Data Quality and Veto Techniques for Searches for Compact Binary Coalescences in LIGO Data

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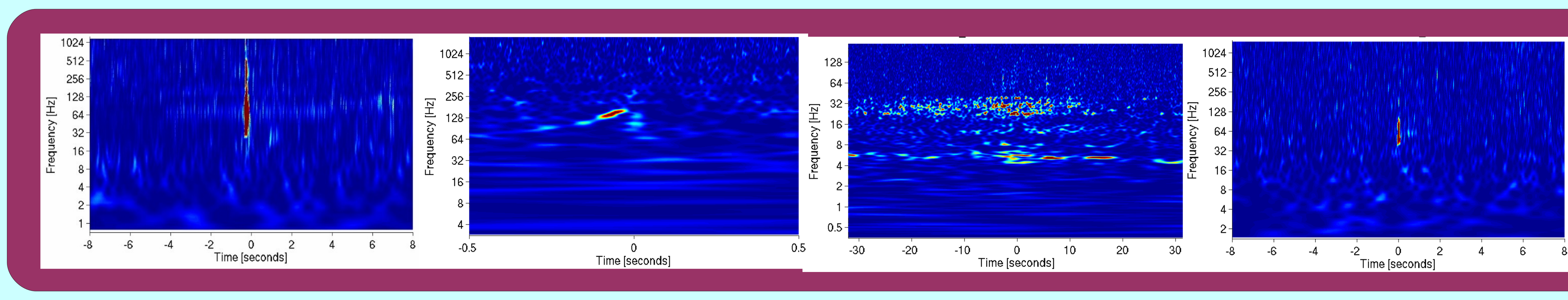
The LIGO detectors [1] are sensitive to a variety of instrumental glitches and environmental disturbances of non-astrophysical origin which increase the false alarm rate in searches for gravitational waves [2]. Using a variety of methods, periods when the interferometers produced data of questionable quality have been identified. We discuss the methods used to determine the deleterious times, and the techniques used to safely and effectively veto triggers from the CBC search pipelines during these times, developed on the first of the two years of the initial data run; this is done with a minimum loss of science time.

(1) Data Quality Studies:

Hundreds of auxiliary channels monitor the LIGO interferometers and their environments to characterize the quality of the collected data. There are two broad categories of transients in LIGO data, instrumental and environmental noises, each containing dozens of identified phenomena require vetoing. Identifying these transients and cataloging when they occur are major tasks undertaken by the Detector Characterization and Glitch groups within the LIGO Scientific Collaboration [3]. Additionally, we search hundreds of the auxiliary channels for transients that are coincident between any of these channels and the differential arm length channel.



The above plots are time-frequency representations [4] of transients in LIGO data. From the left, as example of an overflow in the length sensing and control system, and example of a hardware injection of a simulated gravitational wave signal into the feedback control system, an example of elevated seismic noise coupling in to the interferometer, and an example of electro-magnetic coupling from a glitch in nearby power lines.

(3) Veto Categorization:

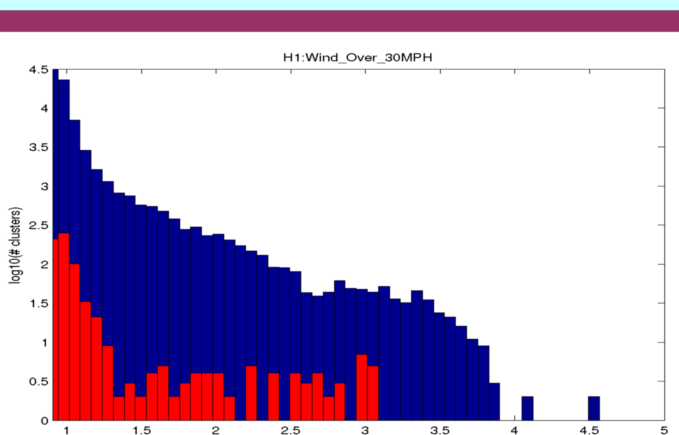
Vetoes are grouped into categories. The veto categories were determined by putting vetoes from the more understood transients, with higher efficiency, higher used percentage, and lower deadtime in the lower numbered categories, and the less understood, less effective, less correlated, and longer intervals in the higher categories. Candidate triggers were then followed up to search for detections after applying each of the following categories of vetoes:

•Category 1: Detector not running in proper configuration

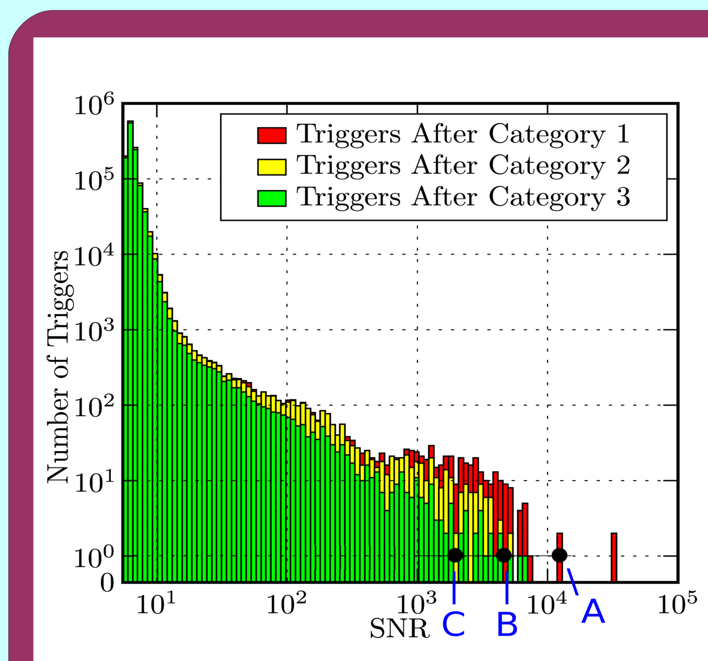
•Category 2: Well understood instrumental problems, such as the overflows seen in **(2)**

•Category 3: Incompletely understood vetoes with statistical correlations to clusters, such as the high winds veto shown below

We vetoed winds elevated above 30 Mph at the Hanford site at category 3, with used percentage of 30%, deadtime of 0.2%, and an efficiency that climbs from 1% to 4\% for clusters with SNR above 500.



At right is a histogram of triggers remaining after veto categories are applied in ascending order. There are three labels: A, B, and C. For illustration only, let us assume gravitational wave triggers at each point.
A is not significant above category 1, but is above category 2, and even more so category 3. Likewise B only is visible above category 3, and C is not distinguishable after any category.



(2) Veto Metrics:

We evaluate the effectiveness of different data quality vetoes on the output of single interferometer searches, clustered in time and above a signal to noise ratio (SNR) threshold of 8, with three metrics:

- Efficiency: percent of clust[illegible] contained in veto interval. Indicates population of cl[illegible] corresponding to transient.
- Used Fraction: percent of v[illegible] intervals containing at least one cluster. Indicates correlation of vetoes with clusters from transients.
- Deadtime: percent of scienc[illegible] time contained in veto intervals. Indicates probability of ran[illegible]omly vetoing clusters.

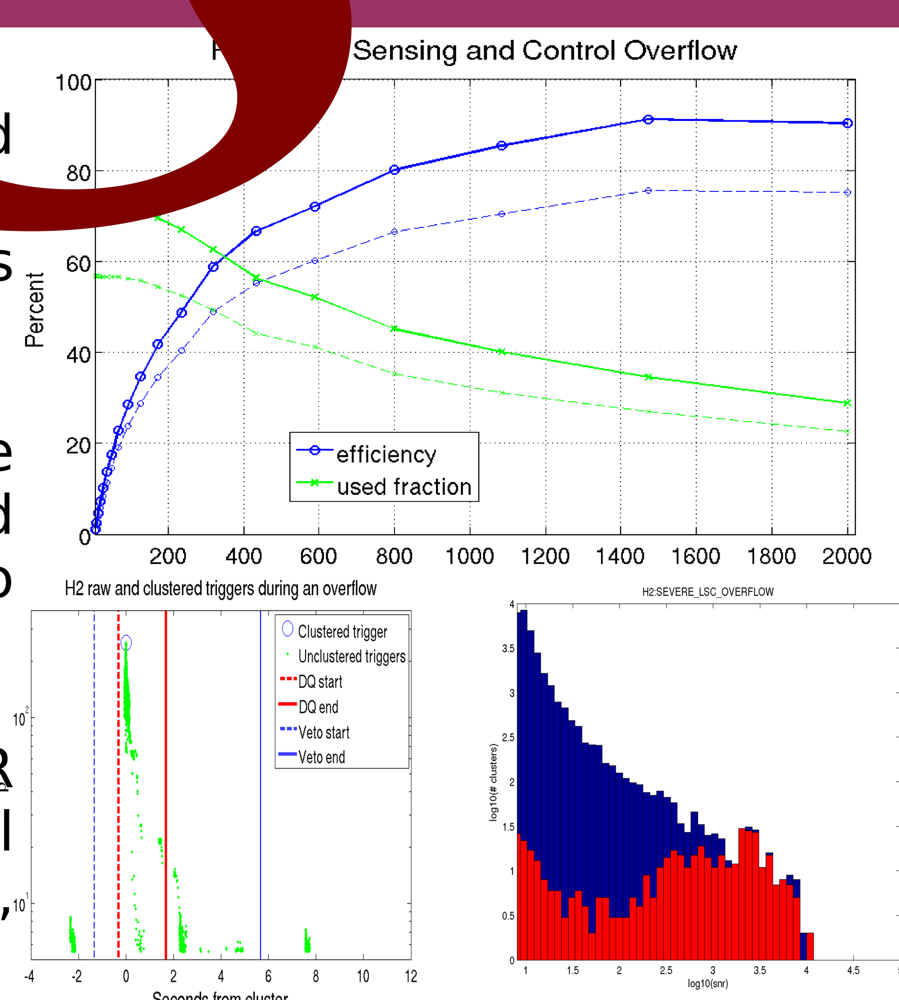
Triggers associated with tra[illegible]sients often occur outside the nominal data quality window, as f[illegible] a broadband transient the coalescence time will be determin[illegible]y the time the various waveforms pass through the most se[illegible]e frequency band of the detector.

Example: Ov[illegible]w

At top, efficiency [illegible]sed fraction versus thresho[illegible] cluster SNR. Dashed lines are before padding added.

At bottom left are example veto intervals, clustered and raw triggers, and veto window paddings.

At bottom right, log-log SNR histogram of clusters. All clusters are plotted in blue, vetoed clusters in red.



(4) Future Work:

Future CBC searches will use the techniques described in this poster, but more work is to be done. We intend to use the experience gained in S5 to finish ongoing automation work both to select the veto window paddings and to provide initial recommendations for veto categorization. Such work includes:

- Automated veto window padding: determination of window paddings currently requires human input, but can find paddings such that unclustered triggers stays below some SNR threshold before and after the cluster from a transient.
- Multiple auxiliary channel veto algorithm: defining vetoes when multiple auxiliary channels glitch coincidently, rather than one at a time, having a strong possibility that the glitching has a non-astrophysical cause.
- Automated categorization using a chi-squared test: for $\langle n_t \rangle$ average trigger rate above some SNR, T_k duration of veto interval k, and n_k actual triggers in interval k, and triggers in Poisson distribution independent of k, categorize by deviation from null hypothesis.

$$\chi^2(\rho) = \sum_{k=1}^{R} \frac{(n_k(\rho) - T_k\langle n_t(\rho)\rangle)^2}{T_k\langle n_t(\rho)\rangle}$$

[1] B. Abbott et al. LIGO: The Laser Interferometer Gravitational-Wave Observatory, *Submitted to Reports on Progress in Physics*, 2009.
[2] B. Abbott et al. Search for Gravitational Waves from Low Mass Binary Coalescences in the First Year of LIGO'sS5 Data. *Phys Rev. D. 79 122001*, 2009.
[3] L Blackburn et al. The LSC glitch group: monitoring noise transients during the fifth LIGO science run. *Classical and Quantum Gravity*, 2008.
[4] Chatterji, S. Ph. D thesis, MIT, 2005
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