LIGO S6 Detector Characterization Studies

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(for the LSC and Virgo, and especially the LSC's Detector Characterization Working Group)

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LIGO-G1000014

Organization of the talk

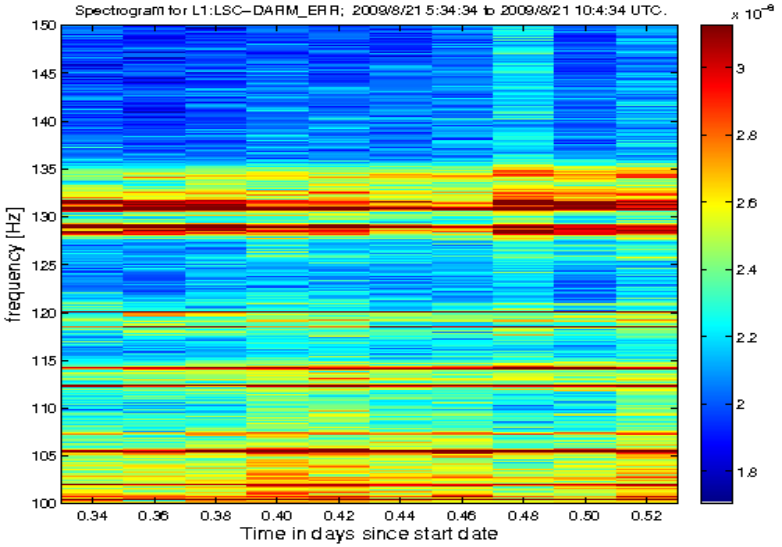
- Detector characterization (Det Char) studies for LIGO's Sixth Scientific Run (S6)
- The search for noise lines affecting pulsar and stochastic searches
- Investigation into "glitches", and the construction or vetoes for inspiral and burst searches
- Some examples and observations from S6 at LIGO Hanford Observatory (LHO) and LIGO Livingston Observatory (LLO)
- Conclusion

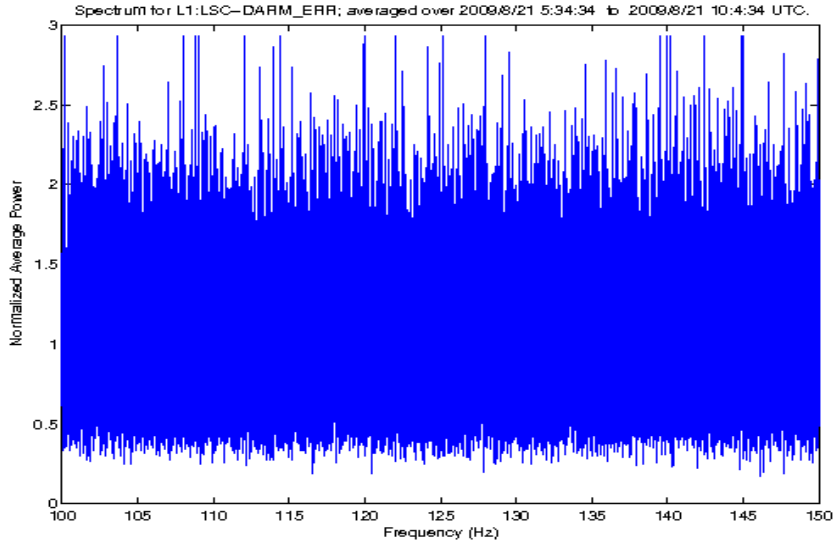
LIGO S6 Det Char Studies

- Many LSC members participate in Det Char studies
- Good mix of data analysts, and scientists at the sites
- G. González leads the LSC Det Char group; J. Smith and L. Cadonati lead the Glitch sub-group
- Typically ~20 people participate in telecons twice a week
- Scientific monitors (scimons) during S6 are required to take week-long shifts at the site so that they can get more involved in detector characterization studies
- There is a long list of potential det char tasks for scimons
- Scimons can define data quality flags based on their direct observations of events at the sites

Fscans and Line Identification

- Fscans (pulsar search code) on strain h(t), auxiliary channels
- Use pulsar search tools to look for noise lines
- Search for coincident lines among other channels
- Example: a significant line at both sites was found to be due to VME CPUs at both observatories

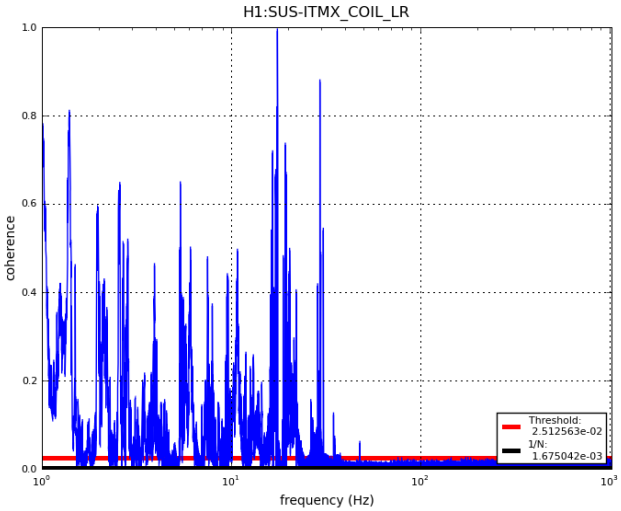


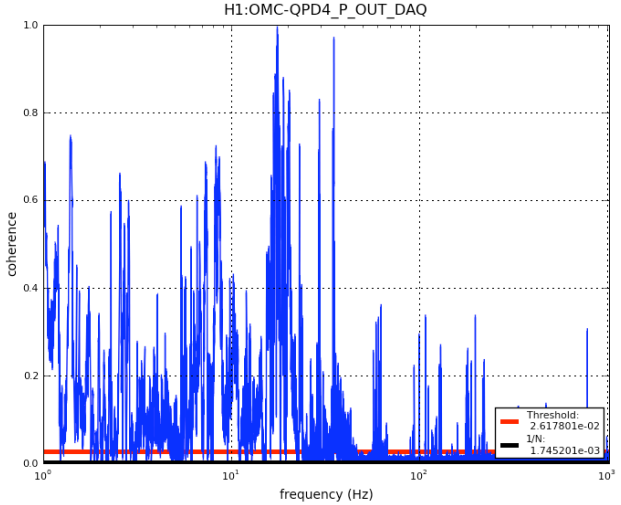


See poster by M.Coughlin on noise line searches

Coherence and Line Identification

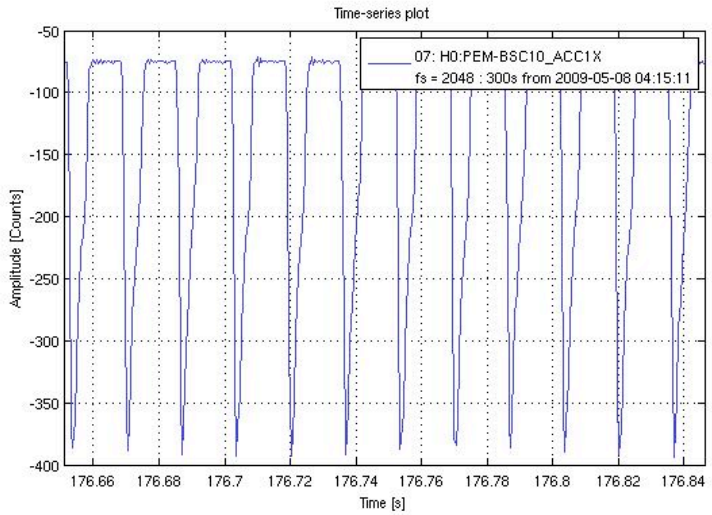
- Coherence calculated between h(t) and numerous auxiliary channels.
- Results of weekly averages are posted
- Web-based tools for searching for significant lines in coherence and Fscan results
- In S6 new problematic (2 Hz harmonic) lines are seen





Dead Channel Monitor (DCM)

- The DCM detects malfunctioning or dead physical environment monitoring (PEM) channels based on various criteria.
- Updates a website every ten minutes with results
- Scimons check this and report any malfunctioning channels seen



List of Dead Channels

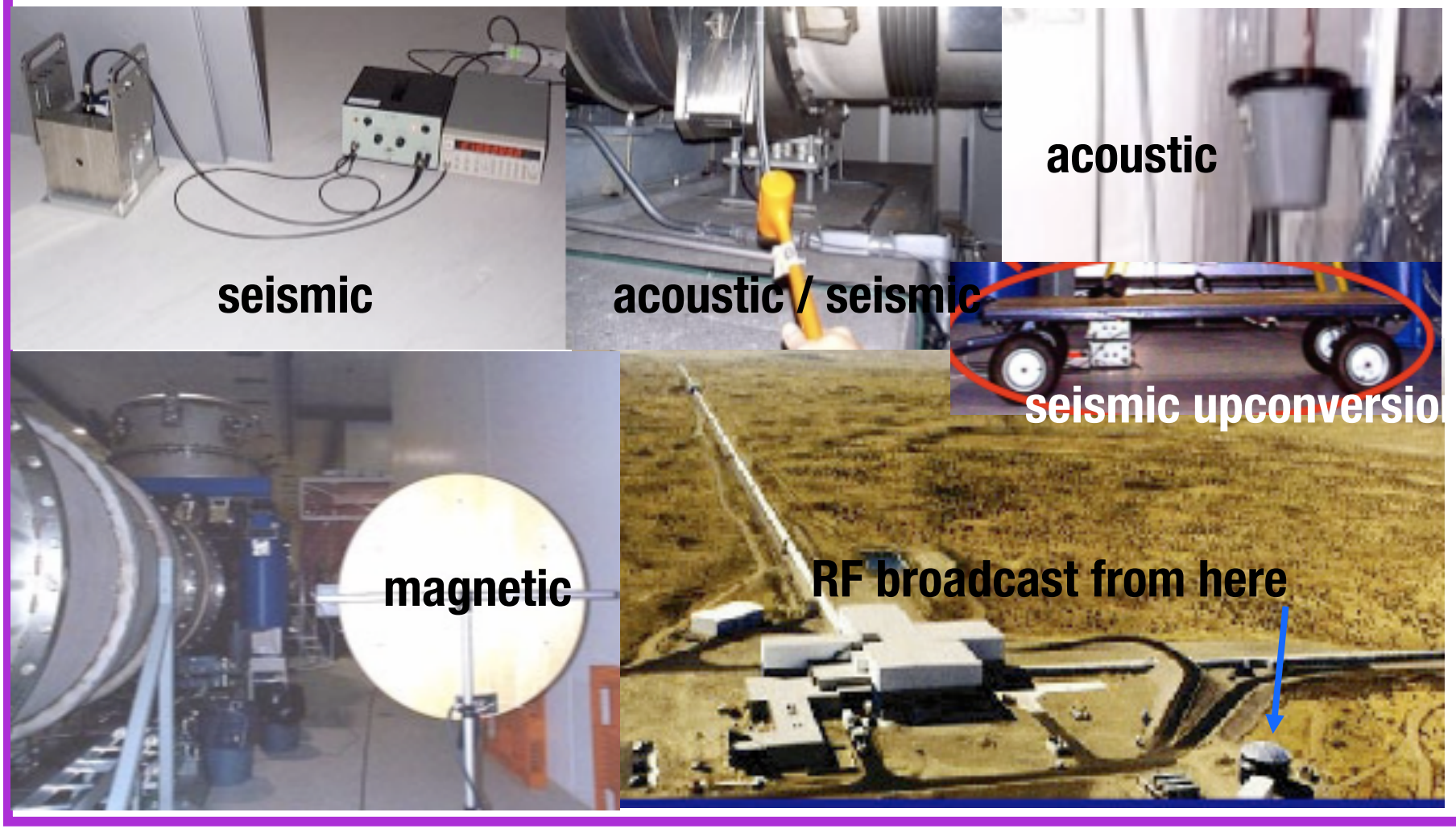
This is a list of dead channels:

H0:PEM-BSC1_MAG1X	RMS out of range
H0:PEM-BSC9_MAGX	RMS out of range
H0:PEM-COIL_MAGY	RMS out of range
H0:PEM-EX_TILTX	RMS out of range
H0:PEM-EX_TILTY	RMS out of range
H0:PEM-IOT1_MIC	RMS out of range
H0:PEM-ISCT10_ACCX	RMS out of range
H0:PEM-ISCT1_ACCY	RMS out of range
H0:PEM-ISCT1_MIC	RMS out of range
H0:PEM-ISCT4_MIC	RMS out of range
H0:PEM-PSL1_MIC	RMS out of range
H0:PEM-PSL2_ACCY	RMS out of range
H0:PEM-RADIO_CS_1	RMS out of range
H0:PEM-RADIO_LVEA_H1	RMS out of range
H0:PEM-ISCT1_MIC	Hardware Glitch
H0:PEM-PSL2_ACCZ	Hardware Glitch

Generated at time:

2009-09-23 6:31:59 (GPS 937722734)

Measuring environmental coupling: "PEM Injections"



Summary of S6a LHO PEM injections

* Acoustic coupling at central building is like S5; coupling levels at interferometer output mode cleaner are already generally lower than at the laser location.

* End station acoustic coupling levels are lower than S5, possibly because of baffle installation.

* Glitches from seismic transients at Y-end were eliminated by lowering EY side servo gain.

Summary of S6A LHO PEM injections

* Seismic upconversion problems for 1.2 Hz ground shaking at both end stations; levels are roughly the same as during S5.

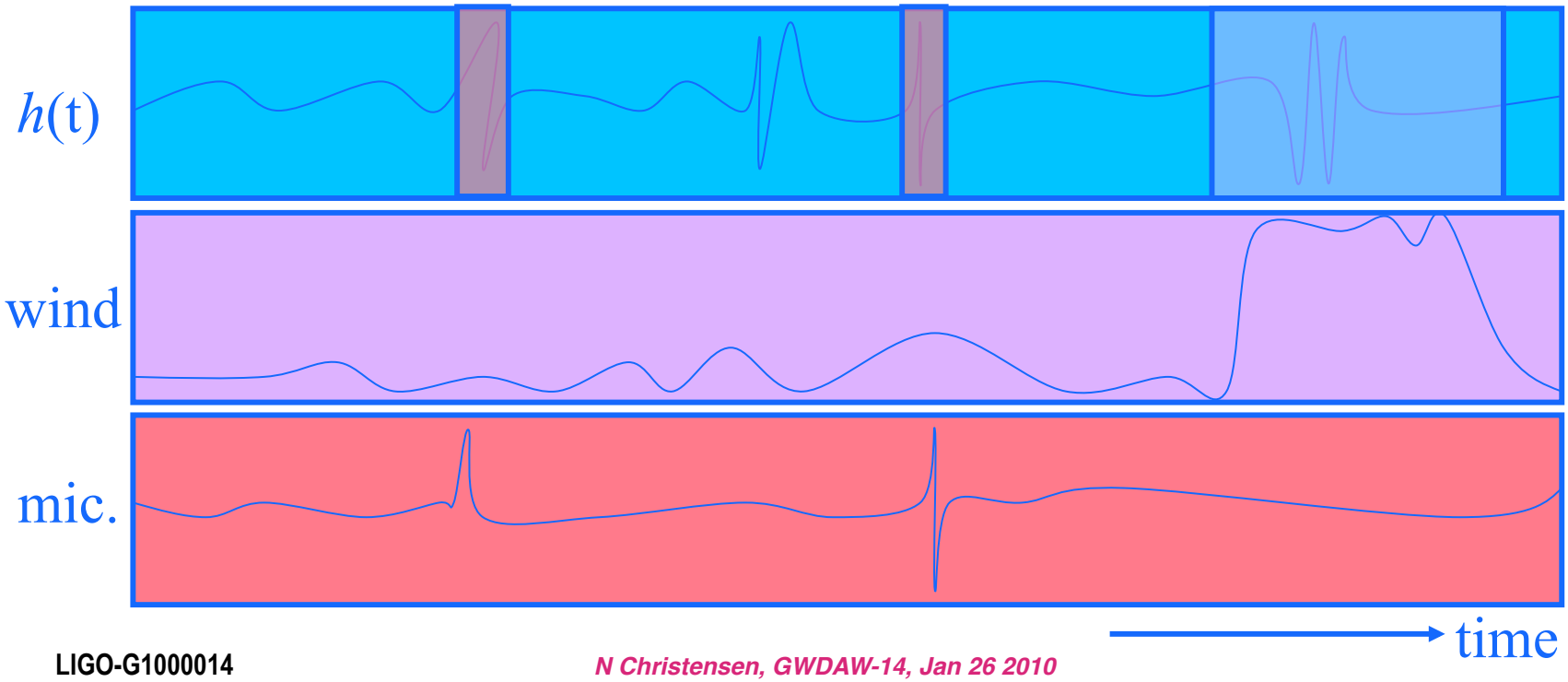
* RF coupling at 25 MHz is at roughly the same level as during S5. LLO is now 2 orders of magnitude below LHO.

* Magnetic field coupling is roughly the same as S5; thus new magnets are all oriented properly.

* Ambient magnetic fields around interferometer output were found to be responsible for the large 60 Hz sidebands in the data. A feed-forward servo has made dramatic improvements.

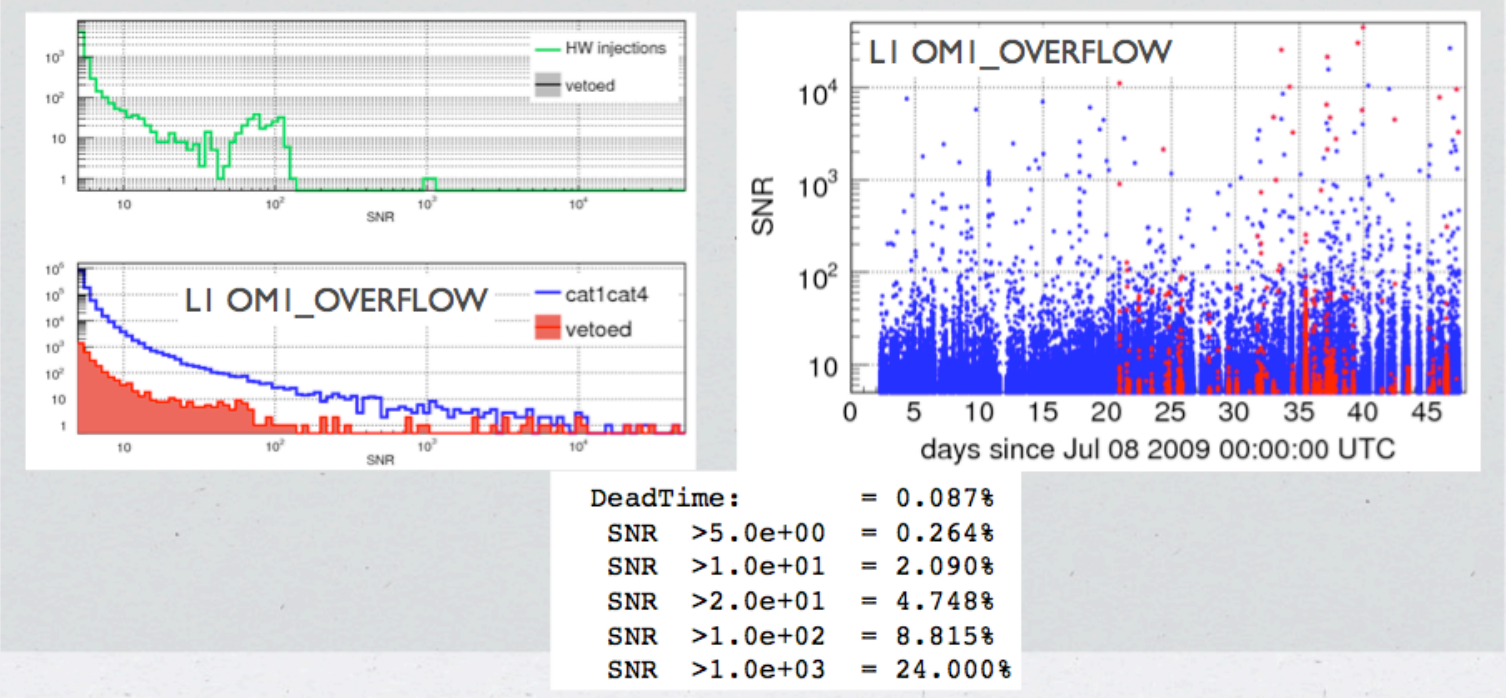
Data Quality and Vetoes

- Data quality flags cut out second to many second long times when we have reason to believe the detector is behaving badly
- Event-by-event vetoes cut out ~100ms to 1s times based on aux channel triggers that have been shown to have a safe and significant relationship with *h*(t) triggers



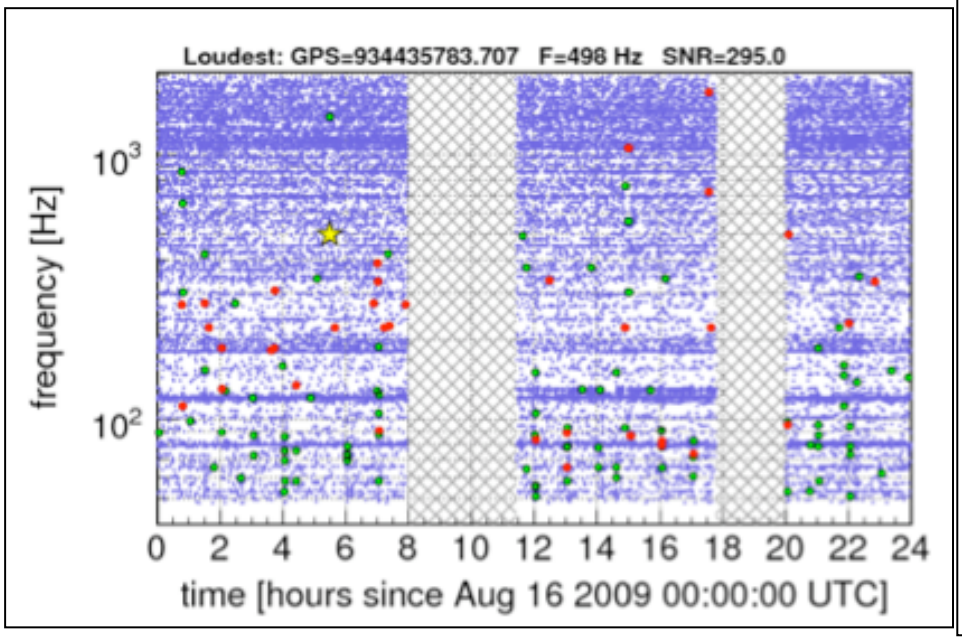
Data Quality Flags

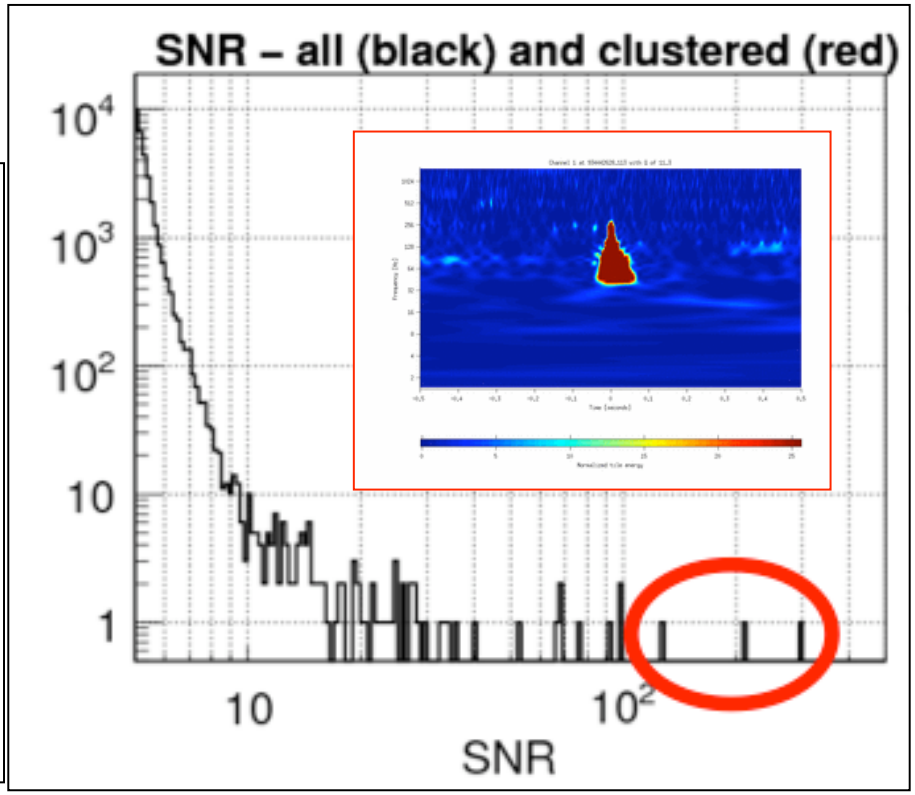
- Online flags produced by Data Monitor Tool
- SciMon flags (e.g. human in control room)
  - New for S6: web insertion of scimon flags
- Offline flags from DetChar (e.g. Autoburt, see below)
- Access via database access tools
- Good progress on checking, ranking



Glitch Studies

- Weekly glitch shifts for L1, H1 with a lot of automated information and tools
- SciMon follow up of loudest Omega (a burst search) triggers
- Independent investigations



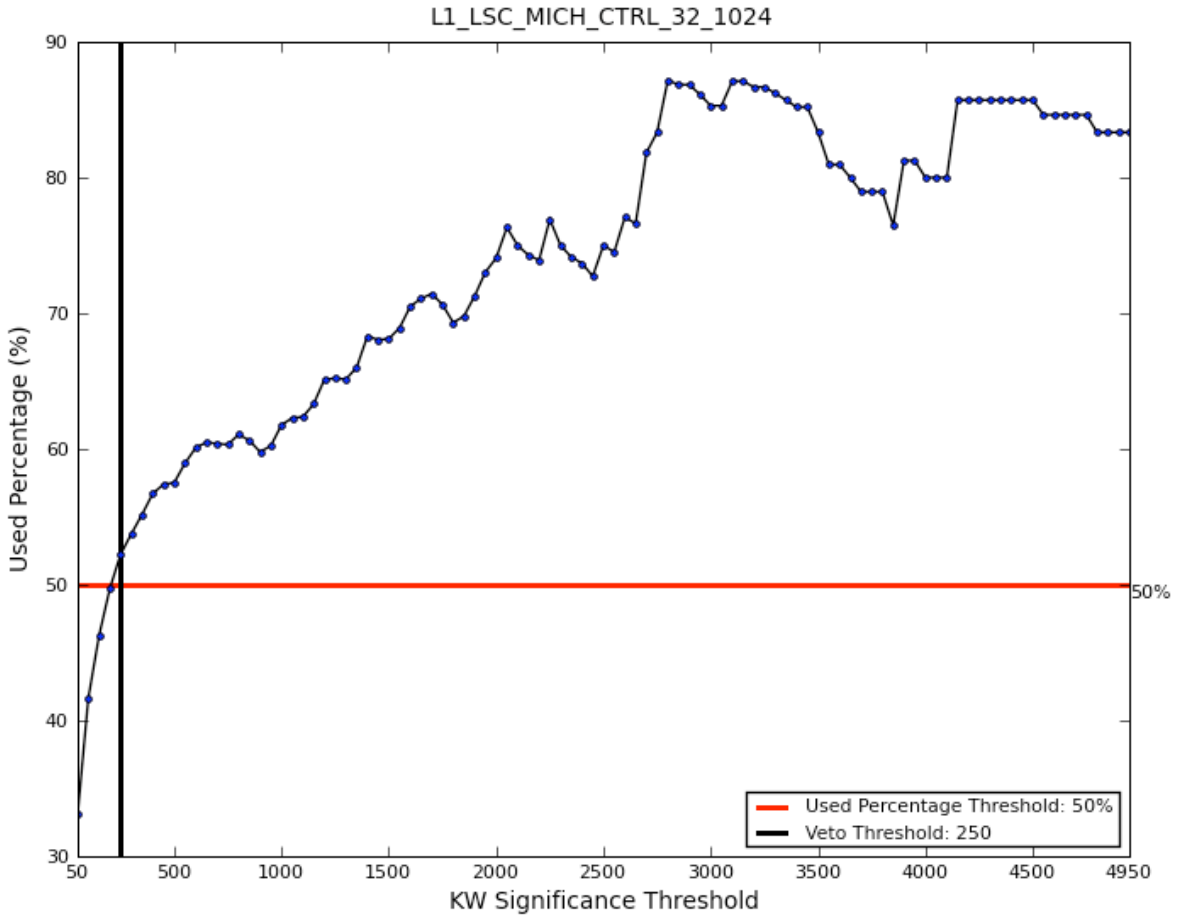


Used Percentage Veto (UPV)

- Using KleineWelle (KW) burst-glitch pipeline triggers
- Used % = Used KW triggers/Total KW triggers
- Raise KW significance threshold until Used % > 50%
- Use with clustered inspiral triggers, +/- 1s veto window.
- Veto has been implemented in S6
- Daily results generated for Det Char studies
- Weekly results to be implemented as vetoes for binary inspirial ihope pipeline
- Applied to H1, L1 and Virgo
- Interesting effects have already been seen; problems identified and corrected

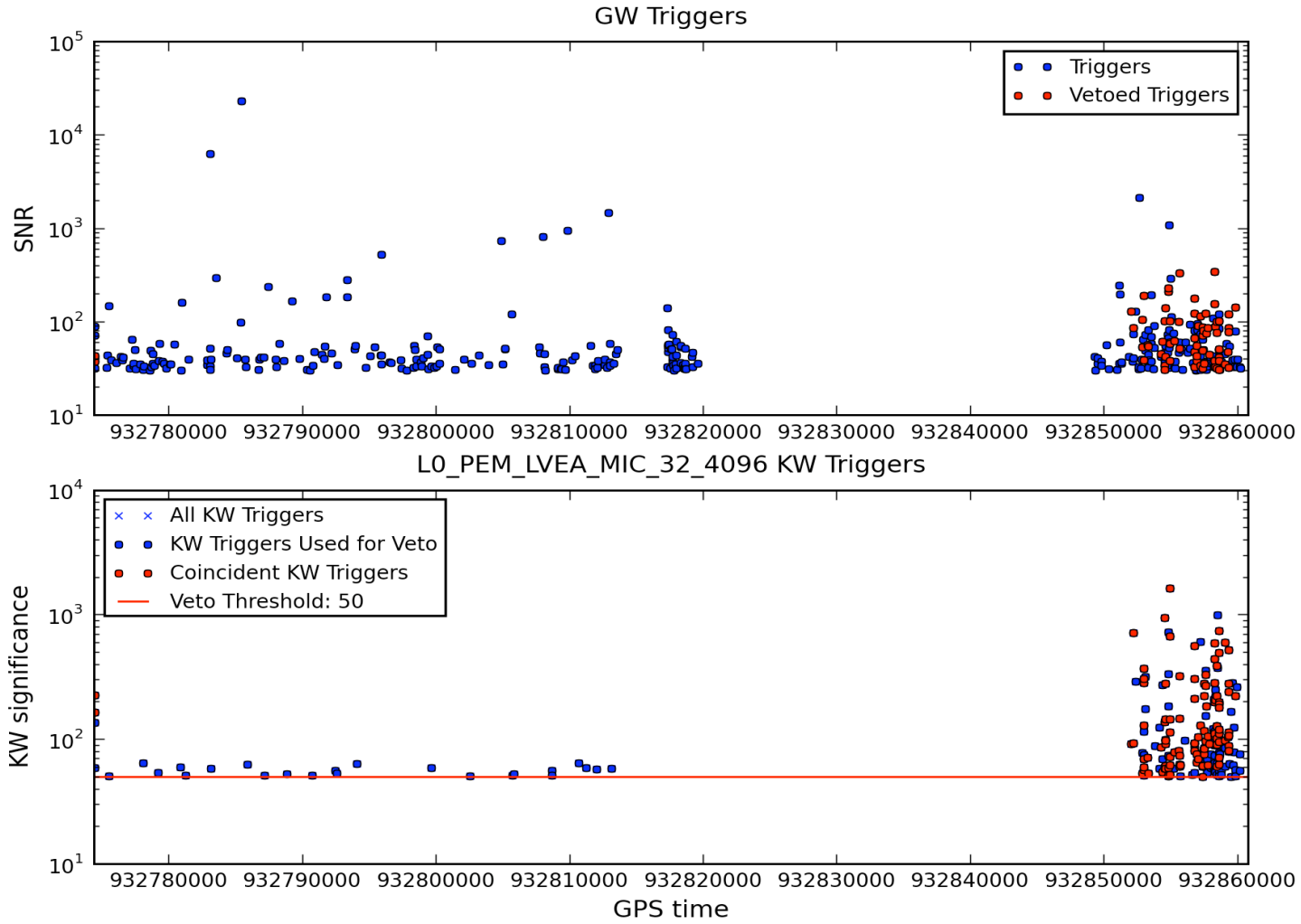
See poster by T. Isogai on the UPV

LIGO Used Percentage Veto Threshold



The used percentage as a function of KW trigger significance for a particular auxiliary channel. UPV picks a threshold significance where the used percentage exceeds 50%, shown as a red line in the plot.

UPV and a Thunderstorm



N Christensen, GWDAW-14, Jan 26 2010

hveto

hveto is another a good way to look for classes of glitches.

1. Finds most significant correlation between an auxiliary channel and DARM_ERR (output channel) in lists of KW triggers made from all channels.
2. Then, deletes all DARM_ERR triggers vetoed by that channel.
3. And then looks again for significant correlation.

"Round 2" winner treated the same as Round 1:
Delete all of its DARM_ERR triggers
and look again, repeating until no significant correlations found.

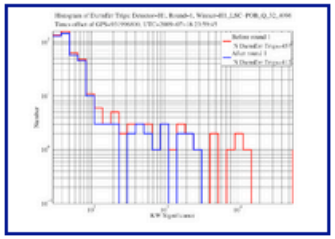
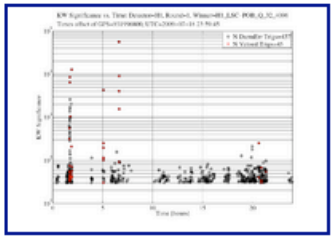
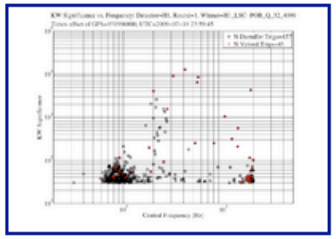
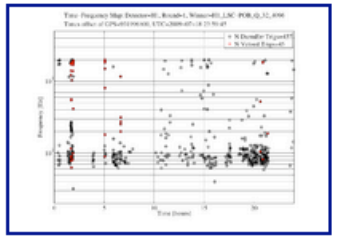
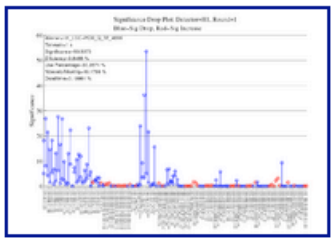
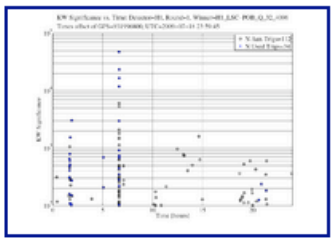
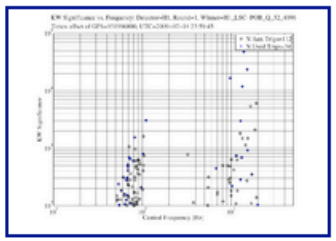
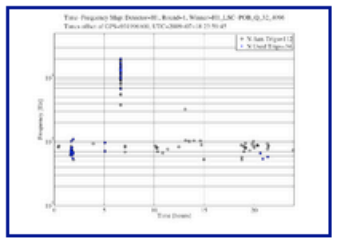
Process converges, and sorts triggers into groups,
as measured by which auxiliary channels were correlated with them.

hveto runs daily, and has been rerun over weeks of S6A, with the results implemented as part of the LIGO – Virgo burst search.

hveto Example: POB Q in H1

Round	Winner	Twin [s]	KW Thresh	Significance	Nveto	Use [%]	Efficiency [%]	Deadtime [%]
1	H1_LSC-POB_Q_32_4096	1	100	53.54	45	30.3571	9.8468	0.1998
2	H1_ASC-QPDY_DC_1_128	1	50	8.73	20	4.6997	4.8544	0.8319
3	H1_ASC-BS_Y_1_256	1	100	6.84	20	4.0153	5.1020	1.1530

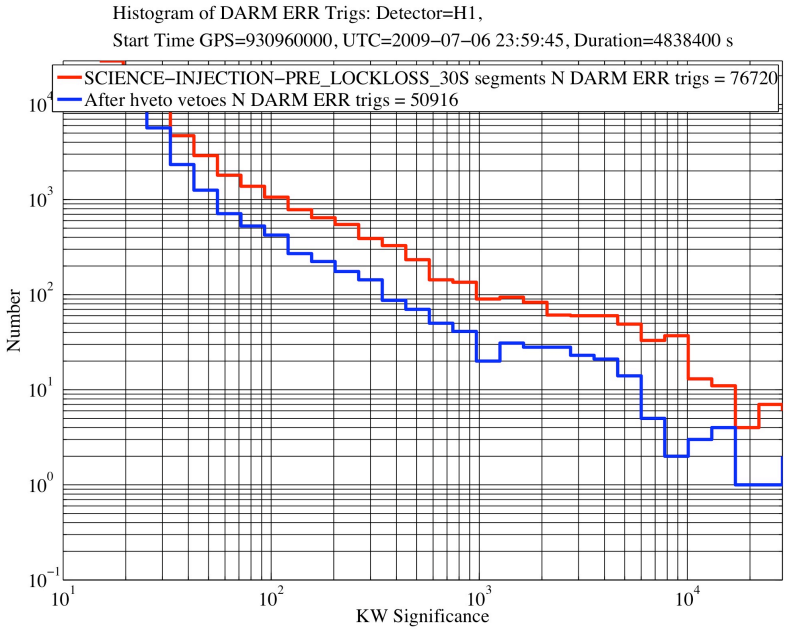
Round 1, Winner = H1_LSC-POB_Q_32_4096, Twin = 1, KW Thresh = 100

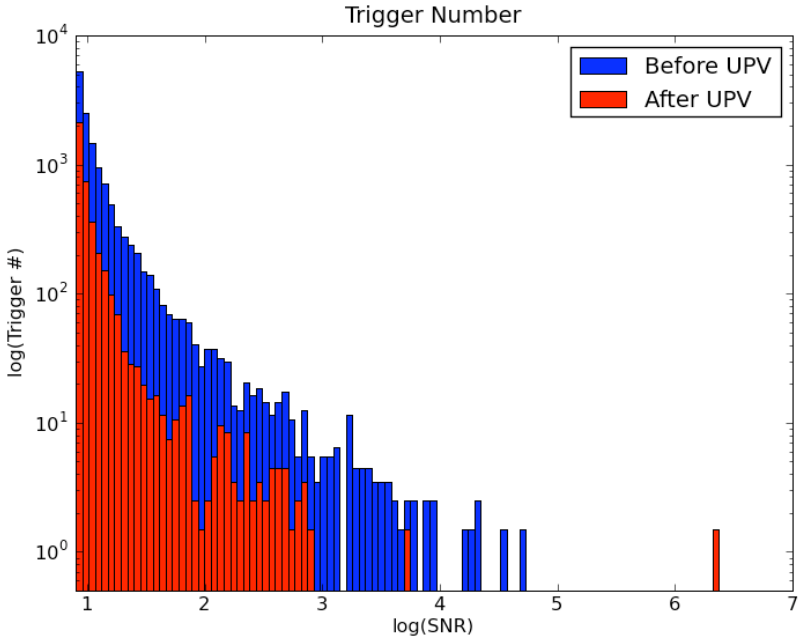
Round Statistics	DarmErr KWsig Histogram	DarmErr KWsig-Time	DarmErr KWsig-Freq	DarmErr Time-Freq
Pre-round segment stats: **[TXT]** Round=1 ---------- Winner=H1_LSC-POB_Q_32_4096 KW Threshold=100 Timewin=1s Significance=53.5373 Ndarmerr=457 Naux=112 Mu=1.1681 Ndarmerr vetoed=45 Naux used=34 Ndevetoed/Naux=40.1786% Inc. Efficiency=9.8468% Use Percentage=30.3571% Inc. Deadtime=0.19981% Efficiency/Deadtime=49.28 Cum. Efficiency=9.8468% Cum. Deadtime=0.19981% **Veto Segments:** **[TXT]** **Vetoed DE Trigs:** **[TXT]**				
Aux Sig Drop	**Aux KWsig-Time**	**Aux KWsig-Freq**	**Aux Time-Freq**	
				

Observations with hveto in S6

- Glitches group into distinctive families.
- There are many such families.
- Rarely, single-channel (or few-channel) families.
  Usually, many channels drop by significant amounts.
- Many channels have high use percentage, but others are have quite poor use percentage.
- Channels typically work well during brief periods of time. Why?

Vetoes Work!

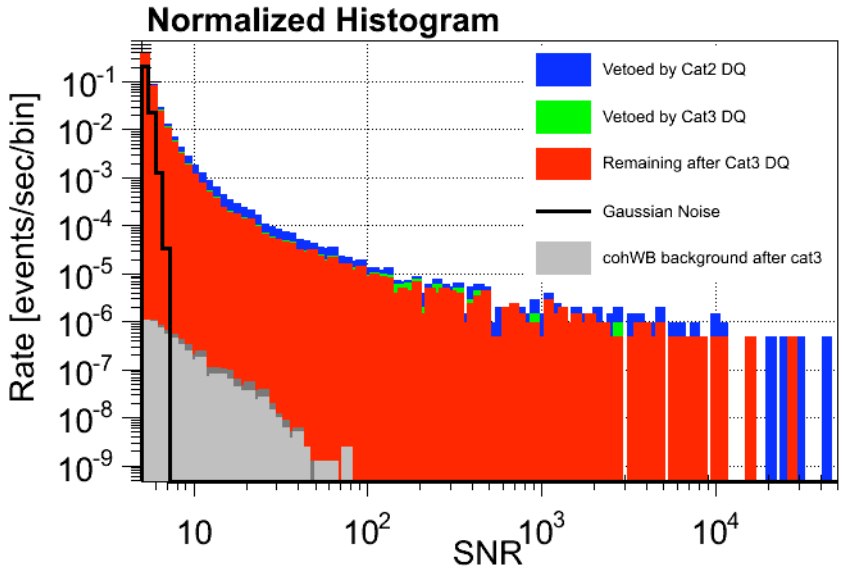




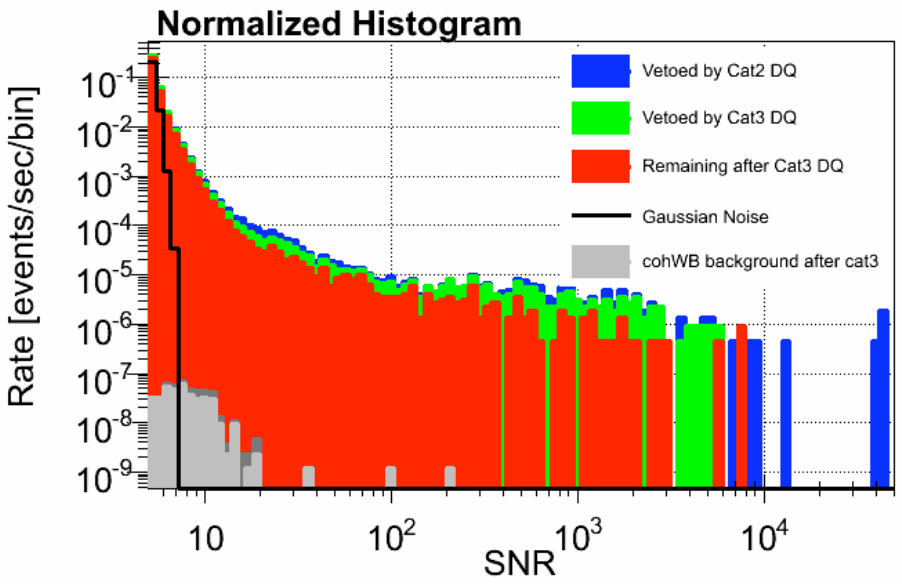
S6a H1 Omega burst triggers vs. SNR: Red, after application of Cat1 flags; Blue, then apply h-veto.

S6a L1 ihope inspiral triggers vs. SNR: Blue, after application of Cat1 and 2 flags; Red, then apply UPV veto.

SNR of CWB Triggers in S6a



L1

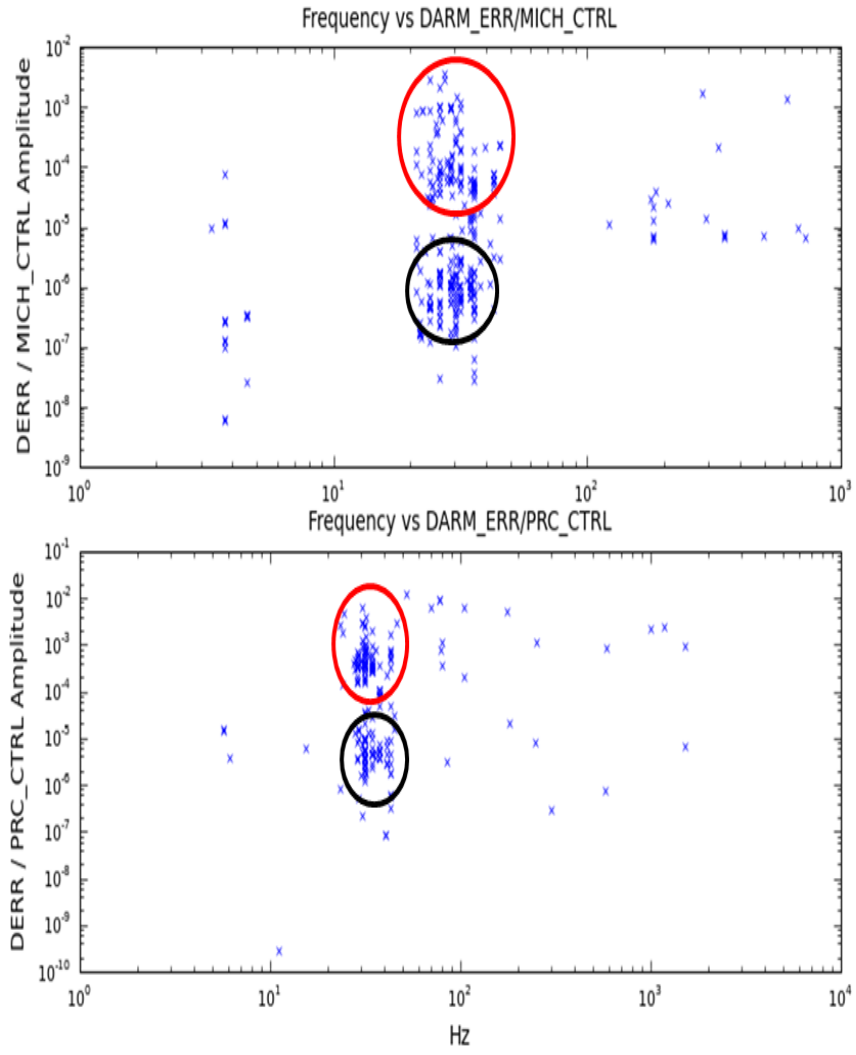


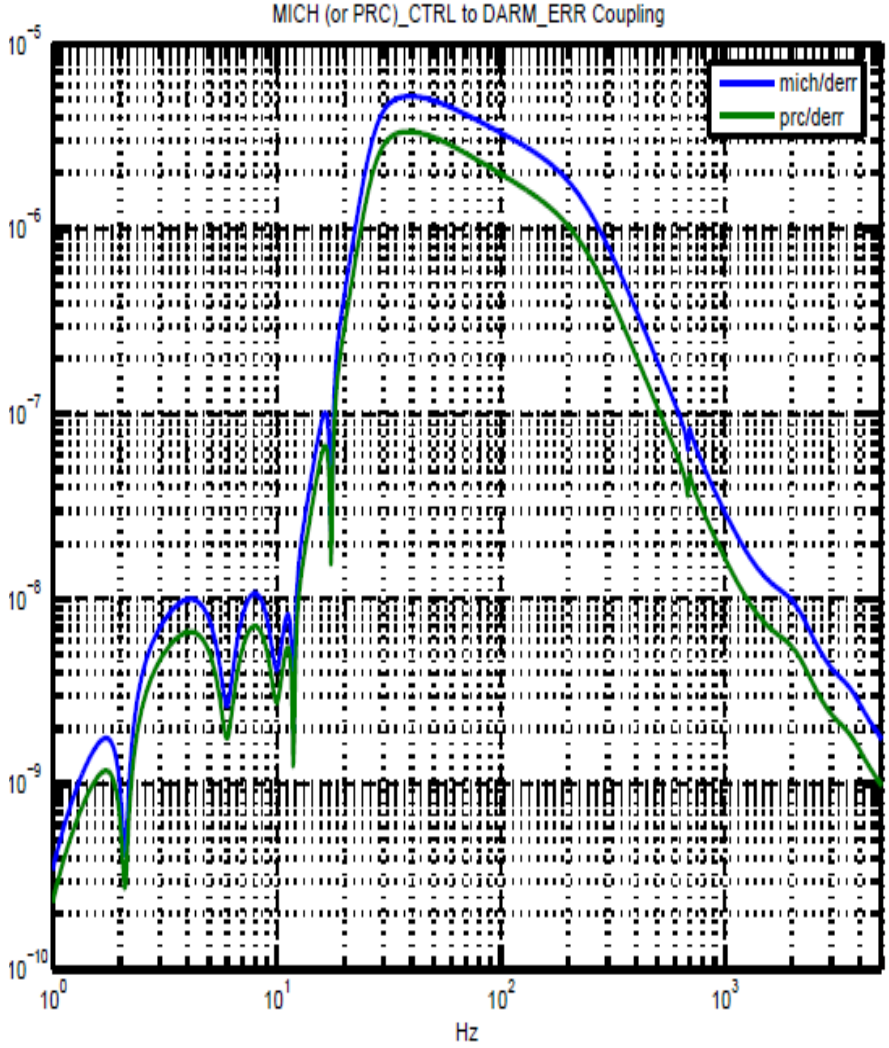
H1

Single IFO SNR plots from coherent Wave Burst (grey) overlaid with the single IFO Omega burst triggers. Black line is Gaussian.

Note that the SNR ~10 events are the problem for the coherent analysis.

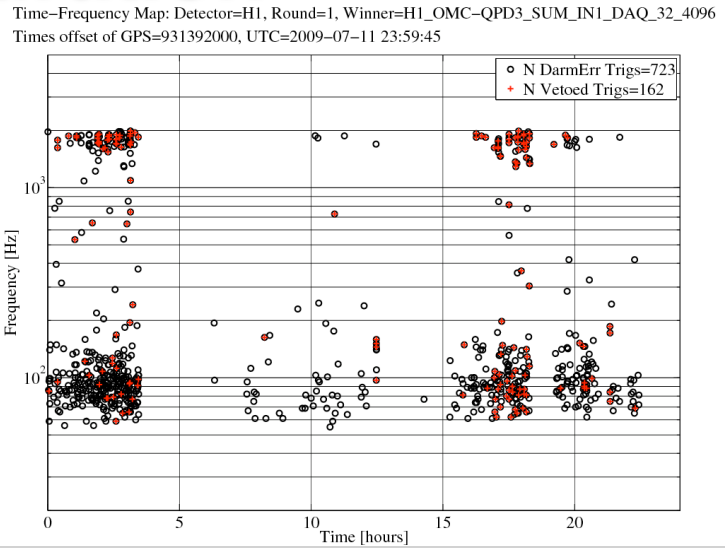
L1 POB I/Q Glitches

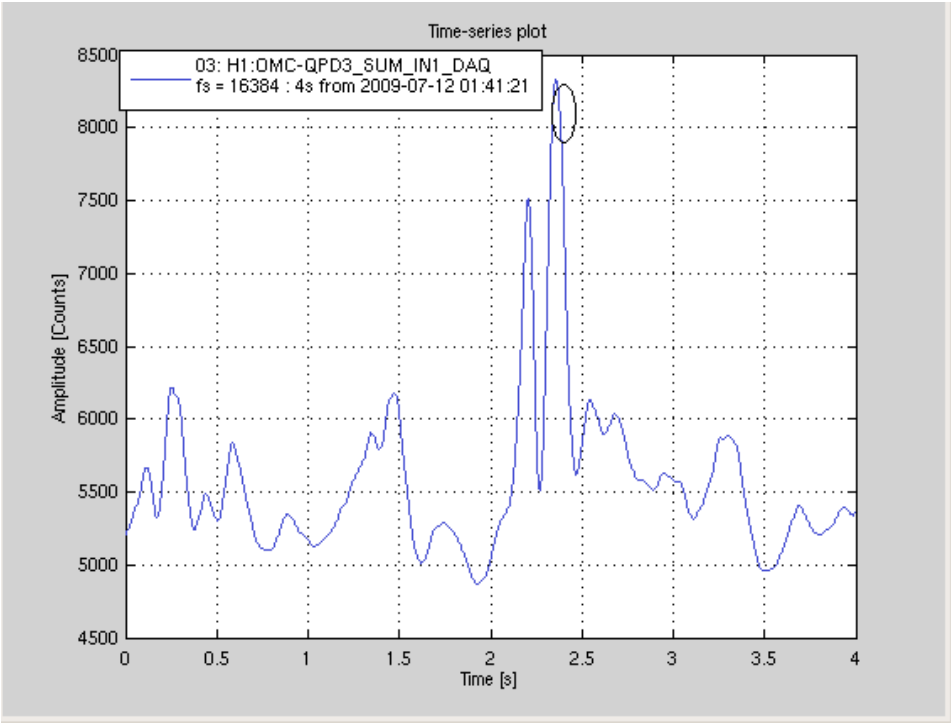


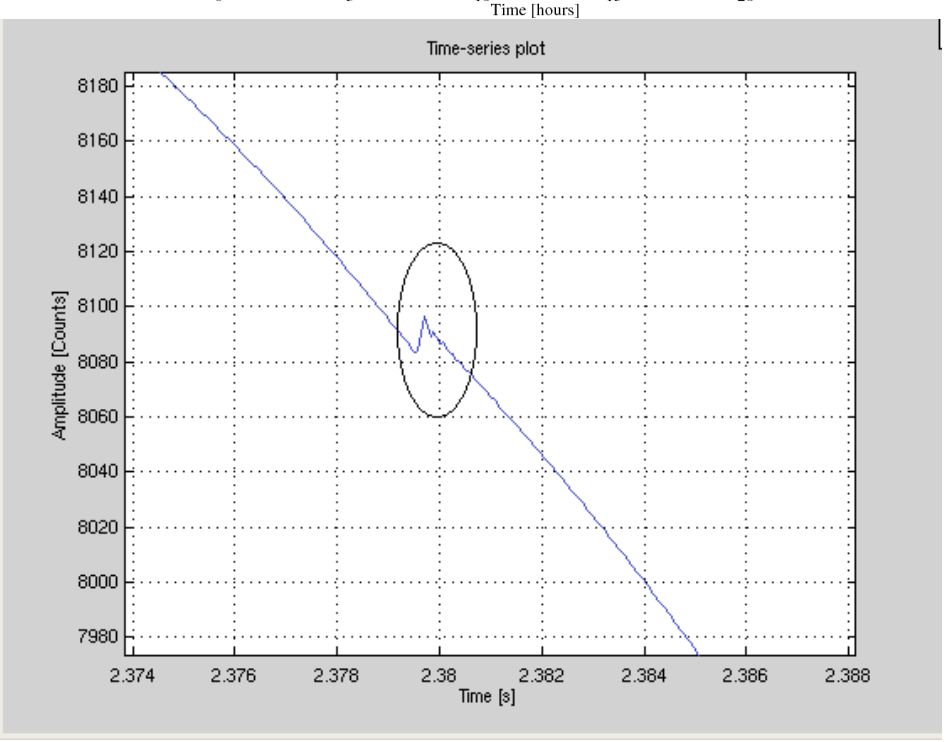


OMC QPD Saturation

- Output mode cleaner quadrant photodiode saturations were coincident with 20-30% of H1 glitches in early S6

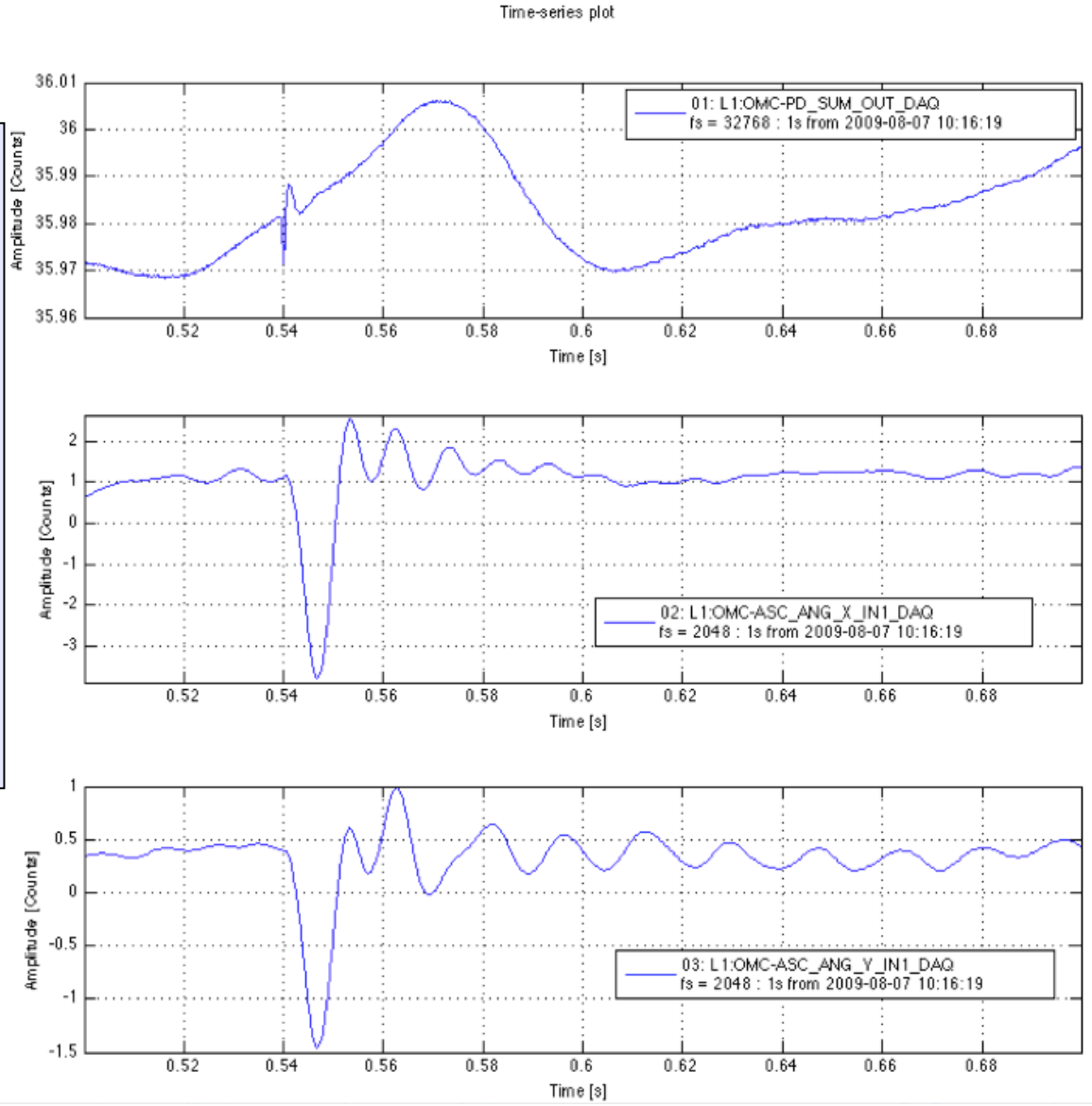






L1 OMC glitches

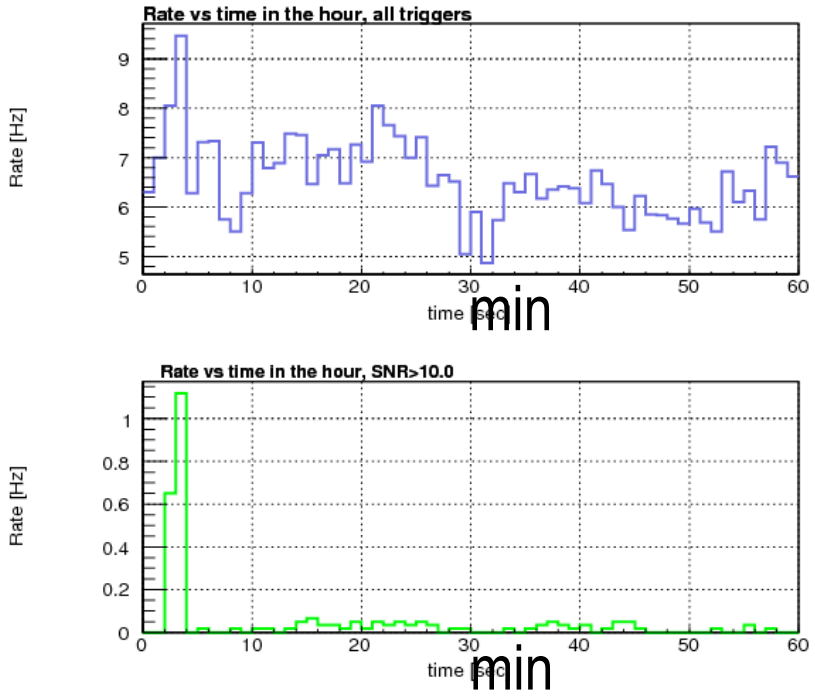
- Identified by loudest event follow-up
- one millisecond downward spike in OMC-PD_SUM, followed by a slower oscillation
- often shows as loudest daily omega trigger
- ongoing investigation



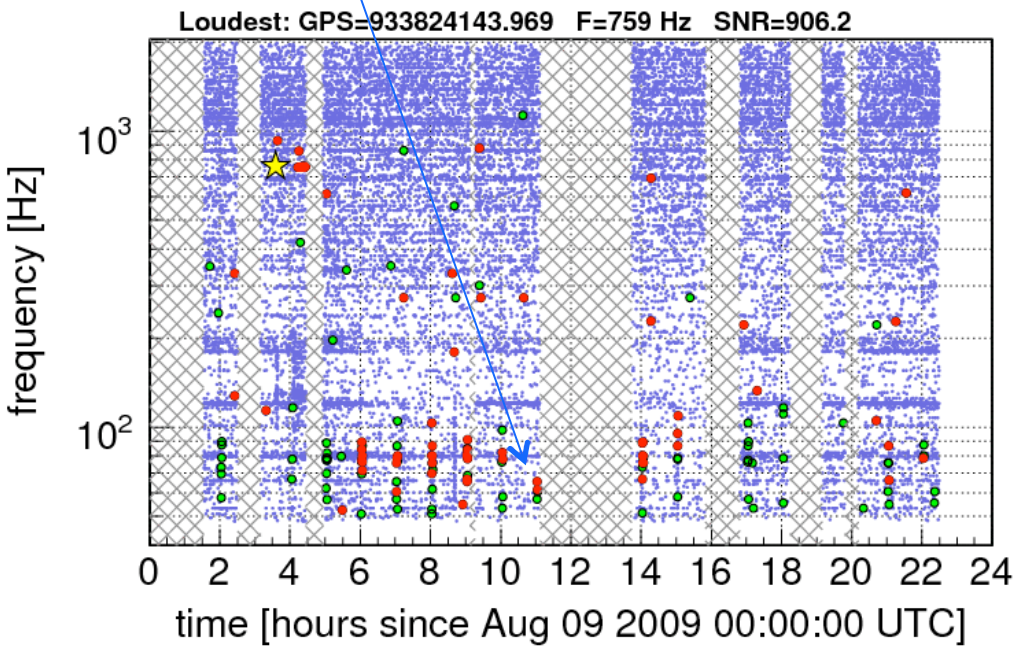
Autoburt Glitches

- Backup snapshots of digital system produce glitches with correlation to (not very high) CPU load spikes
- DQ flagged and removed for S6B

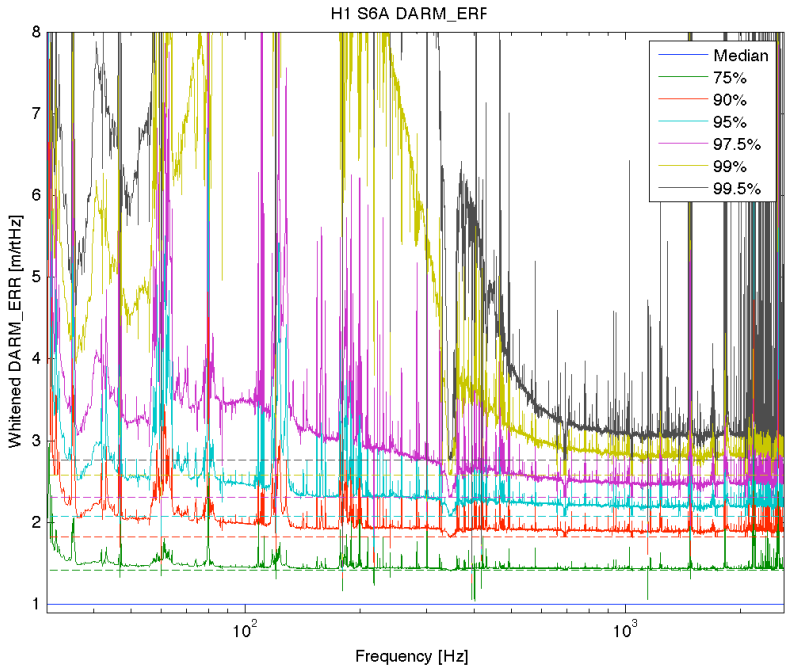
H1:DCH-AUTOBURT_GLITCH_WIDE:1
[933843615 933843855)
Aug 09 2009 09:00:00-09:04:00 UTC

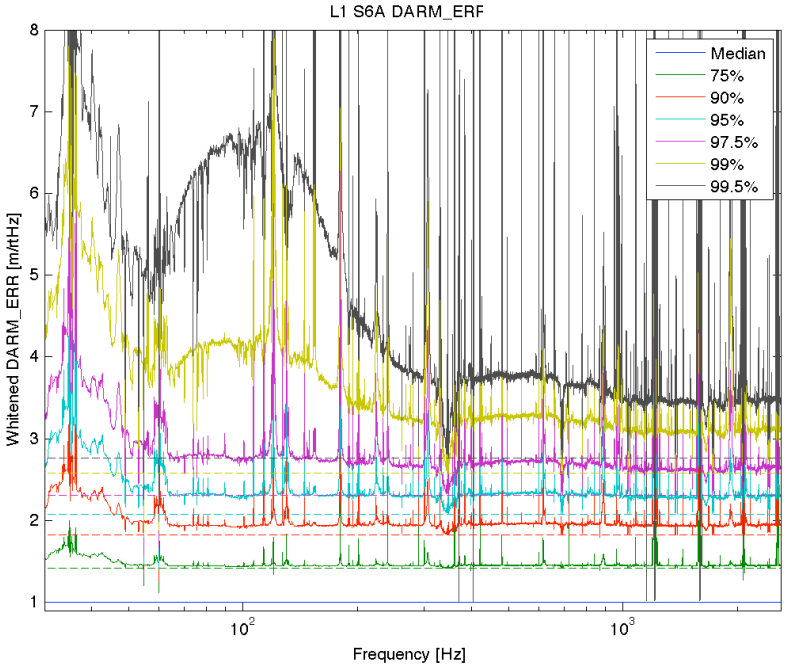


9.5% deadtime ☹



Spectra stationarity





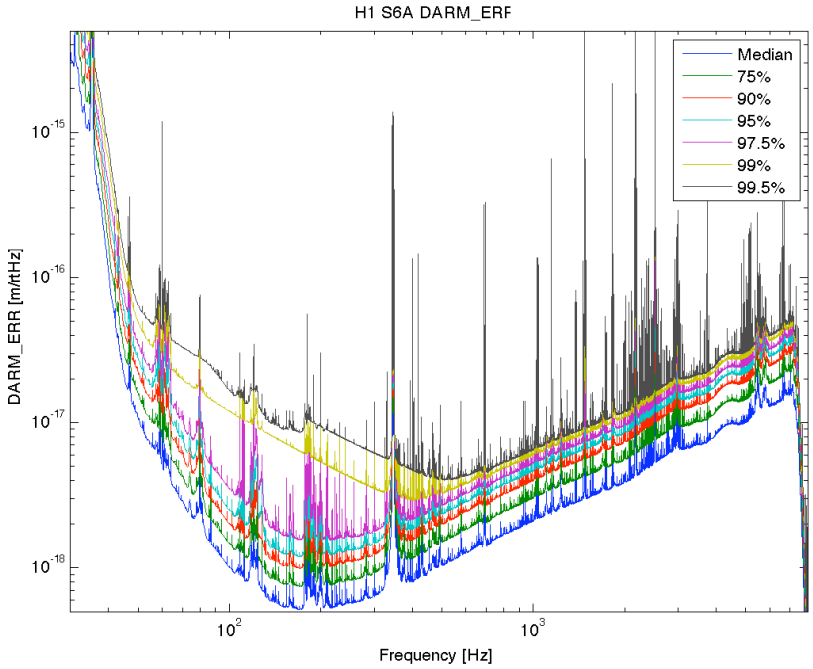
The noise can have a distinct spectral shape while still having gaussian probabilities. To compare to the Rayleigh distribution, the we normalize by the median value for each frequency bin. The dashed lines represent the contour for pure Gaussian noise.

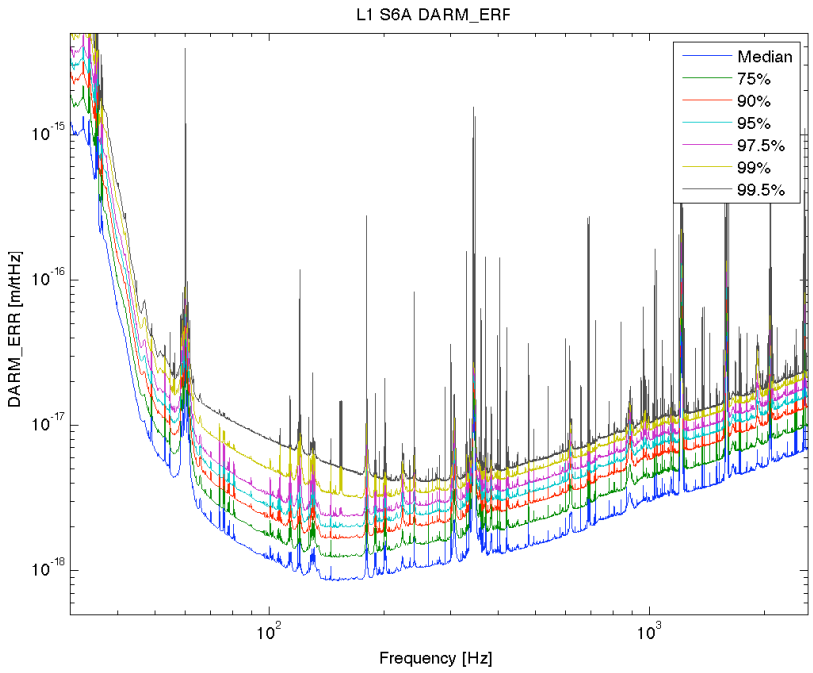
Summary

- A lot of activity in line, glitch, calibration, PEM and other areas during S6
- Very good feedback provided by the analysis groups (burst, inspiral, pulsar and stochastic)
- In S6b (present) we continue to identify and eliminate noise sources
- Right now there is a period of intense activity at the sites by detector characterization group members and commissioners

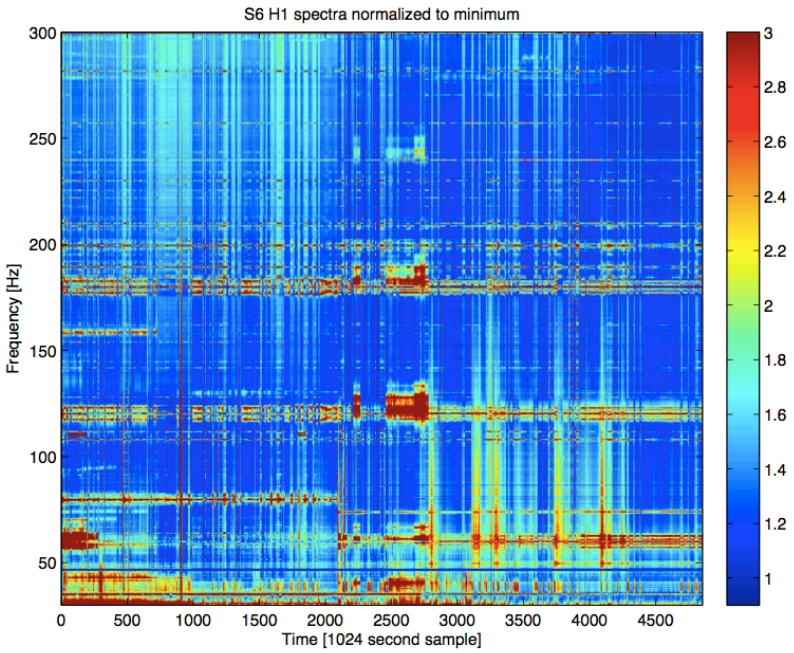
Extra Slides

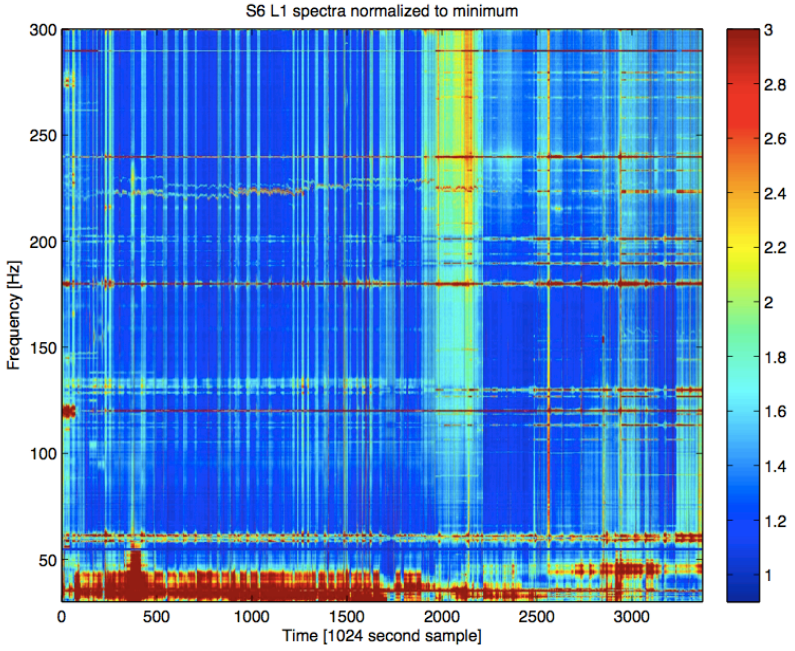
Noise Spectra





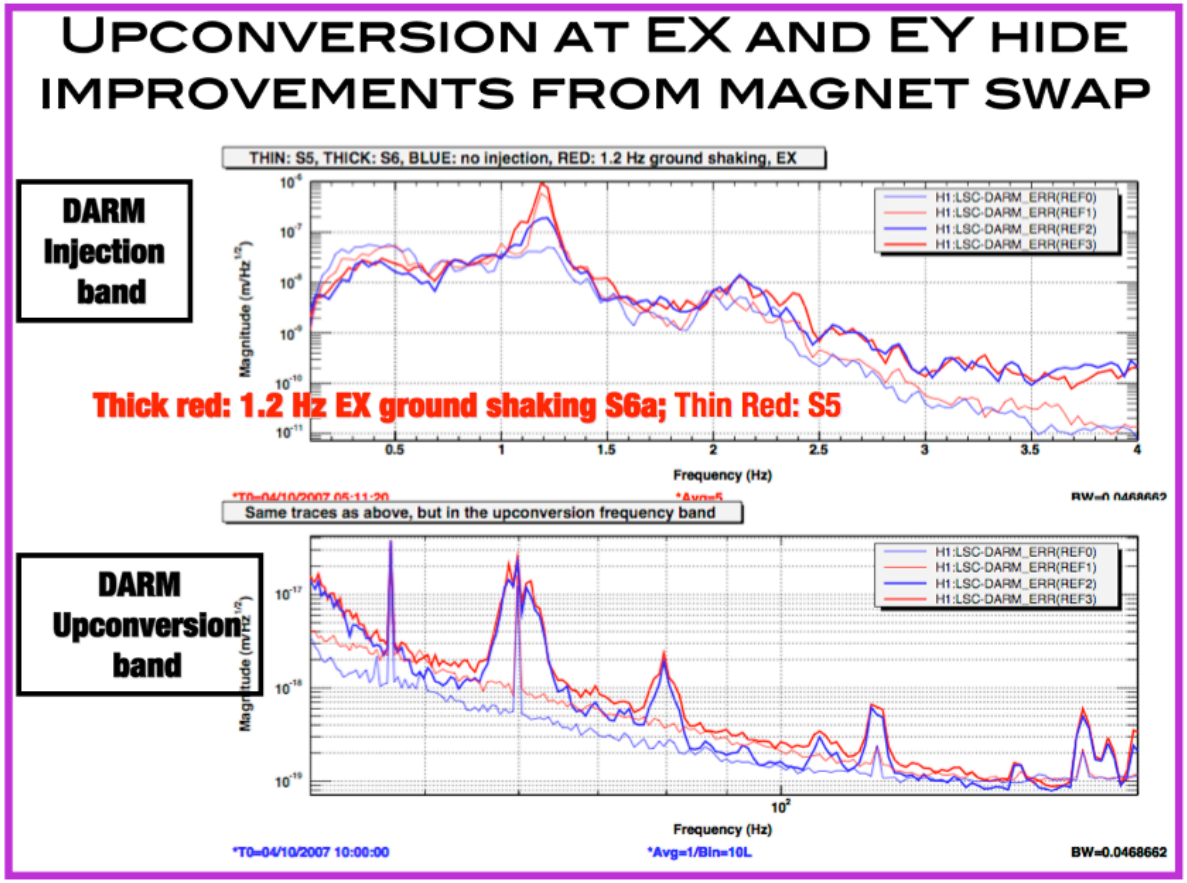
Spectrum stationarity





Detailed PEM Investigations

- Noise injections and response of physical and environmental monitors (PEMs)
- Example: More upconversion noise



Used Percentage Veto – WFS4