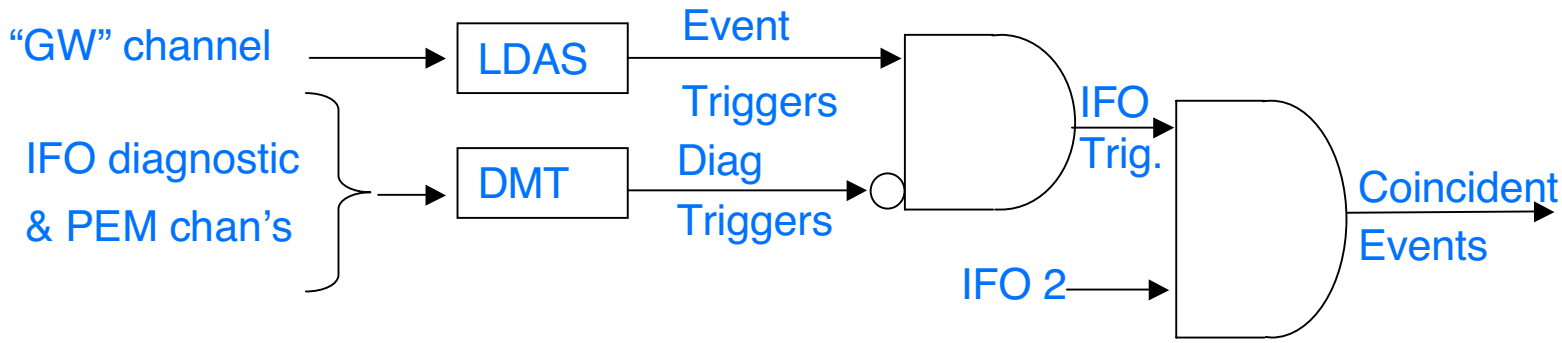
Searching for Gravitational Wave Bursts: An Overview

Sam Finn, Erik Katsavounidis and Peter Saulson for the “Burst Group”

Goals

- Search for gravitational wave bursts of unknown origin
  - » And, consequently, unknown waveform and/or spectrum
- Search for gravitational wave bursts associated with GRBs
  - » Unknown waveform, spectrum (Finn et al. Phys.Rev. D60 (1999) 12110)
- Anticipated form of results
  - » Bound on rate of fixed-strain events v. strength
    - – Nominal sgnal model: fixed-strength 1 ms width Gaussian pulse “sources” distributed on sphere surrounding Earth
  - » Bound rate of cosmic gravitational wave bursts (v. strength)
    - – Nominal signal model:fixed strength 1 ms width Gaussian pulse distributed according to galactic model
  - » Bound gravitational wave burst strengths coincident with gamma-ray bursts
    - – No signal model: focus on inter-detector cross-correlation immediately preceding GRB

Data processing pipeline



- *Processing + Interpretation = Analysis*
- Nomenclature
  - » Diagnostic trigger: indicator for instrumental artifacts
  - » Event trigger: indicator for gravitational wave events
  - » IFO trigger: event triggers not vetoed
  - » Coincident events: "simultaneous" IFO triggers
- Methodology
  - » Learn on playground, execute on remainder

Burst Analysis Team

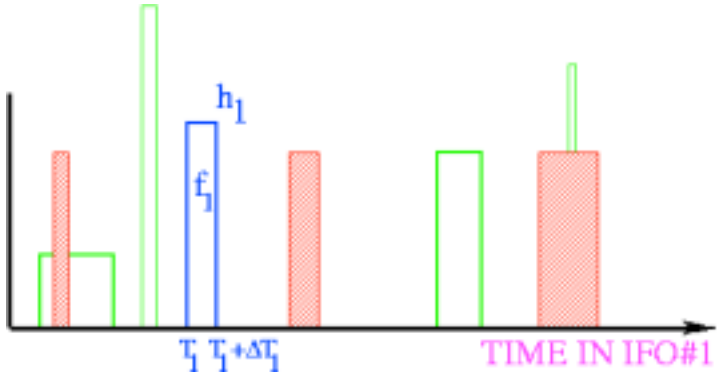
- Multi-institution, LSC led team effort
  - » Tight LIGO Lab/LSC integration
  - » Cooperation & shared responsibilities across institutions
- Major contributions:
  - » Leads: PSU, Syracuse
  - » Event trigger generation: LIGO/CIT, LLO, LSU, LIGO/MIT, PSU, UWM
  - » Veto trigger generation: LIGO/CIT, LHO, LIGO/MIT, Oregon, Syracuse
  - » Veto & Coincidence analysis: LHO, LIGO/MIT, Oregon, PSU
  - » Simulations: LIGO/CIT
  - » Interpretation: PSU, Syracuse
  - » GEO data integration: GEO, LIGO/MIT, PSU, Syracuse

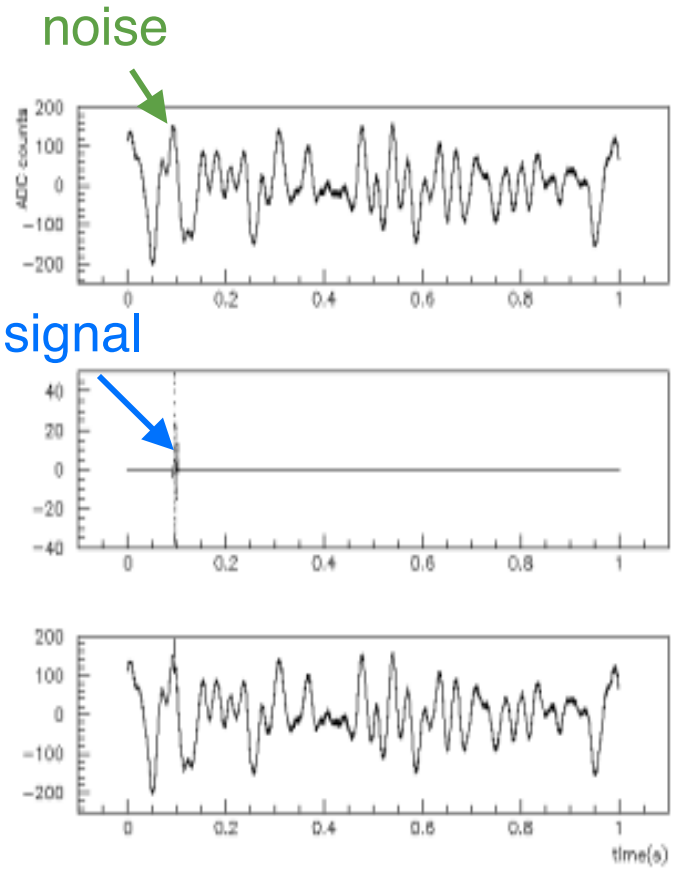
Event Trigger Generation

- How to search for GWBs of unknown character?
  - » Establish a meaningful statistic and look for outliers
- "Slope"
  - » Evaluate "best line" through interval τ (~1 ms) of data. When/while slope exceeds threshold generate a trigger. (Pradier et al. Phys.Rev. D63 (2001) 04200)
- "TFCluster"
  - » Create time-frequency plane of short-time DFTs. Search for clusters of bins with excess amplitude (Sylvestre, accepted Phys. Rev. D)
- Two in development
  - » "Power"
    - – Like TFCluster, but focused on clusters of particular shape (Anderson et al., Phys.Rev. D63 (2001) 042003)
  - » BlockNormal
    - – Change-point analysis: look for changes in time of mean, variance of data as signal of GWB onset (Finn & Stuver, in progress)

A sample burst search

- classical problem of extraction of signal in presence of noise
- signal morphology: unknown
- generate candidate event lists and characterize them
- apply diagnostic vetoes

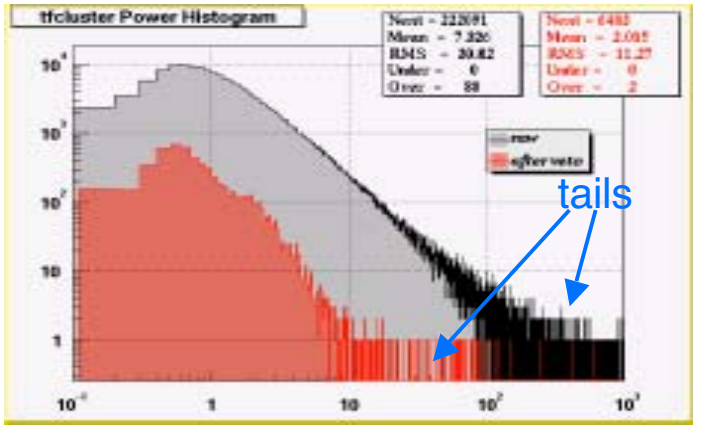


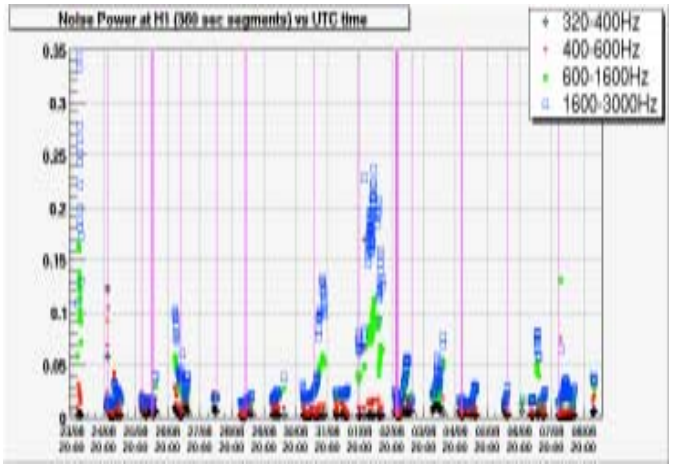


LIGO-G020483-00-Z

Coincidence: purpose

- Noise always generates false signal events
  - » Set threshold to acceptable false rate
  - » Trade: better false rate, worse sensitivity to real signals
  - » Tails, non-stationarity drive threshold up for same false rate
- Real signal events are correlated across detectors
  - » (almost) all false events are not
- Require “coincidence” between IFOs to increase sensitivity at fixed false rate

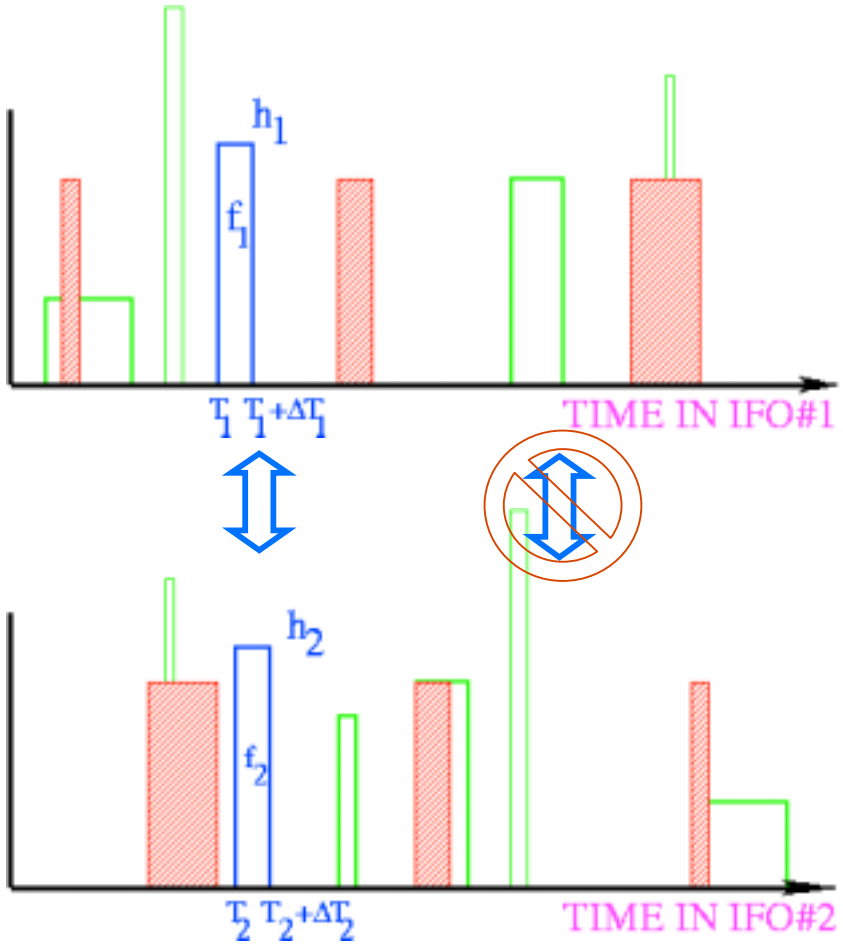




LIGO-G020483-00-Z

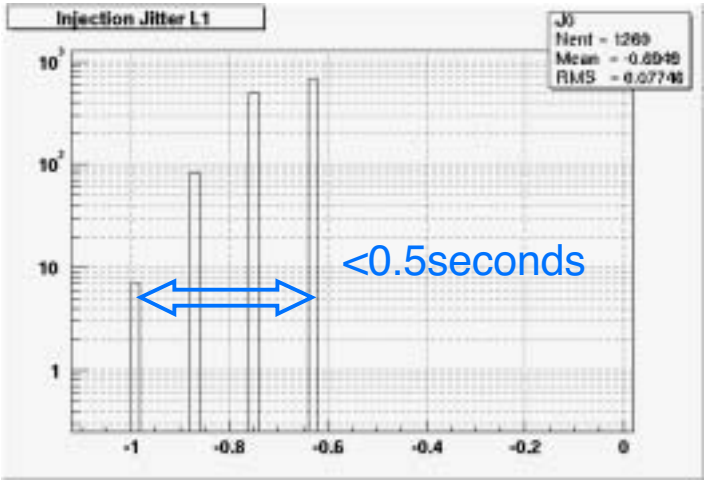
Coincidence Analysis

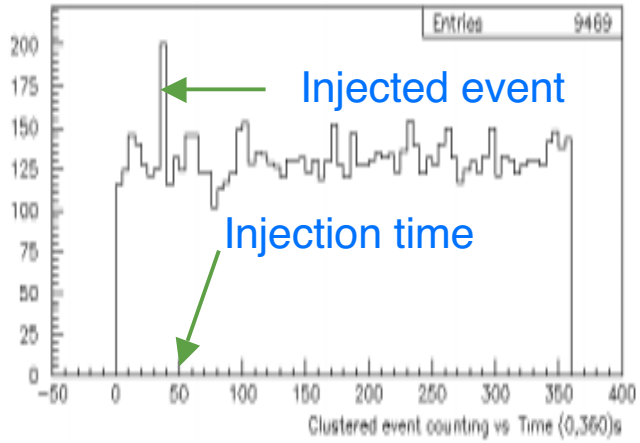
- bring together event lists from other IFOs
- basic assumption: consistent with a plane wavefront incident on network detectors
- use temporal coincidence
- correlate extracted features of candidate bursts:
  - » strength (power, strain, spectra)
  - » time-frequency features (central frequency, bandwidth, duration)
  - » cross-correlation of raw time series



Issues for a Coincidence Analysis

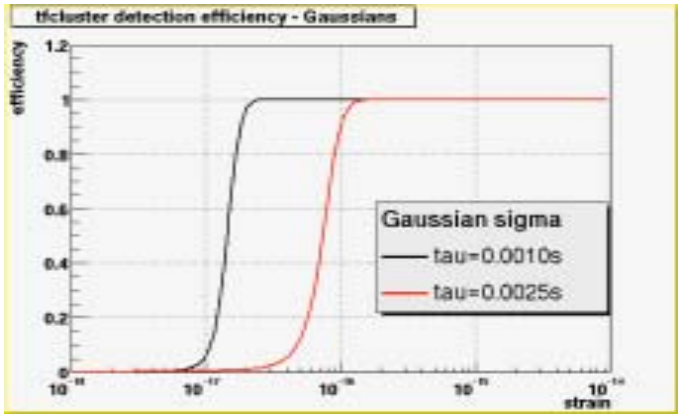
- define temporal coincidence
  - » limited by resolution of spectrograms and time-domain fits
  - » intrinsic travel time between sites (LLO-LHO ~10ms)
- use software and hardware injections to establish cuts
  - » Time, amplitude, other extracted features match
- need response functions to translate ADC counts to mirror motion and v.v.
  - » very important
  - » changes with time!





Issues for a Coincidence Analysis

- establish IFO-IFO (-IFO…) end-to-end coincidence pipeline and apply on:
  - » simulated data (injections) to measure detection efficiencies
  - » real data to extract coincidence
- if coincidences are of astrophysical origin, they vanish after random time-shifts => use this to estimate the background
- IFO-IFO:2(3) IFO-IFO-IFO 0(0)



Number of IFO-IFO coincidences

"Nov 1" Burst Group S1 analysis Goals

- Search for bursts of unknown origin (using data from the 3 LIGO ifos.)
  - » Give upper limit for bursts of fixed strength, in rate-strength plane.
- Search for bursts associated with gamma-ray bursts.
- Make first pass at burst search in GEO data.
  - » Joint GEO/LIGO burst search, through formation of temporal coincidences.

Status of “Nov 1” analysis

- Unknown origin burst search
  - » Calibrated on playground data
  - » Veto strategy designed
  - » Full data set has been run through trigger generators
- Gamma-ray burst search
  - » Cross-correlation software tested
  - » Testing to understand statistics of cross-correlation in data
- GEO/LIGO analysis
  - » Subset of GEO data analyzed with LIGO software and with GEO software
  - » Temporal coincidences to be made this week
- Report writing this weekend!