Simulating radio emission from air showers with CORSIKA 8

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for the CORSIKA 8 collaboration

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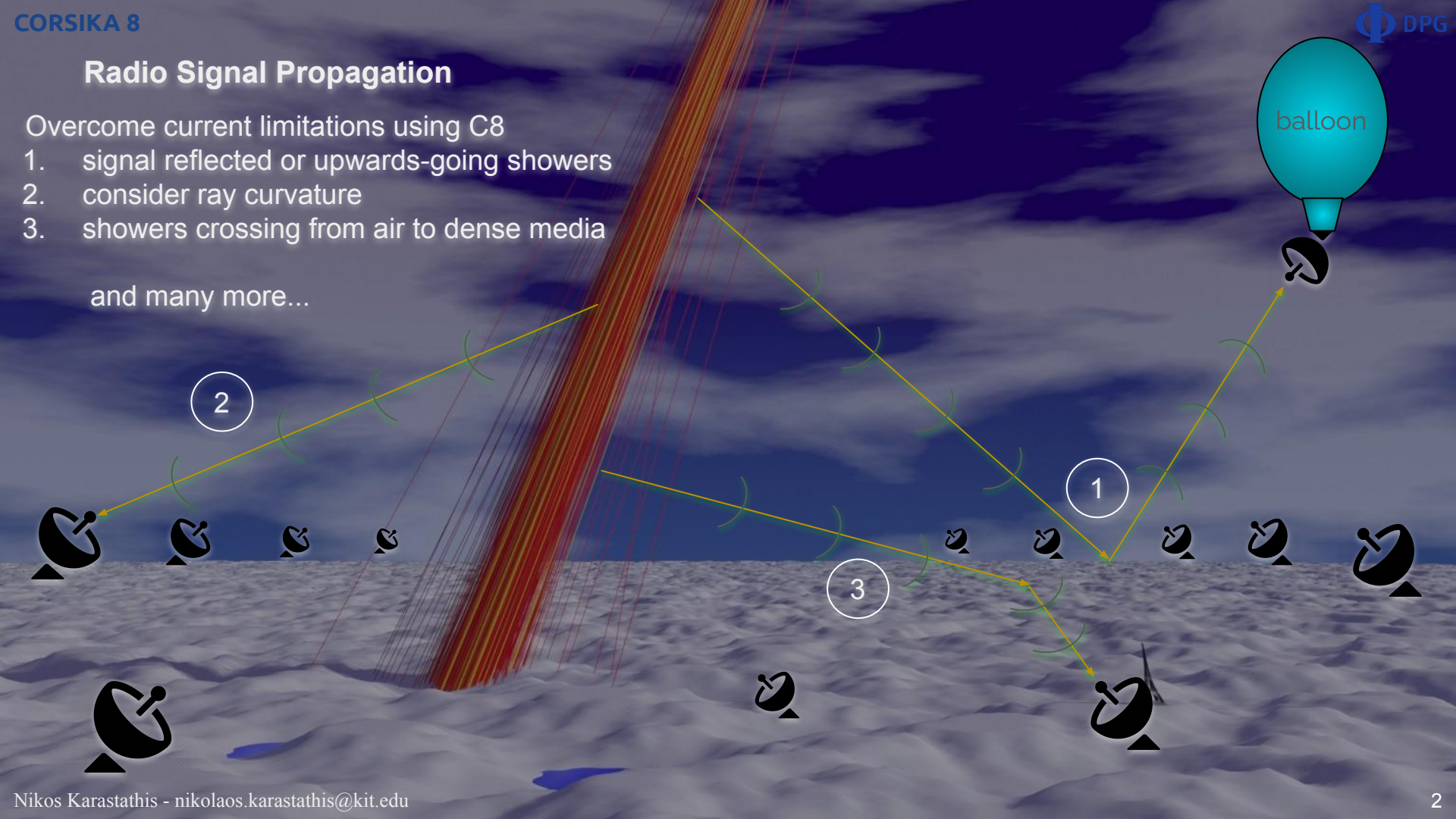
DPG

Radio Signal Propagation

Overcome current limitations using C8

1. signal reflected or upwards-going showers
2. consider ray curvature
3. showers crossing from air to dense media

and many more...



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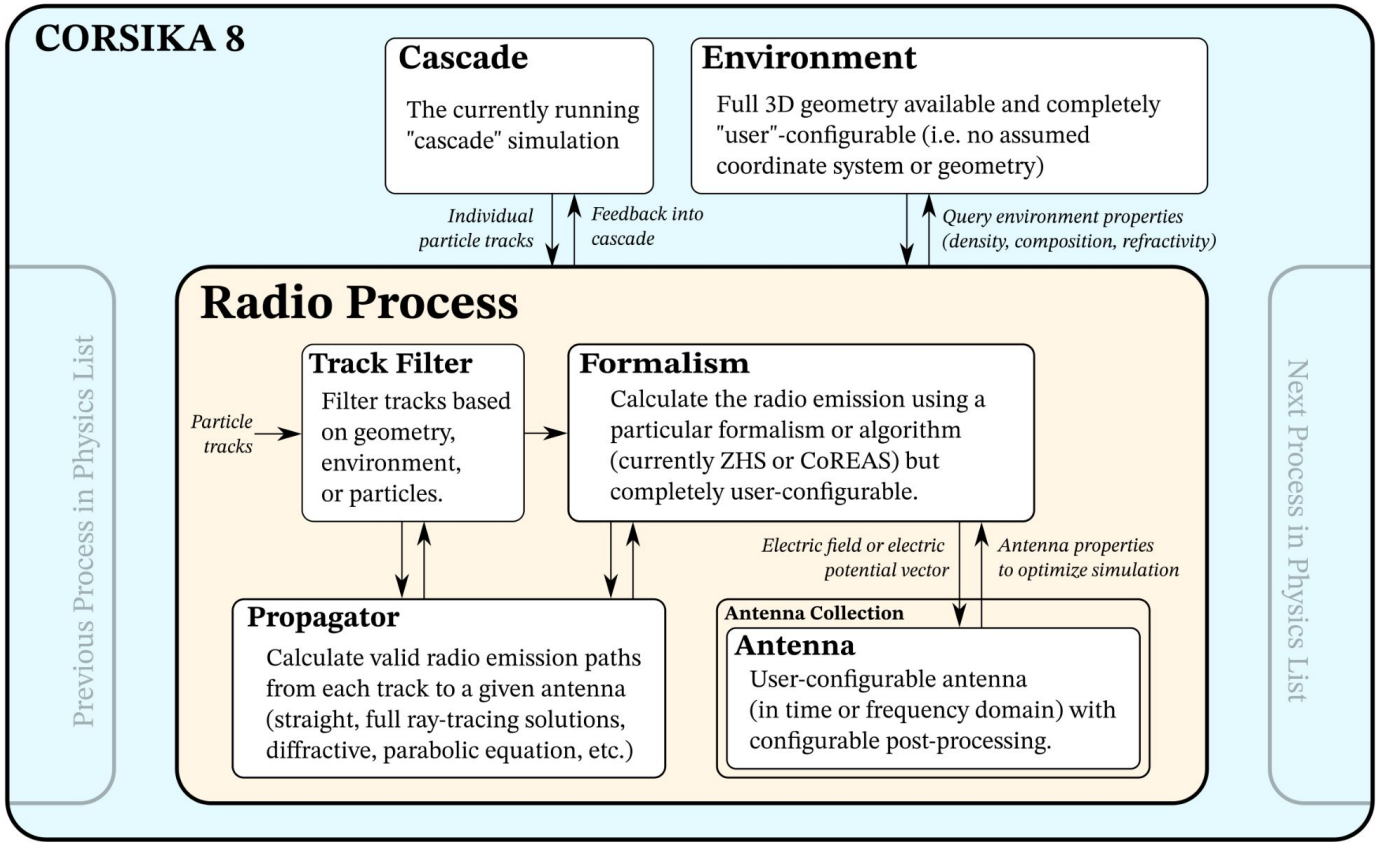
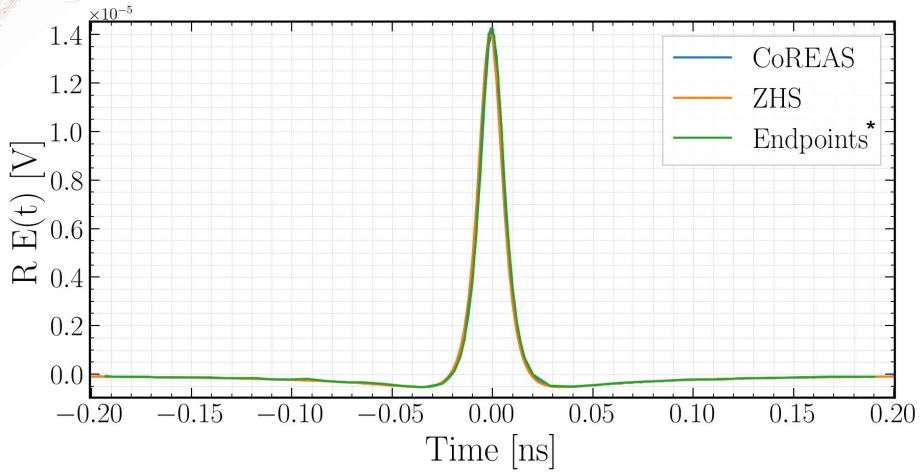
Radio module architecture

User-configurable parameters

- Filter
- Formalism
- Propagator
- Antenna



Electron in a uniform magnetic field

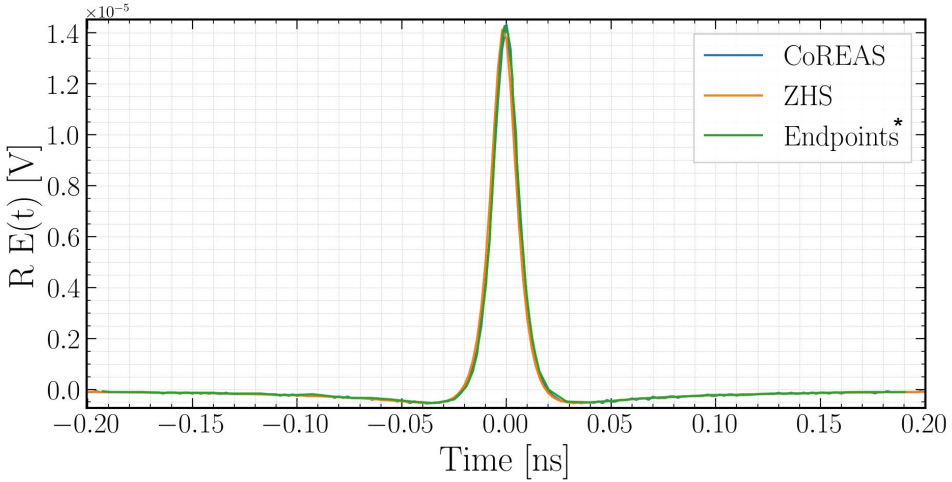


→ CORSIKA 8 tracking algorithm

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.

→ 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.



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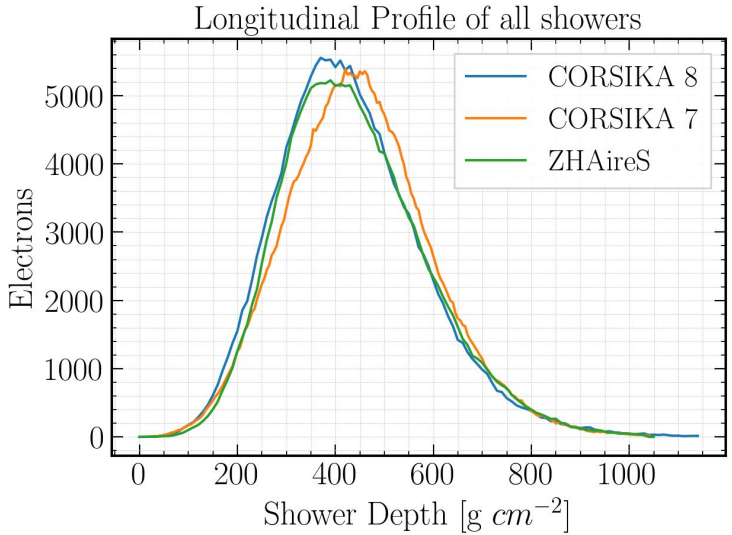
* T. Huege, C.W. James, H. Falcke and M. Ludwig, Proc. 32nd Int.Cosmic Ray Conf. (2011)4, 308 [1112.2126]

Simulation of an extensive air shower

- 10 TeV electron-induced vertical shower
- US Standard atmosphere - uniform refractive index (n=1.000327)
- Horizontal geomagnetic field B = 50 μT aligned in the x direction
- $X_{\max} \approx 430\, g\, cm^{-2}$
- Star-shaped grid of antennas - 20 concentric rings (25m - 500m)

Comparison

- CORSIKA 8 - CoREAS
- CORSIKA 8 - ZHS
- CORSIKA 7 - CoREAS
- ZHAireS



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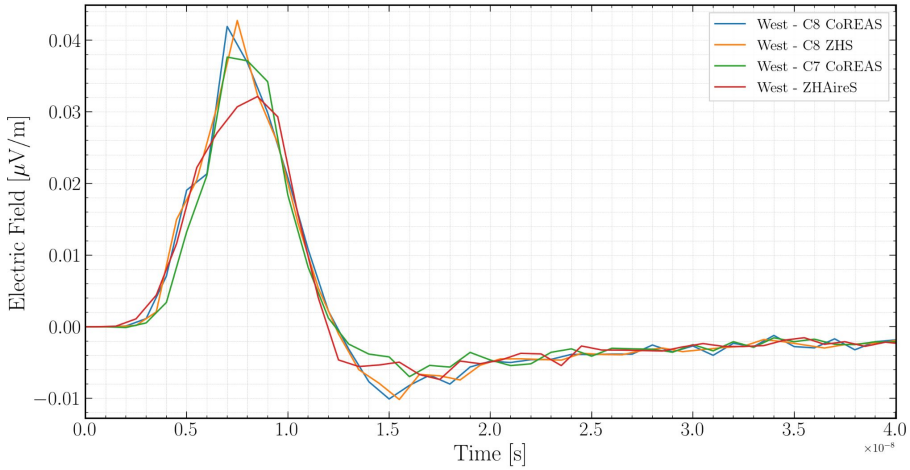
Pulses comparison

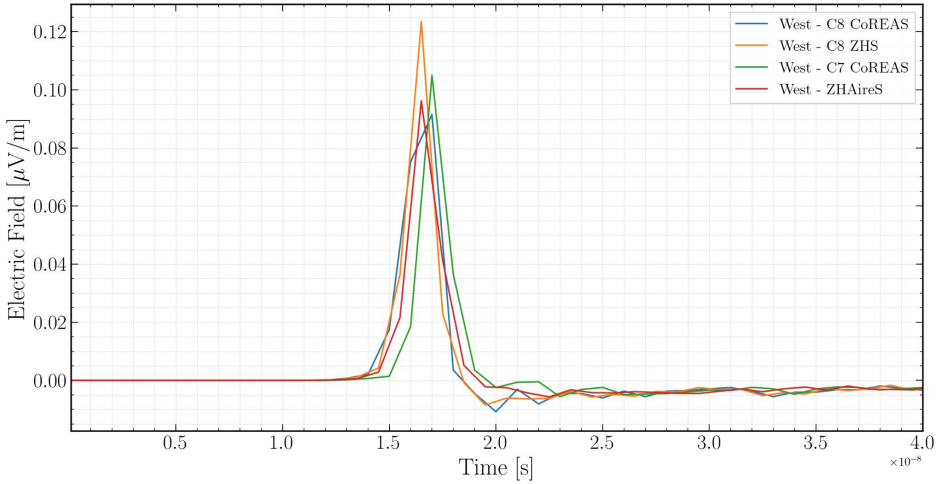


Antenna at 50m from the shower core

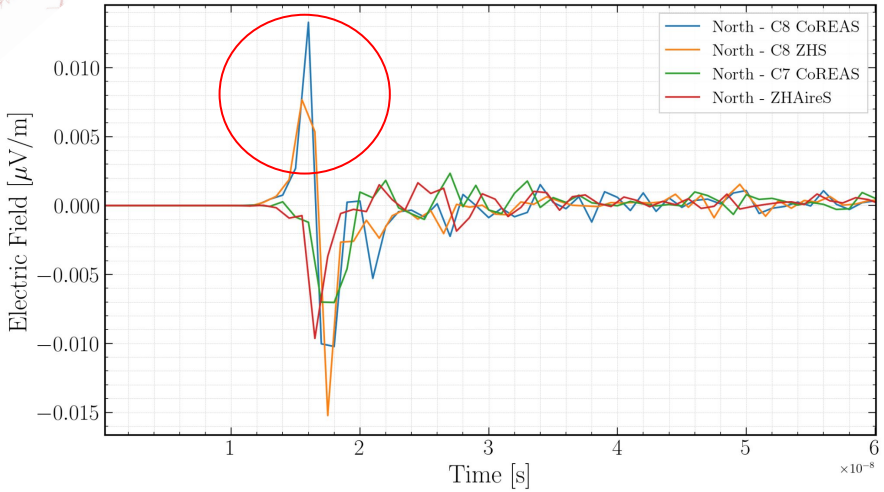
- Very good agreement between C8 (both formalisms) and C7
- ZHAireS seems slightly off

Antenna at 200m from the shower core

- Very good agreement between C7, ZHAireS and C8 CoREAS
- C8 ZHS is a bit higher

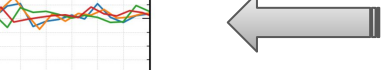


Polarization properties



Antenna at 200m from the shower core

- Polarization behaviour matches
- C8 pulses have a bipolar structure affecting the symmetry



Antenna at 200m from the shower core

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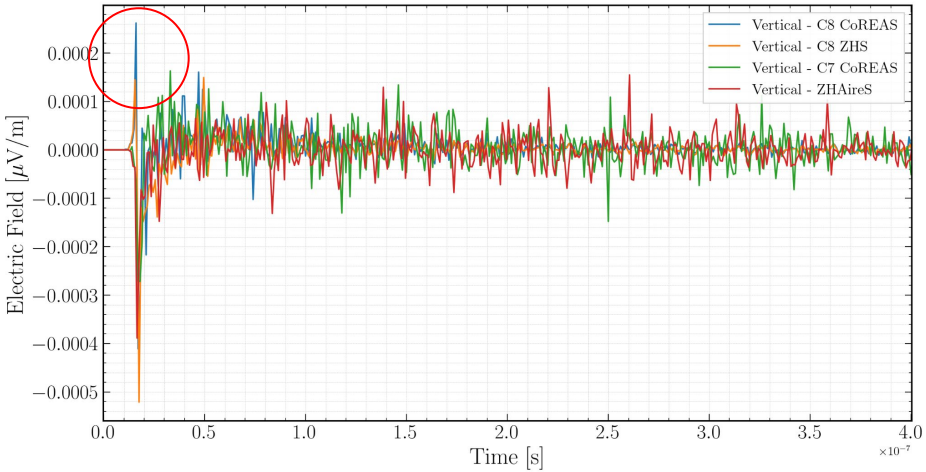
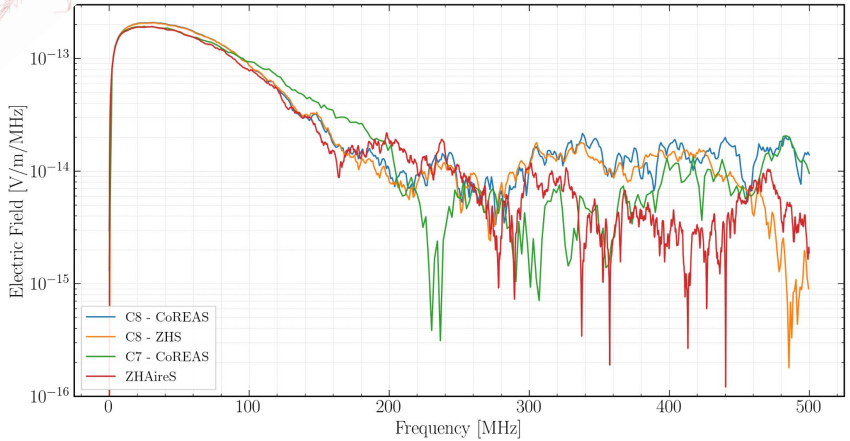


Frequency spectra comparison

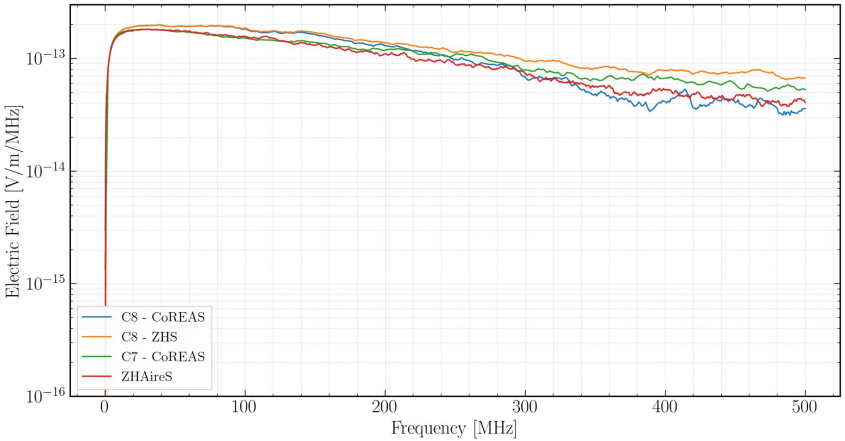


Antenna at 50m from the shower core

- Increase in power below 80 MHz for C8 spectra
- Increase in power between 300 and 400 MHz for C8 spectra
- C8 CoREAS and C8 ZHS diverge after 420 MHz
- Overall decent agreement

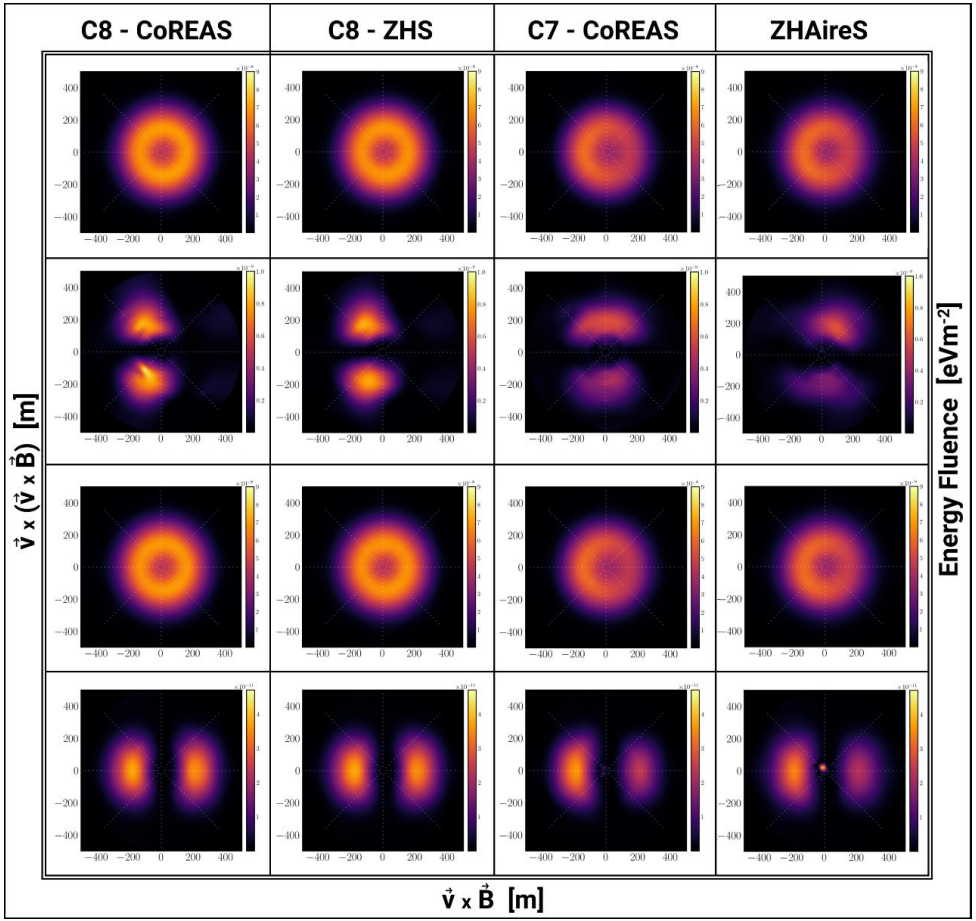
Antenna at 200m from the shower core

- Slight increase in power below 200 MHz
- C8 CoREAS and C8 ZHS diverge slightly after 200 MHz
- Overall decent agreement



Energy fluence 2D maps (30 - 80 MHz)

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



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Summary

- Radio module is designed to support next generation experiments
- Tested and validated in simple scenarios with and without C8 tracking
- Electron showers simulated show good agreement between C8 with C7 and ZHAireS in absolute amplitude of the pulse
- Agreement of polarization characteristics between C8 with C7 and ZHAireS
- North and Vertical polarization show a weird bipolar structure of the C8 pulses
- Very good agreement between CoREAS and ZHS algorithms in C8
- 2D fluence maps provide interesting observations and point us to investigate further

Radio module in C8 is capable of calculating the radio emission like C7 and ZHAireS. At this stage we are investigating unwanted behaviours and improvements in performance. The next step is the implementation of more sophisticated signal propagation scenarios.