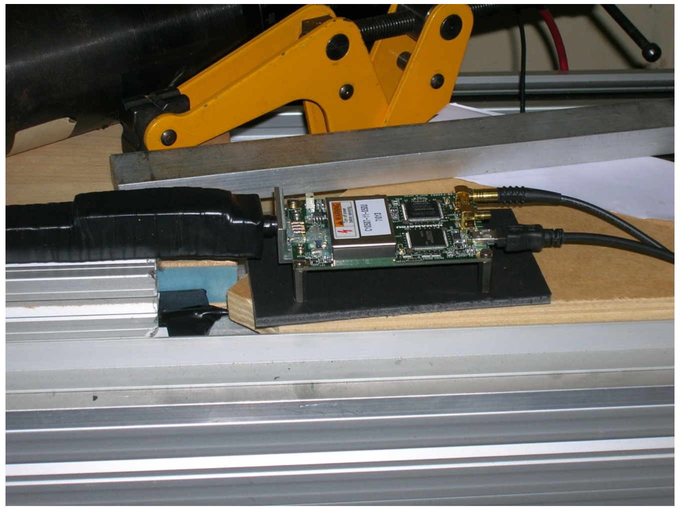
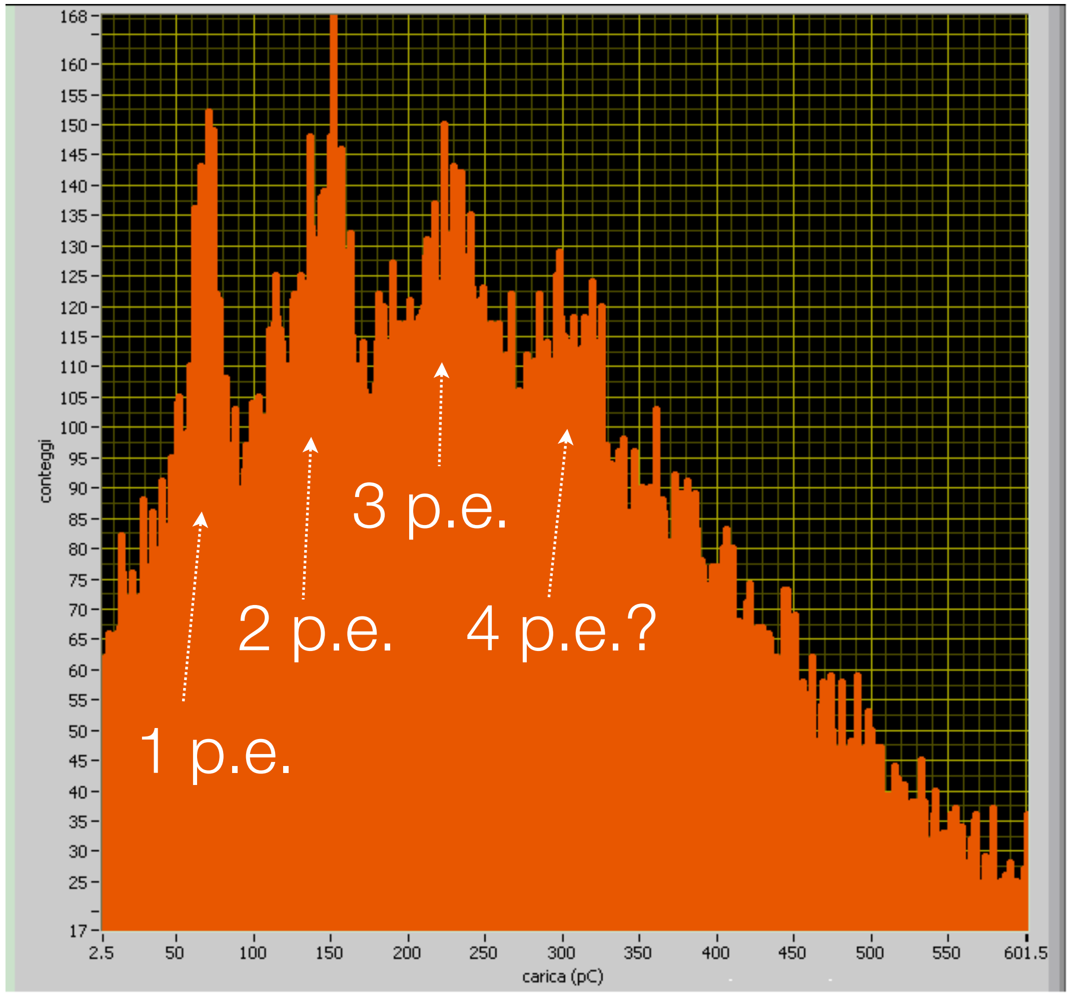
R&D Status in Rome

F. Bellini, G. Cavoto, R.Faccini, S. Morganti, F. Orio, G. Piredda, C. Voena
University of Rome & INFN Rome
(Cuore + SuperB)

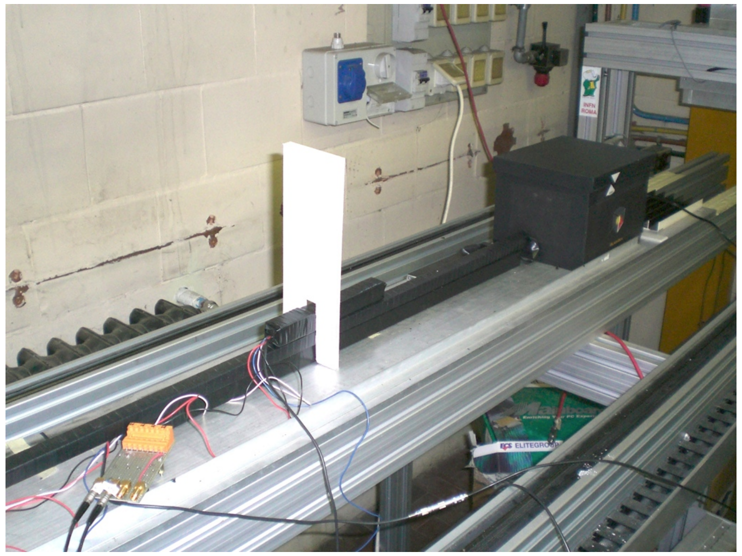
In previous episodes

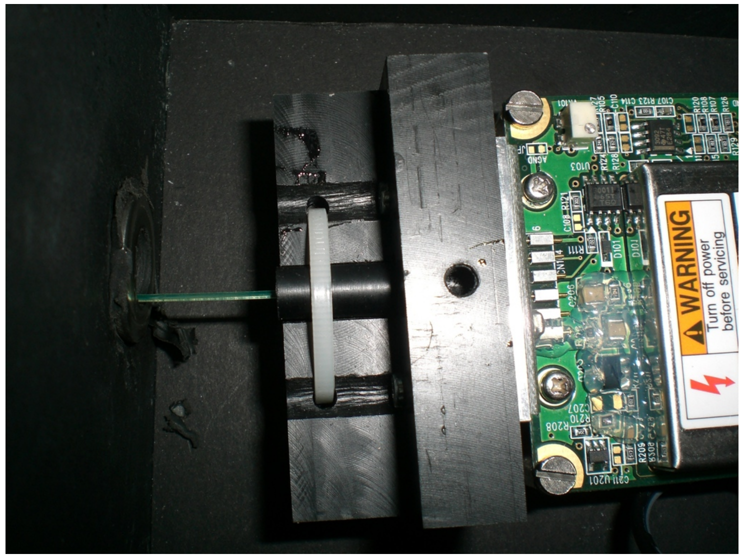
- Characterization of Low Voltage Compact PMT (subsequently used for Cosmic Rays Triggers)
- Our first look at MPPC response:
  - Dark Count rate (470KHz@0.5 p.e.) in the range quoted by Hamamatsu. It depends on Temperature
  - Efficiency lower than expected (not shown in this zero suppressed plot) due to the trigger setup and the poor optical coupling between fiber and sensor.
- Action items:
  - Control sensor's temperature (cooling the device) to limit dark count
  - Re-design trigger system





MPPC studies in Cosmic Rays Runs





More efficient trigger:

Use of two “fingers” of plastic scintillators, coupled with low voltage compact PMC.

Geom. eff. = 99%

New coupling:

Increased reproducibility of the setup.

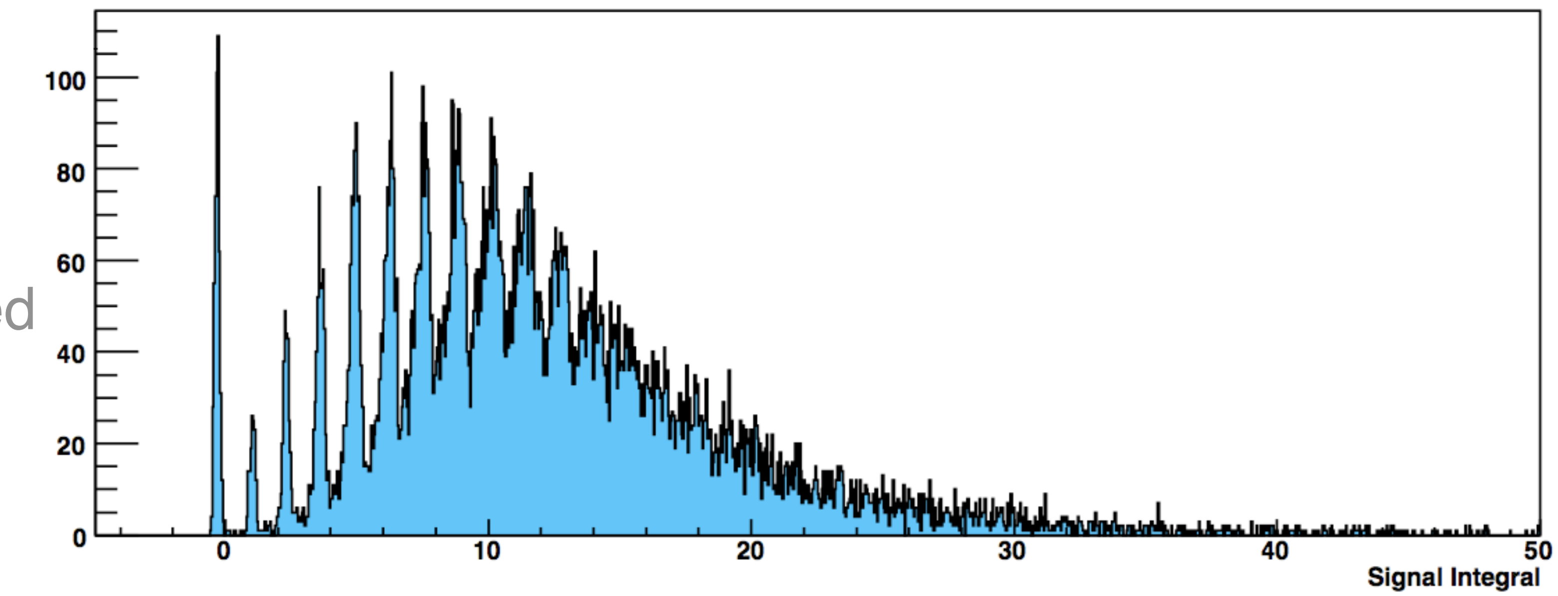
Optical coupling improved by using optical grease.

New DAQ:

Use of a 1GS oscilloscope to acquire the signals (waveforms) to be analyzed offline.

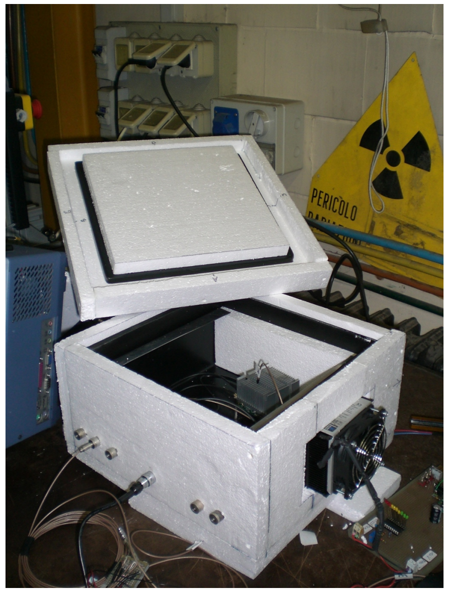
Our second try with Cosmic Rays

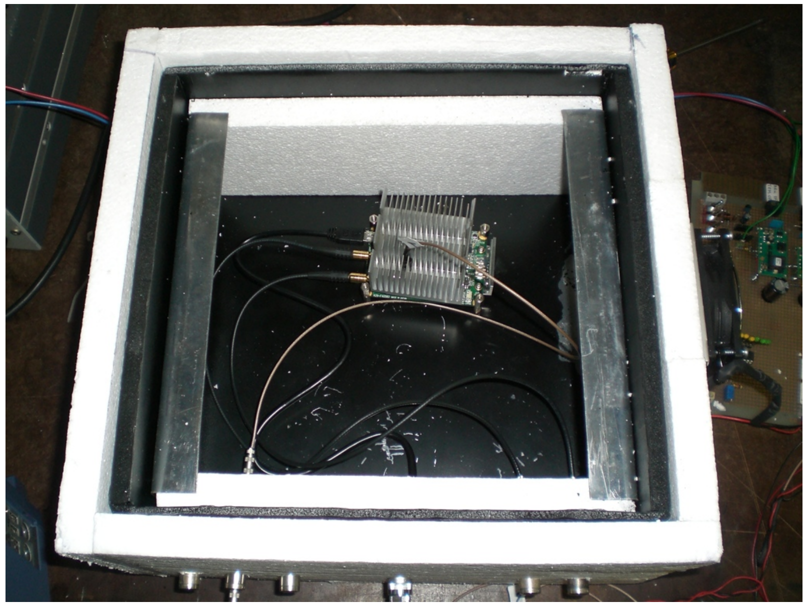
- Cleaner spectrum and better efficiency .
- To relate the measured spectrum with incoming photons distribution many fit algorithms have been tested



- Not found a simple way to relate incoming signal and MPPC response
- Incoming photon distribution spoiled by:
  - Fluctuations in the Dark Counts (temperature variation during the run)
  - Intrinsic features of the sensor like Crosstalk and Afterpulses

CrioBox
(Blackbox with Peltier Cell)

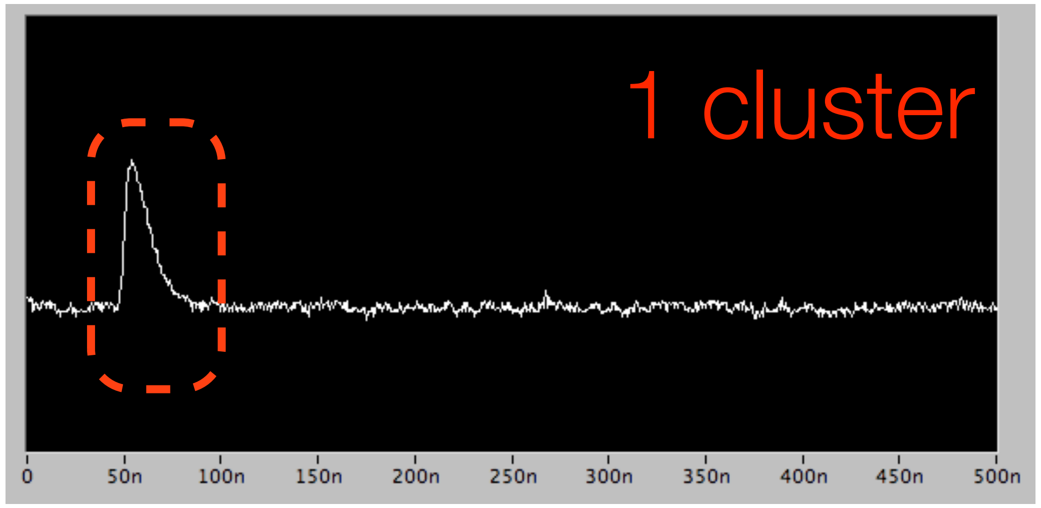


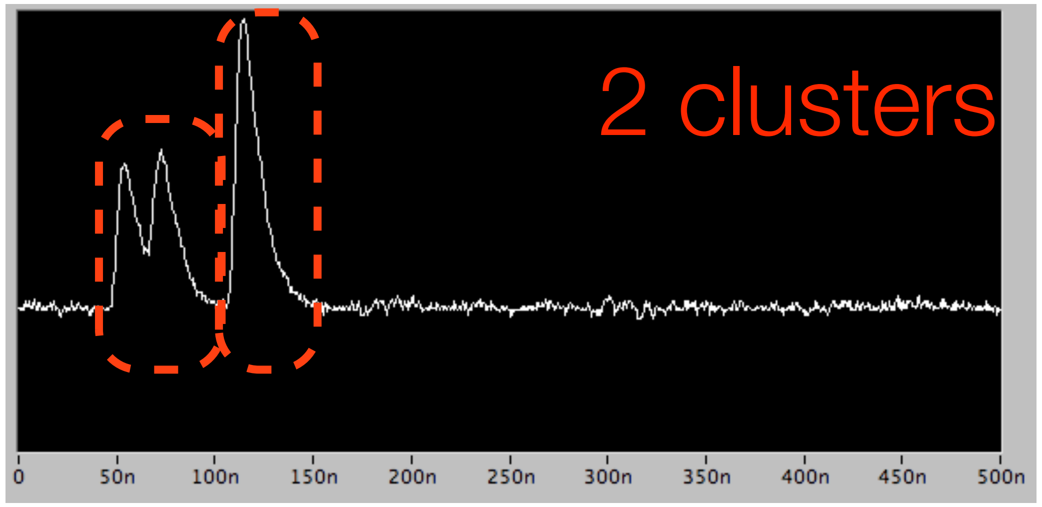


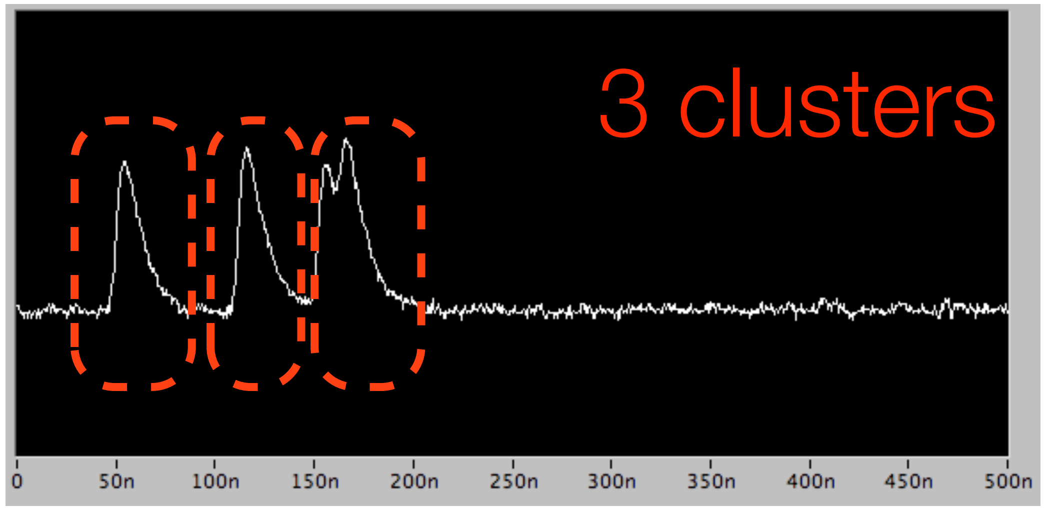
Dark Count Run

How to understand a MPPC: Dark Count Run

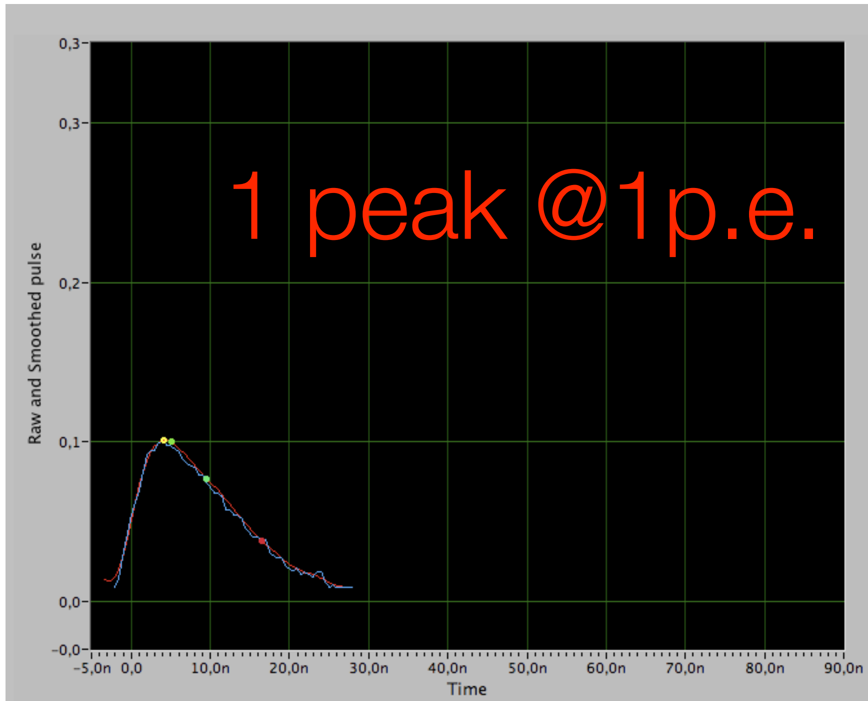
- Self-triggered MPPC
- Temperature is maintained constant during the run at 24.0°
- Main source of dark counts is the extraction by thermal excitation of electron-hole pairs in the active area of device
- Acquired waveforms are more complex than single p.e signals
- We define CLUSTER each signal or bunch of signals started by a pulse over threshold, ending when the signal goes back to (nearly) zero.

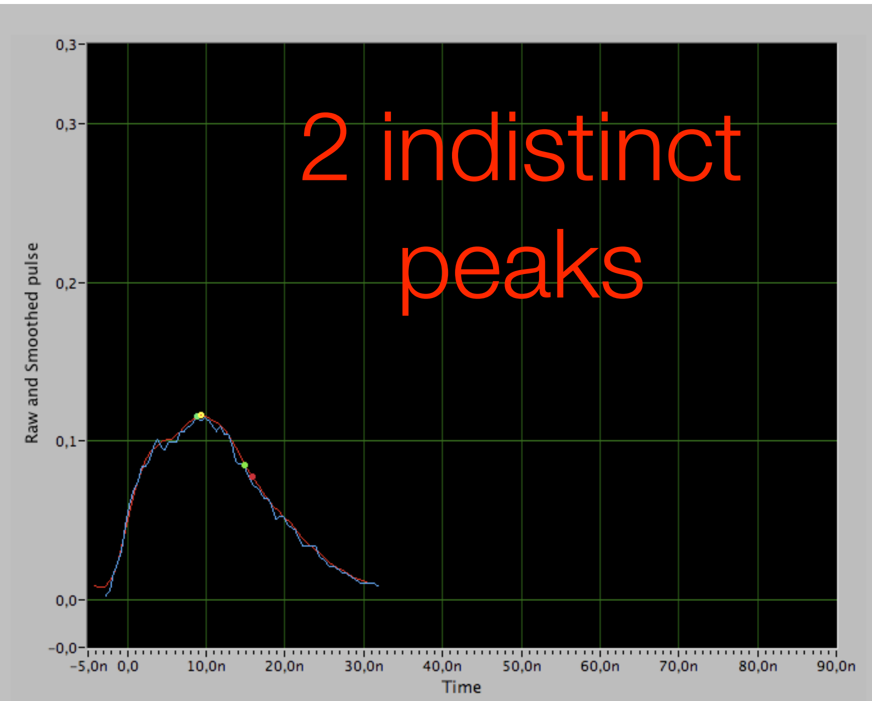




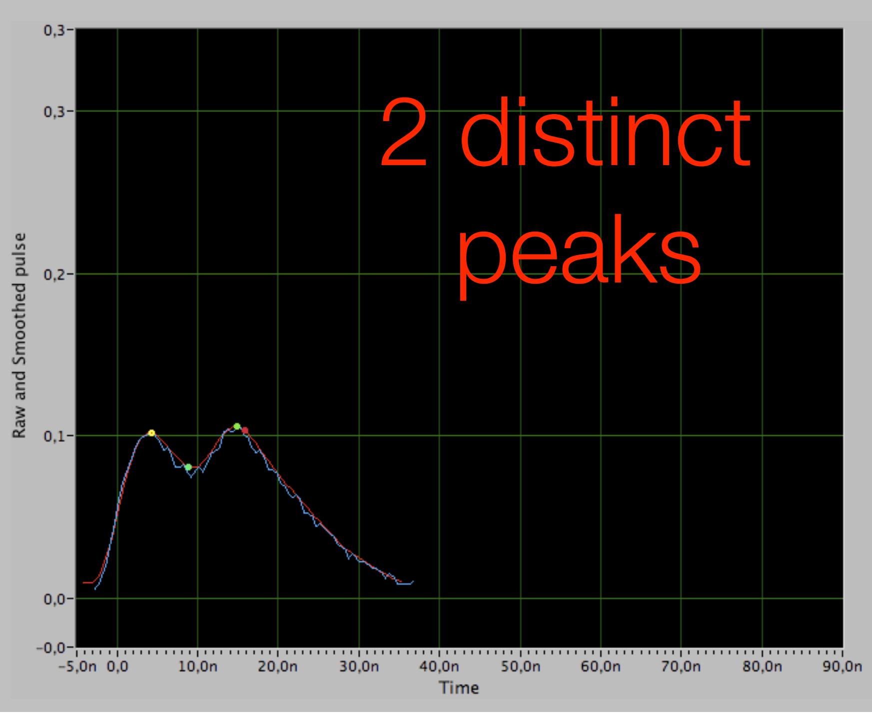


Dark Count Run: some characteristic waveforms

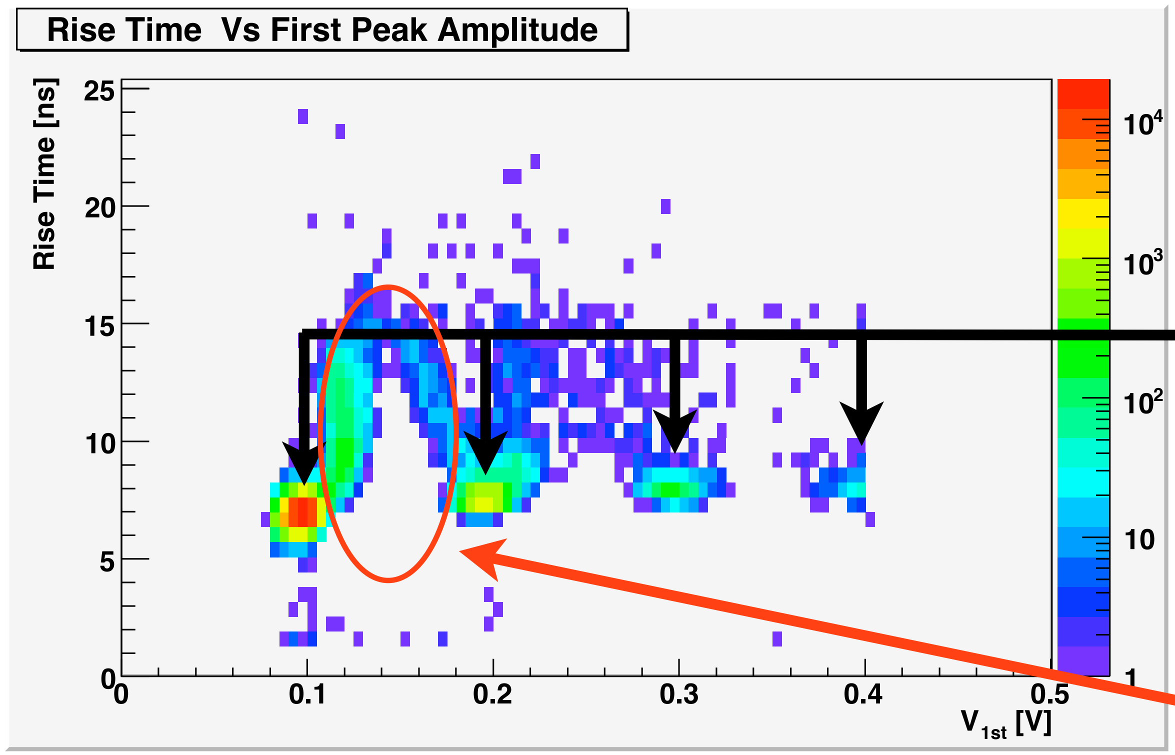


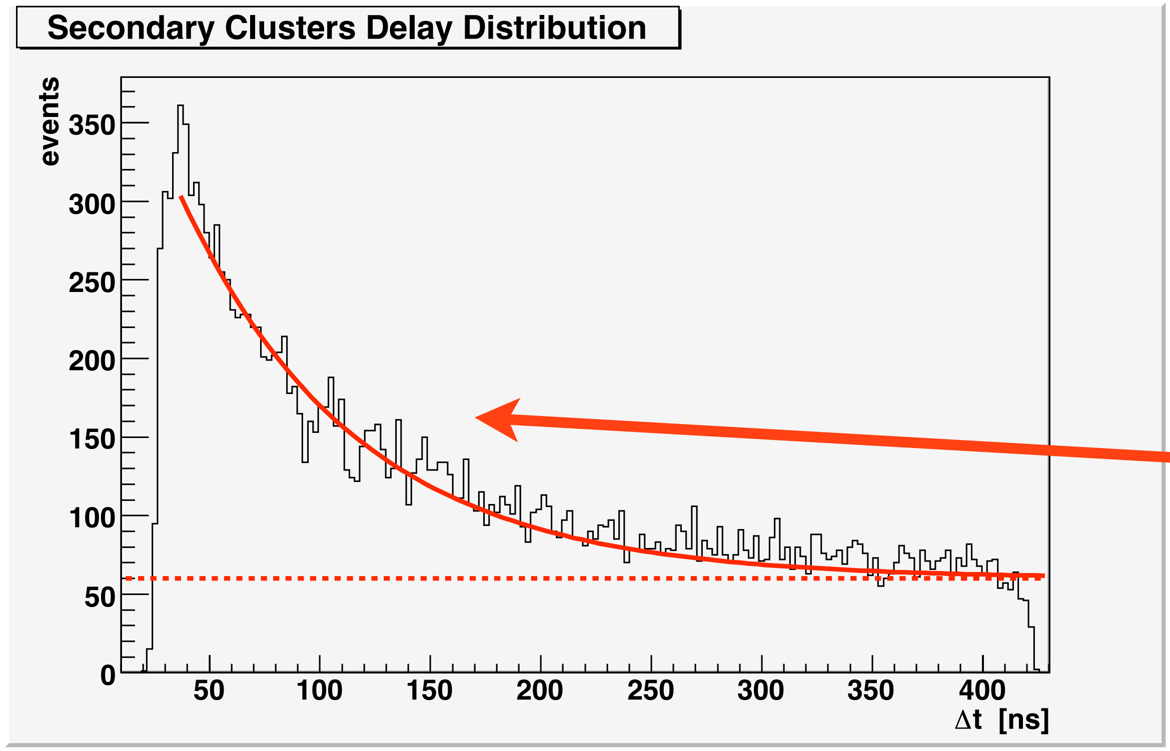


- Each cluster is analyzed and fitted to measure the number, the amplitude and the position of its peaks, its duration and its integral.



Dark Count Run Analysis





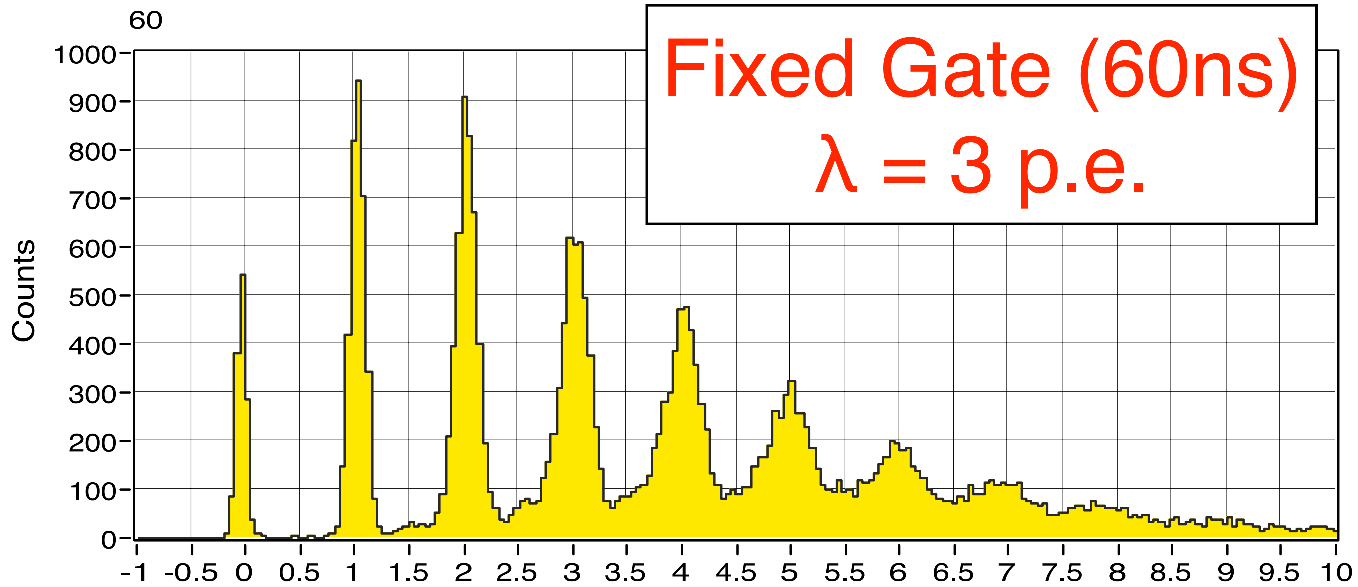
- By selecting the first cluster triggered in the acquisition window and looking at the rise time vs the first peak amplitude we can see that:
  - a single electron-hole pair extraction can generate prompt signals corresponding to a multiple number of one p.e (crosstalk induced by photons emitted during the avalanche)
  - slower secondaries (electrons emitted during the avalanche and diffusing in the lattice) can generate in close pixels partially quenched avalanches overlapped to the first one
- Electron diffusion can induce a new avalanche even after the complete development of the first cluster as shown in the secondary clusters delay distribution that has an exponential decay wrt the first cluster

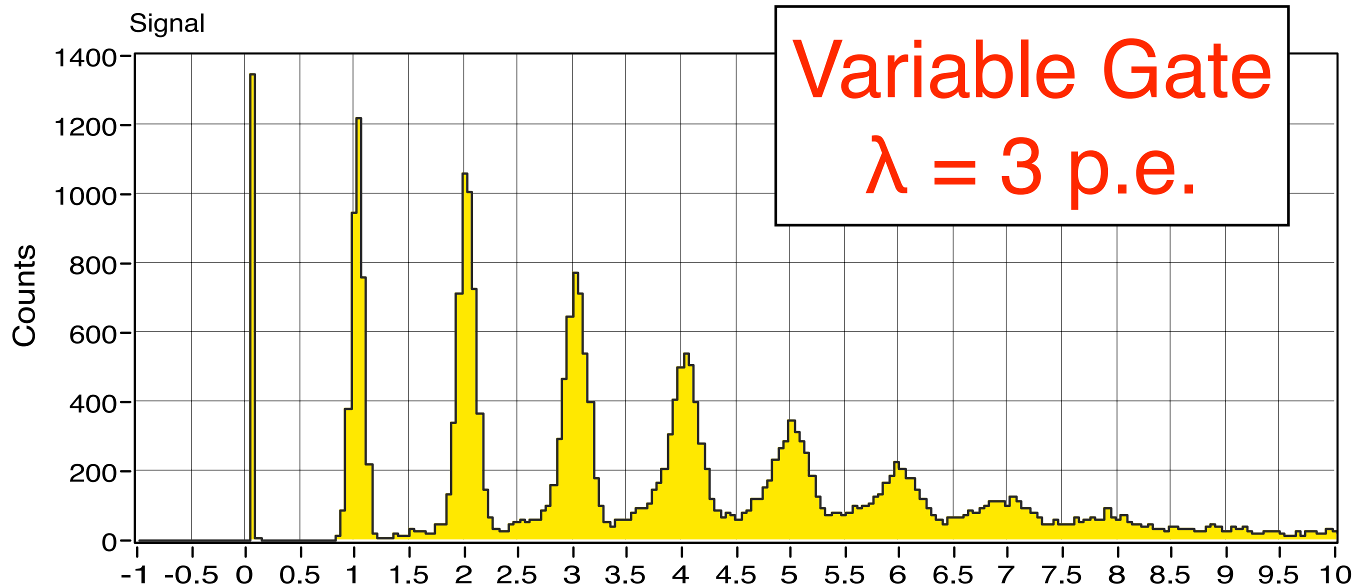
Building an MPPC Emulator (1)

- The measured spectrum is hence the convolution of the Poisson distribution of the incoming signals plus the (quite complex) MPPC response to a single induced avalanche
- We take as representative of the MPPC response to a single hit on one pixel the waveforms sampled in the Dark Count Run
- Since every waveform has at least one prompt pulse (plus any other produced by crosstalk and afterpulses), summing up (randomly) n waveforms we can emulate a pulse equivalent (both in the prompt and non prompt component) to those generated by n hit cells.

Building an MPPC Emulator (2)

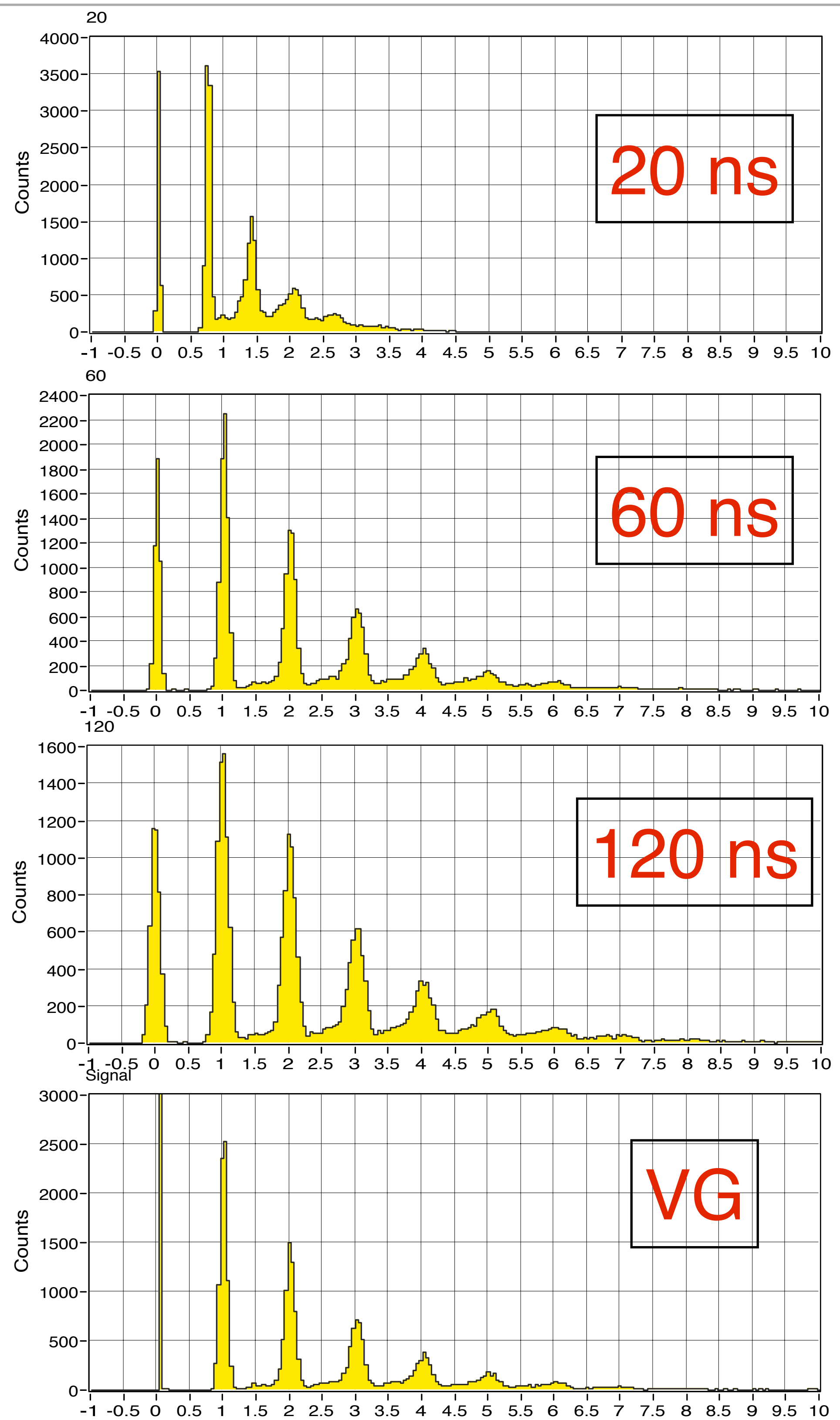
- Emulated events are processed by the same analysis chain of physical events.
- Two pulse integration methods adopted:
  - Fixed Gate as in standard ADC
  - Variable Gate, where the possibility to identify the first cluster is exploited and the signal integration carried only over it

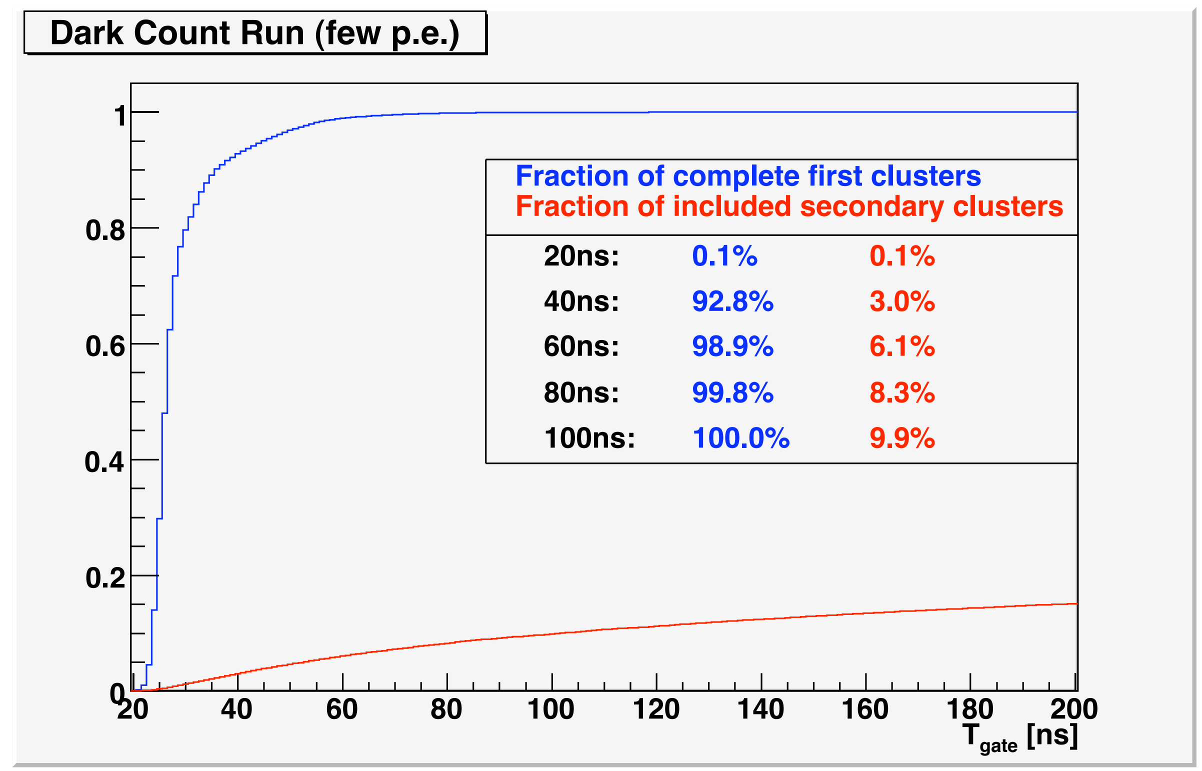




1p.e.-normalized spectra

The choice of T_{gate}

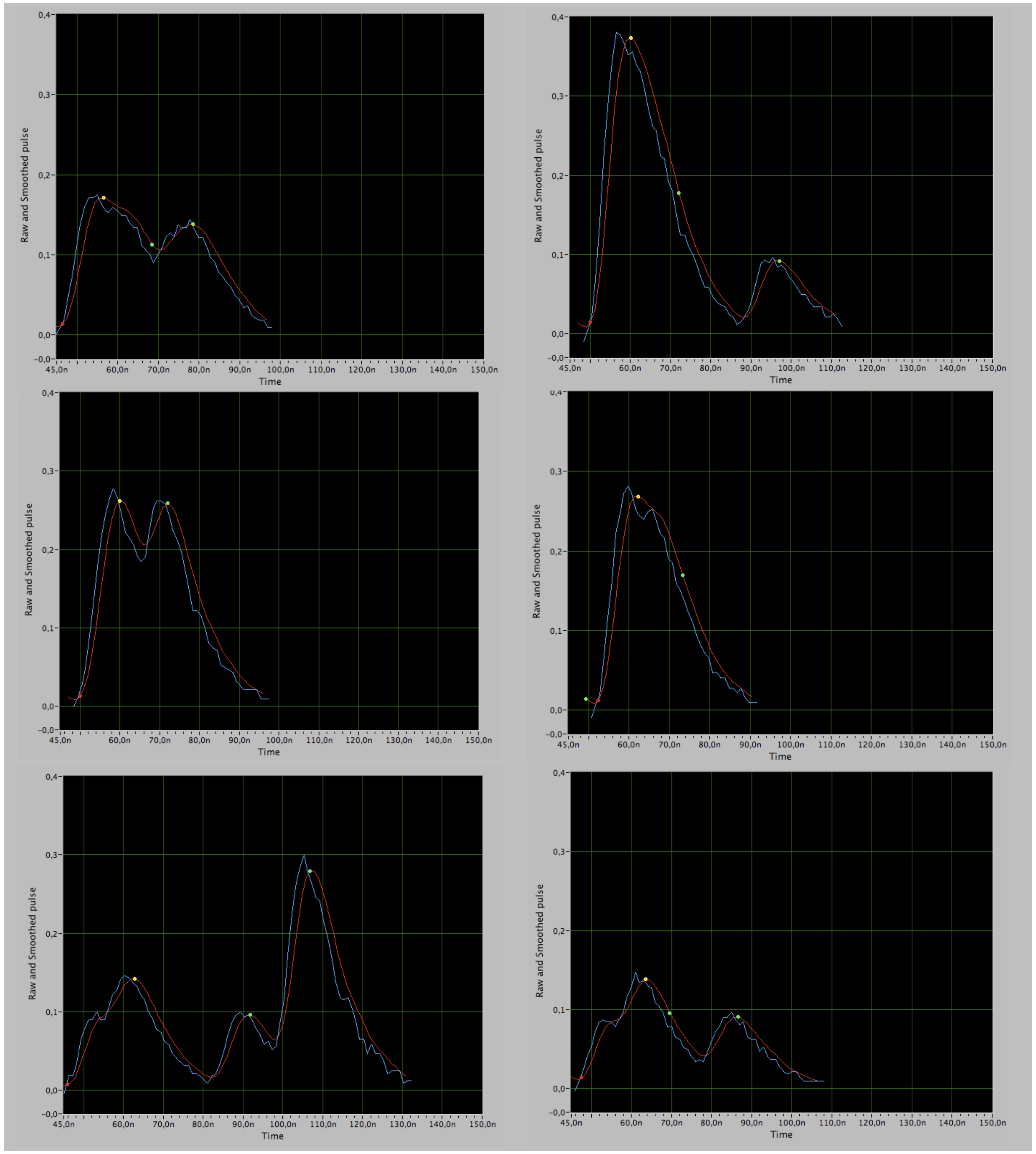




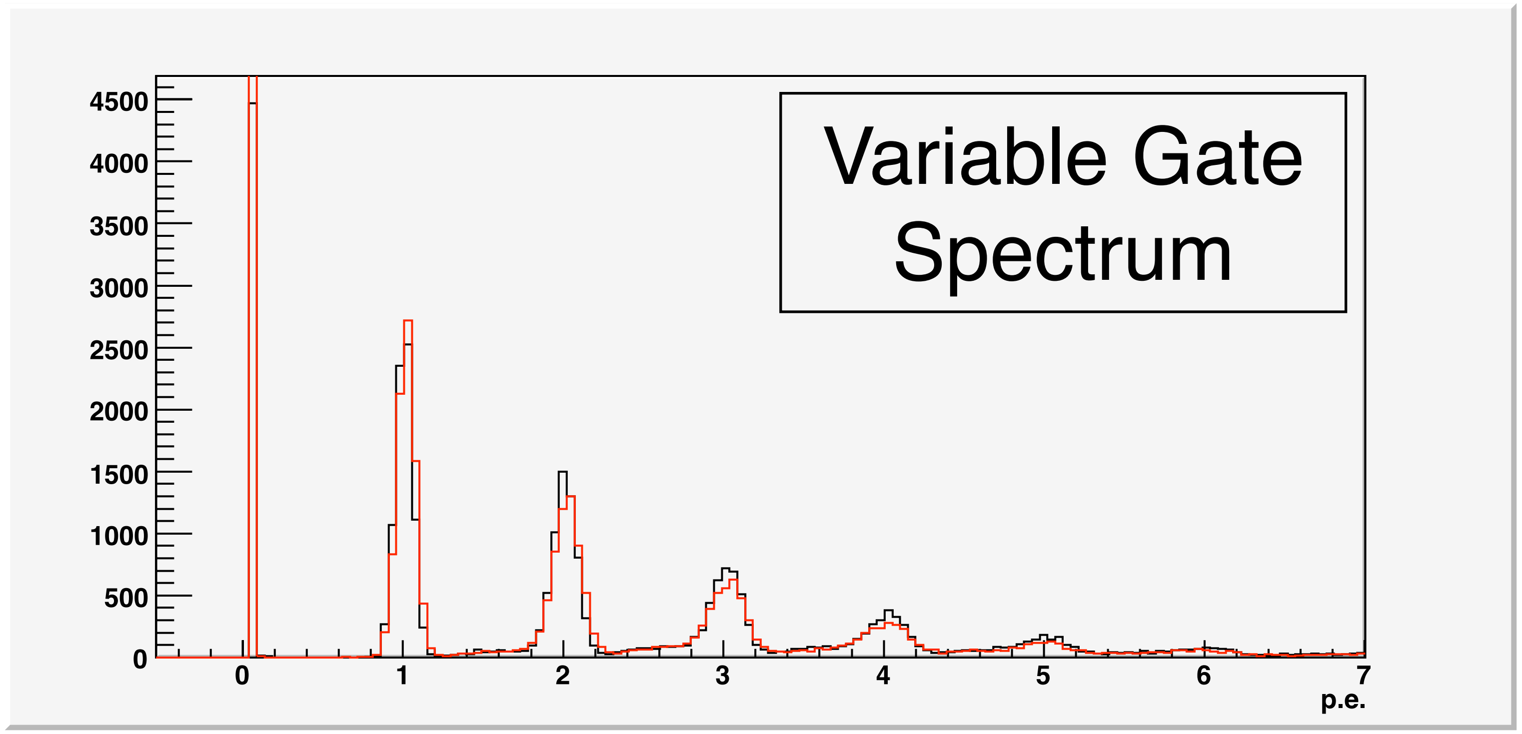
- The integration of fractions of waveforms lead to the degradation of the resolution (increase of non gaussian tails)
- Depending on the mean number of p.e., could be more useful to use one T_{gate} or another
- Variable T_{gate} (cluster integration) prevents all these problems

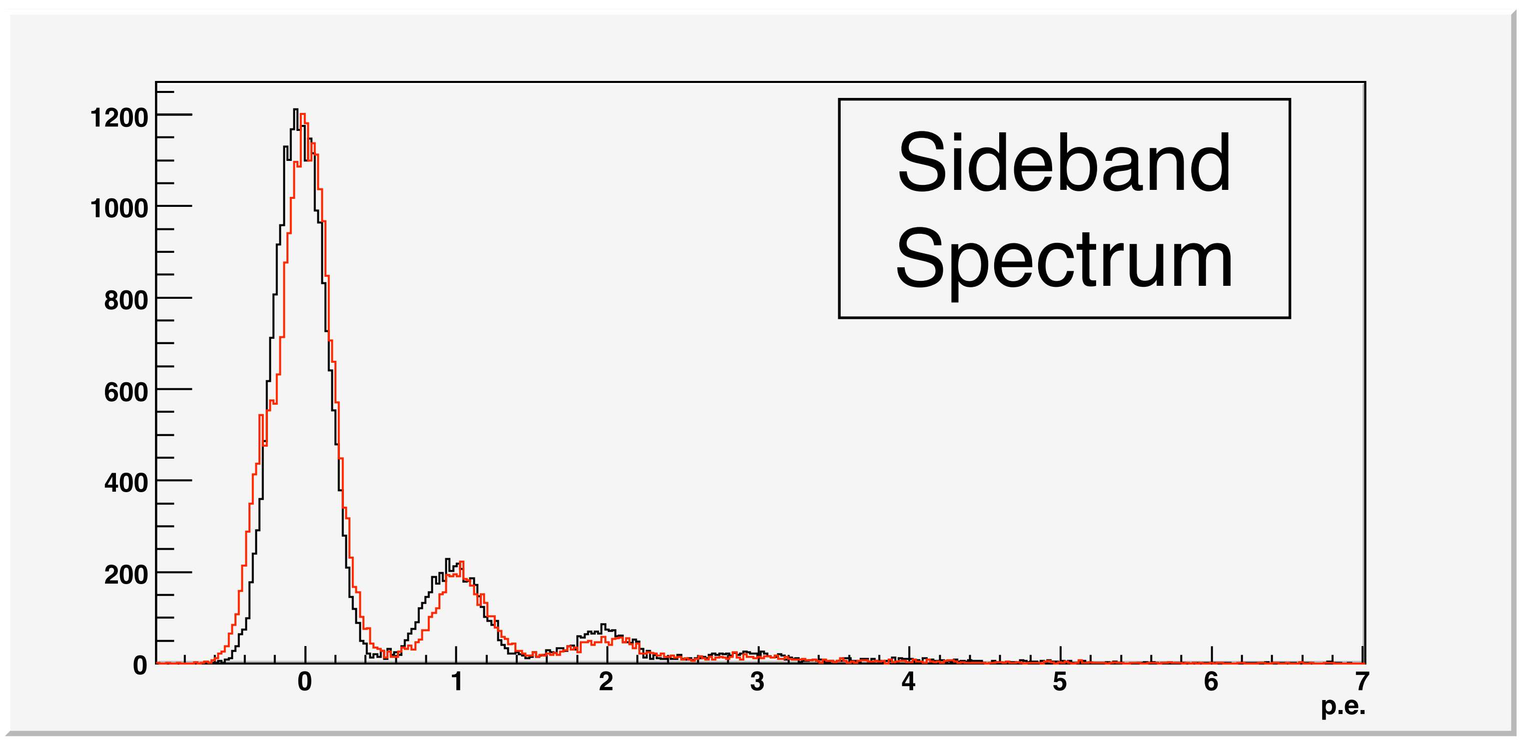
Pulsed LED Run (to test emulator performances)

- Few photons emitted by a pulsed LED and passing through a diaphragm are collected by an optical fiber and carried to the MPPC
- The acquisition is triggered by the signal that turns the LED on
- MPPC is maintained at the same temperature of the Dark Count Run



Comparison between LED Run and emulation



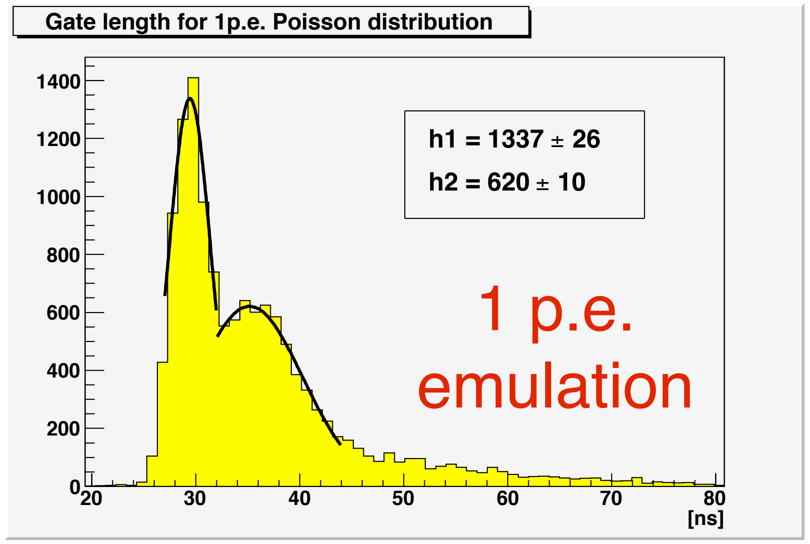


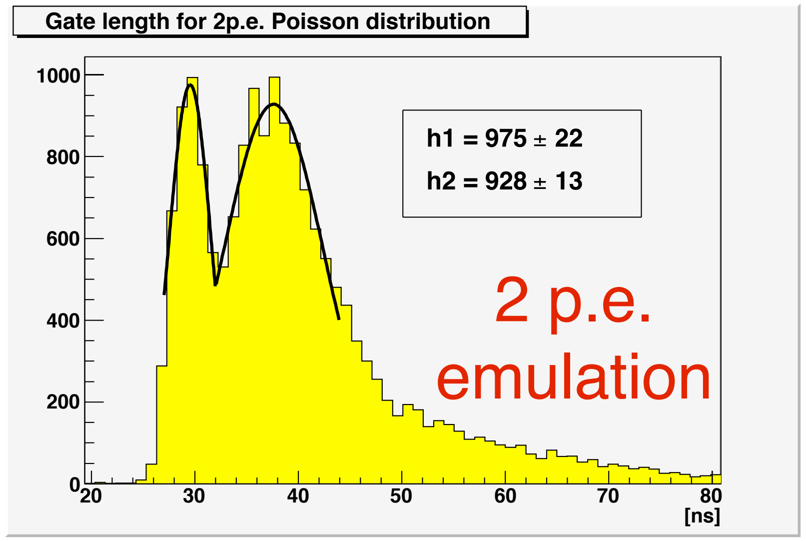
LED

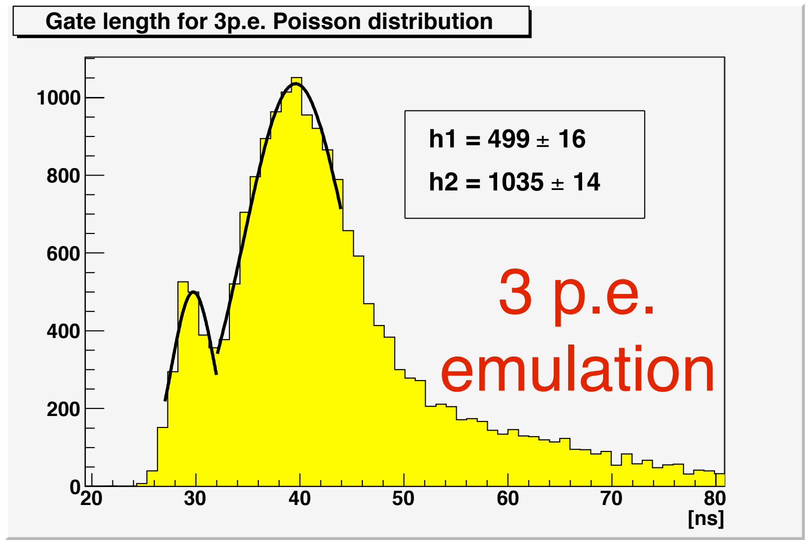
Emulation @1.6 p.e.

- Good agreement between LED Run and 1.6 emulation:
  - In the signal (represented by the triggered clusters, integrated with VG)
  - In the sideband (i.e. all the waveforms in the acquisition window, except the triggered cluster)
- Both signal and background are well reproduced

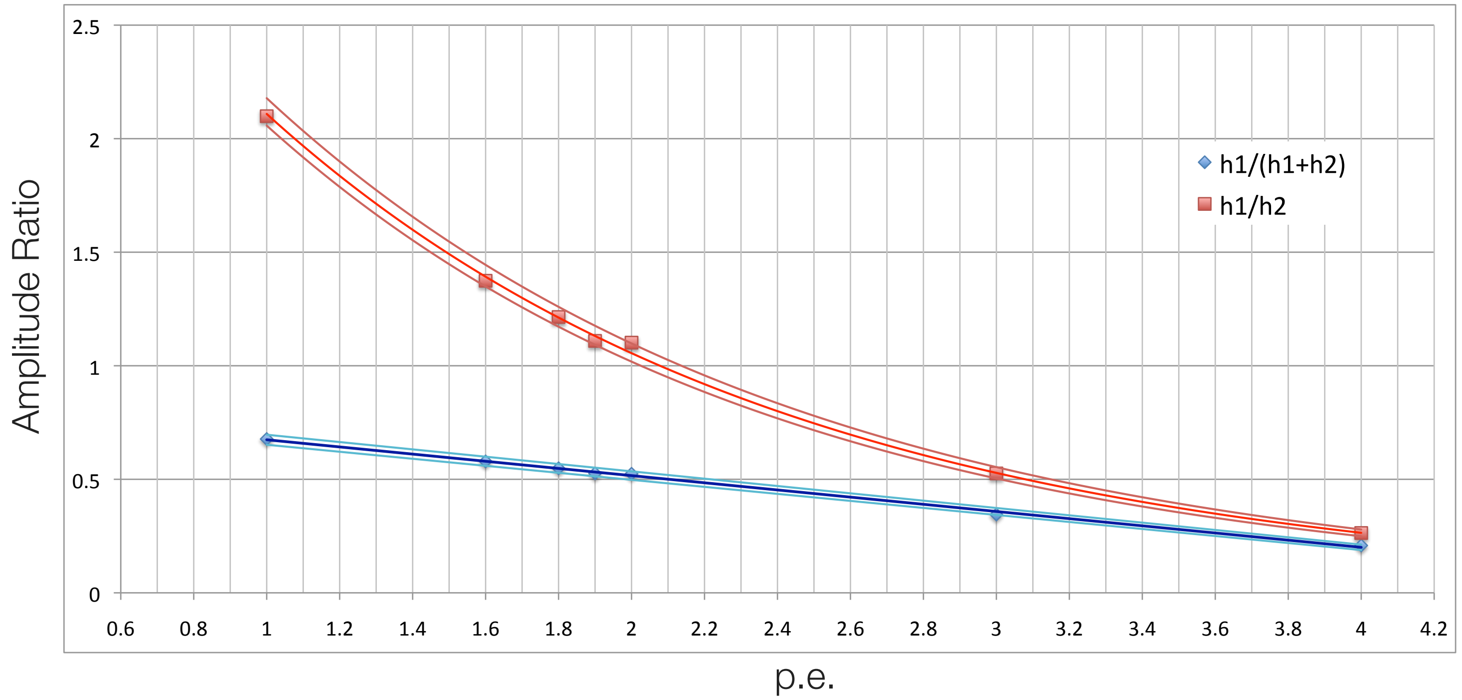
Cluster duration
and its connection with the Poisson distribution







- Using the emulator and the cluster finding capability of our acquisition, we tried to see if cluster length can be used to infer the average number of primary photons hitting the MPPC.
- For n (number of hit pixels) less than 5, the cluster duration shows two clear peaks which population depends on the relative weight of the events with one cell or more than one cells fired.
- Calling h1 the first peak height and h2 the second peak height in the cluster duration plot, the quantities h1/(h1+h2) and h1/h2 vs the mean value of the Poisson distribution of the emulated events are shown below



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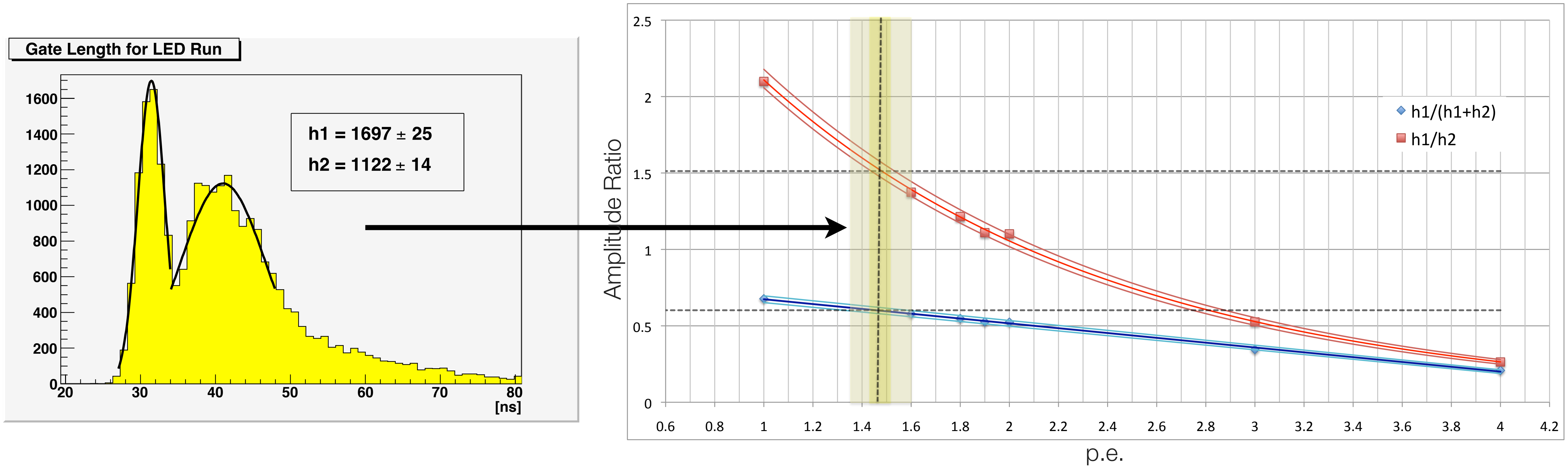

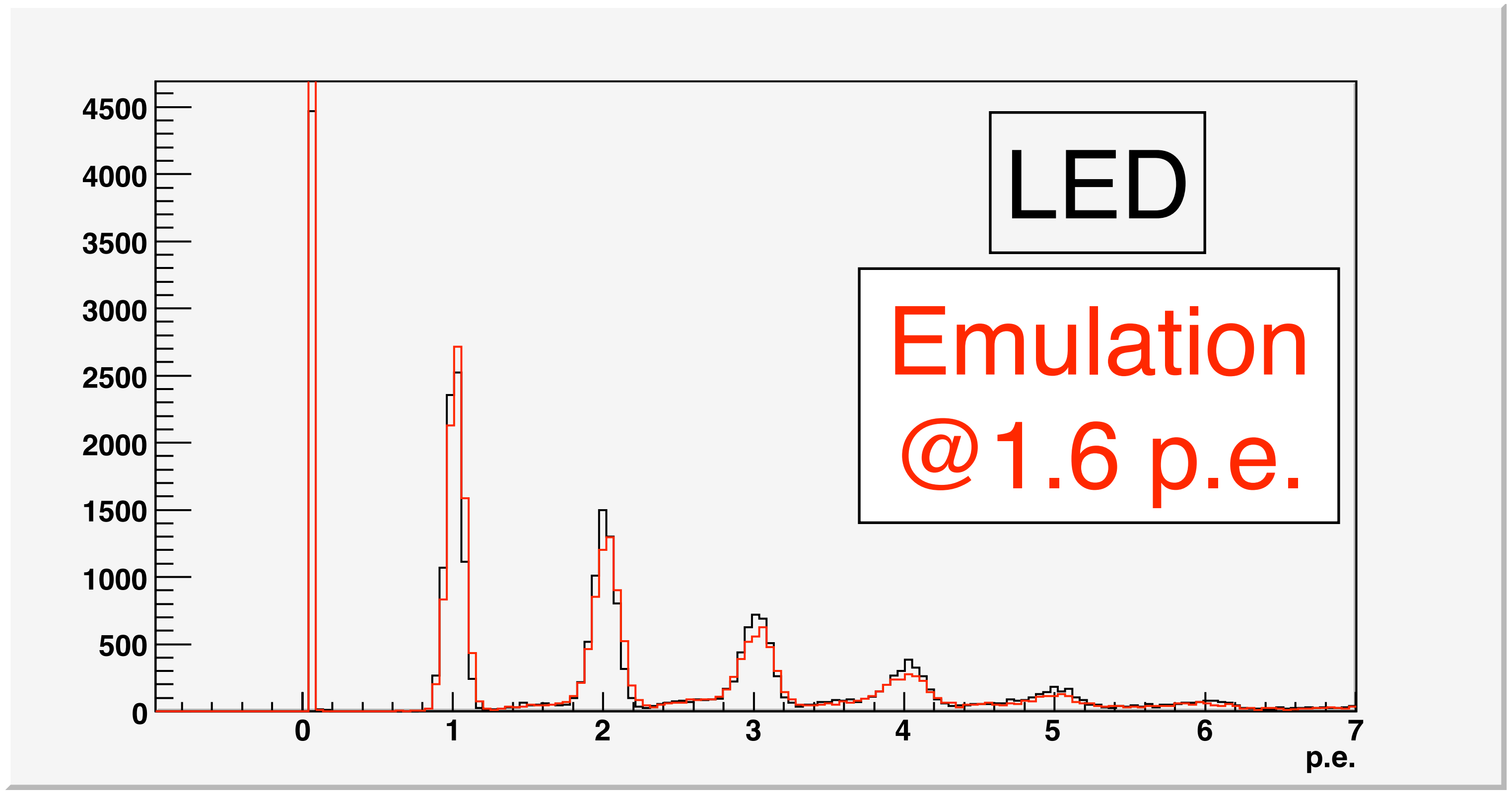

- The value found (1.5 p.e.) is consistent with our previous results
- Physics runs and emulated runs are almost equal, and we can infer the average number of primary photons using the emulator!

Conclusions and future plans

- We have a stable setup with trigger, cooling and DAQ under control
- We started to understand MPPC output signal
  - Implemented an emulator that reproduces the shape of signal starting from first principles and Dark Count run
  - Validated the emulator only up to five p.e. on a LED run

- Plans:
  - Finalize validation of the emulator with higher luminosity LED runs
  - Improve background subtraction of Dark Count as input of emulator
  - Optimization of mechanical and optical coupling based on estimated original number of p.e.