Veto Selection for Gravitational Wave Event Searches

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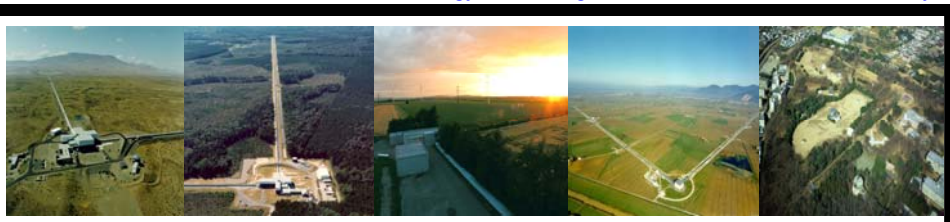
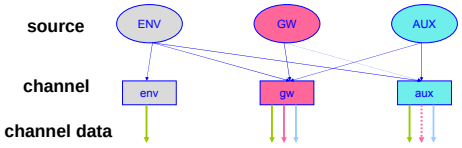


1: Large laser interferometers for gravitational-wave detection

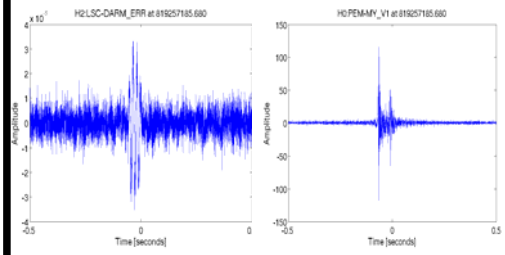
- The LIGO, GEO, VIRGO and TAMA detectors are collecting data with better sensitivity than ever before
- The first gravitational wave (GW) signals detected may be impulsive events, perhaps from core-collapse supernovae or compact binary mergers, lasting a few milliseconds or hundreds of milliseconds
- In any single detector, the signal may look like an instrumental "glitch"
- **Removing instrumental and environmental artifacts is paramount in establishing detection of GW events such as these**

2: Event-by-event vetoes

- A signal in the gravitational wave channel may be caused by an environmental disturbance, transient noise in part of the interferometer, … or a real gravitational wave! How to tell?



- Thousands of other channels monitor the environment and auxiliary interferometer sensing and control signals
- These additional channels ***may*** be reliable indicators of the disturbances causing GW channel glitches — can then be used to define vetoes
- For example, could this trigger in the Hanford 2-km interferometer (left) have resulted from a power line transient (right), or is their time coincidence accidental?

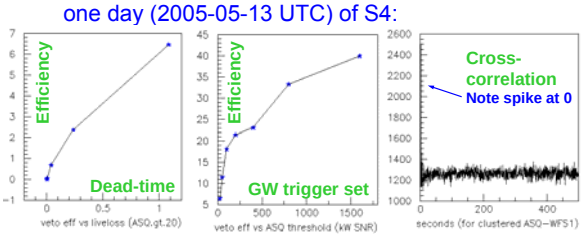


3: How to evaluate "goodness" of a veto ?

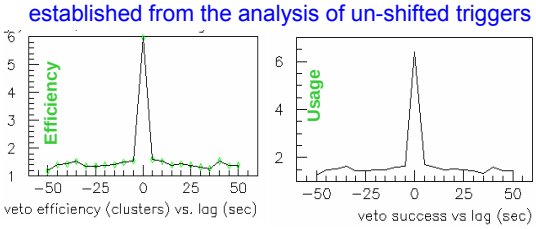
- Do a statistical comparison of GW channel triggers and ENV / AUX channel triggers
  - Efficiency: fraction (%) of GW channel triggers rejected
  - Usage: fraction (%) of veto triggers used to veto GW channel triggers
  - Dead-time: fraction (%) of live-time lost due to the duration of the veto triggers
  - Cross-correlation: histogram of $t=t_{gw}-t_{veto}$ for all possible pairs
- A veto condition has several parameters: channel to be used, significance threshold for veto triggers, time-coincidence window between the GW and veto channels, …
- Goodness of a veto also depends on the set of GW channel triggers used to evaluate it
- A rigorous goodness criterion would ideally simplify the tuning process for the selection of veto channels and tuning of veto parameters

4: Example from LIGO's S4 run

- Overall veto strategy and way of thinking matured through LIGO's early runs and within the burst, inspiral and glitch groups
- Goodness of WaveFrontSensor1 veto during one day (2005-05-13 UTC) of S4:



- Time-shifted comparison of GW and veto triggers can shed light on the significance of quantities established from the analysis of un-shifted triggers



- Visually, these plots suggest that this channel provides a good veto condition — veto efficiency is much greater than we would expect by chance
- How can we quantify this?

5: A new figure-of-merit for goodness of a veto

- Several figures-of-merit have been considered within the LSC
- In choosing veto conditions for LIGO S5 burst searches, we have used:
  P = Poisson probability of getting ***n**** or more zero-lag coincidences, given background rate μ_B determined from time-shifted coincidences
- This represents the "significance" of the veto condition, or how unlikely is the observed correlation by random chance
- To be conservative / robust against small-number statistical fluctuations:
  ► For μ_B, use a 90% upper limit on the true background rate, e.g. if 20 time-shifts yielded 0 coincidences, set $\mu_B = 2.303 / 20 = 0.115$
  ► For ***n****, use the number of zero-lag coincidences ***minus one*** — in case data contains a real GW event, excludes it from the significance!
- Example channels found to be good vetoes in the Livingston instrument in S5:
  L1-ISCT1ACCX (thresh 35, window 25 ms) : $n^* = 160–1$, $\mu_B = 1.05 \rightarrow P = 5.2\times10^{-128}$
  L1-EXMAGZ (thresh 1600, window 100 ms) : $n^* = 17–1$, $\mu_B = 0.1 \rightarrow P = 2.4\times10^{-23}$

6: Optimizing veto parameters

- For a given channel, consider different thresholds and window durations
- Parameters giving max significance are not necessarily the best to use
- Consider the *incremental* benefit of lowering the veto threshold and/or lengthening the veto window duration — do if significance is high enough
- Example: channel with window→150 ms: $\Delta n^* = 85$, $\Delta\mu_B = 5.75 \rightarrow P = 2.8\times10^{-61}$
- Future plan: also consider the different veto channels sequentially, i.e., choose the best veto channel with best parameters and then evaluate the goodness of other veto channels for the *remaining* GW channel triggers

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