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Cosmic IT: A portable cosmic ray detector

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Summary. — Cosmic ray detectors represent an interesting tool for the didactics of modern physics. The Cosmic it detector, designed by the INSULAB group, is a fully portable detector assembled inside a lightweight suitcase. It consists of three modules of plastic scintillator bars, which operate in coincidence. The electronics chain allows measuring the arrival time and the time over threshold (TOT) of the signal generated by each scintillator module, which could be used to retrieve the deposited energy. In this paper we briefly present the basic structure of the detector along with the result of data taking on a private DA40ng light airplane.

1. – Introduction

Cosmic ray detectors represent a valid tool to involve high school students and teachers with the world of particles and modern physics by integrating frontal lessons with challenging laboratory experiences. In general, modern physics experiments can be expensive, difficult to approach and, in many cases, require radioactive sources, which are usually unavailable in schools. On the other hand, the sky is a free inextinguishable source of particles that can be detected in quite a simple way. Many examples of compact and low-cost cosmic ray detectors can be found in literature [1-8]. The Cosmic it detector, designed by the INSULAB group, is completely portable and easy to use outside the laboratory. The detector has been fully characterized in [9, 10] in terms of efficiency and of some well-known features of cosmic rays, such as the dependence of the rate on the zenith angle. Furthermore, the detector has been taken on several trips (one in collaboration with the *Liceo Scientifico Statale Galileo Ferraris, Varese*) proving to be effective in measuring rate dependence on altitude. In this article we present the basic structure of the detector along with the results obtained by collecting data during a trip, from Lugano to Bern, on a private DA40ng light aircraft.

2. – The INSULAB portable detector

The assembled detector is shown in fig. 1. It consists of three overlapping modules, each containing four scintillator bars whose light is taken to a PhotoMultiplier Tube (PMT) [11] with WaveLenght Shifter (WLS) fibers [12]. The modules efficiency is approximately 90% [9, 10]. The electronics chain (composed of an amplifier [13], a discriminator [14] and an FPGA [15]) allows not only counting the single cosmic rays but also measuring the arrival time and the time over threshold (TOT) of the signal

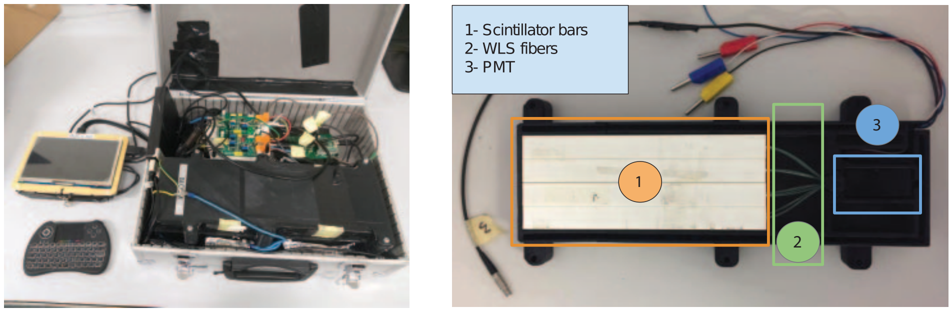

Fig. 1. – Left: the assembled detector. Right: the module components: the scintillator bars and the PMT are contained inside a 3D printed PLA box.

generated by each scintillator module, which could be used to estimate the deposited energy. Data are acquired and processed by a Raspberry PI 3 B+ [16], with a majority of two out of three. In case of particularly noisy conditions, such as electronic noise from external sources, the offline analysis allows selecting only the events in which all the three scintillator modules detected a particle. The whole setup is assembled inside a lightweight aluminium suitcase. A touch screen display [17] with a simple and intuitive Tcl/Tk interface allows starting and stopping data acquisition. The GPS coordinates and the current time are recorded by a Digilent Pmod GPS receiver [18].

3. – In flight data taking

The increase of the cosmic ray flux with altitude has been measured by putting the detector on a light airplane. The rate can be evaluated by considering the ratio of the number of counts and the acquisition time or by computing the decay constant of the exponential fit of the distribution of the arrival time between subsequent events. The TOT analysis has shown the presence of interference from a non-directional radio beacon (NDB), which is a radio transmitter, that does not allow using the time distribution for rate computing. Excluding the events with a large TOT (and hence a large amplitude), rate has been computed correctly (fig. 2). Figure 3(top) presents the rate per minute dur-

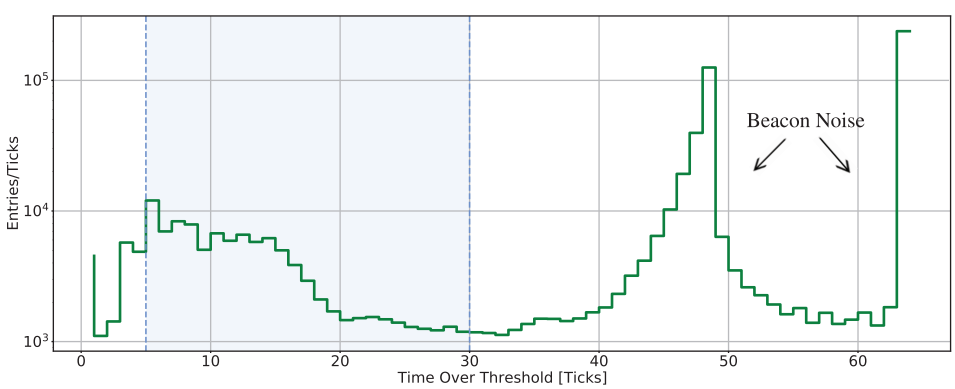

Fig. 2. – Time Over Threshold spectrum: one tick corresponds to 5 ns. The blue area represents the interval of values selected for the rate computation.

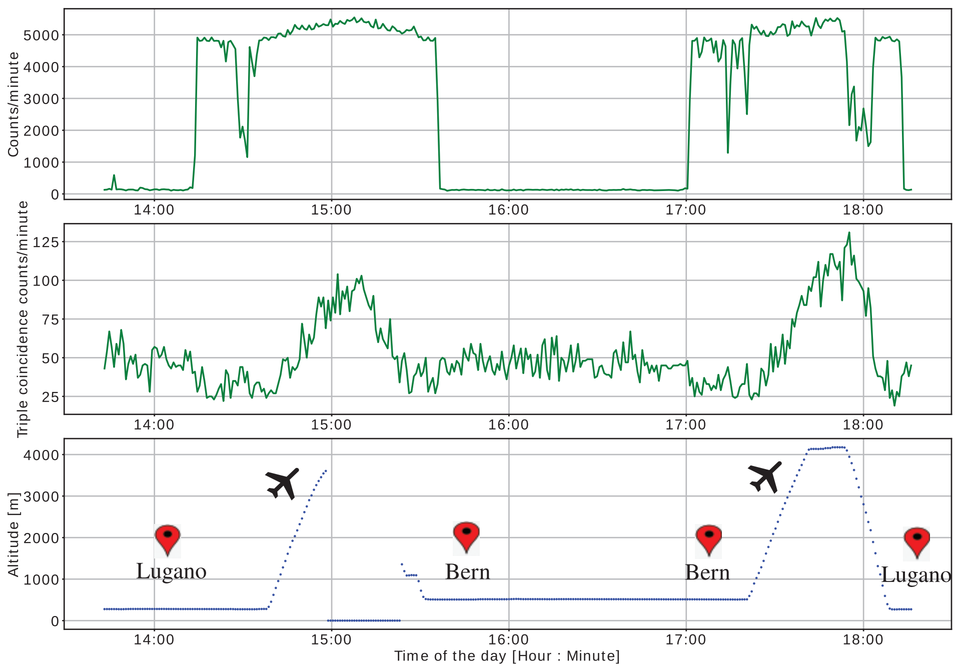

Fig. 3. – On top: the counts per minute obtained by the portable detector during the flight. The large event rate regions are due to the interference of the aircraft beacon. Center: count rate after the cut in TOT on each module that excludes noisy events. Bottom: the airplane trip; for half an hour from 15:00 the GPS receiver stopped working.

ing the flight: the large rate regions are due to the beacon interference. Figure 3(center) presents the rate after applying the TOT cut on all the modules. The trend of the cosmic ray flux as a function of altitude is complicated to evaluate since it depends on several factors, such as the variation of the atmospheric density and the solar activity. Never-

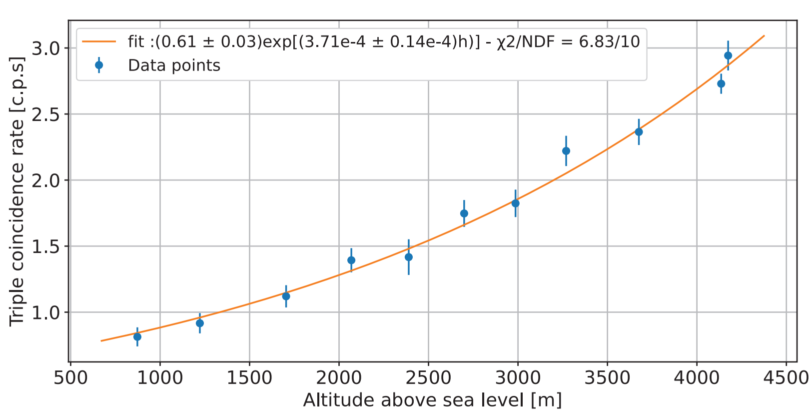

Fig. 4. – Cosmic ray rate as a function of the altitude with the data of the flight from Lugano to Bern on a light aircraft. Data are well described by an exponential.

theless, below 10 km from the sea level, the flux approximately grows exponentially with the altitude as shown in [19]. Figure 4 presents the computed rate, as a function of the altitude above sea level; data are well described by an exponential.

4. – Conclusion

In this article we presented the basic structure of the COSMIC IT detector, designed by the INSULAB group, and the results obtained by collecting data during a trip, from Lugano to Bern, on a light aircraft. The detector proves to be effective in measuring rate dependence on altitude. Furthermore, it is completely portable, easy to use outdoors and has an intuitive interface, representing a valid tool for the didactics of modern physics for high-schools and bachelor degree students([1]).

REFERENCES

[1] Bocci V. *et al.*, *J. Phys.: Conf. Ser.*, **898** (2017) 102011.
[2] Axani S. N. *et al.*, *J. Instrum.*, **13** (2018) P03019.
[3] Bretz H. P., *PoS*, **EPS-HEP2015** (2015) 361.
[4] Blanco F. *et al.*, *Eur. J. Phys*, **30** (2009) 685.
[5] Hansen S. *et al.*, *IEEE Trans. Nucl. Sci.*, **51** (2004) 926.
[6] Grazzi S. *et al.*, *Nucl. Instrum. Methods Phys. Res.*, **976** (2020) 164275.
[7] Collier M., Lawrence Berkeley National Laboratory, 34 (2022) LBNL–51419.
[8] Twitty C. and Matis H., *Guide to using the Berkeley Lab Cosmic Ray Detector*, Lawrence Berkeley National Laboratory (2000) https://escholarship.org/uc/item/1td086rv.
[9] Bomben L. *et al.*, *J. Instrum.*, **16** (2021) P12008.
[10] Selmi A., Thesis, *Costruzione e test di un rivelatore portatile per raggi cosmici*, https://doi.org/10.13140/RG.2.2.23546.62404 (2019).
[11] Hamamatsu, *Metal Package PMT Photosensor Modules H5773/H5783/H6779/H6780 Series*, http://pdf.datasheetcatalog.com/datasheet/hamamatsu/H6780-03.pdf.
[12] Kuraray, *Wavelength Shifting Fibers*, http://kuraraypsf.jp/psf/ws.html.
[13] Analog Devices, *AD8002*, https://www.analog.com/en/products/ad8002.html.
[14] Analog Devices, *AD8561*, https://www.analog.com/en/products/ad8561.html.
[15] Altera, *Cyclone IV FPGAS*, https://www.intel.co.uk/content/www/uk/en/products/programmable/fpga/cyclone-iv.html.
[16] Rapsberry Pi 3 Model B+, https://www.raspberrypi.org/products/raspberry-pi-3-model-b-plus/.
[17] WaveShare, *7inch Capacitive Touch Screen*, https://www.waveshare.com/7inch-hdmi-lcd-c.htm.
[18] Digilent, *pmod GPS*, https://reference.digilentinc.com/reference/pmod/pmodgps/start.
[19] Lipari P., *Astropart. Phys.*, **1** (1993) 195.

([1]) A *Guide on How to Use* and further web material, in line with what has already been done and referenced, is under preparation.