

Update 22/01/2025

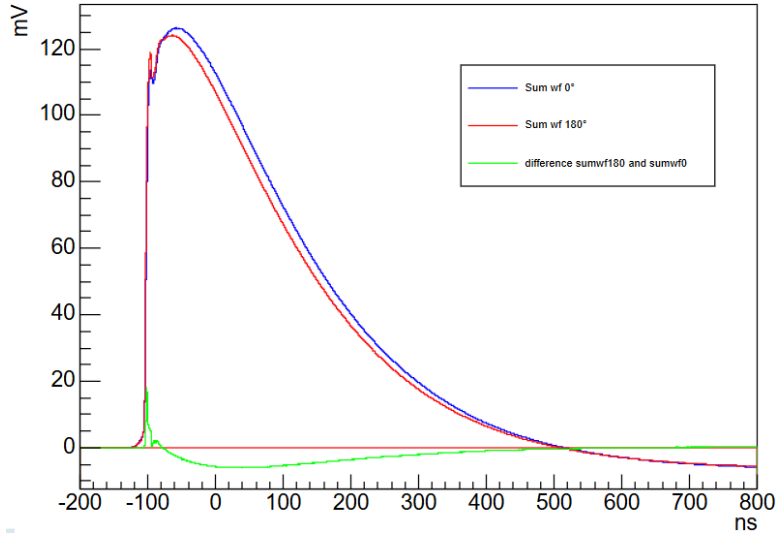
FCC Naples



Work of:
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di Fisica Nucleare Napoli)

Signal extraction Strategy of November-Dicember 2024 with our CAEN led driver

sum of tot wf BSO e+ 10GeV



In figure: sum of all waveforms at 0° and 180°:

→ proxy of what the “average” response looks like

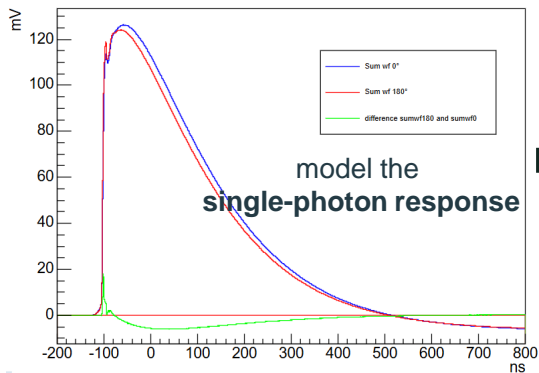
→ We want to model the shape as function of the **single photon shape** and characteristic scintillation time, with C photons considered prompt.

→ Once that is done **we fit the waveform and extract C and S components**

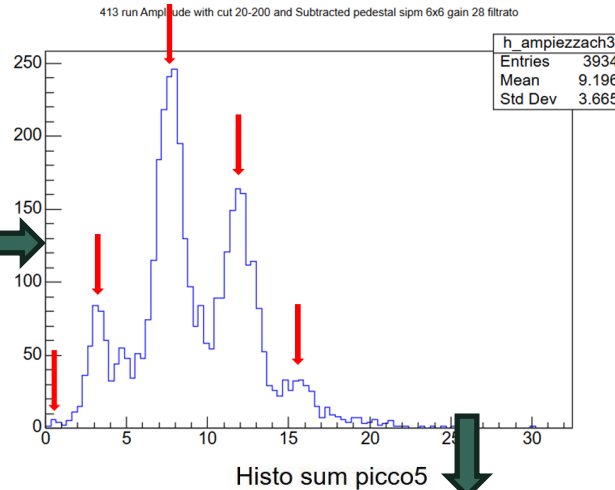
→ We need to model the **single-photon response!**

Signal extraction Strategy

sum of tot wf BSO e+ 10GeV

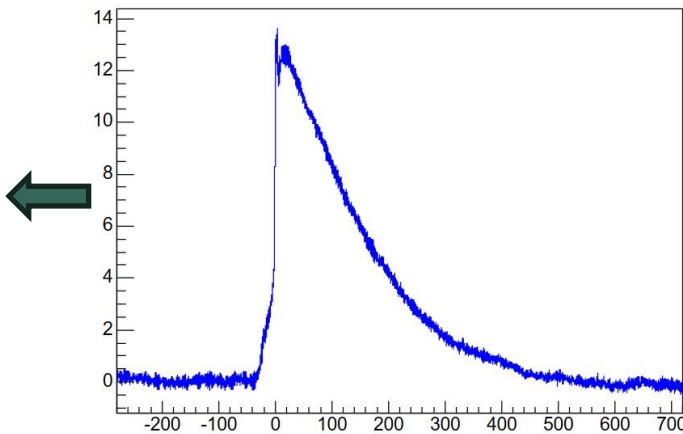
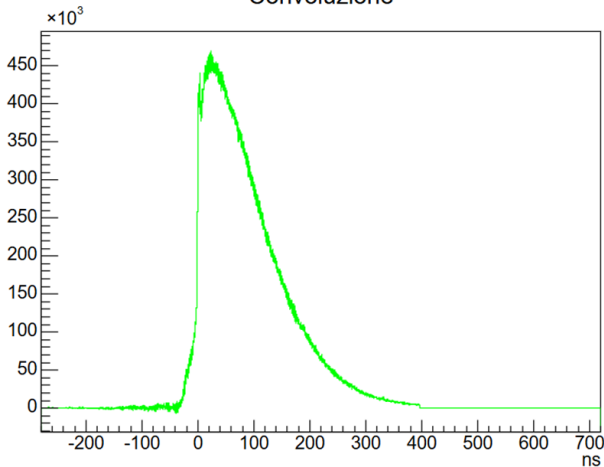


“Dark” measurement:
I have studied the amplitudes of the wf, there is the presence of 5 distinct peaks. Then what I did was to study the wf corresponding to these 5 peaks and I made the average wf for each peak



I used for the convolution the shape of the average wf for peak 5 of the dark measurements + an exponential that represent time of fall of BSO

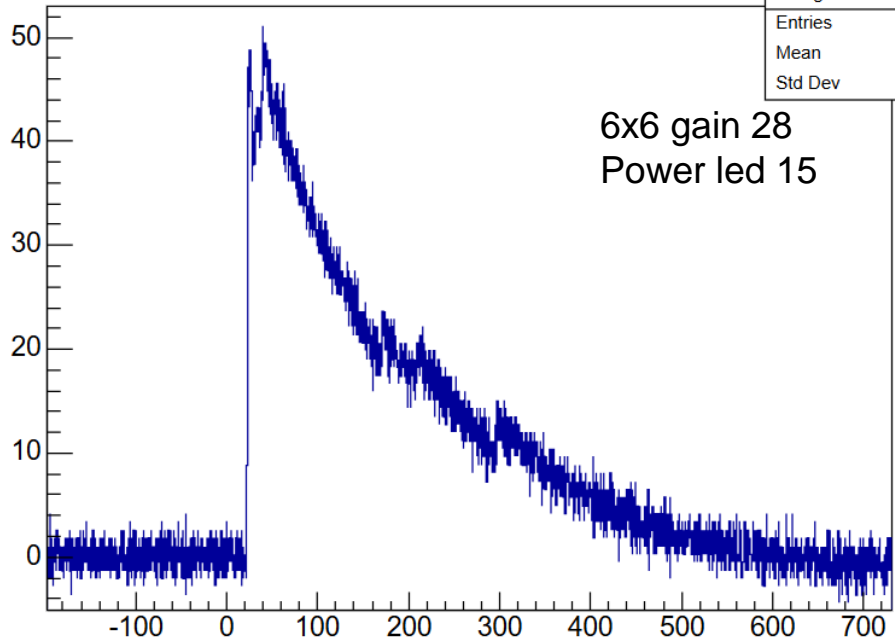
Convoluzione



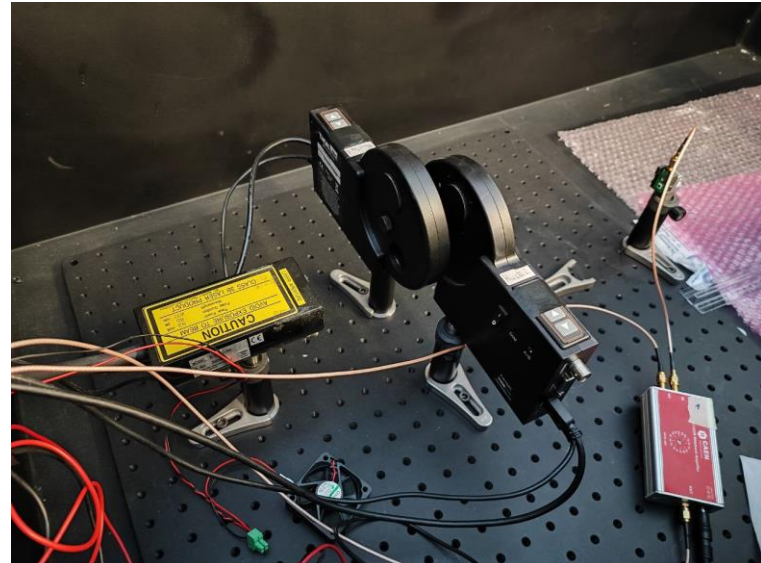
Now: Measurements with Picoseconds light pulser Guarino's LAB

- I made measurements with the PLP laser for the SiPM 6x6 at the gain configurations used at the test beam

istogramma run_420 event_6457



6x6 gain 28
Power led 15

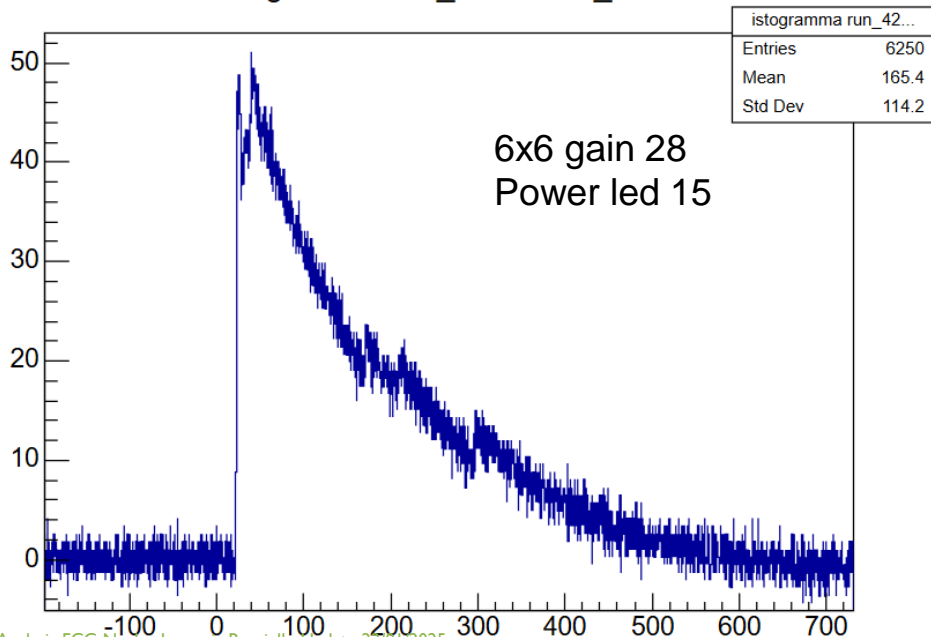


Measurements with Picoseconds light pulser

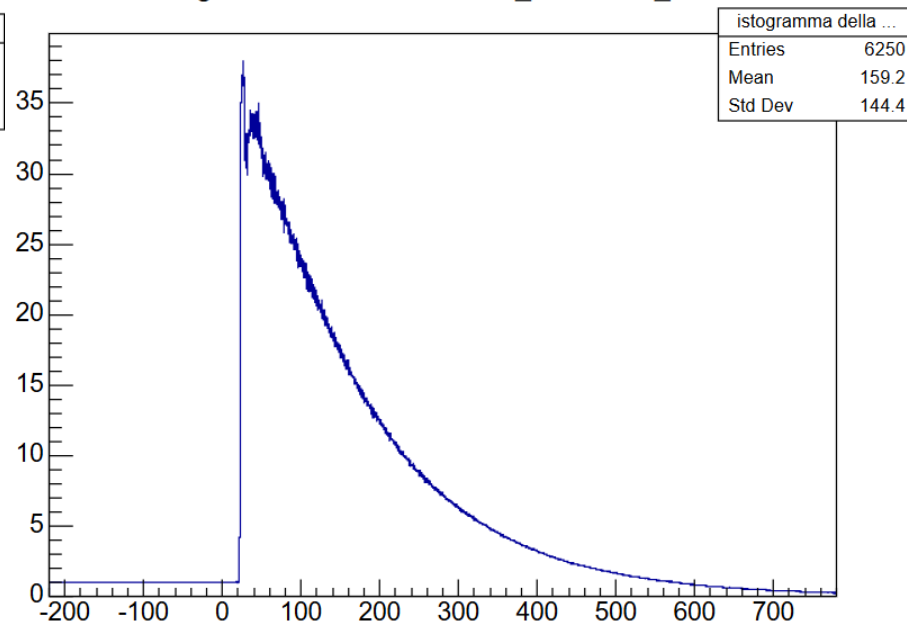
- I made measurements with the PLP laser for the SiPM 6x6 at the gain configurations used at the test beam
- Here we are in a range of ~ 9 photons

SiPM	Gain	Gain amplitude conversion	Method	$p_0 + error$	$p_1 + error$ [mV/n _{pe}]
6x6	28	25,12	A	0,4±0,1	3,46±0,02
6x6	28		B	15±1	3,49±0,006

istogramma run_420 event_6457



istogramma della somma run_420 event_6457

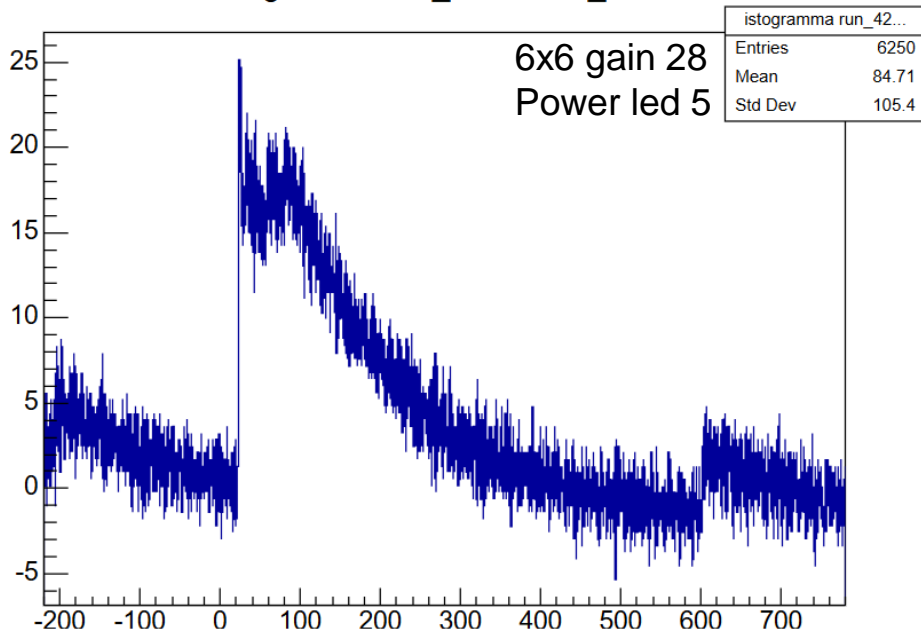


Measurements with Picoseconds light pulser

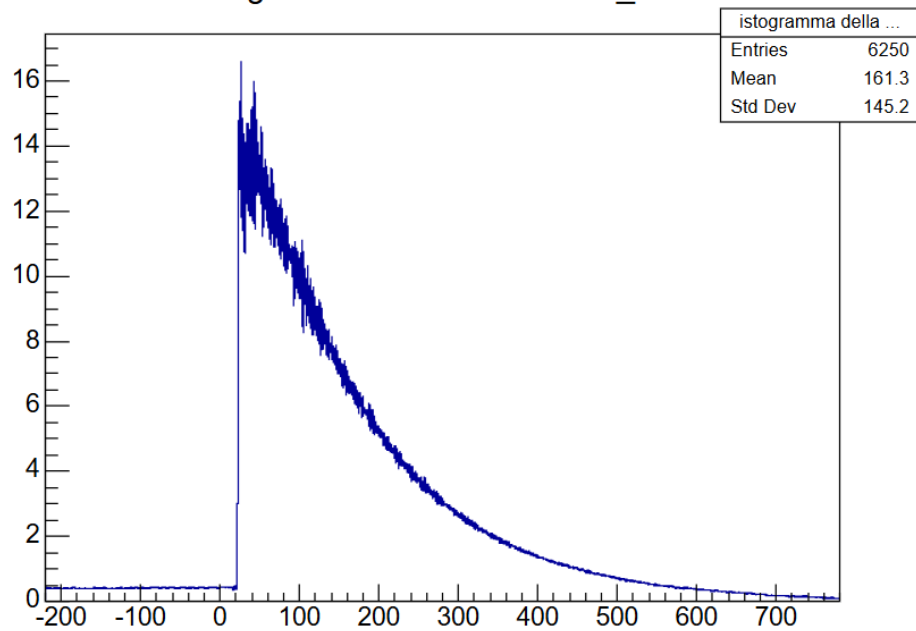
- I made measurements with this laser for the SiPM 6x6 at the gain configurations used at the test beam
- Here we are in a range of ~4 photons

SiPM	Gain	Gain amplitude conversion	Method	$p_0 + error$	$p_1 + error$ [mV/n _{pe}]
6x6	28	25,12	A	0,4±0,1	3,46±0,02
6x6	28		B	15±1	3,49±0,006

istogramma run_423 event_4579

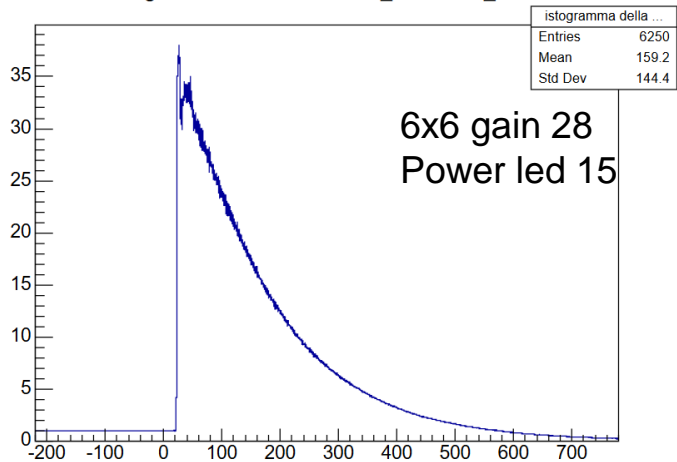


istogramma della somma run_423

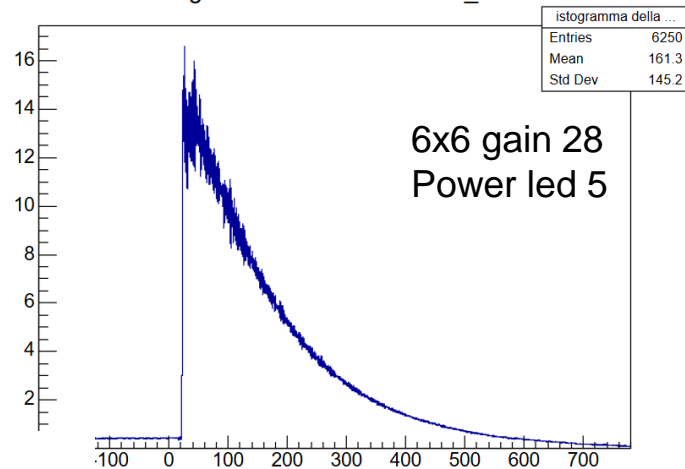


Preliminary Measurement Comparison

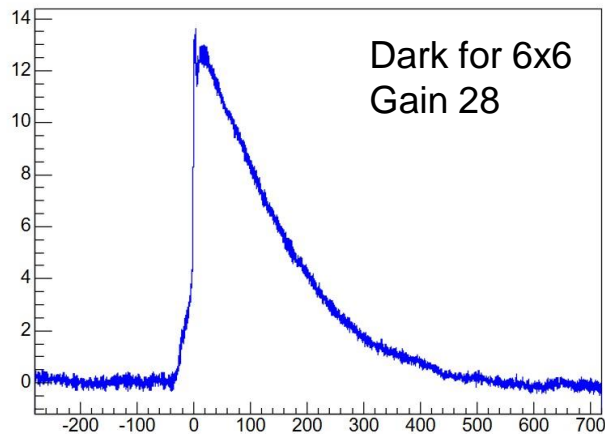
istogramma della somma run_420 event_6457



istogramma della somma run_423



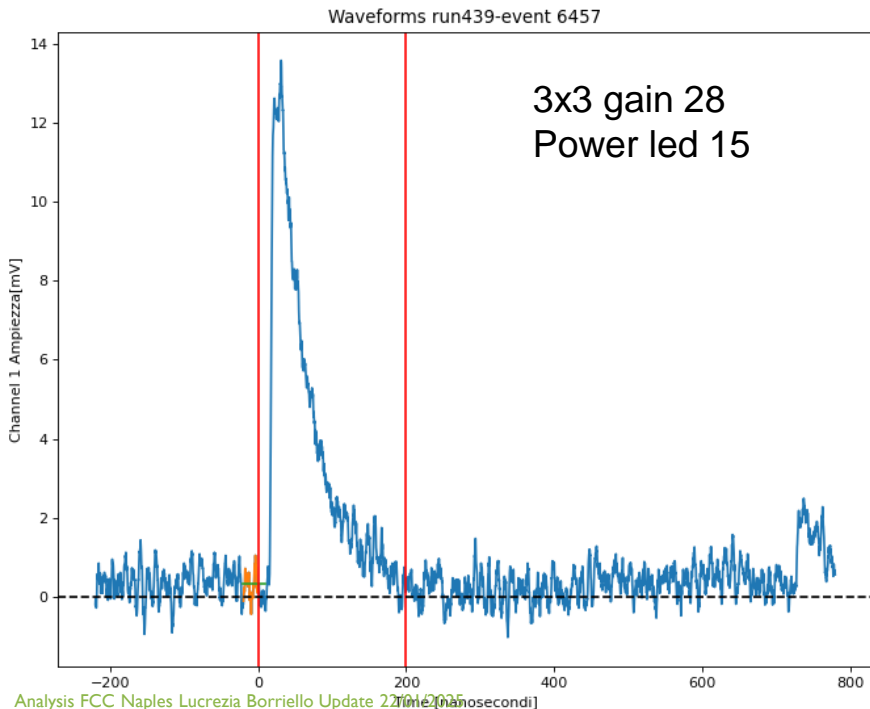
Histo sum picco5



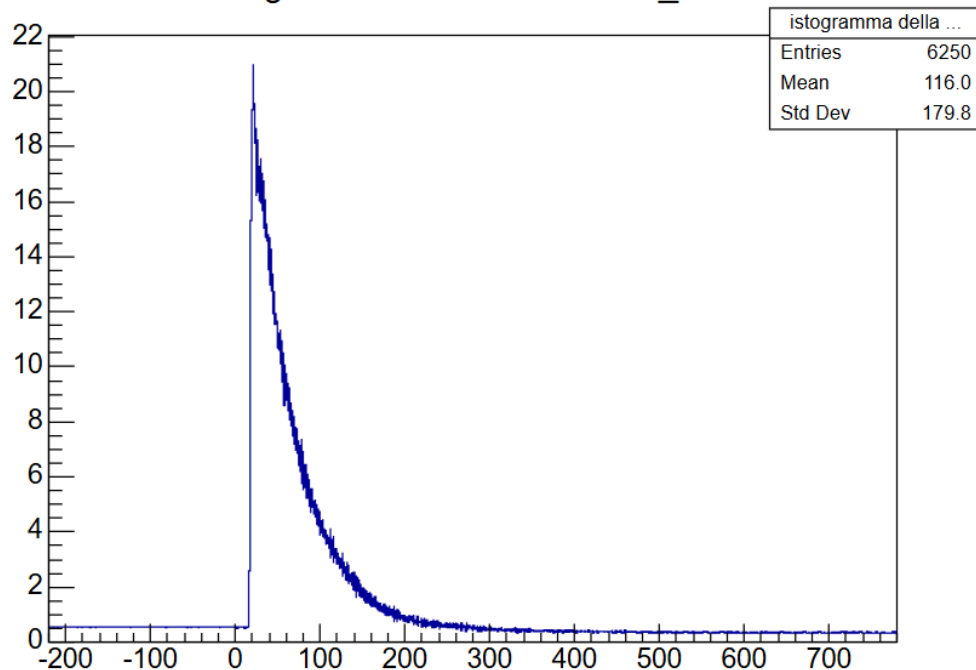
Measurements with Picoseconds light pulser

- I made measurements with the PLP laser for the SiPM 3x3 at the gain configurations used at the test beam
- Here we are in a range of ~20 photons

SiPM	Gain	Gain amplitude conversion	Method	$p_0 + error$	$p_1 + error$ [mV/n _{pe}]
3x3	28	25,12	B	-1,4±0,4	1,236±0,002



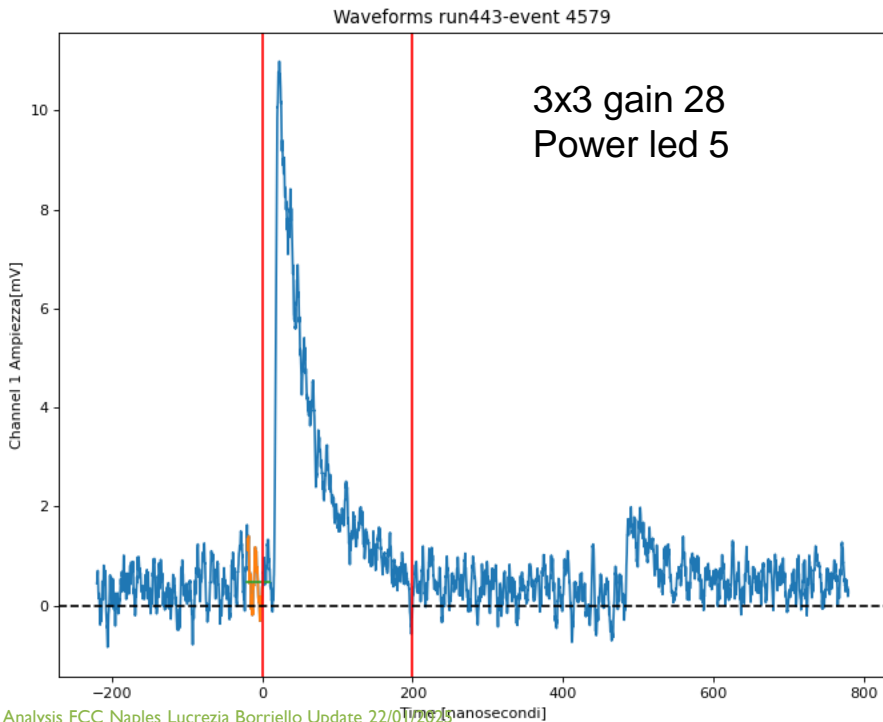
istogramma della somma run_439



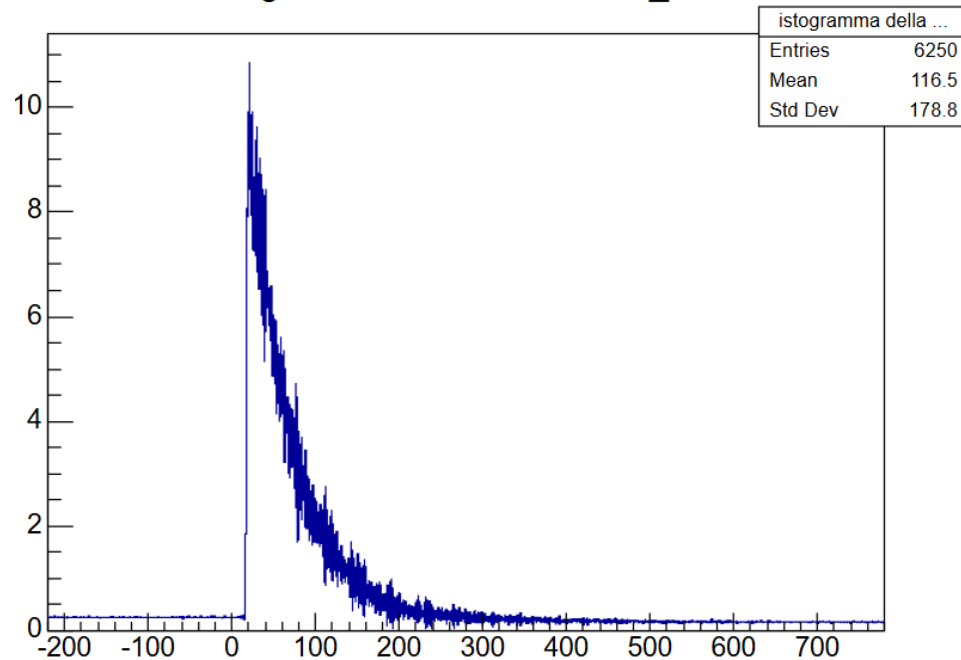
Measurements with Picoseconds light pulser

- I made measurements with the PLP laser for the SiPM 3x3 at the gain configurations used at the test beam
- Here we are in a range of ~ 10 photons

SiPM	Gain	Gain amplitude conversion	Method	$p_0 + error$	$p_1 + error$ [mV/n _{pe}]
3x3	28	25,12	B	-1,4±0,4	1,236±0,002

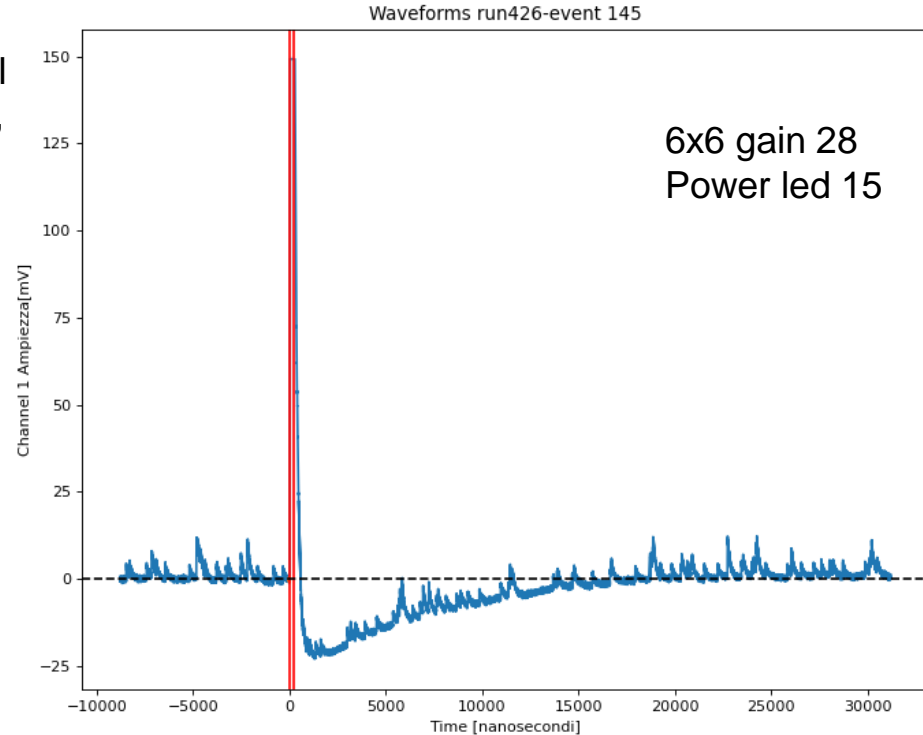


istogramma della somma run_443



Undershoot Measurements with Picoseconds light pulser

- I made measurements of the undershoot of the sipm with the PLP laser for the SiPM 6x6 and 3x3 at the gain configurations used at the test beam
- Undershoot in a SiPM occurs in the electrical signal produced by the device. After the main signal peak, the signal may show a descent below the baseline level before gradually stabilising again.

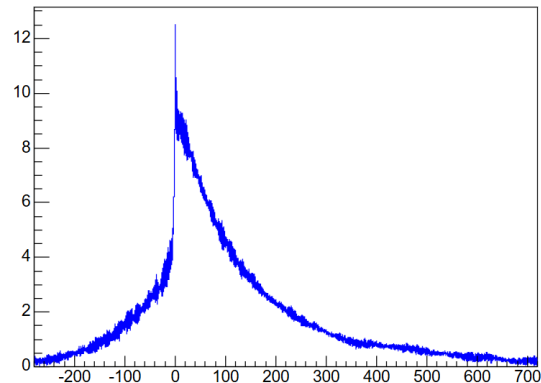
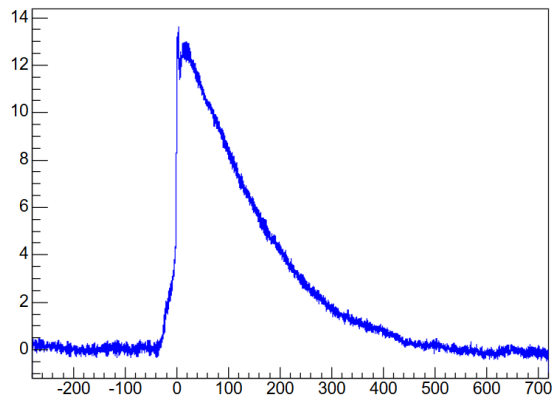
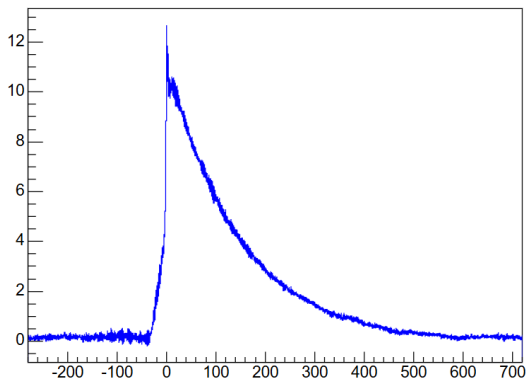
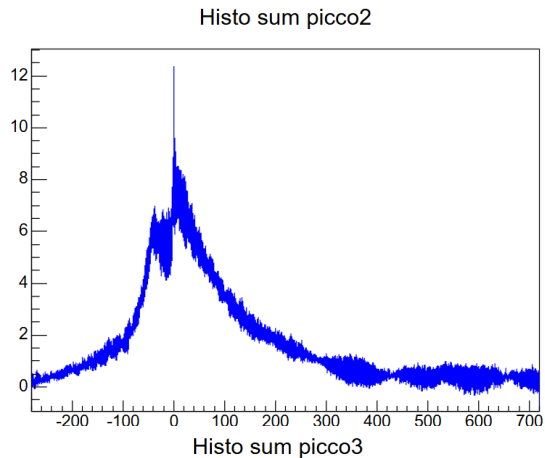
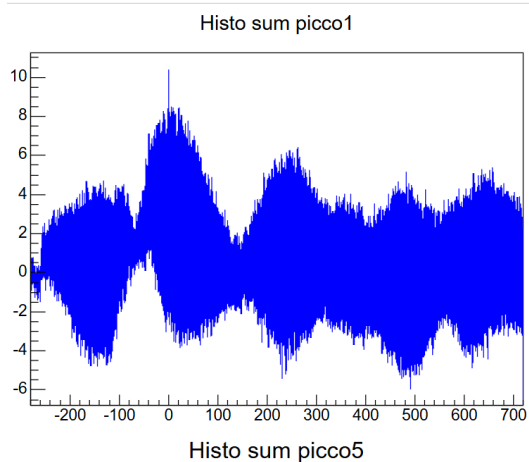
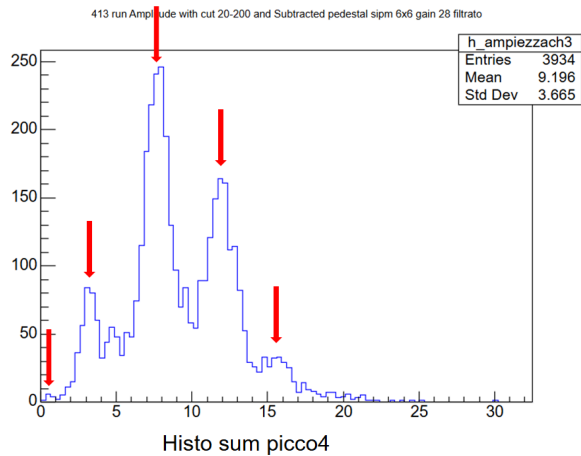


Summary of PLP Measurements

20/01/2025 sipm 6x6		preamp 2			
misure led PLP	run	gain	configurazione	le power	ti
		417	28 nn		15
misura undershoot		419	28 2x5		15 r
		420	28 4x5		15
		421	28 4x5		10
		422	28 4x5		6
		423	28 4x5		5
sipm 6x6		gain			
ho ripreso una misu		436	28 4x5		13
21/01/2025 sipm 6x6		preamp 2			
misure led PLP	run	gain	configurazione	le power	ti
molti fotoni		424	28 3x5		15
ancora più fotoni		425	28 3x3		15
misura undershoot		426	28 3x3		15
molti fotoni		427	18 3x3		15
ancora più fotoni		428	18 2x3		15
ritorno a pochi foton		429	18 4x5		15
		430	18 4x4		15
		431	18 4x5		10
		432	18 4x5		6
		433	18 4x5		5
		434	18 4x5		13
misura undershoot		435	18 6x2		15

sipm 3x3		preamp 1			
misure led PLP	run	gain	configurazione	le power	trigger led PLP
~30 fotoni		439	28 3x4		15
		440	28 3x4		13
		441	28 3x4		10
		442	28 3x4		6
		443	28 3x4		5
~100 fotoni undershoot		444	28 1x2		15
		445	28 1x2		15
~70 fotoni		446	18 1x2		15
~30 fotoni		447	18 2x4		15
		448	18 3x4		15
		449	18 3x4		13
		450	18 3x4		10
		451	18 3x4		6
		452	18 3x4		5
undershoot		453	18 1x2		15
sipm 3x3		preamp passivo			
misure led PLP	run	gain	configurazione	le power	trigger led PLP
in teoria massimi fo		454 -	1x2		15
		455 -	1x2		13
		456 -	1x2		10
		457	1x2		6
		458	1x2		5

dark measurements for single-photon resolution studies sipm 6x6 gain 28

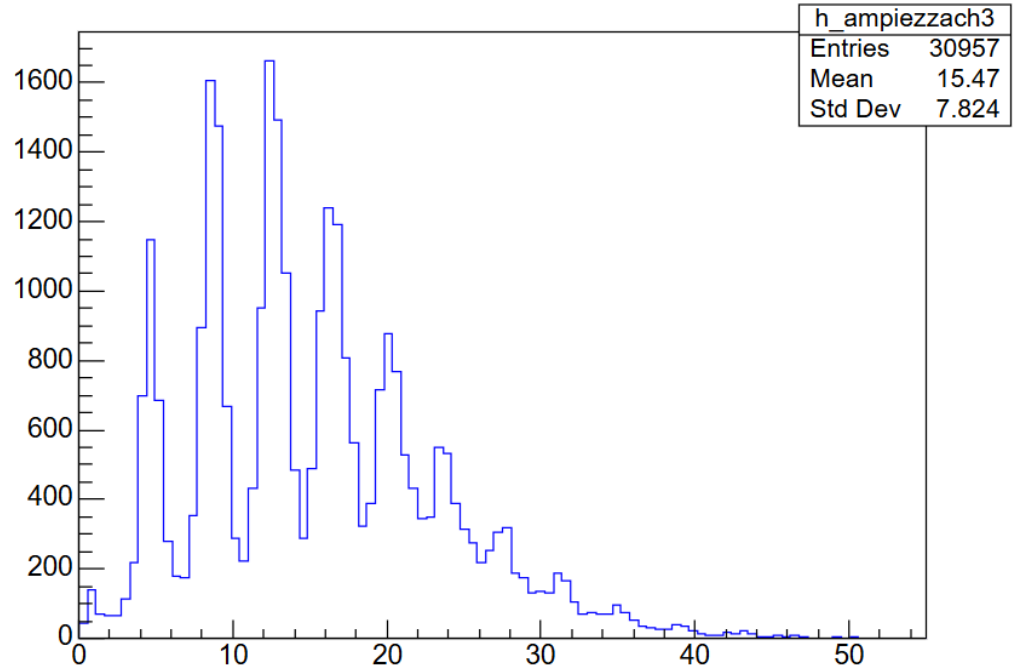


Measurements with frequency led 6

I have studied the amplitudes of the wf, what is observed is the presence of 10 distinct peaks.

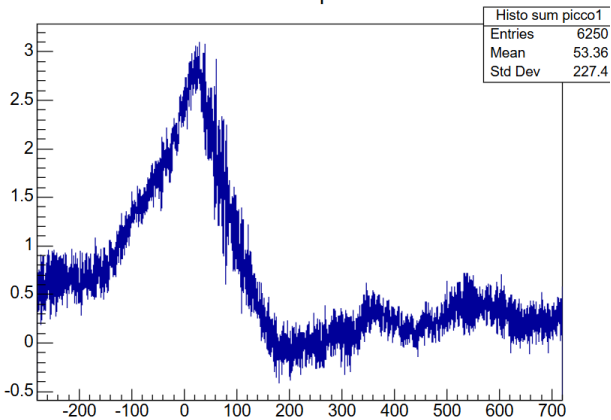
Then what I did was to study the wf corresponding to these 10 peaks and I made the average wf for each peak

412 run Amplitude with cut 20-200 and Subtracted pedestal sipm 6x6 gain 28 filtrato

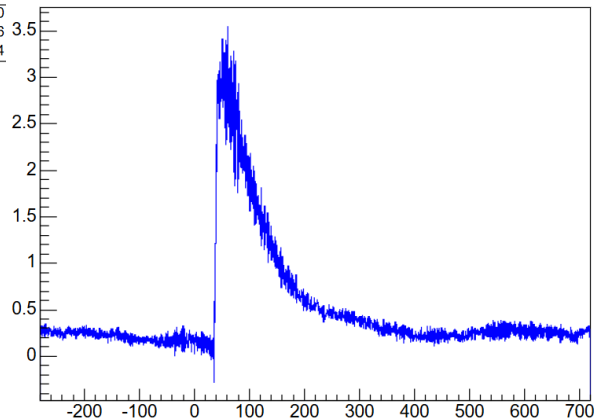


Measurements with frequency led 6 for SiPM 6x6 gain 28

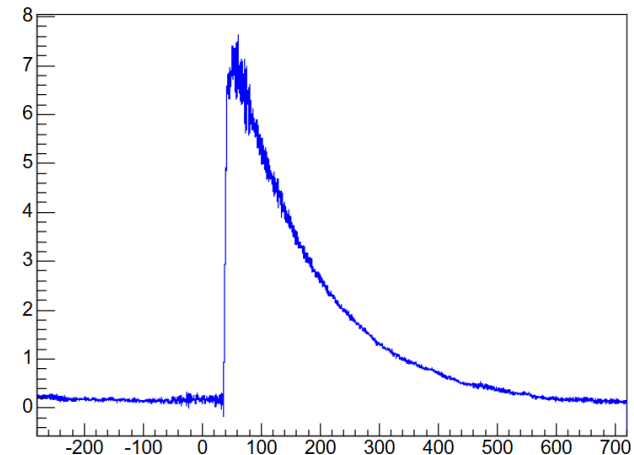
Histo sum picco1



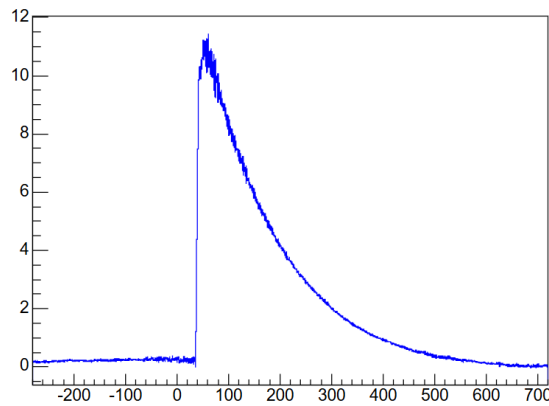
Histo sum picco2



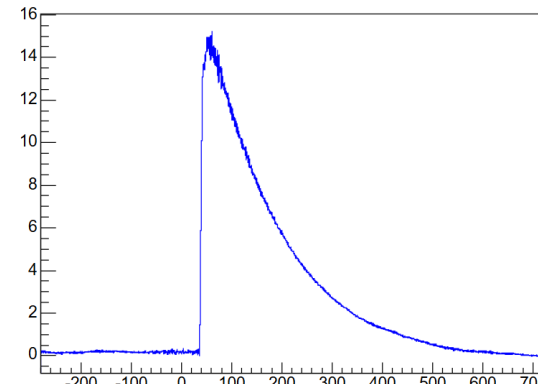
Histo sum picco3



Histo sum picco4



Histo sum picco5

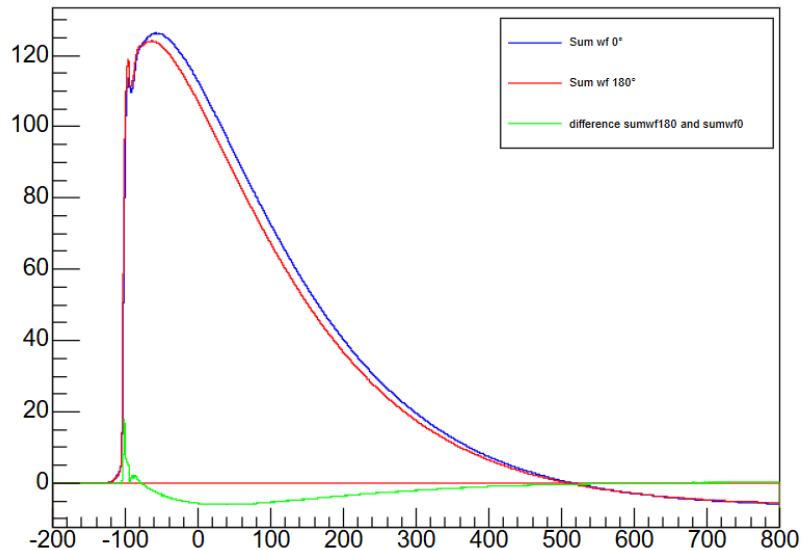


In this case we see that there is no presence, as in the case of the dark, of the initial peak.

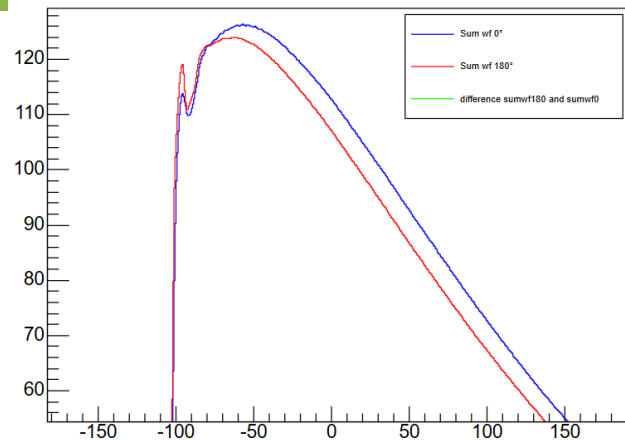
This may be due to the led

Waveform study for the BSO with e+10GeV

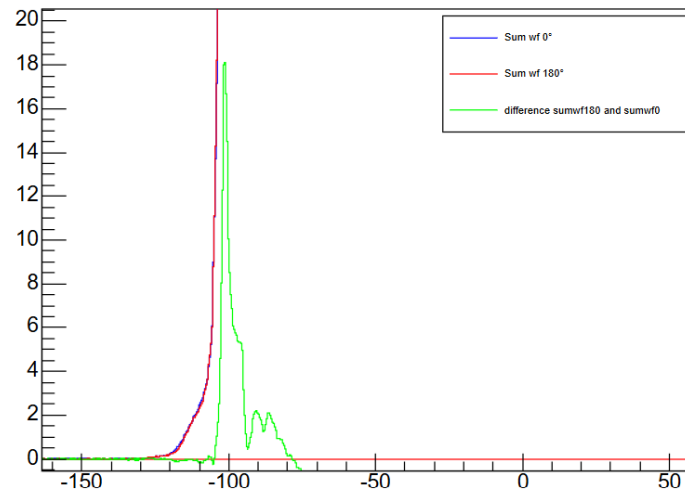
histo sum wf BSO e-



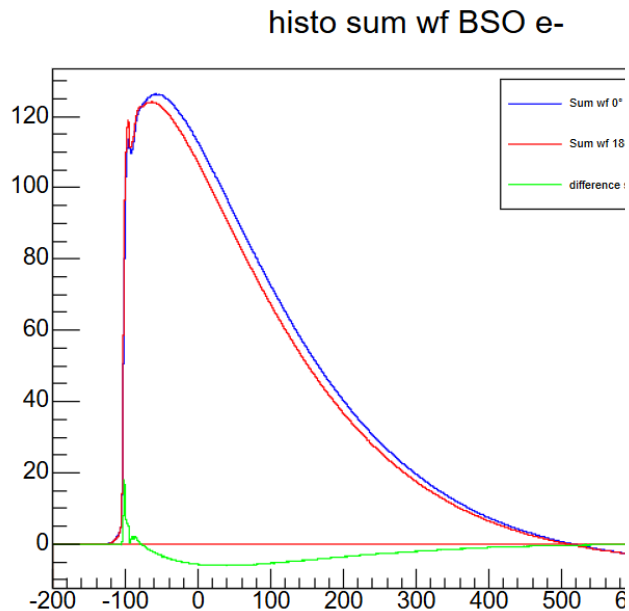
histo sum wf BSO e-



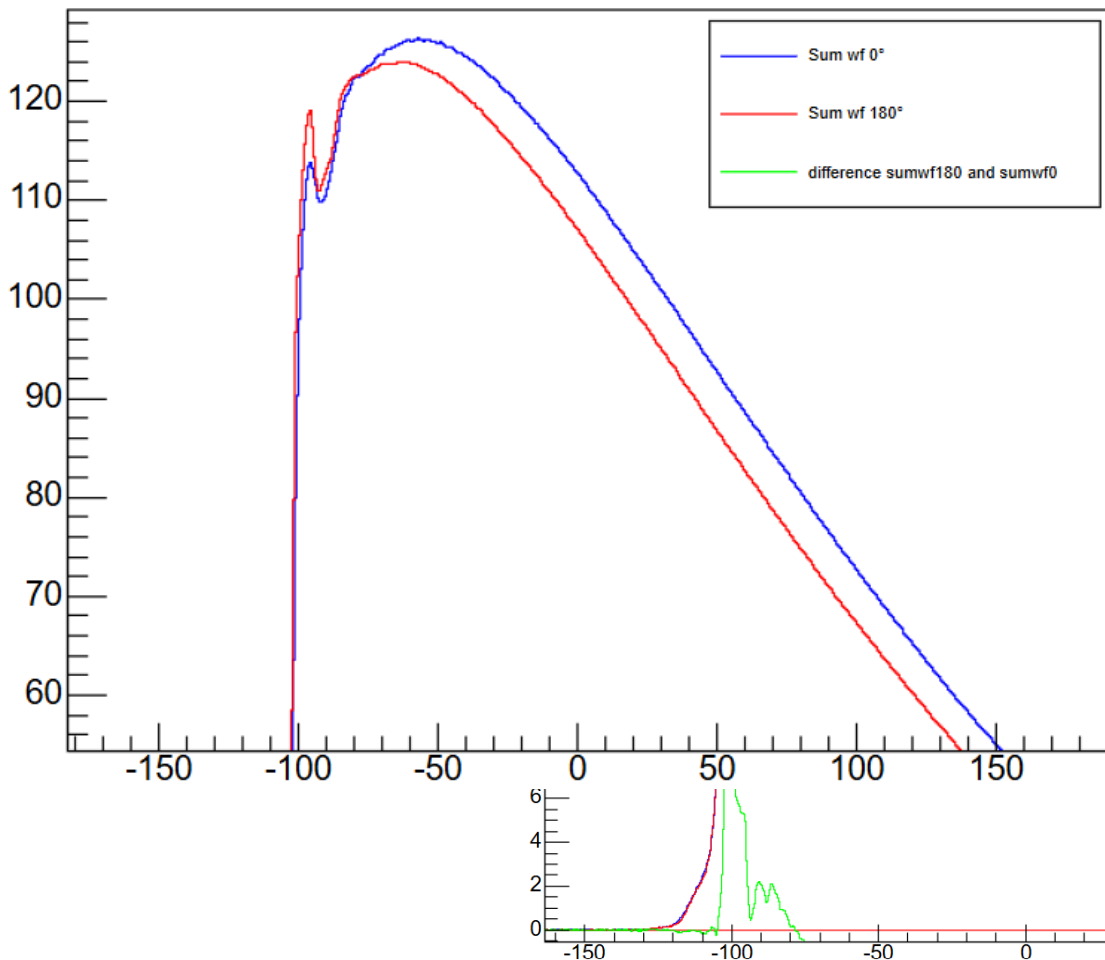
histo sum wf BSO e-



Waveform study for the B

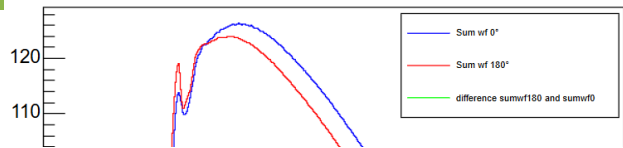


histo sum wf BSO e-



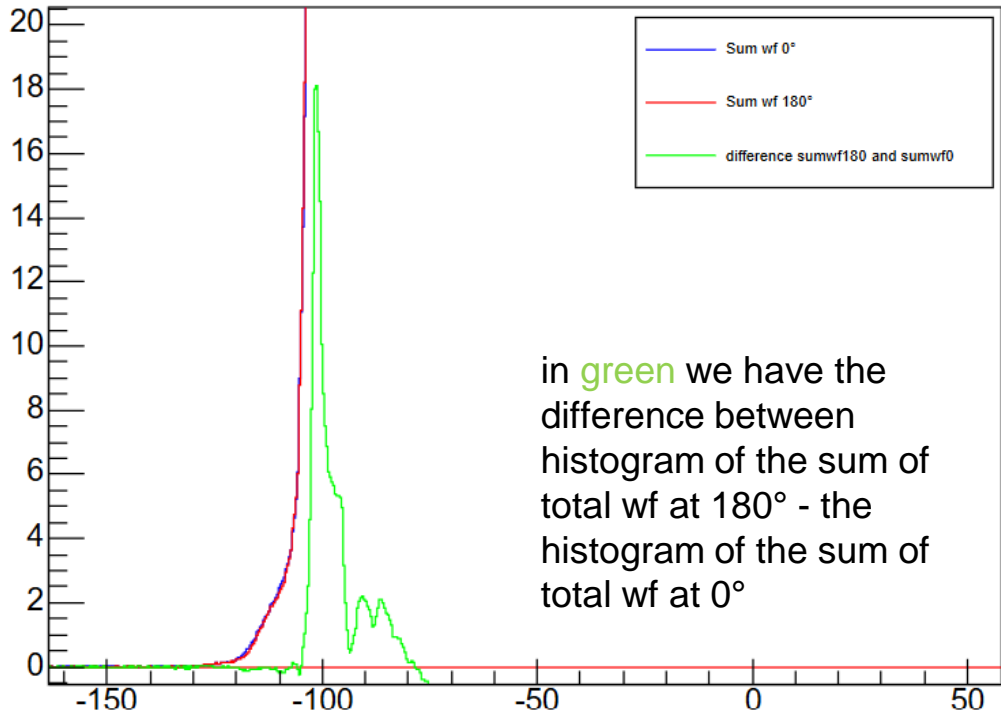
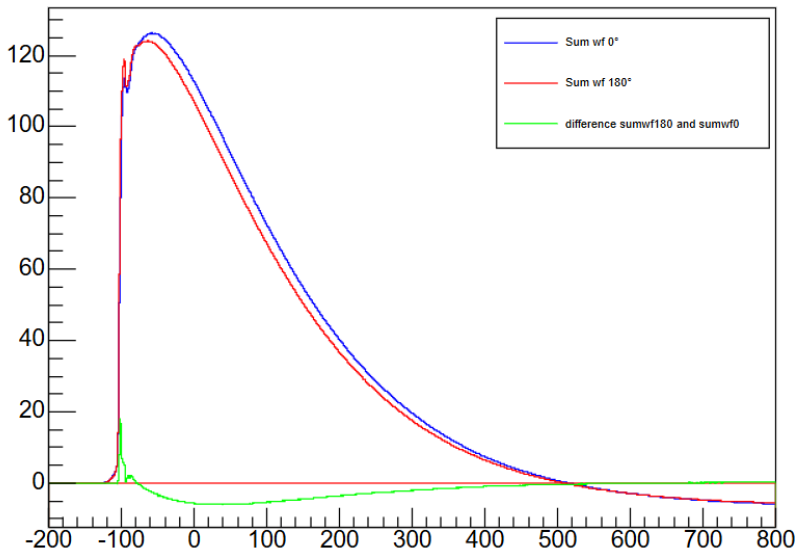
Waveform study for the BSO with e+10GeV

histo sum wf BSO e-



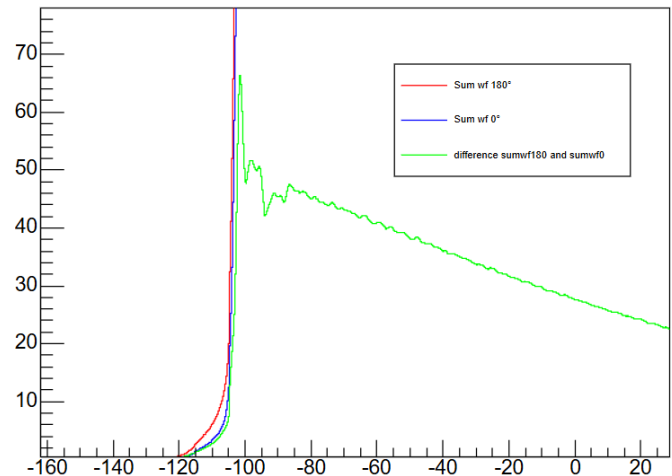
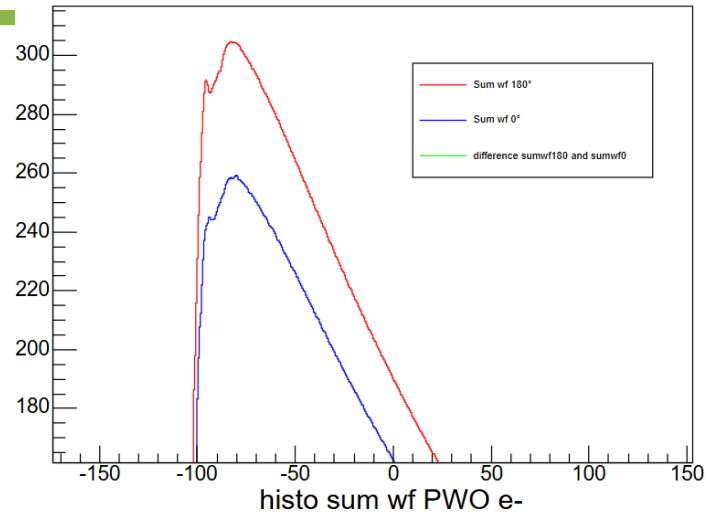
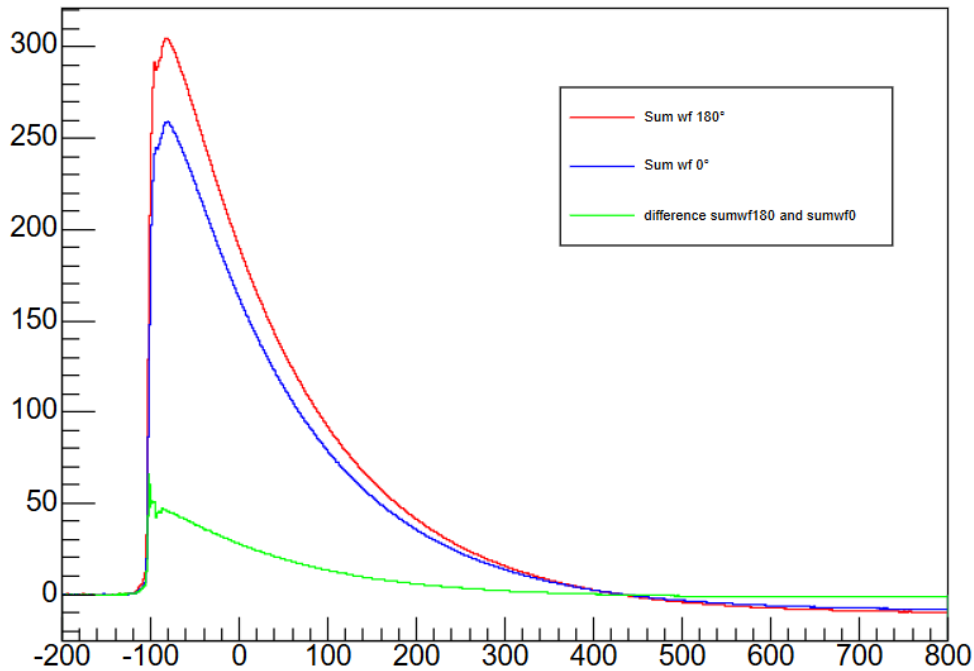
histo sum wf BSO e-

histo sum wf BSO e-

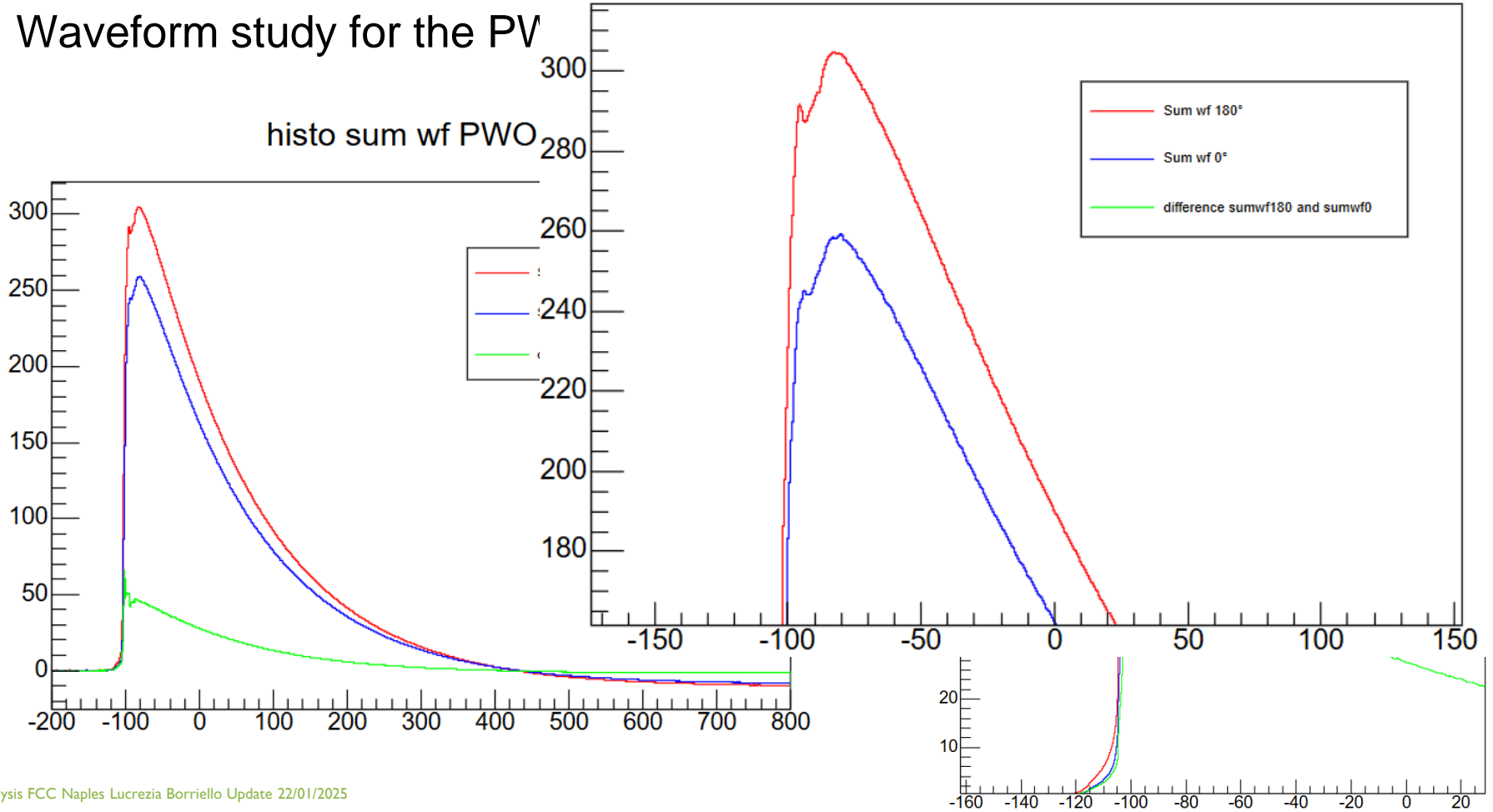


Waveform study for the PWO with e+10GeV

histo sum wf PWO e-



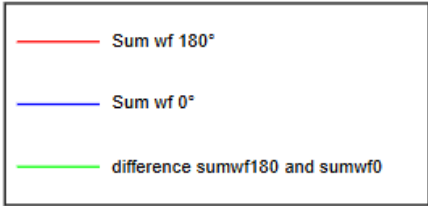
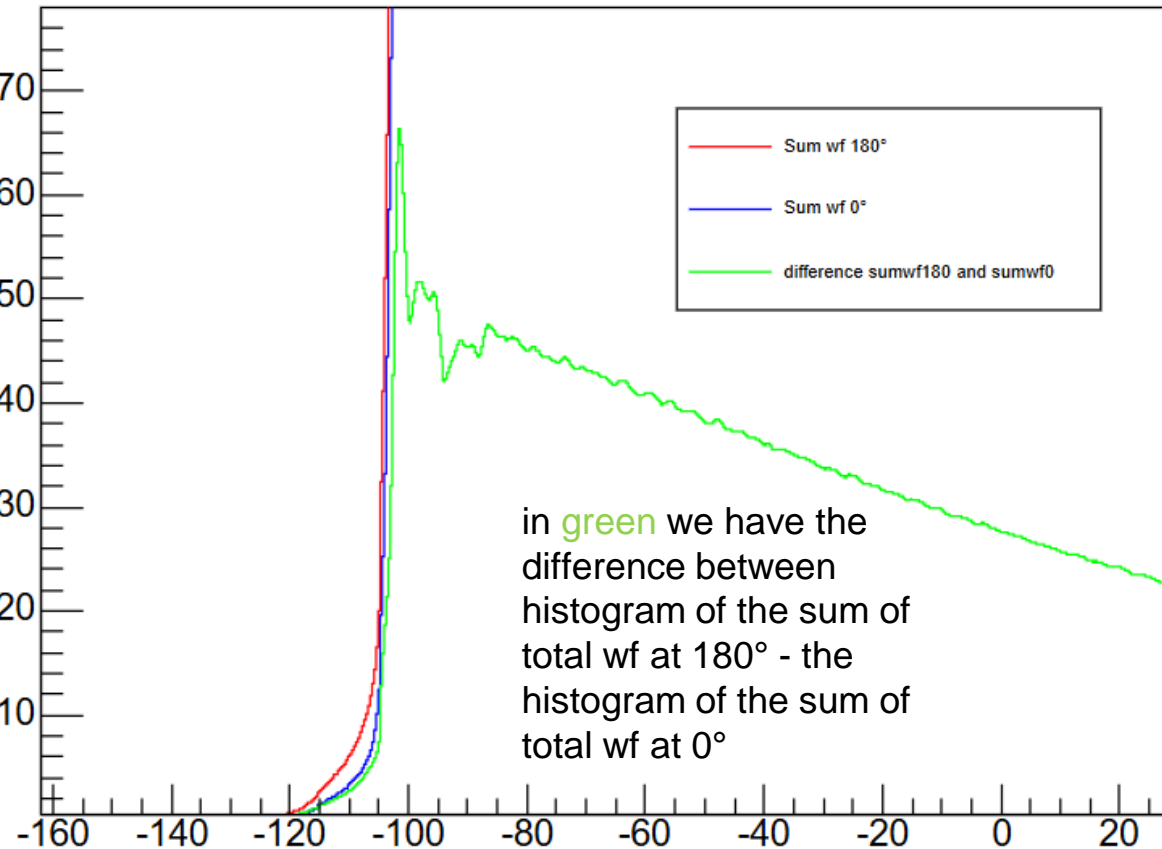
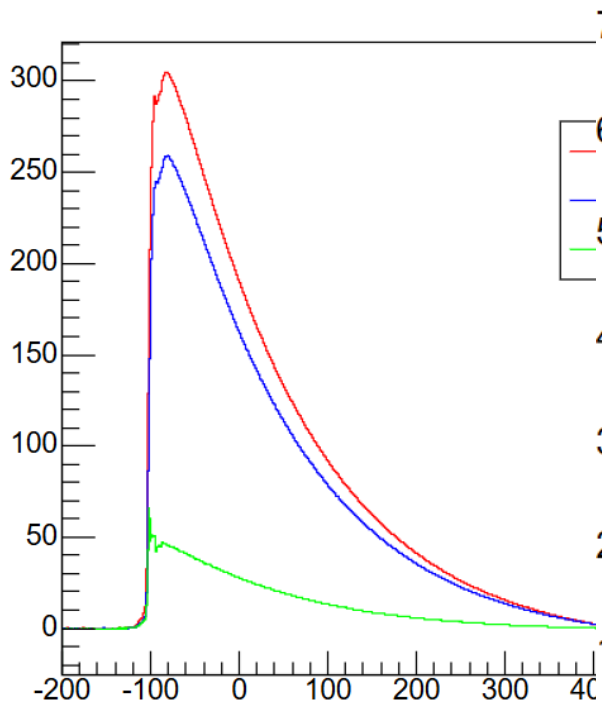
Waveform study for the PV



Waveform study for the F

histo sum wf PWO e-

histo sum wf PV



in green we have the difference between histogram of the sum of total wf at 180° - the histogram of the sum of total wf at 0°

Evidence of single-photon resolution studies

- I made dark measurements of the SiPM specifically, study the shape of the single photon.

Why these studies?

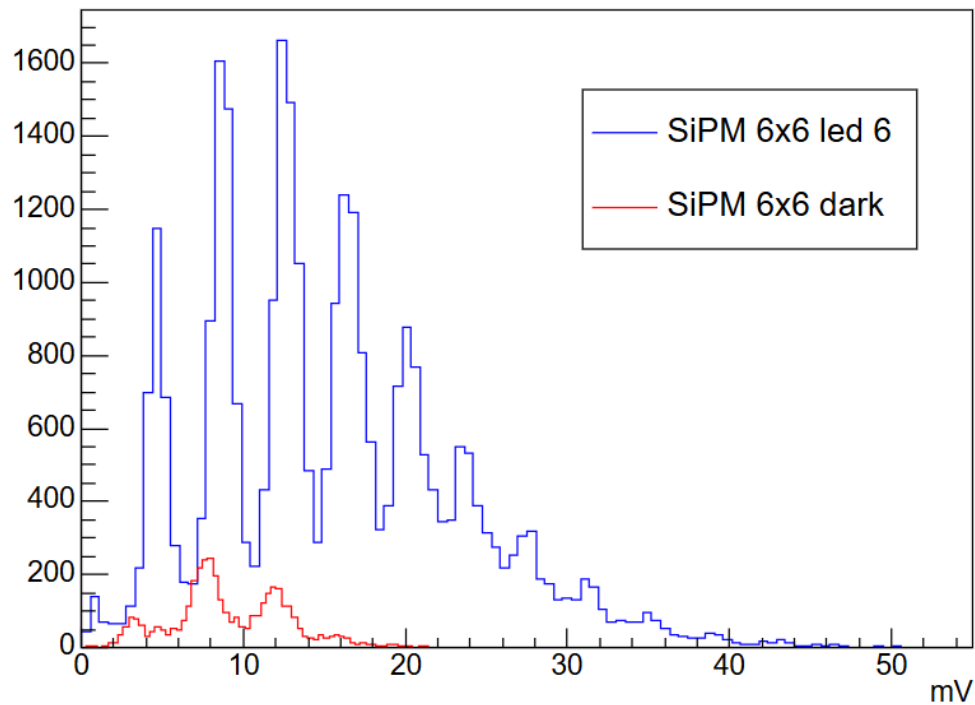
- because we could use the single photon shape as a template to fit individual wf
- Specifically, it could help to fit the first peak of the wf



Backup Slides

Amplitude comparison with led and dark

Confronto con dark



Summary SiPM 6x6 Calibration

SiPM	Gain	Gain amplitude conversion	Method	$p_0 + error$	$p_1 + error$ [mV/ n_{pe}]	$\tau(ns)$	conversion factor charge $\tau(1 - 0,0497)$
6x6	28	25,12	A	0,4±0,1	3,46±0,02	132,26	125,7
6x6	28		B	15±1	3,49±0,006		
6x6	18	7,94	A	1,31±0,06	1,161±0,005	120,72	114,7
6x6	18		B	3,0±0,4	1,156±0,003		
6x6	24	15,85	A	0,20±0,05	2,27±0,01	149,72	142,3
6x6	24		B	17,5±0,7	2,169±0,003		

Summary SiPM 3x3 Calibration

SiPM	Gain	Gain amplitude conversion	Method	$p_0 + error$	$p_1 + error$ [mV/ n_{pe}]	$\tau + error(ns)$	conversion factor charge $\tau(1 - 0,0497)$
3x3	28	25,12	B	-1,4±0,4	1,236±0,002	46,9±0,2	44,61
3x3	24	15,85	B	-0,9±0,2	0,785±0,002	45,2±0,2	42,93
3x3	18	7,94	B	-0,3±0,1	0,401±0,002	46,3±0,6	44,02
3x3	Passive Preamp	-	B	0,064±0,005	0,0425±0,0009	18,3±0,3	17,41

Gain conversion factor at various temperatures

$$V_{OV}(26^{\circ}C) = V_{OP}(25^{\circ}C) - V_{BD}$$

$$V_{BD}(T^{\circ}) = V_{BD}(25^{\circ}) + 0,034 \frac{V}{^{\circ}C} \delta T \begin{matrix} \text{This is in case of temperature increase} \\ \text{from } 25^{\circ}C, \text{ or in case of temperature} \\ \text{decrease} \end{matrix} \Rightarrow V_{BD}(T^{\circ}) = V_{BD}(25^{\circ}) - 0,034 \frac{V}{^{\circ}C} \delta T$$

$$G(26^{\circ}C) = \alpha V_{OV}(26^{\circ}C) = \text{calculated} \rightarrow \alpha = \frac{G(26^{\circ}C)}{V_{OV}(26^{\circ}C)}$$

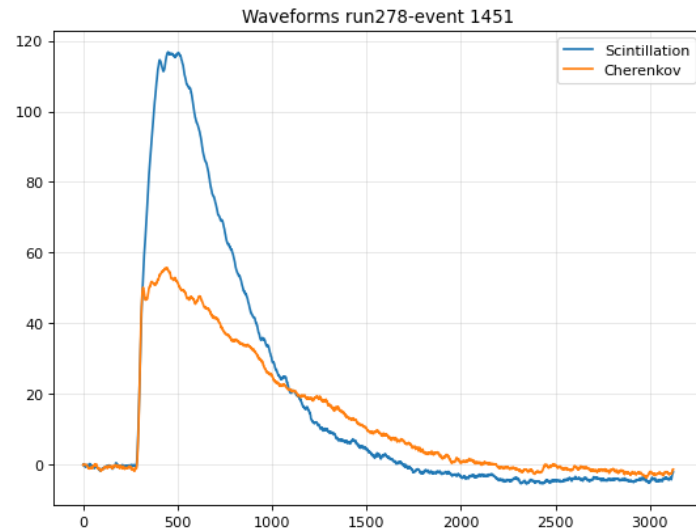
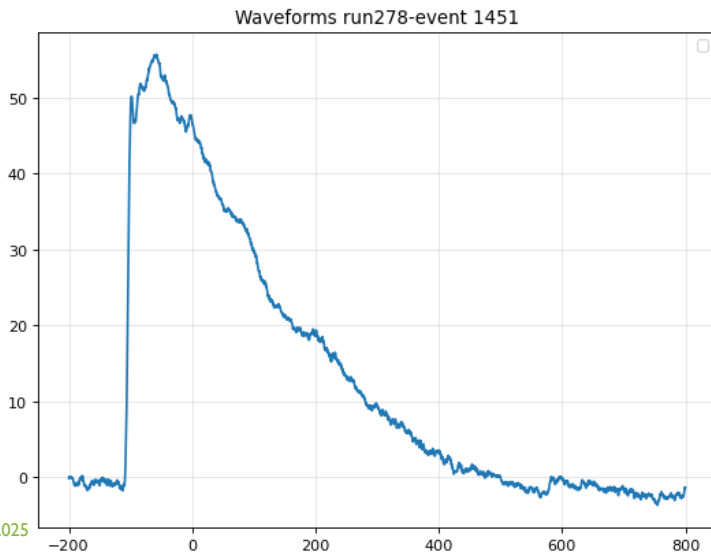
$$G(23^{\circ}C) = \alpha V_{OV}(23^{\circ}C)$$

We then have the 26°C gain and we want to know how much is the gain at 23°C:

SiPM	$V_{OP}(V)$ tabulated 25°C	$V_{BD}(V)$ tabulated 25°C	$V_{OV}(26^{\circ})$	$G(26^{\circ}C)$	α	$V_{OV}(23^{\circ})$	$V_{BD}(23^{\circ})$	$G(23^{\circ}C)$
6x6	40,7	38	2,67	3,461	1,30	2,77	37,93	3,59
3x3	44	39	4,97	1,236	0,25	5,07	38,93	1,26

Analysis of the 264-278 BSO angular scan with e+ 10GeV

- Ch1 CAEN amp 18
- CH2 CAEN amp 18 e Filtro UG11
- CH3 LYSO
- CH4 MPC
- CH5 Plastico 1x1x1 cm3
- CH6 Trigger signal (from MIB plastic)



2D Histogram and fit for BSO e+10GeV

```
# Calcolo l'integrale delle waveforms
```

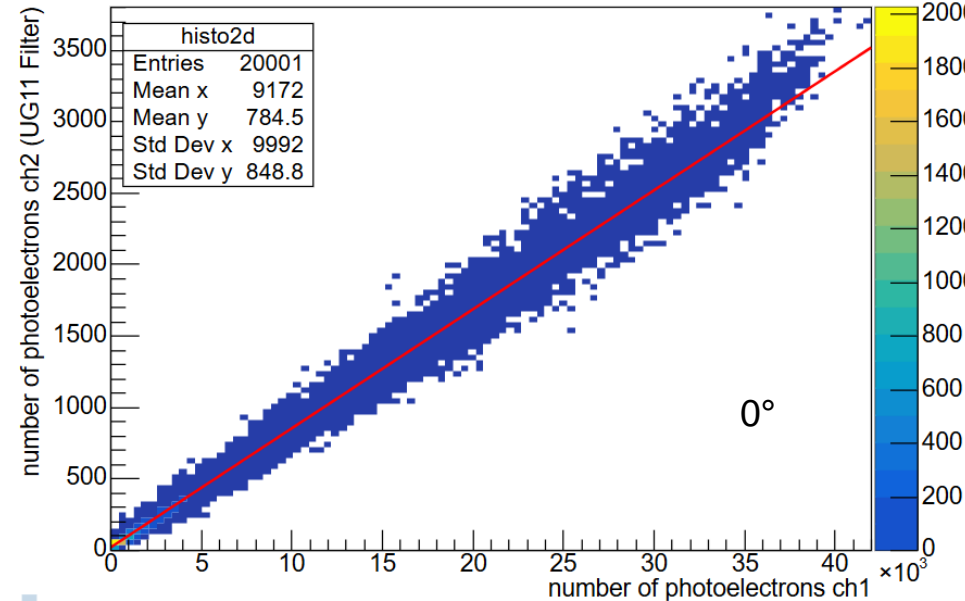
```
integral_ch1 = np.sum(np.abs(wf_channel1))
```

```
integral_ch2 = np.sum(np.abs(wf_channel2))
```

```
a=integral_ch1/(44.02*0.401)
```

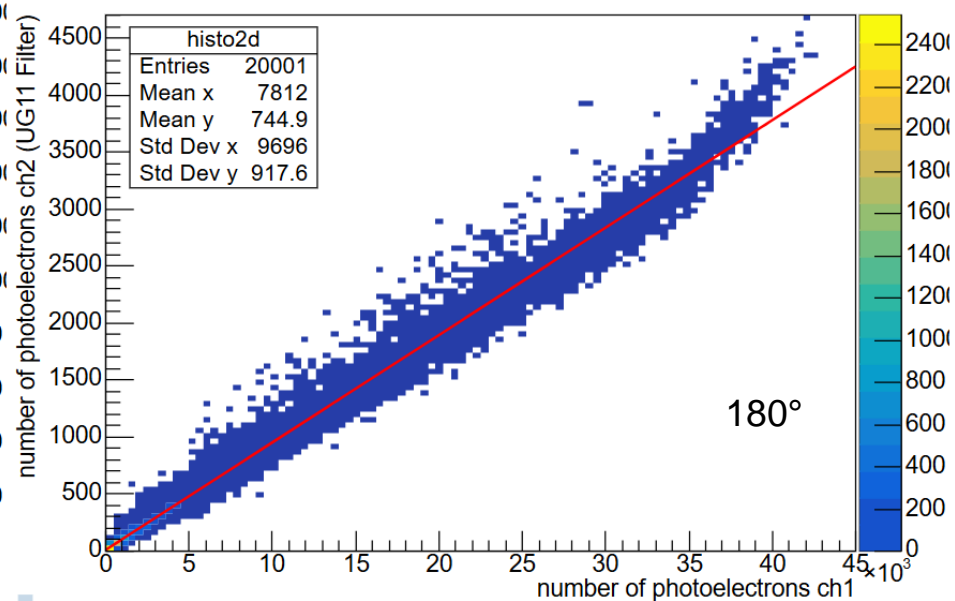
```
b=integral_ch2/(114.7*1.16)
```

number of photoelectrons ch2 vs number of photoelectrons ch1 run278



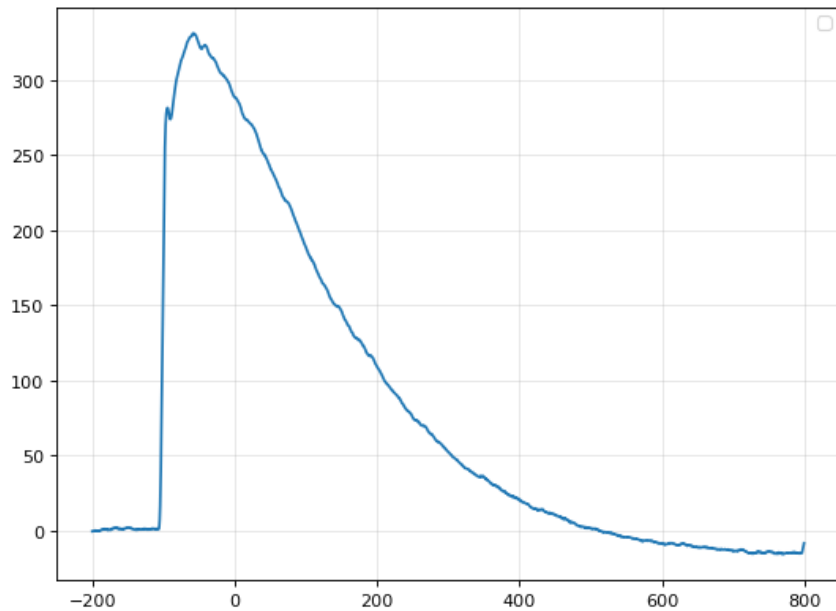
- If there were only scintillation the slope would always be equal depending on the angle

number of photoelectrons ch2 vs number of photoelectrons ch1 run264

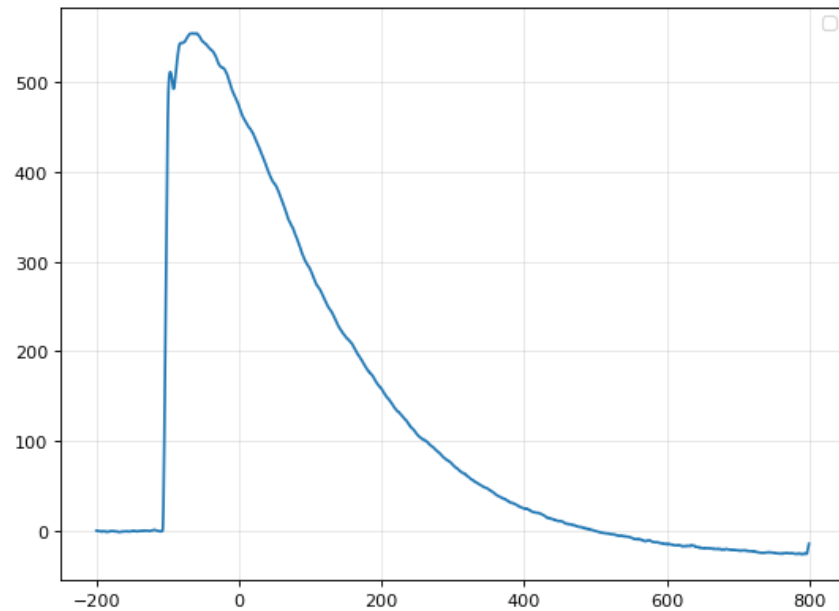


Wf for BSO e+10GeV

Waveforms run278-event 12478

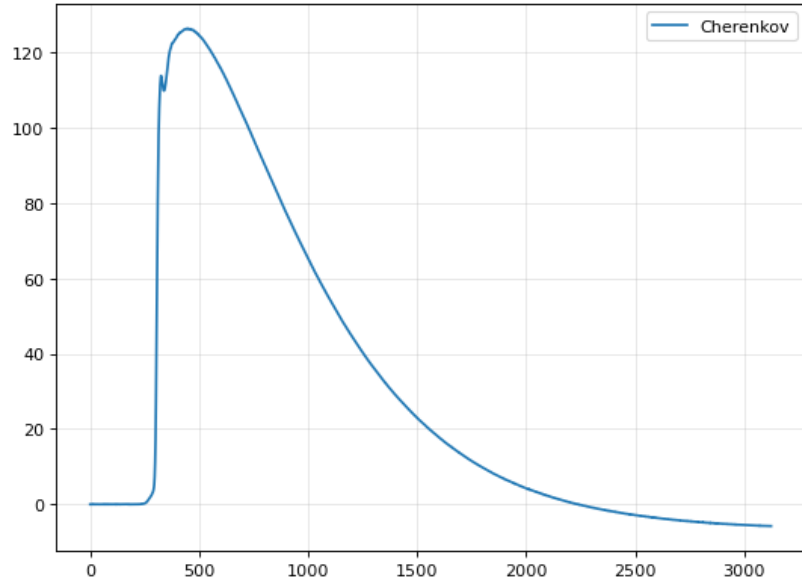


Waveforms run264-event 5787

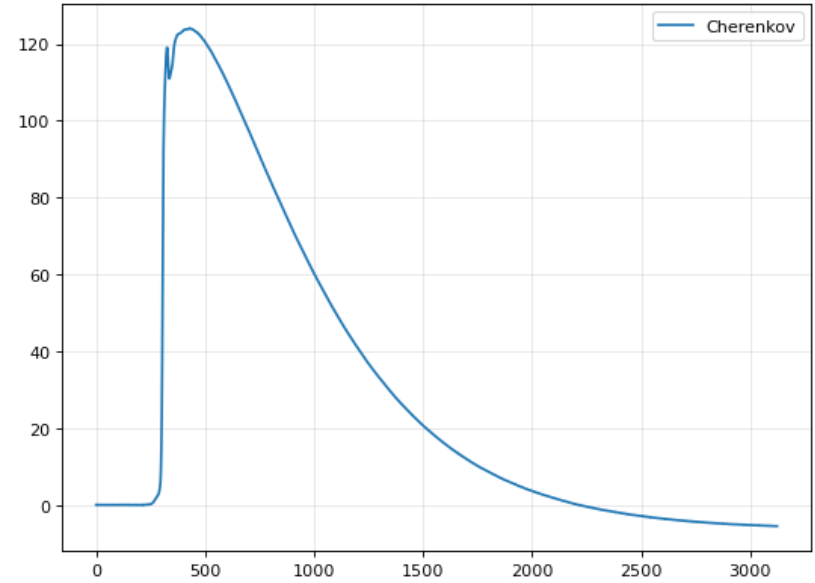


Wf for BSO e+10GeV

Sum Waveforms run278



Sum Waveforms run264



Calibration procedure

We want to calibrate the Silicon Photomultiplier (SiPM) that we used at the test beam: 2 SiPM of different sizes and using a variable-gain preamplifier that allows us to have various gains.

Procedure:

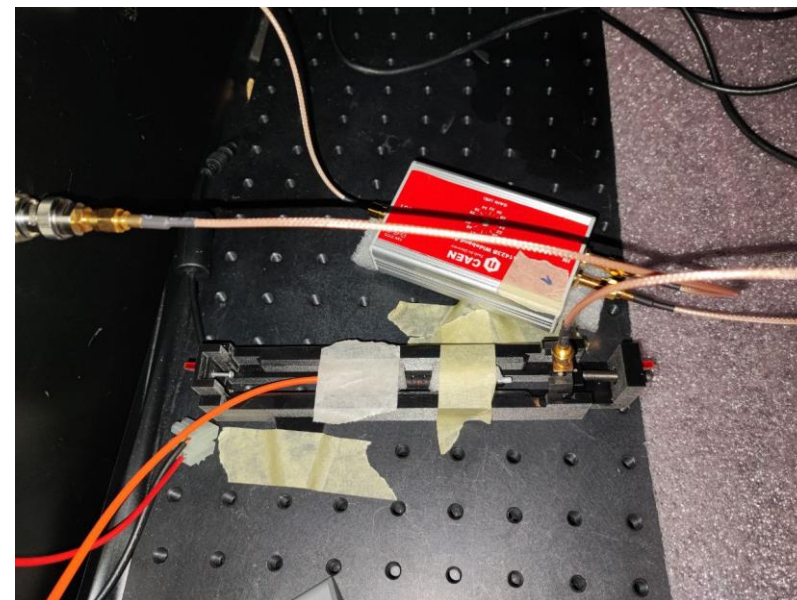
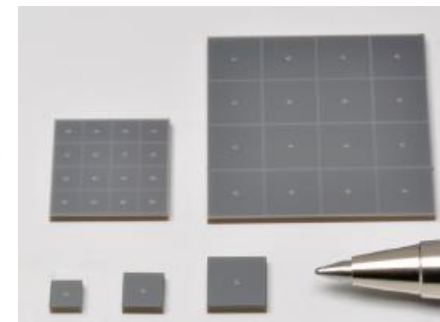
- Reproduce the SiPM - Preamplifier - Oscilloscope chain in the Naples lab
- Use a led drive that to generate light for our sipm in a controlled way
- Acquire our signal with the oscilloscope
- Calibrate the SiPM response to derive the number of incoming photons.

Two different methods have been used (to be described in the next slides):

- A) Waveform integral measurement from the amplitude (Peak id)
- B) Photoelectrons counting (PE Count)

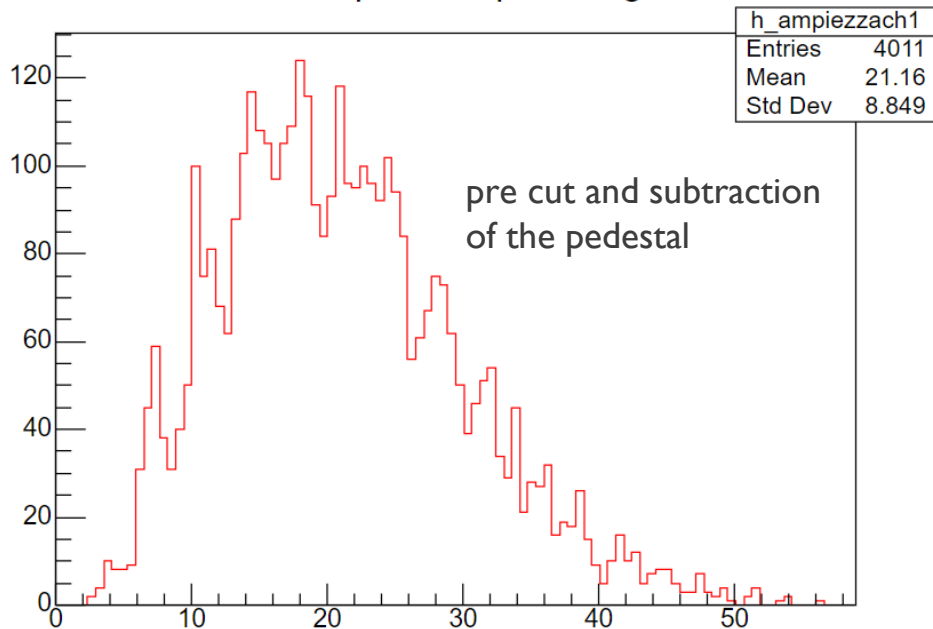
Setup:

- SiPM Hamamatsu S14160-6050HS:
 - photosensitive area $6 \times 6 \text{ mm}^2$
 - number of pixels= 14331
- SiPM Hamamatsu S14160-3010PS:
 - photosensitive area $3 \times 3 \text{ mm}^2$
 - number of pixels= 89984
- Preamplifier CAEN serie A1423B:
 - Gain range from +18dB to +54dB
- CAEN Led Driver SP5601
- CAEN NIM HV Power supply module N1419ET
 - 4 Ch Reversible 500 V/200 μ A
- Tektronix Oscilloscope MSO66B:
 - 1,5 GHz Bandwidth
 - 6 Analog channels

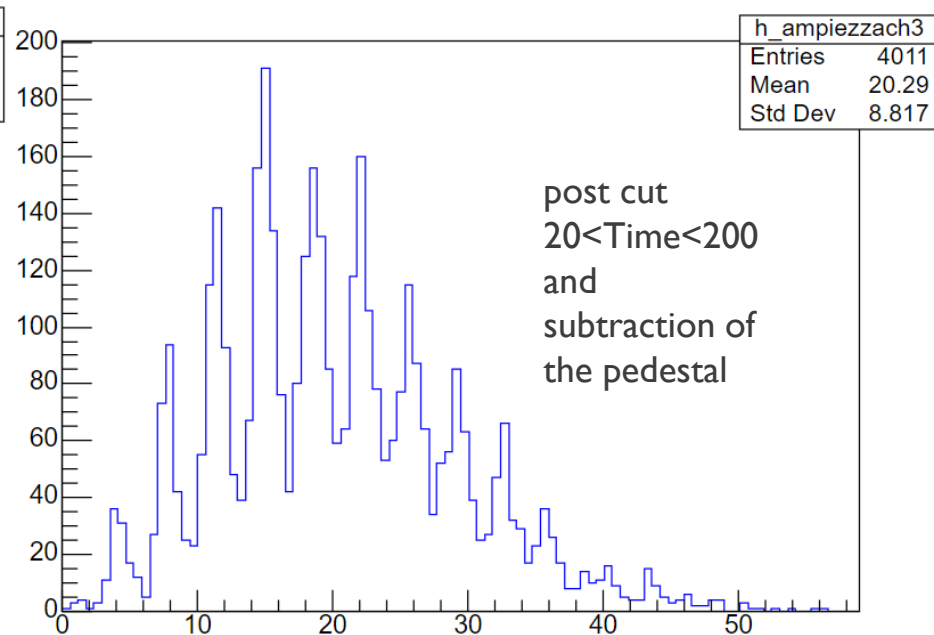


SiPM 6x6 at Gain 28 Calibration

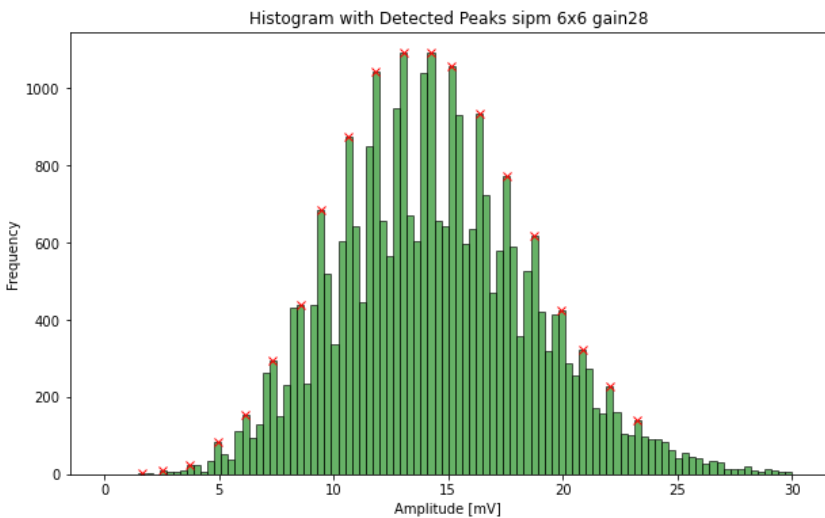
371 run Amplitude sipm 6x6 gain 28



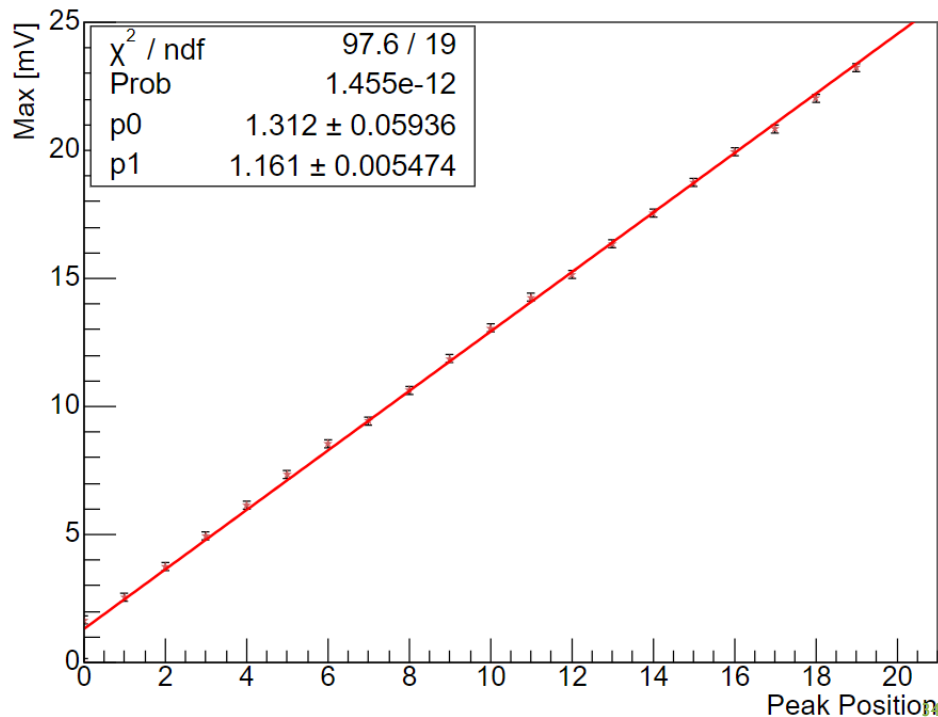
371 run Amplitude with cut 20-200 and Subtracted pedestal sipm 6x6 gain 28 filtrato



SiPM 6x6 at Gain 18 Calibration

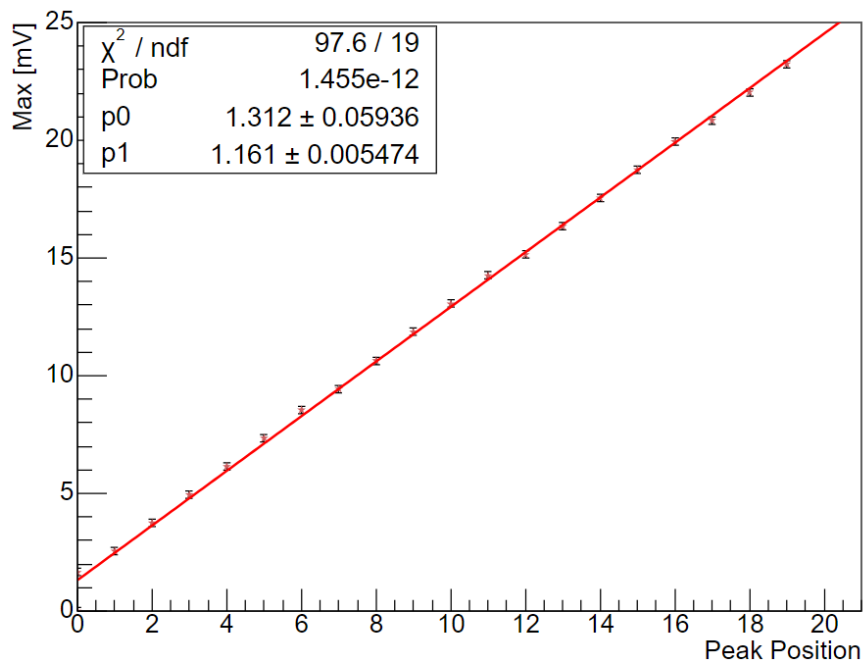


Max vs Peak Position SiPM 6x6 at Gain 18

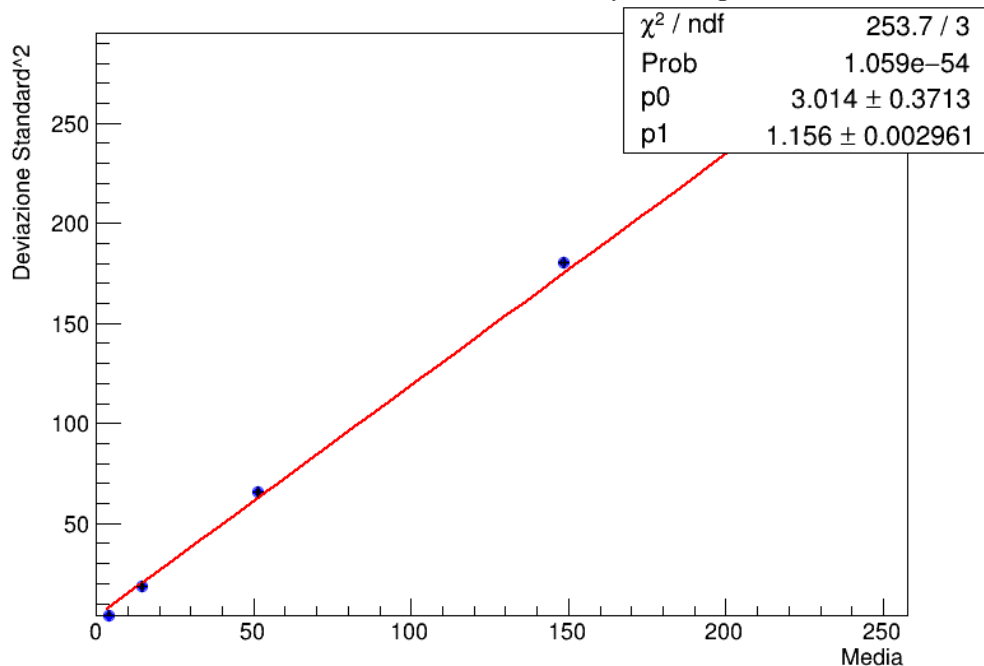


Calibrations SiPM 6x6 Gain 18 with other method and Comparison 2 methods

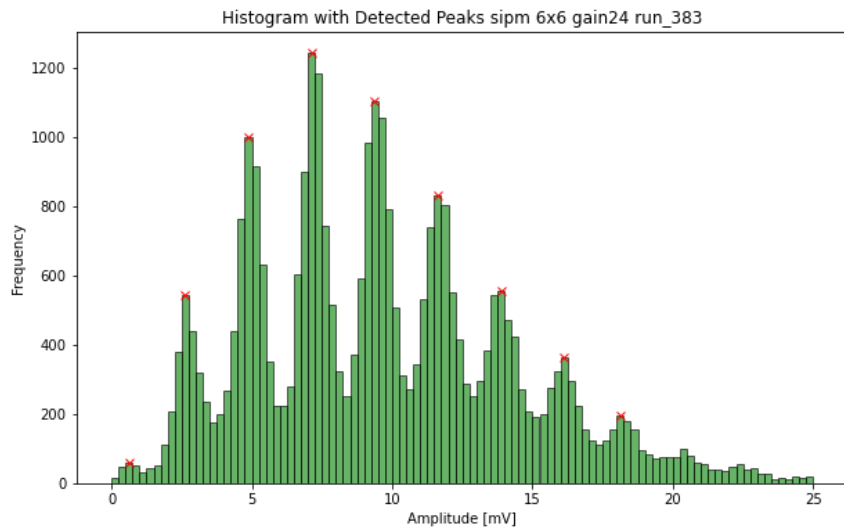
Max vs Peak Position SiPM 6x6 at Gain 18



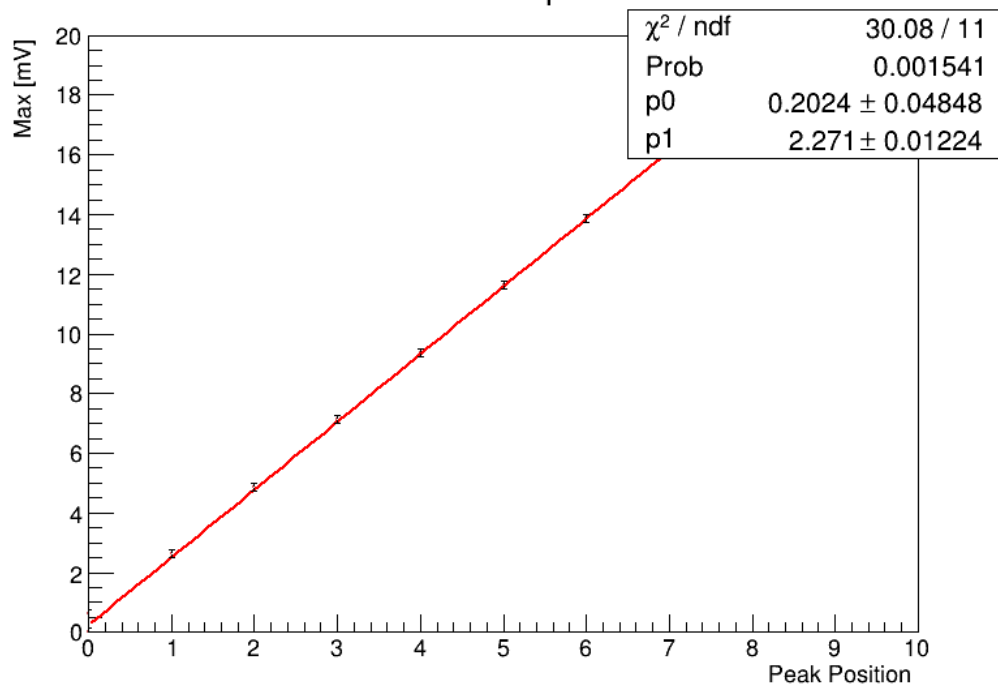
Standard Deviation² on Media sipm 6x6 gain18



SiPM 6x6 at Gain 24 Calibration

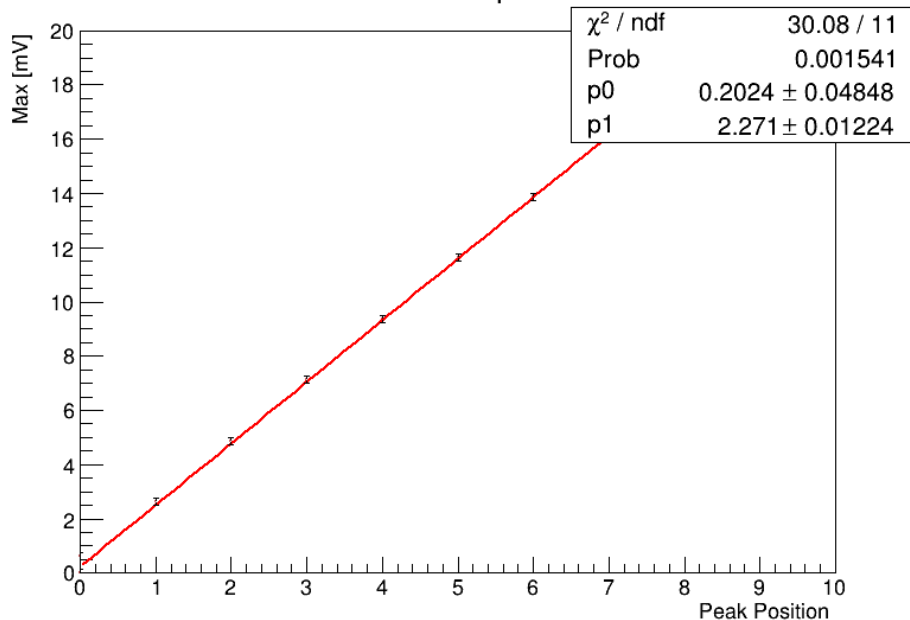


Max vs Peak Position sipm 6x6 at Gain 24

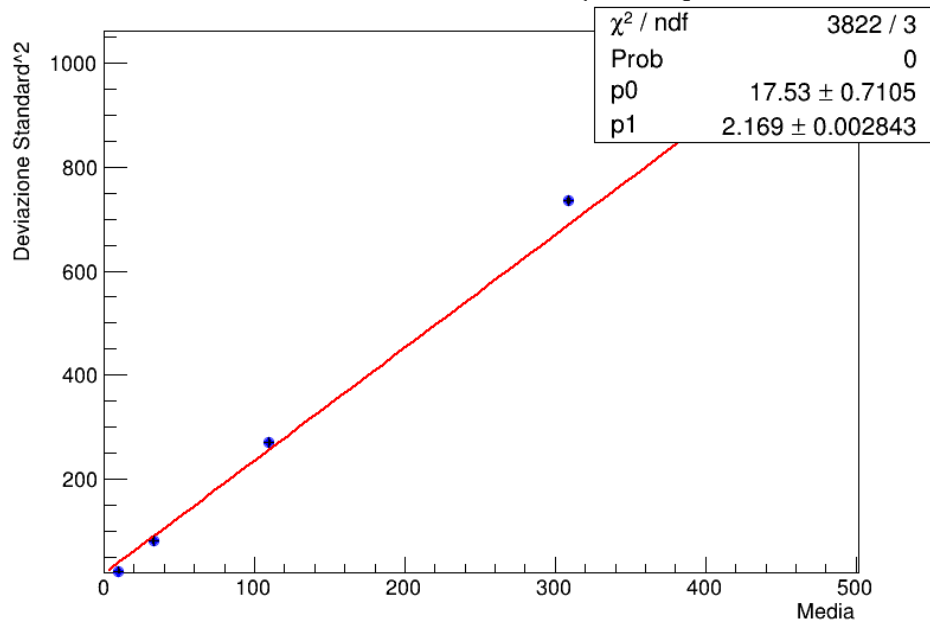


Calibrations SiPM 6x6 Gain 24 with other method and Comparison 2 methods

Max vs Peak Position sipm 6x6 at Gain 24

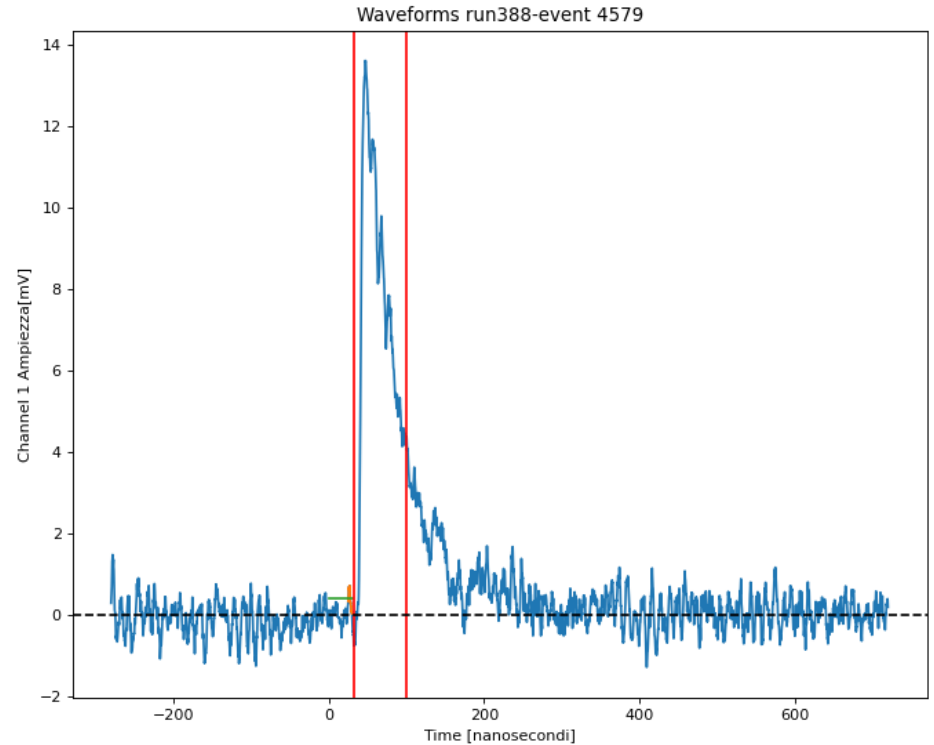


Standard Deviation^2 on Media sipm 6x6 gain24



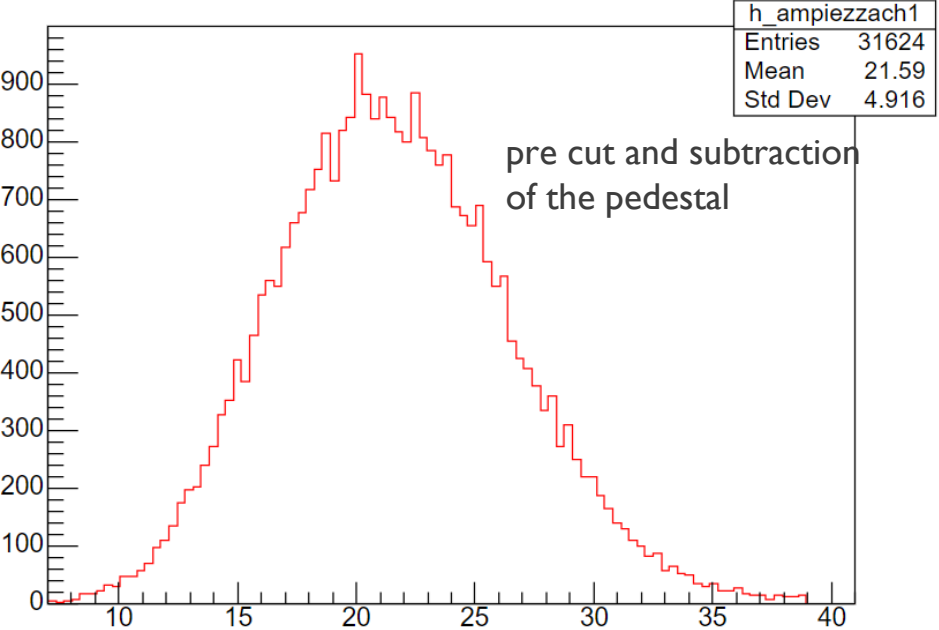
Calibrazioni sipm 3x3 Gain 28

- Power supply 44V
- CAEN Preamplifier at gain 28
- In red= cut on waveform at $33 < \text{Time} < 100$
- In orange= pedestal to subtract

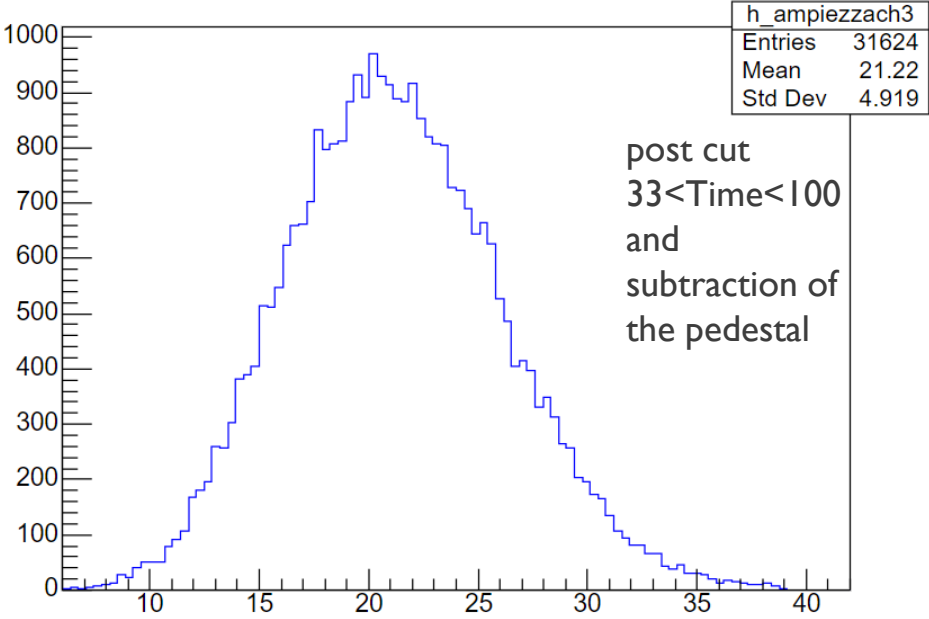


Calibrazioni sipm 3x3 Gain 28

389 run Amplitude sipm 3x3 gain 28

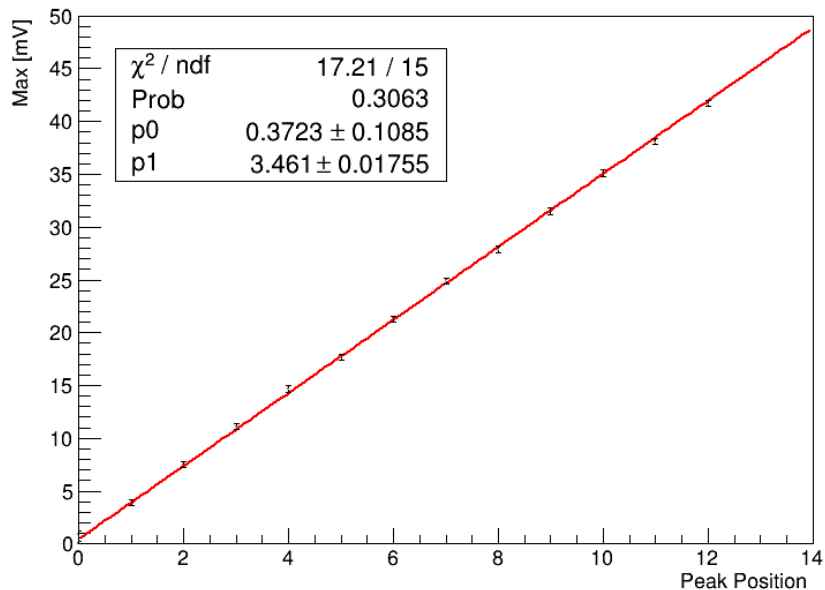


389 run Amplitude with cut 33-100 and Subtracted pedestal sipm 3x3 gain 28

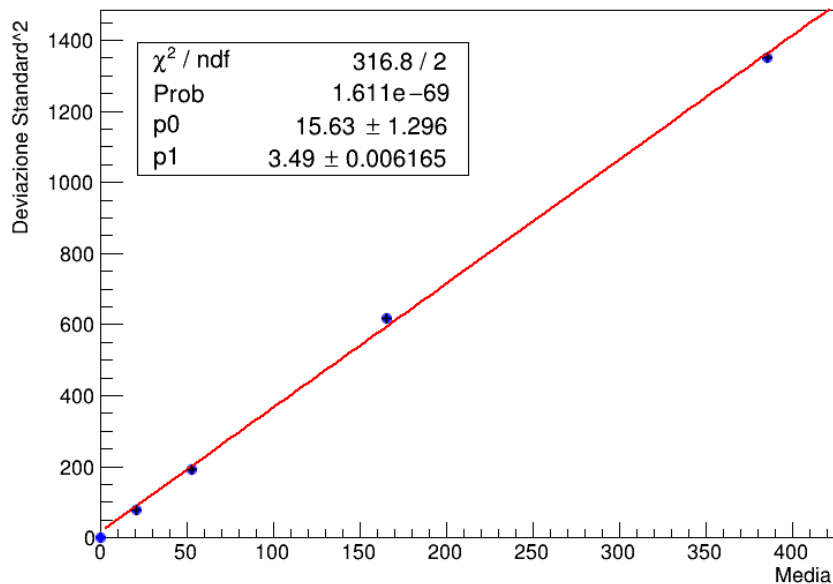


Comparison 2 methods

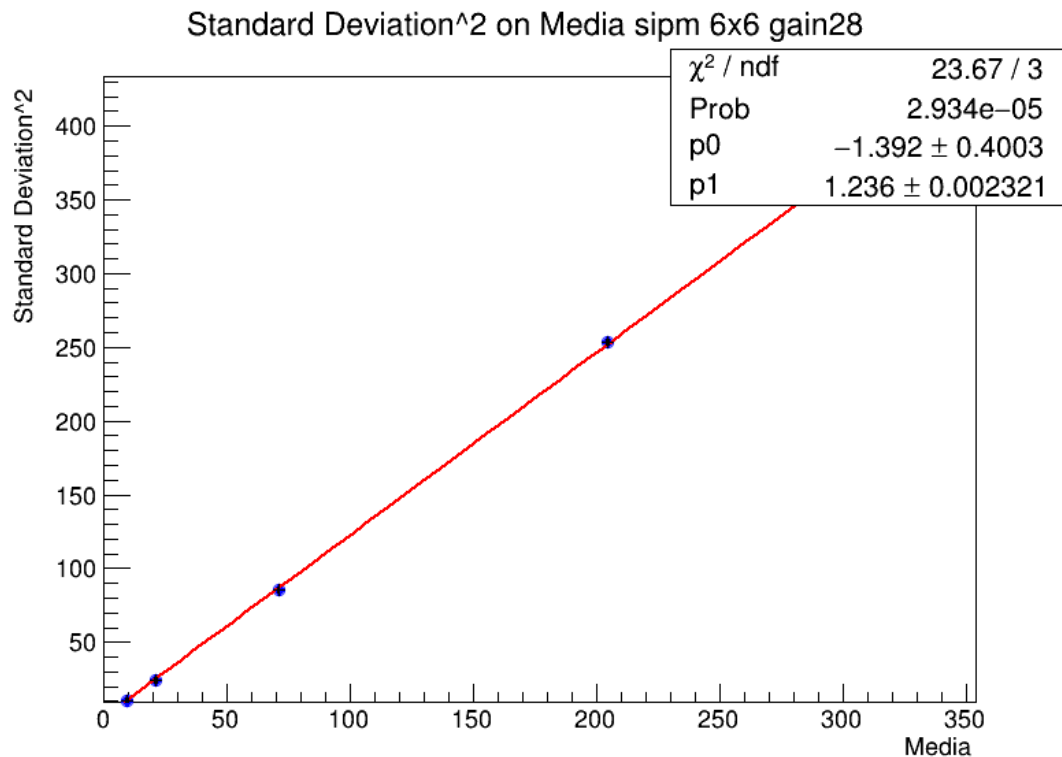
run_372 Max vs Peak Position sipm 6x6 Gain 28



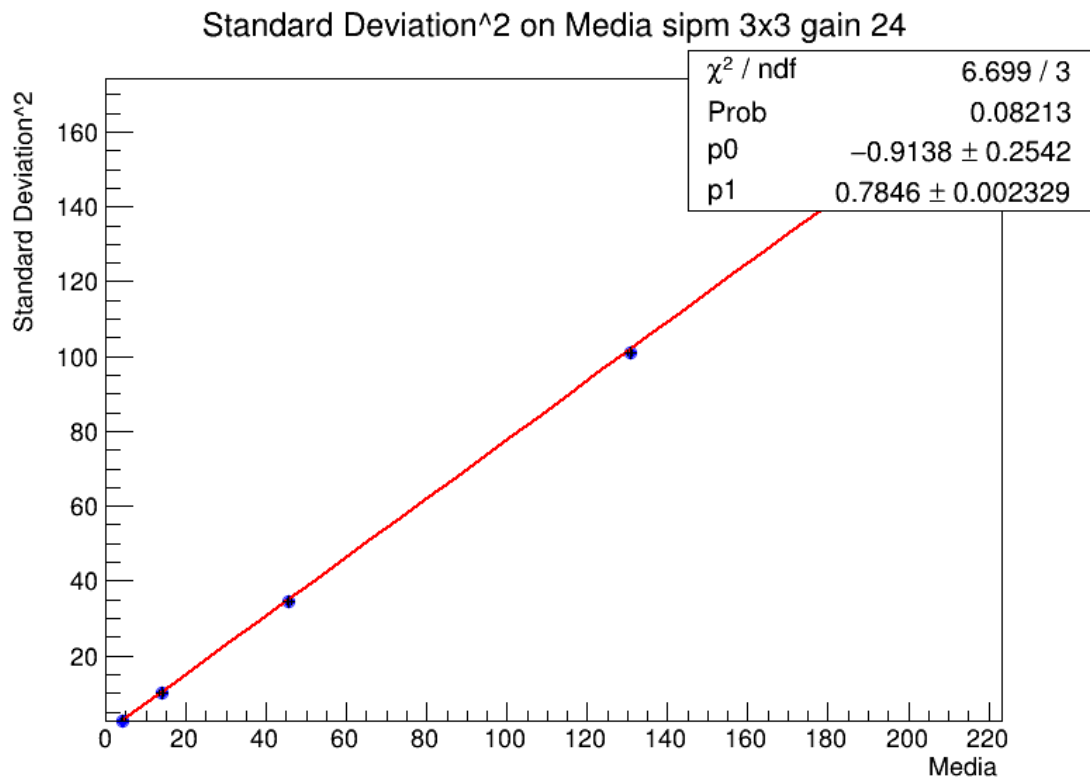
Standard Deviation^2 on Media sipm 6x6 gain28



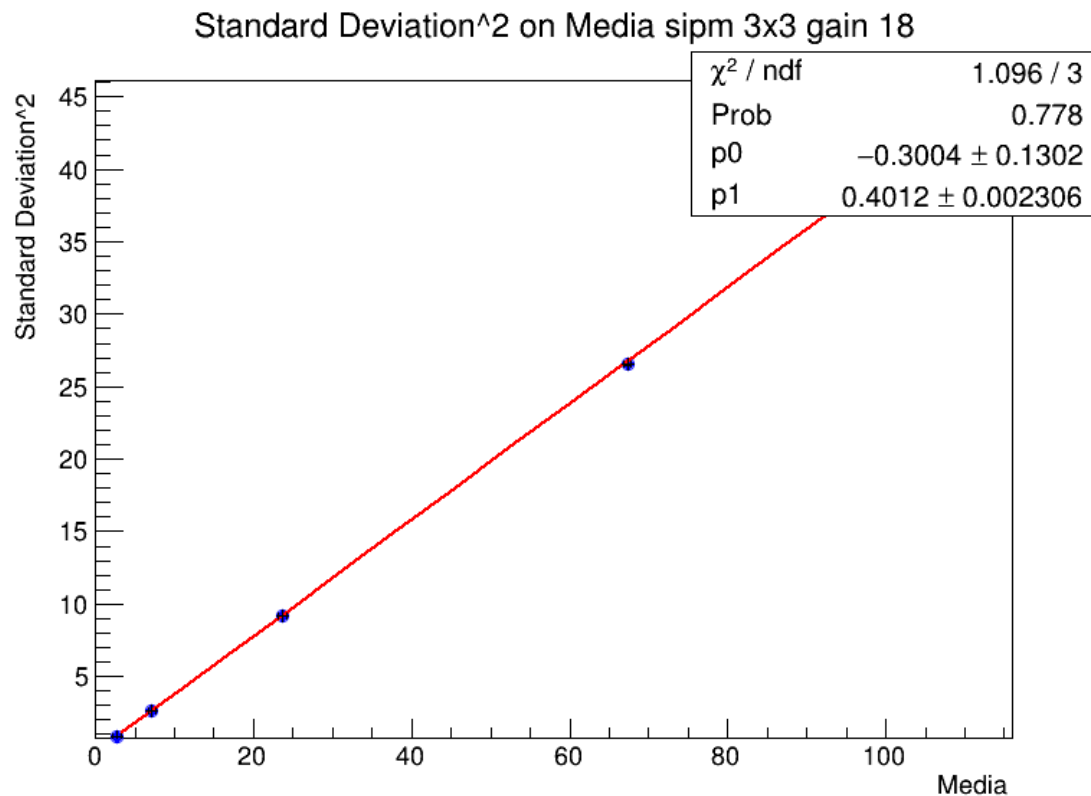
Calibrations SiPM 3x3 Gain 28 with other method



Calibrations SiPM 3x3 Gain 24 with other method



Calibrations SiPM 3x3 Gain 18 with other method



Calibrations SiPM 3x3 with passive preamp with other method

