Glitch investigations with kleineWelle

Reporting on work done by several people:
L. Blackburn, L. Cadonati, E. Katsavounidis (MIT)
and A. Di Credico (Syracuse U)

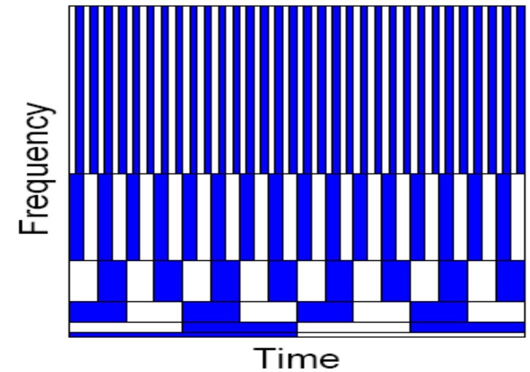
kleineWelle

(L.Blackburn, S. Chatterji, E. Katsavounidis)

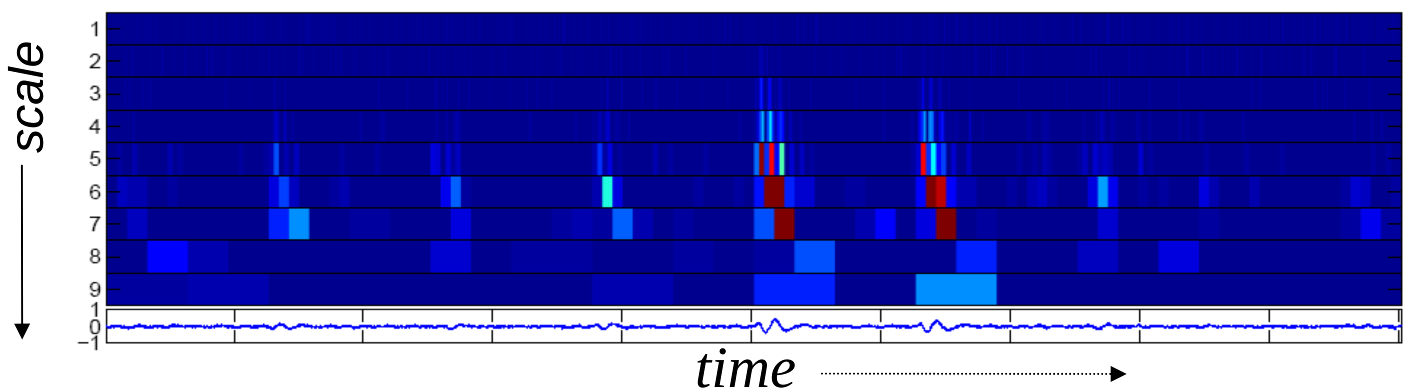
kleineWelle uses the *Discrete Dyadic Wavelet Transform* to decompose the timeseries into a logarithmically-spaced time-frequency plane

Continuous Wavelet Transform:

$$W_f(u, s) = \int_{-\infty}^{\infty} h(t) \frac{1}{\sqrt{2^s}} \psi\left(\frac{t-u}{2^s}\right) dt$$



The decomposition provides high time resolution at high frequency (low scale), and low time resolution at low frequency (high scale). Example of S3 glitches:



L.Blackburn (MIT)

kleineWelle -2

kleineWelle is implemented in DMT and makes use of the Linear Predictive Error Filter library, LPEFilter (S. Chatterji), to whiten the data prior to the wavelet decomposition.

kleineWelle output currently consists of a single multicolumn ASCII table for each channel analyzed. Each line represents one trigger (a single cluster which passes the significance threshold) with columns corresponding to the following parameters:

1) cluster absolute start time
2) cluster absolute end time
3) cluster central time (weighted by normalized energy)
4) cluster central scale (weighted by normalized energy)
5) total unnormalized energy of the cluster
6) total normalized energy, *Ec*, of the cluster
7) the number of tiles, *N*, which were clustered together to form the trigger
8) the derived cluster significance, *S*, a function of *Ec* and *N*.

Detector characterization

Goal: Find features in the data that produce high levels of noise or anomalous behavior

How we tried to achieve it:

Rate and Rate vs significance plots (Lindy)

Time series and spectrograms of interesting events/minutes (ADC)

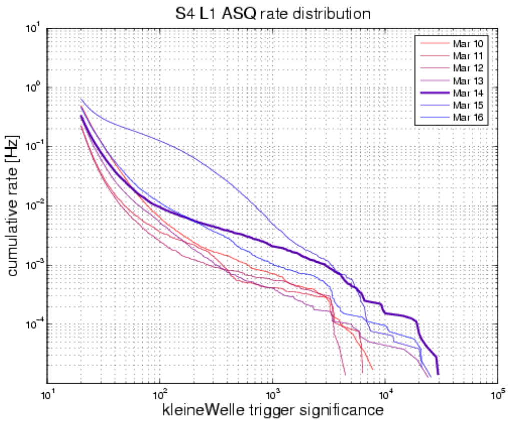
Diagnostics (frequency, significance vs time, position in segment) of the AS_Q glitches, auto-correlograms (Erik, Laura)

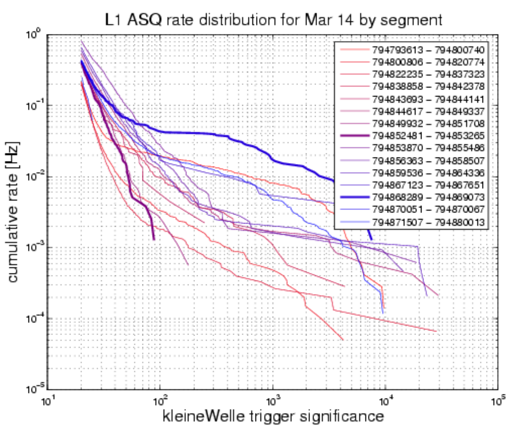
Lindy's trigger production and report

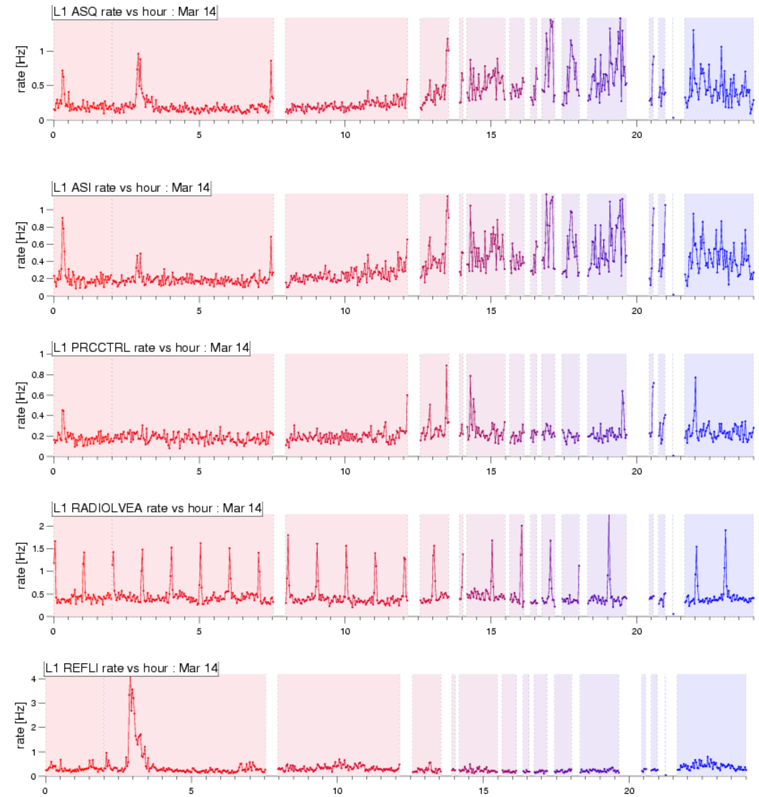
http://lancelot.mit.edu/~lindy/s4

- Triggers were produced for AS_Q and several other channels with a very low latency time (few hours – 1day)
- The choice of auxiliary channels to be analyzed was dictated by the study of the E12 data
- Focus on rate plots and rate vs significance plots. What features of the data are highlighted by these plots? overall behavior of the detector: rates describe how "noisy" the detector is. Comparison is made with previous days/segments/runs
- In order to understand how the AS_Q (or DARM_ERR) signal is correlated to other channels, we can compare 'instant by instant' the rates of different channels
- This kind of study is very useful to find direct correlations between channels – less in finding subtler effects.

Lindy’s plots: March 14 – L1







ADC detector characterization

http://www.physics.syr.edu/research/relativity/ligo/restricted/dicredic/S4analysis.html

Rate is an important factor, but not the only one for characterizing the data.

Some of the most interesting events could be huge outliers in otherwise quiet periods of data taking. In order to cover the cases of high rate/low significance triggers (noise) and low rate/high significance triggers (outliers) My choice has been to base the selection on the total significance of the AS_Q glitches in one minute of data.

1) Low rate/ Low significance	NO	
2) Low rate/ High significance	YES	(Outliers – Burst analysis)
3) High rate/ Low significance	YES	(Noise – Detector characterization)
4) High rate/ High significance	YES	(Noise – Data Quality cut)

In a “good day” the analysis will reveal a combination of cases 2) and 3).

In a “bad day” case 4) minutes will appear too. In general a different kind of noise will show up as the detector conditions change.

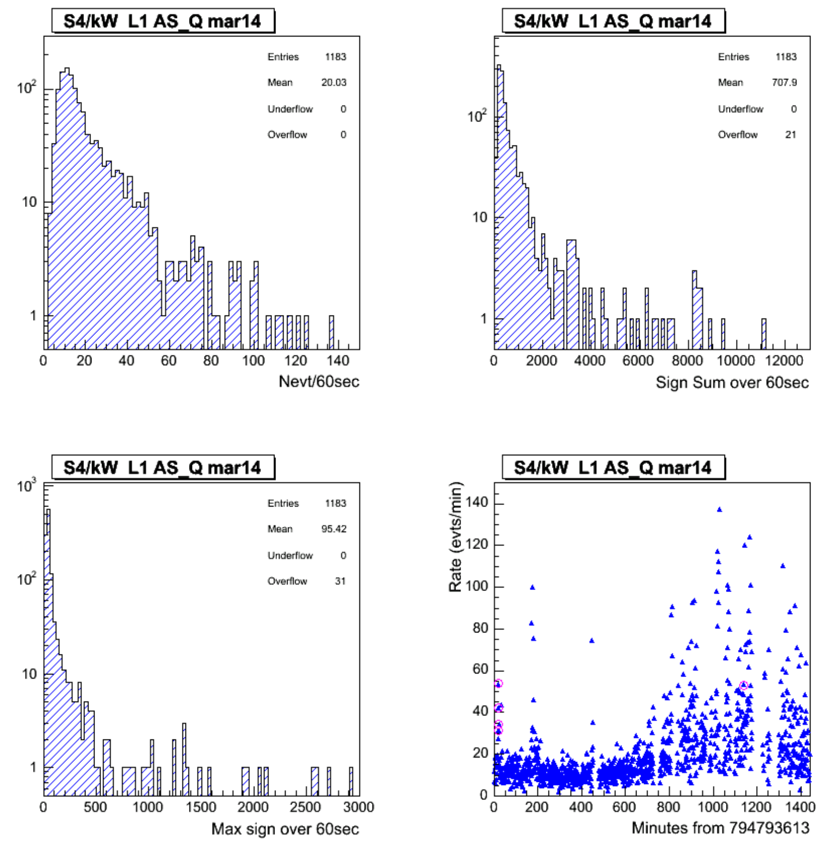
ADC's plots – Mar 14 L1

RECIPE:

- Every day is divided in 1440 minutes and for each full minute in science mode the total significance of the AS_Q glitches contained in that minute is computed.

- After sorting them, the 5 (or more) minutes with the highest values of total significance are selected for further study.

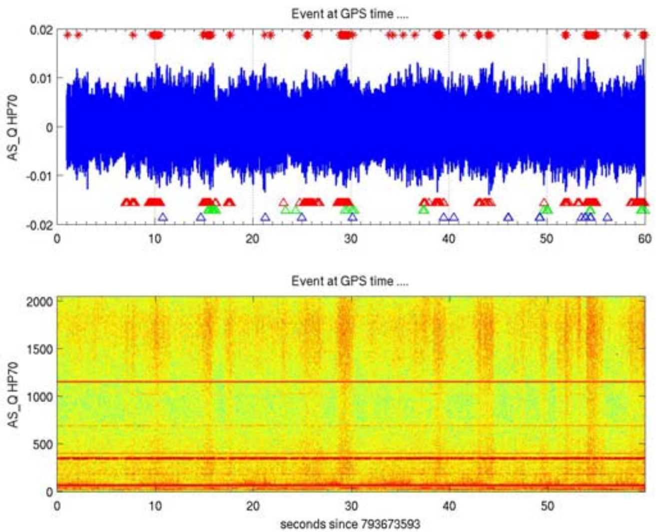
- Thus we look at these minutes by retrieving the frames and plotting AS_Q time series and spectrograms.

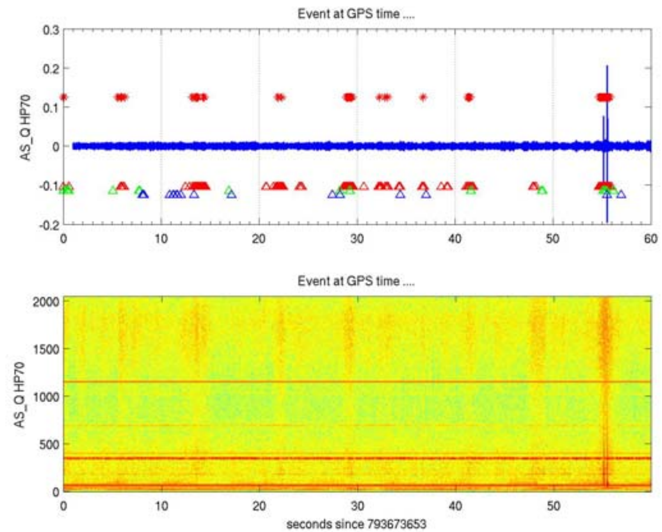


A. Di Credico
Syracuse University

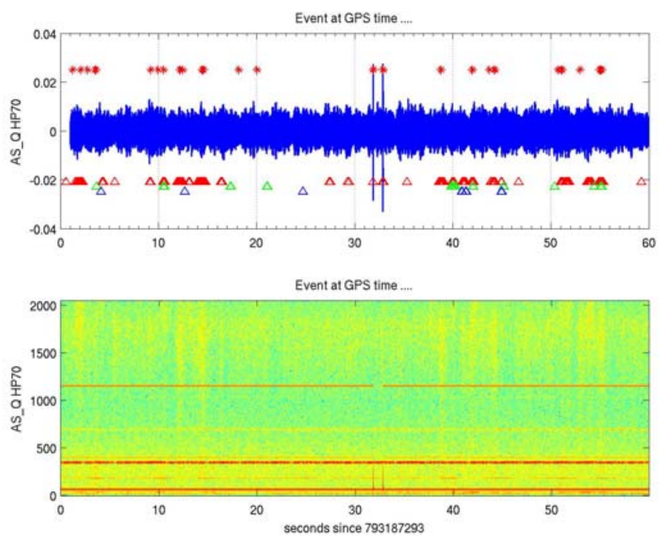
L1 noise plots

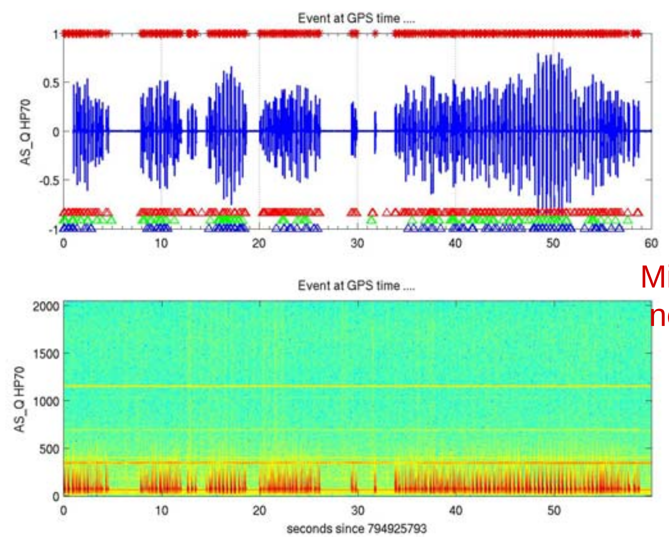
Broadband noise





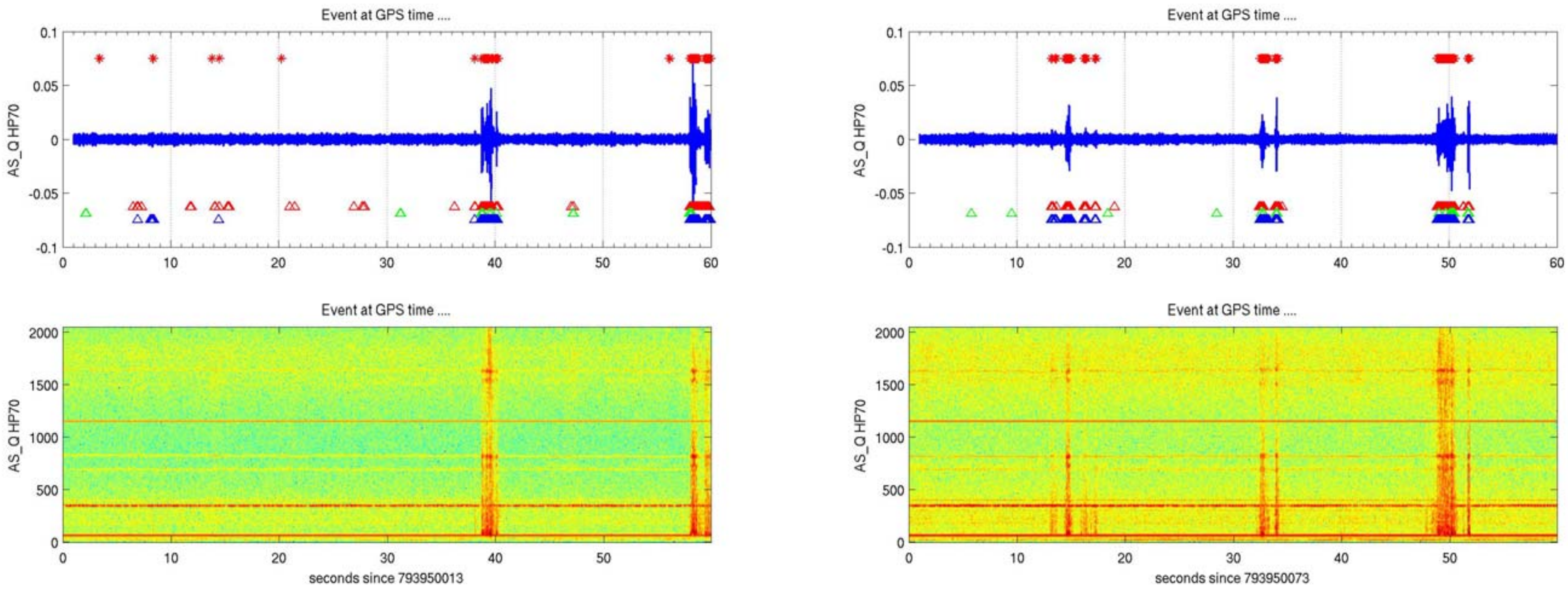
Calibration dropout





Micro-seismic noise

L1: Mar 04

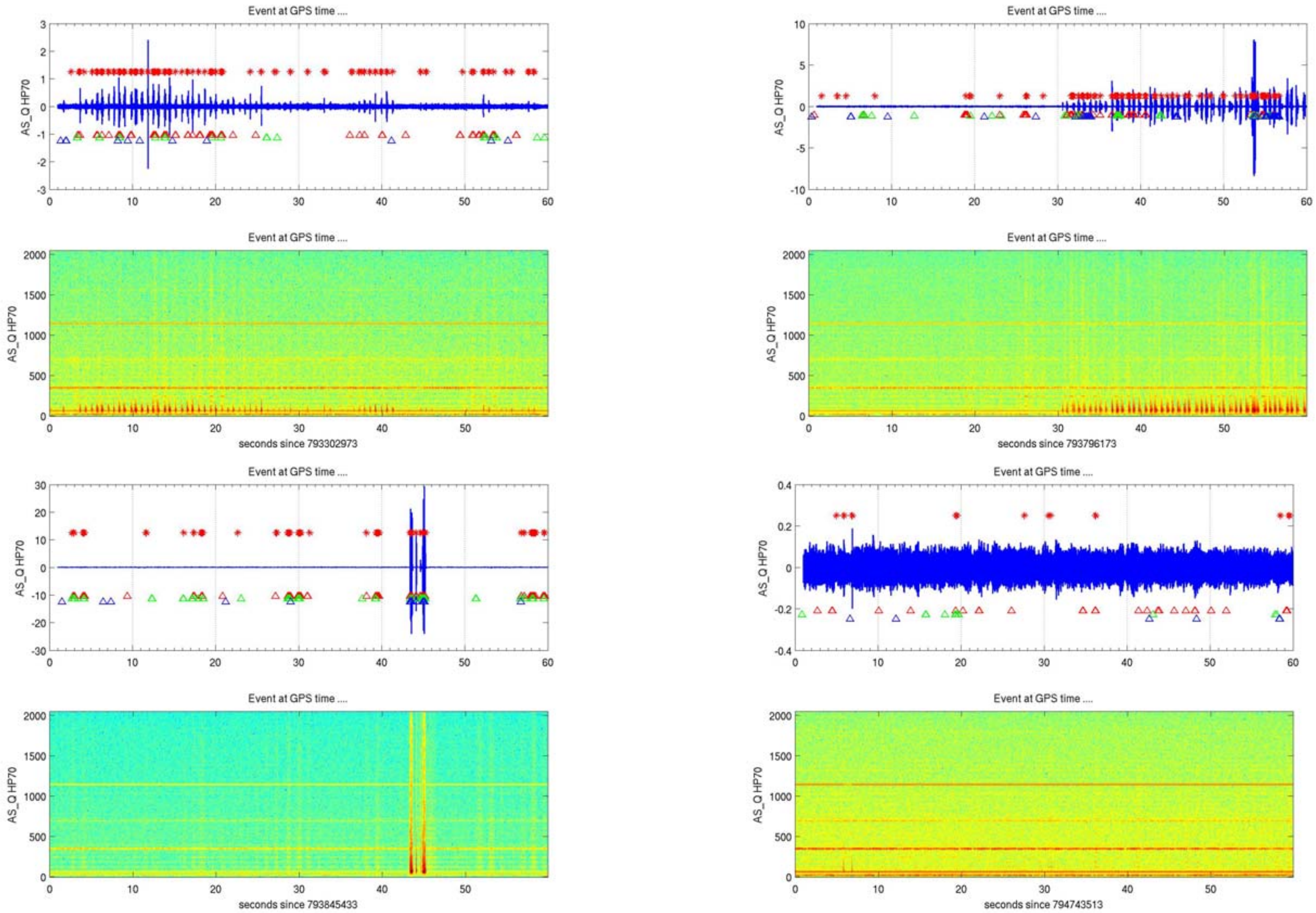


What is this?

5:40UTC (00:40EST) – 23:40 of March 3rd at Livingston

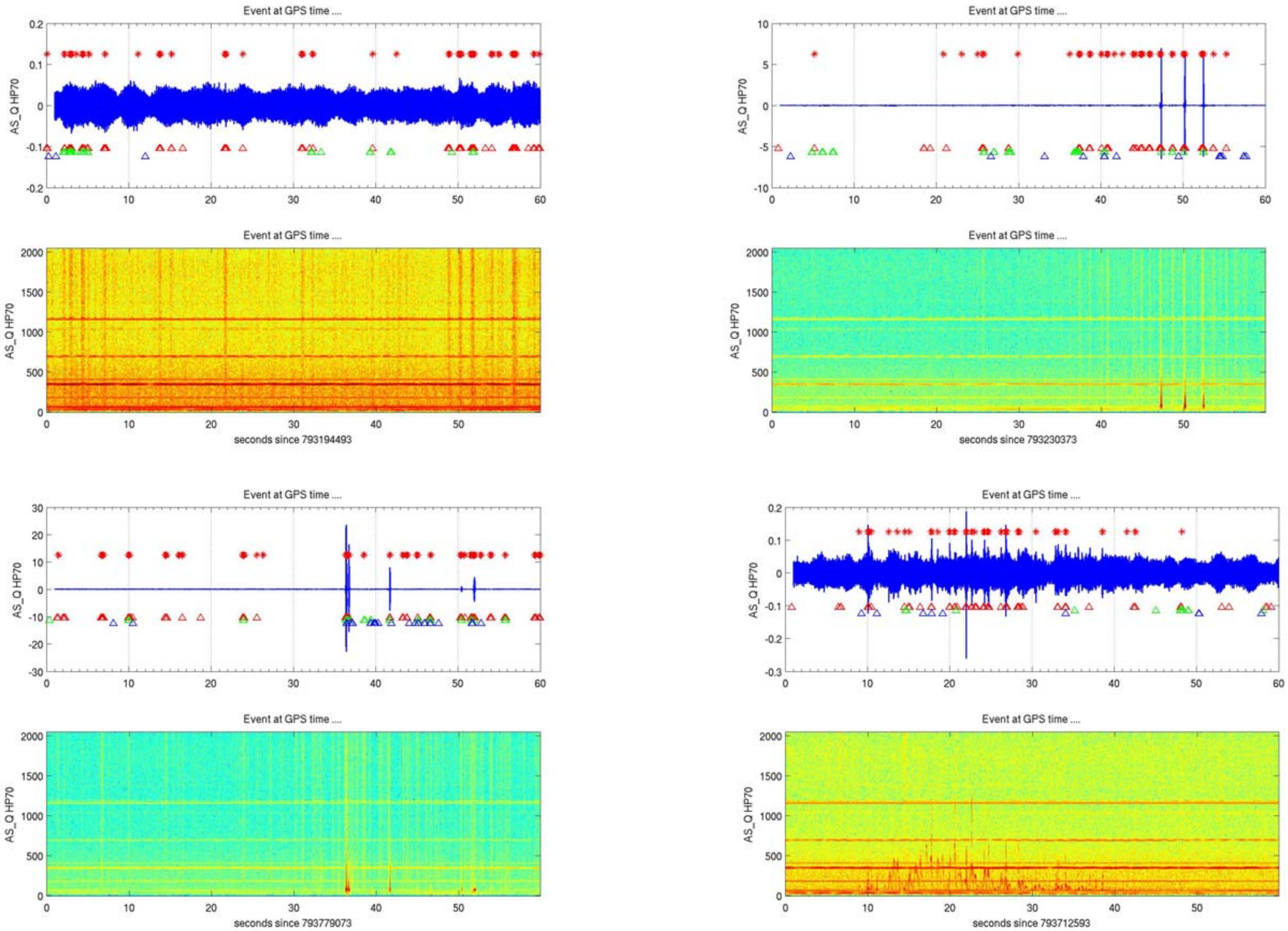
Reported in the e-log as “Unexplained lock loss with no obvious causes at 11:42pm” (L. Cadonati)

H1 noise plots



Calibration dropout

H2 noise plots



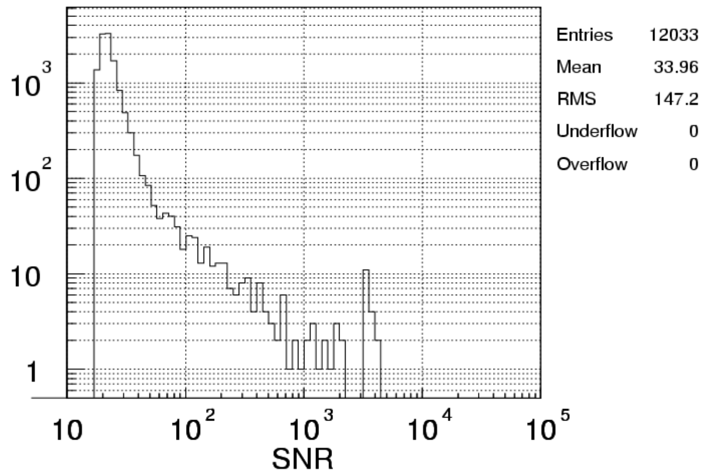
Laura's diagnostics and veto studies

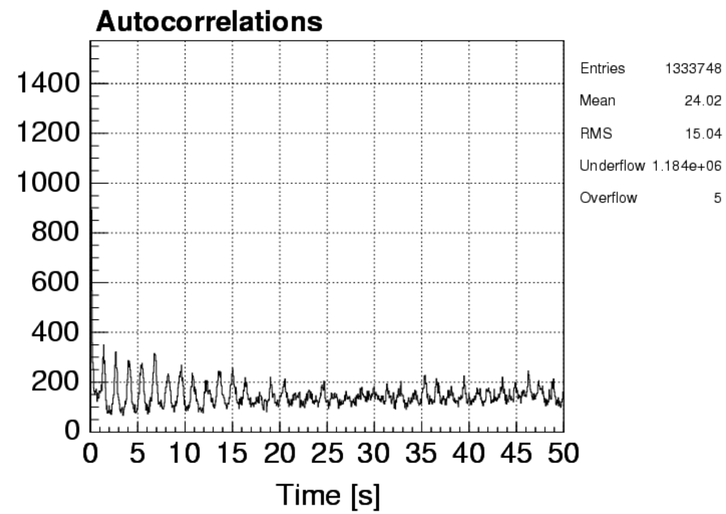
http://lancelot.mit.edu/~cadonati/S4/online/S4report.html

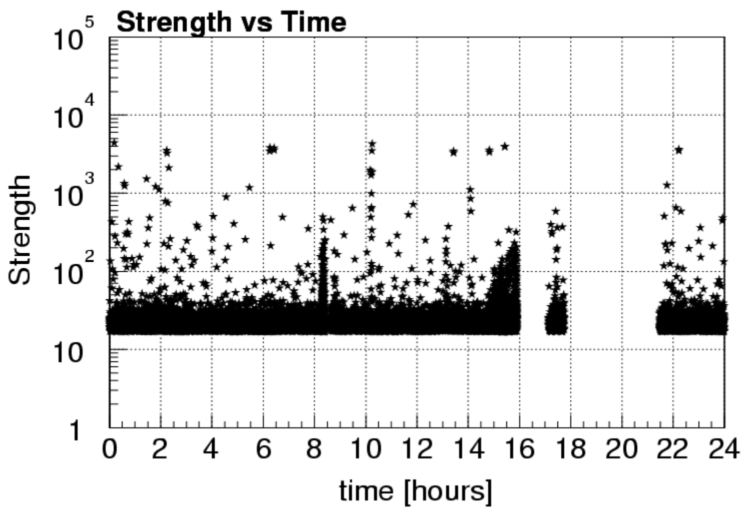
Daily study of the kleineWelle triggers features, including:

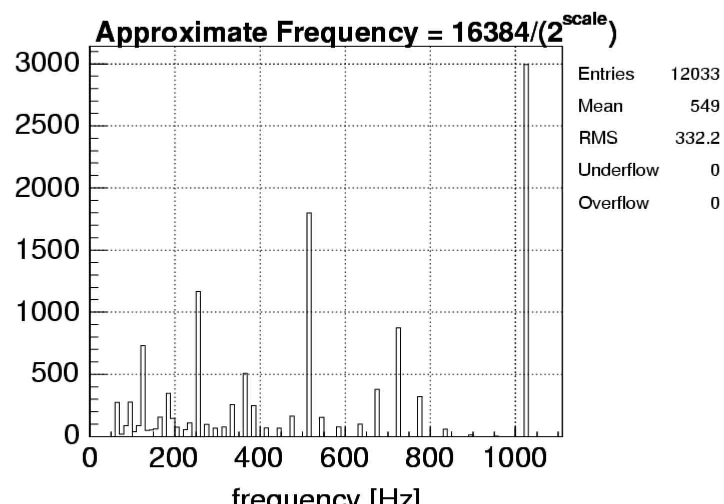
- Significance distribution (absolute and versus time) – looking for tails and anomalous shapes
- Rate (sec,min) plots - finding the "hot" periods
- Time between consecutive events
- Autocorrelations
- Frequency and duration distribution

Laura's plots : Mar19 - L1









Erik's diagnostics and veto studies

http://lancelot.mit.edu/~kats/daily.html

Exhaustive collection of day-by-day and segment-by-segment distributions and plots of AS_Q in relation to specific auxiliary channels:

Aim to:

- Look for specific anomalies of the event time distribution (within the day or segment)

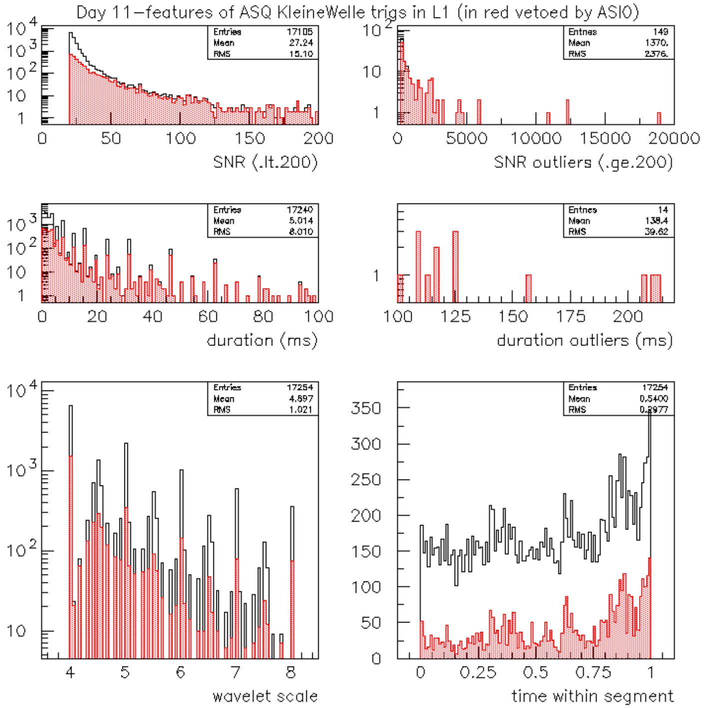
  Compute auto-correlograms and cross-correlograms

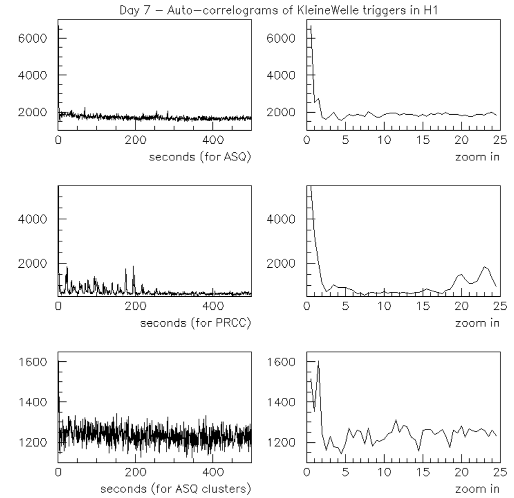
- Look for interesting vetoes and at the same time study AS_Q

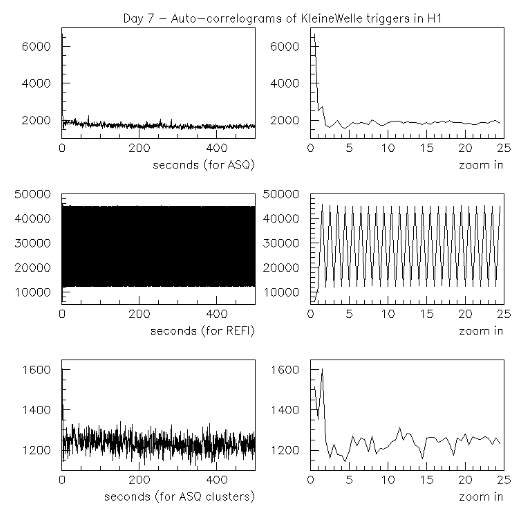
  Compute efficiency, lifetime loss (dead time) and success ratio, based on the AS_Q and on the AUX threshold value and draw lag-plots.

- Thousands of plots to be looked at and interpreted

Erik’s summary plots







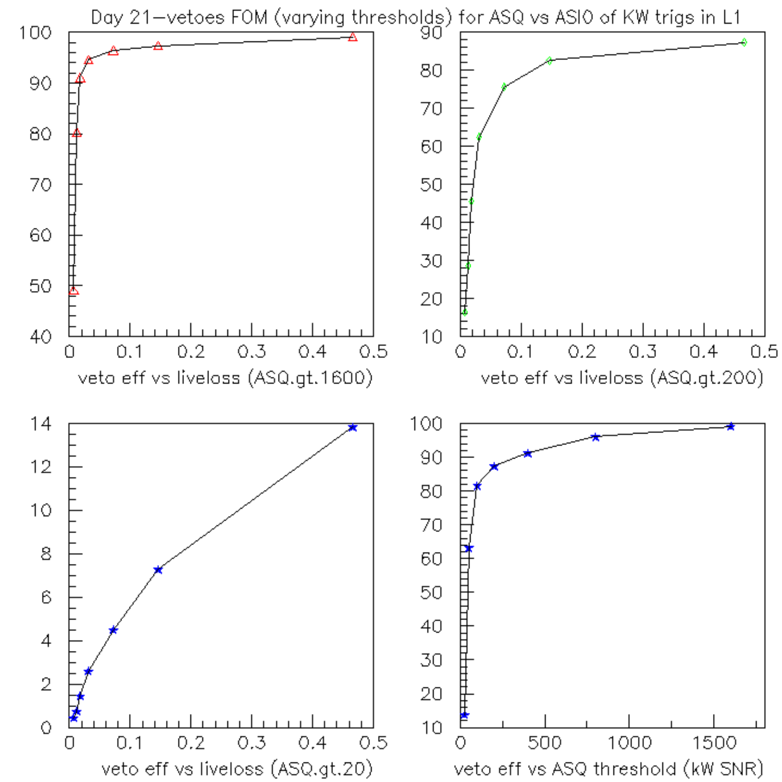
Veto studies

Several ways to approach the veto search:

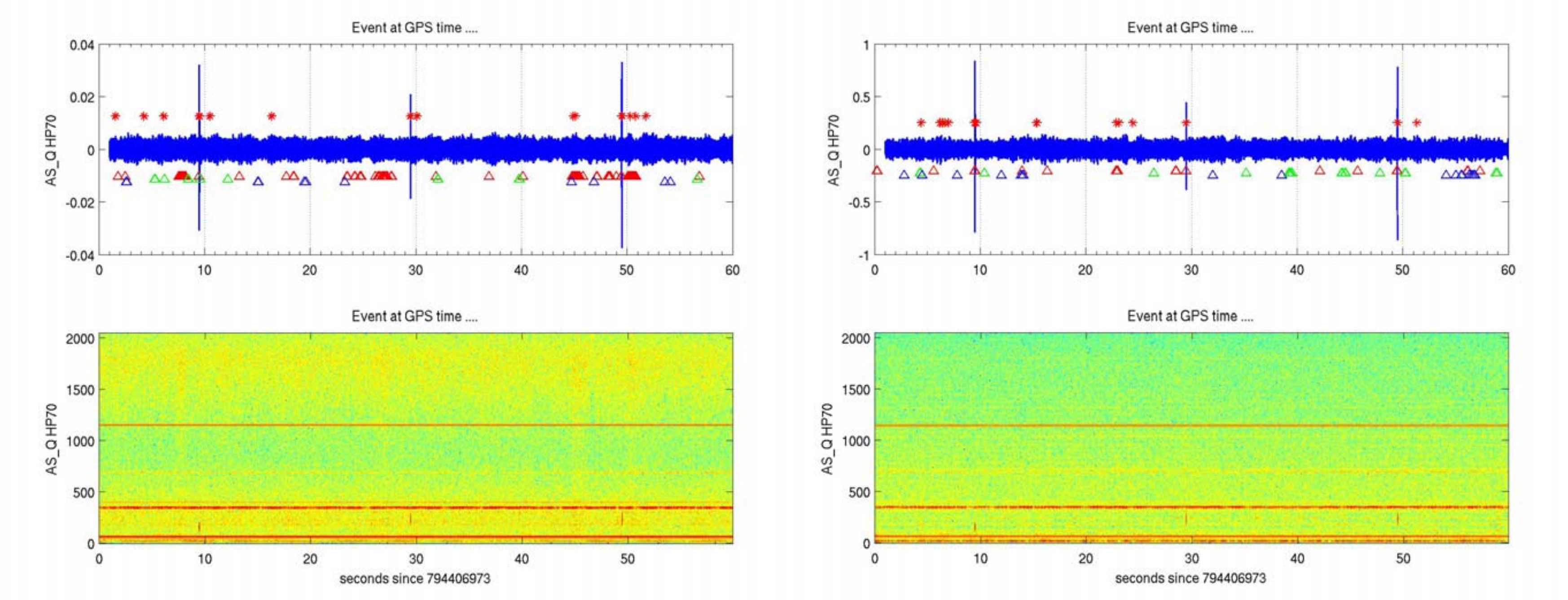
- Comparison of rate vs time and rate/significance distribution between AS_Q and several Aux channels (Lindy)
- Veto analysis limited to the largest peaks in noisy minutes (ADC)

-Systematic computation of veto efficiency, dead-time and success rate for all channels, all IFO's, all days with different threshold choices in AS_Q and auxiliary channel siginificances. (Erik)

-Several channels were found to be interesting – above all LSC-AS_I

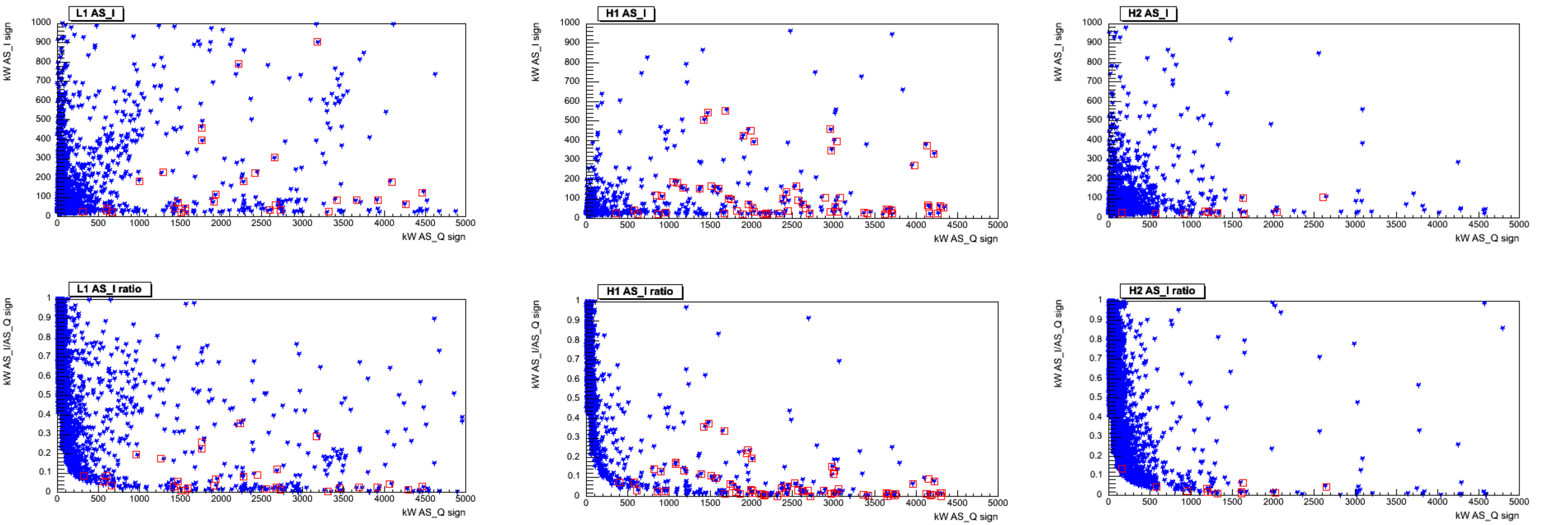


Burst Hardware Injections



Burst Hardware Injections were 'found" by the loudest minute search in L1 and H1 and were efficiently recognized by kleineWelle. It looks like AS_I finds them too …

How to use hardware injections: veto safety



Although AS_I looks like the most promising veto, there are safety considerations to be taken into account when deciding its adoption. A cut in the AS_I glitch significance and/or coupling with AS_Q will be needed in order to be considered as a safe veto.

Summary

During S4, several searches have been going on using the online kleineWelle trigger production. Different aspects of the data have been looked at and are reported in several web-pages.

A collection of pointers to these reports can be found at:

http://lancelot.mit.edu/~cadonati/S4/online/S4report.html

It has been exciting to follow the S4 run almost in real-time, but also very time consuming. Some of the analyses are already automatized, some are not (but will be) and there is definitely need to involve more people in the interpretation of the data.