

# Photodetector Choice for B0 EMCAL: Geant4 Simulation and Estimates

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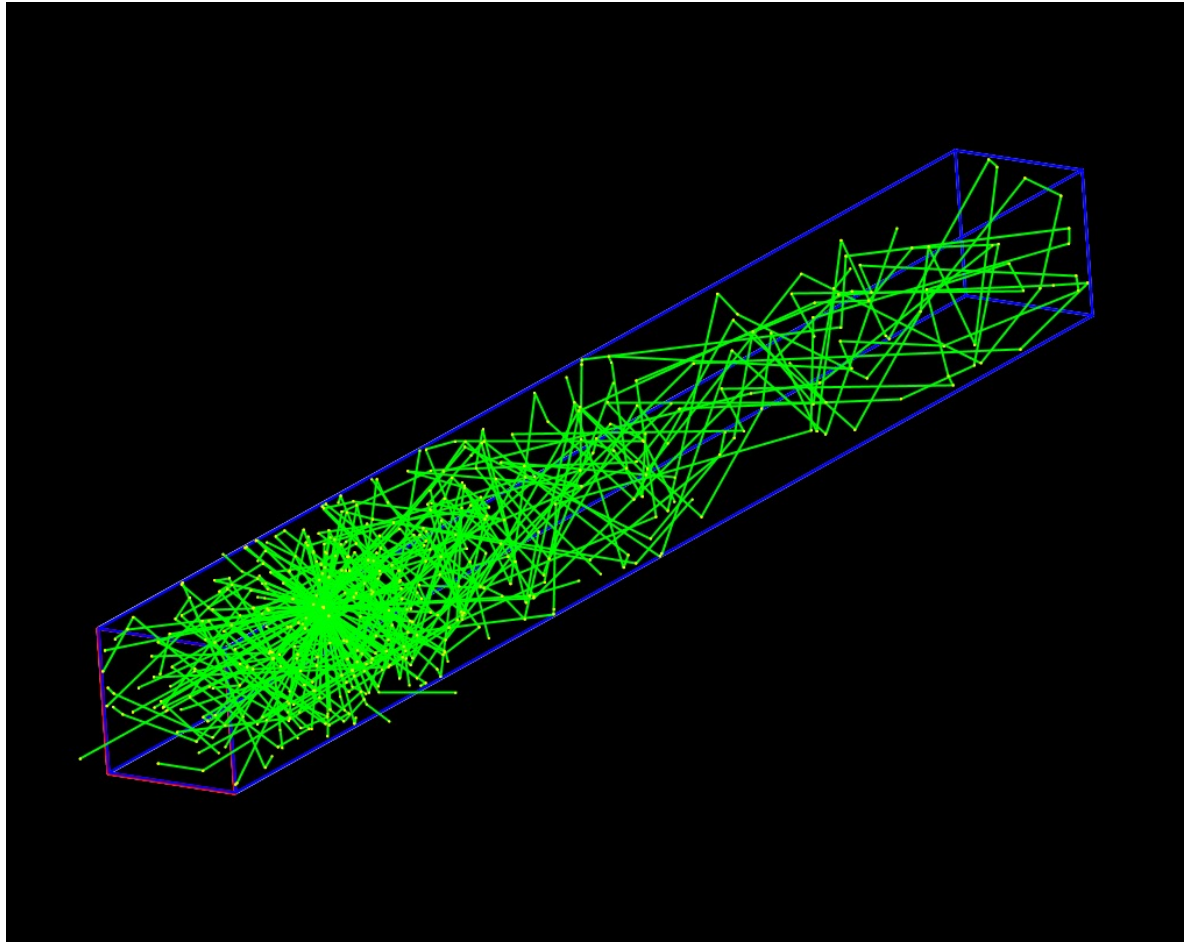
# Outline

- Geant4 simulation of PWO crystal with attached SiPM hit by 50 MeV and 100 GeV gammas;
- Scintillation photon arrival time at SiPM at different PWO surface reflectivities;
- SiPM choice.

## PWO properties

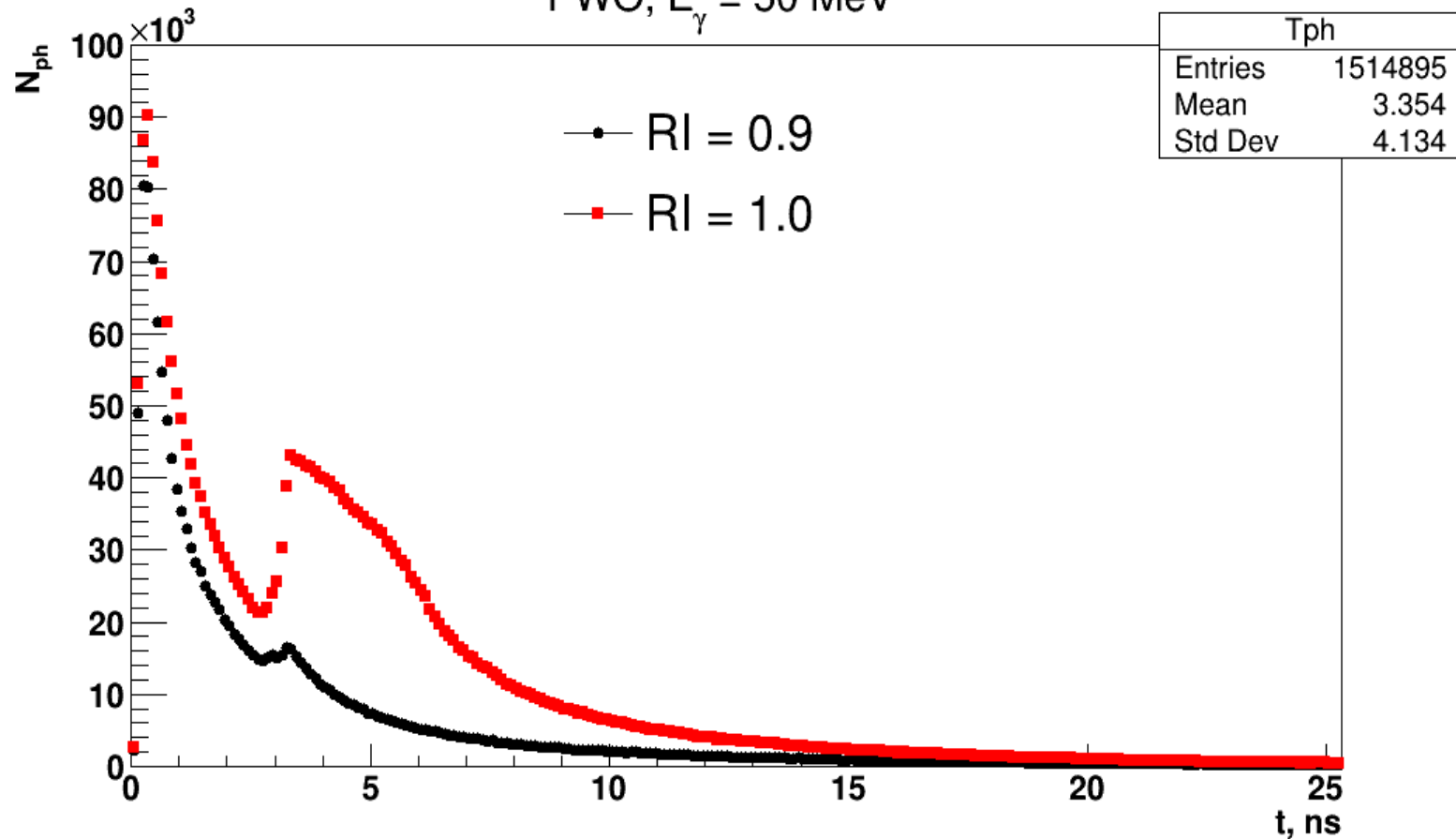
|                              |  |
|------------------------------|--|
| Density (g/cm <sup>3</sup> ) | 8.28   |
| Refraction index             | 2.16   |
| Speed of light (cm/ns)       | 13.88  |
| Photon yield (1/MeV)         | <b>100</b> – 200 (assuming 100 for this presentation)      |
| Decay time constant (ns)     | 1.67 – 6.7 (fast, 55 – 70 %)<br>6.6 – 30 (slow, 30 – 45 %) |
| Attenuation length (cm)      | 100 – 200  |

2x2x20 cm<sup>3</sup>  
PWO crystal (LY  
= 100 ph/MeV)  
with 300  $\mu$ m  
thick Si chip on  
its front surface



# Time of scintillation photons arrival into SiPM (1000 events)

PWO,  $E_\gamma = 50$  MeV



# Properties of SiPMs

| Hamamatsu<br>MPPC | Sens.<br>Area<br>(mm <sup>2</sup> ) | PDE<br>(%) | V <sub>br</sub><br>(V) | Dark count (kcps)<br>Typ. (Max.) | C <sub>t</sub> (pF) | RC (ns,<br>R=50 Ω) | Number<br>of pixels |
|-------------------|-------------------------------------|------------|------------------------|----------------------------------|---------------------|--------------------|---------------------|
| S14160-3015PS     | 3x3                                 | 32         | 38 ± 3                 | 700 (2100)                       | 530                 | 26.5               | 39984               |
| S14160-3010PS     | 3x3                                 | 18         | 38 ± 3                 | 700 (2100)                       | 530                 | 26.5               | 89984               |
| S14160-6010PS     | 6x6                                 |            |                        | 3000 (10000)                     | 2200                | 110                | 359011              |

SiPM advantages: low operating voltage and power consumption, high gain, sensitivity to low light pulses, negligible nuclear counter effect, some experience within ePIC collaboration (EEEMCAL) including beam test;

SiPM disadvantages: lower PDE, saturation at high intensities of light pulses (nonlinearity 20% at occupancy 50%) and as a result low dynamic range, optical cross-talk, recovery (“dead”) time;

# SiPM S14160-3015PS 4442 pixel per mm<sup>2</sup>

|  | 50 MeV<br>Refl. = 1.0 | 50 MeV<br>Refl = 0.9 | 100 GeV<br>Refl = 1.0 | 100 GeV<br>Refl = 0.9 |
|--|-----------------------|----------------------|-----------------------|-----------------------|
| Number of photons<br>at Si boundary            | 3130                  | 1515                 | 5.83x10 <sup>6</sup>  | 1.76x10 <sup>6</sup>  |
| Number of photons<br>per mm <sup>2</sup>       | 7.8                   | 3.8                  | 14575                 | 4400                  |
| Number of photons<br>per mm <sup>2</sup> x PDE | 2.5                   | 1.2                  | 4664                  | 1408                  |
| Number of signal<br>photons/SiPM               | 22                    | 11                   | 42k                   | 12.6k                 |
| Total signal photons<br>[16 SiPM/crystal]      | 350                   | 175                  | 670k                  | 200k                  |
| Fraction of fired<br>pixels                    |                       |                      | 1.05                  | 0.32                  |
| Nonlinearity, %                                |                       |                      | 38.1                  | 14.3                  |

# S14160-3010PS 10000 pixel per mm<sup>2</sup>

|  | 50 MeV<br>Refl. = 1.0 | 50 MeV<br>Refl = 0.9 | 100 GeV<br>Refl = 1.0 | 100 GeV<br>Refl = 0.9 |
|--|-----------------------|----------------------|-----------------------|-----------------------|
| Number of photons<br>at Si boundary            | 3130                  | 1515                 | 5.83x10 <sup>6</sup>  | 1.76x10 <sup>6</sup>  |
| Number of photons<br>per mm <sup>2</sup>       | 7.8                   | 3.8                  | 14575                 | 4400                  |
| Number of photons<br>per mm <sup>2</sup> x PDE | 1.4                   | 0.7                  | 2624                  | 792                   |
| Number of signal<br>photons/SiPM               | 13                    | 6                    | 23.6k                 | 7.1k                  |
| Total signal photons<br>[16 SiPM/crystal]      | 210                   | 100                  | 377k                  | 114k                  |
| Fraction of fired<br>pixels                    |                       |                      | 0.26                  | 0.08                  |
| Nonlinearity, %                                |                       |                      | 12.1                  | 3.9                   |



# S14160-6010PS 10000 pixel per mm<sup>2</sup>

|  | 50 MeV<br>Refl. = 1.0 | 50 MeV<br>Refl = 0.9 | 100 GeV<br>Refl = 1.0 | 100 GeV<br>Refl = 0.9 |
|--|-----------------------|----------------------|-----------------------|-----------------------|
| Number of photons at<br>Si boundary            | 3130                  | 1515                 | 5.83x10 <sup>6</sup>  | 1.76x10 <sup>6</sup>  |
| Number of photons per<br>mm <sup>2</sup>       | 7.8                   | 3.8                  | 14575                 | 4400                  |
| Number of photons per<br>mm <sup>2</sup> x PDE | 1.4                   | 0.7                  | 2624                  | 792                   |
| Number of signal<br>photons/SiPM               | 50                    | 25                   | 94.4k                 | 28.5k                 |
| Total signal photons [4<br>SiPM/crystal]       | 200                   | 100                  | 377k                  | 114k                  |
| Fraction of fired pixels                       |                       |                      | 0.26                  | 0.08                  |
| Nonlinearity, %                                |                       |                      | 12.1                  | 3.9                   |

# Conclusions

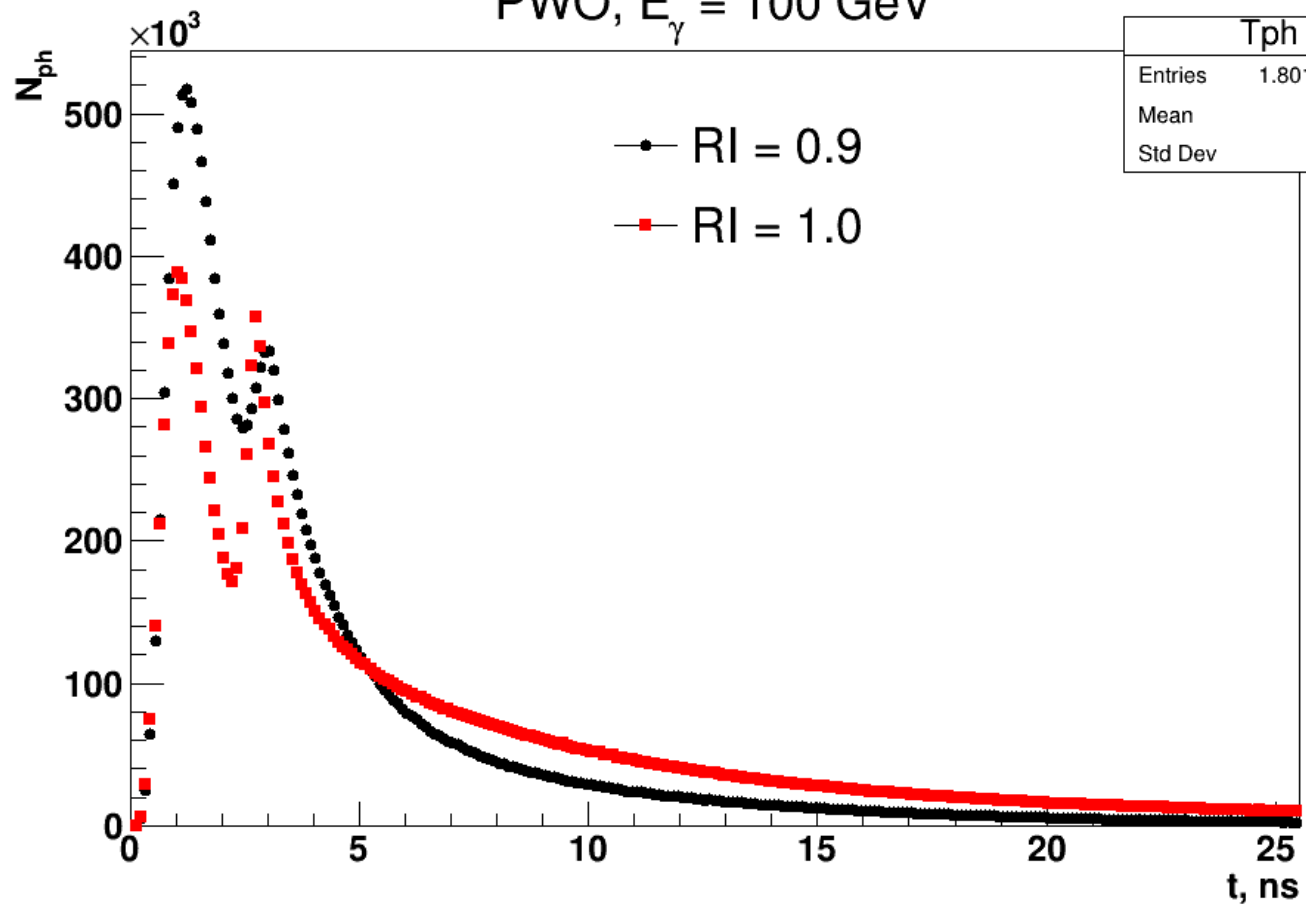
- S14160-3015PS SiPM is not a good choice for B0 EMCAL with PWO because of saturation/non-linearity for hard photon response.
- S14160-3010PS (6010PS) looks like meet requirements
- Higher light yield PWO better for soft photons, nonlinearity still manageable,
- what is expectation for electron EMCal?

## Open issues:

- Realistic PBO optical parameters: reflectivity, crystal-SiPM interface;
- Number of SiPM per crystal needs to be sufficient to reconstruct soft photons with good resolution;
- SiPM response to time spread light from crystal is under study;
- Should talk to colleagues from backwards EMCal.

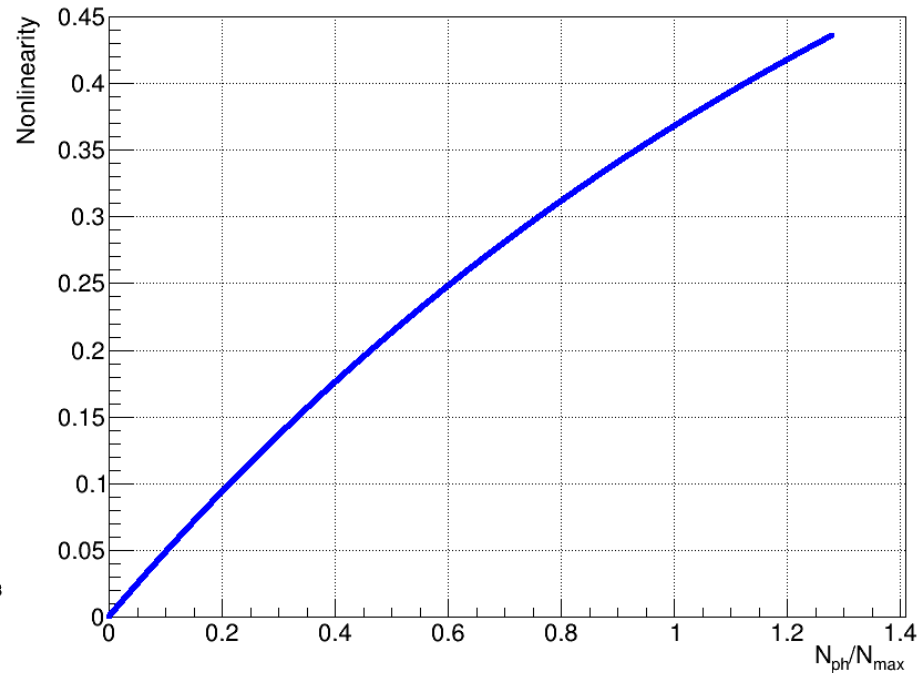
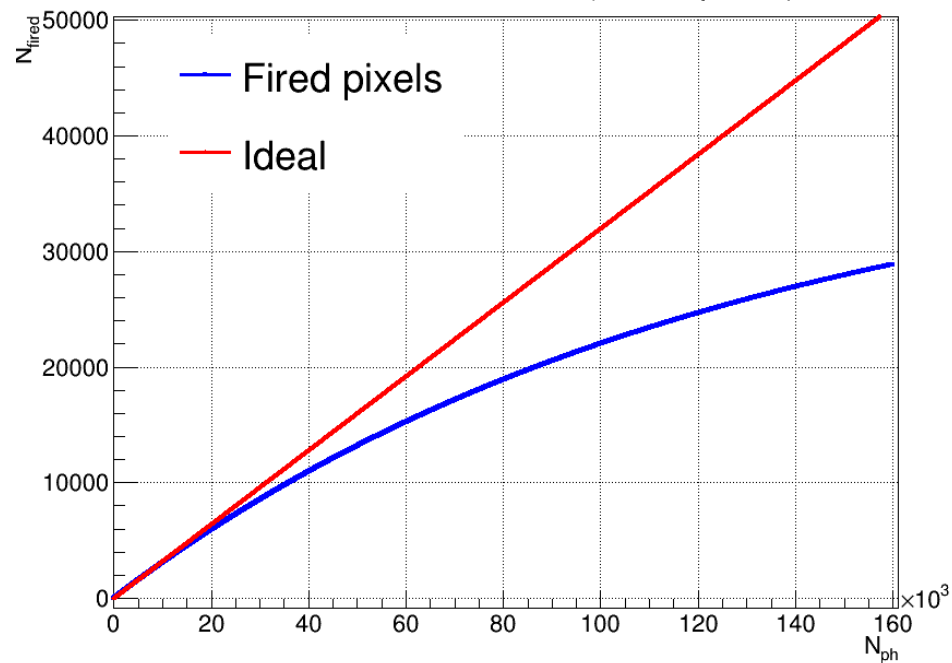
- Spares

PWO,  $E_\gamma = 100$  GeV



# SiPM nonlinearity

Hamamatsu S14160-3015 (39984 pixels)



# SiPM Simulation

SimSiPM\* is a C++ library to describe and simulate SiPM response to distributed in time photons

`*) SimSiPM: a library for SiPM simulation`

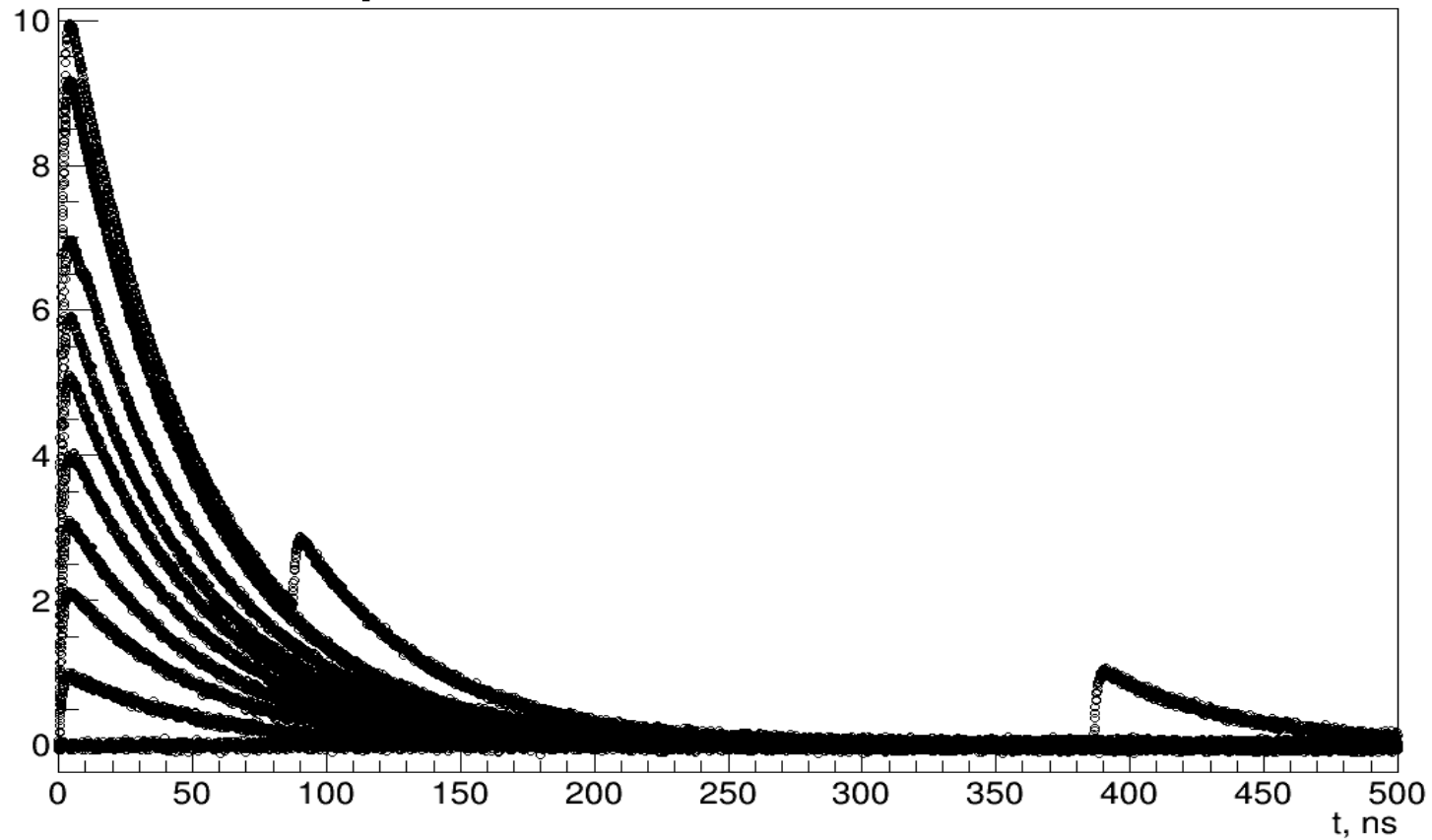
`Edoardo Proserpio and Romualdo Santoro`

`Como, Italy`

`2021,`

`url = {https://github.com/EdoPro98/SimSiPM}`

# 0-10 photoelectrons waveform



# 0-10 photoelectrons waveform

