Status of the LIGO-TAMA Joint Bursts Search

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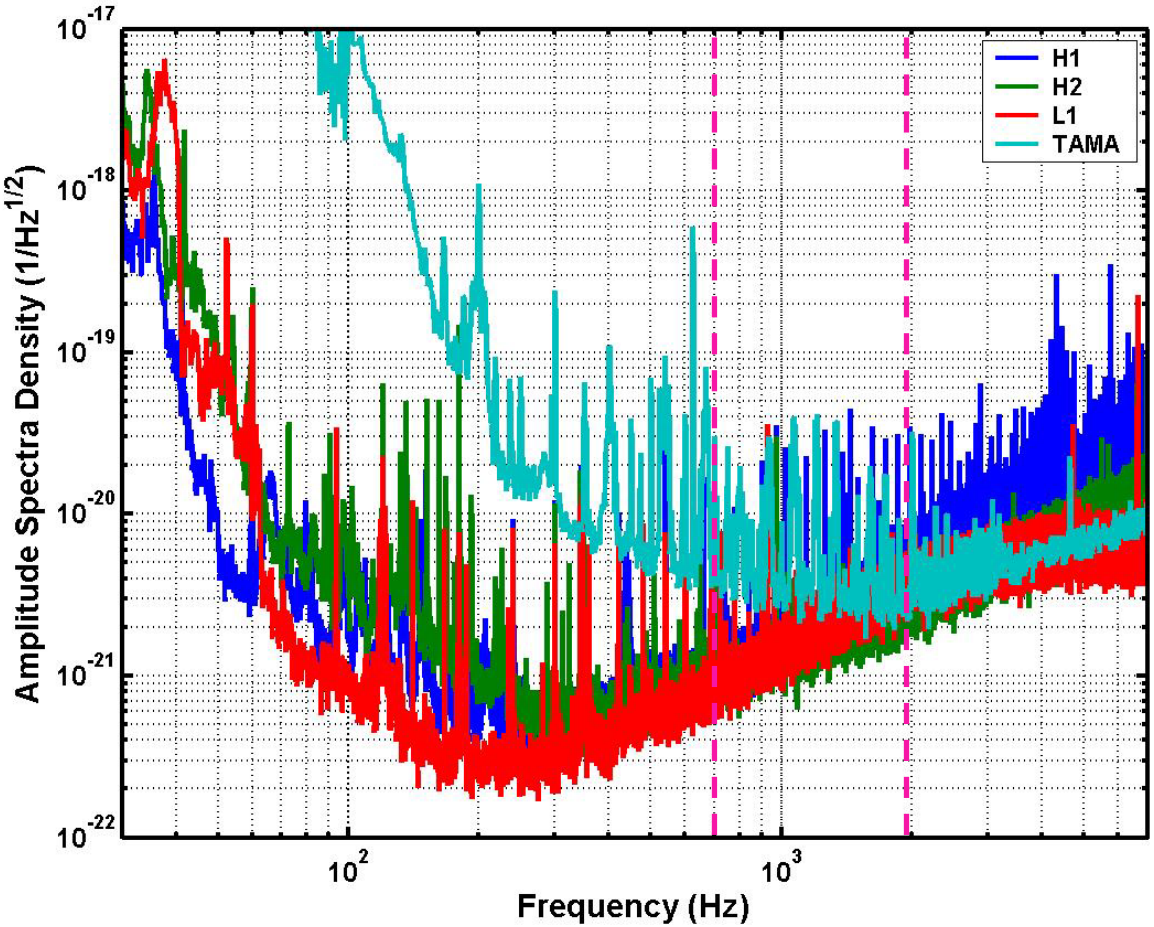
Outline

- Background
- Science with LIGO-TAMA
- Analysis Overview
- Upper Limits
- Remaining Tasks and Schedule

Un-triggered Bursts Analysis

- The LIGO S2 un-triggered search for generic GWBs at high frequencies has been carried out jointly with TAMA.
  - » LIGO-only search: 100-1100Hz
  - » LIGO-TAMA search: 700-2000Hz
- Philosophy of LIGO-TAMA: Use machinery and techniques common with the LIGO-only low-frequency search
  - » ETGs, coincidence, r-statistic, time lags, MDC simulation frames, low false rate (<<1/S2), rate vs strength upper limits, …
- Seek optimal ways to combine LIGO and TAMA for best science.

LIGO-TAMA in S2/DT8



LIGO and TAMA look with best sensitivity at different frequencies:

- Tune for signals near minimum of envelope, [700-2000]Hz.

Duty cycles:

H1	74%
H2	58%
L1	37%
T1	81%

- Take advantage of excellent T1 duty cycle.

Science with TAMA

- TAMA-LIGO 4X search has several interesting features:
  - » 4X coincidence allows for searches with very low false rates (<1/yr).
  - » Extra time lags allow much more accurate background estimates
    - – LIGO 2-site network = 47 lags in (-115s,+115s)
    - – LIGO-TAMA 3-site network = 47^2 = 2209 lags in (-115s,+115s).
  - » *Not yet explored:* Extra non-aligned site with long baseline: exploit for sky direction? polarization information?

- But 3X searches also valuable:
  - » Can use TAMA as substitute for a missing LIGO detector.
  - » Eg: H1-H2-T1 coincidence allows us to use the large amount of H1-H2 data that would otherwise be lost because of poor L1 duty cycle (Brady, Cadonati, Katsavounidis; also done in joint inspiral search).

Data Sets

H1-H2-L1-T1	250hr
H1-H2-⌉L1-T1	325hr
H1-H2-L1-⌉T1	62hr
total LIGO-TAMA	637hr
total LIGO-only 3X	312hr

⌉L1 ≡ L1 not operating

⌉T1 ≡ T1 not operating

- TAMA *doubles* total usable data set
  - » Better chance of "getting lucky" in a search
  - » Cut rate upper limits in half
  - » Cost: some loss in efficiency (minor effect)

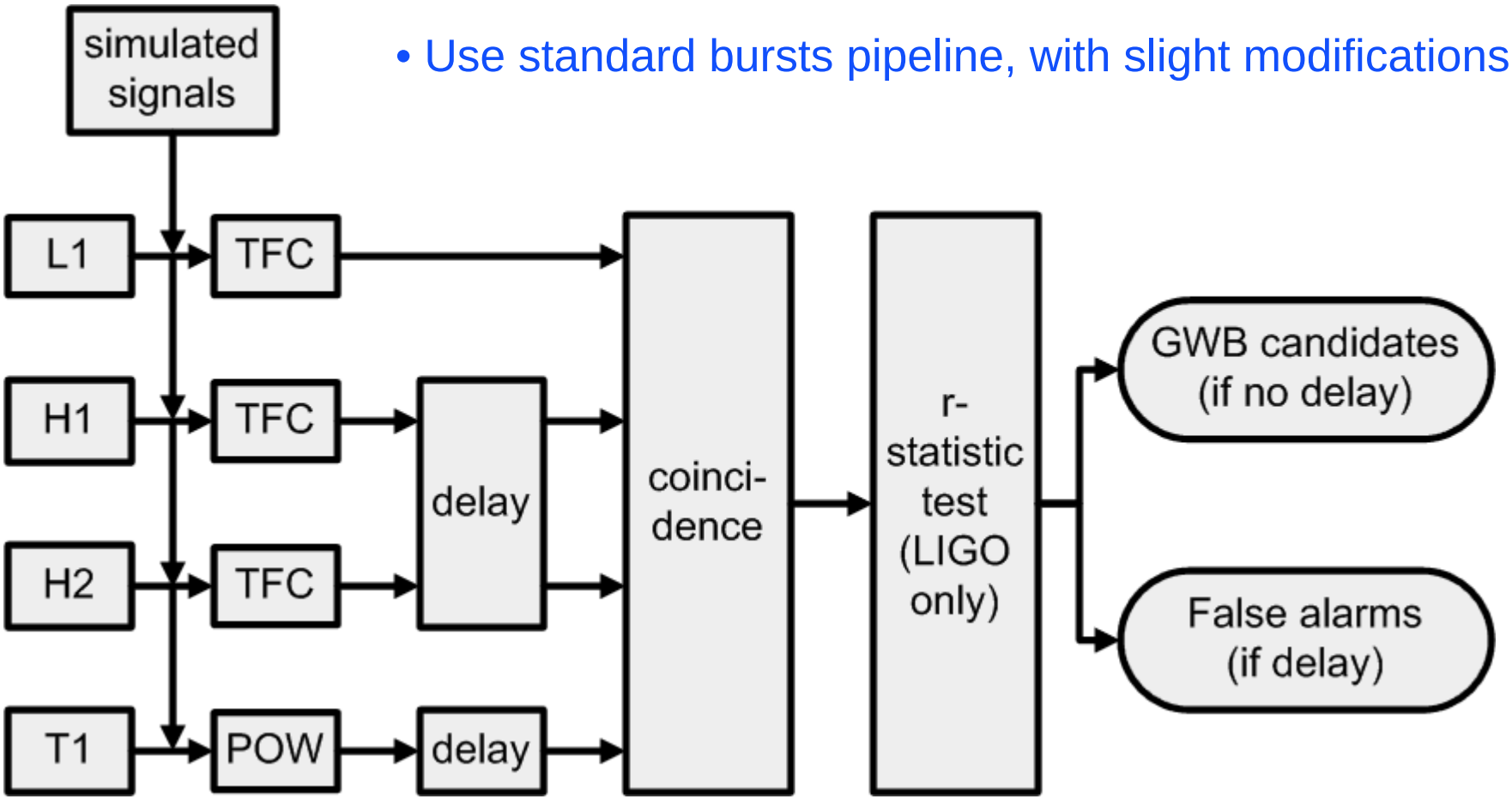
$$R(h) = \frac{N}{\epsilon(h)T}$$

- Response: Analyze all H1-H2-(L1 or T1) data
  - » H1-L1-T1, H2-L1-T1: small amount of data, much higher false rate. Ignore.

Analysis: Novel Bits

- 3 independent data sets:
  - » Must derive single upper limit from 3 independent experiments.
- No access to TAMA data (only triggers exchanged):
  - » Compare LIGO-TFClusters triggers to TAMA-Power triggers
    - – TFClusters triggers have peak time, duration, SNR, central frequency, and bandwidth.
    - – TAMA triggers have peak time, duration, SNR, but no central frequency or bandwidth.
    - – Coincidence is based on time overlap only. No SNR or frequency comparison.
  - » No r-statistic test with TAMA

Analysis Pipeline



- Use standard bursts pipeline, with slight modifications

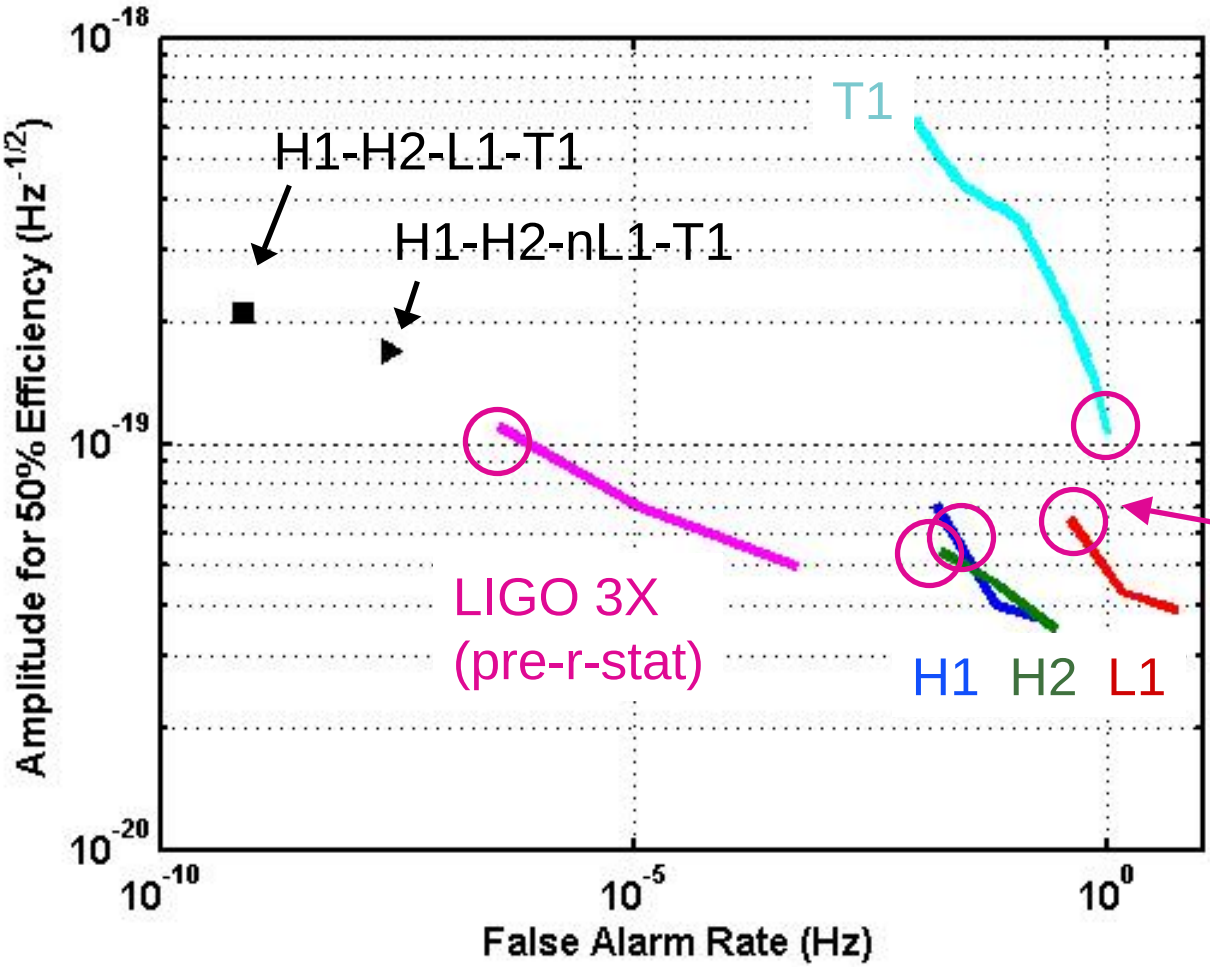
Simulations

- One set of MDC frames has been exchanged: SG13
  - » sine-Gaussians
  - » Q = 8.9
  - » f_0 = {700, 849, 1053, 1304, 1615, 2000}Hz
  - » isotropic sky distribution
  - » random linear polarization
  - » total ~16800 injections, distributed over LIGO 3X times (H1-H2-L1-T1 and H1-H2-L1-nT1)

Tuning Philosophy

- Use single tuning for all three data sets.
- Tune for best efficiency at each false rate.
  - » single-IFO: use to fix TFClusters parameters
  - » multi-IFO: select bpp/SNR to match efficiencies
- Select multi-ETG rate & r-statistic threshold for << 1 event from background.
  - » H1-H2-L1-T1 and H1-H2-nL1-T1 have ~same observation time, so efficiencies are averaged
  - » H1-H2-nL1-T1 dominates false rate.

Efficiency vs False Rate



From SG13 simulations

Effective coincidence windows:

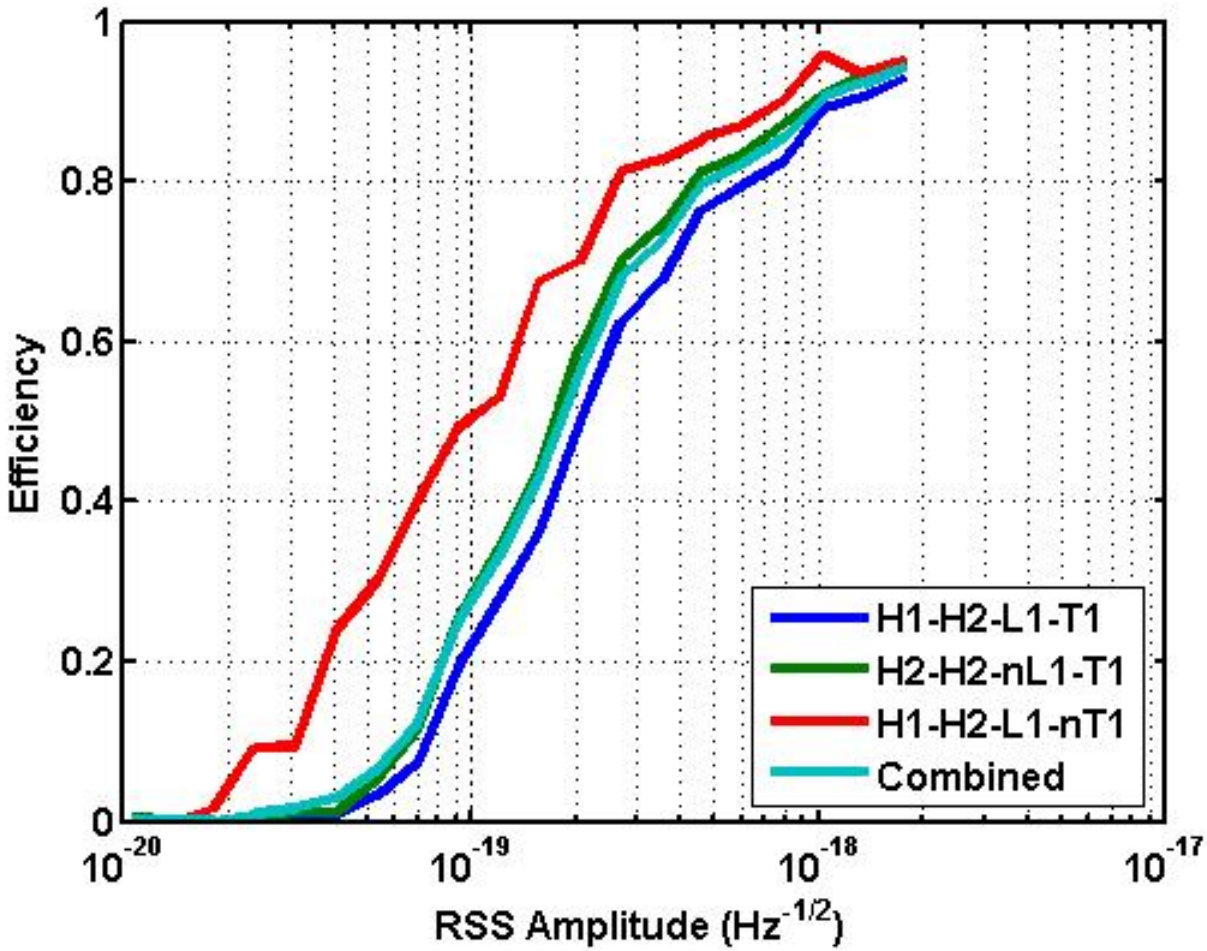
20ms (LIGO-LIGO)
43ms (LIGO-TAMA)

Chosen single-IFO operating points

Full Data Set Results

- Full data set box has been opened and final upper limits have been calculated.
  - » No surviving coincidences (after r-statistic) for any of the network combinations.
  - » Rate upper limit of 0.13/day.
  - » $h_{rss}^{50\%} = 2 \times 10^{-19} Hz^{-1/2}$ averaged over networks, analysis band.

Network Efficiency

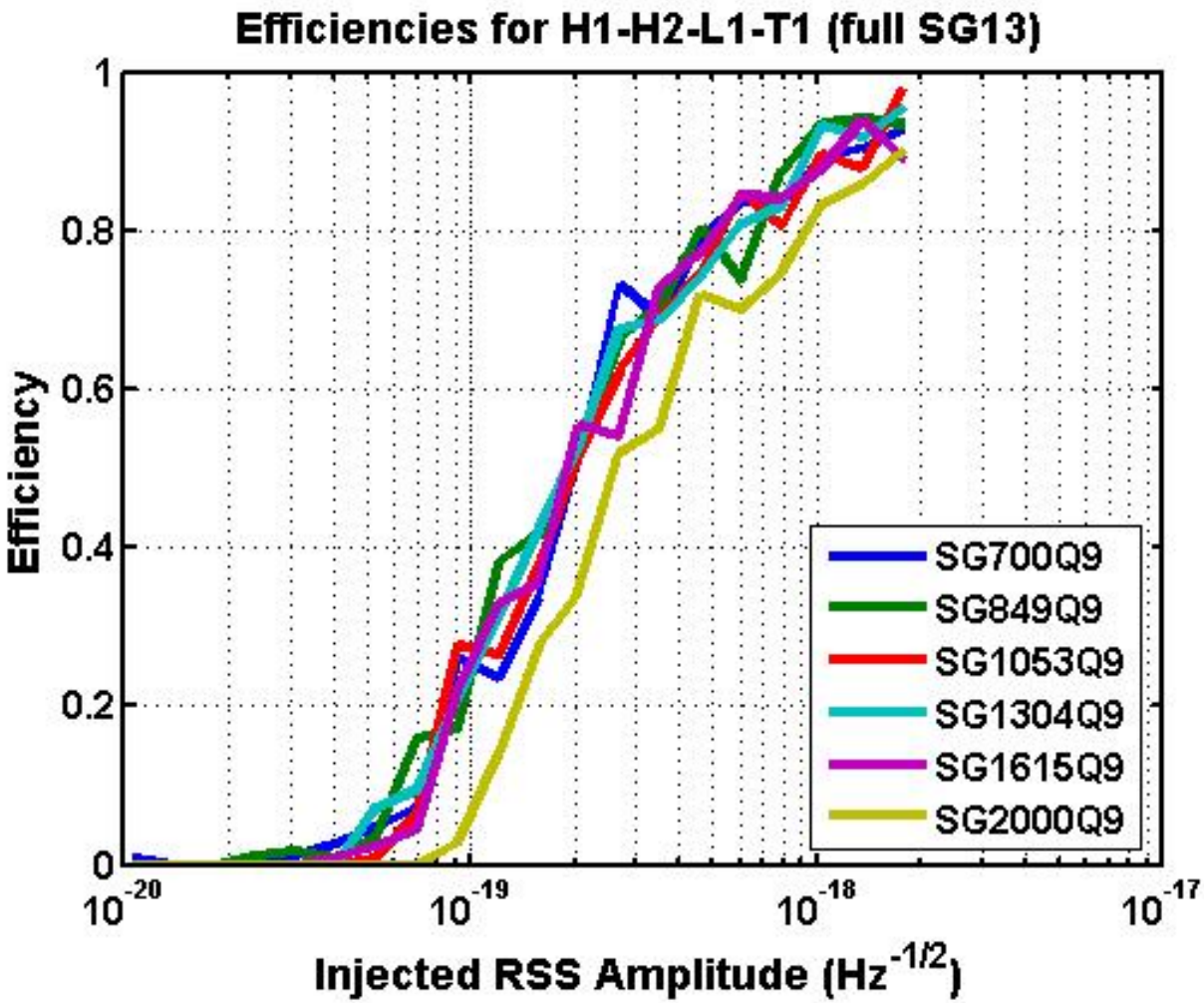


SG13 simulations

(Q=8.9 SG over [700,2000]Hz, with sky & polarization averaging)

Different network combinations have similar efficiency (factor ~2 in 50% point).

Network Efficiency, by f_0



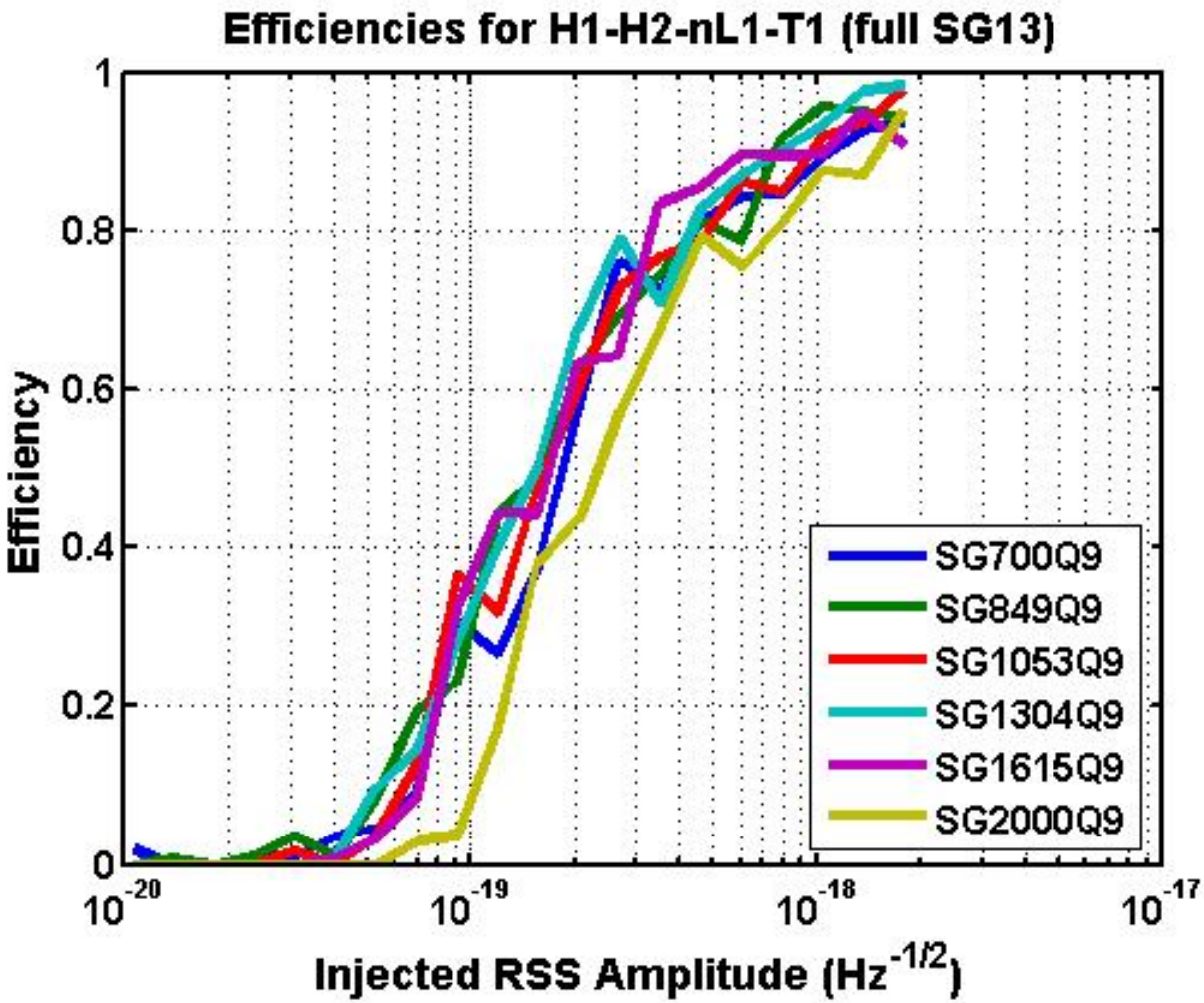
4X detection

SG13 simulations

separately by central frequency

All about the same.

Network Efficiency, by f_0



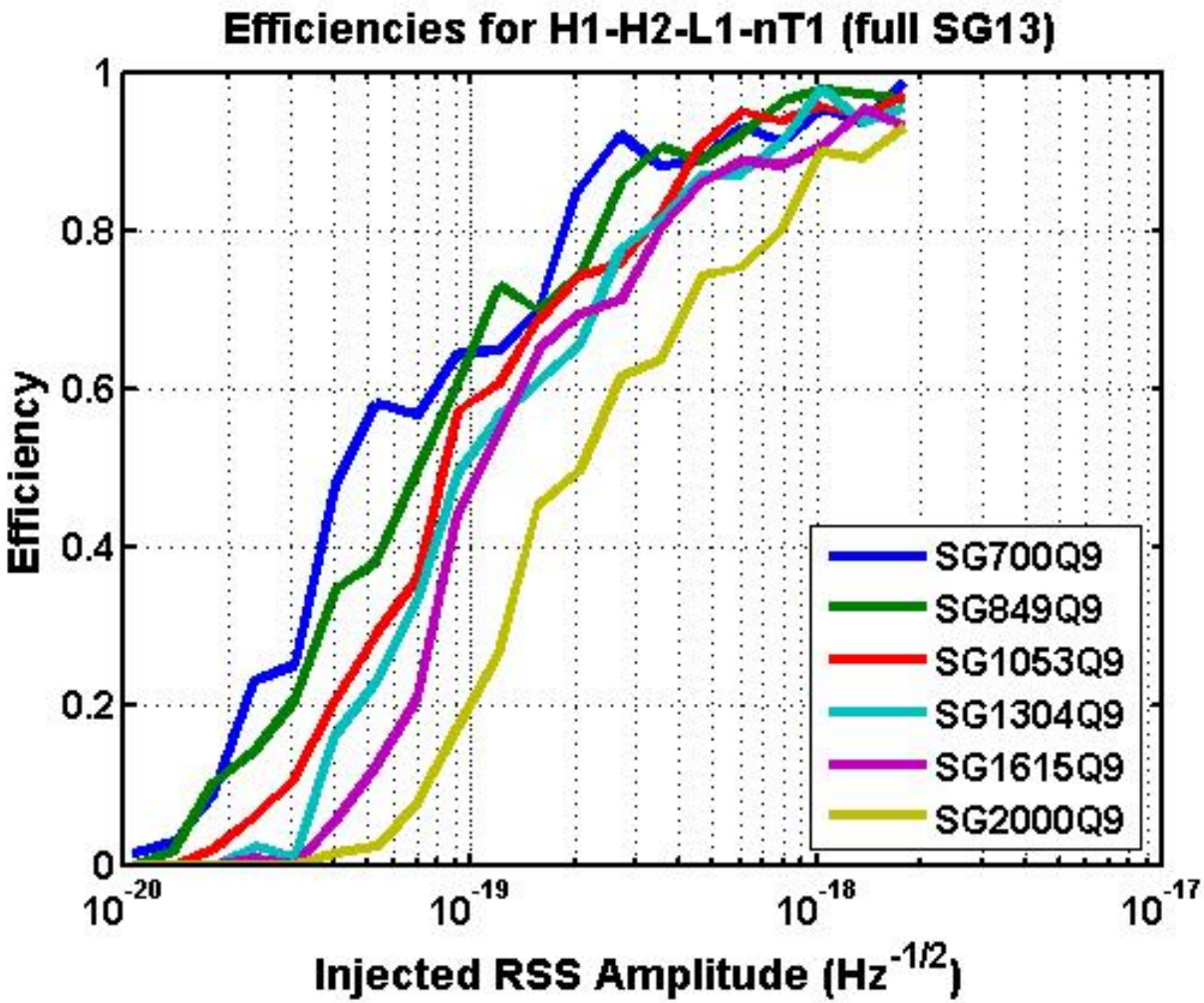
3X detection (no L1)

SG13 simulations

separately by central frequency

All about the same.

Network Efficiency, by f_0



3X detection (no T1)

SG13 simulations

separately by central frequency

Better at lower frequencies – TAMA limits sensitivity there.

Upper Limits

Full data set, including N before/after the R-Statistic:

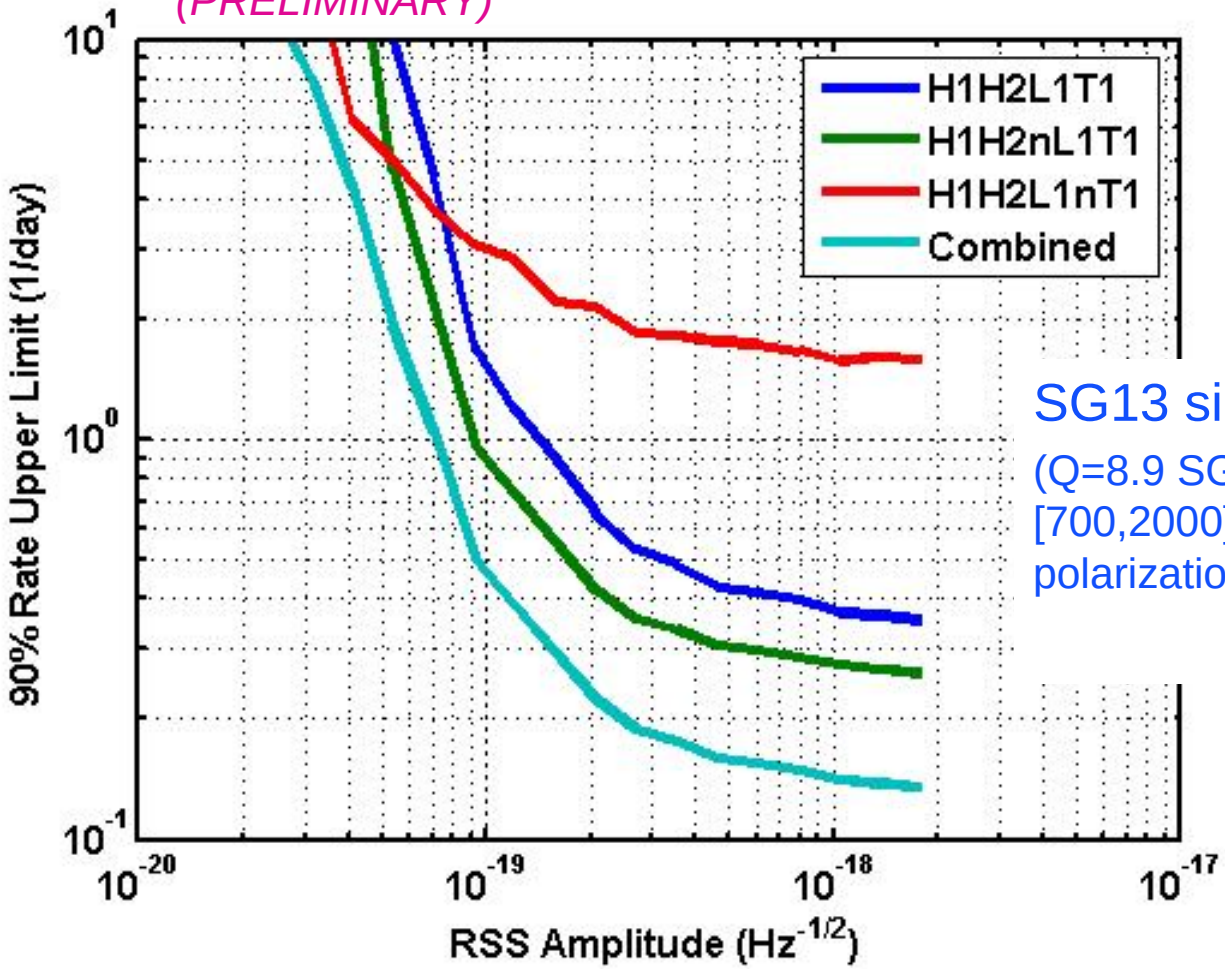
Network	T (Ms)	N	R_{bck} (nHz)	N_{bck}	$R_{90\%}$(1/day)	$h_{50\%}$ ($Hz^{-1/2}$)
H1-H2-L1-T1	0.64*	0/0	<0.75	<5e-4	0.33	2.1×10^{-19}
H1-H2-⌉L1-T1	0.84*	3/0	<27	<0.023	0.25	1.7×10^{-19}
H1-H2-L1-⌉T1	0.14	0/0	<165	<0.023	2.41	0.97×10^{-19}
Combined**	1.6	3/0	n/a	<0.046	0.13	1.8×10^{-19}

*TAMA livetimes to be finalized.

**Treating all 3 data sets as one experiment (all have N_{bck}~0).

R vs h Upper Limits

(PRELIMINARY)



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R vs h Upper Limits

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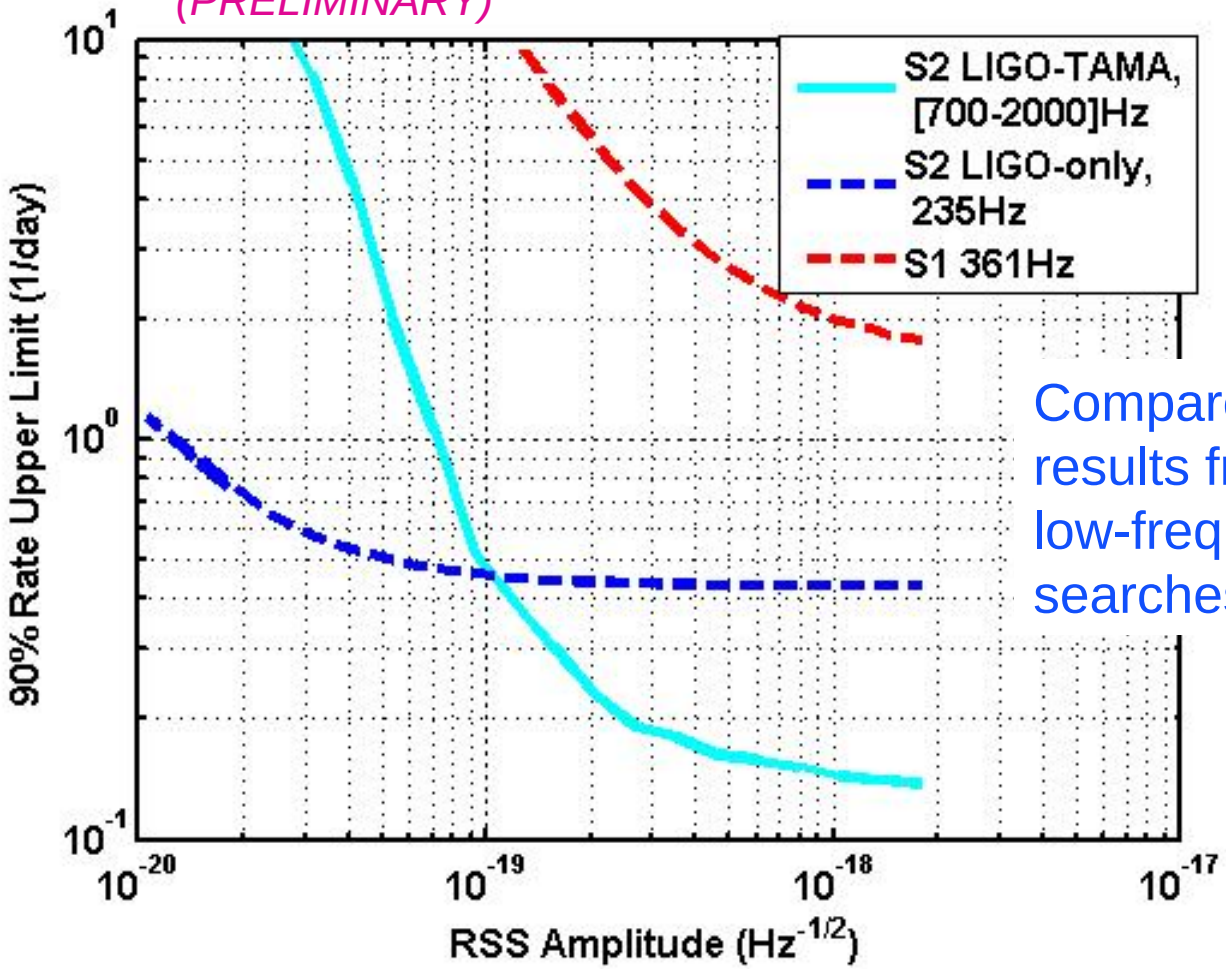

Compare to best results from S1, S2 low-frequency searches.

Summary & Outlook

- TAMA-LIGO joint search for GWBs in S2 is in late stages.
  - » High-frequency search complementary to LIGO-only search at low frequencies.
  - » Two main parts:
    - – 4X: very low false rate
    - – 3X: lots of additional observation time
  - » No GWB candidates survived pipeline.
    - – Rate upper limit of 0.13/day.
    - – $h_{rss}^{50\%} = 2 \times 10^{-19} Hz^{-1/2}$ averaged over networks, analysis band.
- Remaining issues:
  - » livetime to be finalized (account for TAMA veto deadtime)
  - » review (esp TFClusters)
- Paper draft in preparation.
  - » Hope to present at GWDAW.
- S3?
  - » Exploring value of joint S3 search with LIGO, TAMA, GEO representatives.