The Small-Sized Telescopes for the Southern Site of the Cherenkov Telescope Array

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ABSTRACT

CTA will use three telescope sizes to efficiently detect cosmic gamma rays in the energy range from several tens of GeV to hundreds of TeV. The Small-Sized Telescopes (SSTs) will form the largest section of the array, covering an area of many square km on the CTA southern site in Paranal, Chile. The SSTs will provide unprecedented sensitivity to gamma rays above 1 TeV and the highest angular resolution of any instrument above the hard X-ray band.

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Introduction

CTA has finalised the technology that will be used for the SSTs. The telescopes will be a dual-reflector, Schwarzschild-Couder, design, based on the ASTRI and CHEC prototype telescope structure and camera (Fig. 1, 2). The optical configuration leads to a large field of view and a small plate-scale (and consequently a compact, cost-efficient camera).

The SST Programme has recently been established to finaslise the SST design and provide all SSTs as an in-kind contribution to the CTA Observatory. The Programme will incorporate lessons learnt from all SST prototyping efforts

Optics & Mechanics

The SST optical design (Fig 3, 4) features a primary reflector 4.3 m in diameter constructed from 18 hexagonal mirrors. The monolithic secondary mirror sits 3.0 m from the primary, with a diameter of 1.8 m. The focal plane is located 0.52 m from the secondary mirror and has a radius of curvature of 1.06 m. The ASTRI-Horn prototype successfully provided a robust optical validation of a Schwarzschild-Couder telescope for the first time in 2017.

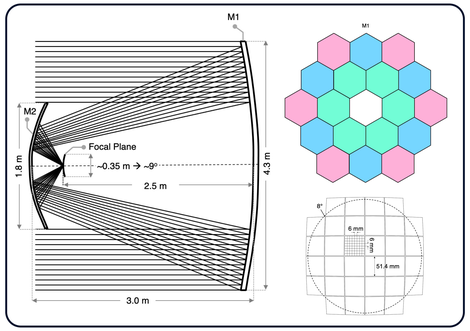

Fig. 3: Overview of the SST optical system, layout of primary reflector mirrors, and the focal plane layout.

Fig. 1: The ASTRI-Horn prototype at the Catania Astrophysical Observatory.

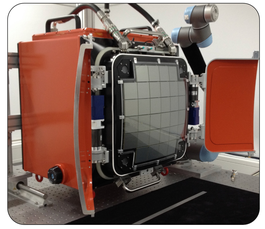

Fig. 2: The CHEC-S camera prototype undergoing laboratory tests.

Camera

The SST Camera design features (Fig. 5) 2048, 6 mm x 6 mm, SiPM pixels, implemented as 32 tiles arranged to approximate the curved focal plane and attached to electronics modules based on the TARGET ASICs for digitisation (at 1 GSa/s) and triggering. A backplane and timing board provide camera-level triggering with nanosecond precision and readout of 128 ns waveforms from all pixels on a 10 Gbps link. A door system & entrance window provide protection and minimise NSB transmission. LED flashers provide an internal calibration source. The camera is liquid cooled by an external chiller.

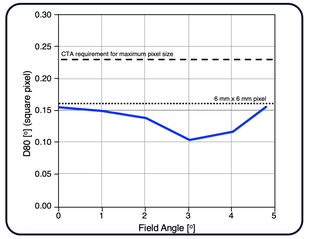

Fig. 4: SST point spread function (80% enclosed energy) vs. off-axis angle.

On-Sky Verification

Preliminary verification of the SST concept was performed by installing CHEC-S on the ASTRI-Horn prototype in 2019. Over two observing campaigns the on-sky performance, interfaces, and camera installation procedure were investigated. Fig 6 shows a selection of Cherenkov images captured; comparison to simulations showed a good match, as did trigger rates vs. threshold for varying NSB conditions. The camera was also used for astrometry, using a second readout chain to reconstruct the pointing direction of the telescope.

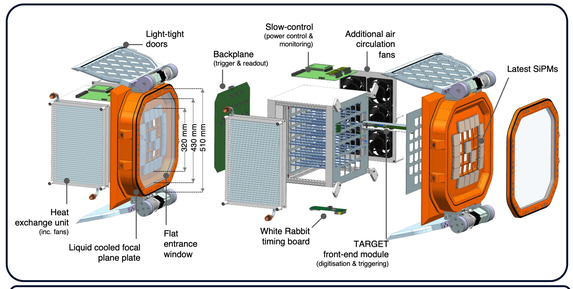

Fig. 5: An overview of the camera CAD indicating the major sub-systems, integrated (left) and exploded (right). Note - the external enclosure is not shown.

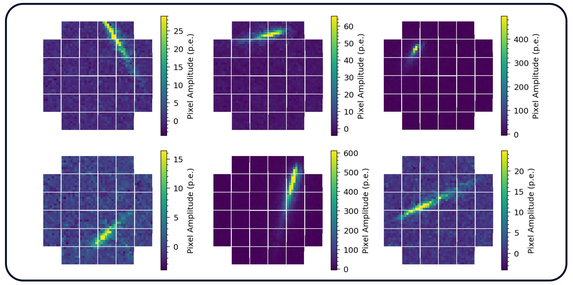

Fig. 6: Examples of Cherenkov images recorded with the CHEC-S camera installed on the ASTRI-Horn telescope.

ACKNOWLEDGEMENTS

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