CORAM (Cosmic Ray Mission): an Outreach Program 100 Years after Pacini and Hess Works

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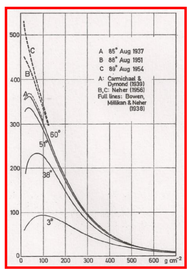
ABSTRACT

The CORAM experiment is an outreach program carried out by researchers of the University of Salento and INFN Lecce in collaboration with several high schools of the Lecce area. High School students and their teachers are involved in the design, construction and test of a detector for the measurement of the cosmic ray flux as a function of the atmospheric depth. The detector is made of scintillator layers read by APDs (Avalanche Photo Diodes) interleaved with iron absorbers and put into coincidence. We present here the results of a test campaign using a first detector prototype that was carried at different altitudes up to 2100 m (Campo Imperatore, L'Aquila) and at the INFN Laboratori Nazionali del Gran Sasso. The experiment might also be hosted on a atmospheric balloon. The INFN encouraged and supported this outreach activity by funding the detector and Data Acquisition System (DAQ).

CORAM AIM



At the beginning of the 20th century D. PACINI [1] 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. At the same time, V. HESS [2] measured the radiation intensity variation with the altitude, discovering that going up in the atmosphere with a balloon the electroscope discharged more quickly.
These independent measurements demonstrated the existence of radiation coming from the outer space named COSMIC RAYS.
The CORAM project main goal is to perform an experiment similar to the one made by Hess, by using a setup simple enough to be used for educational purposes.

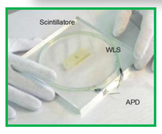
The Italian Space Agency, ASI, agrees to host the experiment on a balloon to perform measurements at very high altitude; nevertheless the setup is designed to be functional also for measurements performed by students at or below mean sea level.
Waiting for the balloon launch, a first measurements campaign has been organized with the high school students at Laboratorio Nazionale del Gran Sasso (L'Aquila, Italy).

	m (above MSL)	g/cm²
Brecciarola	65	1028
Navelli	684	955
LNGS outdoor	990	920
Fonte Cerreto	1120	906
Rocca di Cambio	1270	889
Rocca di mezzo	1366	879
Monte Cristo	1453	870
Campo Imperatore	2140	799

Measurements have been performed underground (INFN – LNGS) and at different altitudes while carrying the detector up to Campo Imperatore, a plateau at around 2100m asl.

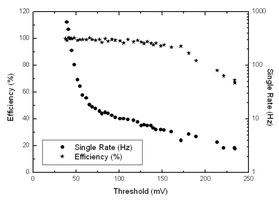
Moreover, the students could visit the INFN underground laboratory to experience the research and experiments that take place there.

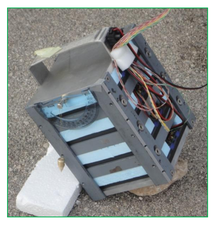
EXPERIMENTAL SETUP



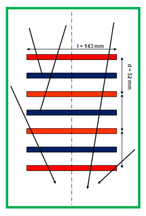
- The project foresees 4 tiles of plastic scintillator interposed with iron absorbers [3].
- Each tile has dimensions of 15x15x1 cm³ and a density of 1.032 g/cm³ (BC-412).
- Scintillation light is detected by 2 APDs - 1 mm² sensitive area, and it is collected through a wavelength-shifting (WLS) optical fiber of 1 mm diameter.
- WLS fiber flexibility allows for packing them in circular coils, thus increasing the light collection efficiency over the plastic volume.
- Frontend electronics, placed over the tile, discriminate signals from the APD data and give a digital LVDS output

The first student measurement was to define the electronic frontend discrimination threshold for each tile.
These tests have been done in the Lecce laboratory.
Efficiency has been measured versus the threshold values together with the single counting rate.

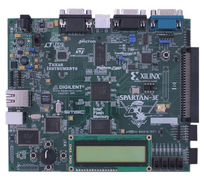




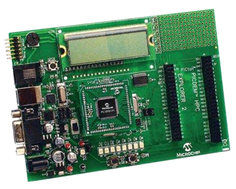
After the efficiency measurements the detector has been assembled for the first test campaign.



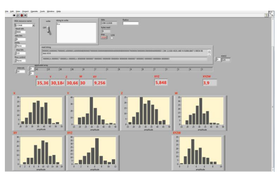
DAQ



- An FPGA (Xilinx Spartan 3E 500K) counts the events inside a defined time window.
- A look-up-table is used for coincidence computing. Results are sent to a μC



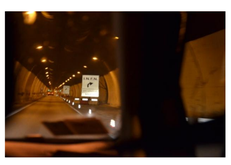
- A μC (MicroChip PIC18F87J50) receives data from FPGA and timestamps it with time information from a GPS (Trimble iQLassen)
- Moreover the μC acquires both inner and outside temperature of the detectors and the their inclination to the horizon, defines the time window, saves data on an SD-Card and finally sends data serially to the balloon telemetry system through an UART .

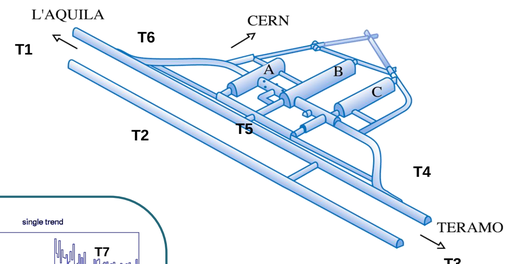


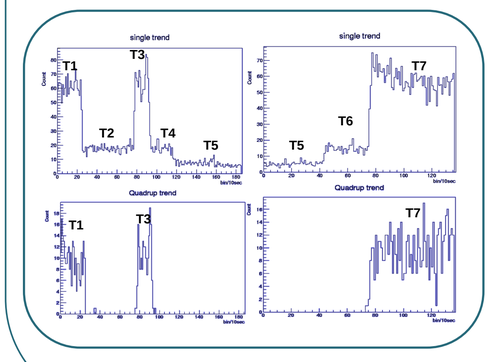
- The graphical user interface was developed by using LabView software .
- The software averages received values and allows the user to specify the duration of the coincidence time window.

EXPERIMENTAL RESULTS

LNGS Tunnel Measurements







Measurements performed driving the detector from the LNGS office building to the underground laboratory tunnel:
- T1 and T3 indicates measurements done on the outdoor highways
- T2, T4 and T6 indicates measurements done on the highways under the mountain
- T5 is in laboratory experimental area

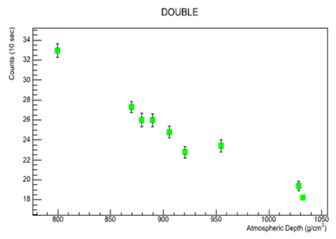
Background estimation ~1.4 Hz (T6)
Intrinsic electronic noise ~0.4 Hz (T5)

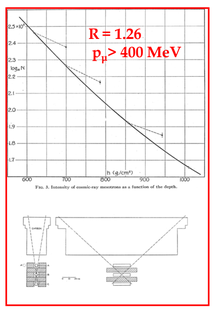
The double, triple and quadruple coincidence rates are below the detector sensitivity (< 100 mHz) under the mountain, according to the prediction.

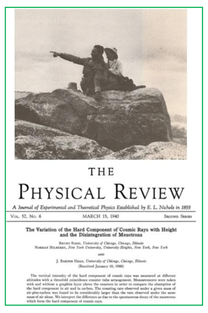
Measurements at different altitudes

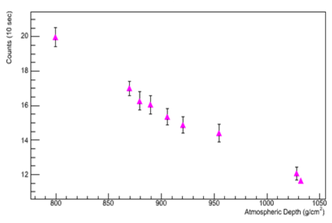
R = counts @ 2100m / counts @ MSL

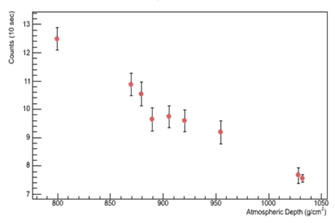
R_{double} = 1.94 p_μ> 115 MeV
R_{tripe} = 1.71 p_μ> 130 MeV
$R_{quadruple}$ = 1.66 p_μ> 180 MeV



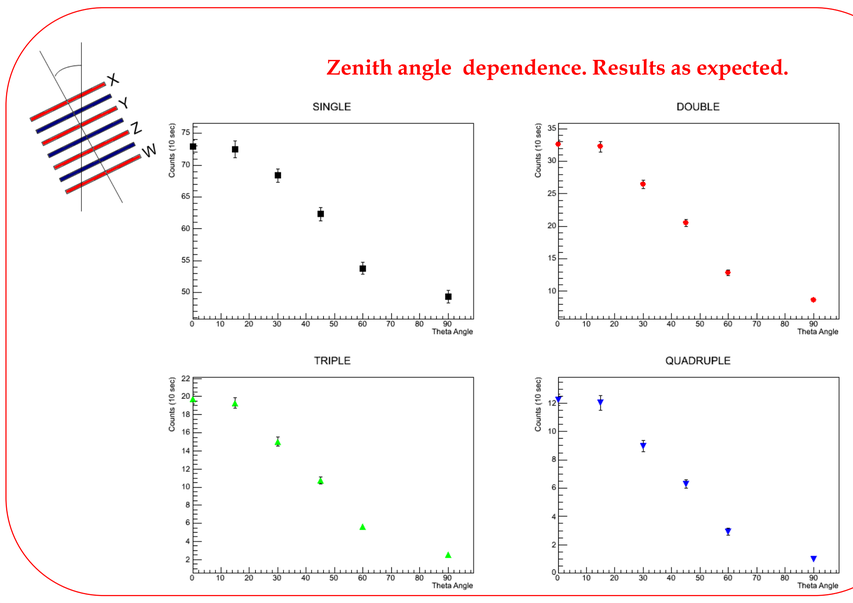






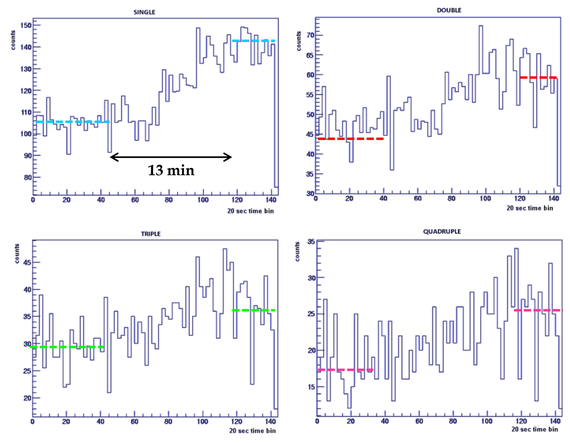


Zenith angle dependence. Results as expected.



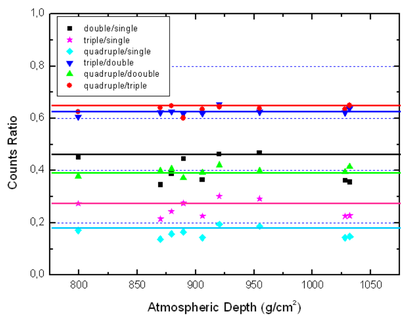
Measurements performed on the cableway: FONTE CERRETO (1100 m) – CAMPO IMPERATORE (2100 m)

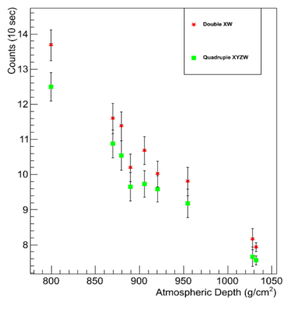
Measurements performed during the cableway ride from 1100 m to 2100 m at Mean Sea Level (MSL)

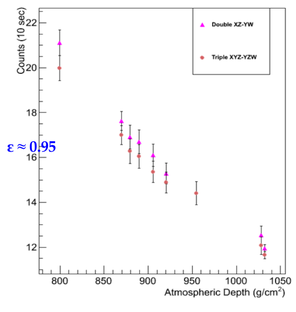


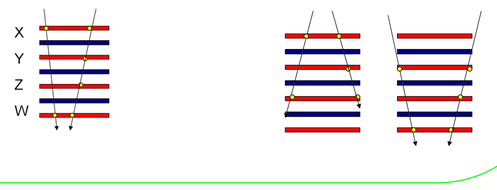
Efficiency Studies

- Considering single tile efficiency measured in Lecce laboratory (~92%) and the acceptance calculation, the ratios are consistent with the measurements.
- The ratios do not depend on the altitude.









CONCLUSIONS

The main goal of the CORAM project is to repeat an experiment similar to the one performed at the beginning of the century by the V. Hess group. Several High School students are involved in this project as part of an educational outreach initiative.
A detector has been assembled in Lecce with the students' collaboration using scintillating plates read by using APDs. A first test campaign has been organized in March 2012 at the INFN LNGS (L'Aquila, Italy). Several measurements of single, double, triple and quadruple coincidence counting rates have been performed both at different altitudes and underground. The results are presented.

REFERENCES

[1] D. PACINI, *La radiazione penetrante alla superficie ed in seno alle acque*, **Nuovo Cimento**, **3** (1912) 93.

[2] V. HESS, **Phys. Z**, **13** (1913) 1084.

[3] A. AKINDINOV et Al., **Nucl. Instr. Meth. A**, **539** (2005), 172.