E7 Burst Search Status Report

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Outline

1. Bursts and burst searches
2. Untriggered search
3. Triggered search

Burst search

Our job is to search for transient events, especially those that are poorly modeled. Thus, we can't use the matched-template technique. Instead, we look for "something unusual."

Three LDAS filters ("DSOs") are now being used to recognize candidate signals:

- Excess power in tiles in the time-frequency plane
  - Flanagan, Anderson, Brady
- Clusters of high-power pixels in the time-frequency plane.
  - Sylvestre
- Time-domain templates for large slope or other simple features
  - Daw

We are also searching for unusual features coincident with external triggers, specifically gamma ray bursts.

ALLEGRO and GEO data were also collected during E7.

Burst search interpretations

Untriggered search:

1. "Instrumental" interpretation

   Search for coincident transients in our ifos, with no prejudice about the form of the signals or the nature of their sources.

   Calibrate against <u>fixed-strength</u> waveforms <u>arriving at ifos</u>.

2. Astrophysically-motivated interpretation

   Look for transients with features suggested by our (limited) understanding of supernovae, black holes, etc.

   Calibrate against <u>fixed-luminosity</u> waveforms distributed in space.

Triggered search:

3. Coincidences with GRB triggers

   Analyzed by technique of Finn, Mohanty, and Romano.

   Are the outputs of our ifos <u>different just before GRBs</u>? Test via ifo-ifo cross-correlation.

Snapshot of status of E7 analysis

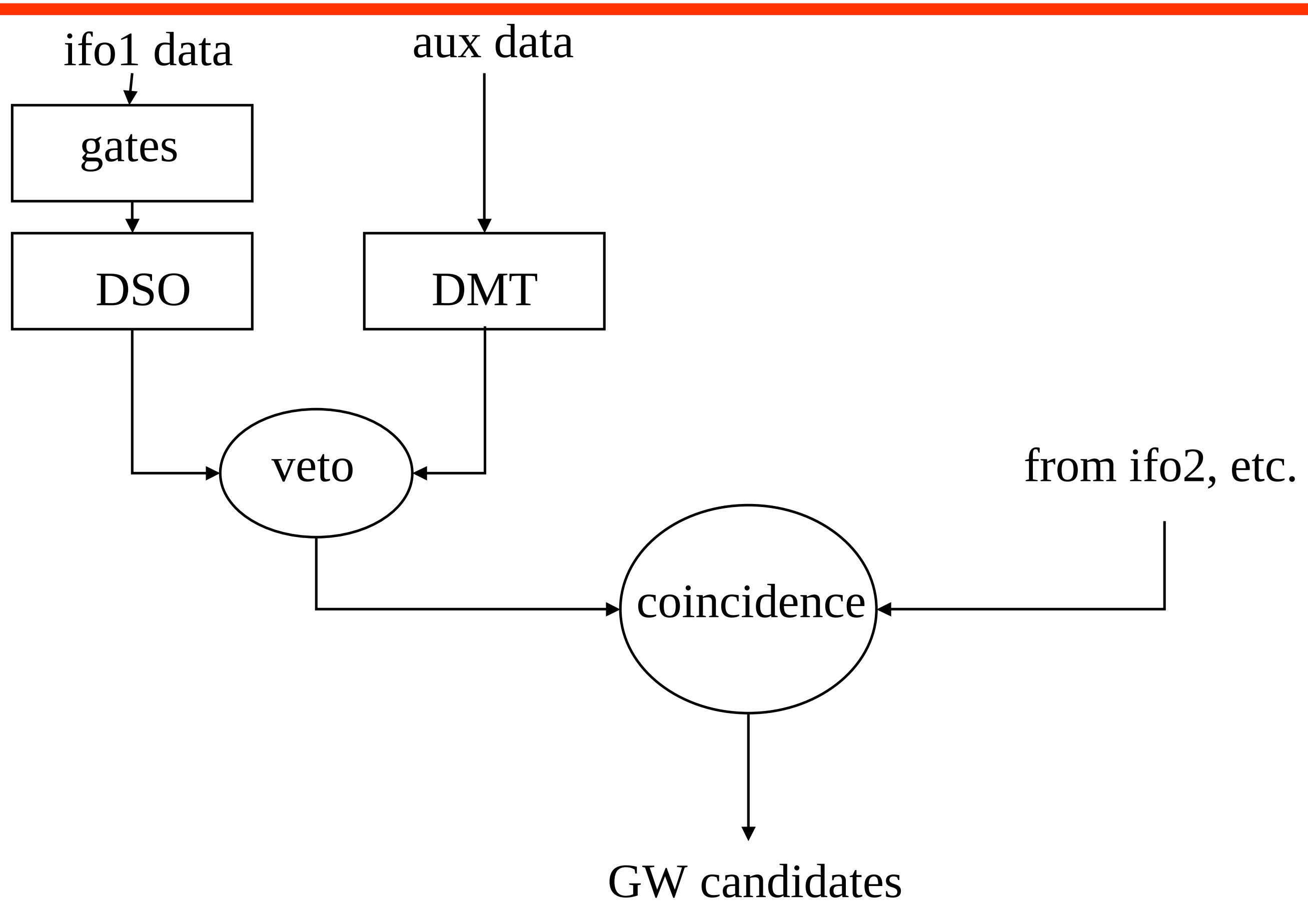
Still tuning our methods on E7 playground data.

(We have devoted our attention to H2 and L1, but not H1.)

We hope to finish tuning, run pipeline in production mode soon.

Full pilot analysis of all E7 data carried out by Julien Sylvestre for his Ph.D. thesis.

Untriggered search pipeline (simplified schematic)



Burst pipeline

- Triggers generated by LDAS filters, written to DB.
- Vetoes generated by DMT monitors looking at PEM channels and at internal ifo diagnostic signals, written to DB.
- Event Tool reads DB to define candidate events:
  - Ignore triggers at times that are vetoed
  - Analyze events from all ifos to determine which are coincident
  - Draw histograms, analyze statistics of coincidences.
- Calibration of efficiency by injection of simulated signals into real (playground) data.
- Calibration of false coincidence rates by searching time-shifted data ("lag plots").

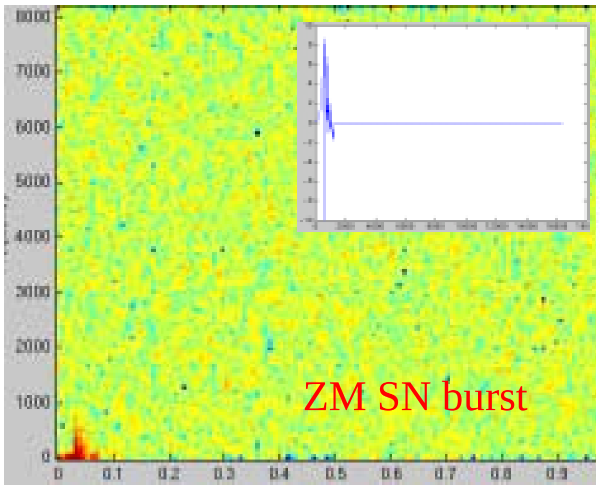
Tests of Burst DSOs: Goals

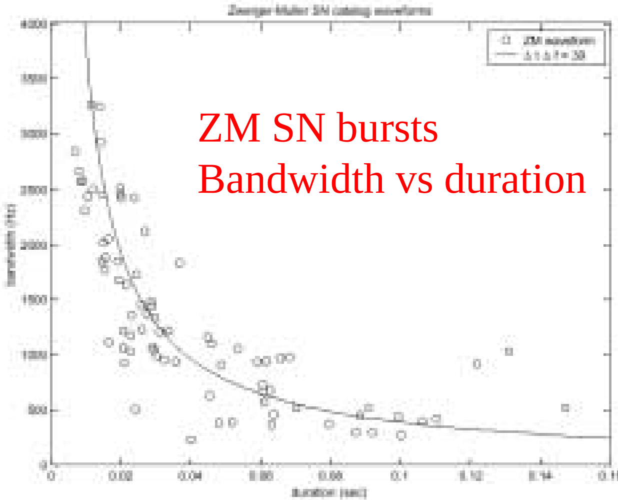
Test burst search analysis chain from:

- IFO (ETM motion in response to GW burst) $\rightarrow$
- data stream into LDAS $\rightarrow$
- search algorithms in LDAS $\rightarrow$
- burst triggers in database $\rightarrow$
- post-trigger analysis (optimizing thresholds and vetoes, clustering of multiple triggers, forming coincidences) $\rightarrow$
- detection efficiency for different waveforms, amplitudes, source directions, and different search algorithms

(During S1, we'll compare simulated signals injected into IFO with signals injected into data stream, to make sure we understand IFO response.)

Burst waveforms: t-f character





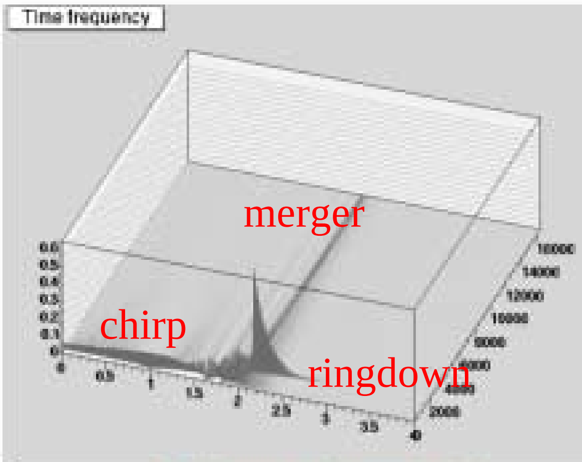


Fig. 3 Spectrogram of a composite signal

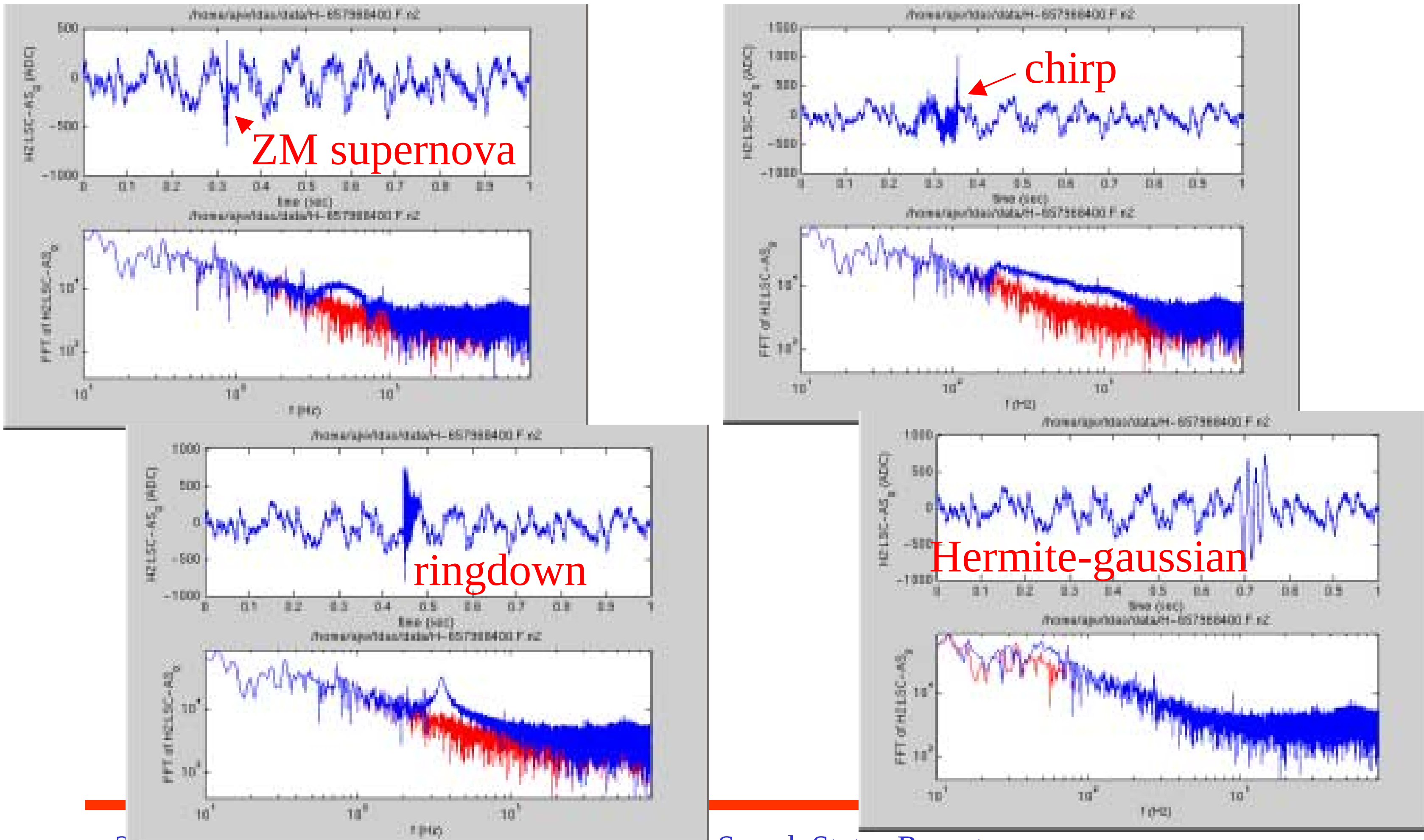
Generic statements about the sensitivity of our searches to poorly-modeled sources need to take account of the t-f “morphology”…

- Ringdowns: long duration & small BW to short duration & large BW
- Chirps: long duration, large BW
- Merger: short duration, large BW
- Zwerger-Muller or Dimmelmeier SN waveforms: in between

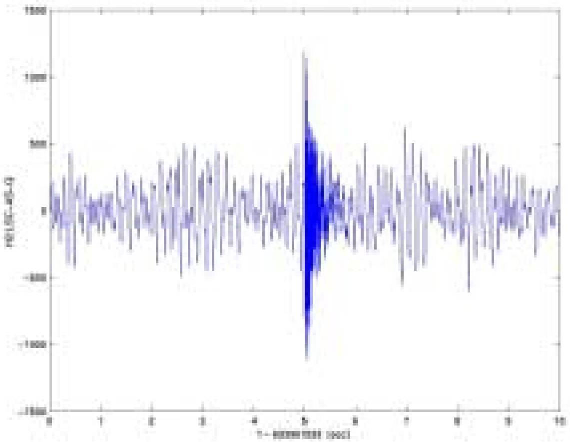
  (These SN waveforms are *distance*-calibrated; all others are parameterized by a peak or rms strain amplitude.)

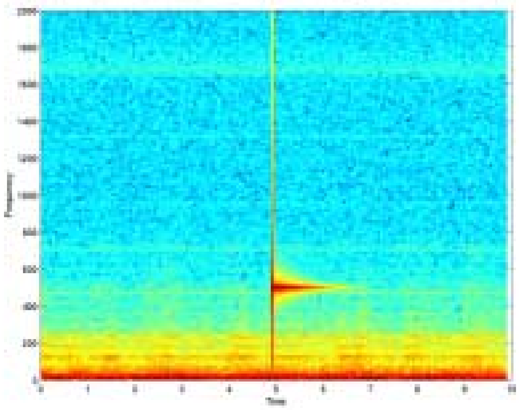
Menagerie of burst waveforms

buried in E2 noise, including calibration/TF

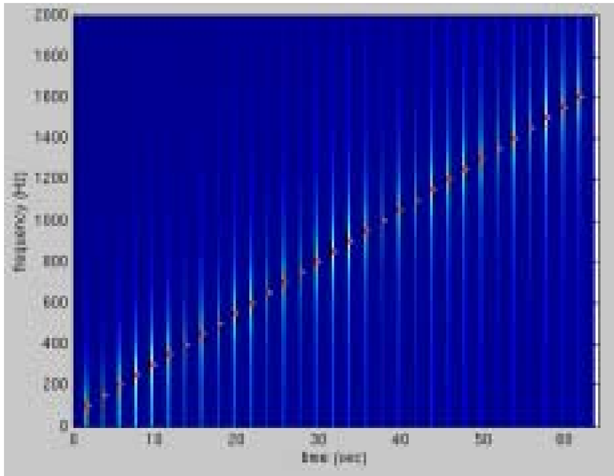


Damped sinusoid waveform ("ringdown")



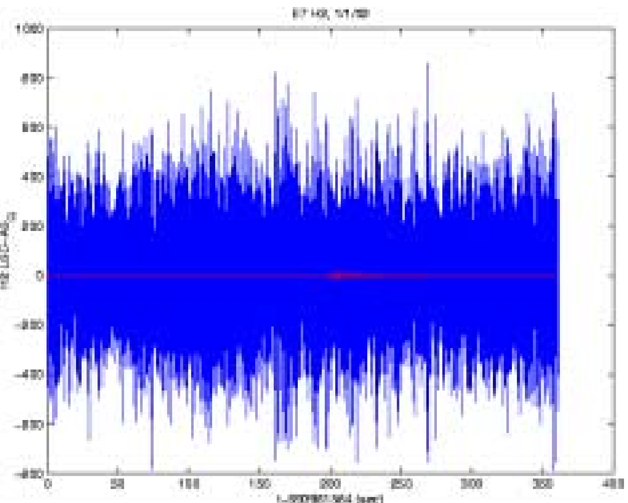


Damped sinusoid in 10 seconds of data from H2:LSC-AS_Q from E7 playground



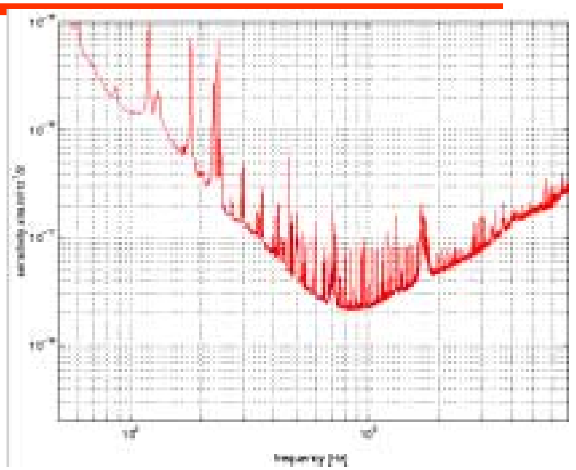
A series of damped sinusoids can be used as a "swept sine" calibration of burst search efficiency

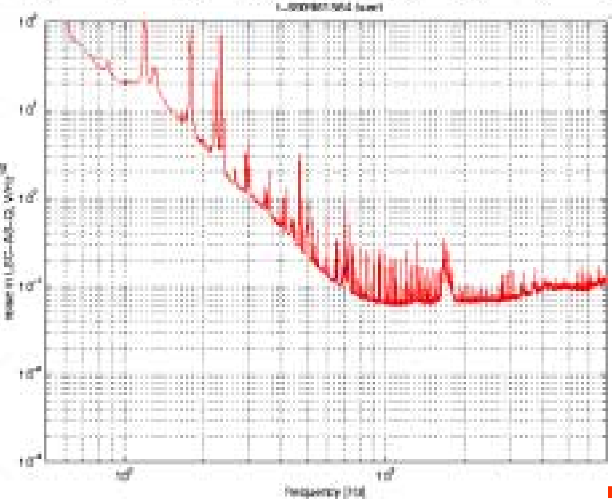
Add bursts to data



Time series (360 sec).
Noisy E7 data in blue.
Series of 20
damped sinusoids, in red.

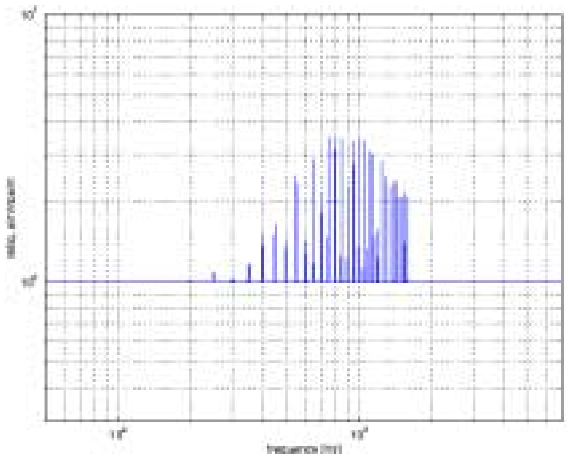
Calibrated strain
noise spectrum





AS_Q Noise spectrum.
See forest of lines
Between 200-1500 Hz?

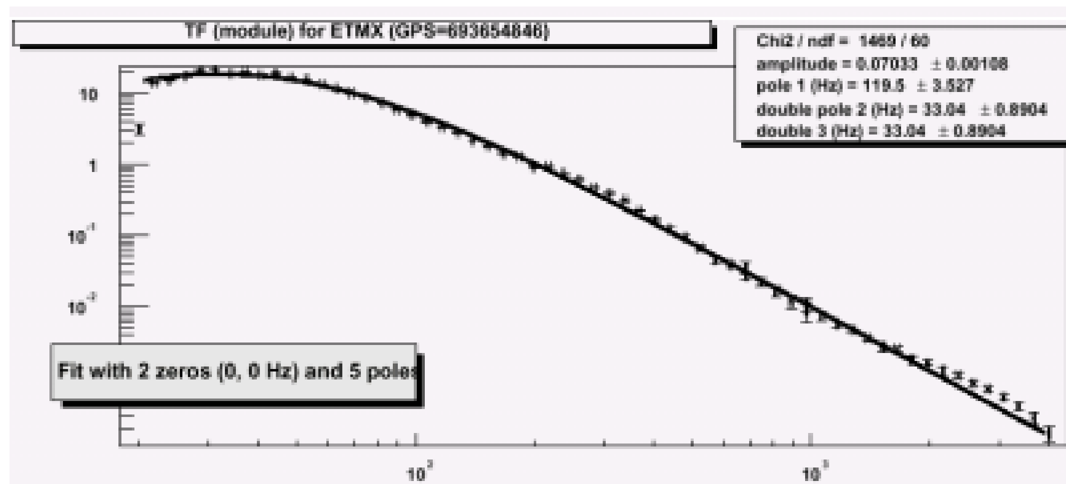
Ratio of noise spectra,
With/without injected signal



What we need to know about the IFOs

- Transfer function for injection from GDS into ETMx/y
  - (counts/nm * pendulum TF)
- Response function from ETMx

  To LSC-AS_Q

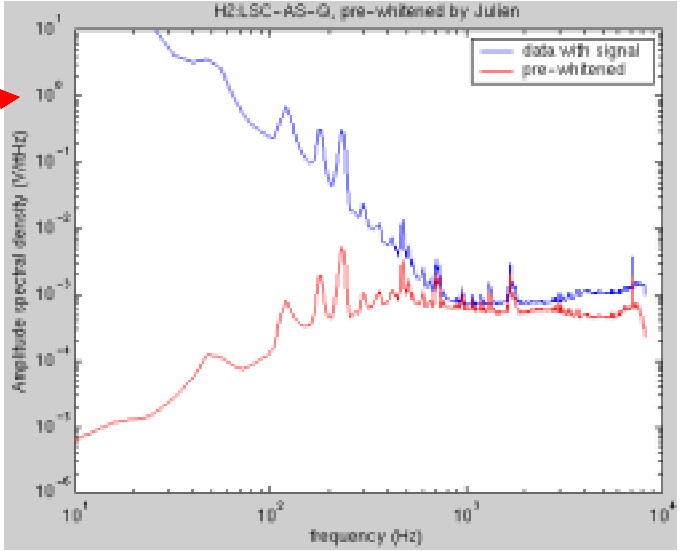


Both of these are available from calibrations

- For tfclusters & power, need IFO noise spectrum. Currently, this is estimated from the data read in to the LDAS job. This can, and does, bias the result. It's not a big bias, for small signals; but a better way should be developed…

Head-to-head comparison of search algorithms in LDAS/LAL

- Run *power*, *tfcluster*, and *slope* DSOs with (almost) identical pre-processing (in datacondAPI)
- Pre-whiten, re-sample, detrend the data (AS_Q) in datacondAPI.



- Simulated signals are read in, filtered through IFO response function, and added to data in datacondAPI.
- Signals are injected with varying waveform, amplitude, delays
- So far, full E7 playground triple-coincidence data is used (3.7 hours spanning 2 week run)
- In last few days, 1554 LDAS jobs successfully completed at ldas-mit:

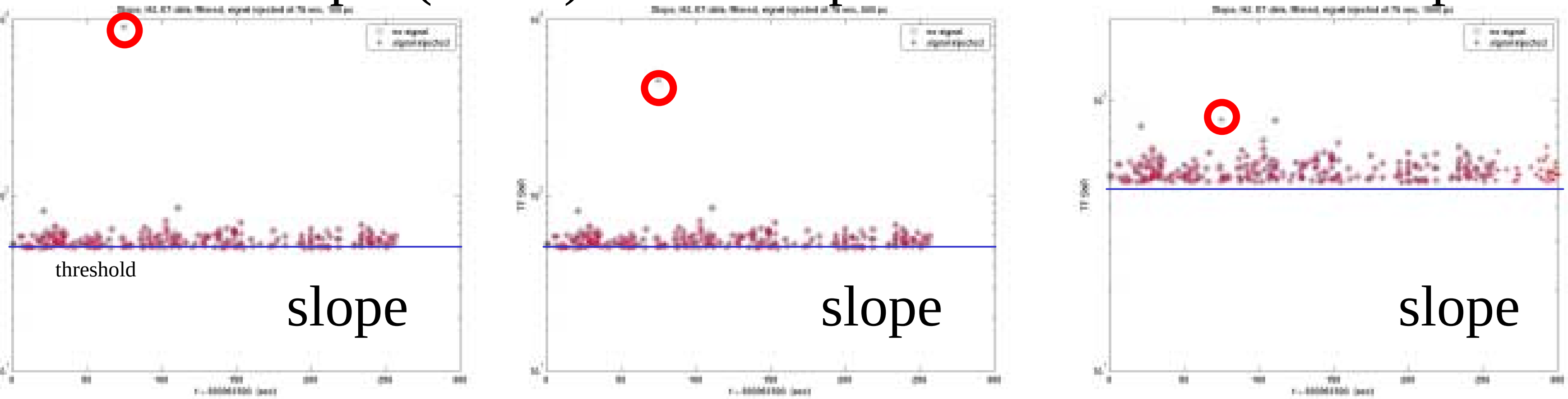
(3 DSOs) x (2 ifos) x (1 waveform) x (7 amplitudes) x (37 360-second intervals)

- Much more to come; it’s all automated now!

Search code triggers vs. time for Z-M waveform injected at 75 seconds (N.B.: distances improperly calibrated here)

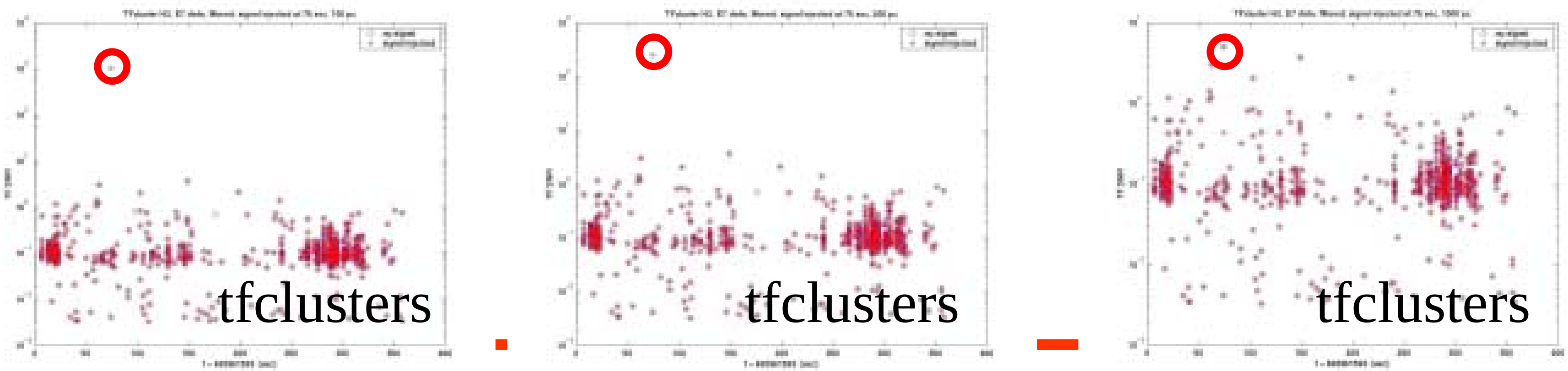
SN at 0.1 pc (ouch!) 0.2 pc 1.0 pc

Trigger “power” →



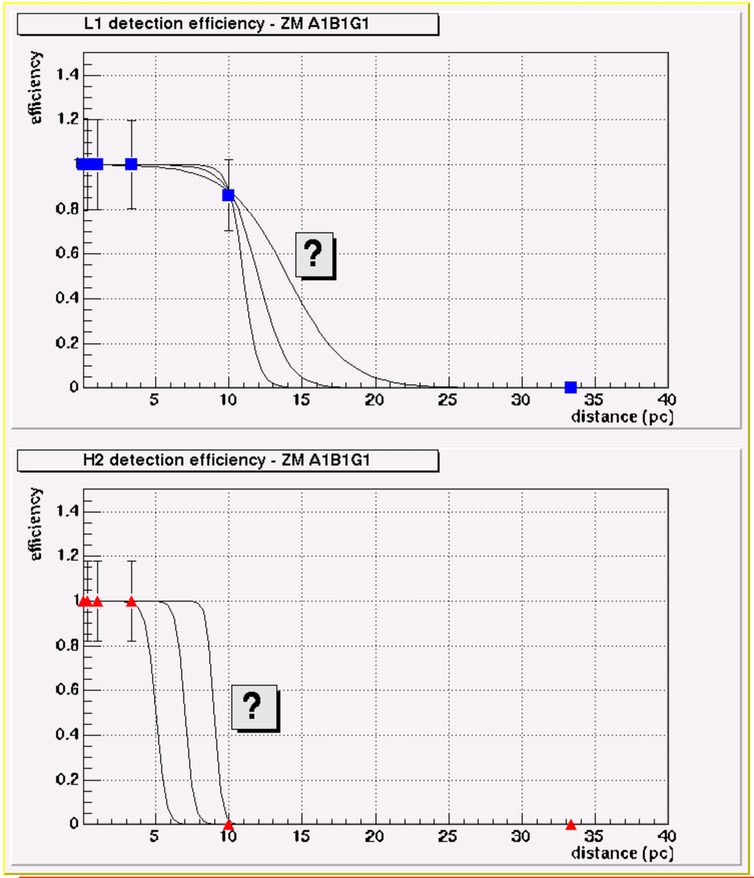
Time →

* With signal; o without signal injected.
NO VETOES APPLIED. Vetoes get rid of most of these triggers!

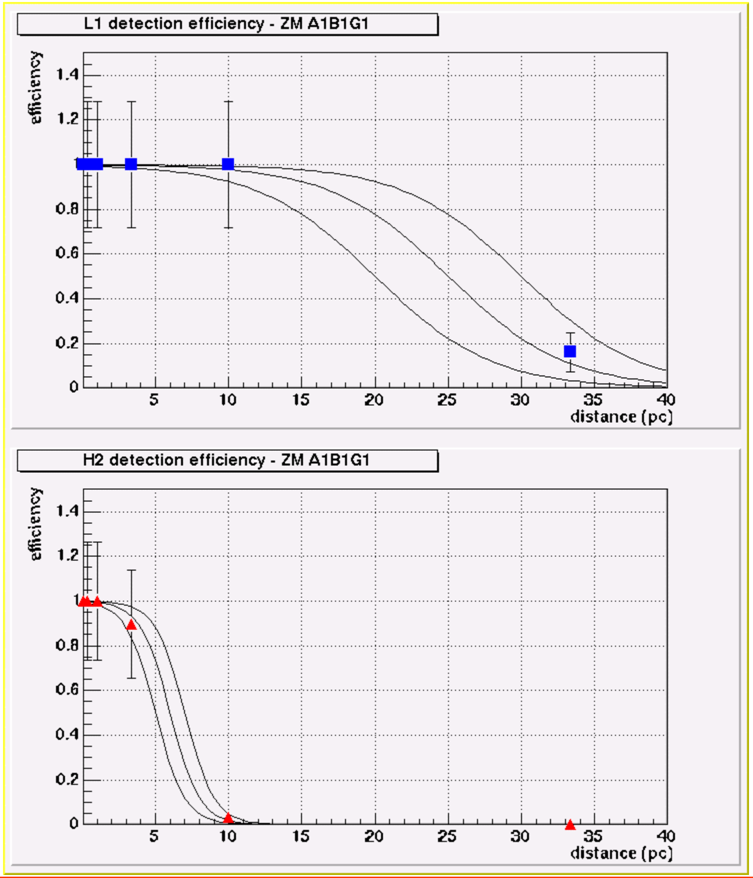


DSO efficiency for test waveform
ZM A1B1G1 (N.B.: error in distance scale)

TFCLUSTERS



slope

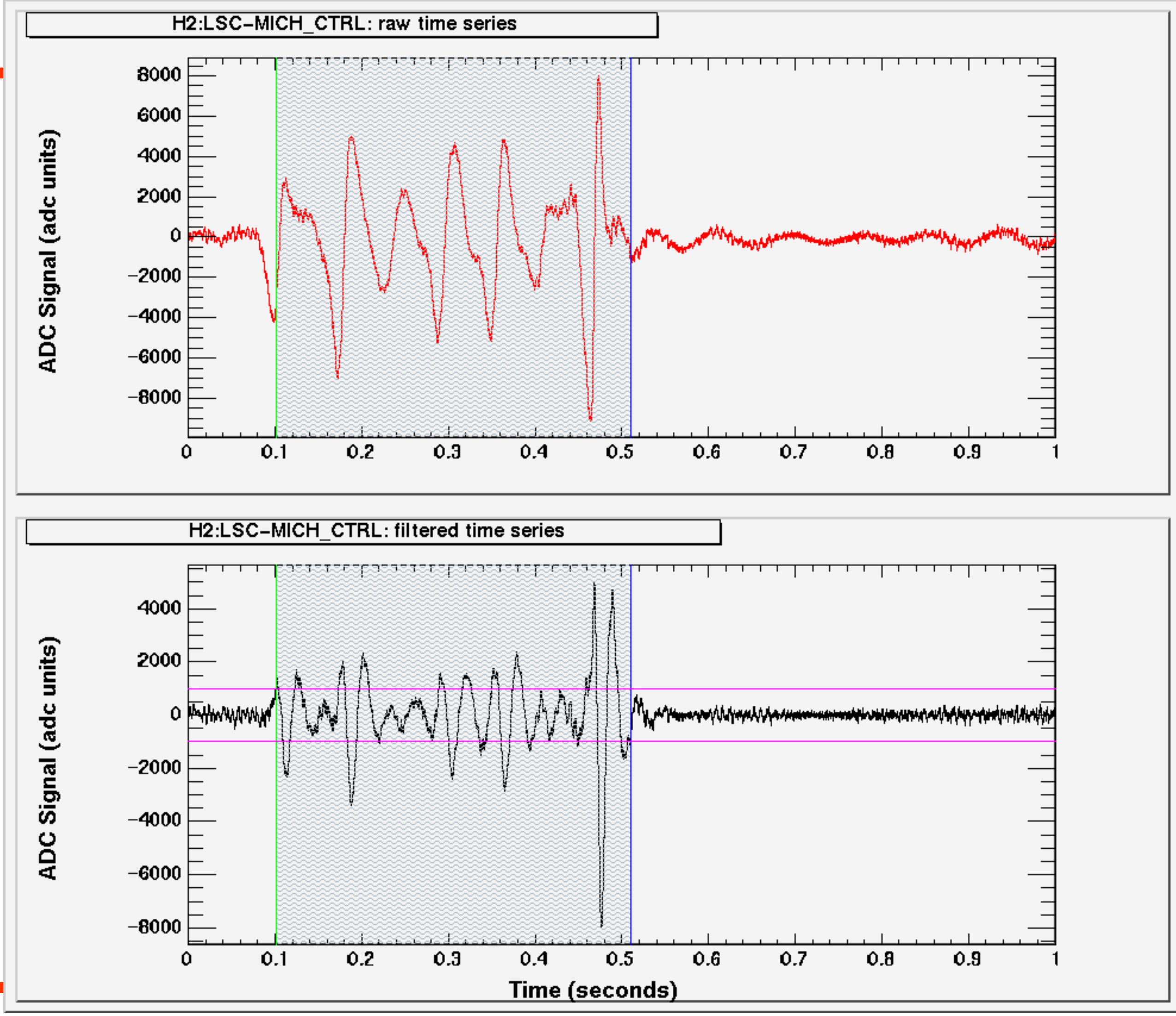


Start of the veto chain: absGlitch

absGlitch first filters the time series. (Here, 30 Hz HP.)

Finds times when signal crosses fixed threshold.

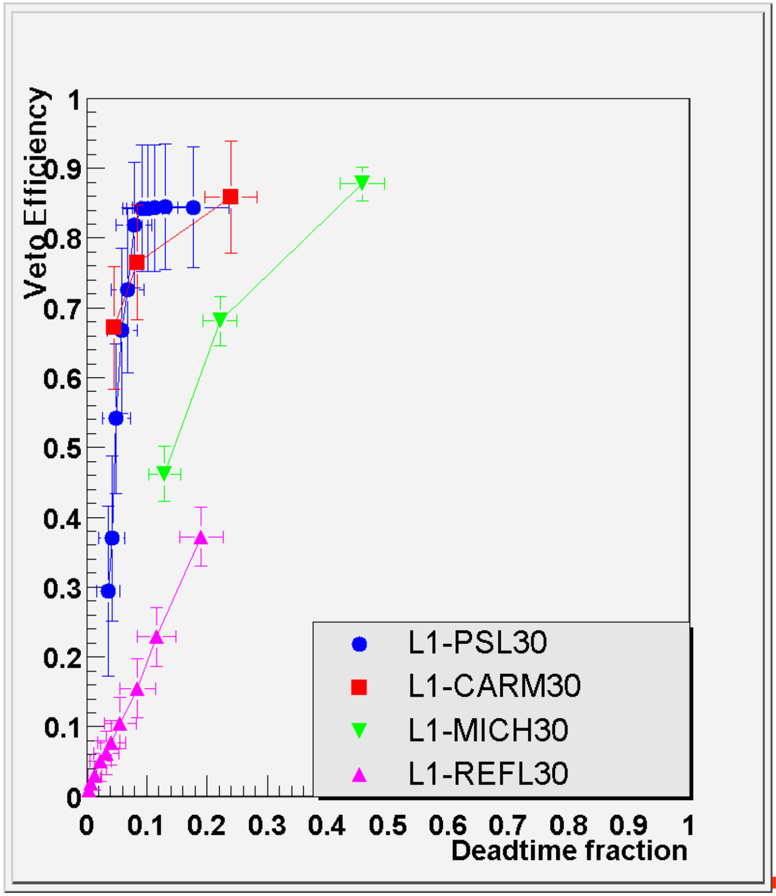
Calculates strength and duration, recorded to DB.

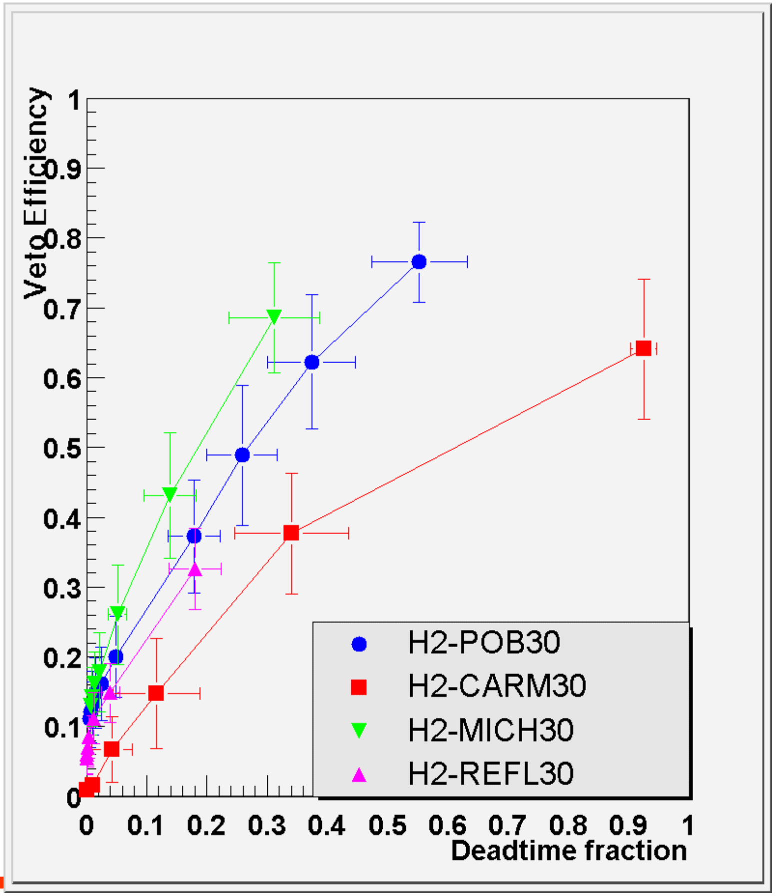


Efficacy of vetoes at tagging false TFCLUSTERS events

PSL glitch cleans up L1.

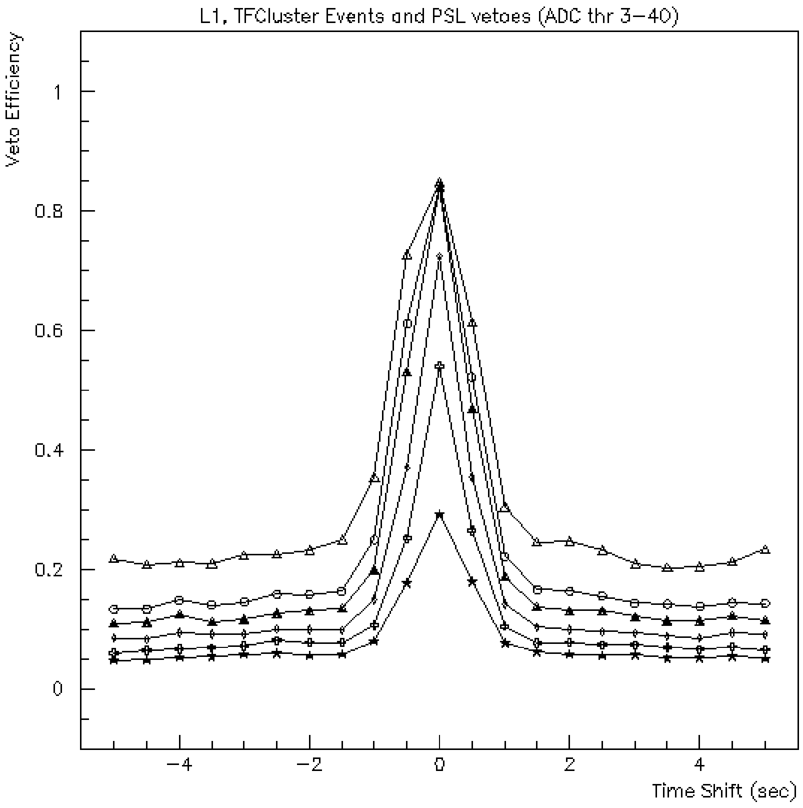
MICH glitch some use at H2.



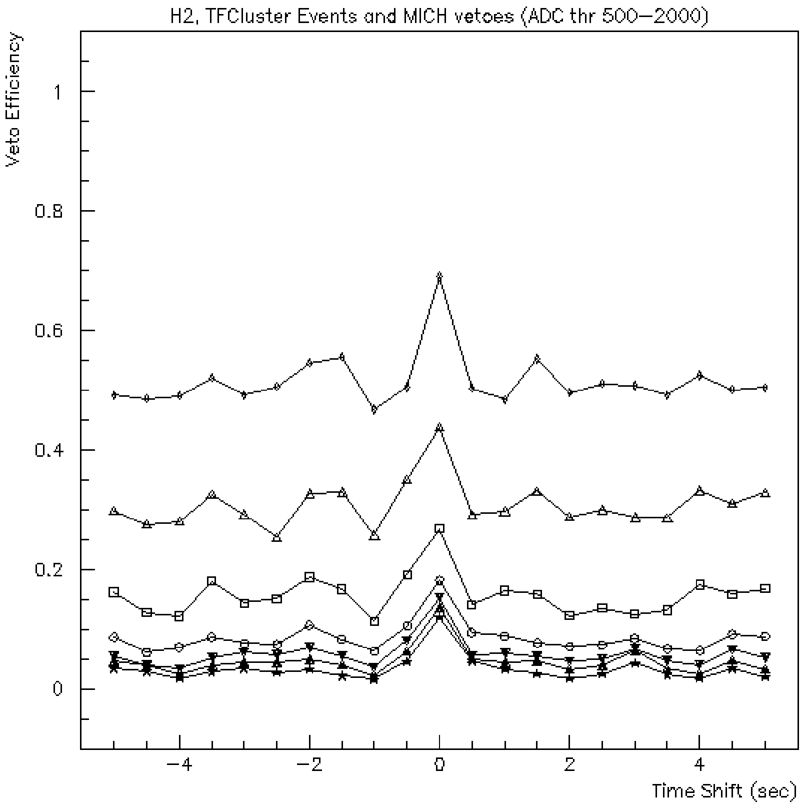


Lag plot for vetoes

L1, PSL



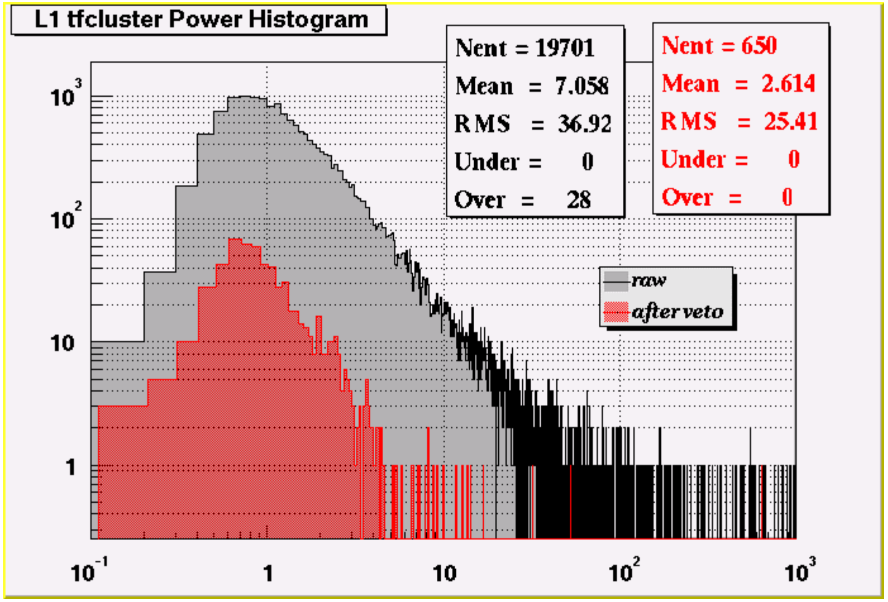
H2, MICH

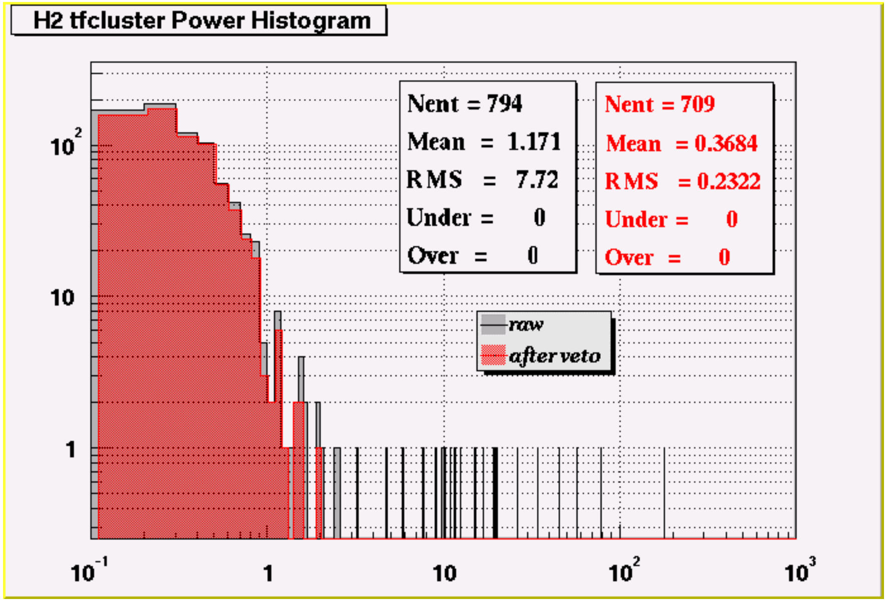


TFCLUSTERS event histogram, before and after vetoes

At both ifos, broad tail of events is cleaned up by vetoes.

L1 had lots of PSL glitching, so bulk of histogram is affected. H2 was much cleaner to start with, so only tail is removed.



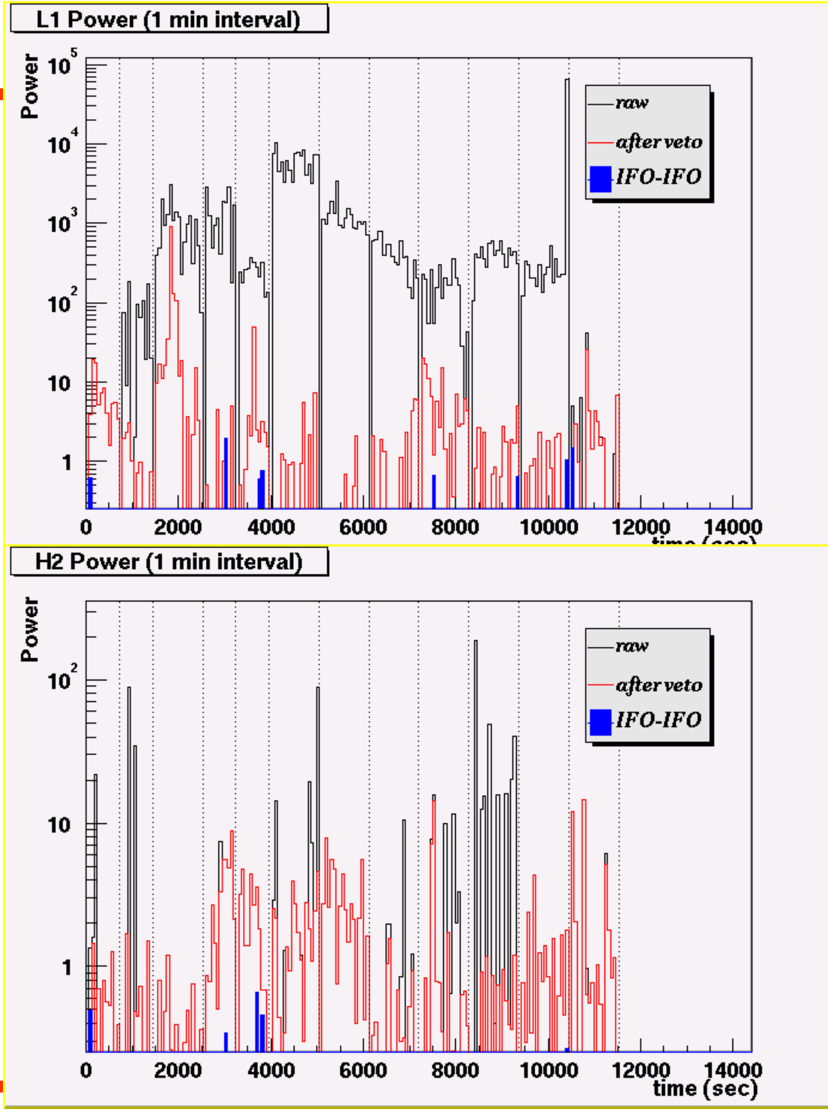


Ifo-ifo coincidence

Many events remain after vetoes. (Rates not too dissimilar at 2 ifos, ~few per minute.)

Next, require events be coincident in time, within +/- 0.5 sec.

Only 10 events in 3 hours meet this requirement.

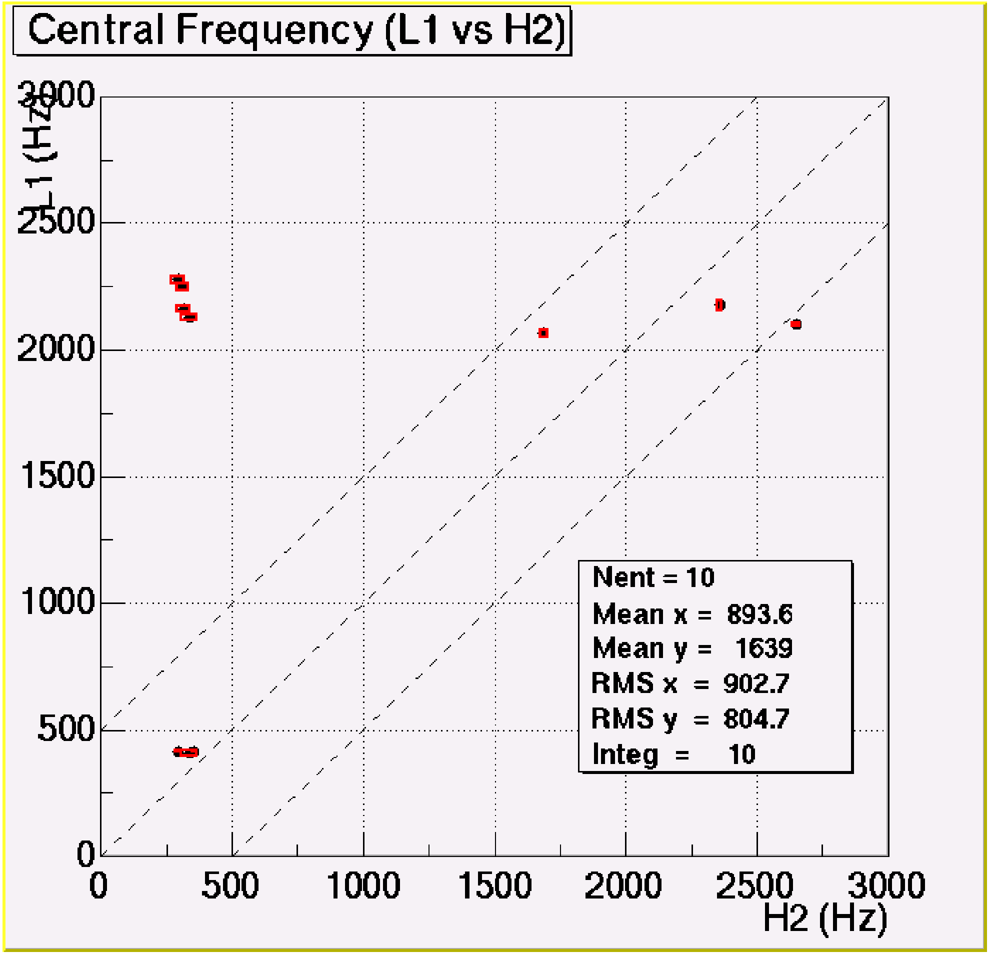


Frequency test of temporal coincidences

In addition to temporal coincidence of events, we require that TFCLUSTERS give a central frequency at the two ifos that are within 500 Hz of each other.

(This is a placeholder requirement. Optimization is TBD.)

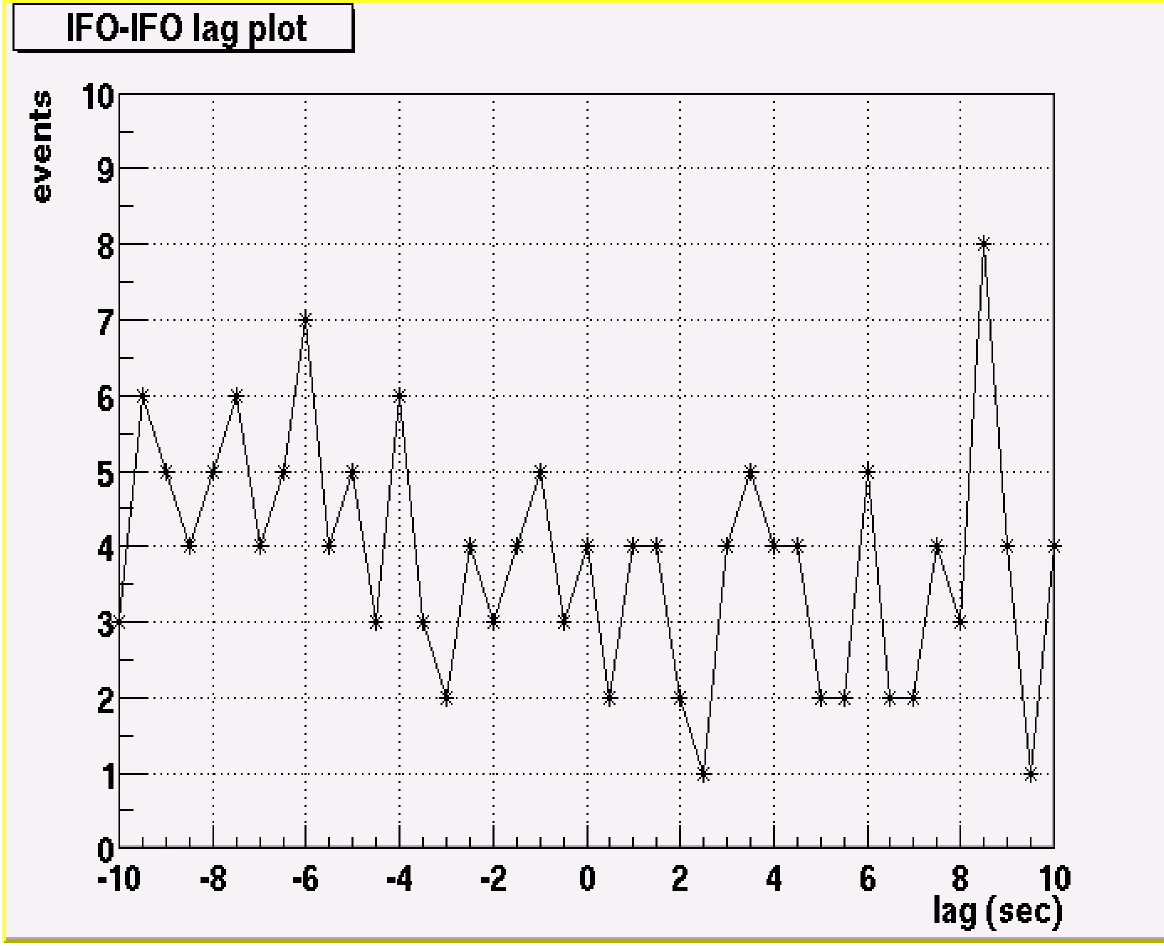
4 events survive.



Coincidence Lag Plot

Compare number of coincidences with number of false coincidences from many trials using non-physical time shifts between data streams. (0.5 to 10 sec.)

Clearly, nothing special about zero lag.

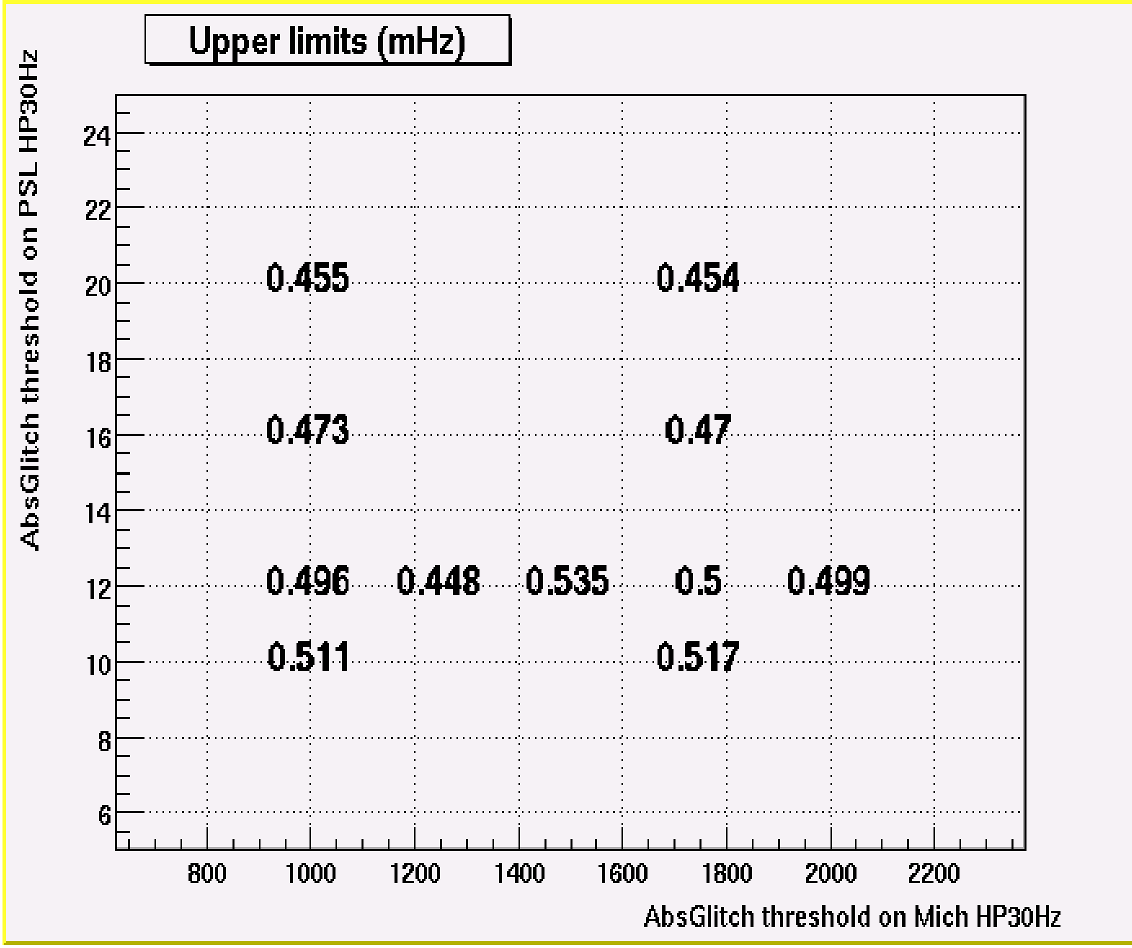


Burst rate upper limits vs. veto threshold

Explore the upper limit on TFCLUSTERS *coincident event rate*, as a function of veto thresholds.

(L1 PSL glitch threshold is important; H2 MICH threshold is less so.)

These are the 90% c.l. upper limits of F-C confidence belts that include zero. <u>No detection.</u>



Remaining steps to a science result in the untriggered search

- Finish tuning vetoes.
  (almost done)
- Finish measuring efficiency of DSOs.
  (almost done)
- Push E7 data through pipeline.
- Determine false-alarm rate from time-shifted coincidences.
- Express upper limit in rate-strength plane.
- Do Monte Carlo for astrophysical interpretation.

Julien Sylvestre's Ph.D. thesis results

- Julien has carried to completion a full pipeline analysis of E7 data.
  - DSO: TFCLUSTERS
  - veto generation: custom code ("GIDE"), applied to PSL at L1, MICH_CTRL at H2
- Interpreted using specific astrophysical models for calibrated waveforms.
  - Set upper limits on rate density for models of neutron star bar mode instabilities, core collapses, and black hole binary mergers.
- Julien defends his thesis Monday. Good luck!

E7: Triggered Burst Search
Gamma Ray Bursts during the run

- 16 GRB triggers for the duration of E7
- Various degrees of confidence
  - From		Unconfirmed cosmic event
  - To		Confirmed cosmic event
- Various degrees of directional information
  - No arrival direction information.
  - At best crude arrival direction.
  - Between ecliptic latitudes …
  - Portion of annulus contained between ecliptic latitudes…
  - Large box with coordinates …
  - There are two possible arrival directions, defined by the intersection of two annuli.
  - Triangulation gives an annulus centered at …
- This is still promising, the analysis is ongoing

E7: Triggered Burst Search
Several Spacecrafts and Varying Quality

Detector	DATE
▪ ULYSSES	01/12/28
▪ BEPPOSAX GRBM, ULYSSES, KONUS WIND	01/12/28
▪ BEPPOSAX GRBM	01/12/30
▪ BEPPOSAX GRBM	01/12/31
▪ KONUS WIND	02/01/02
▪ BEPPOSAX GRBM	02/01/02
▪ GCN/HETE	02/01/05
▪ BEPPOSAX GRBM	02/01/06
▪ ULYSSES, KONUS WIND	02/01/06
▪ GCN/HETE	02/01/08
▪ GCN/HETE	02/01/08
▪ GCN/HETE	02/01/10
▪ BEPPOSAX GRBM	02/01/12
▪ KONUS WIND, BEPPOSAX, HETE	02/01/13
▪ KONUS WIND, BEPPOSAX	02/01/13
▪ ULYSSES, HETE	02/01/14

This data here is the property and courtesy of various experiments (Ulysses, Konus, SAX, and HETE) and networks (IPN and GCN). It may not be used for any purpose without the prior approval of the corresponding group.

A Statistical Approach

(based on the method proposed by Finn, Mohanty, and Romano, gr-qc/9903101)

- Cross-correlate time series between two (or more) interferometers (direction info is also used)
  - Takes care of some uncorrelated noise while GWB signal can remain
- Repeat it for all triggers where ifo data exist
- Compute cross-correlation also for many OFF trigger times
- Build the ON and OFF trigger distributions
- Compare the distributions and determine the statistical significance of the difference
  - Student-T test is OK if the distributions are well behaved

Assumptions, Details, Uncertainties and Challenges

- Choice of ON and OFF source distributions
  - According to models up to date the GW arrives before the GRB trigger
    - Slice before each trigger is used for ON trigger set
    - 20 – 50 randomly distributed slices after each trigger is used for OFF trigger set
- Calibration / Validation with simulated waveforms
  - Band limited white noise, ZM catalog and modulated sine wave
  - Playground data trials indicate well-behaved distributions and method sensitivity
- Are the distributions well-behaved (i.e., normal)?
  - Student-T test is a good choice for now
- Effect of vetoes is still a question.
  - They should help as long as the ON trigger slices are not vetoed
  - Should lead to much improved OFF trigger distributions
- Effect of post-veto glitchiness must be dealt with (if it exists)
- Effects of whitening / pre-filtering strategies must be surveyed
- Best treatment of widely varying of source direction information…
- Optimal choice of time slice size and offset
- Effect of non-stationarity between slices and triggers
  - Playground data trial did not raise alarms, probably ok at this sensitivity

Implementation: LDAS DSO + Matlab

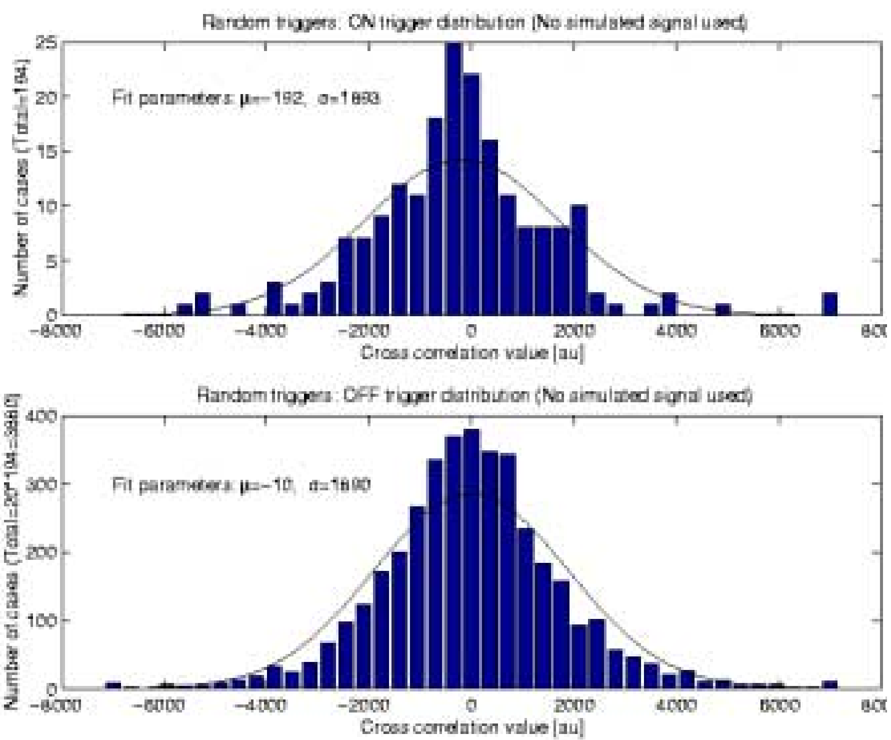
- Obtain GRB timestamps and directions from DB
- Use veto information
- Grab data from both interferometers around the trigger
- Pre-condition data (extra whitening, filtering, line removal, etc.)
- Pick several OFF trigger slices
- Use of expected time delay between interferometers due to direction of GRB source
- Compute and record cross-correlations for ON trigger and for each OFF trigger slice

Presently the statistical part is done in Matlab based on the DSO output

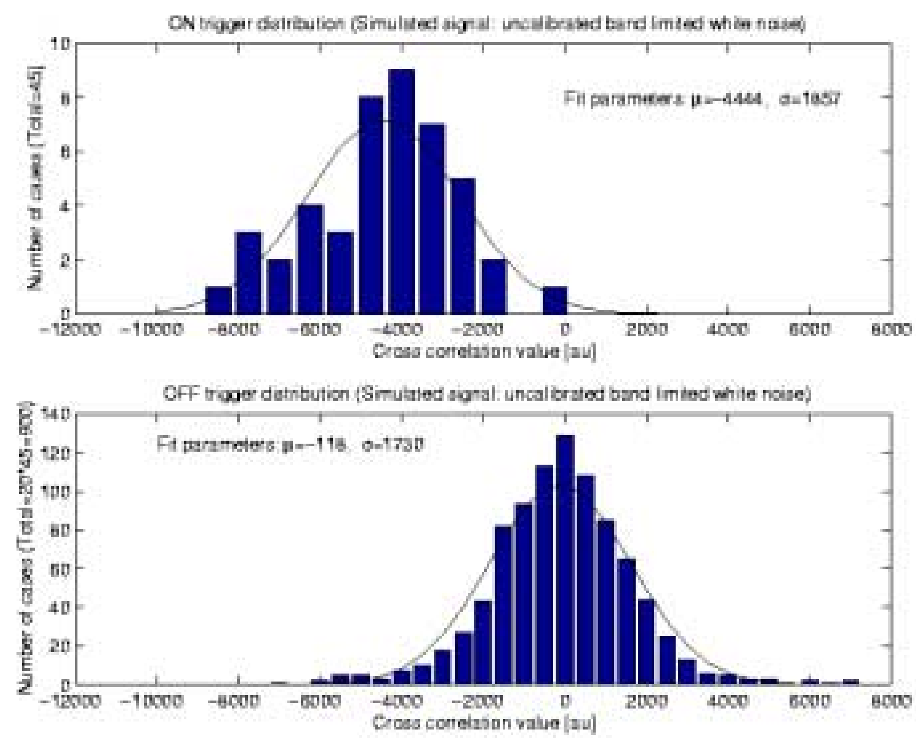
* Planned but not done yet

Test of triggered search DSO with E7 playground data

“ON” times chosen at random



inject BL white noise for “ON” times



The outlook for S1

- We have working DSOs.
  - Some ideas for new ones also being pursued.
- We have learned how to work with vetoes.
  - Ifo improvements probably mean cleaner data, and thus from-scratch study of best vetoes for S1.
- We have exercised almost all of the full path from data ingestion to scientific conclusions.
  - A few of the back-end (interpretation) steps still need work.
- To S1, and beyond!