Method for a safe statistical veto using IFO channels

Stefan Hild (AEI Hannover)

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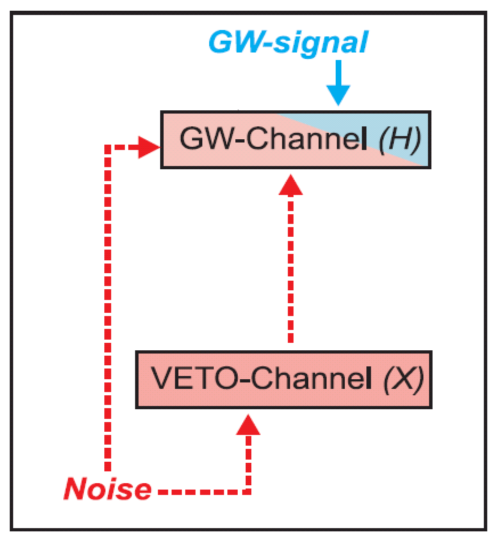
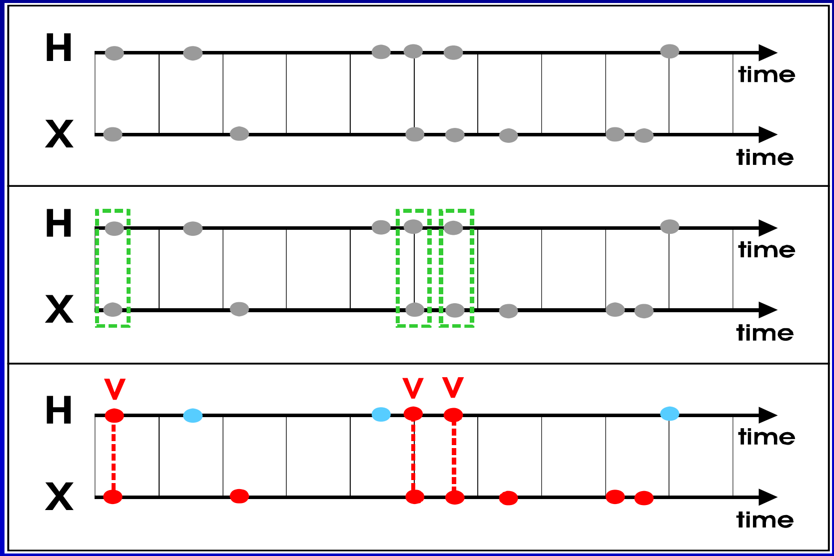
Standard statistical veto

- Events in H originate from GW and Noise (recorded in X)





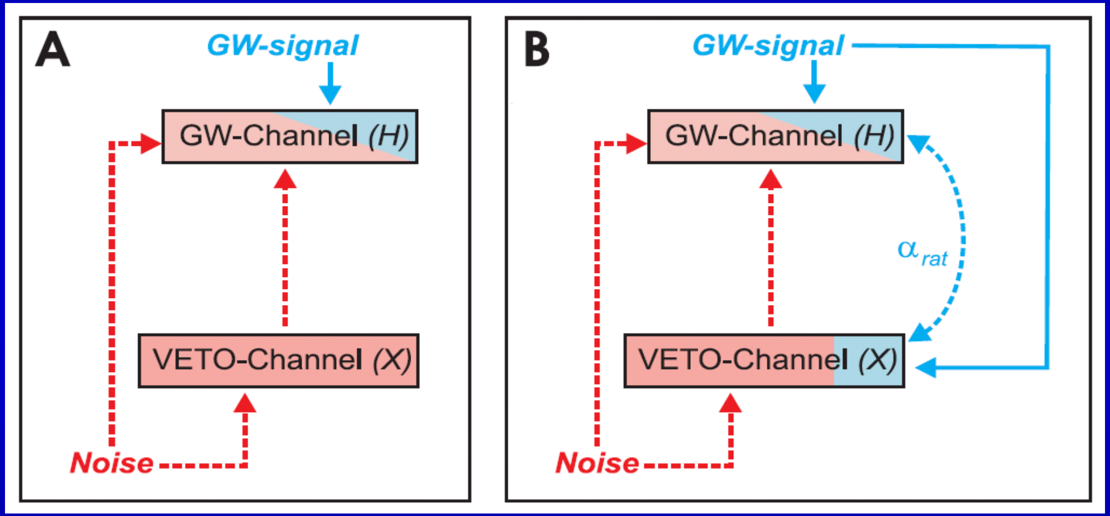
- Events in H that occur at the same time as events in X are vetoed.

$$| \, t_0^H[i] - t_0^X[j] \, | \quad < t_{\mathrm{win}}$$

- The standard statistical veto only works for veto channels containing no traces of GW signal (seismometers, microphones, magnetic field sensors, ...).

Limitations of the standard statistical veto

- As soon as X contains GW signals the application of a standard statistical veto would veto potentially real GW signals.
- Unfortunately many promising 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*** ***(we DON'T want to veto)***

Separate two populations by the amplitude ratio of the coincident events

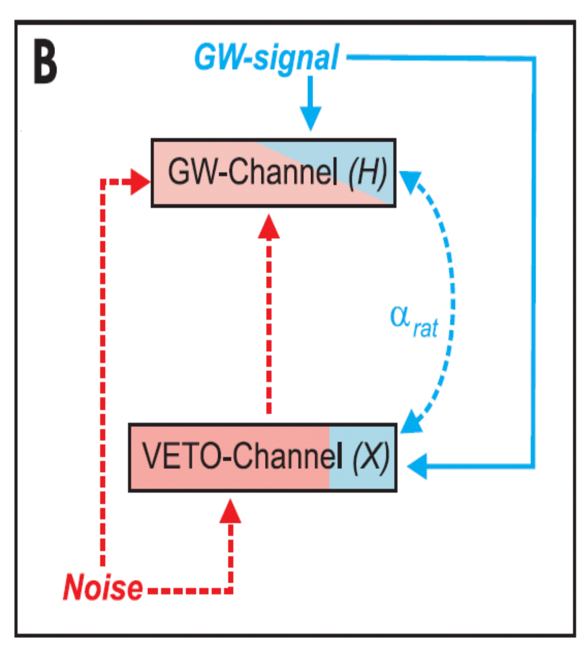
If event *X*(j) originates from the event *H*(i) their amplitude ratio has to correspond to:

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

To get a safe veto method we have to compare the amplitude ratio of the two coincident events with the amplitude ratio a GW-signal would have:

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

If $$\frac{a^X[j]}{a^H[i]} \neq |\alpha_{\mathrm{rat}}[i]|$$ ***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) $|\alpha_{\text{rat}}[i]|$

Allow for overall error Δa_{tot}

VETO CONDITION

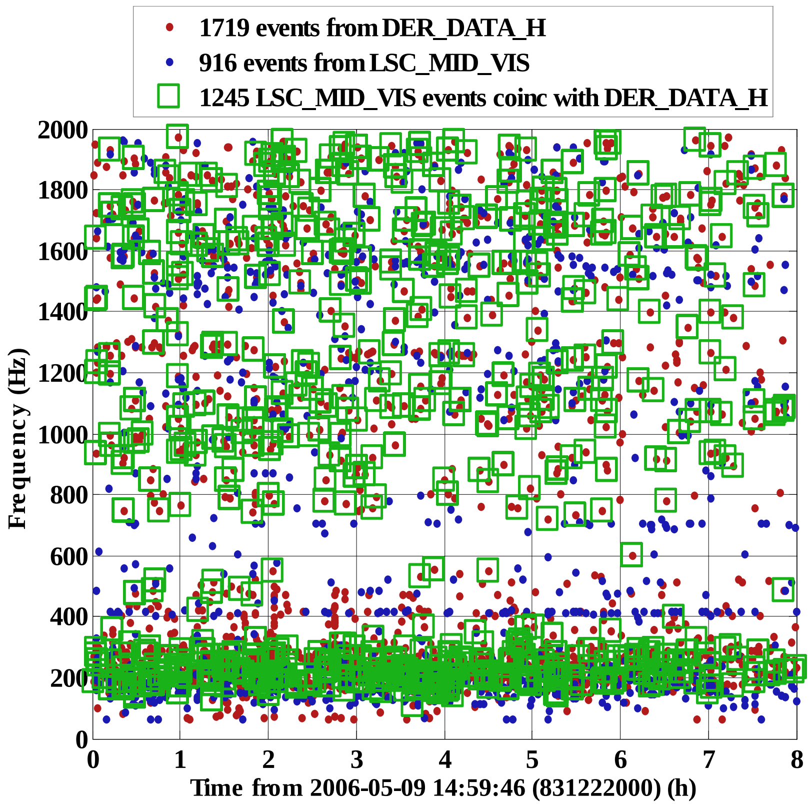
Two coincident events *H(i)* and *X(j)* are vetoed in the case that the amplitude ratio matches one of these requirements:

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

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

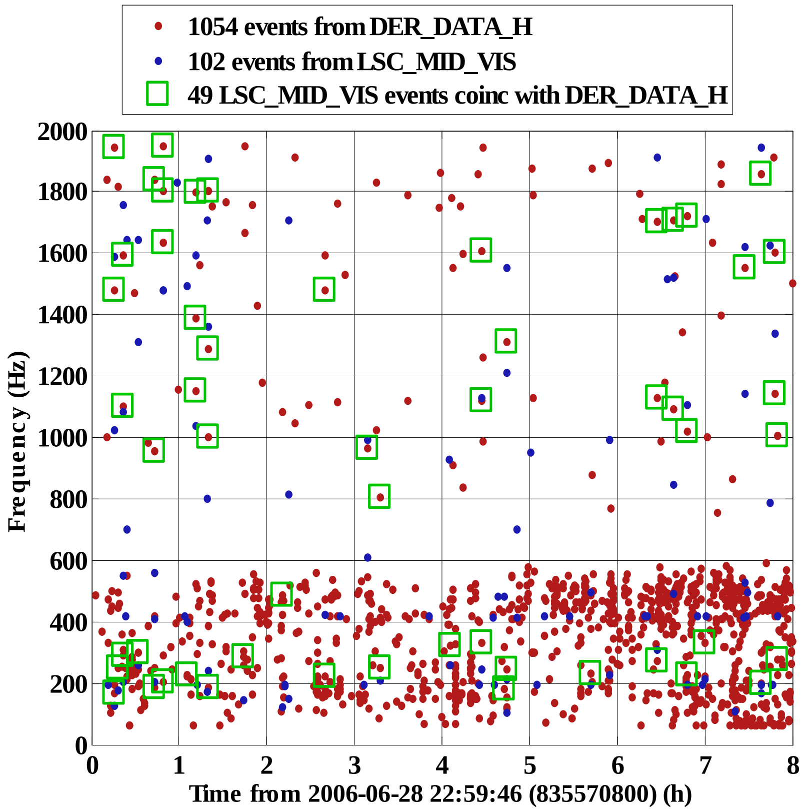
Dust falling through main output beam

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}.

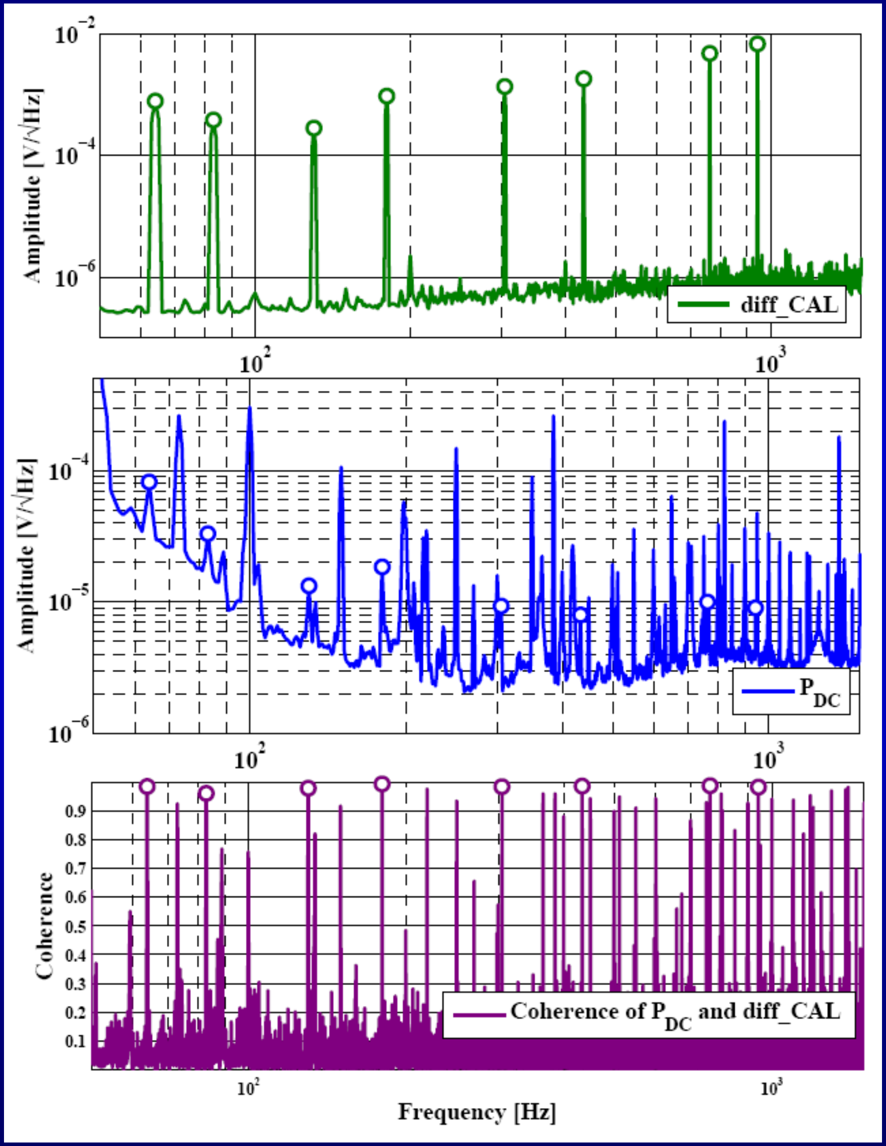
P_{DC} contains traces of GW-signal

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.



Application of the method (Example: ‚Dust-Veto‘)

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

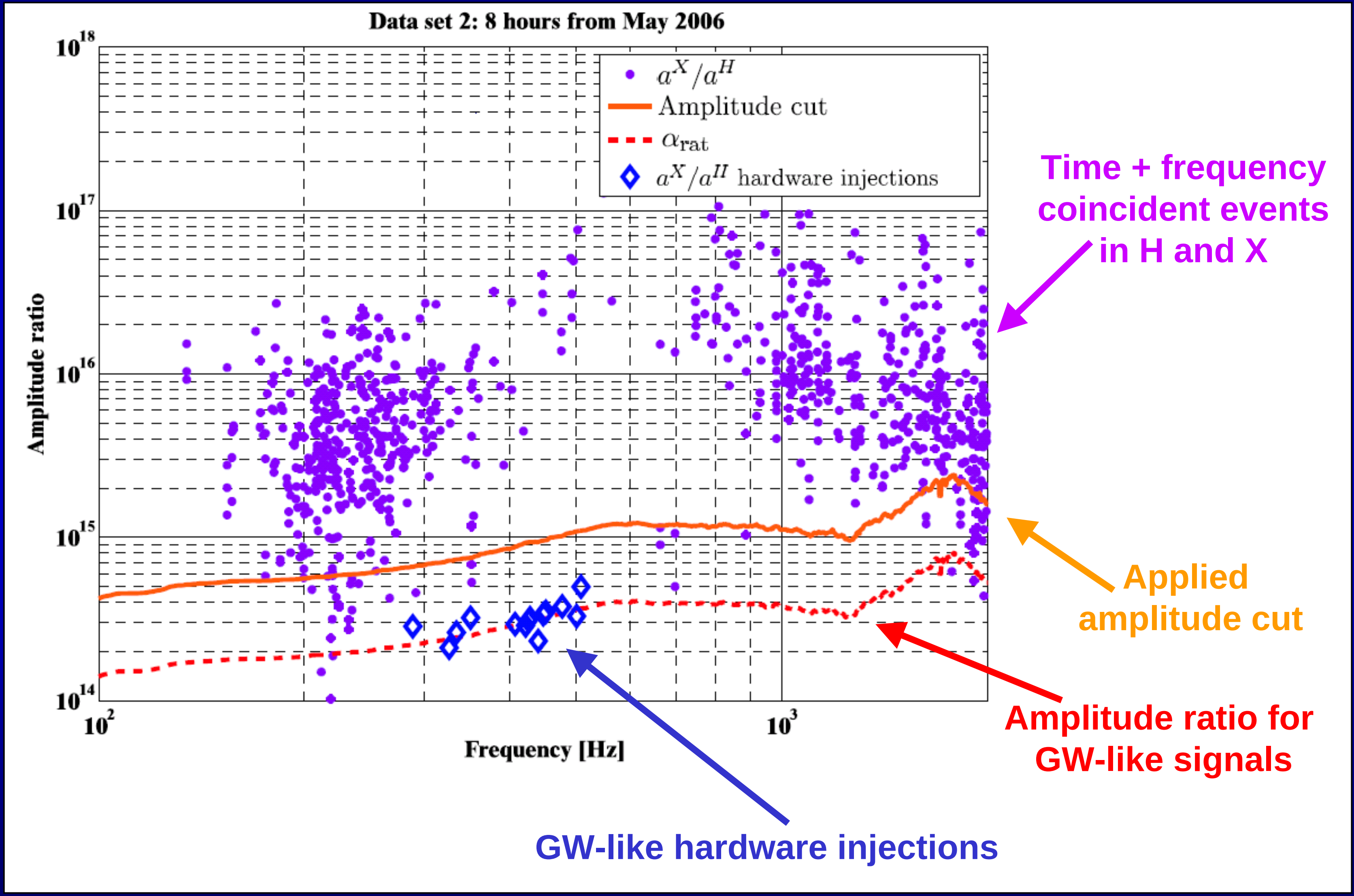
$$\left|f_0^X[j] - f_0^H[i]\right| < 1\mathrm{kHz}$$

Frequency coincidence

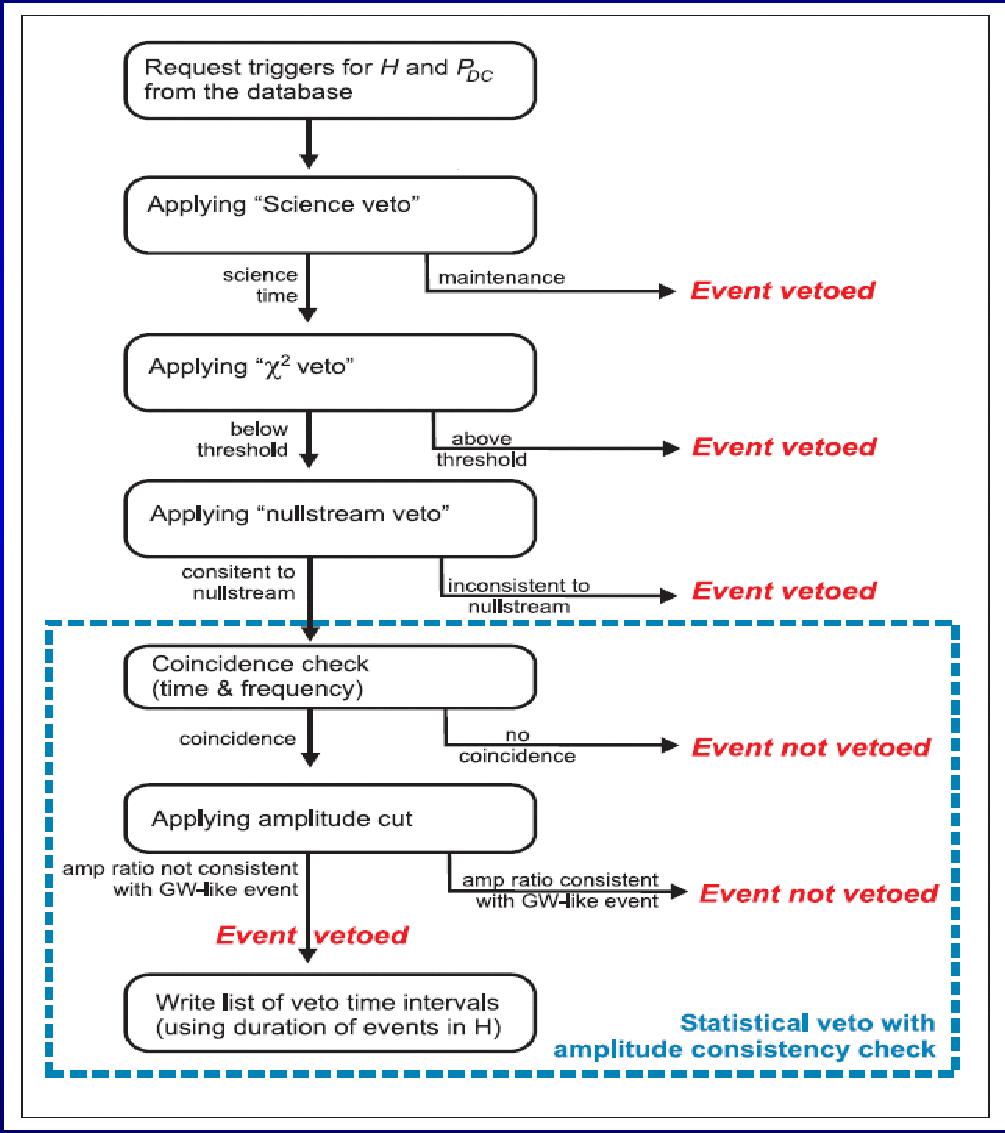
$$\frac{a^X[j]}{a^H[i]} > 3\,\alpha_{\mathrm{rat}}[i]$$

Amplitude cut
(amplitude consistency check)

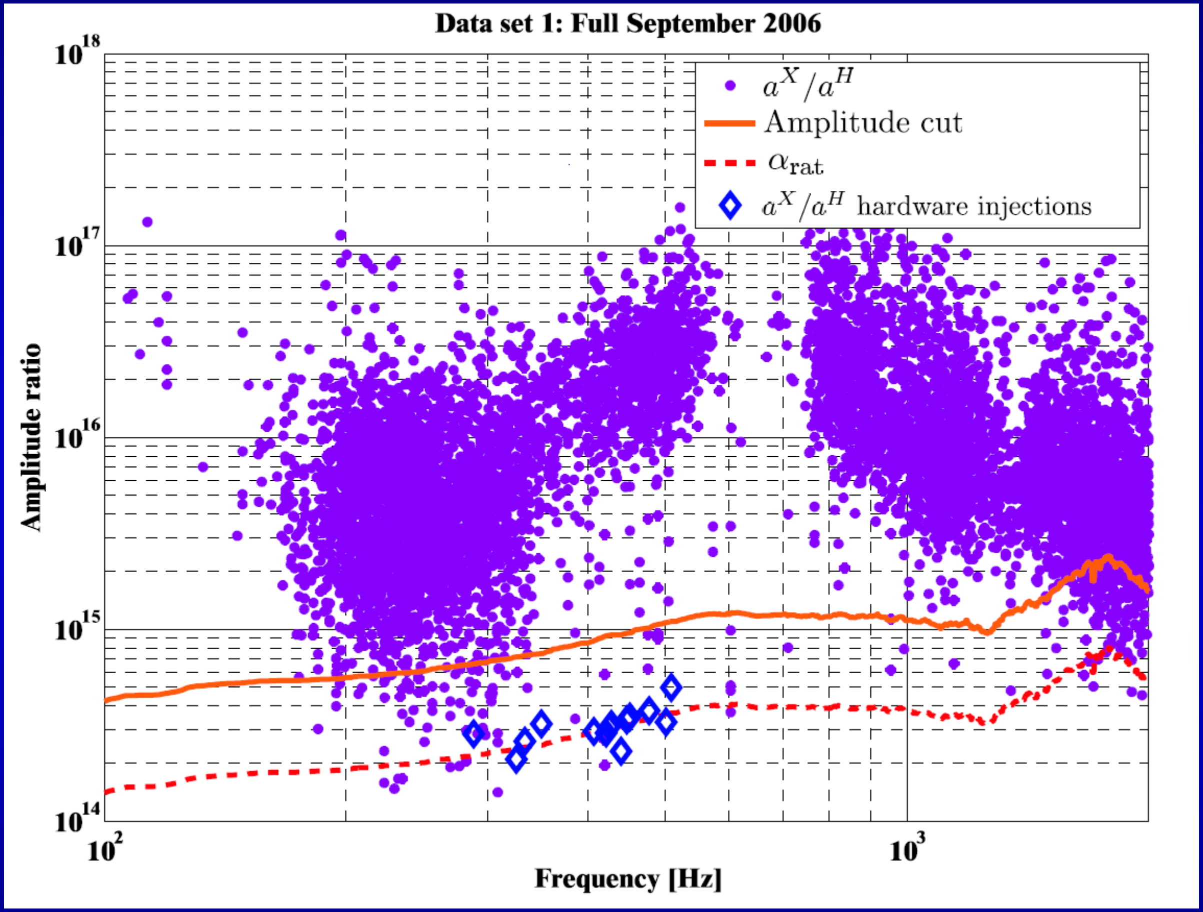
Dust-Veto: High dust concentration period (Data set 2)



Full veto pipeline (for GEO S5 data)



Dust-Veto: Low dust concentration period (Data set 1)

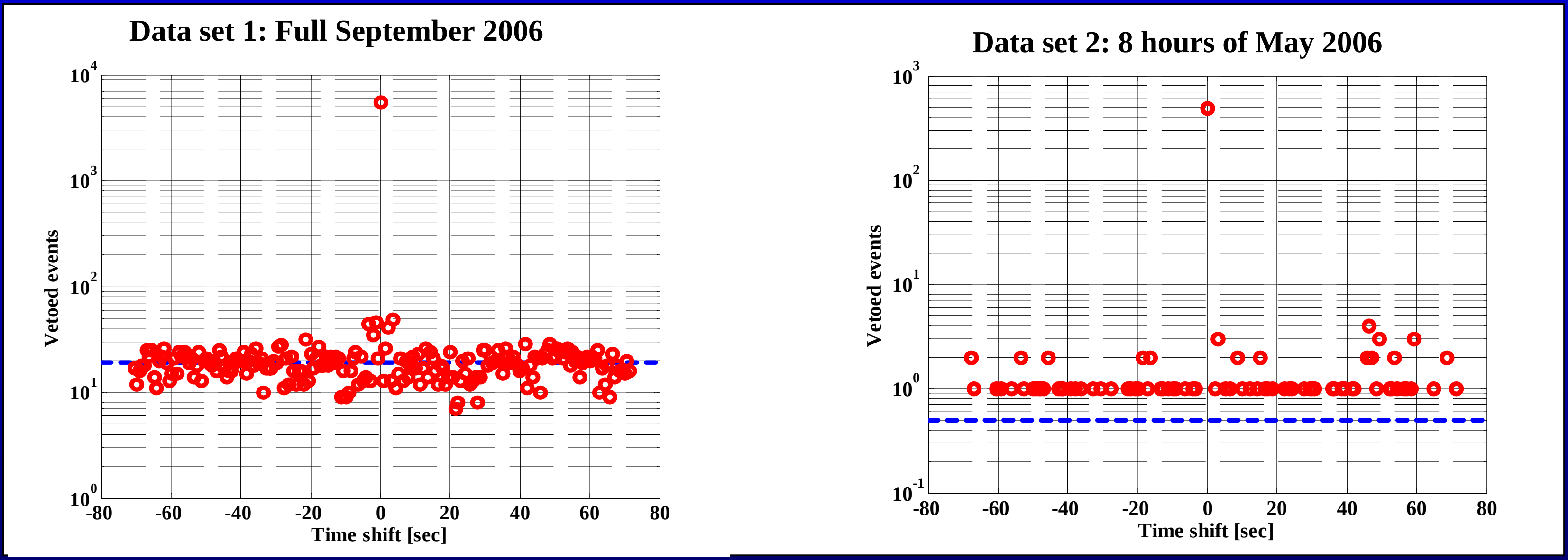


Application to S5 data from GEO600 gives encouraging results.

Summary of the veto performance

Data Set	1	2
Total number of events in H	96454	2281
Total number of events in $\mathcal{P}_{\mathrm{DC}}$	26600	615
Event rate in $H[\mathrm{h}^{-1}]$	134	285
Event rate in $\mathcal{P}_{\mathrm{DC}}[\mathrm{h}^{-1}]$	37	77
Number of events vetoed	5517	491
Efficiency [%]	5.72	21.5
Background [%]	0.02	0.02
Significance	286	1075
Use-percentage [%]	20.7	79.8

S. Hild et al: „A statistical veto employing an amplitude consistency check " , submitted to Class. Quantum Grav.



This new method is easily applicable for all other GW detectors.

Short reciepe for statistical veto with amplitude consistency check

Is there a promising IFO channel ***X*** showing coincidence events with GW channel ?

no

No veto

yes

Check if ***X*** contains traces of GW signal (using differential armlength actuators)

no

Safe to apply Standard staistical veto

yes

Measure $|\alpha_{\mathrm{rat}}[i]|$ many times (different timescales).

Non stationary

No veto

stationary

Evaluate Δa_{tot} .

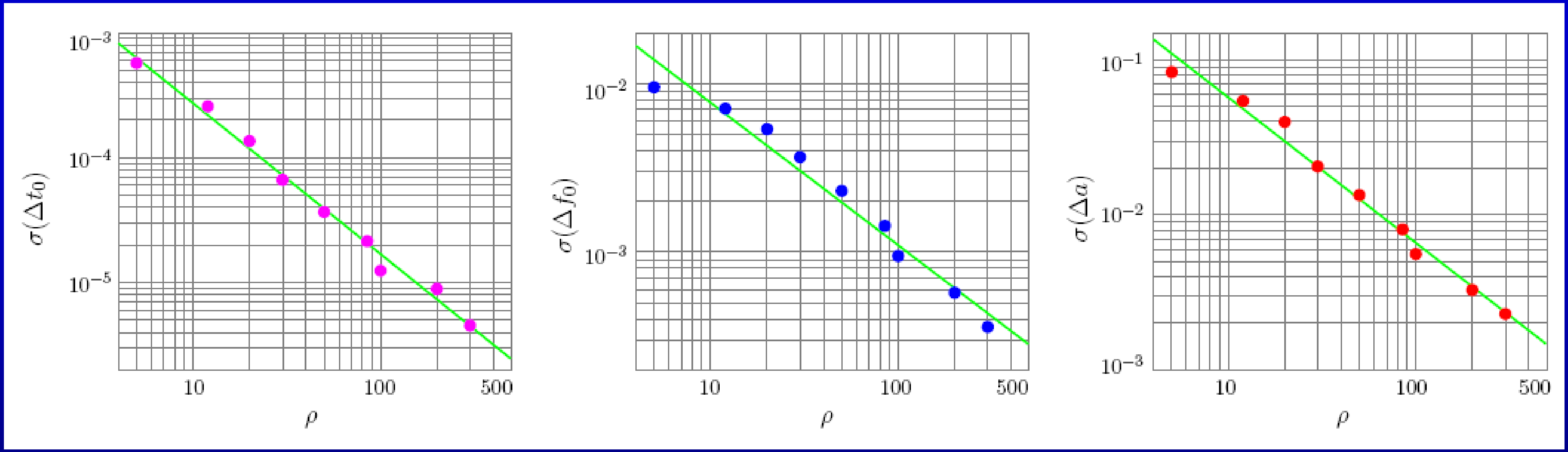
Define amplitude cut.

END

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)



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