

RADAR ECHO TELESCOPE



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On behalf of:
RET collaboration

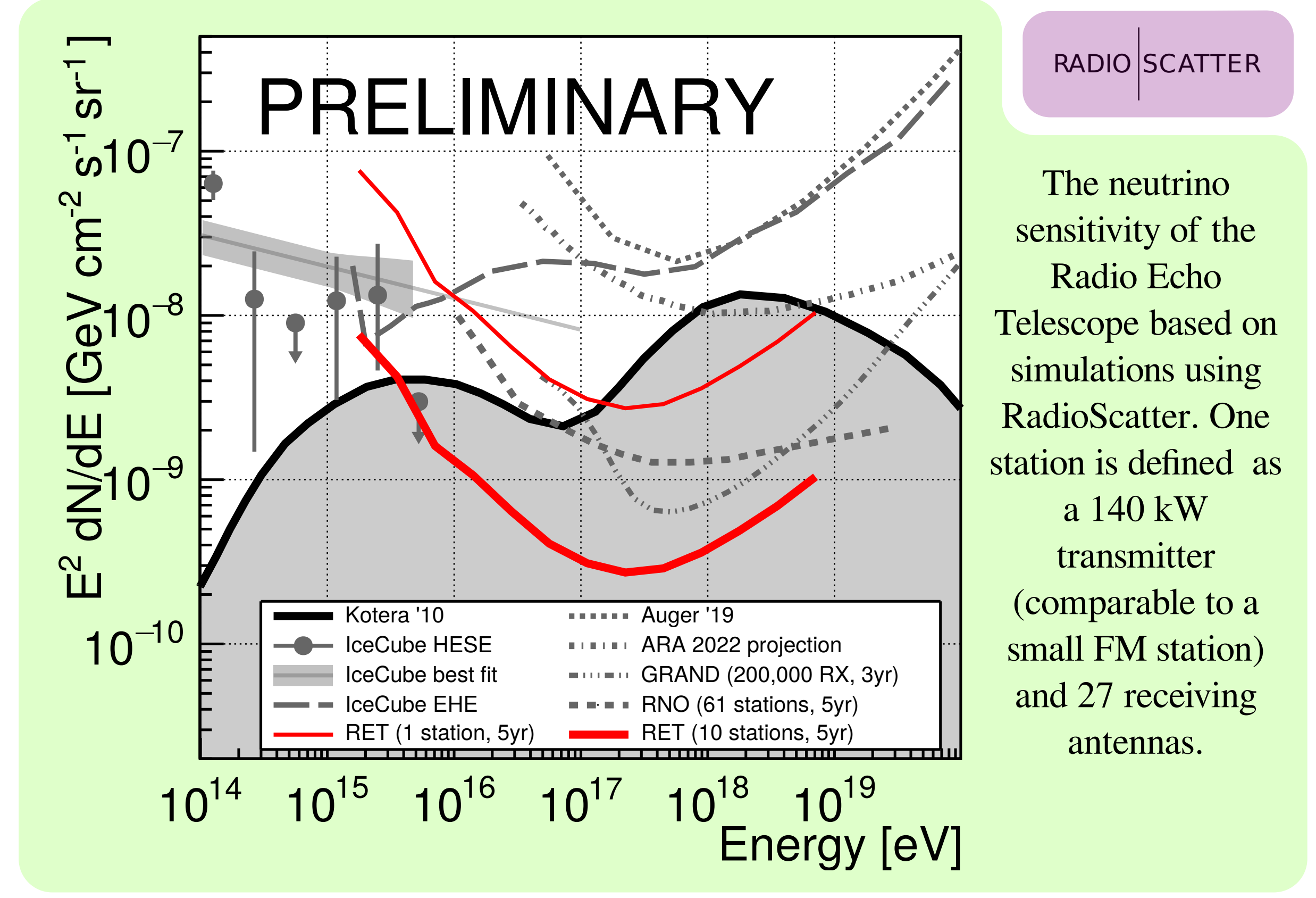
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Introduction The Radar Echo Telescope (RET) is a new proposed detector to target neutrinos with energies in excess of 10 PeV. Our international collaboration is developing the technology and expertise to deploy an in-ice radar system capable of detecting the ionization clouds left in the wake of ultra-high-energy neutrino-induced cascades deep in the ice (RET-N), and from ultra-high-energy cosmic rays at the surface of the ice (RET-CR). We recently made the first definitive observation of a radar echo from a particle shower (see poster abstract #478) [1]. Here we describe the simulation efforts currently underway addressing all aspects of the radar detection problem.

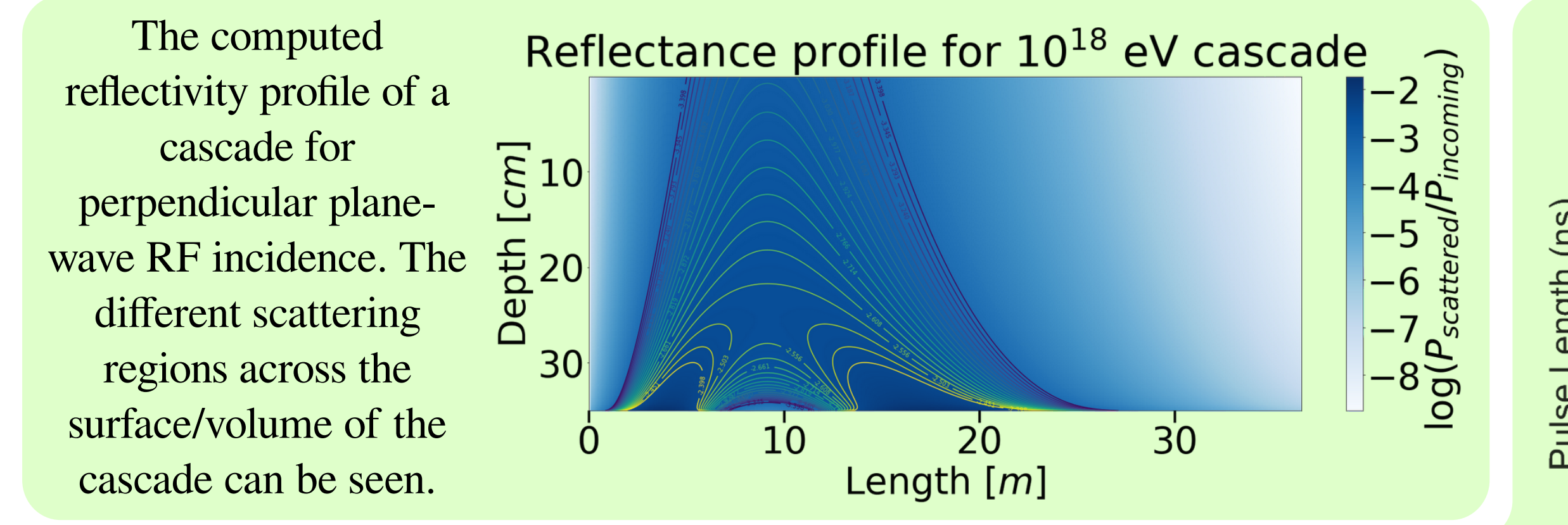
Neutrino Sensitivity

- RET-N has good projected sensitivity to neutrinos with > 10 PeV energies
- Fully-featured, first-principles radar echo simulation code RadioScatter [3]
 - Particle-level
 - Harnessing power of Geant4



Macroscopic scatter models

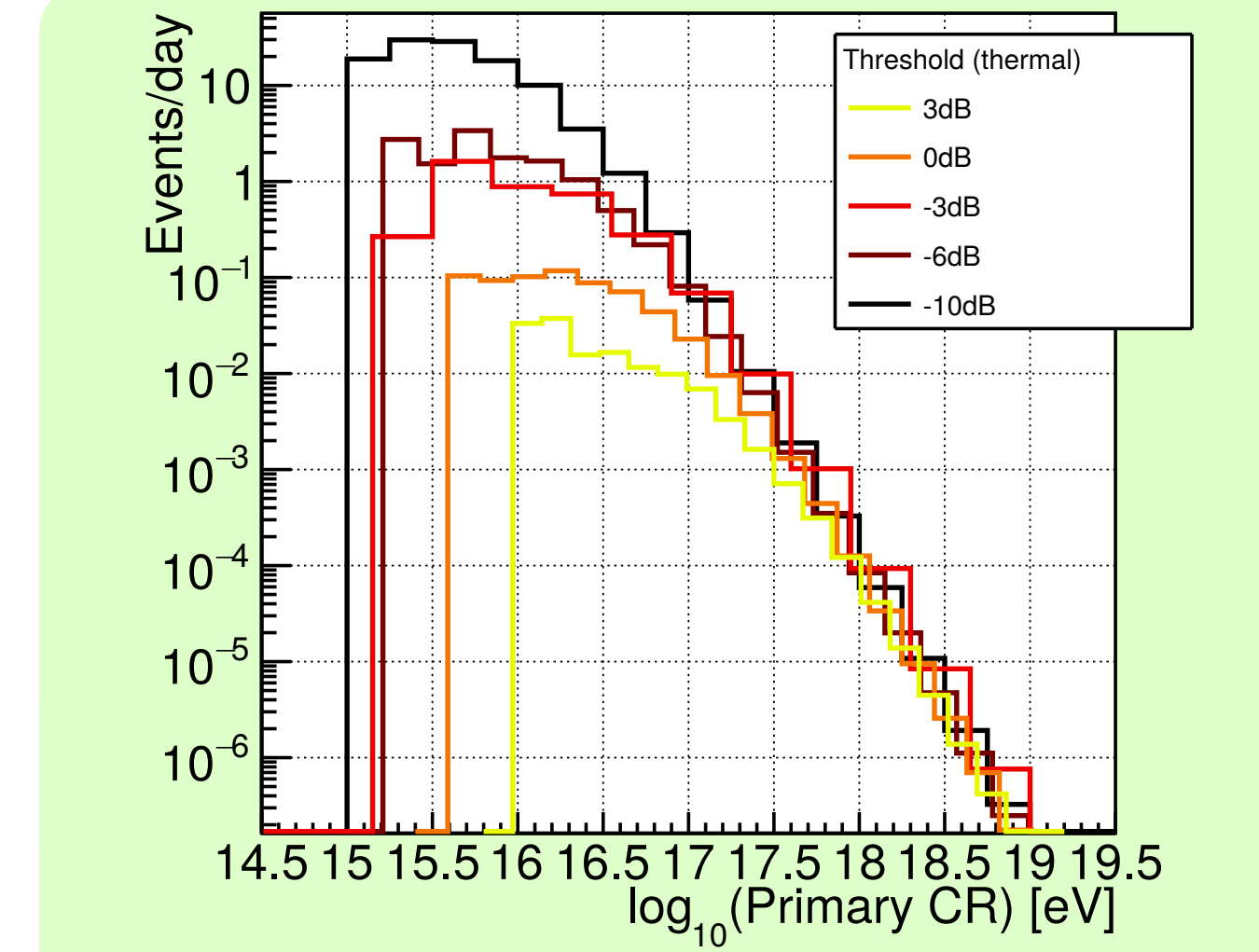
- Radar echo simulation can be done using a macroscopic framework, reducing the cascade volume to a macroscopic collection of coherently scattering points [2]
- The expected signals depend highly on cascade position and direction, providing good handle on event reconstruction even at single antenna level and allowing for intuitive understanding of received signal's features



The pulse duration w.r.t. the cascade orientation. Two different regimes are seen, inside and outside the Cherenkov cone. As expected, the pulse length is minimised at the cone itself, where the associated electric field signal is fully coherent in phase.

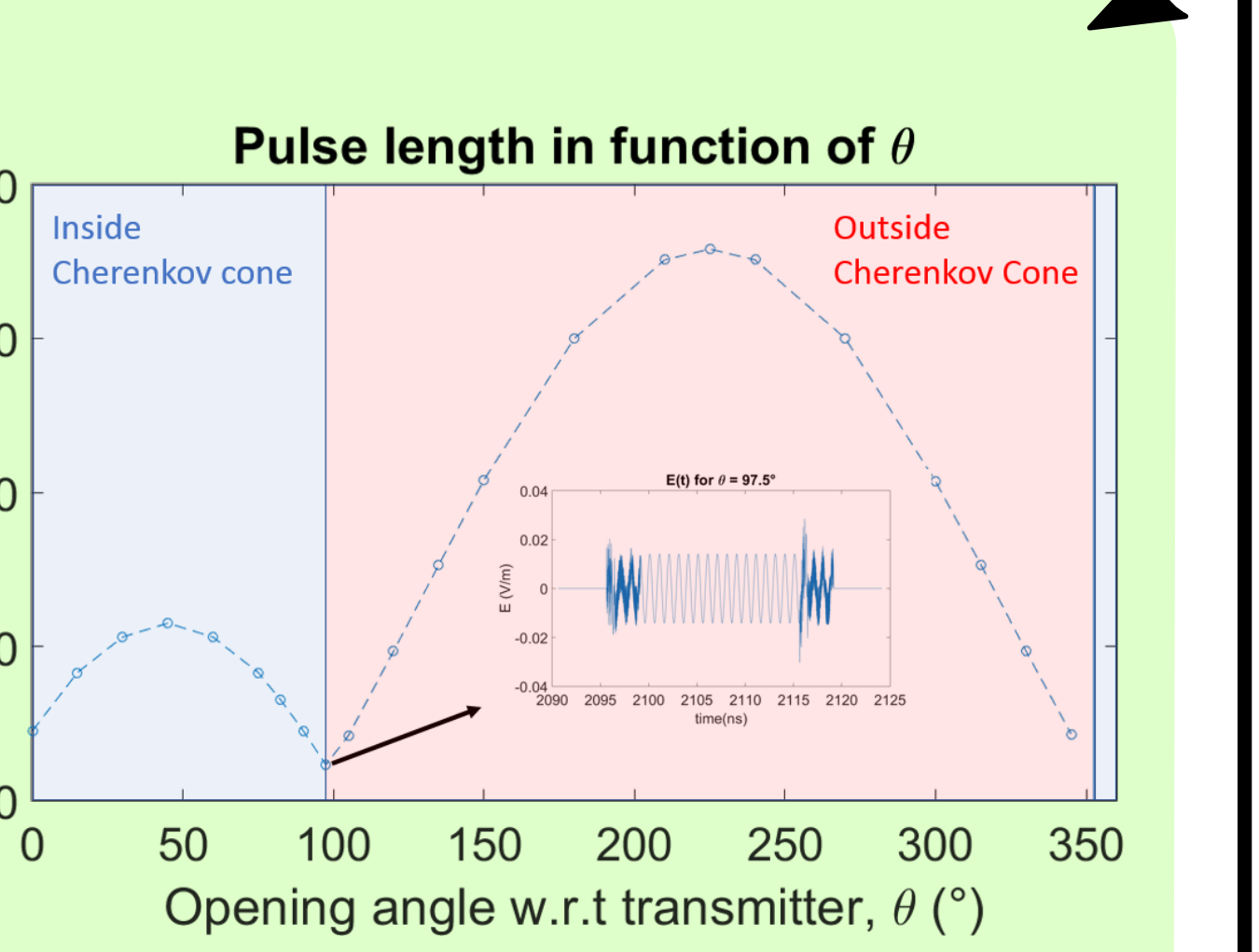
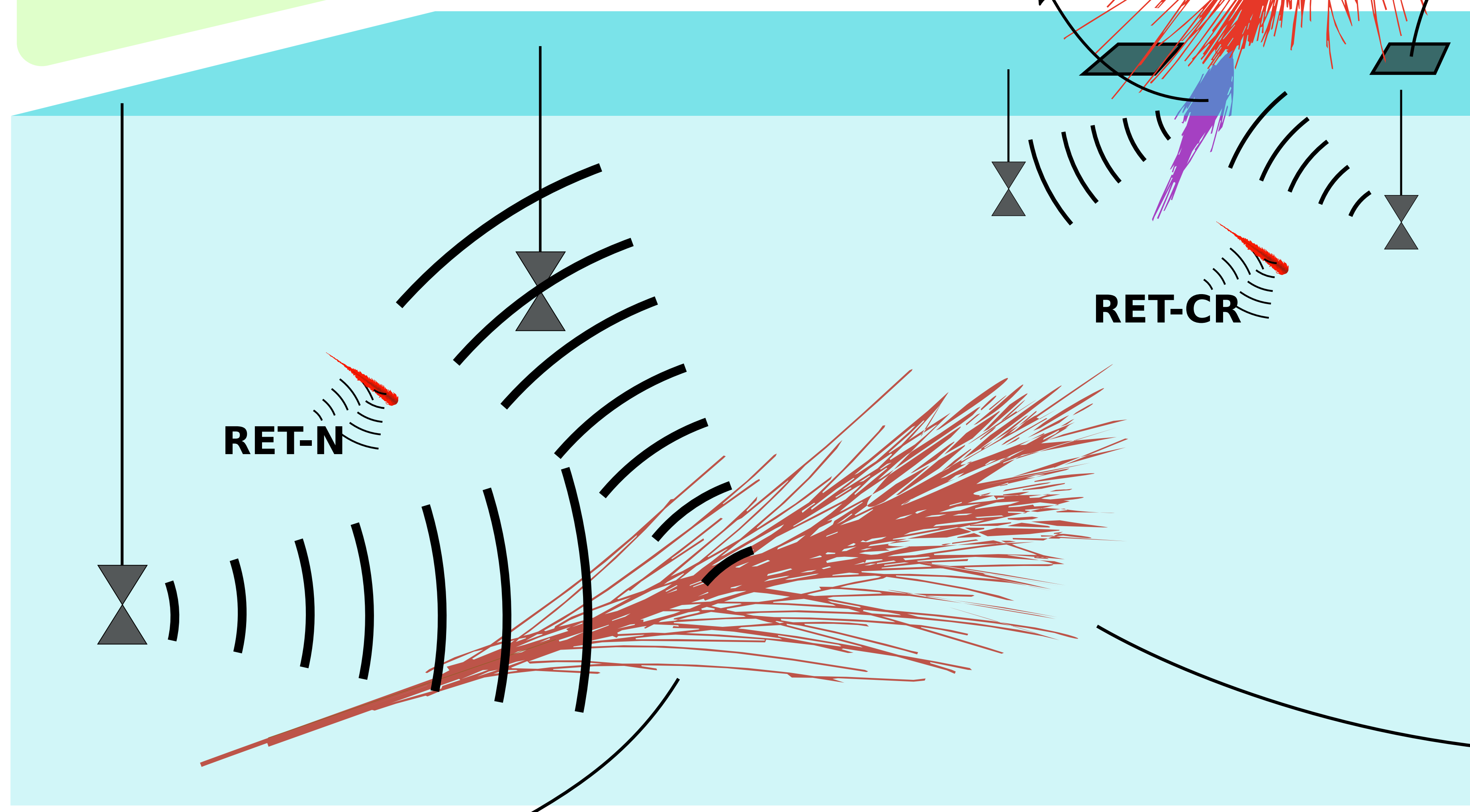
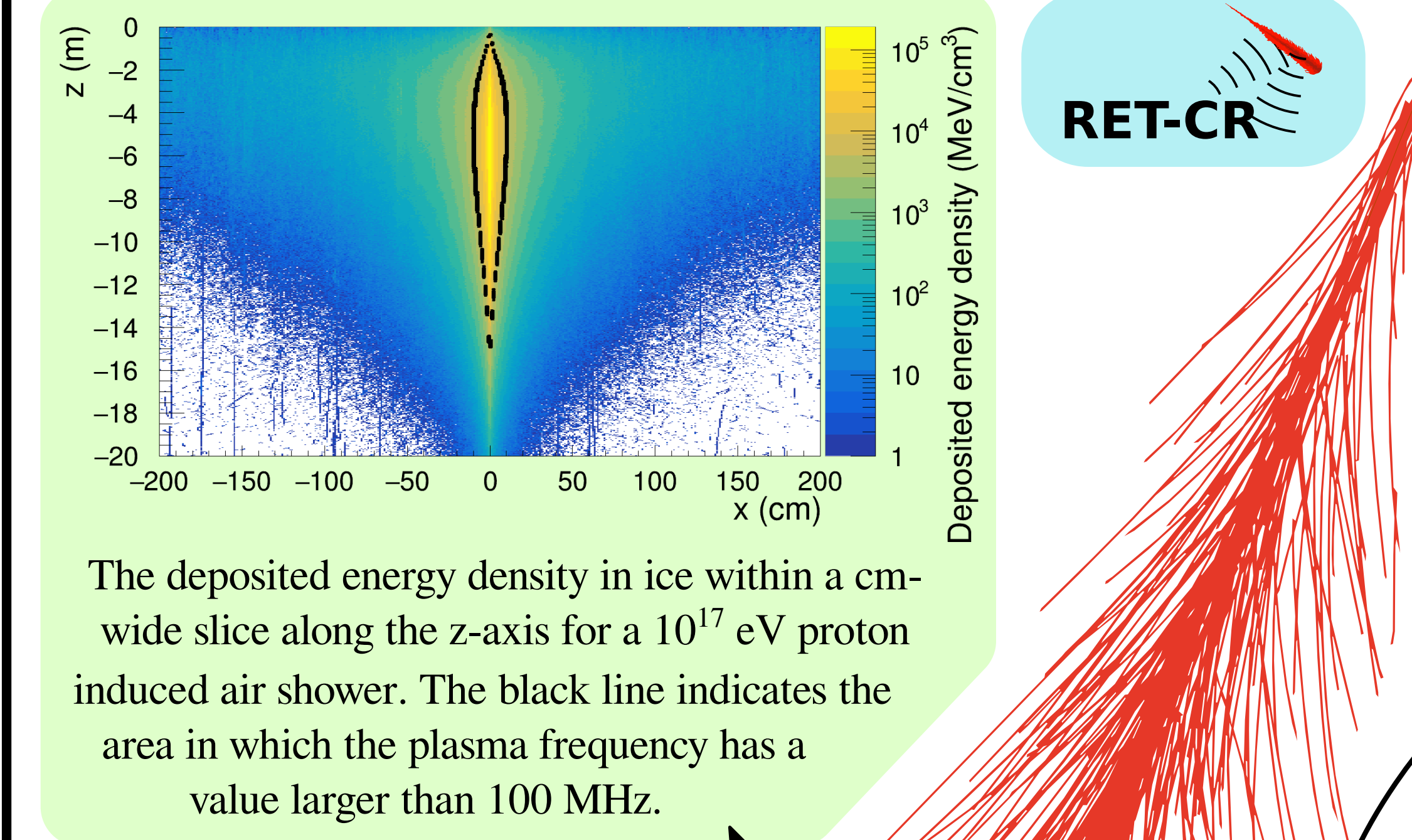
Cosmic Ray Sensitivity

- RET-CR will detect in-ice cascades from atmospheric cosmic ray cascades
- Event rate: > 1 event per day at 10 PeV
- Uses surface trigger, and serves as a testbed for RET-N



In-ice Particle Cascade from Air Showers

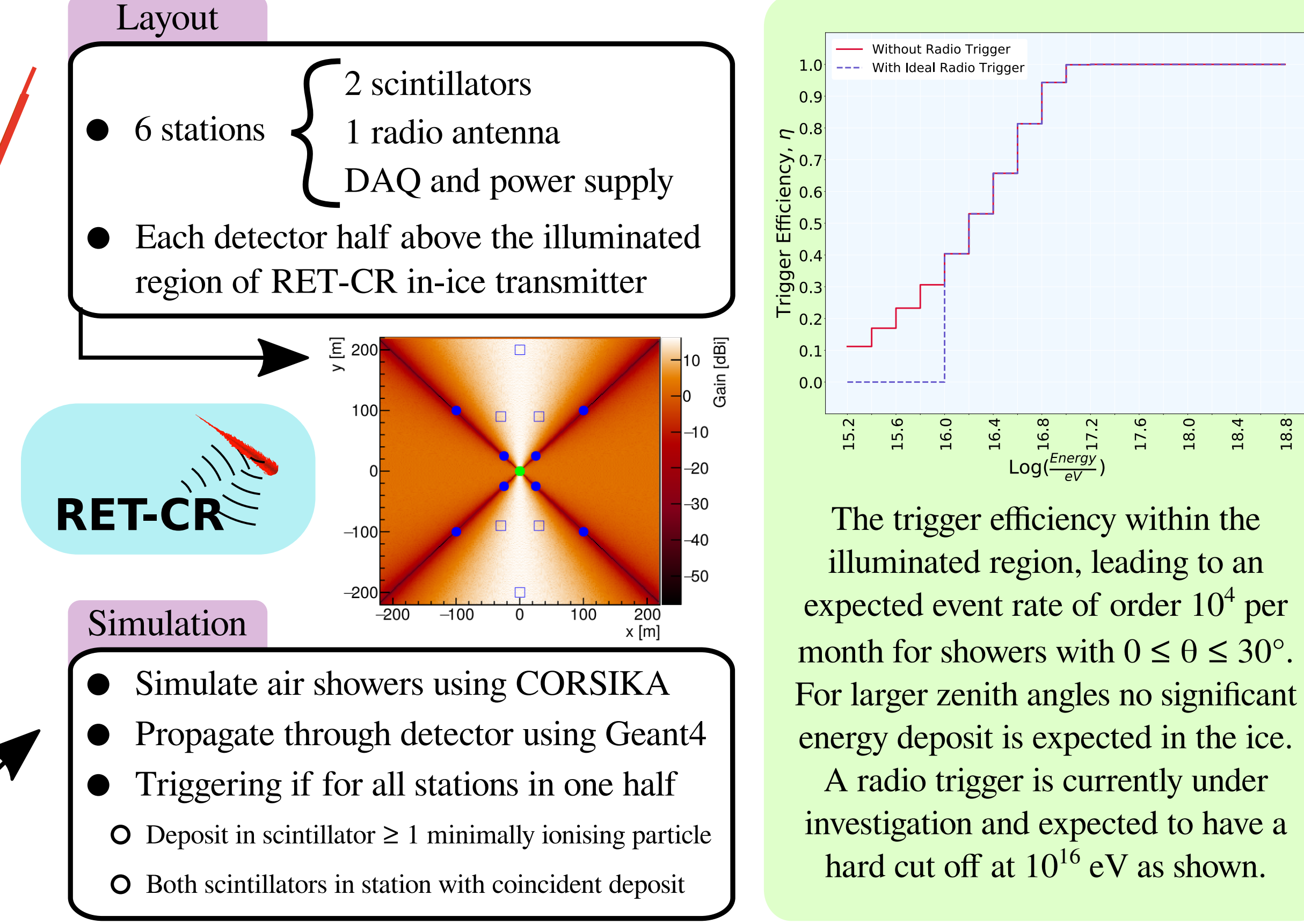
- Simulate air showers using CORSIKA
- Propagate through ice using Geant4
- Calculate deposited energy density and corresponding plasma frequency



Conclusion

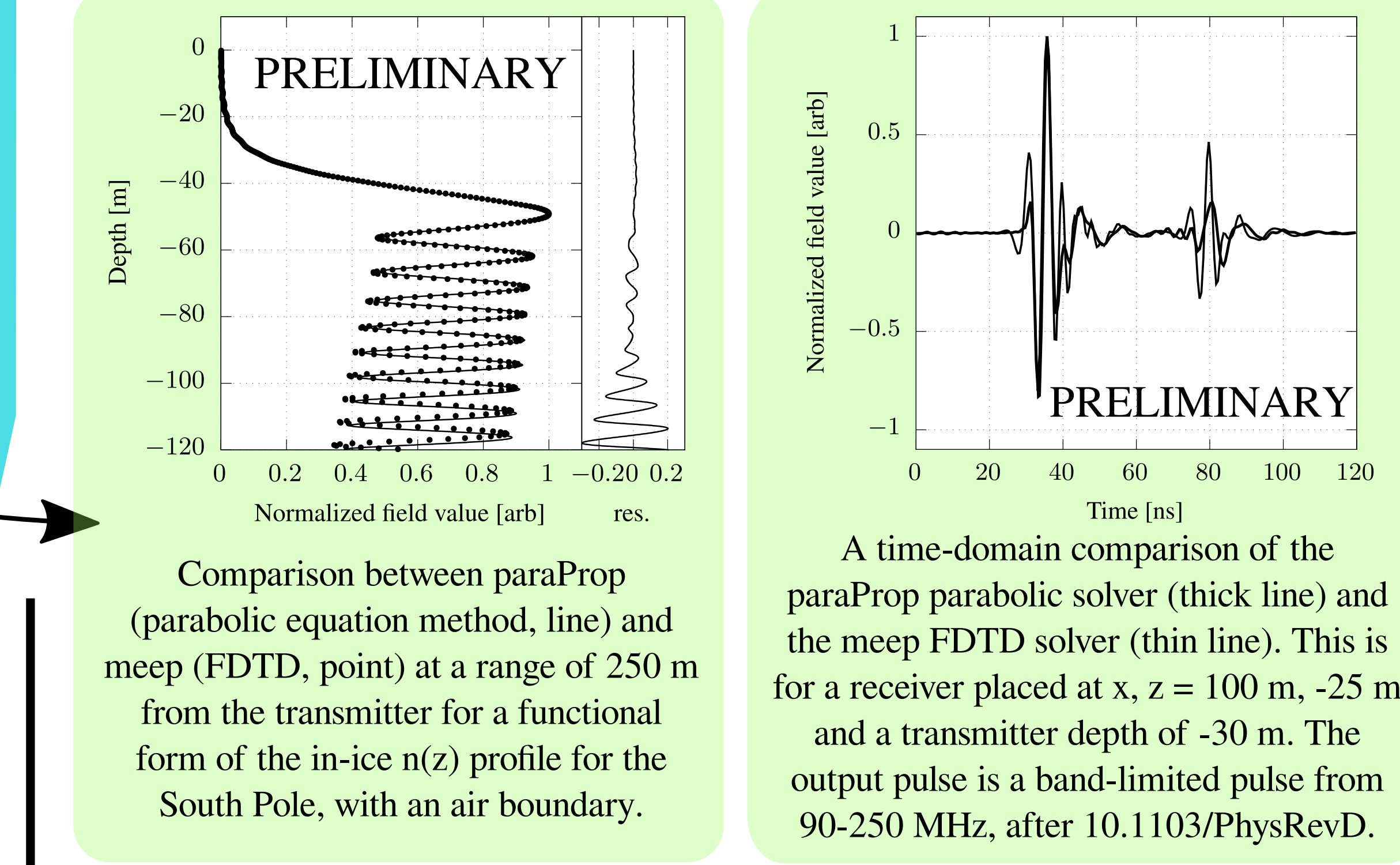
We presented a new, novel, radar detection technique to probe high-energy particle cascades in dense media. This method will be used in ice by the Radar Echo Telescope (RET). Fully-featured, first-principles radar echo simulations show that RET has a good projected sensitivity to neutrinos with > 10 PeV energies. Macroscopic scatter models show that the expected signals depend highly on cascade position and direction, providing good handle on event reconstruction. Proof of principle for this detection technique will be provided by detecting cosmic-ray air shower cores penetrating a high-altitude ice surface. For this, an additional surface component will be installed to trigger the radar DAQ using the radio emission and particle content of high-energy cosmic-ray induced particle cascades. We expect an event rate of order 10^4 per month.

Surface Detector as External Trigger



Ice Properties

- Determine radio profile of near surface transmitters due to electrical properties of firm (top ~200 m of an ice sheet), extending existing studies to Antarctic ice [4], [5]
- Simulate using parabolic solver techniques, verifying against FDTD simulations
- Calculate max and time-dependent E-field accurately and efficiently as function of position
- Under development - to be included in future models and simulations



References

- [1] S. Prohira, et. al., Phys. Rev. Lett. 124, 091101 (2020), arXiv:1910.12830
- [2] K. D. de Vries, K. Hanson, and T. Meures, Astropart. Phys.60,25 (2015), arXiv:1312.4331
- [3] S. Prohira and D. Besson, Nucl. Instrum. Meth.A922, 161(2019), arXiv:1710.02883
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- [5] P. Allison et al., arXiv:1908.10689 [astro-ph.IM], (2018)