Comparison between SiPMs and PMTs for SAND calorimeter

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for the Lecce group

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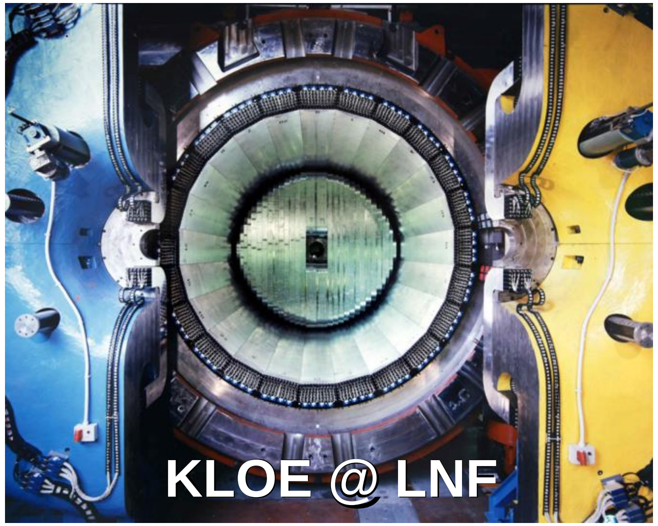
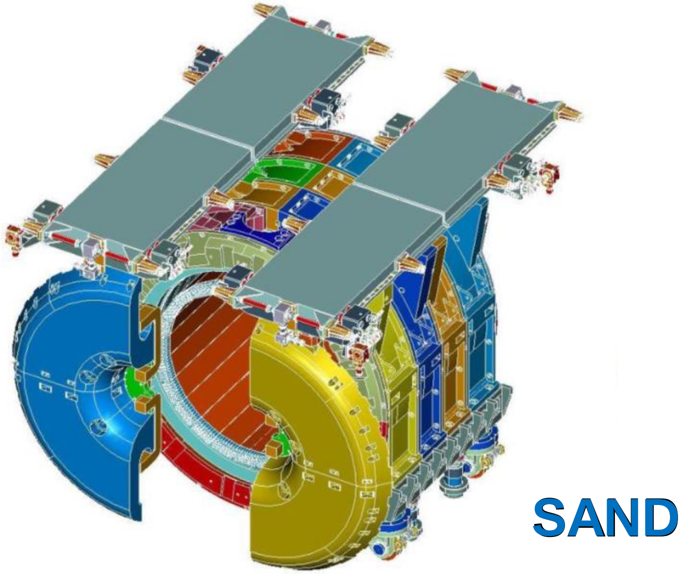
6-7 November, 2023

Motivation of the study: possibility/opportunity for using SiPMs in SAND ECal





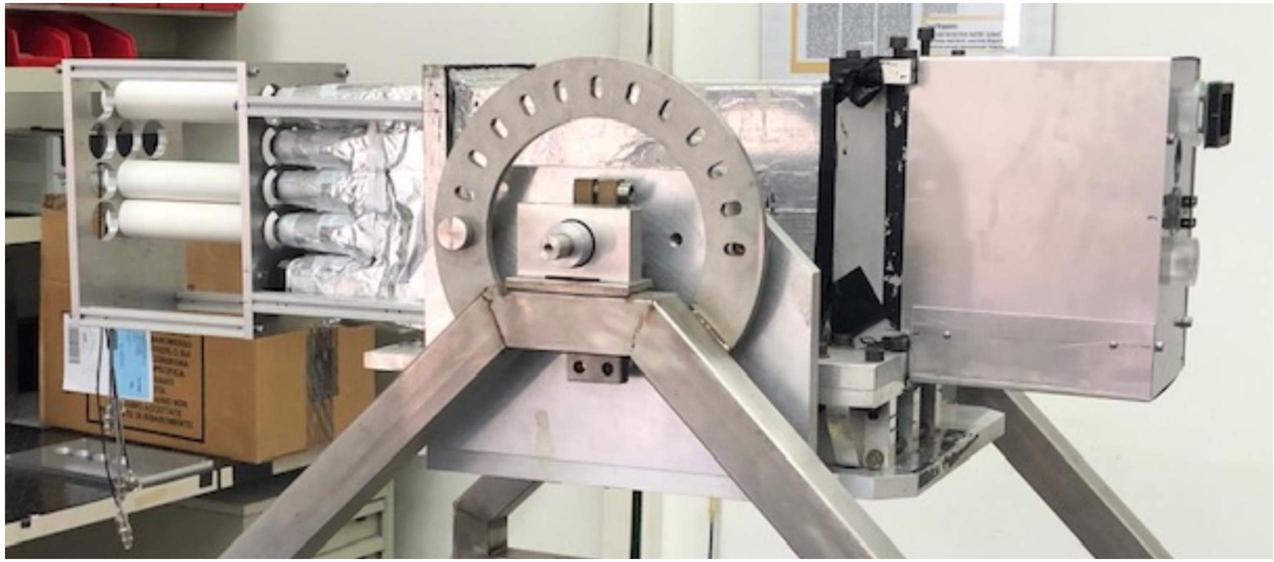
<u>Advantages of **PMTs**</u>

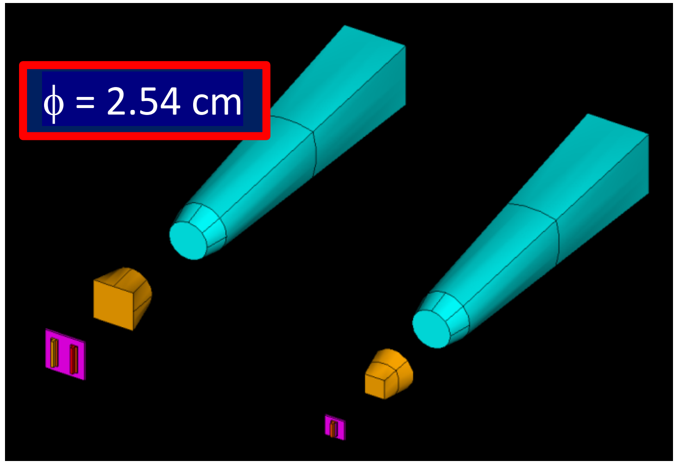
- ✓PMTs already used in the KLOE experiment at LNF
- ✓Fast and strong signals (with low noise)

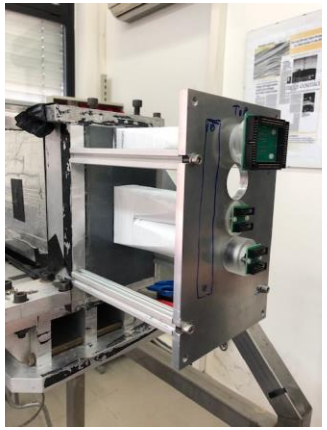
<u>Advantages of **SiPMs**</u>

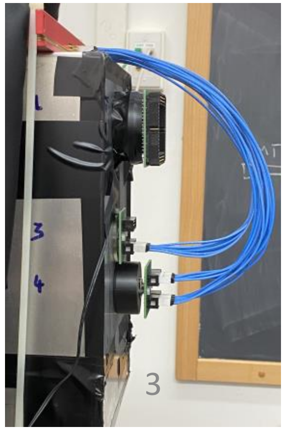
- ✓Not sensitive to the magnetic field
- ✓Compactness and Low cost
- ✓Operation at low voltage

Experimental setup and tools





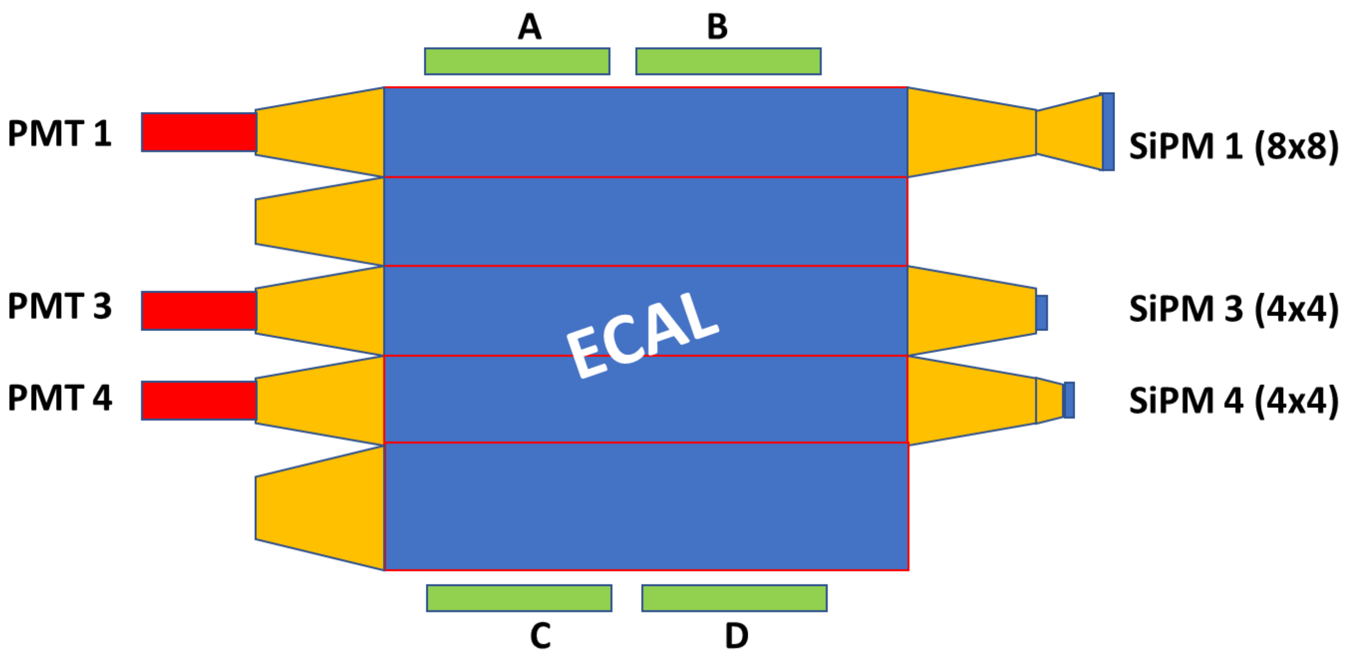




Coupling surfaces

Light guide	**490 mm^2**
4x4 SiPM	**169 mm^2**
8x8 SiPM	**666 mm^2**

Layout of experimental setup



Hamamatsu-R5946 **PMTs**

Hamamatsu **SiPM arrays** **S14161-3050HS-04**
S14161-3050HS-08

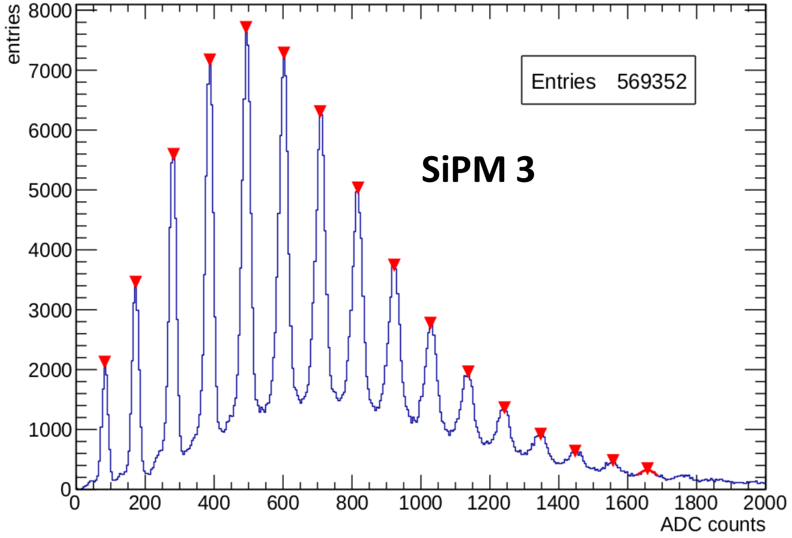
Readout board **CAEN FERS-DT5202 (64 Ch Board)**

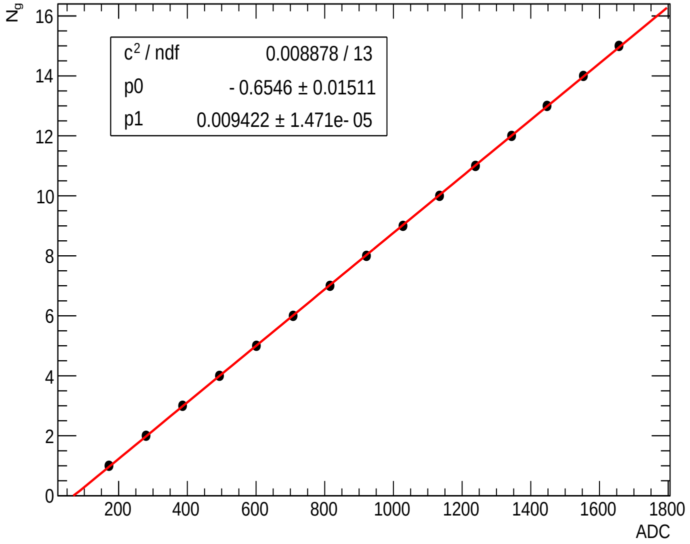
Gain, Threshold **optimized**

SiPM calibration **V_{bias} set to get uniform single-Ch rate**

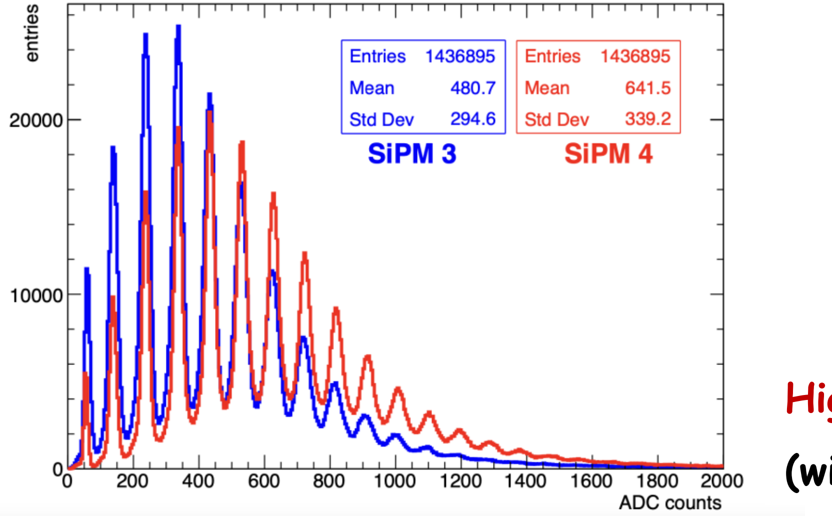
A, B, C, D: plastic scintillators for **external muon trigger**

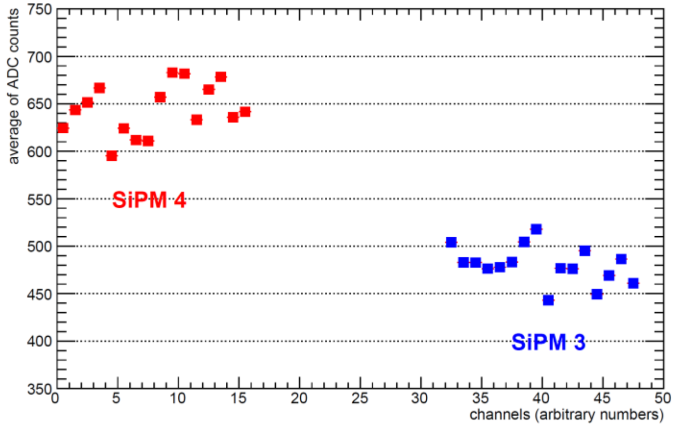
SiPM characterization and calibration





Correlation between number of collected p.e. and peaks of ADC counts, with a linear fit



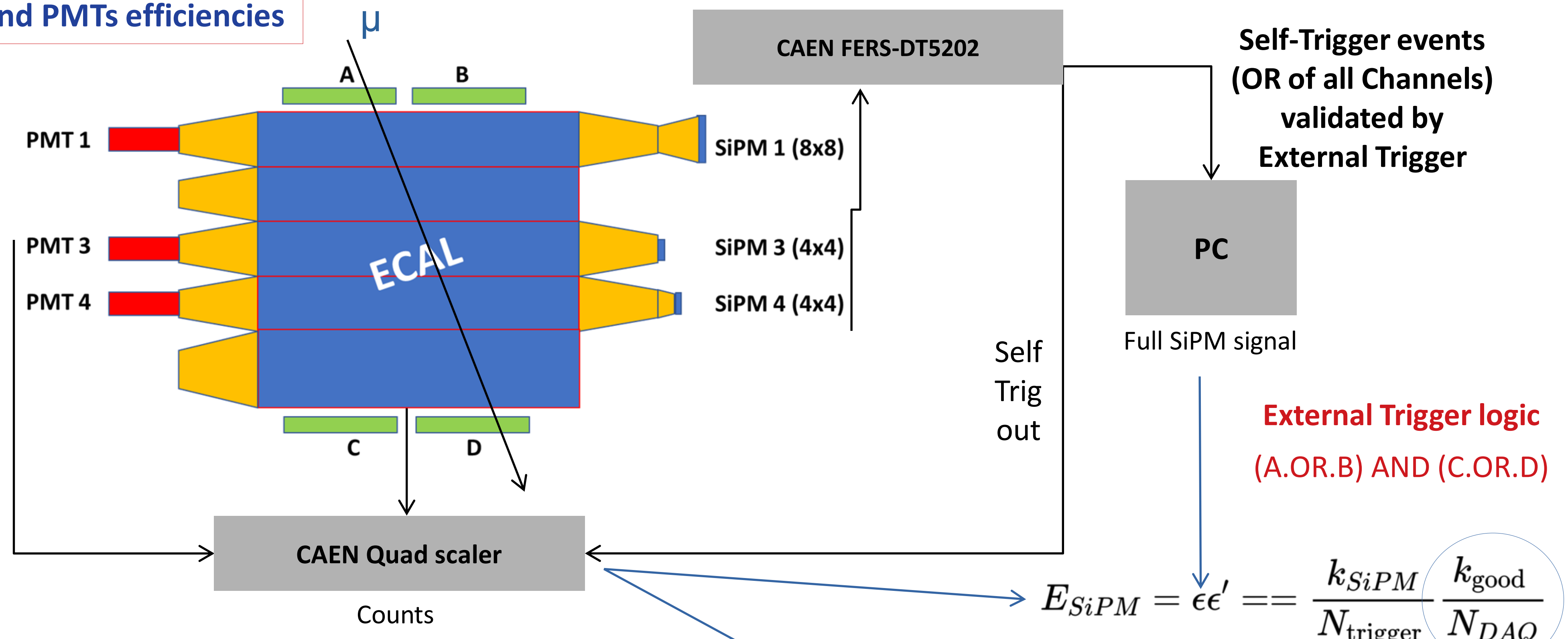


Higher light collection by SiPM 4

(with the adapter to connect SiPM and light guide)

Efficiency measurement: configuration and method

Comparison between SiPMs and PMTs efficiencies



$$E_{SiPM} = \epsilon\epsilon' == \frac{k_{SiPM}}{N_{\text{trigger}}} \frac{k_{\text{good}}}{N_{DAQ}}$$

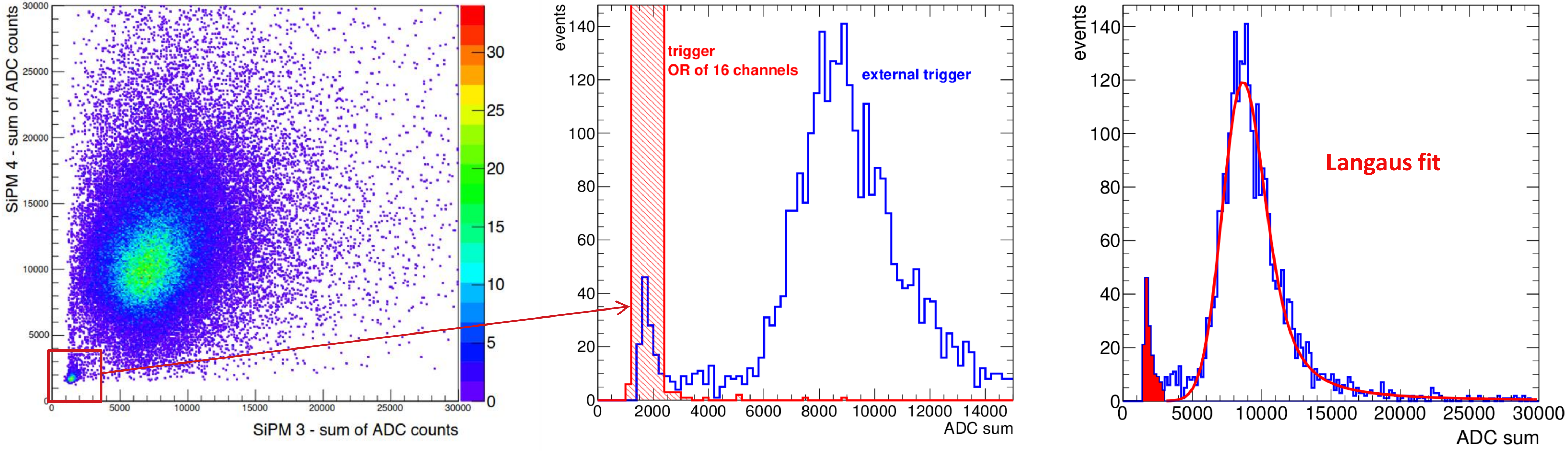
$$E_{PMT} = \frac{k_{PMT}}{N_{\text{trigger}}}$$

Removal of noise events (see next slide)

k_{SiPM} = SiPM events validated by the external trigger

k_{PMT} = coincidence PMT signals above 40 mV threshold

Efficiency measurement: results

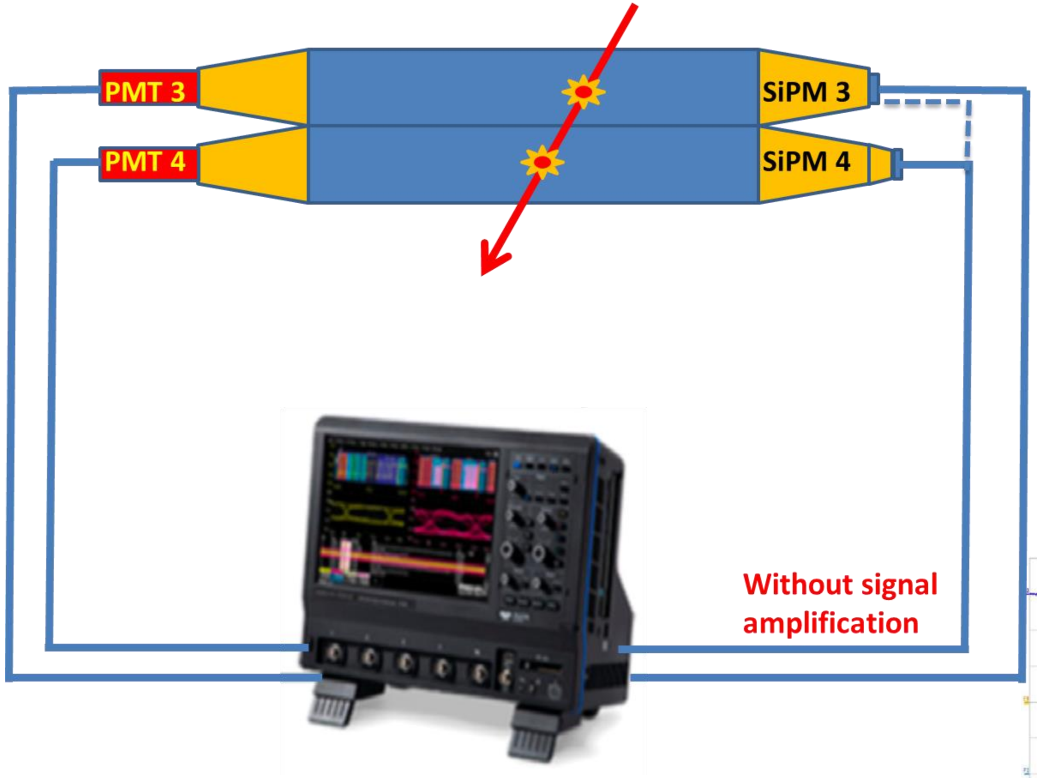


Residual events from dark noise removed by an off-line cut

E PMT 3	E PMT 4	E SiPM 3	E SiPM 4
$92.06^{+0.14}_{-0.15}$	$91.17^{+0.15}_{-0.16}$	$90.70^{+0.22}_{-0.23}$	$90.82^{+0.23}_{-0.25}$

- ✓ **Similar result** for PMT and SiPM
- ✓ **PMT slightly better**, in this configuration

Time resolution measurement: configuration and method



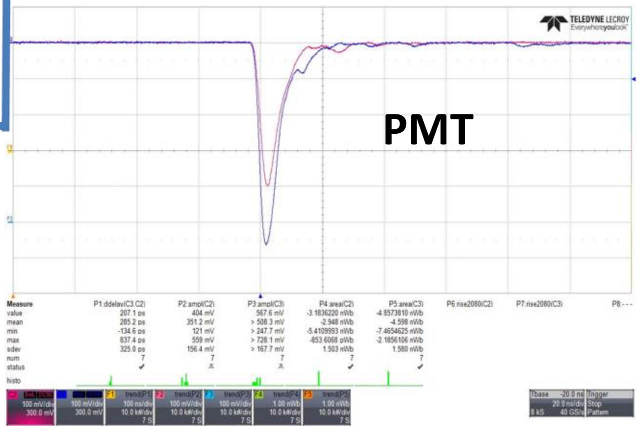
Time difference of the two signals at 50% of amplitude

$$\Delta t = t_4^{50\%} - t_3^{50\%}$$

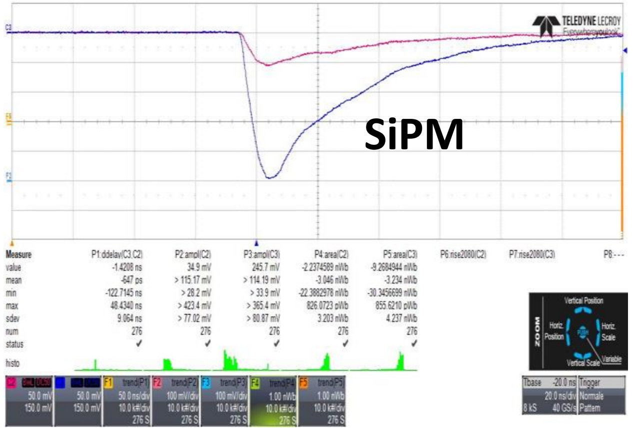
- PMT 3 and PMT 4
- 2 channels of
  a) two different SiPM matrices (3 and 4)
  b) the same SiPM matrix

SiPM analog signals extracted by a proper custom circuit

- Oscilloscope Teledyne Lecroy Waverunner 640Zi
- 40 GHz sampling rate
- No amplification

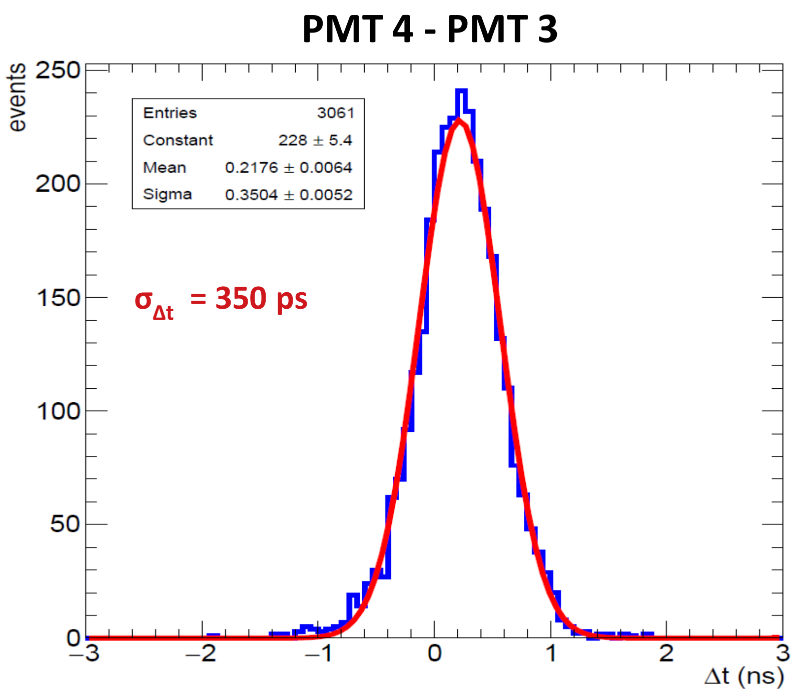


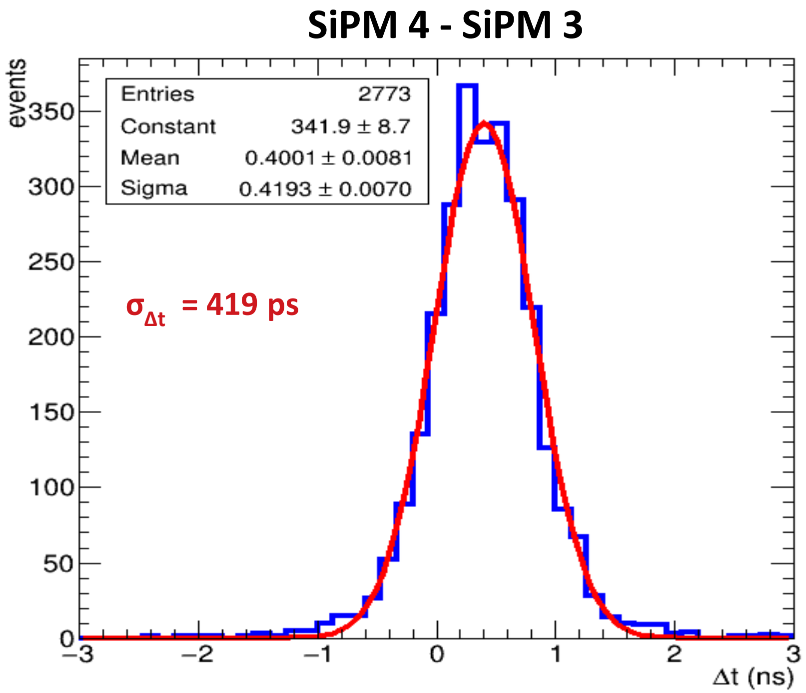
PMT signal duration ~20 ns



SiPM signal duration ~80 ns

Time resolution measurement: results





A MC simulation has been implemented to take into account the **time jitter** due to the **different particle paths** (geometrical jitter)

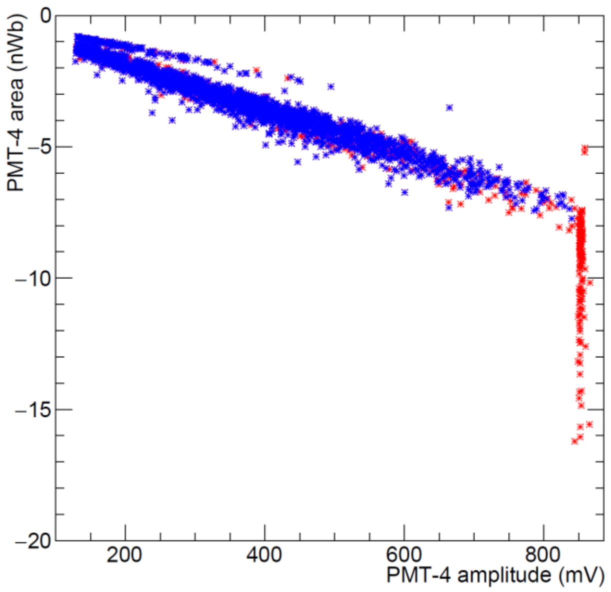
$$\sigma_{\Delta t} \Rightarrow \sigma_{channel}$$

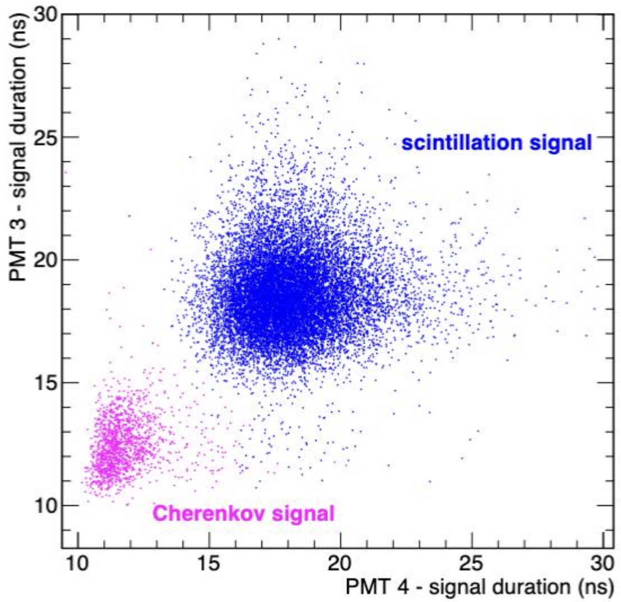
	Entries	$\sigma_{\Delta t}$ [ps]	$\sigma_{SingleCh}$ [ps]
SiPM 4-3	2773	419 ± 7	269 ± 5
PMT 4-3	3049	350 ± 5	217 ± 4

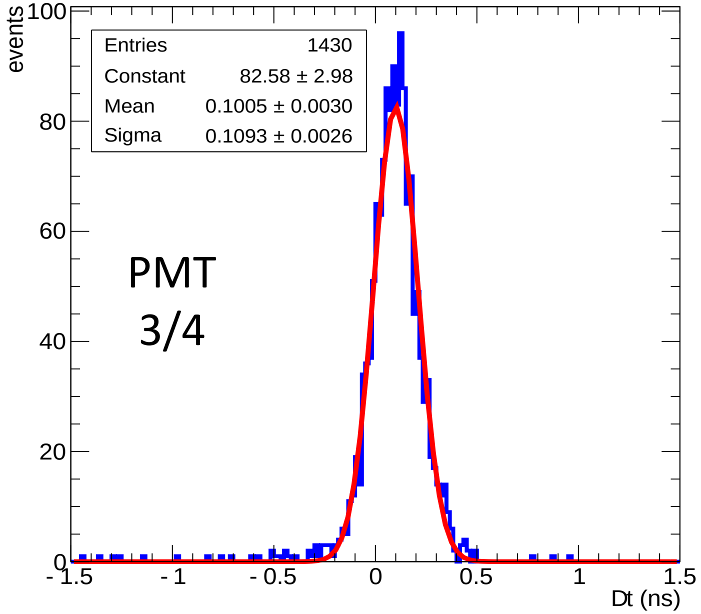
Using MC to consider the geometrical jitter

PMT time resolution slightly better than the SiPM one

PMT Time resolution: Cherenkov light







Area ~ (a/2) x amplitude

a ~ signal duration

Signal duration of PMT3 vs PMT4

Two signal populations:

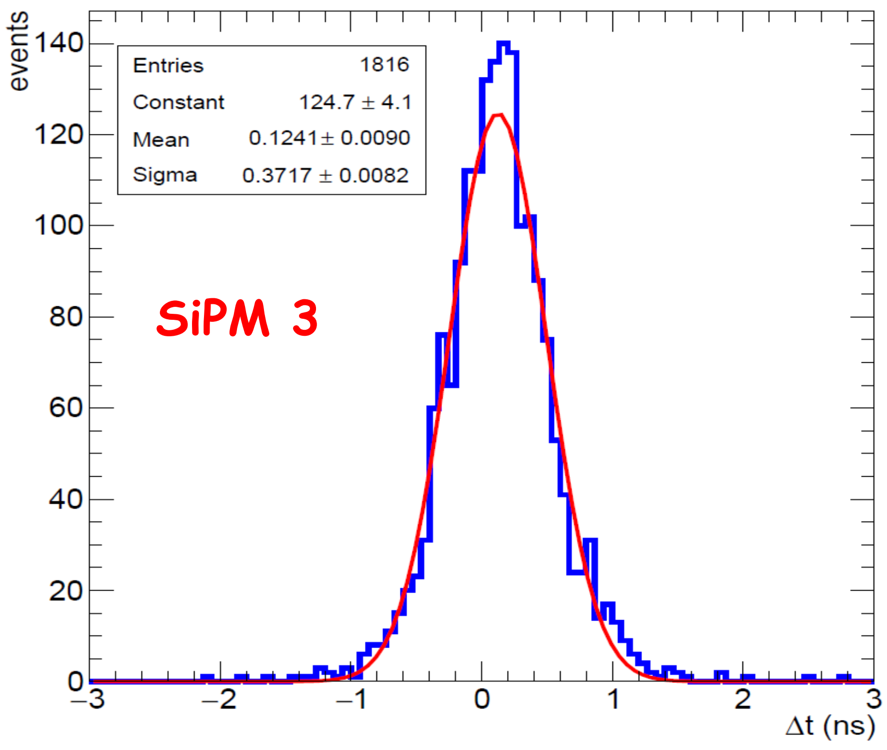
- **fiber scintillation light**
- **Cherenkov light from Winston cones**

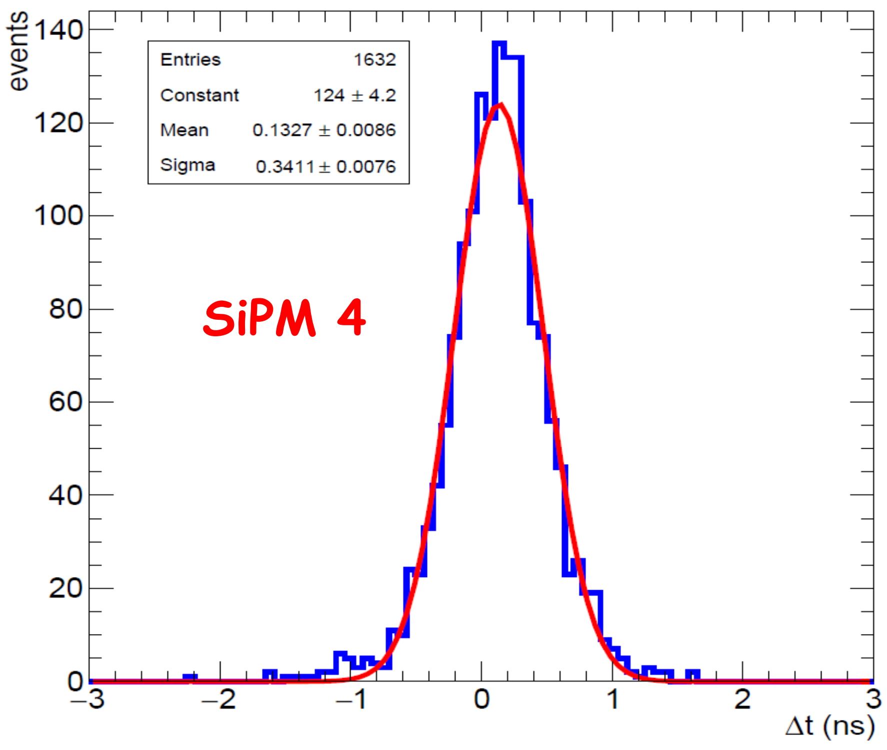
Cherenkov light from Winston cones

$\sigma_{\Delta t}$ **= 109 ps**

$\Rightarrow$ σ_t **~ 70 ps**

SiPM time resolution: 2 channels from the same sensor





$$\sigma_{t(Ch)} = \sigma_{\Delta t} / \sqrt{2}$$

	$\sigma_{\Delta t}$ [ps]	$\sigma_{SingleCh}$ [ps]
SiPM 3	372 ± 8	263±6
SiPM 4	341 ± 8	241±6

Time resolution measurement: results

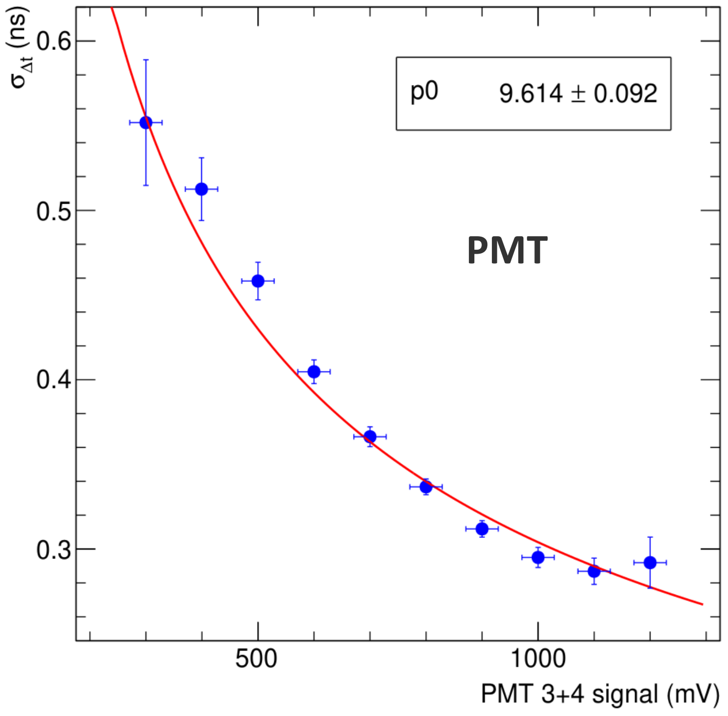
Time resolution as a function of deposited energy

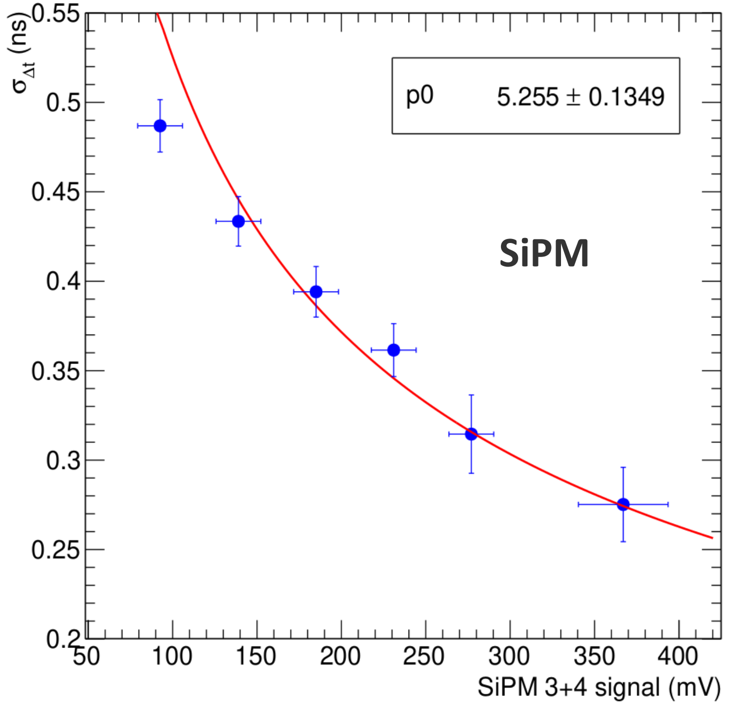
For KLOE:

$$\sigma_t = 54 \text{ ps}/\sqrt{E(\text{GeV})}$$

This work:

$$\sigma_t = p_0/\sqrt{signal\ (\text{mV})}$$





Technical paper submitted to DUNE-APB

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Nuclear Instrum. Methods A

Study of SiPMs for calorimetry applications

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Abstract

The KLOE electromagnetic calorimeter is expected to be reused in the Near Detector complex of the DUNE experiment at Fermilab. The possible substitution of traditional Photomultiplier Tubes (PMTs) with Silicon Photomultipliers (SiPMs) in the refurbished calorimeter is the object of this investigation. A block of the KLOE lead-scintillating fiber calorimeter has been equipped with light guides and external trigger scintillators. The signals induced by cosmic rays and environment radioactivity have been collected on one side by SiPM arrays, and on the opposite one by conventional PMTs. Efficiency, stability, and timing resolution of SiPMs have been studied and compared with KLOE-PMTs performances. Conclusions about the convenience of substituting PMTs with SiPMs are drawn.

Conclusions

- **SiPMs** and **PMTs** coupled with the **KLOE calorimeter** were compared, focusing on
  - detection efficiency
  - timing resolution
- **Different optical couplings** have been tested for adapting **SiPMs** to the KLOE light guides
- From this study, the **SiPM performances** are **similar to** the **PMT** ones, the last anyway being slightly better
- The obtained results suggest to use the **PMTs** for the readout of **SAND ECAL**, although SiPMs can be a possible backup solution
- A **DUNE techical paper** containing this study and its results is proposed

BACKUP

Cross check

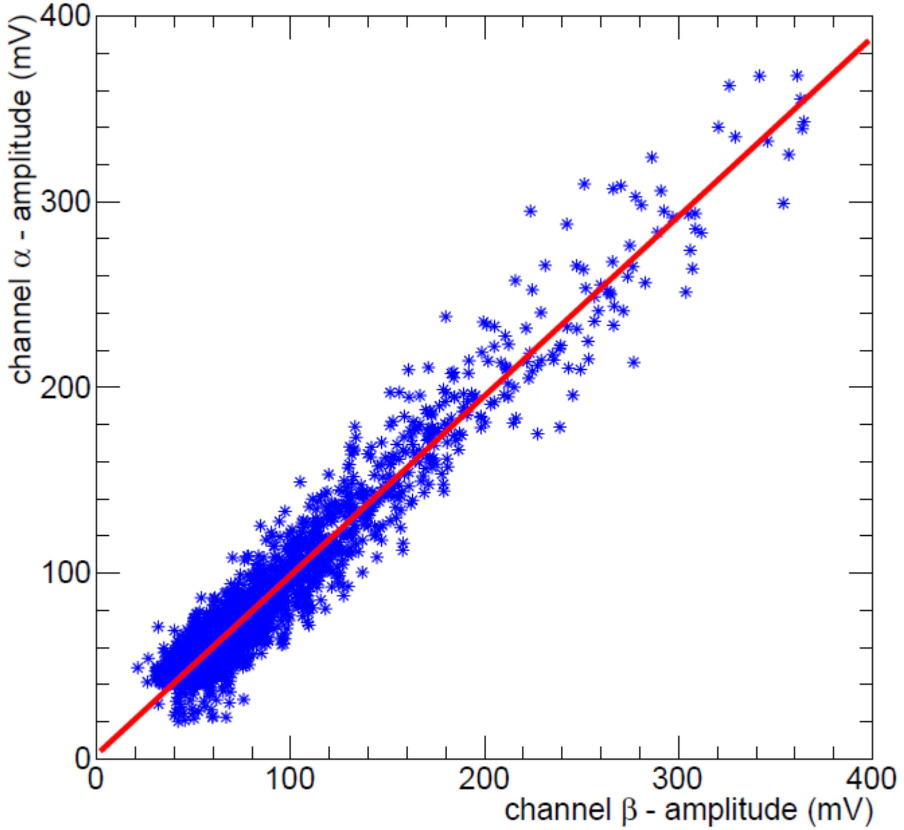

Figure 15. Signal amplitude of channel α versus amplitude of channel β of the same SiPM array.

Cross check

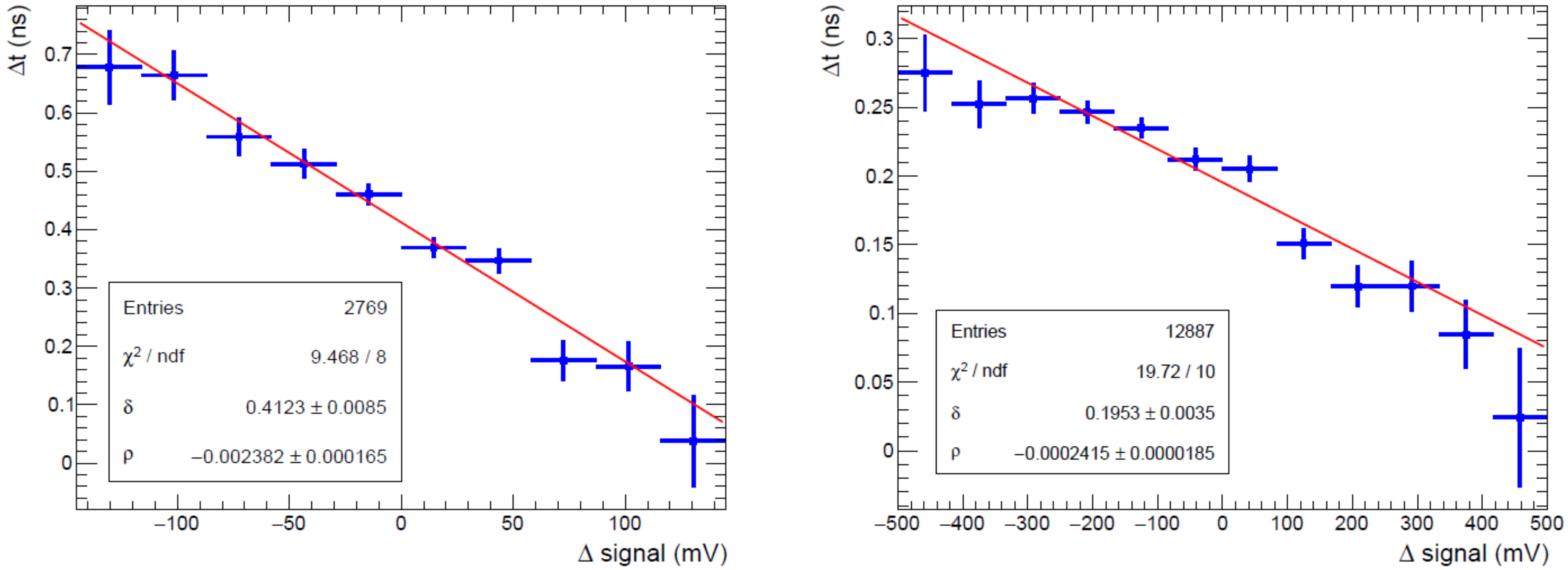

Figure 16. Time difference vs signal amplitude difference (profile). Left: SiPM. Right: PMT.