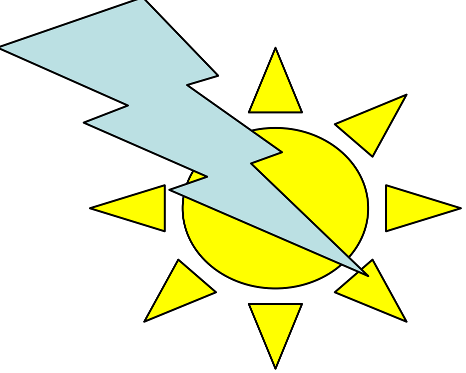


Mirror Suspension Control VSR1 learning

E. Majorana
INFN

MSC workgroup

LSC-Virgo joint meeting

Hannover 25-10-2007

LIGO-G070744-00-Z

outline

I. MSC status at VSR1 startup: quick reminder.
II. MSC tuning during VSR1.
III. Noise issues.
IV. Post-VSR1 considerations and perspective.

I. MSC status at VSR1 startup: quick reminder

Mirror Suspension Control at VSR1 startup: essentials

Compensation of actuator non-linear recoil:
for both Marionette and SuperAttenuator.

Global-**I**nverted-**P**endulum-**C**ontrol (partial):
to increase Pos/Acc sensor crossover frequency (up to 70 mHz)
without significant μSeism re-injection (0.15-0.7 Hz).

Pos/Acc prefiltering strategy tunable on-the-fly
according to the wind (0.02-0.7) or sea (0.15-0.6) disturbance.

Lock force hierarchically controlled through 4 marionette (two FP arms):
to avoid saturations at low frequency.

Local control roll-off (NI,WI,BSyaw) reduced
to improve stability.

IMC Suspensions (MC,IB) non-optimized and with no V-damp.

II. MSC tuning during VSR1

MSC tuning and improvement during VSR1

- NI-WI LVDT/ACC : anti-Wind => anti-Sea => anti-Wind (Jun 5)
- MARIO lock re-allocation on NI-WI OFF (NE,WE only) (Jun 6)
- BS LC tuning to improve regions with small phase margin (Jul 4)
- µSeism-Free Reconstruction of PR top stage Err Signal (Jul 6)
- EQG Guardian to disable GIPC in case of EarthQuake (Jul mid)
- NI-WI mirror re-centring on beam (Jul mid)
- GIPC and mSFR complete configuration (Sep 15)

Overall

Mirror Suspension Control Noise:

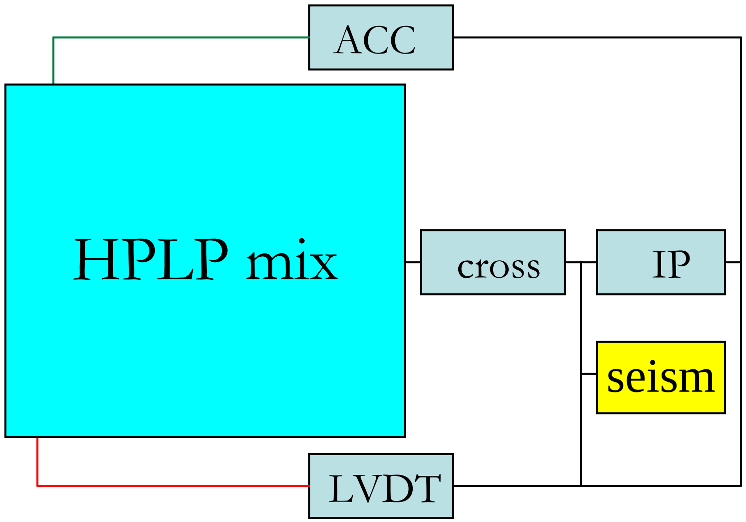
no significant limitation of present Virgo sensitivity.

Open issues:

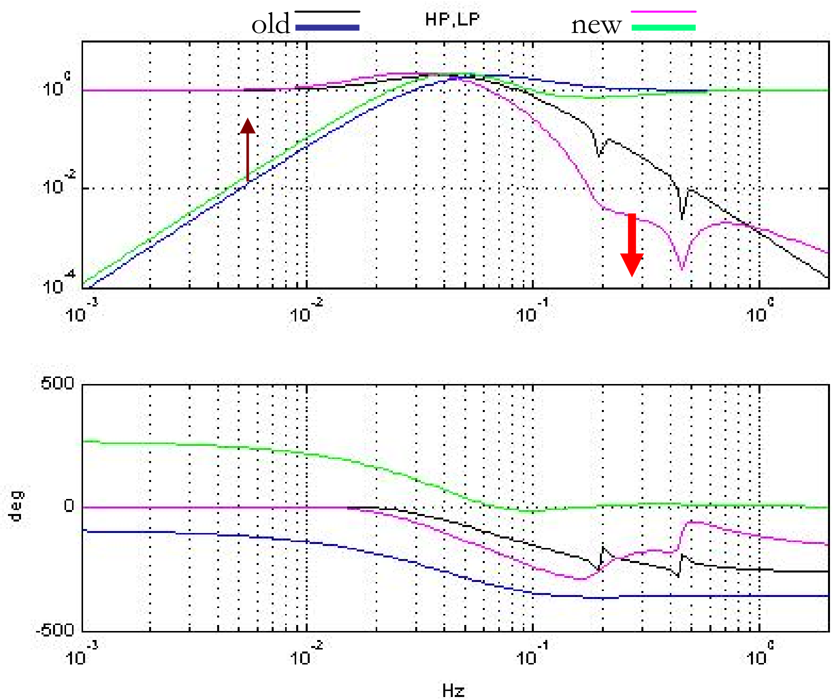
worse sensitivity during bad weather days (µseism and wind).

Initial Vs final: sensor prefiltering

hybrid filters (on-the-fly tuning)



Example..



VSR1: sensor prefiltering tuned, after few days, to reject wind diturbance injected by accelerometers.

mix =0.5 'medium' attenuation of LVDT μseism noise
Compared to the starting config (crossover @ 50 mHz

mix =0 (wind-earthqukes, f <70mHz):
"aggressive" attenuation of accelerometer tilt noise.

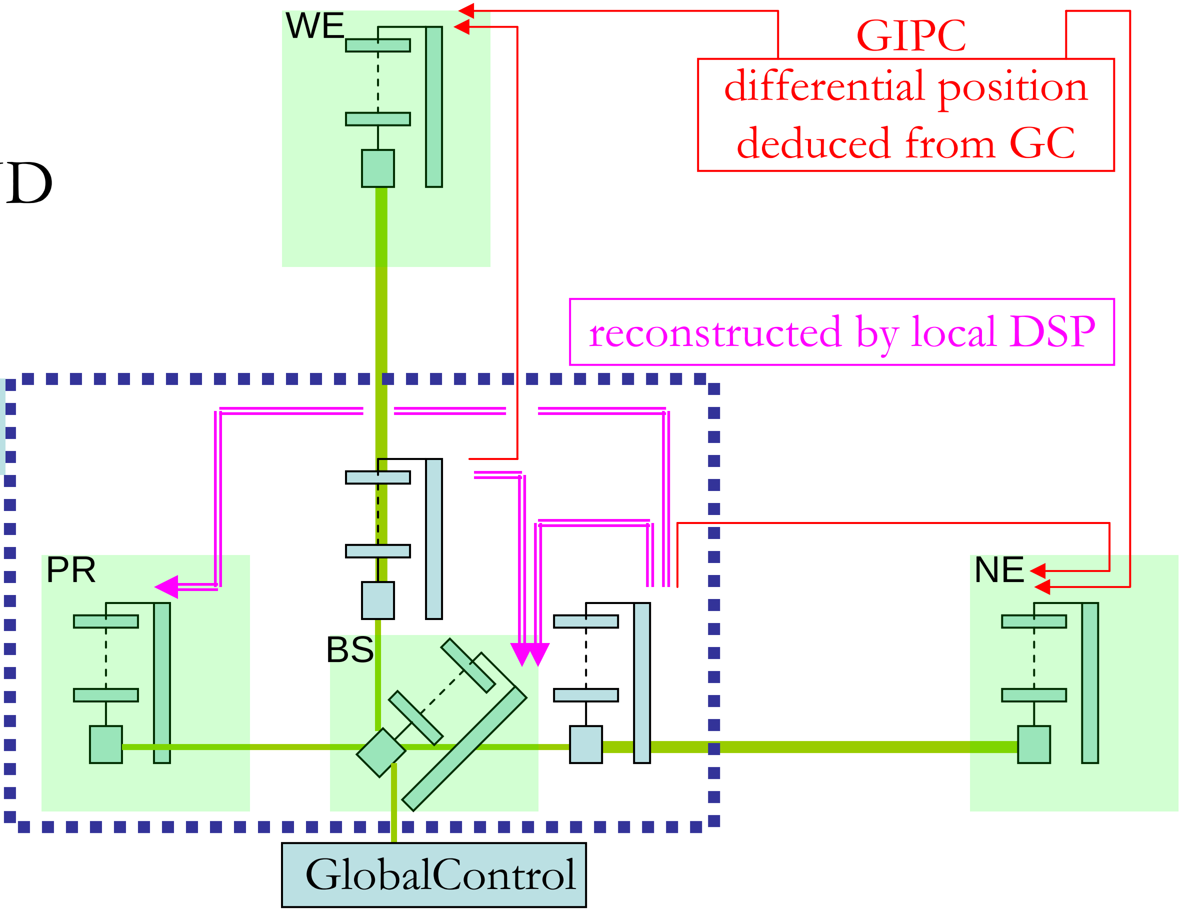
mix =1 (μseism, 150-600 mHz) :
"aggressive", slightly worsened against tilt noise.

Initial Vs final: overall control strategies

μseism **incoherent**
along the arm baseline
=>μSeism reduced at END
sites by using position
referred to INPUT;

Also the Acceleration !

μseism **coherent**
in the central area
=>μSFR possible
by referring PR and
BS to NI and WI



INPUT TOWERS AS GROUND REFERENCE

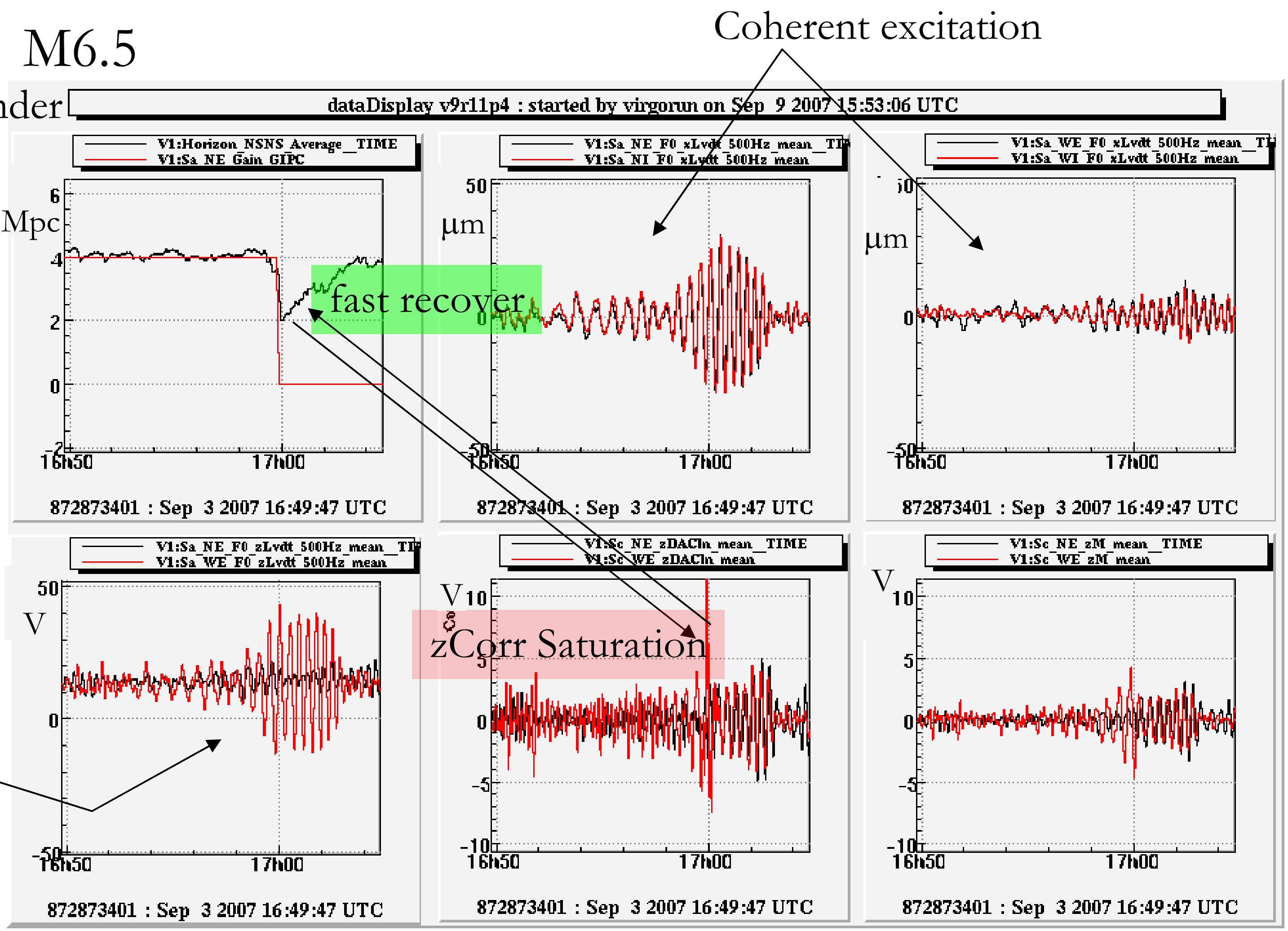
MSC Vs robustness (1): earhquakes/H^{NSNS} drops/EQG patch

M6.5

GIPC cannot be used under coherent excitation (far EQ*)

An automated Guard to disable GIPC: EQG

Top-stage corr. from locking



4-min to recover H instead of 30-40 min without EQG

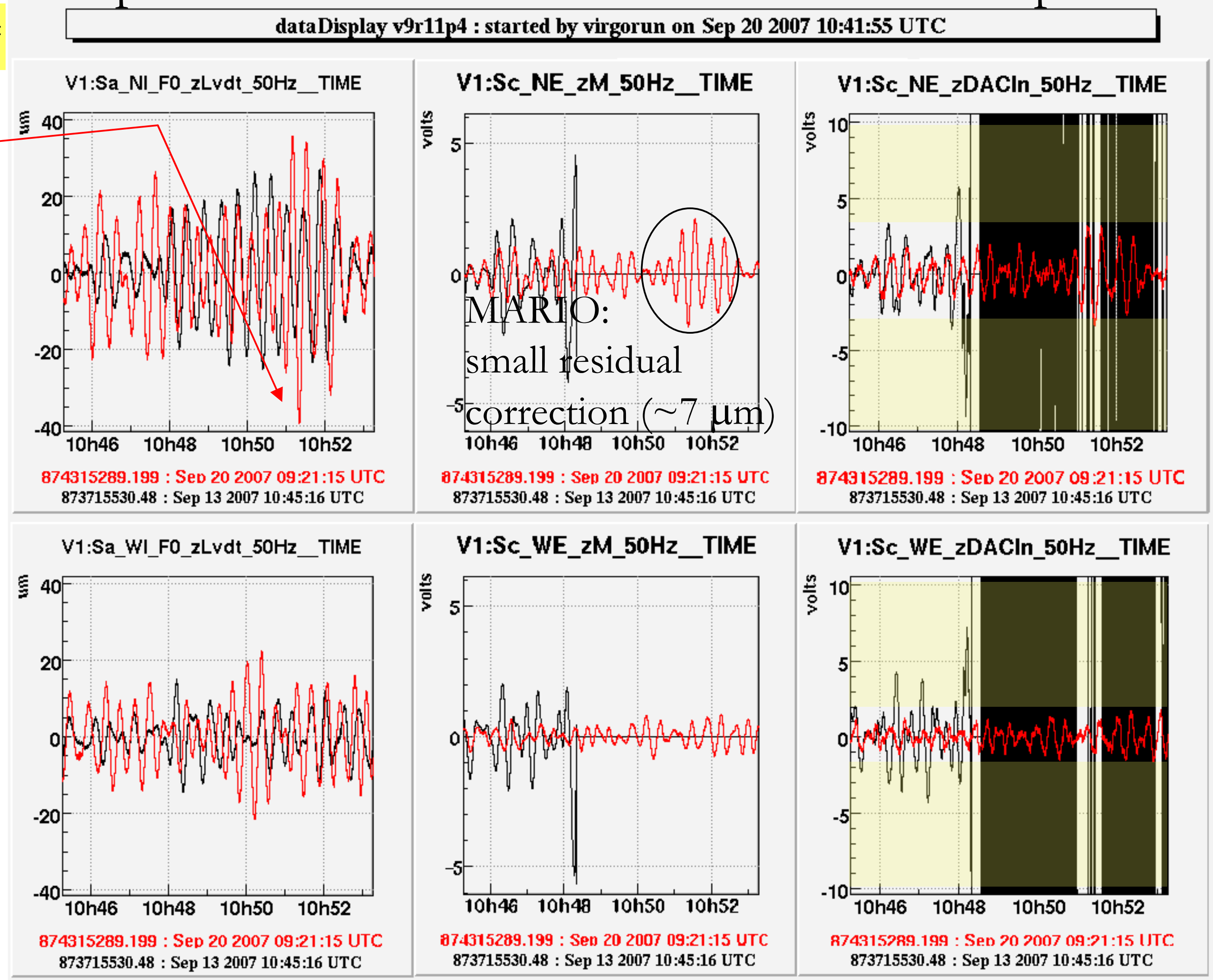
(*MSC talk at LSC-Virgo May07, plenary):

MSC Vs rrobustness (2): earhquakes/stable GIPC

Comparison of two events with similar local amplitude

A “lucky” occurrence !*

40 μm peak



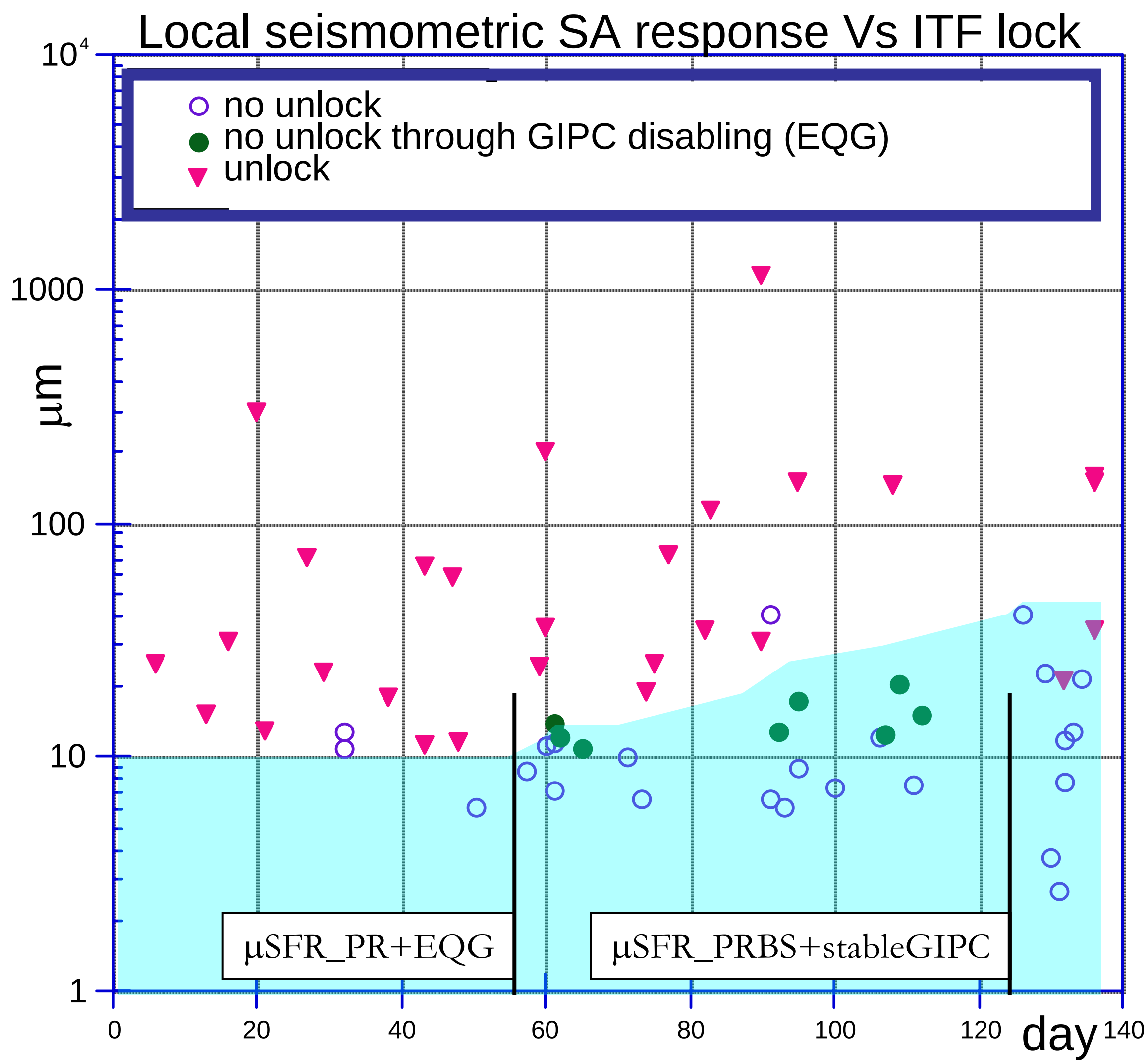
Previously we had saturation as the amplitude was less than **20 μm**

The system is much more robust .

Correction dynamics more than doubled.

(*Indonesia M6.8, Sep-20-08.31):

MSC Vs roboustness (3): earhquakes overall

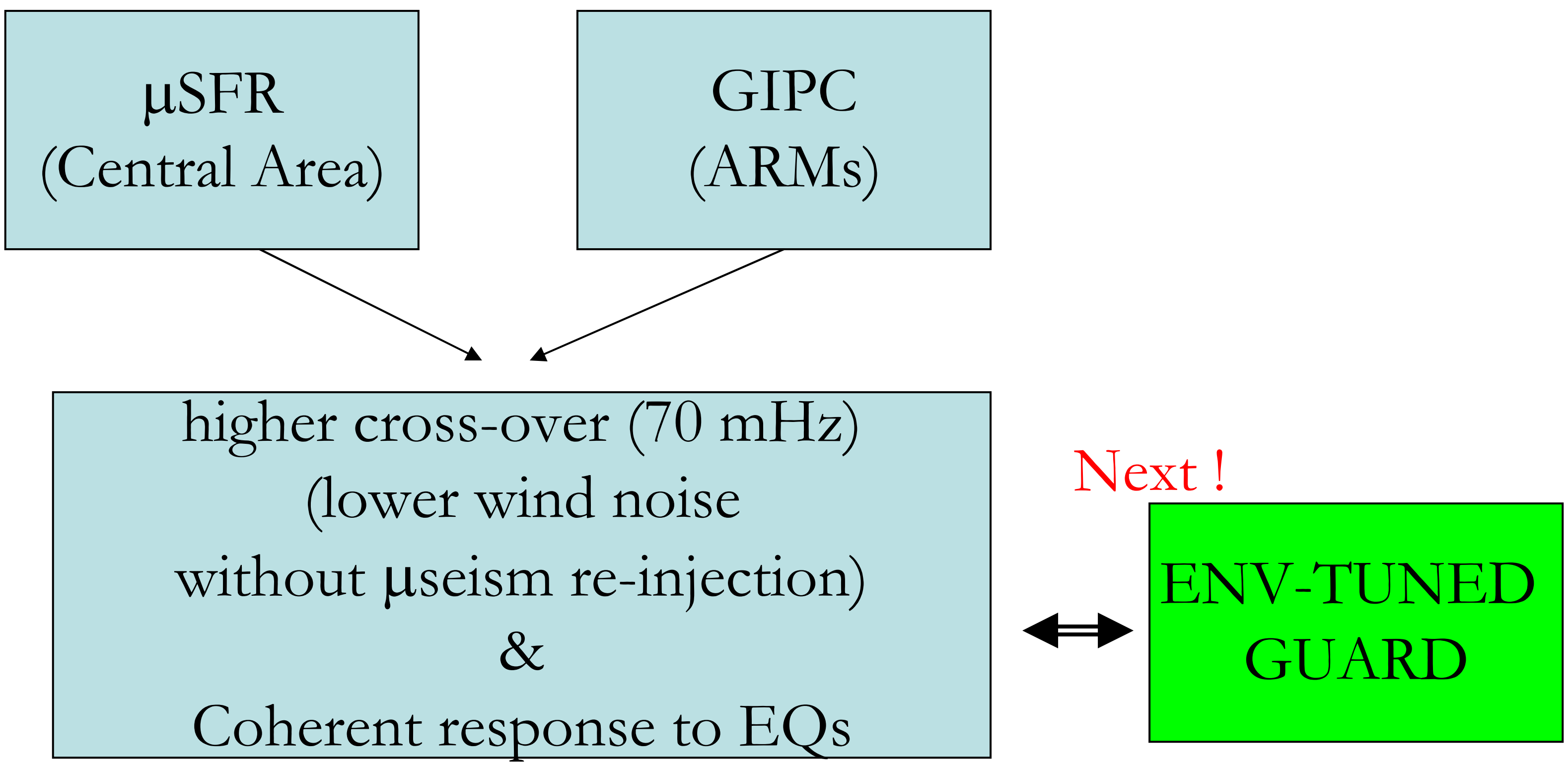


EQG action no longer needed. We use EQG as alarmed on-line seismometer

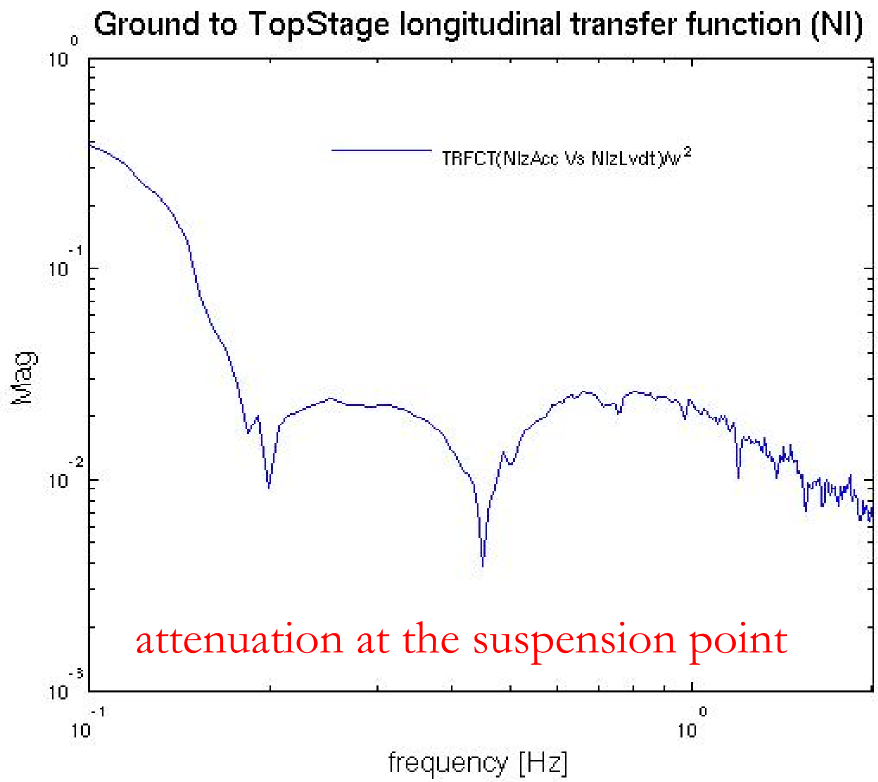
Sub-conlcusion II

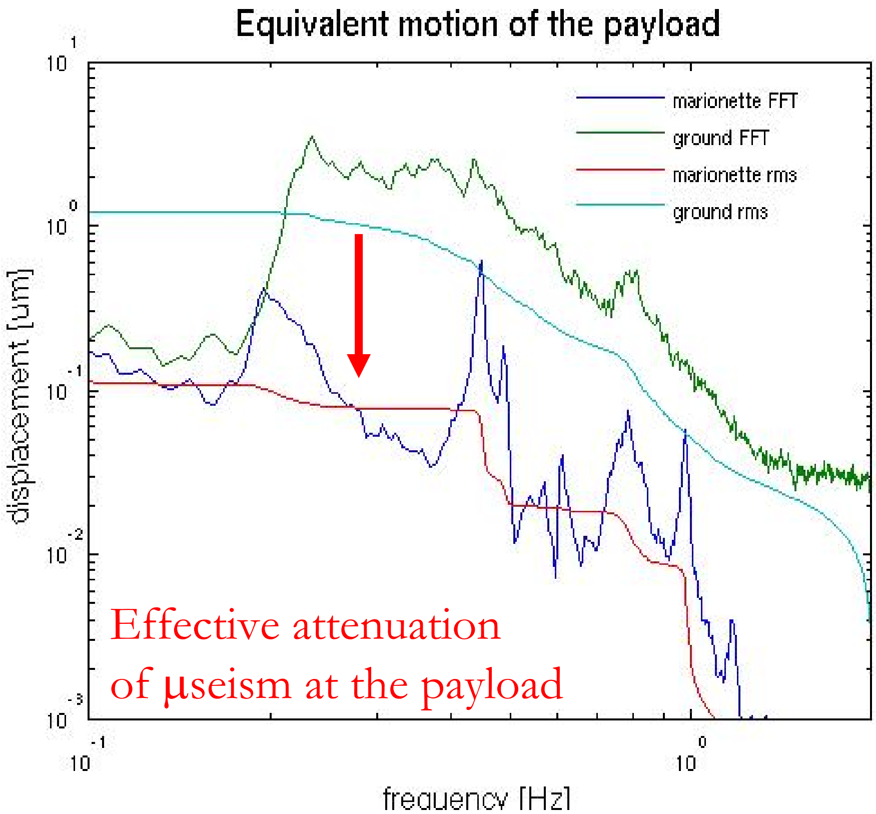
Top-stage control strategies involving suspension operation **as-a-whole** improve disturbance rejection capability.

EQ GUARD used in monitor mode.



MSC Vs µseism (3) : main path/payload motion

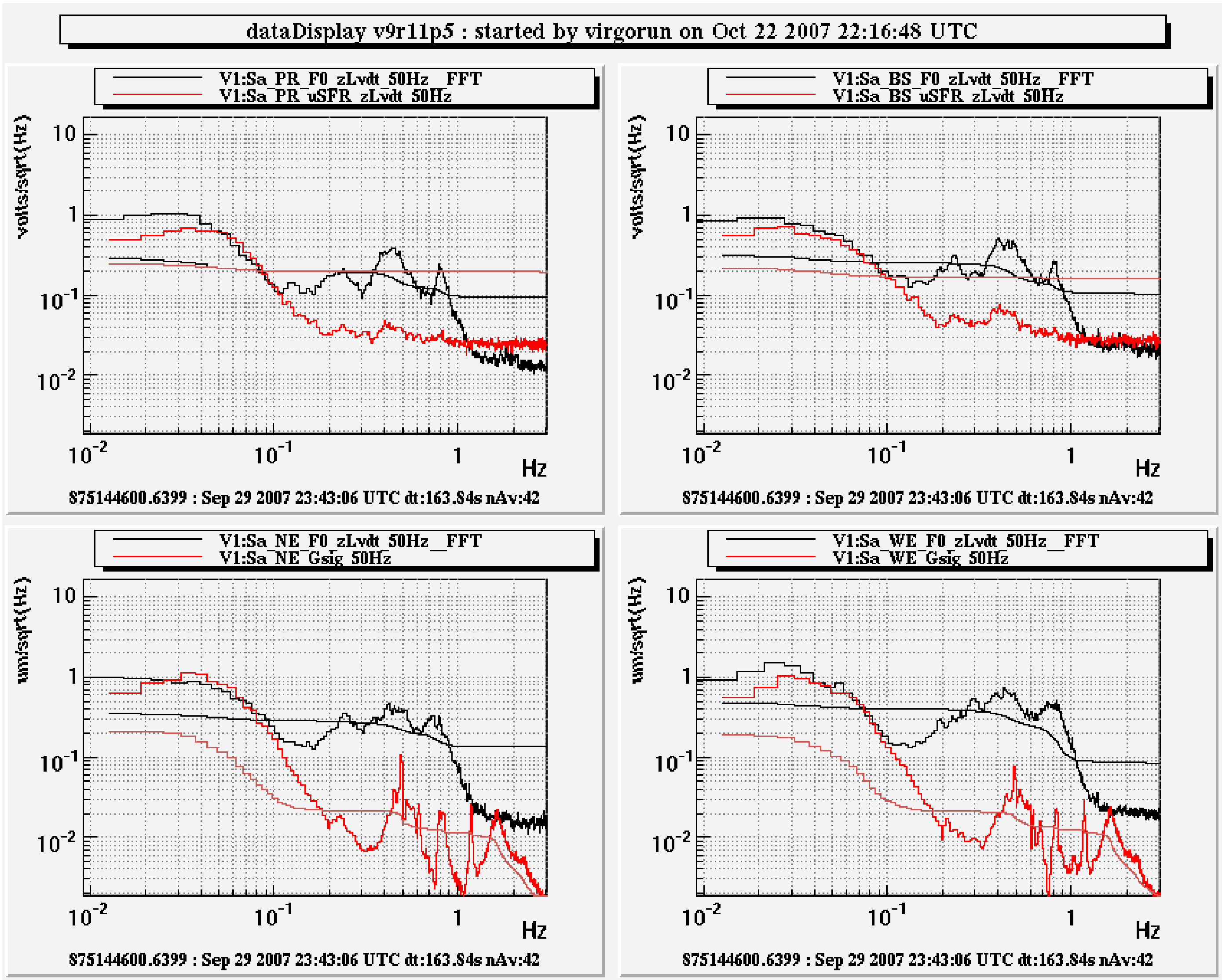




The lock force applied to the marionette corrects the residual payload motion, whose rms above 100 mHz is ~ 1 order of magnitude smaller than the ground motion.

MSC Vs µseism (4) : rejection VSR1start-VSR1stop

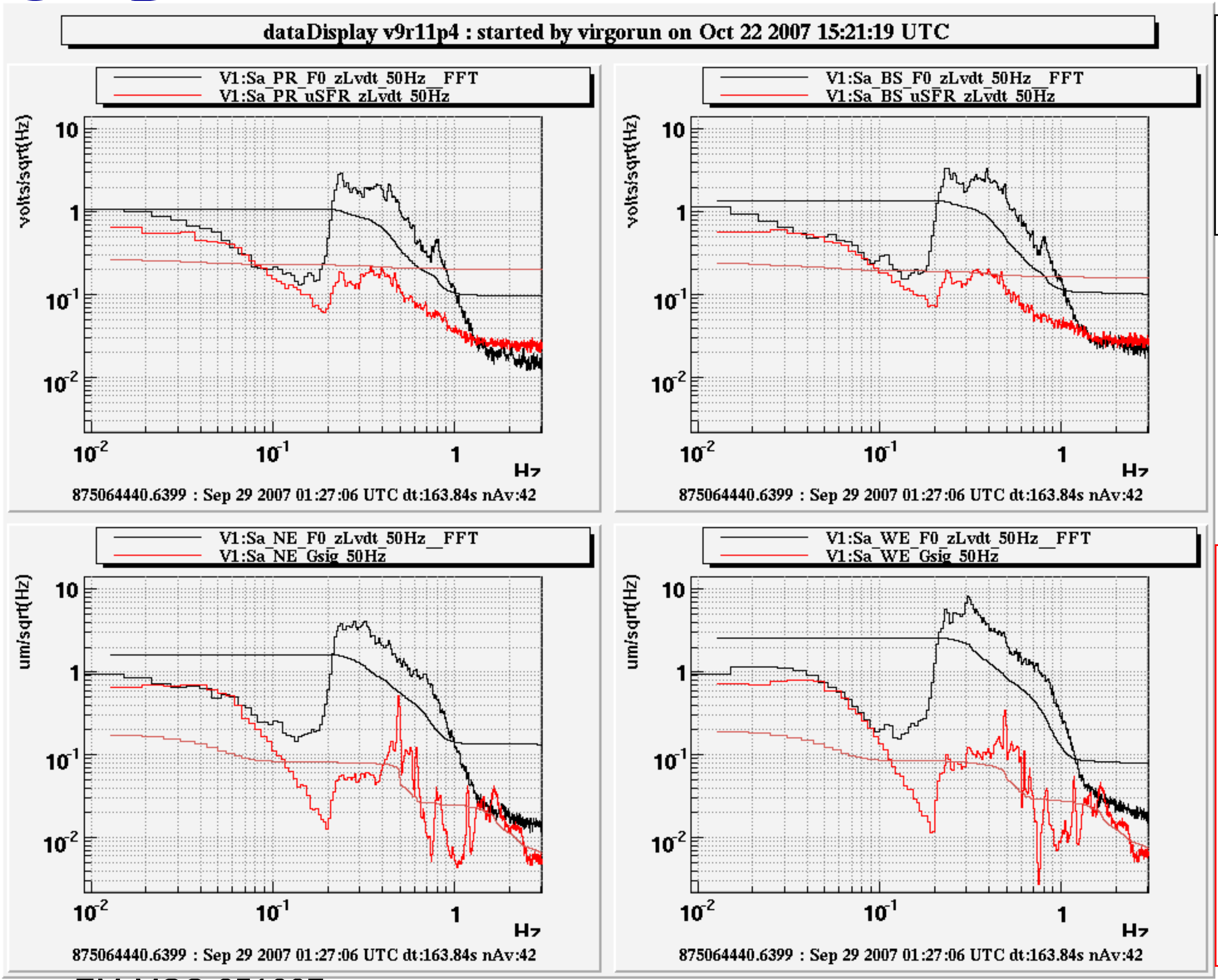
quiet



Monitoring of channels used for top-stage control at VSR1 start setup.

Combined channels used at VSR1 stop: **µSFR** (µSeism-Free Reconstruction) and **GIPC** (Global-Inverted-Pendulum Control)

MSC Vs µseism (5) : rejection VSR1start-VSR1stop



Monitoring of channels used for top-stage control at VSR1 start setup.

Combined channels used at VSR1 stop:
µSFR (µSeism-Free Reconstruction)
and
GIPC (Global-Inverted-Pendulum Control)

MSC Vs µseism (1): high µseism day during VSR1

µseism decrease | Horizon increase | unaddressed noise bump

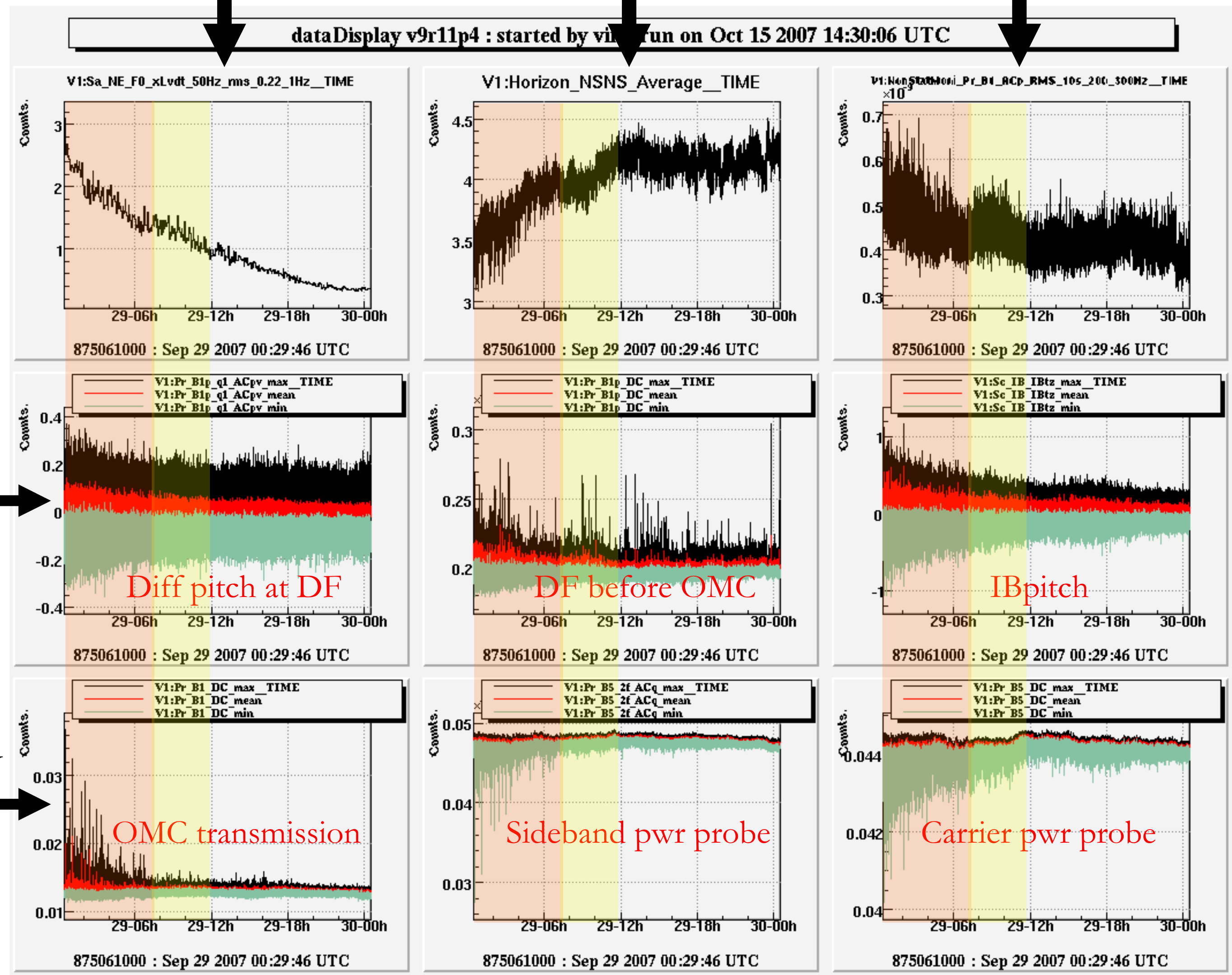
µseism > 1.5 μm_{rms}
Sensitivity ↘ stability ↘

1< µseism < 1.5 μm_{rms}
Sensitivity ↘

µseism < 1 μm_{rms}:
No effect

main misalignment indicators

main stability indicators



Noise impact study using VSR1 data and sub-conlcusion III

Higher gain for injection bench angular control (pitch) necessary to **improve stability** during high sea activity.

Even though the μseism disturbance is the the range of suspension resonant frequencies, the overall impact at the level of the mirror is relatively small:
a factor 10 of rms at the ground worsens by a factor 2 the accuracy of controlled signals at the ITF level.

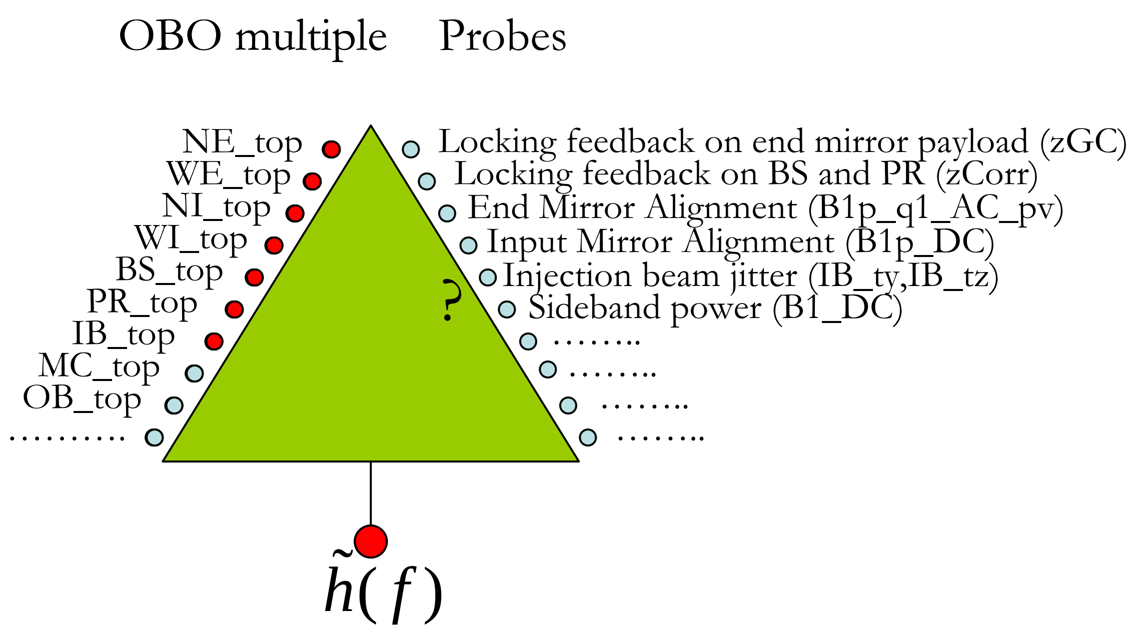
What is the coupling path ? →

III. Noise issues

IV. Post-VSR1 considerations and perspective.

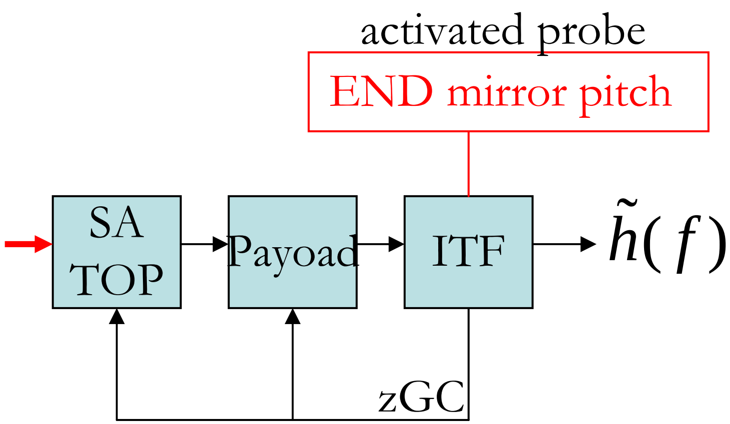
OBO: attempts for systematics

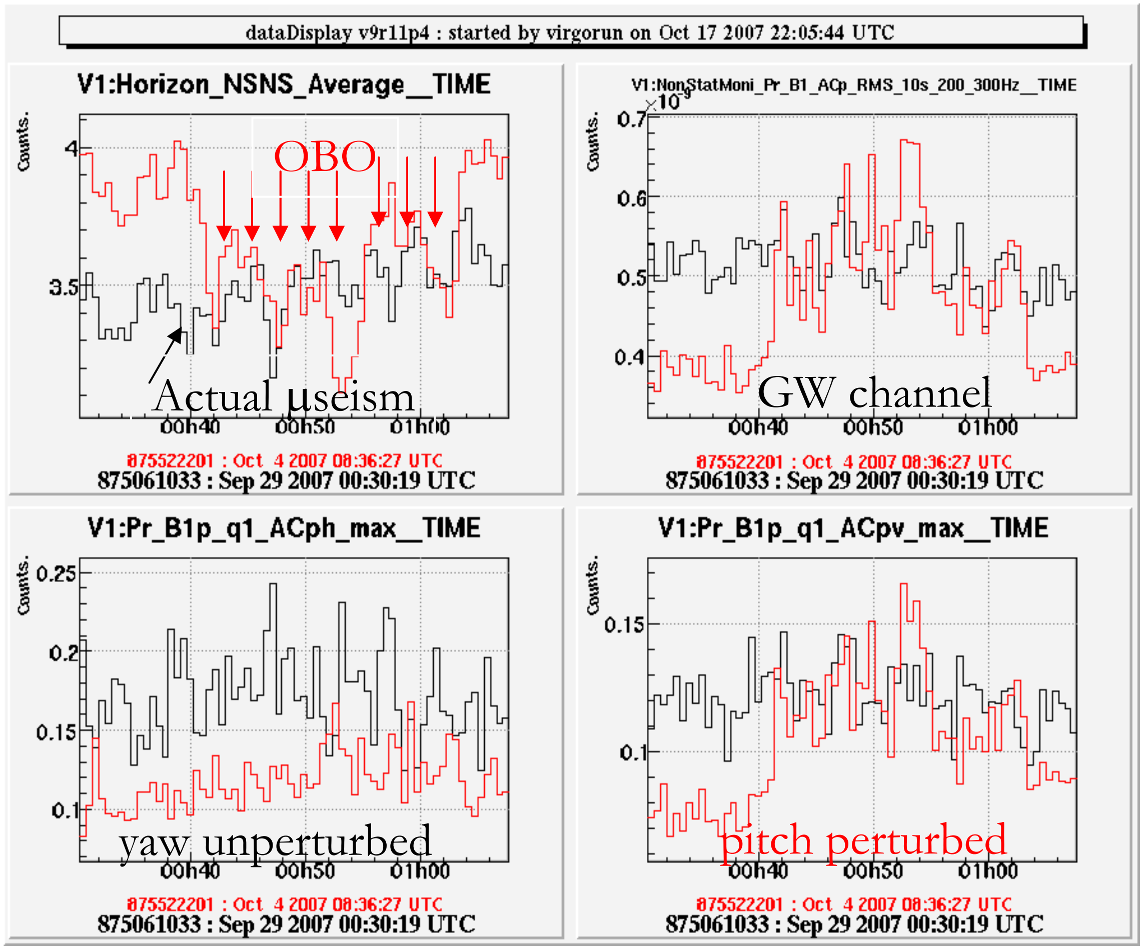
One-By-One injection
to mimic μseism disturbance occurred during VSR1



4 entry-points: END, INPUT,BS,PR,ISYS
3 d.o.f: longitudinal (z), transversal (x), vertical (y)

OBO: injection at NE-WE top-stage, a "positive" clear result.

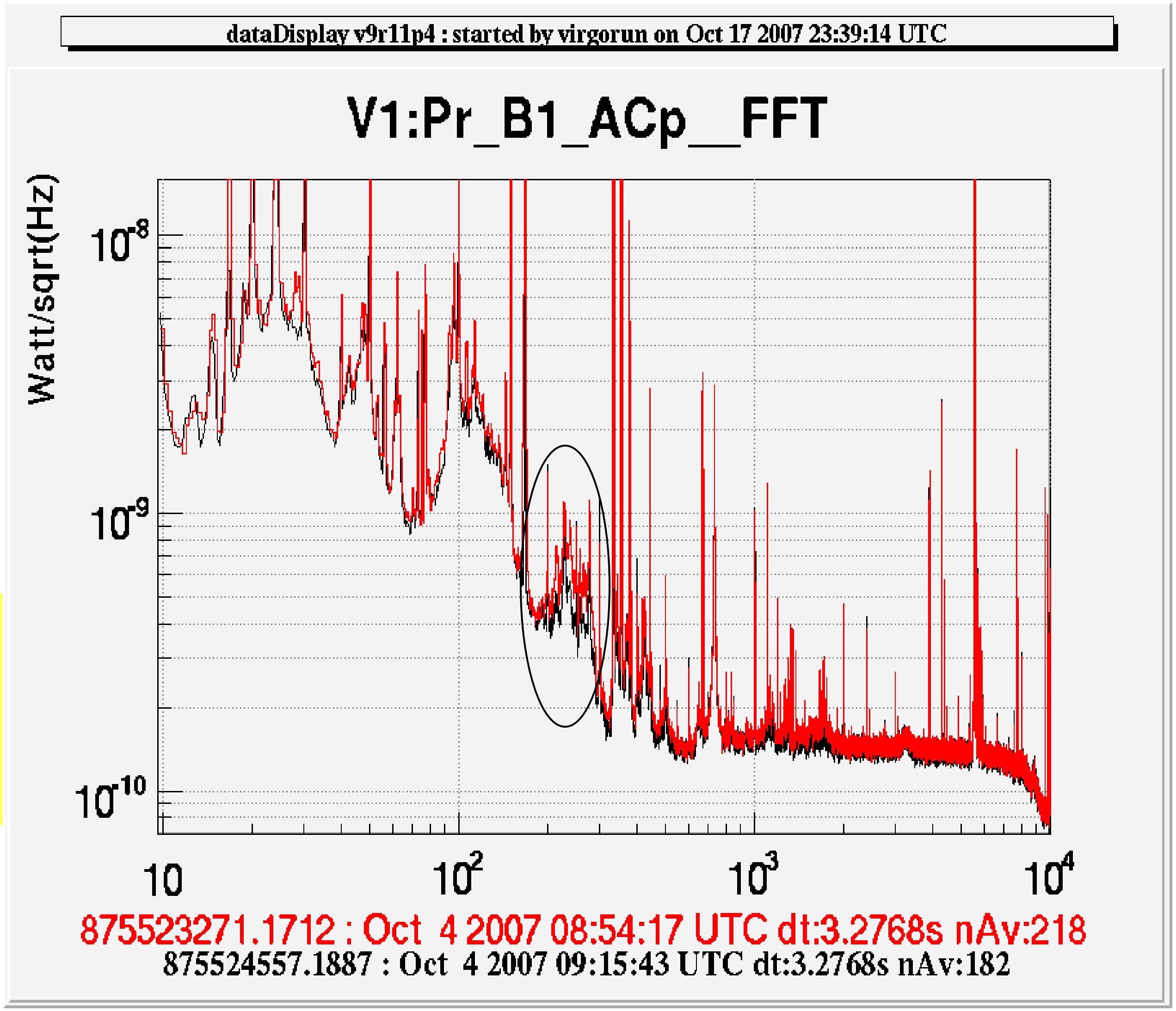




An efficient way to produce Horizon drops similar to actual one as µseism rms is ~ 3 µm is through mirror pitch noise (consistent with VSR1 experience).

significant effect 200-300 Hz

Injection @ NE-WE

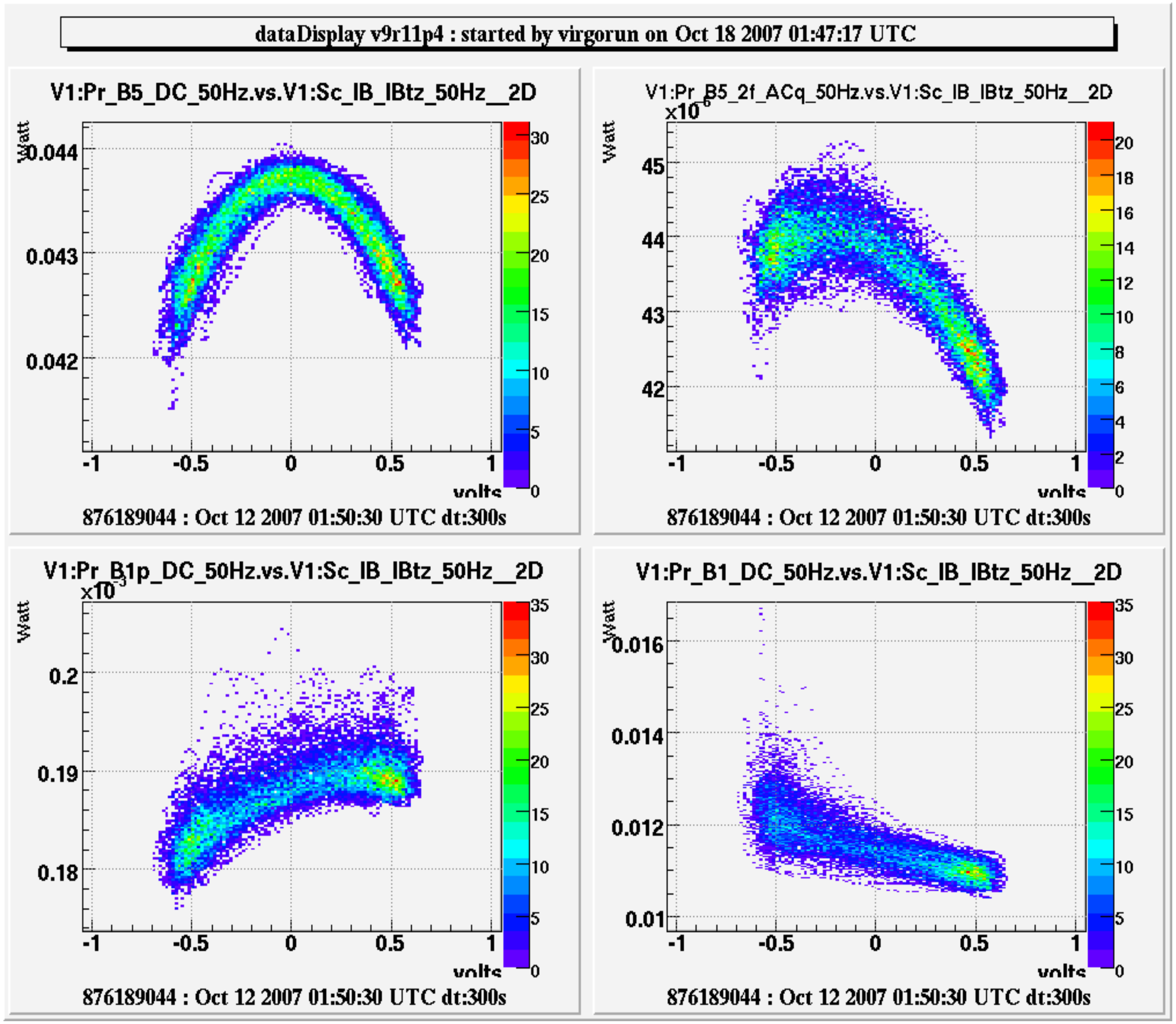


As expected, due to GIPC, injections @ NI-WI produce very similar effects.

OBO: injection at IMC top-stages

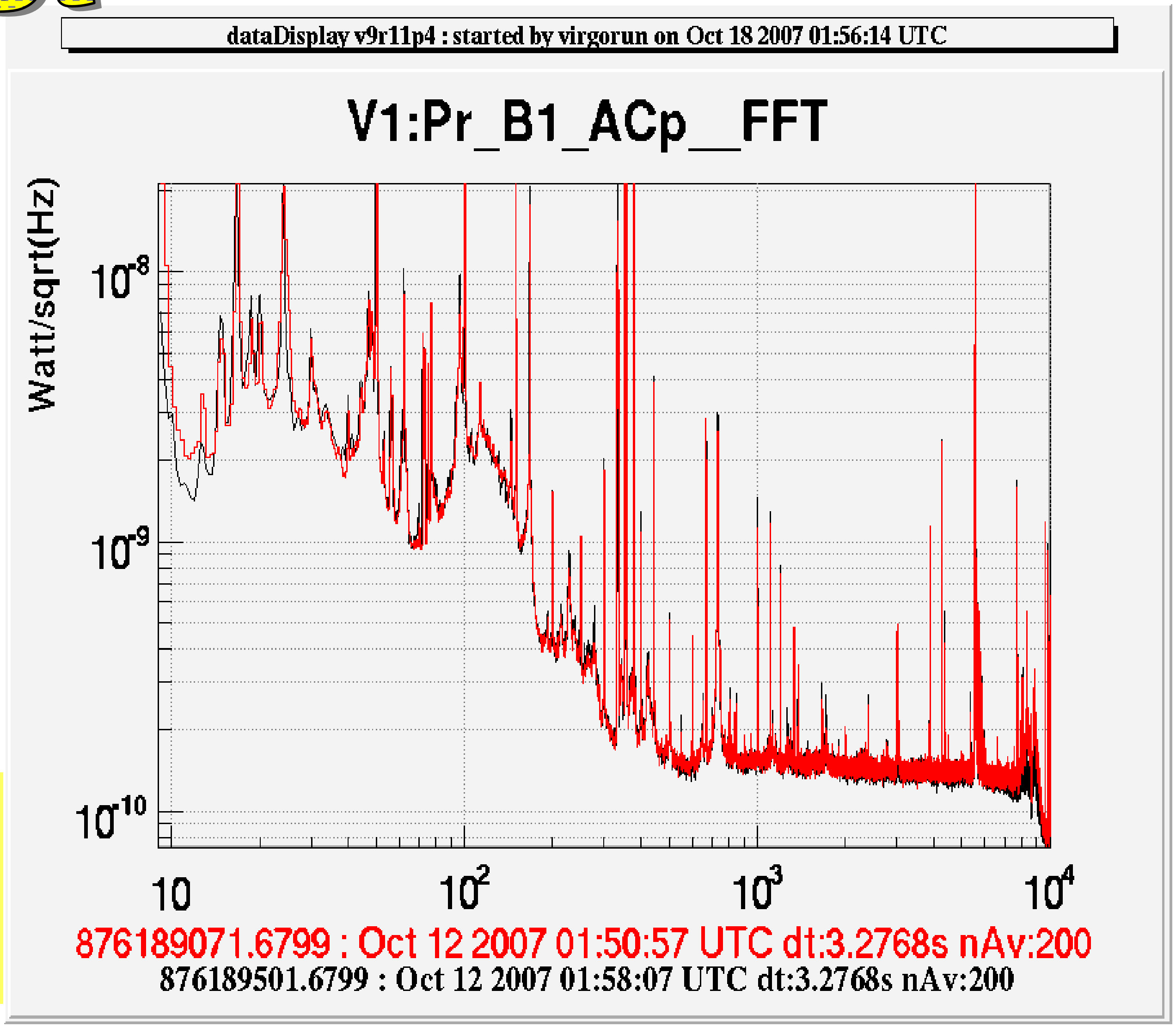
Very difficult to excite the IB simply injecting pseudo μSeismic noise at the top-stage.

Power fluctuations close to the actual ones only by using a strong line, tuned on IB main pitch mode.



no effect

Injection @ InputMC



a surprisingly "negative" clinical result, Some hidden path…

Sub-conlcusion IV and summary

In spite of suspension resonances, normally there is no environmental µseismic effect on the sensitivity.

High µseism means that the ground shake in the range 0.2-0.7 Hz can increase **up to 10 times**, worsening mirror control signals by a factor **2**.

Two main effects

ITF Power fluctuations

Improvement of IB angular control (coming soon)

Specific coupling with sensitivity due to diff.pitch

In order to cope with a noise bump at 200-300 Hz (that should be removed) we can:
- **decrease** the gain demand to alignment control (by setting input mirrors under AA)
- **improve** the strategy (higher LVDT/Acc crossover and tuned reallocation techniques).

Quite reasonably achievable to gain a factor 2

Not used

STANDARD CONFIGURATION FOR LONG SUSPENSIONS

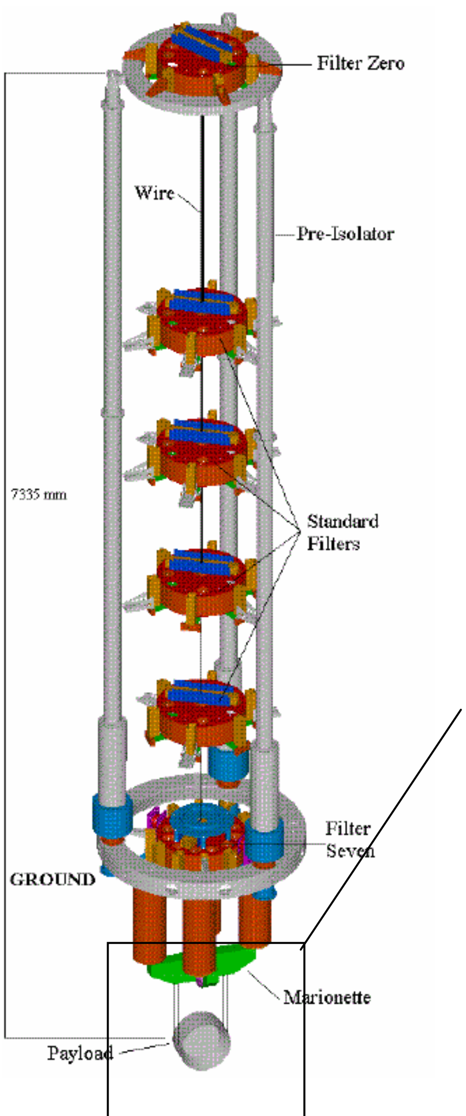
stage	variable	actuator ref
SA TOP	**Pos/Accel** 3D+yaw	Ground(~)/stars
SA BOTTOM	**Position** yaw	Ground
PAYLOAD	**Position** 2D+pitch/yaw	SA BOTTOM

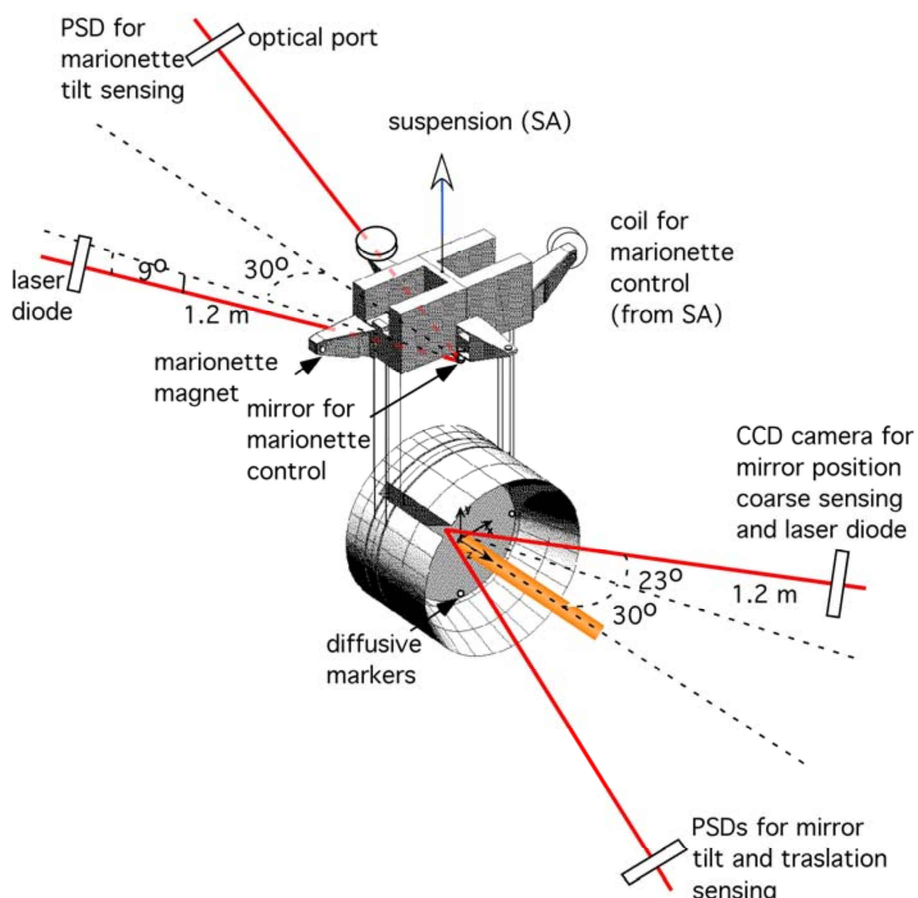
Basic requirements: sensing and actuation diagonalization

+

hiearchical control

Virgo “standard-super-attenuator”suspension …

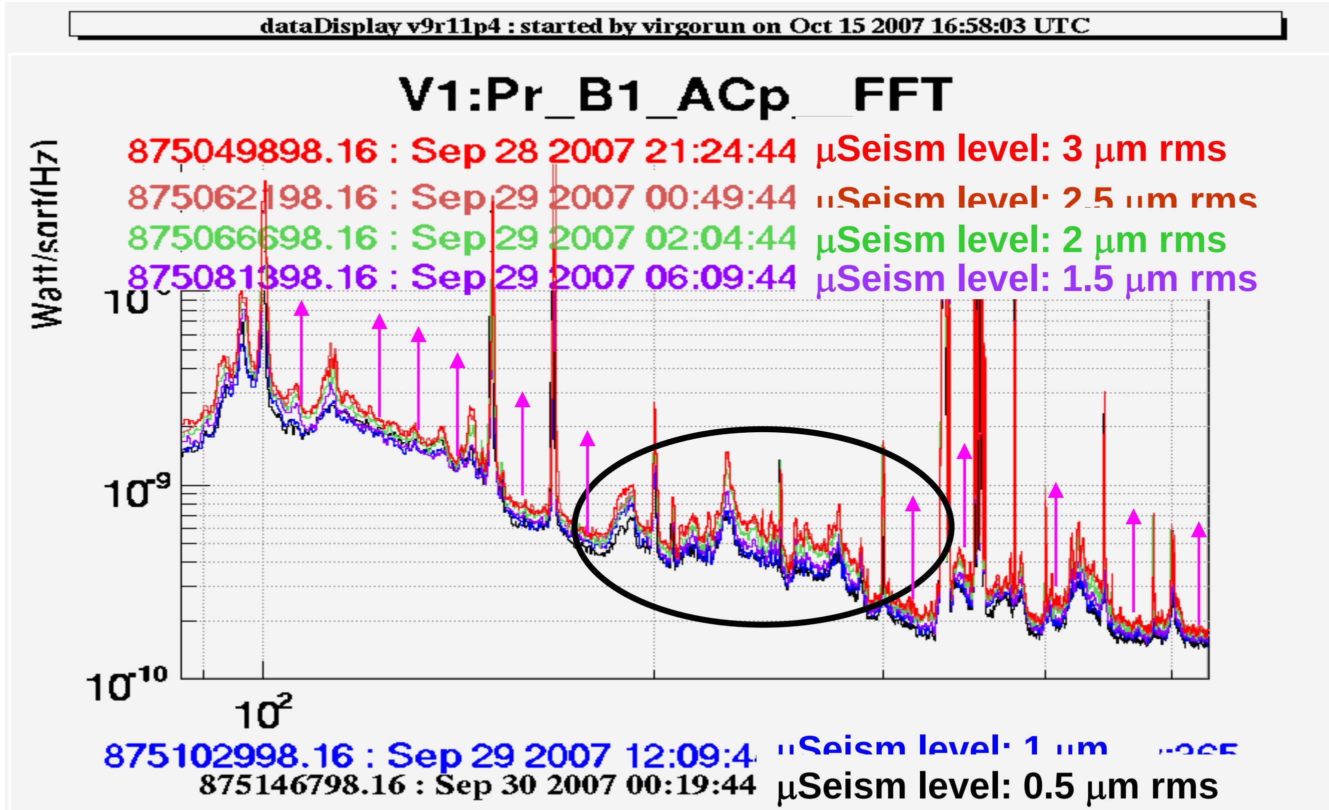




Soft isolator concept:

1. very efficient passive attenuation
2. active controls for normal mode damping

μseism Vs VSR1 sensitivity: quicklook to the data/ μseism > 1.5 μm_{rms}

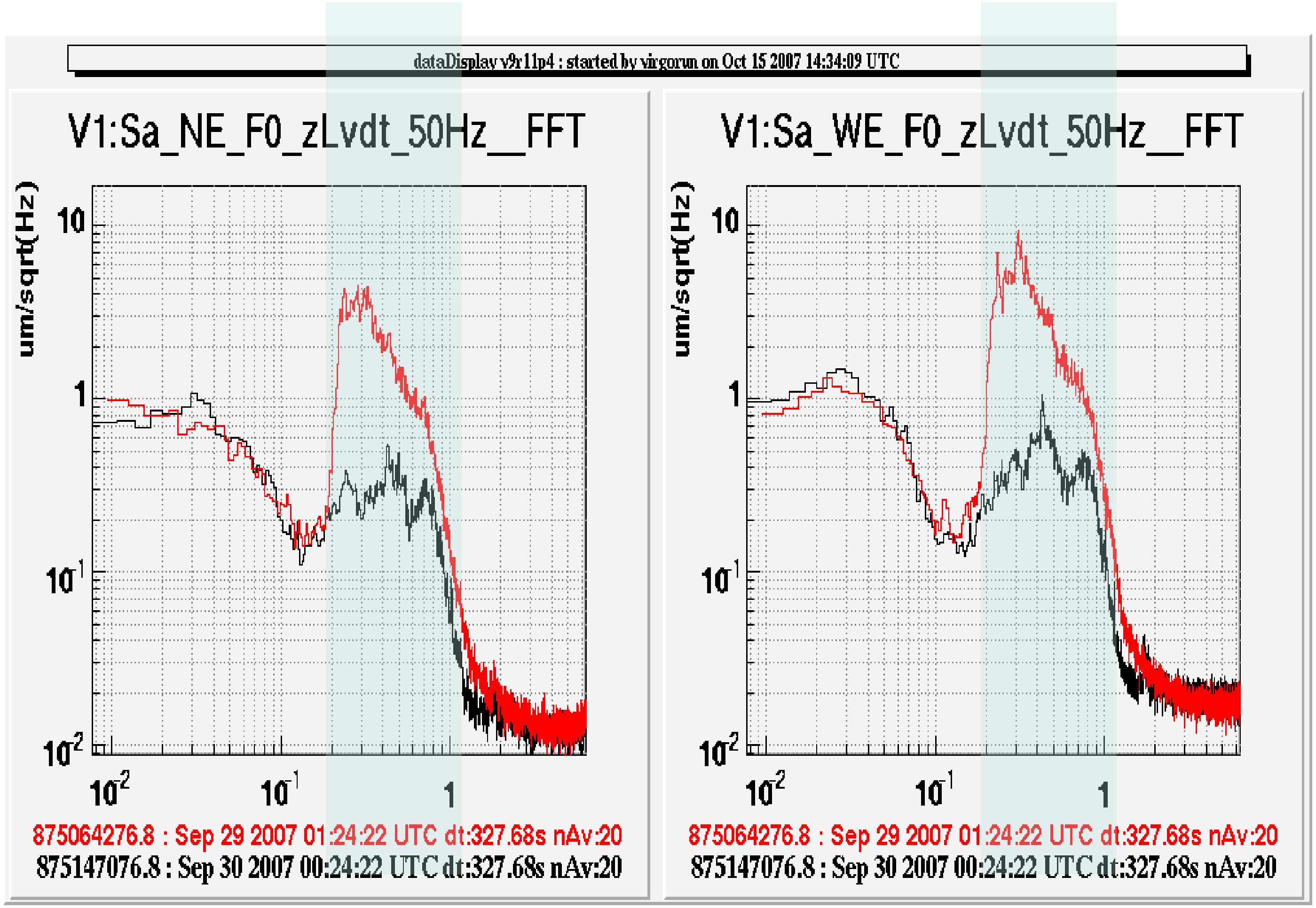


100-500 Hz: power fluctuations due to injection misalignment driven
+
specific bump coupled to ITF pitch misalignments

Other features:
10-100 Hz: glitches uncorrelated to power fluctuations
500-10000 Hz: small noise floor fluctuations well correlated to power fluctuations

MSC Vs μseism (2): main path/ground excitation

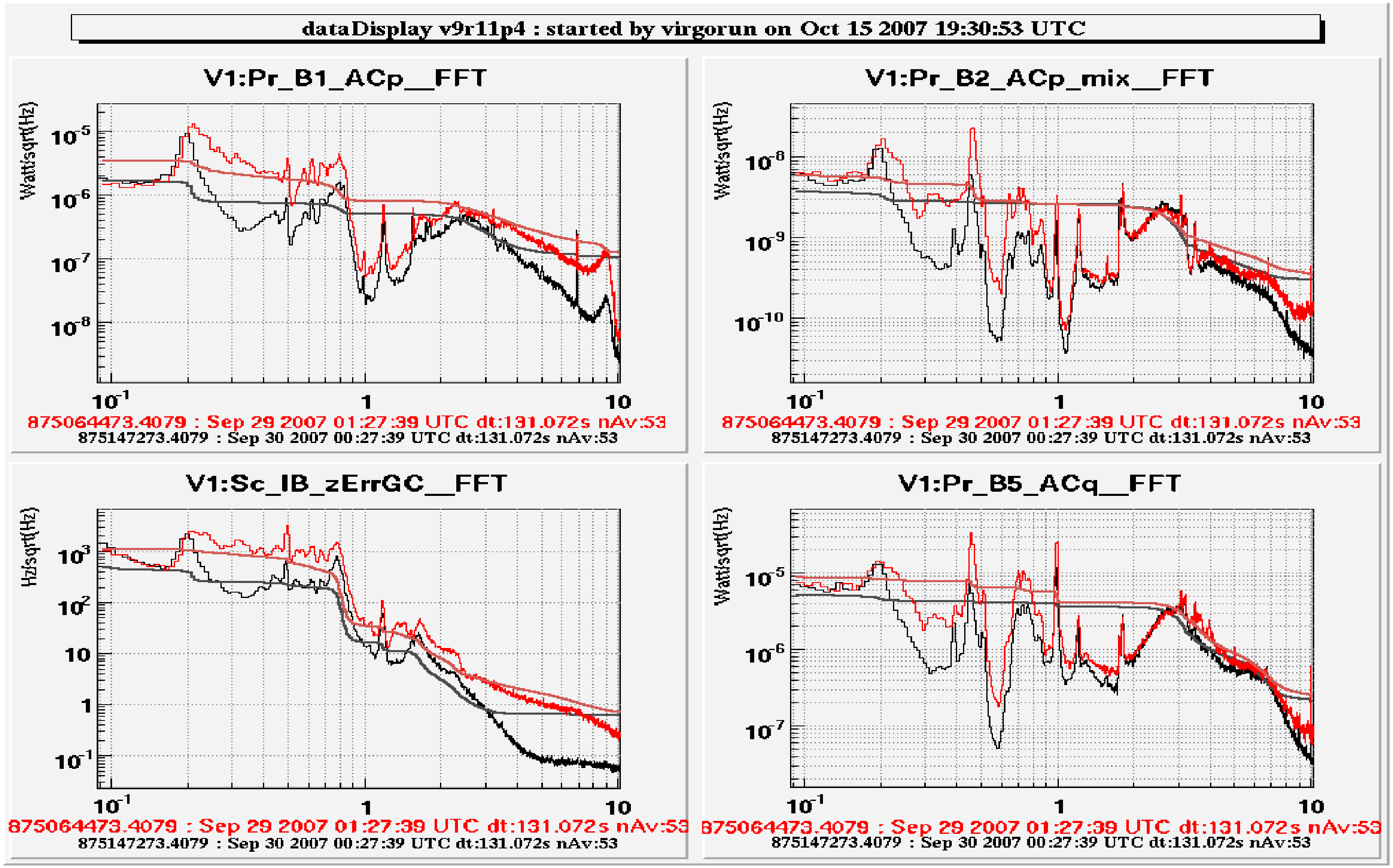
LVDT sensor measures the position of top-stage suspension point (top of the IP) with respect to a grounded rigid mechanical frame.



Top-stage LVDT channels provide the best measurement of ground noise

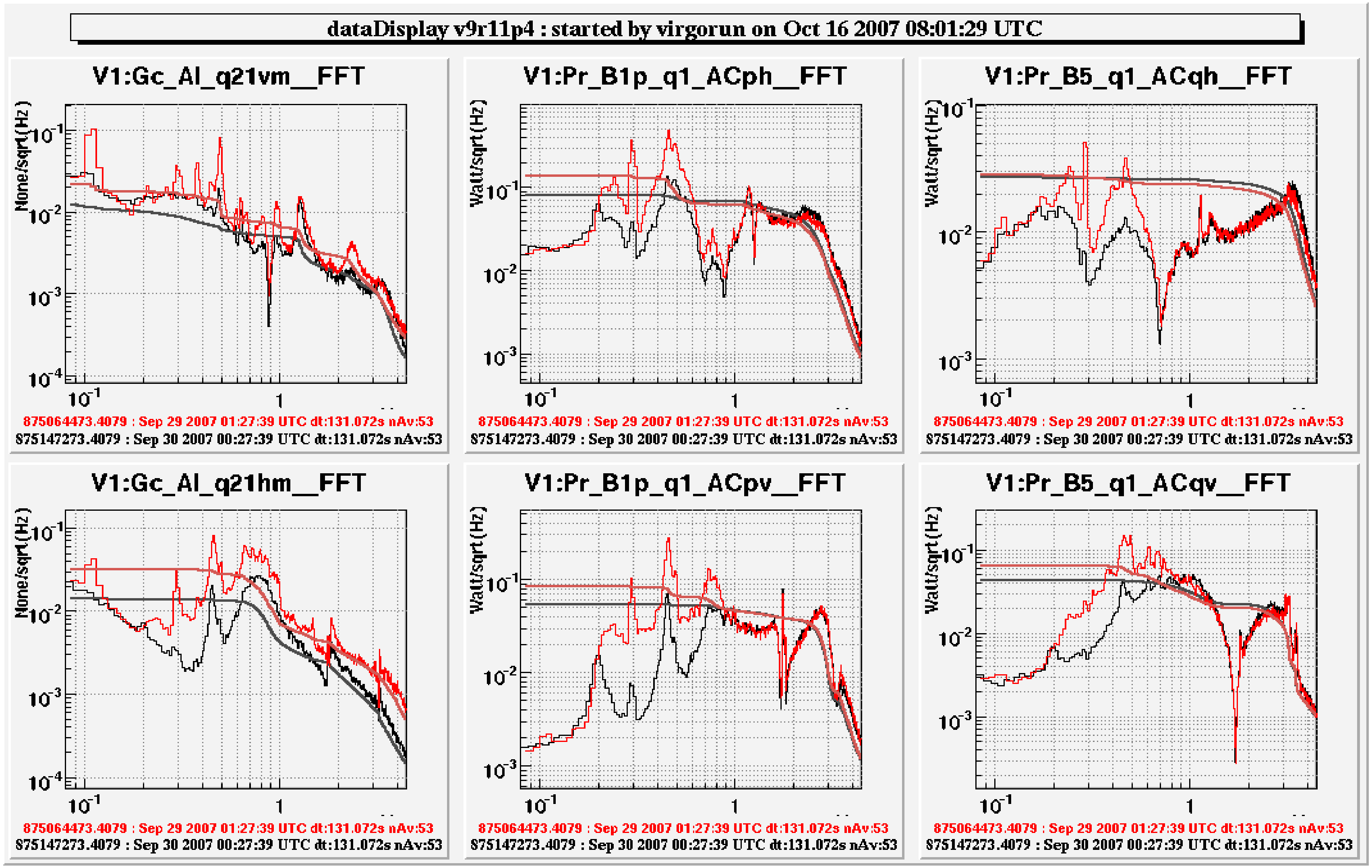
MSC Vs µseism (6) : residual impact

Impact on the ITF longitudinal error signals



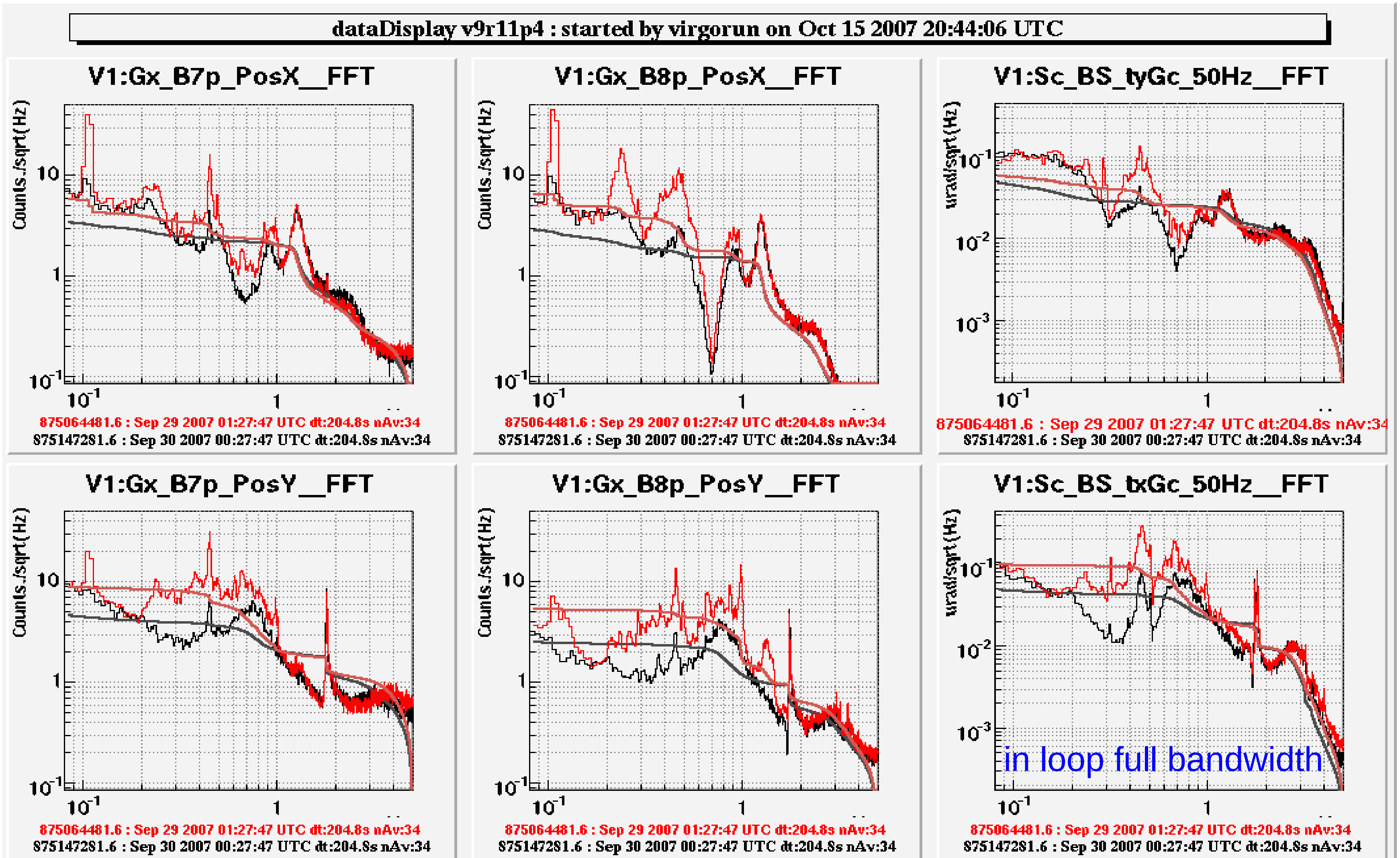
MSC Vs µseism (7) : residual impact

Impact on the ITF angular error signals, in loop full bandwidth



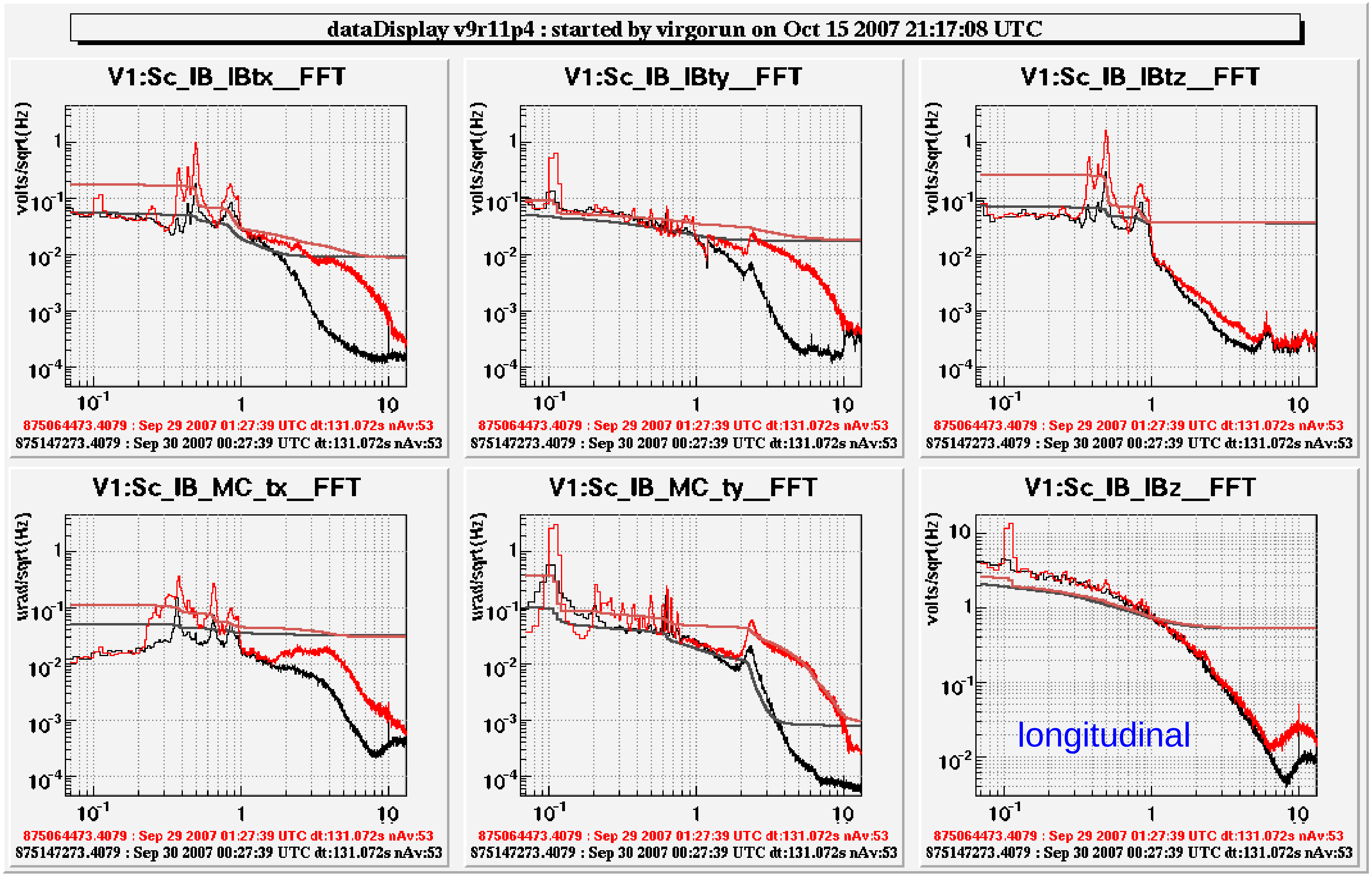
MSC Vs µseism (8) : residual impact

Impact on the ITF angular error signals, DC controlled



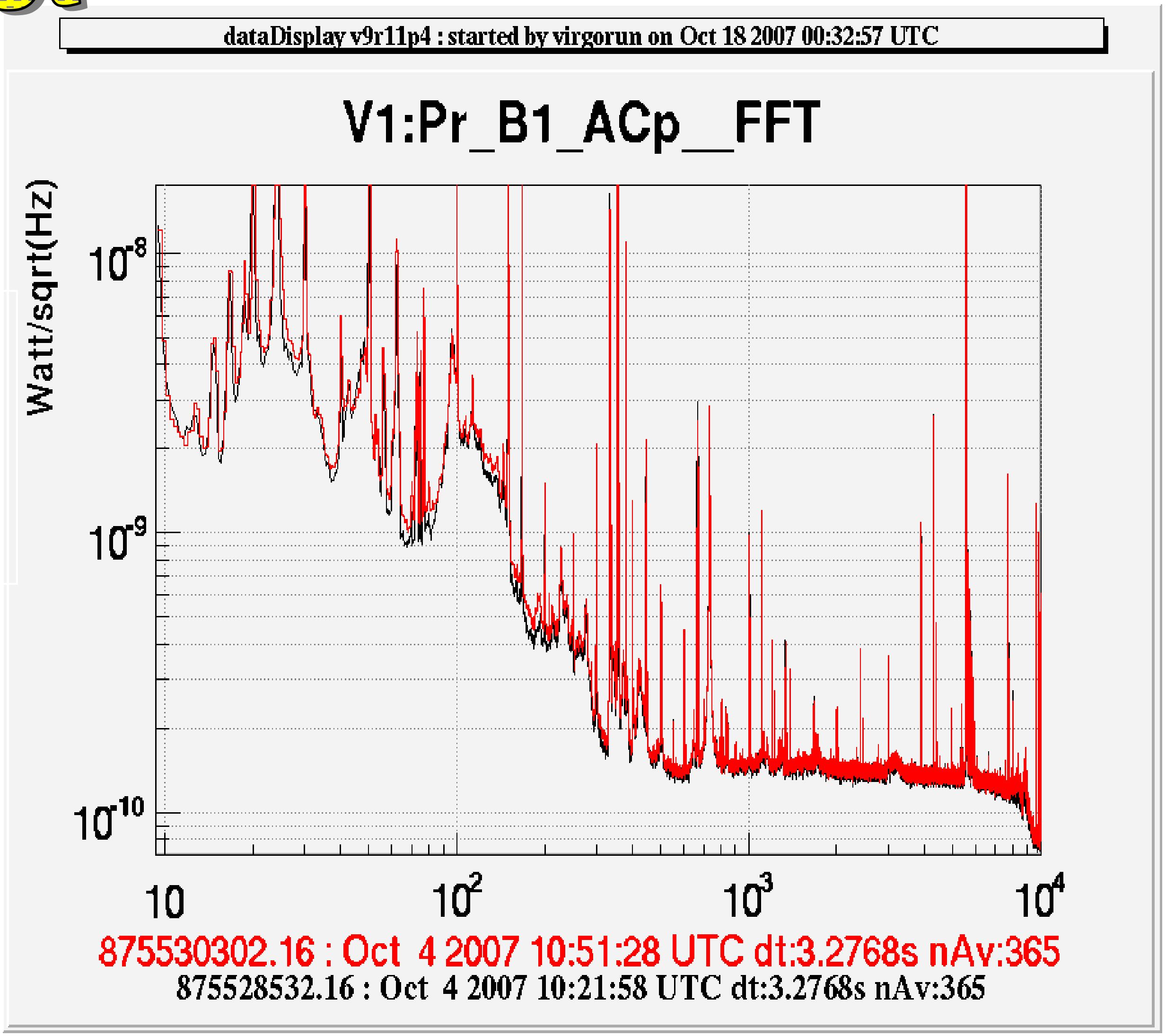
MSC Vs μseism (9) : residual impact

Impact on the IMC angular error signals, in loop



Injection @ BS

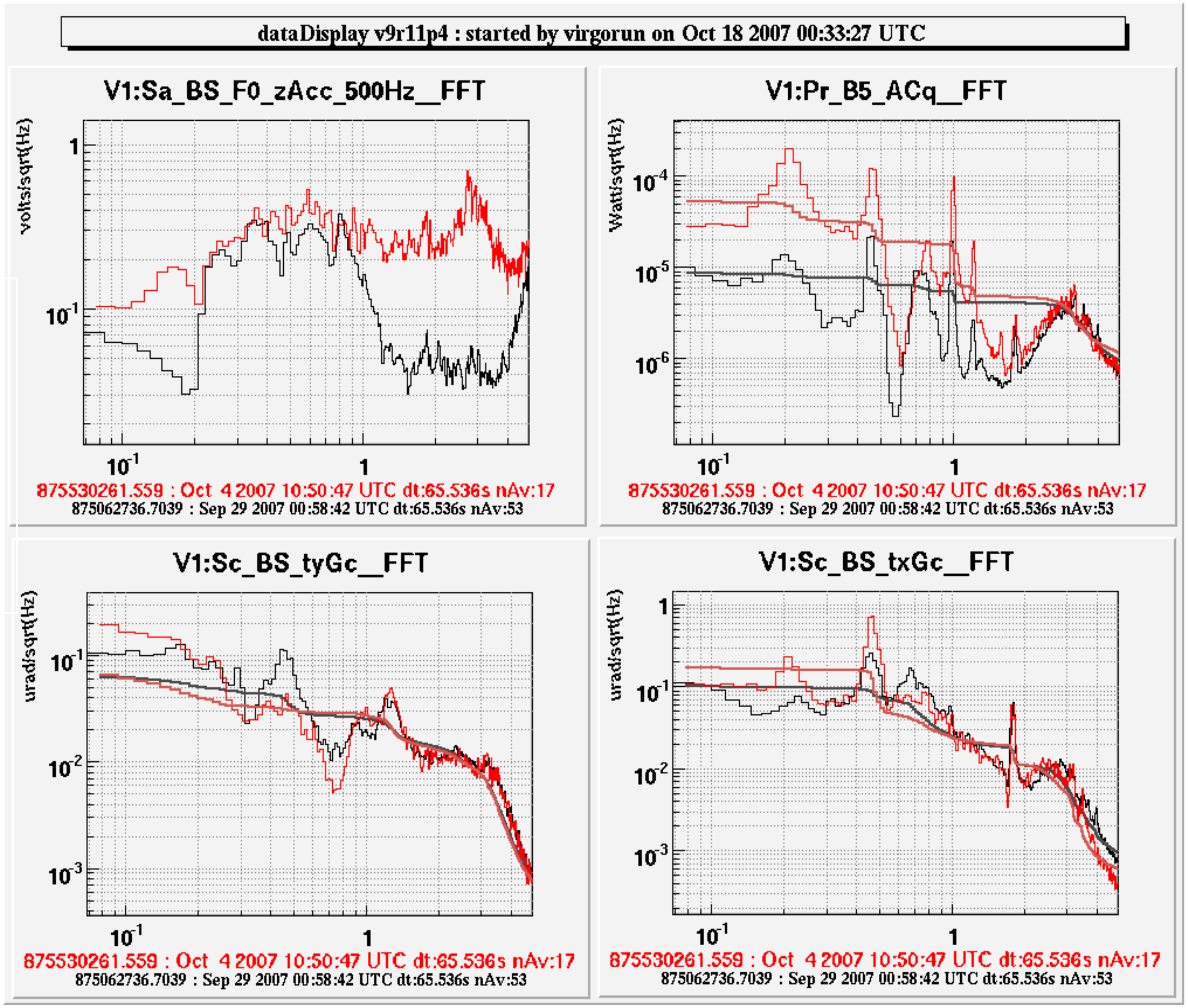
small effect



Not enough to explain the noise in actual condition, considering that the applied disturbance was much larger in OBO tests.

Noise injection at BS suspension top-stage

With a similar excitation of the top stage, the longitudinal accuracy is much worse.
The angular motion is larger in tx, smaller in ty.



Noise budget now + what next? (E. Tournefier)

Control noises: further reduction

- sensing/driving matrices improvements / 8 MHz?
- angular control filters/ better signals with new end benches telescope

Actuator noise is not far at low frequency => new coil driver (more filtering)

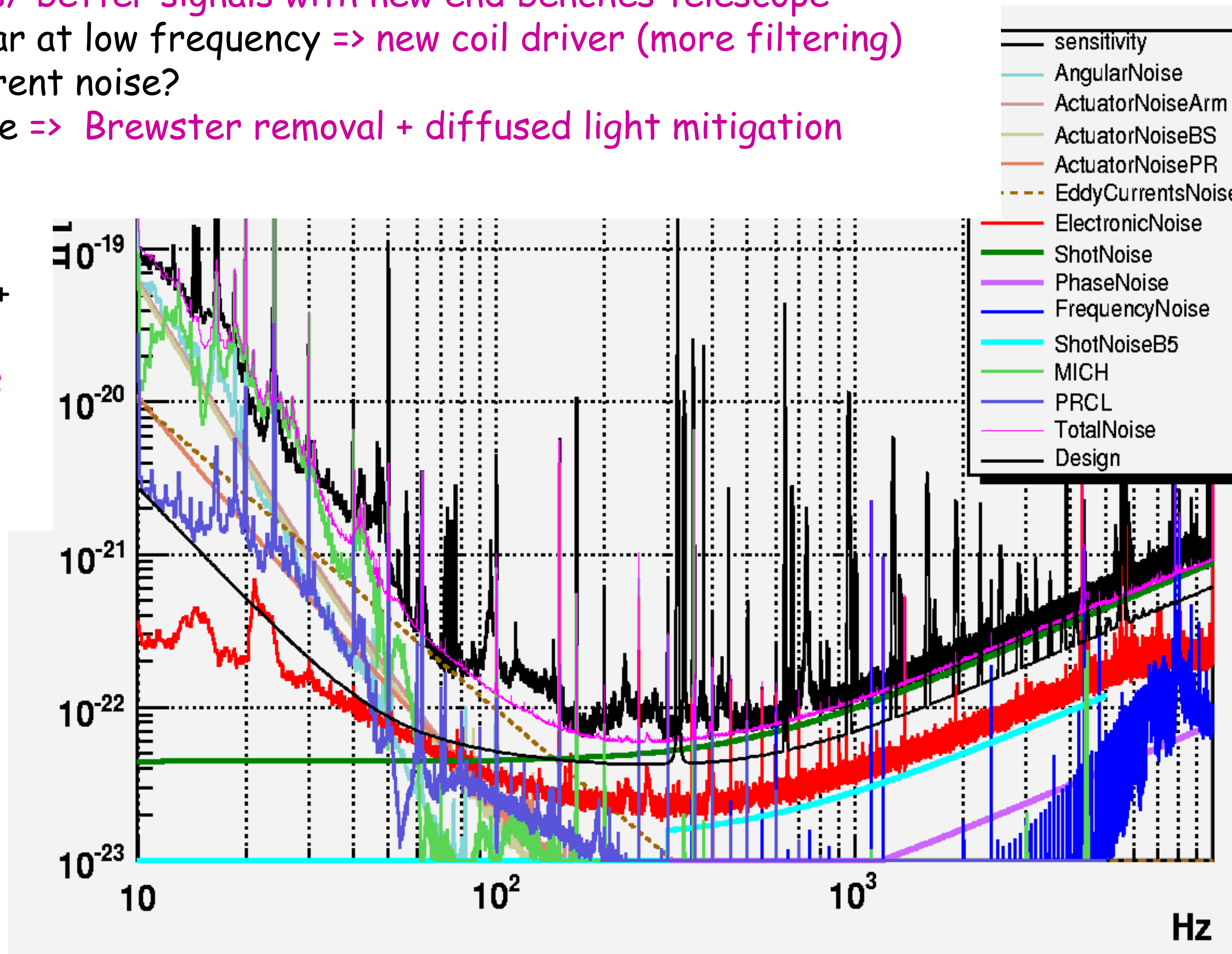
Where is the Eddy current noise?

Remaining mystery noise => Brewster removal + diffused light mitigation

700 Hz monster??

Cleaning of the mirrors + TCS

will the error signals get cleaner?



EM-MSC-251007