Cosmic muon hodoscope based on CAEN FERS electronics

1. Introduction:

It is well known that the Bethe-Bloch formula describes the average energy lost by charged particles when travelling through matter, while the fluctuations of energy loss by ionization of a charged particle in a thin layer of matter was theoretically described by Landau in 1944 [1]. For thin absorbers [2], where the total energy lost by the particle is well below its total energy (ΔE « Emax), strong fluctuations around the average energy loss exist. The resulting energy-loss distribution is asymmetric and is well described by the Landau Distribution. The distribution is defined as the inverse Laplace transform of the function ss, but a reasonable approximation is given by the following relation:

$$L(\lambda) = \frac{1}{\sqrt{2\pi}} exp\left[-\frac{1}{2}\left(\lambda + e^{-\lambda}\right)\right] \quad (1)$$

where λ characterizes the deviation from the most probable energy loss,

$$\lambda = \frac{\Delta E - \Delta E^{m.p.}}{\xi} \quad (1)$$

and depends on:

- ΔE, the actual energy loss in a layer of thickness x.
- $\Delta E^{m.p.}$, the most probable energy loss value in a layer of thickness x.
- ξ, a scale factor.

In particular, $\Delta E^{m.p.}$ and ξ depend on the material density and thickness and on the particle energy. Given the same detector, the value of these parameters is almost constant for Minimum Ionizing Particles (MIP) and ultra-relativistic particles, which will thus give rise to approximately the same Landau distribution.
In the work presented in this AN, the hardest component of cosmic rays (mainly composed of relativistic and ultrarelativistic muons) was selected and their loss of energy in thin (≈ 1 cm) layers of plastic scintillators was measured. A fit via a Landau distribution was finally performed and was demonstrated to well describe the acquired data.

2. Experimental Setup:

The measurement was performed taking advantage of the following setup (Figure 1):

- **A5202 board** based on Citiroc-1A chips and specifically designed for the readout of large SiPM arrays [3];
- **Polystyrene-based Scintillators**, each one having a dimension of 47 × 47 × 10 mm^3, with 4 layers (each layer have two layers Pb and Scintillators) for the coupling to the SiPMs.
- Hamamatsu S13360-6050CS SiPMs, each one having an active area of 6 × 6 mm^2.
- 2.54 mm pin header adapter for FERS-5200 [4].

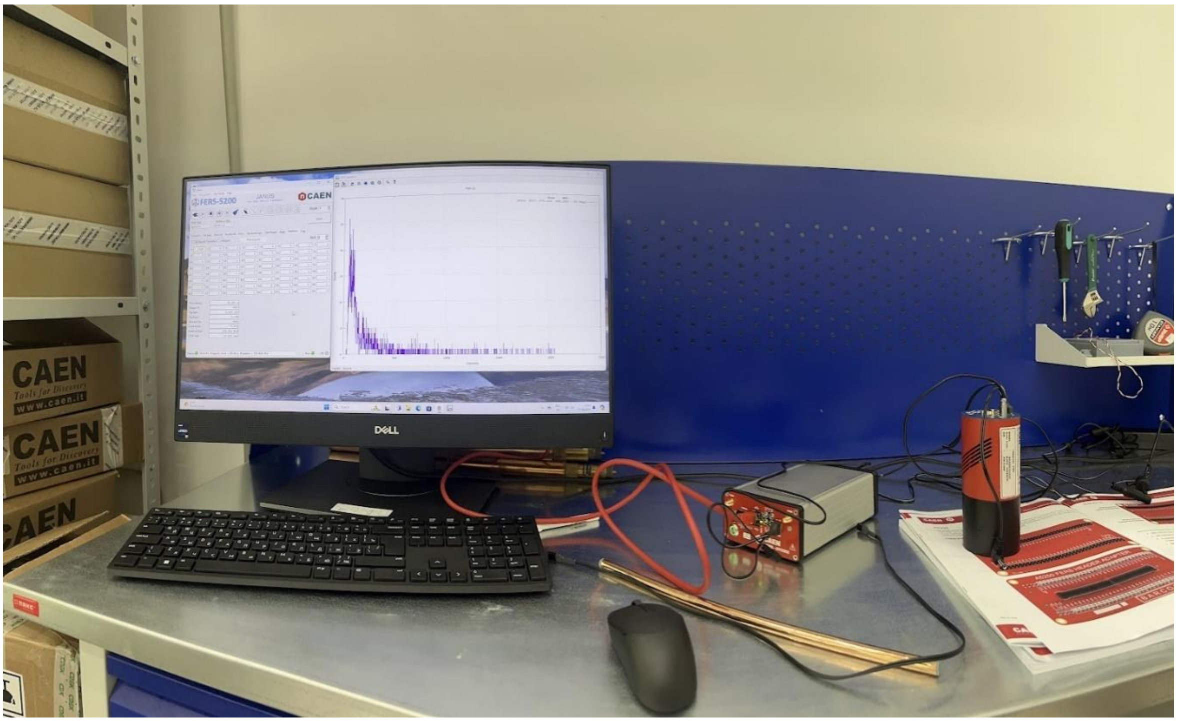

Figure 1 –Testing FERS-5200 electronics by CAEN

3. Описание работы над проектом:

3.1. Installation.

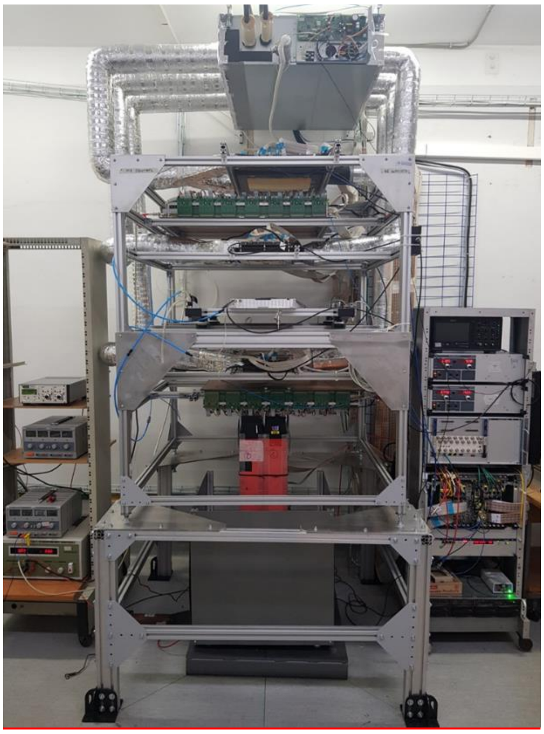
Figure 2 – Picture of the experimental setup with hodoscope in the middle (red).

3.2. Study of the signal degradation along the cables.

Before performing the cosmic ray loss of energy measurement, a characterization study of the cables will need to perform, to understand if a significant signal attenuation or degradation (i.e. loss of resolution) was expected in the propagation of the signal along the

cables. For such purpose, use three A5261 cables having variable lengths (up to 3 m) and connect to SiPM.
Which result is cables and connectors chosen will be completely or not adequate to perform the measurement proposed? How should be affected by significant signal losses or degradations, Where the SiPMs will be placed far away (up to 3 m) from the readout board?

3.3. Acquisition Configuration and Results.

The Janus software [5] (release 1.1.5) was used to control the A5202 board and to define all the relevant settings of the data acquisition. The first measurement will be performed in Spectrosocopy Mode and the PHA values of the incident particles were saved to an Ascii list file to perform an offline analysis.
The result of the acquisition can look like in Fig. 3 and shows the presence of a rapidly decreasing spectrum with a bump positioned at ≈ 1500 ADC Channels.
Once the correct functioning of the experimental setup was tested, repeat the measurement with the complete list in **Tab. 1** of settings used for the measurement.

Parameter	Value
Acquisition Mode	SPECTROSCOPY
Bunch Trigger Source	TLOGIC
Trigger Logic	AND2_OR32
Ch Enable Mask Chip 0	0x0 0xC0000000
Ch Enable Mask Chip 1	(Only CH62 and CH63 enabled)
Fast Shaper Input	LG-PA
TD Coarse Threshold	185
Gain Selection	LOW
TLogic Mask Chip 0	0x0
TLogic Mask Chip 1	0xC0000000 (Only CH62 and CH63 enabled)
LG Gain	15
LG Shaping Time	25 ns
Hold Delay	100 ns
MUX Clock Period	300 ns

Tab. 1: Janus software settings for the cosmic ray acquisition in Spectroscopy Mode (TLOGIC used as ”Bunch Trigger Source”).

Collect the same number of events as those in the first measurement ted. How coincidence request increased the contribution to the total spectrum of the PHA values positioned at ≈ 1500 ADC Channels, i.e. the contribution from relativistic and ultra-relativistic muons?

3.4. Analysis of the output Results.

Do realize an offline analysis of the output Ascii file with ROOT [6] and fit perform to the values with a Landau distribution (see Eq. 1) summed to a 2nd order polynomial.

4. Prerequisites.

1. Knowledge of the basics of electrical engineering, such as voltage, current (DC and AC), power.
2. Knowledge of the basics of computer (installing apps, drivers, IP configuration)
3. Knowledge of the program to analysis data (Python, ROOT)

5. Recommended literature.

[1] L. Landau, On the Energy Loss of Fast Particles by Ionization, J. Phys. USSR 8 (1944) 201.
[2] Grupen, Claus, et al. Particle detectors. Vol. 11. Cambridge: Cambridge university press, 2008.
[3] https://www.caen.it/products/dt5202/
[4] https://www.caen.it/products/a5250-header-adapter/
[5] UM7946 – Janus Software User Manual.
[6] Rene Brun and Fons Rademakers. "ROOT - An Object Oriented Data Analysis Framework". In: Proceedings AIHENP' 96 Workshop, Lausanne, Sep. 1996, Nucl. Inst. and Meth. in Phys. Res. A. Vol. 389. 1997, pp. 81–86. URL: http://root.cern.ch/.

6. Recommended number of participants:

2–3 persons.

7. Supervisors:

1) Temur Enik, Head of the group at the Laboratory of High Energy Physics named after. Veksler and Baldin, c.p.t.s., Assistant professor, H-index - 32 Scopus-ID – 57194770293, A leading scientist in the field of experimental nuclear physics and cosmic ray physics, applied nuclear physics and particle physics.
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3) Dias Kereibay, Junior Researcher at the Laboratory of High Energy Physics, H-index - 3, Scopus Author ID: 57645548900
4) Sergey Romakhov, Engineer at the Laboratory of High Energy Physics