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THE MULTI-TELESCOPE TRIGGER OF THE HEGRA IACT SYSTEM

A. Daum[1], G. Hermann[1], M. Heß[1], G. Rauterberg[2], for the HEGRA collaboration

[1]*Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg, Germany*
[2]*Institut für Kernphysik, Universität Kiel, D–24118, Germany*

ABSTRACT

The HEGRA–collaboration is operating a system of imaging atmospheric cherenkov telescopes for the search of sources of TeV–γ–rays (see O.G. 10.3.17). Air showers are observed in stereoscopic mode with several telescopes simultaneously. To trigger the telescope system a versatile multi–level trigger scheme has been implemented, which allows a significant reduction of the energy threshold with respect to single telescopes. The technical implementation of this trigger scheme, and the performance of the system trigger are described.

INTRODUCTION

Imaging atmospheric Cherenkov telescopes (IACT) have been proven to be the most powerfull instruments in TeV–γ–ray astronomy. The high sensitivity of these instruments results from the large effective collection area, governed by the size of the light pool of air showers and from an effective hadron suppression, achieved by the imaging technique. Further improvements of the Cherenkov technique have been obtained by coupling several telescopes to a system for stereoscopic observations of air showers. The HEGRA–collaboration has installed such a stereoscopic system during the last two years and first measurements show very encouraging results (Daum et al. 1997).

In order to fully exploit the advantages of stereoscopic observations, already on the trigger level only events should be selected, where at least two telescopes give useful images. Furthermore the trigger scheme should suppress as much as possible background triggers, generated by the light of the night sky, by local muons, and also by hadronic showers, while maintaining high efficiency for genuine γ–showers. In addition, it should allow to operate the system at a low energy threshold. Besides these physiscs requirements, technical aspects have to be taken into consideration, like e.g. the limited bandwidth of typical data acquisition systems of IACTs of some tens Hz. Finally the trigger should be controllable by software in order to be able to quickly adjust the proper trigger conditions.

THE MULTI–LEVEL TRIGGER

The trigger of the HEGRA–IACT system has been especially designed for this experiment. All major components are built following the VME–standard and are controllable by CPUs. The trigger scheme is organized on two levels: the first level trigger, which is generated locally at each telescope, and the second level trigger, wich is built up once in a central station.

The local trigger

Each telescope of the stereoscopic system is equipped with the identical trigger and readout electronics. It is controlled by a local CPU. The trigger electronics of a telescope is built up from essentially 3 different kinds of logic modules: the Discriminator–Monitor Cards (DMC), a majority unit, and since spring 1997 an additional topological trigger unit. On the DMCs 16 channel are integrated. They contain discriminators, a multiplexed scaler, ADCs for the measurements of the dark currents of the PMTs , and a latch register, which is accessible by the VME–Bus and gives the information on which channels have fired. The thresholds of the discriminators can be set independently by VME–access. Also by software control each single channel can be excluded independently from the trigger decision. This feature is used to disable single channels dynamically from the trigger, which are affected by direct light from stars. The digital discriminator signals are summed up in groups of 8 channels on the discriminator cards, and routed to the majority unit, which releases the local telescope trigger. There the outputs of all DMCs are summed up and discriminated with a software adjustable threshold, corresponding to the minimal number of pixels required for the trigger. Alternatively, additional digital outputs of the discriminators are feed into a topological trigger, which requires at least two triggering pixels to be neighbors. The module of the neighbor trigger is based on programmable gate arrays. With this logic, accidental background triggers, caused by the light of the night sky, are reduced by a factor of about 48, while genuine γ–showers are maintained to more than 95 %, given a fixed threshold (Köhler et al. 1996) . The implementation of the neighbor trigger allows to lower the discriminator thresholds by about 25 % and to reduce the energy threshold of the telescopes, resulting in an increase of the detection rate for γ–showers. In the normal operation mode the topological trigger is used. However for special run modes the trigger can be switched automatically by software to the majority mode.

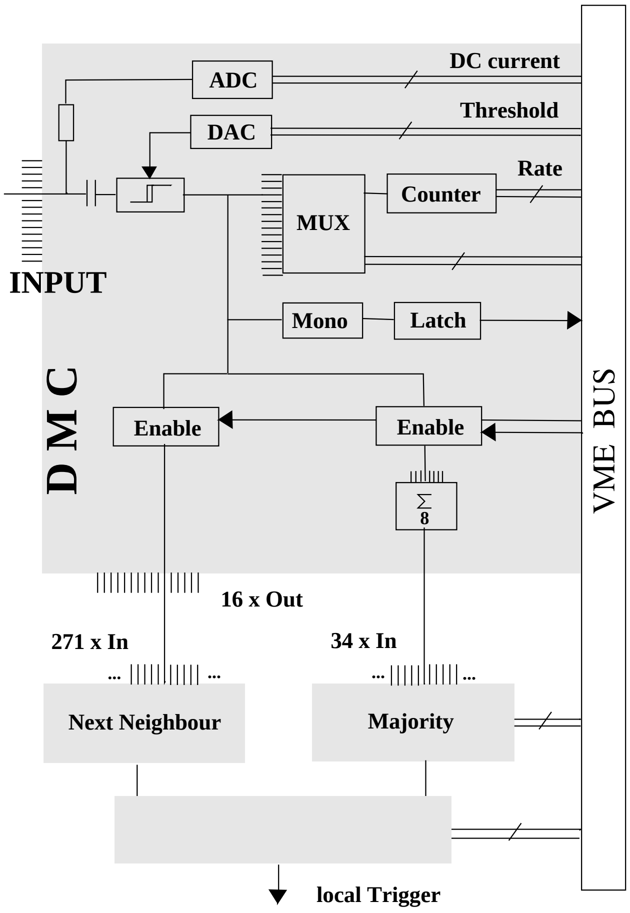

Fig. 1: Principle layout of the local trigger electronics.

Presently the duration of the discriminator output signals is set to 15 nsec, resulting in an effective coincidence window of 12 nsec. The delay of the trigger signal with respect to the PMT–pulses amounts to 60 to 90 nsec, depending on the trigger mode.
The local trigger signals of the telescopes are then routed to the central station.

The central trigger

The main task of the central station is to derive a trigger decision if at least a preset number of telescopes, typically two, have triggered within a given coincidence time. The central station essentially consists of a delay line, a majority unit and of an event grader to submit trigger signals and event numbers. All modules are completely computer controlled.
The telescopes of the stereoscopic system are arranged on a square with e length of about 100 m. Depending of the direction of the observations the arrival time differences of the light front at the different telescopes amount up to 400 nsec. Therefore the local trigger signals from the telescopes will not arrive simultaneously at the central station. In order to compensate these arrival time differences, the central trigger is equipped with programmable delay lines for the incoming trigger signals. The delays are updated continuously in steps of 10 nsec, as the relative orientation of the telescopes changes during tracking an object. Therefore it is possible to operate the central trigger with a much shorter coincidence window resulting in a reduced rate of accidental coincidences. Actually the coincidence time is set to a conservative value of 70 nsec.

The global trigger signal is then sent to all telecopes of the system and the read-out of the events is started. Together with the trigger signal an event number, generated by an event grader, is submitted to the telecopes, for the synchronization of the data.

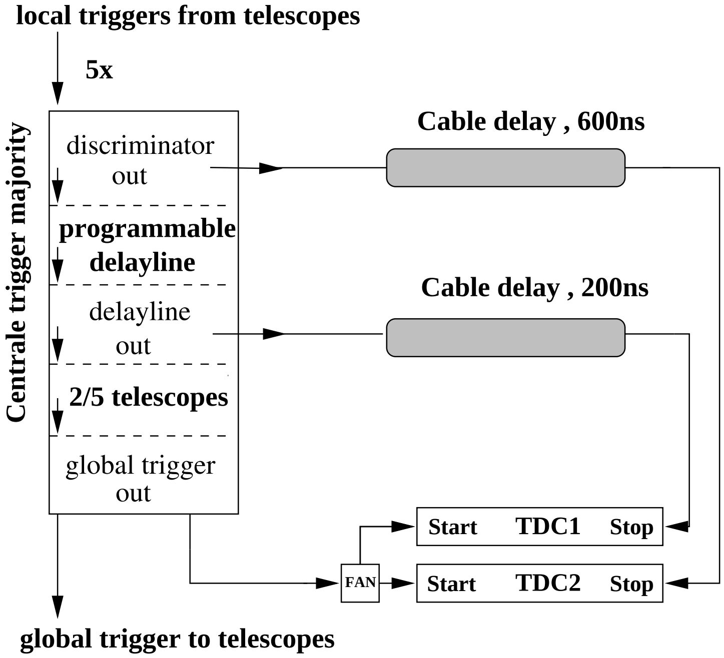

Fig. 2: Sketch of the centrale trigger logic of the HEGRA IACT array. The modules and connectors used for the calibration of the TDCs are not marked in.

TRIGGER RATES

First measurements of the trigger rates of the telescope system were performed during the build-up phase of the stereoscopic system in 1996 with a system of 3 telescopes. During this periode the neighbor trigger was not yet implemented, and the local trigger decision has been derived from the majority. The system rate was measured as a function of the threshold of the single pixels and for different required trigger multiplicities of the telescopes in the central station (1/3, 2/3 and 3/3 telescopes). The zenith angle under which the measurements were done was 10°. The result is shown in Figure 3. For the trigger condition 'any out of 3 telescopes' the system trigger rate is dominated by accidental triggers, caused by the light of the night sky. For pixel thresholds well below 20 photoelectrons it is consistent with the expected random trigger rate, as calculated from the measured single-pixel rates and the width of the coincidence window. In order not to be dominated by dead time effects, the pixel thresholds for this trigger mode should be set to about 18 to 20 photoelectrons. The requirement of the coincidence of 2 or even 3 telescopes demonstrates the power of the system trigger. Due to this condition accidental triggers are strongly suppressed. The threshold of the single pixels can be lowered down to ≈ 8 p.e. or even less without being dominated by accidental triggers: a random trigger rate of about 1 kHz of the single telescopes and a coincidence window of 70 ns leads to a random system trigger rate of less than 0.5 Hz. The implementation of the neighbor trigger at each telescope leads to a further reduction of accidental triggers by a factor of about 2500 for 2 telescope coincidences. Consequently the single pixel thresholds and thus the energy threshold can be lowered even further.

Table 1 gives an overview of typical trigger rates of the HEGRA IACT system of 4 telescopes with its current configuration. Presently the neighbor triggers are being installed in the 4 telescope system and further investigations on the trigger properties will be performed (Lampeitl et al. 1997).

ACKNOWLEDGEMENTS

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Table 1: Local telescope trigger rates and system trigger rate of the IACT system of 4 telescopes.

local rate 2/271 > 8p.e. without next neighbor	local rate 2/271 > 8p.e. with next neighbor	system rate 2/4 telescopes
$\approx$ 1kHz	$\approx$ 30Hz	$\approx$ 12Hz

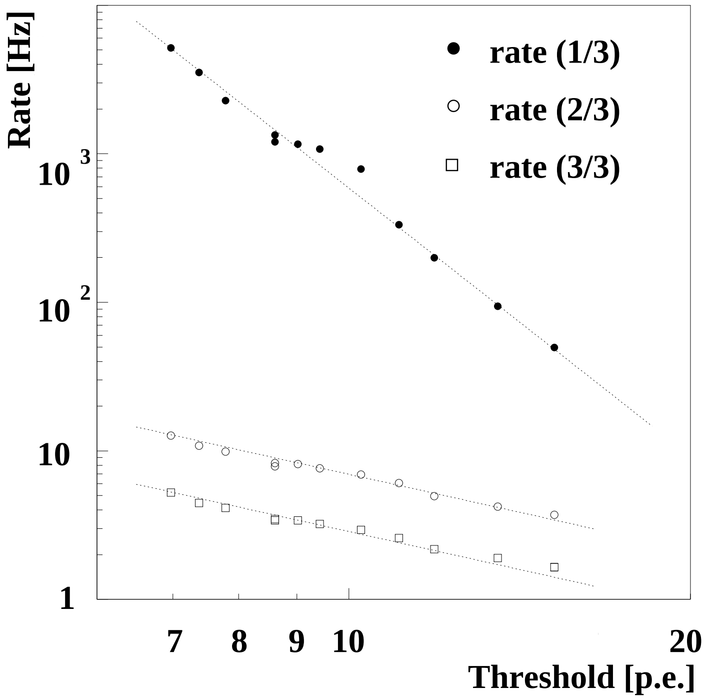

Fig. 3: Trigger rates of a 3 telescopes system as a function of the threshold of the single pixels for different adjustments of the trigger multiplicity of the telescopes.

REFERENCES

A. Daum et al. (HEGRA), submitted for publication (1997)
H. Lampeitl et al., in preparation (1997)