LIGO

Glitch Investigation Update

Laura Cadonati
for the Glitch Investigation Group
LSC meeting, Hanford
November 12, 2003

Glitch Investigation

Partecipants

- MIT: Adhikari, Ballmer, **Cadonati**, Desai, **Katsavounidis,** Rawlins
- SYRACUSE: Bernstein, Dalrymple, Di Credico, Frei, Magri, Saulson
- CIT: Shawhan, Zweizig
- LSU/LLO: Gonzalez, Zotov
- OREGON: Ito, Schofield
- CARLETON: Christensen, Steussy
- FLORIDA: Klimenko, Franzen
- PSU: Ashley

Goals

- identification of outliers (> 4-5 sigma) from the online DataBase population.
- correlation of glitches among channels and with AS_Q
- definition of segments with unacceptable glitch rates
- identification of a usable veto for the Burst and Inspiral analysis groups

http://ligo.mit.edu/ldas/dc/index.html

LIGO

S2

Summary slide at the August LSC meeting (G030412-00):

- The pursue of glitches is ongoing – so far analyzed only interferometer channels
  - » MICH_CTRL, AS_I, POB_Q, AS_DC
  - » Testing validity of these channels as vetos for Burst and Inspiral analysis
- Performing reruns of AS_Q and AUX channel glitch search
  - » different methods
- Veto safety tested with hardware injections
- Next: PEM channels
  - » lots of work still needed …

AS_I: known to be unsafe

S2: glitchMon vs Burst Candidates

Data set

- **Single-IFO playground list**:
  - 44 hours at L1
  - 98 hours at H1
  - 76 hours at H2.

Burst candidates

- produced from TFCLUSTERS+BurstDSO
- high-threshold run, with rates (100-3000Hz) of the order of 0.1Hz

Diagnostic triggers: glitchMon

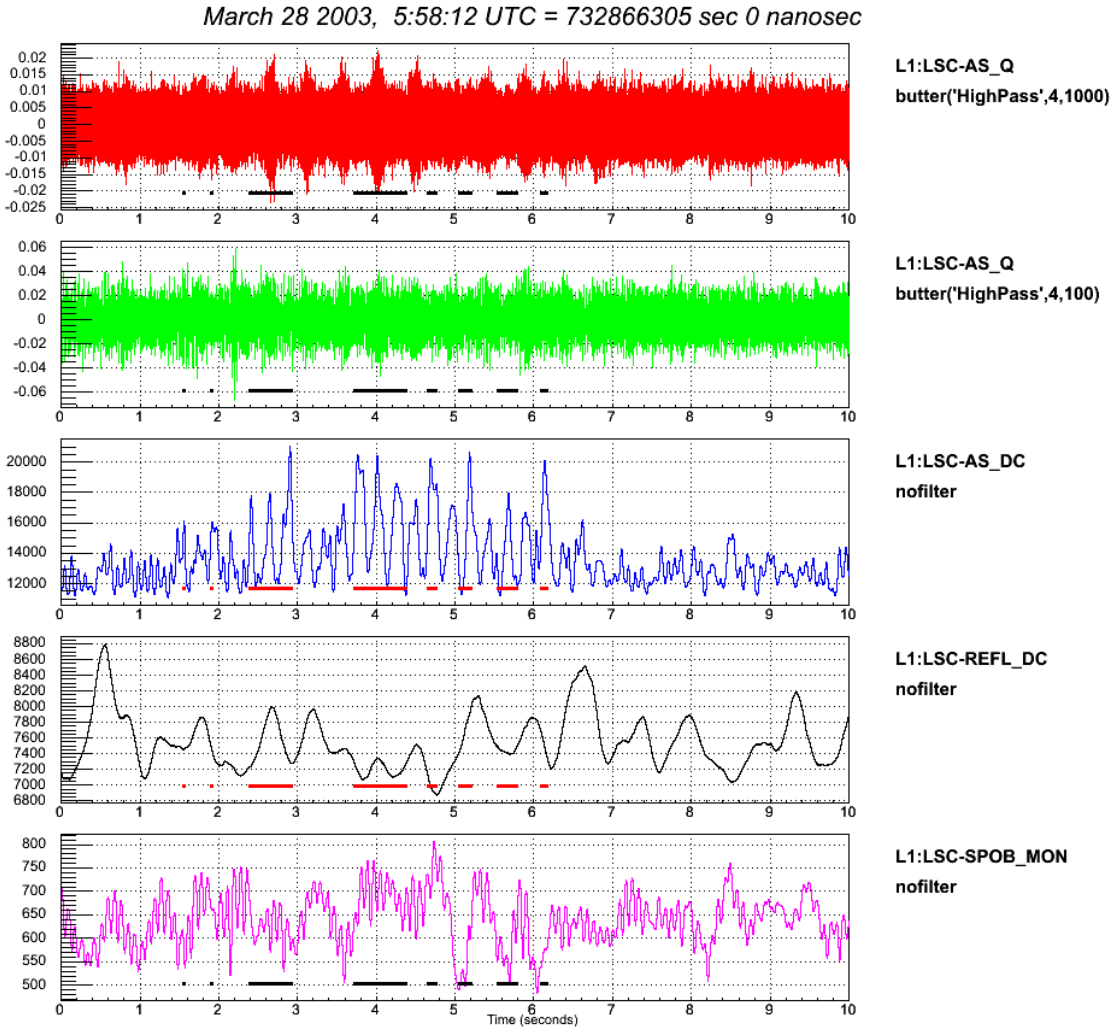
- **Threshold:** Scan between 3 σ and 6 σ
- **Minimum separation:** 0.25 seconds
- **Minimum duration:** 1 ms
- **Minimum density:** 0.1 (10% of the trigger duration must be above threshold)

Non-linear coupling
AS_DC - AS_Q

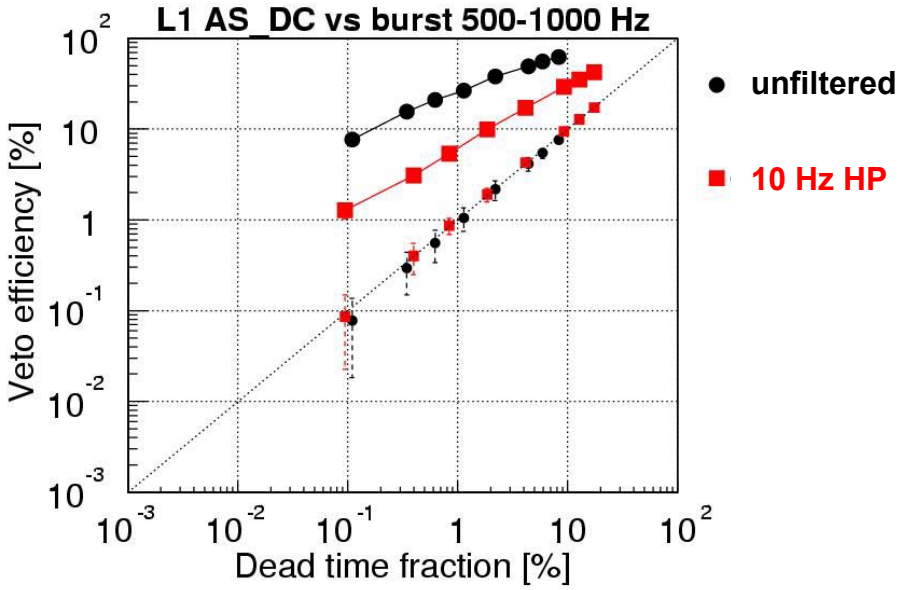
At all three IFOs, burst candidate events best correlated with glitches in unfiltered AS_DC.
Similar effects seen in SPOB_MON and WFS*

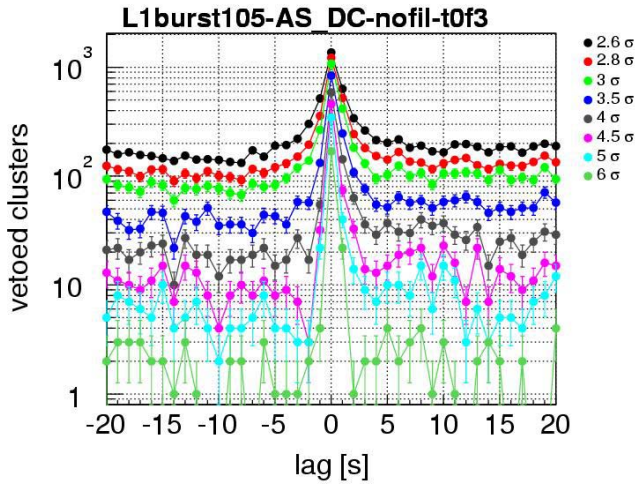
"At low frequencies, the model is that there is a broadband noise level in AS_Q which increases monotonically with the AS_DC level. e.g. the stack shakes, the mirrors twist and the light level seen in AS_DC doubles for ~1 sec.
In a whitened time frequency plot this looks like a broad band, 1 sec glitch in AS_Q. It will show up at all frequencies where no other noise source is dominant.

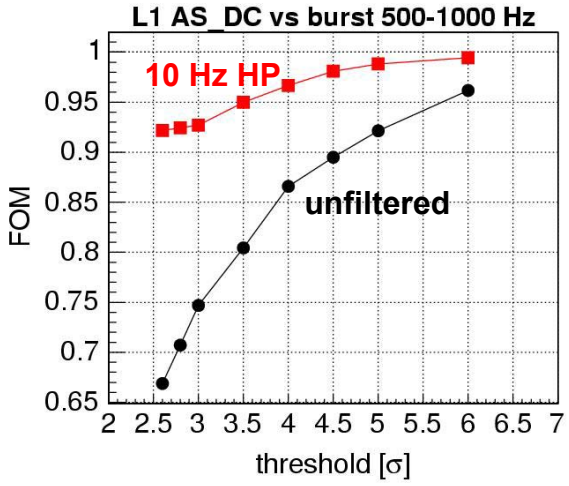
The SPOB_MON veto is also a low frequency veto. The model here is that as the effective sideband recycling gain goes down, the gain in all of the LSC servos goes down. Of these, DARM is the first to go unstable and so we see a burst centered around the lower end of the 'phase bubble' (65-70 Hz). " (Rana)



AS_DC as a burst veto?





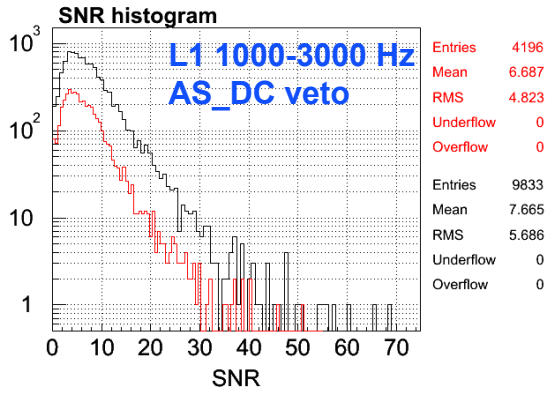


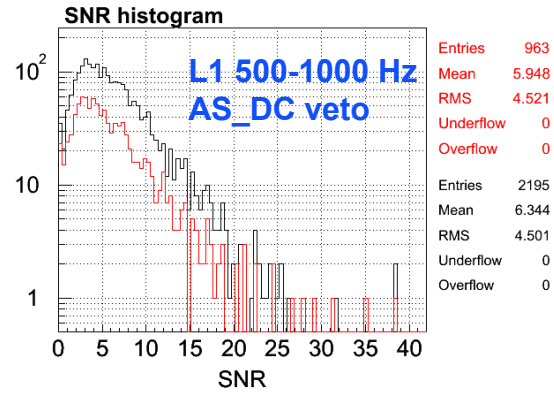
ε = veto efficiency (fraction of vetoed AS_Q)
τ = deadtime fraction

Figure of merit:
FOM = sqrt(1-ε)/(1-τ) ≈ sqrt(N_{res})/T_{live}

Need to consider: allowable deadtime
And effectivity to remove outliers, safety

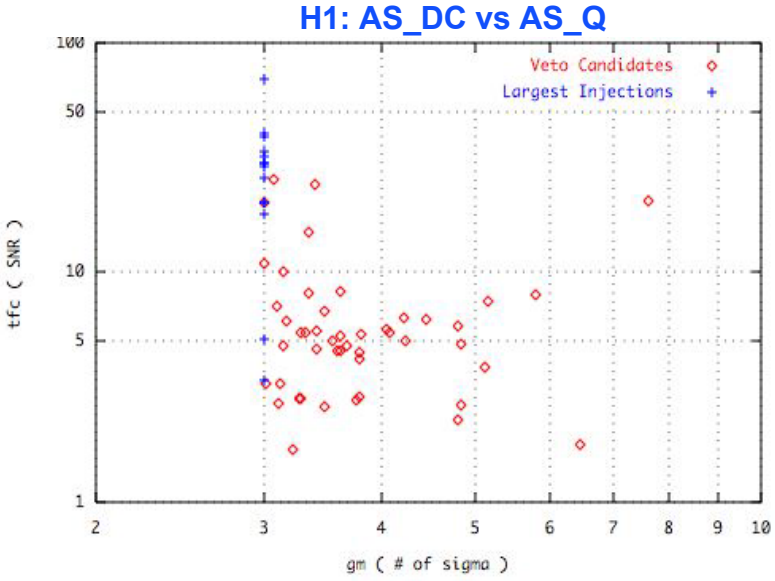
Usable vetos?





SNR histograms before and after veto

How effective at removing outliers?
How safe?
Need final set of triggers for a definite answer



M. Ito

Study of veto safety with hardware injections

LIGO

L1

Few % ε, lag peak 100–500Hz

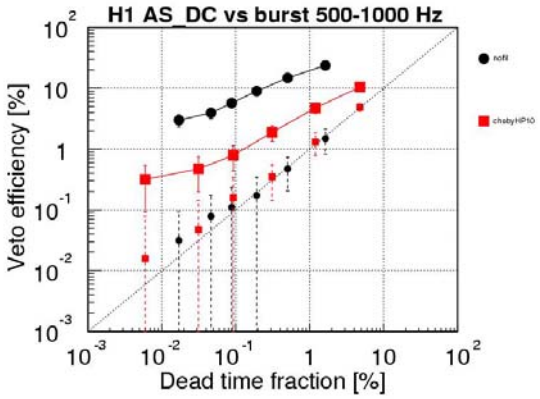
- **LSC:** AS_Q, AS_I, REFL_Q, POB_Q (unfiltered, 10, 70, 100 Hz HP)
  MICH_CTRL, PRC_CTRL, **POB_I**, REFL_I (10, 70, 100 Hz HP)
  AS_DC, REFL_DC, SPOB_MON (unfiltered, 10Hz HP)
- **ASC: WFS1_QP, WFS1_QY,** WFS2_QP, WFS2_QY, WFS2_IP, WFS2_IY (unfiltered, 10Hz HP)
- **SUS:** ETMX_OPLEV_PERROR/YERROR, ITMX_OPLEV_PERROR/YERROR,
  RM_OPLEV_PERROR/YERROR, BS_OPLEV_PERROR/YERROR (unfiltered, 10Hz HP)
- **PEM: RADIO_LVEA**, HAM4_ACCX, HAM4_MIC (comb 60)

ε=20-24% deadtime=2.6%

ε=20-30% deadtime=1.3%

glitchMon	config	deadtime	100 - 500 Hz	500 – 1000 Hz	1000-3000 Hz
LSC-AS_DC	nofilt, 3σ	4.4%	37%	49%	59%
LSC-SPOB_MON	nofilt, 3σ	1.7%	8%	15%	9%
OR		5.8%	41%	56%	62%
AND		1.7%	14%	20%	19%

H1



- **LSC:** AS_Q, AS_I, REFL_Q, POB_Q (unfiltered, 10, 70, 100 Hz HP)
  MICH_CTRL, PRC_CTRL, POB_I, REFL_I (10, 70, 100 Hz HP)
  AS_DC, REFL_DC, SPOB_MON (unfiltered, 10Hz HP)
- **ASC:** WFS1_QP, WFS1_QY, WFS2_QP, WFS2_QY, WFS2_IP, WFS2_IY
  WFS3_IP, WFS3_IY, WFS4_IP, WFS4_IY (unfiltered, 10Hz HP)
- **SUS:** ETMX_OPLEV_PERROR/YERROR, ITMX_OPLEV_PERROR/YERROR,
  RM_OPLEV_PERROR/YERROR, BS_OPLEV_PERROR/YERROR (unfiltered, 10Hz HP)
- **PEM:** RADIO_LVEA, BSC2_ACCX, BSC3_ACC1X, BSC7_MIC, HAM4_ACCY, BSC10_MAGY (comb 60, 10Hz HP)

glitchMon	config	deadtime	100 - 500 Hz	500 – 1000 Hz	1000-3000 Hz
LSC-AS_DC	nofilt, 3σ	1.6%	2%	24%	25%
LSC-SPOB_MON	nofilt, 3σ	3.2%	4%	21%	17%
OR		4.4%	5%	34%	33%
AND		1.4%	1.7%	19%	16%

LIGO

H2

REFL_DC and unfiltered REFL_Q ε~5-6% τ~1-2%

- **LSC:** AS_Q, AS_I, REFL_Q, POB_Q (unfiltered, 10, 70, 100 Hz HP)
  MICH_CTRL, PRC_CTRL, POB_I, REFL_I (10, 70, 100 Hz HP)
  AS_DC, REFL_DC, SPOB_MON (unfiltered, 10Hz HP)
- **ASC: WFS1_QP, WFS1_QY,** WFS2_QP, WFS2_QY, WFS2_IP, WFS2_IY (unfiltered, 10Hz HP)
- **SUS:** ETMX_OPLEV_PERROR/YERROR, ITMX_OPLEV_PERROR/YERROR, FMX_OPLEV_PERROR/YERROR, FMY_OPLEV_PERROR/YERROR, RM_OPLEV_PERROR/YERROR, BS_OPLEV_PERROR/YERROR (unfiltered, 10Hz HP)
- **PEM: RADIO_LVEA**, BSC4_ACCX, BSC4_ACCY, BSC4_ACCZ, HAM10_MIC, HAM8_MIC, HAM7_MIC (comb 60, 10Hz HP)

ε=30-47% deadtime=6%

ε=5-9% deadtime=1.5%

glitchMon	config	deadtime	100 - 500 Hz	500 – 1000 Hz	1000-3000 Hz
LSC-AS_DC	nofilt, 3σ	2.2%	12%	20%	19%
LSC-SPOB_MON	nofilt, 3σ	1.7%	2.7%	4.3%	4.6%
OR		4%	14.5%	23.4%	22%
AND		0.5%	1.7%	4.5%	5%

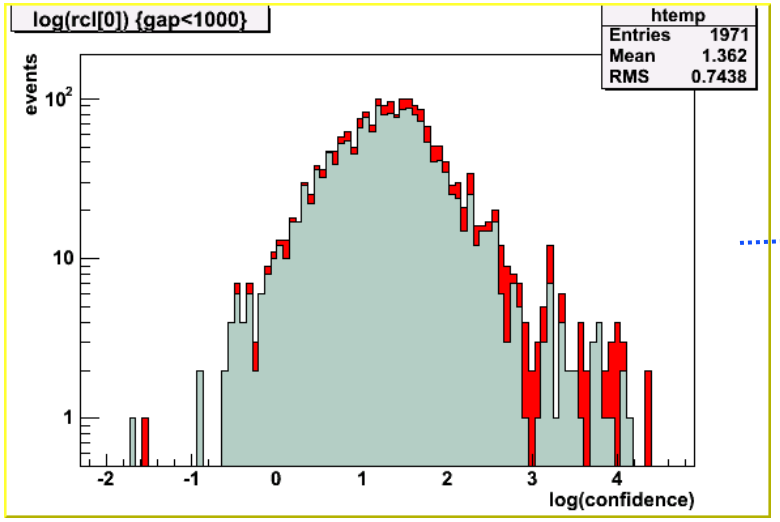
LIGO

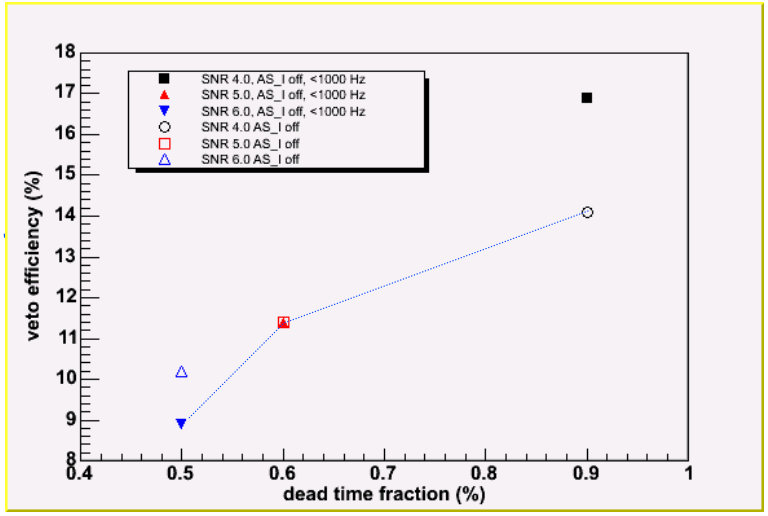
Different burst trigger sets

- Veto decision still pending - performance depends on trigger sets (frequency in particular)
- As trigger sets for the Burst analysis are becoming available, we are measuring efficiency and veto safety (TFCLUSTERS, POWER, WAVEBURST, BLOCKNORMAL)
- Inspiral group has not found AS_DC as useful (see talk by P. Shawhan)

WaveMon vs WaveBurst

Triple coincident (3 IFOs) off-time Waveburst triggers vetoed by L1 Wavemon triggers (50 % of S2, red all WB, blue vetoed WB):





WaveMon Veto threshold SNR 4.0
ε=14% τ=1%
65 channels (AS_I excluded)
WaveBurst 0 - 4kHz

Ken Yoshiki Franzen, UF

Glitches in E10 and the first week of S3

Scanned the database for AS_Q/aux correlations

So far only analyzed glitches from glitchMon

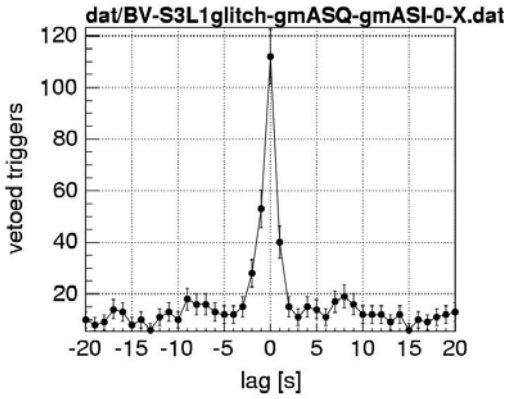
- Science segments in the first week of S3 (downloaded on friday Nov 8):
  - » L1: 17 segments >=600 sec (17 hours, 231 AS_Q events)
  - » H1: 38 segments >=600 sec (118 hours, 1377 AS_Q events)
  - » H2: 46 segments >=600 sec (106 hours, 1866 AS_Q events)
- Science segments in E10:
  - » L1: 6 segments >=600 sec (2 hours, 76 AS_Q events)
  - » H1: 61 segments >=600 sec (117 hours, 358 AS_Q events)
  - » H2: 114 segments >=600 sec (62 hours, 917 AS_Q events)

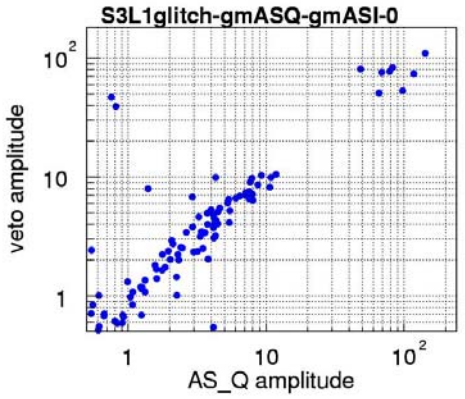
Several correlations seen (will not necessarily be true on burst candidates).

L1: AS_I

70 Hz high pass, > 4σ
(same as AS_Q)

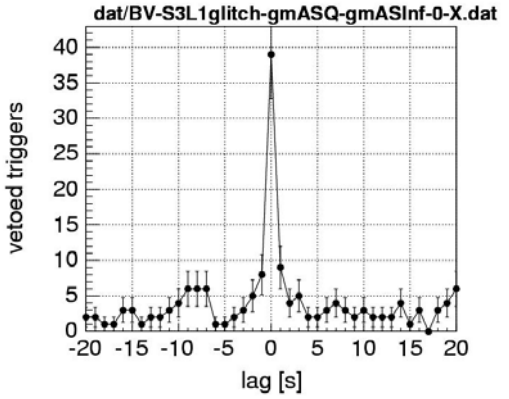
Efficiency = 48.5% (25% in E10)
Success = 25% (13% in E10)
Deadtime=0.5% (2% in E10)

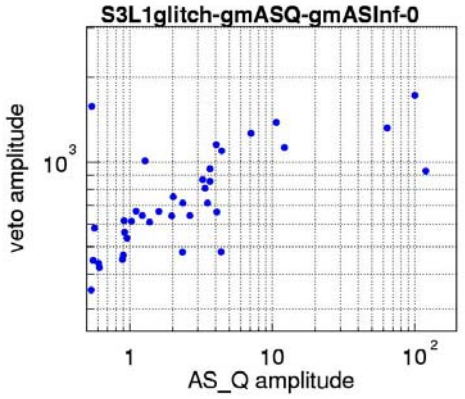




NO HP filter applied, > 4σ

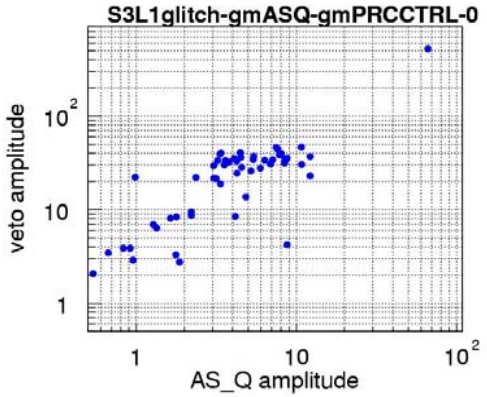
Efficiency = 17%
Success = 40%
Deadtime=0.07%
(no relevant correlation seen in E10)

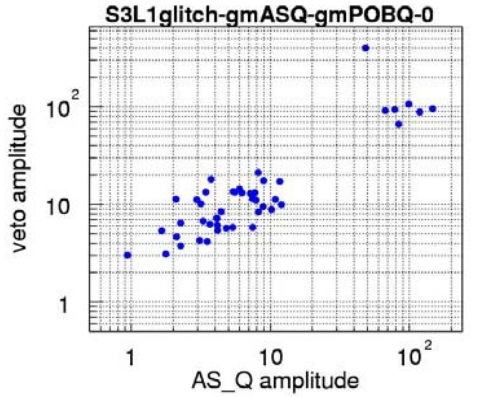




More correlations at L1 (E10,S3)

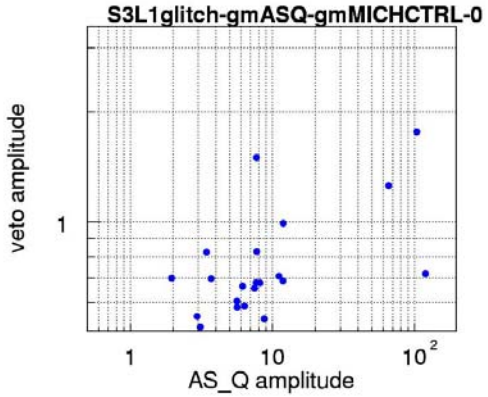
channel	HP filter	Run	Dead time	Efficiency	Success
POB_I	70Hz	E10	0.7%	88%	90%
		S3	---	---	---
MICH_CTRL	70Hz	E10	0.4%	59%	100%
		S3	0.11%	26%	79%
PRC_CTRL	70Hz	E10	0.7%	84%	95%
		S3	0.08%	22.5%	87%
POB_Q	70Hz	E10	---	---	---
		S3	0.04%	19.5%	96%





Peaks in lag plot also seen in:

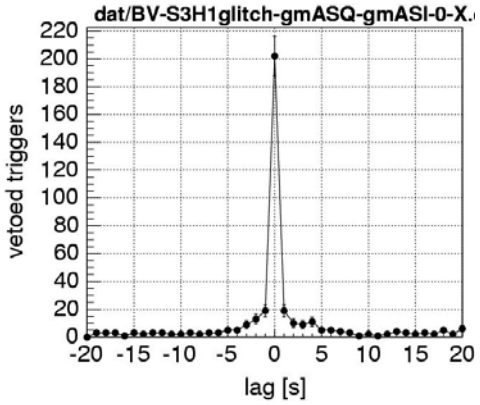
WFS1_QP, WFS1_QY 10 Hz HP
8-10% efficiency/success
<1% deadtime

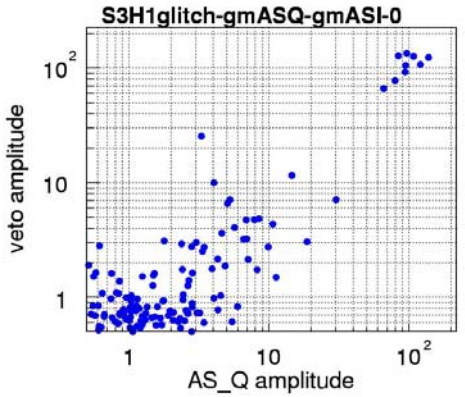


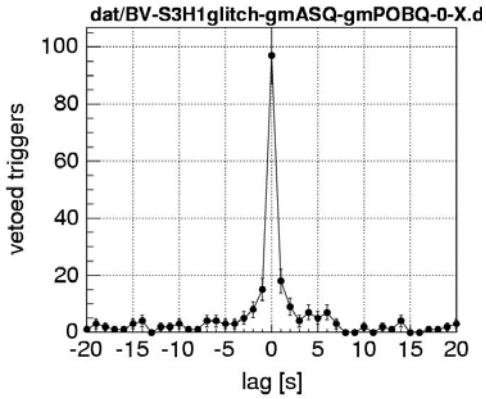
Correlations at H1 (E10,S3)

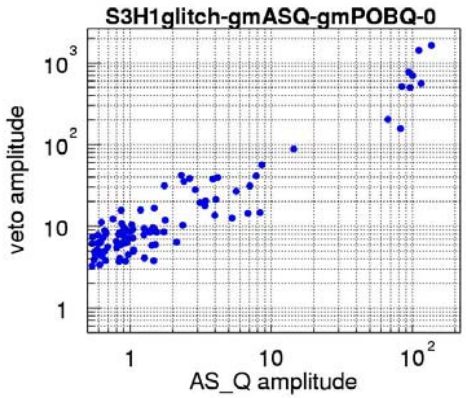
channel	HP filter	Run	Dead time	Efficiency	Success
AS_I	70Hz	E10	0.07%	23%	22%
		S3	0.02%	15%	70%
POB_I	70Hz	E10	1.5%	20%	1.7%
		S3	0.05%	11%	25%
POB_Q	70Hz	E10	0.04%	10%	33%
		S3	0.01%	7%	56%
SPOB_MON	10Hz	E10	0.03%	9%	17%
		S3	0.04%	4%	14%

Peaks in lag plot also seen in:
AS_I no filter
AS_Q no filter
REFL_Q 70 Hz HP
REFL_DC 10Hz HP
WFS1, WFS2 10 Hz HP



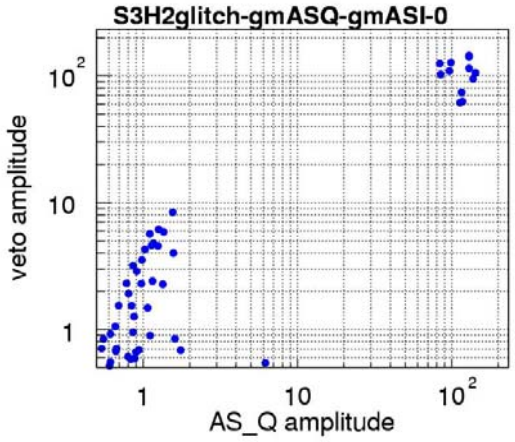


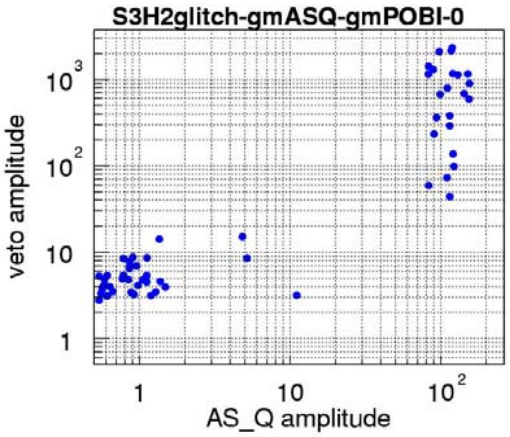


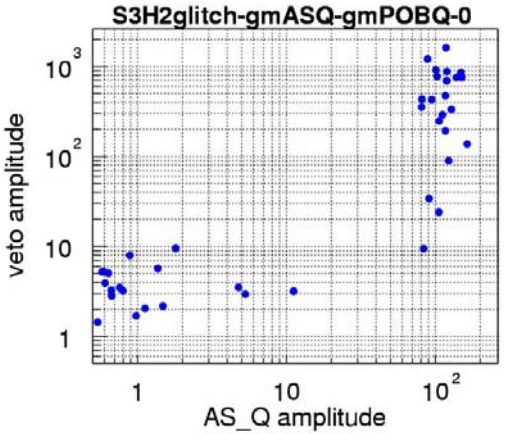


Correlations at H2 (E10,S3)

channel	config	Run	deadtime	Efficiency	Success
AS_I	70Hz HP	E10	0.09%	30.5%	43.5%
		S3	0.07%	10.5%	42%
POB_I	70Hz HP	E10	0.06%	25%	55.5%
		S3	0.01%	5%	72%
POB_Q	70Hz HP	E10	0.01%	6%	98%
		S3	0.01%	3.5%	79%
REFL_I	70Hz HP	E10	< 0.01%	4%	50%
		S3	< 0.01%	1%	70%
REFL_Q	70Hz HP	E10	0.01%	1.5%	98%
		S3	0.01%	5%	90%





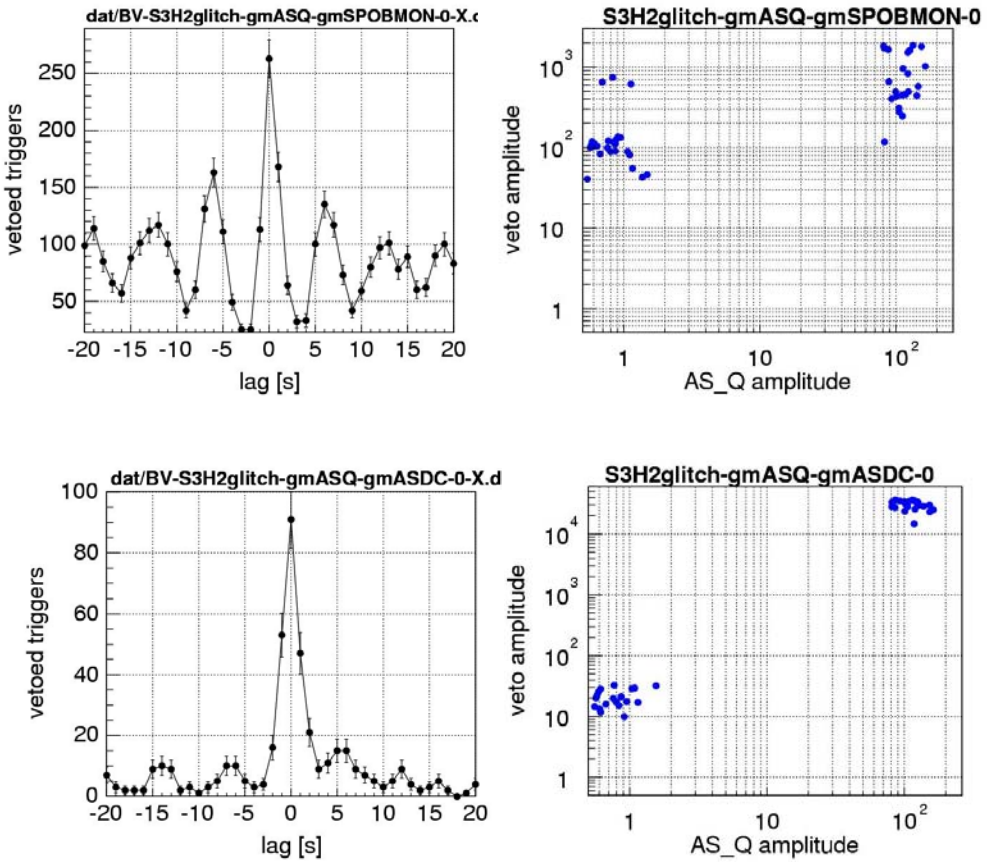


Correlations at H2 (E10,S3)

channel	HP filter	Run	Dead time	Efficiency	Success
AS_Q	nofilt	E10	0.05%	11%	42%
		S3	0.02%	7.5%	53%
AS_DC	10Hz	E10	0.04%	6%	52%
		S3	0.2%	5%	15%
SPOB_MON	10Hz	E10	0.4%	23%	7%
		S3	1.7%	14%	2%
AS_AC	10Hz	E10	<0.01%	5%	96%
		S3	<0.01%	1.2%	81%

Unfiltered AS_I similar to SPOB_MON

Similar to AS_AC (high success, few% efficiency):
REFL_DC,
ASC-QPDX_DC, ASC-QPDY_DC
PSL-FSS_FAST



LIGO

Summary

- S2 glitch investigation:
  - » Broad rerun over channels/filters ~ complete
  - » Non-linear correlations AS_DC (SPOB_MON, REFL_DC) and broadband bursts
  - » to-do: PEM vs H1-H2 coincidences at LHO
- E10/S3 glitch investigation:
  - » Scanned glitchMon triggers in the database (1st week of S3 only): some interesting correlations visible in lag plots and scatter plots.