# 6 Very High Energy Gamma Ray Astronomy with CTA

D. Florin, A. Gadola, R. Gredig, B. Huber, A. Manalaysay, S. Steiner, U. Straumann, A. Vollhardt

*in collaboration with:* ETH Zürich, Jagiellonian University Cracow, MPI für Kernphysik Heidelberg, University of Leeds, Universität Tübingen.

The full CTA collaboration consists of 115 institutes from 23 countries.

(CTA)



The Cherenkov Telescope Array (CTA) is a planned next generation array of Imaging Atmospheric Cherenkov Telescopes (IACTs), and is the successor to the current generation of IACTs including MAGIC [1], H.E.S.S [2], and VERITAS [3]. These telescopes are used to detect Very High Energy (VHE) gamma ray photons, in the range of tens of GeV to tens of TeV, emitted from exotic (i.e. non-thermal) astrophysical sources such as quasars, supernovae and their remnants, gamma-ray bursts, and dark matter annihilations. See our contribution to the previous annual report for further details on the motivation for CTA.

## Active Mirror Control

Current and future imaging air Cherenkov telescopes use large primary mirrors that are composed of multiple mirror "facets" pieced together to form a much larger mirror. This design facilitates an easier construction of the primary mirror to high optical tolerances, compared with a single large mirror. Each mirror facet is attached to the telescope structure at three fixation points. Between the telescope structure and each fixation point is a rod of adjustable length. Varying the length of individual rods on a single mirror facet allows the orientation of the facet to be fine-tuned.

We have developed a system of wirelessly controlled mechanical actuators that attach to the mirror fixation points that allow the facet orientations to be adjusted remotely, as part of an Active Mirror Control (AMC) system. A fixed rod is attached to one of the three fixation points, while movable actuators are attached to the other two fixation points. Prototype models of the actuators were produced in the middle of 2009 and have been under continuous outdoor tests since then, completing so far nearly three million full cycles of extension and retraction.

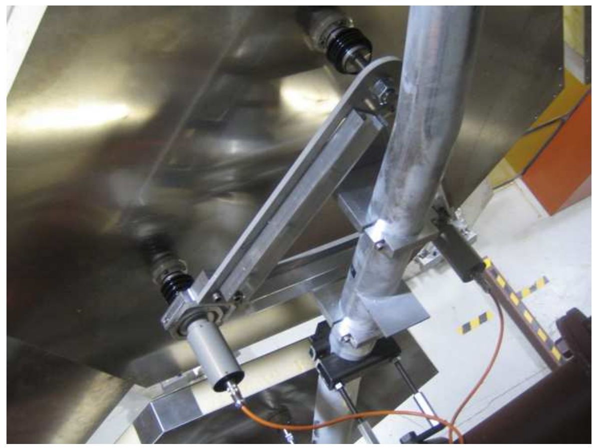

FIG. 6.1 – *Two UZH AMC actuators mounted on the prototype telescope quarter dish in DESY Zeuthen.*

The Medium-size Telescopes (MST) planned for CTA will be constructed after a series of two prototype structures. The first prototype is a quarter section of the full telescope, for which construction has already begun at DESY Zeuthen, in Germany. The quarter dish is outfitted with "dummy" mirrors (to simulate the size and mass of the real mirror facets), two of which are attached via UZH actuators. Figure 6.1 shows two of the UZH actuators attached to the quarter dish and powered in Zeuthen, assembled in June of 2011.

A full MST prototype will be constructed in Berlin in late of 2012. For the purpose of this proto-

Fig. 6.2 – *AMCs during mass production at UZH, to be used in the full Medium-size Telescope CTA prototype.*

type, we have mass-produced 200 AMC actuators. Figure 6.2 shows a sample of these devices during assembly at UZH. Along with the actuators, the rotatable gimbals that fix the actuator to the telescope frame, and the power cables and power distribution system have been produced.

## FlashCam

FlashCam is a proposed possible camera design for CTA that focuses on using a fully digital data and trigger pathway. It differs from more traditional IACT camera designs in that data is digitized continuously, as opposed to having first an analog trigger pipeline that is then used to decide when to digitize the stored analog data. Traditional techniques typically feature an effective sampling rate of around 2 GS/s. However, creating a continuously digitized 2 GS/s pathway is prohibitive both in terms of cost and power consumption for an array of cameras that each consist of thousands of channels. Interestingly, our collaborators at the Max Plank Institute for Nuclear Physics (MPI-K) in Heidelberg, Germany have shown that adequate instrumental and timing resolution can be achieved by using a system that samples at a rate of 250 MS/s. A telescope array of such digitizers is feasible, and is currently being prototyped.

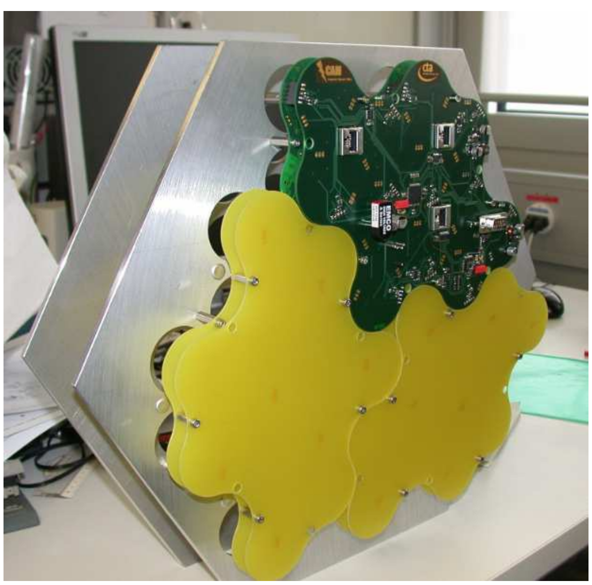

Fig. 6.3 – *Prototype of a section of the full FlashCam mechanics.*

A prototype model is being constructed at UZH that includes the full electronics chain of the real camera, with only twelve pixels. Figure 6.3 shows the mechanical structure of the prototype with two sets of dummy boards and one set of production electronics. Two boards are used in this case; the first board, closest to the photomultiplier tubes (PMTs), contains the high voltage divider and signal preamp. The second board contains the high voltage generation and slow control devices. Figure 6.4 shows the assembled twelve-pixel group from the front, with production PMTs from Hamamatsu Photonics specially designed for CTA. This device allows each PMT to be tested separately.

Fig. 6.4 – *Assembled twelve-pixel group of the FlashCam photon detection plane.*

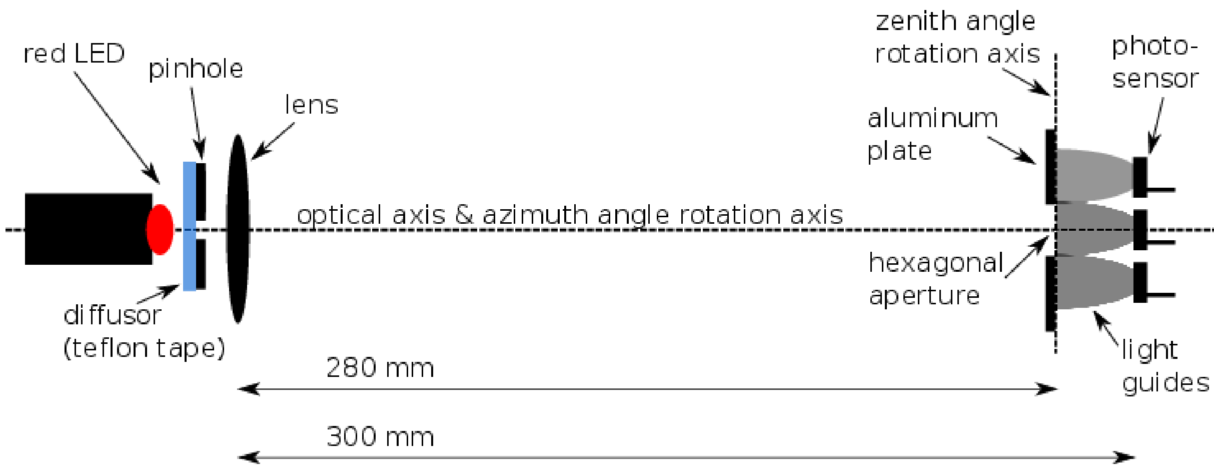




FIG. 6.5 – *Schematic of the test setup used for measuring the optical properties of the solid light concentrators used in the G-APD camera.*

## Solid Light Concentrators

Individual pixels of IACT cameras are in general equipped with special light concentrators that focus incident light onto the entrance area of the photosensors. With the aid of light concentrators, the sensitive area per pixel is increased and a nearly borderless full coverage of the full camera area is achieved.

In conjunction with the FACT group at the ETH-Zurich, our group has contributed extensively to the development of parabolic solid light concentrators made from injection-molded polymethyl methacrylate, and to the assembly of the FACT optical front plane. The light concentration is based on total internal reflection. The exit area is tailored to the sensitive area of commercial 3×3 mm$^2$ Geiger-mode avalanche photodiodes (G-APDs). The design and fabrication of these devices has gone through three production iterations, starting from machined Plexiglas to the final injection molded pieces mentioned above. A test setup (Fig. 6.5) has been produced at UZH to measure the optical properties of each prototype design, including transmission efficiency and angular acceptance roll-off. Additionally, the performance of the optical coupling between light concentrator and G-APD has been extensively studied with this setup. The full set of final light cones have been produced and assembled into the optical front plane of FACT, seen in Figure 6.6, which is now in operation.

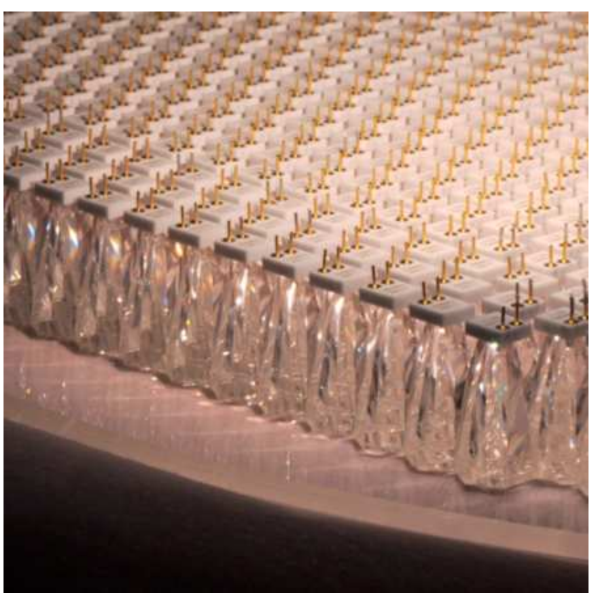

FIG. 6.6 – *Installed solid light cones with G-APDs optically glued to the exit aperture of the cones.*

[1] J. A. Coarasa *et al.* (MAGIC Collaboration), J. Phys. Soc. Jap. Suppl **77B**, 49 (2008).

[2] B. Opitz *et al.* (HESS Collaboration), AIP Conf. Proc. **1223** 140 (2010).

[3] D. Hanna *et al.* (VERITAS Collaboration), J. Phys. Conf. Ser. **203** 012118 (2010).