OG 10.3.18

THE DATA ACQUISITION OF THE HEGRA CHERENKOV TELESCOPE SYSTEM

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ABSTRACT

Since December 1996 the HEGRA collaboration is operating a stereoscopic system of 4 Imaging Atmospheric Cherenkov Telescopes (IACTs) on the Canary Island of La Palma (Daum, 1997). The IACT system is dedicated to the investigation of cosmic TeV γ-rays. In order to make full usage of the unique advantages of a stereoscopic system of telescopes, new readout electronics and data acquisition software was developed. This contribution gives an overview of the general layout of the readout electronics and the online software.

OVERVIEW OF THE LAYOUT OF THE DAQ

A unique feature of a stereoscopic system of telescopes is the ability to operate as a system already on the trigger level. The inter-telescope distances of 70-80 meters, matched to the diameter of the Cherenkov light pool on ground produced by a TeV gamma ray initiated air shower, create the need to buffer the recorded light pulses for several μsecs to account for the delay time of the system trigger decision. This is done by using a 120 MHz Flash ADC system (FADC) which pipelines its digital data into a hardware ring buffer of 34μsec depth. Unless a system trigger occurs, which will stop the FADC, this recording is dead time free.

The readout electronics is locally placed nearby the telescopes in order to minimize risks and costs of long cable trees. Each telescope is controlled by a CPU which is placed inside the electronics in VME standard and is connected via Ethernet to a main computer. Apart from the electronics placed nearby each telescope there is a central station, performing the system trigger decision. This station submits the system trigger and a following event number via a trigger cable to each telescope. When a system trigger occurs all telescopes, also the ones without local trigger, are read out. The event data package of each telescope and the central station is tagged by the common event number.

A main computer receives data and monitor packages from the telescopes and the central station via Ethernet. Based on the common event number tag an online event building is performed by the main computer. This allows for subsequent online reconstruction of the shower geometry from the stereoscopic views of the several telescopes. A graphical display enables the operator to monitor the quality of the incoming data using various panels, including fully reconstructed showers. Operator control of the system requires only few commands, which are submitted by mouse click menus. Background software performs all necessary jobs for synchronized data taking of a system of telescopes.

THE READOUT ELECTRONICS

The detector placed in the focal plane of each telescope is a matrix of 271 photomultiplier tubes (PMTs). Attached to each tube there is a voltage divider board and a preamplifier. Such a unit is called a pixel.

The readout electronics is based on VME standard and is designed to allow for fully computer controlled experimental setup. A 120 MHz, 8 bit FADC system records the amplitude and time shape of the light pulses. Discriminator modules are used for single pixel trigger decisions. In addition they monitor the pixel trigger rates and DC currents. Each telescope has a trigger module which decides on the trigger of a whole camera by using the information of all discriminator modules. The spare FADC channel 272 is used to record the (shaped) trigger signals. This record is analysed offline and provides a measure of the telescope trigger timing. The readout electronics is described in more detail elesewhere (Panter, 1995).

THE TRIGGER SCHEME

The trigger scheme contains two subsequent decisions, the single telescope trigger and the system trigger:

At each telescope, first a single pixel trigger is created by comparing the amplitude to a certain threshold. Second, a pixel coincidence (12 nsec window) trigger is formed by a majority decision. Based on the single pixel triggers, an additional check for a next neighbor (NN) trigger pattern is performed. All parameters are set by computer control, allowing e.g. to enable/disable single pixels for trigger, to set single pixel threshold and majority level of pixel coincidence and to enable/disable the NN pattern ckeck .

The system trigger decision is created in a central station which receives the single telescope triggers. By using computer controlled delays one is able to compensate the pointing dependent differences in light arrival times at the telescopes and to use a short (70ns) gate for the telescope coincidence decision. The required number of coinciding telescopes can be set by computer control.

More details on the trigger of the IACT system are presented elsewhere (see Hermann, Hess et al., OG 10.3.20).

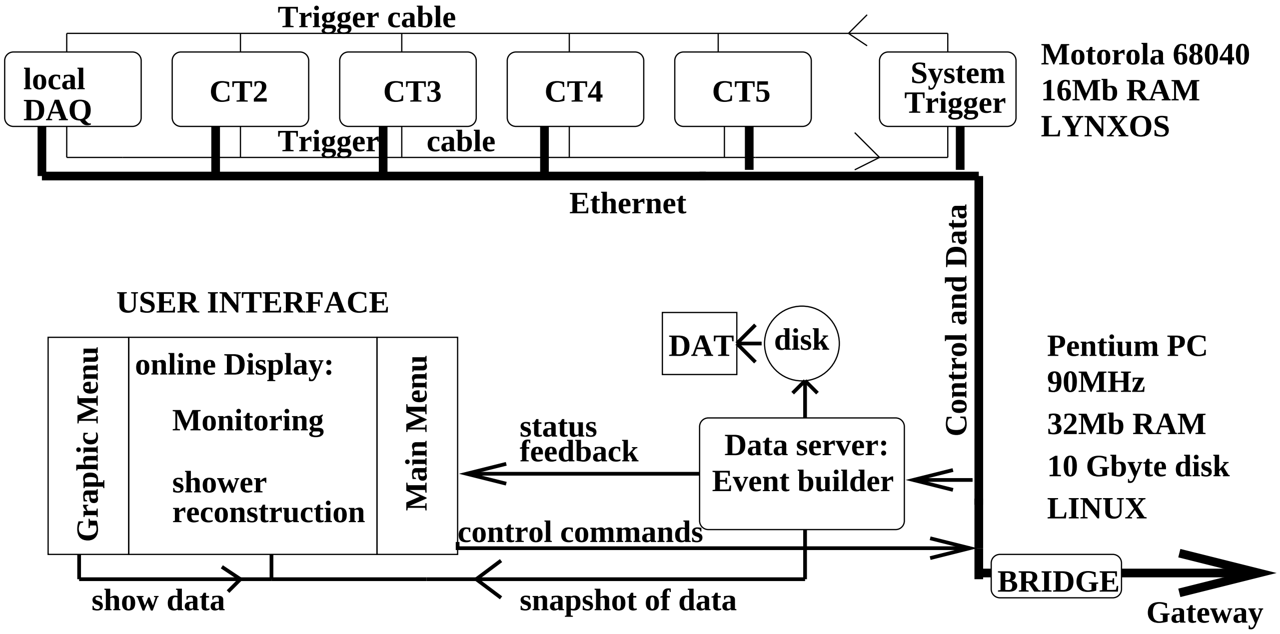

Fig. 1: Overview of the architecture of the DAQ of a 5 CT system.

THE ONLINE SOFTWARE

Figure 1 gives an overview of the architecture of the DAQ. A basic feature is a client/server architecture of the several front end processors (Motorola 68040) placed inside the VME crates and the main computer (Pentium PC). Those client CPUs are connected by local ethernet to the server PC which provides system software (LynxOS) to download during boot as well as NFS mounted hard disk to download user executables and to access configuration files. The LynxOS is a real time system which includes VME interrupt handling. There are four packages running on the several computers:

User Interface and Online Display. On the main computer there is a graphical online display and user interface available to allow for control of the system of telescopes by a single operator from a single terminal by easy mouse click actions (see Figure 2). The mouse click menus are implemented by using the Tk/Tcl package. The graphical display is based on the VOGL library. The menus adapt the en/disabled status of their buttons automatically and guide the user by popup infos and online help menus in case of non allowed actions or warning/error levels indicated by the monitoring system (see

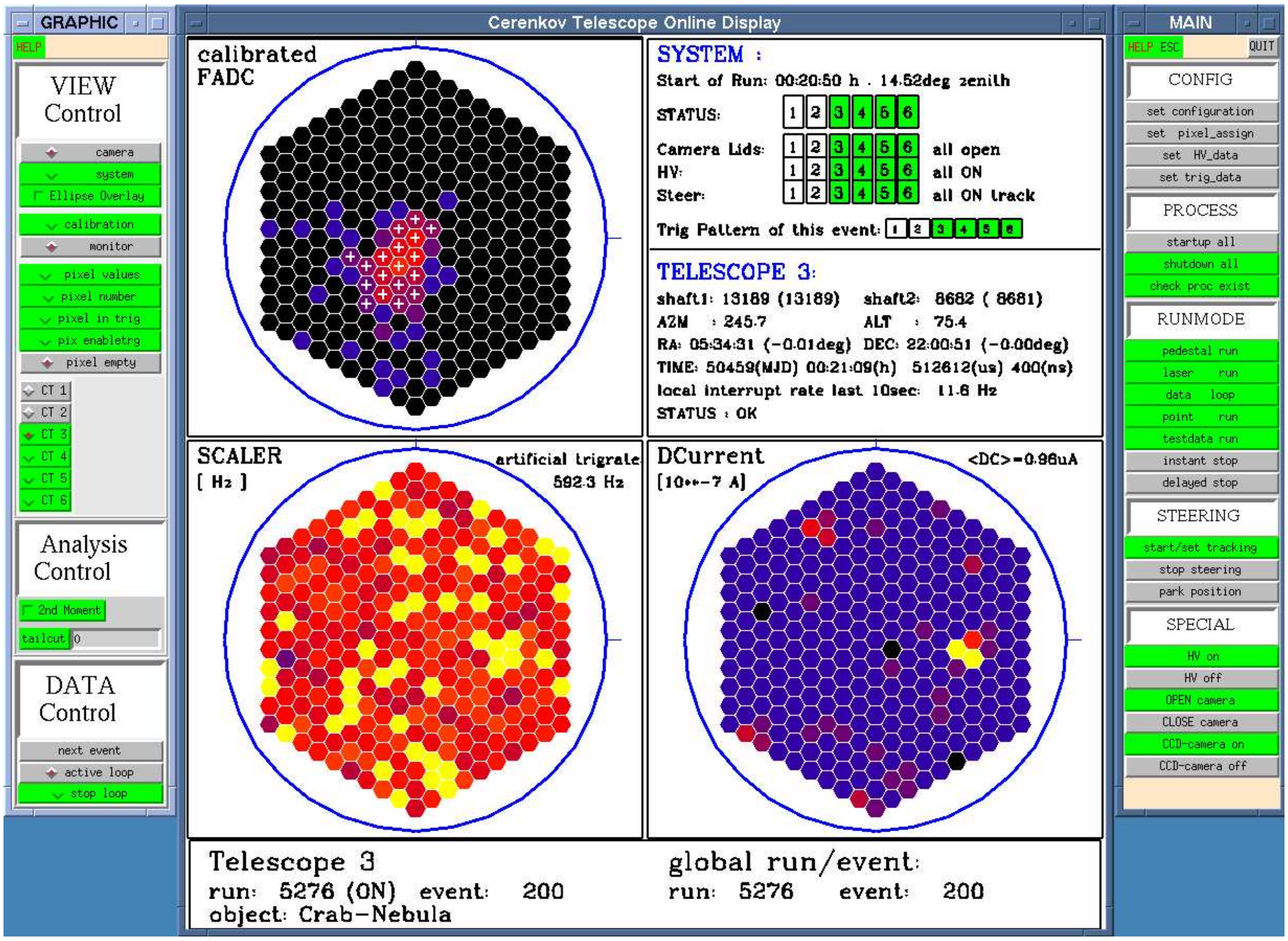

Fig. 2: The online terminal consists of a main user interface to control a system of telescopes by a easy mouse click menu (right hand side), a graphical online display showing a snapshot of data currently taken (middle) and a graphic interface to select the various panels available in the online display.

below). The operator initiated requests cause background actions which can be very complex, consisting of C-code programs, Unix shell scripts, remote logins to other CPUs and command/data transfer by UDP via ethernet. The online display provides extended information on the status of the system and the currently taken data including the display of full geometrical reconstructed air shower events.

Event Builder. The main Pentium PC receives data packages from the several VME CPUs and performs online event building. The packages contain multiple events, thus encreasing the efficiency of network transfer. A crucial point in online event building results from possible asynchronous dead time of individual telescopes, resulting in missing event data of this telescope and thus requiring a smart event building algorithme to manage incomplete events without being trapped in a status where the ability of efficient event building is lost. The processed data is stored on hard disk and transferred to DAT tape during day time. Snapshots of processed data and the received status informations are fed through to the online display. Background processes which synchronize the data taking of the system and adapt the status of the menus also get the status informations from the event builder process.

Telescope Process. Locally at each telescope operates a main process consisting of several subprocesses running in parallel, so-called threads. Each of those threads has a certain priority in order to minimize DAQ deadtime. All threads have access to the same stack and allow for parallel readout, data sparsification and data network transfer by a global accessible ring buffer. There are additional threads for monitoring, i.e. of DC currents and of single rates of the PMTs and for steering of the telecope axis and for receiving control commands. Based on the PMT currents trigger conditions are adapted dynamically to high background levels in individual pixels. Pixels with high currents due to bright stars, and therefore generating high single pixel trigger rates, are disabled from trigger. Monitoring generates a status word consisting of several status, warning and error levels which is fed through to the online display and thus allowing for easy to understand coloured flags and status strings in the upper right corner of the online display (see Figure 2). In addition there are several automatic security switches implemented like HV switch-off to avoid damage of the PMTs by too much light. Telescope tracking is stopped if it is hitting into not allowed regions, i.e. below horizontal or forbidden azimuth regions. Experts can access the processing of the VME CPUs directly via a user interface. This interface is implemented as a line interface and provides also a set of histograms for better interpretation of the data. This local process at each telescope can run in stand-alone mode, providing the full range of user actions like starting of the steering, which are in the usual case of running as a system reserved to the main graphical interface. This stand alone ability is dedicated for maintenance work when the DAQ is started from a terminal placed nearby the local readout electronics.

Central Station Process. The process running at the central electronics station and controlling the system trigger decision makes use of the same tools already described at the telescope processes. Apart from the control of the vital VME electronics for system trigger, the software controls the electronics in CAMAC and NIM standard, i.e. calibration and readout of TDCs, which are used to measure the relative trigger timing of the telescopes and the timing after the compensation delays. This allows for online monitoring of the proper timing at the telescope coincidence decision.

Table 1: Overview of the Trigger Conditions and the Deadtime Fraction

	single pixel	single telescope	system of telescopes
trigger condition	10mV ($\approx$8p.e.)	2 out of 271 (+NN pattern)	2 out of 4
trigger rates	0.2 - 5 kHz	0.1 - 2 kHz (20-25 Hz)	10 - 13 Hz
deadtime fraction	$< 0.02\%$	$< 0.6\%$ ($< 0.1\%$)	$< 3\%$

PARAMETER SETTINGS AND PERFORMANCE OF THE DAQ

Table 1 summarizes the current settings of trigger conditions and the dead time fraction of the DAQ. By far the largest deadtime fraction occurs due to system triggers which start the whole readout at each telescope. In principle this local deadtime at the telescopes is highly correlated in time but due to the parallel architecture of the local DAQs there are some uncorrelated effects leading to incomplete events, i.e. at least one telescope missed the system trigger. System event packages consisting of all telescopes, i.e. no missing data of a telescope due to uncorrelated dead time or inefficiencies in data networking, data buffering or online event building, are called "golden events". The fraction of golden events relative to the number of system triggers is $\geq$98%. The resulting amount of data written to hard disk is approximately 500Mbyte per hour of data taking.

Since the commissioning of the telescopes the DAQ demonstrated its reliability and efficiency by recording observational data of several objects, leading to the highly significant detection of 3 sources in the TeV energy range.

REFERENCES

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