The MAGIC Data Quality Check Software

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Abstract: Imaging Atmospheric Cherenkov Telescopes are complex instruments consisting of several subsystems which have to run properly and synchronously in order to guarantee high quality observations. The MAGIC experiment makes use of a dedicated data quality check software, running at the end of each observation night. It performs a series of quality checks based on different hardware and software aspects to verify that the response of the main subsystems is optimal. Data quality check plots are produced daily and are accessible through a MAGIC internal web page to provide useful information about the telescopes and to pinpoint a possible failure or degradation of the performance. Each morning, a dedicated analyzer checks the automatically produced daily check report and alerts the experts in case of any major anomaly that could affect the data quality. In addition, for each data run a hardware data quality bit is generated, indicating the hardware status of the entire system as well as a weather quality bit. The data quality check software is being updated whenever a crucial hardware change has been introduced.

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1 Introduction

After the latest upgrade, taken in summer of 2012, the MAGIC observatory at the Canary Island of La Palma consists of two identical 17 m Imaging Atmospheric Cherenkov Telescopes (IACT) [1], [2]. Successful and reliable telescope operation requires that all the subsystems (telescope drive system, PMT camera, calibration, active mirror control, GPS clock, readout and data acquisition system (DAQ)) work properly and synchronously in order to provide the high quality data. Also the weather and atmospheric conditions relevant for the data taking are monitored by additional subsystems. Each of these subsystems operates as an autonomous unit, but their information is gathered together by a specially developed Central Control (CC) program [3]. Every 10 seconds the CC program saves into a special report file the values of all relevant parameters for each different subsystems. The DAQ system writes a new sub-run file approximately every minute, and at that instant saves into a DAQ report file the values of 14 different parameters for each of the 1039 camera pixels. The number of entries in a DAQ report file is equal to the number of sub-runs plus the number of dedicated calibration and pedestal runs. Following each data taking night, the two report files provided by the CC and DAQ programs are automatically processed and the plots showing the status of the telescopes subsystems, including weather and atmospheric conditions, and the status of the DAQ are published on an internal web page. The published plots are subsequently analyzed by a dedicated tool of the MAGIC data quality check (MAGICDC) software which verifies whether the parameter values are within predefined limits. The output is a text file sent to the

Figure 1: A crontab time-based job scheduler runs the MAGICDC steering scripts which in turn run Mars executables and macros.
collaboration, including possible warnings on any hardware problems or bad data quality.

A recent implementation to the data quality check software is a hardware status bit which is assigned to each run and sub-run. Together with a weather quality bit, also assigned to each run and sub-run, it is a useful input for data quality selection which is the first step in data analysis.

Finally, each day a scheduled operator checks the published plots of data quality check and the daily check report. In case of any failure or anomaly which could affect the data taking, the operator is in charge of alerting the experts.

The MAGICDC software comprises shell scripts which handle the transport of input and output files, and run different Mars (a ROOT-based MAGIC software package) executables and macros, as is shown in Figure 1. The MAGICDC jobs are automatically executed each day as soon as all the input files are available.

2 Quality check of the MAGIC telescopes subsystems

The first step of the MAGIC daily data quality check is the performance check for all the subsystems of the two MAGIC telescopes. All subsystem reports are written by the Central Control program to an ASCII file. This file is processed by a dedicated part of the MAGICDC software. The plots obtained from the MAGIC CC report display information for all relevant subsystems either as a function of time, as a correlation of two or more different variables, or as a camera display view. The produced plots allow a quick identification of a potentially malfunctioning system/subsystem, the timing of the malfunction, the identification of affected data, and the origin of failure/malfunction.

The subsystems overseen by the Central Control are: the drive system, the camera system, the active mirror control, the trigger electronics, the calibration box, the star guider, the weather station, and the LIDAR. Each of these subsystems, in turn, is a complex system comprising a number of components. For example, the MAGIC camera consists of 1039 pixels, whose single performance profoundly affects the data quality. MAGICDC checks eight different physical quantities for each of these 1039 channels: high voltage, direct current, discriminator thresholds, temperature, PIN diode current, vacuum cavity laser diode bias, trigger delay, and individual pixel rates. In addition to these individual pixel/channel parameters, also the status, the temperature and the humidity in auxiliary camera systems (camera lid, camera protection system, camera cooling system) are constantly monitored. To have a deep insight into the camera operation, plots with different parameters and correlations among them are produced. The value of a large number of parameters are required to stay within pre-defined range. For example, the median temperature of the receiver boards is required to stay within (30 – 45°C). The mean relative humidity read out from the four sensors placed in the camera housing is required to stay below 50%. An example of a limit depending on other parameters is the low voltage box on the side of the camera housing, which is not water-tight, and its temperature depends on the outside temperature, which has larger seasonal variations than the required range of temperature variation in the box itself (≈25°C). So, the limits for the temperature in the low voltage box are function of the external temperature. Trigger rates have a more complex limits definition: they depend on

1. CCD camera tracking positions of bright stars used for an absolute pointing correction.
the light condition during data taking, the condition of the atmosphere (clouds, height of clouds, calima), the galactic or extragalactic origin of source and its zenith angle. There are several loose limits applied to the rates at different trigger levels. The tightest limit, instead, is the limit on stereo/coincidence trigger rate for the data taken under dark (i.e. no-moon) light conditions for extragalactic sources. In order to obtain high-quality data, this value, scaled with a phenomenologically estimated zenith angle dependence \((\cos(z.a.)^{0.35})\), is required to stay within \(150 - 400\) Hz. Another example of a parameter which can strongly influence the quality of the data is the discriminator threshold (trigger level 0) of any individual pixel.

To account for different light conditions, the discriminator threshold is adjusted automatically for each individual pixel using a dedicated routine called "Individual Pixel Rate Control" (IPRC). The aim of the IPRC is to achieve a stable trigger rate under varying light conditions. Figure 2 shows a check plot for the discriminator threshold settings during one night. On that particular day, shown in the figure, there was a clearly visible cluster of pixels with a significantly lower value of discriminator thresholds (lower left plot). The problem was recognised during the daily data analysis, and consulting the MAGICDC plots, the origin was quickly traced to a faulty receiver board which was subsequently replaced.

3 Quality check of the MAGIC Data Acquisition System

After the recent upgrade, the readout for both telescopes is performed by the Domino Ring Sampler version 4 chip (DRS4) with a sampling speed of 2 GSamples/s [7]. The large sampling rate preserves the timing structure of the recorded light flashes and enables an improved background rejection.

During data taking the MAGIC DAQ performs a simple analysis of the recorded data. After each run (being data, calibration or pedestal), a mean charge, a mean arrival time and their RMS in each camera pixel are written to the DAQ report file produced by a dedicated tool of the DAQ software. MAGIC DAQ also determines whether the charge measured in a given pixel belongs to a cosmic-ray image or to the background and stores this information in the DAQ report file. A charge in a pixel, by definition, is considered to belong to the cosmic-ray image (cosmic event), if it is triggered by the predefined data trigger and if its charge lies above a certain threshold. This threshold is adjusted in such a way that it is not influenced by background fluctuations due to electronic noise, night-sky background light or stars. Since a typical shower produces signal only in a few to a few tens of pixels, the charge in the remaining pixels is mostly due to a background. The DAQ calculates a "hit fraction of cosmic events" for each pixel, dividing the number of times the charge in a pixel was considered to be cosmic event by the number of total data triggers (nor calibration neither random/pedestal trigger) for each sub-run.

These data written for each sub-run and each pixel to the DAQ report are processed by the MAGICDC software which produces plots of various DAQ parameters, either as a camera display view or as a function of the sub-run number (i.e. time). Using the DAQ output file, MAGICDC software calculates an estimate of the calibration constant and the number of photoelectrons for each pixel. In addition to the Central Control plots, these DAQ plots provide complementary information on the status of the camera(s) during data taking.

Figure 4 shows the mean charge measured in each pixel for different types of run in the camera display view. Here, MAGICDC monitors the behaviour of the overall mean. Additionally, checks are performed in order to search for clusters of pixels which show coherent deviations from the mean.

4 Calibration data check

The aim of the calibration is to extract and calibrate the signal in each channel of the MAGIC telescopes. The output of the calibration procedure is the number of photoelectrons, which in turn, is proportional to the number of photons reaching a given pixel when it is illuminated by a uniform calibration light source [8]. The calibration procedure consists of the following steps undertaken before each data run: taking of the pedestal run, taking of the calibration run in which the camera is uniformly illuminated with short light pulses whose time spread is comparable to the one of the Cherenkov flash, calculation of the calibration
constant and the arrival time. To account for any change in the light detection and amplification system during data taking, interleaved calibration and pedestal runs are taken with a rate of 25 Hz.

The MAGIDC software checks all the relevant steps of the calibration procedure. A dedicated script labelled "DAQChecking" (see Figure 1) creates a nightly run summary file which pairs corresponding calibration and pedestal runs for each observed source and its wobble positions. The Mars program sorcerer [4] extracts the information from the night run summary file, calculates the calibration coefficient and the arrival time of each pixel, and produces the corresponding root file which contains plots of all the relevant parameters of the calibration procedure. Following that, a shell script steers the calibration data check which runs a Mars executable on these output ROOT-files and produces plots which are published on the dedicated MAGIC internal data quality check web page.

These plots show, in camera display view, and as a function of time, the mean and the RMS of the charge in each pixel for calibration and pedestal runs, the mean and RMS of the calibration constant, the mean and RMS of the number of photoelectrons and the mean and RMS of the arrival times for calibration and data runs. In summary, these plots provide a detailed insight in the complete calibration procedure and ensure a quick tracking and understanding of the origin of a potential problem related to the calibration. As an example of the calibration data check plots, Figure 4 shows the estimated number of photoelectrons (phe) versus the pixel index and its distribution for a typical interleaved calibration run.

5 Analysis data check

On the same computer cluster used to perform the above mentioned data quality checks, the on-site analysis (OSA) software is running a set of scripts which steer the entire MAGIC analysis chain and provide data on a daily basis in a suitable format for performing individual source analysis. Information of the shower image stored by OSA are based on the Hillas parametrization [9] and are saved in ROOT format by usage of the Mars executable star [4]. The output is given separately for each source, telescope and wobble position. The same MAGICDC script "DAQChecking" which controls the production of the plots for the calibration check is used to run dedicated jobs which extracts distributions and camera display view of the Hillas parameters for the observed source and its wobble position and publishes it on the internal MAGIC data check web page. As an example Figure 5 shows in a camera display view distribution of the centre of gravity (CoG) for a source observed in stereo wobble mode giving asymmetric distribution in camera display view. Obviously any "hole" in CoG plots indicates a severe problem which profoundly affects the data quality. Typically, OSA completes its tasks by 12:00 UTC on the day following the data taking. The plots of the distribution of the Hillas parameters provide a further insight in the performance of the MAGIC telescopes.

6 Conclusions

The MAGICDC software together with OSA software allow experts from the MAGIC collaboration an insight into any system failure before 12:00 UTC, enabling fast reaction to hardware malfunctions. Although the report about the data quality check is produced automatically by MAGICDC, the inspection of the daily check report is performed each day by a daily check operator, who makes the final decision whether it is necessary to send out an alert. Typically, the MAGICDC allows the operator to detect one critical status per month.

The MAGICDC upgrades follow upgrades of the telescopes or auxiliary systems such as LIDAR which has been installed at the MAGIC site [5]. MAGICDC will perform checks of the stereo Hillas parameters as soon as OSA software provides them. Soon, the MAGICDC will be upgraded to perform long term studies of telescope parameters and correlations among them, providing even more insight into stability and functioning of MAGIC telescopes.

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References

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