7 Very High Energy Gamma Ray Astronomy with CTA

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(CTA)

The Cherenkov Telescope Array (CTA) is the 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 gamma rays 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. When these gamma rays enter the Earth's upper atmosphere, they create an electromagnetic shower comprising many highly-energetic charged particles. Those particles traveling faster than light in the atmosphere produce Cherenkov photons that travel in a cone to the ground. The IACTs can detect these Cherenkov photons and reconstruct the electromagnetic shower by imaging it with multiple telescopes, taking into account the photon arrival times. The reconstructed shower can then be used to determine the direction and energy of the initial gamma ray.

The goal of CTA is to build improved and larger versions of the current IACTs, based upon the lessons learned and exploiting new technologies. CTA is approaching the final R&D stage and heading towards first telescope prototypes. Efforts at UZH include primarily a mirror alignment system and a first fully digital IACT camera.

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

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

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

7.1 Mirror actuators

The mirror actuators are mounted to the primary mirror segments to enable an automatic alignment of each segment. In-house and field tests of the past couple of years have demonstrated that the actuators work reliably, and that all requirements are fulfilled. A first serious test with a large number of actuators was possible after the commissioning of the first mid-size telescope (MST) prototype in Berlin. The experiences gained in Berlin were incorporated in the next generation of actuators of which 450 have been ordered for the first large-size telescope (LST).

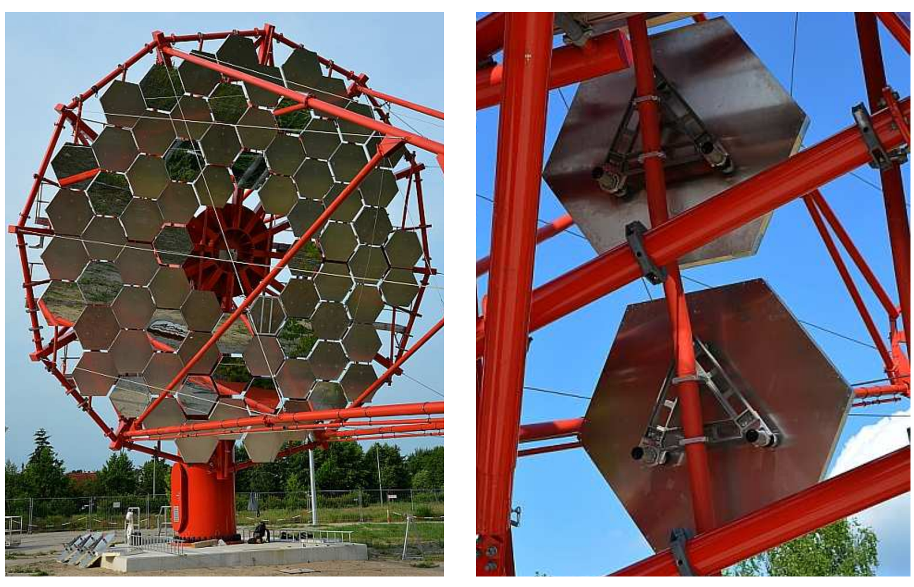

FIG. 7.1 – The MST prototype in Adlershof Berlin with real and dummy mirrors (*left*), and the UZH actuators mounted on the support of the telescope structure seen from the back (*right*).

FIG. 7.2 – Pictures of the camera body. From left to right: front view with half closed lid, rear view with closed doors and rear view with open doors showing the two electronic racks.

7.1.1 Pre-series for MST prototype

After having mounted some actuators on the quarter dish at the DESY Zeuthen Institute, a pre-series has been produced which was installed in May 2013 on the first midsize telescope prototype in Adlershof, Berlin next to the synchrotron source BESSY II. Figure 7.1 shows the 12 m diameter dish of the MST prototype equipped with real and dummy mirrors. Sixteen mirrors have been equipped with actuators from the University of Tübingen and the remaining sixty with UZH actuators. The mounting was done by us while the cabling and the commissioning were done by colleagues from DESY Zeuthen.

7.1.2 Series production for the first LST prototype

After the production, the installation and the operation of the actuators on the MST prototype, a slightly modified version of the actuator has been designed and ordered in larger numbers (225 sets, each consisting of two actuators and a fix point) in collaboration with the University of Tokyo and the MPI München, both heavily involved in the development and production of the LST. Most parts have been delivered and are ready to be assembled at IWAZ, a home for agility disabled people in Wetzikon.

7.2 The FlashCam camera

FlashCam [1] is a camera design for CTA incorporating a fully digital data and trigger pathway. In the more traditional IACT design the data first enter an analogue trigger pipeline where a decision is made whether or not to digitize the stored analogue data. Such schemes typically feature an effective sampling rate around 2 GS/s. A continuously digitizing 2 GS/s pathway is, however, prohibitive both in terms of cost and power consumption for an array of hundreds of cameras with thousands of channels each. Interestingly, our collaborators at the Max Planck Institute for Nuclear Physics (MPI-K) in Heidelberg have demonstrated with simulations that adequate performance can be achieved with a 250 MS/s sampling rate. The scheme has been studied during the past years and has meanwhile entered the prototyping phase. FlashCam is essentially divided into four main parts: the detector plane with the photo sensors, the readout electronics, the slow control including the cooling, and the camera body. The body and the detector plane are the two main parts developed, built and tested here at UZH.

[1] G. Pühlhofer *et al.*, (FlashCam Collaboration), arXiv 1211.3684 [astro-ph.IM] (2012).

7.2.1 The camera body

The in-house design rigid camera body (see Fig. 7.2) houses the photon-detector plane (Sec. 7.2.2) and the readout electronics as well as the slow control electronics required for the many actuators and sensors. Most components were made in our mechanical workshop but particularly large parts were ordered from appropriately equipped companies. The camera body is built around an inner frame. The sandwich-like front plate has 1764 holes for the photo sensors equipped with light concentrators and detector modules described further below.

The case was produced by Krapf in Amriswil, a company specialized in temperature-insulated van bodies, and indeed shows the typical look of such a van body.

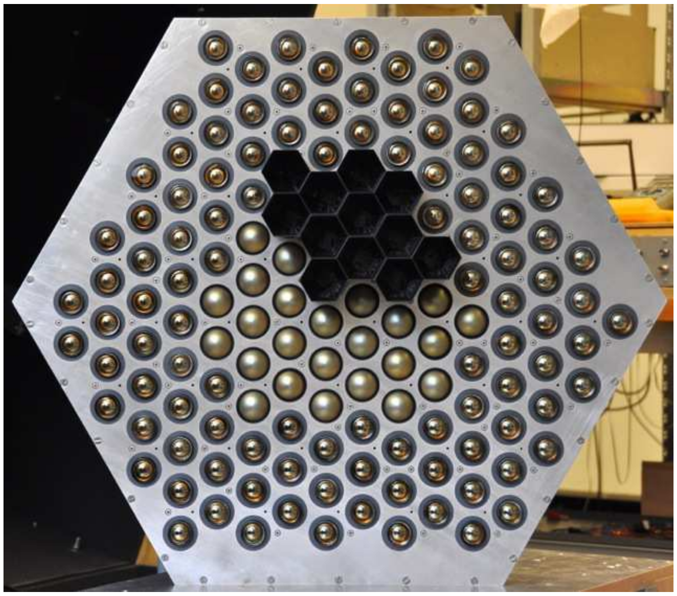

FIG. 7.3 – The 144-pixel prototype photon detector.

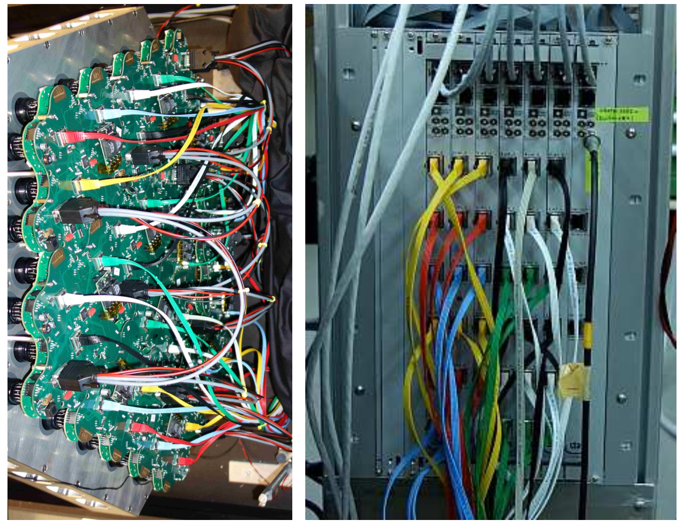

FIG. 7.4 – Left: the photon-detector plane from the back. Right: the readout mini-crate with six FADC boards and one trigger board.

The case insulation helps to better control the temperature inside the camera. The camera weight including cooling and all electronics will be around 1.6 to 1.7 t. The large steel frame needed to hold and rotate the heavy camera body was made by our mechanical workshop. Some mechanical parts like the movable sealing of the lid and various sensors for ambient light, smoke, water, etc. still remain to be installed.

7.2.2 The photon-detector plane

Last year the photon-detector-plane (PDP) electronics of FlashCam has been specified. The PDP is built on individual boards, each containing 12 photo detectors (photomultiplier tubes = PMTs), a high voltage generator, analogue signal amplification and slow control for the board functionalities. Twelve prototype boards were ordered for a 144 pixel mini-camera (Fig. 7.3 and 7.4). Three modules contain Hamamatsu PMTs, the current favorite PMT of CTA, and the remaining nine modules contain spare Photonis PMTs as used in the H.E.S.S. cameras. September last year the first light was seen with all 144 pixels simultaneously. The characterization of the whole setup is now almost completed and the results look very promising. Figure 7.5 shows as an example the dependence of the charge resolution on number of photo-electrons measured with a Hamamatsu and a Photonis PMT. The results not only satisfy the CTA requirements but even the design goals.

After finishing the characterization of the present PDP modules and the associated readout electronics an improved version will be tested before ordering the $\mathcal{O}(70)$ modules needed for a fully equipped camera.

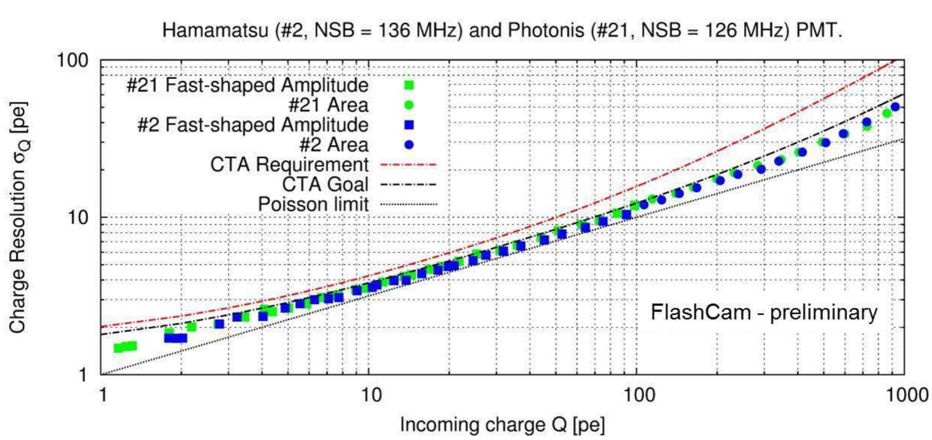

FIG. 7.5 – Dependence of the charge resolution on number of photo-electrons measured with a Hamamatsu and a Photonis PMT.