Glitch and veto studies in LIGO's S5 search for gravitational wave bursts

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Glitch study requirements

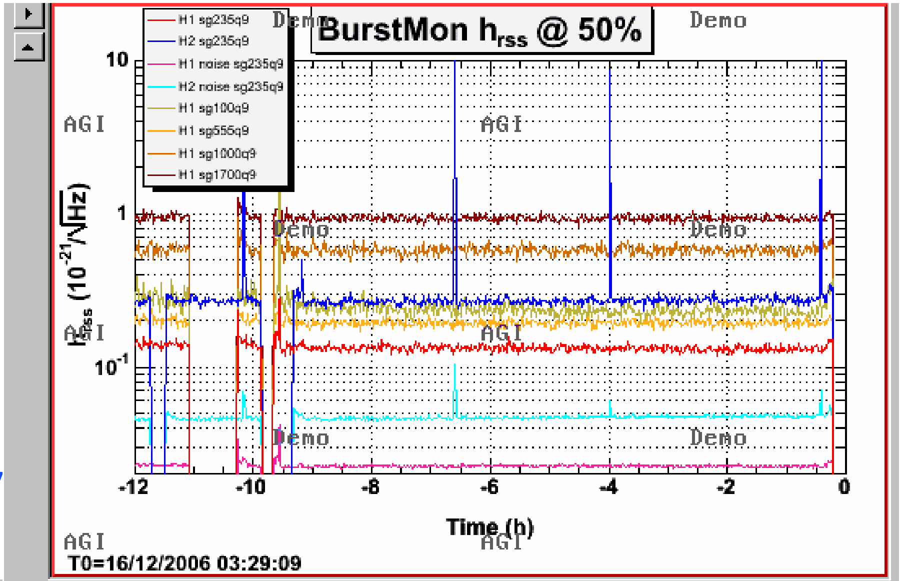
- Low latency (seconds to hour), control-room feedback
  - » Support real-time operations for immediate action on the instruments
  - » Guide operators and shift workers
- One day to one week feedback
  - » Support “online” astrophysical analyses
  - » Provide trends of the instruments’ behavior over longer strides
- Month(s) feedback
  - » Driven by data analyses groups, primarily, bursts and inspiral
  - » Ultimate clean up of data for deep into the noise searches
  - » Provide feedback for long-term planning and understanding of the instruments
- Documentation, archiving and easy to use
  - » Still space for improvement!

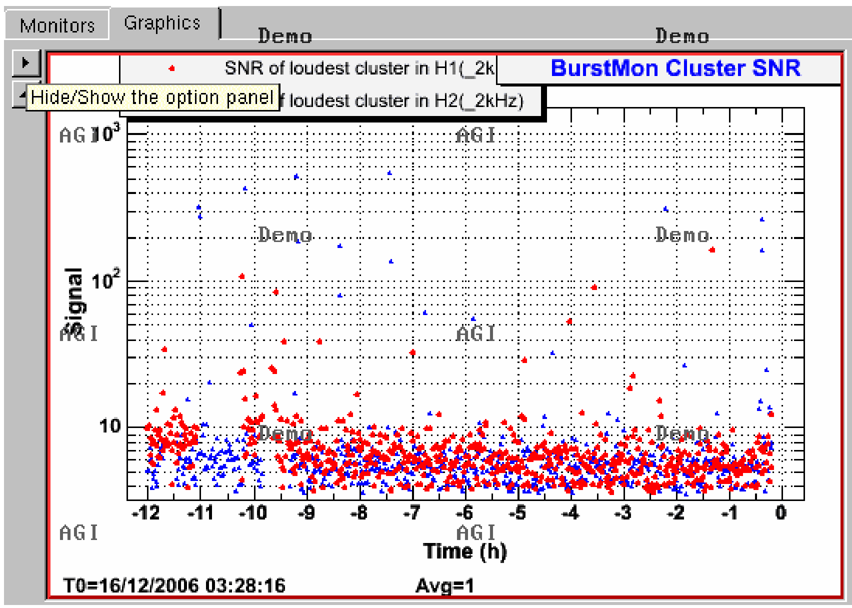
Tools for glitch study

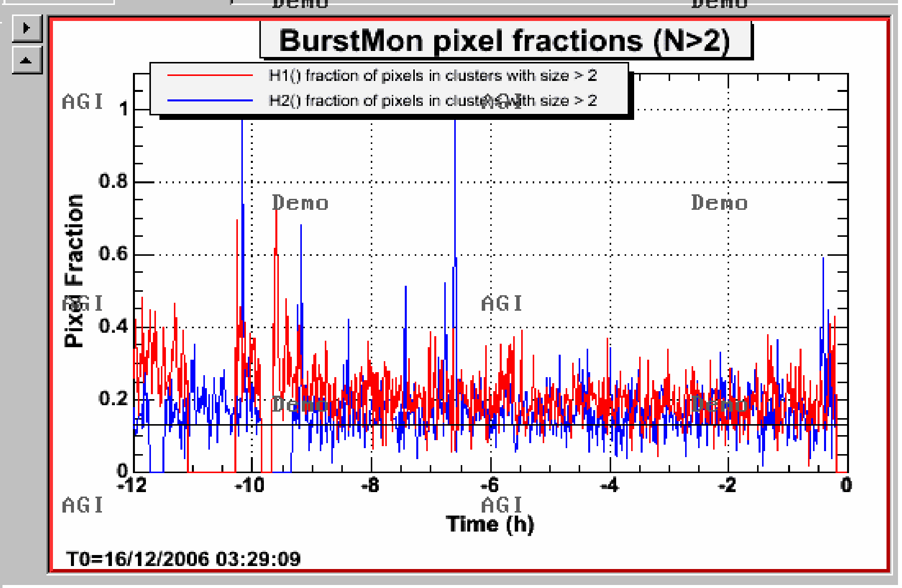
- Data Monitoring Tool (John Zweizig, Caltech)
  - » True, real-time applications
  - » General data-mining and watching processes at multiple levels
    - – Gravitational wave, auxiliary, data-acquisition specific
  - » Science monitors, burstmon (Sergey Klimenko et al, Florida)
- Electronic detector logbooks !
- BlockNormal (Shantanu Desai et al., PSU)
  - » Daily glitch studies
- KleineWelle (Lindy Blackburn et al., MIT)
  - » Quasi-real time and offline processing
- Q-pipeline (Shourov Chatterji, Caltech and INFN)
  - » The LIGO instruments’ time-frequency microscope
- Burst and Inspiral event generators
  - » Event-driven in-depth analysis both online and offline

BurstMon

- Variant of WaveBurst
- SNR of loudest cluster
- Monitor glitch rate
  - » Noise non-stationarity and non-Gaussianity
- Monitor detector sensitivity

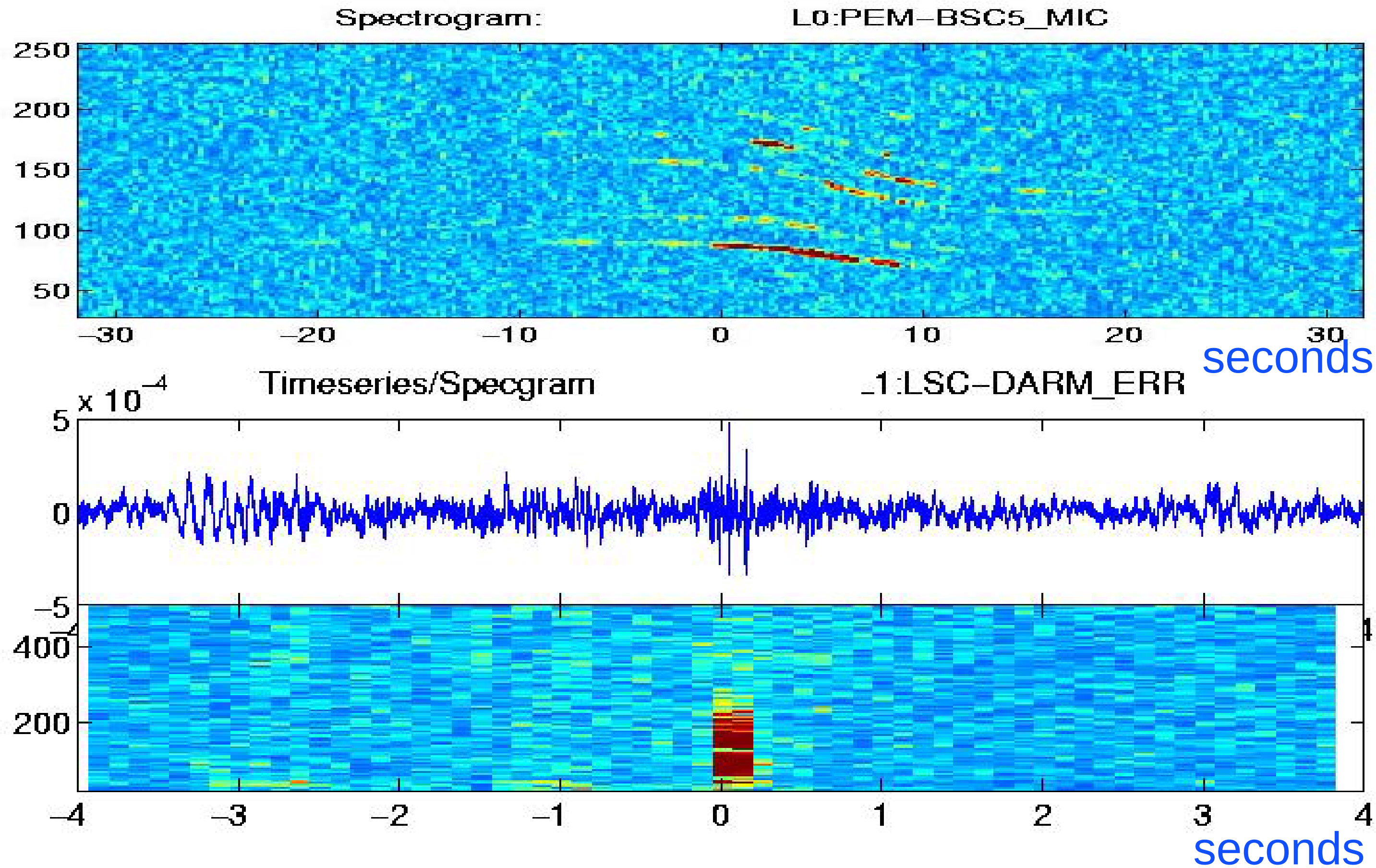






Glitch studies with BlockNormal

- Time-domain search for noise that doesn't look like background noise
- Identify outlier events on single-instrument basis characterize them using the 'Event Display' and Q-scans

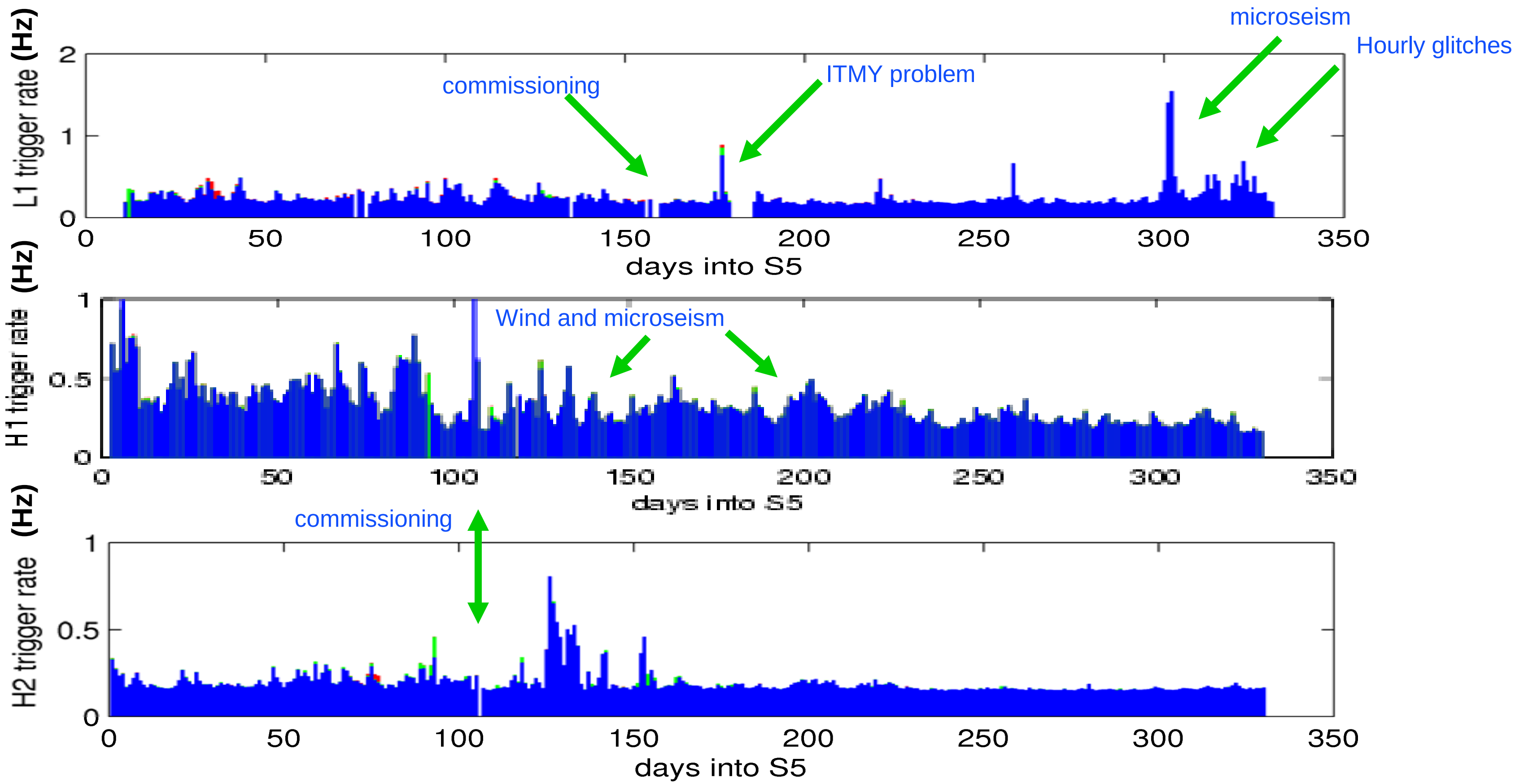


Glitch studies with KleineWelle

- Use the *Discrete Dyadic Wavelet Transform*
  - Decompose time-series into a logarithmically-spaced time-frequency plane
  - Identify pixels that are unlikely to have resulted from noise fluctuations
- Generate triggers with rate-based tuning of O(0.1)Hz
  - Provide information on the start time, stop time, frequency, number of time-frequency pixels involved
  - Threshold on probability of event resulting from Gaussian noise (significance)
- Analyze all gravitational-wave channels and a massive (300+) number of auxiliary channels in quasi-real time
  - Identify features in the data
  - Examine correlations with GW channel -- veto analysis
  - Study time-variability
  - Scan and classify single and multi-IFO outlier GW events

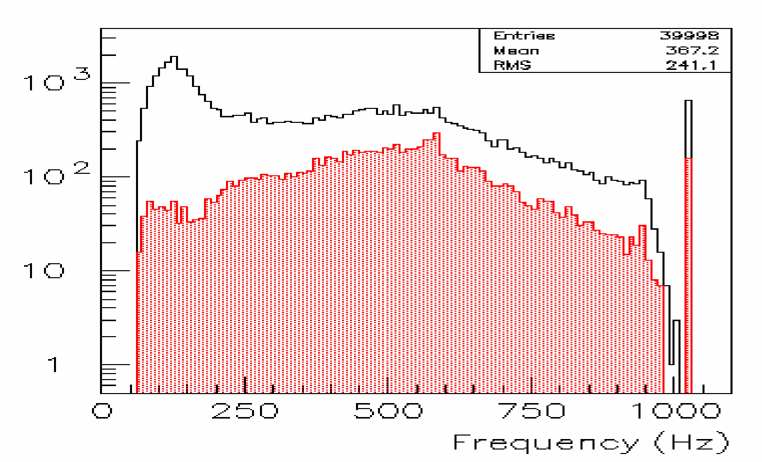
Glitch rates so far in S5

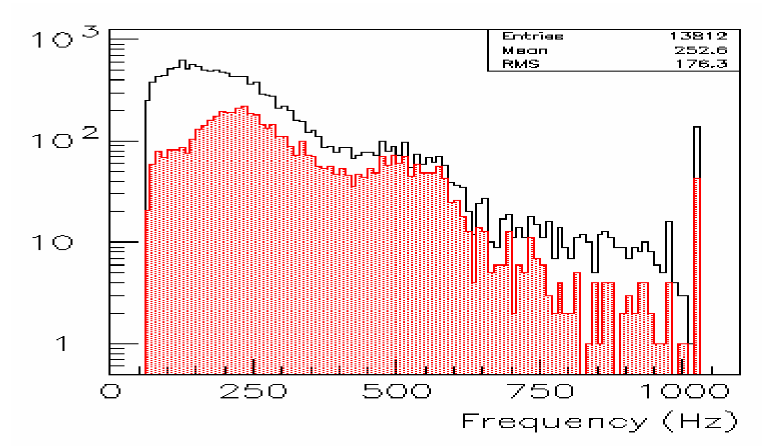
- Singles rates (in Hz), raw, (red), after category 2 data quality (green) and after cat-3 (blue) (DQ categories: see Laura's talk)



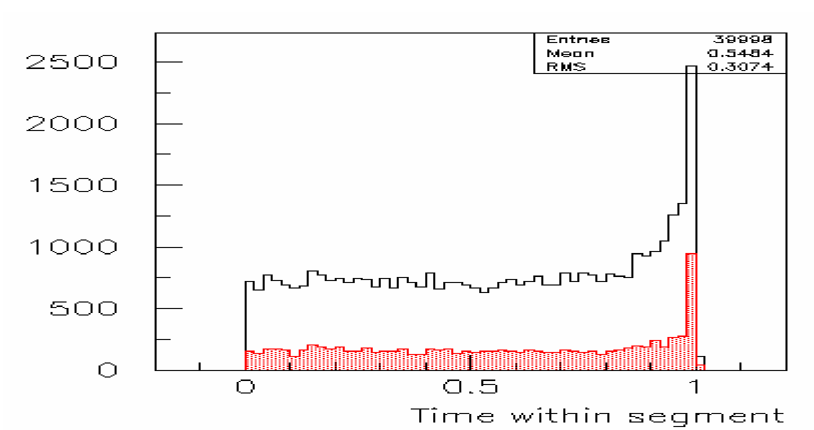
Trigger features

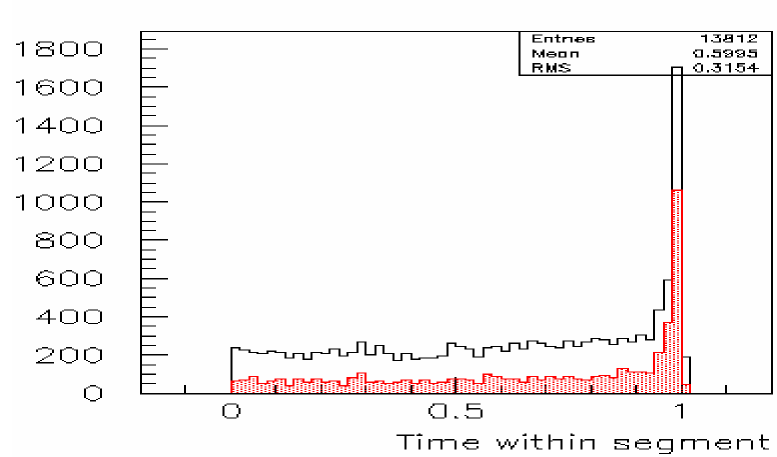
- Low frequency glitches in H1/L1 during first part of S5





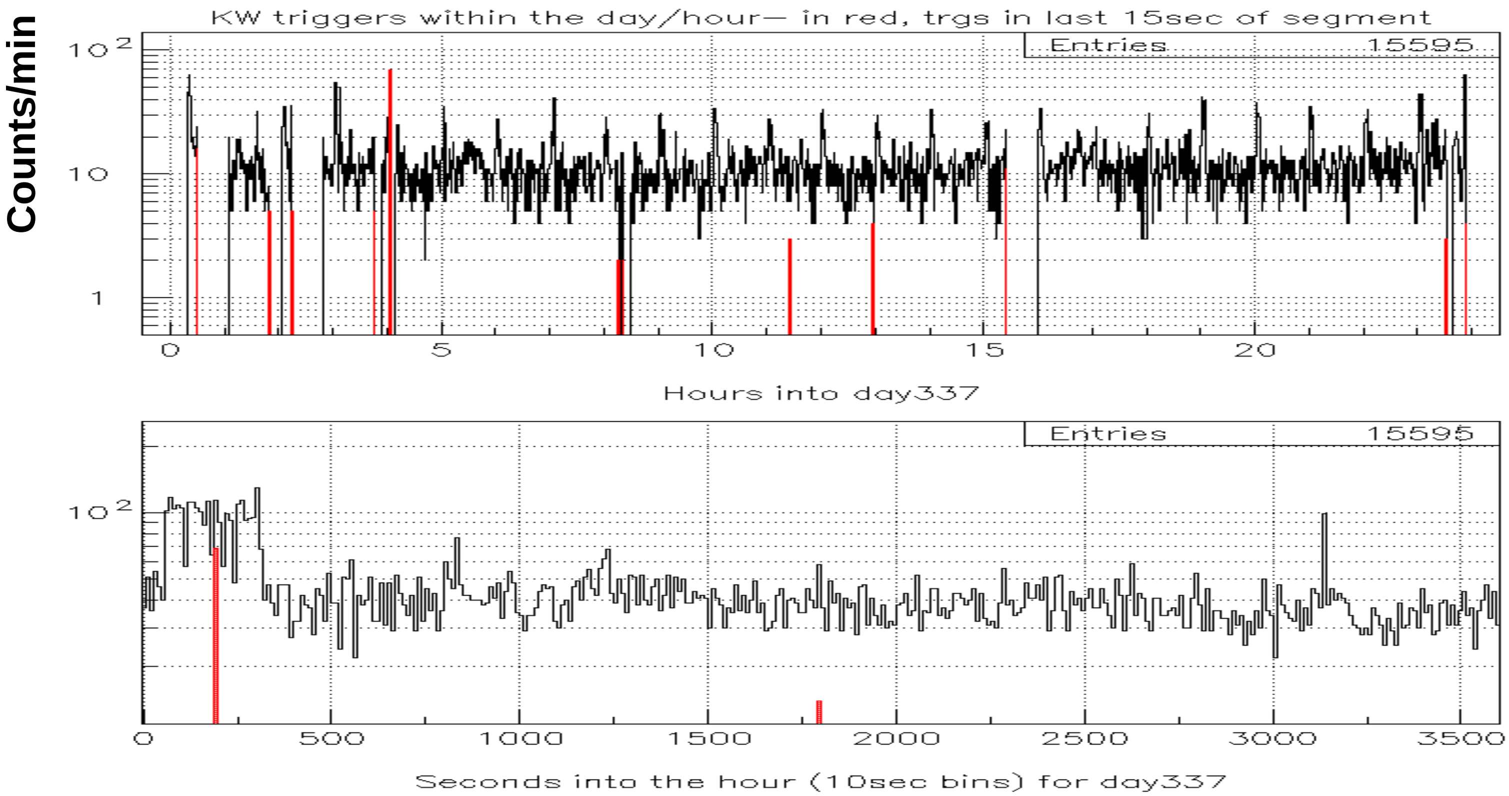
- Plenty and loud glitches toward the end-of-lock





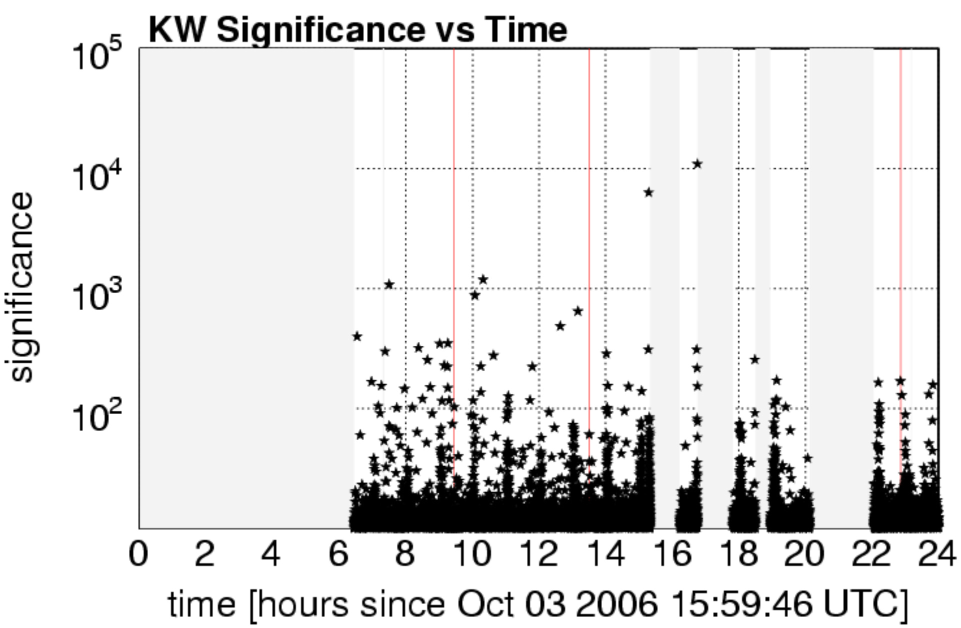
Hourly glitches in LLO

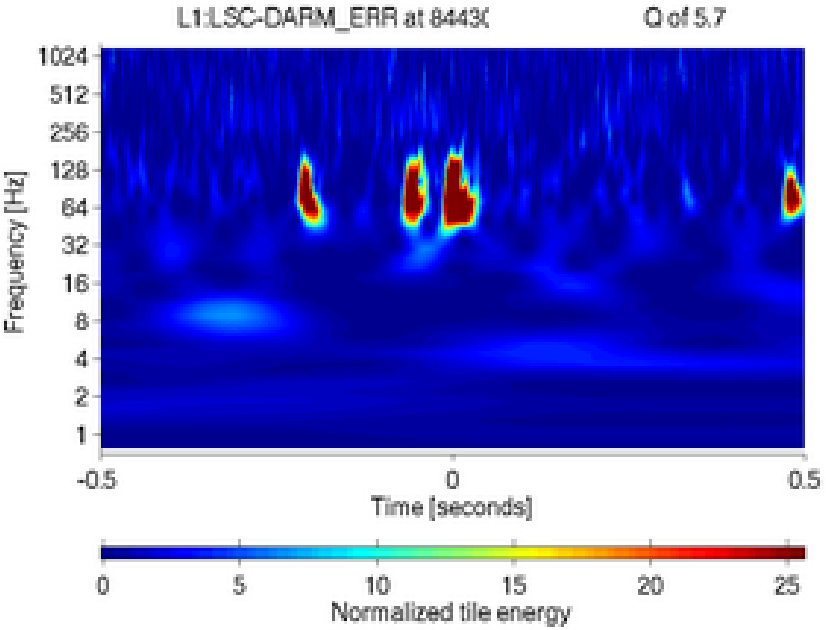
- Started Oct 3, 2006 and have been coming and going
- Attributed to BURT (=Back Up and Restore Tool) snapshots performed by the DAQ on an hourly basis- mechanism not fully understood, but problem currently is not present



More on hourly glitches in LLO

- Bursts of high significance, low frequency glitches

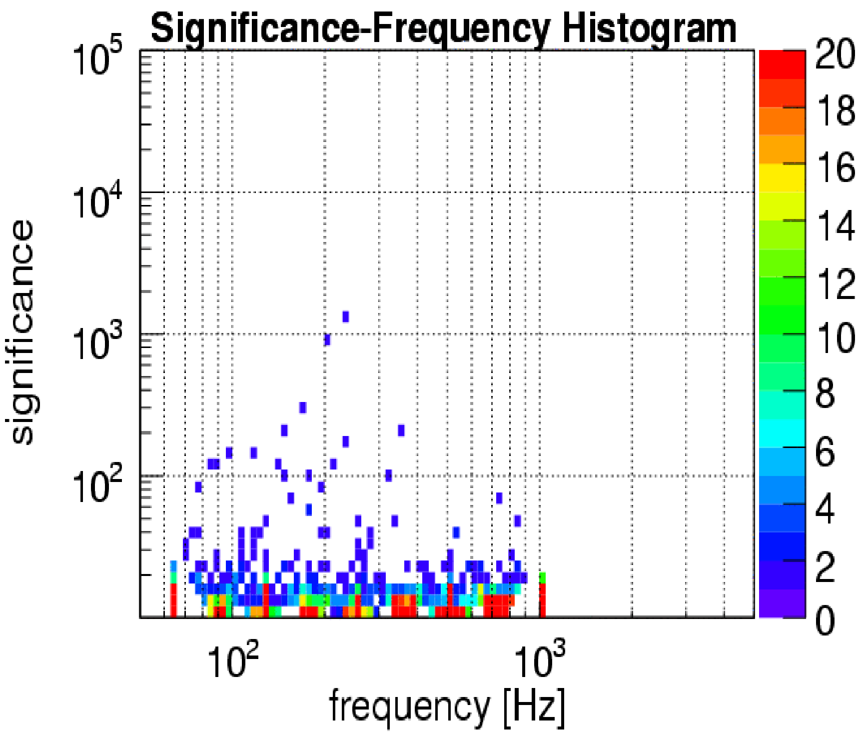




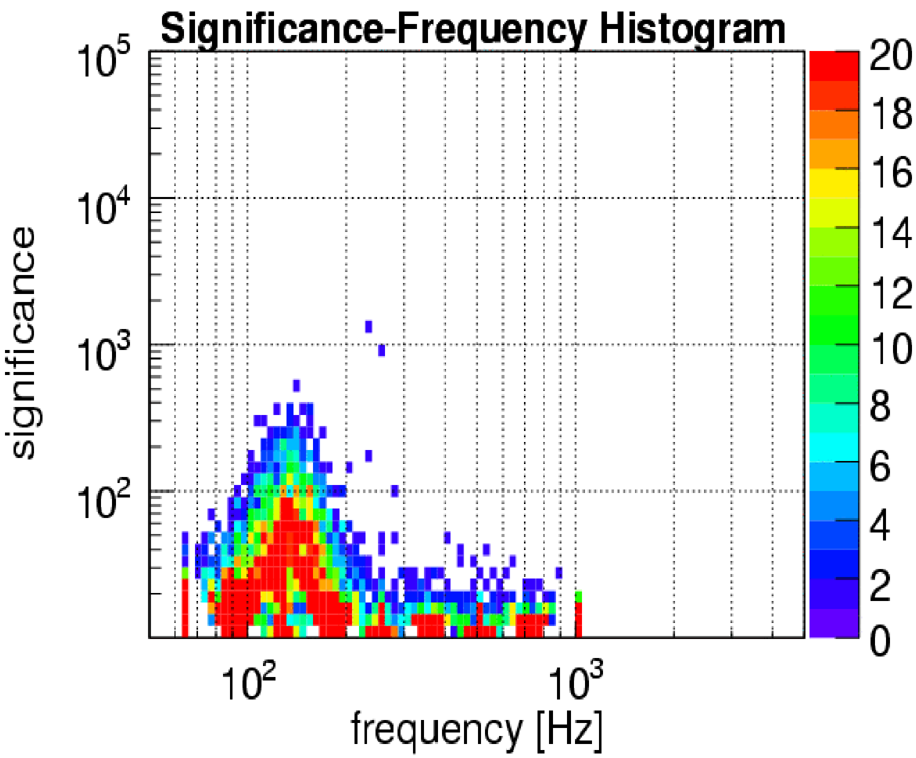
Effects of high microseism

- Increase of low frequency glitches

Low microseism at LLO (Oct 02, 2006)

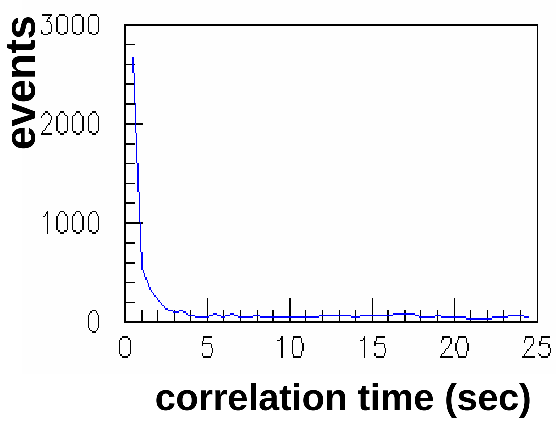


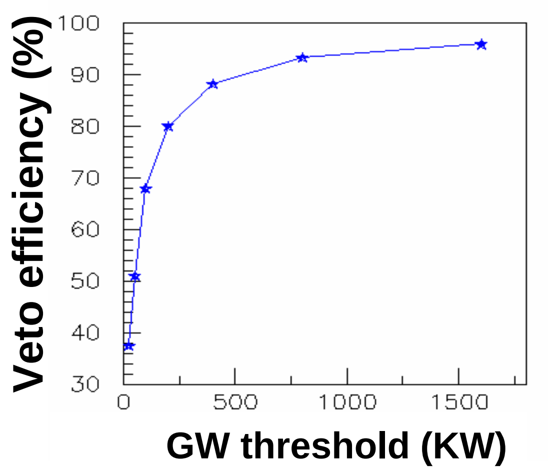
High microseism at LLO (Oct 15, 2006)

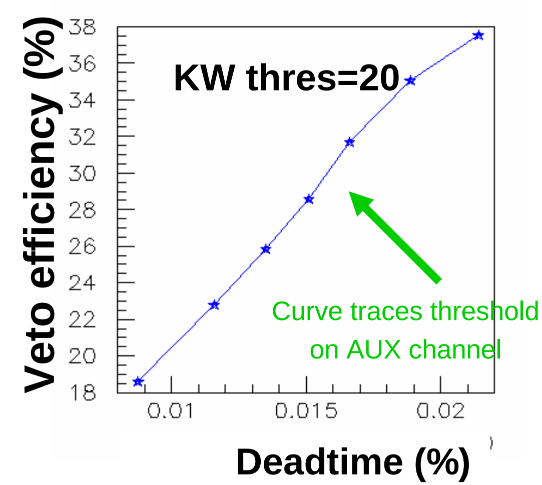


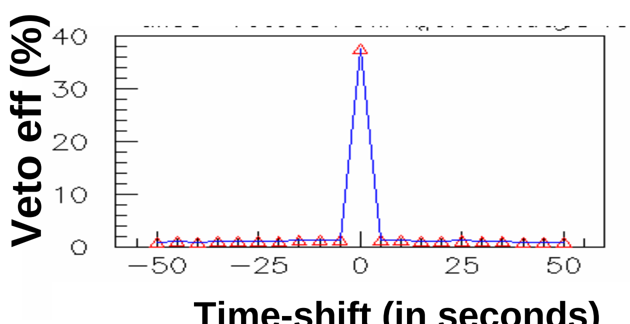
GW-AUX correlations and vetoes

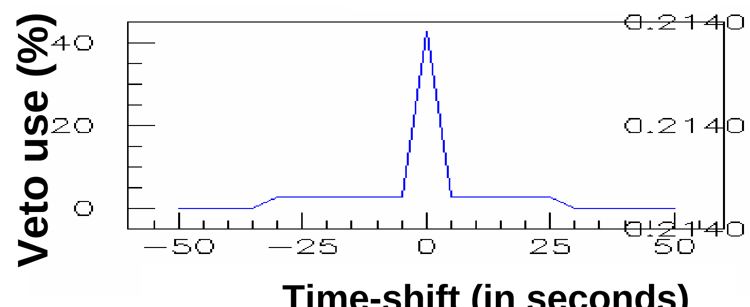
- Features studied in a first pass:
  - » Overlap as a function of trigger frequency and trigger amplitude
  - » Formal veto analysis, i.e., study of the veto efficiency vs dead time, time-lag analysis, use percentage
  - » Cross-correlations
- GW – ASI example in L1 over the first 103 days of S5





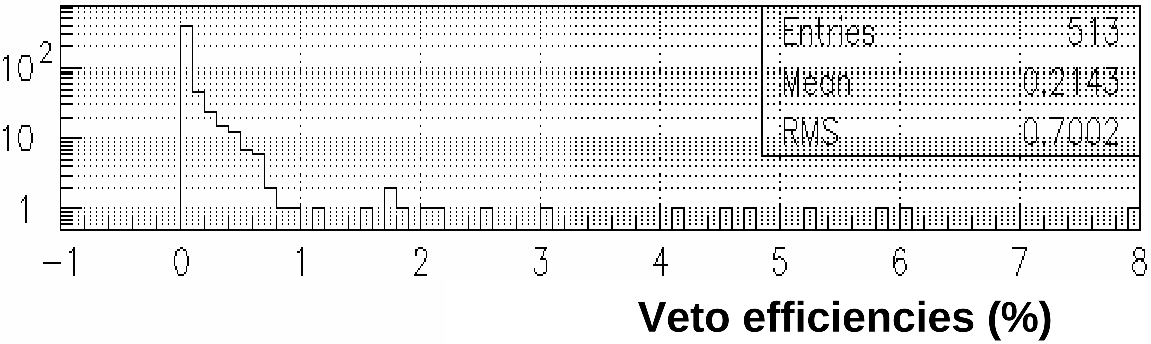


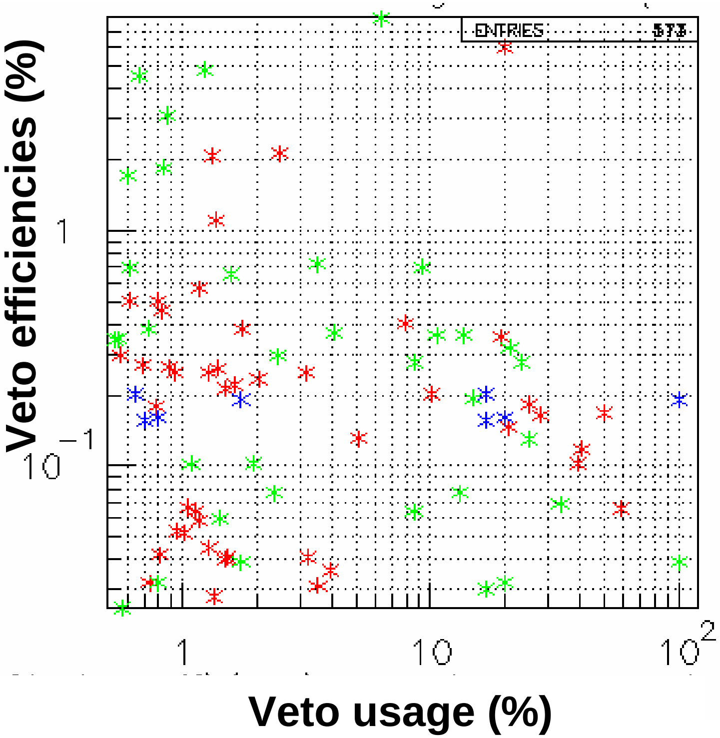




Veto choices

- A collective analysis of correlations between kleinewelle triggers from 300+ detector channels and the gravitational-wave channel
- Environmental channels in LLO vs low threshold GW triggers (three distinct auxiliary channel thresholds):



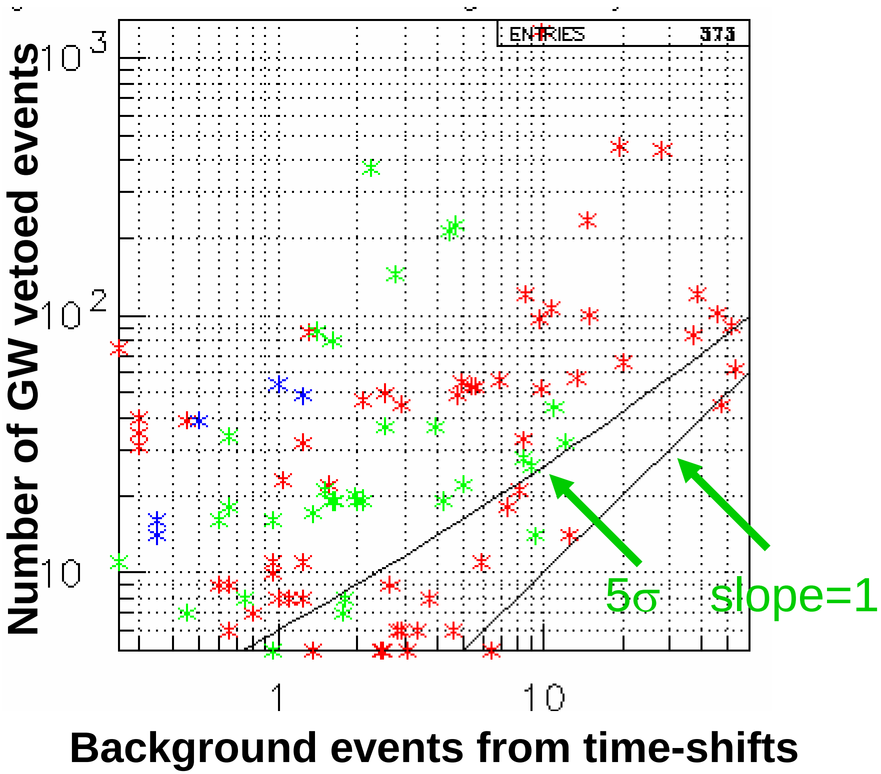


- Interferometric channels are also analyzed in the same way after their ‘safety’ is established using hardware injections (see Muyngkee Sung’s talk)

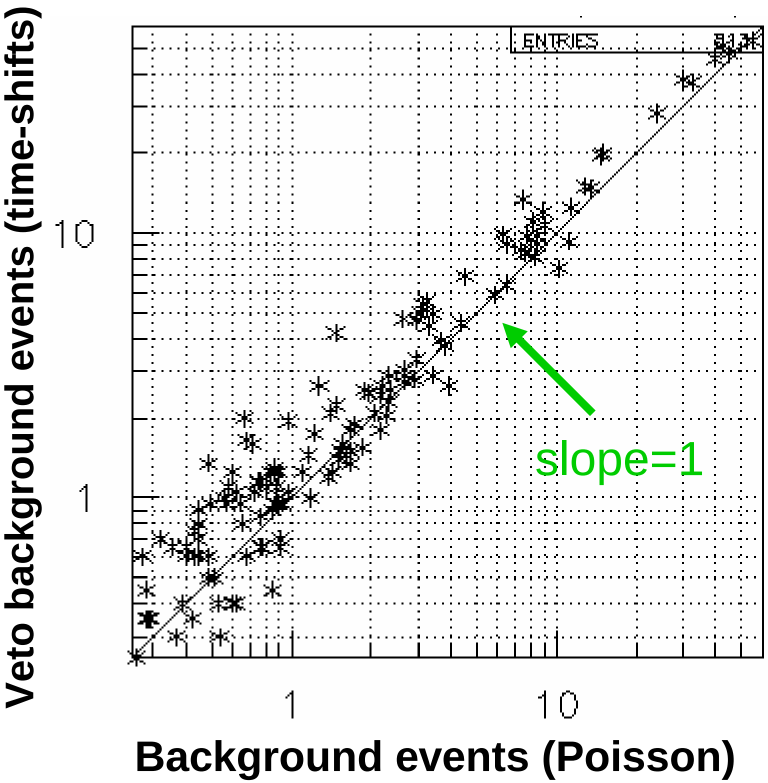
Channel-ranking principle

- Compare GW-auxiliary channel coincidences to expectation from background; cast the answer in terms of Poisson probability (see poster by Erik K and Peter Shawhan)
- Environmental channels in LLO vs low threshold GW triggers:

Veto significance for three distinct auxiliary channel thresholds, low (red), medium (green) and high (blue):



Good understanding of the accidentals (background) in GW-auxiliary channels coincidences:



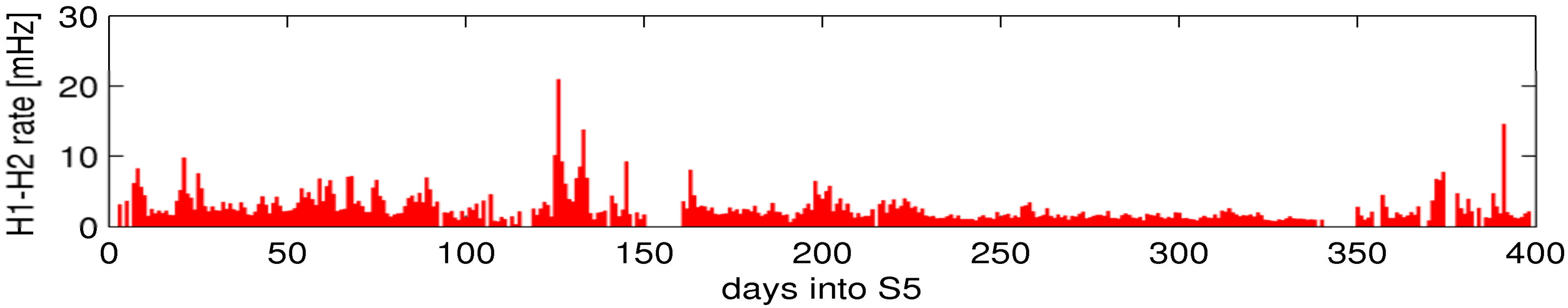
Veto choices in H1 for first 5 months of S5

- Veto-yield on H1 single-instrument gravitational wave transients of ~10^{-21} sqrt(Hz) and above is at the 1% level for environmental channels and at the 10% level for interferometric channels
- Resulting dead-times at the level of 0.5%

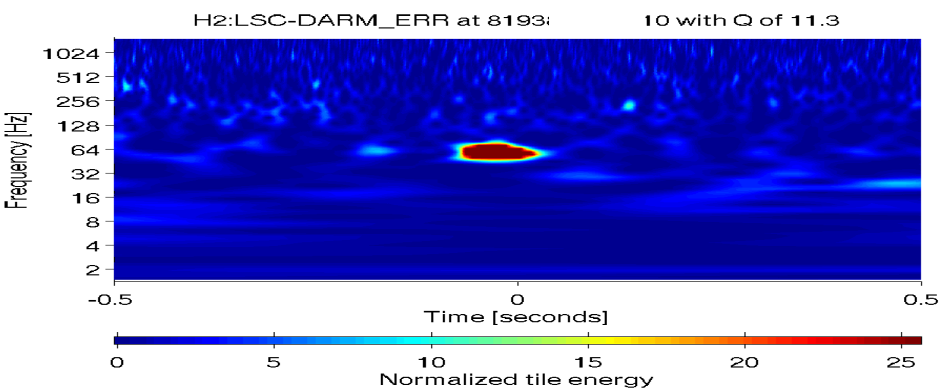
Preliminary-
work in progress!

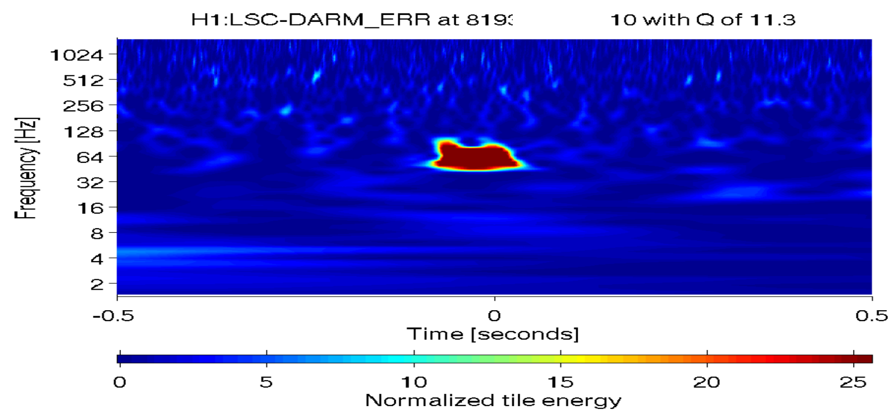
Channel	GWT		AxThr	_Dur_	Deadtime	Nveto	Nbkg	Prob
bsc1accy	104	best:	104	0.100	0.000 %	9	0.00	6.9e-13
bsc2accx	104	best:	104	0.100	0.000 %	8	0.00	4.8e-11
bsc2accy	104	best:	101	0.100	0.003 %	8	0.05	1.8e-09
bsc3accx	104	best:	104	0.050	0.000 %	7	0.00	2.9e-09
bsc4accx	104	best:	104	0.100	0.000 %	9	0.00	6.9e-13
bsc4accy	104	best:	104	0.100	0.000 %	9	0.00	6.9e-13
bsc7accx	104	best:	104	0.100	0.000 %	8	0.00	4.8e-11
bsc8accy	104	best:	104	0.100	0.000 %	8	0.00	4.8e-11
ham1accz	104	best:	104	0.100	0.001 %	8	0.05	1.8e-09
ham3accx	104	best:	104	0.100	0.000 %	8	0.00	4.8e-11
ham7accx	104	best:	101	0.150	0.003 %	9	0.15	2.9e-09
ham7accz	104	best:	101	0.150	0.004 %	10	0.15	1.1e-10
ham9accx	104	best:	104	0.150	0.008 %	10	0.30	5.3e-09
iot1mic	104	best:	101	0.100	0.001 %	9	0.15	2.9e-09
isct1accx	104	best:	104	0.150	0.000 %	8	0.05	1.8e-09
isct1accy	104	best:	104	0.150	0.001 %	8	0.05	1.8e-09
isct1accz	104	best:	104	0.150	0.001 %	8	0.05	1.8e-09
isct1mic	104	best:	101	0.100	0.001 %	9	0.15	2.9e-09
isct4accy	104	best:	104	0.200	0.001 %	10	0.00	8.8e-15
isct4accz	104	best:	104	0.200	0.001 %	11	0.00	1e-16
isct7accy	104	best:	101	0.100	0.001 %	8	0.00	4.8e-11
isct7accz	104	best:	101	0.200	0.005 %	10	0.40	3.2e-08
lveaseisx	104	best:	104	0.100	0.000 %	8	0.00	4.8e-11
lveaseisy	104	best:	101	0.050	0.001 %	9	0.00	6.9e-13
lveaseisz	104	best:	104	0.100	0.000 %	8	0.00	4.8e-11
psl1accx	104	best:	101	0.100	0.007 %	17	0.10	2.4e-23
psl1accz	104	best:	101	0.100	0.016 %	13	1.60	1.7e-06

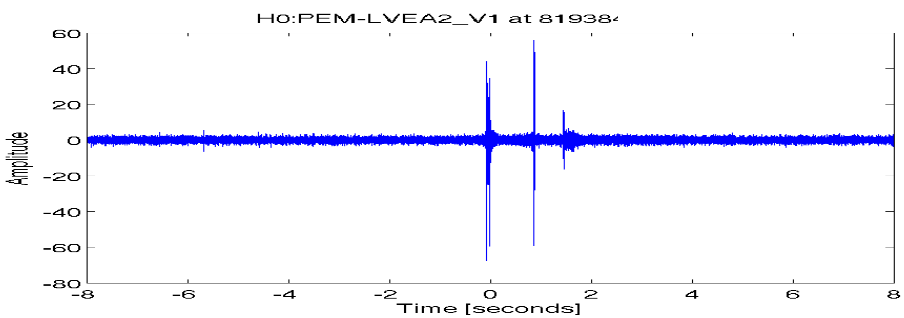
H1-H2 coincidences

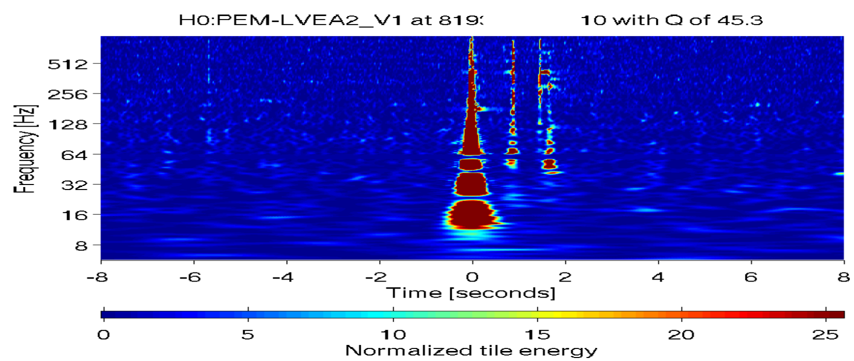


- Coincidence analysis and event classification has provided evidence of events resulting from extreme power line glitches reflected all across the H1-H2 instruments



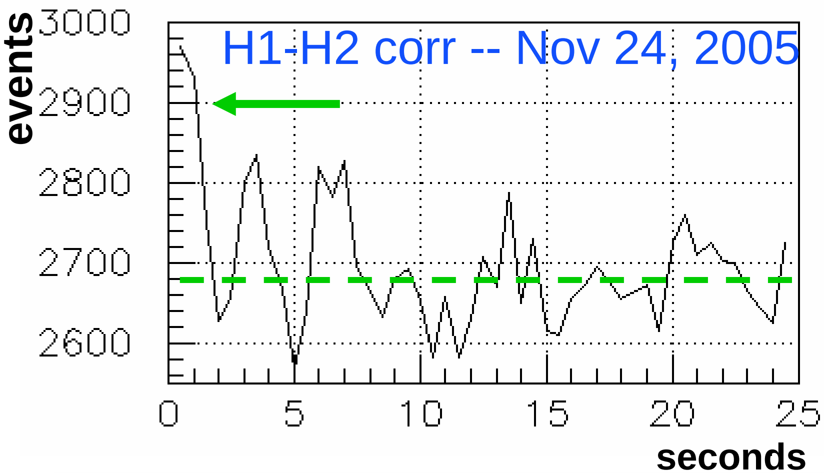


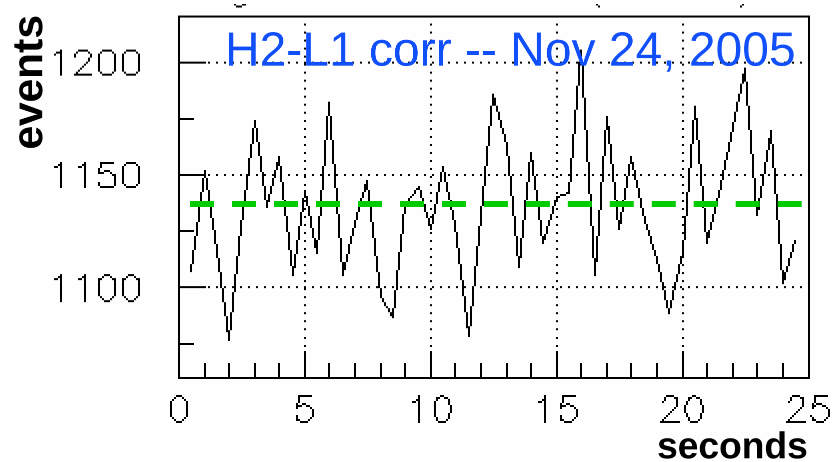


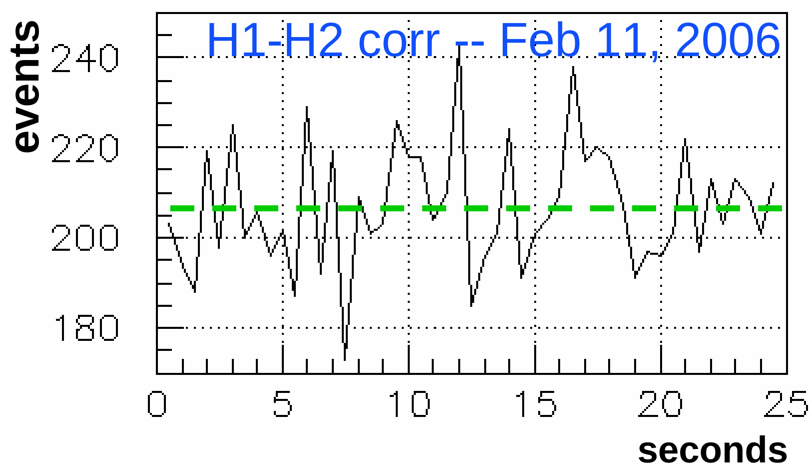


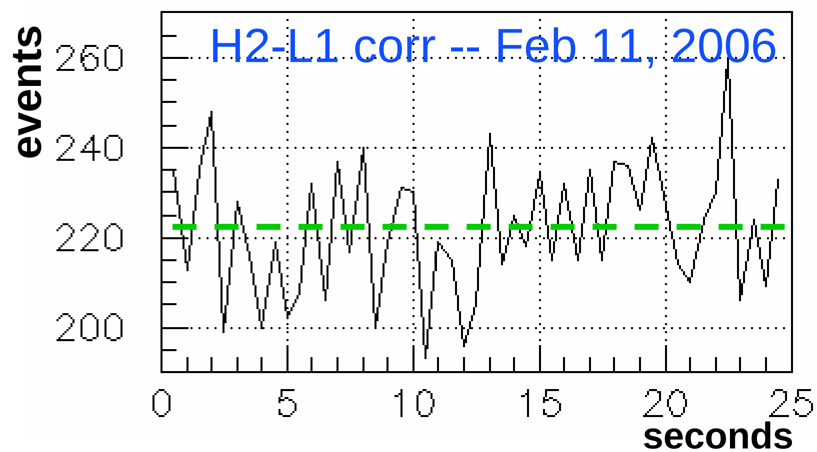
H1-H2 coincidences

- Outlier H1-H2 vs closer to the noise floor H1-H2 events may be generated by different mechanisms
- Cross correlograms in two days with extreme rates (high, top, and low, below)

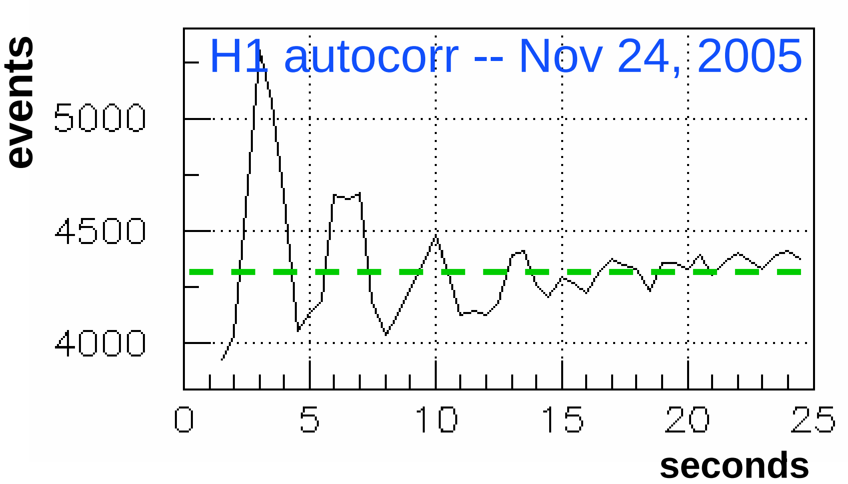


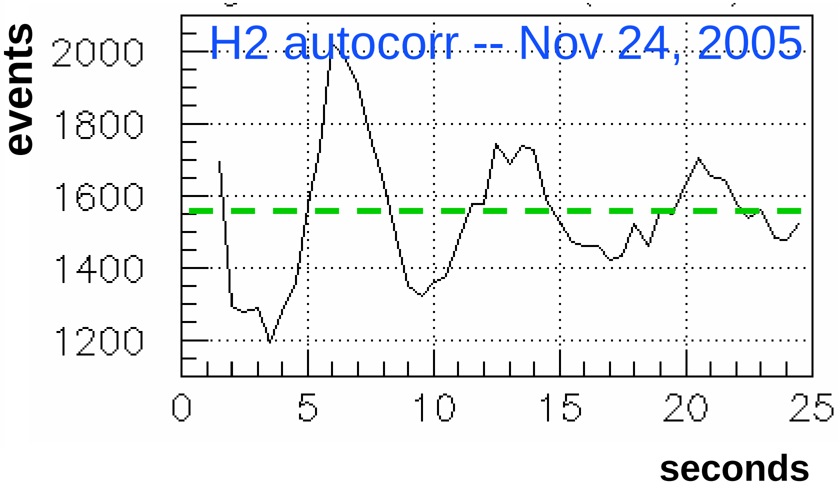






Signal autocorrelations





seconds

Summary and outlook

- Significant progress -with respect to previous LIGO science runs- in following up features in the detectors
- Multiple methods are identifying interesting events to be followed up
- Numerous auxiliary detector channels analyzed in quasi-real detector in assisting detector monitoring and detector characterization
- Rigorous tools for establishing veto criteria are maturing
- Bring to real-time as much as possible of the glitch work so that to be able to support a real-time astrophysical search in the future