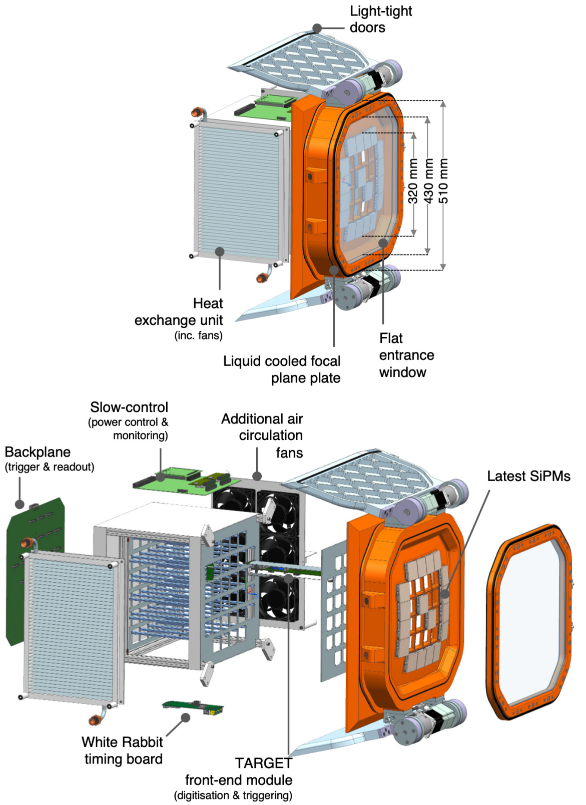
silicon photomultipliers (SiPM) as light sensors on a tile. Each tile is connected to a front-end electronics module based on Application Specific Integrated Circuits (ASICs), that provide SiPM bias control, waveform digitisation and a first-level camera trigger. The sampling rate is set to 1 GSa/s, and the size of the readout window digitised from the storage array to 96-128 ns to capture off-axis events as they transit the focal plane.

A slow-signal digitisation chain is included to track the pointing of the telescope via stars during normal operation. The 32 camera modules are connected to a custom back-plane that provides the interface for power, clock, trigger and data.



A CAD view of the SST Camera.

The camera includes an illumination system to provide calibration via fast, variable intensity, LED flashes. An entrance window and external door system provide protection from the elements. Thermal control of the camera is via an external chiller.

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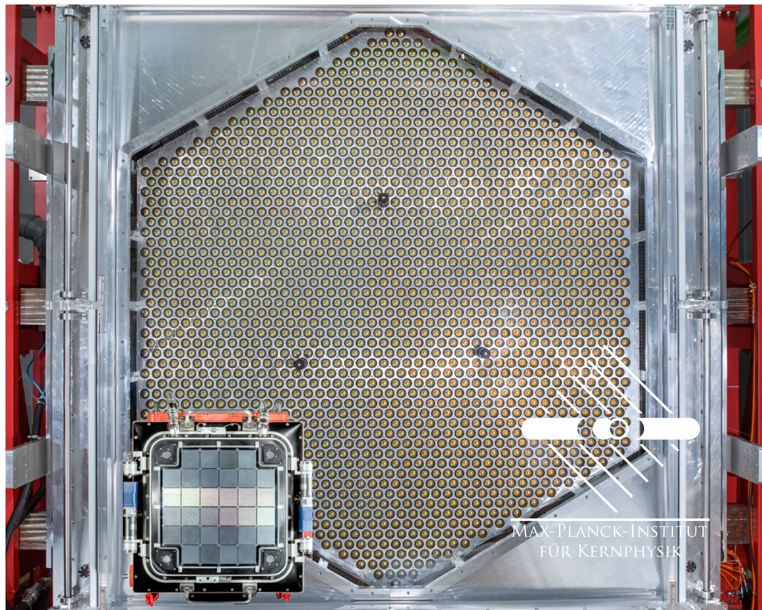
cherenkov telescope array

High Performance Cameras

for the Cherenkov Telescopes of CTA



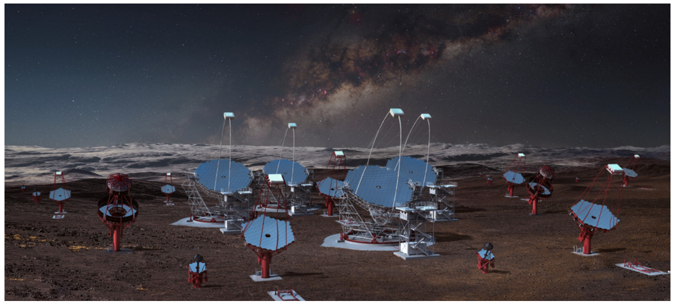
High Performance Cameras for the Cherenkov Telescopes of CTA

Despite – or in fact because of – the great success of gamma astronomy with Cherenkov telescopes like H.E.S.S., there are still numerous open scientific questions. The Cherenkov Telescope Array (CTA) is a next-generation instrument for gamma astronomy at the highest energies. It will exceed the performance of present instruments by an order of magnitude and is to address these questions. Overall up to 118 telescopes with three different mirror sizes of about 4 m, 12 m and 23 m diameter are planned for CTA at two sites in the northern and southern hemispheres, respectively, covering a large energy range from about 10^{10} to above 10^{14} eV.

Cameras for Cherenkov telescopes

Cameras for Cherenkov telescopes must be able to resolve the faint flashes of atmospheric Cherenkov light from gamma- and cosmic-ray initiated particle cascades, which last only a few nanoseconds, against the background light of the night sky. In addition, they must be capable of capturing many thousand exposures per second.

In a first construction phase of CTA, 14 medium-sized telescopes will be built at the southern and 9 at the northern site. 37 small-sized telescopes distributed over an area of several square kilometres will be deployed at the southern site only. Given their large number, CTA cameras must be cost-effective and high performance, furthermore easy to maintain, consume little power, and at the same time work reliably and safe.

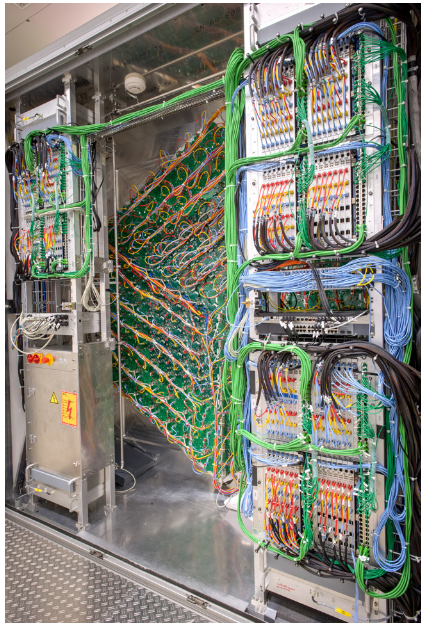


Rendering of the southern CTA array. © G. Pérez Diaz (IAC) / M.-A. Besel (CTAO) / ESO / N. Risinger (skysurvey.org)

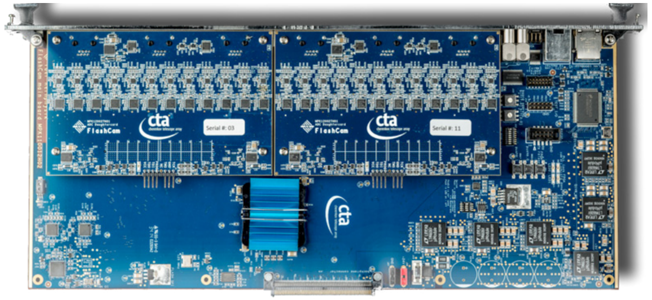
FlashCam: for medium-sized telescopes

Together with several European partner institutes, the MPIK has developed a novel camera type called FlashCam, which fulfils these requirements and is designated for implementation in medium-sized CTA telescopes of the southern array. The central functional elements of FlashCam are a photon detector plane and digital high-speed read-out electronics, which are both designed in a highly modular manner.

The photon detector plane consists of 147 identical electronics modules each equipped with 12 photomultiplier tubes (38 mm diameter) as light sensors. These are capable of resolving ultrashort light pulses of a few nanoseconds duration, consisting of a few up to several thousand photons, and to convert them into a measurable electrical signal. These signals are then continuously digitised by the read-out electronics with a sampling rate of 250 MHz and a resolution of 12 Bit, and are available for subsequent digital signal processing and storage. This takes place in parallel in several steps on up to 96 FPGA-based processors which extract events (Cherenkov images or "exposures") from the digital raw-data flux of up to 5.3 TBit/s. Therefore, it is required that within a few nanoseconds several neighbouring light sensors detect a signal which exceeds the light of the night sky. Subsequently, the digital information of the extracted exposures is buffered on the FPGAs, and is ready for read-out via ethernet to a standard computer. The electronics, firmware, and software, developed at MPIK, make it possible to capture and process without loss of information more than 30 000 exposures per second.



Rear view of FlashCam with electronics units and cabling.



FlashCam electronics module, developed at MPIK, with 24 analogue to digital converters and an FPGA-based processor.

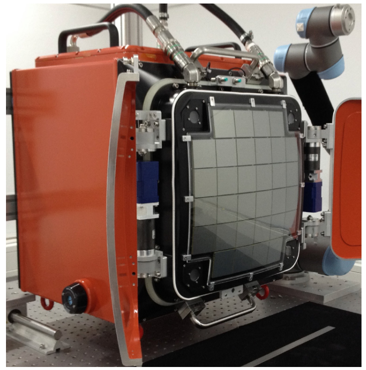
Photon detector plane and read-out electronics are mounted in a 3.0 m × 3.0 m × 1.1 m thermally insulated case with water cooling. FlashCam weighs around 2 tonne.

Since October 2019, an advanced FlashCam prototype camerais installed in the central 600 m² H.E.S.S. telescope and routinely used for astrophysical observations. The camera is working extremely stable and reliable with an availability of more than 98%.

SST Camera: for small-sized telescopes

The small-sized CTA telescopes (SSTs) will have a dual-mirror optical design. This results in compact telescopes with good image quality and a large field of view. An international team lead by MPIK is developing a novel camera for the SST. The SST Camera will feature a curved focal plane, to match that required by the telescope optics, with a radius of curvature of ~1 m and a diameter of about 35 cm, which is approximated by tiling the camera with 32 identical photosensor modules.

The SST Camera is based on the CHEC-S prototype and with a mass of under 90 kg, and a size of under 60 cm × 60 cm × 50 cm, it is significantly more compact than it's large FlashCam cousin. A total of 2048 pixels provide a high resolution: per module 64 each 6 × 6 mm² small



The CHEC-S camera installed in the lab at MPIK during testing.