A statistical veto method employing a back-coupling consistency check

Stefan Hild, P. Ajith and M. Hewitsion
(AEI Hannover)

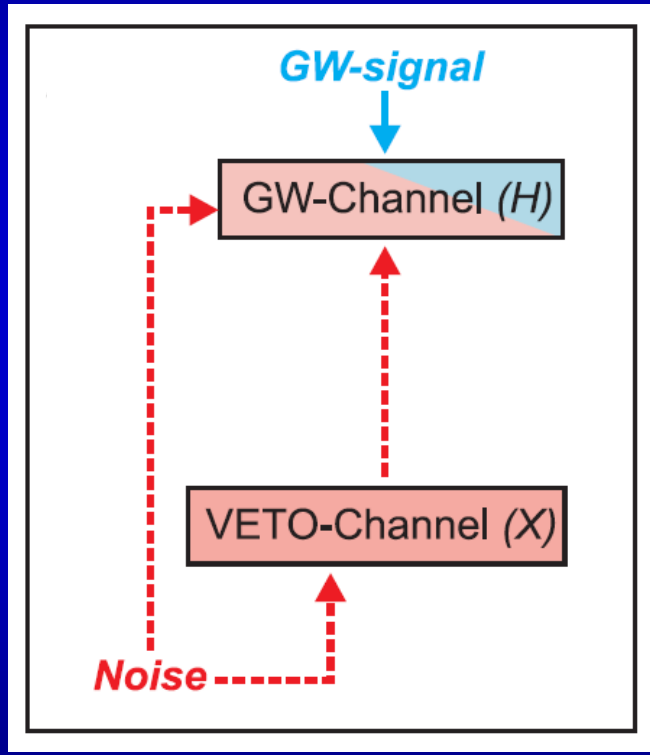
LIGO-G060641-00-Z

Standard statistical veto

- Noise couples into both: *H* and *X*
- Events in *H* are partly correlated with events in *X.*
- Veto condition: Events in H and X occure at the same time

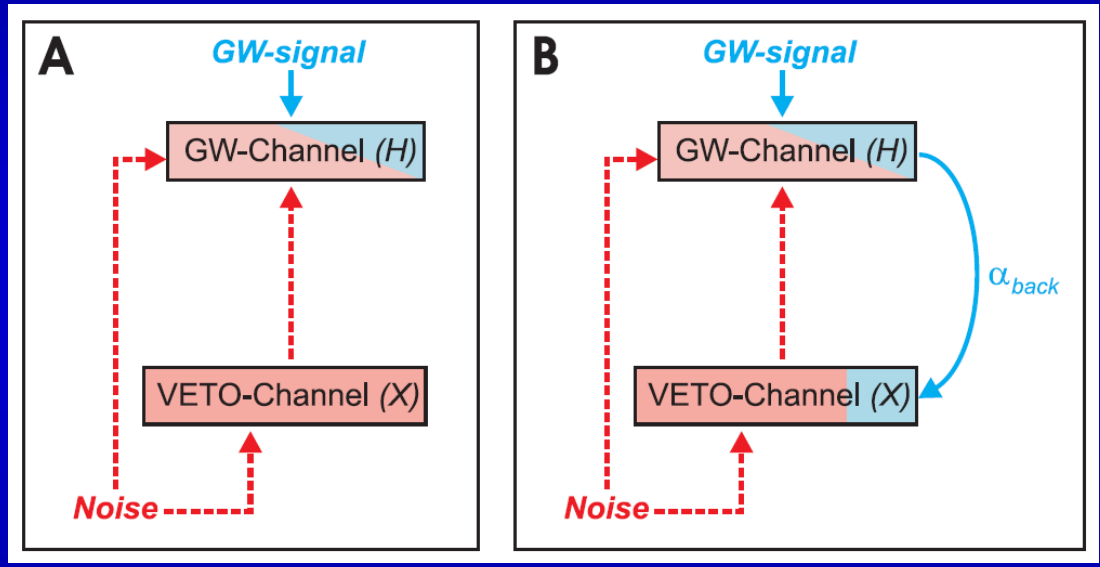
If there is any GW-signal in *X*
=> *high false veto rate*

Standard statistical veto works fine only for GW-free veto channels, like microphones or magnetometers



Veto channels containing traces of GW-signal

Unfortunately many promissing veto channels may contain traces of GW-signal, for example Interferometer signals (light powers, control signals, ...)



Two populations of coincident events:

- ***Events originating from noise*** ***(we want to veto)***
- ***GW-like events coupling back to X*** ***(we DON'T want to veto)***

Seperate two populations by amplitude ratio of the coincicent events

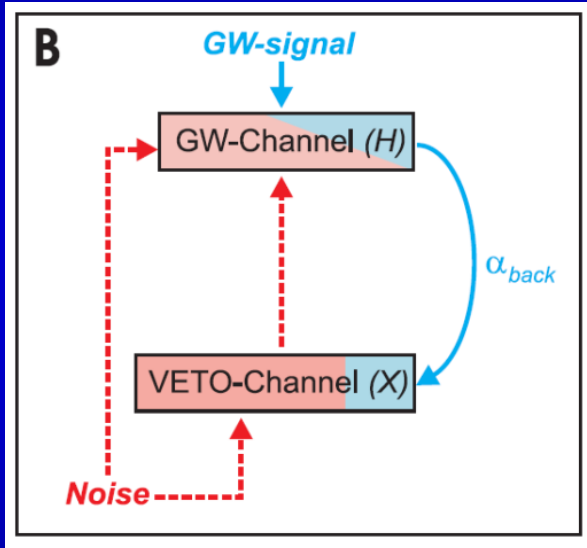
If event *X*(j) originates from the event *H*(i) their amplitude ratio has to correspond to the transfer function for back-coupling:

$$\frac{a^X[j]}{a^H[i]} = |\alpha_{\mathrm{back}}[i]|$$

In order to get a safe veto method we have to compare amplitude ratio of the two coincident events with the back-coupling transfer function:

If $\frac{a^X[j]}{a^H[i]} = |\alpha_{\mathrm{back}}[i]|$ ***H(i)* is not vetoed**

If $\frac{a^X[j]}{a^H[i]} \neq |\alpha_{\mathrm{back}}[i]|$ ***H(i)* gets vetoed !**



Real world scenario

In reality we have to allow for some inaccuracies:

- Error in the amplitude estimation of the two events $\Delta a^H[i]$ $\Delta a^X[j]$
- Error in back-coupling transfer function (measurement, non stationarity) $\Delta\alpha_{\mathrm{back}}$

Allow for overall error Δa_{tot}

VETO CONDITION

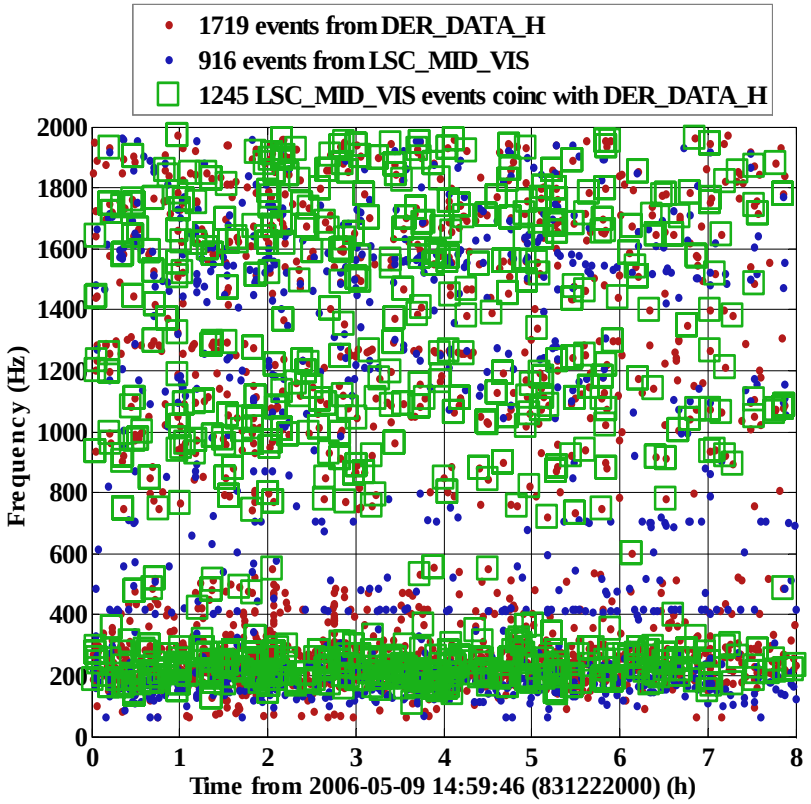
Two coincident events *H(i)* and *X(j)* are vetoed in the case that the amplitude ratio matches one of these requirements:

$$\frac{a^X[j]}{a^H[i]} < \frac{|\alpha_{\mathrm{back}}[i]|}{(1+\Delta a_{\mathrm{tot}})},$$

$$\frac{a^X[j]}{a^H[i]} > |\alpha_{\mathrm{back}}[i]|\,(1+\Delta a_{\mathrm{tot}})$$

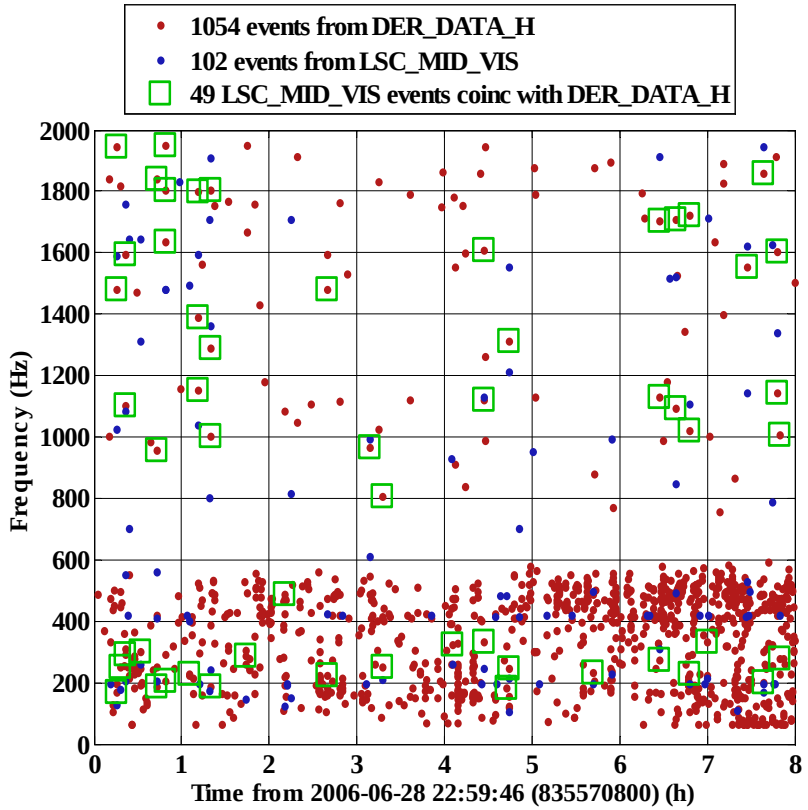
Dust falling through main output beam

high dust concentration (broken AC)



Time coincidence window = 10ms

low dust concentration



Time coincidence window = 10ms

When dust is falling through the main output beam, coincidence glitches are induced to H and P_{DC}.

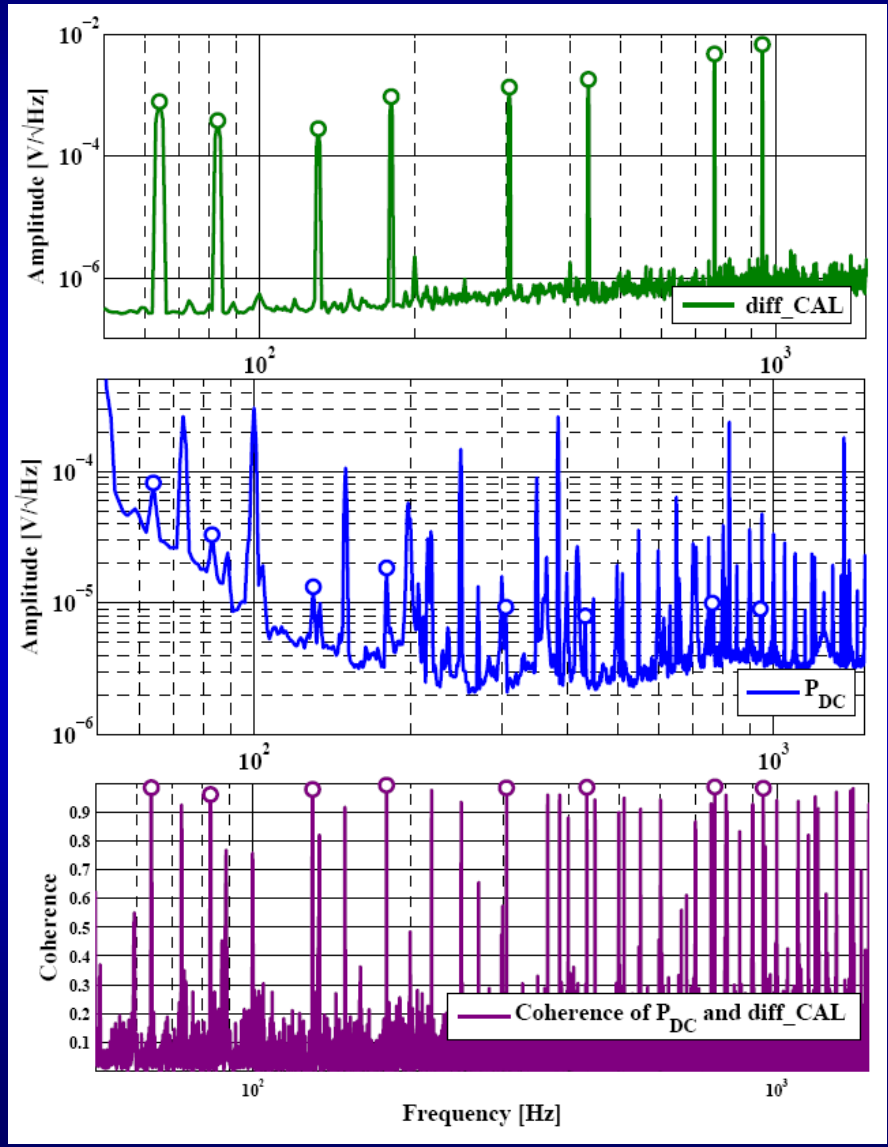
P_{DC} contains traces of GW-signal

What is P_{DC} ?

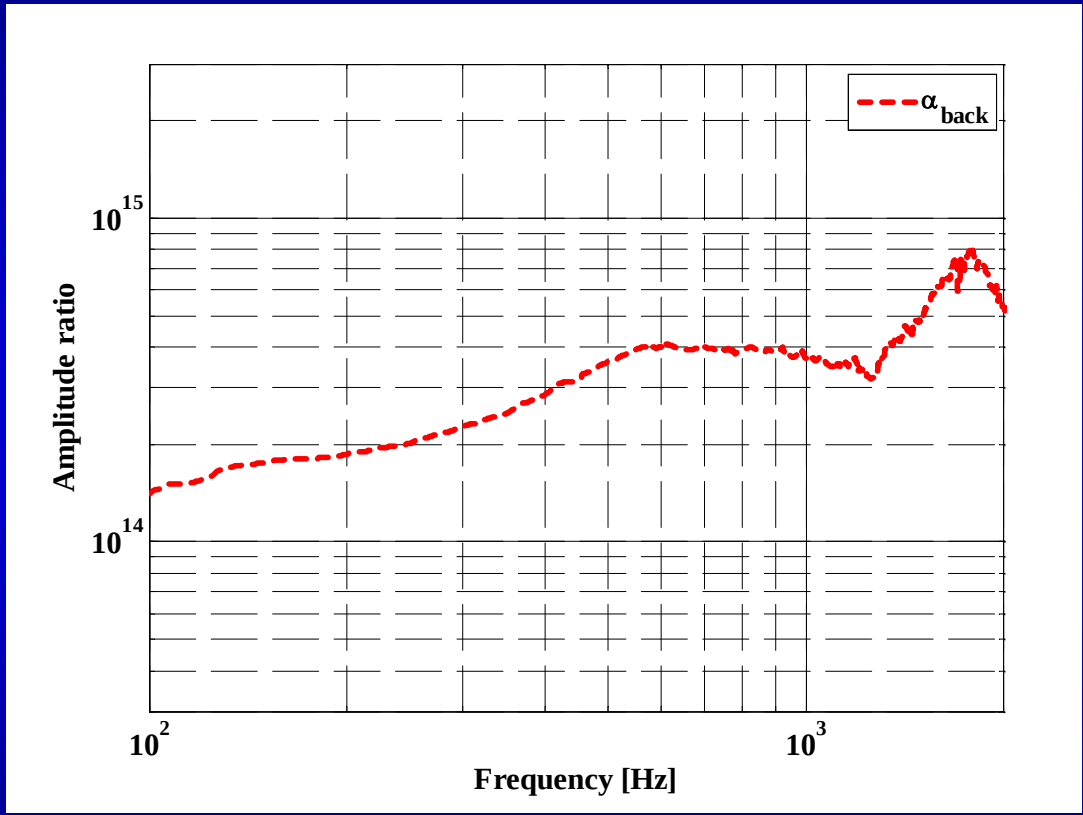
It is the DC light from the main dark port photo detector.

It contains traces of GW-signal.

Hardware injections of sinusoidal signals show coherence of 1.



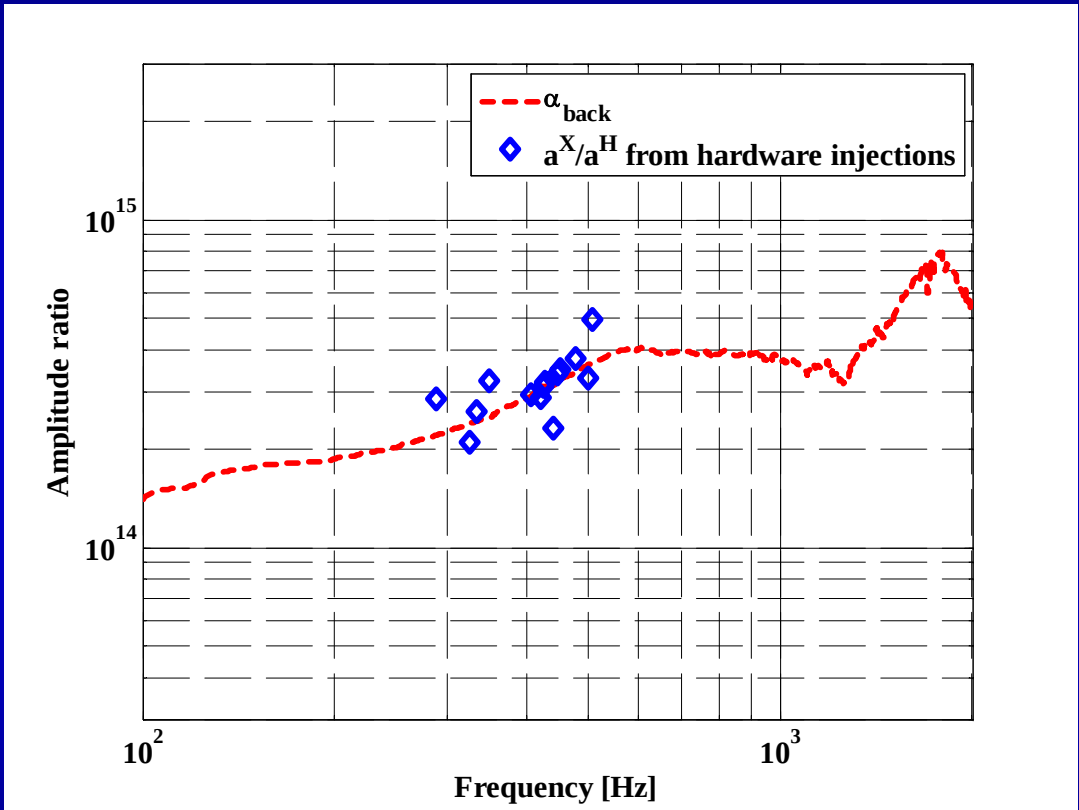
Determine back-coupling transfer function



Injecting differential arm length noise (to mimic the effect of a GW) and then measure transfer function from H to P_{DC} ?

Sine-Gaussian hardware injections

Injecting sine-Gaussians into differential arm length servo.



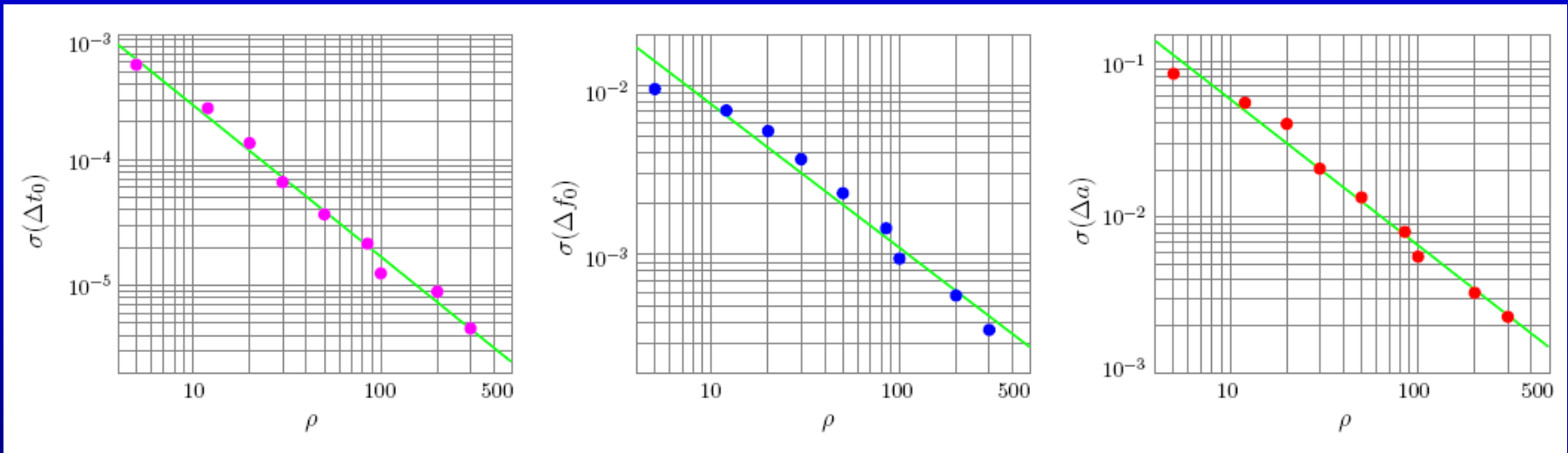
277 injections detected in ***H*** => 14 Injections also detected in P_{DC}

The injections found in P_{DC} match the back-coupling transfer function.

Determine overall error

Need to determine Δa_{tot} **!!**

1. Back-coupling TF was measured to vary less than +/-50% over months.
2. Maximum error in amplitude estimation of mHACR using 3 sigma gives 60% for events of SNR = 4
   (sine-Gaussian injections into Gaussian noise)



1. For the real data we will allow for 200% error in amplitude estimation.

Application of a statistical veto employing a back-coupling consistency check

Application to two data sets of GEO S5 data:

- Data Set 1: Full September 2006 (low dust concentration)
- Data Set 2: 8 hours from May 2006 (high dust concentration)

Final set of three veto conditions:

$$\left|t_0^X[j] - t_0^H[i]\right| < 8\,\mathrm{ms}$$

Time coincidence

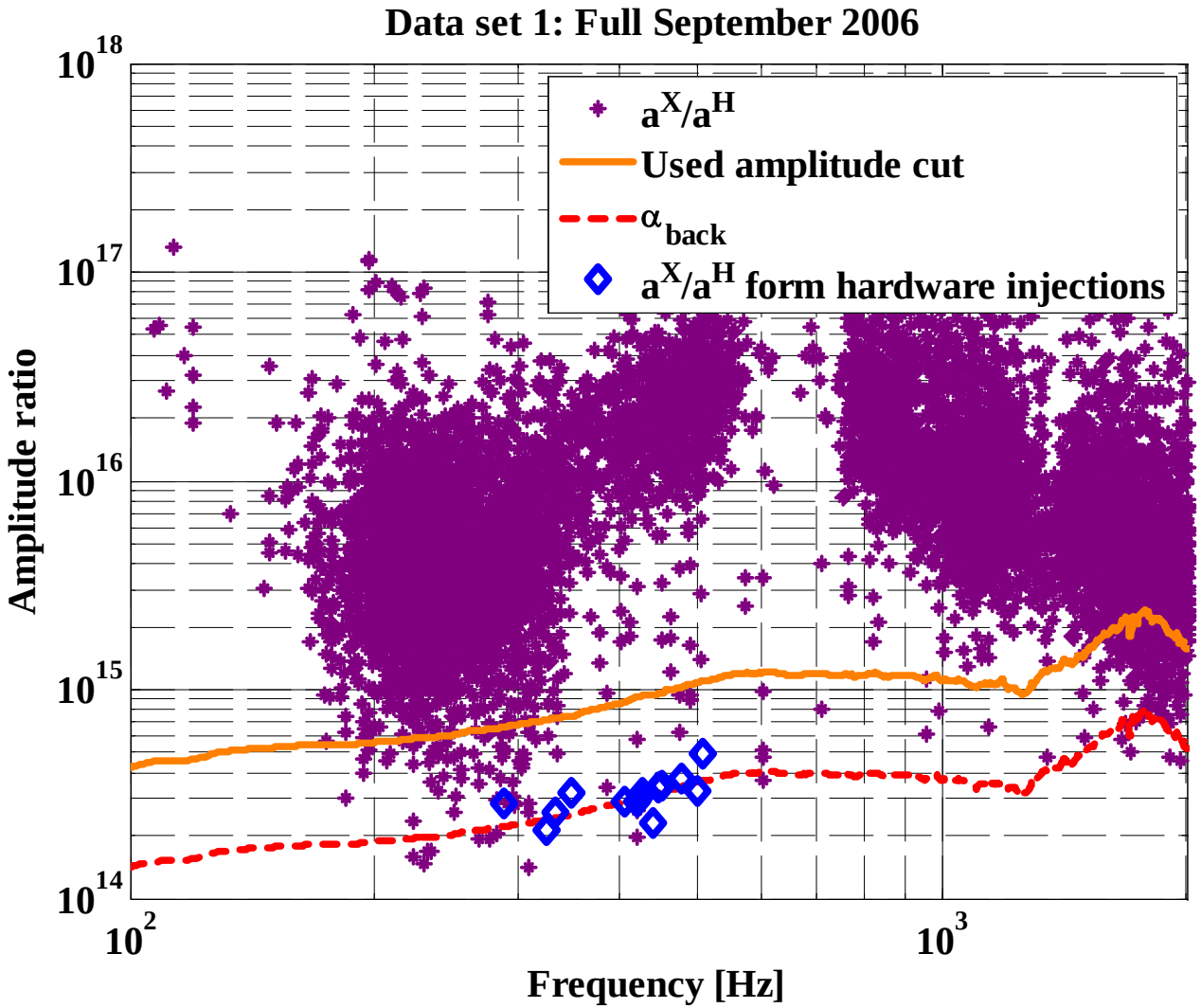
$$\left|f_0^X[j] - f_0^H[i]\right| < 1\mathrm{kHz}$$

Frequency coincidence

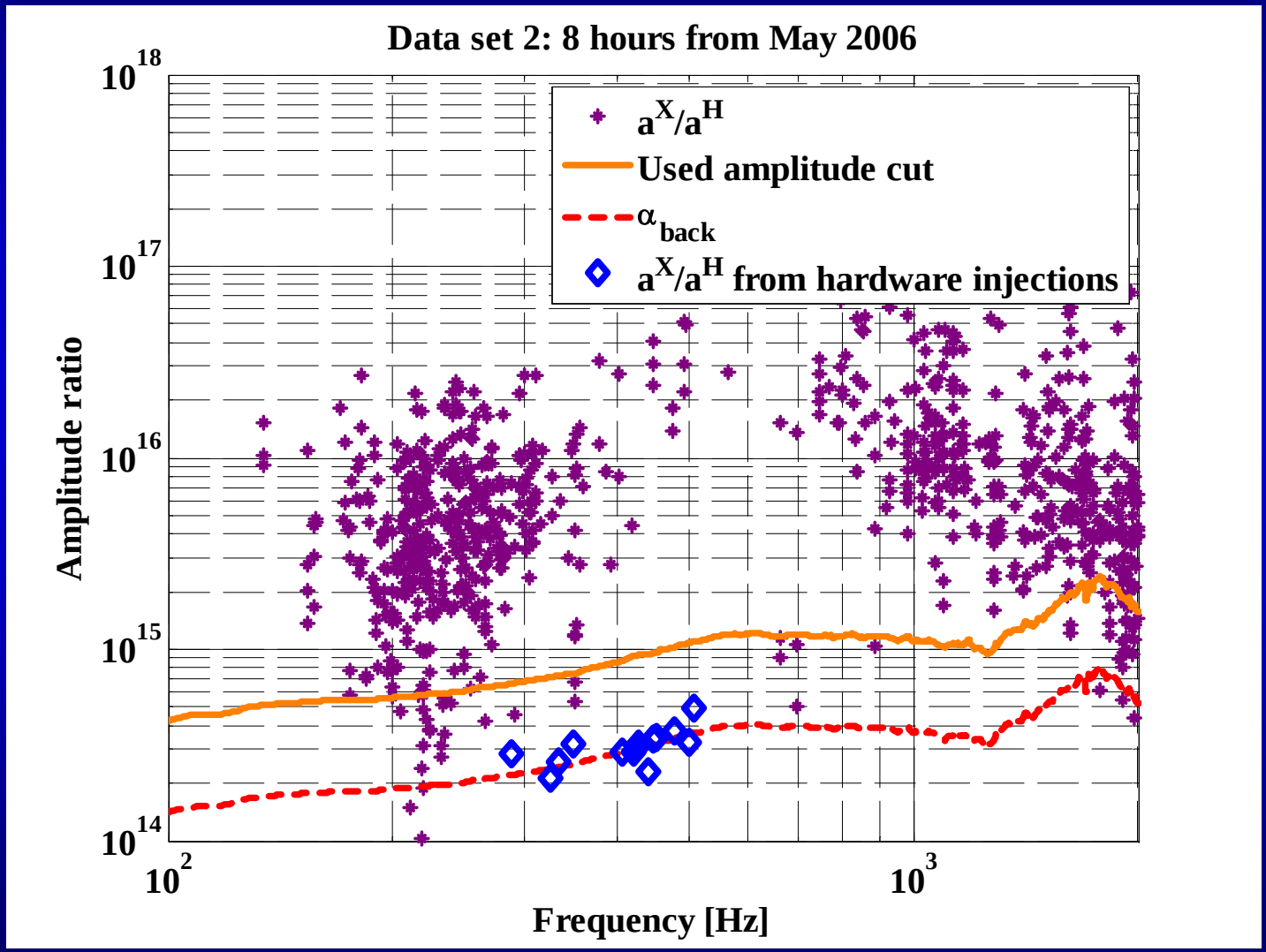
$$\frac{a^X[j]}{a^H[i]} > 3\,\alpha_{\mathrm{back}}[i]$$

Amplitude cut
(checking that the ratio is not consistent with back-coupling)

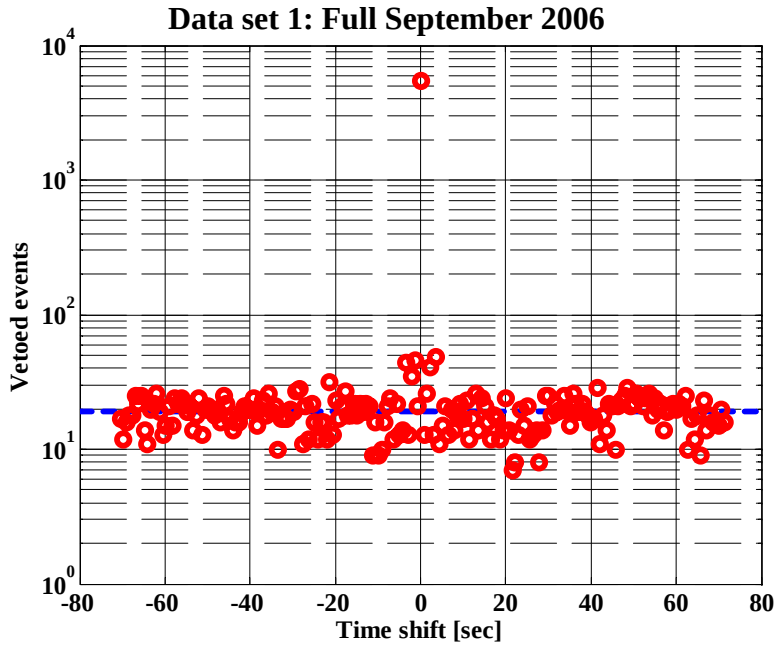
Data set 1

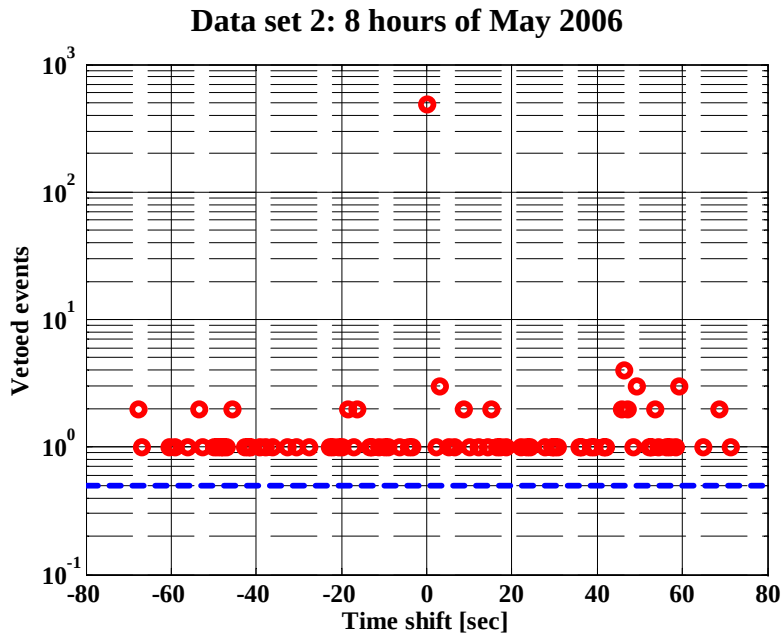

Data set 1: Full September 2006
10^{18}
10^{17}
10^{16}
10^{15}
10^{14}
Amplitude ratio
10^{2}
10^{3}
Frequency [Hz]
a^X/a^H
Used amplitude cut
α_{back}
a^X/a^H form hardware injections

Data set 2


Data set 2: 8 hours from May 2006
10^{18}
10^{17}
10^{16}
10^{15}
10^{14}
Amplitude ratio
10^{2}
10^{3}
Frequency [Hz]
a^X/a^H
Used amplitude cut
α_{back}
a^X/a^H from hardware injections

Summary of the Veto Performance





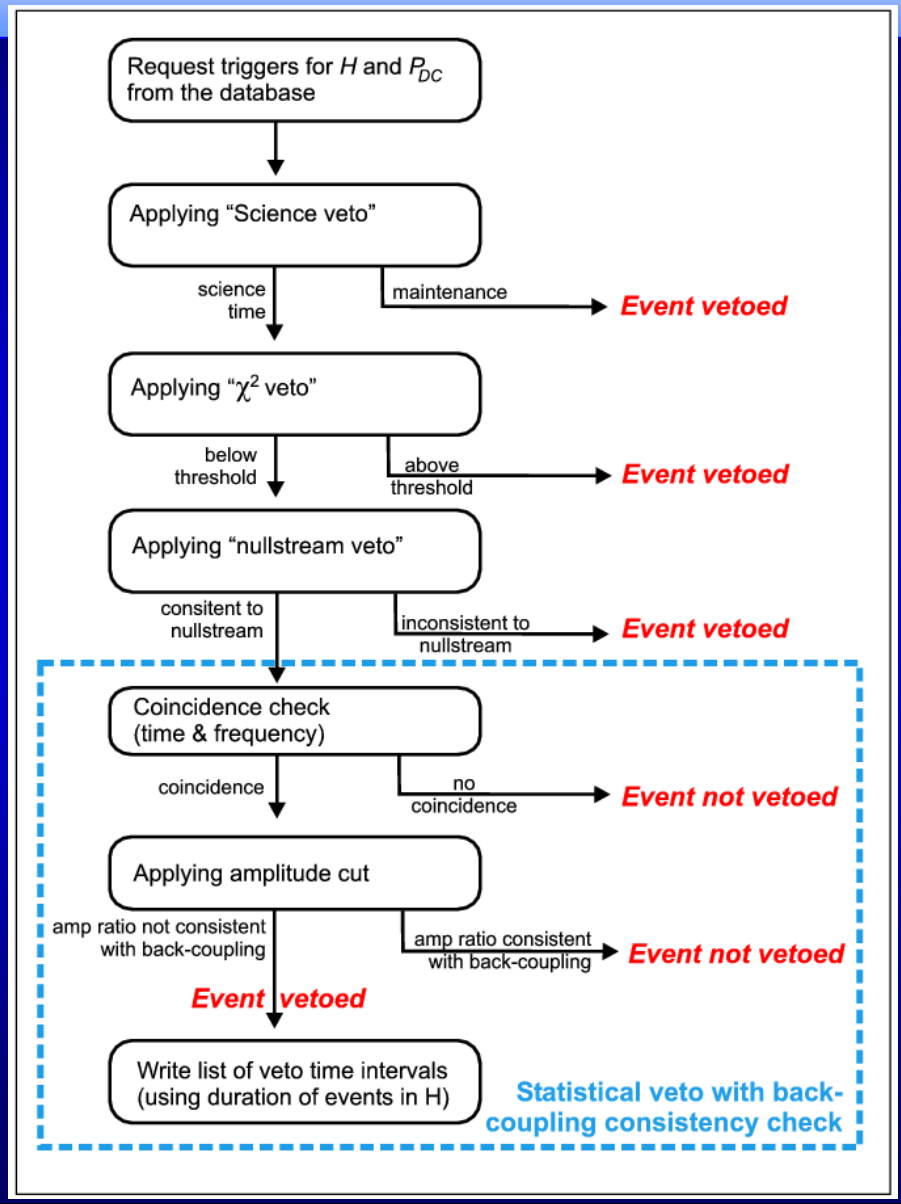
Data Set	1	2
Efficiency [%]	5.72	21.5
Background [%]	0.02	0.02
Significance	286	1075
Use-percentage [%]	20.7	79.8

Summary

- We developed a method for safe statistical vetoes using interferometer channels (potentially containing traces of GW-signal).
- This method employs an additional back-coupling consistency check.
- Application to GEO S5 data showed a good performance.
- The method is generally applicable.

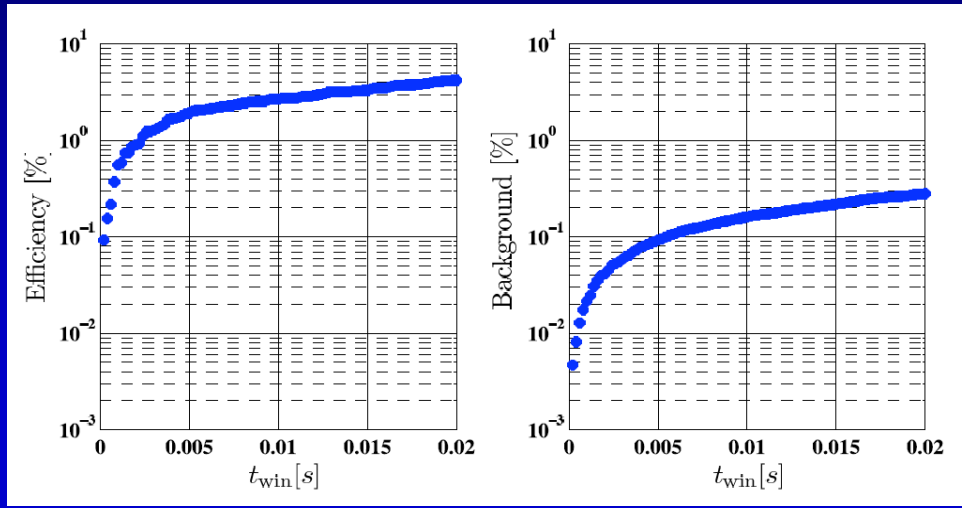
E N D

Full Veto pipeline used for Data Set 1

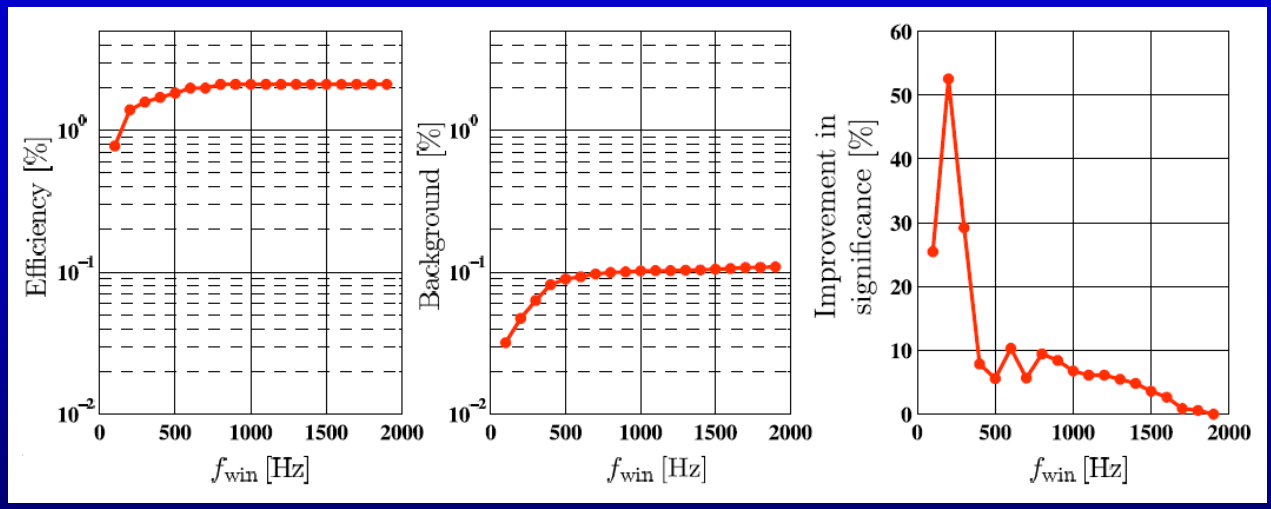


Example from GEO 600: Mains monitor

Application of a **single** co-incidence window for ***time:***



Application of a **multi** coincidence window for ***time (6ms)*** and ***frequency:***



Efficiency to Background ratio (Significance) improved !