Nuclear Instruments and Methods in Physics Research A 604 (2009) S44–S45

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

Radio in Auger-offline

Julian Rautenberg

Bergische Universität Wuppertal, Department of Physics, 42097 Wuppertal, Germany

for the Pierre Auger Collaboration[1]

ARTICLE INFO

Available online 19 March 2009

Keywords:
Cosmic rays
Radio-detection
Air showers
Pierre Auger Observatory
Offline software
Framework

ABSTRACT

The Pierre Auger Collaboration started an R&D task force to investigate the extension of the Observatory with a self-triggering antenna array for the detection of extensive air showers by their radio-signals. First signals measured with test-set-ups require establishing an environment for the analysis of data and simulations. Extending the general offline software framework developed within Auger for radio-detection offers many short-term as well as long-term benefits.

1. Introduction

In October 2006 the Auger Collaboration started to install different test set-ups to explore the possible use of radio technique at the southern site of the Pierre Auger Observatory [1]. The radio-quietness of the Pampa Amarilla in Argentina offers very good environmental conditions for radio-detection. The Pierre Auger Observatory with its hybrid event detection will allow to collect an unprecedented variety of information on single air-showers when adding radio as additional detection method. At this stage the primary aim of radio-detection at Auger is to understand the emission mechanism in detail for energies accessible with the Pierre Auger Observatory, i.e. above 10^{18} eV. Beginning with the first measurements of air showers with radio, the air-shower information of the "standard" detectors are necessary to confirm the radio-measurements. Therefore, combination of the different inputs are very valuable as has been shown by LOPES at KASCADE-Grande [2].

2. The Auger offline framework

The collaborative effort of a large number of physicists developing a variety of applications over the projected 20 year lifetime of the experiment places a strong demand on the flexibility and robustness of the software framework. Its main task is to support simulation and reconstruction of events using surface, fluorescence and hybrid methods. The ability of the software to be extended in case of future detector upgrades like radio-detection has been an additional demand for the framework. Such extensions add additional data-formats to the existing ones that the Auger offline framework has to handle. The aim of collaboration members to be able to replace existing algorithms of any physics analysis requires that the portions of the code directly used by physicists should not assume a particularly detailed knowledge of the full power of C++ and object-oriented design.

The Auger offline framework [3] comprises three principal parts as depicted in Fig. 1: a detector description providing access to configuration and performance data of the detectors, an event structure accumulating detected, simulated and reconstructed event information and a collection of pipelined processing modules. This ansatz offers a clean modularization of algorithms acting on the event-structure, allowing an easy exchange of single processing modules to test different methods.

The task of the offline framework is not only to reconstruct the air-shower from the detector measurement. For real data it is the full chain from applying detector calibrations to the detector quantities towards the shower quantities, where also additional corrections, e.g. for the atmospheric conditions have to be applied. The framework is also used for simulated events. Here, the framework takes the huge task of the detector simulation for given simulated air-showers. For radio-detection the physics of the air-shower is simulated using CORSIKA [4], and the REAS2 [5] package simulates the radio emission. The full data-flow for the combined simulation and reconstruction is shown in Fig. 2.

3. Implementation of radio-detection in the Auger offline framework

The first detection of radio-signals for events measured with the Pierre Auger Observatory requests the reconstruction of the shower quantities from the radio-signals [6,7]. This differs from

E-mail address: julian.rautenberg@uni-wuppertal.de

[1] Av. San Martin Norte 304 (5613) Malargüe, Prov. de Mendoza, Argentina.

0168-9002/$ - see front matter © 2009 Published by Elsevier B.V.
doi:10.1016/j.nima.2009.03.032

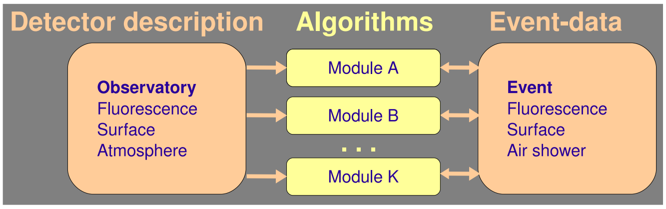

Fig. 1. In the Auger offline framework modules retrieve information from the detector-descriptions and interact on the event-data.

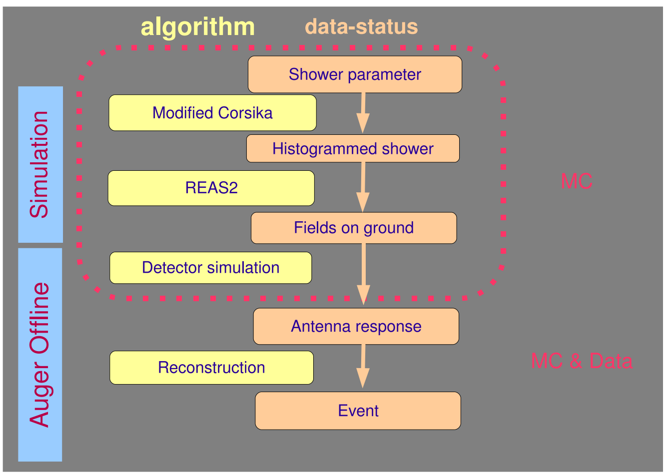

Fig. 2. Dataflow for the simulation of radio-detection. CORSIKA [4] and REAS2 [5] cover the physics simulation of the air-shower and the radio emission, respectively. Their output is processed in the Auger offline framework which incorporates the detector simulation.

the first debugging phase of the radio-detector installations, where monolithic stand-alone programs were targeting at finding air-showers and analyzing the detector and triggering efficiencies. Within the Auger offline framework the task of air-shower reconstruction arrived at a very sophisticated level. It is therefore only natural to add the radio-detector to the existing framework, reusing the already developed algorithms. This integration into the offline framework has the immediate impact of a unique event handling for the combined event, which makes an easy comparison with already existing reconstructed shower quantities possible. It also makes the well developed concepts of the offline framework available for the software development of the radio-detection reconstruction. Member of the collaboration who worked with the framework for other purposes will have easy access to contribute also to this new detection method, opening a field of human resources. More importantly, the framework shows its strength when one wants to compare the results of the different test set-ups or different simulation or reconstruction algorithms, e.g. a different background simulation. Here the sequenced processing pipeline of the framework described in Section 2 allows one to exchange a module, e.g. the module for the simulation of the background, making the effect in the final reconstruction visible. In the end, the framework is unavoidably necessary for the global reconstruction of a super-hybrid event,

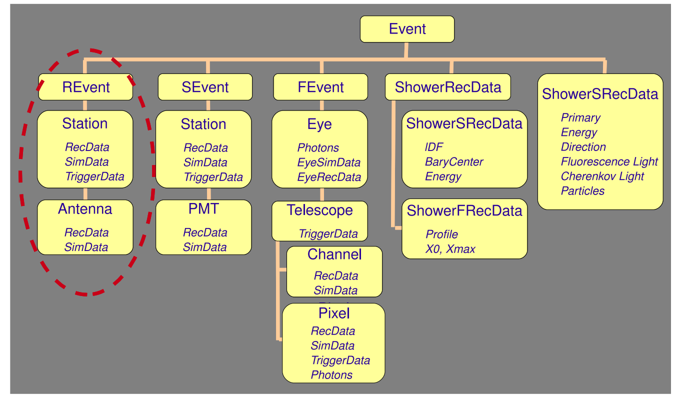

Fig. 3. Scheme of the classes of the event-structure with the additional radio extension marked by the dashed ellipse.

using the radio-detection information in combination with the other detector informations. This would give access to an unprecedented high quality view on air-showers and their development in the atmosphere.

For the concrete implementation of the radio-detection on class level, we note that the set-up of a radio-detector station is quite similar to a surface detector station (SDS). Both take data in form of triggered samples with the order of 10^7 values per second. Both have several channels, SDS have three photo-multipliers and radio antennas have two polarization planes. In common is also the reconstruction of a signal-time and amplitude leading to a geometric 3D shower reconstruction from the timing and a lateral distribution function from the amplitudes at the given distances of the antennas to the shower core. This consideration leads to the implementation of radio closely to the existing SDS one. The additional classes for radio as extension to the existing framework are depicted in Fig. 3.

4. Conclusions

With the first radio-detection of air-showers at the southern site of the Pierre Auger Collaboration the need for an analysis-environment for data and simulations arises. Extending the general offline framework developed within Auger to radio-detection offers at short-term benefits of unique event handling and an easy comparison of different algorithms or test set-ups. At the long-term the global shower reconstruction of a super-hybrid event promises never precedented information of the shower development in the atmosphere.

References

[1] The Pierre Auger Collaboration, Nucl. Instr. and Meth. A 523 (2004) 50.
[2] H. Falcke, LOPES Collaboration, et al., Nature 435 (2005) 313.
[3] S. Argirò, et al., Nucl. Instr. and Meth. A 580 (2007) 1485 (arXiv:0707.1652 [astro-ph]).
[4] D. Heck, et al., Report FZKA 6019, Karlsruhe, 1998.
[5] T. Huege, R. Ulrich, R. Engel, Astropart. Phys. 27 (2007) 392.
[6] J. Coppens, Nucl. Instr. and Meth. A (2009), doi:10.1016/j.nima.2009.03.119.
[7] B. Revenu, Nucl. Instr. and Meth. A (2009), doi:10.1016/j.nima.2009.03.028.