

# Hybrid Ray Tracer

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what?

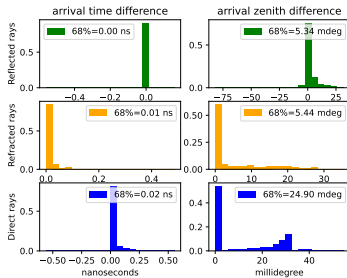


Figure: Hybrid

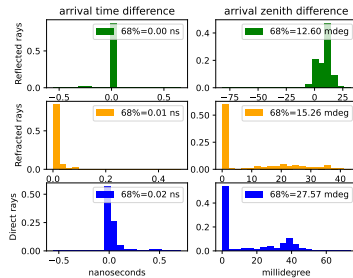


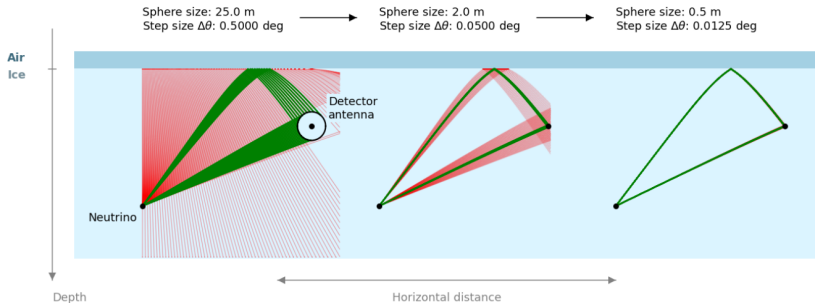
Figure: Iterative

# Why?

- ▶ Complex ice models needed
- ▶ full path might be needed

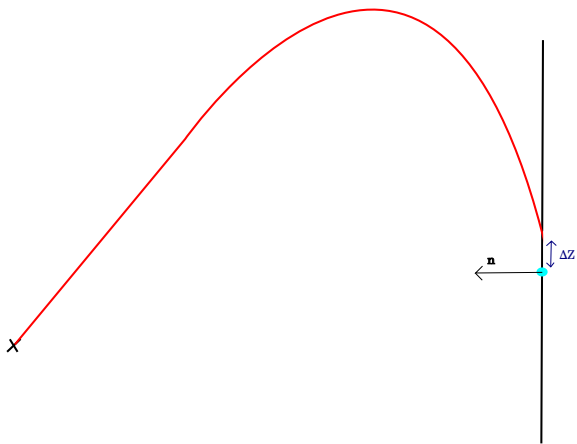
1. How the iterative ray tracer works
2. previous attempt to make it better
3. my attempt to make it better
4. optimisation of my attempt (the hybrid raytracer)
5. final results

# Iterative ray tracer



Non optimal  $\rightarrow$  `scipy.optimize.minimize`

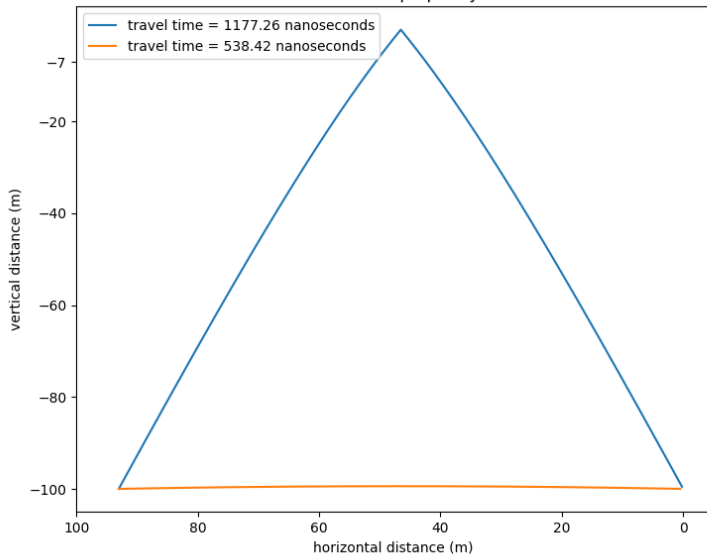
$\Rightarrow$  minimizer



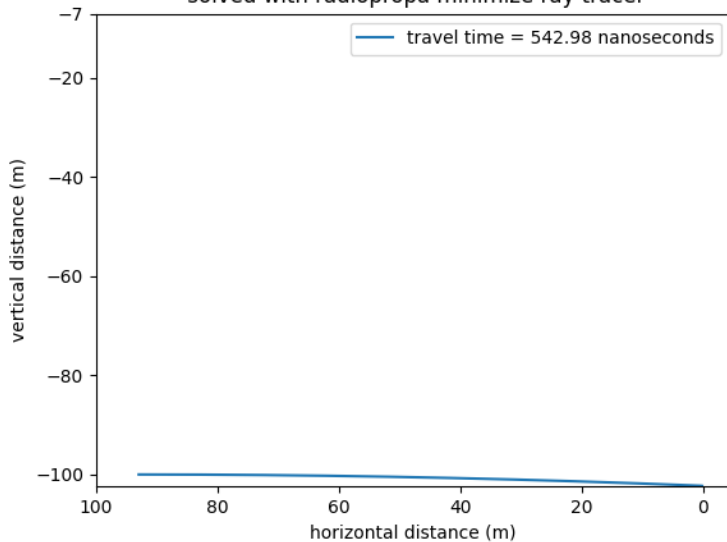
Problem: can't find the intervals for certain cases



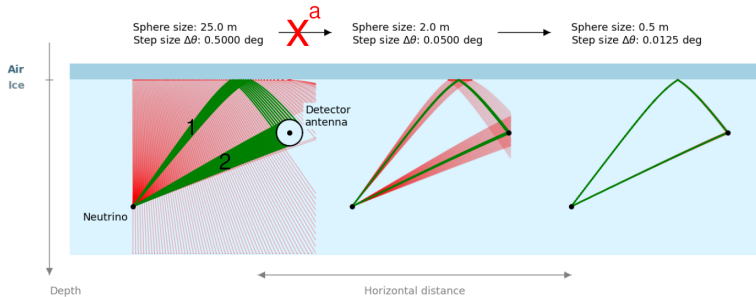
Greenland simple trajectory with GL1 attenuation  
solved with radiopropa ray tracer



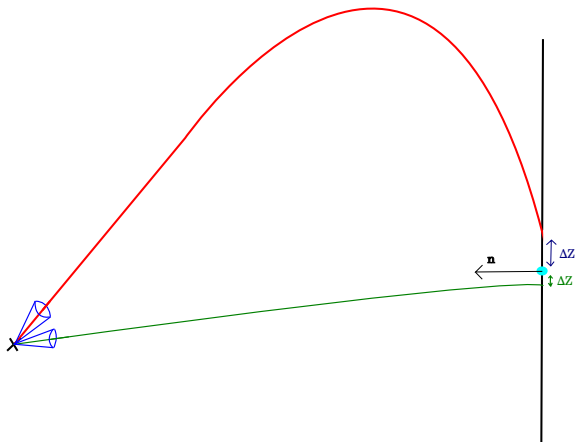
# Greenland simple trajectory with GL1 attenuation solved with radiopropa minimize ray tracer



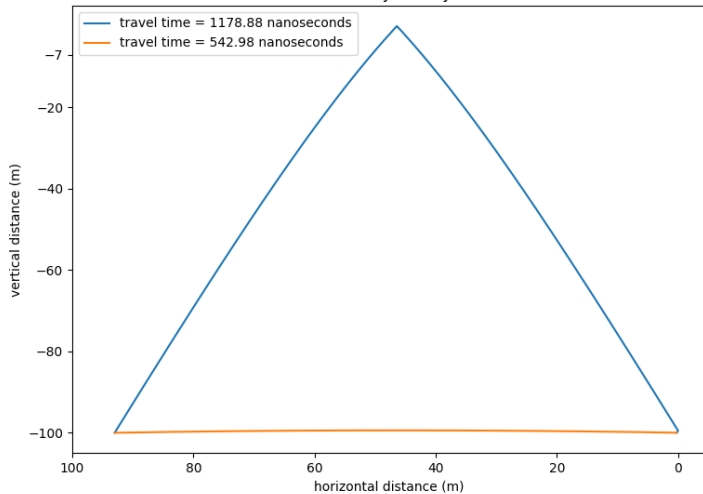
My solution



<sup>a</sup> process is broken out of as 2 distinct launch regions (region 1 & 2) are found.



Greenland simple trajectory with GL1 attenuation  
solved with hybrid ray tracer



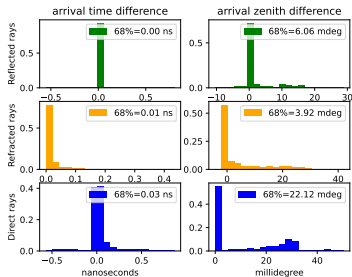


Figure: Hybrid

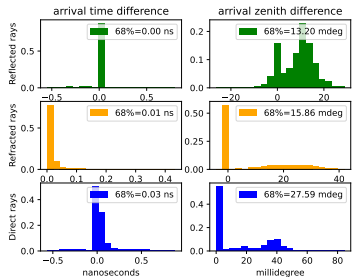


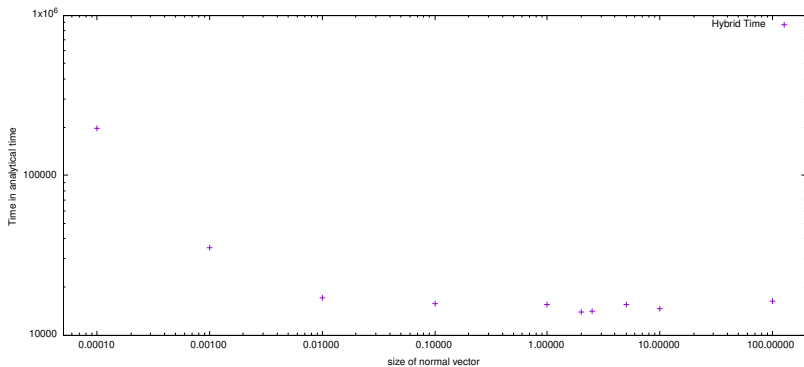
Figure: Iterative

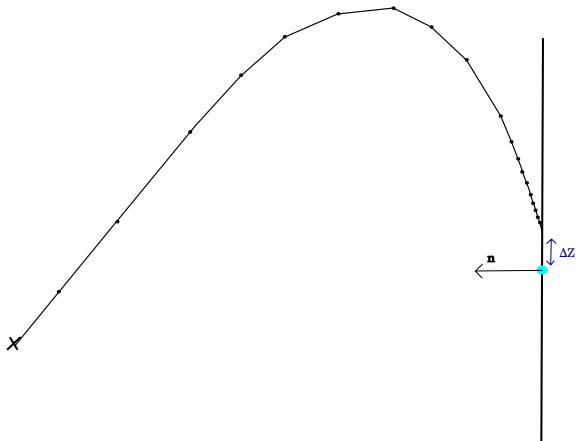
Whilst  $\approx 15\%$  faster

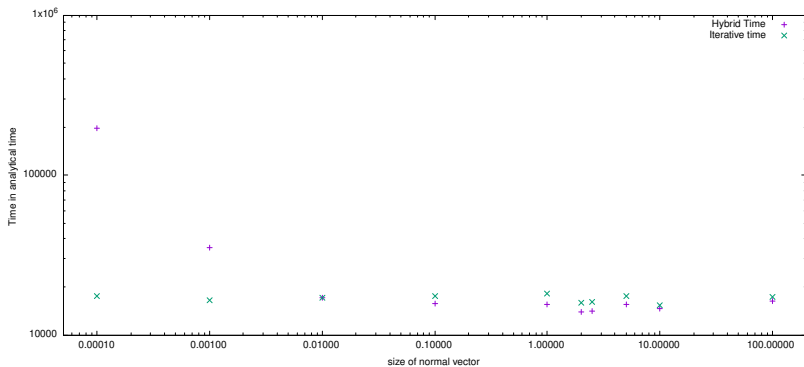
# Optimization

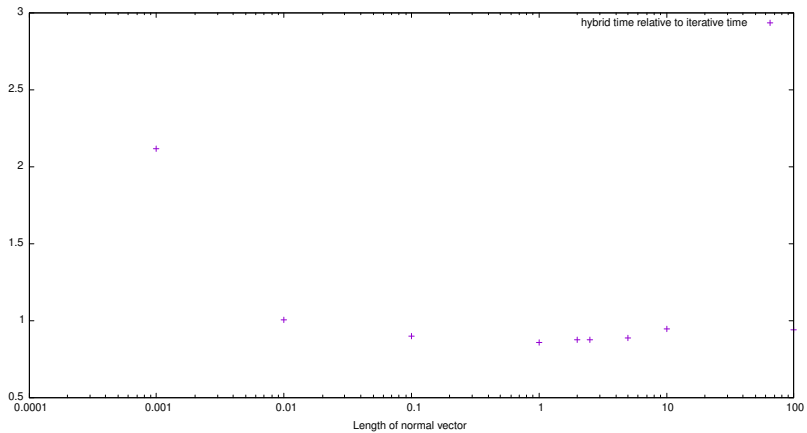


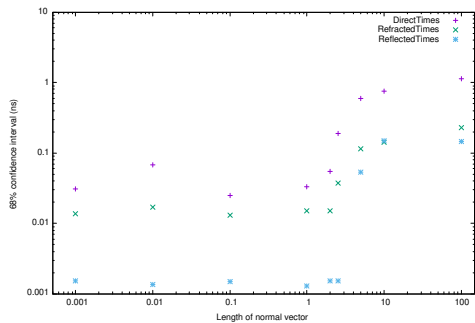
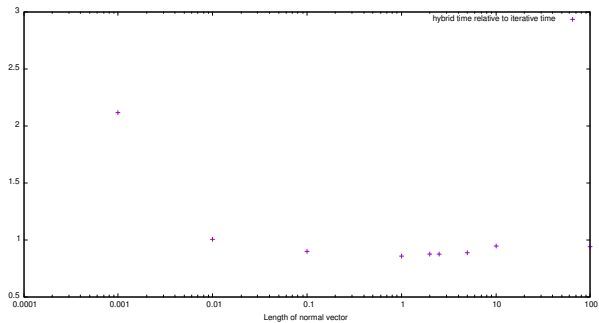
Length of the normal vector:

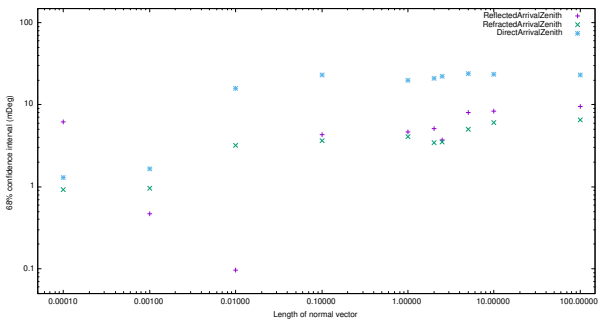
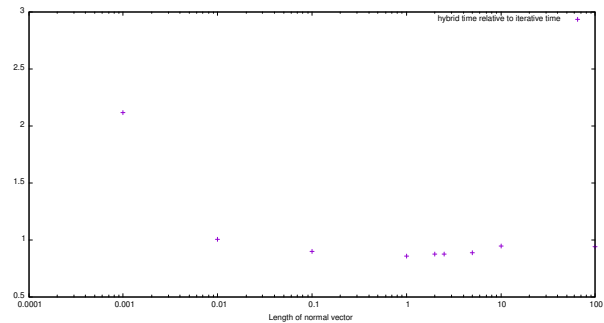


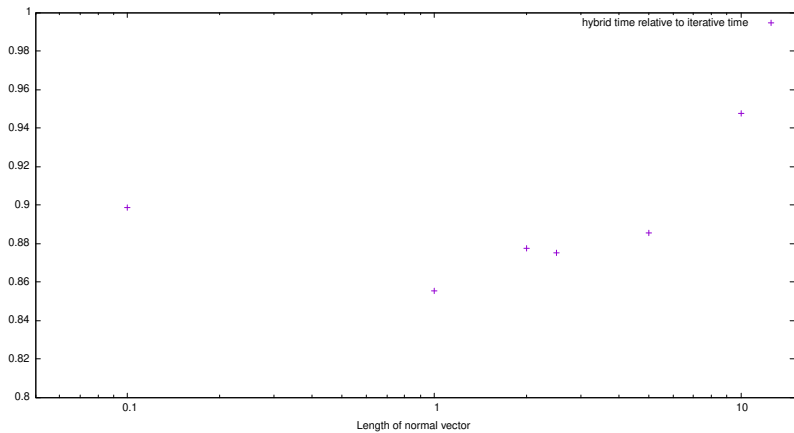






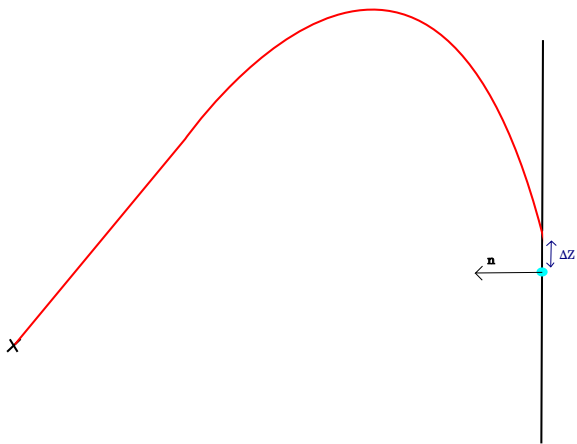


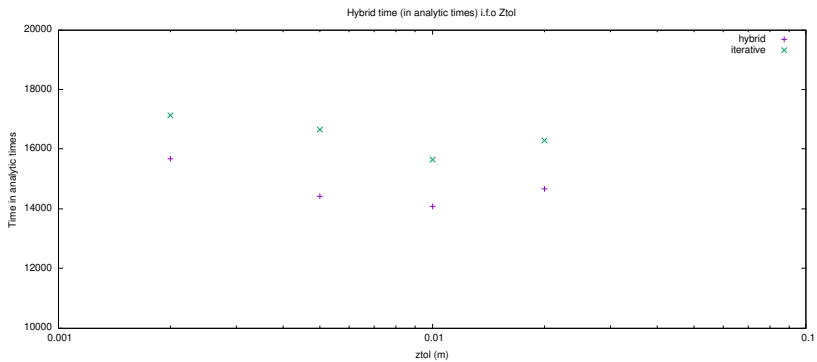


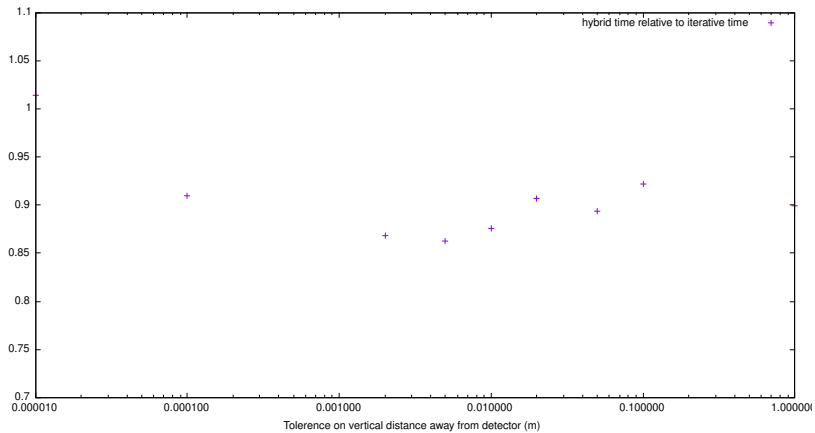


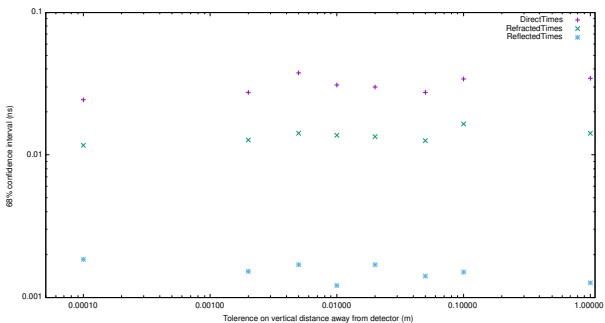
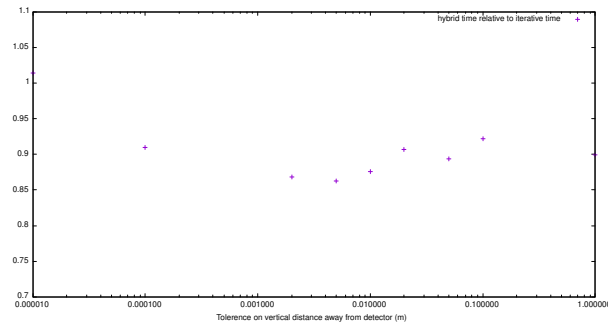
First optimization conclusion:  
Take the normal vector length to be 1 meter.

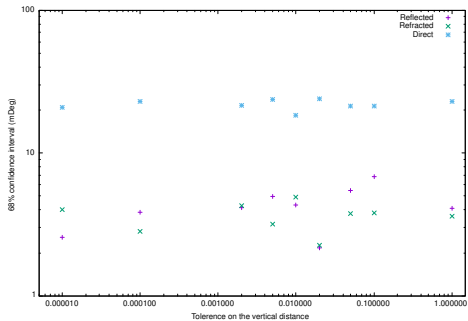
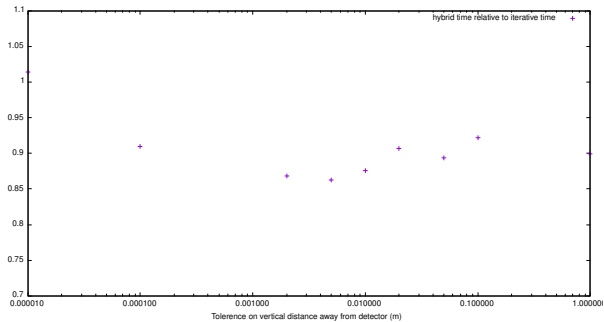






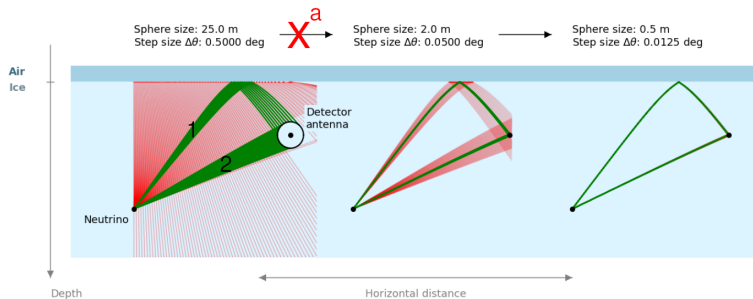






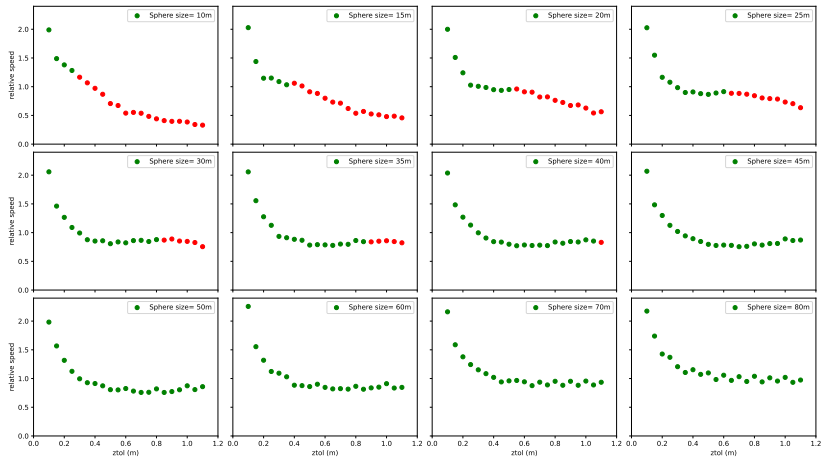
Second optimization conclusion:  
Take  $z_{tol}$  to be 0.05 m.

# Sphere Size & Step Size



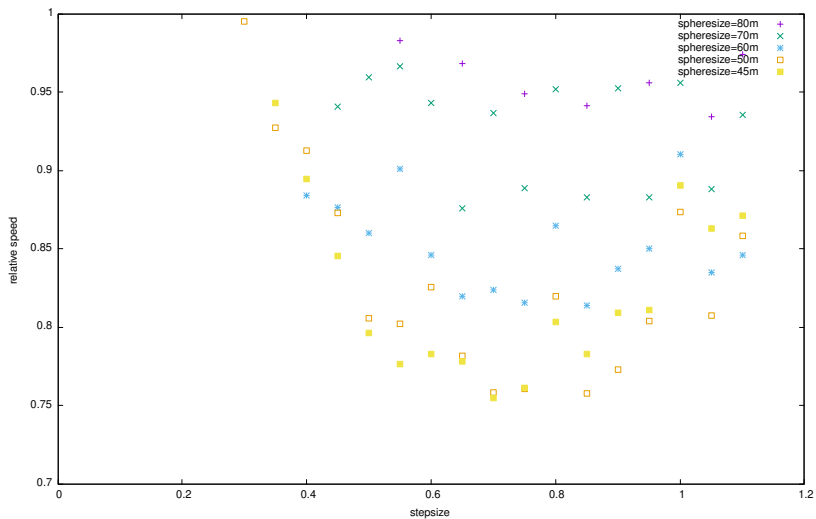
<sup>a</sup> process is broken out of as 2 distinct launch regions (region 1 & 2) are found.

# Sphere Size & Step Size





# Sphere Size & Step Size



# Final Result

- ▶  $\text{norm} = 1\text{m}$
- ▶  $\text{ztol} = 0.05\text{m}$
- ▶ Sphere size = 45m
- ▶ step size = 0.7

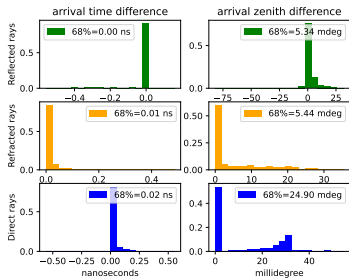


Figure: Hybrid

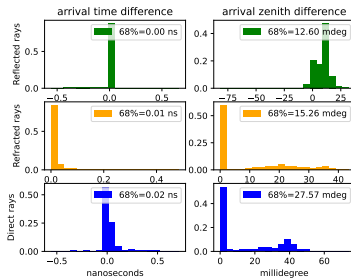


Figure: Iterative

- ▶ iterative :1.627s
- ▶ hybrid : 1.226s (32.7% faster)
- ▶ analytic: 9.719e-05 seconds

## What if the same sphere and stepsize?

- ▶ iterative :1.80317s
- ▶ hybrid : 1.35776s (32.8% faster)
- ▶ analytic: 9.8812e-05 seconds

Exactly the same  $\sigma$ 's