Searching for gravitational waves with Virgo

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for the Virgo Collaboration

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Outline

- Ground base detector network

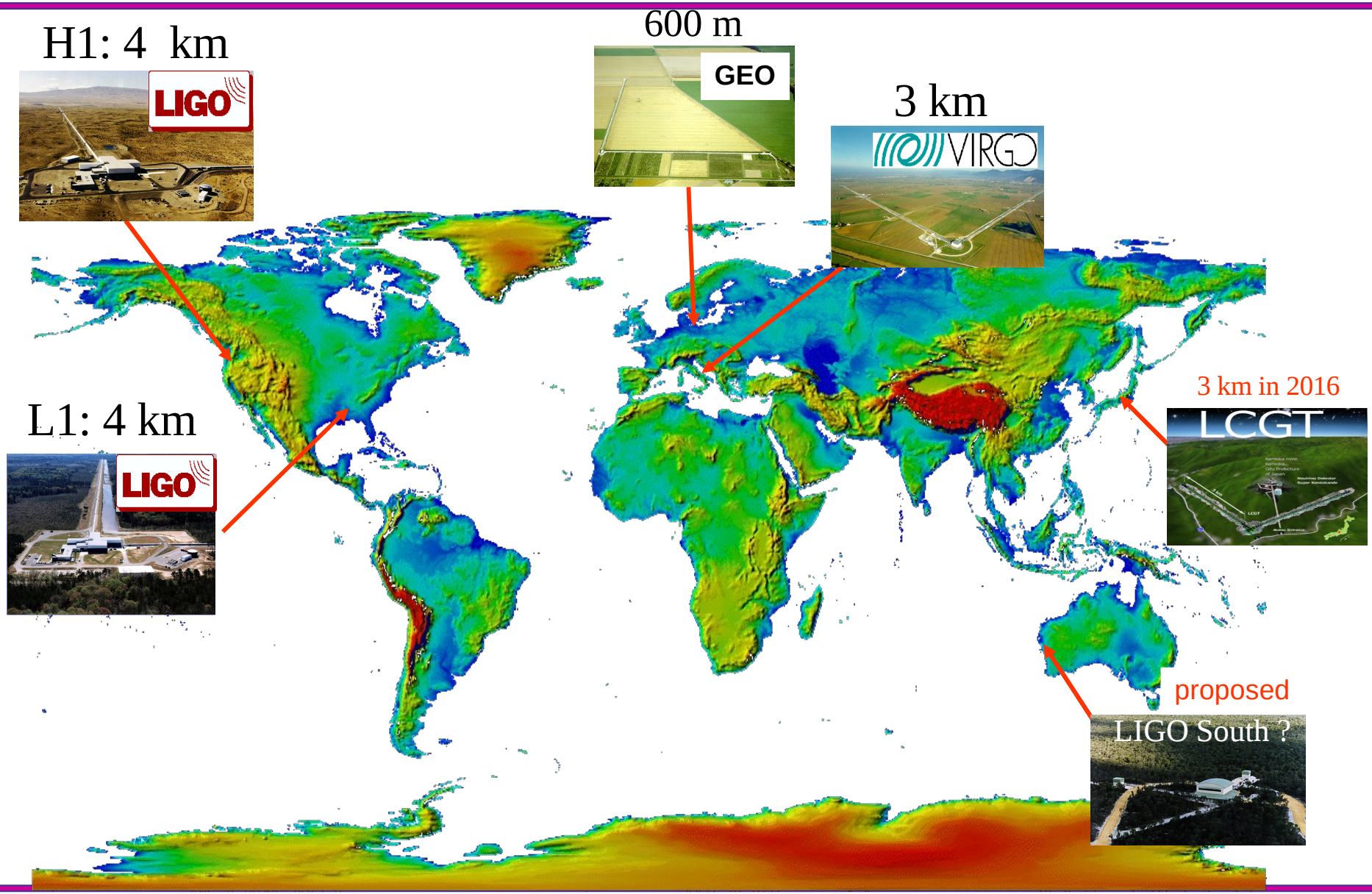
- Virgo in 2009-**2010**-2011
  - Virgo in brief before 2009
  - VSR1 run performance
  - Virgo upgrade: Virgo+
  - VSR2/VSR3 runs
  - 2011

- Advanced Virgo preparation

Virgo Collaboration

LAPP Annecy
NIKHEF Amsterdam
RMKI Budapest
INFN Firenze-Urbino
INFN Genova
INFN LNF
LMA Lyon
INFN Naples
OCA Nice
LAL Orsay
APC Paris
LKB Paris
INFN Padova-Trento
INFN Perugia
INFN Pisa
INFN Roma 1
INFN Roma 2
POLGRAV Warsaw

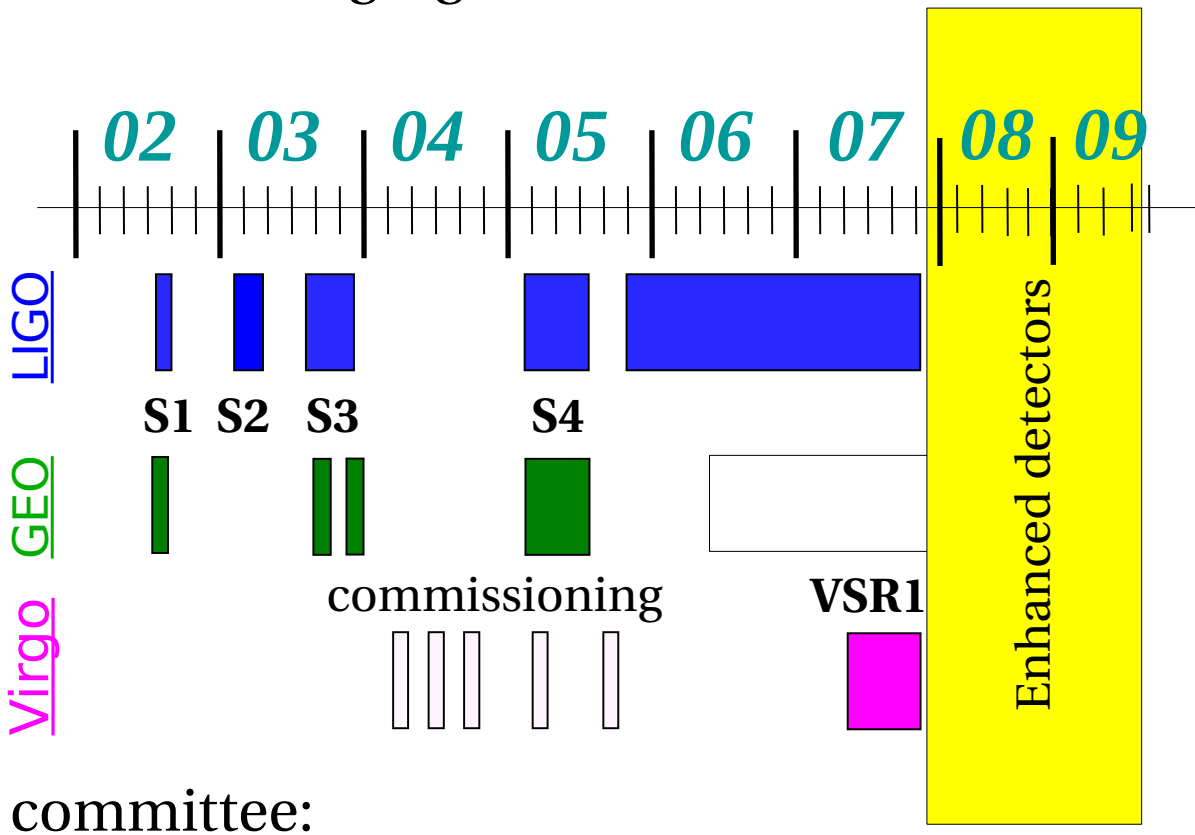
The GW network



Data taking is a LSC-Virgo joint affair since 2007

- LSC-Virgo Memorandum of Understanding signed in 2006

- 1st Virgo Science Run (VSR1) started mid 2007 before the end of S5

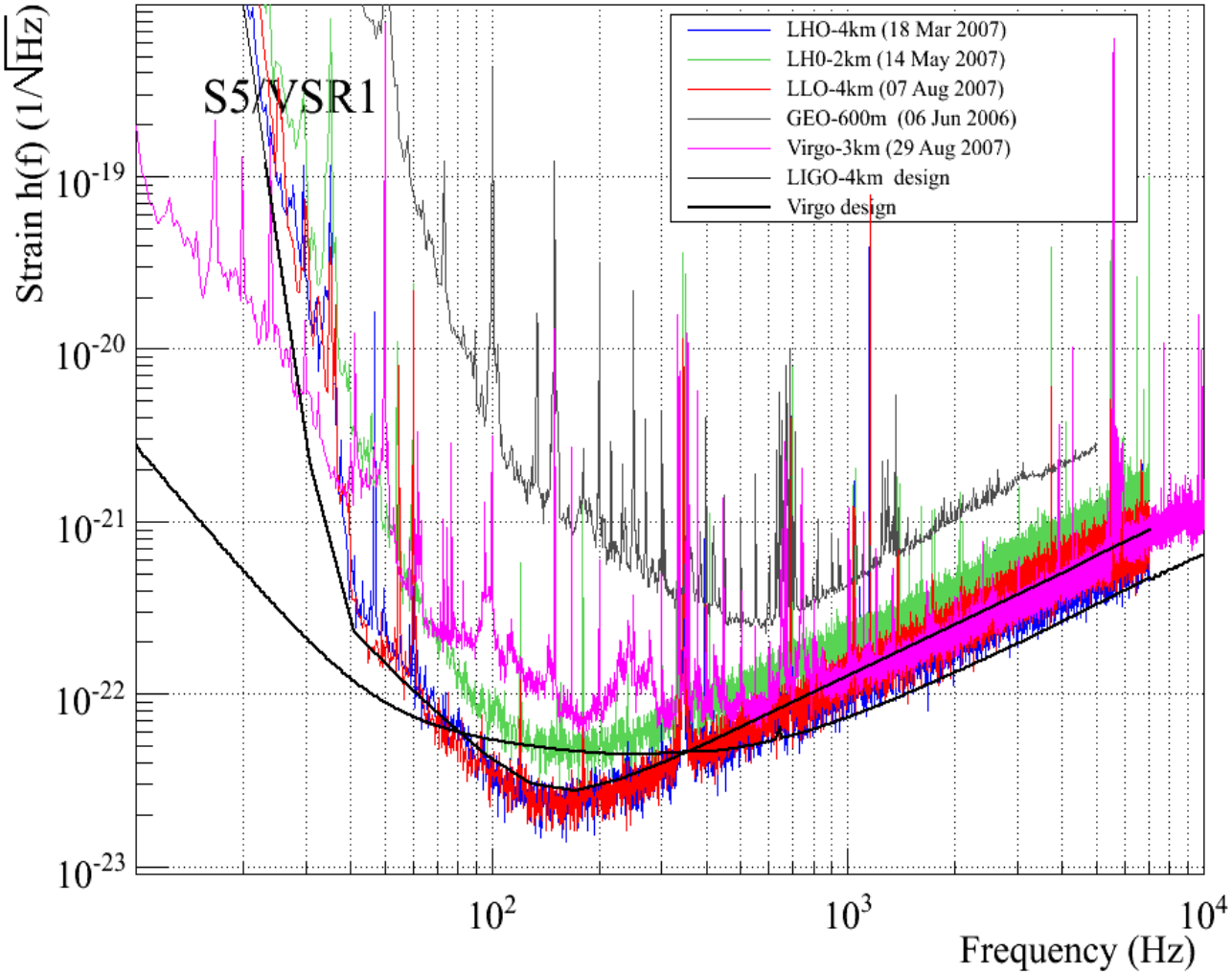


- joint LSC-Virgo run planning committee:

- discuss science runs

- discuss commissioning breaks

S5/VSR1 sensitivity



End of 2007 status:

S5: LIGO @ design sensitivity
VSR1: better than S5 below 40 Hz but not yet Virgo design sensitivity

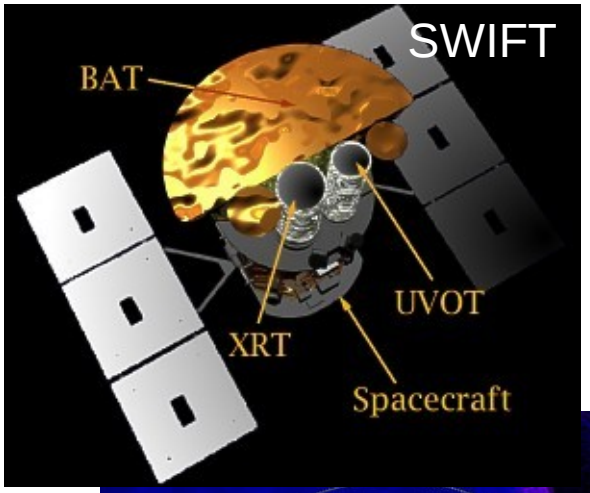
--> Virgo+ program (2008-2009) (and eLIGO in view of a S6/VSR2 joint run mid 2009, before Adv Detectors)

--> Joint S5/VSR1 first GW searches (see talks by P. Shawhan and D. Brown)

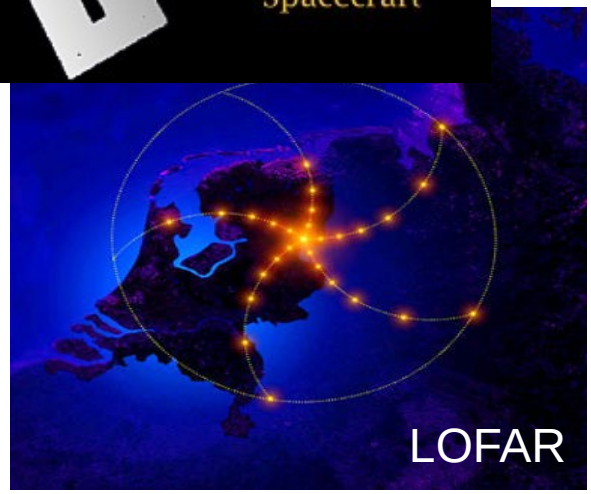
--> start thinking to external collaborations (see talk by S. Marka)

The global network

- Multi-messenger astrophysics: ~20 Memorandum of Understanding or Target of Opportunity signed or pending
  - Wide-field optical follow-ups: TAROT, QUEST, ROTSE, PI of the Sky, skymapper, PTF
  - Radio telescopes: LOFAR, Arecibo, EVLA
  - Neutrino detectors: IceCube and ANTARES
  - NASA satellite missions: RXTE, Swift, Fermi LAT and GBM



- Numerical relativity: NINJA collaboration with NR groups
  - Access to database of waveforms (with spins)
  - Study BBH detection efficiency and strategies
  - BBH parameter estimation



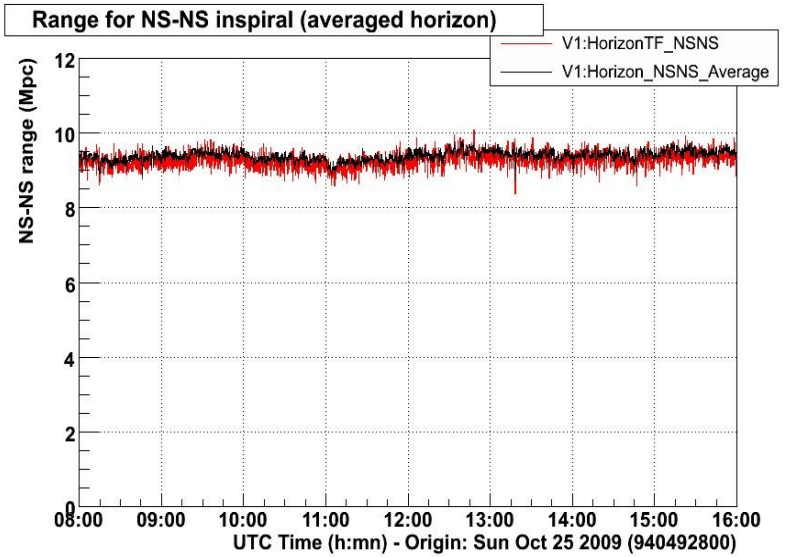
Virgo+

- Nov 2007 --> June 2009
- Main upgrades:
  - Laser system: from 10 → 25 Watt
  - Thermal Compensation System: ring+central heating
  - Electronics: ADCs and DSP replacement, Global Control, …
  - North End mirror replacement (after viewport accident)
  - Viewports replacement
  - Central building electrical network and grounding
  - Infrastructure works to noise reduction
- Virgo+ commissioning started in Nov 2008
- Noise mitigation, especially at low frequency (<200 Hz)

Virgo+ NSNS range: ~ 20 Mpc

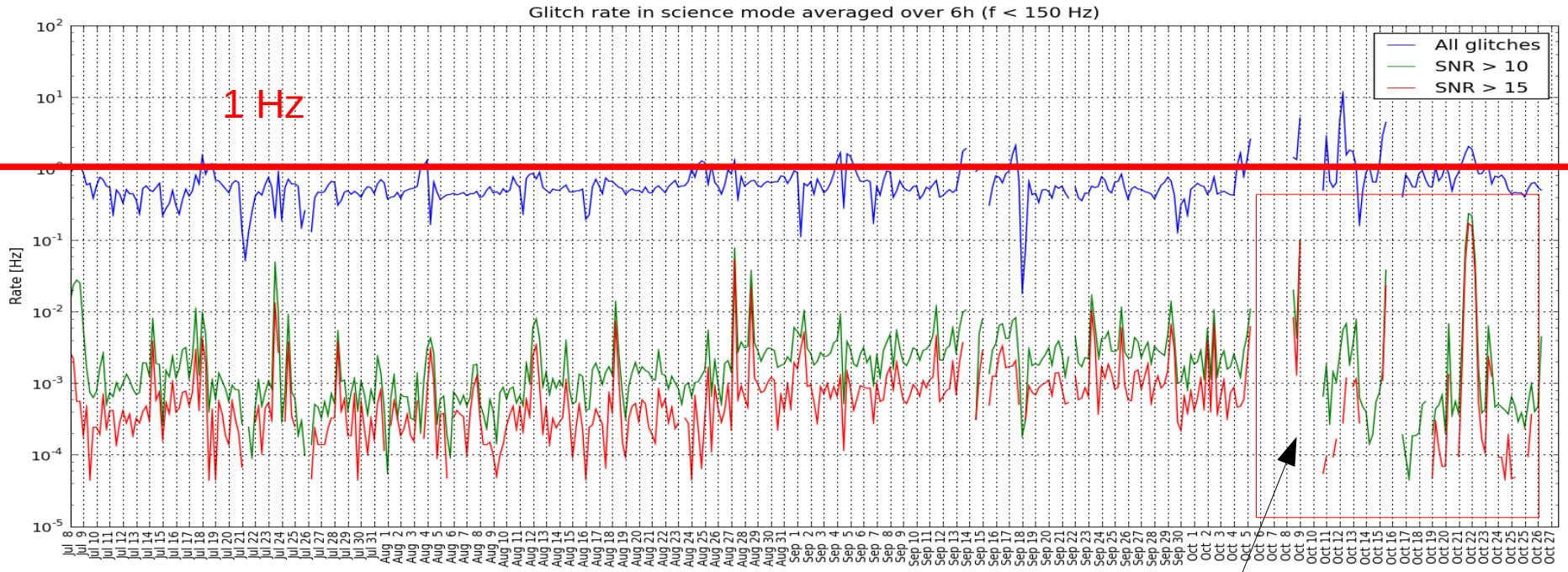
Virgo+ and VSR2 preparation

- Until VSR2 start (July 2009), important work to reduce noise
  - Reduction of diffused light noise (bench alignments, isolation of pumps and fans), magnetic studies and reductions, dust protections
  - TCS power stabilization



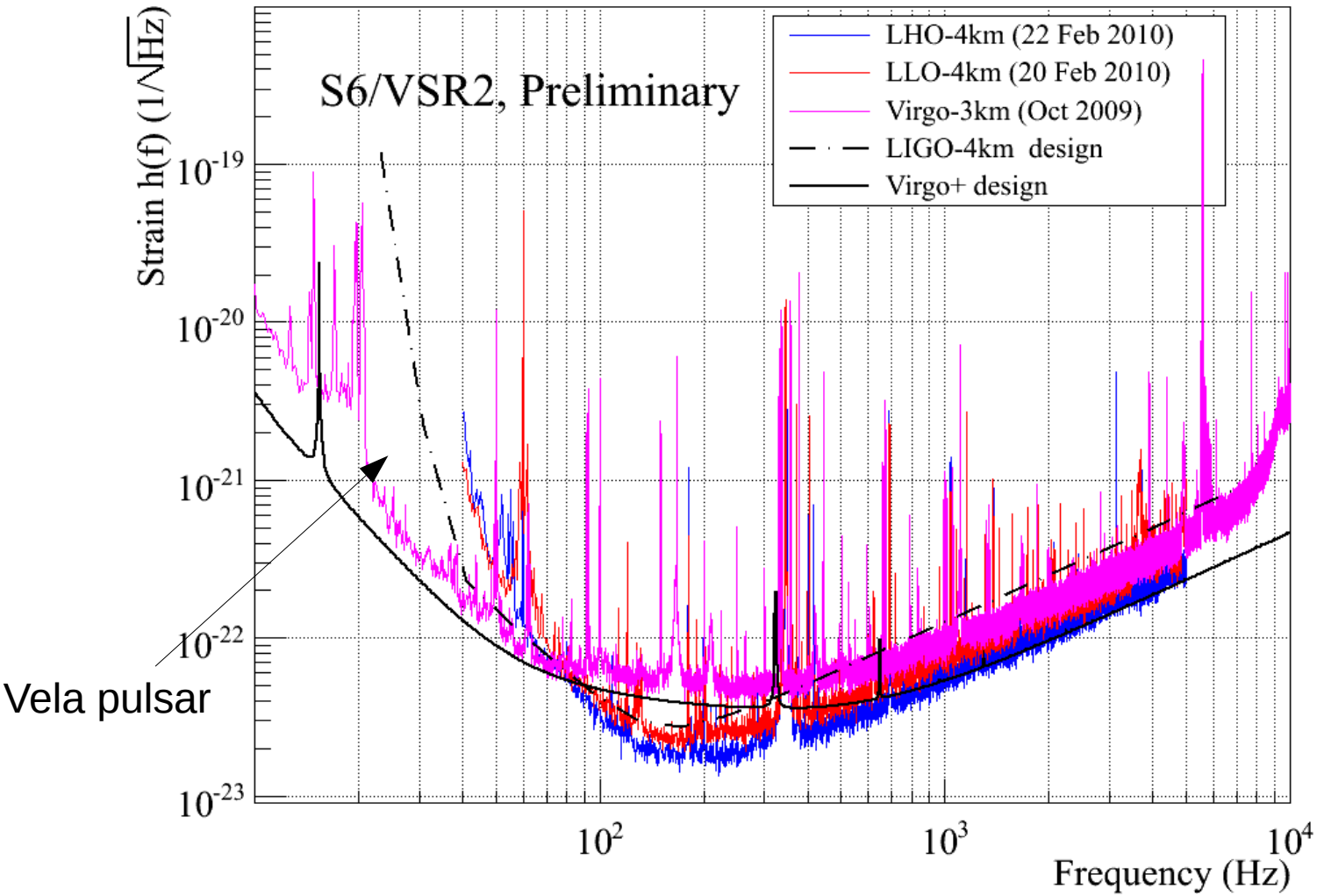
- VSR2 start on july 2009
  - Stable interferometer: duty cycle ~ 85%
  - NSNS range ~ 8-10 Mpc
  - BBH range (10-10 Msun) ~ 40-45 Mpc
  - Rather good glitch rate
    - factor 10 lower than VSR1
    - main loud glitch vetoed

VSR2 performance: glitch rate



Oct 2009: commissioning break: reduction of high SNR glitch

VSR2 sensitivity



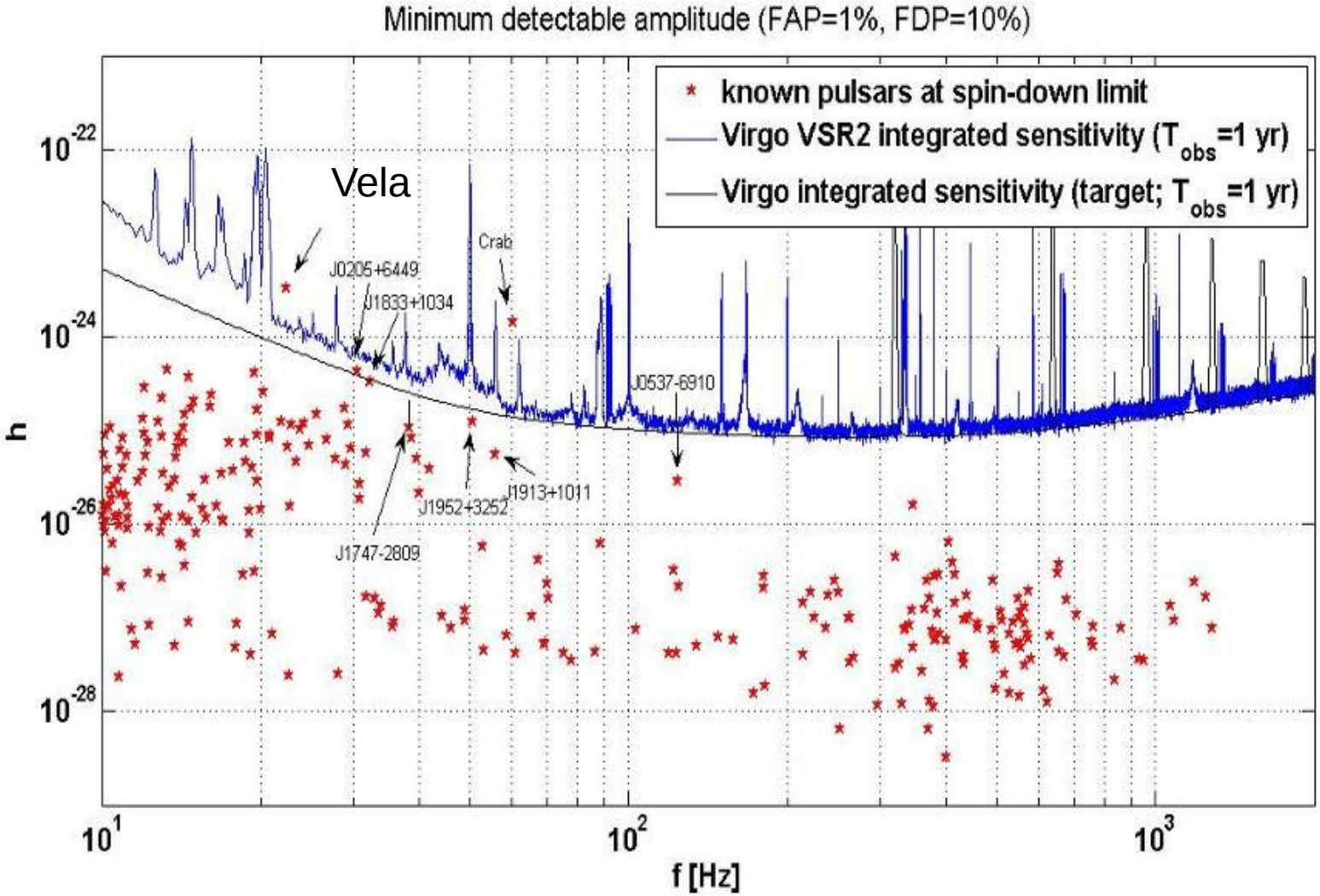
VSR2 (2009):

--> Virgo design sensitivity finally reached

--> high duty cycle (90%)

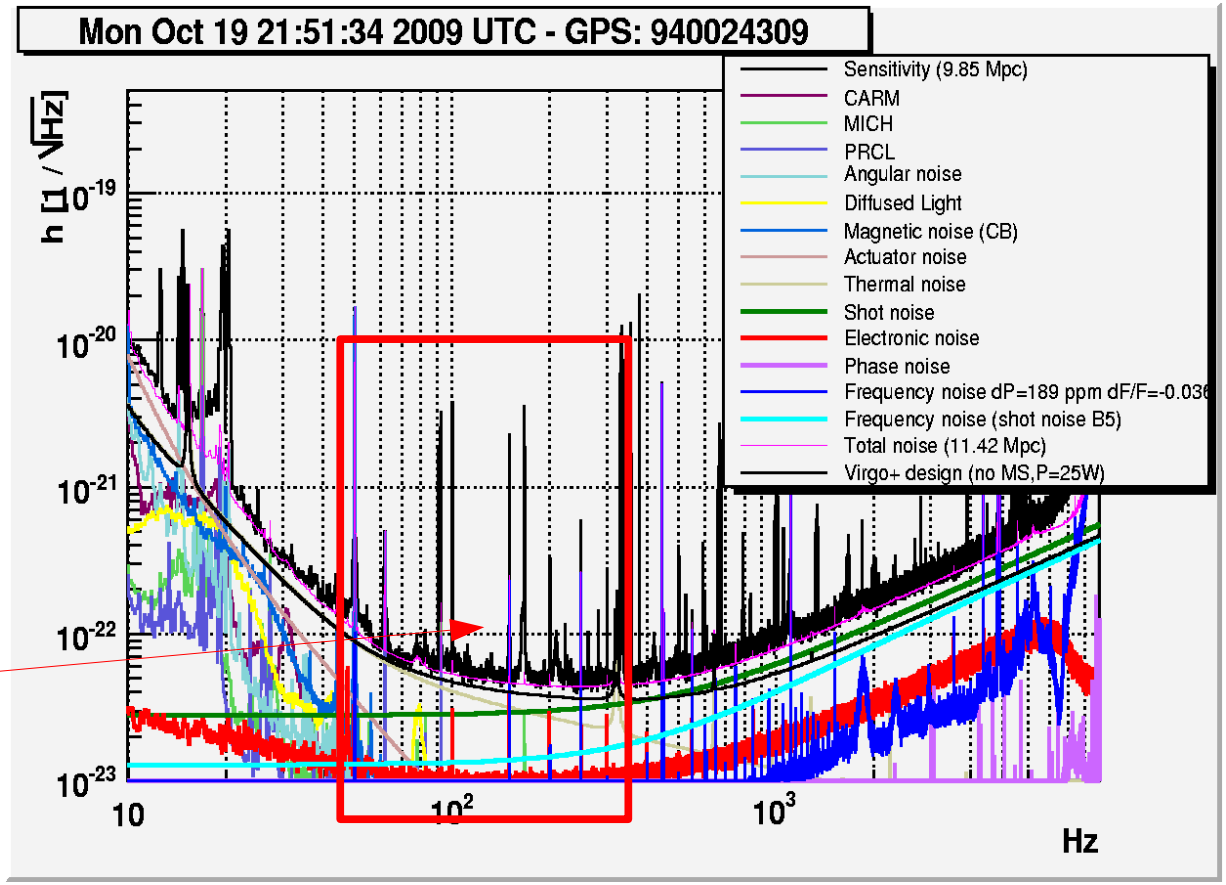
--> best ever sensibility at low frequency

GW from low frequency pulsar



With VSR2 sensitivity spin-down limit will probably be beaten for few low frequency pulsars (including Vela)

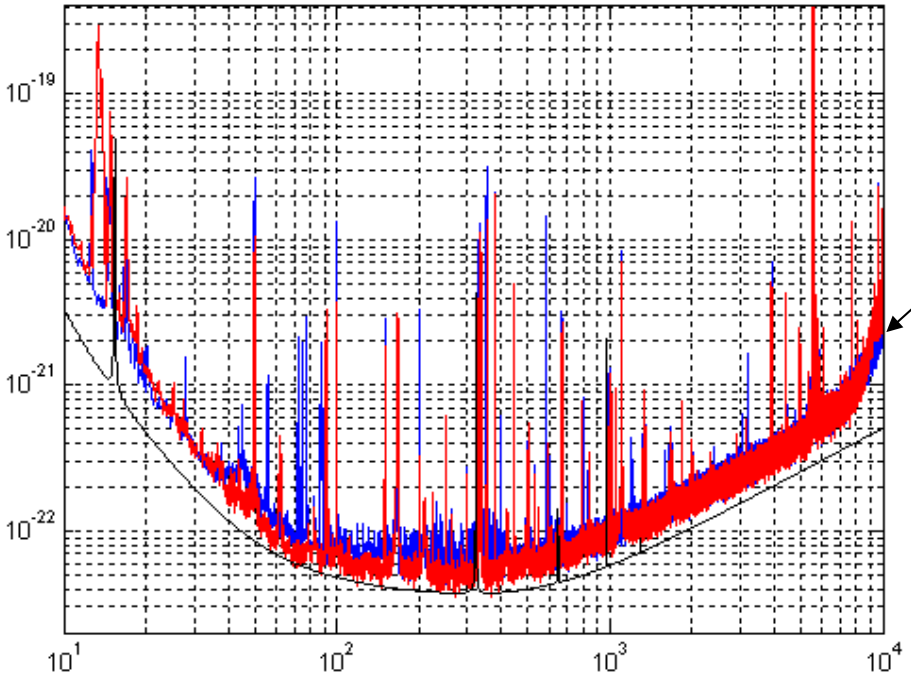
VSR2 noise budget in october 2009



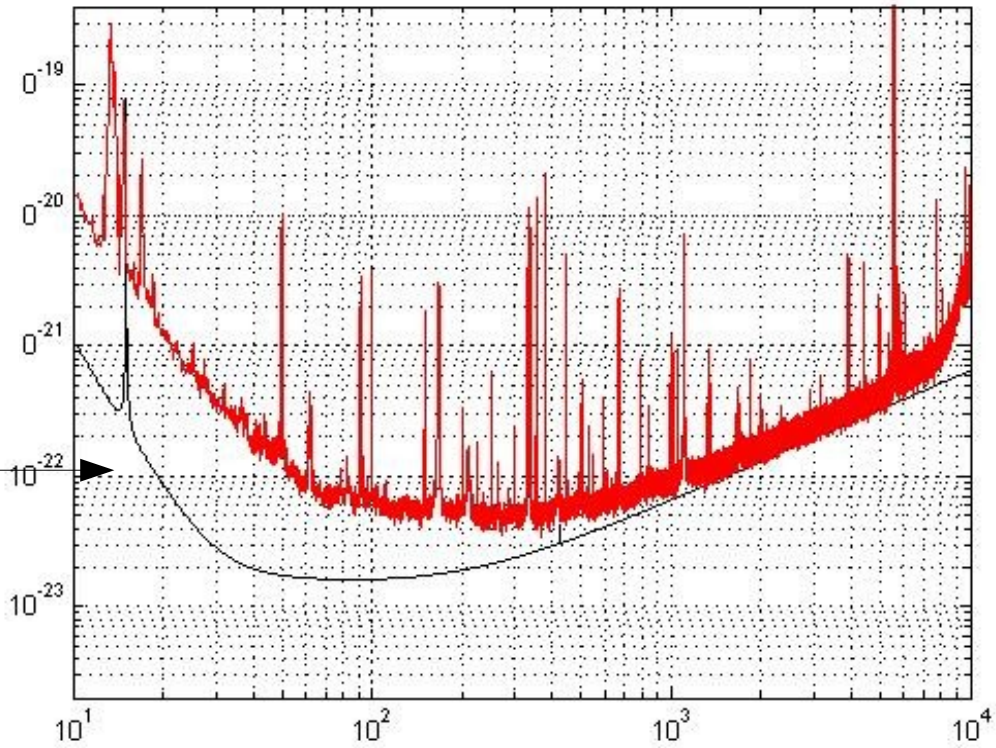
Thermal noise

Noise budget with input power 17 Watts --> good understanding of different noise
The total noise (pink curve) also includes the expected thermal (pendulum and mirror) noises
What else can we do to improve the sensitivity?

Path to Virgo monolithic suspension



The horizon corresponding to the expected Virgo+ (25 watt) without monolithic suspension is about 12-13 Mpc



The expected horizon for "theoretical" Virgo+ with Monolithic suspensions is calculated as 47 Mpc

Monolithic suspensions installation

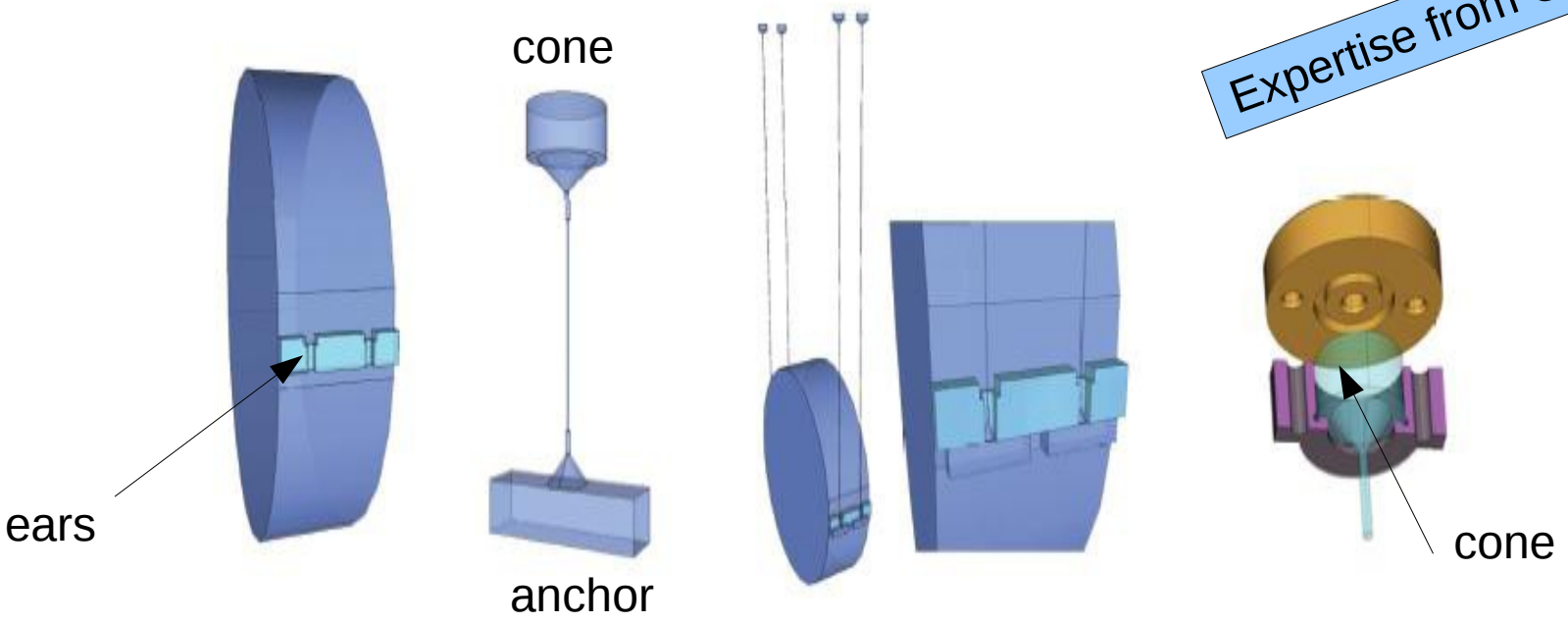
- VSR2 stops after 6 months of data taking (January 8th 2010)
- Plan:
  - Installation of 4 Fabry Perot Cavity mirrors with monolithic suspension (FB cavity finesse increase 50 --> 150)
  - Commissioning of "MS Virgo+"
  - (Re-)join S6 before the end (Oct 20th 2010) to test online transient searches sending alerts to optical telescopes and Swift satellite

--> Rather tight schedule, but not impossible

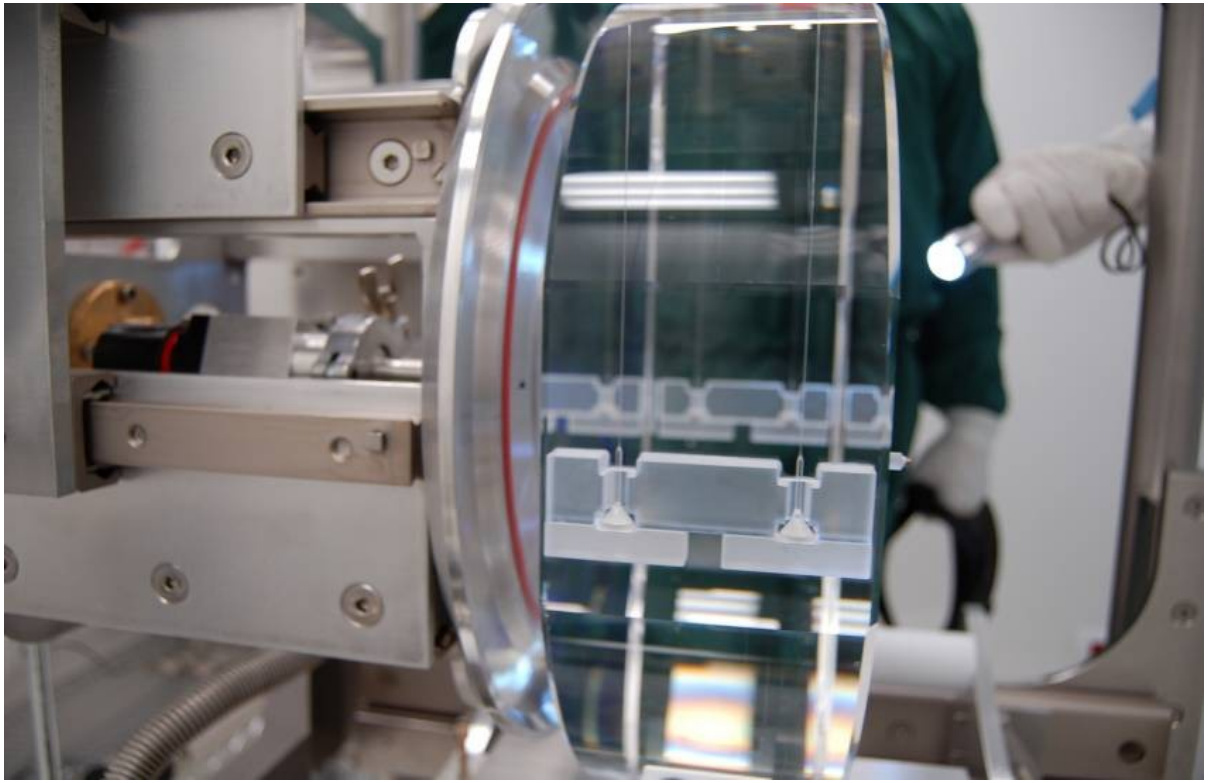
Virgo monolithic suspension

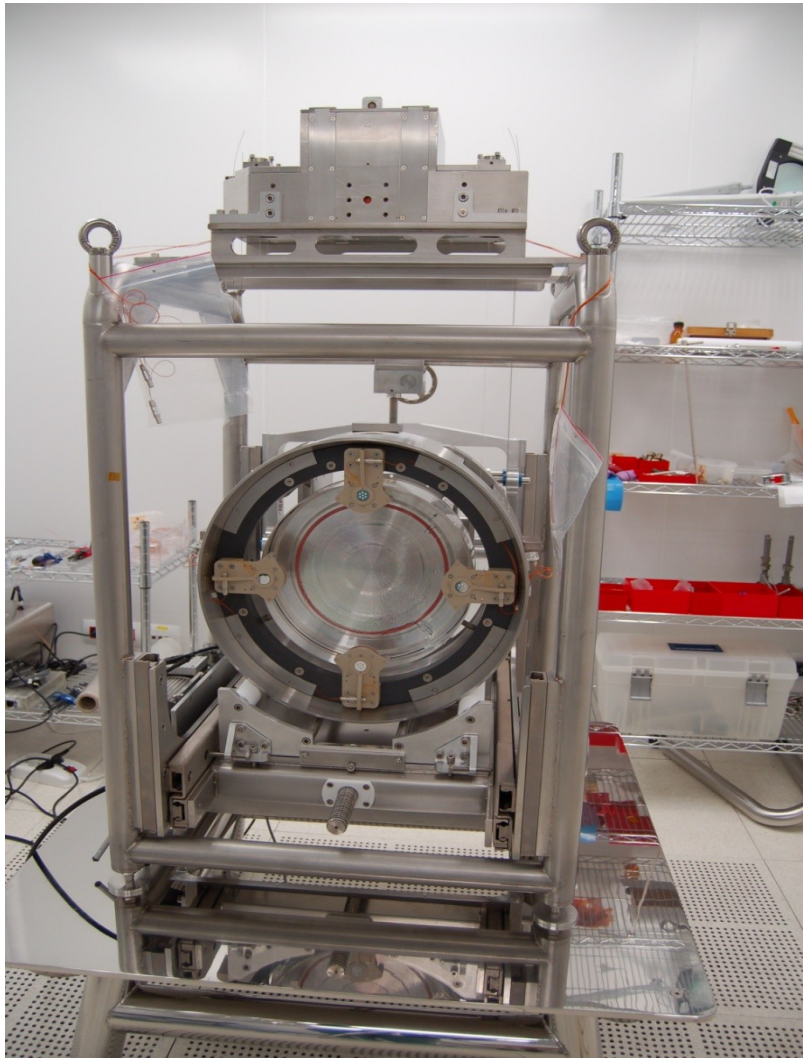
In order to have a fully monolithic last stage of the suspension, fused silica wires have to be properly attached to the mirror.

--> Ears are glued to mirror (silicate bounding) and wires are anchored to ears.



Virgo Monolithic suspension installation





Virgo Monolithic suspension commissioning

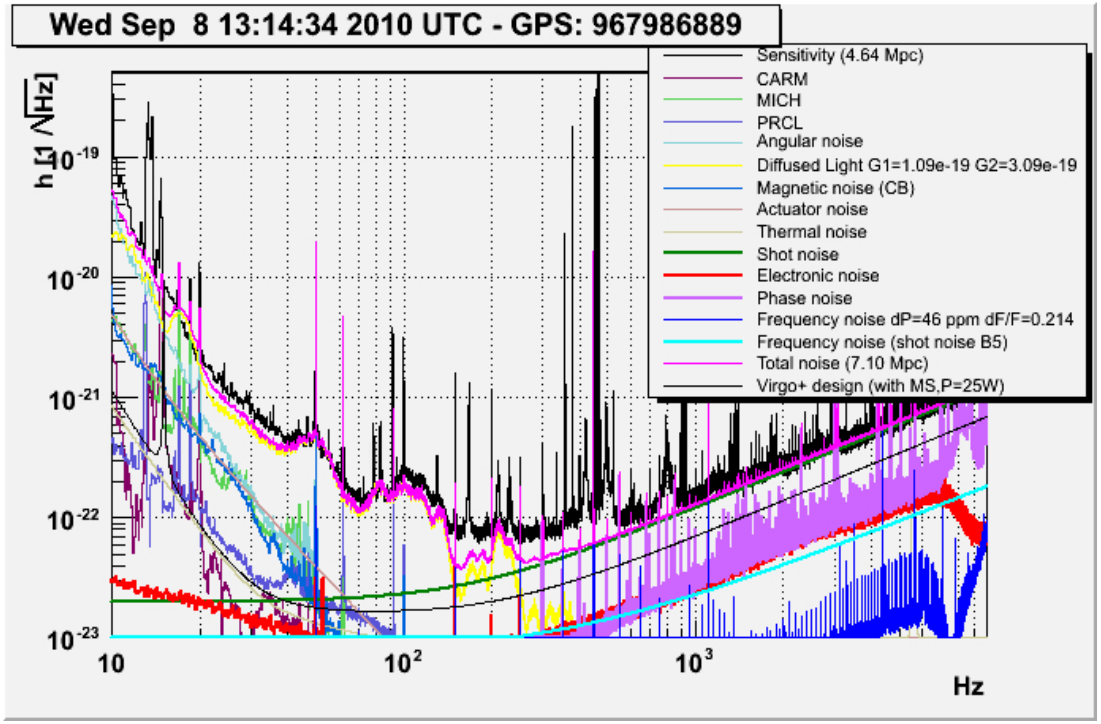
In June: found asymmetry in end mirrors

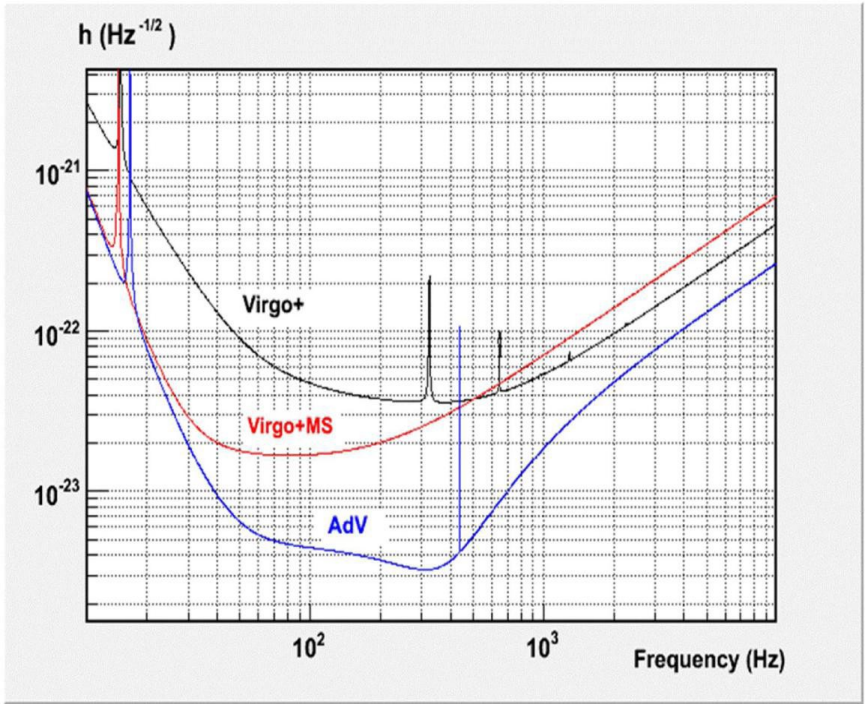
- The polishing of the end mirrors was not as good as in the past
- The measured ROC show a difference of about 100 m (incorrect specifications)

-->Dark fringe is 3 Watt bright (filtered by Output Mode Cleaner): too bright!

-->Diffused light on detection bench is a problem

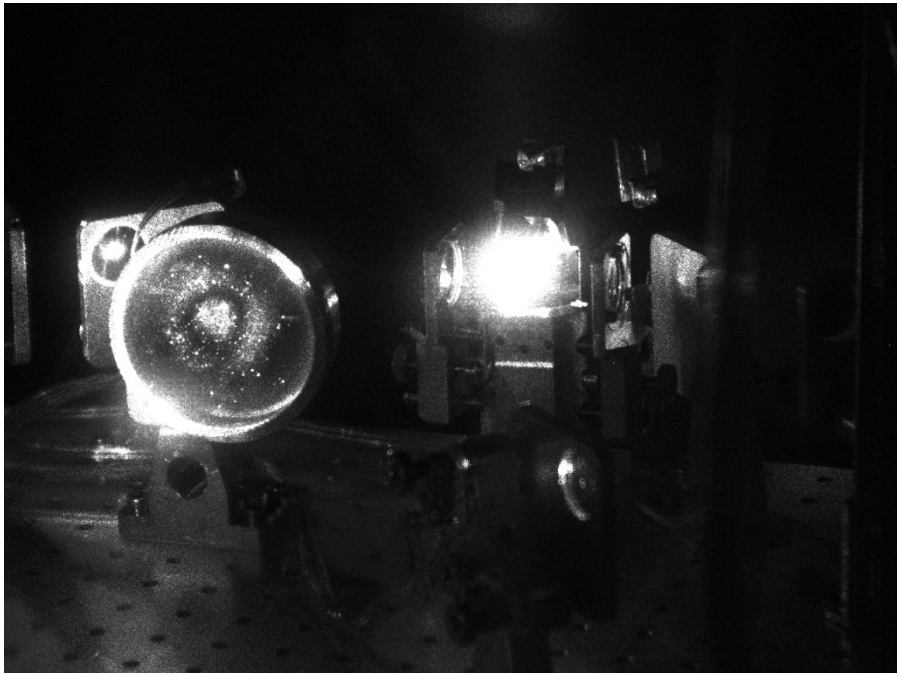
-->No sensitivity improvement wrt VSR2



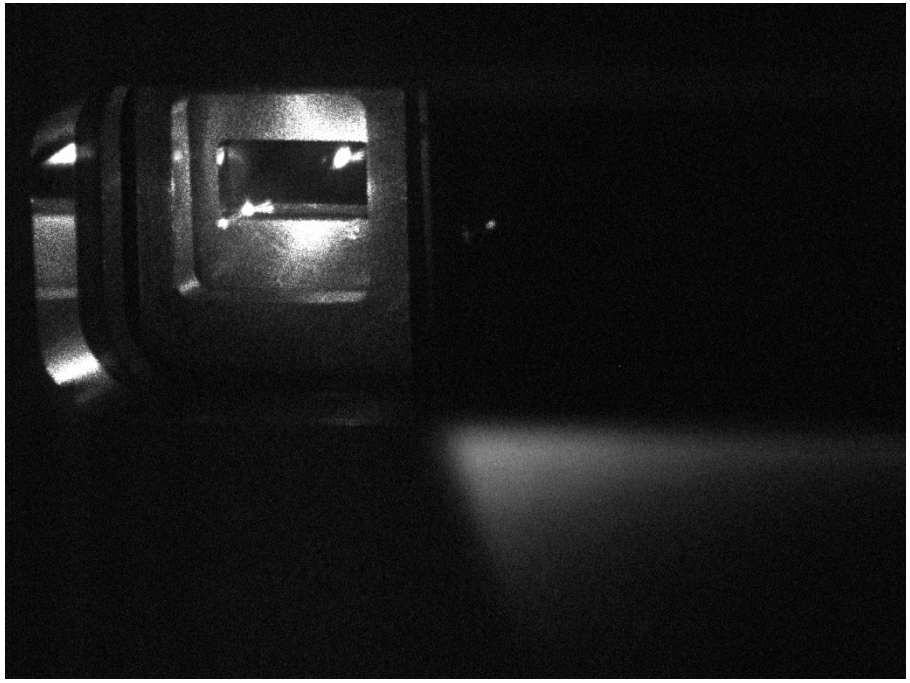


VSR3 diffused light problem

The prism, the most brilliant object



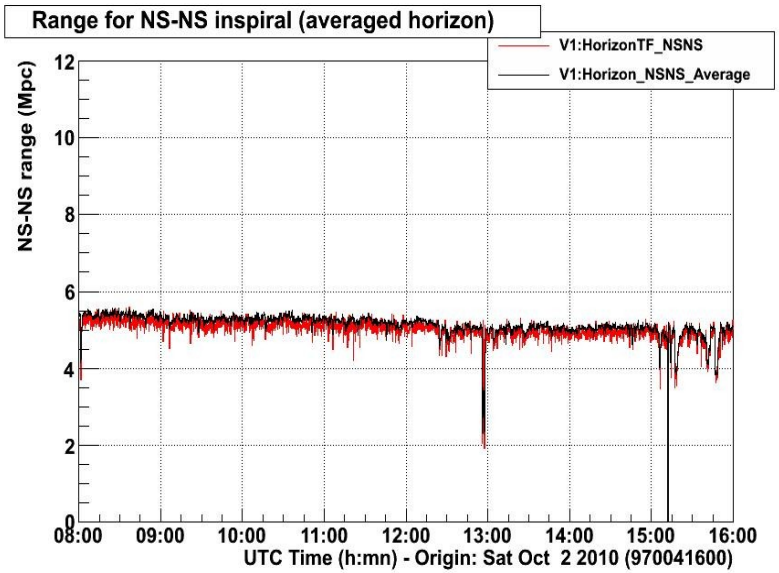
Dumper on detection bench



VSR3

- Despite the difficulties, decision taken to re-join S6 asap: Aug 11 2010 in order to maximize triple detector observation time
  - High glitch rate (15 x higher than VSR2)
  - Noise mitigation coming very late with

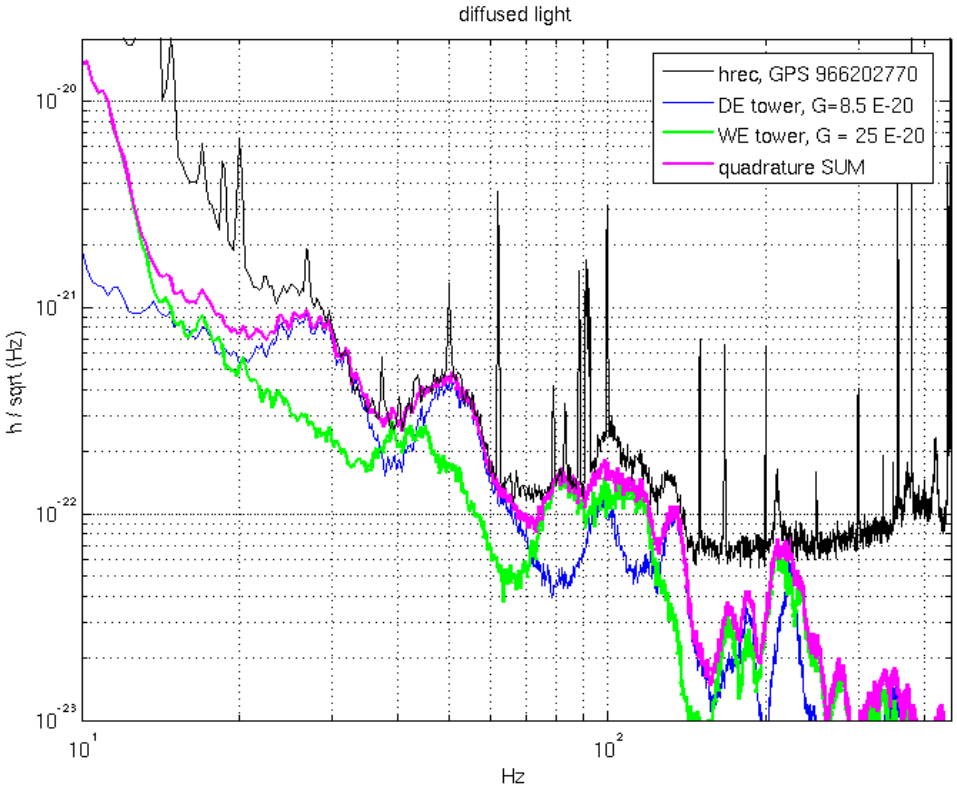
  very few commissioning break during run.

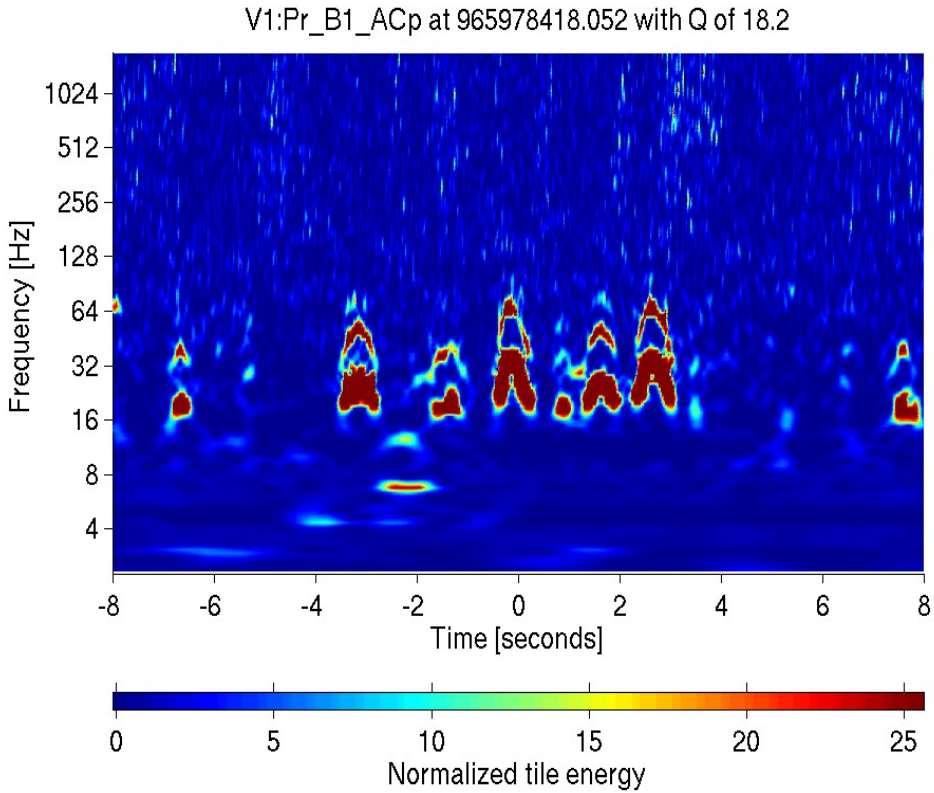


- End of august 2010: high frequency glitch rate reduction (DAQ temp)
- September 2010: 5 days commissioning break to fix diffused light on West End external bench

--> low latency transient searches + electromagnetic follow up program

VSR3 diffused light noise projection





Detection bench dominates 30 – 50 Hz and contributes significantly up to 150 Hz
West End bench contributes 40 and 100 Hz region--> sep 2010 commissioning break attenuates noise

Compact binary coalescence low latency search

- Virgo pipeline: Multi Band Template Analysis (MBTA)
- 2PN matched filter search
- Online MBTA is running since the beginning of S6/VSR2
  - 3-fold LIGO-Virgo coincidence with ~ 140 s of latency
  - threshold tuned to keep the false alarm under control
  - sky location reconstruction using timing information

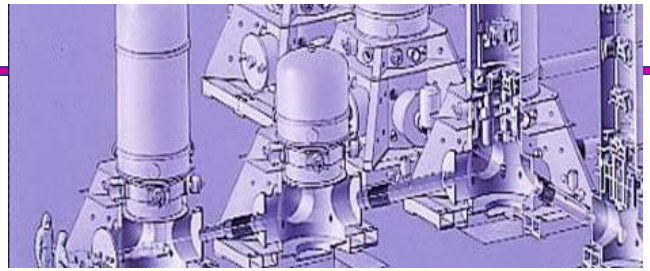
- Candidates are sent to an event database (GraceDb) and then to telescopes if they fulfill a complete checklist.

End of 2010 program - 2011

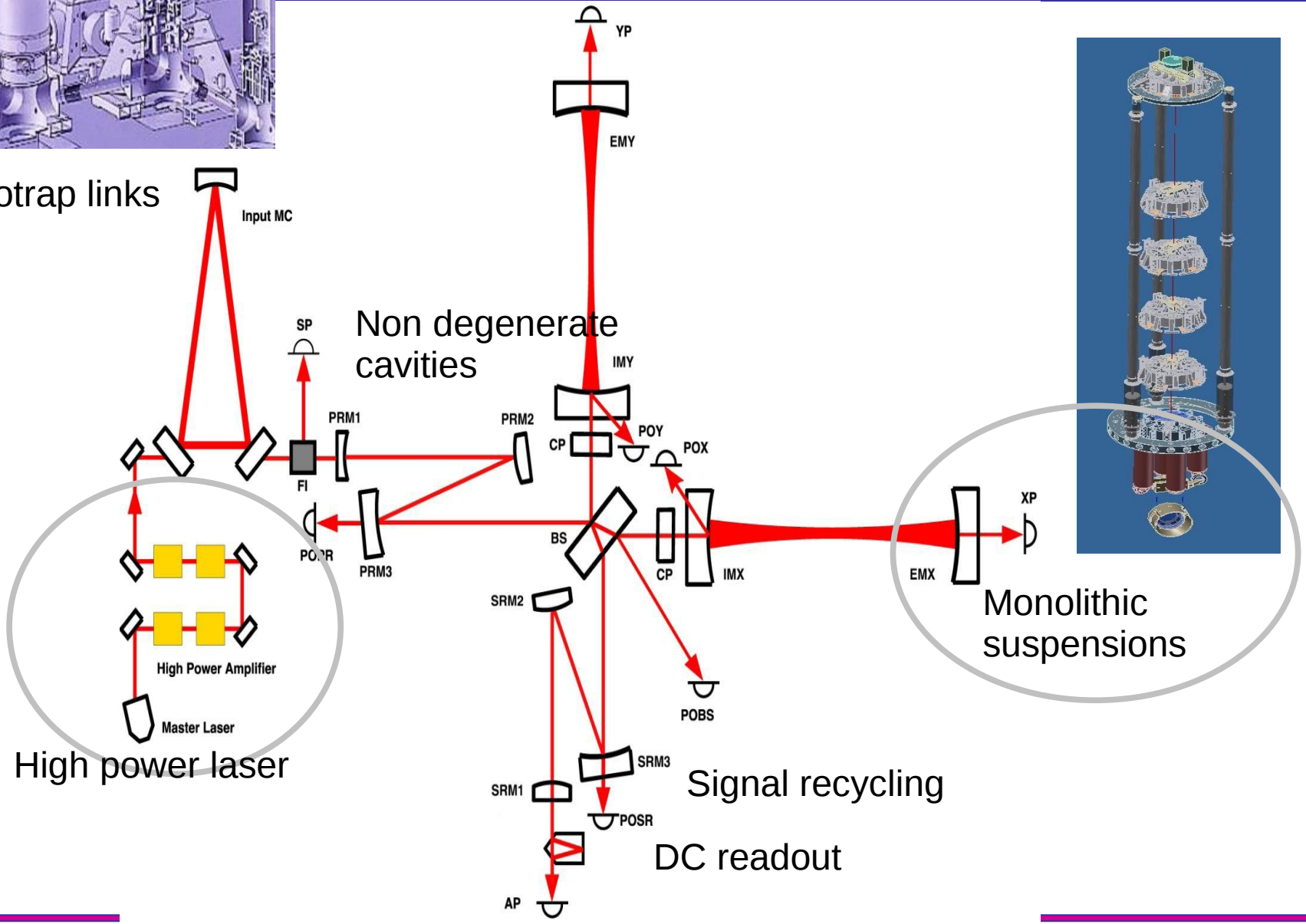
- Priority will be given to commissioning to improve the sensitivity
  - Ring heater installation to fix the end mirror Radius of curvature
  - Diffused light on the detection bench
  - Noise mitigation
  - Run Virgo in astrowatch mode (nights & week ends if Virgo is stable)

- 4th Science run foreseen beginning of 2011 (in coincidence with GEO): 6 month run until Advanced Virgo starts

Advanced Virgo baseline design



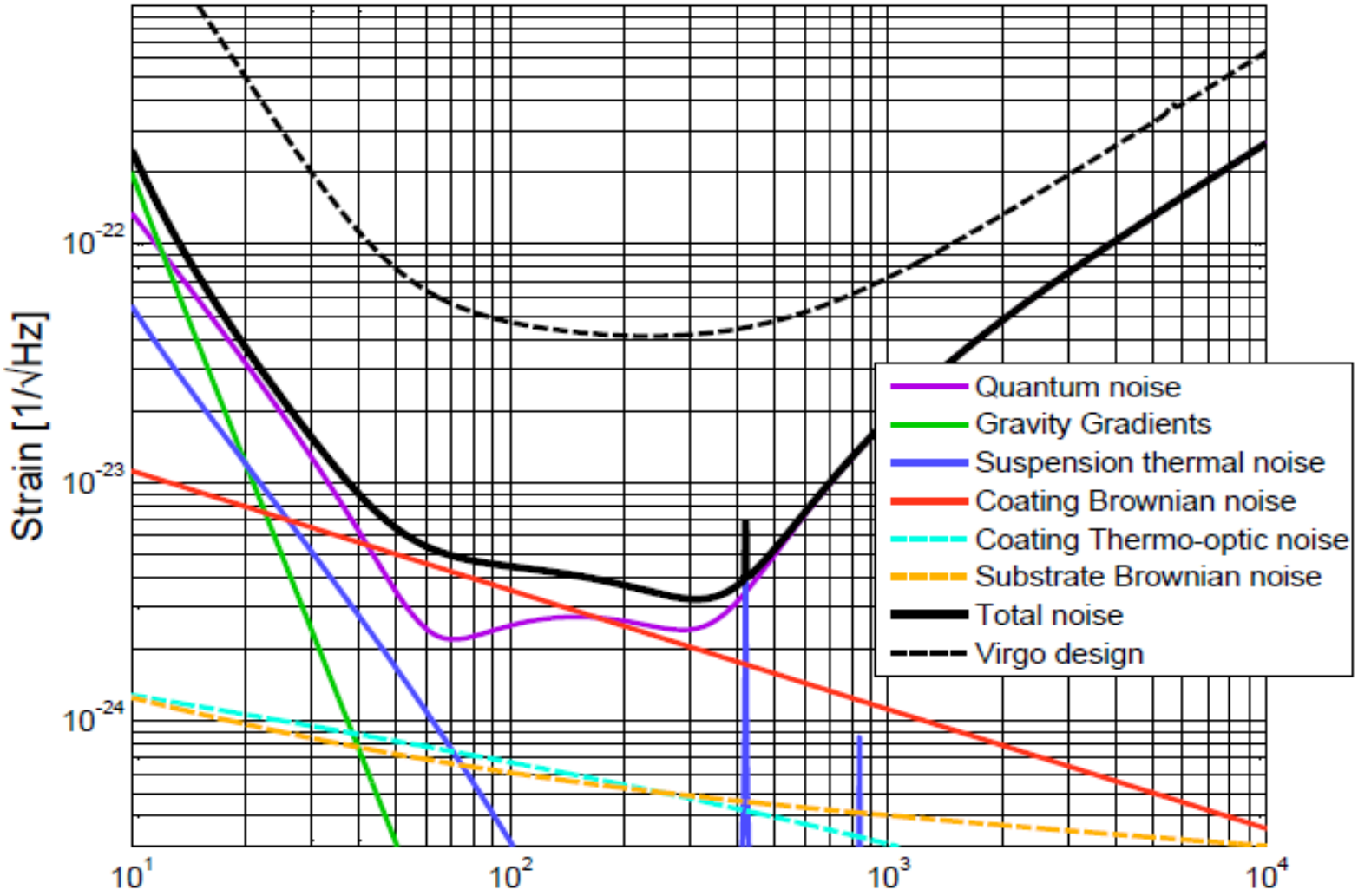
Large cryotrap links



Advanced Virgo main features

- Laser: high power laser (200 W) + thermal effects
- Optical configuration:
  - need to enlarge the spot on input mirrors to decrease brownian thermal noise
  - signal recycling
- Payload
- Improve vacuum in long arms

Advanced Virgo design sensitivity



Advanced Virgo timeline