HCAL-J COSMIC RAY TEST AT JLAB

18 June - 26 July 2018

Introduction

During the summer 2018, in particular in the range time 18 June - 26 July 2018, I started, in collaboration with Catania and JLab people, the cosmic rays test of some HCAL-J modules; the purpose of our test was the assessment of the performances of HCAL-J and its single components, before starting to use it for the experiments in Hall A at JLab.

We particularly studied a 4x4 matrix of modules and respective PMTs, configured as shown in Figure 1; so we tested 16 HCAL-J complete modules, using four trigger paddles (called BS11, BS12, BS07, BS14) placed on the top of the first subassembly.

Totally, we used 24 signal long cables and 24 HV short cables (8 for the 4 paddles on the top of the frame and 16 for the 16 modules of HCAL-J; for the cable connections see the ppt file: “hcal cosmic ray map”).

Module 0	Module 1	Module 2	Module 3
Module 4	Module 5	Module 6	Module 7
Module 8	Module 9	Module 10	Module 11
Module 12	Module 13	Module 14	Module 15

Figure 1. 4X4 matrix of modules and respective PMTs that we chose to start the cosmic rays test.

1. HV System Program

At the beginning we put on the HV for each HCAL-J module and we checked the value of HV that gave us a current value about 600 - 615 μA. This operation was useful to verify if the all the modules, and in particular the PMT’s was working good.

We found the values written in table 1:

HCALn°bars	HV (Volt)	Current (μA)	HV System Ch. Name
HCAL0 Ch.9	-1400	-613.7	L11.8
HCAL1 Ch.10	-1380	-604.7	L11.9
HCAL2 Ch.11	-1380	-606.5	L11.10
HCAL3 Ch.12	-1380	-609.0	L11.11
HCAL4 Ch.13	-1400	-611.6	L10.0
HCAL5 Ch.14	-1380	-606.7	L10.1
HCAL6 Ch.15	-1390	-607.6	L10.2
HCAL7 Ch.16	-1390	-611.3	L10.3
HCAL8 Ch.17	-1380	-607.2	L10.4
HCAL9 Ch.18	-1380	-606.1	L10.5
HCAL10 Ch.19	-1390	-607.6	L10.6
HCAL11 Ch.20	-1380	-605.8	L10.7
HCAL12 Ch.21	-1390	-610.3	L10.8
HCAL13 Ch.22	-1390	-611.2	L10.9
HCAL14 Ch.23	-1380	-609.7	L10.10
HCAL15 Ch.24	-1380	-607.6	L10.11

Table 1.

(P.S the first 8 channels are occupied by the paddles)

2. Stability of PMT's

During the tests we evaluated also the operation of each used module and PMT; we set the value of HV for each phototube in order to have the same mean amplitude and studied the stability of the phototubes by repeating the measurements with the same HV.

Ch.	HV	Ch.	HV
0	1349	8	1341
1	1337	9	1337
2	1305	10	1314
3	1397	11	1340
4	1316	12	1405
5	1301	13	1287
6	1330	14	1297
7	1280	15	1401

Table 2. HV value for each PMT

3. ADC Spectrum with vertical cuts

We analyzed the response of each ADC channel: as an example we show the typical spectra for the modules 5 and 9, when imposing the quadruple coincidence for the vertical path (see Figure 2) identified by the modules 1, 5, 9 and 13.

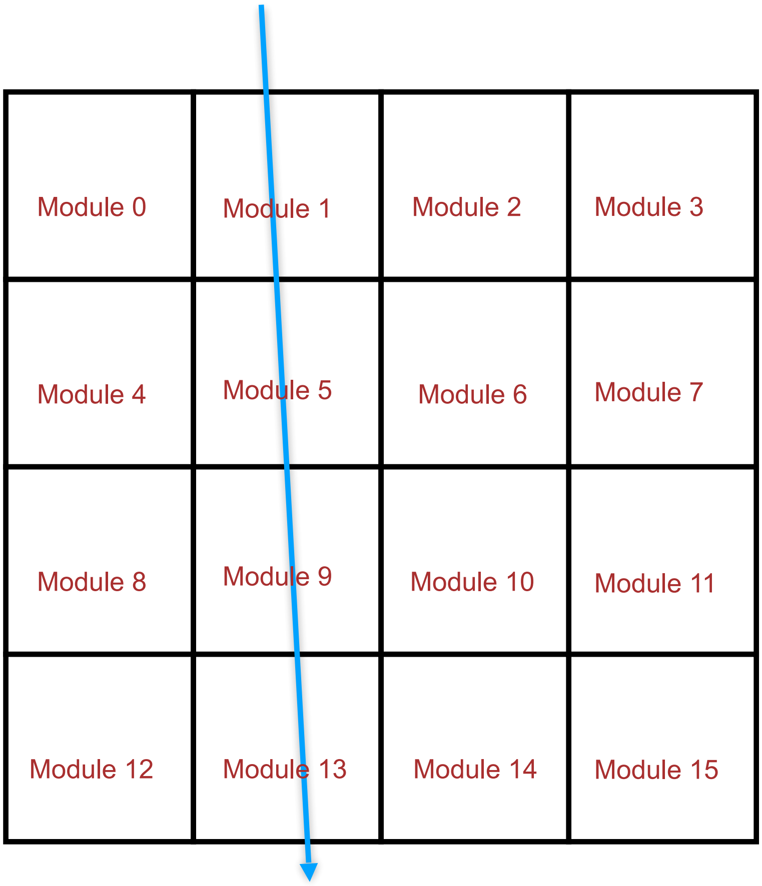


Figure 2. Example of vertical path.

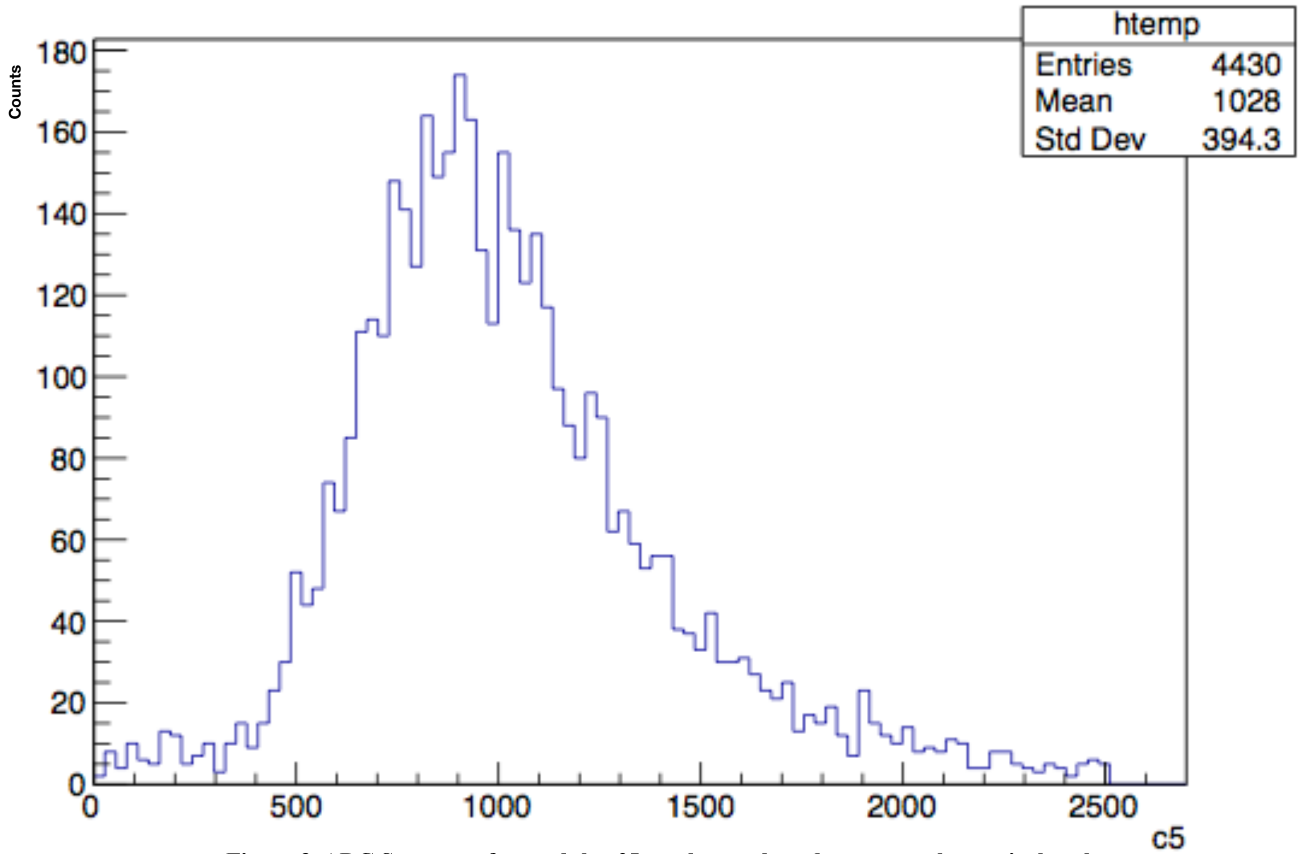


Figure 3. ADC Spectrum for module n°5; we have selected events on the vertical path (1, 5, 9, 13).

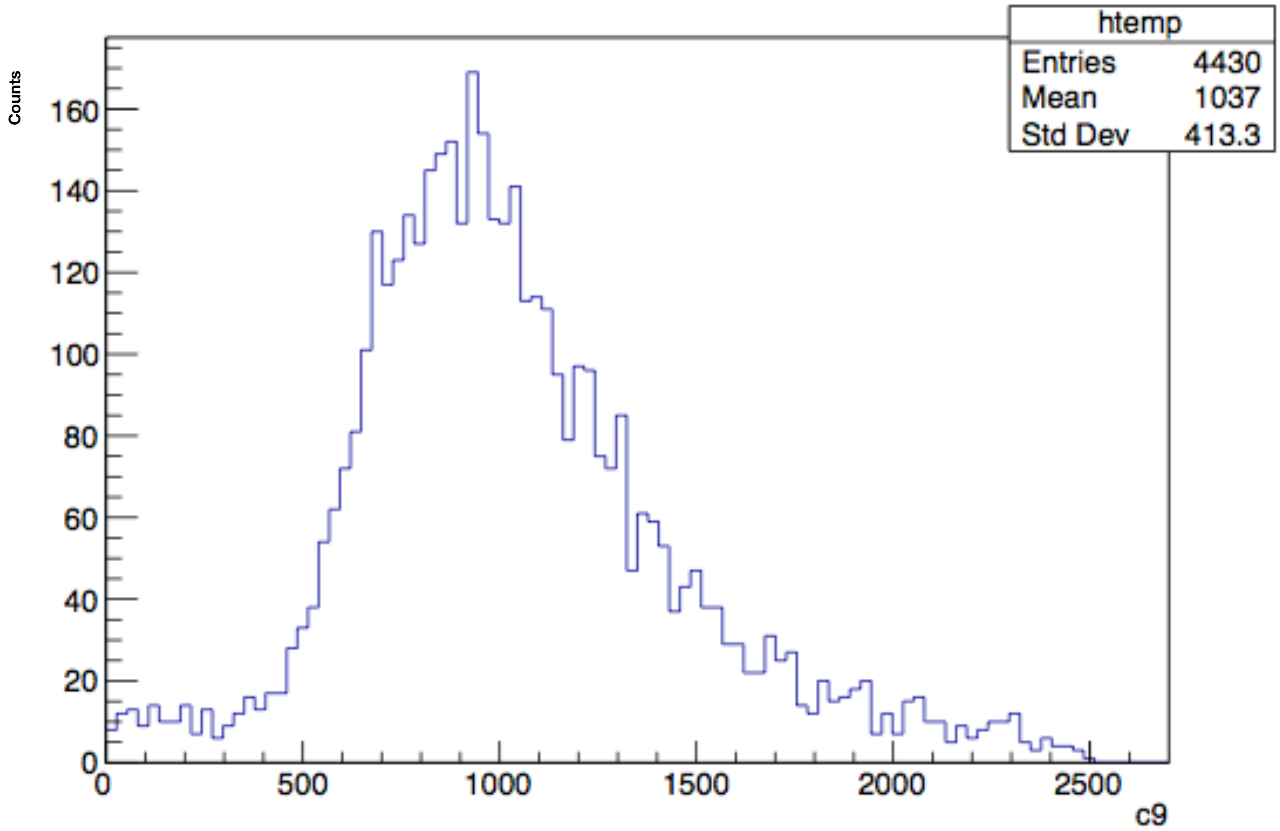


Figure 4. ADC Spectrum for module n°9; we have selected events on the vertical path.

4. Avg. Amplitude vs. HV study

We studied also the gain of the PMT's when changing the value of the HV; we found the following results:

HV	A_1	A_2	μ	σ
1151	89 ± 3	85 ± 4	87	2,82
1201	208 ± 5	195 ± 4	201	8,5
1251	450 ± 8	420 ± 10	435	21,2
1301	953 ± 16	984 ± 17	968	6,36
1351	1704 ± 26	1779 ± 27	1741	53,7
1401	3166 ± 56	3202 ± 46	3184	25,5
1451	5421 ± 96	5365 ± 106	5393	39,6
1501	8772 ± 152	8962 ± 135	8867	134,3

Table 3. Gain for each PMT evaluated changing the HV value.

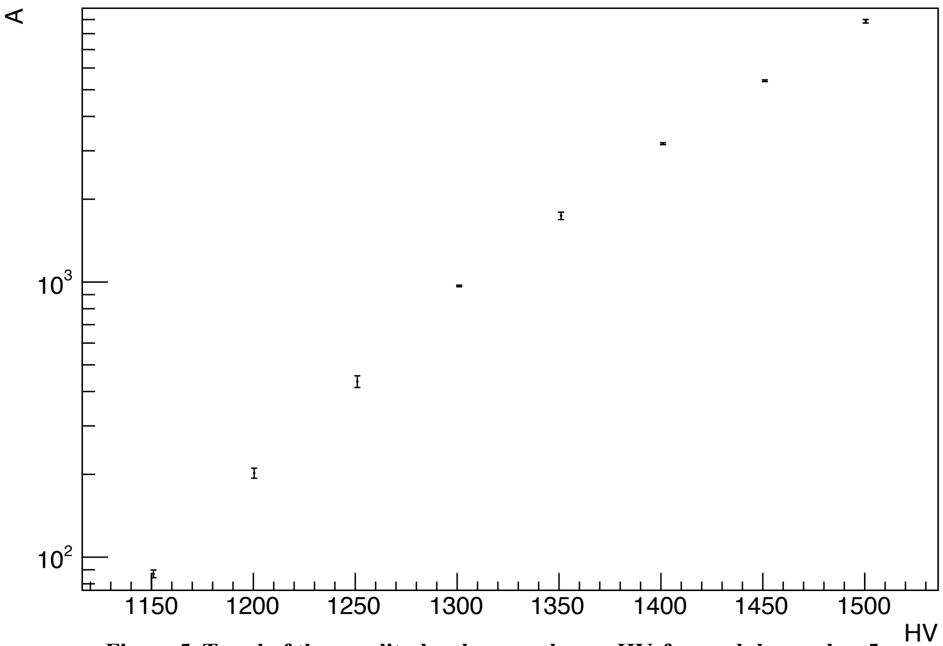


Figure 5. Trend of the amplitude when we change HV, for module number 5.

5. Time resolution

Before to start the time resolution analysis , I studied, using low and high cuts, the window where there is the signal; I found that the signal is present in the range 30-45 bins so I reduced the study in this window. Following an example of time spectrum:

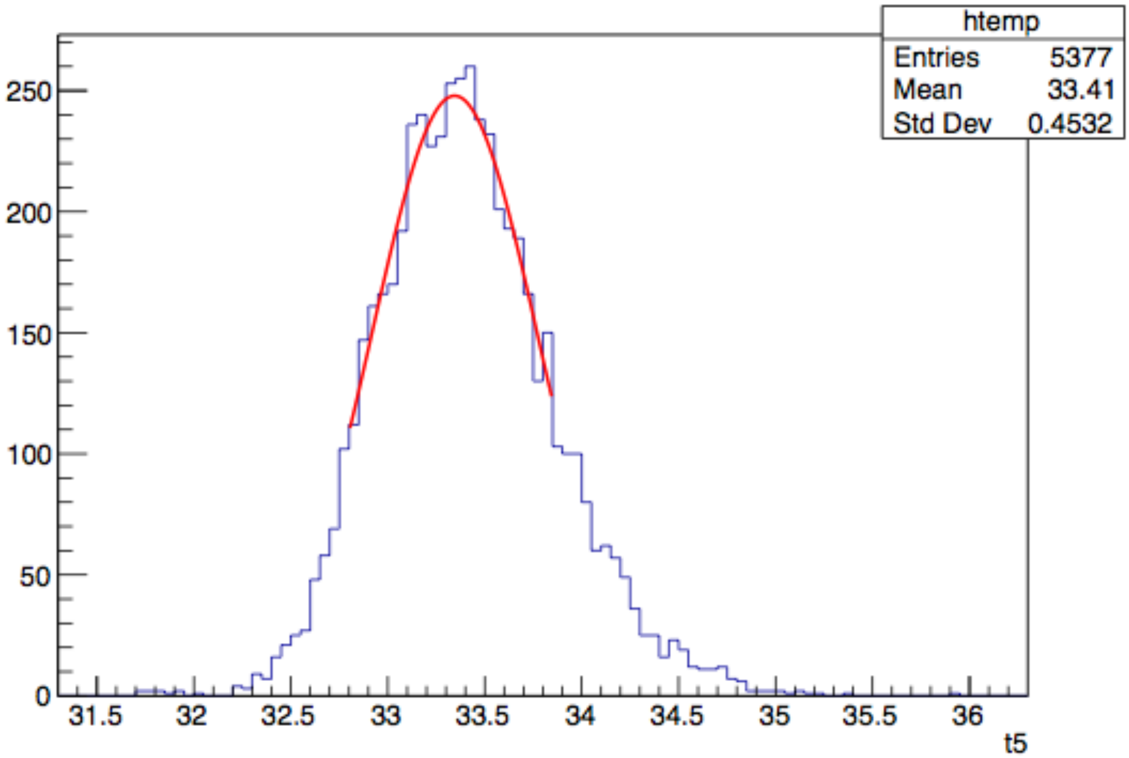
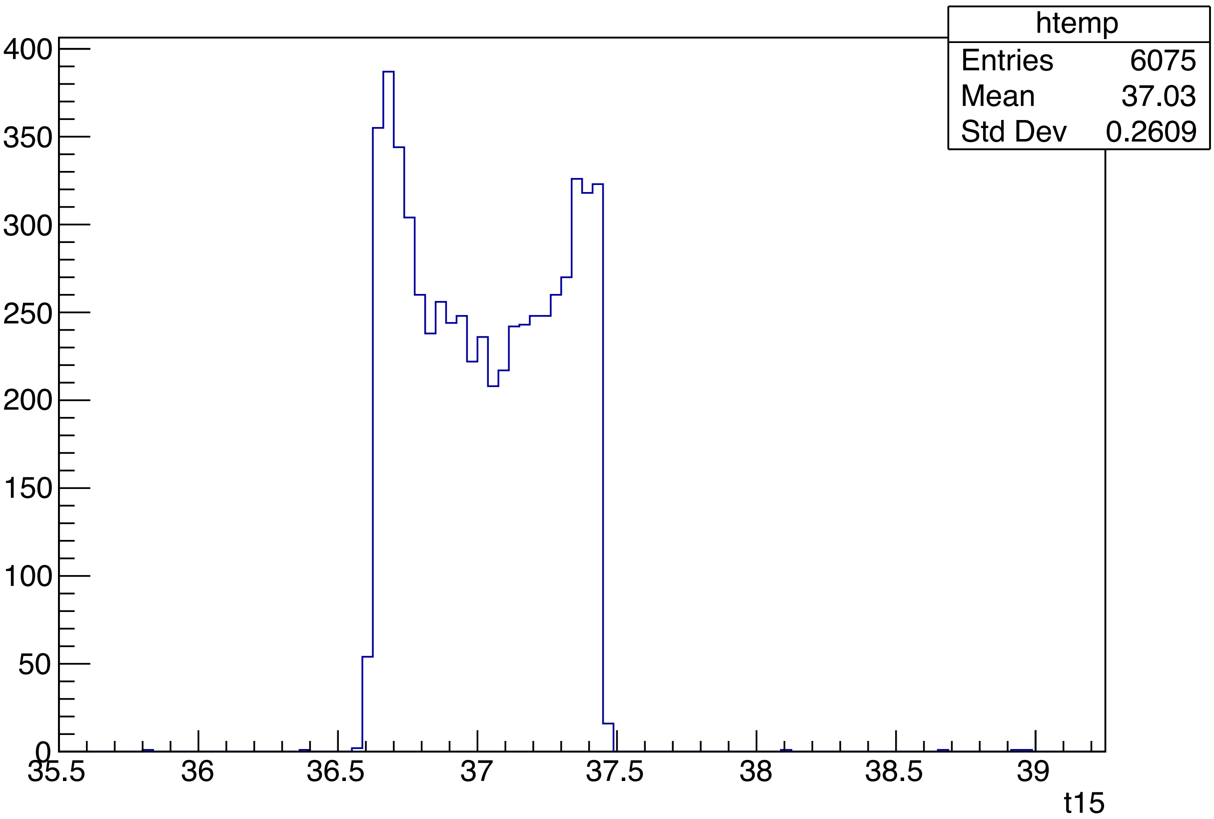


Figure 6. T5 (time peak in channel number 5) with vertical track

So we can estimate for HCAL-J, with cosmic-rays, a time resolution about 1.8 ns from 15 cm track in module: if we subtract the jitter value (figure 7.) we can calculate a time resolution about 1.48 ns.



6. Photoelectron peak

The photoelectron peak is useful to calibrate the PMTs and to evaluate its gain; in particular with the photoelectron peak spectrum (that show us the charge distribution outgoing from the PMT when in the first dynode we have only one electron) we can value the absolute gain of the PMT. For this analysis I used two different runs: number 200 and number 202 and I studied only the PMT in the channel number 5 (PMT-190206).

Run 200

Channel 5 → 1501 Volt

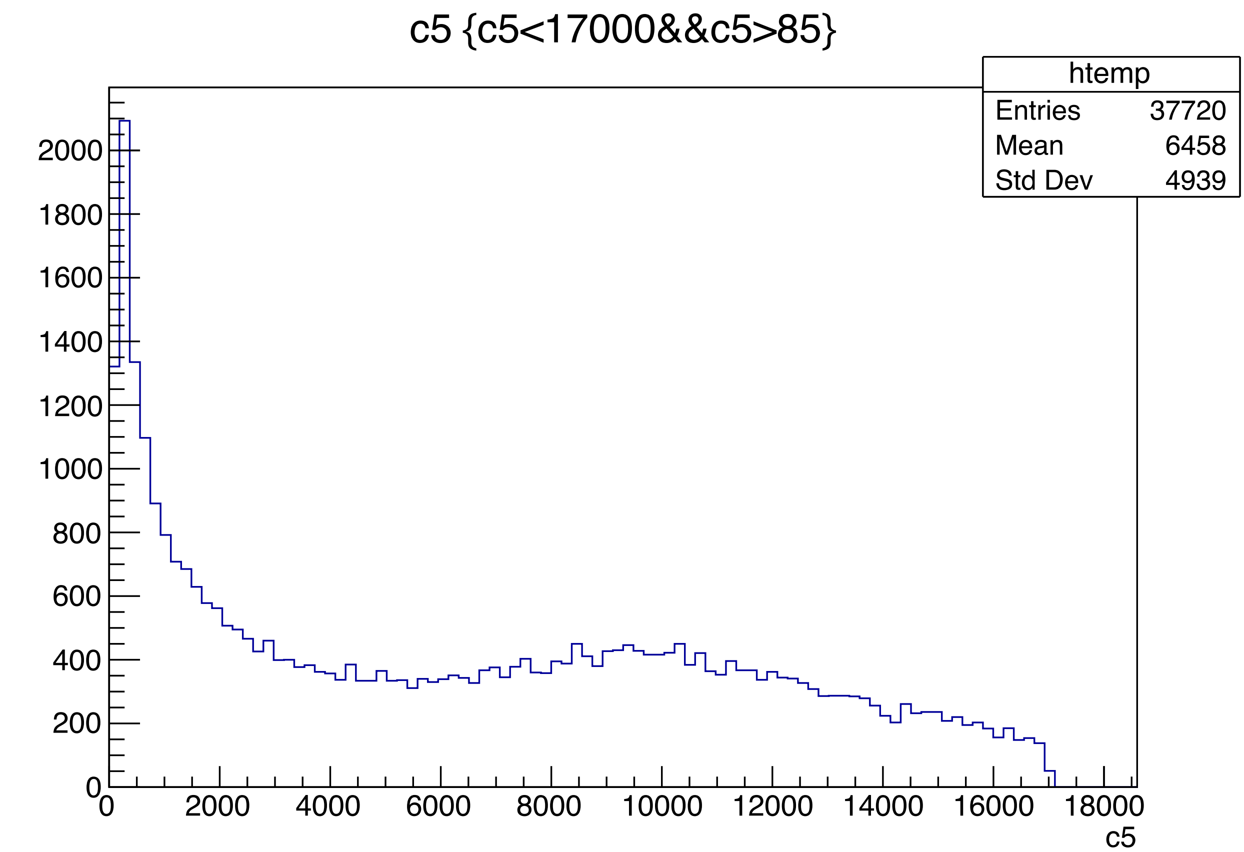


Figure 1: Spectrum of channel 5 in which we can see the 2 peaks together: single photoelectron peak and signal peak.

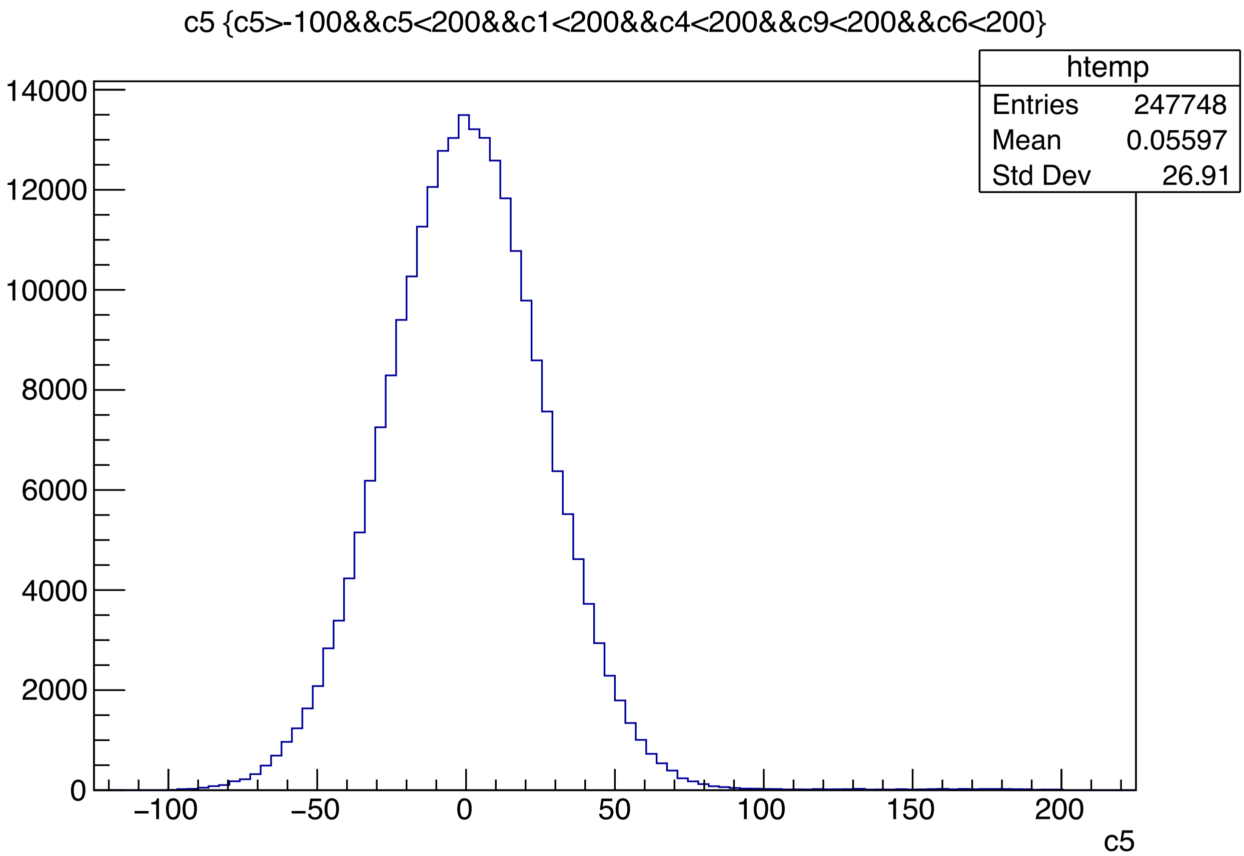


Figure 2: Pedestal. Events when the particle did not pass through the module 5.

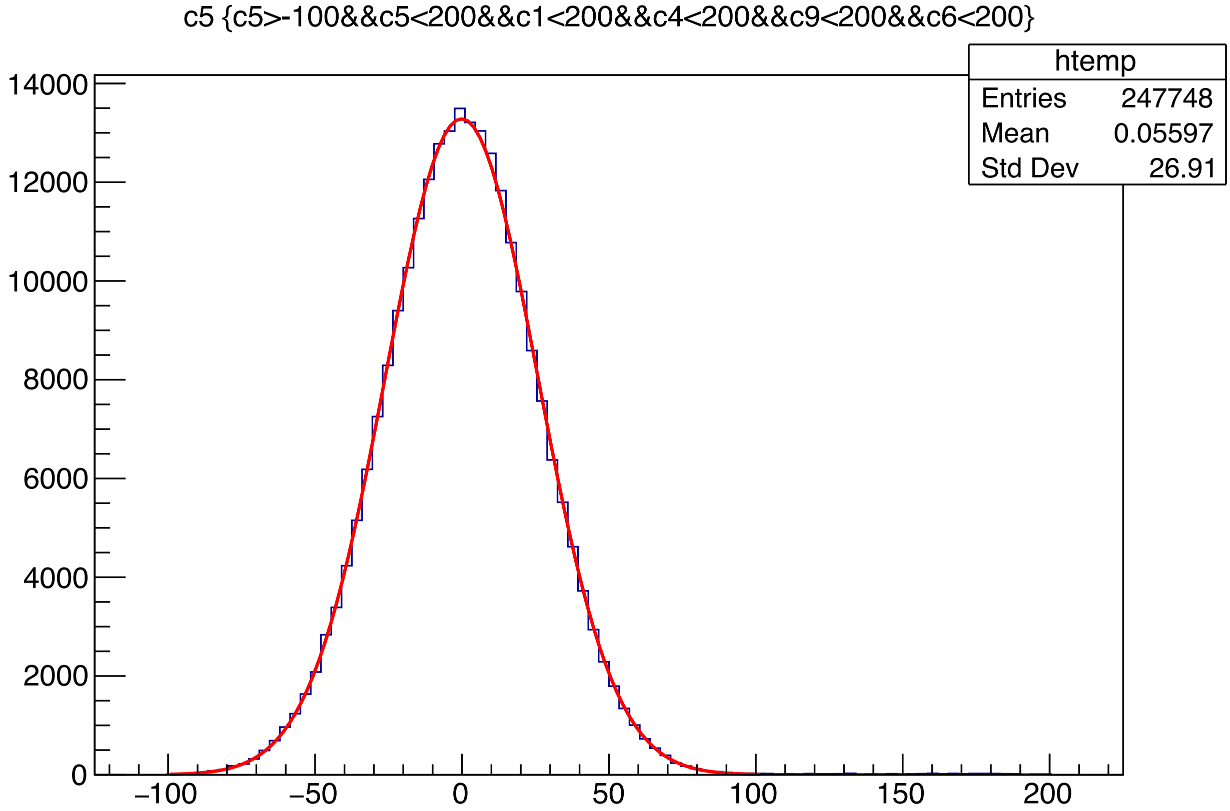


Figure 3: Gaussian Fit of the pedestal.

Fit parameters:

Mean: -0.157 ± 0.006

sigma: 25,89 ± 0.004

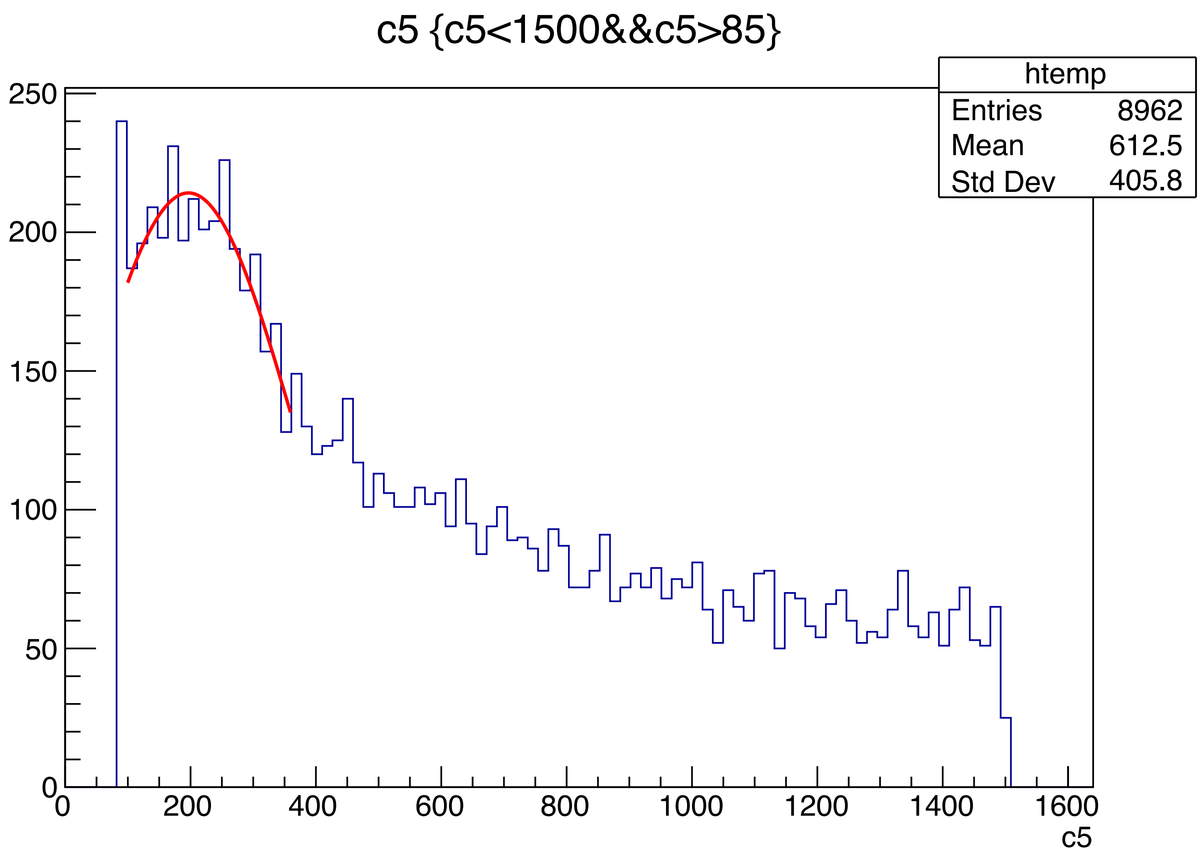


Figure 4: Spectrum of photoelectron peak in channel 5. The macro h_timeV.C should subtract the pedestal.

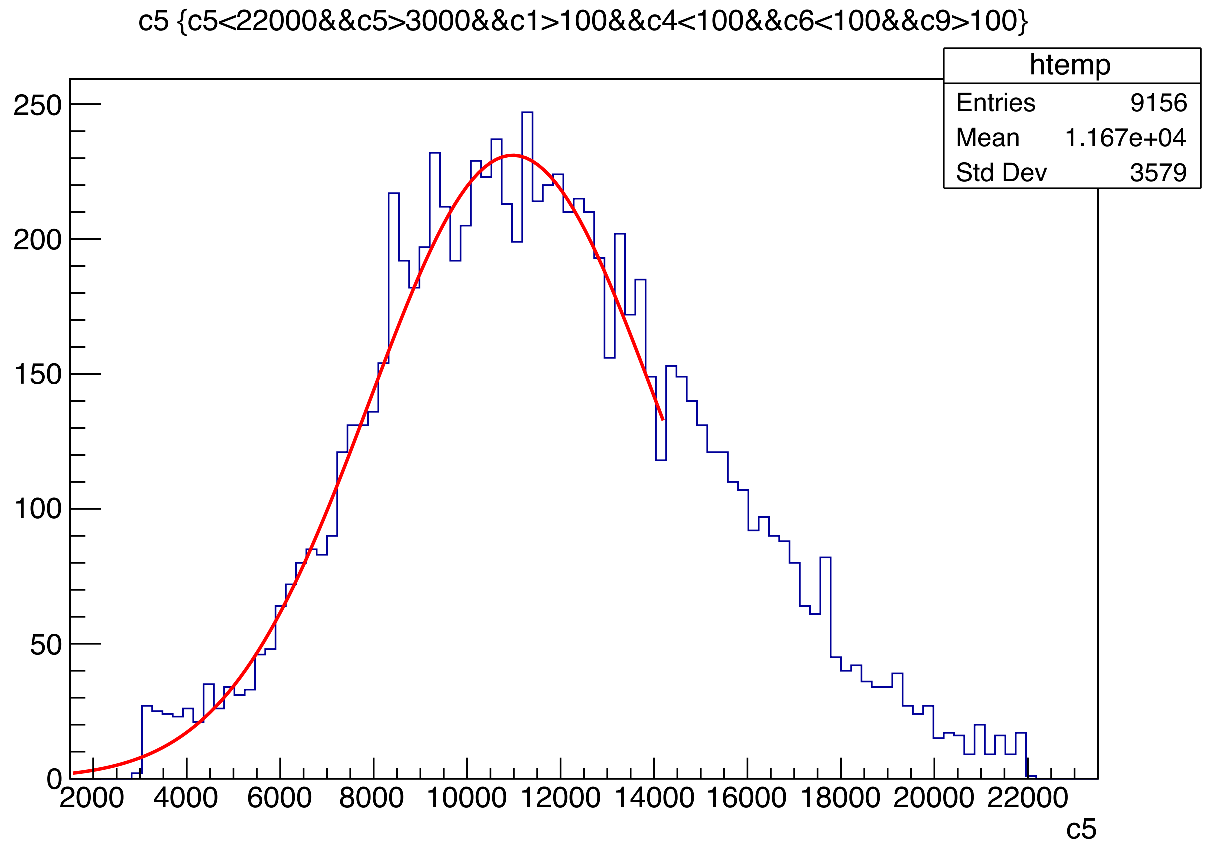


Figure 5: Spectrum of ADC signal peak for channel 5

The ADC channel of photoelectron peak is 196,7.

The ADC channel of the signal peak is 10976,2.

So the number of photoelectron in module number 5 is :

N= Q(signal)/Q(1phe) = 55,8.

Run 202

Channel 5 → 1601 Volt

I did the same analysis and I found : Q(signal)= 36795,4. Q(1phe)= 526

N= Q(signal)/Q(1phe) = 69,9.

APPENDIX A _ CODA Program

✦ Open a new terminal

msqld

✦ Open a new terminal

source coda_user_setup

startcoda

✦ Open a new terminal

ssh daq@intelsbshcal1

source coda_user_setup

source setup_clrlpc

./startroc2

✦ If you need to go in panel the configuration of the program:

Open a new terminal

ssh daq@intelsbshcal1

cd git/ti/test

cedit

✦ If you need to change the fADC window:

Open a new terminal

ssh daq@intelsbshcal1

cd git/ti/rol/fadc_list_sd.C. ——-> you can modify this file

make

APPENDIX B_HV System

✦ Open a new terminal

./hvc LOWER

P.S if you have problem use the README.

APPENDIX C_ List of the script code and ROOT analysis macros useful for the data analysis

analyzer replay_hcal_test.C\(n°run\) ——> to create the .root file of the run

root -l fadc_n°run.root ——> to open the run data

root -l /macros/h_dis1.C\(n°run\) ——> to open the run with event display

root -l /macros/h_timeV.C\(n°run\) ——> to analyze time and ADC channel (with pedestal subtraction)