Cosmic ray tagging with light signal and measurements of scintillation pulse shape at 6x6x6

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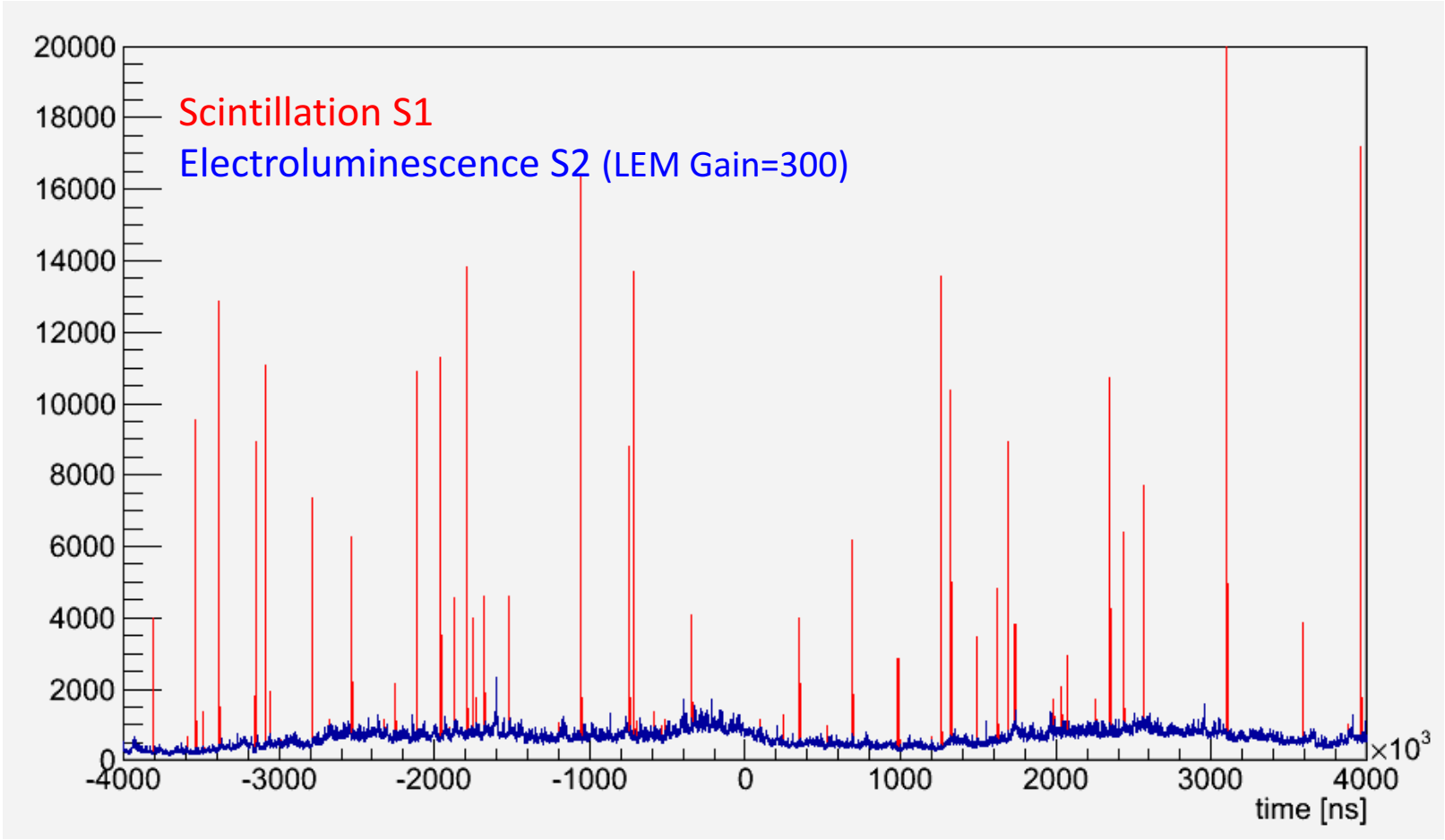
Summary of studies performed for 6x6x6

- Tagging of cosmic muons with light signals
  - Development of the threshold method
  - Impact of acquisition sampling, 400ns vs 25ns
  - Impact of light absorption length

- Measurement of scintillation pulse shape
  - Principle of the measurement
  - Methode
  - 25ns vs 400 ns sampling

All the studies have been performed with **Qscan**, after fixing the light simulation code [cfr M.Vidal, SB 06/04/2016] and using the Light Maps available at that time [by Silvestro]

Cosmic muons' light signal in 8 ms window



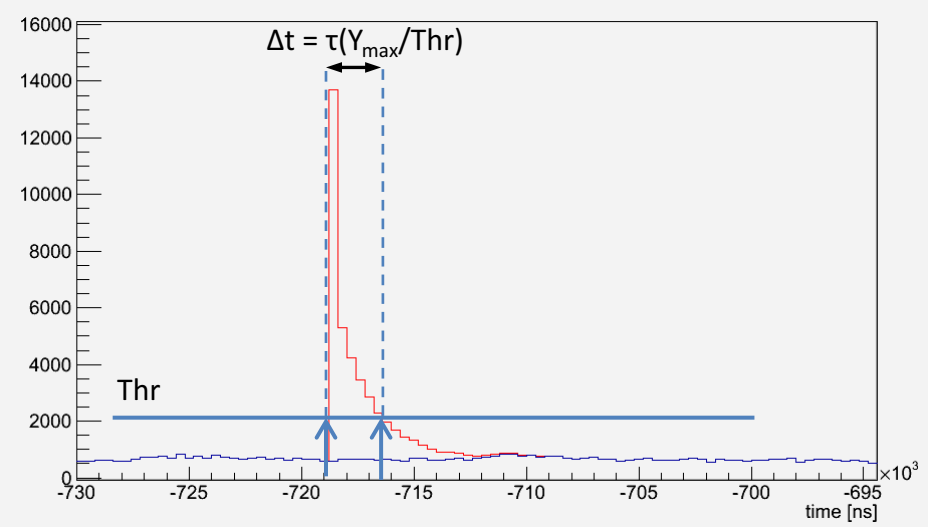
Can we use a simple threshold to tag cosmic muons?

Cosmic muon tagging with a threshold

Definition of quantities to evaluate the muon tagging performance:

- "Efficiency": probability to tag a muon's S1 =
  (Number of S1 peaks above threshold) / (Number of muons crossing fiducial volume)

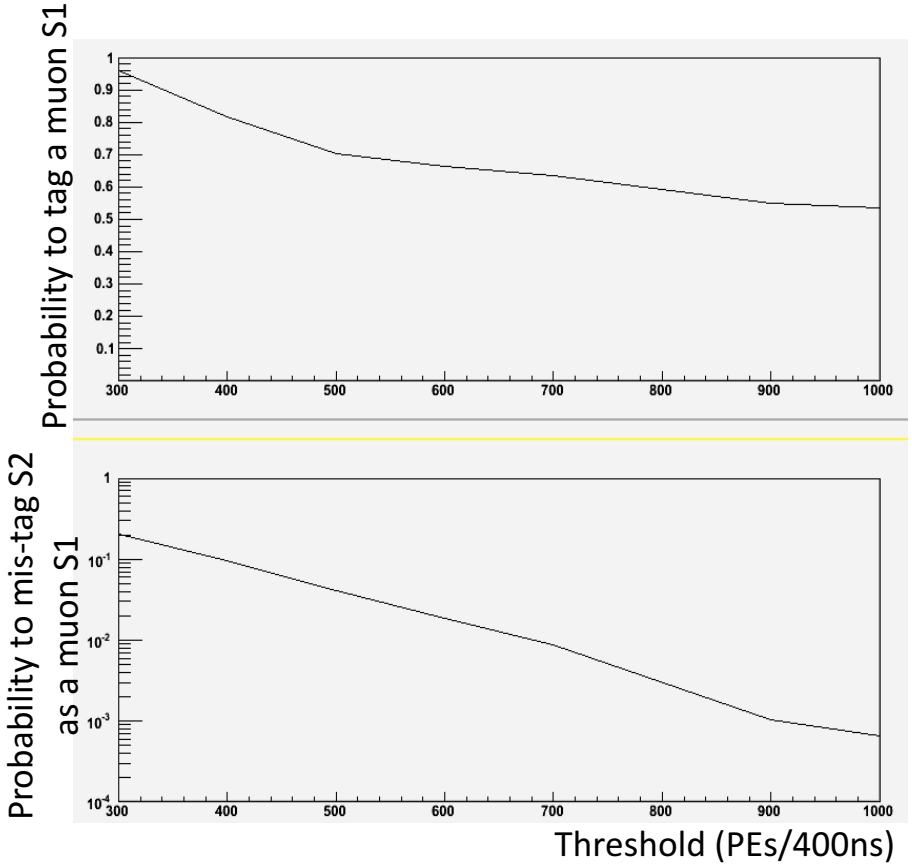
Finding S1 peaks:
- look for bin above threshold
- do not look for a new peak until the 1.6 µs exp has gone back below threshold



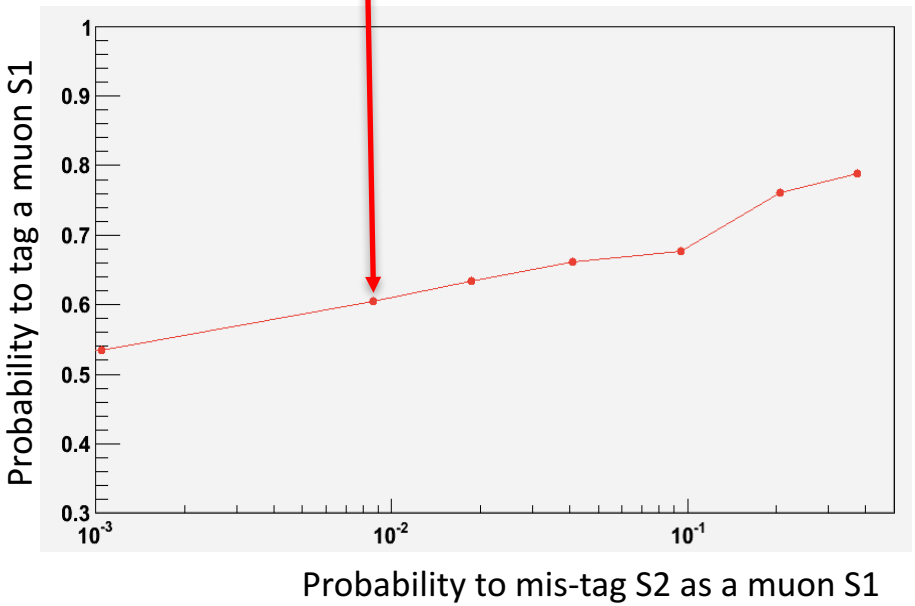
- "Background" : probability to tag a S2 signal as a muon's S1 =
  (Number of S2 bins above threshold) / (Total number of S2 bins)

[Note: the fact that S1 is superimposed to S2 is taken into account by adding an "average S2" to the S1 histogram]

Cosmic muon tagging with a threshold



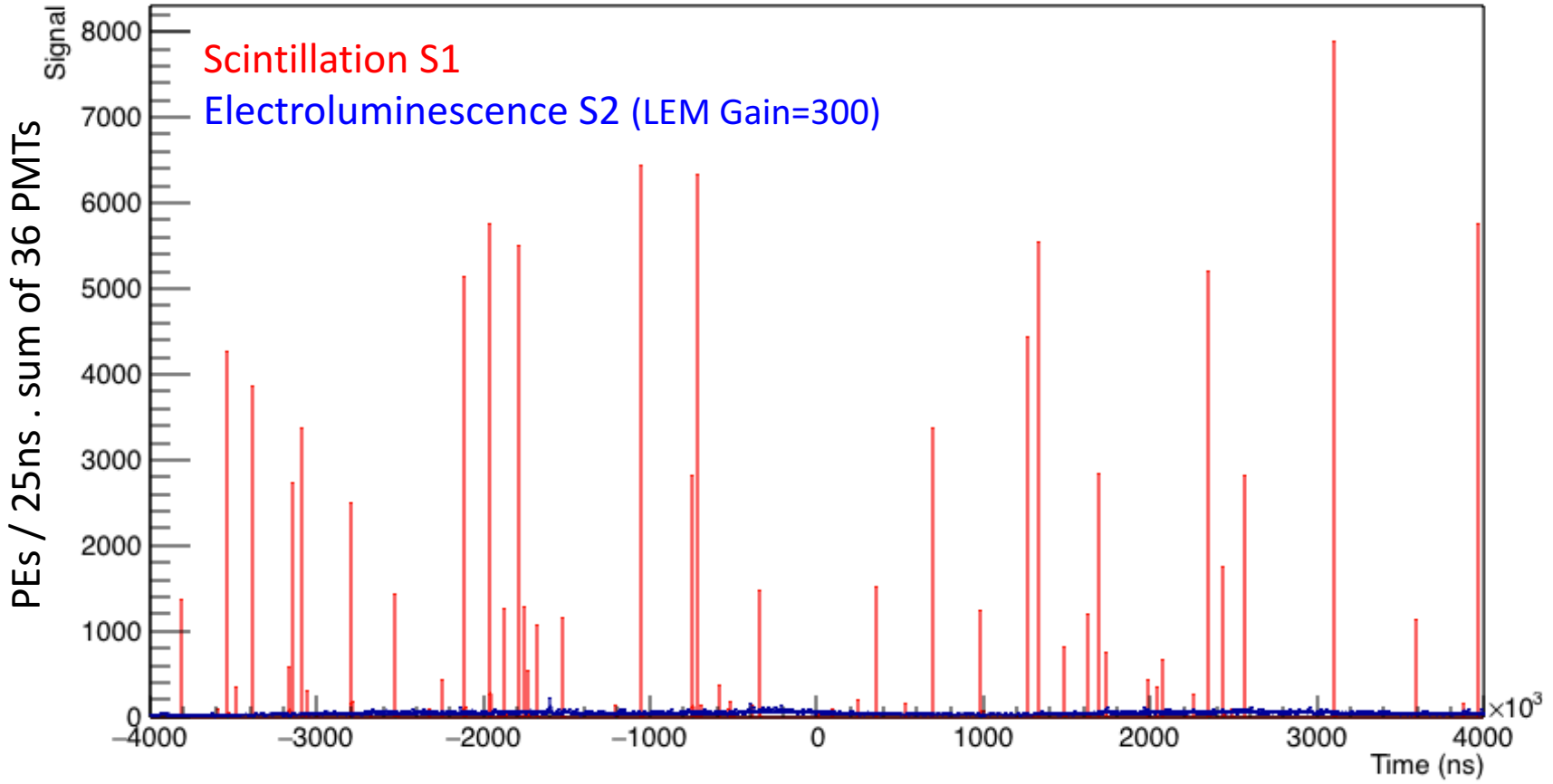
e.g. mis-tag of 1 % S2 as S1 results in 60 % S1 efficiency



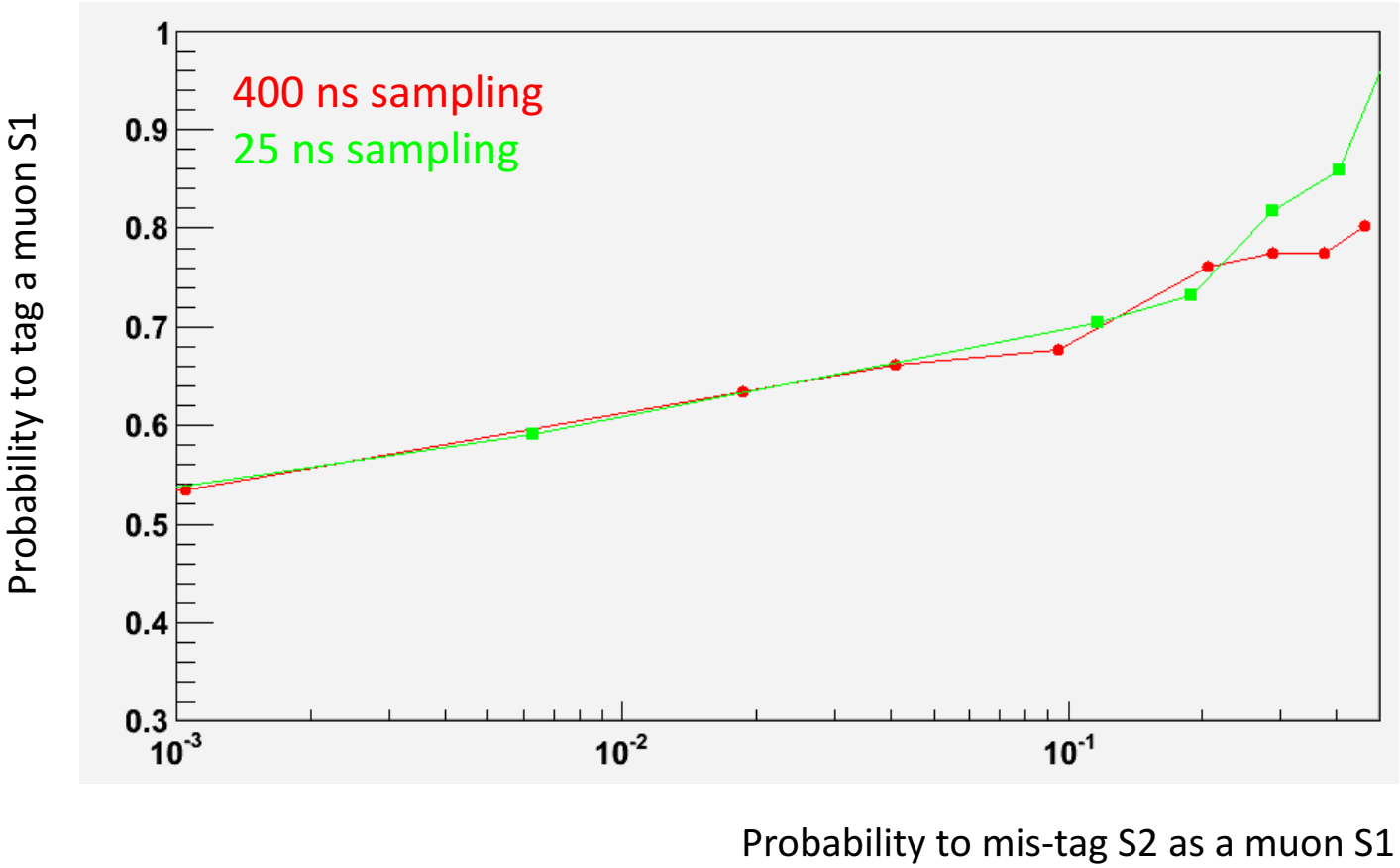
Conclusion: a simple threshold allows for efficient tagging of cosmic muons' S1 above the "continuous" S2

Muon tagging: impact of acquisition sampling

The LRO cards actually sample at 25 ns.
Would the tagging improve if data was acquired with this sampling ?
(although probably unfeasible, due to data rate/size, as discussed at SB/TB)



Muon tagging: impact of acquisition sampling



Conclusion: sampling at 25ns during beam spill would not improve significantly the efficiency for tagging cosmics with a simple threshold on the total signal

Muon tagging: impact of light absorption length

- In the Geant4 simulation (both LightSim and Qscan), the light absorption length was λ_{abs}= 30 m
- A much smaller λ_{abs} has been measured in LAr TPCs (ArDM, DarkSide)

=> What is the impact of λ_{abs} on the light signals from cosmic muons ?

- Studies in LightSim were performed by the LAPP group, evaluating the impact on light collection at the PMTs
- We implemented the attenuation in Qscan and studied the effect on cosmic muon light tagging [presented at SB 27/07/2016]

Implementation of light absorption in Qscan

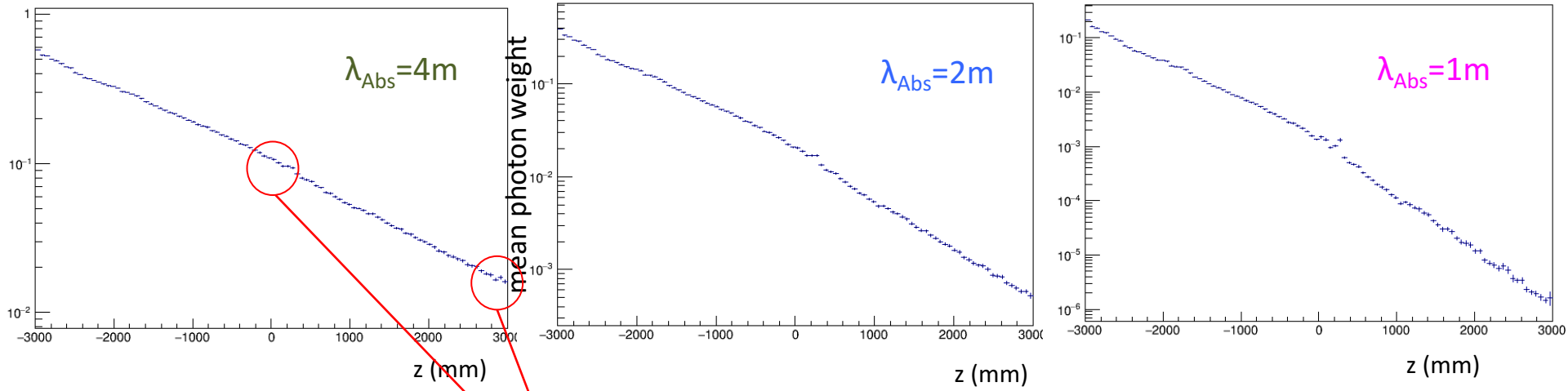
- A simple way to implement light absorption in Qscan, using the existing light maps calculated with $\lambda_{Abs}=\infty$: give to each photon a weight

computed from light maps

$$w = \exp\left(-\frac{t_{travel}\cdot c/n}{\lambda_{Abs}}\right) = \exp\left(-\frac{D_{travel}}{\lambda_{Abs}}\right)$$

This approach has limitations for very small λ_{Abs}, as explained in the presentation by LAPP group. We will eventually need the generation of new light-maps.

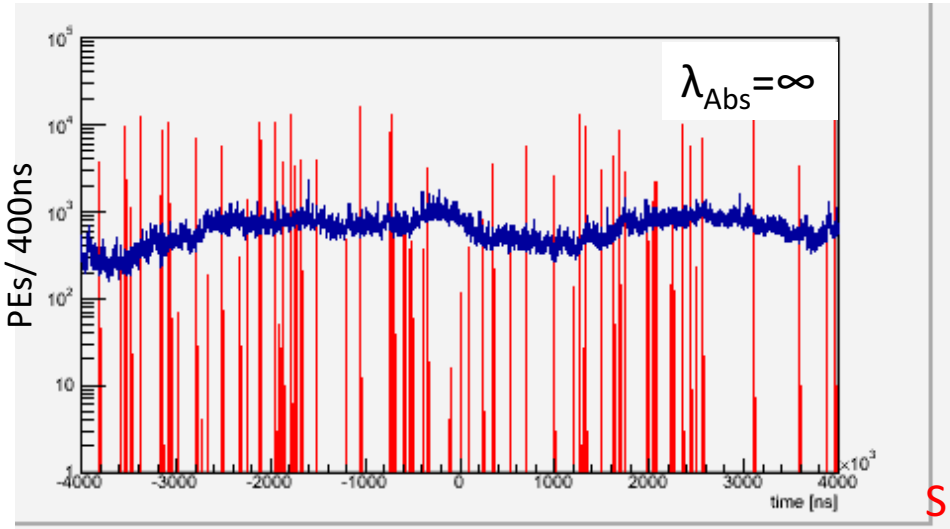
We have plotted the average value of this weight, representing the light reduction factor w.r.t. $\lambda_{Abs}=\infty$, as a function of the z coordinate of the photon production point

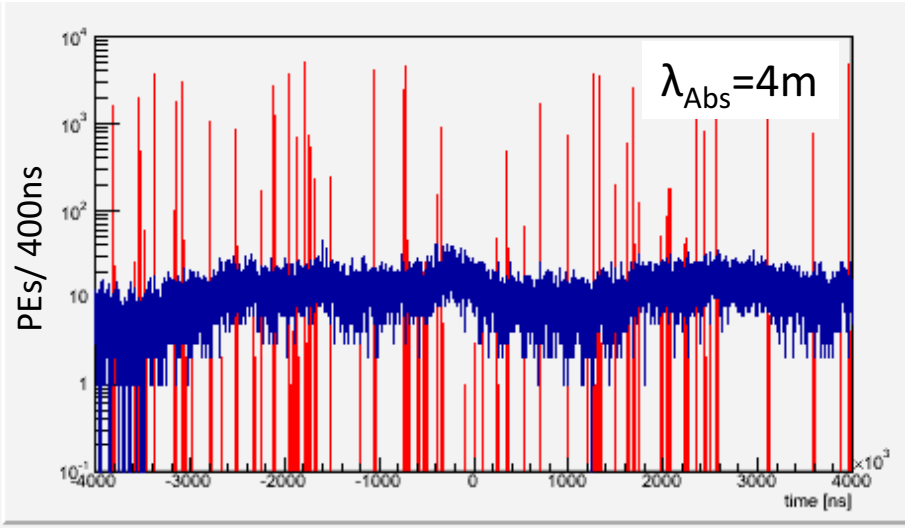


S2 reduction (z=3m): 2×10^{-2} 5×10^{-4} 10^{-6}

<S1 reduction> (z=0): 10^{-1} 10^{-2} 10^{-3}

Muon tagging: impact of light absorption length

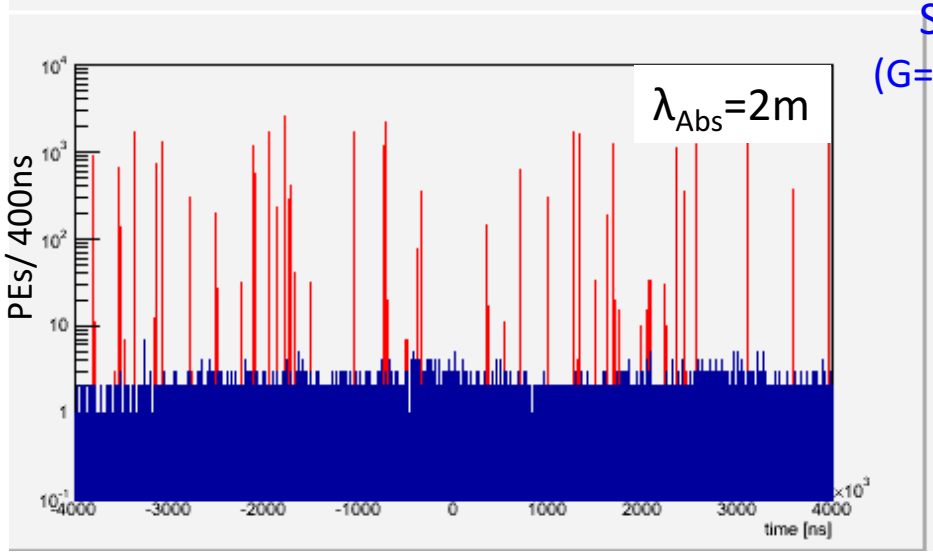


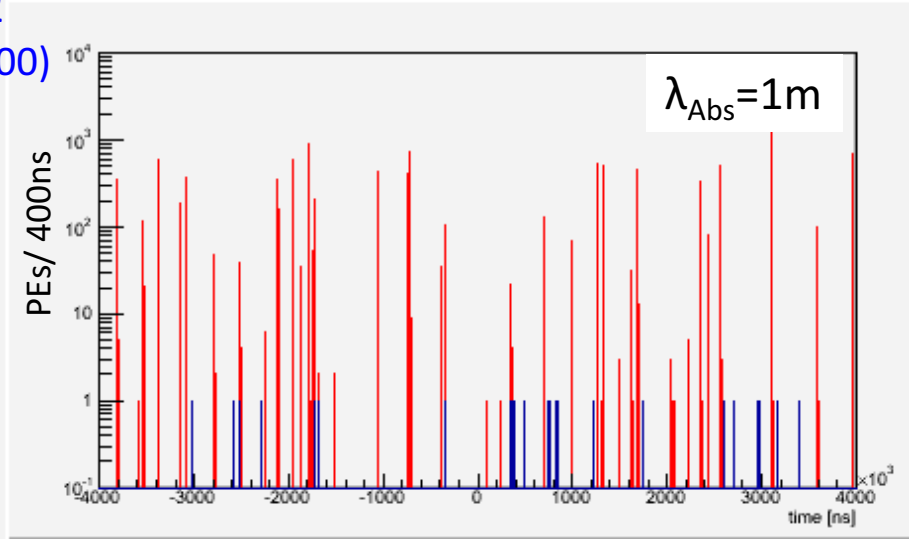


S1

S2

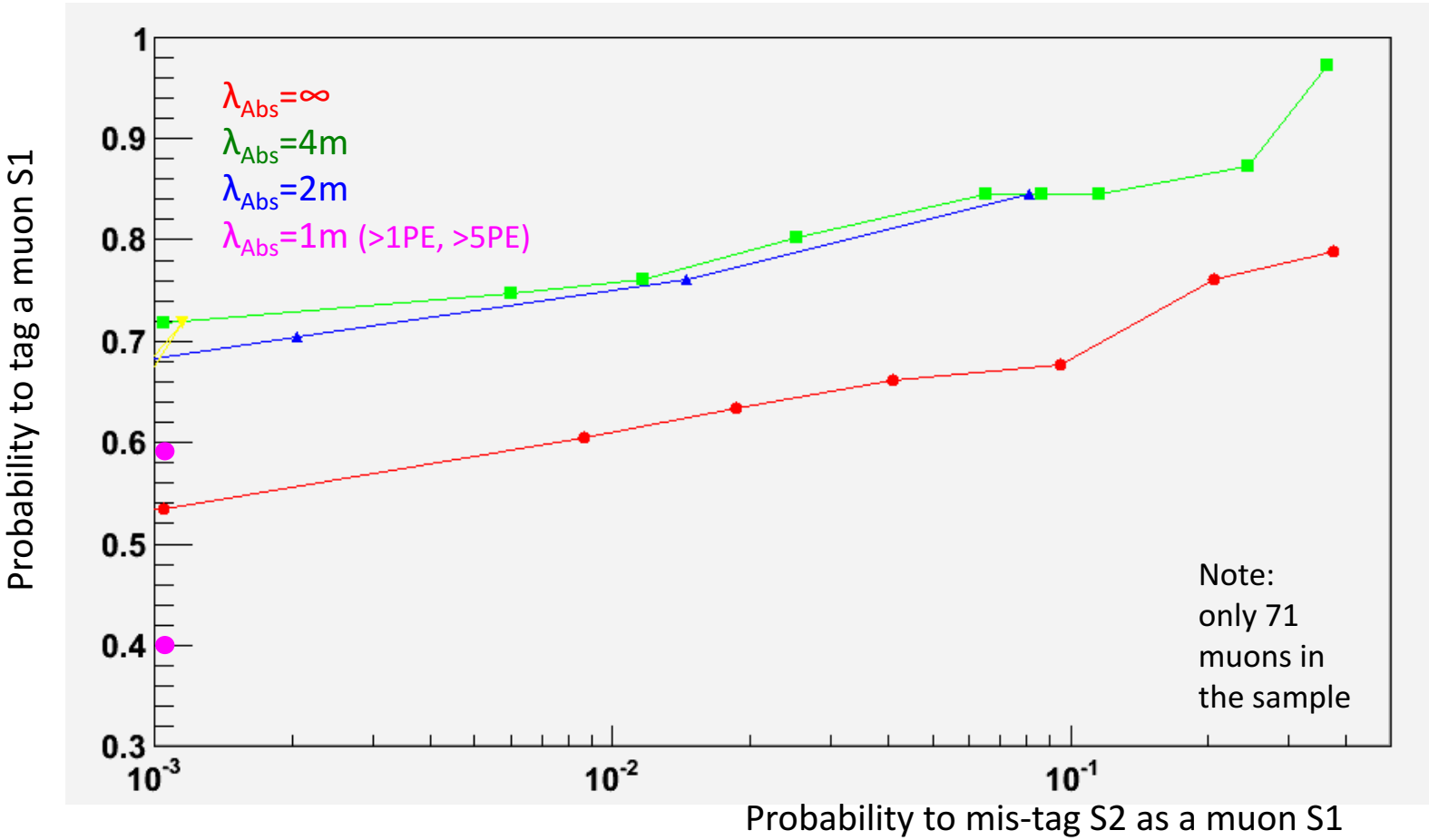
(G=300)





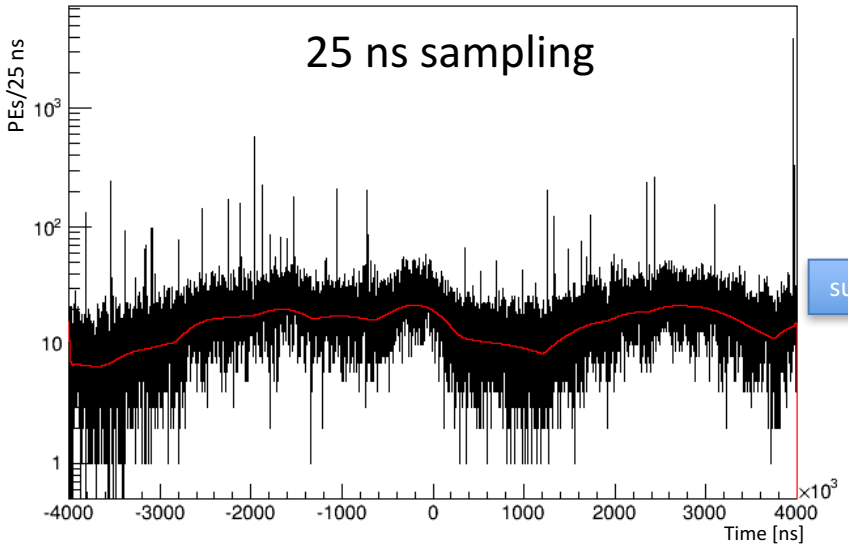
Muon tagging: impact of light absorption length

With “Marie’s method” (a simple threshold)



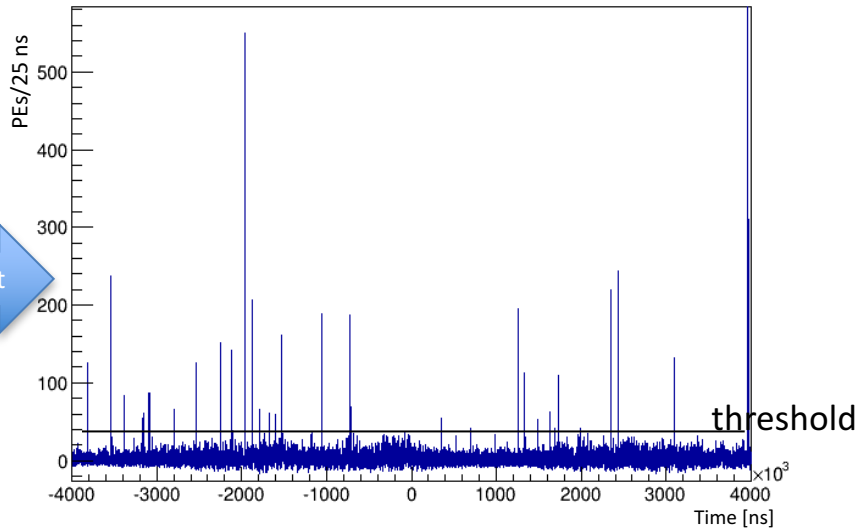
Conclusion: a shorter λ_{abs} improves the capability to tag muons S1, because of the reduction of the S2 background (but it will worsen the possibility to use light for calorimetry !)

Ideas on how to improve the μ-tagging:



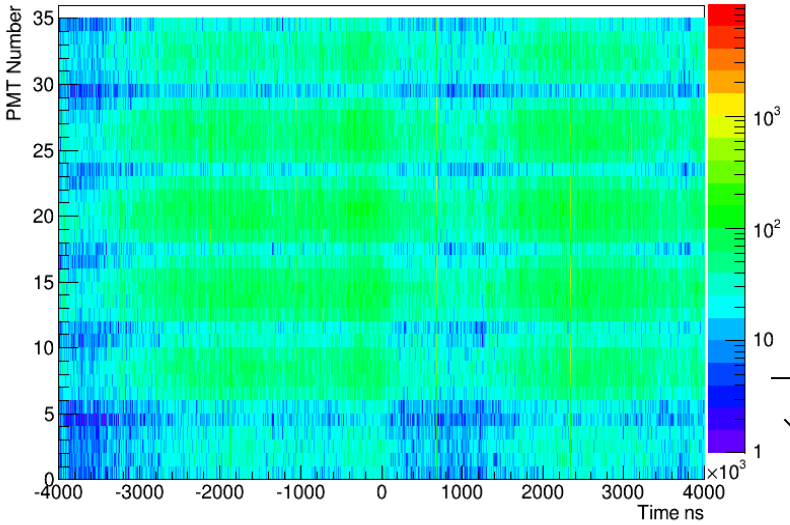
Use TSpectrum (Root Package peak finding) to estimate S2 background-red

substract

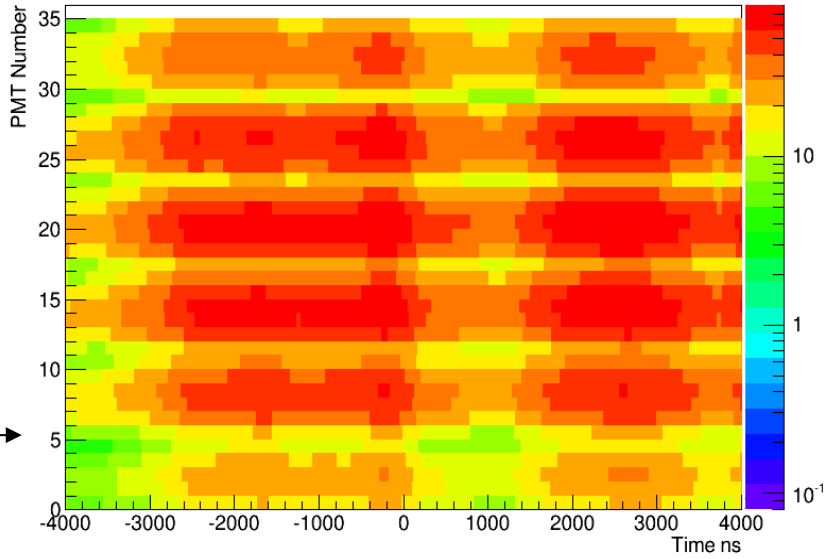


Pulse finder – peak crosses threshold and time over threshold > X

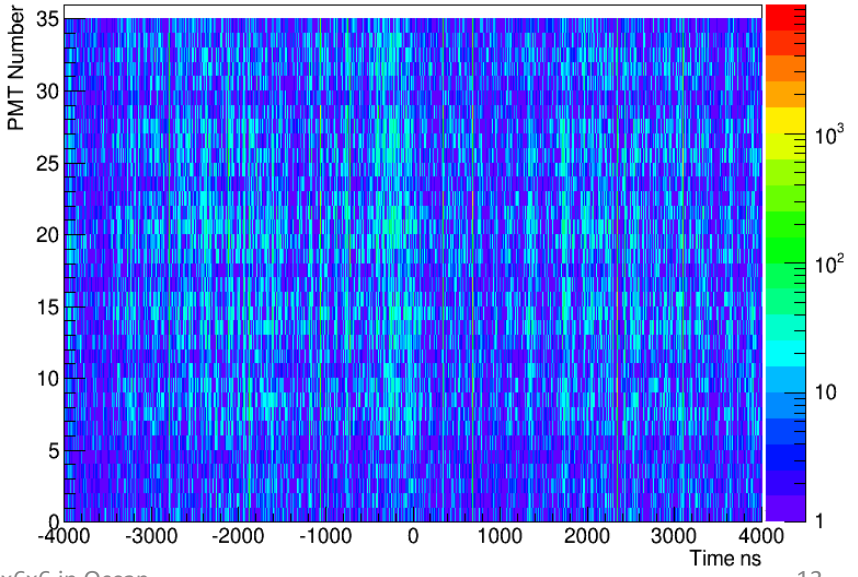
Stack all PMT signals together ...



S2 estimation



subtracted



Each waveform done individually then stacked together for the same event

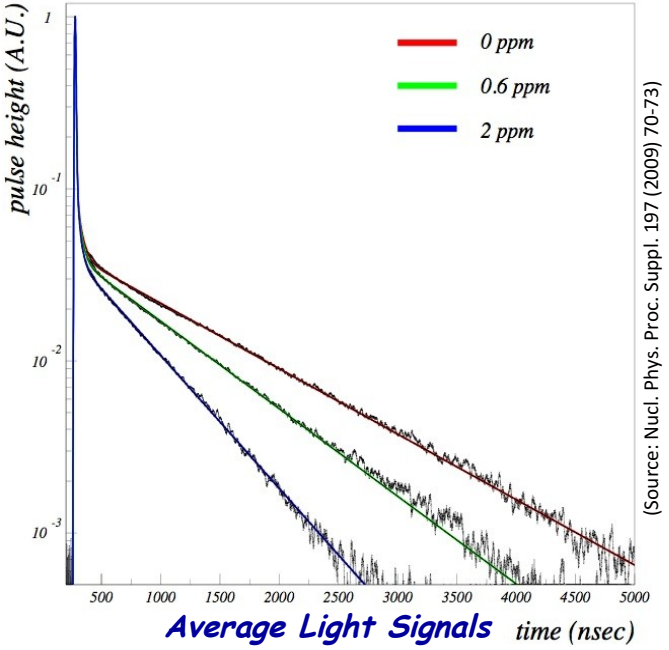
Scintillation Pulse Shape can tell us about contaminants

Measuring the long time-constant

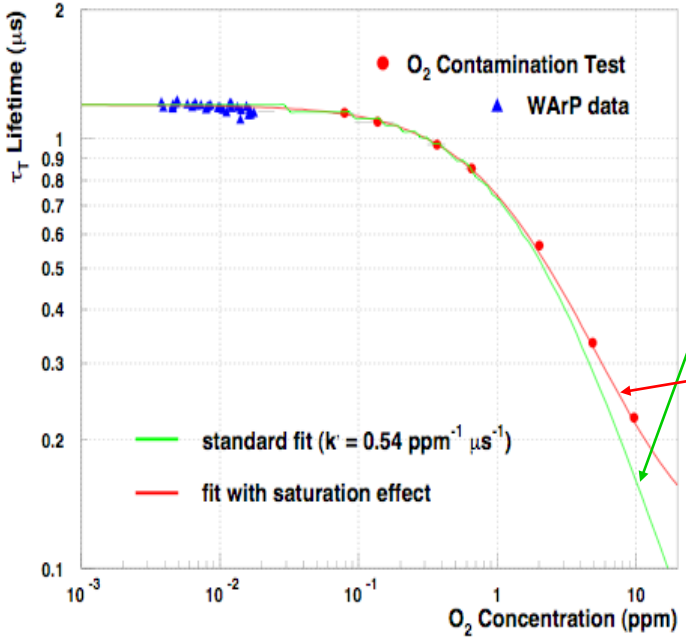
- Source: R.Acciarri: « Effects of Nitrogen and Oxygen contamination in liquid Argon »

  11th Topical Seminar on Innovative Particle and Radiation Detectors, Siena 2008 (Nucl. Phys. Proc. Suppl. 197 (2009) 70-73)

  - Clear effect on the long time-constant
- How?
  - We considered online analysis on FPGA
  - Use waveforms from cosmic-muon triggered events to fit muon scintillation pulses (25 ns sampling)



(Source: Nucl. Phys. Proc. Suppl. 197 (2009) 70-73)



(Source: Nucl. Phys. Proc. Suppl. 197 (2009) 70-73)

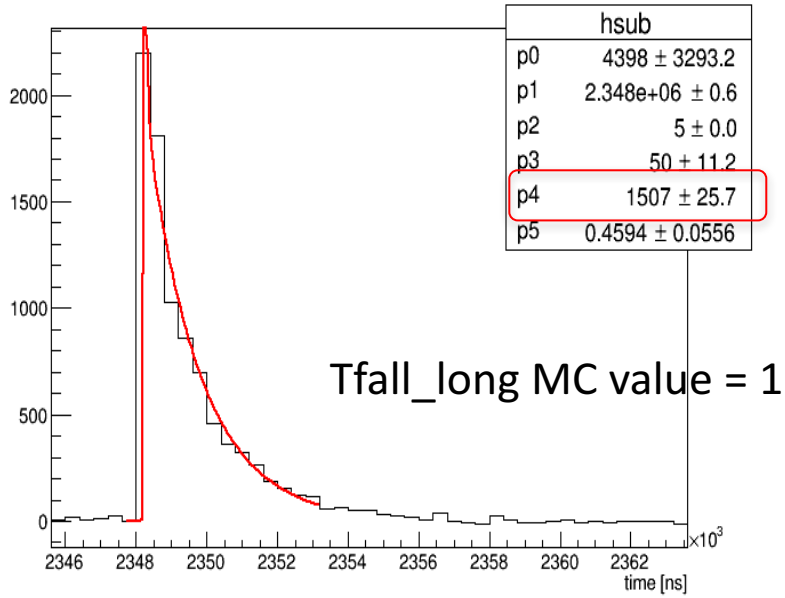
Measuring the long time-constant by fitting PMT signal individually

Liquid Argon scintillation pulse shape quite complicated but with known elements

- Trise – PMT (known and short)
- Tfall_short – previously measured
- **Tfall_long – to measure = ”p4” in the fitter**

Relative amplitudes of short/long time constants – previously measured

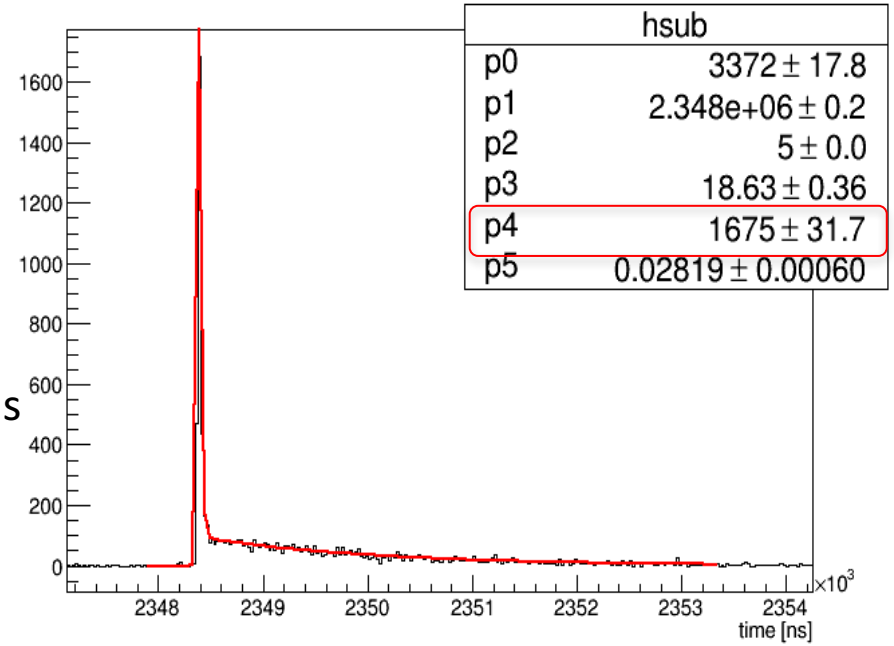
Include wavelength-shifter response?



Fitting with **400ns** sampled waveform is limited

No info on short time constant

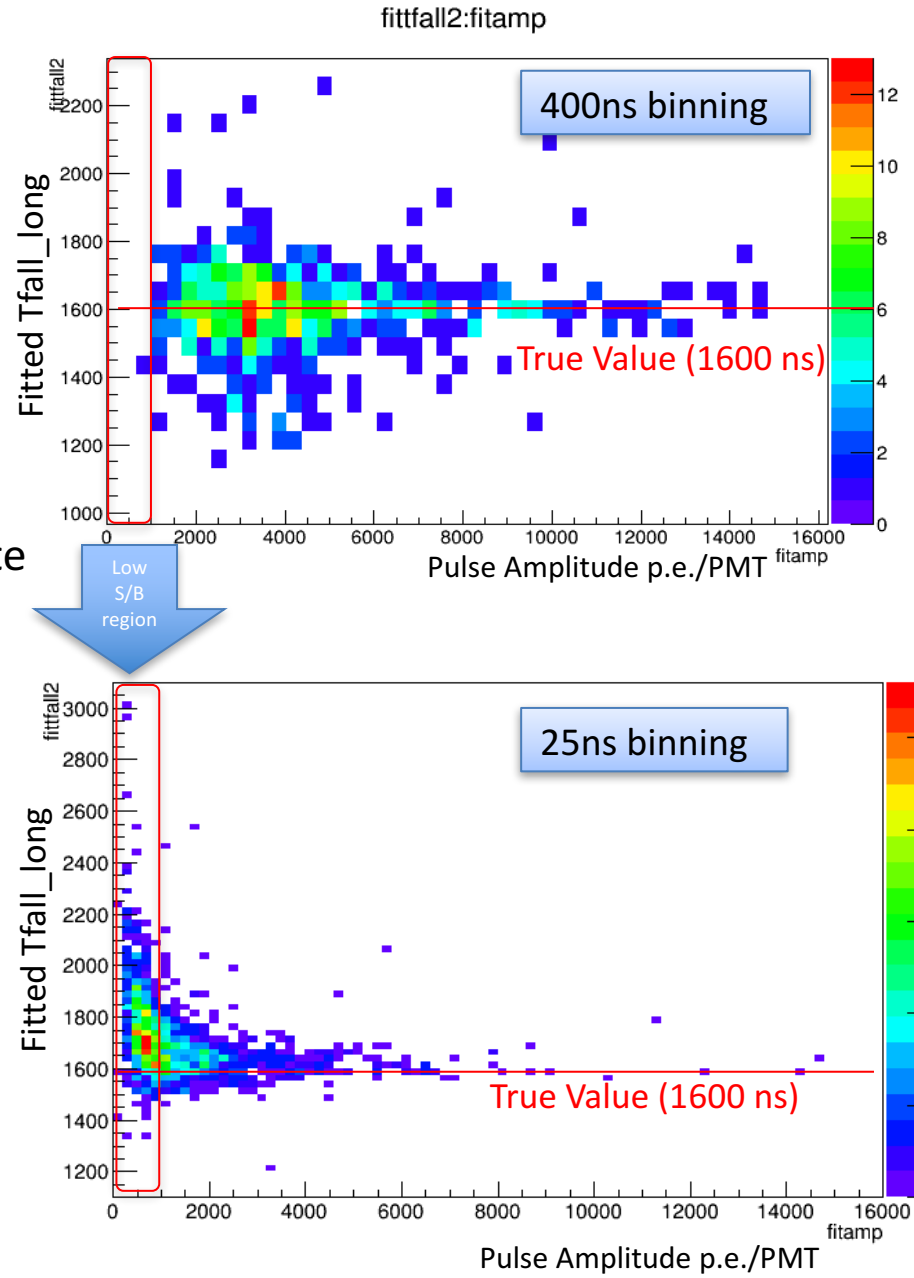
Tfall_long MC value = 1600 ns



Fitting with **25ns** waveform

Measuring the long time-constant:

- 400 ns binning works better for higher S/B
  - Largest events (i.e. crossing cosmic muons)
  - Lower S2
  - Less dependent on background subtraction
- Finer digitisation gives more ability to separate Short and long components
- Simulations need to include:
  - Effect of wavelength-shifter
  - Better description of electronics



Summary

Studies on light signal in 6x6x6 performed with Qscan

- Tagging of cosmic muon signal with a threshold on the sum of the 36 PMTs
  - good efficiency over the electroluminescence background
  - sampling at 400ns does not worsen the performance w.r.t. an ideal sampling at 25 ns
  - light absorption mainly reduces S2 and does not affect significantly S1 tagging efficiency
  - We have shown an idea of how to improve the simple threshold method (e.g. Root Tspectrum)
- Pulse shape
  - Measuring the pulse shape will indicate the liquid purity
  - Using cosmic-muon tagged events digitised at 25ns will allow better estimations of the pulse shape
  - Simpler than implementing an on-board algorithm

Thank you!