E7 analysis: Inspiral Group Report

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(co-chair)

LSC Inspiral Upper Limit Group

Inspiral Group Membership

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Inspiral Search

- Look for chirp signals from binary systems which spiral together by gravitational wave emission in LIGO band

- LDAS Filters to detect these signals
  - » Inspiral DSO: [D. Brown et al] uses template based search strategies
  - » Fast Chirp Transform DSO: [L. Wen, P, Charlton, T. Creighton et al] uses time-frequency method based on chirp waveforms

- Coordinated activities with GEO
  - » Substantially different sensitivities reduce power of coincidence

- Interpretation
  - » Look for inspiral candidates, calibrate based on population uniformly distributed in space, produce rate limit.

Analysis Pipeline
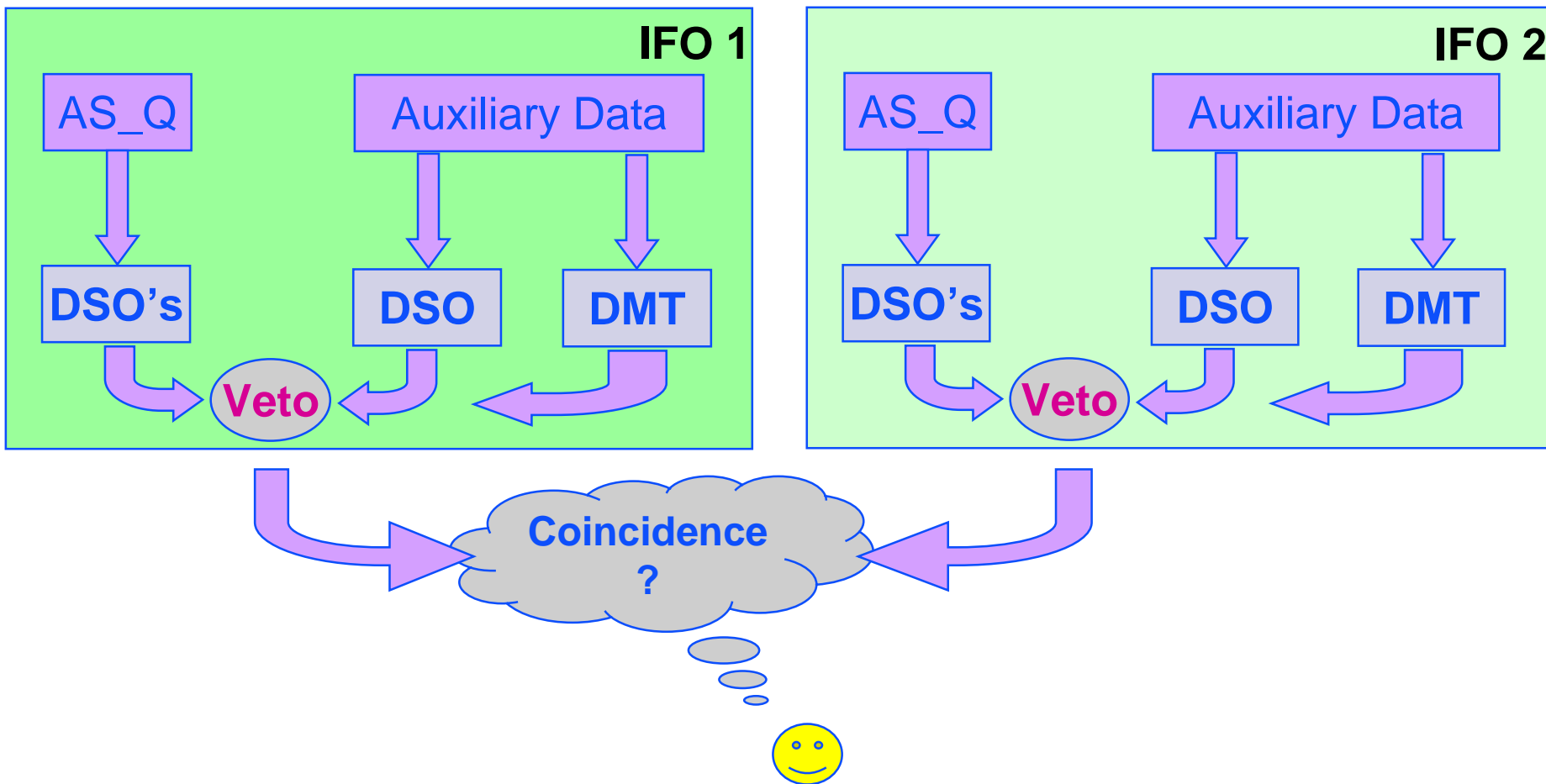
Where are we now?

- **All data has been analyzed**
  - » H1, H2, L1:LSC-AS_Q analyzed using inspiral DSO

- **Detector characterization**
  - » In coordination with burst group on playground data
  - » Explored DMT tools
  - » Explored inspiral DSO on MICH_CTRL, POB_Q, REFL_Q
  - » Identified cattle guard LLO, 300 Hz resonance at LHO
  - » Optimization studies carried out

- **Calibration using simulated injections**

- **Coincidence studies**

- **Final results**
  - » Not yet available for all data not, for playground only

Testing Inspiral DSO

1.3, 2.0 Msun

D = 12kpc

1.8, 1.9 Msun

D = 5kpc
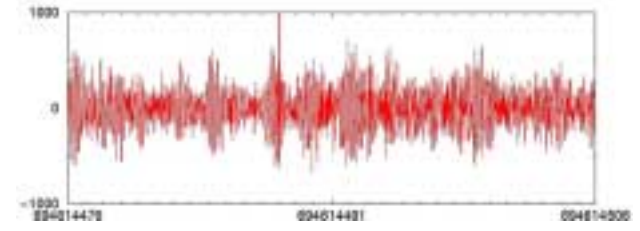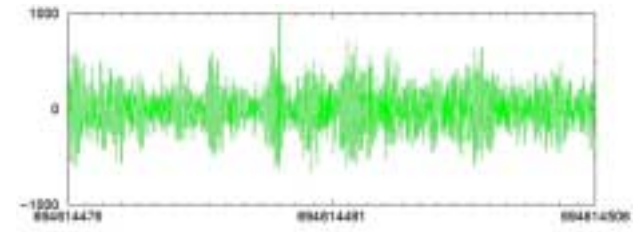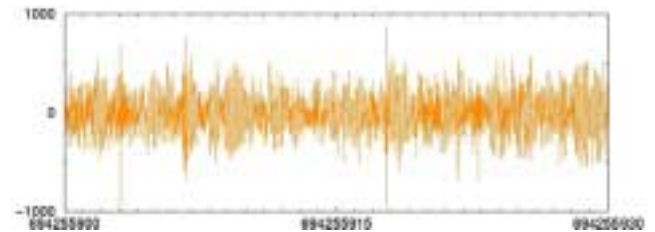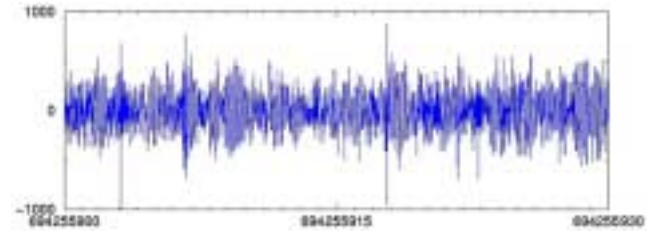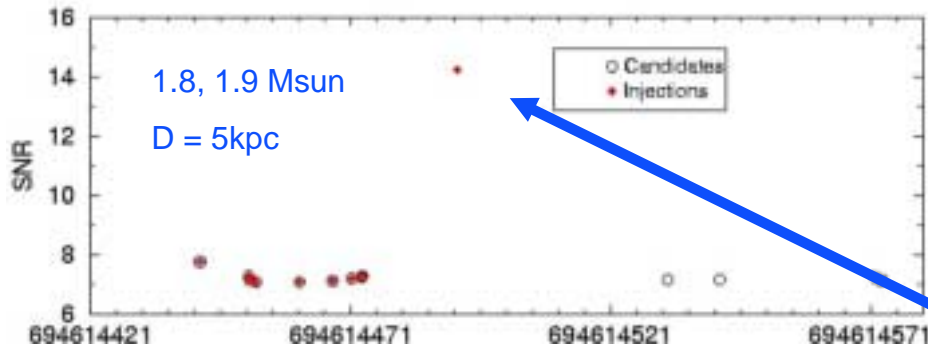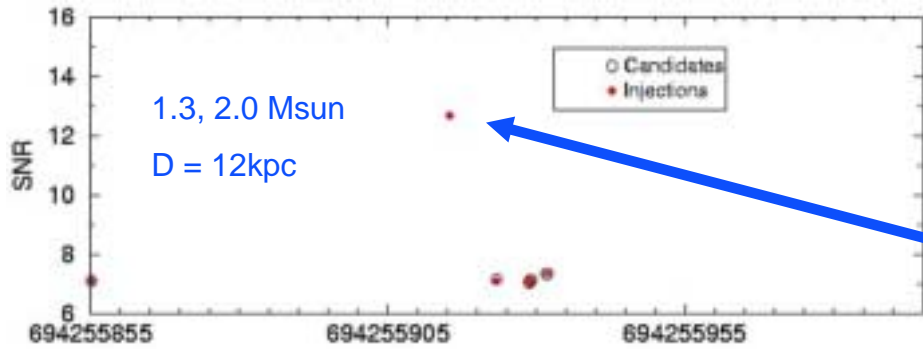
Sensitivity to Optimally Oriented Neutron Star Binary with SNR = 8

LIGO

H2 (green): maximum distance < 14kpc
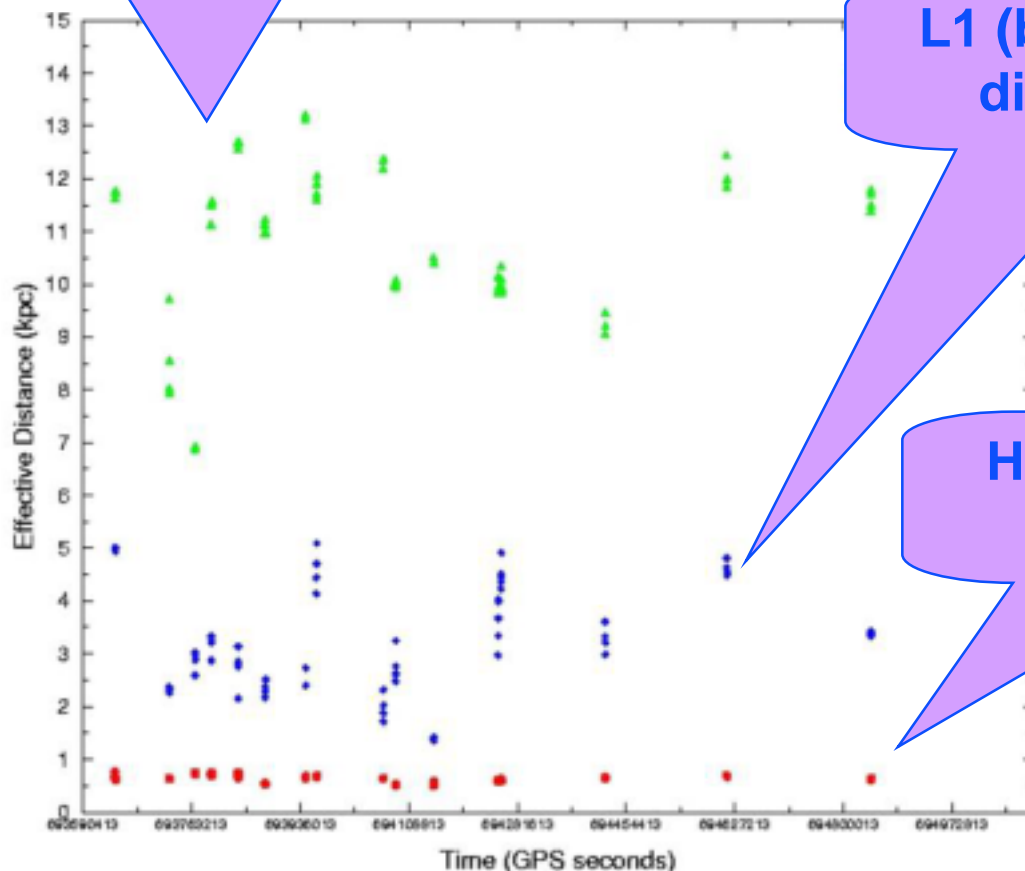
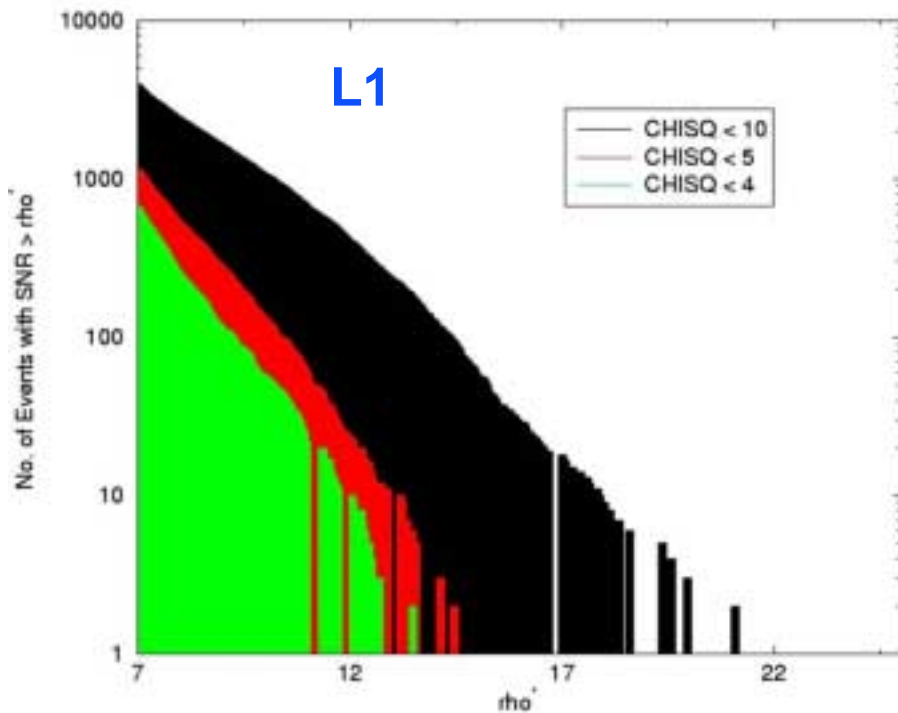L1 (blue): maximum distance < 5kpc

H1 (red): maximum distance < 1kpc

And the winners are ……..

Rauha and Isabel
13.2 kpc
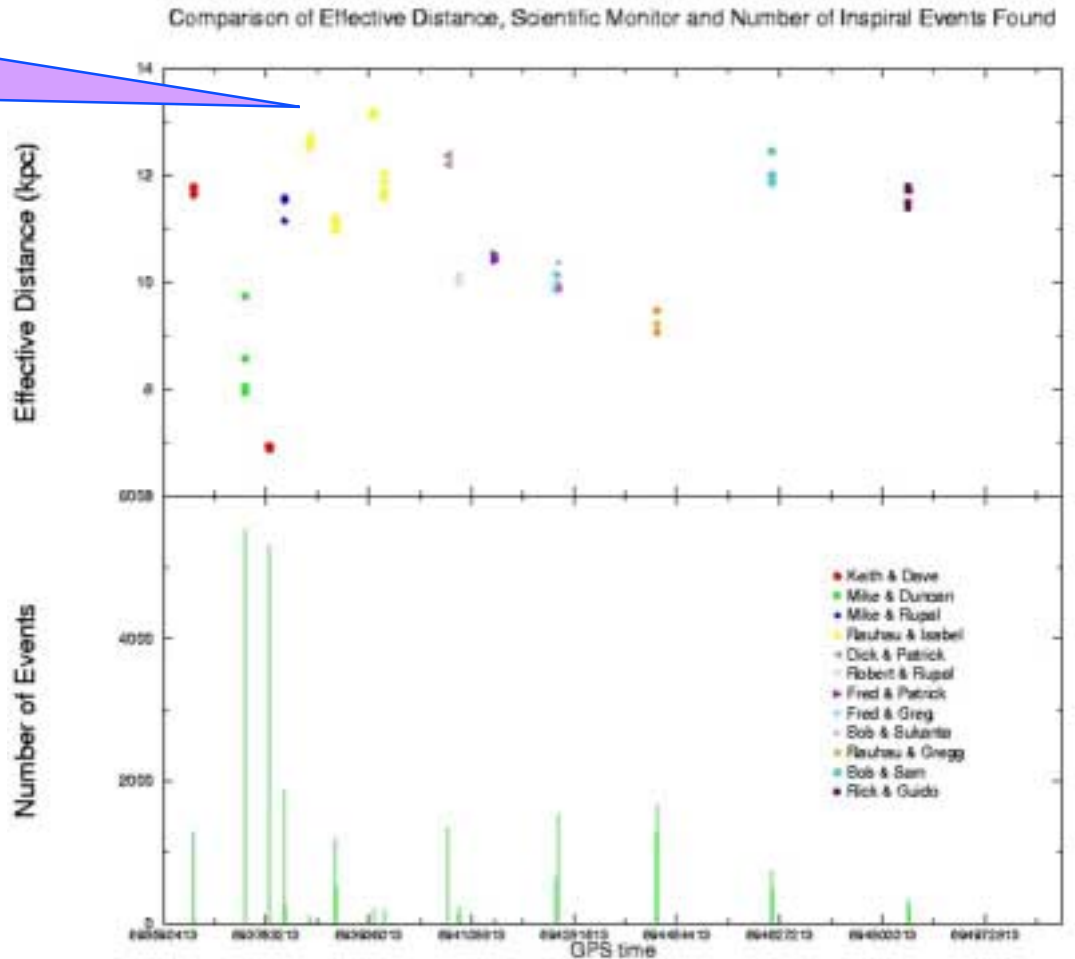
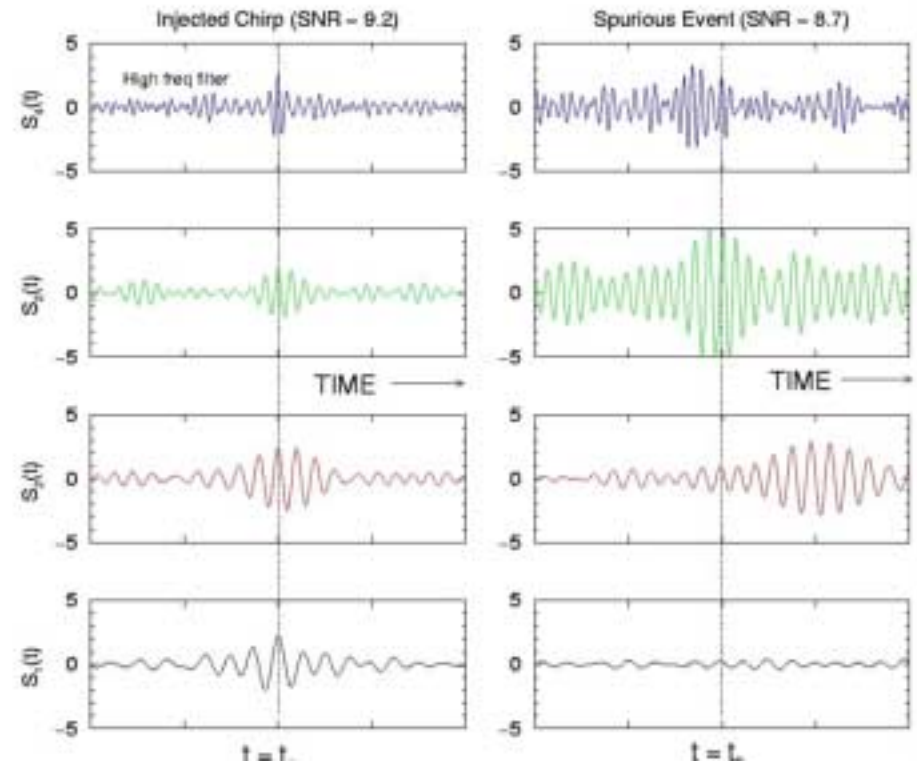# Candidate Events in L1 and H2
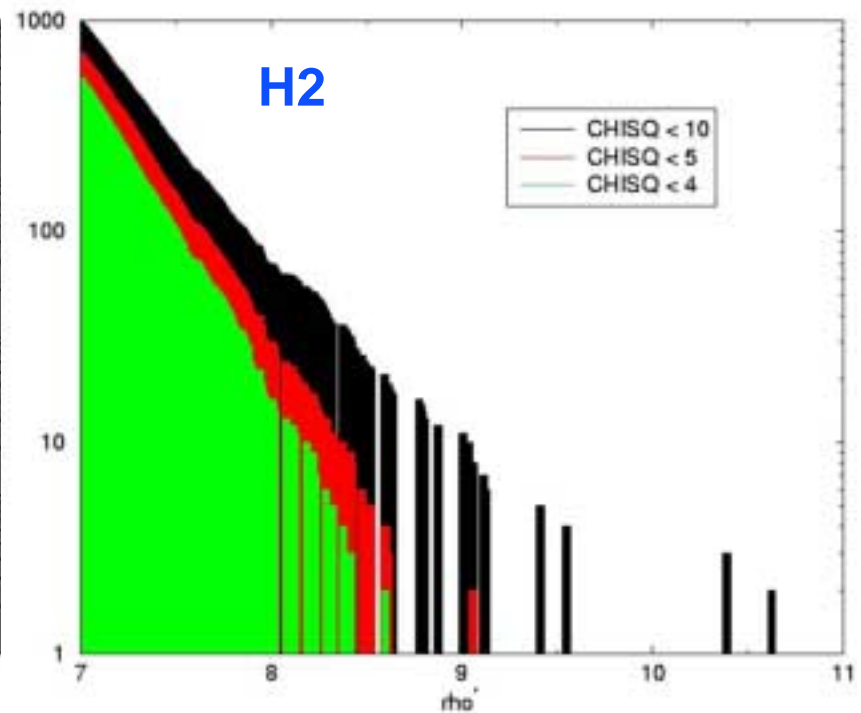
Signal Based CHISQ test

- Break inspiral template into 8 pieces each of which should accumulate 1/8 of the total SNR

- Construct

$$\chi^2 \propto \sum_{i=1}^{8} (\rho_i - \rho/8)^2$$

- In Gaussian noise, this is distributed Chi squared 14 degrees of freedom

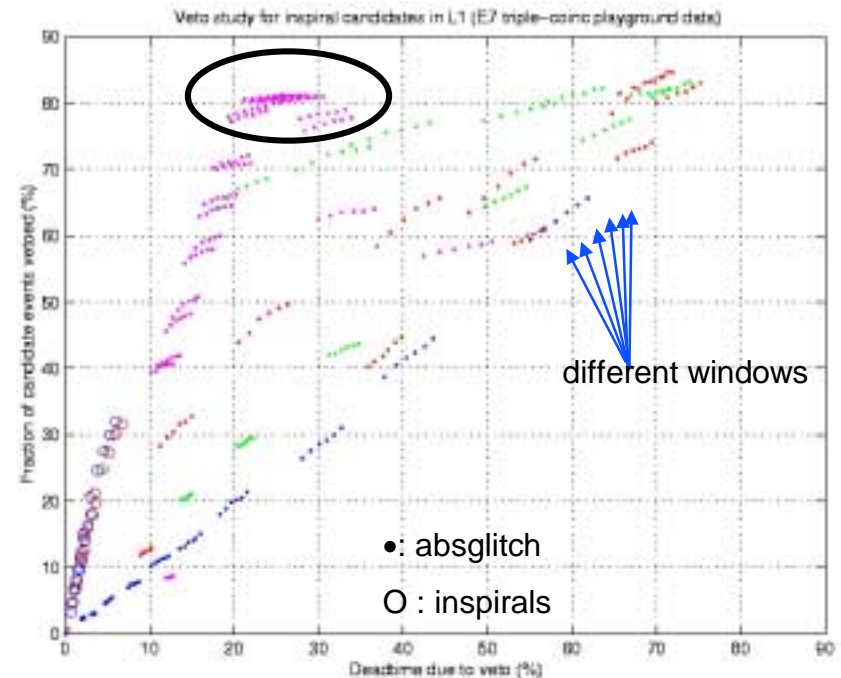Injected Chirp (SNR ~ 9.2) Spurious Event (SNR ~ 8.7)

LIGO Detector characterization and auxilliary channel vetoes

- Many different DMT tools used to examine interferometer and PEM channels
- Most useful were absGlitch and inspiral templates.
- Looked at other channels at times (+/-0.5s) when templates recorded "inspiral events" in AS_Q
- PEMs (accelerometers, seismometers, microphones, voltage line monitors) did not pan out as good vetoes for inspiral events
- Cattle guard at LLO – time-frequency methods
- Band limited RMS (Daw)– resonance at LHO first identified using inspiral DSO.

Veto optimization

POB_Q channel
filtered with "inspirals" SNR>7,
window of +/-0.2 seconds
eliminates 63.1% of event candidates
while introducing a deadtime of 8.6%.

PSL channel,
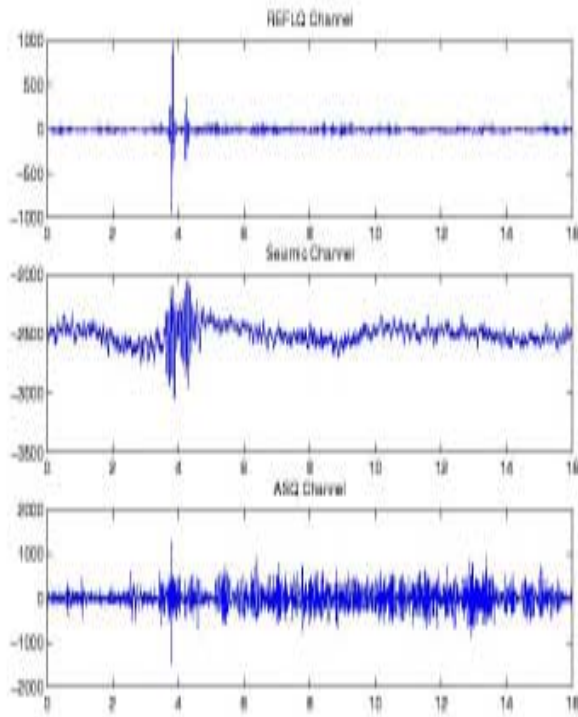filtered with absglitch at 30 Hz, threshold of 12,
window of +/-0.05 sec
eliminates 80.3% of event candidates
while introducing a deadtime of 21.3%.

- MICH_CTRL
- POB_Q
- REFL_Q
- CARM_CTRL
- PSL-ISS_ACTM_F

• : absglitch

O : inspirals

different windows
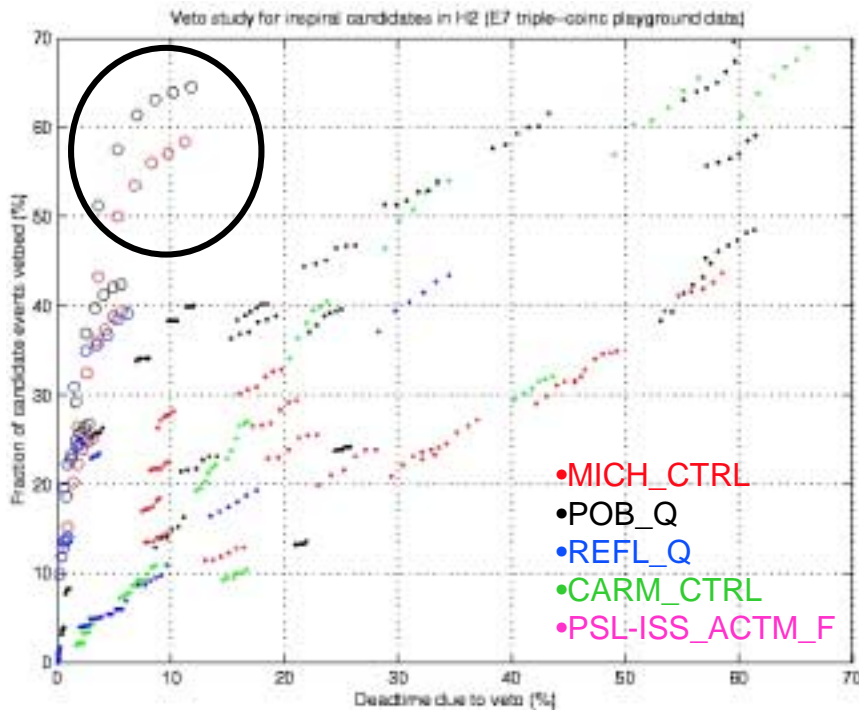
Violin mode ringing up in H2

Power Spectra Used In Computation of Effective Distance

Resonance excited at times with bad effective distance
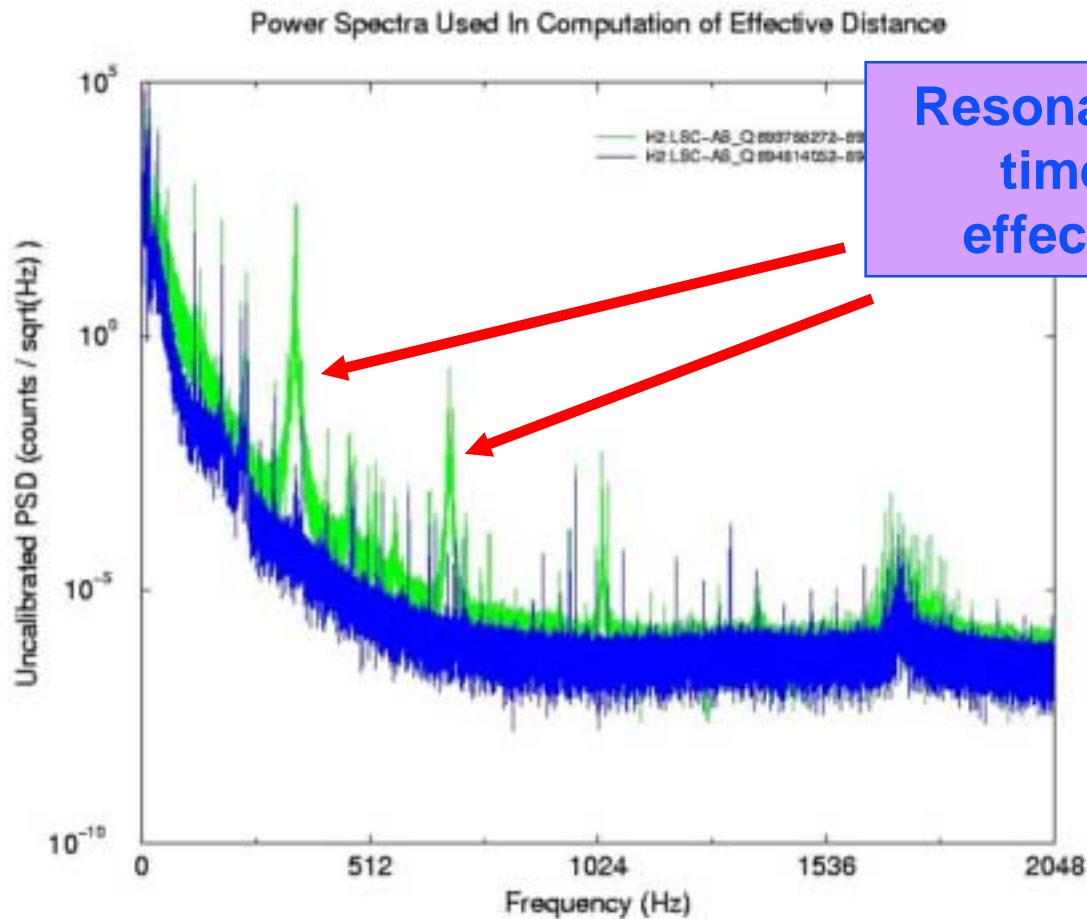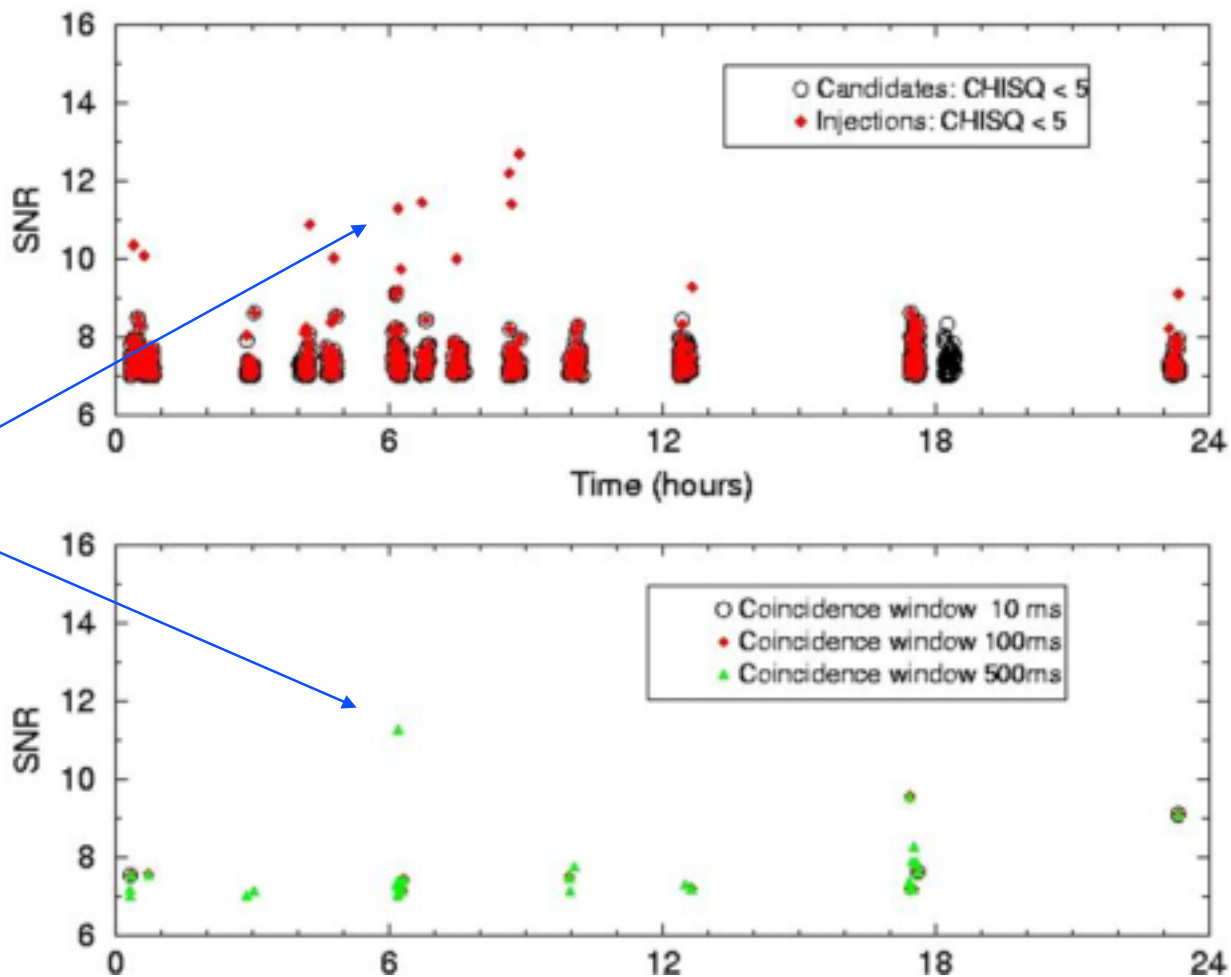
Cattle guard in L1

- Events found with "PSLmon" on REFL_Q (MICH)

- Low frequencies (<100 Hz)

- ~Tens of events in the playground set
- Only one in triple coincidence playground set,

- NOT picked up by inspiral search (!)

LIGO Coincidence analysis without strength consistency

One simulated injection survives coincidence with window of 500ms, but this coincidence with noise in L1

Tuning on playground data
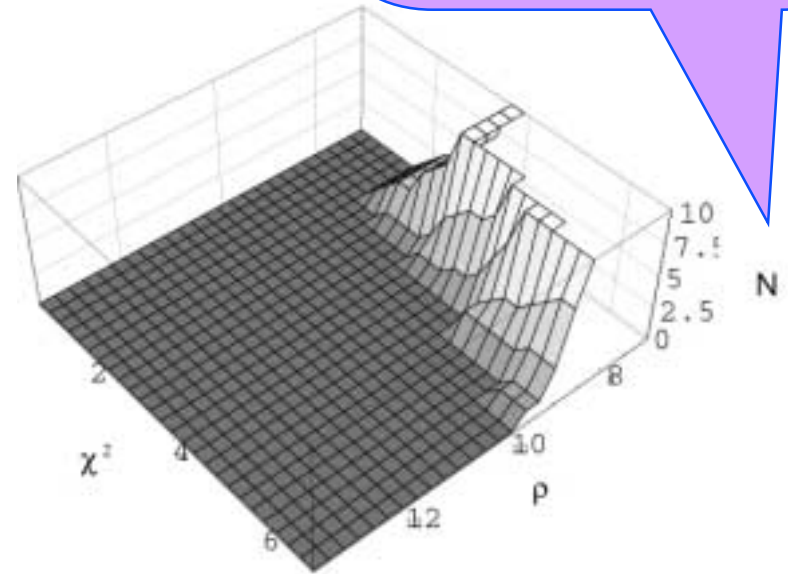
- Use the 90% confidence limit on rate as a figure of merit.
- Population
  - » Binaries with elements in 1-3 Msun
  - » Uniform distribution to 30 kpc
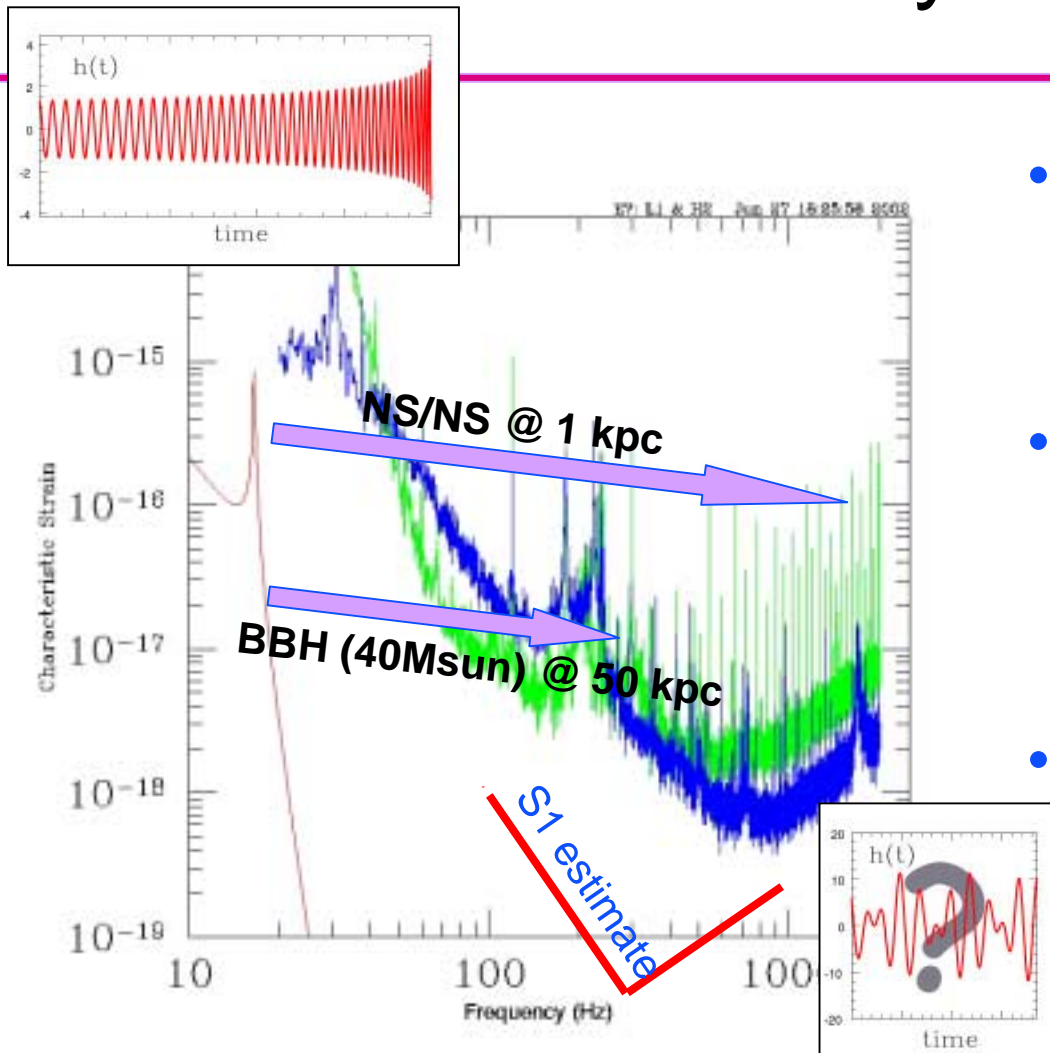- Rate limit

$$R_{90\%} \propto 1/(\varepsilon T)$$

- Where the efficiency ε is the fraction of signals detectable from this population and T is observation time

Efficiency and number of events after MICH_CTRL and REFL_Q veto

Binary Inspiral

- **Neutron Star Binaries**
  - » Known to exist (Hulse-Taylor)
  - » LI GO I : D_{eff}=20Mpc, R< 1/(3yr)
  - » R < 4 x 10^{-14} / kpc^3/Yr

- **NS/BH, BH/BH**
  - » New science: rates, dynamics of gravitational field, merger waves
  - » LI GO I : D_{eff}<100Mpc, R< 1/(yr)

- **General properties:**
  - » Clean systems which can be accurately modeled (Blanchet, Damour, Iyer, Will, Wiseman, …….)

Efficiency and Rate Limit

Efficiency decreases with decreasing CHISQ and increasing SNR thresholds
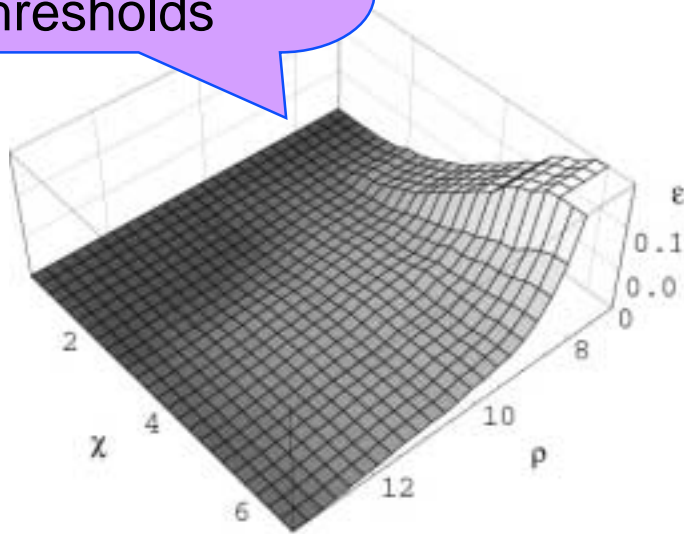
Smallest rate limit at CHISQ < 4.5 and SNR > 9.

Rate < 1/kpc³/Yr

Extrapolate to S1: **10^{-5} / kpc³ /Yr**

Closeout of E7 analysis

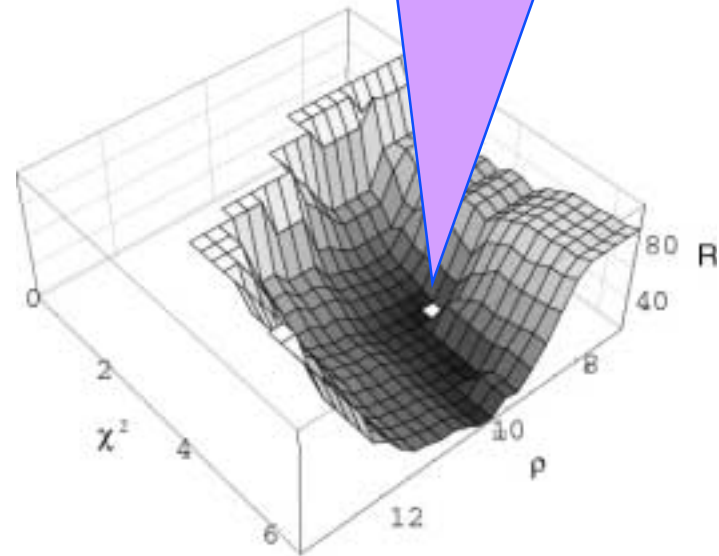- Finish analysis by producing the rate limit with the full data set

- Finish report by 1 October 2002

Proposals for S1 analysis

- **Interferometers to include in effort:**
  - » 3 LIGO, GEO and TAMA (????)

- **Binary Neutron Star Search**
  - » All infrastructure developed during E7 except source distribution model must now include structure of Galaxy, LMC, SMC, other ....
  - » Which rate limit statistic should we use?
  - » Target date for complete analysis of data is 1 Oct 2002
  - » Threshold optimization on playground data set by 7 Oct 2002
  - » Upper limit by 14 Oct 2002
  - » Draft paper by mid-late December 2002

Proposals for S1 analysis

- **Binary black hole search**
  - » Can use most of the infrastructure developed for E7 analysis
  - » Needs new waveform generator in LAL
  - » Needs new template bank generation in LAL
  - » Needs detailed veto study without benefit of chi-squared test
  - » Coordination with burst detection of merger is new dimension

- **Schedule:**
  - » Target date for complete analysis of data is ?? ??? 2002
  - » Threshold optimization on playground data set by ?? ??? 2002
  - » Upper limit by ?? ??? 2002
  - » Draft paper by late December 2002

Proposals for S1 analysis

- ## Low-mass binary search
    - » Can use most of the infrastructure developed for E7 analysis and S1 BNS analysis
    - » Includes MACHO binaries and possible rapidly rotating stellar collapse models.

- ## Schedule:
    - » Target date for complete analysis of data is ?? ??? 2002
    - » Threshold optimization on playground data set by ?? ??? 2002
    - » Upper limit by ?? ??? 2002
    - » Draft paper by late January 2002