Toward neutrino analysis with empty detector

Thomas Salagnac

LPSC

12 October 2016

Simulation : Modification of the neutrino generator

Add possibility to generate neutrinos :

- in any kind of material
- in user specified volumes
- without solid angle distribution
  $\Rightarrow$ statistic in each volume will be only proportional to the number of H times the volume size

Modification of the tree which contains neutrino and IBD products information :

- Move "ν event" tree (NuTree) in the main output with "G4 events" tree (NCF) and "real data like" tree (Data)
- Number of entries in "neutrino event" tree will now match the number of "G4 event" entries
  1 ν event = 2 (average) G4 events = 2 entries in "nu events" (duplicated info.)
  $\Rightarrow$ little extra of 160 Mo in output size for 1 M of ν event
  $\Rightarrow$ but easier to use

Algorithm to search for coincidence

- First, cuts applied on single events : **tag single events**
  example : tag *"prompt"* and *"delayed"* events with energy cuts

- **Search for coincidence :** test every possible pairs as coincidence
  - Cuts applied on single tag
    example : ask *"prompt"* tag for the first event and *"delayed"* tag for the last event
  - Cut applied on delta time (check if delayed event is in the time window wrt prompt event time)
  - Cut applied on the coincidence candidate
    example : ask for max charge in the same cell between prompt and delayed event

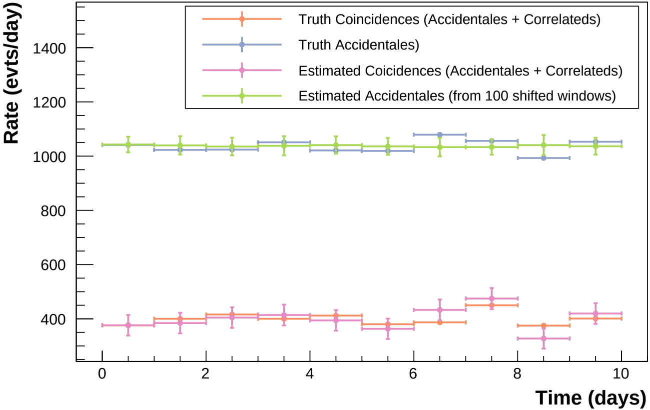
- Algorithm is also designed to work with multiple coincidences (nb of event > 2)

- Not committed yet (soon)

Verification of the algorithm by simulation

Simulation of dummy events to check the algorithm for 10 days of data taking, with :

- 1000 Hz of fake prompt
- 400 evts/day of correlated
- 6 Hz of fake delayed

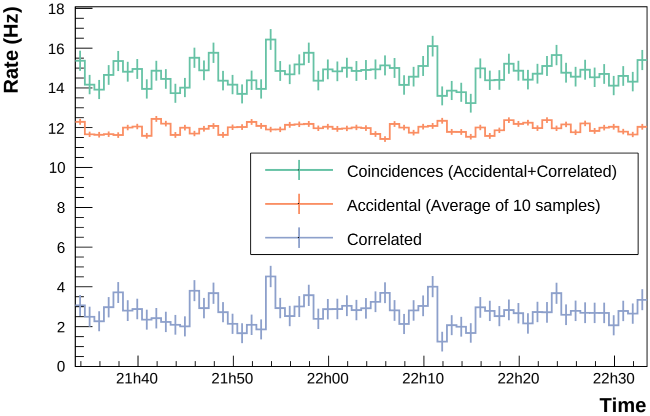


Estimation of average accidental rate using several coincidence selections with different shifted time windows from prompt event

Analysis "neutrino" run : rate

Run "neutrino" : without liquid scintillator

- ~400 Hz of single rate
- trigger only in the inner detector
- threshold on charge sum of 4 PMTs : 20 PEs

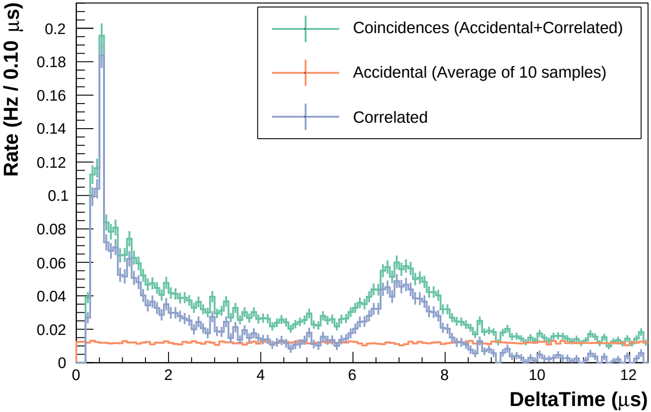


No additional cut applied

Average rate of correlated coincidences $\sim 2,7 \pm 0.1\,\mathrm{Hz}$

Analysis "neutrino" run : delta time ΔT

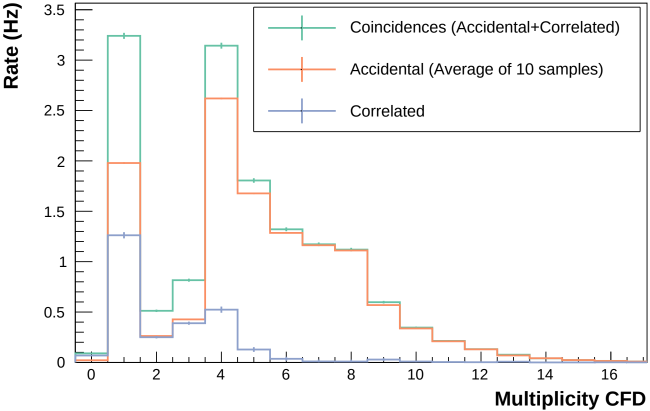
ΔT = time of delayed event - time of prompt event
ΔT distribution for correlated = coincidences - accidental (corrected from time shift)



1st afterpulse at $\sim 0.5\,\mu s$: H^+
2nd afterpulse between $[6-8]\,\mu s$: N_2^+, Ar^+, O_2^+ or/and CO_2^+
Exponential contribution ?

Analysis "neutrino" run : PMT multiplicity

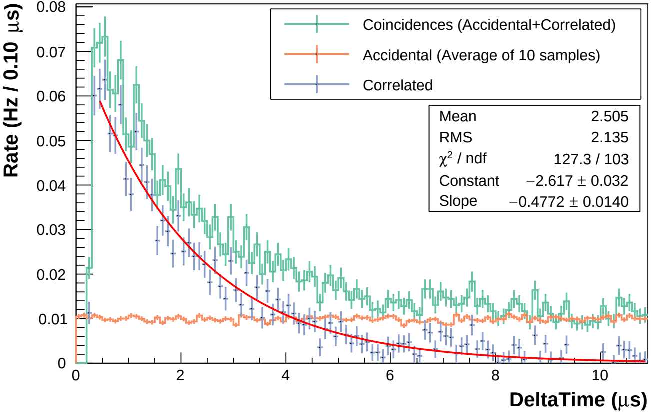
PMT multiplicity = number of PMTs which have seen a signal (> CFD threshold)



Expect afterpulse events to have a PMT multiplicity = 1
Cut on multiplicity > 1 should remove after pulse

Analysis "neutrino" run : delta time with cut on multiplicity > 1

Correlated rate decreased of 50% after cut on multiplicity : $2,7 \pm 0.1\,\mathrm{Hz} \longrightarrow 1.4 \pm 0.1\,\mathrm{Hz}$



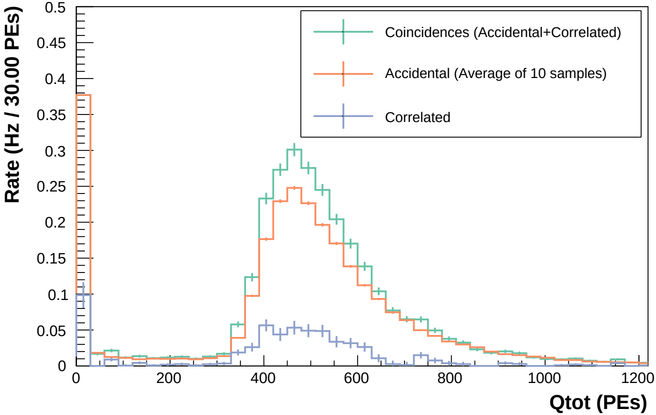
Exponential fit $= K.e^{-\Delta T/\tau} \Rightarrow \boldsymbol{\tau = 2.10 \pm 0.06\,\mu s}$

Average muon survival-time in acrylic $\sim 2.17\,\mu\mathrm{s}$

Exponential contribution caused by "*muon stop* " in buffer

Analysis "neutrino" run : prompt charge distribution in veto

Select events with 90% of the total charge in the target and with PMT multiplicity > 1

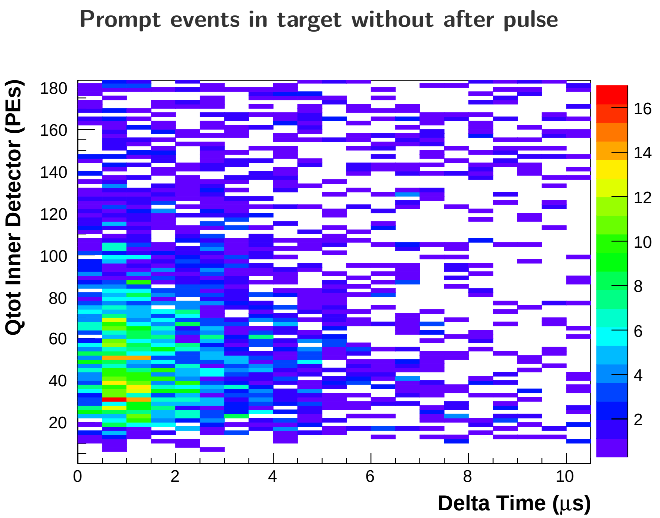


Peak at 500 PEs caused by muon going through veto muon $\Rightarrow \sim 80\%$ of prompt events

Some events don't produce any signal in veto $\Rightarrow \sim 20\%$ of prompt events

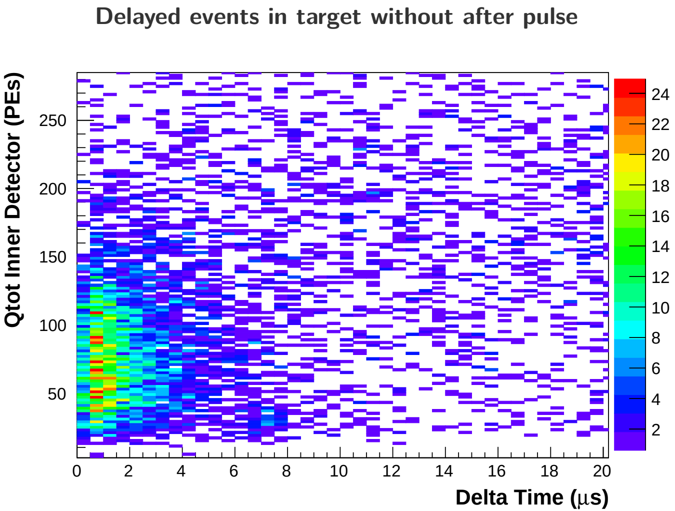
$\Rightarrow$ Need to be investigating !

Analysis "neutrino" : delta time $\Delta\mathrm{T}$ vs prompt target charge Qtot



Cut on delta time ΔT or cut on charge $Qtot$ to reject correlated ?

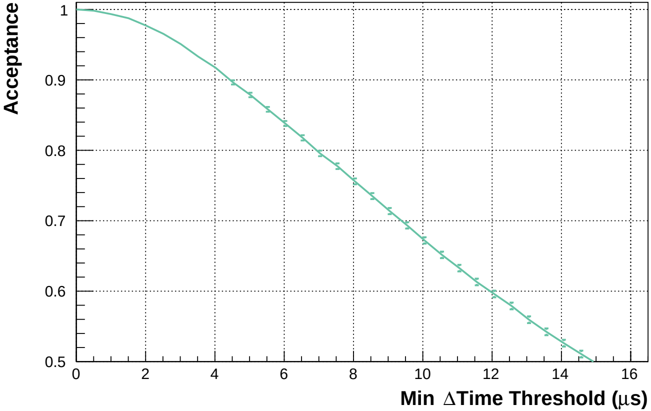
Analysis "neutrino" : delta time ΔT vs delayed target charge Qtot



Cut on delta time ΔT or cut on charge $Qtot$ to reject correlated ?

Simulation "neutrino" : acceptance of ΔT threshold

Acceptance of coincidence events from IBDs versus lower threshold on **delta time $\boldsymbol{\Delta}$T**



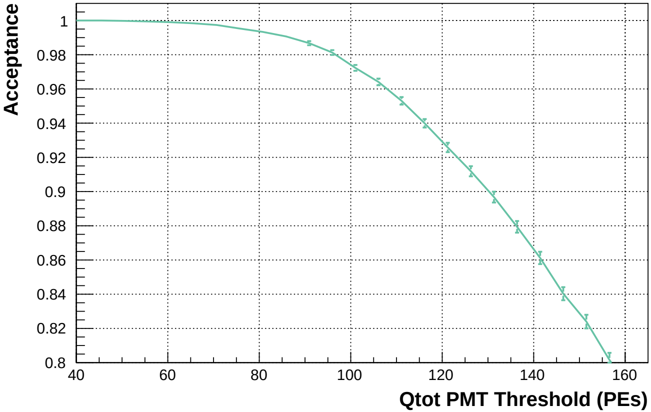
Cut on lower delta time threshold has a big impact on the neutrino acceptance

$\Rightarrow$ not really interesting to reject correlated coincidences

Simulation "neutrino" : acceptance of PMT Qtot threshold

Acceptance of prompt events from IBDs versus **charge threshold by PMTs**

Take into account only prompt events with a visible energy Evis > 2 MeV

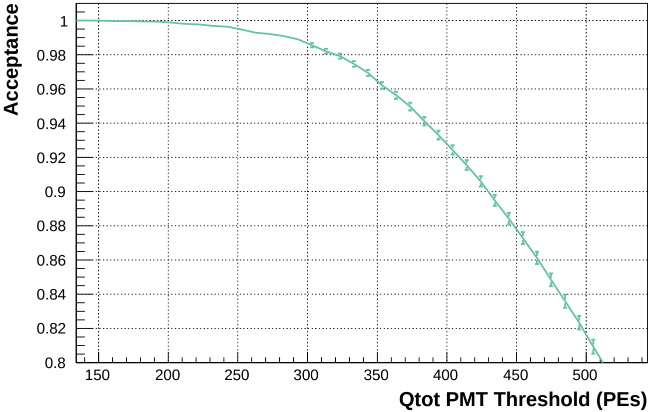


For threshold of [60-90] PEs ⇒ -0.5% / 10 PEs
For threshold > 100 PEs ⇒ -2% / 10 PEs

Simulation "neutrino" : acceptance of Qtot sum threshold

Acceptance of prompt events from IBDs versus **sum of charge threshold on 4 PMTs**

Take into account only prompt events with a visible energy Evis $>$ 2 MeV



For threshold of [200-300] PEs $\Rightarrow$ -0.1% / 10 PEs
For threshold $>$ 100 PEs $\Rightarrow$ -1% / 10 PEs

Conclusion

With empty detector and a threshold on 20 PEs for the sum of 4 PMTs :

- Correlated coincidences in Target + GC : 2.7 Hz
  - $\sim$ 50% afterpulses
  - $\sim$ 50% of "muon stop" (cherenkov + e^+/e^- from muon decay)
- Afterpulse events easily removed with a cut on the PMT multiplicity > 1
- "muon stop" events can be removed with a cut on the full charge > 150 PEs

Work to do :

- Need to investigate "muon stop" events with undetected prompt in the veto
- Commit and integrate the coincidence algorithm in the analysis software (soon)

Backup

Different steps of coincidence search algo

A Read next event in preprocessed date file

B Apply **cut on single** event → tag single event

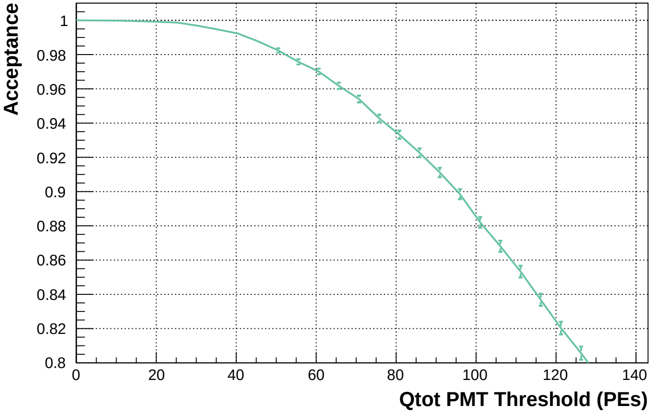
C Store event in buffer, if event fit in time window for selection, *go to step A*

D **Search for coincidence** : with first event in buffer as prompt candidate

1. Apply **single tag cut** on prompt candidate, if cut fail *go to step A*
2. Use next event in buffer as delayed candidate
3. Apply **time window cut** between prompt and delayed candidates, if cut fail *go to step 2*
4. Apply **single tag cut** on delayed candidate, if cut fail *go to step 2*
5. Apply **cut on full coincidence**, if cut fail *go to step 2*
   (e.g.: ask for max charge in the same cell between prompt and delayed event)
6. Store coincidence
7. If end of buffer not reach *go to step 2*
8. Pop out first event in buffer and *go to step A*

Simulation "neutrino" : acceptance of PMT Qtot threshold

Acceptance of prompt events from IBDs versus **charge threshold by PMTs**



Simulation "neutrino" : acceptance of Qtot sum threshold

Acceptance of prompt events from IBDs versus **sum of charge threshold on 4 PMTs**