MAGIC-TDAS 00-05
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PIXEL CALIBRATION, EVENT PREPROCESSING, PHYSICS ANALYSIS

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March 3, 2000

Abstract

This document shows all the steps from the FADC data to physical results. This is the main part of the MAGIC analysis and reconstruction software (MARS). If you look into the document about the General Use Cases, this procedure is connected with the use case **Reconstruction** and the use case **Analysis**. So the description here is just for a better understanding of how the analysis chain may look like.

All contributions are welcome!

Contents

1 Layers

The process of going from the FADC data (and also a lot of other data, i.e. motor data, weather data, LIDAR, etc.) to find final physical results can be seperated in different layers. In this document we identified three or four layers. These layers are described in the following:

1.1 First layer: pixel calibration

This part of the analysis will be done **pixel-by-pixel**. At the end of this analysis step, it will be possible to calculate the number of Cerenkov photons per Pixel $N_{C,i}$ from the real raw FADC data and the output of this layer.

This layer has to extract from the raw data the following calibration data:

1. **Determination of the pedestals P_i and its RMS**
   MAGIC will measure the amplitude of the signal in two branches with different gains – one is the High Gain and the other the Low Gain branch ($P_{H,i}$ and $P_{L,i}$). For each of these branches we need to determine the Pedestal. Due to the big number of stars and their movement in the camera, this determination of the pedestals has to be done very often - perhaps we should have a pedestal for each event. This needs a closer look!

   There exists more than one possiblity to get the pedestals. One can extract the pedestals from special pedestal events or from the raw data. This needs further investigations!!!

2. **Absolute light calibration**
   MAGIC will have (hopefully) a progressive light calibration system, that allows you to measure for each pixel the absolute number of Cerenkov photons per pixel $N_{C,i}$.

   The light calibration system may have the following design[1]. A light source (Laser or LEDs) placed at the center of the mirror dish will send a given number of photons N_γ to each pixel of the camera. A light attenuator with different, but fixed attenuation levels will be used to measure the response to different N_γ's. The result may look like Figure 1. Using such a correlation it is possible to calculate from the integrated FADC-content I_{FADC} the number of cerenkov photons per pixel $N_{C,i}$.

3. **arrival time calibration**
   Due to different cable length and may be due to different transit times in electronic there will be a (hopefully) small difference in the arrival times of synchronous cerenkov photons in different pixels. To use the full power of FADC, it is neccessary to calibrate these difference in the arrival time.

All these different pixel-by-pixel calibrations are neccessary to determine for each pixel:

- $N_{C,i}$ - amout of cerenkov light
  From the FADC values it is possible to determine the number $N_{C,i}$ of cerenkov photons in each pixel. And it is also possible to calculate the **error** of this measurement.

- the arrival time of cerenkov light
  From the shape of the signal in the FADC slices it will be possible to calculate some timing information of the cerenkov light. This can be the mean value and the width (RMS) of the timing. Also the starting time of the signal may be an interesting quantity.

[1] This is my impression about the system, that I got from discussions with T. Schweizer.

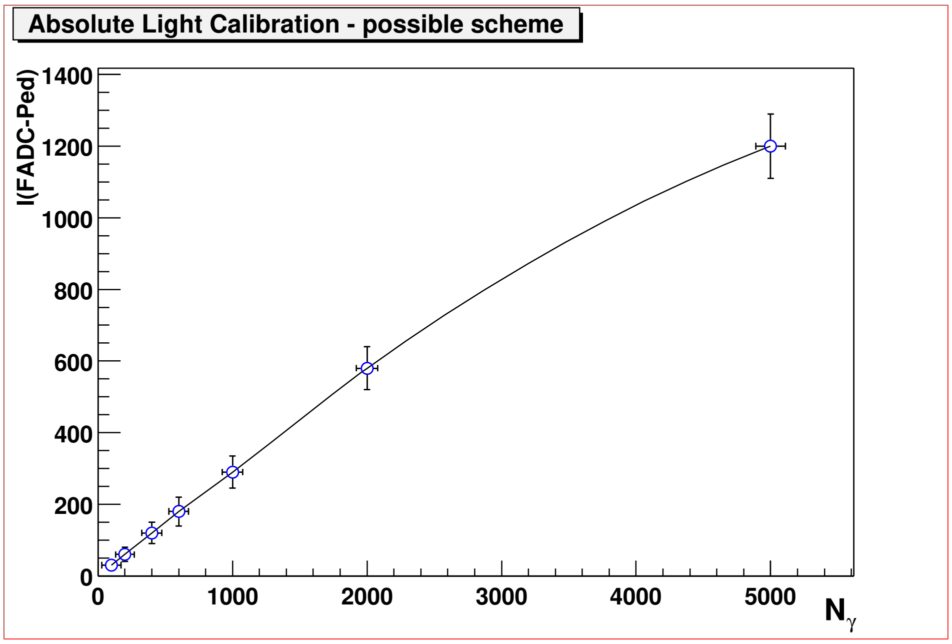

Figure 1: A possible output of the absolute light calibration system. The integrated FADC content (after the subtraction of the pedestal) is plotted as a function of the number of photons N_γ emitted by the light source.

1.2 Second layer: event pre-processing

This part of the analysis will be done on an **event-by-event** basis. At the end of this layer (or analysis step) the parameters describing the image will be available. The following steps are neccessary:

1. **cleaning of the camera image**
   Due to different reasons (StarLight, LONS, electronic problems, etc.) not all the information in the camera is connected with the image of a shower. In order to eliminate these contributions the image has to be cleaned. This image cleaning is not only a cleaning in space (this means looking of neighbouring pixels.), but also a cleaning in time (by comparing arrival times in differnet pixels one may identify FADC entries that are not originating from the shower.)

2. **determination of image parameter**
   The cleaned image will be used to determine image parameters. But therefore a lot of other informations from the MAGIC system are needed. I want to emphasize here only the importance of the knowledge of the camera movement. Because the camera can oscillate, it is neccessary to know where the center of the camera is. This can be done with the camera oscillation monitor.

After this layer we have on an **event-by-event** level base some particular parameters. These parameters are the starting point for the next layer.

1.3 Third layer: physical analysis

In this layer we are not interested in pixel-by-pixel or event-by-event information, but we are rather dealing with **samples of events**. At this stage we want to obtain physical results, i.e. significances or fluxes of the data sample. But to reach this results, one has to take a lot of systems into account. The results may depend on the weather (i.e. hadron rate as a function of atmospheric pressure), or one is dependent on other results. The energy spectrum can be determined only if one uses MonteCarlos simulations. The results will of course depend on the cuts and methods used. So one has really to know what are the correlations between all the different inputs.

To be a little more specific, the following methods will be a part of this layer. But for sure a lot of other ideas exist!

1. **application of γ enrichment or γ/hadron seperation cuts**
2. **determination of significance for γ signal**
3. **estimation of physical quantities**
    - impact parameter of the shower
    - energy of the shower
    - gammaness of the shower
4. **determinaton of raw distibutions**
    - dN_{Shower}/dE
    - $dN_{Shower}/d\Theta$
    - dN_{Shower}/dt
5. **unsmearing of raw distibutions**
6. **determination of absolute γ-fluxes or upper limits**
   This can be done as a function of time and energy.

All these steps of obtaining physical results one is influenced by the data one can gain from all the different systems of MAGIC. For example, the LIDAR can provide information about the trancparency of the atmosphere. This transparency has influence on the estimation of energy.

The results of this layer are used as input for the next layer.

1.4 Fourth layer: Further analysis

All the following analyses are more or less decoupled from the detector. They take the ouput of different samples-of-data.

1. **analysis of the energy spectrum**
   From the energy distribution obtained above one can determine the spectral index, cutoff energy, hardness ratio, etc.
2. **timing analysis**
   I.e the search for periodicities.
3. **correlation studies**
   (fluxes at different energies, time lags, ...)
4. **pulsar studies**

1.5 technical studies

As mentioned above there is a connection between the the physical results and the Monte Carlo Simulation. It is not possible to get any physical result without doing MC studies. So the program must contain the possiblity to do the following studies:

1. **energy scale**
2. **energy threshold**
3. **acceptances**
   as a function of energy and zenith angle for different particles
4. **angular resolution**
5. **absolute flux scale**

Because MAGIC will use a lot of new informations (i.e. the LIDAR) it will be neccessary to evaluate the correlations of the new systems and the results from MAGIC. This is the only way to benefit from this informations.

2 Remark

This document does not claim to contain all the different analysis methods of all the layers. This documents wants to outline the main trunk of analysis. It also wants to point out some connections between different systems from the whole MAGIC device. It is very important to connect all these subsystems for the maximum profit. The knowlegde of these interconnection is very important.