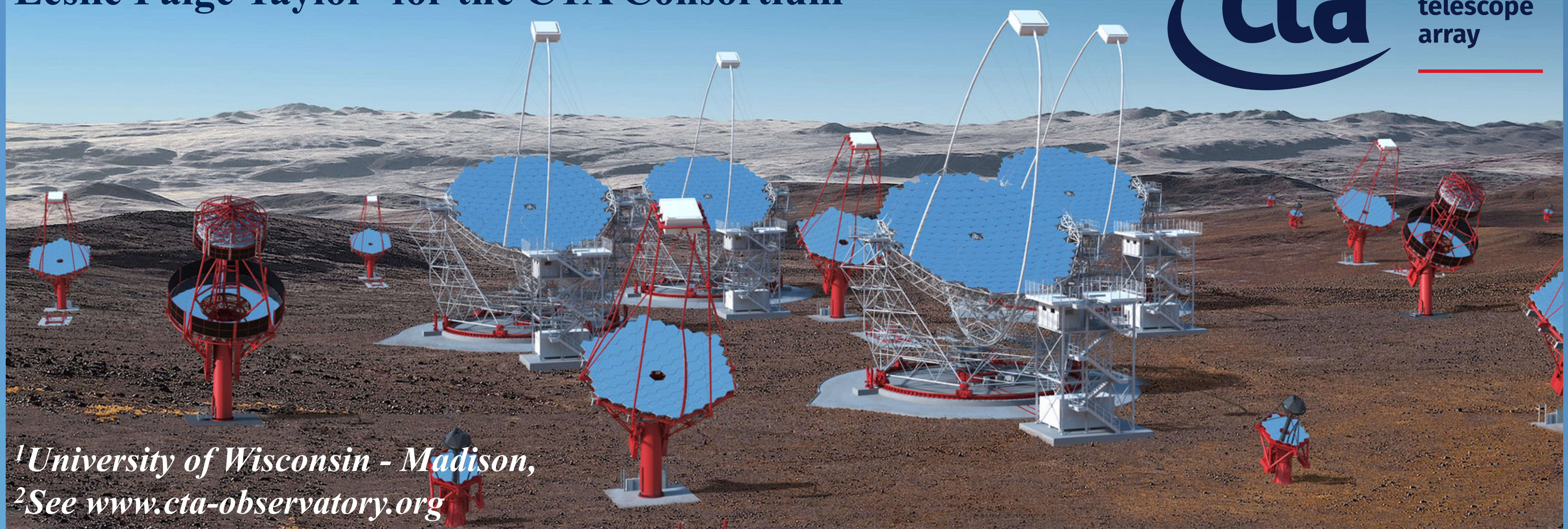
Design and Upgrade of the Prototype Schwarzschild-Couder Telescope Camera

Leslie Paige Taylor[1] for the CTA Consortium[2]

cta cherenkov telescope array



[1]University of Wisconsin - Madison,
[2]See www.cta-observatory.org

SCT Camera Design

The pSCT is located at the Fred Lawrence Whipple Observatory in southern Arizona. It uses a novel dual mirror design which results in a small plate scale, allowing the use of Silicon Photo-multipliers (SiPMs) as image sensors. The pSCT camera has a hierarchical design comprised of 9 sectors each with their own backplane PCB. Each sector can hold up to 25 modules Each module is comprised of a focal plane module (containing 64 image pixels) and front end electronics. Modules are inserted through the front lattice and connect to backplane electronics through the back bulkhead (Figure 1). Currently only the central sector is populated with modules. [1]

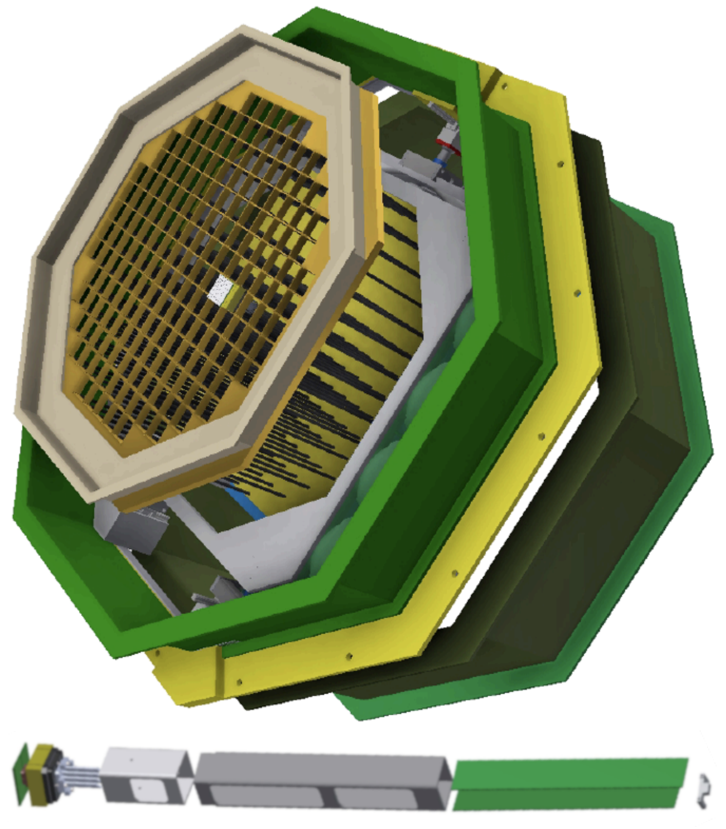
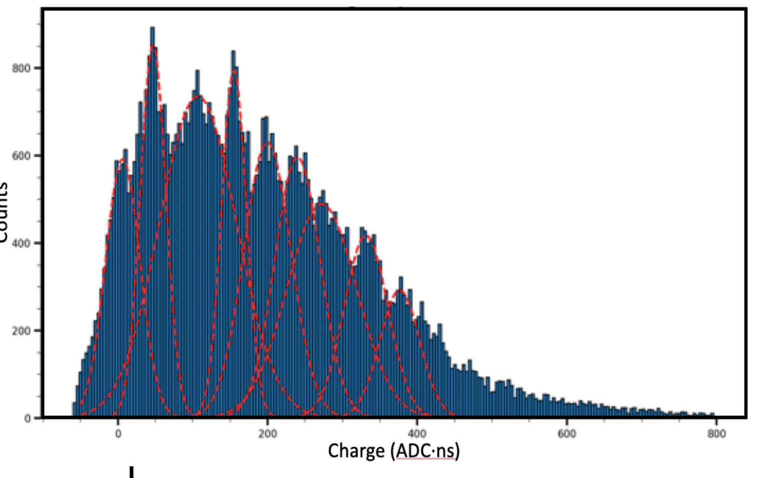


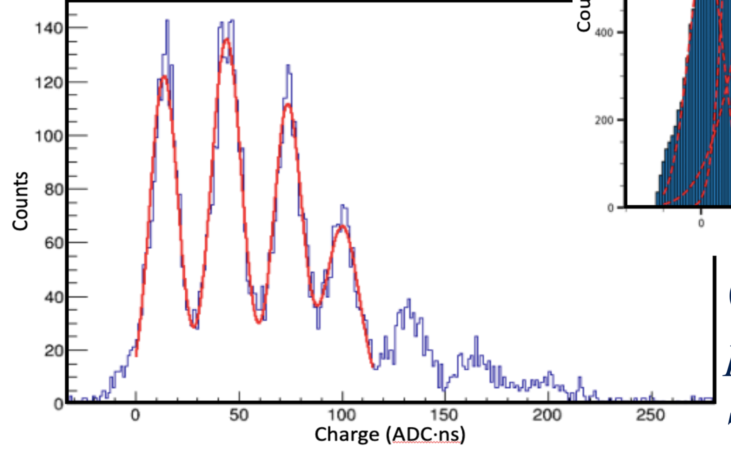
Figure 1: *Exploded view of the pSCT camera and one module. [1]*

Camera Upgrade

Camera module SiPMs and front end electronics are undergoing an upgrade. Figure 2 shows charge distributions of current and upgraded modules, illustrating a significant improvement in resolution. Additionally, the focal plane will be fully populated with upgraded modules increasing the number of modules from 25 to 177, number of pixels from 1600 to 11,328 and the field of view from 2.7° to 8°.

(a): Right plot. *Charge spectrum produced using current camera modules..*





(b): Left plot. *Charge spectrum produced using upgraded FBK SiPMs & front-end electronics.*

Figure 2: *The upgraded modules have lower noise and show a significant improvement in the charge spectrum resolution.*

Crab Detection

Observations of the Crab Nebula were taken in ON/OFF mode, meaning observations of the source (ON) were taken directly before or after observations of an offset field (OFF). OFF observations were chosen to cover the same elevation angles as the ON source observations. 48 observations of the Crab Nebula were taken, resulting in 21.6 hours of ON source exposure time and 17.6 hours of OFF source exposure time. When possible, ON source observations were taken simultaneously with VERITAS.

Events classified as showers were cleaned and parameterized using a simple geometrical moment analysis, resulting in Hillas image parameters. Length and width are particularly useful for differentiating gamma-ray and hadronic showers while the α parameter (angle between the shower ellipse axis and the camera center) can be used to identify a signal from a source.

Because the pSCT and VERITAS are co-located (Figure 3), VERITAS can provide independent information about air showers which are observed simultaneously by both instruments (Figure 4). 2.2 hours of coincident observations resulted in 18 coincident gamma-ray events and 11597 cosmic-ray events (as classified by VERITAS). These events were identified via timing coincidence between the two instrument's observations. Using only this 2.2 hours of simultaneous observation, selection criteria were established. Cuts were designed to retain 95% of the gamma-ray sample. These cuts were then applied to a separate sample of pSCT-only ON/OFF observations of the Crab Nebula.

Figure 5 shows the distribution of the α parameter for both ON and OFF source observations. At low values of α an excess in ON-source observations corresponds to a statistical significance of 8.6σ. [2] This detection of the Crab Nebula demonstrates successful construction and operation of the pSCT. The fully upgraded pSCT will be a powerful next-generation instrument.

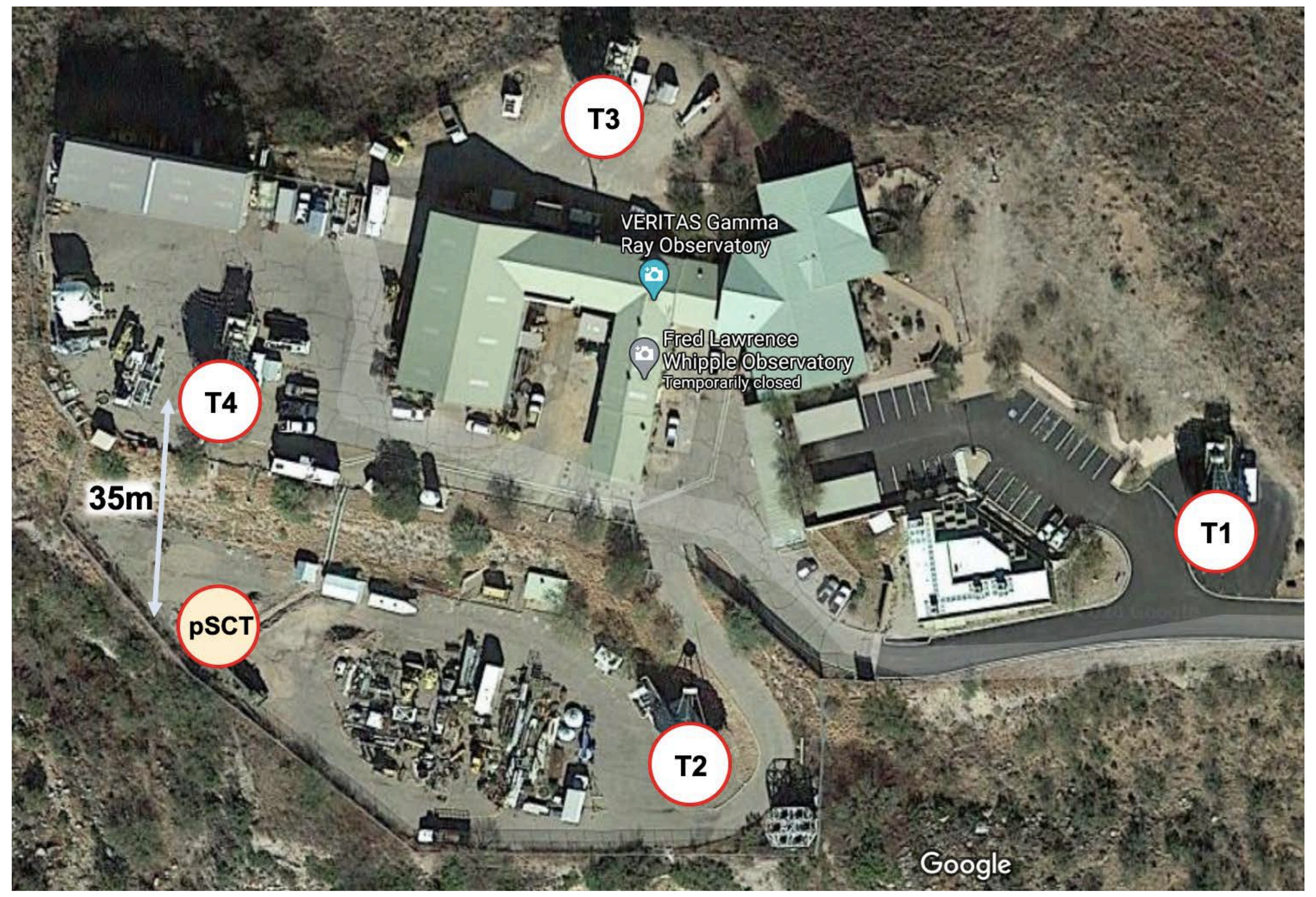


Figure 3: *Location of the pSCT in relation to the four VERITAS telescopes. VERITAS telescope-4 and the pSCT are located close to one another - only 35 m apart.*

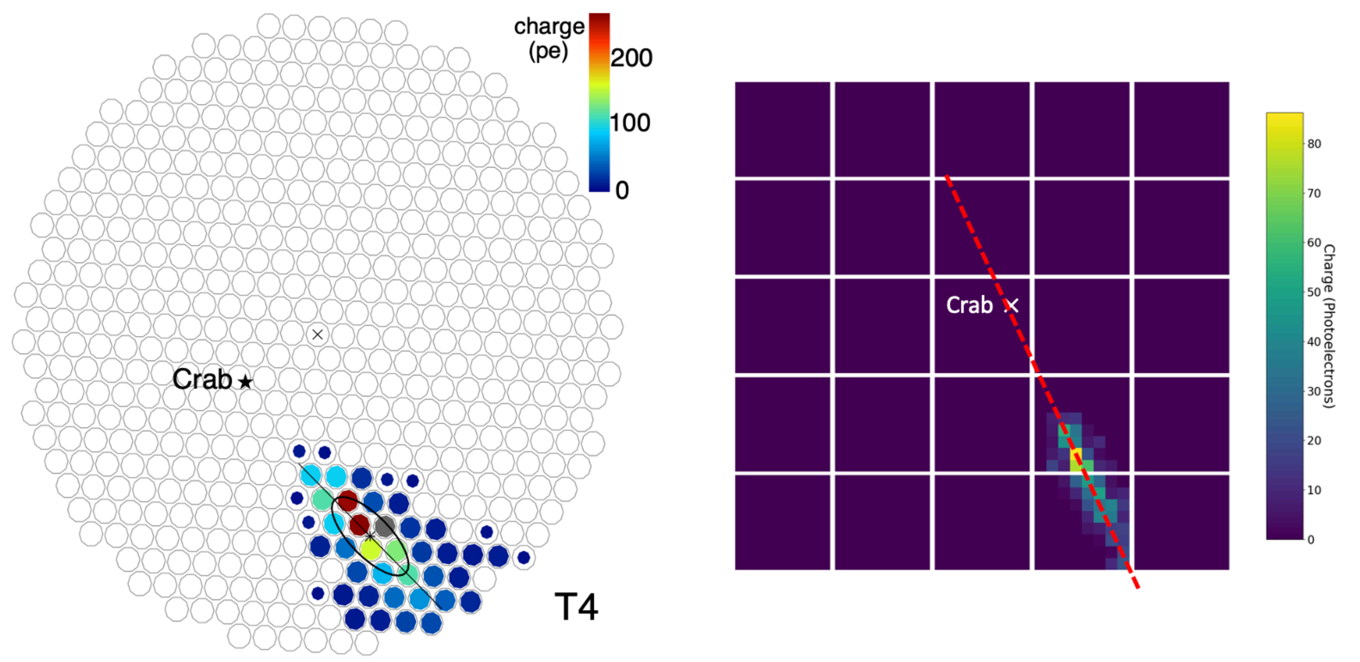


Figure 4: The same air shower event observed by VERITAS telescope-4 (left) and the pSCT (right). [2]

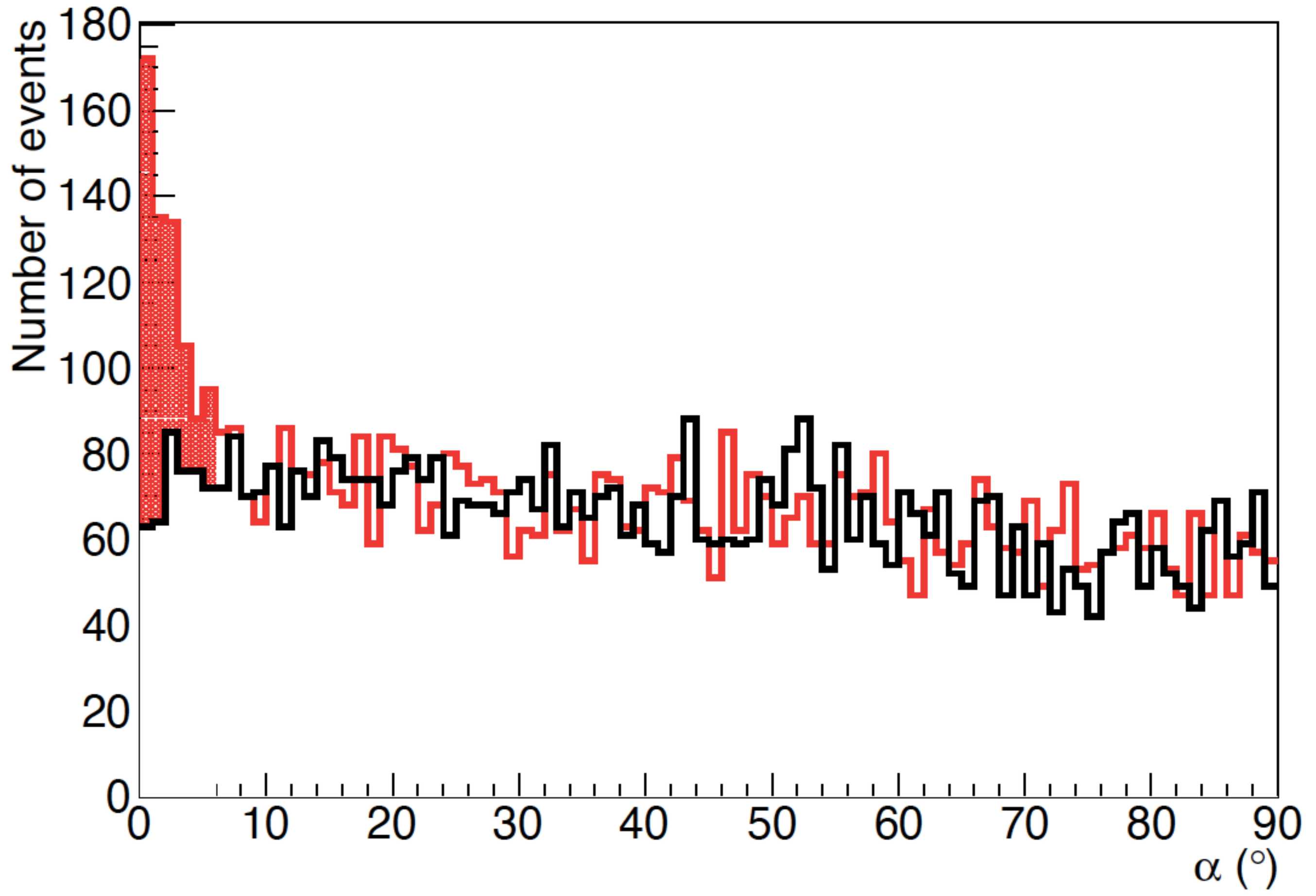


Figure 5: Distribution of the α parameter for matched ON (red) and OFF (black) Crab Nebula source observations, after applying selection cuts. The ON-source excess at low α, corresponds to a statistical significance of 8.6σ. [2]

Primary Author:
Leslie Paige Taylor
ltaylor23@wisc.edu

REFERENCES

[1] Adams, C.B., et al. "Design and performance of the prototype Schwarzschild-Couder Telescope camera," J. Astron. Telesc. Instrum. Syst. 8(1), 014007 (2022), doi: 10.1117/1.JATIS.8.1.014007.

[2] Adams, C. B., et al. "Detection of the Crab Nebula with the 9.7 m prototype Schwarzschild-Couder telescope." Astroparticle Physics 128 (2021): 102562.

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