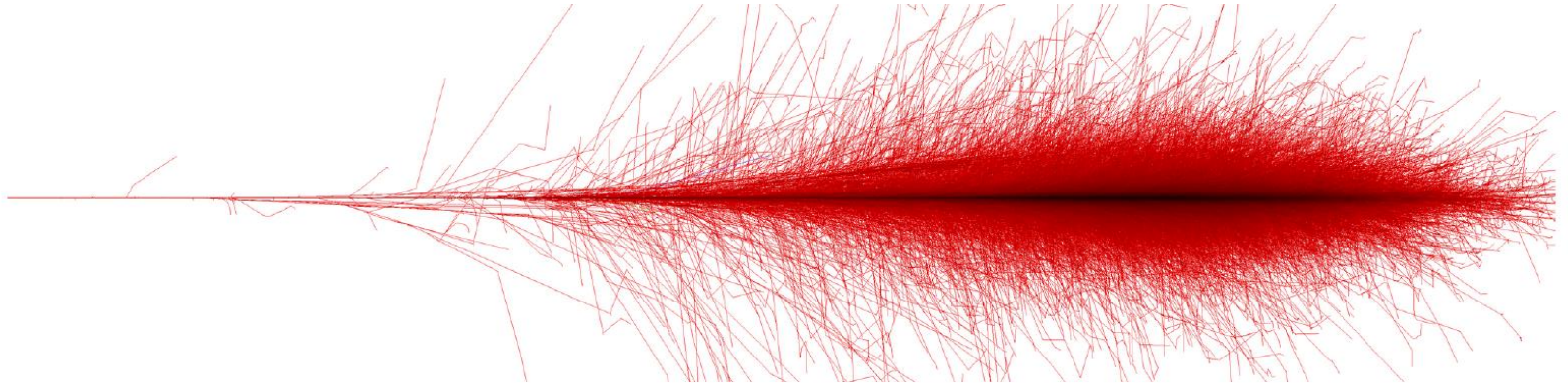


# The radio interface and how to generalize it

Tim Huege (KIT & VUB)



# State of discussions so far

- Issue on GitLab

Adapt RadioPropagator to suit the needs of dens-media and cross-media showers

# Current state in code

- for a given particle position and antenna position, the Propagator is called
- it will give back a vector of SignalPaths that connect source and antenna
- the SignalPaths have relevant information that can be queried for the E-field calculation by the Formalism, for example refractive index at source, time delay along path, emit vector and receive vector
- This is no longer sufficient in case of signal propagation in dense media with strong refractive index gradients, or for cross-media showers.

# How to generalize? Build on NuRadioMC

- for a given particle position and antenna position, a Propagator is instantiated; in its constructor, it will determine the relevant signal paths and store the relevant information
- the Propagator will provide an interface so that the Formalism can query the relevant information to calculate the E-field (such as emit vector, refractive index at source, time delay along path)
- for every solution found, the Formalism will calculate the E-field; then, the E-field needs still to be "propagated" to the antenna, taking into account media effects; this involves in particular
  - rotation of the electric field vector such that it is perpendicular to the (-)receive vector at the antenna location
  - application of Fresnel coefficients for any media boundaries with discontinuities in refractive index
  - application of attenuation factors (could be frequency-dependent)
  - (later: application of electric field modifications related to media birefringence)
- for this, the Propagator instantiated earlier will offer a method that applies these effects to the provisional E-field provided by the Formalism
- at the end, the Propagator object is deleted (creation and deletion are not good in terms of thread-safety, maybe can overcome by creating only once and re-using, but the issue is already present in the current design where we create and destroy SignalPaths)

# But it is even more complex

- There are always at least two trajectories that often have significant differences in receive vector and time delay. Those can't be added together into a single electric field trace as it would result in the loss of arrival information, and thus, the antenna response can't be applied anymore. I see two solutions for that:
  - Several electric fields with similar arrival directions and times could be stored at each observer position.
  - The antenna response becomes part of the CORSIKA8 simulation to directly provide the voltage output.
- The Fresnel coefficients depend on polarization and are complex, i.e., they can introduce a phase shift. Probably need to work in frequency domain.
- The attenuation through ice is frequency dependent and needs to be calculated per line integral along the path for every frequency. Probably needs tabulation.
- It is likely very useful to store the electric field in spherical coordinates ( $e_R$ ,  $e_\Theta$ ,  $e_\Phi$ ).

# How to continue?

- First step: Port Uzair's work from C7 to C8?
- Generalize the propagator along the way?
- Who is able to engage on this path?