LSC – Virgo joint Burst searches

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Outline

- Benefits of joint analysis
- First joint analysis (sep 2006)
- Present dataset : S5/VSR1
  - Coincident methods
  - Coherent methods
- Summary and outlook

Benefit of joint analysis

- Better sky coverage using LIGO and Virgo
- Improved detection efficiency
  - Coincidences to reduce FA rate
  - Coherent consistency to discriminate glitch from real event
- Allow directional searches
- Improved source reconstruction
  - Sky position
  - Waveforms extraction

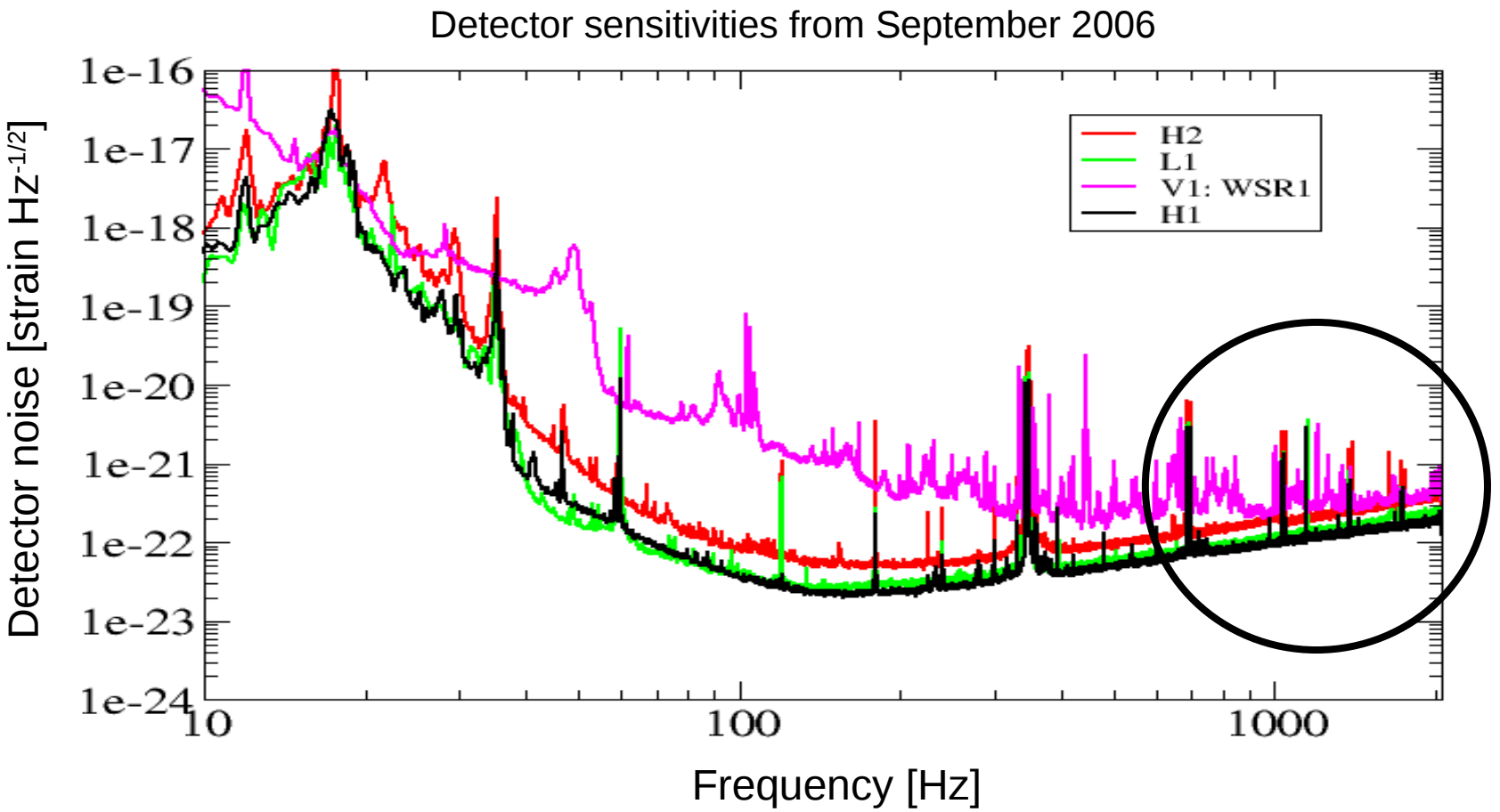
First steps

First joint real data analysis

- 68 hours in September 2006
  - Ligo's 5th Science Run (S5)
  - Virgo's 1st weekend science run (WSR1)
- Include LIGO, GEO and Virgo detectors
- Apply both coherent and coincident methods
- First look before S5/VSR1 analysis
- Use different types of signals for different network configurations
- Results presented here are done in coincident analysis with Power Filter (*G.M. Guidi et al 2004 Class. Quantum Grav.* ***21*** *S815-S820*)

S5/WSR1 data set

- Coincident analysis focused only on 800 to 2000 Hz.

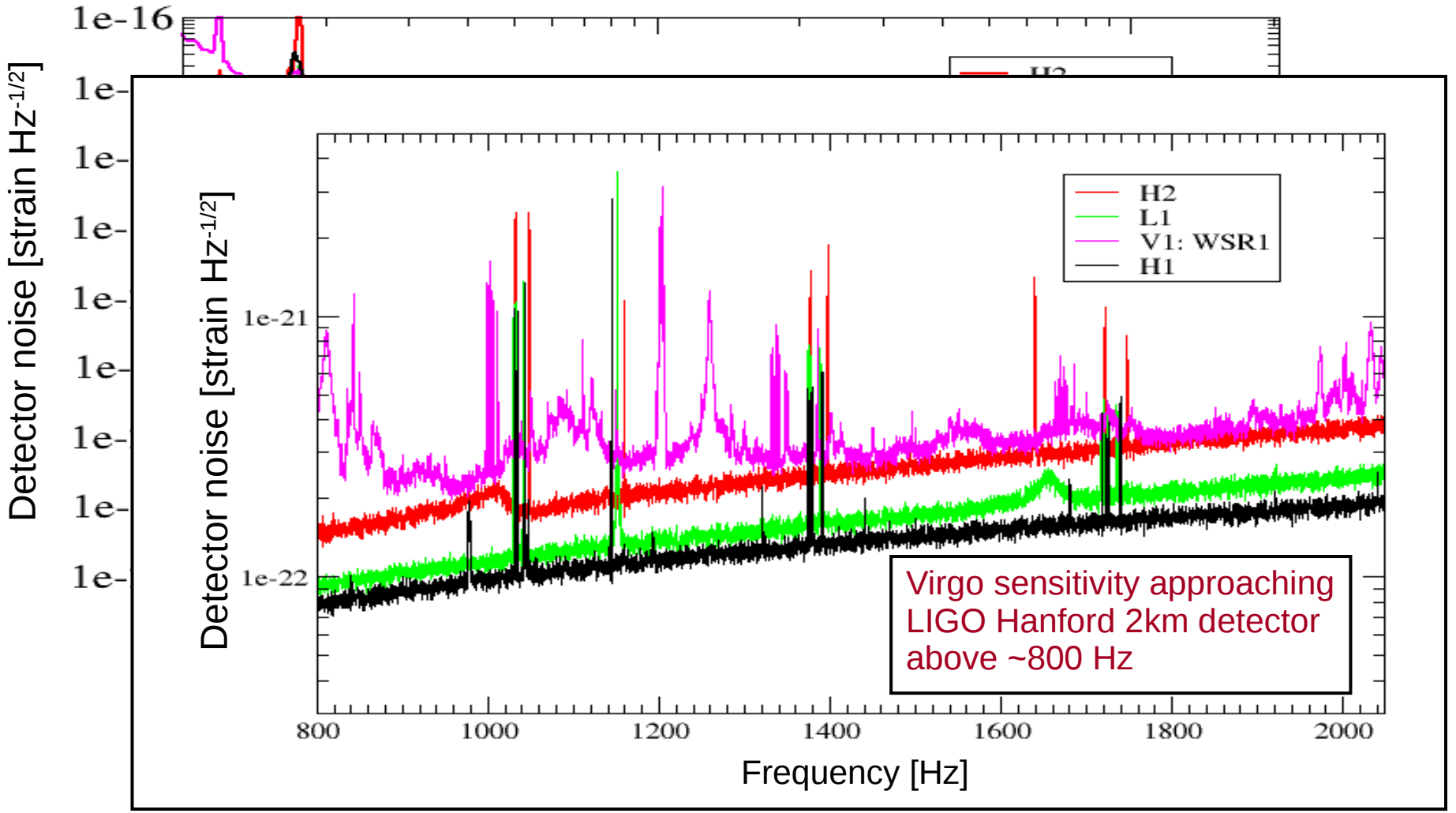


Frequency [Hz]

S5/WSR1 data set

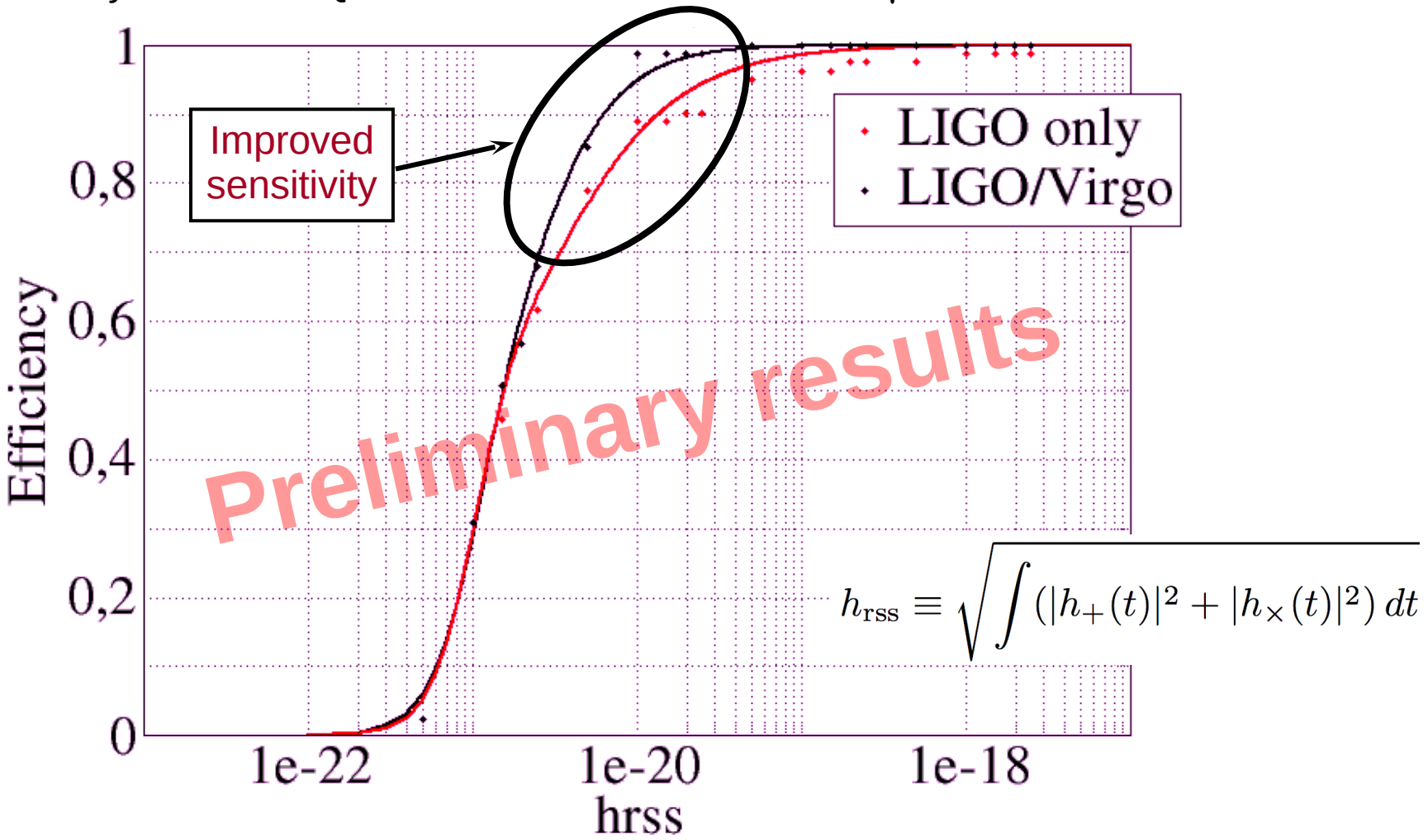
- Coincident analysis focused only on 800 to 2000 Hz.

Detector sensitivities from September 2006



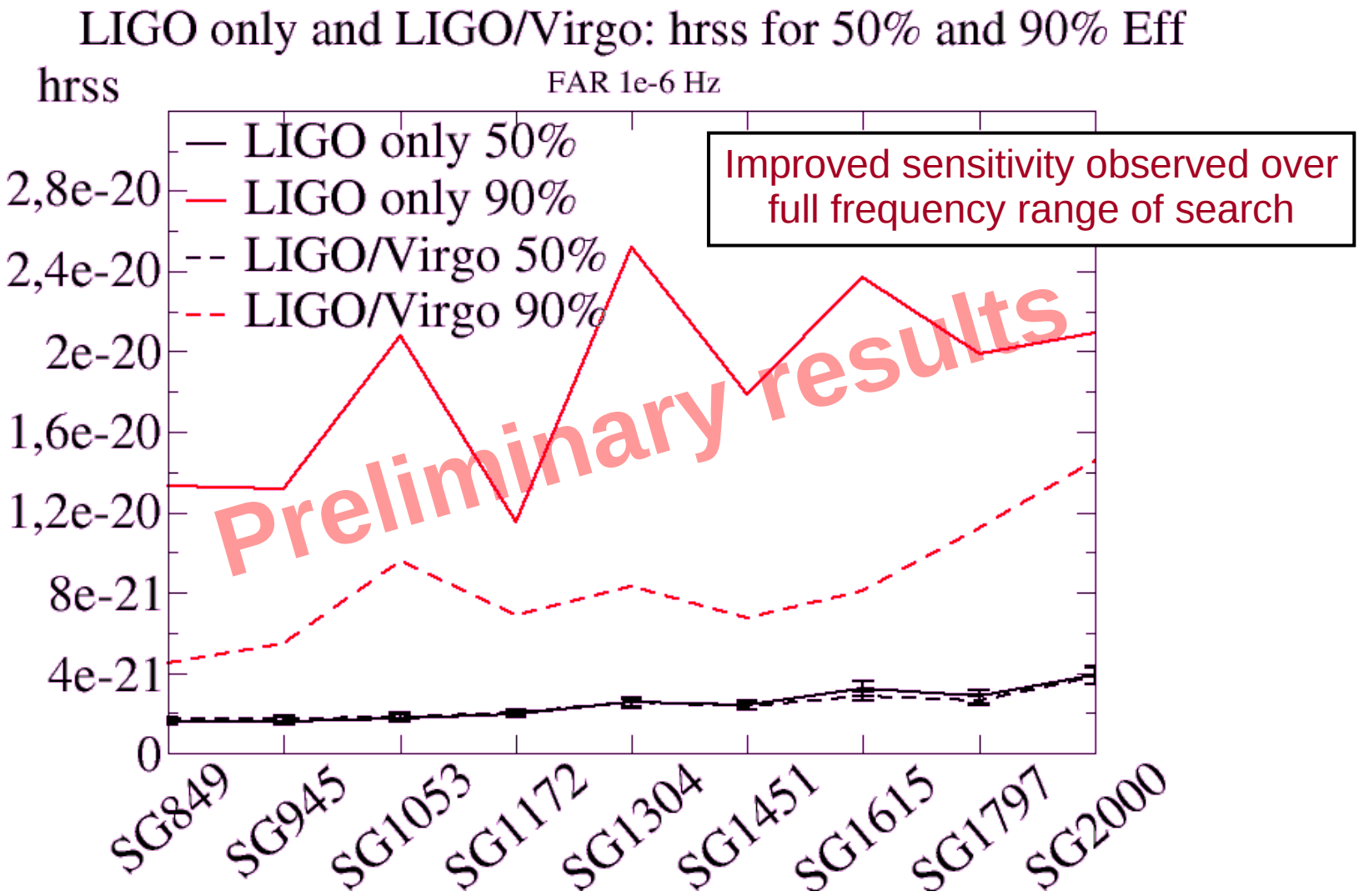
Coincident analysis with PF

Sensitivity to 849 Hz Q 9 sinusoidal Gaussians at a 1 μHz false detection rate



Comparison of LIGO only (H1L1) and LIGO/Virgo (H1L1+H1V1+L1V1) sensitivities

Coincident analysis with PF

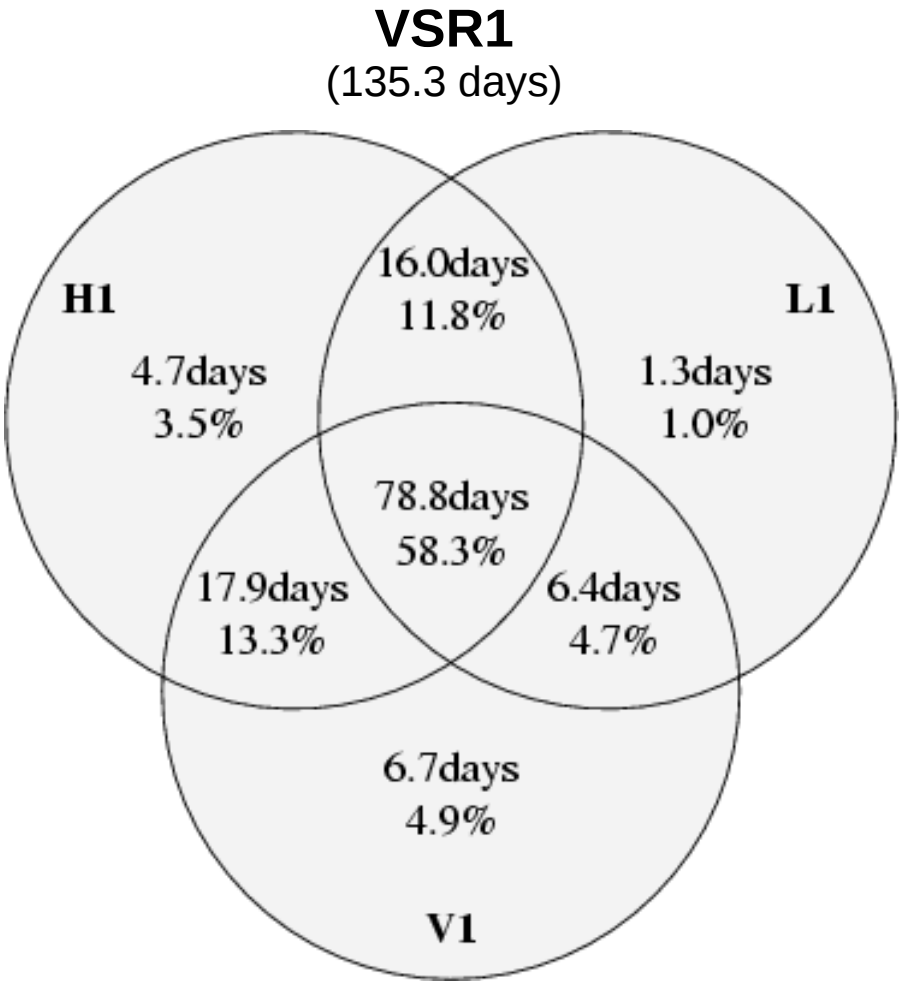


Comparison of LIGO only (H1L1) and LIGO/Virgo (H1L1+H1V1+L1V1) sensitivities

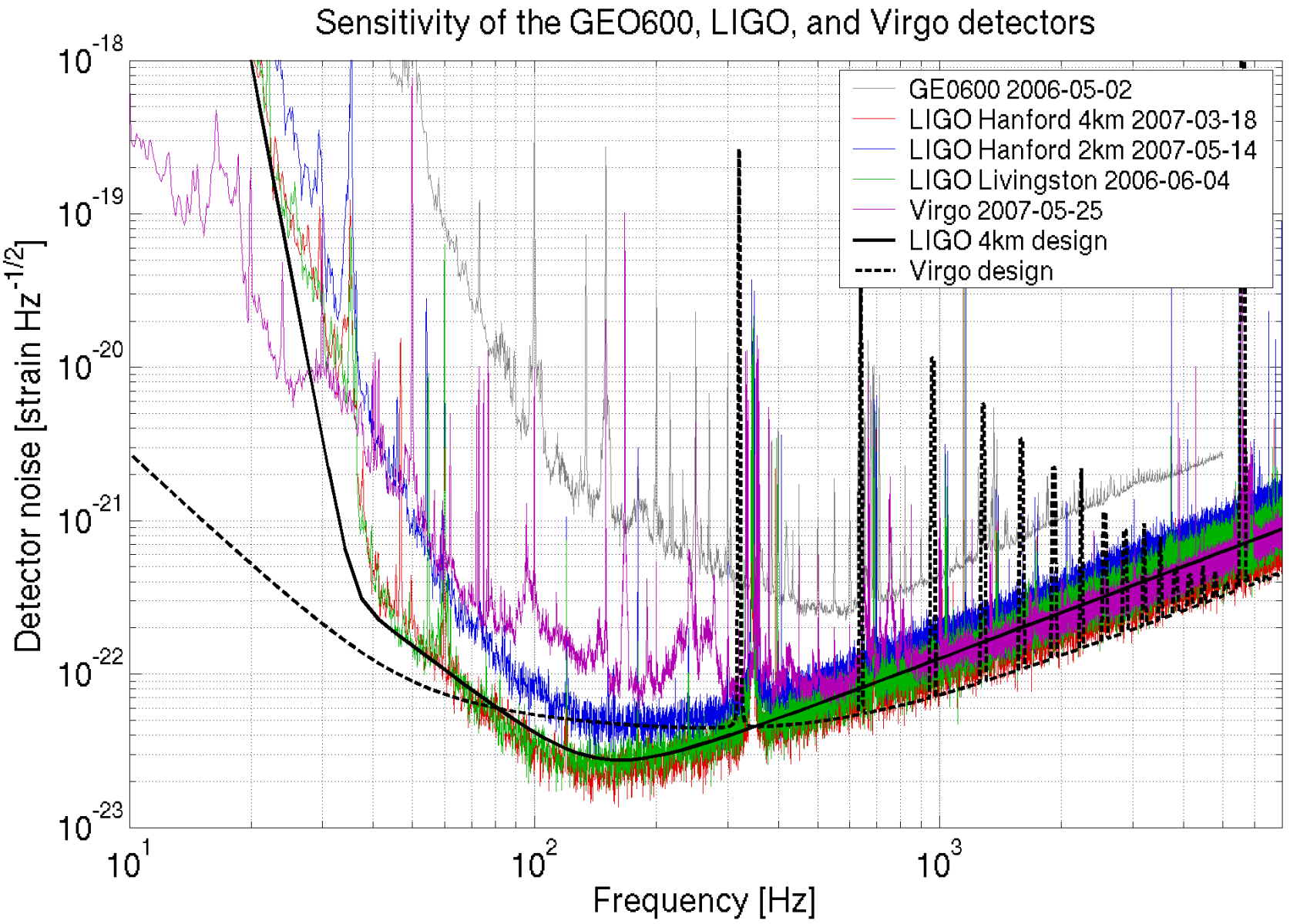
S5/VSR1 “era”

S5/VSR1

- From 18th of May up to 1st October
- Networks:
  - 58 % of duty cyle triple coincidences between H1, L1 and V1
  - 54 % of duty cyle including H2

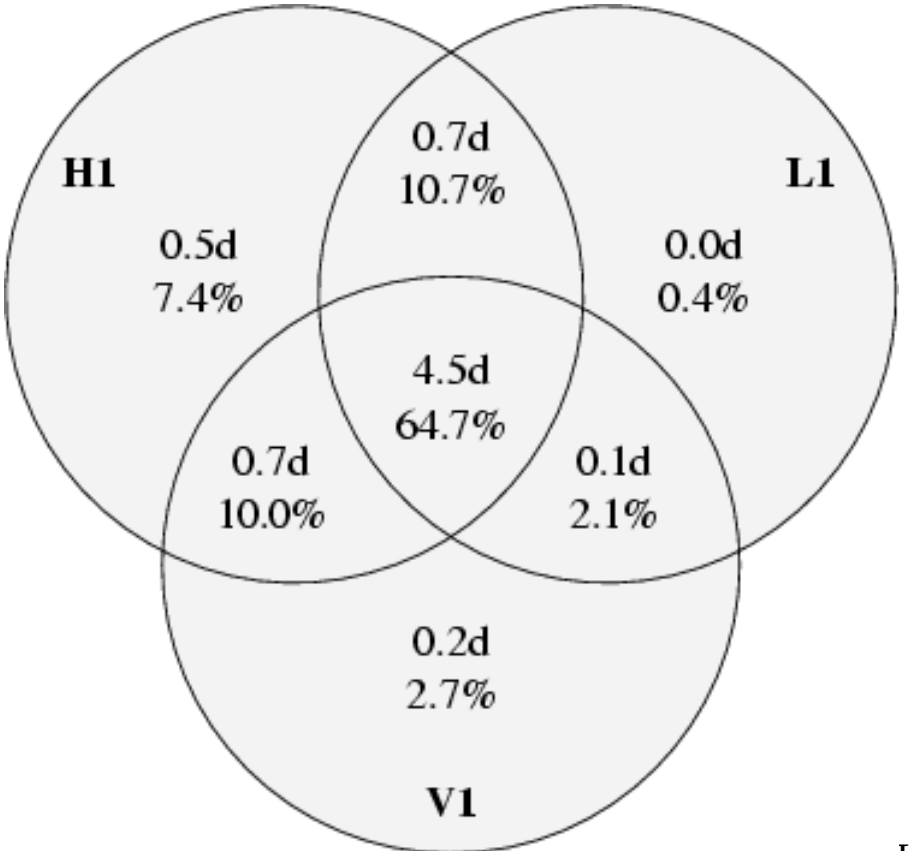


G1: 98.3 days (72.7%)
G1H1H2L1V1: 55.2 days (40.8%)


Sensitivity of the GEO600, LIGO, and Virgo detectors
GE0600 2006-05-02
LIGO Hanford 4km 2007-03-18
LIGO Hanford 2km 2007-05-14
LIGO Livingston 2006-06-04
Virgo 2007-05-25
LIGO 4km design
Virgo design
Detector noise [strain Hz^-1/2]
Frequency [Hz]
10^-18
10^-19
10^-20
10^-21
10^-22
10^-23
10^1
10^2
10^3

Playground – one week of data

- We are using one week of data as playground at beginning of August 2007 (JW1)
- Networks available



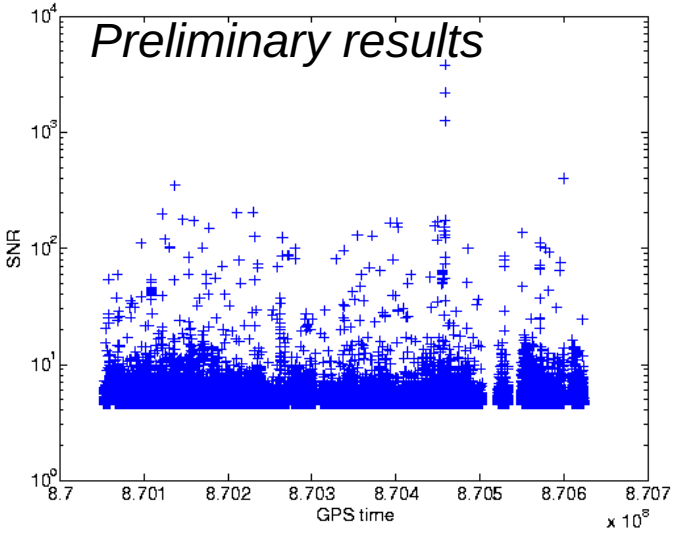
Configuration	Livetime
H1	6.52 days (93.1 %)
H2	6.13 days (87.5 %)
L1	5.47 days (78.2 %)
V1	5.30 days (75.7 %)
G1	5.44 days (77.7 %)
H1H2L1	4.93 days (70.4 %)
H1H2L1V1	3.99 days (57.0 %)
H1H2L1V1G1	3.00 days (42.8 %)

Coincident methods

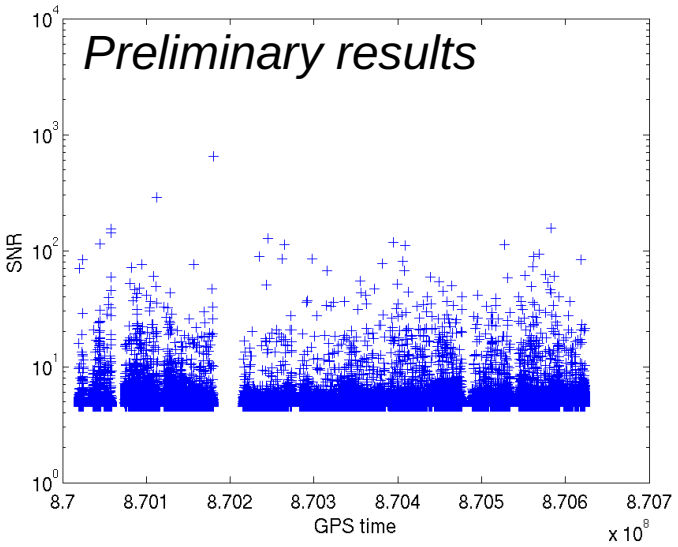
- Use 2 pipelines:
  - Peak Correlator : Matched filtering using Gaussian templates between 0.5 ms and 10 ms,
  - Q pipeline : templated matched filter search for waveforms that are sinusoidal Gaussians after whitening.
- Considered union of all double coincidences in the H1L1V1 network
  - 20 ms for Hanford-Livingston sites
  - 40 ms for LIGO-Virgo sites
- Coherent follow-up with remaining triggers using X-Pipeline

Coincident methods

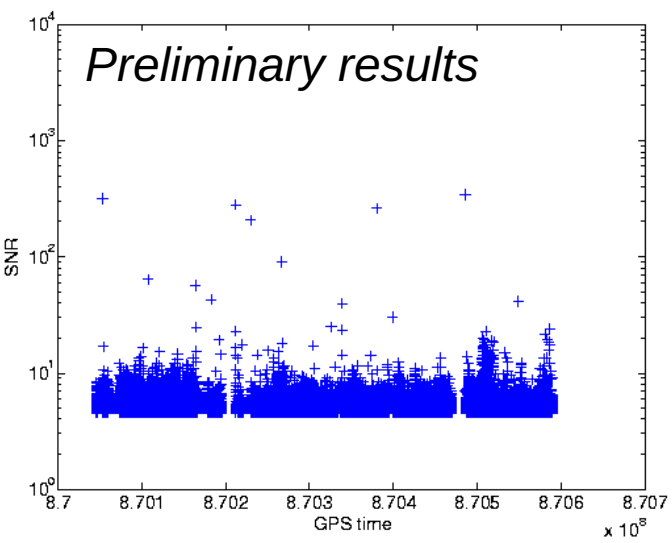
- Peak Correlator :
  - Preliminary DQ and no veto applied
  - SNR vs time (before any analysis)



H1



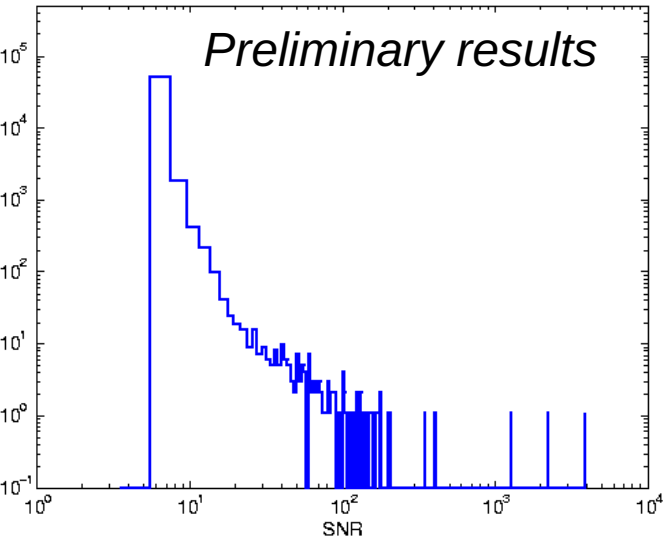
L1



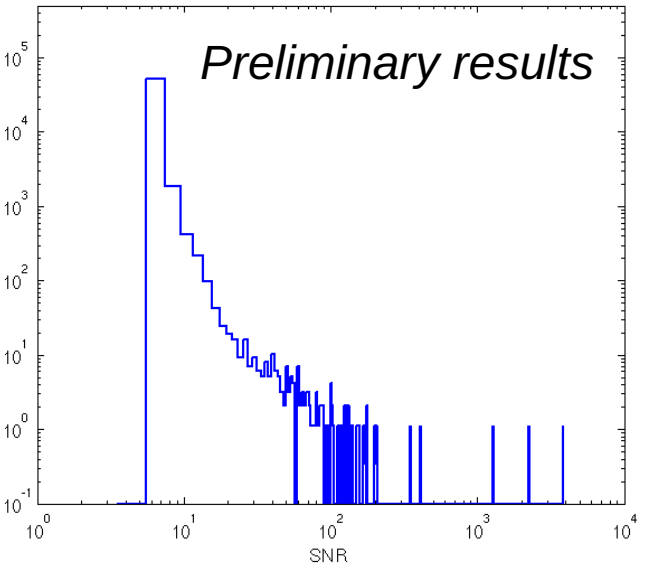
V1

Coincident methods

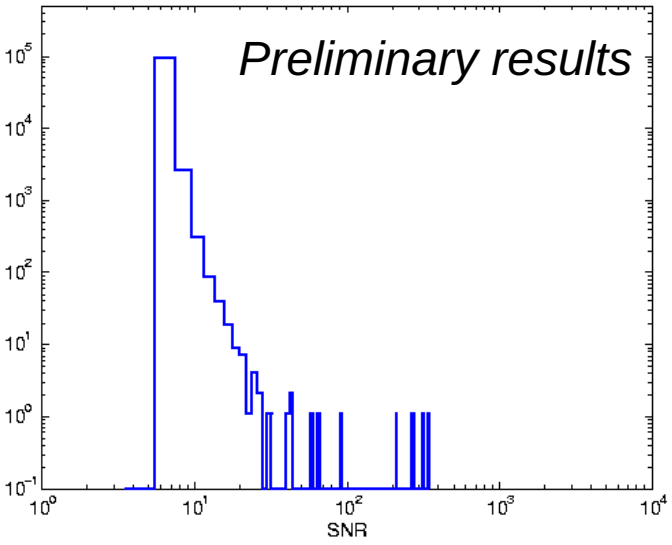
- Peak Correlator :
  - Preliminary DQ and no veto applied
  - SNR distributions (before any analysis)



H1



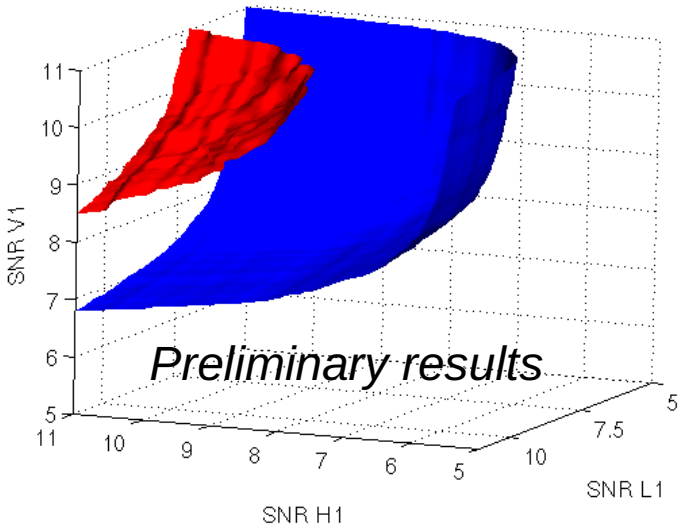
L1



V1

Coincident methods

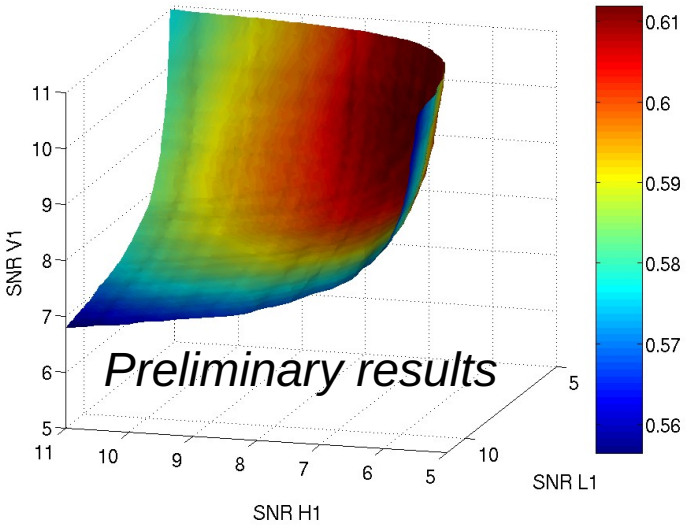
- Determine SNR thresholds for a given FA rate for the network
- Calculate the averaged efficiency for theses configurations
- Keep the one which maximize the efficiency



FA rate in the network vs SNR cut
blue : 1e-6Hz; red : 2e-7Hz

For each point on the blue plane, obtain averaged efficiency

FA 1e-6

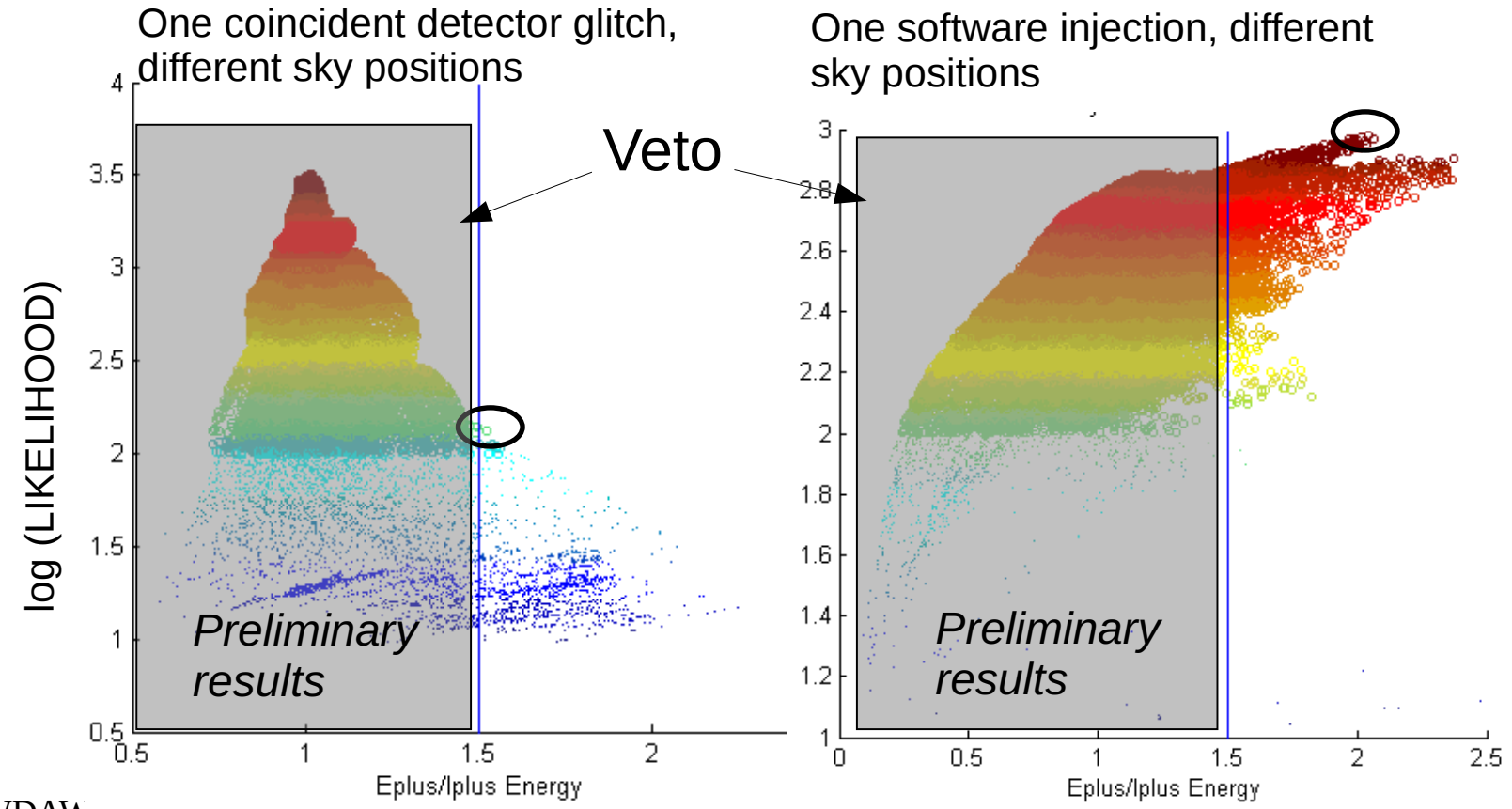


Averaged efficiency on the network vs SNR threshold

Coherent methods

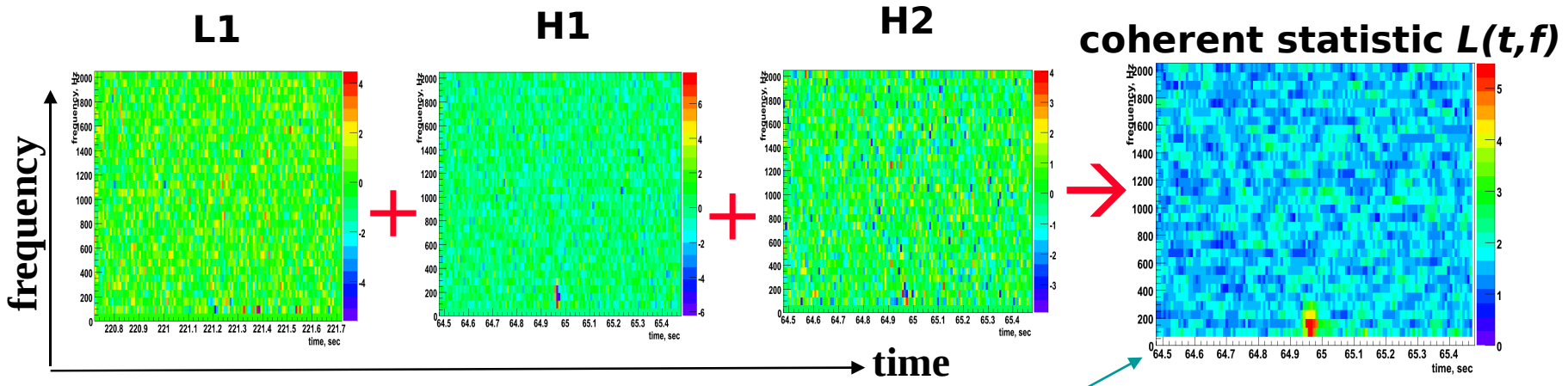
- Coherent follow-up of candidates from coincident pipeline with X-Pipeline
- Uses cross-correlation techniques (with appropriate projections) to distinguish coincident detector glitches from gravitational waves

Choose the sky position with well correlated waveforms and high likelihood to represent each event



Coherent methods

- Use a fully coherent end-to-end pipeline for unmodeled all-sky search : coherentWaveBurst
- Time-frequency analysis done with wavelets
- Allows source reconstruction and waveform extraction



$$L(t,f) = \max_{h_+ h_\times \theta\varphi} \sum_k \frac{1}{2\sigma_k^2(f)} \left[x_k^2[t,f] - \left(x_k[t,f] - \xi_k[t,f] \right)^2 \right]$$

$$\xi_k = h_+ F_{+k} + h_\times F_{\times k}$$

Coherent method

- cWaveBurst on JW1 dataset :
  - Preliminary DQ and no veto applied
  - Correlated amplitude vs time (time shifted streams)

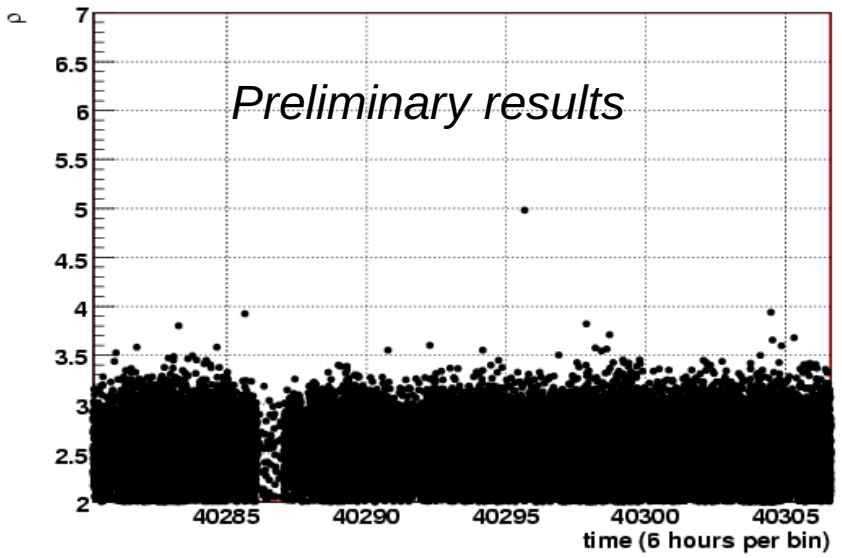
$$2L = \sum_{i,j} \langle x_i x_j \rangle C_{ij} = E_{i=j} + E_{i \neq j}$$

$$cc = \frac{ecor}{ecor + null} \qquad ecor = \sum_{i \neq j} L_{ij}$$

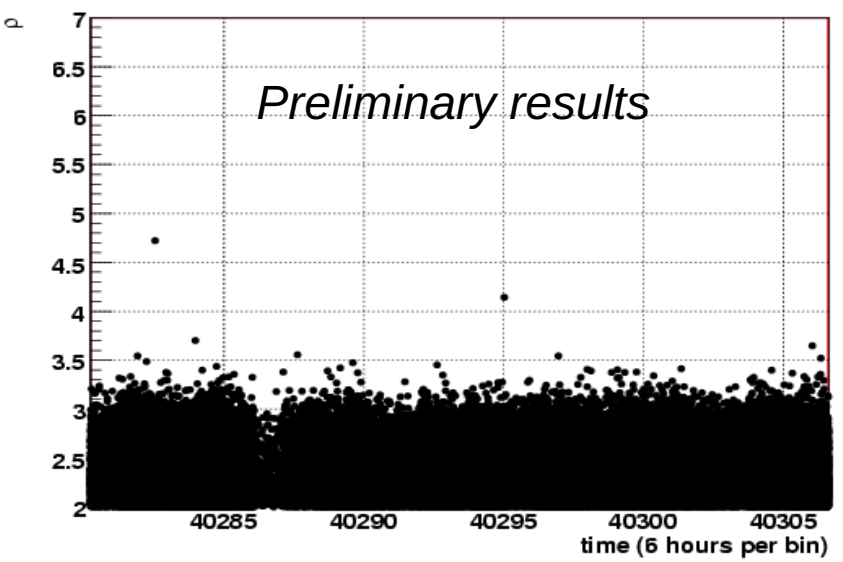
$$\rho = \sqrt{\frac{|ecor|}{n}} \; cc$$

$$n = number\ of\ detectors$$

LIGO only



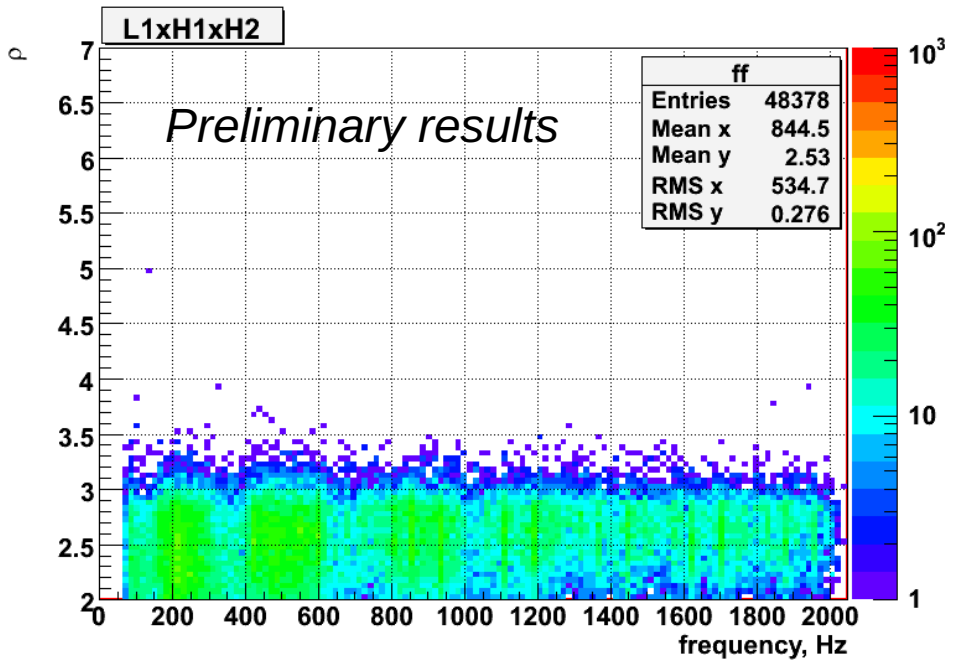
LIGO+Virgo



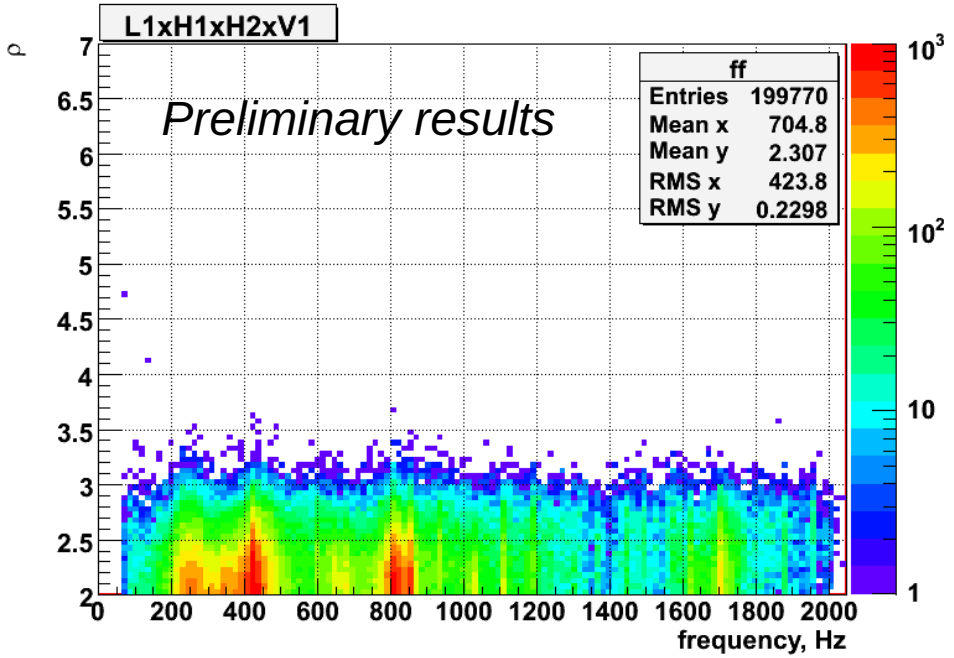
Coherent method

- cWaveBurst on JW1 dataset :
  - Preliminary DQ and no veto applied
  - Correlated amplitude vs frequency (time shifted streams)

LIGO only



LIGO + Virgo



Summary and outlook

- Work on first joint analysis presents an improvement in detection efficiency
- VSR1 data are less glitchy than WSR1 and give a better overlap with LIGO
  - Could foresee some improvement adding Virgo to the LIGO network
  - Should allow a better source reconstruction
  - Results on the playground will arrive soon
- Still need to define the analysis for the complete data set