Calibration of the Virgo interferometer

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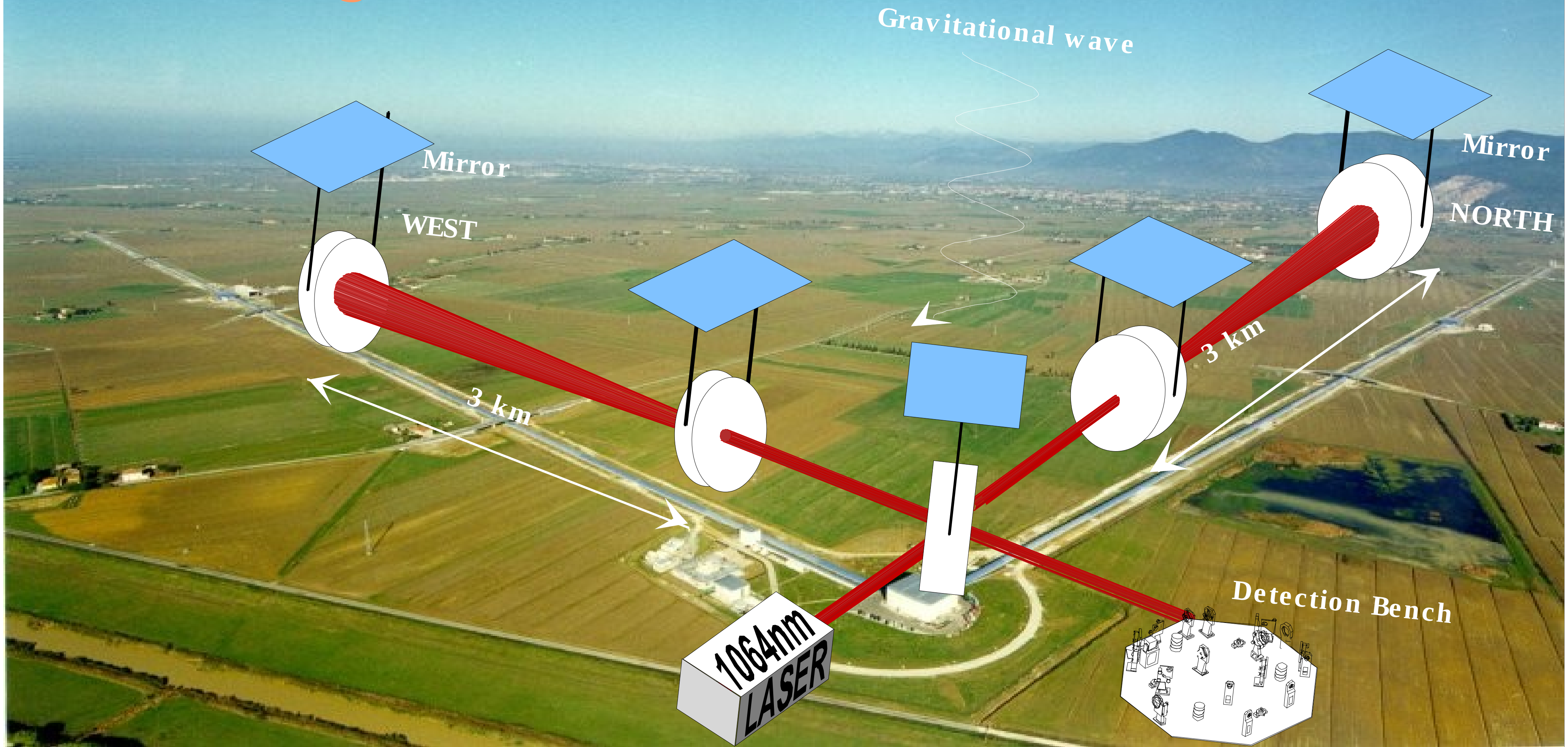
Virgo

Michelson Interferometer (giant) for gravitational wave detection



What does calibration mean for an interferometer (ITF)?

- Effect of a GW into the output signal
  - Output signal is in Watt on a photodiode
  - No GW (+ no noise)

    $\rightarrow$ the ITF is "locked" on the dark fringe
  - A GW passes by

    $\rightarrow$ the ITF try to move away from the dark fringe
- Calibration: to quantify this effect
  - The ITF response is not flat in frequency
    - The mirror positions are disciplined by control loops
    - The Fabry-Perot cavities also act like filters

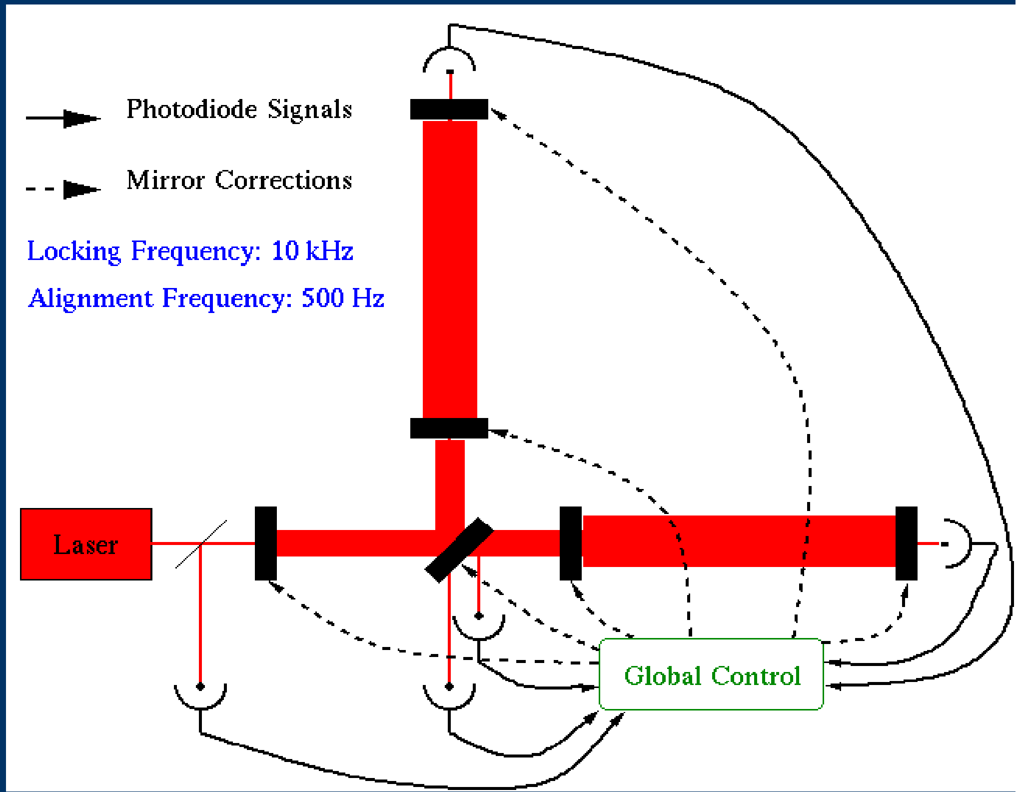
  ➔ Want to characterize the ITF on the full bandwidth

How to realize a calibration?

- Characterize the ITF on the full bandwidth
  - In frequency domain, *the calibration*:
    - Inject broadband movement on the mirror
    - Measure the transfer function of the ITF
  - In time domain, *the reconstruction*:
    - Inject permanent "lines" to monitor on-line the ITF response level in several frequencies
    - Input to a model of the ITF response
- Inject a calibration signal (white noise or frequency line):
  - *Principle* : move a mirror
    - Use the position control of the mirror
    - Use an auxiliary laser

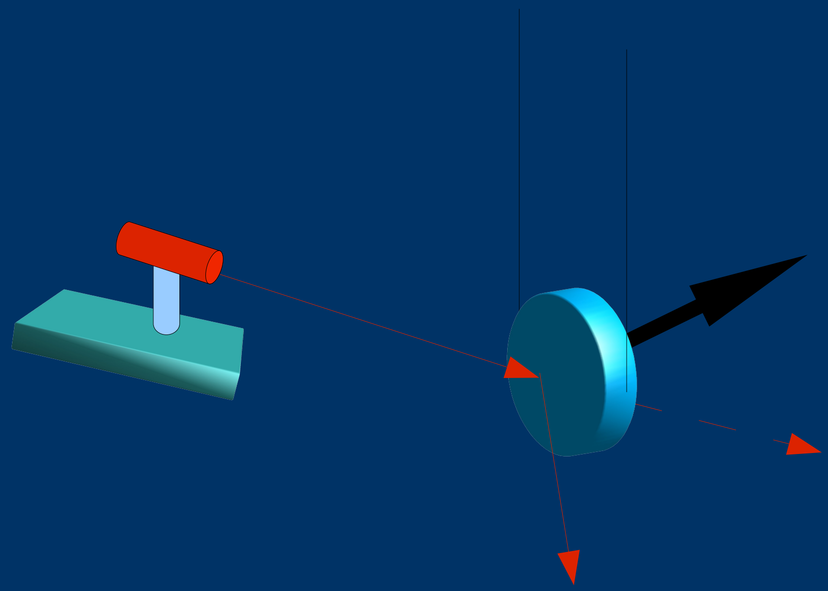
The "classical" calibration

- Mirrors position controlled
  - Control loop with feed back
  - Injection of calibration signal in the correction
- Utilization of actuators of the control system
- Need to calibrate these actuators



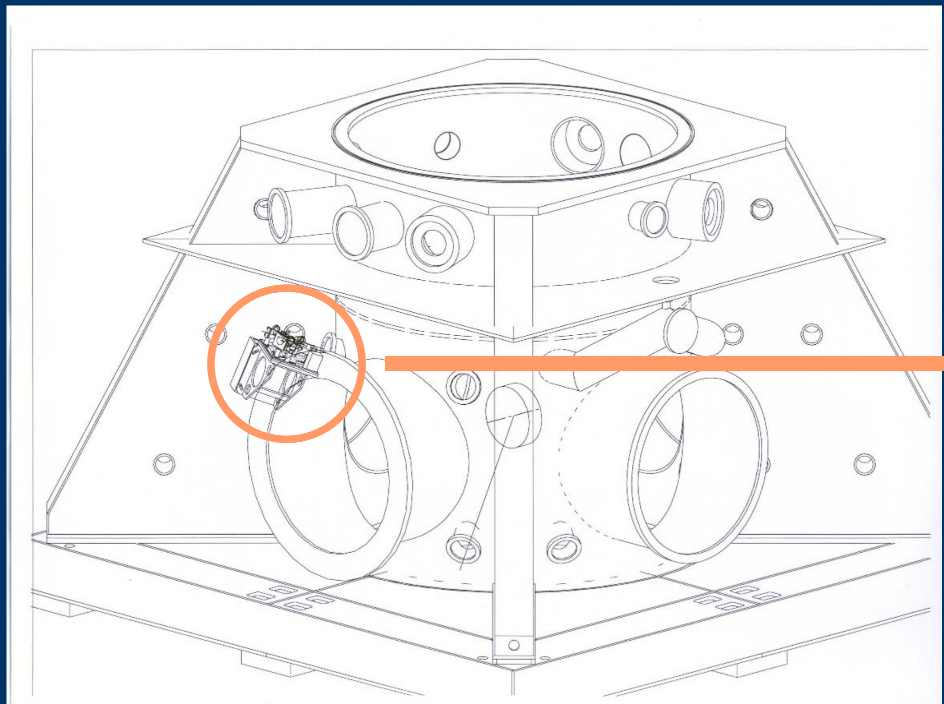
The optical calibrator

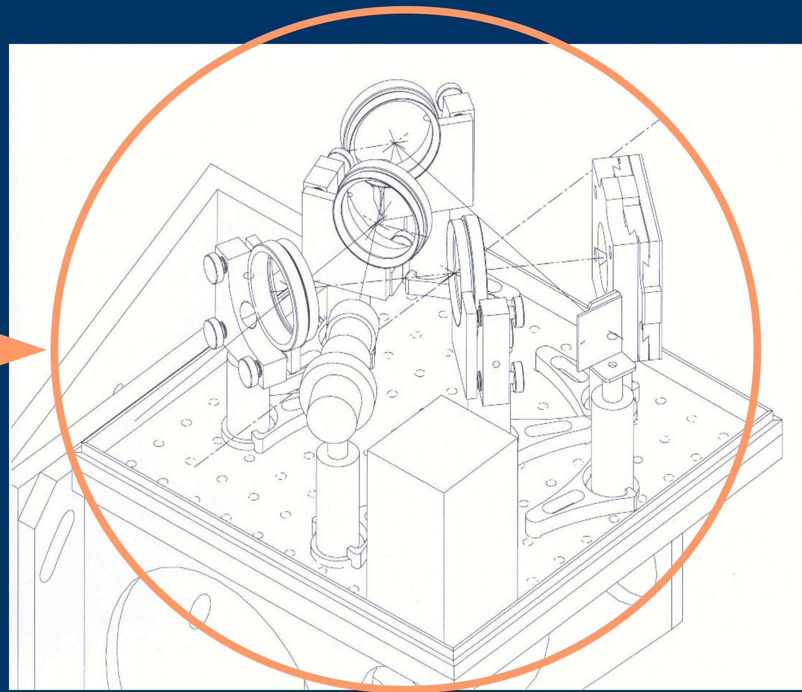
- *Aim* : Better accuracy on the sensitivity measurement
  - Independent of the interferometer control
  - Redundancy
- *Principle* : Auxiliary laser
  - Action on the mirror by radiation pressure
  - Modulation of the laser power by the calibration signal



Optical calibrator : realization

- Hardware installed on two mirrors :
  - optical bench, setup and aligned
  - electronics for monitoring and control of the stabilized laser installed
- To be tested soon





Calibration and sensitivity curves

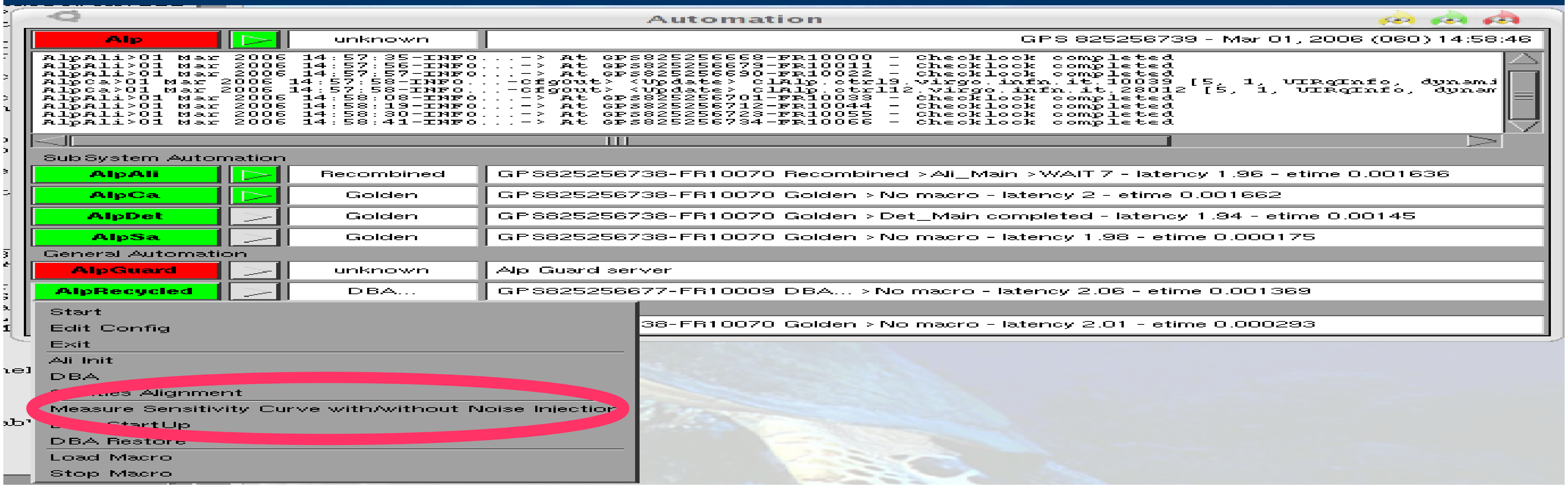
- Using calibration
  - Computation of the transfer function (TF)
    - White noise injection

$$TF = \frac{Injected\ \ noise\ \ (meters)}{Interferometer\ \ response\ \ (Watt)}$$

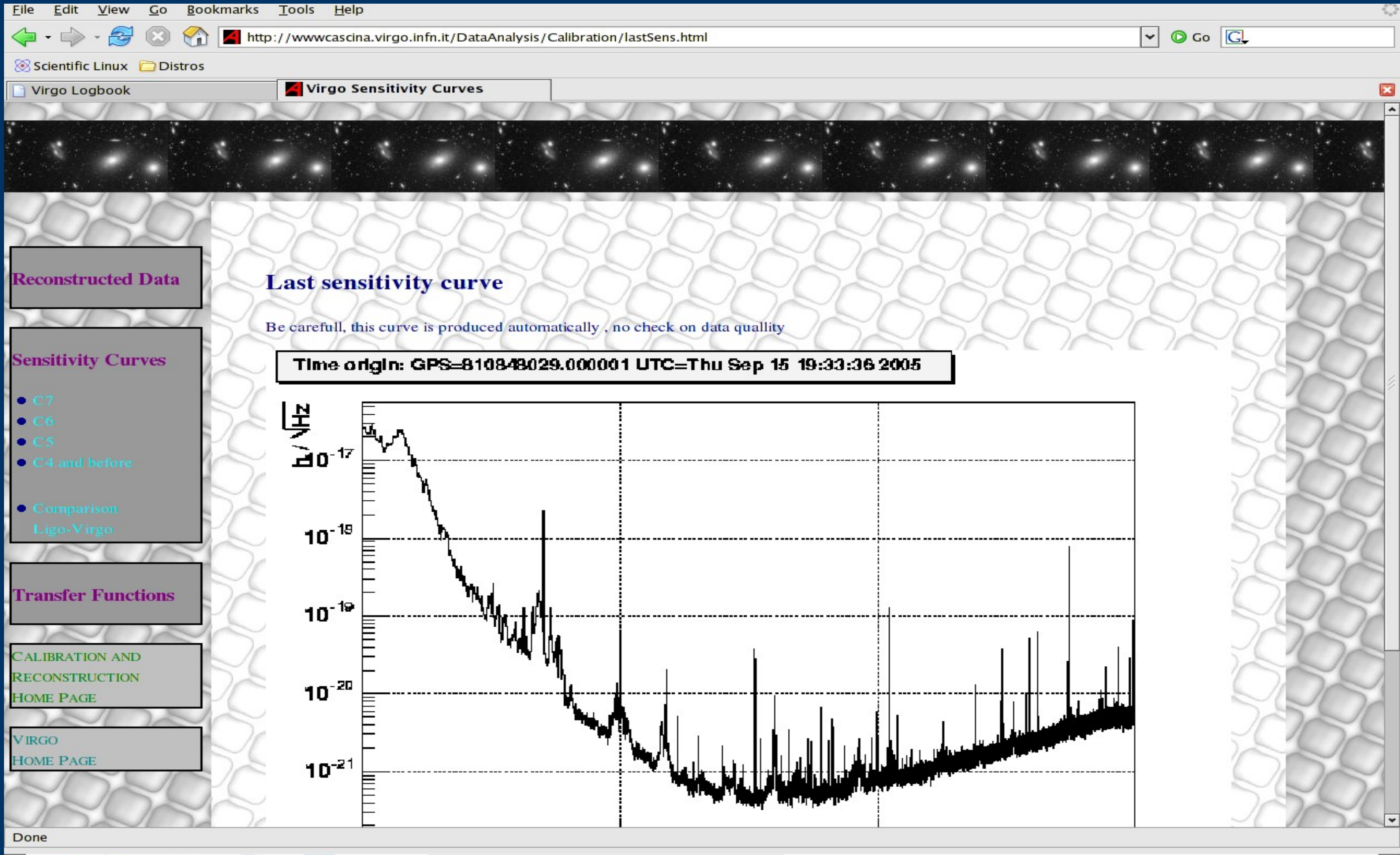
  - Computation of the sensitivity curve
    - Select 5 minutes of “science mode” data
    - Compute interferometer output signal spectrum (FFT)
    - Multiply by the TF
- Using reconstructed data
  - Compute directly the spectrum (FFT) of h-reconstructed data

Automation

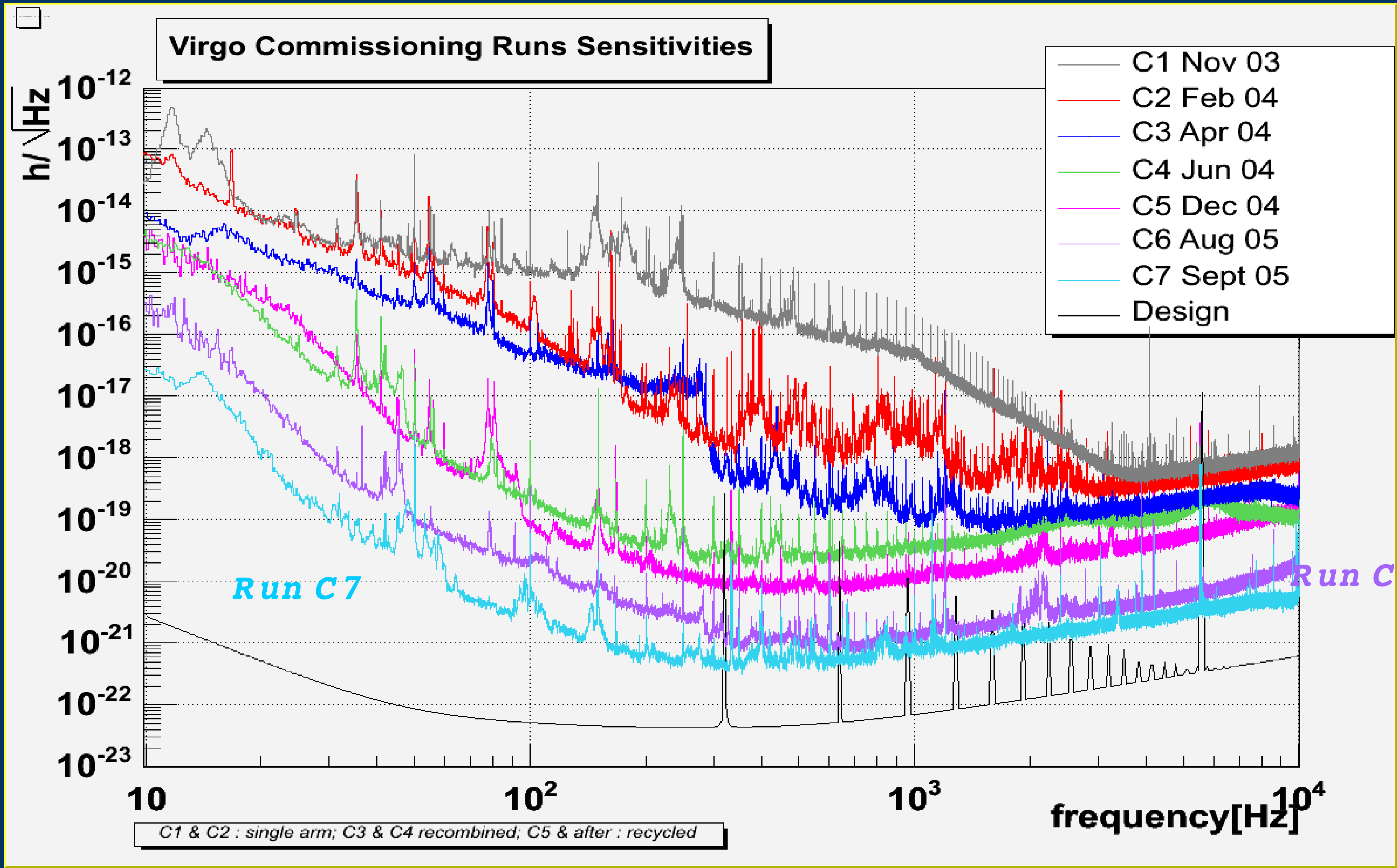
- Detector is getting closer to data taking
  - ➔ Automation of all usual tasks has started
- Calibration automation :
  - Data taking with "noise" injection
  - Data taking in science mode
  - Computation of the sensitivity curve
  - Last curve is automatically available on the web



The calibration web page



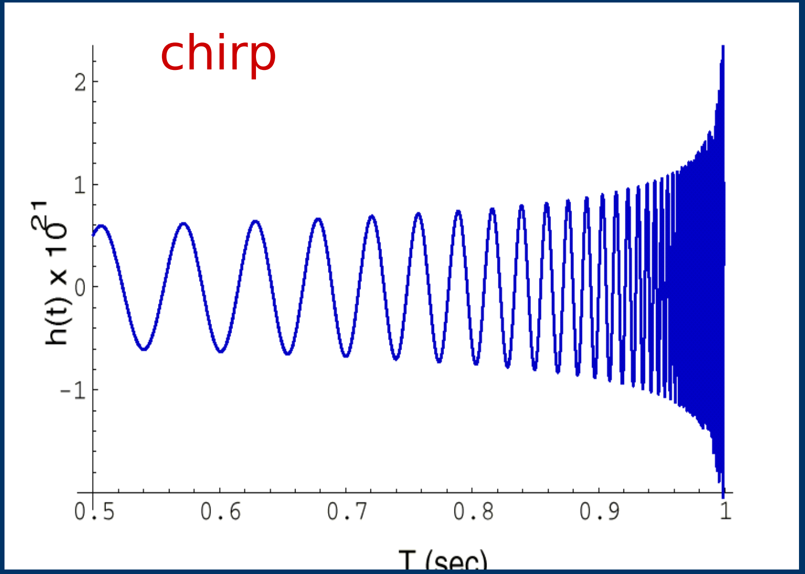
Sensitivity curves



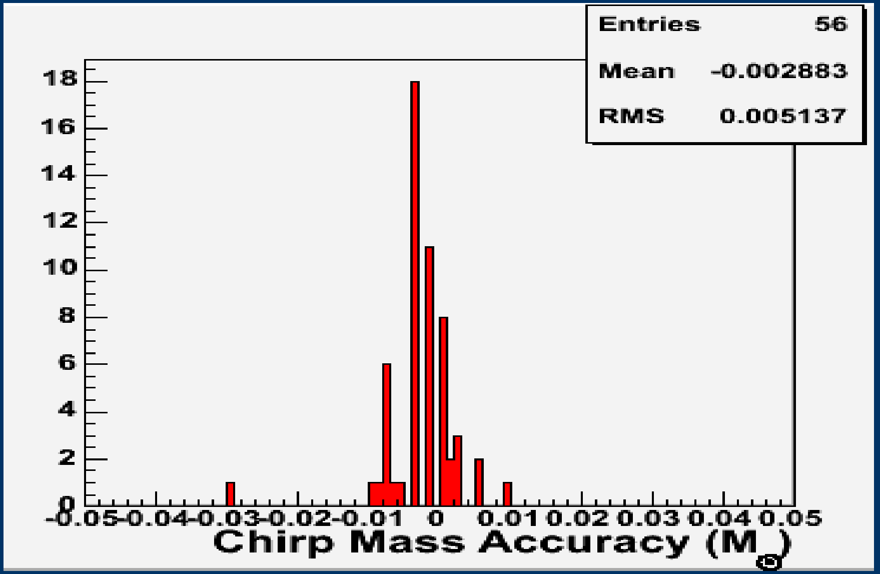
Hardware events injection

Use of the calibration signal injection procedure

- Inject realistic GW event signals
- The analysis software find out the events
- Global test of the h-reconstruction



Example of waveform injected: chirp from a binary inspiral



Example of the accuracy on a reconstructed parameter : the chirp mass of the binary
$M=((m1m2)/(m1+m2))^{3/5}x(m1+m2)^{2/5}$

By-product of the h-reconstruction

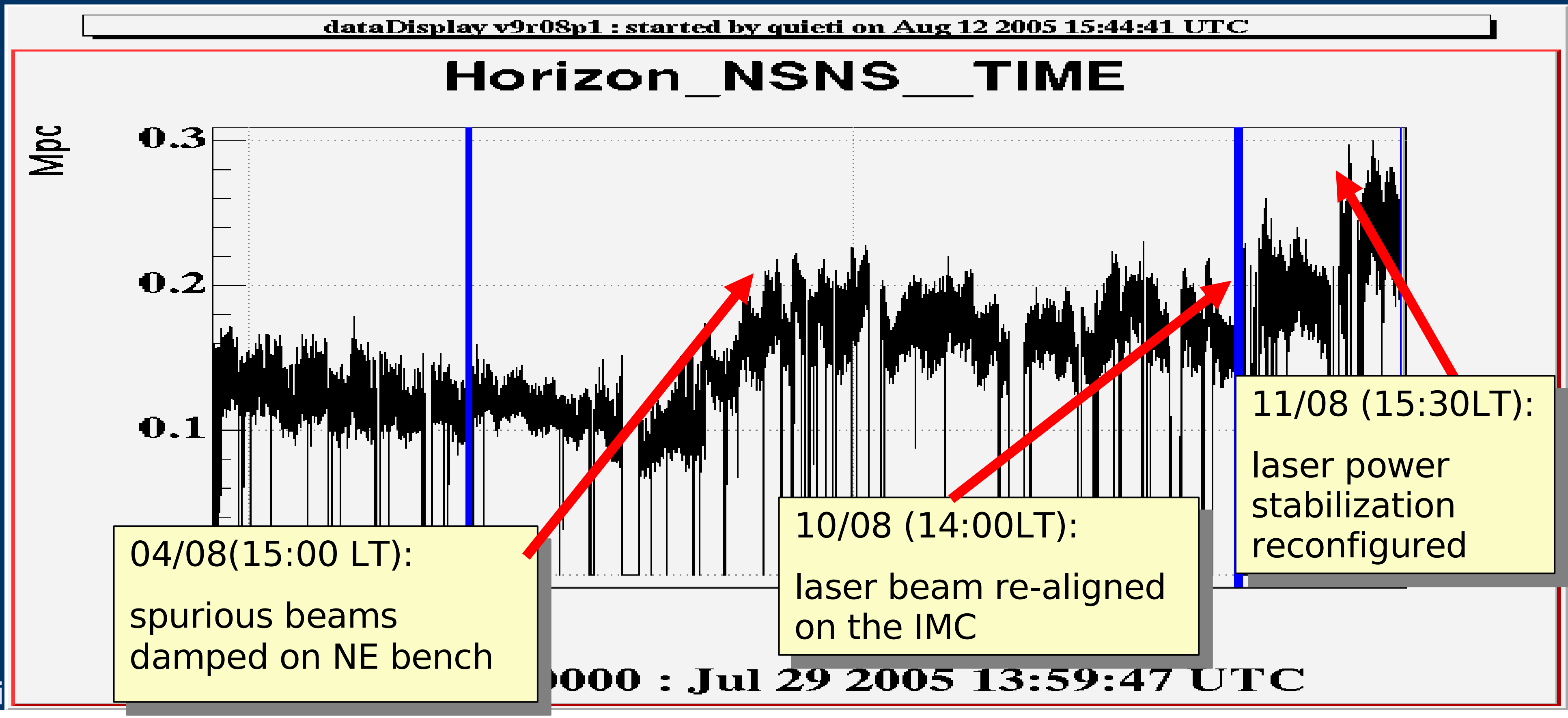
Tool for commissioning:

Binary inspiral range, "horizon" :

distance until which we can detect a "standard event"

(NS-NS inspiral optimally oriented)

above a conventional level



Conclusion

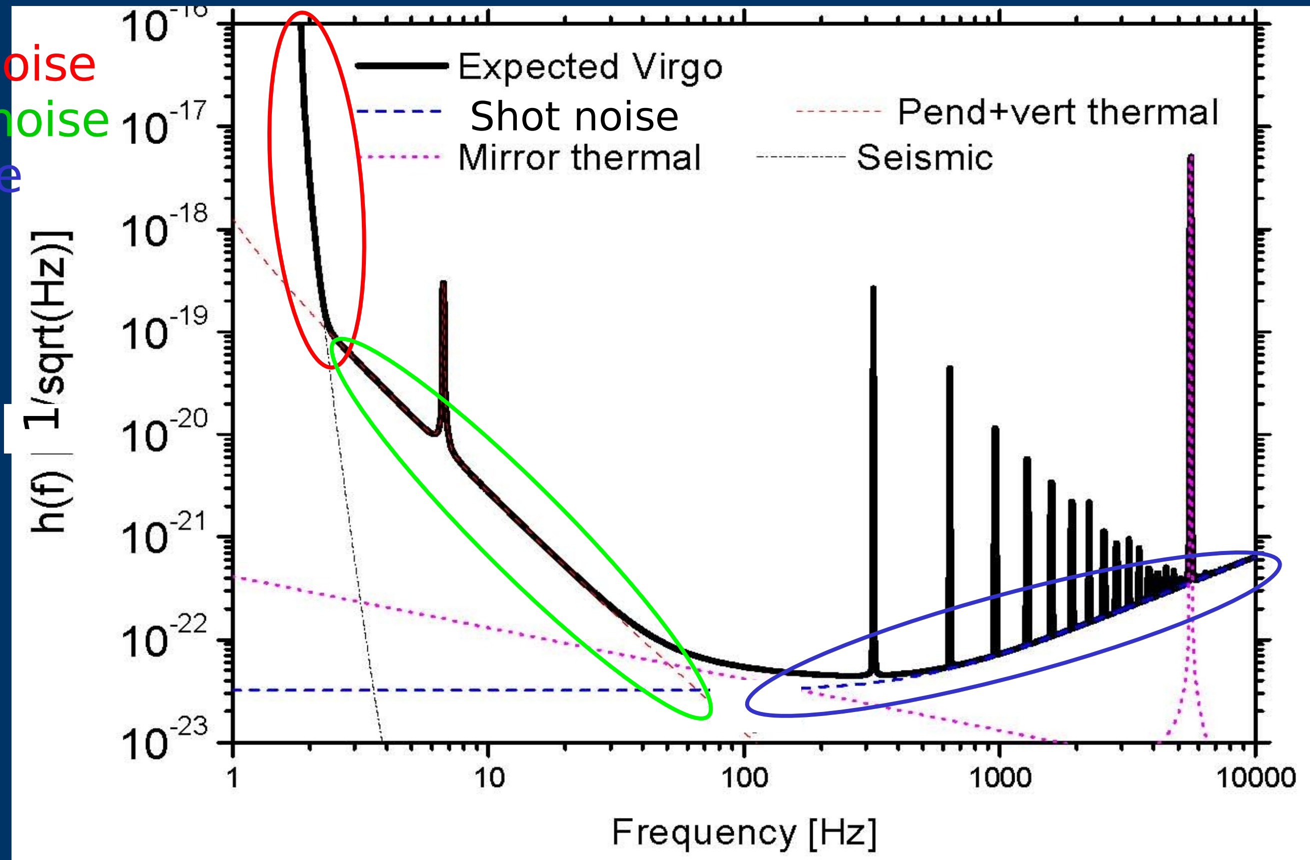
- Calibration of Virgo interferometer is now "routine", fully automated
- Cross-checks are possible and planned with the optical calibrator
- h-reconstruction runs on-line during data taking
- Both are providing useful tools for the commissioning

Spares slides

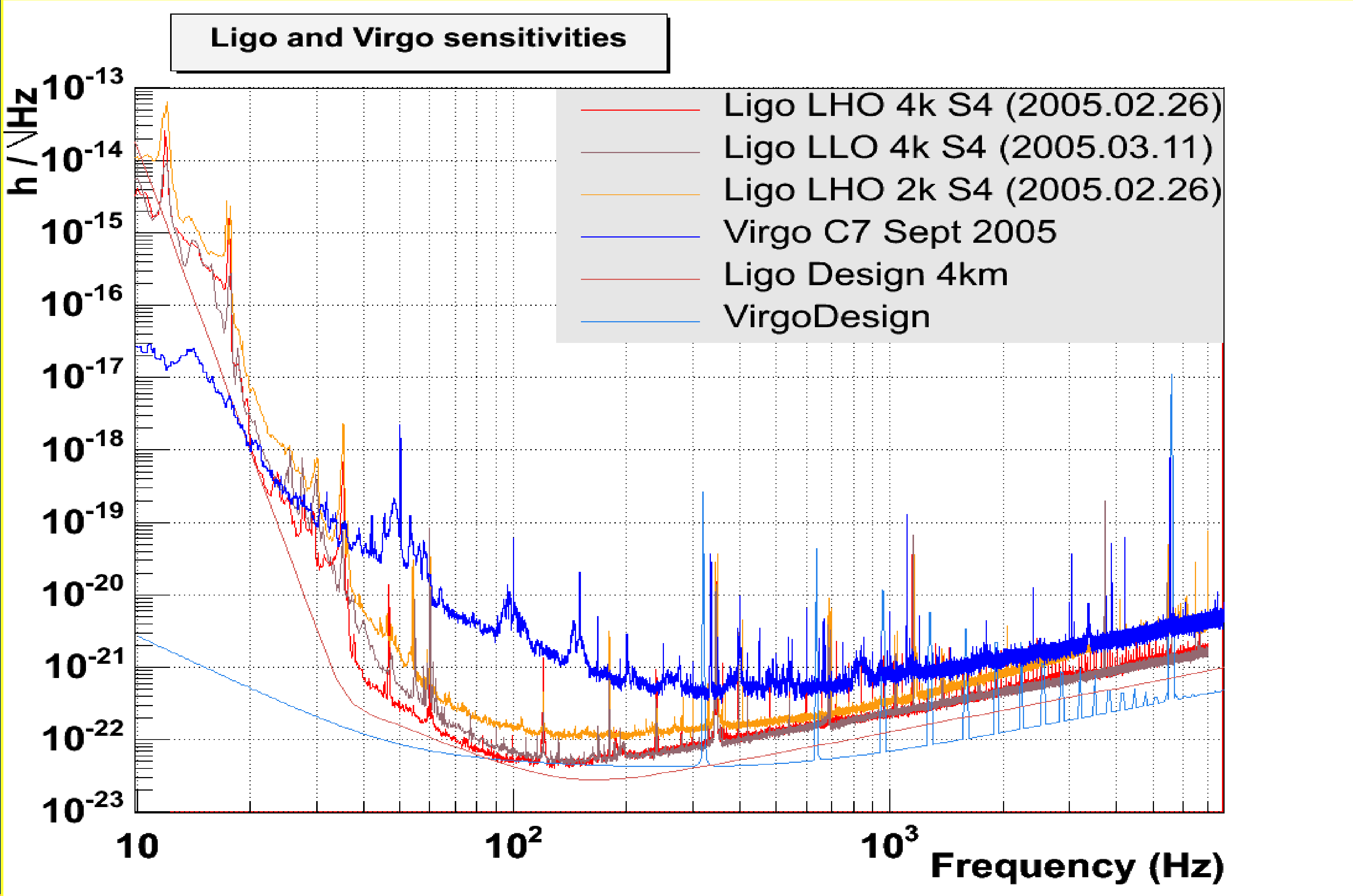
VIRGO design sensitivity

Main sources of noise limiting the VIRGO design sensitivity

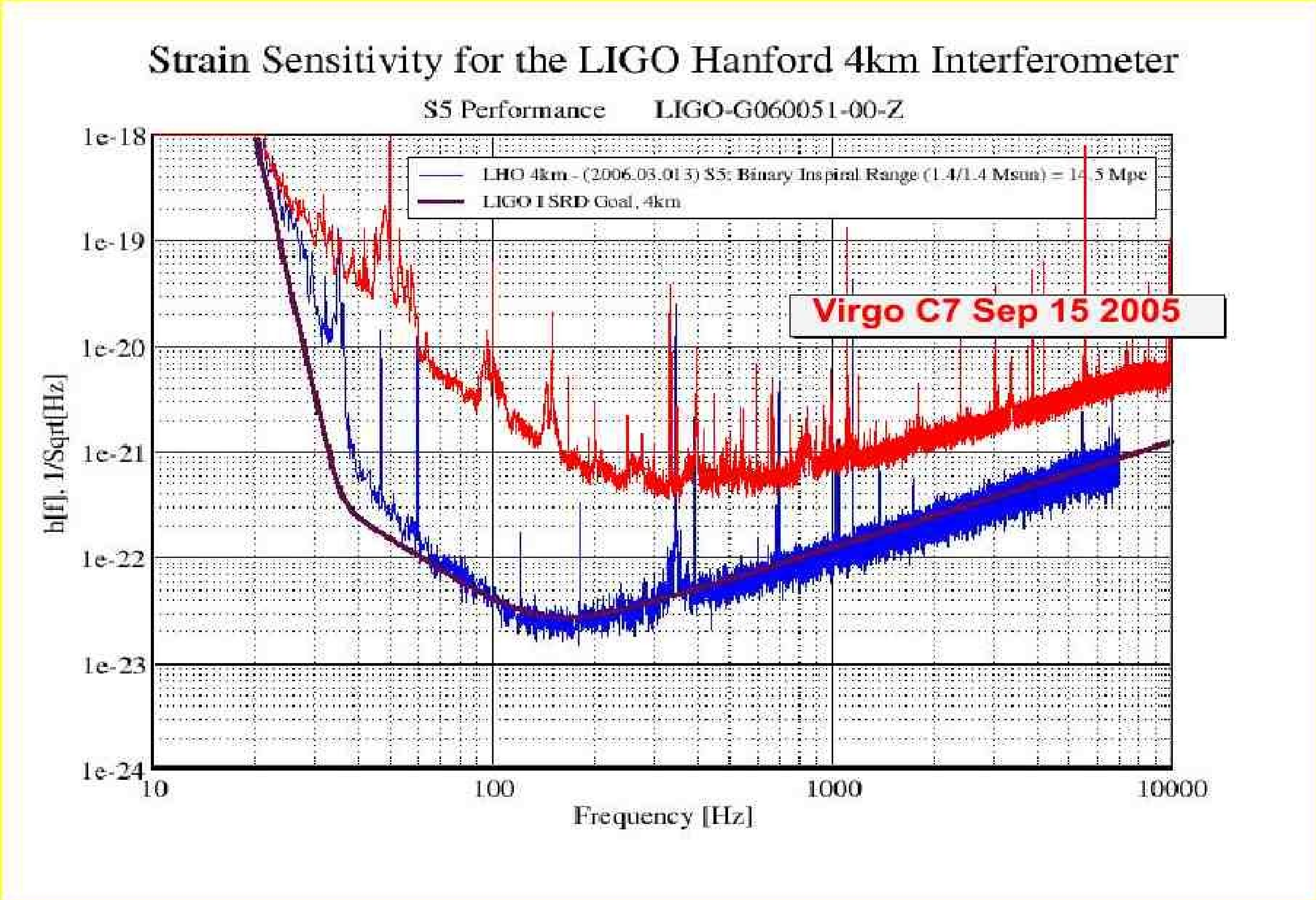
Seismic noise
Thermal noise
Shot noise



LIGO/Virgo sensitivity



Last LIGO/Virgo comparison



Ligo-Virgo common data taking

- LIGO is already at its nominal sensitivity
  - Taking data for one year
- Virgo getting close to its nominal sensitivity
  - Data taking together with LIGO at the end of the year
- Analysis will be done in common
- Upgrades already planned for both detectors