# Status of the **LIGO-AURIGA** Joint Burst Analysis

F. Salemi
*Italy, INFN and University of Ferrara*
on behalf of
the AURIGA Collaboration and the LIGO Scientific Collaboration

Amaldi Conference - June 20-24, 2005

LIGO-G050671-00-Z

# Scope of this talk

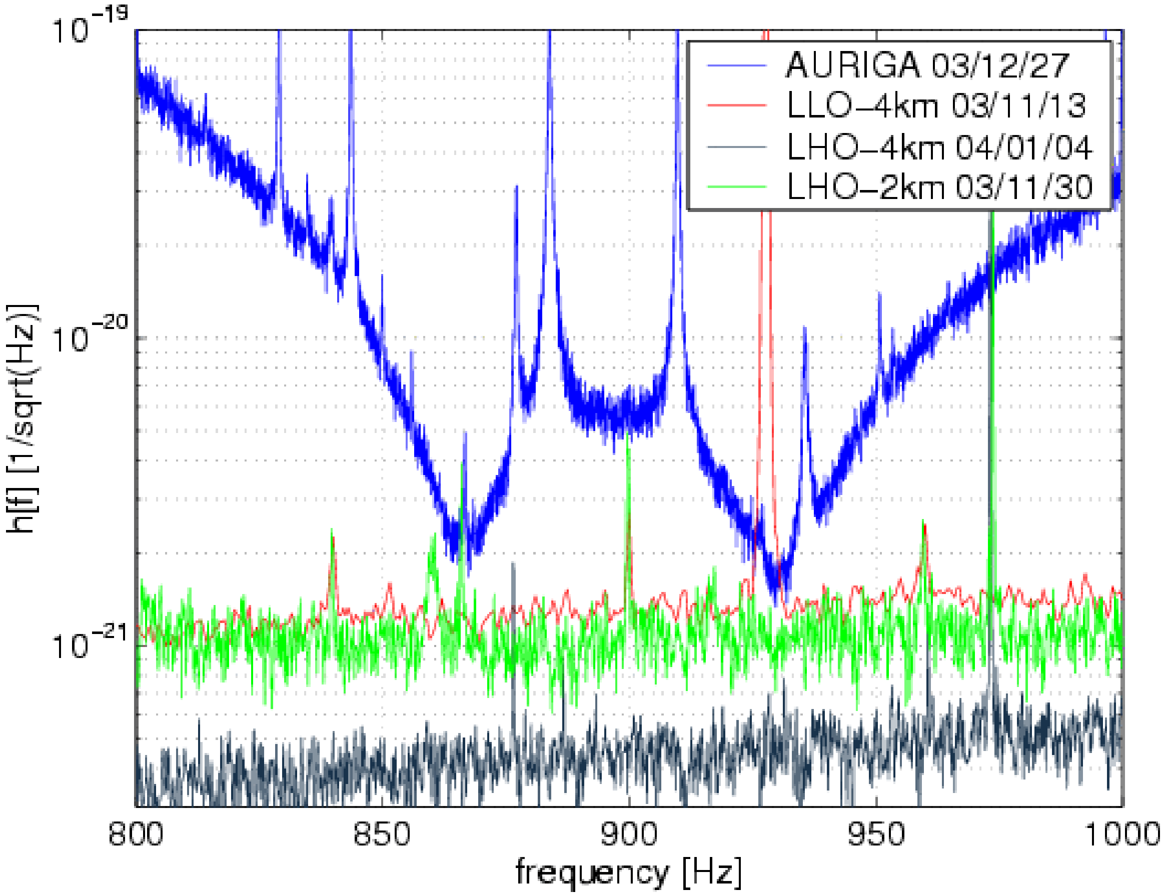
First LIGO-AURIGA coincidence search:
*setting up methodologies for joint observations between bars and interferometers*

LIGO S3 run: Oct 31 2003 – Jan 9 2004
AURIGA run 331: Dec 24 2003 – Jan 14 2004

- data selection and validation
- description of the tuning procedure for the network analysis and preliminary estimate of how the tuning affects detection efficiency and accidental coincidence background
- preliminary evaluation of the network efficiency via injections of simulated signals

# Sensitivity Spectra

single-sided PSD




Best performance during the 331 and the S3 run:

•LIGO S3: large rate of transients, noise variability

•AURIGA run 331: poor data quality (un-modeled excess noise)

Main scope of analysis of this data set: study of IFO-bar methodologies on actual data.

# Data Selection Criteria

1. LIGO's data selection criteria

    1. Applied all data quality flags selected for the S3 LIGO-only analysis (e.g. exclude periods of high seismic activity, dust in enclosures, timing errors, DAQ overflow)➔ LIGO data-analysis previous talk by Katsavounidis
    2. Require all three (two) interferometers in operation➔ triple (double) coincidence

2. The veto implemented on the AURIGA side to compensate run-specific effects and the correspondent loss in live time

    1. Wide-band glitches 4%
    2. Epoch veto based on Monte Carlo detection efficiency 42%

# Observation time

LIGO S3 run: Oct 31 2003 – Jan 9 2004

AURIGA run 331: Dec 24 2003 – Jan 14 2004

| | |
|---|---|
| Coincident Run | 389 hr |
| Coincidence run (after removal of 10% playground data set) | 352 hr |

Exchanged data:

| | |
|---|---|
| LIGO H1-H2-L1 triple-coincidence (with DQ flags) (-84%) | 61 hr |
| LIGO H1-H2 double coincidence (with DQ flags)(-50%) | 193 hr |
| AURIGA net of wide-band (-4%) and epoch veto(-42%) | 211 hr |

Intersection:

| | |
|---|---|
| AU-H1-H2-L1 | 36 hr |
| AU-H1-H2 | 108 hr |

# Analysis method (method 2)

•No assumption on direction, minimal assumptions on waveform (e.g. duration, signal with some power in AURIGA band).

•The r-statistic test (within *CorrPower* ) is applied to the LIGO interferometers around the time of the AURIGA triggers.

•$h_{rss}$ at each LIGO detector is estimated with the burst parameter estimation code (Note: this portion of the analysis is not mature for presentation)

•Efficiency for classes of waveforms and source population is performed through Monte Carlo simulation, via software injected signals.

•The accidental rate (background) is estimated from "off-source" data sets, where LLO and LHO data streams are independently time-shifted with respect to the AURIGA data stream.

# Thresholds

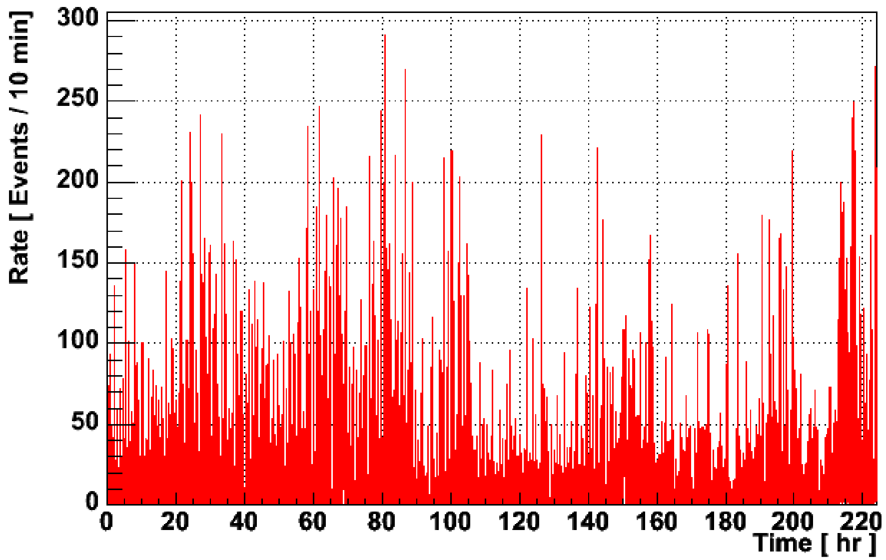
1. AURIGA: for the analysis of run 331 data, the exchange threshold is SNR > 4.5. This threshold would ensure a satisfactory significance of the candidate events in Gaussian noise, but this is not the case for the noise performance of run 331: under these conditions a more suitable threshold for IGEC-style searches would have been SNR>7.
2. LIGO: from first principles, events with $\Gamma<=3$ in Gaussian noise are consistent with the null hypothesis (no correlation) at the 0.1% level or higher: these events can already be discarded. S3 was a "glitchy" run (the LIGO-only used the threshold $\Gamma_0 = 10$ !); we decided to use as starting point/minimal threshold that of S2 ($\Gamma_0 = 4$).
3. The tuning procedure will establish which direction we need to move away from these minimal thresholds.

The tuning procedure is still in progress: we have explored 4-detector coincidences and are working on the AU-H1-H2 triple coincidence. We reserve to freeze thresholds after we have explored both sectors and remain blind to the final result until that point.

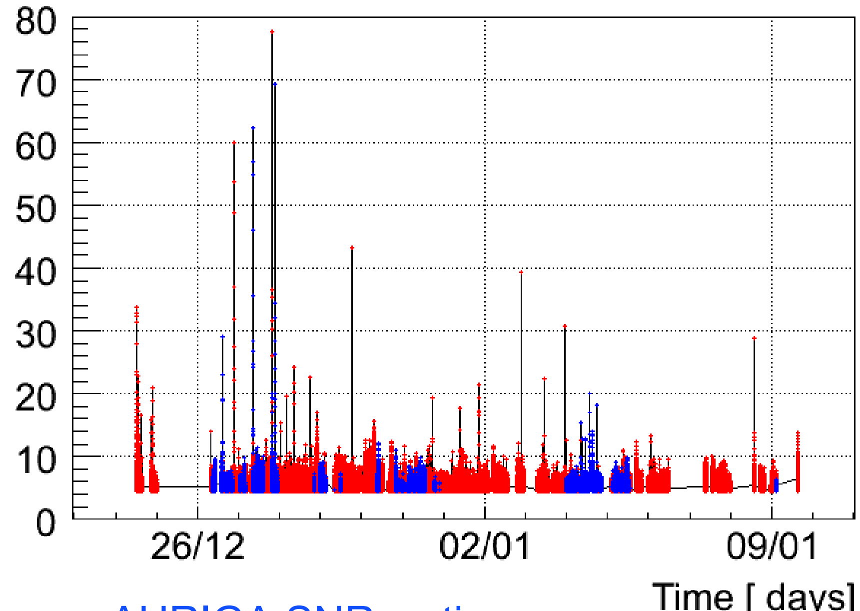
In order to exemplify the procedure, today we will discuss background and detection efficiency for a sample waveform and a trial set of thresholds and how these quantity are affected by the thresholds choice.

# Diagnostic plots of AURIGA triggers

1. AURIGA trigger generation: delta matched filter.
   1. Events characterized by time, its uncertainty, H, SNR
   2. $\sigma_t$ < 45ms (worst case, for SNR=4.5), typical ~ 10ms (average for exchanged events)



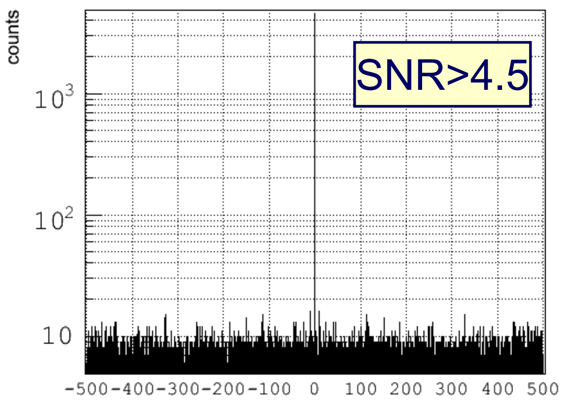

Rate (SNR>4.5) vs “live hours” in the AURIGA dataset



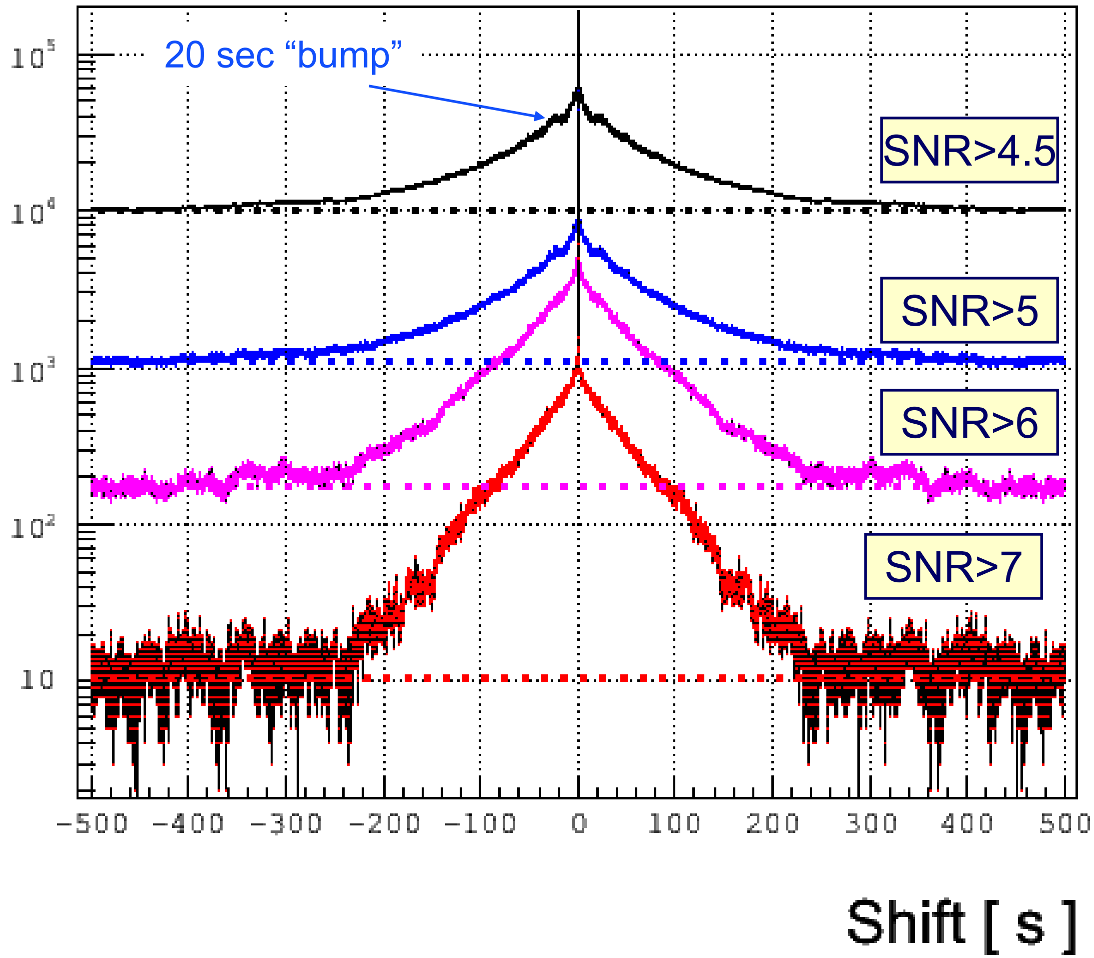

AURIGA SNR vs time
- red=all exchanged data
- blue=AU-H1-H2-L1

# More AURIGA diagnostics

Auto-coincidence in recent run May05




Auto-coincidence in run 331




Auto-coincidences
(100 ms window)

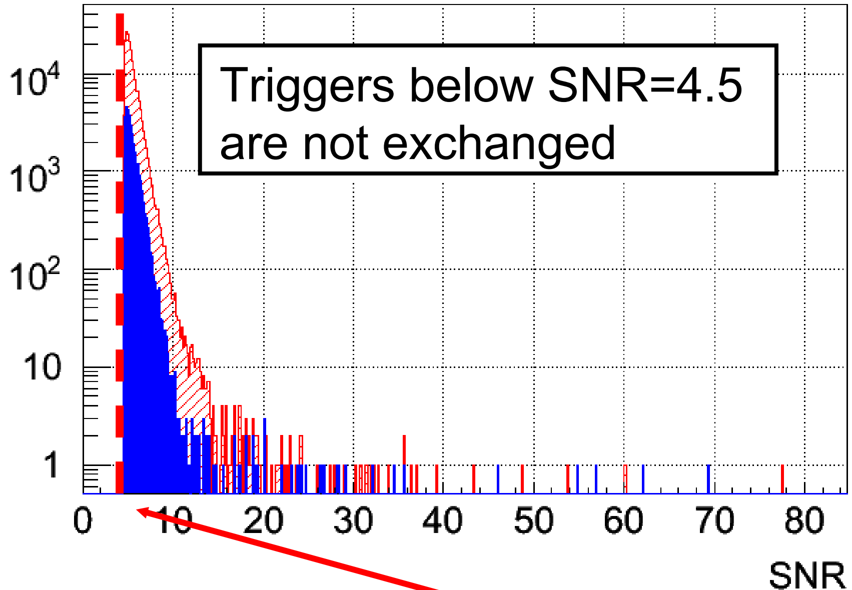
- Evident clusterization of AU exchanged events
- Plateaux reached at ~ 300 sec
- Bump at 20 sec disappears increasing the SNR threshold
- Comparison with a recent run

# LIGO events

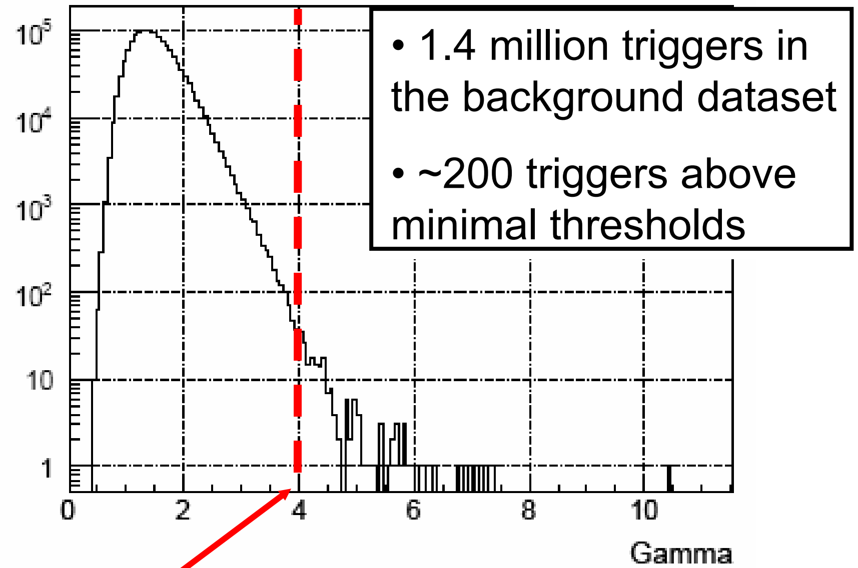
1. Apply r-statistic test in CorrPower
   1. Test 3-ifo correlation in LIGO data around:
      AURIGA event arrival time ± event time uncertainty ± 27 ms (=flight time)
   2. Correlation windows: 20, 50,100 ms 99% overlapping
2. Use $\Gamma$ to make a statement on the coherence among the 3 LIGO interferometers.
3. Impose H1-H2 consistency criteria:
   1. Sign of the H1-H2 correlation
   2. Amplitude cut between H1 and H2 (800-1000 Hz vs broadband? This is not in a mature state, but is already showing promising results in the rejection of background events)

# Testing correlation of LIGO (lagged) data around the time of AURIGA triggers

AURIGA SNR
- red=all exchanged data ➔ N=182515
- blue=AU-H1-H2-L1 ➔ N=31676




LIGO Γ (49 lags, AU-H1-H2-L1)



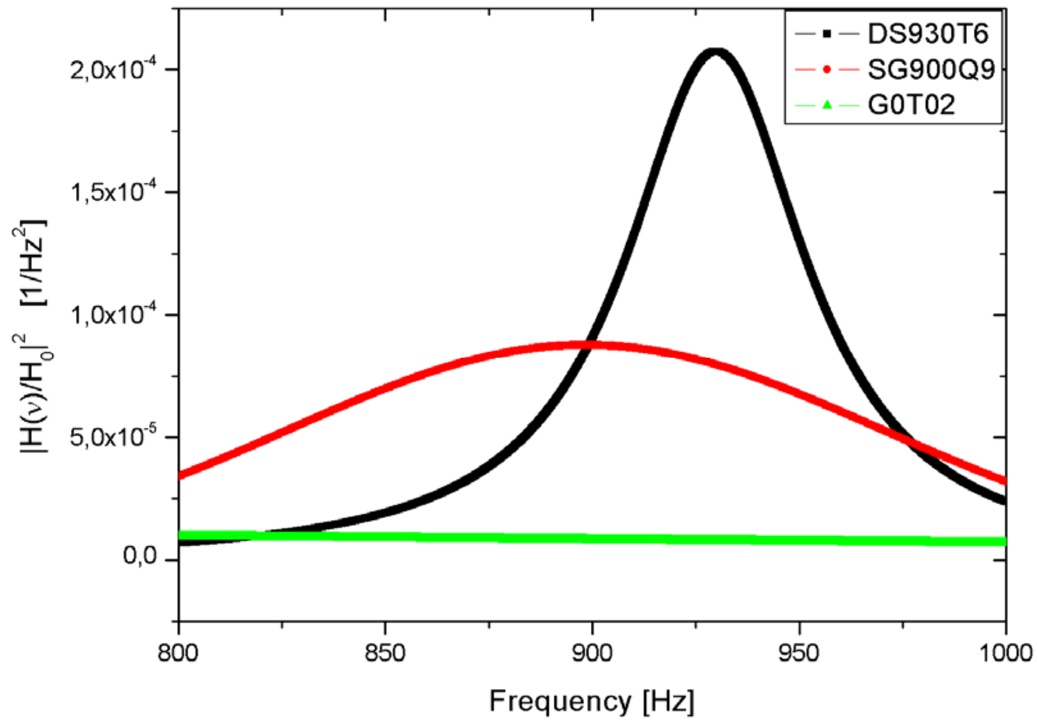

Minimal thresholds

A background set reserved for tuning purposes:

49 time lags among AU, LLO and LHO

No H1-H2 consistency cuts applied yet

# Simulated Waveforms




Fourier transform of simulated waveforms, normalized to total signal energy=1

The sources are distributed isotropically over the sky with random polarization:

- Sine gaussians and cosine gaussians with $\nu_c$ = 900 Hz and Q=9 ($\tau$ = 2.2 ms)
- Gaussians with $\tau$ = 0.2 ms
- Damped sinusoids with $\nu_c$ = 930 Hz and damping time $\tau$ = 6 ms.

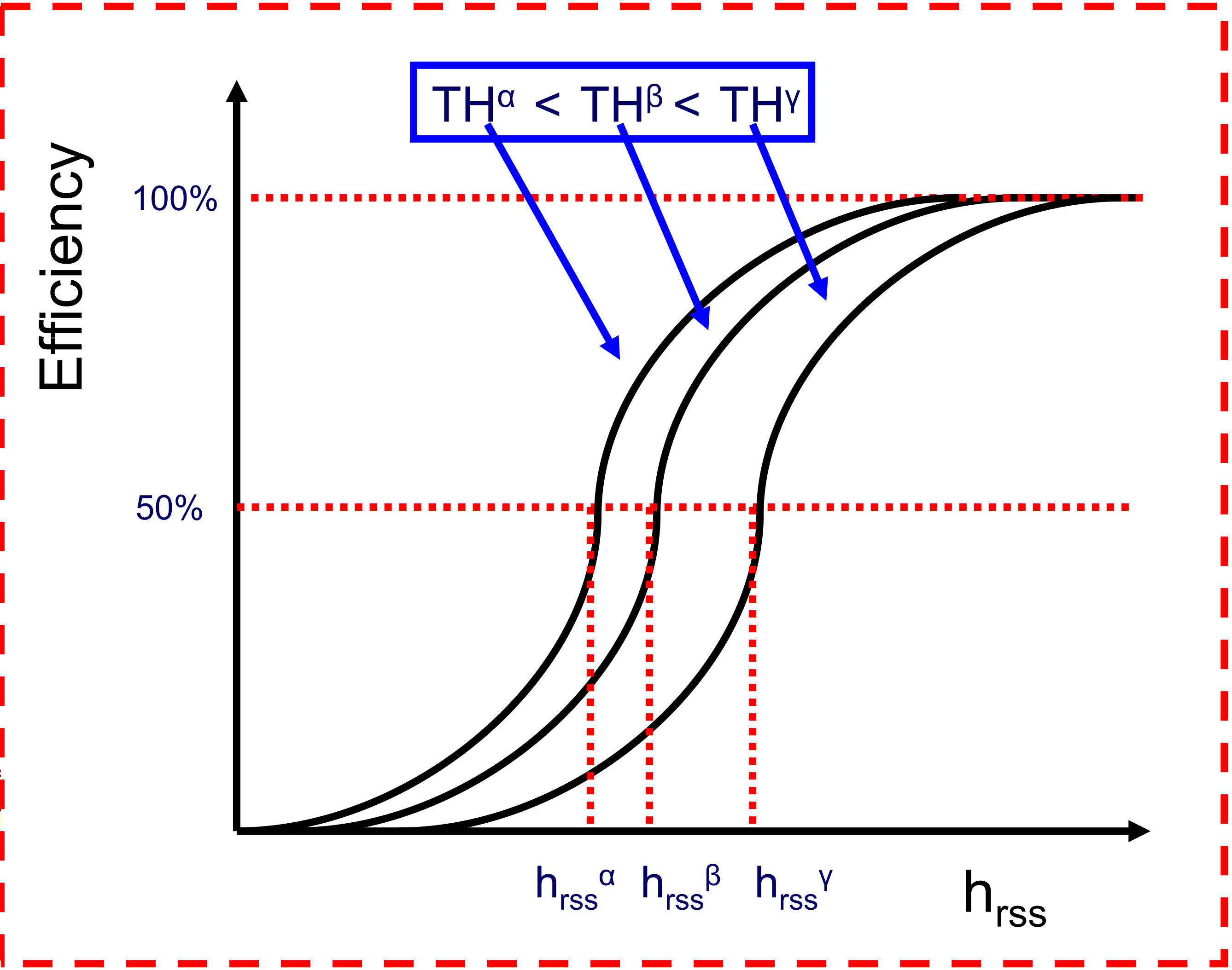
**In the next slides, we focus on Sine/Cosine Gaussians only.**

# Tuning Summary Plot (2-d ROC) using Sine/Cosine Gaussians ($\nu_c$=900Hz Q=8.9)

Preliminary background events contour lines are conservative: ongoing studies of H1-H2 amplitude cut are promising for suppression of false events.

The response is dominated by AURIGA sensitivity/noise: better increase LIGO threshold to suppress false alarms and preserve efficiency

Trial threshold for illustr



# Efficiency curve for sine/cosine gaussians with trial set of tuning parameters

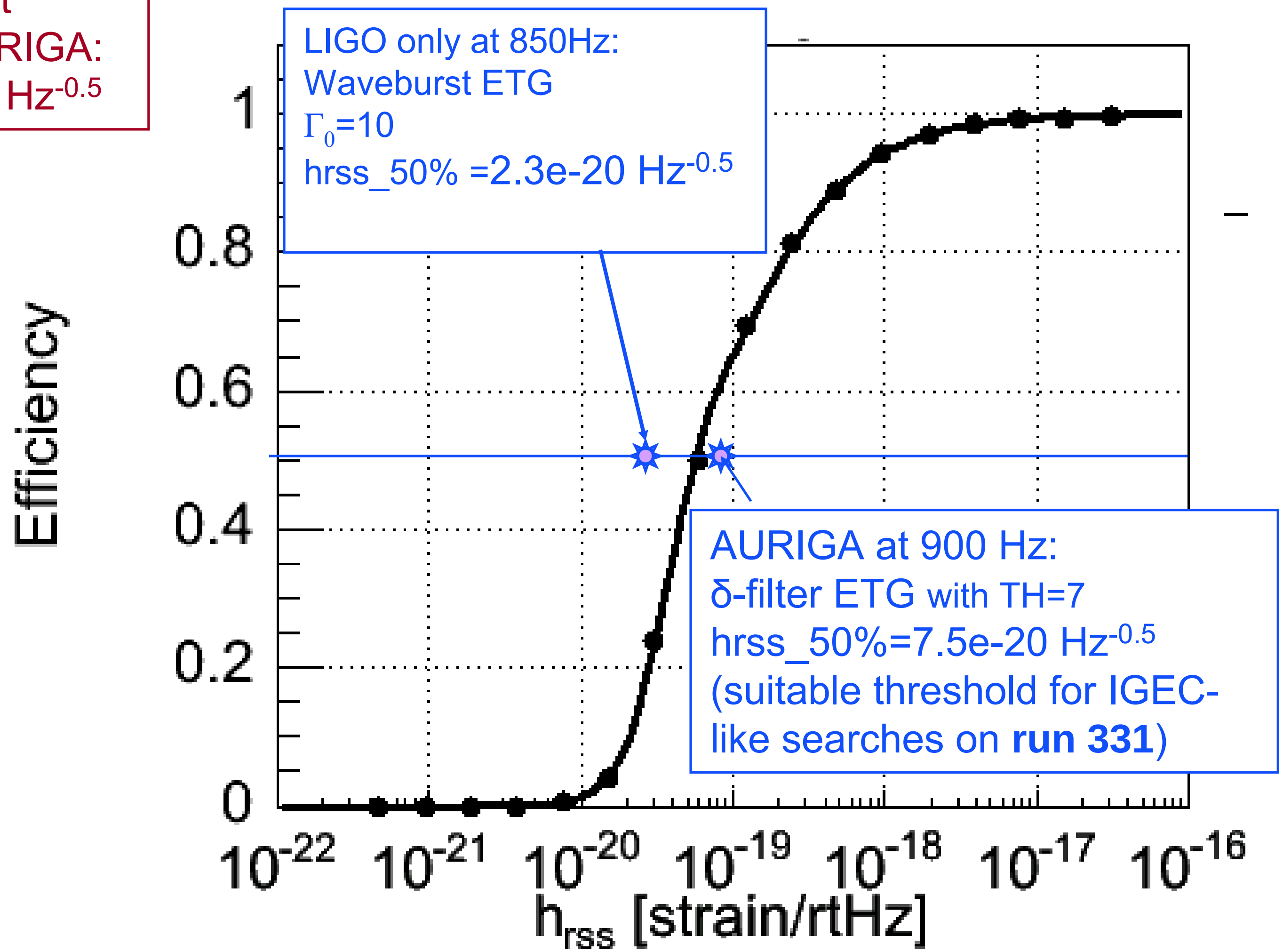
Efficiency curve for the joint analysis, dominated by AURIGA: 50% efficiency at ~5.5e-20 $Hz^{-0.5}$

Tuning tests performed so far indicate that the efficiency curve changes by at most 10% as the tuning parameters are changed in the range that is being considered.

AURIGA TH = 4.5

$\Gamma_0$ = 6 is not critical for the efficiency (see tuning plot)

Preliminary studies on the introduction of an H1-H2 amplitude cut would give at most a 5-10% loss in hrss_50%.



# Outlook

1. Steps needed to complete the “all-sky” S3-run331 coincidence analysis:
    1. Complete characterization and implementation of an H1-H2 amplitude cut for false events suppression.
    2. Repeat analysis of triple coincidence AU-H1-H2
    3. Fix thresholds and open the box for zero-lag coincidences
2. Still exploring possibilities for a targeted, directional joint analysis.

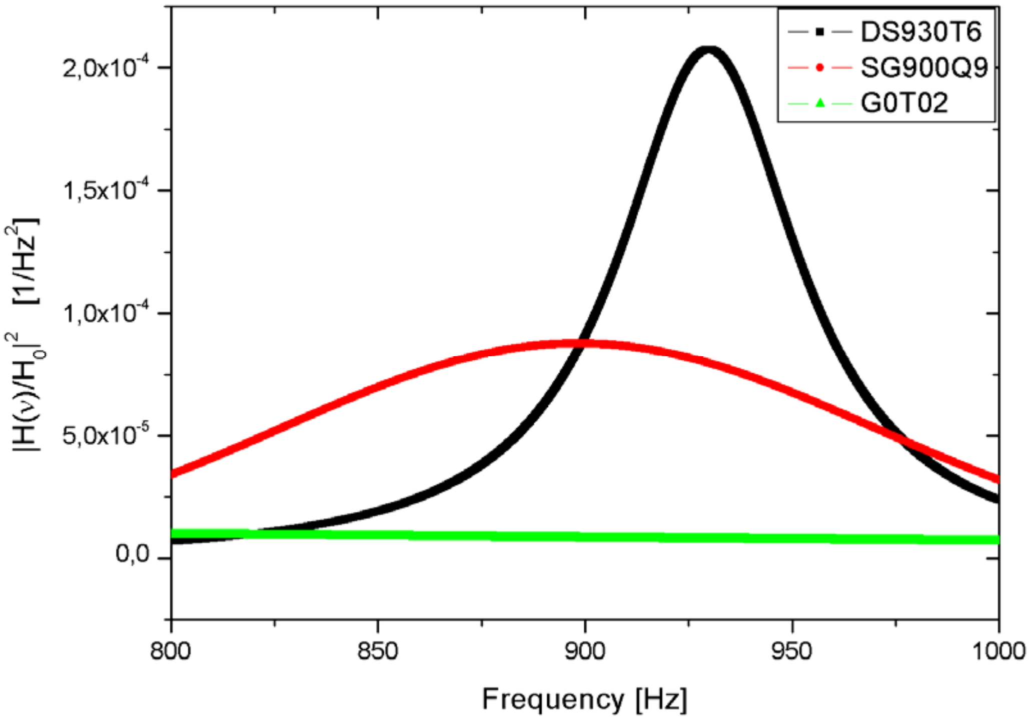
# Extra slides

# MDC Injections + Table

The sources are distributed isotropically over the sky with random polarization:

• Sine gaussians and cosine gaussians with $\nu_c$ = 900 Hz and Q=9 ($\tau$ = 2.2 ms)
• Gaussians with $\tau$ = 0.2 ms
• Damped sinusoids with $\nu_c$ = 930 Hz and damping time $\tau$ = 6 ms.

**In the next slides, we focus on Sine/Cosine Gaussians only.**




Using trial thresholds: SNR>4.5 $\Gamma$>6

| Waveform | N injected | hrss_50% [1e-20/rtHz] | hrss_90% [1e-20/rtHz] |
|---|---|---|---|
| **SG900Q9+CG900Q9** | 1348 | 5.5 | 0.51 |
| **GA0T02** | 698 | 15 | 1 |
| **DS930T6** | 2045 | 5.6 | 0.34 |