CONSTRUCTION OF AN EXPERIMENTAL APPARATUS FOR THE ACQUISITION OF COSMIC RAYS

Students:

D'Amico Valerio
Danza Francesco
Lanzi Alessia
Negroni Silvia
Tardella Matteo

Tutors:

Mirazita Marco
Orlandi Aldo
Pesci Walter

Chapter 1 : Introduction

The aim of our work is the construction of a detection apparatus for the measure of the particles' energy. Profiting by cosmic rays we make the detectors calibration. Cosmic rays come from stars and galaxies: they are characterized by two components. The primary component travels across the universe arriving to our atmosphere and It is formed by:

- Photons
- Neutrinos
- Protons (79% of Hadrons)
- α particles (15%)

The secondary component is the result of the interaction of the primary component with the atmosphere and it is formed by:

- electromagnetic shower (electrons + photons)
- Hadronic shower (pions, kaons)
- Neutrinos
- **Muons**

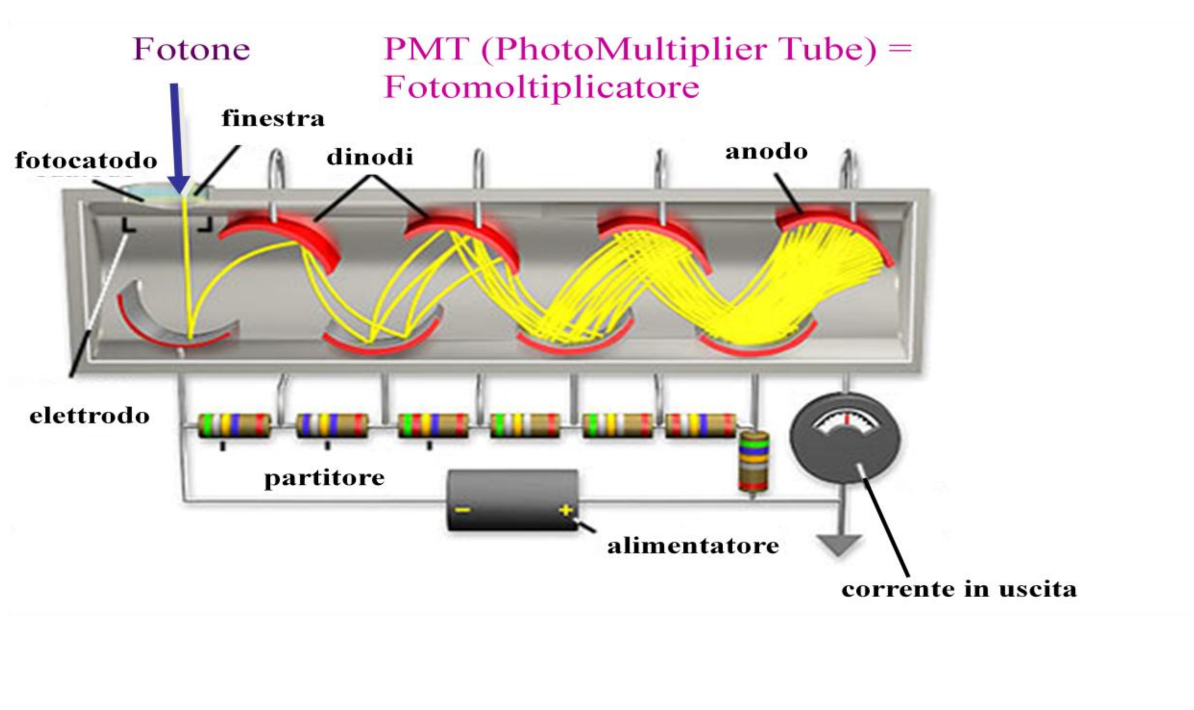
Muons are only particles that are able to arrive to the sea level.

Chapter 2 : Detectors

We used two different kinds of detectors: scintillators and lead glasses. The former is a plastic detector in which a charged particle loses energy exciting the atoms of the material, then the atoms in the de-excitation process emit a small isotropic flash of visible light in a very short time. The amount of light is proportional to the energy lost by the particle. The latter is a detector based on the Cherenkov effect. A charged particle traveling at a velocity greater than that of the light emits electromagnetic radiation collinear to the direction of the particle. This is similar to the production of a sonic boom when an airplane is traveling through the air greater than sound waves can move through the air. Even if the amount of light is lower than the scintillator' one, it allows the separation between fast lighter particles (like electrons and muons) and slow heavier particles (like protons and other hadrons).

While the emission of light occurs in different ways, both the detectors we used had the light transformed into electric signal by a photomultiplier tube (PMT). PMTs is made by a photocathode which absorbs the light emitting electrons, and a series of dynodes at high voltage (1000V or more) that amplify the emission of electrons producing a measurable electric signal.

Fig.1 Photomultiplier



During the experiment we used two scintillators 1.1 cm thick and two lead glasses 8.9 cm thick disposed as shown in fig 2.

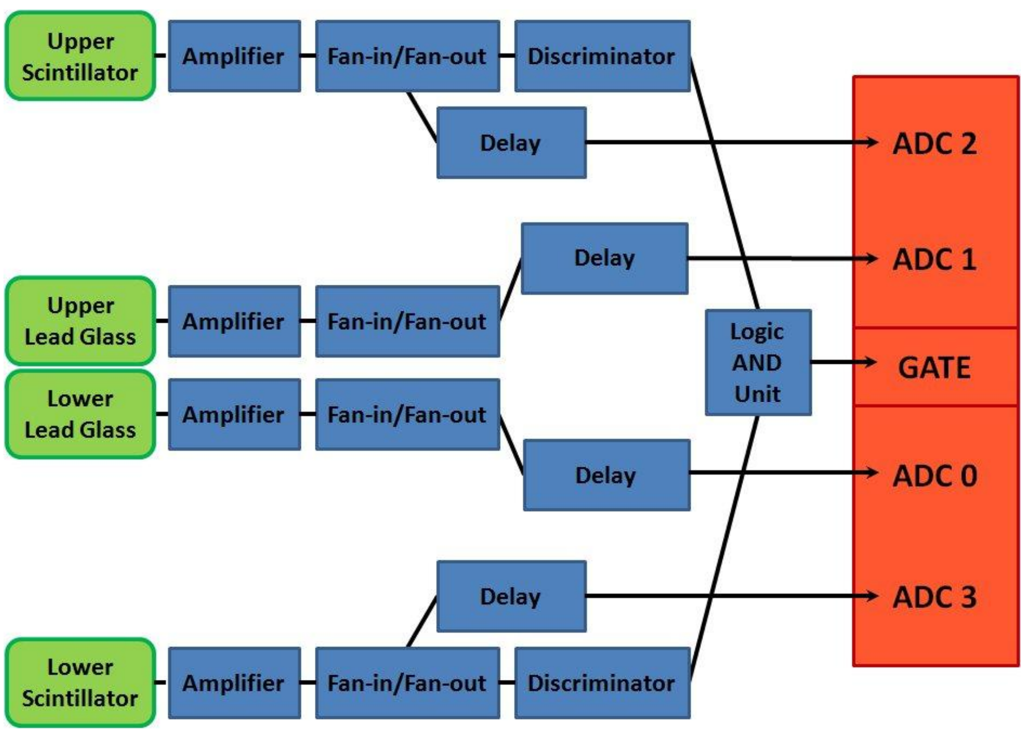
Chapter 3 : Acquisition system

The acquisition system is used to analyze and register signals out coming from the PMTs of the detectors. It is made up by the following modules:

1. Amplifier — It increases the amplitude of a signal.
2. Fan-in/Fan-out — it produces four equal output signals from the sum of up to four input signals.
3. Discriminator — It receives an analog impulse and gives an output signal of a fixed amplitude (800 mV) only if this overcomes the pre-established threshold.
4. Logic And Unit — It gives an output signal when two or more input signals come at the same time.
5. Delay — It delays signals.
6. ADC — Analog-to-Digital-Converter encodes incoming signals into digital numbers, analyzing the charge; it needs a gate signal to enable the readout of the input signal.

The Fig.2 shows the scheme of the electronic chain that we built

Fig. 2- electronic scheme



The scintillators are amplified by a factor of 10 and sent to two different fan in/fan out (FI/FO) inputs. We made the gate of the ADC by sending one out of the two FI/FO of the scintillators to discriminators (upper scintillator threshold is 31 mV, lower scintillator one is 66 mV) and the out of these modules to the input of the logic And Unit.

We also sent a second output of the two FI/FO to the input of the ADC using a delay (upper scintillator: ADC channel 2 with a delay of 40 ns; lower scintillator: ADC channel 3 with a delay of 39 ns)

Lead glasses' signals are sent to the ADC inputs trough a similar chain. Upper and lower LGs are amplified respectively by a factor of 100 and 50, delayed by 0 ns and 6,5 ns and connected to ADC channel1 and to ADC channel 0.

The ADC input signals are acquired by a pc program which uses "LabView" libraries and creates data files. Then these are analyzed using Paw.

Chapter 4 : Voltage curves

Each ADC input is characterized by the so-called “pedestal”: the value that the channel outputs when there are no inputs. We measured these values by doing an acquisition without any input signal. You can see the results in the second column of the table 1. Then we started measuring the voltage curve of each PMT which gives the peak position as a function of the H.V. We made three runs at different voltages as reported in table 1. For each run and each PMT we filled a histogram shown in figure 2, 3, 4. The histograms have been fitted by superimposing to a Gaussian for the peak a first or second order polynomial for the background.

Figure 2 – Results of run 5

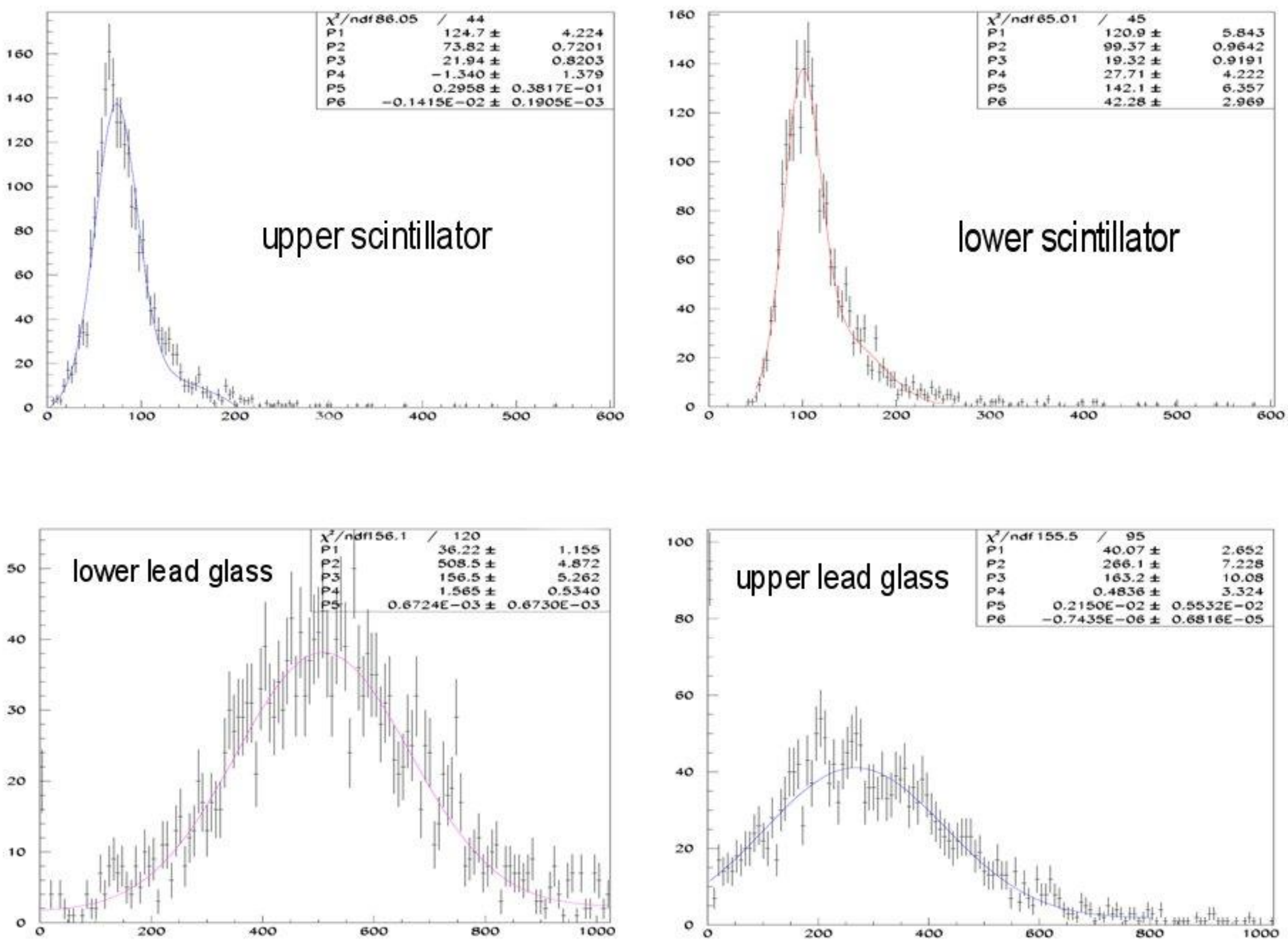


Figure 3 – Results of run 6

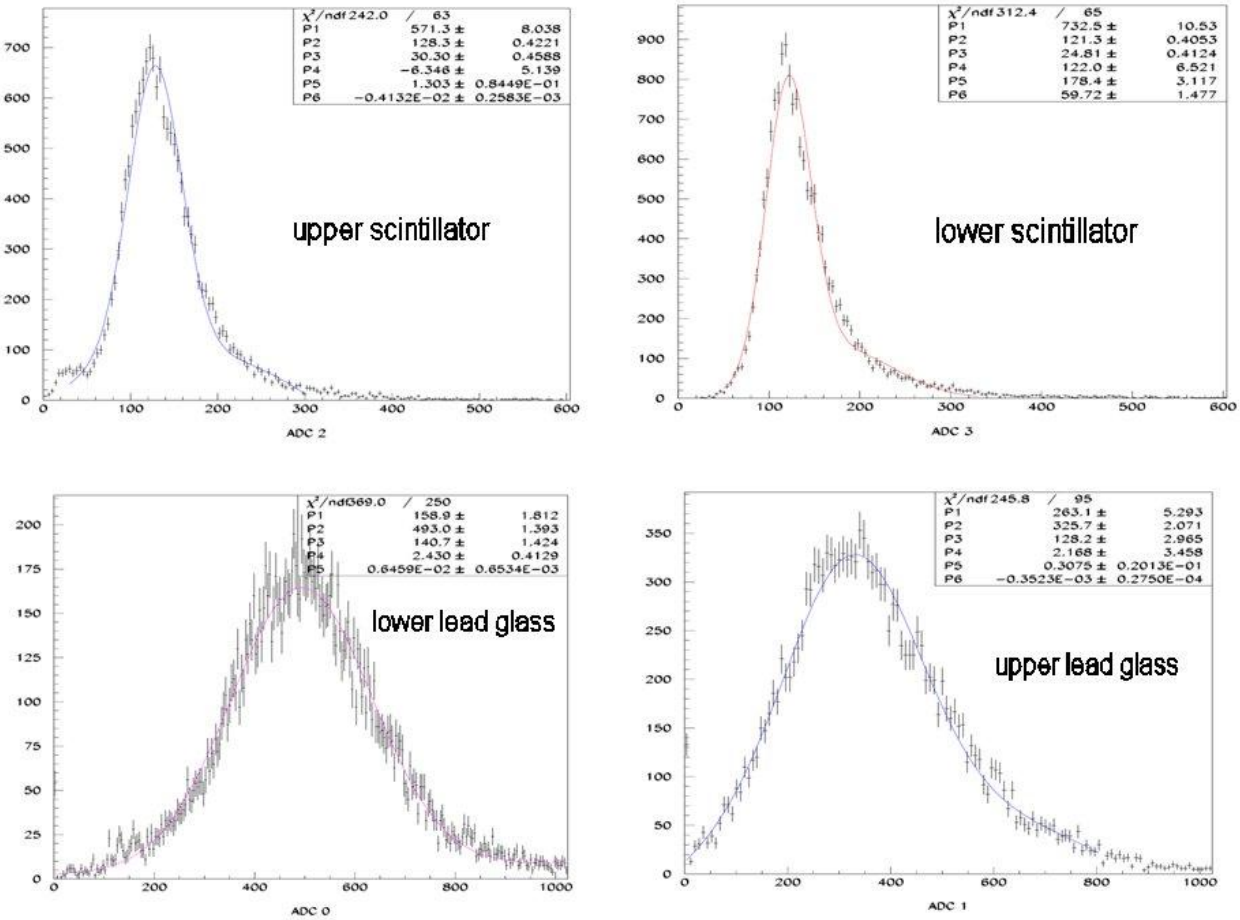
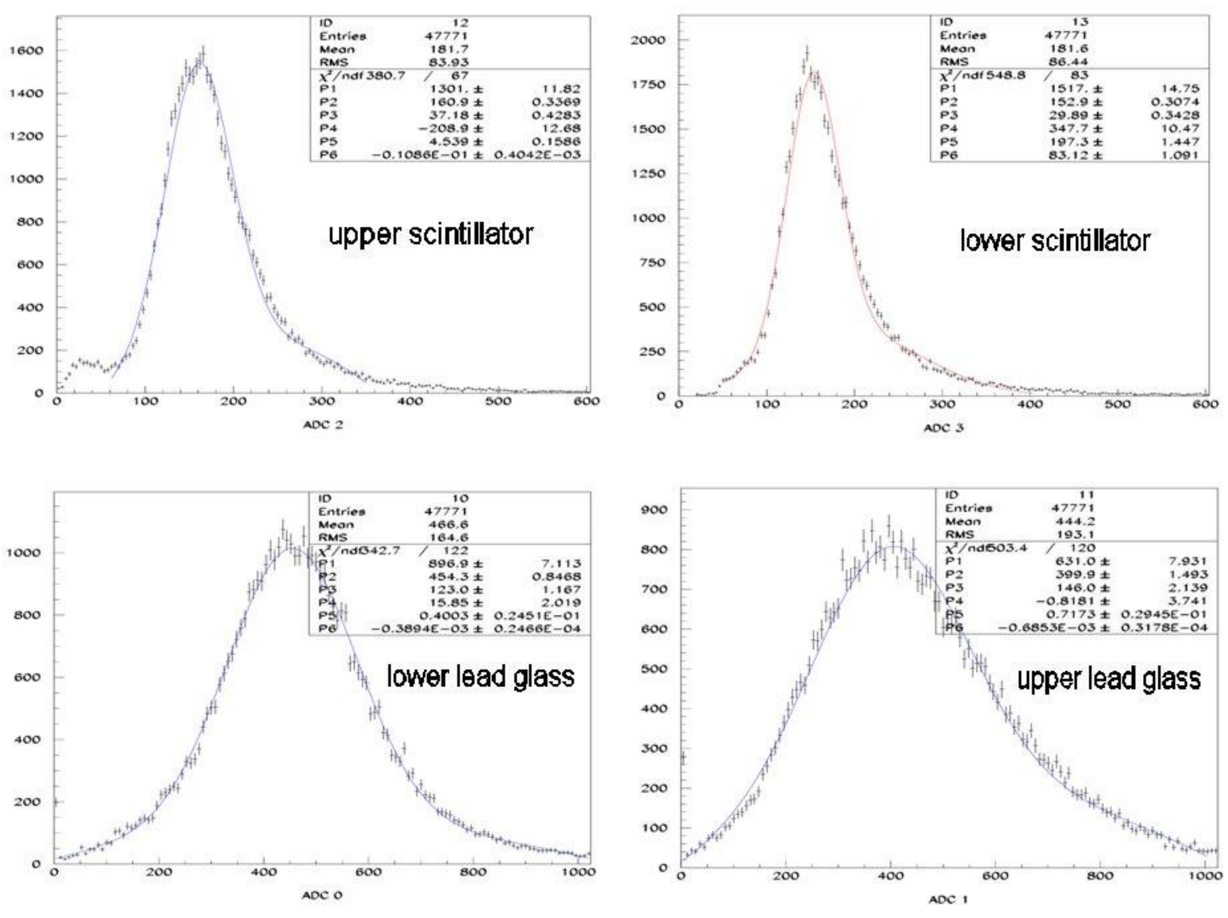
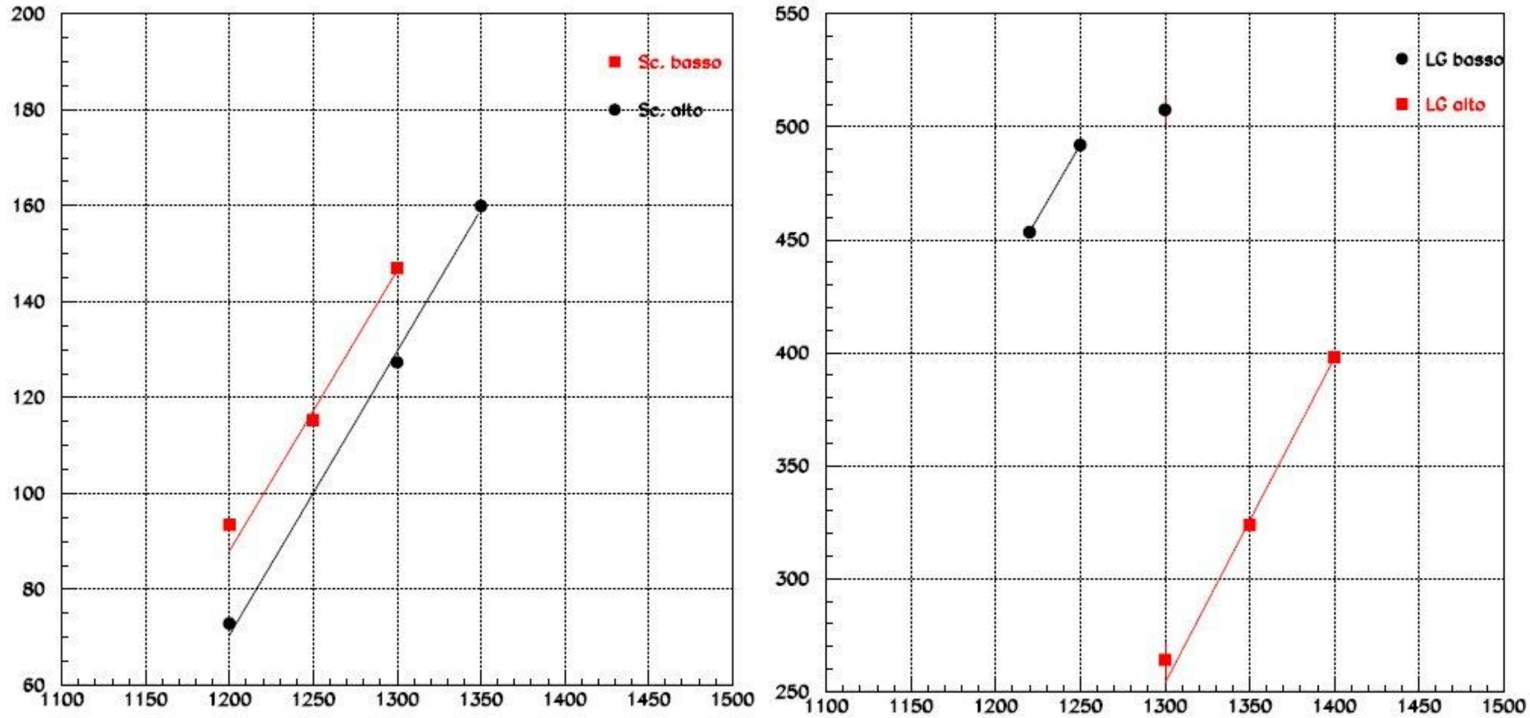


Figure 4 – Results of run 7



After subtracting pedestals from the peaks we made the voltage curves in fig. 5

Fig 5 voltage curves



From these curves we calculated the voltages necessary in order to have lead glasses peaks at around 400 and scintillators peaks at around 140. These voltages are:

Upper Scintillator 1316 V
Upper lead glass 1371 V
Lower lead glass 1198 V
Lower Scintillator 1287 V

We then made a new run with these new voltages and fig, 6 shows that we obtained the decided peak positions within less than 10% approximation.

Figure 6 – run 10

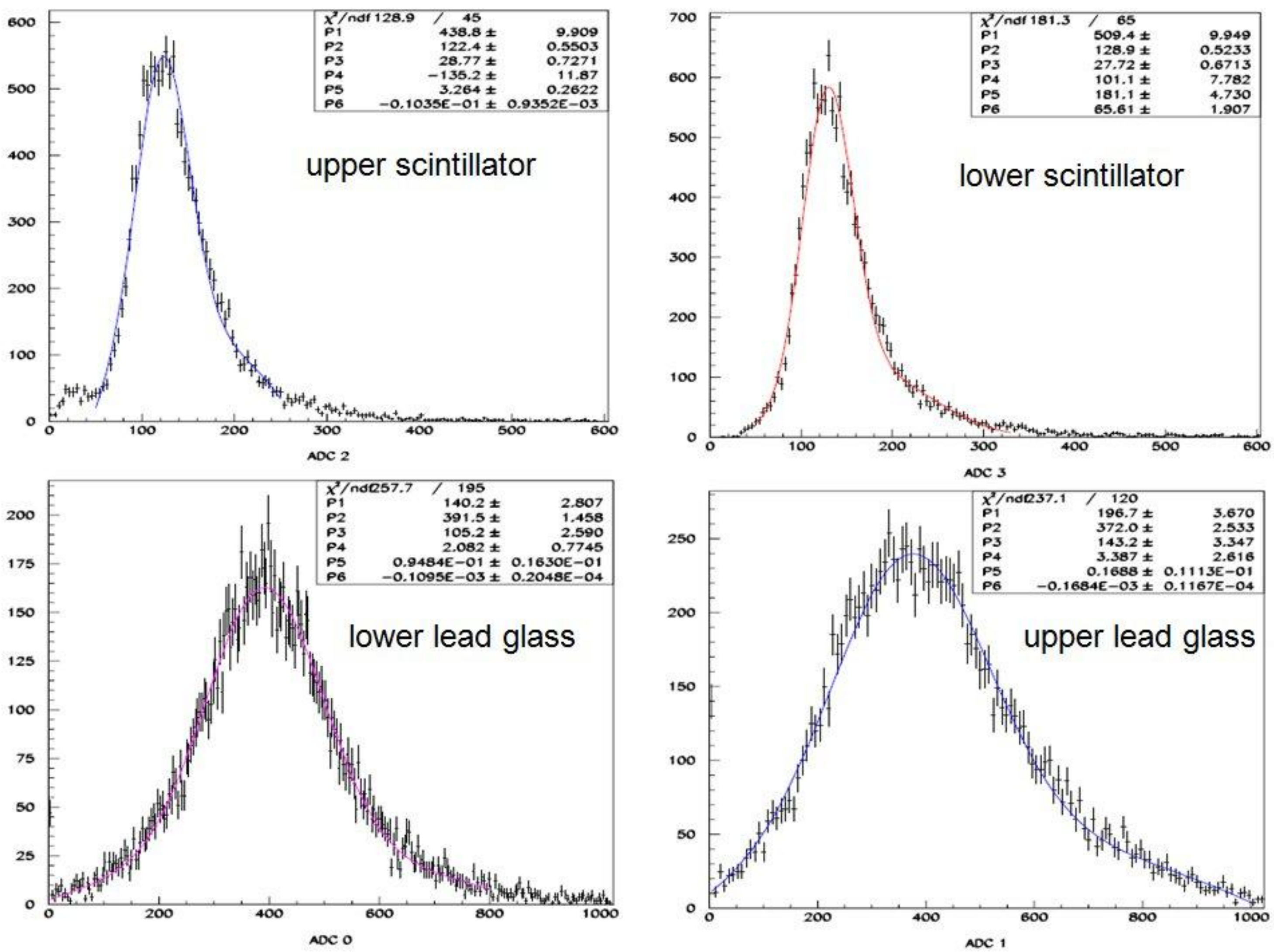


Table 1 – Results of runs at different voltages

ADC	Pedestal	Run	Voltage	Peak
0	1	5	1220	454.3 ± 0.8
		6	1250	493.0 ± 1.4
		7	1300	508.5 ± 4.9
1	2	5	1300	266.1 ± 7.2
		6	1350	325.7 ± 2.1
		7	1400	399.9 ± 1.5
2	1	5	1200	73.82 ± 0.72
		6	1300	128.3 ± 0.4
		7	1350	160.9 ± 0.3
3	6	5	1200	99.37 ± 0.97
		6	1250	121.3 ± 0.4
		7	1300	152.9 ± 0.3

Chapter 5 : calibration curve

A calibration curve is a graph which determines the relation between the energy lost by particles and the peak positions measured by ADC. To calculate these curves for our detectors we added two inputs on the ADC out of the previous 4 ones: ADC4 receives the sum of both scintillator signals, while ADC5 receives the sum of both lead glass signals.

Then we made another run (run 11) with these six channels, establishing the peaks of our new acquisitions (fig. 7). Due to the limited ADC range (0-1024) we lost almost half of the peak of the sum of the two lead glasses.

We calculated the energy lost by muons passing through the detectors using fixed tables taken from “Physics Letters B”, vol. 667 (2008).

A muon with an average energy of 4GeV loses 2 MeV/cm through the Scintillator and 5.8 MeV/cm through the lead glass. With these numbers, and knowing the thickness of the detectors we obtained the calibration curves showed in fig. 8. We can see that the scintillator response is perfectly linear, as it has to be, while that of the LGs is not linear because of the problem in measuring the sum of the two modules.

Fig.7 - run 11

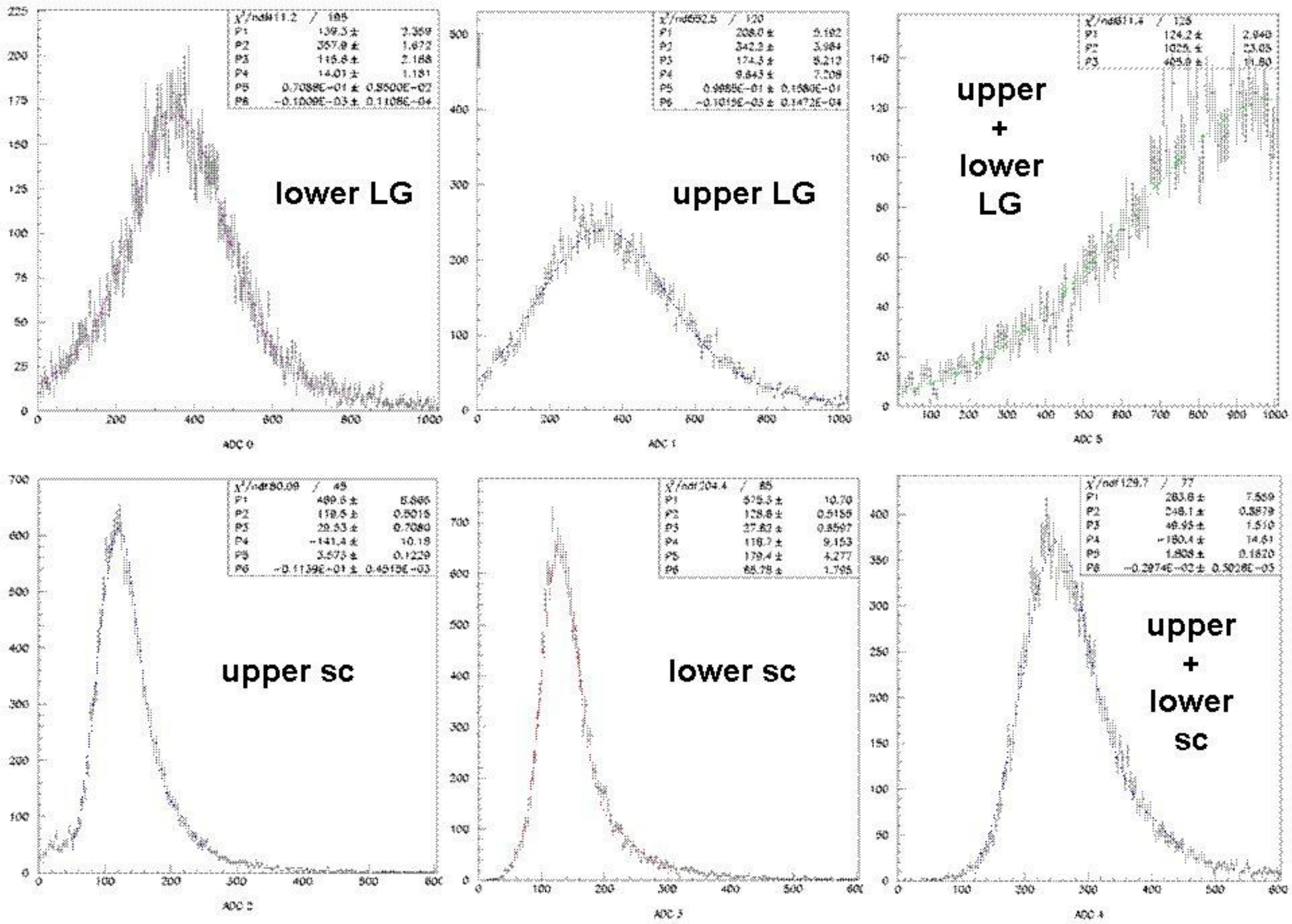


Fig.8 – calibration curves