R&D and technical activities for The Pierre Auger Observatory

P. Bernardini [1 2] C. Bleve[12 3] G. Cataldi[2], M. R. Coluccia[12], A. Corvaglia, [2] P. Creti,[2] S. D'amico[4 2], I. De Mitri[12], U. Giaccari[12], G. Mancarella[12], G. Marsella [42], D. Martello[12], M.Panareo[42], L.Perrone[42], C. Pinto[42], M. Settimo[12 5] and the AUGER Collaboration

[1]Dipartimento di Fisica, Università del Salento, Italy

[2]Istituto Nazionale di Fisica Nucleare sez. di Lecce, Italy,

[3]now at the Dept. of Physics, Bergische Universität Wuppertal, Germany ,

[4]Dipartimento di Ingegneria dell'Innovazione, Università del Salento, Italy

[5]now at the Dept. of Physics, University of Siegen, Germany ,

1. Validation of the AUGER software

The offline in Auger is a continously evolving environment. As the development task proceeds a build or release is ready for creation and validation. In a quickly evolving environment, a large effort is required in order to identify and track down problems, conflicts and omissions that can raise between the pieces of code. The process of controlling the modifications to the software and determining wheter or not a certain piece of code fulfills a set of requirements is therefore a time consuming task that must be adressed as much as possible in a general way.
For this reason the design and development of a software that is able to technically validate the per diem modifications to the software has been developed inside the Lecce group[1]. We refer to this software as technical validation.
The main idea behind the technical validation is to monitor that a set of physical quantities does not drastically change during the software development process and in case it does change it sends an alert message to the developers responsible of the change asking for information. The tests implemented are launched daily in the BuildBot[2] environment and report a pass/nonpass test on a waterfall web-page.

2. Implementation of Worker Nodes on Demand

The process of simulation and reconstruction of large data sets in Auger is a computationally demanding issue. For such a reason the Grid is used. A Grid allows a computational service with secured services for running applications at distributed computational resources, dynamically aggregating a computational capacity of individual computers. The use of condition data (i.e.atmosphere status, *real* geometry and calibration) requires specific configuration of the systems delivering the services and is therefore hardly used on the Grid sites. For doing so we would need a clear decoupling of data access, and storage services from the requirement of end-user knowledge of the physical location and configuration of the system that delivers the service. This is usually accomplished from Cloud Computing.

The WNoDeS[3] is a software that INFN is developing and that provides on-demand, integrated access to boths Grids and Clouds through virtualization technologies. The use of WNoDeS has been adopted for the main Italian Auger Grid based at CNAF(Bologna), and our group is strongly involved in the effort. This is unique inside the collaboration and allows the use of Grid also for the Reconstruction and analysis of large data samples, dependent from condition data (atmosphere status, *real* geometry and calibration).

3. The Lecce PMT test facility

A new test facility has been built in the Lecce INFN Astroparticle Laboratory in order to test and select the Photomultiplier Tubes (PMTs) useful for the surface detectors of Auger Next as well as for extension of Auger South.
The North emisfere as well as extensions of the Southern part will profit of continuous test study and optimization of PMT.
In Auger South, the Cherenkov light is detected by three 9" PMTs (XP1805 from Photonis). On March 2009 Photonis announced the end of photomultiplier production, therefore the need to select a new PMT from other companies. Moreover, more extensive studies to ensure good response, calibration and triggering properties need to be performed in order to minimize the possible failures, in configuration where only one PMT can be employed as foreseen in Auger Next. In the set-up where only one PMT is used, the failure will traslate into the loss of one detector of the surface array with a direct consequence for the

physics performance.
The measurement program follows the performance specifications required for the Auger experiment. The PMTs need to have a large dynamic range, a good linearity, a low counting rate and a low breakdown. In order to check these parameters we setup a test facility in the Astroparticle Lecce Laboratory. Fig. 1 shows the schematic view of this setup and of the data acquisition system.
Two dark boxes are aveilable in the laboratory eachone hosting one PMT at a time. The detector under test can be positioned looking towards the box roof where a light source is positioned. Dark tight connectors plate for signals transmission and power up is on the box panel.
We have characterized a PHOTONIS PMT (XP1805) instrumented with one of the bases designed for the Auger experiment that is powered up by a custom made DC-DC HV power supply. The light source we used to perform the measurements consists of a LED Pulser controlled through a National Instruments USB-2659 Board connected to the data acquisition computer. The board has 48 digital I/O used for trigger generation, 4 digital analog converter (DAC) with 16 bit resolution and 2.8 MS/s with $I_{MAX} = 5$ mA/DAC. The DAC are used for LED pulse amplitude control. The board is also connected to the DC-DC power supply in order to control and monitor remotely the HV set on the PMT.
A blue LED (470 nm, 45 deg viewing angle) is used and in order to have fast turn-on turn-off response (short pulses) an appropriate LED driver has been designed. The LED driver discharges quickly a charge stored on a reference capacitance. This charge is proportional to the number of the photon generated by the Led in a short time. The LED is positioned in the center of a small box housing the driver. This box is mounted on a mechanical bracket that allows to put the LED at different positions respect to the PMT for non-linearity measurements.
The signals from anode and dynode are sent to a digital oscilloscope of 4 GSa/s sampling and 1 GHz bandwith (AGILENT MSO6104A) connected to the computer through GPIB. The data acquisition user interface is written in LABVIEW. Using this graphical interface, it is possible to set the HV on the PMT, the LED voltage and the oscilloscope channels, moreover all the information from the run are saved on a ascii file: this includes waveforms from dynode and anode, the events number, and all the set parameters. The offline data analysis is performed using the ROOT analysis framework: ad hoc MACROS have been developed for peak finding, charge calculation, and spectra. The first phase of PMT test at the Lecce facility has been concluded with the full characterization of one PHOTONIS PMT (XP1805). The measurements performed are: dark pulse rate, single photoelectron spectrum, gain vesus voltage, non-linearity, after pulse ratio, dynode to anode ratio.
The existing setup allows to plan test on different PMT (Hamamtsu) as well as extensions of measurements program with the introduction of new detectors like SiPM (Silicon PhotoMultiplier) or APD (AvalanchePhotoDiode).

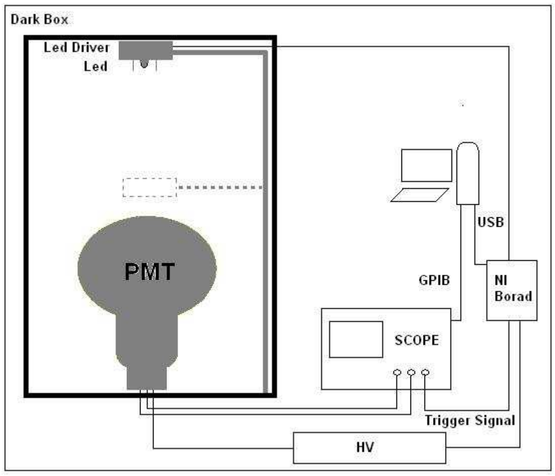

Figure 1. Schematic view of the experimental setup.

4. SDECO PMT test facility

Since February 2010 a group from Lecce is in charge to manage the SDECO PMT test facility in Malargüe. It is running since 2002 and has been fully used in order to test all the PMTs actually deployed in the AUGER array. The system has been designed to completely test 12 PMTs at the same time[4]. The entire system is controlled by a PC based on a Linux OS4 which control the DAQ based on a CAMAC system and some dedicated boards to control, through a NIM multipurpose I/O PCI (6025E) board, HV and LED controllers. In the last two years the system showed some problems of stability that have been easily solved by the team, but a number of upgrades are necessary. In particular the following have been realized last year: A new UPS (filtering) with 3kW and 0,5 h autonomy has been installed and a new GROUND system has been realized. This was necessary to avoid sudden blackout and to filter the power lines. The Lecce group also realized and installed a new signal Splitter with the Anode and Dinode signals from PMTs in order to have attenuated anode signals (1 at 84%

and 2 at 8%) and to allow a monitoring of them through an oscilloscope. The new Splitter was re-designed in order to make it more precise, easy to use and stable. Finally, in order to monitor the LED sources and to automatically set the correct control voltages to start the automatic procedures for the full PMT test, a new software routine have been developed. The single photoelectron emission condition is found by an iterative procedure. The data are recorded. A systematic control of the working point is a useful tool for monitoring the LED system aging. In 2011, a new DAQ system based on VME will be developed in Lecces Astroparticle Laboratory.

5. The AMY project

An air shower dissipates virtually its entire energy budget trough ionization, producing an initial tenuous plasma with an electron temperature of order 10^5K or more. The ionization and subsequent disexcitation of mulecular nitrogen in the N_2^+ 1N and 2P states leads directly to the optical N_2 fluorescence that is observed.

The hot air shower plasma cools rapidly on nanosecond time scales, distributing its thermal energy through collisions with the neutral molecules, primarly N_2, which has the largest cross section and number density. This rapid cooling process leads to additional excitation of rotational, vibrational, electronic valence, and other modes of kinetic energy distribution among molecules, many of which can also lead to subsequent emission. In turn, the hot electrons themselves, while producing this excitation, can produce their own emission, such as continuum bremsstrahlung emission or recombination radiation. The fraction of total radiated energy in optical fluorescence, compared to the total available energy budget for secondary radiation is very small leaving much possible radiative energy still unaccounted for. Yet the possibility for observing secondary air shower plasmas emission other then optical fluorescence is an active field of exploration. A possible alternative emission is microwave emission. This has been explored through accelerator experiments[5], but the yield and the spectrum is still unclear. For such a reason a measurements of the microwave radiation has been proposed at the DAFNE Beam Test Facility of the Laboratory Nazionali di Frascati and is in preparation in the Lecce AstroParticle Laboratory.

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