E7 Inspiral Search Status Report

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(co-chair)

LSC Inspiral Upper Limit Group

LIGO-G020424-00-Z

Inspiral Group Membership

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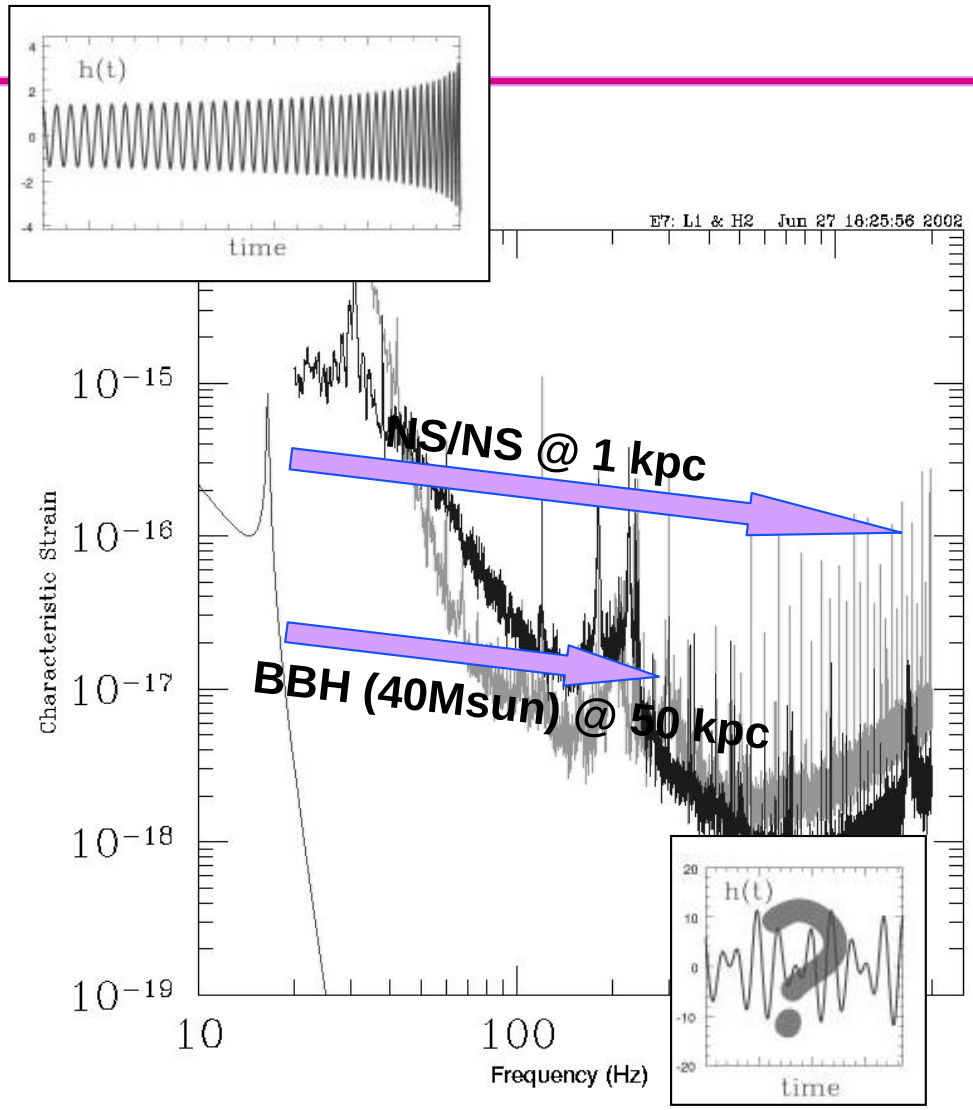
Outline

- Binary inspiral waveforms and expected rates
- Template based search strategies
  - » Matched filtering
  - » Signal based vetoes
- Detector characterization
  - » Overview of approaches
  - » Candidate reduction versus dead time
- Upper limit analysis of playground data set
  - » Monte Carlo injections
  - » Efficiency as function of thresholds
  - » Multi-detector analysis

Binary Inspiral

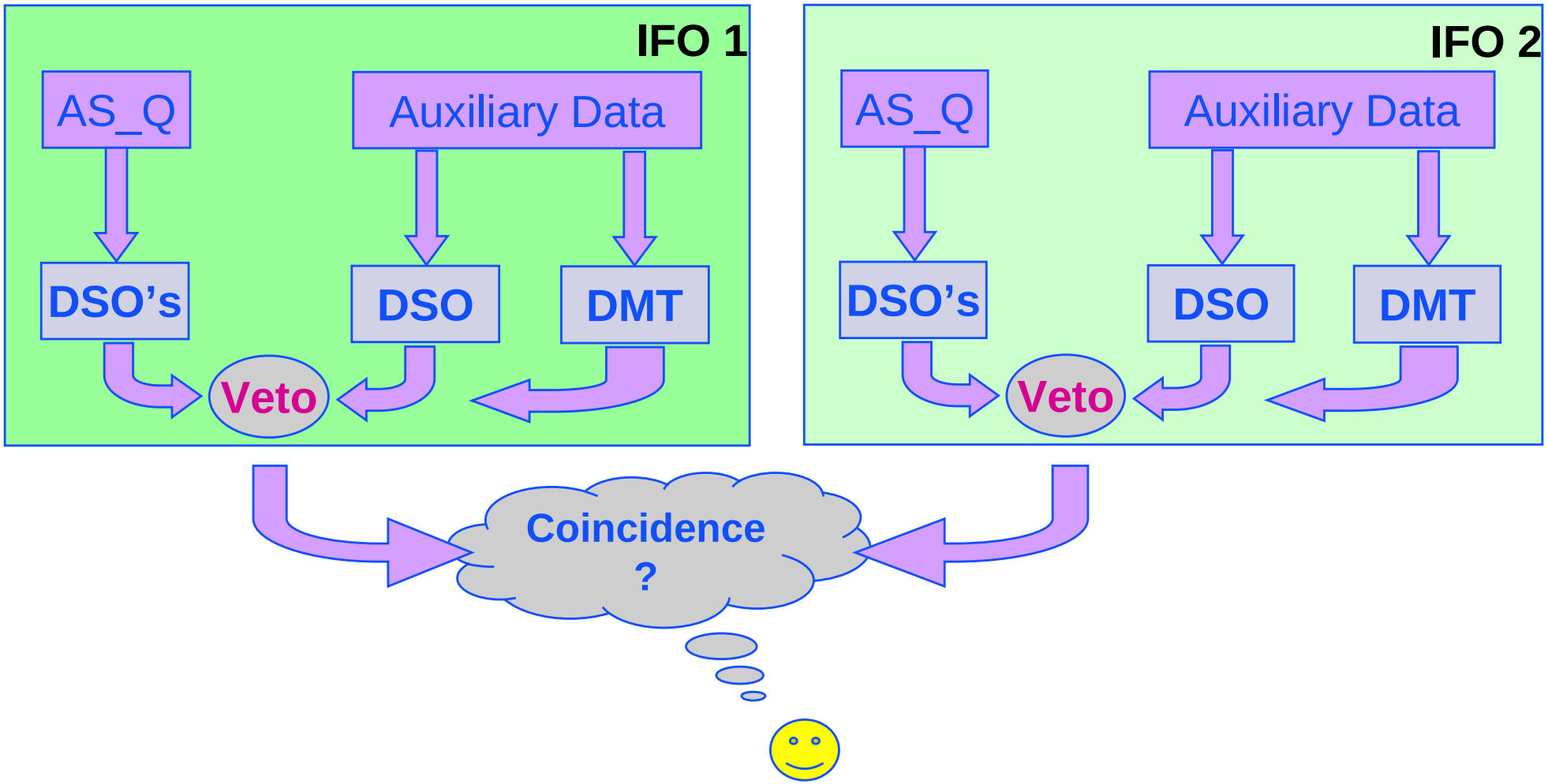


- Neutron Star Binaries
  - » Known to exist (Hulse-Taylor)
  - » LIGO I: D_{eff}=20Mpc, R< 1/(3yr)
  - » R < 4 x 10^{-14} / kpc^3/Yr
- NS/BH, BH/BH
  - » New science: rates, dynamics of gravitational field, merger waves
  - » LIGO I: D_{eff}<100Mpc, R< 1/(yr)
- General properties:
  - » Clean systems which can be accurately modeled (Blanchet, Damour, Iyer, Will, Wiseman, …….)

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.

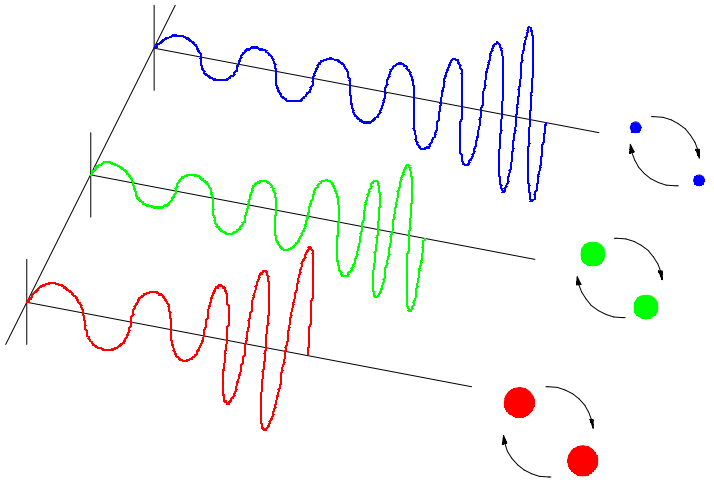
Analysis Pipeline



Where are we now?

- All playground data has been analyzed many times
  - » 5 hours of data distributed over E7 run
  - » H1, H2, L1:LSC-AS_Q analyzed using inspiral DSO
- Detector characterization
  - » In coordination with burst group
  - » 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 (preliminary)
- All reported results are for playground only

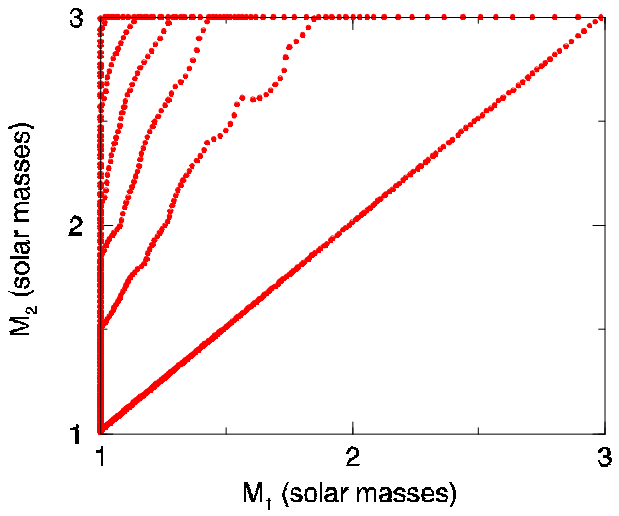
Template Based Search
Inspiral DSO



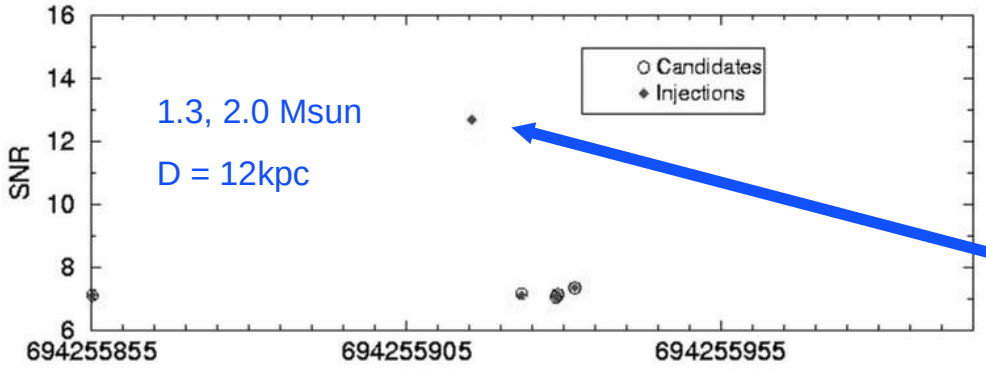
For each binary, specif M1, M2, Spin1, Spin2 giving a different waveform

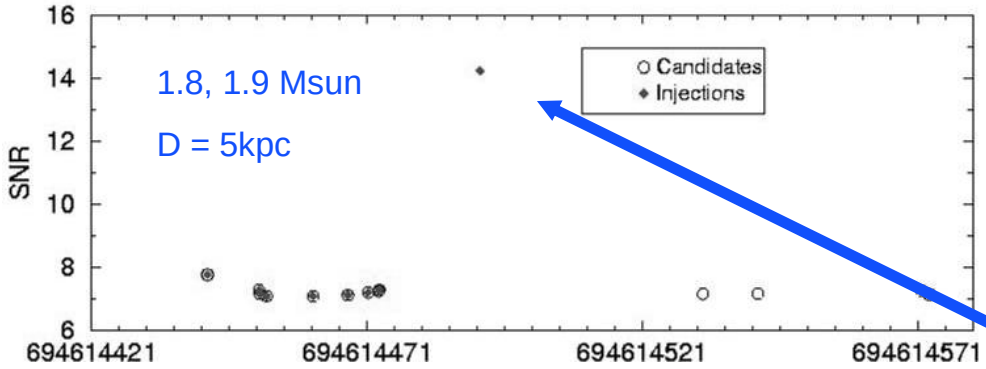
Restricted search to non spinning binaries. Discrete set of template waveforms labeled by M1, M2:

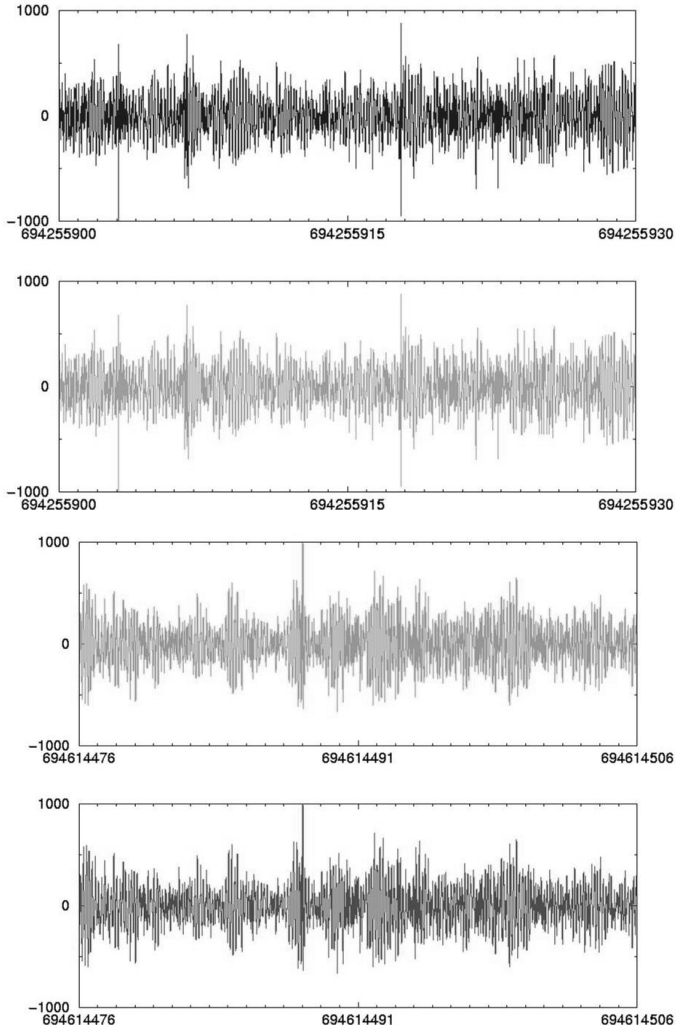
600 templates



Testing Inspiral DSO





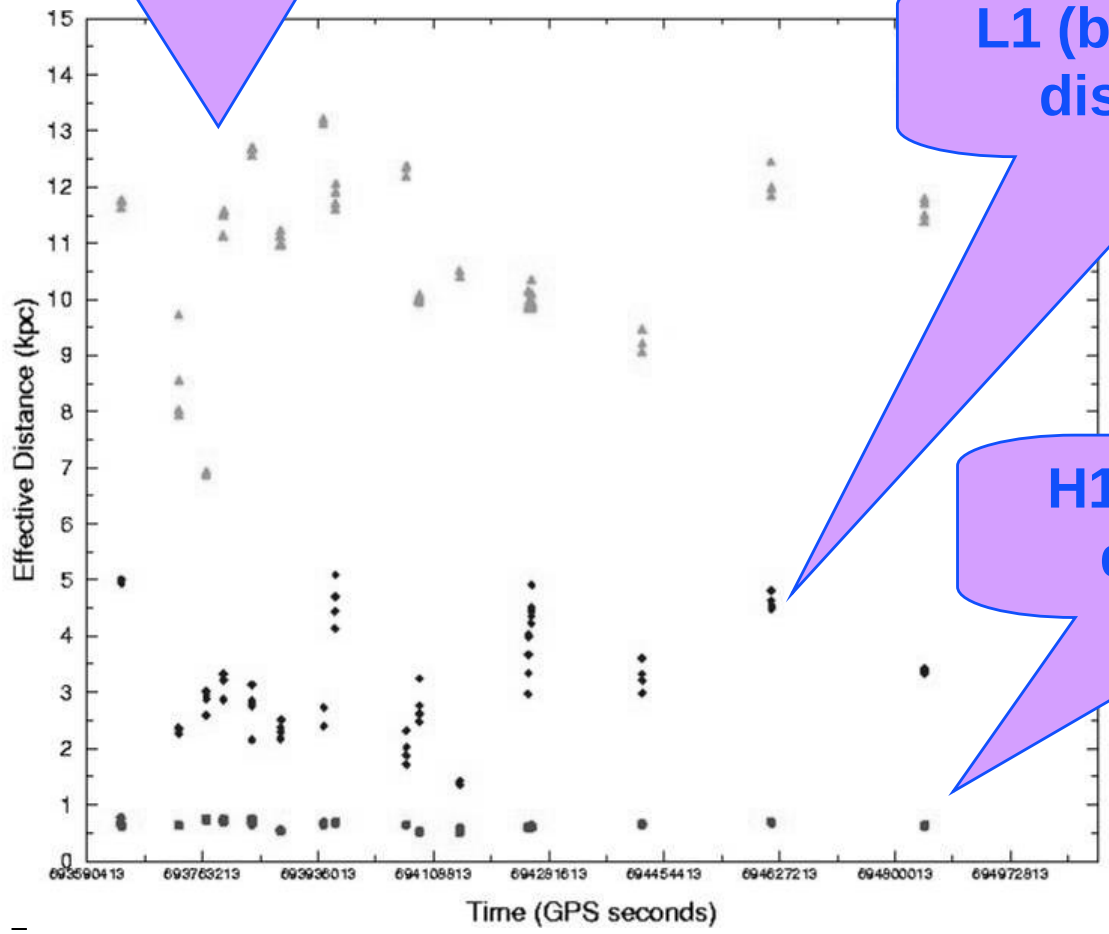


Sensitivity to Optimally Oriented Neutron Star Binary with SNR = 8

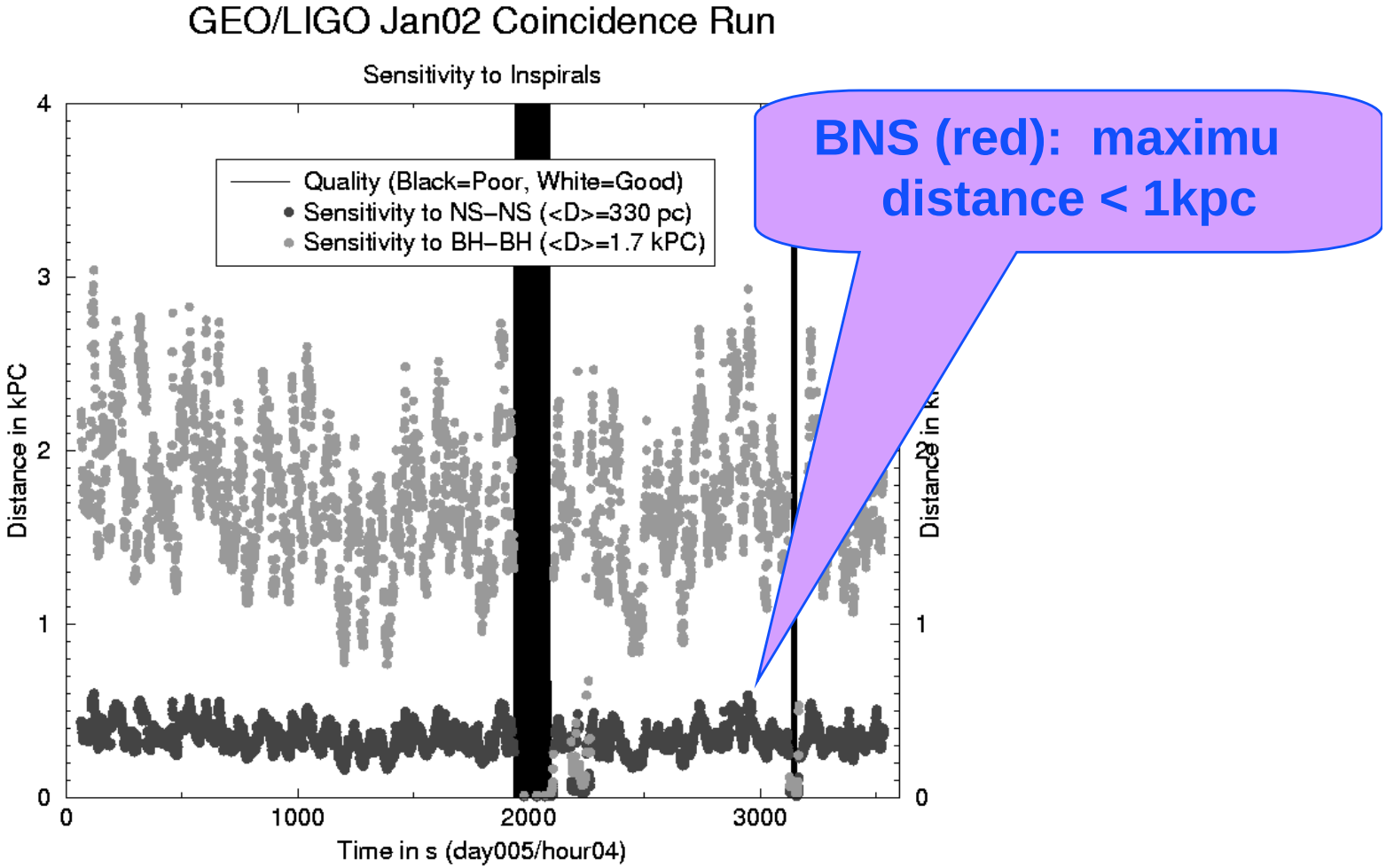
H2 (green): maximum distance < 14kpc

L1 (blue): maximu distance < 5kpc

H1 (red): maximu distance < 1kpc

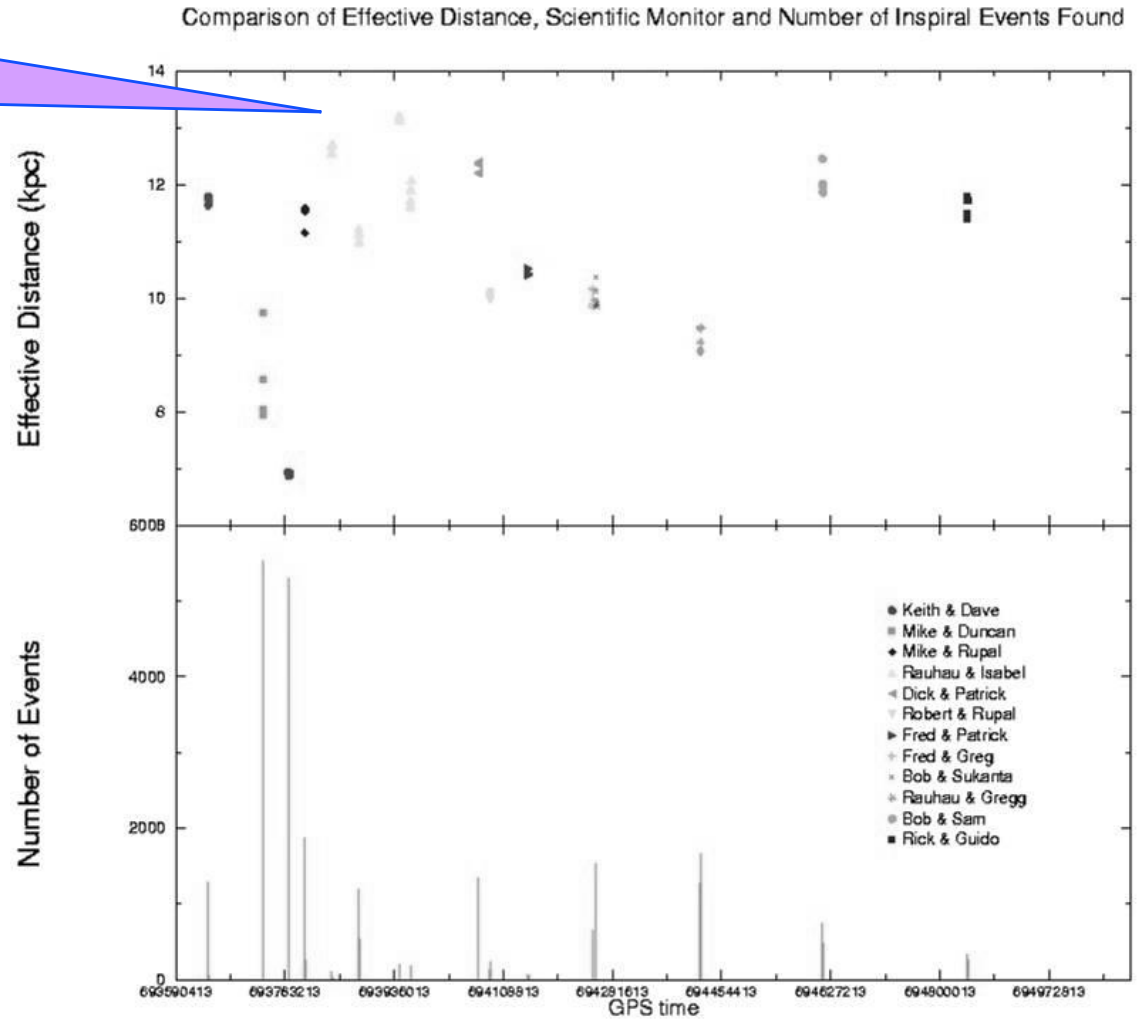


GEO Sensitivity

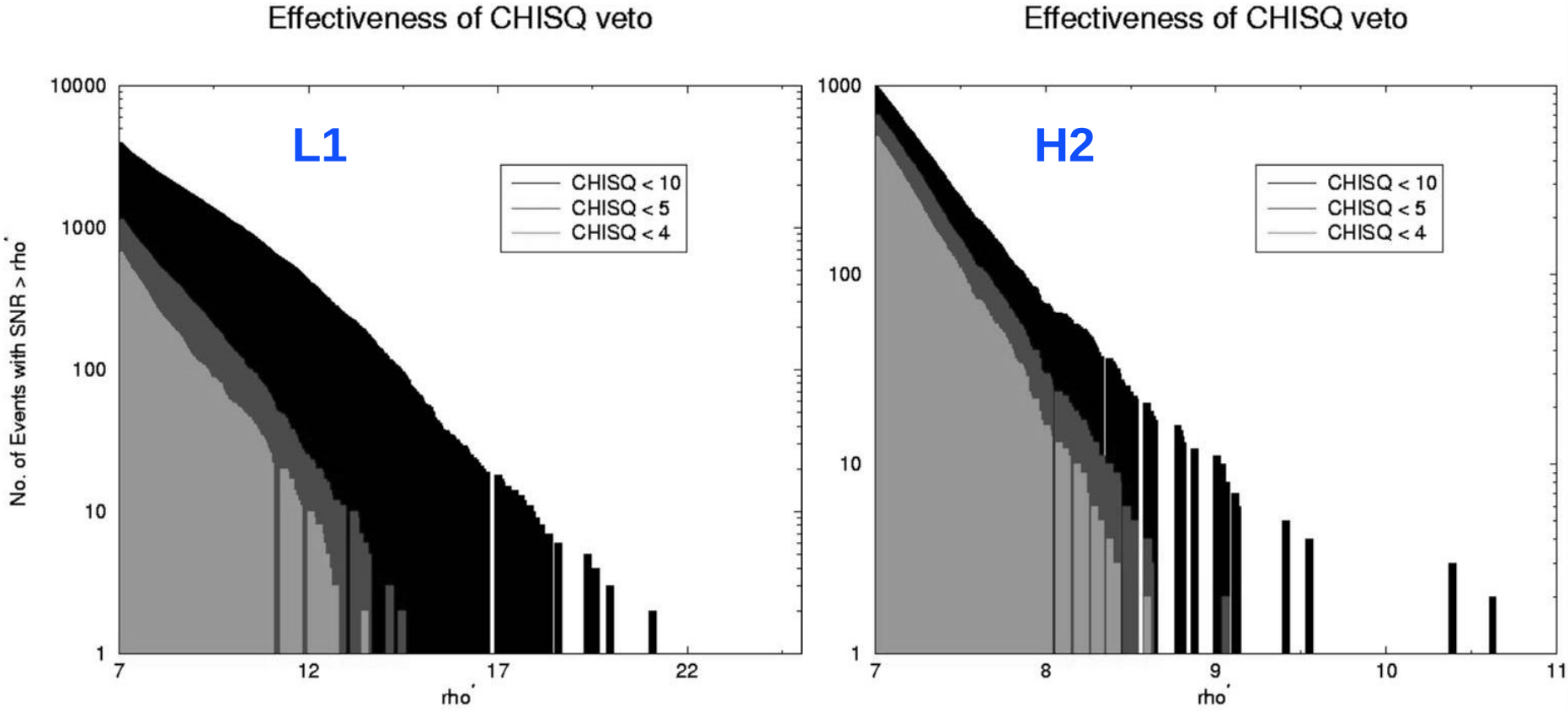


And the winners are …….

Rauha and Isabel
13.2 kpc



Candidate Events in L1 and H2

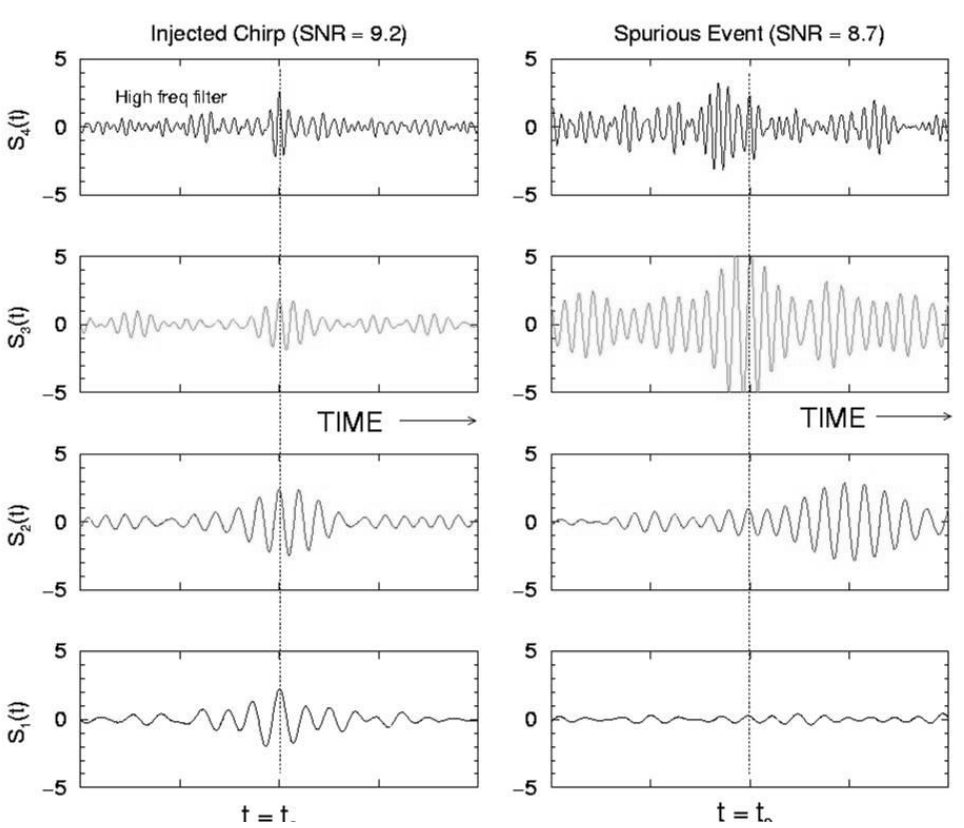


Signal Based CHISQ test

- 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



LIGO Detector characterization and auxilliary channel vetoes

- Many different DMT tools used to exami 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.

Hanford 2km

- Inspiral “events” in AS_Q were often also seen i other channels.
- Could register events in these channels by eye, or using absGlitc
- Inspiral templates register “events” coincident with AS_Q in H2:LSC-POB_Q, H2:LS -MICH_CTRL

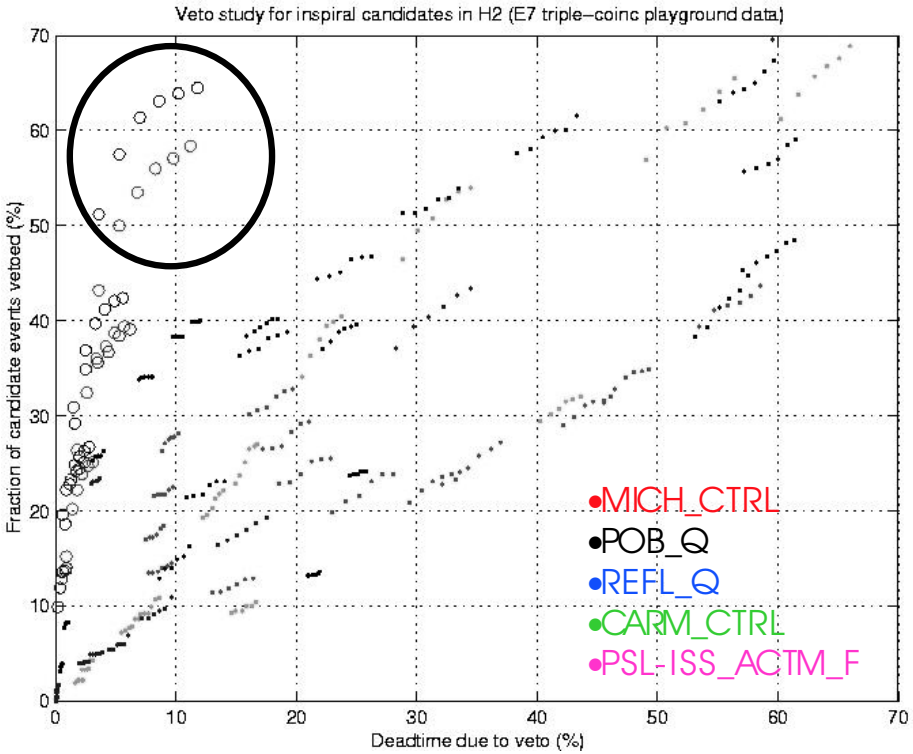
Example: MICH_CTRL “inspirals” used to veto AS_Q inspirals in H2 within +/- 0.3 seconds in triple coinc, playground

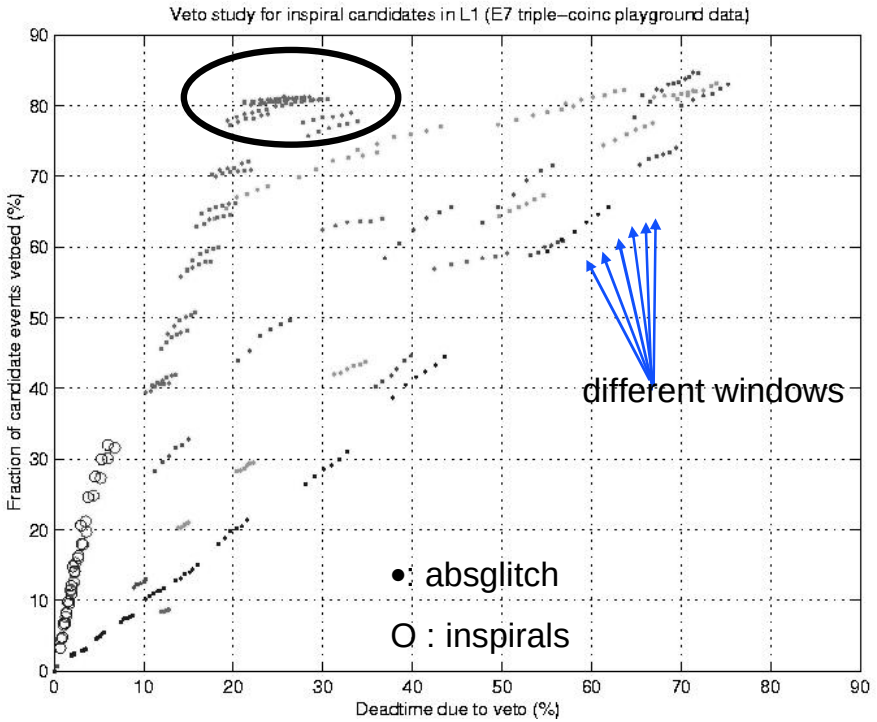
Start	Dur	Veto	used/%	Cand	cut	cut%	dead%
693641112	936	5274	259 (4.9%)	108	50	**46.3%**	**11.5%**
693768272	1082	4661	1567(33.6%)	1873	1194	**63.7%**	**13.6%**

Veto optimization

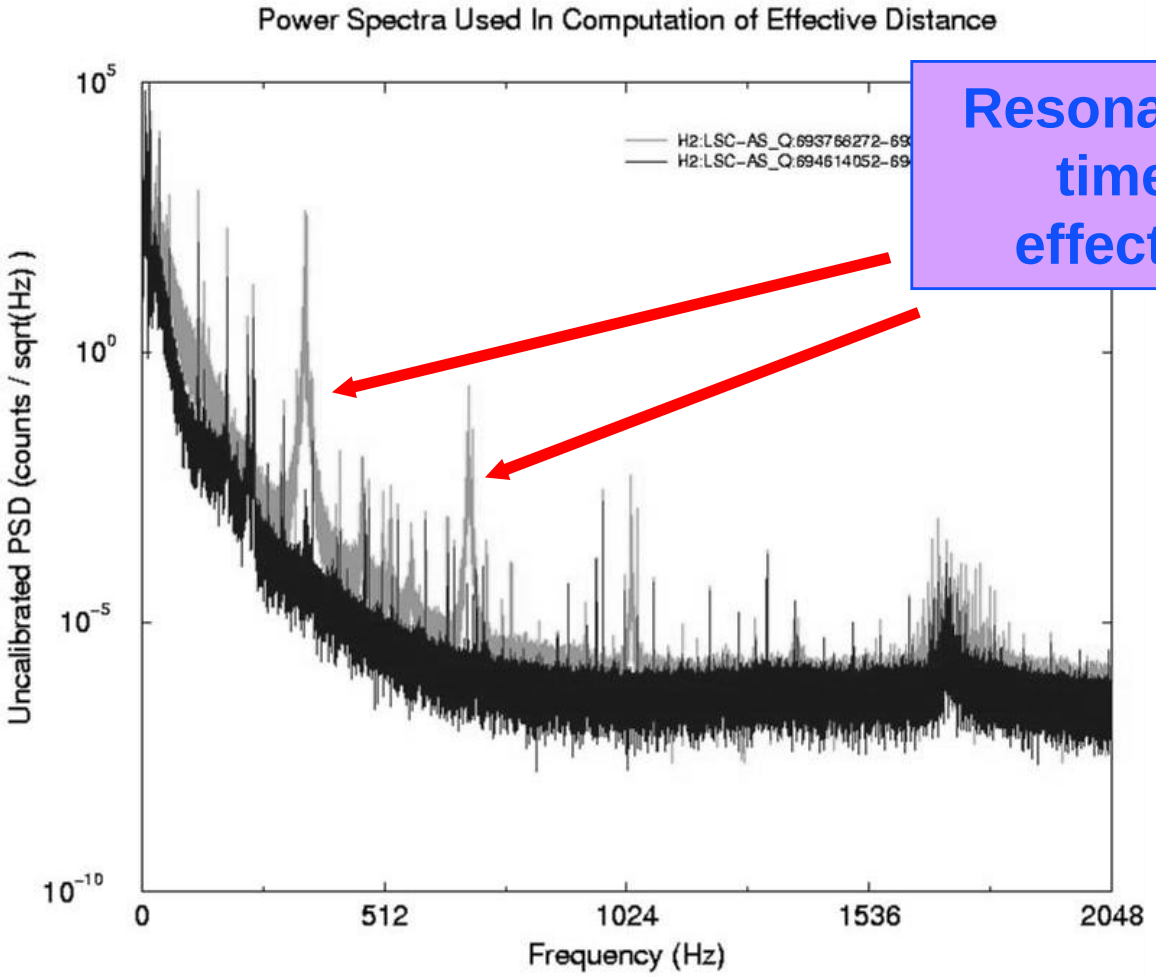
POB_Q channel
filtered with "inspirals" SNR>7,
window of +/-0.2 seconds
eliminates 63.1% of eventcandidates
while introducing a deadtime of 8.6%.

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





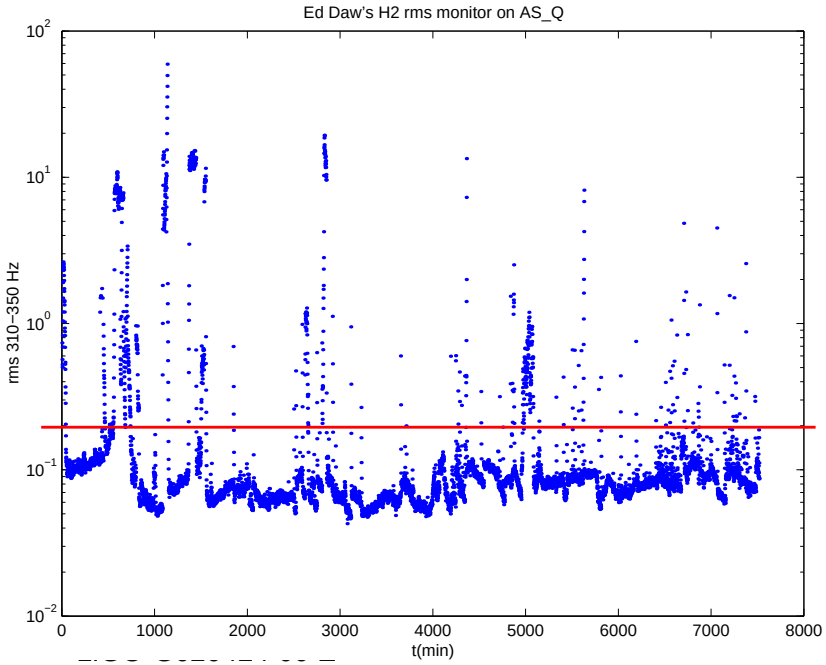
Violin mode ringing up in H2



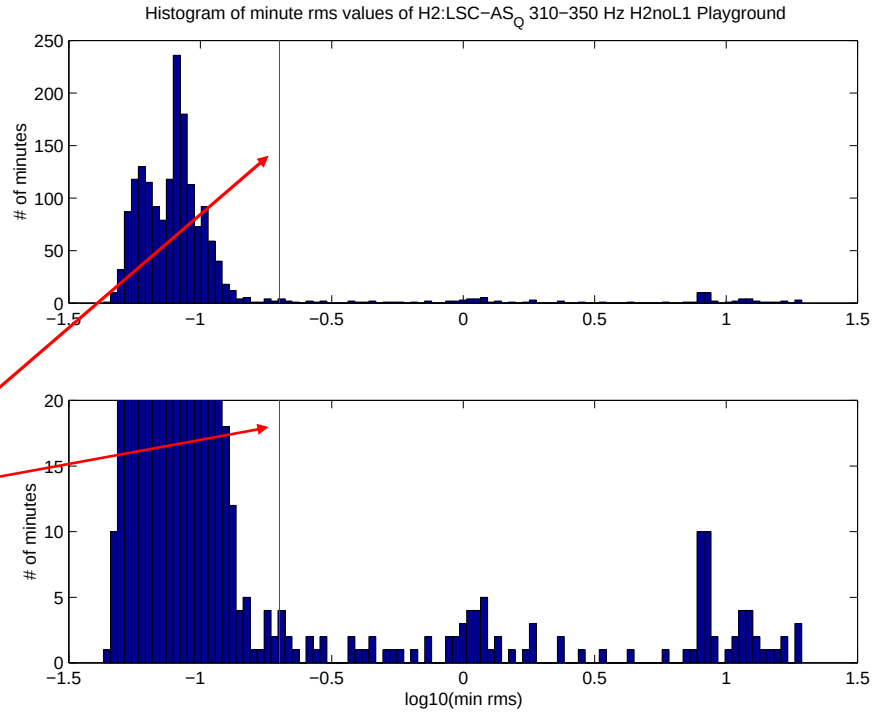
Resonance excited at times with bad effective distance

Violin mode veto using Daw's band-limited RMS monitor

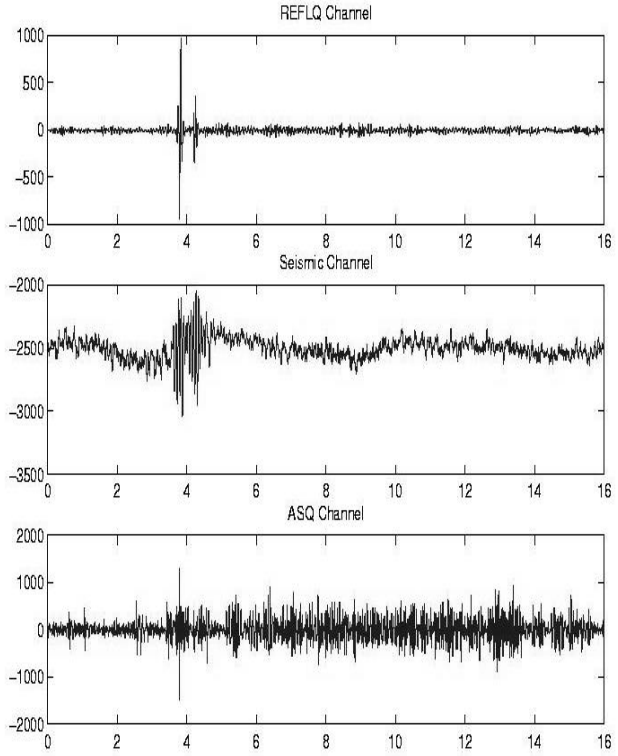
Two entire segments (of 16) in "triple coincidence playground" with much larger event rates can be vetoed with this monitor.



Threshold



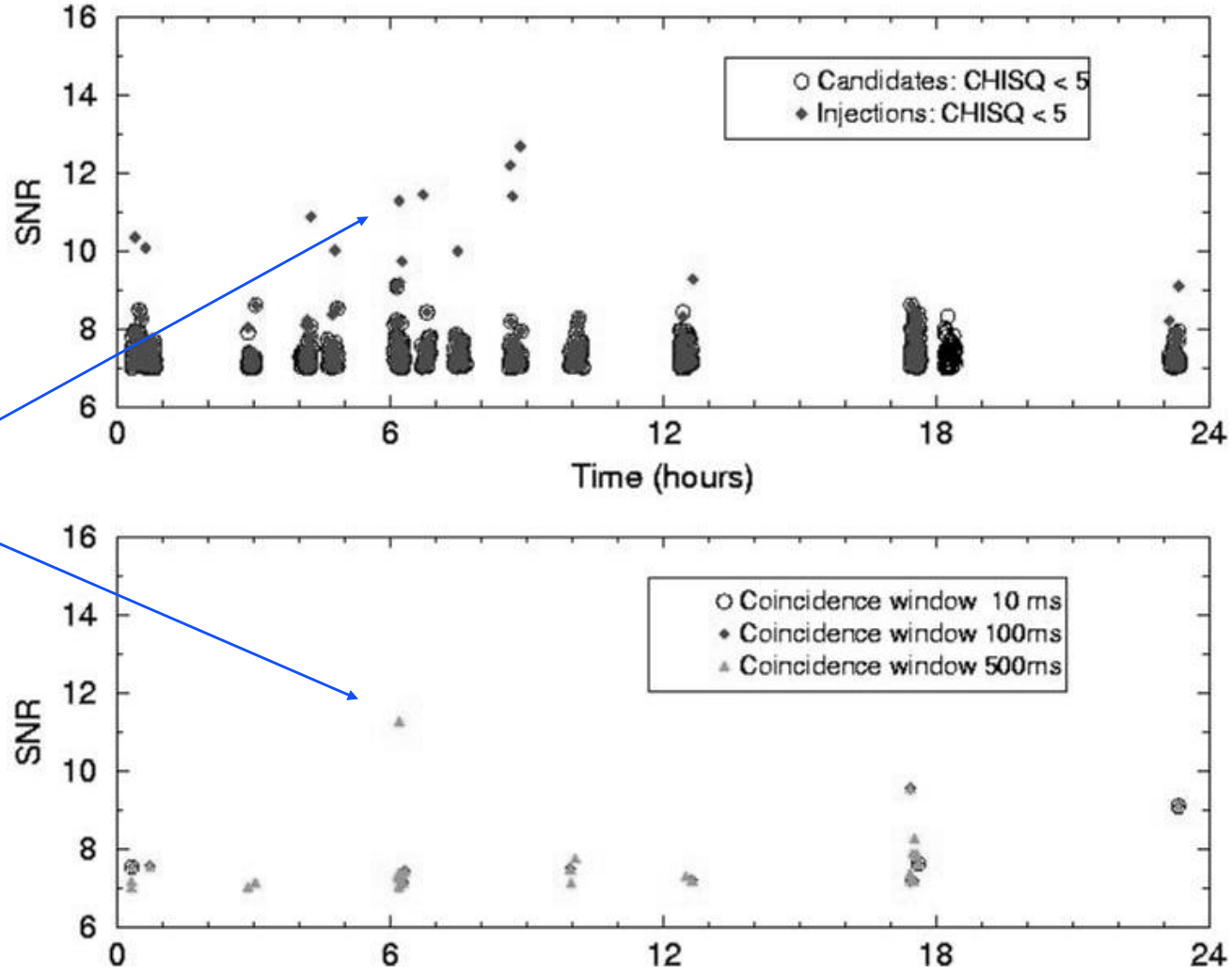
Cattle guard in L1



- 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 (!)

Coincidence analysis

Only one simulated injection survives coincidence with window of 500ms



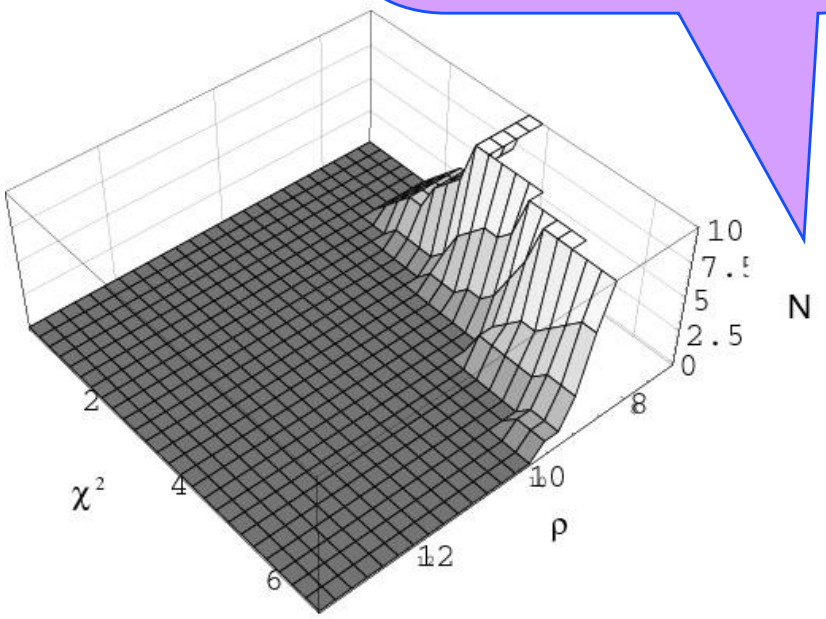
Tuning on playground data

- 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

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

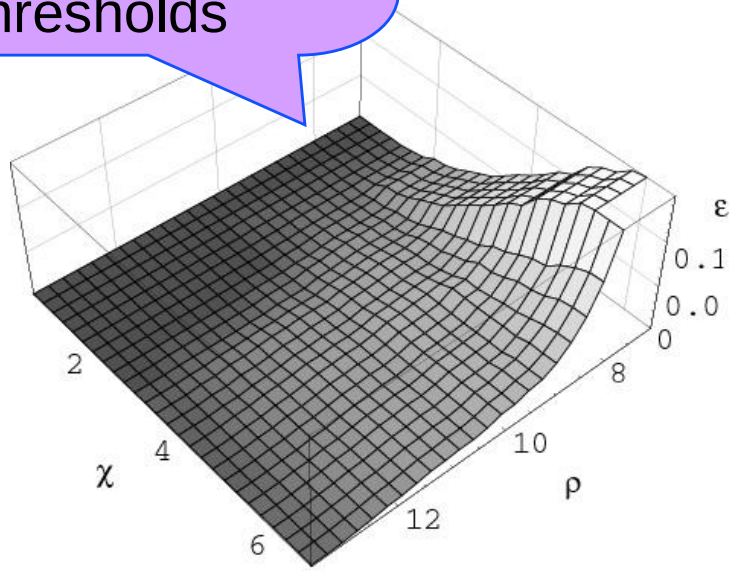
- Where the efficiency ε is the fraction of signals detectable from this population and T is observation time

Efficiency and number of events after MICH_CTRL and REFL_Q vet



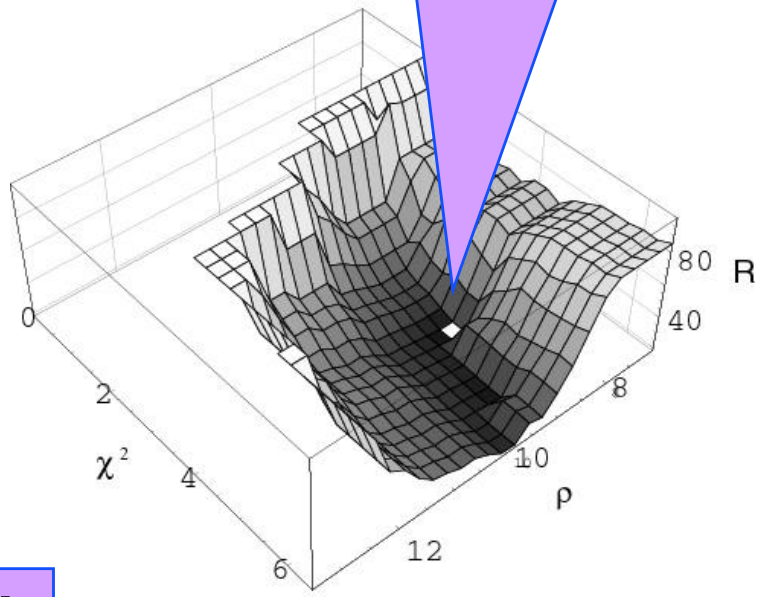
Efficiency and Rate Limit

Efficiency decreases wit decreasing CHIS and increasing SNR thresholds



Smallest rate limit at CHISQ < 4.5 and SNR > 9.

Rate < 1/kpc^3/Yr



Extrapolate to S1: **6 x 10^{-5} / kpc^3 /Yr**

What next?

- Choose method & thresholds to determine upper limit
- Run through all E7 data with DSO's
- Perform simulated injections on E7 data
- Determine an upper limit

- Follow up work
  - » What about ringdown and merger as further evidence of detection
  - » Full automation of the pipeline

- S1
  - » Hardware injections to test end-to-end