



E10/S3 burst injections

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for the Burst Group, esp Julien Sylvestre

Many thanks to Szabi Marka and Peter Shawhan

- Goals of Burst injections
- Waveforms
- E10 Injections – by eye
- Preliminary results on ETG detections
- S3 injections
- Conclusions

Results from S2 Hardware Injections:
L. Cadonati, August 2003 LSC meeting, [G030428-00-Z](#)



Goals for Burst injections

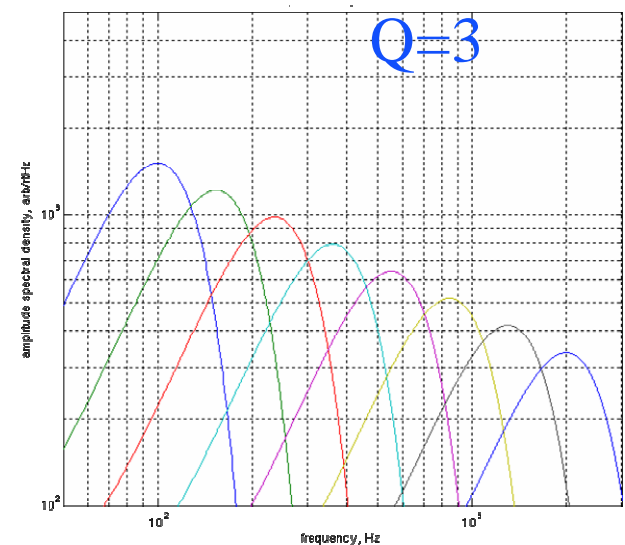
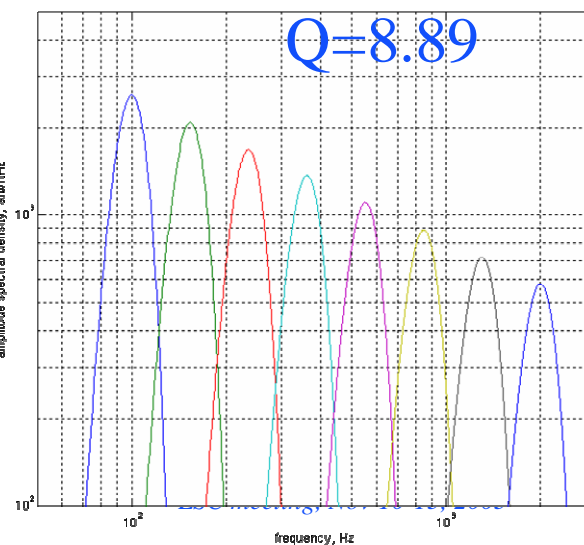
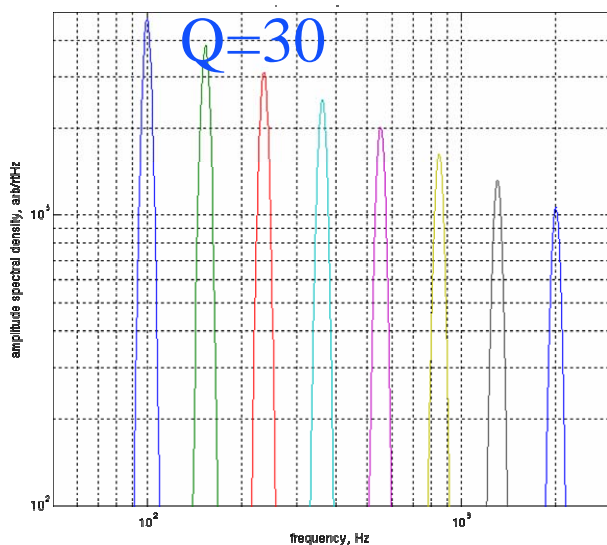
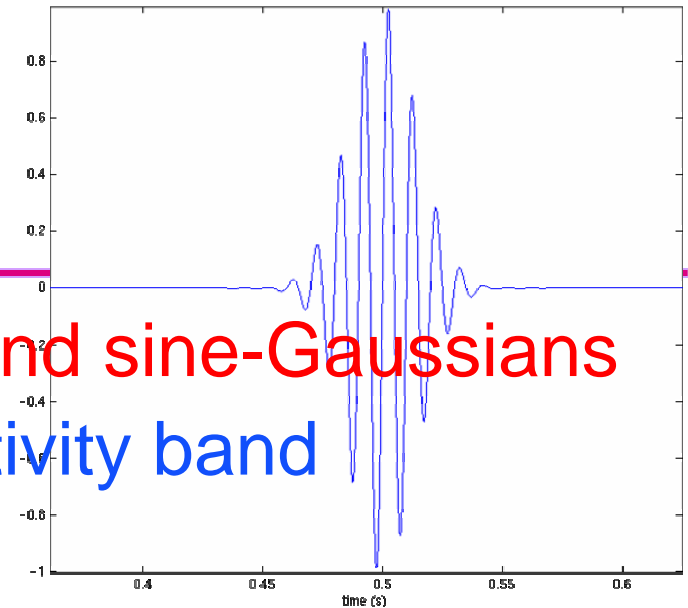
- Do the Burst EventTriggerGenerators detect the injections?
Where is the detection threshold?
Does detection efficiency fall for high amplitude injections?
(Does IFO lose lock?)
- Exercise all ETGs under development
- Quantitative comparisons of ETG-reconstructed with injected values of h_{rss} , f_0 , t_{start}
- Quantitative comparisons of ETG response to hardware and software injections with identical parameters
 - » We do SW injections with high statistics, to evaluate efficiency; real comparisons between SW and HW validates the SW efficiency evaluations
- Quantitative test of calibration information
- Monitor stability of IFO & ETG response over time



waveforms

Begin with now-standard **narrow-band sine-Gaussians**

- “swept sine” over the LIGO sensitivity band
- just as was done for S1 and S2
- Standard waveform for evaluating detection efficiency of burst ETGs, for which large statistics software simulations exist





Only sine-Gaussians?

Can we inject and detect your favorite waveform
(ZM, ringdown, BH merger, etc) ?

- Rather than spend precious injection time on many different waveforms, choose to focus on fewer waveforms to (hopefully) gain sufficient statistics per waveform/amplitude to enable quantitative tests.
- *The more injections, the better!!*
- If people feel that it is important or helpful to run their waveforms, speak up!



E10 injections

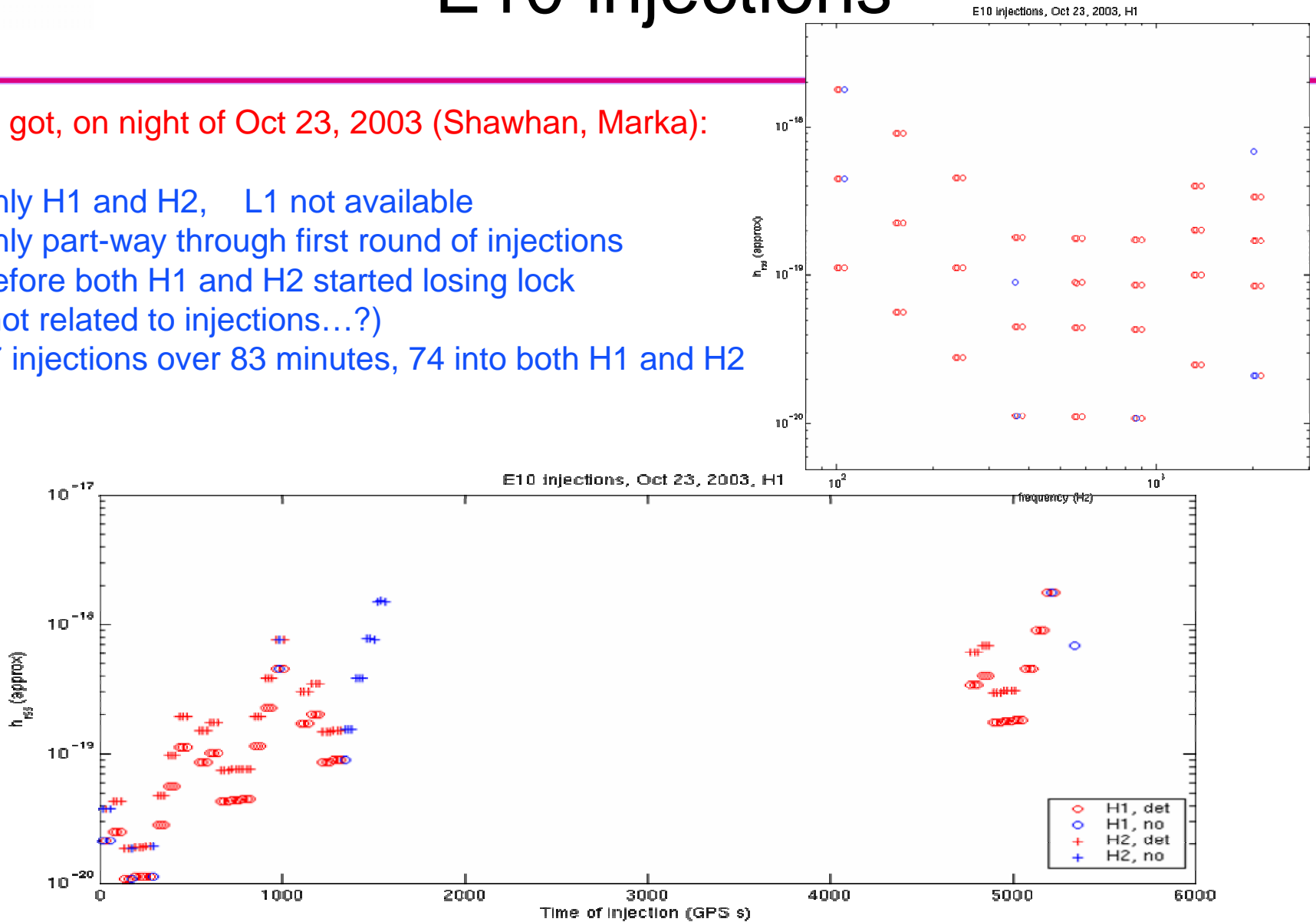
- Requested series of sine-Gaussians for E10:
 - » 8 central frequencies from 100 Hz → 2000 Hz
 - » Three different values of Q: 3, 8.89, 30 (for S3: only Q=8.89)
 - » 6 different amplitudes, ranging from 5x noise to 5000x noise (for S3: 5x noise to 500x noise)
 - » Noise at the 8 central frequencies are eyeballed from S2 curves (for S3: S3 curves!)
 - » Compensate for actuation function at SG central frequencies, using detailed model (DC calib, pendulum, control filters) for H1 and L1; no detailed model available for H2, use simple model (DCcal, pendulum).
 - » Space injections by 20 seconds (for S3: 10 seconds)
 - » Simultaneous in H1, L1, H2, with same values of h_{rss} for each IFO (during S2, injected with roughly same SNR for each IFO).
- Requested that the full list of injections be repeated *as many times as possible*.



E10 injections

What we got, on night of Oct 23, 2003 (Shawhan, Marka):

- Only H1 and H2, L1 not available
- Only part-way through first round of injections before both H1 and H2 started losing lock (not related to injections...?)
- 97 injections over 83 minutes, 74 into both H1 and H2





LIGO

Seeing sine-Gaussian injections in data spectrograms (1/16 s x 16 Hz)

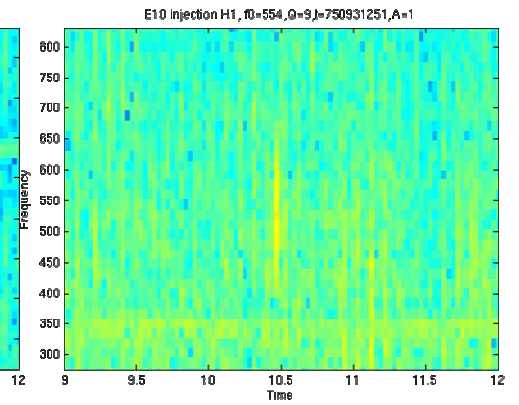
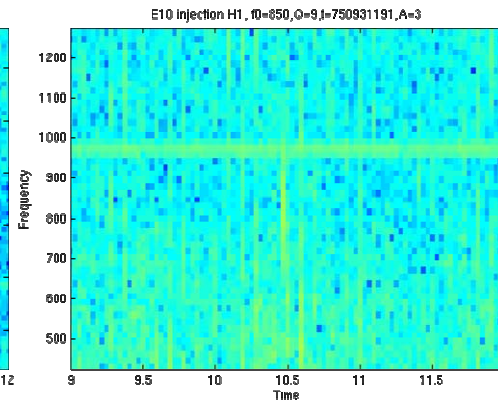
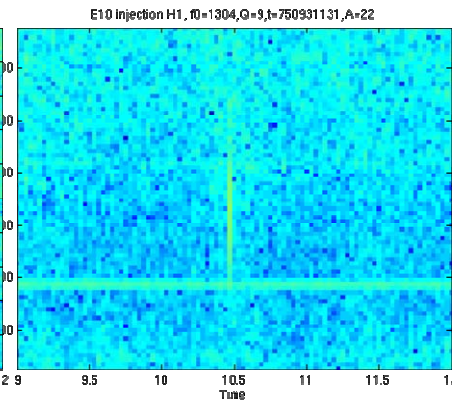
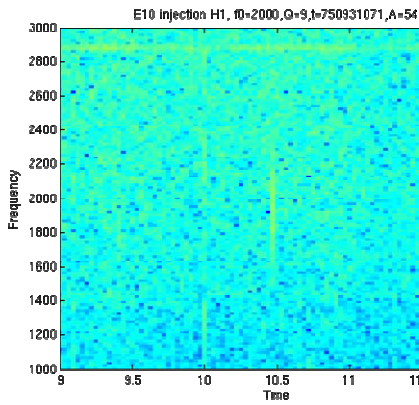
H1 Injections with ~middle amplitude range, sine-Gaussians, $Q=8.9$

2000

1304

850

554

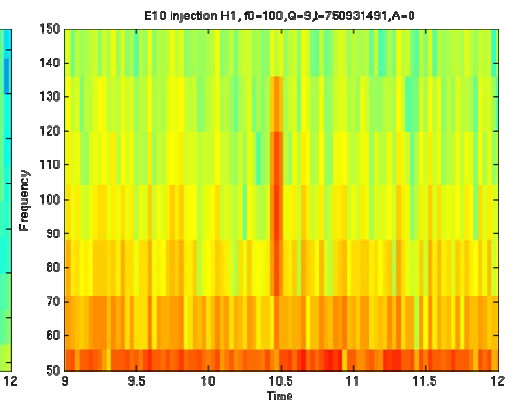
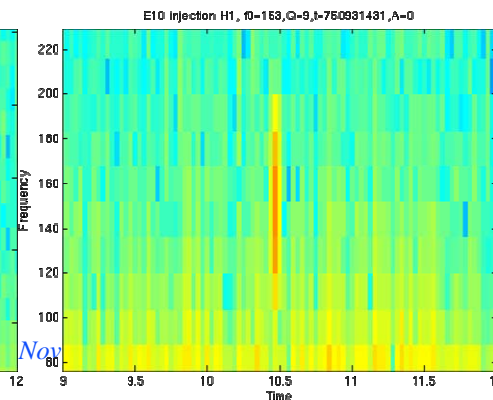
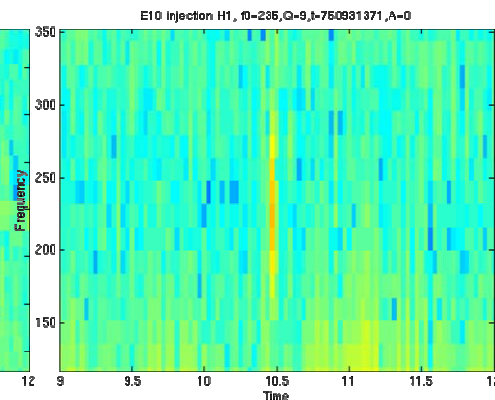
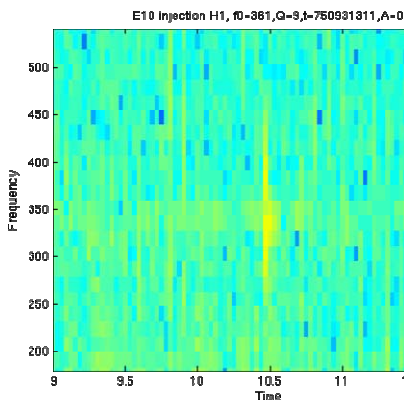


361

235

153

100

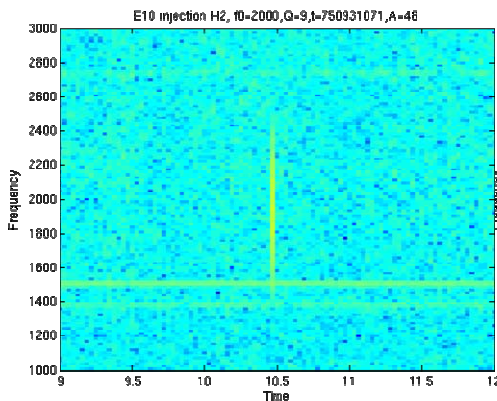




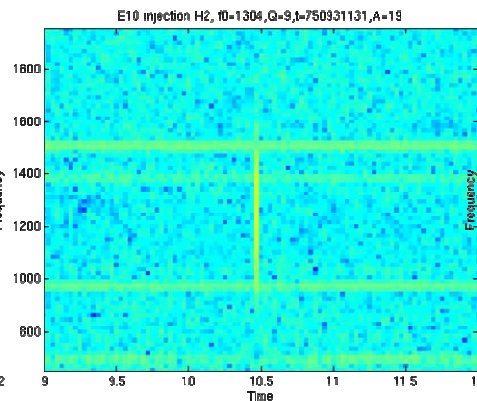
Seeing sine-Gaussian injections in data spectrograms

H2 Injections with \sim middle amplitude range, sine-Gaussians, $Q=8.9$

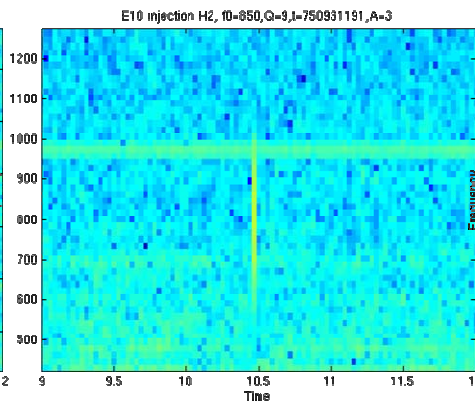
2000



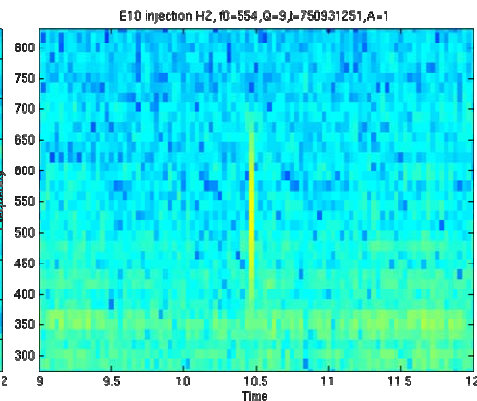
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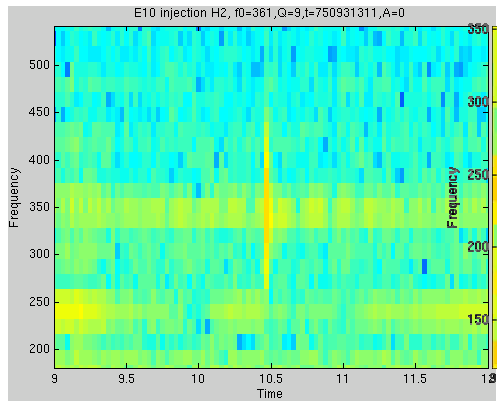
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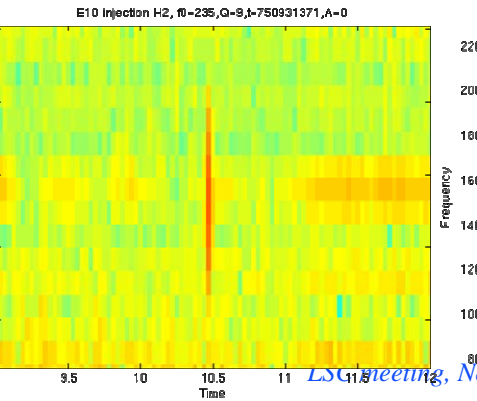
554



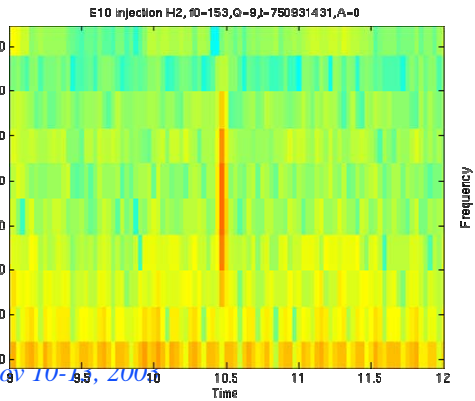
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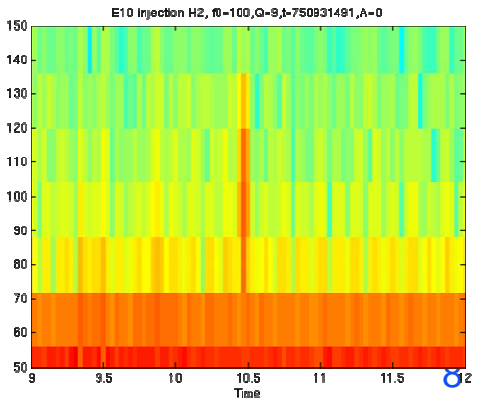
235



153



100





Injections with different Q

On steeply sloping noise curves, low-Q waveforms are more evident at frequencies significantly away from f_0 (554 Hz, here)

Q=30

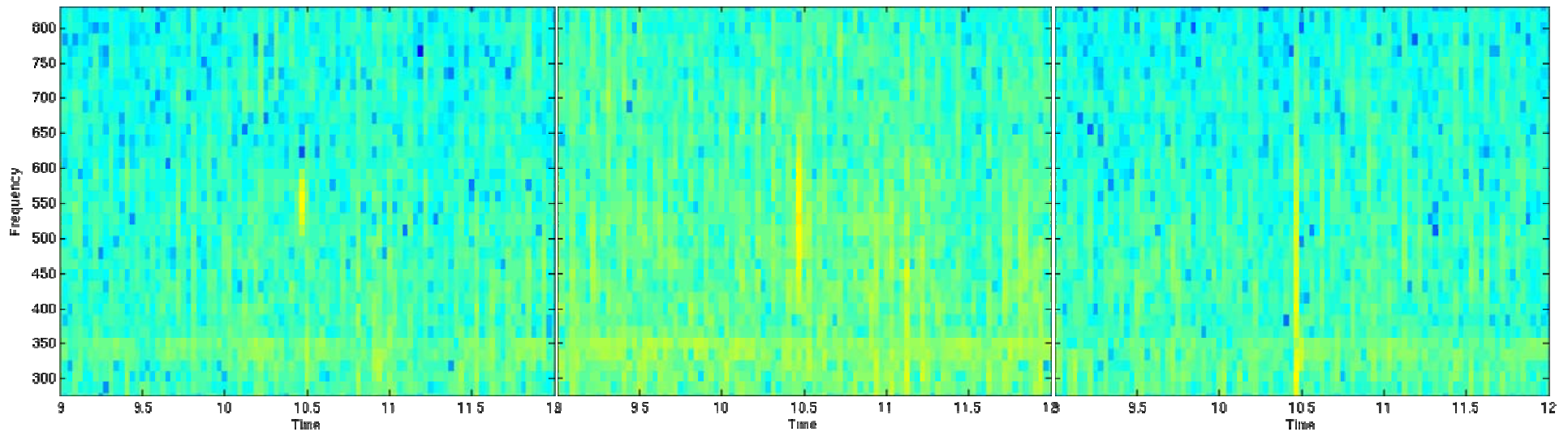
E10 injection H1, $f_0=554, Q=30, I=750931231, A=1$

Q=8.89

E10 injection H1, $f_0=554, Q=9, I=750931251, A=1$

Q=3

E10 injection H1, $f_0=554, Q=3, I=750931211, A=2$





E10 injections, h_{rss} vs f_0

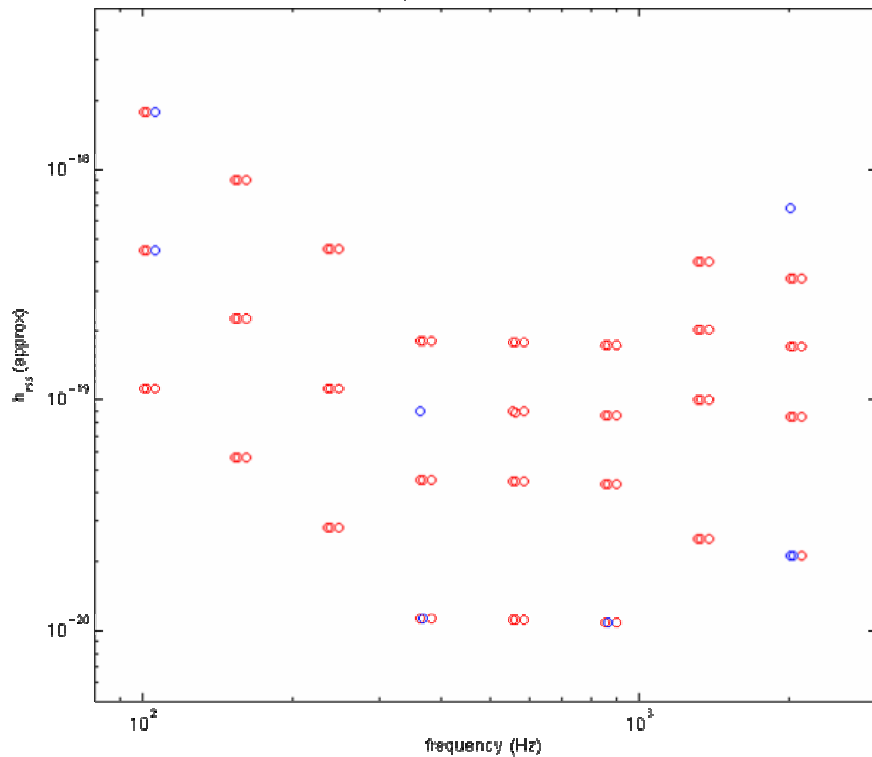
Red: TFCLUSTERS detected

Blue: TFCLUSTERS not detected

(almost entirely because the triggers are shortly followed by lock loss)

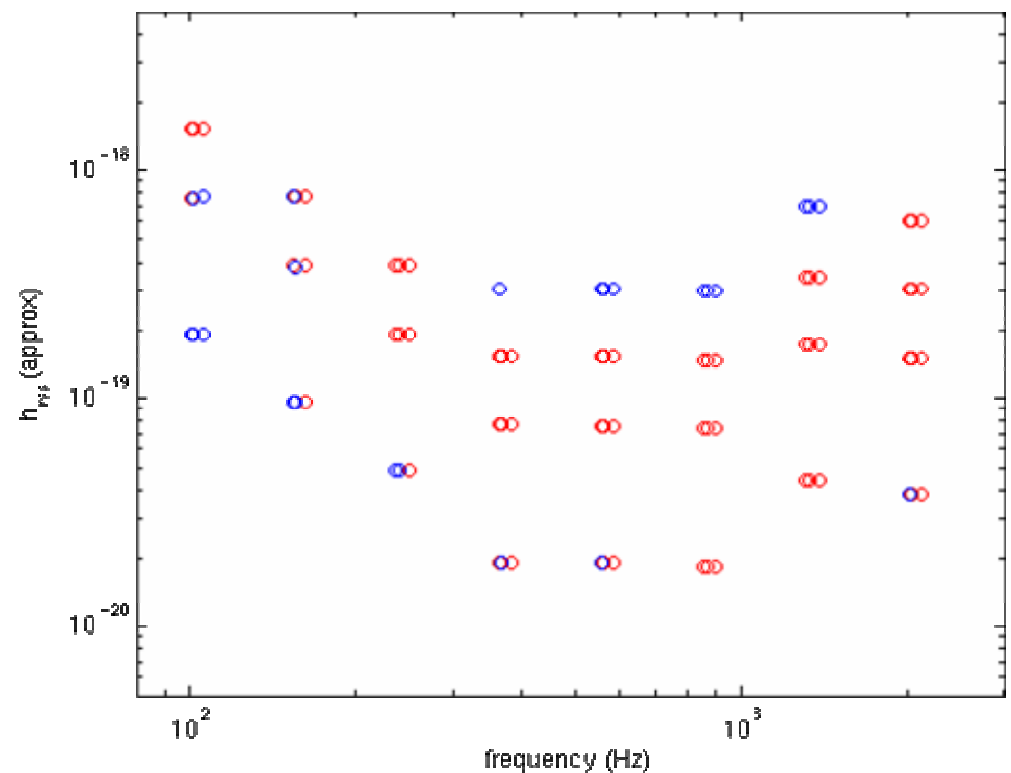
H1, h_{rss} vs f_0

E10 injections, Oct 23, 2003, H1



H2, h_{rss} vs f_0

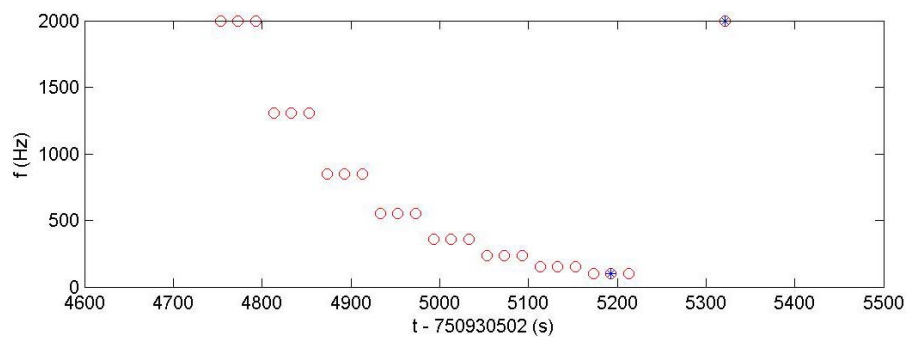
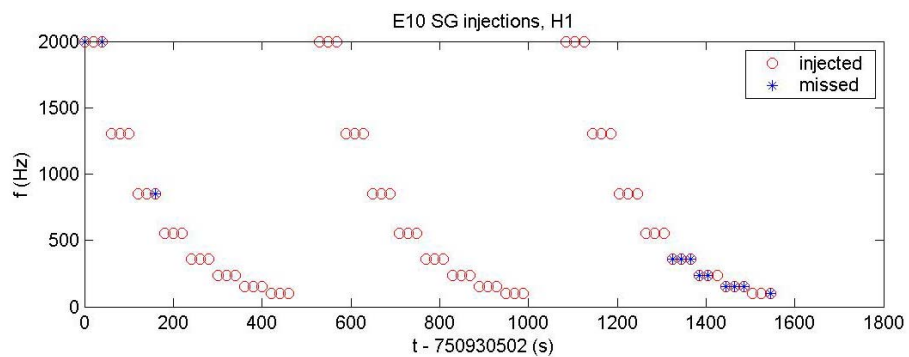
E10 injections, Oct 23, 2003, H2





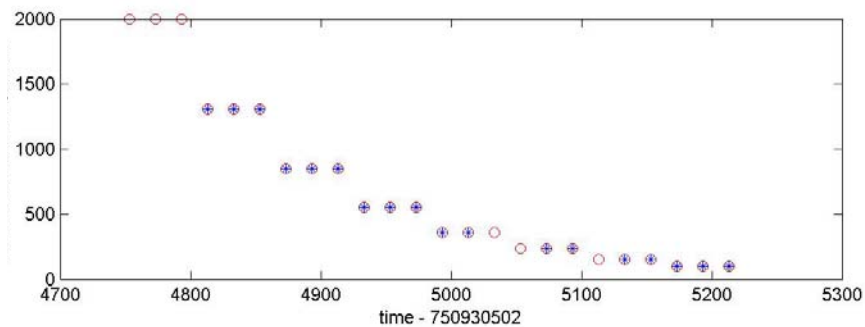
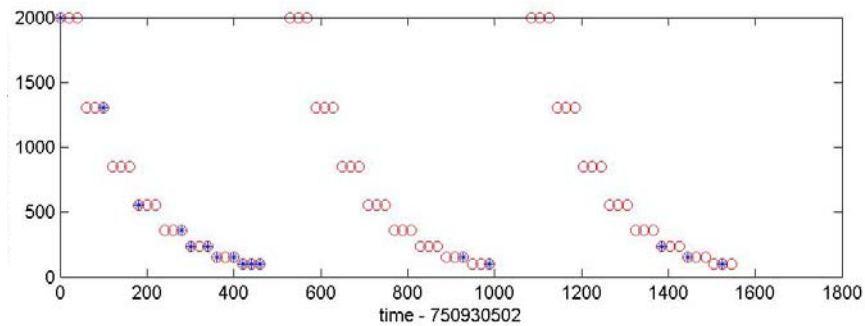
E10 injections, f_0 vs t_{inj}

H1



Julien Sylvestre, CIT

H2

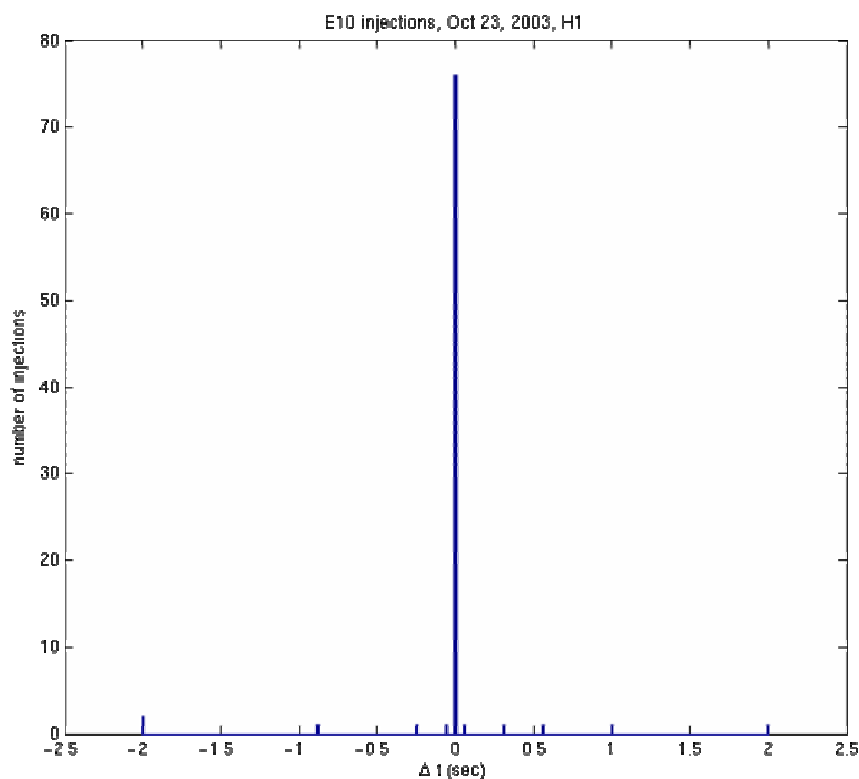




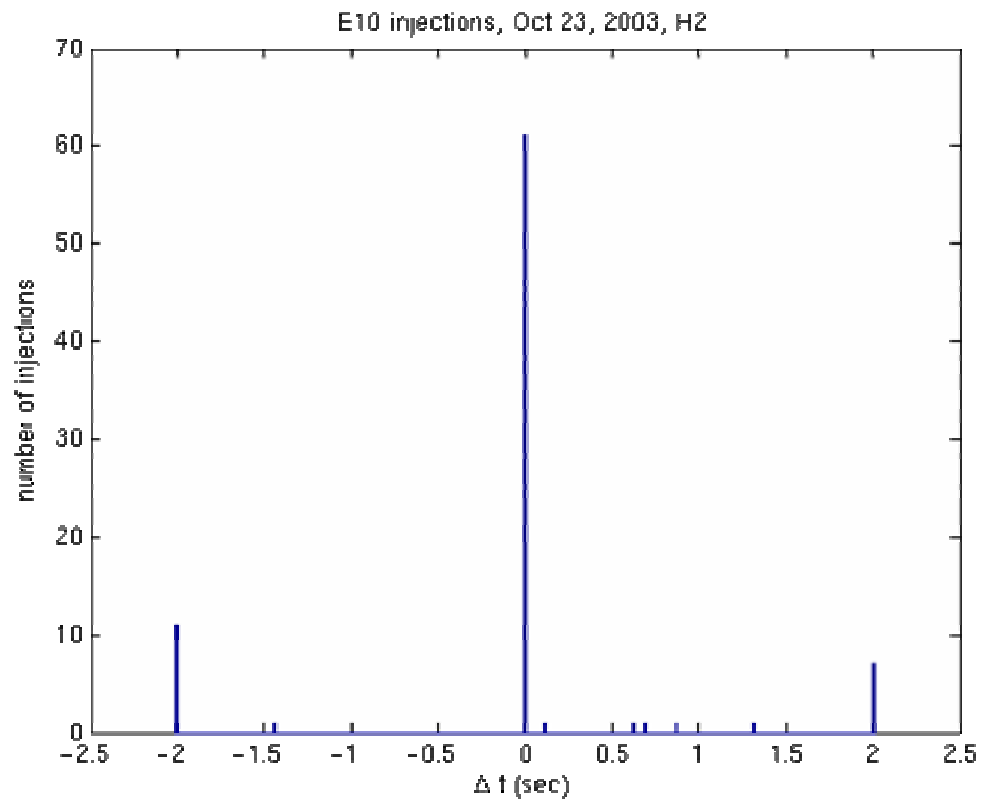
E10 injections, $\Delta t = t_{inj} - t_{trig}$

TFCLUSTER time reconstruction (1/16 second bins; no parameter est)

H1, Δt



H2, Δt

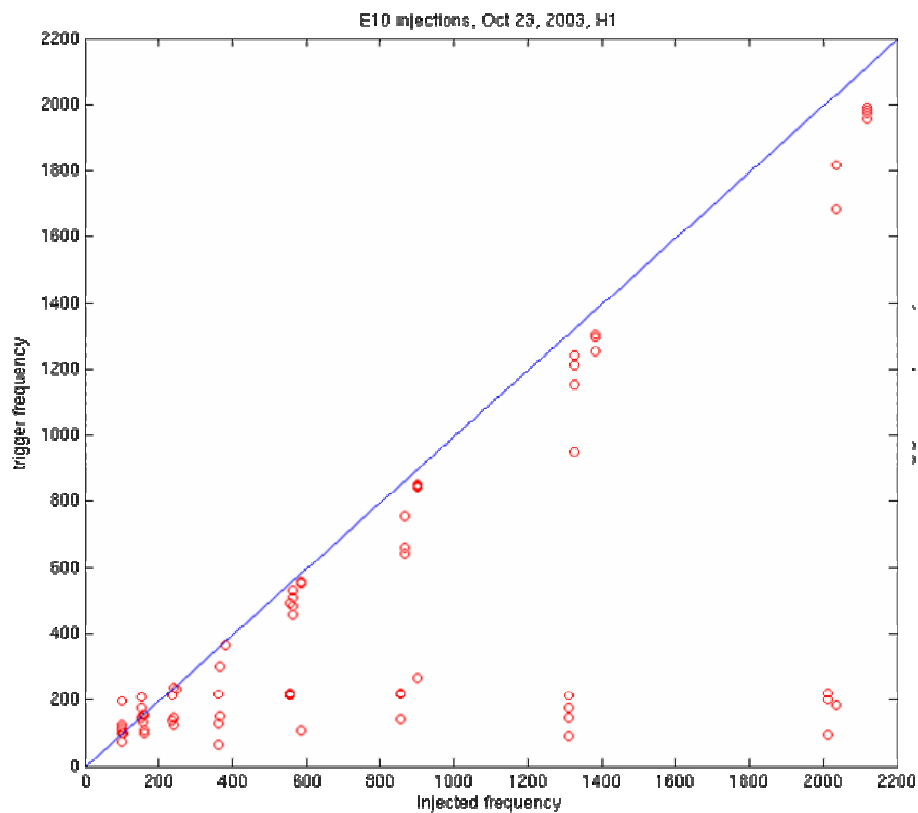




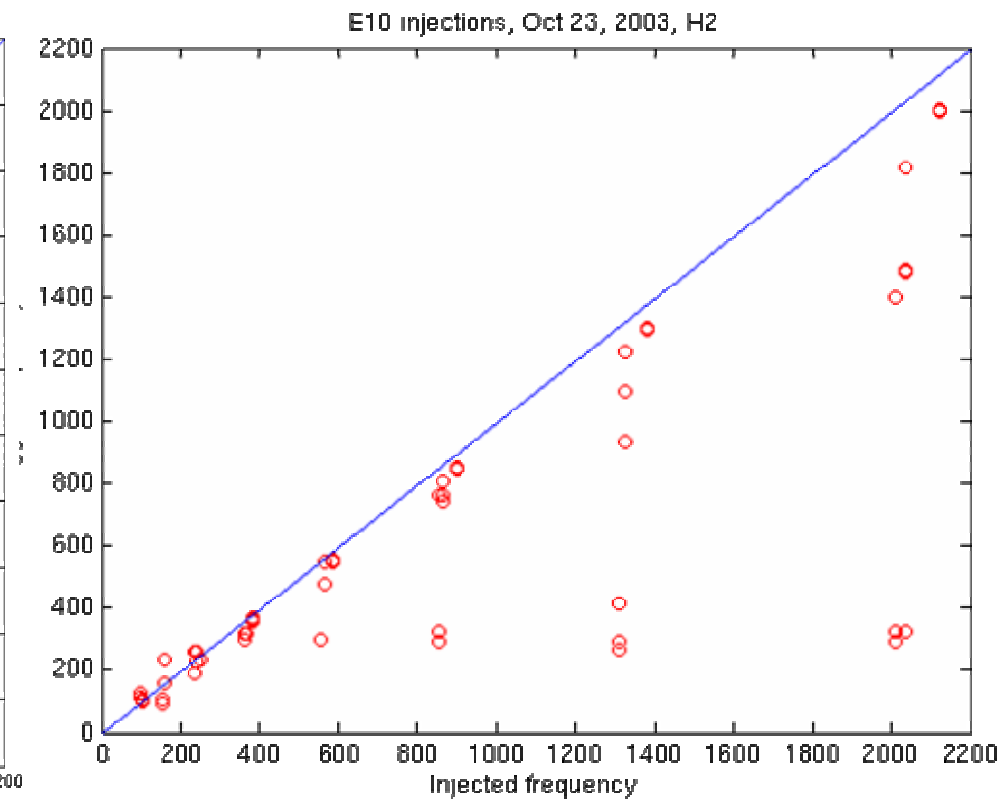
E10 injections, f_{inj} vs f_{trig}

TFCLUSTER freq reconstruction (16 Hz bins; no parameter est)

H1, f_{inj} vs f_{trig}



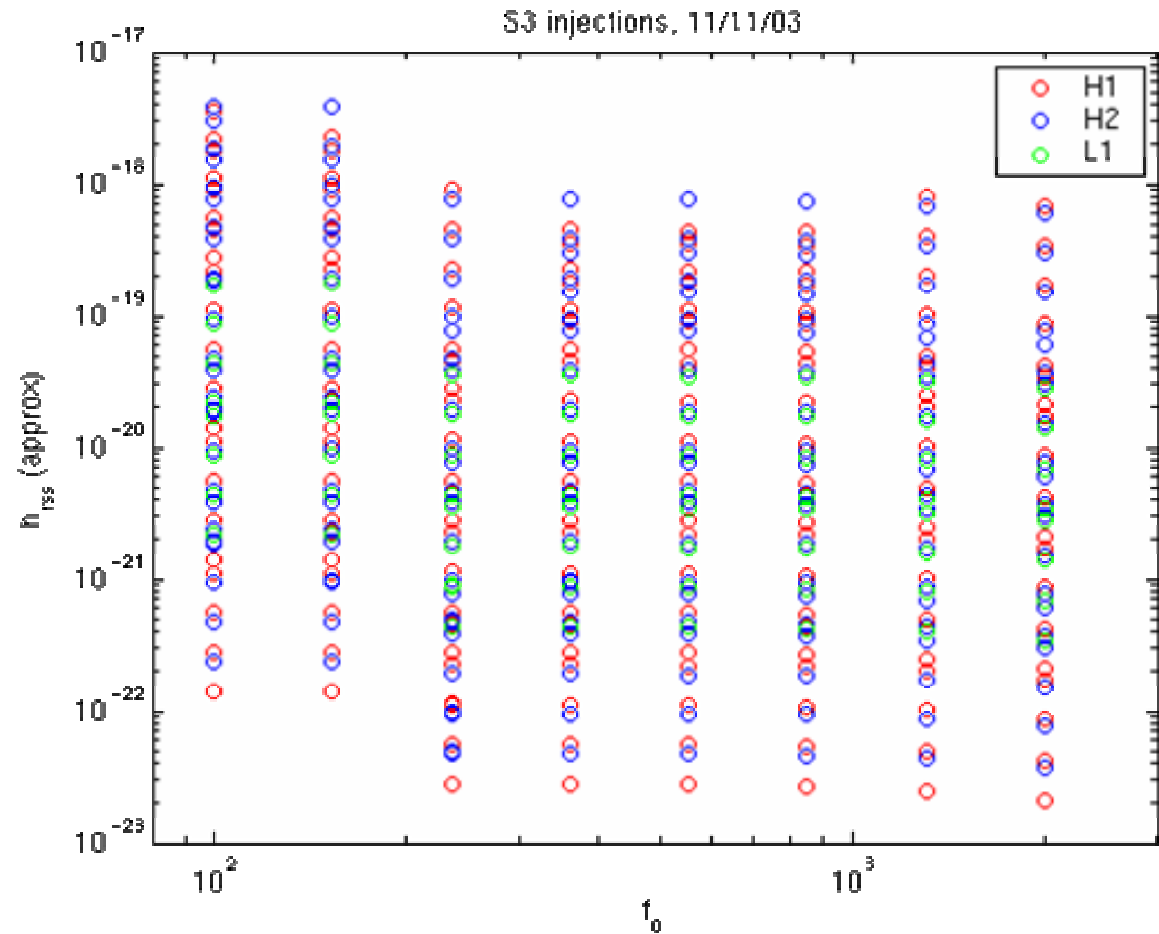
H2, f_{inj} vs f_{trig}





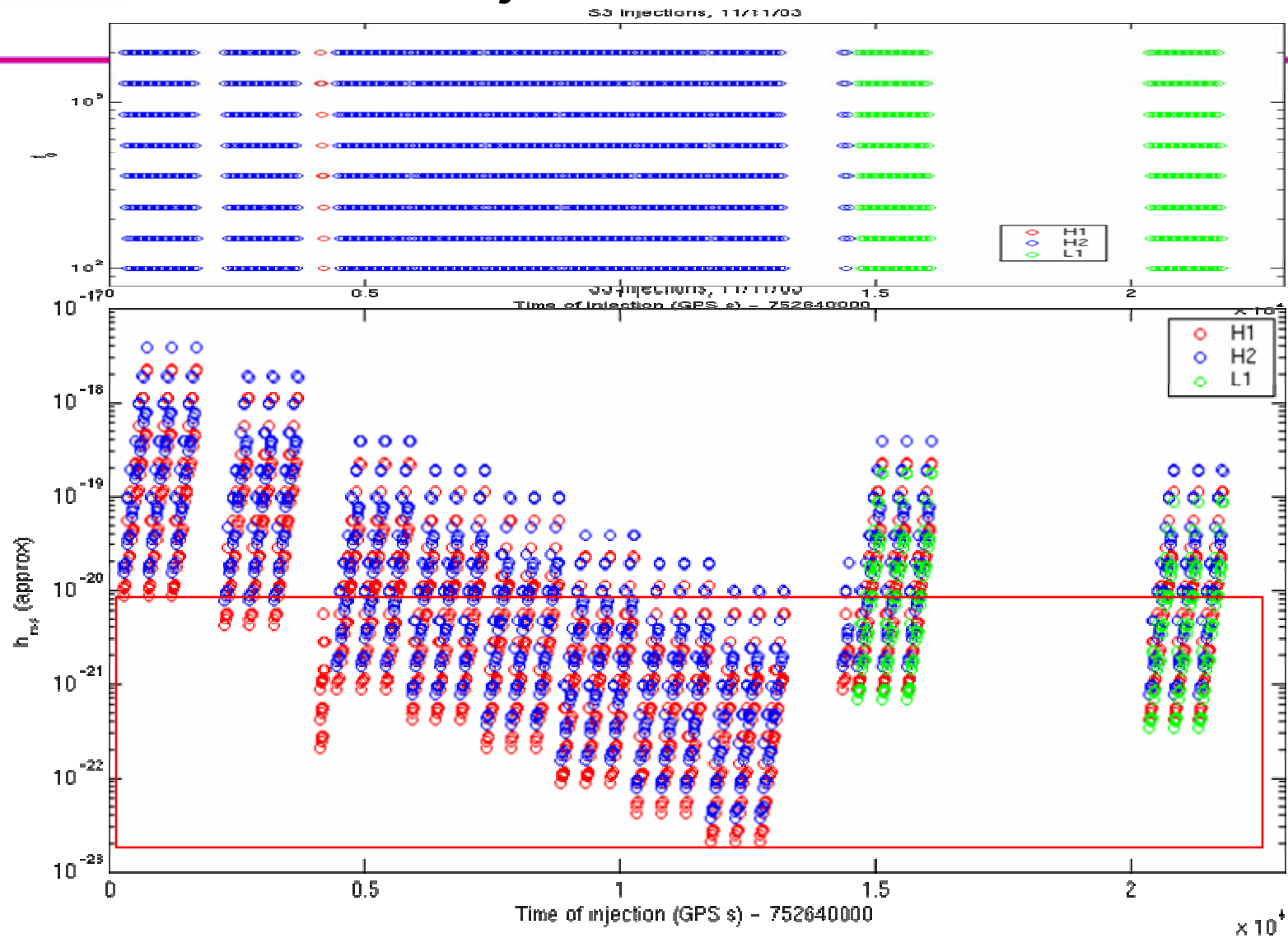
S3 injections

- Tuesday night (Nov 11-12, 2003), over 6.4 hours.
- MANY SG's with $Q=3, 8.9, 30$, 8 central frequencies, ~60 amplitudes. Mostly in H1 and H2, but also some in L1.
- IFOs fell out of lock with the loudest injections, but injections continued anyway!
- Last night (Nov 12), H1 and H2 only, 8 SGs, $Q=8.9$, 6 amplitudes, 6 repetitions ~ 290 injections



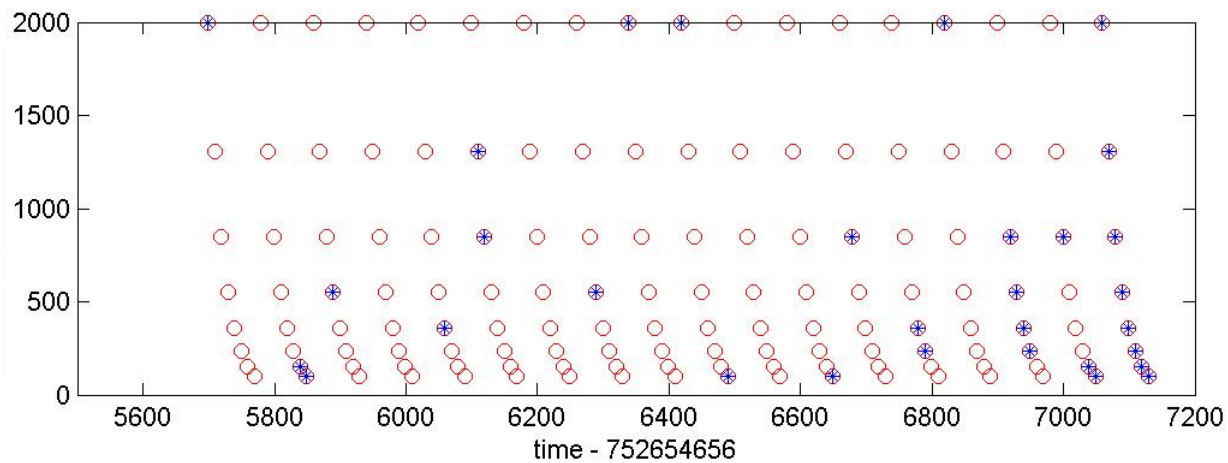
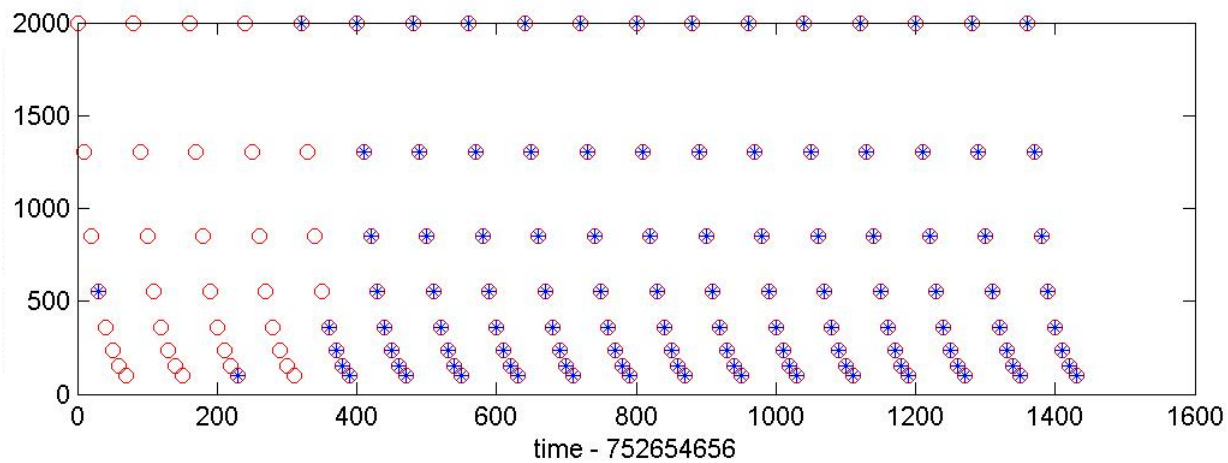


S3 injections on 1/11/03



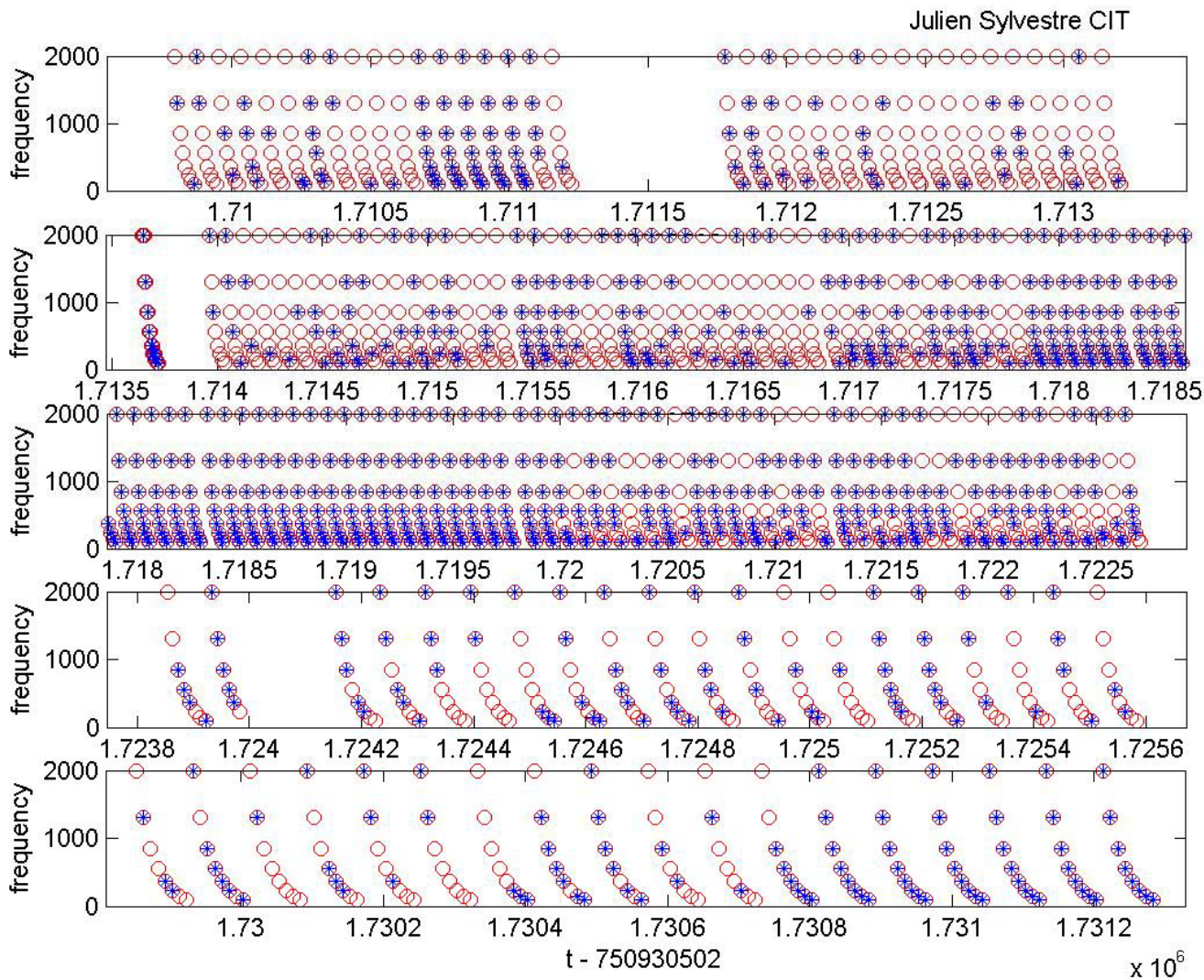


S3 injections into L1

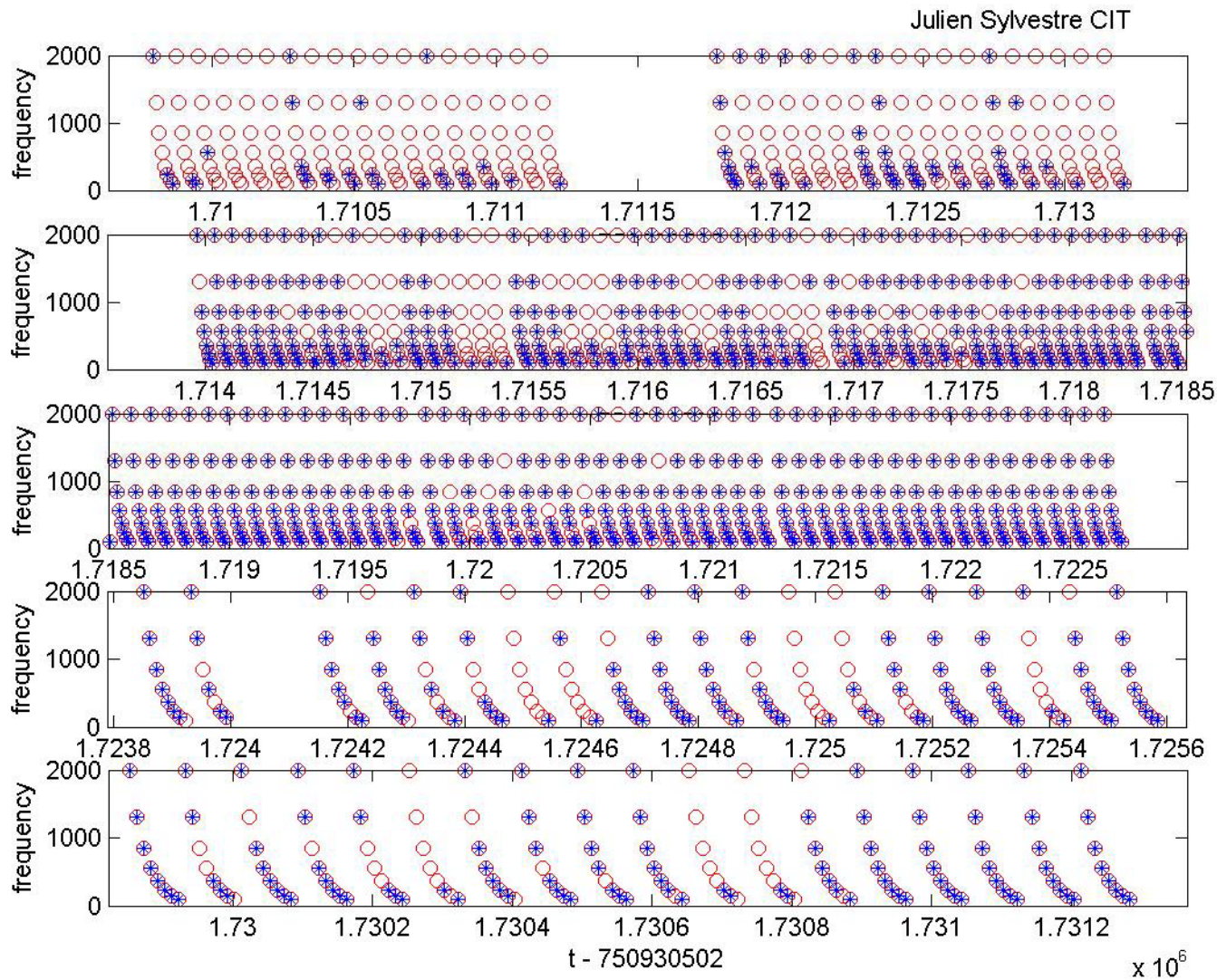




S3 injections into H1



S3 injections into H2





Goals for Burst injections

- **Do the Burst ETGs detect the injections?**
Where is the detection threshold?
Does detection efficiency fall for high amplitude injections?
(Does IFO lose lock?)
- Exercise all ETGs under development
- **Quantitative** comparisons of **ETG-reconstructed with injected values** of h_{rss} , f_0 , t_{start}
- **Quantitative** comparisons of ETG response to **hardware and software injections** with identical parameters
 - » We do SW injections with high statistics, to evaluate efficiency; real comparisons between SW and HW validates the SW efficiency evaluations
- **Quantitative** test of **calibration** information
- **Monitor stability** of IFO & ETG response over time