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A simulation tool for a Silicon Photomultiplier coupled to a scintillating fiber

Monte Carlo Simulation

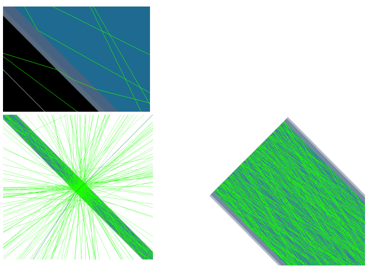
A Geant 4 based simulation was implemented. In order to reproduce the measurements, Minimum ionizing electrons from Sr 90 are collimated on 250 um multi-clad square fiber coupled to a 1.3x1.3 mm^2 SiPM with 50 um pixels.

G4OpticalSurface definition with optical properties for each medium

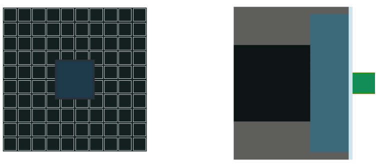
G4LogicalBorder used to simulate separation border between different fiber media

Multi-clad BCF 12 (LY 8000 ph/ MeV)
Trapping efficiency 7.3%
Att. length 2.7 m
Core polystyrene n=1.6
Clad 1 Acrylic n=1.49
Clad 2 Fluor Acrylic n=1.42

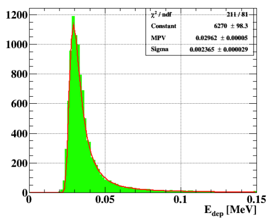
Simulation of both double and single read-out setup



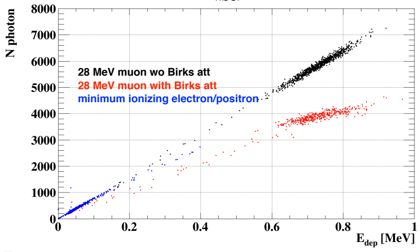
Accurate simulation of the Silicon Photomultiplier geometry.



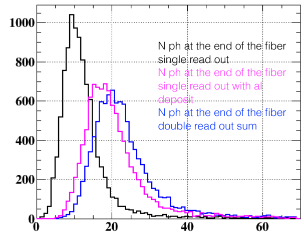
Energy deposit distribution due to Sr90 electrons



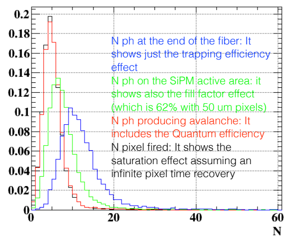
Number of photons generated vs Energy deposit in fiber

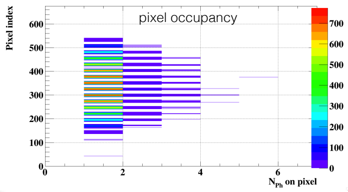


Number of photons distribution at the end of the



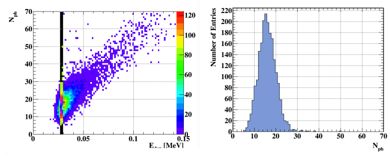
Modulation of the number of photons from the end of the fiber to single pixel hit of the Silicon Photomultiplier



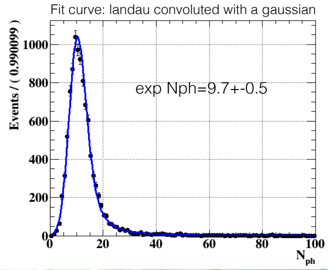


For each value of the energy deposited in the fiber, which is a value Landau distributed, the number of photon at the end of the fiber is gaussian distributed. As a consequence, the distribution of the number of photons at the end of the fiber fits with a landau convoluted with a gaussian. For a large number of photons at the end of the fiber (case of muons), this curve becomes a gaussian.

Number of photons at the end vs energy deposited in the fiber



Fit curve: landau convoluted with a gaussian

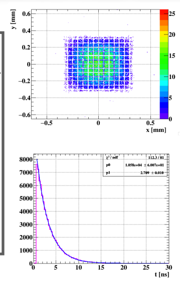


Silicon Photomultiplier response simulation

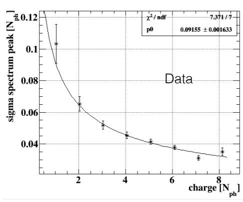
The information in terms of position and arrival time on SiPM surface is used by a C++ program, based on the algorithm described in [1], to generate the signal waveform.

Method description:

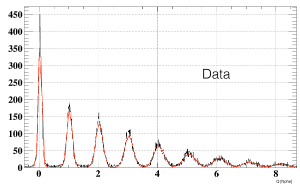
1. The single pixel signal is produced with a probability given by the quantum efficiency (~35% divided by the fill factor) times the discharge probability (almost 1).
2. Not uniform single pixel gain obtain by data
3. A crosstalk signal is generated in the near pixels with a probability of 1 %.
4. Pixel saturation effect is taken into account assuming a time recovery of 15 ns
5. Dark current pulses are randomly generated on the SiPM surface
6. After pulse probability ~0



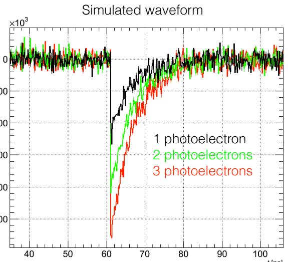
Spectrum peak sigmas as a function of the charge expressed in photoelectrons



Charge spectrum measured and fitted with multiple gaussian



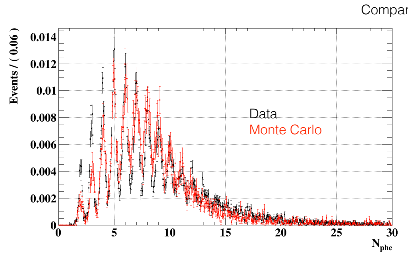
Simulated waveform

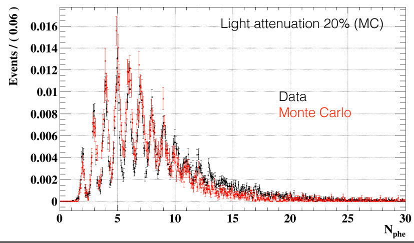


All the parameters for the waveform description are extracted from the data:

- rise time from waveform fit
- decay time from waveform fit
- noise level, from charge spectra peaks fit
- pixel gain variation from charge spectra peaks fit

Comparison with Sr90 data





The comparison is performed using a spectrum of the sum of the charge collected by the two SiPMs in the double read-out configuration where the dark current contribution is negligible.

[1]Pulko, J. Schneider, F.R. Velroyen, A. Renker, D. Ziegler, S.I. A Monte-Carlo model of a SiPM coupled to a scintillating crystal Instrumentation JINST 7 (2012) P02009.