6 Very High Energy Gamma Ray Astronomy with CTA

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(CTA)

The Cherenkov Telescope Array (CTA) is our best candidate for the next generation of Imaging Atmospheric Cherenkov Telescopes (IACTs). IACTs are used to detect very high energy gamma rays (from GeV to tens of TeV). Sources for such gamma rays are both galactic and extragalactic, including quasars, supernovae and their remnants, gamma-ray bursts, and possibly dark matter annihilations. The signal to be detected is a faint and very fast Cherenkov light flash, allowing the reconstruction of the primary gamma ray's energy and direction.

CTA is approaching the final R&D stage aiming at a first telescope on site in 2016/17. We contribute primarily to the production of a mirror alignment system (see report from 2011/12) and the design and production of the body and the photomultiplier-based detector modules of the first fully digital IACT camera. The past year was devoted mainly to the completion of the camera body mechanics and safety system, preparations for the production of the large series of detector prototype modules and to the writing of the technical design report which will be completed soon.

6.1 FlashCam

FlashCam [1] is a camera design suited for the mid-size telescopes of CTA. The output signals of 1764 photomultiplier tubes are amplified and transmitted via commercial CAT6 cables to the readout electronics which digitizes them at a rate of 250 MS/s and with a dynamic range of 12 bit. The digitized signals are then combined to form patches of up to 21 channels uniformly distributed over the whole pixel area. The real-time evaluation of the patch-information generates a trigger for the readout of the whole camera. The pixel data are sent to a server for post-processing to be collected by the array's computer farm where the information of several telescopes may be combined.

The main parts developed at UZH are the detector modules and the camera body including the mechanics, the cooling system and the safety control system. Last year mainly engineering tasks have been performed and a big step was made towards a fully functional camera.

6.1.1 The camera body mechanics and cooling

The camera body (see Fig. 6.1), a 3x3x1 m^3 shelter for the camera electronics, has been completed during the last year and is now at a stage where different tests of the electronics and the mechanics can be performed.

FIG. 6.1 – Camera seen from the back with doors open. The four bluish modules mounted at bottom and top of the two electronic racks are the heat exchangers with associated fan drawers. The safety control cabinet (see Sec. 6.1.2) is seen in the lower half of the left rack. The remaining rack space is allocated to readout crates. Two empty crates can be seen in the rack on the right.

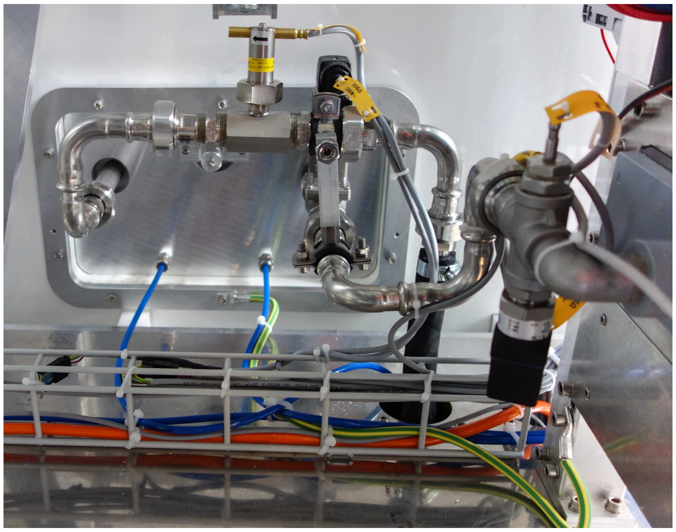

Fig. 6.2 – Panel with in- and outlet of the cooling liquid for the heat-exchangers. The necessary temperature, pressure and flow sensors are installed.

The cooling of the electronics is realized with water-air heat exchangers. The readout electronics and the safety control cabinet are installed into two racks forming four sectors. Each sector has its own heat exchanger including speed-regulated fan drawers. Figure 6.2 shows the piping of the cooling system installed in the camera body. First tests have shown a good performance. Figure 6.3 shows for instance the dependency of the cooling system pressure drop on the liquid flow. Such characterizations of the system are needed later for the operation in the moving telescope to compensate for the elevation of the camera.

A camera window protecting the sensitive electronics and optics against water, dust, and even animals was foreseen from the beginning. It turned out difficult to find a producer of large UV-transparent windows with the required optical quality. A 'dummy' Plexiglas test window was installed recently instead (see Fig. 6.4), doubling the thermal resistance ($R_{th} \sim 8.5$ K/kW before and ~ 18.0 K/kW after installation).

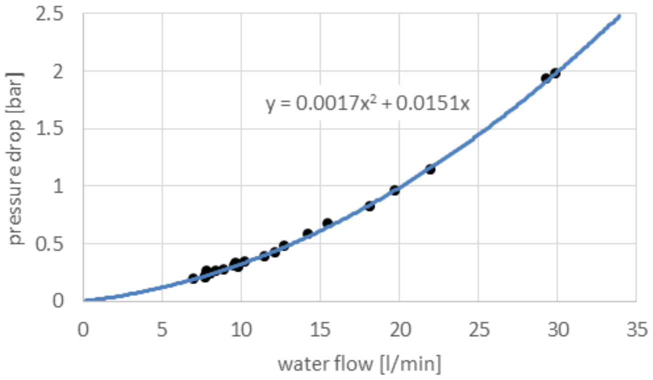

Fig. 6.3 – Pressure drop of the camera cooling system versus liquid flow, as measured with the sensors of the control system (black dots). The data show a quadratic dependency.

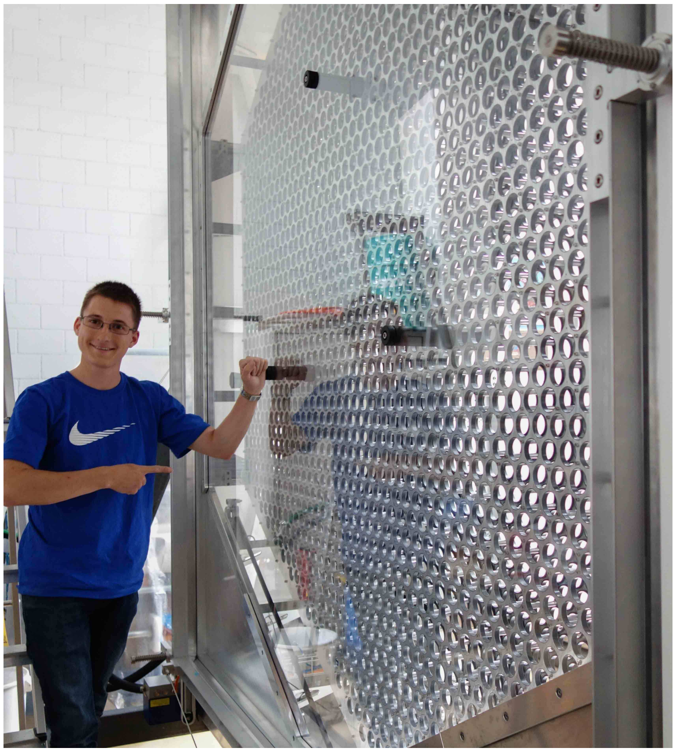

Fig. 6.4 – David Wolf in front of the Plexiglas test window mounted on the detector support. Three pixels had to be sacrificed to support the window and prevent damage under its own weight while the camera is rotated.

The equipment must resist heavy rain and even hail. While the water tightness will be tested by the end of May 2015, the hail tests have already started as a bachelor work with encouraging results so far.

The camera body will be mounted into a prototype telescope structure in Adlershof near Berlin (see also last year's report). The loading and unloading of the camera into the telescope's camera frame, the cooling performance under different elevation angles, and the mechanical compatibility will be tested. These results may lead to some modifications in the two planned pre-series camera bodies.

6.1.2 The camera safety control

The safety control system of the camera (shown in Fig. 6.5) must protect the camera electronics under all circumstances. The system, containing a variety of sensors for parameters like ambient light, temperature, pressure, water leaks, current and power supply performance, is built around the rugged and compact FPGA based compact RIO (cRIO) system of National Instruments. In very critical cases the implementation is totally hardwired. Elaborate sequences involving all possible situations, for instance the opening and closing of the cam-

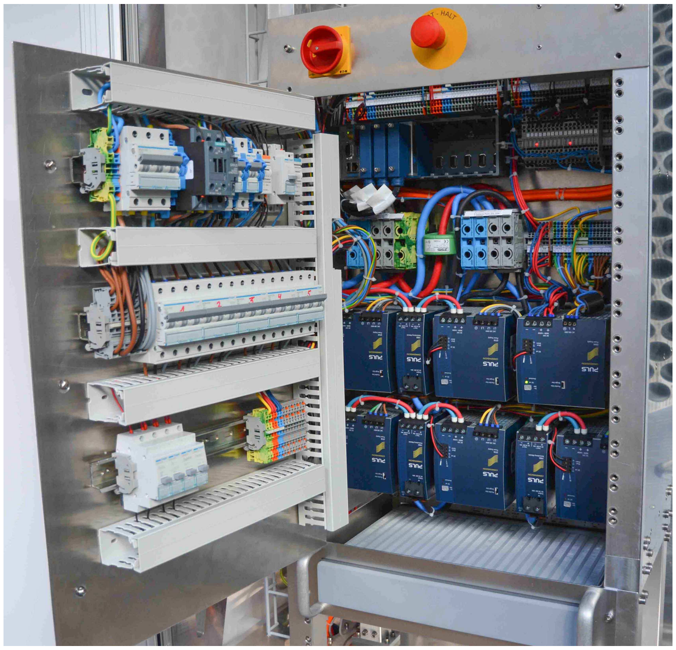

FIG. 6.5 – The safety control cabinet with circuit breakers for the 230 VAC safety and 3x400 VAC physics power and the redundant 24 VDC power supplies. The cRIO control system is installed at the top left side.

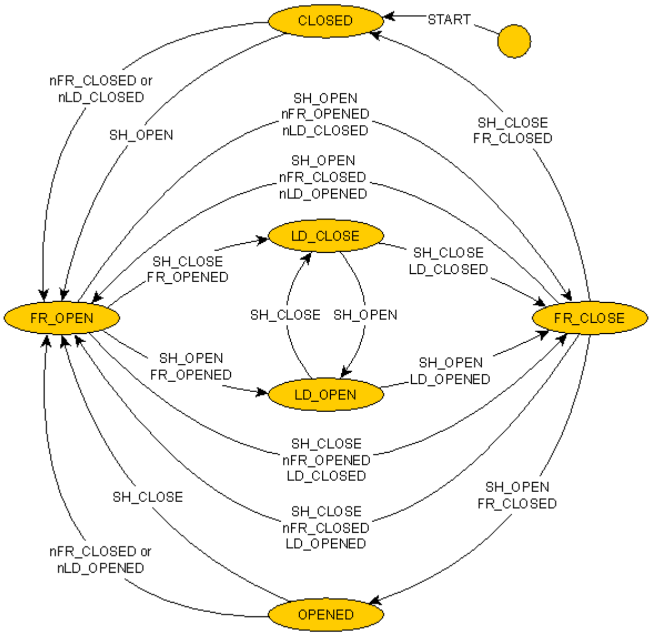

FIG. 6.6 – State diagram for the opening and closing procedure of the camera lid as hardwired in the safety control.

era lid (Fig. 6.6), have been developed. A Labview graphical user interface steers all functionalities.

Figure 6.7 shows the block diagram of the safety system as currently implemented in the prototype camera. Tests of the different functionalities have been performed successfully.

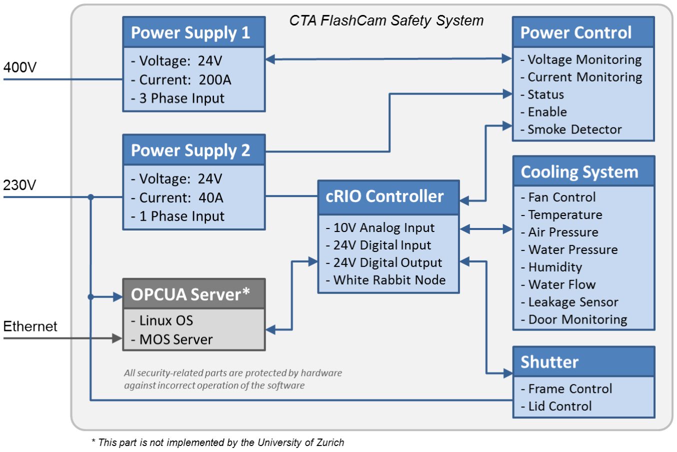

FIG. 6.7 – Block diagram of the camera safety system as implemented in the prototype camera.

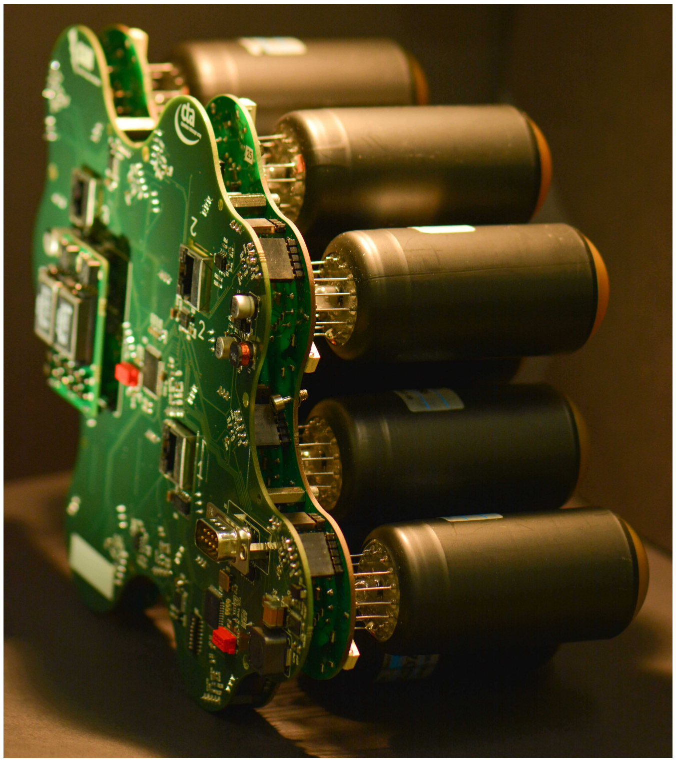

FIG. 6.8 – The latest version of the detector module with twelve PMTs. The small piggyback board houses the high-voltage generators.

6.1.3 The photon-detector module

The photon-detector module (Fig. 6.8) has already been presented in more detail in last year's report. The module has twelve photomultiplier tubes, high-voltage generators, amplifiers, a CAN-bus controller and a microcontroller on board. The amplified analogue signals of the detectors are transmitted via commercial CAT6 cables to the readout electronics. Since last year, small improvements have been made on the electronics and finally the electronics for 70 modules have been ordered. This will fill half of the camera (in total there will be 147 modules installed). Half of this order will be equipped with 8-dynode PMTs while the other half will have 7-dynode PMTs, which have the same dimensions but different pinout and a marginally better timing performance. The mixed assembly in the prototype camera will allow a cross-check of the two PMTs and their performance and help to choose the best candidate for the final version of the photon-detector module.

The wire-up scheme of the over 440 cables from the photon-detector modules to the readout is a tricky task especially without having enough modules at hand where the cables can be plugged into. Cheap dummy boards with heating resistors to simulate the power dissipation and a CAN-bus controller to test the CAN bus chain have been developed and installed in the camera (Fig. 6.9). Together with the real modules they will complement the camera to test the possible wire-up options, which currently are evaluated. More dummy boards have been ordered to complete the whole camera and to finalize the cabling without having to use the more fragile photon-detector modules.

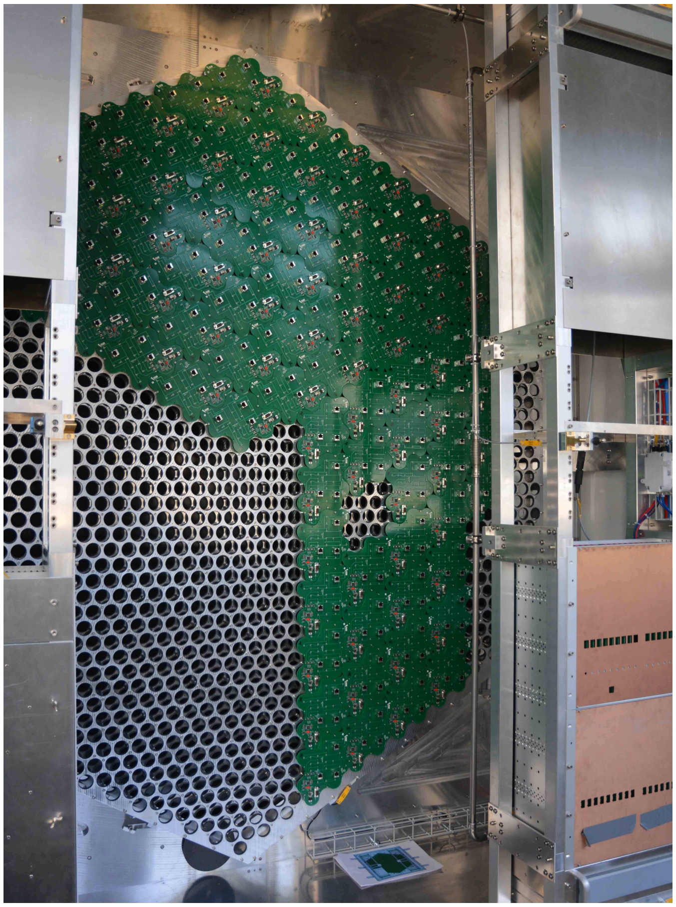

FIG. 6.9 – Rear view of the open camera. About half of the photon-detector plane is already equipped with dummy heating boards.

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