Virgo Status

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for

The Virgo Collaboration

Plan of the talk

- VIRGO Detector Layout
- Interferometer Controls
- Last years main activities
- Virgo Science Runs
- VSR1 Detector Performances
- Next Steps
  - Virgo+
  - Advanced Virgo
- Conclusions

VIRGO

• Gravitational wave detector based on a laser interferometer with 3km long arms

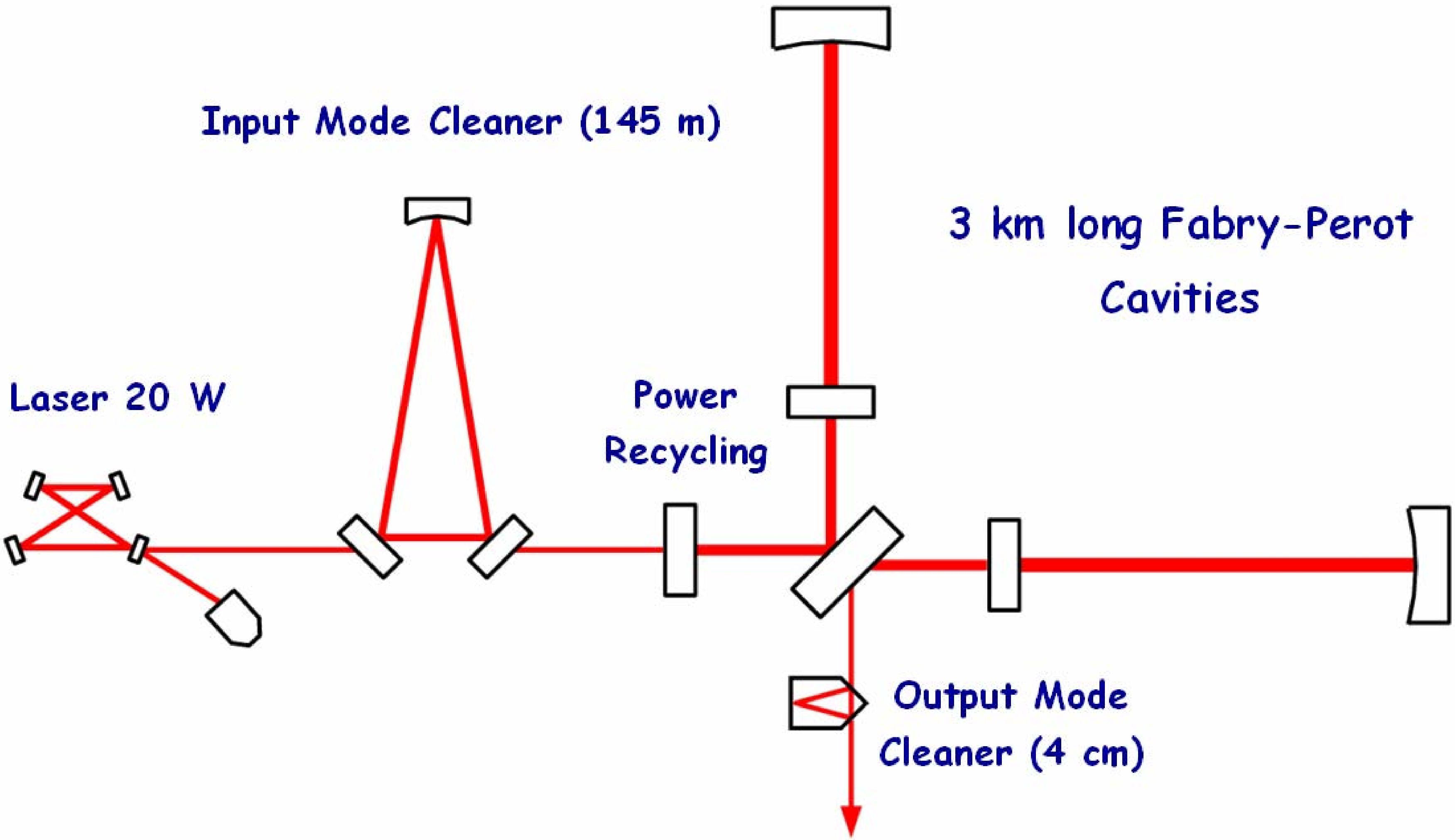
• Located in Cascina near Pisa (Italy)

• Built by a French-Italian collaboration supported by INFN in Italy and CNRS in France. Virgo Collaboration composed by those laboratories:

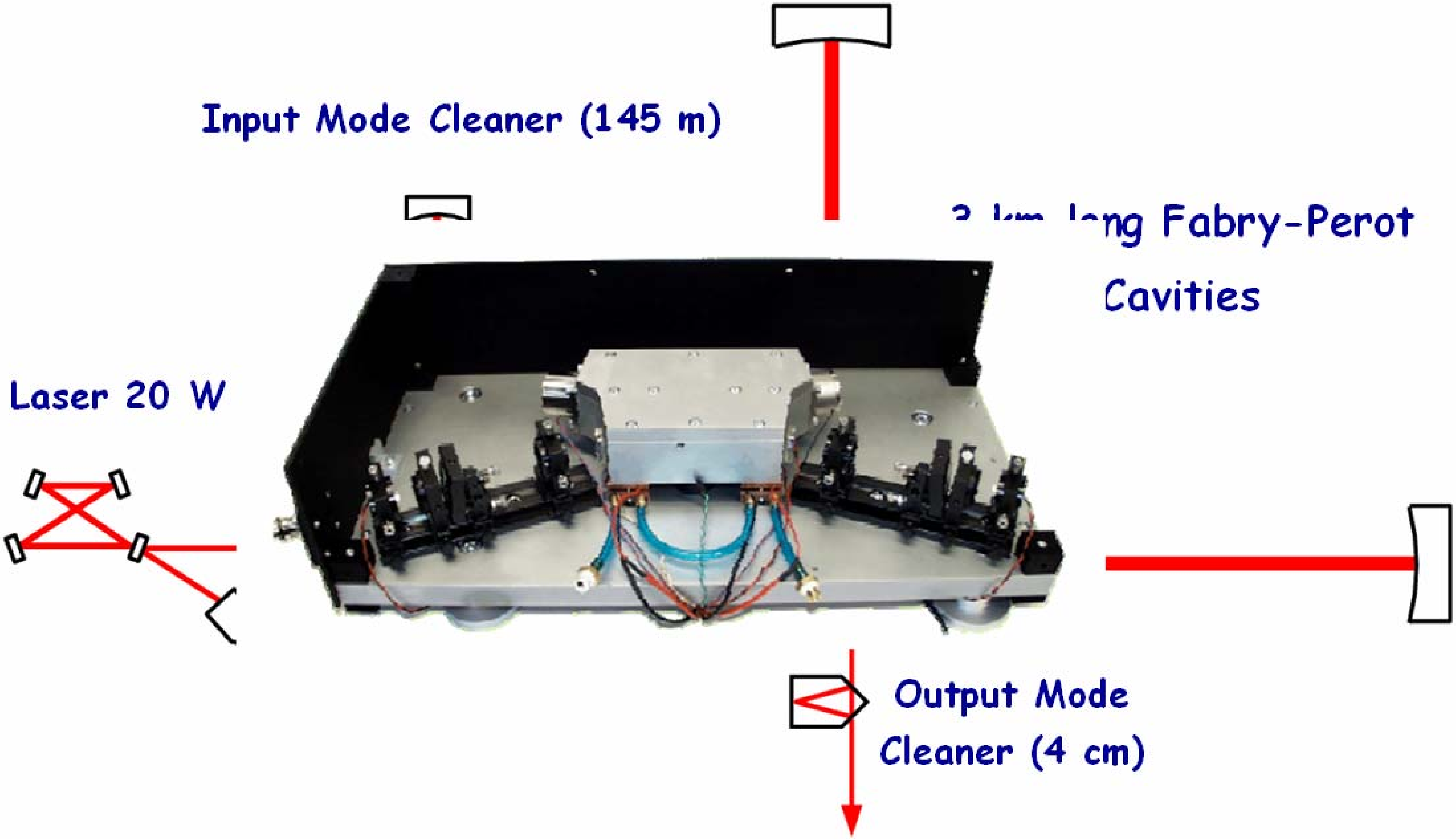
LAPP–Annecy, INFN-Firenze/Urbino, IPN–Lyon & ESPCI–Paris
INFN–Napoli, OCA–Nice, NIKHEF–Amsterdam, LAL–Orsay, INFN–Perugia,
INFN–Pisa, INFN–Roma 1, INFN–Roma 2, INFN-Trento/Padova

• A new actor since 2001: European Gravitational wave Observatory (EGO) consortium set-up by INFN and CNRS at the Virgo site

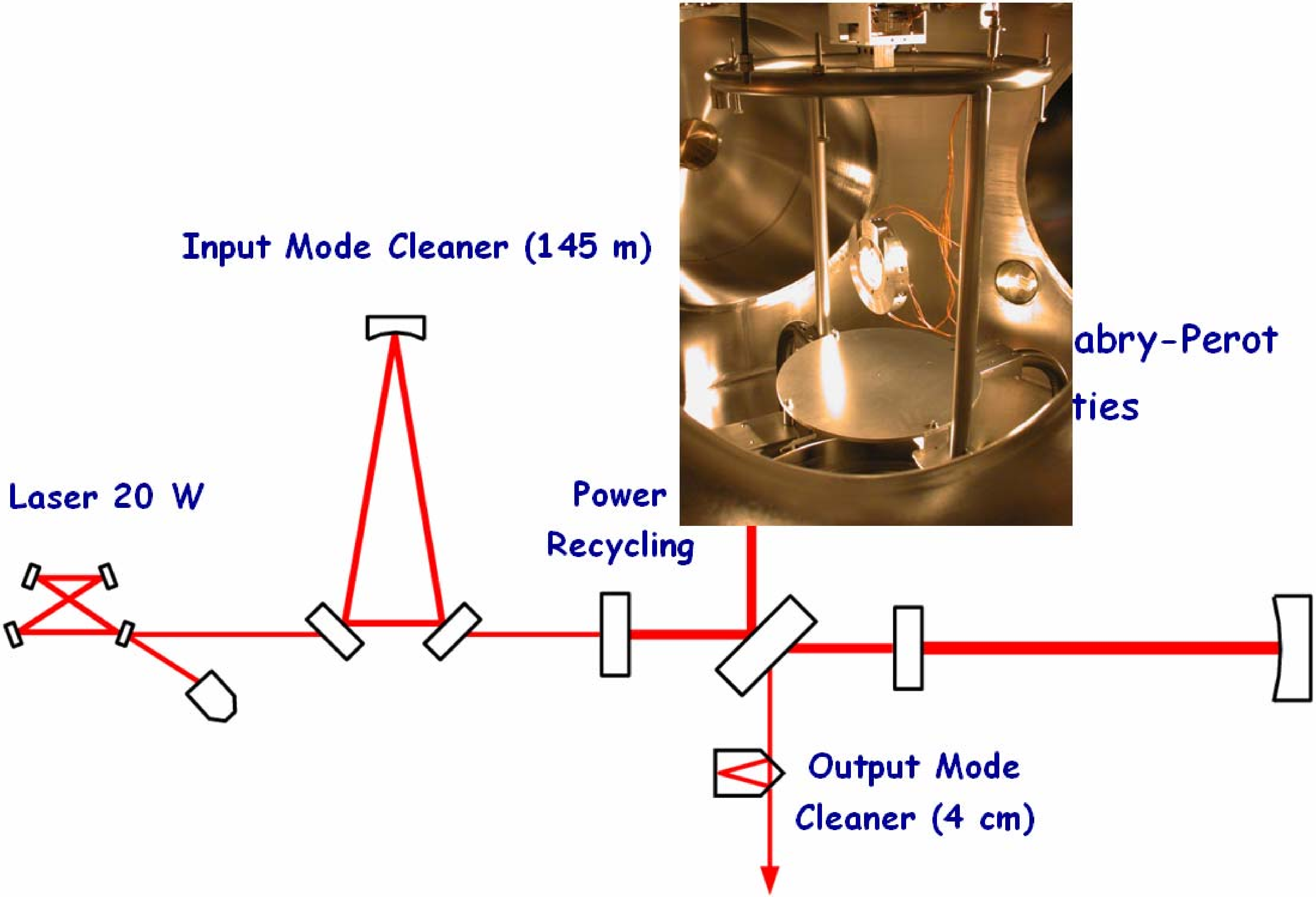
VIRGO Detector Layout



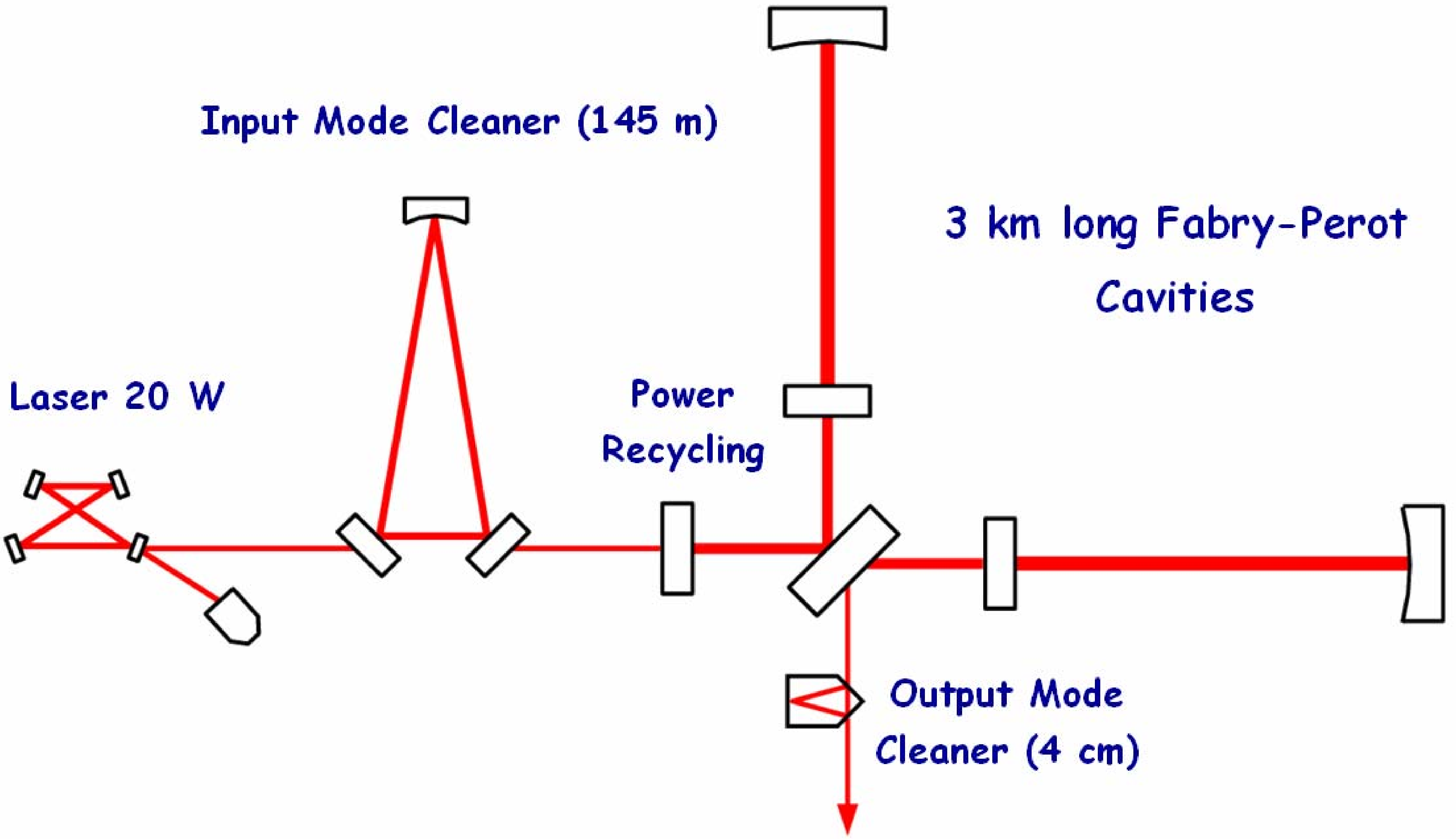
VIRGO Detector Layout



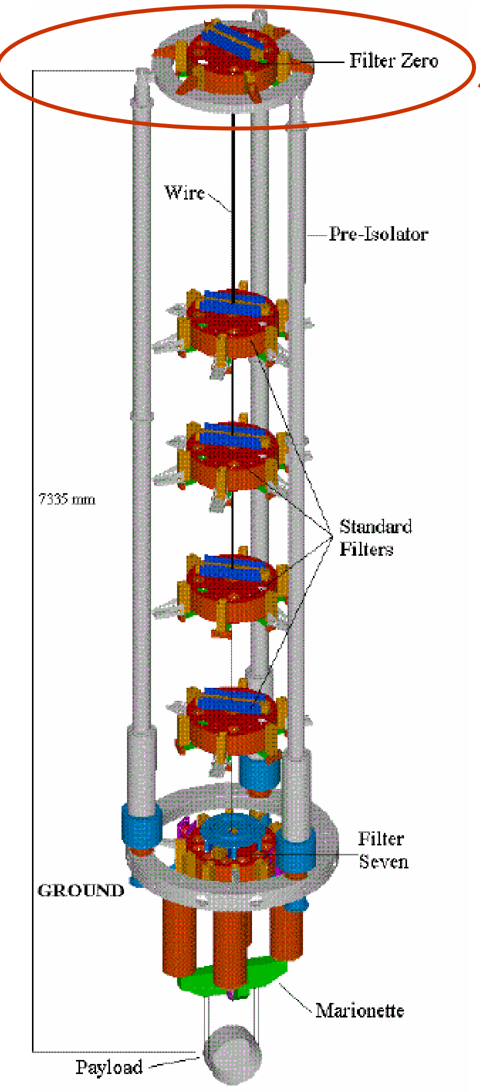
VIRGO Detector Layout

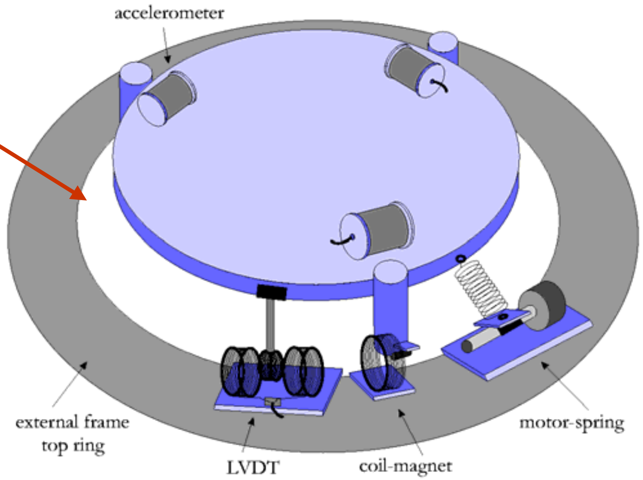


VIRGO Detector Layout



Mirror Suspensions

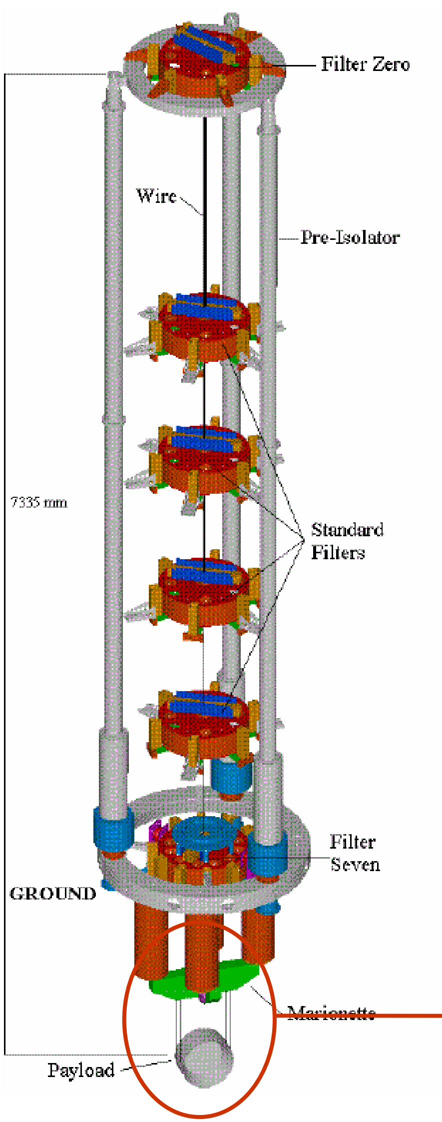


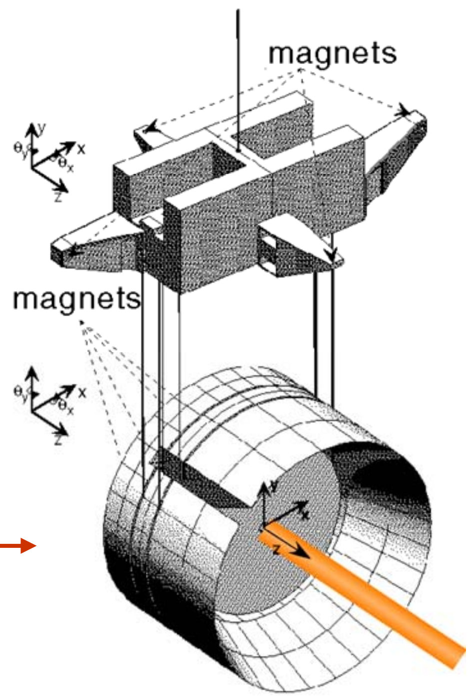


- Suspended test masses: filter seismic noise
- Attenuation factor of 10^{15} at 10 Hz
- Residual motion of the suspension point at the mechanical resonances, confined below 4 Hz, is dumped by an active feedback control (Inertial Damping) based on 3 positioning sensors (LVDT) and 3 accelerometers

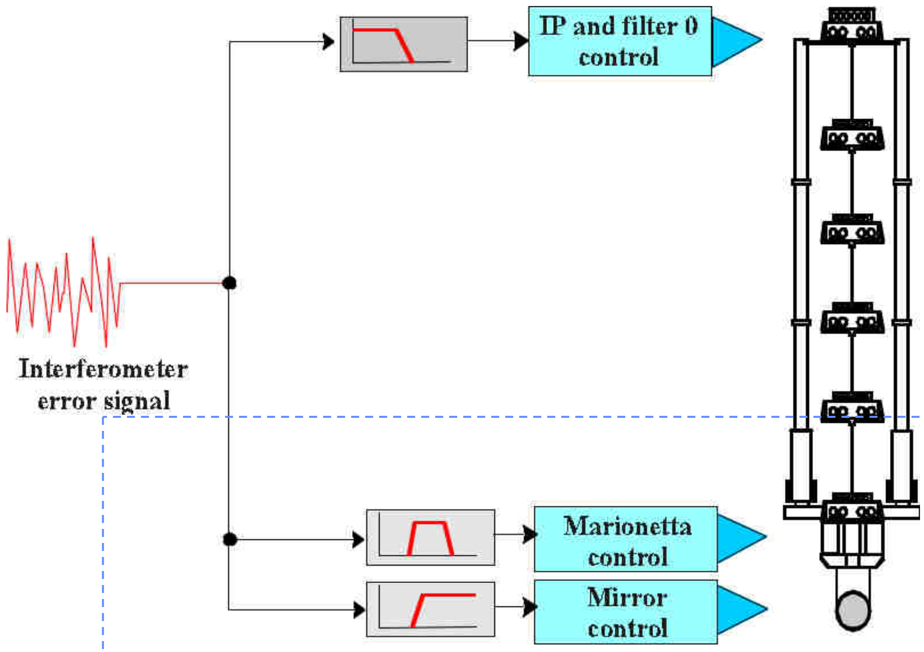
Mirror Suspensions

- Local Control on Marionette: control system based on optical lever sensors, ground connected. Reduce mirror angular motion and keep the ITF aligned within fractions of μrad r.m.s.
- Local damping on Reference Mass (RM): recover the position of each mirror after an ITF un-lock without exciting the mechanical mode of the filter chain



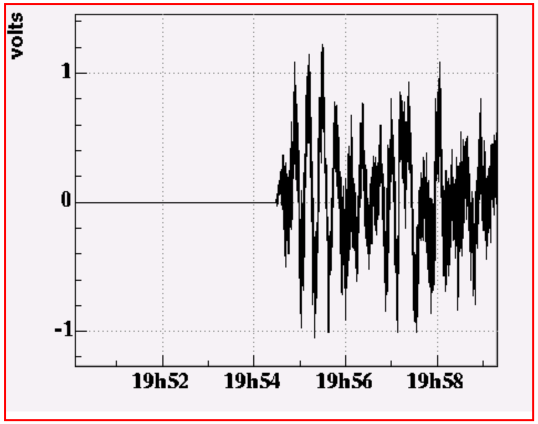


Suspensions Hierarchical Control

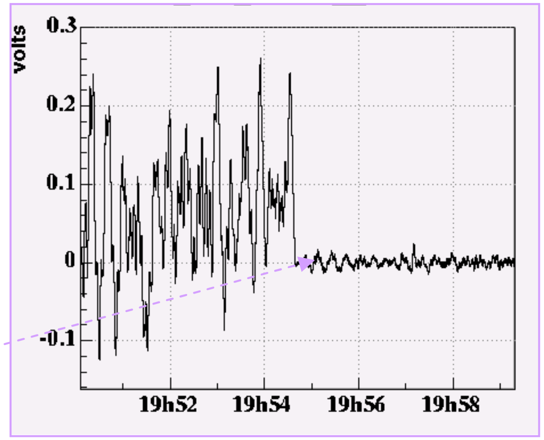


RE-ALLOCATION OF THE FORCE

Corrections sent to the Marionette coil/magnets

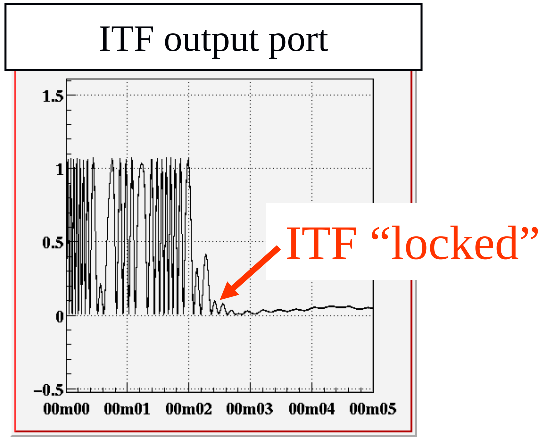


Corrections sent to the mirror coil/magnets



Magnetic actuation force on the mirror reduced
Switch to low noise coil drivers

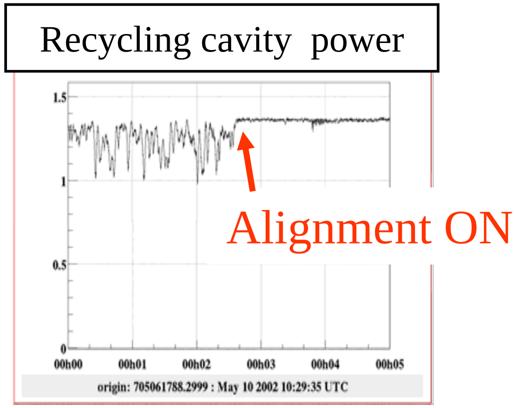
1: longitudinal control



- lock the optical cavities at resonance,
- keep the Michelson on the dark fringe
- stabilize the laser frequency

LOCKING

2: angular control

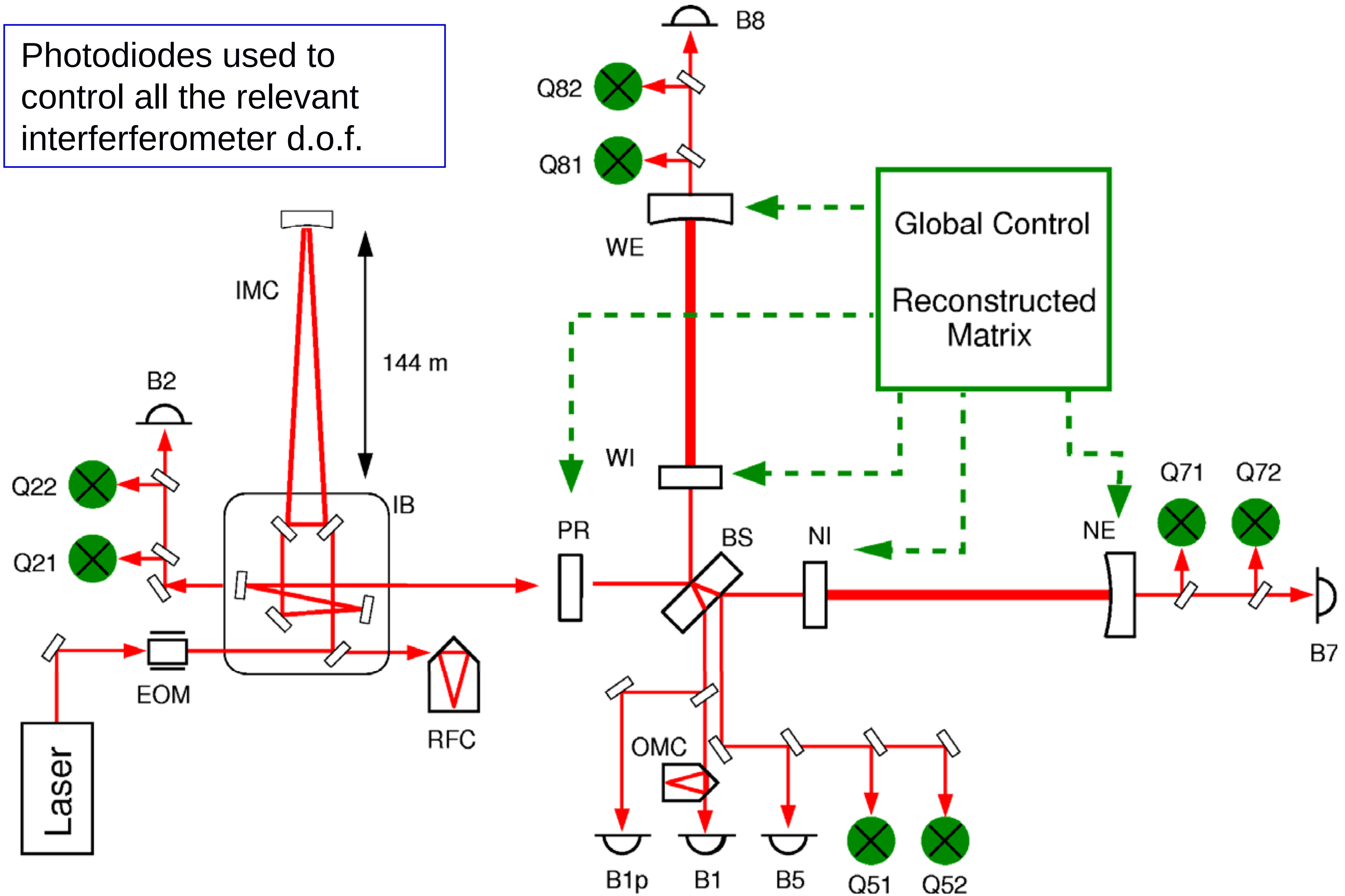


- Keep mirrors aligned below 100 nrad rms, to stabilize the power stored in the cavities and to increase locking duration

ALIGNMENT

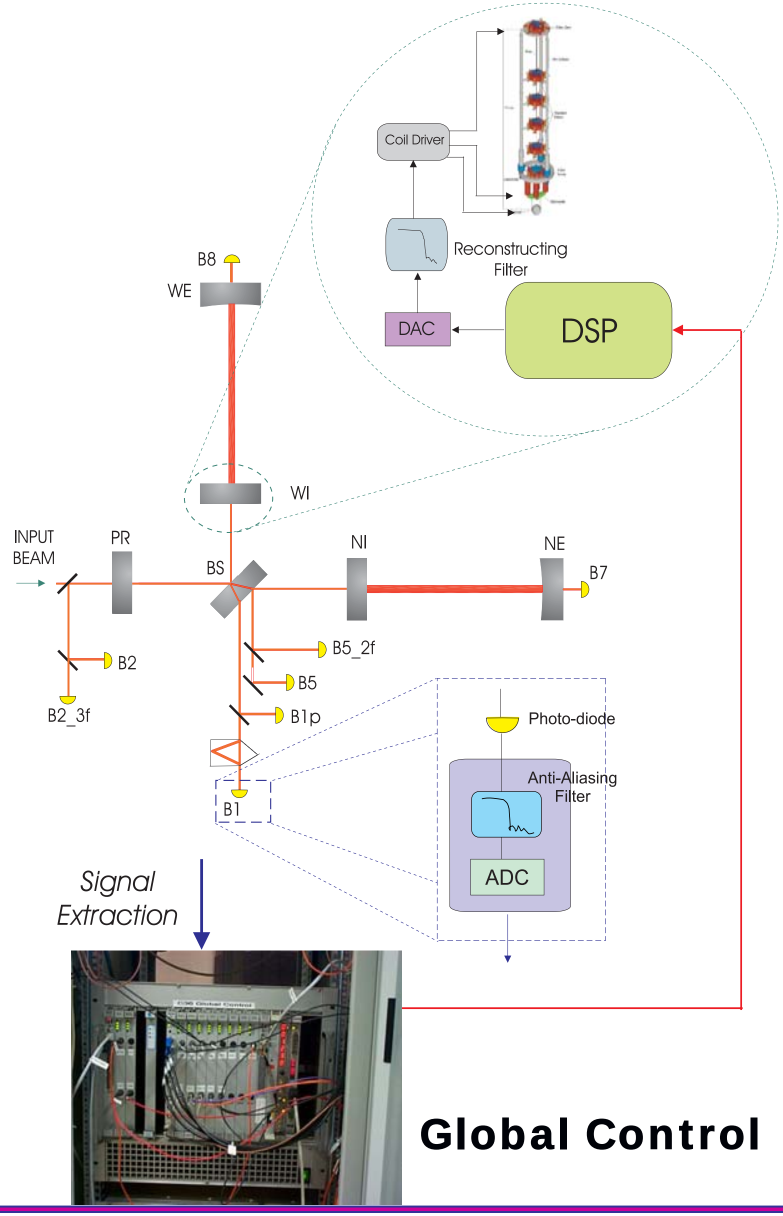
Interferometer Controls

Photodiodes used to control all the relevant interferferometer d.o.f.



Interferometer Controls

- Global Control
  - Signals are acquired with 16-bit ADCs @ 20 kHz
  - Data are transferred via optical links to the Global Control which computes correction signals
  - Corrections signals are sent to the DSPs of the involved suspension, passed through DACs and applied to the mirror

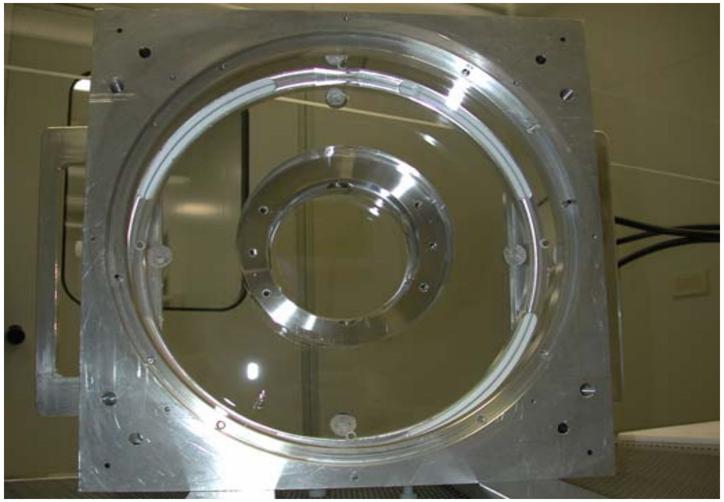


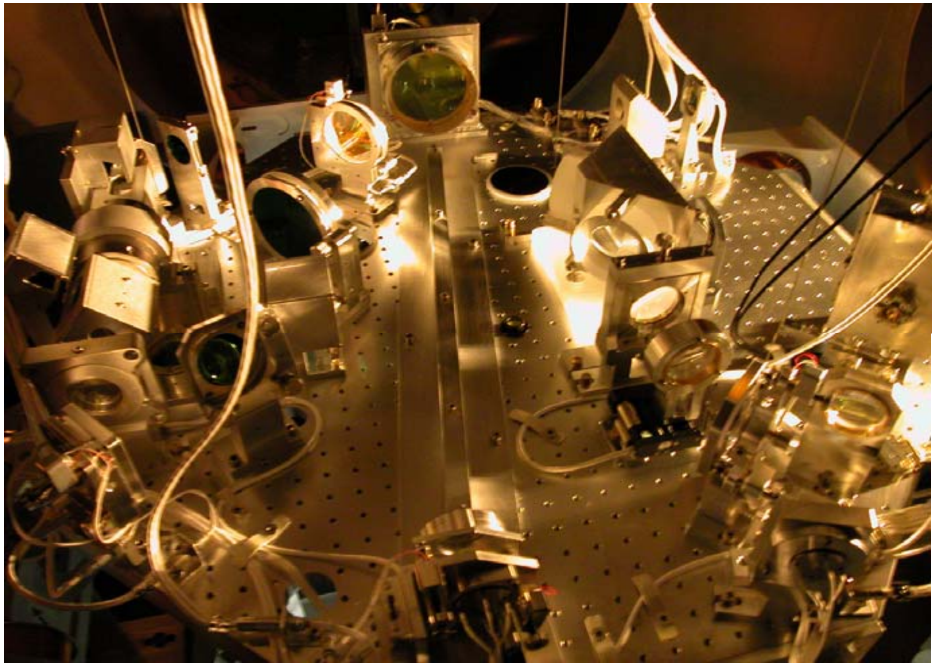
Last years summary

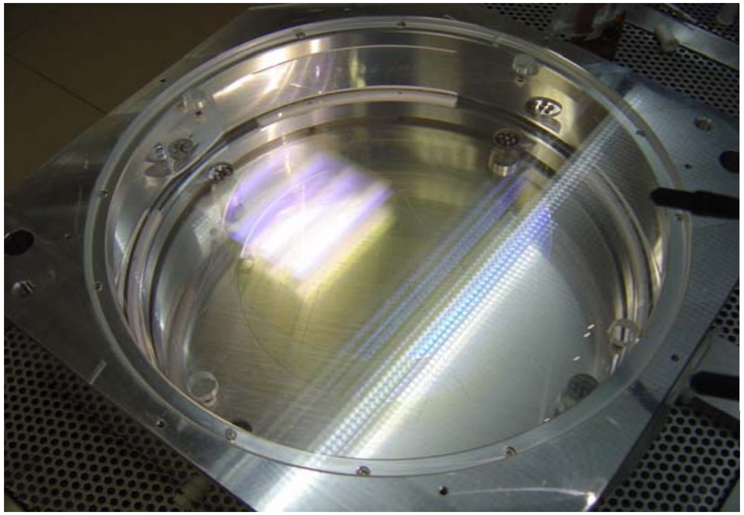
- Sept 2003: start the commissioning of Virgo
  - Problem back reflected light by the injection system
    - $\Rightarrow$ Need to work at reduced power (0.7 instead of 7 Watts)
- End 2005: shutdown to upgrade the injection system + new PR mirror
- Early 2006: restart commissioning
  - Stable lock, good enough sensitivity $\Rightarrow$ started Weekend Science Runs
  - Many noise sources addressed
  - Improved detector stability
- May 2007: start first science run (VSR1) in coincidence with LIGO S5 run

2005 Shutdown

- New input bench
  - with Faraday isolator
  - with input parabolic telescope
- New power recycling mirror
  - Better mechanical properties: monolithic mirror instead of composite
  - higher reflectivity 92% -> 95%







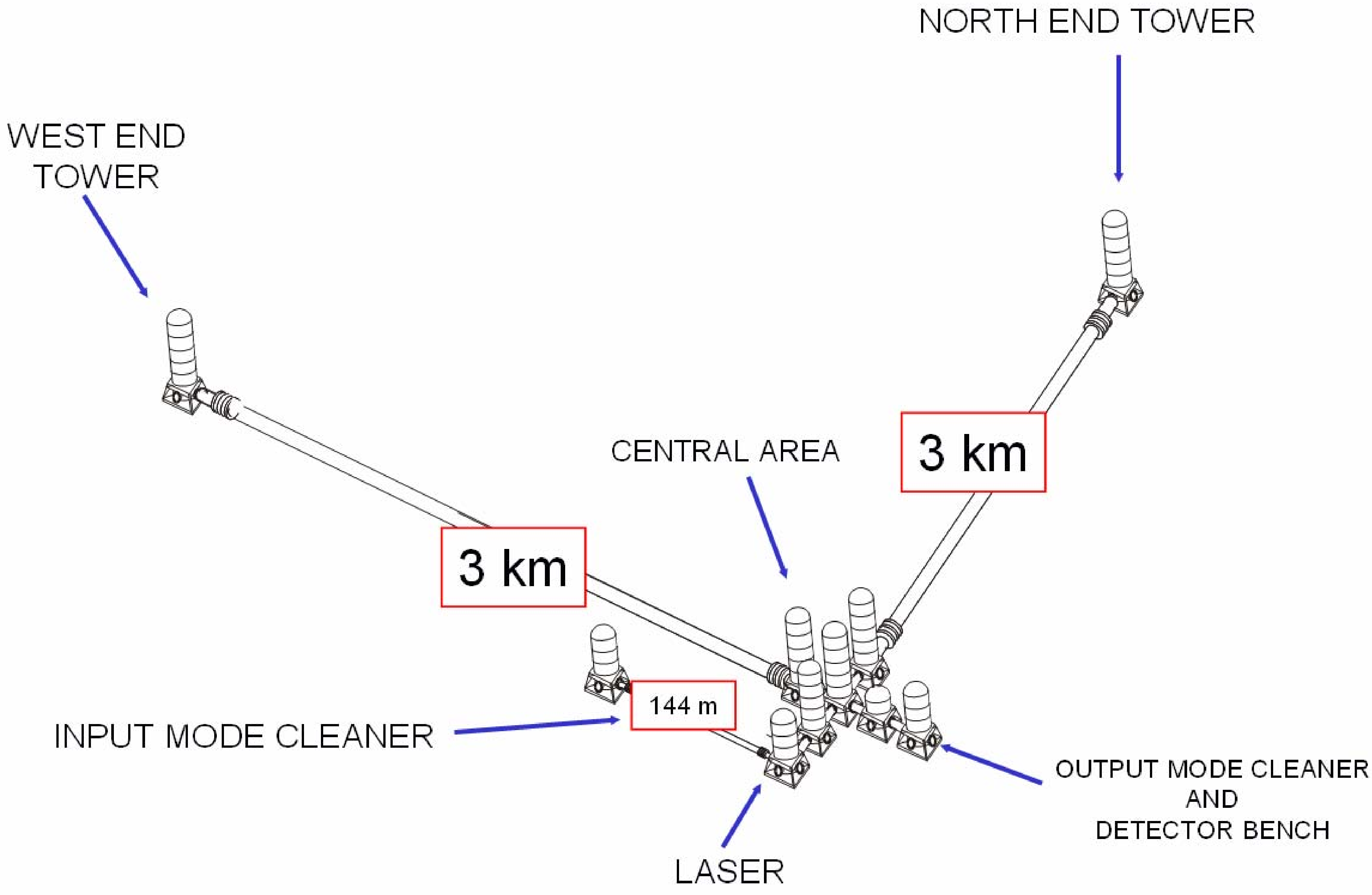
Noise Reduction

- Many noise sources addressed in the last months of commissioning before VSR1 implying:
  - fine tuning of the control systems
  - better protection of the ITF sensors from external disturbances
  - environmental noise reduction
- Example: acoustic noise source reduced adding isolating enclosures on all in-air optical benches

Detector Stability

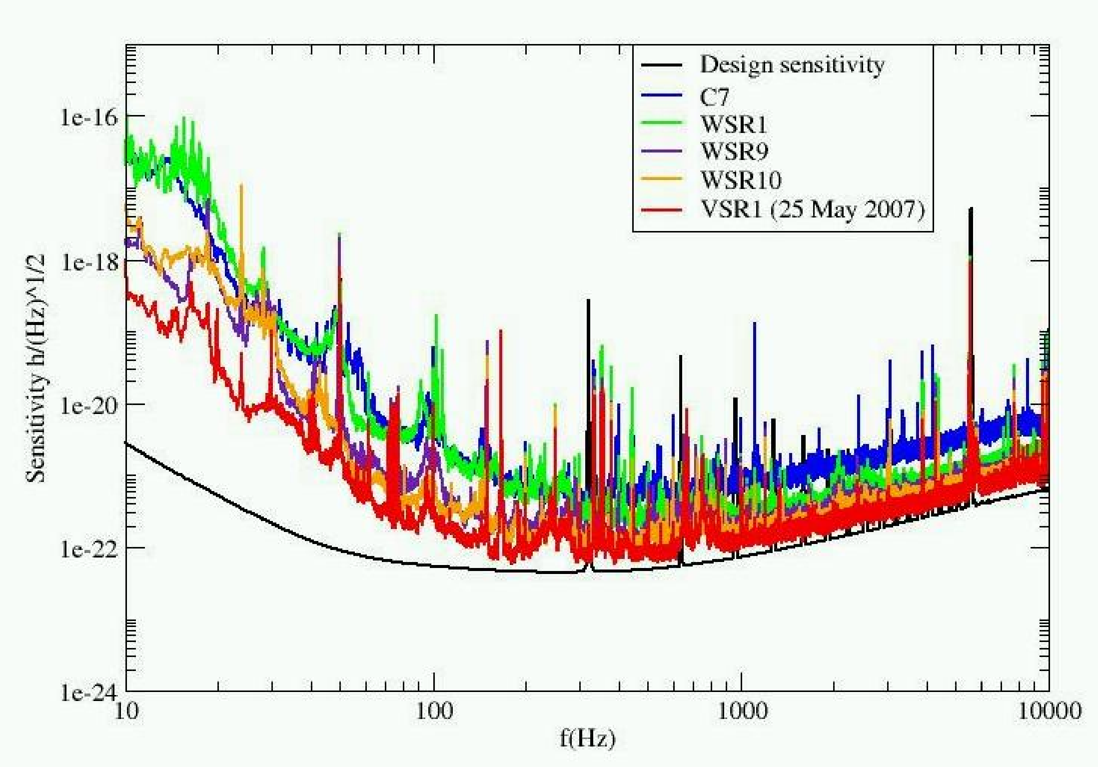
- Detector stability mainly enhanced via several improvements at suspension control level
- Problem Statement:
  - Inertial Damping is using LVDTs, sensitive to µseism between 200 mHz – 1 Hz and accelerometers, noisy below 100 mHz
  - The control is implemented with LVDTs till 100mHz and with accelerometers over
- Strategy evolution to minimize those noises:
  - Better frequency crossover: better filtering of µseism noise from LVDTs.
  - Main idea: do the above difficult optimization only on input towers, then on the others towers position signal is differential respect to the input towers.
  - Towers on the Central Area, µseism coherence: difference between the LVDT signal on the same axis
  - 3 Km distant towers, no µseism coherence: the locking force is used as position signal.
  - With this mechanism the crossover frequency on all towers except input could be moved to the optimal one

Detector Stability



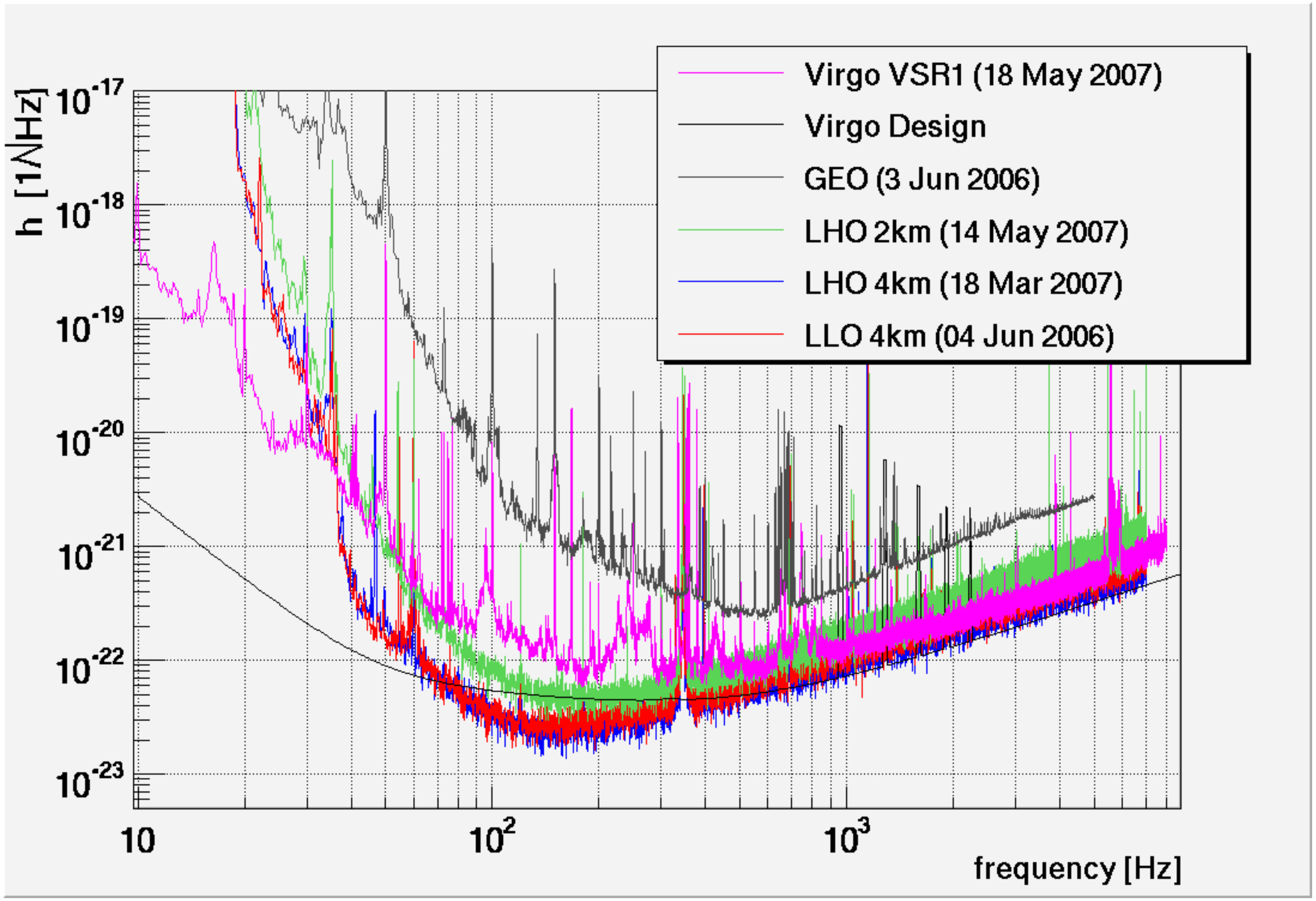
Virgo Science Runs

- 10 Weekend Science Runs (WSRs) from Sept 2006 to March 2007:
  - final tuning of
    - shifts organization
    - automatic procedures
  - checking
    - detector reliability
    - data taking process



Virgo Science Runs

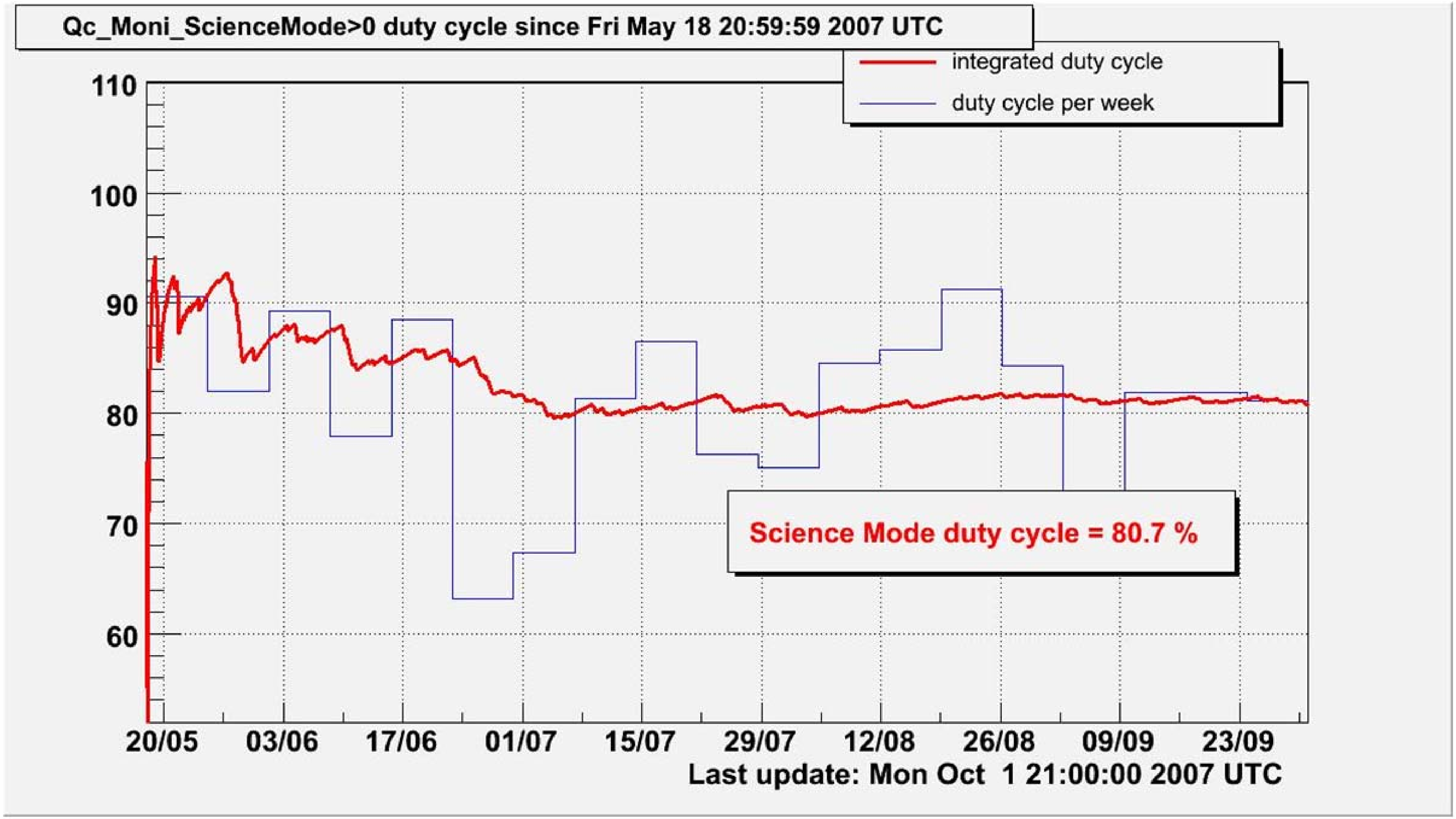
- The first VIRGO Science Run (VSR1)
  - ◆ started on May 18th, 2007 in coincidence with the last period of LIGO S5 run.



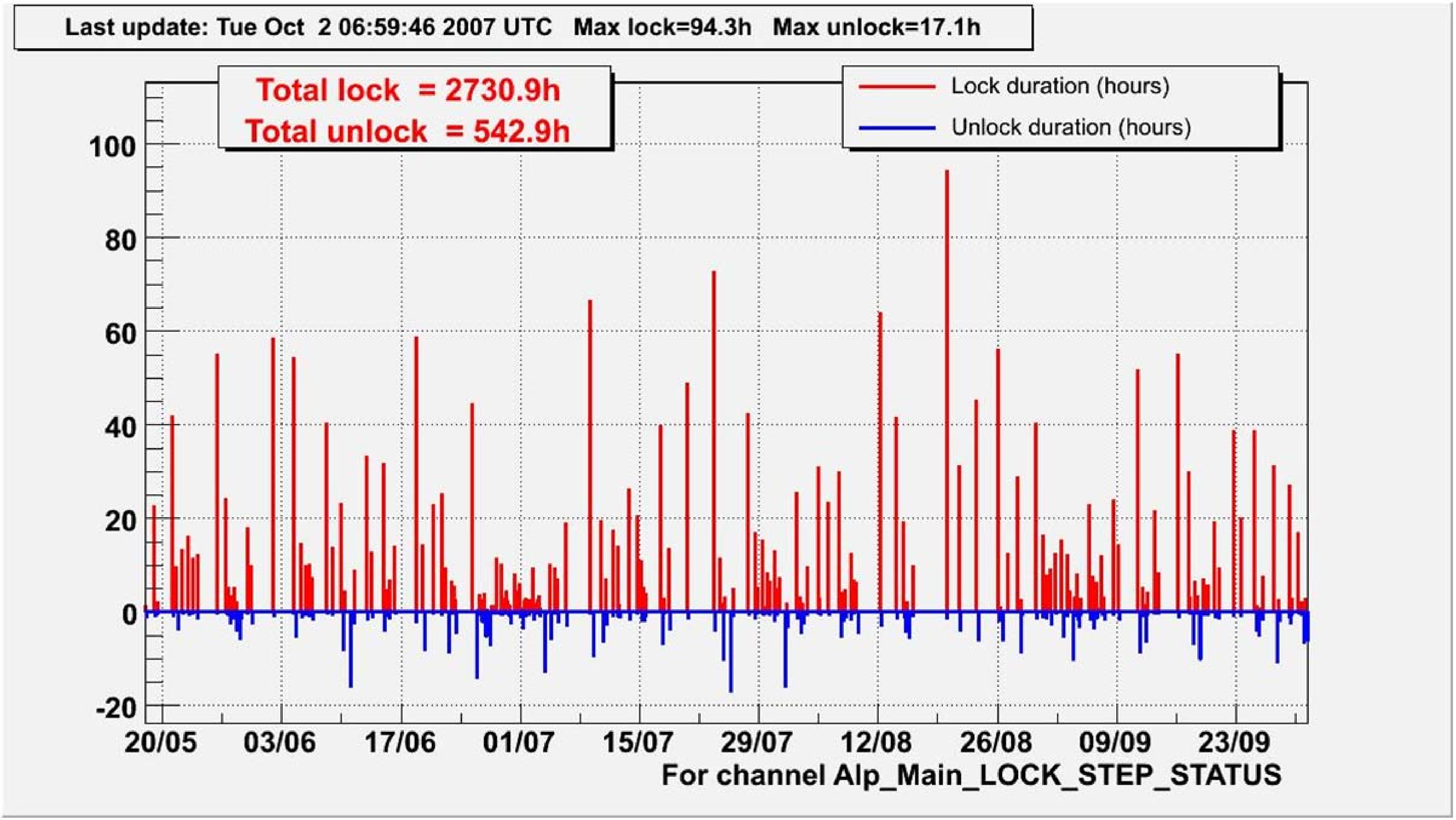
The interferometric network

- LIGO Scientific Collaboration (LSC) – VIRGO agreement
  - joint DA committee and run organization committee
  - full data exchange,
  - joint data analysis and joint publications.

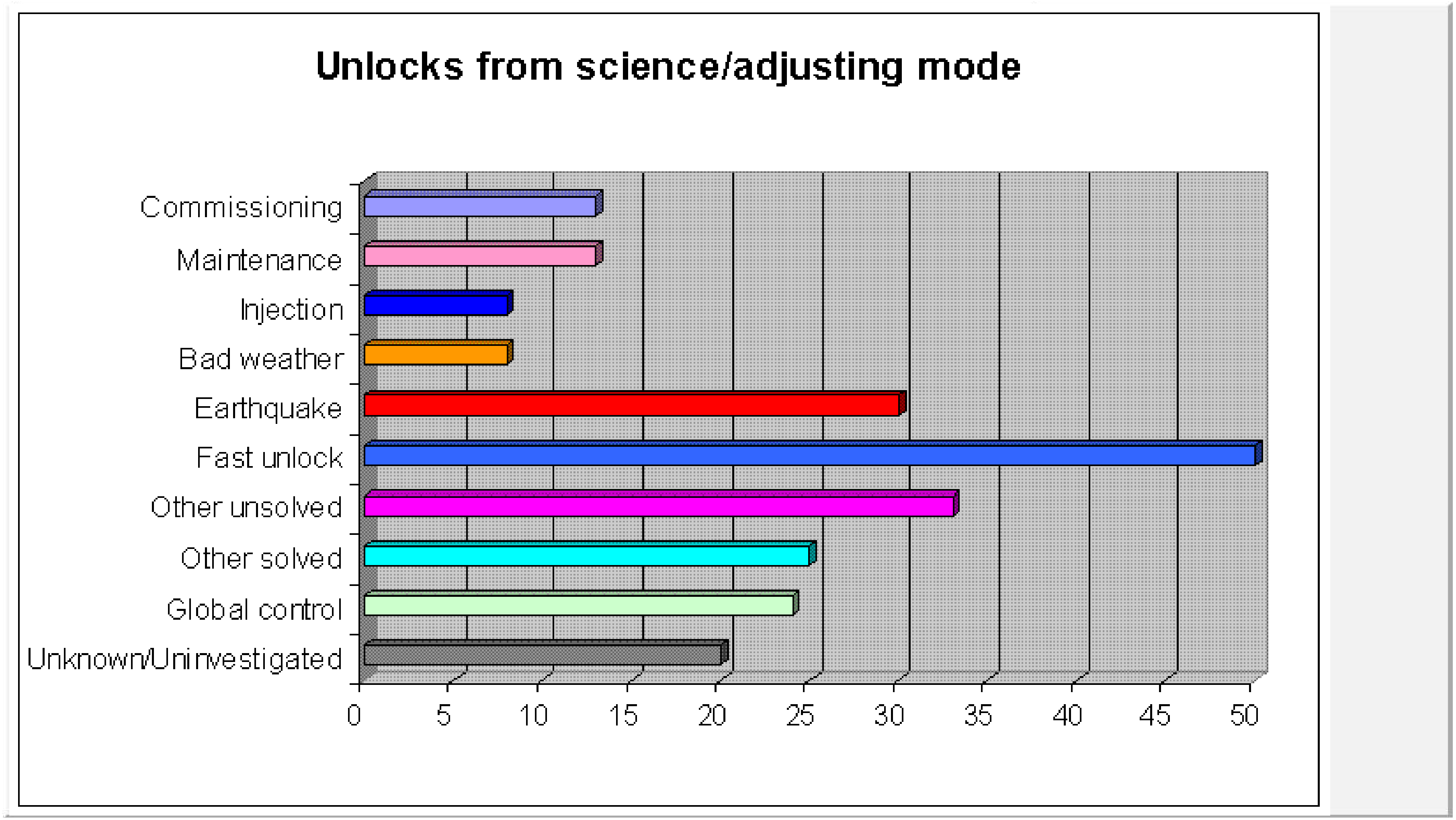
VSR1 statistics



VSR1 statistics

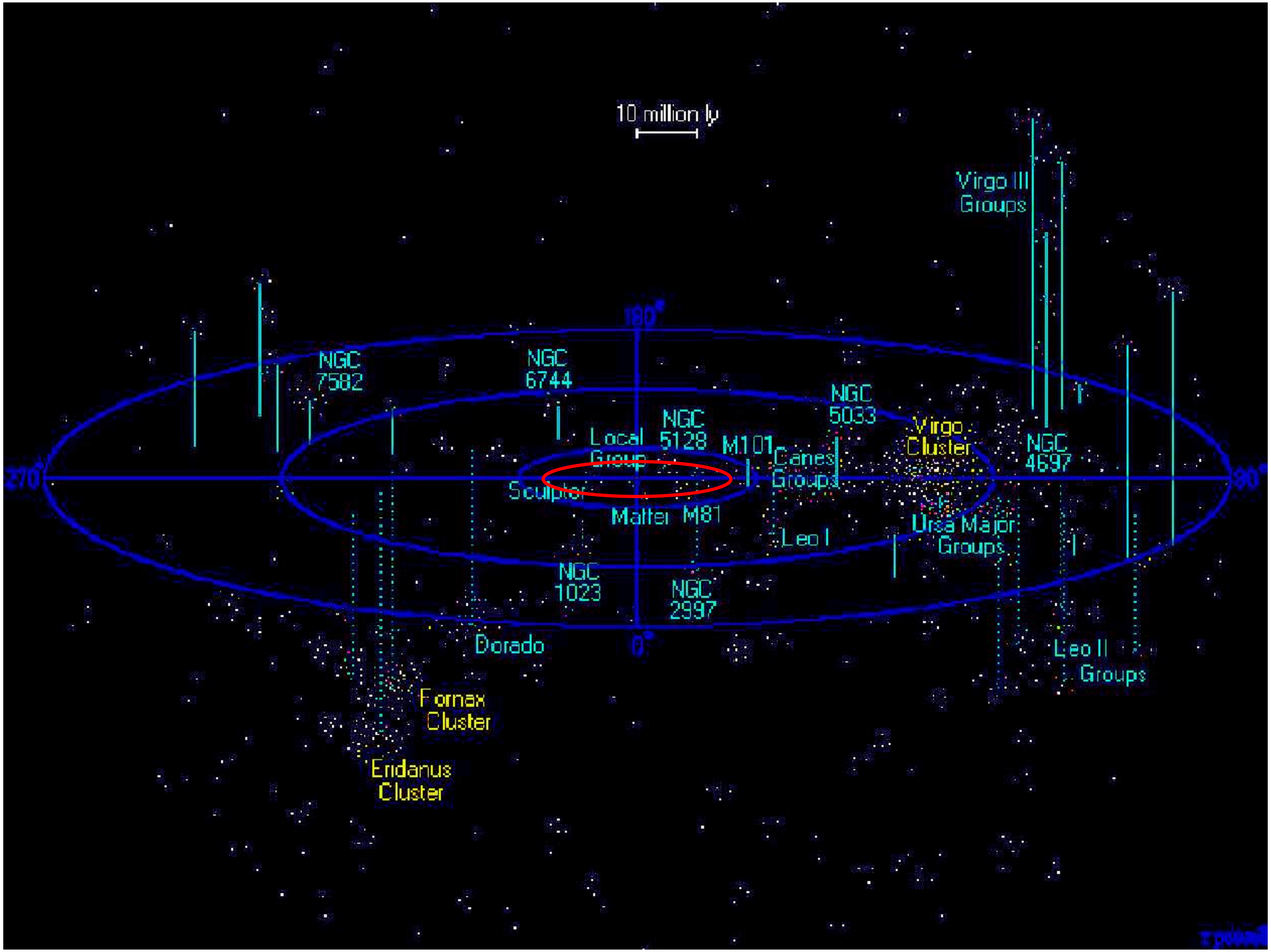


VSR1 statistics



Horizon

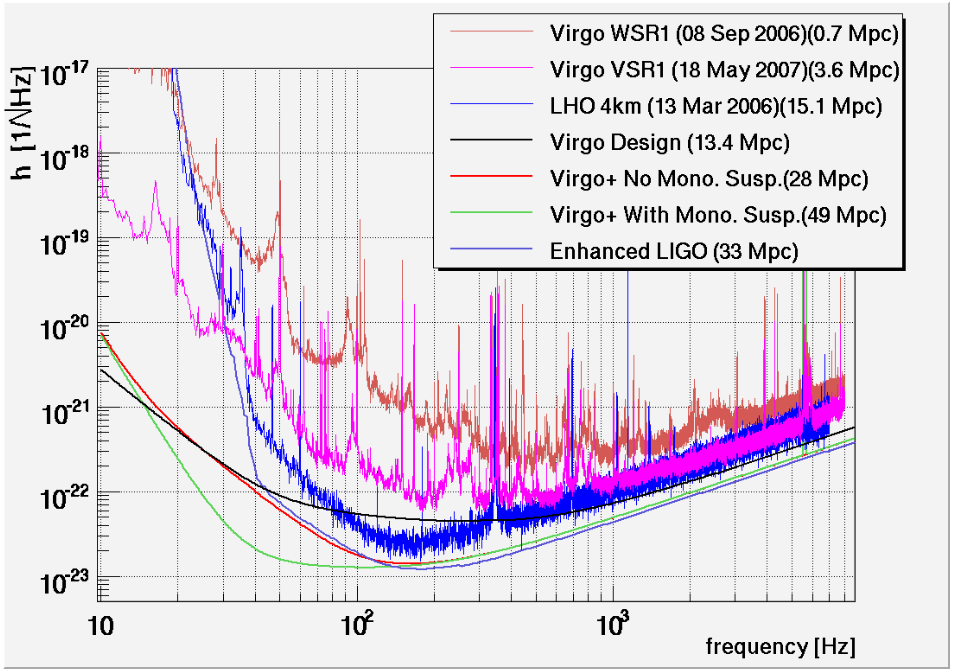
Horizon: distance at which GW from 1.4/1.4 SM inspiral binaries could be detected



Next Steps

- The VIRGO design sensitivity will allow testing some of the present gravitational wave amplitude upper limits.
- Even if a first detection could be possible, the sensitivity of VIRGO and LIGO detectors are not sufficient to open the era of gravitational wave astronomy.
- Any potential gravitational wave signal detection should be done by a coincidence of different interferometers having a common sensitivity on a large bandwidth to be considered as a network.

A detector upgrades campaign (VIRGO+ & AdV) to be implemented in parallel with other GW detectors (eLIGO & advLIGO) has started.



Virgo+ & AdV

- Virgo+
  - Intermediate upgrade to some subsystems (increase laser power, Fabry-Perot cavity finesse increase, new control system electronics, …).
  - Goal: sensitivity improved by 2 to 3 times over Virgo design
  - ready to go back to Science mode in the second half of 2009 in coincidence with enhanced-LIGO (S6)
- Advanced Virgo (AdV)
  - Some major upgrades (high power, monolithic suspension upgrade, new topologies, larger/heavier mirrors, new coatings, …).
  - Goal: sensitivity improved by about 10 times over Virgo design.
  - Installation should start possibly in 2011.

Conclusions

- VSR1succesfully completed
  - The achievement of almost four years of commissioning
  - BNS average horizon distance at 4 Mpc level and good duty cycle in science mode (~ 81%)
  - Joint LSC-Virgo analysis of VSR1 and coincident S5 data underway
- Virgo+ & AdV
  - open the era of gravitational astronomy