Toward the First LSC-VIRGO Joint GW Search for Binary Neutron Stars

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- Project1a (2005):
  - 3 hours of simulated H1 and V1 detector noise
  - A variety of simulated waveforms:Binary Neutron Star inspirals, unmodeled Bursts.
  - Applied LSC and Virgo search algorithms
  - Characterized and compared search algorithm performance.

- Project1b (2006):
  - 24 hours of simulated triple coincident (H1, L1, and V1) data
  - Injection populations of simulated waveforms.
  - Demonstrated benefit of union of two detector networks
  - Demonstrated sky position reconstruction and astrophysical parameter estimation

- Project2a (2006):
  - First exchange of real data occurred on 2006 June 15
  - ~3 hours of non-coincident L1, H1, and V1 data including:
    - Periods of lock loss
    - Periods of good and bad data quality
    - Hardware injections of burst and inspiral waveforms
  - Data quality and veto segment information also exchanged
  - Applied LSC and Virgo search algorithms

- The LIGO Scientific and Virgo collaborations have entered into an agreement to jointly analyse data from the GEO, LIGO, and Virgo detectors
- Sharing of data started in May 2007 with Virgo's first long science run in coordination with LIGO's fifth science run

- Project2b:
  - To identify ***options*** and ***issues*** for the upcoming joint analysis of Binary Neutron Stars, 3 days of coincident data (February 2007) from Virgo's Week-End Science Run (WSR8) and LIGO's fifth science run were exchanged and analysed
  - The analysis of these data is ongoing. Here we report about the first steps for a possible use of the extended network including LIGO (H1, H2, L1) and Virgo (V1) detectors.

All the results presented are thus to be considered as **preliminary results**

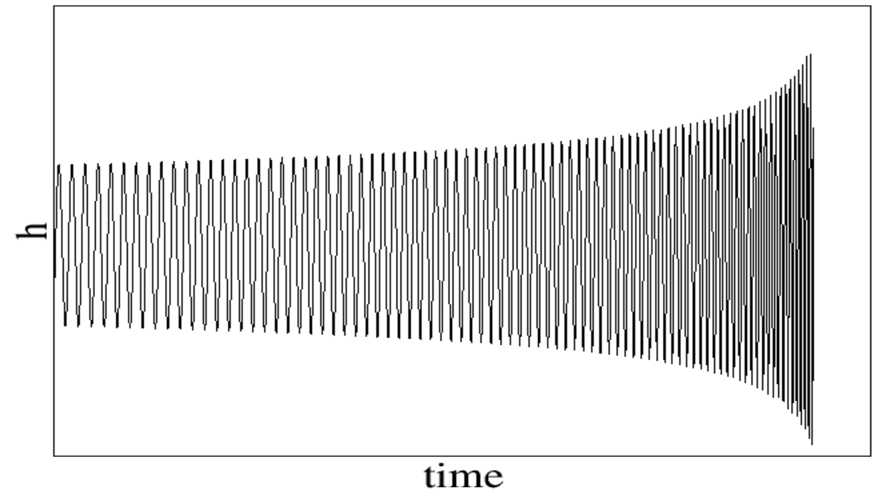
- Each collaboration has shared the *calibrated* channel h(t) and the data quality informations (***vetos***) necessary to identify the *good* time period to analyze
- The analysis has been focused on the search of Gravitational Waves originating from Coalescing Binary Neutron Stars (BNS)

- Virgo's *Multi-Band Template Analysis* pipeline was used
  - accurate models (***templates***) for these signals exist
  - it is then possible to construct a Template Bank including, to a chosen accuracy, the signals for the expected range of the BNS systems parameters

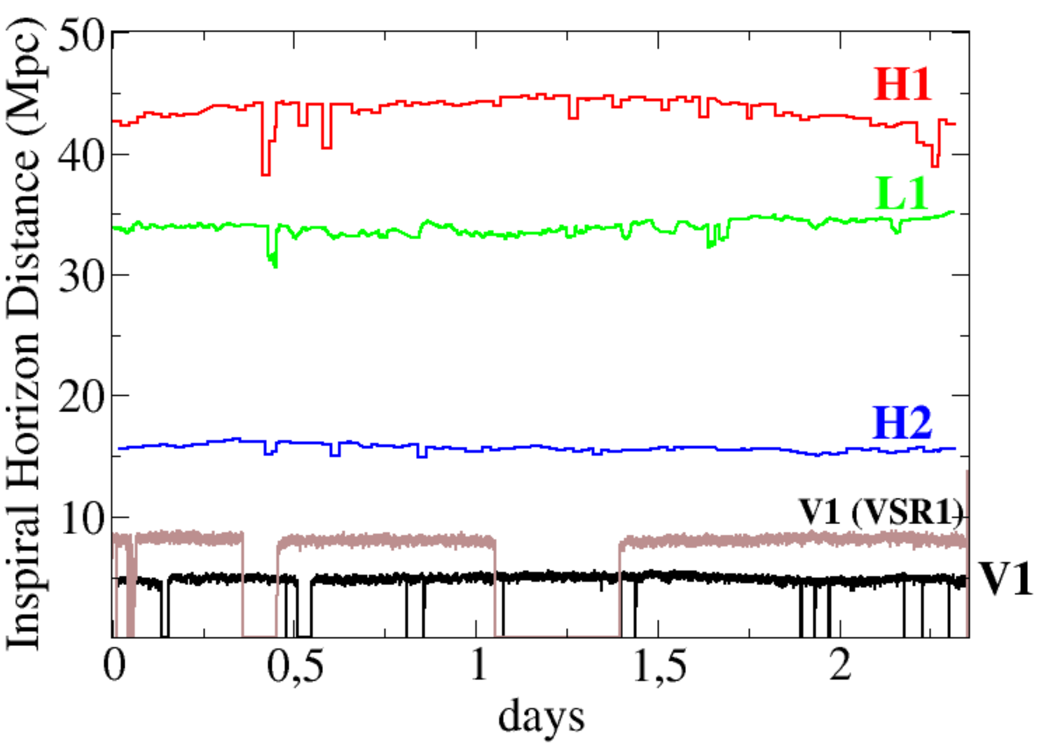
  normalized correlation of the templates from the Template Bank with the channel h(t) where the signal is possibly present is the output (***SNR***) of the pipeline

- This is the first presentation of MBTA analysis of real joint data
- LIGO pipeline and Virgo's *Merlino* pipeline will do the analysis too
- All the pipelines are under review by the two collaborations

- Neutron Stars' Masses = [1, 3] solar masses
- The signal is expected to enter in the Interferometers' frequency band during the last seconds (~10-50 s) before the coalescence

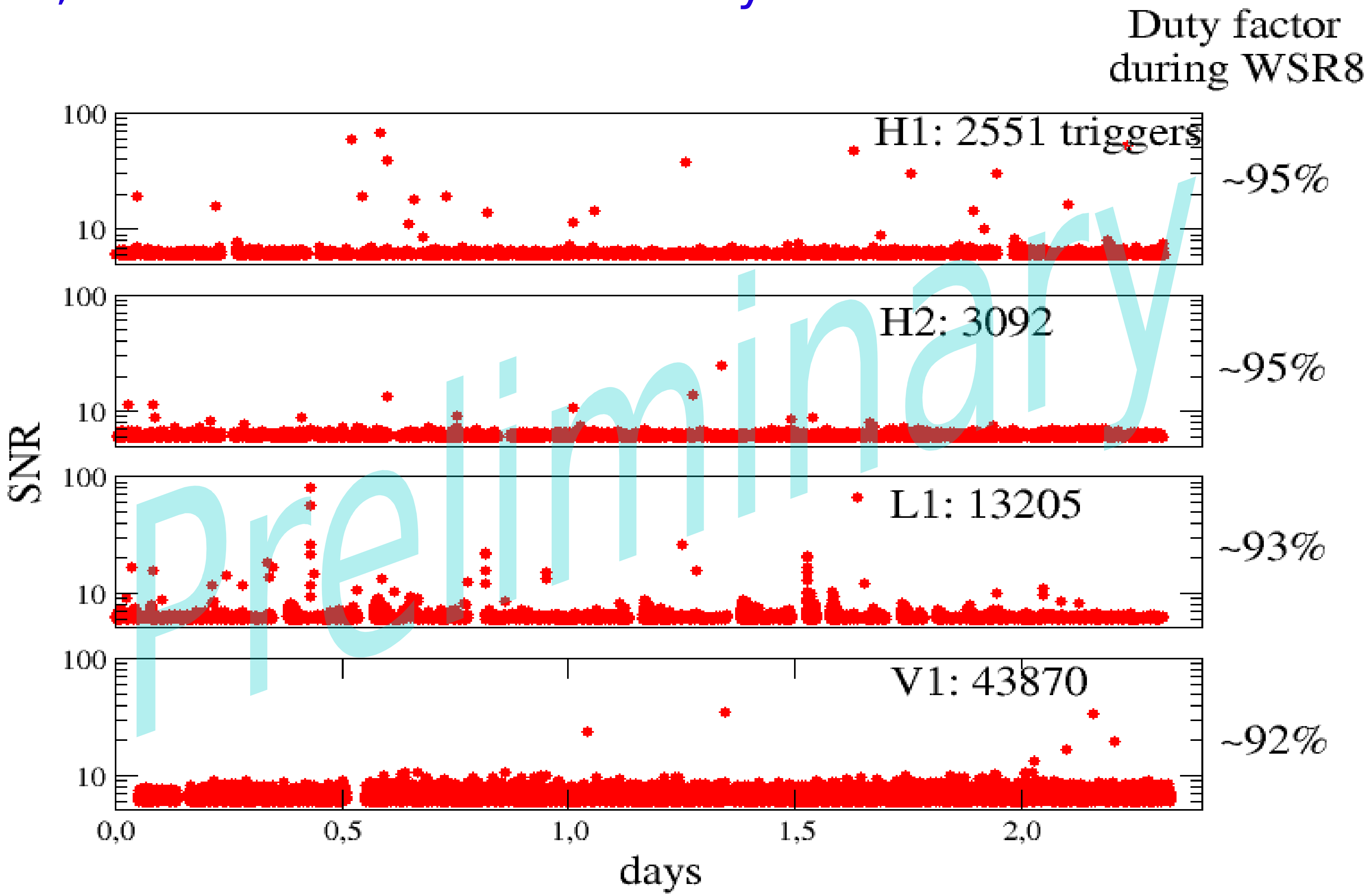


Distance to optimally oriented 1.4, 1.4 Mo BNS at SNR = 8



- During WSR8, the LIGO sensitivity to these signals is higher than Virgo's but, depending on the source sky position, it is still possible for Virgo to contribute to the signal's identification

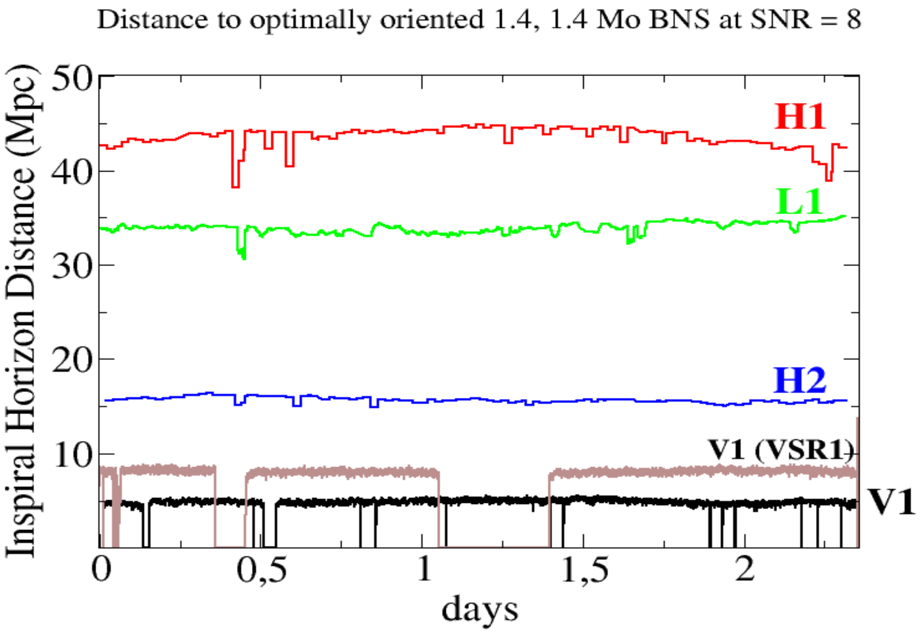
- ***Data cleaning***: after first-level vetoes, and SNR threshold of 6, data are far from stationary .....



- .... but before applying more specific cleaning procedures, we must be sure that they do not affect the detection efficiency

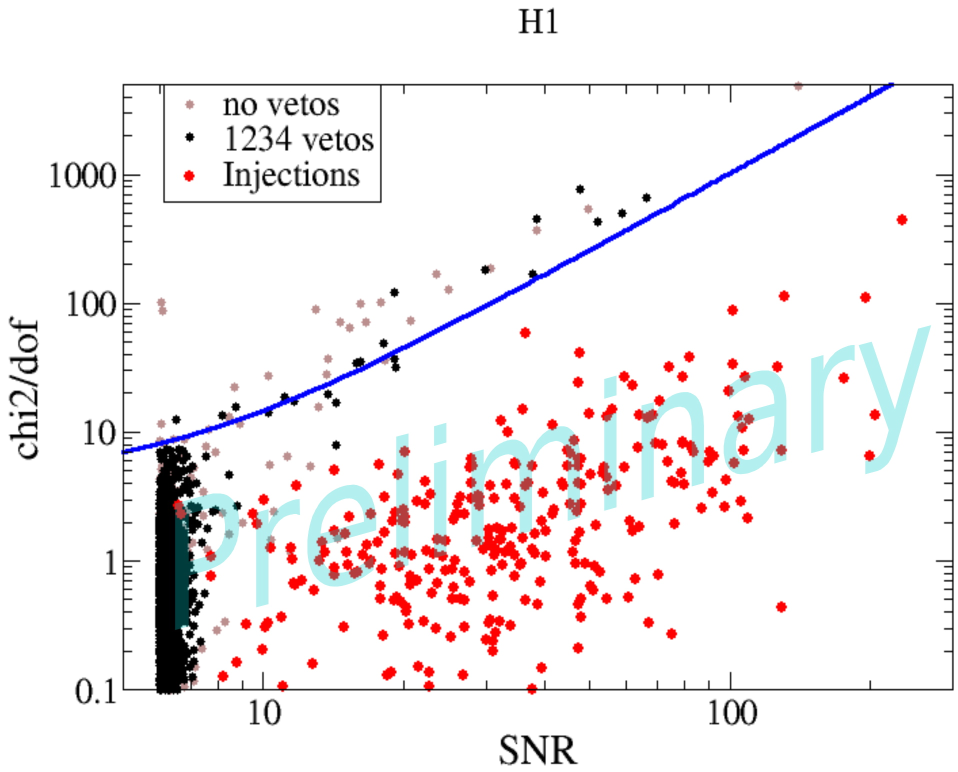
We coherently inject in the noise data simulated BNS signals:

- with different masses and BNS orbital parameters
- uniform distribution in a spherical volume of radius 5Mpc (well within LIGO's reach)

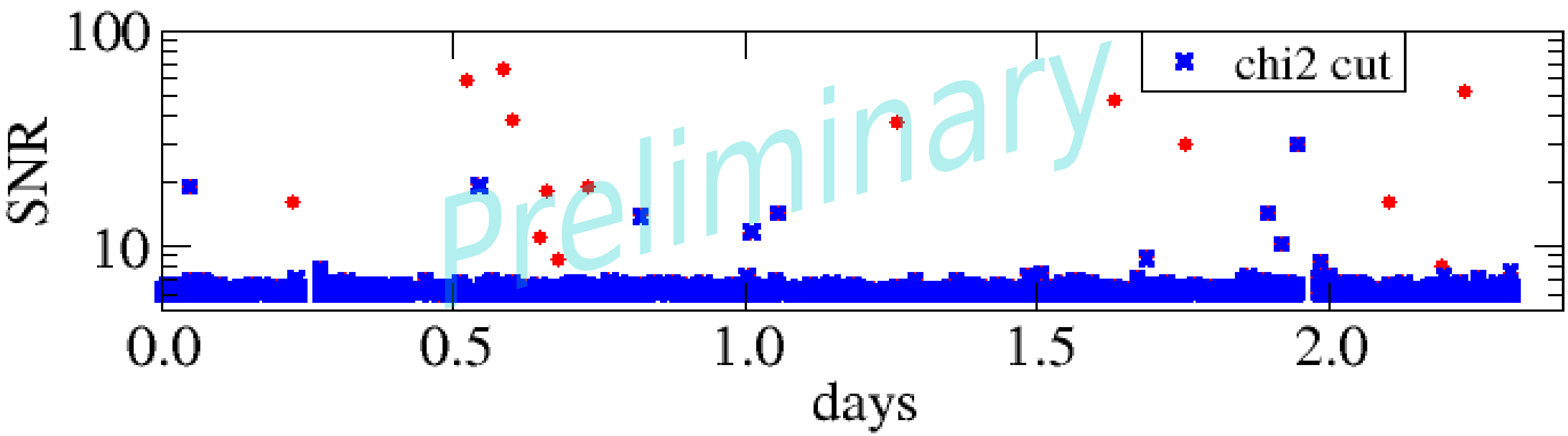


- The efficiencies for the ITFs reflect the their WSR8 sensitivity and stationarity: H1 has a nearly full efficiency, H2 and L1 have a less but high comparable efficiency; the efficiency of V1 is lower than the efficiency of LIGO's ITF.

..... we can then apply a signal-based two-bands χ^2 consistency check, which suppresses background noise in all ITFs,



- and clean the single ITF data:

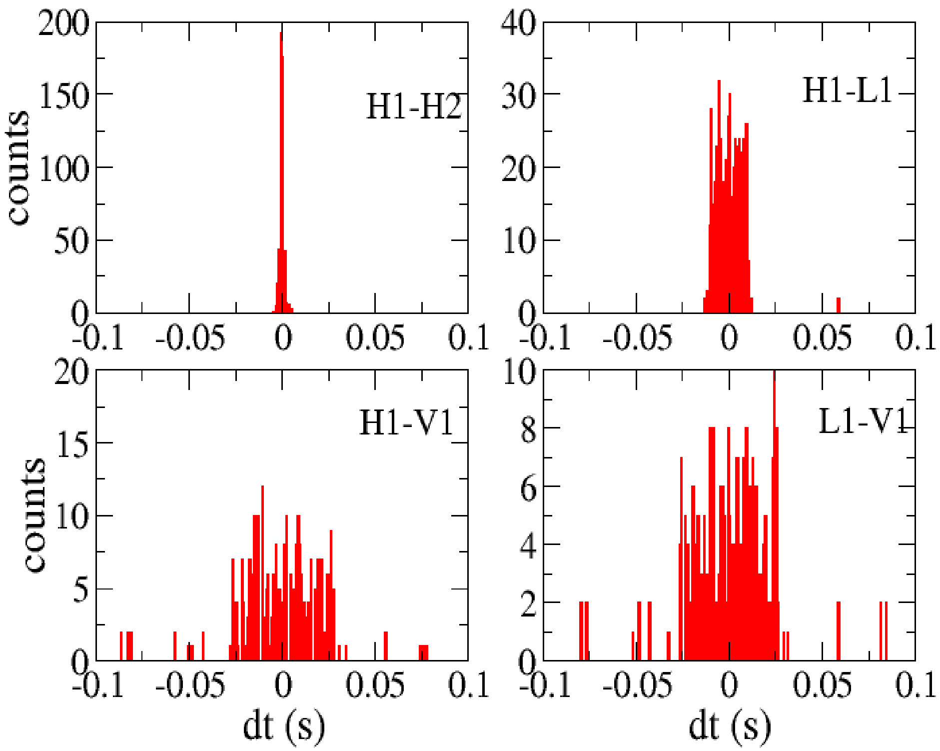


- Several network configurations can be considered:
  - OR of 6 pairs (H1-L1, H1-V1, H1-H2, ..)
  - OR of 4 triples (H1-H2-L1, H1-L1-V1, ..)
  - quadruple (H1-H2-L1-V1)

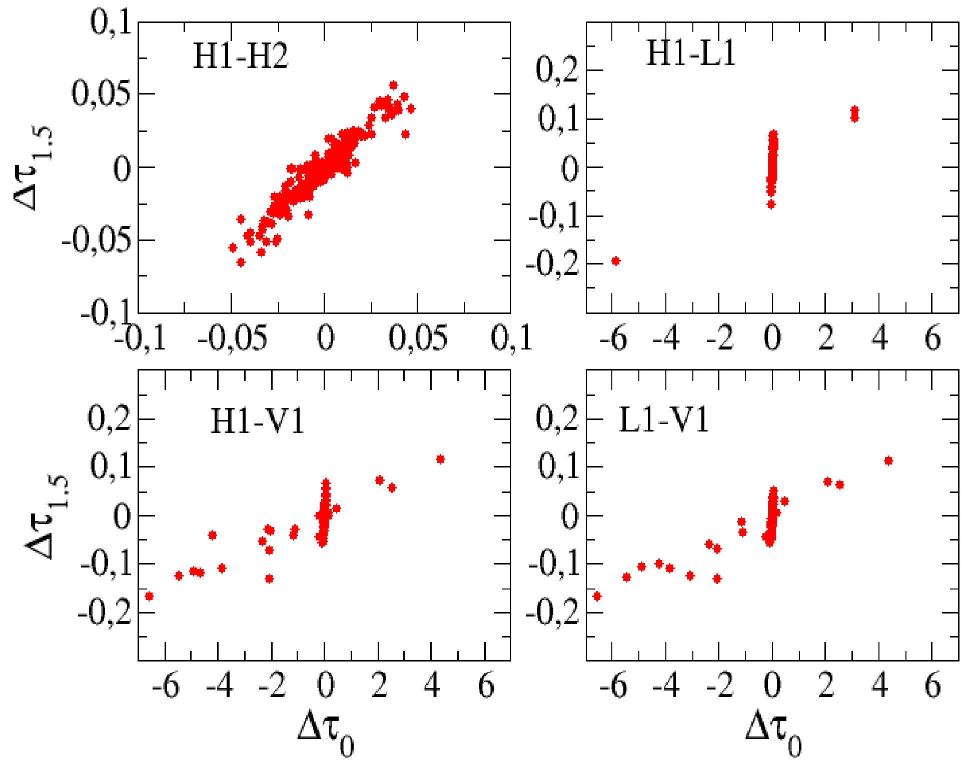
- While imposing stricter coincidence configurations increases the detection confidence, it can decrease the detection efficiency.

- Coincident network analysis requires accurate tuning of coincidence parameters (arrival times, masses, ..), in order to decrease accidentals without decreasing the detection efficiency ….. look again at the injections.

- Δt between injections arrival times:



- $\Delta\tau_0$ and $\Delta\tau_{1.5}$(functions of the two masses):



- Applying *loose* conditions on these coincidences:
  - reduce significantly the background for the H1-H2 pair
  - has little effect on the others pairs

- **Detection efficiencies of the network combinations:**
  - PAIRS:
    - The OR of the pairs has nearly full efficiency for the injected population
    - Pairs with Virgo see injections which are not seen by the LIGO-only pairs.
    - These injections can come from a sky position particularly favorable to Virgo with respect to LIGO detectors.
  - TRIPLES:
    - The OR of the triples detects ~75% of the injected population
    - To determine the source sky position, we need the signal to be seen by at least 3 non-co-located detectors:

      nearly a third of the injections has been detected by H1-L1-V1 or H2-L1-V1!

Actual Virgo sensitivity (**Virgo Science Run 1**) for BNS is a factor ~2 better than in WSR8

- Benefits of including Virgo in the forthcoming joint search for GW from BNS coalescences:
  - increase in detection efficiency for signals coming from sky locations particularly favorable for Virgo
  - possibility of determining the source sky position
  - increase in detection confidence

- Results from LIGO's and Merlino pipelines are forthcoming.
- Coherent analysis and Monte-Carlo-Markov-Chains analysis will also be used for source sky position and parameter estimation.

Full benefit will be reached when Enhanced-LIGO and Virgo+ will be working in network