

# The monitoring system of the Pierre Auger Observatory and its additional functionalities

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**Abstract.** To ensure smooth operation of the Pierre Auger Observatory a monitoring tool has been developed. Data from different sources, e.g. the detector components, are collected and stored in a single database. The shift crew and experts can access these data using a web interface that displays generated graphs and specially developed visualisations. This tool offers an opportunity to monitor the long term stability of some key quantities and of the data quality. Quantities derived such as the on-time of the fluorescence telescopes can be estimated in nearly real-time and added to the database for further analysis. In addition to access via the database server the database content is distributed in packages allowing a wide range of analysis off-site. A new functionality has been implemented to manage maintenance and intervention in the field using the web interface. It covers the full work-flow from an alarm being raised to the issue being resolved.

## I. INTRODUCTION

The Pierre Auger Observatory is measuring cosmic rays at the highest energies. The southern site in Mendoza, Argentina, has been completed during the year 2008. The instrument [1] has been designed to measure extensive air showers with energies ranging from  $10^{18} - 10^{20}$  eV and beyond. It combines two complementary observational techniques, the detection of particles on the ground using an array of 1600 water Cherenkov detectors distributed on an area of 3000 km<sup>2</sup> and the observation of fluorescence light generated in the atmosphere above the ground by 24 wide-angle Schmidt telescopes positioned in four buildings on the border around the ground array. Routine operation of the detectors has started in 2002. The observatory became fully operational in 2008 with the completion of the construction.

## II. ONLINE-MONITORING FOR THE PIERRE AUGER OBSERVATORY

For the optimal scientific output of the observatory the status of the detector as well as its measured data have to be monitored. The Auger Monitoring tool [2] has been developed to support the shifter in judging and supervising the status of the detector components, the electronics and the data-acquisition.

The detector components are operated differently and therefore the monitoring of their status have different

requirements. The stations of the surface detector (SD) operate constantly in an semi-automated mode. Data acquisition must be monitored and failures of stations or of their communication must be detected. The data-taking of the fluorescence detector (FD) can only take place under specific environmental conditions and is organized in shifts. The sensitive cameras can only be operated in dark nights with not too strong wind and without rain. This makes the operation a busy task for the shifters that have to judge the operation-mode on the basis of the information given.

The basis of the monitoring system is a database running at the central campus. The front-end is web based using common technologies like PHP, CSS and JavaScript. An interface has been developed for the generation of visualisations. Alarms for situations that require immediate action are first filled into a specified table of the database that is checked by the web front-end.

The content of the database is mirrored on a server in Europe using the MySQL built-in replication mechanism. This way not only the shifter and maintenance staff on site can use the monitoring, but it is also available for experts all around the world.

## III. HIGHER LEVEL QUANTITIES IMPLEMENTATION

The data collected in the database can be used to derive higher level quantities such as the up-time of the FD telescopes. This quantity is of major importance since it is a necessary ingredient of flux measurements. The dead-time of each telescopes is recorded in the database. Together with the run information and other corrections retrieved from the database the total uptime for each telescope can be determined individually. The up-time is calculated only for time-intervals of ten minutes, balancing the statistical precision of the calculated up-time due to statistics with the information frequency. A program to execute the calculation is running on the database server and fills continuously the appropriate tables in the database. The web-interface displays the stored quantities. An example of one night of data-taking is given in Fig. 1. The up-time is available in quasi real-time for the shifter as a diagnostic and figure of merit.

## IV. DATABASE DISTRIBUTION FOR ANALYSIS USE

The information collected in the database is a valuable source for analysis, i.e. for studies of the long term stability of the detector. With increasing measurement

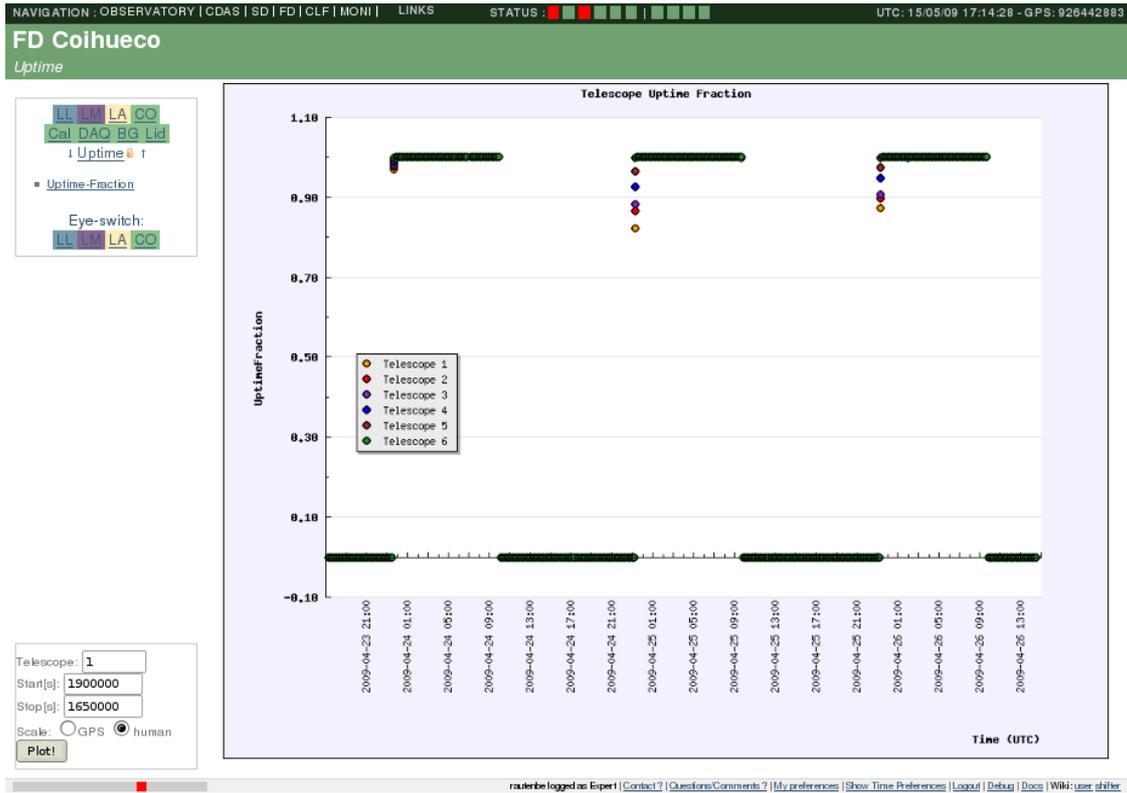


Fig. 1. Example of the web-interface for the display of the uptime. Shown is the uptime-fraction for the six telescopes of one FD building and three nights data-taking.

time the accumulated data is too large for the online usage by the shifter, who usually focuses on the most recent data with high priority on the immediate response of the monitoring system. On the other hand, for analysis usually only a small part of the database is used. Therefore the database is split into monthly pieces containing only single components of the database. These pieces can be transported and used off-site for analysis. Only the most recent portion of the database is retained for use by the online monitoring system, keeping the response of the system fast for the shifter.

## V. MAINTENANCE AND INTERVENTION MANAGEMENT

For the operation of the surface detector an additional web feature has been developed to manage hardware maintenance and operations in the field triggered by alarms. This is a new part added to the SD section of the Auger Online Monitoring web site and covers the full work-flow from an alarm being raised to being resolved.

In order to check all the components of a SD station various sensors are installed in each station. The calibration process runs online every minute and the sensor measurements and the calibration data are sent to the central data acquisition server every six minutes. These data are transferred to the monitoring database. Analysis software checks the database contents once per day to detect long-term problems such as PMT instabilities, dis-

charging batteries, etc. and fills the database alarm table. The dedicated SD alarm web page allows the shifter to view the alarm table in a user friendly way. Since the table can be huge when all alarms are displayed, selection tools are also provided. They allow to look for a particular set of alarms. From an alarm table link, the shifter can easily have access to the web page of the particular SD station, where he can look at different plots in order to judge the reliability of the alarm. An example for a web page displaying an alarm is given in Fig. 2. From the same page the shifter can consult the history of all alarms that previously occurred on the station and view all the maintenance done or planned for it. Tools are also provided to plot any monitoring or calibration data of the SD station as a function of time.

When a shifter notices an alarm on the Auger Online Monitoring web site, he performs some analysis to check if it is a real alarm requiring an action. He may write a summary into a file and add illustrative plots. Then he contacts the SD Scientific Operation Coordinator (SOC) and SD experts by sending them an email, using the contact link displayed on the footer of every Auger Online Monitoring web page. The link displays a new web page allowing the shifter to enter the the email subject, a comment via a text area, and optional files to upload. After reception of the email, the SD SOC or SD experts can either click on the link automatically added to the email to create a new maintenance request

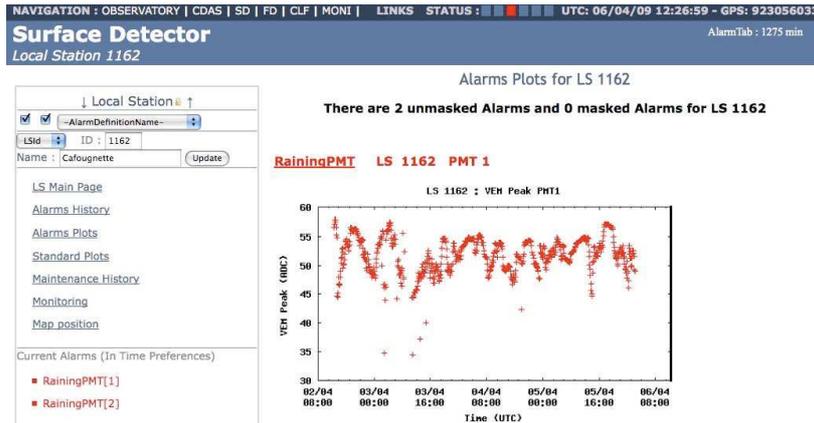


Fig. 2. Example of the web-interface for the display of an SD station alarm plot.

with fields filled out automatically, or connect to the website and add one or more maintenance requests as displayed in Fig. 3. The SD SOC or an SD expert associates then one or several predefined actions to the maintenance request. They can create a mask for one or several types of alarms from the maintenance web page, so that corresponding alarms will not appear by default in the shifter pages.

maintenance-crew member fills in the actions actually done using the intervention report web page. Doing this “closes” the intervention. Actions not executed can be planned again in another intervention. When no pending action exists on the maintenance, the SD SOC or an SD expert can close the concerned maintenance request, which automatically unmask the associated masked alarms.

All maintenance, actions and interventions are stored in database tables. Specific web pages with associated tools have been designed in order to view and manage maintenance and interventions.

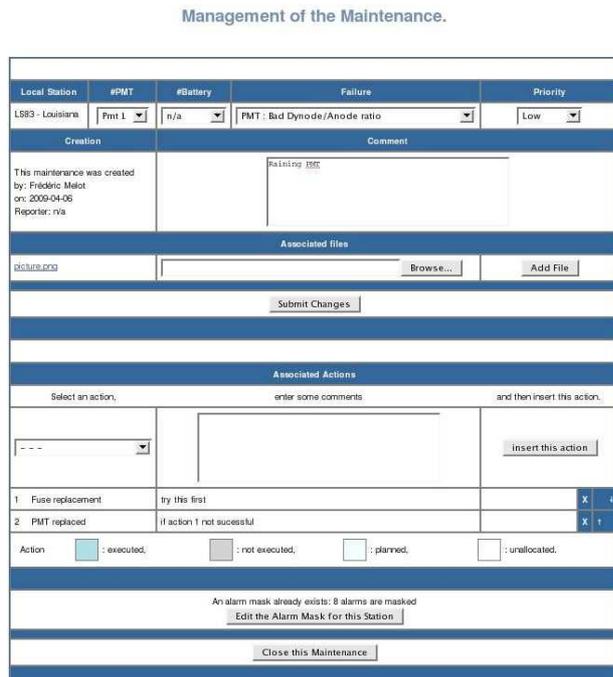


Fig. 3. The web interface available to manage a maintenance.

The task of the SD SOC consists of planning one or several interventions and associating maintenance actions to them. The web interface has been designed to provide the necessary tools to help him. A predefined road map is provided that describes what has to be done during the intervention in order to help the maintenance crew in their work. Returning from the intervention, a

## VI. SUMMARY

A monitoring tool has been developed for the Pierre Auger Observatory to ensure the quality of the recorded data. Data from different sources are collected and stored in a database accessible for the shift crew and experts via a web interface that displays generated graphs and specially developed visualisations. Higher level quantities such as the on-time of the fluorescence telescopes are derived in nearly real-time and added to the database for further analysis. In addition to access via the database server the database content is distributed in packages allowing a wide range of analysis off-site. A new functionality has been implemented to manage maintenance and intervention in the field using the web interface. It covers the full work-flow from an alarm being raised to the issue being resolved.

## REFERENCES

- [1] Pierre Auger Collaboration [J. Abraham et al.], *Nucl. Instr. Meth. A* **523** (May, 2004), 50–95.
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