Radio emission in extensive cosmic ray air showers – detection with LOPES

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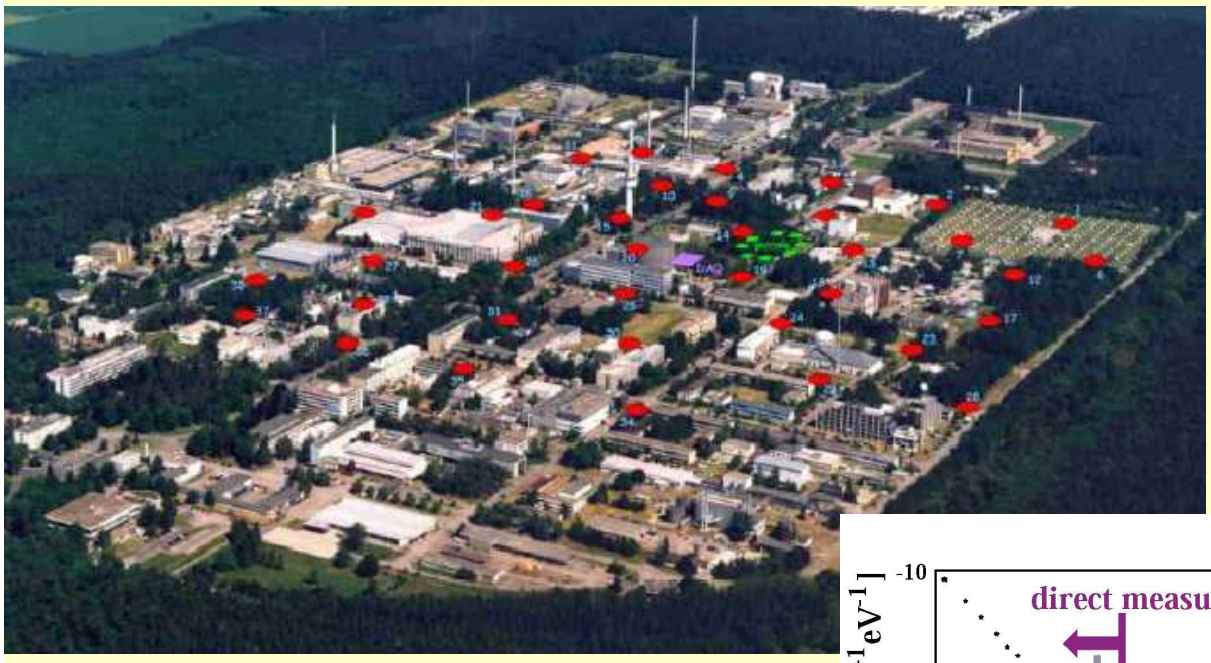
LOPES collaboration:
-) KASCADE-Grande, FZK
-) U Nijmegen, NL
-) MPIfR Bonn
-) Astron, NL
-) IPE, FZK

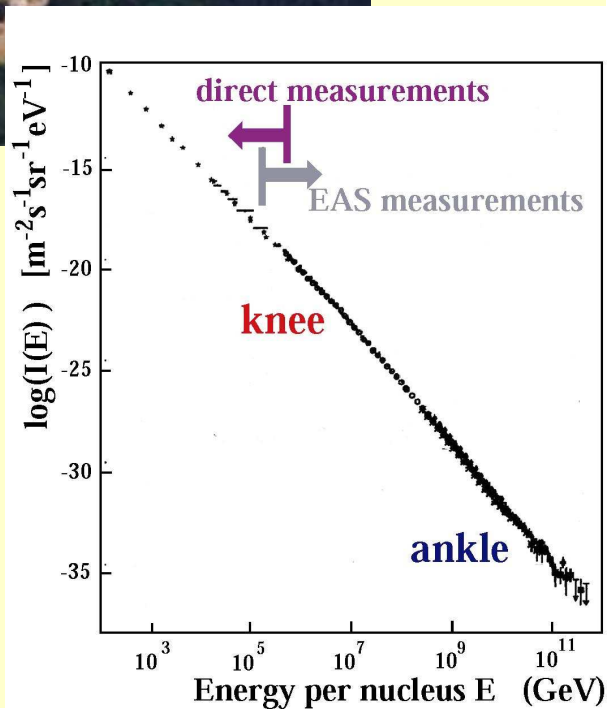
KASCADE–Grande cosmic ray air shower experiment

- measurements of EAS in the primary with energy range E_0 =100 TeV – 300 PeV
- multi–detector experiment to determine as much as possible shower parameter



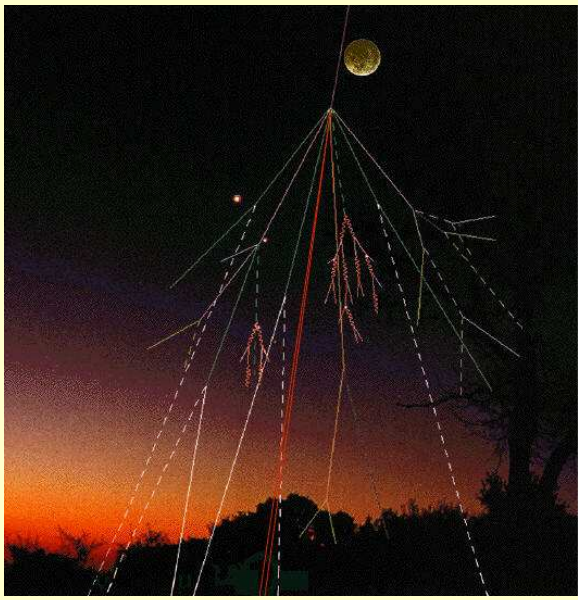
main task:

- primary energy E_0 spectrum
- prim. particle mass A
- understanding interactions models

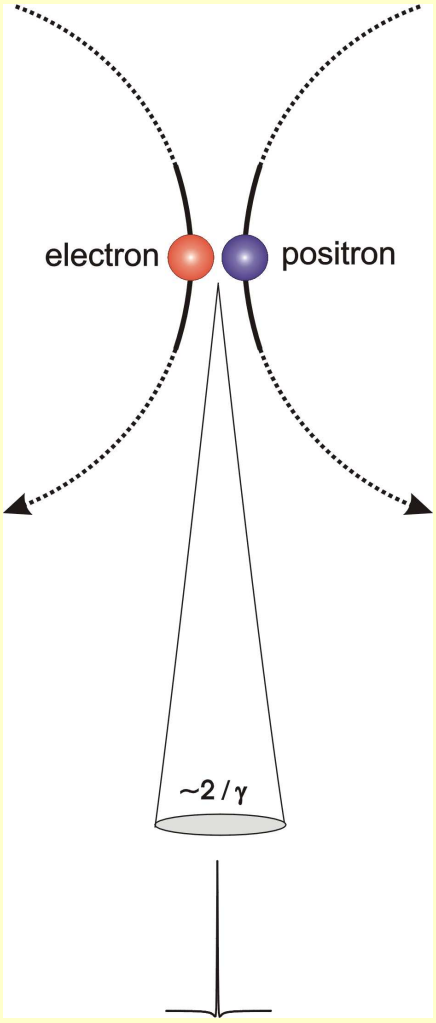


Radio emission produced in cosmic ray air showers

- primary high energetic particle interacting with molecules
- radiation probably due geomagnetic emission process
- charge separation in earth's magnetic field



➡ classical electric dipol



- gyration of electrons along a small arc

➡ emission of synchro-tron radiation

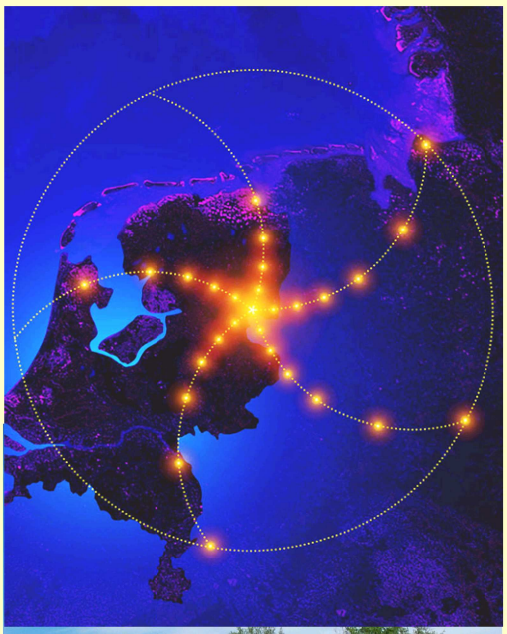
- air showers emits radio pulses, known since 1965
  Problems:
  - success of other methods
  - radio interference
  - theory of emission process

Radio emission produced in cosmic ray air showers II

- radio emission measurements from air showers could give several benefits:
  - data from all over the shower evolution, so complementary to particle detectors
  - large collecting area for low costs
  - higher duty cycle than fluorescence and Cherenkov telescopes
  - effective RFI suppression allows measuring in polluted (populated) areas
- this can be achieved by new digital radio telescopes
- possible improvement for other experiments, e.g. Auger

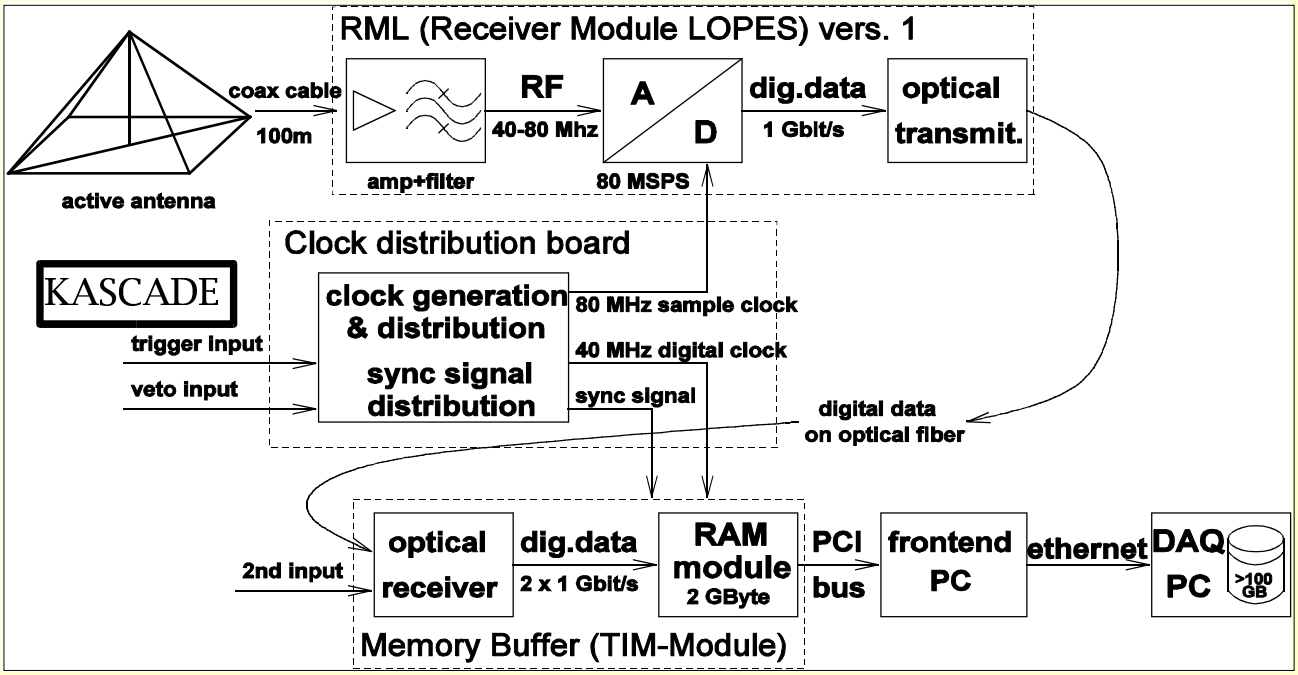
LOPES = LOFAR Prototype Station

- 40 – 80 MHz frequency range
- 10 antennas in the first phase, 30 antennas in the second phase, just installed and ready for running
- set up at the KASCADE–Grande site

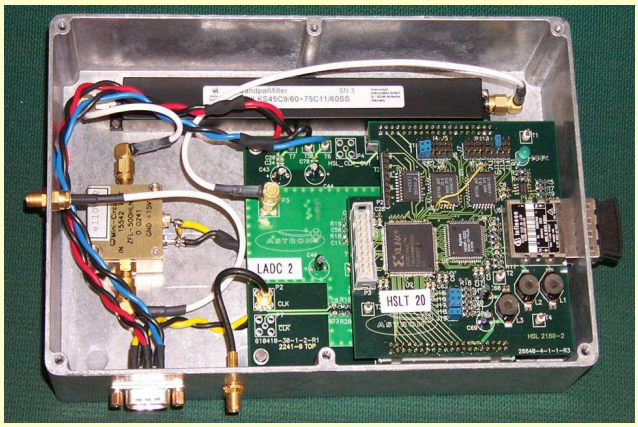


- LOPES–Goals:
  - develop techniques to measure the radio emission from air showers
  - determine the radi–ation mechanism of air showers
  - My work:
    absolute calibration and correlation of the radio signal with air shower parameters

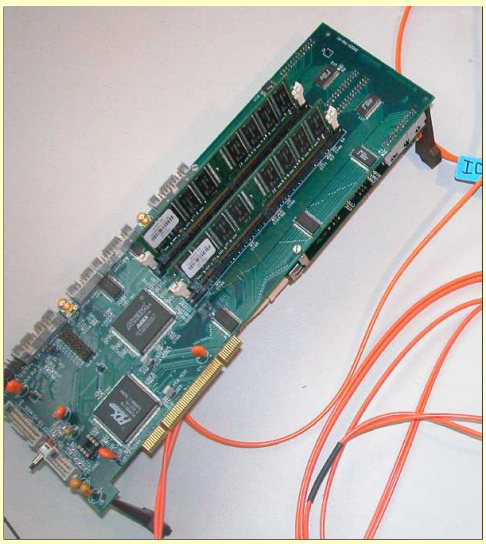
Detection and signal processing



Layout of the electronic system

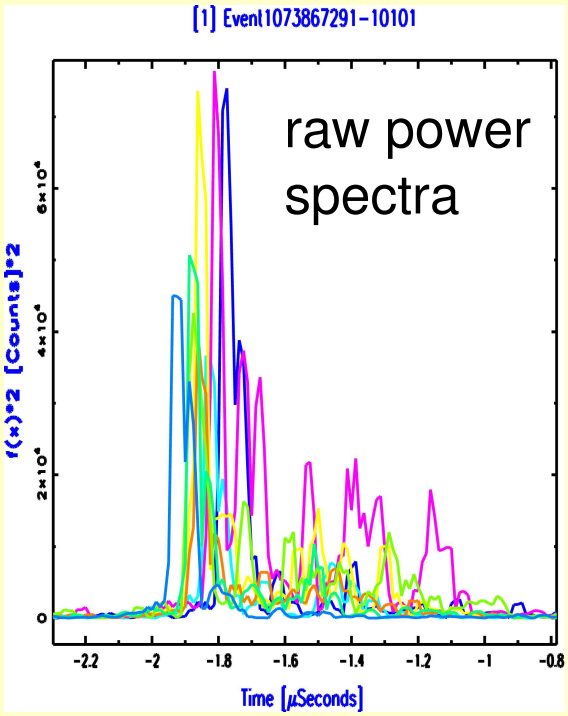


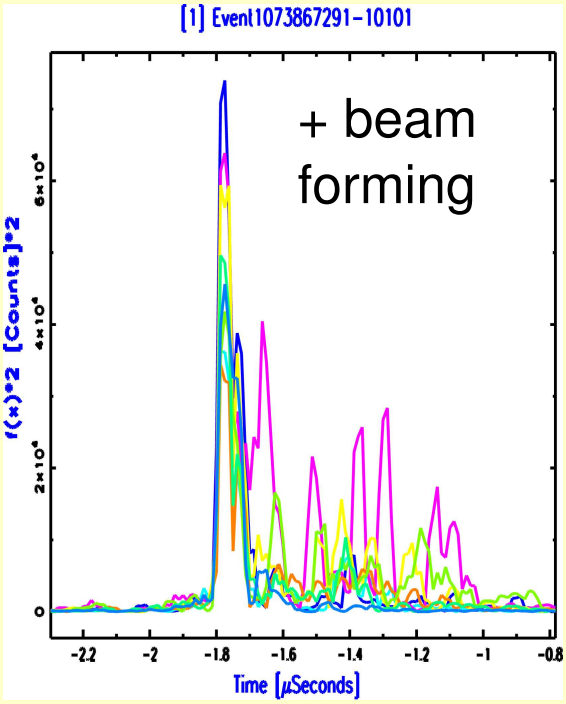
Receiver Modul



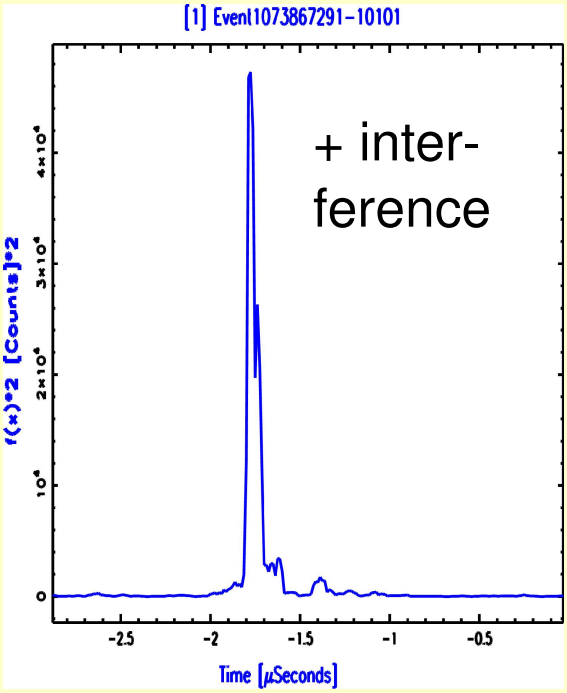
Memory Buffer
TIM–Module

Event analysis with use of the air shower parameters





A. Horneffer et al. 2004



My work

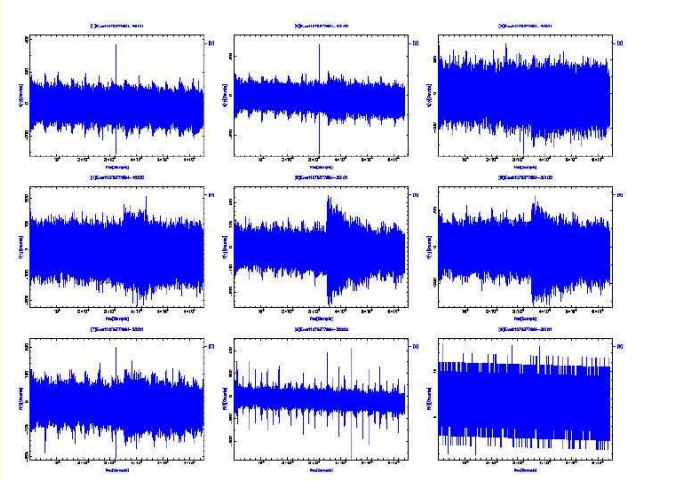
- absolute calibration of the detected radio signal
- search for a correlation between radio signal and EAS parameter

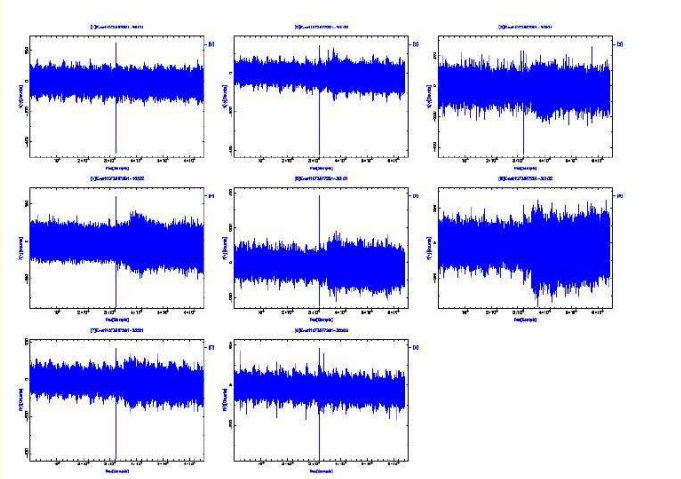
  signal = $f(E_0)$, = $f(A)$, = $f(\Theta, \Phi)$
- Including:
  - improvement of the electronical system
  - reduction of the noise (better S/N–ratio)
  - analysis of the environmental dependence
  - development of software tools and pipelines

Summary

- cosmic ray air showers emits coherent radio pulses through geosynchrotron radiation
- new digital radio antenna system, LOPES as a prototype for LOFAR
- absolute calibration and correlation of the received radio emission with EAS parameters

Selection criteria for radio events





Raw data (voltage amplitude over time) from the antenna for a time intervall of 800 µsec

Reconstruction

incoherent coherent