GW burst vetoes using known instrumental couplings:

Application to GEO S5 data

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VETOES USING KNOWN INSTRUMENTAL COUPLINGS

- **Method** A veto strategy making use of the measured coupling of detector subsystems to the detector output (channel H).

- **Basic idea** The noise in an instrumental channel X can be *transferred* ('projected') into channel H using the measured transfer function from X to H. If a particular burst trigger originates in X, data in channels X and H should be consistent with the transfer function.

- **Advantage** Allows us to veto a trigger with a very high confidence – very low accidental veto rate. Uses the full information contained in the data.

ALGORITHM

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Noise vector (Fourier domain) in *X*, mapped into *H*

Noise vector (Fourier domain) in *X*

Transfer function from *X* to *H*

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- **Step 3** Test the consistency of $\tilde{x}'(f)$ and $\tilde{h}(f)$. If consistent, veto the trigger.

TEST STATISTIC

- Possible to use different statistics to test the consistency of $\mathbf{h}$ with $\mathbf{x}'$.

- **Null-stream** Construct a 'null-stream' between $\mathbf{h}$ and $\mathbf{x}'$.

$$\tilde{\boldsymbol{\delta}} = \tilde{\mathbf{h}} - \mathrm{proj}_{\tilde{\mathbf{x}}'} \tilde{\mathbf{h}}$$

Compute the *excess-power* statistic ϵ from $\boldsymbol{\delta}$ and $\mathbf{h}$. If the glitch originates in *X*, $\epsilon_\delta << \epsilon_{\mathrm{h}}$.

REF P. Ajith, M Hewitson, J R Smith and K A Strain, CQG **23** 5825-5837 (2006).

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Projection operator

$$\mathrm{proj}_{\,\tilde{\mathbf{u}}} \tilde{\mathbf{v}} = \frac{\langle \tilde{\mathbf{v}}, \tilde{\mathbf{u}} \rangle}{\langle \tilde{\mathbf{u}}, \tilde{\mathbf{u}} \rangle} \, \tilde{\mathbf{u}}$$

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- **Cross-correlation** Compute the linear cross-correlation coefficient between $\mathbf{h}$ and $\mathbf{x}'$.

$$r = \mathrm{Re}\,\frac{\left\langle \tilde{\mathbf{x}}', \tilde{\mathbf{h}} \right\rangle}{||\tilde{\mathbf{x}}'||\ ||\tilde{\mathbf{h}}||}$$

If the glitch originates in X, $r \simeq 1$.

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HARDWARE INJECTIONS IN GEO

- **Injections** Sine-Gaussian burst injections into different subsystems to mimic four different noise sources: laser amplitude and frequency noise; phase and amplitude noise of MI control sidebands. One hour long injections for each channel. One injection in every 12 sec.

- **Transfer functions** Transfer functions were measured one week before.

- **Analysis** Accidental rate was estimated by performing 62 time-shifts (from -100s to 100s). Veto analysis on HW injections showed that more than 95% of the injections can be vetoed with an accidental rate of 1 per day.

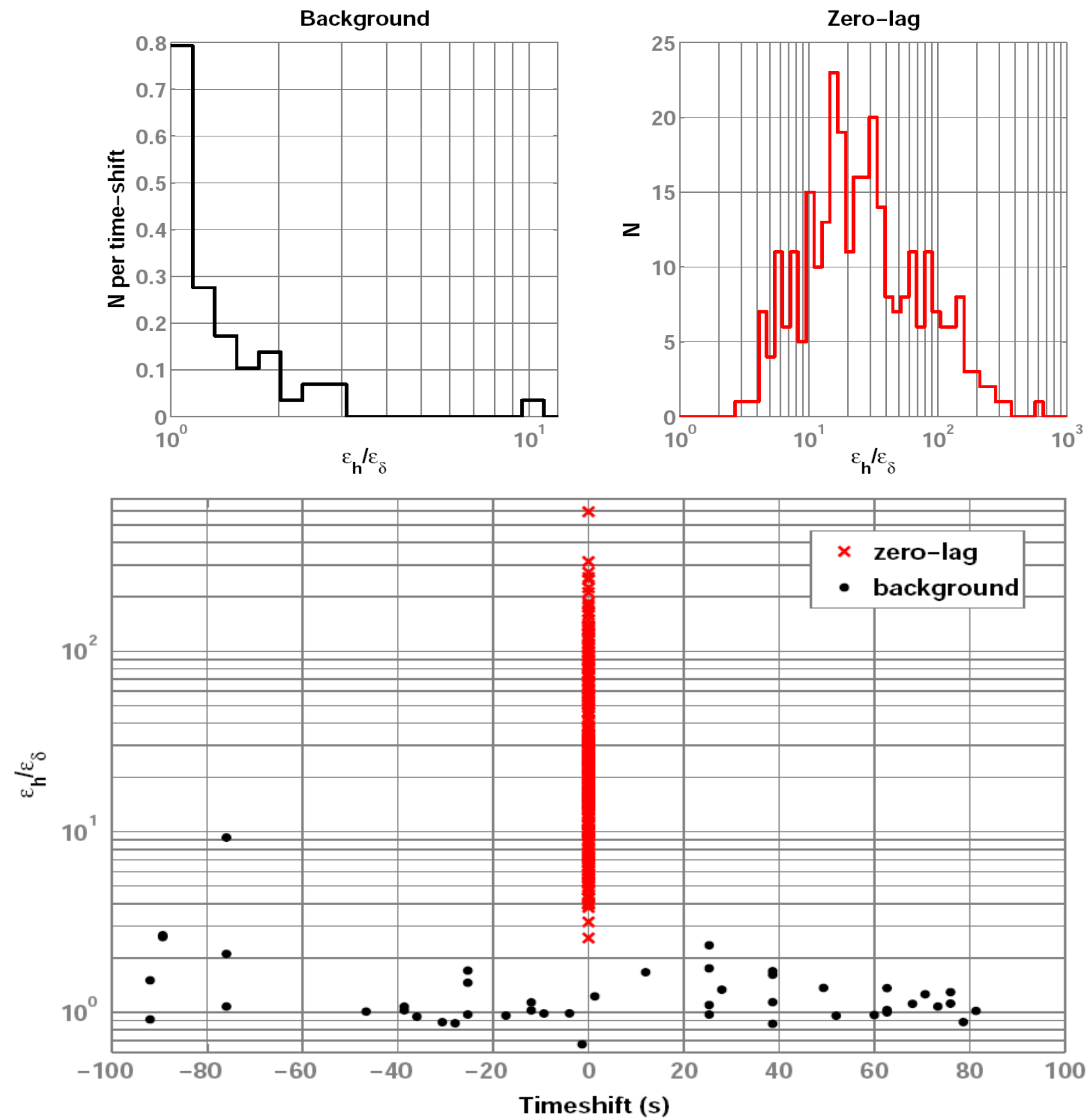
HARDWARE INJECTIONS

An example

- Oscillator phase noise channel: Analysis using null-stream statistic

- Coincident triggers with $\epsilon_h / \epsilon_\delta > 2.6$ are vetoed.

- 99.6 % of the injections can be vetoed with an accidental rate of 1 per day.



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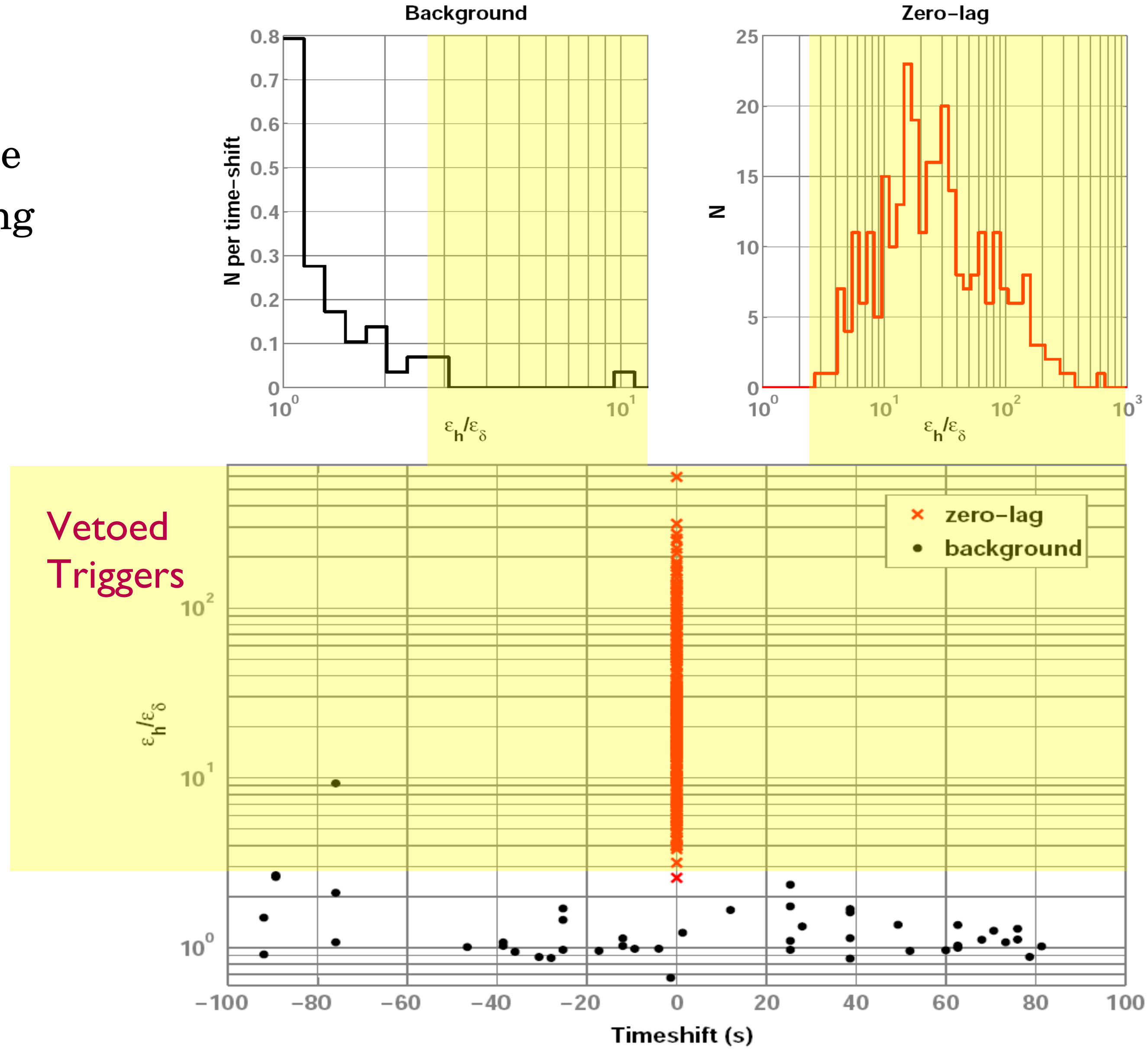

HARDWARE INJECTIONS

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- Oscillator phase noise channel: Analysis using cross-correlation statistic

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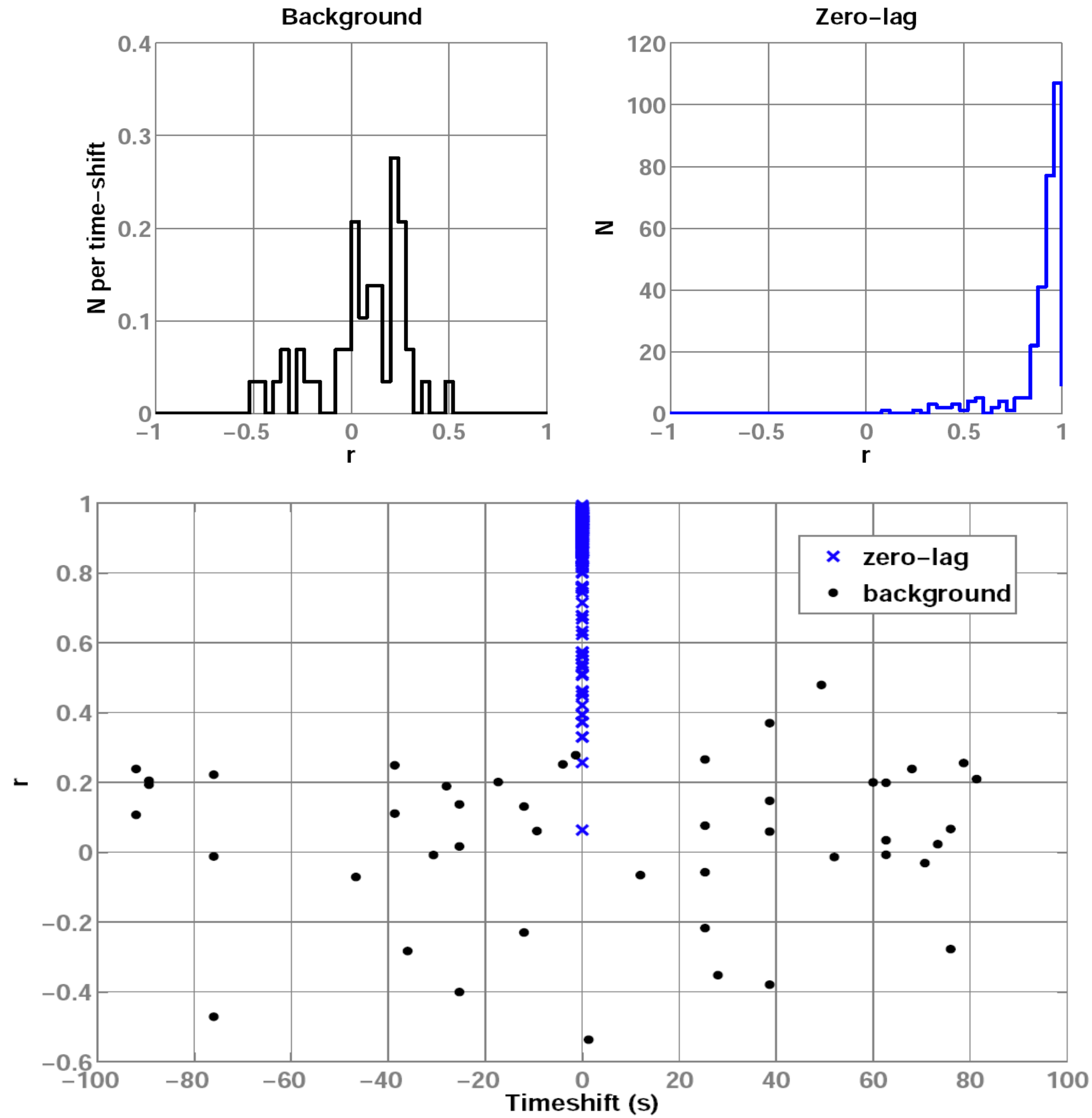

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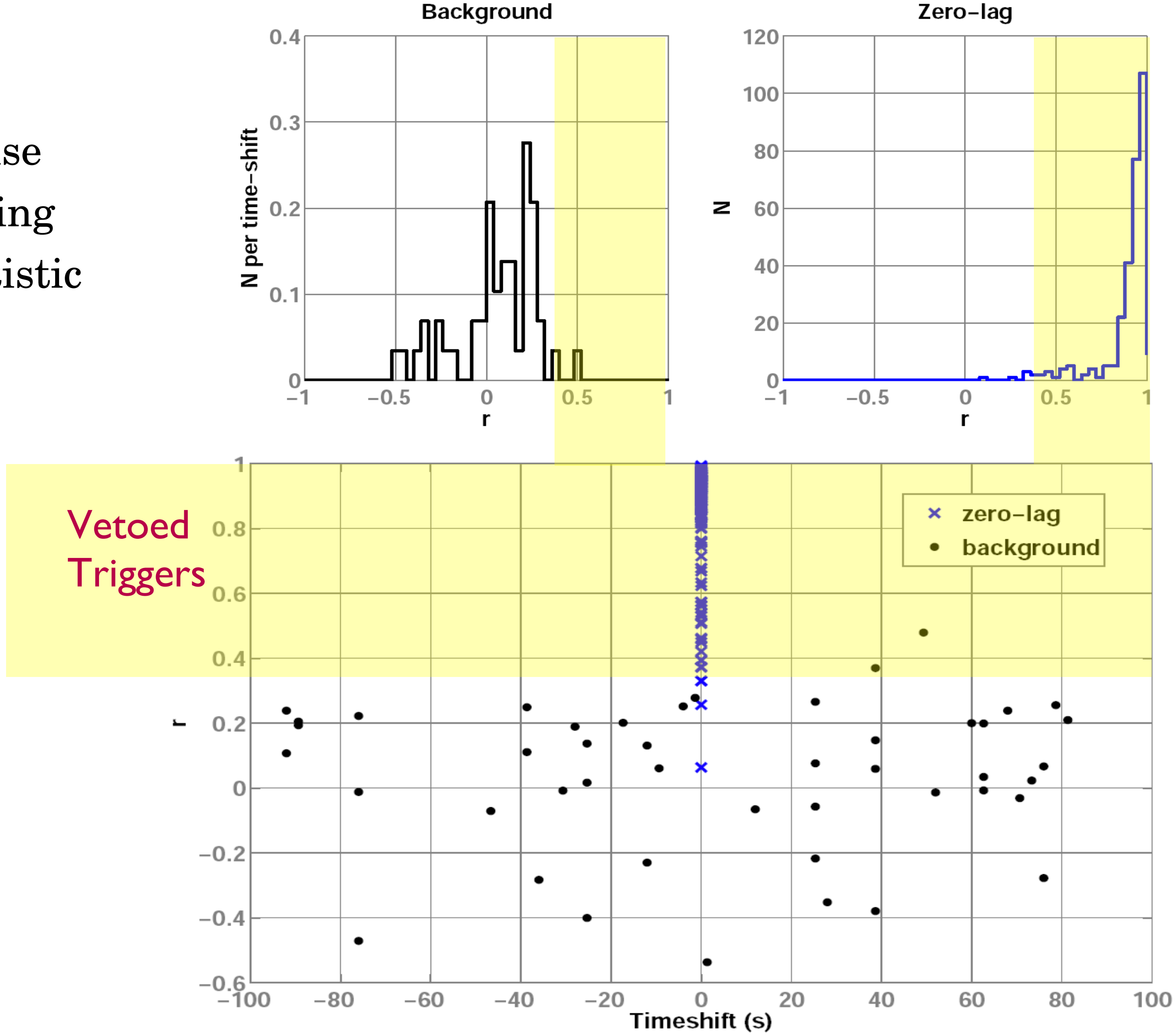
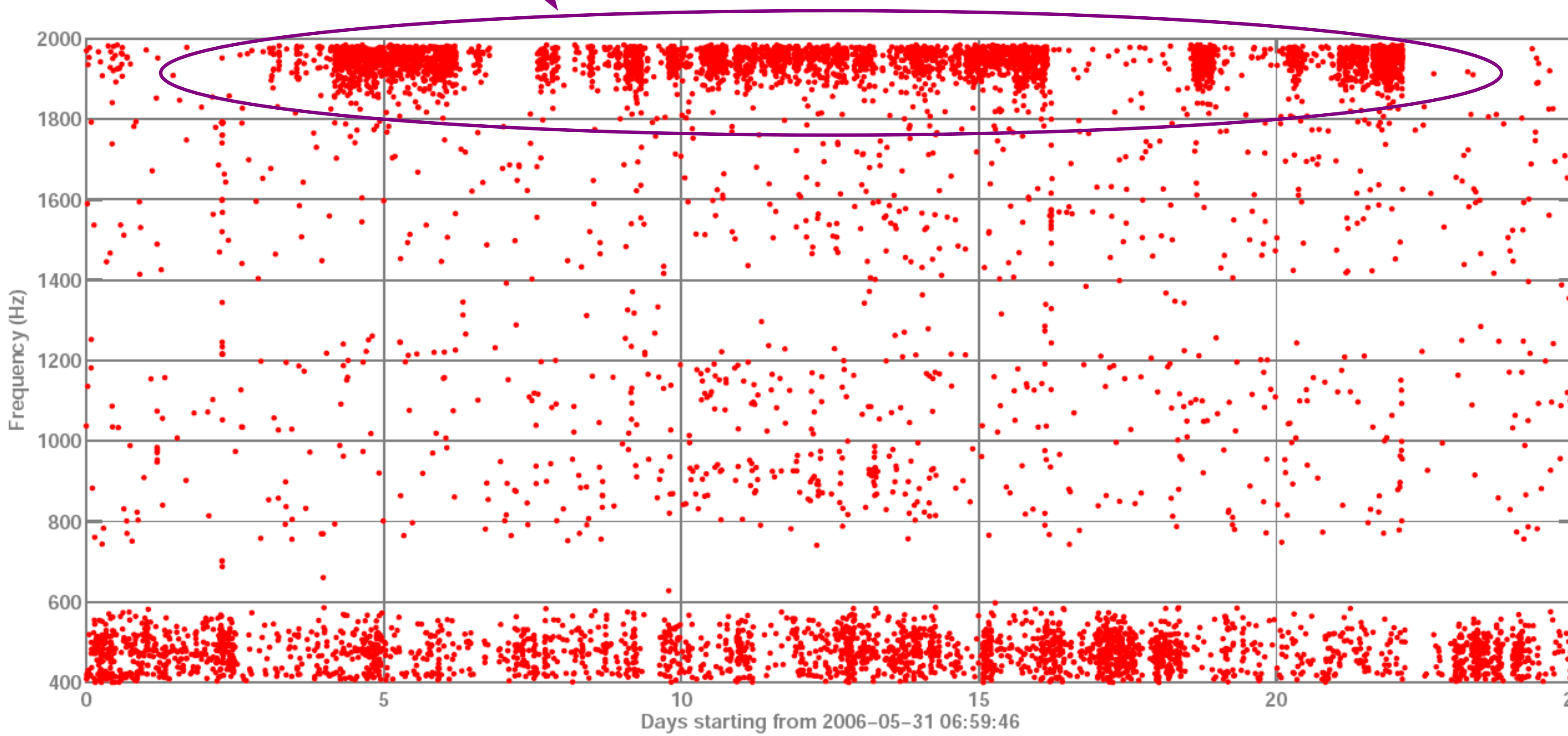


APPLICATION TO GEO S5

- Excess glitch rate was observed in June 2006, due to glitches in the laser frequency noise.
- Analysis using the PR EP as veto channel showed that 90 % of the coincident triggers with this channel can be vetoed.



APPLICATION TO GEO S5

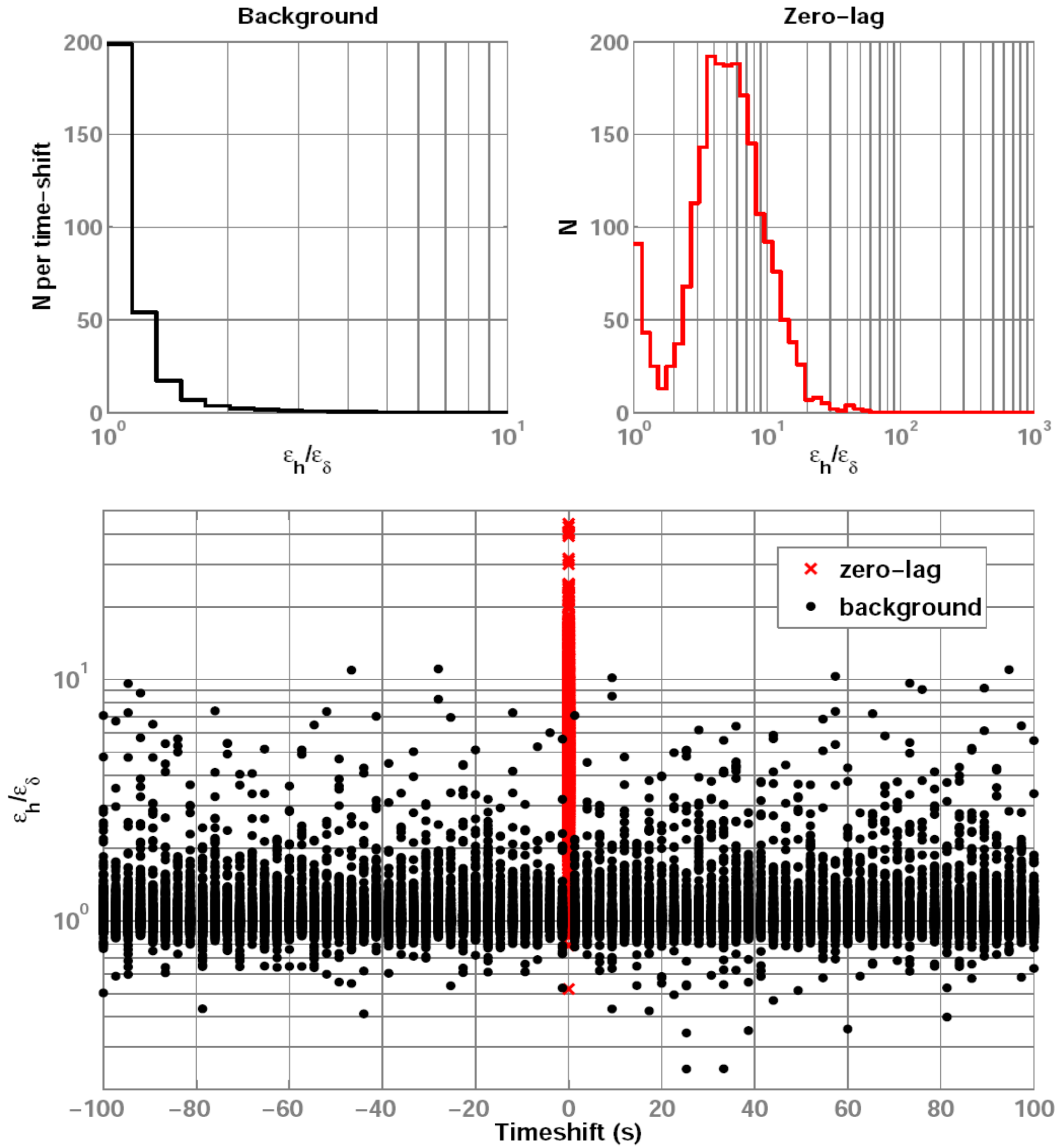
Vetoing laser frequency noise glitches

- Power-recycling error point (MIC_EP) as veto channel. Analysis using null-stream statistic.

- 5 days of data from June.

- Coincident triggers with $\epsilon_h / \epsilon_\delta > 3.94$ are vetoed.

- 61 % of the coincident triggers can be vetoed with an accidental rate of 1 per week



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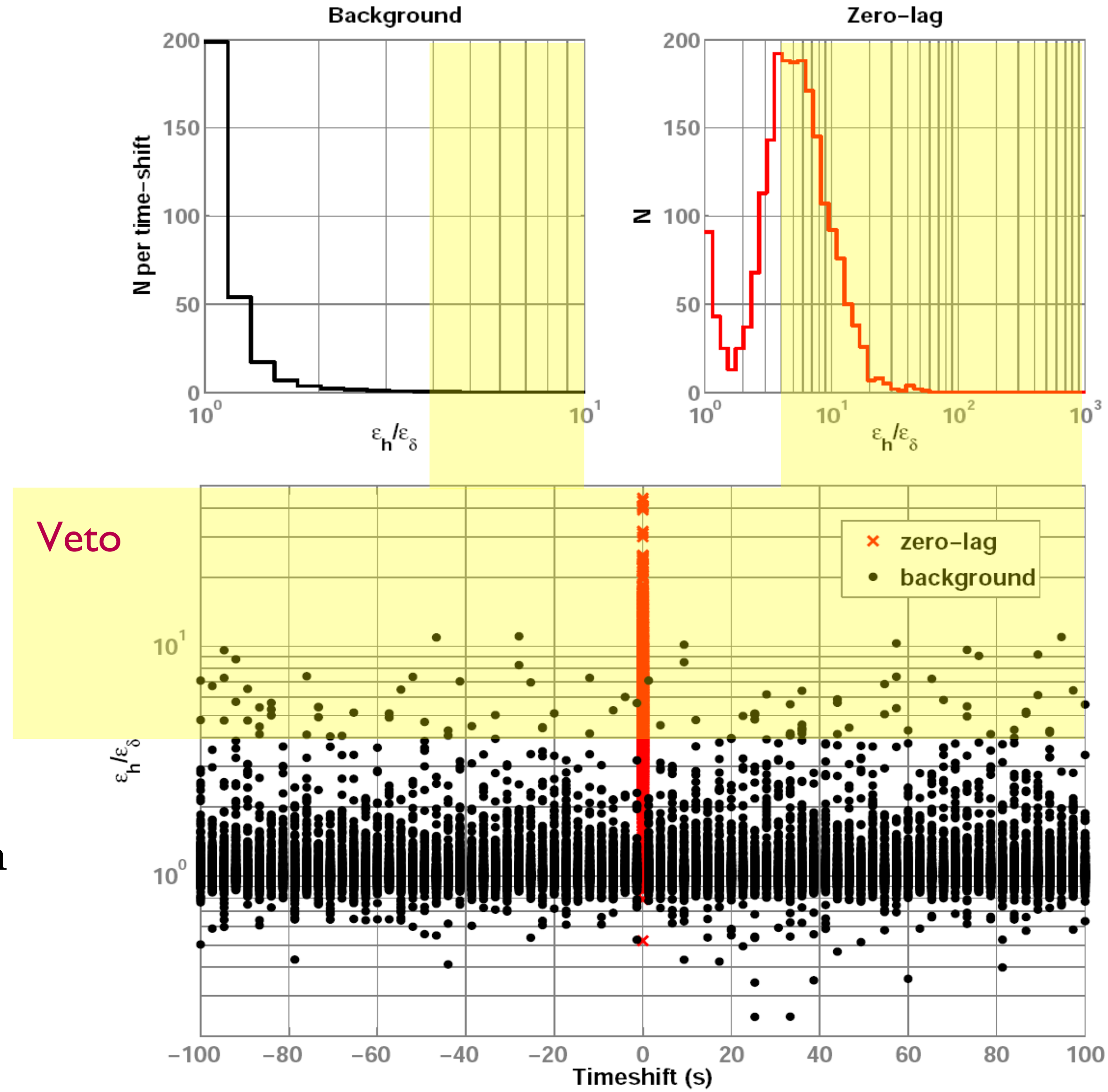

APPLICATION TO GEO S5

Vetoing laser frequency noise glitches

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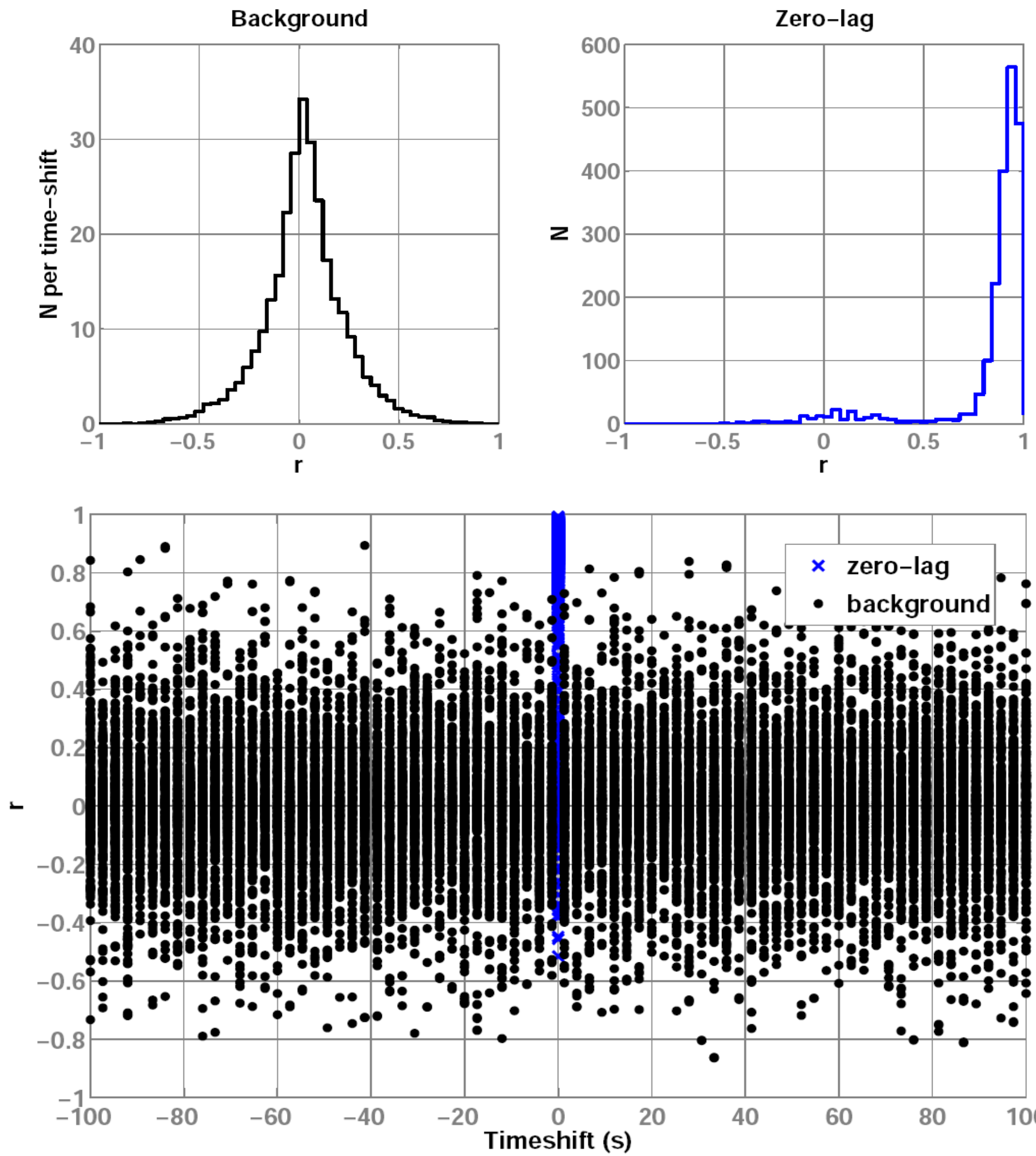
- 5 days of data from June.
- Coincident triggers with $r > 0.69$ are vetoed.
- 90 % of the coincident triggers can be vetoed with an accidental rate of 1 per week



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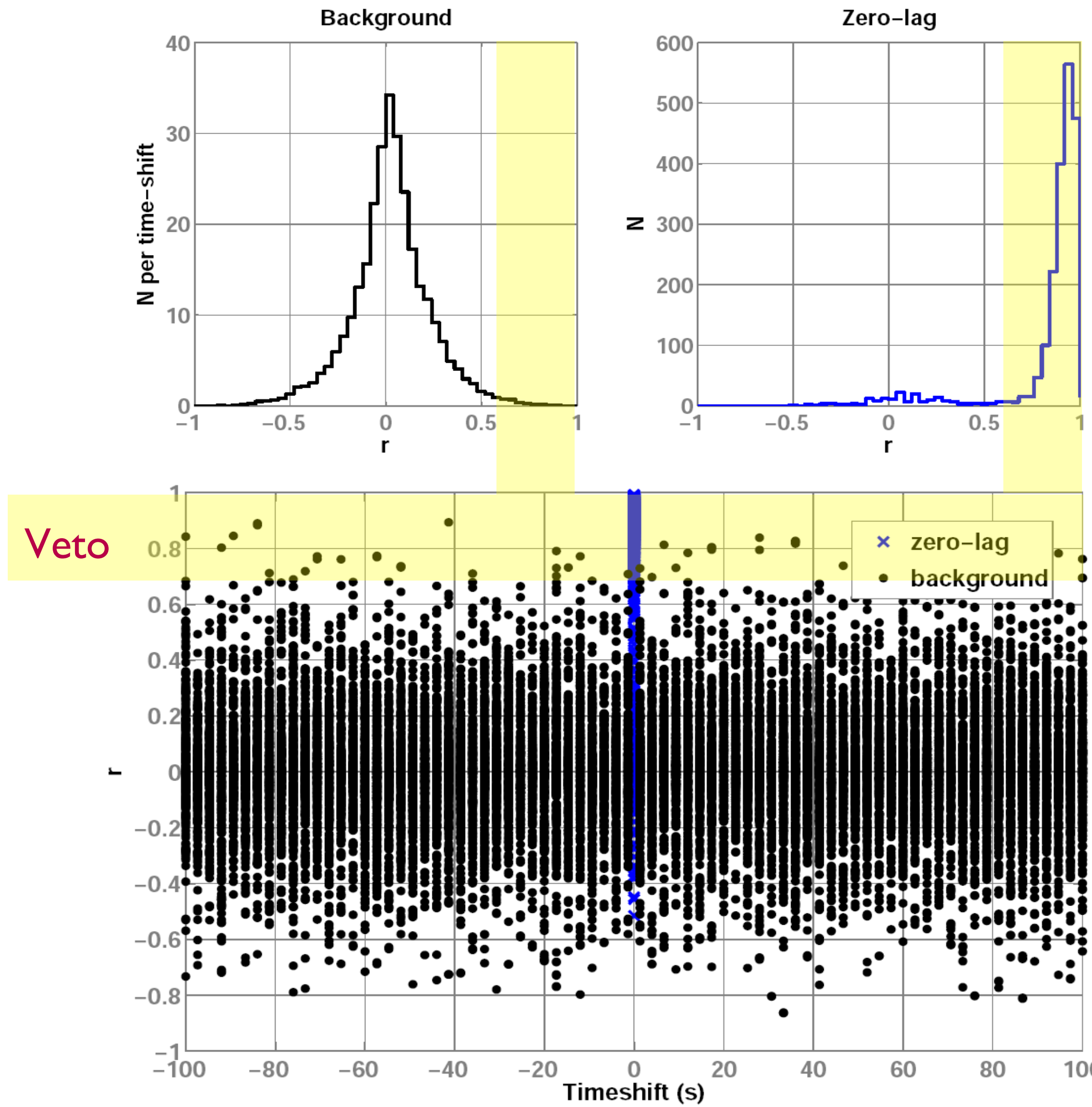
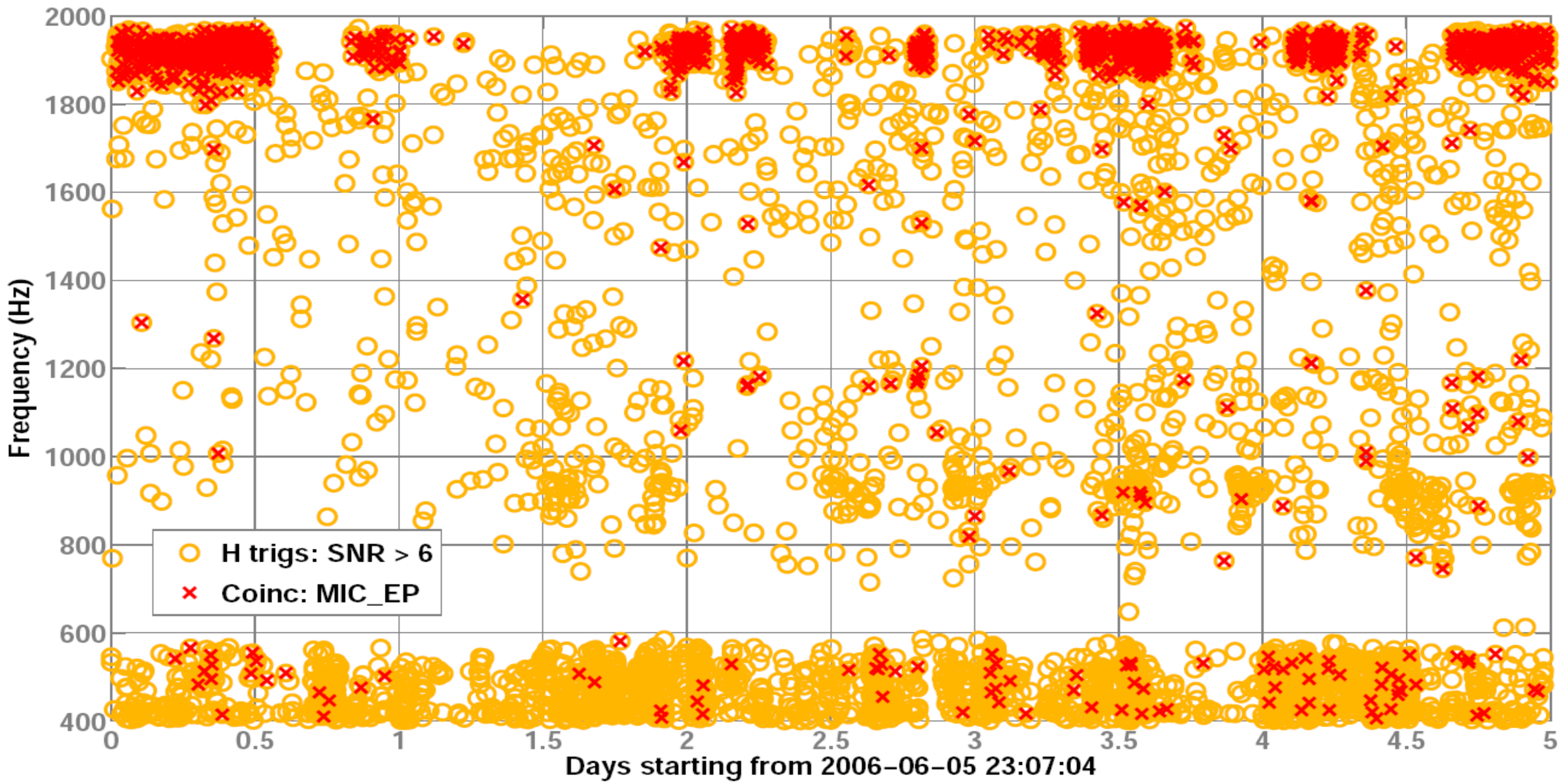


APPLICATION TO GEO S5

TF plot Time-frequency plot of *H* triggers with SNR > 6.

Summary

N. Trigs **5331**
Coinc **38 %**

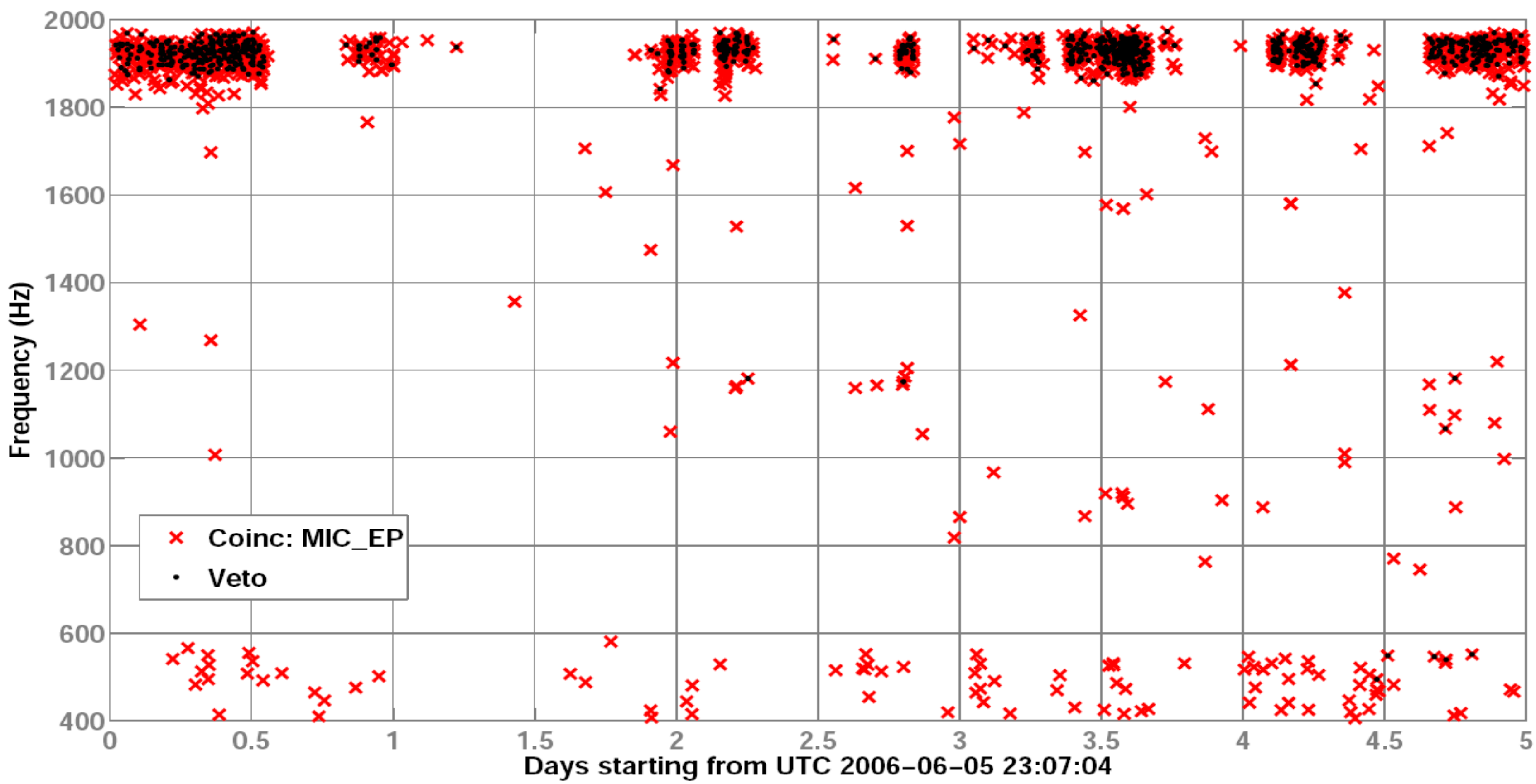


APPLICATION TO GEO S5

TF plot Time-frequency plot of coincident triggers vetoed using the null-stream statistic

Summary

N. Trigs **5331**
Coinc **38 %**
Veto **24%**

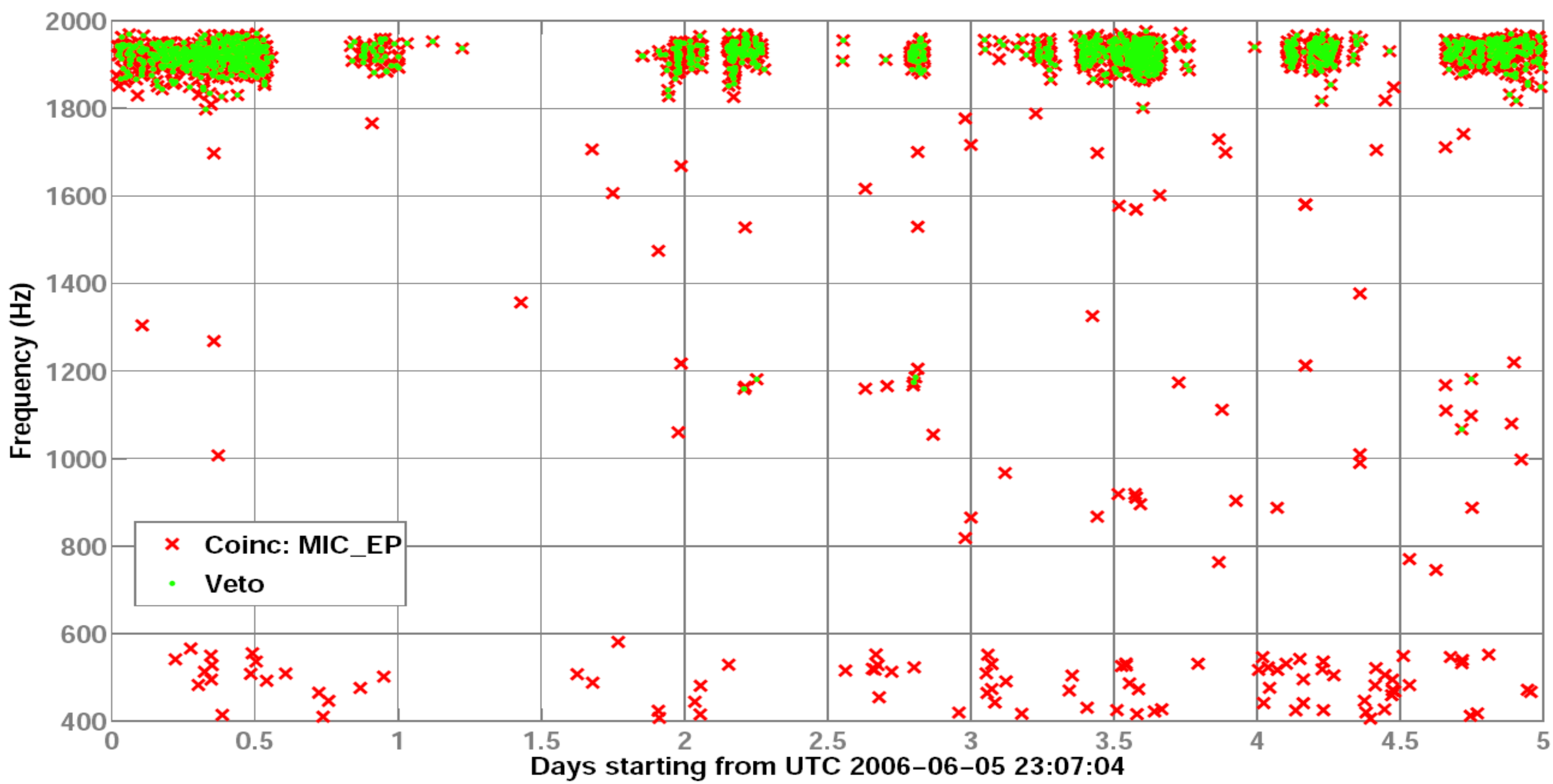


APPLICATION TO GEO S5

TF plot Time-frequency plot of coincident triggers vetoed using the cross-correlation statistic

Summary

N. Trigs **5331**
Coinc **38 %**
Veto **34.5 %**

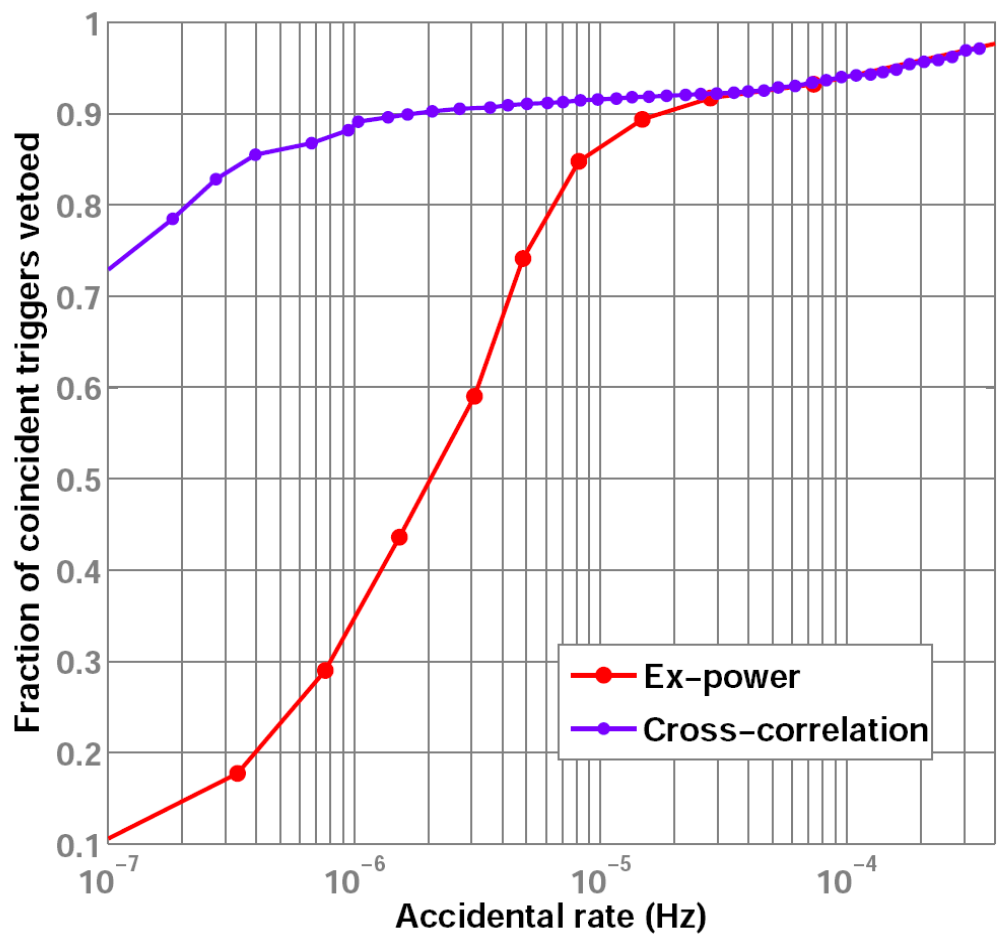


COMPARING THE TWO STATISTICS

Comparing the performance

- For this particular case, the cross-correlation statistic seems to be more powerful.

- But this depends on a number of parameters (errors in the transfer function measurements, stationarity of the noise and transfer functions etc.) and should not be taken as the general answer.



SUMMARY

- Formulated and demonstrated a veto method making use of known instrumental couplings.
- Basic idea: If a non-stationarity in the channel H is causally related to one in channel X, they have to be consistent with the transfer function from X to H.
- Tested the robustness of the veto by performing hardware injections (mimicking instrumental glitches) in GEO 600.
- The method was found to be very useful in vetoing the frequency noise glitches in the S5 run of GEO 600.