Update 14/03/2025

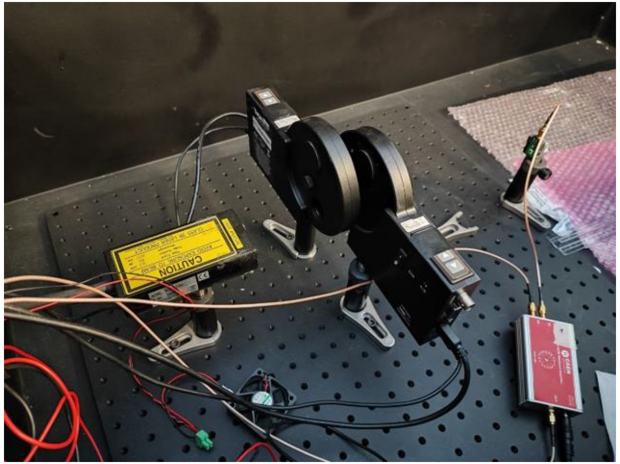
FCC Naples

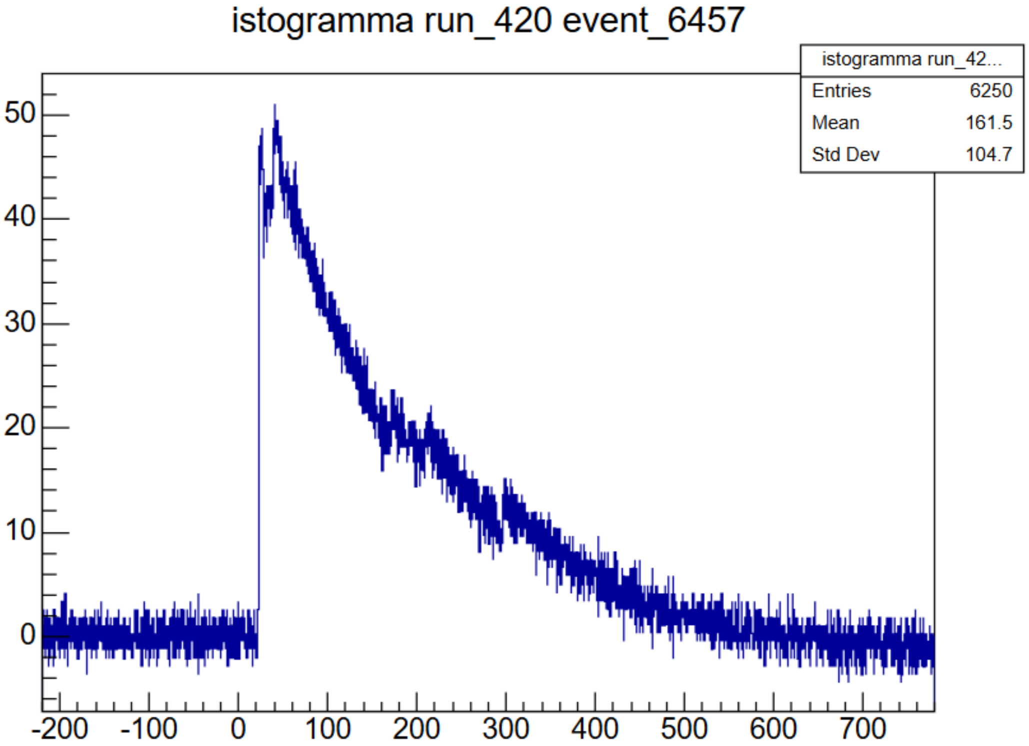
Work of:
Lucrezia Borriello (Istituto Nazionale di Fisica Nucleare Napoli)

SiPM 6x6 at Gain 28 Calibration with PLP Led

I tried to calibrate the 6x6 sipm with measurements taken with the PLP laser to see if they matched the calibrations made previously

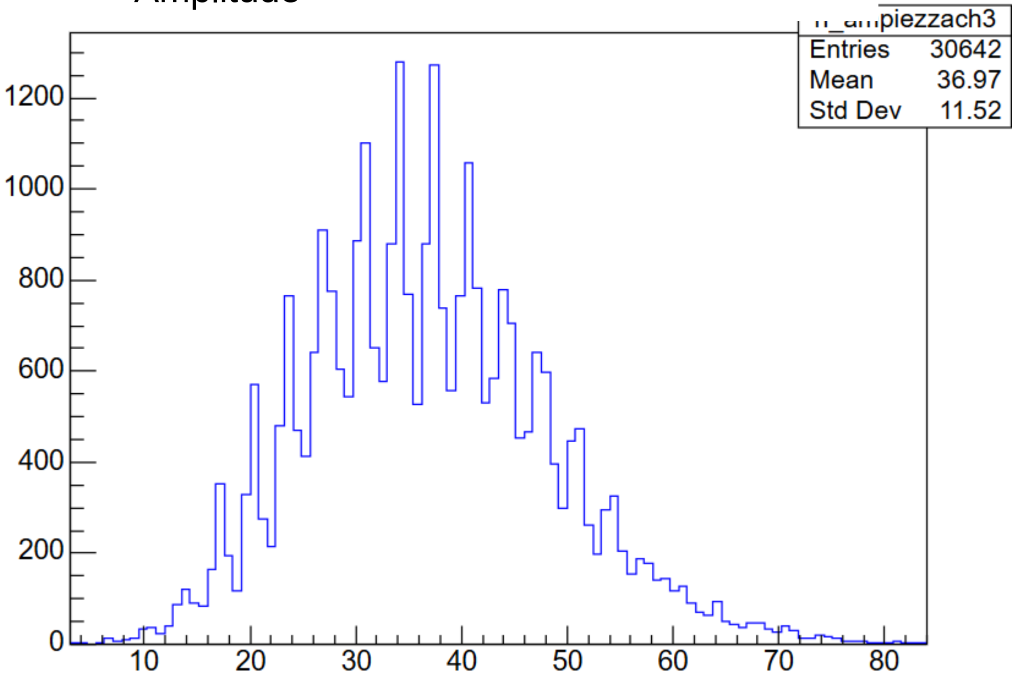
this waveform is the case where with the lens system I was able to put myself in a range of a few photons



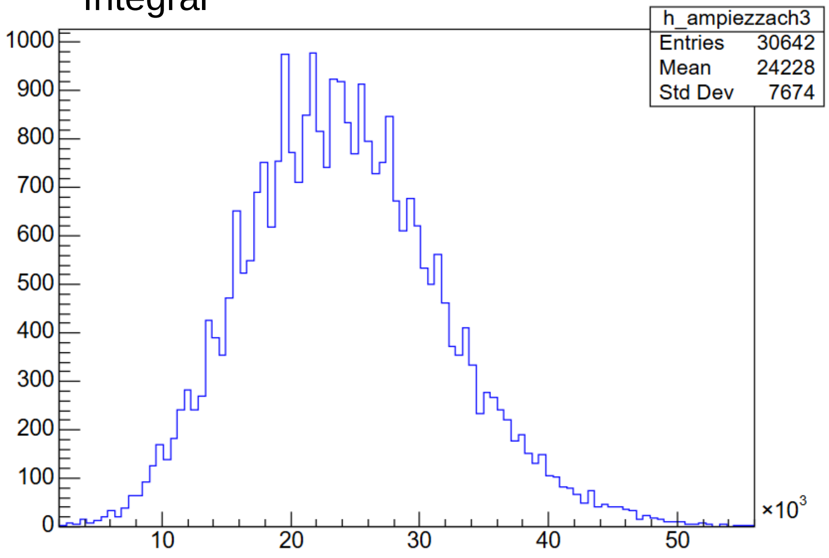


SiPM 6x6 at Gain 28 Calibration with PLP Led

Amplitude

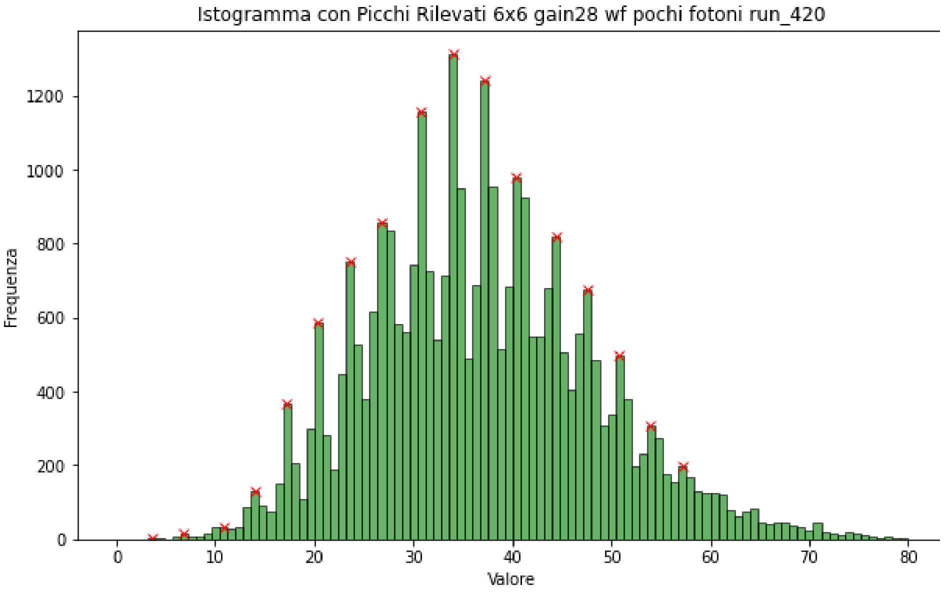


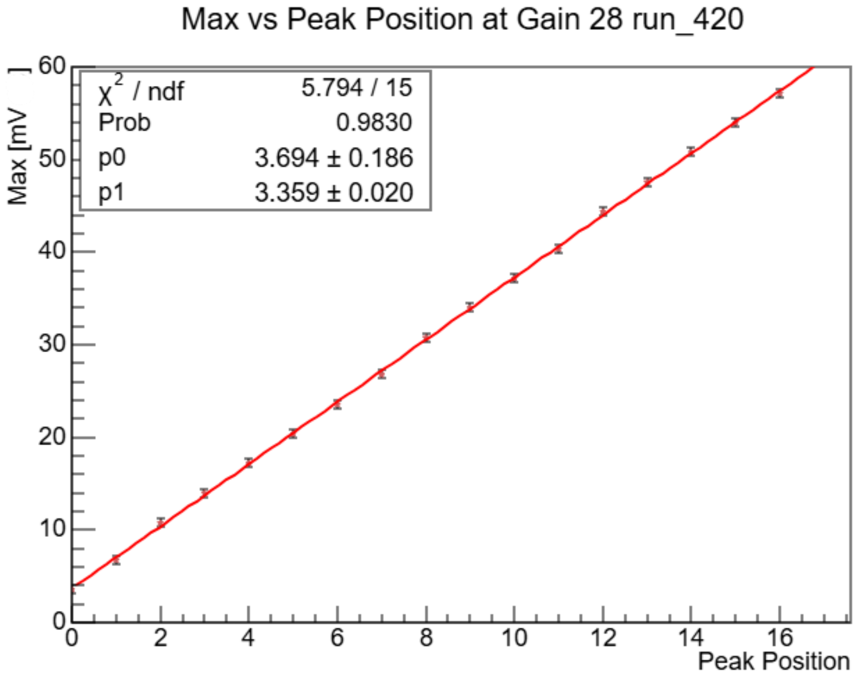
Integral



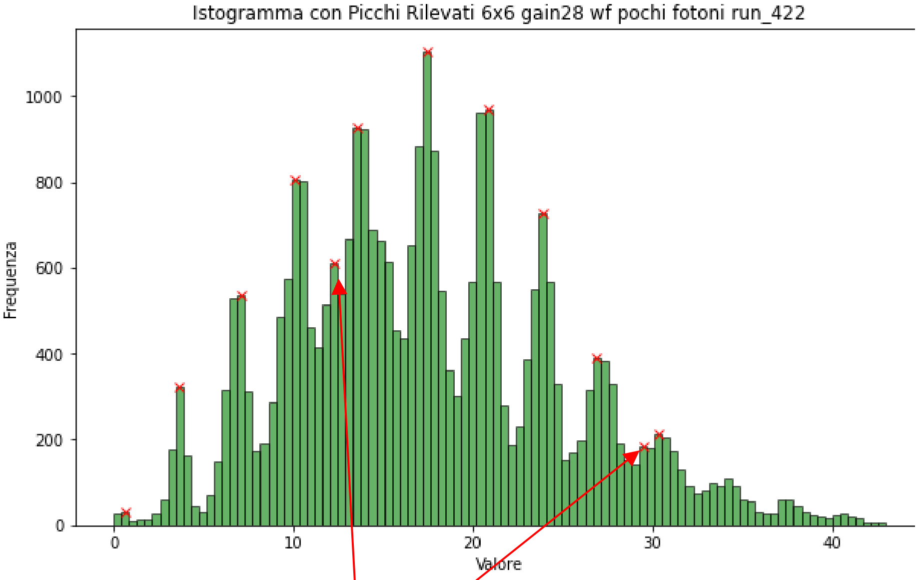
From this we understand that we can only derive a calibration from amplitudes and not from integrals, since with integrals we do not have a definition of peaks

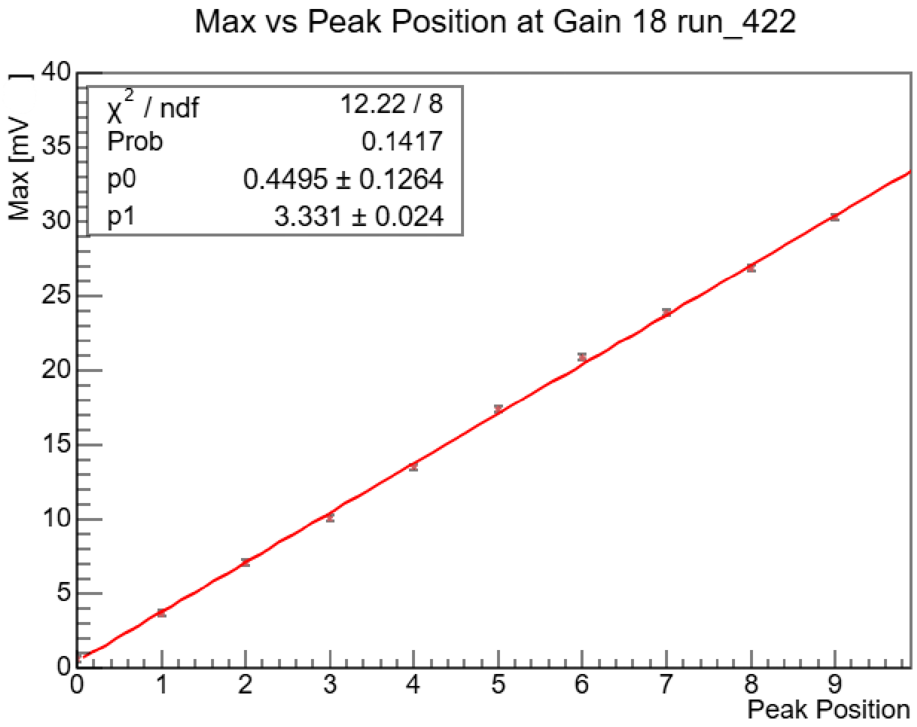
SiPM 6x6 at Gain 28 Calibration with PLP Led few photons and led power 15
Method A: pick id





SiPM 6x6 at Gain 28 Calibration with PLP Led with few and led power 6

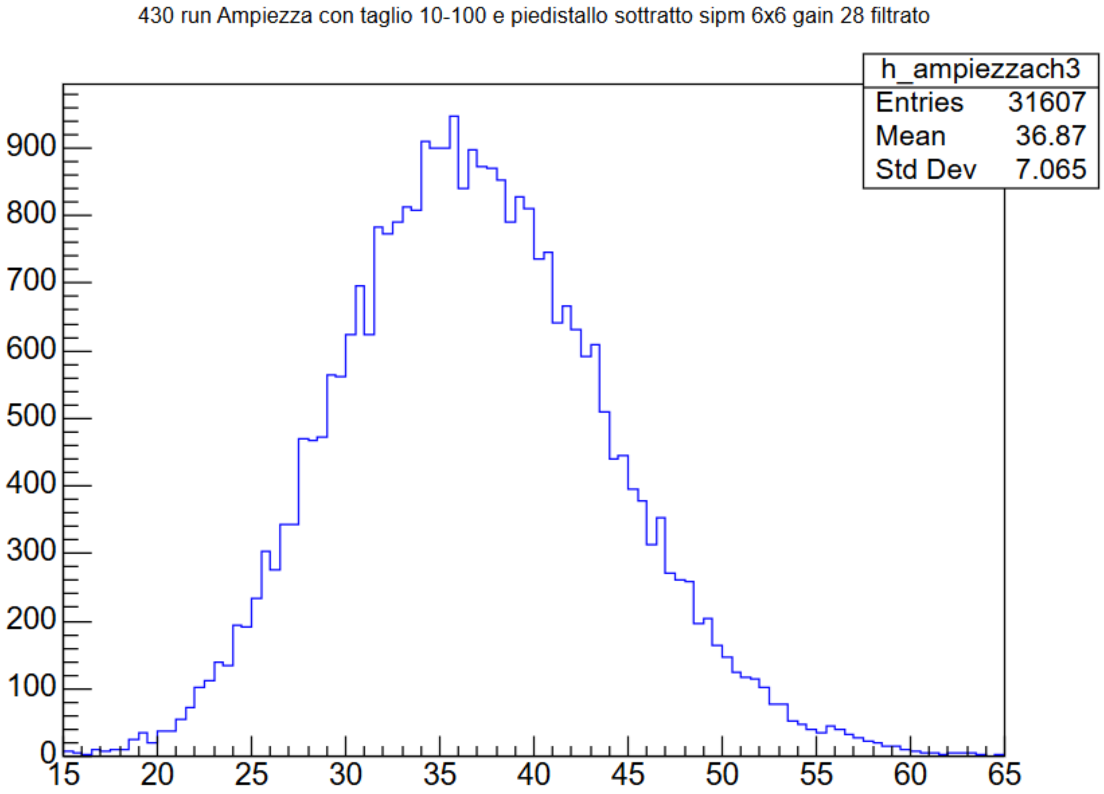




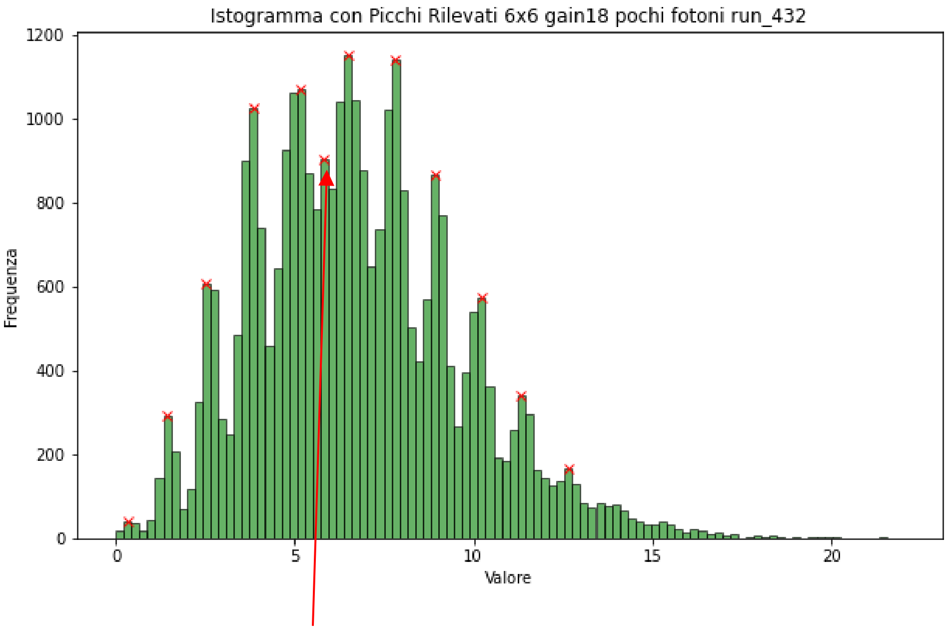
N.B. I deleted these points that were wrong

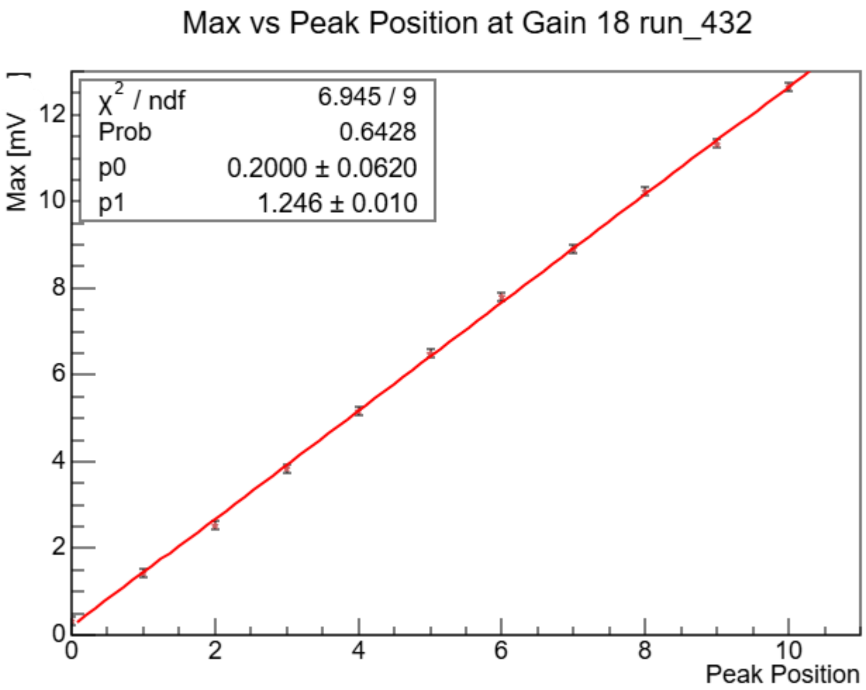
SiPM 6x6 at Gain 18 Calibration with PLP Led few photons and led power 15

In this case we are not able to find picks, even with stringent cuts



SiPM 6x6 at Gain 18 Calibration with PLP Led few photons and led power 6





N.B. I deleted this point which was wrong

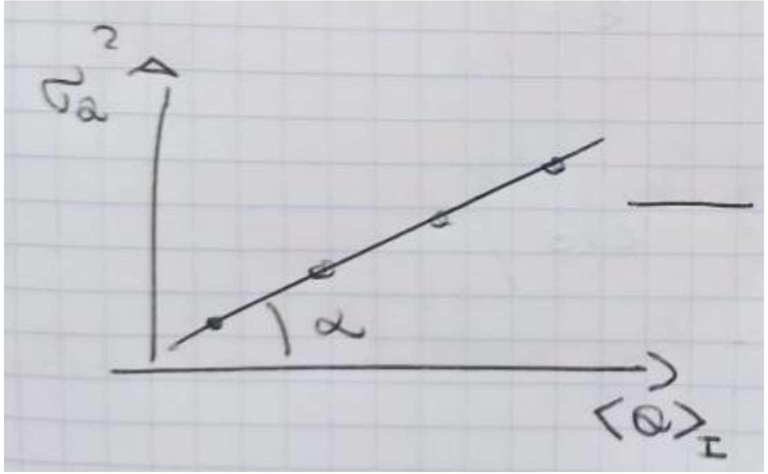
Calibrations SiPM 6x6 Gain 28 with other method

Another method is to base on the hypothesis that the n_{pe} follows a Poissonian statistic so we have that:

$$A = \alpha n_{pe} \qquad \langle A \rangle = \alpha \langle n_{pe} \rangle = \alpha\mu$$

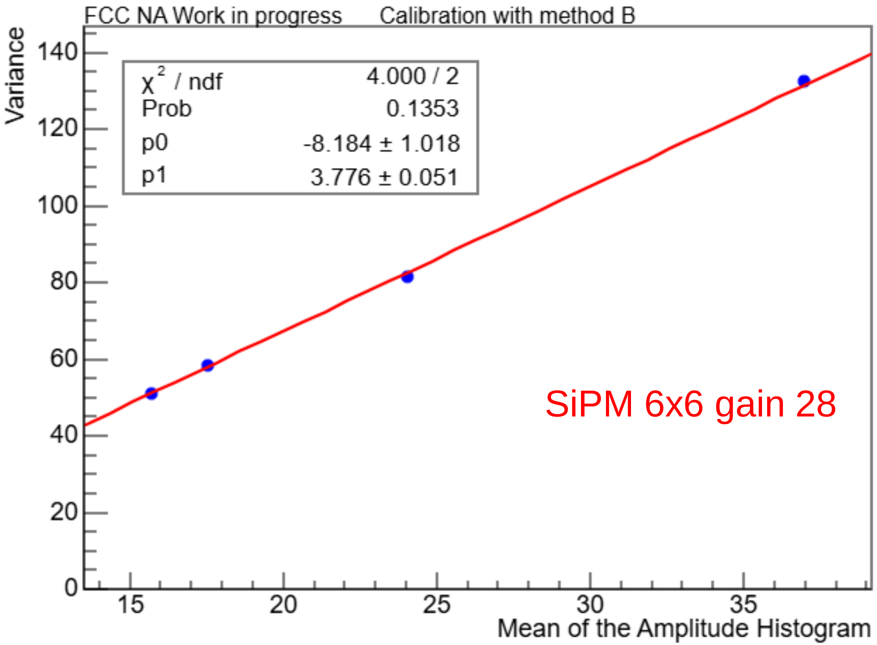
$$\sigma_A = \alpha\sigma_{pe} = \alpha\sqrt{\mu} = \sqrt{\alpha}\,\sqrt{\langle A \rangle}$$

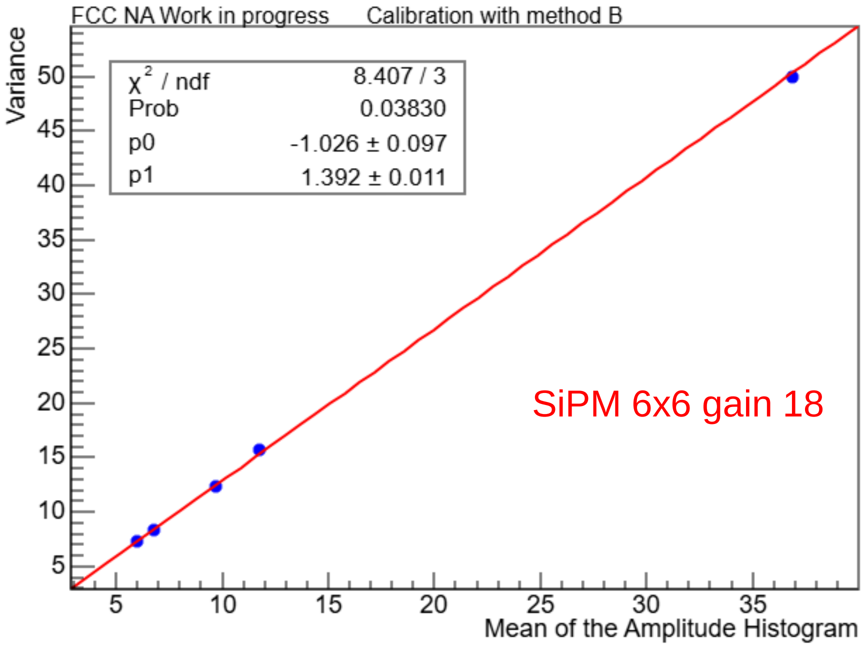
$$\frac{\sigma_A^2}{\langle A \rangle} = \alpha$$



In this case we measure at different power of the led

SiPM 6x6 Calibration with PLP Led few photons with method B





From Amplitude to Charge

From the fit of the amplitude we get: $A = p_0 + p_1 n_{pe}$

To have the conversion in charge, we fit the downslope front of our waveform.

We fit with $e^{-\frac{x}{\tau}}$, and we get factor τ.

Taking as a function:

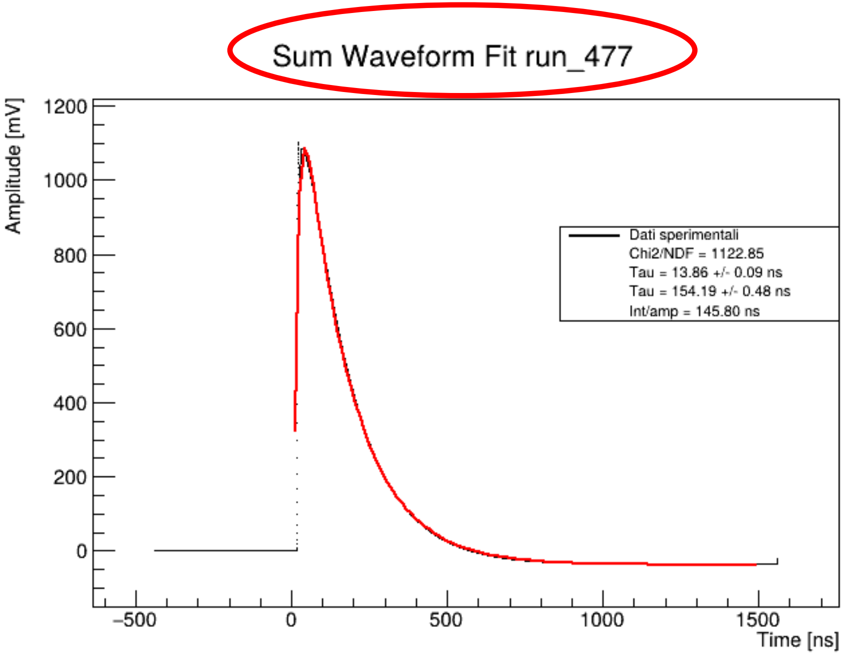
$$f(x) = A\, e^{-\frac{x}{\tau}}$$

And going to do the integral

$$I=\int_0^{3\tau} f(x)dx = \underbrace{A\tau(1-e^{-3})}_{\alpha}$$

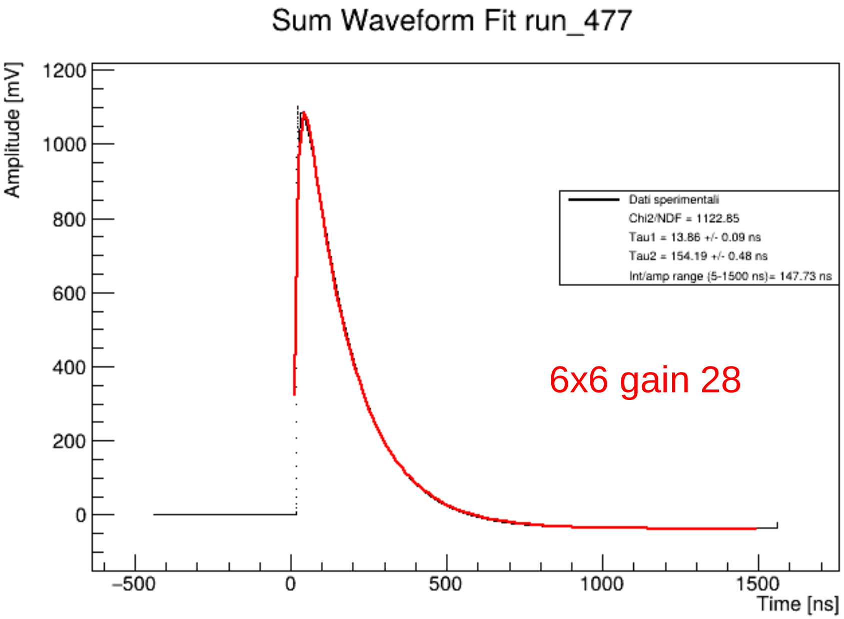
We get the factor that we need to switch from amplitude to charge

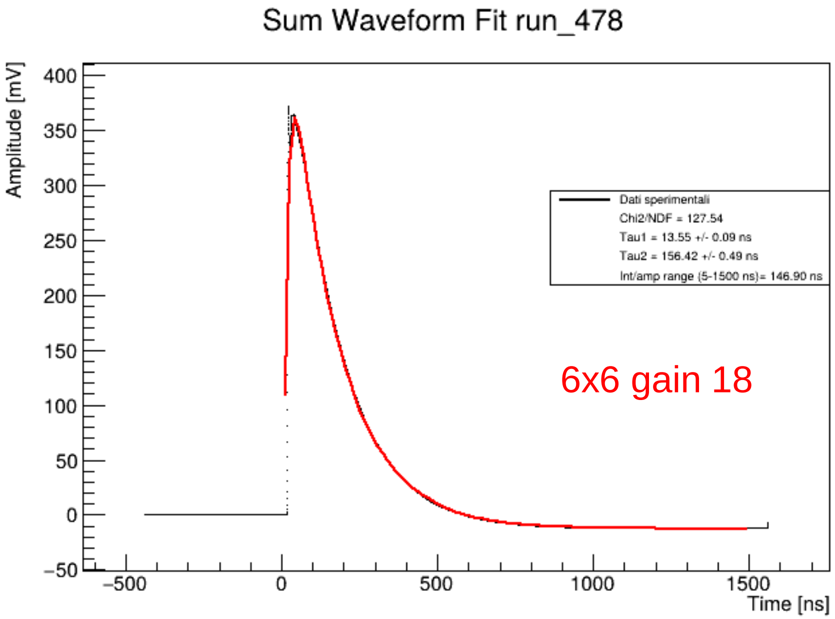
In this case I use the Sum of the waveform



So our conversion in photon number is $A = p_0 + \alpha p_1 n_{pe}$

SiPM 6x6 Calibration with PLP Led few photons fit of sumwaveforms





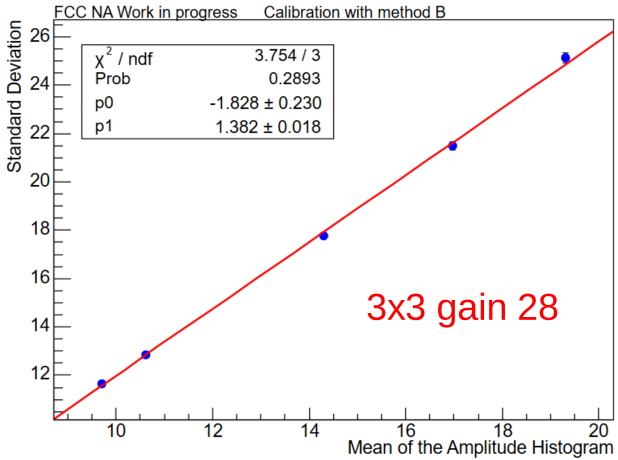
Summary SiPM 6x6 Calibration with PLP Led with method A

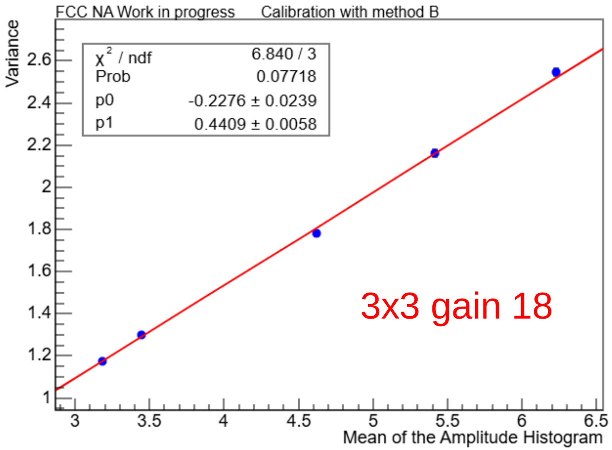
SiPM	Gain	Gain amplitude conversion	Power	$p_0 + error$	$p_1 + error$ [mV/n_{pe}]	$\tau(ns) + error(ns)$	conversion factor charge $\tau(1-0{,}0497)$	Integral/amplitude
6x6	28	25,12	15	3,7 ±0,2	3,36±0,02	154,19±0,48	146,53	147,73
6x6	28		6	0,45±0,1	3,33±0,02			
6x6	18	7,94	15	-	-	156,42±0,49	148,64	146,90
6x6	18		6	0,20±0,06	1,25±0,01			

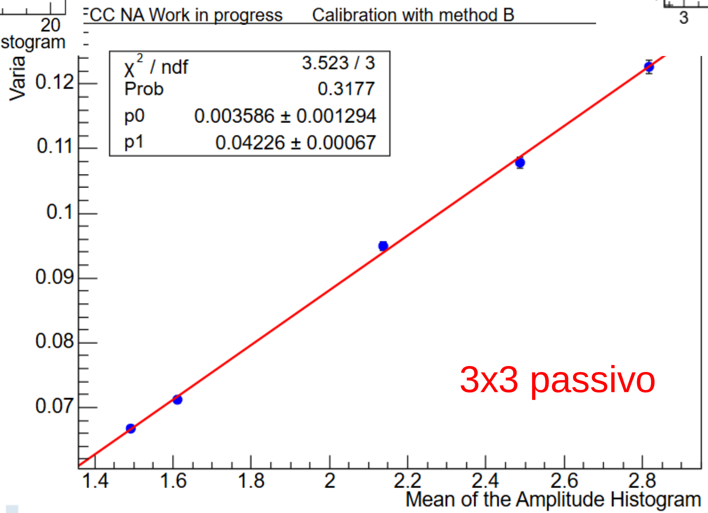
Summary SiPM 6x6 Calibration with PLP Led with method B

SiPM	Gain	**Gain amplitude conversion**	$p_0 + error$	$p_1 + error$ [mV/n_{pe}]	$\tau(ns) + error(ns)$	conversion factor charge $\tau(1-0{,}0497)$	Integral/amplitude
6x6	28	25,12	-8±1	3,78±0,05	154,19±0,48	146,53	147,73
6x6	18	7,94	-1,0±0,1	1,39±0,01	156,42±0,49	148,64	146,90

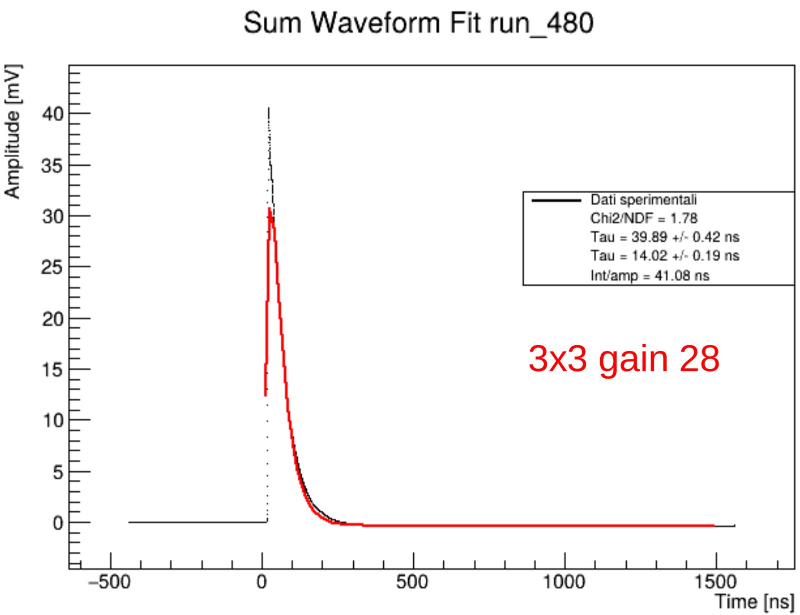
SiPM 3x3 Calibration with PLP Led few photons with method B

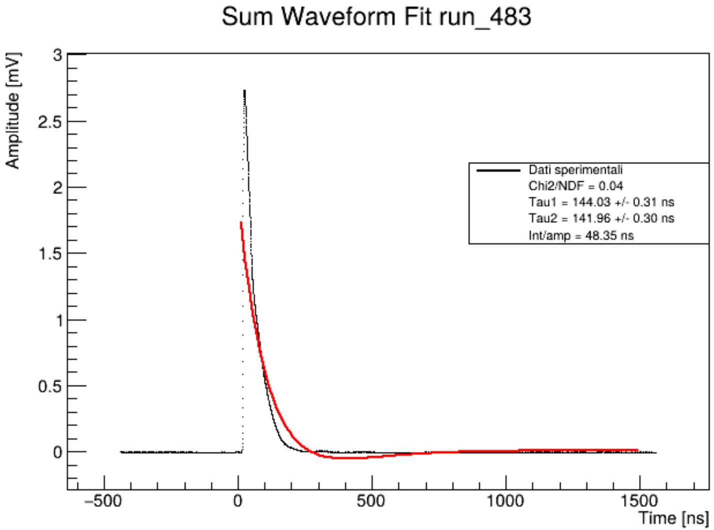






SiPM 3x3 Calibration with PLP Led few photons fit of sumwaveforms

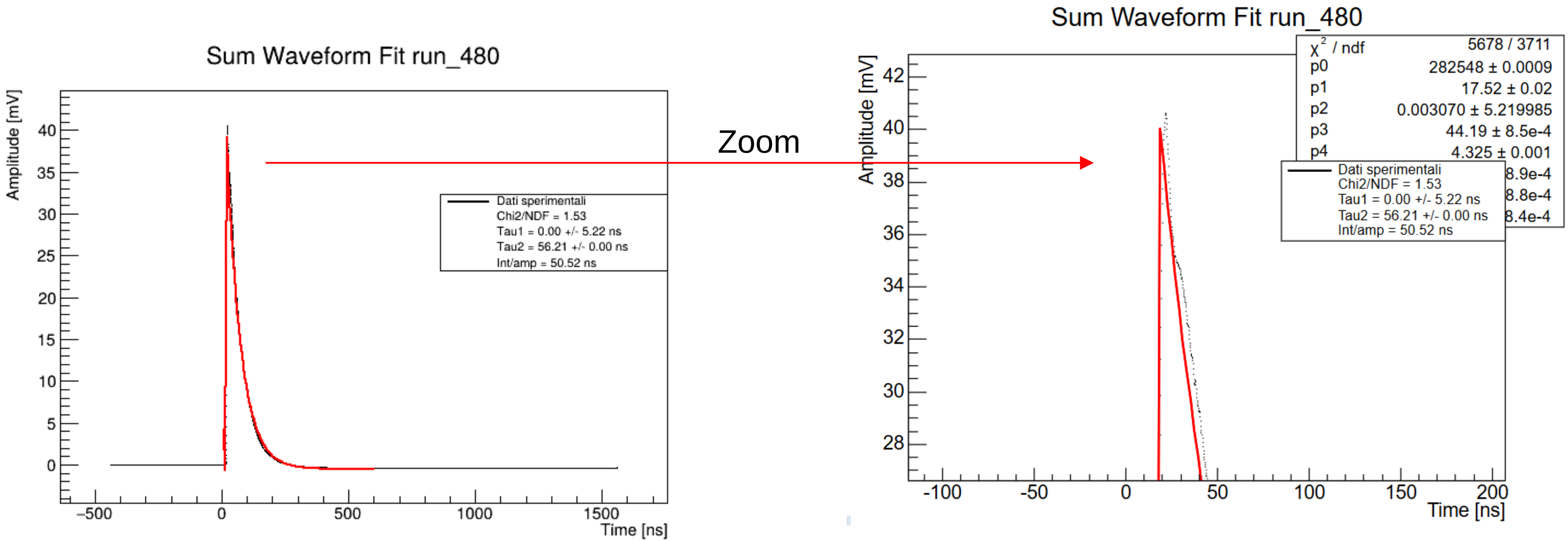




[0]*exp(-x/[1]) + [2]*exp(-x/[3])+[4]

Last week I had problems fitting the waveform for the various gain of the sipm 3x3, in this case I was using a double exponential+constant, but this was obviously not right

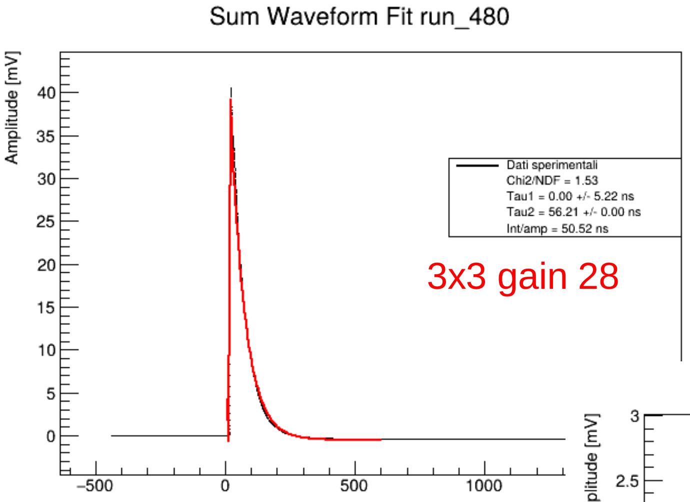
SiPM 3x3 Calibration with PLP Led few photons fit of sumwaveforms

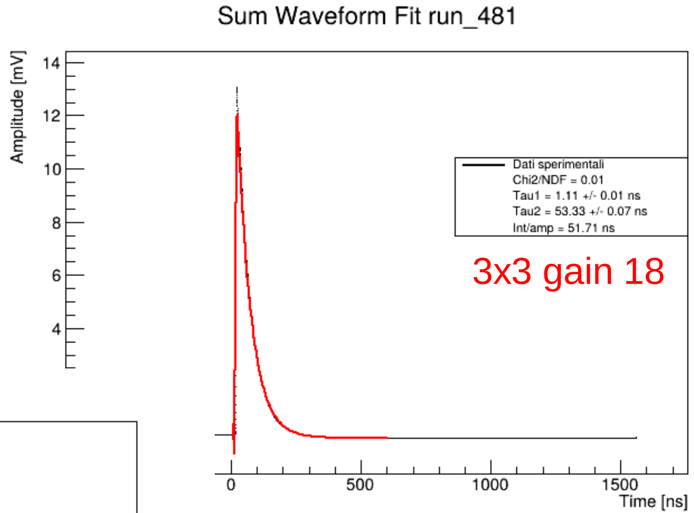


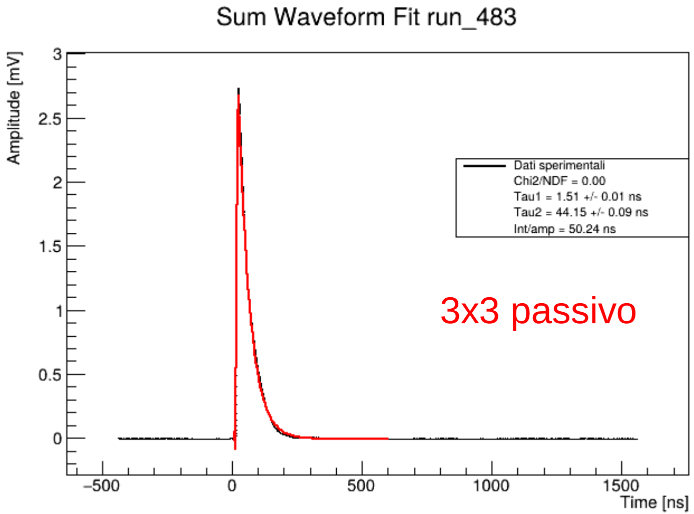
(1/(1+[0]*TMath::Exp(-(x-[1])/[2]))*[3] + [4]*TMath::Exp(-(x-[5])/[6]) + [7])

To try to solve the problem with the fit I changed my fit function from a double exponential to a sigmoid+exponential+ constant

SiPM 3x3 Calibration with PLP Led few photons fit of sumwaveforms







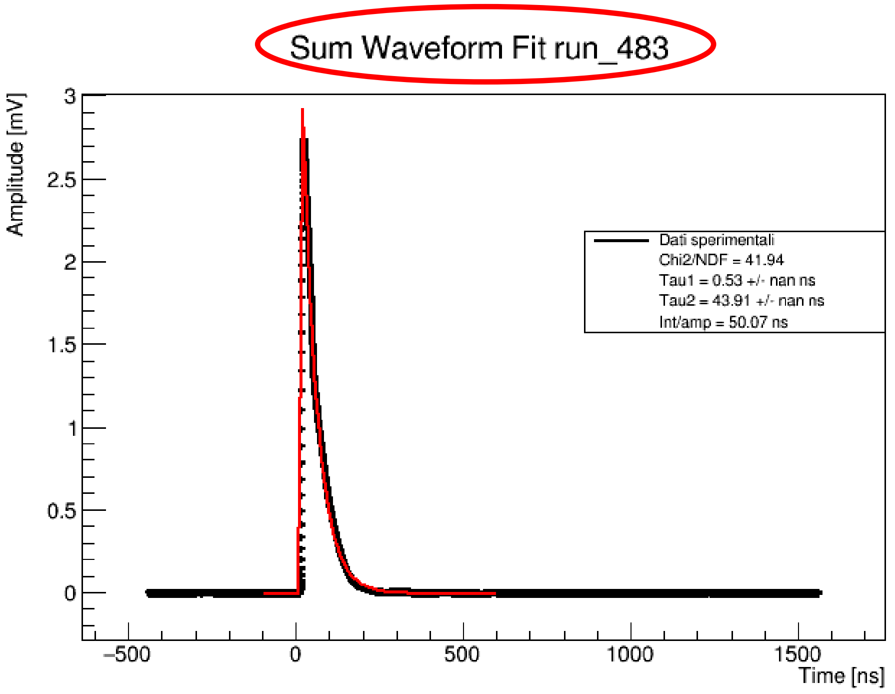
Range Fit 5-600

All fits obtained using as function sigmoid+exponential+ constant

Summary SiPM 3x3 Calibration with PLP Led with method B range fit 5-600

SiPM	Gain	**Gain amplitude conversion**	$p_0 + error$	$p_1 + error$ [mV/n_{pe}]	$\tau(ns) + error(ns)$	conversion factor charge $\tau(1 - 0{,}0497)$	Integral/amplitude
3x3	28	25,12	-1,8±0,2	1,38±0,02	56,21±0,00	53,41	50,52
3x3	18	7,94	-0,23±0,02	0,441±0,006	53,33±0,07	50,67	51,71
3x3	-	-	0,004±0,001	0,0423±0,0007	44,15±0,09	41,95	50,24

SiPM 3x3 Calibration with PLP Led few photons fit of sumwaveforms

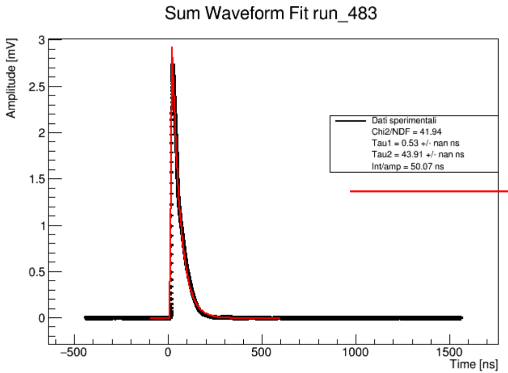


-Range Fit -100-600

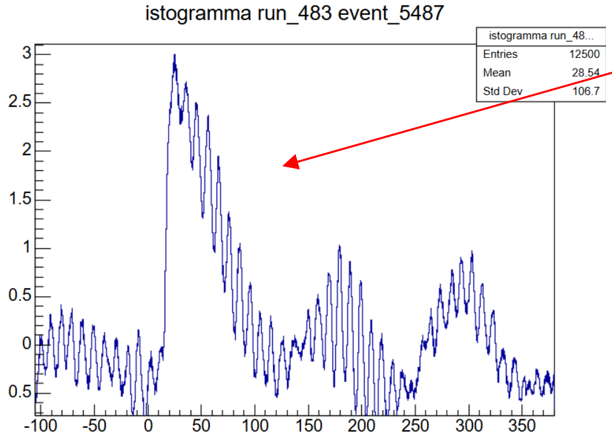
-The fit is obtained by using a sigmoid+exponential+decreasing exponential (which simulates the behaviour of the RC) as a trait function on the Sum of all wf

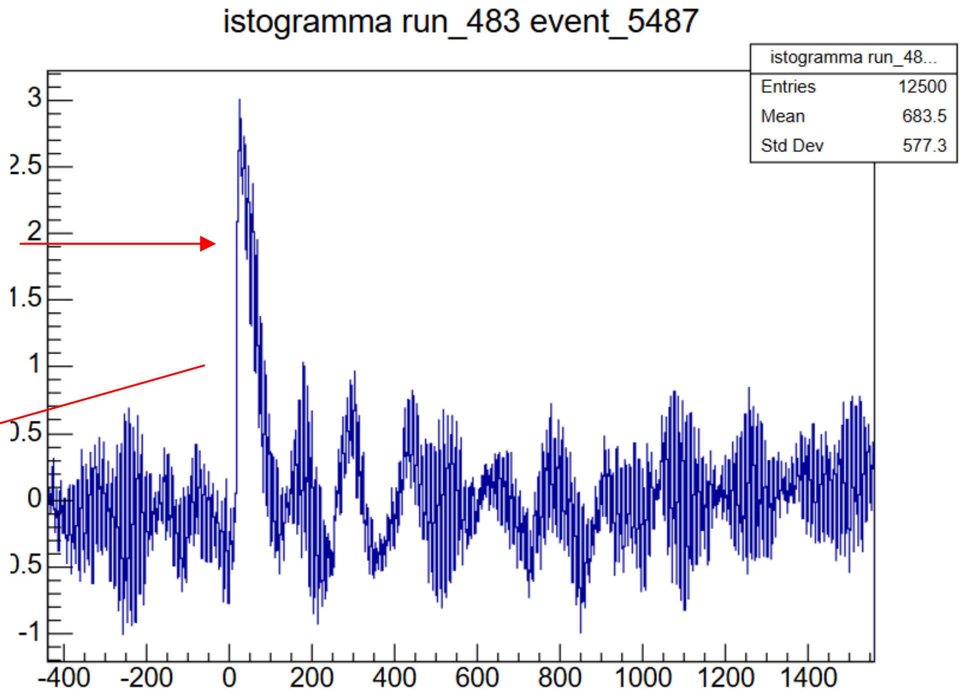
```
(([0]/(1+TMath::Exp(-(x-[1])/[2]))+[3])*(x<=[1]) + ([6]*TMath::Exp(-(x-[1])/[4])+[3]-TMath::Exp(-(x-[1])/[5]))*(x>[1]))
```

SiPM 3x3 Calibration with PLP Led few photons fit of sumwaveforms

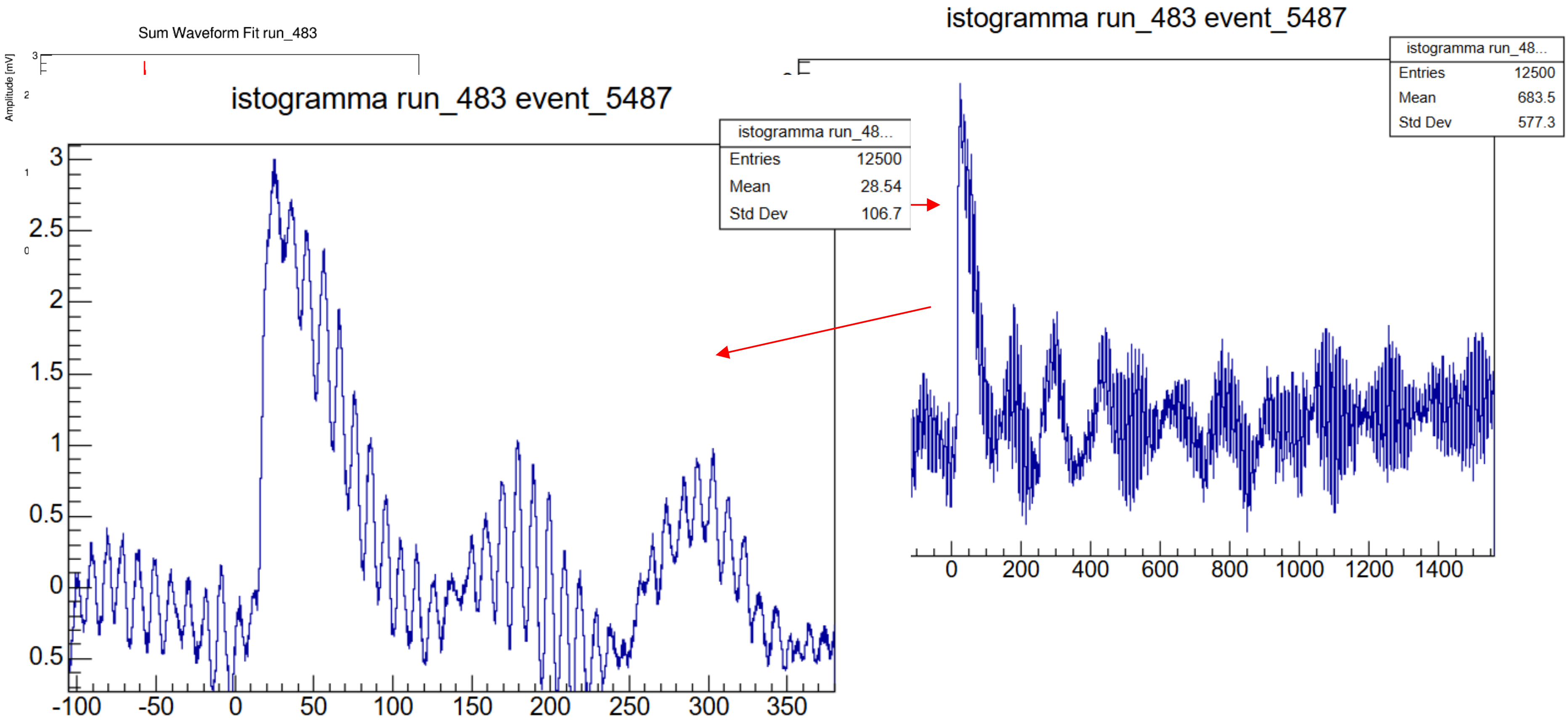


If we look not at the sum of the wf but at the wf of the individual event then we observe something like





SiPM 3x3 Calibration with PLP Led few photons fit of sumwaveforms



SiPM 3x3 Calibration with PLP Led few photons fit of sumwaveforms

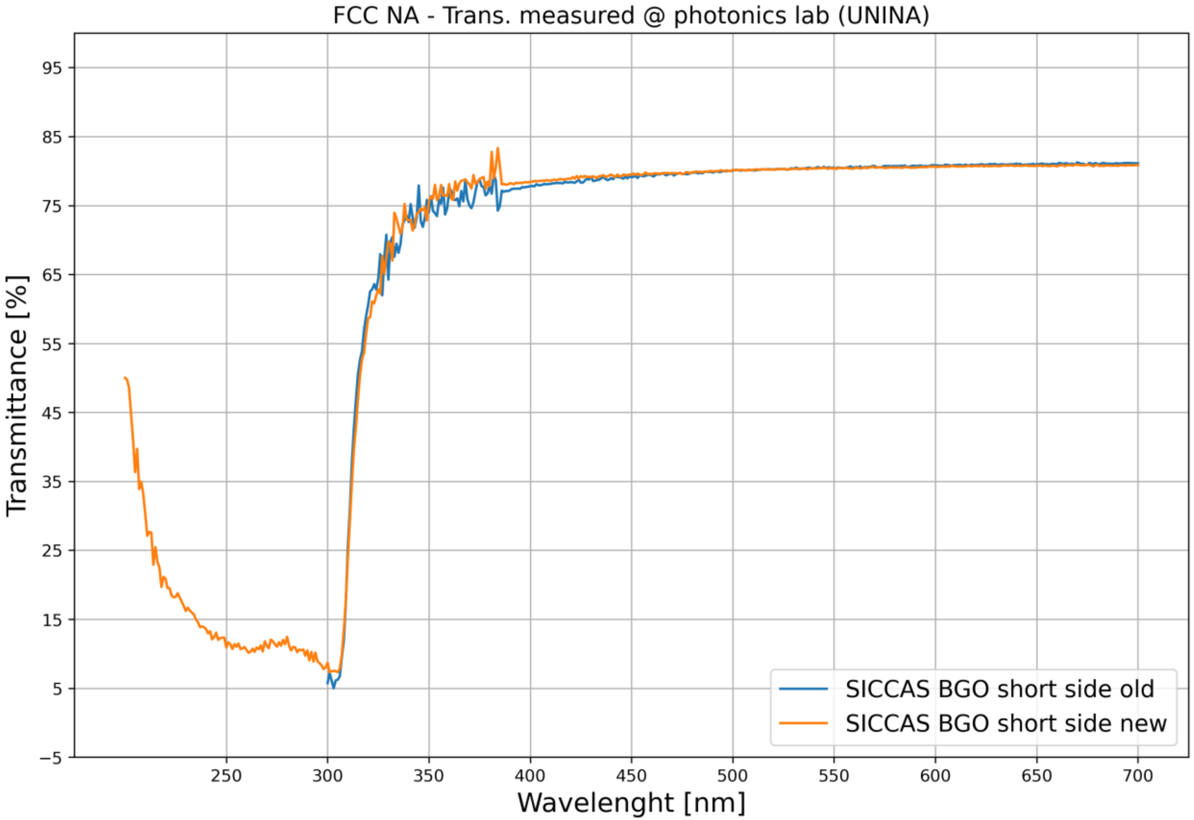
NEXT STEPS

-Perform a fit on single event and not on the sum of wf
-Mabye perform a fit on a single event with a moving average to reduce noice

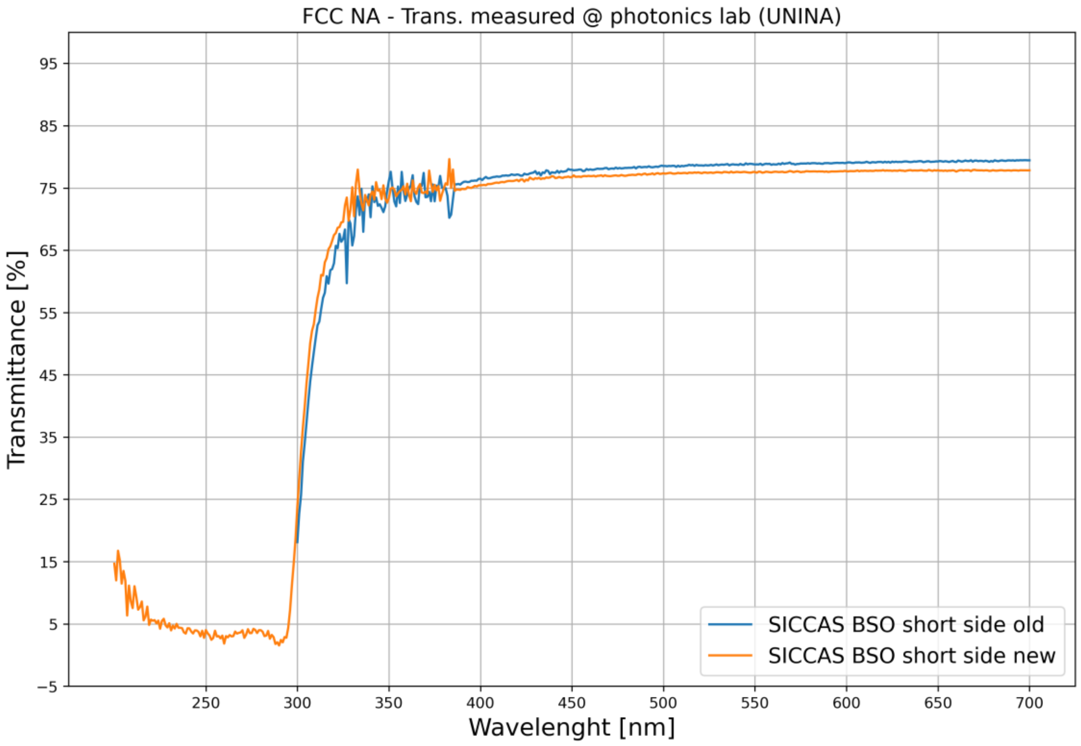
Crystal measurements in Sasso’s laboratory Part 2

I took measurements on the crystals in the Sasso laboratory with a range of 200-700 nm, in the plot there are the measurements taken on 24 February (old) and the new measurements taken on 28 February (new)

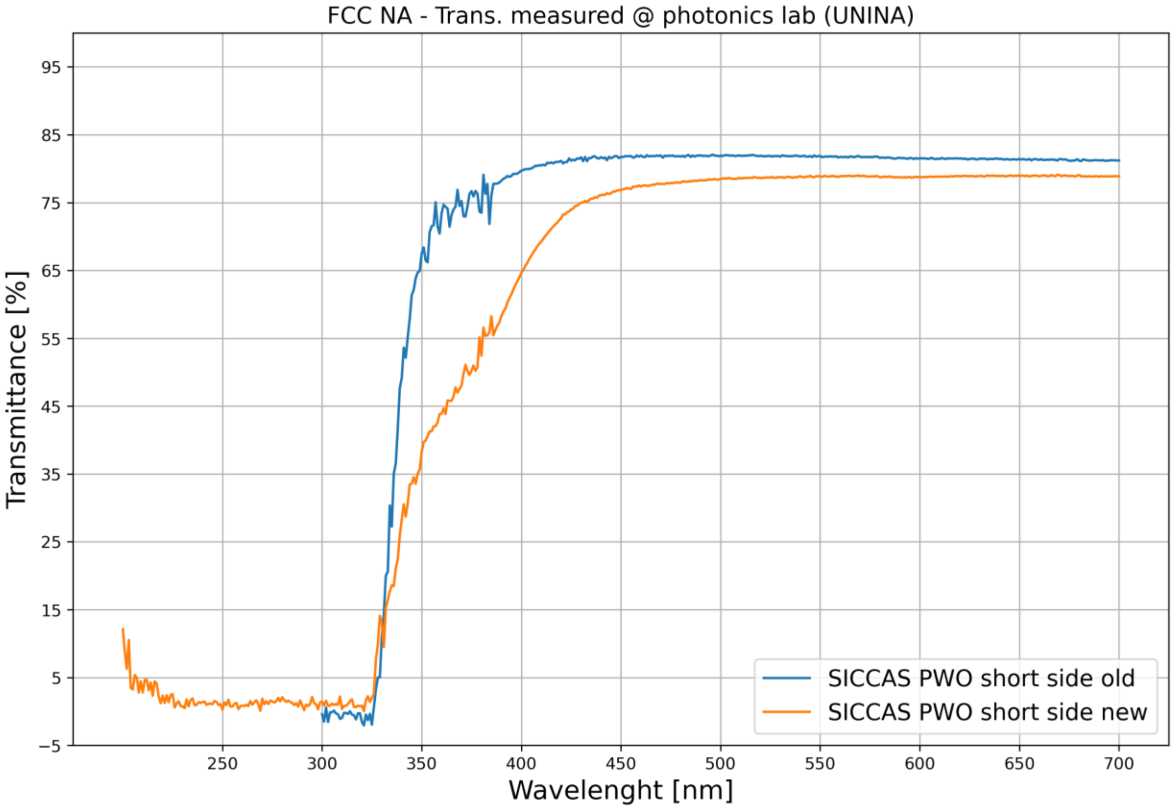
Lambda 35



Crystal measurements in Sasso's laboratory Part 2



Crystal measurements in Sasso's laboratory Part 2



Backup Slides

Summary of PLP Measurements

20/01/2025	sipm 6x6	preamp 2			
misure led PLP	run	gain	configurazione le	power	t
	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	t
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 fotor	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	444	28	1x2	15	
undershoot	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	

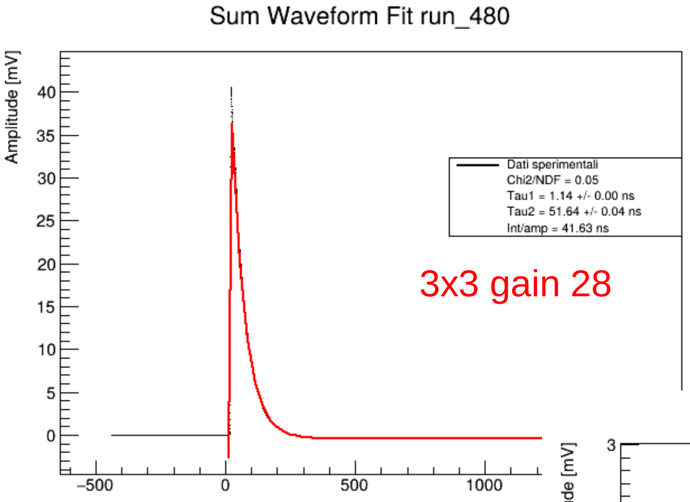
Summary SiPM 6x6 Calibration with LED CAEN

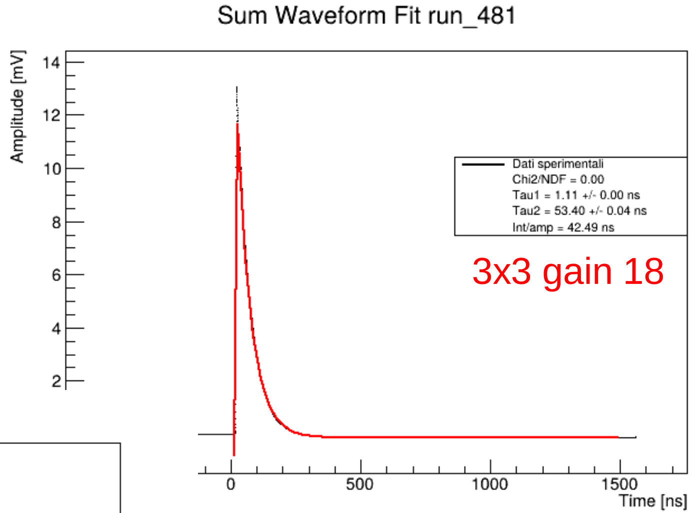
SiPM	Gain	**Gain amplitude conversion**	Method	$p_0 + error$	$p_1 + error$ [mV/n_{pe}]	$\tau(ns)$	conversion factor charge $\tau(1-0{,}0497)$
6x6	28	25,12	A	0,4±0,1	3,46±0,02	132,26	125,7
6x6	28		B	15±1	3,49±0,006		
6x6	18	7,94	A	1,31±0,06	1,161±0,005	120,72	114,7
6x6	18		B	3,0±0,4	1,156±0,003		
6x6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

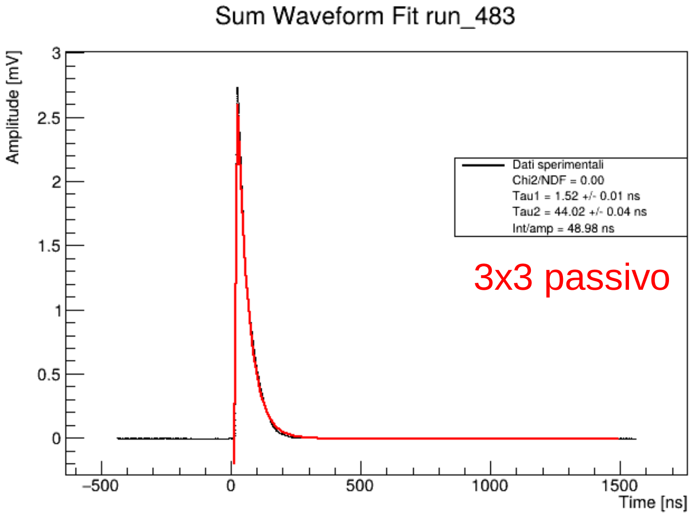
Summary SiPM 3x3 Calibration with LED CAEN

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

SiPM 3x3 Calibration with PLP Led few photons fit of sumwaveforms







Range Fit 5-1500

Summary SiPM 3x3 Calibration with PLP Led with method B range fit 5-1500

SiPM	Gain	**Gain amplitude conversion**	$p_0 + error$	$p_1 + error$ [mV/n_{pe}]	$\tau(ns) + error(ns)$	conversion factor charge $\tau(1 - 0{,}0497)$	Integral/amplitude
3x3	28	25,12	-1,8±0,2	1,38±0,02	51,60±0,04	49,03	41,63
3x3	18	7,94	-0,23±0,02	0,441±0,006	53,40±0,04	50,74	42,49
3x3	-	-	0,004±0,001	0,0423±0,0007	44,02±0,04	41,83	48,98

Gain conversion factor at various temperatures

$$V_{OV}(26°C) = V_{OP}(25°C) - V_{BD}$$

$$V_{BD}(T°) = V_{BD}(25°) + 0{,}034\frac{V}{°C}\ \delta T$$ ⟹ This is in case of temperature increase from 25°C, or in case of temperature decrease ⟹ $$V_{BD}(T°) = V_{BD}(25°) - 0{,}034\frac{V}{°C}\ \delta T$$

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

$$G(23°C) = \alpha V_{OV}(23°C)$$

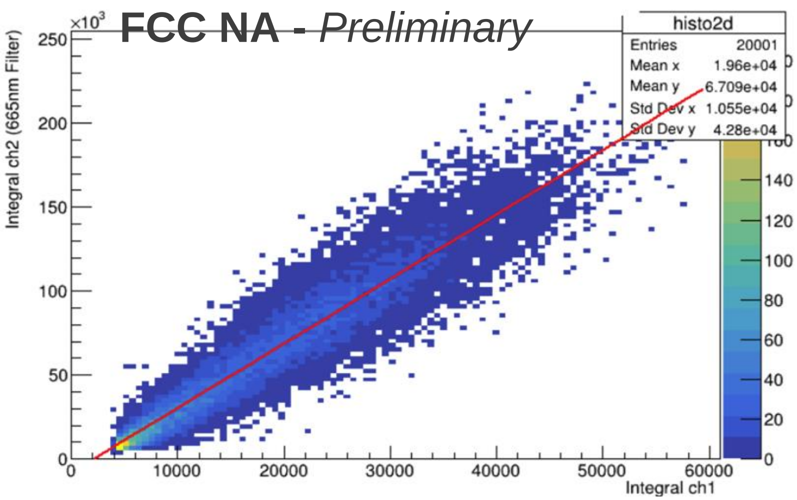
We then have the 26°C gain and we want to know how much is the gain at 23°C:

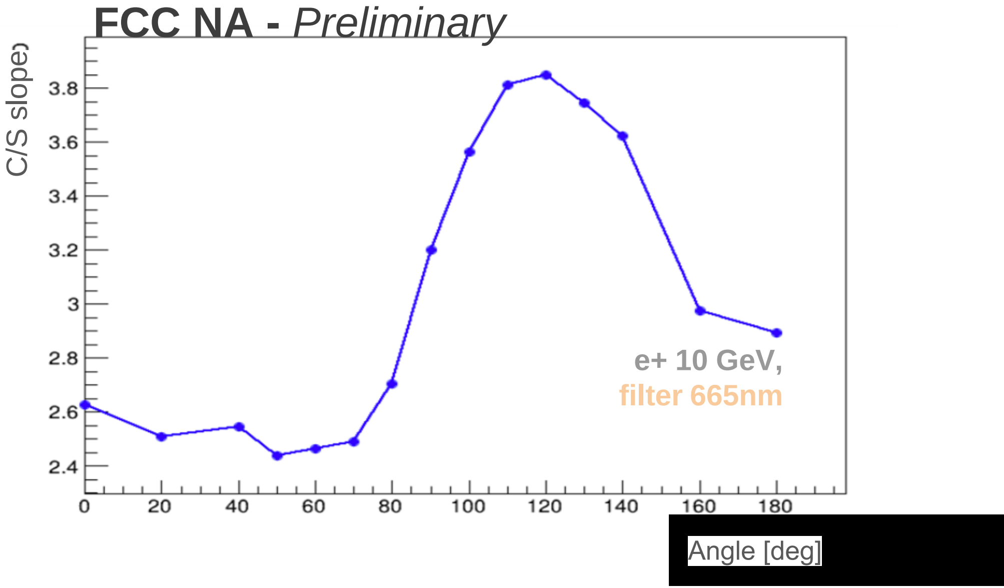
SiPM	$V_{OP}(V)$ tabulated 25°C	$V_{BD}(V)$ tabulated 25°C	V_{OV}(26°)	G(26°C)	α	V_{OV}(23°)	V_{BD}(23°)	G(23°C)
6x6	40,7	38	2,67	3,461	1,30	2,77	37,93	3,59
3x3	44	39	4,97	1,236	0,25	5,07	38,93	1,26

Study of C/S Variation in angular scan with PWO

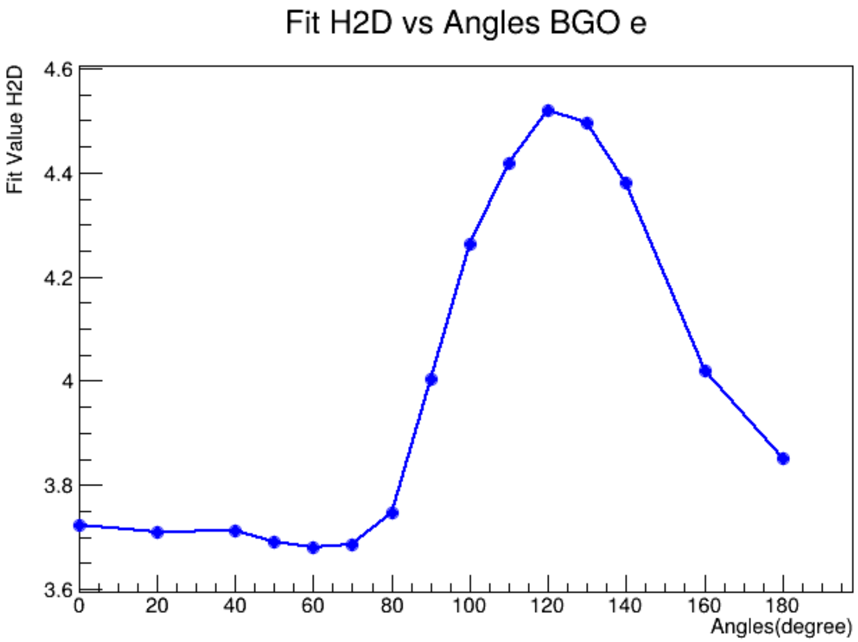
- We studied the 2D histogram of the integrals of channel with the filter dominated by contribution cherenkov on the integral of channel without filter dominated by scintillation.

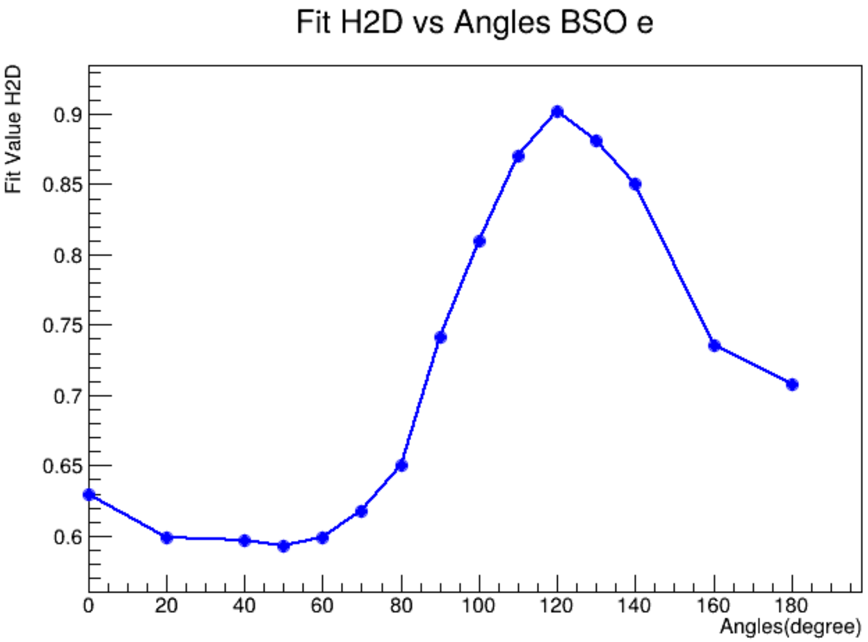
- Then we performed a linear fit, since if there were only scintillation the slope would always be equal depending on the angle. I have done this for all the runs of the angular scan





Study of C/S Variation in angular scan with BGO and BSO





Setup:

- SiPM Hamamtsu S14160-6050HS:
  -photosensitive area 6x6 mm^2
  -number of pixels= 14331

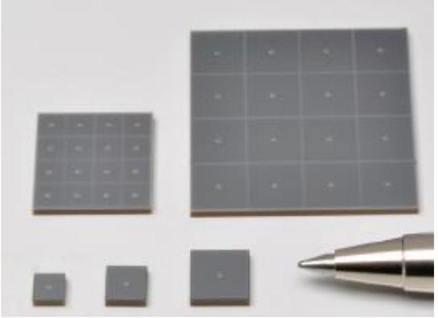
- SiPM Hamamatsu S14160-3010PS:
  - photosensitive area 3x3 mm^2
  - number of pixels= 89984

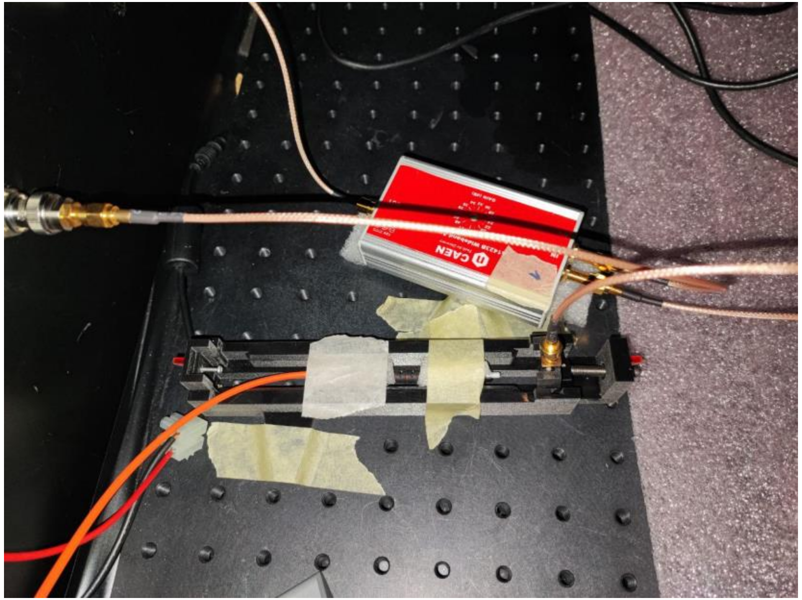
- Preamplifier CAEN serie A1423B:
  -Gain range from +18dB to +54dB

- CAEN Led Driver SP5601

- CAEN NIM HV Power supply module N1419ET
  - 4 Ch Reversible 500 V/200 µA

- Tektronix Oscilloscope MSO66B:
  - 1,5 GHz Bandwidth
  - 6 Analog channels





SiPM 6x6 at Gain 28 Calibration method A)

From the fit of the amplitude we get: $A = p_0 + p_1 n_{pe}$

To have the conversion in charge, we fit the downslope front of our waveform.

We fit with $e^{-\frac{x}{\tau}}$, and we get factor τ.

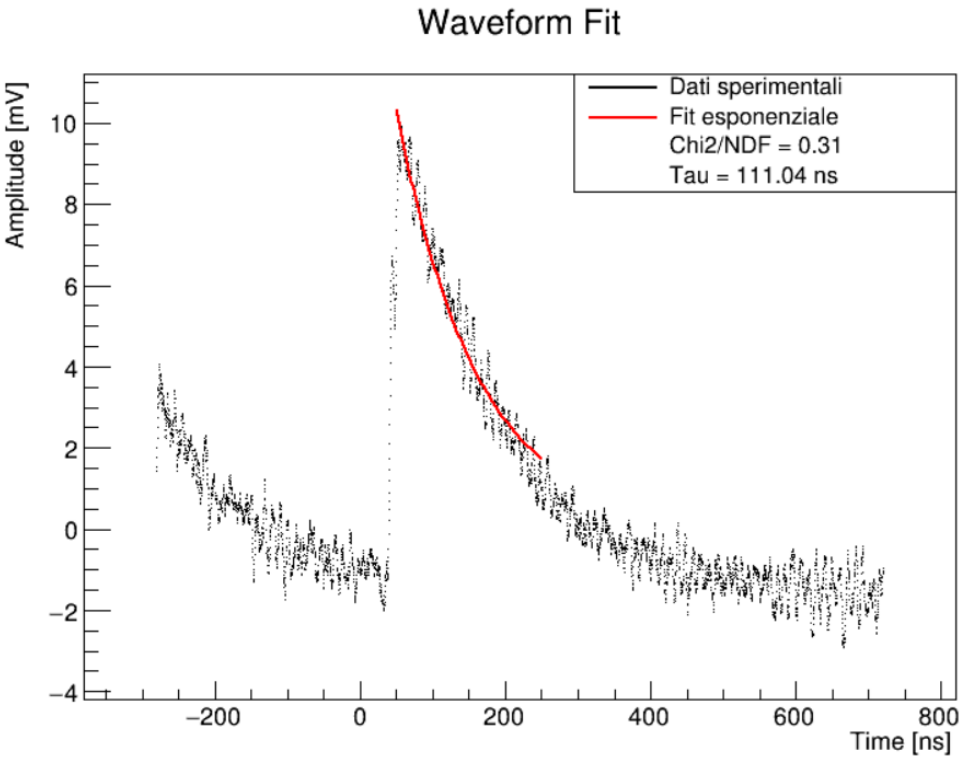
Taking as a function:

$$f(x) = A\, e^{-\frac{x}{\tau}}$$

And going to do the integral

$$\int_0^{3\tau} f(x)dx = A\underbrace{\tau(1 - e^{-3})}_{\alpha}$$

We get the factor that we need to switch from amplitude to charge



So our conversion in photon number is $A = p_0 + \alpha p_1 n_{pe}$

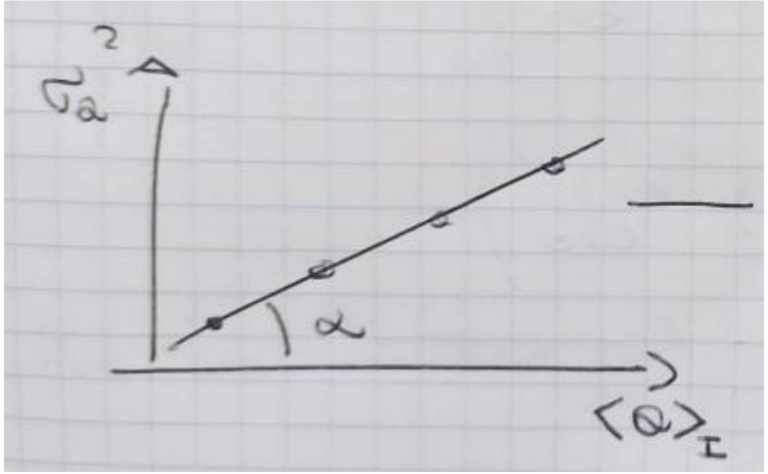
Calibrations SiPM 6x6 Gain 28 with method B)

Another method is to base on the hypothesis that the n_{pe} follows a Poissonian statistic so we have that:

$$A = \alpha n_{pe} \qquad \langle A \rangle = \alpha < n_{pe} > = \alpha\mu$$

$$\sigma_A = \alpha\sigma_{pe} = \alpha\sqrt{\mu} = \sqrt{\alpha}\sqrt{< A >}$$

$$\frac{\sigma_A^2}{< A >} = \alpha$$



In this case we measure at different power of the led