Status of the Muon Decay studies in KM3NeT/ORCA6

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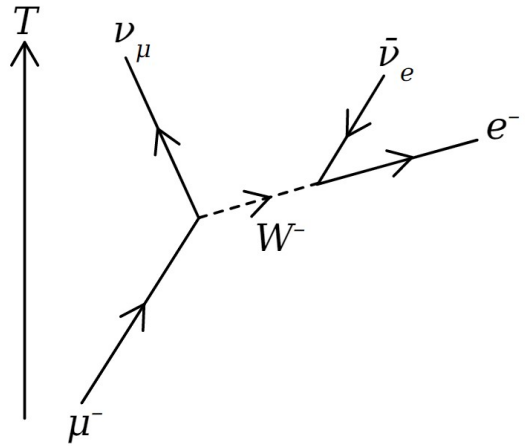
Contents

- Introduction
- Muon decay simulations
- Michel electron signals
- Backgrounds for Michel electron:
  - deep sea optical background - ^{40}K decays; bio luminescence
  - Scattered Cherenkov light from stopping muons
  - PMT afterpulses
- Summary and outlook

Muon Decays

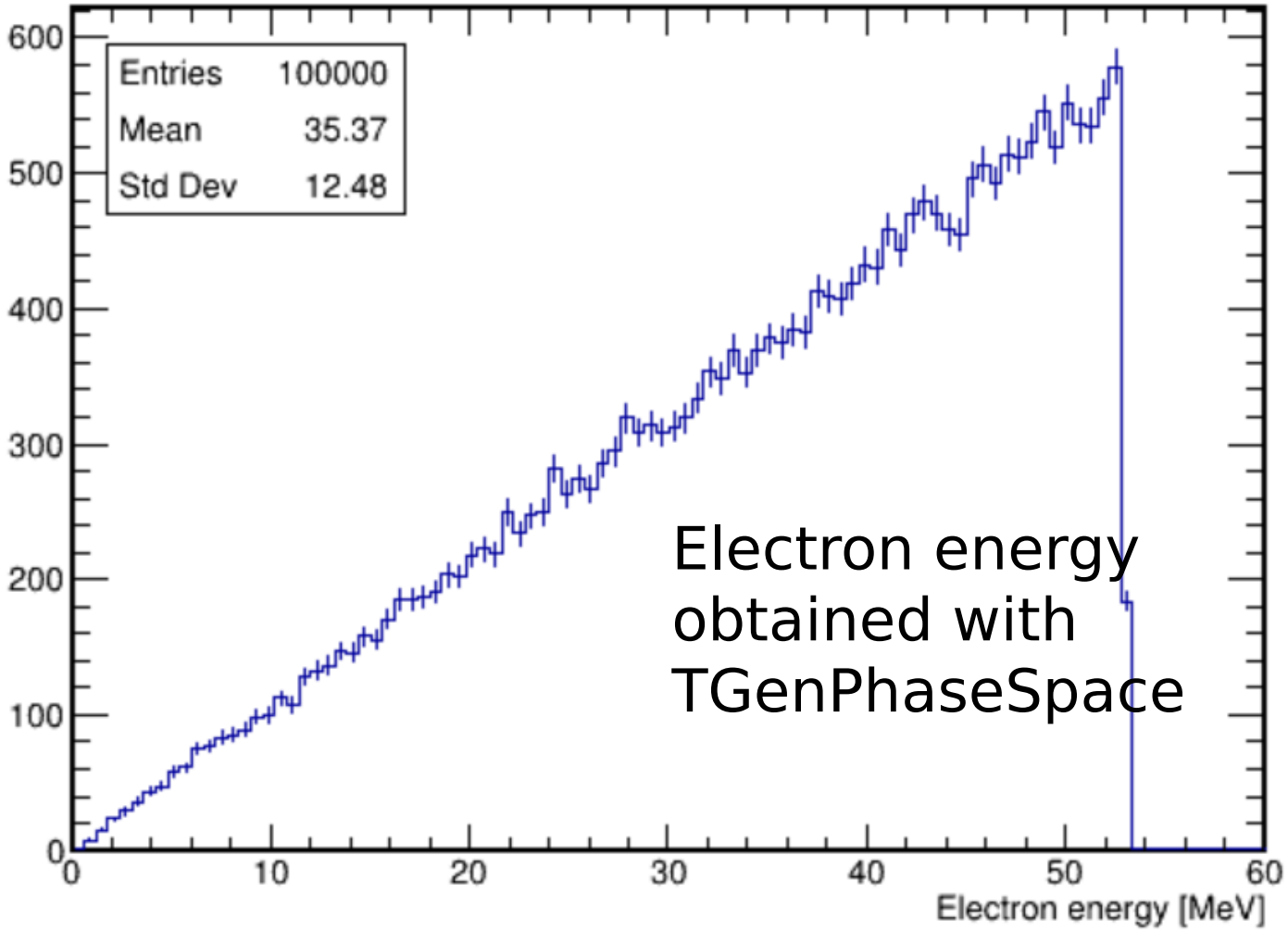


$\mu \rightarrow e + \nu_\mu + \nu_e$ 100%

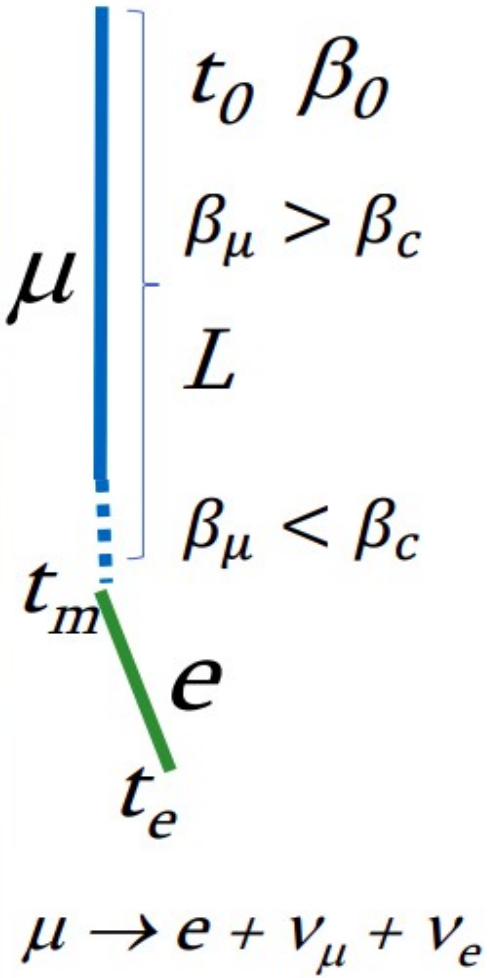
$m_\mu = 105.6583745 \pm 0.000002$

$\tau_\mu = (2.1969811 \pm 0.0000022)$

$\tau_{\mu+}/\tau_{\mu-} = 1.00002 \pm 0.00008$



Muon Decays



$$\mu \rightarrow e + \nu_\mu + \nu_e$$

Muon propagation time: $t_L = \dfrac{2L}{\beta_0 c}$

For L=200 m, and $\beta_0 \approx 1$ (E_μ>10 GeV) $t_L \approx 1.3$ μsec

Muon decay time:

$$t_m - t_e = \Delta t \qquad f(\Delta t) = \exp\left(-\frac{\Delta t}{\tau}\right)$$

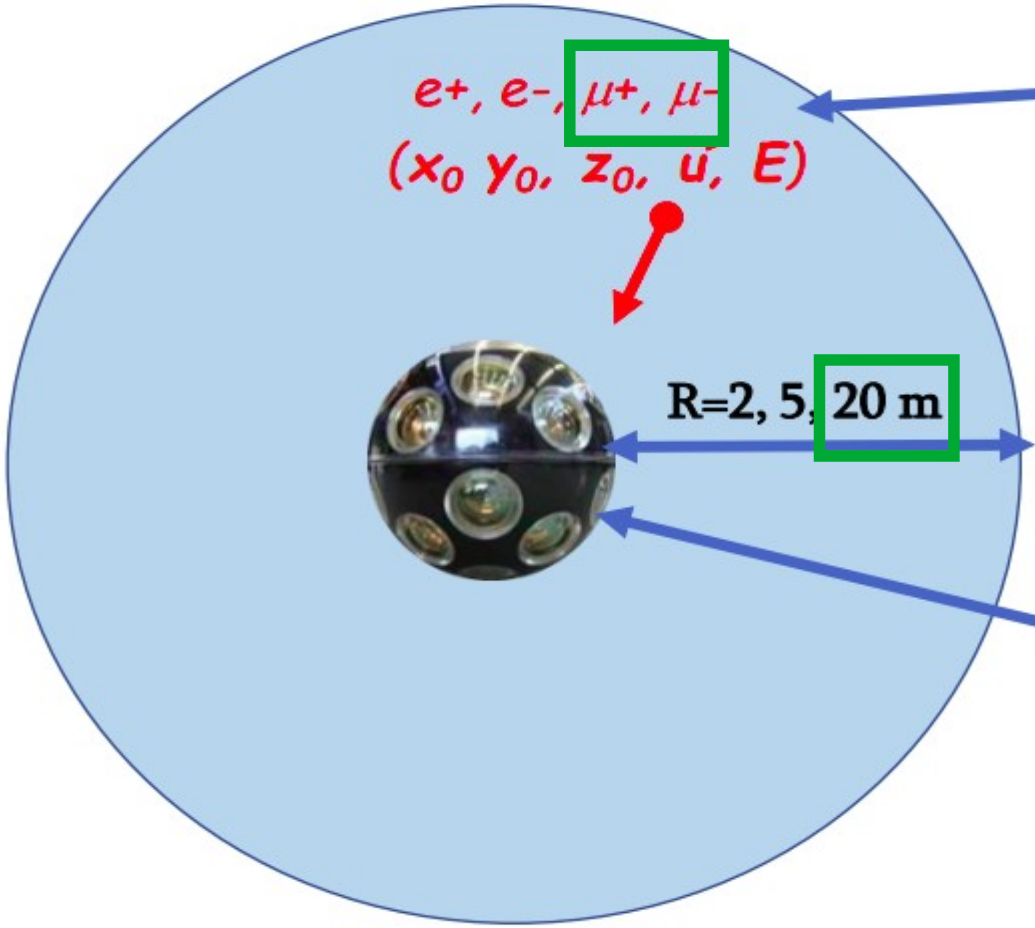
Cherenkov condition:

$$\beta_C \geq \frac{1}{n} \qquad E_k = \left(\frac{n}{\sqrt{n^2-1}} - 1\right) m \qquad n = 1.35$$

$$E_k(\mu) = 52\ MeV \qquad E_k(e) = 0.25\ MeV$$

E_k - *kinetic energy*

Muon Decay Simulations



Electron energy:
Phase space;
Muon energy 1, 150 MeV

```
start_event: 1 1
track_in:   1    431.289 583.66 188.463 0.134057 0.761815 0.437741 0.0512832  0.000000 3
end_event:
start_event: 2 1
track_in:   1    429.864 582.397 189.867 0.977938 0.839597 0.970802 0.0453897  0.000000 3
end_event:
```

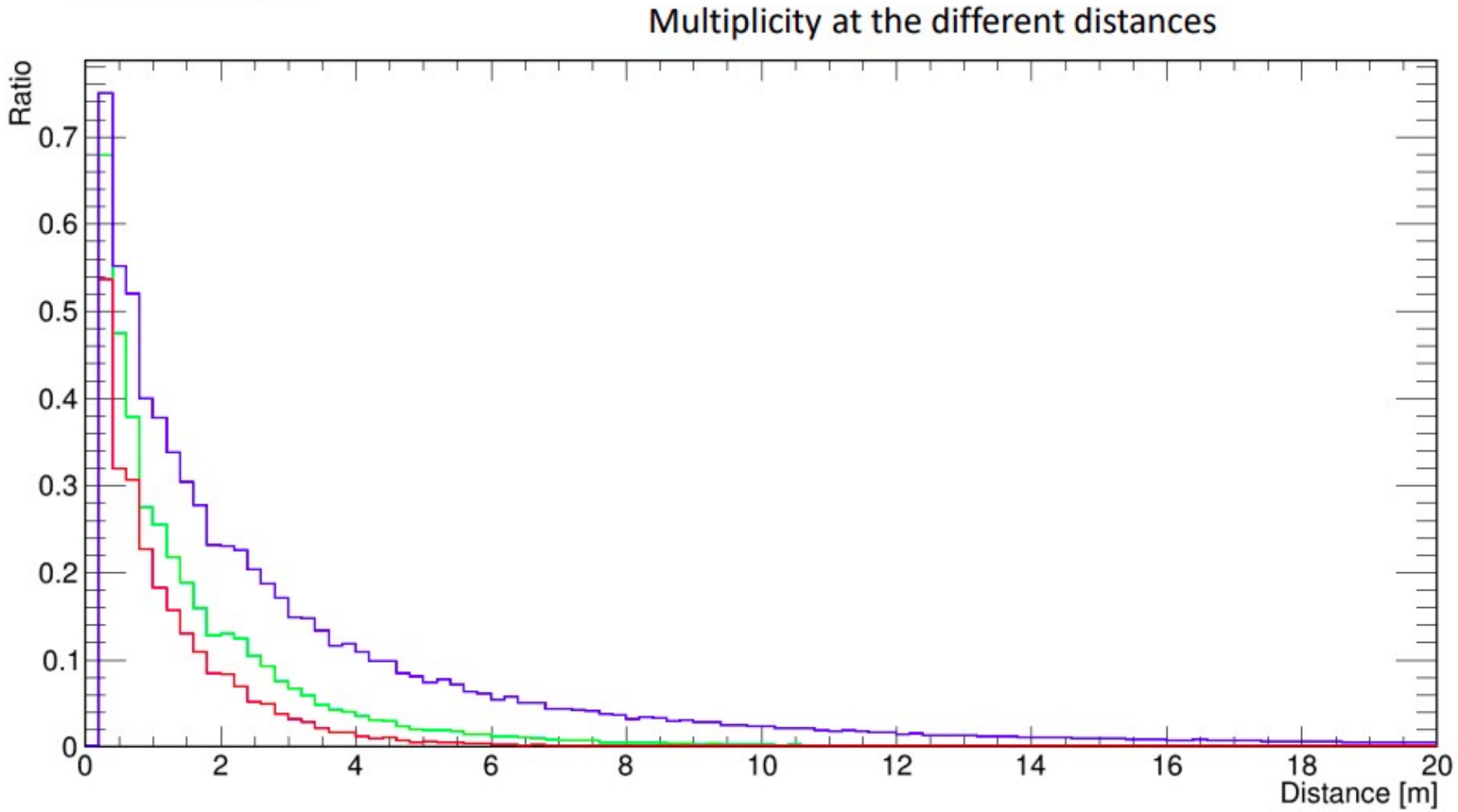
Light & Detector (single DOM) simulations with KM3Sim

Hits from Michel electron

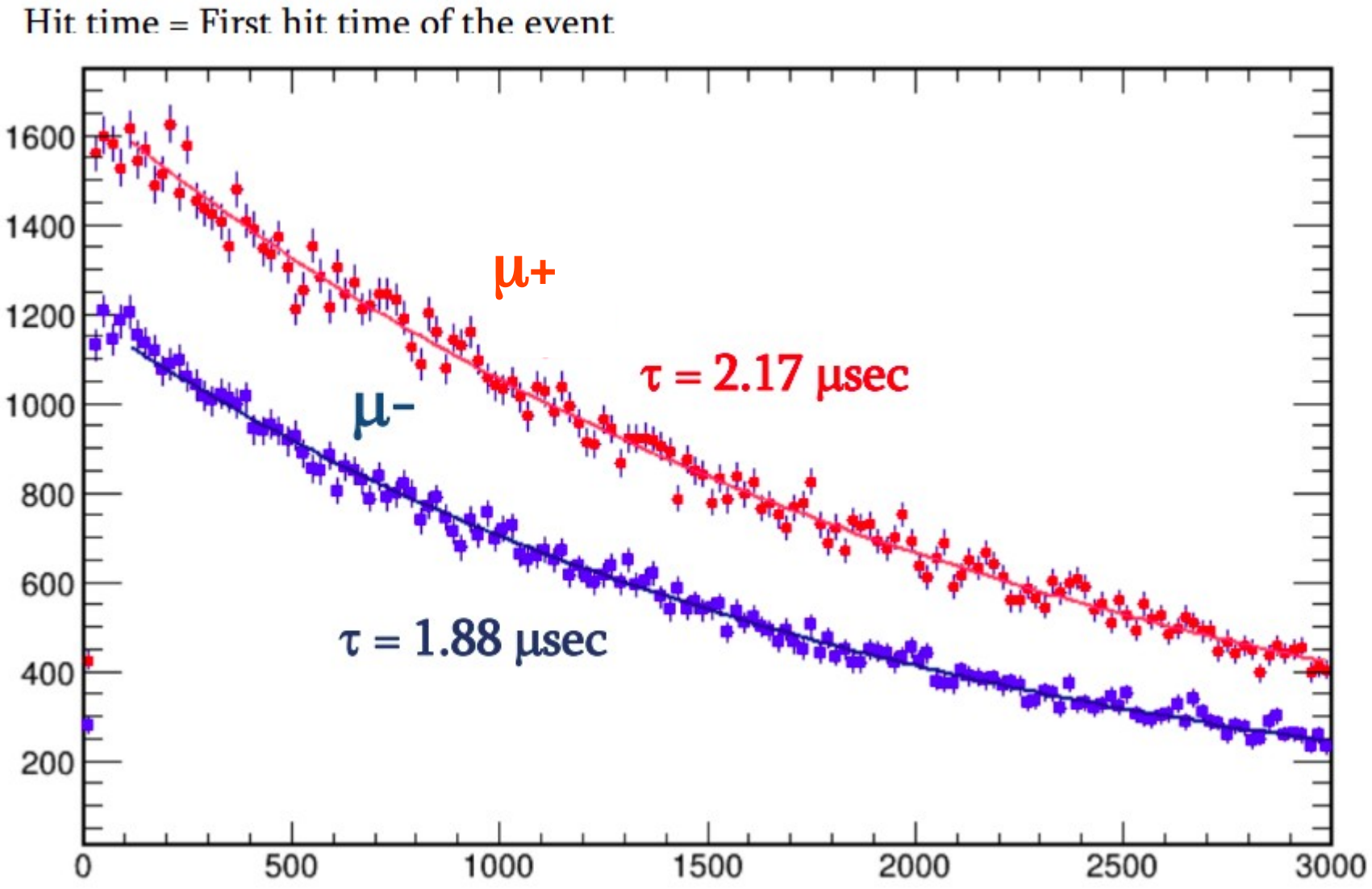
Hit Multiplicity in a single DOM

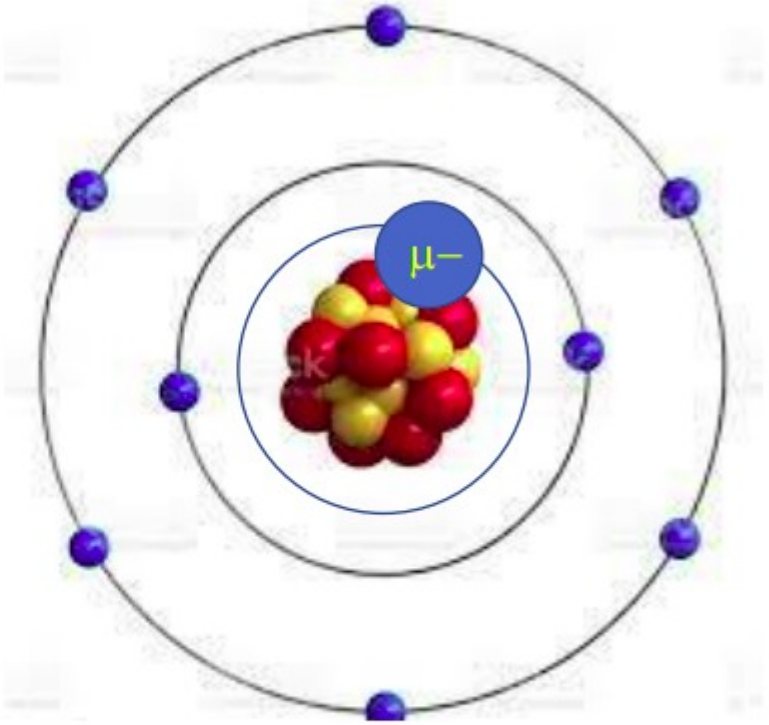
$$Ratio = \frac{number\ of\ envents\ with\ multiplicity > m}{number\ of\ all\ events}$$

m=0,1,2



Muon Decay reconstruction in a single DOM





$\mu^- + p \rightarrow n + \nu_\mu$

D.F. Measday,
Physics Reports 354 (2001) 243

Muon decay simulations in ORCA6

2.9×10^5 Muons stopping inside detector volume obtained from 1000 atm muon v7.1 production files ($\sim 1.6 \times 10^7$ events ~ 24 days)

→ decays with ROOT TGenPhaseSpace with corresponding mean lifetime

```
start_event: 170 1
track_in:   1    407.1350055811927 730.082423503678 470.7 0.11690043655418146 -0.36210766479199624 -0.9247769066279332 121.26509797460454 0.000 5
track_in:   2    456.50757201525073 577.1472825990655 80.12310734649577 0.8456182058434933 0.5822953211609274 0.7748345015570521 0.02323166110484152 3564.9489058938298 2
end_event:
```

↓

Light & ORCA6 Detector simulations with JSirene
(including Michel electrons)

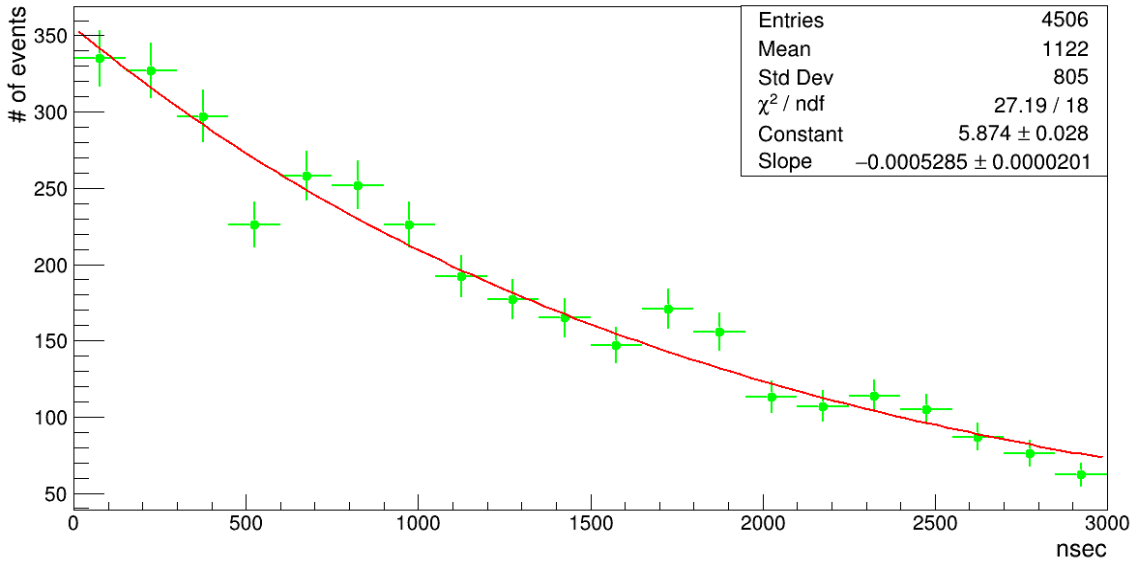
↓

Background and event reconstruction is done with JPP

Muon decay reconstrucion in ORCA6

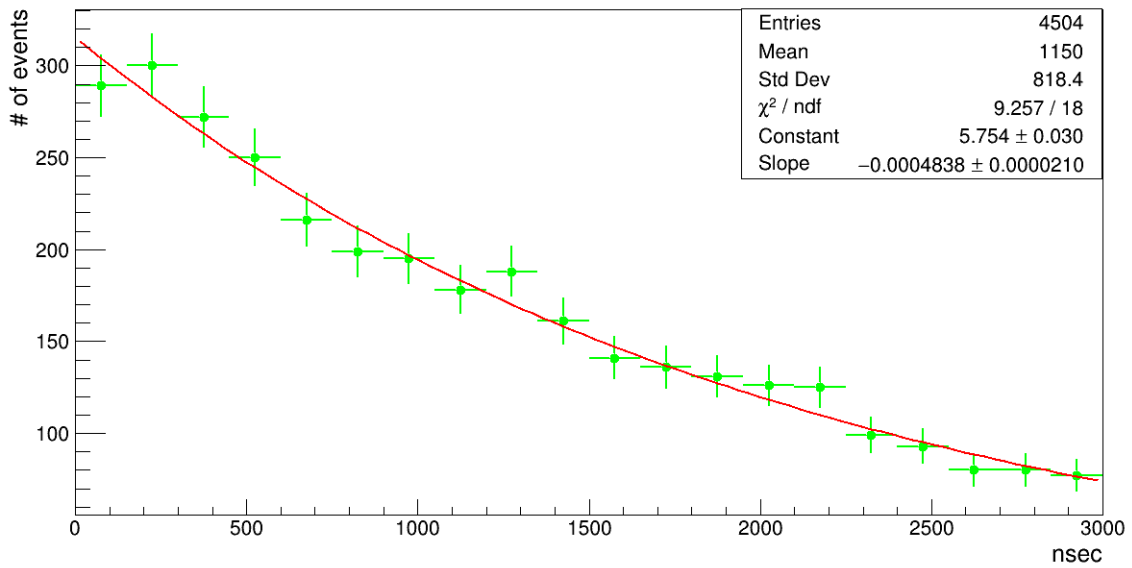
Reconstructed decay times in closest DOMs for muons and antimuons from MC hits

Input τ = 1879ns
Output τ = 1892ns



Muon

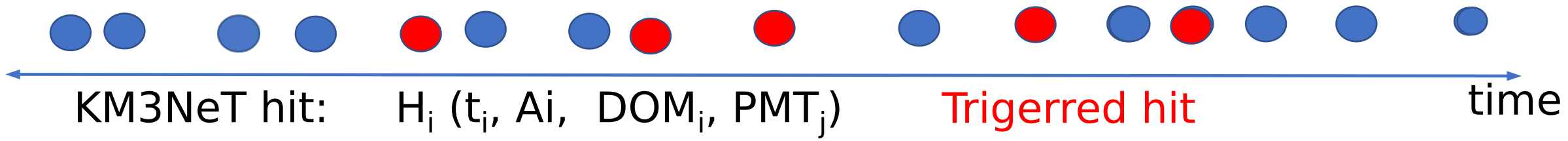
Input τ = 2197ns
Output τ = 2067ns

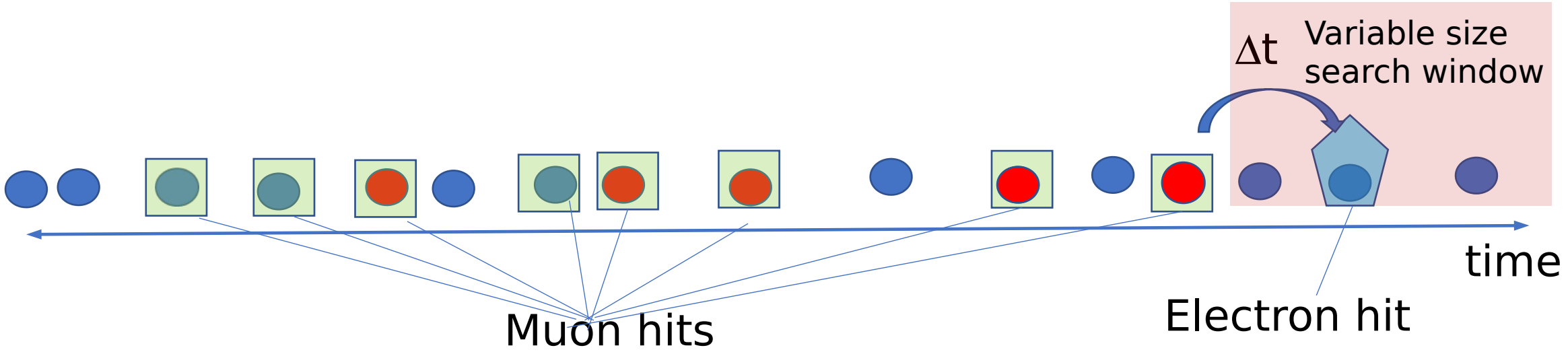


Antimuon

KM3NeT Event

KM3NeT events is a collection of the hits (PMT signals) in the selected time interval

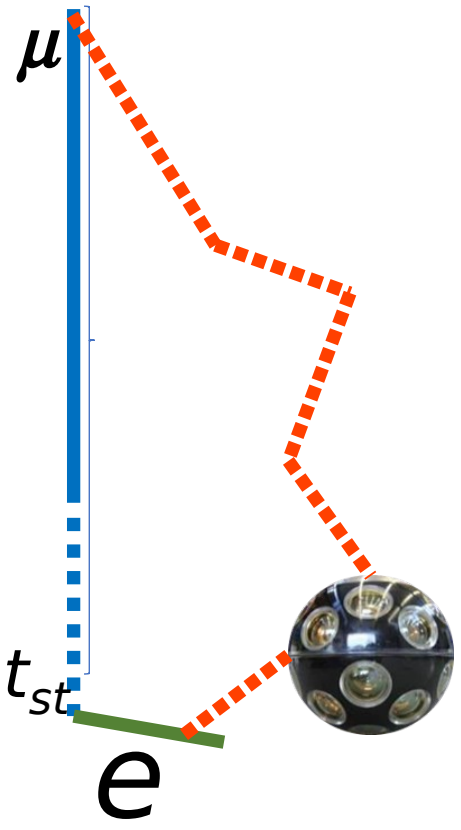




Michel electron backgrounds

Backgrounds for Michel electron signal:

deep sea optical background - ^{40}K decays; bio luminescence
Scattered Cherenkov light from stopping muons
PMT afterpulses

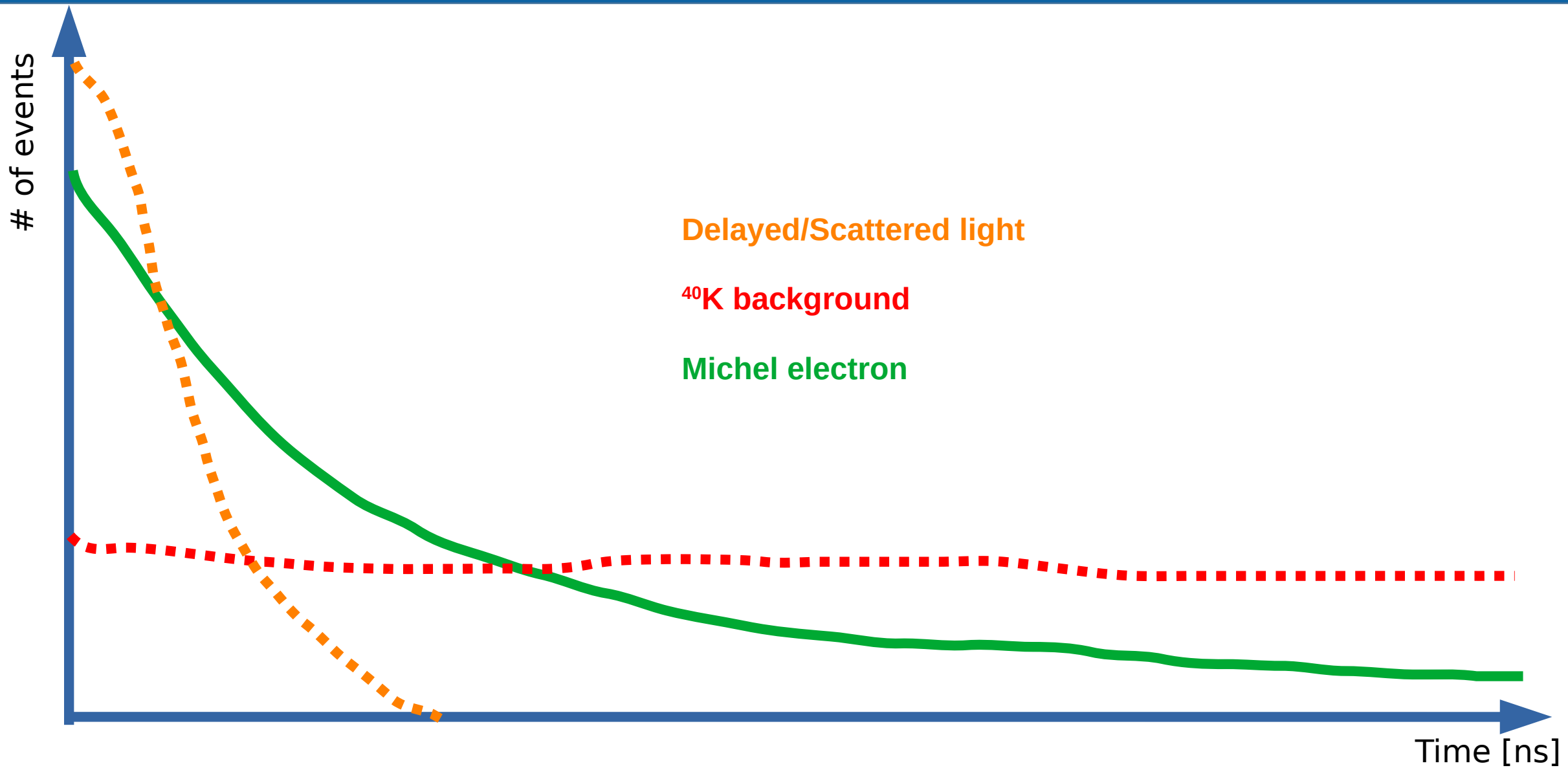


$t_{eh} = t_{st} + t_{ep}$

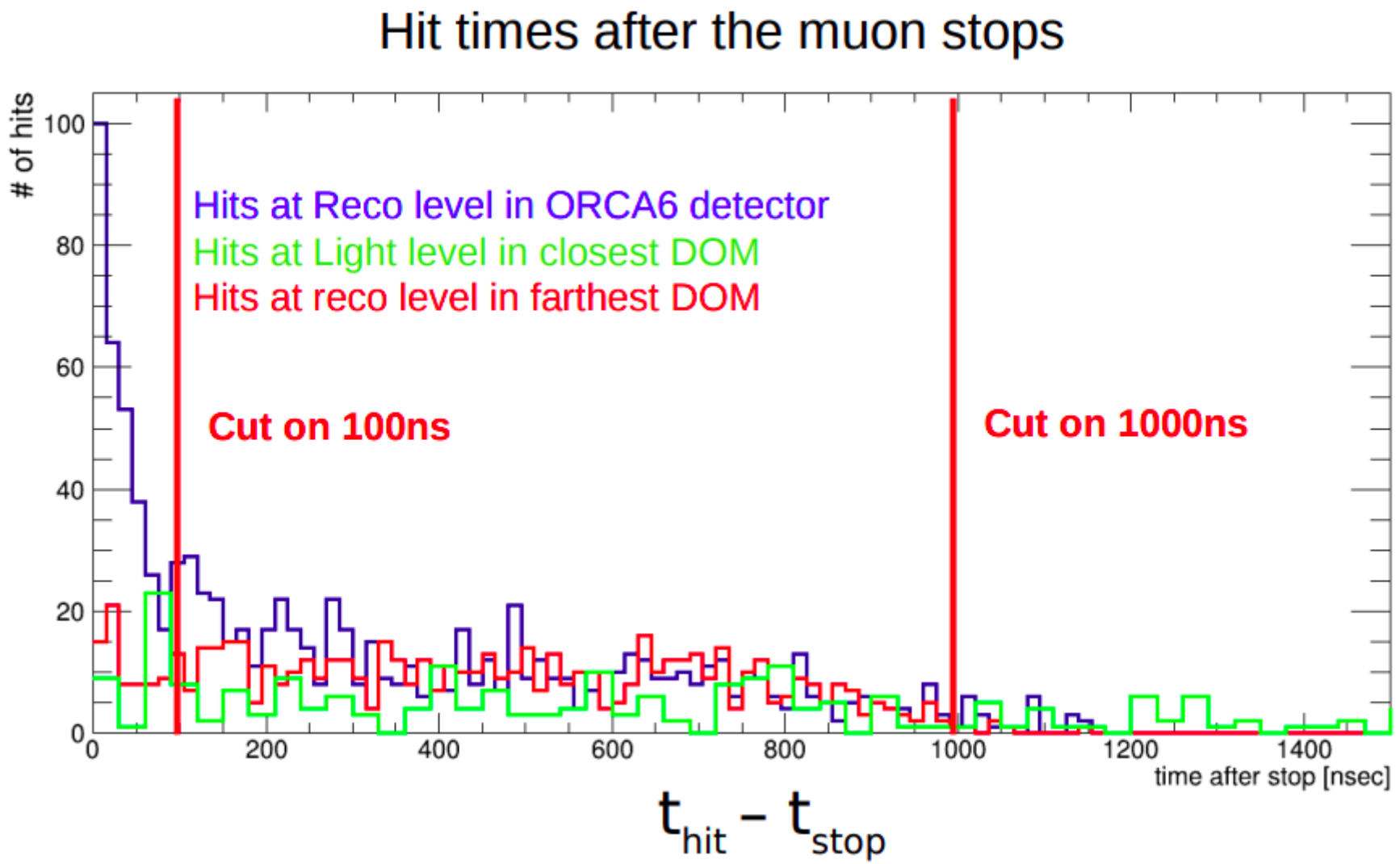
t_{eh} is electron hit time
t_{st} is muon stopping time
t_{ep} is electron photon flight time

Scattered photons from muons could be mistaken with Michel electron photons

Michel electron and background signals



Hit time distribution in the closest DOM



Summary and Outlook

- Muon decays and signals from Michel electron were simulated with the KM3Sim software
- Michel electron simulations were implemented in the JSirene
- Selection cuts under optimization to find the DOM with Michel electron signal
- Main backgrounds for the muon decay signals are identified as ^{40}K and Cherenkov light from the muon propagation in the sea water
- Selection of ORCA6 data MC events for analysis and searching for muon decays