Advanced Virgo
Detector Monitoring and Data Quality

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on behalf of the Virgo collaboration

Outline

- Advanced Virgo in the GW observatories era
- Current status of Advanced Virgo
- Some Detector Monitoring tools
- The Data Quality of Advanced Virgo
- Gating and Glitch removal

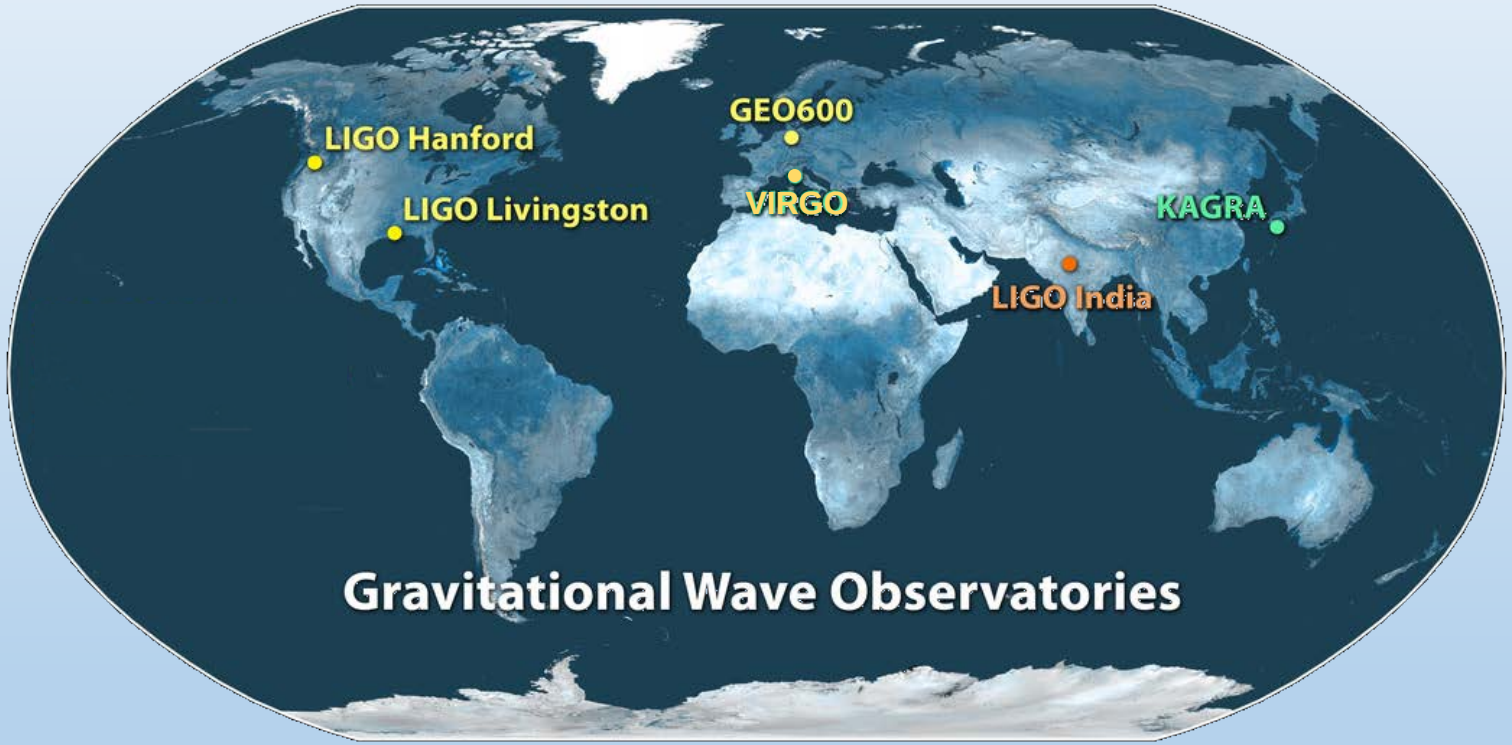
Advanced Virgo in the GW observatories era

Run O1: first GW detections (GW150914 and GW151226) made with Advanced LIGO detectors and LSC+Virgo analysis

Advanced Virgo detector soon included within International GW observatories network for **runs O2 and O3**.

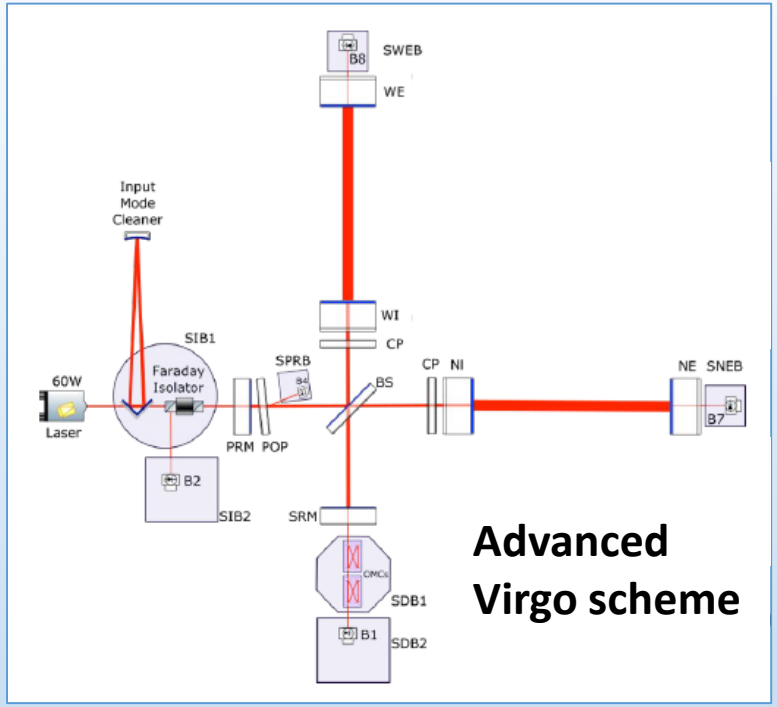
Detector Monitoring and Data Quality are important components of Advanced Virgo

to select/confirm the events detected by the **GW observatories network**
and to propose them to **EM followup**.



Advanced Virgo current status

- Installation almost complete
- North arm first lock at the end of April
- Free Michelson data taken mid-June
- Commissioning activity and noise investigation started on subsystems.
- But problems with monolithic suspensions of mirrors.
- Replacing them with steel wires, while investigating.
- Current plan is still to start full interferometer lock and commissioning work before September 2016
- And to be able to participate to run O2…




One of the new suspended benches

Detector Monitoring and Data Quality

Detector monitoring and data quality were already quite efficient in previous runs (2007 to 2011).

"The characterization of Virgo data and its impact on gravitational-wave searches", CQG, Vol 29, Nbr 15, 2012

Some components have been improved
Some new components are under development.
I will present here only some of those components in which I am more deeply involved.

Some Detector Monitoring tools

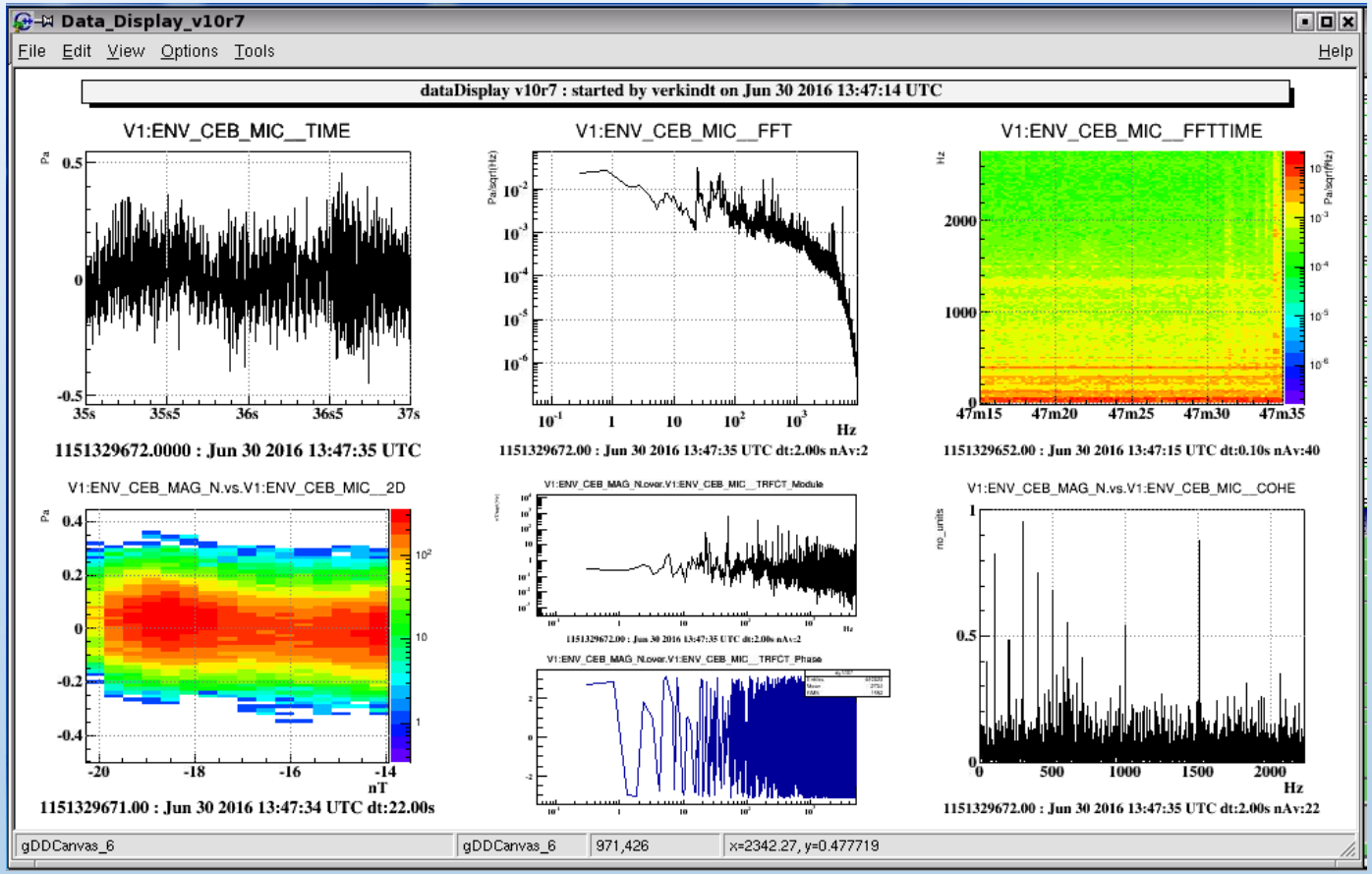
The data Display : to visualize data online

The MonitoringWeb : to monitor in-time the trend of various Virgo components

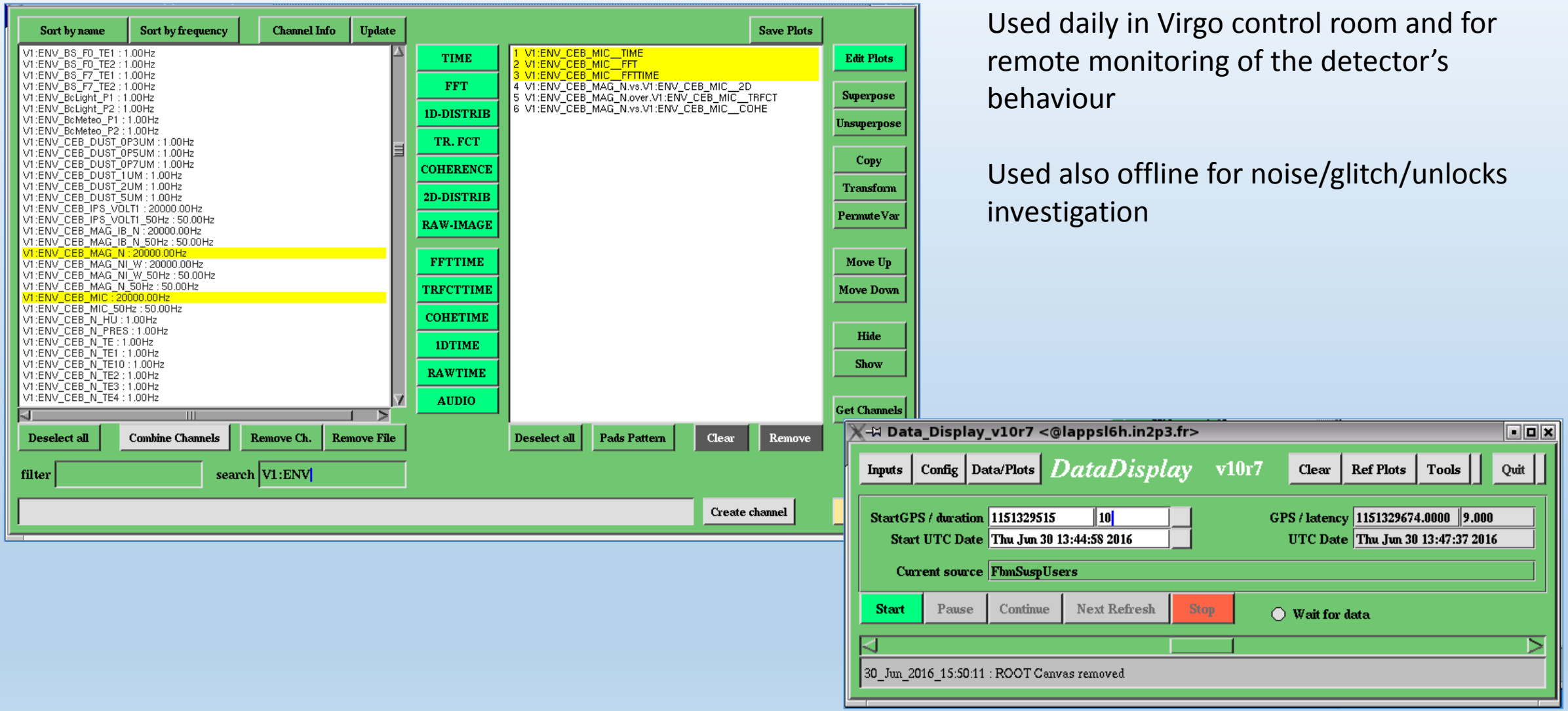
The Detector Monitoring System : to monitor online the Virgo detector subsystems

The data Display

- Software tool based on ROOT
- Read frame formatted data and visualize them offline and online
- Provide various signal processings and various types of plots



The data Display



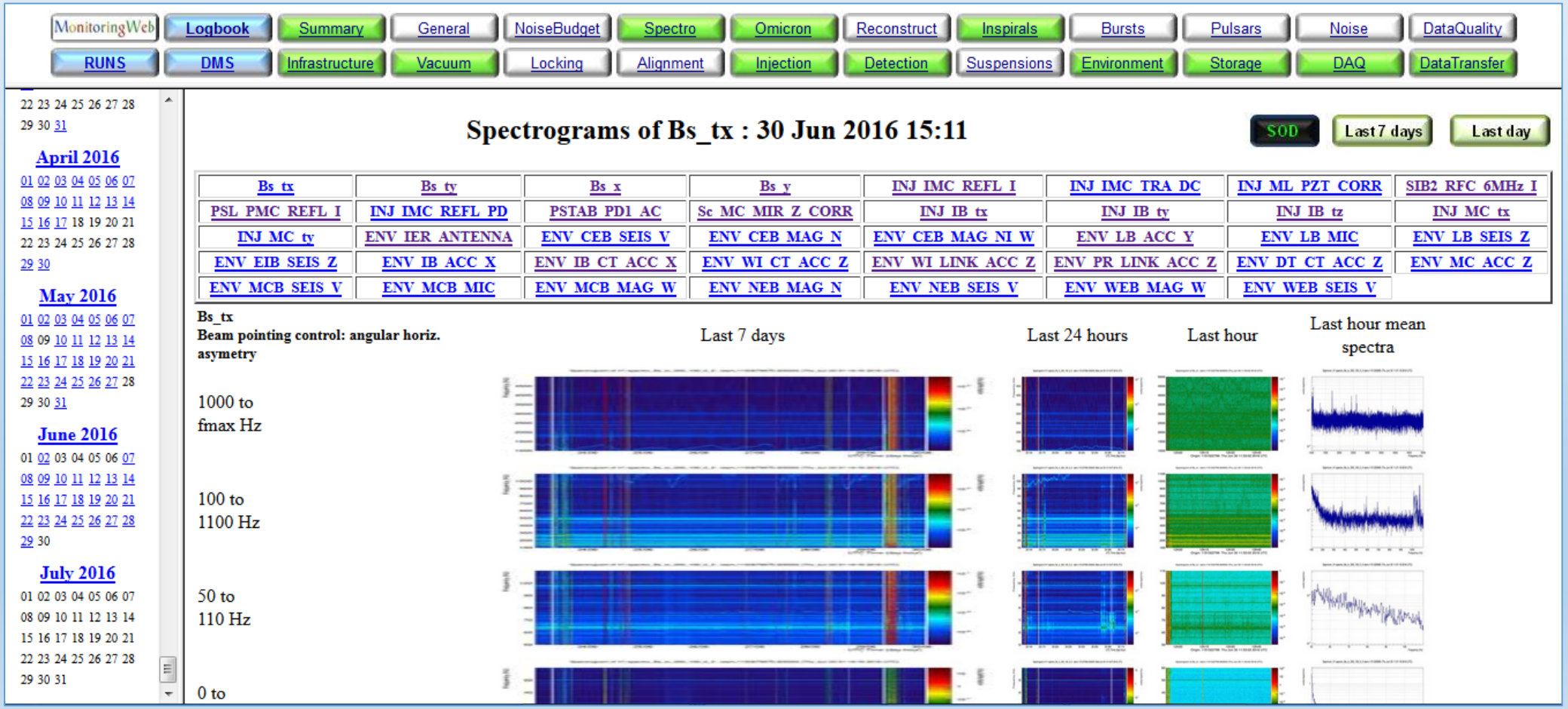
Used daily in Virgo control room and for remote monitoring of the detector's behaviour

Used also offline for noise/glitch/unlocks investigation

The MonitoringWeb

- Similar to the LIGO Summary pages
- Provide online and daily archived plots about the status of various Virgo subsystems

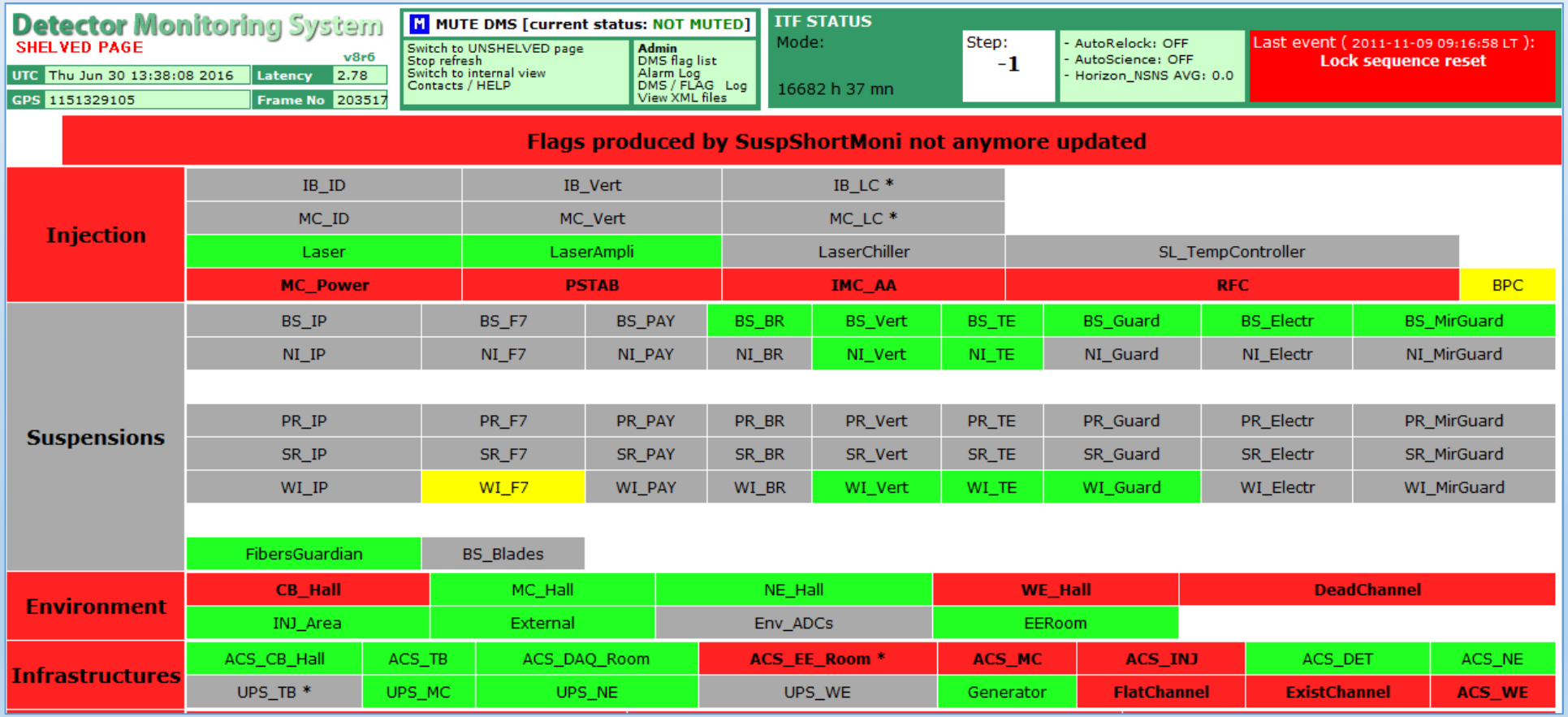
  This includes also spectrograms, data transfer status , data storage status, online data quality status, etc…



The DMS (Detector Monitoring System)

Provides online information with red/green flags and alarms about various parts of the Advanced Virgo detector

Provides also low latency Data Quality flags to be used by the online and offline GW searches



Advanced Virgo Data Quality

Main complement of detector monitoring is the Data Quality.

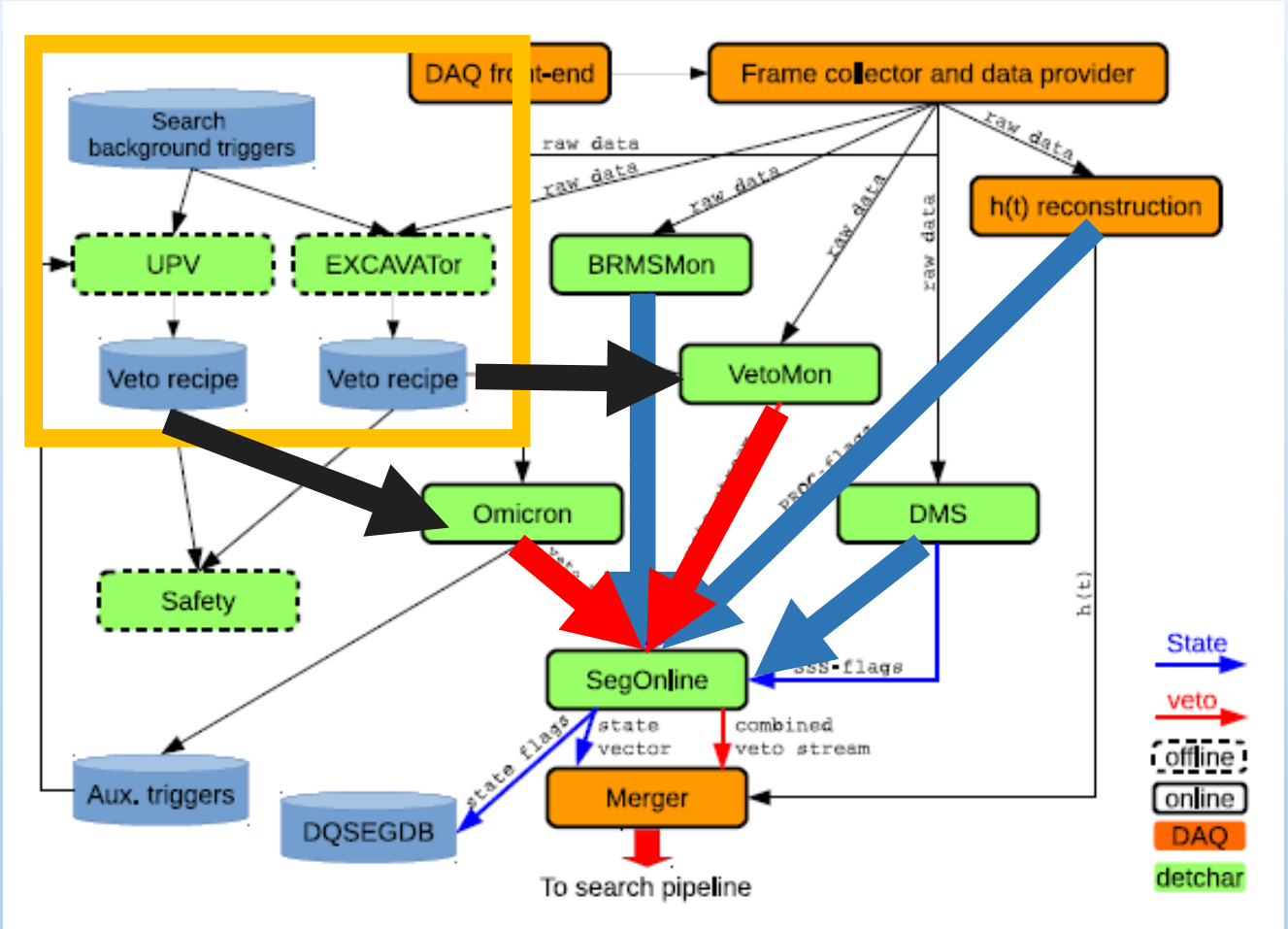
Its aims are:

- To provide reliable online quality flags and efficient offline quality flags for O2 and O3 observing runs
- To mitigate any impact of non-stationnary noise coming from sources not removed by commissioning work
- To reduce as much as possible the data analysis backgrounds
  while keeping low any deadtime not coming from detector unlocks.

Advanced Virgo Data Quality

Main strategy for online Data Quality:

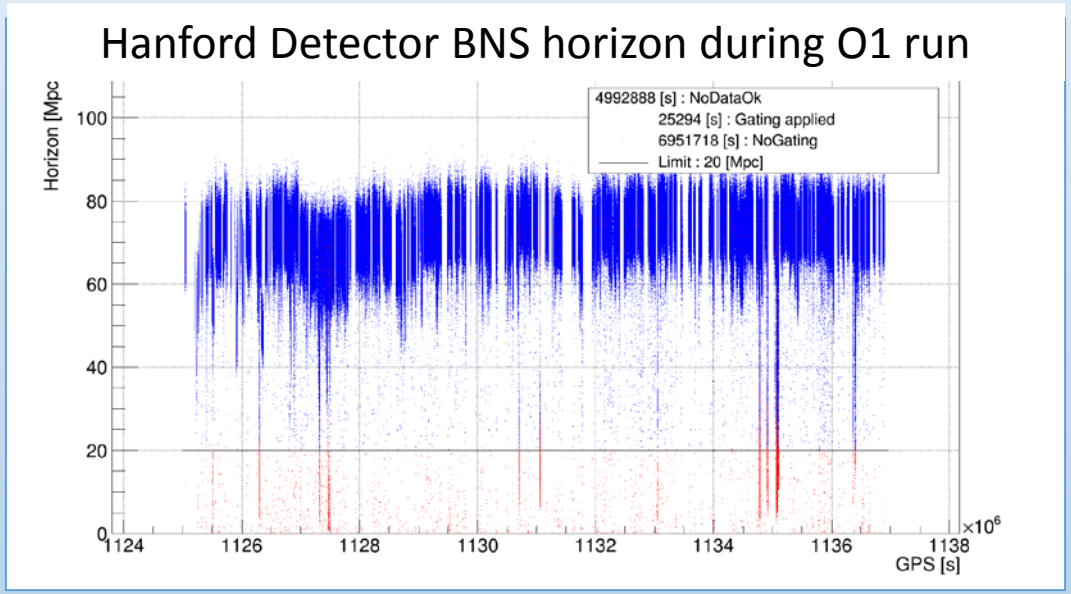
- Provide a generic flag DQ_VECTOR at 1 Hz
- Provide a set of reliable/efficient analysis-dependent vetos at 100 Hz
- Base the online veto production on veto recipes updated periodically.
- Veto recipes set offline using the searches background triggers



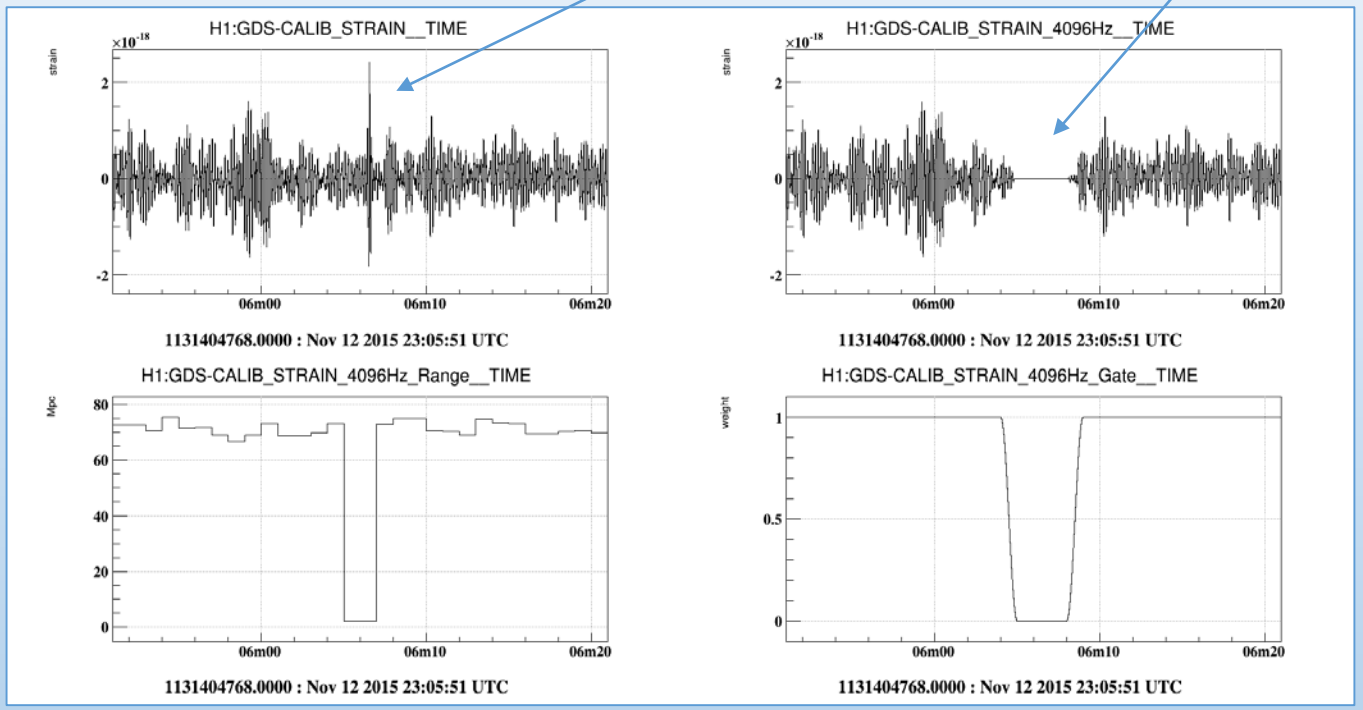
- To be added : gating of data and glitch removal (new)

The Gating of data

Gating : an alternative to the exclusion of data sets by vetos
Motivated by the need to keep data flow for the analysis pipelines



BNS = Binary Neutron Stars



AdVirgo Gating developed for MBTA online GW search in O1

One possible step further: **the glitch removal (or mitigation)**
Could help to reduce background while preserving as much as possible the percentage of data analyzed

Glitch removal in Advanced Virgo: Silentec

C code running a non-linear regression method based on Volterra series and Robust Fast Orthogonal Search

Initially developed in matlab by G. Guidi and F. Piergiovanni

Currently developed in C by V. Germain and myself

- Properties:
  - List of auxiliary channels to reconstruct the glitch in the main channel
  - Linear & bi-linear reconstruction → Takes into account the up-conversions
  - Orthogonality
  - Estimation of the **contribution Q** of every auxiliary channel (and product of channels)

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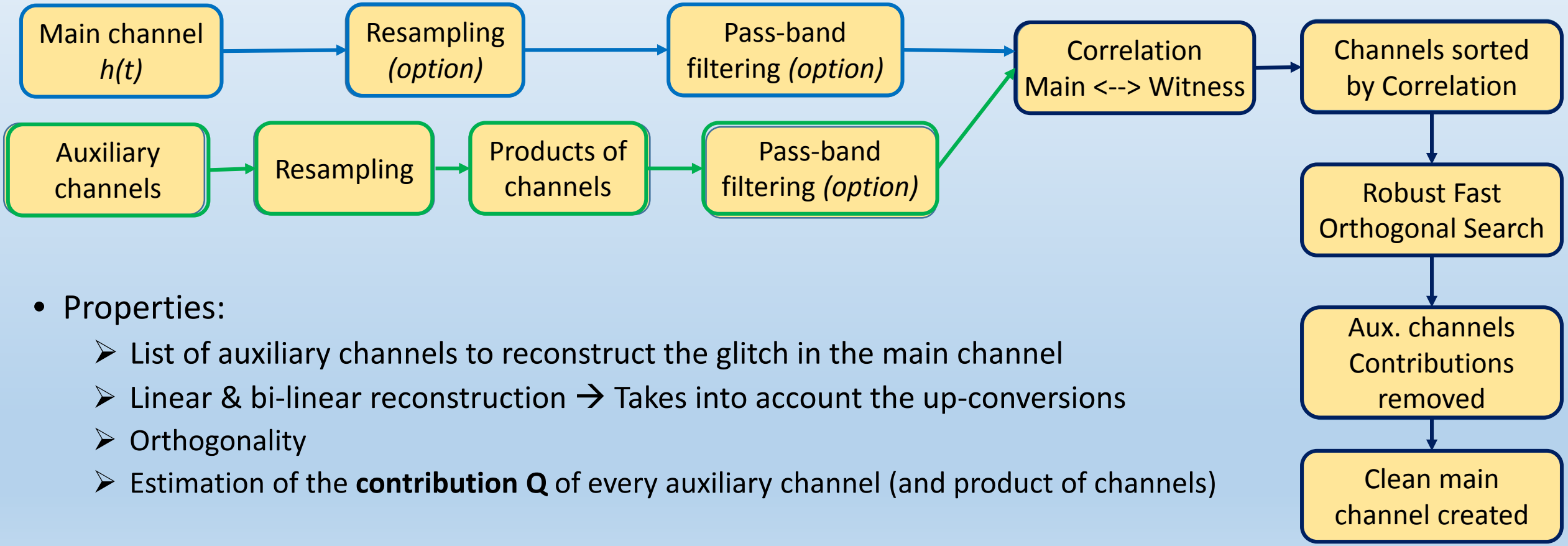

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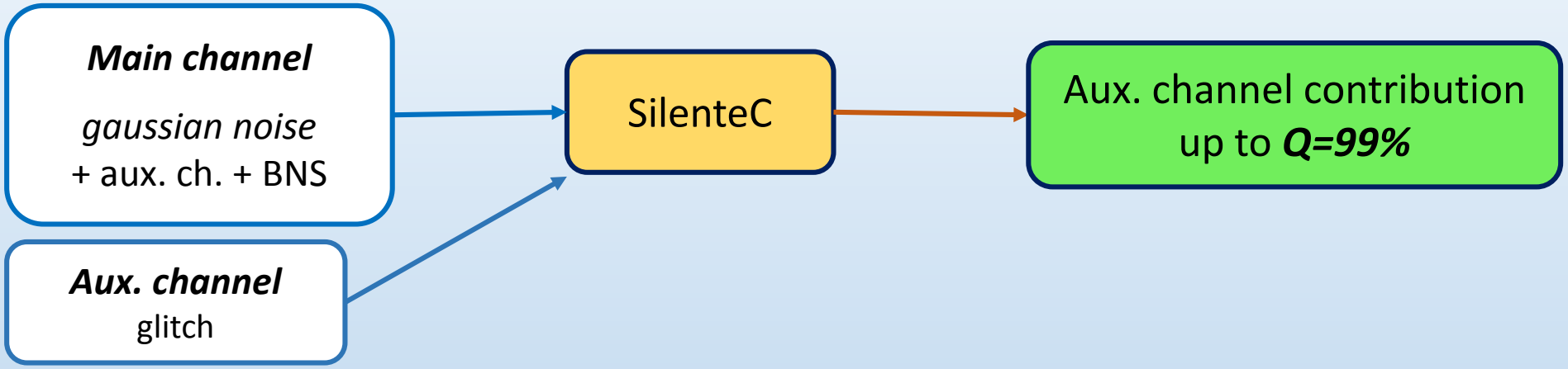
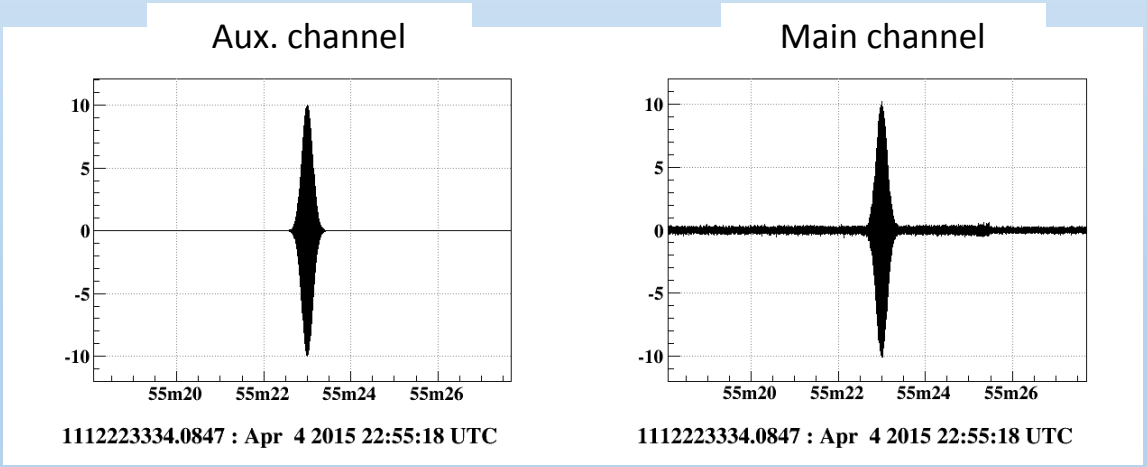
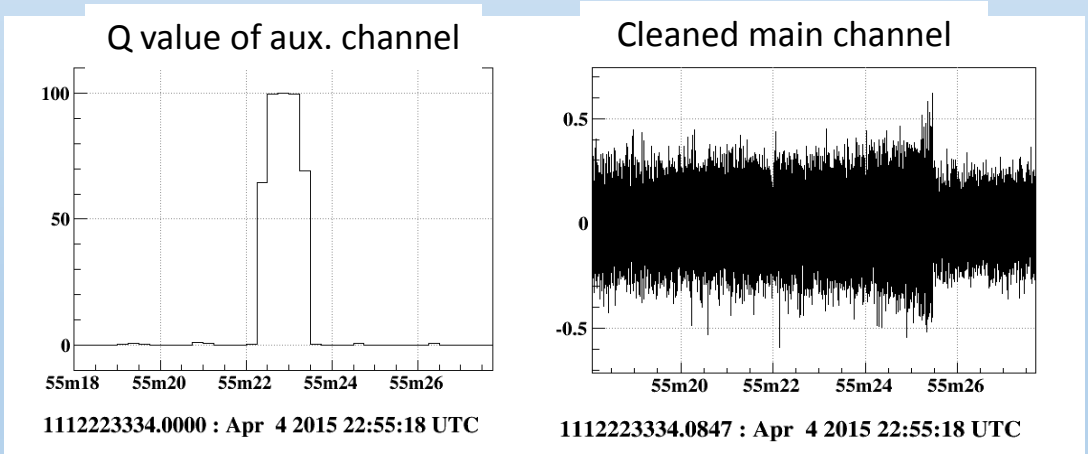
Glitch removal in Advanced Virgo: Silentec

A simple test: a simulated glitch superposed to a Binary Neutron Star (BNS) signal

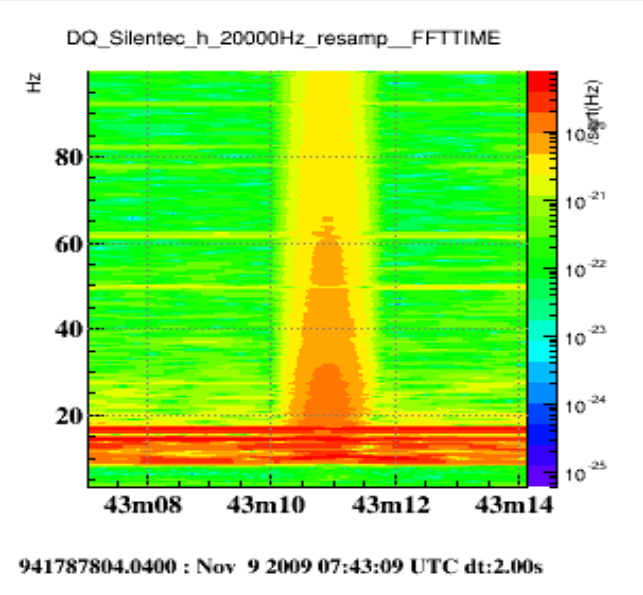




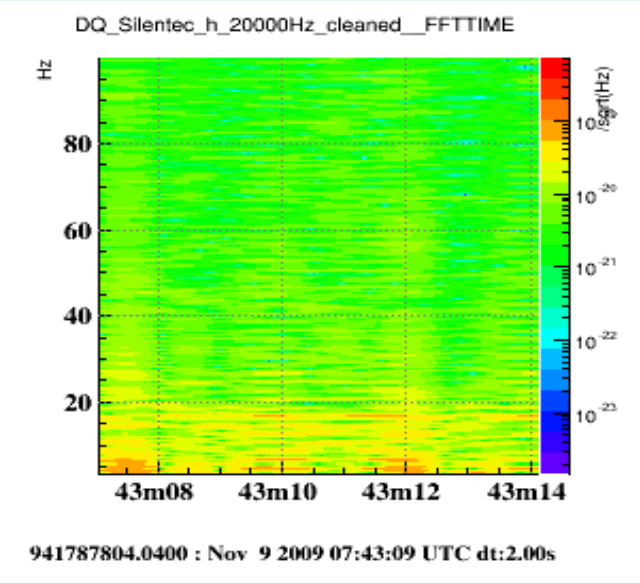


Glitch removal in Advanced Virgo: Silentec

h(t)



h(t) cleaned

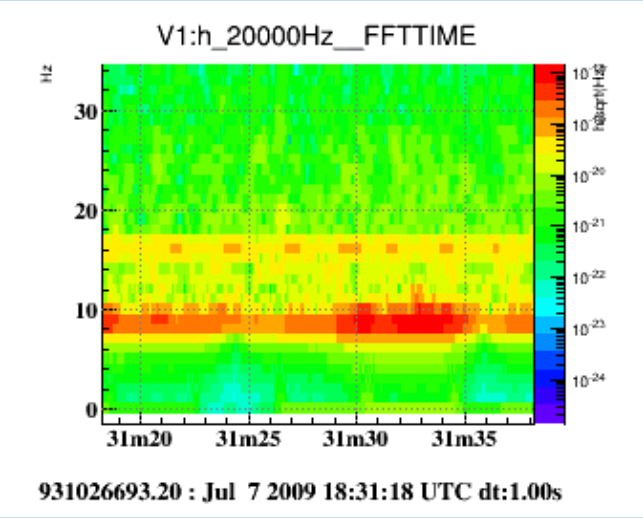


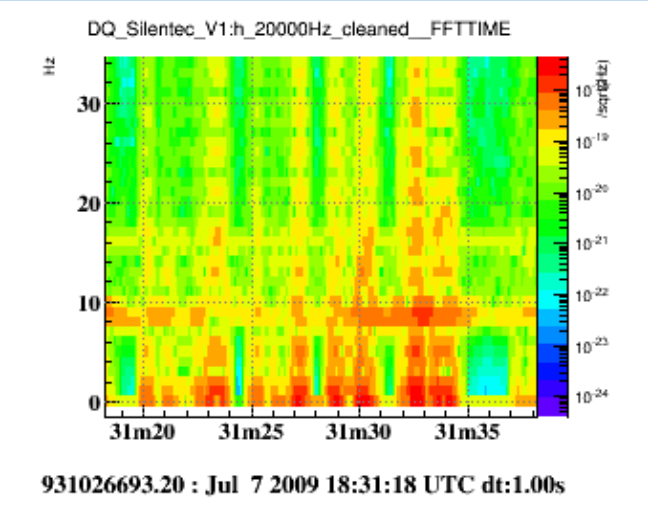
A glitch in VSR2 data associated to a drop of Binary Neutron Star range below 2 Mpc

Silentec trying to remove seismic, acoustic and magnetometer channels contributions

Quite successful cleaning in the frequency range of the glitch

Preliminary





A glitch in VSR2 data associated to an identified seismic noise

Silentec trying to remove all seismic channels contributions

Some cleaning in the frequency range of the glitch…
but additional noise introduced…

Still investigating

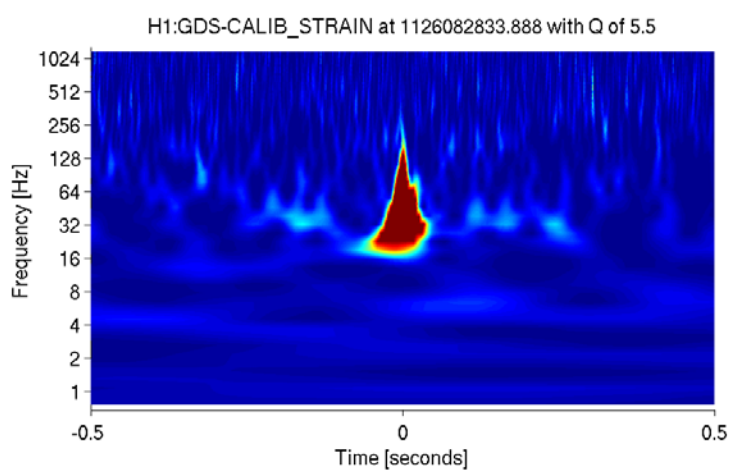
Summary

- Advanced Virgo is coming to full interferometer commissioning phase and is pushing hard to be part of O2 run
- Several monitoring tools are ready or under improvement
- Data Quality strategy is going to be fully implemented and tested
- New tools like « glitch removal » will help noise investigation and will improve data analysis results

Backup slides

Glitch removal in Advanced Virgo: Silentec

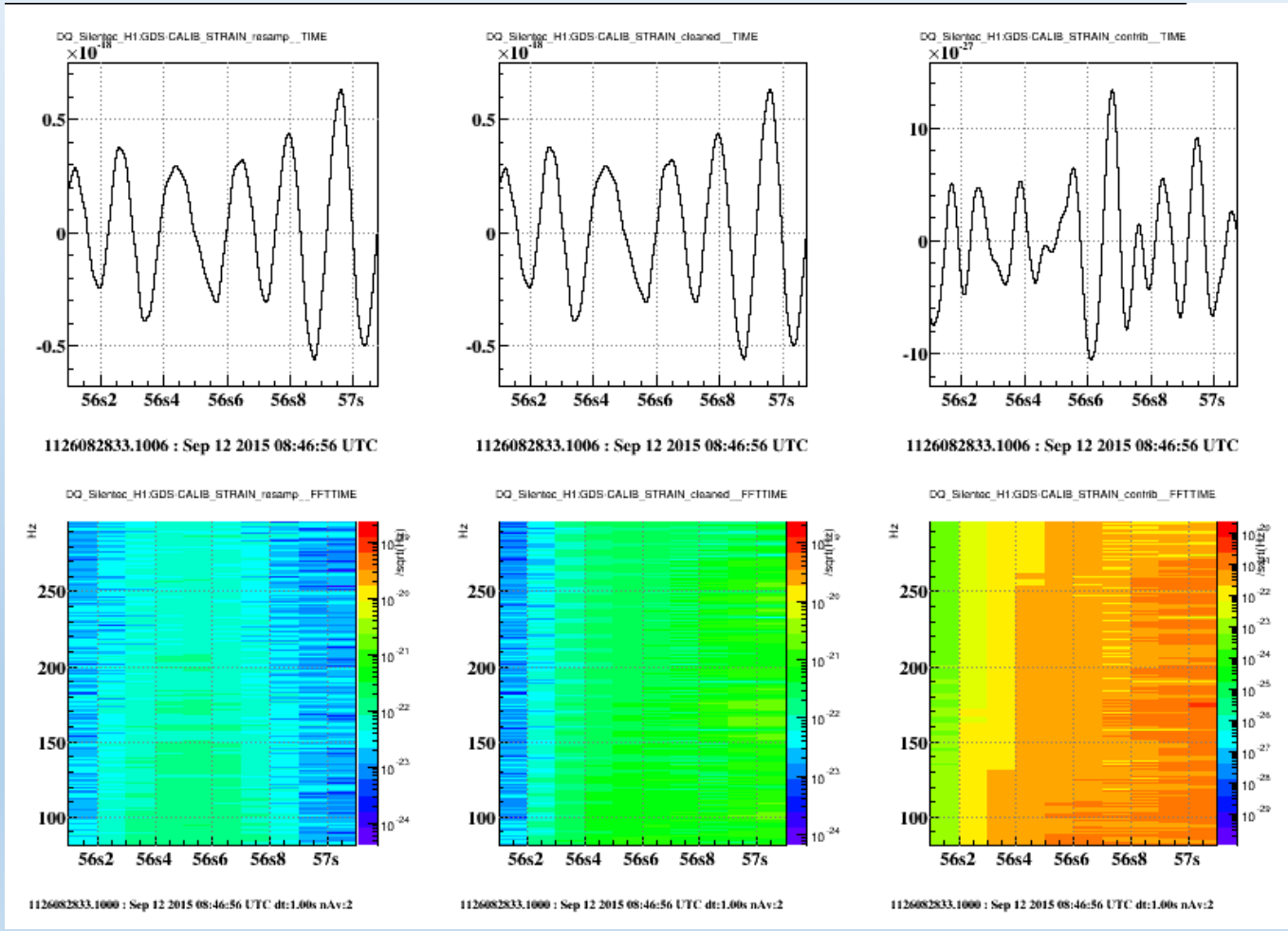
Looking at a **O1 blip glitch**: searching for contributions from Output Mode Cleaner channels and part of Environment Monitoring channels



h(t) resampled at 1024 Hz

h(t) cleaned

sum of contributions above threshold of 5%



<u>Threshold at 5%</u>

The main contributing aux. channels are:

[1] **H1:OMC-ASC_Y1_I_OUT_DQ : Q=5.86154%**

[2] others : Q=13.7731%

[3] unmodeled : Q=80.3654%

Virgo Data Quality: Impact on data analysis results

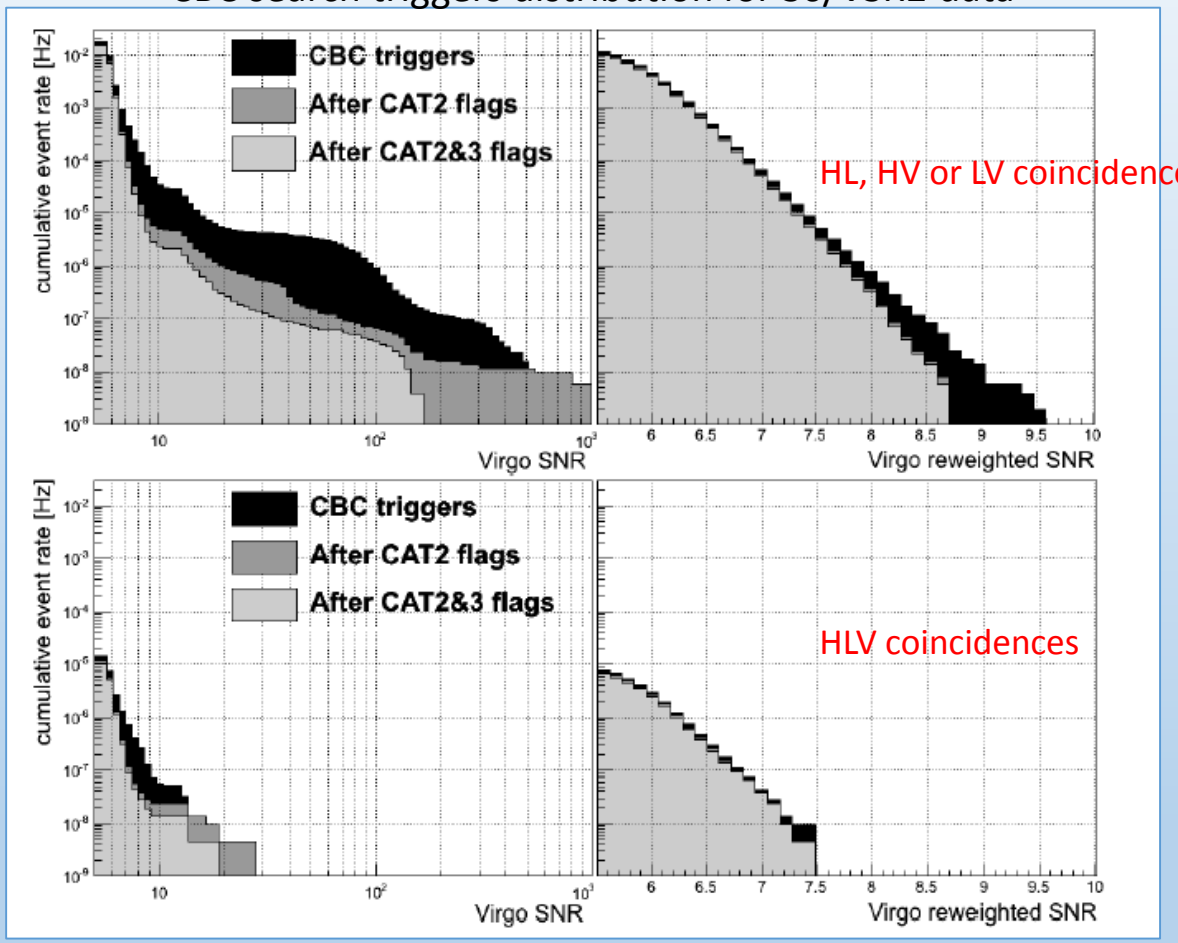
Most of false alarms removed by coincidence with other GW detectors

Remaining coincident events are mainly glitches

Background whose distribution tail lowers the significance of any GW candidate.

Data Quality vetos reduces this distribution tail.

CBC search triggers distribution for S6/VSR2 data



Detector Monitoring and Data Quality

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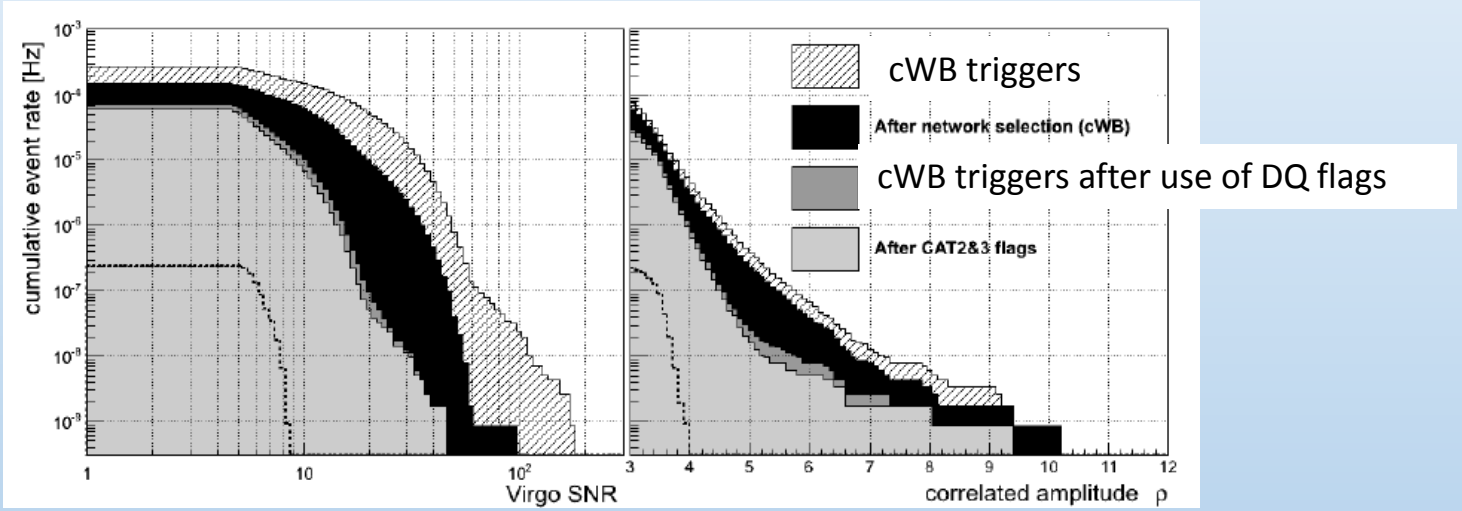
Effect of DQ flags on the SNR distribution of the cWB burst search triggers for data of the run VSR2 (2009)



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The main components:

- Data Quality flags based on the Omicron trigger generator and the UPV algorithm
- Data Quality flags based on the Excavator algorithm
- Data Quality flags provided by the Detector Monitoring System
- Alternative or complementary new tools: gating of data and glitch removal