CORAM (COsmic RAy Mission): final DAQ and International Cosmic Day (ICD)

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For the centenary of discovery of the cosmic ray radiation in 2012, a group of researchers from Lecce Physics Department and INFN proposed an experiment on cosmic rays for outreach and educational purposes. Several High School students were involved in this activity, named CORAM (Cosmic RAy Mission), that provided the design, construction and test of a detector for the measurement of the cosmic ray flux as a function of the atmospheric altitude.
Being an outreach program, the main goal of CORAM is the dissemination of (astro) particle physics, and related techniques, among high school students, through the measurements of several properties of the *natural particle beam* given by cosmic rays. In a first phase, students and teachers attended several seminars concerning the introduction to particle and cosmic ray physics, covering also the basic concepts related to detection techniques and data acquisition and analysis. Then they were fully involved in the design and building of a *cosmic ray detector*. Detailed test results can be found in [1]. Some properties of the cosmic ray flux can then be measured and data analyzed and compared with our current knowledge on this topic.
A first detector prototype has been realized and used for a test campaign with the students. The detector is made by scintillator layers readout by APDs (Avalanche Photo Diode) interposed with appropriate absorber layers and put into coincidence. The dependence of the cosmic ray flux (above a given energy threshold) on the altitude has been investigated by means of a set of measurements done in Lecce and in several places on the Gran Sasso massif in central Italy, up to about 2100 m a.s.l. [2].This approach allowed students to repeat (part of) the same type of investigations made in the summer 1939 by Bruno Rossi and J. Barton Hoag going from Chicago to Mount Evans [3]. The detector prototype, moreover, wereused in several public events like "Notte della Ricerca".
In this work, the final Data Acquisition System (DAQ) developed for the detector is described and the International Cosmic Day (ICD) event is presented.

1. Detector Description

The detector is made of four tiles of plastic scintillator [4] interposed with iron absorbers. Each tile has dimension of $14.3 \times 314.3 \times 1cm^3$ and density of 1.032 g/cm^3 (BC-412); iron absorbers have the same size but a 2 cm thickness. Scintillation light is detected by two APDs (Avalanche Photo-Diodes) with $1mm^2$ sensitive area and it is collected through a wavelength-shifting (WLS) optical fiber of $1mm$ diameter. Fibers flexibility allows for packing them in circular coils thus increasing the light collection efficiency over the plastic volume.
Each detector is provided by an electronics frontend board on top which allows for discriminating signals from the two APDs.
This setup has been chosen because it allows enough stability and it avoids to use high voltage supply as for the case of photomultipliers. Moreover, through the coincidence of four horizontal tiles, it is possible to detect particles with minimum energy of around $100MeV$, for a m.i.p.
Due to the relatively simple setup, we decided to acquire just the single rate coming from each detector and the double, triple and quadruple coincidences at $1Hz$ frequency.

2. The DAQ System

The acquisition system has been engineered to create a compact object, redundant and which can be easily used for several measurements in the field. We present such acquisition system and the electronics used.
The DAQ must collect the signals from the detector, digitize and integrate them with the information for geolocation; perform time stamping and transfer such information to the computer.

As we said in the previous section, each detector is provided by an electronics frontend board

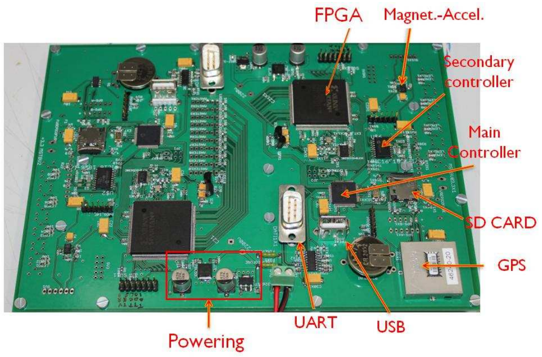

Figure 1. The DAQ PCB-board.

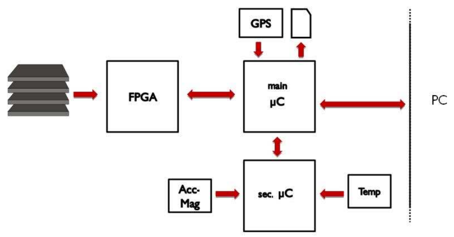

Figure 2. The DAQ scheme.

on top that processes the signals from the two APDs. Therefore DAQ system can be simply implemented using a Field-Programmable Gate Array (FPGA), to manage the parallel processes logic, and a microprocessor (μC) for the communication with the computer. Moreover DAQ is provided of a GPS module for the coordinates (latitude, longitude and height) and time stamping. All data will be saved also locally in a mass storage device.
In Fig.1 the PCB-board devoloped for the CORAM DAQ is shown. It is possible to see that the DAQ is made completely redundant by duplicating the circuit.
In Fig.2 is shown the DAQ system scheme. Data are processed from the FPGA (Xilinx Spartan 3E 500K) in a defined time window through a look-up-table for coincidence counting. Moreover FPGA labels each count with a specific flag (single count plane 1, etc.), increase the detected event counters and transfers the data to the μC (MicroChip PIC18F87J50). The micro controller provides the timestamp with the time information from a GPS receiver integrated in the DAQ. Moreover, it also provides the environment temperature records, defines the time window for data acquisition, saves data on a SD-Card and finally sends them serially to a computer for test purpose. An appropriate graphical user interface was also developed using the LabView [5] software.

3. The International Cosmic Day 2012 and 2013

To celebrate the 100th anniversary of Victor Franz Hess's discovery of cosmic particles on August 7, 1912, DESY Accelerator Laboratory (Hamburg), Fermi National Laboratory (Chicago) and CERN (Geneva) organized the International Cosmic Particle Day. This is an international project for the High School students that take place every year stating from 2012. Students from across the globe can participate and ask questions like: what are cosmic particles? Where do they come from? How can they be measured? Scientists working to answer these questions invite school students to join up for a day of experimentation in this fascinating field. During the ICD, the students are in contact with the research activities, can carry out a little experiment on cosmic rays, analyze the data, compare their results with other groups connected via web with other universities or research centers in the world. They can work for a day as an international collaboration.
Our group did partecipate to the two editions, ICD2012 and ICD2013. In both case, our students measured the zenith angle distribution of air shower particles. In Fig.3 the map that gives an overview of the partecipating institutes for the 2013 edition. In this case we use our detector with the final DAQ described in the previous section. Fig.4 shows the measurements results that the students published on the web [6]. We had 45 students from 8 High Schools from the Lecce and Brindisi districts working together and interacting with foreing student from all over the world.

4. Conclusion

With the CORAM project we realized a detector prototype for the cosmic rays flux measurements. This detector is a compact, cheap and user friendly device to be used from high school students to detect and study cosmic rays that are a natural and safe source of ionizing particles coming from outer space. The main goal is to disseminate the (astro) particle culture among the High Scholl students.

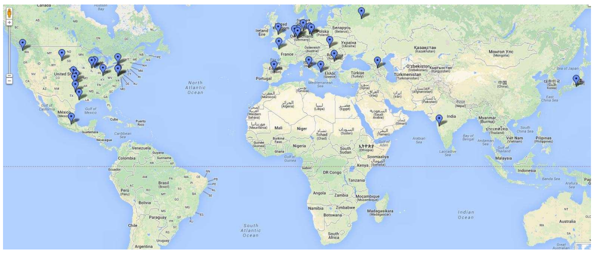

Figure 3. The map of the partecipating institutes for the ICD 2013.

Figure 4. Zenith angle distribution of the cosmic ray air shower.

The final DAQ has been presented and the ICD event has been described. Moreover our device is used in several public events such as "hand-on" experiments, scientific demonstration, simulations, and debates. Finally the project will be integrated in the EEE experiment in several italian High Schools.

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