

The Amplitude Calibration of the Tunka Radio Extension (Tunka-Rex)

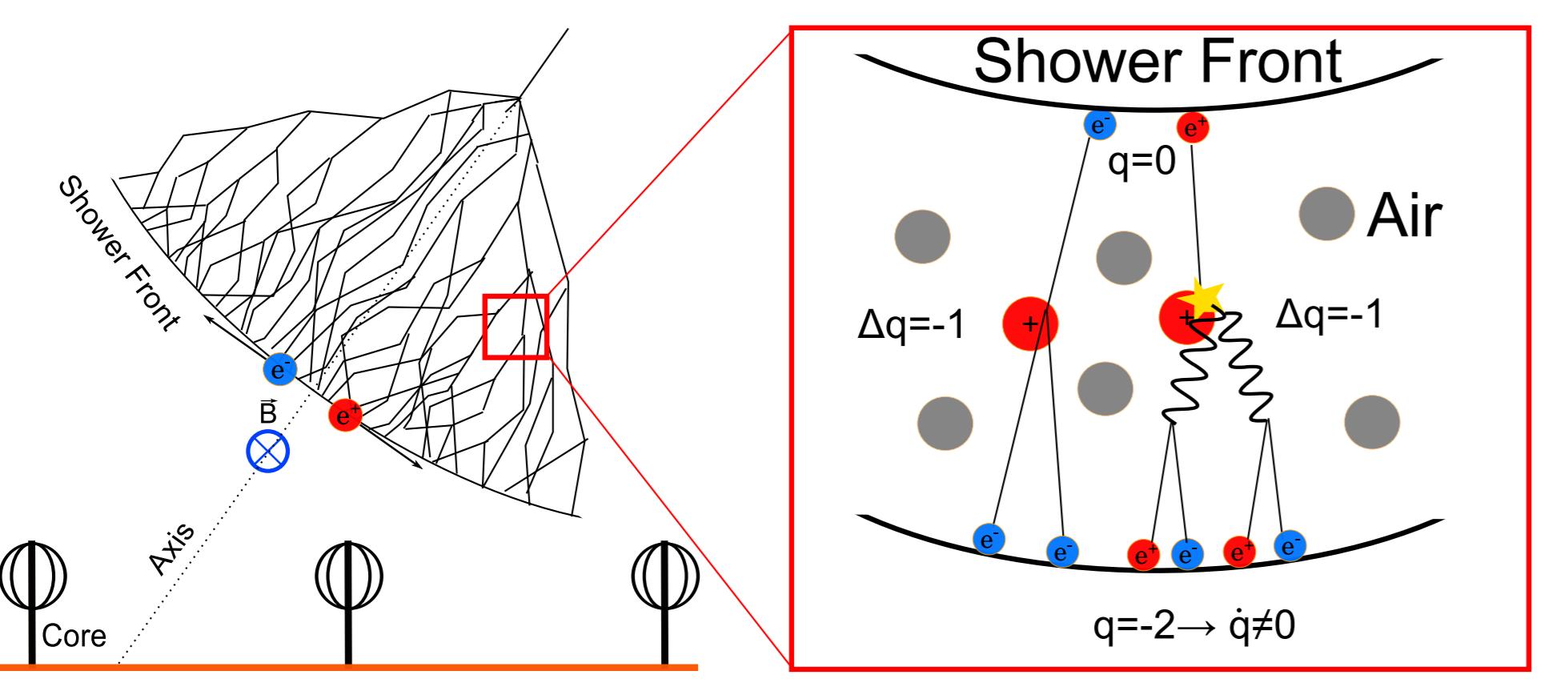


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Radio emission from air showers

- MHz radio pulse from the shower front
- Two important emission mechanisms:

- Geomagnetic effect [1]** **Askaryan effect [2]**
- deflection of $e^+ e^-$
 - time-varying transverse currents
 - time-varying net charge
 - typical contribution 10%



Tunka-Rex [3]

- Radio extension of Tunka-133 [4] (1 km² air-Cherenkov detector for cosmic rays in Siberia)
- Hybrid measurements of air showers with 10^{17} - 10^{18} eV primary energy
- Started 2012, externally triggered by Tunka-133
- 25 antenna stations, 200m spacing,
- 2 Channels per station, 30-80 MHz band

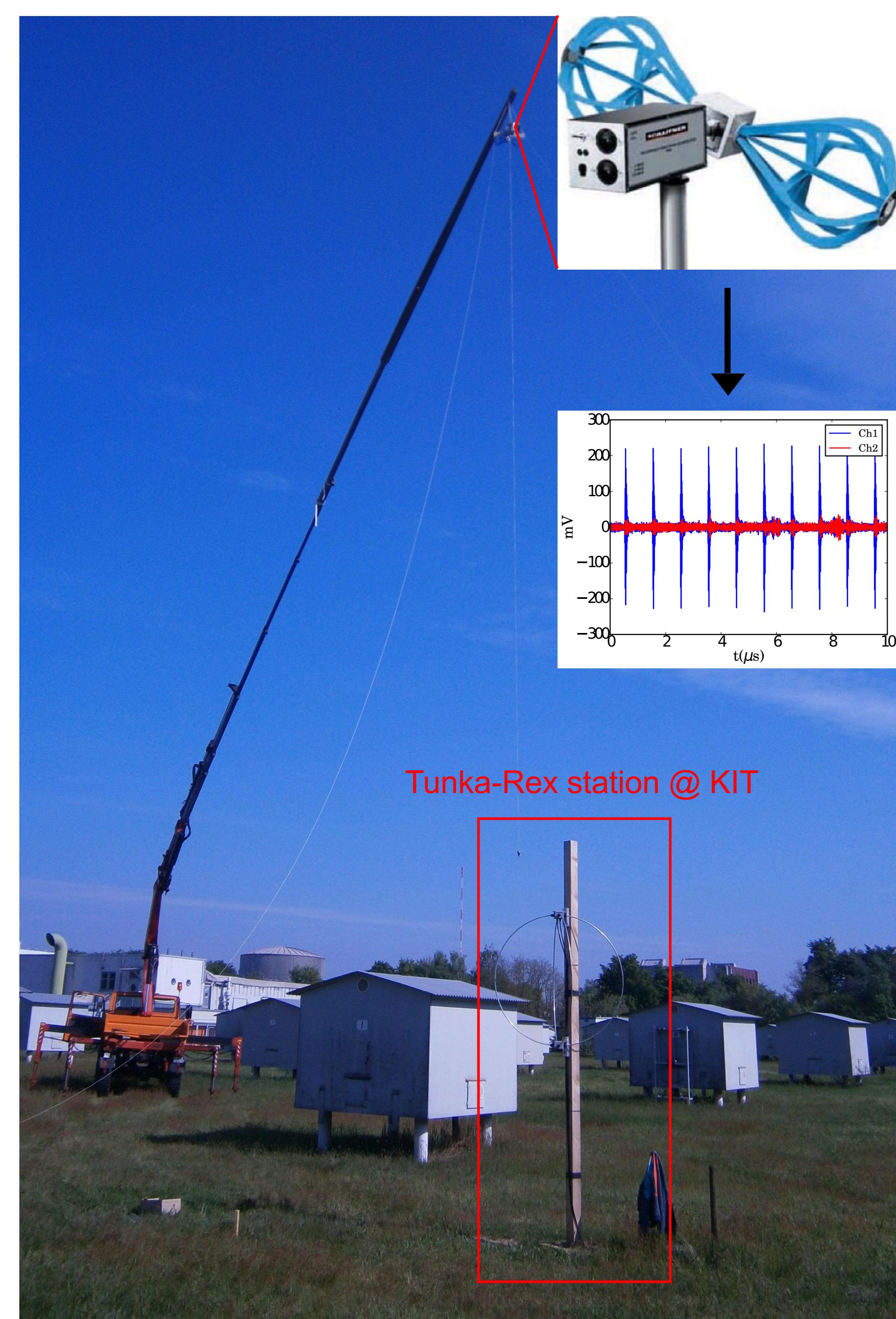
A Tunka-Rex antenna station. It has two SALLA type antennas, aligned along the NE-SW and NW-SE axes.



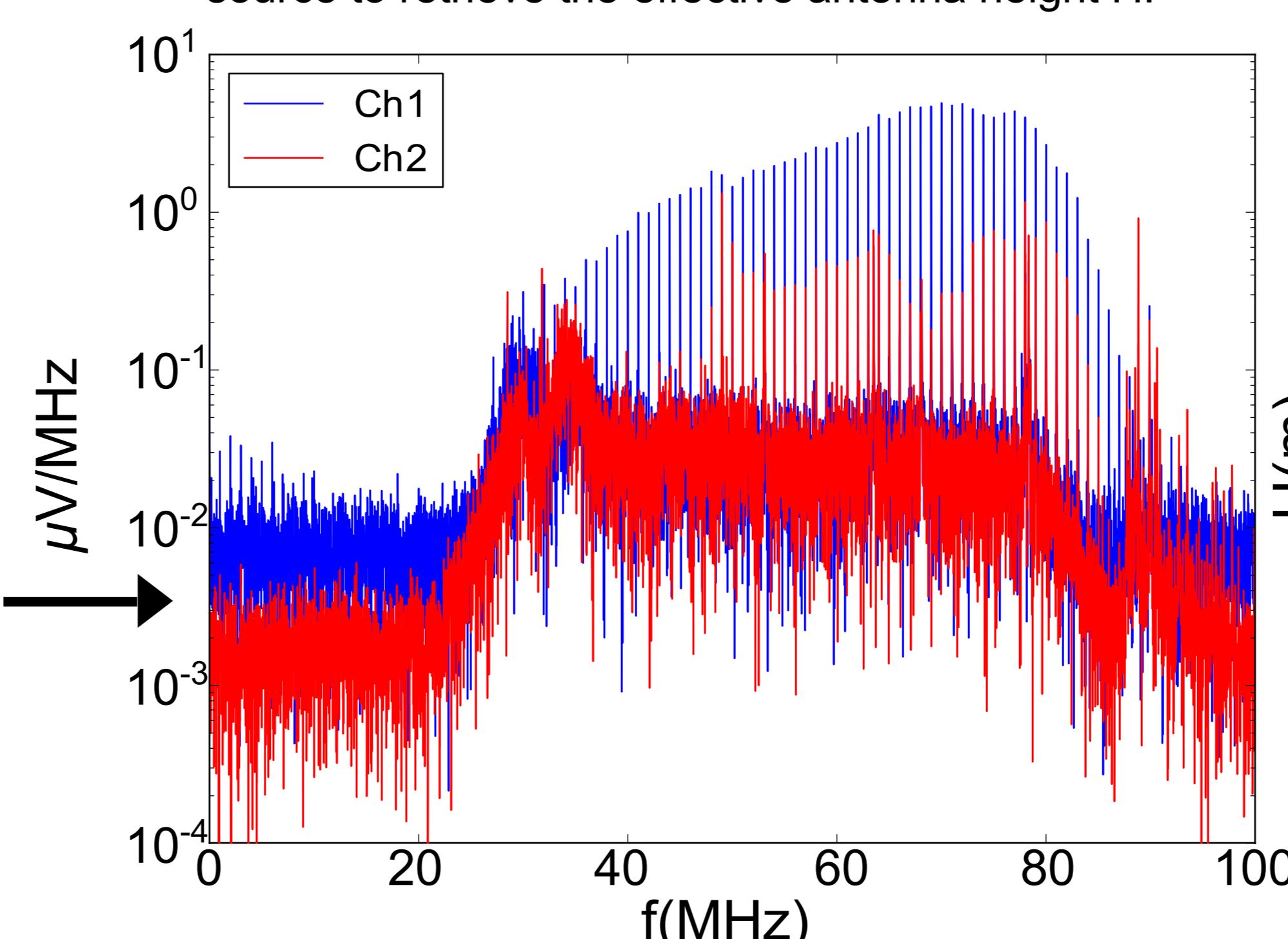
Goals of Tunka-Rex

- Cross-calibration of Radio + air-Cherenkov detector
- Determine **achievable precision** with the radio technique (energy and composition)
- Compare radio emission to model calculations and other experiments

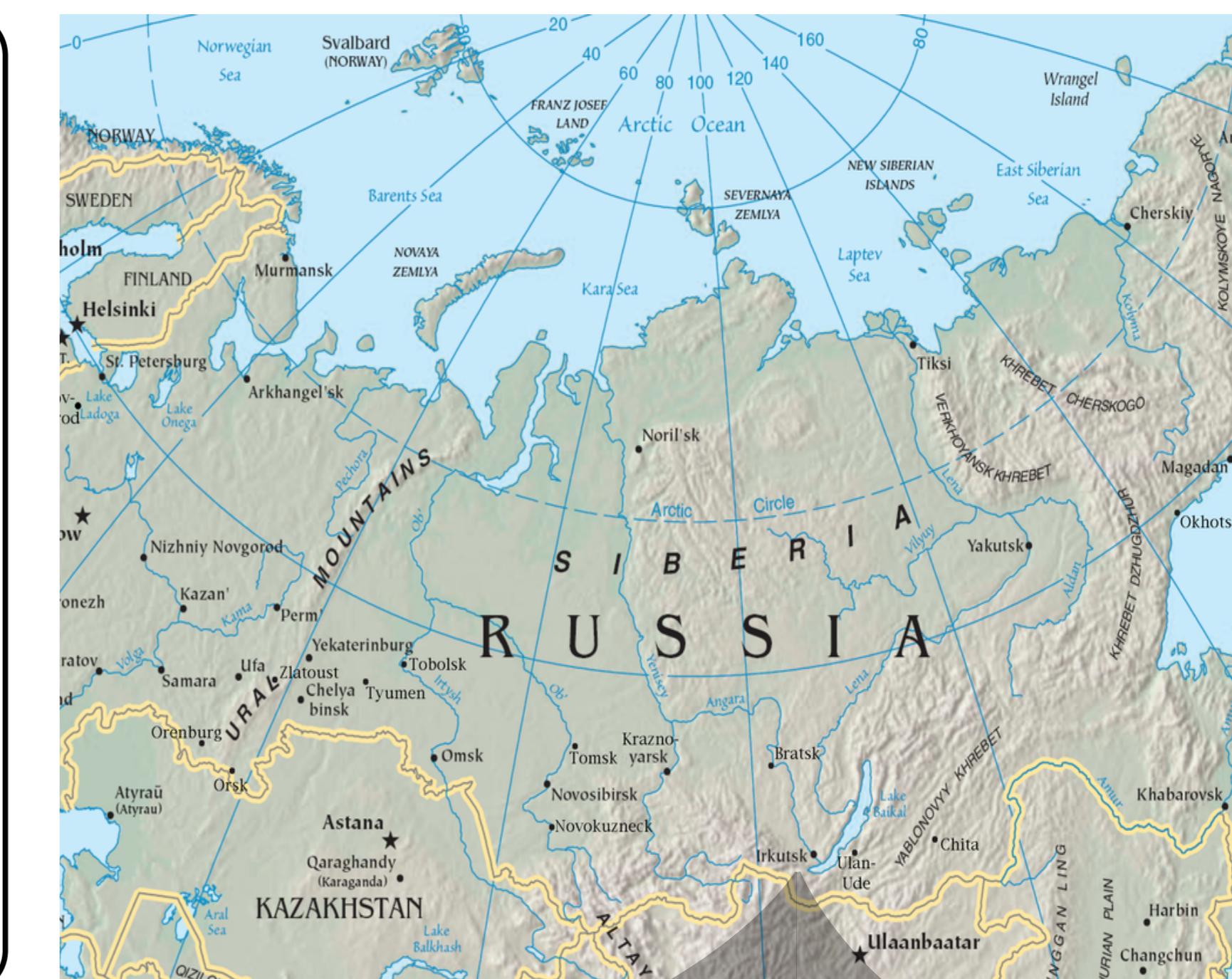
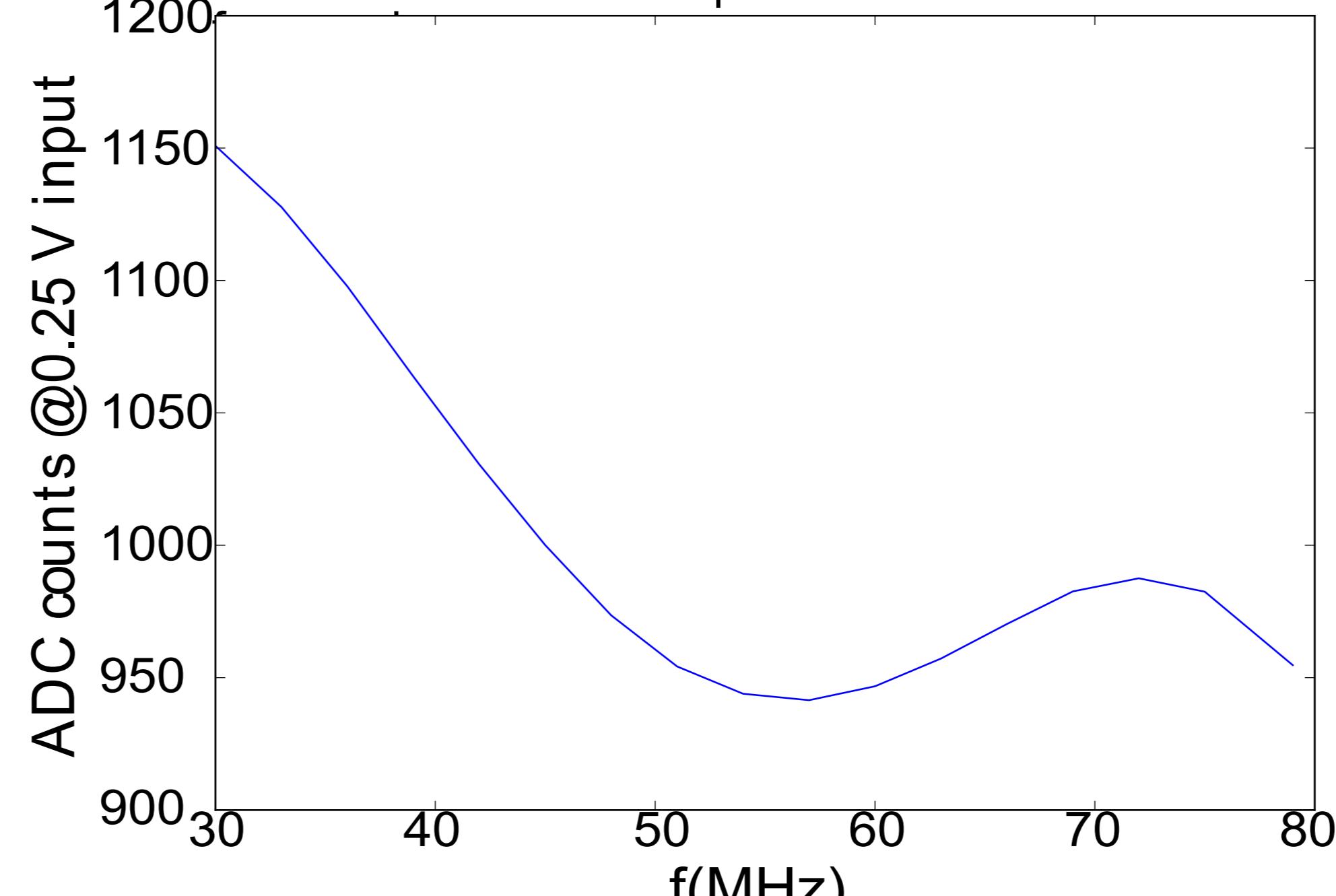
Calibration procedure for a Tunka-Rex antenna in Karlsruhe. The crane holds a calibrated source above the antenna.



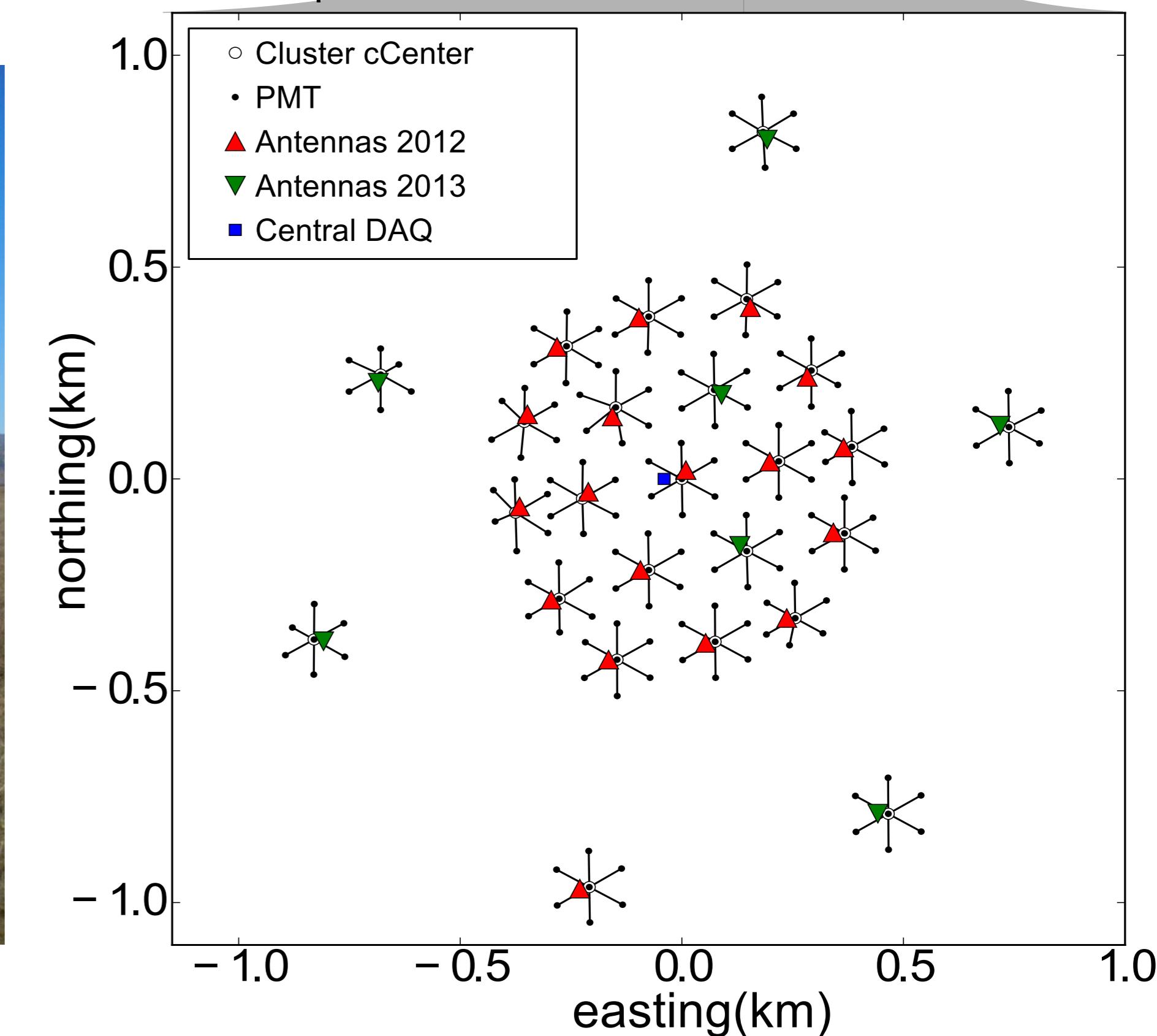
The recorded amplitudes shown in the plot are compared to the emitted Amplitudes of the calibration source to retrieve the effective antenna height H.



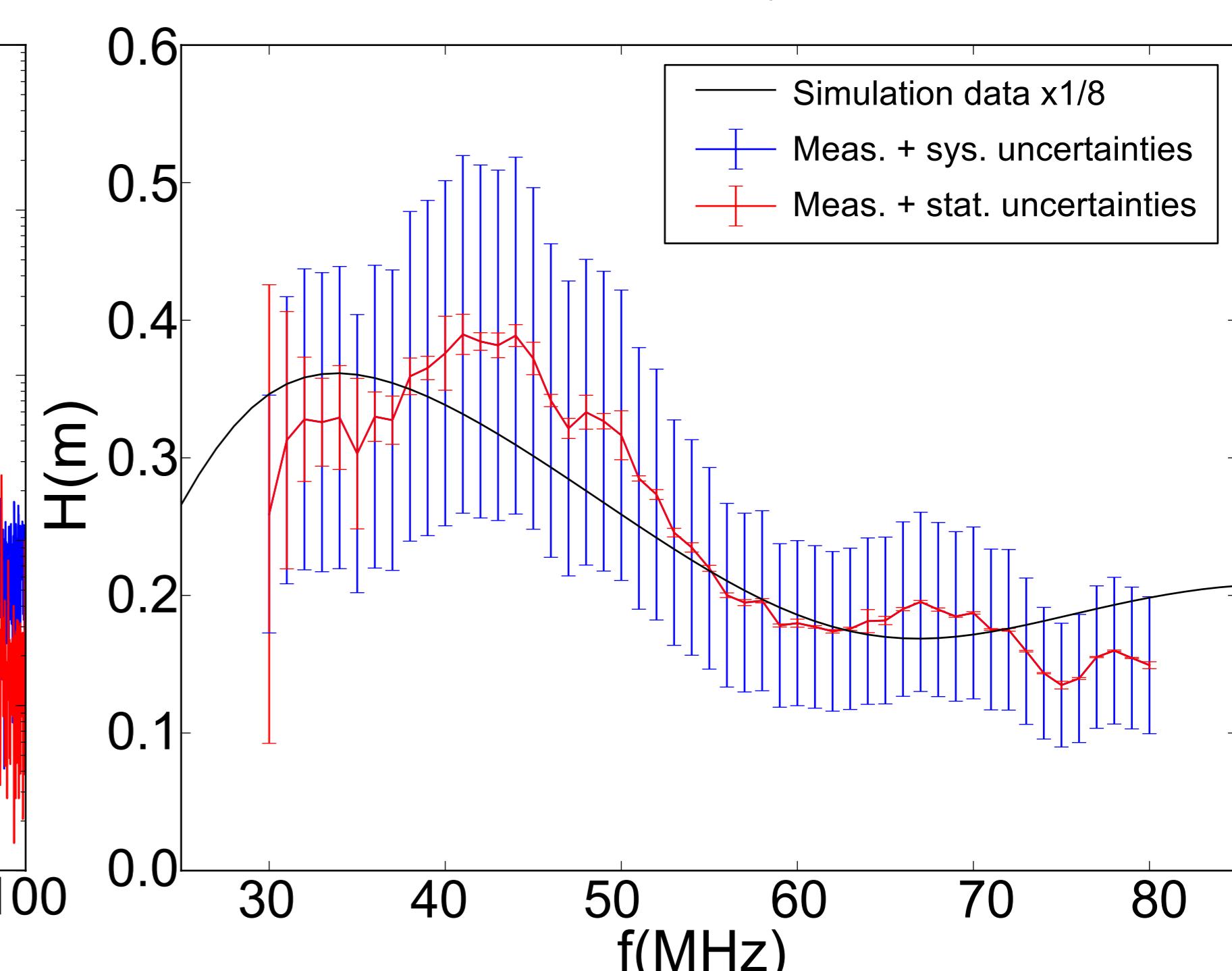
Response of the digitization hardware, measured with sine waves of 0.25 V amplitude at different



Above: Location of Tunka-Rex.
Below: Map of the Tunka-133 clusters and Tunka-Rex.



Calibration results versus antenna simulation. The simulation data are divided by 8.



Calibration of Tunka-Rex

- Original full analog Hardware Chain at Karlsruhe
- Commercial calibrated comb source [5]
- Antenna simulation predicted 8x higher gain, shape comparable
- Directivity and phase from simulation; Amplitude scale from calibration
- All digital and analog components measured and taken into account



References

- [1] F. D. Kahn and I. Lerche, Proc. Phys. Soc., Sect. A 289, 206, 1966.
- [2] G. A. Askaryan, Sov. Phys. JETP 14, 441, 1961.
- [3] D. Kostunin, "The Tunka Radio Extension: latest analysis results", talk on this conference, **Wednesday**, September 3rd, **12:30**, Lecture Hall: MPH.
- [4] N. Budnev, "The Tunka experiment: from cosmic ray to gamma-ray astronomy", talk on this conference, **Thursday**, September 4th, **15:15**, Lecture Hall: HGH.
- [5] TESEQ RSG 1000 + DPA 4000

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