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LIGO-G040522-00-Z

Veto Studies for LIGO Binary Inspiral Triggers

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Thanks to L. Cadonati, A. Di Credico, and L. Blackburn and other members of the Burst Group for discussions and providing veto trigger files.

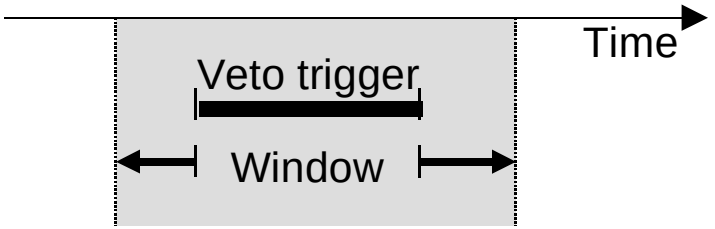
GWDAW, December 16, 2004

General Approach for Auxiliary-Channel Vetoes

Choose various auxiliary channels

Identify "glitches" in these channels

- Have used glitchMon (uses Data Monitoring Tool library)
- Now also using KleineWelle (Wavelet)
- Filters data (usually high-pass), looks for large excursions
- Try different veto trigger thresholds
- Try different "windows" (extend veto effect) :



Correlate with inspiral event candidates and evaluate:

- Veto efficiency (percentage of inspiral events eliminated)
- "Use percentage" (percentage of veto triggers which veto at least one inspiral event)
- Deadtime (percentage of science-data time when veto is on)

LIGO S3 Inspiral Vetoes

LIGO's Third Science Run: November 2003 – January 2004

Improved sensitivity => Environmental monitors are taking on increased importance

Acoustic isolation work has dramatically reduced events seen coincidently in microphones

Vetoes developed by studying playground sections of data:

A set of disjoint segments of of 600 contiguous seconds of data from each of H1, H2 and L1.

Each segment begins at an integer multiple of 6370 seconds. Playground constitutes 9.42 % of the total run.

A sample begins in each solar hour twice every three days

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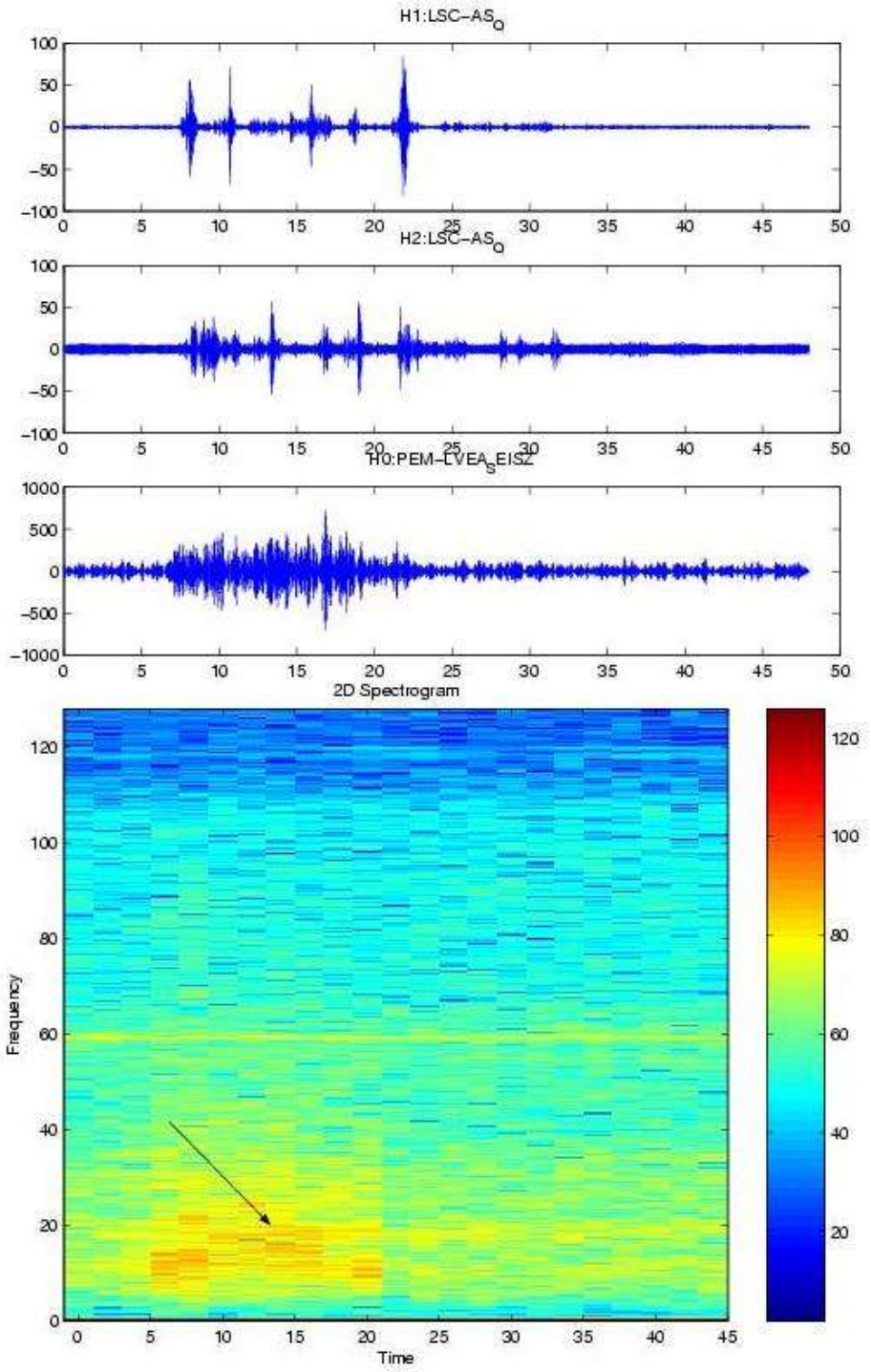
Occasional very large seismic events at Hanford

Dewar Glitches- Now fixed

Seismometer power in 2 to 20 Hz band

Do not happen often, but always produce inspiral triggers



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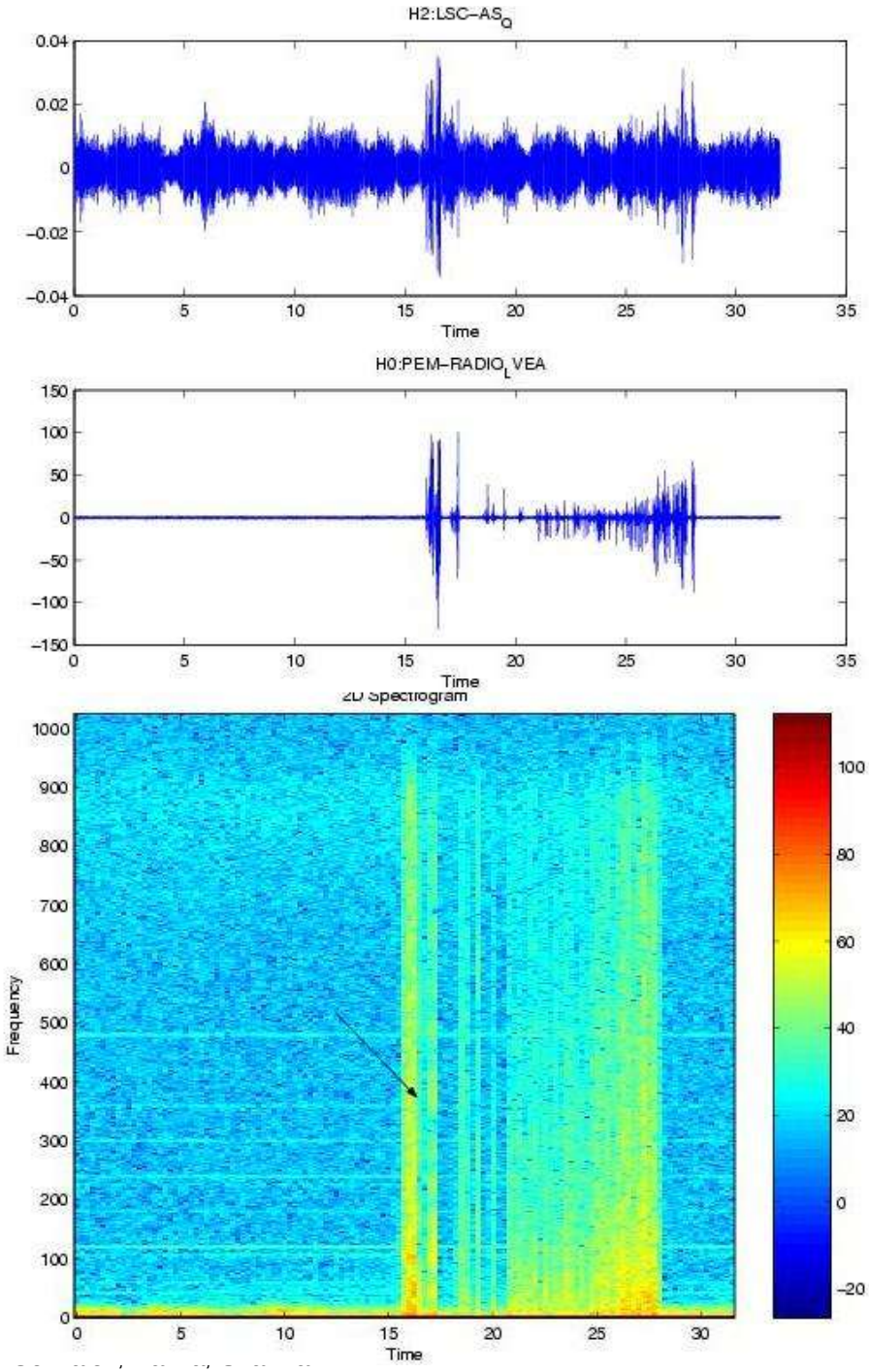
H2: Coincident glitching in radio receiver

Broadband glitch

Happens infrequently and ultimately not a good veto.



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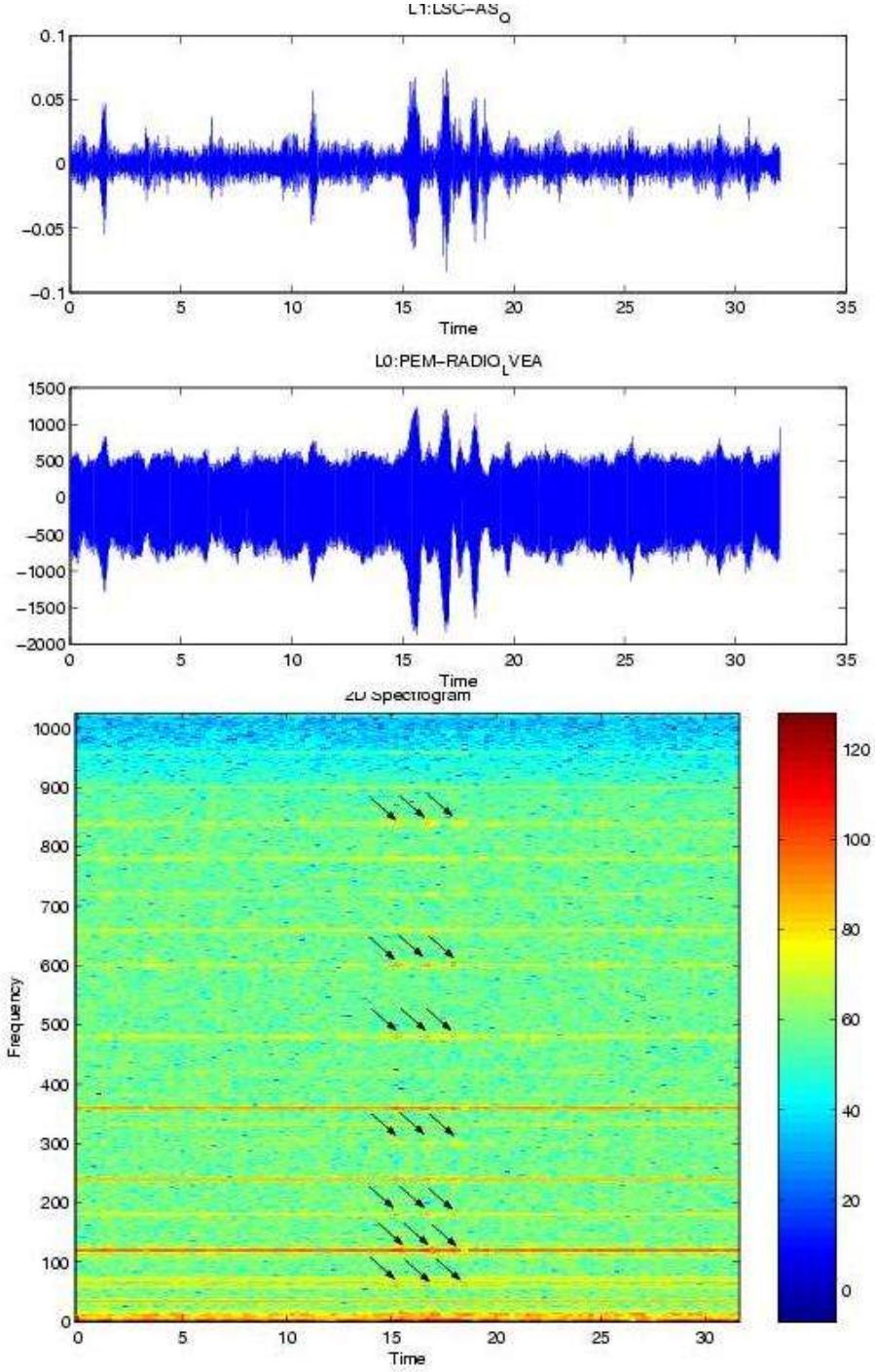
L1: Also has coincident glitching with radio receiver.

Power in radio glitch always at 60 Hz and harmonics.

Not an efficient veto.



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S3 Inspiral Data Quality Cuts

Preliminary Results for H1

Will exclude times with:

- Data outside of official S3 run times
- DAQ overflows
- Missing calibration lines
- Unlocked interferometer
- Airplanes (microphone signature)
- Missing data
- Invalid timing
- No data
- Elevated Seismic Activity

Still Studying, and probably useful:

- Elevated dust levels
- Light Dips arm cavities

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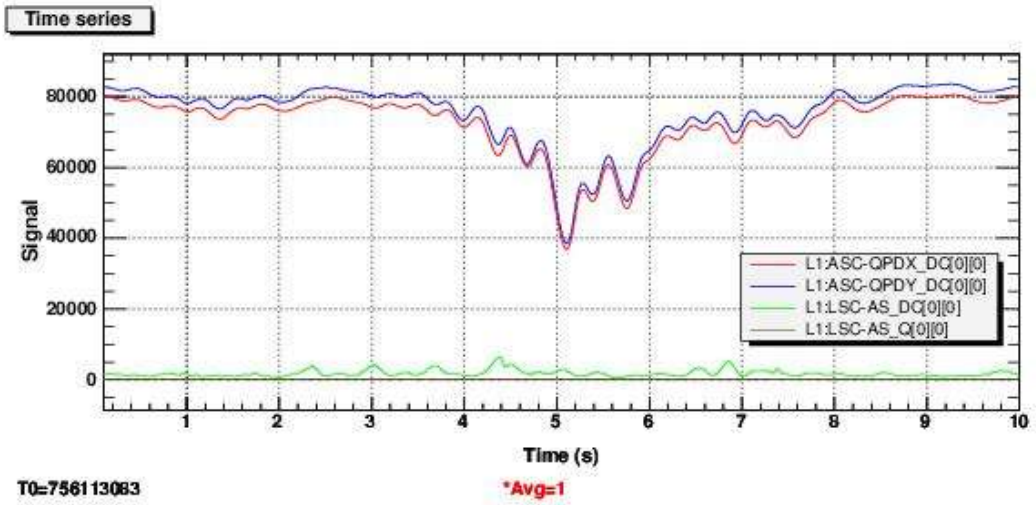
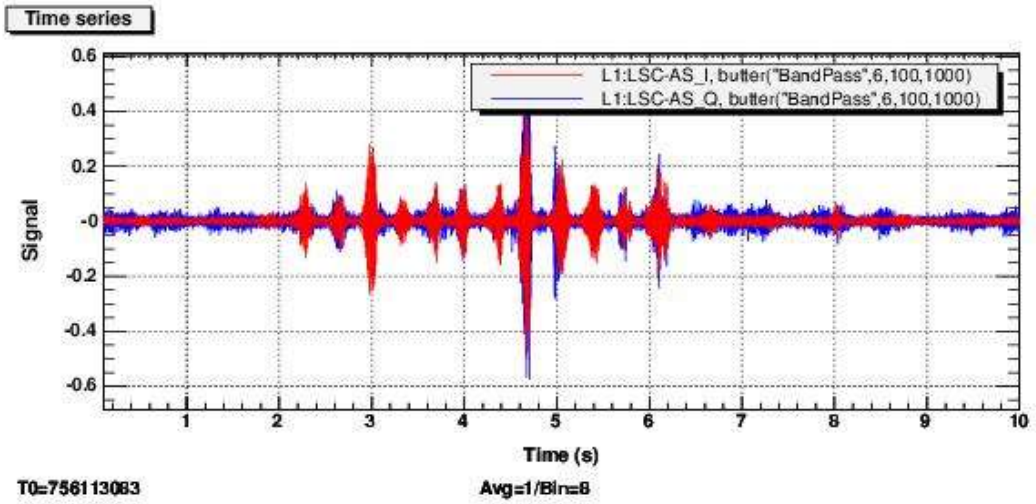
Light Dips in arm cavities at L1

Coincident glitching in gravity wave channel





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Dust Veto

Elevated dust levels due to human intrusion at the dark port tables

Dust in H1:
27 playground segments analyzed by the inspiral code
have a "dust" flag, representing a 4.2% deadtime if used as a veto.

Veto efficiency (clustered inspiral triggers)= 6.0 %
Veto efficiency for clusters with SNR>20= 14.8 %

May use as a veto in upper limit study, but not in a coincident search

Seismic Veto at LHO

SEISMIC_HIGH: Gravel trucks driving by the Hanford Observatory are reliably flagged with a band-limited (3-10Hz) RMS minute trend in seismometer H0:PEM-LVEA_SEISZ

SEISMIC TRANSIENT: glitchMon search on seismometer H0:PEM-LVEA_SEISZ, 2-20 Hz bandpass, the very highest transients (9 or larger), and windows of 20 second duration. LN2 Dewar glitches.

Good Veto Found for H2

H2:LSC-PRC_CTRL: control signal (~force applied) in feedback loop that keep the recycling cavity resonant.

or ...

H2:LSC-REFL_Q: error signal (~residual motion) in feedback loop that keeps the Michelson locked in the dark fringe.

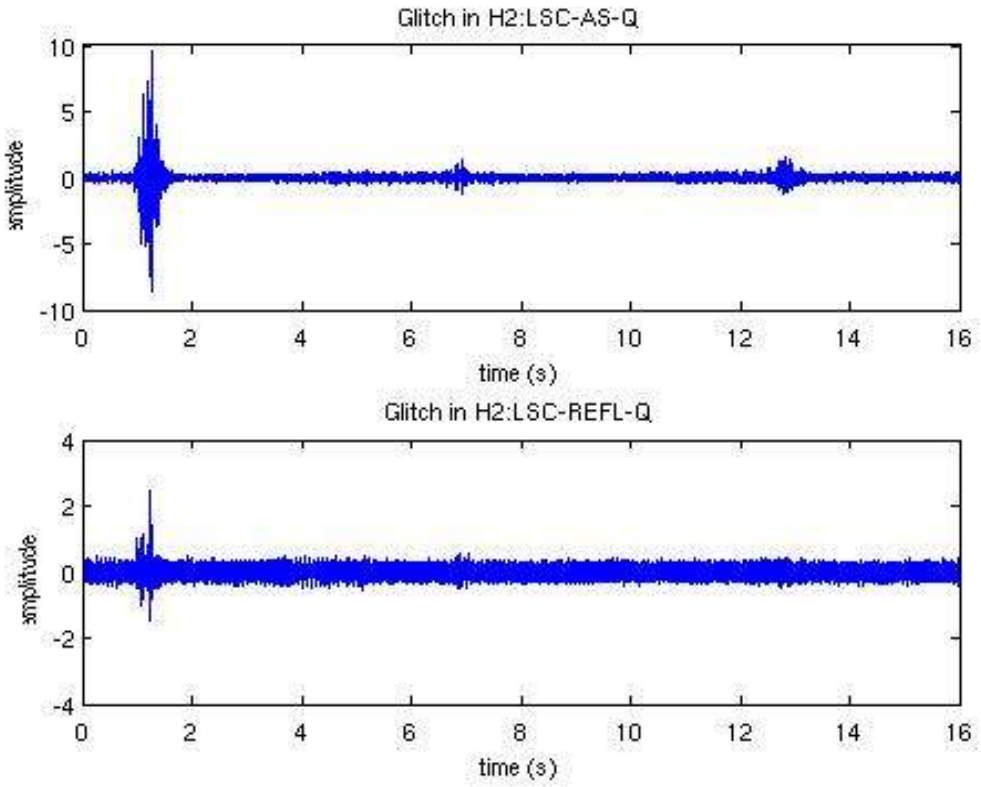
Both of these channel veto similar glitches in H2:LSC-AS_Q

H2:LSC-REFL_Q

Best veto condition:
glitchMon triggers
100 Hz High Pass
event size > 6
window of -1 s to +10s

S3 H2 Veto Result:
28.3% veto efficiency
0.5% deadtime
use percentage 40.3%

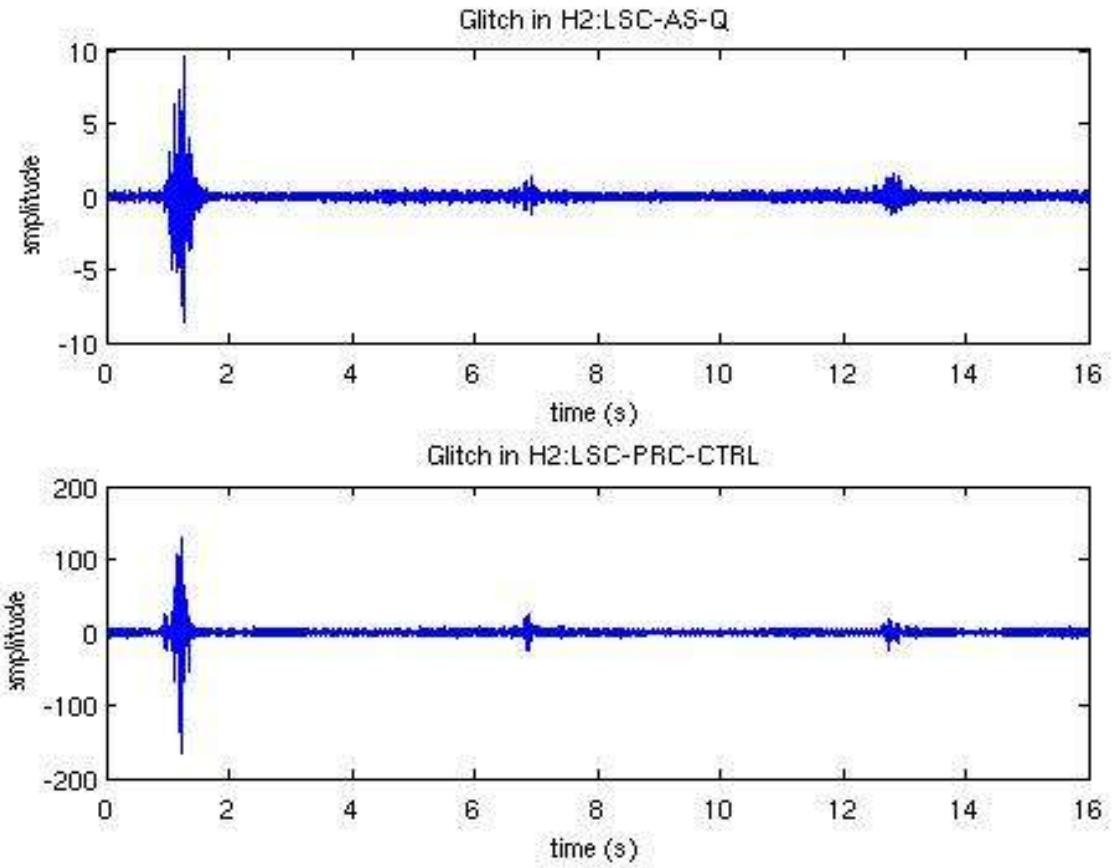
46.5% of inspiral triggers with SNR>10



H2:LSC-PRC_CTRL

Best veto condition:

KleineWelle (wavelet) triggers
70 Hz High Pass
event size > 2000
window of -1 s to +15s



S3 H2 Veto Result:

21.5% veto efficiency
0.4% deadtime
use percentage 51.7%

35.8% of inspiral triggers with SNR>10

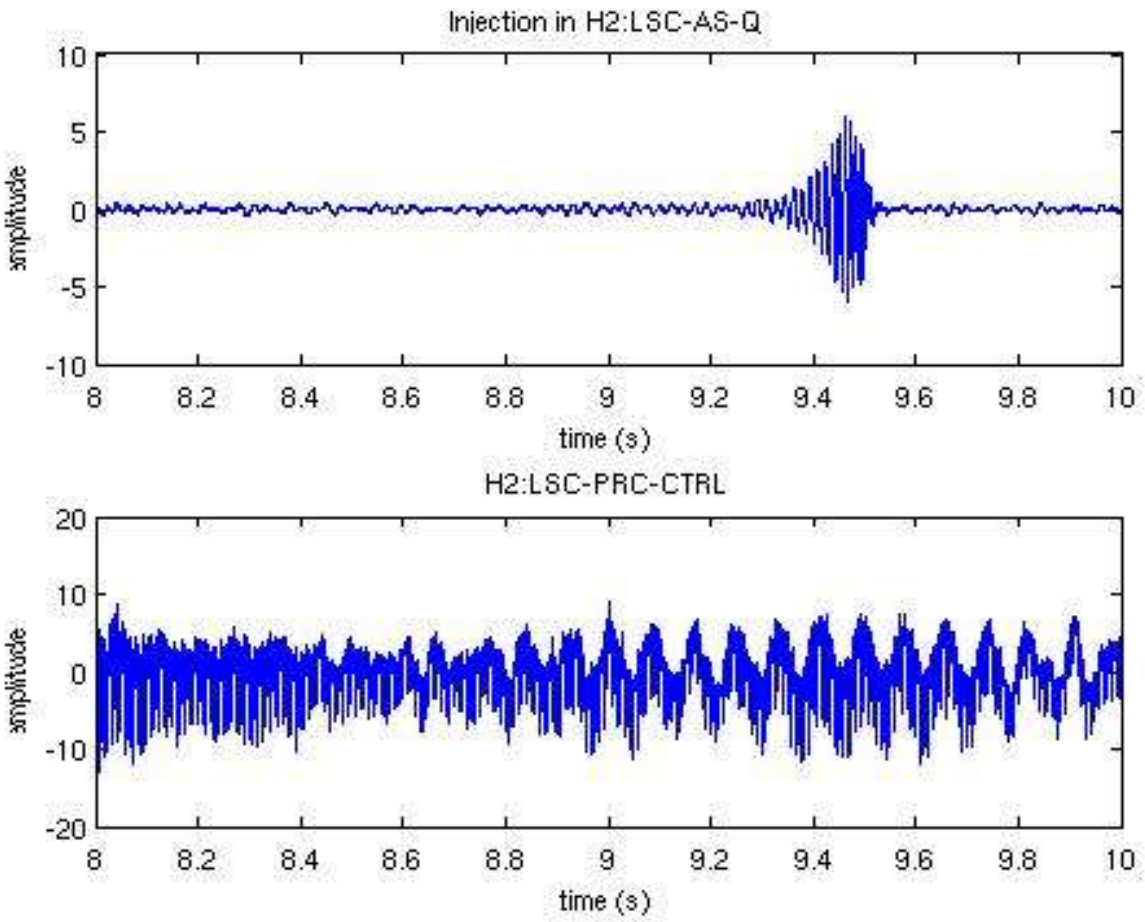
Further optimization of this veto is in progress

Veto Safety: Hardware Injections

Need to be sure that a gravitational wave wouldn't show up significantly in auxiliary channel being used for veto

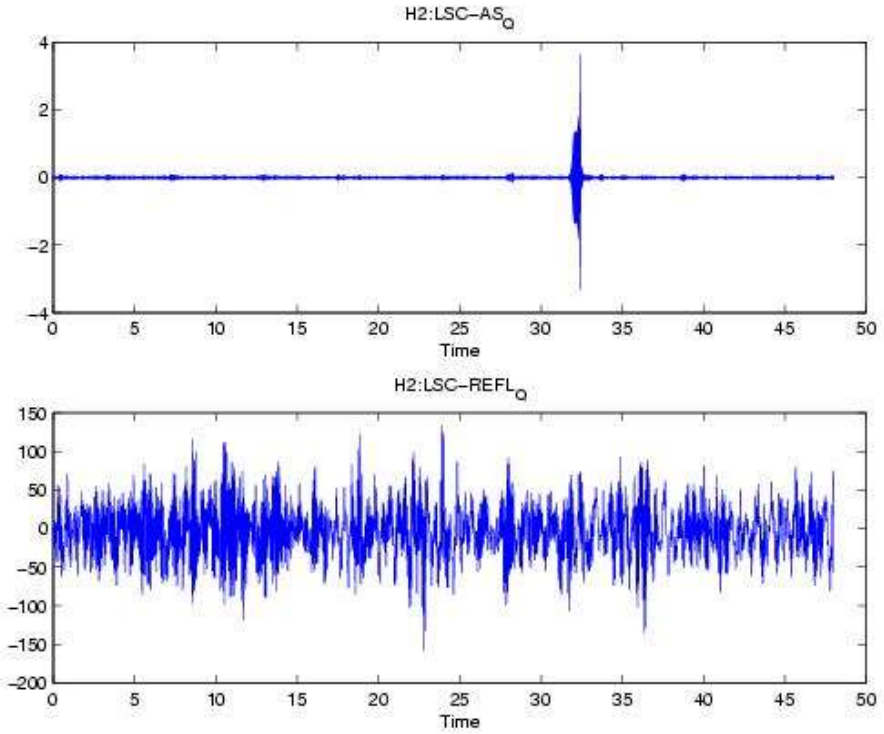
Wiggle one or more arm cavity end mirrors, look for evidence of coupling to auxiliary channel

PRC_CTRL looks safe



Veto Safety: Hardware Injections

REFL_Q looks safe too!

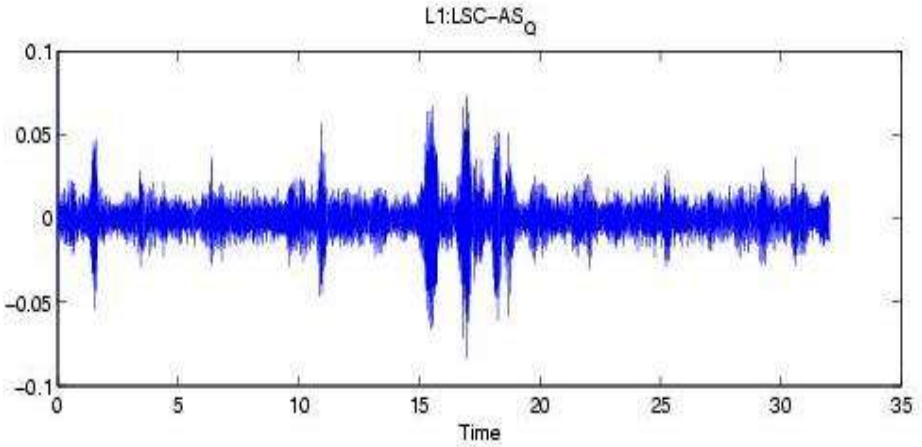


Can We Use AS_I???

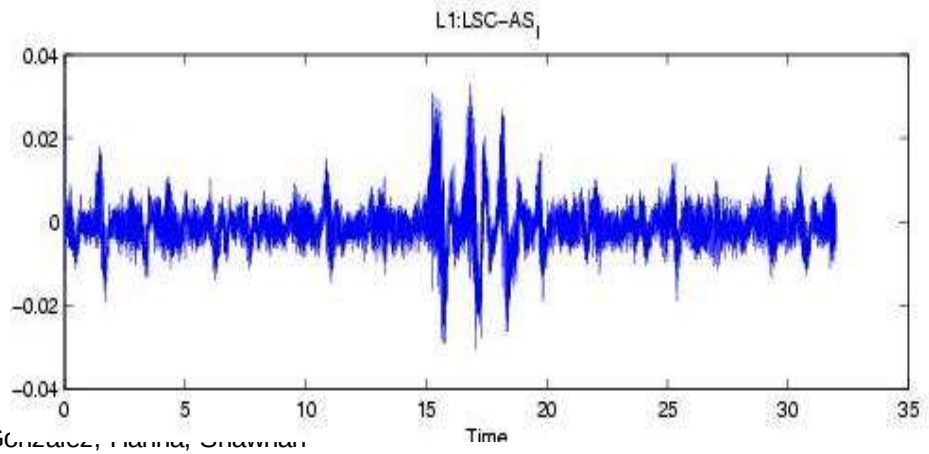
Antisymmetric port signal, demodulated 90° out of phase from gravitational wave signal: AS_I. Similar to GEO P_Q veto

The loudest L1 triggers are produced by a glitch at high frequency,

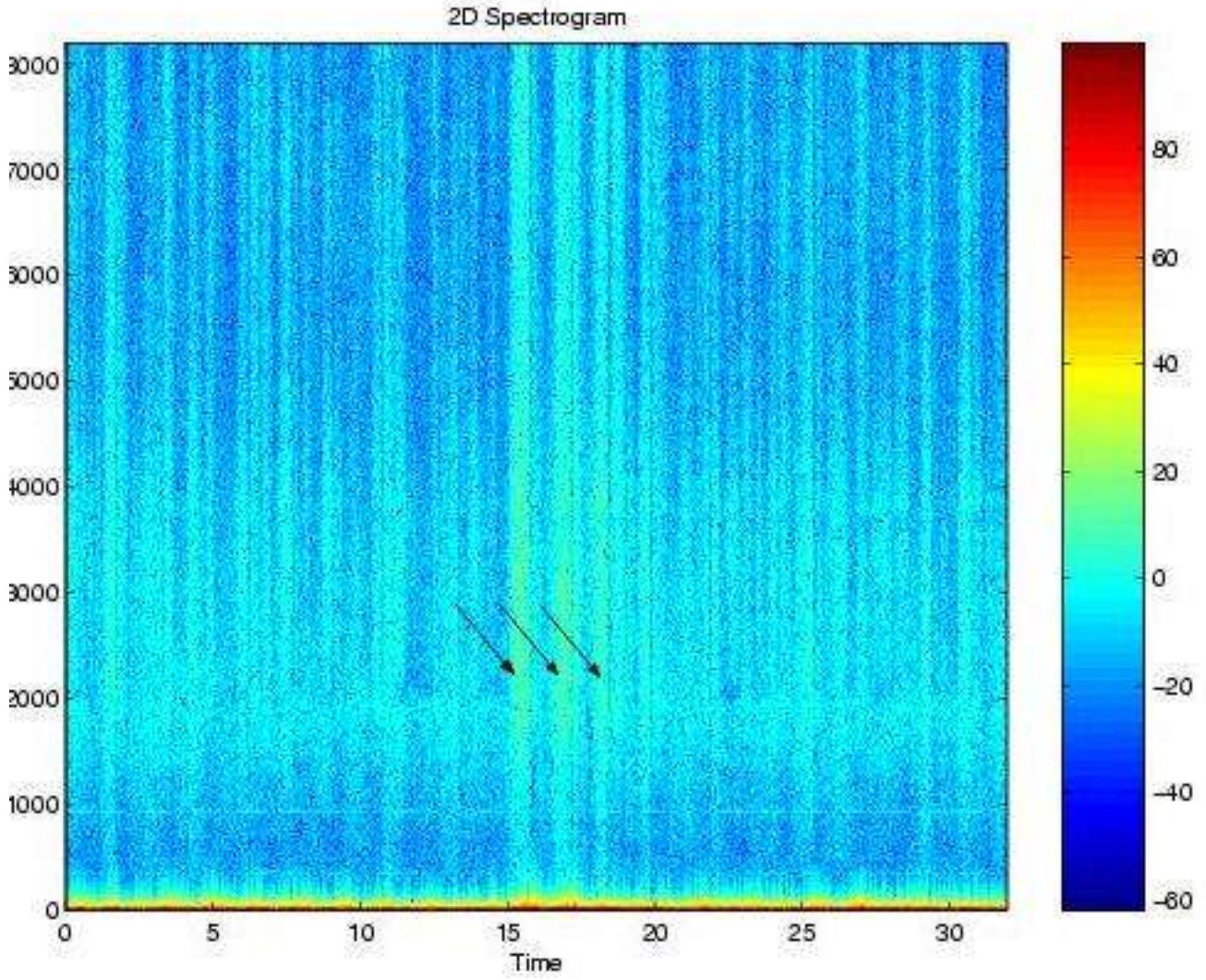
~800 Hz.



At high frequencies, we know the L1 spectrum is dominated by oscillator phase noise.

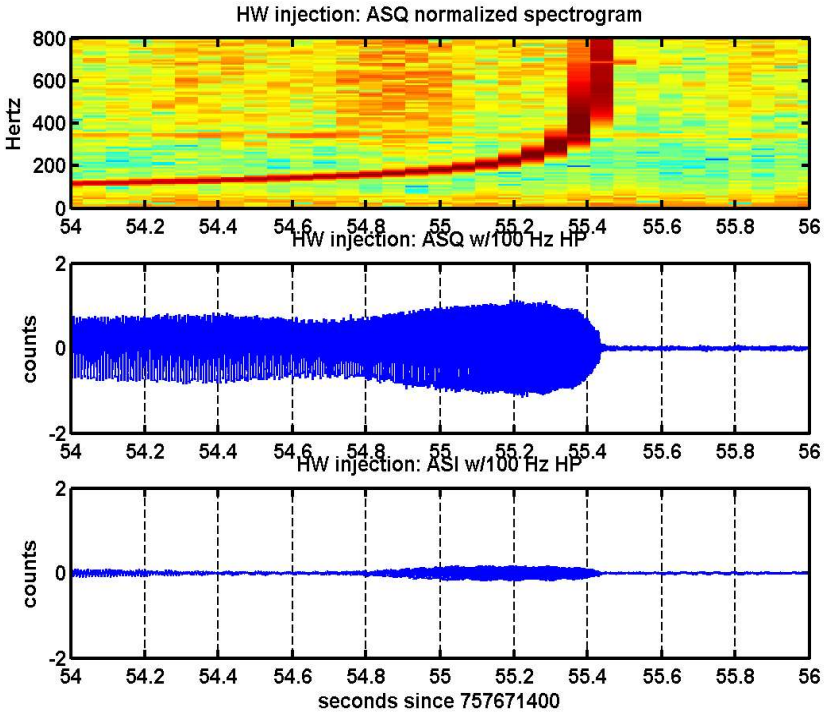


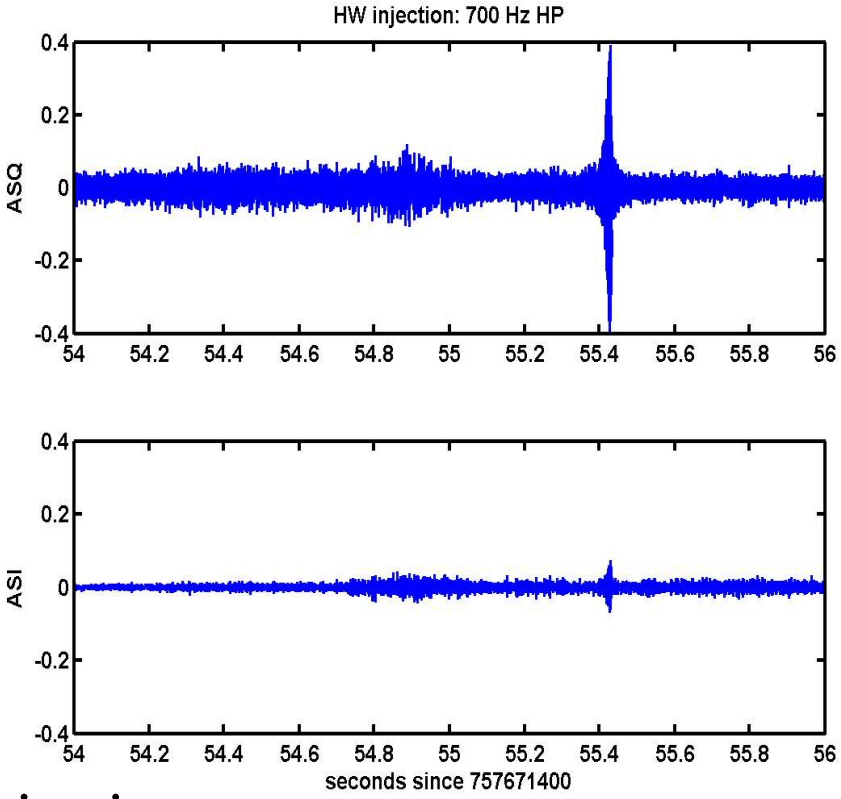
Power in L1:LSC-AS_I Glitches up to Nyquist (8 kHz)



KleineWelle AS_I Triggers: H1 and L1

Veto safety studies in progress for both L1:LSC-AS_I and H1:LSC:AS_I. Look at ratios of AS_Q/AS_I.





Hardware injection

S3 Inspiral Veto Conclusion

Many useful data quality flags exist.

H2 inspiral events effectively vetoed by H2:LSC-PRC_CTRL and H2:LSC-REFL_Q triggers – safe vetoes too.

AS_I looks to be an effective veto for inspiral triggers in L1 and H1, but the safety studies need to be completed

Looking Back: Data Quality Cuts and Vetoes in the S1 Inspiral Analysis

Excluded times with missing or unreliable calibration

5% of L1 data, 7% of H1 data

Applied "band-limited RMS" cut to exclude times with unusually high noise in any of four frequency bands

Entire segments kept or rejected

8% of L1 data, 18% of H1 data

Vetoed H1 events if there was also a large glitch in REFL_I (Reflected port In-phase)

Within a time window of ±1 second

Very clean veto: deadtime = 0.2%

Data Quality Cuts and Vetoes for the S2 Inspiral Analysis

Exclude times with:

- Data outside of official S2 run times
- Missing data
- Missing or unreliable calibration
- Non-standard servo control settings (a few L1 segments)
- I/O controller timing problem at L1

ASQ_UPPERBAND_OUTLIER (H1 only)

- High noise in GW channel, in sensitive frequency band, averaged over 1 minute; “growly” periods noted during the S2 run

AS_PD_SATURATION (H1, H2, L1)

- Saturation of the photodiode at the antisymmetric port. Correlates with a small but significant number of L1 triggers

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Summary of Inspiral Veto Work for S2 Run

Low-frequency cutoff for inspiral search was changed to avoid problematic non-stationary noise at ~70 Hz

We found a moderately good veto for L1

L1:LSC-POB_I, Error signal in power recycling servo loop

For inspiral triggers with SNR>8:
Efficiency = 27% , use percentage = 25% (expect 5% randomly)
Deadtime = 2.5%

Did not find any good vetoes for H1 or H2