Search for burst gravitational waves in LIGO-GEO S4 data

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for
The LIGO Scientific Collaboration

Overview

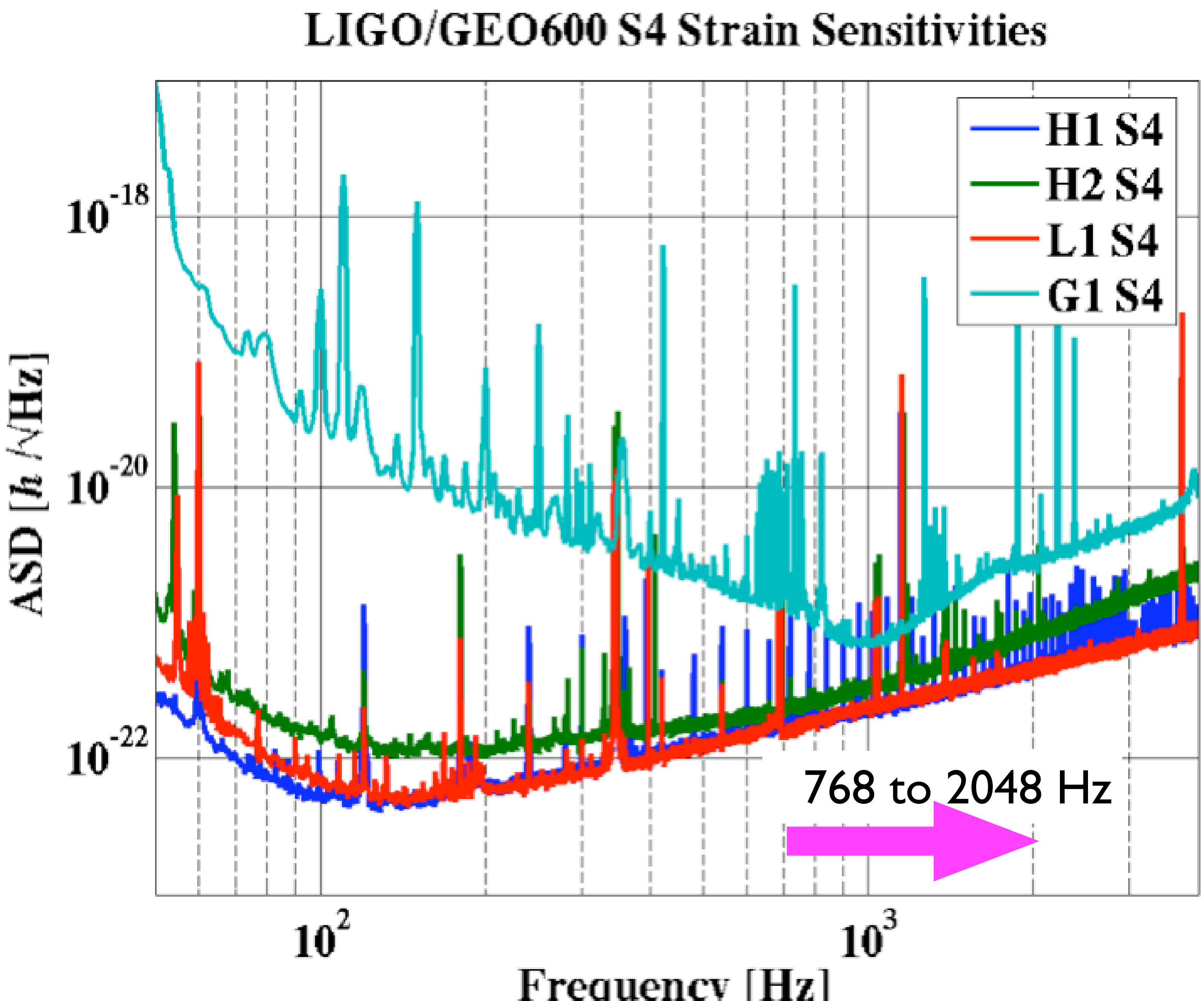
- Overview of S4 and the LSC detectors
- Analysis piplines
- Waveburst-CorrPower analysis overview
- coherent Waveburst analysis overview
- comparison of efficiency
- summary

S4 run and detectors

- S4 run: 22nd of February to 23rd of March, 2005
- four LSC detectors in joint operation
  - H1, H2: Hanford 4 km and 2 km respectively
  - L1: Livingston 4 km
  - G1: GEO 600
- total of 1202645.0 seconds of quadruple coincidence livetime
- detectors at Hanford and Livingston are almost aligned, GEO 600 is not aligned to other detectors

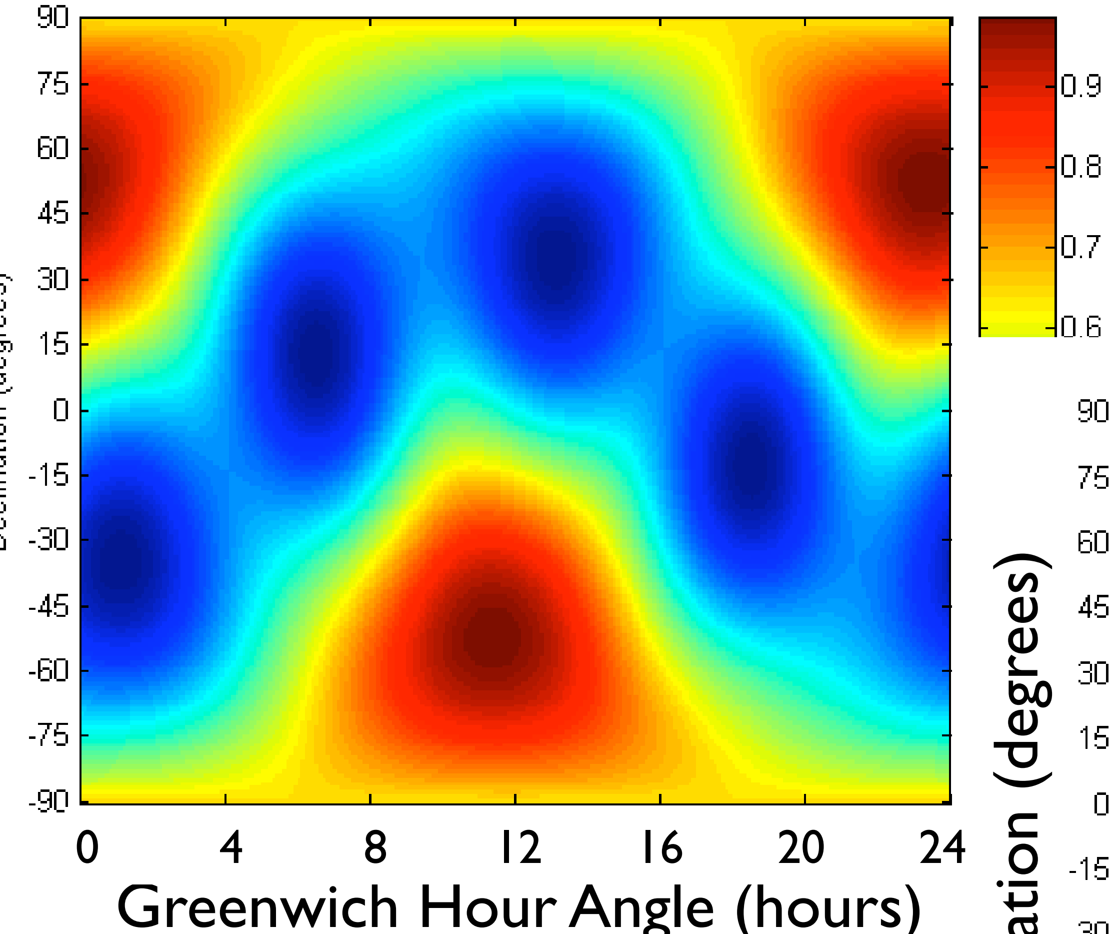
- use both Waveburst-CorrPower and coherent Waveburst pipelines
- compare efficiencies for the same accidental coincidence (background) rate observed for each pipeline
- also compare with LIGO-only network

S4 sensitivities



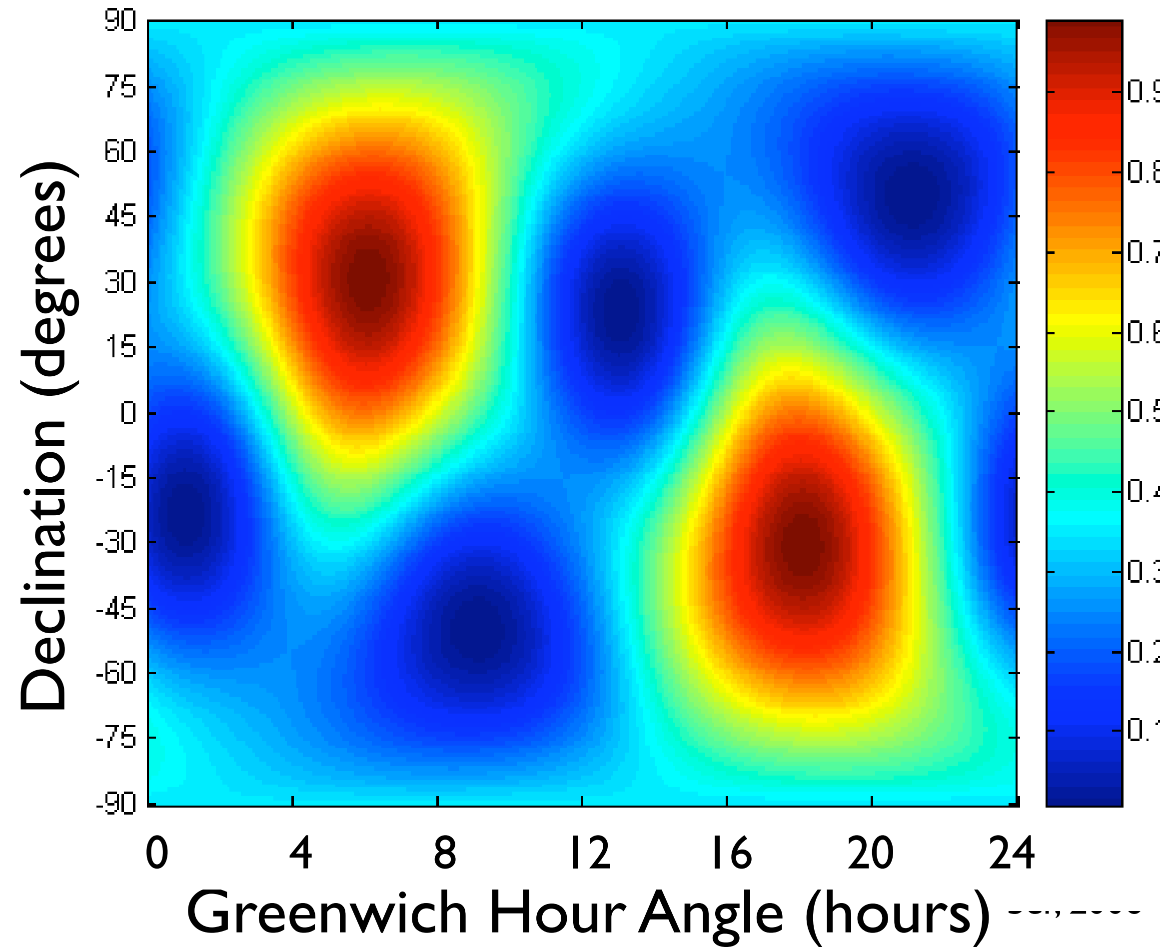
Directional sensitivity

GEO



$F_+^2 + F_x^2$

Livingston

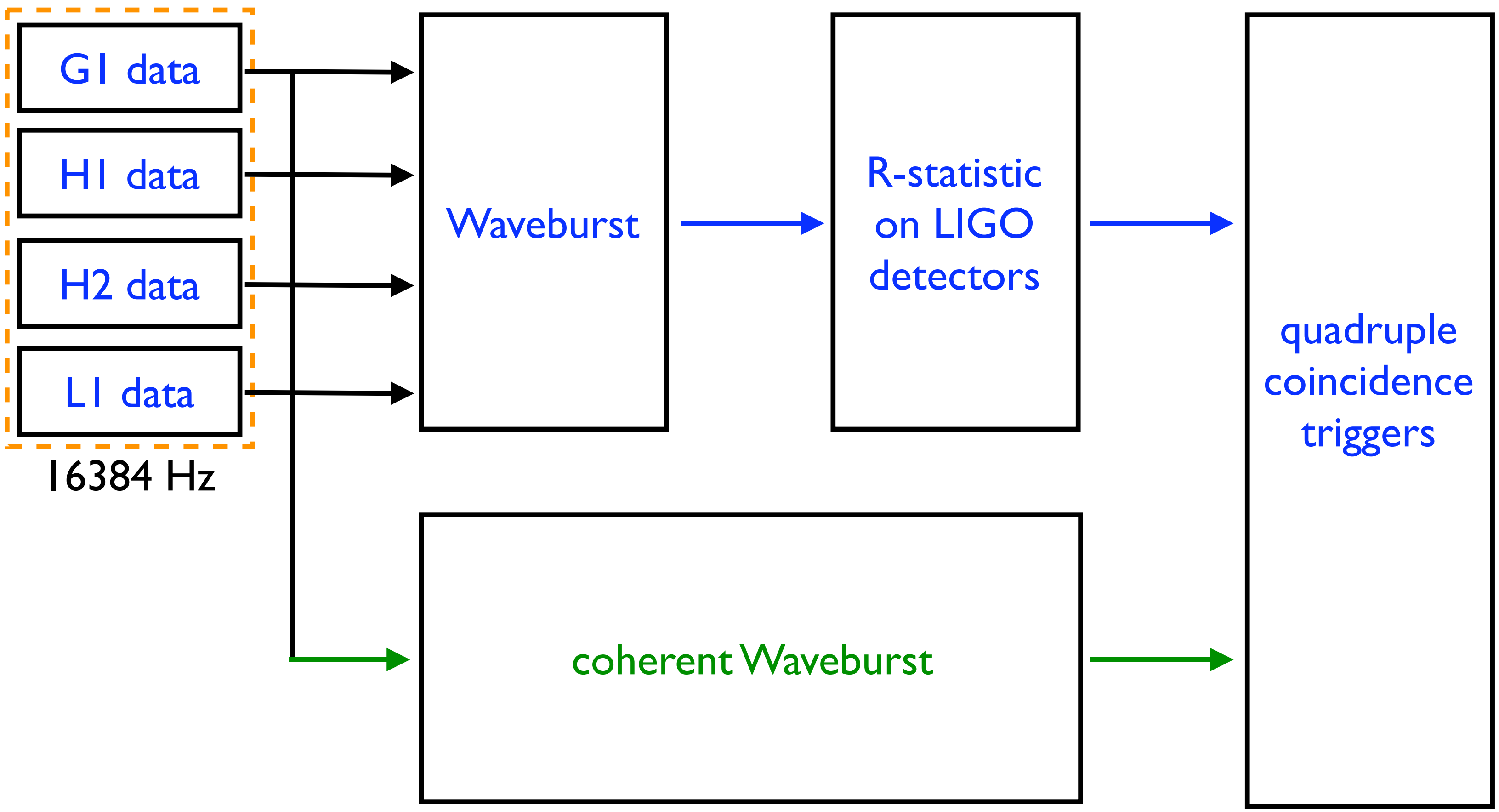


Test bed for
coherent analysis
on real data

G060656-00-Z

Analysis pipelines

blue - Waveburst-CorrPower pipeline



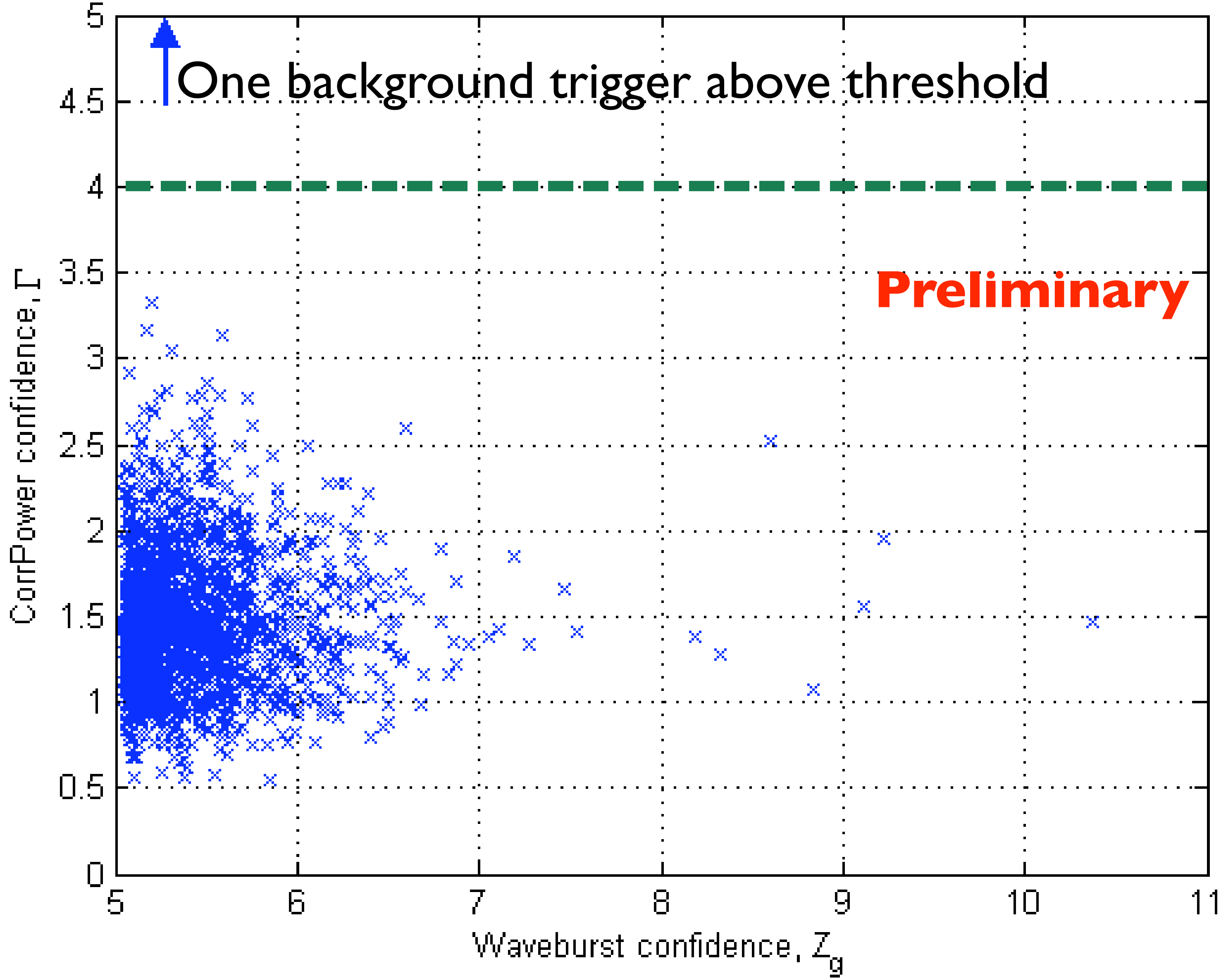
green - coherent pipeline

Waveburst-CorrPower

- process LIGO and GEO data with Waveburst between 768 to 2048 Hz
- Tune thresholds on time shifted data
- 100 time shifts from -156.25 to 156.25 seconds in steps of 3.125 seconds (zero-lag not included)
- use CorrPower to calculate R-statistic of data from LIGO detectors at coincident trigger times
- impose H1-H2 consistency cuts: measured amplitude within a factor of 2 and positive correlation of calibrated signals
- measure efficiency by injecting sine gaussians
- tuning two thresholds:
- Waveburst confidence, Z_g: significance of coincidence excess power
- CorrPower confidence, Γ: significance of R-statistic value compared to that expected for noise

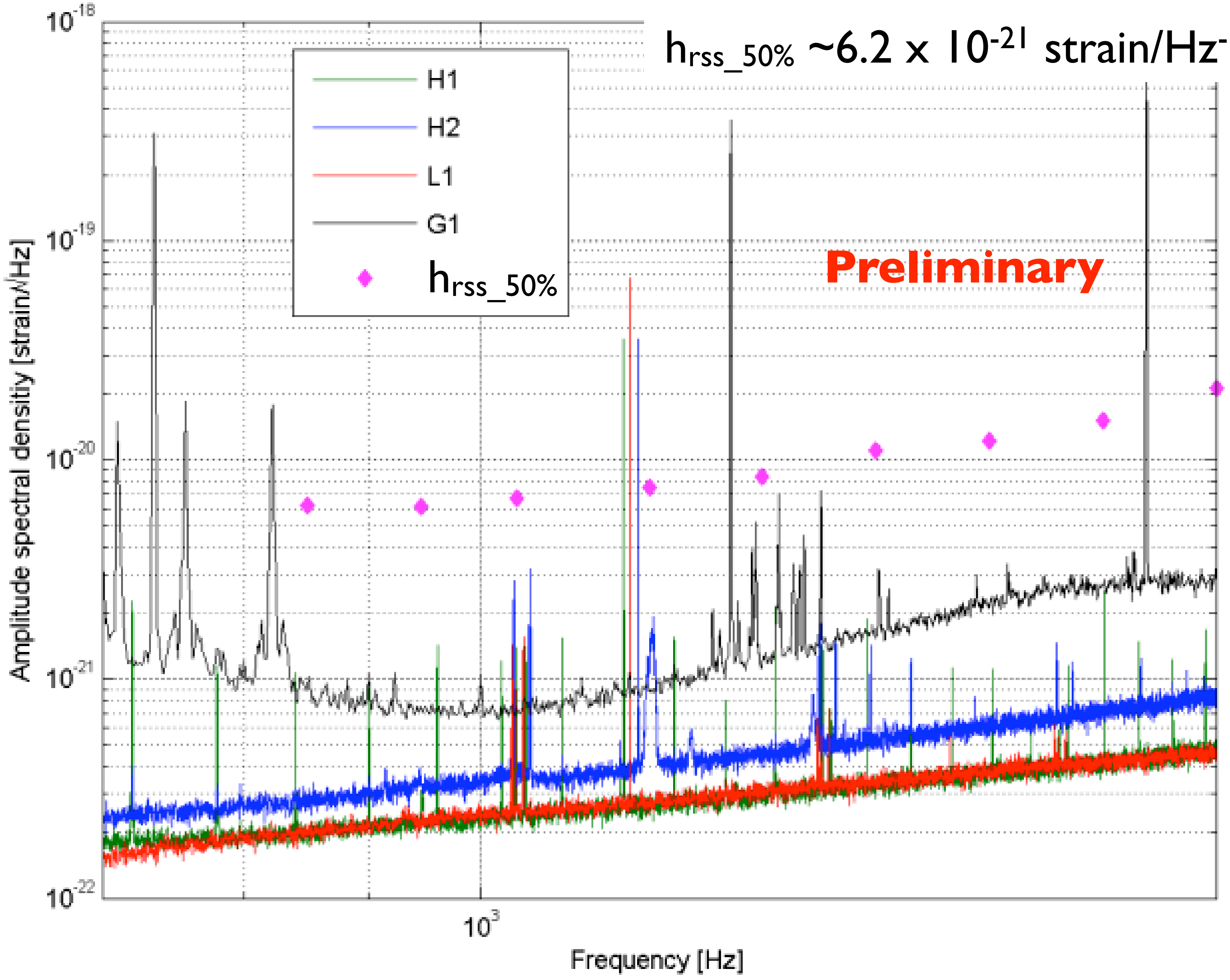
Z_g v Γ background

Waveburst confidence, Z_g, against CorrPower confidence, Γ



Waveburst-CorrPower sensitivity

$h_{rss\_50\%} \sim 6.2 \times 10^{-21}$ strain/Hz$^{-1/2}$ @ 849 Hz



Coherent Waveburst

- coherent Waveburst run from 768 to 2048 Hz
- also tune thresholds on time shifted data set
- 100 time shifts from -156.25 to 156.25 seconds in steps of 3.125 seconds
- apply 3-detector likelihood and networks cuts
- also measure efficiency using sine-gaussian injections

Likelihood cut

$$L = \sum_i \sum_k \frac{1}{2\sigma_k^2} \left[\underline{x_k^2[i]} - \left(x_k[i] - \xi_k[i] \right)^2 \right]$$

from talk by S. Klimenko

Energy normalised by detector noise (SNR)

- threshold on reconstructed energy
- $L_{012}>36$ && $L_{013}>36$ && $L_{023}>36$ && $L_{123}>36$
- where L_{ijk} = snr[i]-null[i] + snr[j]-null[j] + snr[k]-null[k]

- snr[i] - data stream energy for i-th detector normalized by the noise variance,
- null[i] - reconstructed noise energy normalized by the noise variance (null stream)
- 0 - L1, 1 - H1, 2 - H2, 3 - G1

Likelihood cut

$$L = \sum_i \sum_k \frac{1}{2\sigma_k^2}\left[x_k^2[i] - \left(\underline{x_k[i] - \xi_k[i]}\right)^2\right]$$

from talk by
S. Klimenko

Null energy normalised by detector noise

- threshold on reconstructed energy
- $L_{012}>36$ && $L_{013}>36$ && $L_{023}>36$ && $L_{123}>36$
- where L_{ijk} = snr[i]-null[i] + snr[j]-null[j] + snr[k]-null[k]

- snr[i] - data stream energy for i-th detector normalized by the noise variance,
- null[i] - reconstructed noise energy normalized by the noise variance (null stream)
- 0 - L1, 1 - H1, 2 - H2, 3 - G1

Network cut

- also use combined network cut:

$$\sqrt{\rho_{eff}} = \sqrt{rSNR^{C_{net}}} > T$$

- C_{net} - network cross-correlation

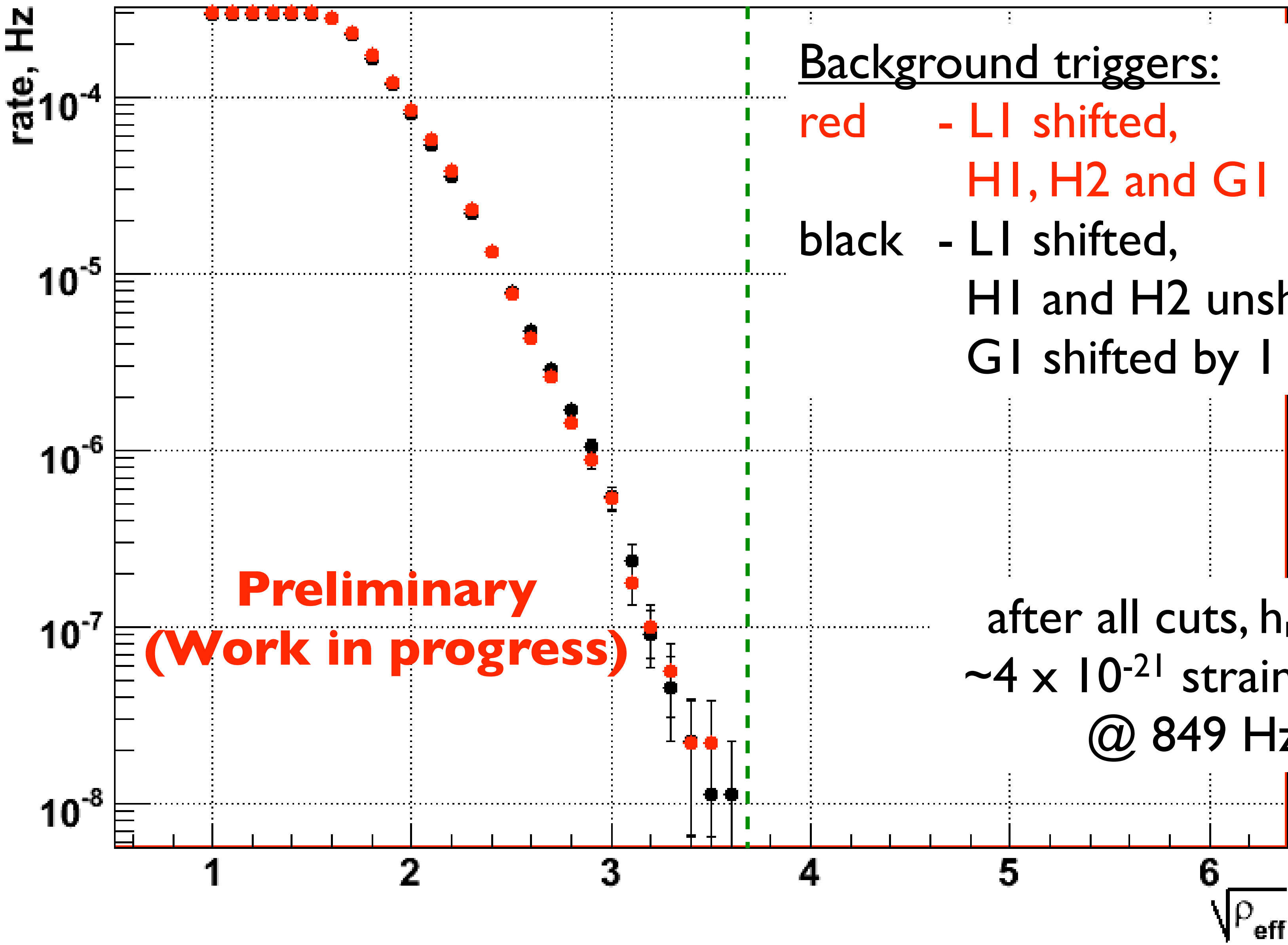
$$C_{net} = \frac{E_{coherent}}{N_{ull} + E_{coherent}}$$

from talk by S. Klimenko

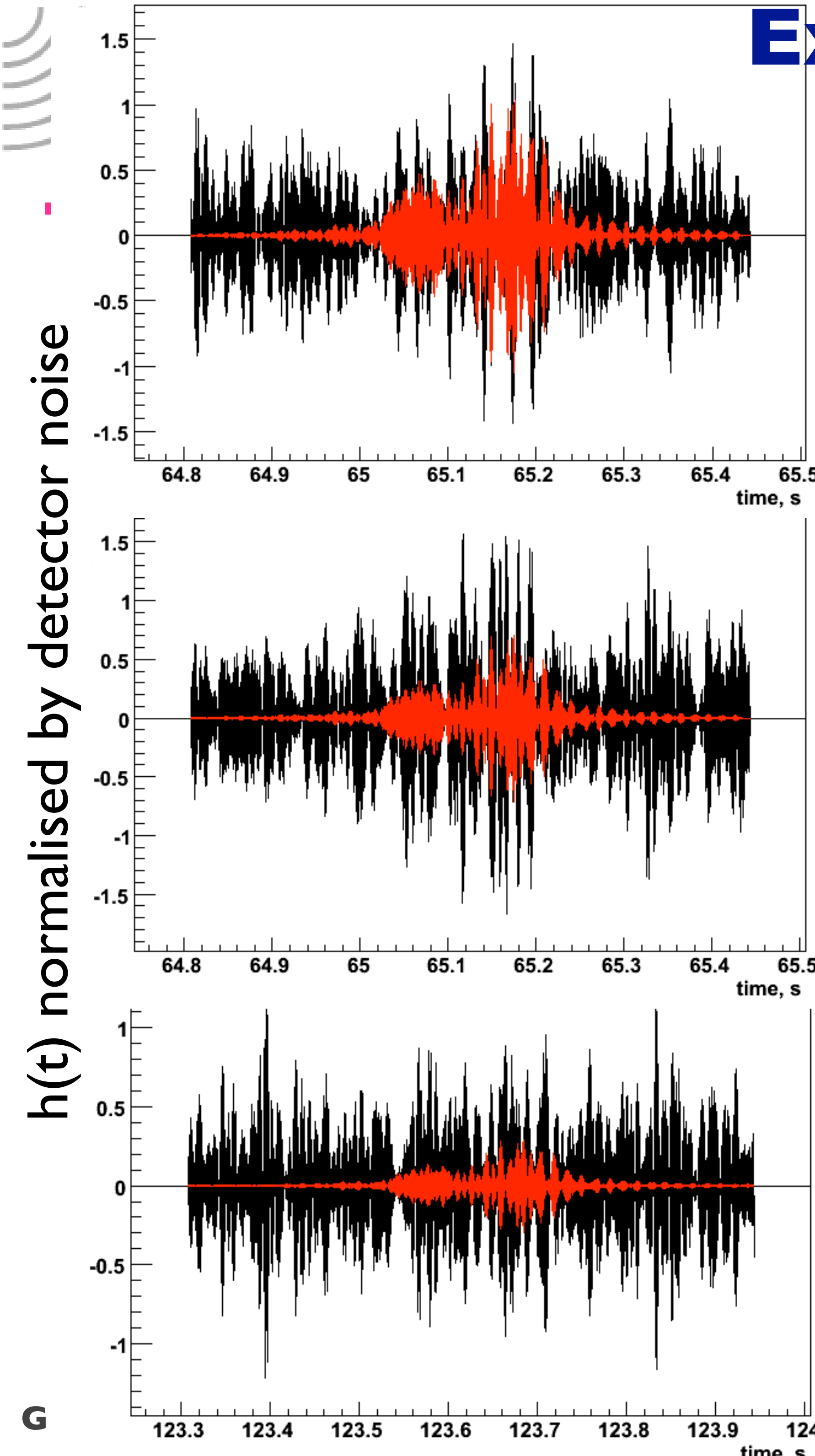
- rSNR - average rank SNR
- from tuning, choose T to be ~3.7, we get 0 accidental coincidences (background)

coherent Waveburst background coincidences

rate vs threshold



Example: LIGO-GEO trigger rejection



- Large glitch in H1 and H2, modest glitch in L1
  - consistent with signal close to null in L1 antenna pattern
- rank SNRs; H1: 53, H2: 40, L1:4
  - hrss [$Hz^{-1/2}$]; H1: 3.2 x 10^{-21}, H2: 3.2 x 10^{-21}, L1: 10^{-21}
- Likelihood ~ 64
- Frequency ~ 1725 Hz
- this glitch was rejected with the inclusion of data from GEO

red - likelihood reconstruction of detector response

black - whited, bandlimited time series

Summary

- have tuned thresholds for Waveburst-CorrPower and coherent Waveburst pipelines
- detection efficiencies for coherent Waveburst pipeline better than Waveburst-CorrPower for LIGO-GEO S4
- coherent Waveburst improves detection efficiencies of LIGO-GEO analysis to level of LIGO-only in S4
- inclusion of GEO to coherent network analysis leads to rejection of glitches

Future plan

- finalise analysis and look for zero-lag coincidences
- write paper comparing efficiencies and background of both pipelines