Simulations of radio emission from air showers with CORSIKA 8

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for the CORSIKA 8 collaboration

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KIT
UNIVERSITY OF HAWAI'I
IGFAE Instituto Galego de Física de Altas Enerxías
USC UNIVERSIDADE DE SANTIAGO DE COMPOSTELA
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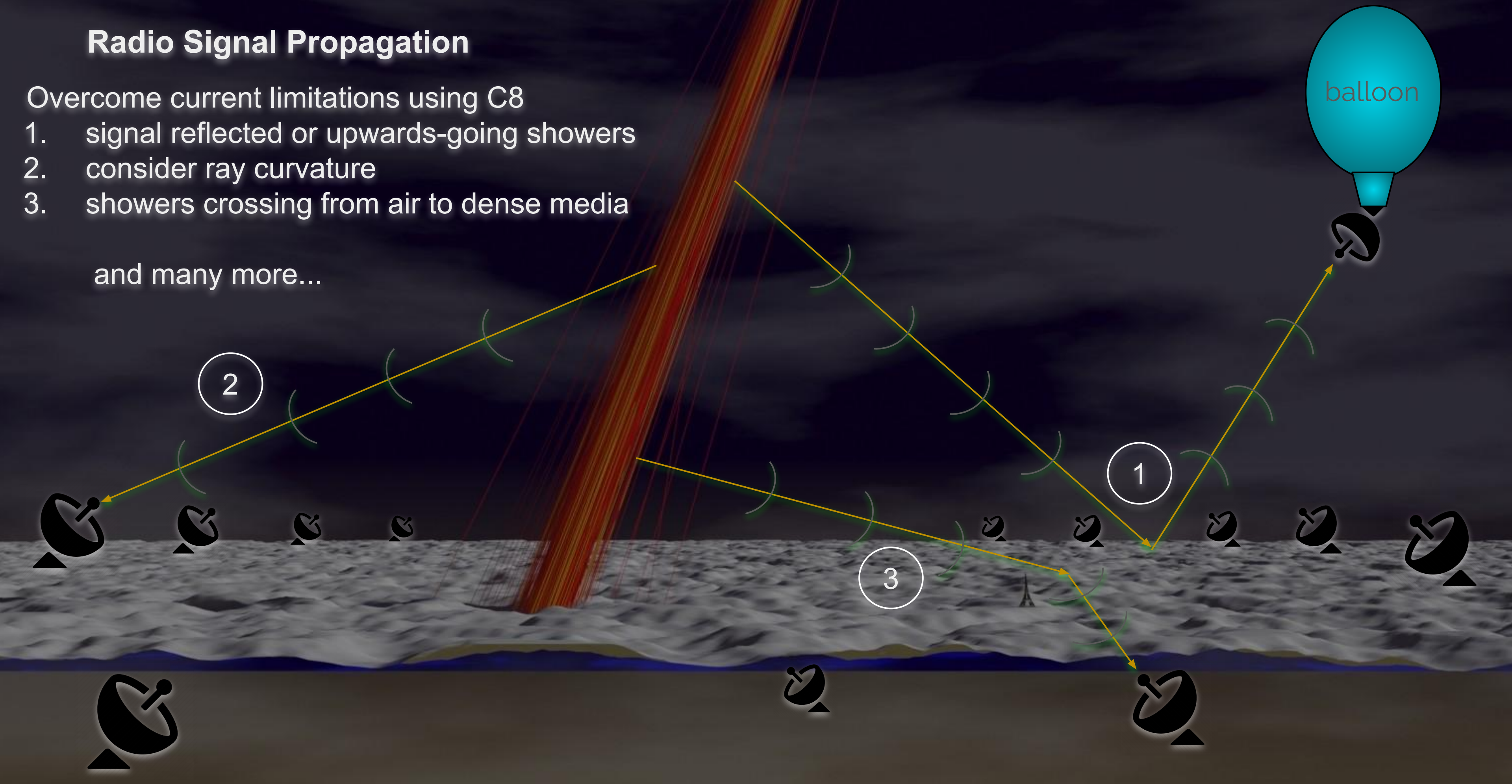
Radio Signal Propagation

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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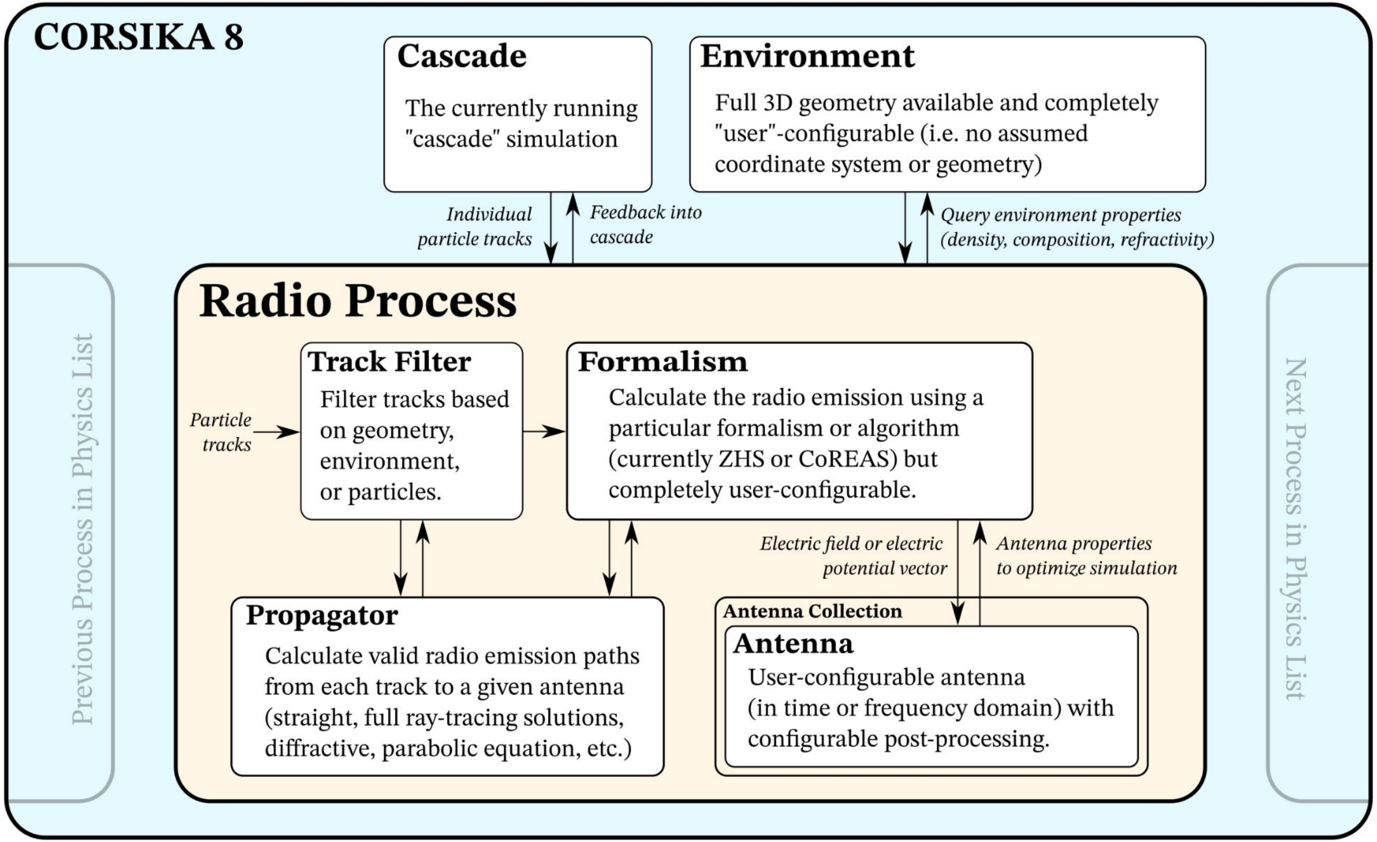
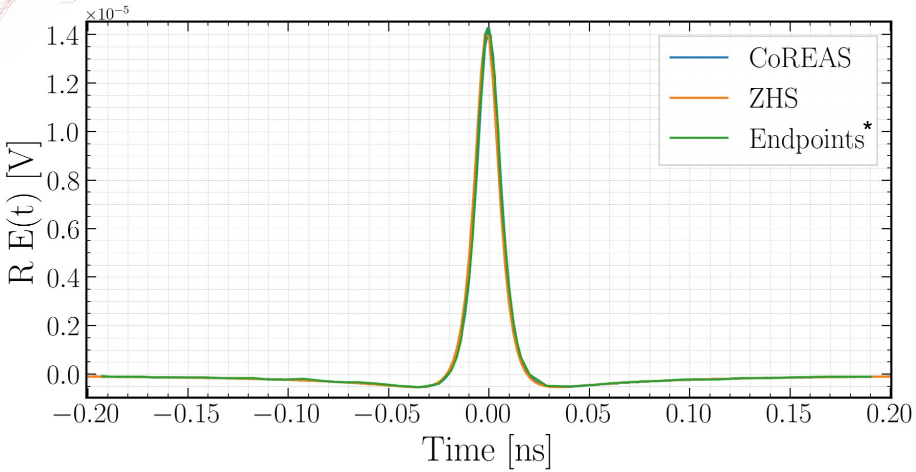
Radio module architecture

User-configurable parameters

- Filter
- Formalism
- Propagator
- Antenna



Electron in a uniform magnetic field

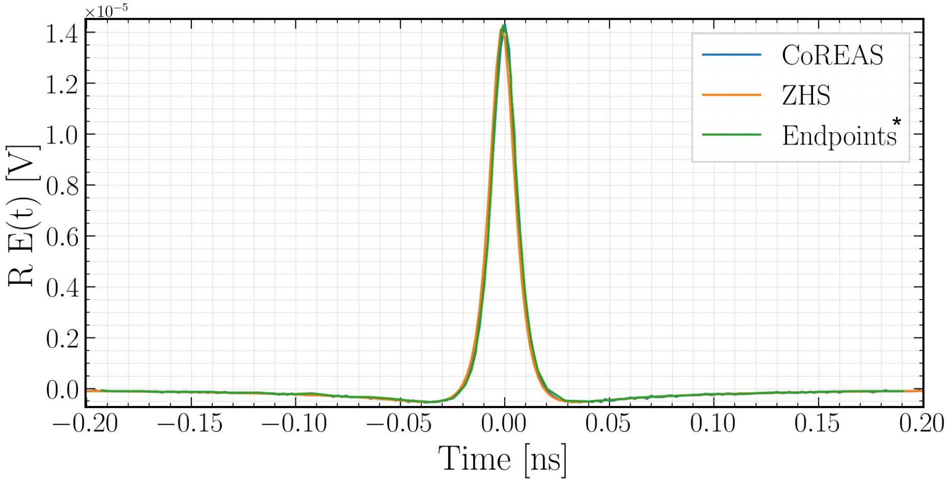


→ Manual tracking algorithm

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.



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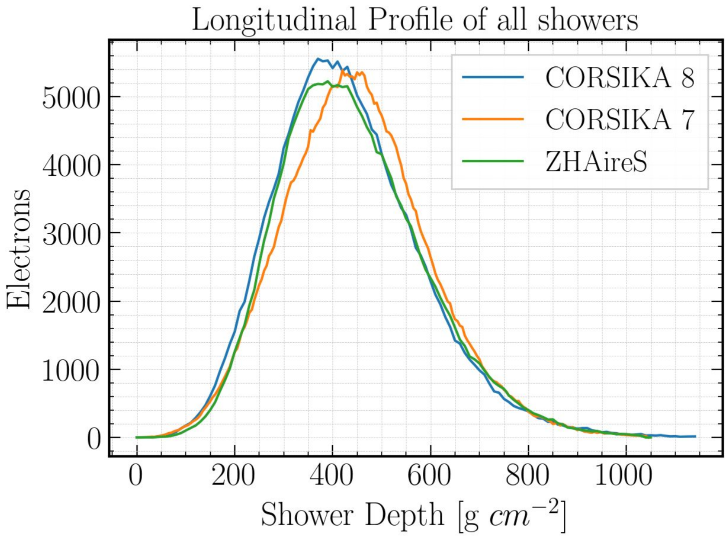
* T. Huege, C.W. James, H. Falcke and M. Ludwig, Proc. 32nd Int.Cosmic Ray Conf. (2011)4, 308 [1112.2126]

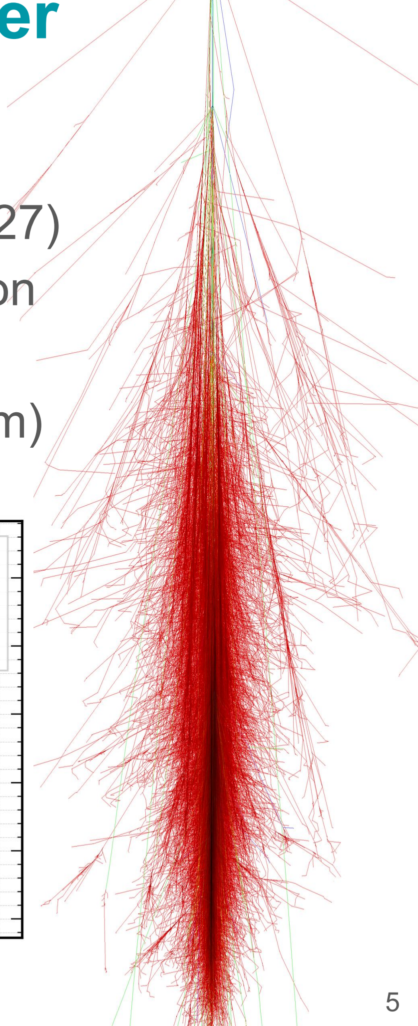
Simulation of an extensive air shower

- 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
- $X_{\mathrm{max}} \approx 430\, g\, cm^{-2}$
- Star-shaped grid of antennas - 20 concentric rings (25m - 500m)

Comparison

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





Pulses comparison

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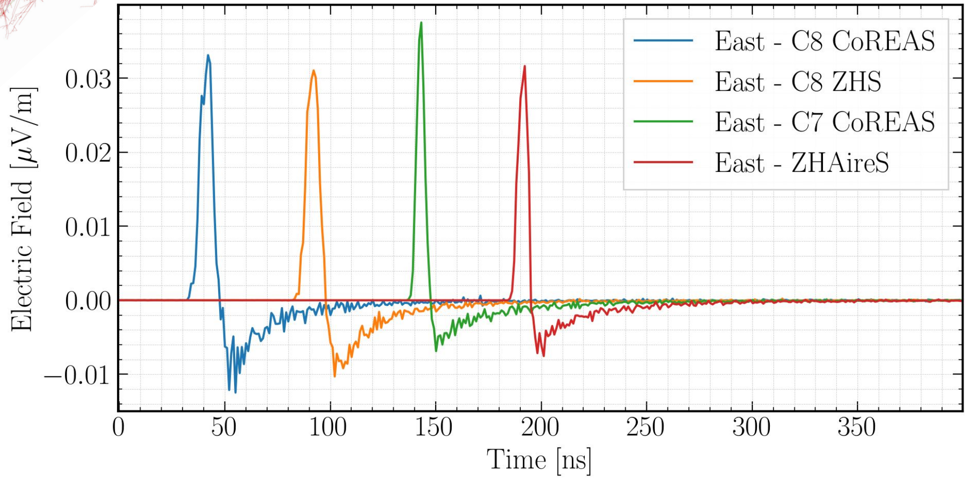
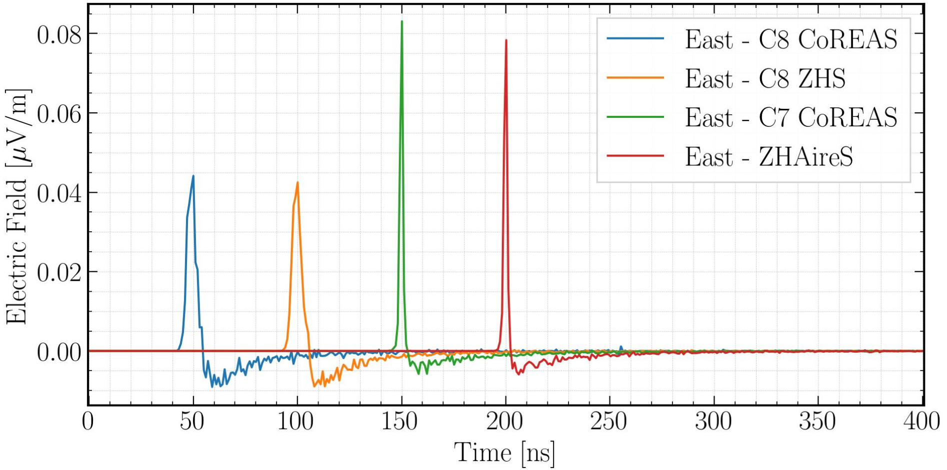


Antenna at 50m from the shower core

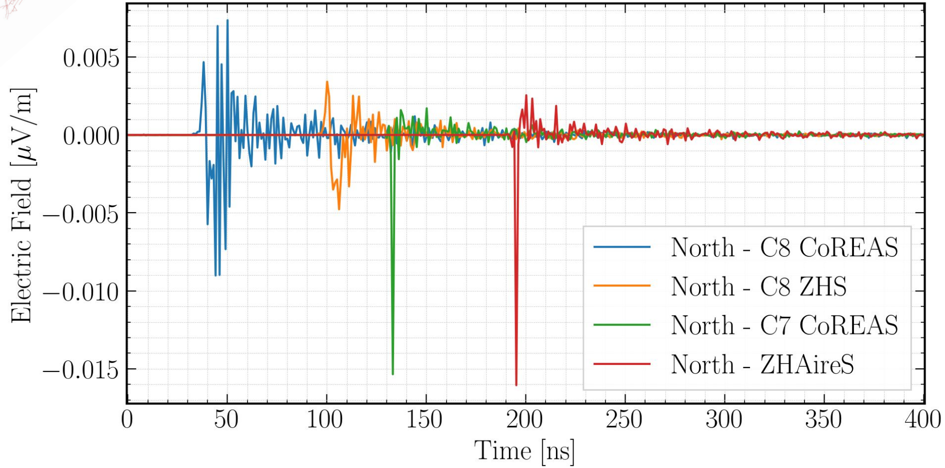
- C8 amplitudes off for approximately 10%
- C8 pulses are wider for approximately 35%
- Time offsets are arbitrary

Antenna at 200m from the shower core

- C8 amplitudes lower for approximately 50%
- C8 pulses are wider for approximately 35%
- Time offsets are arbitrary

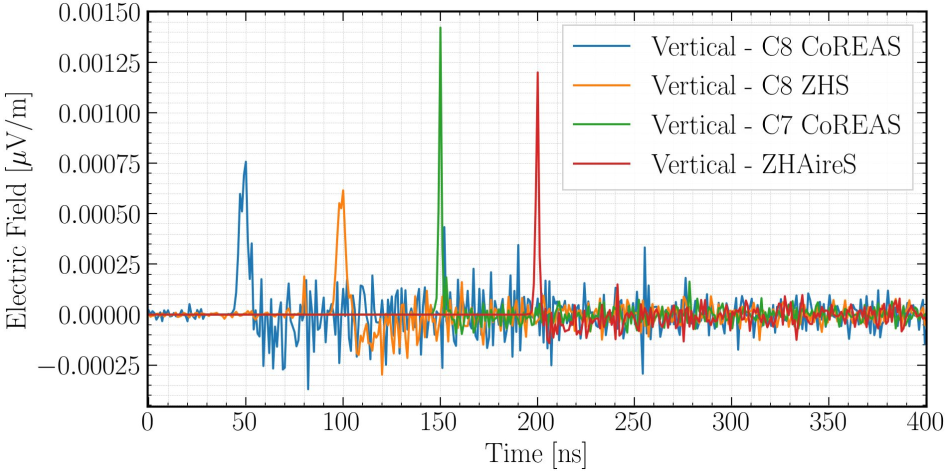


Polarization properties



Antenna at 200m from the shower core

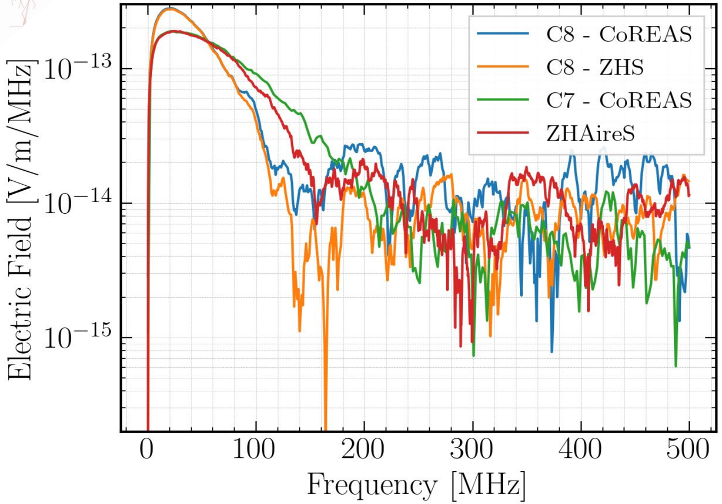
- C8 amplitudes lower of factor of 2
- C8 pulses look wider and more noisy
- Polarization behaviour matches
- Time offsets are arbitrary



Antenna at 200m from the shower core

- C8 amplitudes lower of factor of 2
- C8 pulses look wider and more noisy
- Polarization behaviour matches
- Time offsets are arbitrary

Frequency spectra comparison

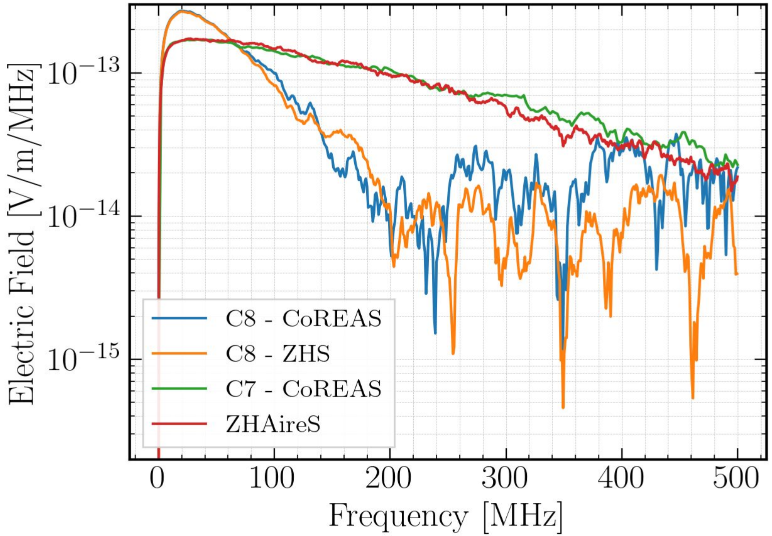


Antenna at 50m from the shower core

- Increase in power below 50 MHz
- C8 spectra fall more steeply
- Drop in power above 60 MHz

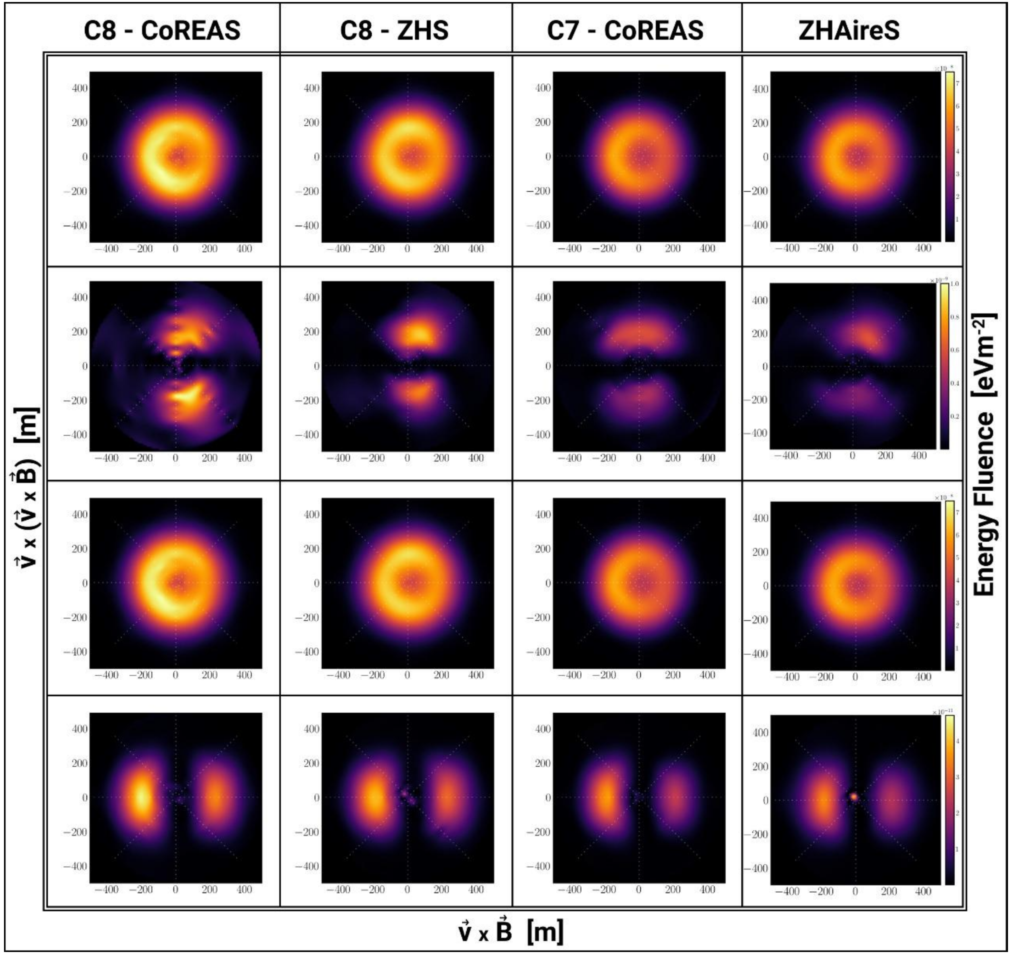
Antenna at 200m from the shower core

- Increase in power below 50 MHz
- C8 spectra fall even more steeply for antennas at 200m
- Drop in power above 60 MHz is more evident at 200m



Energy fluence 2D maps (30 - 80 MHz)

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



Summary

- Radio module is designed to support next generation experiments
- Tested and validated in simple scenarios with and without C8 tracking
- Electron showers simulated where there is better than a factor of 2 agreement between C8 with C7 and ZHAireS in absolute amplitude of the pulse
- Agreement of polarization characteristics between C8 with C7 and ZHAires
- Pulses in C8 are “wider” and have more steeply falling spectra
- Very good agreement between CoREAS and ZHS algorithms in C8
- 2D fluence maps provide interesting observations

Radio module in C8 is capable of calculating the radio emission like C7 and ZHAireS. At this stage we are ready to investigate improvements in performance and implement more sophisticated cases.