Study of SiPMs for calorimetry applications

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ABSTRACT The possible use of SiPM arrays for calorimetry applications is object of investigation. A piece of a lead-scintillating-fiber calorimeter is read by conventional photo-multiplier tubes (PMTs) at one edge and by SiPMs at the other one. Here the experimental set-up and the different couplings of light-guides with SiPMs are reported. Some preliminary results, as light yield and efficiency for SiPMs, compared to PMTs performance, are presented.

Introduction

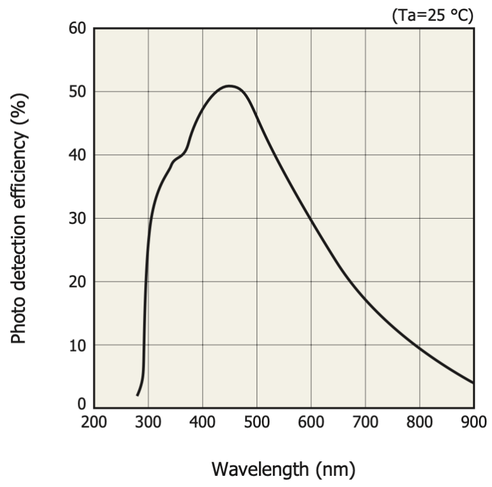
SiPMs, Silicon Photo-Multipliers or Multi-Pixel Photon Counters (MPPCs) **have potentiality and specific advantages for the calorimetry studies**[1]:

- unlike the PMTs, SiPMs are insensitive to magnetic fields
- SiPMs operate at low voltage, then high voltage power supplies are not necessary, with convenience in compactness and cost,
- the SiPM photodetection range is compatible with the typical wavelength-shifted light in the scintillating fibers.

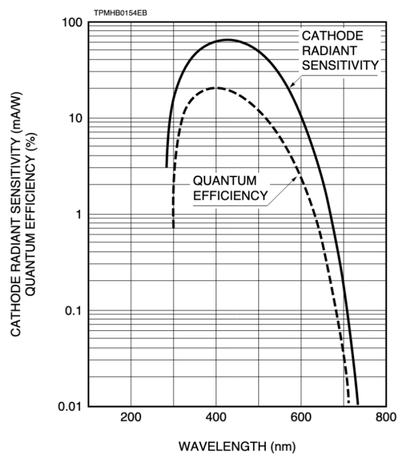
This study is aimed to evaluate the compatibility of SiPM readout of an electromagnetic calorimeter, and the possible capability of SiPMs to allow improvements in efficiency and time resolution, over standard PMT readout.

The SiPMs

We use Hamamatsu S14161 series [2], with 16 (4×4) and 64 (8×8) channels. The SiPM arrays are characterized by a small dead space in the photosensitive area, a gain $\sim 10^6$, a **maximum PhotoDetection Efficiency** $\mathbf{PDE_{MAX} = 50\%}$ at the **wavelength** $\boldsymbol{\lambda_{MAX} = 450}$ **nm**.
The λ_{MAX} value is close to the wavelength peak of the scintillating fibers in the calorimeter.



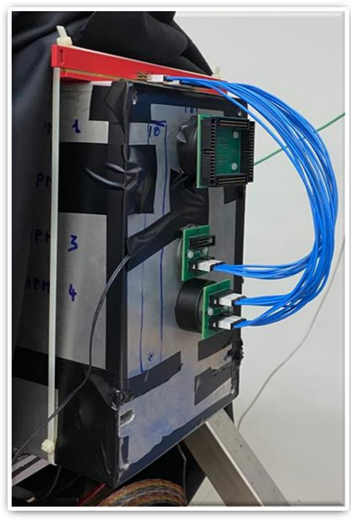
Serial N.	N. Of channels	Effective photosen. area/ch.	Pixel pitch (μm)	N. Of pixel/ch.	Package type	Window refractive index
S14161-3050hd-04	16 (4×4)	3.0×3.0 mm^2	50	3531	Surface mount type	1.57
S14161-3050hd-08	64 (8× 8)	3.0×3.0 mm^2				

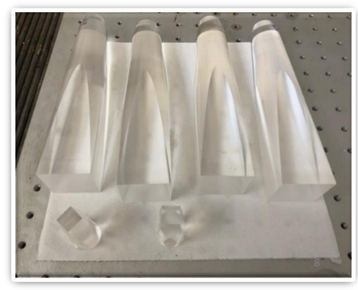


PMT quantum efficiency vs wavelength

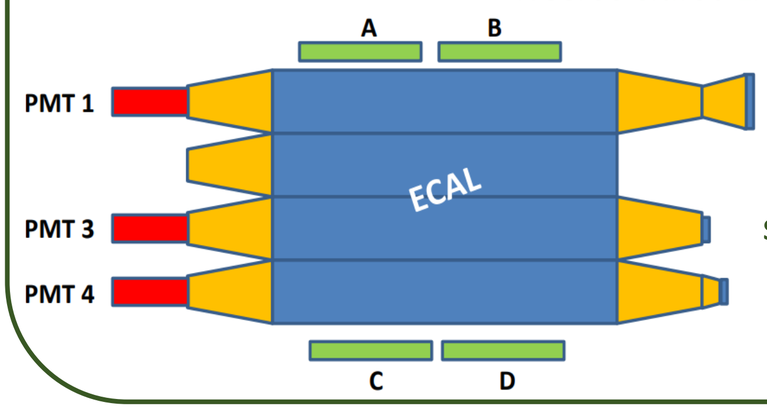
The experimental set-up

A dedicated experimental set-up has been realized with a slice of a sampling calorimeter (ECAL), made of lead and scintillating fibers. The fibers emit in the blue region with wavelength peak $\lambda_p \sim 460$ nm.
The calorimeter is segmented in squared section modules of size 4.3× 4.3 cm^2, characterized by the same features and performances of the KLOE electromagnetic calorimeter [3]. On one side the ECAL modules are read by Hamamatsu-R5946 PMTs connected through light-guides. Similar light-guides are used to connect SiPMs at the other side, employing different configuration of adapters.
For the SiPMs readout, we used a desktop front-end unit, CAEN DT5202, housing Weeroc Citiroc-1A chips.





Light guides



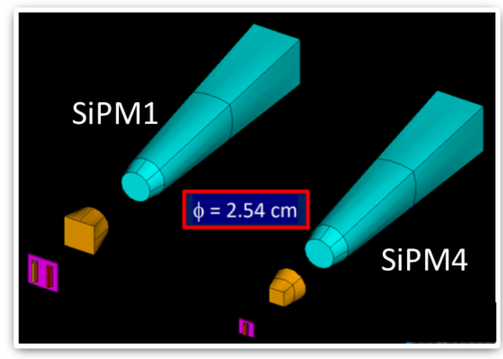
The different couplings under test:

SIPM1) 8x8 channels SiPM coupled by a large adapter to the light-guide,

SiPM2) directly coupling of the SiPM to the ECAL,

SIPM3) 4x4 channels SiPM coupled to the light-guide, without the adapter,

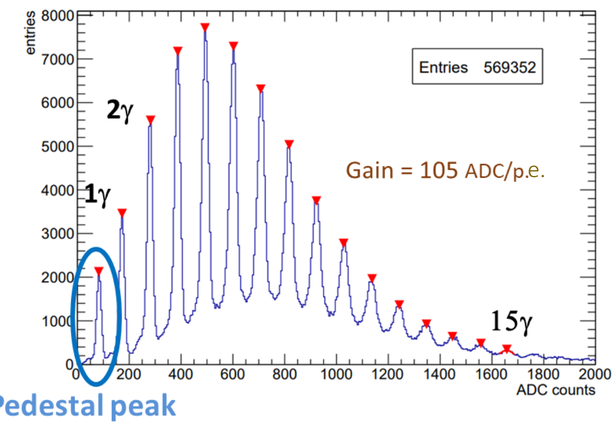
SIPM4) 4x4 channels SiPM coupled by a small adapter to the light-guide.



Adapter to the light-guide

Calibration of light yield

The SiPM charge is readout as ADC. **Each SiPM channel is calibrated separately** by low-voltage (V_{BIAS}) regulation, looking at the self-trigger rate. The SiPMs show stability in energy conversion and the photon spectrum is obtained as in figure.

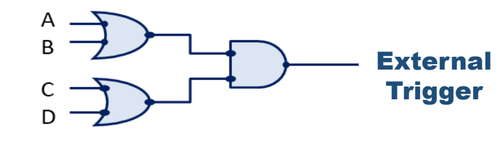


Pedestal peak

From the ADC values of the peaks we get the formula to convert the ADC signal in the number of photoelectrons

$$\mathbf{N_\gamma} = 0.0094\ \mathrm{ADC} - 0.65$$

Efficiency measurements



The SiPM efficiency has been studied using cosmic rays. The trigger is provided by an external system of 4 scintillators (surface ~ 2 x 12 cm^2). During the SiPM data acquisition also the PMTs efficiency is measured. Some preliminary results are presented here (see table). The trigger rate of the "finger" scintillators is a few mHz and the statistics should be improved.

PRELIMINARY RESULTS

ECAL	PMT efficiency (%)	SiPM efficiency (%)
module 3	90.1 ±2.1 3	90.1 ± 2.1
module 4	88.4 ±2.5	89.6 ± 2.5

Next steps

SIPM efficiency with improved statistics.

The front-end unit provides the **pre-amplified signal readout from the SiPM single channel**. It could be used for measurements **of time resolution** compared with the PMTs (~200 ps).

References

[1] S. Gundacker, A. Heering, *Phys. Med. Biol.* **65** (2020) 17TR01

[2] https: // www. hamamatsu.com/ eu/ en/product/ optical-sensors/ mppc/ mppc-array/ S14161-3050HS-08. html

[3] M. Adinolfi et al., *NIM A* 482 (2002) 364