EXPERIMENTAL ACTIVITY :

CONSTRUCTION OF AN EXPERIMENTAL APPARATUS FOR MEASURING COSMIC RAYS

INFN - LNF

Summer Stages

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1. Introduction to cosmic rays

The atmosphere is continually subject to a flux of high energy particles coming from outer space that constitute the primary cosmic radiation. This radiation is made of protons, α particles and electrons.

The interaction of primary cosmic radiation with the atmosphere produces secondary particles: pions that exist in three state of charge (π^0, π^+, π^-) or other mesons .

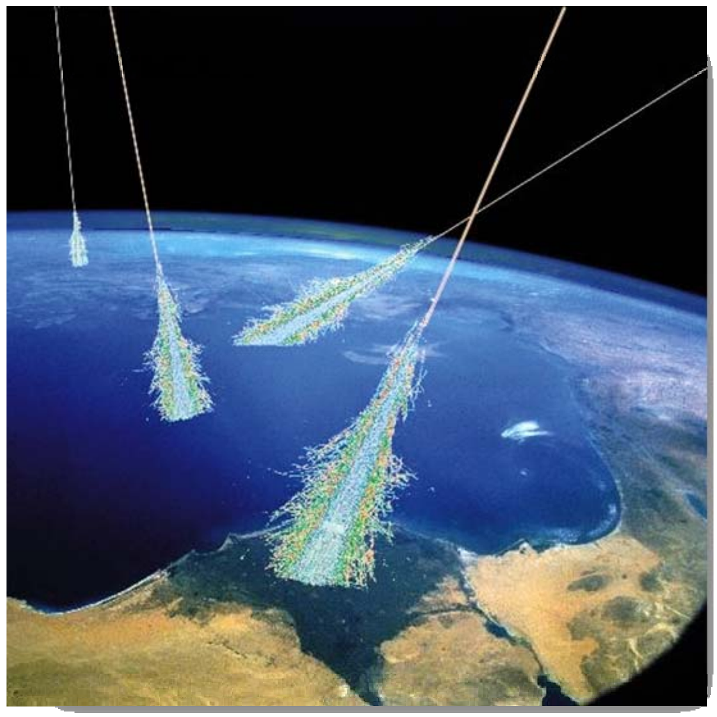


Fig. 1 – view from space of the cosmic

The π^0 decay into two photons (which don't reach the ground level). Charged pions decay in one muon μ and a neutrino.

Slow muons decay in one electron e^- and two neutrinos ν, while fast muons can reach the ground level. Nowadays cosmic rays are used to calibrate particles detectors.

2. Experimental apparatus construction

We built an experimental apparatus to measure the cosmic rays using two scintillators and one lead glass and a series of electronic modules .

2.1 Scintillator

The scintillators are made of polystyrene plastic composed by carbon and hydrogen. The passage of a charged particle through the scintillator produces the emission of fluorescence isotropic light. The amount of this light is proportional to energy lost by the particle, thus its measurement gives information about the particle energy.

2.2 Lead Glass

The lead glass is composed by 48% of Pb and 52% of glass (with a very high refractive index about 4) and is covered by a reflective layer. Čerenkov radiation is electromagnetic radiation emitted when a charged particle (such as a muon) passes through the detector at a speed greater than the speed of light in that medium.

2.3 PMT

At one edge of the scintillators and the lead glass there is a photomultiplier tube (PMT) that transforms the light emitted in the detector in an electric signal trough photoelectric effect. The PMT is made by a cathode and many high voltage dynodes which multiply the electrons coming from the cathode. A sketch of the PMT in ***fig. 2***

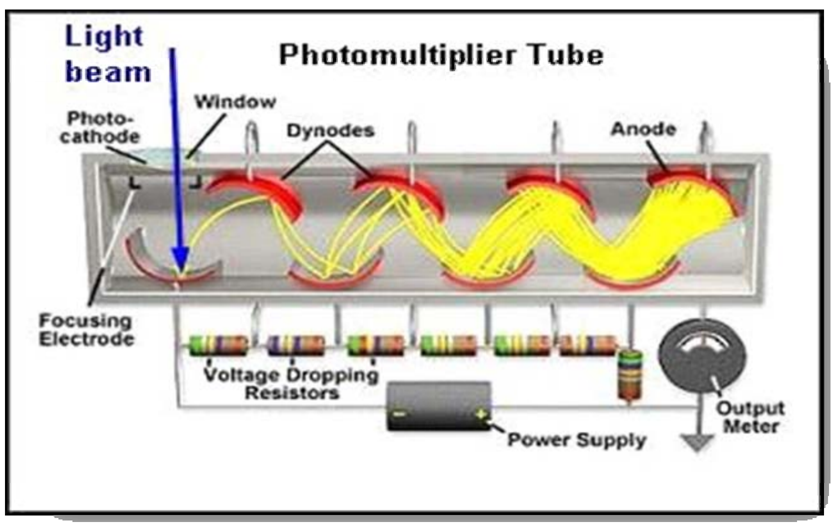


Fig. 2 – scheme of a PMT .

2.4 Elecronics

We used the following electronics modules:

- **HV POWER SUPPLY** *(LeCroy model HV 4032A, 30 Ch)*: It is used to give power to the PMT. Typical HV voltage are ≈ 1350 V.

- **AMPLIFIER**(*LeCroy model 612AM, six Ch variable*) : is a device that increases the amplitude of the input signal by an adjustable factor.
- **FAN IN FAN OUT** (*LeCroy model 428F linear*): It duplicates the input signal up to four equal output signals.
- **DISCRIMINATOR** (*LeCroy model 821, quad*): gives a digital output of fixed amplitude (800 mV) if the analog input signal is bigger than the threshold.
- **AND LOGIC** (*LeCroy model 365AL, 4 fold*): gives digital output if two (or more) inputs come simultaneously .
- **DELAY** *(C.A.E.N., programmable delay 6÷85,5 ns):* delays the signal.
- **ADC** *(LeCroy model 2249A)*: converts analog signals into digital ones analyzable by the computer. Analyzes up to 12 analog inputs in the presence of a signal to the gate.

  This is a formed signal with fixed amplitude of 800mV.

Fig. 3 – Scheme of the electronics

In addiction we also have used a **SCOPE** (TekTronix model TDS3054B) to visualize the output signals coming from the different electronics modules.

The **ADC** is acquired by a computer program that use LabView language. In ***Fig. 3*** we show the scheme of the electric apparatus.

2.5 Acquisition system description

The acquisition system is shown in ***fig.4.*** The output signals from lead glass PMT is sent to the amplifier where is amplified x20, then to Fan In Fan out and finally to the input (0) of the ADC.

The two scintillators outputs are amplified by a factor 12 and then they are connected to the Fan IN Fan Out. One Fan In Fan Out output is delayed and connected to the ADC input (1-2). An other Fan In Fan Out output goes to the discriminator (threshold = 30 mV) and then to the AND logic which output is connected to the ADC Gate.

The disposition of both scintillators and the lead glass is shown in ***fig.5***. Thanks to this position they can select only the cosmic rays which cross all the detectors.

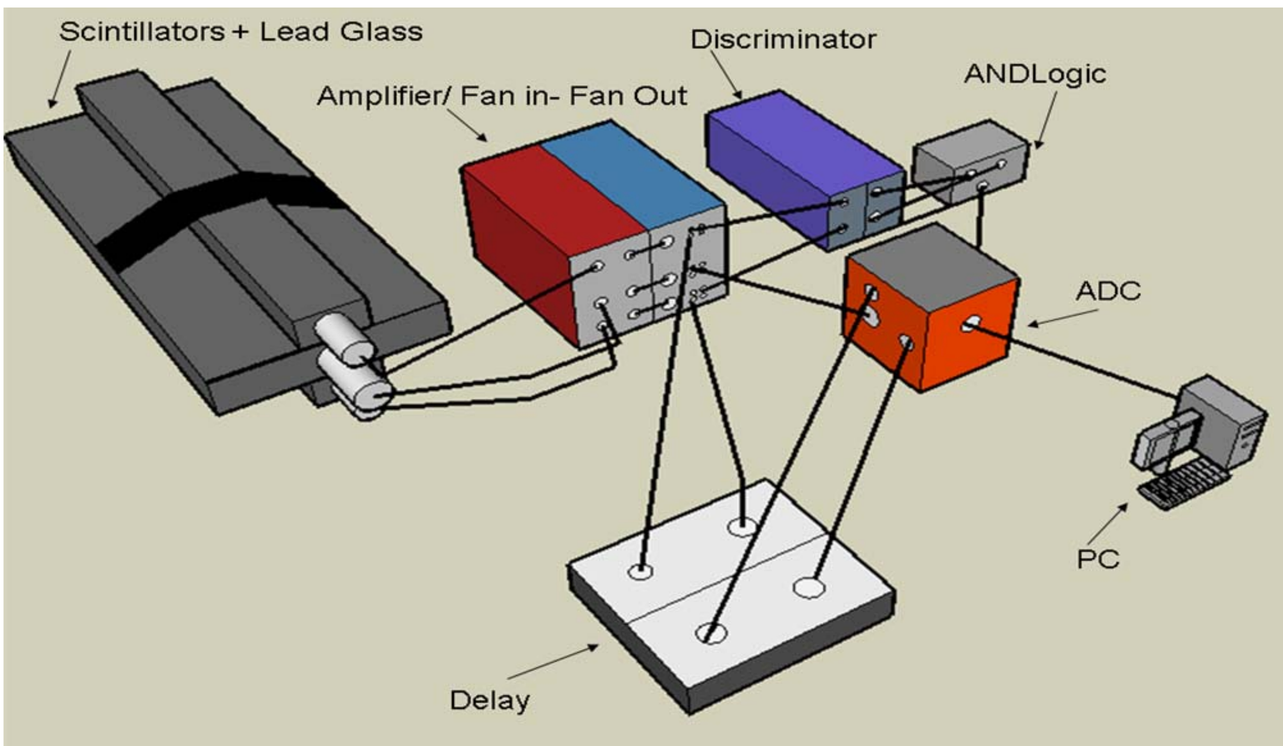


Fig.4 – Scheme of the acquisition

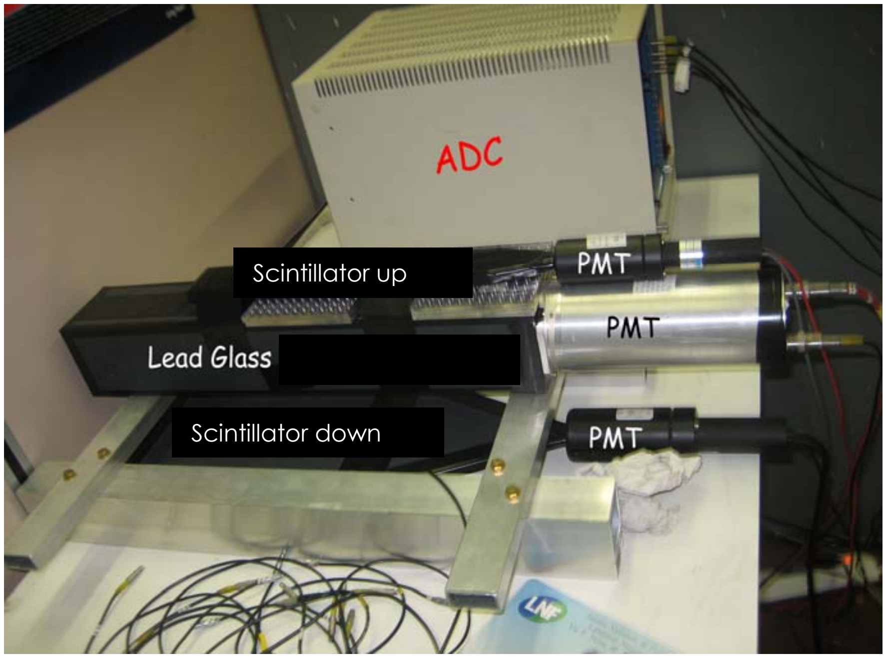


Fig.5 – lead glass and scintillators

3. Voltage curves calculation

We did three runs with three different voltages and the results are shown in ***fig. 6,7,8.*** Each histogram has been fitted with the function:

$$f(x) = P1 \cdot e^{-\frac{1}{2}\left(\frac{x-P2}{P3}\right)^2} \cdot e^{\frac{-x}{P4}} + P5 + P6x + P7x^2$$

to calculate the peak position. These peaks positions are shown in ***Tab .1*** and plotted as a function of the voltage in ***fig. 9.***

Tab. 1 – *peak positions as a function*

Voltage (V)	Scintillator down	Scintillator up	Lead glass
1300	270.1 ± 1.3	349.3 ± 1.7	248.9 ± 1.7
1350	329.1 ± 1.7	443.1 ± 2.1	313.6 ± 2.0
1400	418 .0 ± 3.4	572.9 ± 6.2	396.2 ± 4.2

For each detector, the peak positions of ***fig.9*** have been fitted trough the equation:

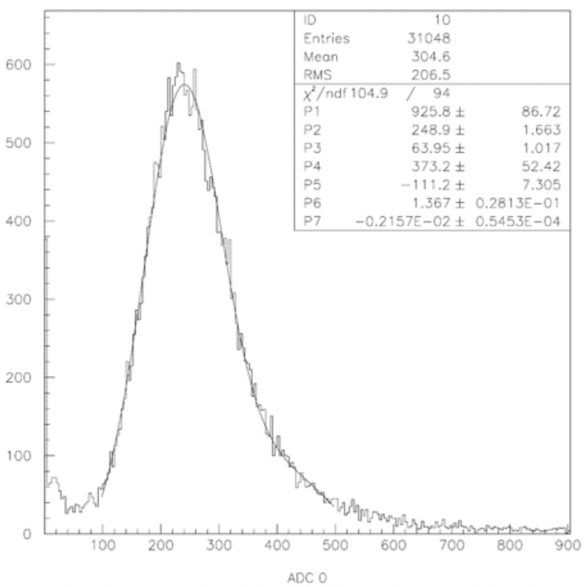
$$f(x) = P1 \cdot V^{P2}$$

obtaining the three voltage curves. With these equations we set our final voltages to each detector corresponding to the value of the peak at 400. These final voltages are reported in ***Tab. 2*** .

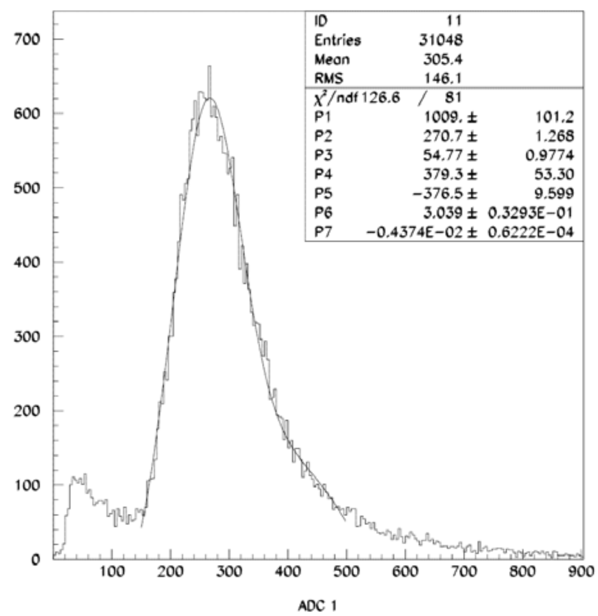
Tab. 2 –*Final Voltage for having peak position at 400*

Detector	Voltage(V)
Lead glass	1402
Scintillator down	1391
Scintillator up	1328

LEAD GLASS



SCINTILLATOR DOWN



SCINTILLATOR UP

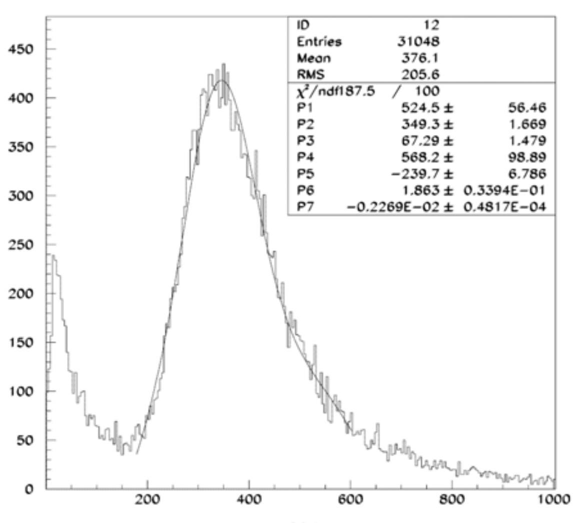
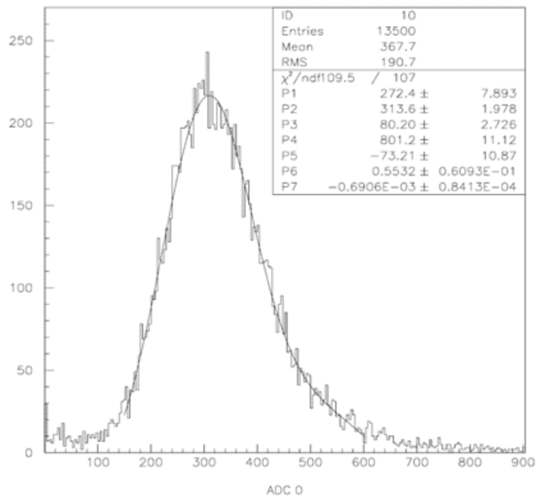
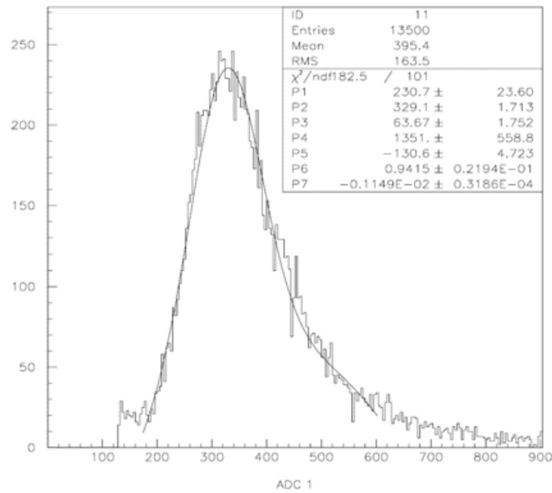


Fig . 6 – ADC distributions at V = 1300 Volt

LEAD GLASS



SCINTILLATOR DOWN



SCINTILLATOR UP

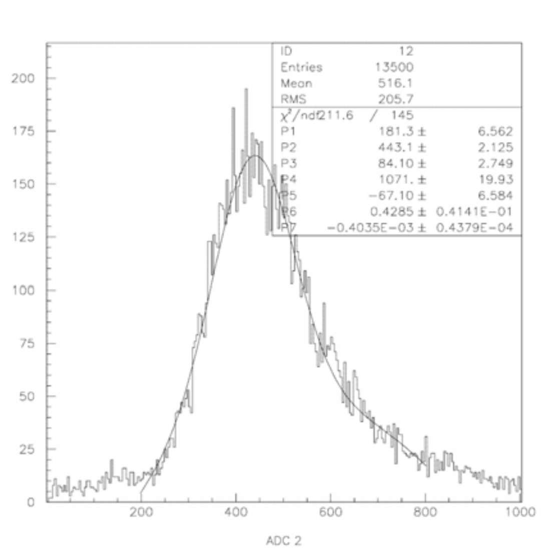
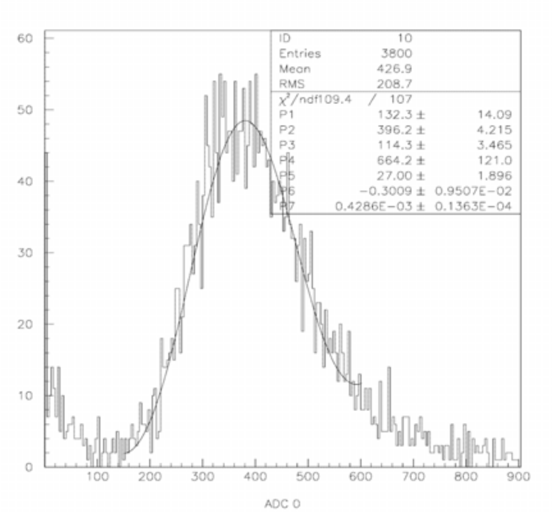
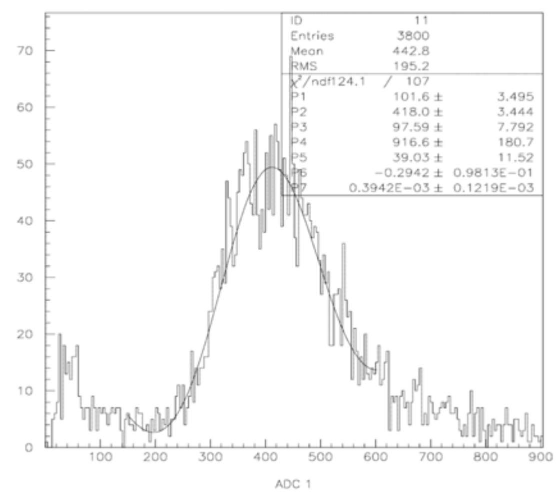


Fig. 7 – ADC distributions at V = 1350

LEAD GLASS



SCINTILLATOR DOWN



SCINTILLATOR UP

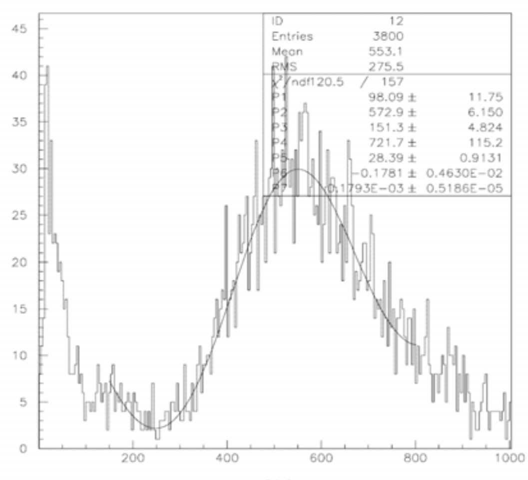
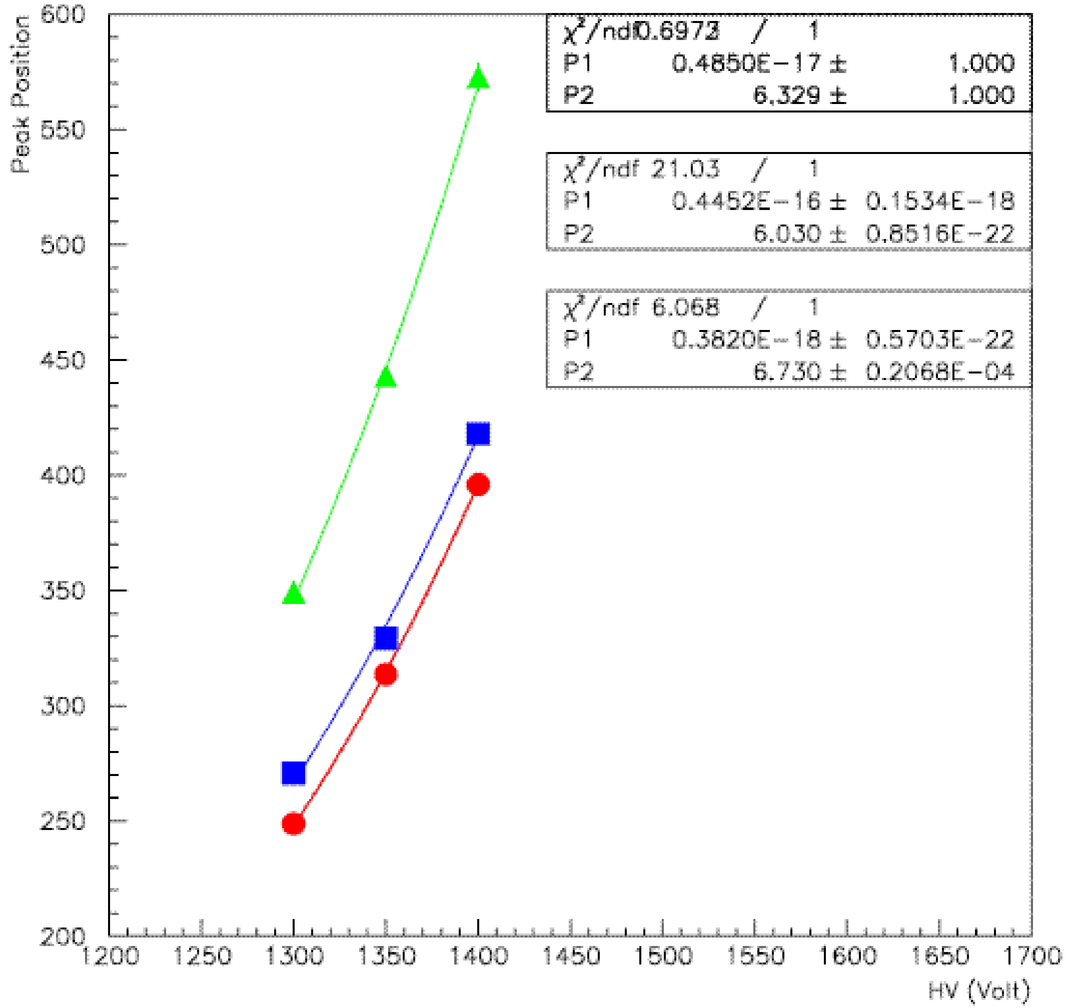


Fig .8 – ADC distributions at V = 1400 Volt

Fig.9 – Voltage curves



4. Study of Lead Glass peak variation as a function of position

We now studied the response of lead glass as a function of the distance from PMT. To detect only the cosmic particles that pass through a specific area of lead glass, we have positioned the scintillator up longitudinally to the lead glass, while the scintillator down was positioned crosswise as shown for example in ***fig. 10***.

The peak values as a function of the three distances are shown in ***fig. 11*** and the peak positions are reported in ***tab.3***. In ***fig. 12*** we show the position of the three peaks as a function of distance from the lead glass PMT. As can be seen, the response of the detector is reduced about 16% at the farther position from lead glass PMT.

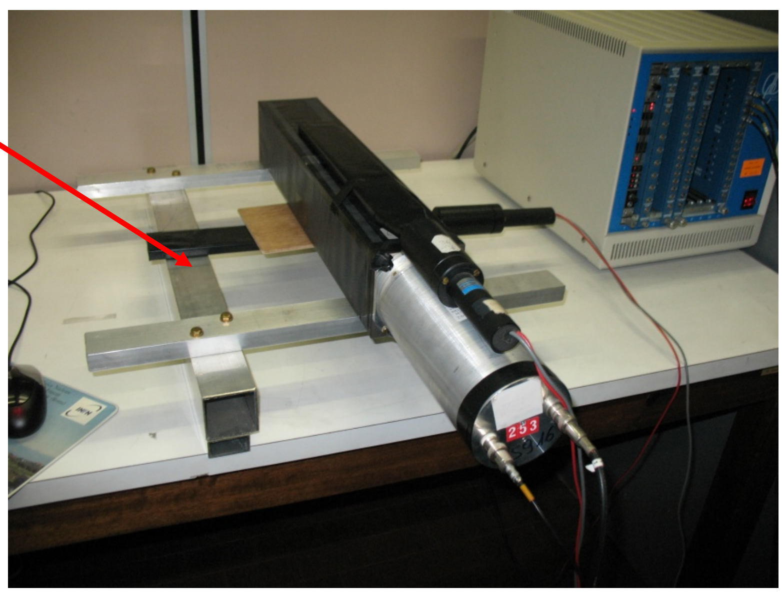
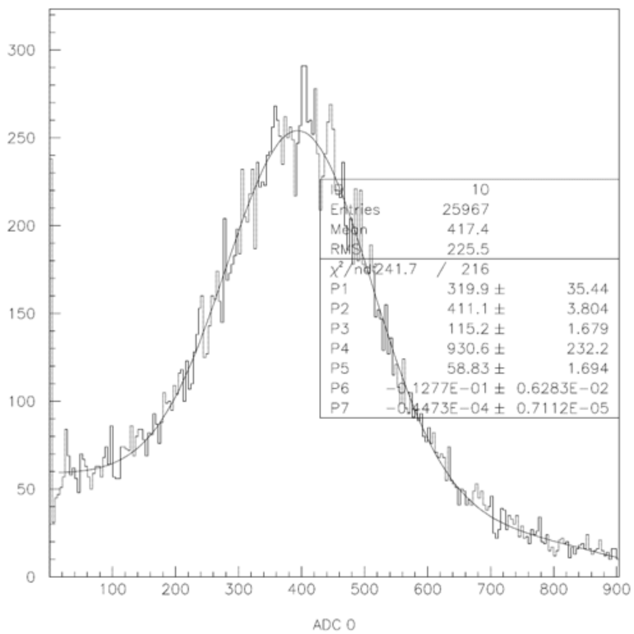


Fig.10 – position of Scintillators

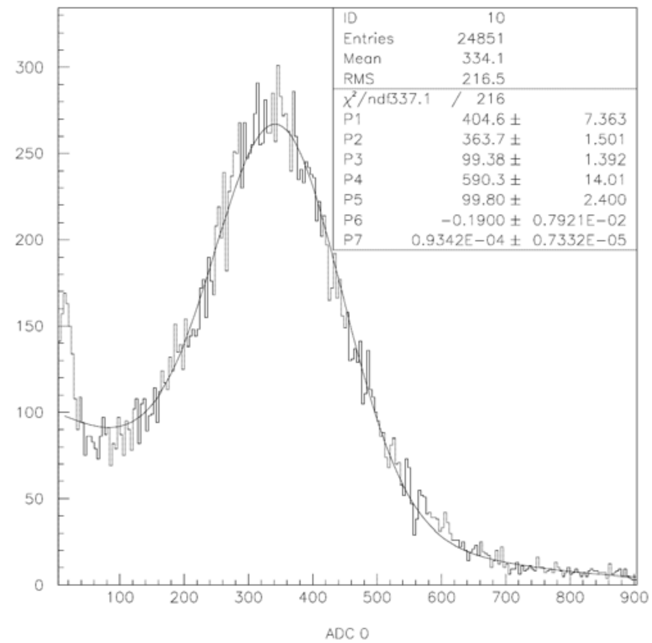
Tab. 3

Scintillator - Lead glass PMT distance (cm)	Peak
13.0	411.1 ± 3.8
27.0	367.7 ± 1.5
44.5	343.6 ± 3.0

Distance = 13.0 cm



Distance = 27.0 cm



Distance = 44.5 cm

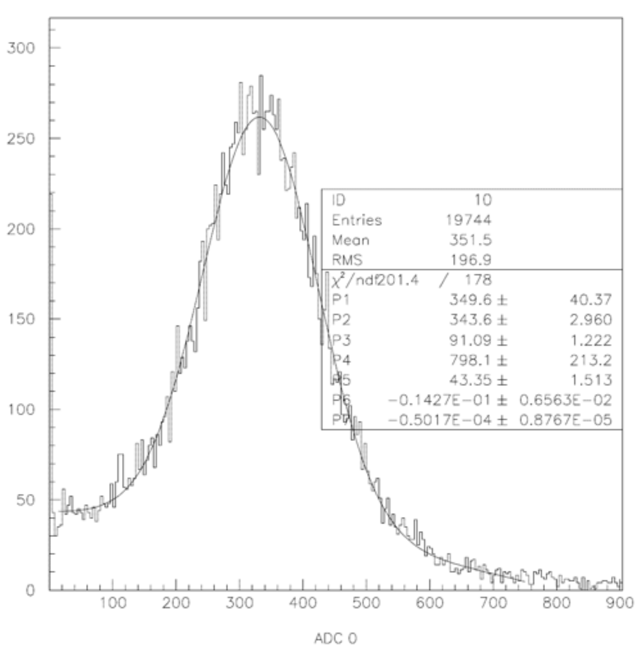


Fig.11 – Lead Glass distribution at the three distances from PMT.

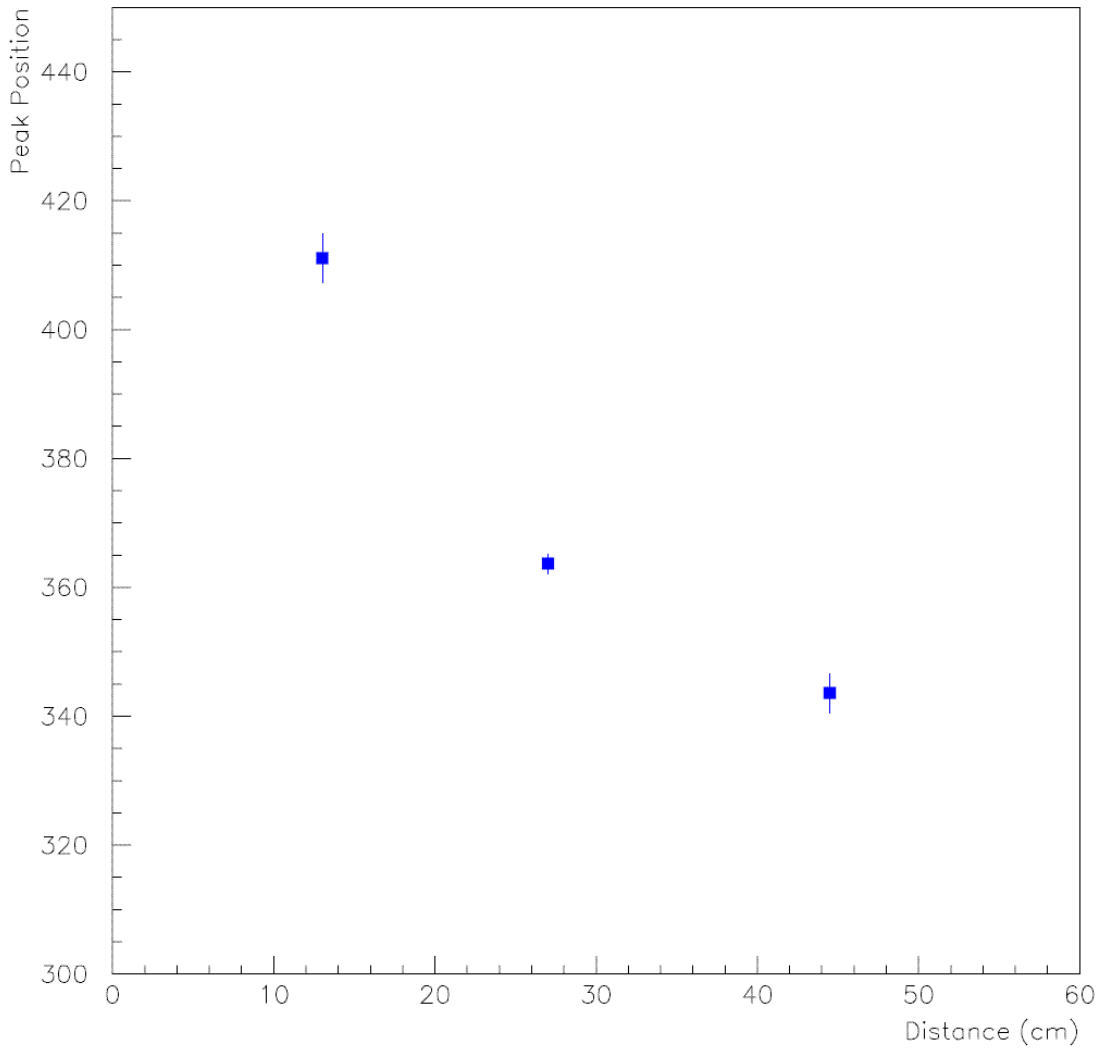


Fig. 12 – The peak positions at the three distances

Conclusions

We set up an experimental apparatus to detect cosmic particles. We measured the voltage curves and studied the peak positions as a function of the distance from PMT. We concluded that the response of the detector decreased about 16% at the farther distance.