Data Quality in Gravitational Wave Burst and Inspiral Searches in the 2nd Virgo Science Run
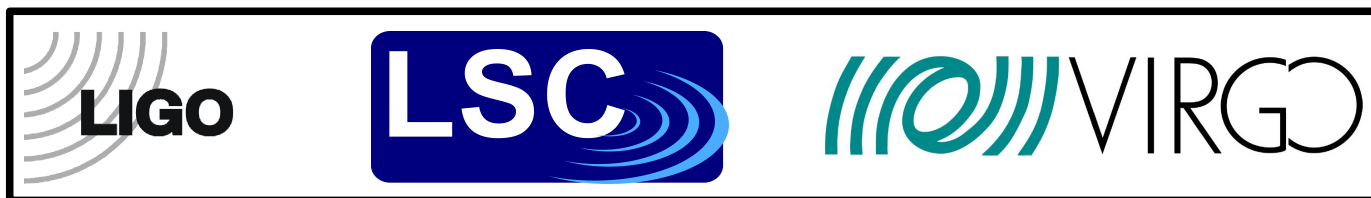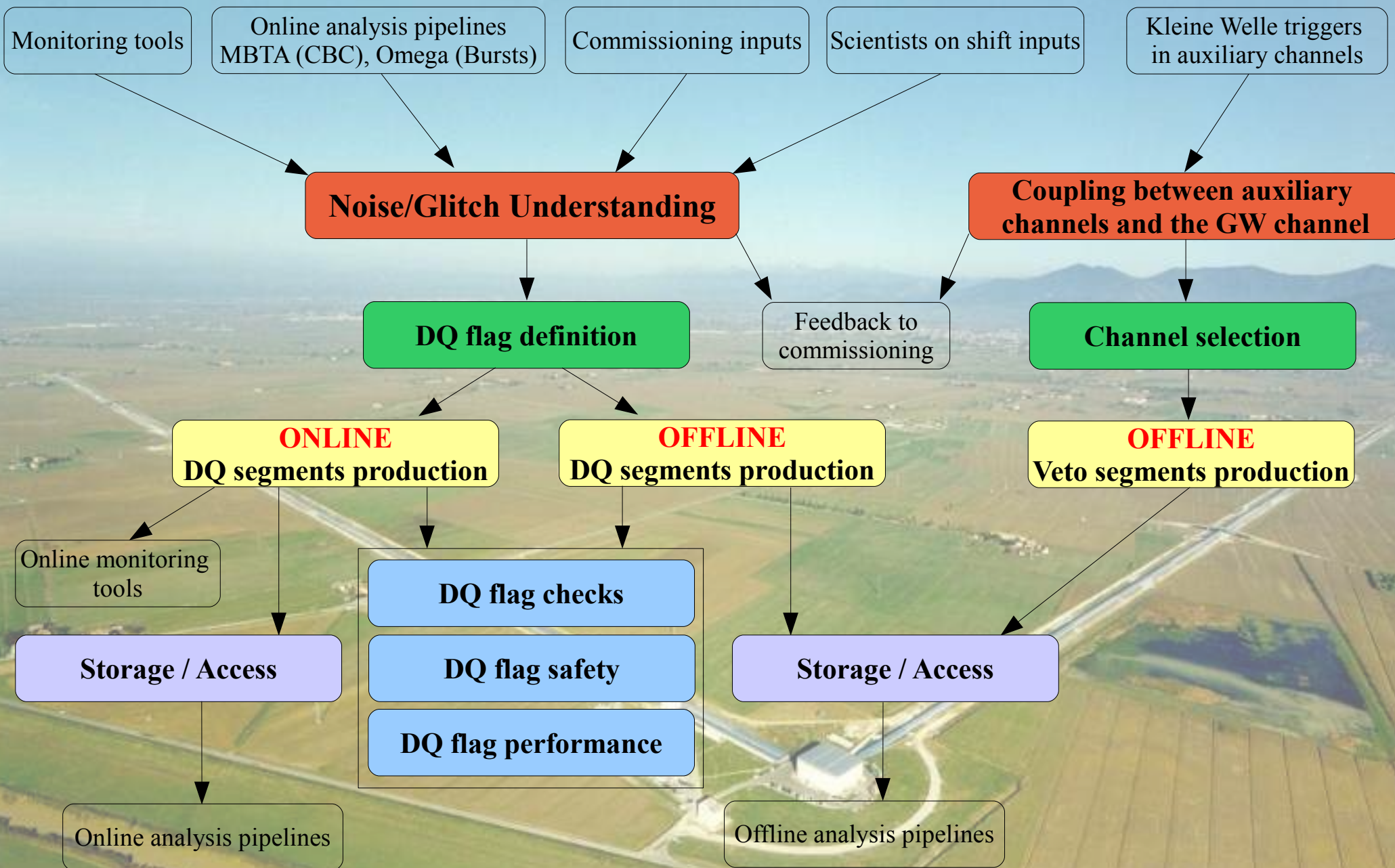
Florent Robinet
For the Virgo and the LSC Collaborations
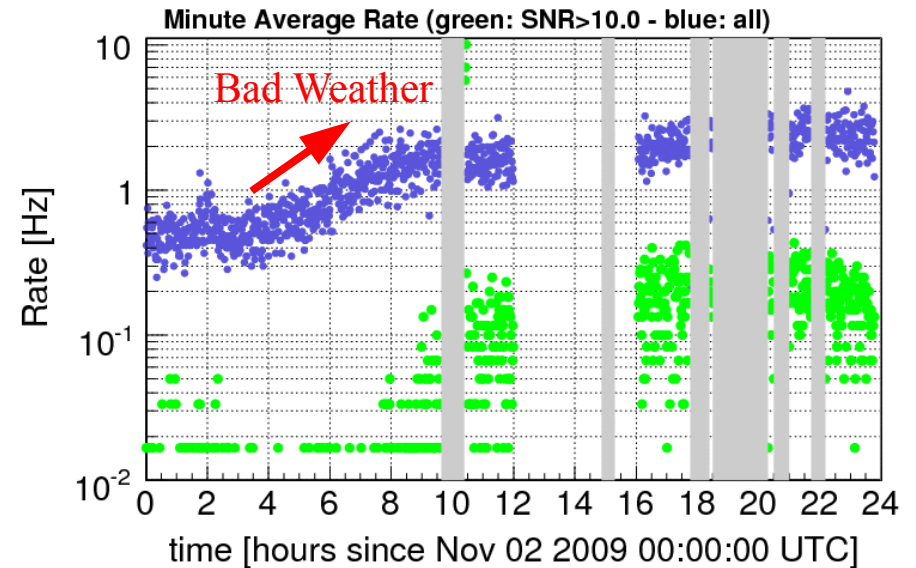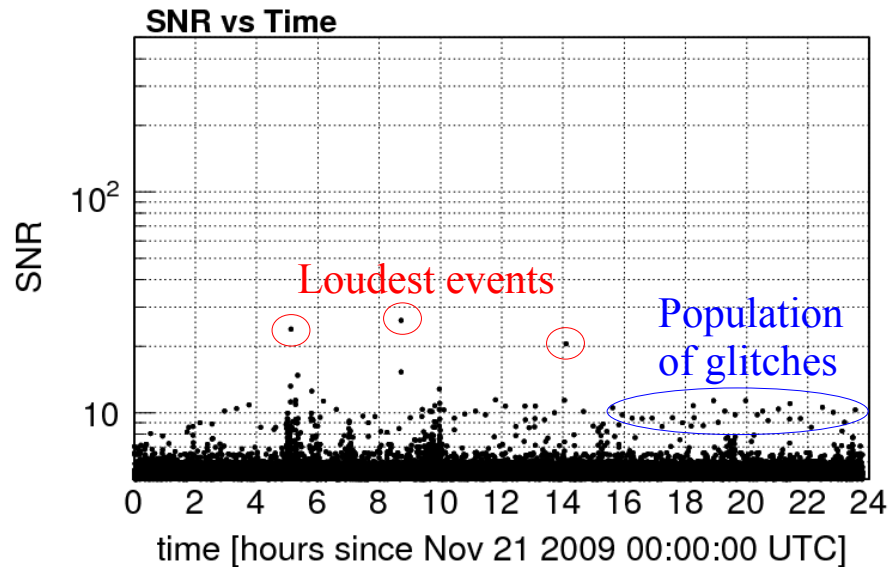
The Virgo Data Quality Group Activities

- **Online Analysis Pipelines**
    Omega for bursts, MBTA for CBC
    Trigger rate variations
    Follow-up of the loudest events

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- **Monitoring Tools**
  Band-RMS
  Spectrograms
  Omega scans
  Environmental monitoring

> 100 auxiliary channels

GW Signal

Injection channel

Magnetic sensor

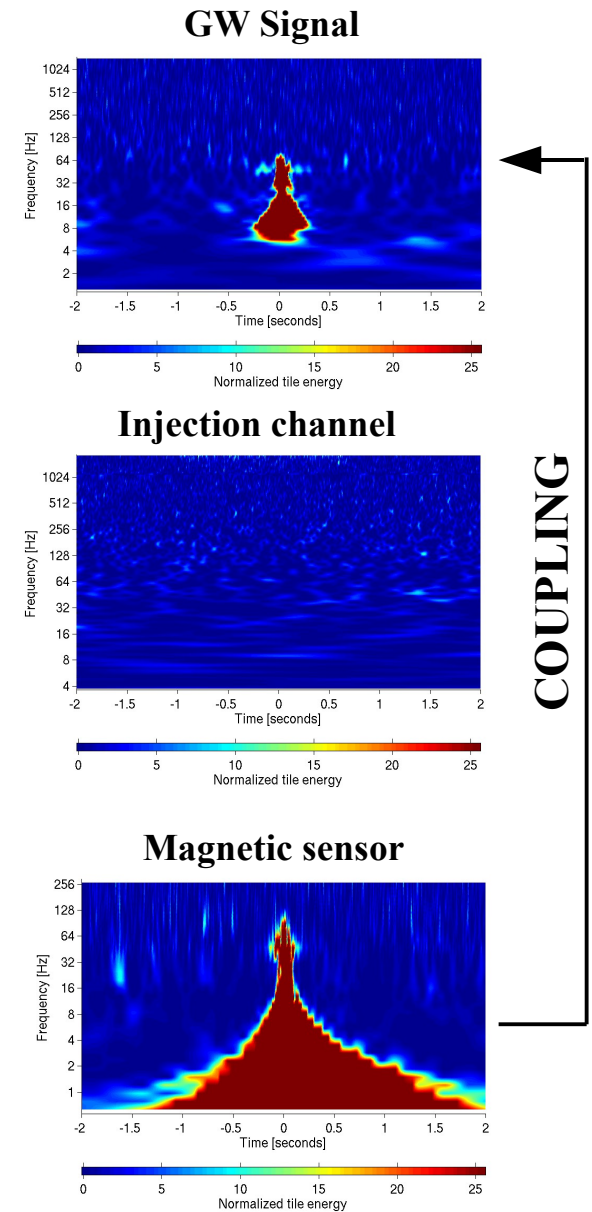COUPLING

Tools for Investigation

- **Online Analysis Pipelines**
    Omega for bursts, MBTA for CBC
    Trigger rate variations
    Follow-up of the loudest events

- **Monitoring Tools**
    Band-RMS
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    Unique knowledge of the interferometer
    Work on the detector on a day-by-day basis
    Strong interaction between the DQ group
    and the commissioning team

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- **Scientists on Shift**
  Shift report in the logbook
  Weekly glitch investigation

DQ Categories

DQ flags have been divided into **5 categories** for a better use by analyses :

CAT 1 : **Obvious problems on the detector. CAT1 periods have to be removed to redefine the science data.**

Ex. : <u>Missing h(t)</u>

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Ex. : <u>Flags defined by hand in case of a serious malfunction of the detector</u>
Usually, these kind of flags are introduced offline later,
based on observations of commissioners / shifters.
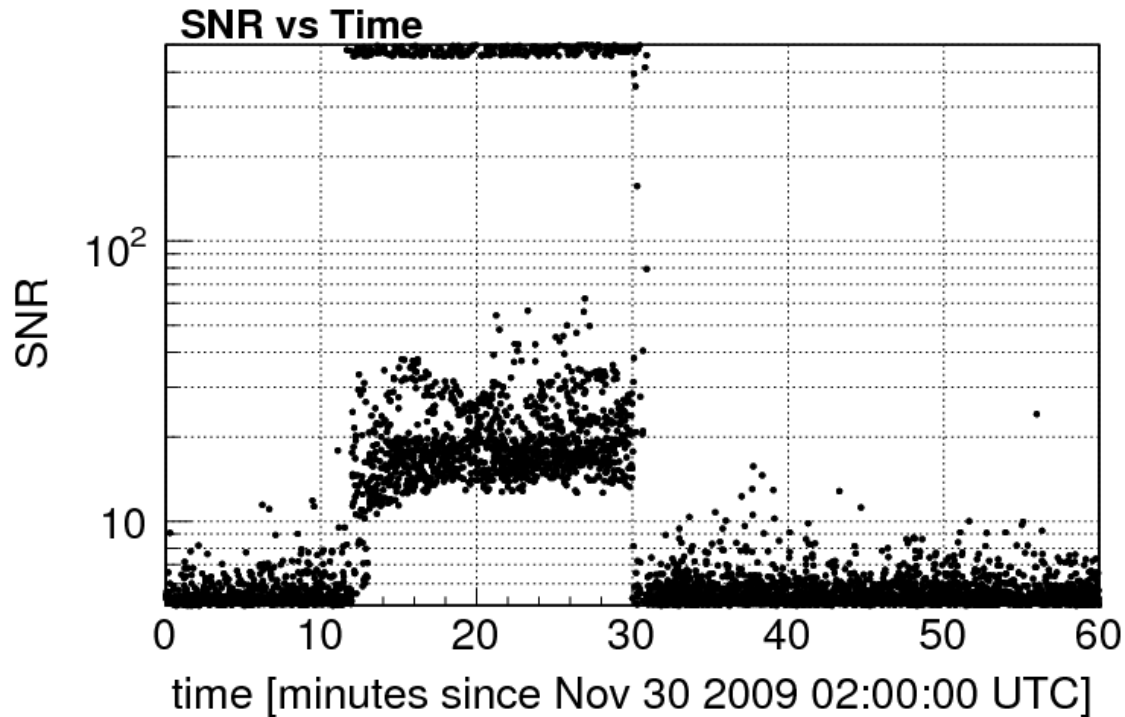
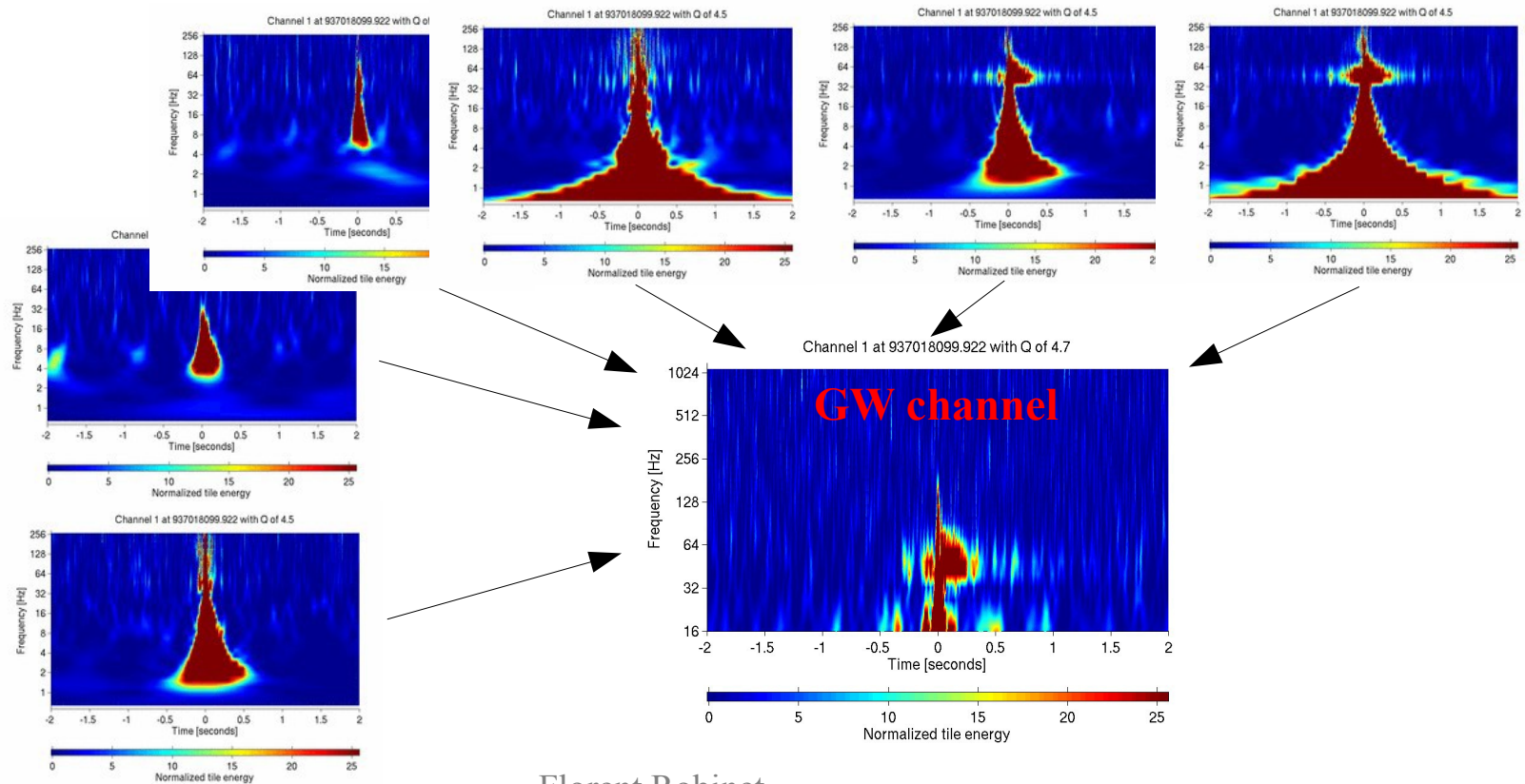

Thermal Compensation System failure

DQ Categories

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Ex. : <u>Magnetic glitches</u>. A 50Hz glitch is seen by all the magnetometer at the same time.

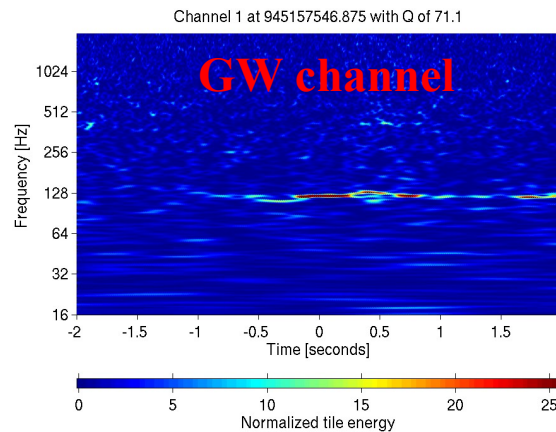DQ flags have been divided into **5 categories** for a better use by analyses :

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Ex. : <u>Acoustic glitches</u>.

Airplane event detected by a microphone

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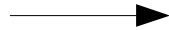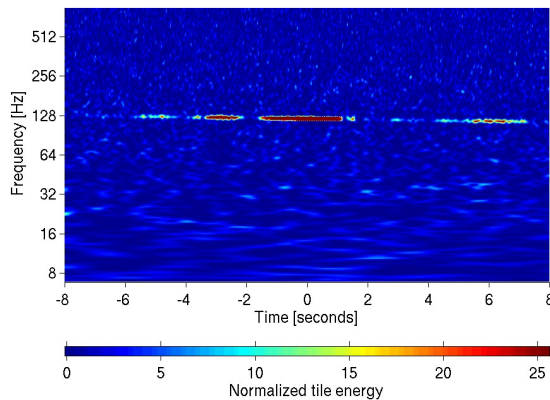
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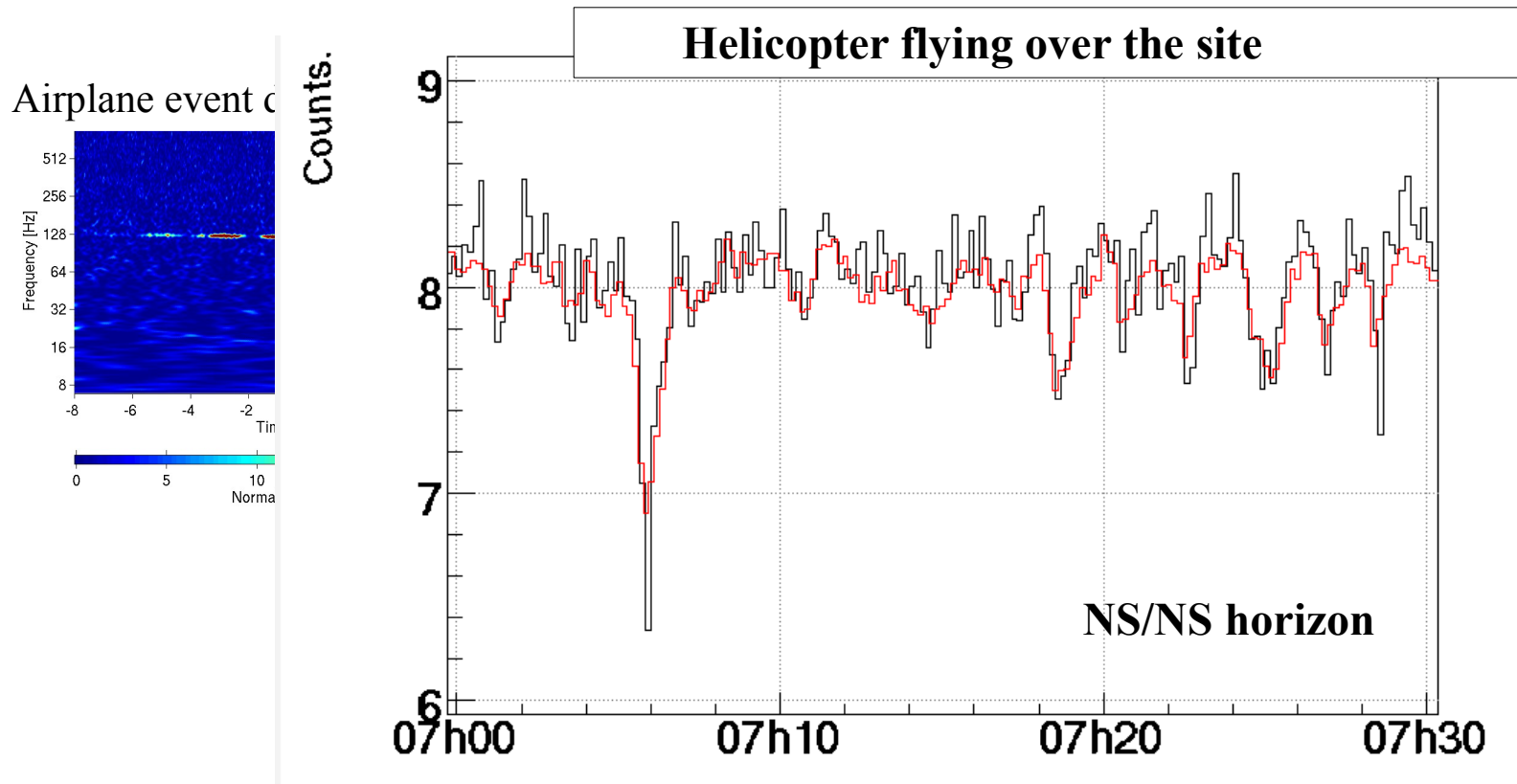
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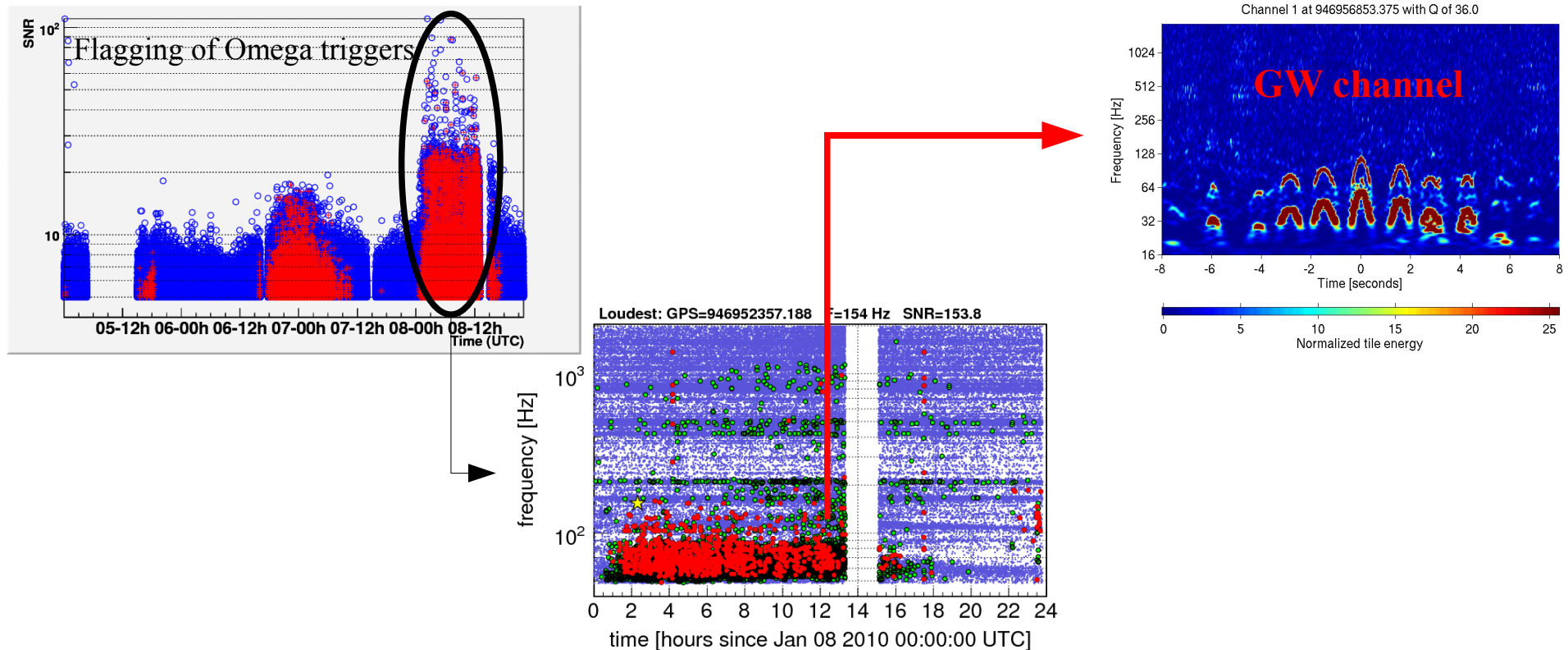Ex. : Severe micro-seismic activity *see I. Fiori's talk*

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The validity of a GW candidate flagged by a CAT3 should be controlled carefully.

Ex. : <u>seismic glitches</u>
2 seismic glitches of the same amplitude will not have the same impact on the GW channel.
CAT3 vetoes plays a big role in the follow-up studies.

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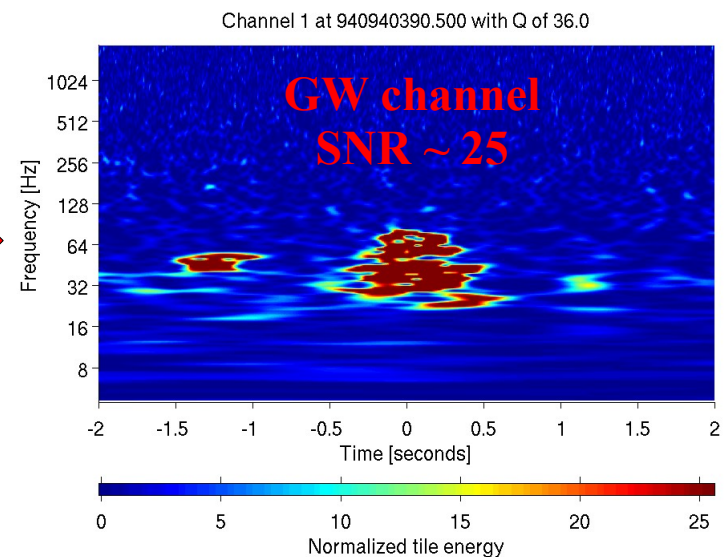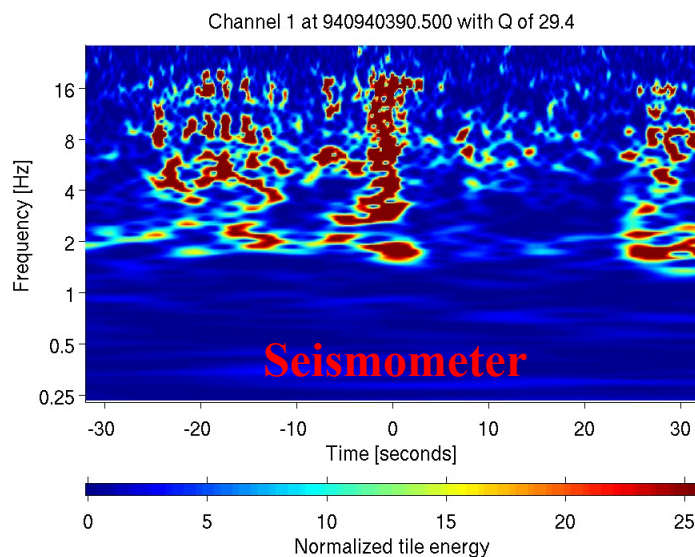
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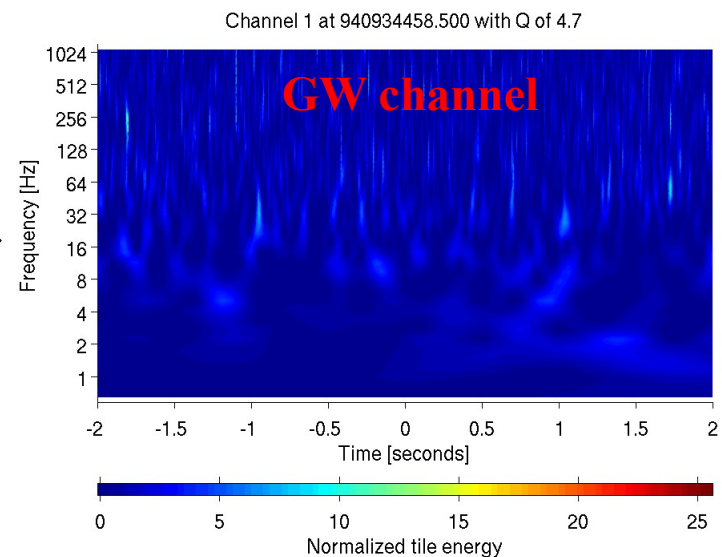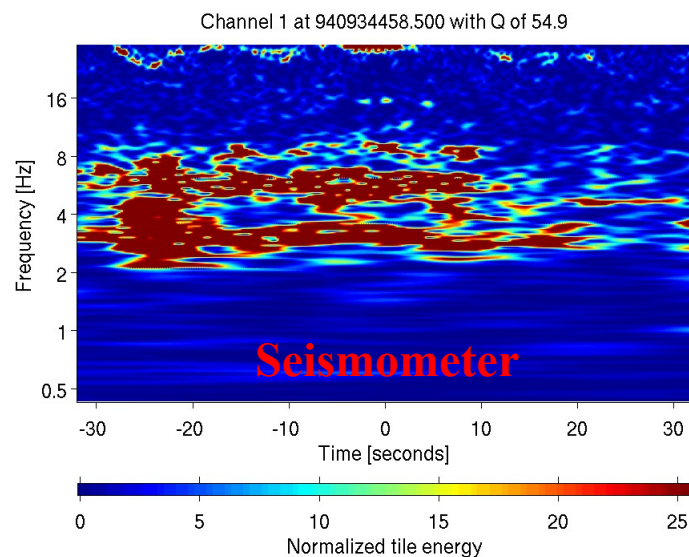
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Ex. : <u>Same as CAT2 but with stricter threshold</u>

CAT2 micro-seismic flag

CAT3 micro-seismic flag with a lower threshold

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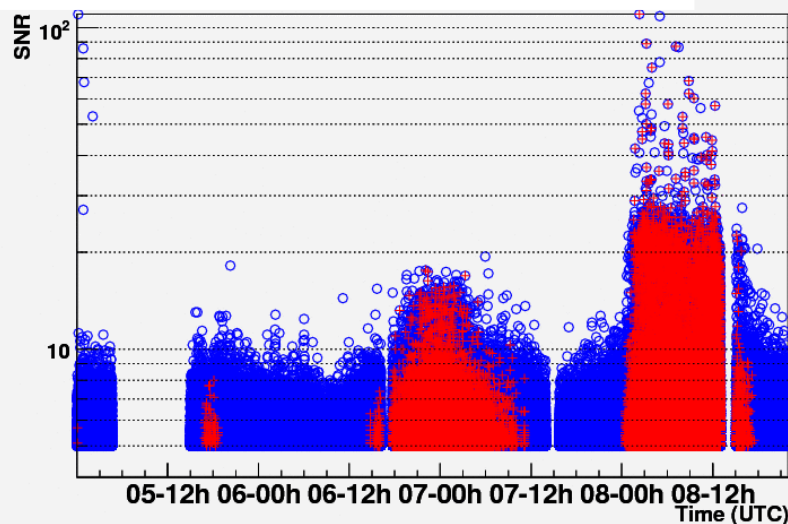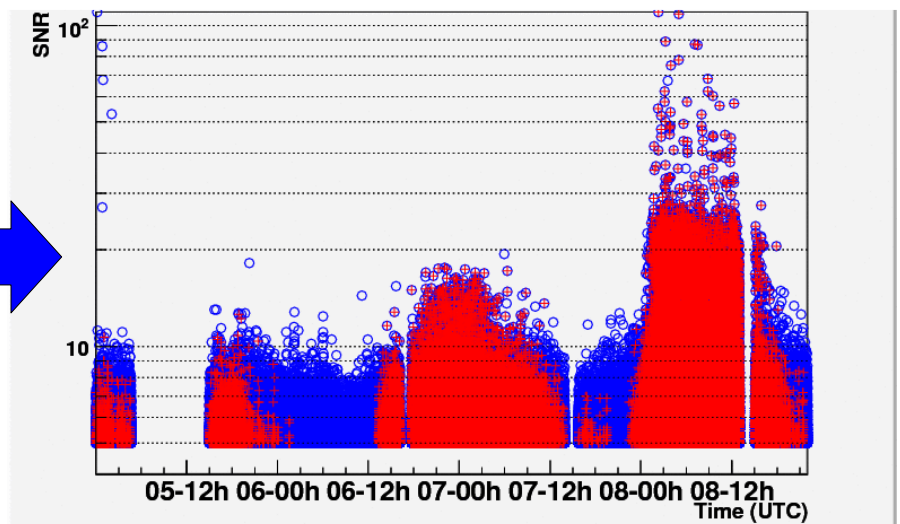
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CAT5 : **Advisory flags to track problems on the detector but no direct impact on the GW channel**
Ex. : 300sec after the lock starts the detector is known to be unstable.

TOTAL **~ 70 DQ flags**

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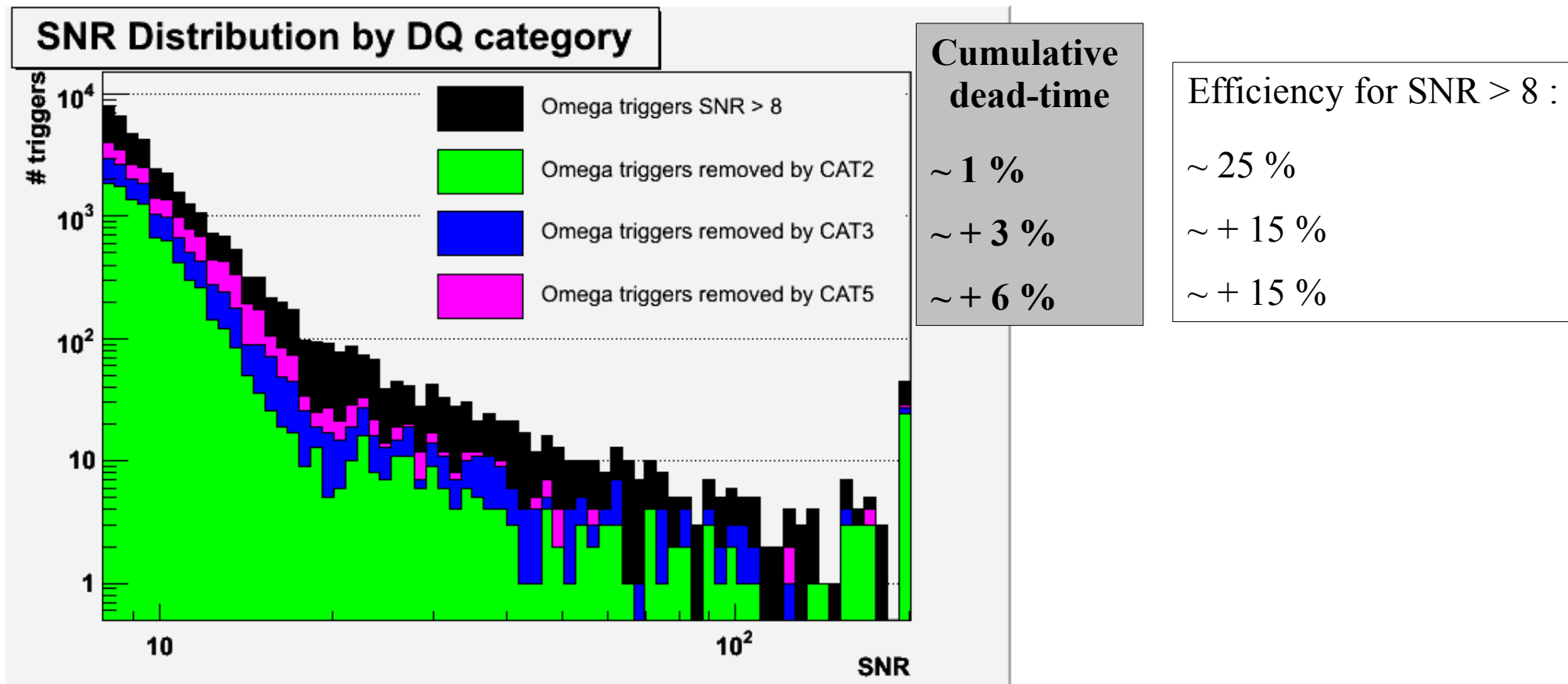To be removed from the GW candidate list

CAT5 : **Advisory flags to track problems on the detector but no direct impact on the GW channel**
Ex. : 300sec after the lock starts the detector is known to be unstable.

TOTAL ~ 70 DQ flags
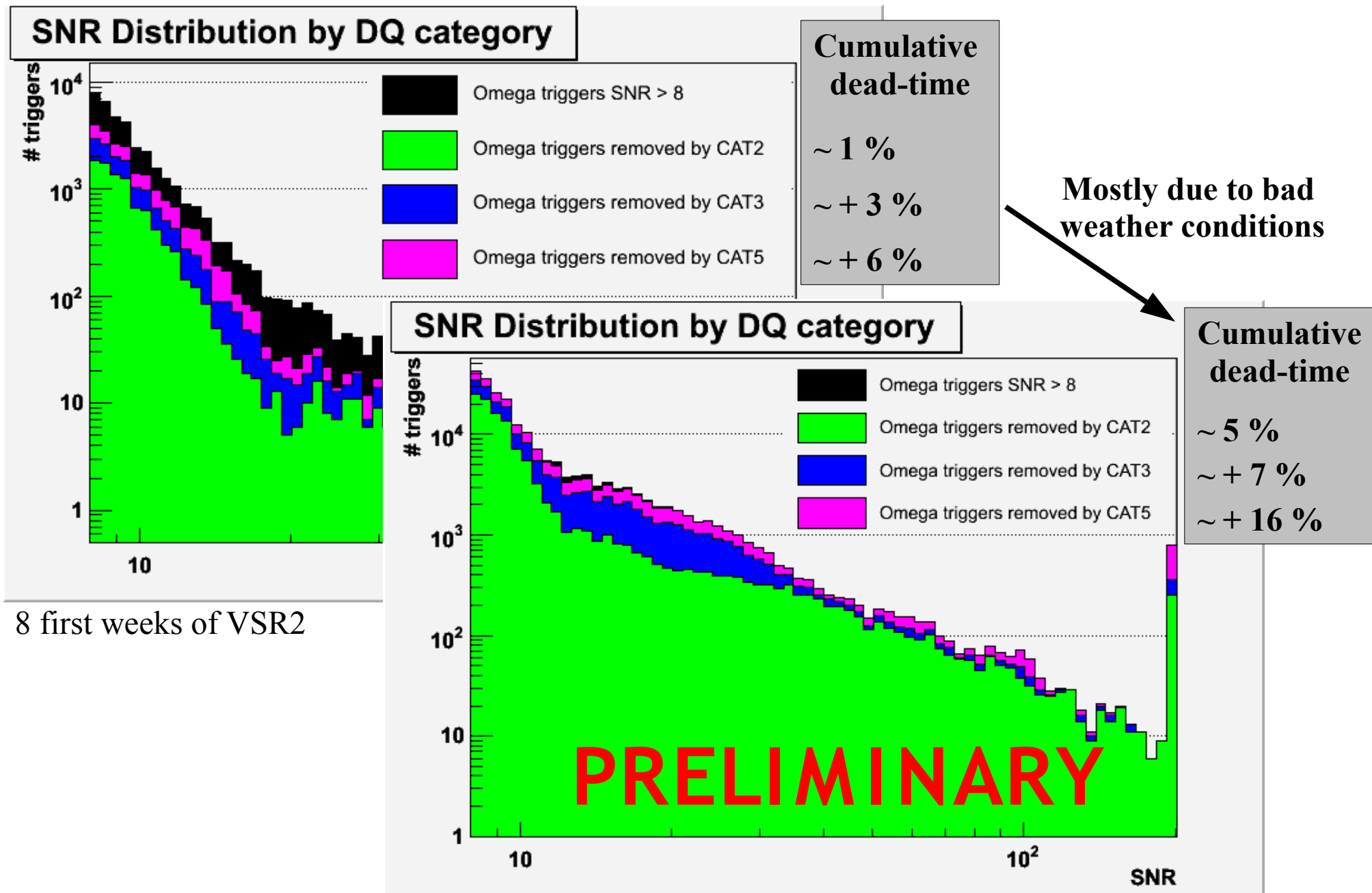
> **The safety of all DQ flags has been checked**
> A flag is declared unsafe if the number of flagged hardware injections is larger
> than dead-time × total number of hardware injections

DQ Impact for Bursts

SNR Distribution by DQ category

triggers vs SNR

- Omega triggers SNR > 8 (black)
- Omega triggers removed by CAT2 (green)
- Omega triggers removed by CAT3 (blue)
- Omega triggers removed by CAT5 (magenta)

8 first weeks of VSR2

Cumulative dead-time	Efficiency for SNR > 8 :
~ 1 %	~ 25 %
~ + 3 %	~ + 15 %
~ + 6 %	~ + 15 %

SNR Distribution by DQ category

- Omega triggers SNR > 8
- Omega triggers removed by CAT2
- Omega triggers removed by CAT3
- Omega triggers removed by CAT5

Cumulative dead-time

~ 1 %

~ + 3 %

~ + 6 %

Mostly due to bad weather conditions

SNR Distribution by DQ category

- Omega triggers SNR > 8
- Omega triggers removed by CAT2
- Omega triggers removed by CAT3
- Omega triggers removed by CAT5

Cumulative dead-time

~ 5 %

~ + 7 %

~ + 16 %

PRELIMINARY

8 first weeks of VSR2

19 last weeks of VSR2

DQ Impact for Inspirals (MBTA)

SNR Distribution by DQ category

Legend:
- MBTA triggers SNR > 7 (black)
- MBTA triggers removed by CAT2 (green)
- MBTA triggers removed by CAT3 (blue)
- MBTA triggers removed by CAT5 (magenta)
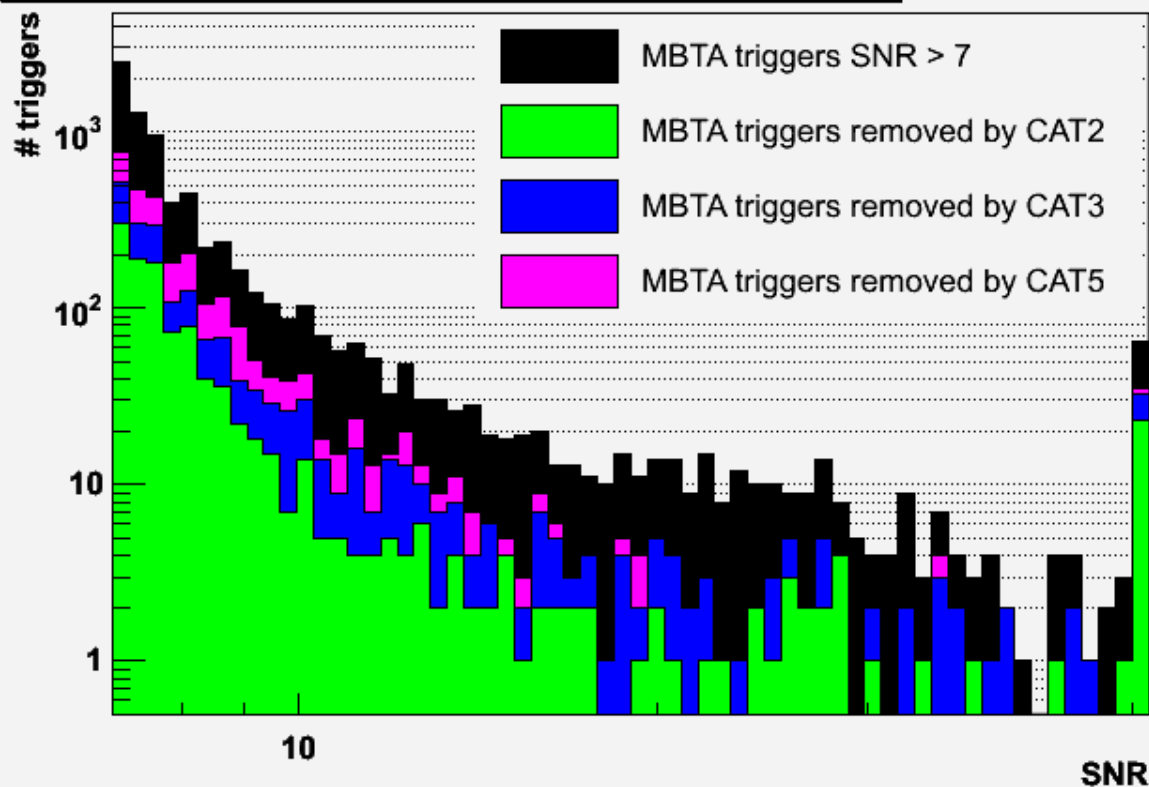
Cumulative dead-time

~ 1 %

~ + 3 %

~ + 6 %

Efficiency for SNR > 7 :

~ 14 %

~ + 11 %

~ + 12 %

8 first weeks of VSR2

Veto Based on Auxiliary Channels

Kleine Welle is a fast filtering algorithm used to produce triggers on multiple channels (>200 at Virgo) :
• Environmental channels : seismic, magnetic, acoustic...
• Optical channels : photodiode signals, laser monitoring
• Control channels

The most useful channels are selected by looking at the **correlations with the GW triggers**.

2 strategies are used to define the vetoes :

Burst strategy :

    1)   Channels are ranked according to their efficiency to remove GW triggers.
    2)   - Only channels with a large statistical significance are used (LIGO).
           - Only channels with a large efficiency/use-percentage are used (Virgo).
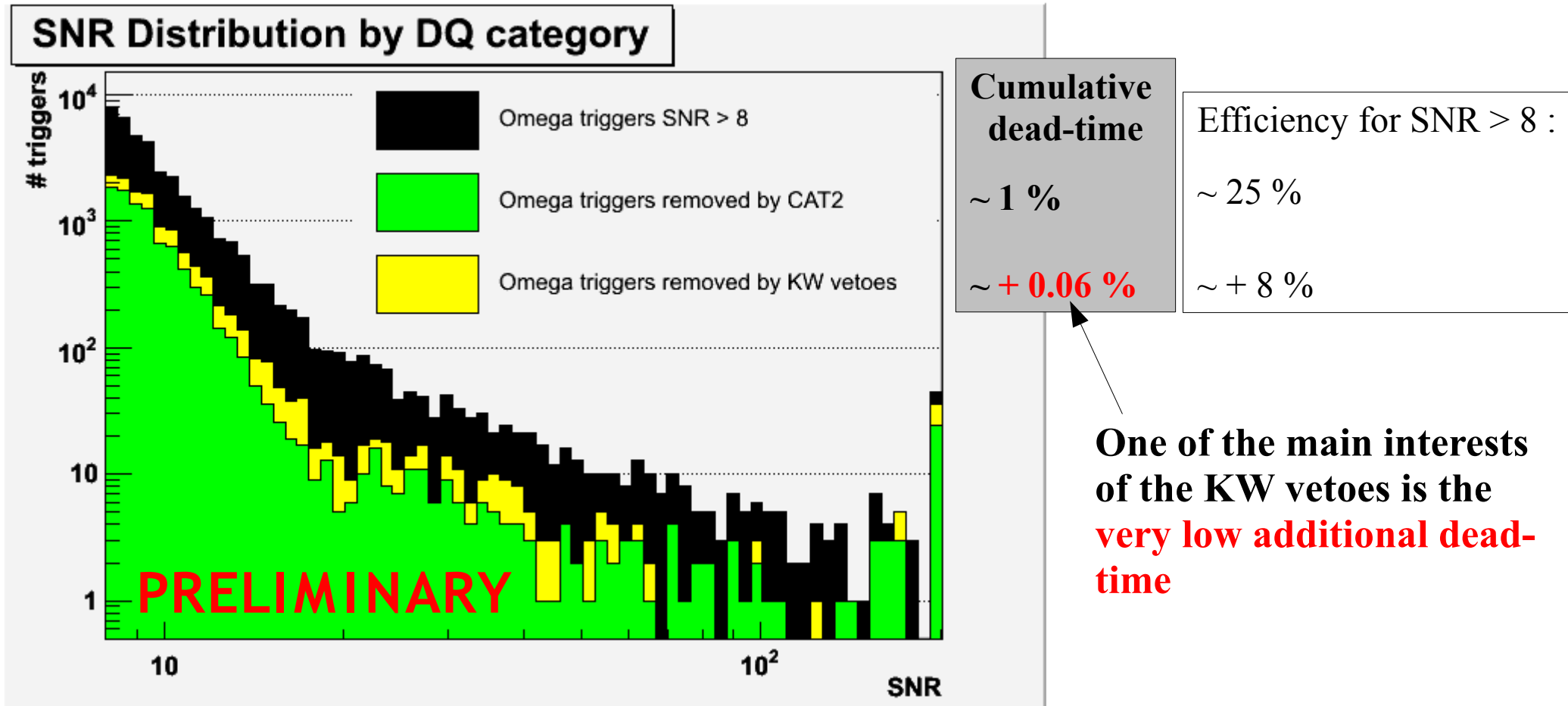
CBC Strategy :

    Only channels with a use-percentage > 50% are used (both for Virgo and LIGO)
    See T. Isogai's poster

→ **All the strategies give consistent results**

SNR Distribution by DQ category

triggers (y-axis), SNR (x-axis)

Legend:
- Omega triggers SNR > 8 (black)
- Omega triggers removed by CAT2 (green)
- Omega triggers removed by KW vetoes (yellow)

PRELIMINARY

Cumulative dead-time

~ 1 %

~ + 0.06 %

Efficiency for SNR > 8 :

~ 25 %

~ + 8 %

One of the main interests of the KW vetoes is the very low additional dead-time

8 first weeks of VSR2

For VSR1, a specific veto was originally introduced for dust-induced events. A genuine GW signal should create a signal in the in-phase channel (ACp) and not in the quadrature channel (ACq).

The PQ veto is based on coincident KW triggers in ACp and ACq ($E_{ACq} > E_{ACp}$).

This veto can be defined only in Virgo since the demodulation phase is monitored and kept at a well-tuned value.

Very low dead-time (< 0.5 %).
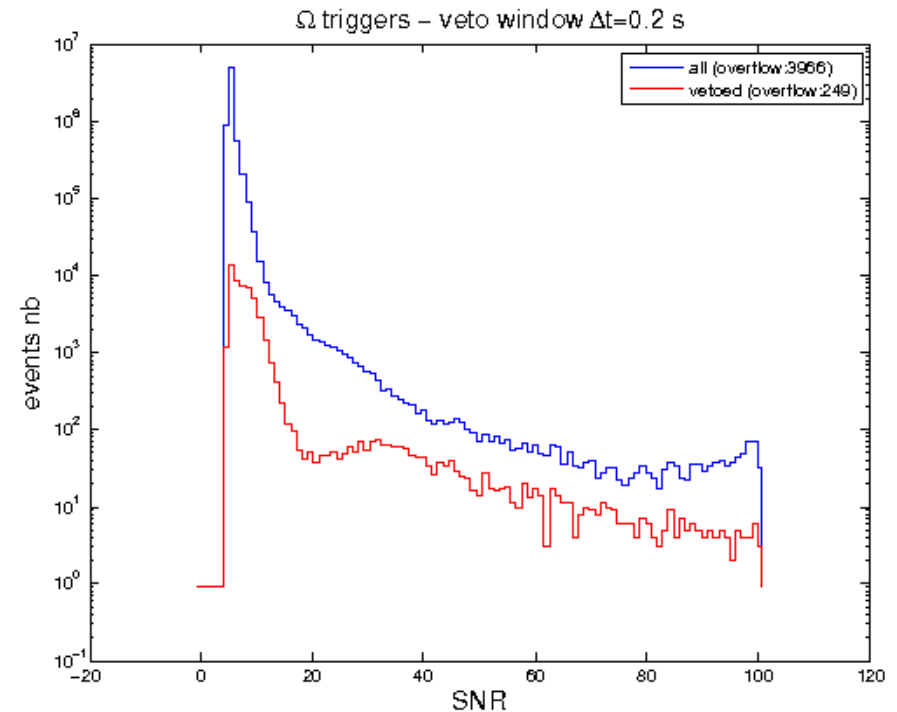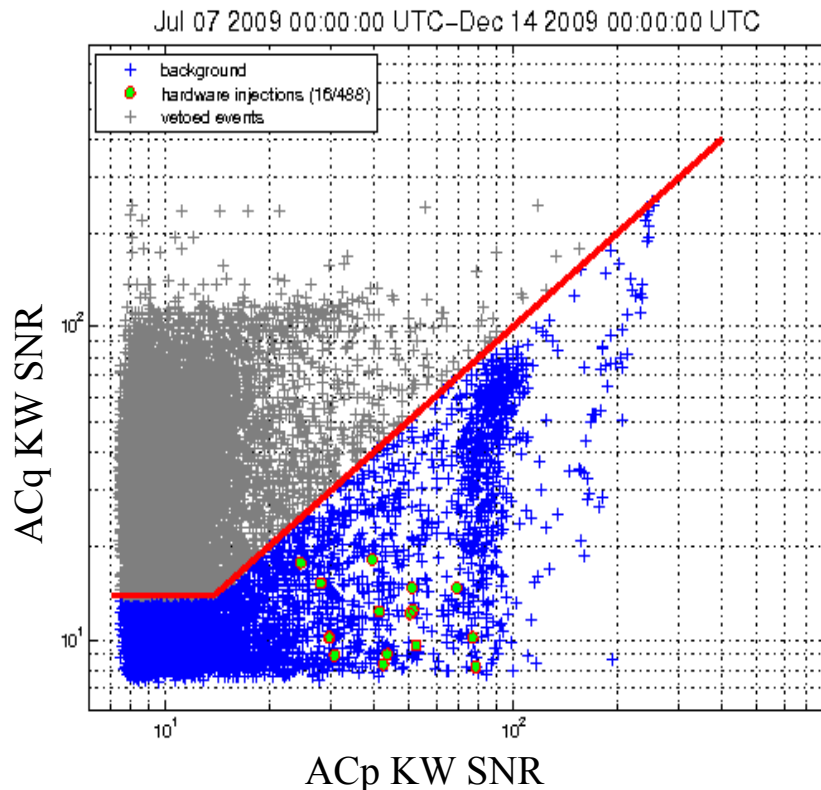
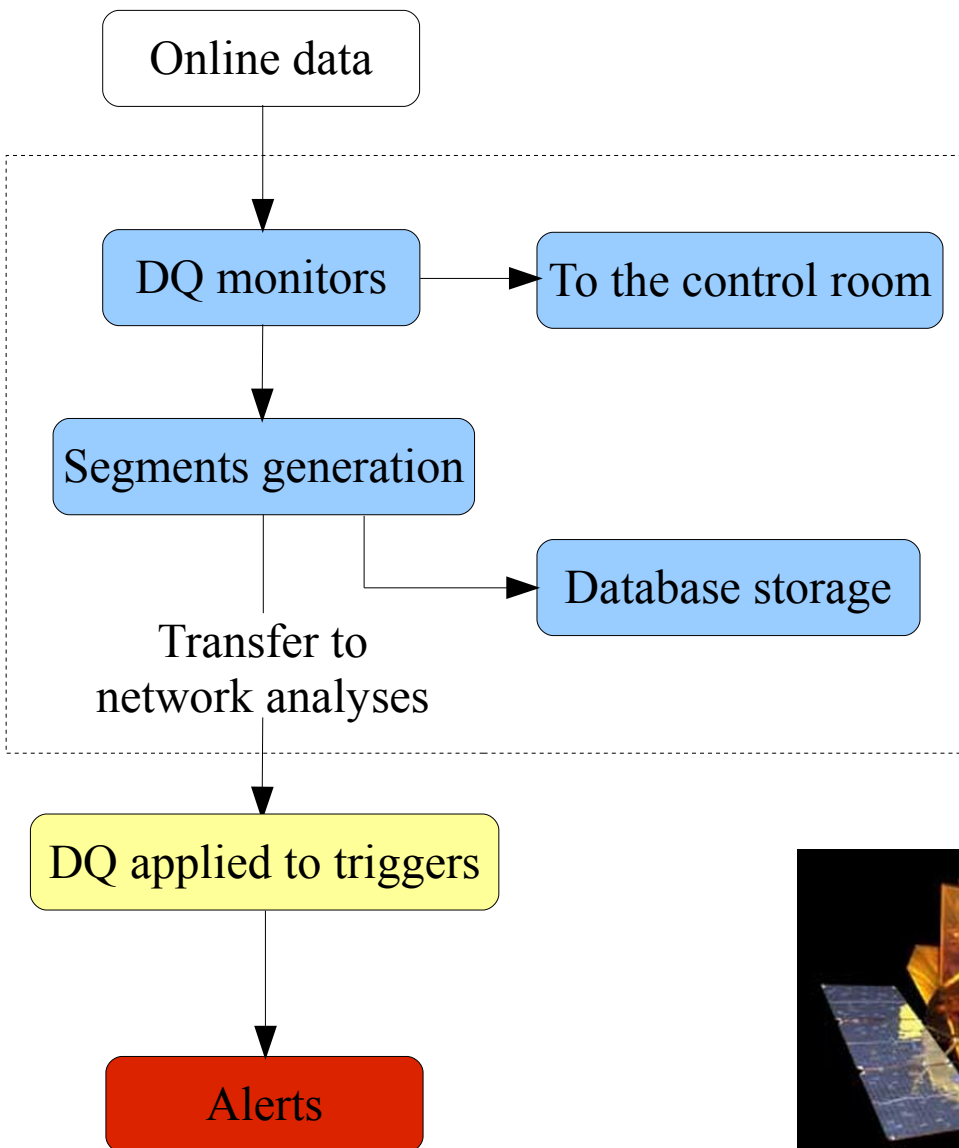Safety is checked on hardware injections (green points).

DQ Storage

MySQL database to store DQ and veto segments.

Web interface to retrieve and combine segment lists.

Very practical tool for follow-up studies.

The Virgo database is frequently synchronized with the LIGO database.
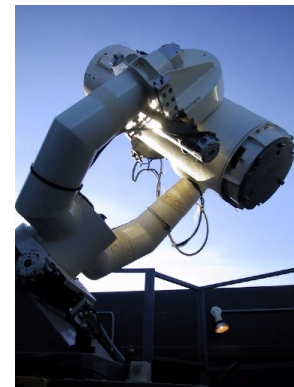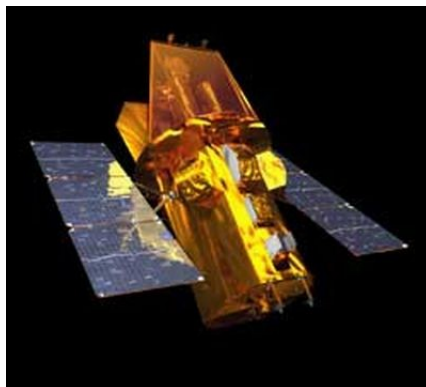
Online Data Quality

DQ monitors have been developed to produce DQ flags with a few seconds latency.
(~70 flags)

Monitor outputs are used in the control room by the shift crew.

Segments are generated and sent to the analysis computers within the minute.

Candidate alerts (*see Erik Katsavounidis's talk*)

Flow diagram (left side):

- Online data
  - → DQ monitors → To the control room
    - → Segments generation
      - → Database storage
    - Transfer to network analyses
      - → DQ applied to triggers
        - → Alerts

Conclusions

- The **data quality work** has become **more and more crucial** to aim at a GW detection.
- The Virgo Data Quality Group is an essential piece between the detector and the analyses groups.

- **Large efforts** have been made to understand the **noise of the new VSR2 detector**.

- About **70 DQ flags** have been defined and are produced online.
- **Correlations with auxiliary channels** have been studied and used to produce powerful vetoes (KW)

- **Many checks** have been performed to insure the **veto reliability** :
    - Segment checks
    - Safety against signal injections
    - Performance over analyses pipelines
    - Categorization of the flags

- Application of the Virgo vetoes over the analyses triggers show that a **large fraction of events can be flagged** with a limited dead-time.
- Some **glitches remain unexplained** and are under investigation.
- More **improvements are expected** in the next few weeks.