Simulating the radio emission from air showers with CORSIKA 8

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for the CORSIKA 8 collaboration

Outline

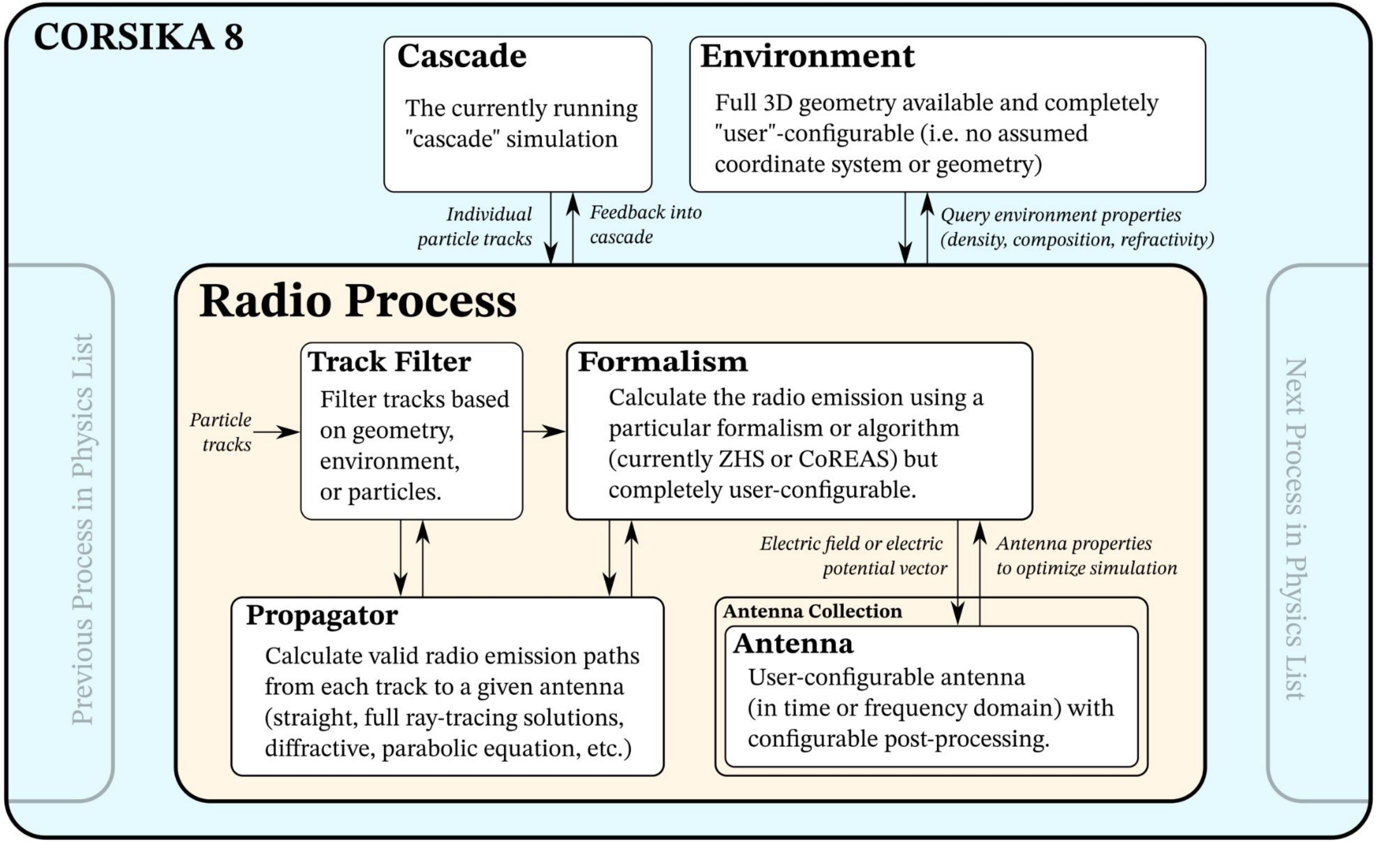
- Ideal ICRC poster
- Iron shower studies & problems
- Discussion

Important plots (but not final) & structure for ICRC poster

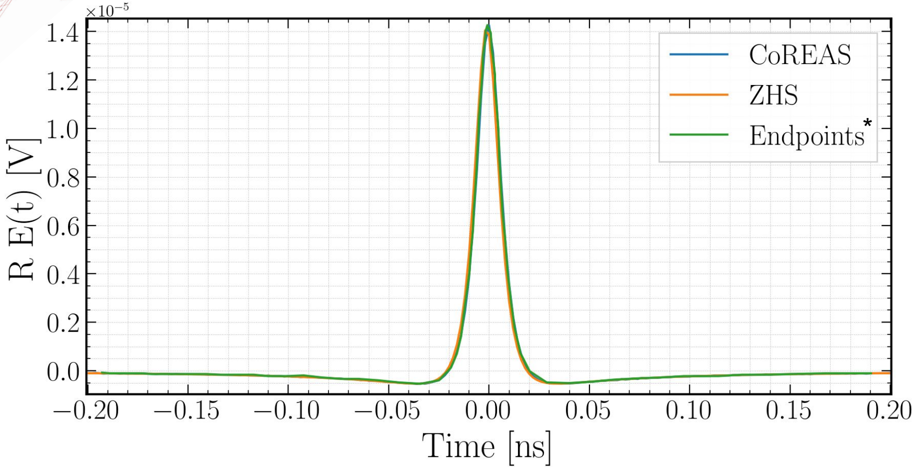
Radio module architecture

User-configurable parameters

- Filter
- Formalism
- Propagator
- Antenna



Electron in a uniform magnetic field

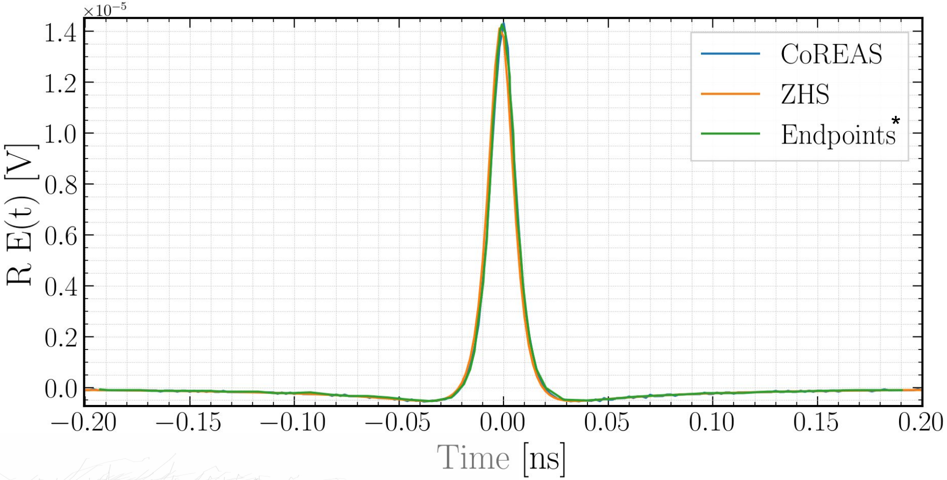


→ Manual tracking algorithm

100.000 points on a circle (L = 100m) connected by straight track segments. The relativistic electron of fixed energy, is allowed to travel on these tracks.

→ CORSIKA 8 tracking algorithm

Used C8’s LeapFrog magnetic field tracking algorithm. Created a suitable environment with the corresponding values for magnetic field and gyrofrequency of the relativistic electron.



* C.W. James, H. Falcke, T. Huege and M. Ludwig, doi: 10.1103/PhysRevE.84.056602

100PeV Iron shower

- branch: testing-branch-May23
- corsika.cpp
- em cuts = 0.5MeV
- hadron cuts = muon cuts = 0.3GeV
- thinning: ε = 1e-6, max weight = 100
- seed = 2723141261

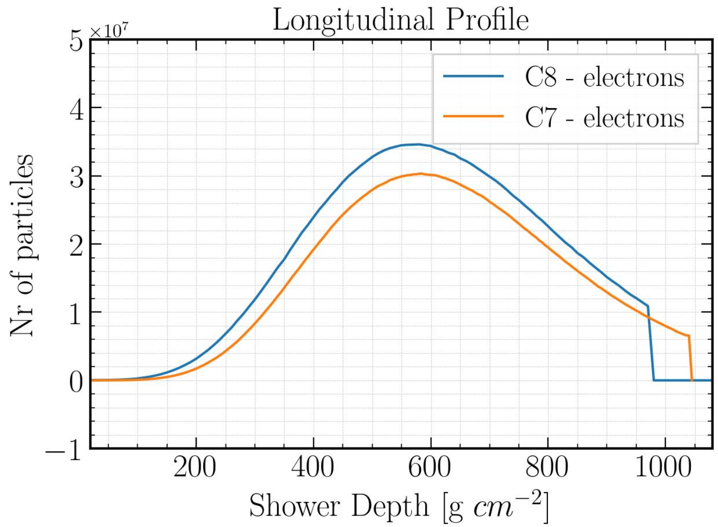
Simulation of an extensive air shower

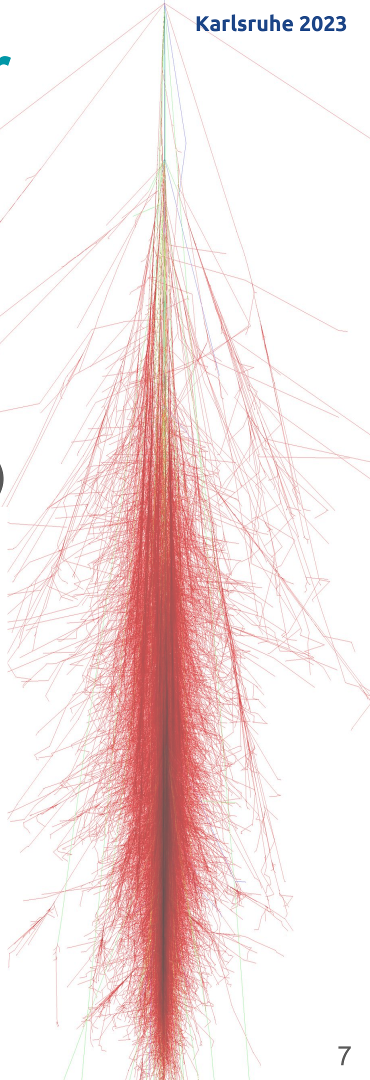
- 100 PeV iron-induced vertical shower
- US Standard atmosphere – Gladstone Dale law refractive index
- Horizontal geomagnetic field B = 50 µT aligned in the x direction
- $X_{\max} \approx 570\, g\, cm^{-2}$
- Star-shaped grid of antennas – 20 concentric rings (25m - 500m)

Comparison

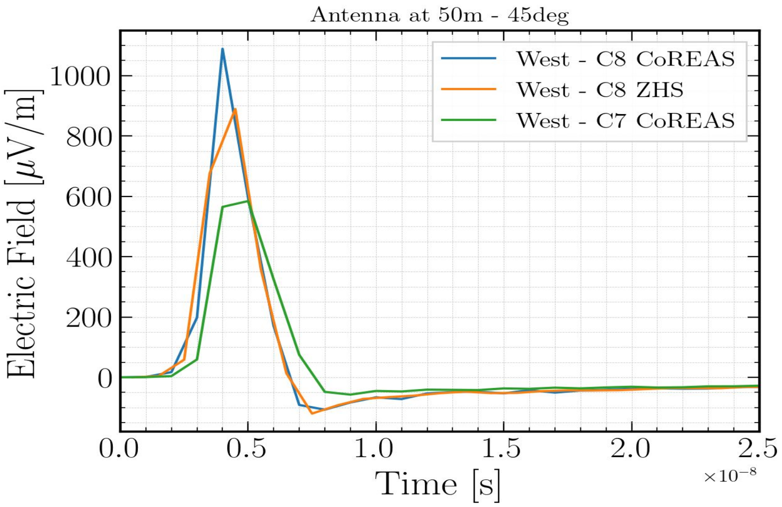
- CORSIKA 8 – CoREAS
- CORSIKA 8 – ZHS
- CORSIKA 7 – CoREAS

PROPOSAL 7.5.1
FLUKA
SOPHIA
SIBYLL
PYTHIA8





Pulses comparison

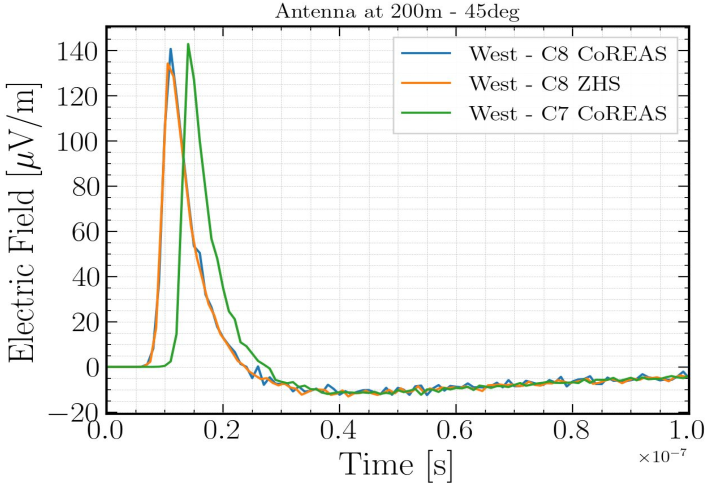


Antenna at 50m from the shower core

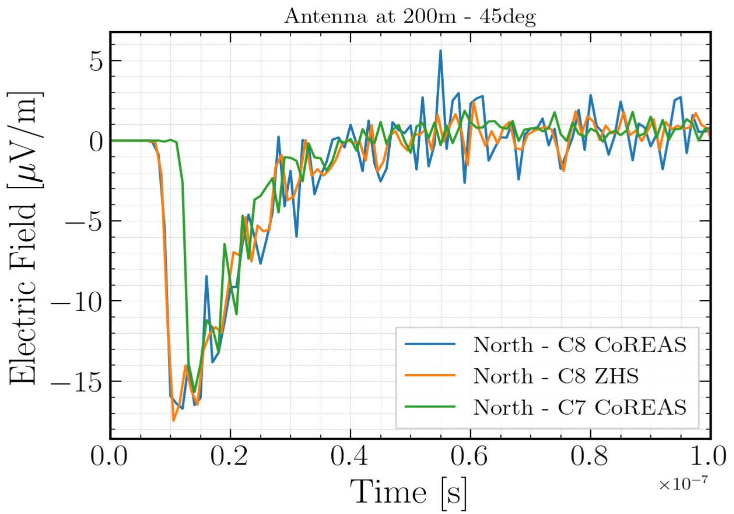
- Close to the shower core the amplitude is 50% off compared to C7
- ZHS and CoREAS are ~15% off

Antenna at 200m from the shower core

- Very good agreement between C7 and C8 in pulse amplitude
- Offset in time



Polarization properties

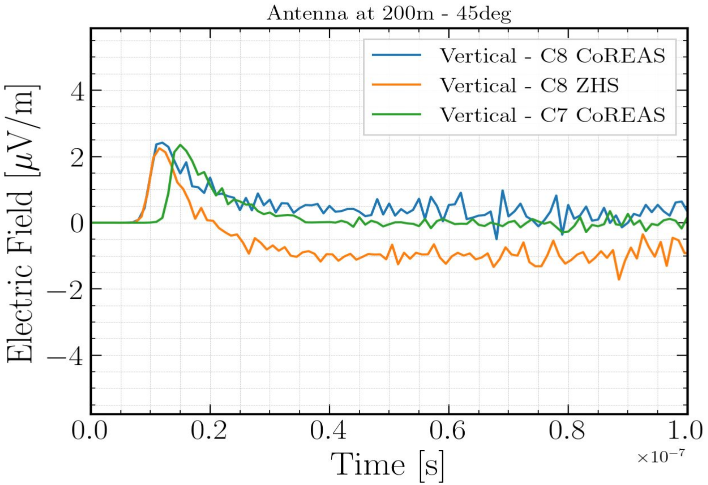


Antenna at 200m from the shower core

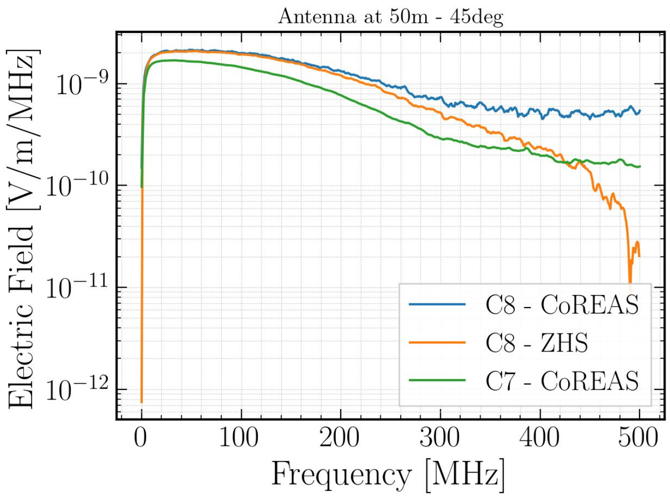
- Polarization behaviour matches
- Good agreement in pulse amplitude
- Offset in time

Antenna at 200m from the shower core

- Good agreement in pulse amplitude
- Offset in time
- ZHS shows weird behaviour of negative electric field values



Frequency spectra comparison

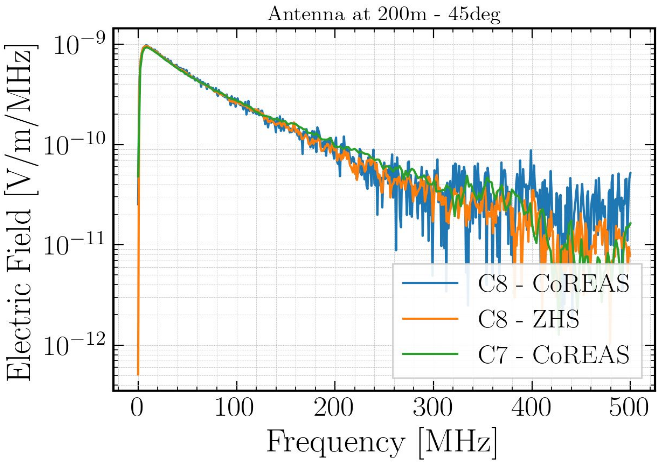


Antenna at 50m from the shower core

- Overall more power in C8 vs C7
- C7 and C8 CoREAS show similar behaviour
- C8 ZHS has a sudden drop in power after ~400MHz

Antenna at 200m from the shower core

- Overall similar behaviour
- C8 CoREAS seems more "noisy"
- C8 ZHS starts from much lower power at 0MHz



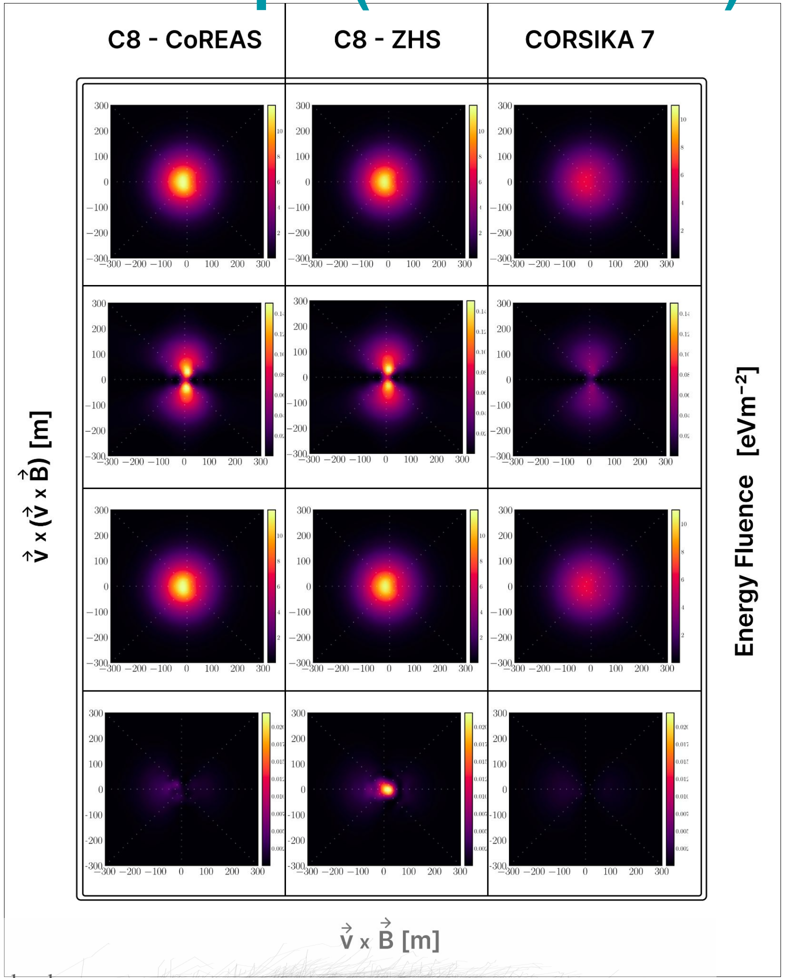
Energy fluence 2D maps (30 - 80 MHz)

All polarizations →

$\vec{v} \times \left(\vec{v} \times \vec{B}\right)$ →

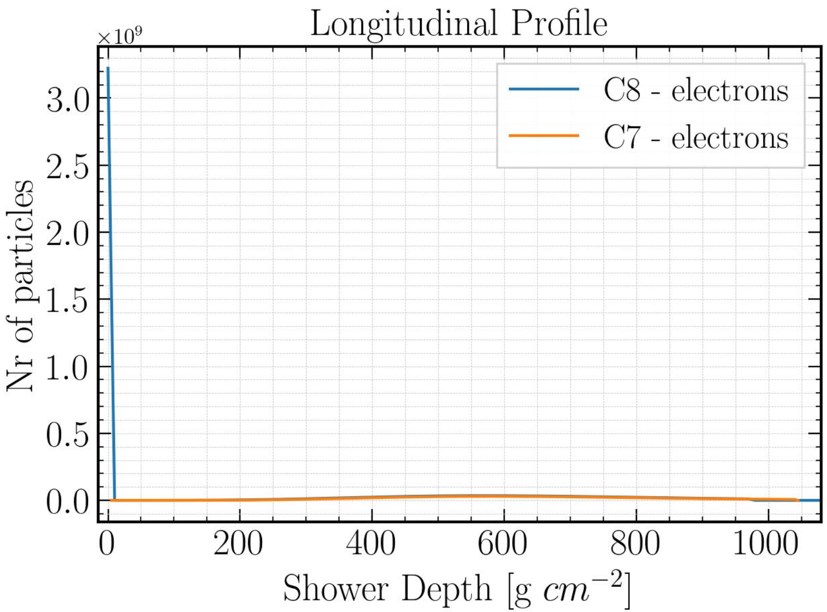
$\vec{v} \times \vec{B}$ →

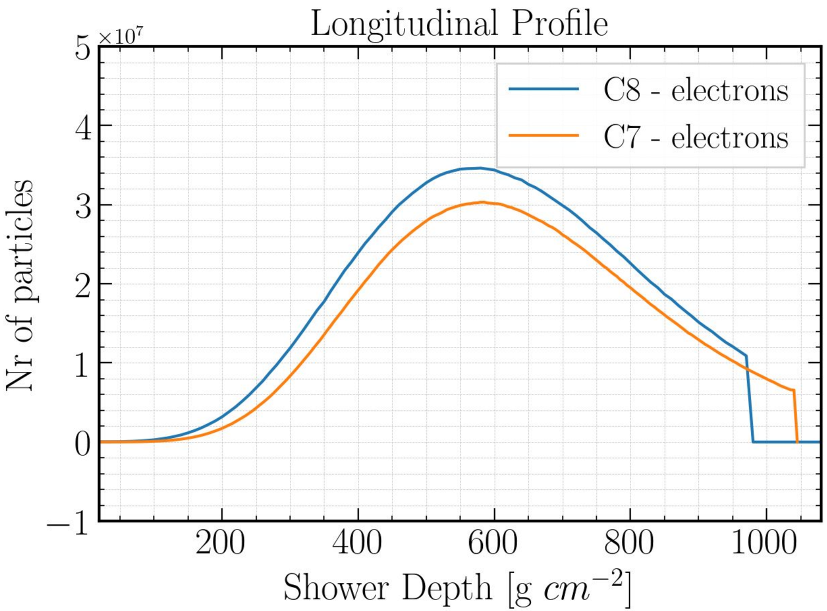
$\vec{v}$ →



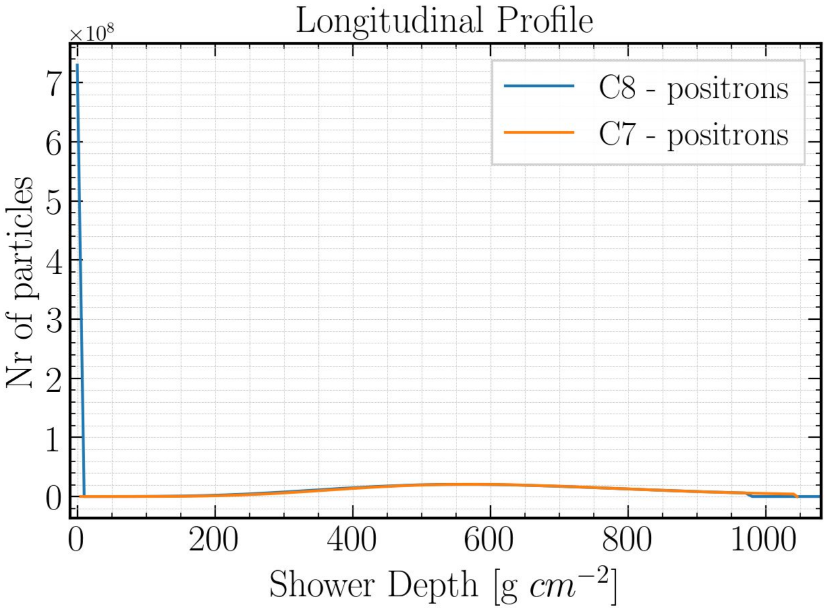
Problems I noticed studying iron showers with radio on

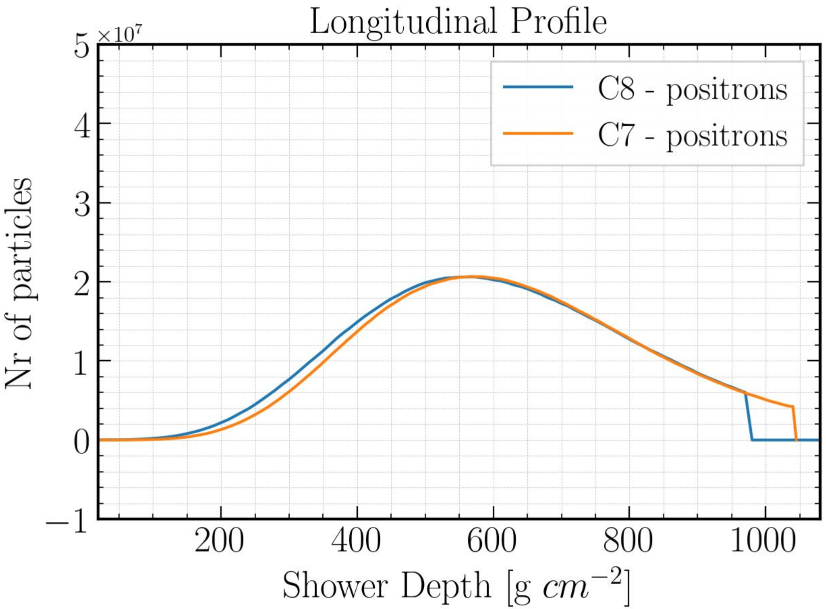
Closer look to longitudinal profiles



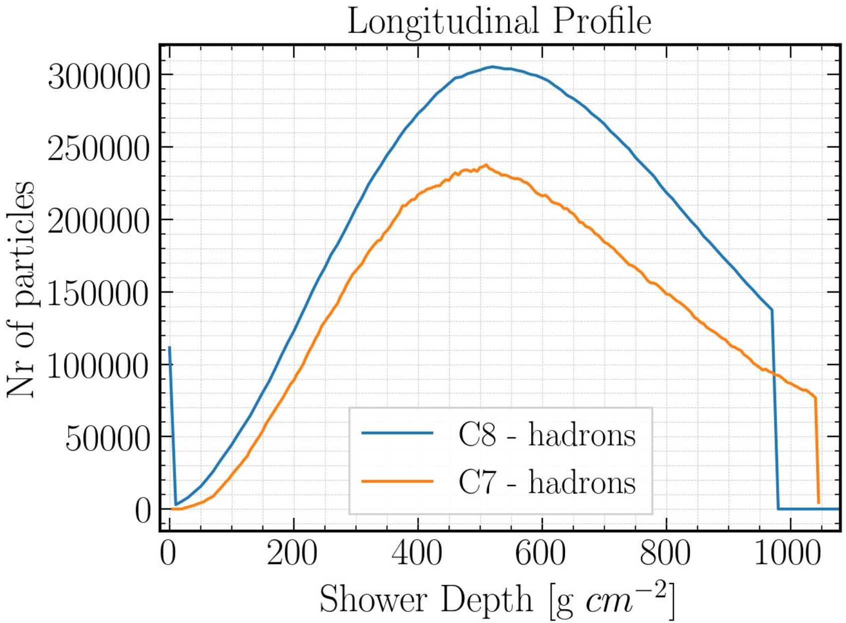


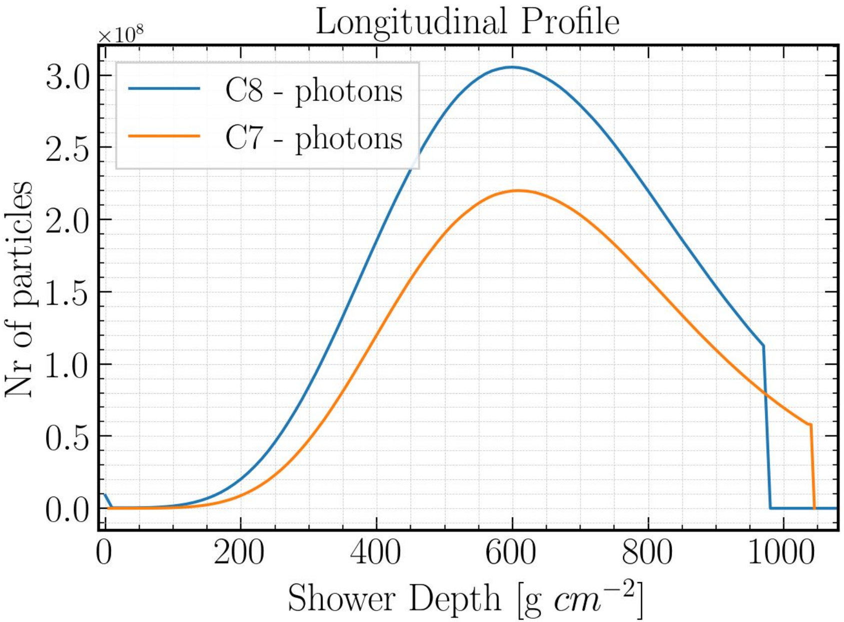
Closer look to longitudinal profiles



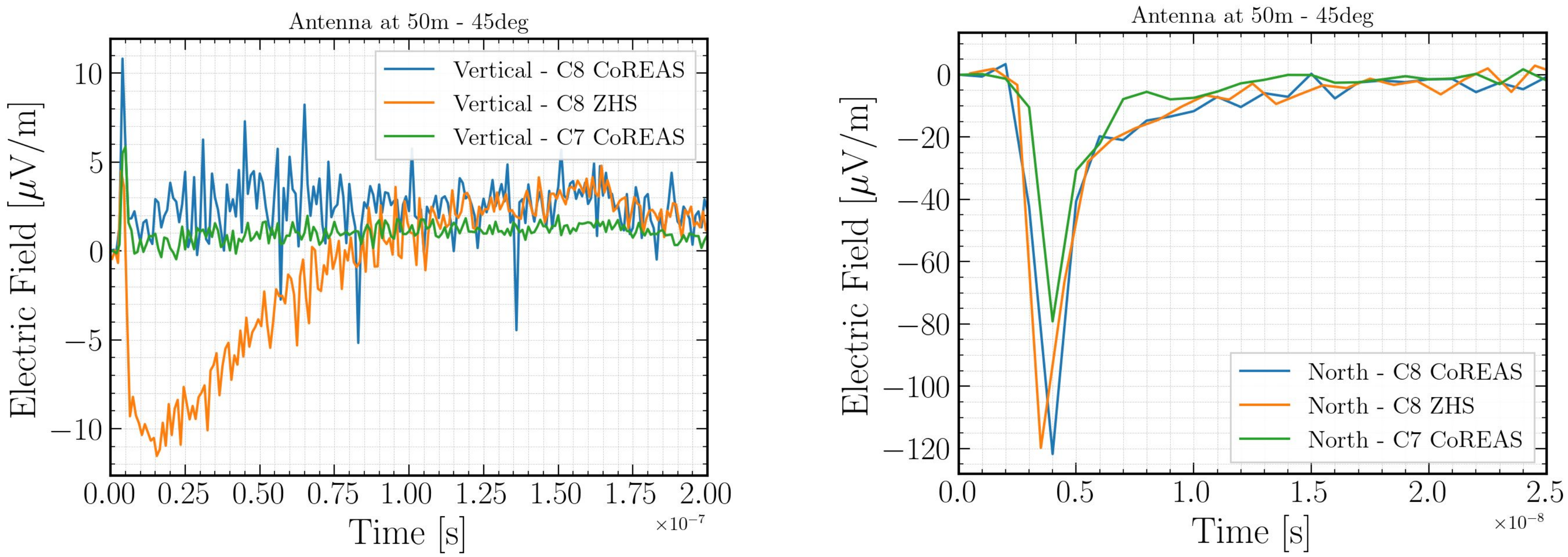


Closer look to longitudinal profiles

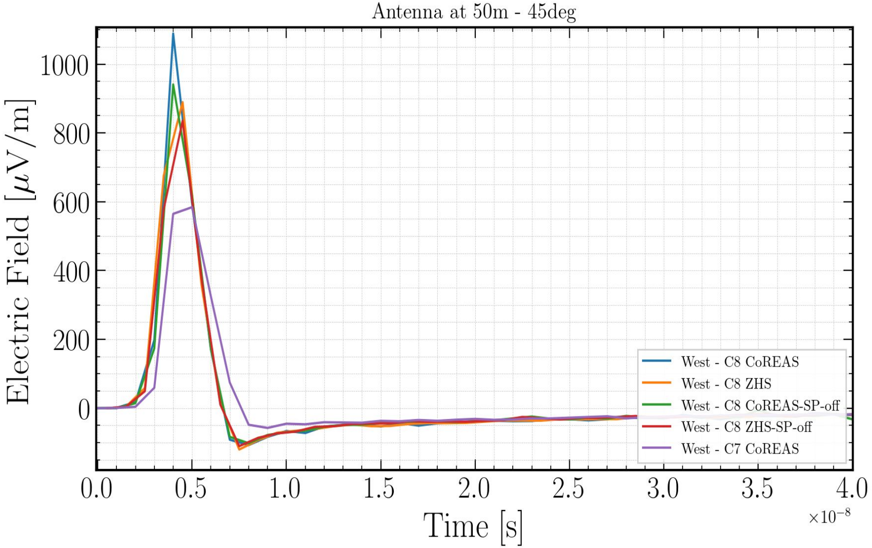


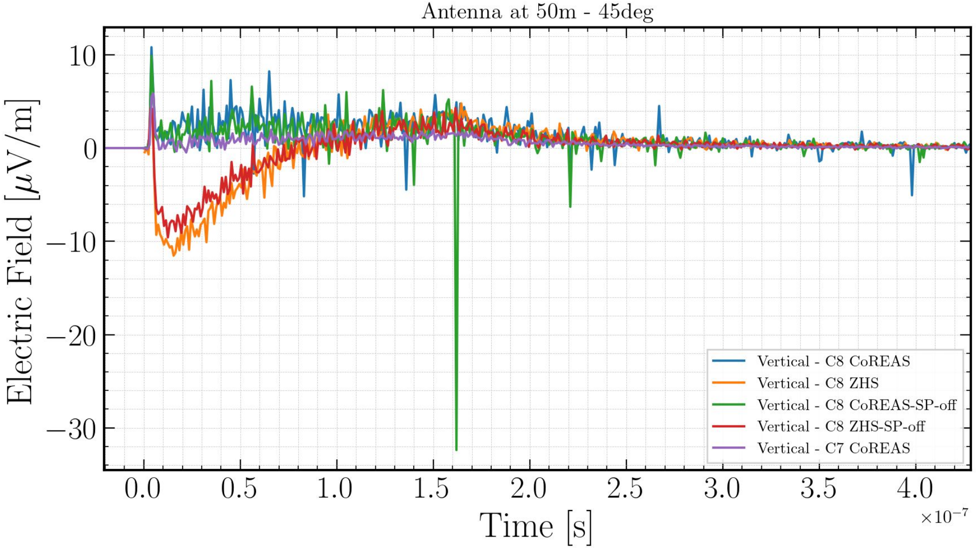


Pulses close to shower core is where we see most problems



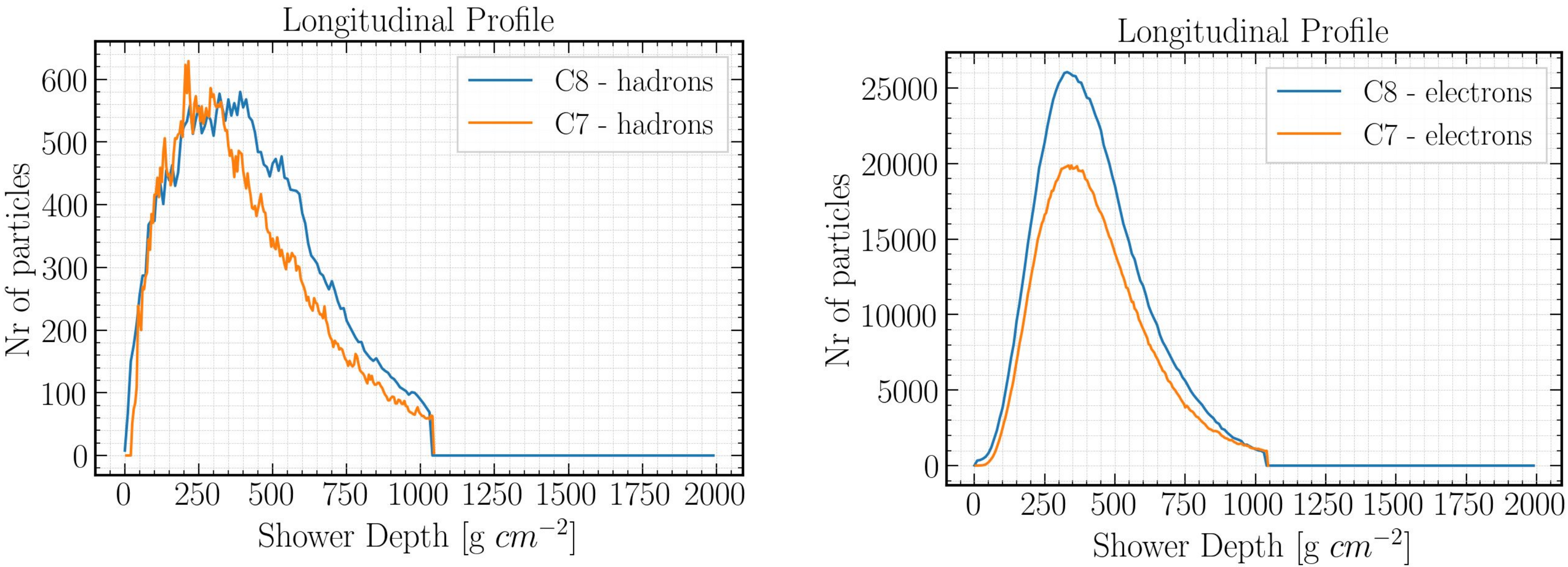
I thought the issue might be related to MR 451 - stochastic photon





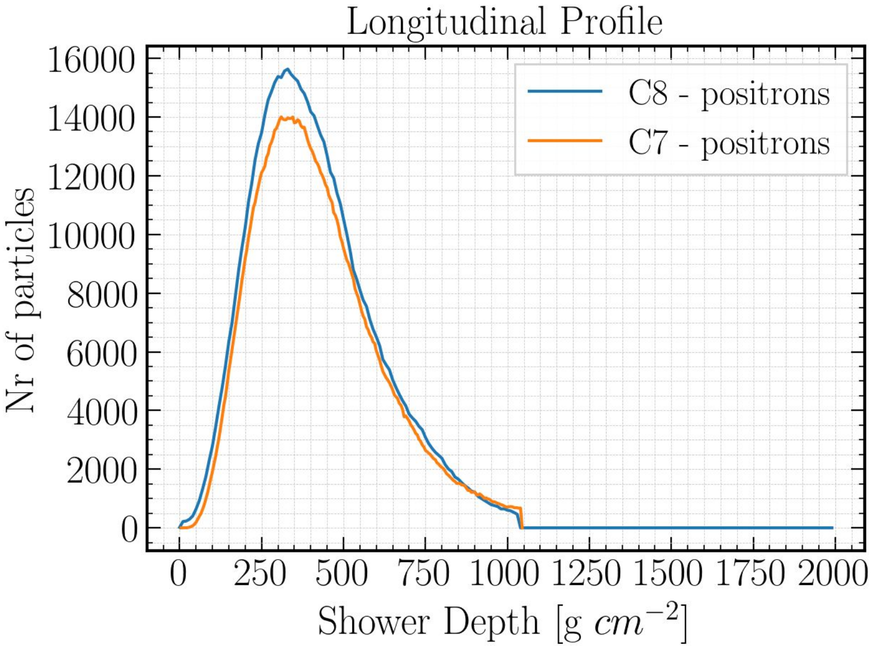
But not! Things do seem better with MR 451 turned on.

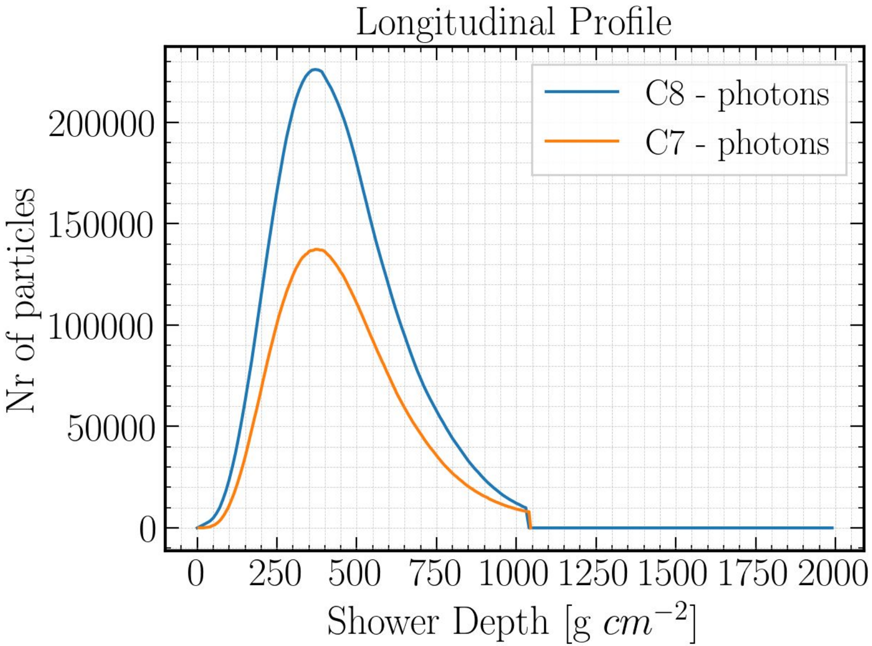
I tried a 100 TeV iron shower



Things seem better in this simpler scenario

I tried a 100 TeV iron shower





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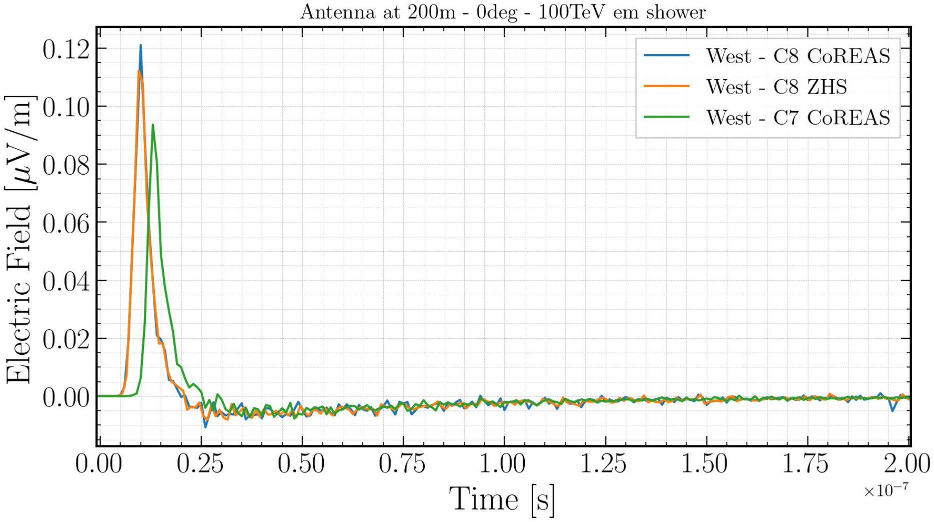

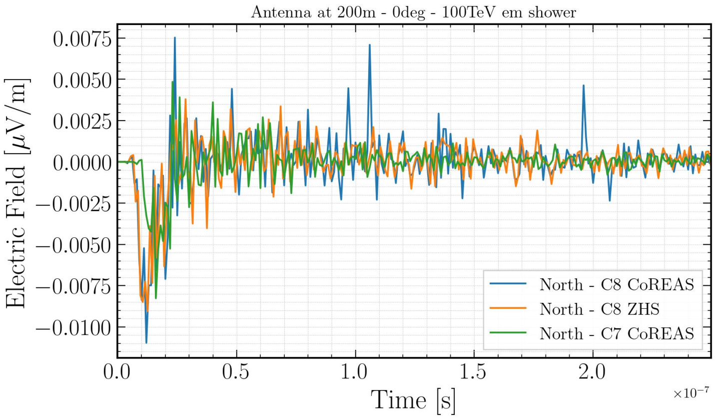

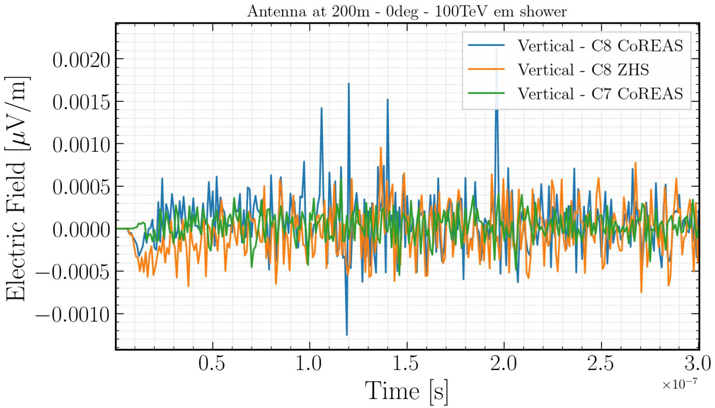

Discussion

- Maybe there is something wrong in the configuration I run (?) – Although, I noticed this behaviour in multiple iron showers I simulated.
- Maybe the time offset on my pulses could be explained because of my new propagator (?). I am worried because it keeps track of all the particles – even the ones leaving the atmosphere or are deep into the ground. But this alone is not enough to explain the problems I see.
- The most worrying thing is how at 0 g/cm^2 the shower starts with many many electrons, positrons and hadrons. I cannot explain this.
- V pol for ZHS is rather odd. I want to add a ZHAireS sim to see if it has the same behaviour.
- I have been informed that there is a recent nice fix from PROPOSAL which I would like to try out.
- Any thoughts?

Thank you!