Vetoes for transient gravitational-wave triggers using instrumental-coupling models

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In collaboration with
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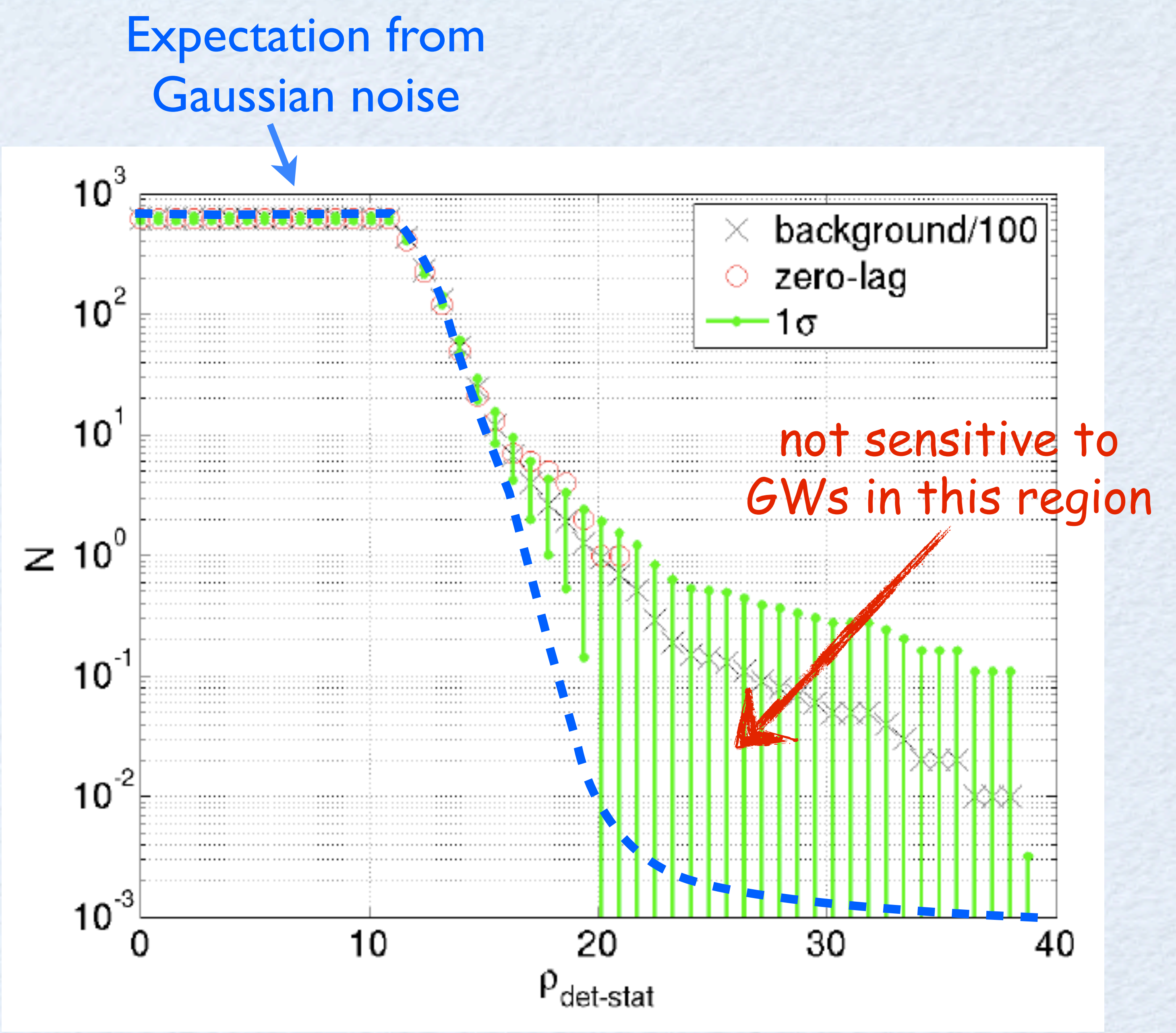
Search for transient GW signals

- Modern interferometric detectors are highly complex instruments. Data are plagued with a large number of noise transients.
- These noise transients limit our ability to search for real GW transients.
- Important to develop robust techniques to distinguish between spurious noise transients and real GW signals.



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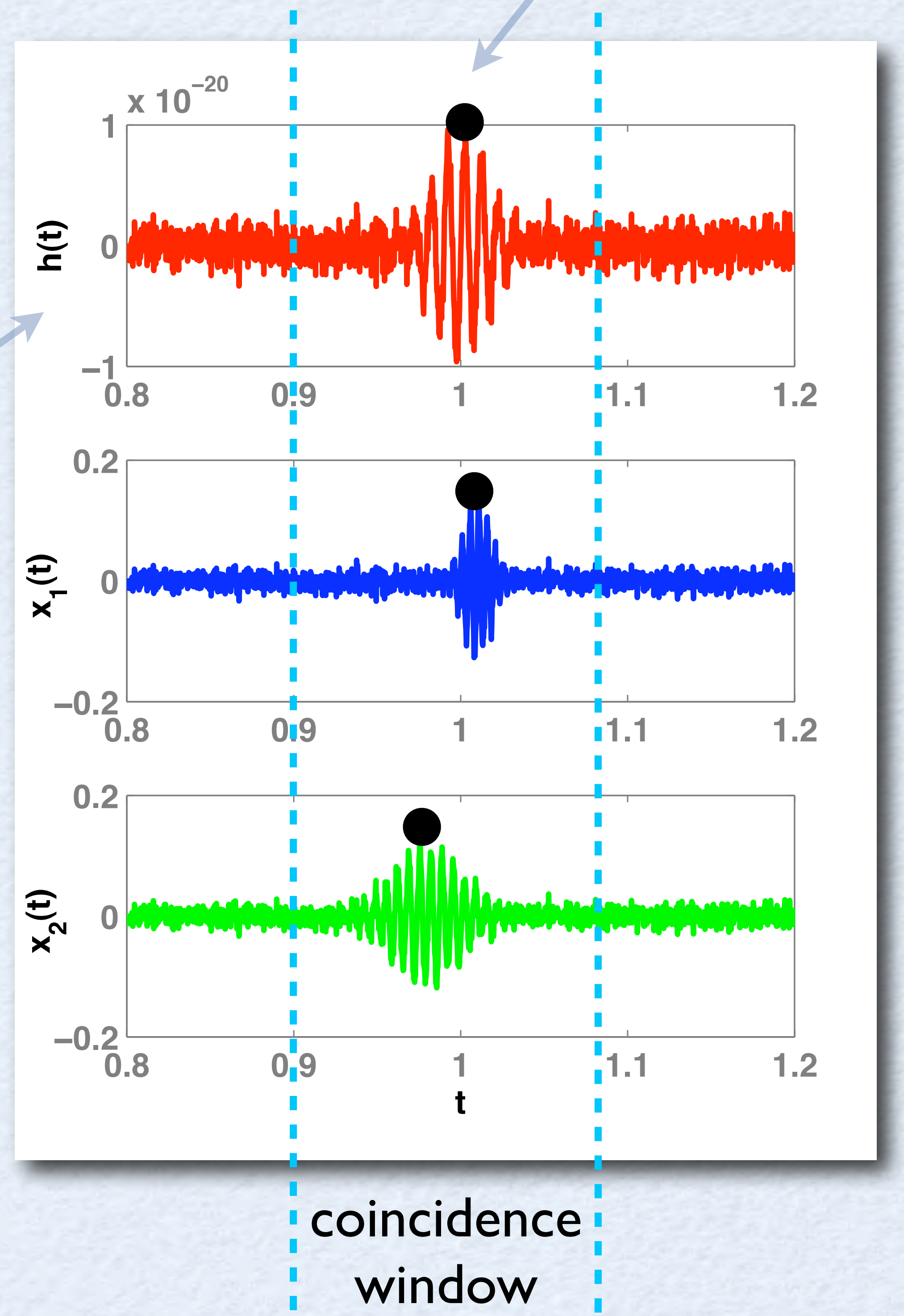
Veto Method

- **“Traditional” veto methods** Ask whether a glitch in in the GW channel *H is* time-coincident with one in an instrumental channel X_i.

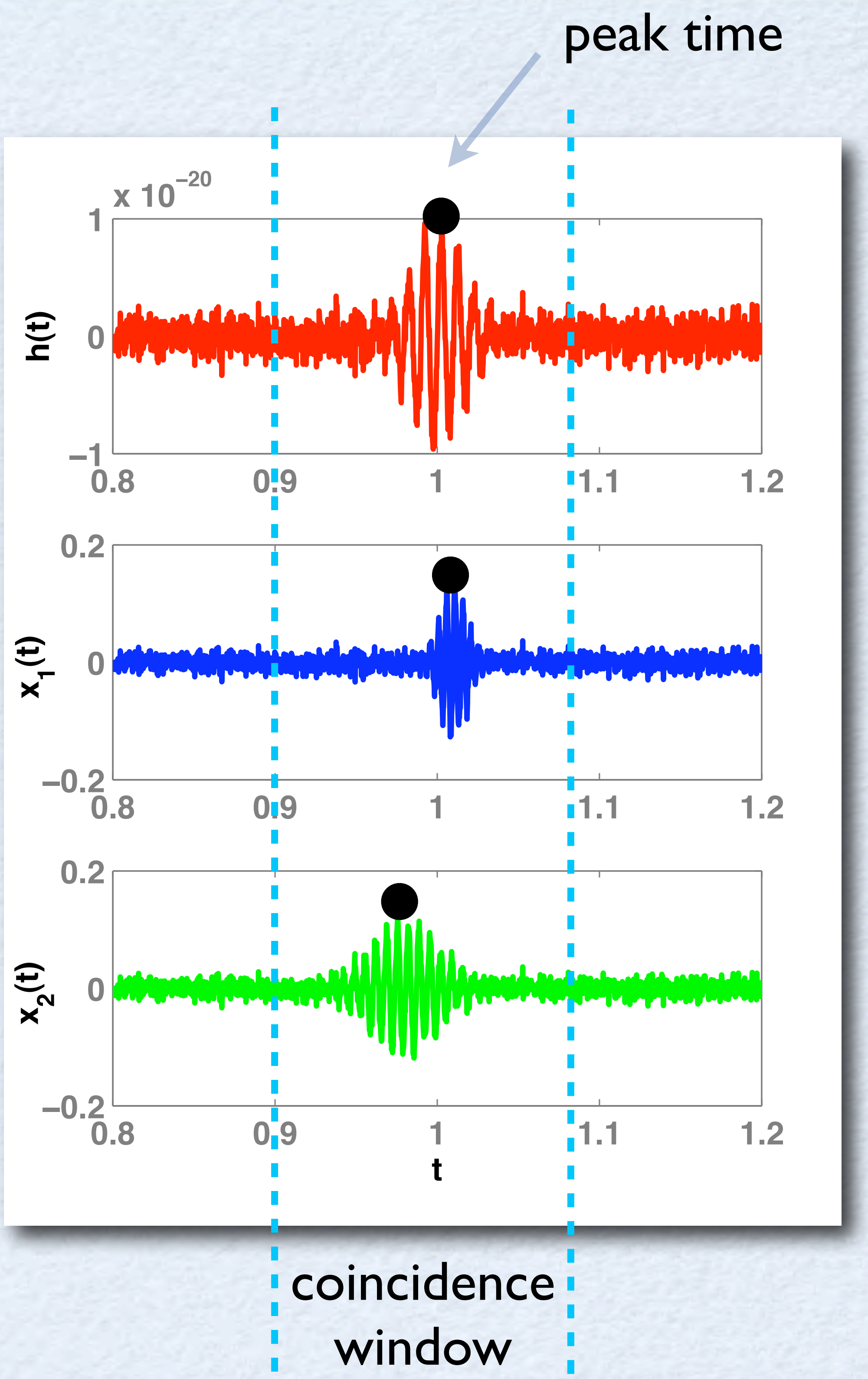


Veto Method

- **"Traditional" veto methods** Ask whether a glitch in in the GW channel *H is* time-coincident with one in an instrumental channel X_i.

- **"New" method** Ask whether the *H* data at the time of the trigger is *consistent* with the data from an instrumental channel, or, a combination of instrumental channels.

- **Consistency check** is based on our understanding of the coupling of different noise sources/channels to *H*.



Noise coupling, transfer functions...

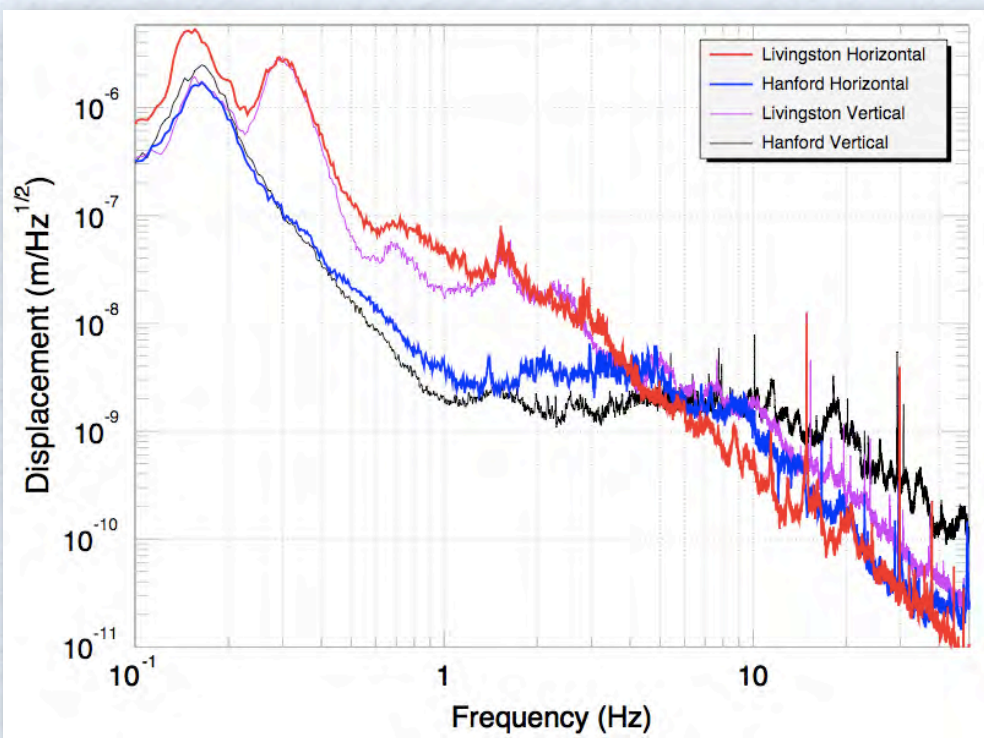
seismic noise acting here $N(f)$

pendulum transfer function

seismic noise measured here $N(f)\, f^{-2}$

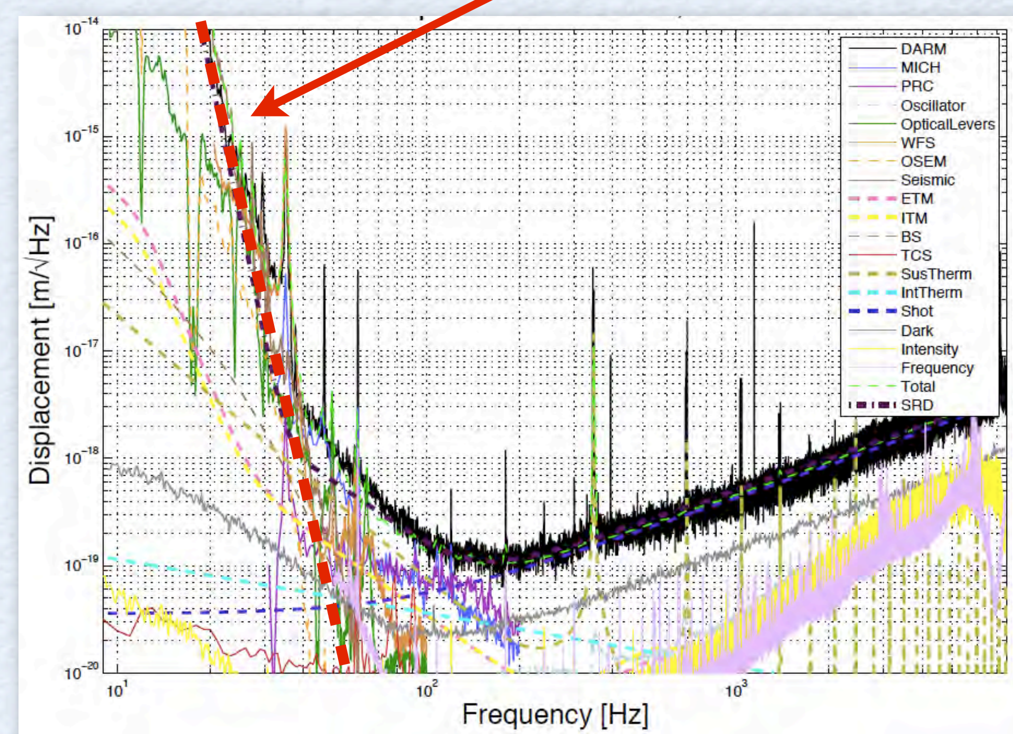
Noise coupling, transfer functions...

seismic noise of the ground



transfer function

seismic noise coupling to the GW channel (estimate)



Linear-coupling model

- Approximate the coupling of an instrumental channel to the GW channel by a linear coupling transfer function.

linear filter

an instrumental channel

GW channel

$$h(t) \sim \mathcal{F}\left[x_i(t)\right]$$

Time domain

transfer function

$$\tilde{h}(f) \sim \mathcal{T}(f)\, \tilde{x}_i(f)$$

Fourier domain

Vetoes using linear coupling model

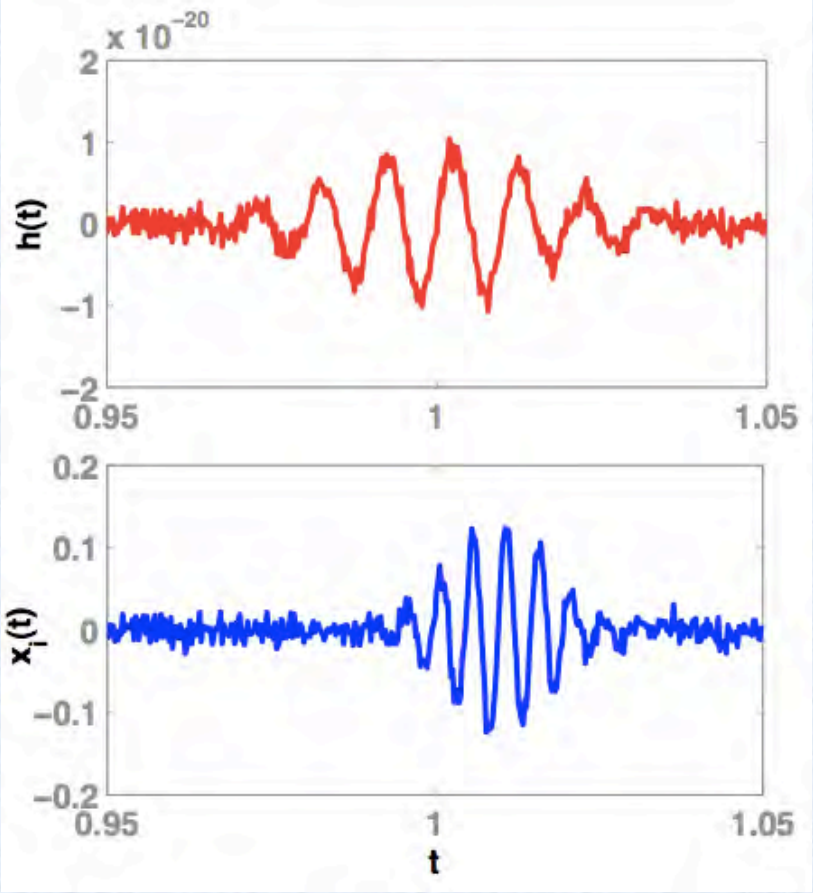
- Identify coincident glitches in H and X_i by running the appropriate ETG.
- If the transfer function $\mathcal{T}(f)$ from X_i to H is known, data in X_i (at the time of the trigger) can be "transferred" to H:

$$\tilde{p}_i(f) = \mathcal{T}(f)\,\tilde{x}_i(f)$$

- Consistency of the glitches can be checked by computing the linear correlation coefficient:

$$r \equiv \left\langle \tilde{\mathbf{p}}_i, \tilde{\mathbf{h}} \right\rangle$$

- Background distribution of r estimated from time-shifted data.



H

X_i

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Vetoes using linear coupling model

- Found to be very effective in GEO S5 run.

threshold on
cross correlation

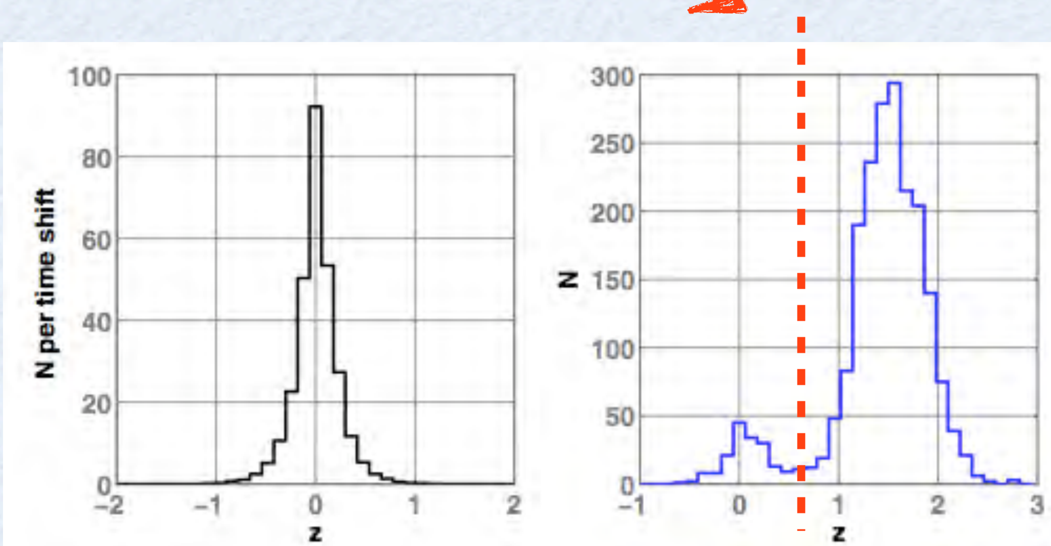
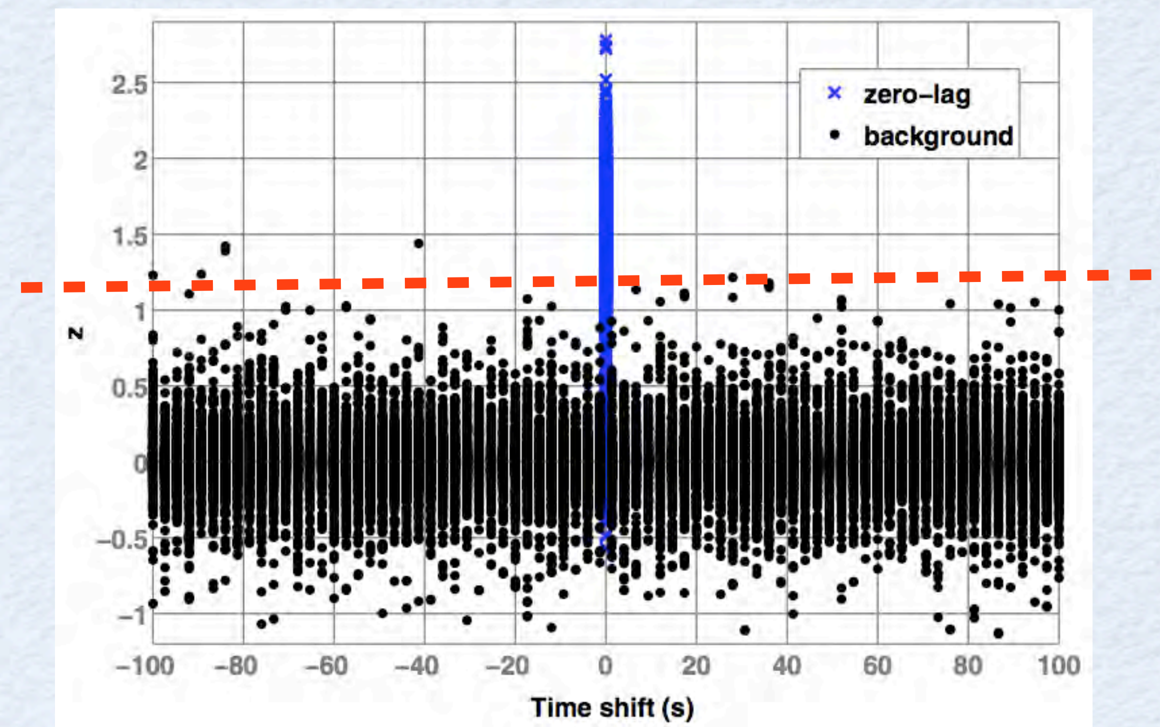


FIG. 10 (color online). Histograms of the cross-correlation statistic z computed from the time-shifted analysis (left panel) and the zero-lag analysis (right panel).



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Vetoes using linear coupling model

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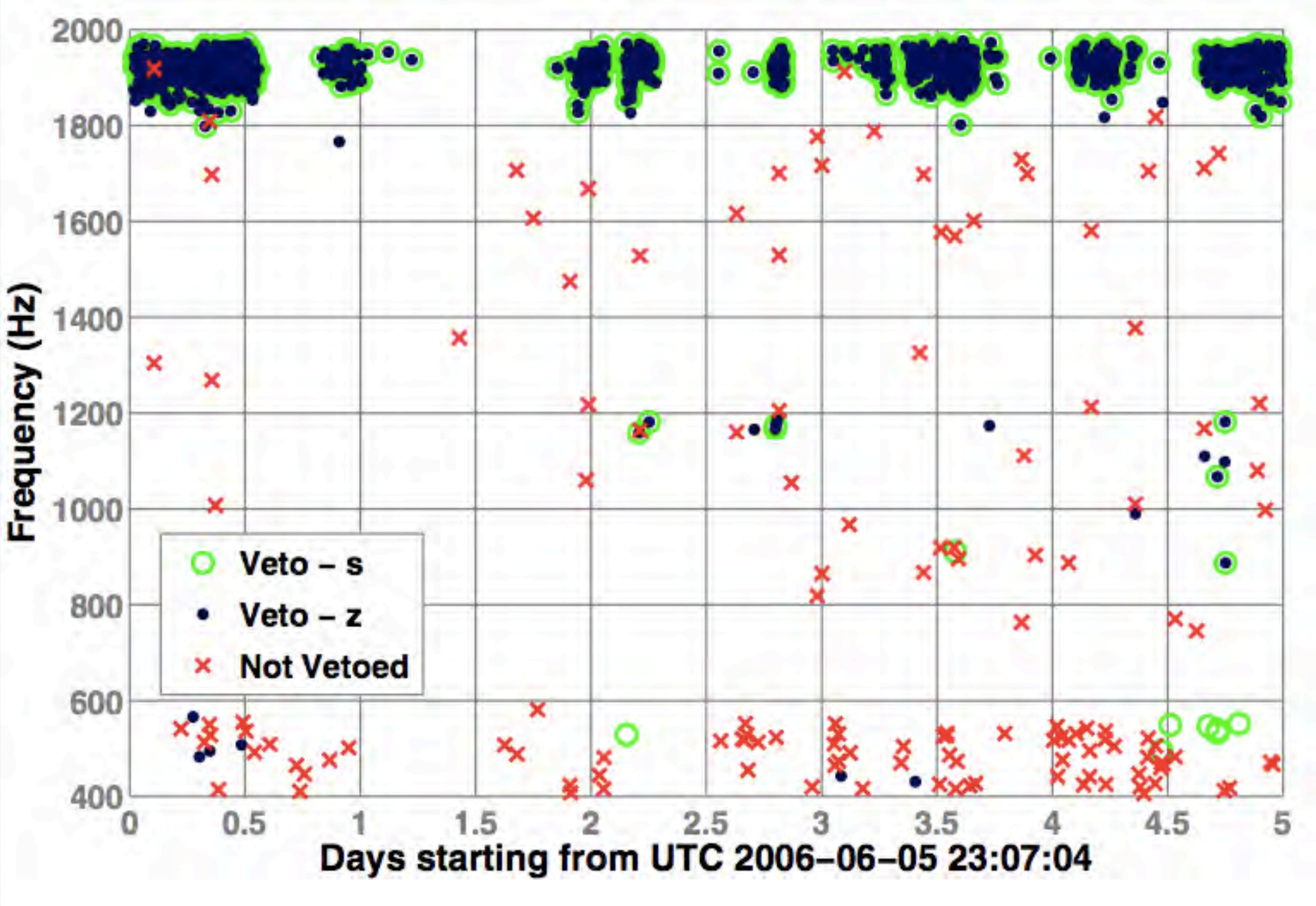
Time-frequency plot of burst triggers from mHACR burst ETG



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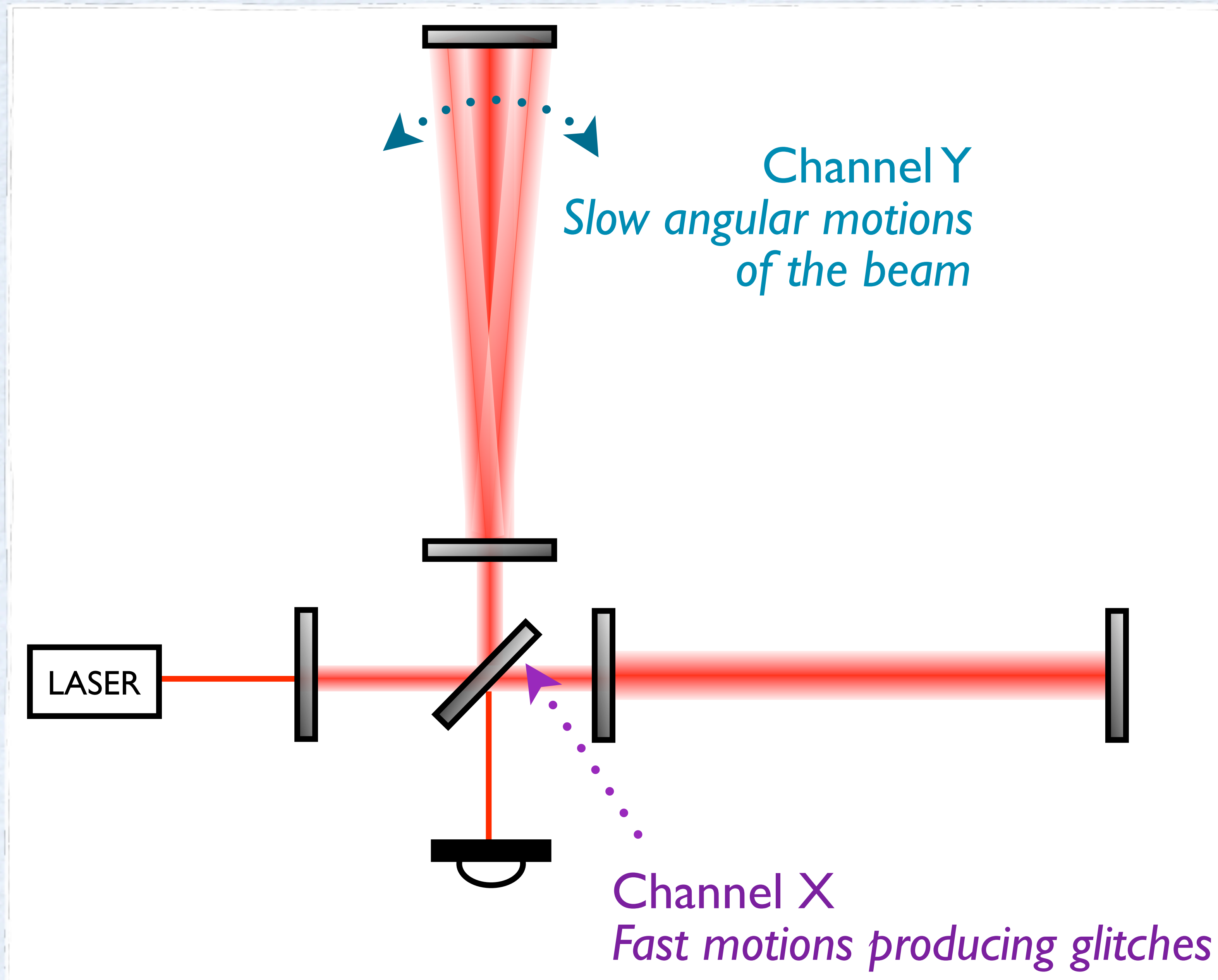
Vetoes using bilinear-coupling model



Vetoes using bilinear-coupling model

fast motions (channels recording glitches)

a pseudo channel

$$p_{ij}(t) = x_i(t)\, y_j(t)$$

slow angular motions of the beam

linear filter

$$h(t) \sim \mathcal{F}[\, p_{ij}(t)\,]$$

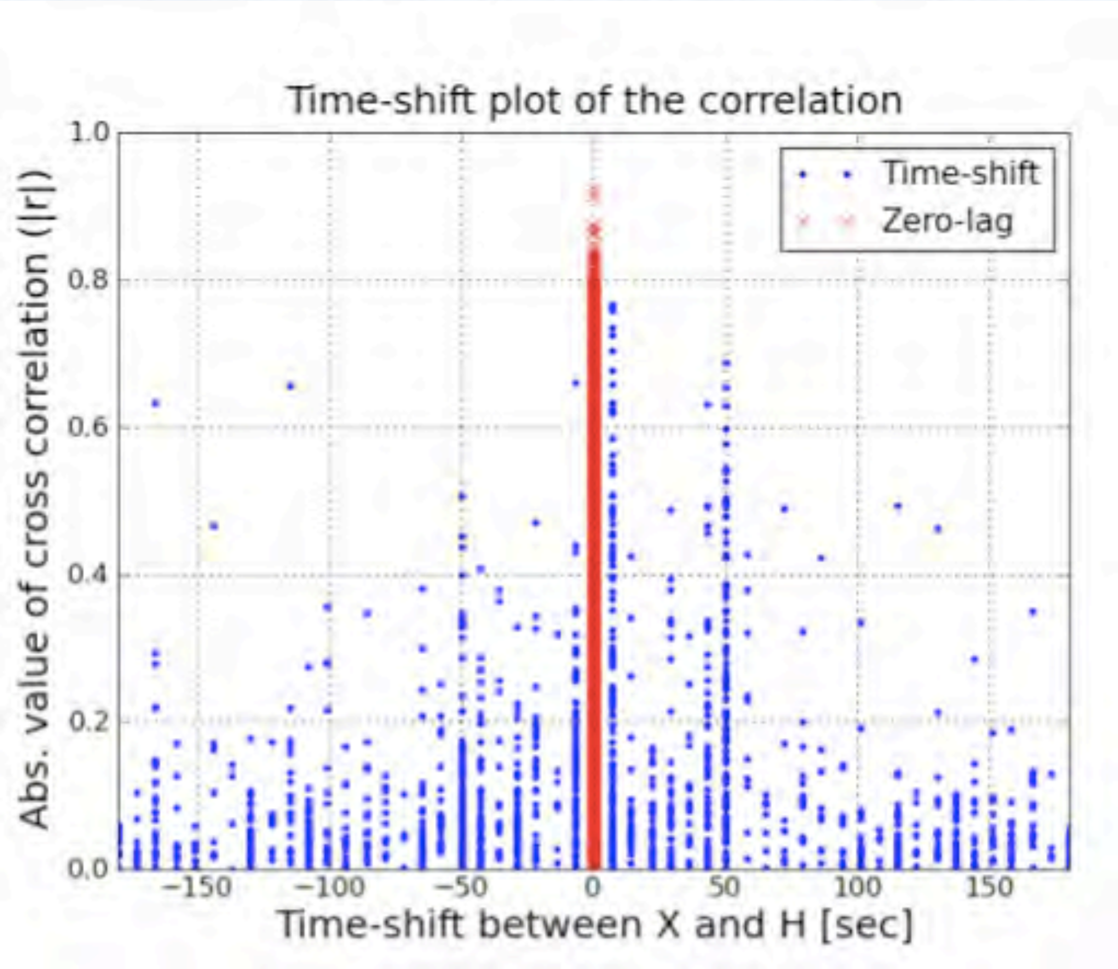
- Testing the consistency of glitches in *H* and P_{ij}

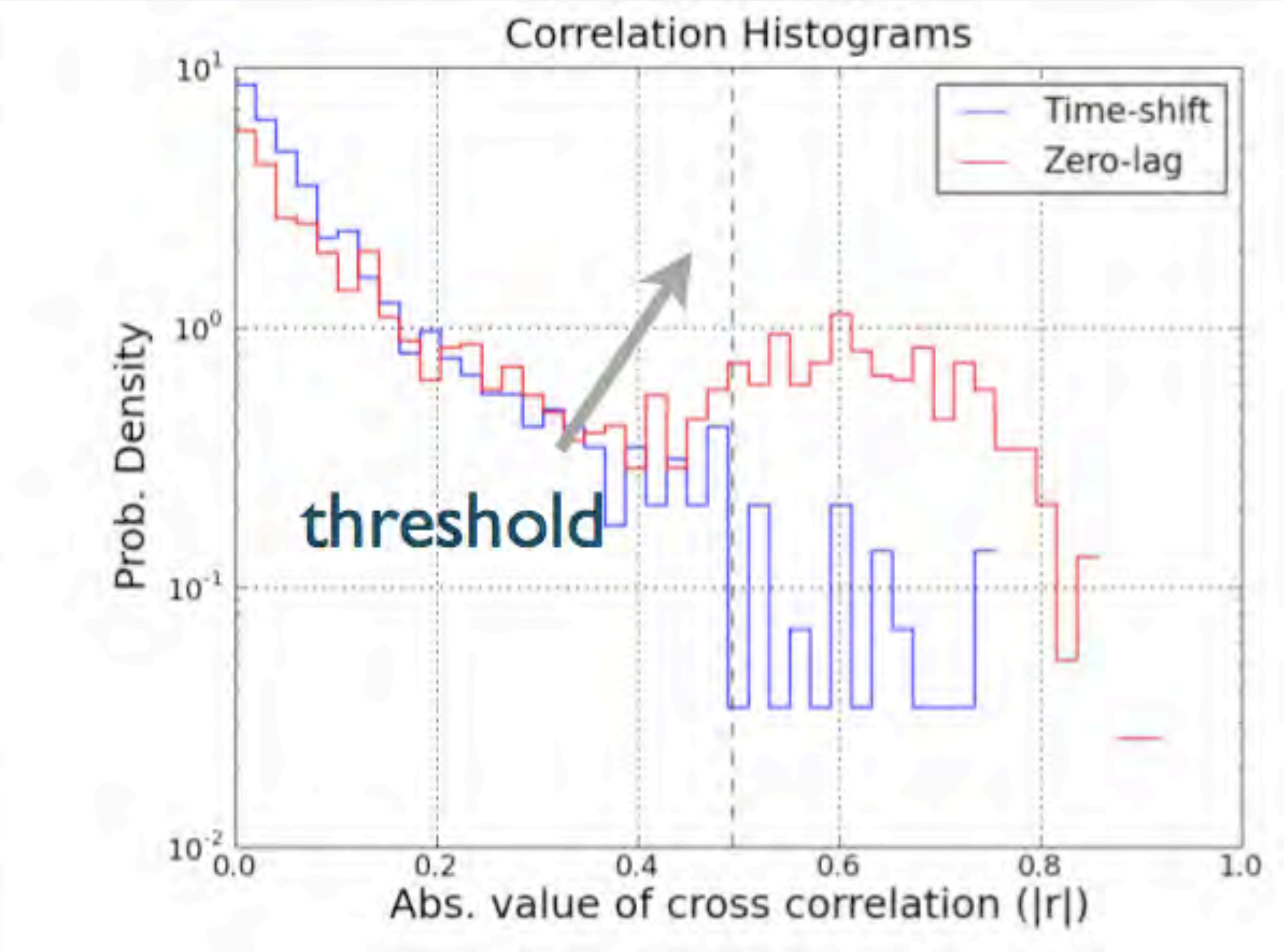
$$r \equiv \left\langle \tilde{\mathbf{p}}_{ij}, \tilde{\mathbf{h}} \right\rangle$$

(assumption: transfer function is "flat" in the frequency band of the glitch)

Implementation in LIGO data

- Veto analysis performed on KleineWelle triggers coincident in *H* (H1_DARM_ERR) and instrumental channels X_i. Used different candidates for Y_j.

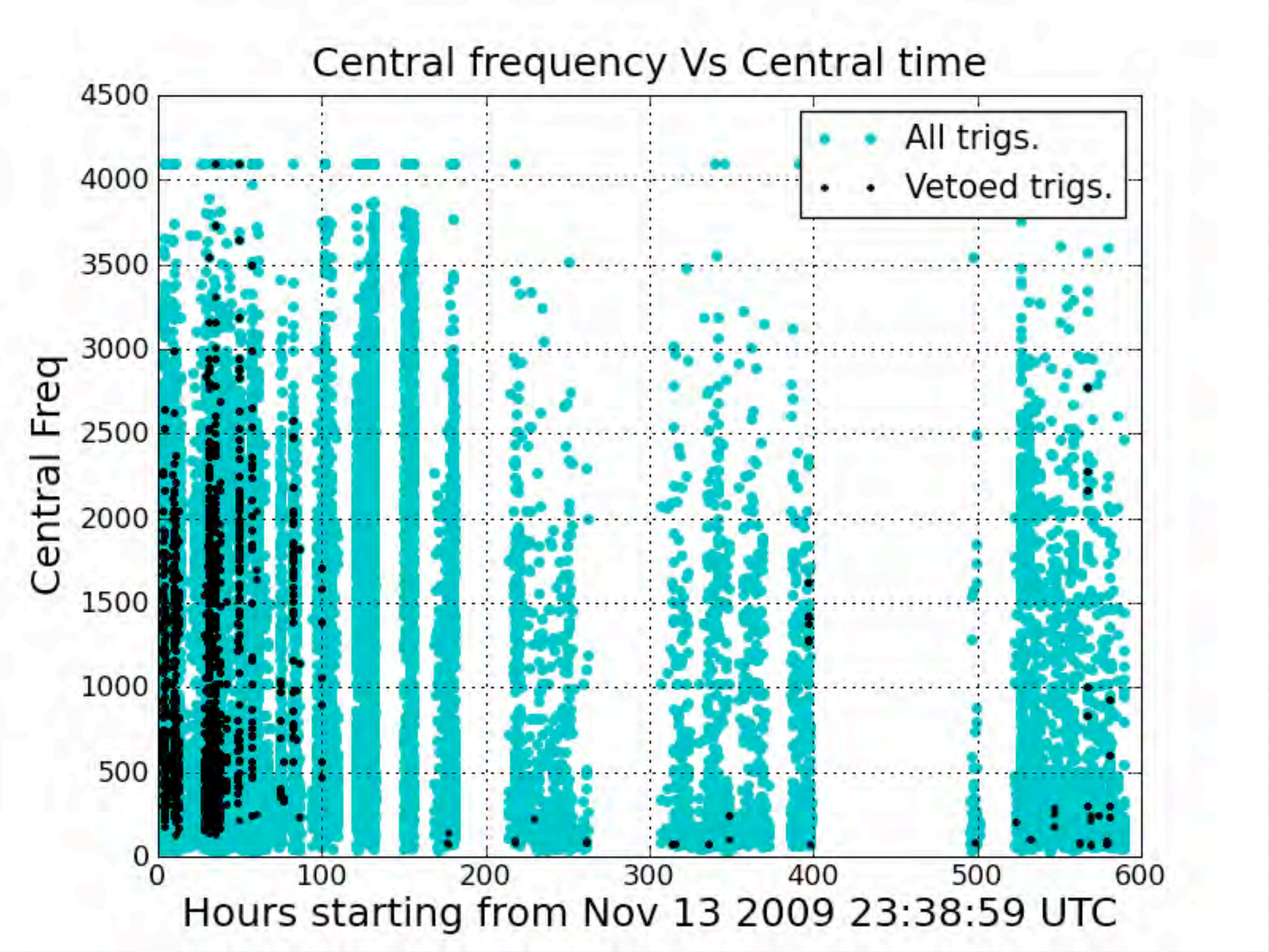




Chan *X* = H1:LSC-PRC_CTRL, Chan *Y* = H1:ASC-QPDY_P (August 21-28, 2010)

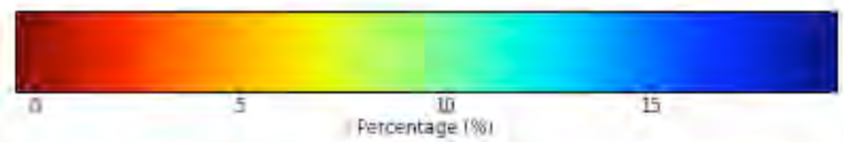
IMPLEMENTATION IN LIGO DATA

Time-frequency plot of burst triggers from KleineWelle burst ETG



Implementation in LIGO Data

Veto efficiencies for different bilinear combinations



"Fast" channels

"Slow" channels

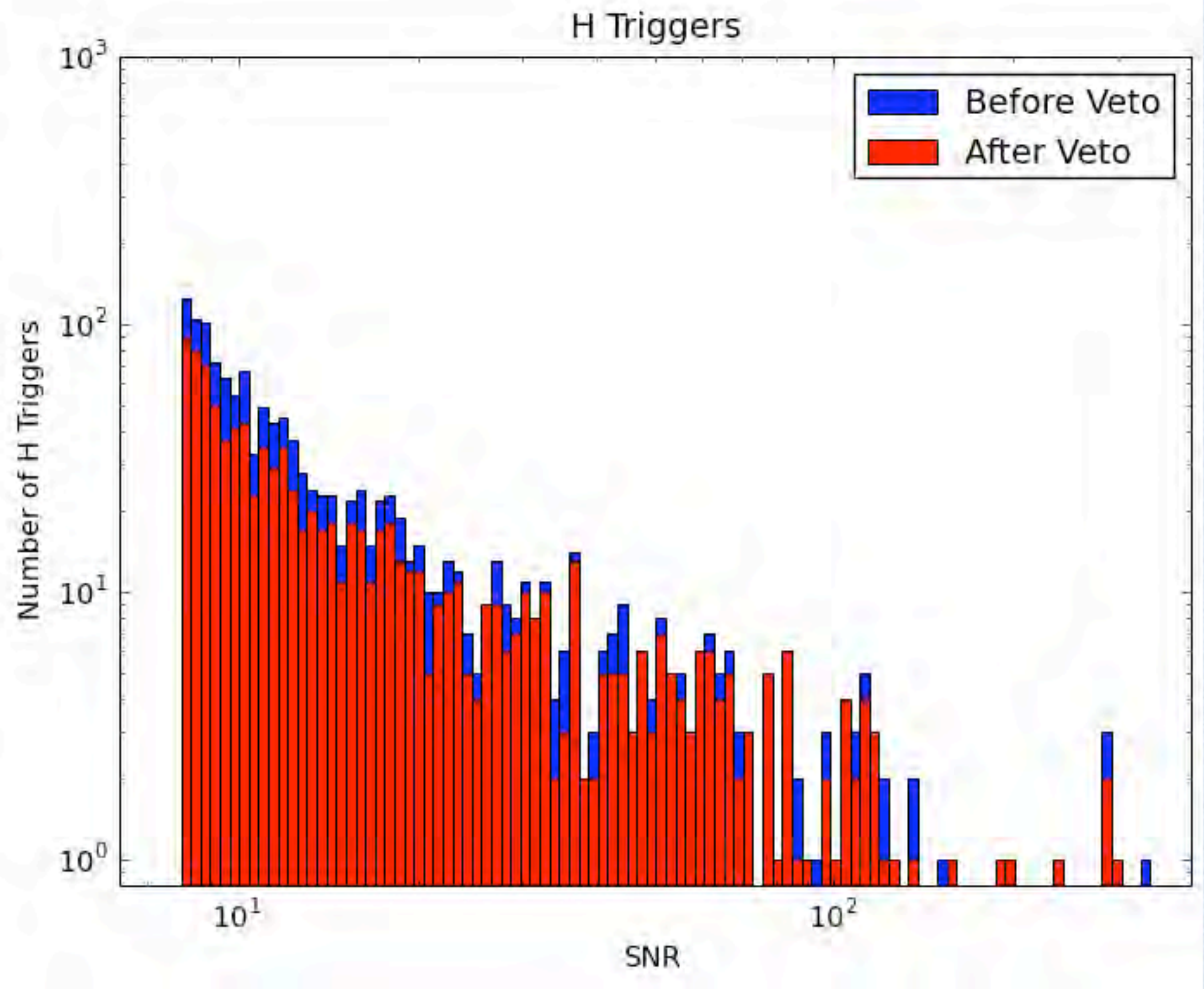
Channel Name	H1:ASC-ETMX_P	H1:ASC-ETMX_Y	H1:ASC-ETMY_P	H1:ASC-ETMY_Y	H1:ASC-ITMX_P	H1:ASC-ITMX_Y	H1:ASC-ITMY_P	H1:ASC-ITMY_Y	H1:LSC-MICH_CTRL	H1:LSC-PRC_CTRL
H1:LINEAR	6.92%	10.10%	6.31%	11.27%	11.33%	10.29%	8.70%	11.08%	11.27%	15.74%
H1:ASC-QPDX_P	6.74%	10.10%	6.67%	7.41%	8.57%	7.72%	8.14%	9.06%	13.60%	14.21%
H1:ASC-QPDX_Y	10.23%	10.23%	2.08%	7.17%	8.82%	9.06%	4.04%	6.06%	13.84%	15.19%
H1:ASC-QPDY_P	9.55%	8.94%	3.98%	6.92%	9.74%	8.45%	5.21%	6.80%	12.19%	14.45%
H1:ASC-QPDY_Y	6.80%	5.57%	6.67%	5.94%	7.66%	8.14%	6.00%	7.35%	10.84%	8.82%
H1:ASC-WFS1_QP	5.63%	5.08%	10.04%	6.12%	9.12%	8.51%	9.80%	9.00%	10.65%	12.12%
H1:ASC-WFS1_QY	8.63%	14.21%	10.10%	9.86%	7.96%	8.88%	7.59%	8.21%	5.08%	8.45%
H1:ASC-WFS2_IP	9.25%	8.76%	8.02%	9.68%	9.49%	9.19%	12.25%	10.35%	10.29%	13.41%
H1:ASC-WFS2_IY	6.43%	10.35%	7.72%	9.49%	7.59%	8.02%	8.39%	10.59%	8.08%	10.04%
H1:ASC-WFS2_QP	9.68%	11.70%	10.96%	14.45%	8.70%	10.84%	9.06%	12.19%	14.21%	11.14%
H1:ASC-WFS2_QY	8.08%	9.55%	7.35%	9.43%	9.25%	9.31%	8.70%	10.41%	5.57%	13.84%
H1:ASC-WFS3_IP	12.74%	7.78%	7.35%	9.37%	12.86%	5.08%	7.23%	8.45%	10.65%	15.74%
H1:ASC-WFS3_IY	10.35%	13.35%	8.27%	14.15%	12.92%	13.90%	10.84%	12.98%	11.88%	15.86%
H1:ASC-WFS4_IP	10.96%	9.49%	9.86%	12.55%	12.86%	8.88%	8.33%	10.10%	12.68%	14.82%
H1:ASC-WFS4_IY	10.59%	9.19%	8.39%	11.27%	12.25%	5.14%	9.98%	8.76%	12.62%	13.90%

[One week of H1 data from August, 2010]

Implementation in LIGO Data

LIGO S6 Analysis

- Use KleineWelle triggers.
- Assume "flat" transfer functions.
- Regularly run on ~150 bilinear combinations.
- Typical (total) veto efficiencies 15-35 %.
- Very low dead times (0.05 - 0.2%).
- High safety (No injections vetoed).
- Veto segments are inserted in to the segment database.
- Can veto low-SNR triggers as well.



Summary and Future Work

- Formulated and implemented a robust veto technique based on instrumental coupling models.

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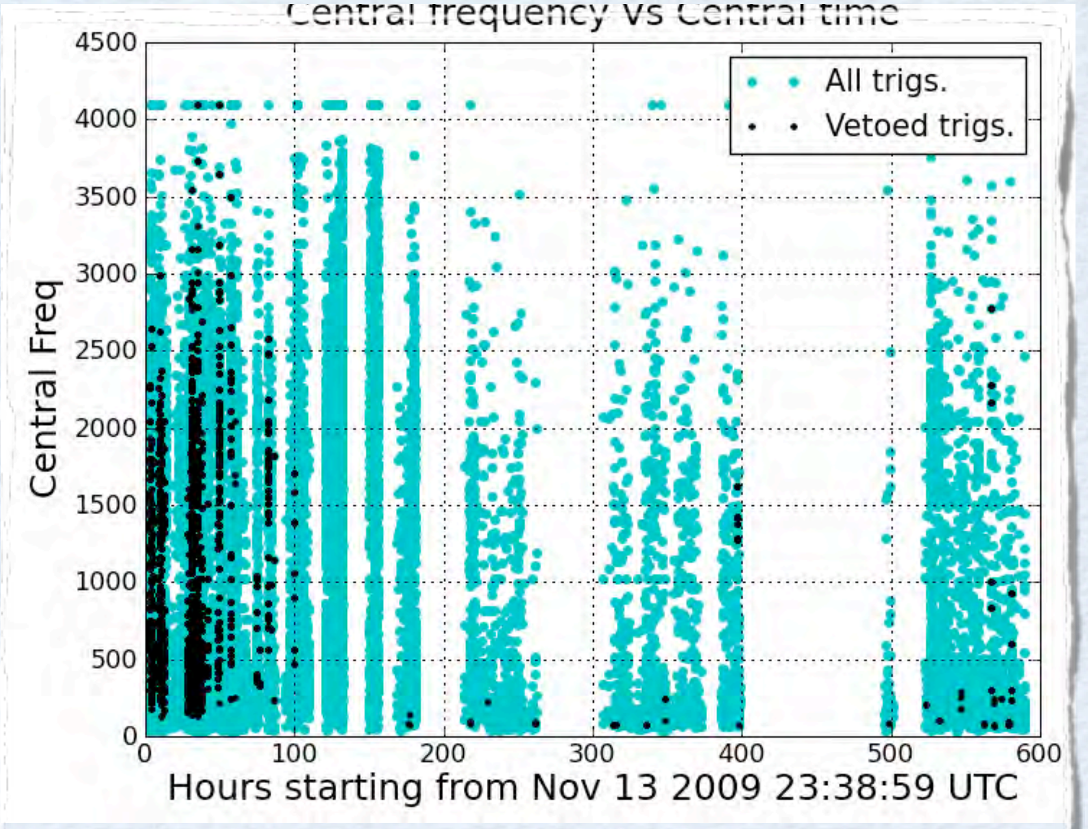

Future work

- **Understanding the glitches** Identify the detector configuration producing glitches, and avoid them through feedback.

- **Glitch subtraction** If there are accurate measurement points of the instrumental noise and reliable ways of predicting the coupling to the GW channel, it might be possible to subtract some of the glitches from the GW data.