Status of Search for Compact Binary Coalescences During LIGO's Fifth Science Run

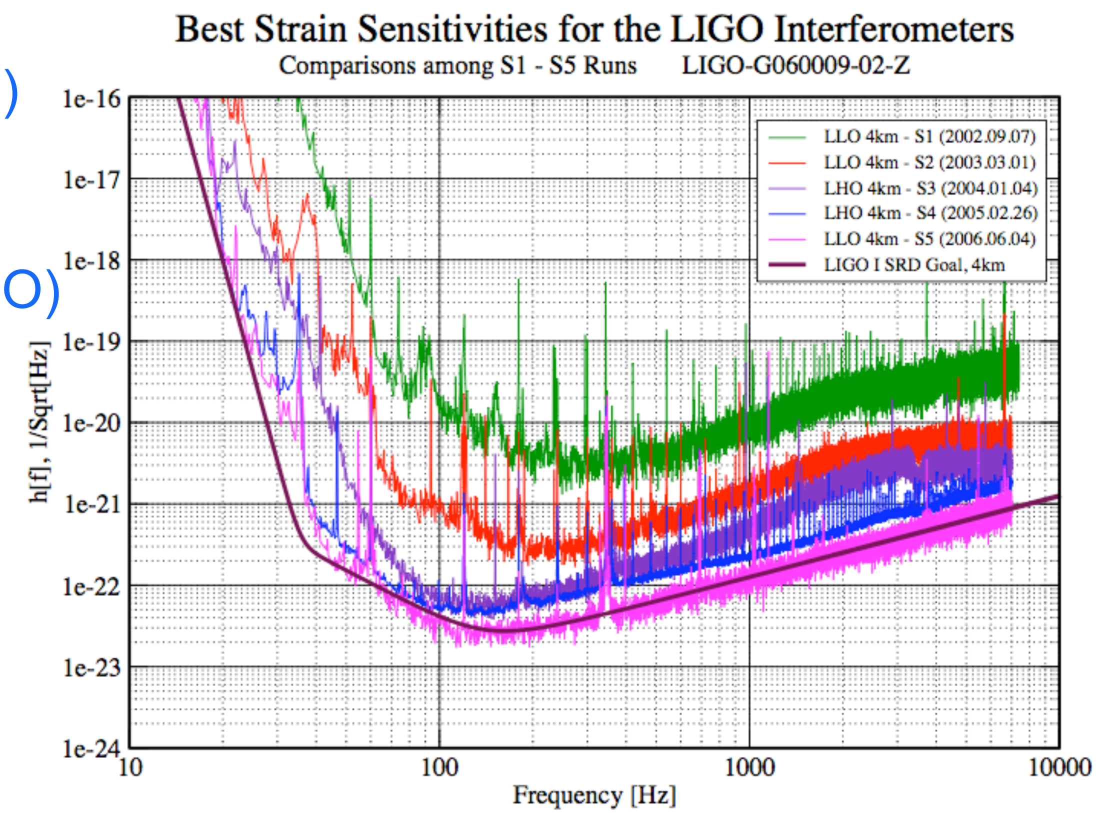
Drew Keppel[1]
for the LIGO Scientific Collaboration

[1]California Institute of Technology

APS April Meeting
Jacksonville, FL 16 April 2007
LIGO-G070225-00-Z

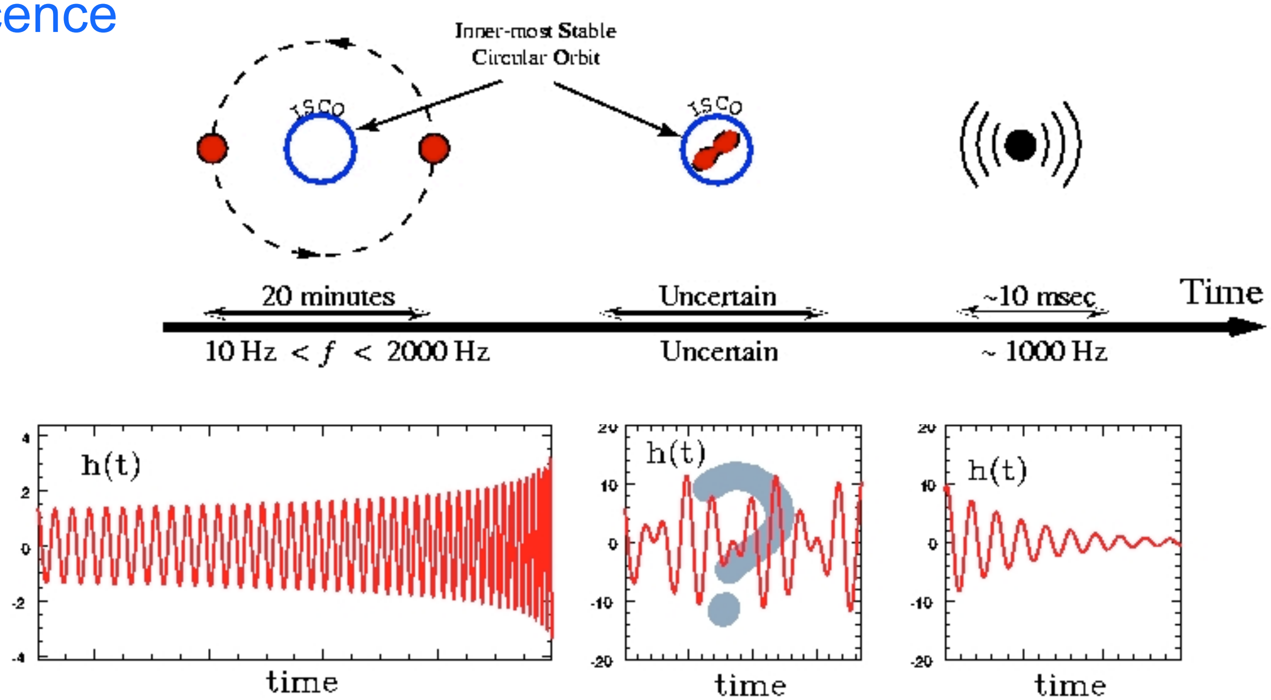
Fifth Science Run

- Hanford Observatory (LHO)
  - » 4k (H1)
  - » 2k (H2)
- Livingston Observatory (LLO)
  - » 4k (L1)
- S5
  - » LIGO's fifth science run
  - » Nov. 4th 2005 - Sept. 2007



Coalescing Binaries

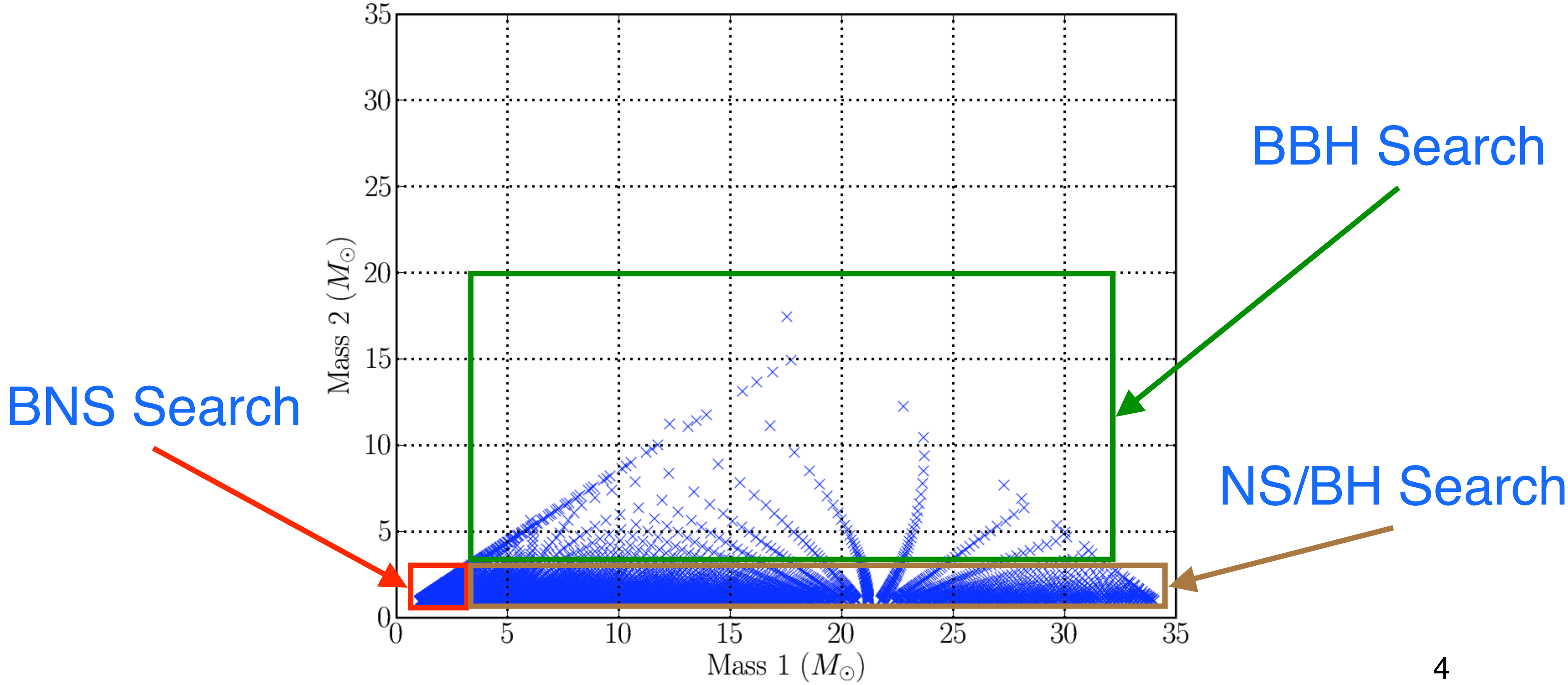
- LIGO is sensitive to gravitational waves from neutron star and black hole binaries
- In this search, we are only looking for the inspiral phase of the coalescence



Inspiral | Merger | Ringdown

Search Pipeline Overview

- Template Bank Generation
  - » Component masses from 1 - 34 $M_\odot$
  - » Maximum total mass of 35 $M_\odot$

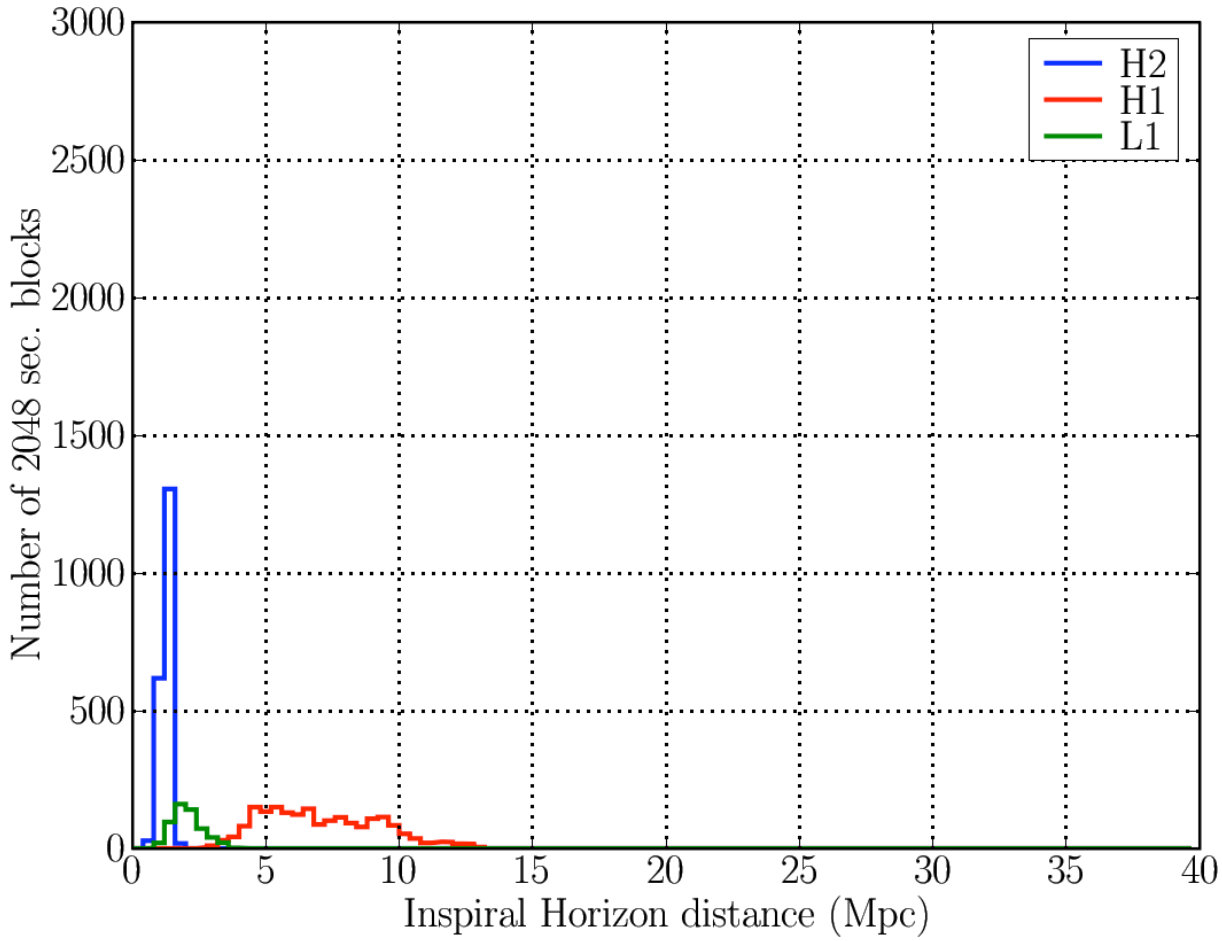


Search Pipeline Overview

- Template Bank Generation
  - Component masses from 1 - 34 $M_{\odot}$
  - Maximum total mass of 35 $M_{\odot}$
- Matched filter search using second order post-Newtonian templates
- Apply vetoes
  - Signal based vetoes
  - Instrumental vetoes
- Apply time, mass, (amplitude) consistency checks
  - Ensure trigger is present in at least two LIGO detectors
  - Leaves us with GW signals as well as accidental coincidences (our background)
- Follow up event candidates remaining at end of pipeline
  - Examine auxiliary channels (e.g. seismic, magnetic, etc.)
  - Extract coherent information from GW signal

Inspiral Horizon Distance

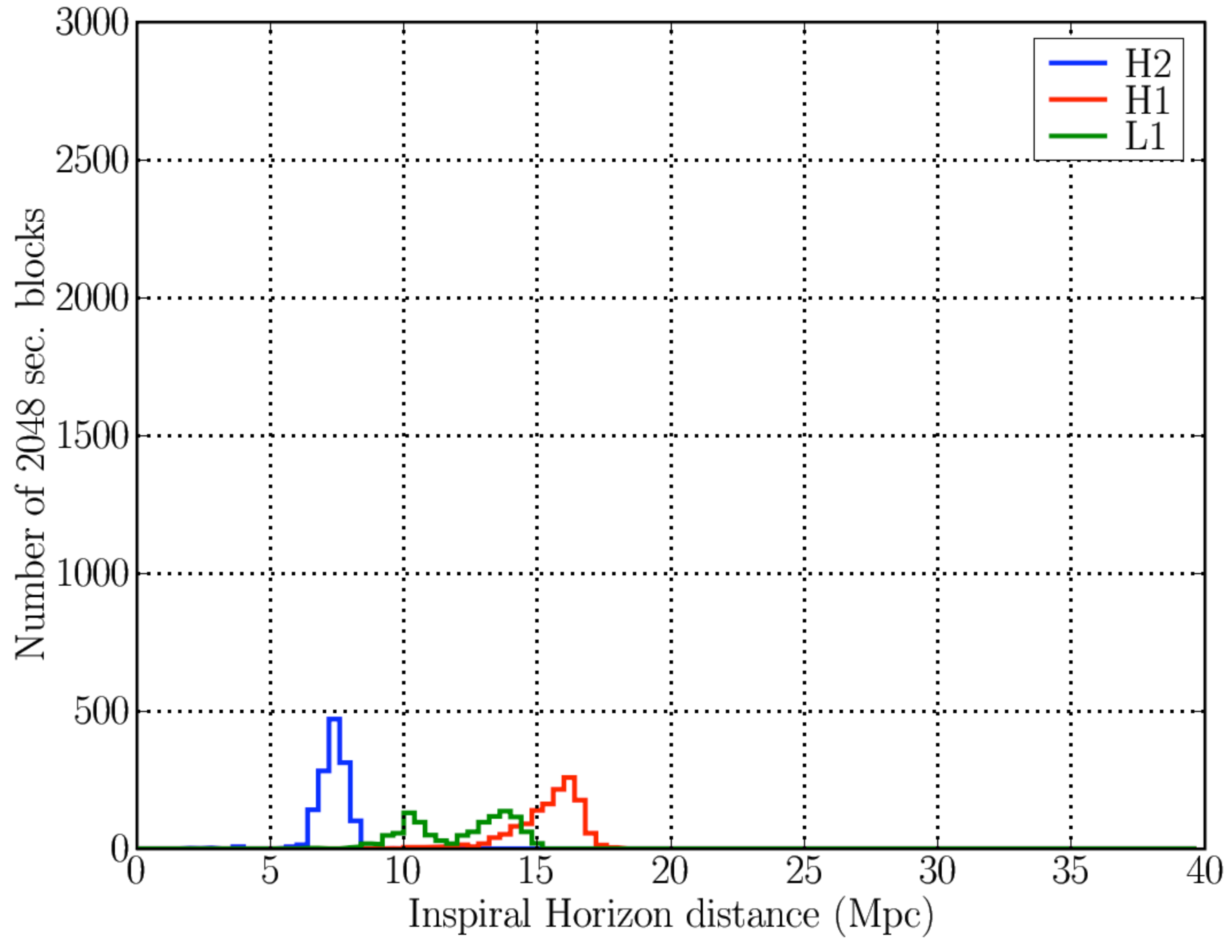
Distance to optimally oriented 1.4,1.4 solar mass BNS at SNR = 8



S3 Science Run
Oct 31, 2003 -
Jan 9, 2004

Inspiral Horizon Distance

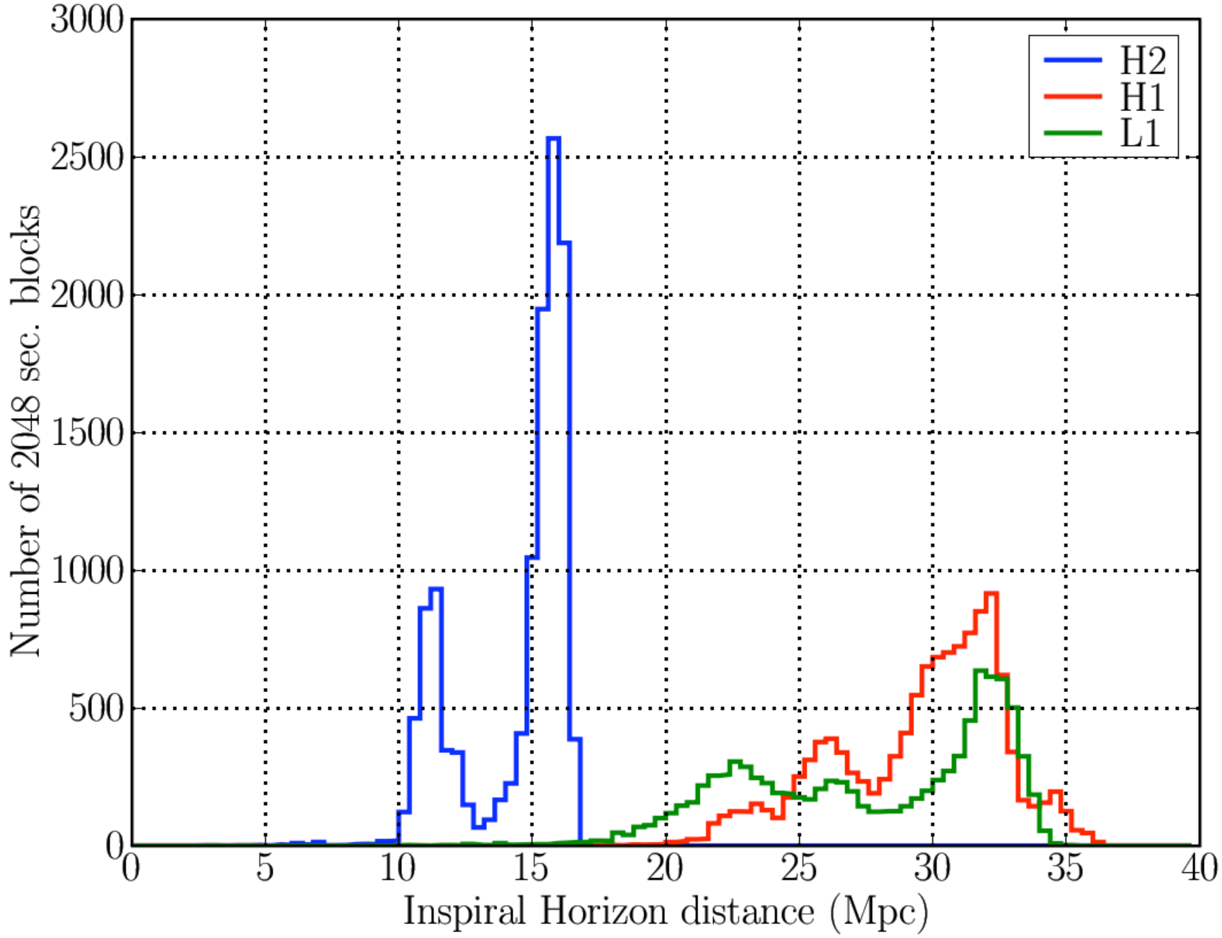
Distance to optimally oriented 1.4,1.4 solar mass BNS at SNR = 8



S4 Science Run
Feb 22, 2005 -
March 23, 2005

Inspiral Horizon Distance

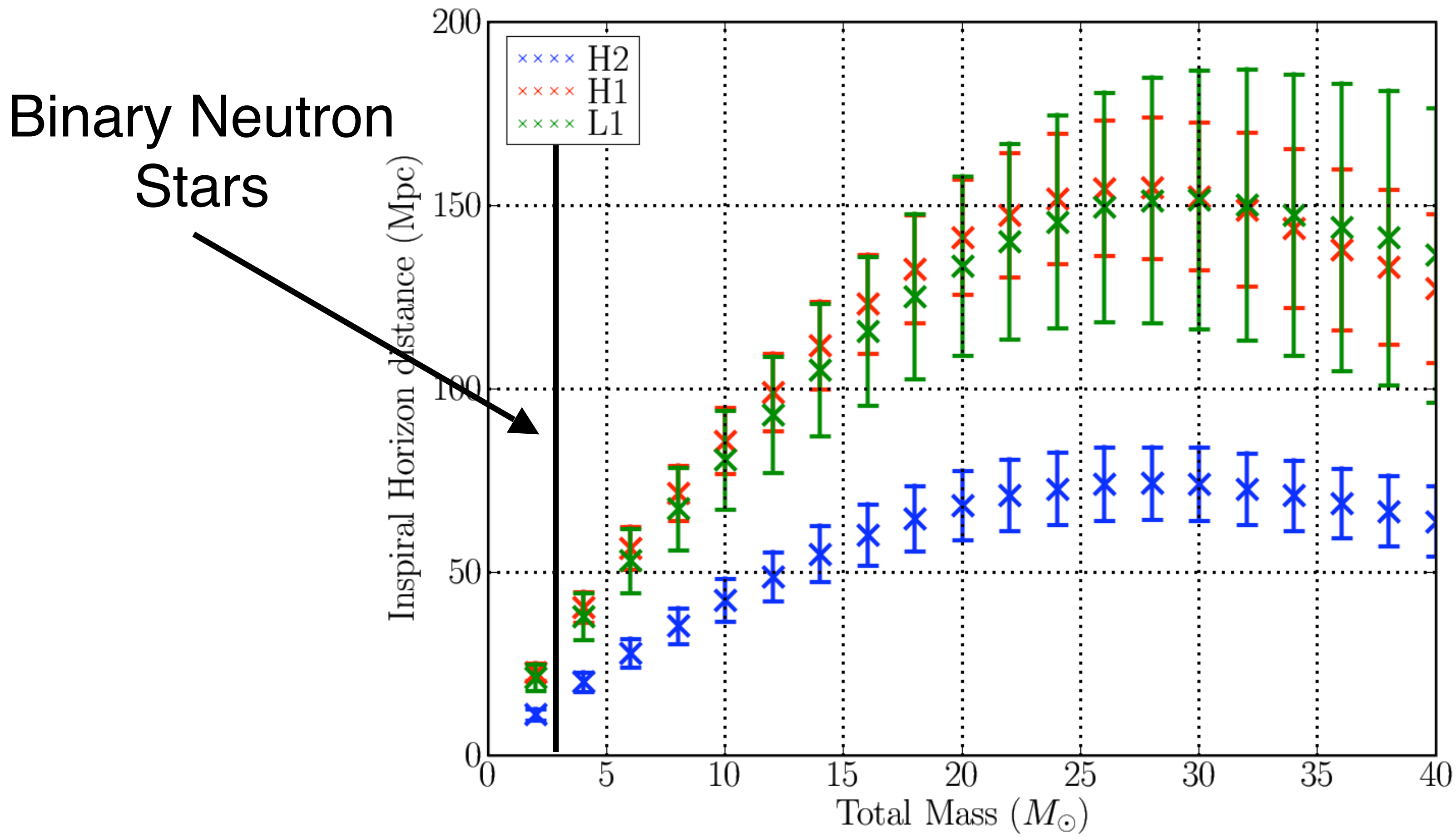
Distance to optimally oriented 1.4,1.4 solar mass BNS at SNR = 8



First Year
S5 Science Run
Nov 4, 2005 -
Nov 14, 2006

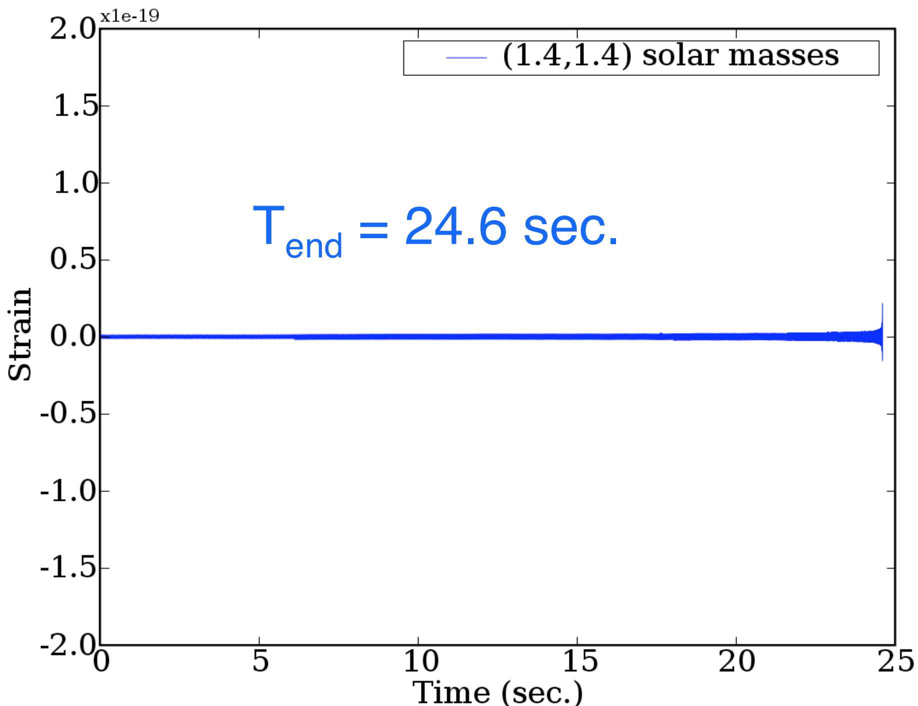
Horizon Distance vs. Mass

- Strength of signal highly dependent on mass of binaries

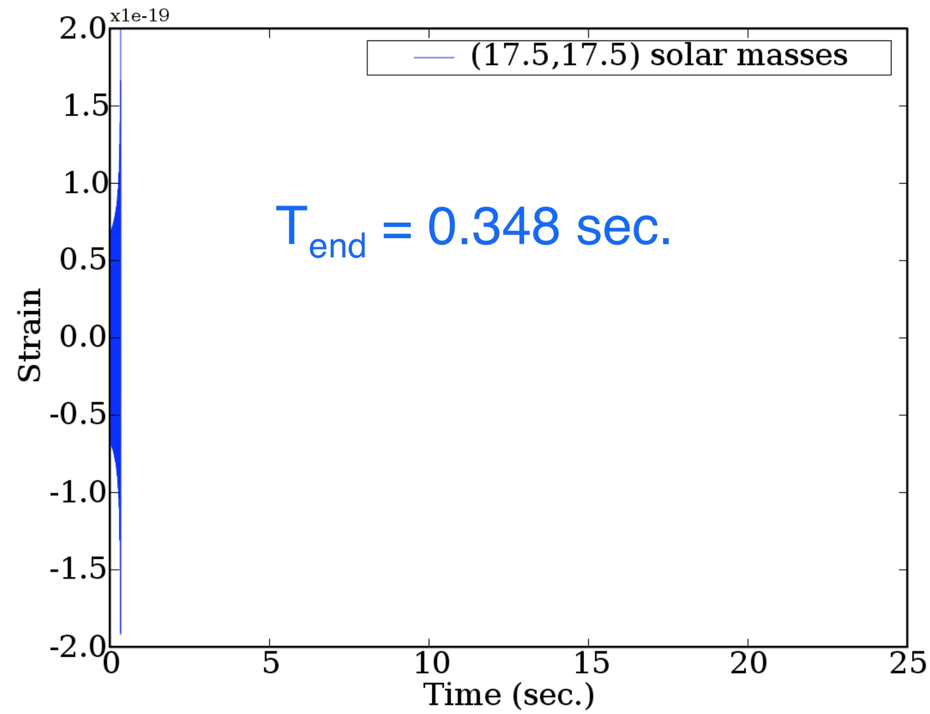


Background Triggers from Playground Data

Mass Region
$M_{chirp} < 2.0$



Mass Region
$M_{chirp} > 8.0$



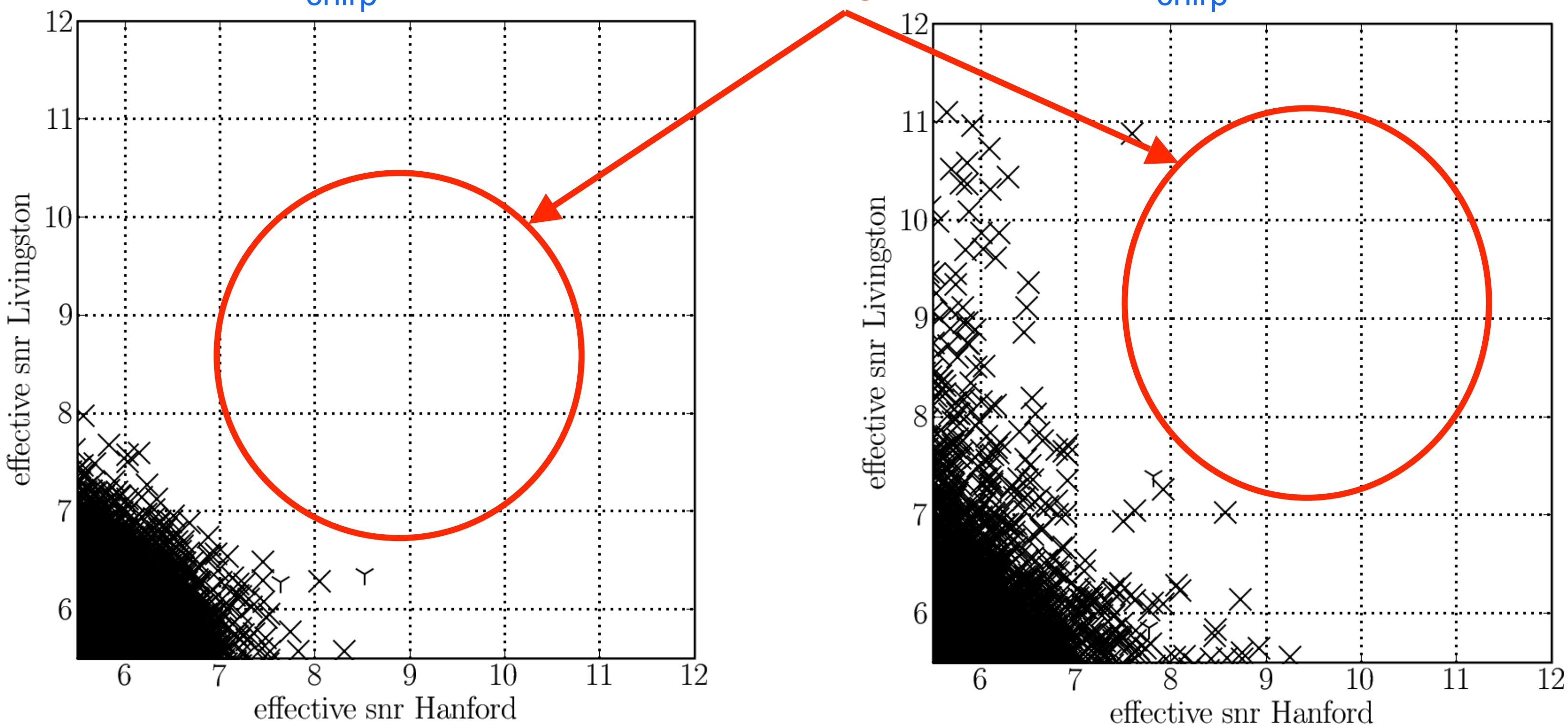
$$M_{chirp} = \eta^{3/5} M_{total} \qquad \eta = \frac{m_1 m_2}{(m_1+m_2)^2}$$

Background Triggers from Playground Data

Mass Region $M_{chirp} < 2.0$

No Background!

Mass Region $M_{chirp} > 8.0$

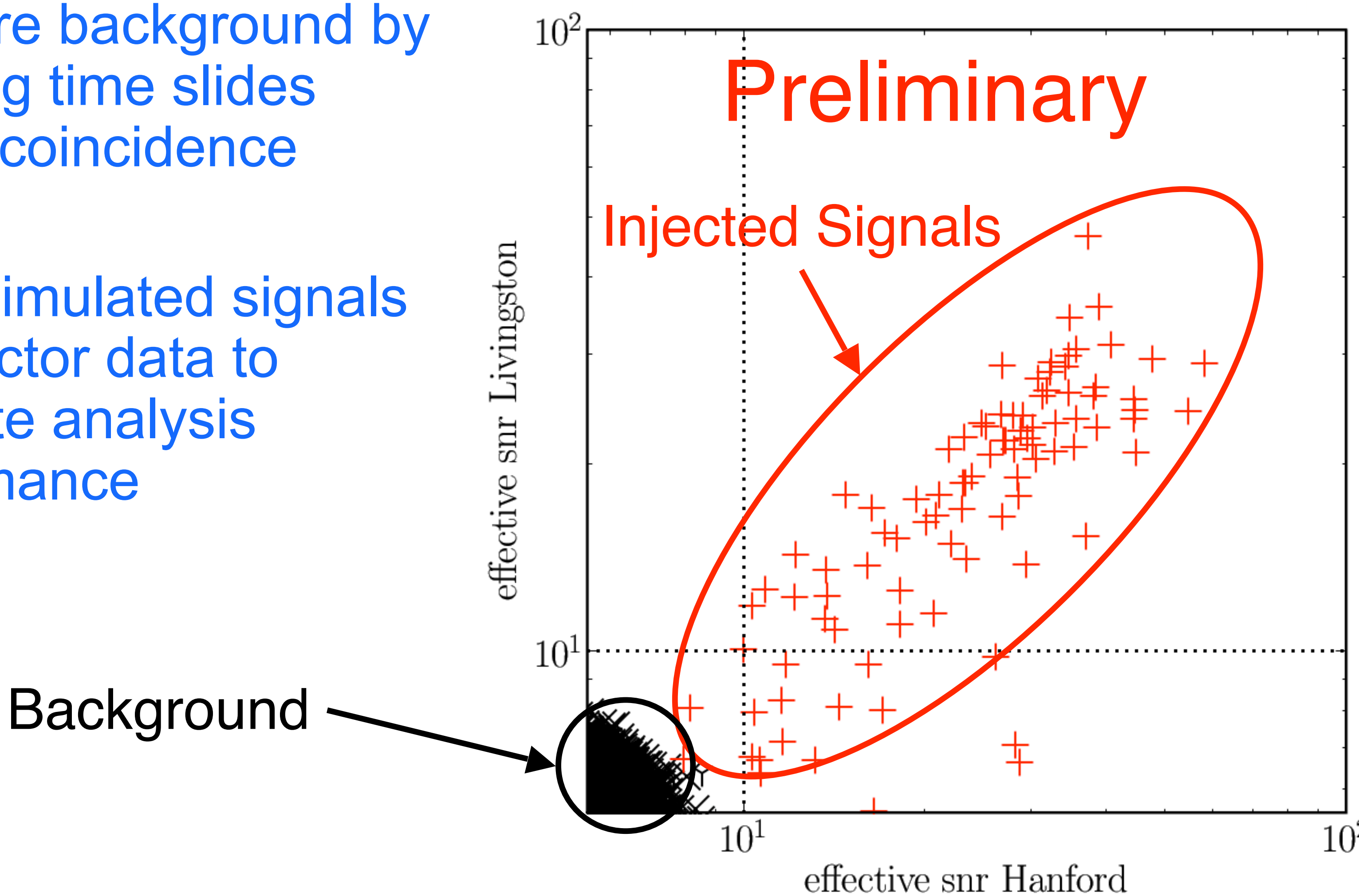


$$M_{chirp} = \eta^{3/5} M_{total} \qquad \eta = \frac{m_1 m_2}{(m_1+m_2)^2}$$

Preliminary

Accidental Coincidences and Simulated Signals

- Measure background by applying time slides before coincidence
- Inject simulated signals to detector data to evaluate analysis performance



Projected Sensitivity

Preliminary

Component Masses ($M_\odot$)	1.4,1.4	5,5	10,10
mean N_g ($L_{10,B}$)	140	2400	11000
T (yr)	0.77		
$(N_g \times T)^{-1}$ ($L_{10,B}^{-1} yr^{-1}$)	9×10^{-3}	5×10^{-4}	1×10^{-4}
Astrophysical Rate[1,2]	$10 - 170 \times 10^{-6}$	$0.06 - 6 \times 10^{-6}$	

- If no detection, we settle for making an upper limit
- First Year of S5 sensitive to ~ 100 MWEGs for BNS

$$1MWEG = 1.7L_{10,B}$$
$$1L_{10,B} = 10^{10}L_{\odot,Blue}$$

[1]V. Kalogera, et al., (2004), astro-ph/0312101v3; Model 6
[2]R. O'Shaughnessy et al., (2005), astro-ph/0504479v2

The End

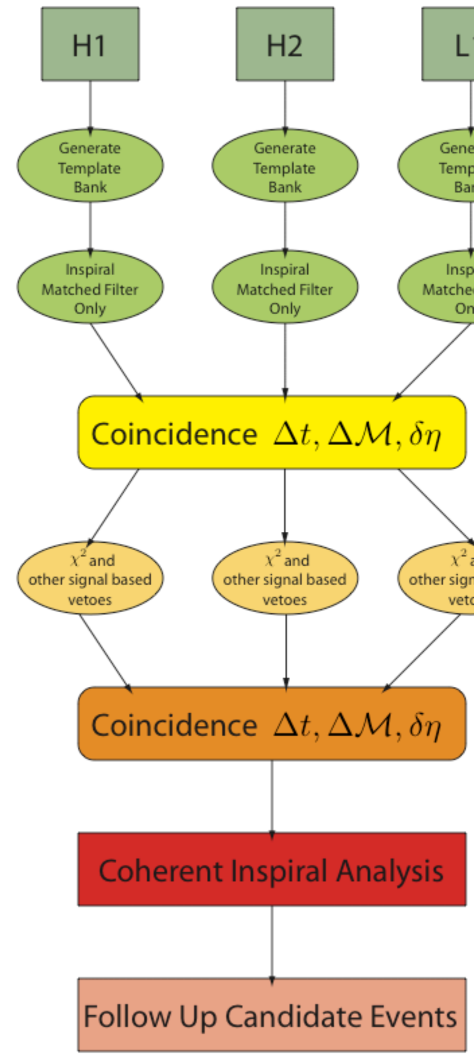
- For S3 / S4 Results, see T. Cokelaer, T11 14:06 (Gravitational Wave Astronomy)

Mass Dependent Background Estimations

- Sorting triggers by mass to give different backgrounds and foregrounds for different mass regions
  - » Allows different loudest events and injection recovery efficiencies for different mass regions
  - » Helps to prevent spurious glitches, which affect the higher mass portion of parameter space, from influencing quieter, lower mass portion of the parameter space

Search Pipeline Overview

- Search for binaries with components between 1 and 35 solar masses
  - » Maximum total mass of 35 solar masses
  - » Use data from three LIGO detectors
- Matched filter search using second order post-Newtonian templates
  - » Generates first stage triggers
- Apply time, mass, (amplitude) coincidence
  - » Ensure trigger is present in at least 2 LIGO detectors
- Apply signal based vetoes e.g. χ^2
  - » Vetoes are expensive: applying after first coincidence saves CPU
- Re-apply coincidence to get candidate triggers
- Construct coherent inspiral statistic
- Follow up event candidates remaining at end of pipeline



Vetoes

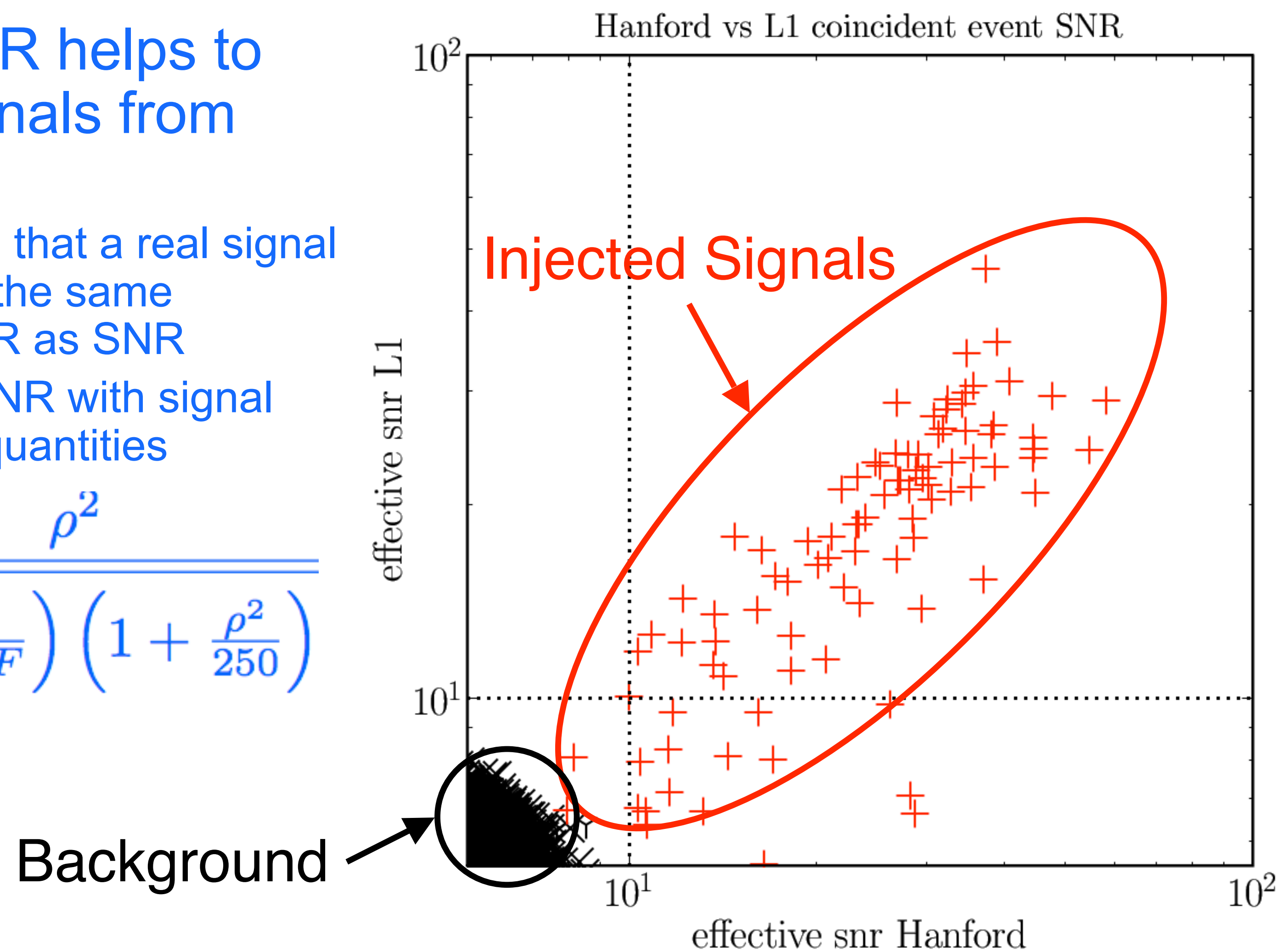
- Two types of Vetoes are used to eliminate background triggers
  - » Data Quality Vetoes
    - – Currently there is a preliminary list of vetoes for the first calendar year of S5
    - – Working with the LSC Burst group to generate a consistent set of vetoes
  - » Signal-Based Vetoes
    - – χ^2 veto (waveform consistency test)
    - – r^2 veto (χ^2 time above threshold)
    - – Effective distance and consistency cut

- Initial tuning for first calendar year very similar to tuning done for S5 Epoch 1 BNS and BBH searches
  - » We were doing something right!

Effective SNR

- Effective SNR helps to separate signals from background
  - » defined such that a real signal has roughly the same effective SNR as SNR
  - » Combines SNR with signal based veto quantities

$$\rho^2_{eff} = \frac{\rho^2}{\sqrt{\left(\frac{\chi^2}{DoF}\right)\left(1+\frac{\rho^2}{250}\right)}}$$



Follow Up Candidates

- We follow up significant triggers lying above our background

- Types of follow ups:
  - » Time - Frequency Maps of GW Channel and Physical Environment Channels
  - » Coherent Analysis
  - » Null-Stream Analysis
  - » Markov Chain Monte Carlo Parameter Estimation
  - » Inspiral-Merger-Ringdown Coherent Coincidence