

# Dead Channel Monitor and Systematic Statistical Approach to Noise Hunting

Kathryn Plant  
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:

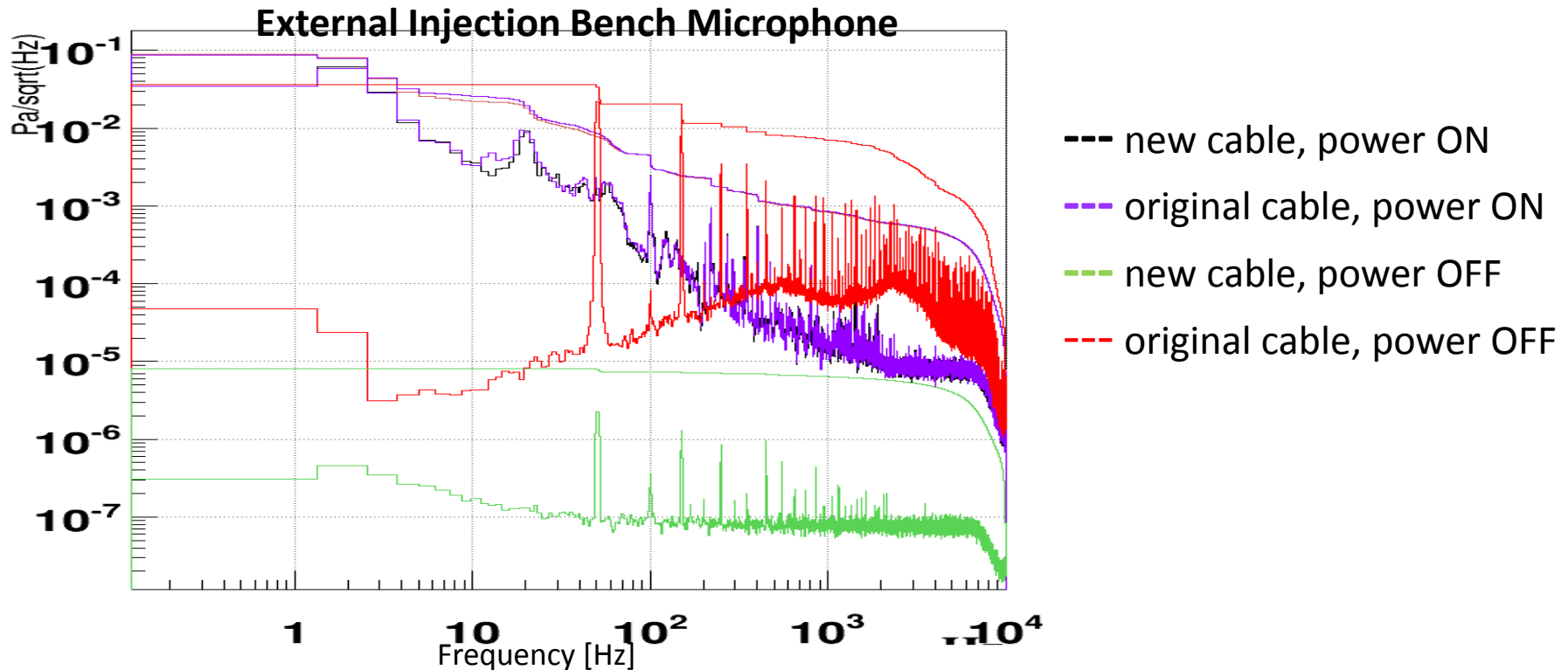
- Set an RMS threshold for each of 48 fast environmental sensors (accelerometers, microphones, etc.)
- Detect sensor dead conditions, including unplugged or powered off.
- Minimize false alarms without missing real events.

## Preliminary work:

- Power-off noise was too high.

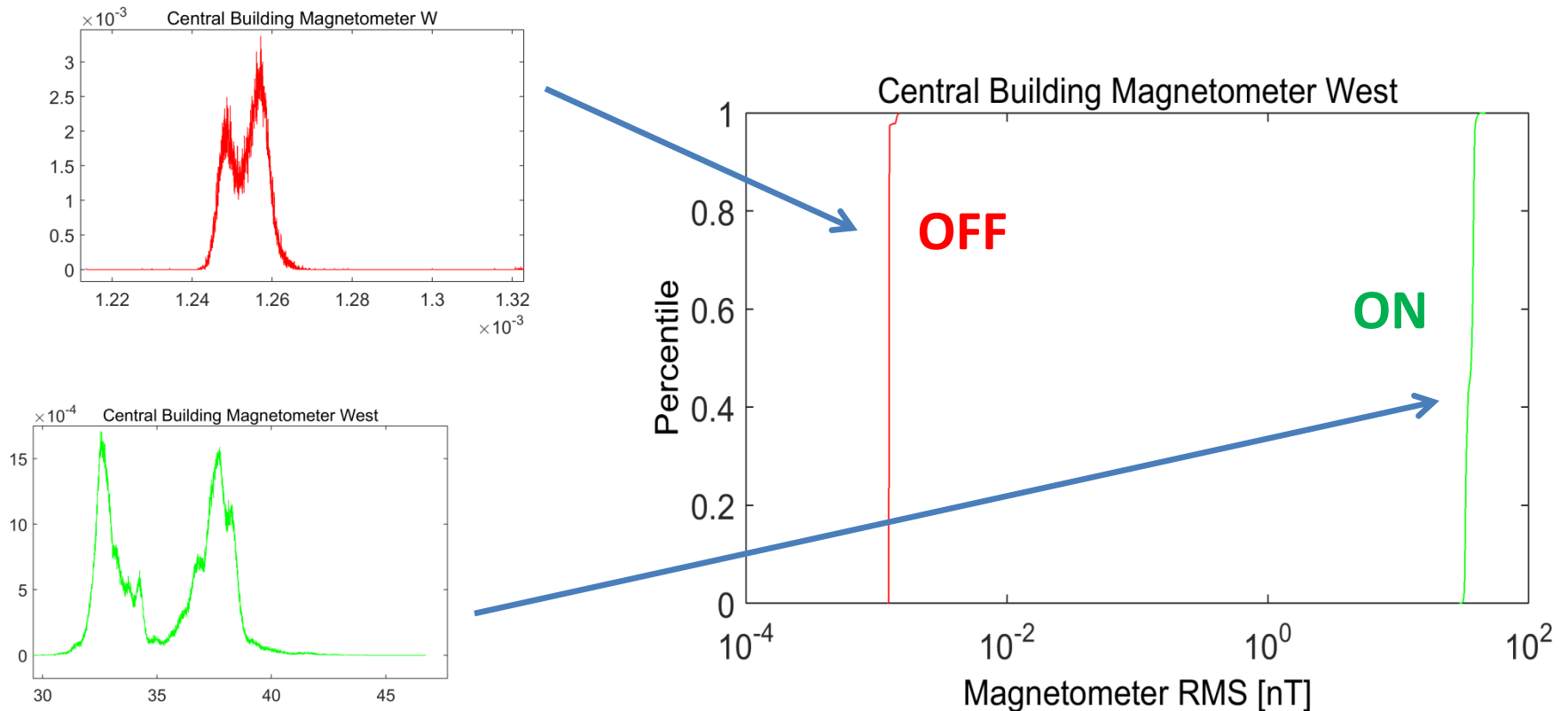
# Preliminary Work

- **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 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

SHELVED PAGE				v8r6		Switch to UNSHELVED page		Admin		8395 h 43 mn		-1		Autokickout: OFF		Last event (2011-11-09 09:16:58 LT)		
UTC Tue Jul 21 06:43:33 2015				Latency 1.99		Stop refresh		DMS Flag list				- AutoScience: OFF		Lock sequence reset				
GPS 1121496230				Frame No 500020		Switch to internal view		Alarm Log				- Horizon_NSNS AVG: 0.0						
						Contacts / HELP		View XML files										
Injection	IB_ID		IB_Vert		IB_LC													
	MC_ID		MC_Vert		MC_LC													
	Laser		LaserAmpli		LaserChiller													
	MC_Power		IMC_AA		BPC													
Suspensions	BS_Vert		BS_Temp		WI_Vert		OB_Vert											
Environment	CB_Hall *		MC_Hall		NE_Hall		WE_Hall		DeadChannel									
	INJ_Area		External		Env_ADCs		EERoom											
Infrastructures	ACS_CB_Hall		ACS_TB		ACS_DQA_Room		ACS_EE_Room		ACS_MC		ACS_INJ							
	UPS_TB		UPS_MC		UPS_NE		UPS_WE *		Generator		ACS_DET *							
Vacuum	OS9boot		TubeServers		TubePumps		Pressure		CompressedAir *		CryoTrap		1500N					
VPM	DetEnvMon		DataCollection		DataAccess		Automation		Injection		Storage							
	ControlRoom		DetectorMonitoring *		DetChar		Minitowers											
DAQ-Computing	Latency																	

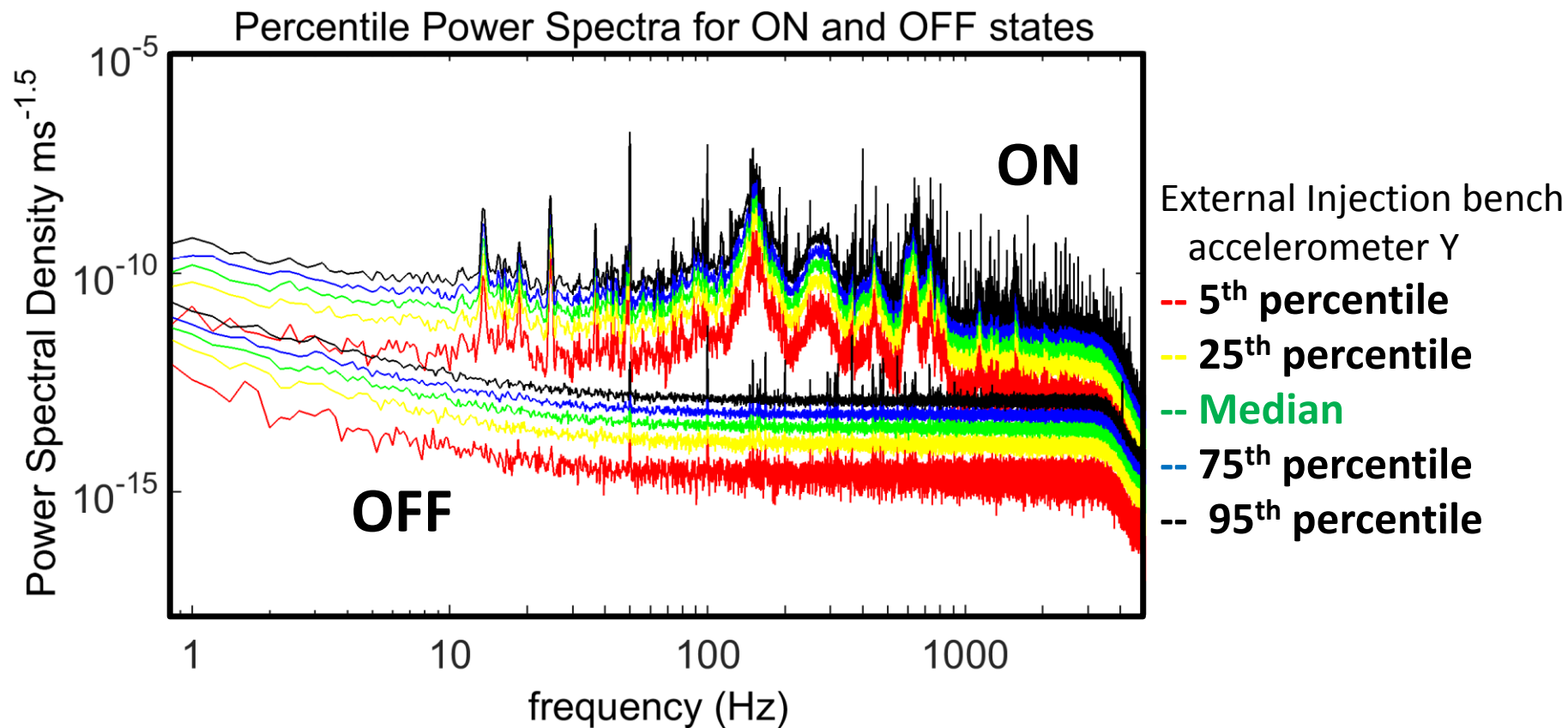
- Dead Channel Main Flag on the DMS page
- 48 subflags

- Subflags are grouped by ADC location

- EE room
- Data acquisition room
- Mode Cleaner Building
- West End Building
- North End Building

DeadChannel_EE															
$\text{rms}(ENV\_IB\_ACC\_X\_1) > 0.00033$ <small>(Val = 0.0047999)</small>				$\text{rms}(ENV\_EAB\_ACC\_Y\_1) > 0.00013$ <small>(Val = 0.0027999)</small>				$\text{rms}(ENV\_LB\_ACC\_Y\_1) > 0.00023$ <small>(Val = 0.0030799)</small>				$\text{rms}(ENV\_EIB\_JMC\_1) > 0.04$ <small>(Val = 0.04799)</small>			
$\text{rms}(ENV\_LB\_SEIS\_X\_1) > 0.00012$ <small>(Val = 0.0012199)</small>				$\text{rms}(ENV\_LB\_SEIS\_Y\_1) > 0.0004$ <small>(Val = 0.0024999)</small>				$\text{rms}(ENV\_LB\_SEIS\_Z\_1) > 0.00023$ <small>(Val = 0.0024999)</small>				$\text{rms}(ENV\_CEB\_SEIS\_X\_1) > 6e-05$ <small>(Val = 0.0006999)</small>			
$\text{rms}(ENV\_CEB\_SEIS\_W\_1) > 1.1e-07$ <small>(Val = 1.104e-06)</small>				$\text{rms}(ENV\_EB\_SEIS\_X\_1) > 1.5e-05$ <small>(Val = 0.0001999)</small>				$\text{rms}(ENV\_EIB\_SEIS\_Y\_1) > 2e-05$ <small>(Val = 0.0001999)</small>				$\text{rms}(ENV\_EIB\_SEIS\_Z\_1) > 1.5e-05$ <small>(Val = 0.0001999)</small>			
DeadChannel_DQA															
$\text{rms}(ENV\_IB\_BD\_ACC\_Z\_1) > 0.0007$ <small>(Val = 0.0079999)</small>				$\text{rms}(ENV\_CEB\_JMC\_1) > 0.007$ <small>(Val = 0.0079999)</small>				$\text{rms}(ENV\_CEB\_MAG\_W\_1) > 3$ <small>(Val = 3.0079999)</small>				$\text{rms}(ENV\_CEB\_IPS\_VOLT1_1) > 0.2$ <small>(Val = 0.2079999)</small>			
DeadChannel_MCB															

# Percentile Power Spectra



- 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:

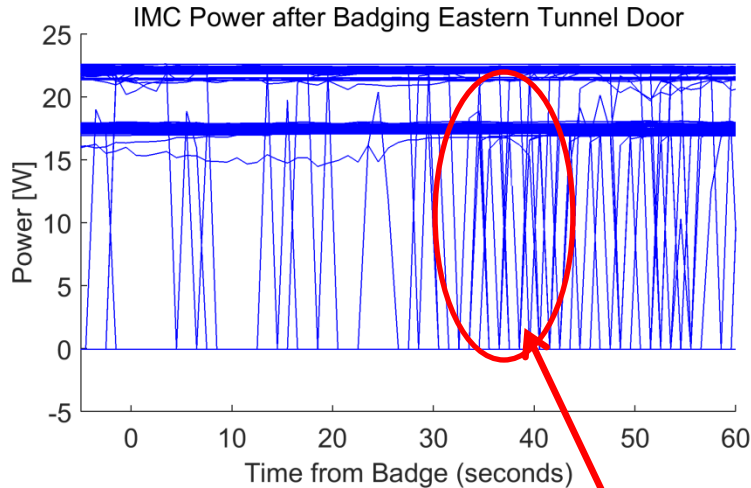
Ranks the channels with the strongest prospective connection to the query events.

# 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

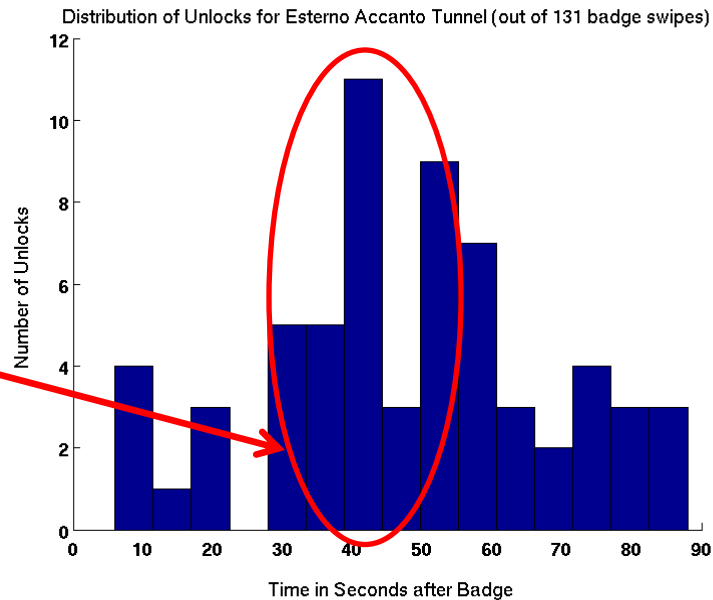


## Approach:

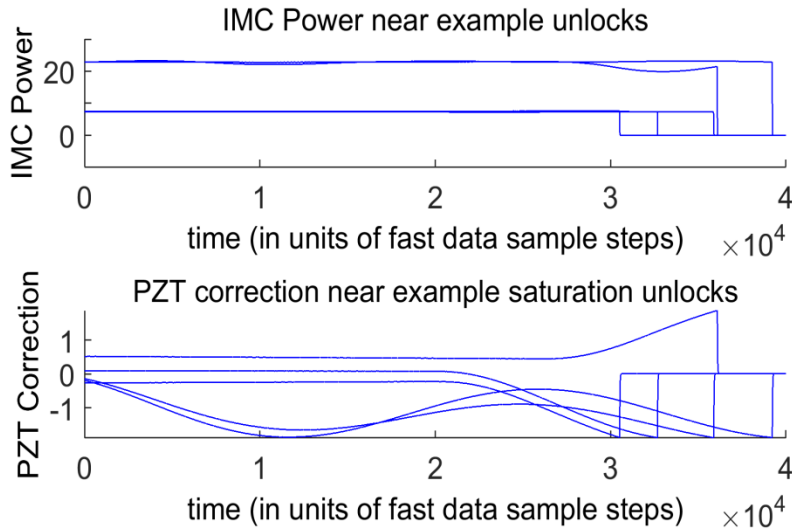
- Look for IMC unlocks in the seconds after a door-badge is swiped.
- Automate this search to look at all the events for all the doors over a timerange of months.

## 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

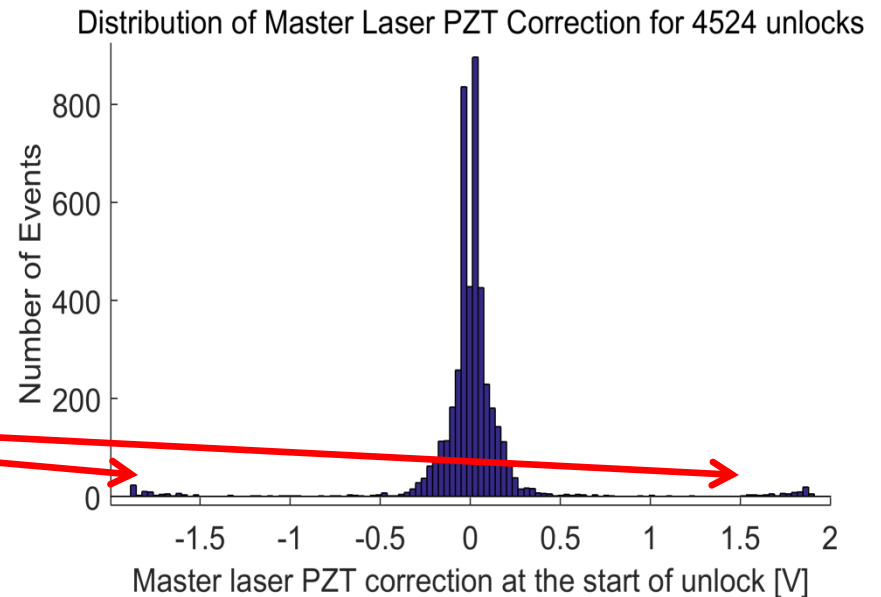


## Approach:

- 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.

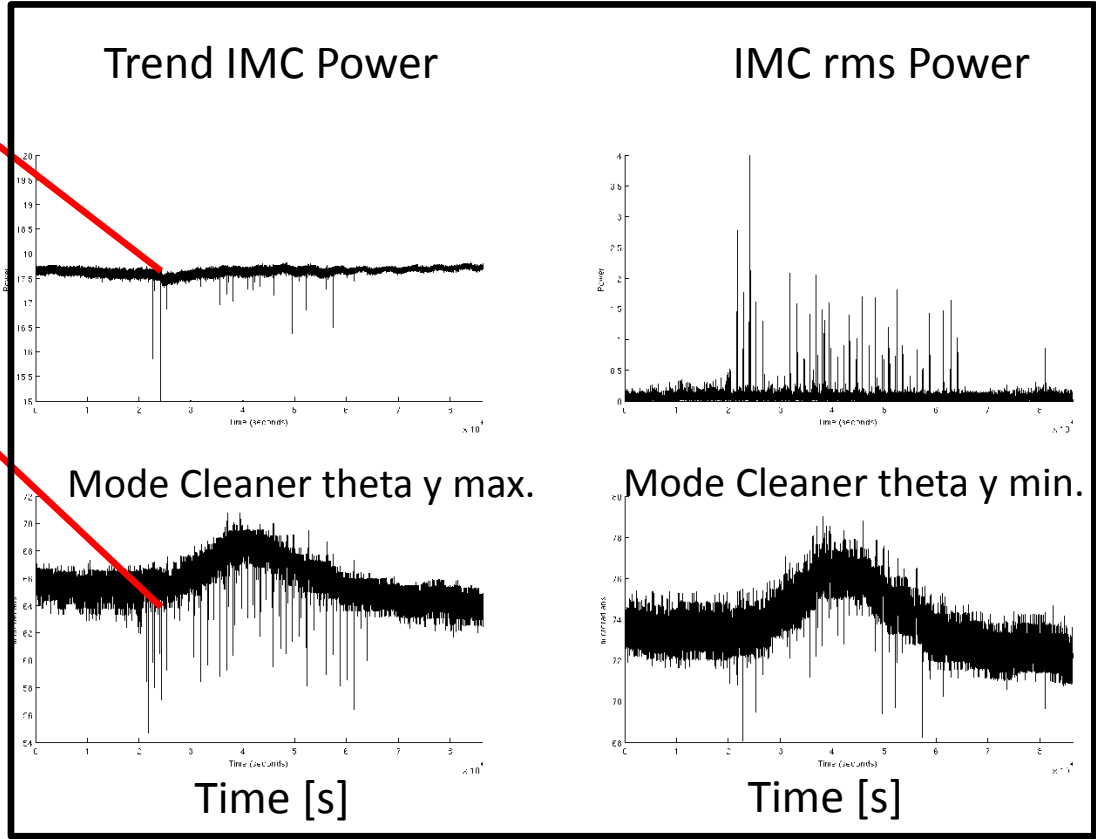
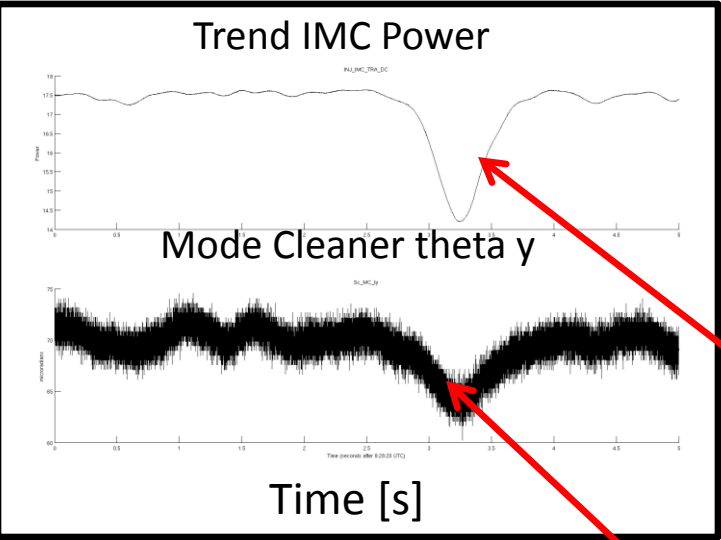
## Results:

- Saturation occurred for 1.6 % of the unlocks (73 out of 4524 unlocks)
- Thus, saturation was a very rare cause of the unlocks.



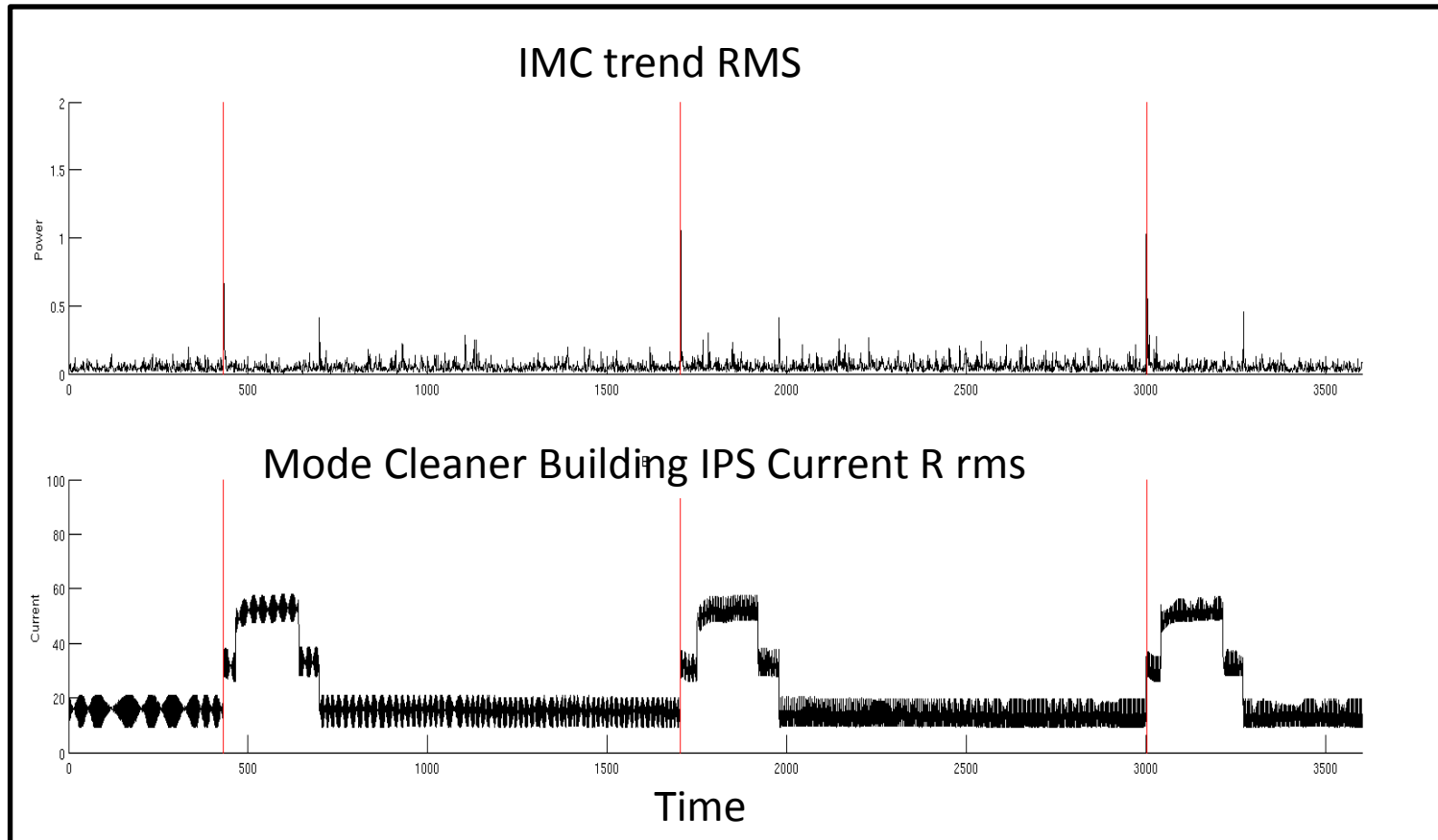
**Now build an automated approach for searching many channels.**

# 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

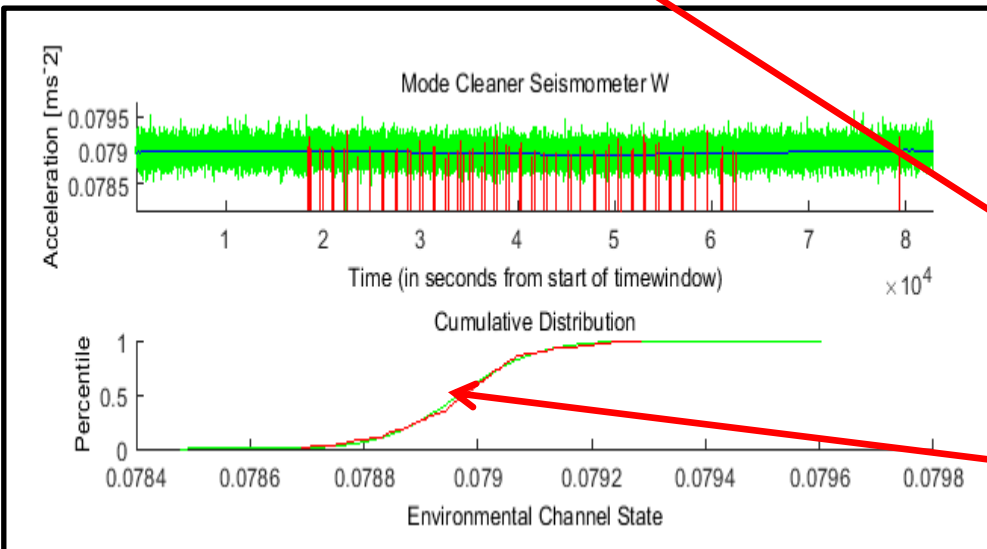
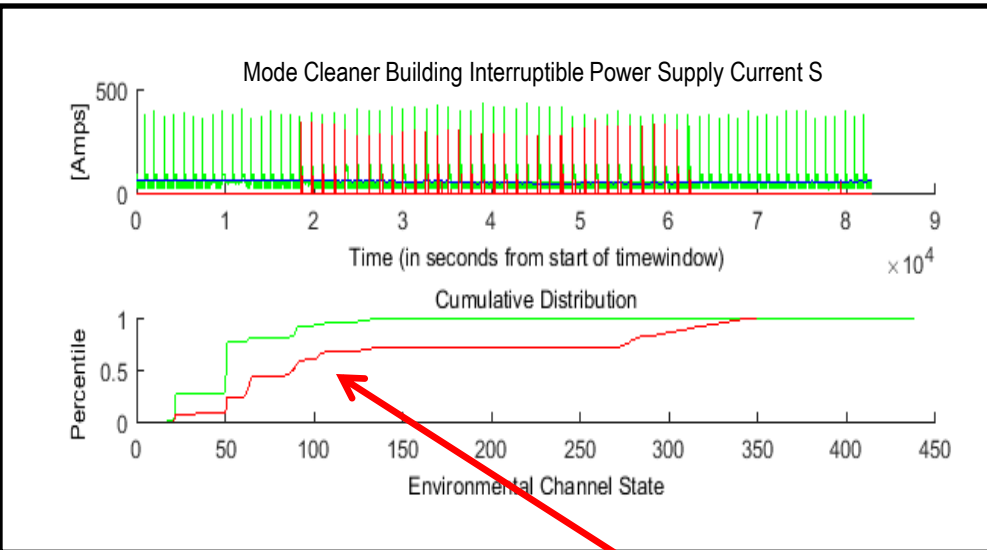


- IMC drops coincide with **chiller turning on**.
- Chiller operation is visible in Mode Cleaner building IPS currents.
- **Goal:** Use PROSPECTOR code to find this connection in a statistically rigorous, automated way.

# 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.

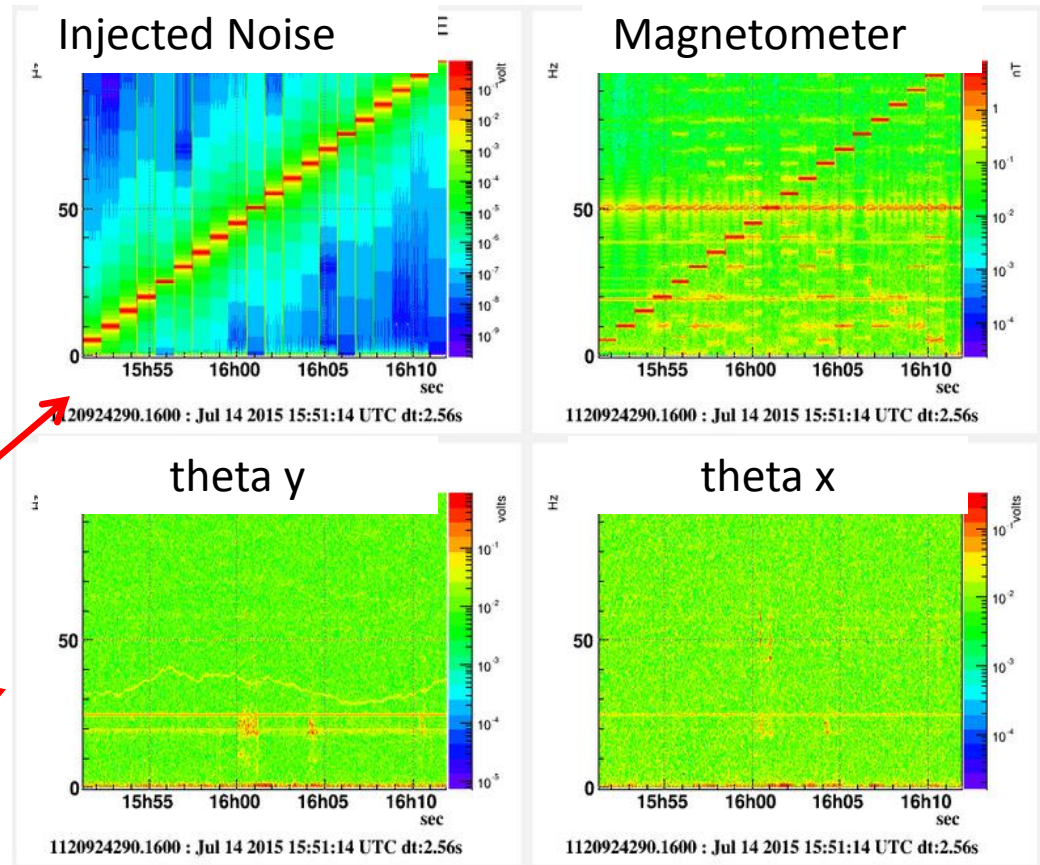


**Maximum difference = 0.53**  
PROSPECTOR ranks this channel higher

**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.



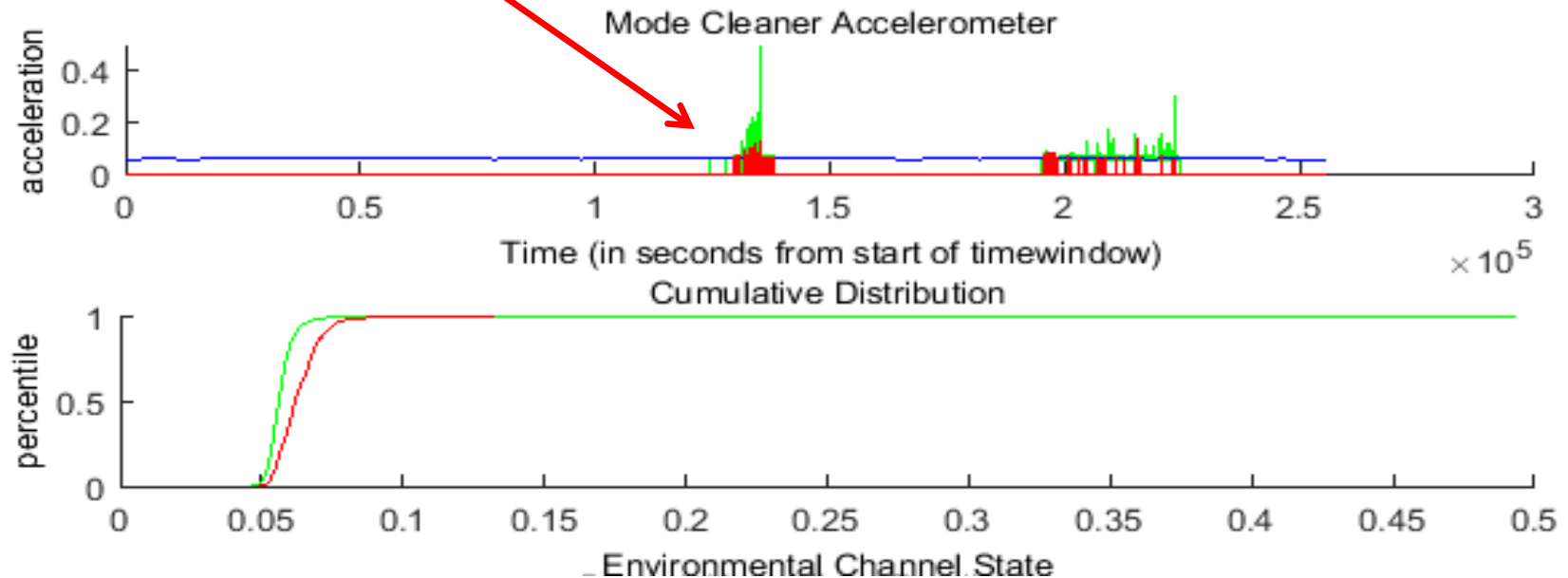
Frequency Sweep

No misalignments

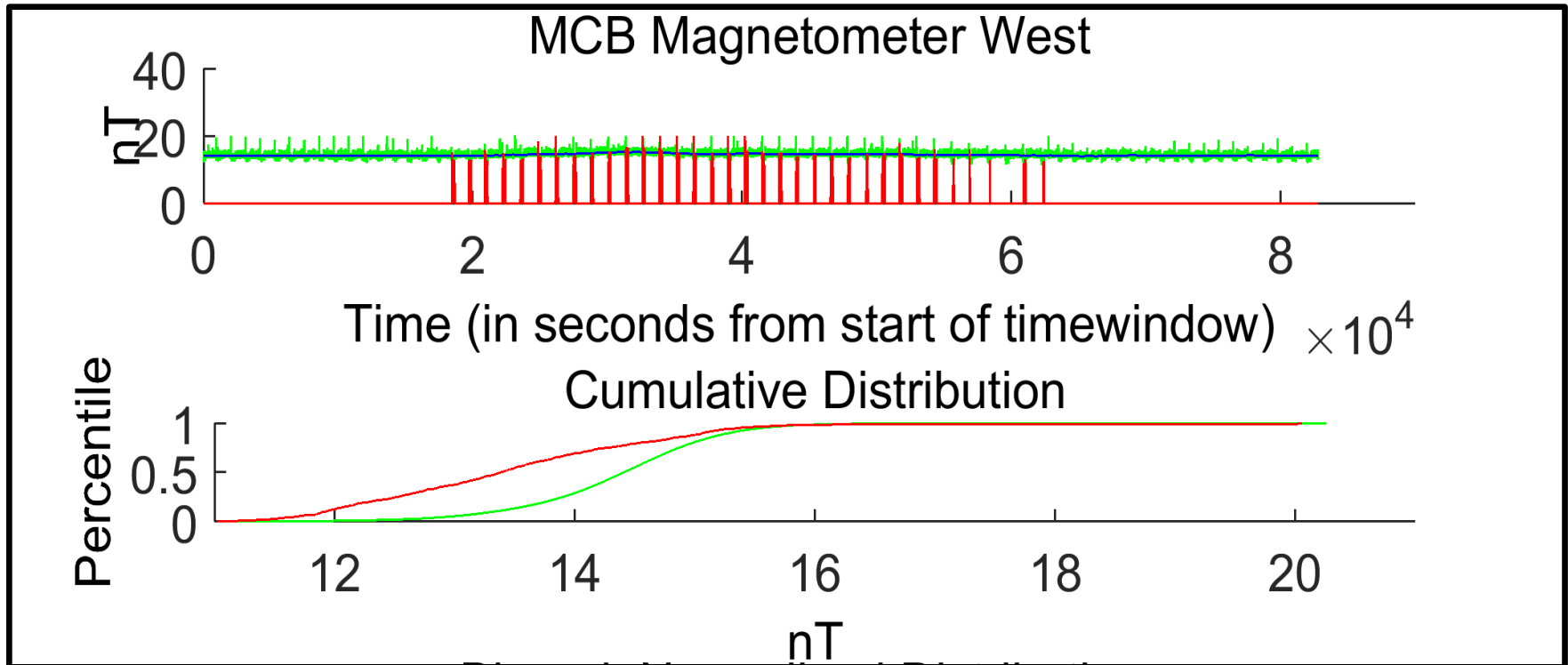


# Seismic events: confirmation that PROSPECTOR works

- 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.