The Status of VIRGO

E. Tournefier for the Virgo Collaboration

GWADW 2004, Aspen

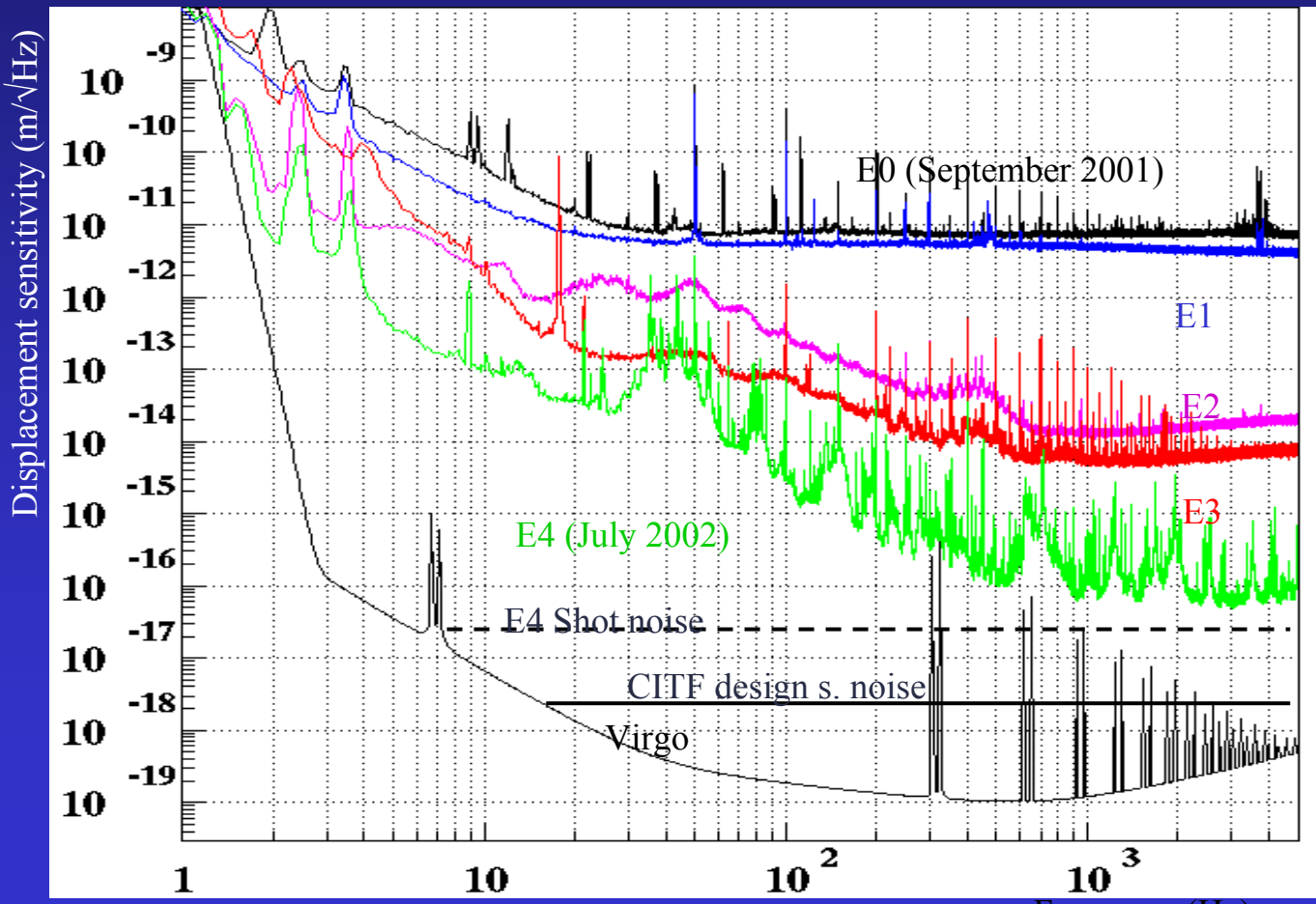
- From the CITF to VIRGO
- Commissioning of the Fabry-Perot cavities
- Next steps

The CITF

The CITF commissioning

- June 01-July 02: Central ITF (CITF) commissioning
  -> 5 engineering runs

E0, E1:
Michelson
E2, E3, E4:
Recycled Michelson



From the CITF to VIRGO: upgrades

A lot of experience gained with the CITF

Problems detected -> several improvements have been prepared for VIRGO

Aug 02: Shutdown for the Virgo installation and upgrades

- Install the Virgo mirrors
- Connect the tubes and install the terminal towers
- Change beam size, modulation frequency

- Upgrade the Input mode cleaner
- Upgrade the control of the suspensions

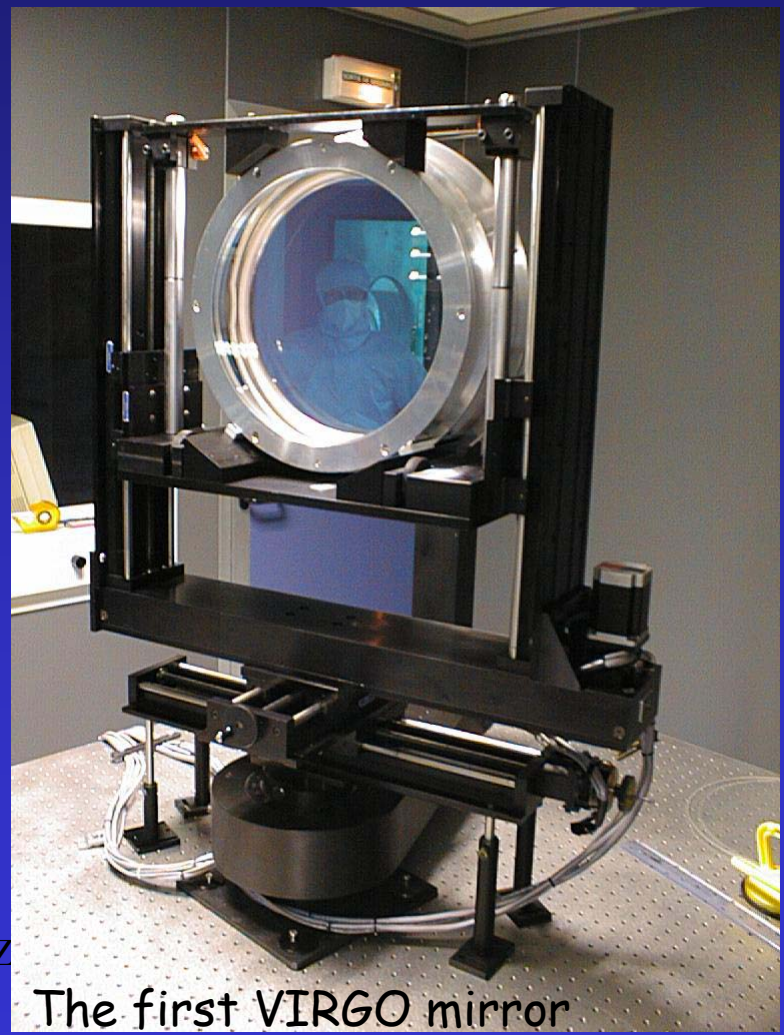
- Jul 03: end of installation
- Aug 03: start the commissioning

The Mirrors

- Coater VIRGO in a class 1 clean room, unique in the world (2.2*2.2*2.4 m)

- Coating features:
  - very low losses: scattering ~ 5 ppm,
    absorption ~ 1 ppm
  - Uniformity on large dimension:
    less than 10^{-3} variation on ∅ 350 mm


Assembly of the NI mirror

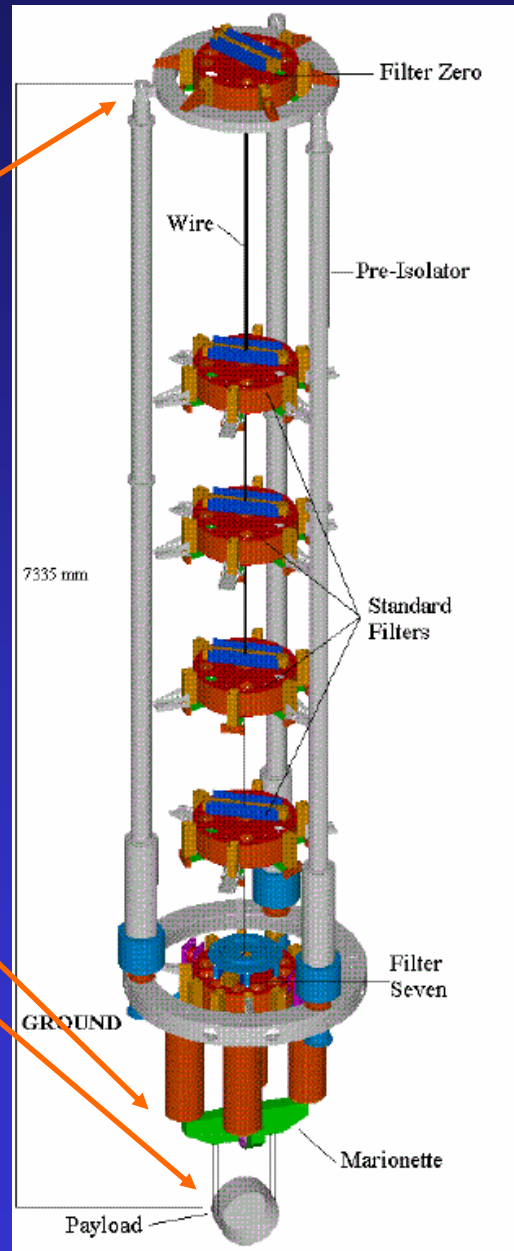

The first VIRGO mirror

The mirror suspensions

The superattenuator is expected to provide an attenuation of 10^{14} at 10 Hz

3 actuation points:

- Inertial damping of the Inverted Pendulum
- Local control of the marionnetta
- Damping of the mirror motion

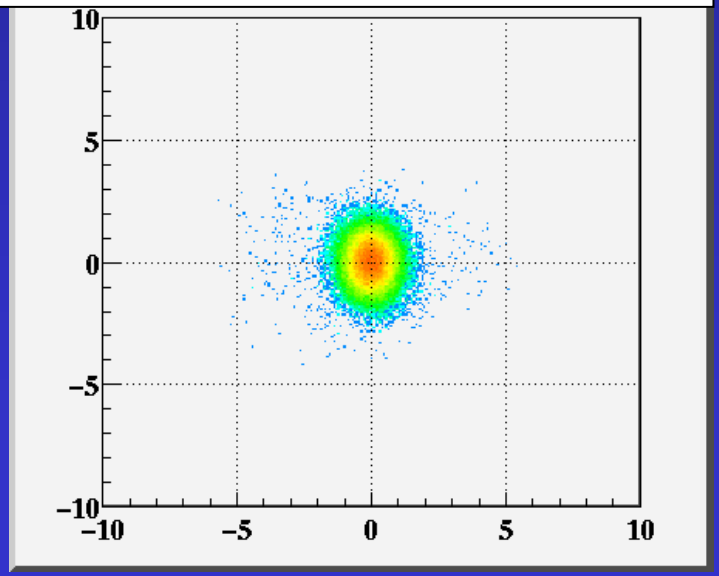


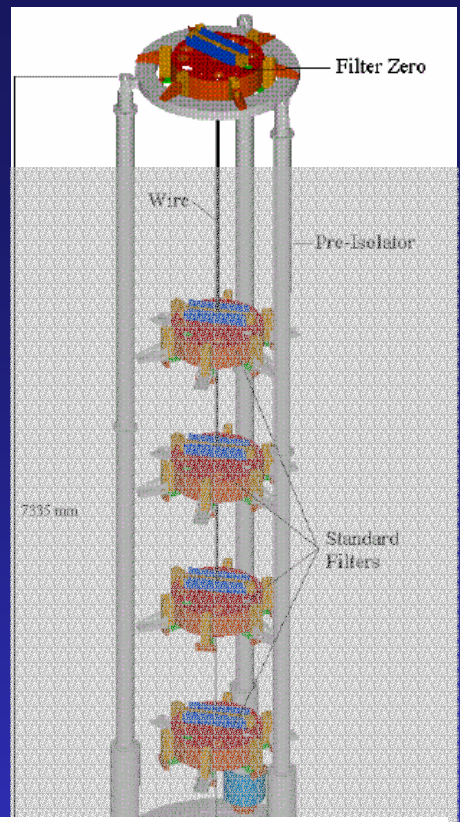
Control of the top stage:

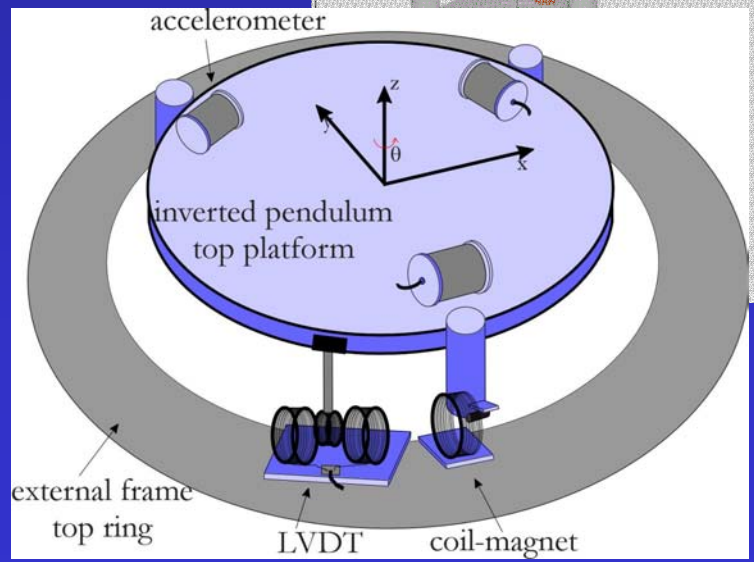
- Horizontal damping using Lvdt's and accelerometers (improved to reduce re-introduction of noise by Lvdt's)

Typical rms horizontal displacement of the top stage: 1μm

Inverted pendulum motion on 24 hrs





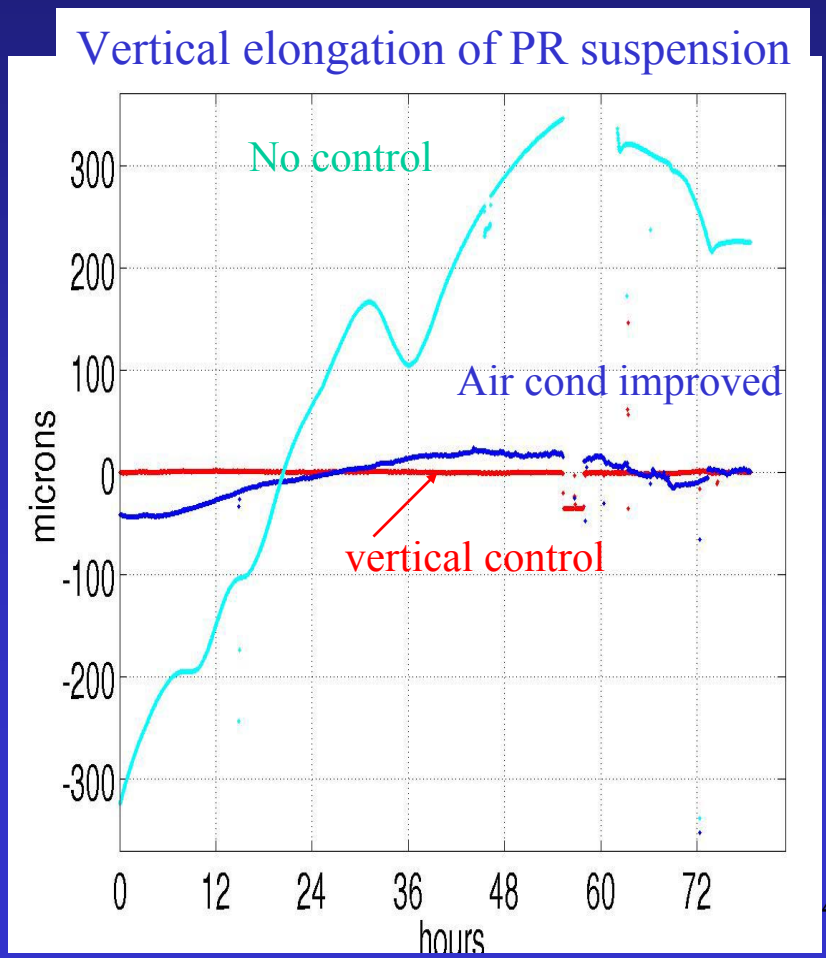


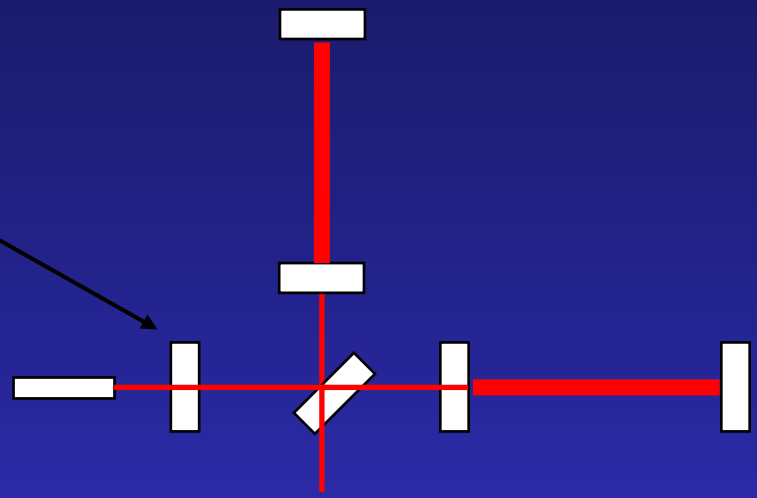
LIGO-G040226-00-Z

Control of the vertical motion:

Important for Power Recycling mirror: it acts as a lens

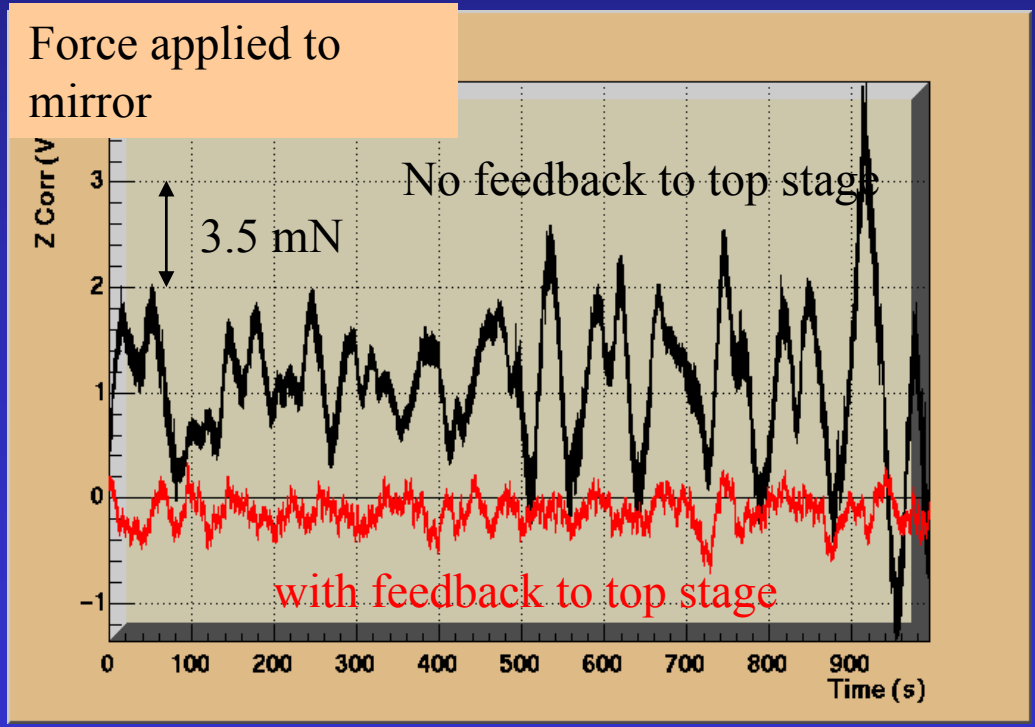
- Vertical control using Lvdt (new)

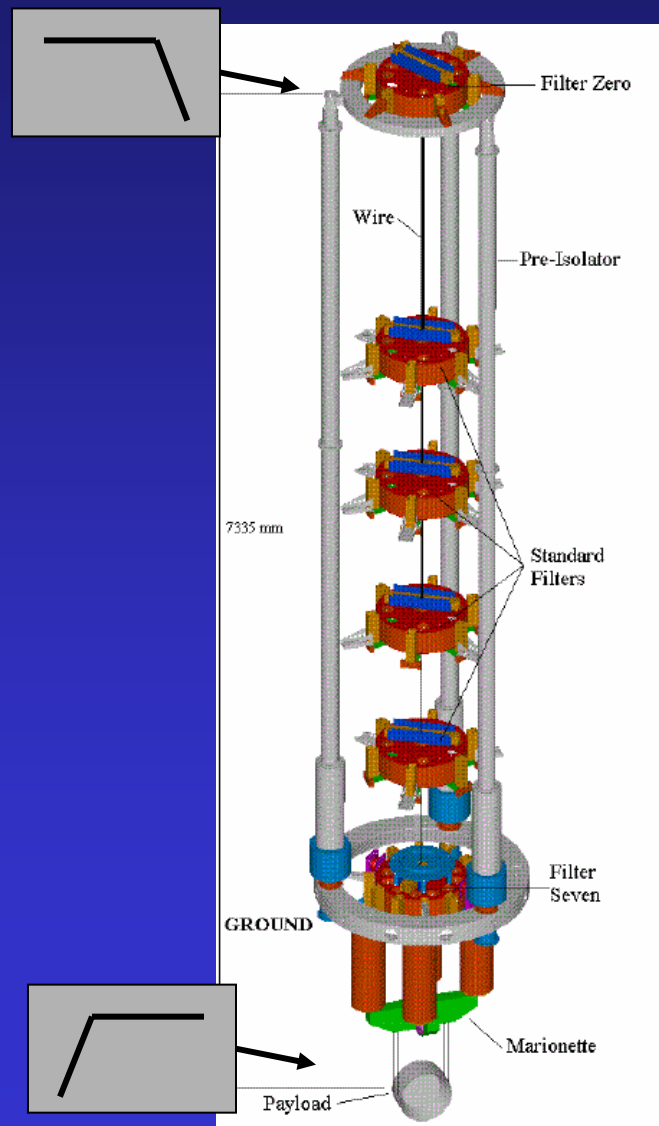




Tide control from the top stage:

- Tide control tested on CITF, to be implemented for Virgo: reallocate the locking force from the mirror to the top stage -> smaller force on mirror -> lower noise from actuator



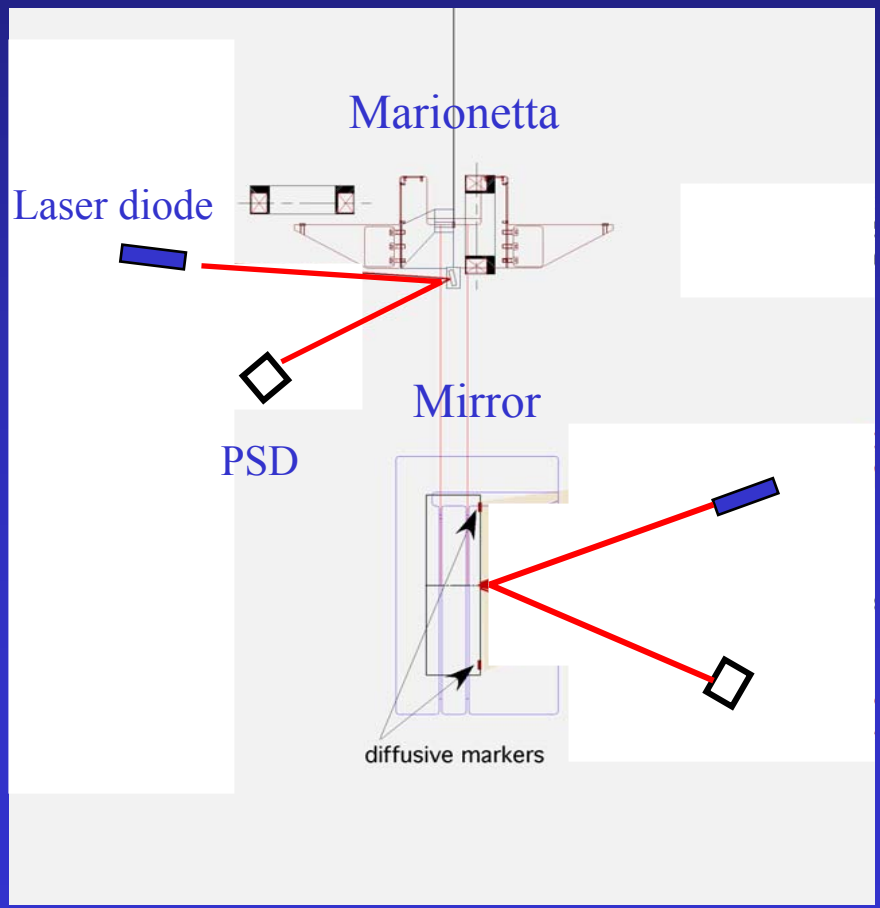


Local control of the Marionetta and of the mirror:

- laser diode coupled to a camera or a PSD device: new on the Marionetta

- The angular readout is done from the marionetta (new) and the mirror
- The correction is sent to the marionetta

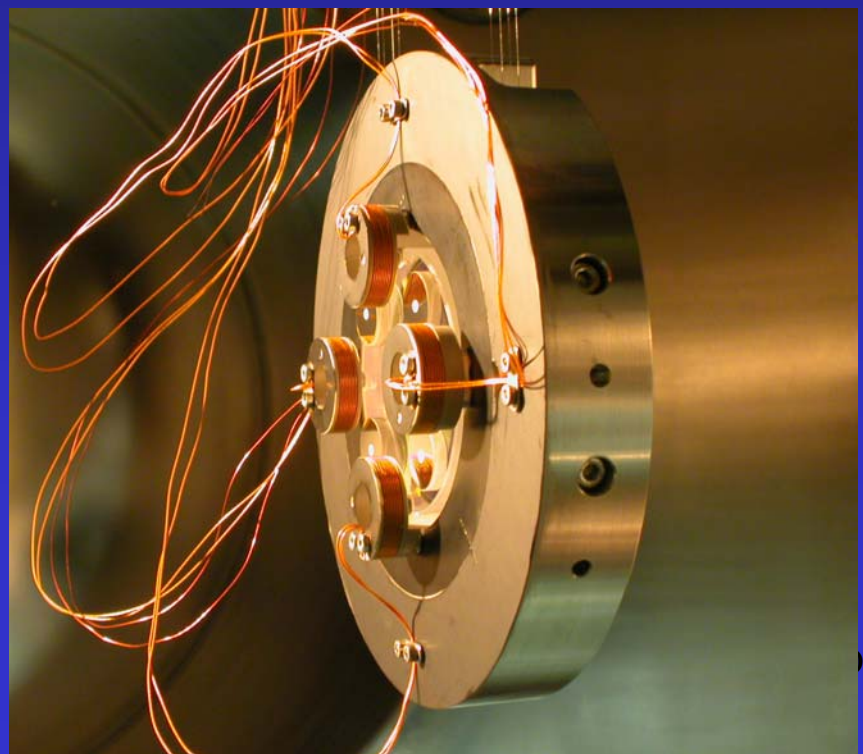
-> typical rms angular motion of the mirror: 1 μrad (see E. Majorana's talk)

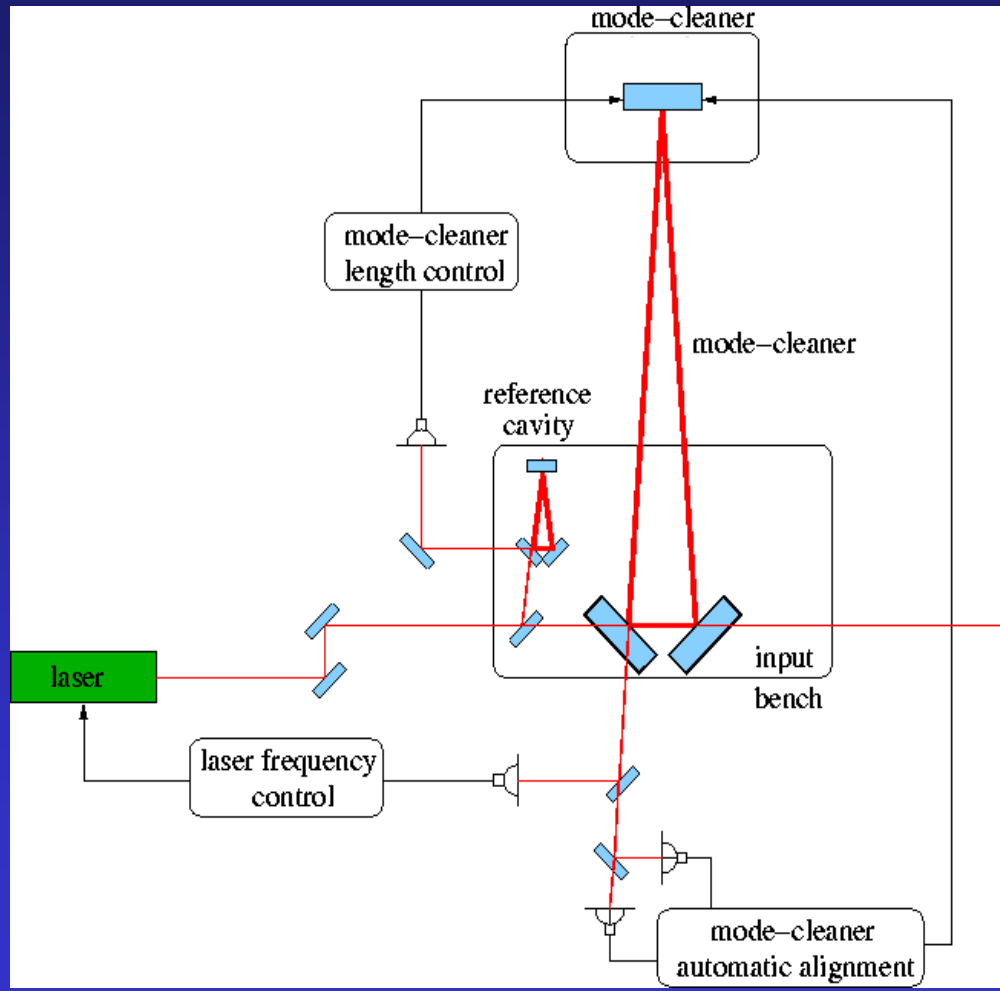


The injection system

Upgrades:

- Change laser: 10W -> 20 W
- Move the Mode Cleaner tower
- Suspend the mode cleaner mirror and install its local controls

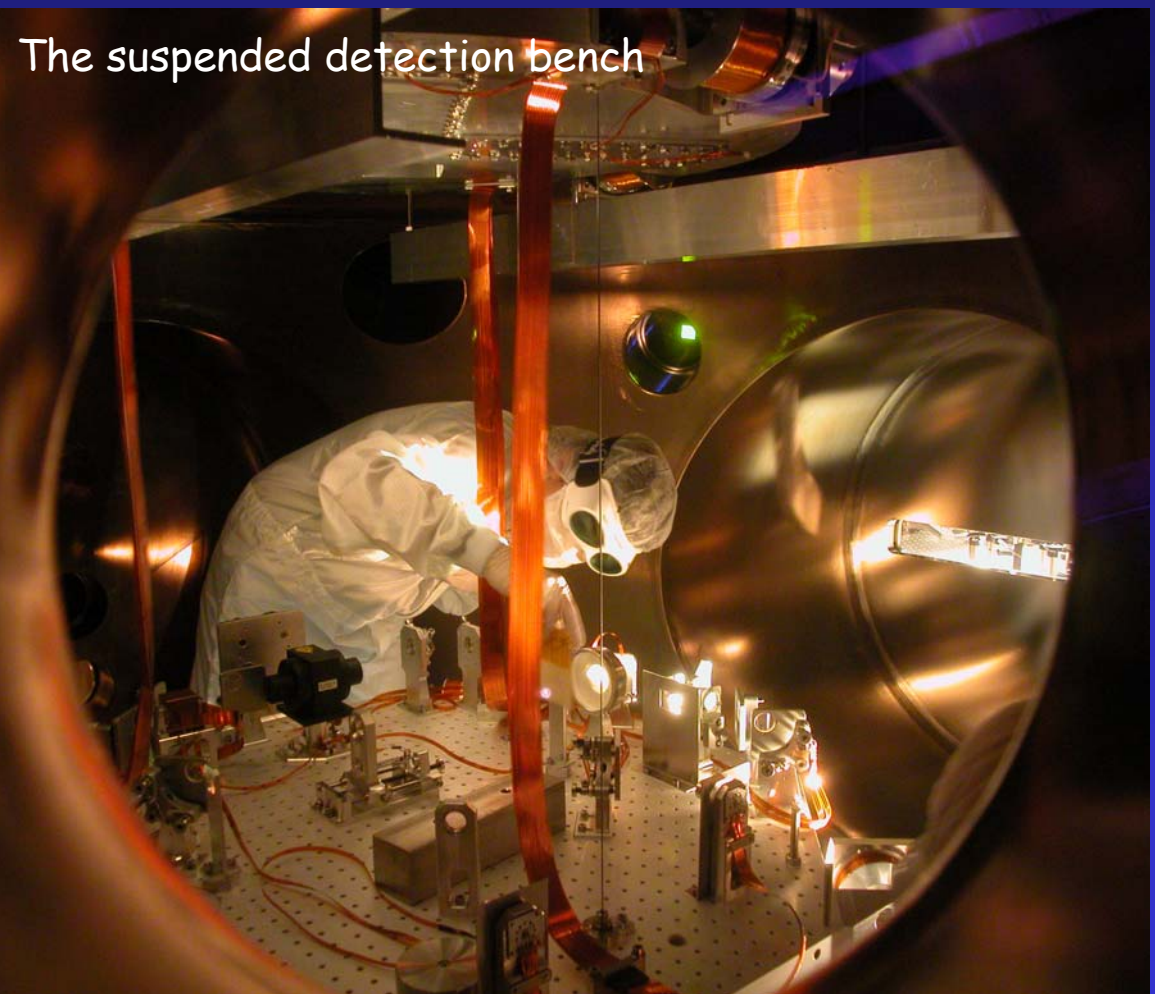




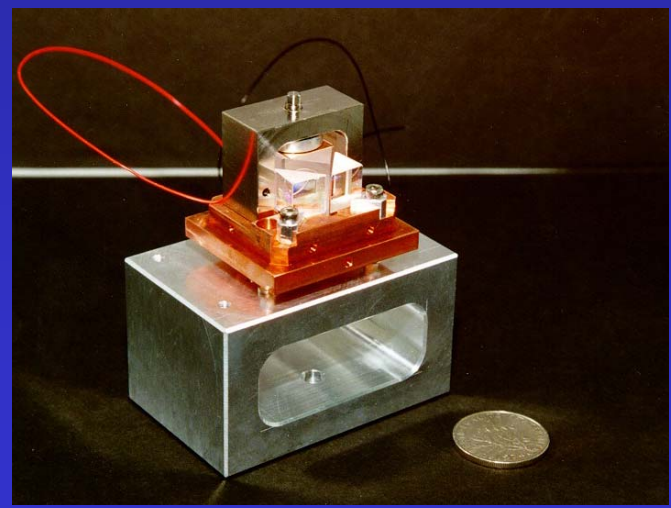
The detection system

- Upgrade of the photodiodes electronics for the new modulation frequency (6.25 MHz)
- Upgrade of the optical system for the VIRGO beam size
- Add of Faraday isolator after the output mode cleaner
- Add the readout of the bad polarisation

The suspended detection bench



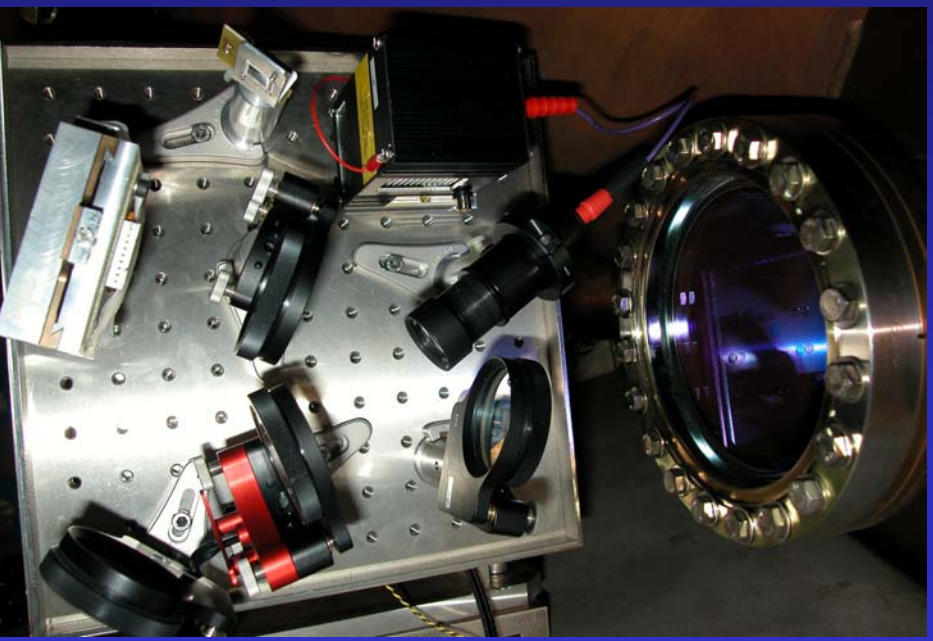
Output mode cleaner filtering the dark fringe



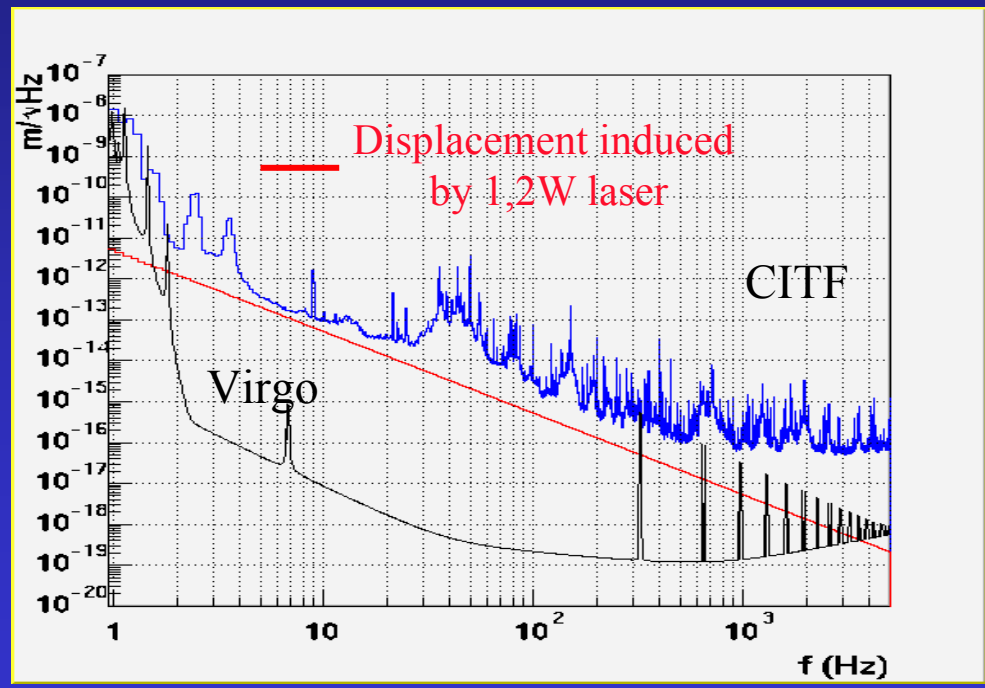
The optical calibrator

Calibration needed to transform photodiode signal into real mirror displacement

Mirror displaced by radiation pressure (1.2W laser diode)



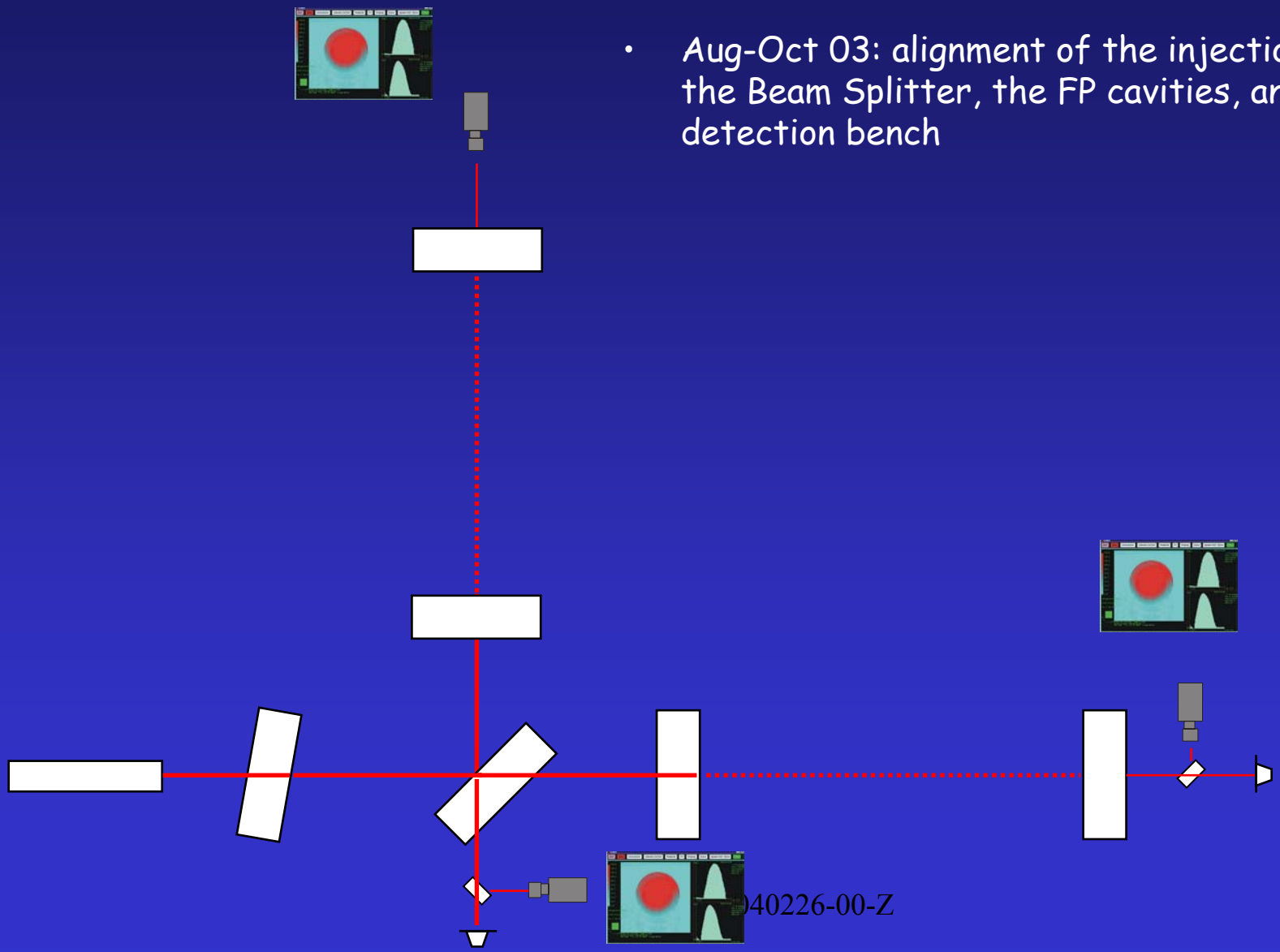
Need to have a good sensitivity before this system can be used



=> use mirror coils now (like for CITF)

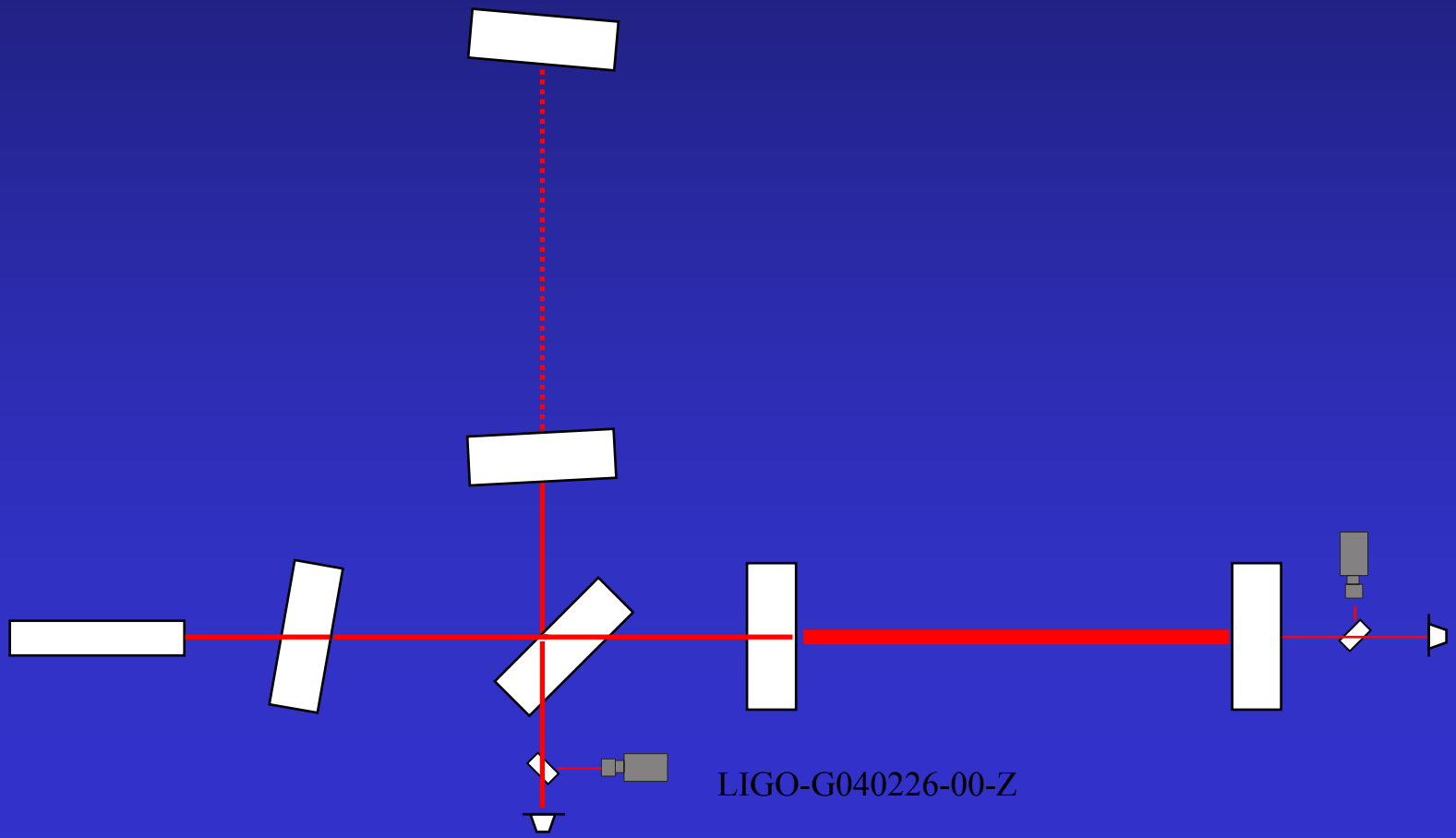
Phases of the commissioning

- Aug-Oct 03: alignment of the injection beam, the Beam Splitter, the FP cavities, and the detection bench

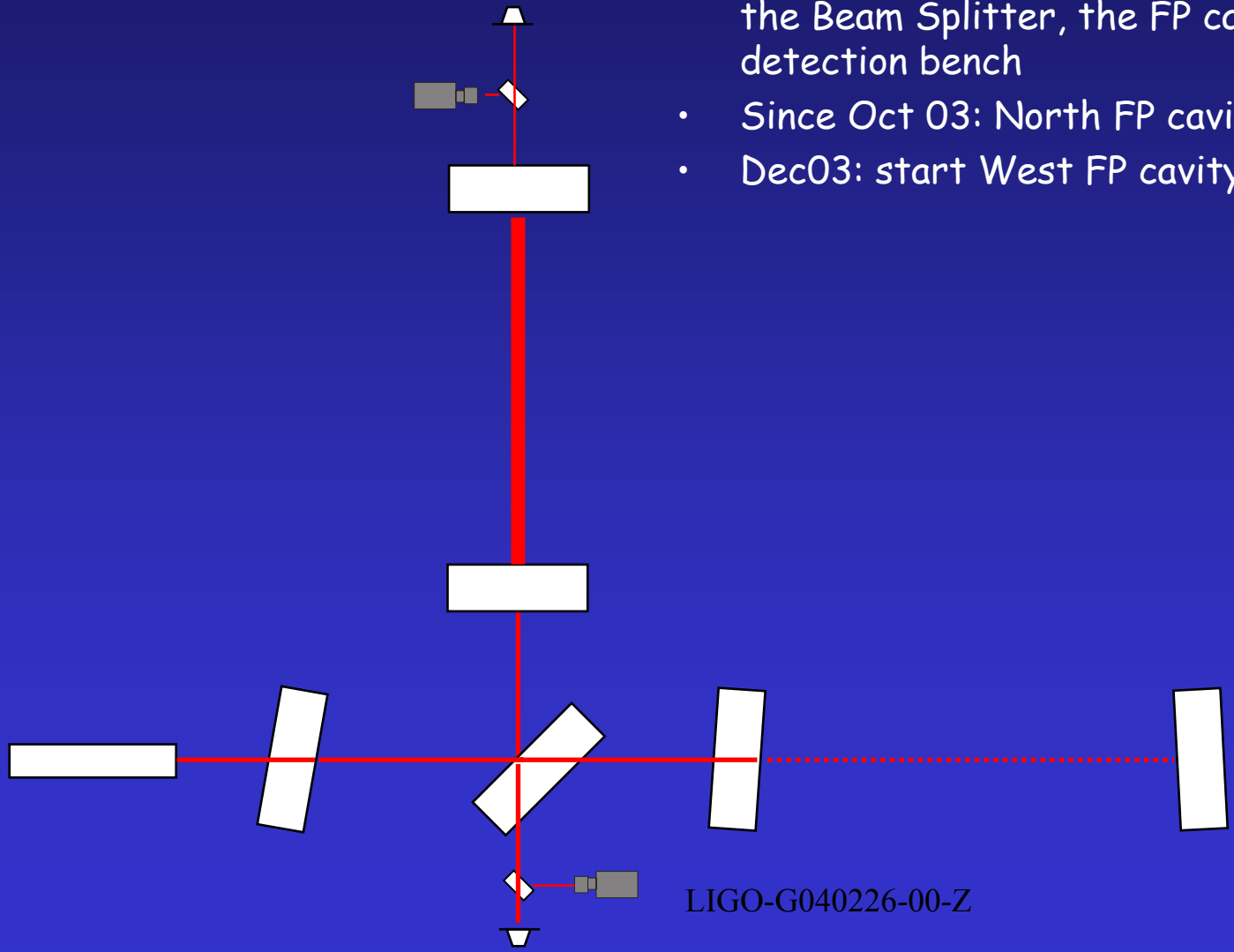


Phases of the commissioning

- Aug-Oct 03: alignment of the injection beam, the Beam Splitter, the FP cavities, and the detection bench
- Since Oct 03: North FP cavity commissioning

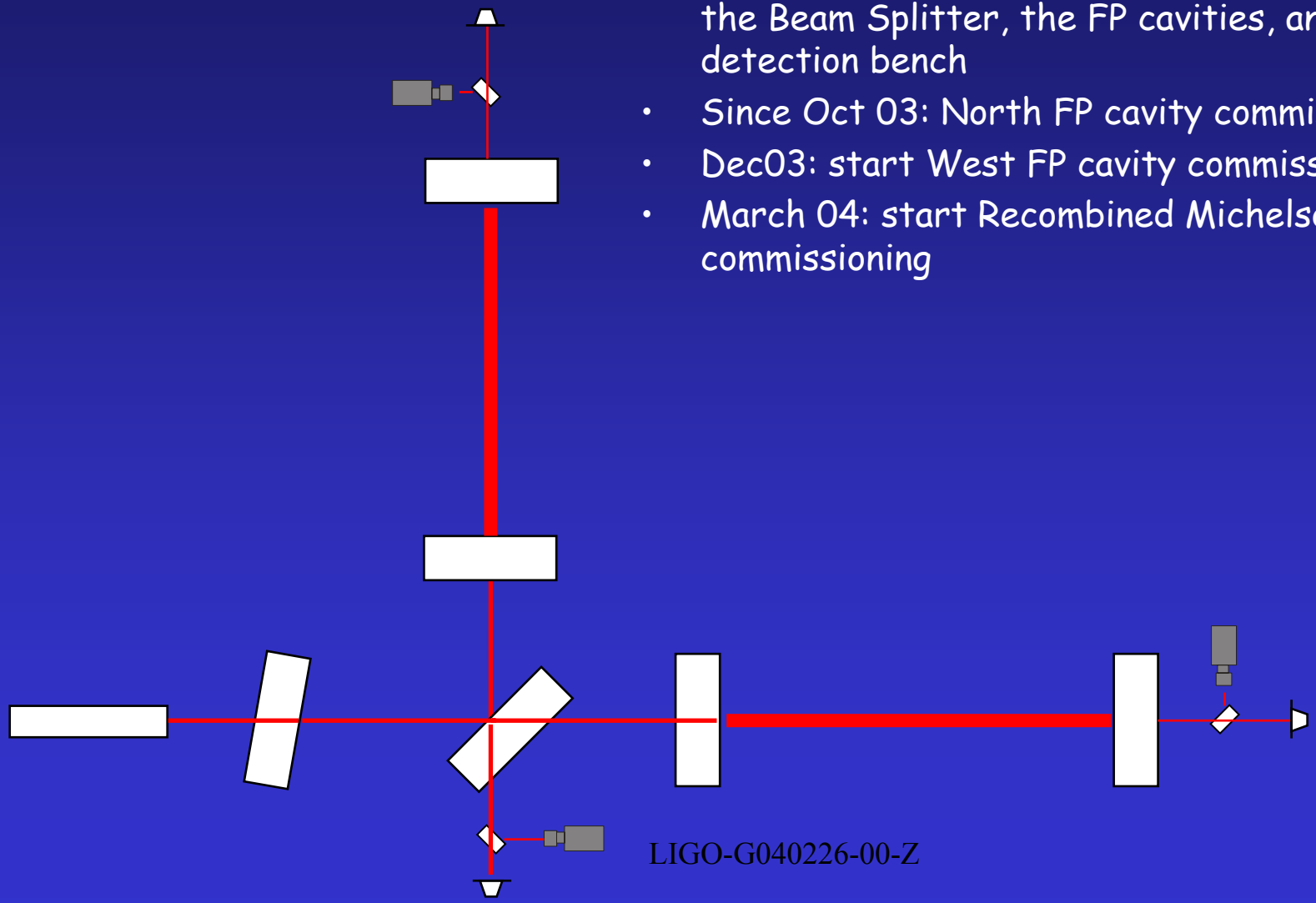


Phases of the commissioning



- Aug-Oct 03: alignment of the injection beam, the Beam Splitter, the FP cavities, and the detection bench
- Since Oct 03: North FP cavity commissioning
- Dec03: start West FP cavity commissioning

Phases of the commissioning

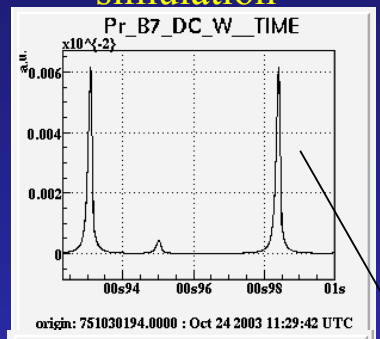


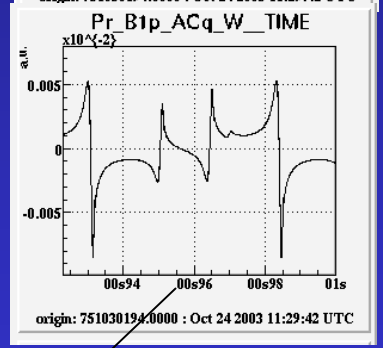
- Aug-Oct 03: alignment of the injection beam, the Beam Splitter, the FP cavities, and the detection bench
- Since Oct 03: North FP cavity commissioning
- Dec03: start West FP cavity commissioning
- March 04: start Recombined Michelson commissioning

North FP cavity locking

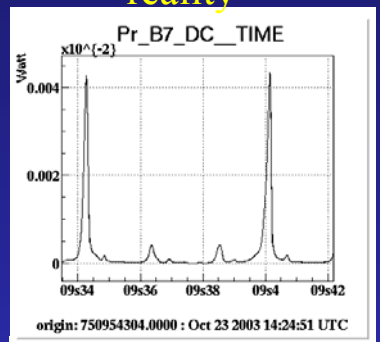
- Alignment of the cavity
- Confront photodiode signals with simulation (SIESTA)

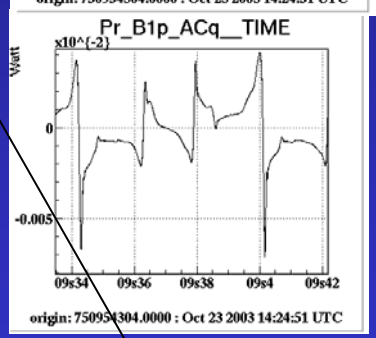
simulation





reality

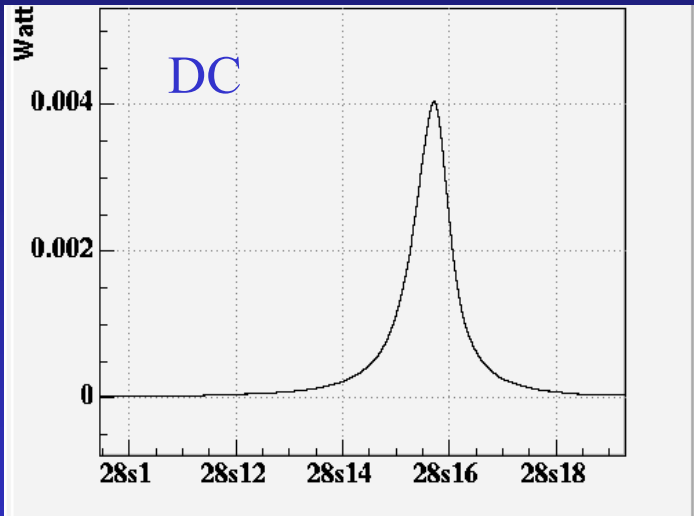




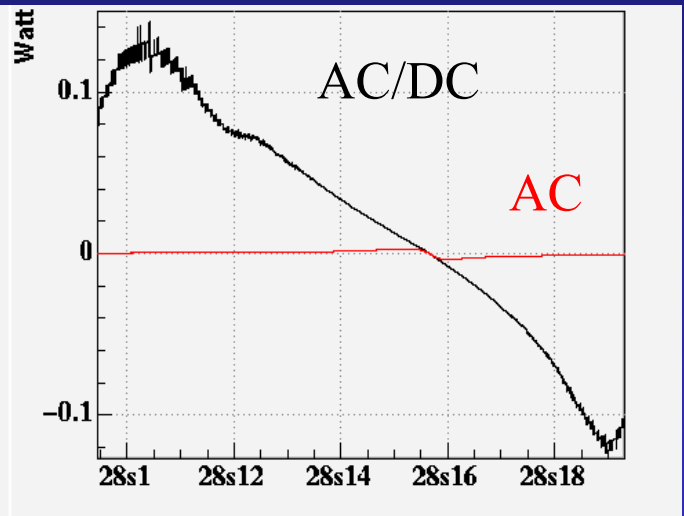
Lock of the FP cavity

- Use the linearized error signal: AC/DC

DC Power stored in the cavity



Error signal



⇒ Time to act is increased by a factor 10 with the linearised signal

⇒ Force on mirror reduced

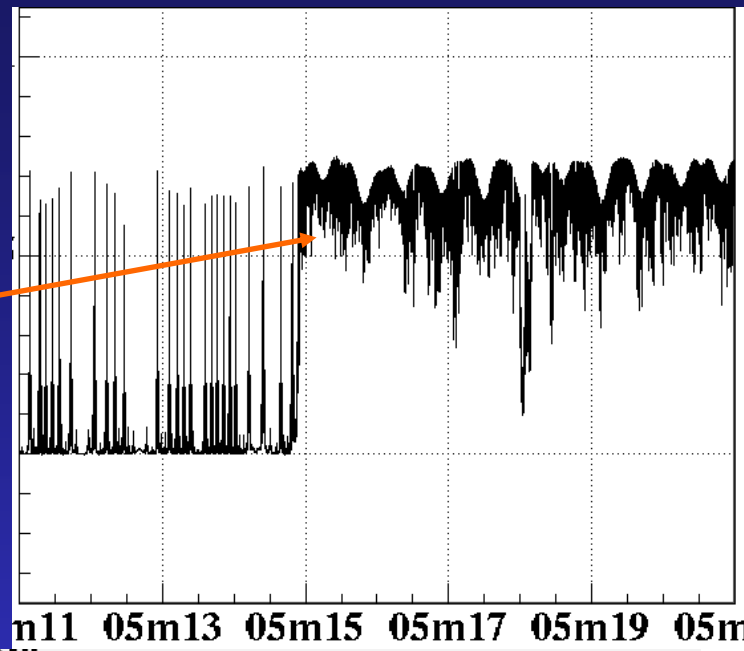
Lock of the FP cavity

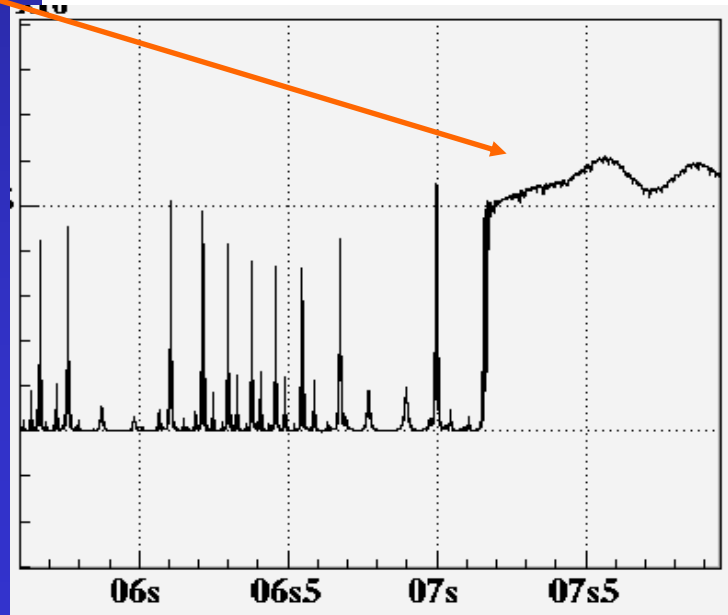
- Oct 28th: first lock of the North FP cavity

Power fluctuations due to:
- laser frequency noise (high freq)
- angular motion of the mirrors (low freq)

⇒ Reduce laser frequency noise
⇒ Implement automatic alignment of the mirrors

The lock of the FP cavities is almost always acquired at first attempt thanks to the low speed of the mirrors: ~2 μm/sec

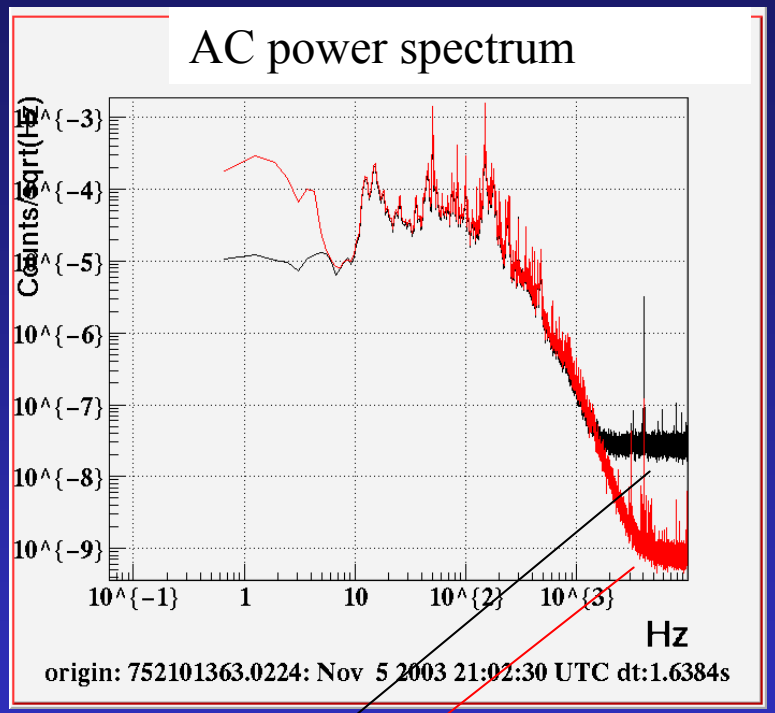




Lock of the Output mode cleaner

- Once the cavity is locked:
  - Lock the output mode cleaner
  - Control the cavity with the OMC output signal

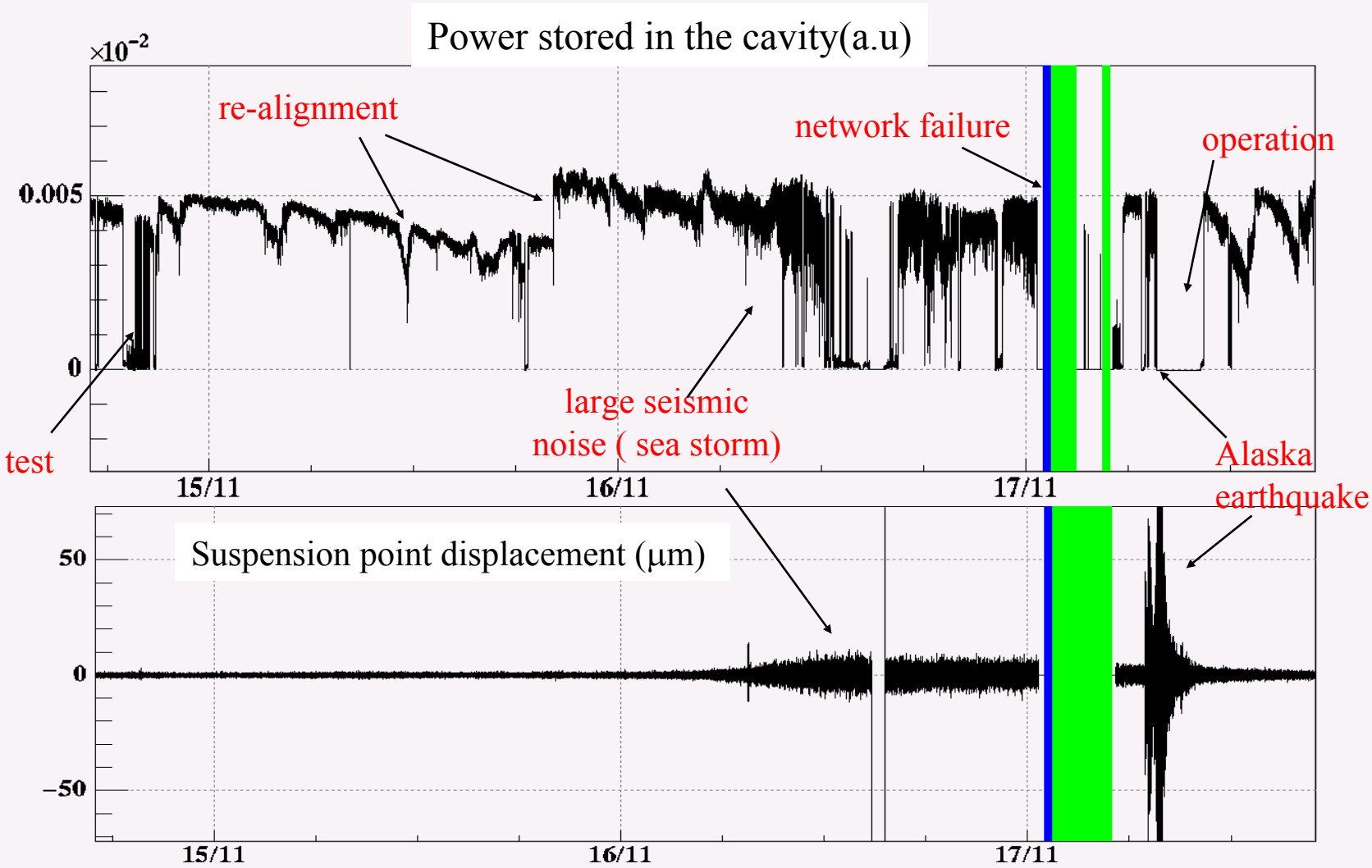
-> improves the sensitivity at high frequencies



First commissioning run: C1

3 days (november 14-17):

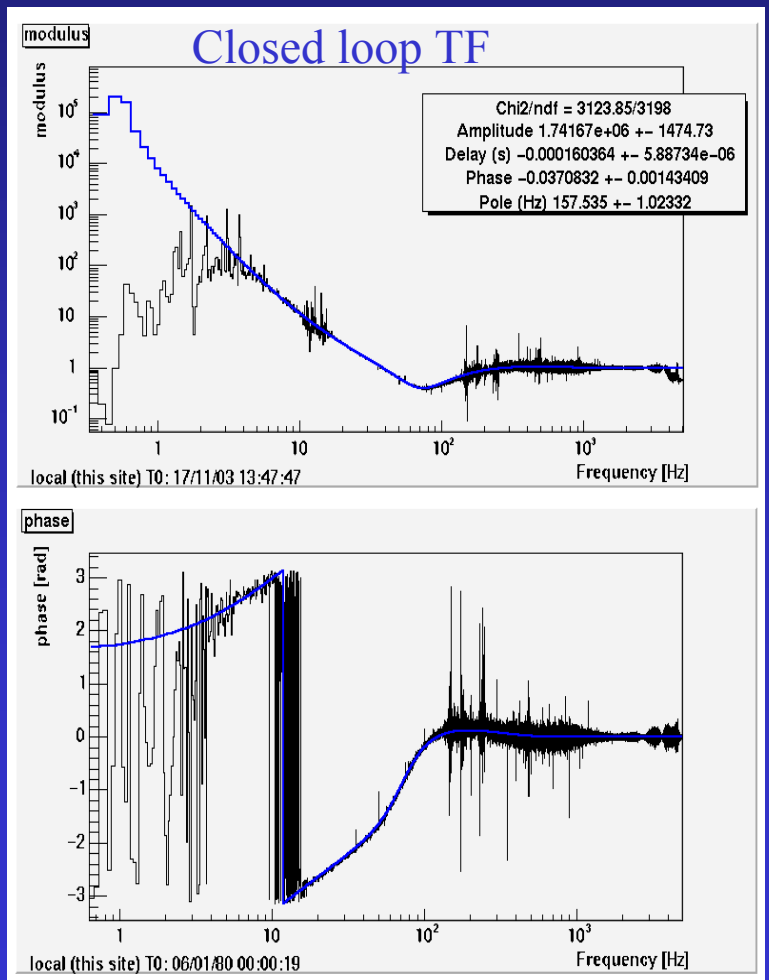
- North FP cavity locked with linearised signal
- Output mode cleaner locked

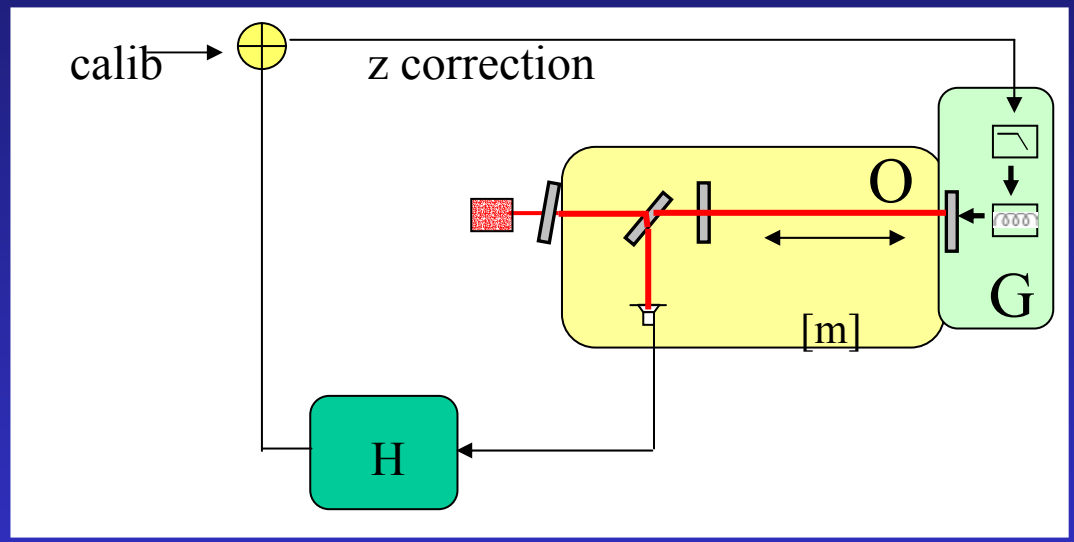


Calibration

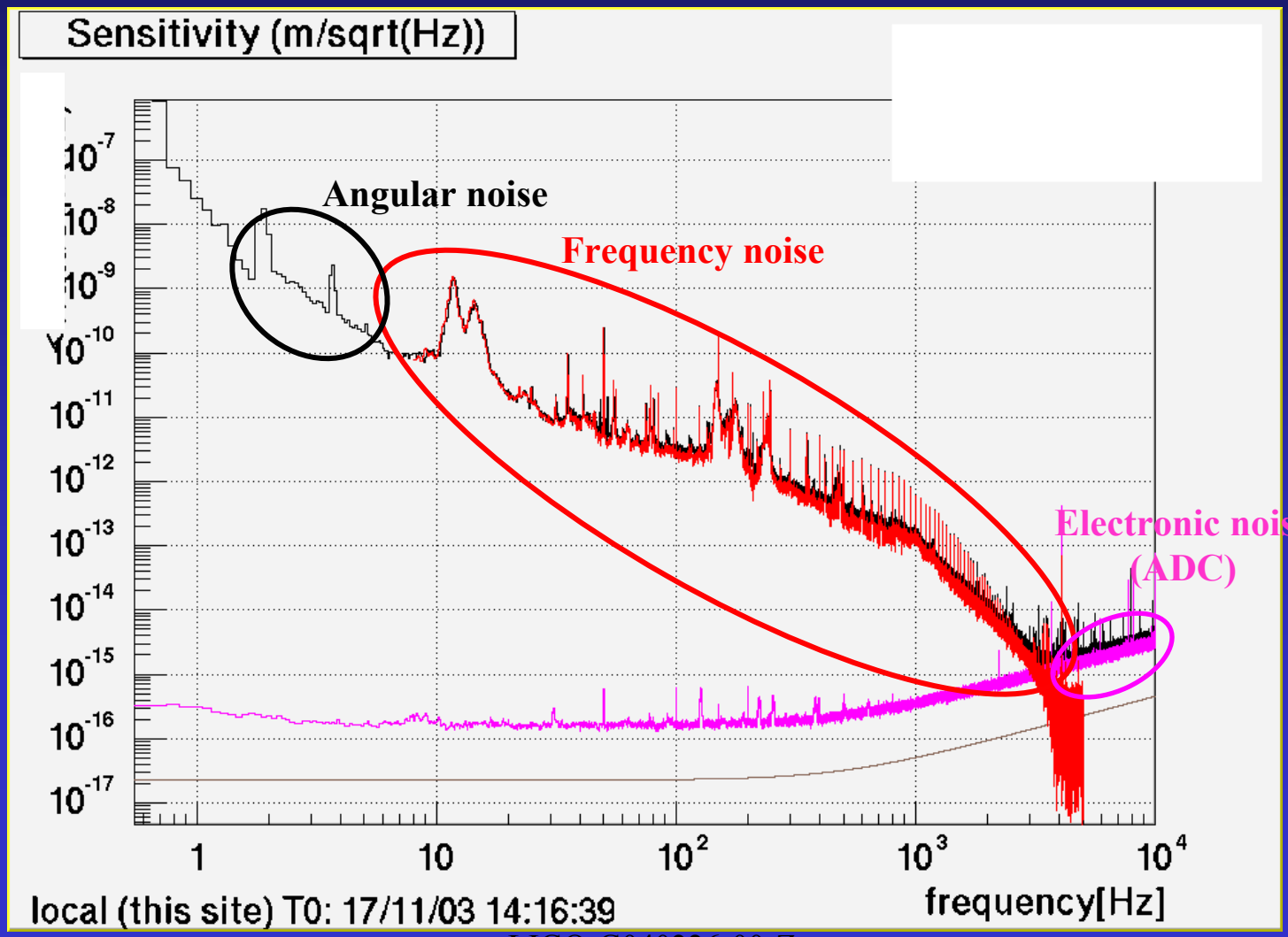
Reconstruction of the sensitivity from the photodiode signal:

-> Measurement of the closed loop transfert function with white noise (injected from mirror coils)





C1 sensitivity



C1 run outcomes

- in normal conditions the lock of the cavity is very stable

- injection system stable: only 1 loss of lock (due to the earthquake)

- sensitive to large seismic noise -> the inertial damping has been improved

- many realignments needed -> the automatic alignment is being implemented

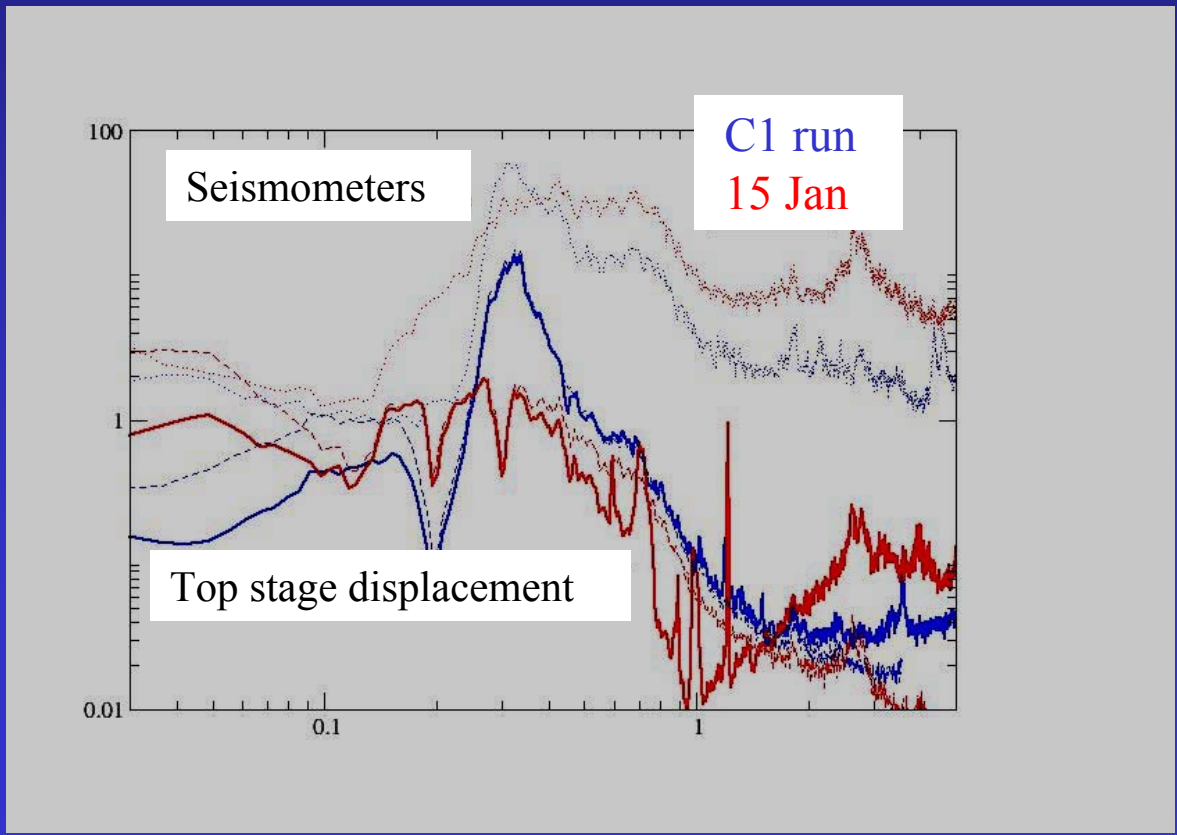
- the sensitivity is limited by laser frequency noise
  -> improve injection control
  -> implement the second stage frequency stabilization

- an acoustic test in the laser lab showed that a lot of the frequency noise is induced by acoustic noise -> improve the isolation

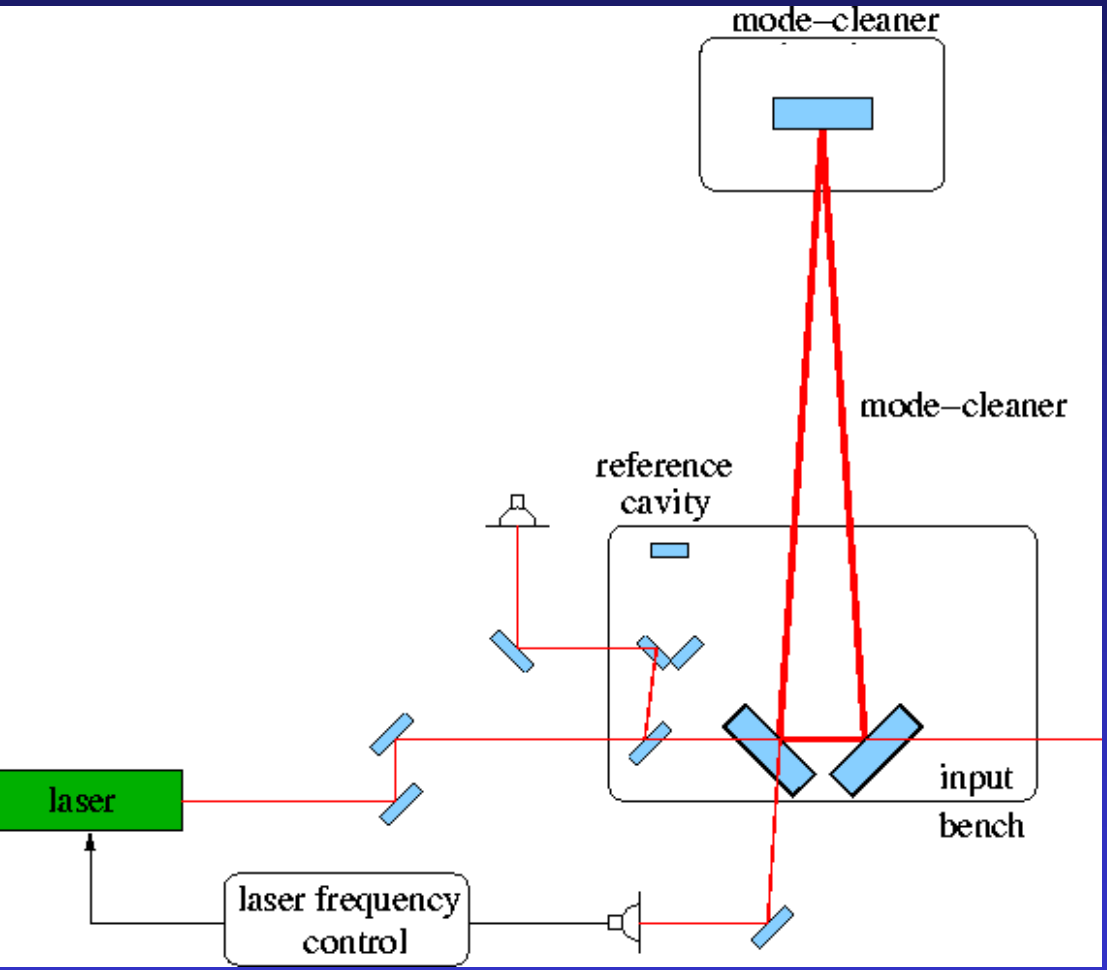
Sensitivity to large seismic noise

- The top stage Inertial Damping uses LVDTs (low frequency) and accelerometers
- Seismic noise is reintroduced by LVDTs -> new filter has been designed to reduce this effect (see E. Majorana's talk)

=> Now implemented on all the towers and works well

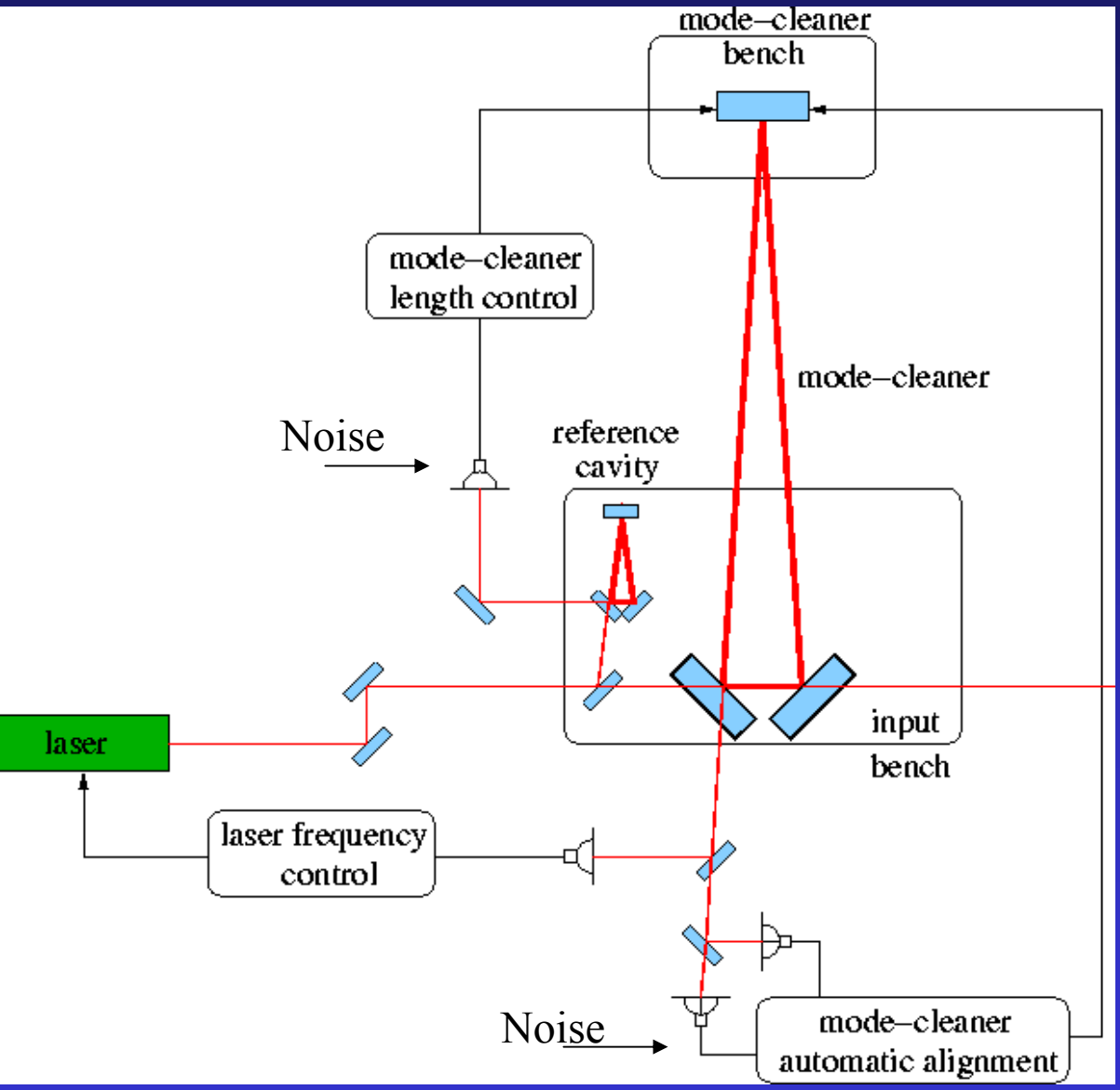


Injection system control



- Input bench and mode cleaner damped with respect to the ground
- Laser frequency locked to mode cleaner length

Injection system control



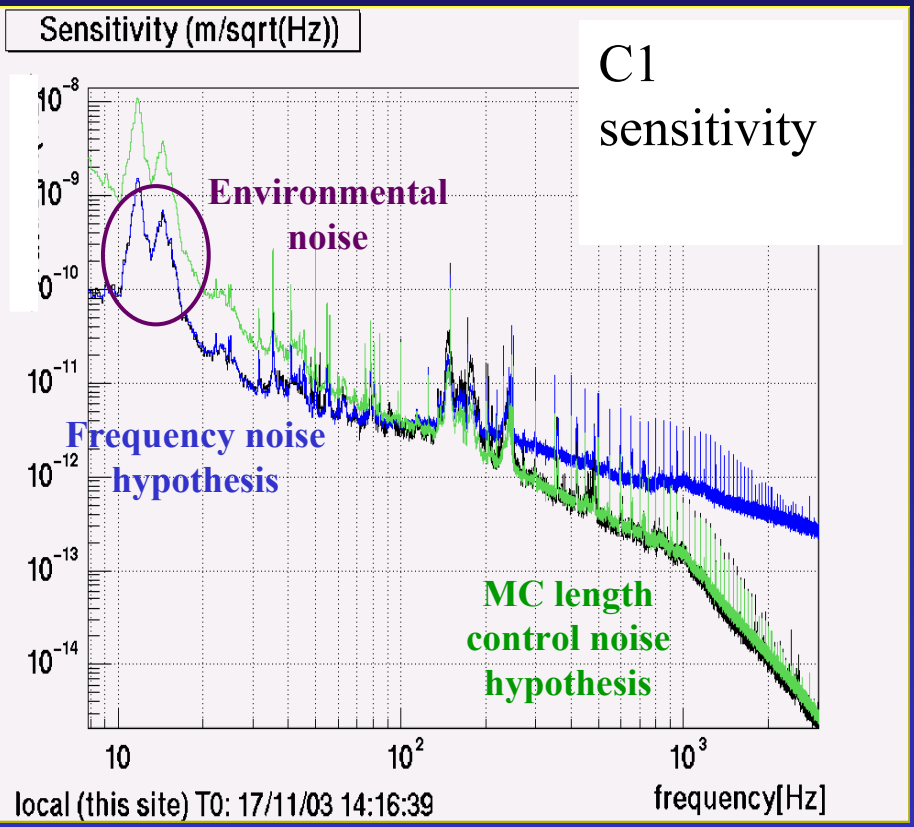
- Input bench and mode cleaner damped with respect to the ground
- Laser frequency locked to mode cleaner length

- Mode cleaner length locked to reference cavity
- Mode cleaner mirror automatically aligned to input beam

Environmental noise introduced through the automatic alignment

Readout noise introduced through MC length control

Improvement of the controls of the injection

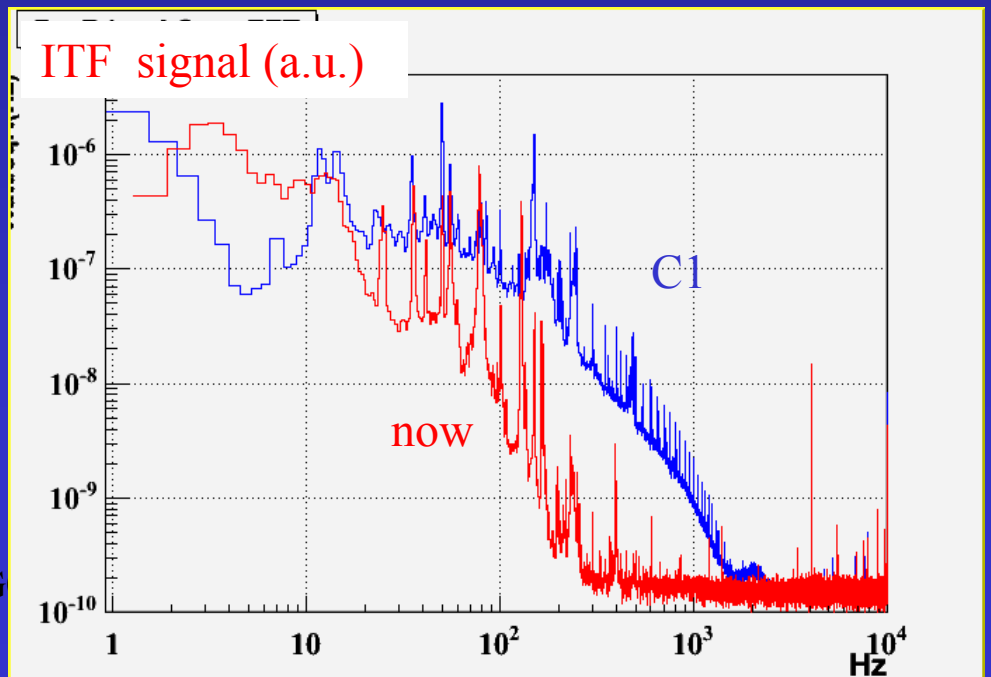


- Automatic alignment control gains reduced

-> less sensitive to environmental noise

- MC control length bandwidth reduced

-> less noise injected at high frequency



Next steps

- The linear automatic alignment is implemented and under test:
  Angular control of the cavity mirrors using signals of quadrant photodiodes
  -> reduce the power fluctuations at low frequency

- Implement the laser frequency stabilization

- Study the mirrors hierachical control: lock from the marionetta in order to reduce the force on the mirror (and therefore the noise)

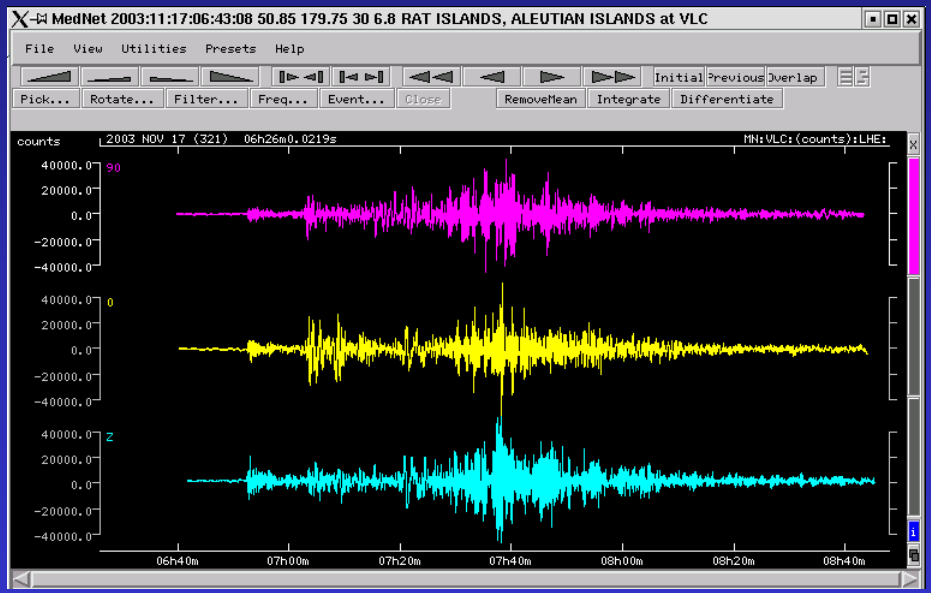
- And start the commissioning of the recombined Michelson

Conclusion

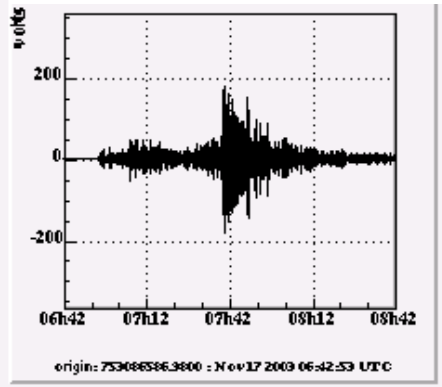
- Summer 2003: End of the Virgo sub-systems upgrade
- Since autumn 2003: Commissioning of Virgo
  - Commissioning of the two Fabry-Perot cavities
  - First run with one cavity
- Now:
  - Implementing the laser frequency stabilisation
  - Prepare the commissioning of the recombined Michelson
  - Next run: end of this week (feb 19-22) with the 2 FP cavities
- Futur:
  - Recombined Michelson: spring 2004
  - Recycled Michelson: end 2004
  - first scientific run: 2005 ?

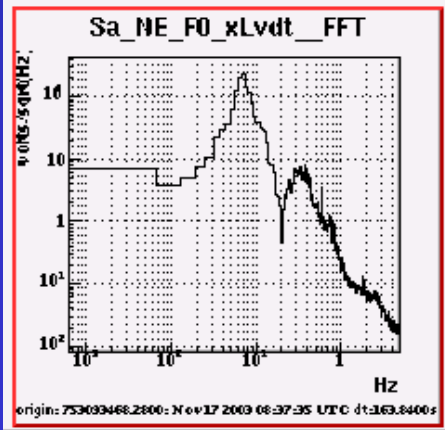
Monday morning earthquake

- Earthquake happened in the Rat Island (Alaska) Nov/17 at 06:43:07 UTC: magnitude 7.3 Richter
- Travel time to Virgo is approx. 1hour
- Peak frequency of the seismic wave at Virgo is approx. 0.70mHz



Top stage displacement





- Earthquake trigger the inertial damping security system of the injection bench suspension
  ⇒ loop was open and input mode-cleaner unlocked

- Second stage of laser frequency stabilisation