

Lunar Detection of UHE Cosmic Particles with LOFAR

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What is it about ?

1. Detecting UHECRs and neutrinos with Radio Antennas (LOFAR HBA) from the near surface Moon(Lunar Askaryan Technique)

Why the Moon ?

1. Moon lack atmosphere (Askaryan '62 and Dagkesamanski et al '89)
2. **Good radio properties**
3. Large detector area/volume (~1700km radius)

Results from previous studies and what we are doing differently

1. Zero/Null detection so far (>1GHz observation except WRST)
2. Low Frequency (110-190Mz bandwidth with 200MHz sampling rate)
3. Beamforming for improved sensitivity (5/24 core stations due to limited bandwidth)

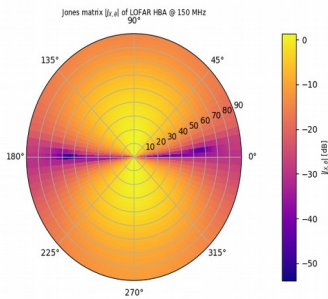
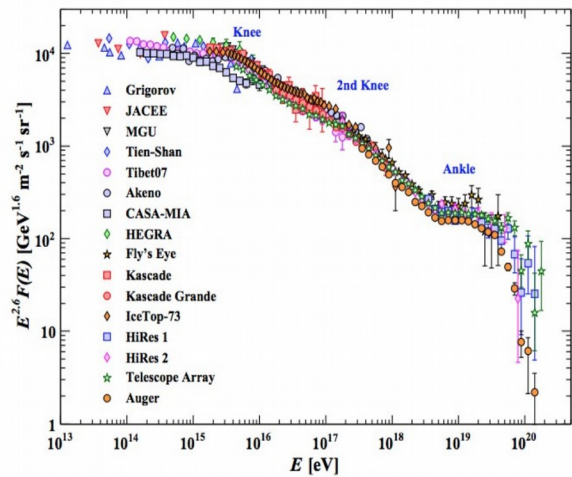


What is the Motivation Here ?

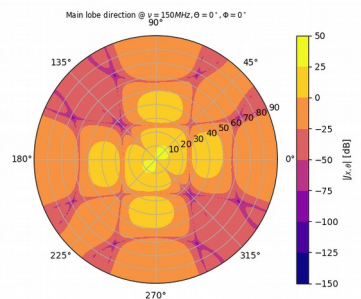
1. Understand the cut-off
2. Put an upper limit on UHECRs or neutrino flux (no detection) to constrain theoretical (top-down) models.

NB:

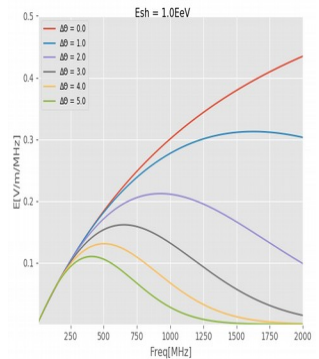
1. At low frequency, the whole lunar surface forms part of detector volume
2. Each station beam is larger the Moon (0.5deg)



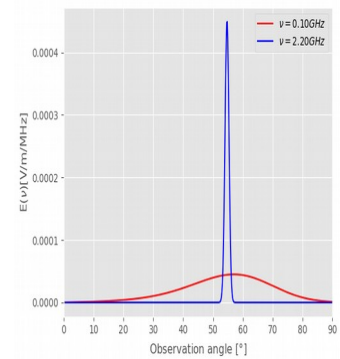
Antenna Pattern for an antenna



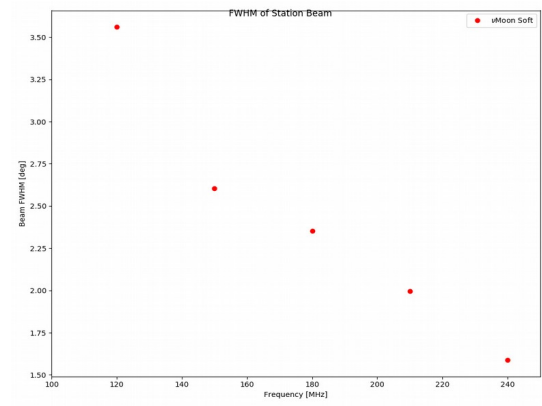
Antenna Pattern for an HBA tile



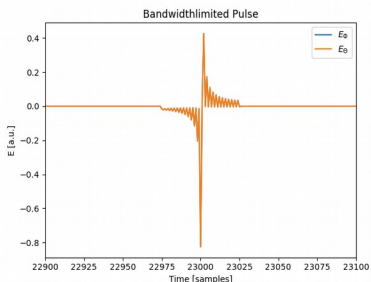
Frequency spectrum



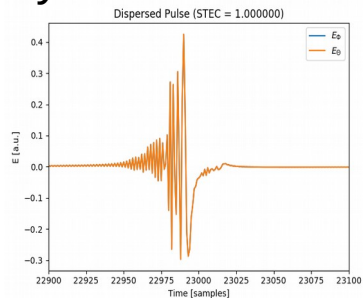
Angular spread



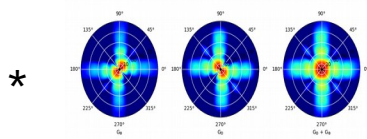
1. Simulation of physical detector



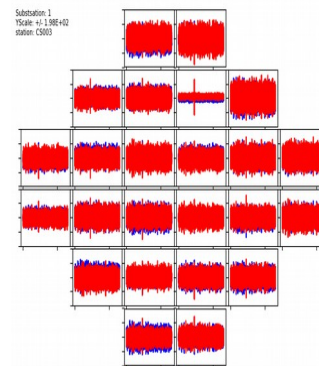
E-field



Dispersed E-field

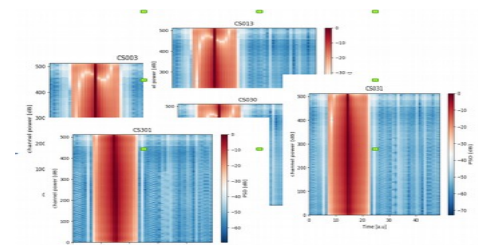


HBA response



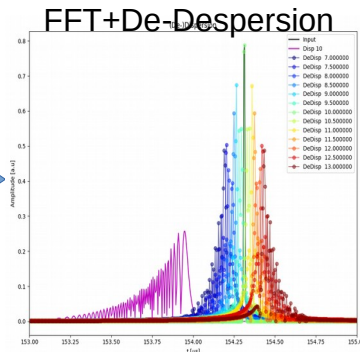
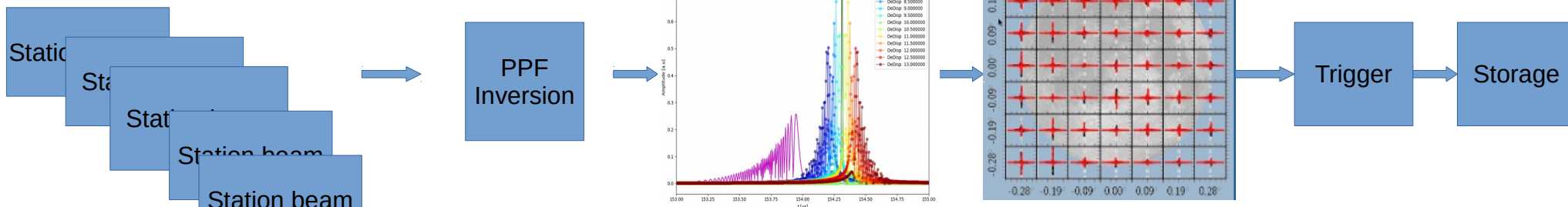
Voltages in sub-stations

2. Simulation of station beams



Station Beams

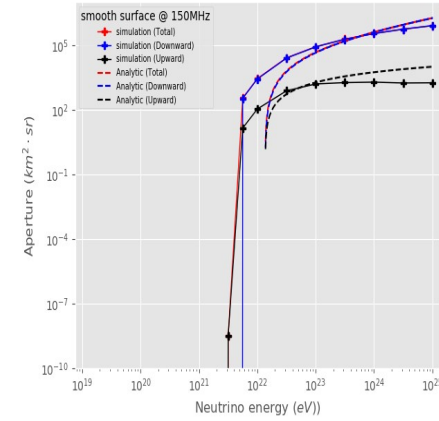
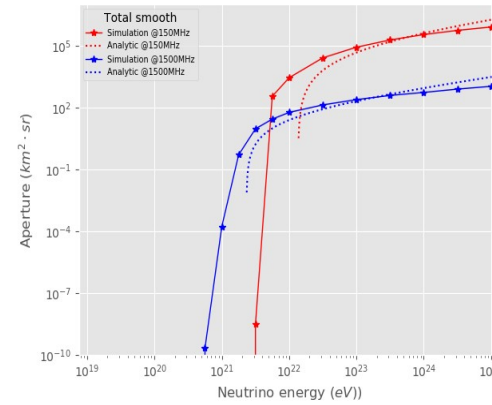
3. Real-time analysis



Lunar detection of UHE cosmic particle

Simulated sensitivity of LOFAR

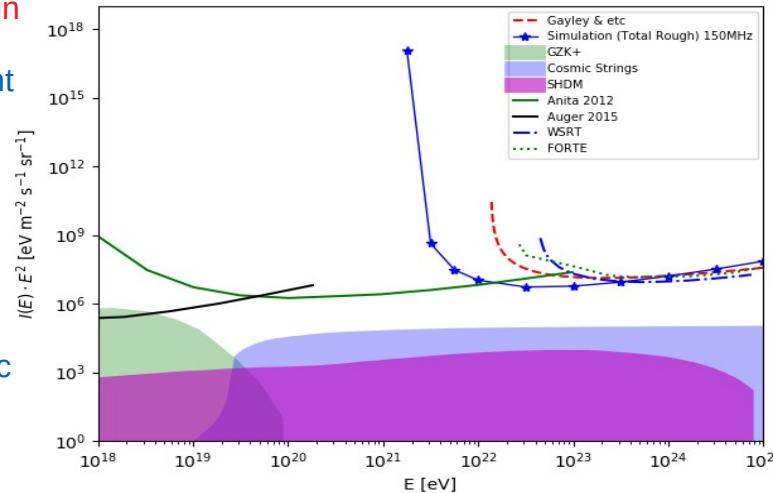
1. Null result requires upper limit.
2. Effective aperture (area * solid angle through which neutrinos is detectable)
3. MC-code for detailed calculation of isotropic aperture for neutrinos (Crs is still in progress)



Assumed a smooth lunar surface

This code is structured as follows:

- * Has many utility functions all written in python to do simple calculations
- * Event Generator to generate all event parameters (vertex, direction, inelasticities, etc)
- * Signal Generator provide the appropriate parameterization for the Askaryan emission in the regolith etc
- * Signal Propagator generate rays isotropically. Implements ray tracing, refraction, solid angle magnification etc
- * Aperture calculator



Lunar detection of UHE cosmic particle

- * Surface roughness included, 5 stations and 100 hours of livetime
- * work in progress for cosmic rays.