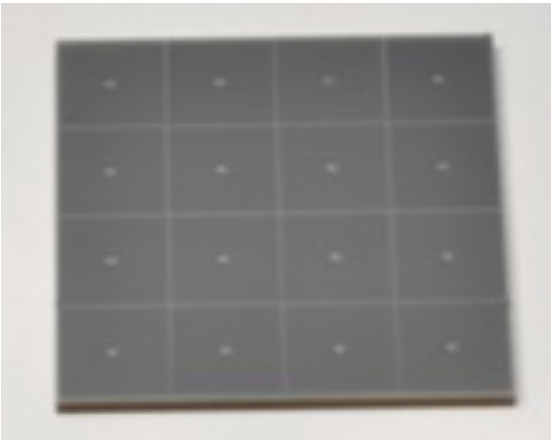
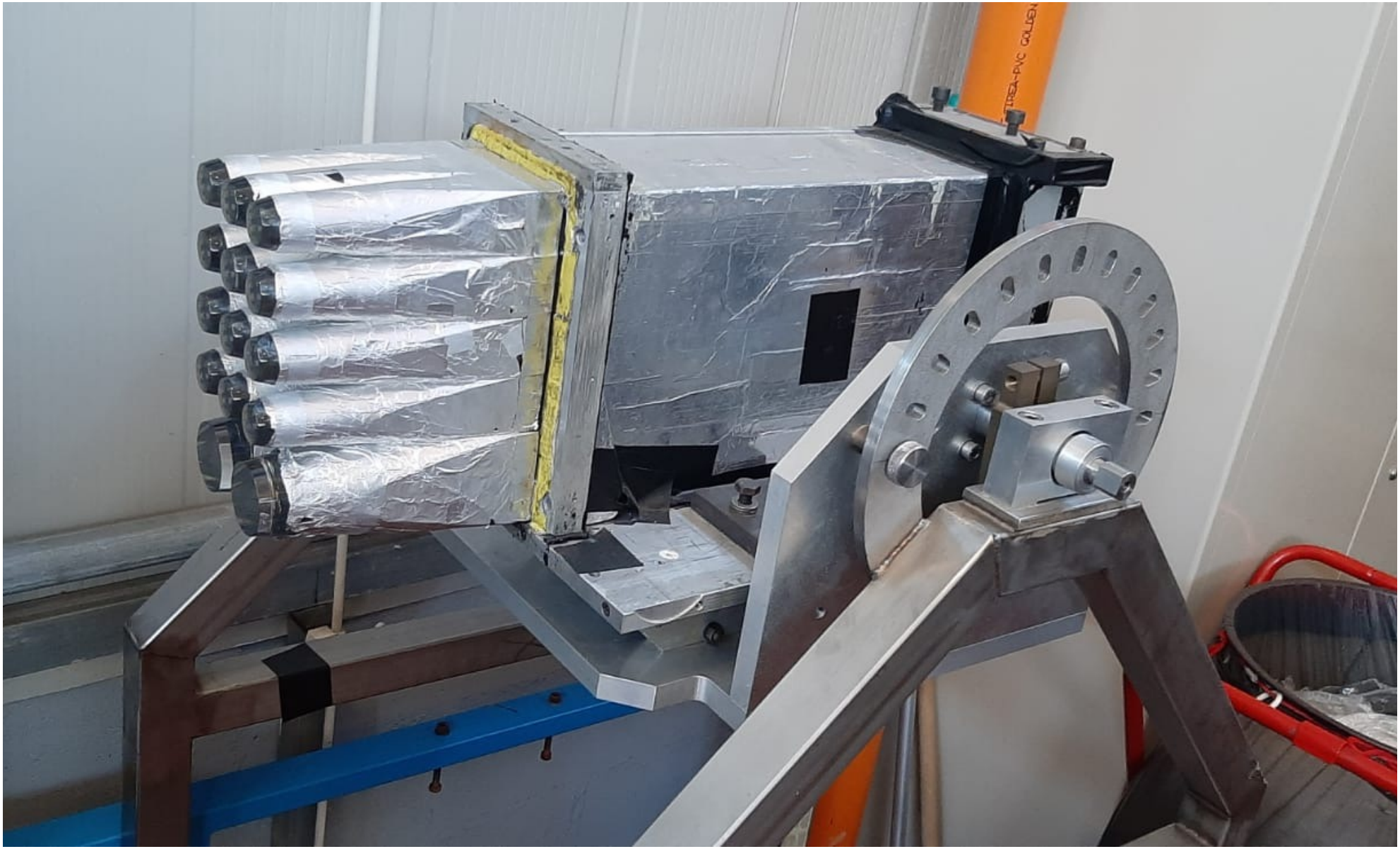


KLOEtoSAND

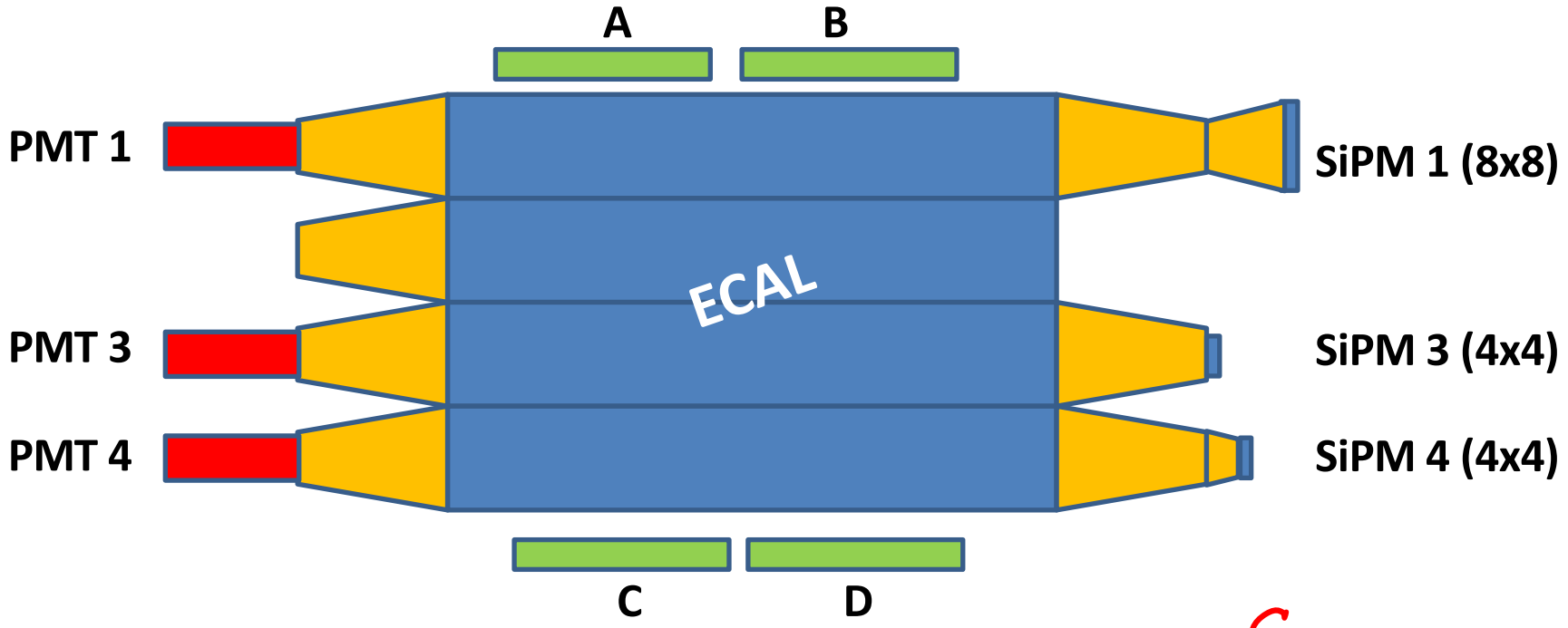
PMT/SiPM comparison

P. Bernardini, A. Corvaglia,
A. Miccoli, M. Panareo,
M.P. Panetta, A. Surdo – Lecce

LNF, November 7, 2022

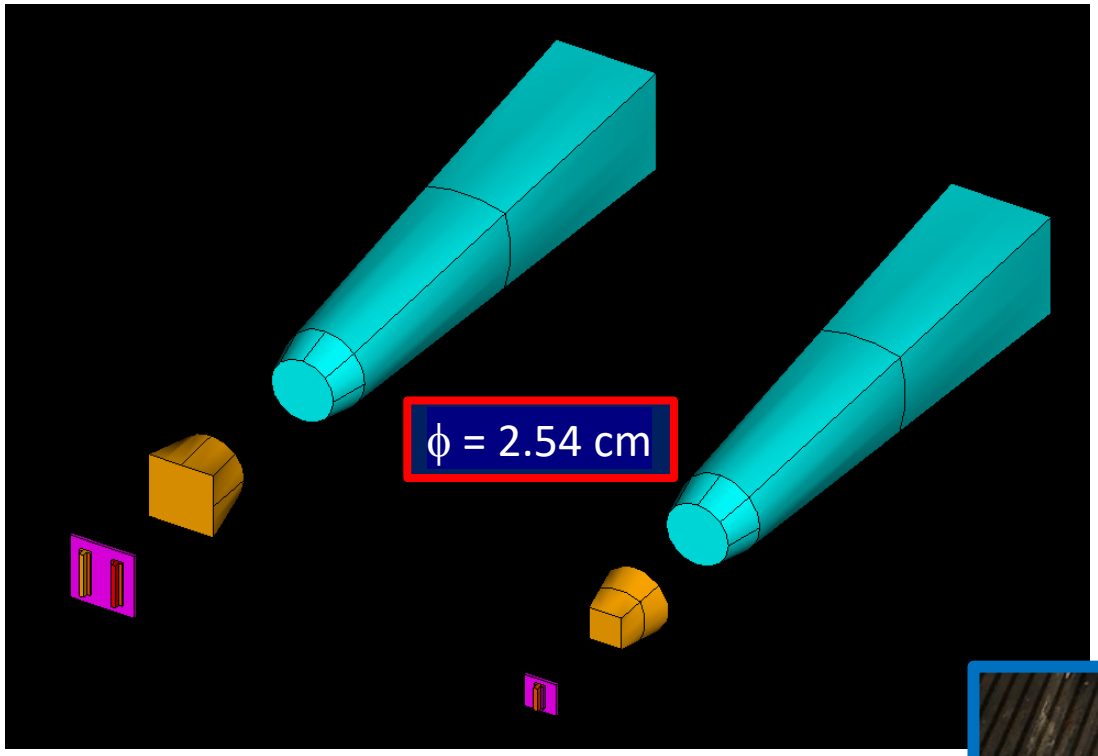


EXPERIMENTAL SETUP



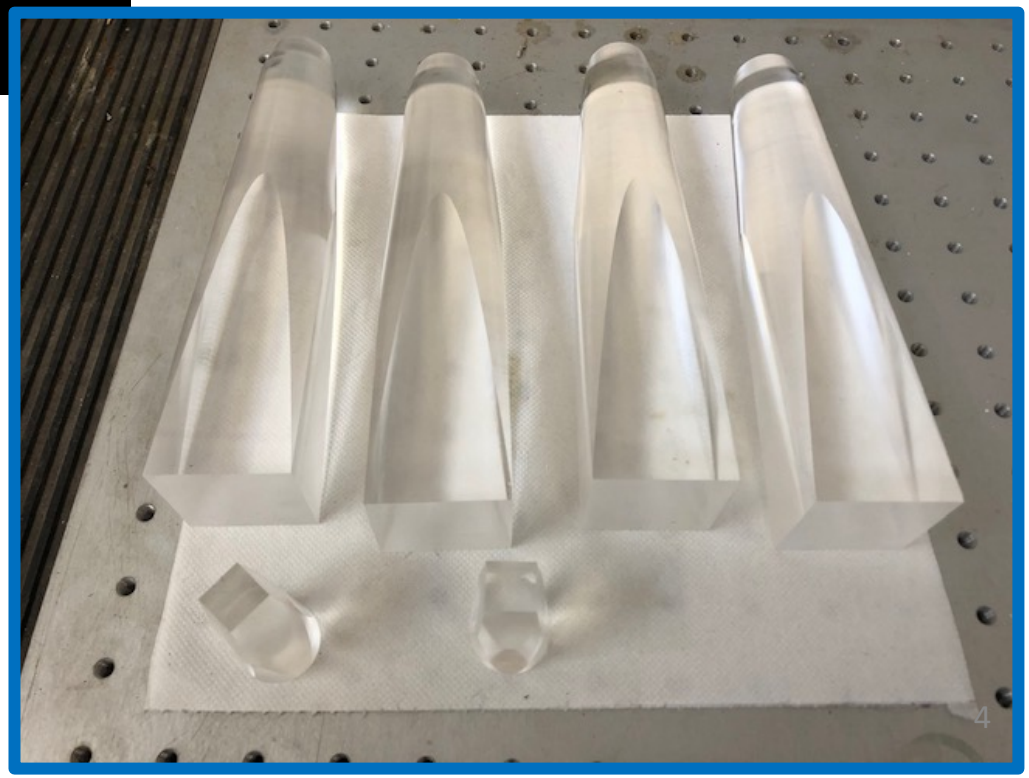
SiPM readout	CAEN DT5702 (32 Channel Board) CAEN DT5202 (64 Channel Board)
Gain, Threshold	optimized
SiPM calibration	Vbias set in order to get single rate ~ 3.5 kHz for each SiPM channel
Lab temperature	~ 20° C

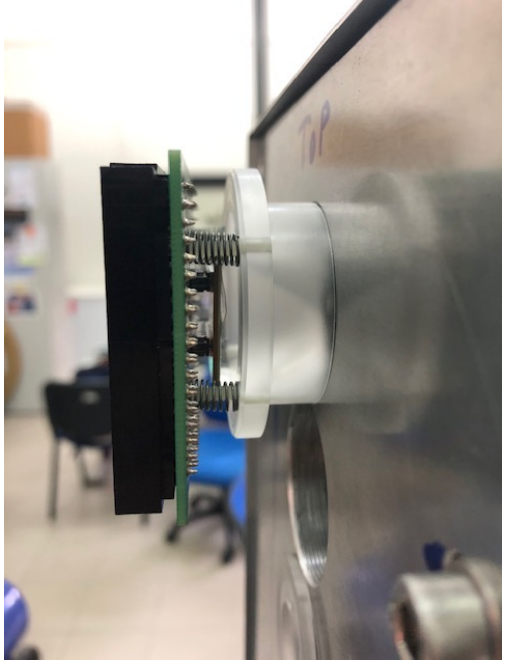
Cosmic rays as trigger



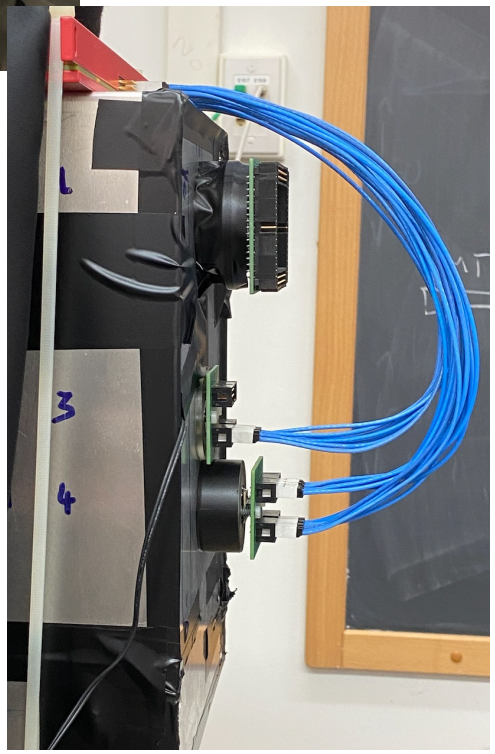
Coupling surfaces

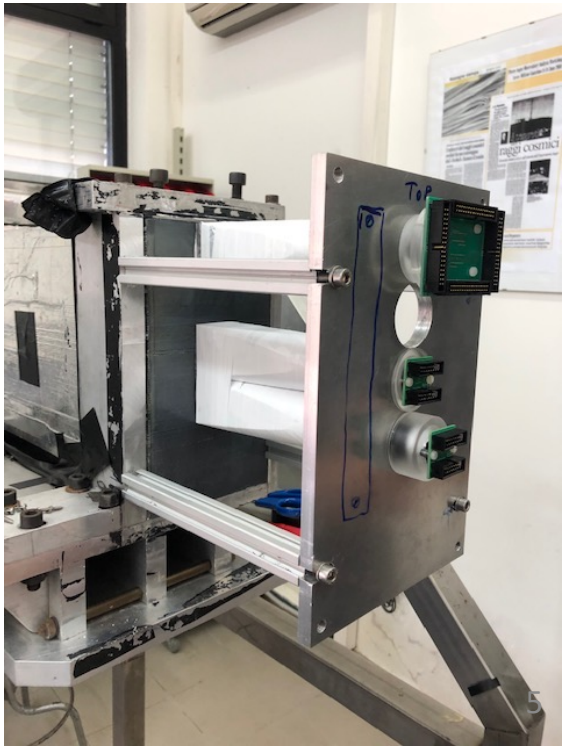
Light guide	490 mm²
4x4 SiPM	169 mm²
8x8 SiPM	666 mm²





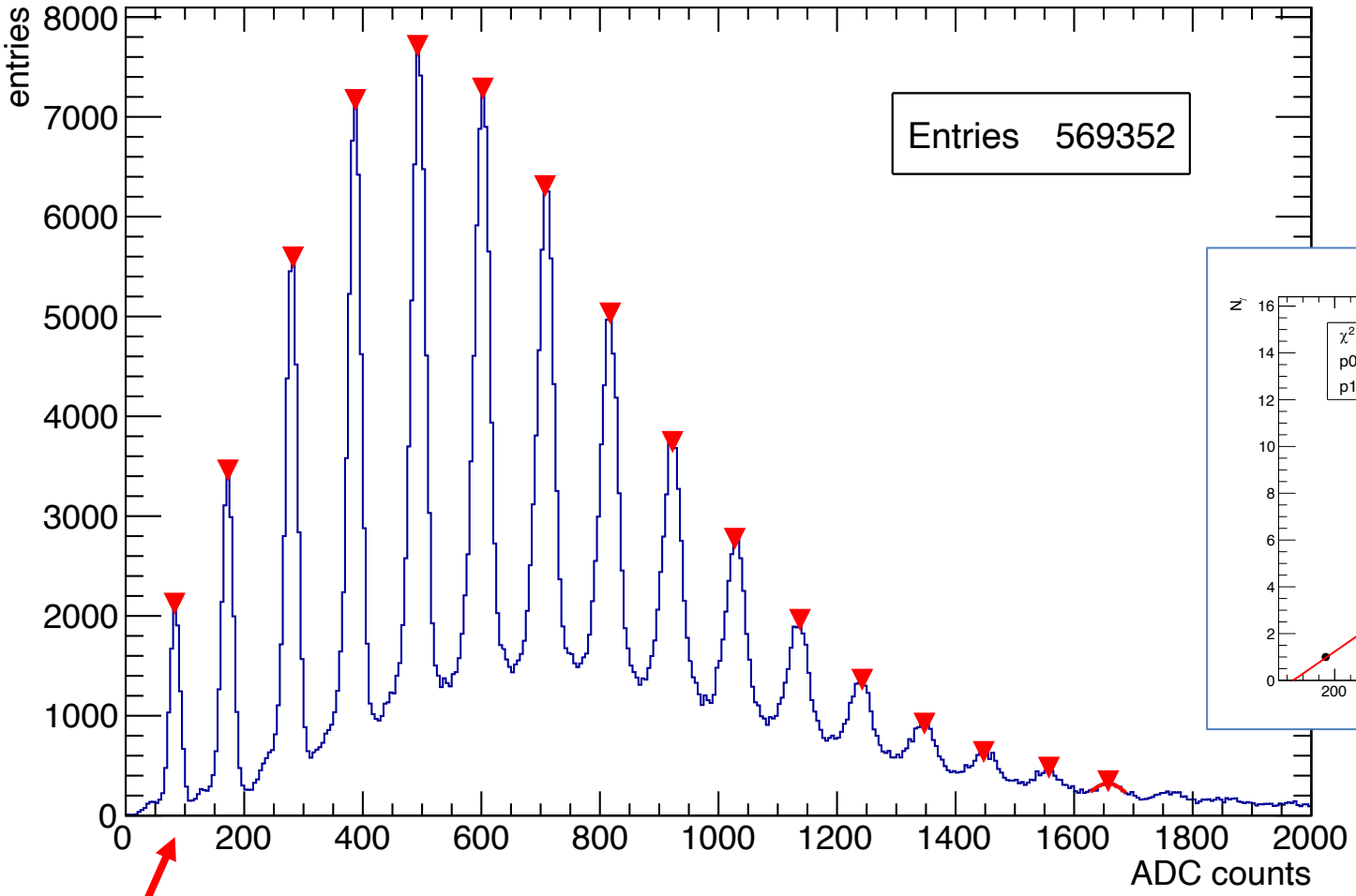
SiPM coupling

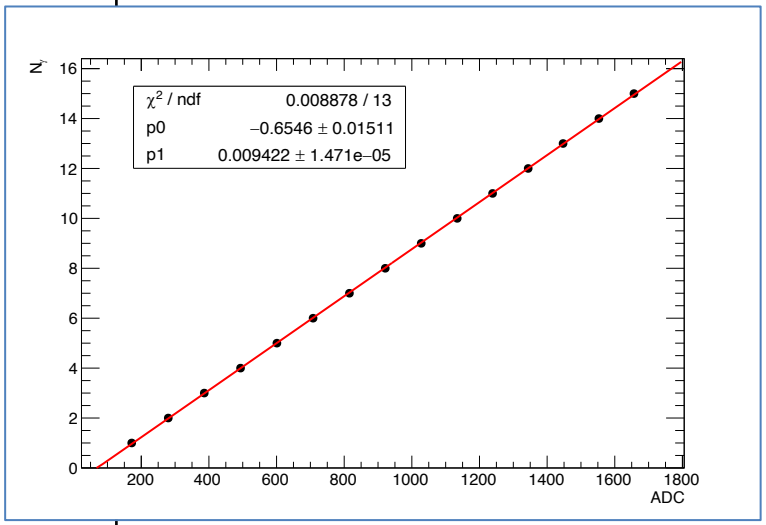




coaxial cables

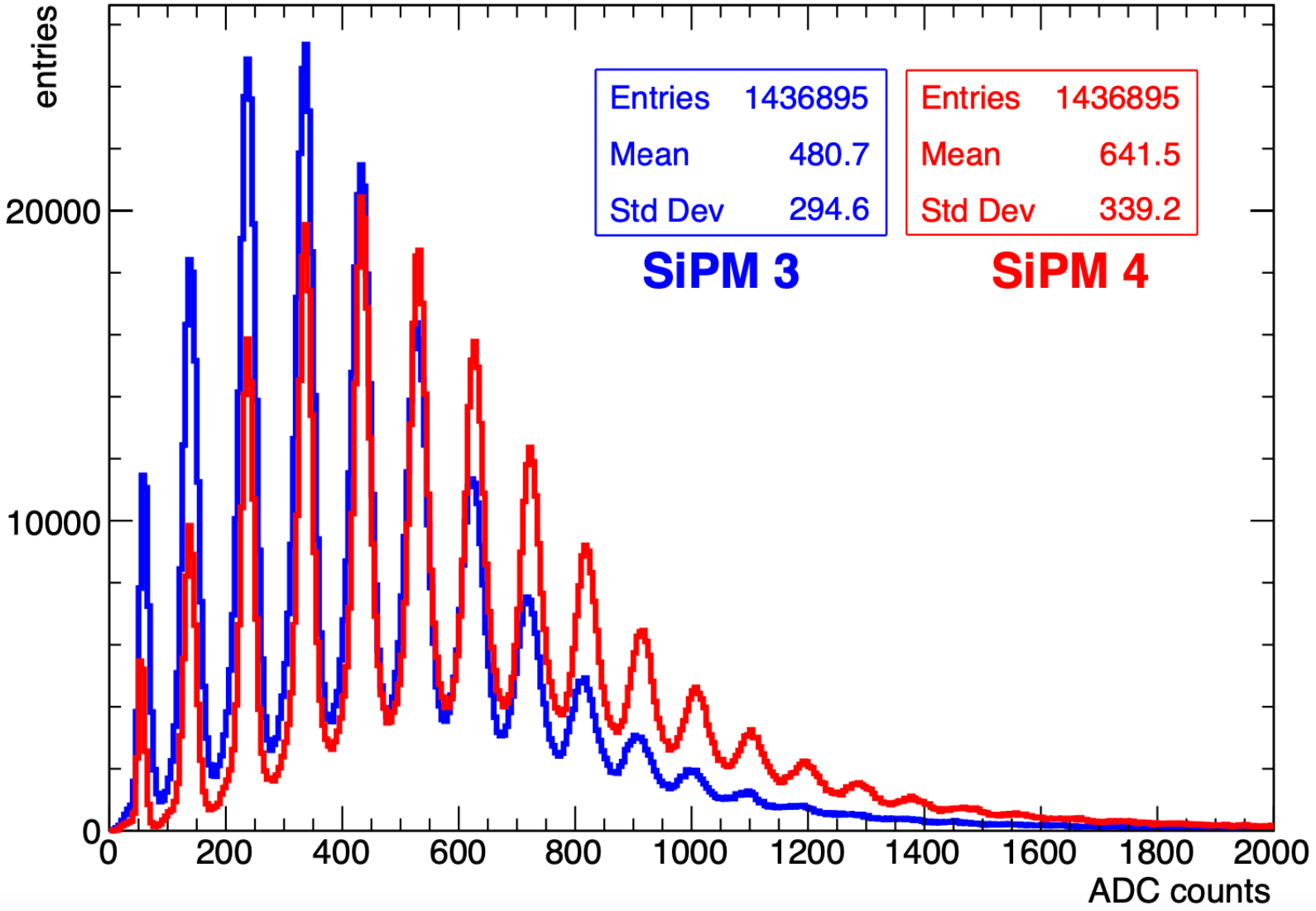
1 entry for each SiPM channel



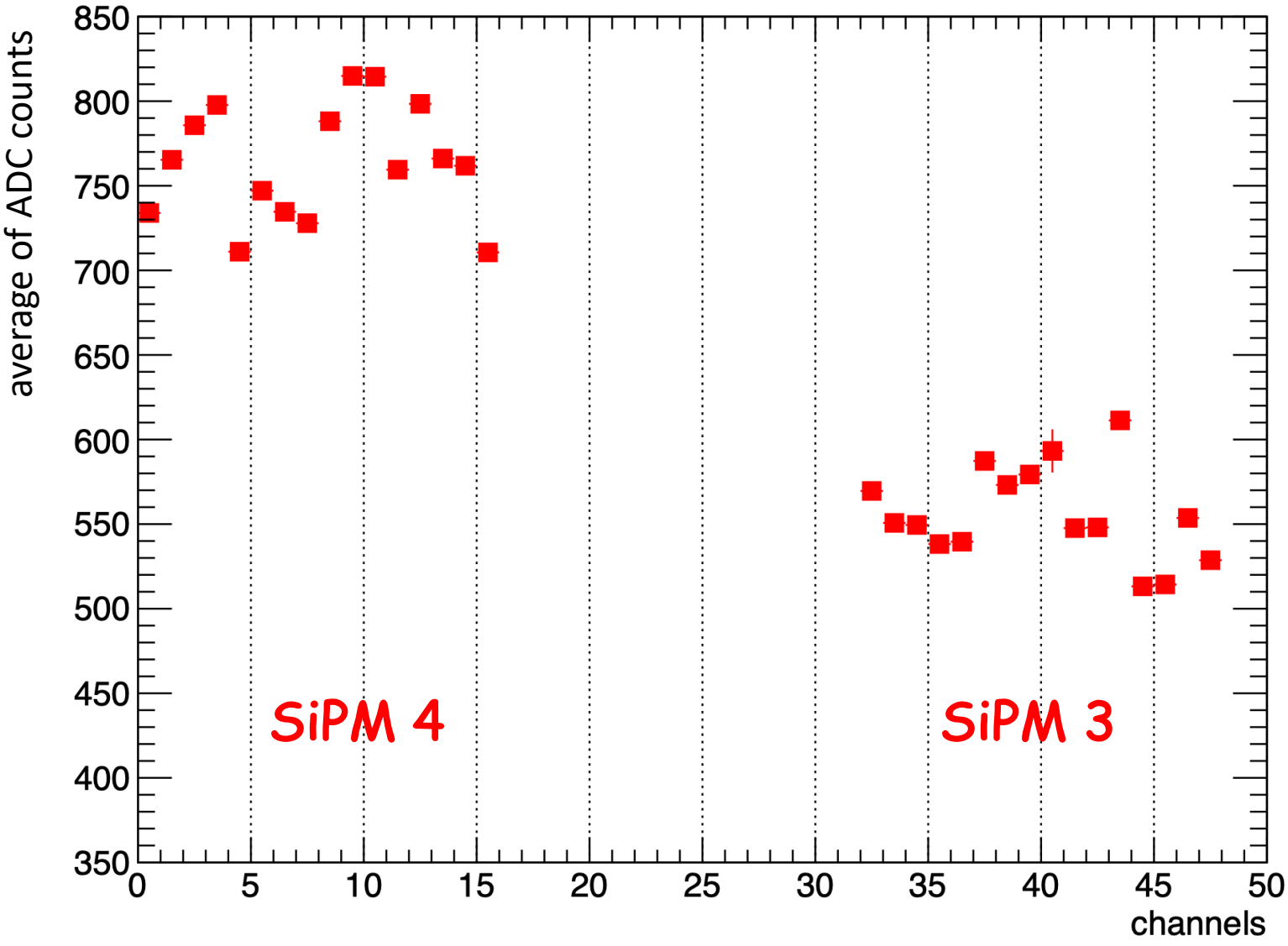


pedestal

$$N_{p.e.} = 0.00942\ ADC - 0.655$$

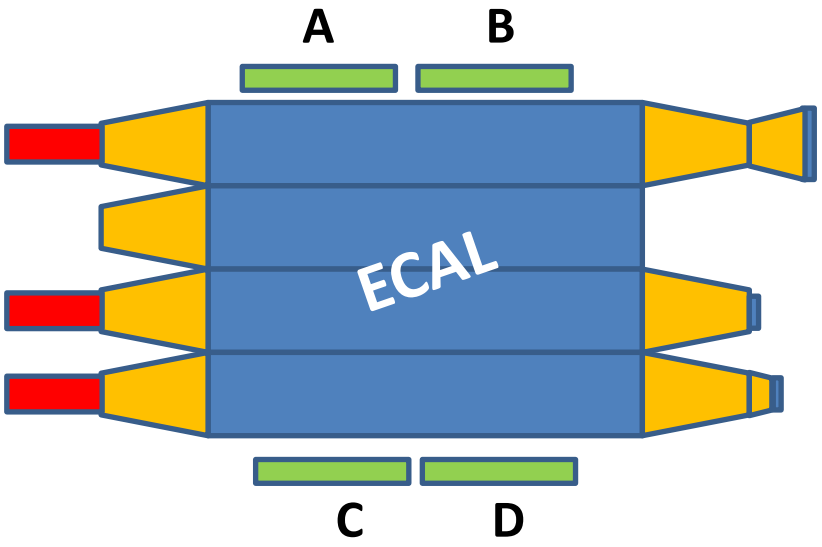


Highest light collection from SiPM 4 (with the adapter to connect SiPM and light guide)



On average the light distribution is uniform
on the different SiPM channels

Efficiency measurement

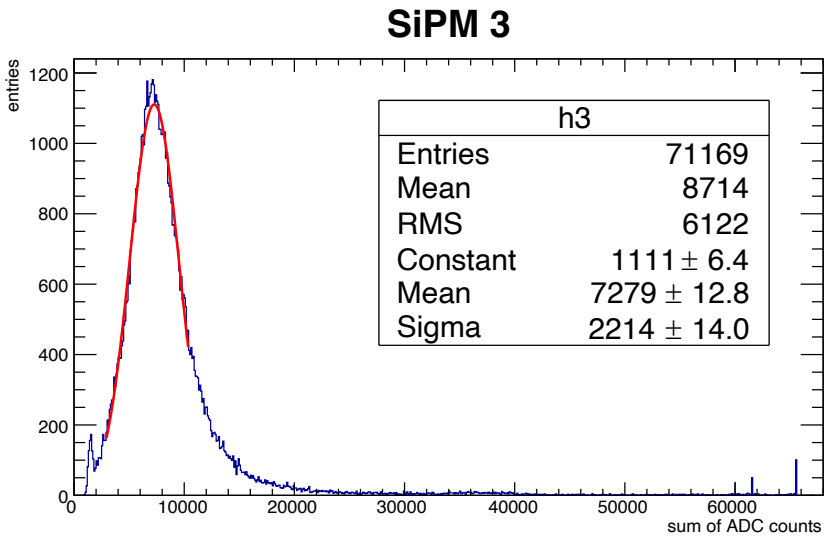


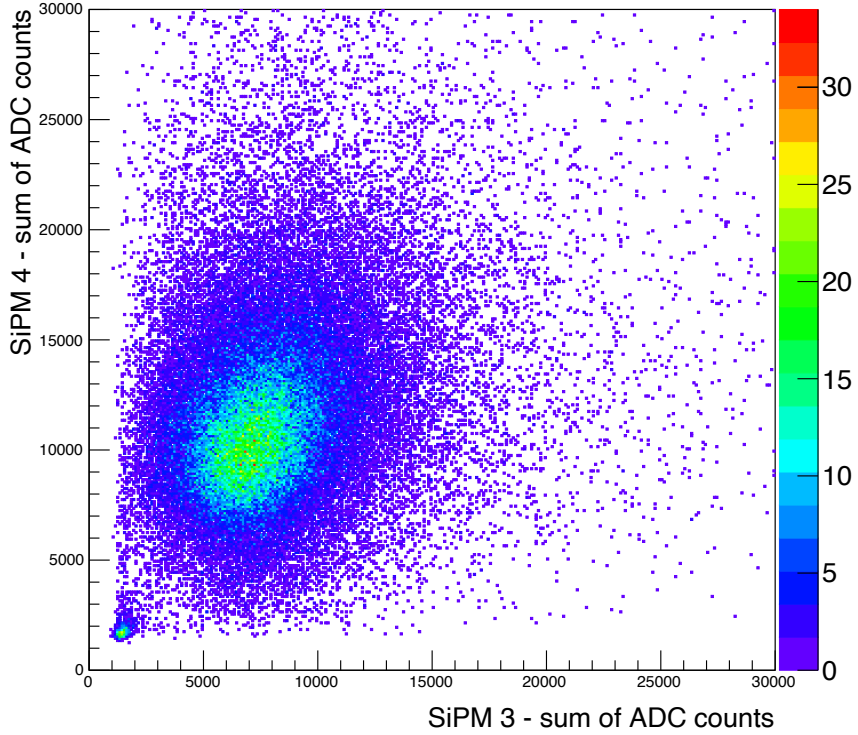
external trigger

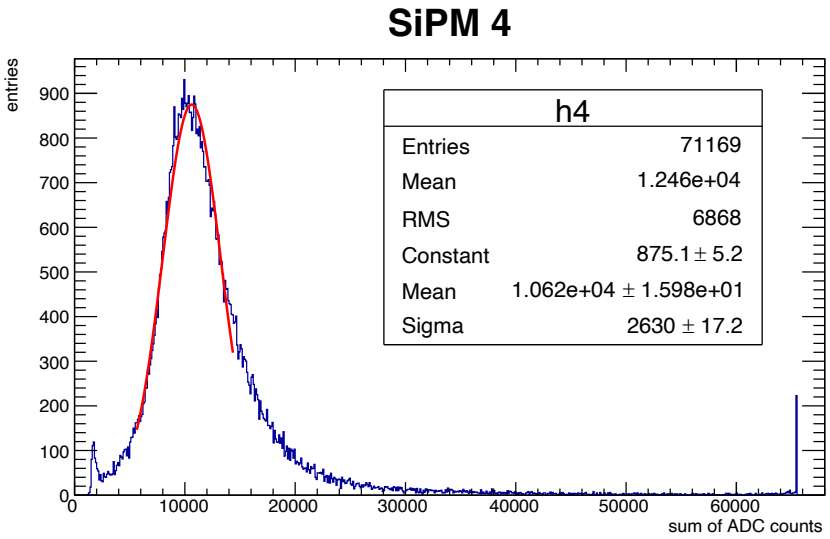
(A OR B) AND (C OR D)

for cosmic rays

Looking at the sum of all SiPM channels an anomalous sample of events is visible



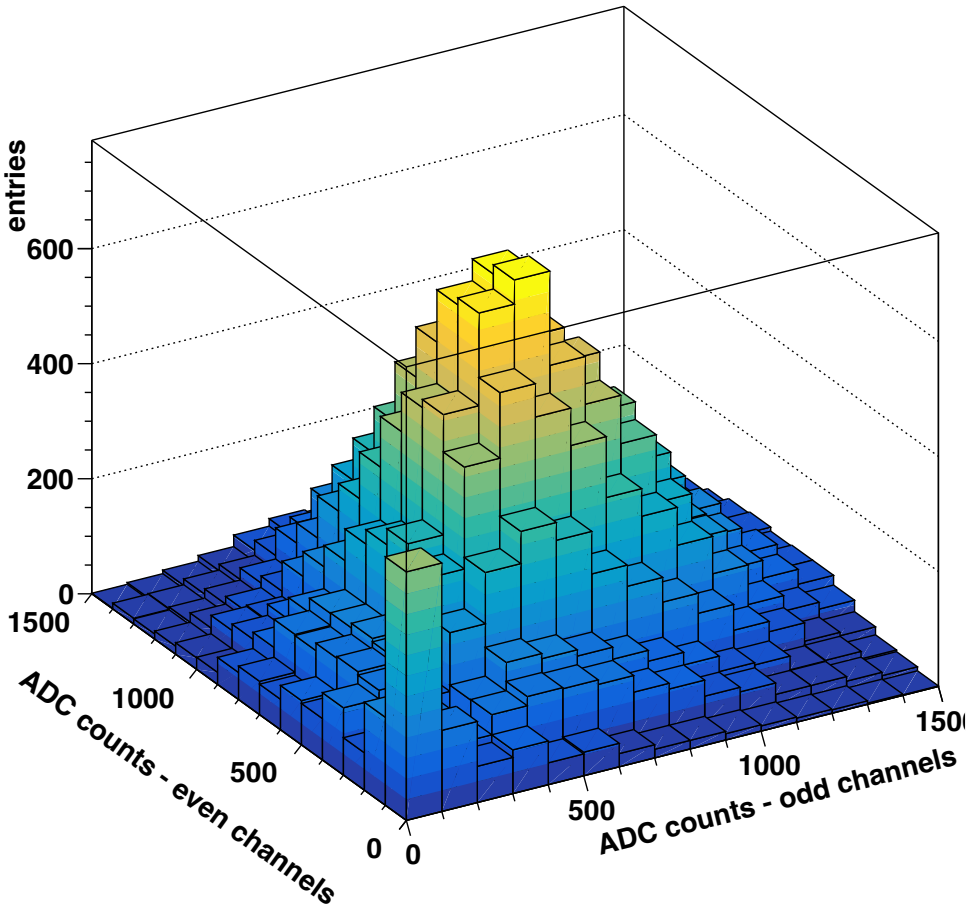




The effect is confirmed when SiPM 3 and 4 are in data taking with the same trigger

Noise = events with pedestal values on all SiPM channels

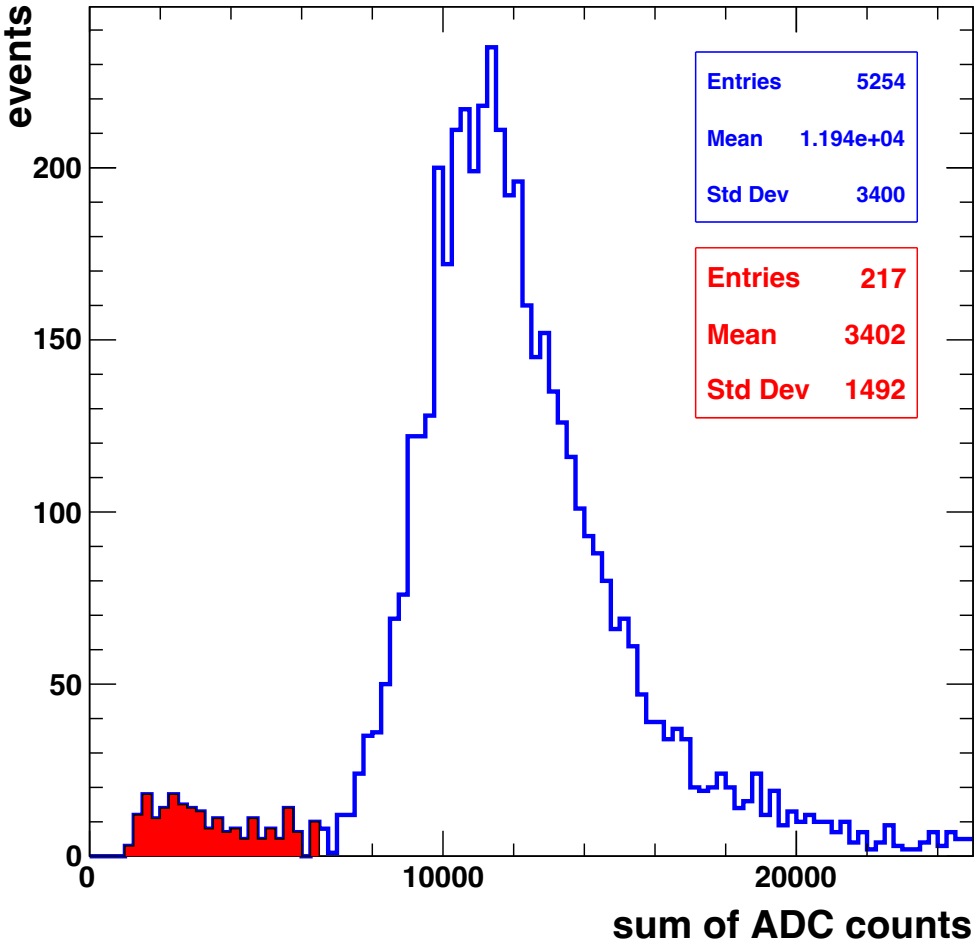
SiPM 4



8 entries for each event
1 entry for each pair of channels

The pedestal events (~ 4%) must be removed

Σ ADC > 6500



Trigger	SiPM 4	Σ ADC < 6500 (to be rejected)	SiPM 4 efficiency (%)	PMT 4	PMT 4 efficiency (%)
7716	7068	290	**87.8 ± 1.1**	6819	**88.4 ± 1.1**

Trigger				PMT 3	PMT 3 efficiency (%)
5722				5191	**90.7 ± 1.3**

Necessary more data to reduce the error below 1%

The efficiencies are comparable

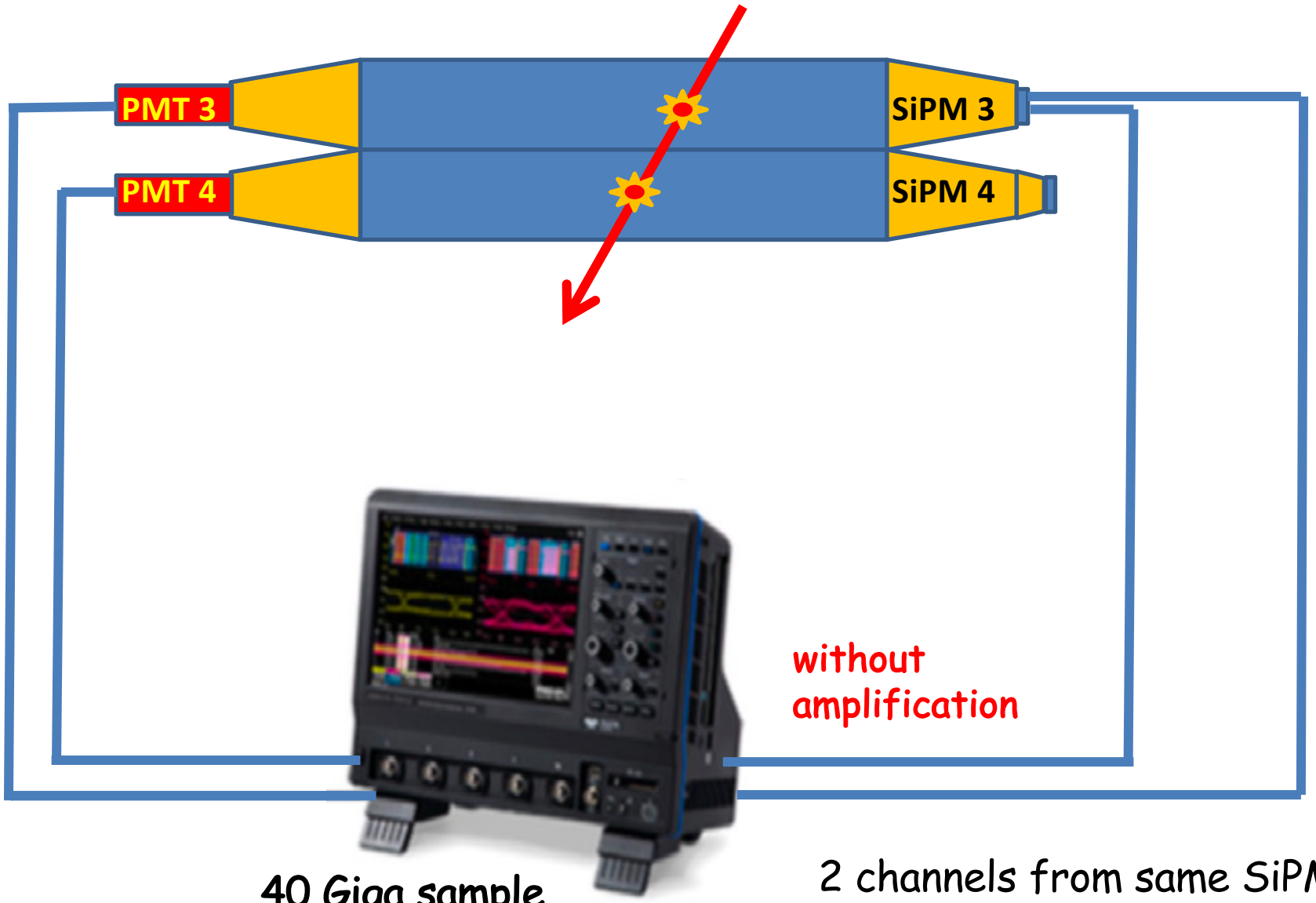
Anyway PMT efficiency is higher

Time resolution

Time resolution
Same SiPM (3 or 4)

$$\Delta t = t_{\alpha}^{50\%} - t_{\beta}^{50\%}$$

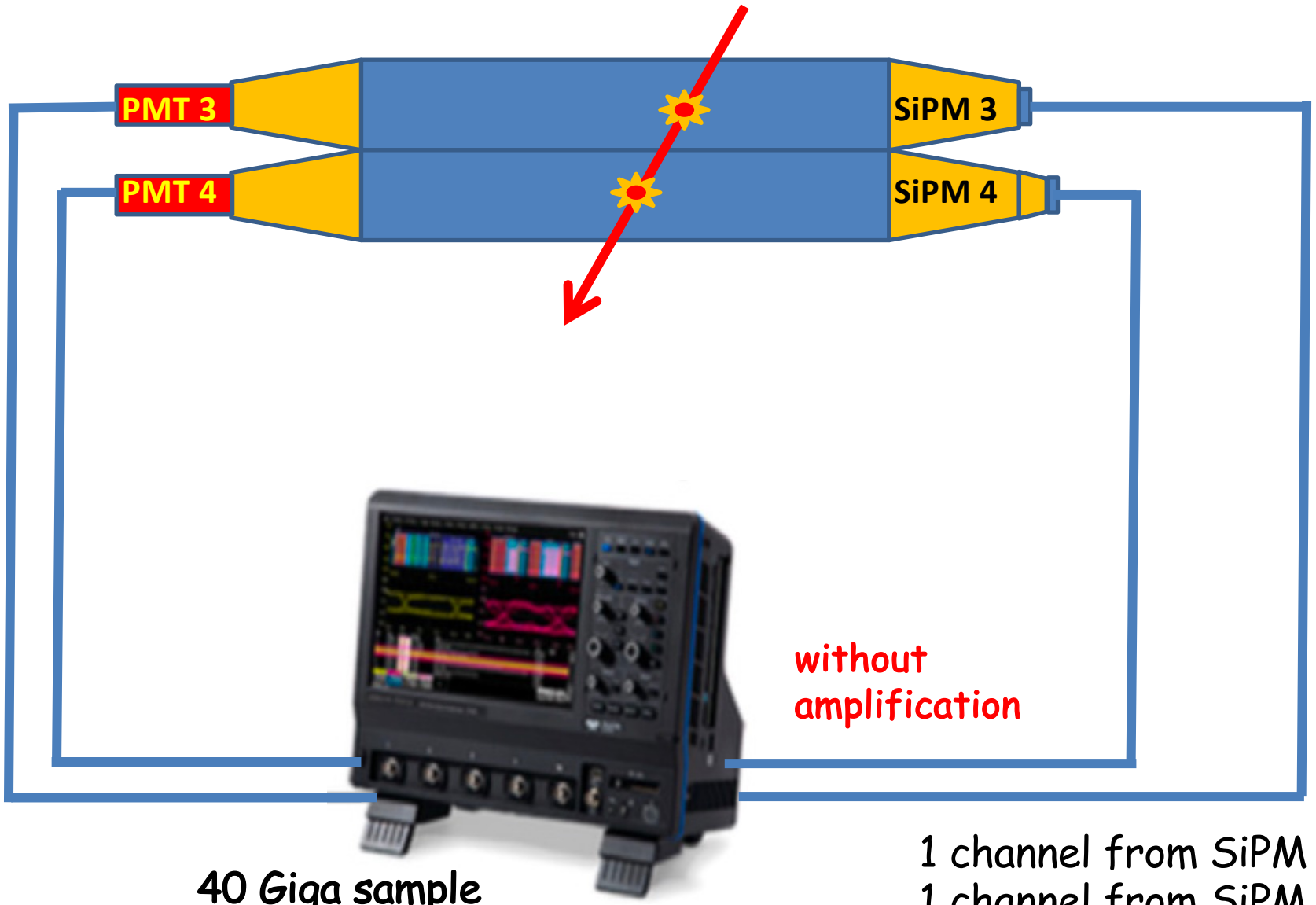
constant fraction method



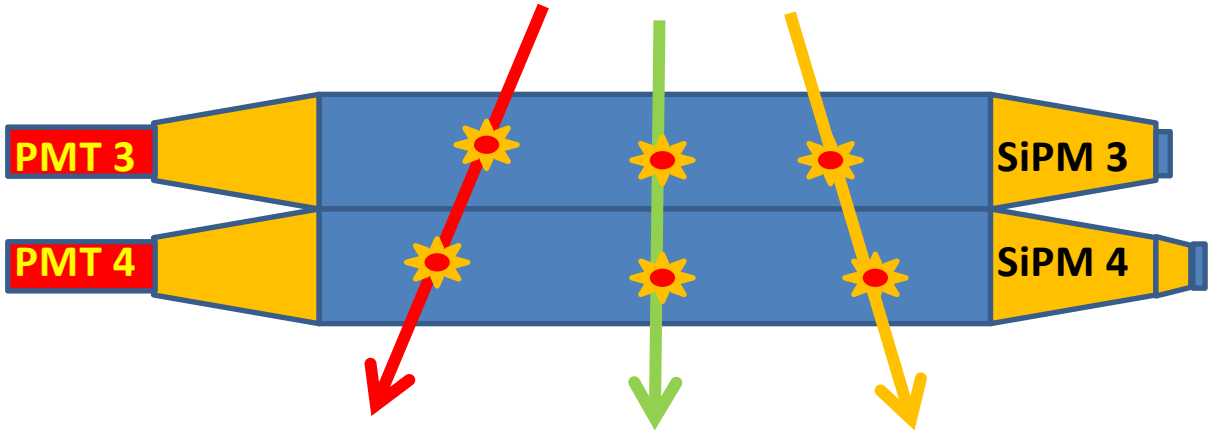
Time resolution
Different detectors (3/4)

$$\Delta t = t_{4\alpha}^{50\%} - t_{3\alpha}^{50\%}$$

constant fraction method

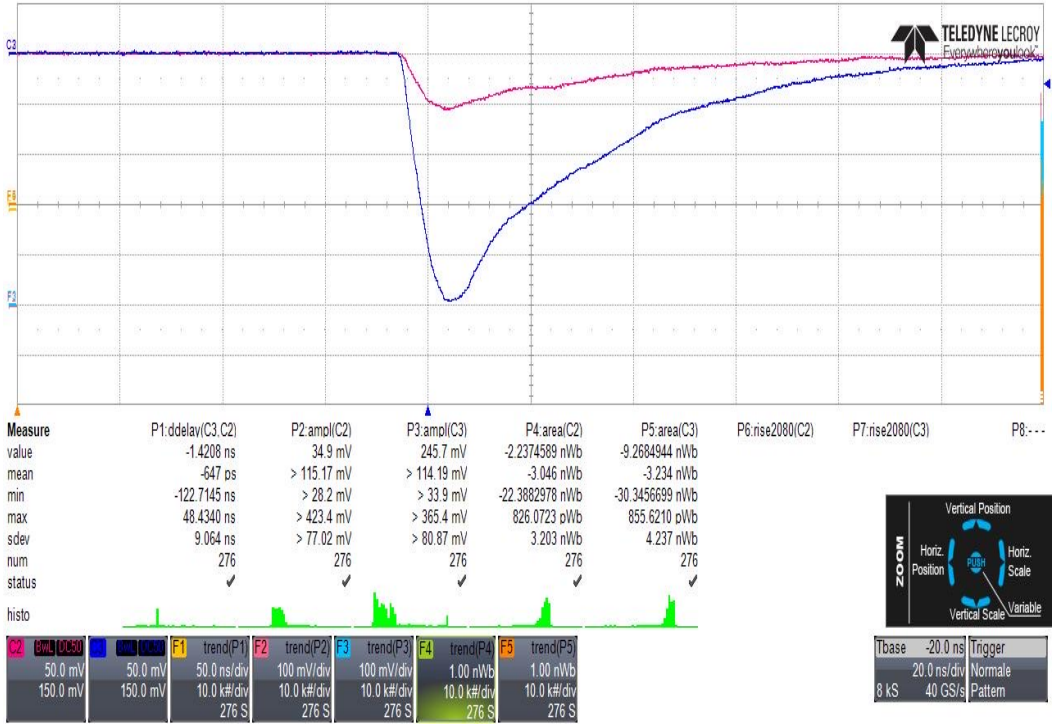


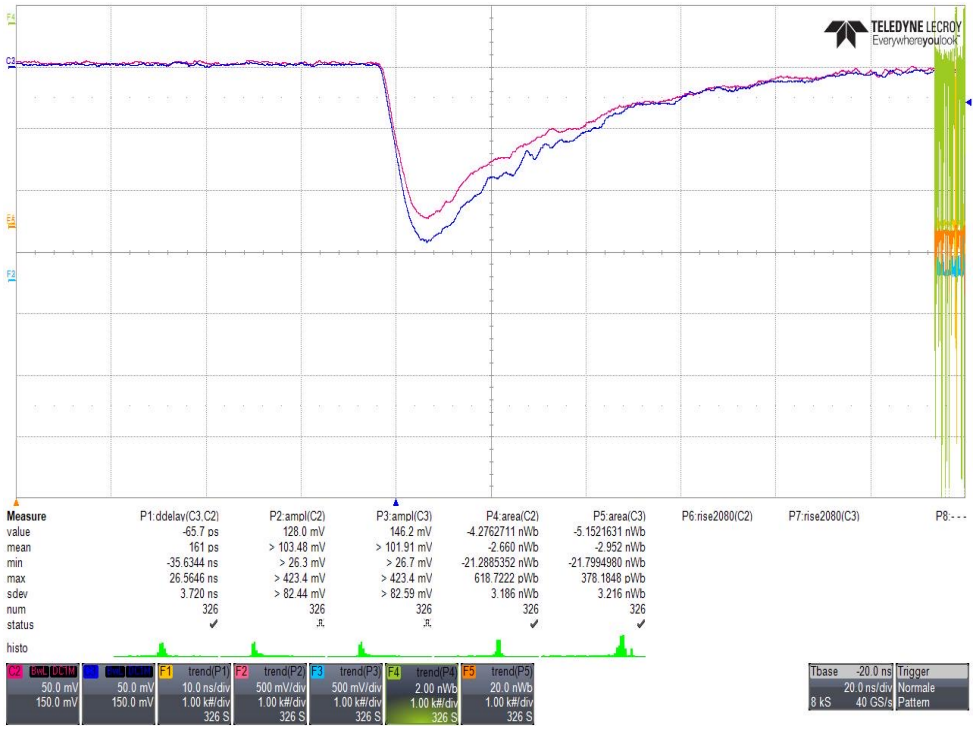
A simulation has been implemented to take into account the time jitter due to the track slope

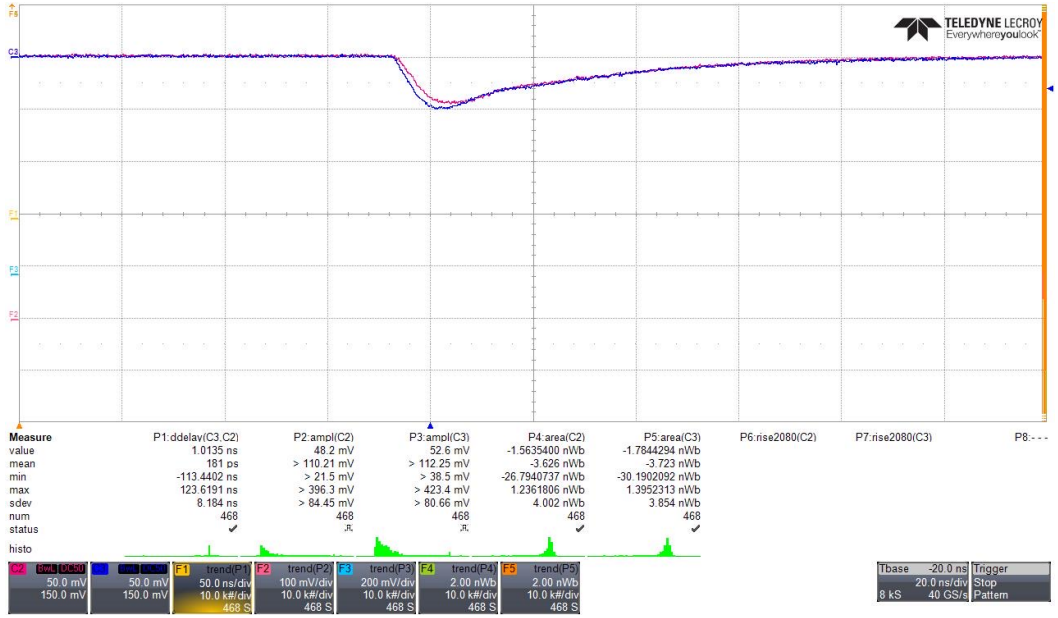


$$\sigma_{\Delta t} \Rightarrow \sigma_{channel}$$

From the measured Δt distribution to the intrinsic time resolution



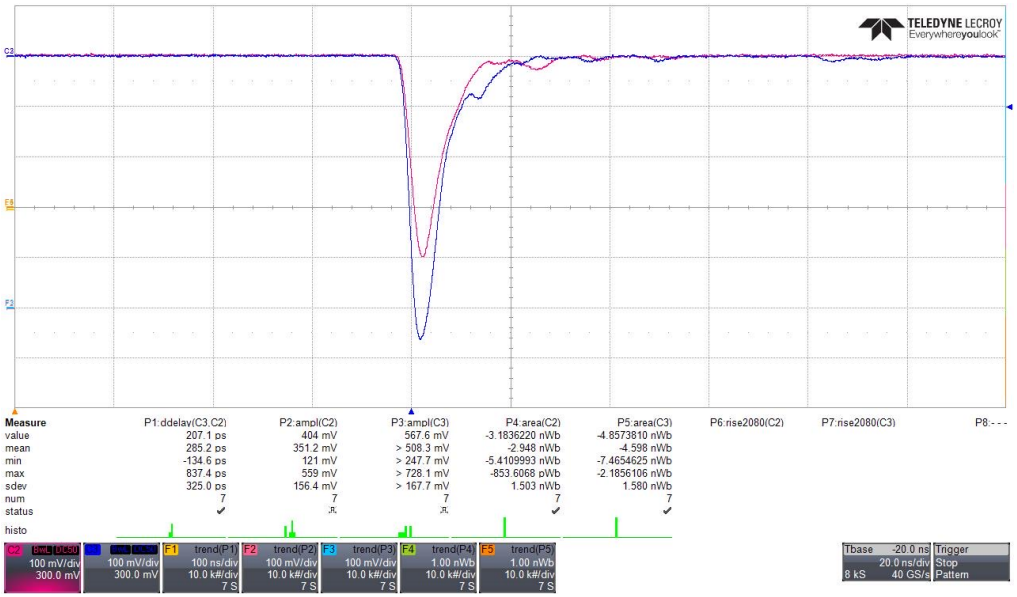


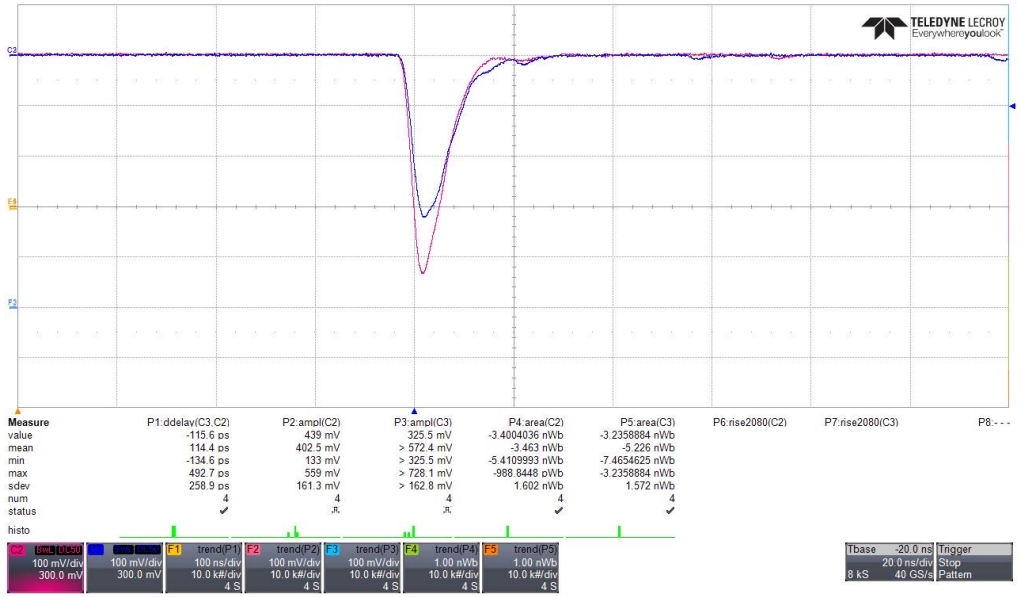


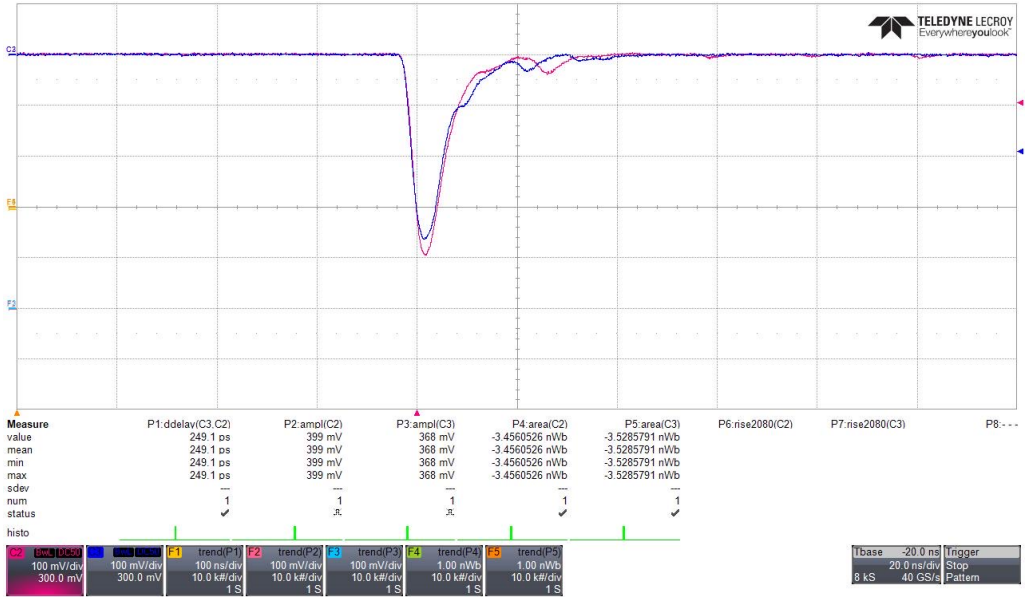
without amplification

SiPM signals

duration = 80-100 ns



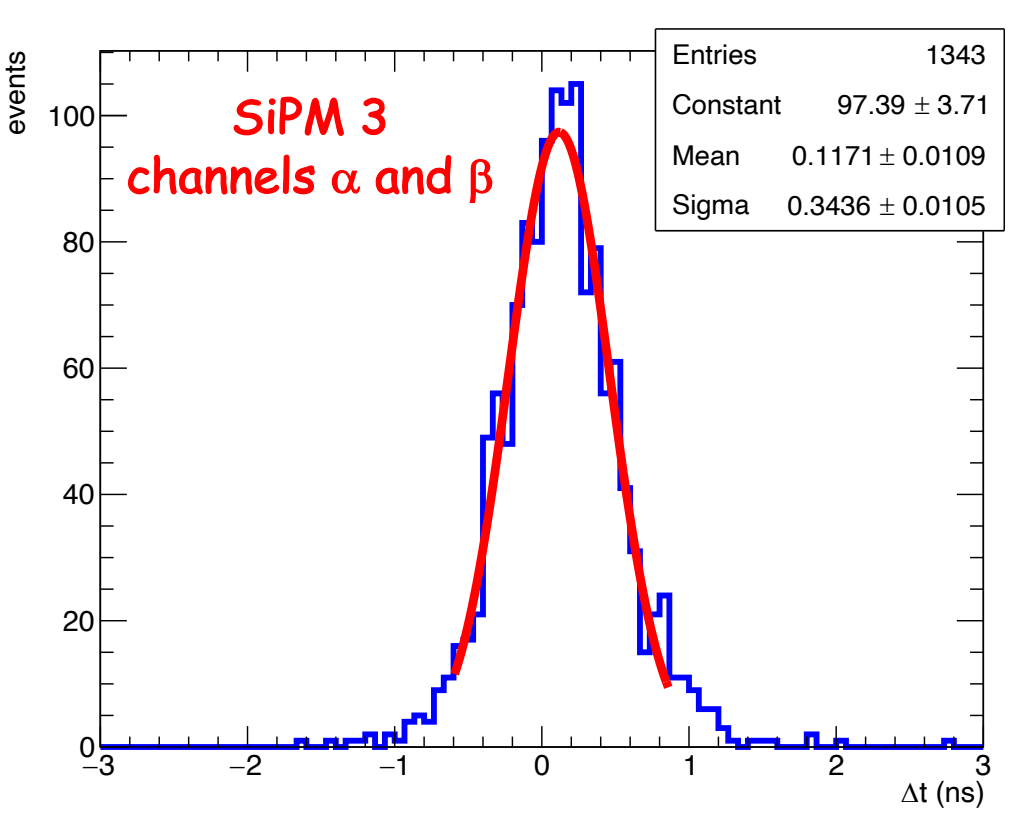


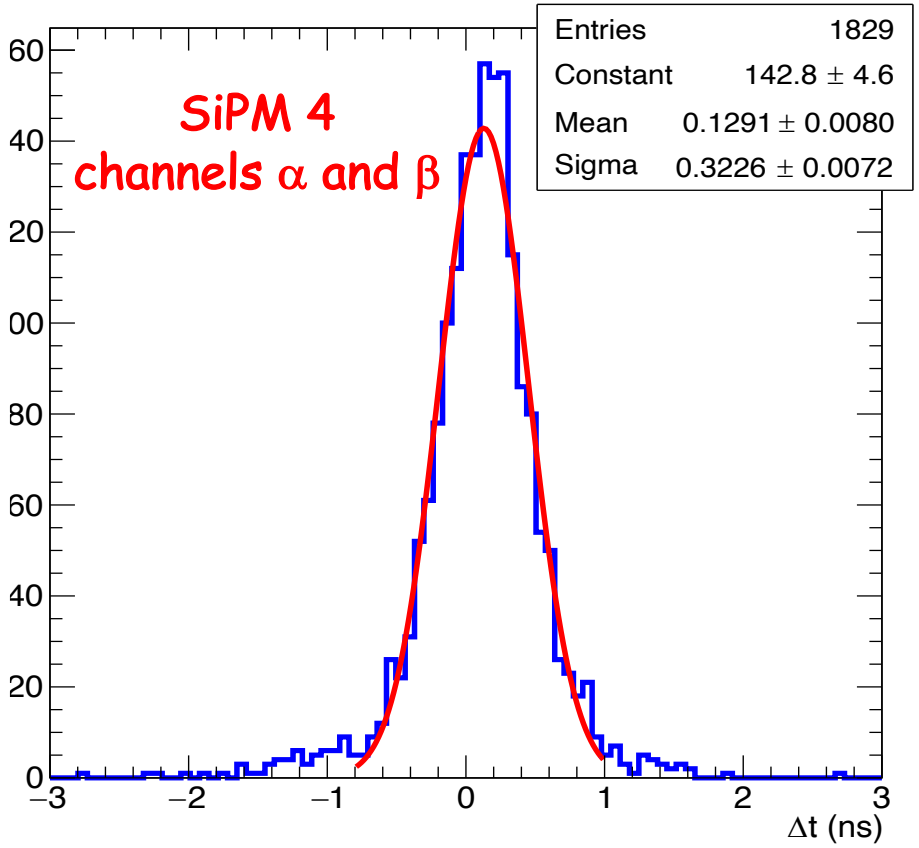


PMT signals

duration 20 ns

Two channels of the same SiPM

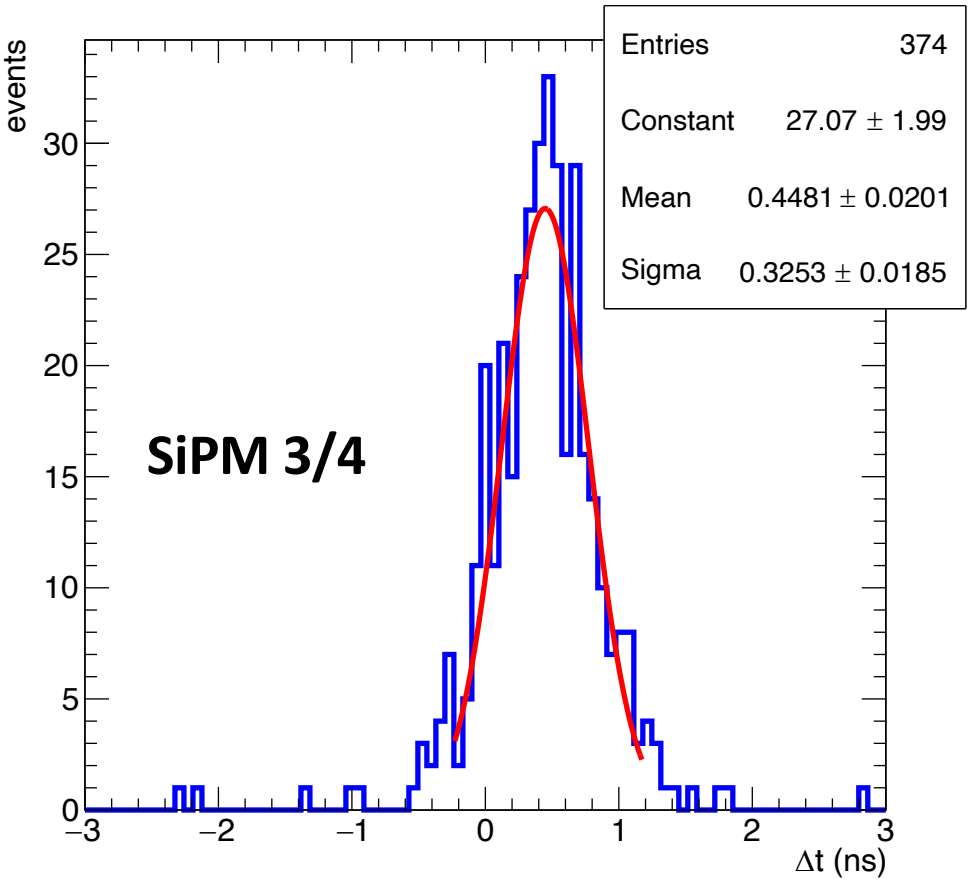


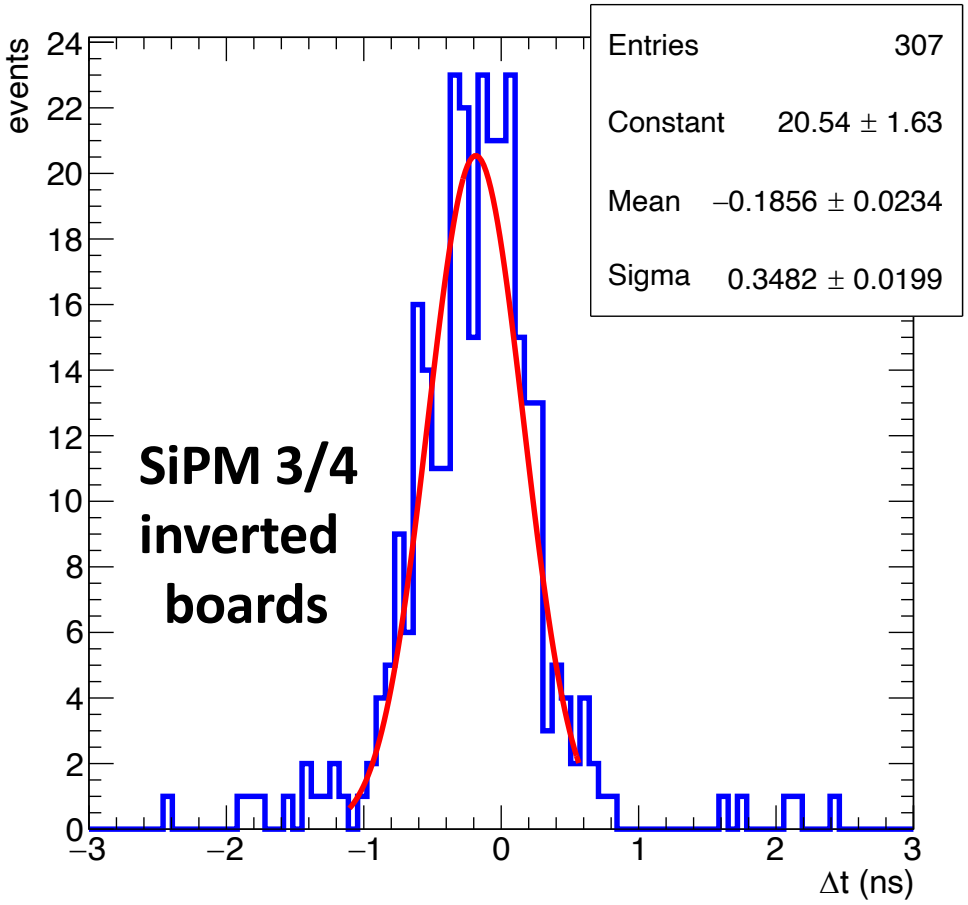


expected $< \Delta t > = 0$ ps => offset ~ 120 ps

$\sigma_{\Delta t}$ ~ 330 ps => $\sigma_{channel}$ ~ 210 ps

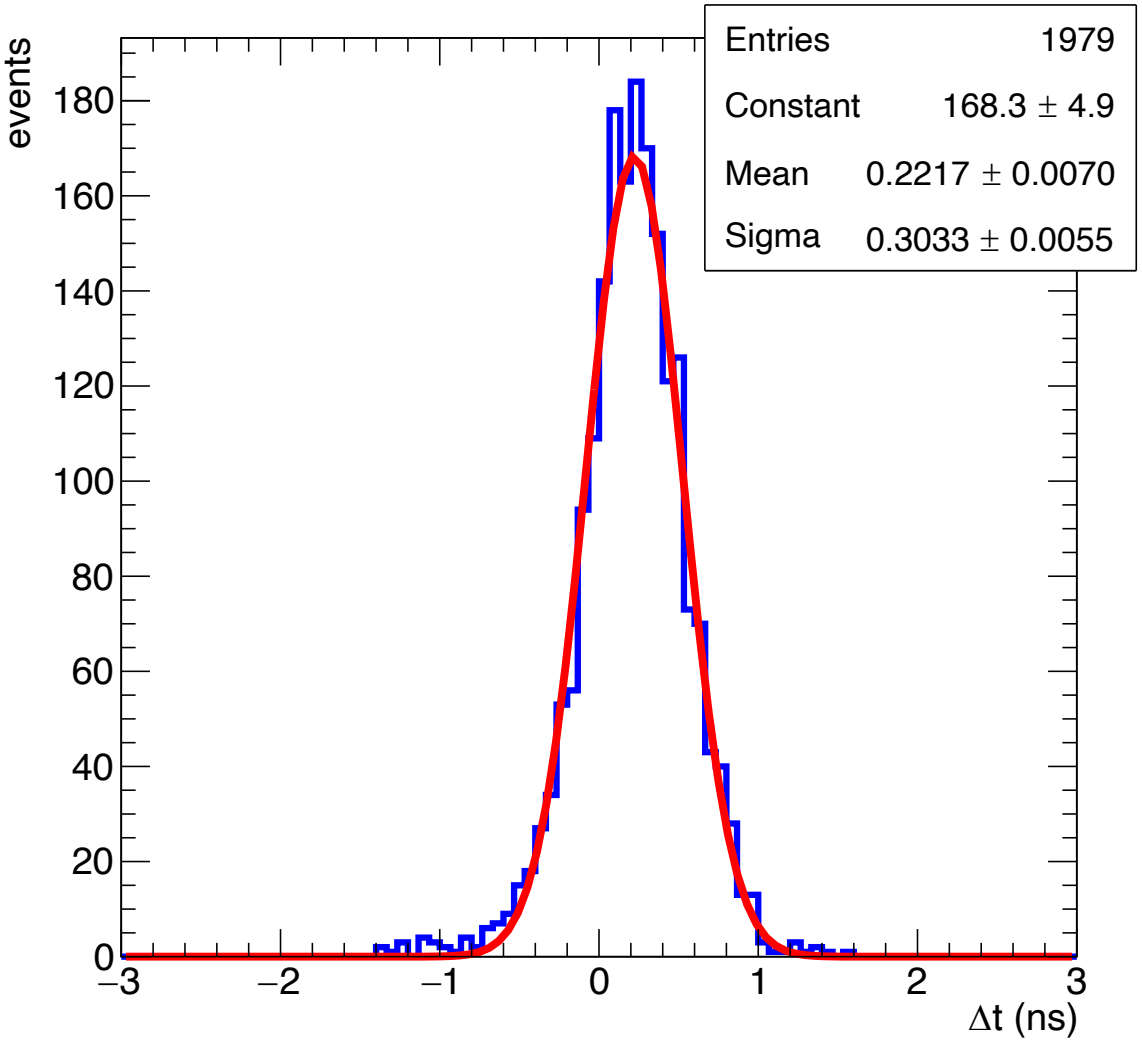
Two channels of different SiPMs





offset ~ 120 ps $< \Delta t > \sim 300$ ps

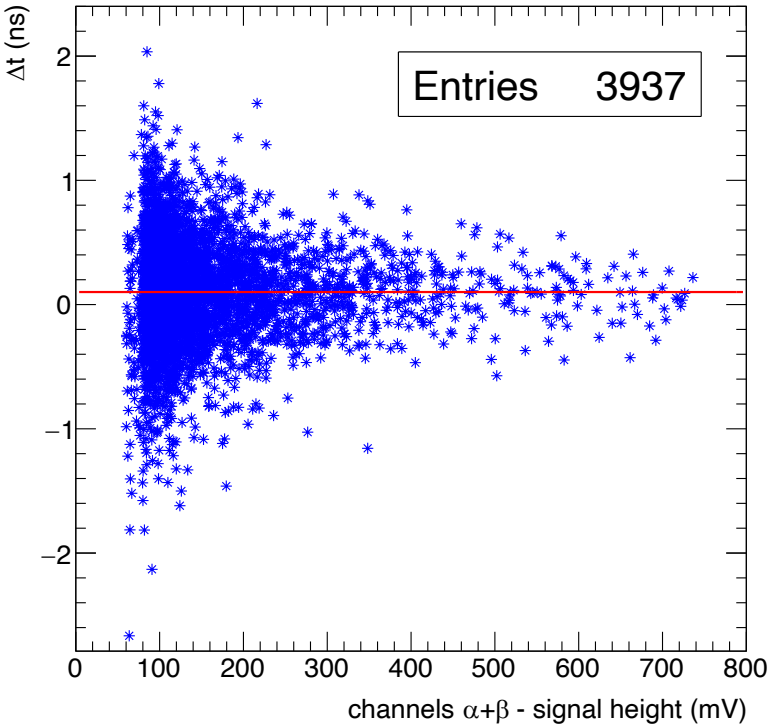
$\sigma_{\Delta t} \sim 340$ ps => $\sigma_{channel} \sim 200$ ps



PMT 3/4

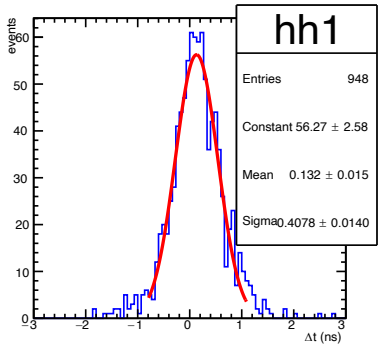
$< \Delta t > = 222$ ps

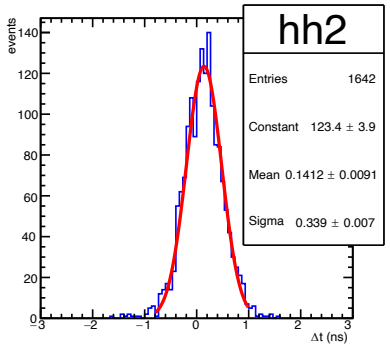
$\sigma_{\Delta t} = 303$ ps => $\sigma_{PMT} \sim 170$ ps

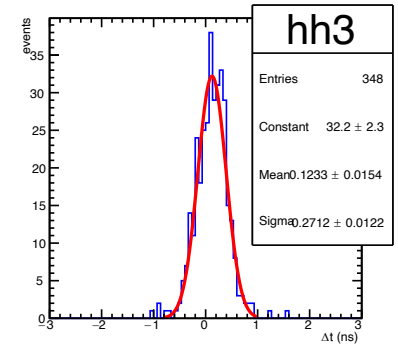


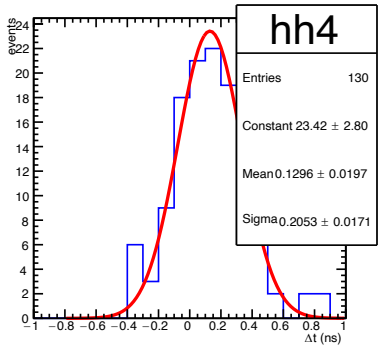
Large sample:

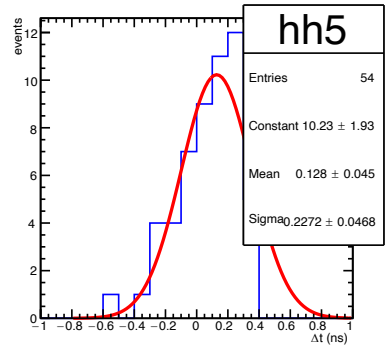
SiPM 3 (α vs β) + SiPM 4 (α vs β)

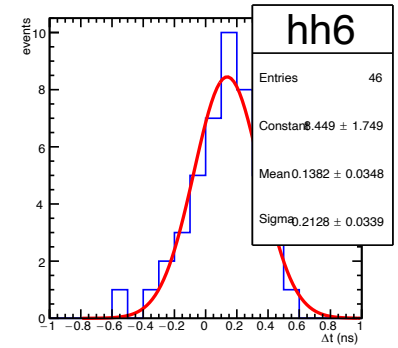






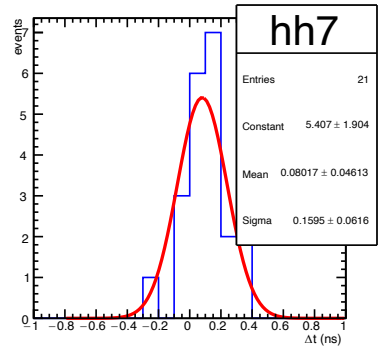


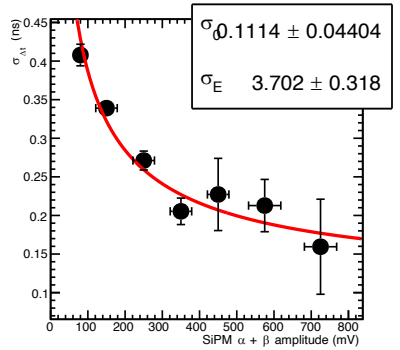




σ_0 = 111 ps from the fit

σ_0 ~ 70 ps for single SiPM





KLOE formula

$$\sigma = \sigma_0 \oplus \frac{\sigma_E}{\sqrt{E_{GeV}}}$$

Summary

$\sigma_{channel}$ ~ 210 ps same SiPM

$\sigma_{channel}$ ~ 200 ps different SiPMs

σ_{PMT} ~ 170 ps different PMTs

Conclusions

- mechanical setup DONE
- assembling of experimental setup DONE
- understanding of SiPM work conditions DONE
- efficiency measurement DONE
- time resolution measurement DONE

TO DO more statistics in order to publish these results

Remarks

- the SiPM performances are not so far from the PMT ones

- the difficulties to couple SiPM with ECAL, the lack of improvement and the cost advise against the substitution of PMTs with SiPMs

- Lecce lab is available for other test on ECAL / SiPM / PMT

BUFFER

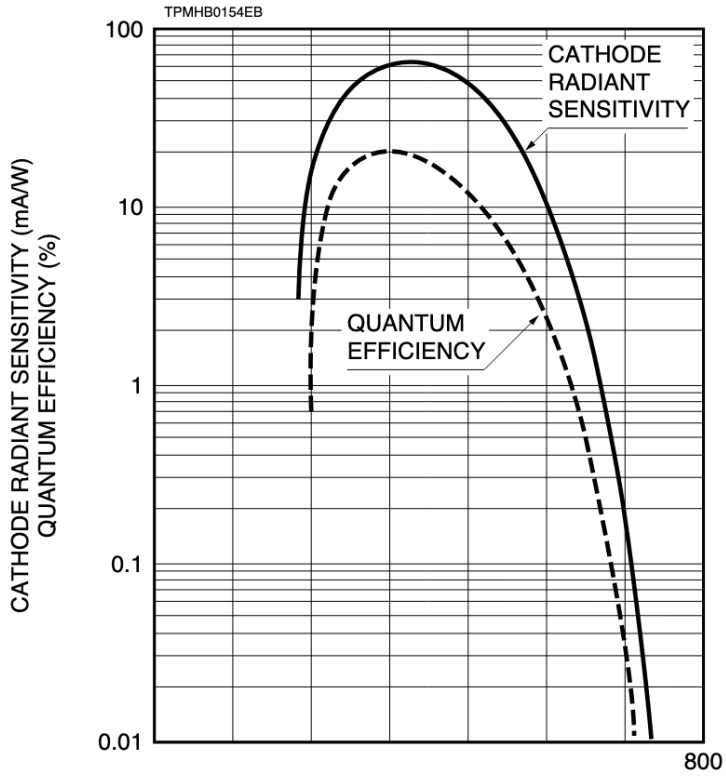
HAMAMATSU

PHOTOMULTIPLIER TUBE R5946

KLOE fibers

$\lambda \sim 460$ nm

Figure 1: Typical Spectral Response

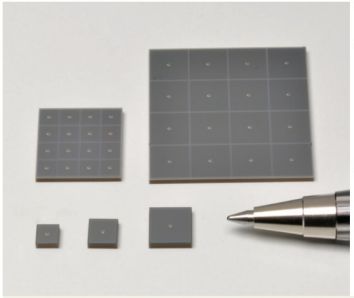


CHARACTERISTICS (at 25°C)

Parameter		Min.	Typ.	Max.	Unit
Cathode Sensitivity	Luminous (2856K)	–	80	–	μA/lm
	Blue (CS–5–58 filter)	–	9.5	–	μA/lm–b
	Quantum Efficiency at 390nm	–	23	–	%
Anode Sensitivity	Luminous (2856K)	–	80	–	A/lm
Gain	At 0 tesla	–	1.0×10^6	–	–
	At 1 tesla	–	2.9×10^4	–	–
Anode Dark Current (after 30min. storage in darkness)		–	5.0	30	nA
Time Response	Anode Pulse Rise Time	–	1.9	–	ns
	Transit Time	–	7.2	–	ns
	Transit Time Spread (FWHM)	–	0.35	–	ns

HAMAMATSU
PHOTON IS OUR BUSINESS

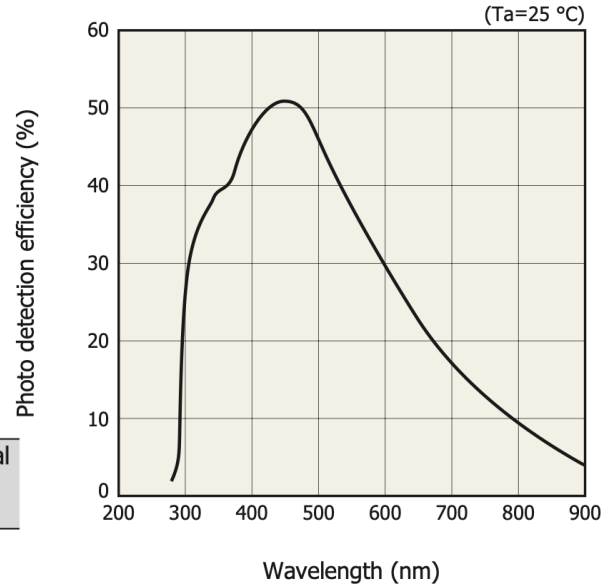
MPPC® (Multi-Pixel Photon Counter)



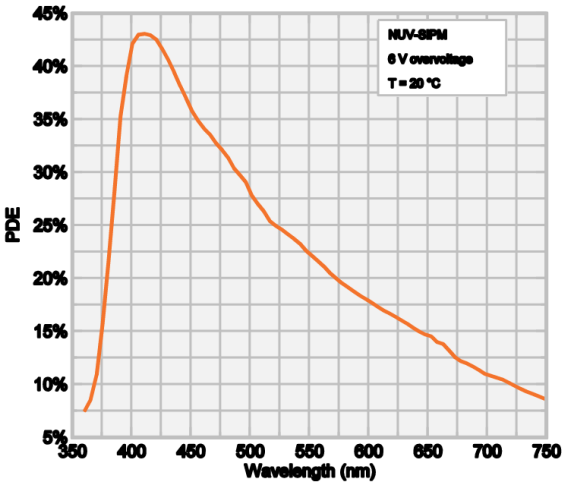
S14160/S14161 series

Low breakdown voltage type MPPC for scintillation detector

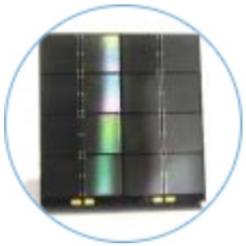
Typ. no.	Number of channels (ch)	Effective photosensitive area/channel (mm^2)	Pixel pitch (μm)	Number of pixels/channel	Package	Window	Window refractive index	Geometrical fill factor (%)
S14160-3050HS	1	3.0 × 3.0	50	3531	Surface mount type	Silicone	1.57	74
S14160-4050HS		4.0 × 4.0		6331				
S14160-6050HS		6.0 × 6.0		14331				
S14161-3050HS-04	16 (4 × 4)	3.0 × 3.0		3531				
S14161-3050HS-08	64 (8 × 8)	3.0 × 3.0		3531				
S14161-4050HS-06	36 (6 × 6)	4.0 × 4.0		6331				
S14161-6050HS-04	16 (4 × 4)	6.0 × 6.0		14331				



λ_{MAX} = 450 nm
PDE_{MAX} = 50 %



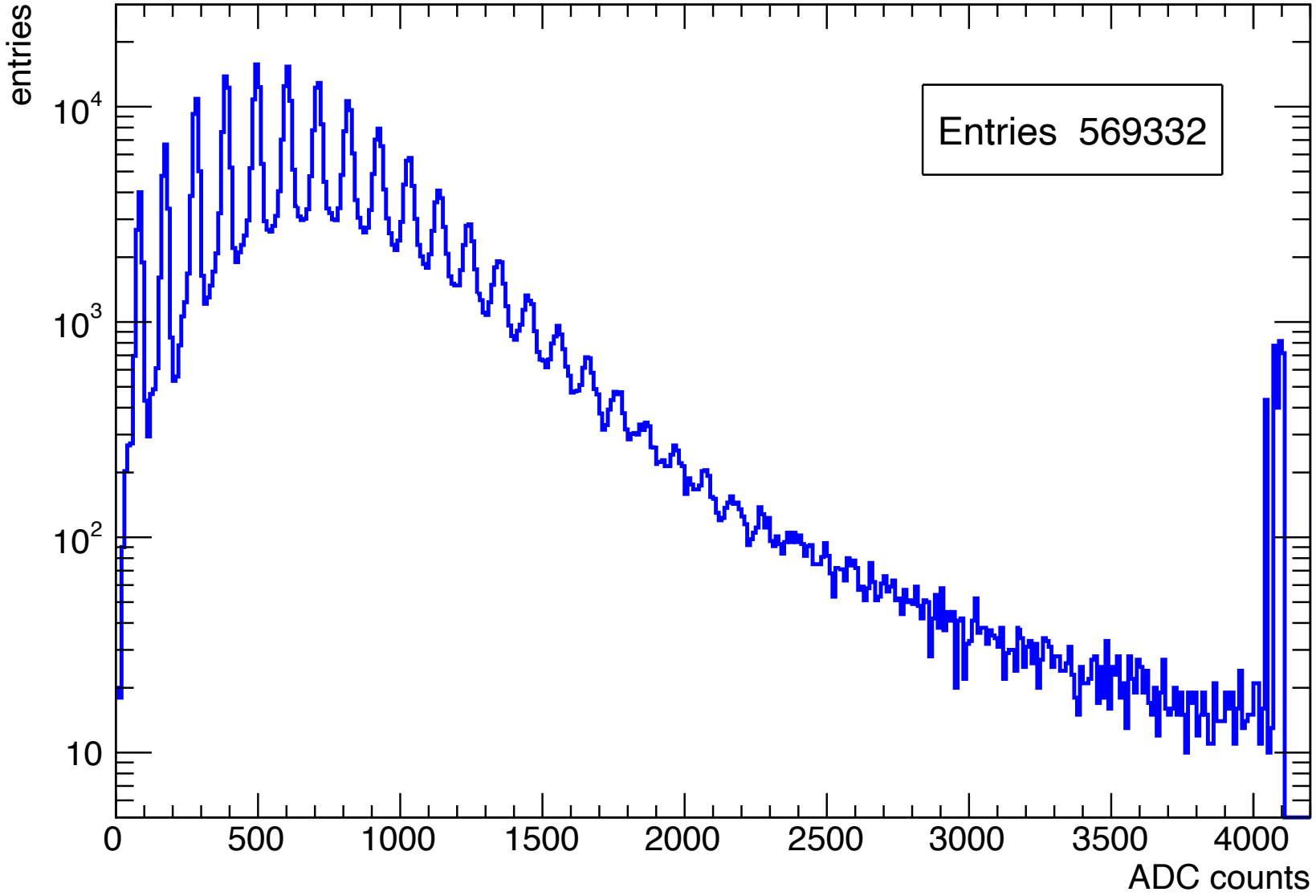
λ_{MAX} = 420 nm
PDE_{MAX} = 43 %

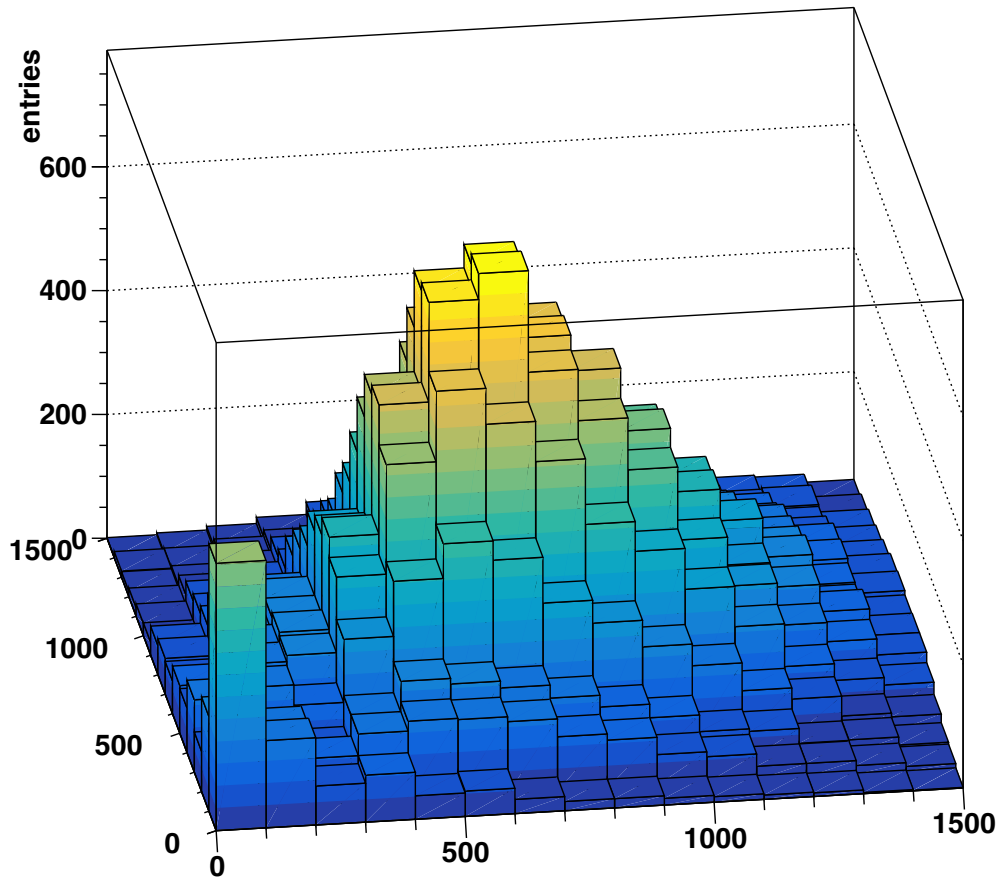


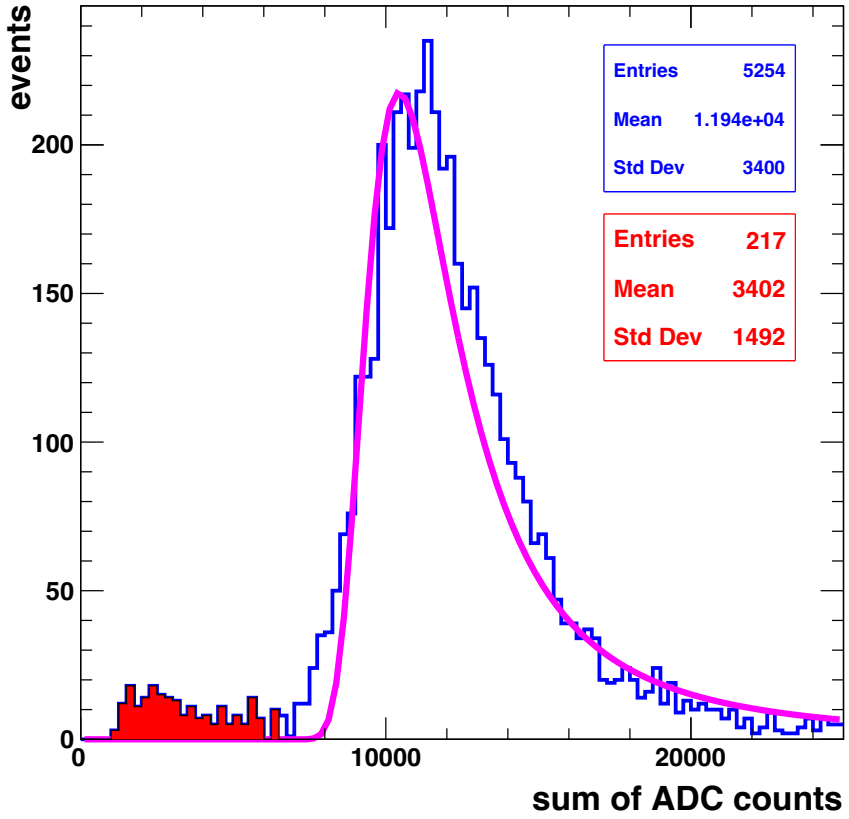
AdvanSiD
Advanced Silicon Detectors

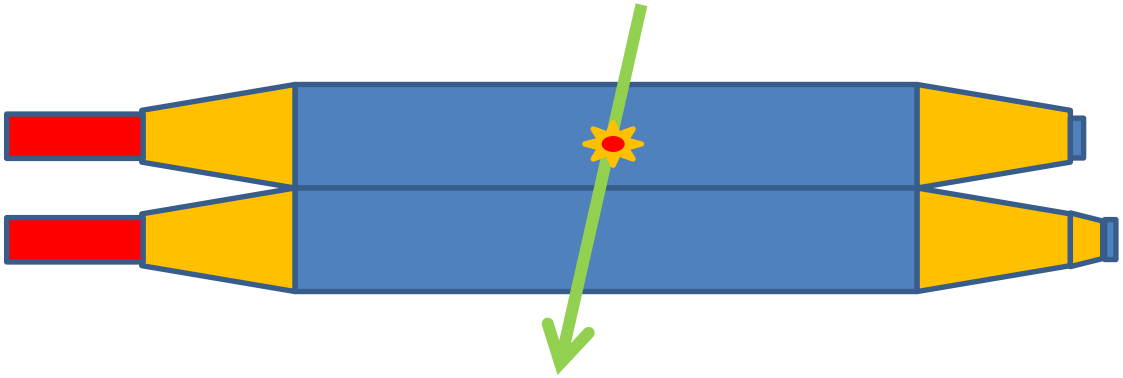
ASD-RGB4S-P-4x4TD, ASD-NUV4S-P-4x4TD

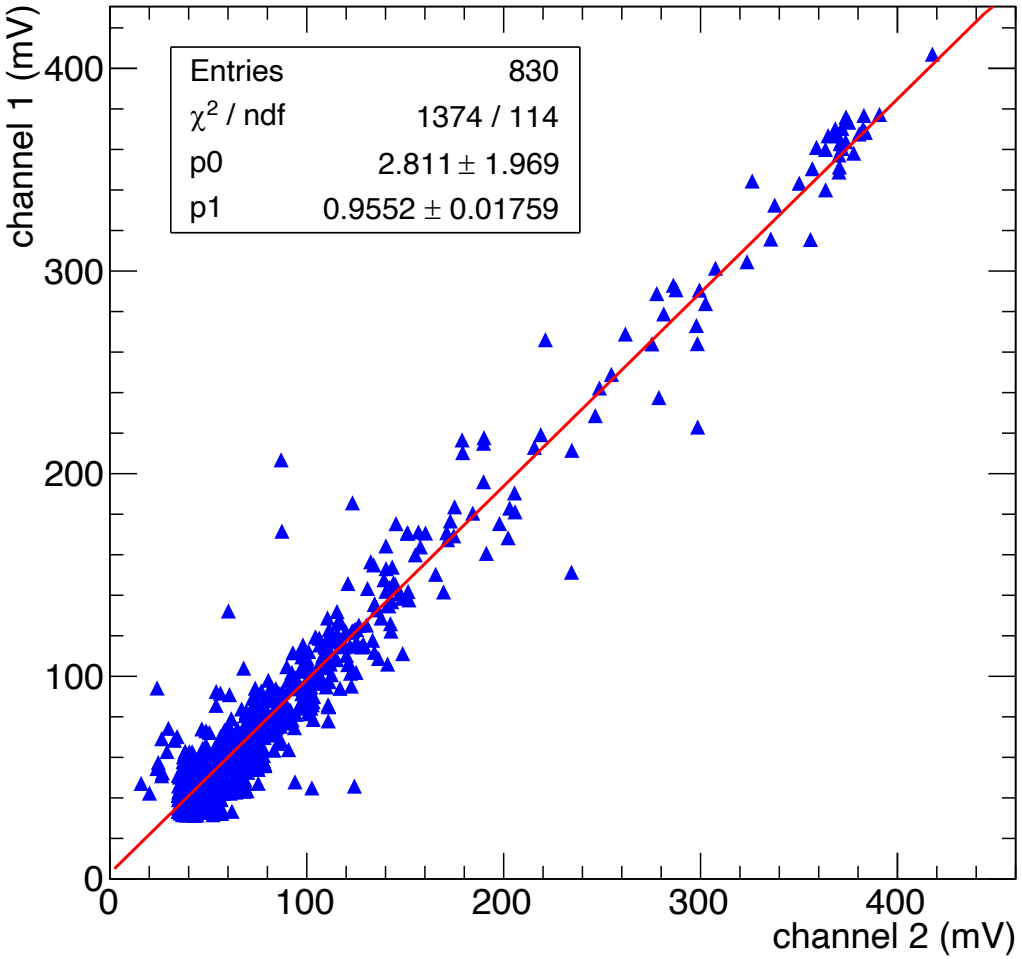
4x4 Hybrid Array of 4x4 mm^2 SiPMs in plastic chip scale package. The detector is completely covered with transparent epoxy layer.


entries
10^4
10^3
10^2
10
Entries 569332
0
500
1000
1500
2000
2500
3000
3500
4000
ADC counts


entries
600
400
200
0
1500
1000
500
0
0
500
1000
1500

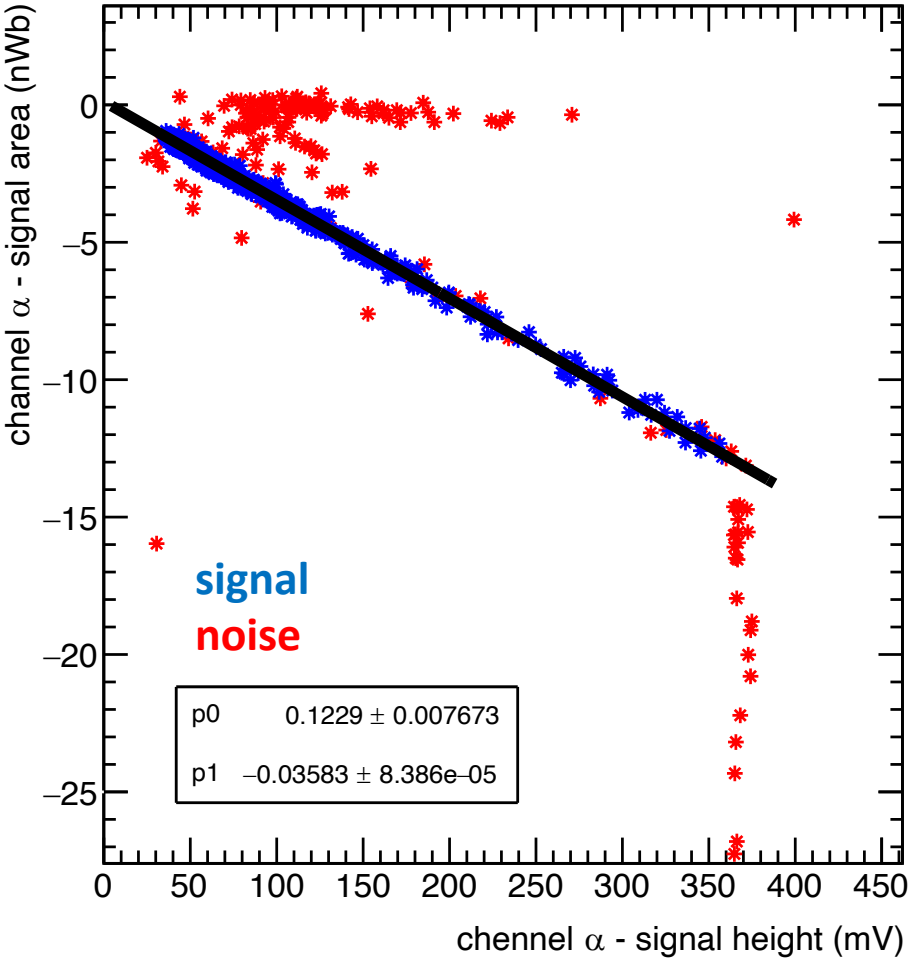

events
200
150
100
50
0
0
10000
20000
sum of ADC counts
Entries 5254
Mean 1.194e+04
Std Dev 3400
Entries 217
Mean 3402
Std Dev 1492



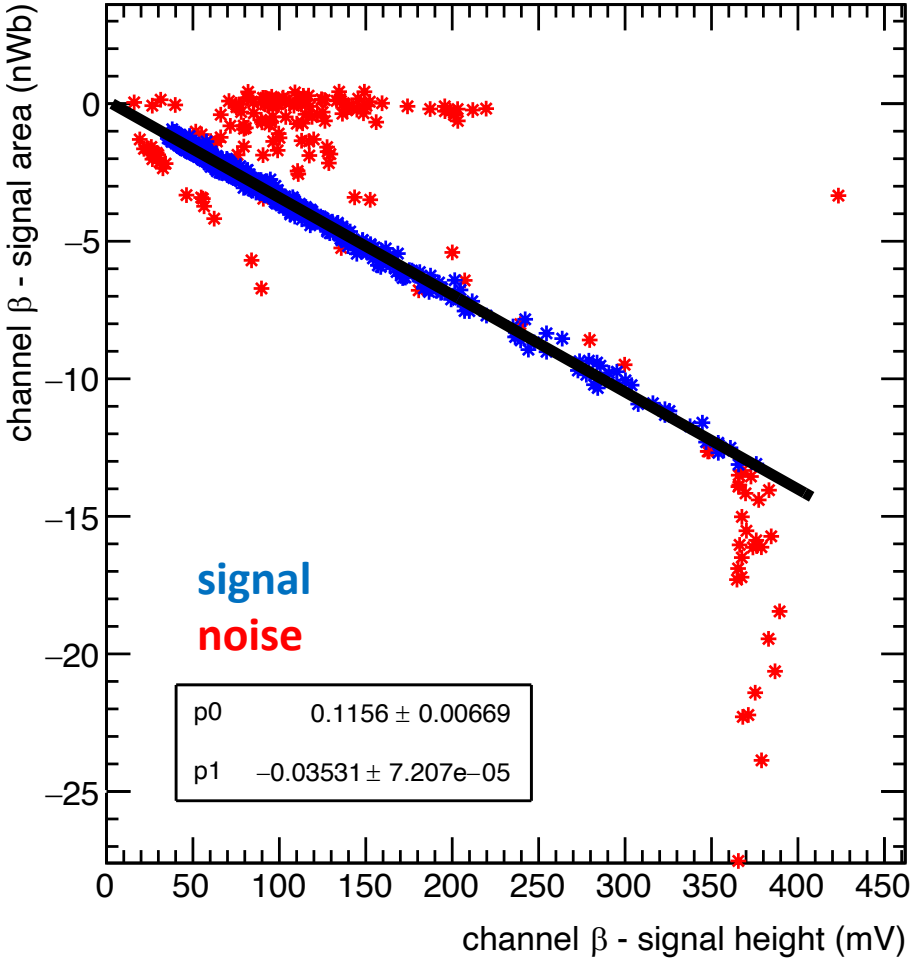


Check on signals from channels of the same SiPM

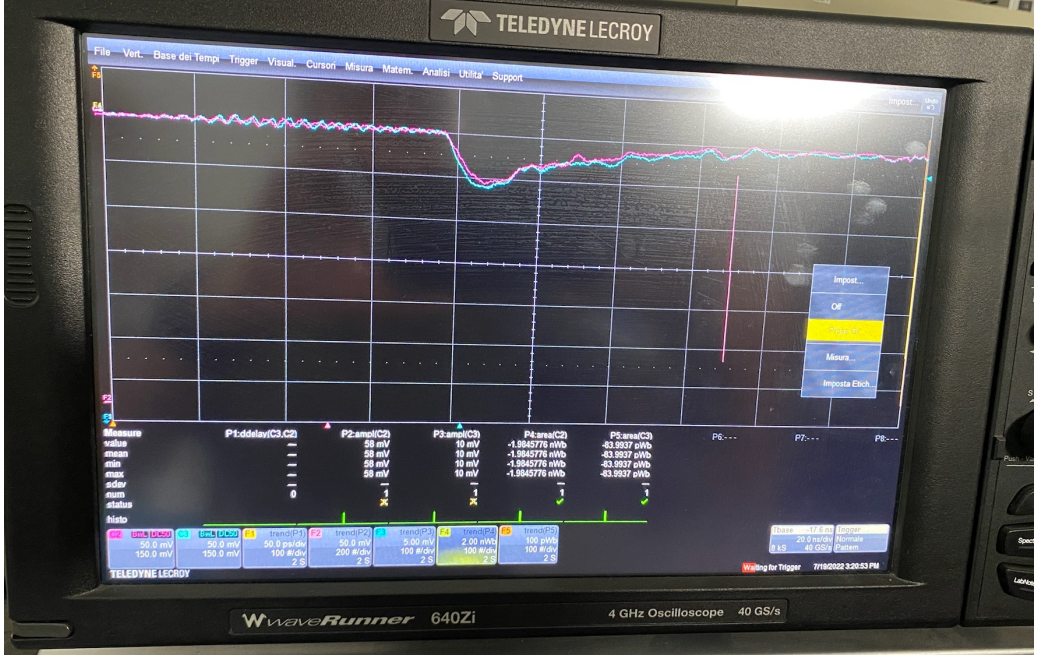
Signal area vs signal height

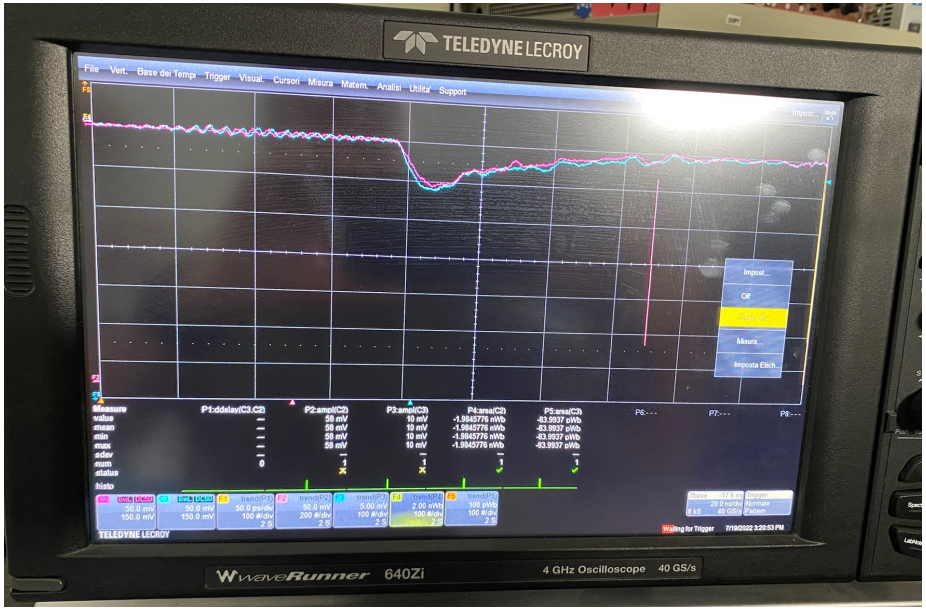


SiPM 3 - channel α



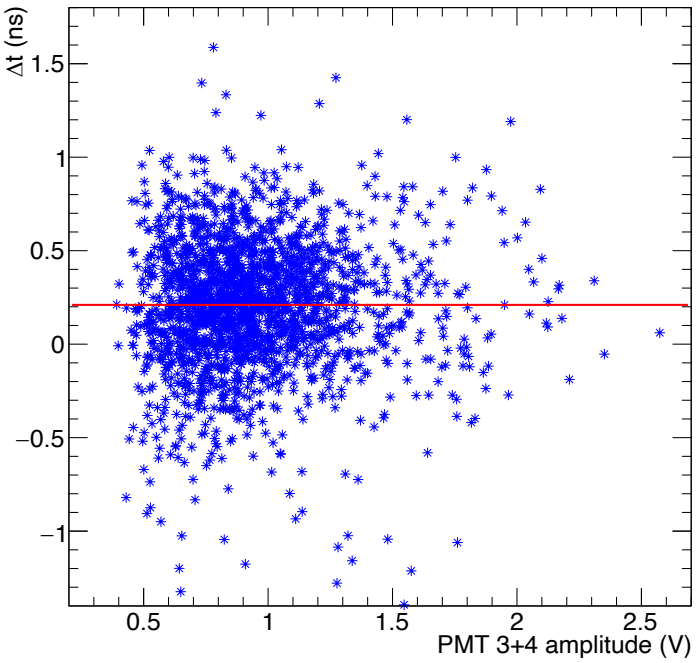
SiPM 3 – channel β



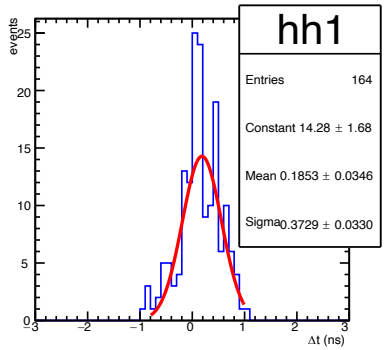


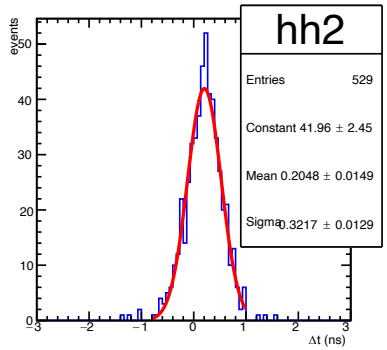
SiPM signals

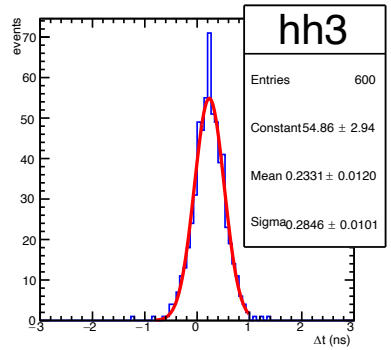
duration = 80-100 ns

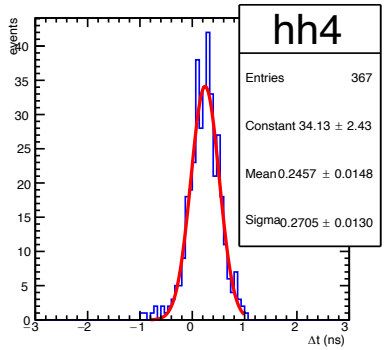


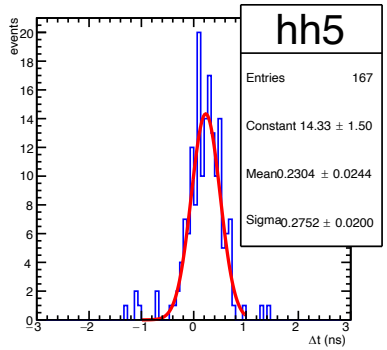
PMT 3 & 4

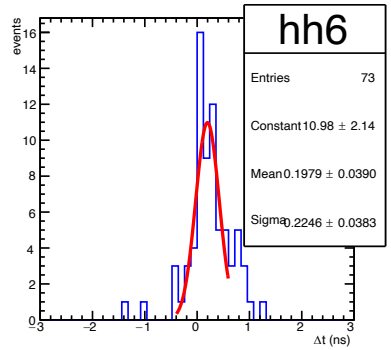






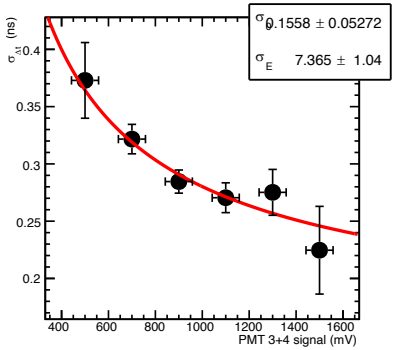






σ_0 = 156 ps from the fit

↳ σ_0 ~ 90 ps for single PMT

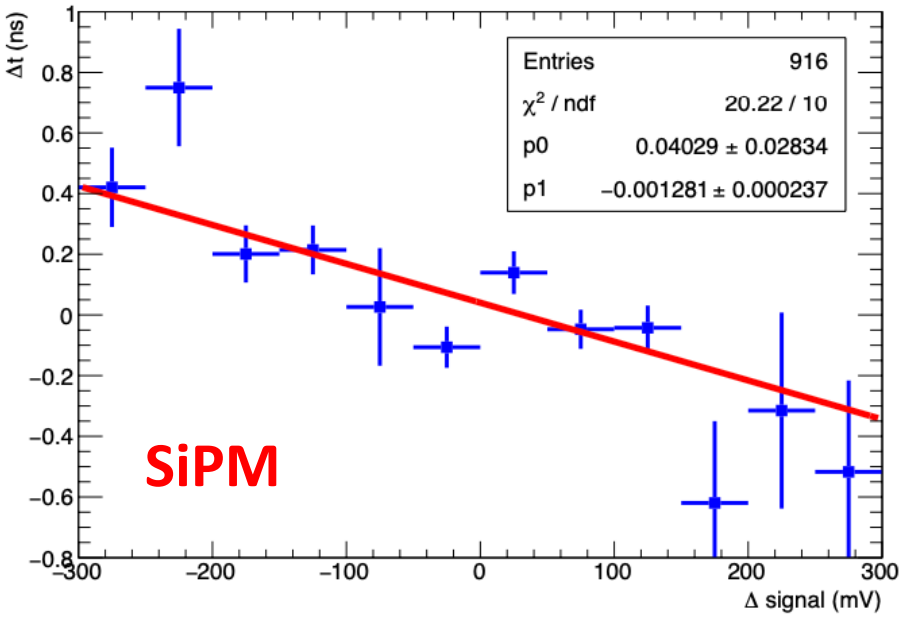


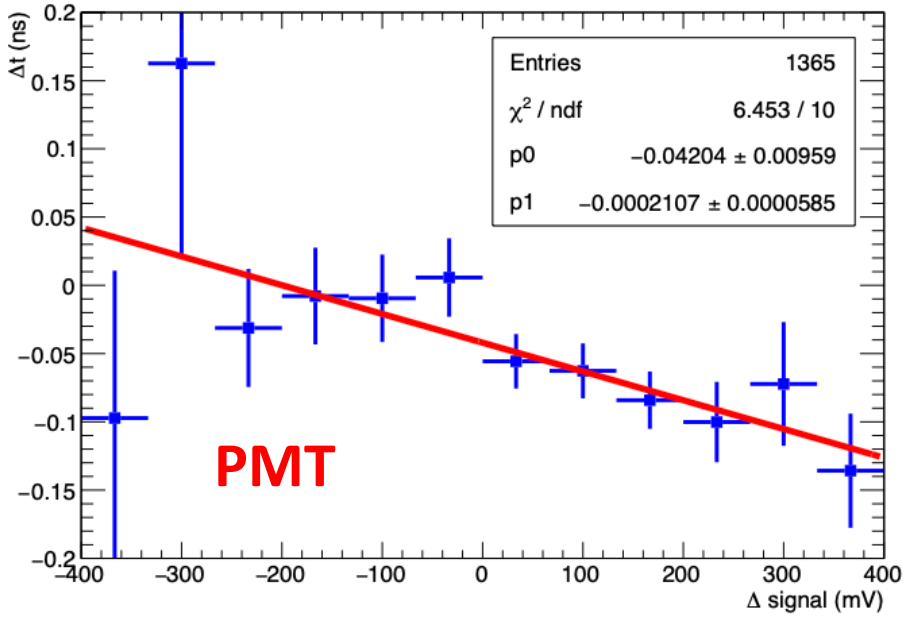
KLOE formula

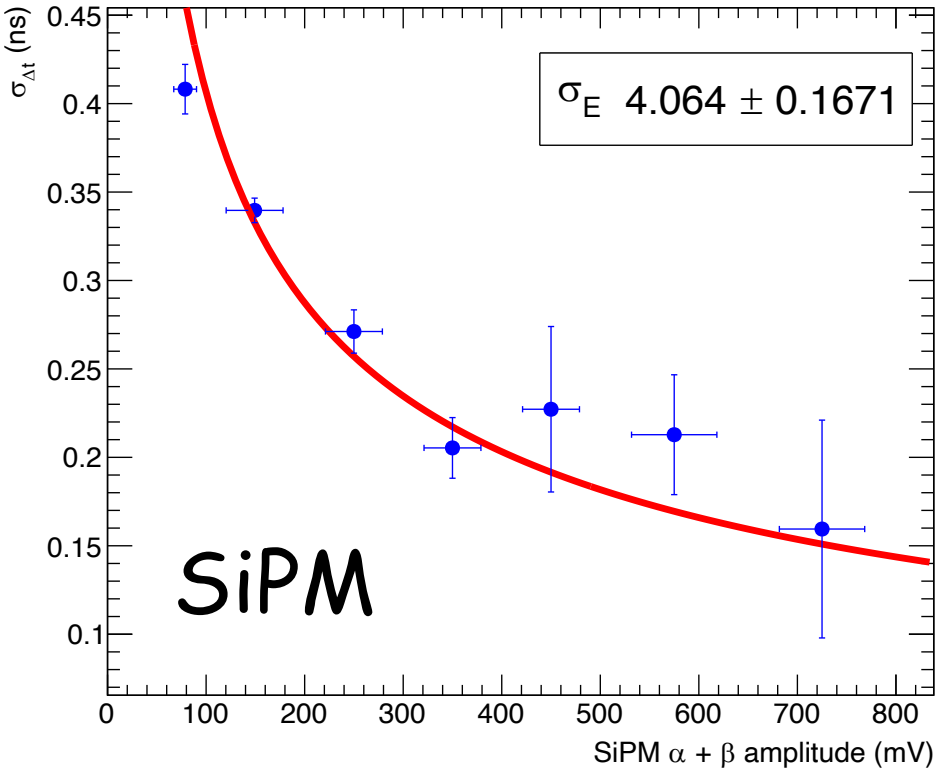
$$\sigma = \sigma_0 \oplus \frac{\sigma_E}{\sqrt{E_{GeV}}}$$

Average Δt vs signal difference

$\langle t_4 - t_3 \rangle$ vs $signal_4 - signal_3$







$$\sigma = \frac{\sigma_E}{\sqrt{E_{GeV}}}$$