Data Quality, Vetoes, and Detection Confidence in Burst Searches

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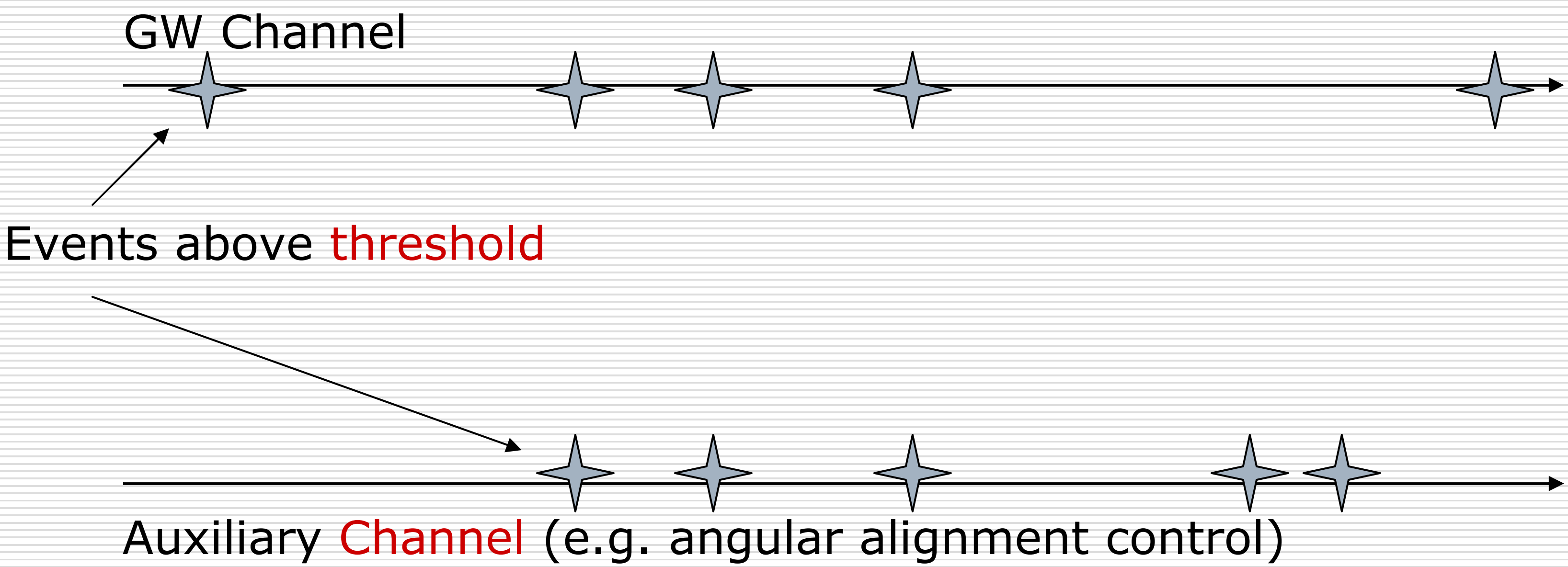
LIGO Data Quality

- Data Quality (DQ) flags identify epochs in Science data which may have a negative impact on the analyses due to errors in data acquisition, poor sensitivity, excessive contribution to the false event rate, or general untrustworthiness of data.
- Data Quality flags are assigned a Category used to determine under what circumstances they are applied. Not all flagged time is automatically discarded as there is a significant impact on analysis live-time (~10% per instrument).

Category 1	**Obvious Data Quality cuts.** These times are not processed by the search pipelines. *(e.g. calibration problems, test injections, photodiode saturations)*
Category 2	**"Unconditional" post-processing cuts:** data is unreliable and there is an established one-on-one correlation with loud transients. *(e.g. saturations in the alignment control system, glitches in the power mains)*
Category 3	**"Conditional" post-processing cuts, for upper limit:** statistical correlation to loud transients. We may still look for detection candidates at these times, exerting caution when establishing detection confidence. *(e.g. train/seismic flags, 1 minute pre-lock-loss, "dips" of light stored in the arm cavities)*
Category 4	**Advisory flags:** no clear evidence of direct correlation to loud transients, but if we find a detection candidate at these times, we need to exert caution *(e.g. high wind and certain data validation issues)*

Event-by-event Vetoes

- Event-by-event vetoes attempt to discard gravitational-wave channel noise events by using information from the many environmental and interferometric auxiliary channels which measure non-GW degrees of freedom.



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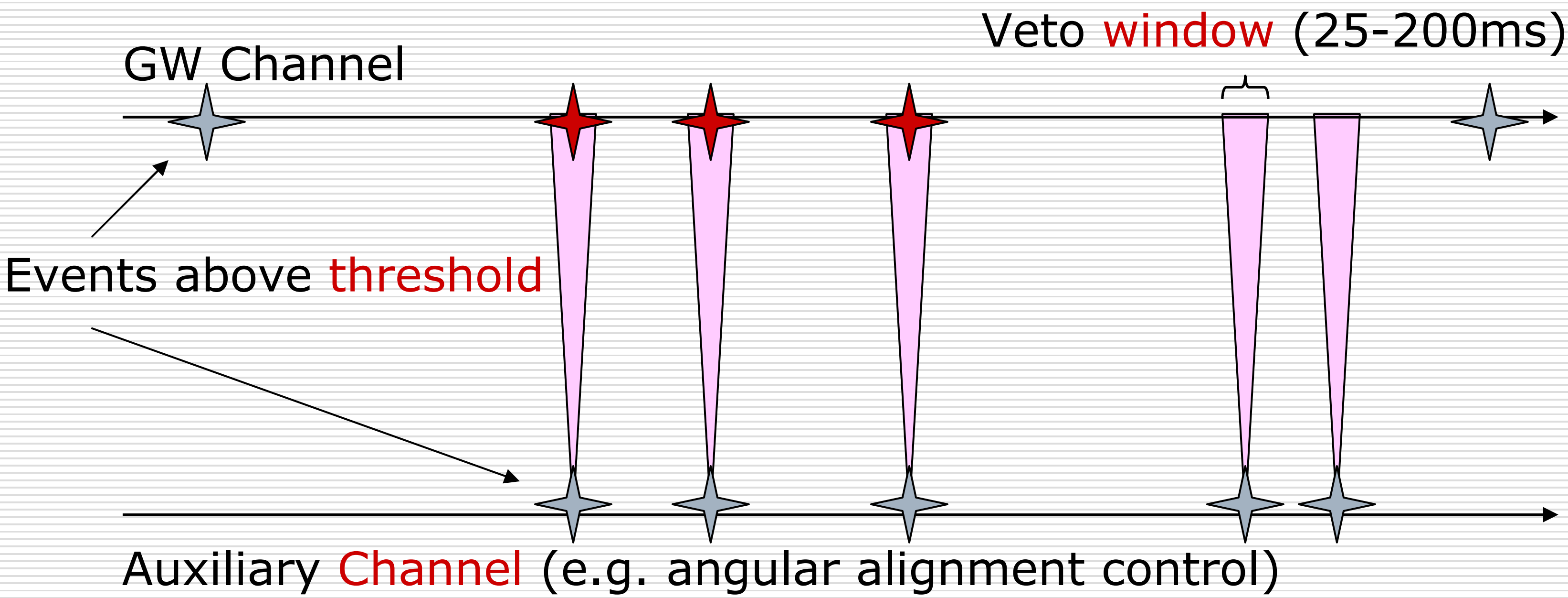

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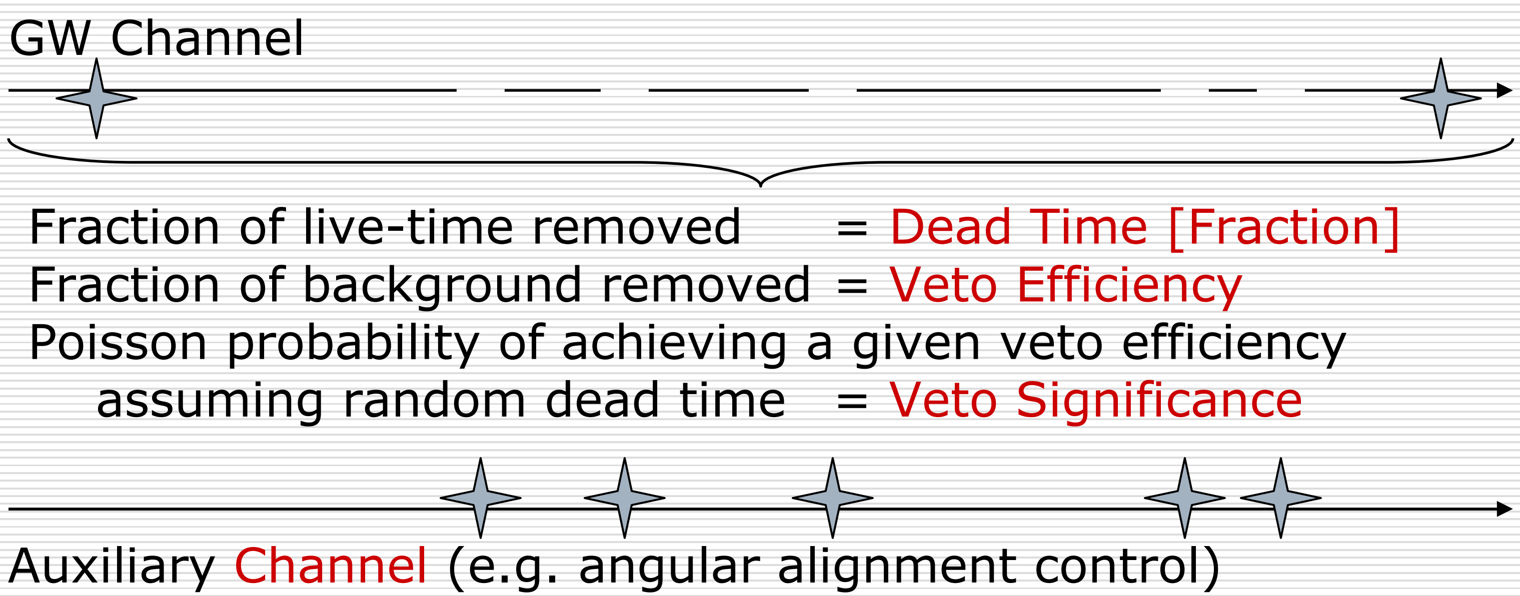
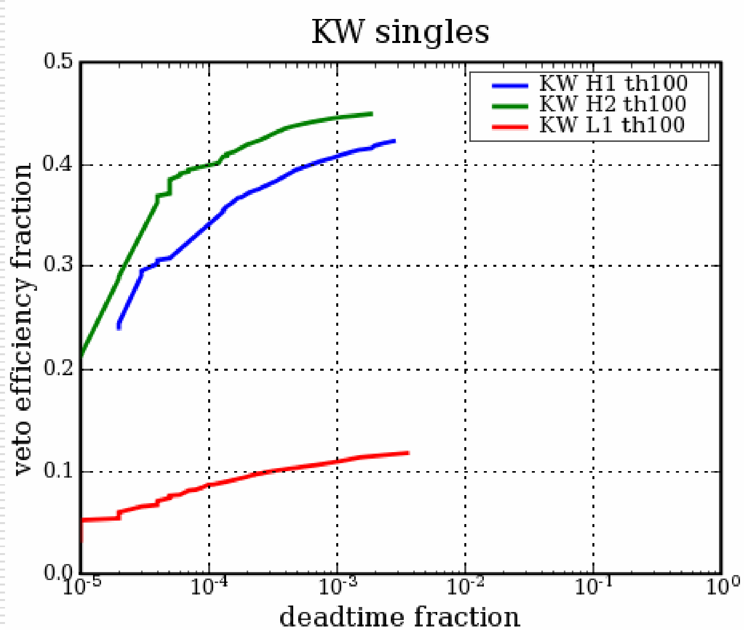


Tuning veto conditions

- The parameter space for tuning event-by-event vetoes is very large:
  - 100's of auxiliary channels
  - Several possible veto windows per channel
  - Several possible thresholds on transient strength per channel
  - Several choices on set of background GW-channel events to tune for
- Veto conditions are largely redundant (different sets of veto conditions veto the same gravitational-wave channel events). It is a poor use of dead-time to apply all vetoes which appear effective by themselves.
- We use hierarchal and iterative methods to choose an optimal ordering of veto conditions. The goal is to maximize the cumulative veto efficiency at any total dead-time.



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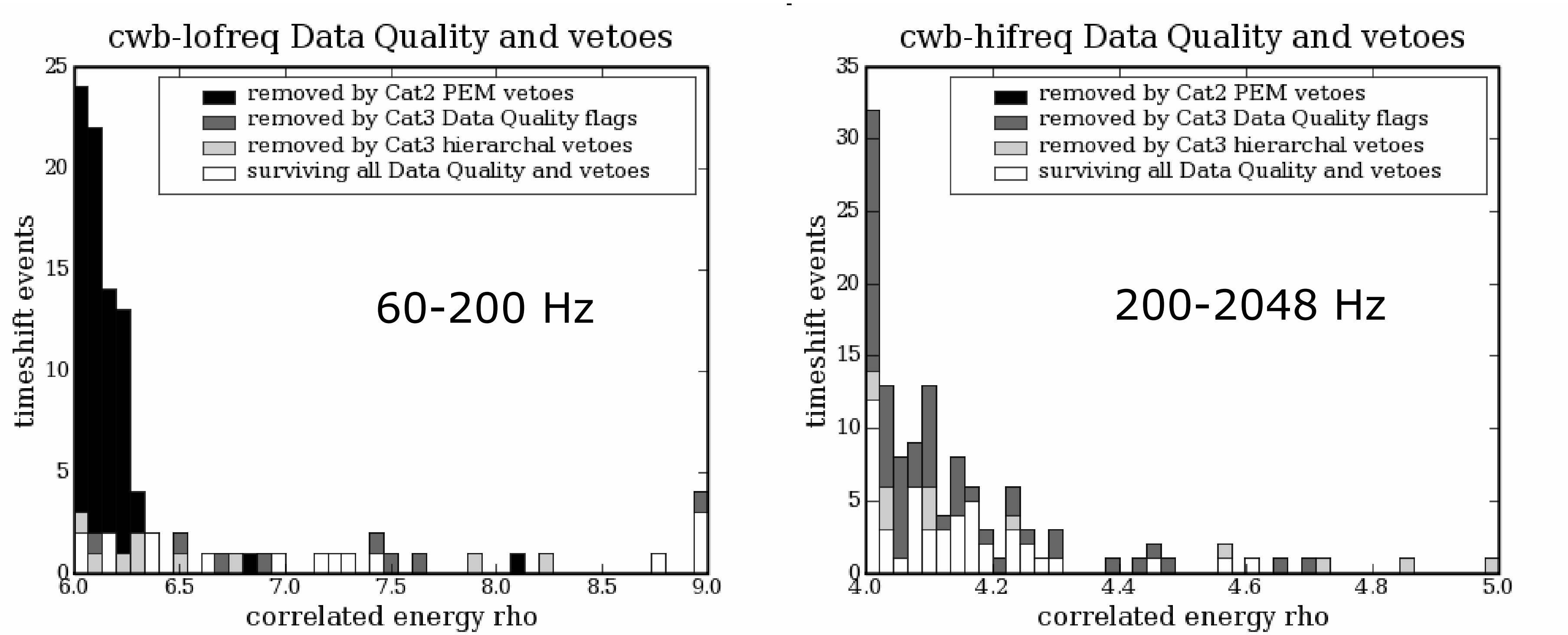
Veto Safety

- Both Data Quality flags and event-by-event vetoes must satisfy safety requirements: they must not systematically reject true gravitational-waves.
- For event-by-event vetoes, we require that the threshold on the auxiliary veto channel be set such that there is no measurable (statistically significant) excess of coincidences between the auxiliary channel transients and the thousands of hardware signal injections in S5.

Performance on S5 2yr background (un-physical time-shift events)

Burst search (Coherent Waveburst) H1H2L1 background (1000 time shifts)



About 50% of the cWB outliers are rejected with a total dead-time of ~15%

Detection confidence for burst outliers

- For any outlier in our analysis, we would like to know the probability of a more convincing event to arise from background.
- This measure of significance is derived from our cumulative distribution of time-shift events from the blind analysis.
- In addition to the output from the blind analysis, the burst group checks outliers against an 80-point detection checklist.
- While follow-up investigation can be done in much more detail than the automated blind analysis, we want to move as many useful checks as possible upstream so that they can be folded into an improved detection statistic.

Detection checklist

- Zero-level sanity (reports in detector logs, check hardware injections)
- Data Integrity (frame file checksum, undocumented injections, check against raw frames)
- Vetoes and state of the instrument (obvious disturbances reflected in auxiliary channels, verify coupling for any proposed veto, check by hand against known disturbances: dust, cosmic rays, power fluctuations, acoustic, …), check quality of calibration
- Detailed properties of the event (construct detailed spectrogram, reconstructed waveform, skymap, compare background from various methods, check signal consistency across interferometers)
- Astrophysical interpretation (check for external EM or neutrino events, catalog sources consistent with skymap, compare waveform against simulations)

Summary

- Data Quality and vetoes assigned to categories ranging from unconditional to advisory. Unified approach used for all burst analyses.
- Event-by-event vetoes chosen automatically using hierarchal methods aimed at maximizing cumulative veto efficiency at fixed dead-time.
- Comprehensive detection checklist prepared for analysis outliers. Useful measurements to be folded into future detection statistics.