Dead Channel Monitor
and
Systematic Statistical Approach to Noise Hunting

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Virgo DetChar meeting 24 July 2015

Overview

- Dead Channel Monitor
  - Use RMS signal to be alerted when an environmental sensor is disconnected or powered off.
- Statistical approach to noise hunting
  - a multipurpose systematic search tool

Dead Channel Monitor in DMS

Goals:

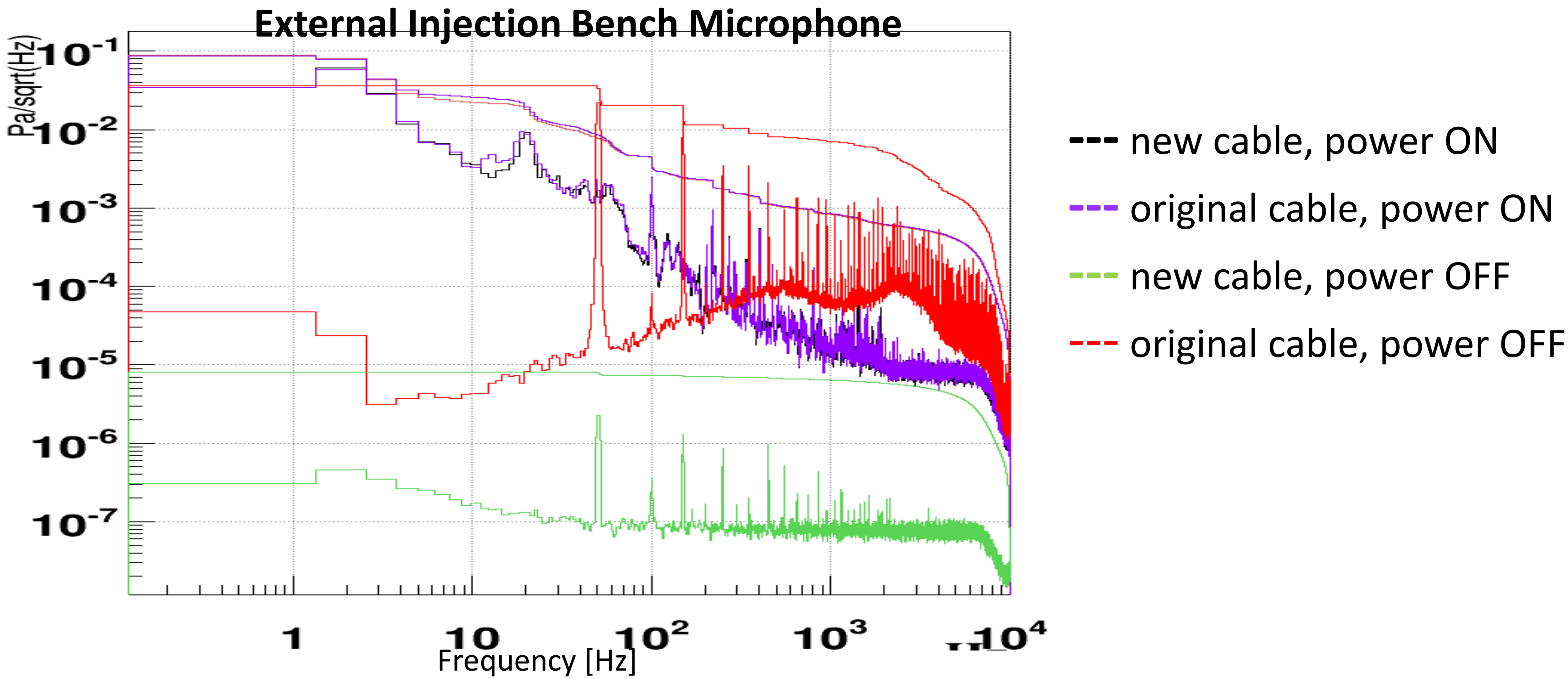
- Set an RMS threshold for each of 48 fast environmental sensors (accelerometers, microphones, etc.)
- Detect sensor dead conditions, including unplugged or powered off.
- Minimize false alarms without missing real events.

Preliminary work:

- Power-off noise was too high.

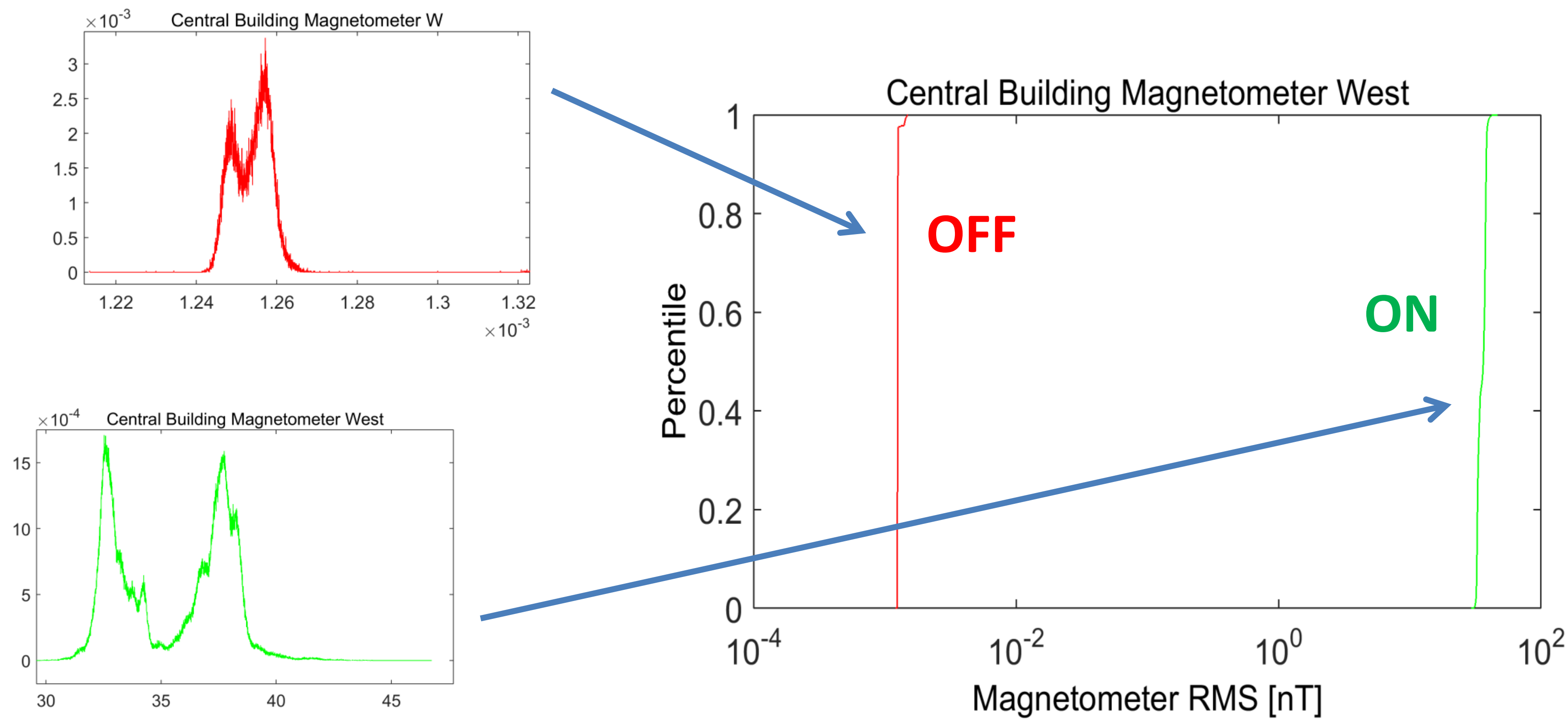
Preliminary Work

- Problem: Power-off noise was as high or higher than power-on RMS.
- Cause: Connecting BNC to 3-pin lemo left one pin unconnected, generating ground loops.



- Solution: Shorting pins 2-3 reduces power-off noise to near ADC level.
- Conclusion: We are now are able to use RMS to distinguish between power-on and power-off states.

Statistical Characterization

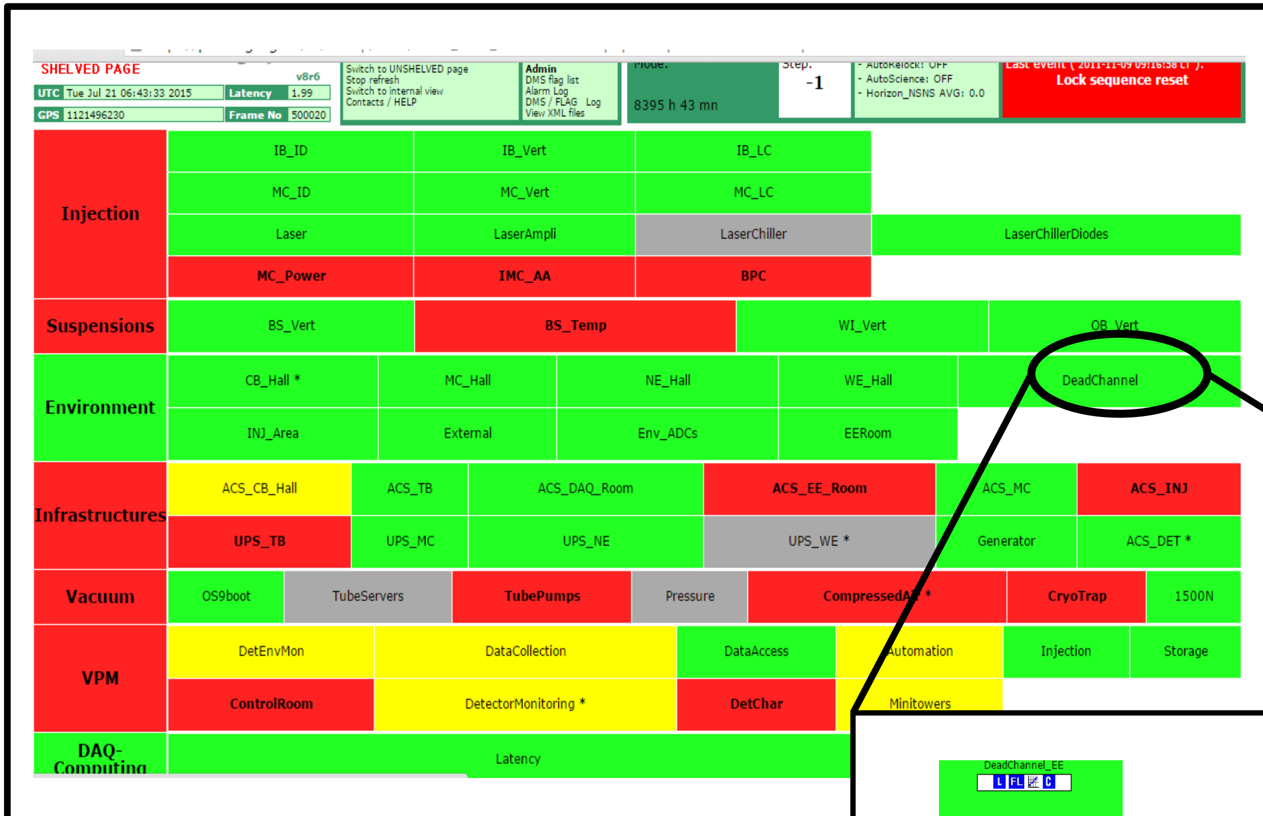


- Look at RMS over a long period of trend data.
- Calculate the empirical cumulative distribution.
- Power-ON and power-OFF distributions are well-separated.
- Trend RMS is not Rayleigh distributed!

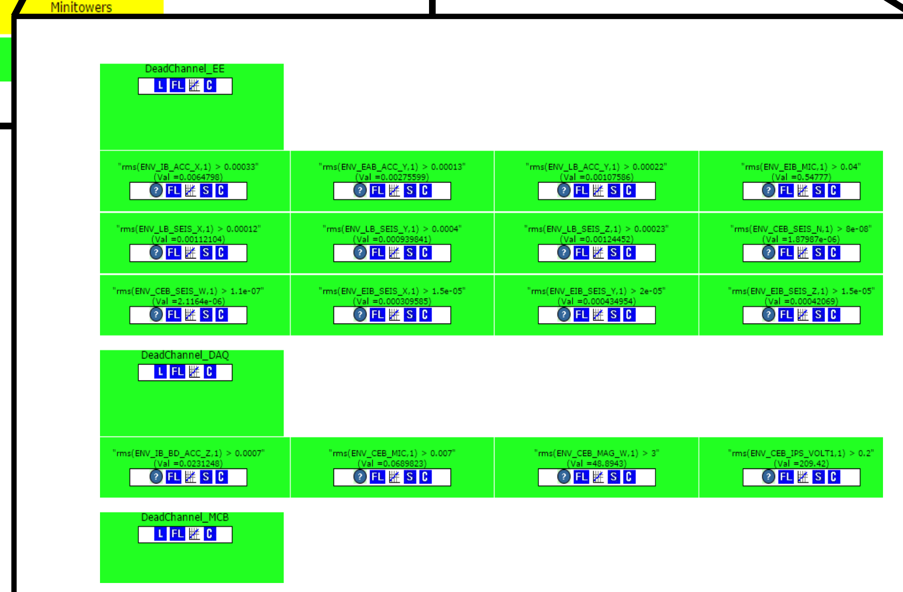
Setting Thresholds in the DMS

- Set threshold at the 0.1 percentile of the power-ON distribution.
  - The RMS is above this threshold 99.9% of the time if the sensor is ON.
- Use persistency requirement of 1 hour to further reduce false alarms.
- Verify that the threshold is above the Power-off 99.9 percentile.

Present Status

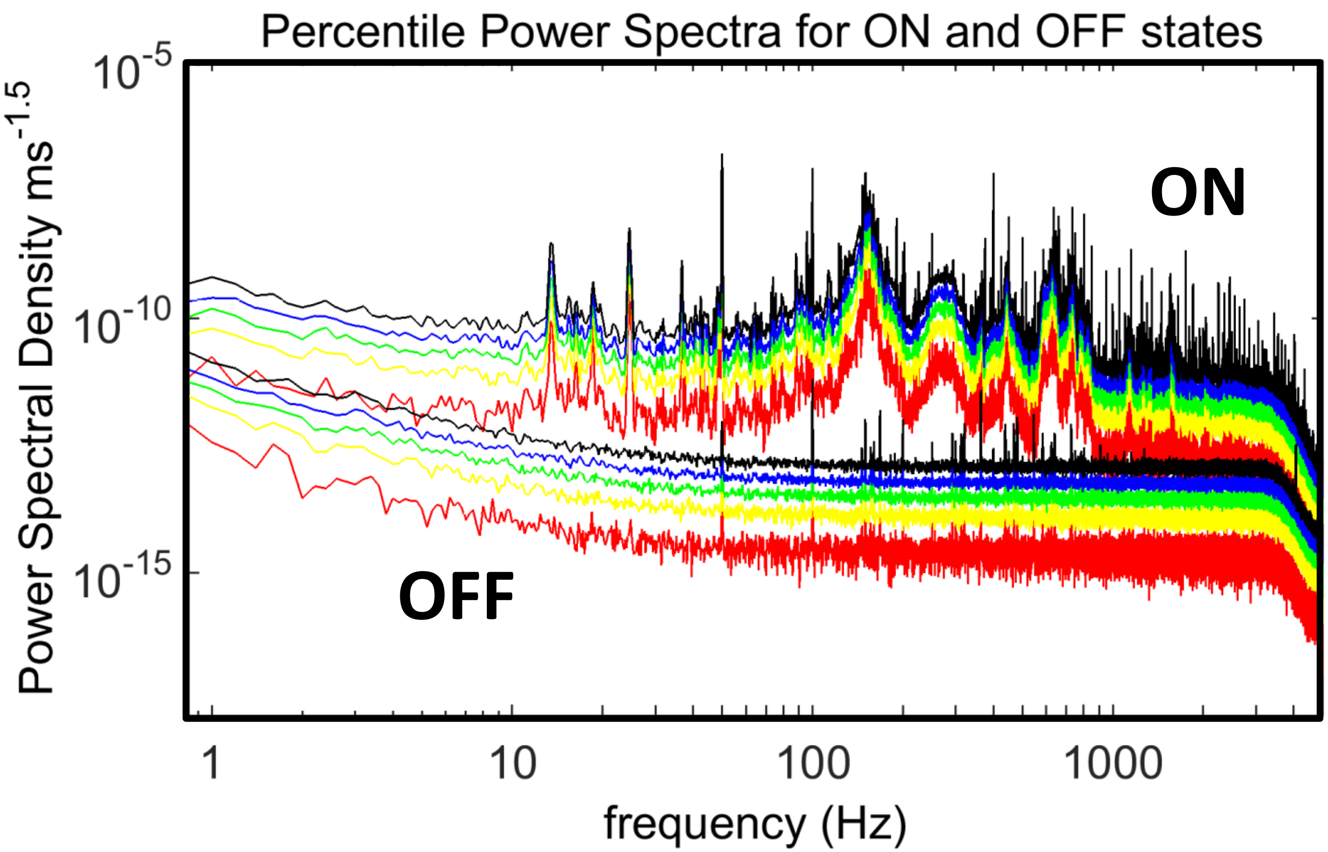


- **Dead Channel Main Flag on the DMS page**
- **48 subflags**



- **Subflags are grouped by ADC location**
  - EE room
  - Data acquisition room
  - Mode Cleaner Building
  - West End Building
  - North End Building

Percentile Power Spectra



External Injection bench accelerometer Y

-- **5th percentile**

-- **25th percentile**

-- **Median**

-- **75th percentile**

-- **95th percentile**

- Look at many 5-second segments of fast data.
- Compute power spectra for each segment.
- Compute cumulative distributions and percentiles for each frequency bin.

Multipurpose Systematic Approach to Noise Hunting

Inputs:

1. Define events in query channel.
2. Choose time to search.
3. Define conditions to exclude.
4. Choose channels to search.

Results:

Ranks the channels with the strongest prospective connection to the query events.

Statistical Approach to Noise Hunting
Preliminary investigations: IMC sudden Unlocks

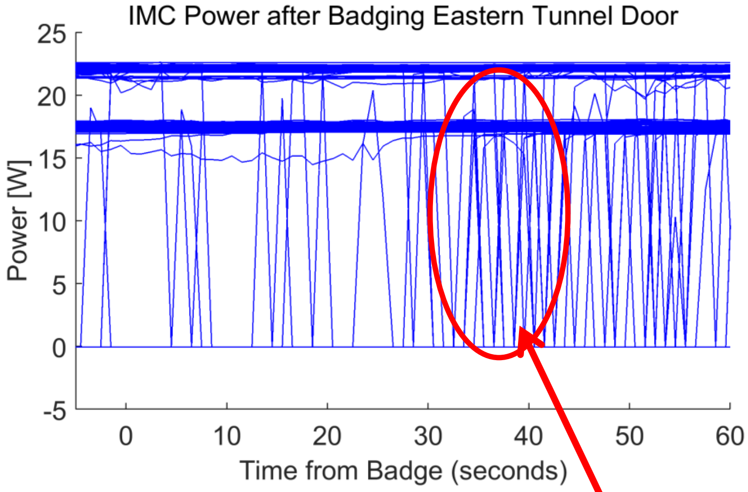
- IMC sudden unlocks:
  - Fast unlocks with unknown cause
  - Easily found in trend data
  - Had been a frequent problem for months

- Motivation for a multipurpose tool:
  - Two preliminary investigations illustrate two types of problem-solving approaches

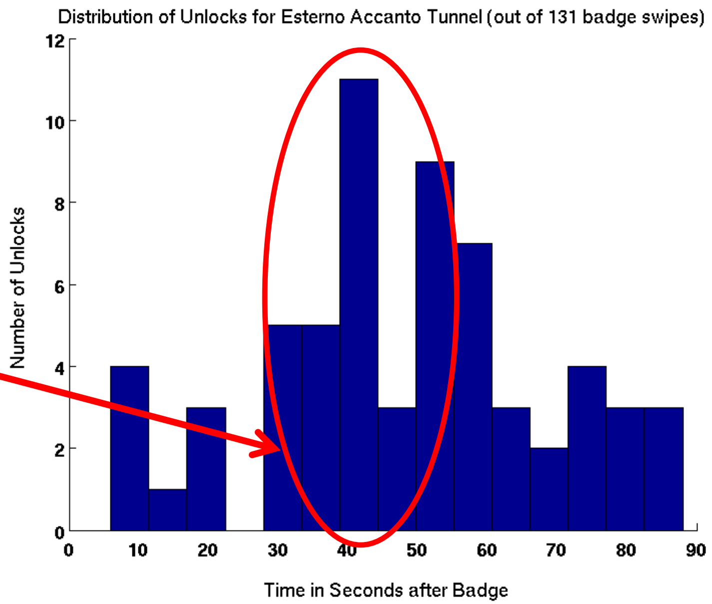
1. Door badging --- Compare two sets of discrete events

2. ML PZT saturation --- Compare discrete events and continuous data

Comparing door badge times to IMC sudden Unlocks

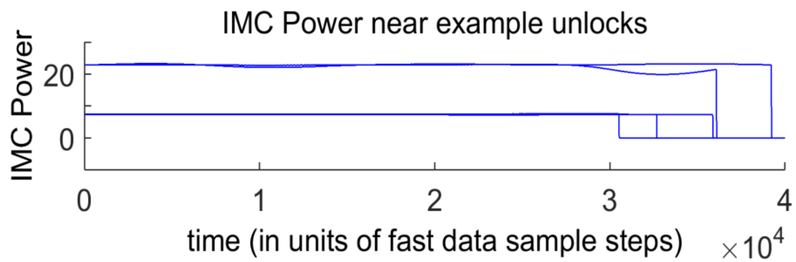


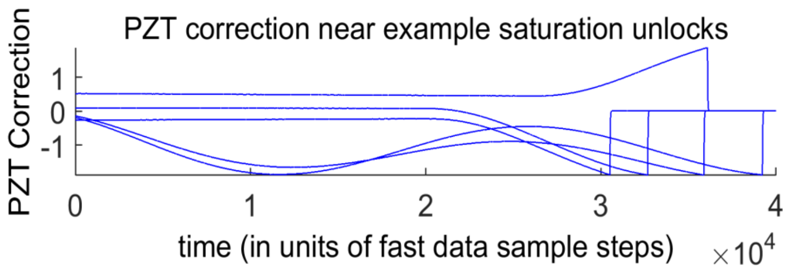
Approach:
-- Look for IMC unlocks in the seconds after a door-badge is swiped.
-- Automate this search to look at all the events for all the doors over a timerange of months.



Results:
-- No direct link between badging and unlocks
-- For one door, unlocks are more common 30-40 seconds after badging.

PZT Saturation as a prospective Cause for IMC Sudden Unlocks





Approach:

-- Do a systematic automated search to find all the sudden unlocks over a timerange of months.

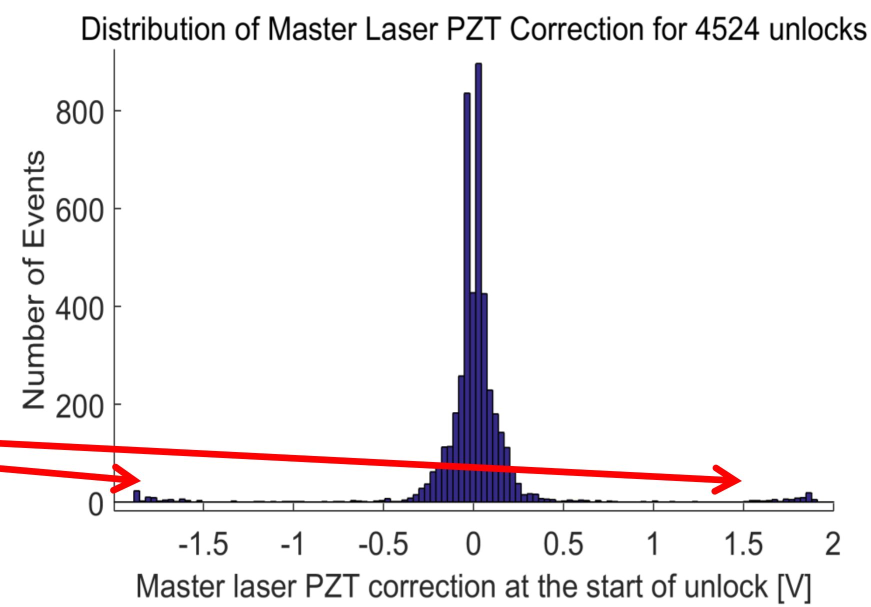
-- Look at the PZT correction fast data just before each unlock.

-- A PZT correction greater than 1.8 V indicates saturation.

Results:

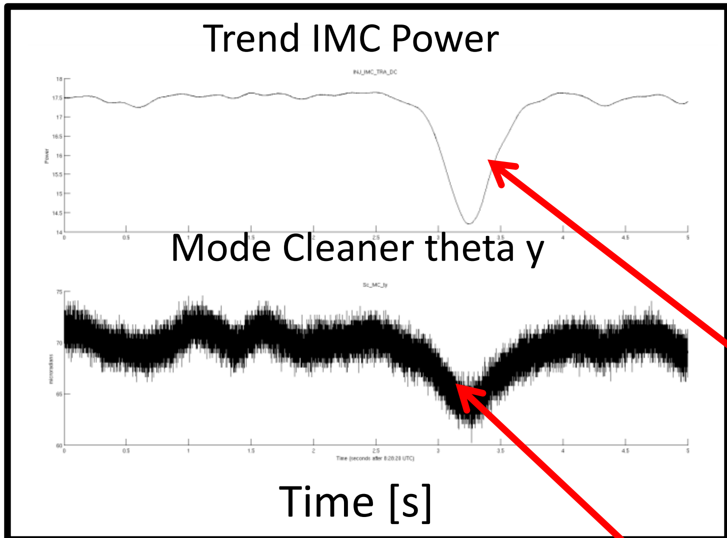
-- Saturation occurred for 1.6 % of the unlocks (73 out of 4524 unlocks)

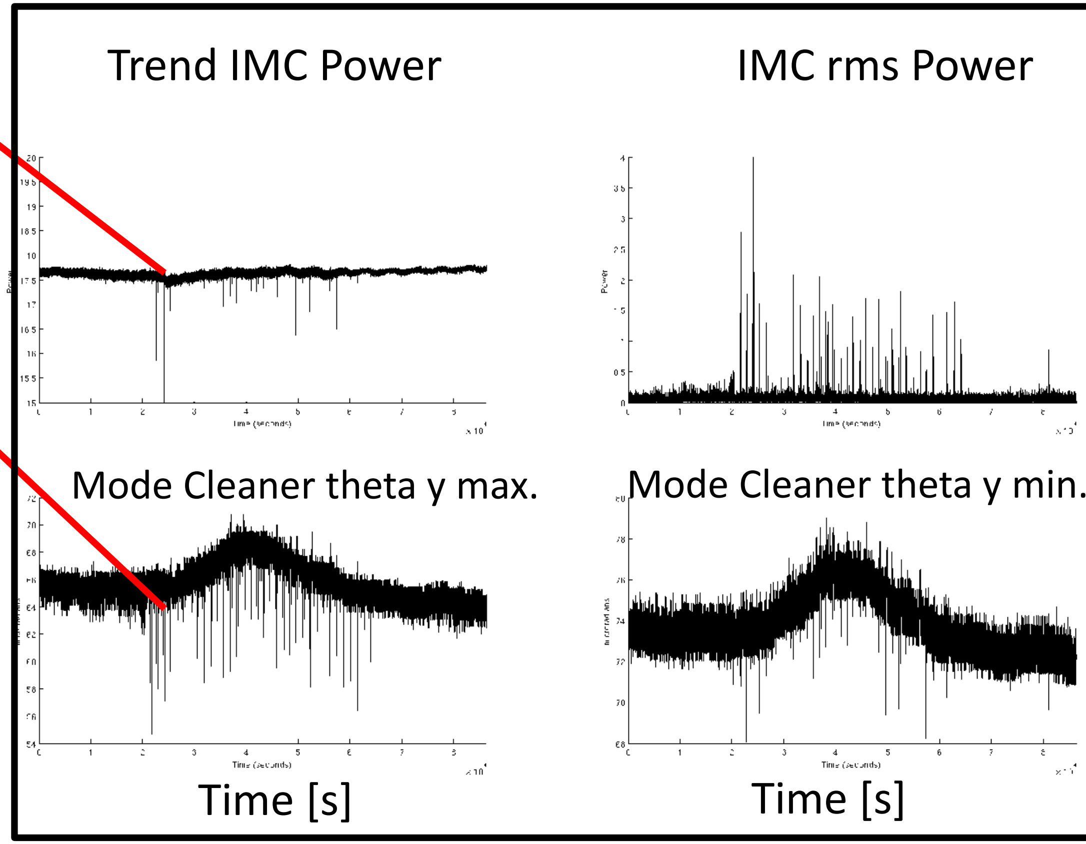
-- Thus, saturation was a very rare cause of the unlocks.



Now build an automated approach for searching many channels.

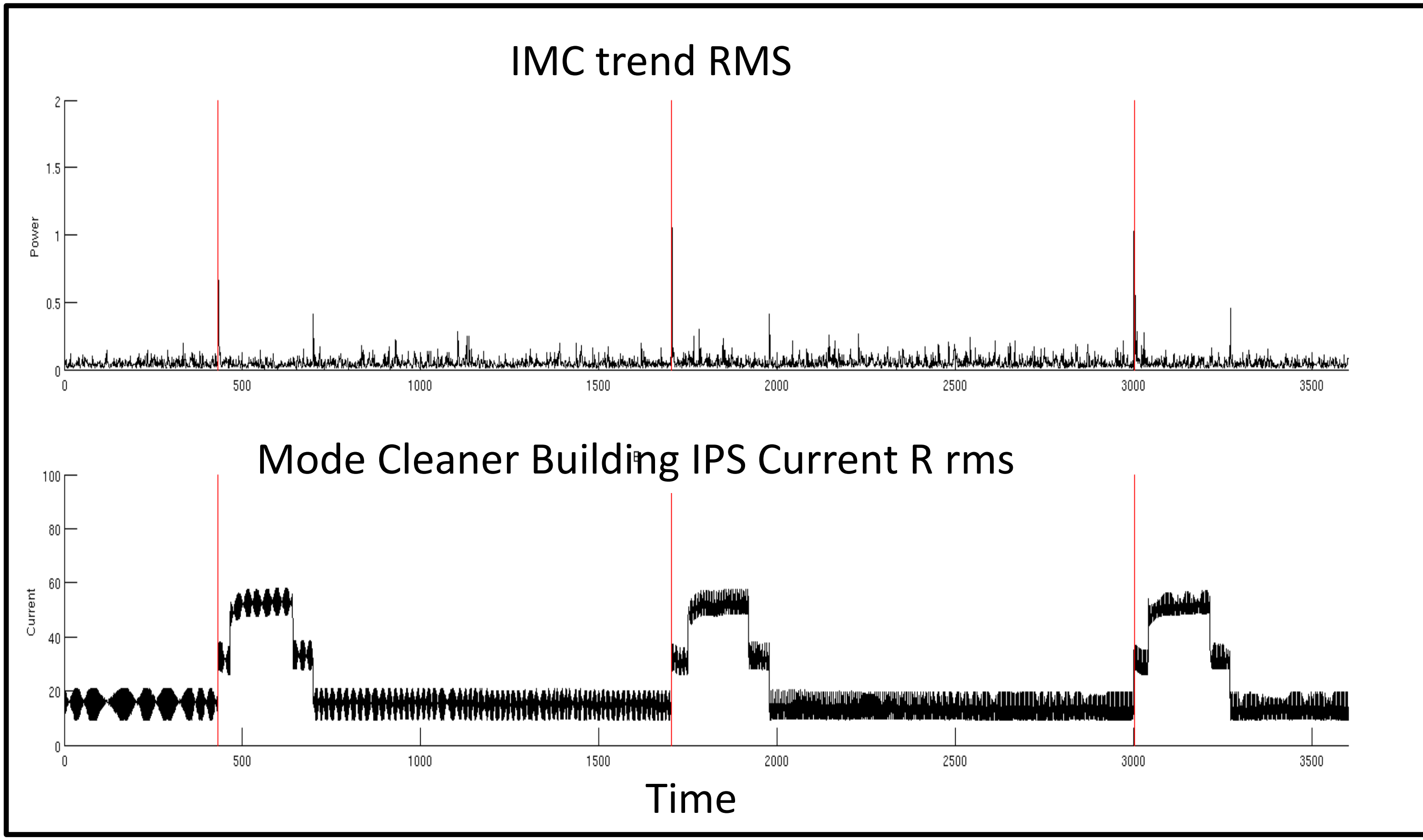
Example Application of the PROSPECTOR Code: Brief misalignments in the IMC





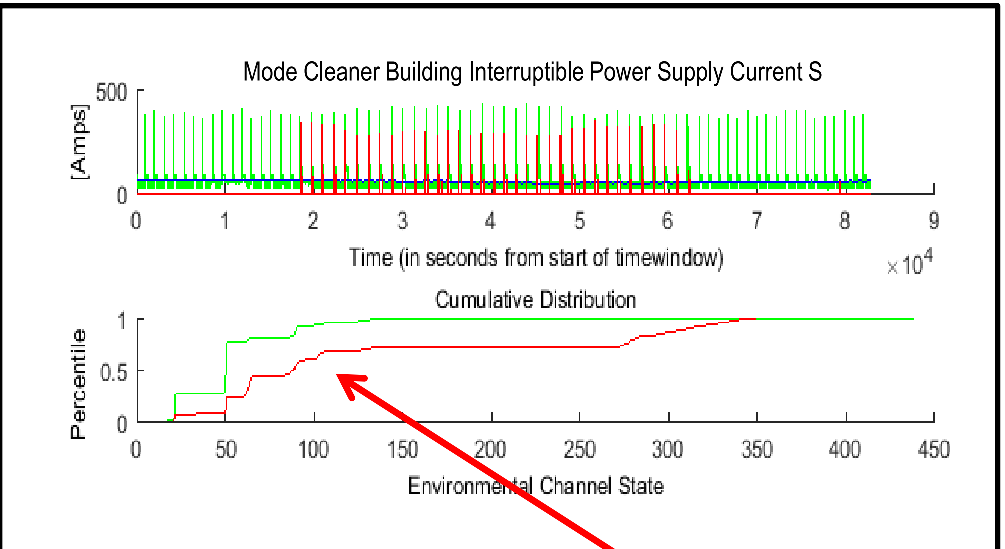
Brief drops in IMC power coincide with misalignments of theta y.

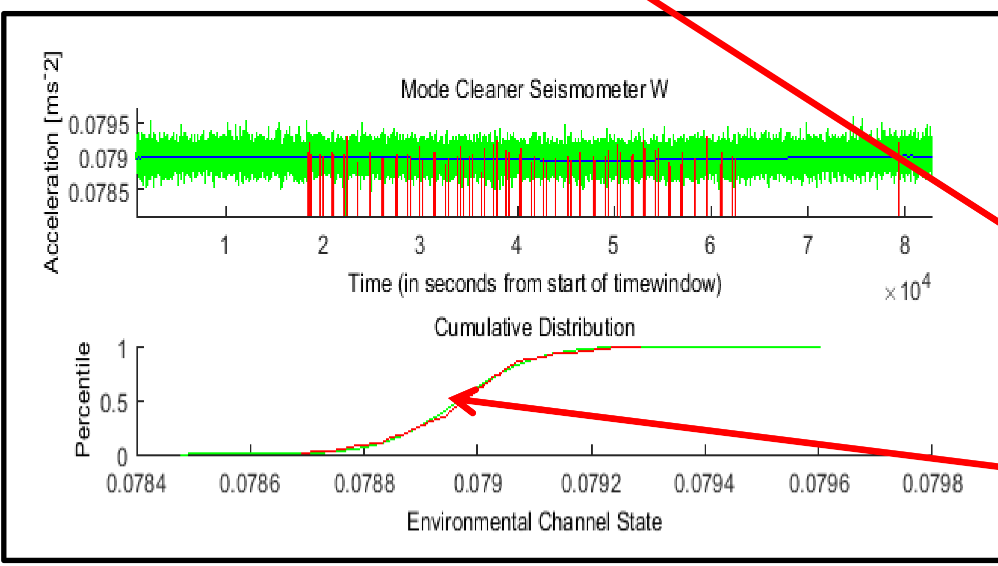
Mode Cleaner Chiller is the cause



- IMC drops coincide with chiller turning on.
- Chiller operation is visible in Mode Cleaner building IPS currents.
- Goal: Use PROSPECTOR code to find this connection in a statistically rigorous, automated way.

PROSPECTOR code successfully finds the chiller





How it works

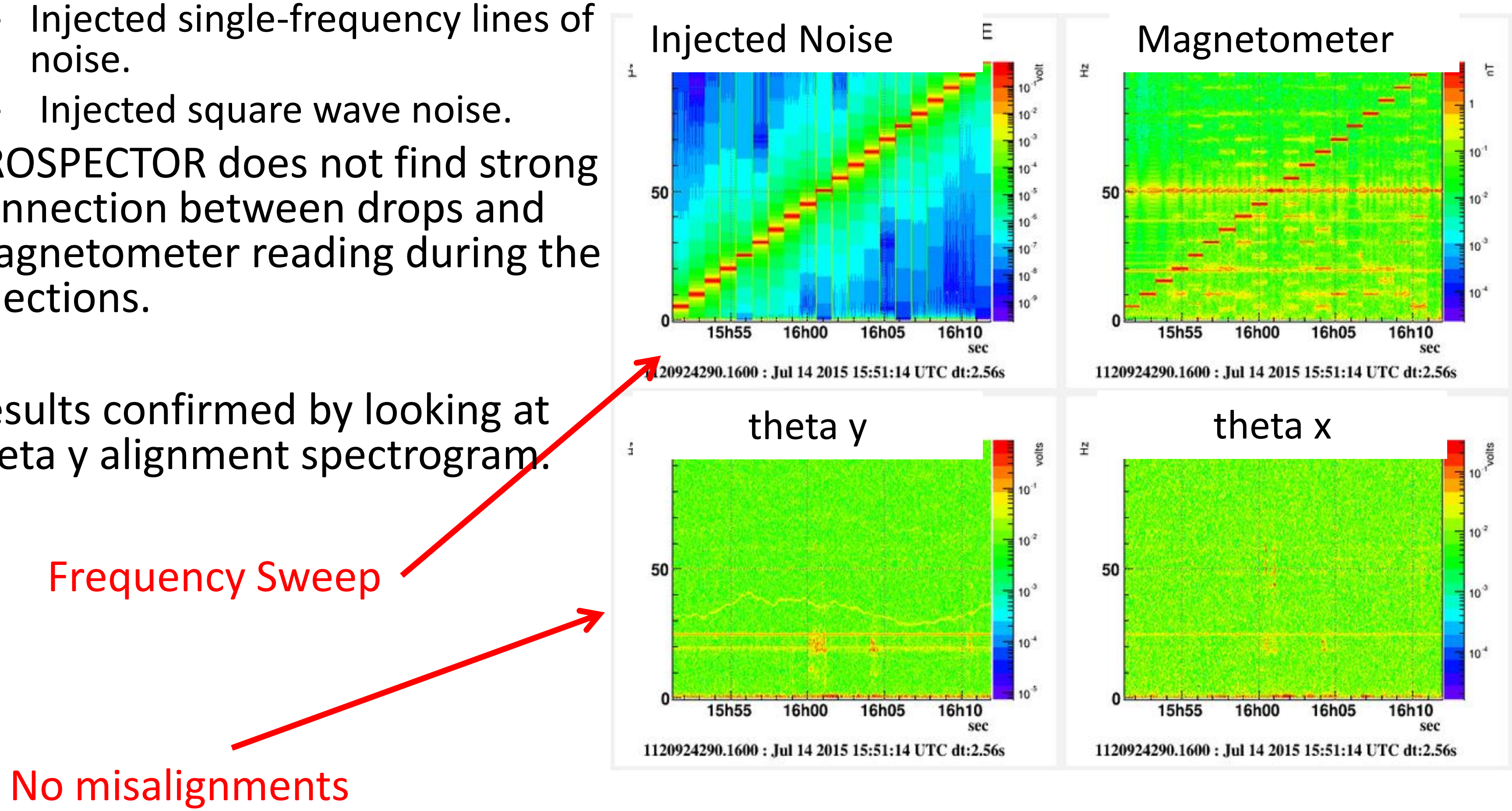
1. Search for precisely defined events in query channel.
2. Filter out unwanted conditions (e.g. look only during local control).
3. Calculate $State = \sqrt{max^2 + min^2}$ for each channel during the events and during all times.
4. Calculate the cumulative distributions for the state during events and all times.
5. Rank channels by the maximum difference between their cumulative distributions.

Maximum difference = 0.53
PROSPECTOR ranks this channel higher

Maximum difference = 0.06

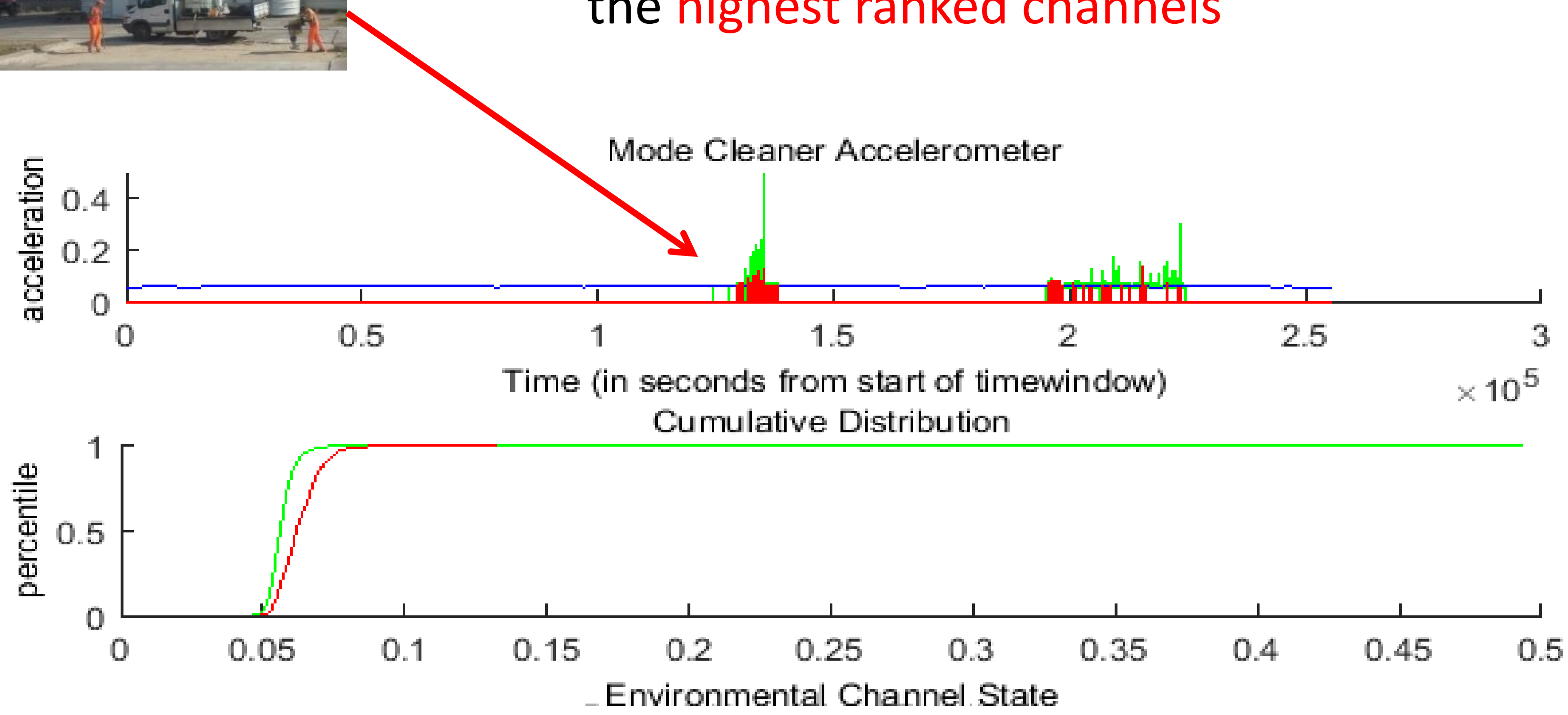
Magnetic Injection Tests

- Use python scripts to inject noise patterns:
  - Injected single-frequency lines of noise.
  - Injected square wave noise.
- PROSPECTOR does not find strong connection between drops and magnetometer reading during the injections.
- Results confirmed by looking at theta y alignment spectrogram.

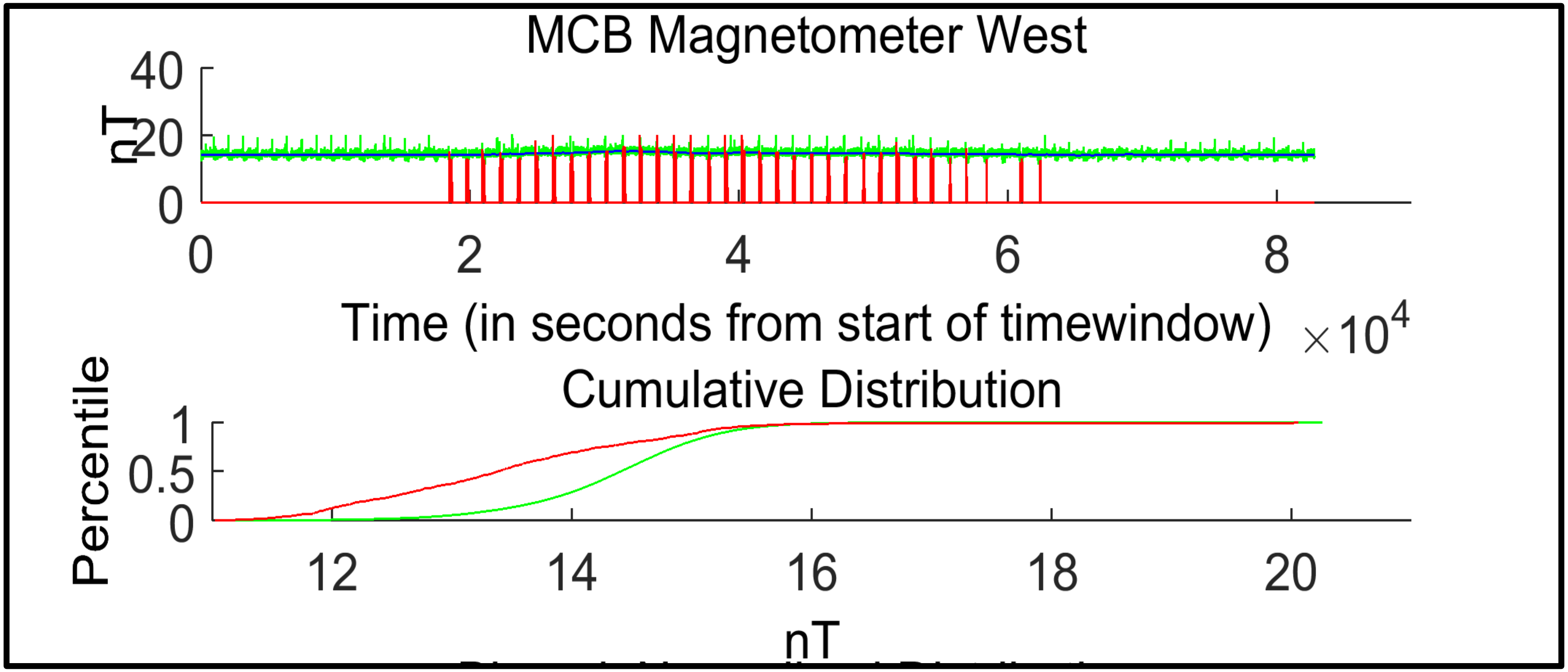


Seismic events: confirmation that PROSPECTOR works

- Ran PROSPECTOR over a time with roadwork being done outside the Mode Cleaner
- It returns seismometers and accelerometers as the highest ranked channels



Another test of PROSPECTOR:
IPS as query channel



- Returning to the chiller problem, define the events in the IPS channel
- Compare IPS to other environmental channels- finds connection to magnetometer. Magnetic noise may still be important to these events even though the injection tests did not trigger drops.
- Compare IPS to suspension channels.

Conclusions: Use of PROSPECTOR

- Systematically find hundreds of events
- Compare query channel to many channels
- Rank the channels with the strongest prospective connection to the events, guiding noise hunting.