Integrating over the Track Length in PDF evaluation

Brían Ó Fearraigh, September 2024

Motivation

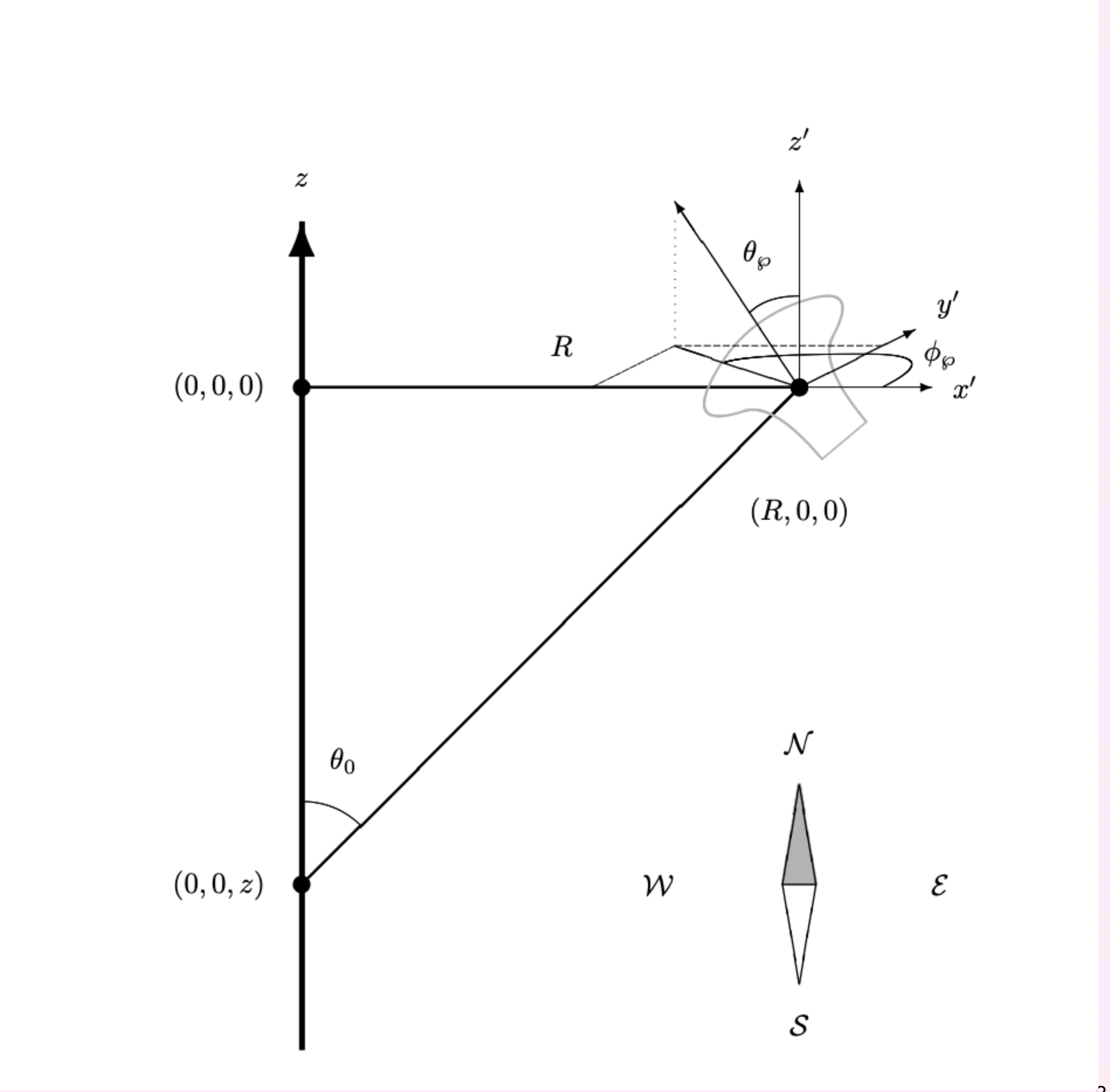
- Proposal from Maarten to more accurately treat scattered muon light in JSirene:
https://indico.cern.ch/event/1317398/

- i.e. to include integration over track length (or equivalently $\cos\theta$) in evaluation of number of photo-electrons for scattered light

- Work by Vladimir shows that a better km3sim-JSirene agreement is reached for longer tracks https://git.km3net.de/simulation/light_gedanken/-/issues/1 .
The 'infinite' track in JSirene may need to be addressed

Motivation

- Currently, number of photo-electrons are estimated for scattered light for $\cos\theta$ between -1 and 1
- To be more exact, for the scattered muon light function, this integration is implicitly done
- Now want to explicitly integrate over $\cos\theta$

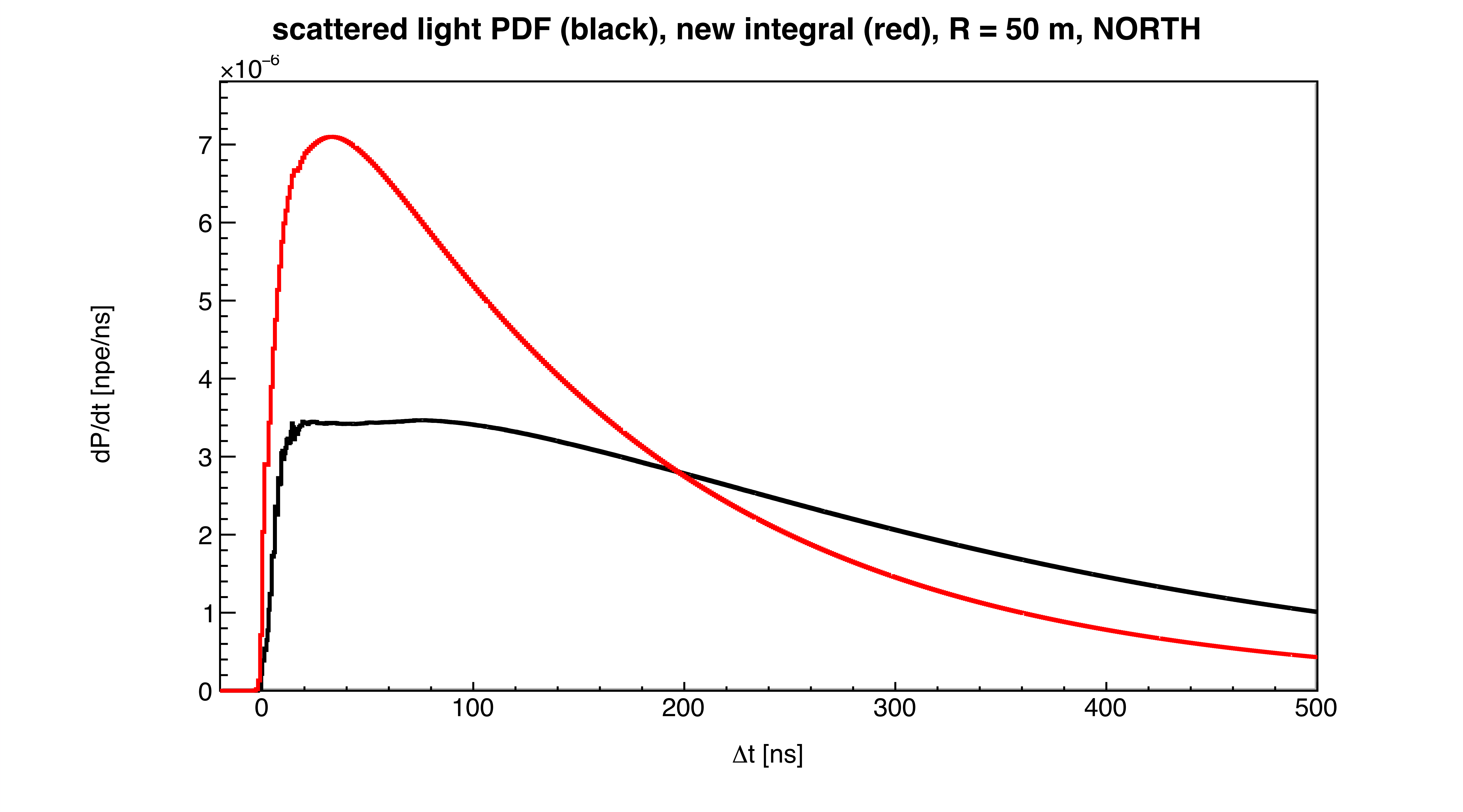


First step

- Make new drawing application to draw photo-electron distributions with this integration included
- Basic numerical integration carried out, development on Jpp branch —JDrawPDM application and JDrawPDM script
- $\int_{-1}^{\cos\theta} \frac{R}{\sin^3\theta} d\cos\theta \, F(\,..\,)$
- $F(\,..\,)$ is the 5D function getScatteredLightFromMuon()
- The “standard” function with the implicit integration is the 4D getScatteredLightFromMuon

First step

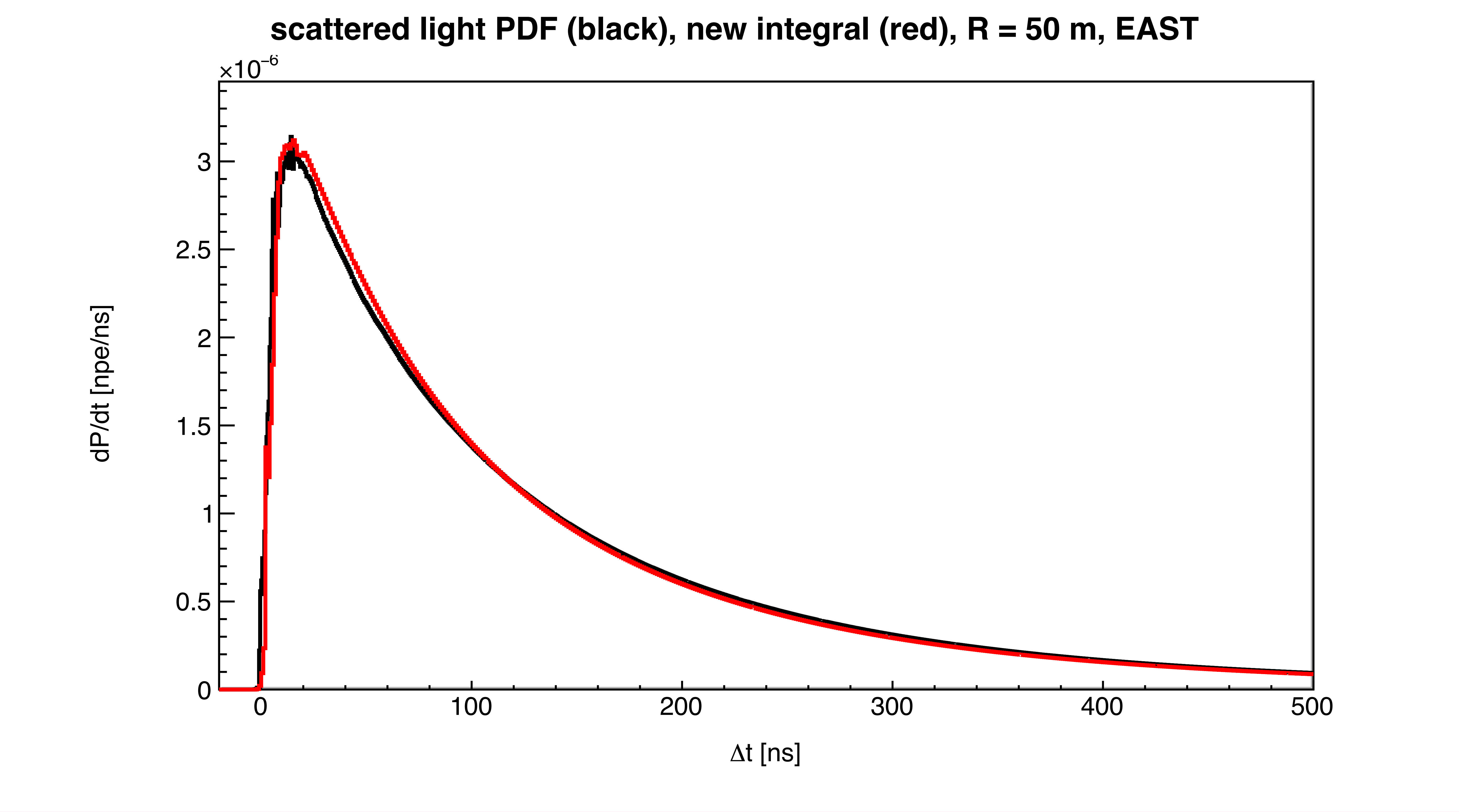
- Test: integral range from -1 to +1 should give the same result as drawing the scattered muon light function
- PMT facing NORTH



First step

- Test: integral range from -1 to +1 should give the same result as drawing the scattered muon light function

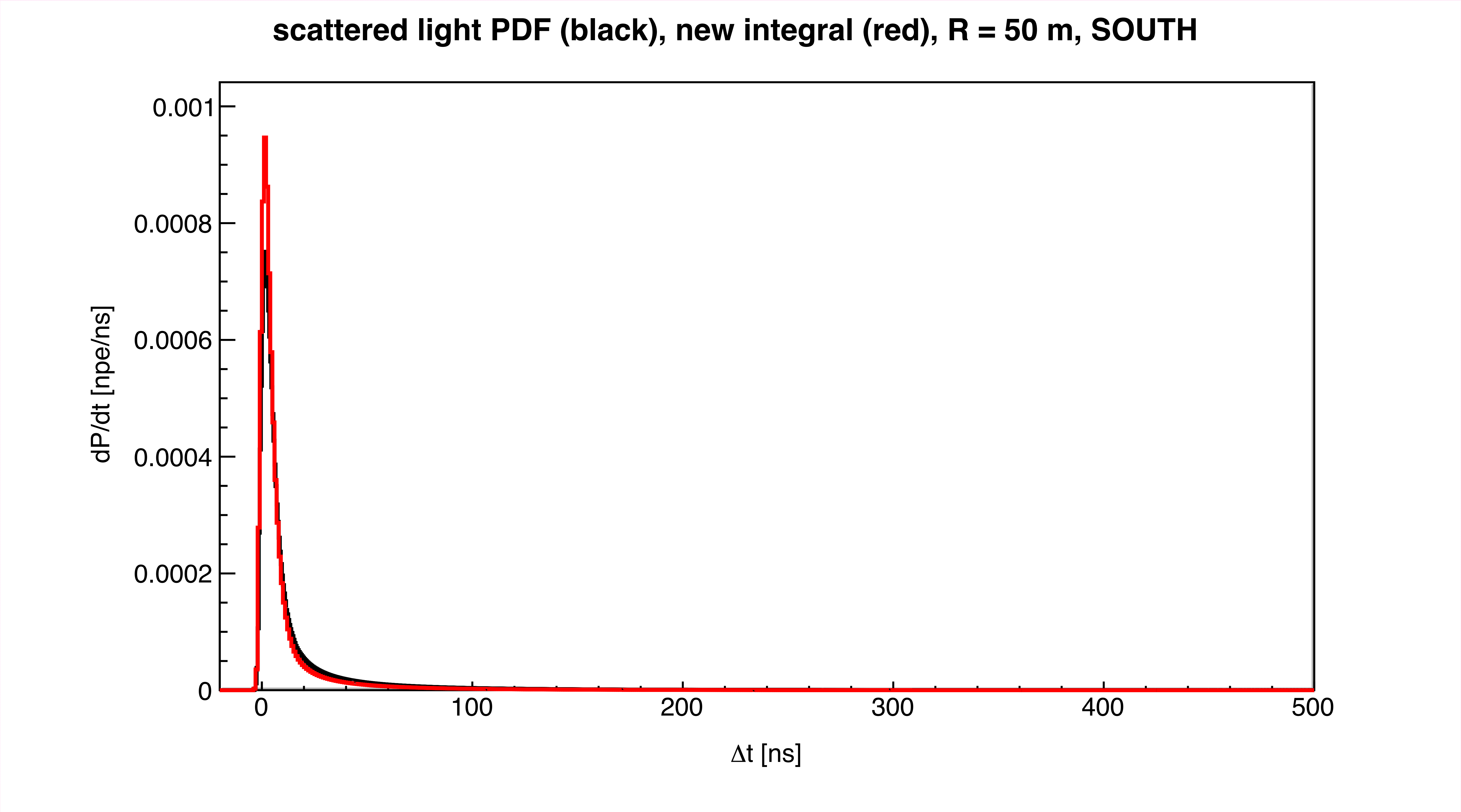
- PMT facing EAST



First step

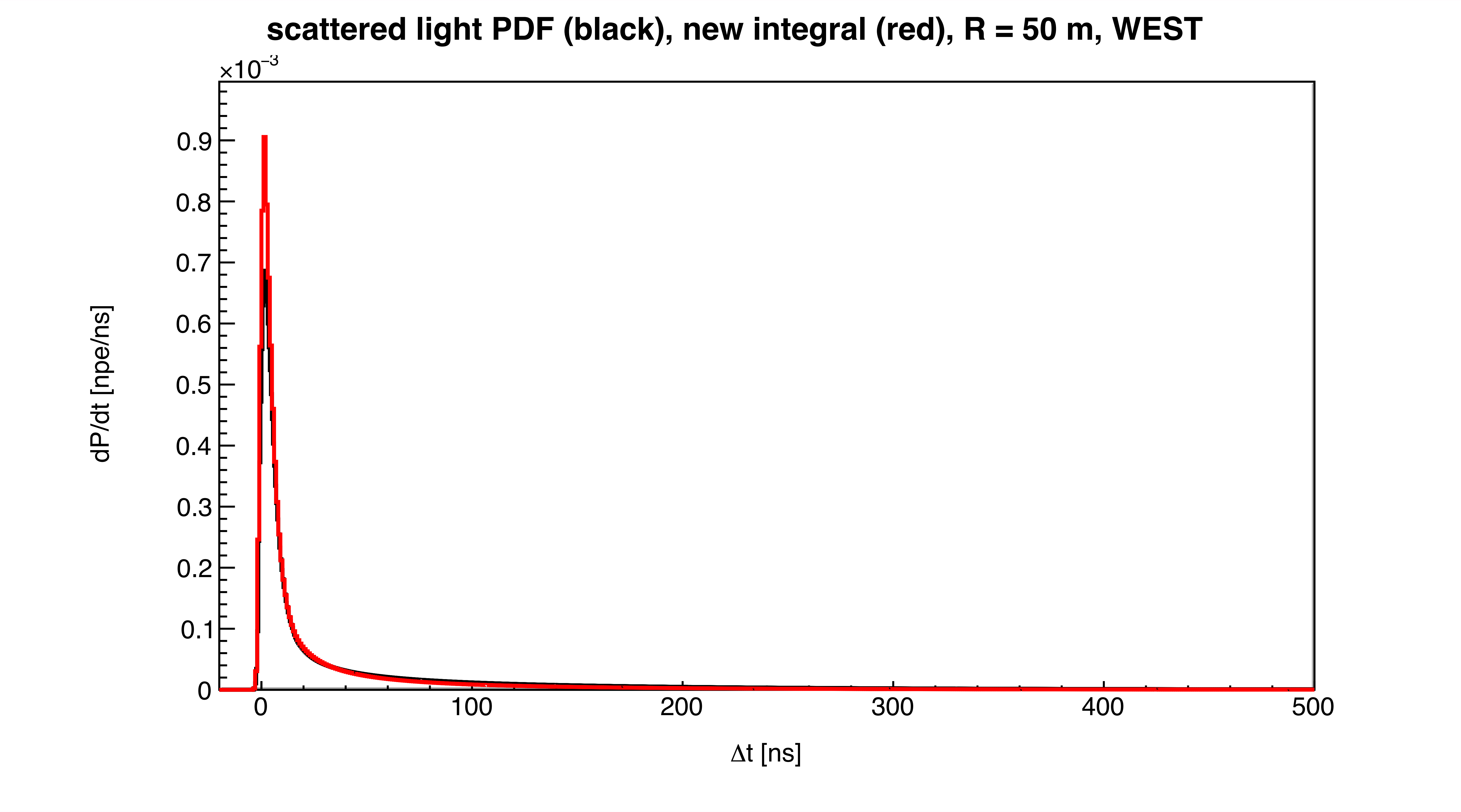
- Test: integral range from -1 to +1 should give the same result as drawing the scattered muon light function

- PMT facing SOUTH



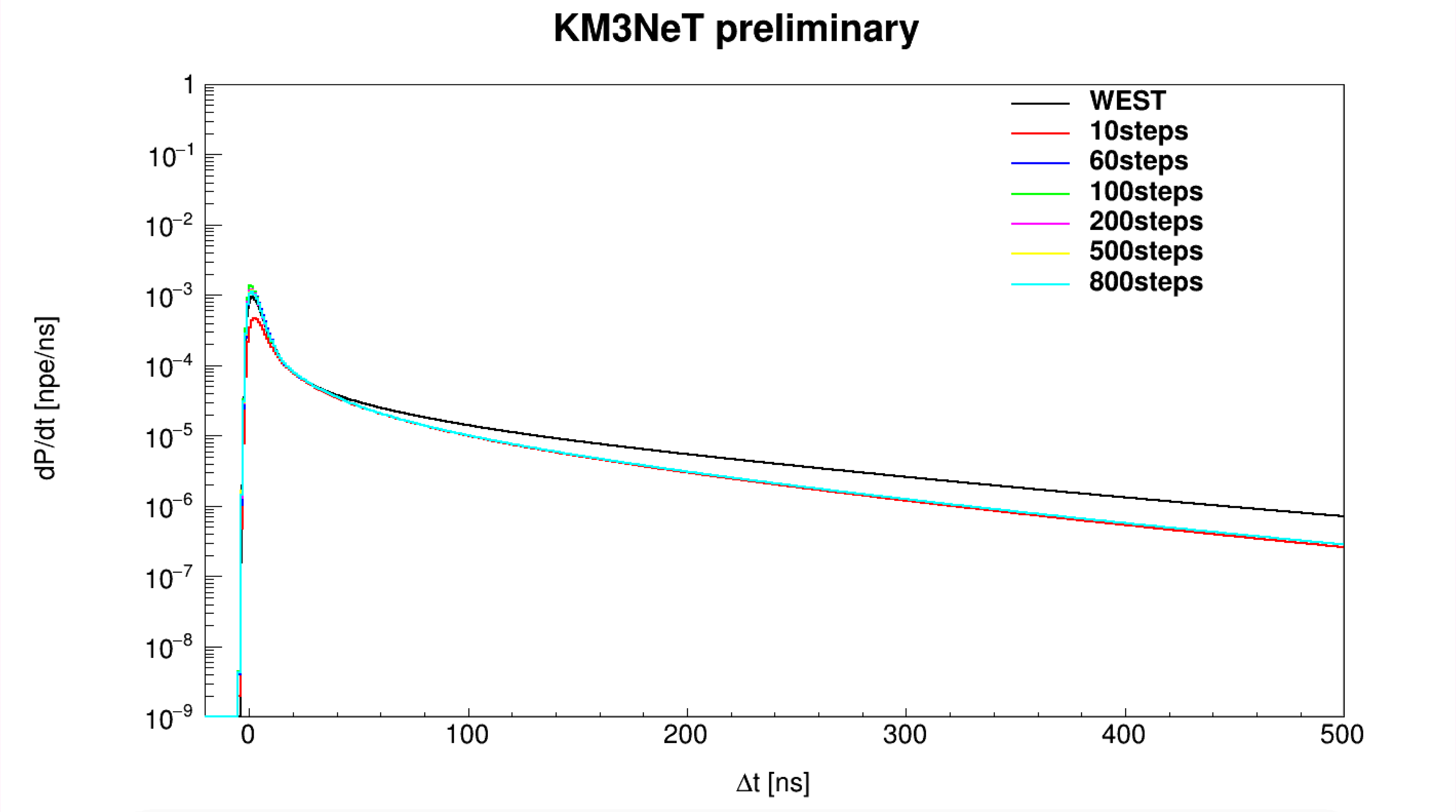
First step

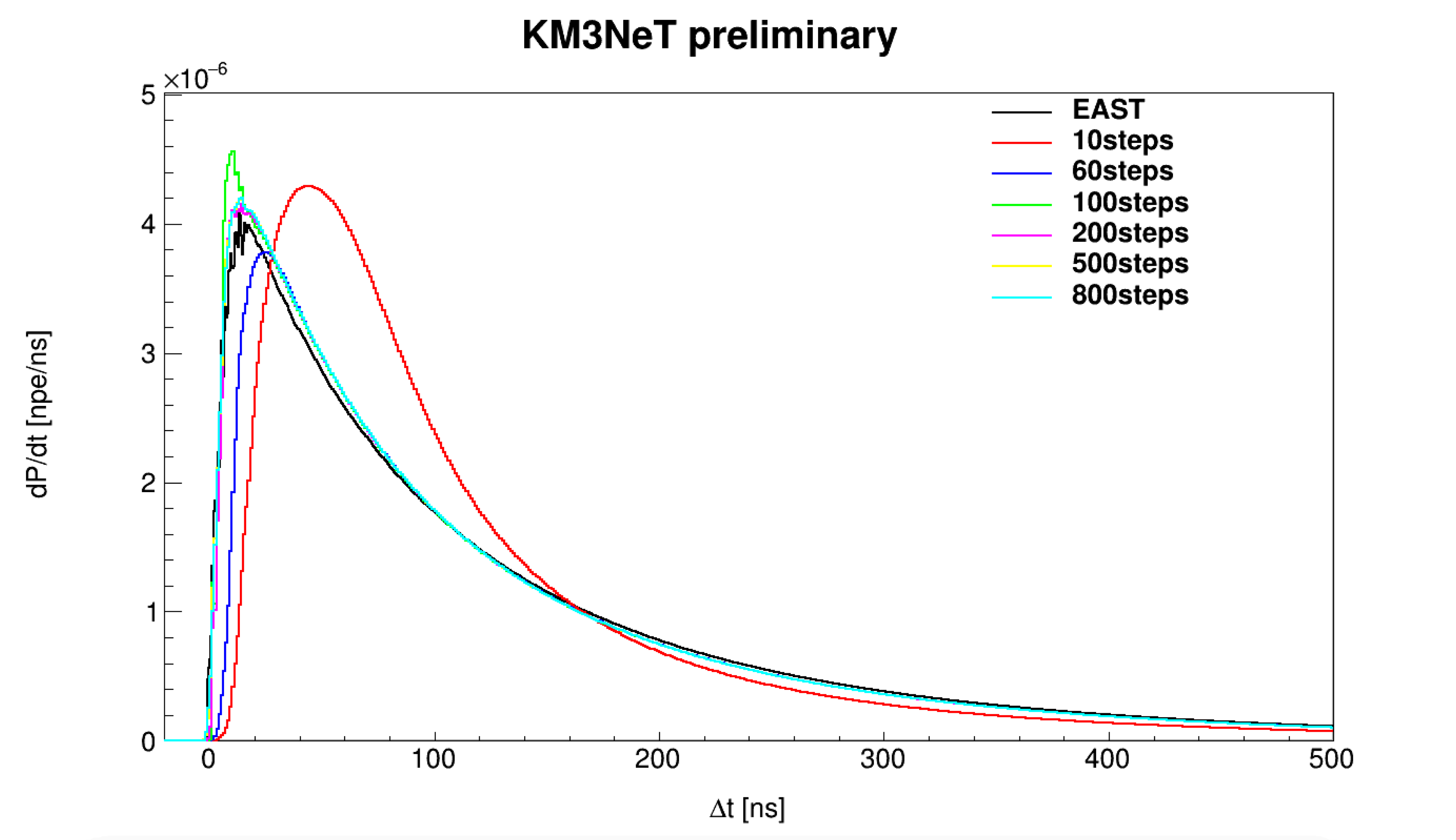
- Test: integral range from -1 to +1 should give the same result as drawing the scattered muon light function
- PMT facing WEST

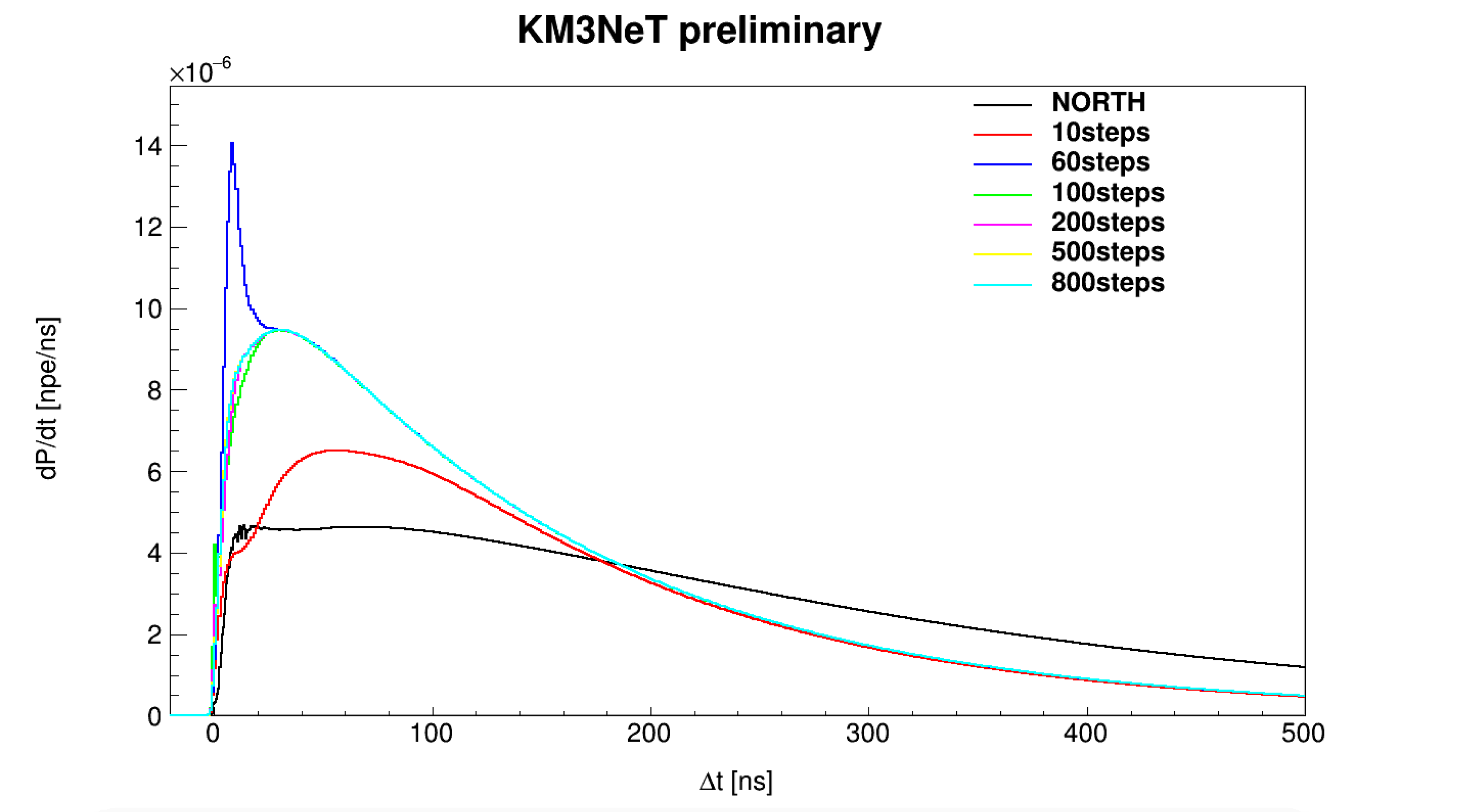


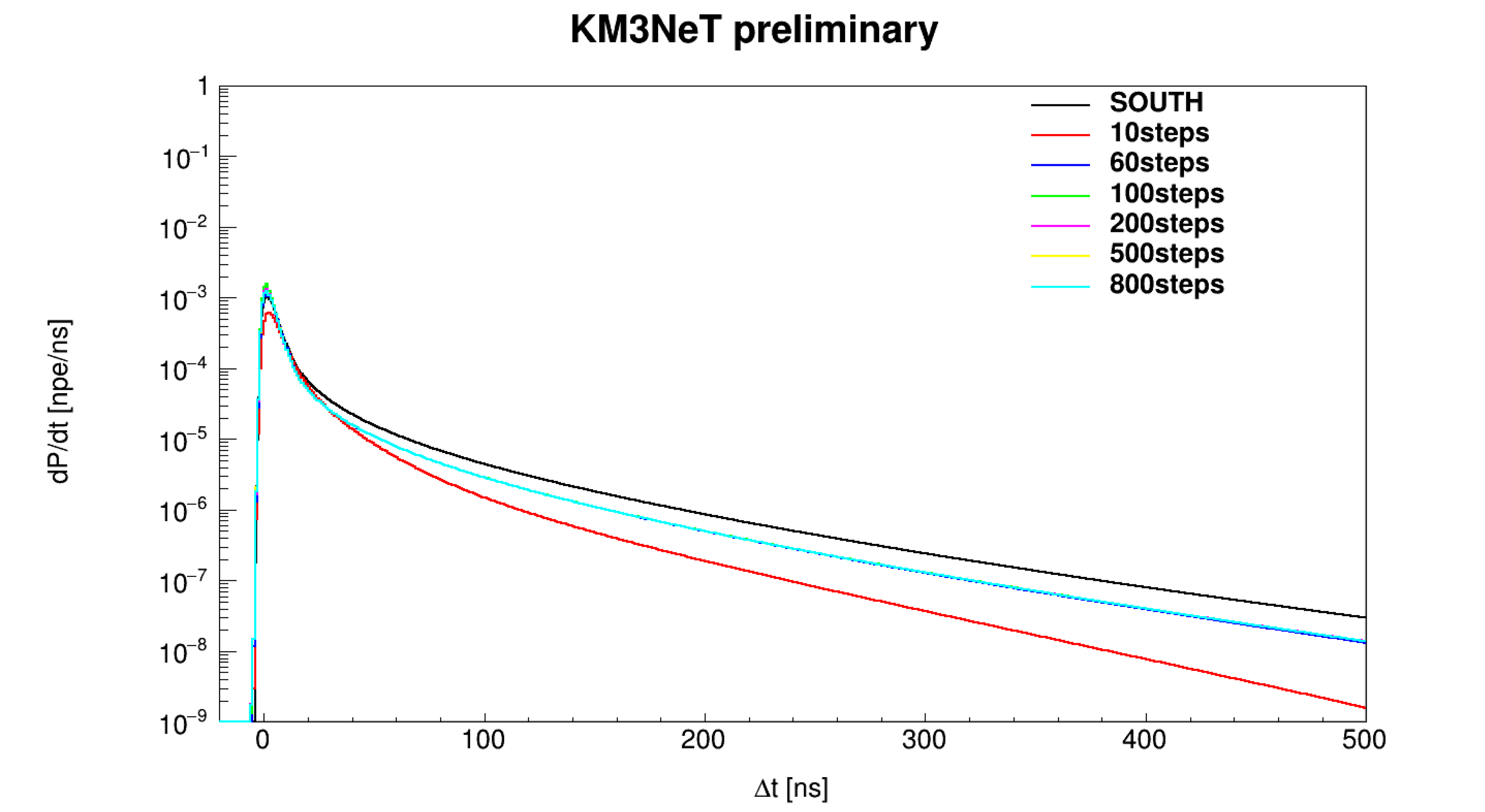
Tests

- Check integration step size
- Compare to standard PDF (black)









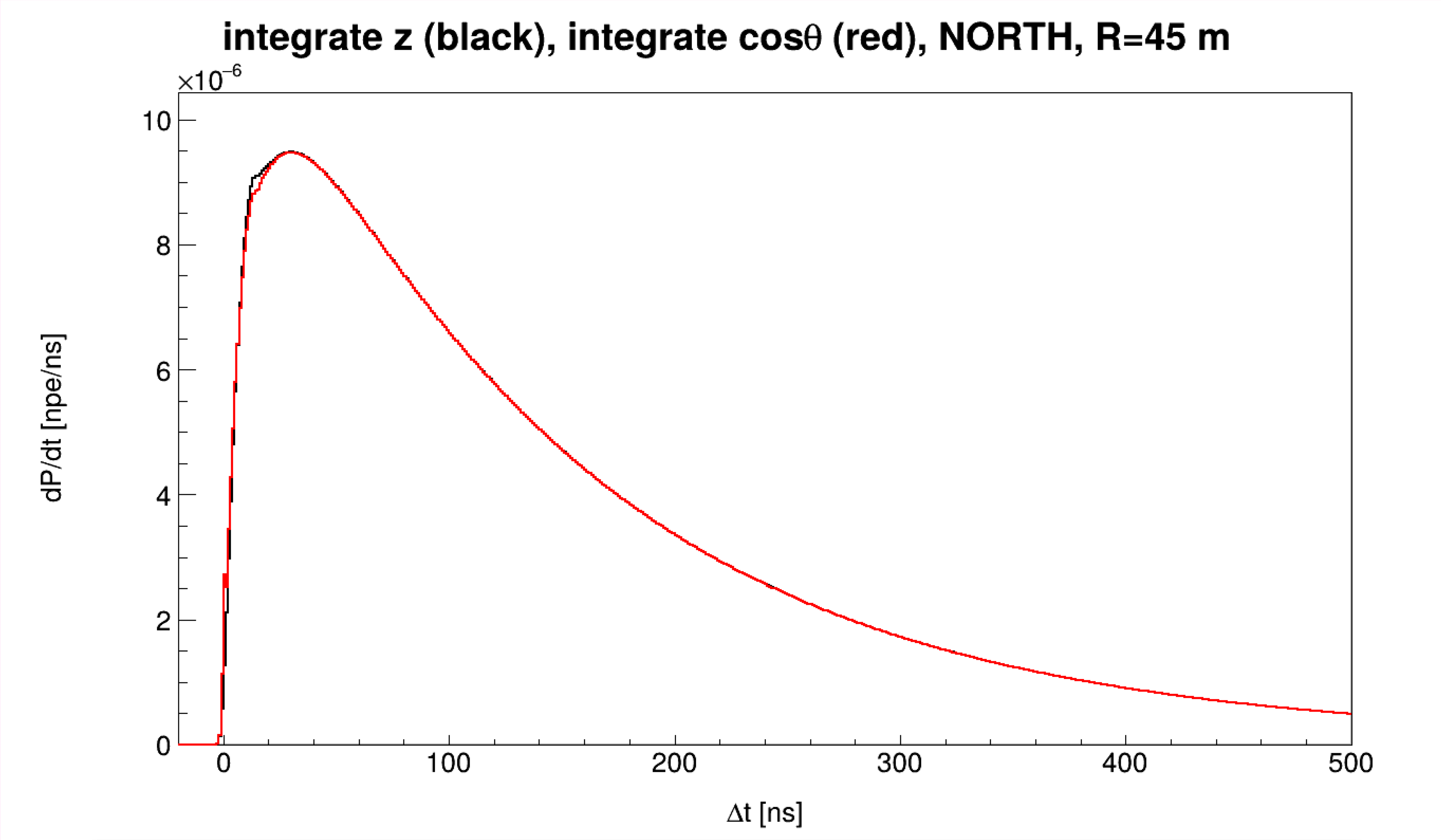
Tests

- Instead of integrating over $\cos\theta$, integrate over z

- Z limits of [-∞,+∞] should be equivalent to $\cos\theta$ from [-1,+1]

  $\Longrightarrow$ Integration gives same result for different variables, differences here are smaller than the difference between "standard" and integrated function

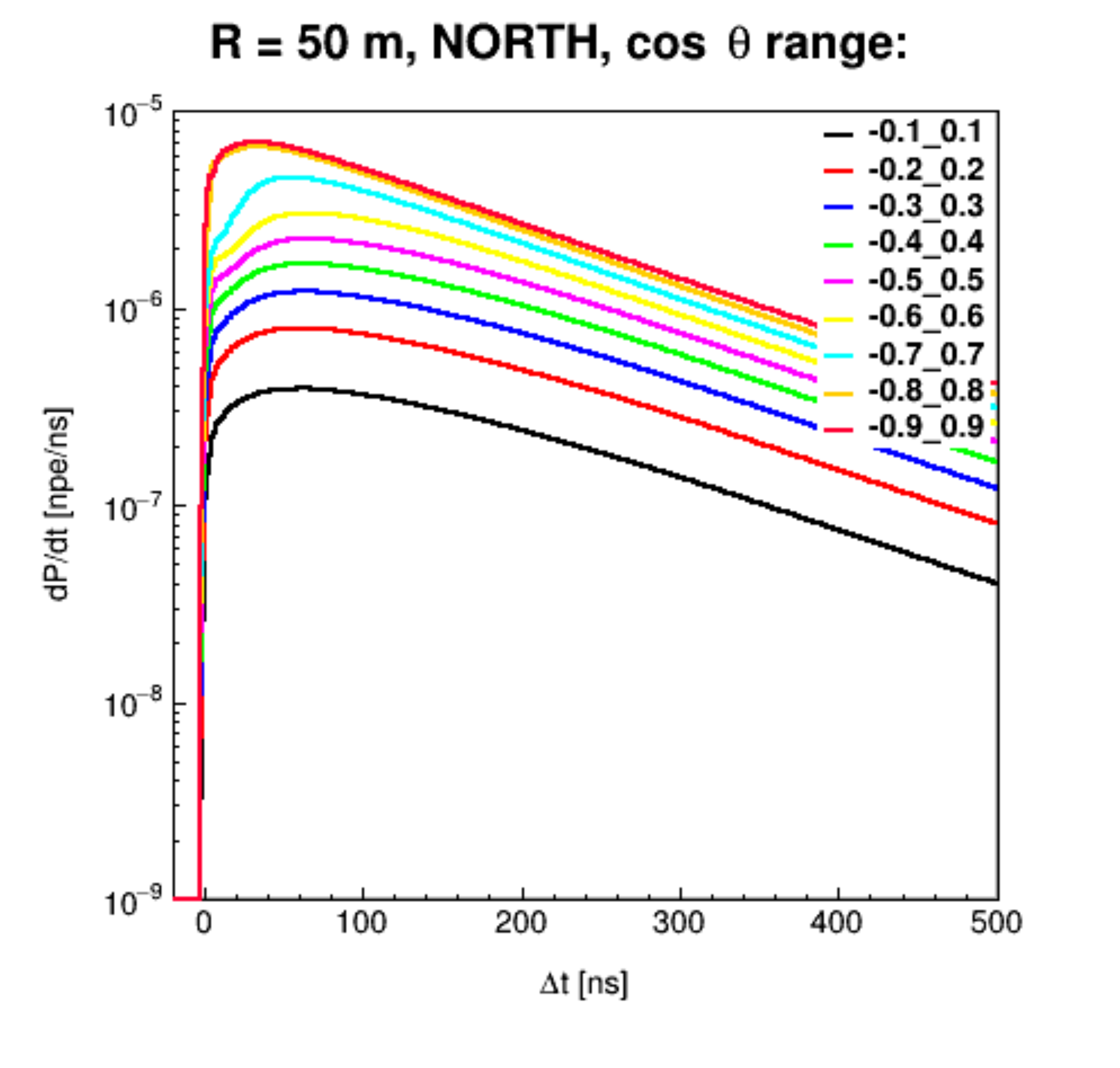
  (Although small differences are there, these differences can be removed by extending the limits used and the number of steps)

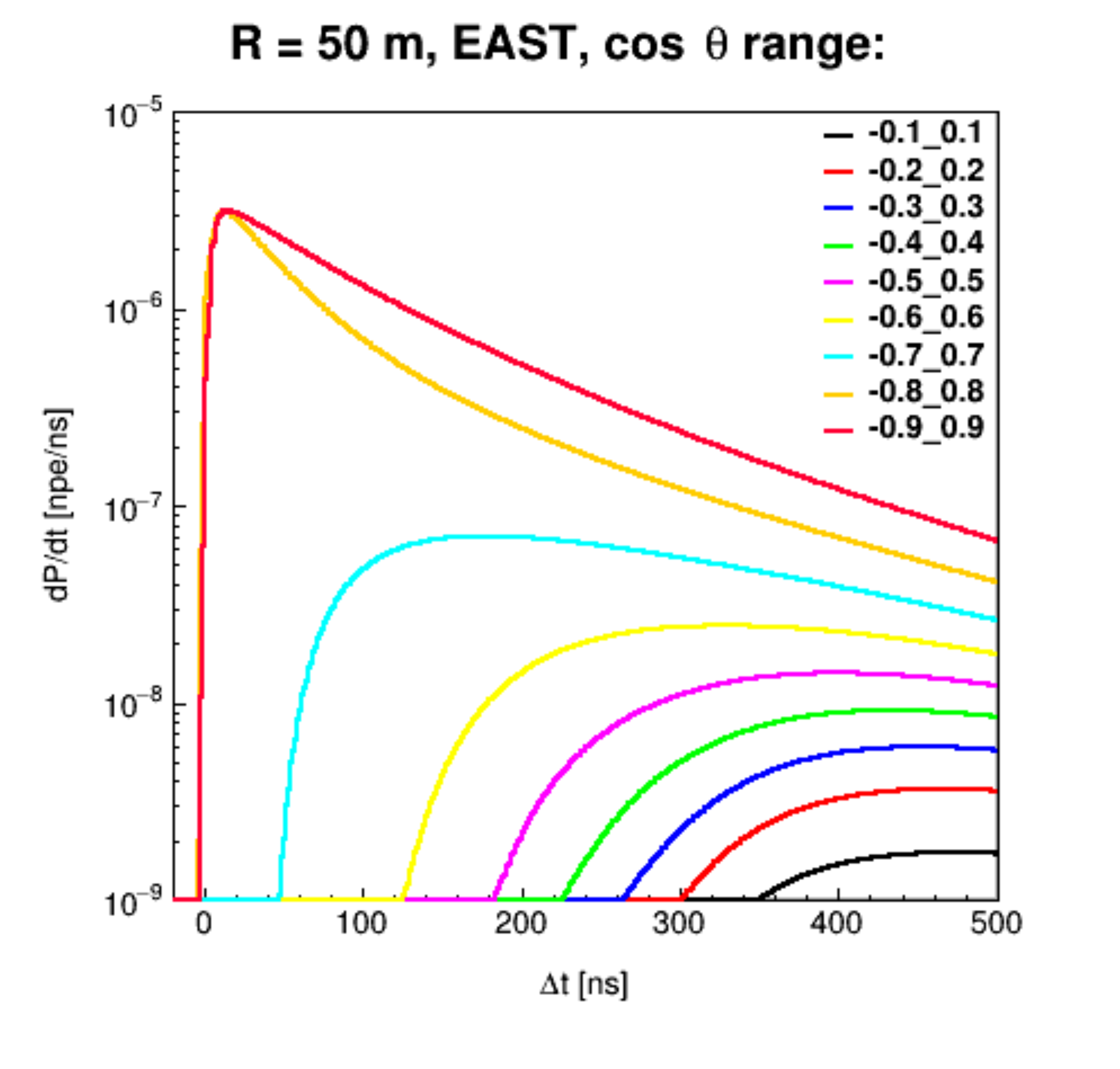


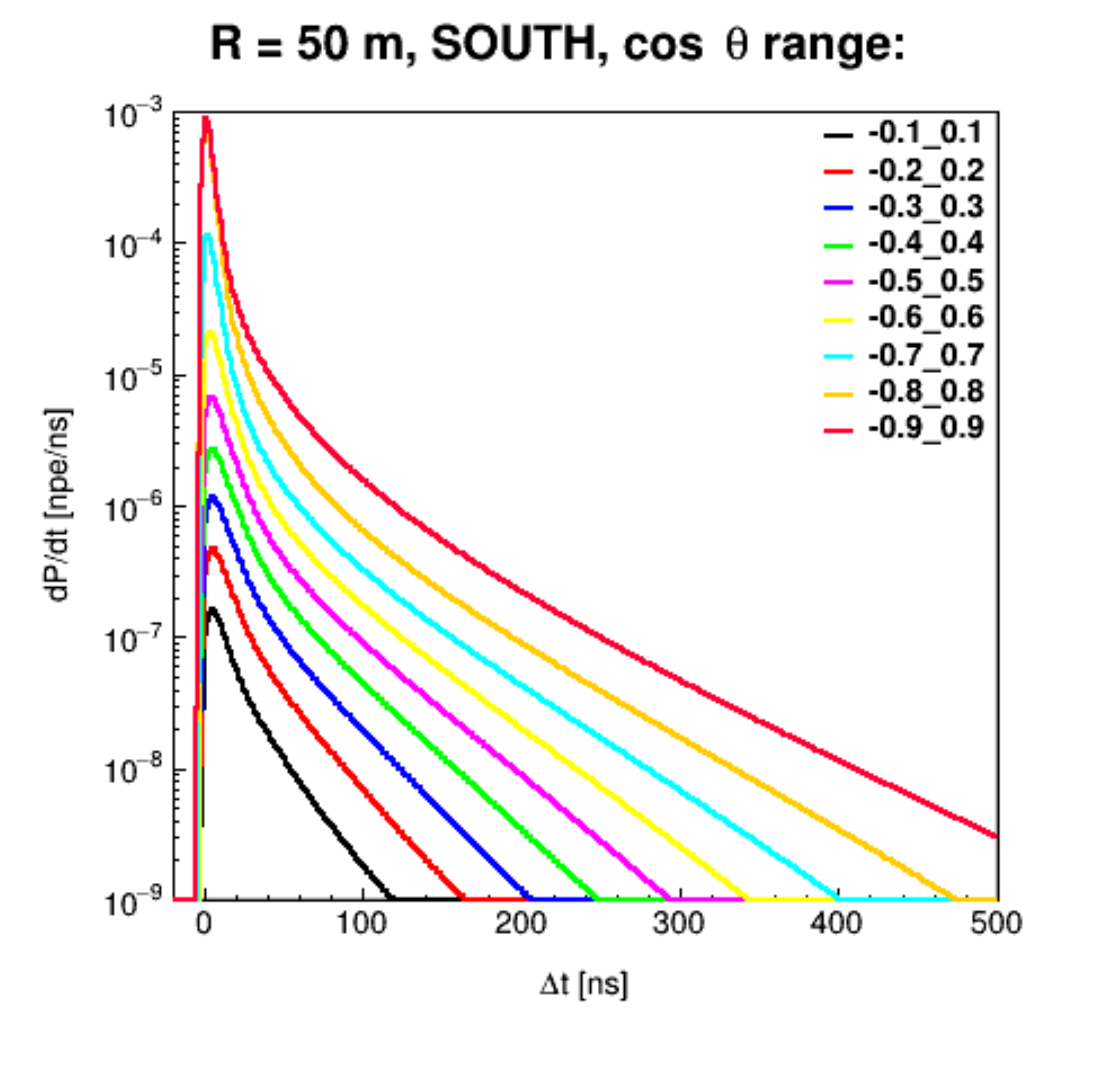
Intermezzo

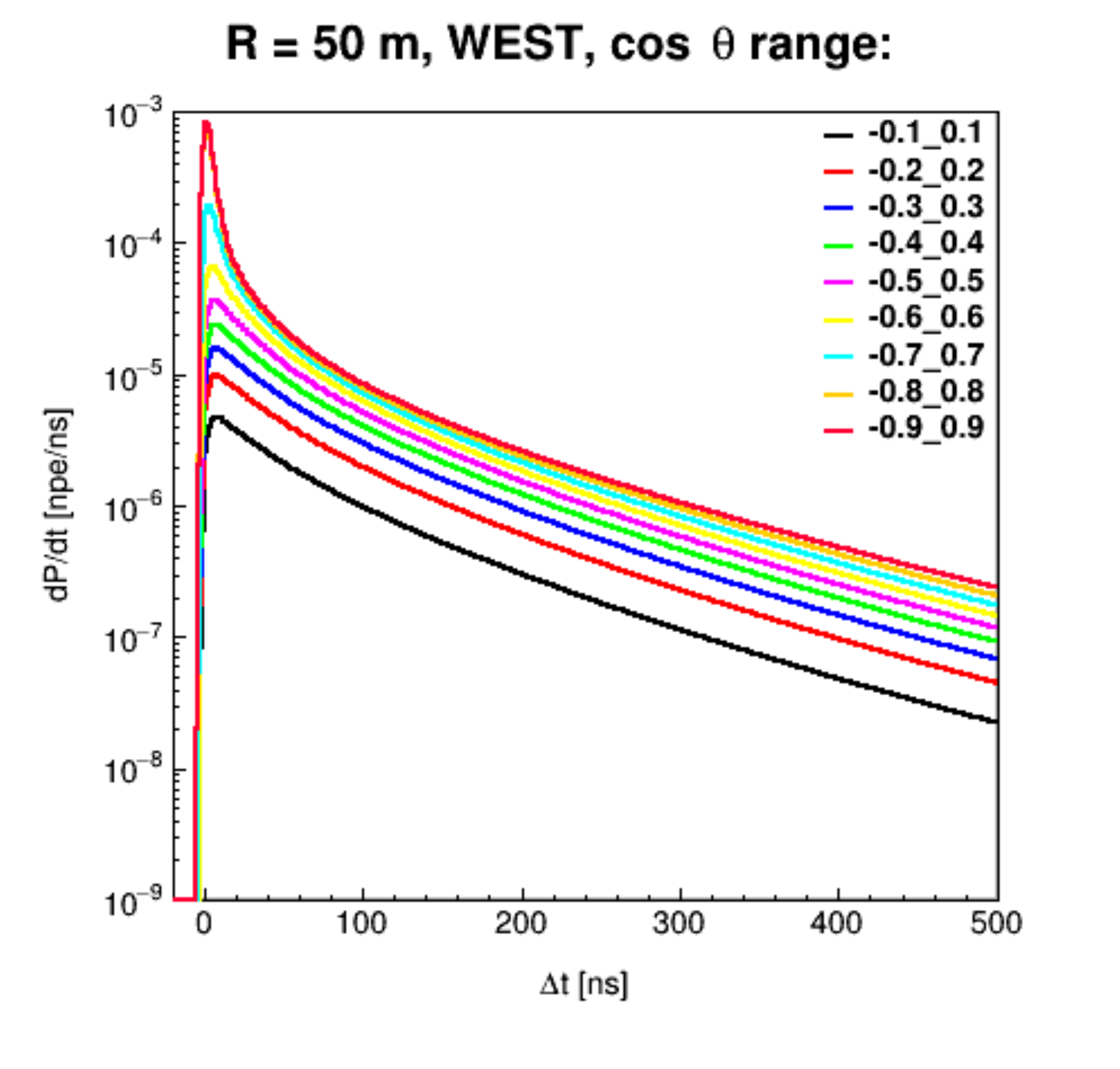
- Widen the section of track length being integrated over, for different PMT orientations

  —> shows what you expect, the wider the integral range the more photo-electrons are produced. For ‘EAST’ the light takes longer to reach the PMT









Tests

- Draw the total PDF (direct + scattered muon light + EM showers + delta rays) and compare to JSirene, KM3SIM
- Show standard PDF (blue distribution), and integration over scattered light function (green)
- Gedanken git project, simulate an example event with defined E, R, z and simulate with JSirene and KM3SIM
- Next slide:
  JSirene (black)
  KM3SIM (red)
  total PDF - implicit integration (blue)
  total PDF - explicit integration (green)
- Also shown here: https://git.km3net.de/simulation/light_gedanken/-/issues/2#note_71656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dP/dt [npe/ns]
Δt [ns]

Tests

- The above is just an example
- Need to explicitly define track start and end point, without knowing these the plots are not easy to interpret

- Another test: the numerical integration currently used is very basic (rectangular rule). For such a comparison with the multi-dimensional integrals already used, I can try using Simpson’s rule/trapezoidal rule
- … Avoid numerical accuracy issues