Cosmic ray attenuation in lead

EEE group ITI Marconi (Pontedera) - 2024-2025:

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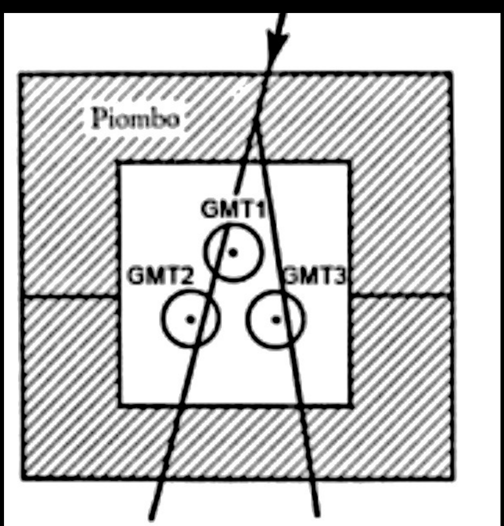
We received our (repaired) cosmic-box on monday 26.05

Intro to the measurement - 1

Cosmic ray particles passing through any medium (air, water, rock …) progressively lose their energy.

The main interactions processes involved in this energy loss are :
– nuclear interactions *(interactions where the strong force is involved)*
– ionization *(neutral atoms or molecules are converted to electrically charged atoms or molecules)*
– bremsstrahlung *(photons and secondary electrons produced by the deflection of a charged particle)*
– pair production *(a high-energy gamma ray is converted into a electron-positron pair in the presence of a charged particle)*

For this reason each material behaves differently w.r.t. cosmic radiation *(water w.r.t. metals for example)*



Bruno Rossi studied this phenomenon using three Geiger-Müller (GM) tubes:

A single particle detected by the first tube (GMT1) could not produce signals in the subsequent tubes (GMT2 and GMT3) at the same time

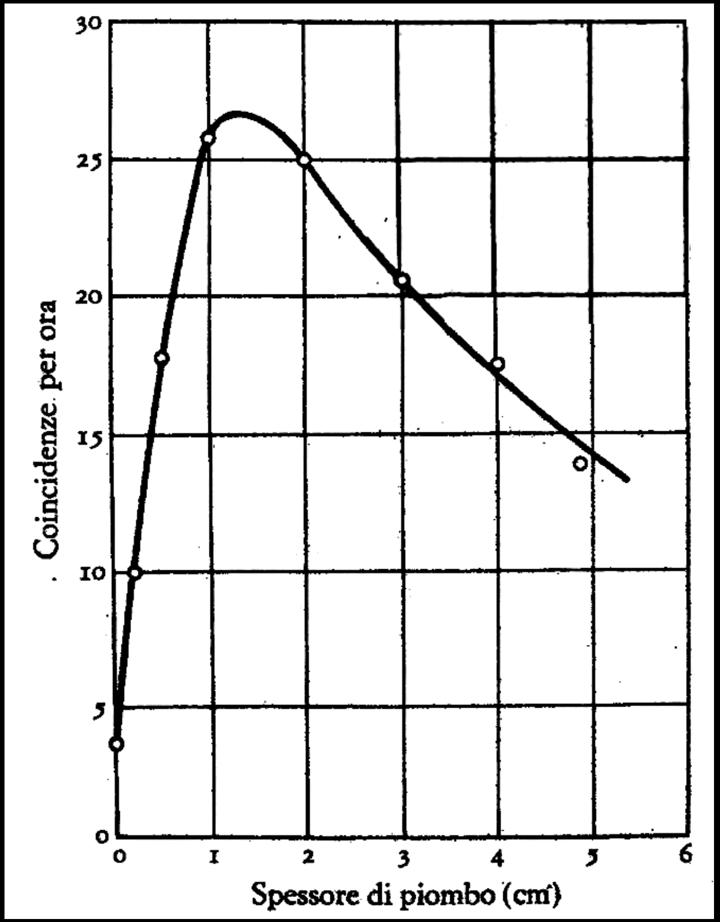
Without screen the coincidence between the three tubes was ~ zero

If a lead screen was present coincident signals in all tubes were recorded
→ *mainly as a consequence of the bremsstrahlung effect occurring in the lead*
(the cosmic rays initiate some showers in the lead)

Intro to the measurement - 2

Rossi produced the “shower curve” which describes the behavior of particle showers as the thickness of the material they pass through varies.

Here shown the “Rossi curve” for cosmic rays induced showers through different thicknesses of lead



<u>Intuitively :</u>
we would expect that as the thickness of the material increases the cosmic rays are progressively absorbed.

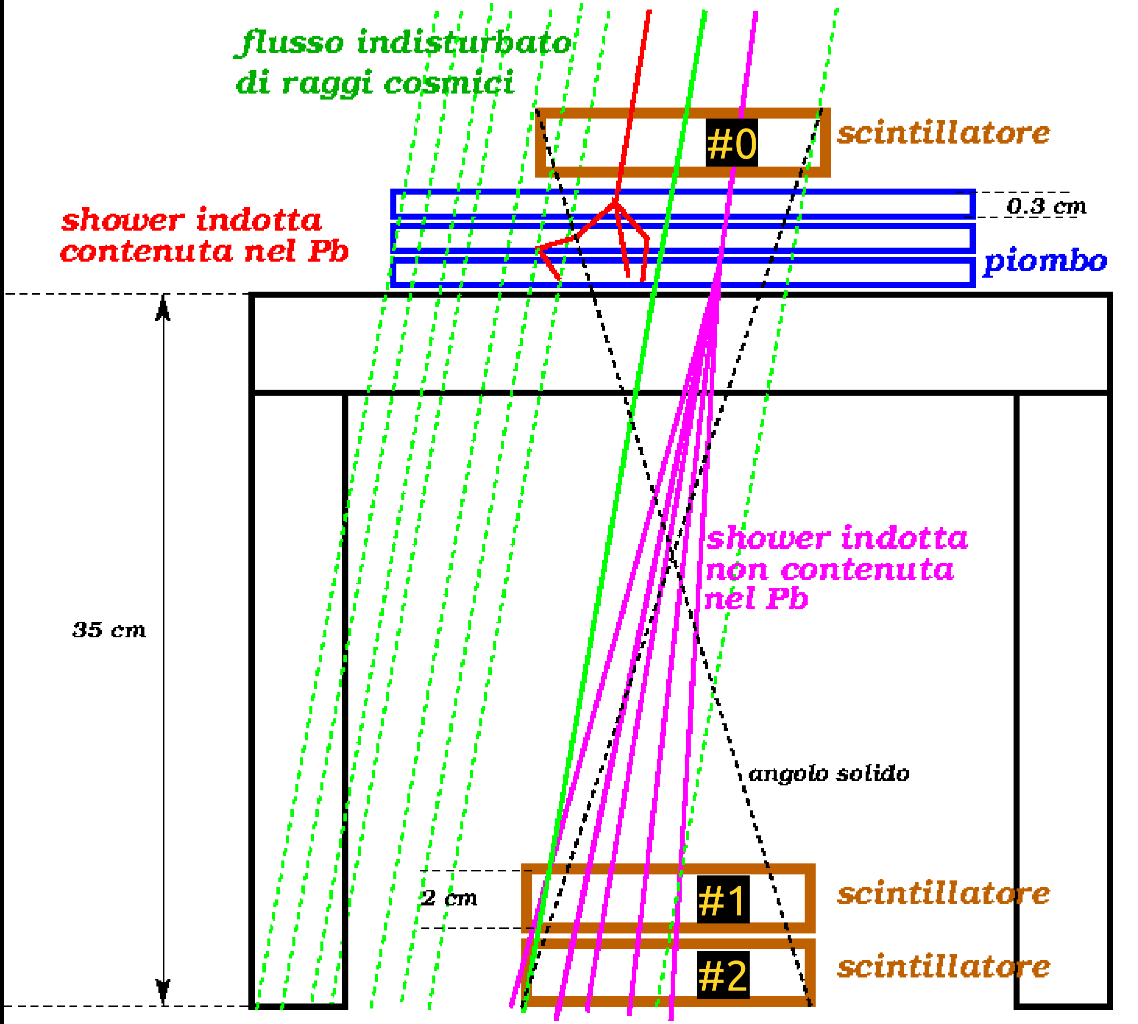
<u>In practice:</u>
(low thicknesses of absorber)
the particle showers are produced within the material and the number of particles increases

(high thicknesses of absorber)
the produced particles are absorbed within the material itself and the number of particles begins to decrease progressively.

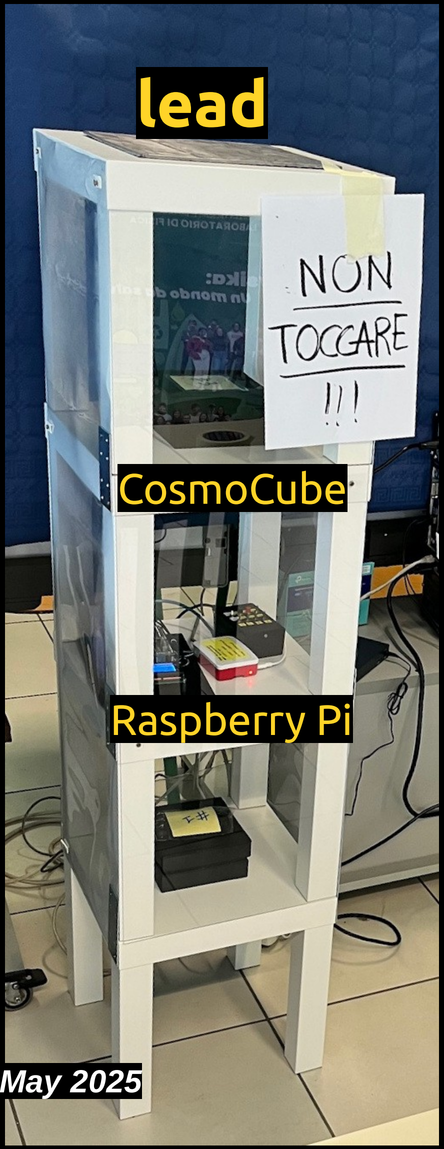
measurement setup - 1

Details of our setup:

– detector: Cosmocube with 4 scintillators
– acceptance: 0.0525 sr
– active area: 0.0144 m^2
– trigger logic: #0 && #1 && #2



measurement setup - 2



We used the CosmoCube and up to a maximum of 6 lead sheets (each 0.3 cm thick) to measure the muon rate between three detectors, separated by a layer composed of an increasing number of stacked lead sheets.

We connected the CosmoCube to a Raspberry Pi to acquire and analyze the measured data via a serial connection, saving all collected data on an SQL server for later retrieval.

Collecting data

Every 10 seconds, the CosmoCube outputs six values via the serial connection:
– uptime (in seconds)
– events counts for each of the 4 scintillators
– number of triggers based on the selected *trigger-logic* :
in our case the logical .AND. between 3 scintillators one on top of the lead and the other two on top of each other at 35 cm below the lead layer.

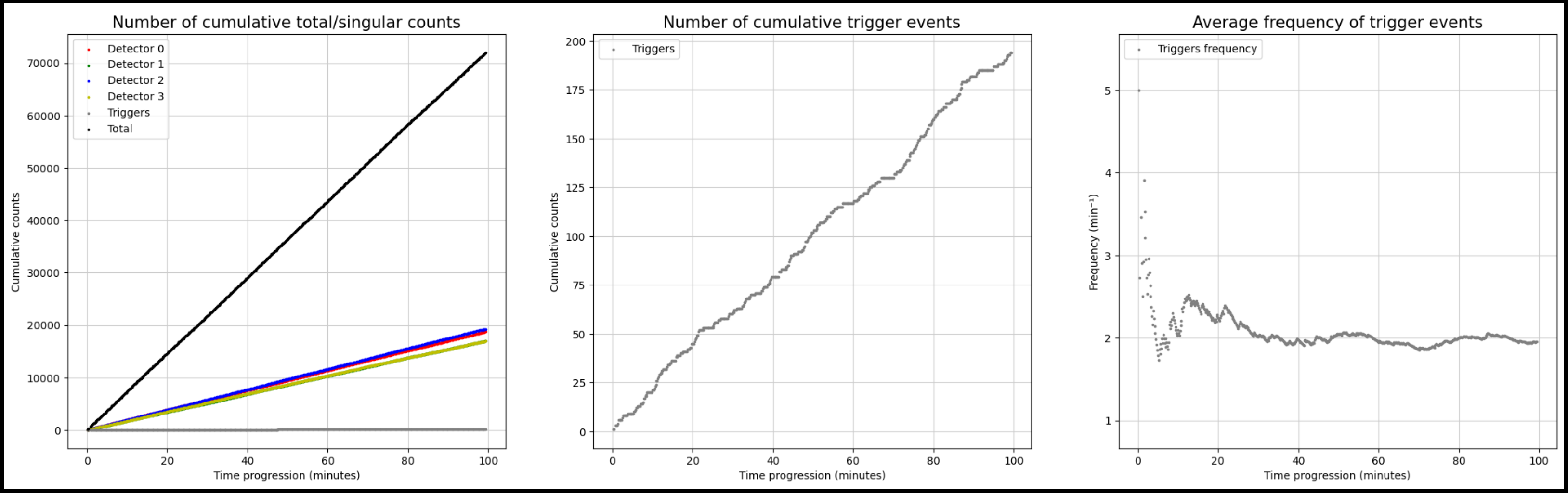
To read the data, we developed a Python script that listens to the serial connection and extracts the values, adding additional information such as the thickness of the lead layer, a timestamp, and a unique ID. This ensures that each entry can be accurately identified when the data is uploaded to an SQL server.

```
eee@raspberry: ~/Documents
eee@raspberry:~/Documents $ python3 serial\ port.py
20 1 53 49 54 70
30 4 81 89 97 101
40 5 122 116 121 126
50 7 156 146 154 155
60 7 187 170 197 183
70 8 209 199 236 213
80 9 234 220 257 232
90 12 270 247 286 267
100 13 300 273 313 291
110 15 328 296 338 314
120 16 351 326 372 336
130 17 383 359 406 363
140 18 424 383 447 394
150 19 449 414 488 416
160 20 487 444 520 440
170 22 517 473 551 470
```

The scripts that reads data from the CosmoCube through a serial connection

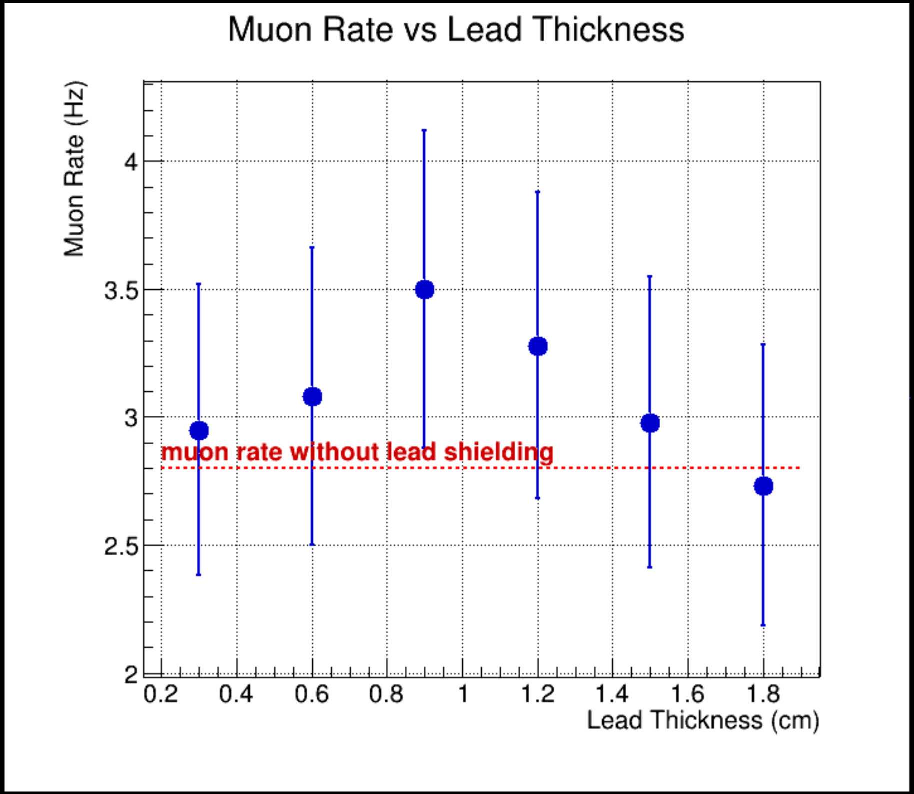
Analyzing the data

We decided to store all the data we collected to a SQL database, divided in different tables, one for each run we decided to make. The same script that reads from the CosmoCube also uploads all the data to the server. So we coded another script that takes the data we specify from the database and plots the data on three different plots. The first one represents the counts of the single detectors and the total sum of the counts of each detector. The second one is a magnification of the gray line of the first plot, the one that represents the number of trigger events. Lastly, the third one shows the average rate of events every minute.



Results

we recorded a rate of 2.8 Hz of coincidence without lead (we expected 3.7 Hz for our acceptance...)
for each thickness we took a 5 min. run (we did 6 runs)
we plotted the average rate of coincidences as a function of the lead thickness
we assign to all points a statistical error



Conclusions

All measures are within the error bars because the effect is small and the statistic that we accumulated is not sufficient Within errors we didn't see any effect

However looking only at the average rate values:
we see a relative maximum for a thickness of 0.9 cm of lead

This compare to the Rossi one that occurs for a thickness of 1.3 cm of lead

The discrepancy could arise from the concrete of the lab ceiling (containing iron) and the plastic of the scintillator that we put on top of the lead
(NB: we noticed that the ratio of ~3.0 cm of plastic and 0.4 cm of lead is about the same of the density ratio between C and Pb)

Many thanks to:

Special thanks to Fabio Morsani and Eduardo Bossini (from the INFN-Pisa) for lending us the Cosmucobe as a temporary replacement of the cosmic box enabling us to do this measurement.