

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

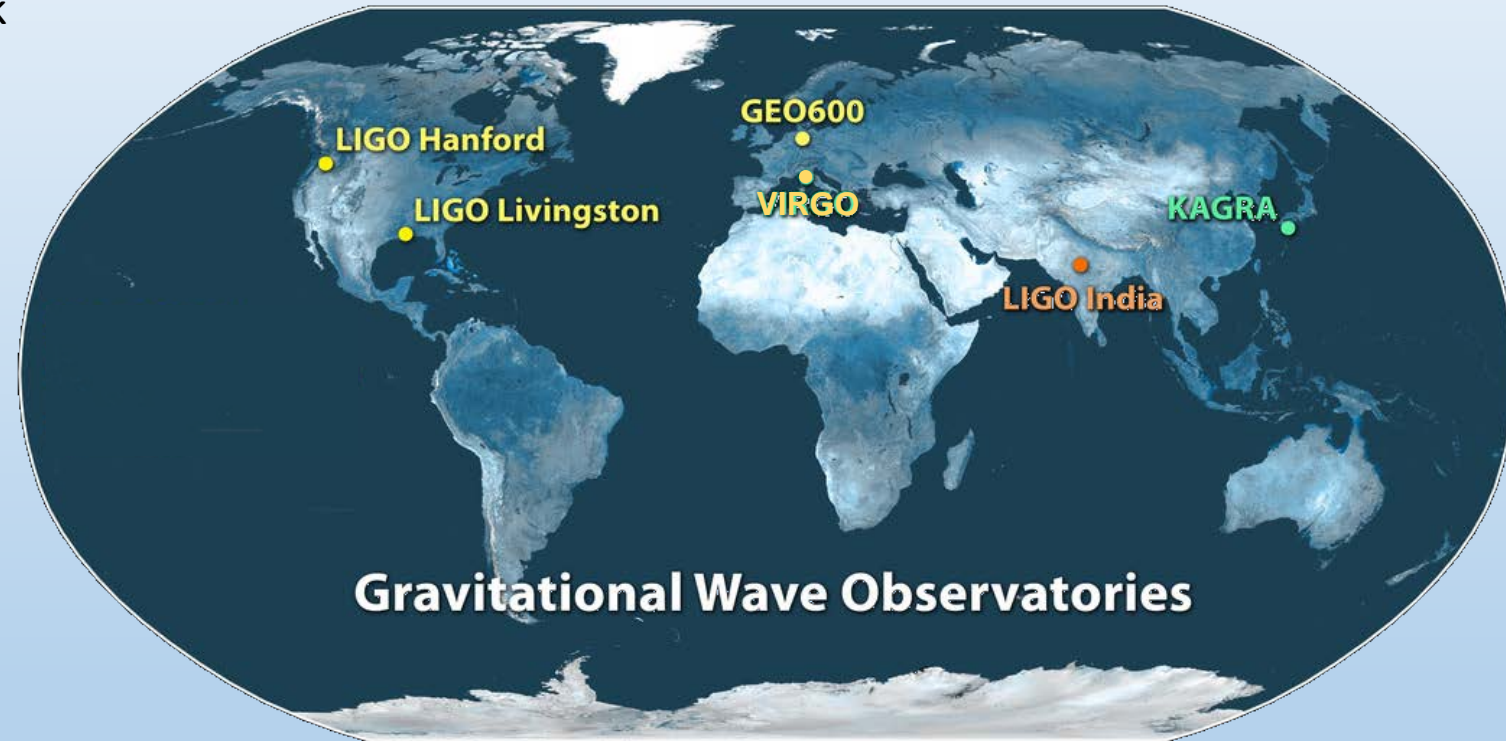
Advanced Virgo in the GW observatories era

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**.

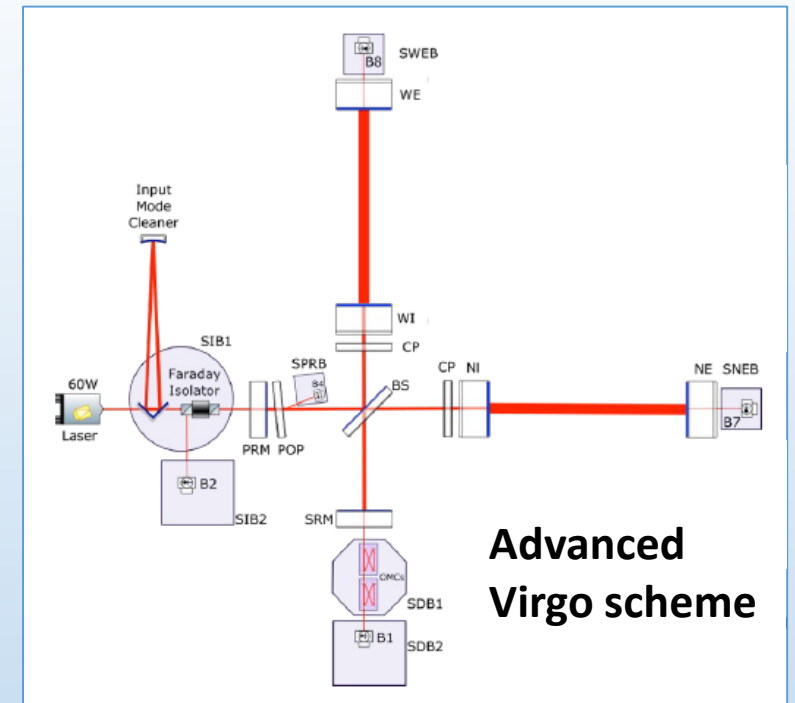
Detector Monitoring and Data Quality are important components of Advanced Virgo

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

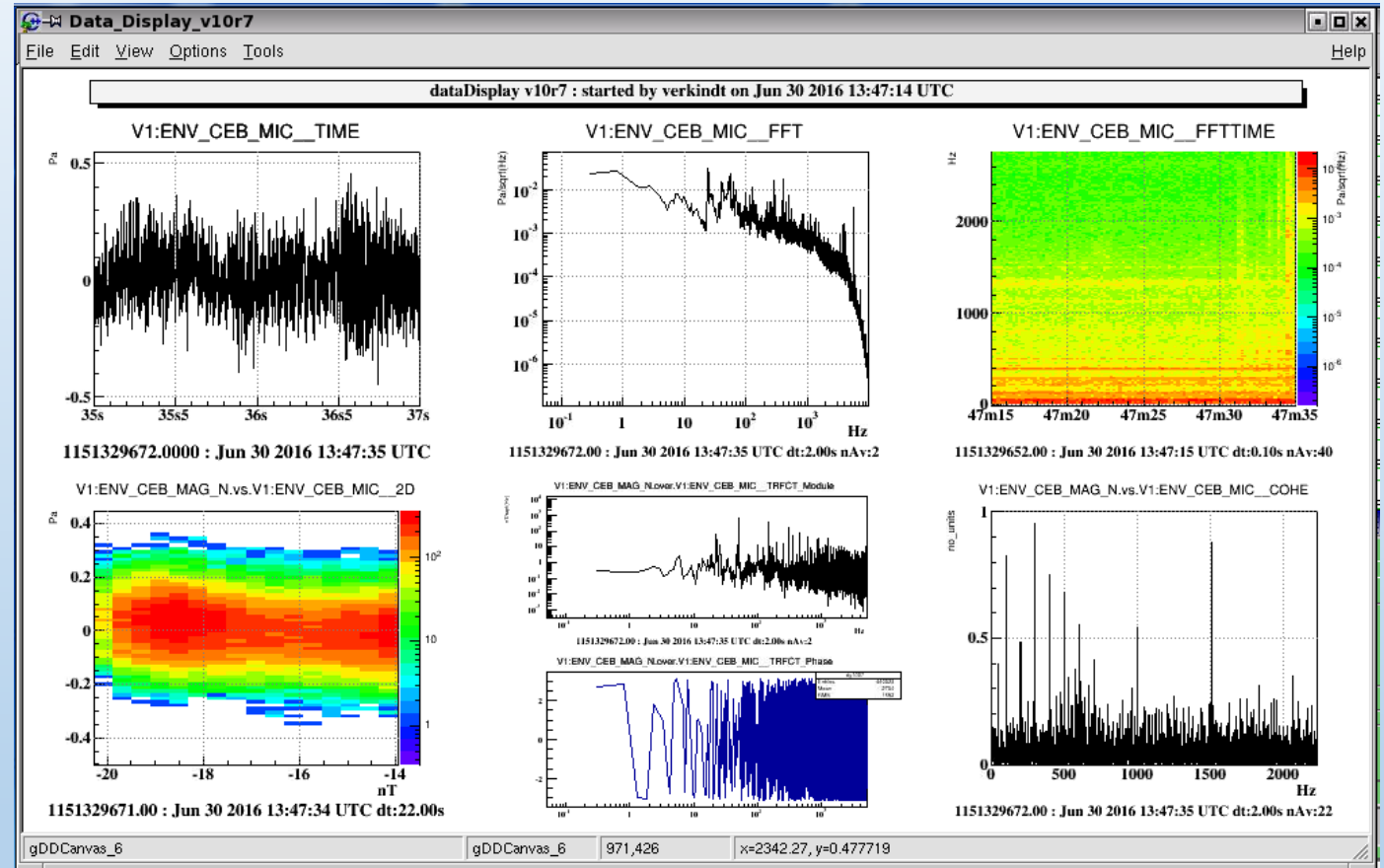
The data Display : to visualize data online

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

The screenshot shows the main interface of the Data Display v10r7 software. It features a green-themed window with several sections:

- Top Bar:** Includes buttons for 'Sort by name', 'Sort by frequency', 'Channel Info', 'Update', and 'Save Plots'.
- Channel List:** A scrollable list of channels on the left, with 'V1:ENV_CEB_MAG_N : 20000.00Hz' and 'V1:ENV_CEB_MIC : 20000.00Hz' highlighted in yellow.
- Plot Selection:** A central column of buttons for various plot types: TIME, FFT, ID-DISTRIB, TR. FCT, COHERENCE, 2D-DISTRIB, RAW-IMAGE, FFTIME, TRFCTIME, COHETIME, IDTIME, RAWTIME, and AUDIO.
- Plot List:** A list of selected plots on the right, including '1 V1:ENV_CEB_MIC_TIME', '2 V1:ENV_CEB_MIC_FFT', '3 V1:ENV_CEB_MIC_FFTIME', '4 V1:ENV_CEB_MAG_N.vs.V1:ENV_CEB_MIC_2D', '5 V1:ENV_CEB_MAG_N.over.V1:ENV_CEB_MIC_TRFCT', and '6 V1:ENV_CEB_MAG_N.vs.V1:ENV_CEB_MIC_COHE'.
- Right Panel:** A vertical stack of control buttons: Edit Plots, Superpose, Unsuperpose, Copy, Transform, PermuteVar, Move Up, Move Down, Hide, Show, and Get Channels.
- Bottom Bar:** Contains buttons for 'Deselect all', 'Combine Channels', 'Remove Ch.', 'Remove File', 'Deselect all', 'Pads Pattern', 'Clear', 'Remove', and 'Create channel'. There is also a search filter set to 'V1:ENV'.

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

Used also offline for noise/glitch/unlocks investigation

The screenshot shows the configuration window for Data Display v10r7. It has a title bar 'Data_Display_v10r7 <@lapps16h.in2p3.fr>' and a menu bar with 'Inputs', 'Config', 'Data/Plots', 'DataDisplay v10r7', 'Clear', 'Ref Plots', 'Tools', and 'Quit'.

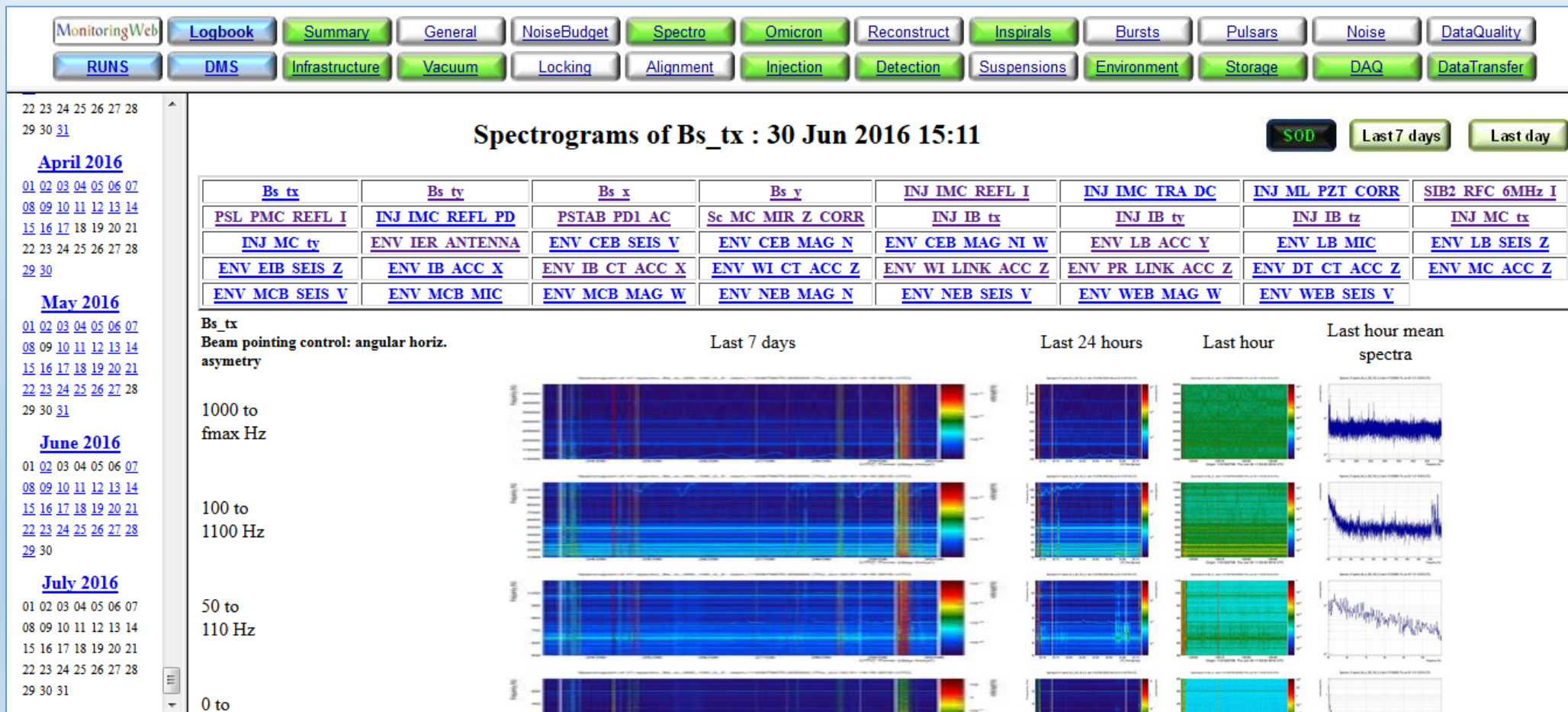
The configuration fields include:

- StartGPS / duration:** 1151329515 | 10
- Start UTC Date:** Thu Jun 30 13:44:58 2016
- GPS / latency:** 1151329674.0000 | 9.000
- UTC Date:** Thu Jun 30 13:47:37 2016
- Current source:** FhmSuspUsers

At the bottom, there are control buttons: Start (green), Pause, Continue, Next Refresh, Stop (red), and a radio button for 'Wait for data'. A status bar at the very bottom shows the message '30_Jun_2016_15:50:11 : ROOT Canvas removed'.

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, online GW search 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

Detector Monitoring System		MUTE DMS [current status: NOT MUTED]		ITF STATUS						
SHELVED PAGE		Admin		Mode:						
v8r6		Switch to UNSHELVED page		Step: -1						
UTC Thu Jun 30 13:38:08 2016		Stop refresh		- AutoRelock: OFF						
Latency 2.78		Switch to internal view		- AutoScience: OFF						
GPS 1151329105		Contacts / HELP		- Horizon_NSNS AVG: 0.0						
Frame No 203517		DMS flag list		Last event (2011-11-09 09:16:58 LT): Lock sequence reset						
DMS / FLAG Log		View XML files								
16682 h 37 mn										
Flags produced by SuspShortMoni not anymore updated										
Injection	IB_ID		IB_Vert		IB_LC *					
	MC_ID		MC_Vert		MC_LC *					
	Laser		LaserAmpli		LaserChiller		SL_TempController			
	MC_Power		PSTAB		IMC_AA		RFC			
								BPC		
Suspensions	BS_IP		BS_F7		BS_PAY		BS_BR		BS_Vert	
	NI_IP		NI_F7		NI_PAY		NI_BR		NI_Vert	
	PR_IP		PR_F7		PR_PAY		PR_BR		PR_Vert	
	SR_IP		SR_F7		SR_PAY		SR_BR		SR_Vert	
	WI_IP		WI_F7		WI_PAY		WI_BR		WI_Vert	
	FibersGuardian		BS_Blades							
Environment	CB_Hall		MC_Hall		NE_Hall		WE_Hall		DeadChannel	
	INJ_Area		External		Env_ADCs		EERoom			
Infrastructures	ACS_CB_Hall		ACS_TB		ACS_DAQ_Room		ACS_EE_Room *		ACS_MC	
	UPS_TB *		UPS_MC		UPS_NE		UPS_WE		Generator	
								FlatChannel		
								ExistChannel		
								ACS_NE		
								ACS_WE		

Advanced Virgo Data Quality

Main complement of detector monitoring is the Data Quality.

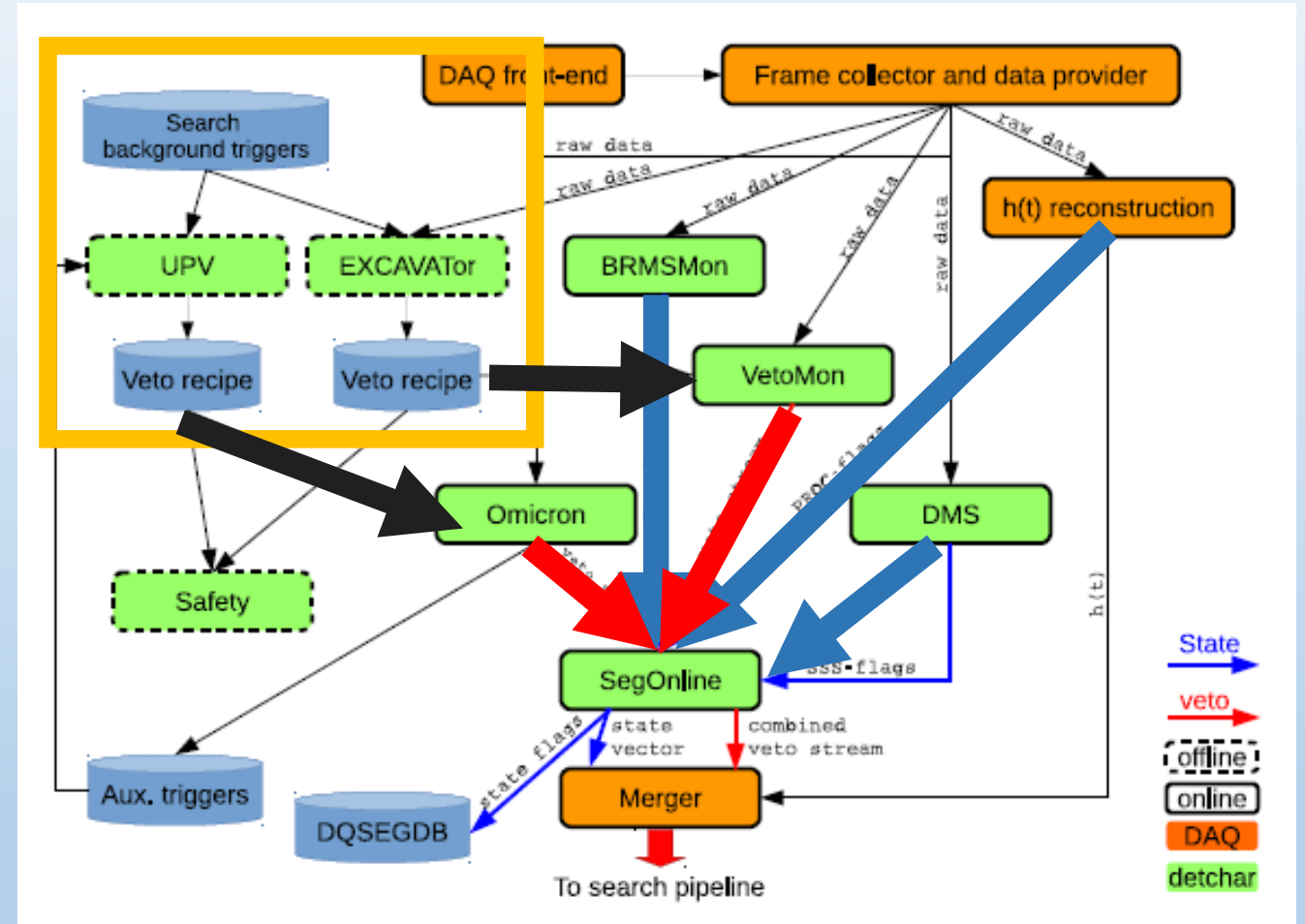
Its aims are:

- To provide reliable online quality flags and efficient offline quality flags for O2 and O3 observing runs
- To mitigate any impact of non-stationary 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



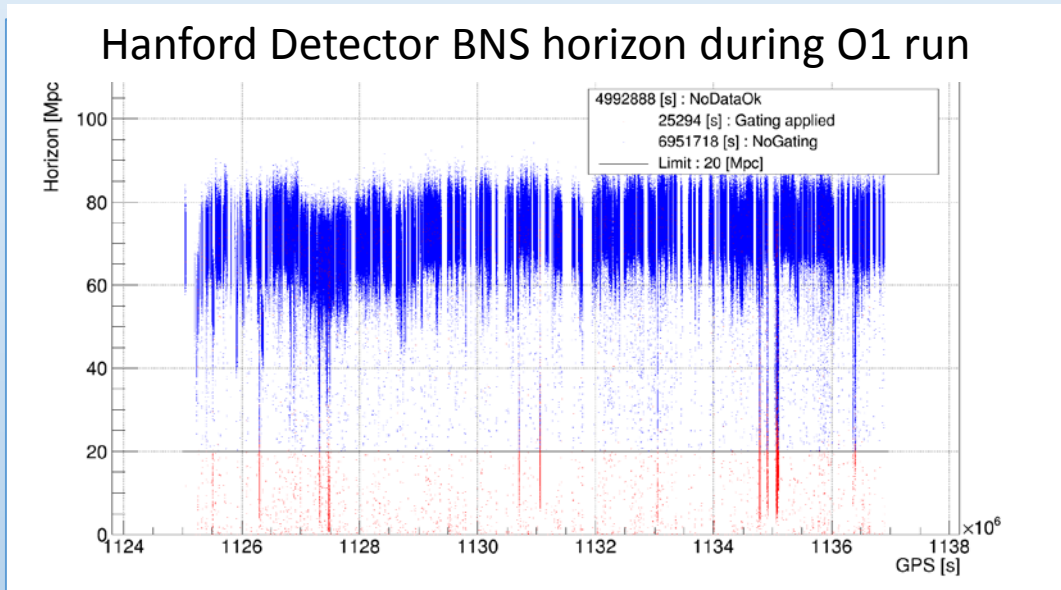
- To be added : gating of data and glitch removal (new)

The Gating of data

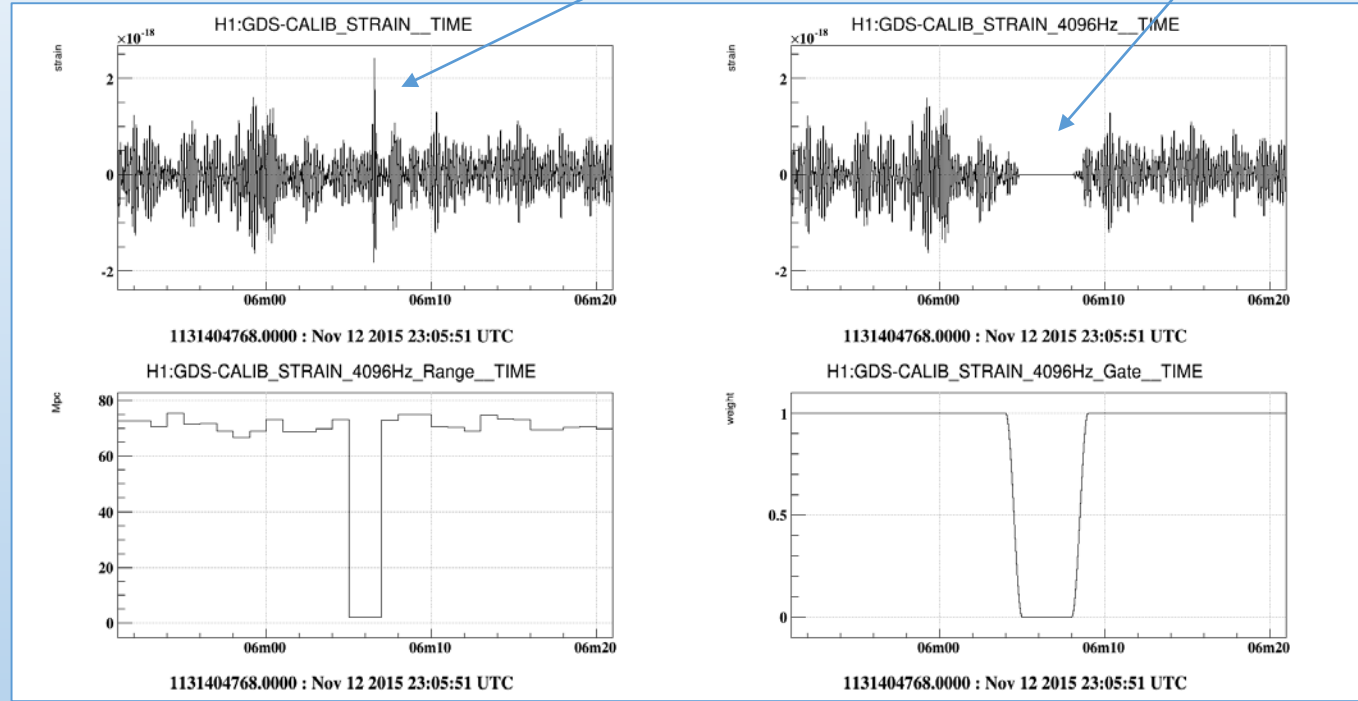
Gating : an alternative to the exclusion of data sets by vetos
Motivated by the need to keep data flow for the analysis pipelines

glitch

Data put to zero



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:

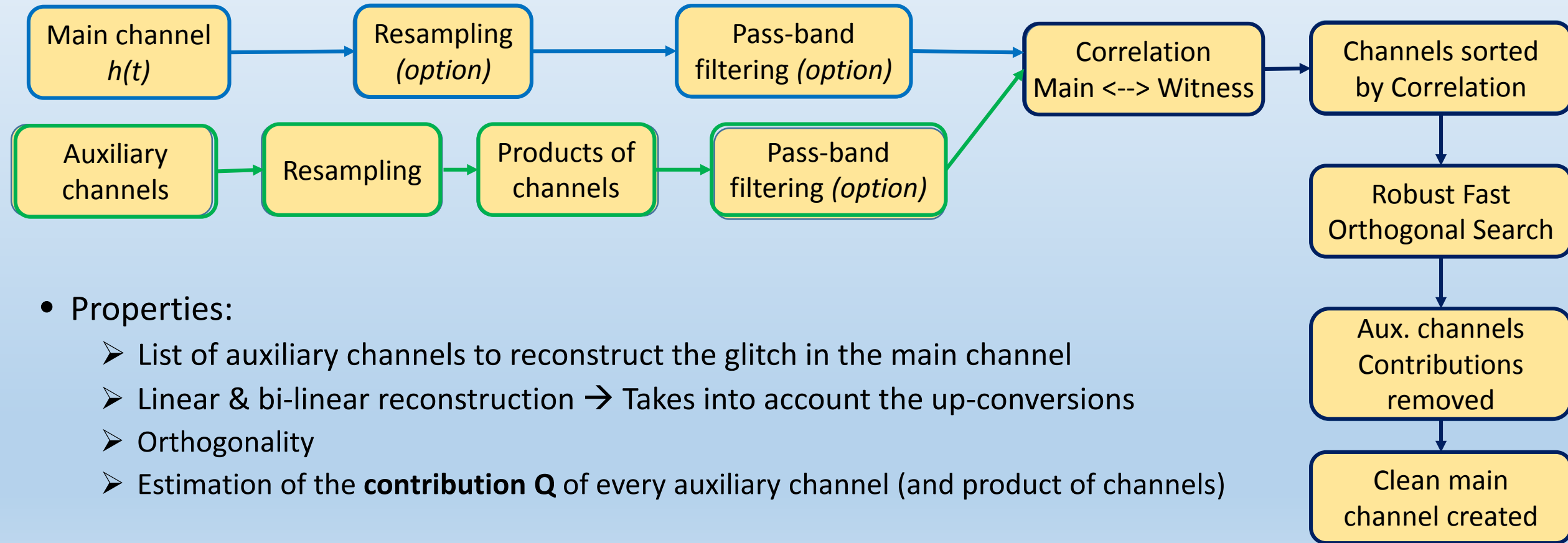
- List of auxiliary channels to reconstruct the glitch in the main channel
- Linear & bi-linear reconstruction → Takes into account the up-conversions
- Orthogonality
- Estimation of the **contribution Q** of every auxiliary channel (and product of channels)

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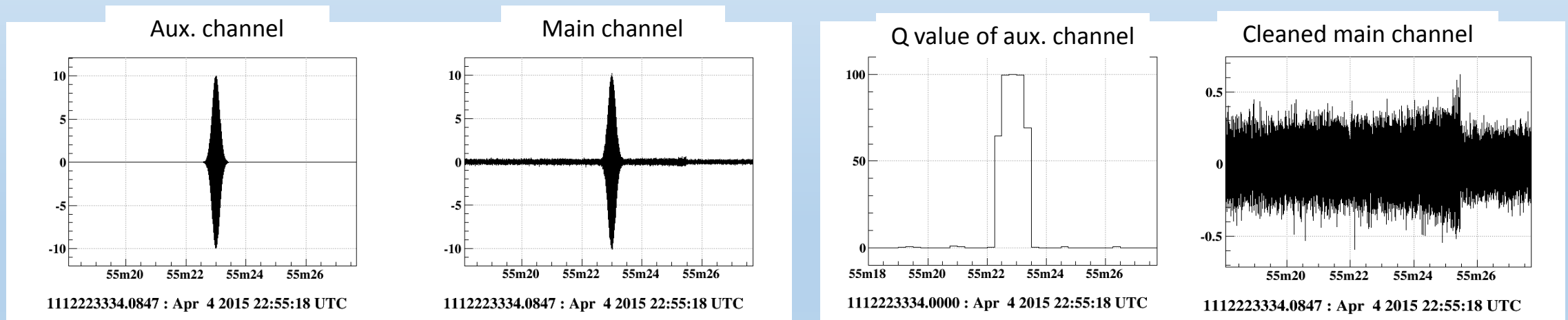
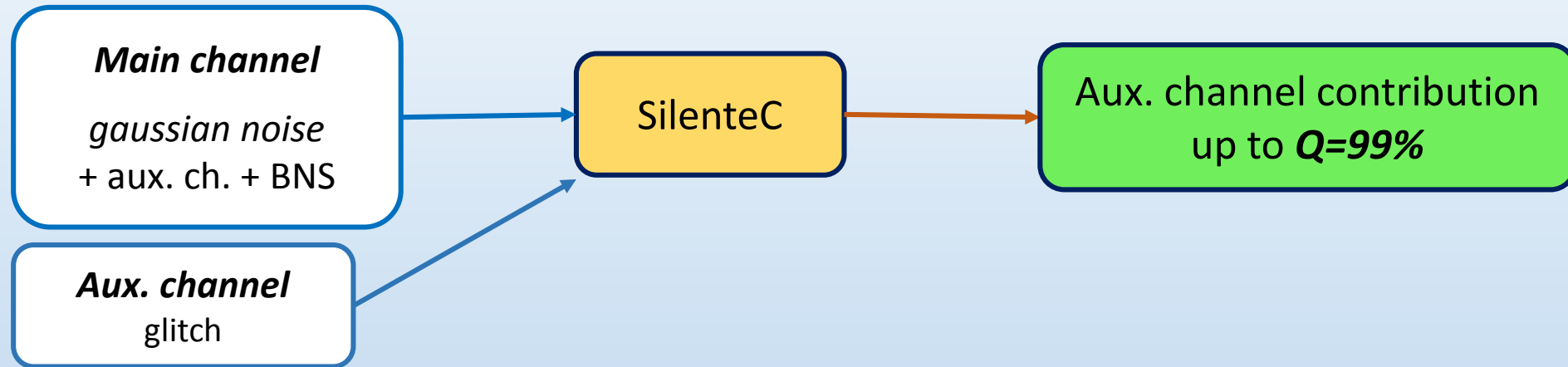


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Glitch removal in Advanced Virgo: SilenteC

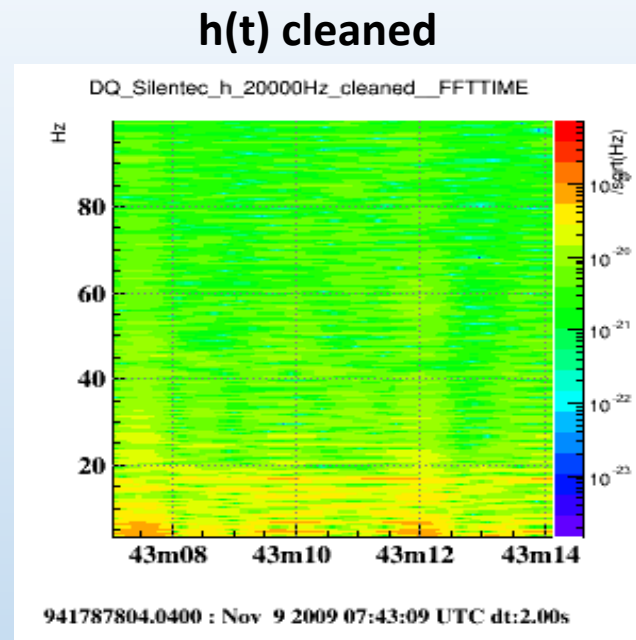
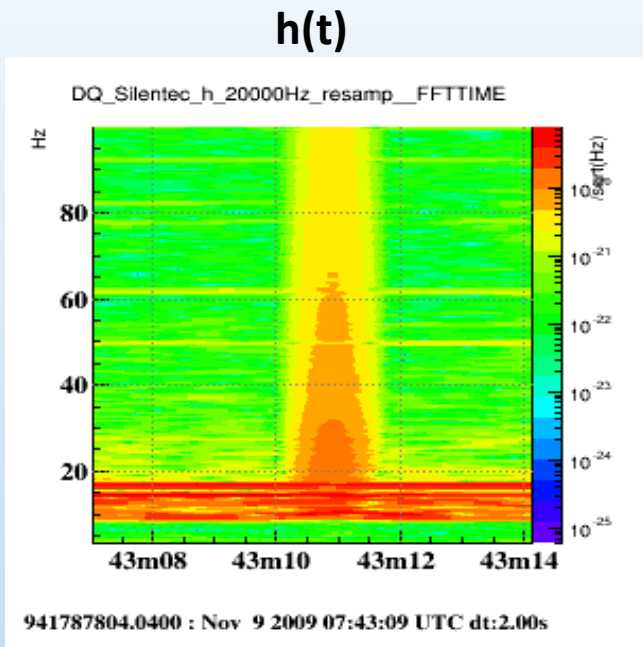
A simple test: a simulated glitch superposed to a Binary Neutron Star (BNS) signal



Glitch removal in Advanced Virgo: Silentec

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



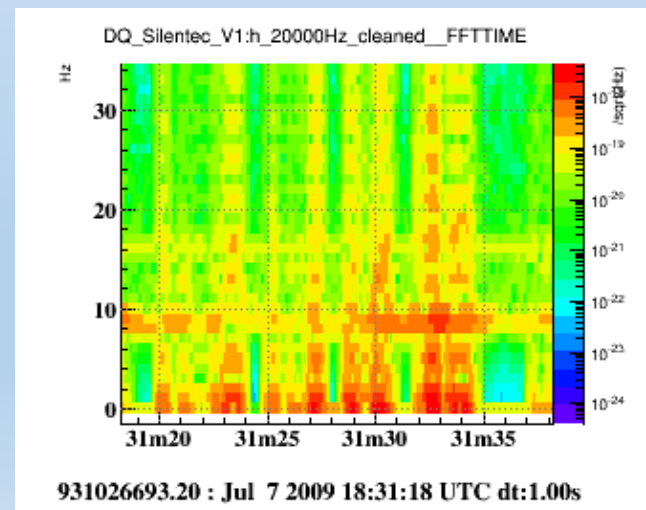
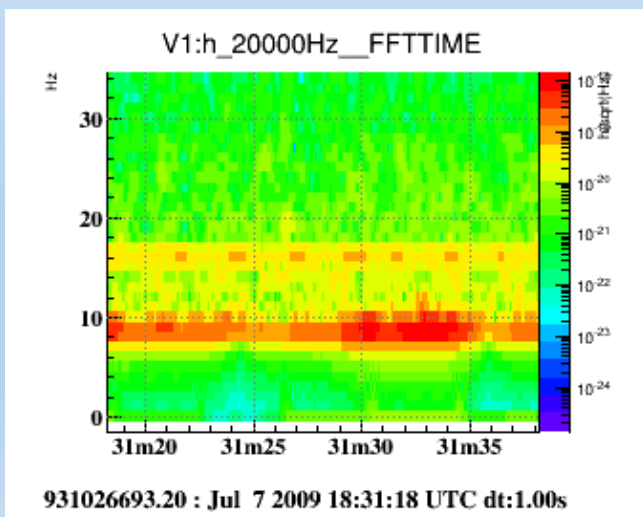
Quite successful cleaning in the frequency range of the glitch



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

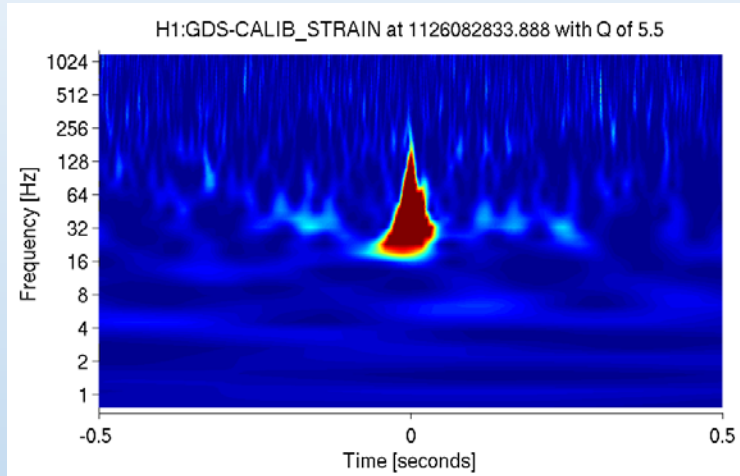
Summary

- 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

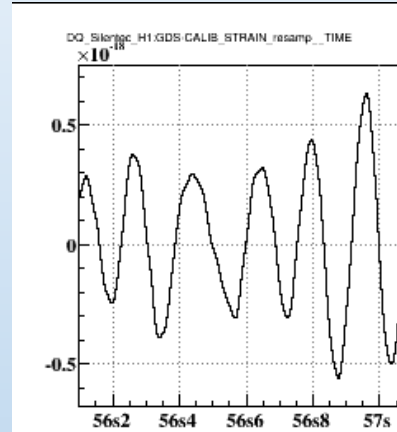
Backup slides

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

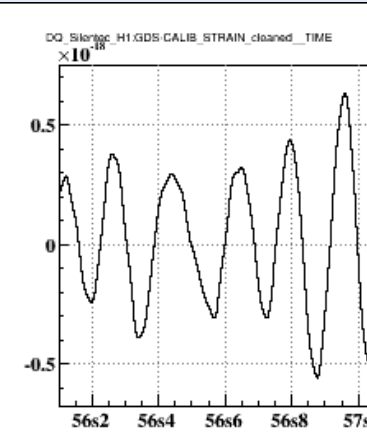


**h(t) resampled
at 1024 Hz**



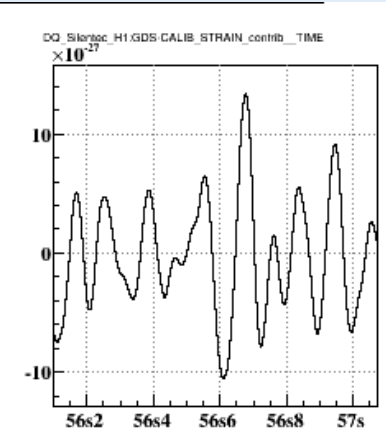
1126082833.1006 : Sep 12 2015 08:46:56 UTC

h(t) cleaned



1126082833.1006 : Sep 12 2015 08:46:56 UTC

**sum of contributions
above threshold of 5%**

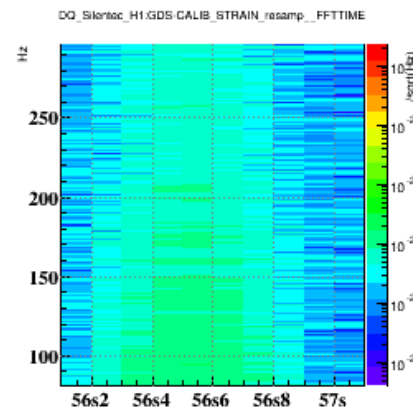


1126082833.1006 : Sep 12 2015 08:46:56 UTC

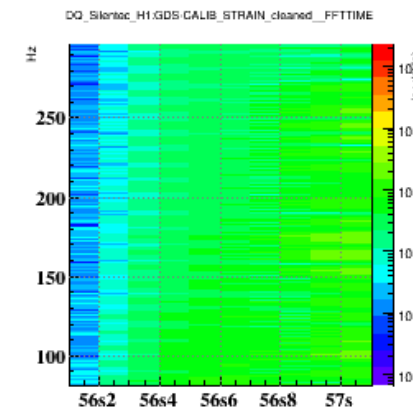
Threshold at 5%

The main contributing aux. channels are:

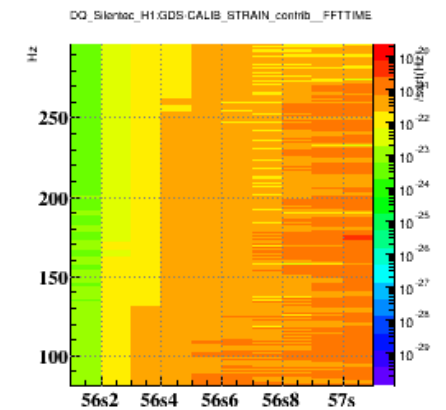
- [1] **H1:OMC-ASC_Y1_I_OUT_DQ** : Q=5.86154%
- [2] others : Q=13.7731%
- [3] unmodeled : Q=80.3654%



1126082833.1000 : Sep 12 2015 08:46:56 UTC dt:1.00s nAv:2



1126082833.1000 : Sep 12 2015 08:46:56 UTC dt:1.00s nAv:2



1126082833.1000 : Sep 12 2015 08:46:56 UTC dt:1.00s nAv:2

Virgo Data Quality: Impact on data analysis results

Most of false alarms removed by coincidence with other GW detectors

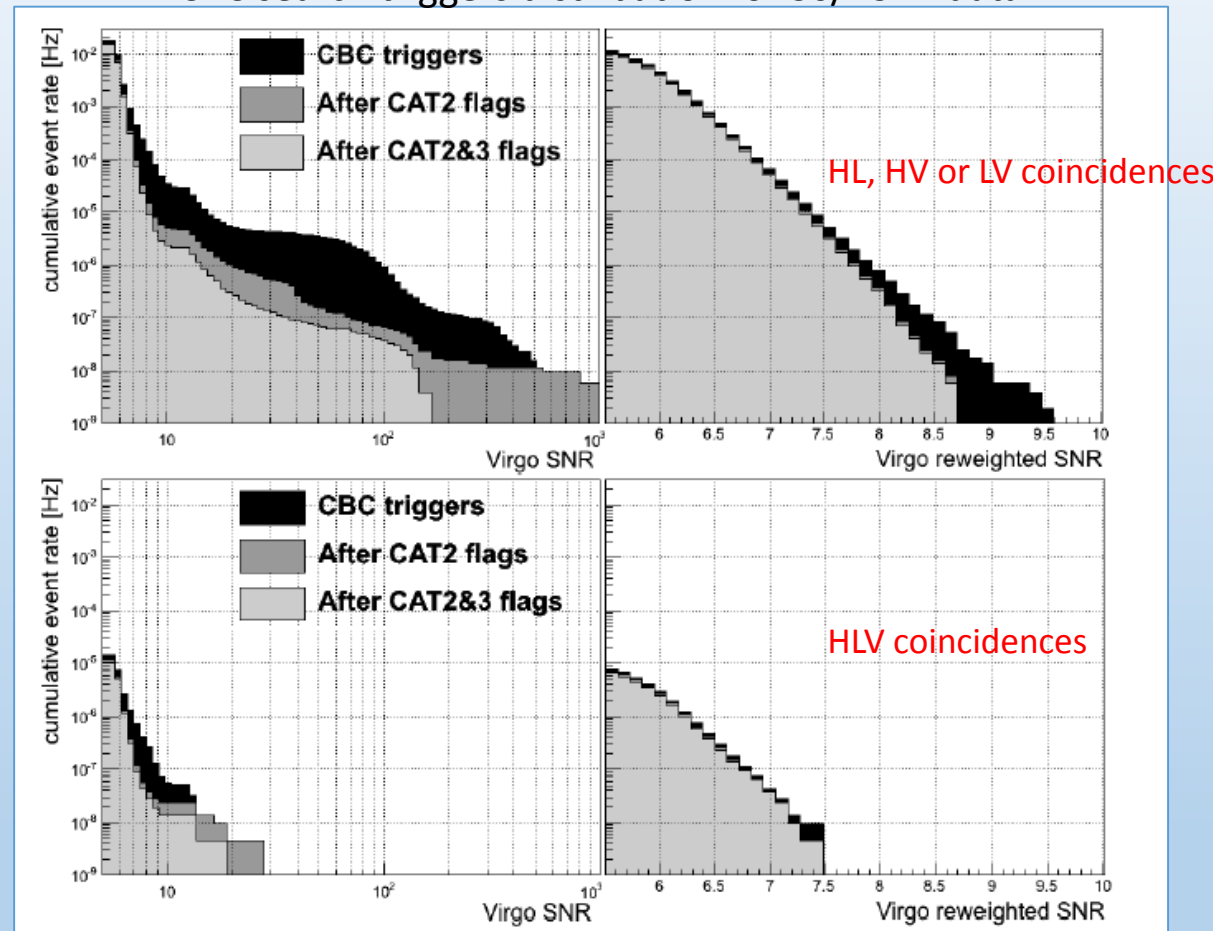
Remaining coincident events are mainly glitches



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

Data Quality vetos reduces this distribution tail.

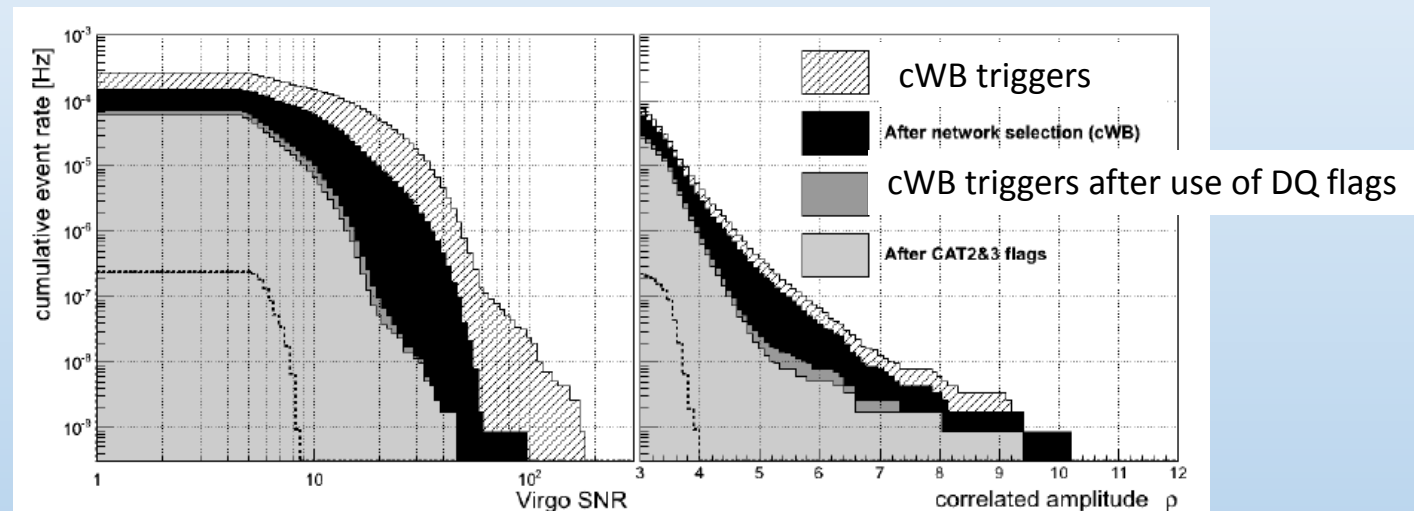
CBC search triggers distribution for S6/VSR2 data



Detector Monitoring and Data Quality

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

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



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

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Some new components are under development.

I will present here only some of those components in which I am more deeply involved.

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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