LIGO Inspiral Veto Studies

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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%

Considered using AS_I (AntiSymmetric In-phase) as a veto for L1

- Abandoned this due to veto safety concerns

Data Quality Cuts for the S2 Inspiral Analysis

Use info in the "S2 Segment Data Quality Repository"

- http://tenaya.physics.lsa.umich.edu/~keithr/S2DQ/

At the outset, 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

Then use playground data to judge relevance of other data quality flags

Checking the Relevance of Data Quality Flags

	Time (sec)		Inspiral triggers in playground				
	Total	Analyzed	SNR>8	SNR>9	SNR>10	SNR>11	SNR>12
H1 Totals	3757262	341968	20436	14980	11359	9368	7867
ASQ_LOWBAND_OUTLIER	14741	1536	625	390	178	32	2
ASQ_OUTLIER_CLUSTER	20407	1800	0	0	0	0	0
ASQ_OUTLIER_CORRELATED	3126	456	390	321	167	32	2
ASQ_UPPERBAND_OUTLIER	22817	1876	15435	12471	10159	8791	7574
AS_PD_SATURATION	72	0	0	0	0	0	0
MICH_FILT	118807	11400	4443	4214	3922	3646	3185
H2 Totals	2958351	260871	65397	25479	13418	8060	4758
AS_PD_SATURATION	4	0	0	0	0	0	0
MICH_FILT	64368	5648	1294	433	164	48	7
L1 Totals	1930967	143742	27625	9728	3310	1028	294
ASQ_LARGEP2P	2699	0	0	0	0	0	0
ASQ_OUTLIER_CORRELATED	840	60	0	0	0	0	0
AS_PD_SATURATION	646	10	813	431	119	28	6
MICH_FILT	203539	17794	6393	1829	497	115	32

Data Quality Flags Judged to be Relevant

ASQ_UPPERBAND_OUTLIER (H1 only)

- High noise in GW channel, in sensitive frequency band, averaged over 1 minute
- Corresponds to "growly" periods noted during the S2 run
- Real concern is nonstationarity of noise
- For "safety", veto only if flag is on for a few consecutive minutes
- This data quality flag cleans up H1 dramatically

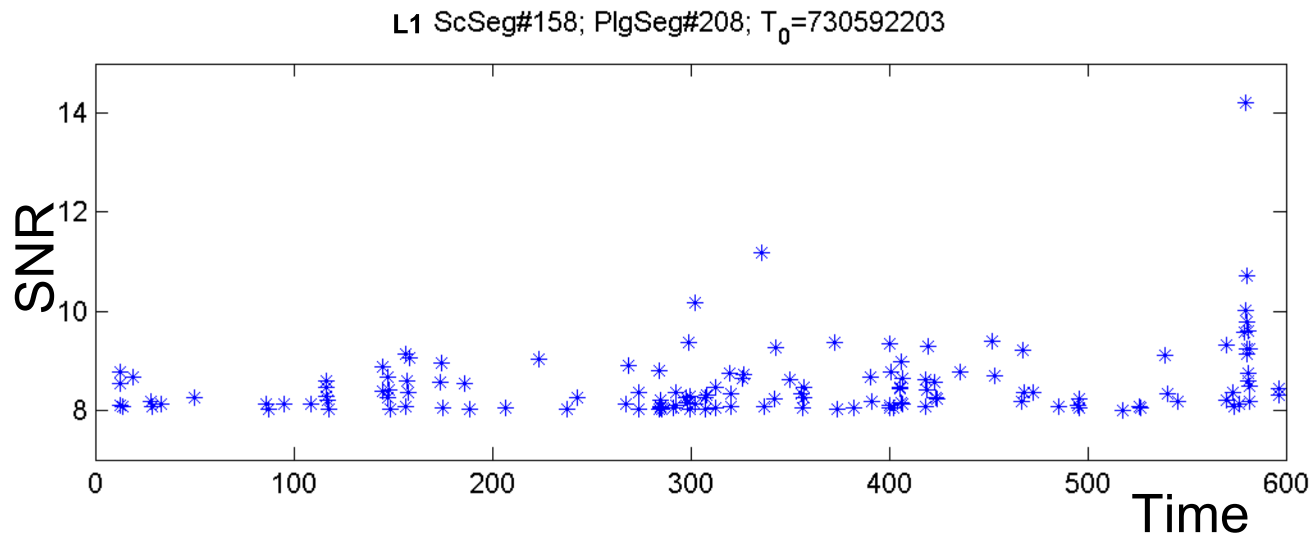
AS_PD_SATURATION

- Saturation of the photodiode at the antisymmetric port
- Correlates with a small but significant number of L1 triggers
- We choose to reject data with this flag in **all three** interferometers

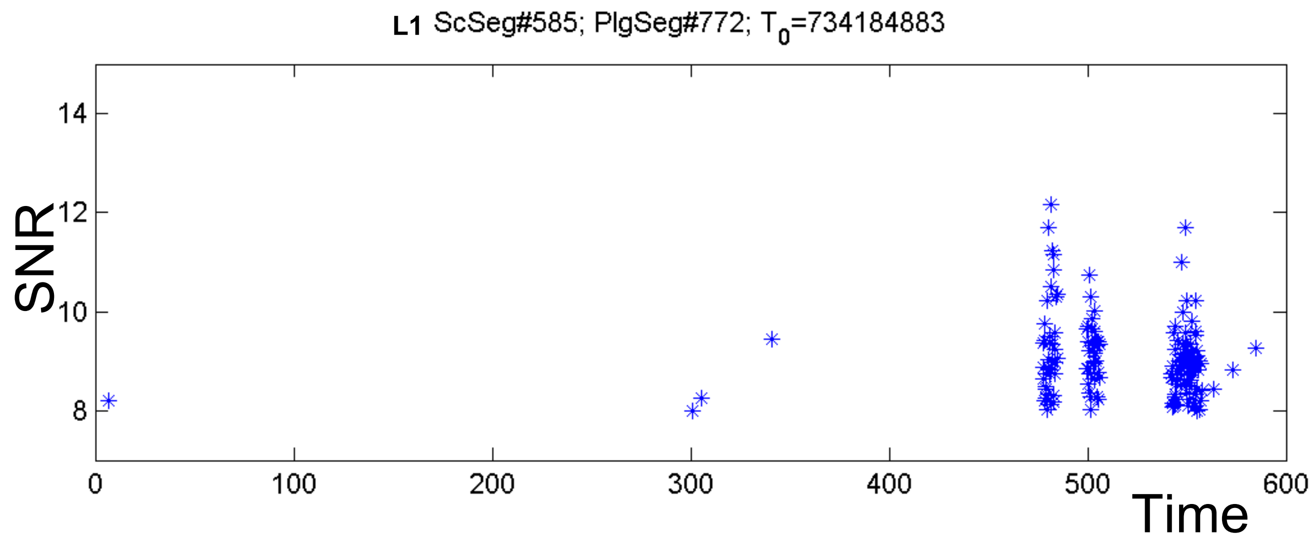
Ignore remaining data quality flags for this analysis

Survey of Inspiral Trigger Rates, Segment by Segment

In segments with high rates, sometimes triggers are spread out…



…and sometimes they form "stripes"



Non-Stationary Noise in Low Part of Sensitive Band

Original frequency range used for inspiral search: 50-2048 Hz

Many of the L1 inspiral triggers were found to be caused by non-stationary noise with frequency content around 70 Hz

A key auxiliary channel, "POB_I", also had highly variable noise at 70 Hz

Physical mechanisms for this:

- Power recycling servo loop (for which POB_I is the error signal) has known instability at ~70 Hz when gain is too high
- When gain of differential arm length servo loop goes too low (due to low optical gain), get glitches at ~70 Hz

Decided to increase low-frequency cutoff to 100 Hz

- Reduced number of inspiral triggers ; small loss of efficiency for BNS

Vetoes for S2 Inspiral Analysis

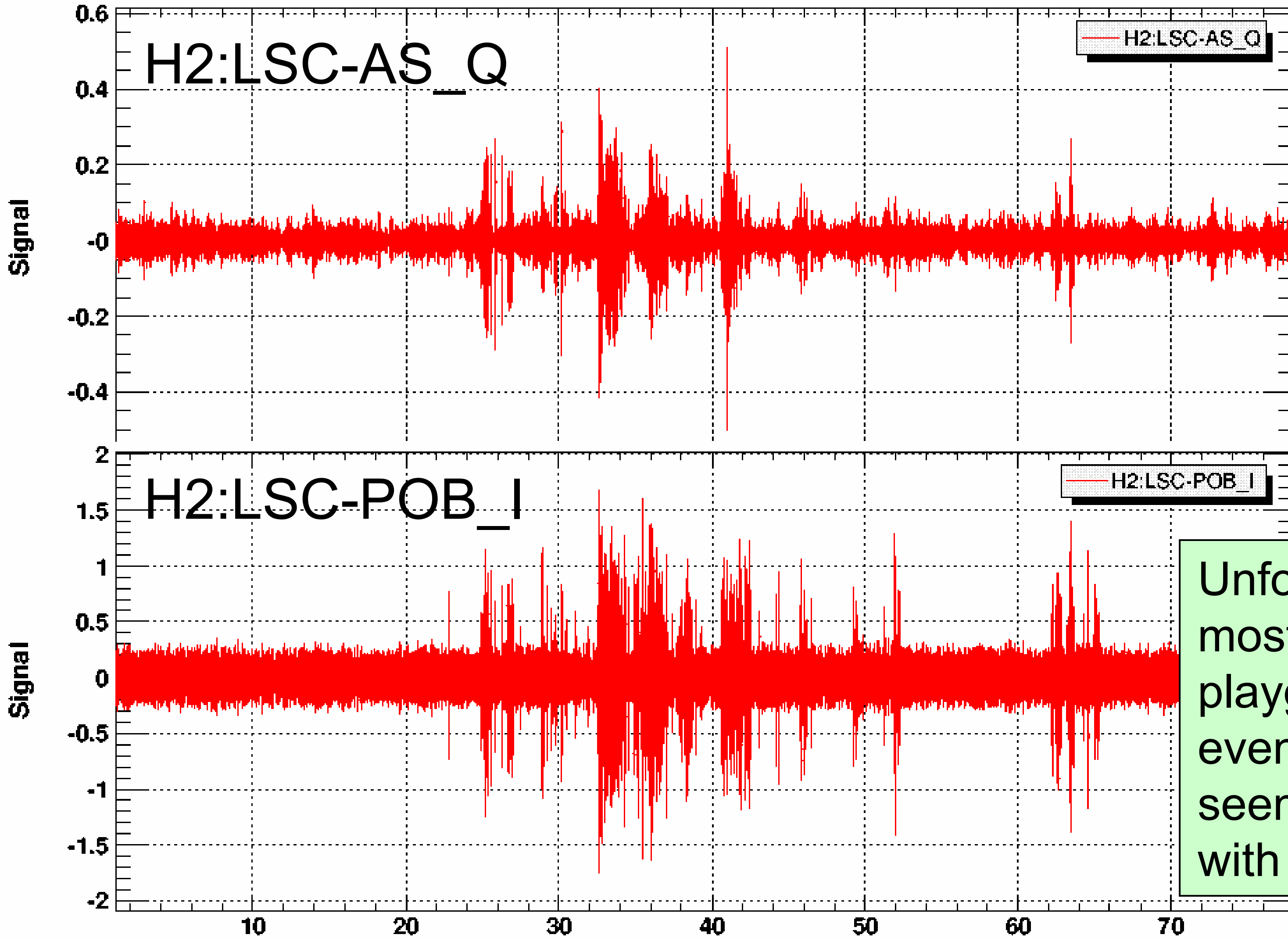
Goal: eliminate candidate events caused by instrumental disturbance or misbehavior

Look for signatures in various auxiliary channels

- Environmental monitoring channels
- Interferometer sensing / control channels other than GW channel

Correlate with event candidates found in GW channel

Correlations Do Exist !



Both with 80-150 Hz band-pass filter

Unfortunately, most of the H2 playground events do *not* seem to correlate with POB_I

Veto Channel “Safety” Studies

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

Study using large-amplitude hardware signal injections

- Wiggle one or more arm cavity end mirrors
- Look for evidence of coupling to auxiliary channel

Some channels have been shown to be safe

- Interferometer sensing channels at reflected and pick-off ports: POB_I , POB_Q , REFL_I , REFL_Q

One channel has been shown to be *un*safe

- Antisymmetric port signal, demodulated 90° out of phase from gravitational wave signal: AS_I

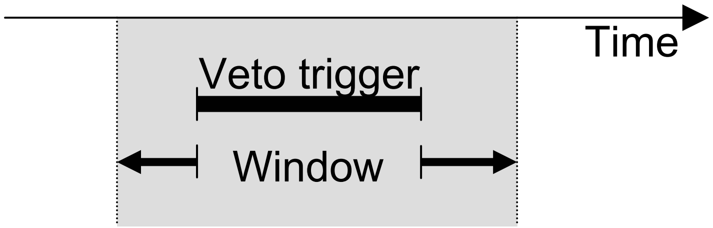
Other prospective veto channels can be checked

General Approach for Auxiliary-Channel Vetoes

Choose various auxiliary channels

Identify “glitches” in these channels

- Have generally used glitchMon (uses Data Monitoring Tool library)
- Filters data (usually high-pass), looks for large excursions
- Try different veto trigger thresholds
- Try different “windows” (extend veto effect) :

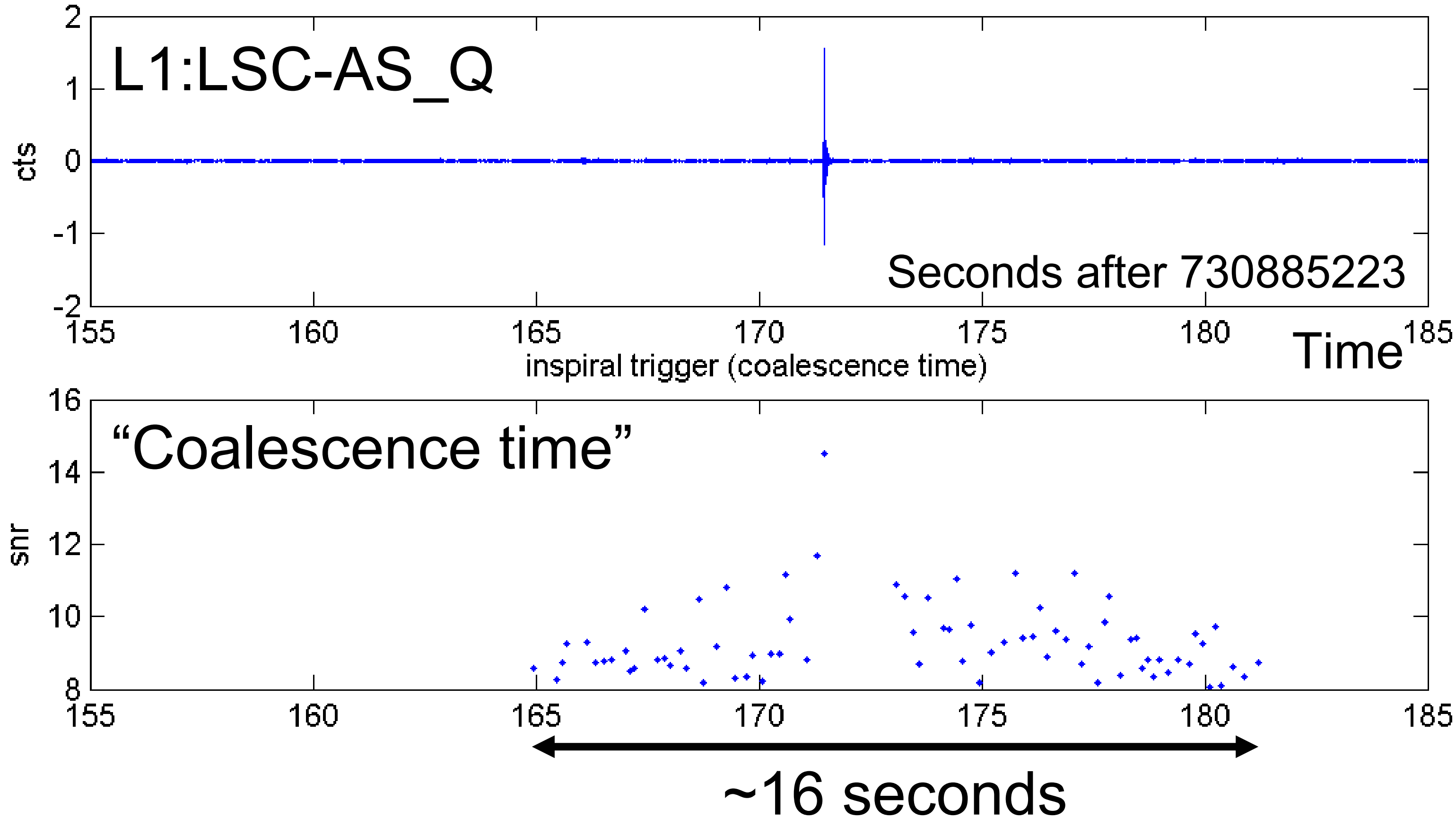


Correlate with inspiral event candidates and evaluate:

- 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)

Inspiral Events Found Near a Big Glitch

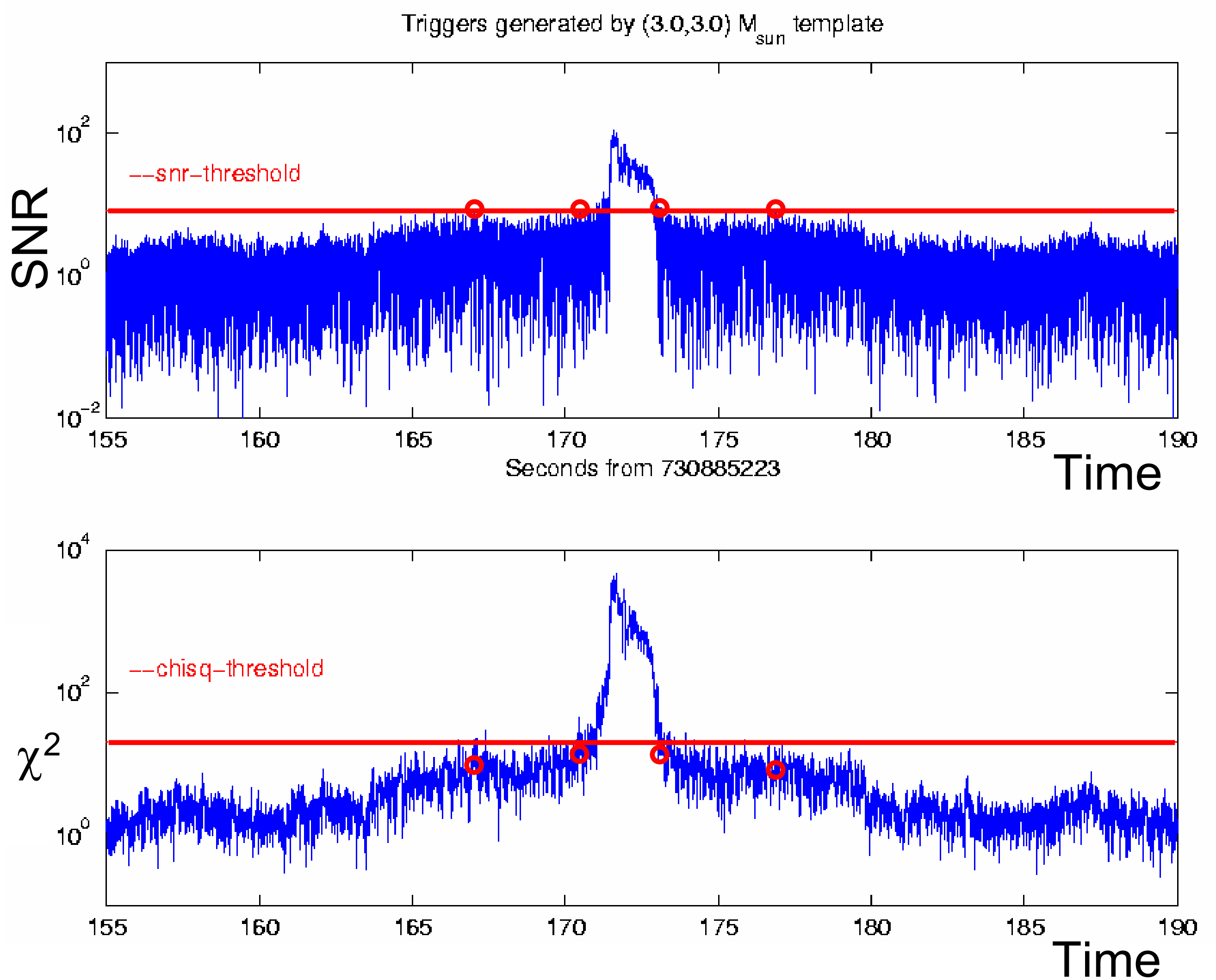
A glitch can yield a calculated inspiral coalescence time far from the time of the glitch



Inspiral Events Found Near a Big Glitch

"Inaccurate" inspiral coalescence times are understood to arise from ringing of the template filter

⇒ Need to use a wide window to eliminate these



“Best” Veto Condition for L1

Parameters:

Channel:	POB_I
Filter:	70 Hz high-pass
Threshold:	7-sigma
Window:	–4, +8 seconds
Deadtime:	2.5%

Evaluation results:

For inspiral triggers with:	SNR>6	SNR>7	SNR>8	SNR>10	SNR>12
Veto efficiency (%)	8.6	18.1	26.8	35.0	22.7
Use percentage	98.2	54.0	25.1	6.9	2.9
Expected random use %	95.8	25.7	4.6	0.5	0.1

Correlation is real, but many loud inspiral triggers survive
Deadtime varies from segment to segment; sometimes quite high

Other channels which showed some promise: MICH_CTRL , AS_DC

Other Results

Environmental monitoring channels do not provide effective vetoes for the S2 data

$\Rightarrow$ Glitches seem to have instrumental origin

Have not found any effective vetoes for H1 and H2

Some statistically significant correlations, but very low veto efficiency

Summary of Inspiral Veto Work for S2 Run

Data quality cuts eliminate high-noise data in H1, plus photodiode saturations

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

- For inspiral triggers with SNR>8:
  - Efficiency = 27% , use percentage = 25% (expect 5% randomly)
  - Deadtime = 2.5%
- Have to decide whether this is worth using

We have not found any good vetoes for H1 or H2