university of groningen / kvi - center for advanced radiation technology

Extensive air showers

Comparing two simulation programs

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Introduction

Two approaches for radio emission of an extensive air shower are compared:

- Microscopic (CORSIKA/CoREAS)
- Macroscopic approach (New analytic code using parametrized sowers)

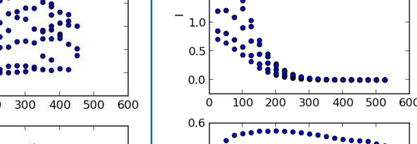
We want to find the optimal parametrization.

Motivation

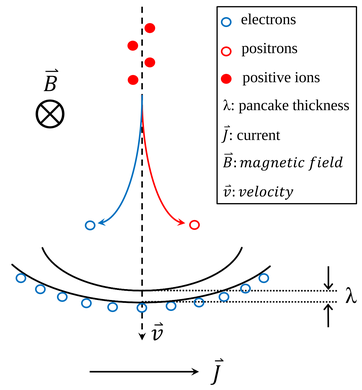
Extensive air showers can provide information about, the electric fields in the atmosphere, necessary to understand lightning.
To extract these fields the radio footprint needs to be fitted to a simulation.

LOFAR

LOFAR settings are used.



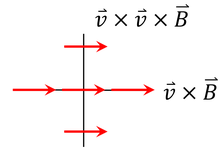
Emission mechanisms



Two main contributions to the radio emission:

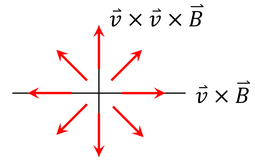
Geomagnetic

-Due to Earth's magnetic field
-Produces a transverse current
-Emission is polarized in the direction of the Lorentz force:



Charge-excess

-Due to ionization of atmospheric molecules and annihilation of positrons
-Emission is radialy polarized:



Stokes parameters

The polarization of the radio emission is characterized by the four Stokes parameters:

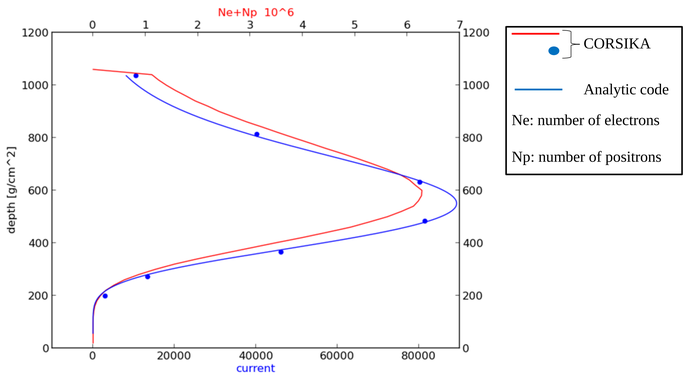
$I = \langle E_x^2 \rangle + \langle E_y^2 \rangle$ = ↔ + ↕

$Q = \langle E_x^2 \rangle - \langle E_y^2 \rangle$ = ↔ − ↕

$U = \langle E_a^2 \rangle - \langle E_b^2 \rangle$ = ⤢ − ⤡

$V = \langle E_l^2 \rangle - \langle E_r^2 \rangle$ = ⟲ − ⟳

Currents

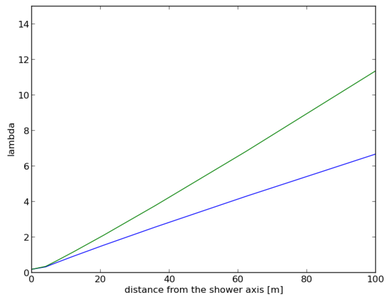


Red curve: total number of electrons plus positrons in CORSIKA.

Blue dots: current in CORSIKA.
Blue curve: current in the analytic code.

Results for a vertical proton shower of 10^{16} eV.

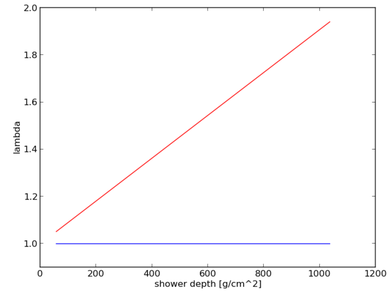
Showerfront thickness



- Left: dependence of λ on distance to the shower axis, R, (red and blue overlap) at X=0.

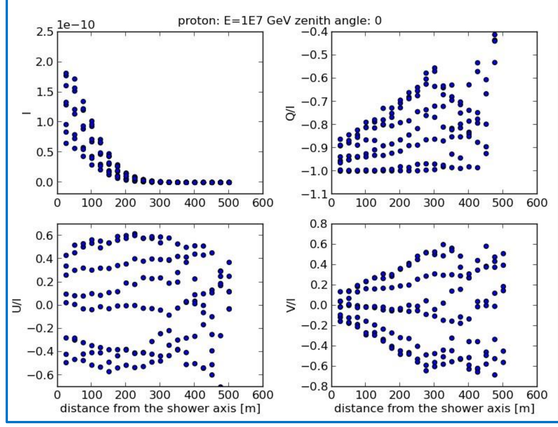
Color coding is the same as used in the figure of the results.

-Right: dependence of λ on penetration depth, X, at R=100 m (NOTE: THERE SHOULD ALSO BE A GREEN CURVE)



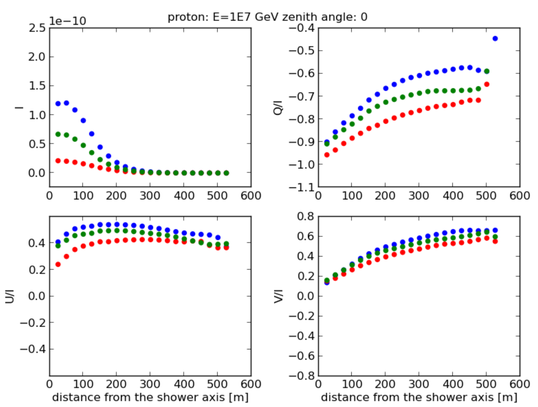
Stokes parameters

CoREAS



Analytic code

Analytic code

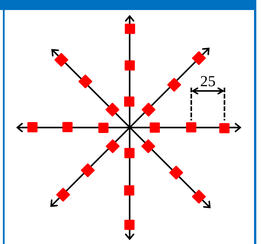


The Stokes parameters as a function of the distance to the shower axis and different azimuth (see picture on the right)

The four plots in the left panel are CoREAS results.

Middle panel: the results from the analytic code where the showerfront thickness increases linearly with distance to the shower axis.

Right panel: results from the analytic code at azimuth = 90º. The meaning of the colors of the dots are as given in the section 'showerfront thickness'.



Positioning of the test antennas with a spacing of 25 meters. The outer antennas are 500 meters from the shower axis.