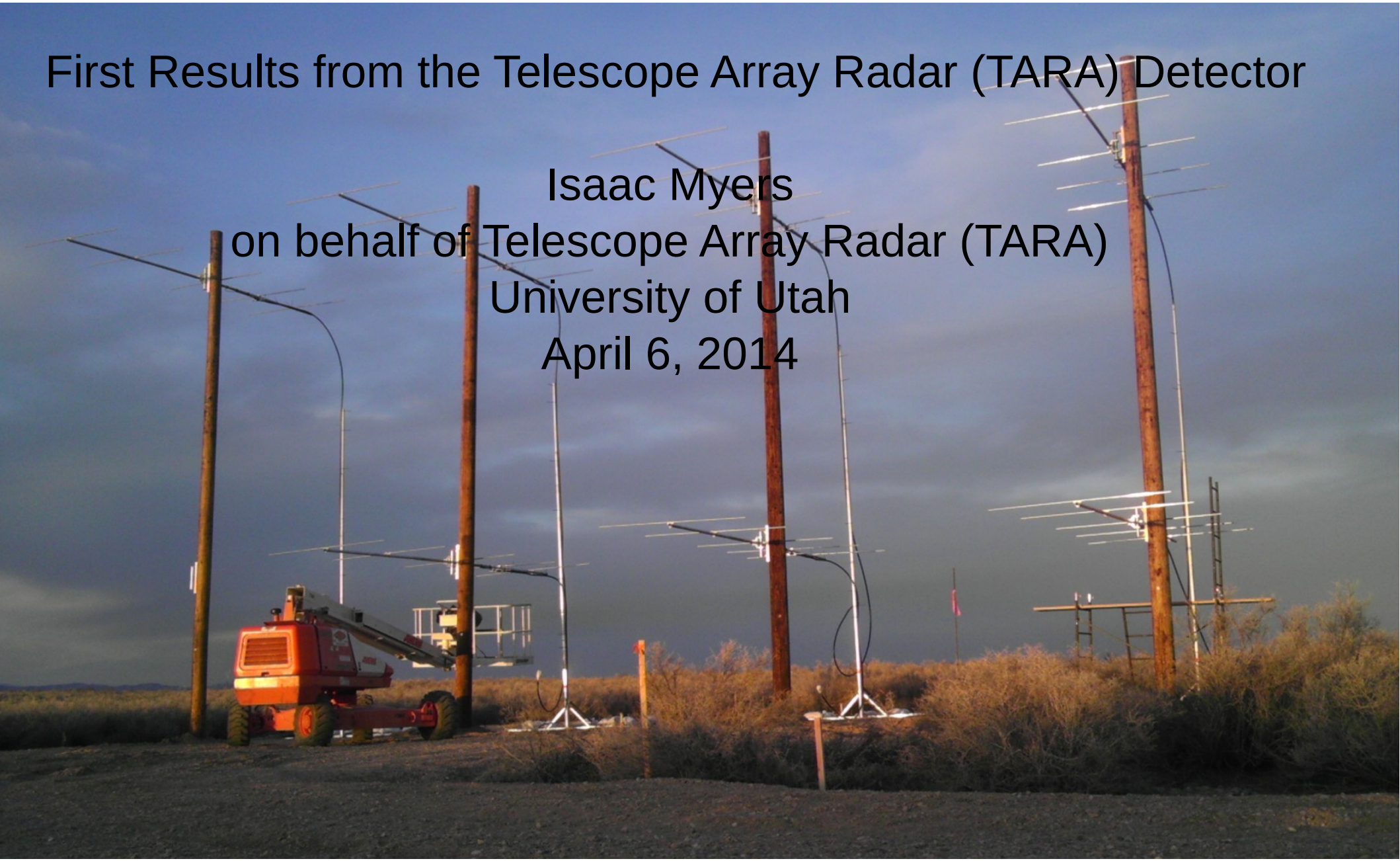
First Results from the Telescope Array Radar (TARA) Detector



Isaac Myers
on behalf of Telescope Array Radar (TARA)
University of Utah
April 6, 2014

TARA

R. Abbasi, M. Abu Bakr Othman, C. Allen, J. Belz, D. Besson, M. Byrne, B. Farhang-Boroujeny, A. Gardner, W. Hanlon, J. Hanson, D. Ikeda, C. Jayanthmurthy, S. Kunwar, I. Myers, T. Nakamura, J. S. Rankin, H. Sagawa, P. Sokolsky, H. Takai, T. Terasawa, G.B. Thomson

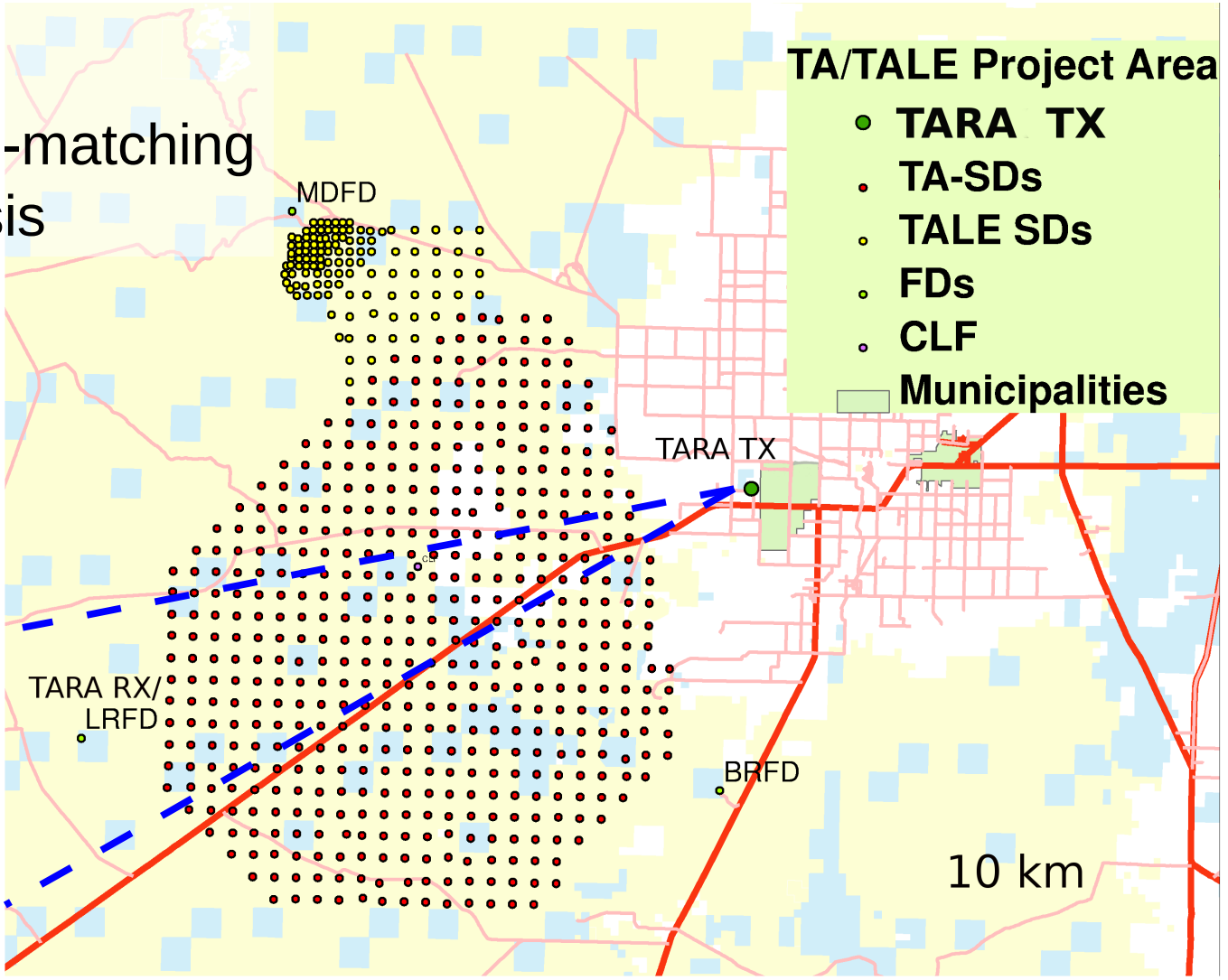
(BNL, Kansas, Nebraska, NIPR, ICRR, Utah)

and the Telescope Array Collaboration

Support: US NSF-PHY, NSF-MRI, W.M. Keck Foundation,
Utah VP for Research, Dean College of Science
Japan Grants-in-Aid for “Exploratory Research”
Salt Lake City TV stations KUTV, ABC4

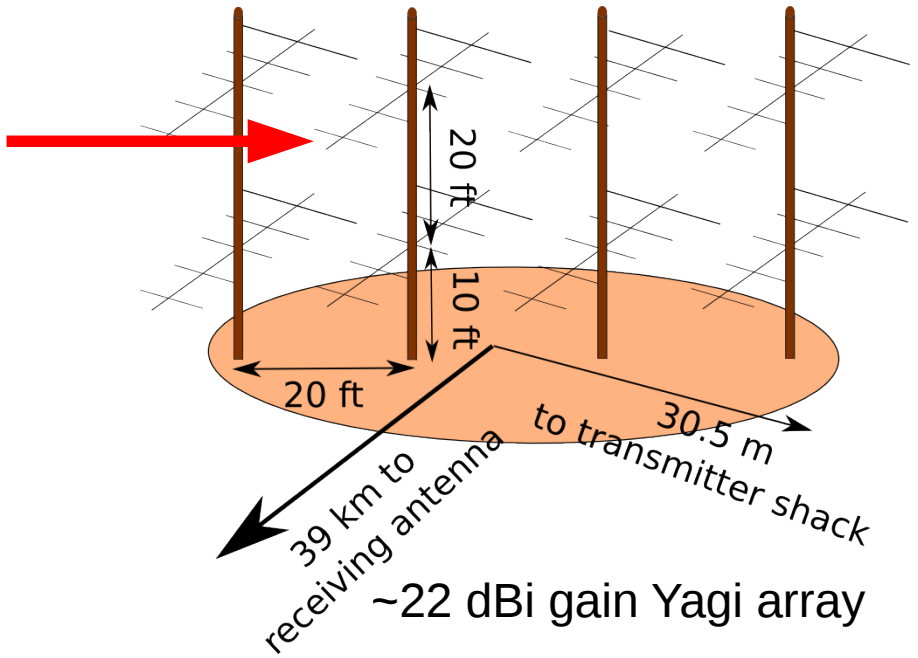
Introduction

- Brief TARA overview
- Transmitter
- DAQ
- TA FD event time-matching
- Waveform analysis

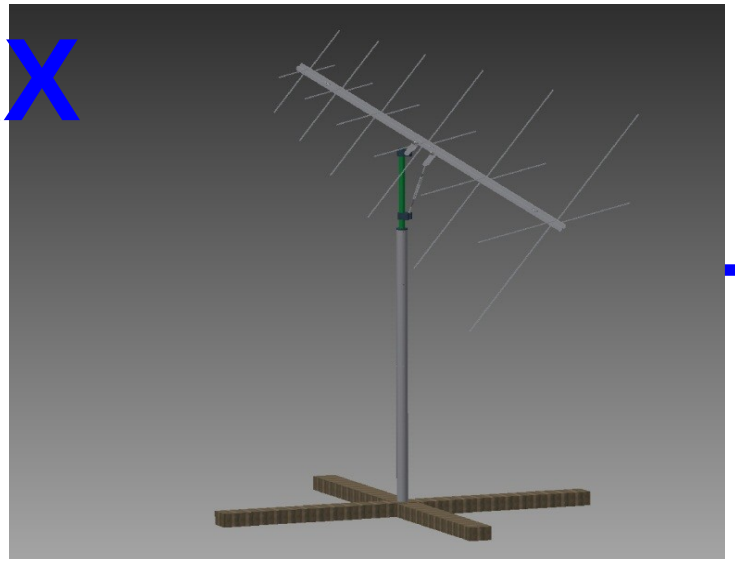


TARA Overview

25 kW typical, > 220 days integrated on-time



~22 dBi gain Yagi array

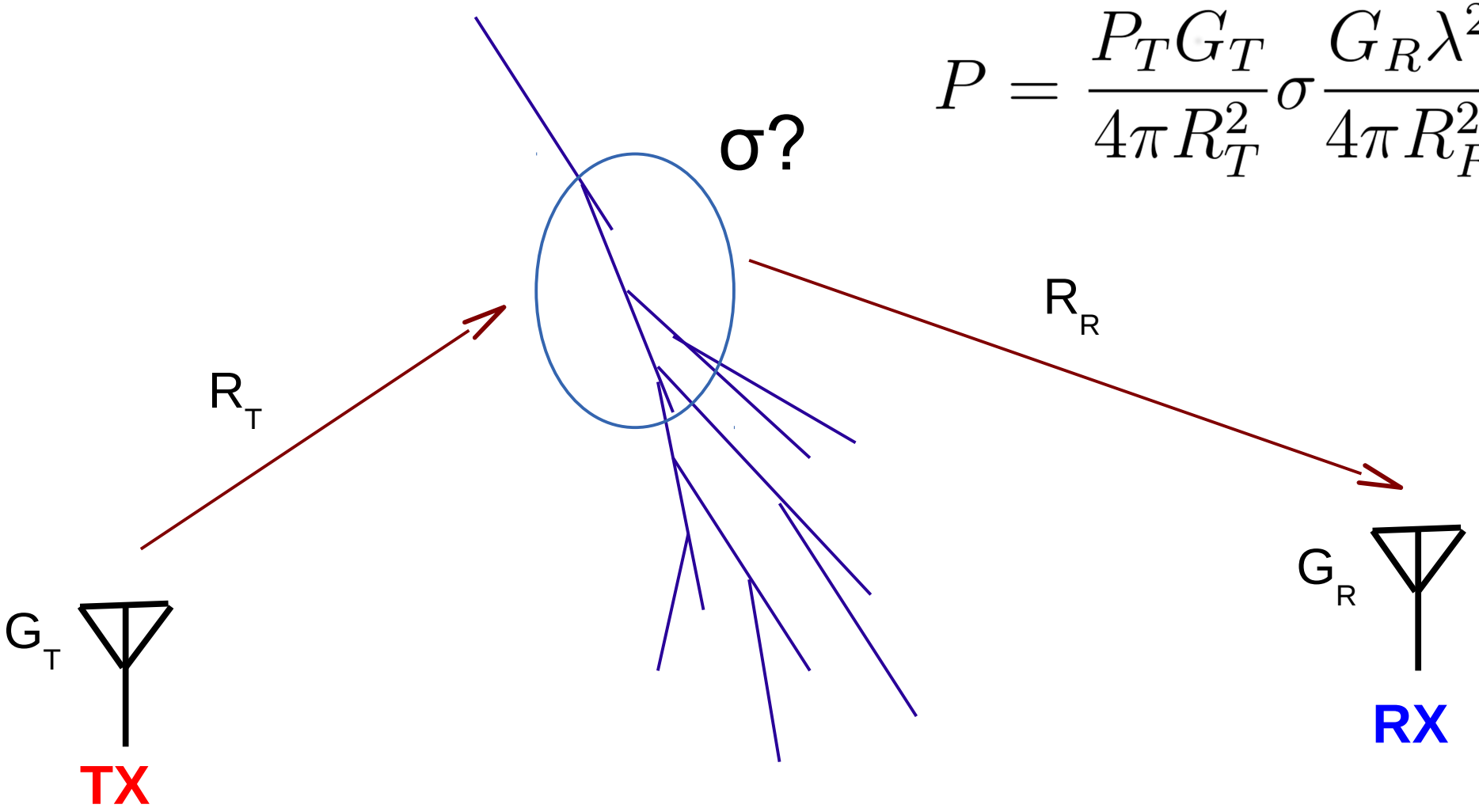


broadband LPDA (log periodic dipole antenna) at receiver site

FlexRIO: 250 MS/s ADC; three trigger modes: FD, self, snapshot; four channels

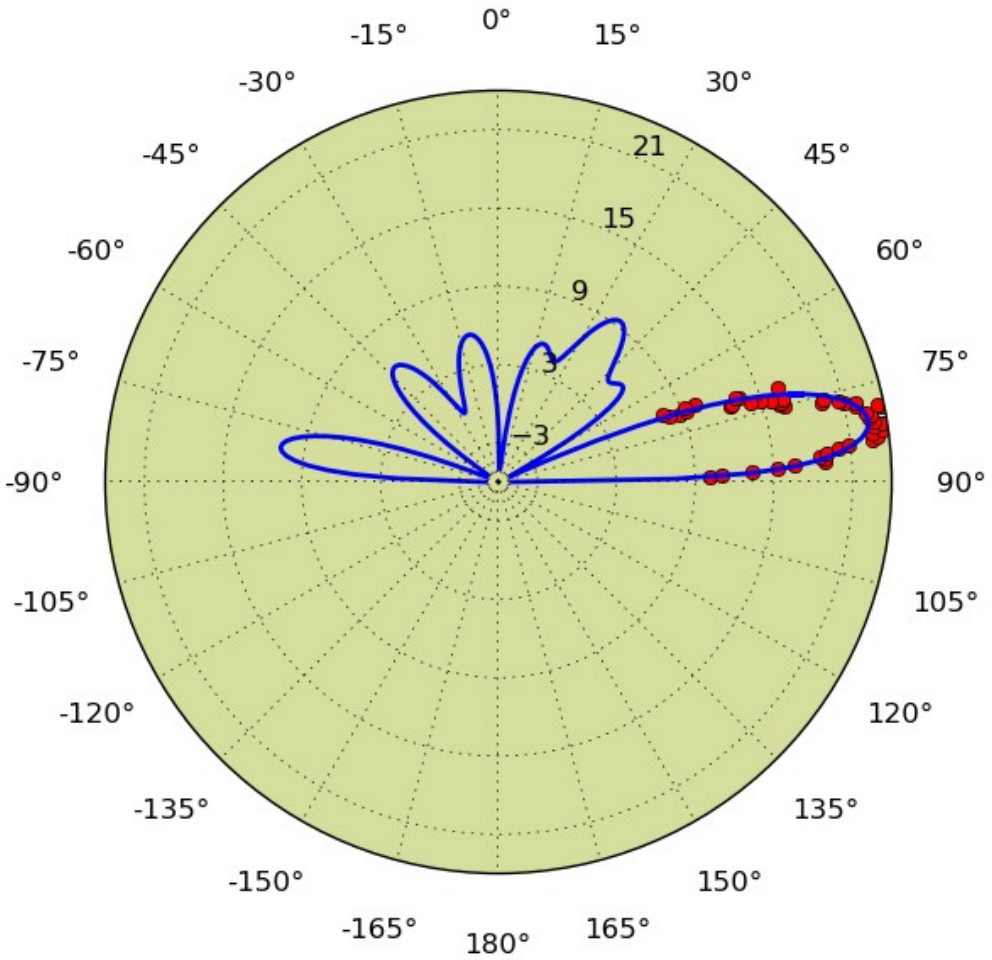
Goal: TA/TARA Coincident Events, Quantify RCS (σ)

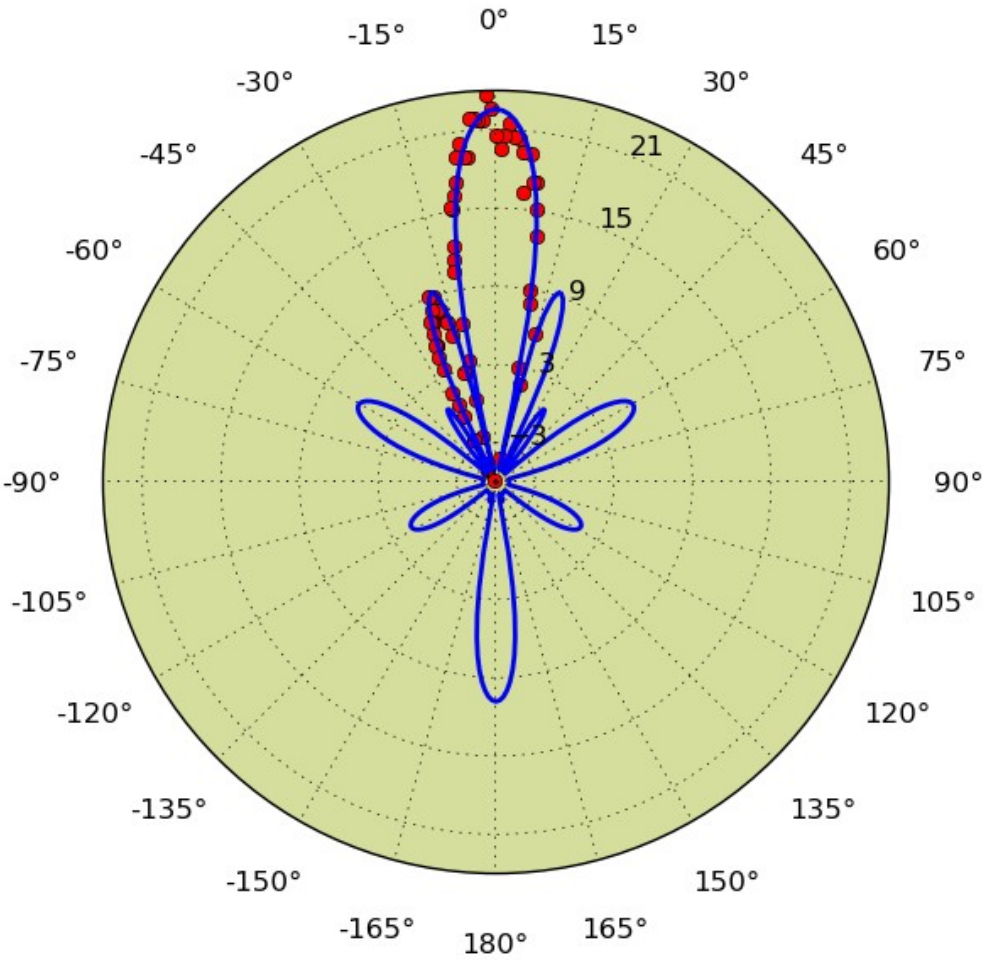
$$P = \frac{P_T G_T}{4\pi R_T^2} \sigma \frac{G_R \lambda^2}{4\pi R_R^2}$$



Calculate or put limits on σ using bi-static radar equation, chirp simulation and Monte Carlo analysis of FD-triggered wave forms

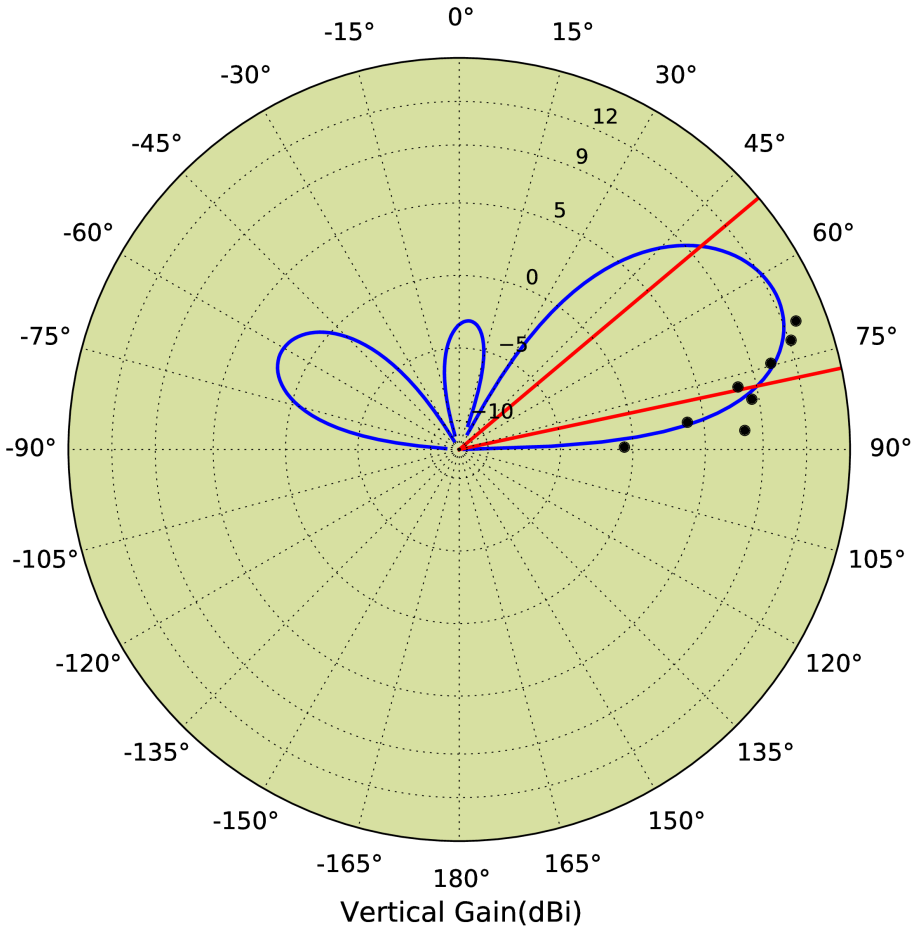
Transmitting Antenna Measurements

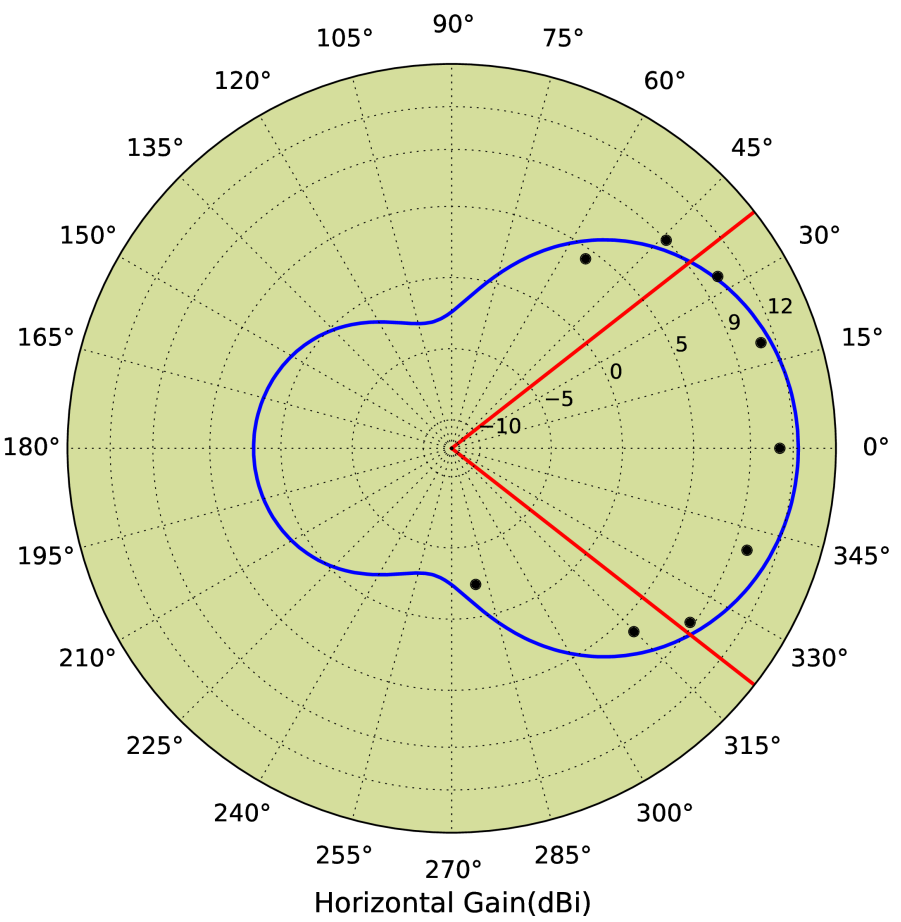




Vertical (left) and azimuthal (right) transmitter antenna radiation patterns at 54.1 MHz. **Theoretical** (Numerical Electromagnetic Code) curves and **scaled data** are shown. Th vertical radiation pattern was measured by lifting a small transmitter in a tethered weather balloon. The horizontal pattern was measured by walking along the ground, perpendicular to the antenna pointing direction, with a hand held spectrum analyzer.

Receiving Antenna Measurements

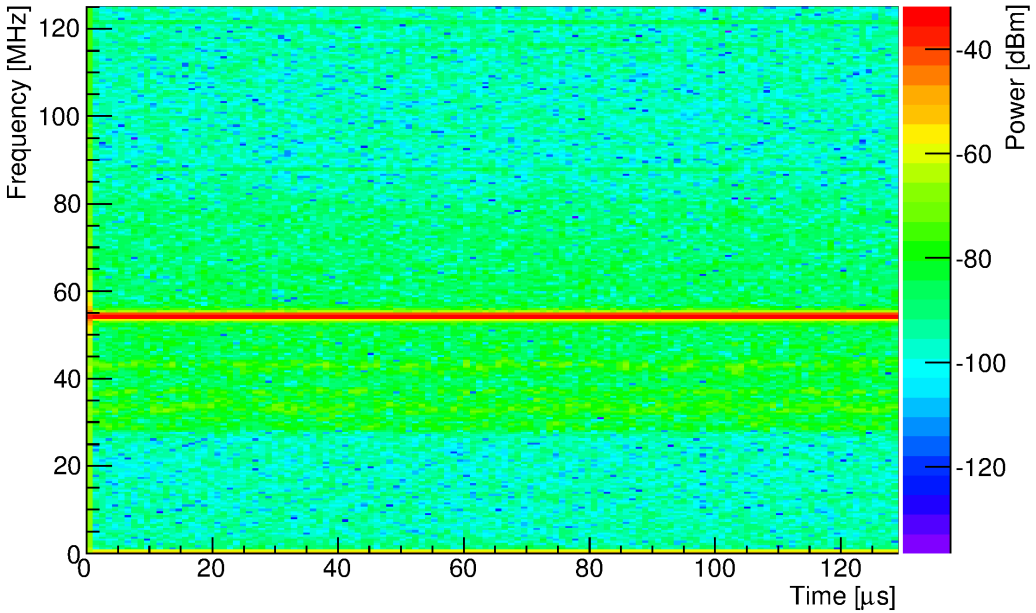


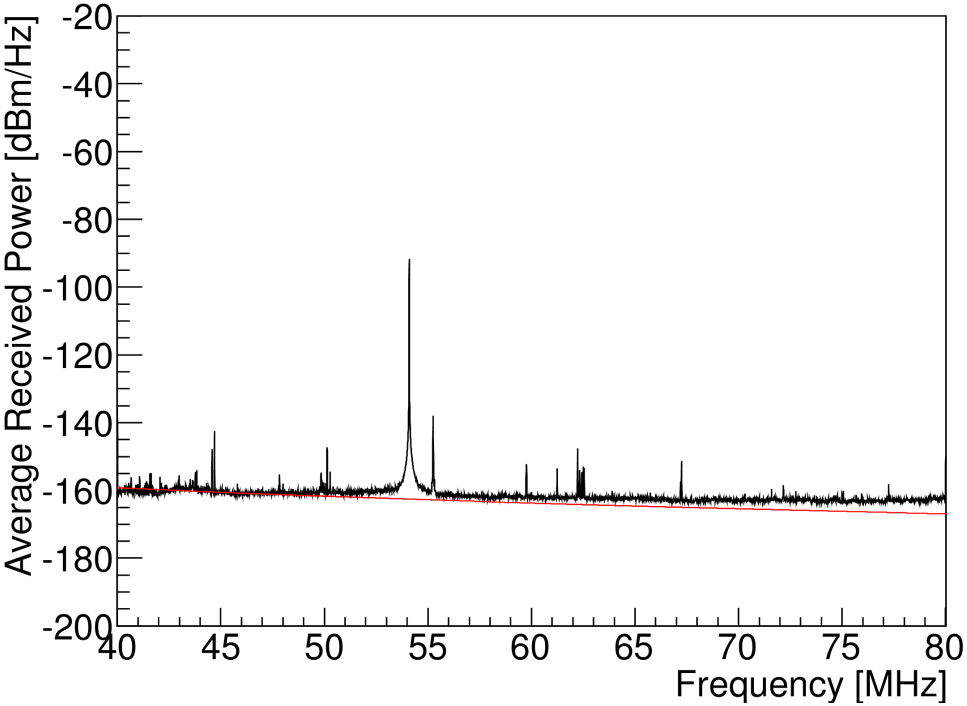


Broadband log-periodic dipole antenna radiation patterns at 54.1 MHz shown with **theoretical** and **scaled** data. The vertical pattern was also measured by floating a small transmitter with a weather balloon.

This measurement will be repeated to get better results.

Receiver RF Chain Calibration



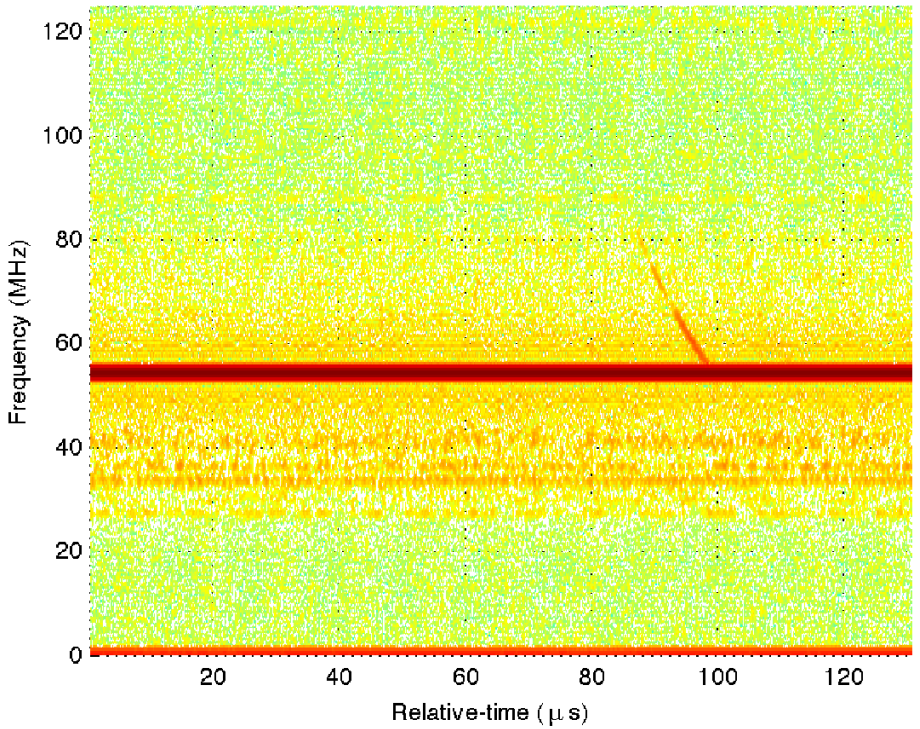


Left: Snapshot spectrogram features from filters and amps: lightning arrestor, RF limiter, 30 dB amp, 40 MHz HP, FM bandstop, 90 MHz LP.

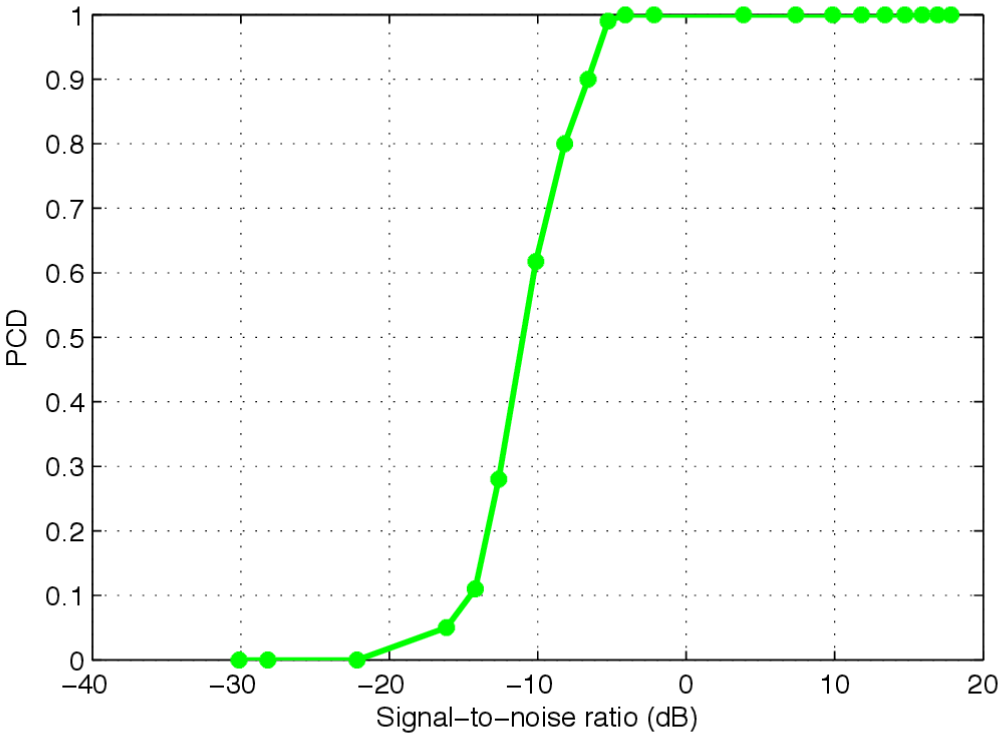
Right: Snapshot daily average noise power (**black**) with Cane* galactic spectrum (**red**)

*H.V. Cane, Spectra of Non-thermal Radiation from the Galactic Polar Regions, Mon. Not. R. Astron. Soc. 189 (1979).

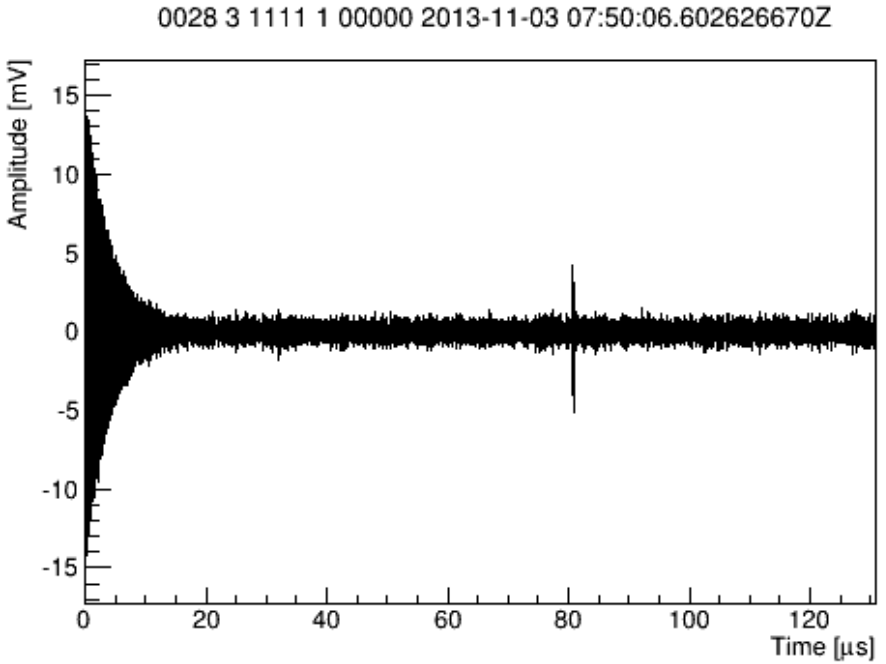
DAQ Testing: Emulation of Simulated Chirp in situ

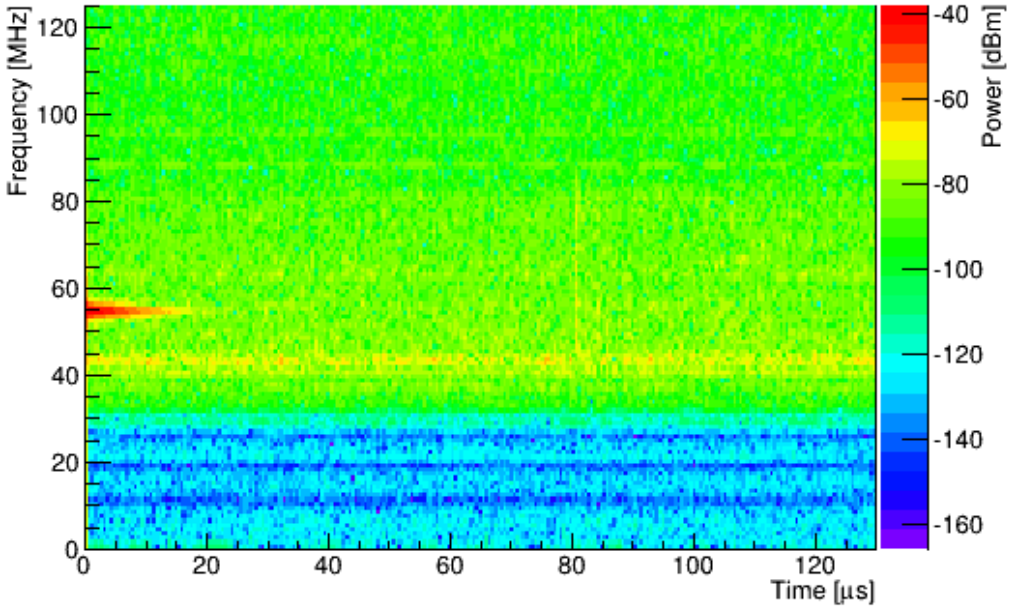


Self-triggered spectrogram of emulated chirp from simulation: **nonlinear, non-constant amplitude**.



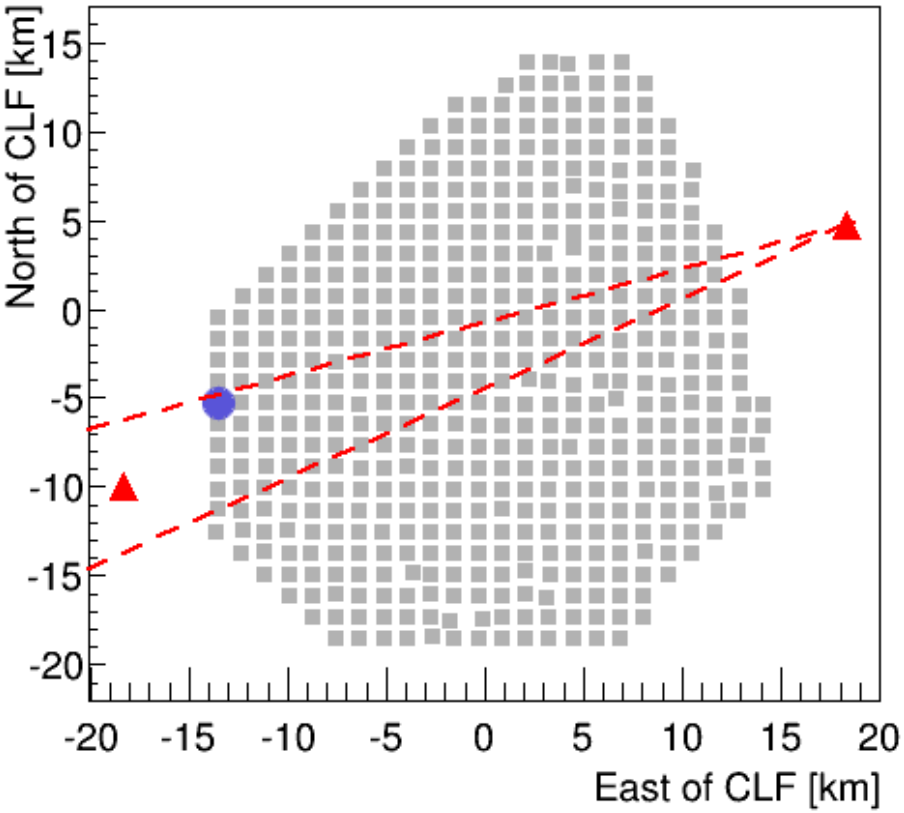
PCD (efficiency) vs. SNR of a simulated chirp wave form transmitted by a dipole antenna. **Conclusion**: -6 dB SNR chirp signals will self-trigger very efficiently.

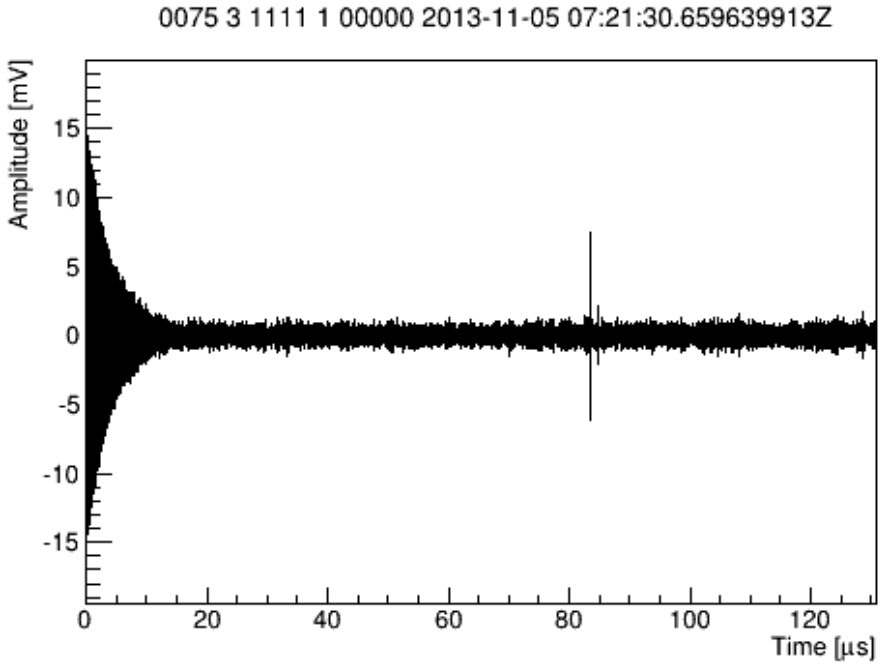


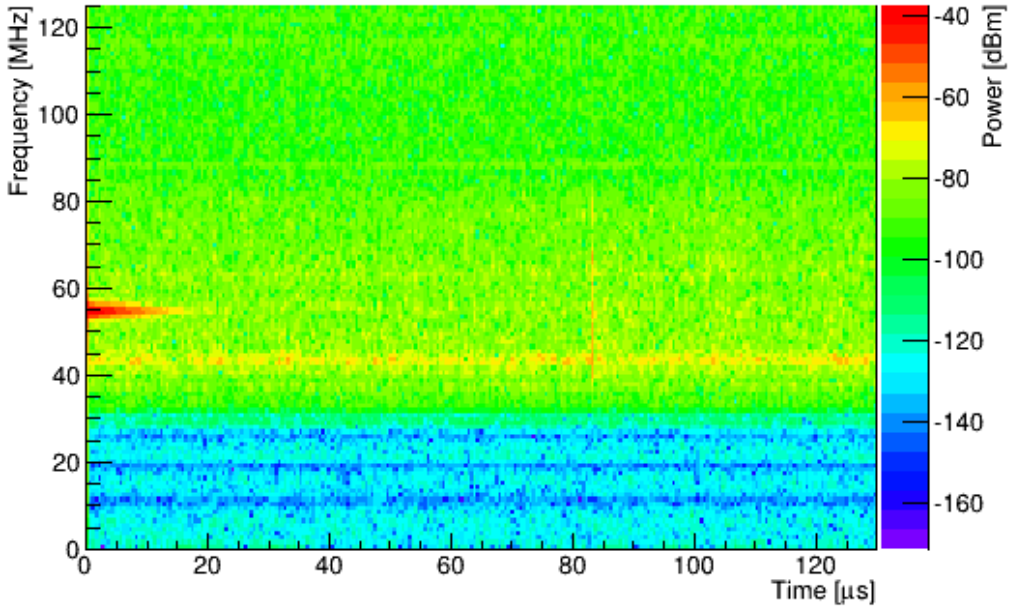


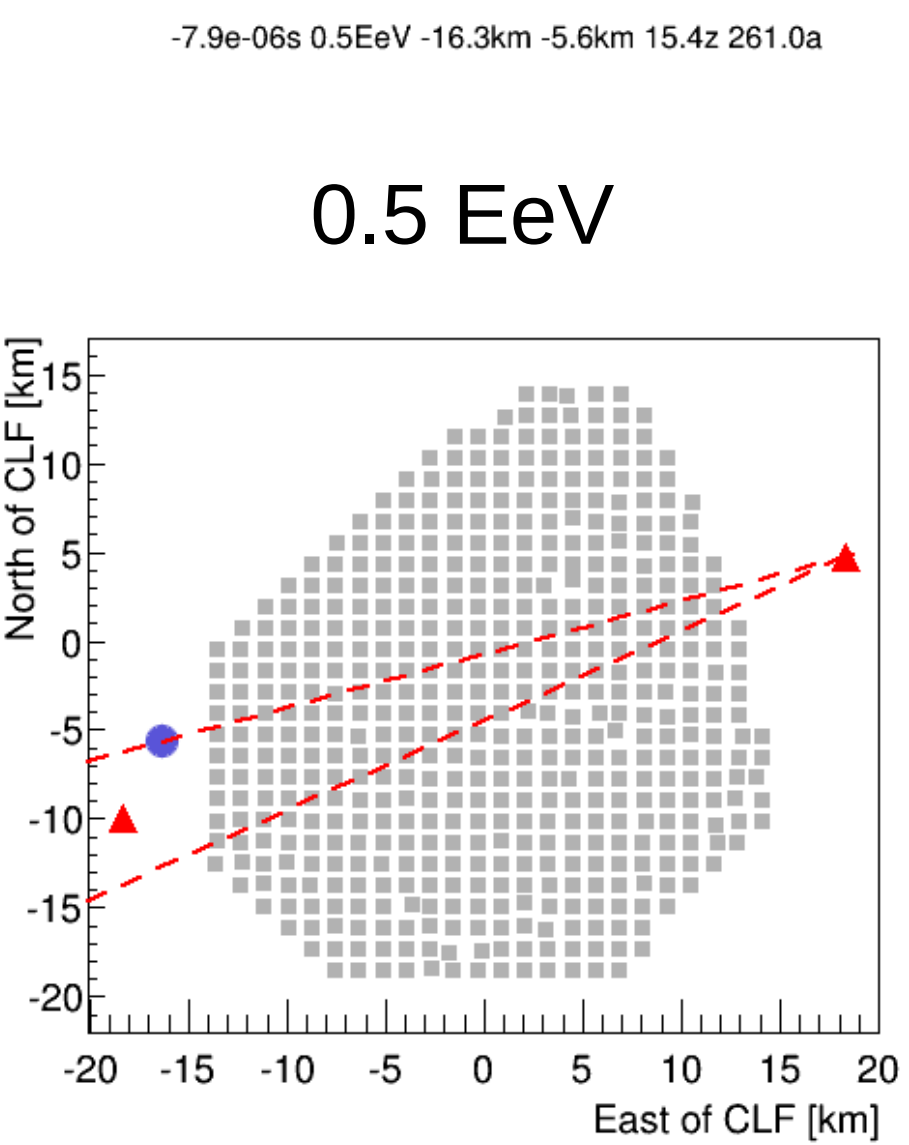
-7.7e-06s 0.3EeV -13.5km -5.3km 24.8z 204.8a

0.3 EeV

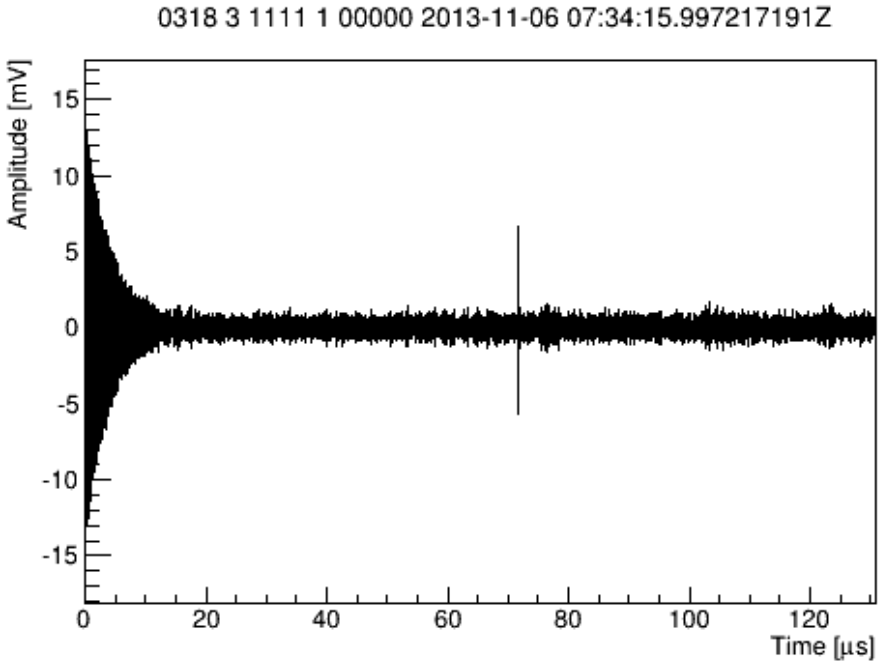


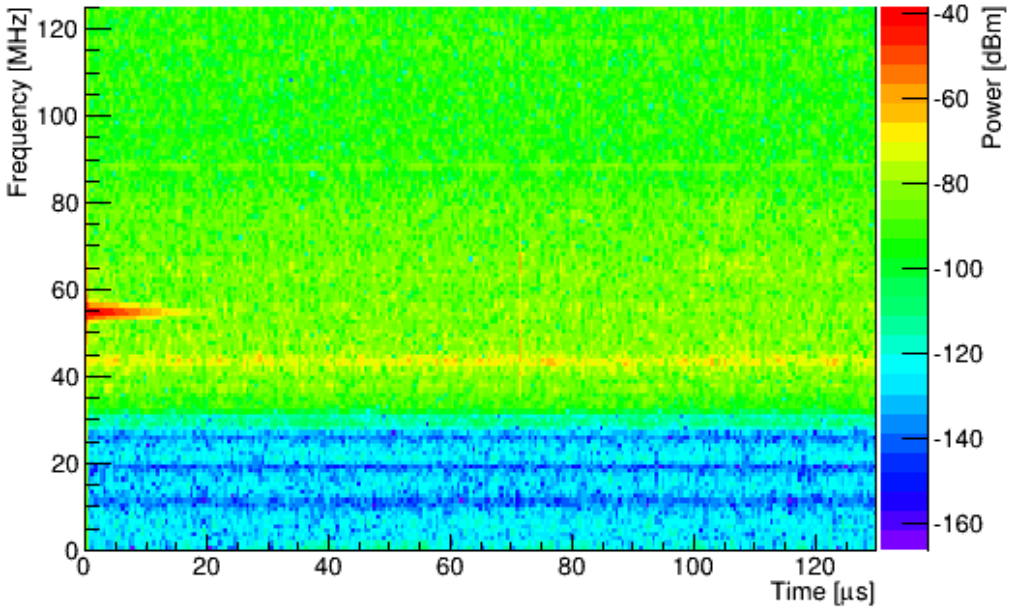

0075 3 1111 1 00000 2013-11-05 07:21:30.659639913Z
Amplitude [mV]
Time [μs]


Frequency [MHz]
Time [μs]
Power [dBm]


-7.9e-06s 0.5EeV -16.3km -5.6km 15.4z 261.0a
North of CLF [km]
East of CLF [km]

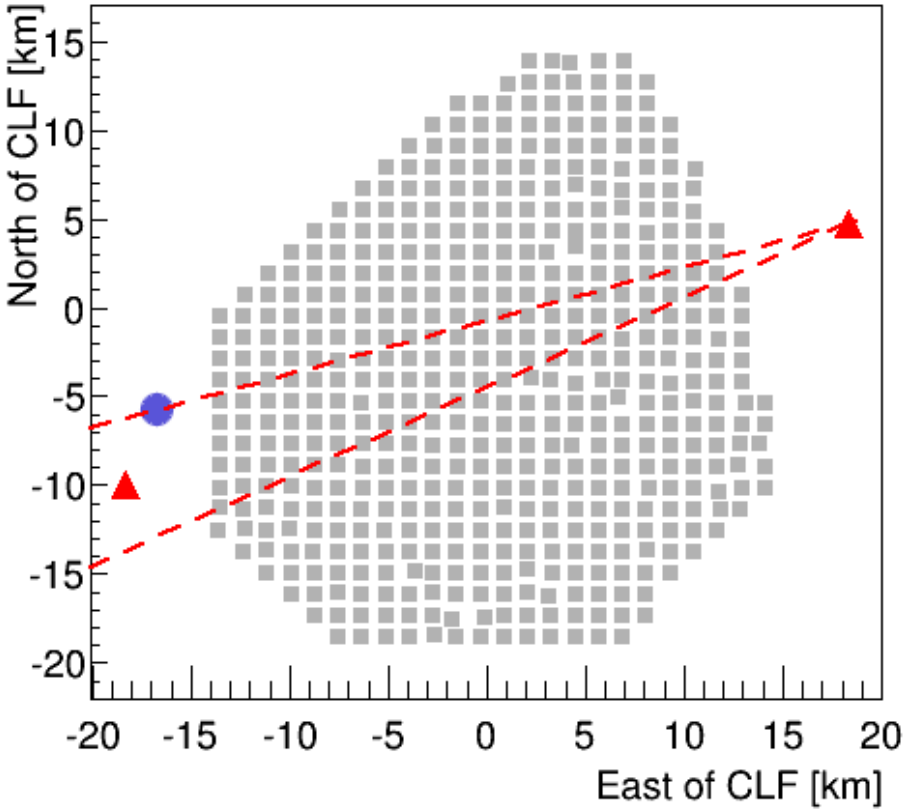
0.5 EeV

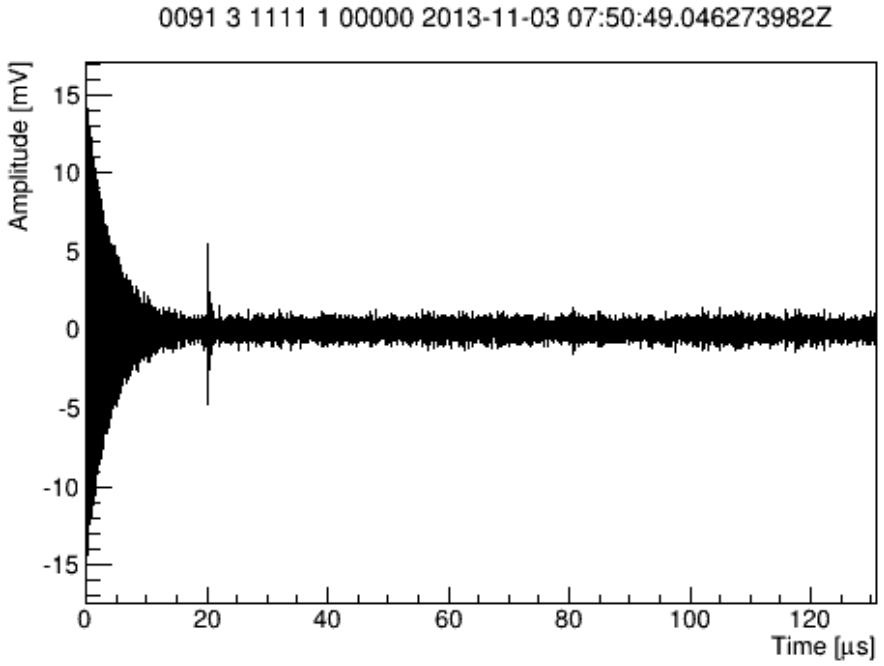


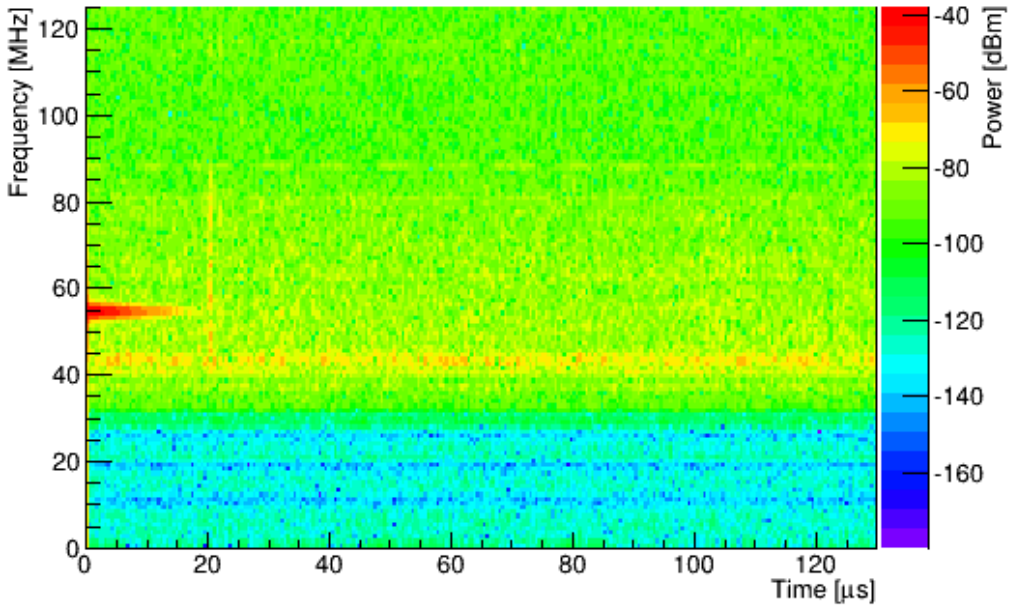


-8.2e-06s 0.6EeV -16.8km -5.7km 12.0z 229.3a

0.6 EeV

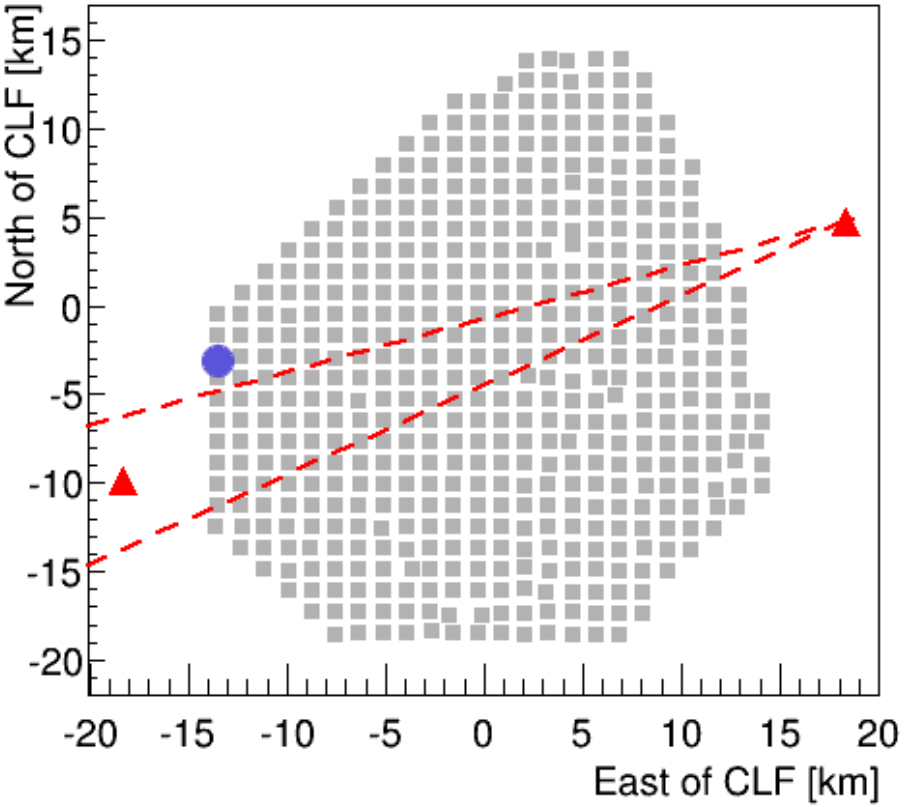


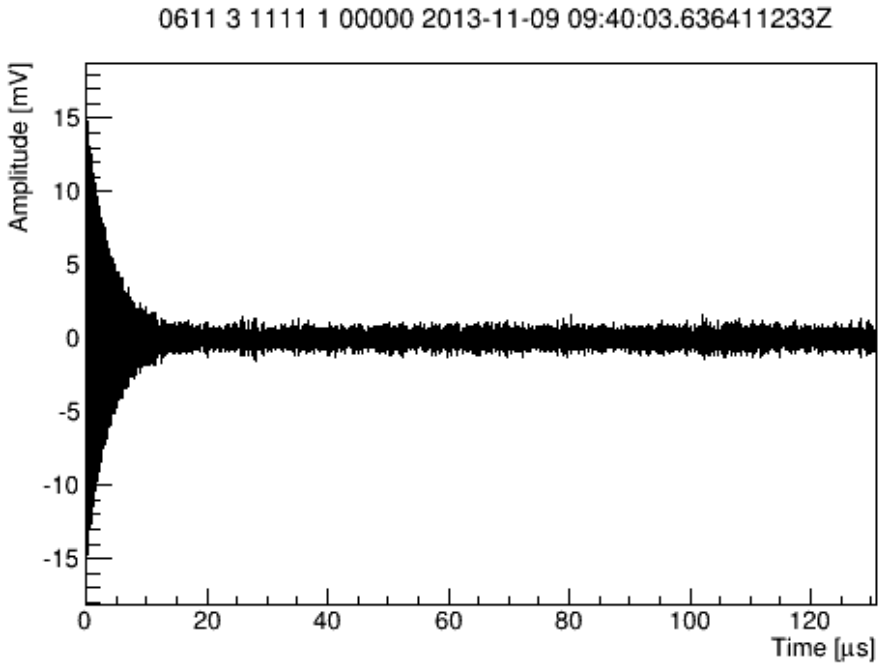


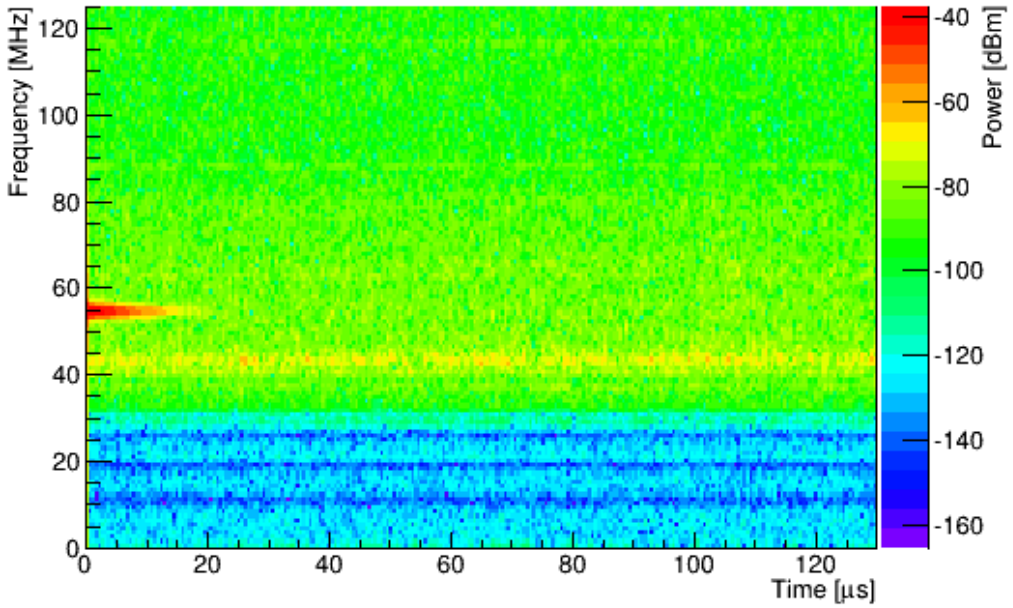


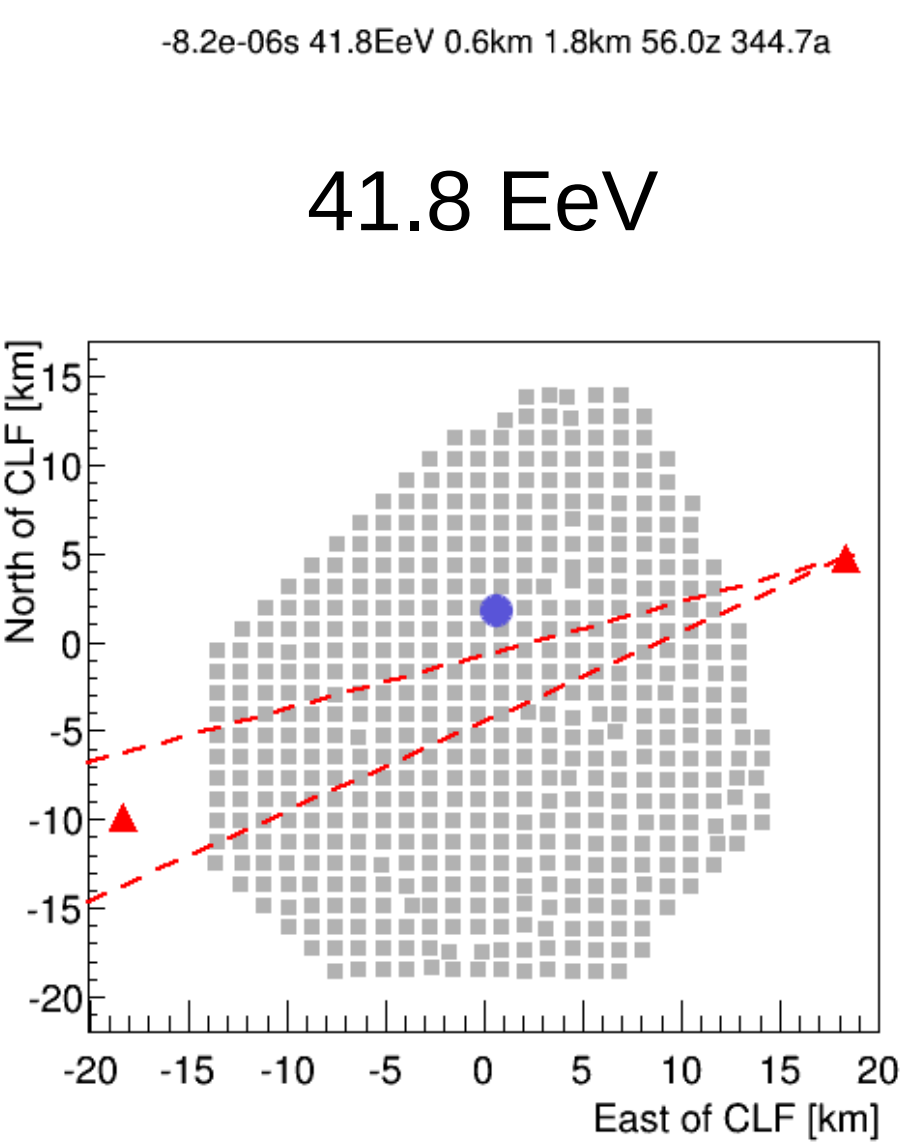
-8.0e-06s 0.7EeV -13.5km -3.1km 33.5z 309.8a

0.7 EeV

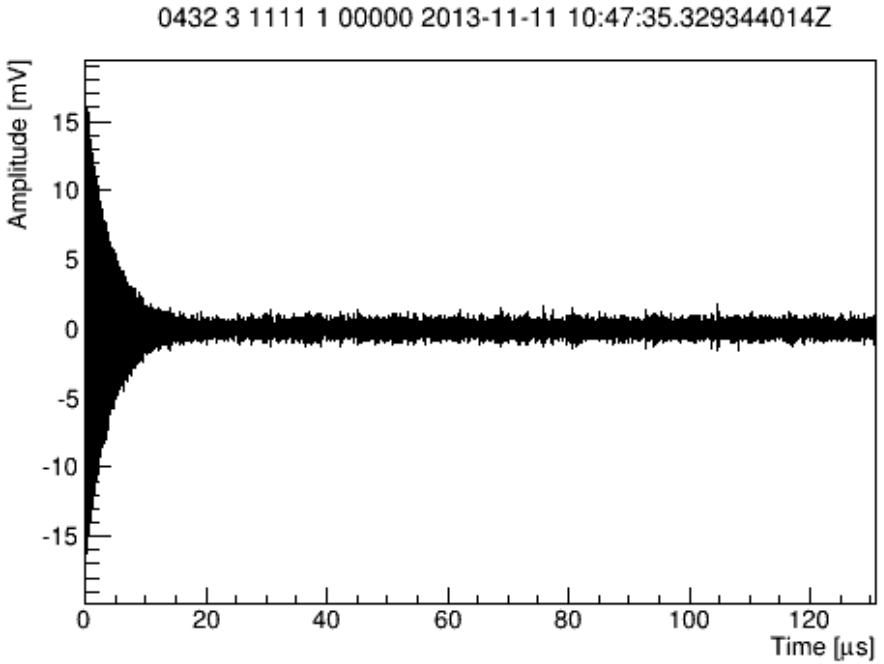


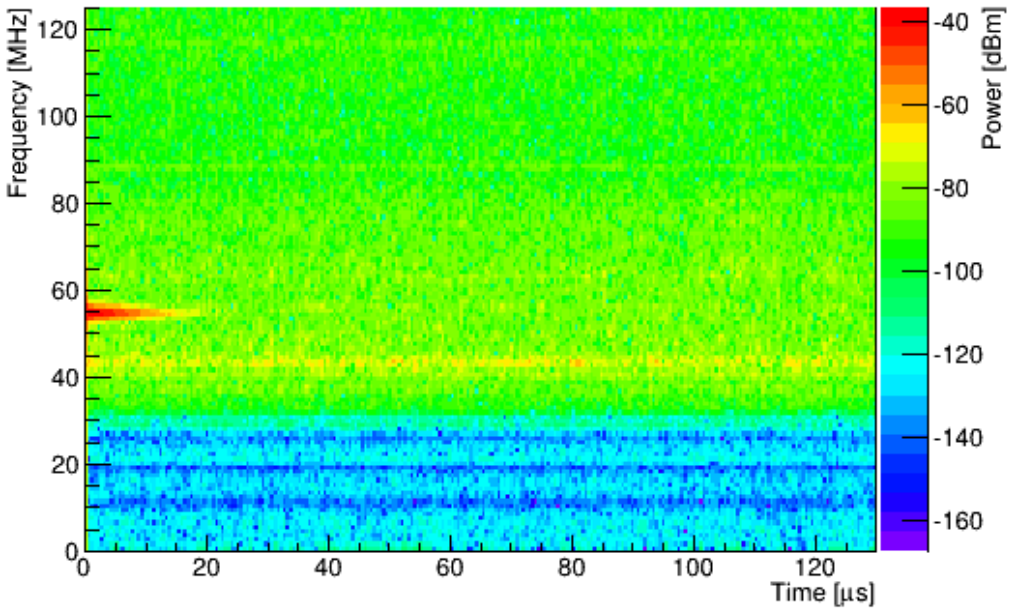

0611 3 1111 1 00000 2013-11-09 09:40:03.636411233Z
Amplitude [mV]
15
10
5
0
-5
-10
-15
0
20
40
60
80
100
120
Time [μs]


Frequency [MHz]
120
100
80
60
40
20
0
0
20
40
60
80
100
120
Time [μs]
-40
-60
-80
-100
-120
-140
-160
Power [dBm]


-8.2e-06s 41.8EeV 0.6km 1.8km 56.0z 344.7a
North of CLF [km]
15
10
5
0
-5
-10
-15
-20
-20
-15
-10
-5
0
5
10
15
20
East of CLF [km]

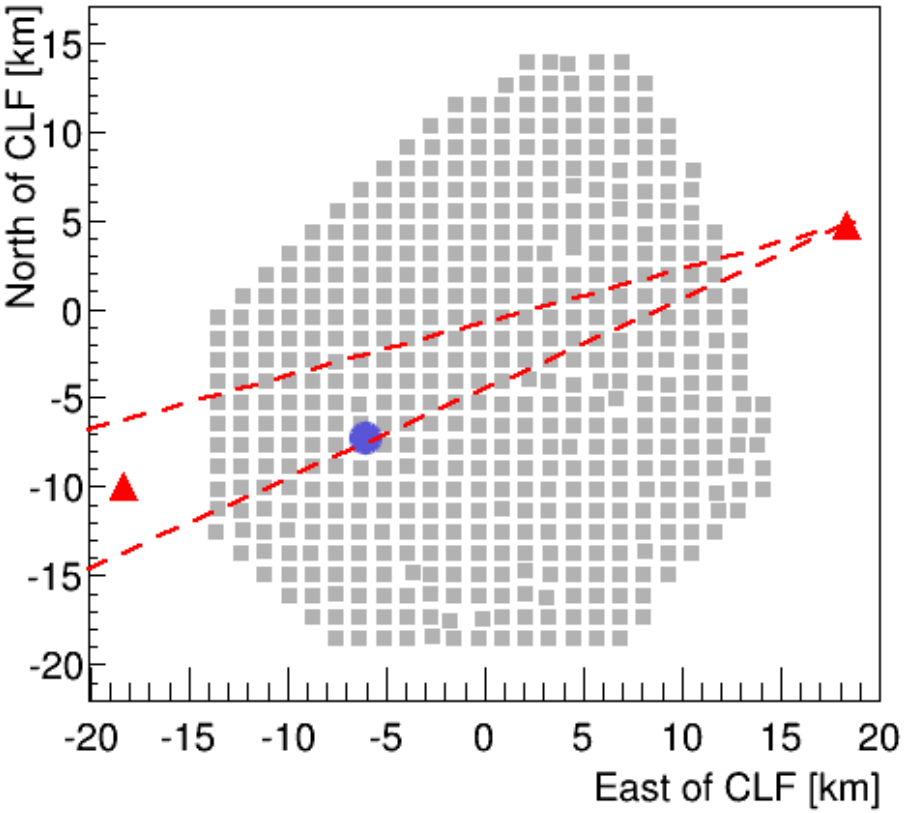
41.8 EeV





-8.0e-06s 22.2EeV -6.1km -7.2km 24.0z 343.3a

22.2 EeV



Time Matching with TA Events

Summary:

- About 800 matched FD event displays (strict cuts) viewed by eye
- Some interesting waveforms, not statistically significant: chance probability 0.3 from random backgrounds
- **Future comparison with loose cuts events**

Measuring the Radar Cross Section (RCS)

- Assume RCS = SF σ_{tw}
- Coincidences?
  1. simulate scatter
  2. determine SF required to produce observed signal
- No coincidences?
  1. simulate scatter
  2. determine SF required for 90% detection efficiency
- Quote SF or 90% c.l. upper limit
- **Mostly done, not ready for showing publicly**

$$P = \frac{P_T G_T}{4\pi R_T^2} \sigma \frac{G_R \lambda^2}{4\pi R_R^2}$$

$$P' = \frac{P_T G_T}{4\pi R_T^2} (SF\,\sigma_{tw}) \frac{G_R \lambda^2}{4\pi R_R^2}$$

*J.W. Crispin and A.L. Maffett, Radar Cross-Section Estimation for Simple Shapes, Proc. IEEE 53 (1965).

Moving Forward

- Remote station deployment, Summer 2014
  - ✔ see Sam Kunwar's talk today, Session K8 (1:30 PM), room 202
- Increase receiver dynamic range
  - ✔ increase amplification
  - phase-tracking carrier canceler, mid 2014
- Increase transmitter power 25 kW → 40 kW
  - ✔ upgrade power amplifiers, April 2014
  - ✔ balance power supply load, mid 2014
  - re-bias amps for efficiency, 40 kW (6.3 MW ERP), 2014
- TARA/TA SD time-matching

End