Gravitational Wave Burst Search in LIGO's 5th Science Run

Laura Cadonati (M.I.T.)
For the LIGO Scientific Collaboration

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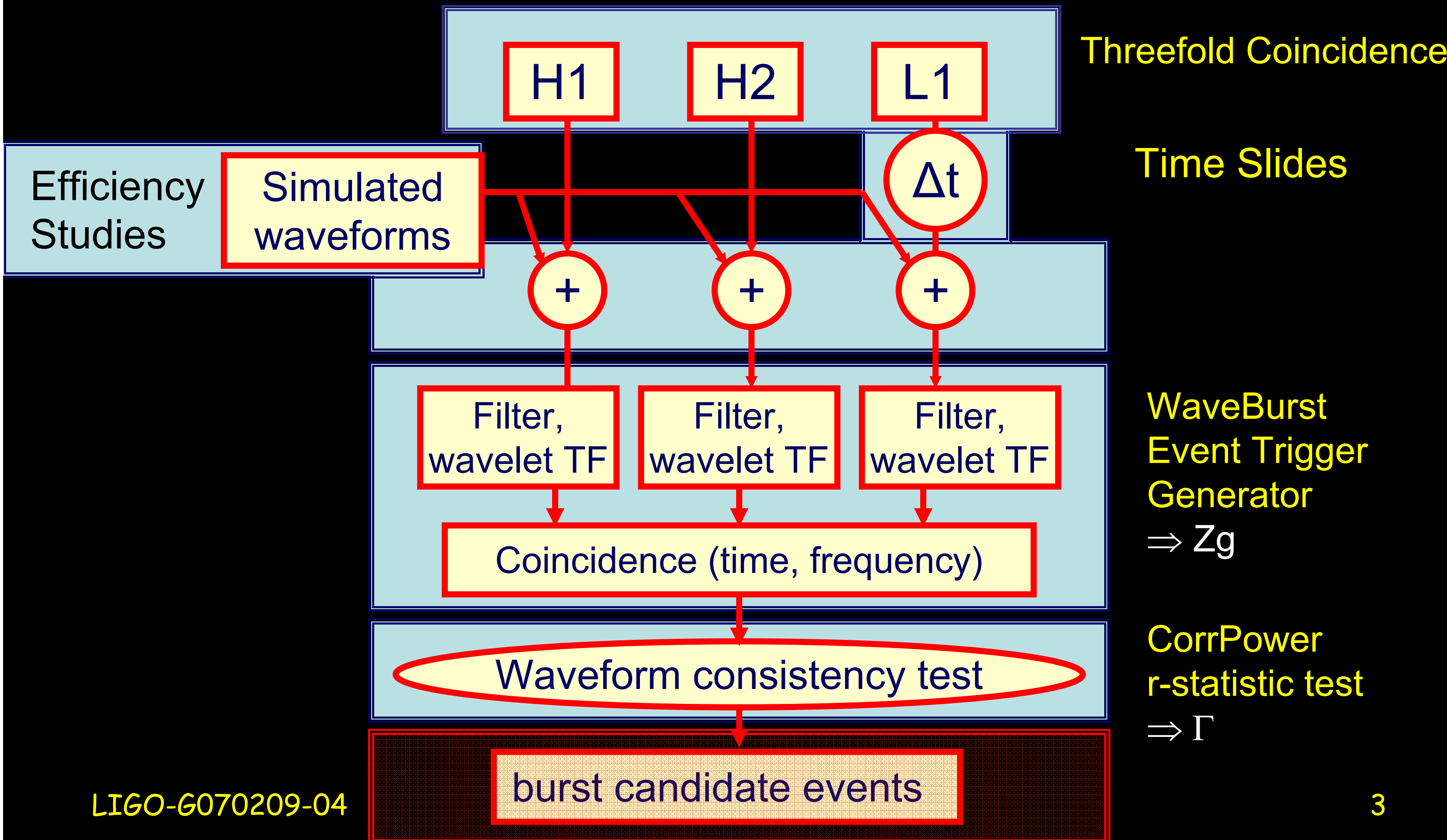
The LIGO Burst Search

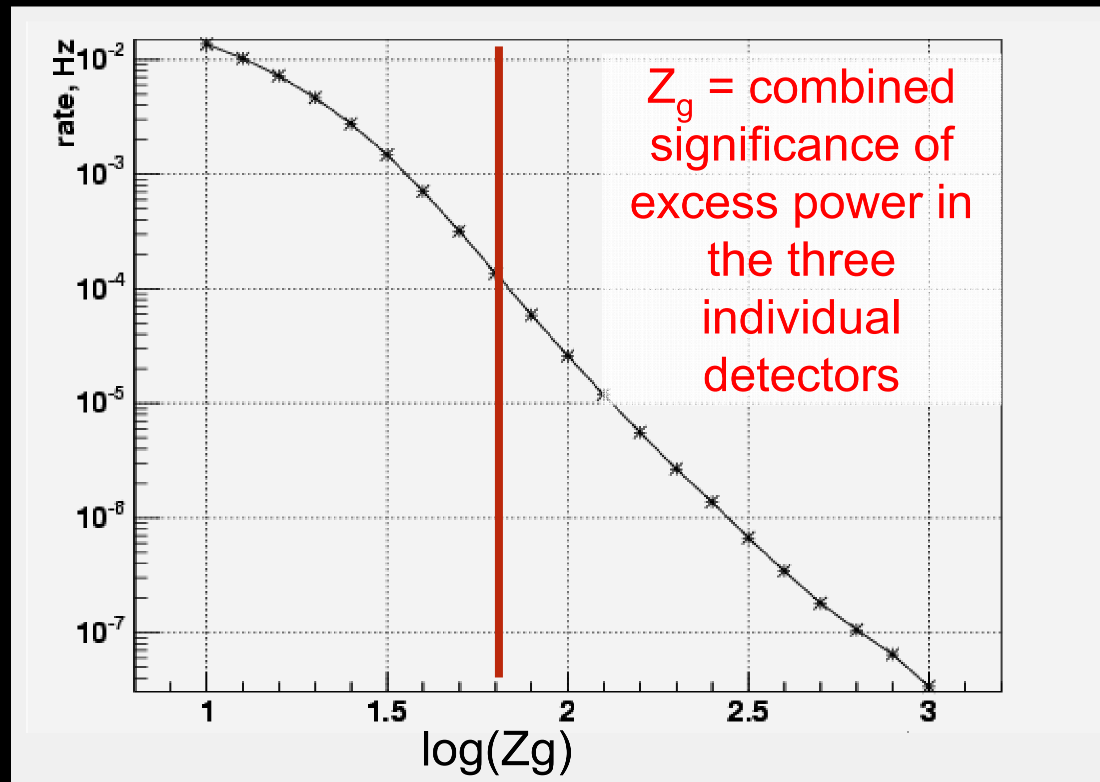
- All-sky search for un-modeled bursts of gravitational waves
  - Supernovae, black hole mergers, serendipitous sources
- Data: first 5 months of LIGO Science Run S5 (long duration, design sensitivity)
  - 54 live-days in triple coincidence; Nov 17, 2005 to April 3, 2006
  - Blind tuning/background estimate on the equivalent of 13 years
- Same method used in the S4 analysis arXiv:0704.0943 [gr-qc]
  - Hierarchical approach: incoherent combination of statistically significant excesses in 3 detectors, with coherent follow-up.
  - See Keith Thorne's talk in this session for more on coincident methods
  - See Igor Yakushin's talk in this session for new fully coherent methods
- Triple coincidence candidates must pass a set of data quality and analysis cuts that effectively suppress false alarms

Burst All-Sky Pipeline



Selection Criteria

Background rate estimated from 100 LHO-LLO time slides



Require:

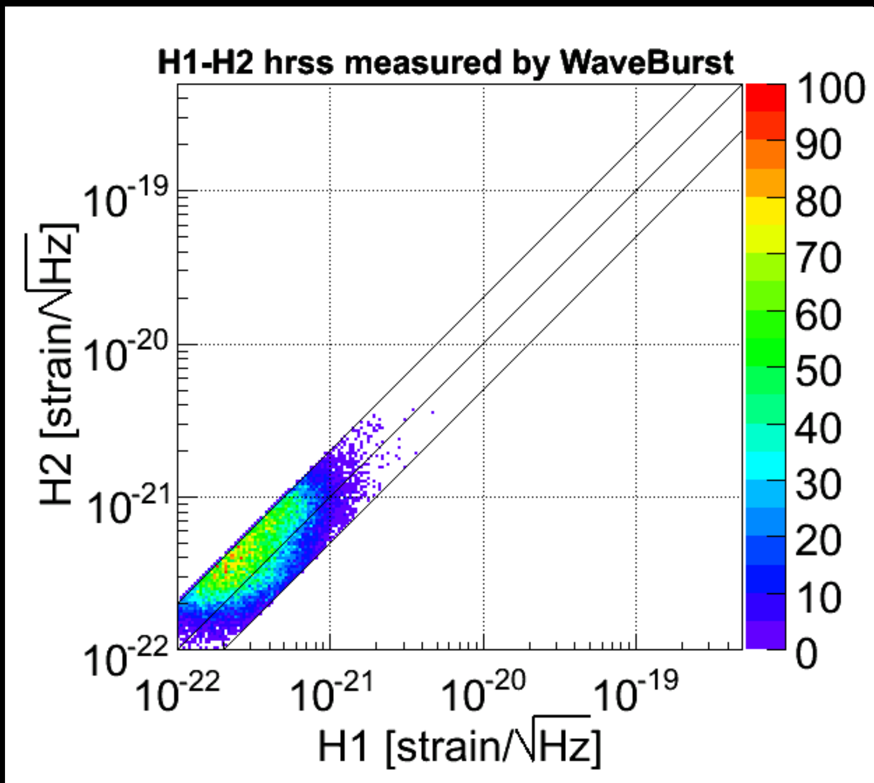
- Frequency: 64-1600 Hz
- Zg ≥ 6.0

Additional cuts:

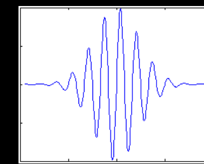
- Data Quality Cuts (talk by Shantanu Desai in this section)
- Analysis Cuts: H1-H2, H1-L1, frequency-dependent threshold

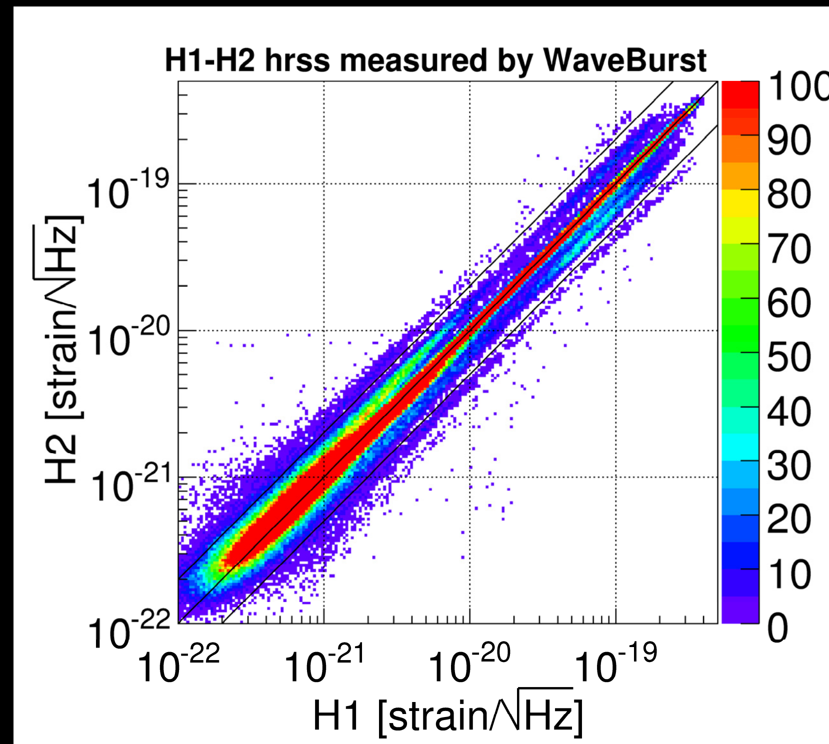
H1-H2 Consistency Checks

100 LHO-LLO time-slides, equivalent to 13.5 years of triple coincidence data



Simulations: Sine-Gaussians Q=8.9,3

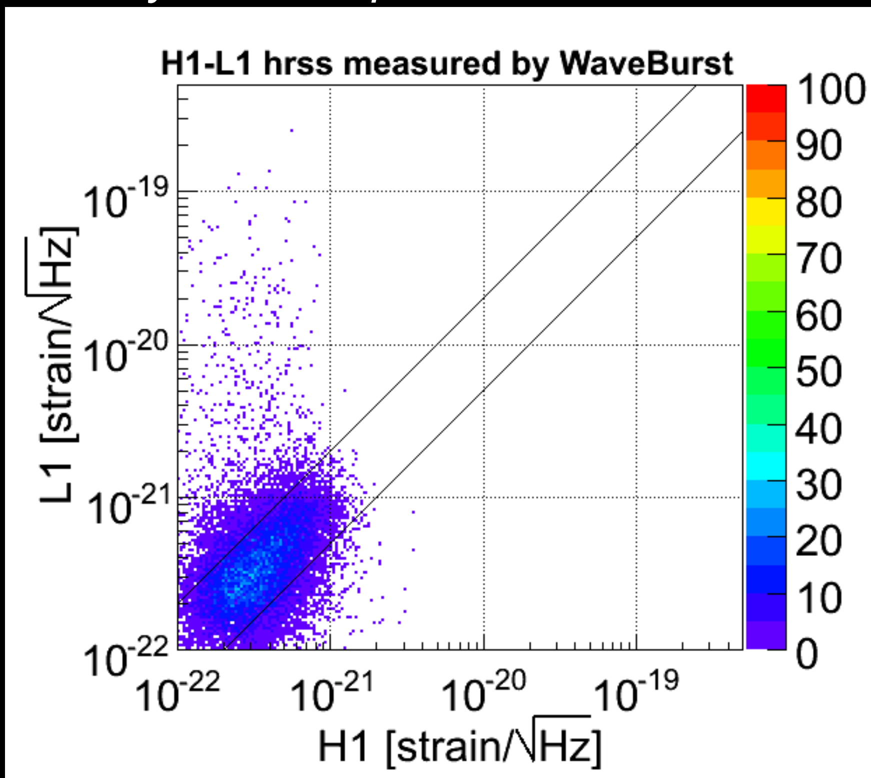




- Estimated amplitudes must agree within a factor of two.
- Signals must be positively correlated

L1-H1 Cut

100 LHO-LLO time-slides, equivalent to 13.5 years of triple coincidence data



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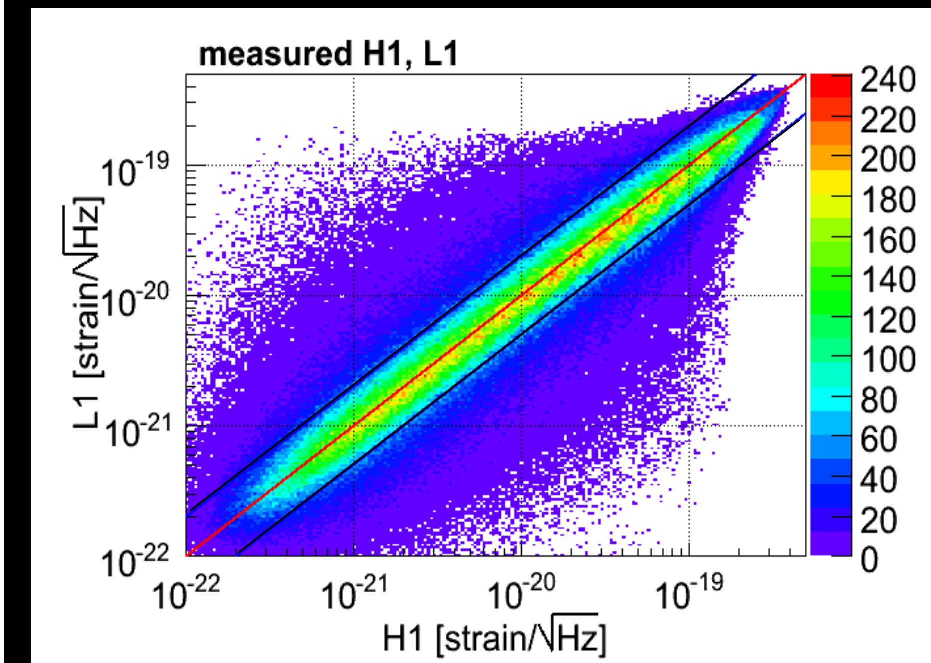
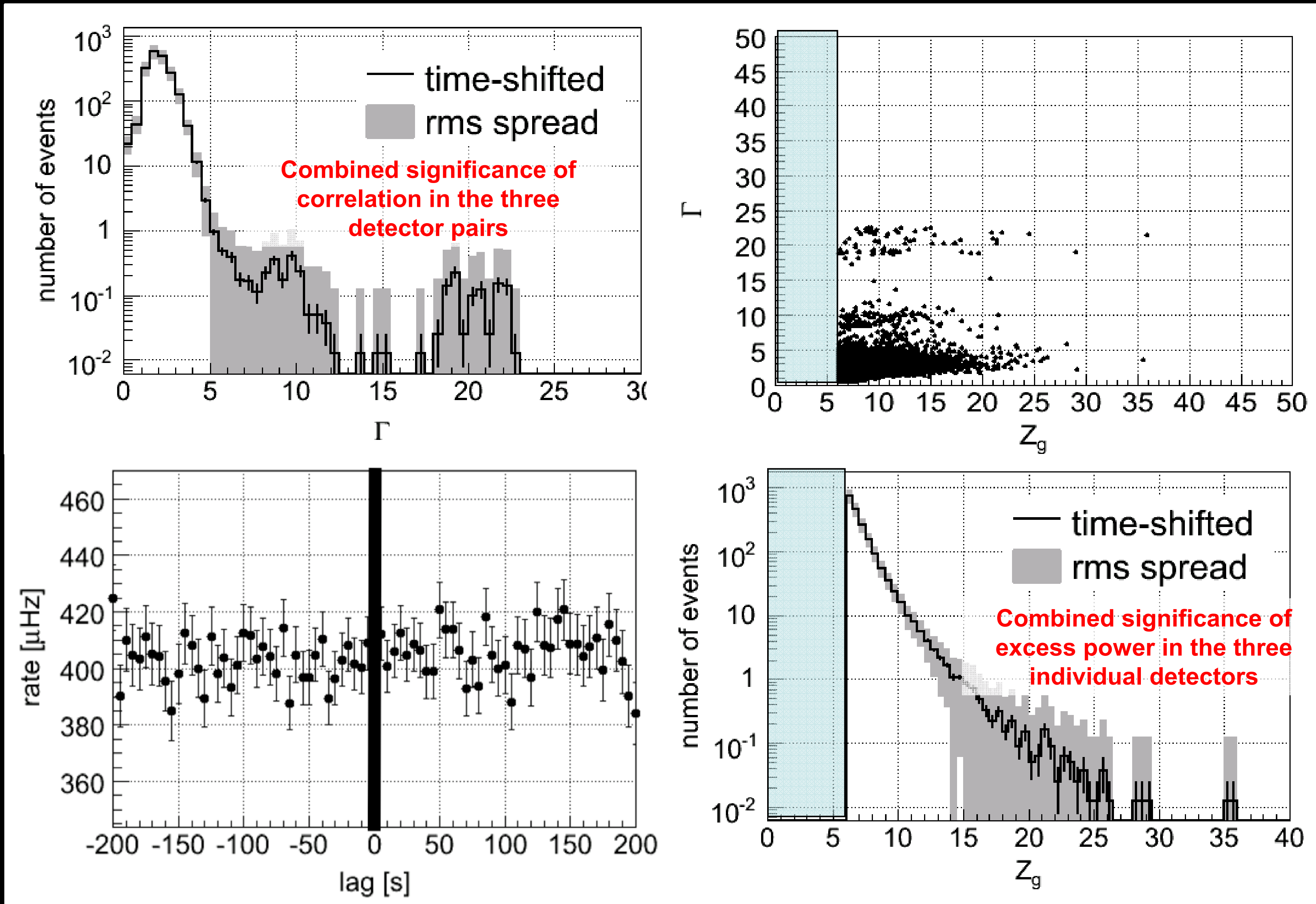


Require $\Gamma_{H1L1} > 3$

less than 0.1% probability to get the measured linear cross-correlation from uncorrelated noise at L1 and H1

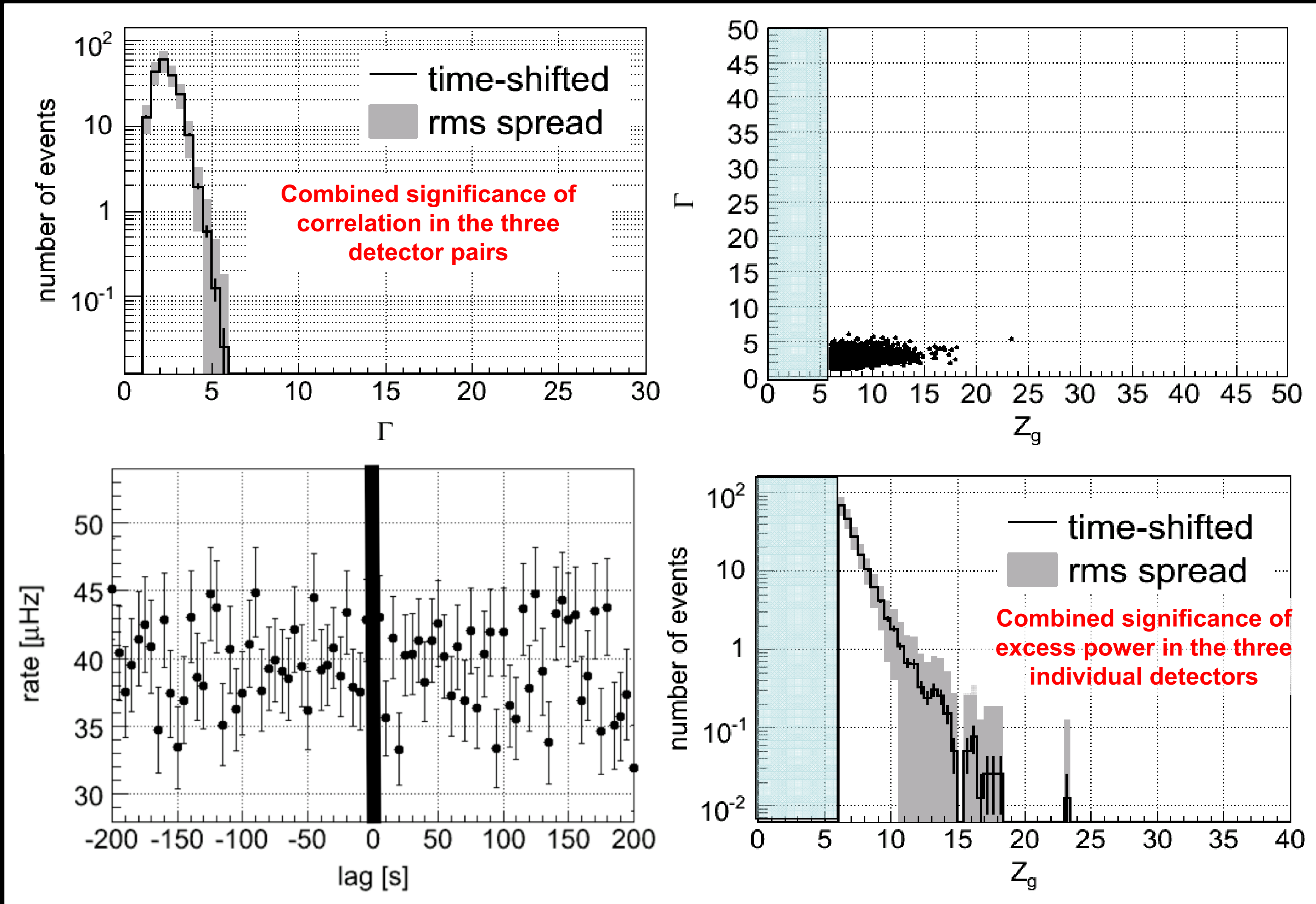
Before Any Cuts

100 LHO-LLO time-slides, equivalent to 13.5 years of triple coincidence data

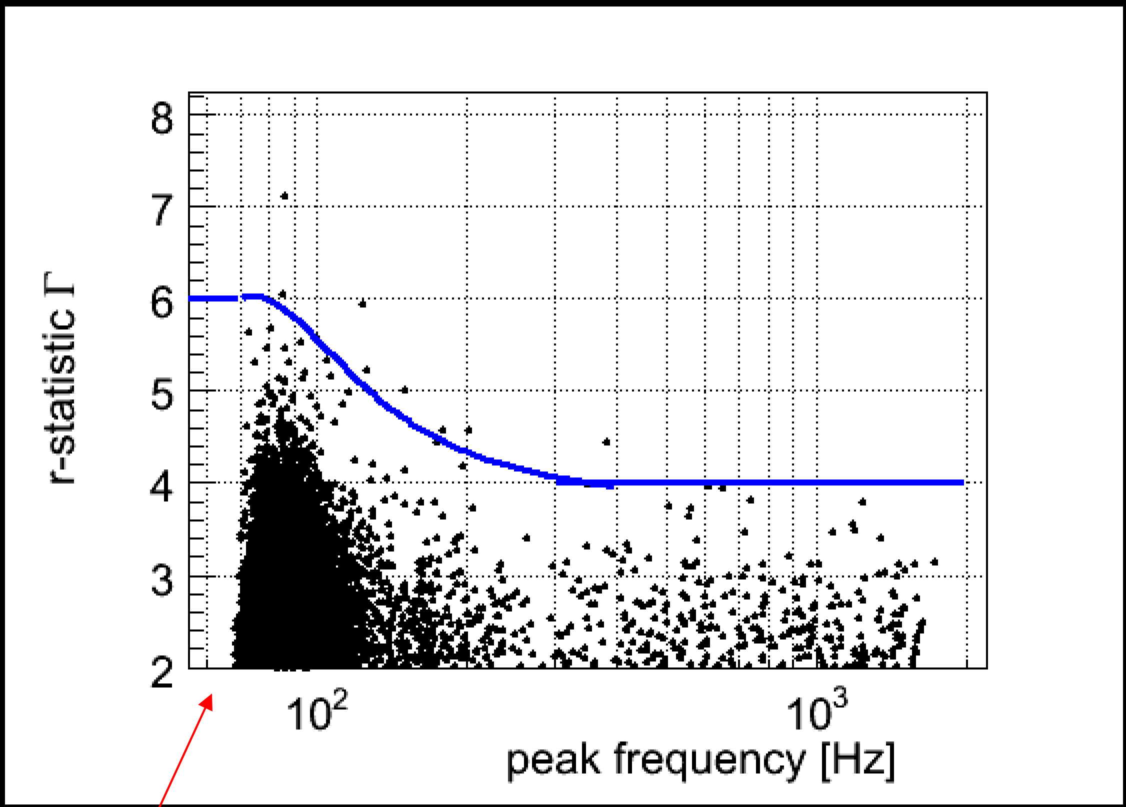


After Analysis and DQ Cuts

100 LHO-LLO time-slides, equivalent to 13.5 years of triple coincidence data



Frequency Dependent Threshold



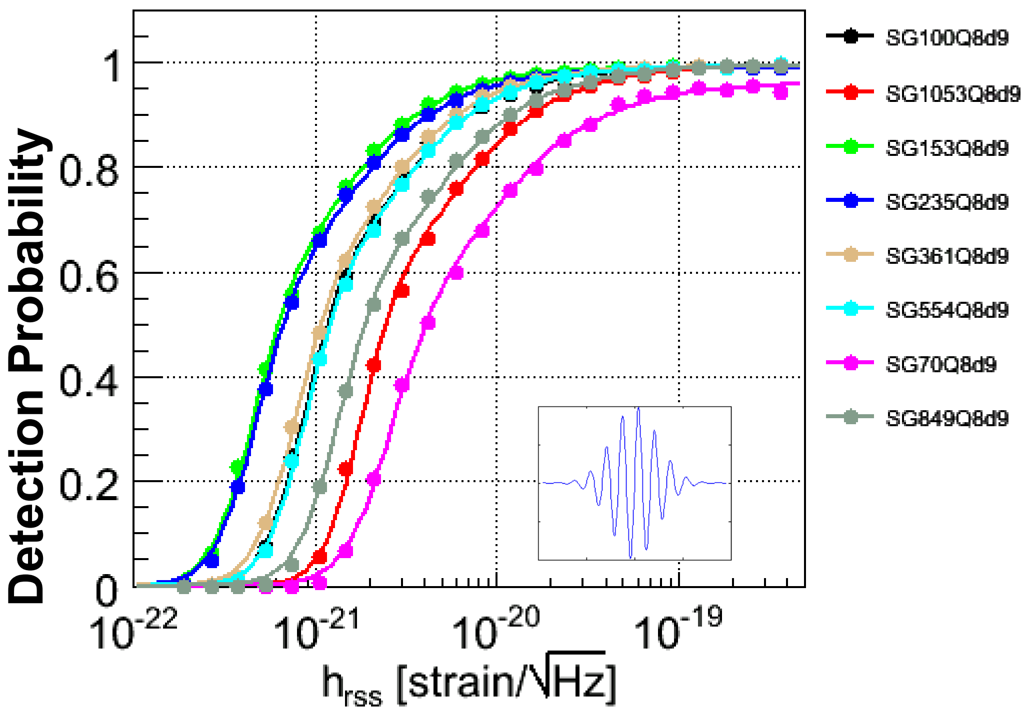
Empirically chosen, frequency-dependent threshold on Γ

~1/(f-64Hz) in 100-300Hz,
4 at high frequency,
6 at low frequency

Target rate of accidentals:
<< 1 per analysis period
Expect 0.06 in early S5,
0.4/year

100 LHO-LLO time-slides, equivalent to 13.5 years of triple coincidence data

Detection Efficiency / Range



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

Instantaneous energy flux:

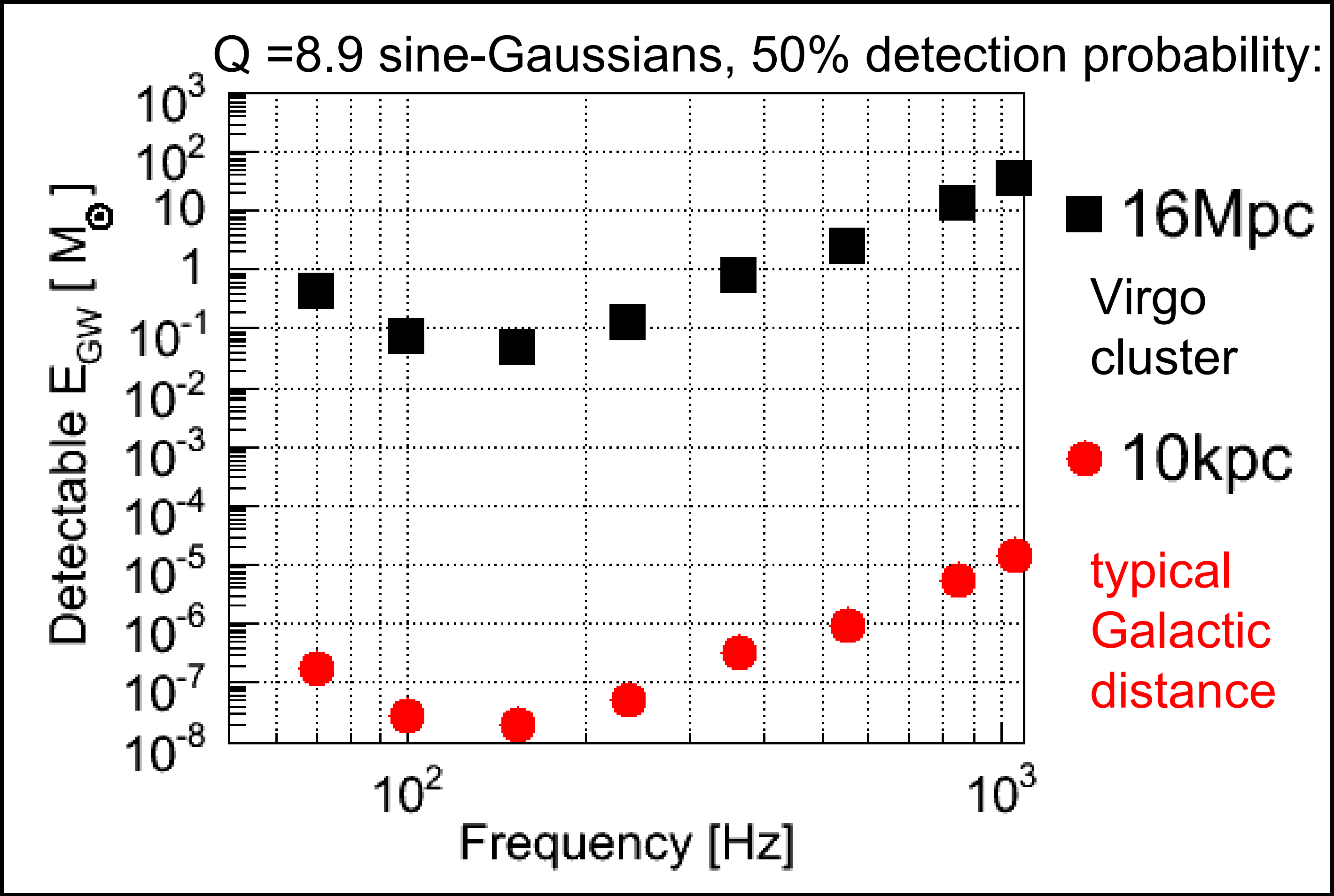
$$\frac{{\rm d}^2 E_{\rm GW}}{{\rm d}A\,{\rm d}t} = \frac{1}{16\pi}\frac{c^3}{G}\left\langle (\dot{h}_+)^2 + (\dot{h}_\times)^2 \right\rangle$$

Assume isotropic emission to get rough estimates

For a sine-Gaussian with *Q*>>1 and frequency f_0 :

$$E_{\rm GW} = \frac{r^2 c^3}{4G}(2\pi f_0)^2 h_{\rm rss}^2$$

Detection Efficiency / Range



For a 153 Hz, Q =8.9 sine-Gaussian, the S5 search can see with 50% probability:

~ 2 × 10^{-8} $M_\odot c^2$ at 10 kpc (typical Galactic distance)

~ 0.05 $M_\odot c^2$ at 16 Mpc (Virgo cluster)

Order of Magnitude Range Estimate for Supernovae and BH Mergers

Model dependent!

Ott, Burrows, Dessart and Livne, PRL 96, 201102 (2006)

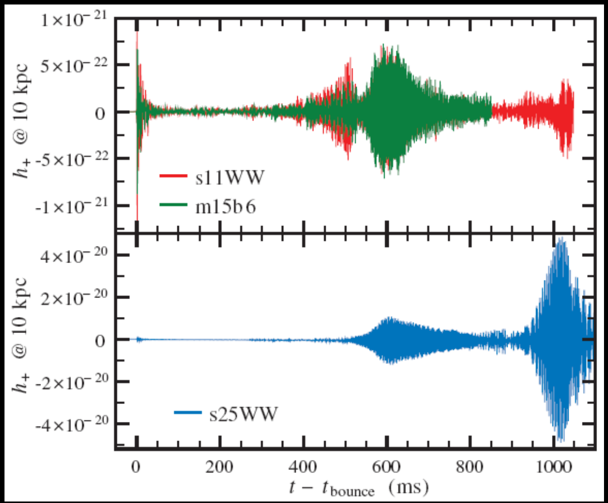
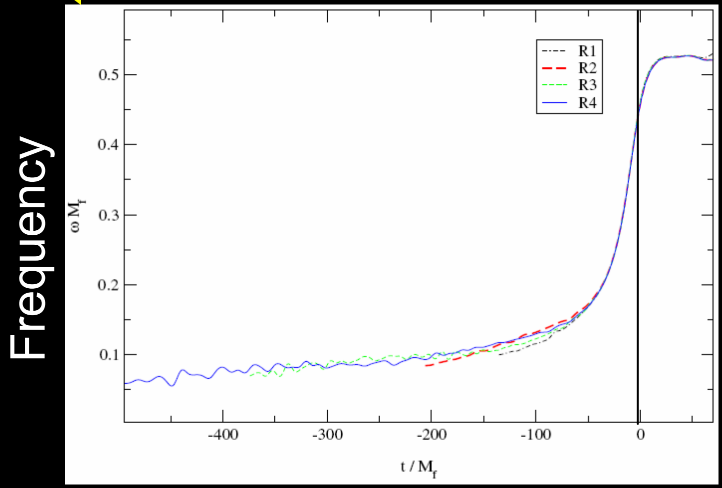


TABLE I. MODEL SUMMARY.

Model	Δt^a (ms)	$\lvert h_{+,max} \rvert^b$ (10^{-21})	$h_{char,max}{}^{b,c}$ (10^{-21})	$f(h_{char,max})$ (Hz)	$E_{GW}{}^d$ $(10^{-7} M_\odot c^2)$
s11WW	1045	1.3	22.8	654	0.16
s25WW	1110	50.0	2514.3	937	824.28
m15b6	927.2	1.2	19.3	660	0.14

11 $M_\odot$ progenitor (s11WW model)
$\Rightarrow$ reach ≈ 0.4 kpc
25 $M_\odot$ progenitor (s25WW model)
$\Rightarrow$ reach ≈ 16 kpc



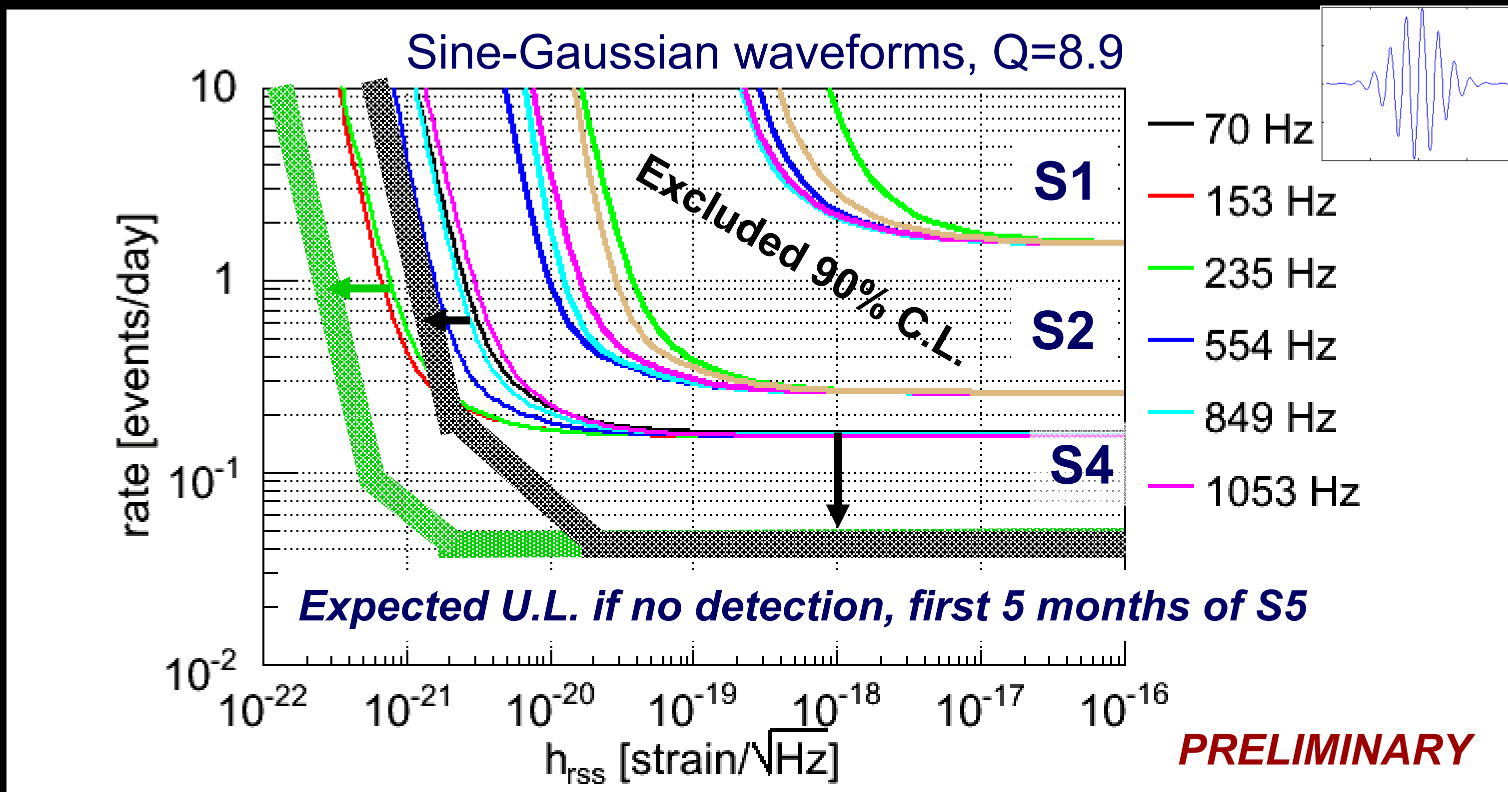
$$f_{peak} \approx \frac{0.46}{2\pi M_f} \approx \frac{15\ \text{kHz}}{(M_f/M_\odot)}$$

Baker et al, PRD 73, 104002 (2006)

Assuming ~3.5% mass radiates in the merger:
10+10 $M_\odot$ binary $\Rightarrow$ reach ≈ 3 Mpc
50+50 $M_\odot$ binary $\Rightarrow$ reach ≈ 100 Mpc

…to be continued…

LSC Burst Search from S1 to S5



$$h_{\rm rss} \equiv \sqrt{\int \left(|h_+(t)|^2 + |h_\times(t)|^2\right) dt}$$