



Status of VIRGO

Francesco Fidecaro (after Lisa Barsotti)

- *University and INFN Pisa* -

on behalf of the VIRGO collaboration

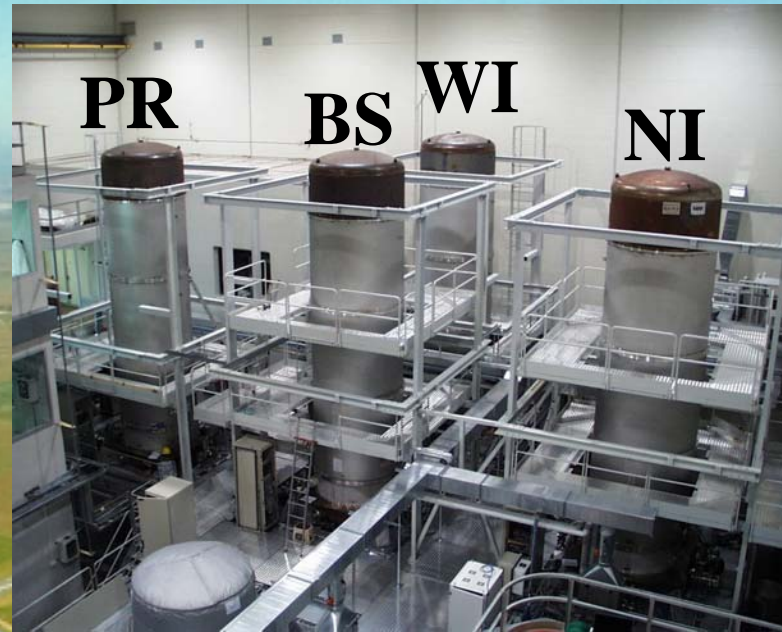
➤ Status of the Commissioning Activity

LIGO-G050035-00-Z



Aspen - January 19th, 2005

VIRGO Optical Scheme



3-km Fabry Perot
cavities in the arms

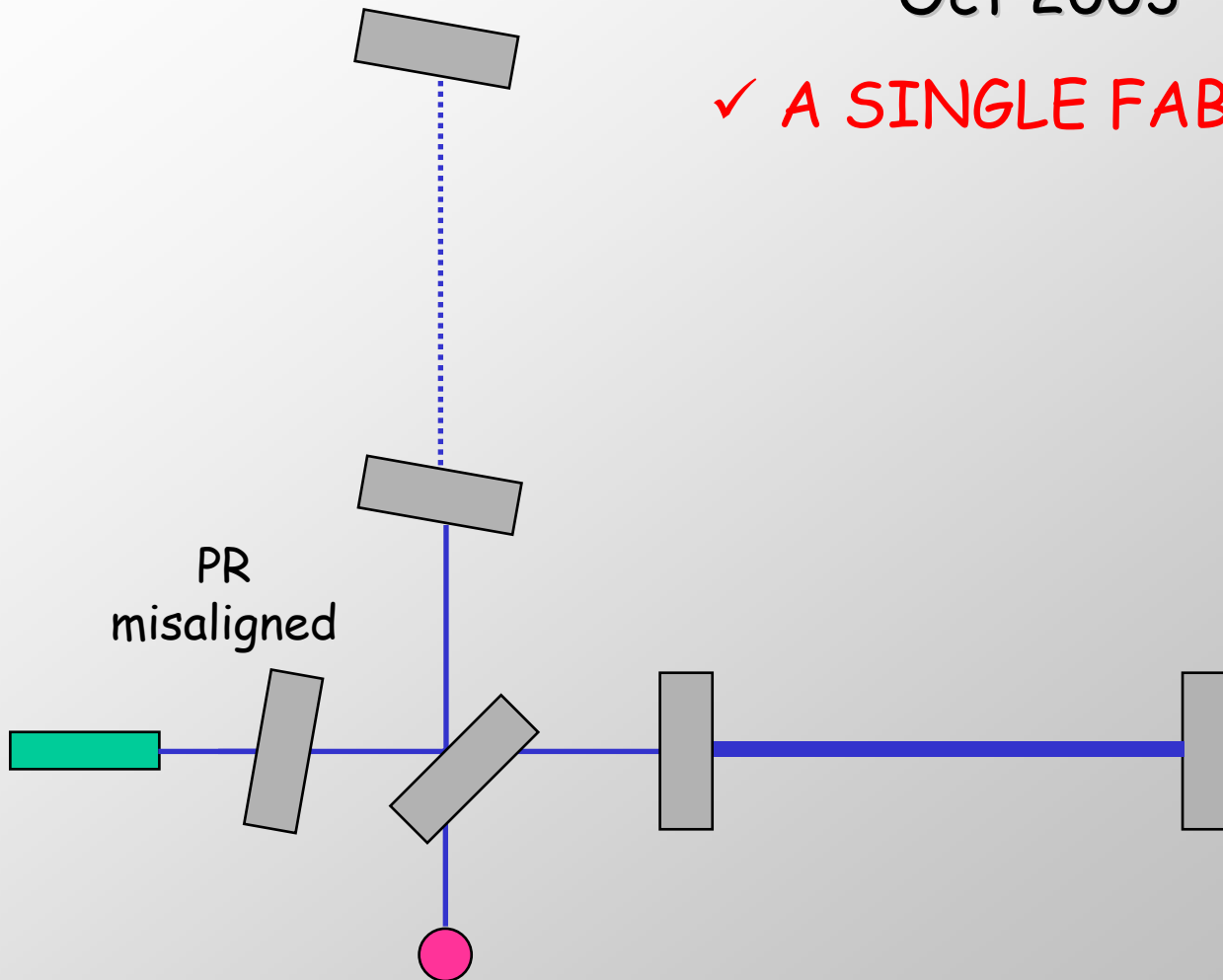


Commissioning Plan

Steps of increasing complexity:

Oct 2003 - Feb 2004

✓ A SINGLE FABRY-PEROT CAVITY

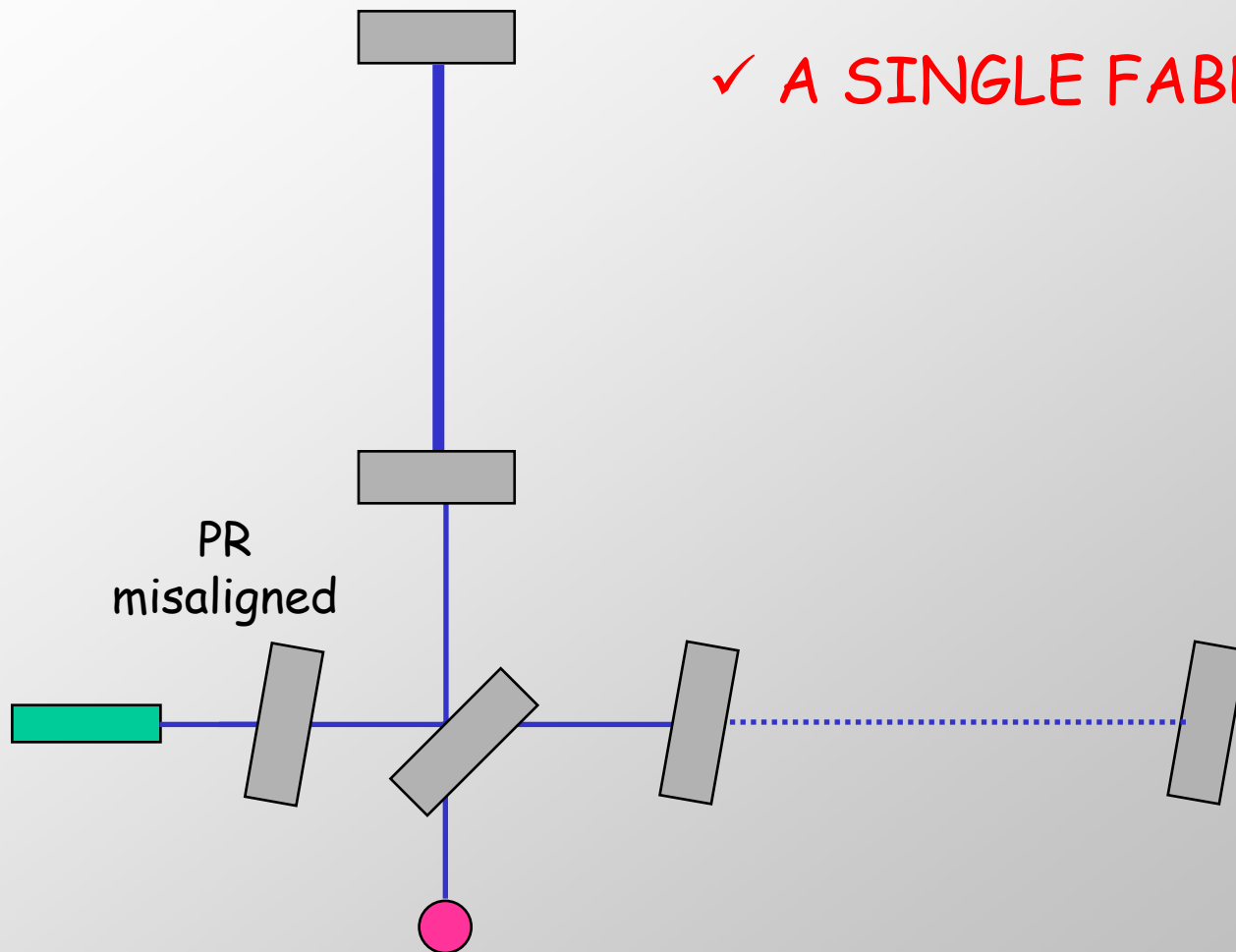


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Commissioning Plan

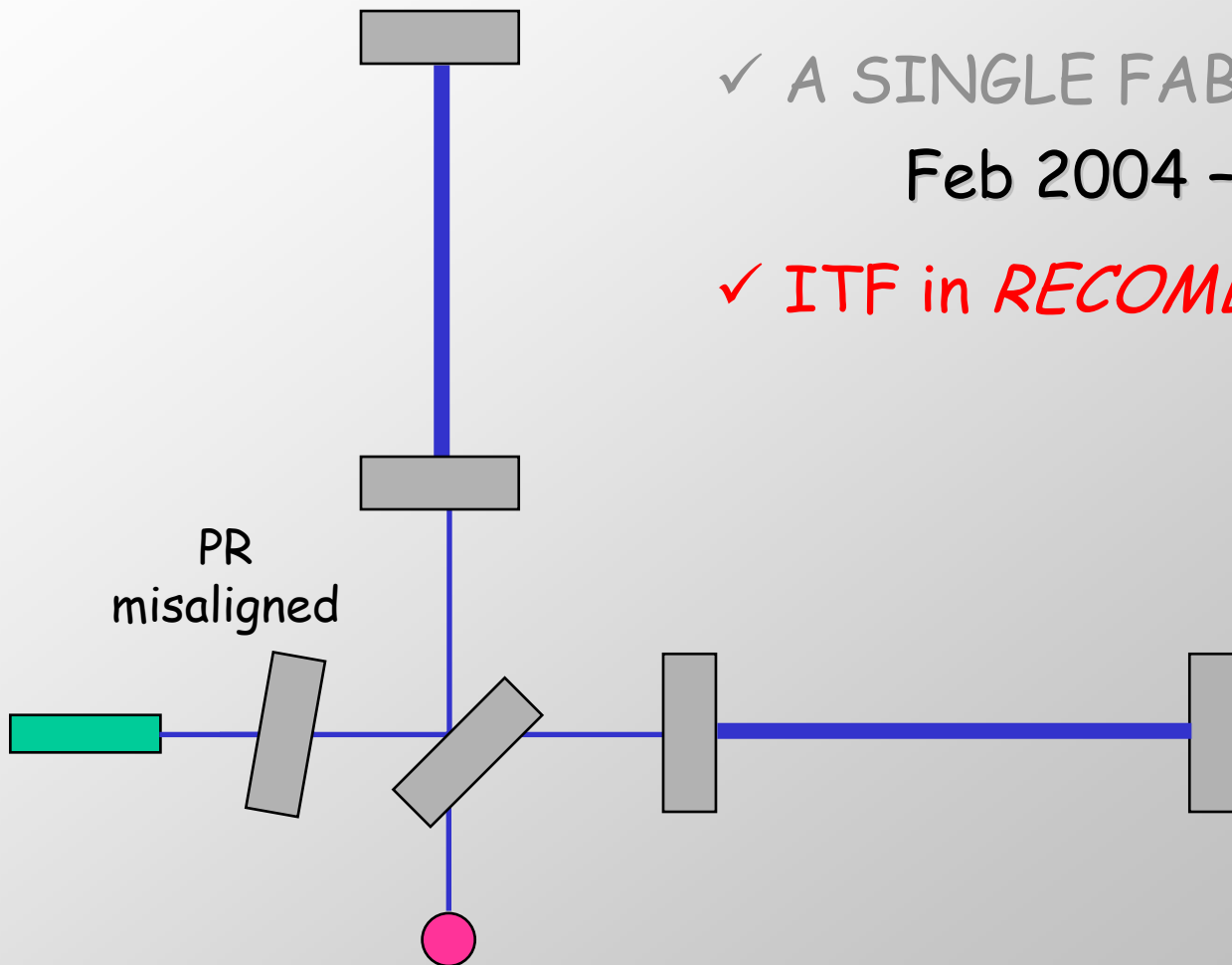
Steps of increasing complexity:

Oct 2003 - Feb 2004

✓ A SINGLE FABRY-PEROT CAVITY

Feb 2004 - Dec 2004

✓ ITF in *RECOMBINED MODE*



Commissioning Plan

Steps of increasing complexity:

Oct 2003 - Feb 2004

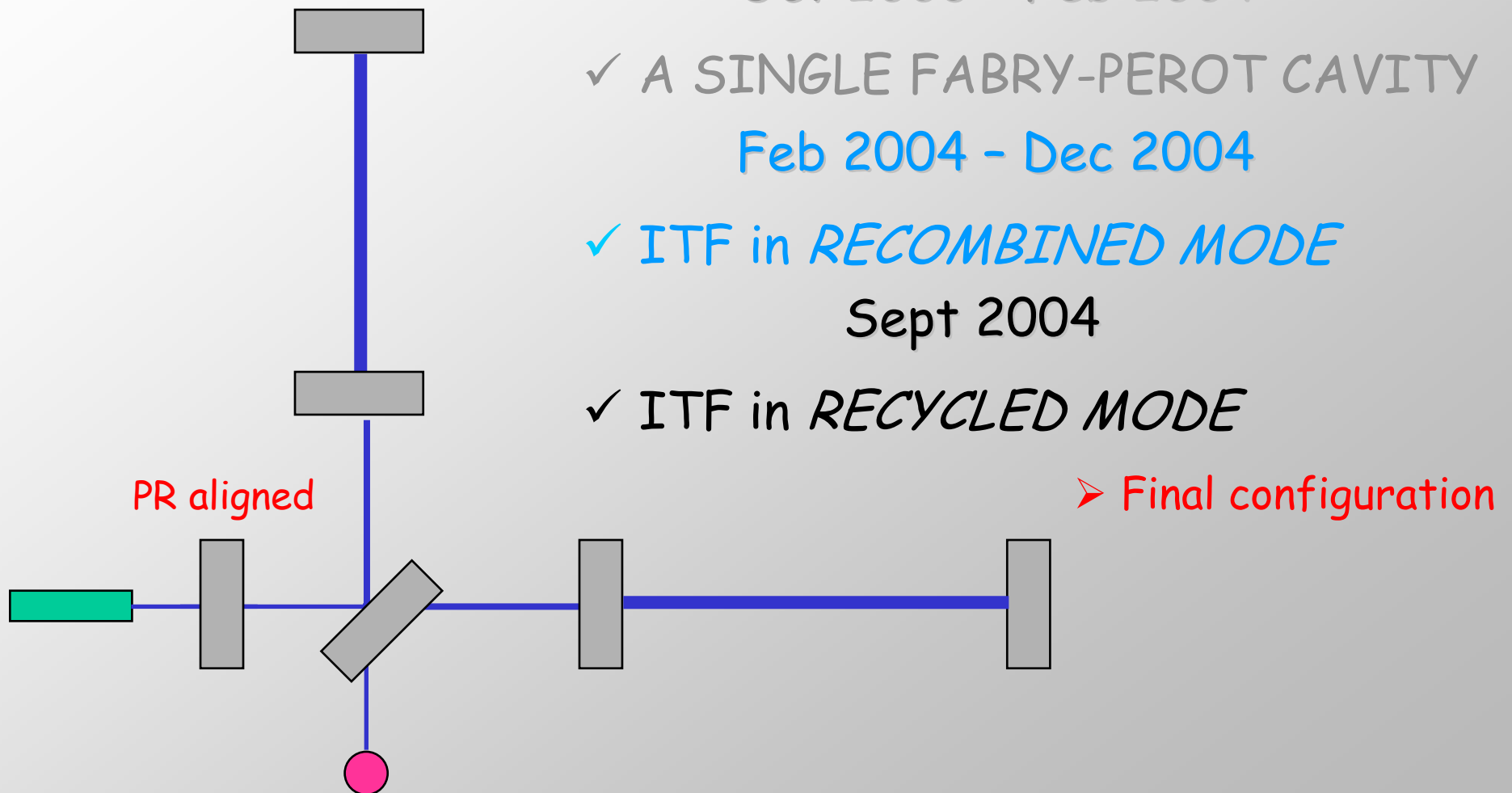
✓ A SINGLE FABRY-PEROT CAVITY

Feb 2004 - Dec 2004

✓ ITF in *RECOMBINED MODE*

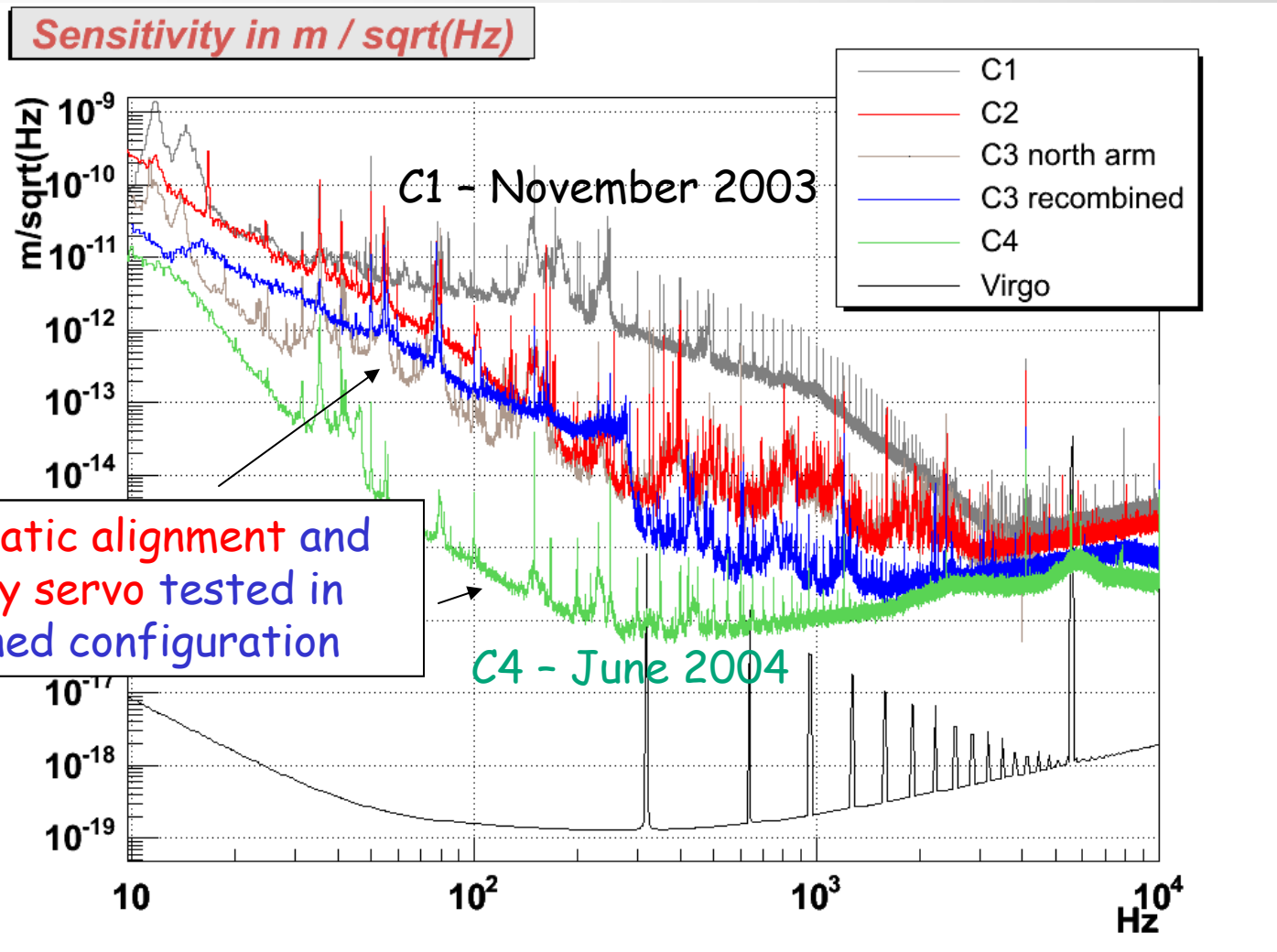
Sept 2004

✓ ITF in *RECYCLED MODE*



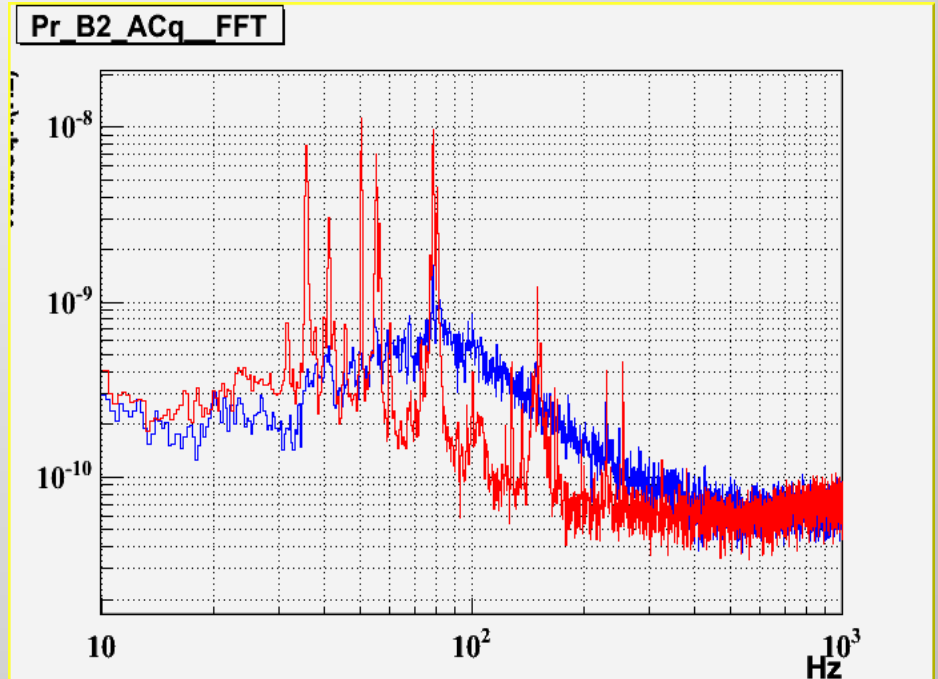
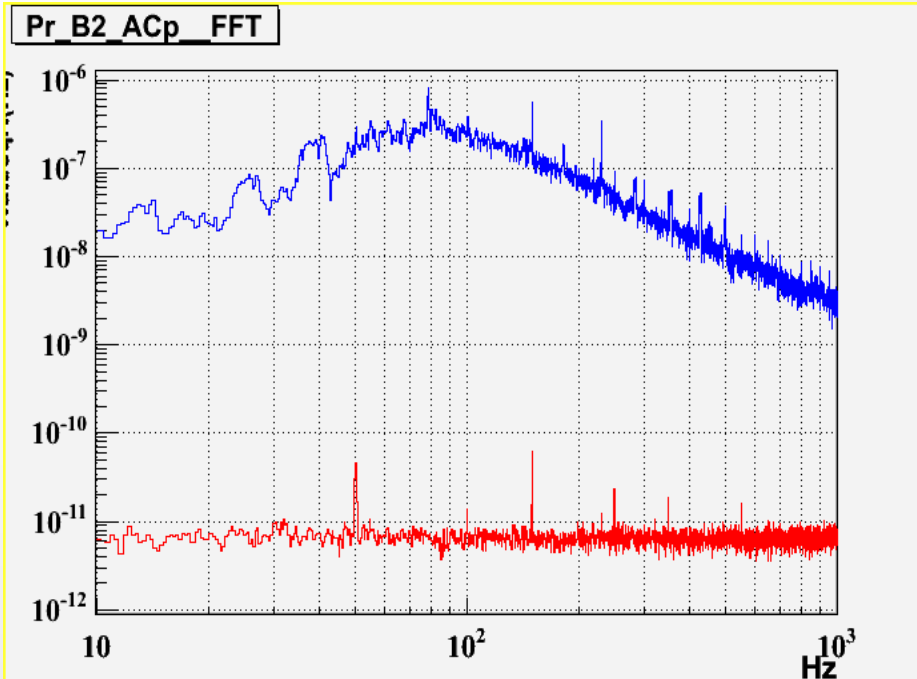
Sensitivity Progress

➤ *From a single arm to the recombined mode*



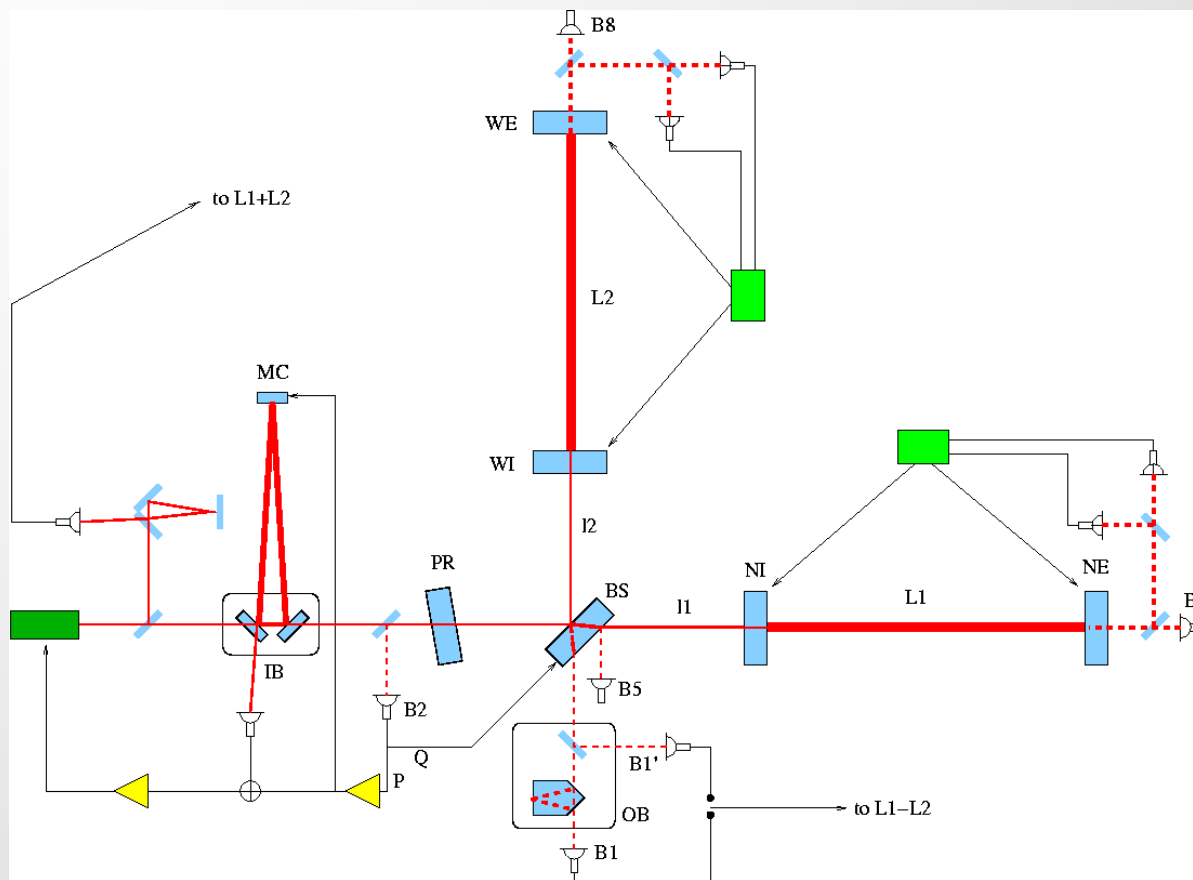


SSFS: OFF vs ON



Commissioning Run C4 - June 2004

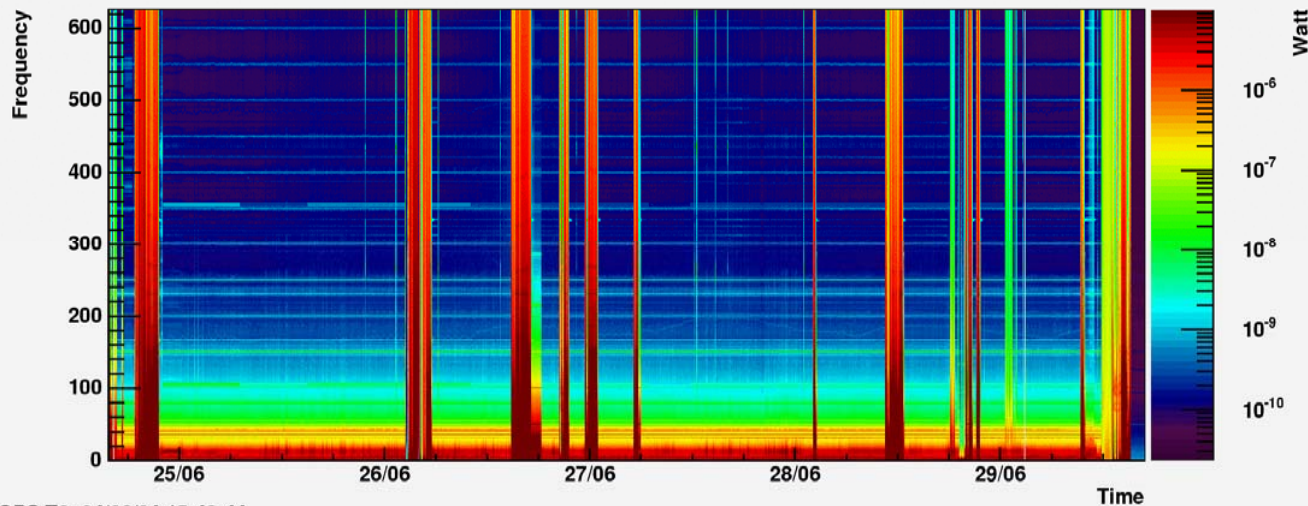
➤ *Recombined Data Taking Mode*



- ✓ ITF controlled with the reflected and the asymmetric beams
- ✓ **Automatic alignment** of the cavities
- ✓ **Laser frequency stabilized** to cavities common mode
- ✓ Cavities common mode locked to **reference cavity**
- ✓ **Output Mode Cleaner locked** on the dark fringe
- ✓ **Tidal control** on both arms

Commissioning Run C4 - June 2004

Spectrogram_spectro_Pr_B1_ACp_300_500_0_625 start=772127004 (Thu Jun 24 15:43:24 2004)

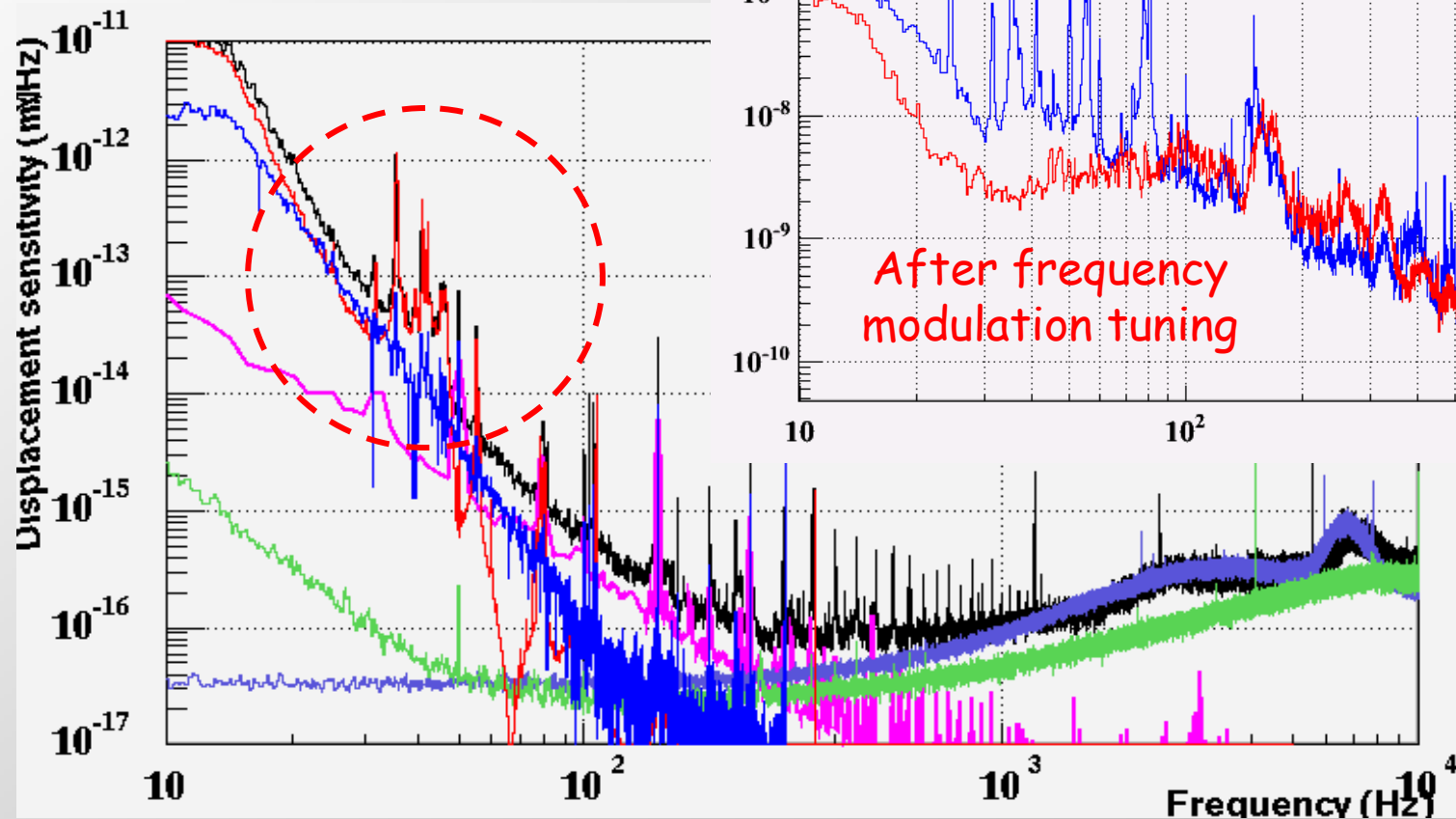


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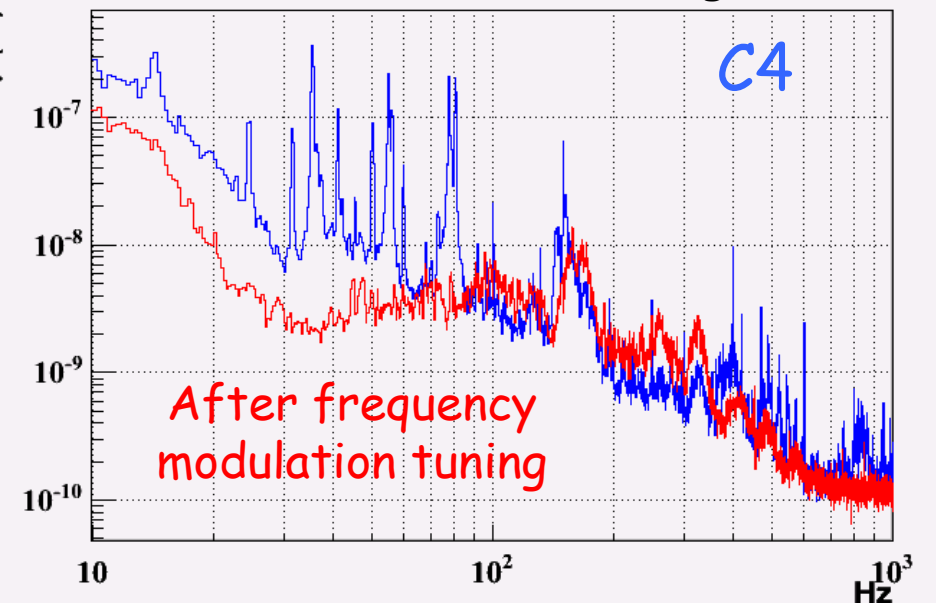
- 5 days of run
- Lock losses understood
- Longest lock ~ 28 h
- *h reconstruction on line*

Commissioning Run C4: Noise Characterization

Coupling of IB resonances into the michelson controller signal due to a mismatch between modulation frequency and input mode-cleaner length (~ 70 Hz)
Problem understood
→ not final solution yet



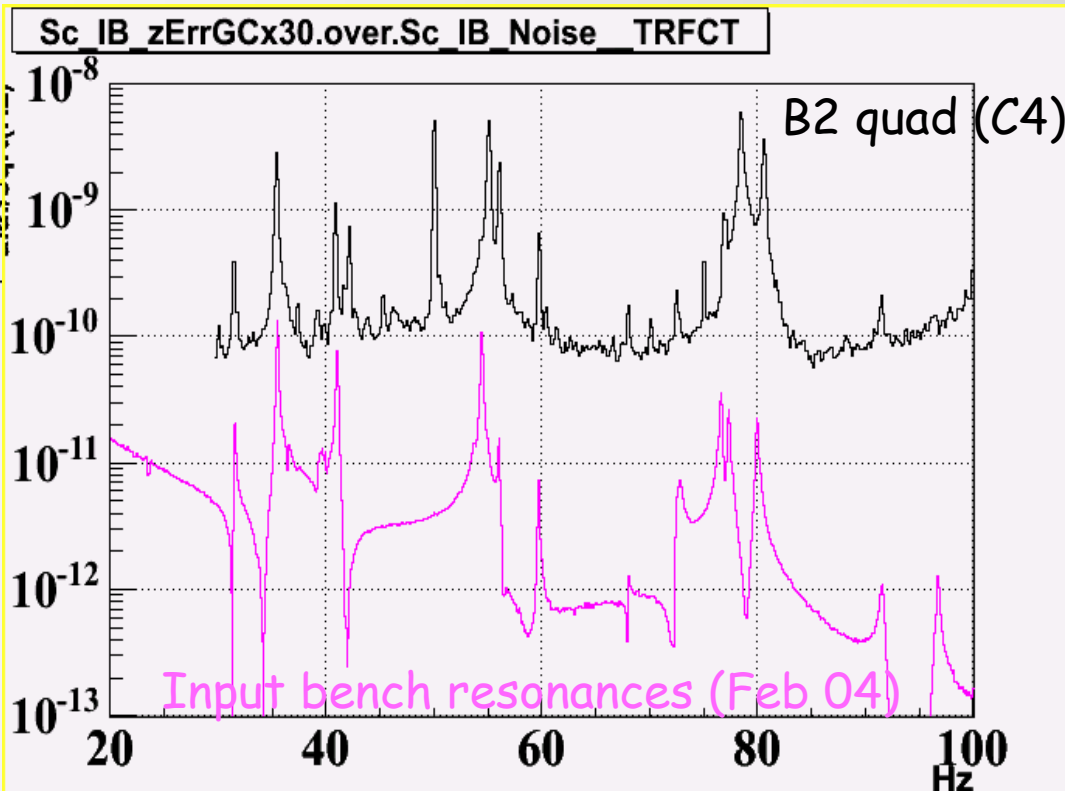
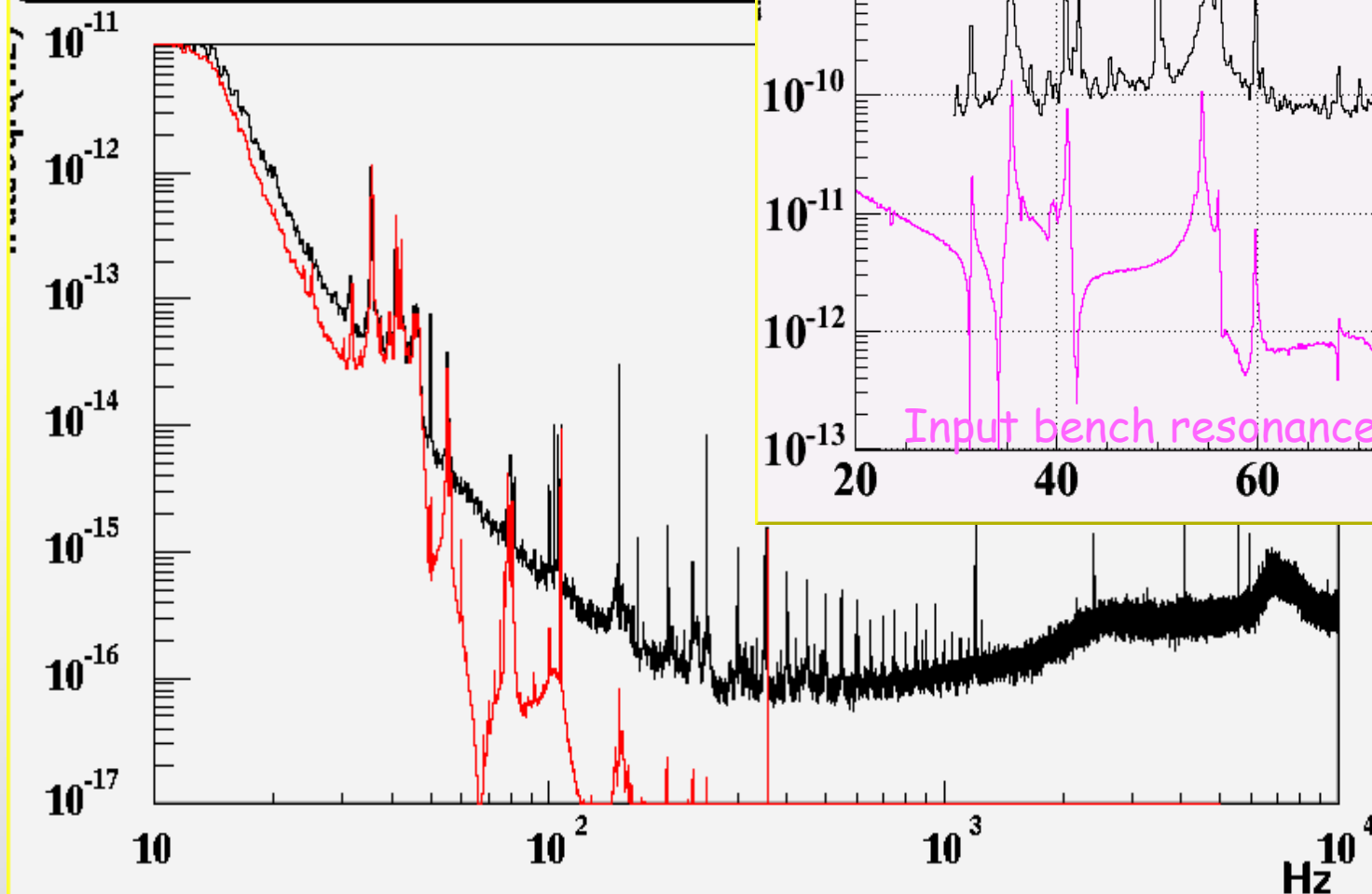
Michelson controller signal



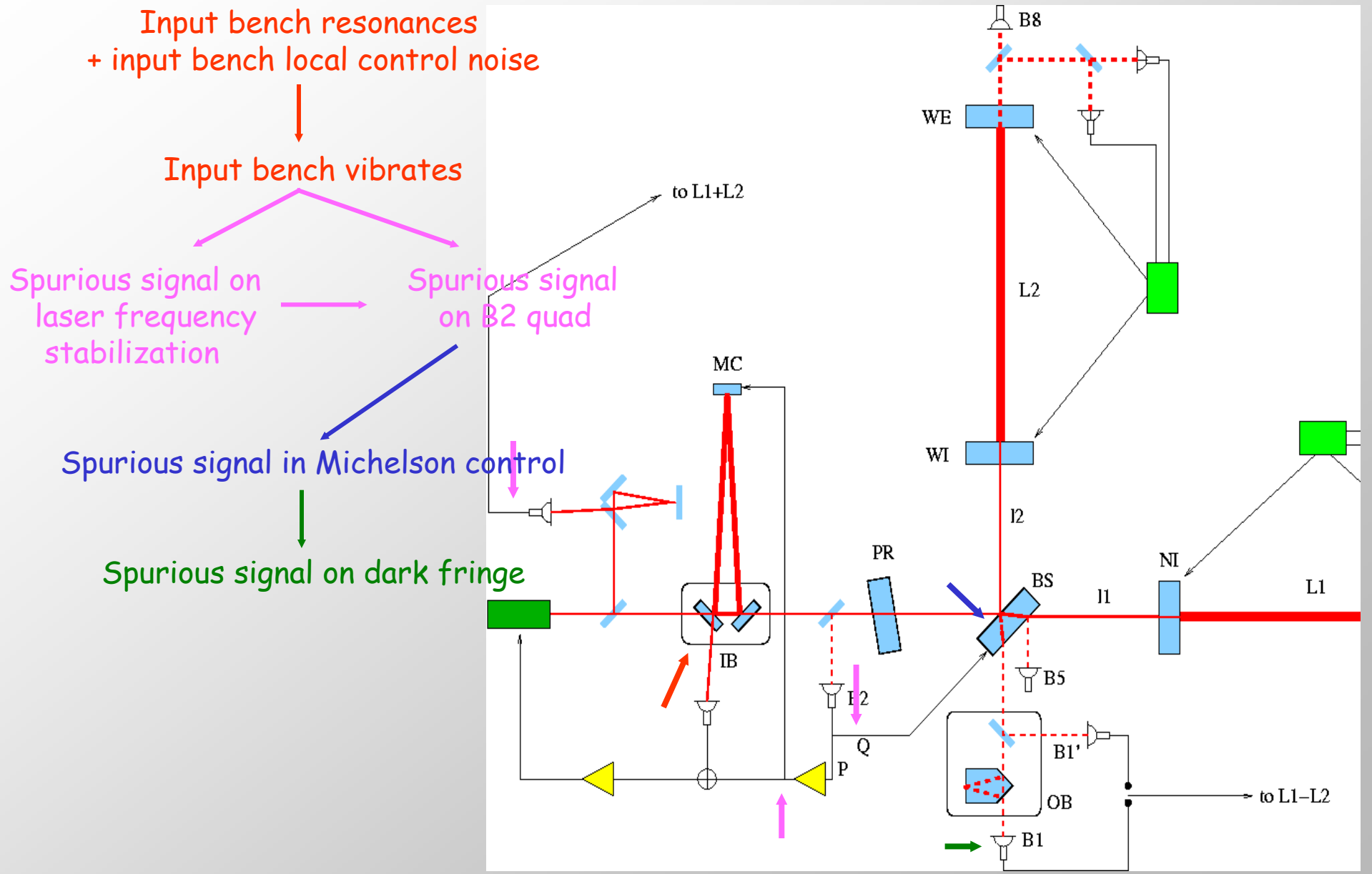
Michelson control noise (I)

- Due to input bench resonances

Virgo: recombined ITF sensitivity during



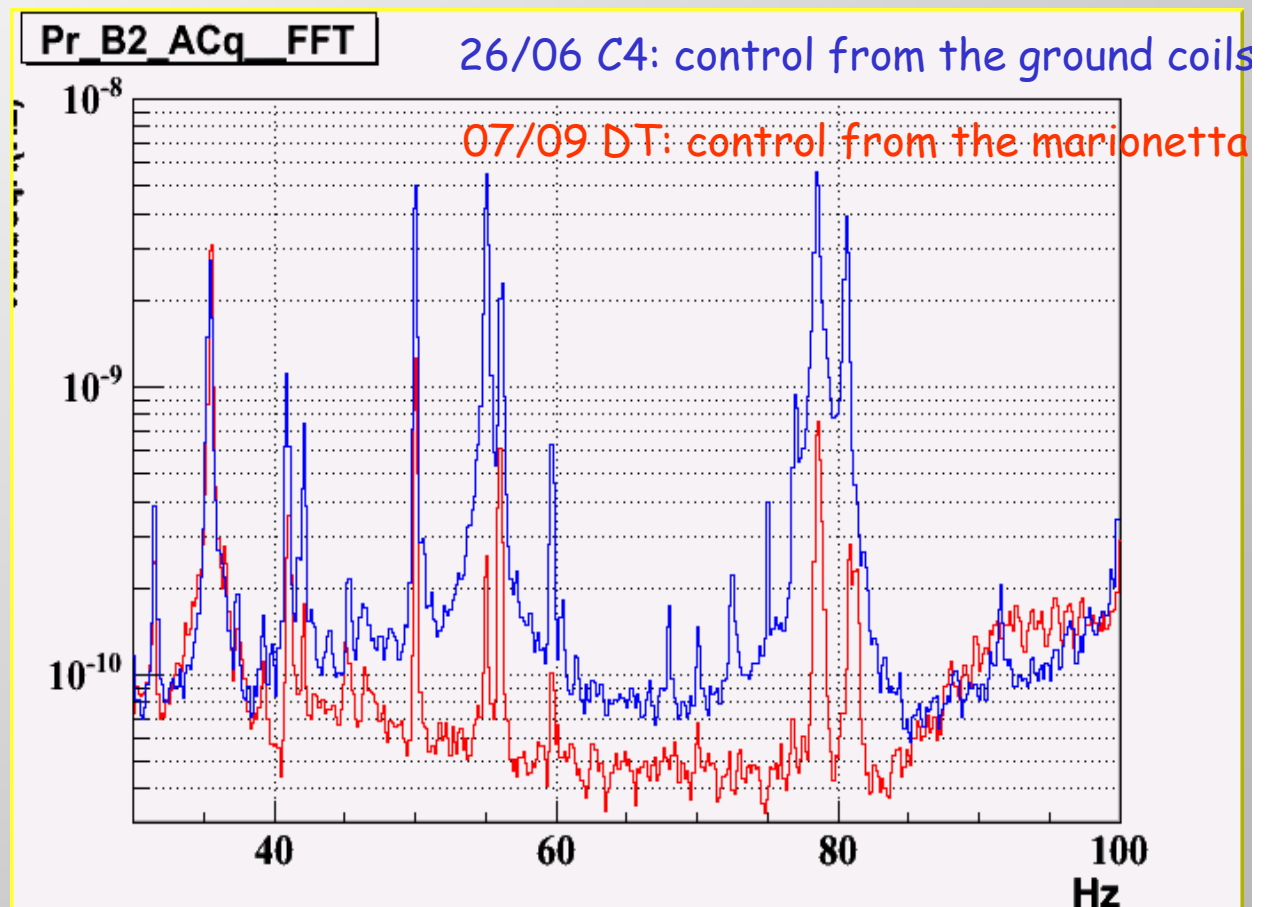
Michelson control noise (II)





Input bench resonances

- Driven by local control noise
- Coherence between coil driver outputs and B2_ACq during C4 confirms this hypothesis
- Better results when driving has been moved from the ground coils to the marionetta Coils
- Large improvement still needed
- The elimination of these resonance's should be part of the input bench upgrade



After C4

➤ July - August

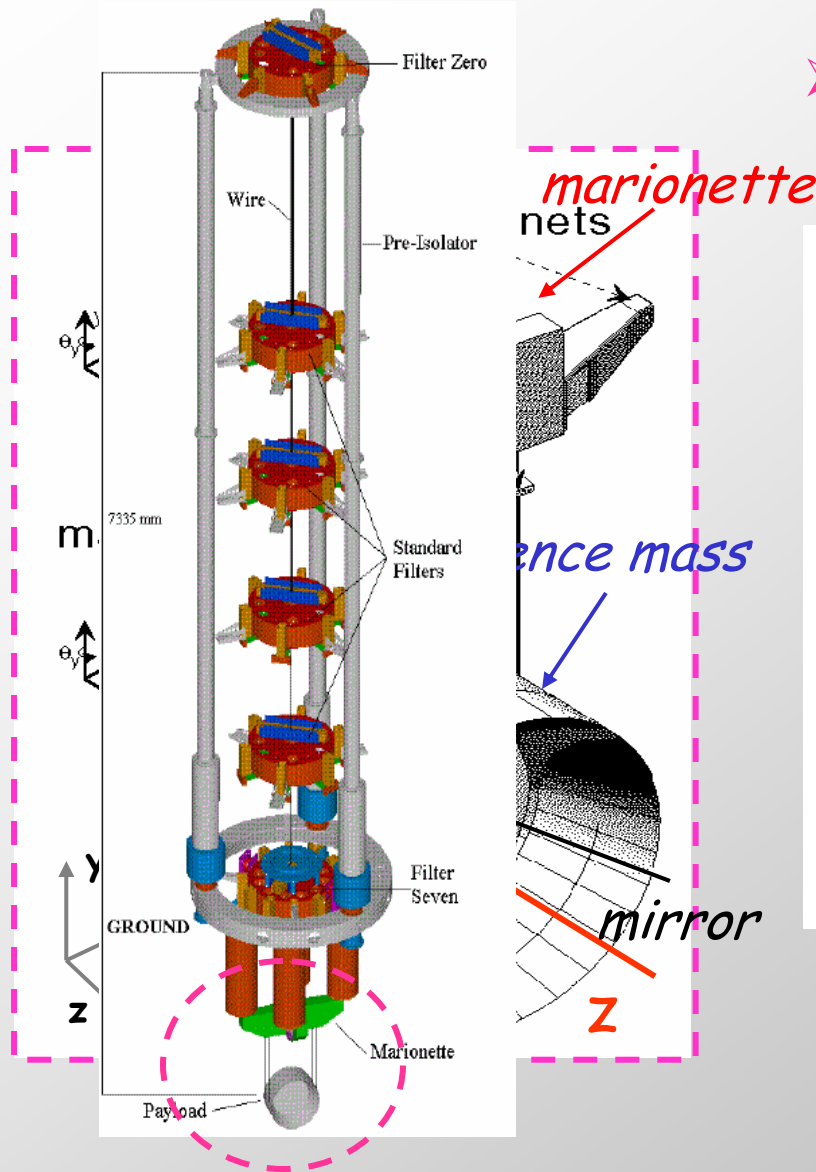
- ✓ Upgrade of the terminal benches -> Re-tuning and improvement of the linear automatic alignment
- ✓ Suspension full hierarchical control started
- ✓ Commissioning of the Recycled ITF started
- ✓ Effect of the backscattered light in the IMC
-> attenuator installed between the IMC and the ITF

➤ Mid September: Re-Start

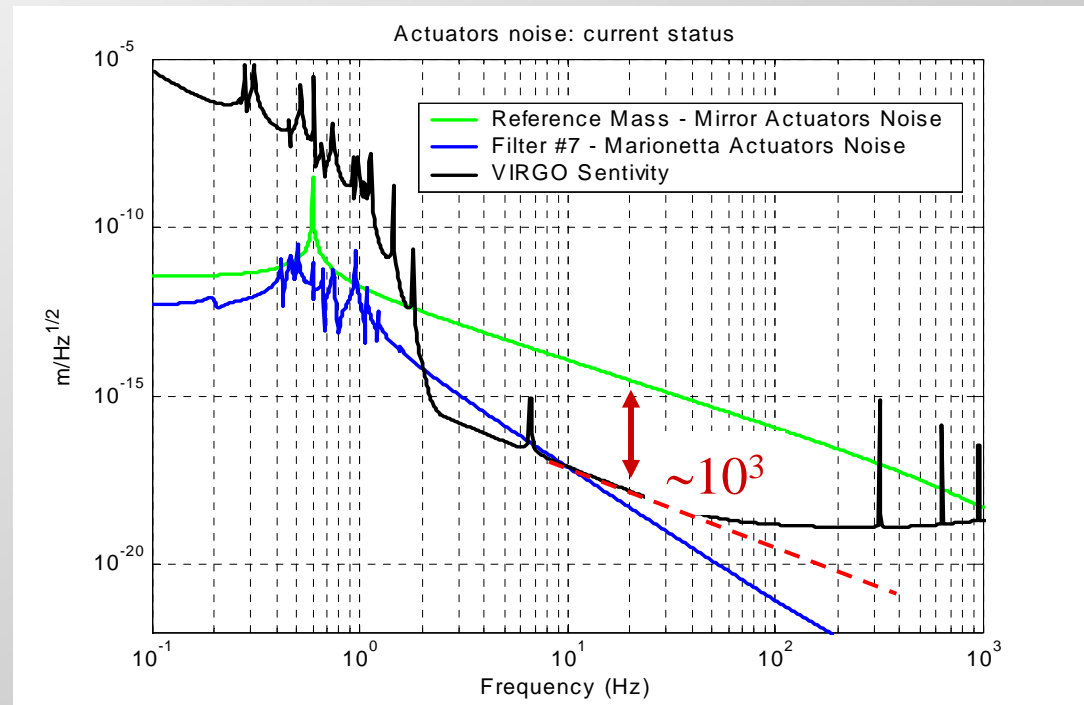
➤ October - November:

- > Recombined ITF locked with the full hierarchical control of the suspensions
- > ITF locked in recycled mode

Suspension Hierarchical Control

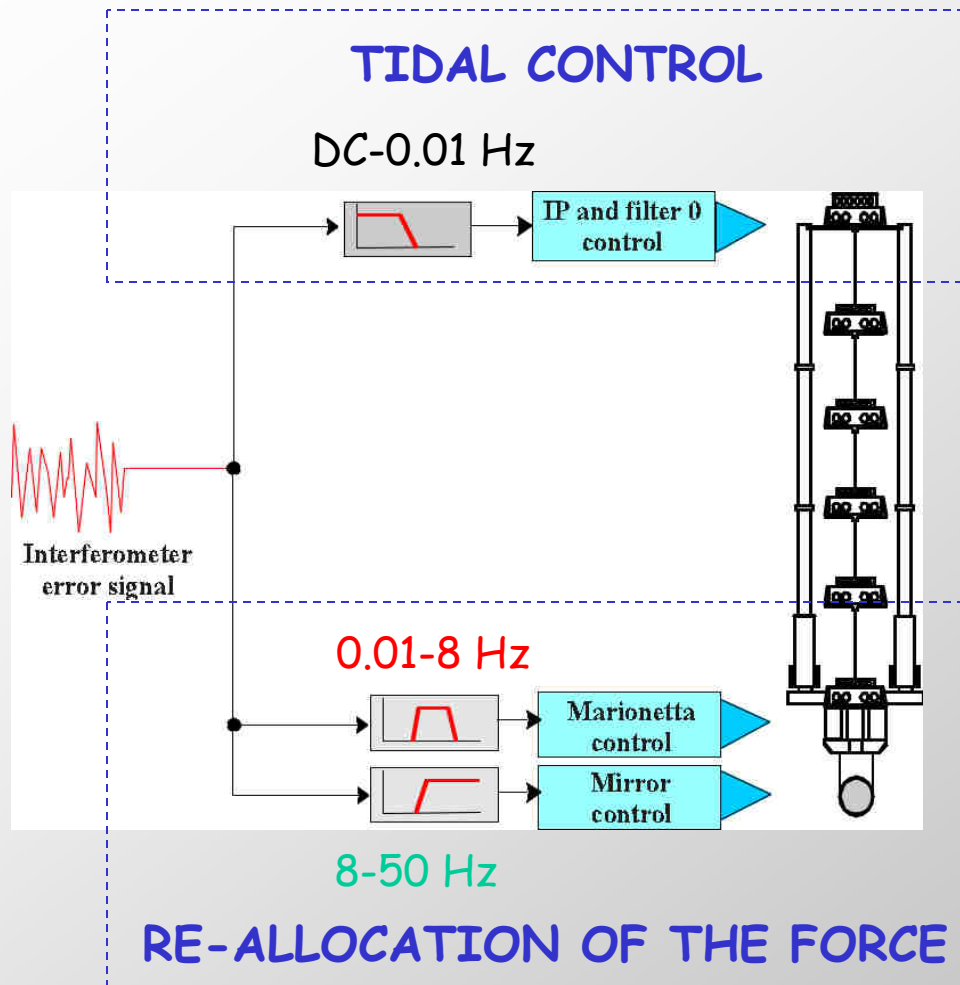


- Locking acquired and maintained acting at the level of the mirror

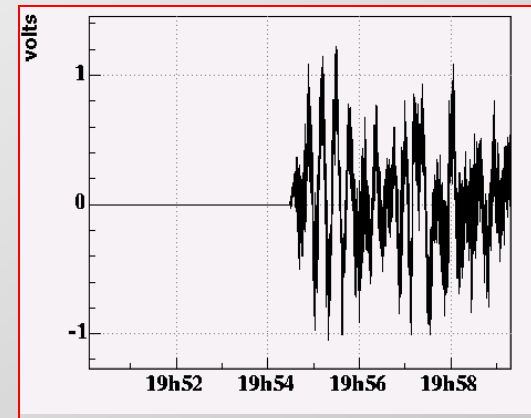


- Reduce the strength of the mirror actuators by a few 10^3 to reach Virgo design sensitivity

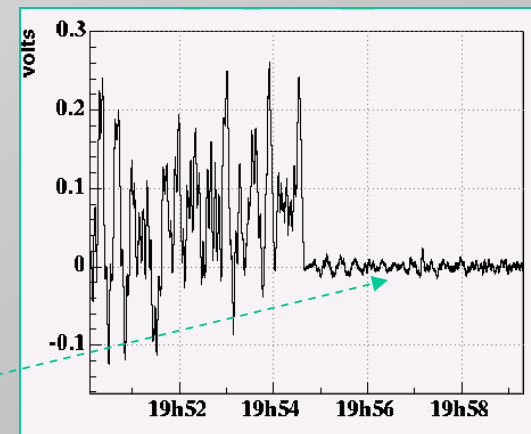
Suspension Hierarchical Control



Corrections sent to the marionette



Corrections sent to the mirror



Force on the mirror reduced of a factor 20

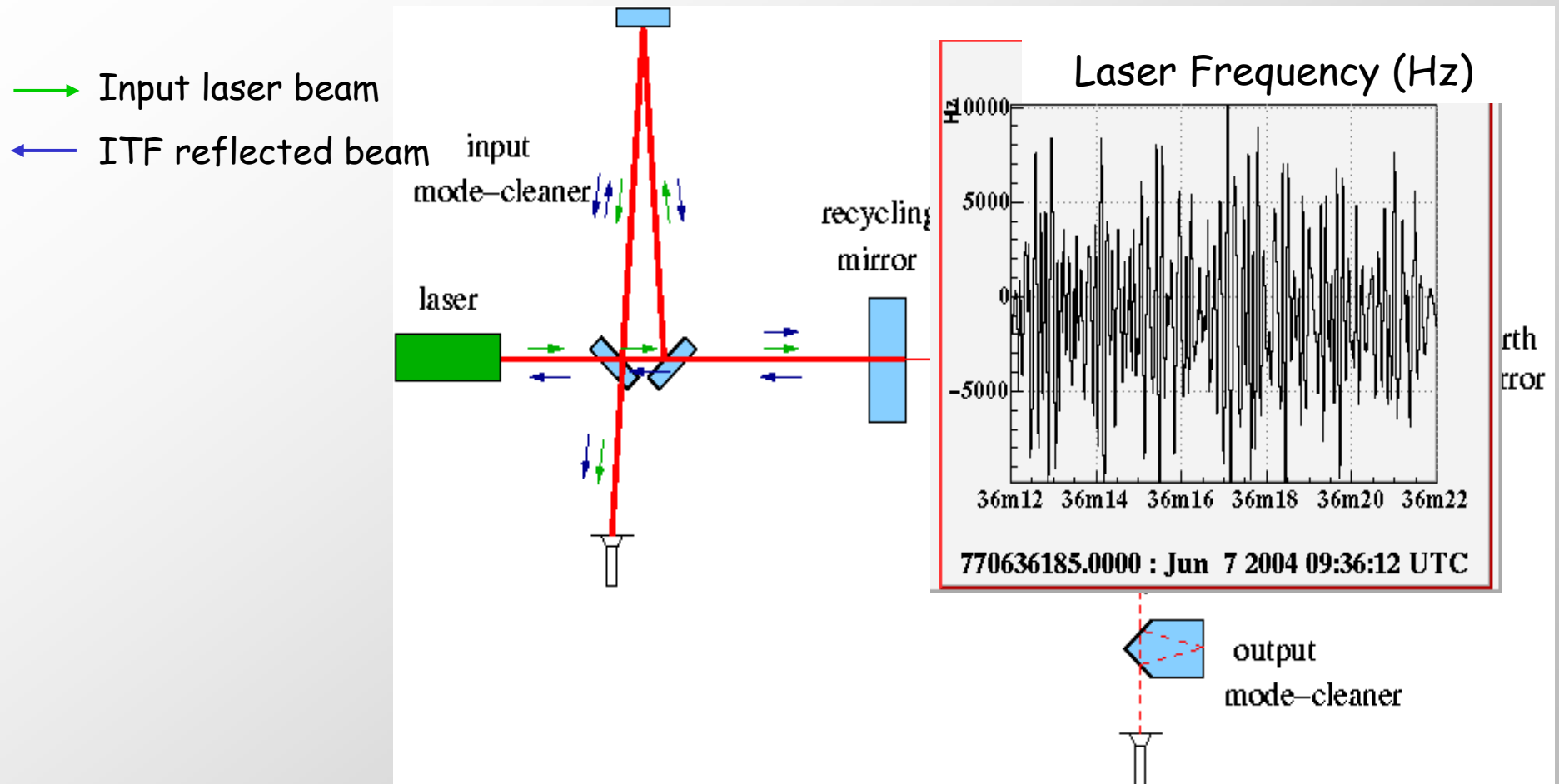
➤ Switch to low noise coil drivers

Suspension Hierarchical Control

➤ SUMMARY

- ❑ Single arm locked with the hierarchical control for the first time in July
→ *controllability of the superattenuator demonstrated*
- ❑ Last main result: hierarchical control of the recombined ITF in the C4 configuration, with automatic alignment and frequency servo engaged
- ❑ Stable lock → tested in the last commissioning run (*C5, 2-6 December 2004*)

Effect of light backscattered in the IMC

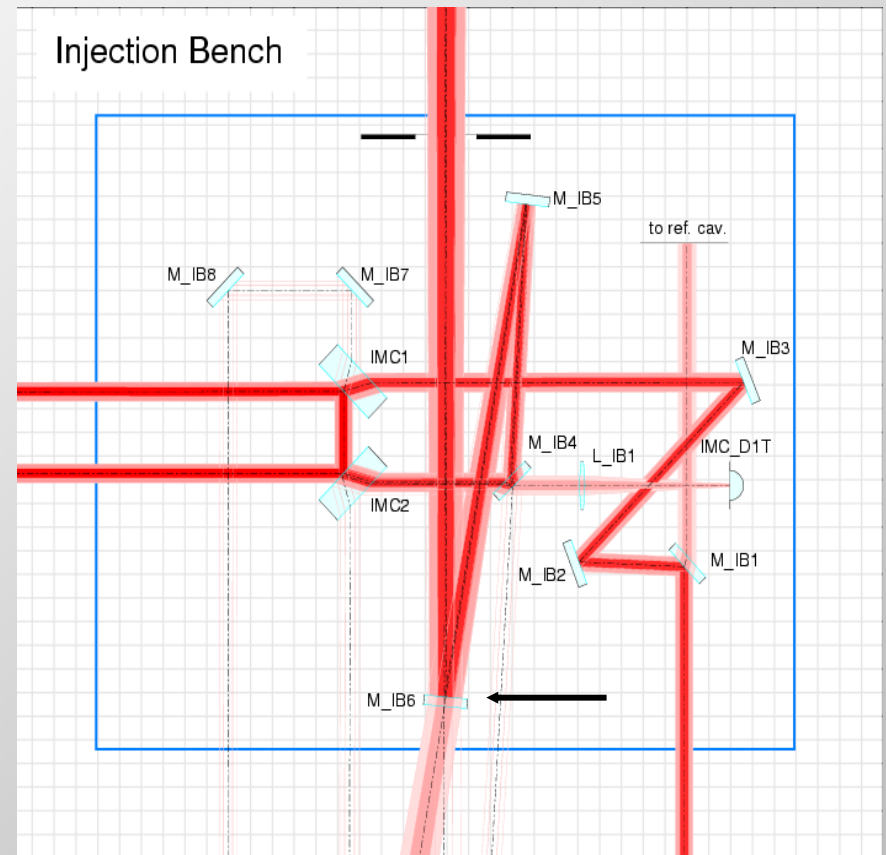
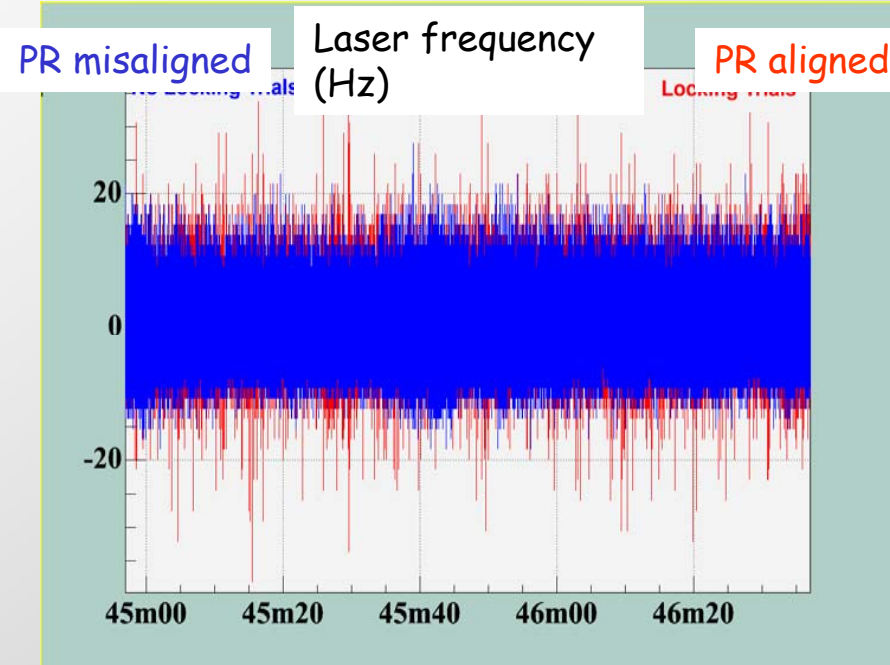


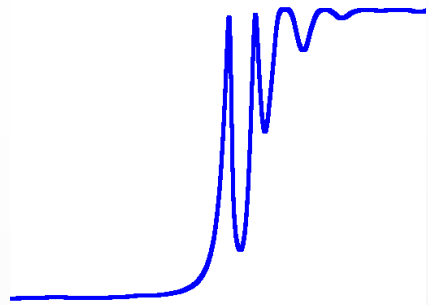
• Solution

- Short term: insert attenuator between the IMC and the ITF
- Mean term: insert Faraday isolator (input bench upgrade)

Attenuator between ITF and IMC

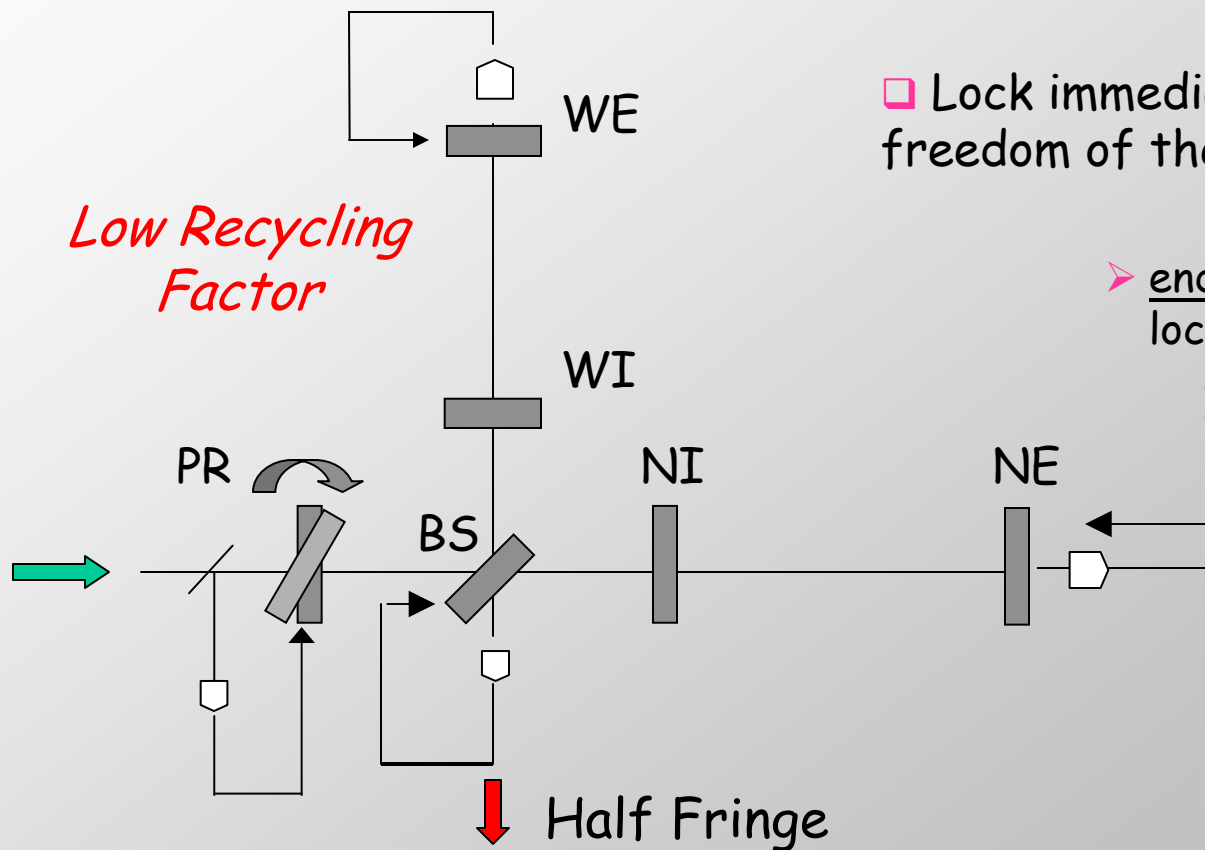
- Insert attenuator between the IMC and the ITF
- Change last mirror of the input telescope (R=100% → R=10%)
- First trial at the beginning of August:
...bad mirror
- Second trial on September 9th: OK





The Variable Finesse Locking Strategy

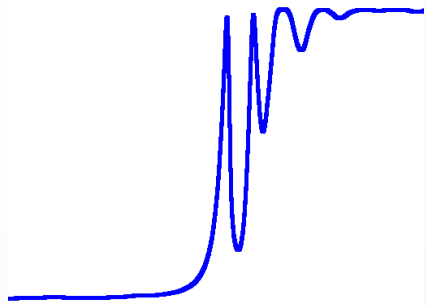
"A recycled ITF with a low recycling factor is similar to a recombined ITF"



Low Recycling Factor

□ Lock immediately the 4 degrees of freedom of the ITF on the half fringe:

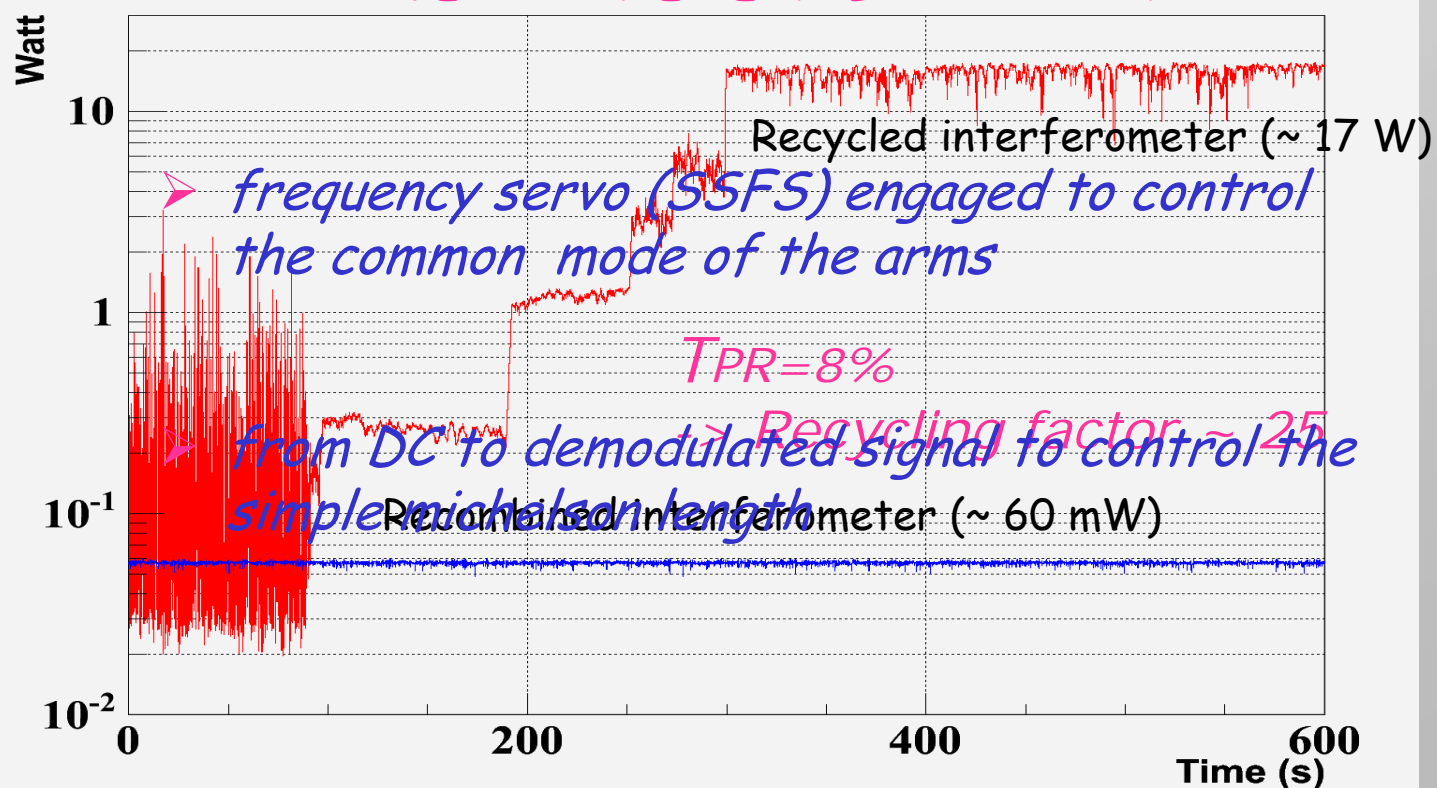
- end photodiodes to acquire the lock of the long cavities
- simple michelson locked on the half fringe with the asymmetric DC signal
- 3f demodulated reflected signal to control the recycling cavity length

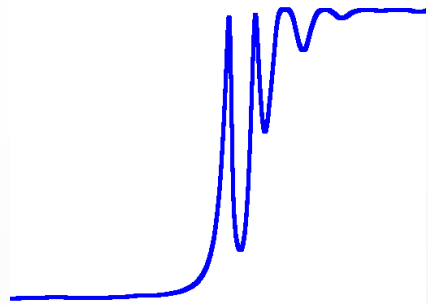


The Variable Finesse Locking Strategy

- With the ITF in a stable state, bring it adiabatically on the dark fringe evolving the control scheme

POWER IN THE RECYCLING CAVITY





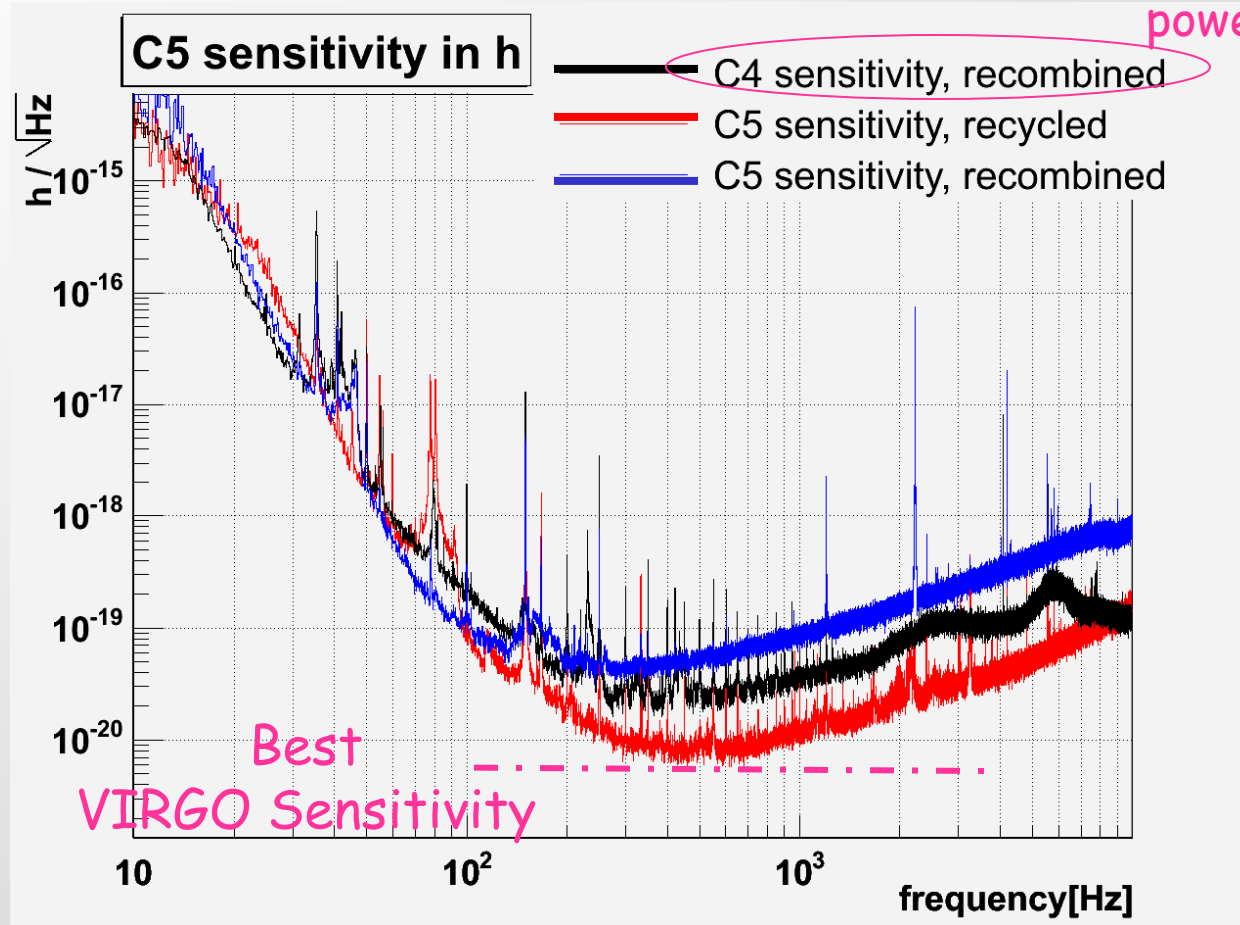
The *Variable Finesse* Locking Strategy

➤ SUMMARY

- ❑ First lock of the recycled ITF on the end of last October
 - ❑ Stable lock of the recycled interferometer ~ 40-50 minutes
 - *no linear automatic alignment yet* → *next step*
 - ❑ Locking procedure tested several times
 - *lock acquired in few minutes*
 - ❑ New original lock acquisition procedure established, combining end photodiodes, frequency servo, 3f-demod signal, slightly misalignment of PR mirror, and lock on the half fringe
- M. Evans (LIGO) and K. Arai (TAMA) present on Virgo site
- ❑ 1 day and half of test in the **last commissioning run C5**

Commissioning Run C5 - December 2004

10 times more
power than C5



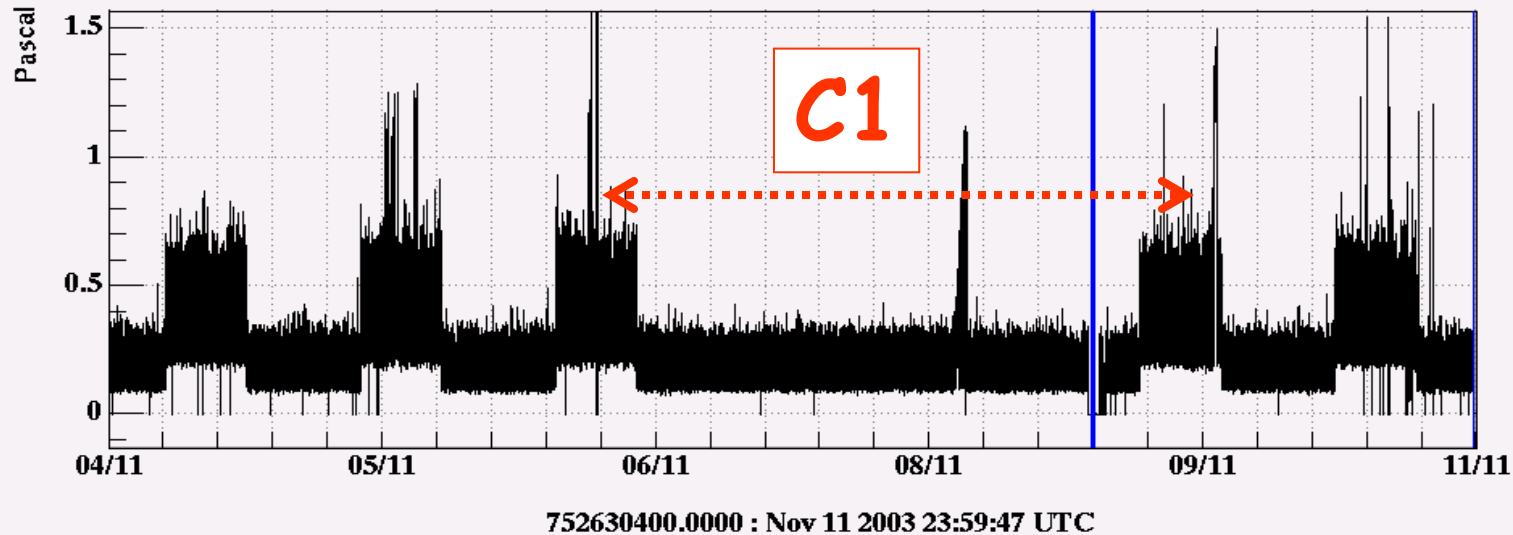
- Injection of bursts and inspiral events during the run
-> Analysis in progress

Coupling to the environment

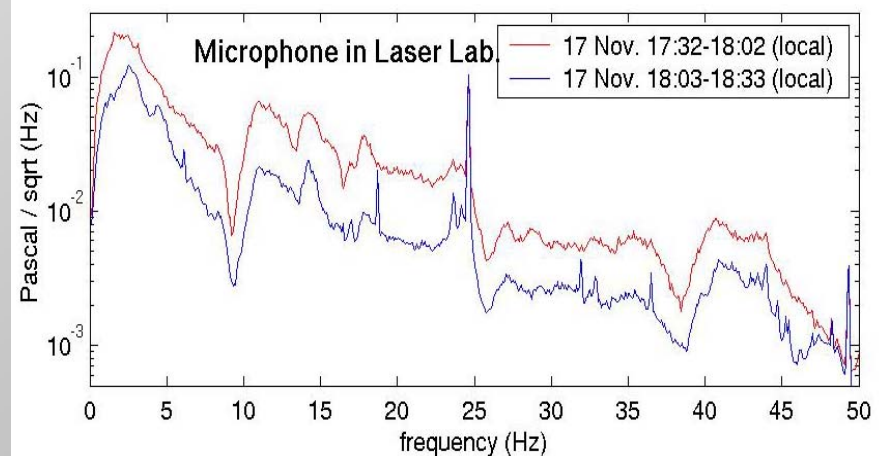
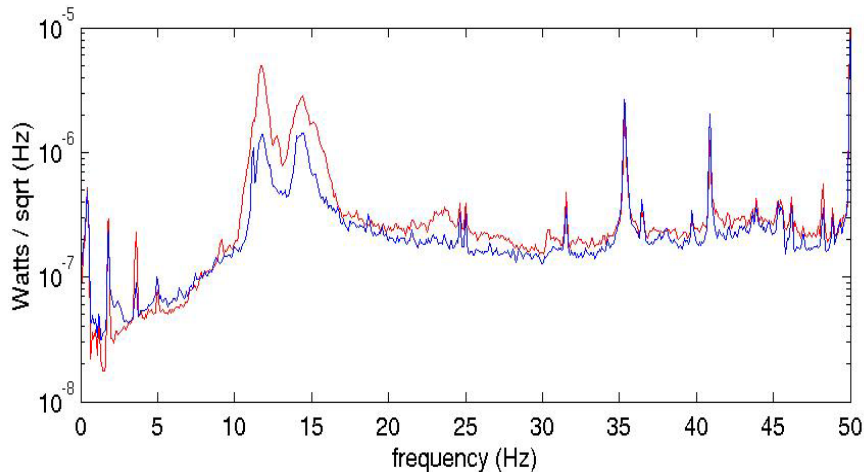
- Laser lab
 - Vibrations and drifts
 - Acoustic coupling
 - Pressure waves
 - Temperature
- Det lab and end benches
 - Vibrations and drifts
 - Temperature

Air Conditioning low/high cycle

RMS acoustic noise in laser lab. microphone



- AC switches to "high power regime" from Monday thr Friday 8:00 - 18:00
- Dark fringe "breaths" at 11. and 14. Hz
- Broadband acoustic noise in laser lab.

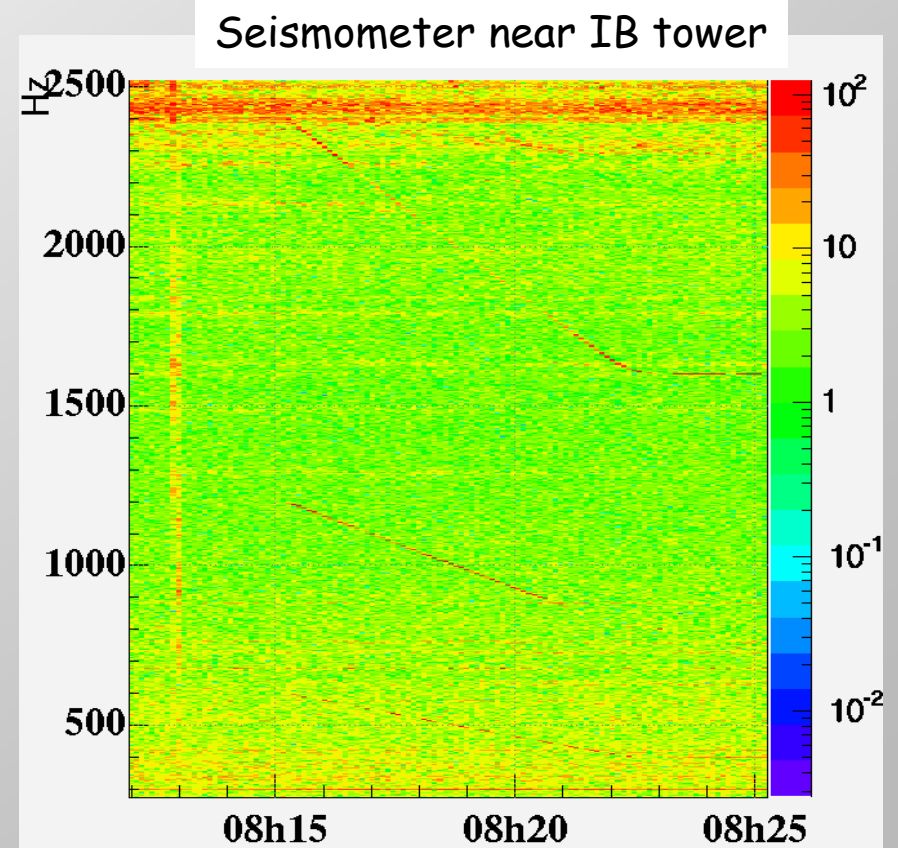
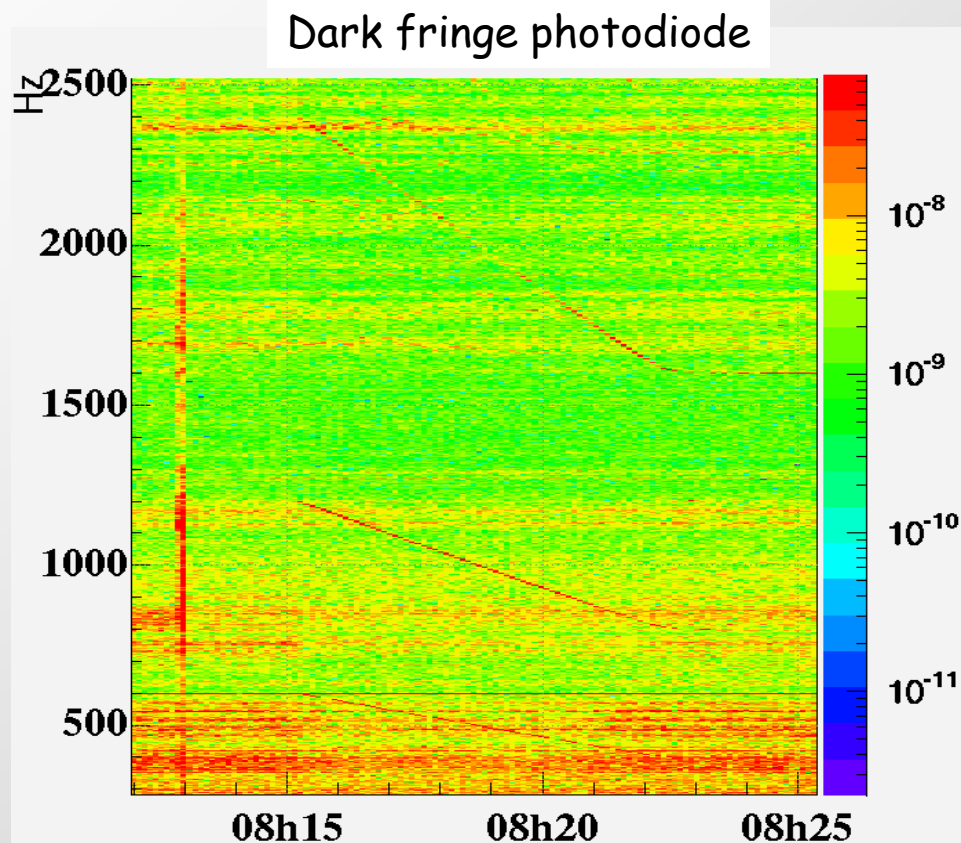


Turbo-molecular vacuum pumps: sweep test

- 1 pump per SA tower (UHV < 10^{-9} mbar in tower lower section)
- magnetically levitated, rotation speed 400 Hz or 600 Hz

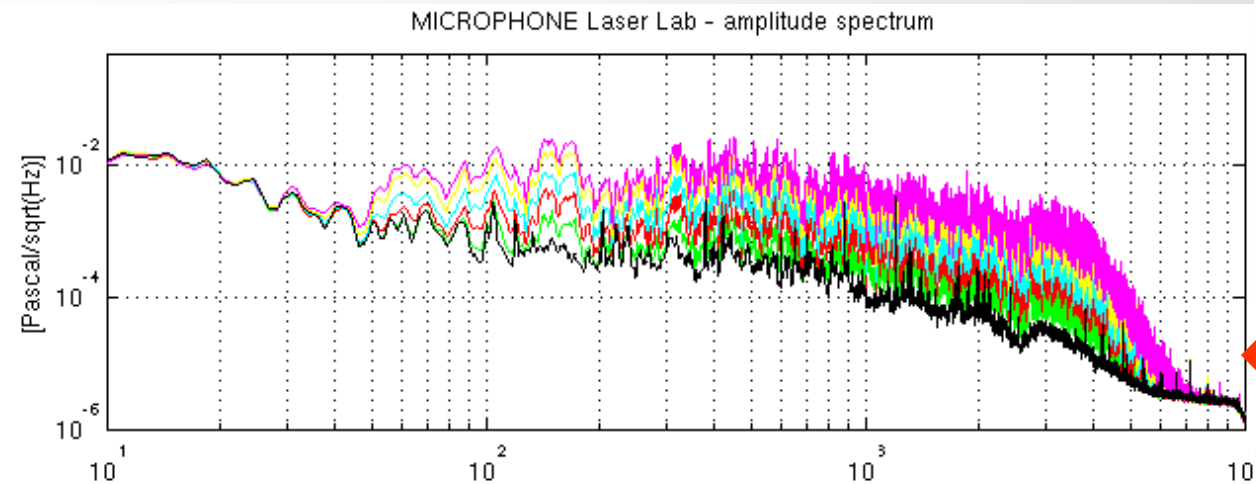
VIRGO - C2 IB tower pump: sweep 600Hz → 400Hz

- fundamental and harmonics sweep coherently in dark fringe and seismometer

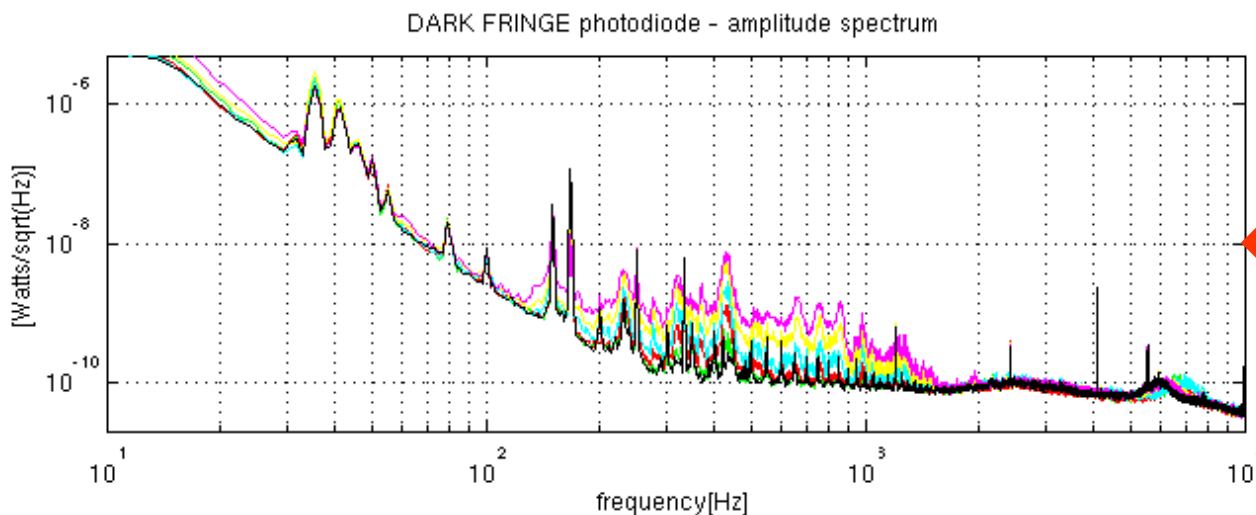


Acoustic test during C4 run

- Broadband white signal sent to a loudspeaker in laser laboratory, with 5 levels of increasing intensity



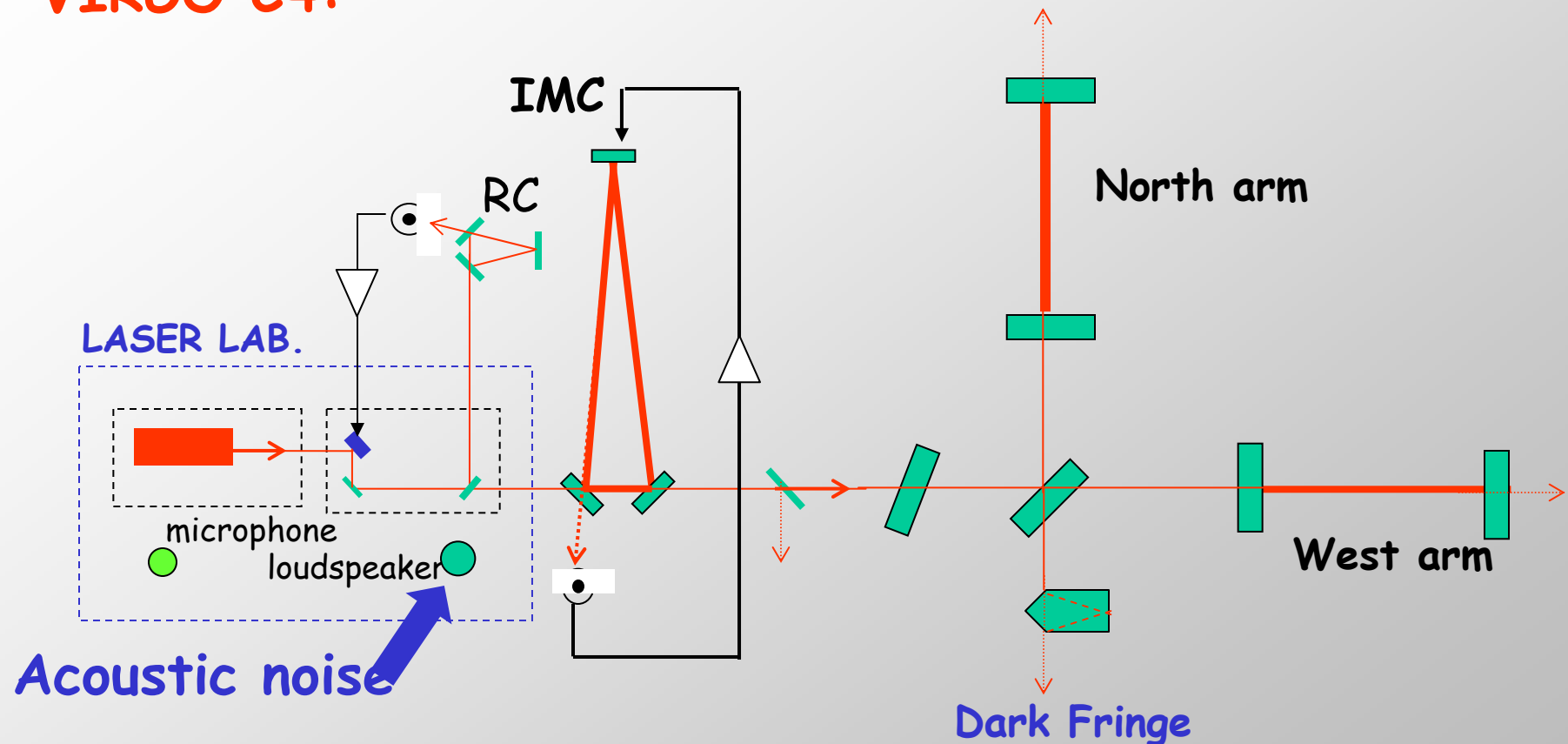
← acoustic noise increase in laser lab. up to ≈ 50 times the standard noise floor at 30-4000 Hz



← noise increase in dark fringe up to ≈ 10 times at [150, 1500] Hz

Effects of acoustic noise: signals layout

VIRGO C4:

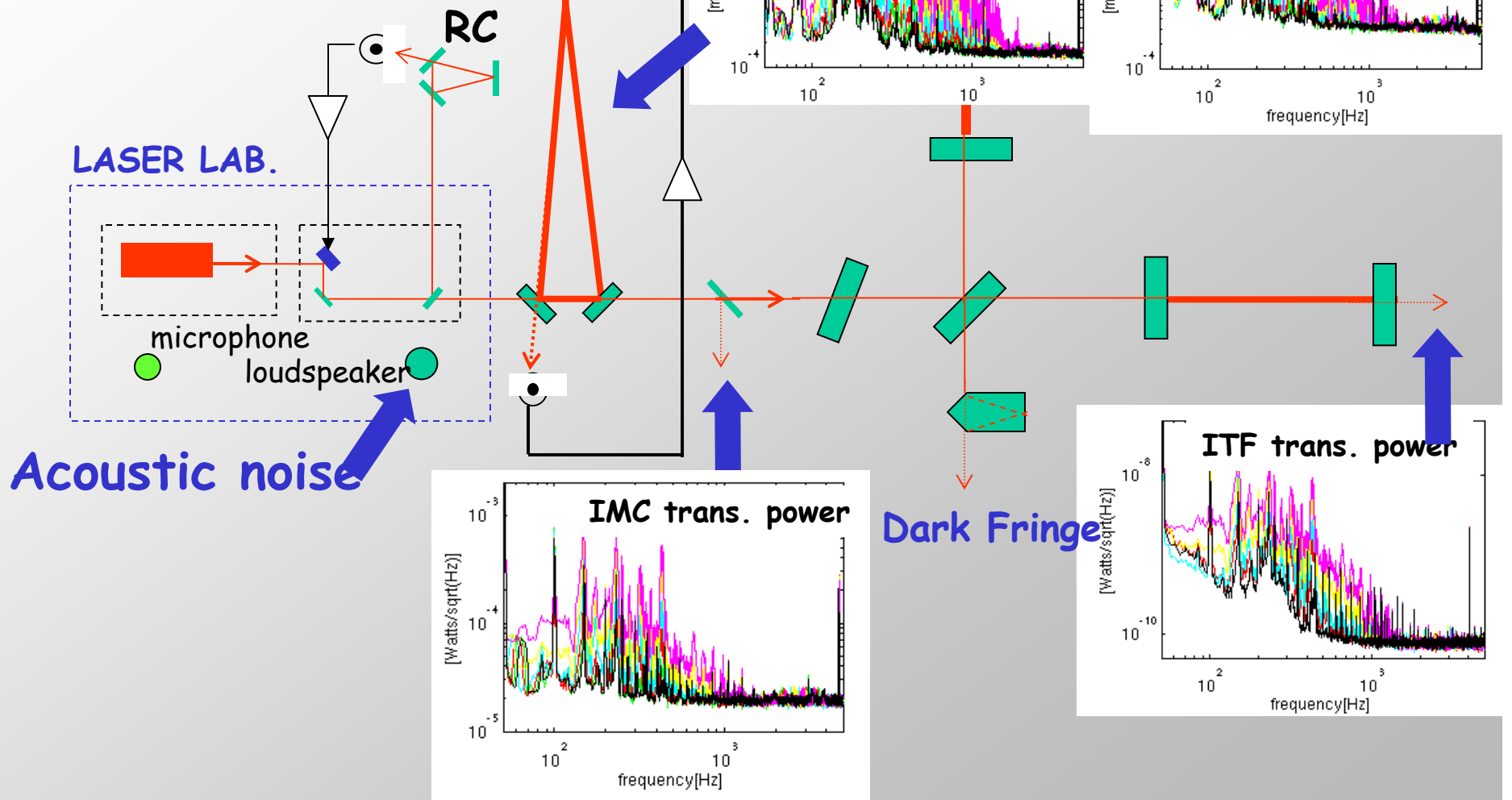


Injection SYS:

- Laser clean room: laser, beam forming optics, photodiodes&piezos on non suspended benches, in air
- Input Mode Cleaner: plane concave triangular FP, 144m, reference cavity, suspended, under vacuum
- Aligment: laser on RC (<1Hz), IMC optical axis (<10Hz)

Effects of acoustic noise: signals layout

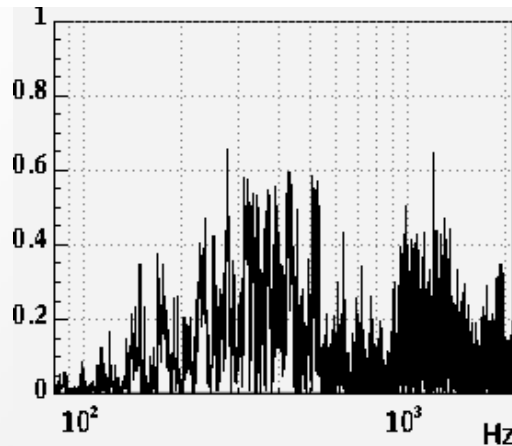
- Misalignments of IMC (α, θ)
- Power fluctuations of MC transmitted beam



Which path to dark fringe ?

A look at coherences: Dark Fringe vs. microphone is low \rightarrow non linear path

Microphone vs. Dark Fringe



Microphone

IMC
 a, θ

Fluctuations of
IMC transmitted
Power

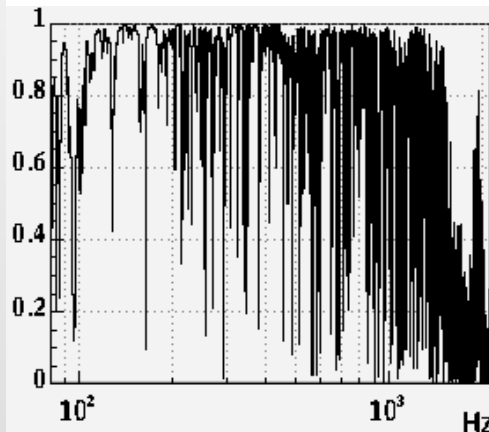
Dark Fringe

Jitter of laser beam is non compensated by IMC alignment control

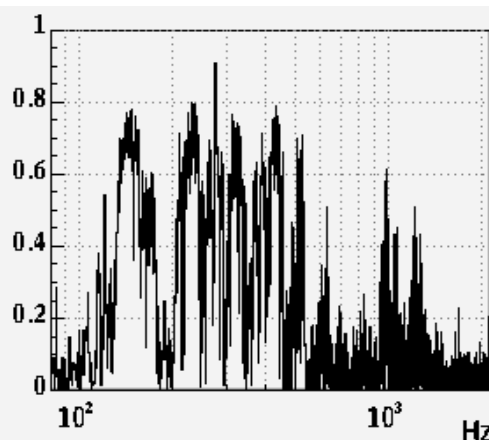
Misaligned MC gives power fluctuations of transmitted beam

Power fluctuations converts into ITF readout noise

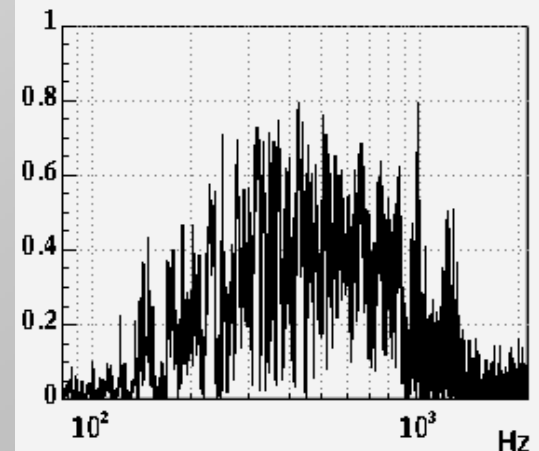
Microphone vs. IMC(a, θ)



IMC(a, θ) vs. IMC out Power



IMC Out Power vs. Dark Fringe



Power noise propagation model

Power noise contribution to Sensitivity : $S_{pn}(t) = \Delta S \frac{\delta P}{P}$

$S(t)$ = sensitivity [m]

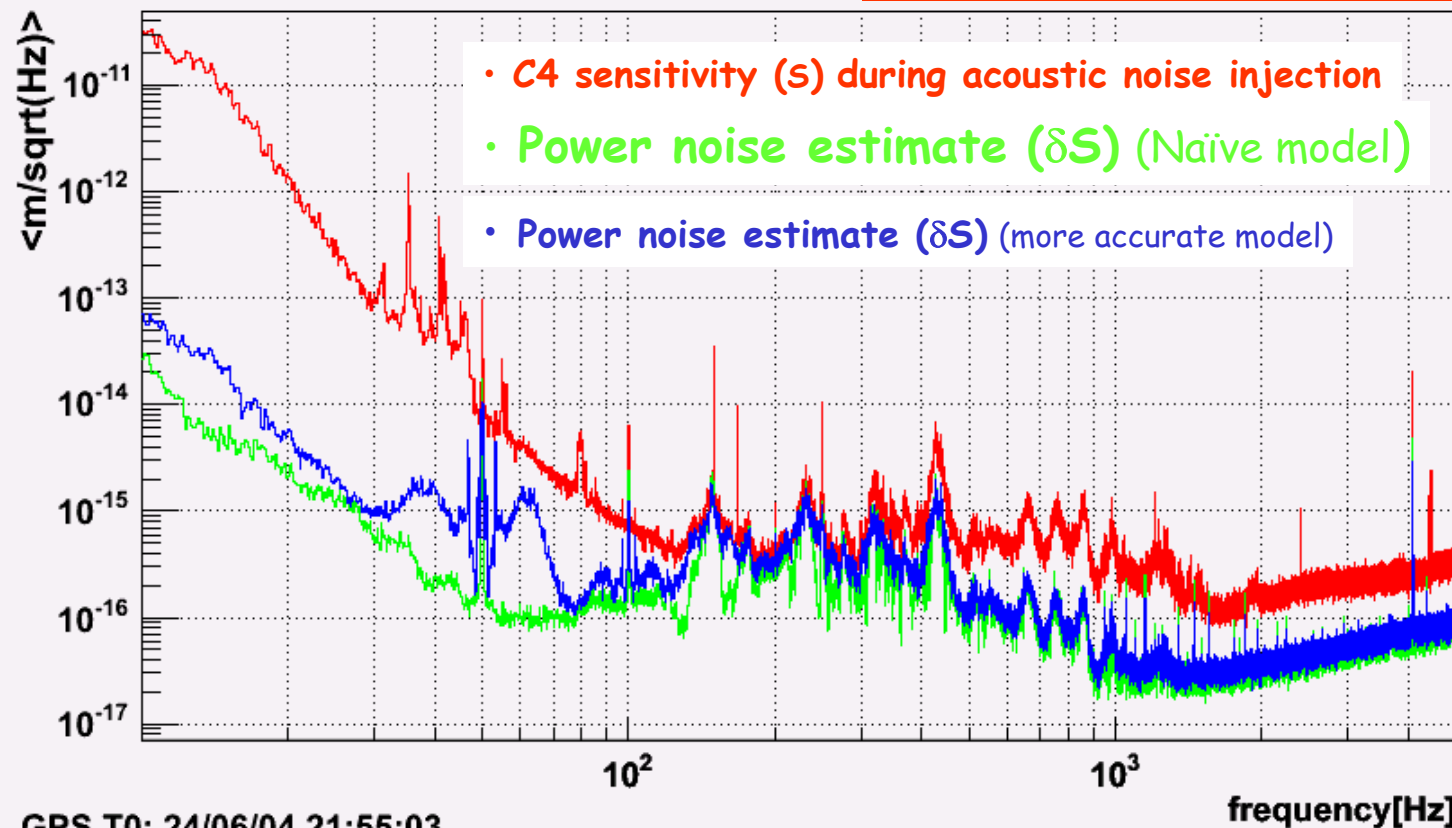
ΔS = displacement from the dark fringe

$\frac{\delta P}{P}$ = relative power fluctuations

1) Naïve model: $\Delta S \equiv S_{RMS}$

2) More accurate model

$\Delta S \equiv$ low freq. part (<50Hz) of S



GPS T0: 24/06/04 21:55:03

frequency[Hz]

Data Analysis Activity

- h reconstruction (*F. Marion - LAPP*)

- Physics group activity:
 - ✓ Burst (*P. Hello - LAL*)
 - ✓ Coalescent Binary (*A. Vicerè - INFN Urbino*)
 - ✓ Pulsar Source Software (*S. Frasca - Roma University*)
 - ✓ Stochastic Background (*G. Cella - INFN Pisa*)
 - ✓ Noise Analysis (*J. Y. Vinet - NICE*)

- Network analysis

Conclusions

- ❑ Well advanced status of the commissioning activity
 - > *Suspension hierarchical control in recombined mode*
 - > *Lock of the recycled ITF*

- ❑ Next steps:
 - > *Linear automatic alignment of the recycled ITF*
 - > *Frequency servo optimization*

- ❑ Last Commissioning Run Data -> *analysis in progress*