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# Cosmic Rays Detector

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Use of Coincidence  
Detector for Measures of  
Cosmic Rays

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Lodovico Lappetito

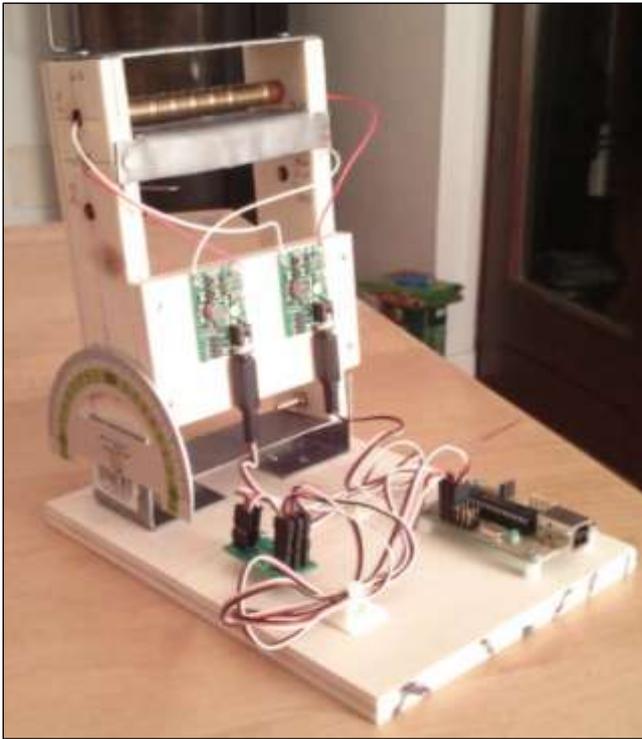
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## Design and Components

- SBM20 Geiger Sensors
- Geiger Adapter
- Coincidence Detector Circuit
- Theremino Master



### The detector assembled

The two geiger tubes are arranged one above the other, aligned with each other, the distance between the two sensors is about 1cm.

A lead screen, 1.2mm thick, is placed above the first sensor and below the second with the aim to shield the sensors from the background radiation originating in the alignment direction of the two tubes.

Another plate of lead is placed between the two tubes in order to shield the second geiger from any radiation coming from the first tube.

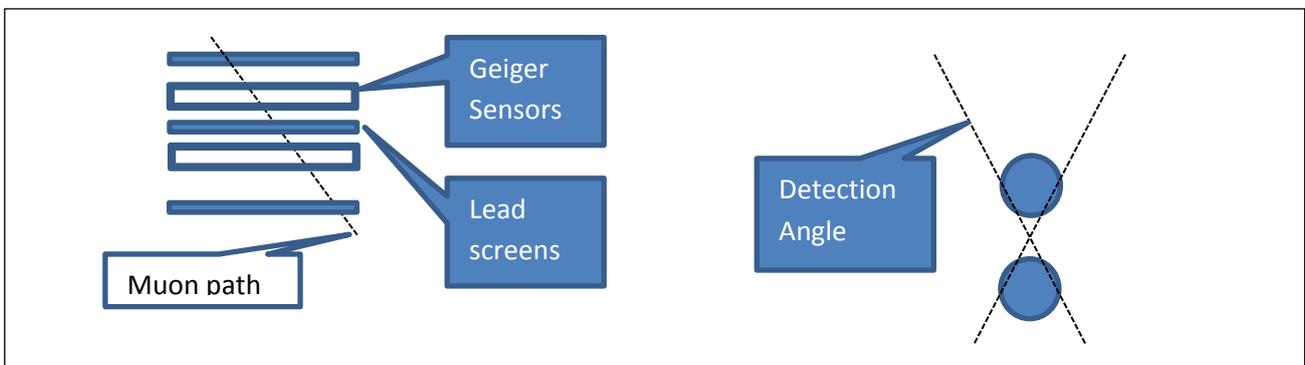
With these expedients, contemporary events recorded by the sensors are thus exclusively those caused by particles moving in the direction of alignment of the sensors, with enough energy to overcome the lead foil.

**Particles with these characteristics are almost exclusively cosmic ray with "extra-terrestrial" origin.**

The alignment of the tubes, the coincidence circuit and the shields make sure that the recorded events are definitely due to secondary cosmic ray muons (see chapter on the theory of cosmic rays).

However the counting rate will be slightly less than the theoretical value due to the limited detection angle, as shown in the following diagram.

### Detector Design

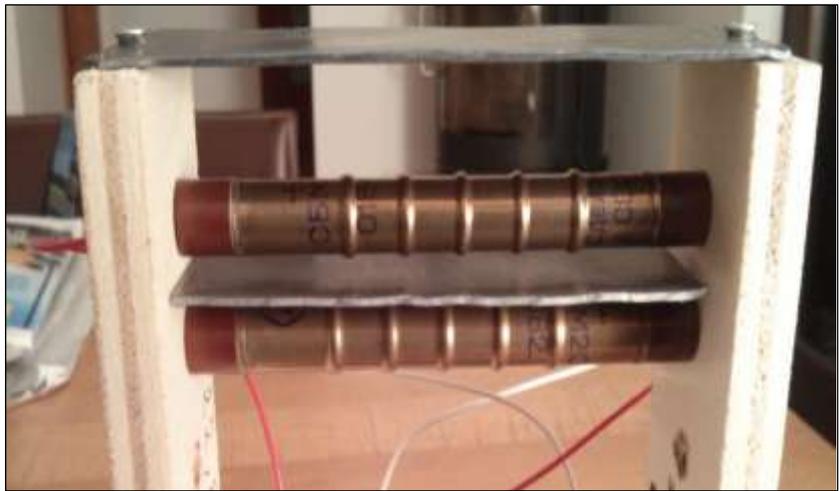
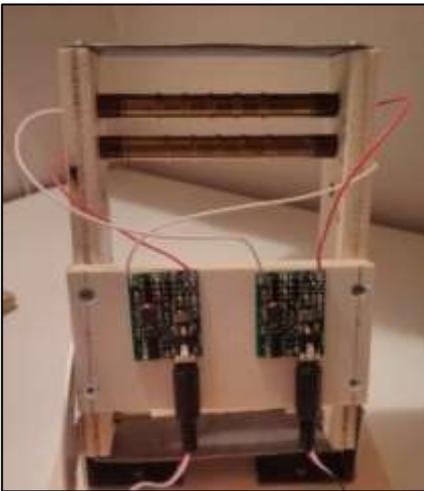


## Detector Construction

The two sensors are placed in a **tilting frame** in order to perform measurements at various angles with respect to the normal to the earth surface.

The radiation intensity (particles flux) should be maximum at an angle of  $90^\circ$  to the horizontal (frame in vertical position) and little or null at an angle of  $0^\circ$  (frame in horizontal position). This difference is due to the different thickness of the atmosphere that cosmic rays have to pass through depending on the direction of origin.

The angular distribution of the particles flux follows a mathematical law (see chapter on the theory of cosmic rays).



Picture of the tilting frame and detail of the sensors with the lead screens

### SBM-20

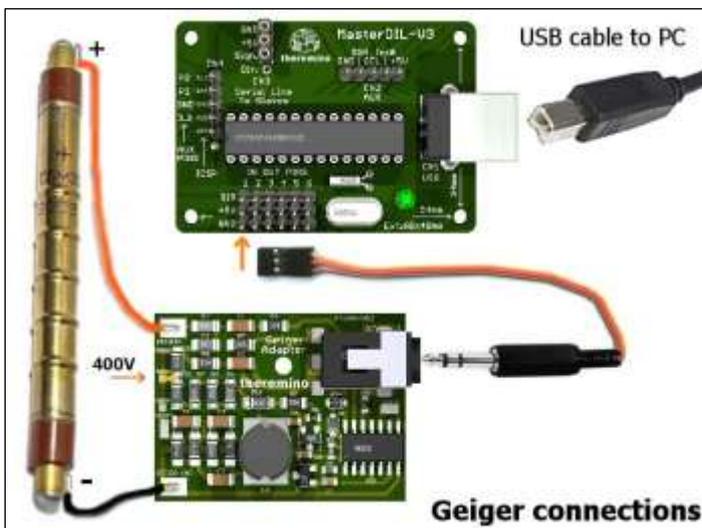
Sens: 24 CPS/mR/h

Bkg: 0.4 CPS

Voltage: 400 volt

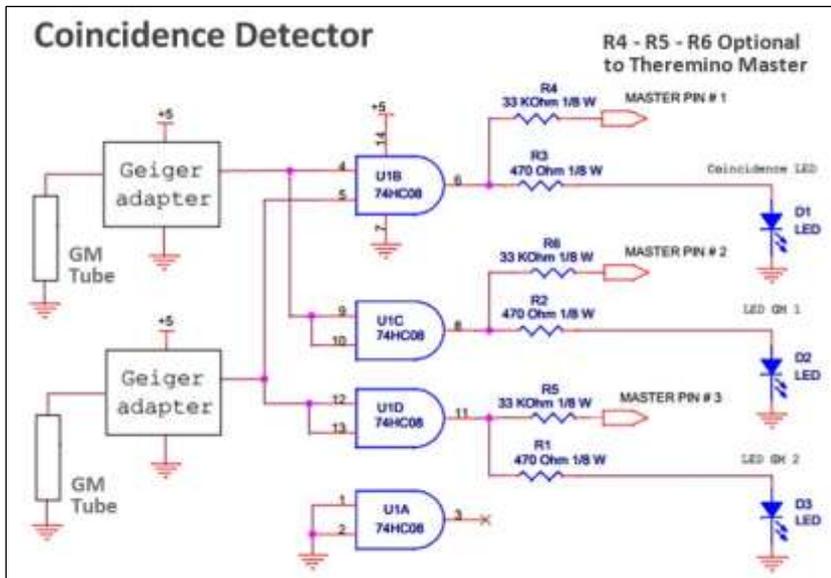
Nominal resistance: 5.6 M

Radiation: Beta + Gamma



Geiger adapter wiring

## Coincidence detector



Coincidence detector circuit

If the two GM tubes (Geiger Muller), emit a pulse at the same time, the U1B gate detects this coincidence with an output pulse.

Contemporary pulses may be randomly generated by two contemporary disintegrations, but the likelihood is very low : about one chance in one hundred thousand (given that the pulses of the tubes last about 100  $\mu$ s and that only few pulses per minute occur).

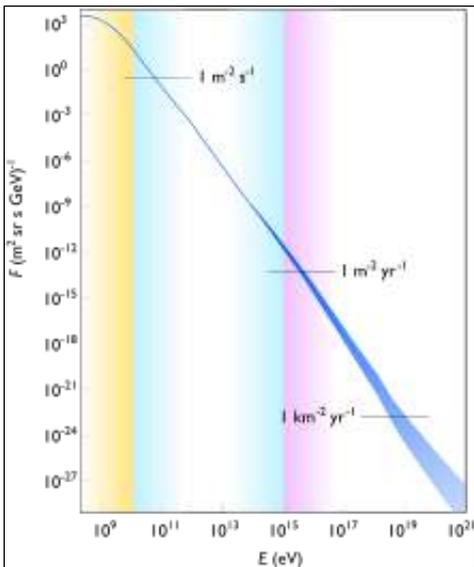
So, if an event is detected, we can say with 99.999 % chance, that was detected a cosmic ray.

The outputs of the two geiger adapter and the output from the coincidence detectors are connected to the Theremino master and configured as counters.

The two independent geiger can be used for making measurements of radioactivity, while the output of the coincidence detector is used to perform counting measurements of cosmic ray flux .

## Cosmic Rays Theory

Cosmic rays are energetic particles coming from outer space. The Earth and any other spatial body, as well as satellites and astronauts in orbit, are exposed to cosmic rays. The cosmic rays nature is very diverse (the kinetic energy of the particles of cosmic rays is distributed over fourteen orders of magnitude), as well as the origin : the Sun, other stars, novae and supernovae (example of energetic phenomena), and even remote objects as quasars.



**Cosmic Rays flux vs Particle Energy**

The part on the yellow background is believed to be from the sun, the part on the blue background of galactic origin, the higher energy part of extragalactic origin.

On average, every second a particle hits every square centimeter surface area on Earth.

Most cosmic rays arriving on Earth are secondary products of swarms formed in the atmosphere by primary cosmic rays, with interactions that typically produce a cascade of secondary particles starting from a single energetic particle.

### Primary Cosmic Rays

Outside of Earth's atmosphere primary cosmic rays are composed primarily of protons and alpha particles (99%), with a small amount of heavier nuclei (~1%) and an extremely minute proportion of positrons and antiprotons. Arrived in Earth's atmosphere, these particles interact with the nuclei of the molecules of the atmosphere, thus forming, in a cascade process, new particles moving forward, which are called secondary cosmic rays.

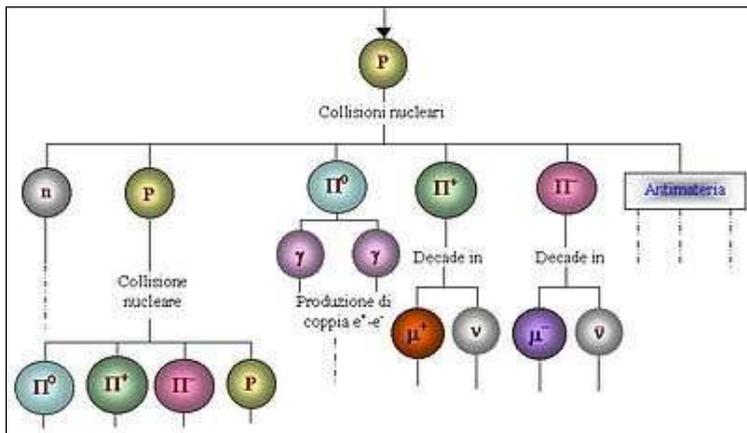
The composition and the energy spectrum have been studied in detail for the primary cosmic radiation. The Hydrogen flux is slightly more than 90%, a little less than 10% Helium,  $7 \times 10^{-4}$  for light elements such as lithium, beryllium and boron, and  $5 \times 10^{-3}$  for other elements Carbon from the Neon.

The energy spectrum follows a power law in the form :

$$\phi \propto E^{-\alpha}$$

with  $\alpha = 2.7$  for energy values less than  $\approx 10^{15} \text{ eV}$ .

## Secondary Cosmic Rays



structure of the secondary cosmic radiation

The secondary radiation at sea level is made of two components (soft and hard) that behave differently when passing through very dense materials (iron, lead, ...).

The soft component (about 30% of the secondary radiation), which is made of electrons and photons and in small part by protons, kaons and nuclei, is able to pass through only a few inches. While the hard component (about 70%), composed of **muons**, can penetrate thicknesses of absorbent materials of more than one meter.

The average flux of the particles that make up the radiation which reach the level of the sea, is estimated :

$$100 \times \frac{\text{particelle}}{m^2 s} \approx 0.01 \frac{\text{particelle}}{cm^2 s}$$

Cosmic rays have an angular distribution with respect to the normal to the Earth surface that can be described by the function :

$$f(\theta) = \frac{4}{\pi} \cdot \cos^2 \theta, \quad \theta \in \left[0, \frac{\pi}{2}\right]$$

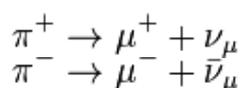
The particles that make up the radiation have high energy. It is estimated that the average flux at sea level has an average energy of 3 GeV. The  $\mu$  lepton (muon), the main component of the secondary cosmic rays, is an elementary particle with spin 1/2, mass :

$$105,658389 \pm 0,000034 MeV/c^2$$

(about two hundred times the mass of the electron), and an average life :

$$\tau_{\mu} = 2,19703 \pm 0,00004 \mu s$$

As mentioned in the introduction, the  $\mu$  are produced mainly in the upper atmosphere by the decay of  $\pi$  :



At the production time they have **relativistic speeds and because of the phenomenon of time dilation** they can reach the sea level, where it is observed that the  $\mu^+$  are about 20 % more of the  $\mu^-$ .

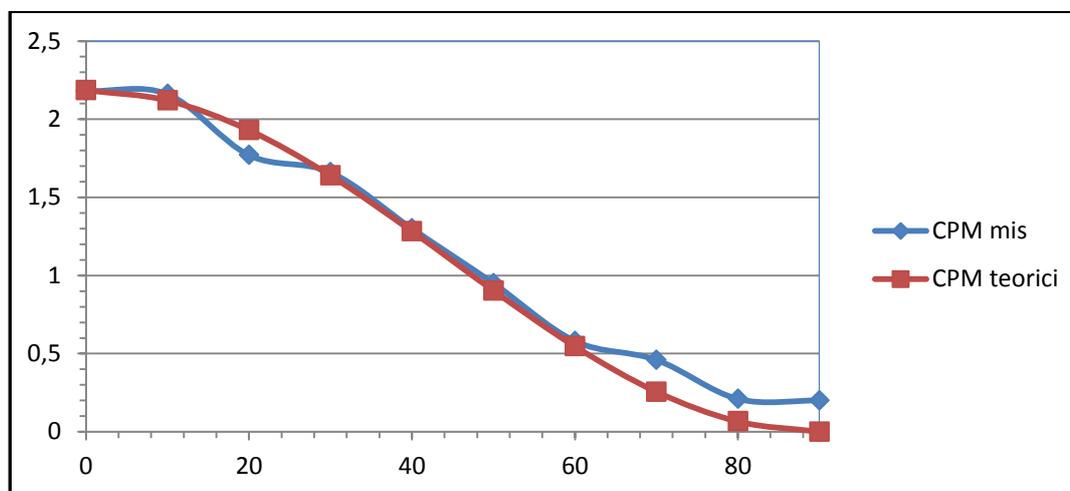
## Measures of Cosmic Rays Flux

In this chapter the results of measurements of the cosmic ray flux are reported. The measurements were made at different times of the day and for every angle was adopted an integration time equal to 3600s (1h).

Sensor area =  $9\text{cm}^2$

Maximum theoretical flux =  $(0,01 \times 9) \times 60 = 5,4\text{cpm}$

Tilt angle (degrees)	CPM (counts per minute) (average on 3600s)	Estimated $\Delta$	Theoretical CPM normalized
90	2,18	$\pm 0,1$	2,19
80	2,16	$\pm 0,1$	2,12
70	1,77	$\pm 0,1$	1,93
60	1,66	$\pm 0,1$	1,64
50	1,30	$\pm 0,1$	1,28
40	0,95	$\pm 0,1$	0,90
30	0,58	$\pm 0,1$	0,55
20	0,46	$\pm 0,1$	0,26
10	0,21	$\pm 0,1$	0,07
0	0,20	$\pm 0,1$	0,00



The detector measures values less than the theoretical ones due to the fact that the detection angle is limited (see construction scheme), for this reason, the theoretical values have been normalized so as to match the maximum.

**From the results we can appreciate a good agreement with normalized theoretical data, this is a proof of the effectiveness of the system in discriminating events due to cosmic rays from spurious events, due to background radiation or due to electronic noise.**