Radio Simulations of Upgoing Extensive Air Showers Observed from Low-Earth Orbit

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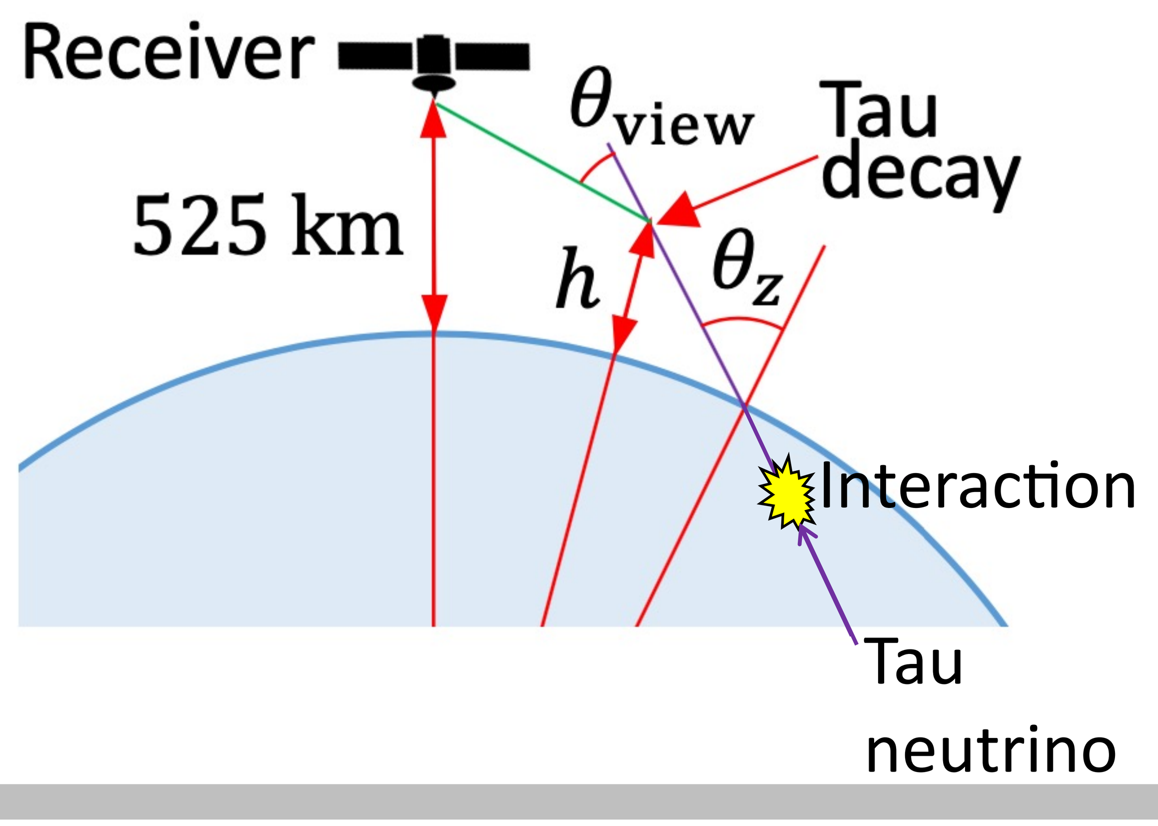
Motivation

nuSpaceSim:

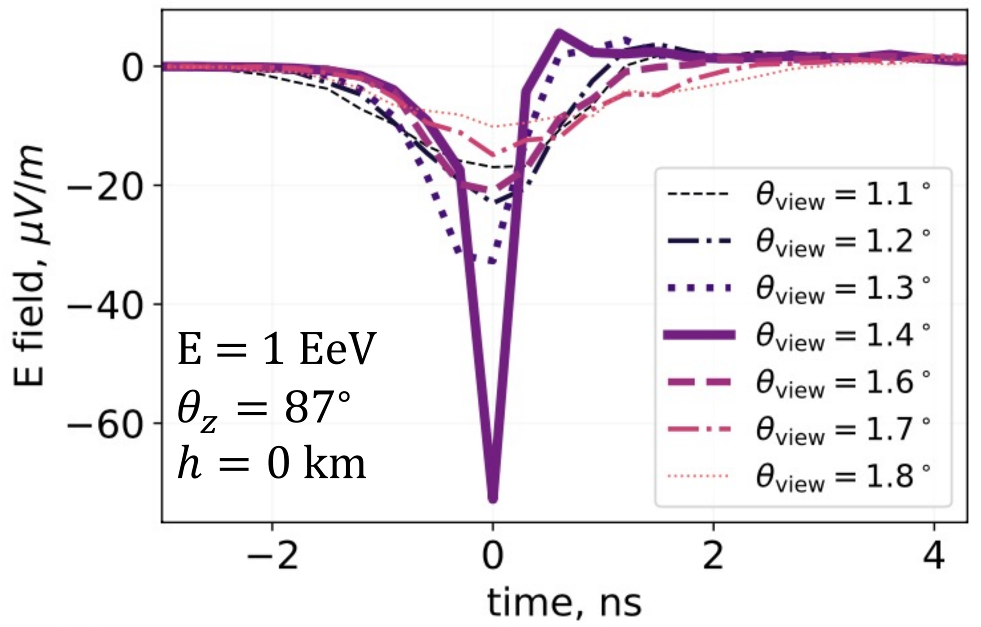
- Upgoing air showers sourced by tau neutrino interactions in Earth
- Detailed simulation development.
- NASA funded effort
- Includes optical and radio emission.

ZHAireS to model radio emission observed from low-Earth orbit.

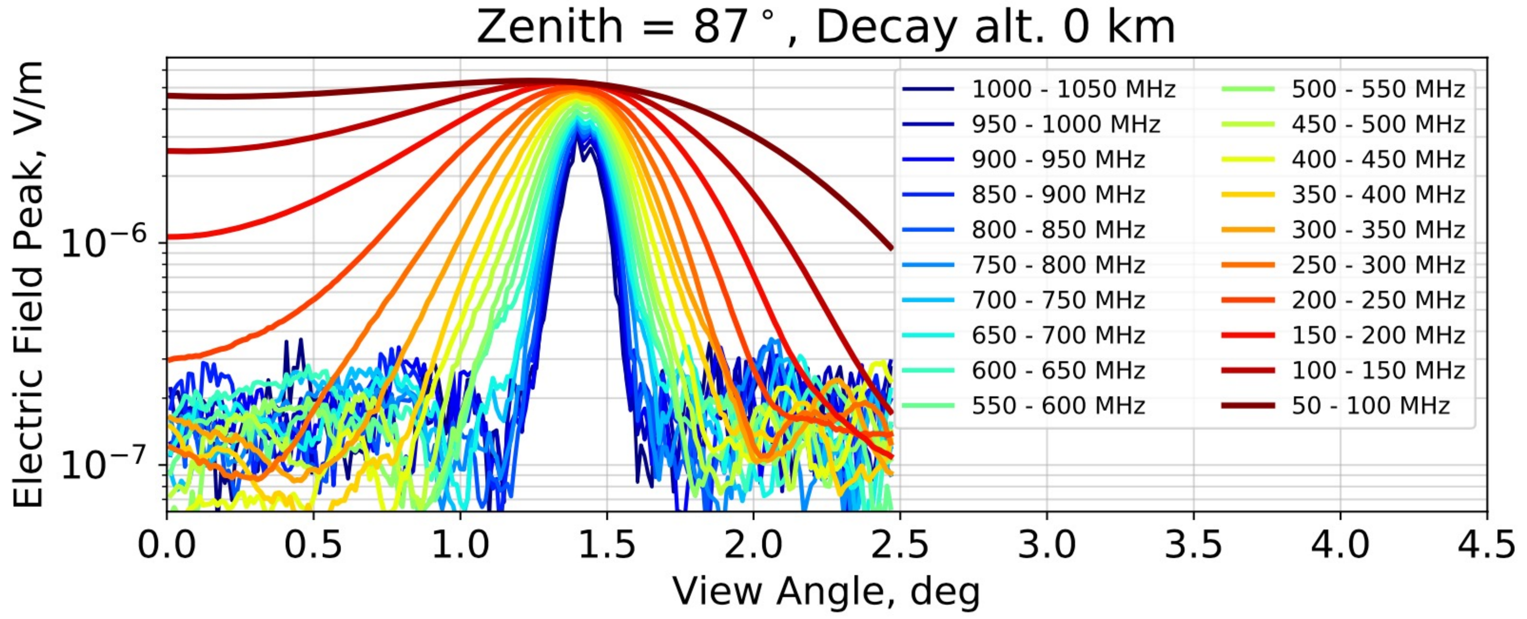


Simulation Setup

- Apply to 525 km altitude observatory.
- AIRES particle shower
- ZHS algorithm with 0.3 ns sampling.
- Zenith angles: 50° – 85 ° (in 5° steps), and 87°, 89°.
- Decay altitudes: 0-9 km in 1 km steps.
- In all cases $\vec{B} \perp$ shower axis.

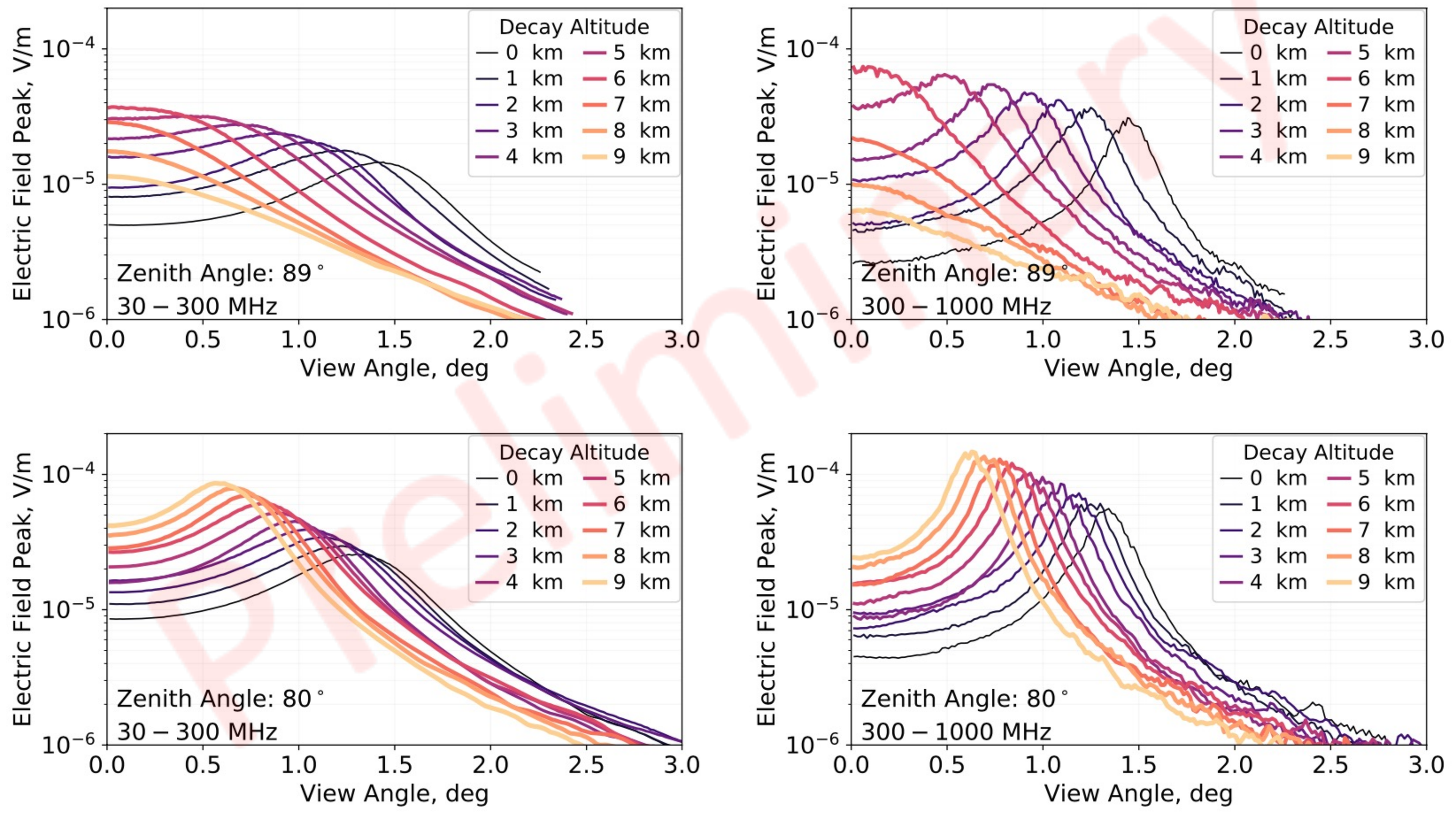


- Time-domain pulse data processed to frequency domain.
- Produce frequency banded radio beam patterns.



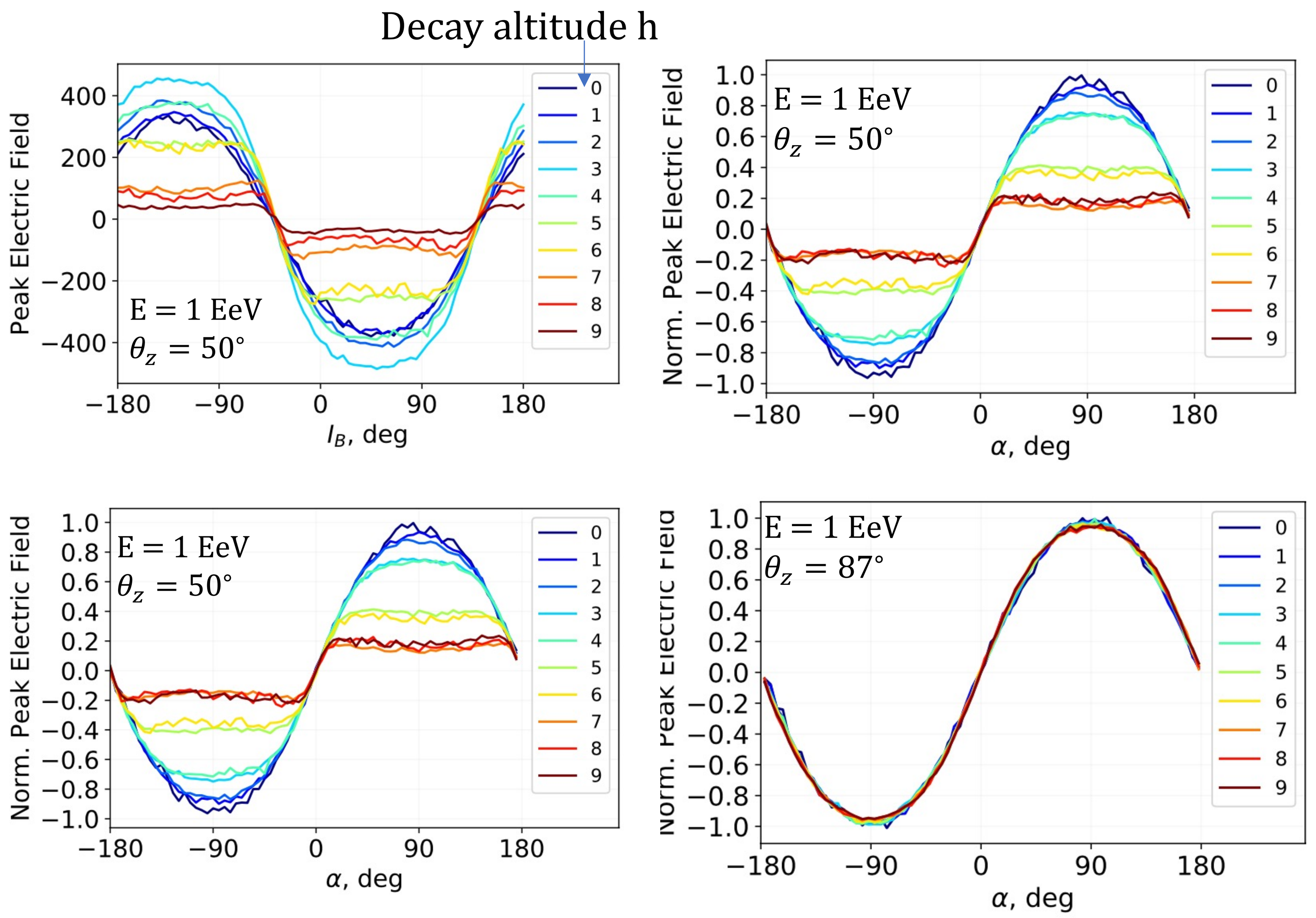
Results 1: Radio Emission

- Processed electric field peaks in VHF (30-300 MHz) and UHF (300-1000 MHz) bands.
- Cherenkov angle and beam width depend on band.
- VHF: weaker signal compared to background but wider beam patterns
  - Good for extreme energies
- UHF stronger signals narrower beam patterns
  - Good for lower energy threshold.



Results 2: Geomagnetic Saturation

- Variation of geomagnetic field inclination angle I_B reveals saturation effect at high altitudes.
- Potentially due to longer scattering interaction lengths in rarified atmosphere.
- Saturation effect deviates from $|\vec{E}| \propto \sin\alpha$.
- Saturation clipping effect is stronger at higher altitudes.
- Larger zenith angles restore $|\vec{E}| \propto \sin\alpha$.
- Shower development contained in less rarified medium compared to more steeply upgoing showers.



Conclusions

1. First results of radio emission from detailed track-level upgoing air shower simulations as observed form low-Earth altitude.
2. Results share similar features with simulations at lower altitudes for ANITA and BEACON.
3. As-of-yet unexplained behavior for nearly horizontal showers currently under investigation.
4. Main new finding is the saturation of geomagnetic radio emission for steep upgoing shower initiated at high altitude.