Search for Gravitational Wave Bursts in Data from the LIGO S4 Run

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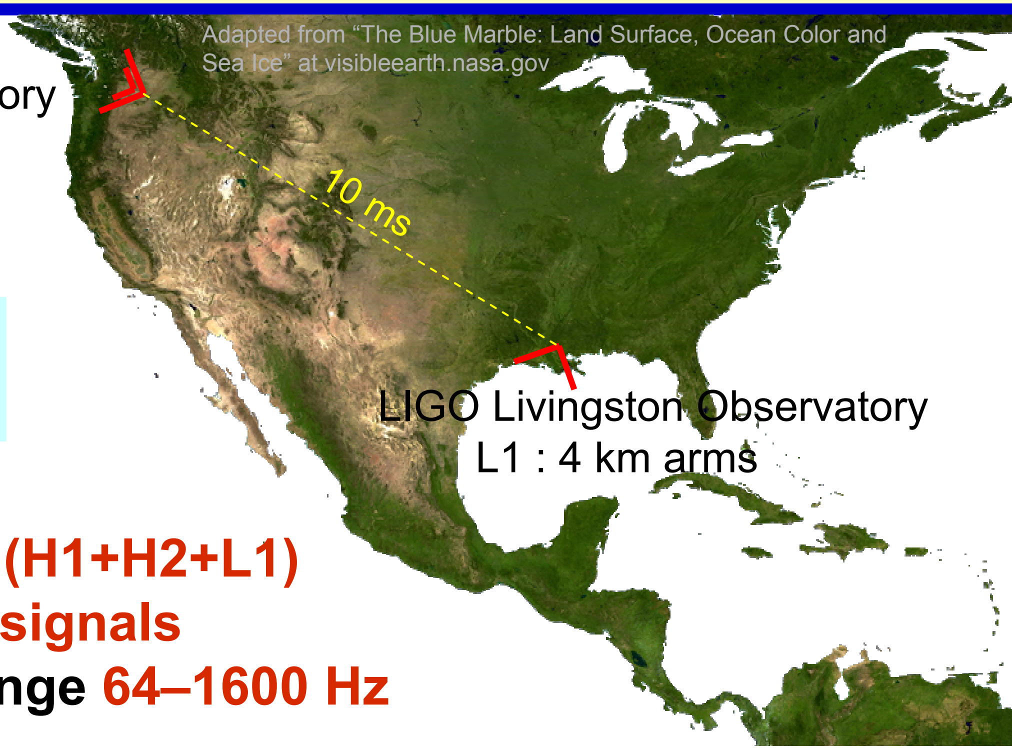
APS Meeting
April 25, 2006

LIGO-G060041-02-Z

Overview of the Search

LIGO Hanford Observatory
H1 : 4 km arms
H2 : 2 km arms



Target: gravitational wave signals of arbitrary form

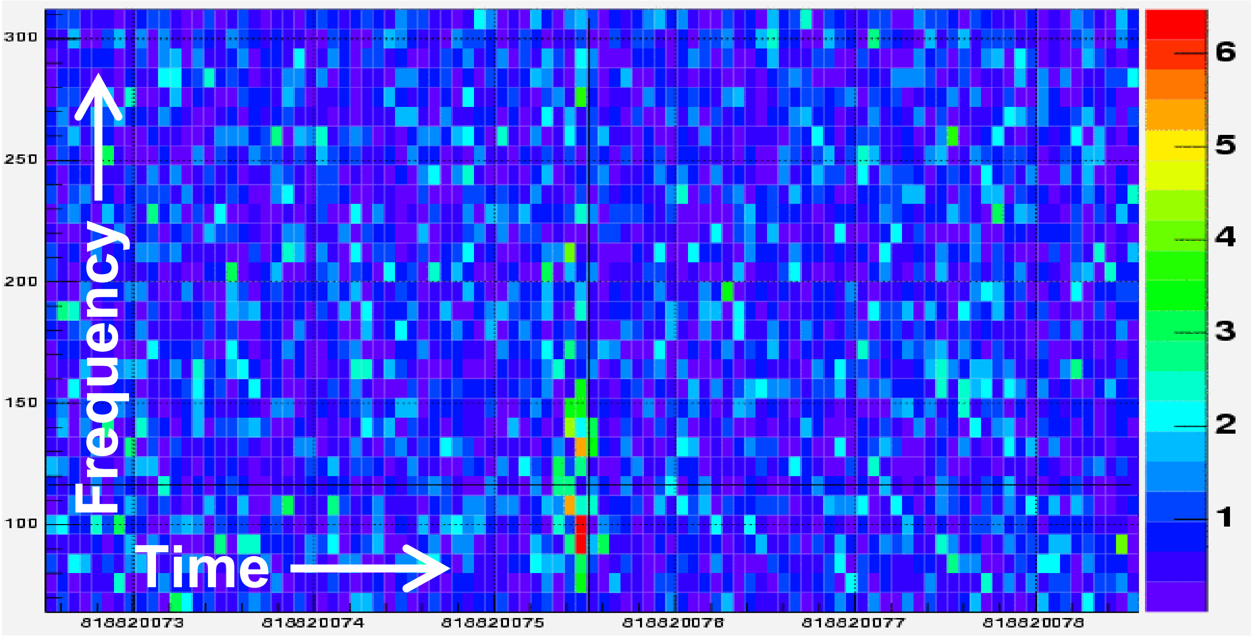
- **Searched triple-coincidence (H1+H2+L1) LIGO data for short (<1 sec) signals with frequency content in range 64–1600 Hz**
- **Used WaveBurst to generate *triggers* at times with excess power in data streams, followed by CorrPower cross-correlation tests**
- **Applied Data quality cuts, significance cuts and veto conditions**
- **Preliminary results being presented today**

WaveBurst Trigger Generation

WaveBurst processed all 3 GW data channels simultaneously

When all 3 interferometers “locked” and in “science mode” configuration

Wavelet decomposition from 64–2048 Hz



WaveBurst Trigger Generation

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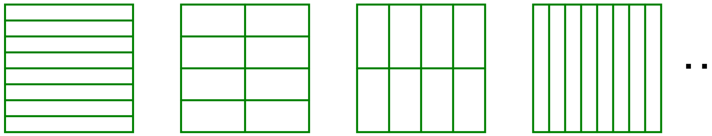
- When all 3 interferometers "locked" and in "science mode" configuration
- Wavelet decomposition from 64–2048 Hz with 6 different resolutions from 1/16 sec × 8 Hz to 1/512 sec × 256 Hz



- Pixel power thresholding, cross-stream pixel coincidence, clustering
- Signal parameter estimation: time, duration, frequency, amplitude

Found coincident clusters for true time series plus 98 time shifts

- Hanford-Livingston relative times shifted by multiples of 3.125 sec
- Used to study / estimate background

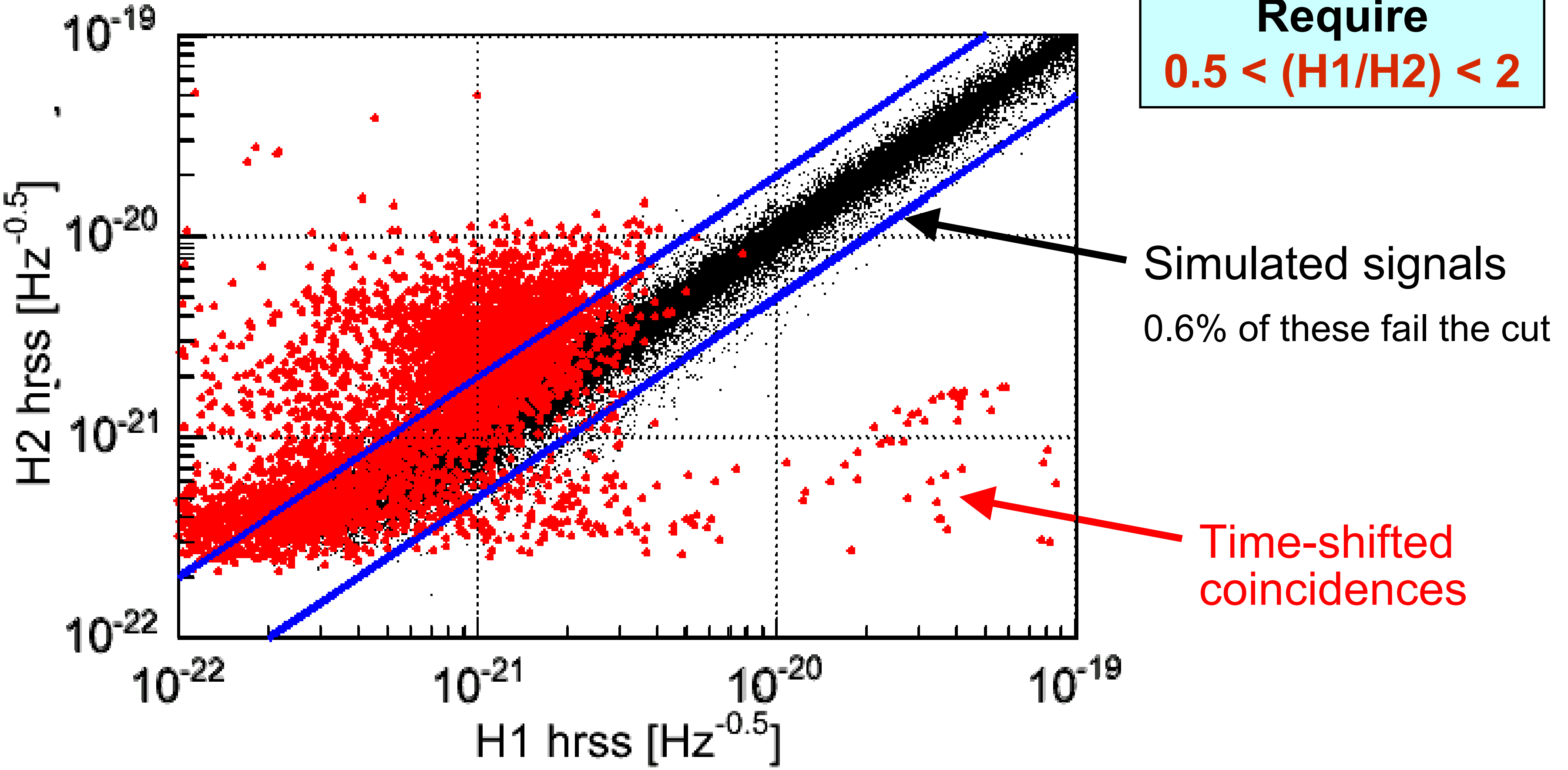
Initial cluster significance parameter cut: GC>2.9
& frequency content cut: Require to overlap 64–1600 Hz band

H1/H2 Amplitude Consistency Cut

Based on calibrated h_{rss} estimated by WaveBurst

$$h_{\mathrm{rss}} \equiv \sqrt{\int (|h_+(t)|^2 + |h_\times(t)|^2)\,dt}$$

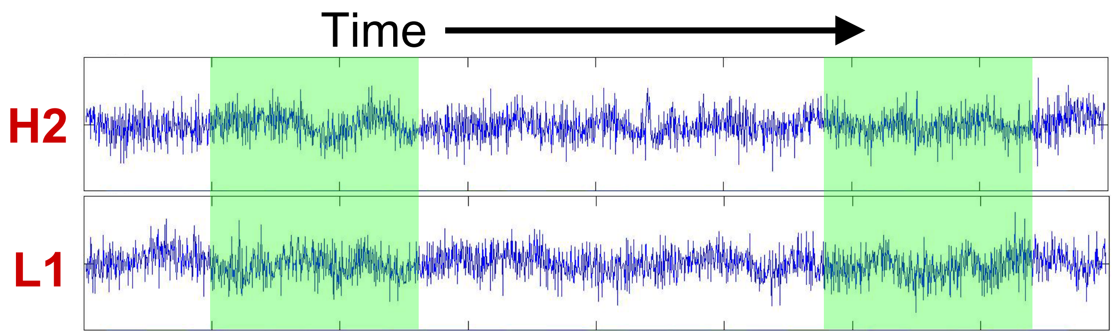
Require
0.5 < (H1/H2) < 2



Cross-Correlation Tests

CorrPower run on raw data at times of WaveBurst triggers

- Calculates normalized cross-correlations (***r*-statistic**) for pairs of detectors
- Integration window lengths: 20, 50, 100 ms
- Relative time shifts: up to 11 ms for H1-L1 and H2-L1



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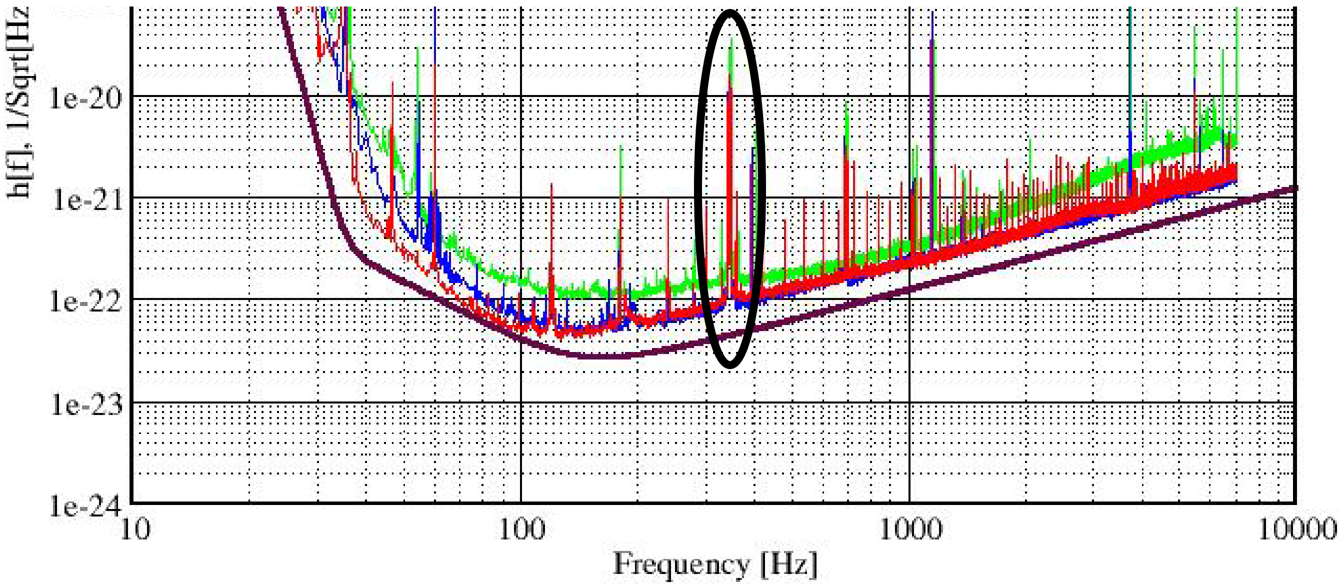
Data conditioning

Bandpass filtered and whitened

Notch filter applied around 345 Hz to avoid violin modes



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Statistics calculated by CorrPower

R0 : signed correlation of H1 and H2 with zero relative time shift

Require R0 to be positive

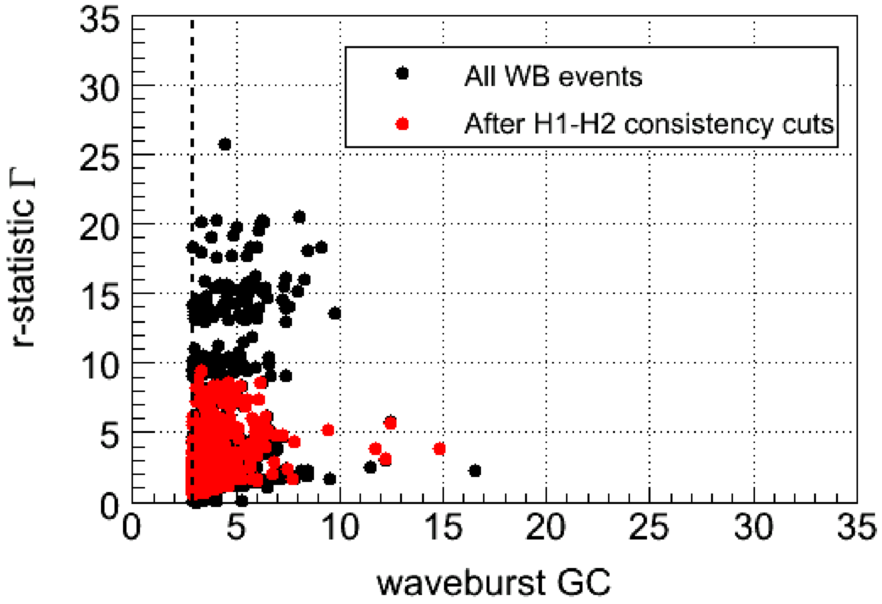
Gamma : mean of three pairwise correlation confidences

Data Quality Cuts

Various environmental and instrumental conditions catalogued; studied relevance using *time-shifted* coincident triggers

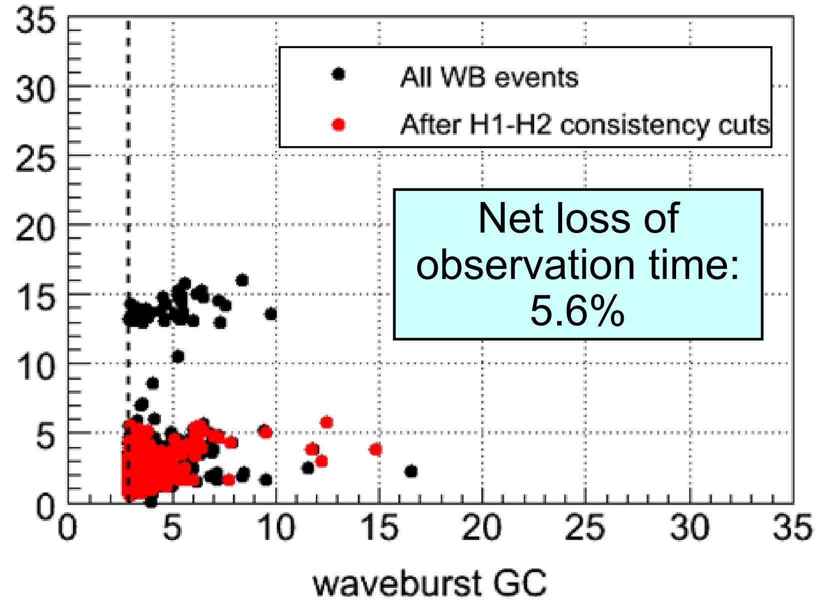
Minimal data quality cuts

Require locked interferometers
Omit hardware injections
Avoid times of ADC overflows



Additional data quality cuts

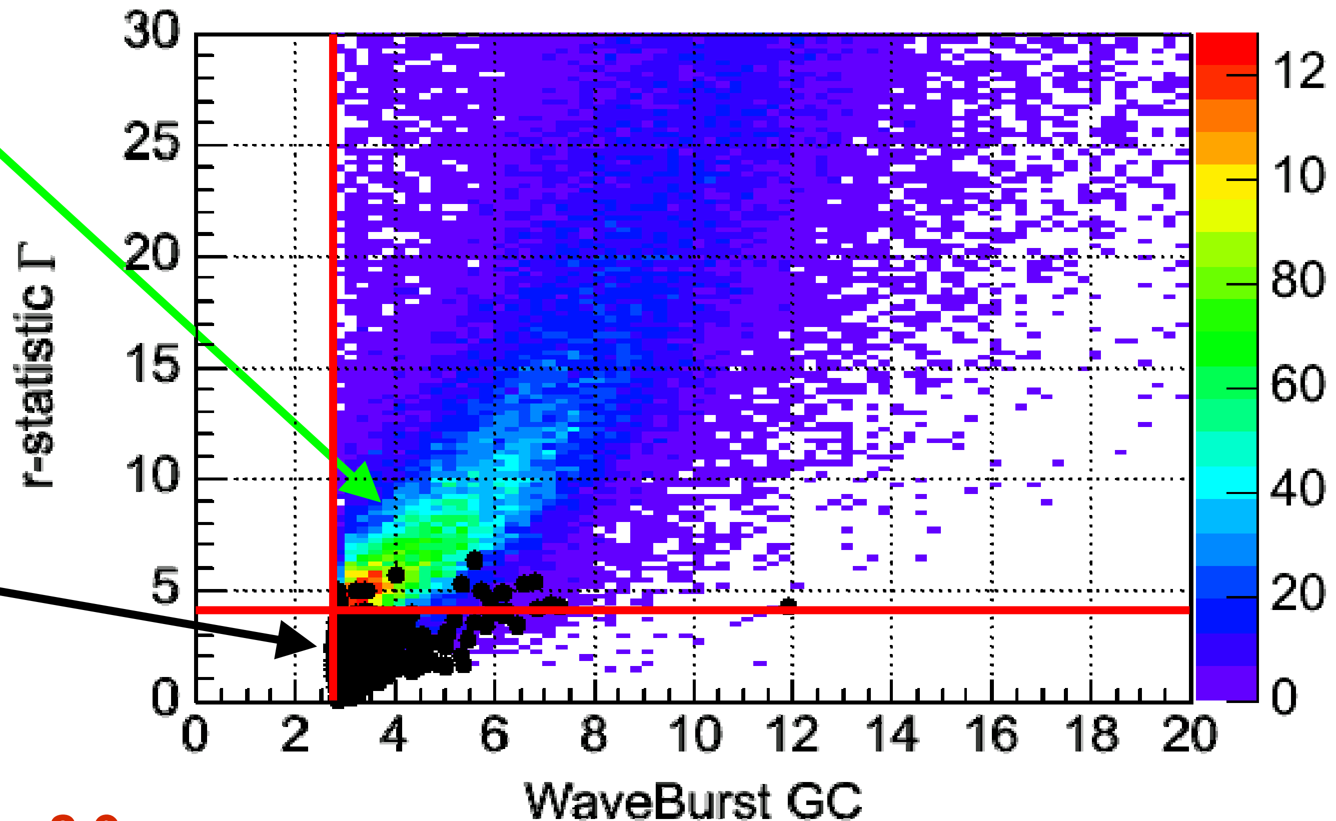
Avoid high seismic noise, wind, jet
Avoid calibration line drop-outs
Avoid times of "dips" in stored light
Omit last 30 sec of each lock



Choice of Final Significance Cuts

Simulated signals

Time-shifted coincidences
(100 shifts, multiples of 5 sec)



Final choices:
WaveBurst GC > 2.9
CorrPower *r*-statistic Gamma > 4

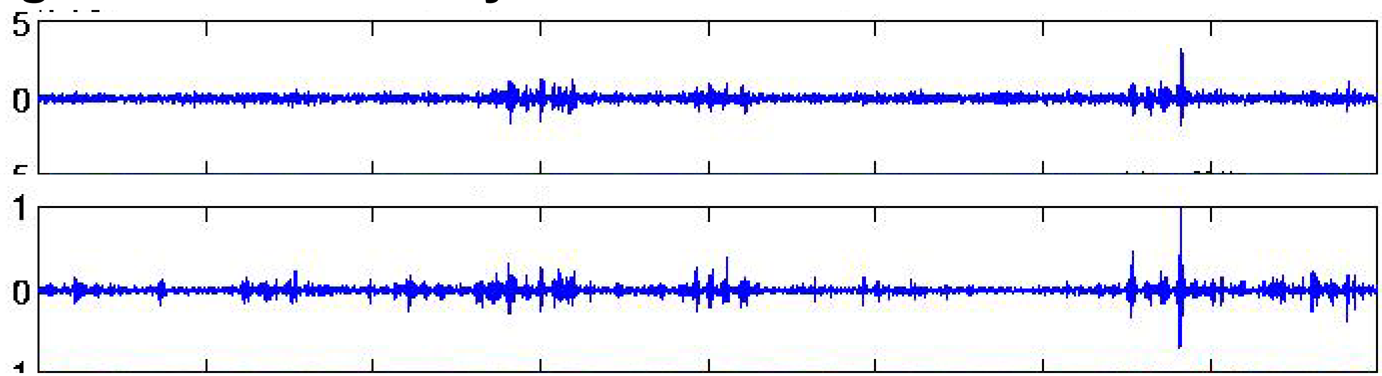
Chosen to make expected background low, but not zero

Auxiliary-Channel Vetoes

Check for glitches in auxiliary channels

GW channel

Beam splitter pick-off



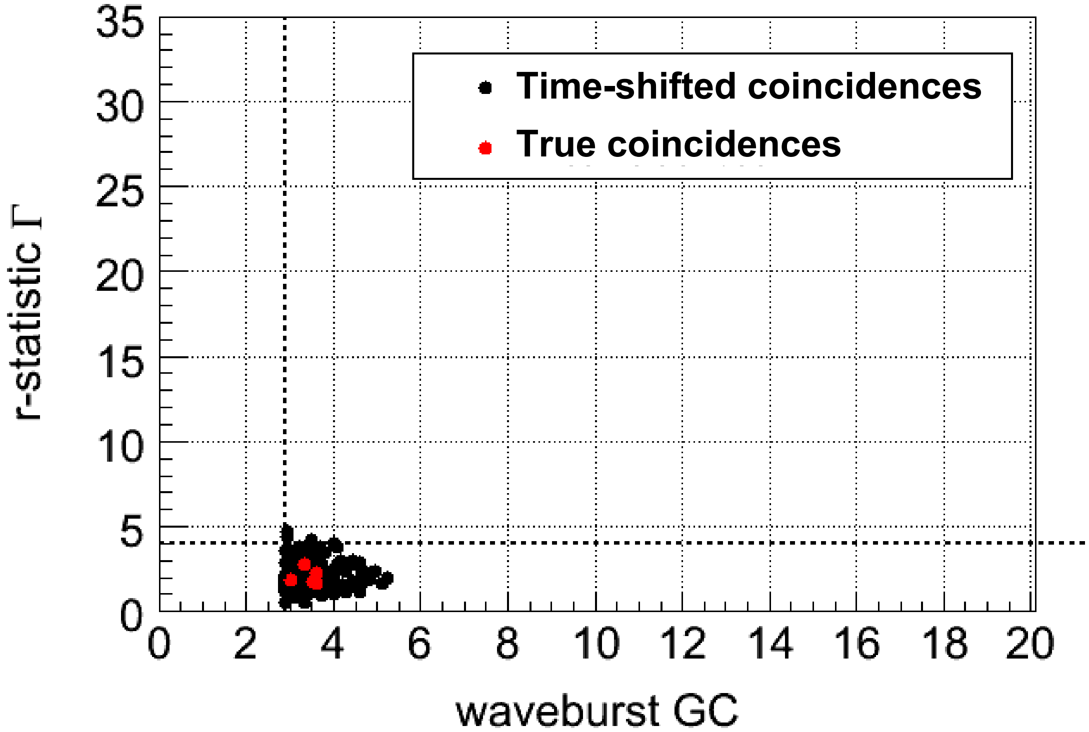
Potential veto lists generated using many auxiliary channels

Final choice of 7 veto conditions based largely on examining time-shifted coincidences with largest Gamma values

Vetoes 6 of the top 10 distinct coincidences, including:

- 2 with strong signals in accelerometers on H1 and H2 optical tables
- 3 with glitches in H1 beam-splitter pick-off channels
- 1 with big signals in H2 alignment system

The Search Result



No event candidates pass all cuts

Background estimate:
3 events out of 77 effective S4 runs
⇒ ~0.04 events

Frequentist one-sided upper limit (90% C.L.)
taking background to be zero (conservative)

$$R_{90\%} = \frac{2.303}{15.53 \text{ days}} = \mathbf{0.148 \text{ per day}}$$

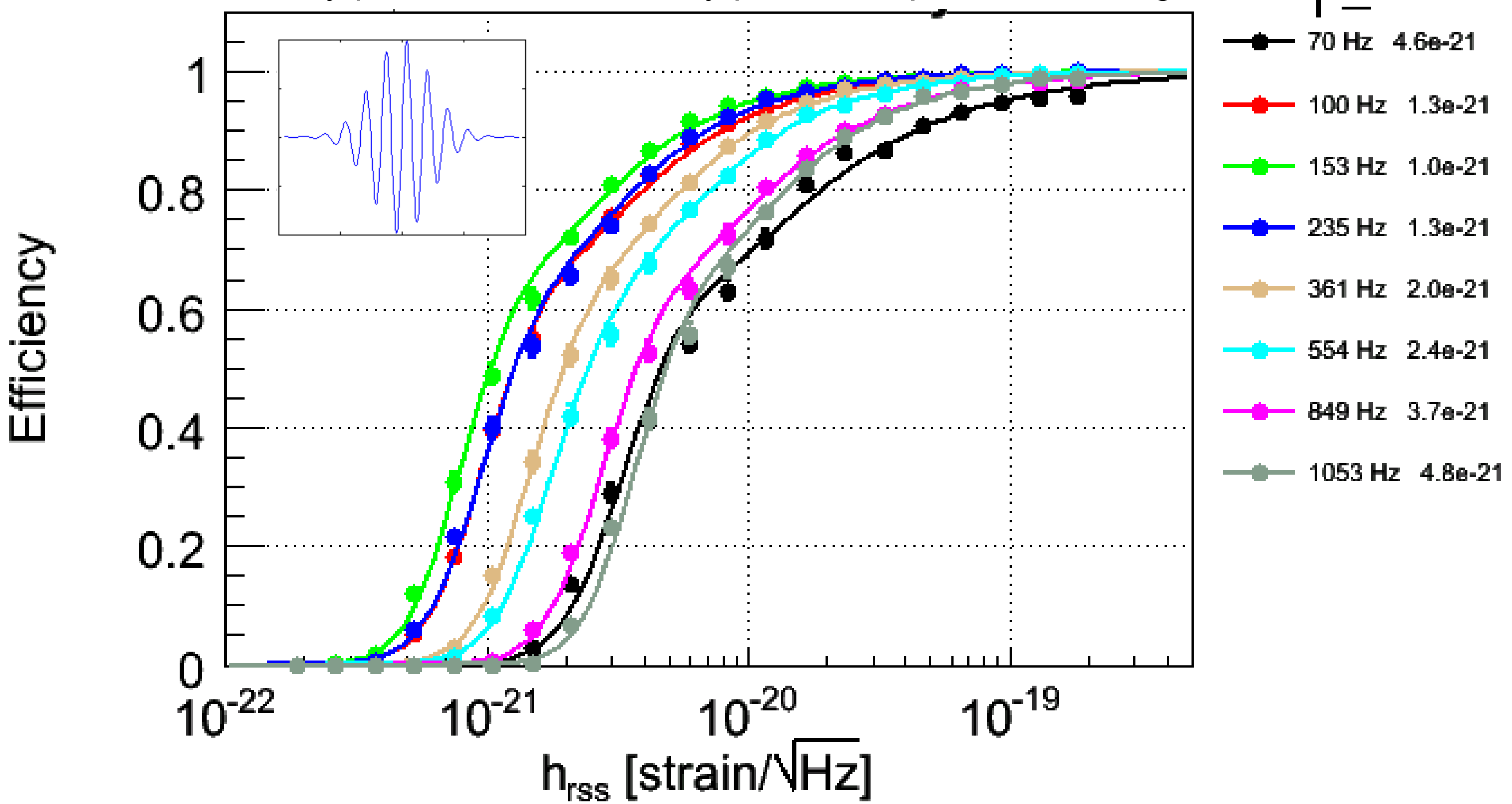
(Published rate limit from S2 run: 0.26 per day)

Efficiency Curve for Q=8.9 Sine-Gaussians (preliminary)

Caveats: preliminary calibration; auxiliary-channel vetoes *not* applied

$h(t) = h_0 \sin(2\pi ft) \exp(-2(\pi ft/Q)^2)$ $\qquad h_{rss} = h_0 (Q/4f)^{1/2} / \pi^{1/4}$

Linearly polarized; random sky position & polarization angle

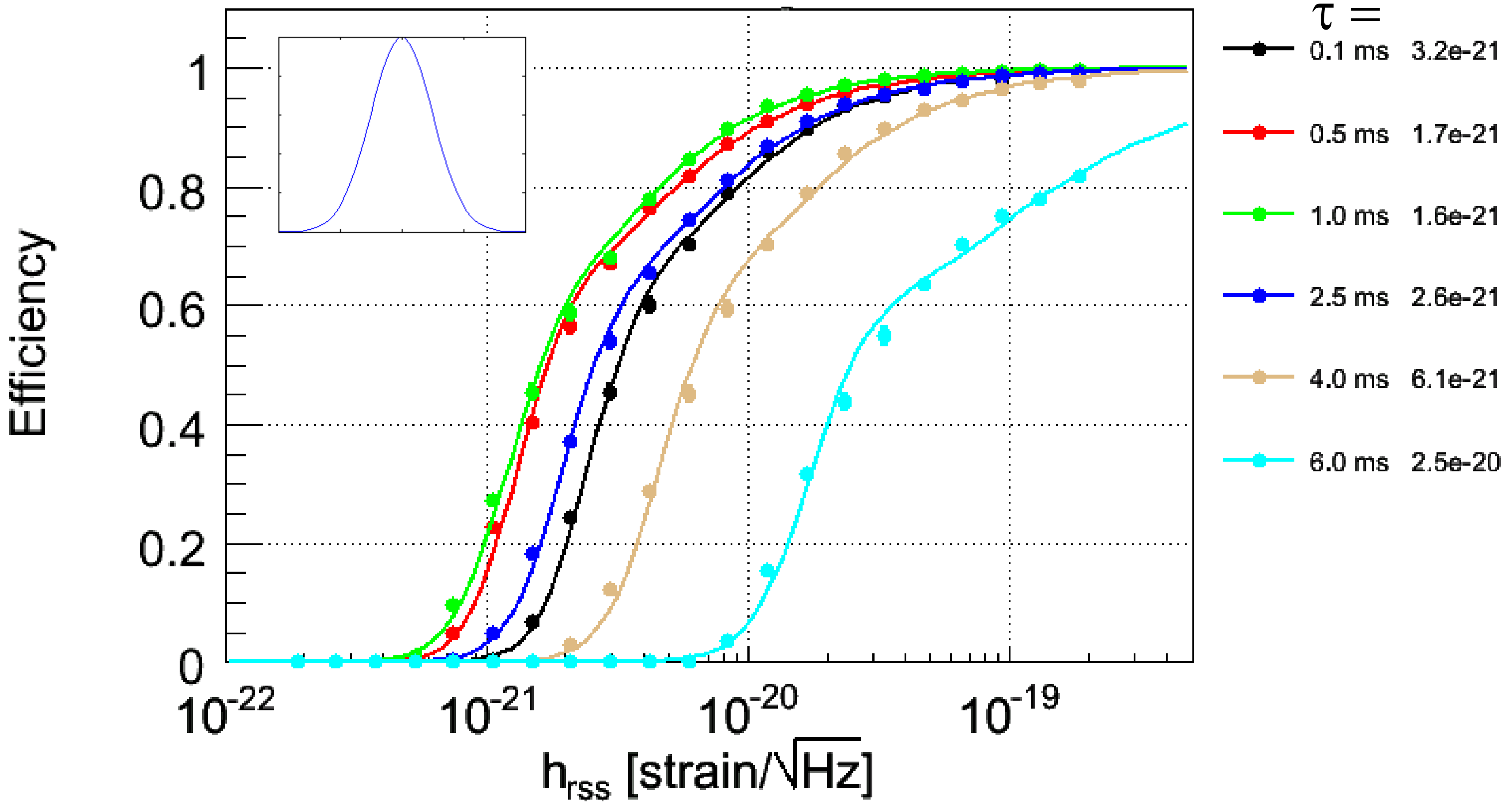


Efficiency Curve for Gaussians
(preliminary)

Caveats: preliminary calibration; auxiliary-channel vetoes *not* applied

$h(t) = h_0 \exp(-t^2/\tau^2)$ $h_{rss} = h_0 (\pi\tau^2/2)^{1/4}$

Linearly polarized; random sky position & polarization angle



Summary of Sensitivities
(preliminary)

h_{rss} at 50% detection efficiency, in units of 10^{-21}

Caveats: prelim calibration, no vetoes

	Freq (Hz)	S4:	S3:	S2:
Sine-Gaussians with Q=8.9	70	**4.6**	–	–
	100	**1.3**	–	82
	153	**1.0**	–	55
	235	**1.3**	9	15
	361	**2.0**	–	17
	554	**2.4**	13	23
	849	**3.7**	23	39
	1053	**4.8**	–	–
	Tau (ms)			
Gaussians	0.1	**3.2**	18	43
	0.5	**1.7**	–	26
	1.0	**1.6**	–	33
	2.5	**2.6**	–	140
	4.0	**6.1**	–	340

S3 values from Classical and Quantum Gravity **23**, S29 (2006).

S2 values from Phys. Rev. **D** 72, 062001 (2005).

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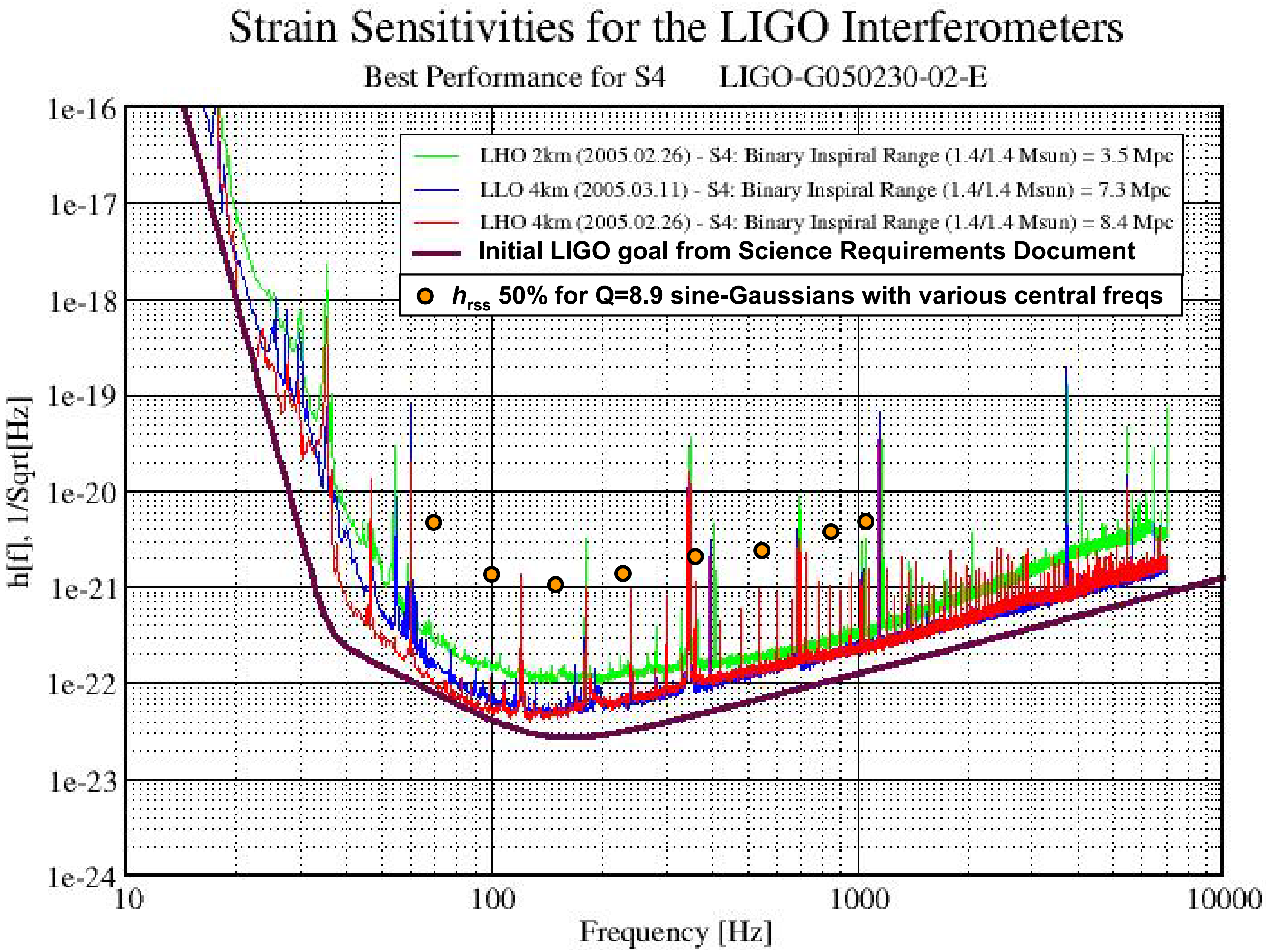
(preliminary)



Summary

We have carried out an all-sky search for gravitational waves using S4 LIGO data

No event candidates pass all cuts

Upper limit on rate of detectable events:
0.148 per day (90% C.L.)

Preliminary

Sensitivity: several times better than published S2 and S3 results