Laboratori Nazionali di Frascati

FRASCATI STAGES STUDENT
June 2008

Acquisition of cosmic rays and measurement of their angular distribution

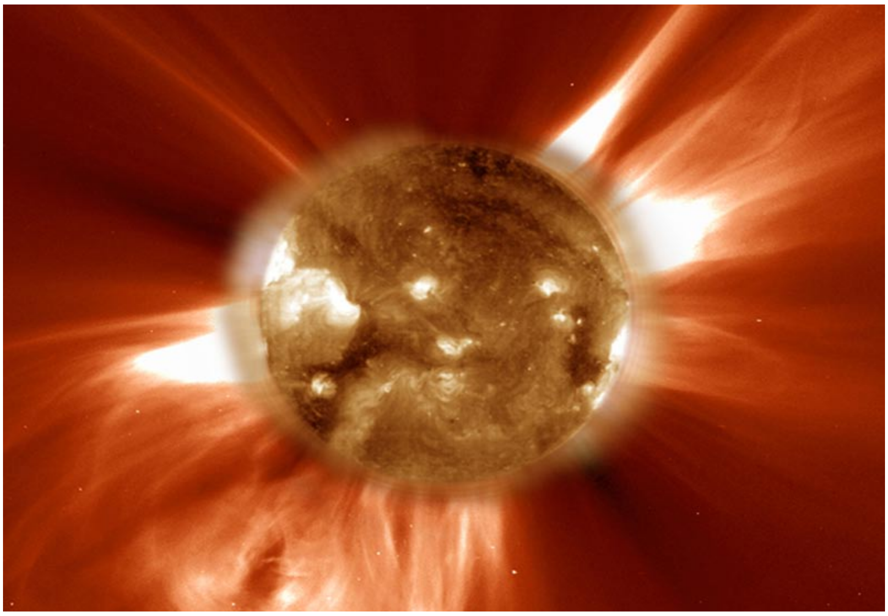
- Cosmic Ray
- Cerenkov Effect
- Elements of a particle detector
- Set up of an acquisition data chain
- Optimization of the parameters for the cosmic rays detector
- Measurement of the cosmic rays angular distribution

HERMES DETECTOR

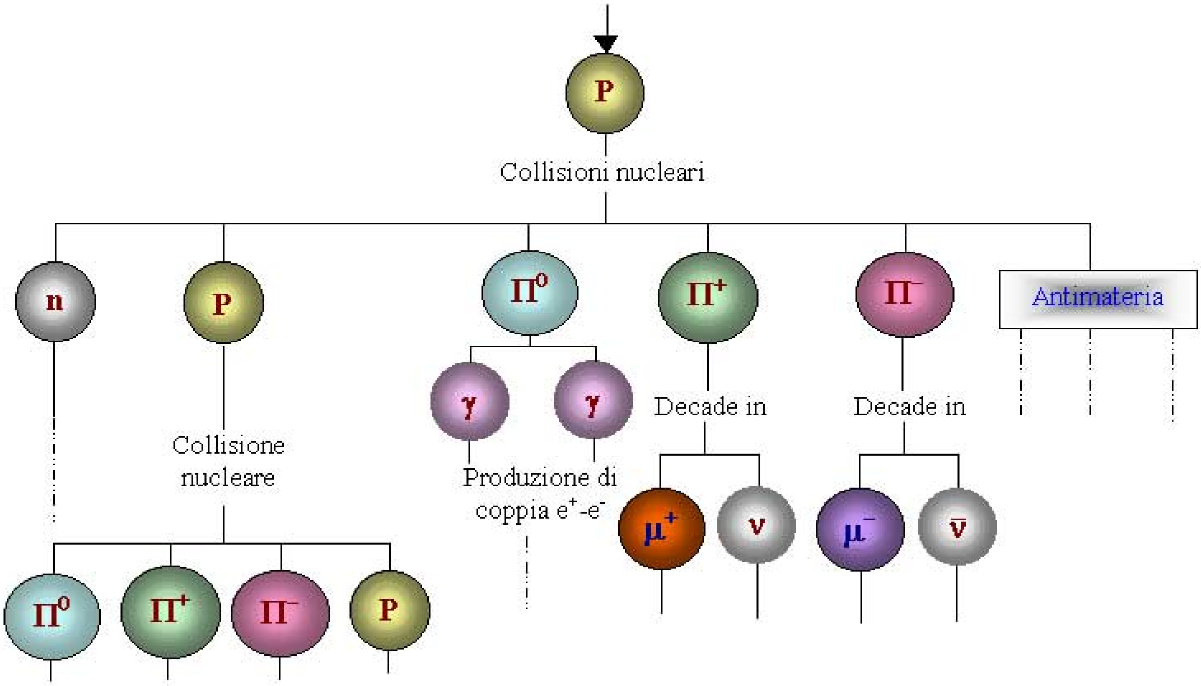
Michele Barbato, Carlo Convenevole, Mario Giuliani, Damiano Maschietti, Giorgio Perniconi
Tutors: Pasquale Di Nezza, Aldo Orlandi

Chapter 1

Cosmic Rays

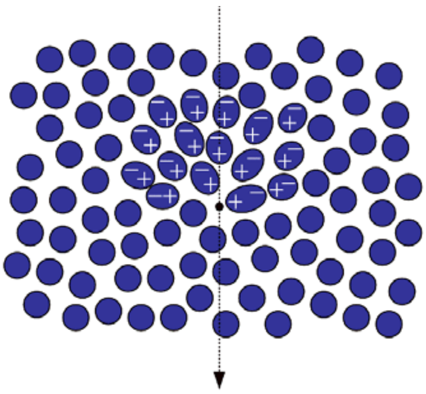


The cosmic rays are a coming energetic radiation from the external space, to which the Earth and any other celestial bodies are exposed to. Their origin is still quiet unknown: the Sun, the other stars, phenomena like novae and supernovae, till remote objects much like the quasar. Outside from the atmosphere the cosmic rays are constituted by protons, electrons, photons, neutrinos, etc… . All these particles make part of the primary cosmic rays that, when catches up the earth come turned aside from the terrestrial magnetic field thus forming, in a process to cascade, a shower of particles (pions, muons, neutrinos…) called secondary cosmic rays. Most of these particles are captured from the atmosphere interacting with the gas in it present; only muons and neutrinos arrive at sea level. The first ones are the particles we are going to select and measure.



Chapter 2

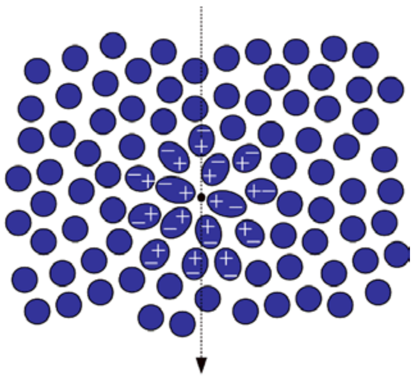
Cerenkov Effect



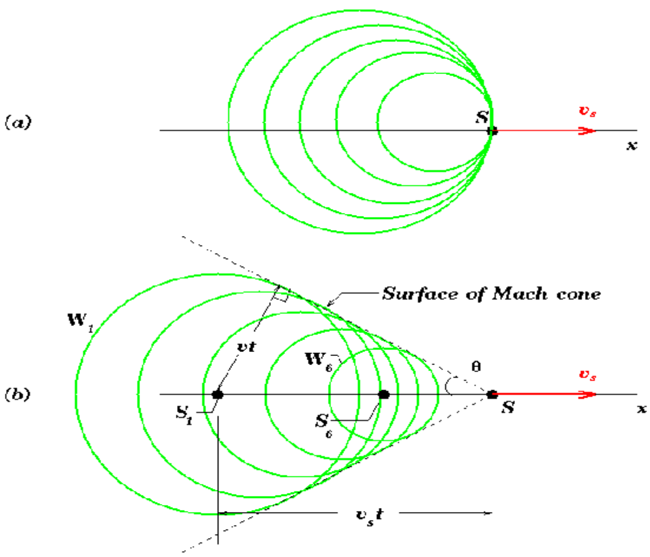
Cerenkov Effect is based on the possibility that a particle exceeds the light speed in a material and it happens only if the particle is electrically charged. When a charged particle passes through a material, it polarizes the surrounding molecules, gone away the particle, the molecules return at the state of rest cancelling each other the energy received from the particle that has polarized them and the molecules don't emit radiation.

This happens if the speed of the particle (V) and the speed of the light (C) are V < C. If V > C the electromagnetic field propagation speed, generated by the charged particle, doesn't reach the particle velocity.

The medium, polarized by the passage of the charged particle, emit the energy absorbed during the polarization in form of photons. So they become source of spherical waves and their common wave front is like a cone left by the charged particle.



The Relativity Theory says that the speed of the light in the vacuum (C = 299.792,458 km/s) can not be exceeded. When a charged particle travels through a dielectric causes electromagnetic field with a destructive interferences, but in a very dense medium the speed of the light is less than the velocity of the particle, so the charged particle travels faster than the electromagnetic field generating an emission of light.



Cerenkov angle can be calculated by this formule:

$$\sin\alpha = \frac{1}{n}$$

Chapter 3

Elements of a particle detector

The particle detector we are using is based on three components, mainly

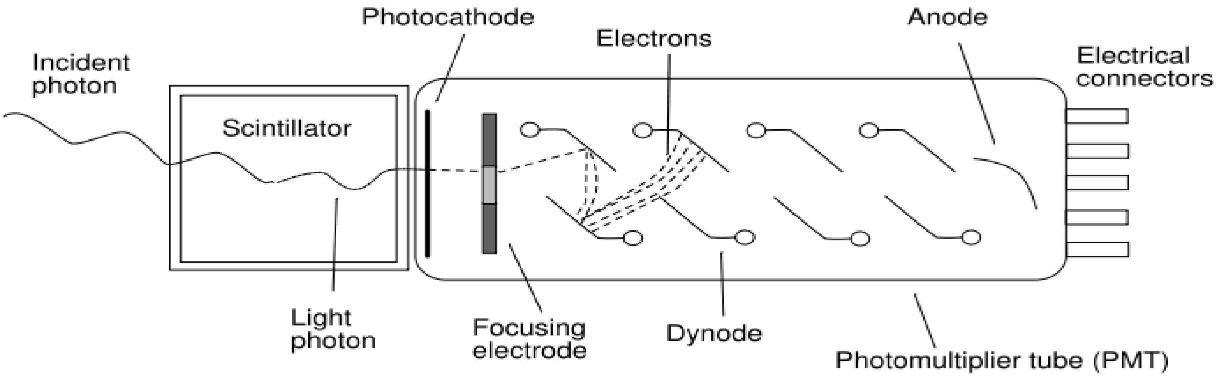
- Lead Glass
- Scintillator
- Photo Multiplier Tube

The lead glass is the medium in which the Cerenkov effect occurs. It is made basically by a mixture of lead and glass, so that in this material the speed of the light is smaller than the particle's one, giving the Cerenkov effect.

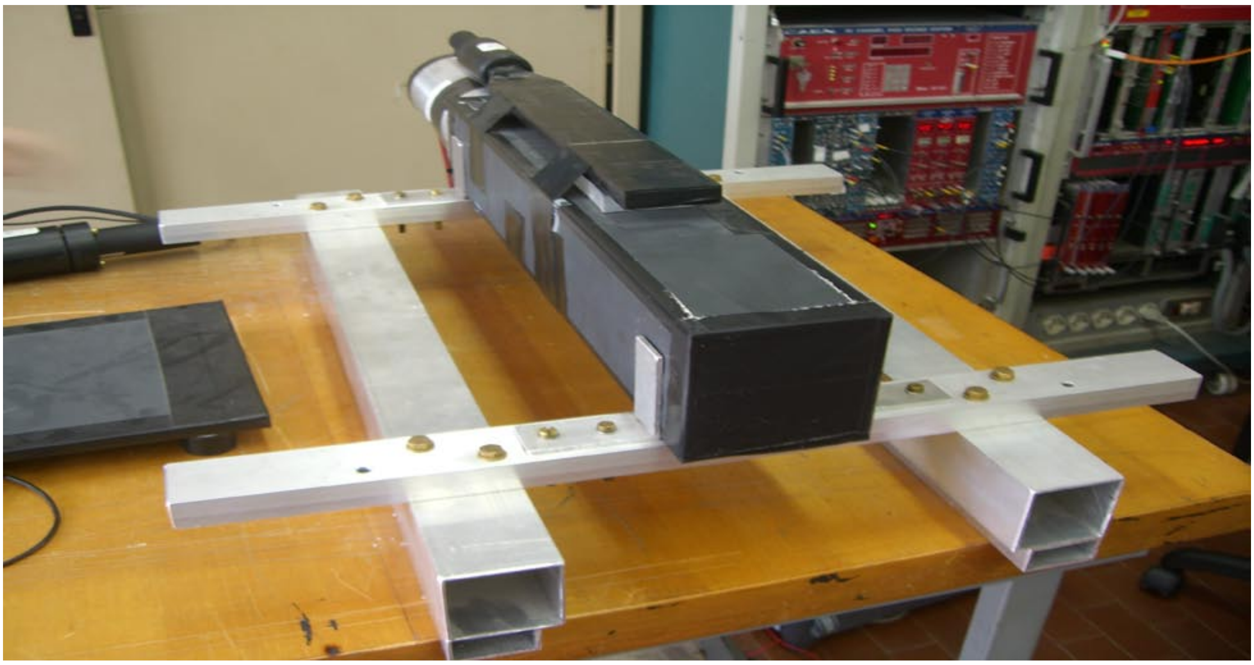
The scintillator is made by a plastic that absorbs the energy gave by the particles that travels through the detector. The atom excited by this energy irradiates a photon. We use two scintillators to be sure that, in a concidence, a real, true particle had cross the detector separating it from the background caused by the PMTs.

The Photomultiplier tubes (PMT) are extremely sensitive detectors of light in the ultraviolet, visible and near infrared. These detectors multiply the signal produced by incident light by as much as 10^8 from which single photons can be resolved.

Photomultipliers are made by a glass vacuum tube which houses a photocathode, several dynodes, and an anode. Incident photons strike the photocathode material which is present as a thin deposit on the entry window of the device, with electrons being produced as a consequence of the photoelectric effect. These electrons are directed by the focusing electrode towards the electron multiplier, where electrons are multiplied by the process of secondary emission.



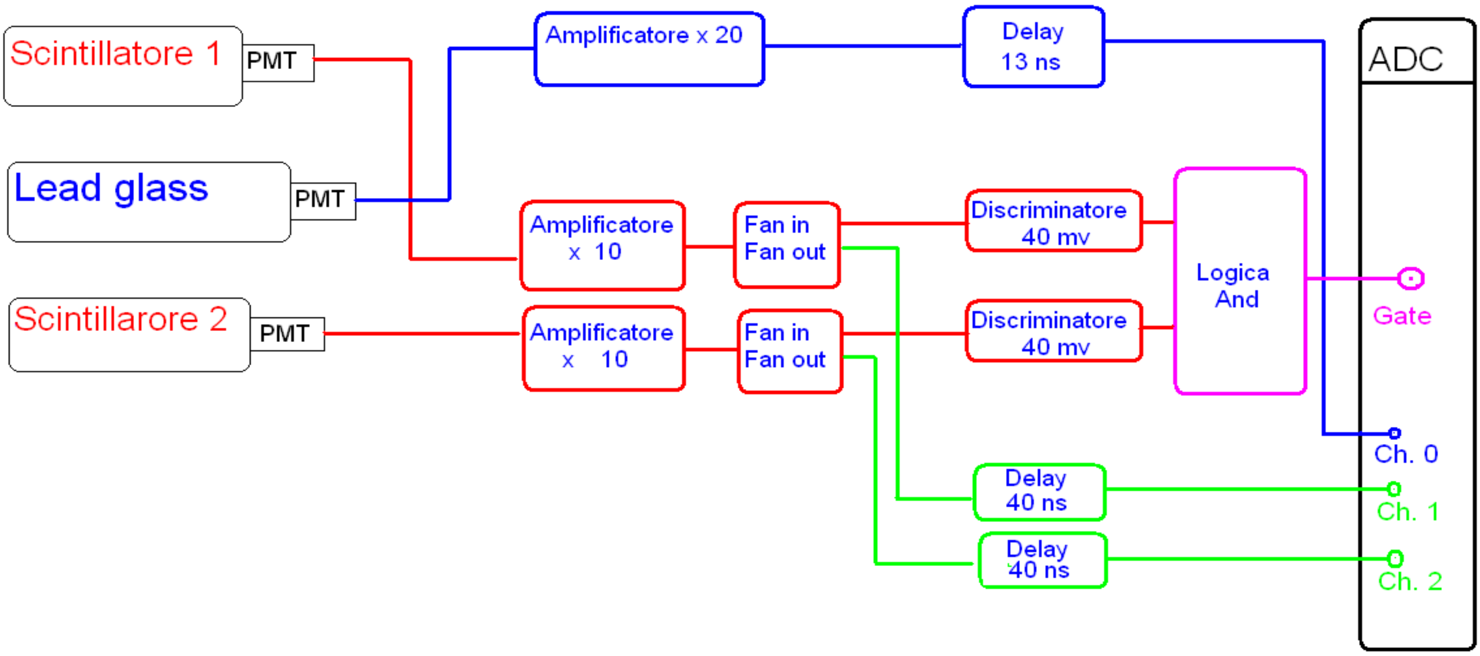
The electron multiplier consists of a number of electrodes, called dynodes. Each dynode is held at a more positive voltage than the previous one. The electrons leave the photocathode, having the energy of the incoming photon. As they move towards the first dynode they are accelerated by the electric field and arrive with much larger energy. On striking the first dynode, more low energy electrons are emitted and these, are then accelerated toward the second dynode. The geometry of the dynode chain is such that a cascade occurs with an ever-increasing number of electrons being produced at each stage. Finally the anode is reached where the accumulation of charge results in a sharp current pulse proportional to the energy of the photon arrived on the photocathode.



Chapter 4

Set up of an acquisition data chain

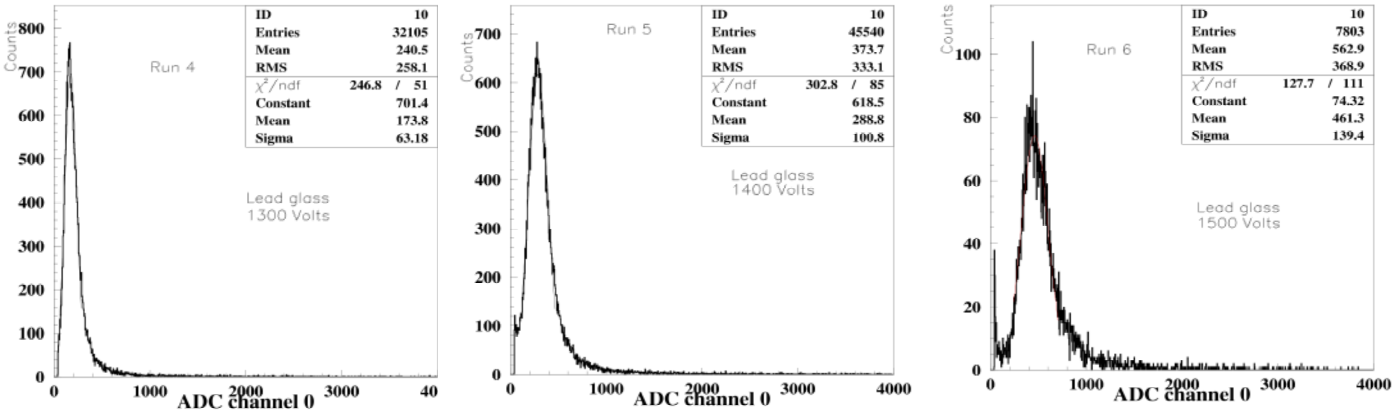
The acquisition data chain starts with the PMT which is connected to an amplifier (scintillator signal is amplified X 10, lead glass signal is amplified X 20). Then the two signals of the scintillators are sent to the “fan in-fan out” that duplicates each of them, so we can sent the same signal to the logica (to produce the coincidence) and to a channel of the ADC (Analogic to Digital Converter, Ch1 or Ch2) to acquire the scintillators data. Then the two signals of the scintillators are sent to the discriminator. The discriminator squares the signals (doing the integral) and establishes the width of the output signal. The discriminator generates an output signal if the input signal is larger than a fixed threshold (THL). Then the squared signals of the scintillators are sent to the logica unit. The logica analyzes the two signals and if they are synchronized generates an output signal of fixed amplitude. Also the logica has a threshold (which is modifiable) and the gate (of the ADC) is opened only if the signals of the scintillators arrive together and if the signals are larger than the threshold. After the fan in-fan out, the scintillator signal that is sent to a channel of the ADC passes through a delay which synchronizes the signal with the gate (opened by the signal of the logica). The lead glass signal passes in another delay to be synchronized with the other signals. Looking at the delays we see that scintillators signals are delayed by 40 ns and the lead glass signal is delayed by 13 ns, so the passage of the signal through the discriminator and the logica takes 27 ns.



Chapter 5

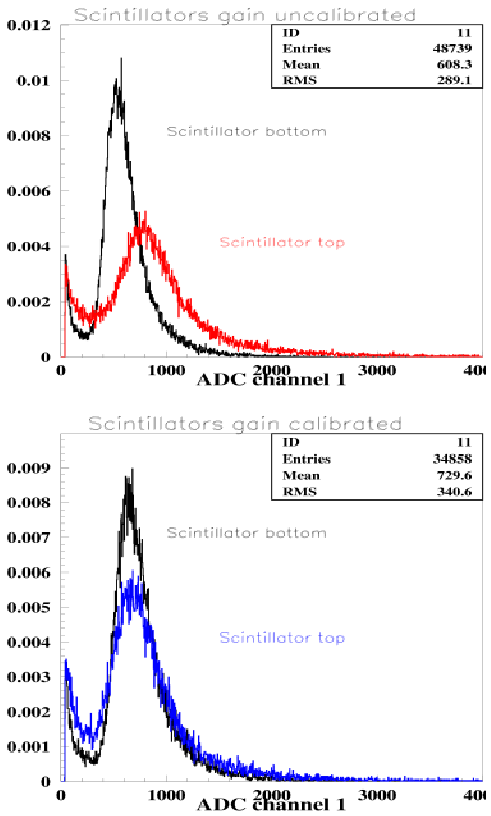
Optimization of the parameters for the cosmic rays detector

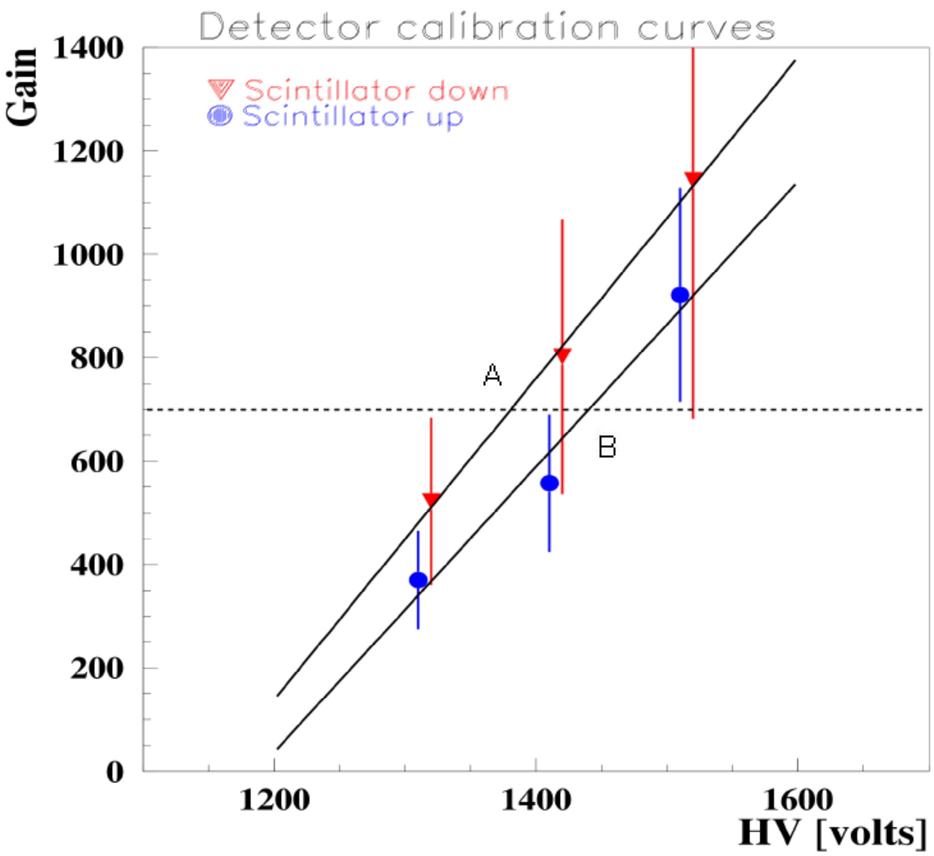
At the beginning of the experiment we noticed how our instrument responds by changing the voltage of PMT. We did three measurements: at 1300volt, at 1400volt and at 1500volt.



X-axis indicates the particle's energy; y-axis indicates the number of events. Each graphic has a background which is not considered. These graphics have also a fit that we use to find the Mean, the Integration and the Sigma.

During this three measurements we saw that the two scintillators have different gains at the same voltage. So we created a curve of calibration in order to have the same gain.





To create the curve of calibration we plotted the gains of the three measurements at three different voltages in a Cartesian system. We did a fit in order to find the calibration curve of each scintillator, then we choose a gain fixing the voltage at the value that we found (point A = 1381 volt; point B = 1440 volt).

Chapter 6

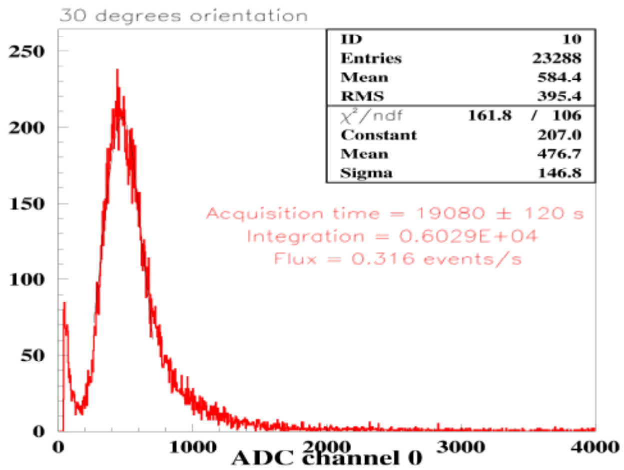
Measurement of the cosmic rays angular distribution

When we have fixed the voltage we have done three measurement at three different position of the experimental setup: 0 degrees, 30 degrees and -30 degrees with respect to the vertical to the ground.

For each measurement we calculated the acquisition time, the count integration in an interval of two sigma, then the flux.

To find the flux we use this formula:

$$\text{FLUX} = \frac{counts}{seconds}$$

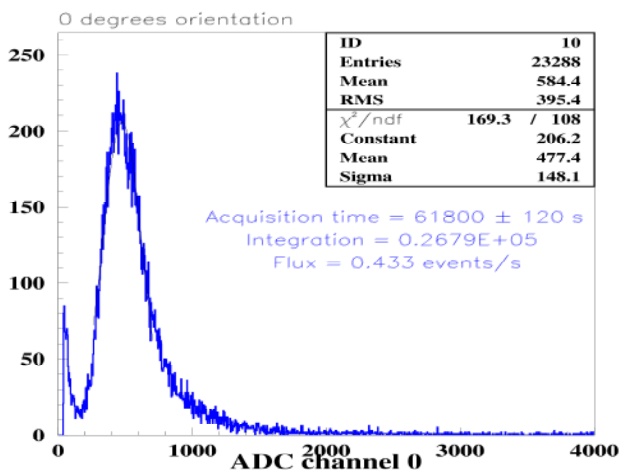


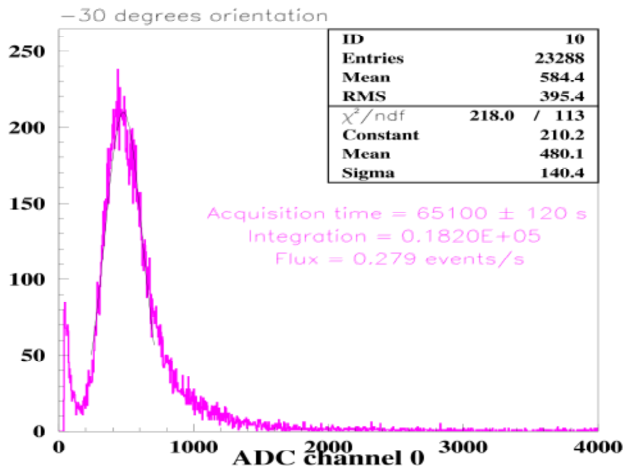
Then, we plotted the flux value in another Cartesian system in order to see the cosmic rays angular distribution.

So we did a fit with two functions:

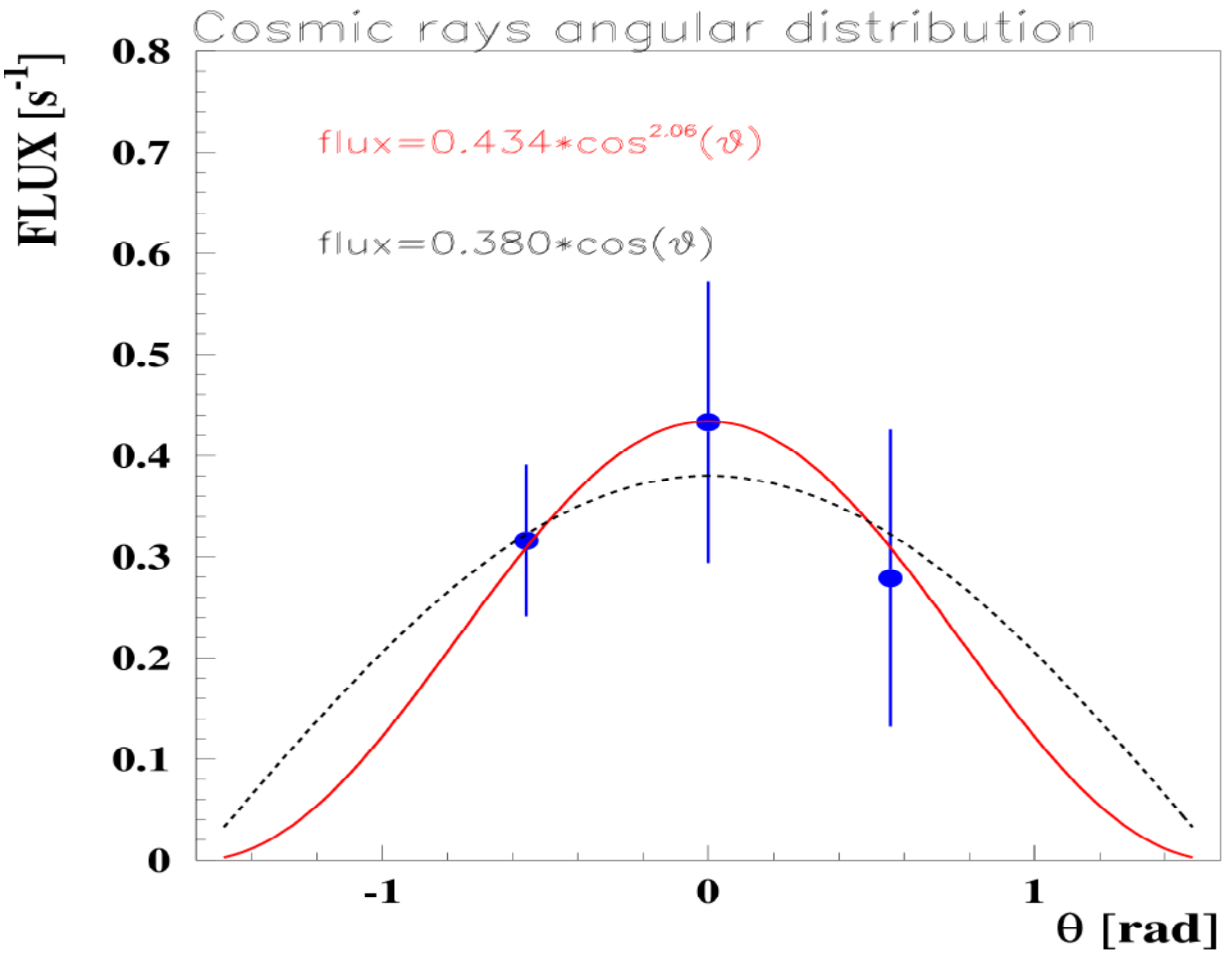
$$\text{Flux} = k \cdot \cos^n(\alpha)$$

$$\text{Flux} = k \cdot \cos(\alpha)$$





Some experimental data seem to show that the cosmic rays angular distribution changes according to the function $\cos^n$, others show the flux changes just according to the function cos.


Cosmic rays angular distribution
FLUX [s^-1]
flux=0.434*cos^2.06(ϑ)
flux=0.380*cos(ϑ)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-1
0
1
θ [rad]