GEANT4 Water Cherenkov simulation : new developments

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- Improve the trigger simulation in the digitization
- Change the event structure
- Changed the Root2ZBS translator

Goal

- Correct simulation of decay particles that occur in delayed triggers (sub-events)
- So far this delayed light was simply removed (it t >~1μs)

$\rightarrow$ no information on decay electrons (means T2K ν_e appearance analysis @ 2KM was different than at SK)

- We want to add sub-events to the MC
  - as a proof of concept that it is possible with ROOT/GEANT4
  - to improve the simulation of decay e- for the T2K analysis

Decay electrons at SK

- In the DATA :

during the first reduction step (on-line?), decay electron events are identified and merged with the event containing the parent muon. The event containing the decay electron is called a 'sub-event'.

- In the MC :

if a secondary particle is produced more than ~950 ns after the first primary, it will belong to a future trigger. Skdetsim postpones the tracking of the particle. At the end of the 1st event, it makes a new event with the postponed tracks, and then 'merges' the 2 events (i.e. the 2nd one becomes a sub-event).

Sub-events only happen if the decay occurs more than ~1μs later...if not the decay electron is 'in gate'. There can be more than 1 sub-event.

- In ZBS a sub-event is a complete event by itself. It has just been 'attached' to its parent event.

- During the reconstruction, after PID, the code checks for the presence of a decay e- in gate and/or for subevents. Subevents are fit separately using a low-e fitter (Kai fit ?). This information is then used in eg the T2K ν_e analysis.

Digitizer Details

The digitizer :

- Finds the trigger t0 (start of a 200 ns sliding window containing ~ 20 hits)

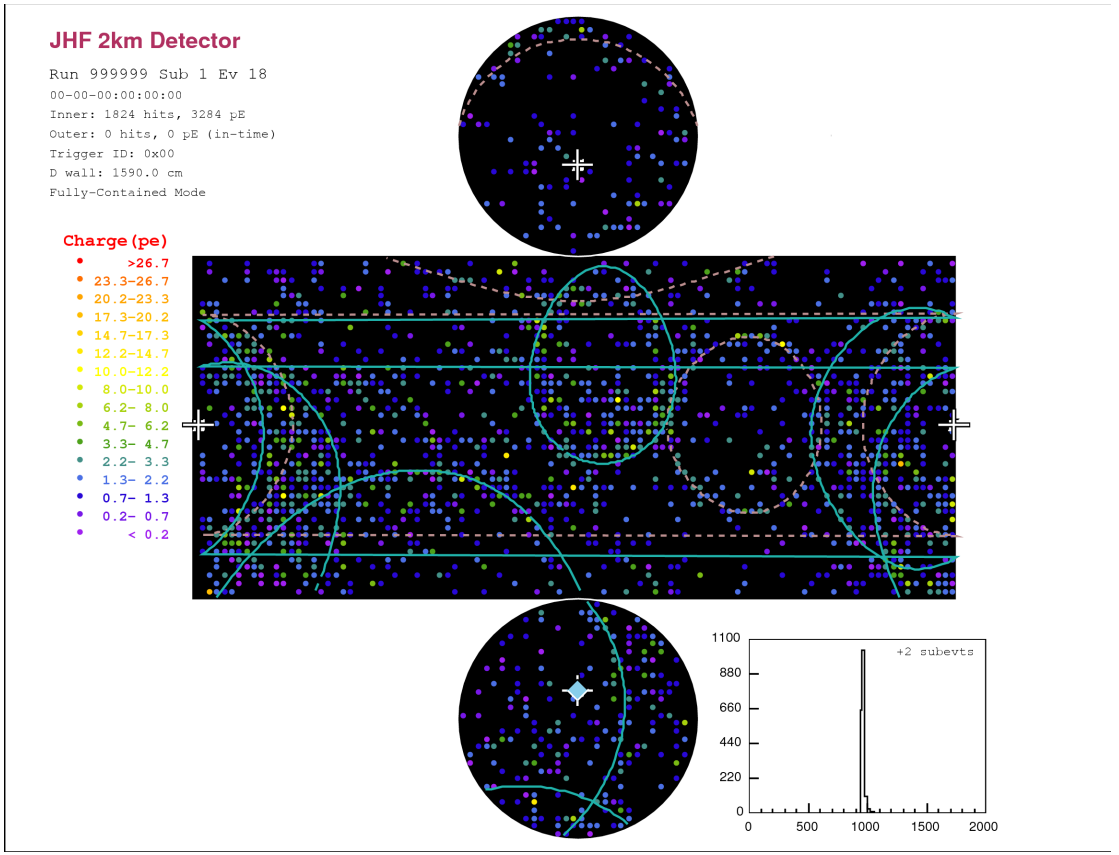
If one t0 has been found, it looks for the next ones

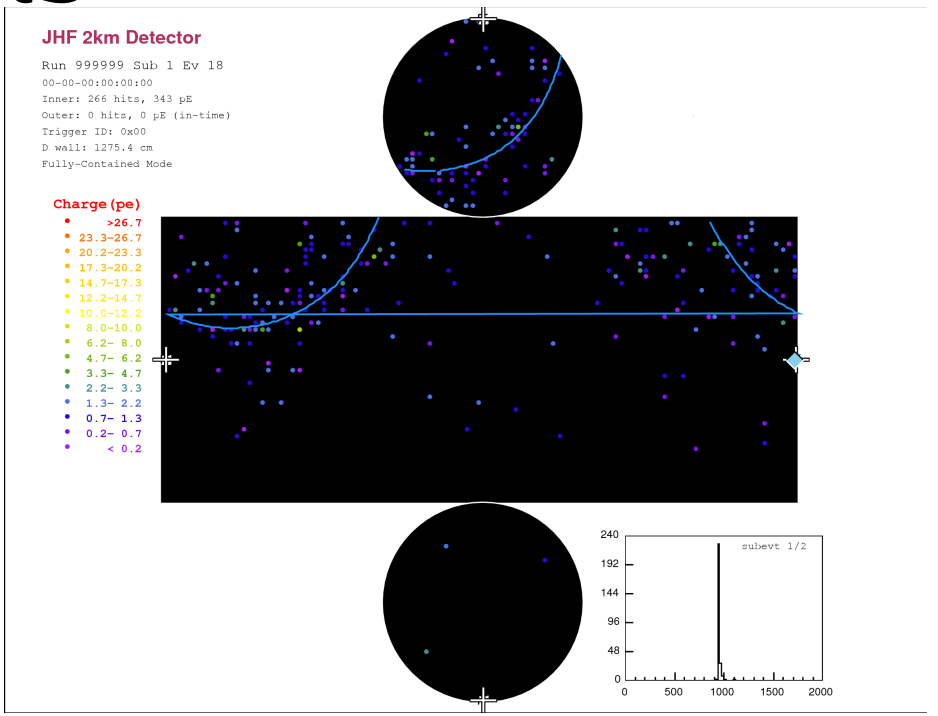
t0 can only vary in increments of 5 ns in the code (taken from skdetsim)

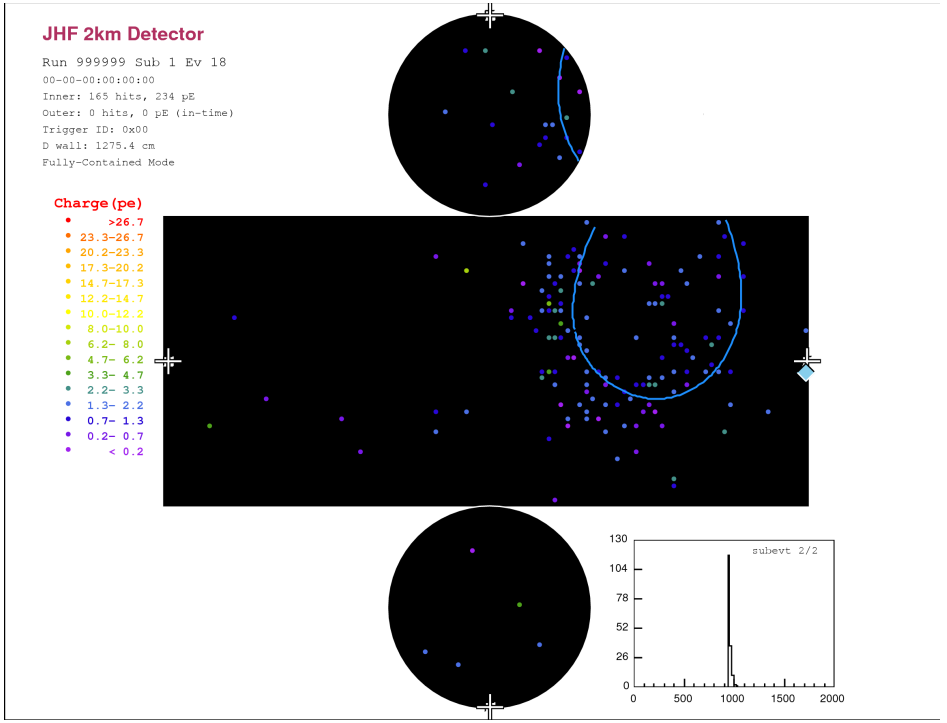
- Counts all hits on PMTs happening within [t0-400 ; t0+950]
- PMTs have an individual integration window of 200 ns after their first hit
- The digitized time is the first hit time, with smearing and an offset to match SK data
- The digitized charge is obtained by shooting random numbers from the 1 pe distribution at K2K-1kton

- So far only the Water Cherenkov hits are affected by this modification.

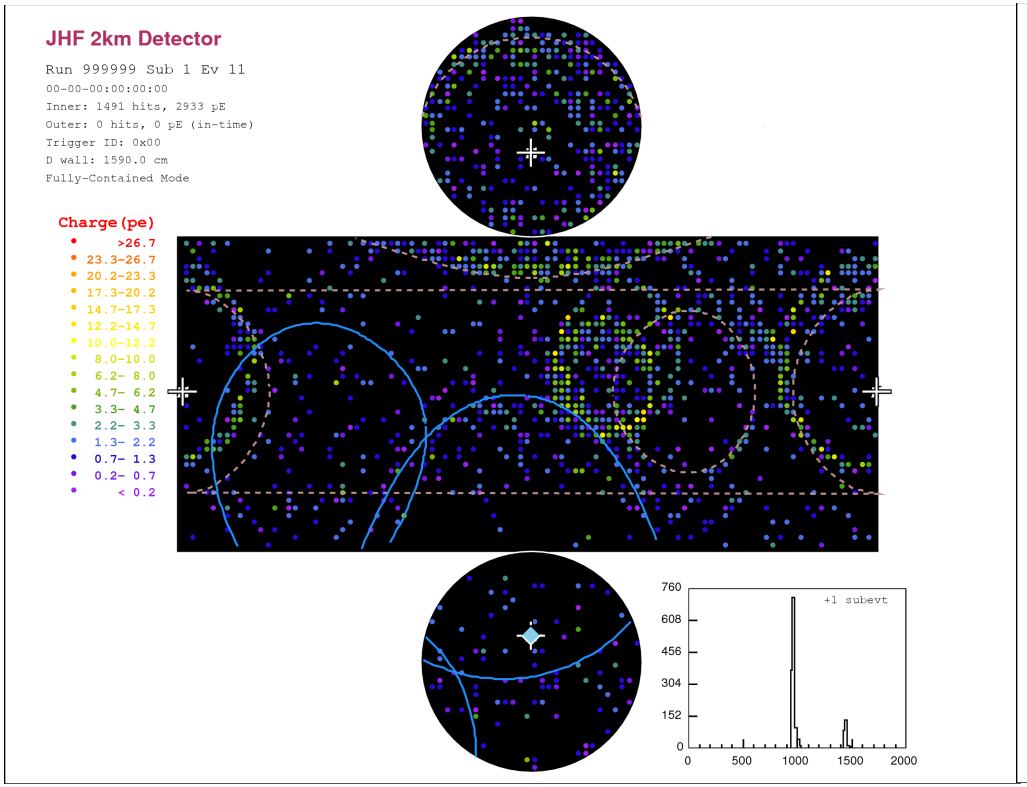
Results

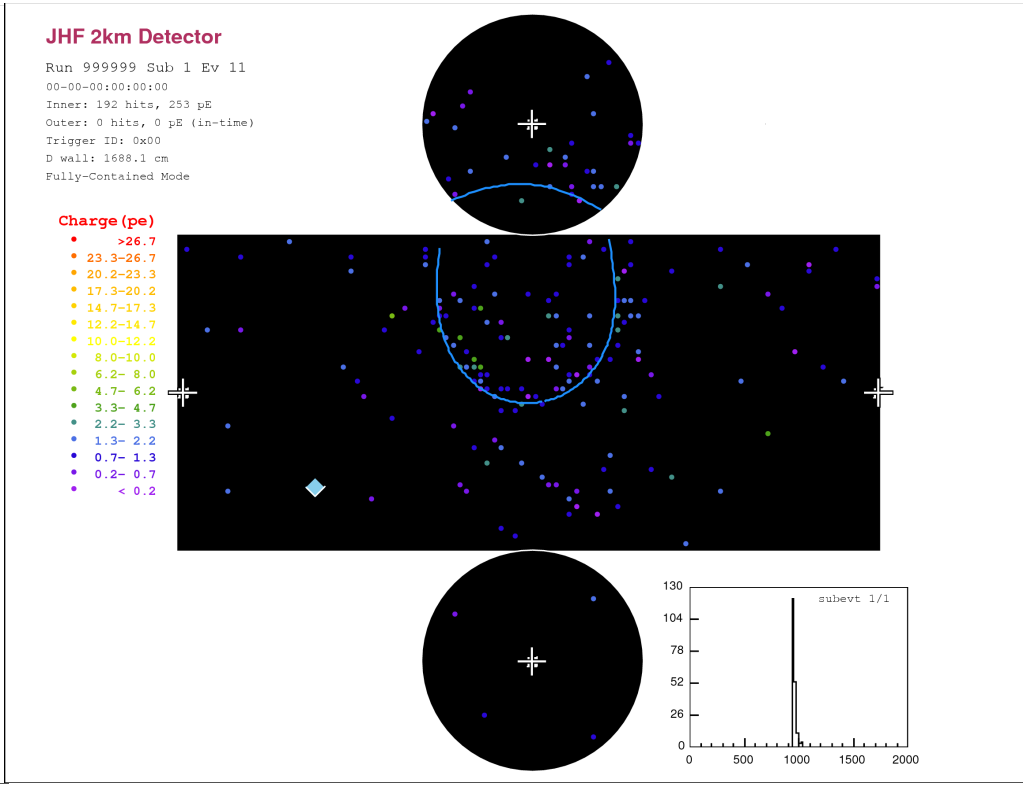

JHF 2km Detector
Run 999999 Sub 1 Ev 18
00-00-00:00:00:00
Inner: 1824 hits, 3284 pE
Outer: 0 hits, 0 pE (in-time)
Trigger ID: 0x00
D wall: 1590.0 cm
Fully-Contained Mode
Charge (pe)
>26.7
23.3-26.7
20.2-23.3
17.3-20.2
14.7-17.3
12.2-14.7
10.0-12.2
8.0-10.0
6.2- 8.0
4.7- 6.2
3.3- 4.7
2.2- 3.3
1.3- 2.2
0.7- 1.3
0.2- 0.7
< 0.2
+2 subevts
1100
880
660
440
220
0
0
500
1000
1500
2000


JHF 2km Detector
Run 999999 Sub 1 Ev 18
00-00-00:00:00:00
Inner: 266 hits, 343 pE
Outer: 0 hits, 0 pE (in-time)
Trigger ID: 0x00
D wall: 1275.4 cm
Fully-Contained Mode
Charge (pe)
>26.7
23.3-26.7
20.2-23.3
17.3-20.2
14.7-17.3
12.2-14.7
10.0-12.2
8.0-10.0
6.2- 8.0
4.7- 6.2
3.3- 4.7
2.2- 3.3
1.3- 2.2
0.7- 1.3
0.2- 0.7
< 0.2
subevt 1/2
240
192
144
96
48
0
0
500
1000
1500
2000


JHF 2km Detector
Run 999999 Sub 1 Ev 18
00-00-00:00:00:00
Inner: 165 hits, 234 pE
Outer: 0 hits, 0 pE (in-time)
Trigger ID: 0x00
D wall: 1275.4 cm
Fully-Contained Mode
Charge (pe)
>26.7
23.3-26.7
20.2-23.3
17.3-20.2
14.7-17.3
12.2-14.7
10.0-12.2
8.0-10.0
6.2- 8.0
4.7- 6.2
3.3- 4.7
2.2- 3.3
1.3- 2.2
0.7- 1.3
0.2- 0.7
< 0.2
subevt 2/2
130
104
78
52
26
0
0
500
1000
1500
2000

Results

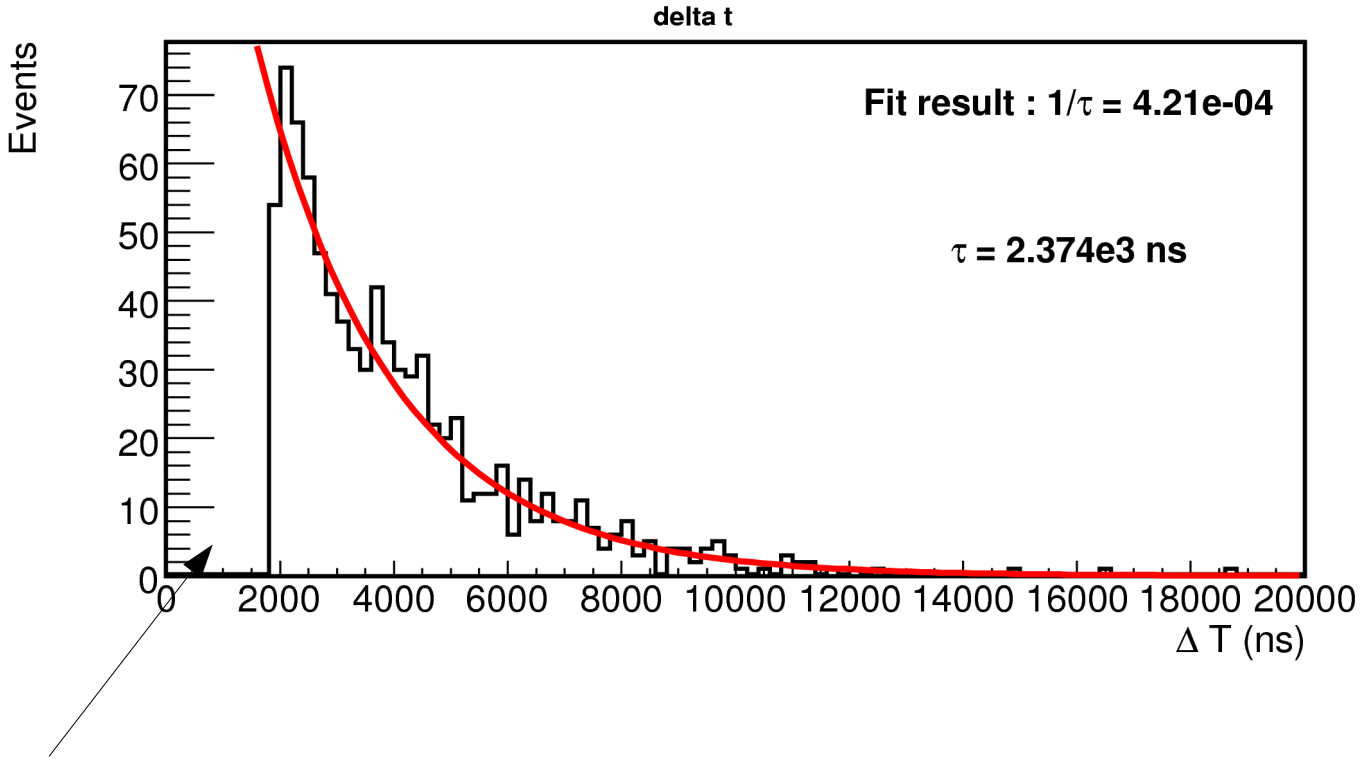




Events with 3 π+ : lots of rings from multiple hadronic interactions in the water, but also decays of π and μ --> multiple subevents.

One useful cross check...

I simulated 2000 mono-chromatic 250 Mev/c anti-muons in the 2KM tank,
and recorded the time difference between the 2 triggers (when they are separate).



In gate e-...

Conclusion

- The subevent mechanism has been added to GEANT4/Root and works fine:
For the moment we just want to mimick SK as the electronics will change anyway.
- For the proposal we will still use the present method for decay e- rejection in the
nue appearance analysis (based on probability calculations at 2KM & sub-event fitting at SK).

Technical details

- An “Event” (JHF2kmRootEvent) now contains a list (TobjArray) of “Triggers” (JHF2kmRootTrigger).
- The previous event structure has been moved to JHF2kmRootTrigger, with very little change
- All the information (tracks, hits, digitized hits) is stored in TClonesArrays. However these arrays used to be static, ie only one copy of them existed in memory.
- I chose to allocate/deallocate new ones as needed by the events

This is supposed to be slower according to the ROOT manual but I have not observed any significant difference so far. This solution seems to be perfectly acceptable. Making the TCAs static is not necessary in our simulation.

- User interface :

```
JHF2kmRootEvent* E = new JHF2kmRootEvent() ; // or get it from the file ....
JHF2kmRootTrigger* T = E->GetTrigger(0) ; // 0 is the main trigger,
                                          // 1 the 1st sub-evt etc.
```