Characterisation of the radio frequency spectrum emitted by high-energy air showers with LOFAR

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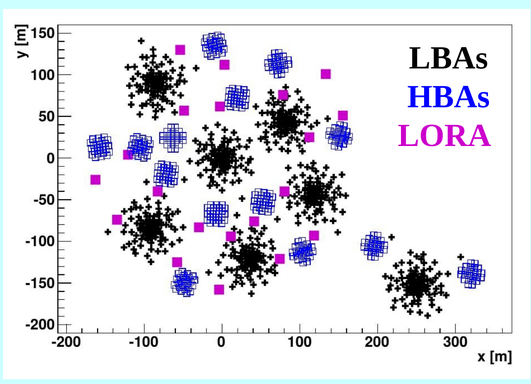
LOFAR

LOw Frequency ARray



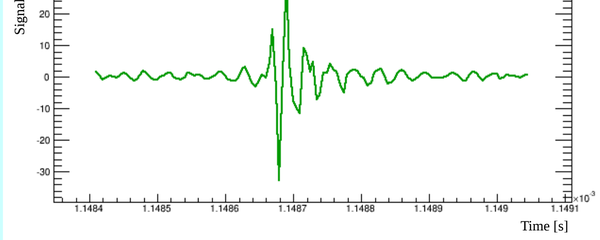
LBA → 30 – 80 MHz

LORA → scintillator array

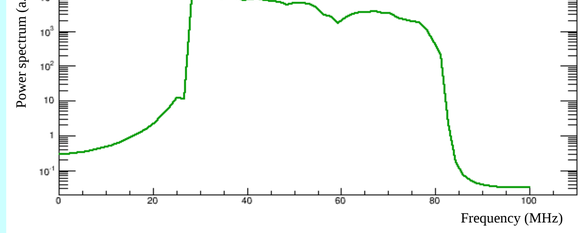
MAIN GOAL

To study radio signal emitted by high–energy cosmic rays (10^{16} – 10^{18} eV) in the frequency domain
→ is it possible to extrapolate information about primary particles by studying radio signals in the frequency domain ?

Time domain

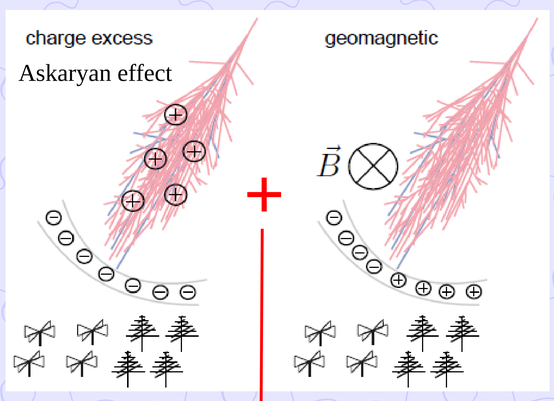


Frequency domain

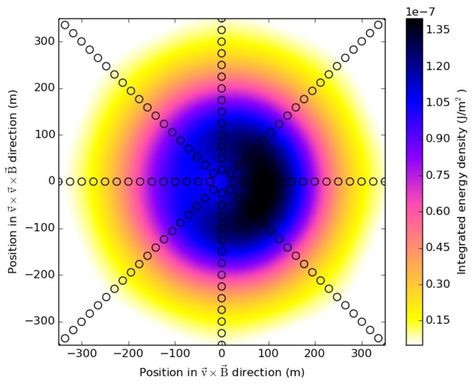


Simulation study of the frequency spectrum

Radio emission processes



Energy density distribution



Analysis method

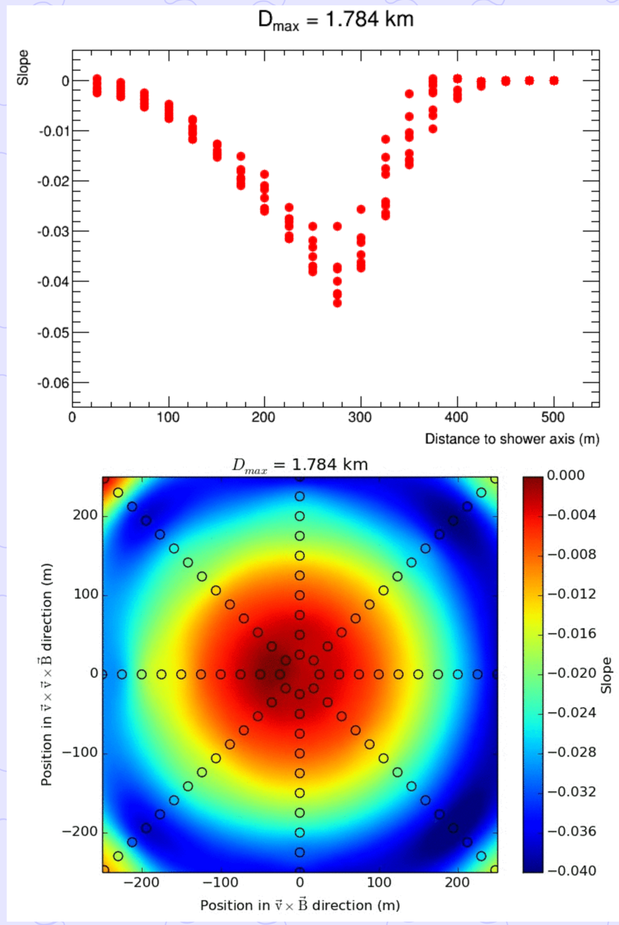
– simulated events generated by primary protons with energies between 10^{17} – 10^{18} eV

– frequency spectrum study performed on the shower plane, i.e. plane perpendicular to the shower axis

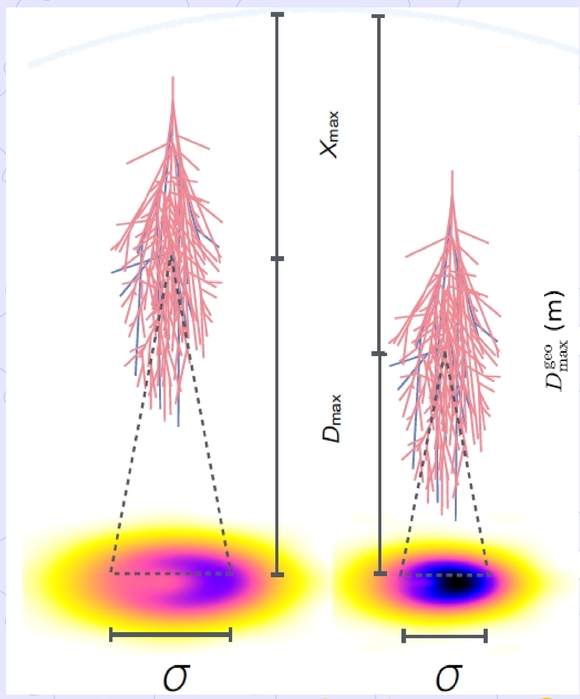
– antenna grid with 25 m distance between each antenna

– the frequency spectrum has been fitted with 1 degree polynomial, and the resulting slope studied as function of distance to the shower axis

– the frequency spectrum depends also on the distance to the maximum shower development X_{max}

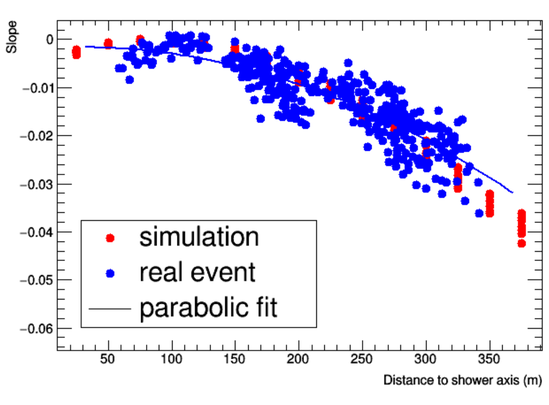


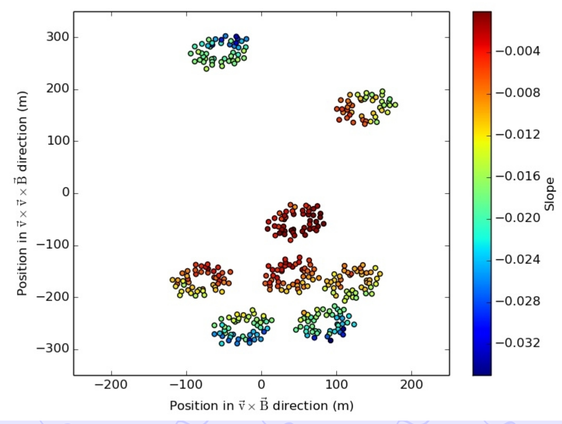
Slope of the power spectrum as function of distance to shower axis and D_{max}



Analysis on real data

Same analysis method has been applied to real data





– the frequency spectrum strongly depends on the distance to the shower axis for simulations and real events

– the Lateral Distribution Function has been used to reconstruct X_{max}

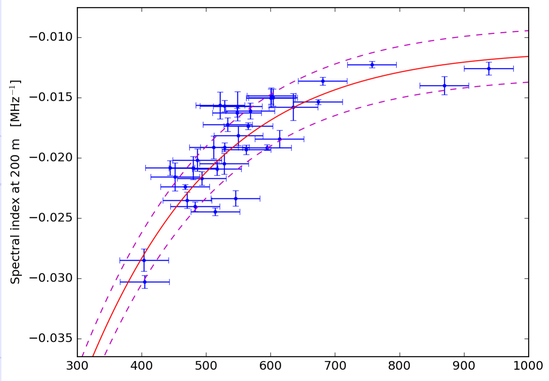
– simulation → X_{max} = 681.12 g/cm^2
real event → X_{max} = 686.44 g/cm^2

– the frequency spectrum depends also on D_{max}, i.e. distance to X_{max}

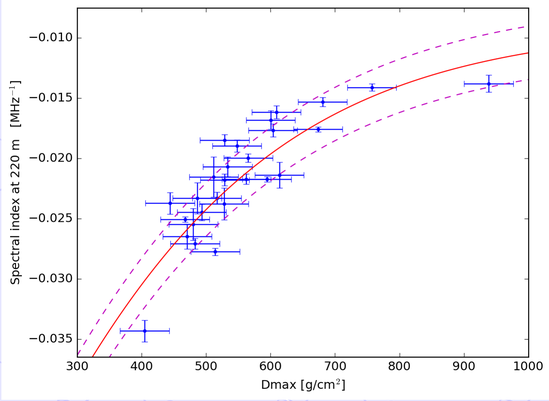
– at a certain distance the slope of the power spectrum as function of D_{max} can be fitted by

$$\frac{\alpha}{1+\exp(-\beta\cdot D_{max})}-\alpha-\gamma$$

Slope vs. D_{max} at 200 m



Slope vs. D_{max} at 220 m



Conclusions

– the frequency spectrum has been studied on simulations and real events

– the frequency spectrum depends on distance to the shower axis and on distance to X_{max}

– it is fundumental to have a good recontruction of the shower core position on ground

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