The Data Acquisition System of the MAGIC Telescope

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for the MAGIC collaboration

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The Universe viewed in Gamma-rays
- Univ. Tokyo Workshop 2002 -

Abstract:

The 17 m diameter Imaging Air Cherenkov Telescope MAGIC [1,2] will be commissioned this year. The extremely fast (~1-2 nsec) Cherenkov signals registered in the camera PMTs are transmitted in analog form over optical fibers, split into a high and low gain channel and digitized using 300 MHz 8 bit Flash ADCs [3]. The digital data produced by the system of 577 FADC channels is readout over one single PCI card by a multiprocessor PC which saves them to a RAID system and a tape library. The system has been designed to record cosmic events with a rate of up to 1 kHz. The 2 level trigger [4] allows to prescale the events and optimize the composition of the recorded data. A parallel acquisition branch allows to record minimal information on events with a much higher trigger rate of up to 1MHz.

Introduction:

MAGIC is a new generation Cherenkov telescope **[1,2]** at the IAC site on the Canary island *La Palma*. A **mirror surface** of 230 m² (**Ø = 17 m**) and a **577 pixel camera** allows to lower the **energy threshold** for **γ** detection down to **~30 GeV**.

The lower threshold opens a wide **physics potential** covering AGNs, pulsars, SNRs, unidentified EGRET sources, γ-ray bursts, Cosmology, particle physics, …

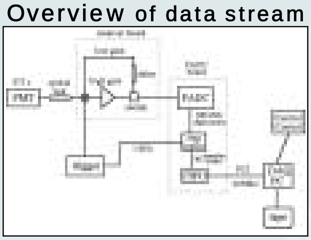
The **Data Taking Chain** of MAGIC consists of:

- **Fast PMTS** collecting the 1-2 nsec FWHM Cherenkov light flashes from **γ**-showers
- **300 MHz Flash ADCs** for fast sampling
- An efficient **2 level trigger** system limiting the **trigger rate** to ≤ **1 kHz**
- A **data acquisition system** capable to process a data rate of **20 Mbyte / sec**

This allows:

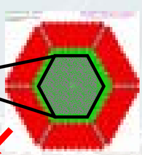
- Effective **light of night sky** and **noise suppression**
- Efficient **rejection** of **hadron** induced air showers

Overview of data stream



Two Level Trigger System:

Trigger input:
325 inner camera pixels



L0: Discriminator
Sets threshold for number of photo electrons per pixel

Level 1:

- 2 – 5 nsec coincidence
- n-fold **next-neighbor logic** (n = 2,3,4,5)
- Implemented with **p**rogrammable **l**ogic **d**evices

Level 2:

- Uses VME SMART modules
- Performs **sophisticated digital pattern recognition**
- Does **preliminary analysis**:
  - mask bright stars, rough center of gravity, energy estimate
- Allows to operate telescope during **moon shine**

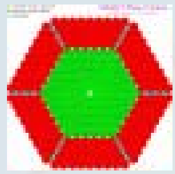
Prescaler:

- Prescales each trigger type independently to optimize the composition of the recorded data and to reduce the trigger rate to less than:
  - **1 kHz** for low frequency trigger chain
  - **1 MHz** for high frequency trigger chain
- Rejects cosmic events during calibration / pedestal runs

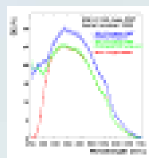
The Camera:

Consists of **577 PMTs** in a hexagonal arrangement of **1.5 m** diameter corresponding to **~ 4 °** Field of View

- **inner area:** 397 PMTs of 1'' Ø (EMI 9116A), 0.10 ° pixels
- **outer area:** 180 PMTs of 1.5'' Ø (EMI 9117A), 0.20 ° pixels



- 6 stage PMTs
- Semispherical **PMT** photocathode
- typical signal response time **1.0 – 1.2 nsec** FWHM
- **Q**uantum **E**fficiency up to **30%**
- Sensitivity to UV light increased with WLS and diffuse scatter coating



Data Processing:

- The readout is controlled by a **FPGA chip** on a PCI (MicroEnable) card
- The FiFos are read out with 4 Bytes @ 20 MHz by a **multiprocessor Linux PC** over one **PCI** card for each high and low frequency data stream
- A **multithreaded readout program**:
  - **Reorganizes** and **merges** incoming data into raw event data format
  - Performs preliminary **online analysis** for **data quality monitoring**
  - Communicates with Central Control via TCP/IP
  - Saves data to **RAID0 disk** system
- **Data rate:** up to **20 Mbytes / sec** (800 Gbytes / night)
- During daytime data is transformed into **ROOT** format and written to **tape**

Analog Signal Processing:

In camera housing:

The PMT signals are amplified by ultrafast and low-noise transimpedance **pre-amplifiers**

Transmission of analog signals from camera to electronics hut:

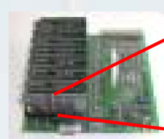
The analog signals are transmitted over **162m** long **optical fibers** using laser diodes (**VCSEL**s, λ = 850 nm).

In electronics hut:

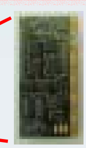
- A **discriminator** with a software adjustable threshold sends a signal to the **trigger** system
- The signal is **stretched** to ~6 nsec FWHM and split into a **high** and a **low gain** channel in order to increase the **dynamic range** to > 1000
- The **high gain** signal is **amplified** further by a factor of 20
- The **low gain** channel is **delayed** by 50 nsec
- If the low gain signal is above a preset threshold it is digitized after the high gain signal by the same FADC using a fast GaAs switch

Digital Signal Processing:

- The analogue signals are continuously digitized with **300 MHz** using **8 bit FADCs [3]**
- Digitized samples are stored in **32 kByte** long **ringbuffers**
- If a **trigger** signal arrives within **< 100 µsec :**
  - The position of the signal in the ringbuffer is determined
  - For each pixel **15 high gain + 15 low gain samples** are written (16 bits @ 40 MHz) to a **512 kByte** long **FiFo buffer**
- The **3.3 nsec** time slices allow timing resolutions below 1 nsec
- The readout procedure of the ringbuffer results in a **dead time** of **< 1 µsec** (~ 0.1 % @ 1kHz trigger rate)



Mother board with 8 FADC cards



FADC card

- The FADCs for the 577 pixels are contained in **4 racks** with **5 crates**. Each crate contains **4 motherboards** equipped with **8 FADC cards** each.
- The data is **multiplexed** and read out into one PC by a hierarchical structures of **interface boards**.

The **time** & **trigger** information for each event is recorded by dedicated **digital modules** which are read out together with the FADC modules.

High frequency data stream:

- Needed because signals from very low energy or very intense episodic sources like GRB emission, pulsar peaks etc exceed the ~ 1 kHz data taking capability of the DAQ
- A **separate high frequency data stream** records only time & trigger information for events triggered by a separate high frequency trigger with rates up to 1 MHz

References:

1. "The MAGIC Telescope" Design Report, MPI-PhE / 98-5
2. Talk by E. Lorenz, this conference
3. "The FADC readout of the MAGIC Telescope", talk by J. Cortina, Snowbird 99
4. D. Bastieri et al., NIM A 461, p. 521 (2001)