



Detection Confidence Tests for Burst and Inspiral Candidate Events

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Motivation

Burst and Inspiral searches are looking for transient signals

⇒ **Both searches are sensitive to non-stationary noise in the detectors**

⇒ **Both searches produce accidental coincident triggers**

⇒ **It is important to distinguish gravitational waves from background triggers**

⇒ **Interesting candidates* are subject to review with our detection checklist**

Goal: Estimate confidence in our gravitational wave candidates

Detection checklist = Standard list of tests

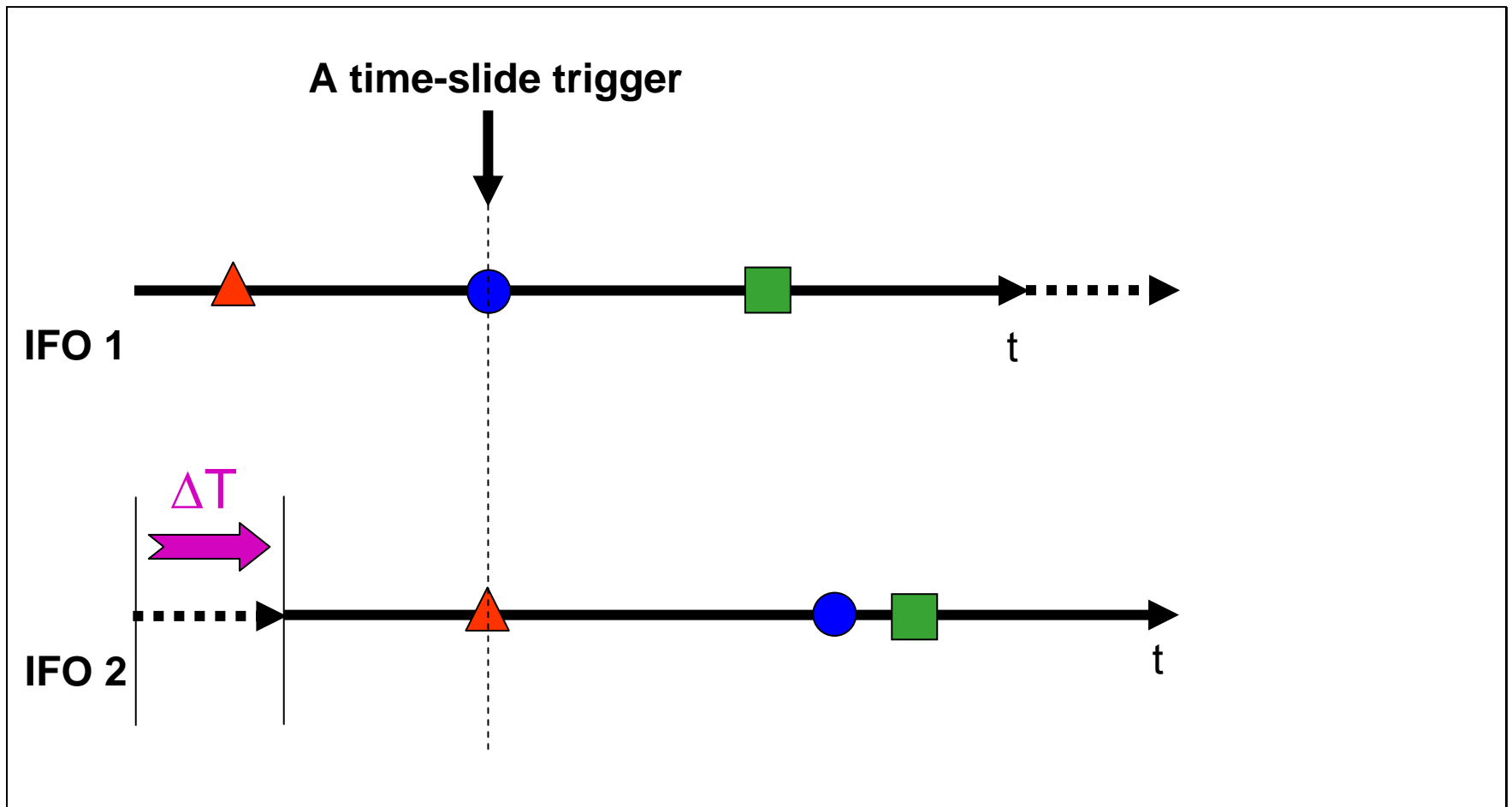
(with many items in different stage of development)

⇒ **Some of these tests will be highlighted in the following slides**

****An “interesting candidate” is a coincident trigger found at the end of the pipeline, which is statistically significant with respect to the estimated background***

Statistical significance of the candidate

The statistical significance of the CBC candidates is estimated from the time-slides triggers



Two examples

- **An inspiral gravitational-wave signal (hardware injection)**

IFO	End Time (ms)	SNR	CHISQ	Chirp Mass	Eta	Mass 1	Mass 2	Eff Dist (Mpc)
L1	xxxxxxxx.888	11.39	25.43	4.77	0.2026	8.92	3.51	69.48
H1	xxxxxxxx.879	12.94	44.24	4.62	0.1284	13.43	2.39	62.44
H2	xxxxxxxx.884	7.49	34.32	4.81	0.2074	8.74	3.63	48.92

- **A background trigger (found with time slide)**

IFO	End Time (ms)	SNR	CHISQ	Chirp Mass	Eta	Mass 1	Mass 2	Eff Dist (Mpc)
L1	xxxxxxxx.896	20.89	278.34	13.22	0.1979	25.44	9.50	11.65
H1	xxxxxxxx.898	5.61	69.38	10.38	0.1348	28.99	5.54	136.03
H2	xxxxxxxx.899	6.24	24.79	15.23	0.25	17.5	17.5	94.44

Both instances of candidates will be used to illustrate the tests of the detection checklist in the following slides...

Status of the interferometers (1/2)

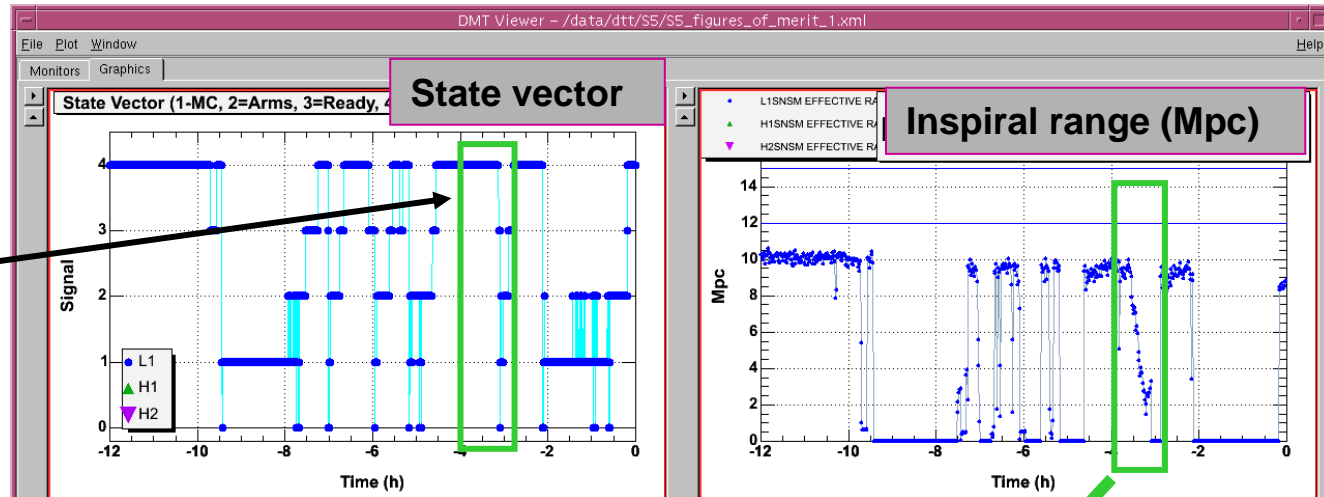
Ex: Status of the L1 detector at the time of the background trigger

⇒ Check figure of merits (state vector, inspiral range, ...)

Figures of merit posted in the elog

State vector:

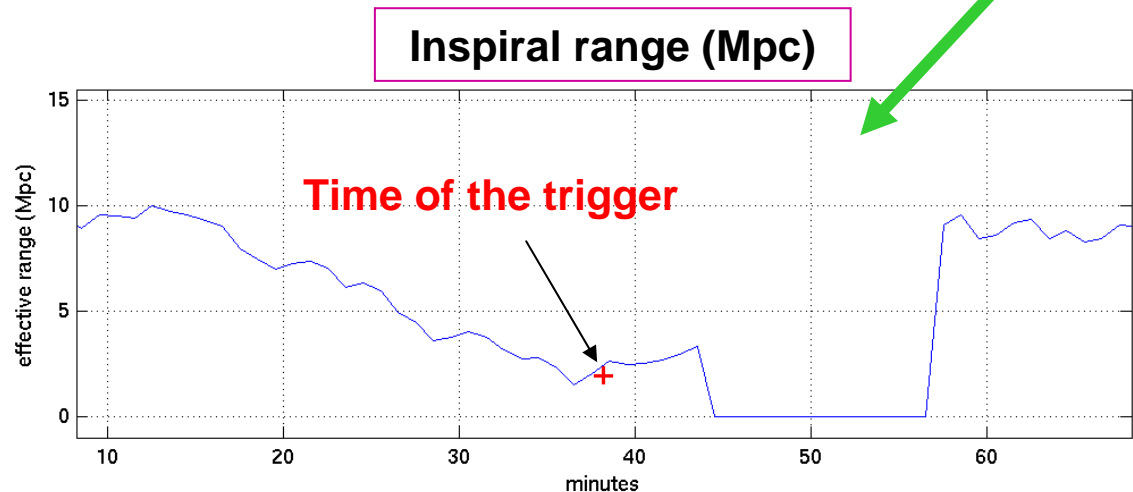
Flag indicating ifo in science mode (4 min before unlock)



Inspirational Range:

(averaged horizon of the inspiral search for a 1.4/1.4 solar mass system)

⇒ **Candidate happens while L1 inspiral range is dropping**



Status of the interferometers (2/2)

⇒ Check list of data quality flags: **“bad inspiral range”**

⇒ Check comments posted by scimon and operator in the elog:

Author: Dan Hoak

“We had a slowly worsening noise spectrum over a period of about thirty minutes today [...] The only hint of trouble was in the WFS; there was a lot of coherence between DARM and WFS1 pitch”

⇒ The candidate is found during a very noisy time at Livingston, which indicates a misbehavior of the detector

⇒ No obvious instrumental cause was found at the time of the candidate (more investigations needed)

Environmental or instrumental causes (1/2)

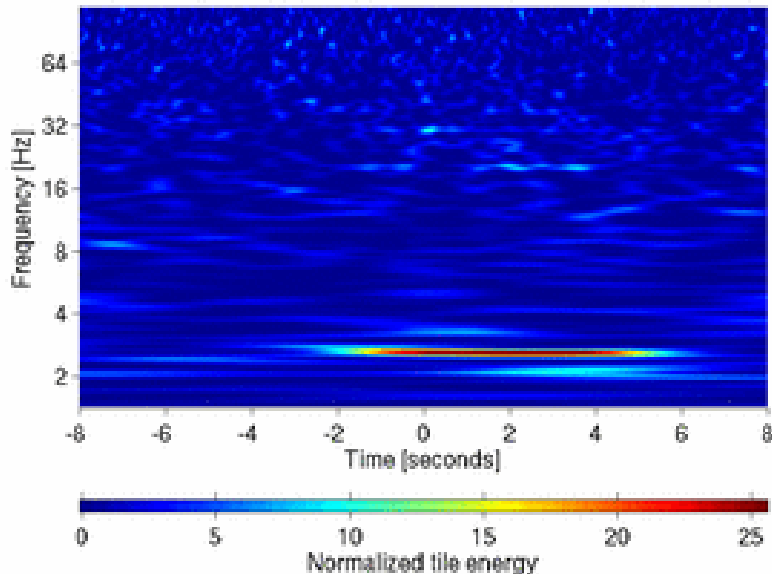
Ex: At time of the inspiral hardware injection

⇒ Check band-limited RMS trends of seismometers

⇒ Check time-frequency maps of auxiliary channels (Qscan)

Seismic transient at the Hanford Mid X station (close to H2 end test mass)

H0:PEM-MX_SEISY



How relevant is a transient found in an auxiliary channel, given its significance ?

- Compare significance at candidate's time to background distribution (estimated by qscans at random times)
- Compare amplitude ratio GW channel / PEM channel with measured transfer function (if available)

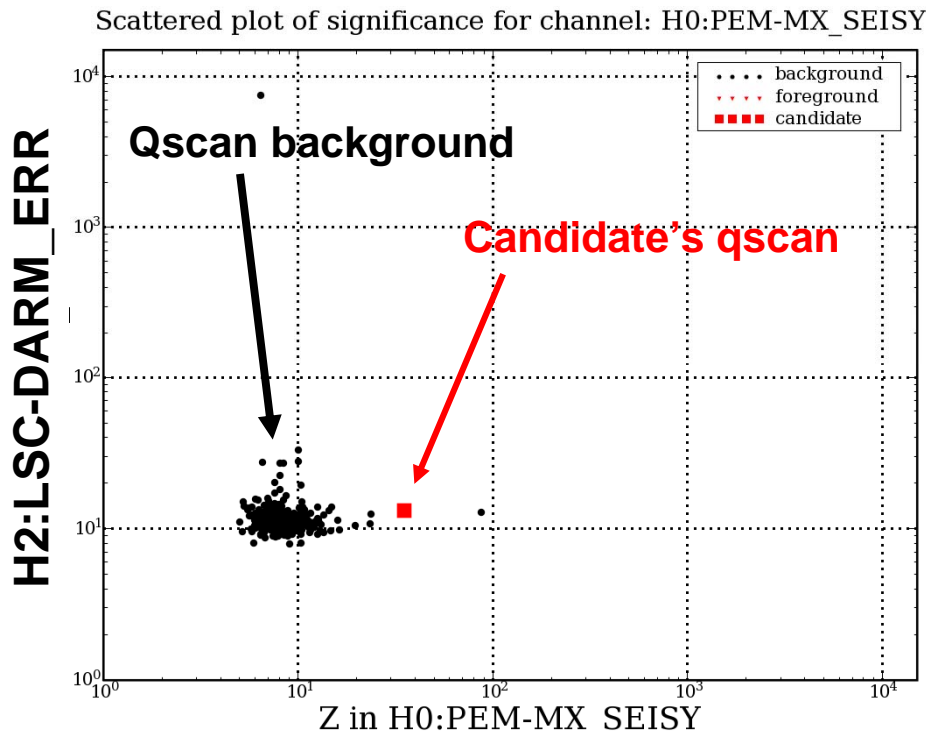
Environmental or instrumental causes (2/2)

Ex: At time of the inspiral hardware injection

⇒ Check band-limited RMS trends of seismometers

⇒ Check time-frequency maps of auxiliary channels (Qscan)

Seismic transient at the Hanford Mid X station (close to H2 end test mass)



At the time of the seismic transient, the significance in the GW channel is consistent with the background

⇒ There is no evidence of a seismic coupling to the GW channel

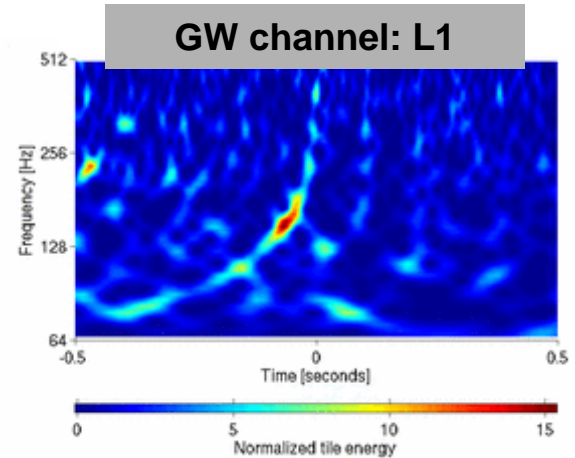
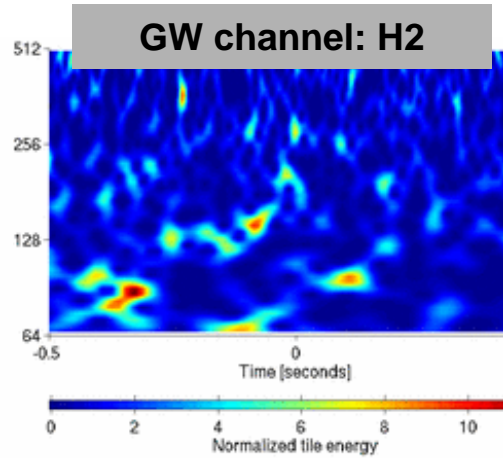
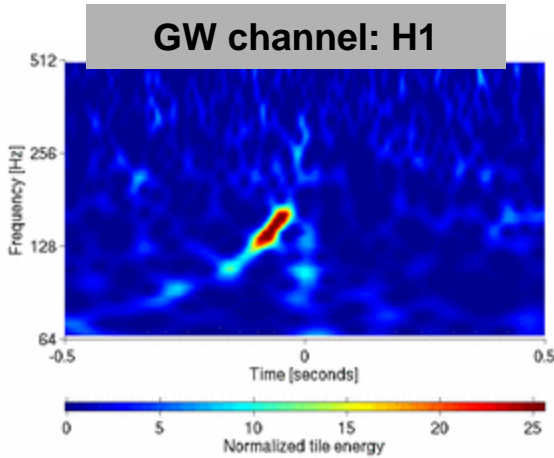
⇒ We can not determine if the candidate is due to this coincident seismic transient.

Candidate appearance (1/4)

⇒ Check time series, and time-frequency spectrograms of the candidate

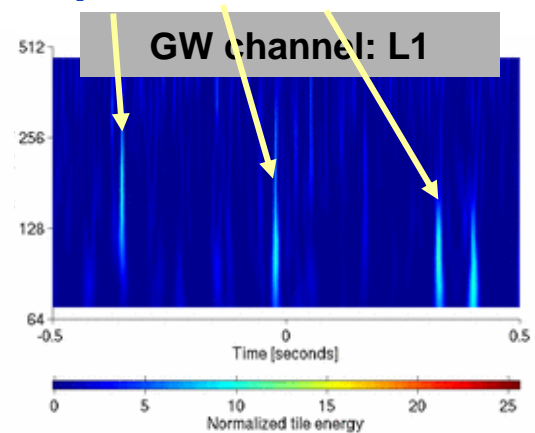
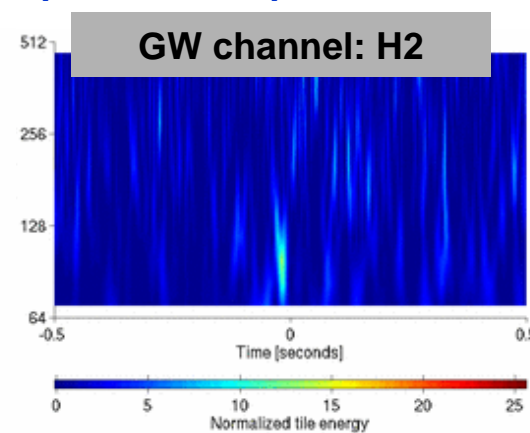
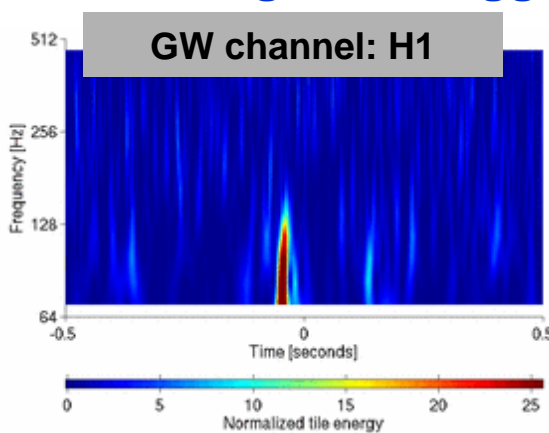
Ex: Inspiral hardware injection

→ **Chirp visible in H1 and L1**



Ex: Background trigger (time slide)

→ **multiple transients at Livingston**

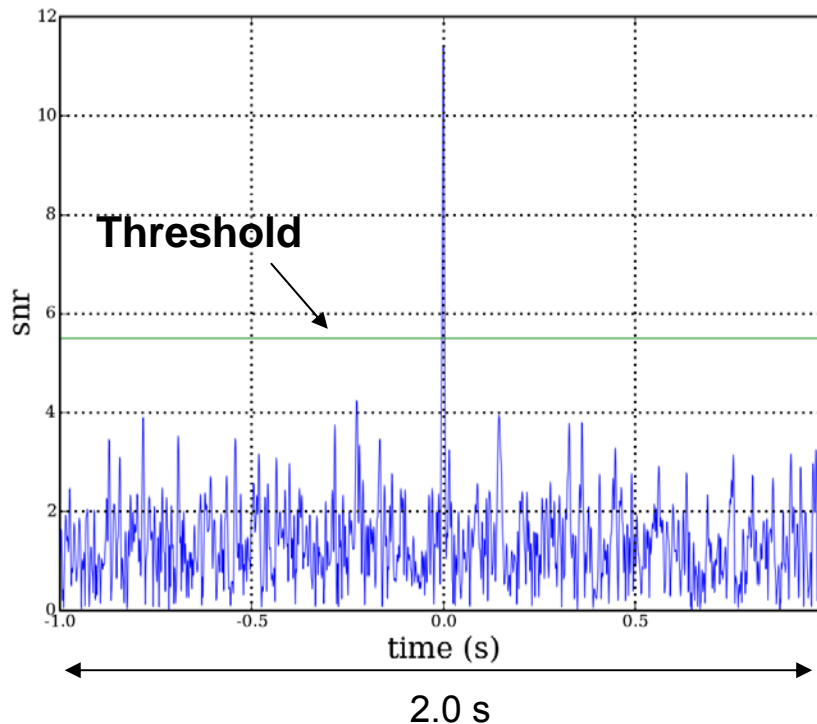


Candidate appearance (2/4)

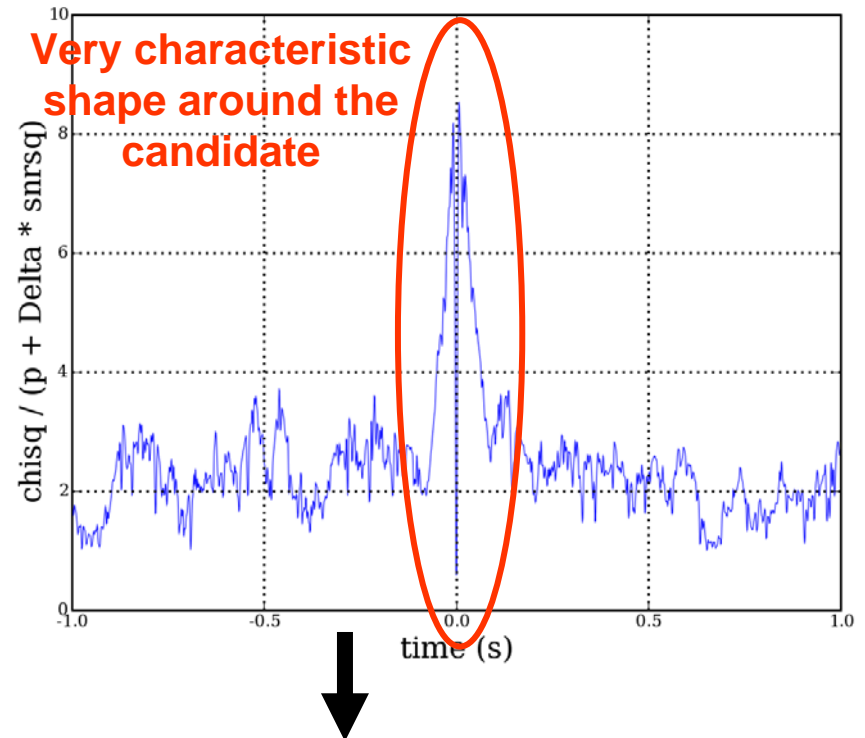
⇒ Check SNR and CHISQ time series after match filtering the data

Ex: Inspiral hardware injection, L1 trigger

SNR time series



χ^2 time series



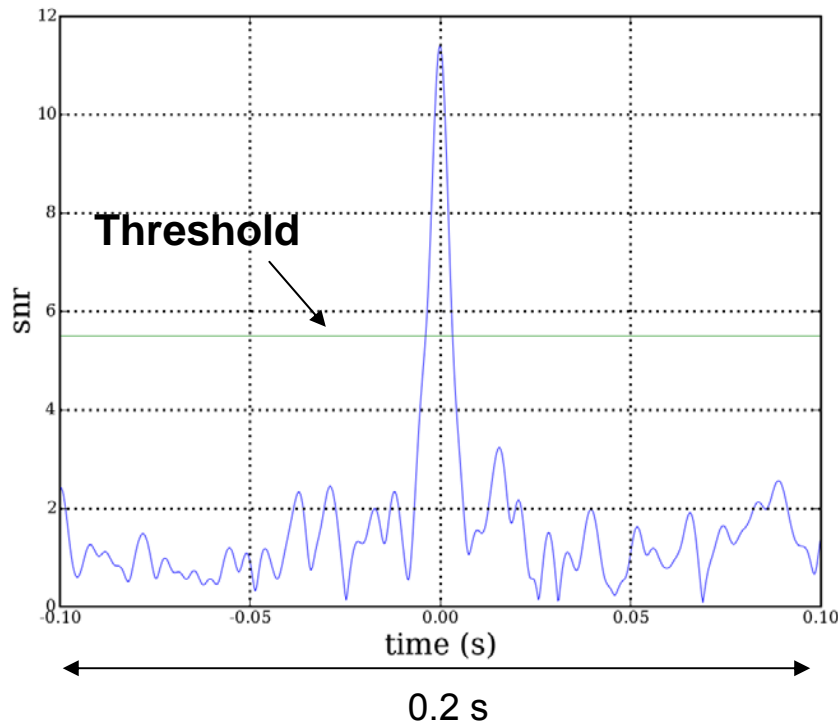
check the consistency between triggered template and signal present in the data

Candidate appearance (3/4)

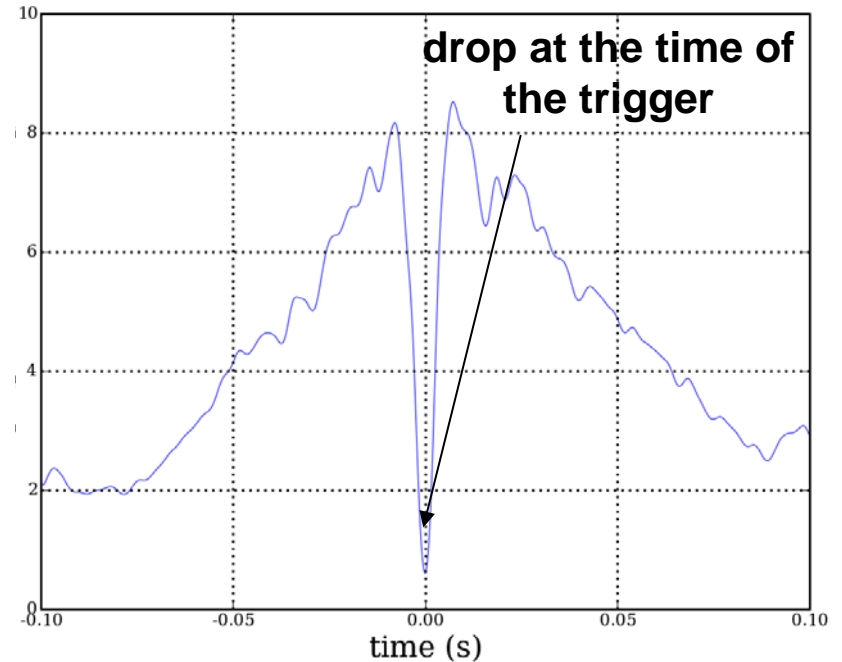
⇒ Check SNR and CHISQ time series after match filtering the data

Ex: Inspiral hardware injection, L1 trigger

SNR time series



χ^2 time series

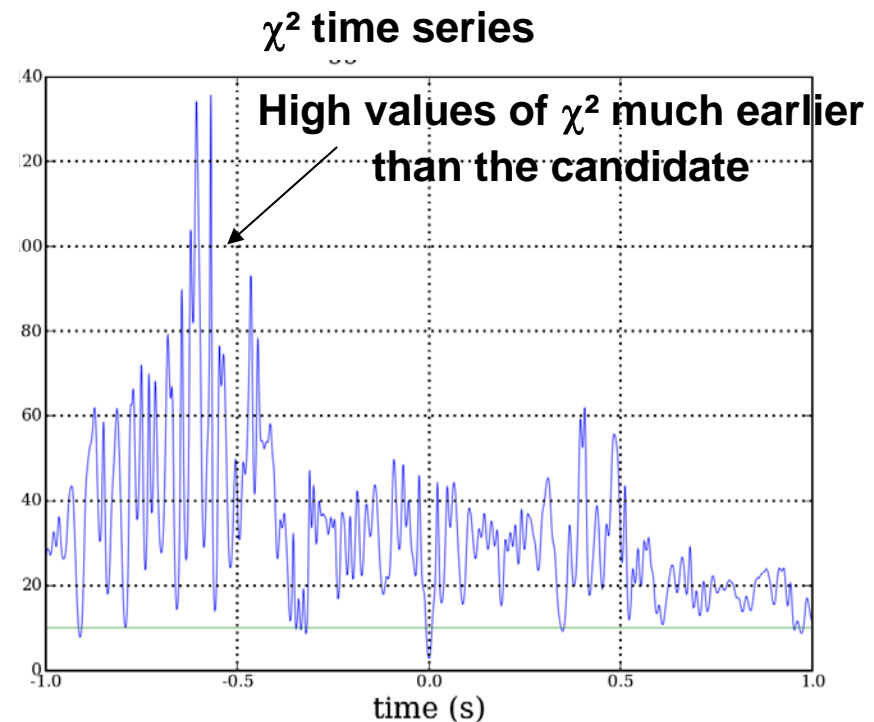
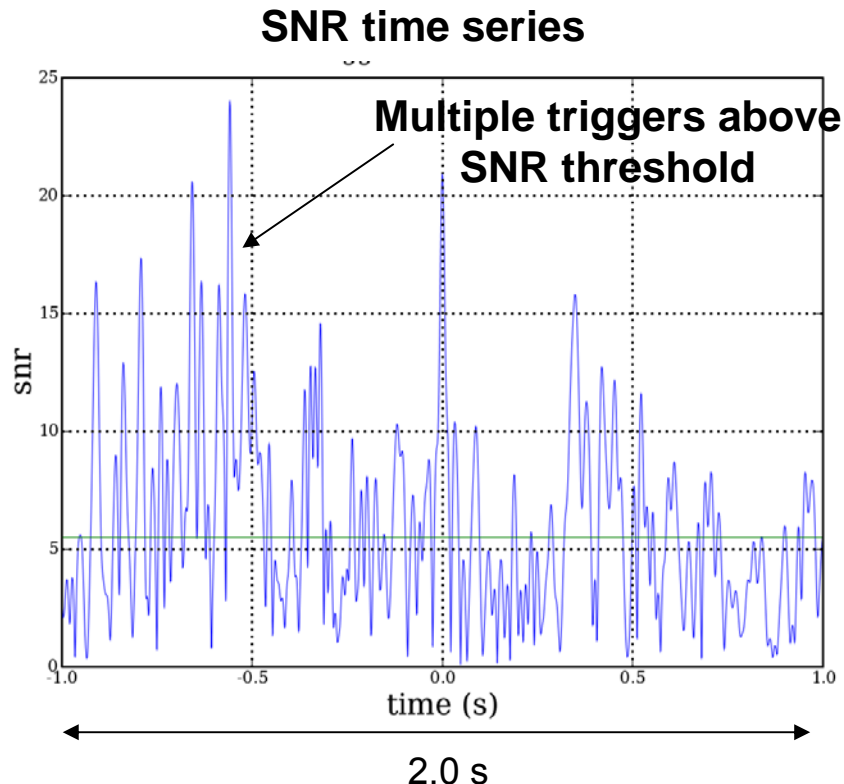


⇒ **The SNR and χ^2 time series appear to be consistent with a detection**

Candidate appearance (4/4)

⇒ Check SNR and CHISQ time series after match filtering the data

Ex: Background trigger in L1



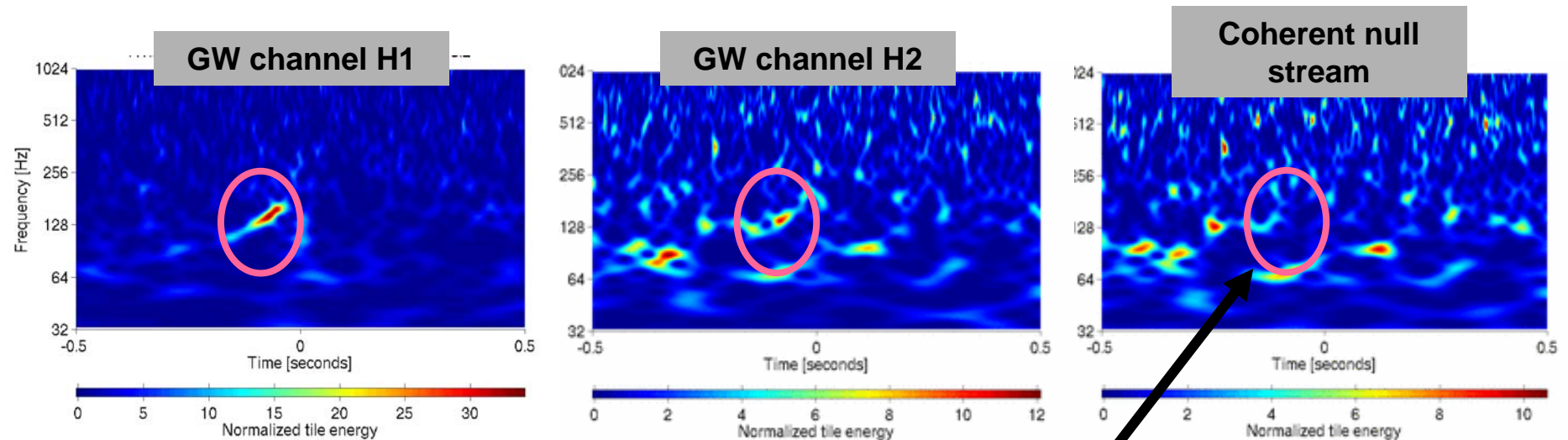
⇒ Both time series show a very noisy period.

⇒ **Thus this candidate cannot be defended**

H1/H2 correlation

Check for signal correlation between colocated interferometers (Qevent)

Ex: Inspiral hardware injection



The “chirp” pattern is removed in the coherent null stream

⇒ This indicates a correlated signal between the H1 and H2 interferometers



Conclusions

- **Burst and CBC groups are developing a list of detection confidence tests**
- **Automation of the inspiral detection checklist is in progress**
- **The inclusion of Virgo in those tests will start soon**

Other presentations related to the detection confidence tests

- **Sukanta Bose for the LSC**, *Coherent multi-detector inspiral searches in LSC's fifth science run*
- **Adam Mercer, Sergey Klimenko**, *Visualising Gravitational Wave Event Candidates with the Coherent Event Display*
- **Yeming Shi, Michele Zanolin and Erik Katsavounidis**, *Distributional tests for gravitational wave transient event detection*
- **Marc van der Sluys, Christian Roever, Alexander Stroeer, Nelson Christensen, Vicky Kalogera, Renate Meyer, Alberto Vecchio**, *Bayesian inference on spinning compact-binary inspirals with ground-based gravitational-wave laser interferometers*
- **Ruslan Vaulin for the LSC**, *Estimating statistical significance of the candidate events in LSC compact binary coalescence search*
- **John Veitch and Alberto Vecchio**, *An Evidence Based Approach to Inspiral Followups*

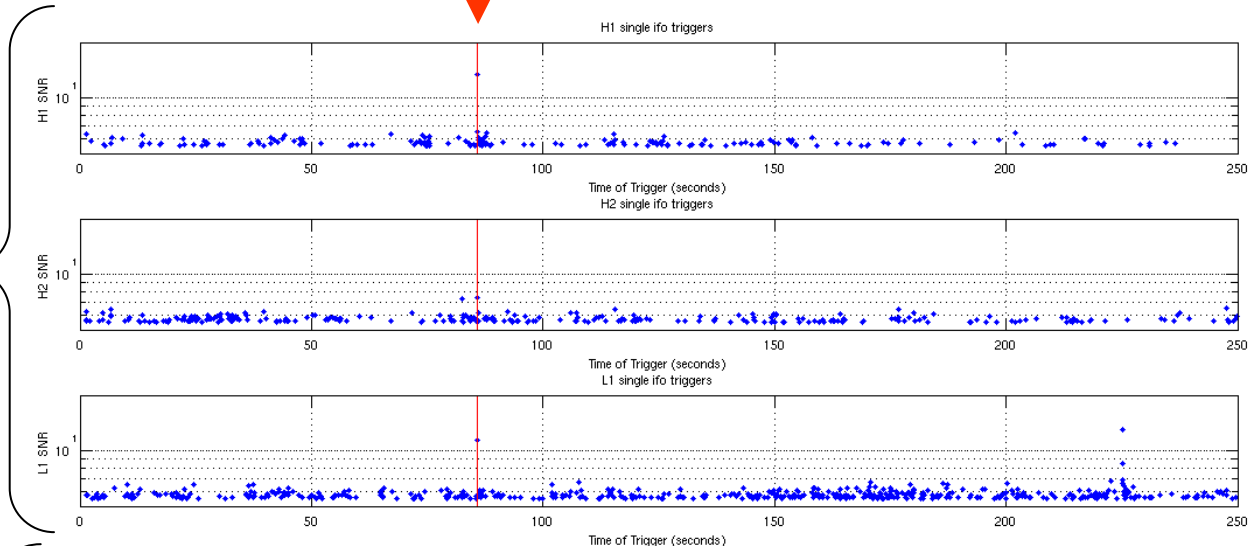
Spares

Inspiral triggers Vs time

Ex: Inspiral hardware injection



**Single
interferometer
triggers (with 50 ms
clustering)**

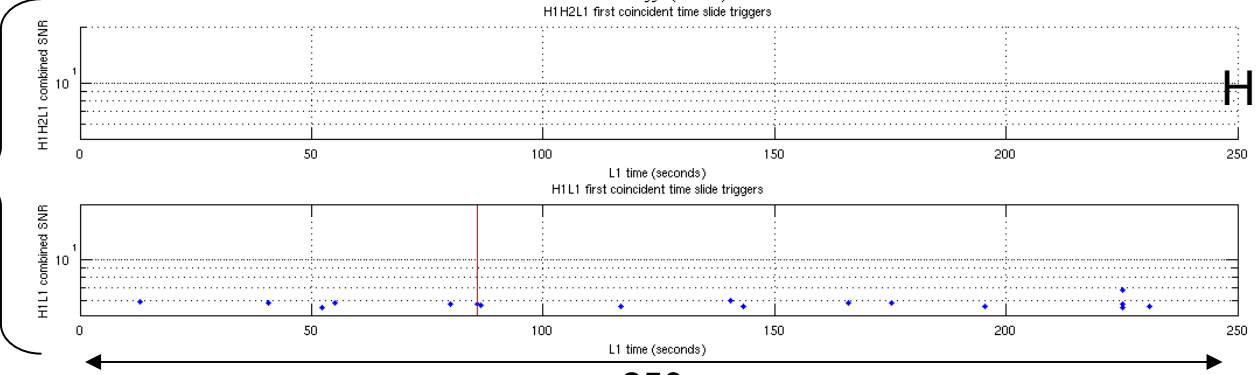


H1

H2

L1

**1st coincident
stage of **time-
slide triggers**
(with 50 ms
clustering)**



H1H2L1

H1L1

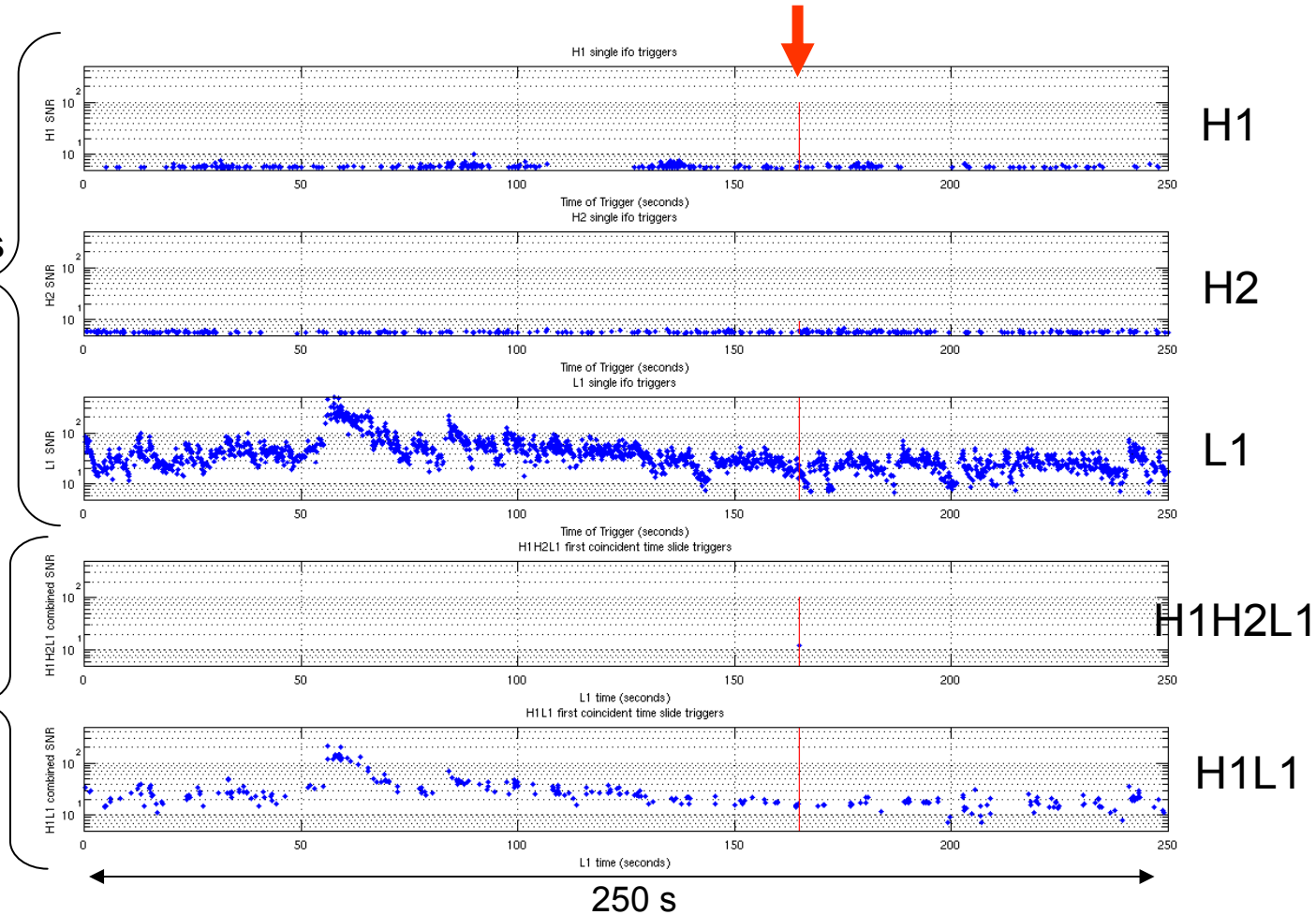
250 s

Inspiral triggers Vs time

Ex: Background trigger (time-slide)

Single interferometer triggers (with 50 ms clustering)
 H1 and H2 data are shifted (time-slides)

1st coincident stage of time-slide triggers (with 50 ms clustering)



⇒ The excess of high SNR triggers in L1 induce H1L1 accidental coincidences

Overview of the detection checklist

Legend: - tests which are identical for both Burst and CBC groups

- tests that involves methods specific to the search

- **Statistical significance of the candidate**
- **Status of the interferometers**
- **Check for environmental or instrumental causes**
- **Candidate appearance**
- **Check the consistency of the candidate estimated parameters**
- **Check for data integrity**
- **Check for detection robustness (ex: versus calibration uncertainties)**
- **Application of coherent network analysis pipelines**
- **Check for coincidence with searches external to our GW searches: other E/M or particle detectors...**