

# Study of Muon Decays in KM3NeT/ORCA6

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# Introduction

- Discussed by Juergen Brunner for ANTARES

Several possible applications for physics (calibration,  $\mu^+/\mu^-$  ratio, . . . )

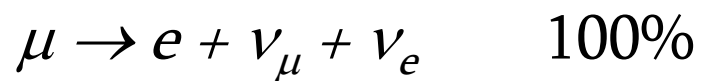
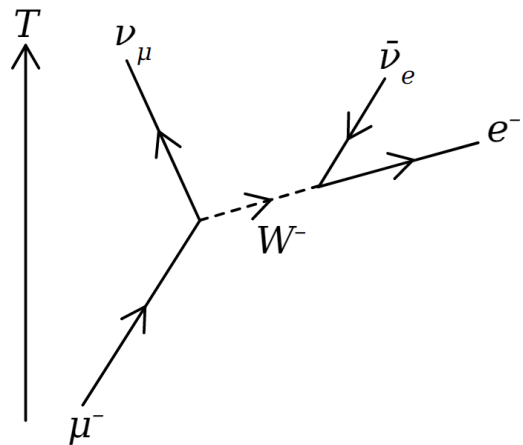
- Study for KM3NeT/ARCA by Dimitry Zaborov (Bari meeting, 2017)

Michel electrons from muon decay: a feasibility study using ARCA data

Search for a time difference for 2 multiple hits in the same KM3NeT DOM

- Current study: KM3NeT/ORCA6 (MC v7)

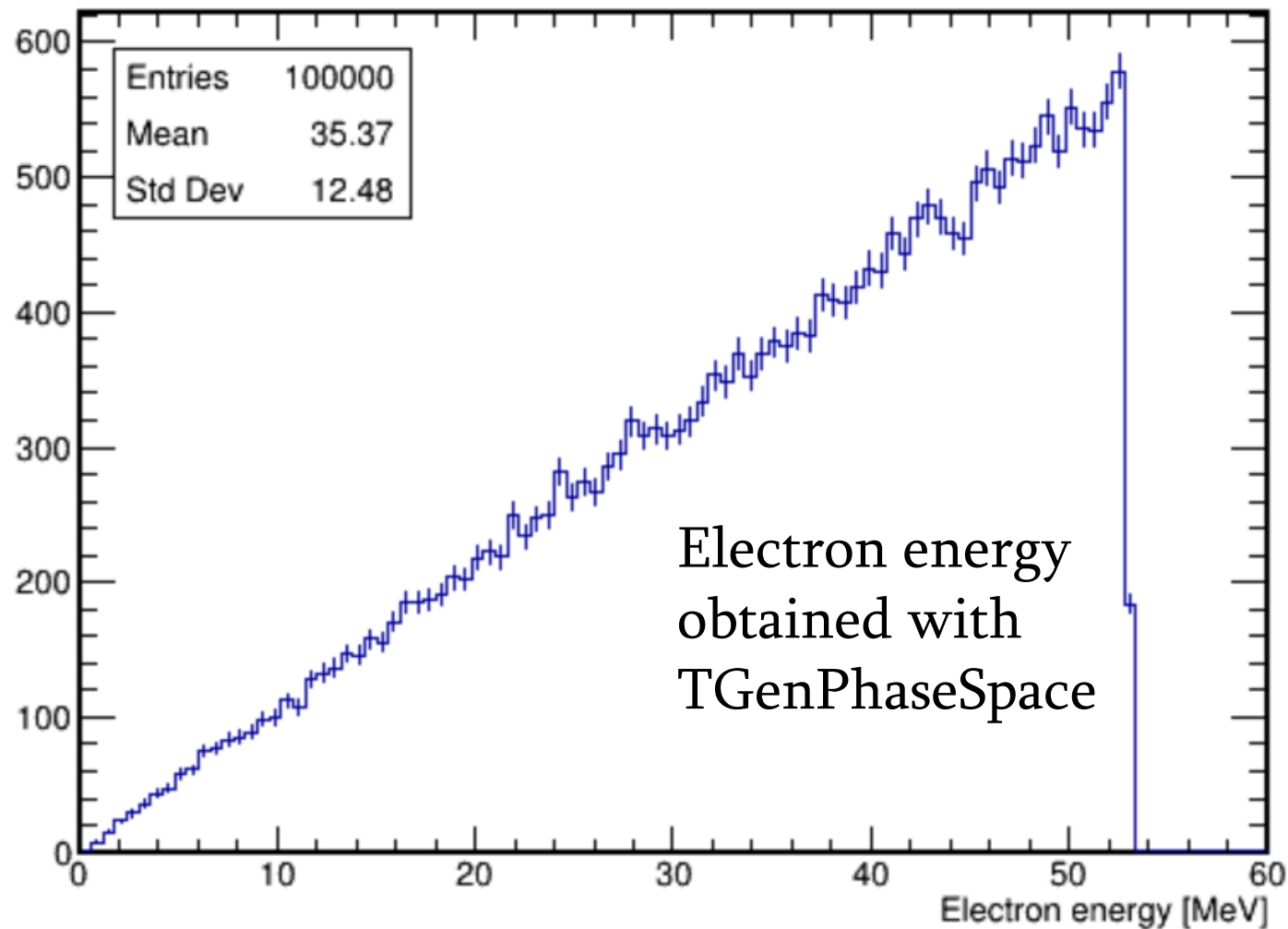
# Muon Decays



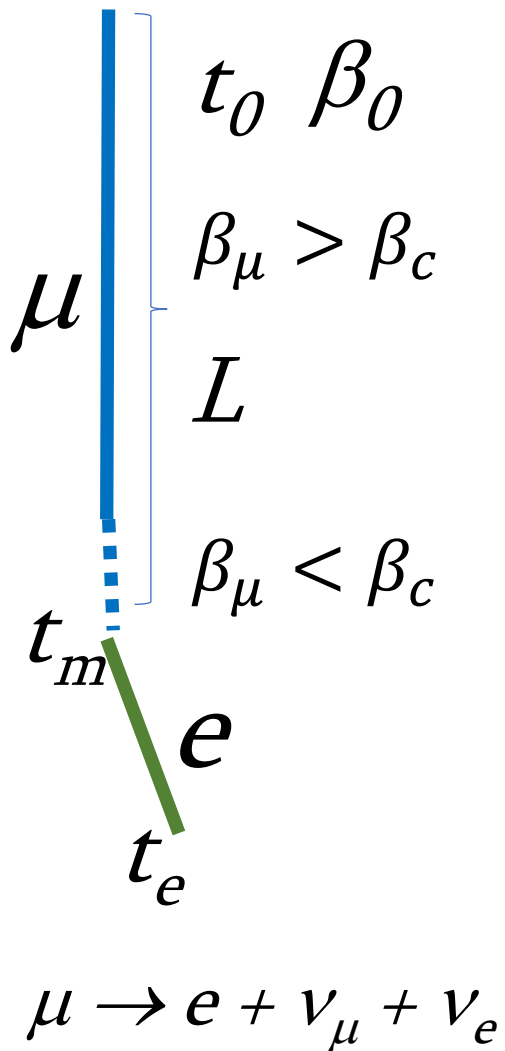
$$m_{\mu} = 105.6583745 \pm 0.0000024 \text{ MeV}$$

$$\tau_{\mu} = (2.1969811 \pm 0.0000022) \mu\text{sec}$$

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



# Muon Decays



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

For  $L=200$  m, and  $\beta_0 \approx 1$  ( $E_\mu > 10$  GeV)  $t_L \approx 1.3$   $\mu\text{sec}$

Muon decay time:

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

*Cherenkov condition:*

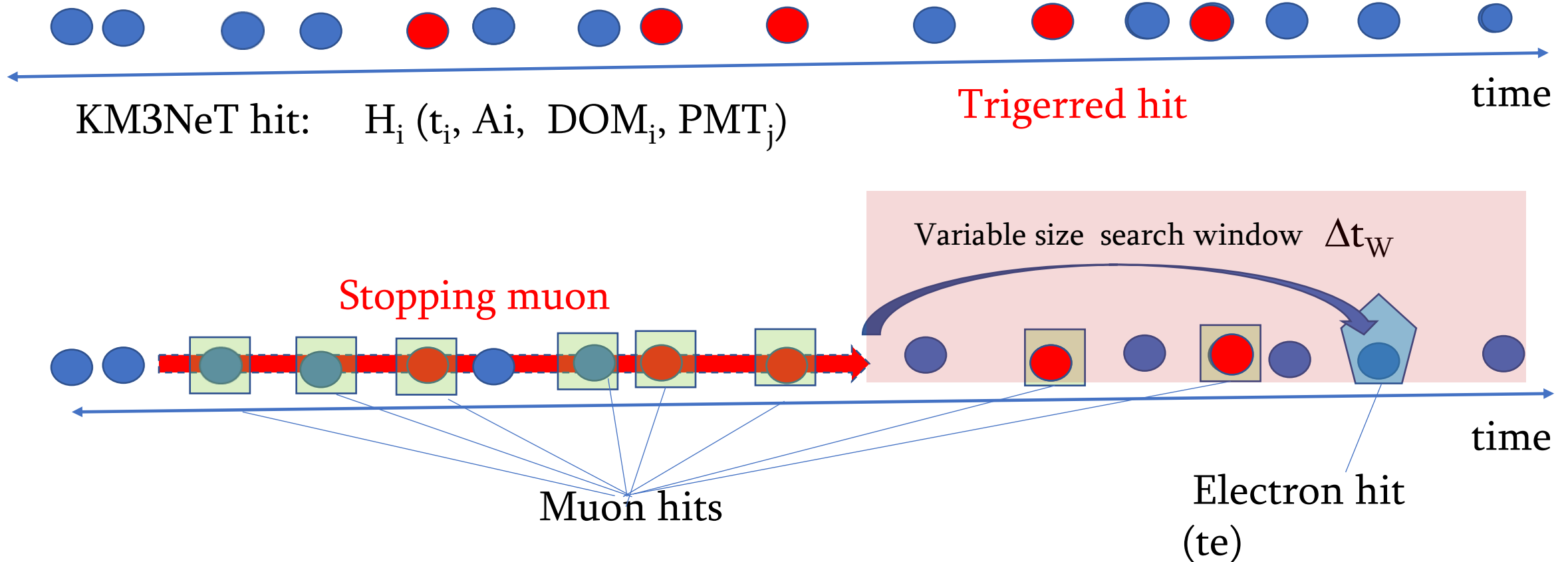
$$\beta_c \geq \frac{1}{n} \quad E_k = \left( \frac{n}{\sqrt{n^2 - 1}} - 1 \right) m \quad n = 1.35$$

$$E_k(\mu) = 52 \text{ MeV} \quad E_k(e) = 0.25 \text{ MeV}$$

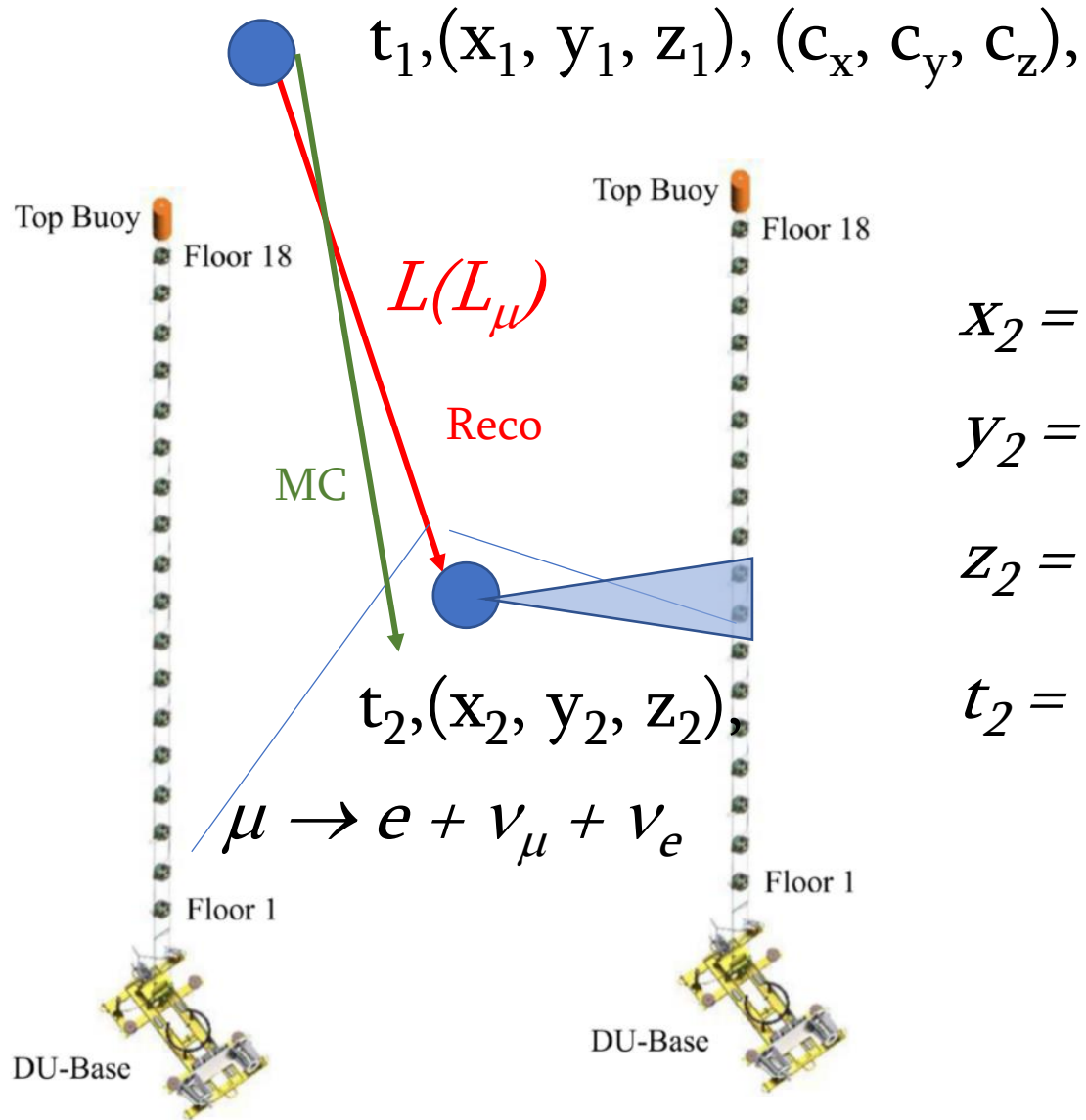
$E_k$  - kinetic energy

# KM3NeT Event

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



# Muon Decay Events



$$x_2 = x_1 + L \cos(x)$$

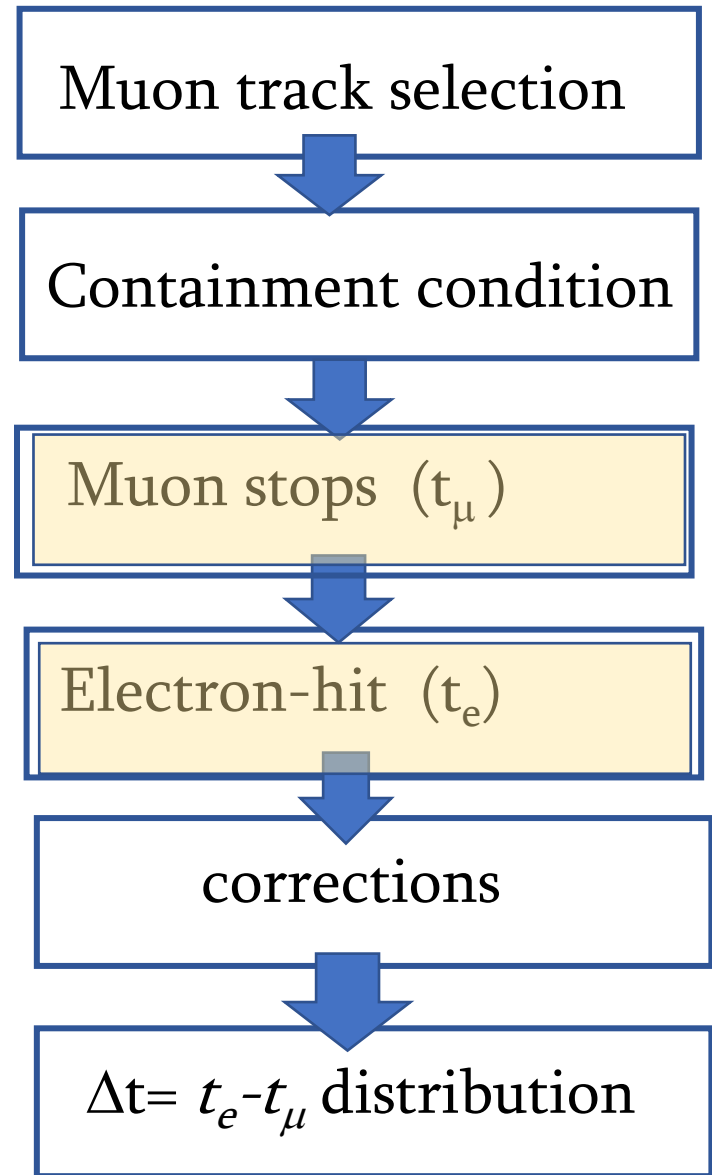
$$y_2 = y_1 + L \cos(y)$$

$$z_2 = z_1 + L \cos(z)$$

$$t_2 = t_1 + 2L / v_\mu$$

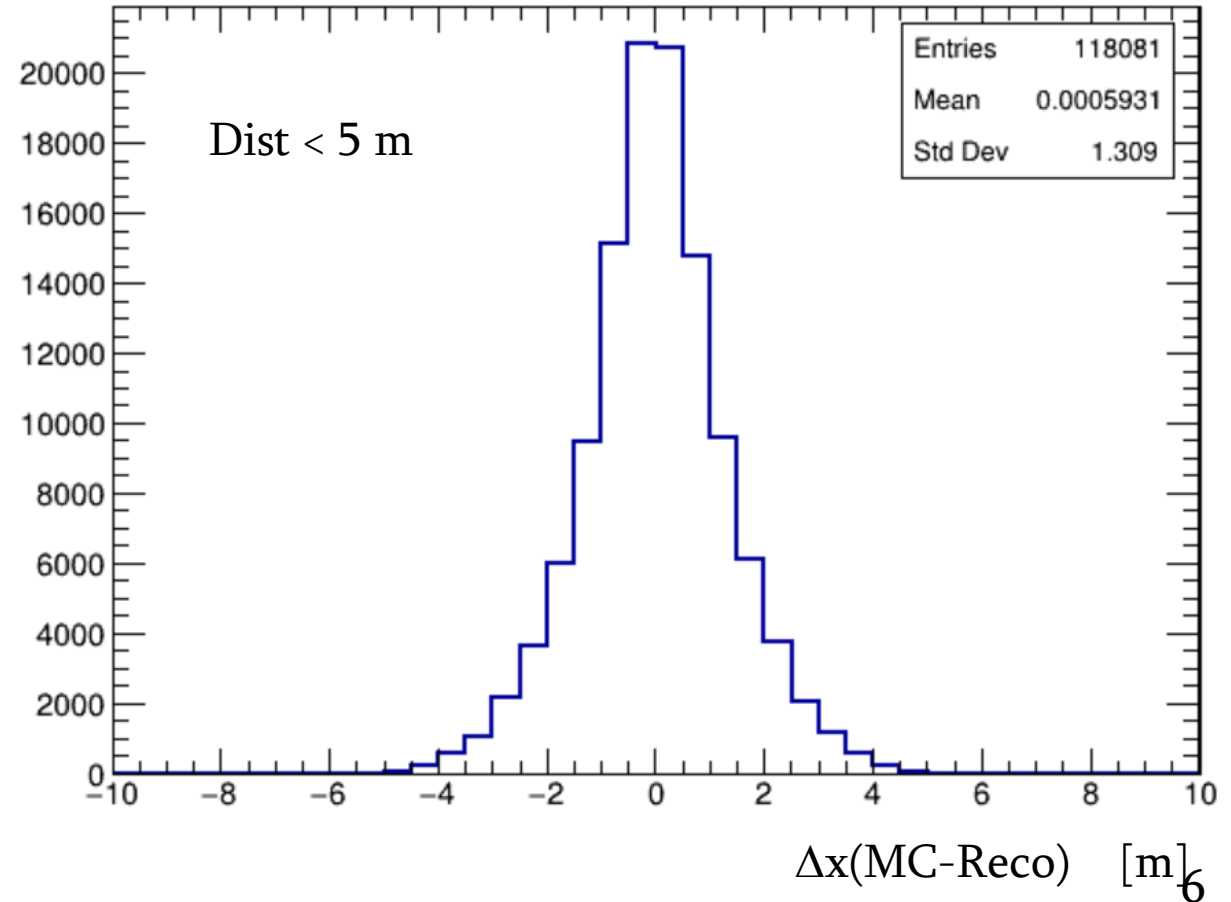
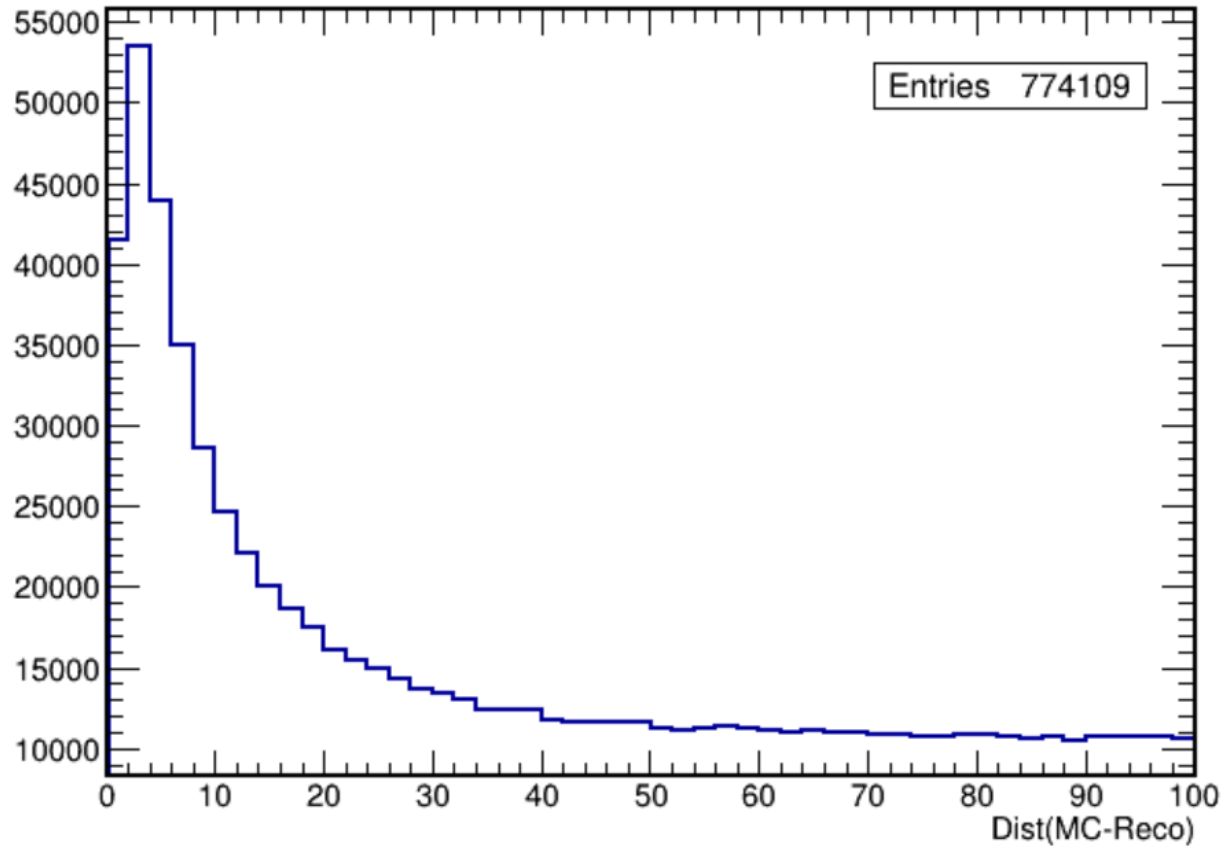
$$v_\mu = c$$

$$\Delta t_\mu = t_e - t_\mu$$

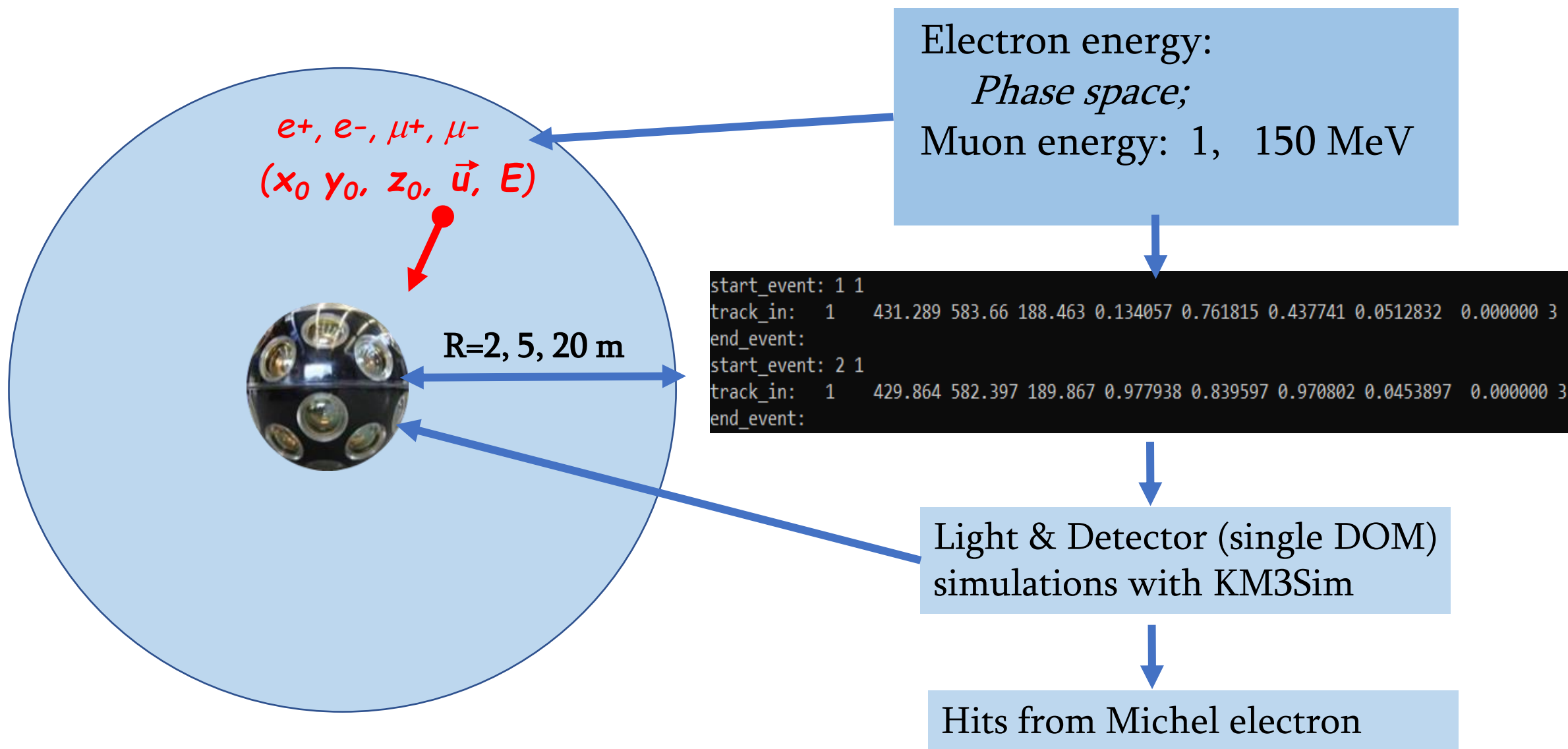


# Stopping Muons

MC data mupage: 600 files (ca. 10% of KMNeT/ORCA6 atm- $\mu$  MC)

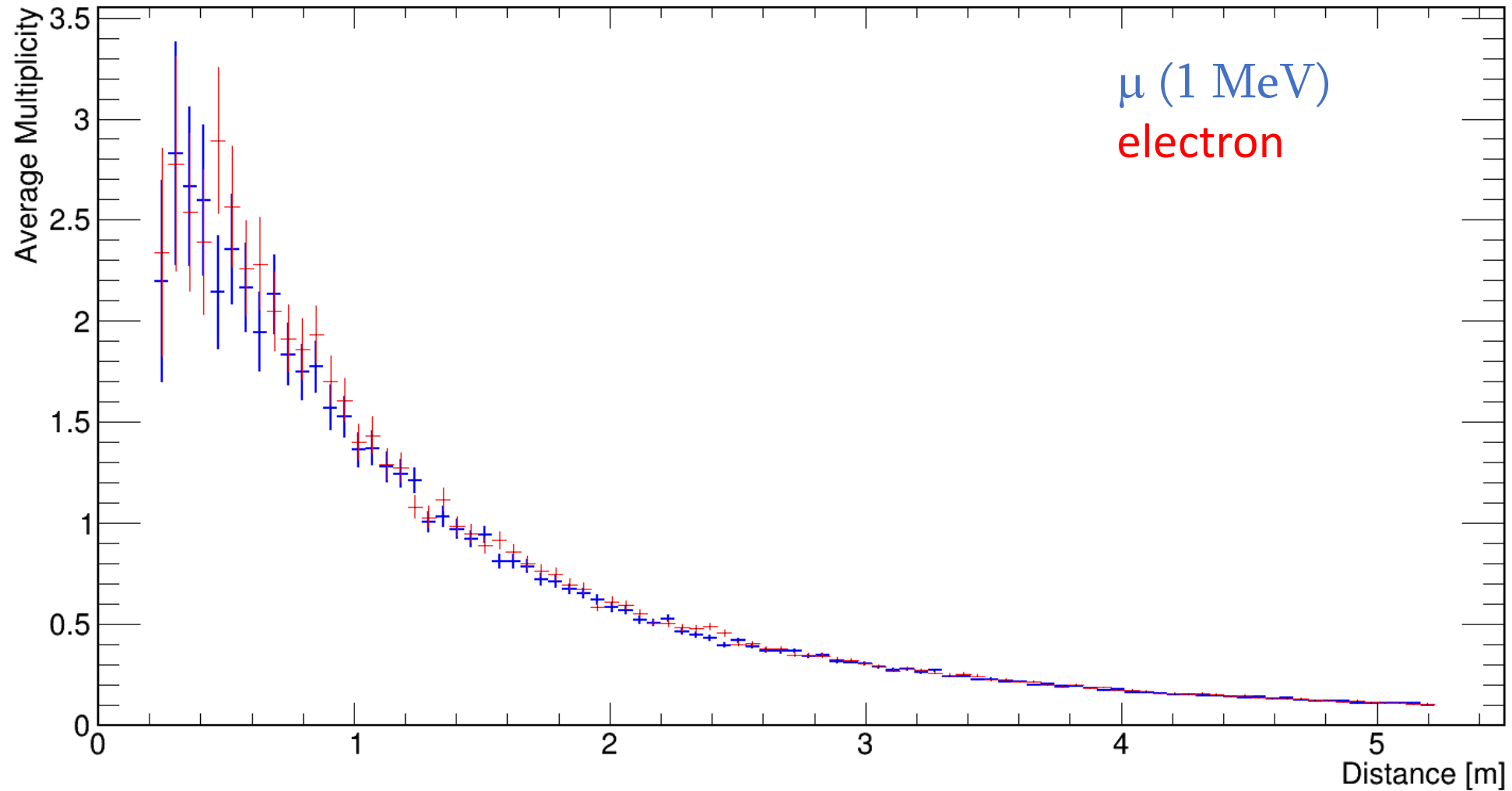


# Simulations of the electron signal (KM3sim)





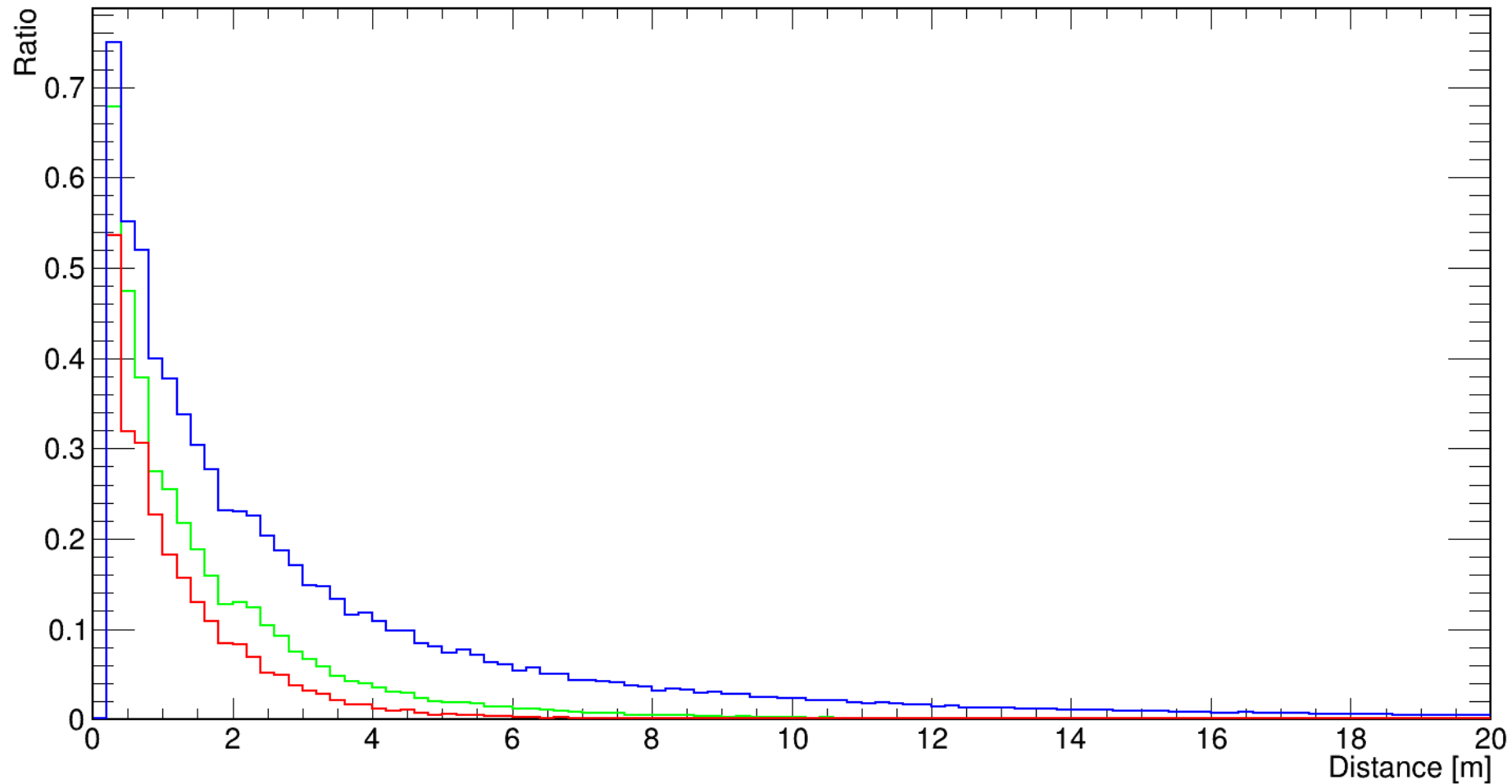
# Muon (1 MeV) and Electron signals



# Michel electron MC

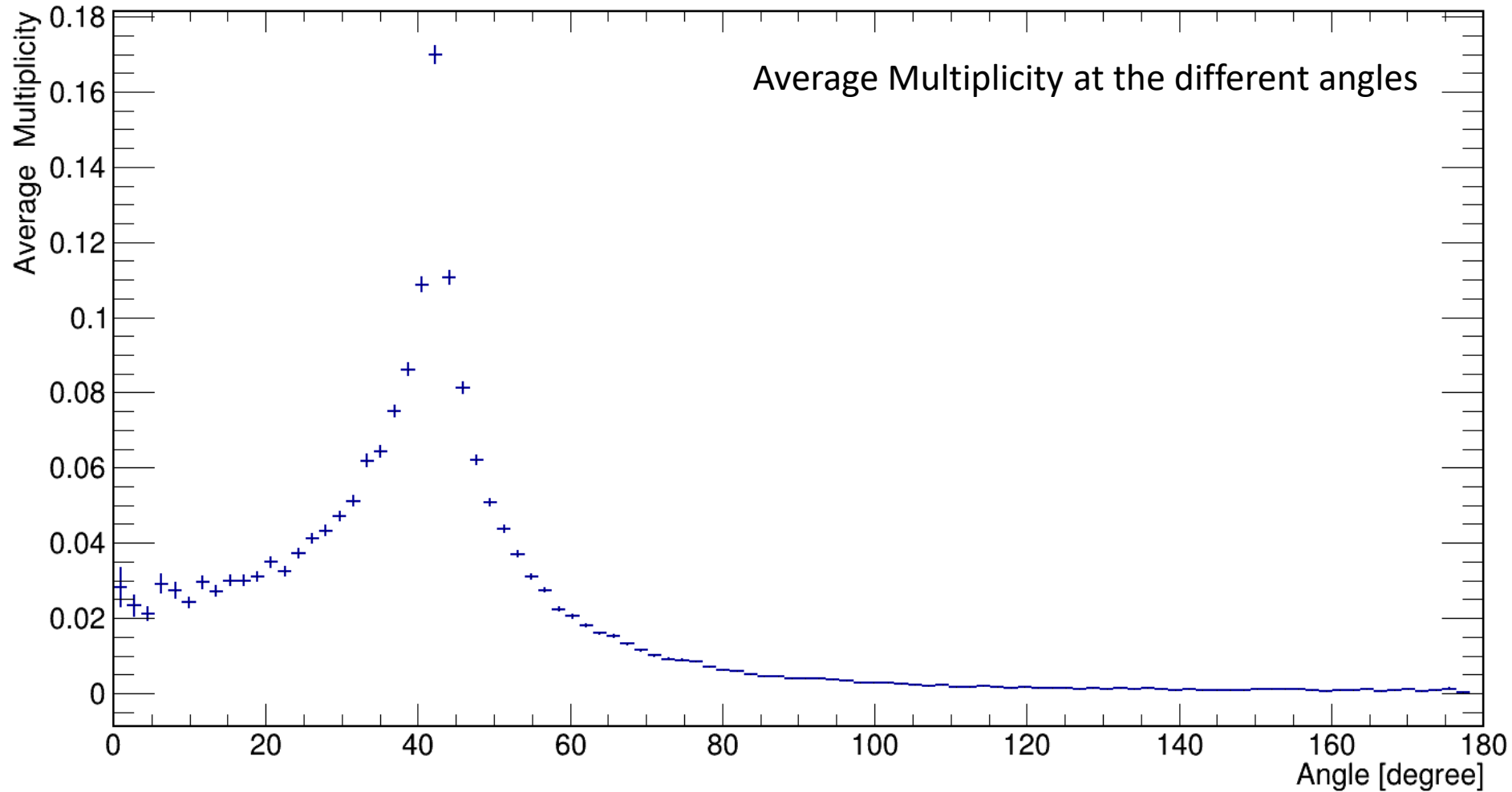
$$\text{Ratio} = \frac{\text{number of events with multiplicity} > m}{\text{number of all events}} \quad m=0,1,2$$

Multiplicity at the different distances



# Michel electron MC

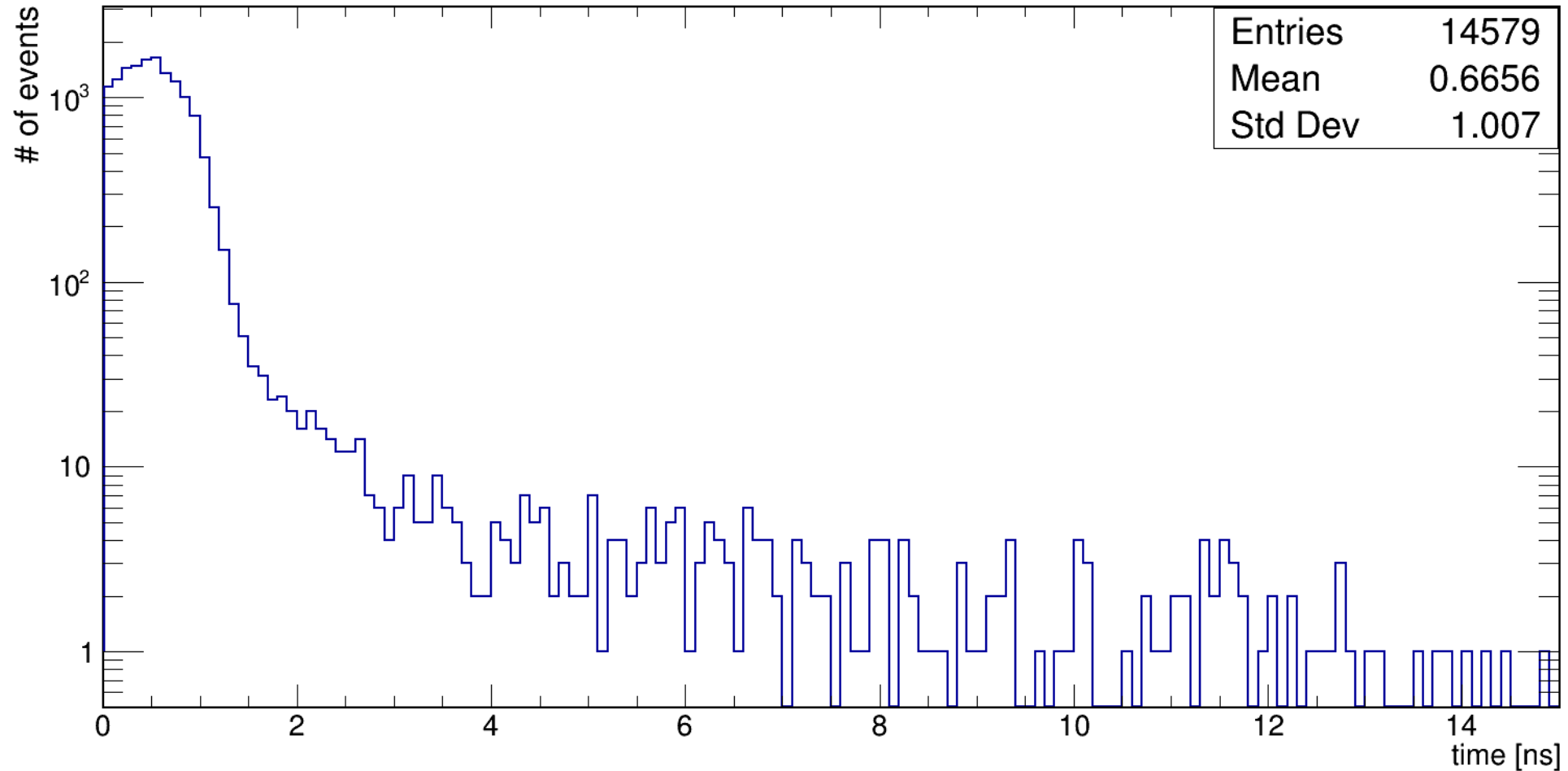
- Michel electron propagation and light are simulated with KM3Sim



# Electron Signal in DOM

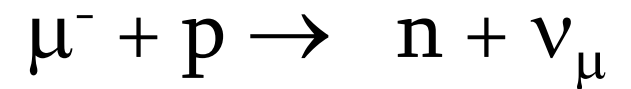
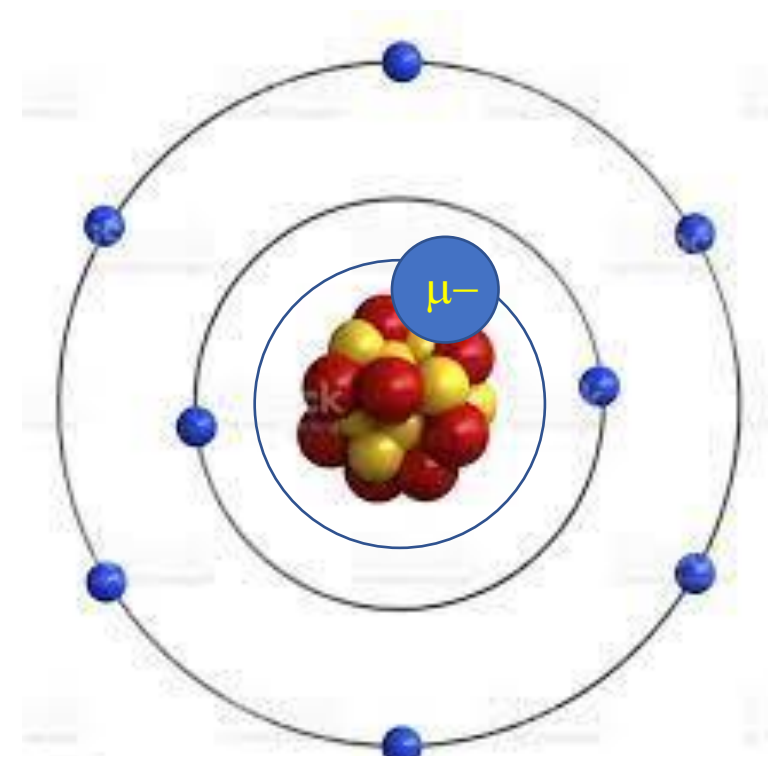
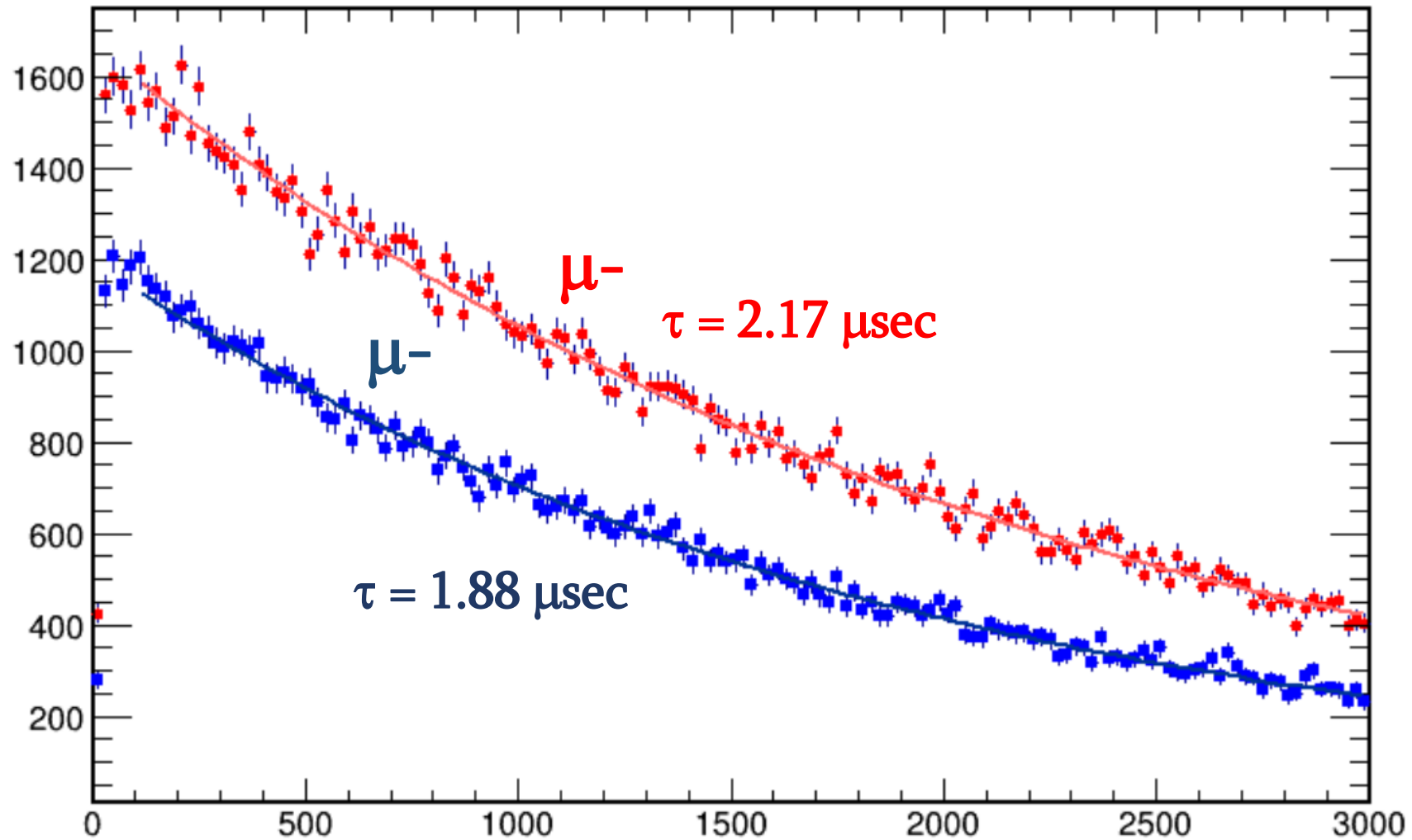
$\Delta t = \text{Last hit} - \text{First hit}$

Event time



# Muon Decays in KM3sim

Hit time = First hit time of the event



D.F. Measday,

Physics Reports 354 (2001) 243  
12

# Summary and Outlook

- ✓ Electron signal from the muon decays has been studied with the KM3sim software
- ✓ Electron signals are detectable in KM3Net DOMs, for  $d < 2$  m
- ✓ Atmospheric muon MC (Mupage/JSirene) not includes muon decays and selected events should be simulated with KM3Sim.
- ✓ Muon stopping point (“stopping muons”) has to be reconstructed with high efficiency and precision
- ✓ Applying MC results to the ORCA6 data (v7) for reconstruction of muon decays