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Radio-emission calculations in CORSIKA 8

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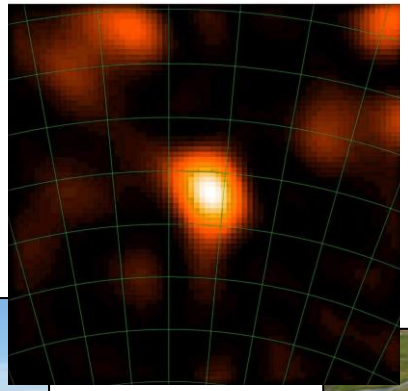
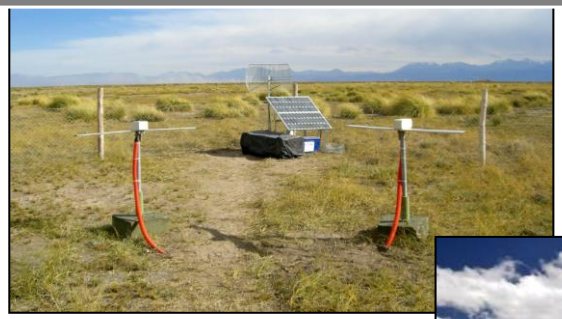



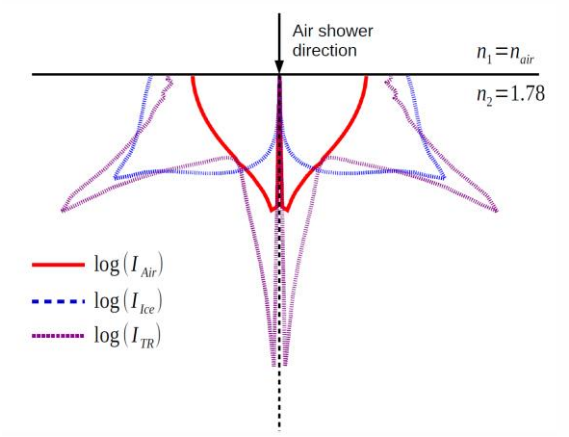


Full Monte Carlo simulations of radio emission

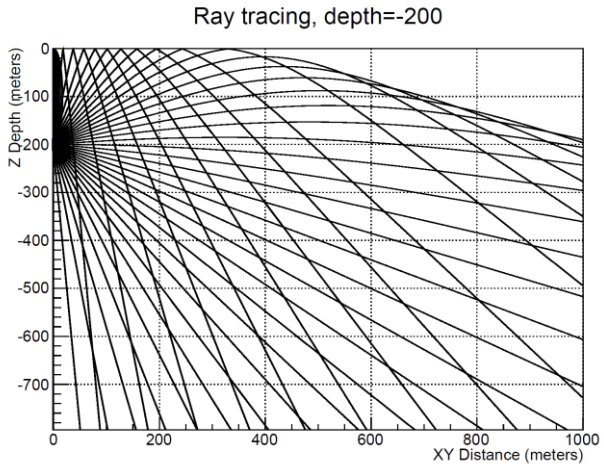
- CORSIKA7 with the CoREAS plugin
  - COAST interface from Fortran to C++
  - Calculate radio emission for e+/e- from individual track segments
  - Endpoint formalism
  - Fully MPI-parallelized
  - Monolithic CORSIKA7 code is not very flexible
- AIRES modified to ZHAireS
  - Calculate radio emission for e+/e- from individual track segments
  - ZHS formalism
  - Also limitations arising from AIRES design
- The existing codes have served us well, but we are running into severe limitations.

Limitations of CoREAS in CORSIKA 7

- the atmosphere is too limited, need transition to dense media
  - in particular for in-ice radio detection of neutrinos



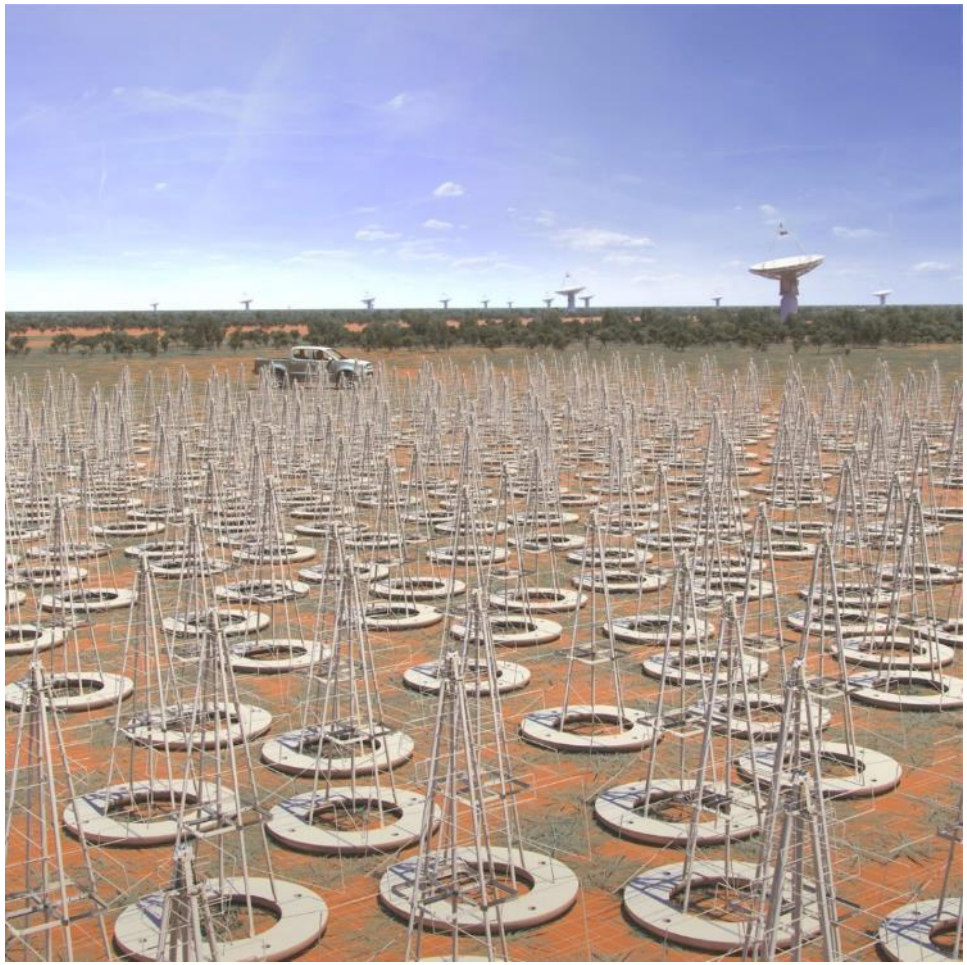
K. de Vries et al., arXiv:1503.02808



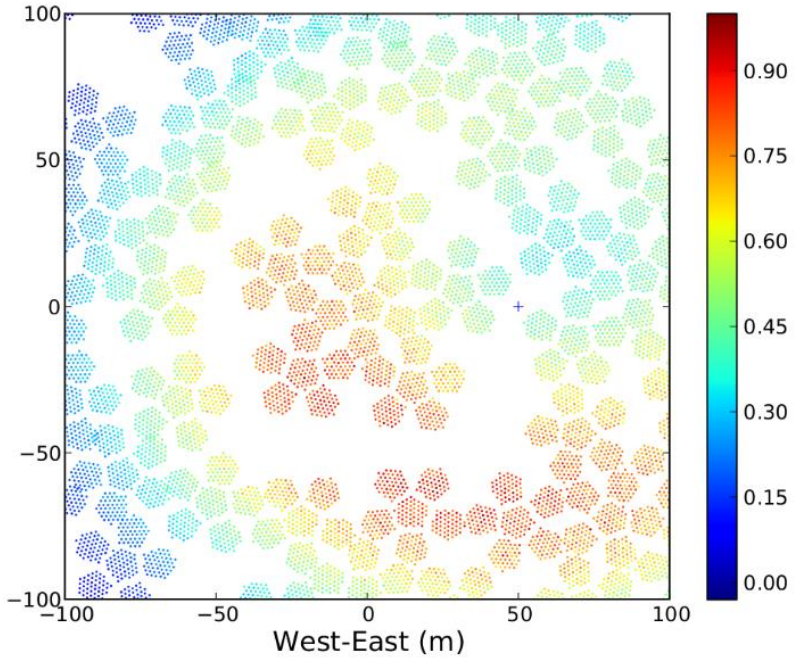
S. Barwick et al., arXiv:1804.10430

- in general, the geometry needs to be more flexible
- need refraction during wave propagation in refractive index gradients
- computation times can be very long (many antennas)
  - could be overcome by GPU parallelisation

Simulations for very dense antenna arrays



- ~70,000 dual-polarized antennas within 750 m diameter



TH et al., ARENA2016 conference, arXiv:1608.08869

Implementing radio in CORSIKA8

- We ***need*** radio in CORSIKA8 sooner rather than later
- The basic framework of CORSIKA8 is ready to start implementing
- Several aspects to come up with a usable code
  - A radio emisison „process“ interfaced to existing code (see Remy‘s talk)
  - An electromagnetic interaction model
  - A magnetic field model and its influence on particles
  - A defined output format (CoREAS and ZHAireS have been using HDF5)
  - A defined input format (configuration files? Python interface? …)
  - A decision on a parallelization framework (should accomodate multi-processor, multi-node, and GPU parallelization)
  - Porting of existing endpoint and ZHS formalisms (easy)
- So far, many of these aspects were not considered pressing, but for the radio community to make progress we need to decide on these soon!

Envisioned implementation of radio

- Radio part should be modular in itself, i.e. decouple
  - Emission calculation (e.g. ZHS vs. endpoints)
  - Signal propagation
    - Straight lines (for air showers/constant density)
    - Ray tracing
    - Full FDTD propagation?
  - Receive module
    - Add emission from all particle tracks (as right now in CoREAS)
    - Keep track of incoming direction of signal -> efield in angular bins
    - On-the-fly convolving with directional antenna response

Summary

- The radio community heavily relies on simulations
- The next-generation experiments run into limitations of CORSIKA7
  - in-ice neutrino detection: atmosphere too limited
  - dense arrays: computing times too long
- We should start with radio implementation in CORSIKA8 now, this will require many decisions that were so far postponed.