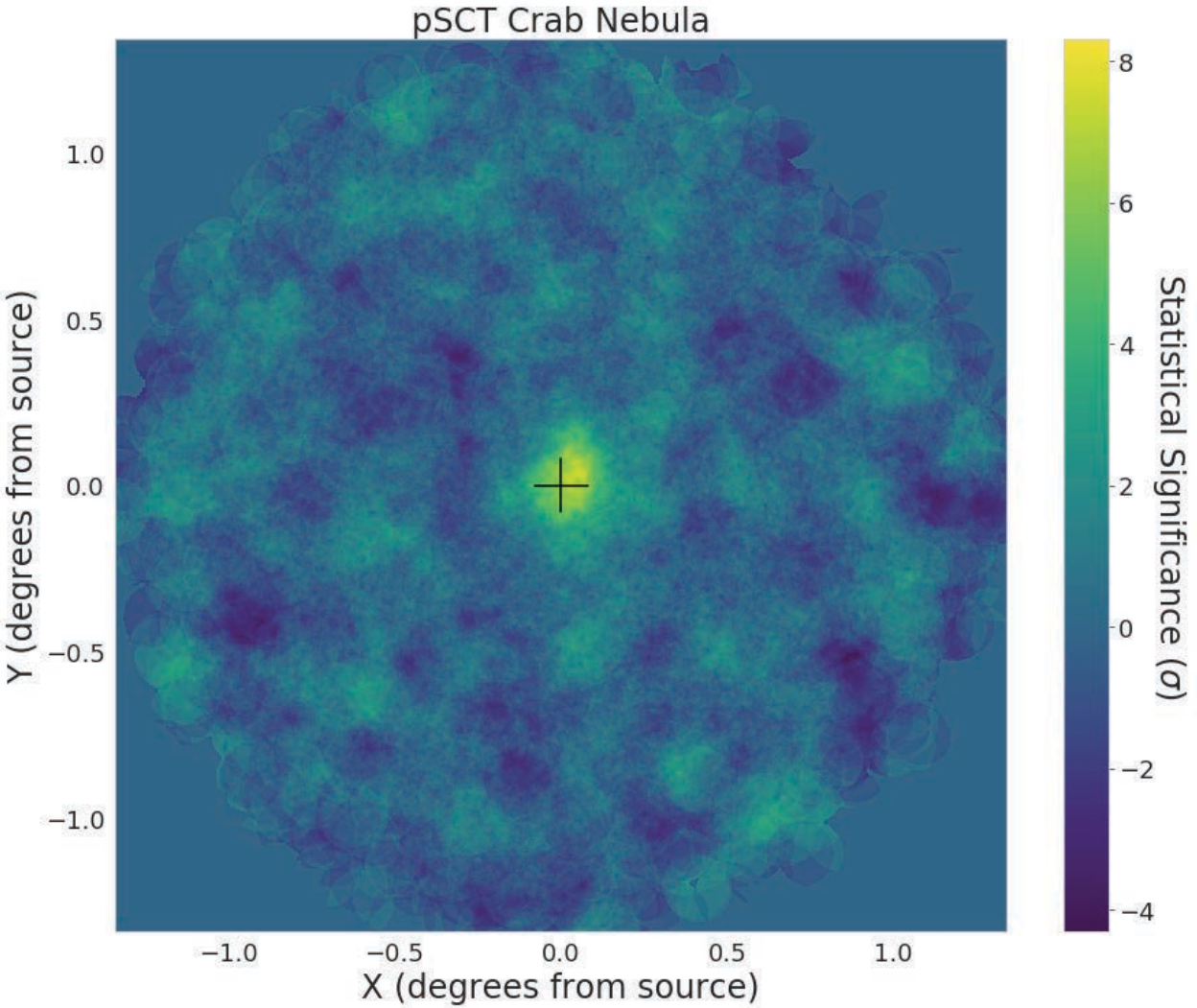


Detection of the Crab Nebula



Crab detection establishes innovative SCT technology for gamma-ray astronomy

Detection of the Crab Nebula



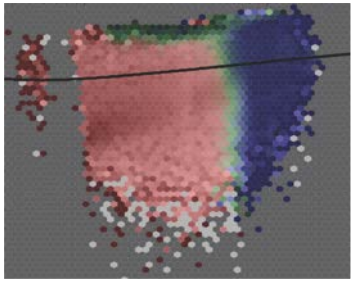
Crab detection establishes innovative telescope technology for gamma-ray astronomy

https://www.cta-observatory.org http://cta-psct.physics.ucla.edu justin.vandenbroucke@wisc.edu

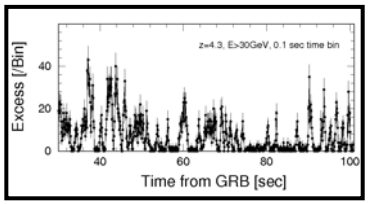
Additional slides

Geometry of an air shower image

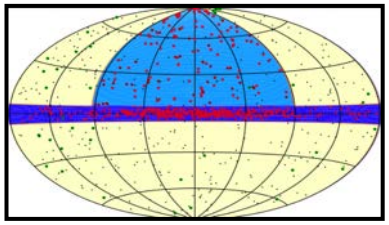
Key Science Projects (KSPs)



Dark Matter Programme

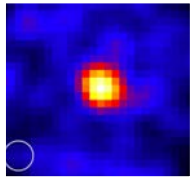


Transients



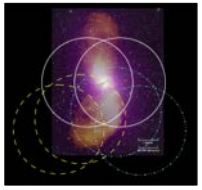
ExGal Survey

Galaxy Clusters



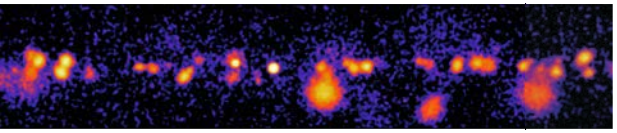
Star Forming Systems

AGN



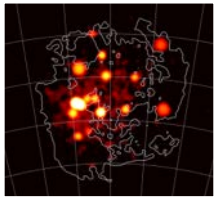
Extragalactic

Galactic

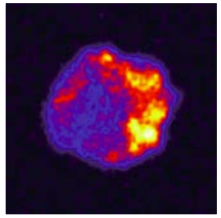


Galactic Plane Survey

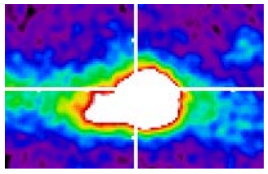
LMC Survey



PeVatrons

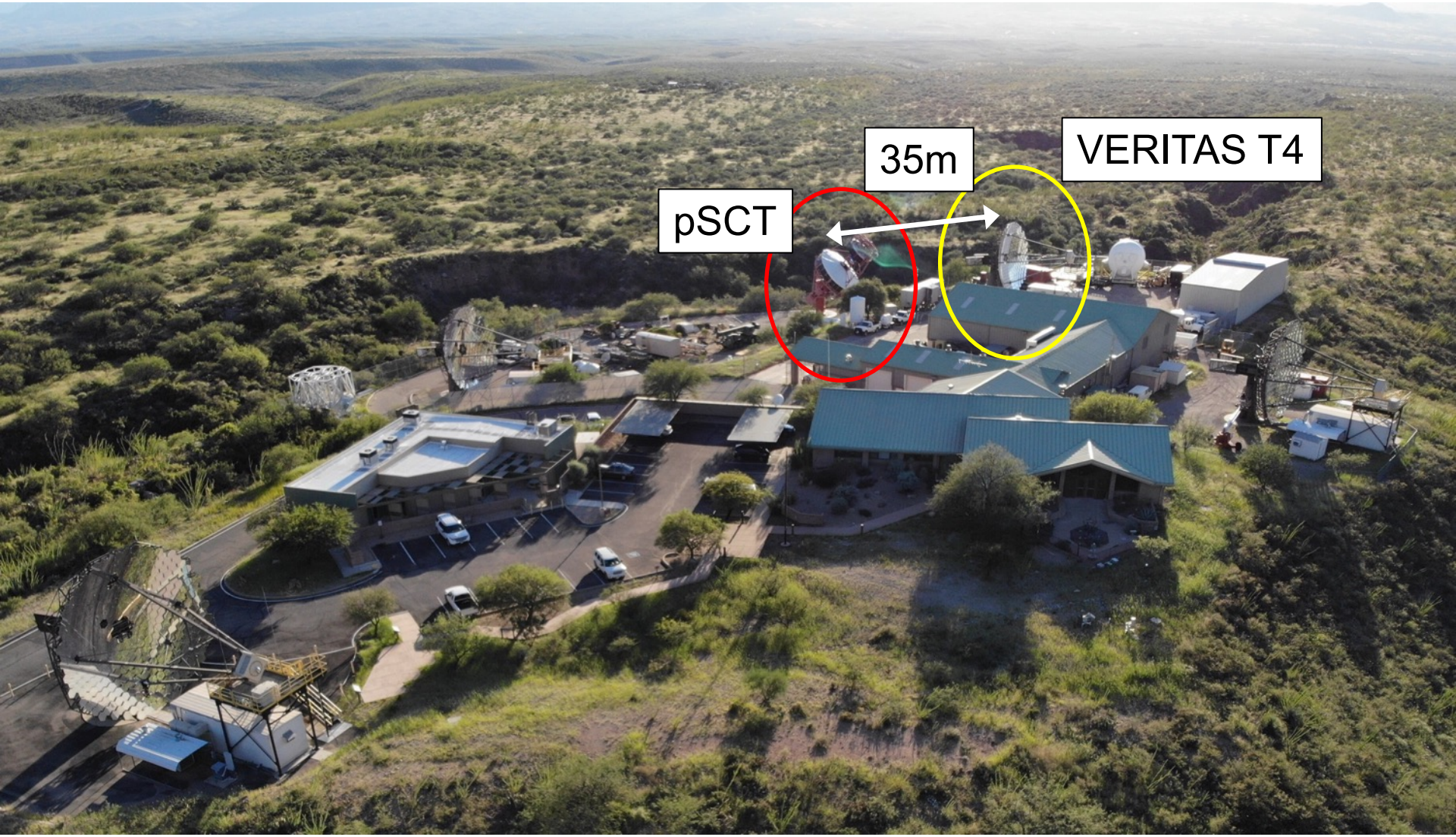


Galactic Centre

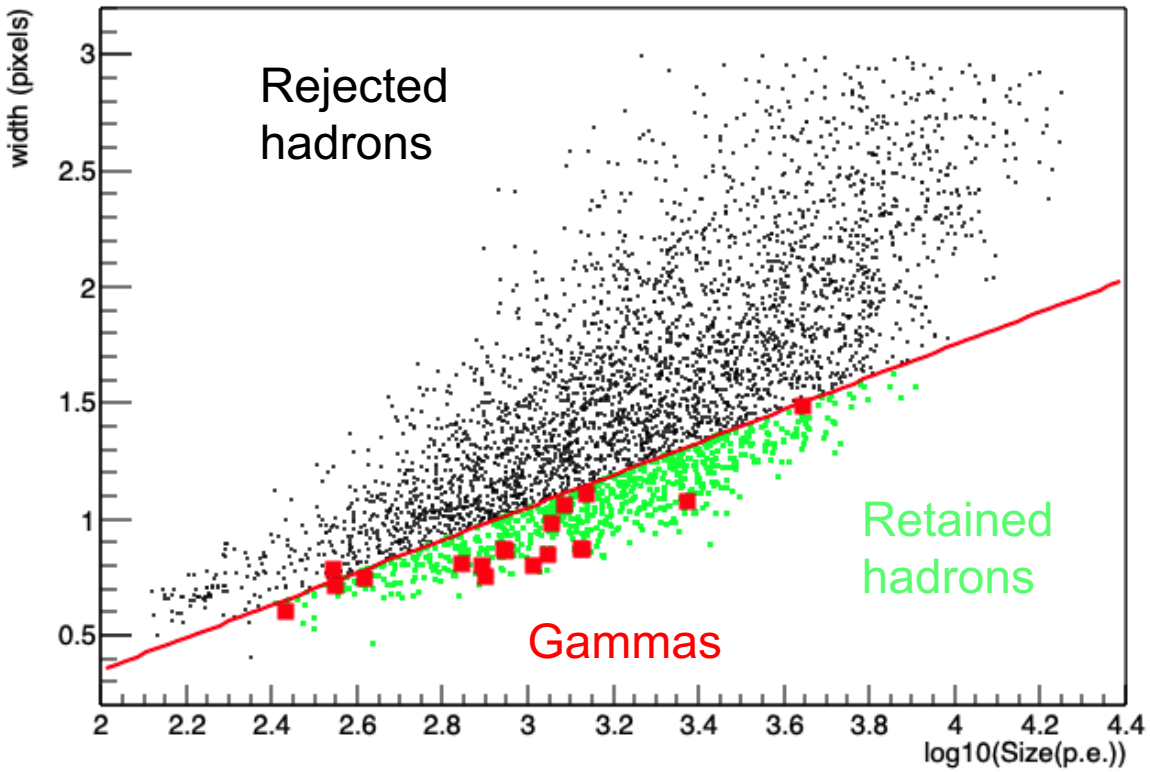


cta cherenkov telescope array

The pSCT is near VERITAS Telescope 4:
2 telescopes can detect the same showers, with similar viewing angle



Optimizing pSCT event selection using VERITAS-tagged gamma/hadron dataset

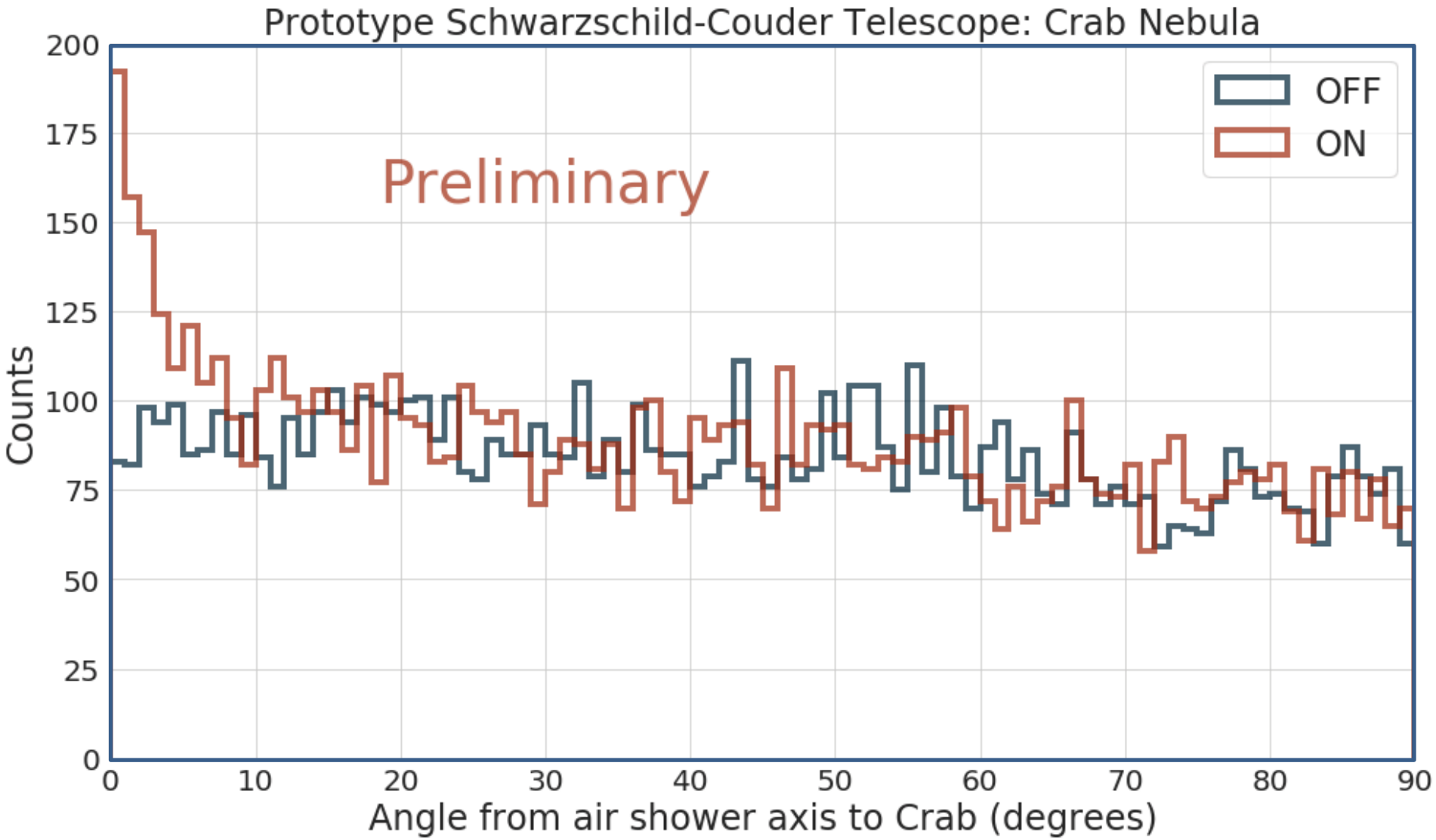


- Punch et al. 1991
- Lewis et al. 1993

Cuts retain 94% of gammas (17/18), reject 95% of hadrons

After developing pSCT cuts on 2.2-hour VERITAS-tagged dataset:
Apply them to a disjoint pSCT-only dataset (19.1 hr ON)

Crab Nebula: Results

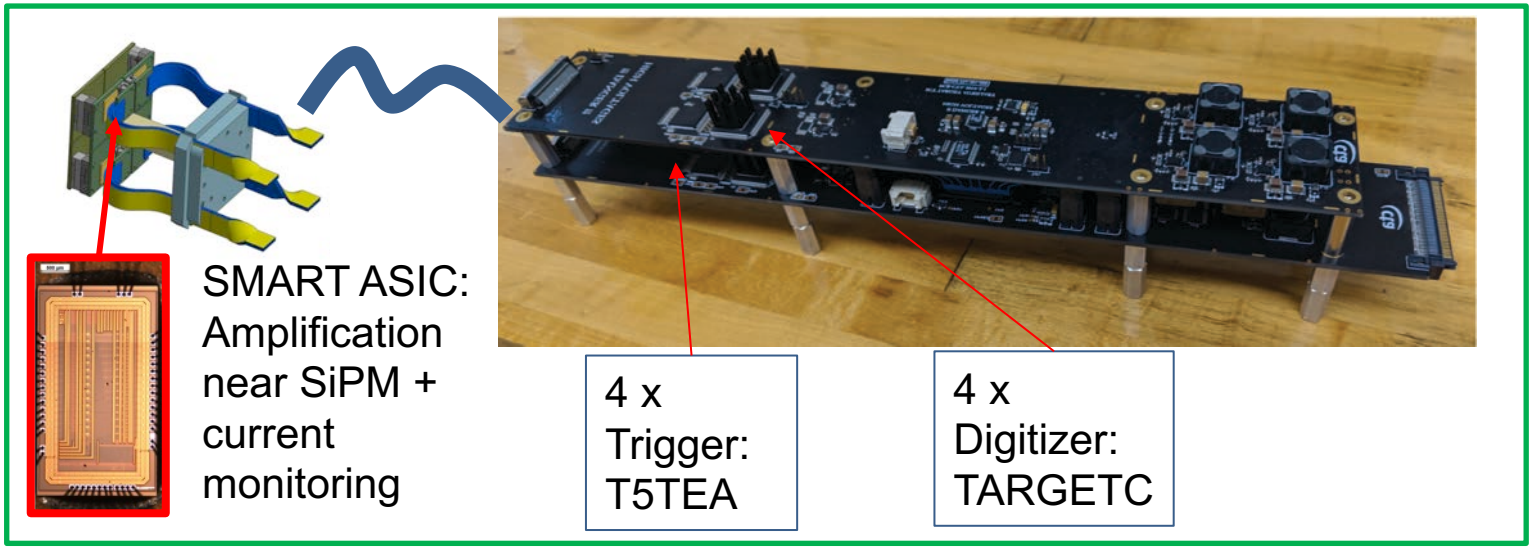


Results presented for the first time at this meeting

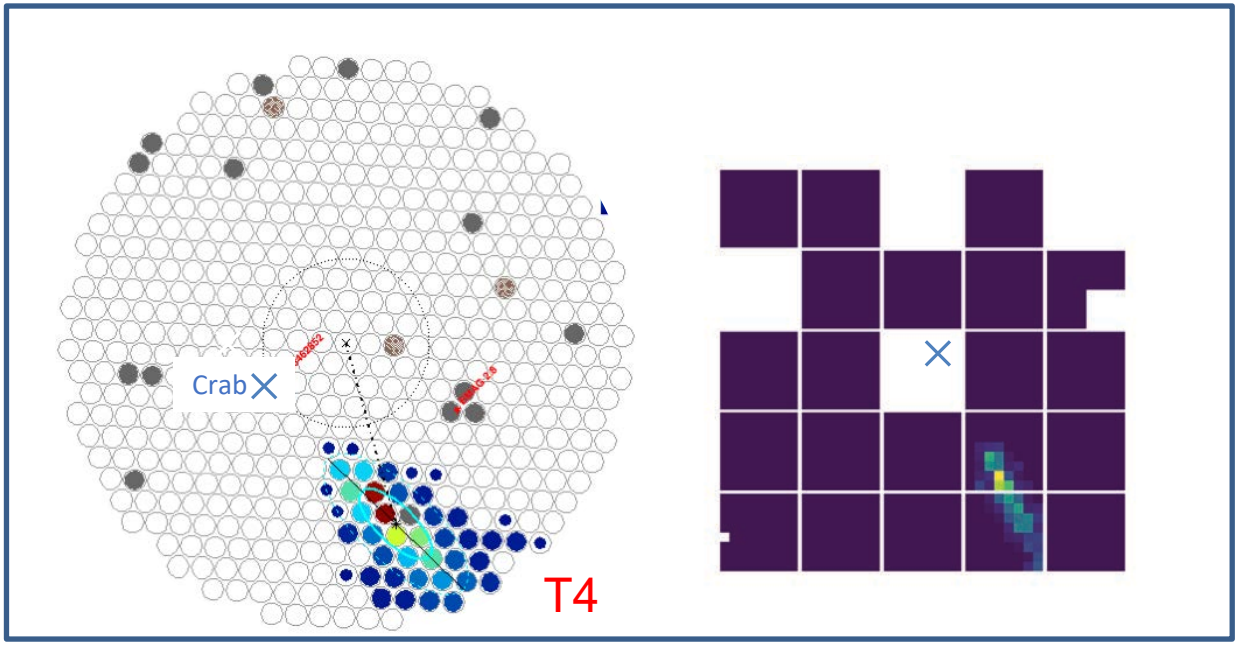
Next steps: camera upgrade project underway

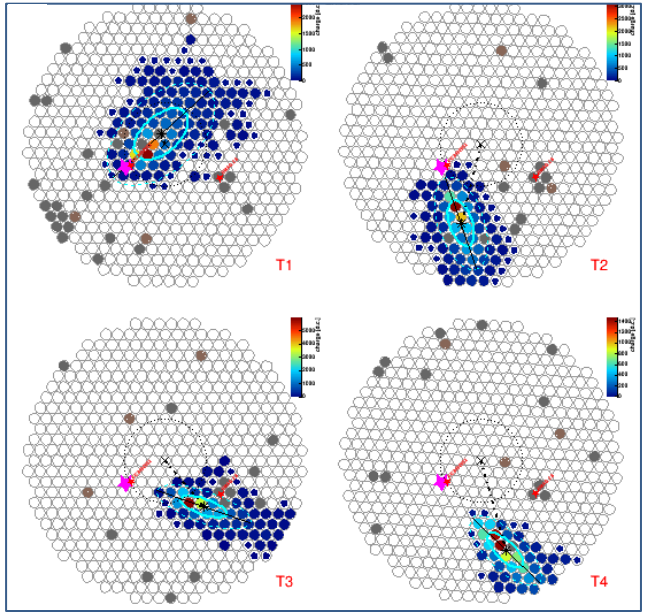
- From, 1600 pixels (2.7° field of view) to 11,328 pixels (8 deg)
- Reduce electronics noise (and gamma-ray energy threshold)
- Additional improvements to shutter, cooling, backplane, DACQ boards
- Funded by NSF (Major Research Instrumentation) and INFN
- Started in 2018, completion planned for 2021-22

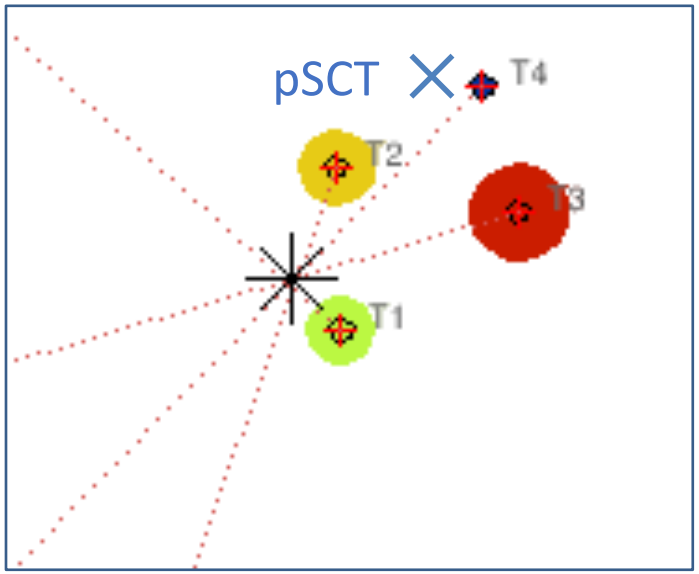
Revised camera module design



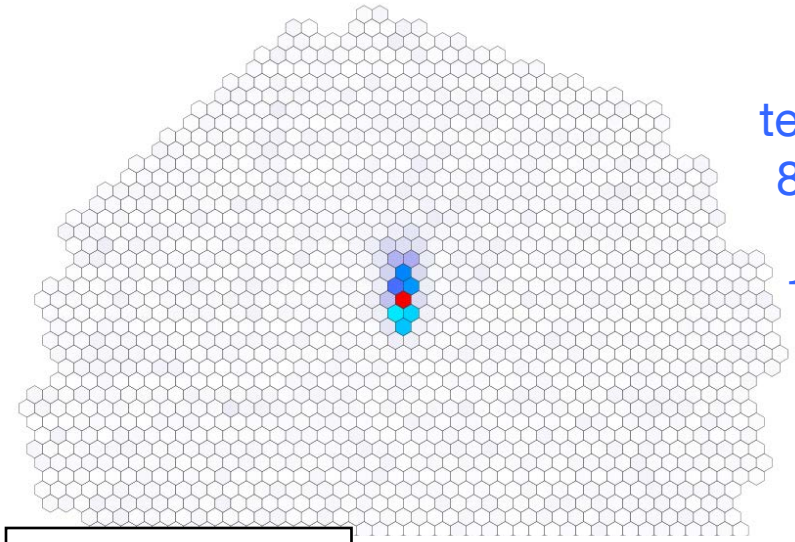
A 3.5 TeV gamma ray detected by both pSCT and VERITAS





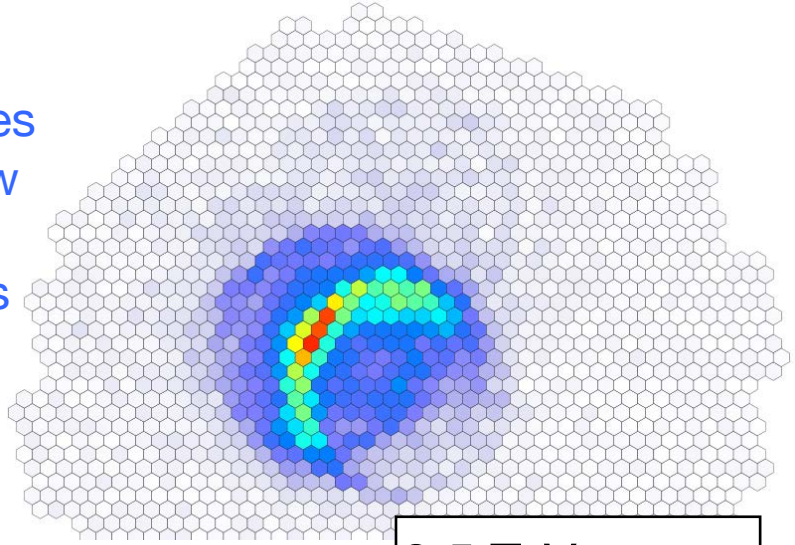


Simulated shower images for two-mirror compared to one-mirror telescope design

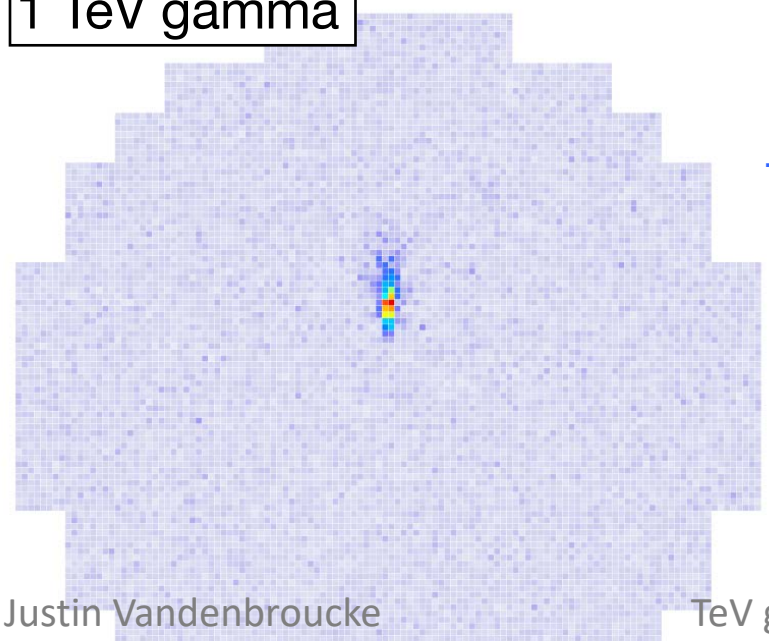


1 TeV gamma

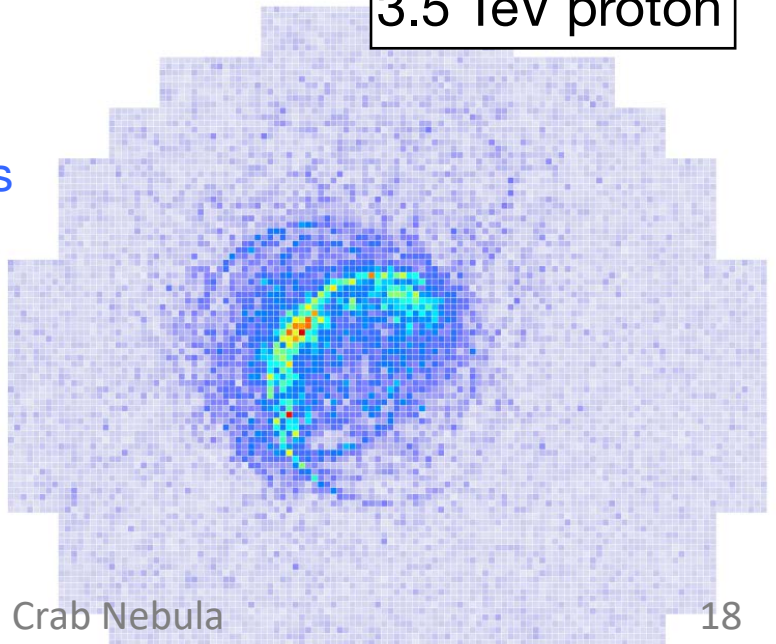
Single-mirror
telescope images
8° field of view
0.18° pixels
1,570 channels



3.5 TeV proton

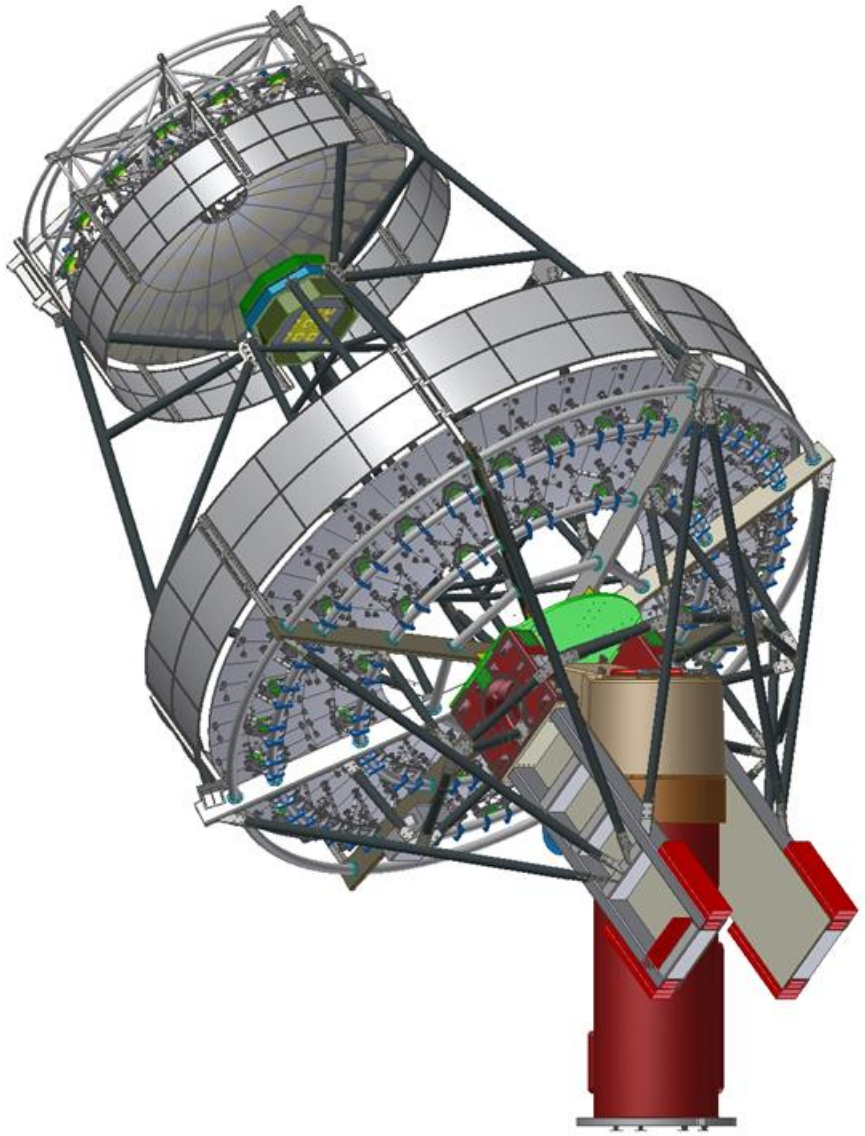


Two-Mirror
telescope images
8° field of view
0.067° pixels
11,328 channels

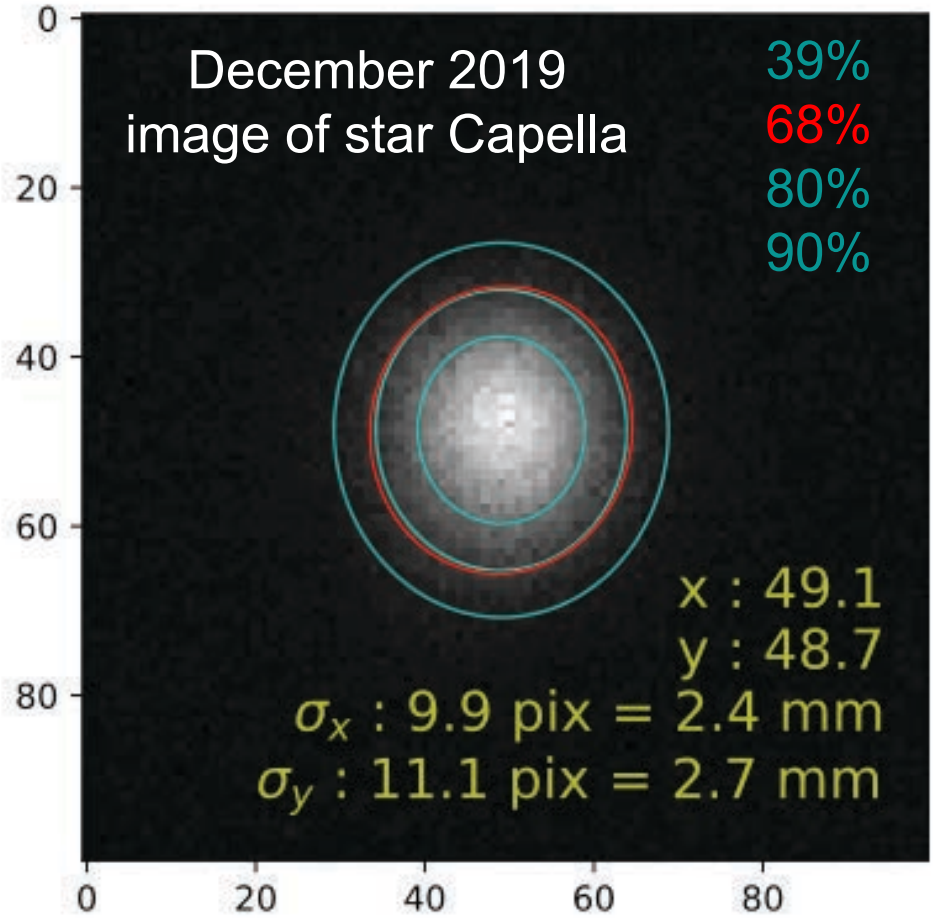


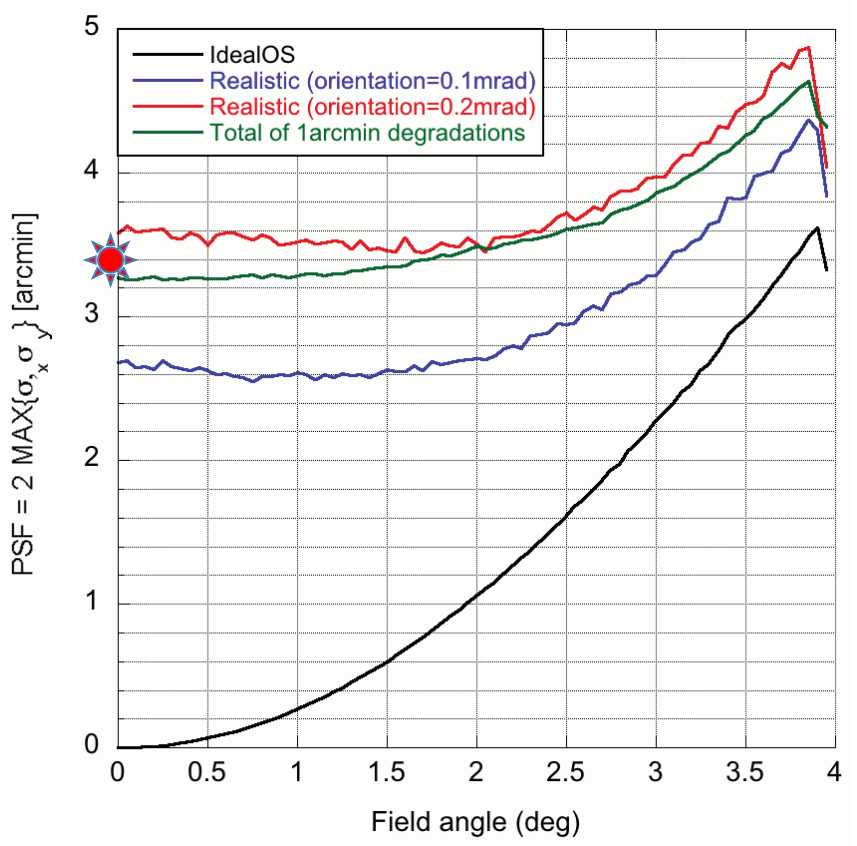
Schwarzschild-Couder Telescope concept: high-resolution optics and camera enabling exquisite imaging

- Dual mirrors allow (1) excellent optical angular resolution over wide (8° diameter) field of view (2) small camera
- Small focal plane for dense, highly integrated photo-sensors (silicon photomultipliers) and electronics (application-specific integrated circuits)
- Improved gamma-ray angular resolution and background rejection allow improved sensitivity and scientific capabilities



First complete alignment of optical system: achieved December 2019



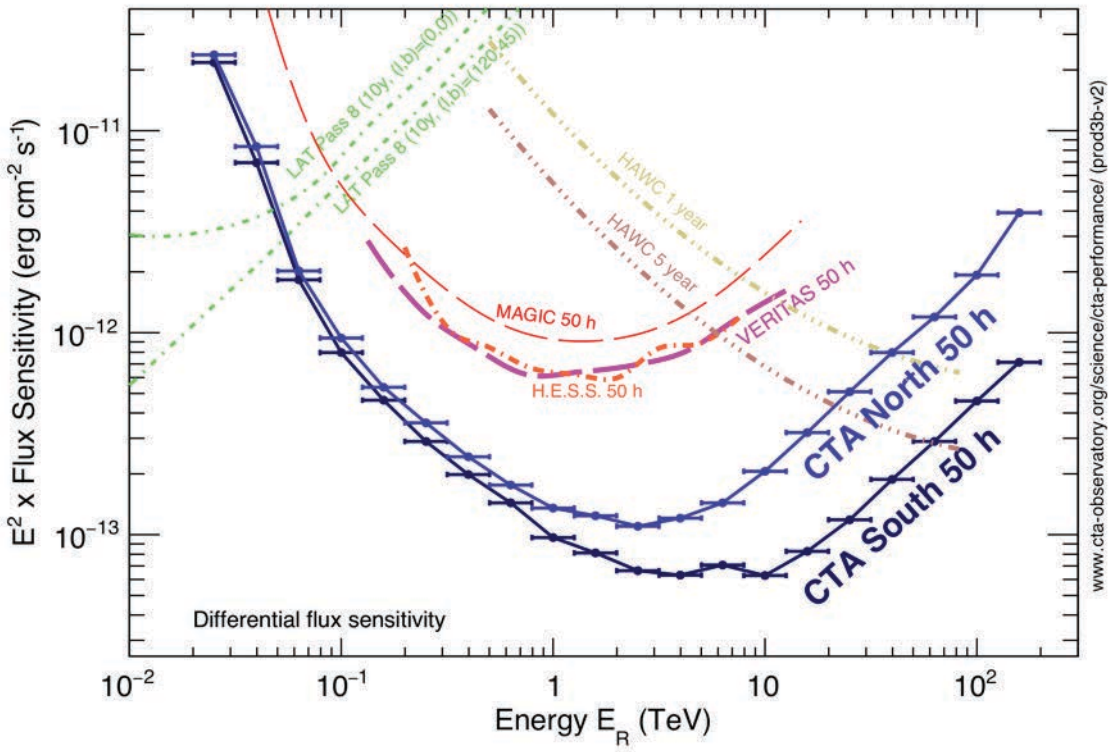


On-axis optical point-spread function measured to be 3.4 arcmin, matching pre-construction expectation

Science with Tera-electron-volt gamma rays, the highest-energy form of light detected from the Universe

- Multi-messenger (neutrino and gravitational wave) counterparts
- Galactic and extra-galactic particle accelerators: black holes and neutron stars
- Transient / time-domain astrophysics
- Dark matter

Sensitivity compared to today's instruments



Simulated Galactic Plane survey