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The CORAM Project (COsmic RAy Mission)

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Summary. — On the occasion of the forthcoming centenary of the cosmic ray radiation discovery, a group of researchers from Lecce Physics Department and INFN proposed to repeat an experiment similar to the one performed by Victor Hess in 1912 for outreach and educational purposes. Several High School students are involved in this activity, named CORAM (Cosmic RAy Mission), that provides the design, construction and test of a detector for the measurement of the cosmic ray flux as a function of the atmospheric altitude. The detector is made by scintillator layers readout by APDs (Avalanche Photo Diode) interposed with appropriate absorber layers and put into coincidence. The experiment will be hosted on an atmospheric balloon from the Italian space agency (ASI Agenzia Spaziale Italiana) that presumably will take off in the summer of 2012. The INFN encouraged and supported this outreach activity by funding the detector and Data Acquisition System (DAQ).

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PACS 01.40.-d – Education.
PACS 01.55.+b – General physics.
PACS 01.50.Pa – Laboratory experiments and apparatus.

1. – Introduction: Experiment goals

At the beginning of the twentieth century, scientists were faced with a problem they could not explain. As a matter of fact there seemed to exist much more radiation with respect to the one produced by natural radioactivity. Several experiments were performed in order to study this fact. Particularly two scientists, Victor Hess in Austria and Domenico Pacini in Italy, simultaneously developed two ingenious and complementary research lines that together would explain the origin of this radiation.

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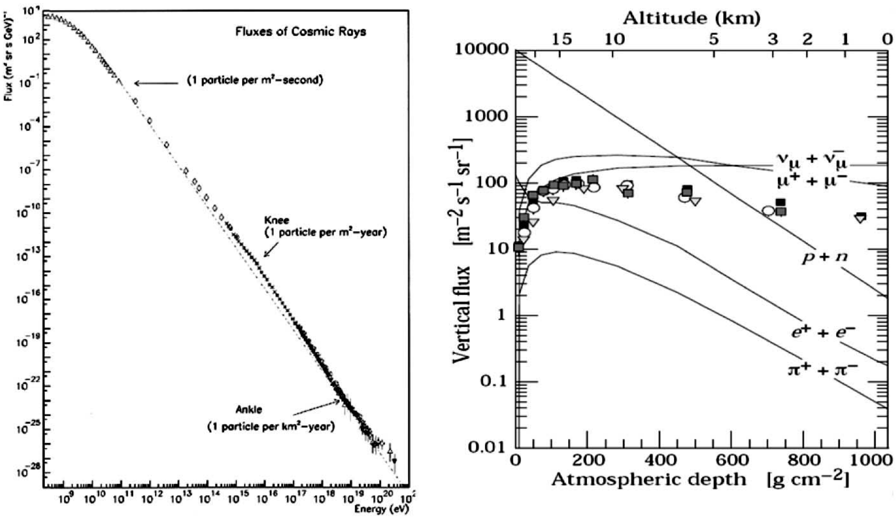

Fig. 1. – Left: primary cosmic rays flux as a function of energy. Right: secondary cosmic rays flux as a function of the atmospheric depth [3].

Domenico Pacini performed several measurements under water in order to establish the variation of an electroscope discharge velocity, *i.e.* the radiation intensity, as a function of the depth [1]. At the same time, Victor Hess measured the radiation intensity variation with the altitude [2], discovering that going up in the atmosphere with a balloon the electroscope discharged more quickly. These independent measurements demonstrated that the unknown radiation came from outer space, hence the name "cosmic rays". For his experiment, Hess received the Nobel Prize for Physics in 1936.

Today it is well known that the cosmic rays hitting the Earth (primary cosmic rays) are mainly composed by atomic nuclei and a small amount of photons, electrons and positrons. Their energy varies in a wide interval reaching about 10^{20} eV. The primary cosmic rays interacting with atmosphere generate particle showers with secondary particles that reach the Earth's surface with a flux of almost 300 Hz/m^2 at sea level (see fig. 1). The vertical flux of the cosmic rays with respect to the altitude is then characterized by a maximum followed by an exponential decay known as Pfotzer plot after the name of the physicist that first performed different measurements with weather balloon and using particle detectors put into coincidence [4].

The position of the Pfotzer plot maximum depends on different factors, like particles type, latitude, detection threshold, however all the components show a peak to around 100–150 g/cm^2 of atmospheric depth, corresponding to about 18 km altitude.

The CORAM project main goal is to perform an experiment similar to the ones made by Pfotzer and Hess, by using a set-up simple enough to be used for educational purposes. The detector has been funded by INFN, while the Italian space agency, ASI, agrees to host the experiment on a balloon, to perform measurements at very high altitude. In any case the set-up is designed to be functional also for measurements performed by students underground or at ground but at different altitudes.

In the following sections we will illustrate experimental set-up, different configurations of the balloon launch, educational program, laboratory experiences with prototype and plans for the future.

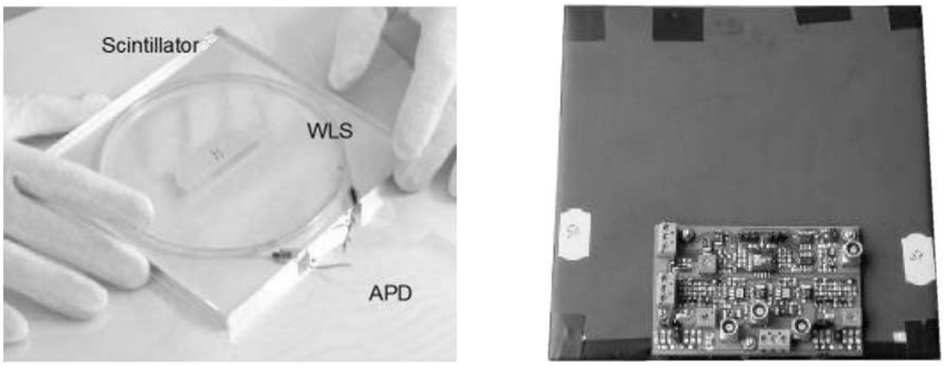

Fig. 2. – Left: detector assembling with plastic scintillator, WLS fiber and APD. Right: detector assembled with frontend board (see ref. [5]).

2. – Detector description

2·1. *The host carrier*. – As mentioned before, the experiment might be host on a atmospheric balloon by ASI. The carrier is composed by several parts: polyethylene balloon, recovery parachutes, nacelle and the flight chain for the mechanical connection between the nacelle and the balloon. The nacelle will host the detector that is sized according to the ASI flight plan (other guests and experiments). The flight chain is composed by several subsystems. One is for the batteries, one for the GPS (Global Positioning System) for localization purpose, and one containing all the components for the balloon recovery.

The balloon can be launched by different sites allowing different kinds of measurements. With a vertical flight will be possible to measure the Pfotzer maximum; with open or closed trajectories (*e.g.*, form Svalbard Islands, Norway) we can measure the flux as a function of the longitude.

After launch, the balloon can be controlled through a radio link; some communication channels are used for the localization and for the flight operational management, the others are available for guest requirements. During the flight it is possible to monitor the altitude, the trajectory and to save the acquired data both locally and at the ground base transmitting through the telemetry subsystem.

2·2. *The detector*. – A schematic view of the detector used for CORAM is shown in fig. 3, left. The project foresees four tiles of plastic scintillator [5] interposed with iron absorbers. Each tile has dimension of $30 \times 30 \times 1\,\text{cm}^3$ and density of $1.032\,\text{g/cm}^3$ (BC-412). Scintillation light is detected by two APDs (Avalanche Photo-Diodes) with $1\,\text{mm}^2$ sensitive area and it is collected through a wavelength-shifting (WLS) optical fiber of 1 mm diameter. Fibers flexibility allows for packing them in circular coils thus increasing the light collection efficiency over the plastic volume (see fig. 2, left).

This set-up 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 100 MeV, for a m.i.p.

From fig. 3 we can see that scintillator tiles are also externally located allowing the measurement of the horizontal flux. The DAQ system will be placed on top of the mechanical structure that altogether will weigh about 80 kg.

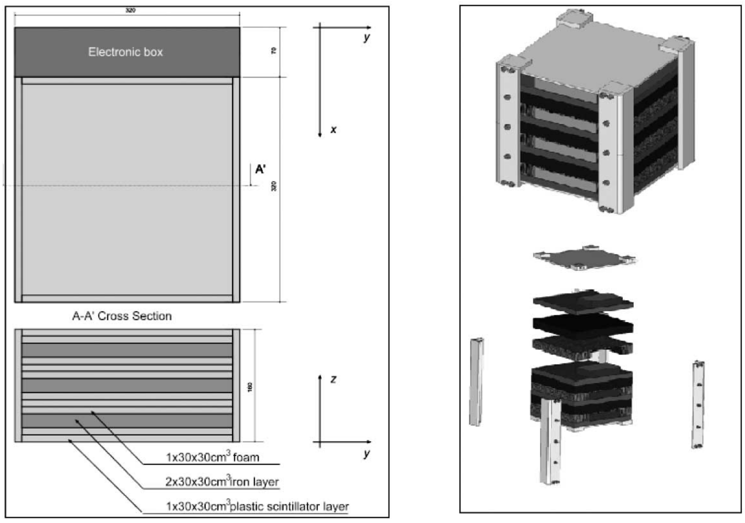

Fig. 3. – Left: schematic view of the CORAM detector. Right: detector prototype scheme.

2·3. *The electronic readout system.* – Due to the relatively simple set-up, we decided to acquire just the single rate coming from each detector and the double, triple and quadruple coincidences at 1 Hz frequency. The readout frequency is adequate according the balloon up/down velocity that is around few meters per second.

As we saw in the previous section (fig. 2, right), each detector is provided by an electronics frontend board 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 balloon telemetry system. Moreover DAQ is provided of a GPS module for the coordinates (latitude, longitude and height) and time stamping.

All data will be saved locally in a mass storage and will be sent to the ground base at a rate of 2400 Bd using the telemetry system of the balloon.

In fig. 4 is schematically shown the DAQ system. The FPGA counters record the single counts and the coincidence counts from the detectors in a time window, for example 1 s,

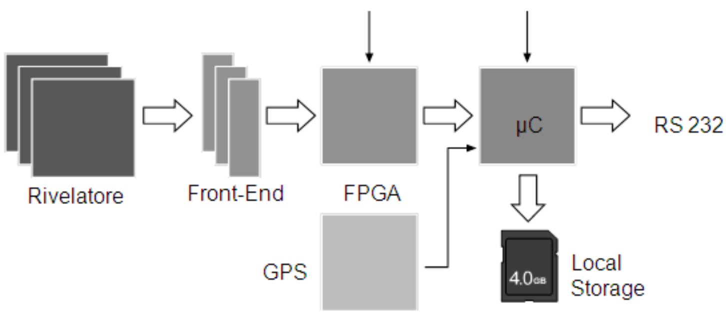

Fig. 4. – Data Acquisition System (DAQ) scheme.

TABLE I. – *High Schools involved in the CORAM project. Teachers work is coordinated by Luigi Merico.*

Istituto di Istruzione Superiore	"F. Bottazzi"	Casarano (LE)
Istituto Tecnico Industriale	"E. Mattei"	Maglie (LE)
Istituto Tecnico Industriale	"E. Fermi"	Lecce
Liceo Scientifico	"L. Da Vinci"	Maglie (LE)
Liceo Scientifico	"G. C. Vanini"	Casarano (LE)
Istituto di Istruzione Superiore	"E. Ferdinando"	Mesagne (BR)
Istituto Statale d'Arte	"N. della Notte"	Poggiardo (LE)

that can be varied during the flight according to the measured rate. At this point the FPGA labels each count with a specific flag (single count plane 1, etc.) and transfers the data to the μC. The μC associates the data to the GPS information and send them to balloon telemetry system.

3. – Outreach program

The CORAM project is an outreach experiment. Almost 30 students from several High Schools of Lecce district (South Italy) are involved together with their teachers (see table I). The balloon launch and the data analysis will be the last steps of a rich educational program that started last year.

In the first phase, dedicated lectures have been given by University Professors to the High School teachers in order to introduce them to the cosmic rays physics. Then, several seminars for the students were organized at the University Physics Department. The seminars program included a detailed description of the experiment, highlighting simple concepts about cosmic rays, particle detection techniques, readout electronics, acquisition system and data analysis.

In a second phase, the students were involved directly in the construction and test of a small prototype (see next section). In small groups, they worked at the Astroparticle Physics laboratory of the University of Salento and INFN Lecce, where the prototype was assembled and tested.

All these parts of the program have been done up to now. Next steps are the functionality test on the final plastic scintillators and the construction of the final CORAM apparatus. This should be done before summer 2012. At that point we will be ready for the balloon launch.

In the mean time, a set of ground measurements has been programmed at Laboratorio Nazionale del Gran Sasso (L'Aquila, Italy). We could measure the particle flux underground and the flux at different altitudes while carrying the detector up to Campo Imperatore, a plateau at around 2100 m. Moreover there will be the possibility for the students to visit the laboratory and the experiments it hosts.

The CORAM project also plans to use the final apparatus during seminars, scientific exhibitions and cultural weeks that will be organized during the next years.

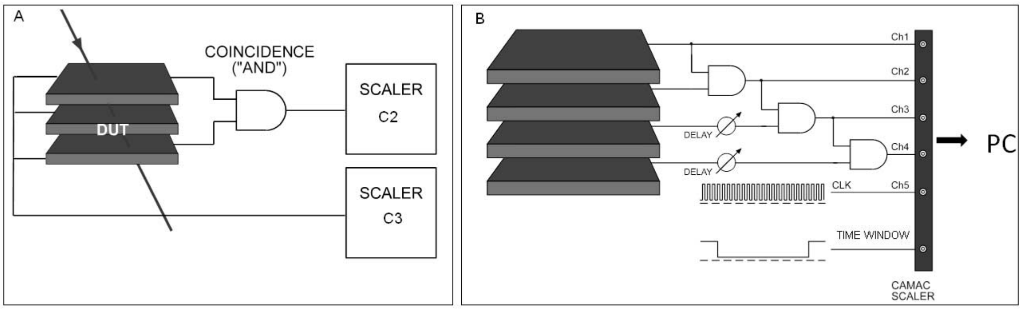

Fig. 5. – A: schematic view of the set-up for the efficiency measurements. B: automatic acquisition system for the prototype.

4. – Prototype and first test results

Figure 3, right, shows the schematic view of the prototype that has been assembled and tested in our laboratory with the students collaboration. The prototype volume is almost a quarter of the CORAM experiment and it is made with four scintillator tiles interposed with three iron absorbers.

The first step was to choose the discrimination threshold of the frontend electronics for each scintillator tile $15 \times 15 \times 1\,\mathrm{cm}^3$ of the prototype. In order to perform this measurement, we fixed the threshold of two tiles simply looking at the single rate expected at the sea level (almost 3 Hz for a $15 \times 15\,\mathrm{cm}^2$ surface). After this, we used a mechanical structure that allows to pile up three tiles: the two with the fixed threshold and the one under test (DUT, Device Under Test) in the middle. We calculated the efficiency of the DUT as the ratio between the value of the coincidence of all the three detectors (C3) and the coincidence of two detectors (C2) excluded the DUT (see fig. 5A). The efficiency

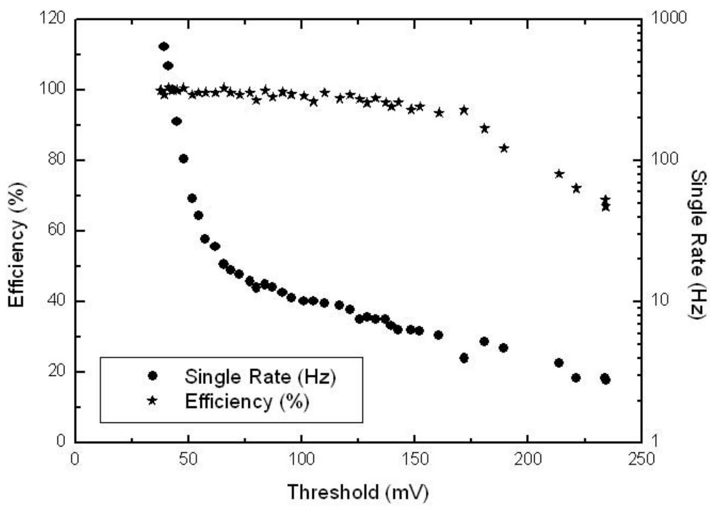

Fig. 6. – Efficiency and single count rate *vs.* the threshold for one scintillator tile.

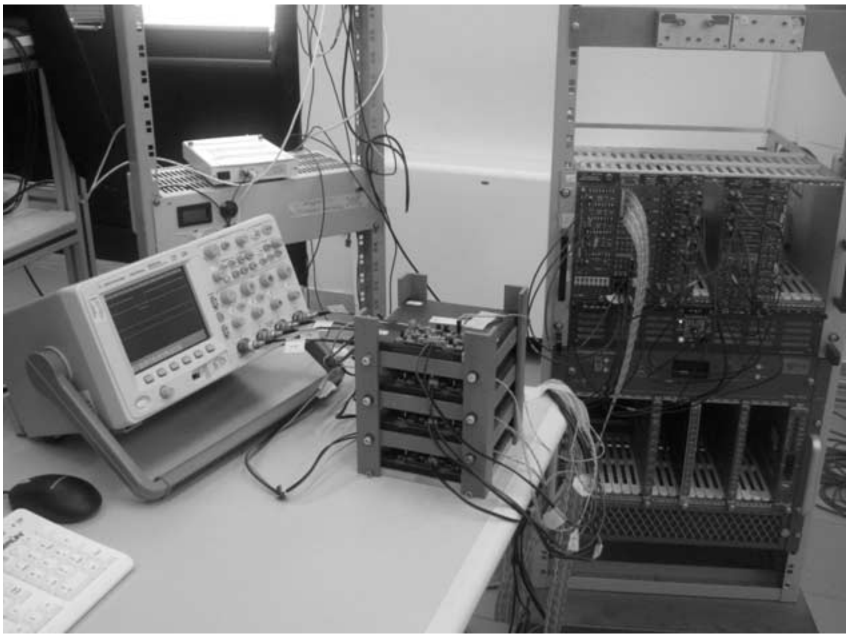

Fig. 7. – The CORAM prototype with electronic acquisition system assembled by the students in the Lecce Physics Department laboratory.

has been measured *versus* the threshold value as can be seen from fig. 6; single counting rate *versus* threshold level is shown in the same plot. The threshold value in this case has been fixed to 130 mV to have the efficiency in plateau and the single counting rate as expected; this measurement has been done for all the detectors.

The prototype has been realized for several reasons, first of all to allow the students to become familiar with the used devices and instruments. Moreover by making a prototype it is possible to estimate the final response of the detector and evaluate any possible problems related to the mechanical structure realizing. In fig. 7 the prototype is shown together with the acquisition system set-up in our laboratory.

The DAQ for this test was developed using NIM (Nuclear Instrumentation Module)([1]) and CAMAC (Computer Automated Measurement And Control)([2]) modules. In this way we realized a complete acquisition system useful to learn how to develop the final DAQ version. Moreover, through this phase, the students could get familiar with hardware construction and related management software. A simple LabVIEW([3]) program has been written in order to save data on a file and to display same statistical information through histograms filling during data taking.

([1]) NIM, www.osti.gov/energycitations/servlets/purl/7120327-MV8wop/7120327.PDF.
([2]) CAMAC, www.cern.ch/ESONE/hibernation.pdf.
([3]) LabVIEW National Instruments, www.ni.com/labview/.

5. – Conclusions

The CORAM project has been presented and the educational activity have been described.

Several High School students are involved in this project that has the main goal to repeat an experiment similar to the one performed by Pfotzer at the beginning of the century. The project provides the construction of a detector for the measurement of the cosmic ray flux as a function of the atmospheric altitude. For this we will profit of the ASI availability to host our set-up on a atmospheric balloon that will take off presumably in summer 2012.

A prototype has been realized and tested in the last year with the students collaboration. Work is in progress for the final set-up construction.

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