

G-GranSasso-DS

P. Menotti e E. Vicari referee interni 2011
L. Palladino A. Paoloni referees GV
G. Prodi G. Zavattini GII

M. Allegrini, J. Belfi, N. Beverini, F. Bosi, B. BouhadeF, G. Carelli, G. Cella, A. Di
Virgilio, I. Ferrante, E. Maccioni, F. Stefani **PI**

A. Ortolan **LNL**

M. Cerdonio e J.P. Zendri **PD**

A. Tartaglia e M.L. Ruggiero **TO**

B. A. Porzio e S. Solimeno **NA**

In collaborazione con

U. Schreiber, A. Gebauer et al. **BKG** and **TUM**

A. Velikozetsev **St. Petersburg**

J.P. Wells et al. Univ. **Christchurch NZ**

Fatto o in fieri

G-Pisa è installato a Virgo

Definizione della proposta G-GranSasso

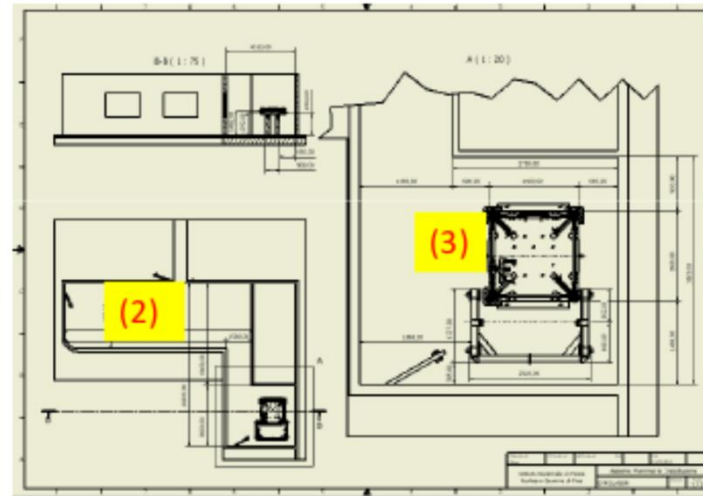
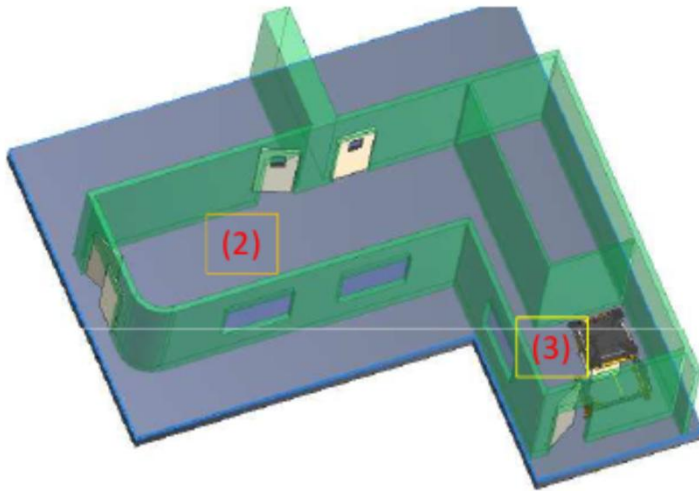
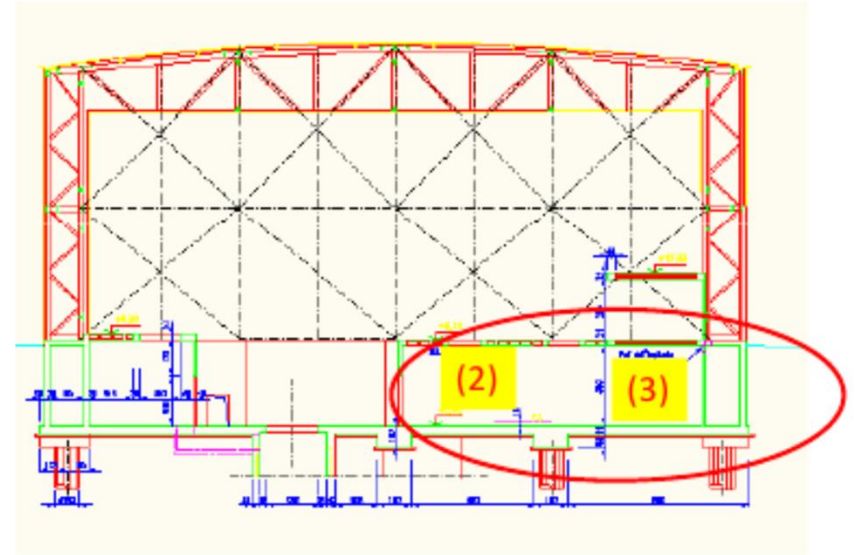
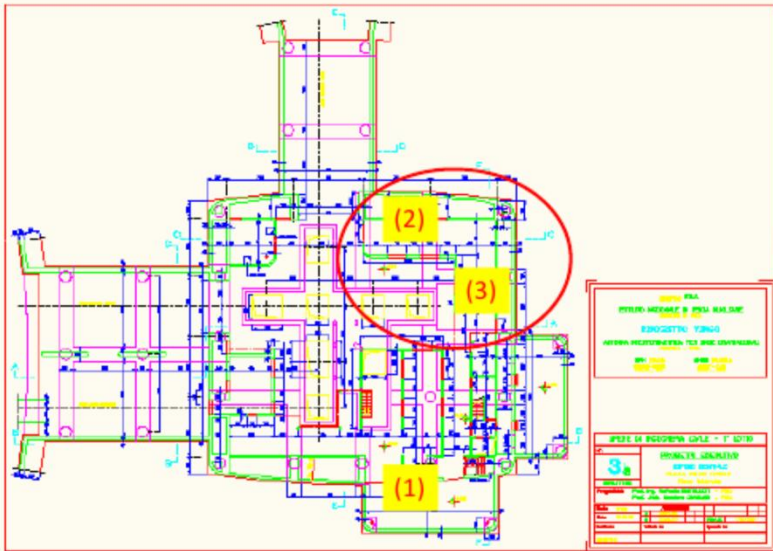
Da fare (da settembre, alla fine del run scientifico di Virgo)

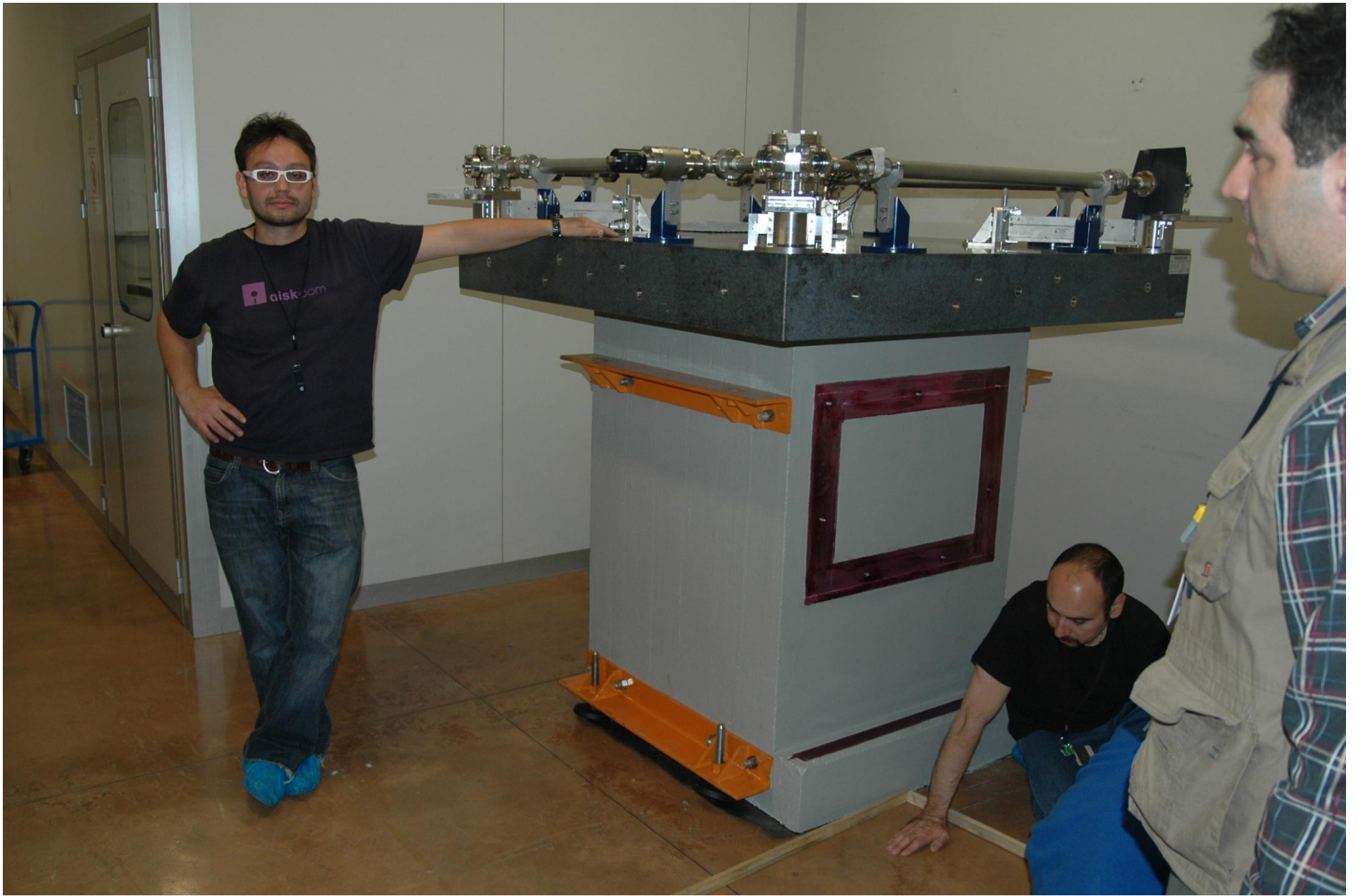
Trasporto e installazione di G-Pisa a S. Piero

Messa in funzione di un laser stabilizzato in modo assoluto sullo iodio

Stabilizzazione del perimetro del ringlaser G-Pisa usando un laser stabilizzato in modo assoluto

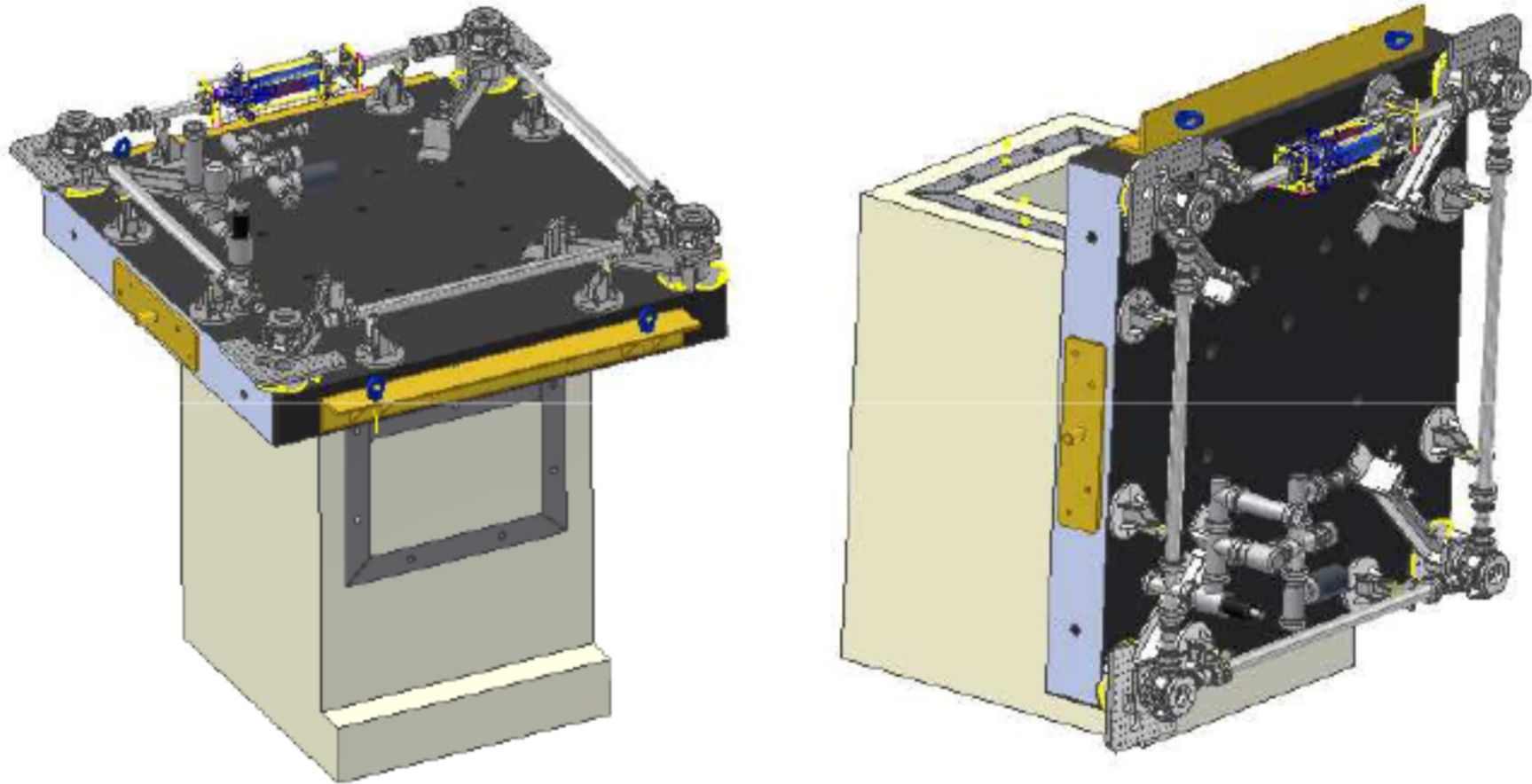
G - Pisa in Virgo



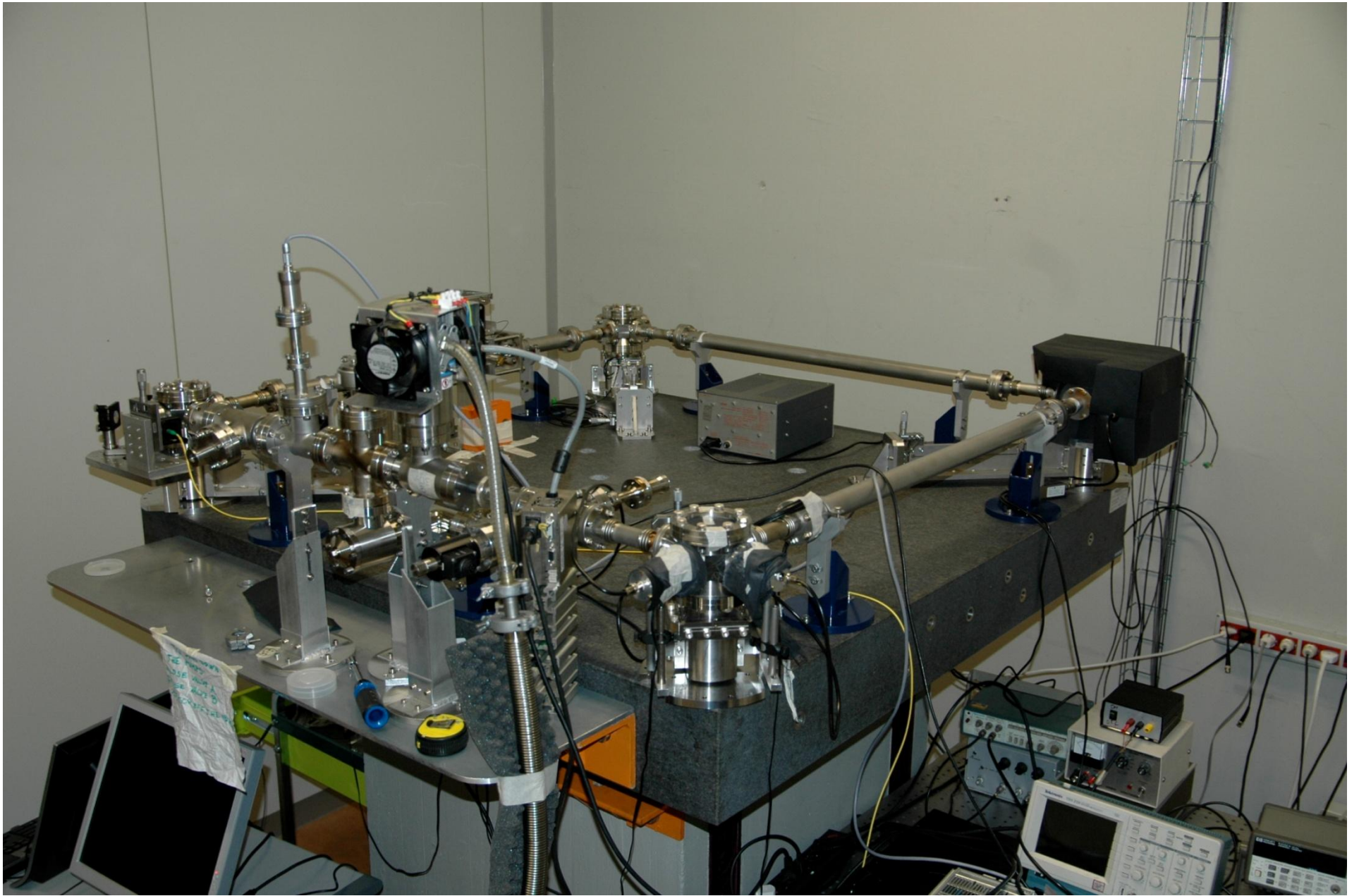


6/14/2011

Due possibili orientamenti, per essere sensibili a due diversi 'tilts'



Accurato lavoro ingegneristico per rendere possibili queste movimentazioni in sicurezza e velocemente



6/14/2011

Caratteristiche 'originali' di G-Pisa

Scarica capacitiva e non induttiva (ridotta radiofrequenza, importante per Virgo)

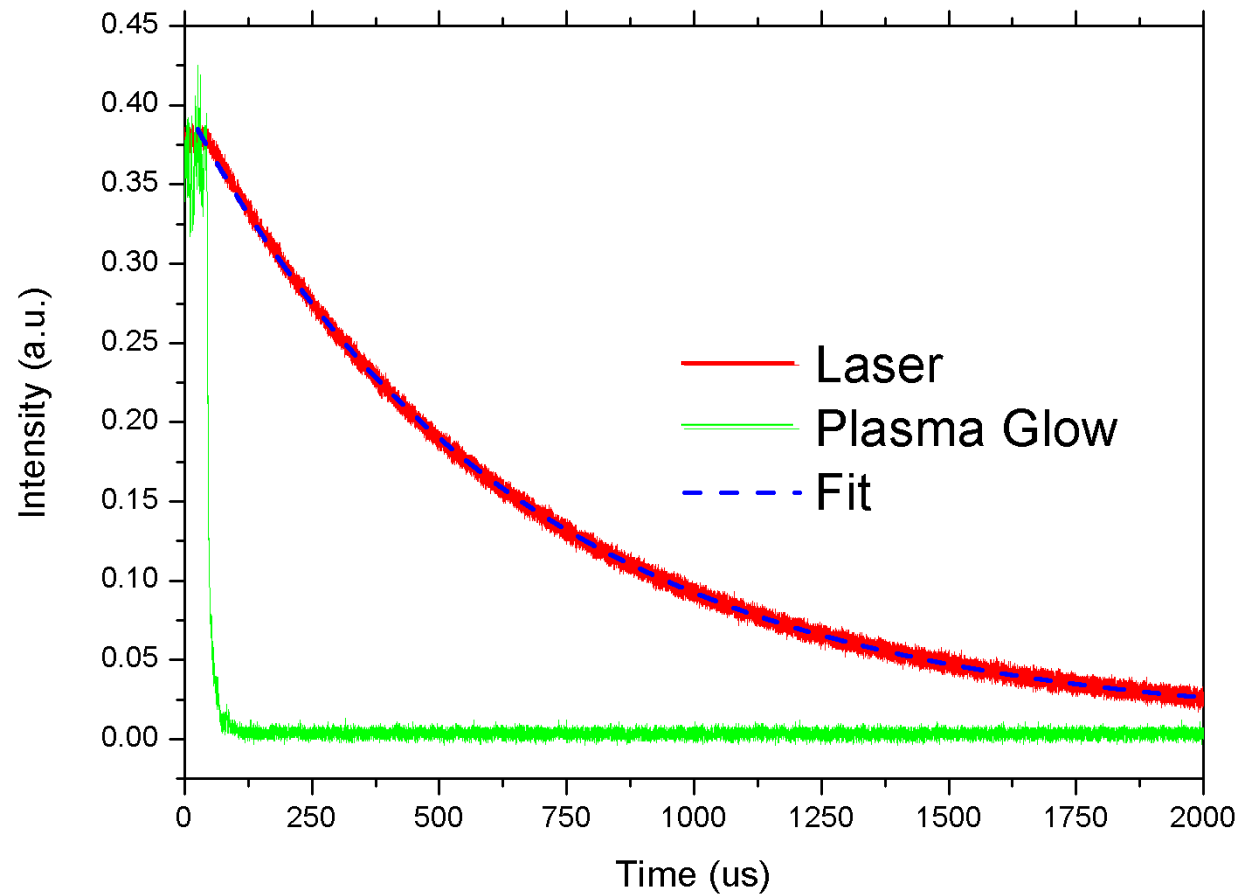
Controllo del perimetro che garantisce un funzionamento costante

Uso dei pompe getters che assicurano performances costanti del gas

Ring down measurements

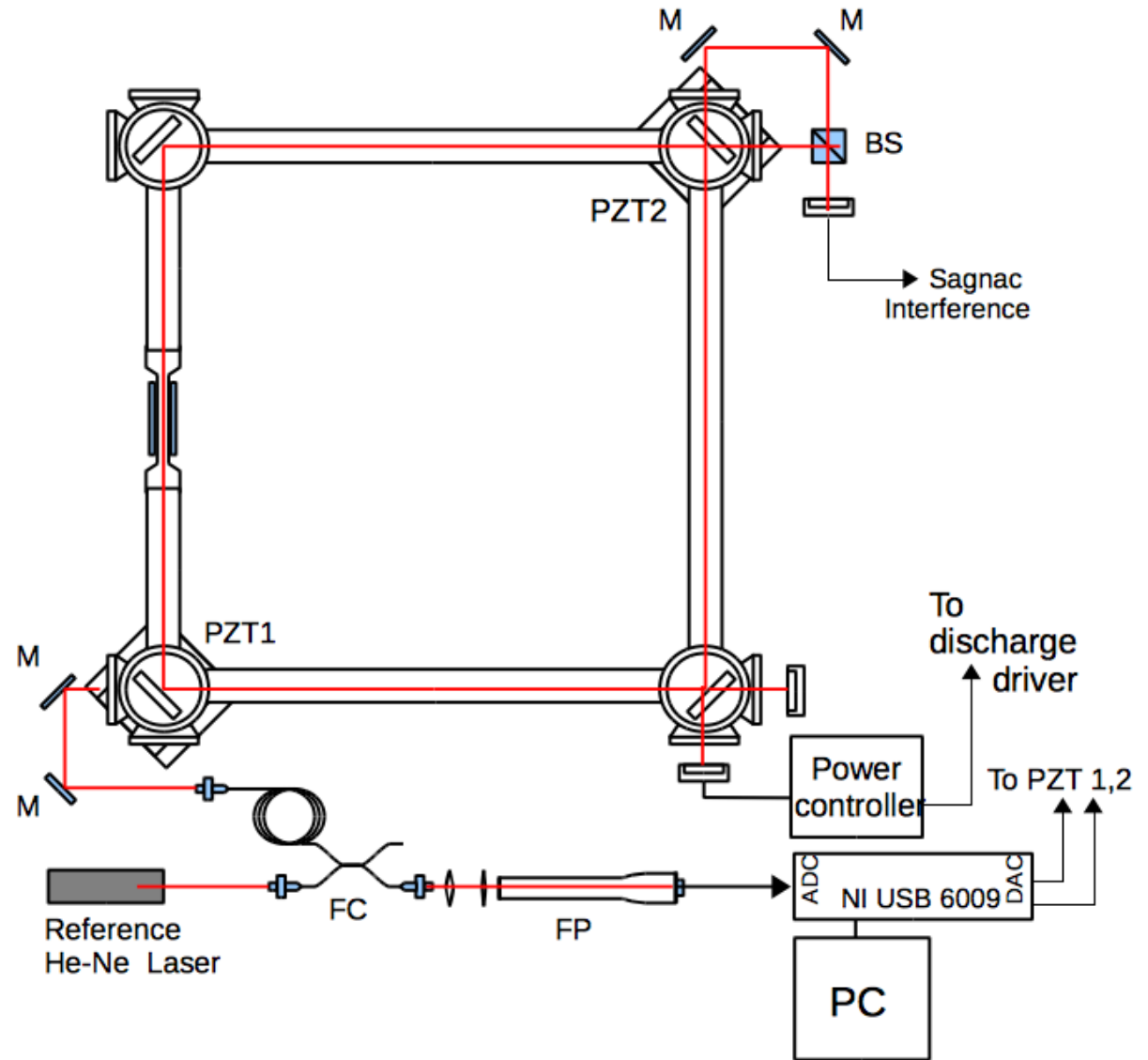
$\tau = 660 \mu\text{s}$; $Q = 2 \times 10^{12}$

Mirror reflectivity $R=99,9992\%$



Diagnostic and control apparatus

- Diagnostic of cavity modes (*Fabry-Pérot spectrum analyser*)
- Diagnostic of the ring perimeter length (*Wavelength comparison with a reference laser through Fabry-Pérot S.A.*)
- Measure of CW beam power intensity (*PD 1*)
- Measure of CCW beam power intensity (*PD 2*)
- Control of the discharge power
- Control of the ring perimeter length (*PZT 1 and PZT 2*)



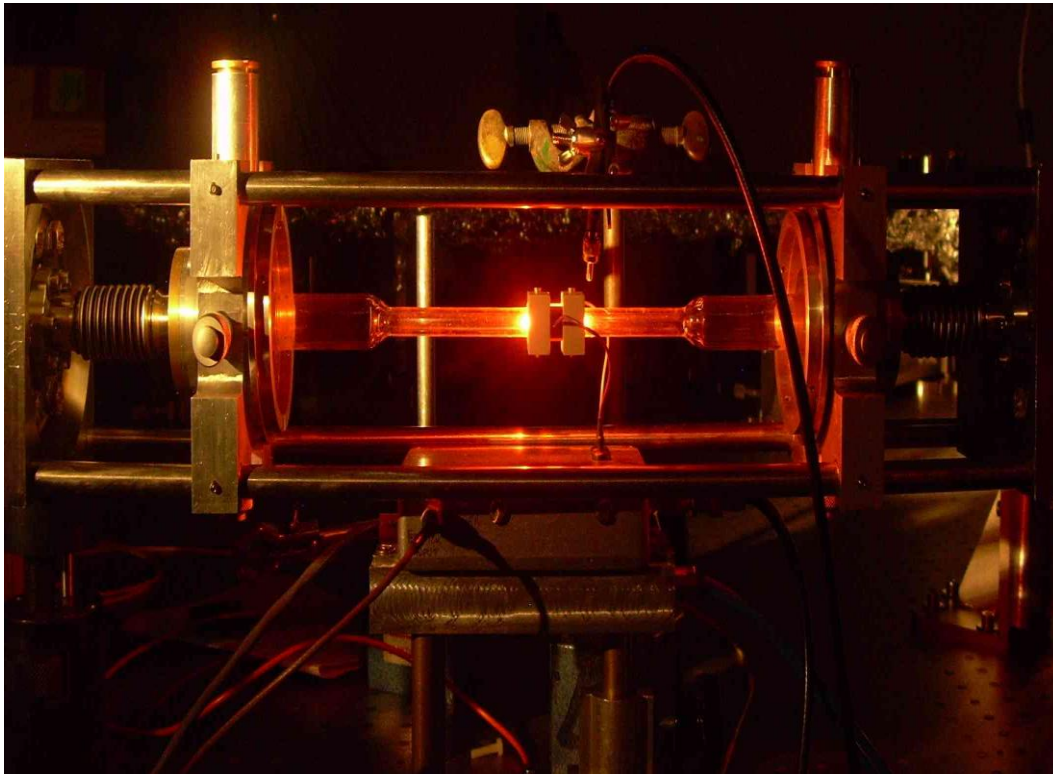
G - Pisa discharge

Plasma discharge with capacitive coupling.

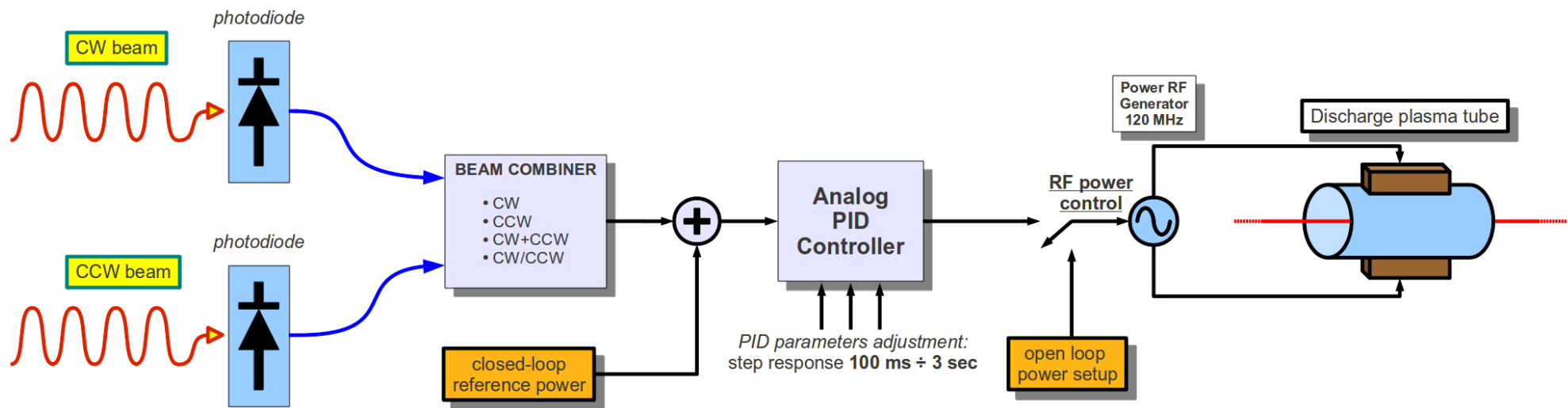
The laser intensity is usually drifting in the time, due to the aging of the gas, ring cavity misalignment, power supply drift

... .

A photodiode read the CCW intensity loop acts on the *r.f.* power in order to stabilize the laser emission intensity



G - Pisa discharge stabilization



Perimeter control

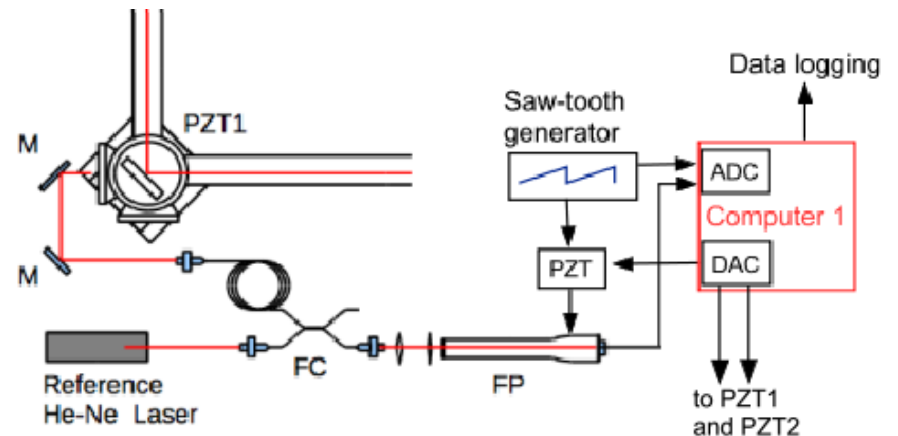
$$f_{Sagnac} = \frac{4A}{\lambda p} \ddot{\Phi} \cdot \Omega$$

For a square ring laser cavity, the resonance conditions impose that,

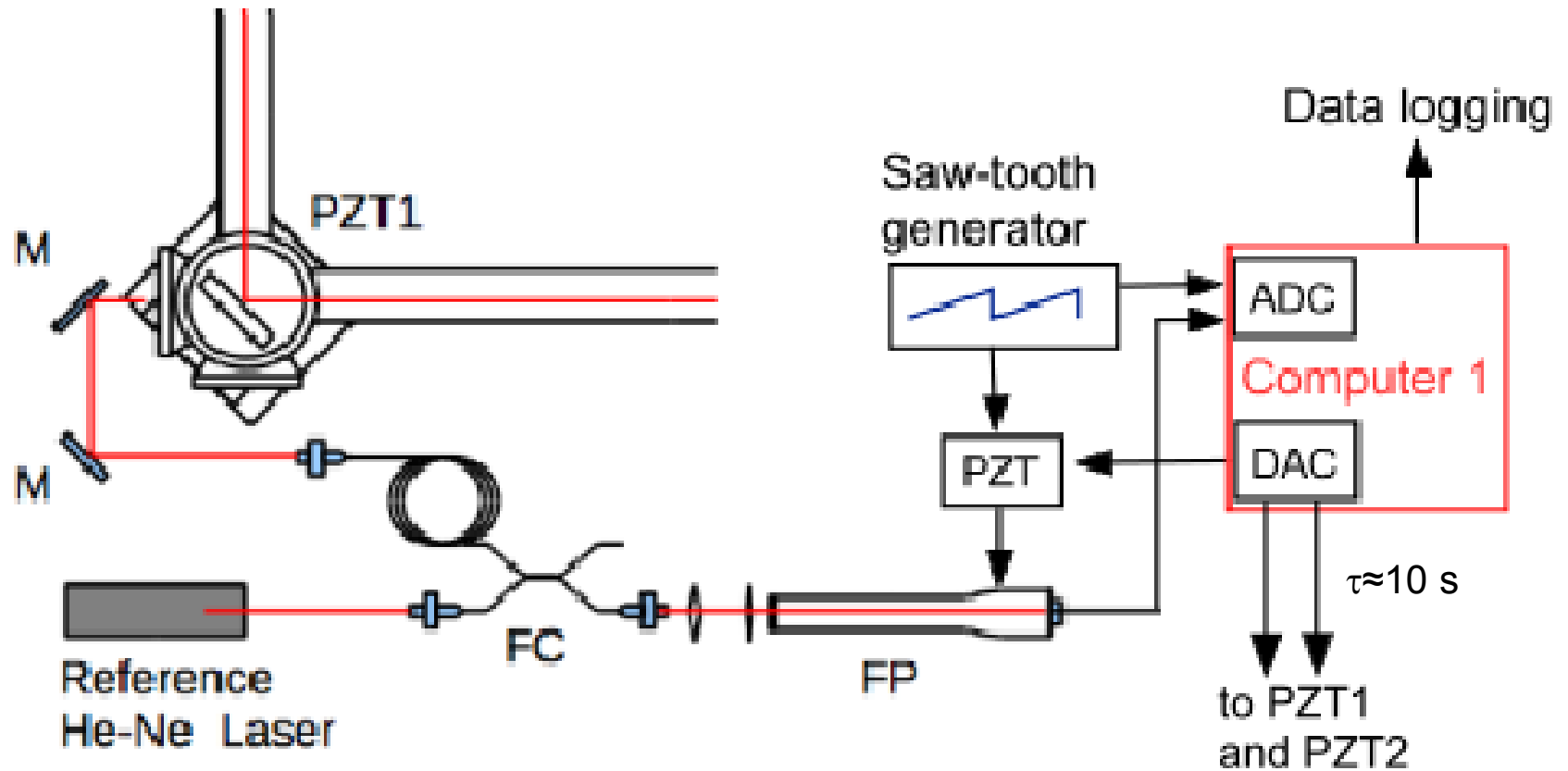
$$p = k\lambda; \quad A = \frac{1}{4}k^2\lambda^2 \quad \Rightarrow \quad A/p = \frac{1}{4}k\lambda^2$$

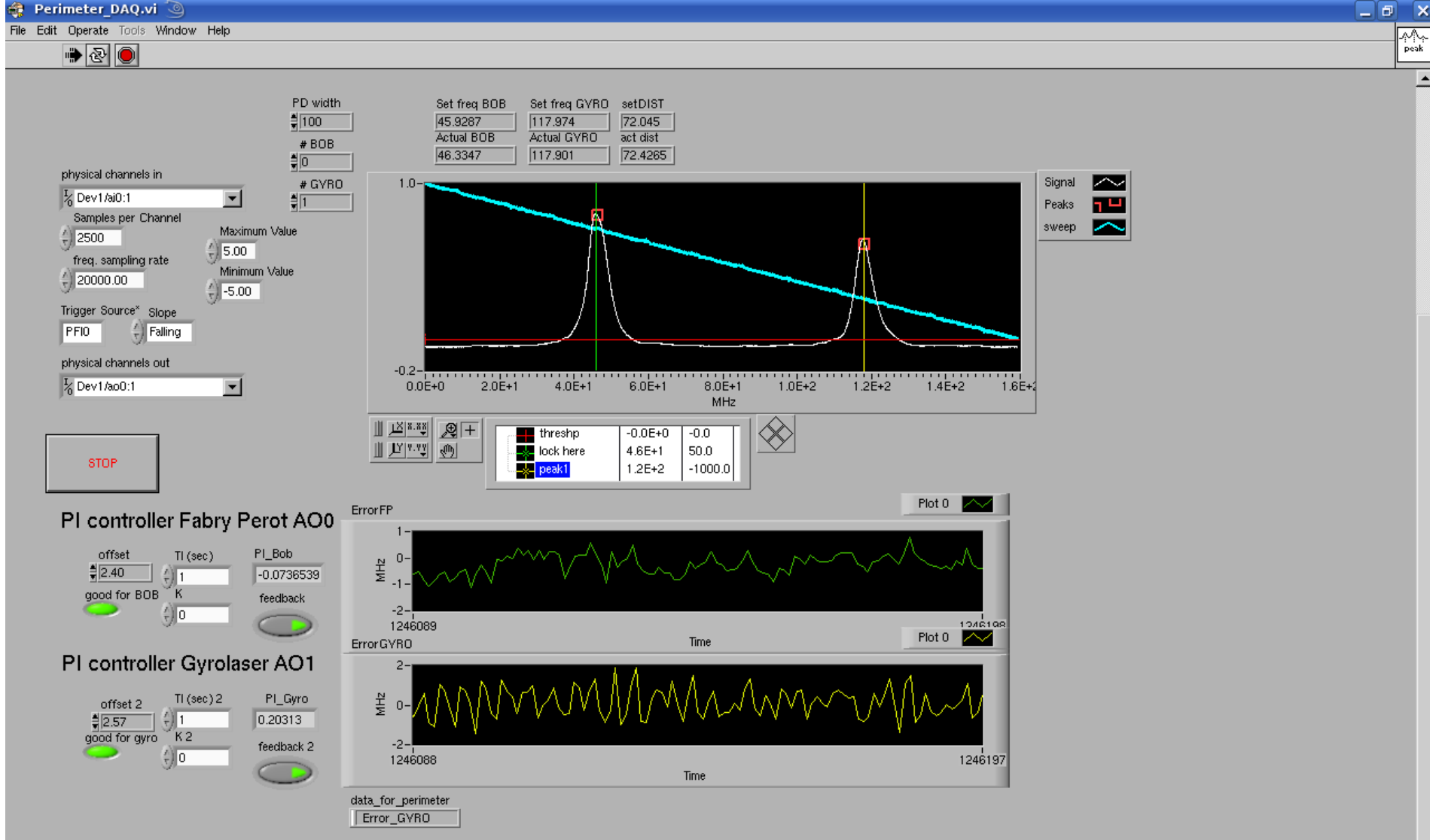
with k integer.

Then, in order to calibrate the gyroscope scale factor it is necessary to lock the emission wavelength to a reference.

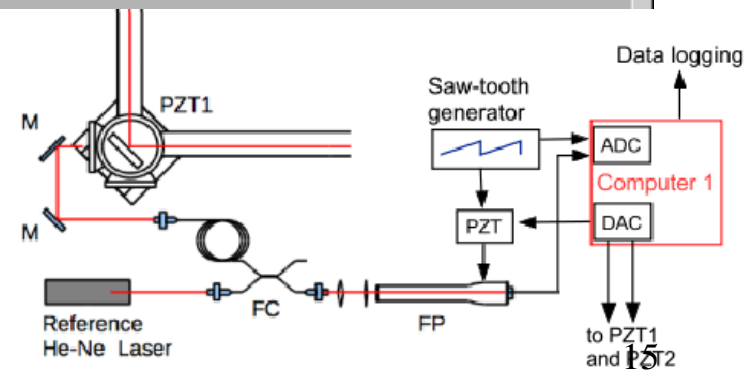


Perimeter control





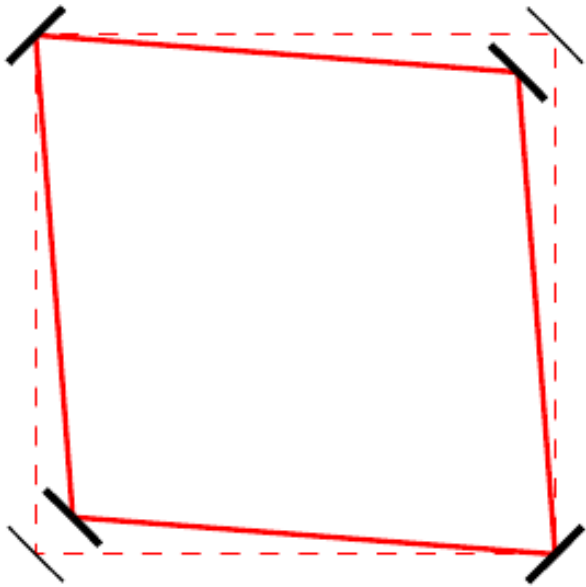
Computer display



Simmetric perimeter stabilization

Acting symmetrically on two opposite mirrors with two PZT the length of the four sides does not changes.

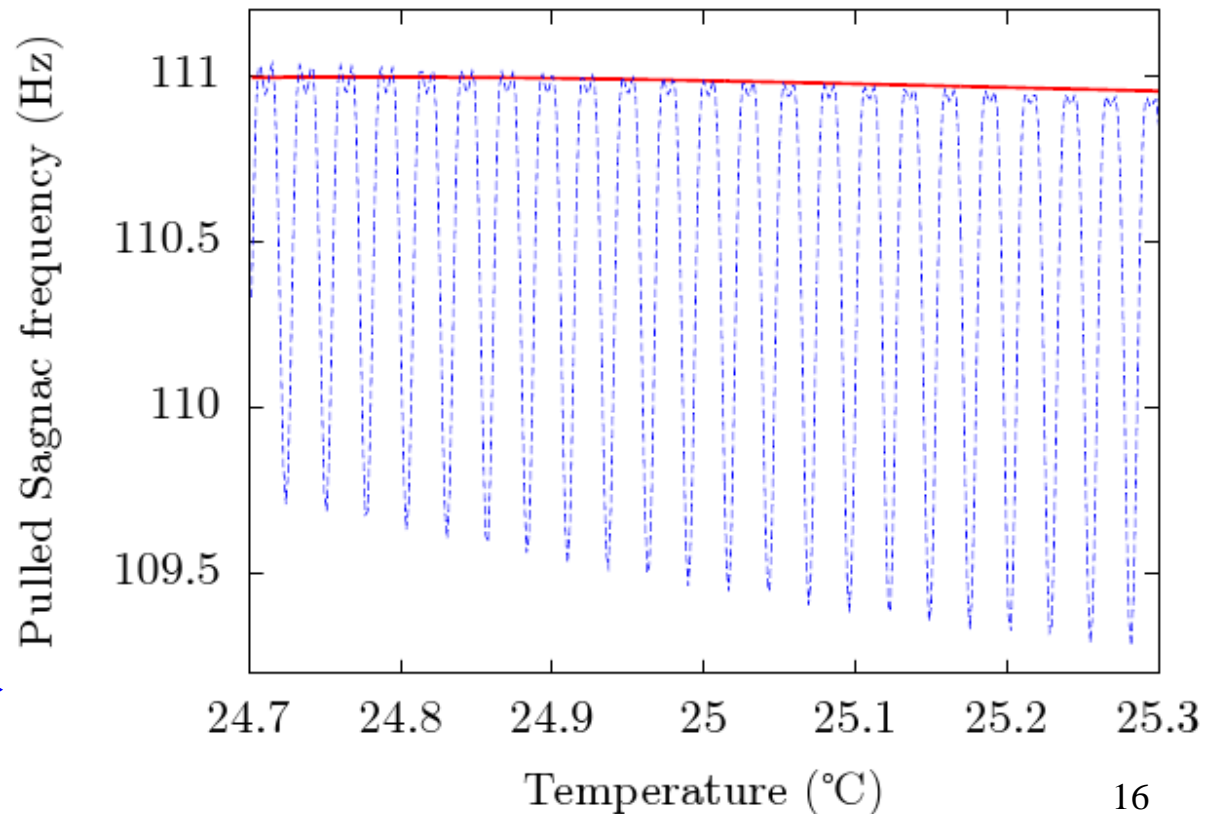
⇒ At the 1st order back- scattering phases do not change



Simulation starting from a non perfect initial condition (one mirror tilted of 1 mrad)



Red line — two pzt correction
Blue line - - - single pzt correction



Simmetric perimeter stabilization

With two PZT we can control two degree of freedom of the ring laser.

1. Acting on one mirror, it is possible to minimize the pulling
2. Acting symmetrically on the two opposite mirrors, to keep it constant

The pulling effect can be effectively monitored by observing the modulation at the Sagnac frequency on the intensity of the laser, induced by back-scattering

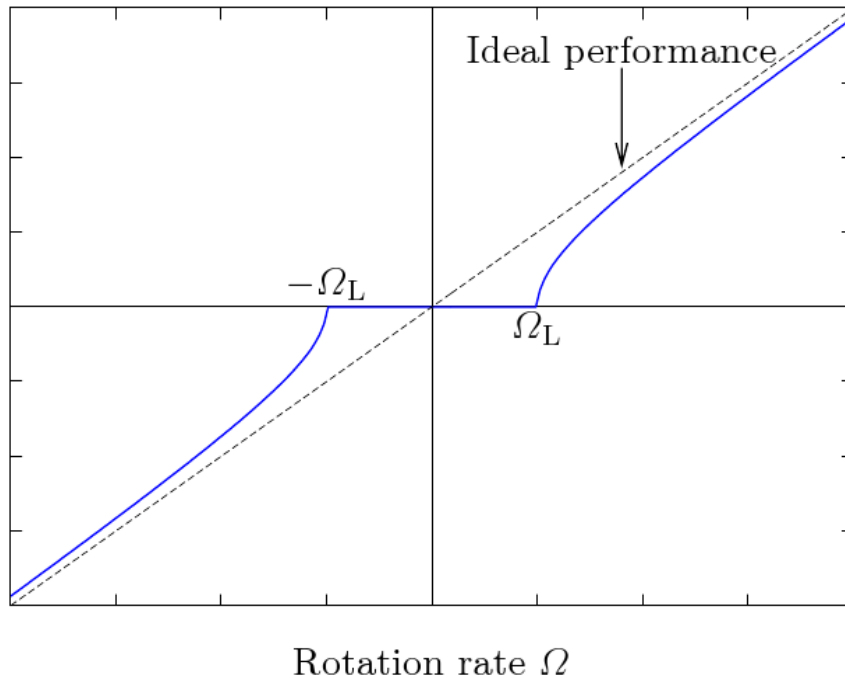
If we suppose symmetry between the two directions:

$$\Delta f_{bs} = \frac{c}{2L} \rho \sin \psi \cos \varepsilon$$

ρ is the backscattering amplitude
 ε is the backscattering phase
 ψ is the instantaneous phase difference between the two counterpropagating beams (*it evolutes at the Sagnac frequency*).

The single beam presents an intensity modulation whose amplitude is proportional to the effective backscattering coefficient

Backscattering



The two counterpropagating beam are coupled by backscattering.
The effective frequency difference is given by:

$$p = \sqrt{f^2 - l^2} \quad \text{for } f > l$$

where $l \equiv \rho/\pi$ is the **lock-in threshold frequency**.

The **coupling parameter ρ** is the sum of the contributions the backscattering by the four mirror:

$$\rho = \sum_i \rho_i \exp(2ikz_i)$$

If $f \leq l$, the two frequencies are locked one to the other (no Sagnac signal)

If $f > l$, there is anyway a frequency pulling

The frequency pulling depends on the **MIRRORS QUALITY**;
but also on the **GEOMETRY** (distance between the mirrors)

Dati da Virgo

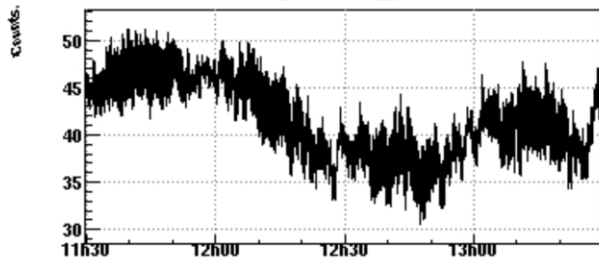
Data_Display_v9r12p7

File Edit View Options Inspect Classes

Help

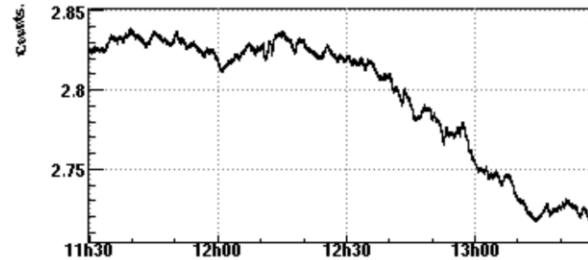
dataDisplay v9r12p7 : started by belfi on Jul 26 2010 13:43:10 UTC

VI:GL_Bcksctr TIME



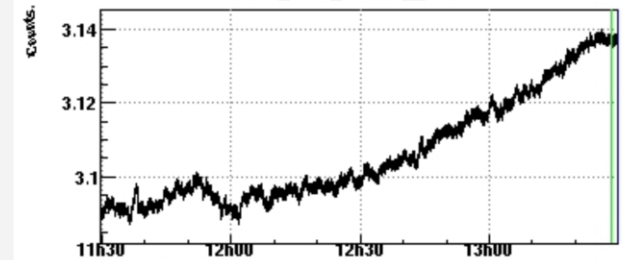
964179001.0000 : Jul 26 2010 11:29:46 UTC

VI:GL_Corr_FP TIME



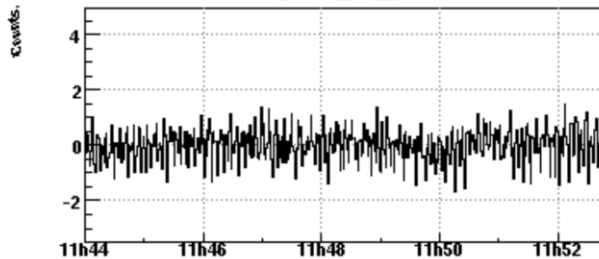
964179001.0000 : Jul 26 2010 11:29:46 UTC

VI:GL_Corr_GYRO TIME



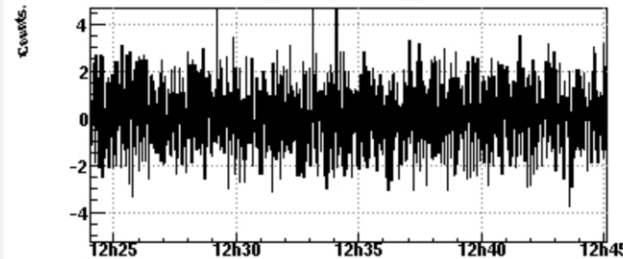
964179001.0000 : Jul 26 2010 11:29:46 UTC

VI:GL_Error_FP TIME



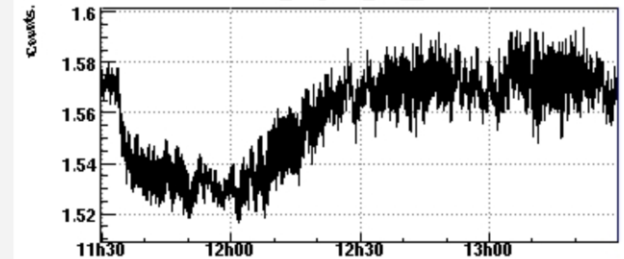
964179855.0000 : Jul 26 2010 11:44:00 UTC

VI:GL_Error_GYRO TIME



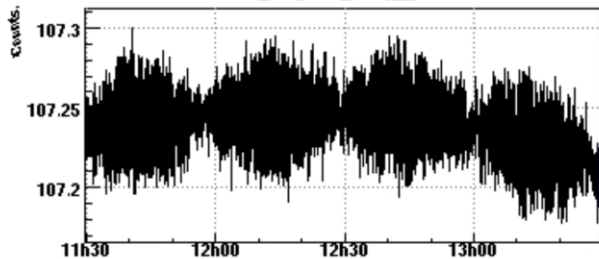
964182258.0000 : Jul 26 2010 12:24:03 UTC

VI:GL_Sagnac_AC TIME



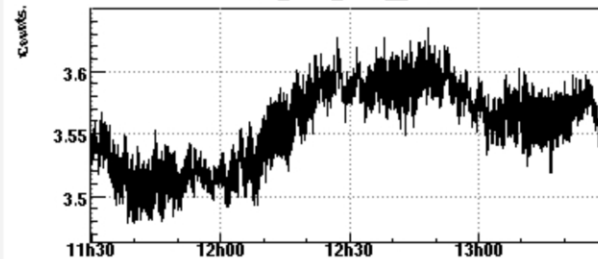
964179001.0000 : Jul 26 2010 11:29:46 UTC

VI:GL_Sagnac_freq TIME



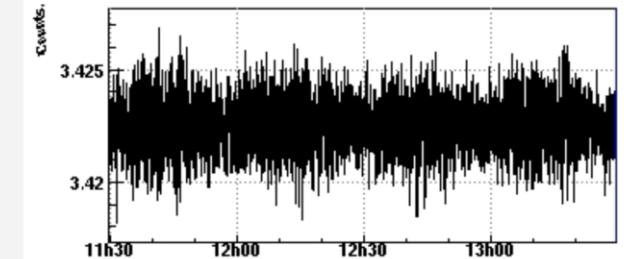
964179001.0000 : Jul 26 2010 11:29:46 UTC

VI:GL_Pow_CCW TIME



964179001.0000 : Jul 26 2010 11:29:46 UTC

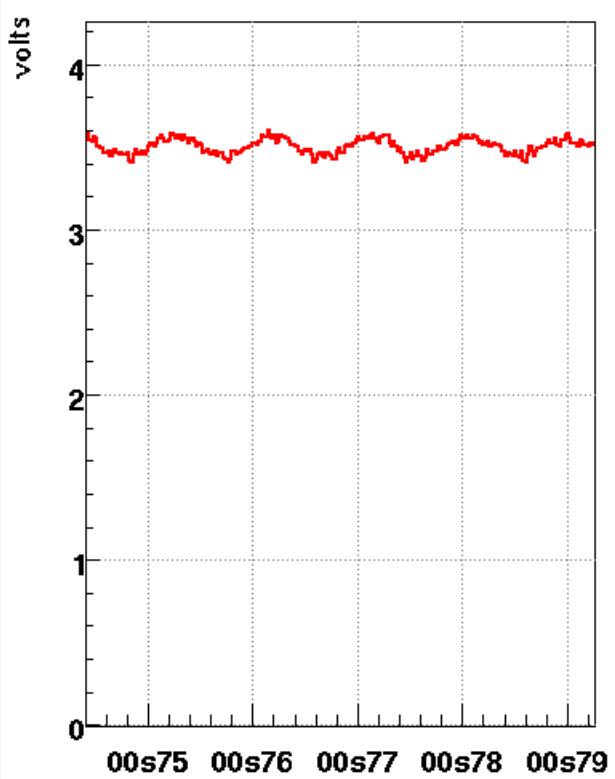
VI:GL_Pow_CW TIME



964179001.0000 : Jul 26 2010 11:29:46 UTC

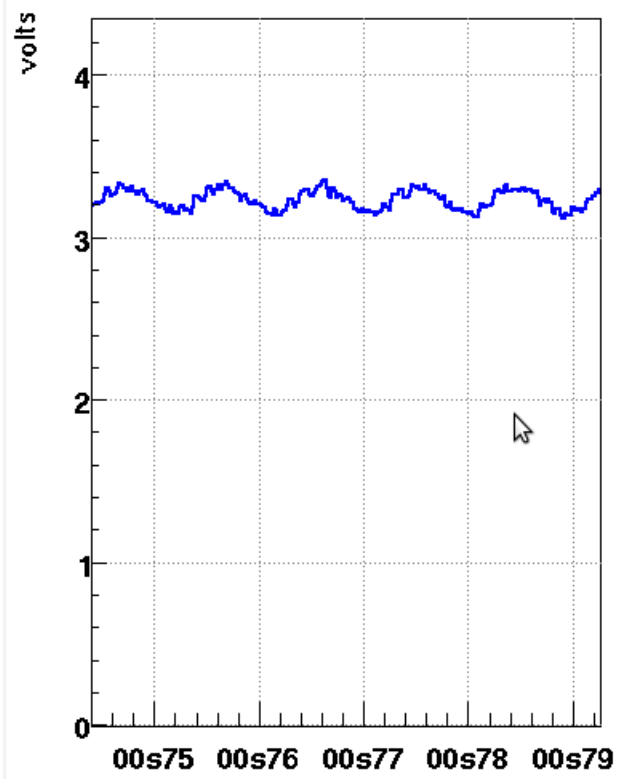
dataDisplay v9r12p7 : started by belfi on Sep 16 2010 16:59:47 UTC

V1:GL_ICCW__TIME



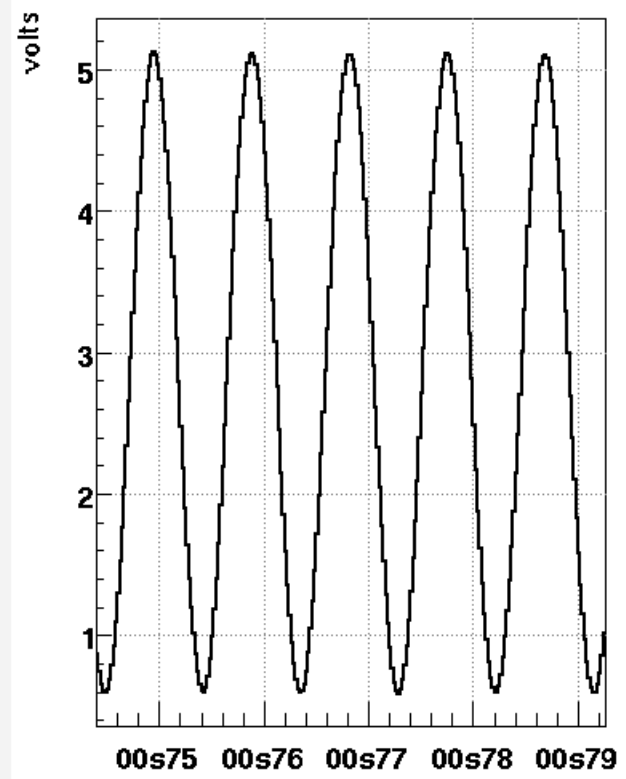
965692875.7440 : Aug 13 2010 00:01:00 UTC

V1:GL_ICW__TIME



965692875.7440 : Aug 13 2010 00:01:00 UTC

V1:GL_SAGNAC__TIME



965692875.7440 : Aug 13 2010 00:01:00 UTC

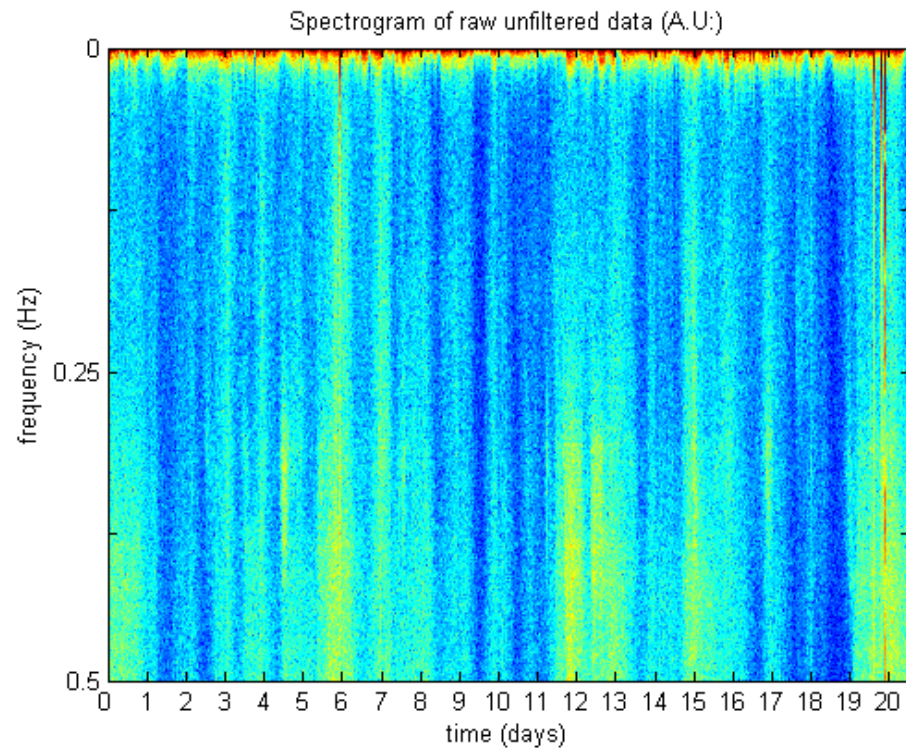
Cosa abbiamo messo in evidenza fino ad ora

- G-Pisa ha lavorato in modo continuativo, 'unattempted', per oltre 1 mese
- Si può operare in modo remoto sui feedback
- Le due orientazioni mostrano performances simili
- Il controllo del perimetro funziona in modo egregio con feedback simmetrico su due specchi
- Non abbiamo evidenza di rumore proveniente dal controllo del perimetro

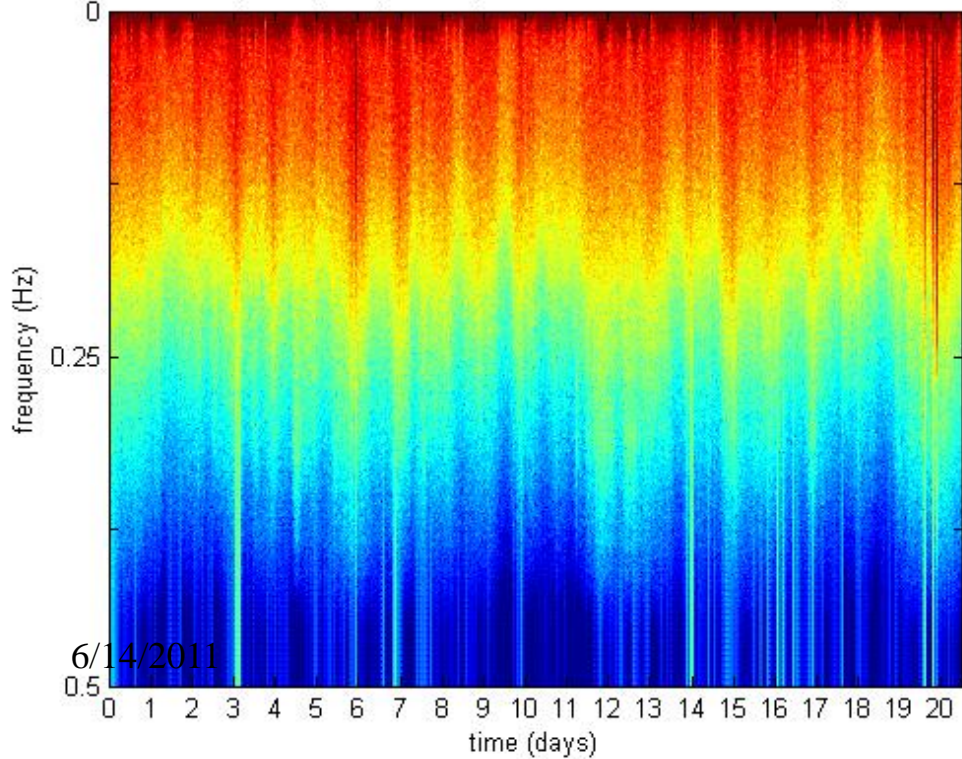
Lasceremo G-Pisa a Virgo fino ai primi di settembre

Breve descrizione dell'analisi

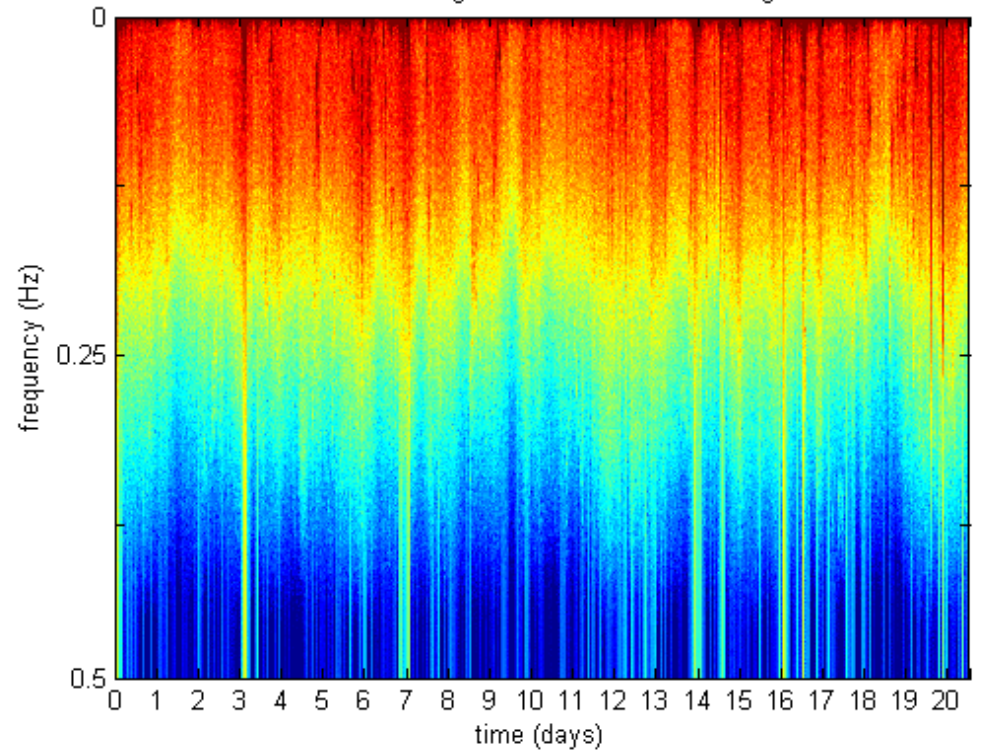
Alto Duty Cycle



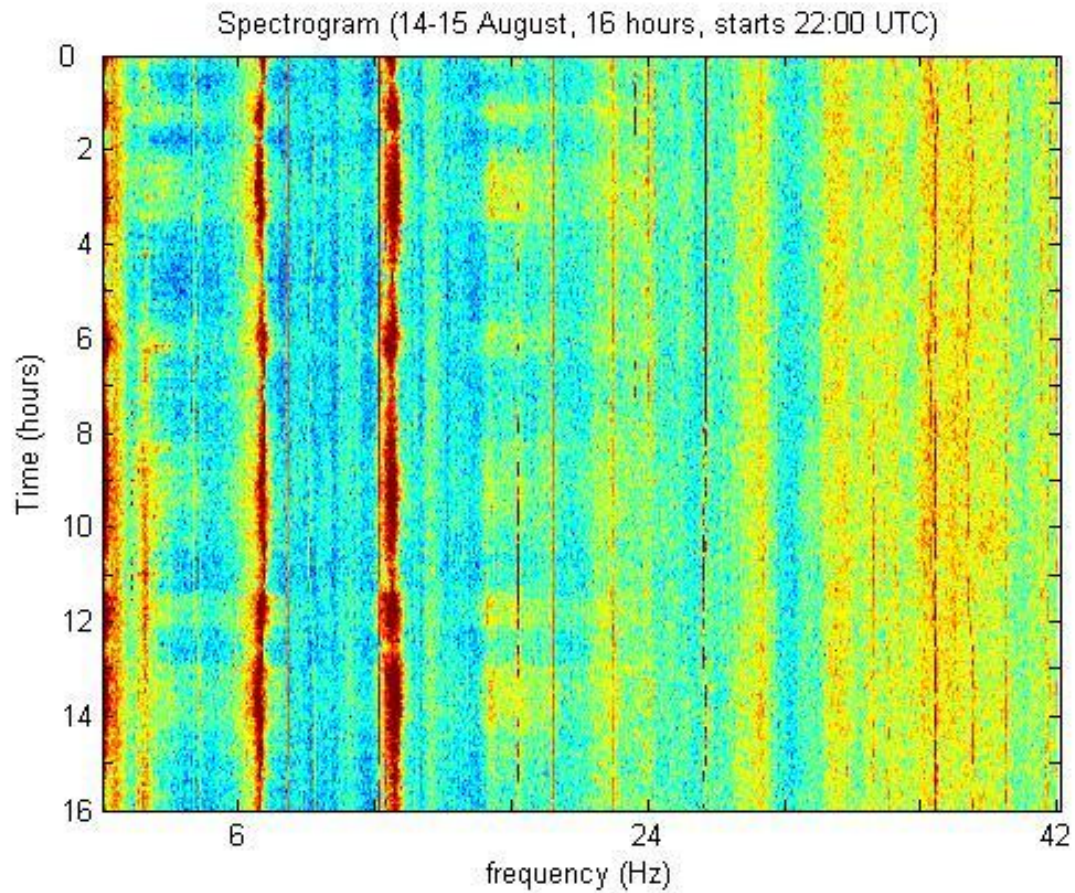
Spectrogram (raw low pass filtered data , below 0.1 Hz)



Spectrogram (data filtered below 0.1 Hz),
backscattering subtracted 1 hour average

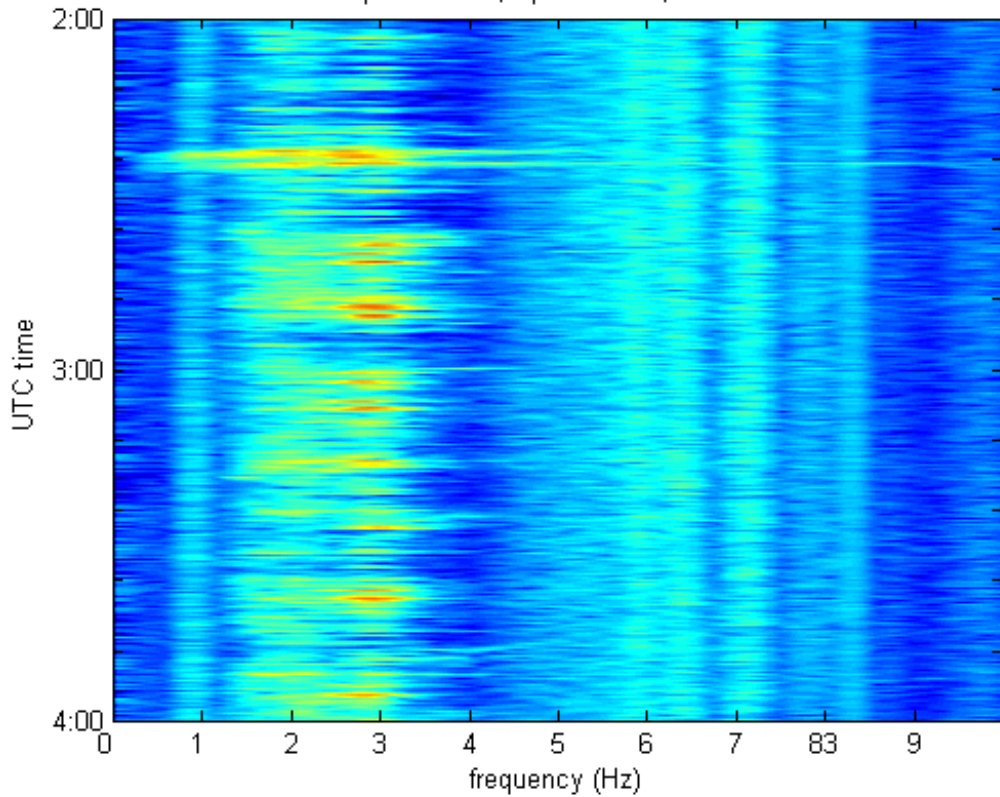


Typical spectrogram (0-42 Hz)



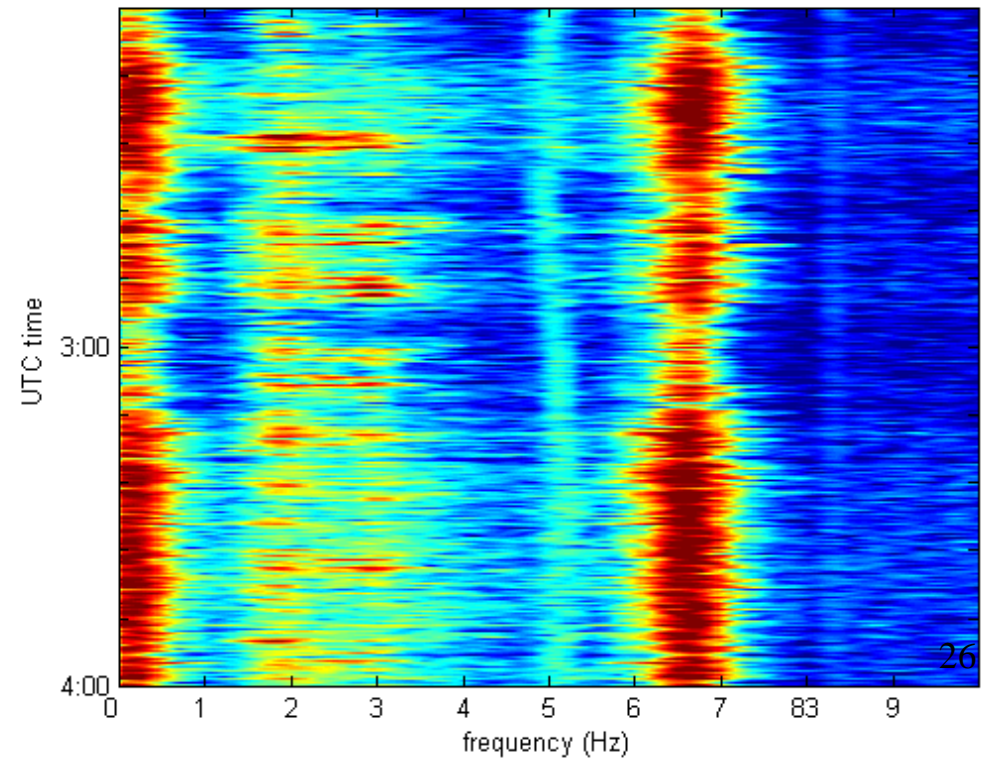
terremoti

September 15, Epicensor13, 2-4 UTC



Terremoto nei Balcani
Non visto dagli accelerometri
Virgo non funzionante
15 settembre 2011

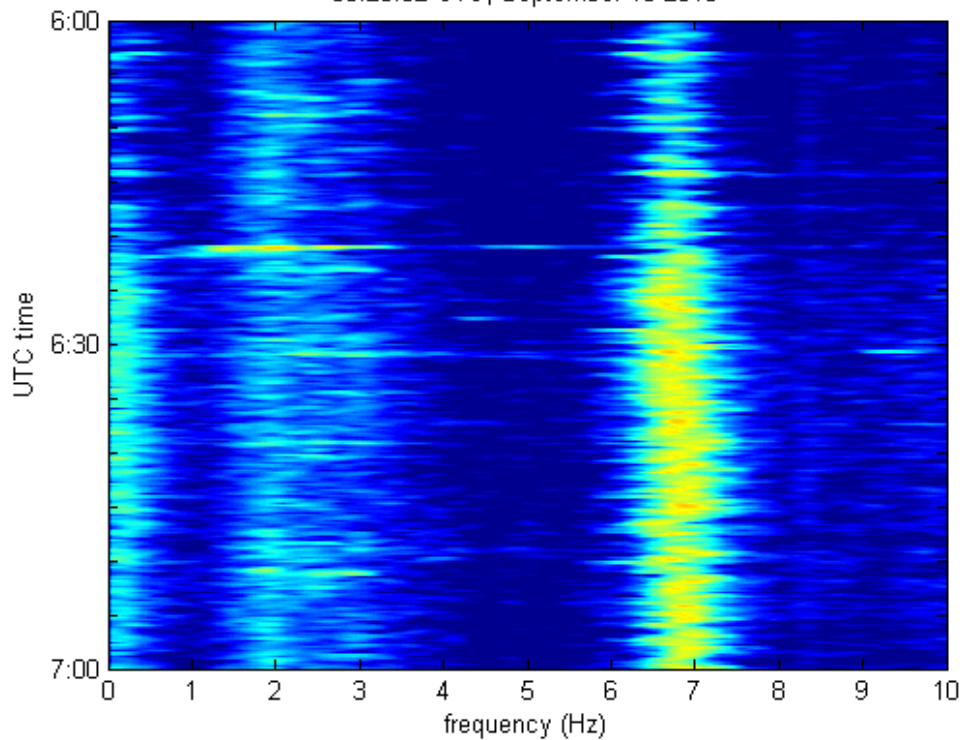
September 15, 2-4 UTC



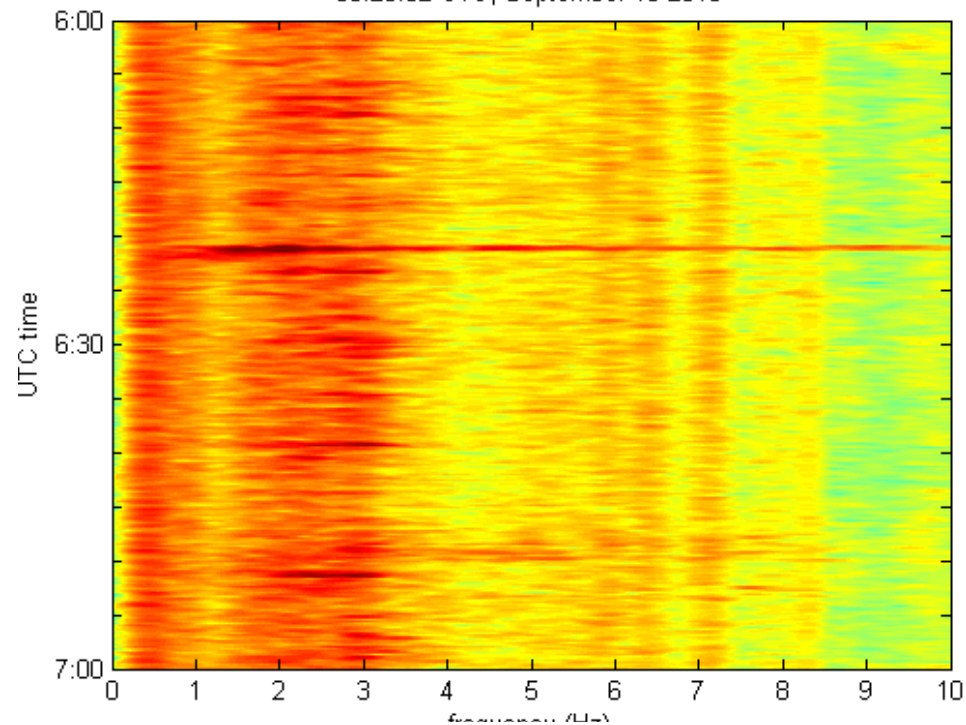
6/14/2011

26

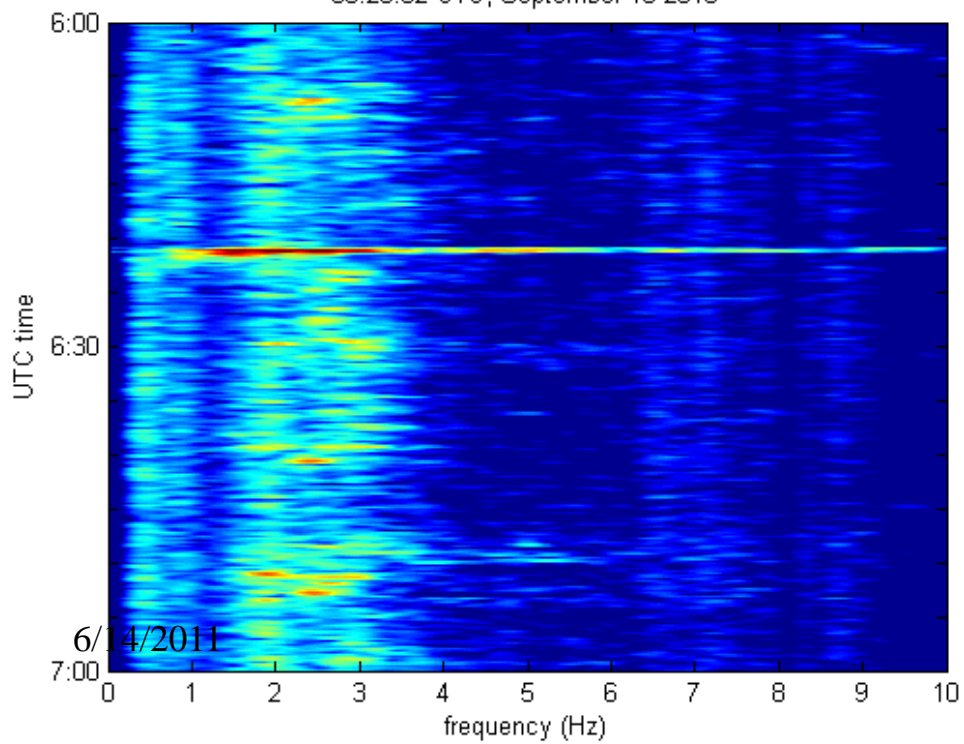
Earthquake Appennini near Modena, Gyrolaser
06:20:32 UTC, September 16 2010



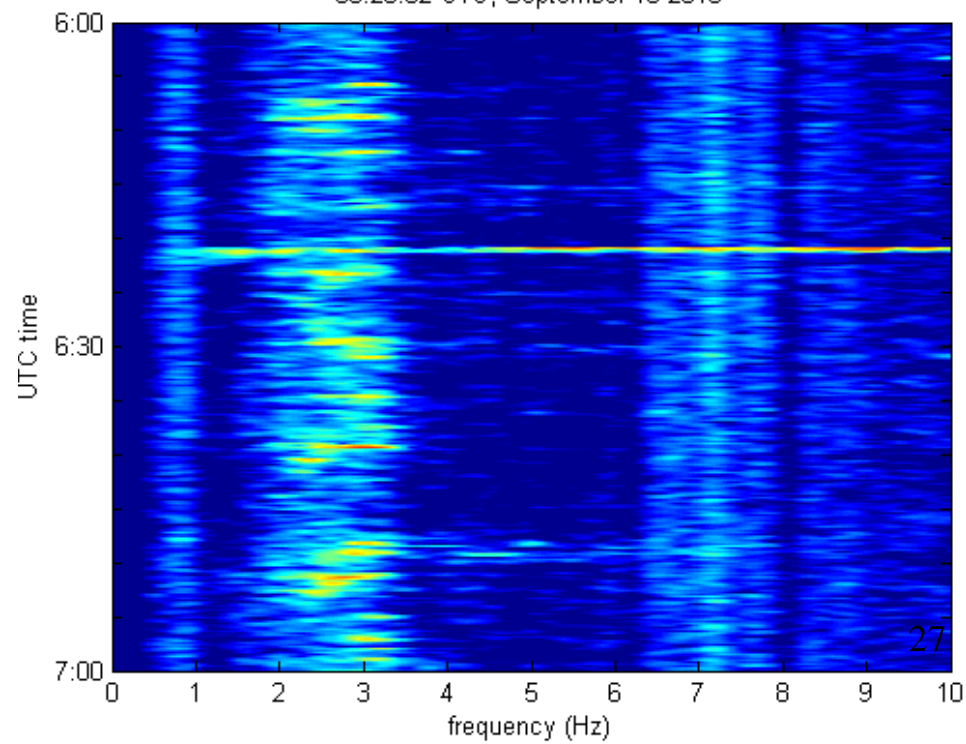
Earthquake Appennini near Modena, Em13
06:20:32 UTC, September 16 2010



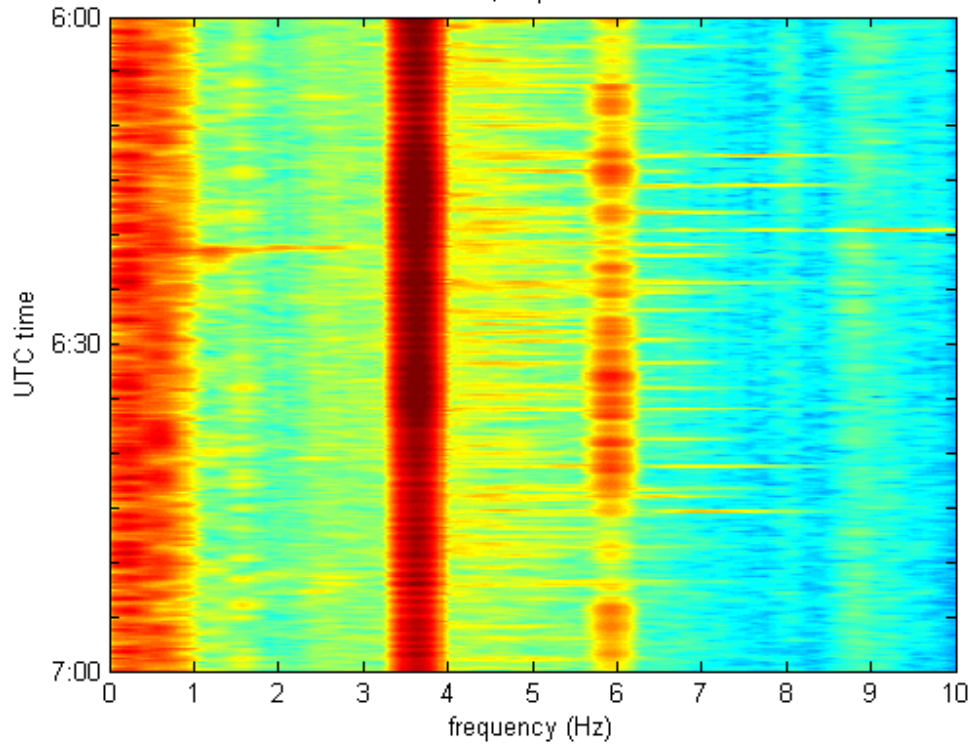
06:20:32 UTC, September 16 2010



Earthquake Appennini near Modena, Episensor15
06:20:32 UTC, September 16 2010

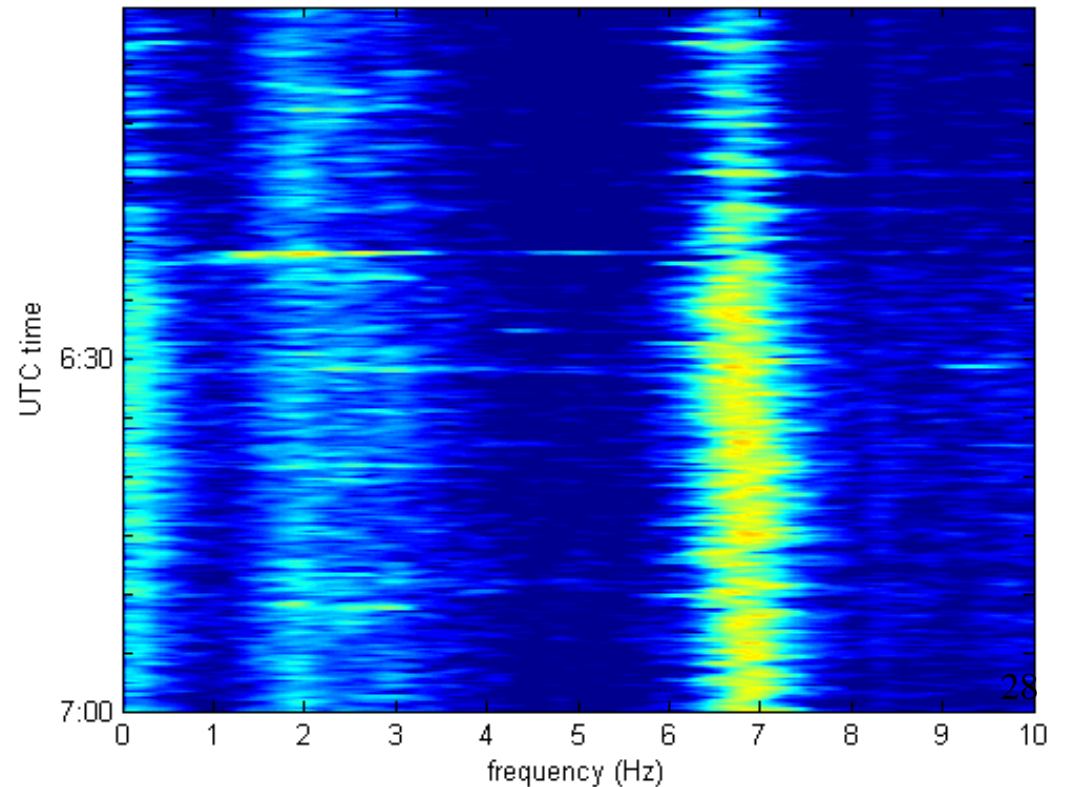


Earthquake Appennini near Modena, DarkFringe
06:20:32 UTC, September 16 2010



- Virgo non è stato influenzato,
- I monitors di jitter angolare di Virgo non hanno mostrato anomalie
- ma la darkFringe lo ha visto**

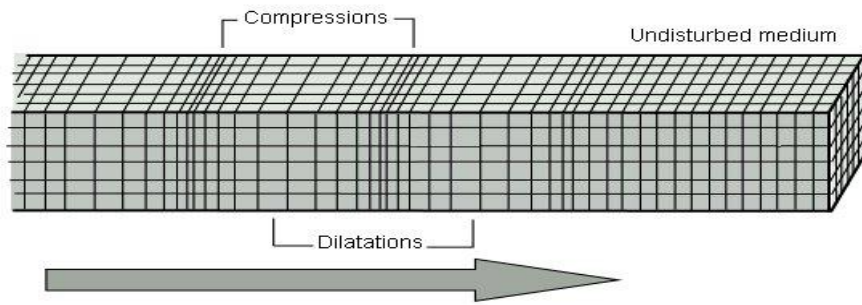
Earthquake Appennini near Modena, Gyrolaser
06:20:32 UTC, September 16 2010



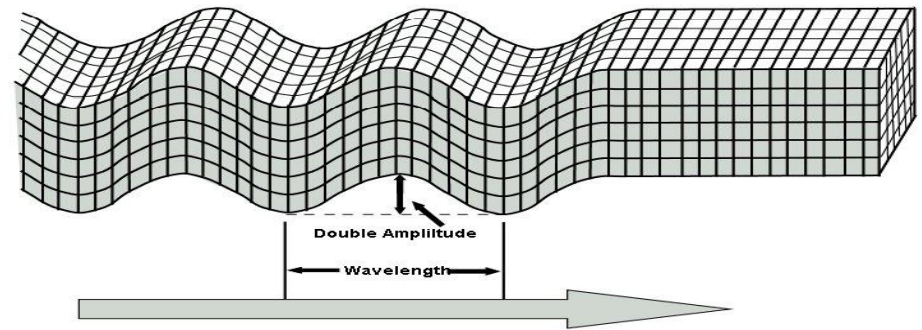
Il grande botto dal Giappone

Onde Sismiche

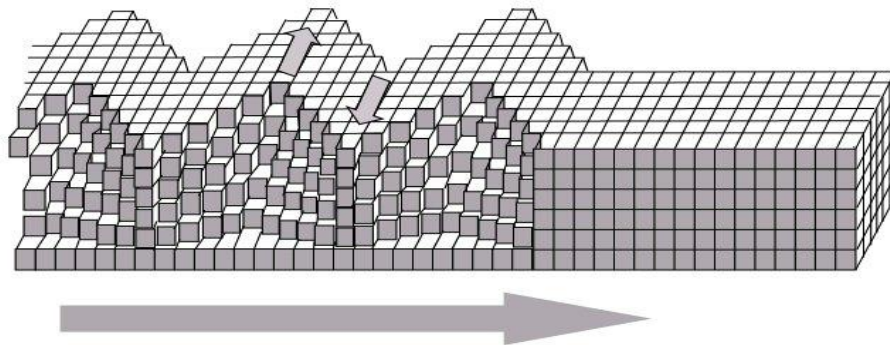
P Wave



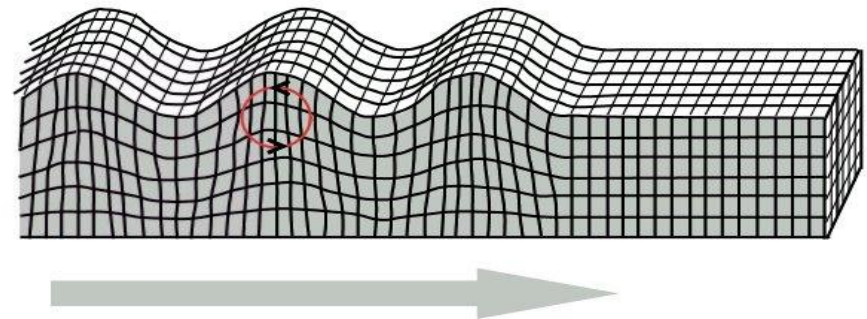
S Wave



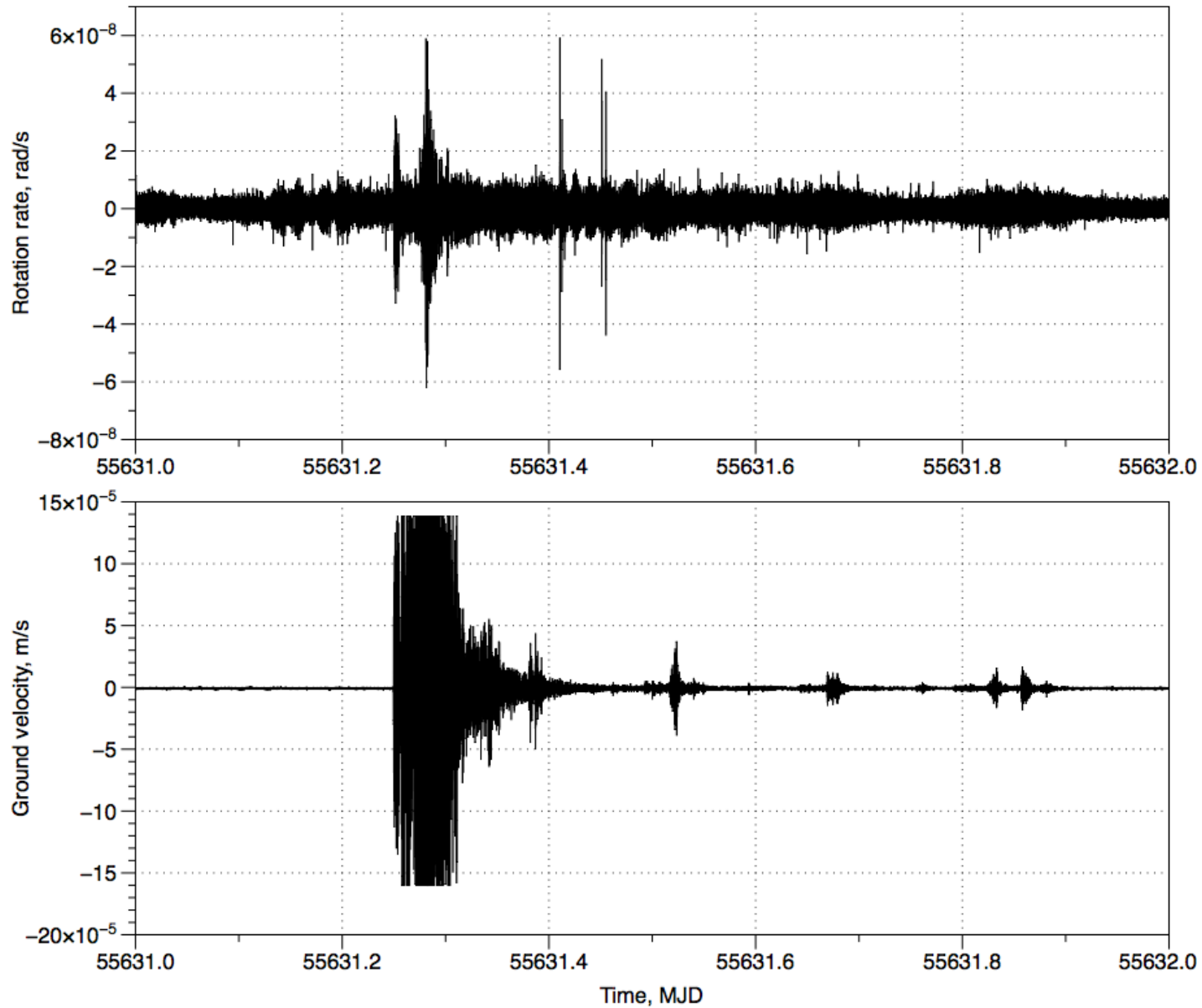
Love Wave



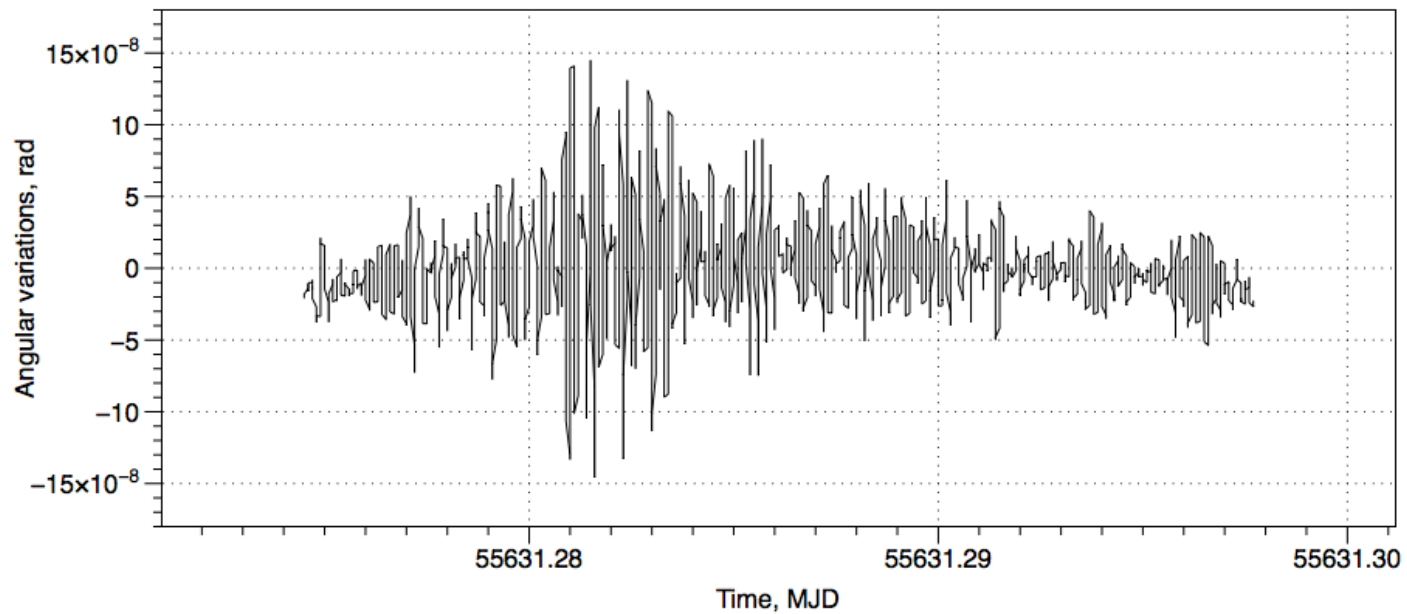
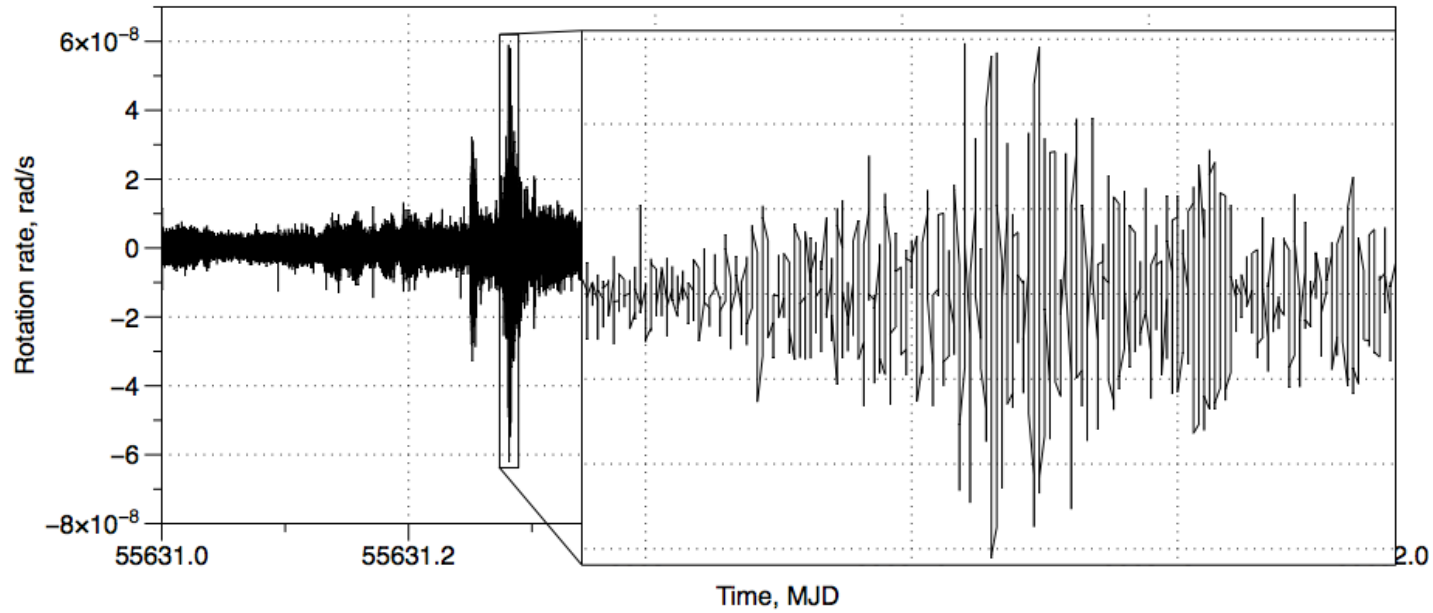
Rayleigh Wave



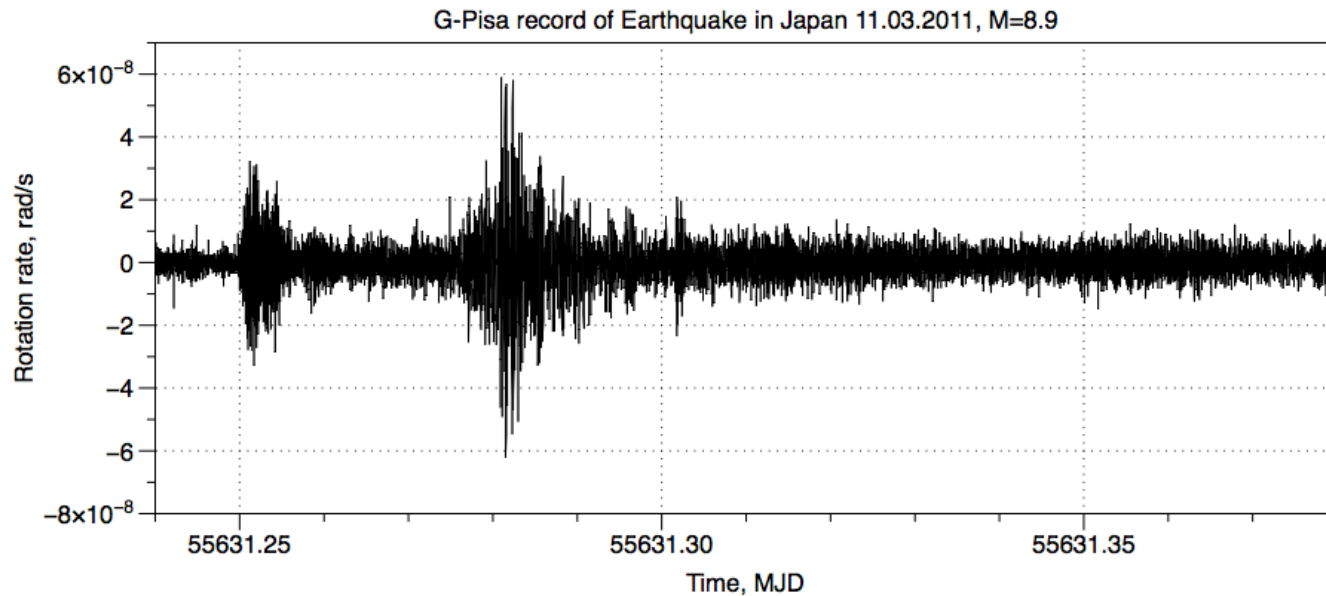
Seismic wave components



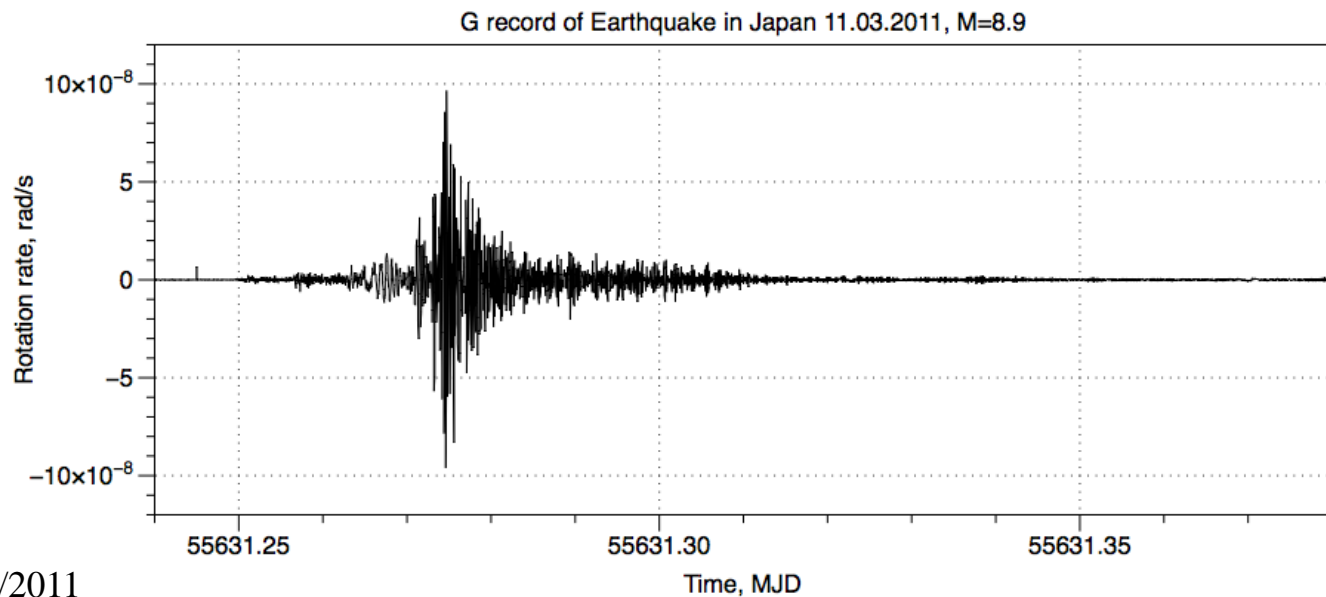
Seismic rotation (tilt)



Horizontal and vertical rotations

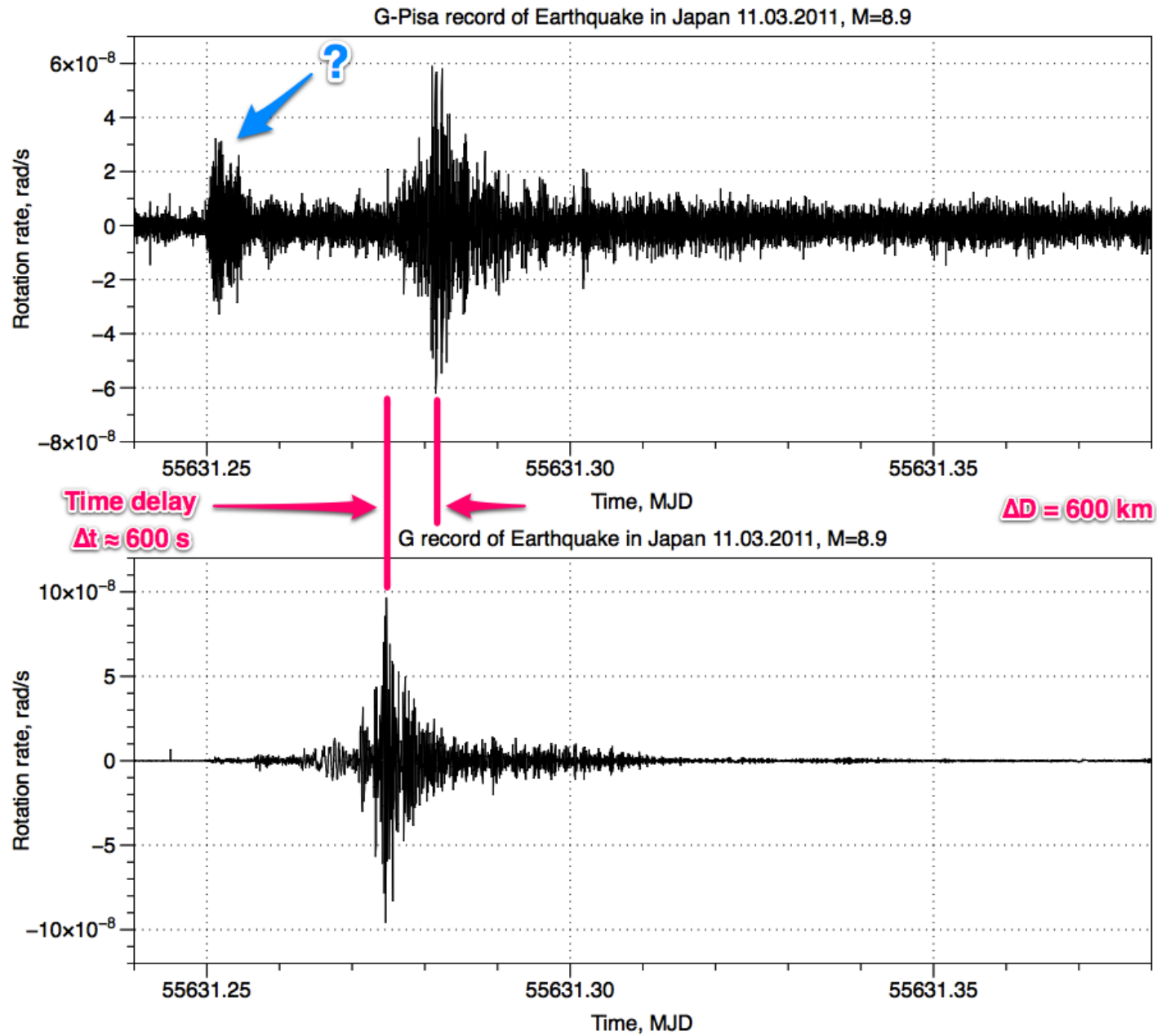


First observation of Rayleigh wave produced by a far away Earthquake



G in Wettzell is horizontally positioned so cannot observe Rayleigh waves, but Love waves

Comparison

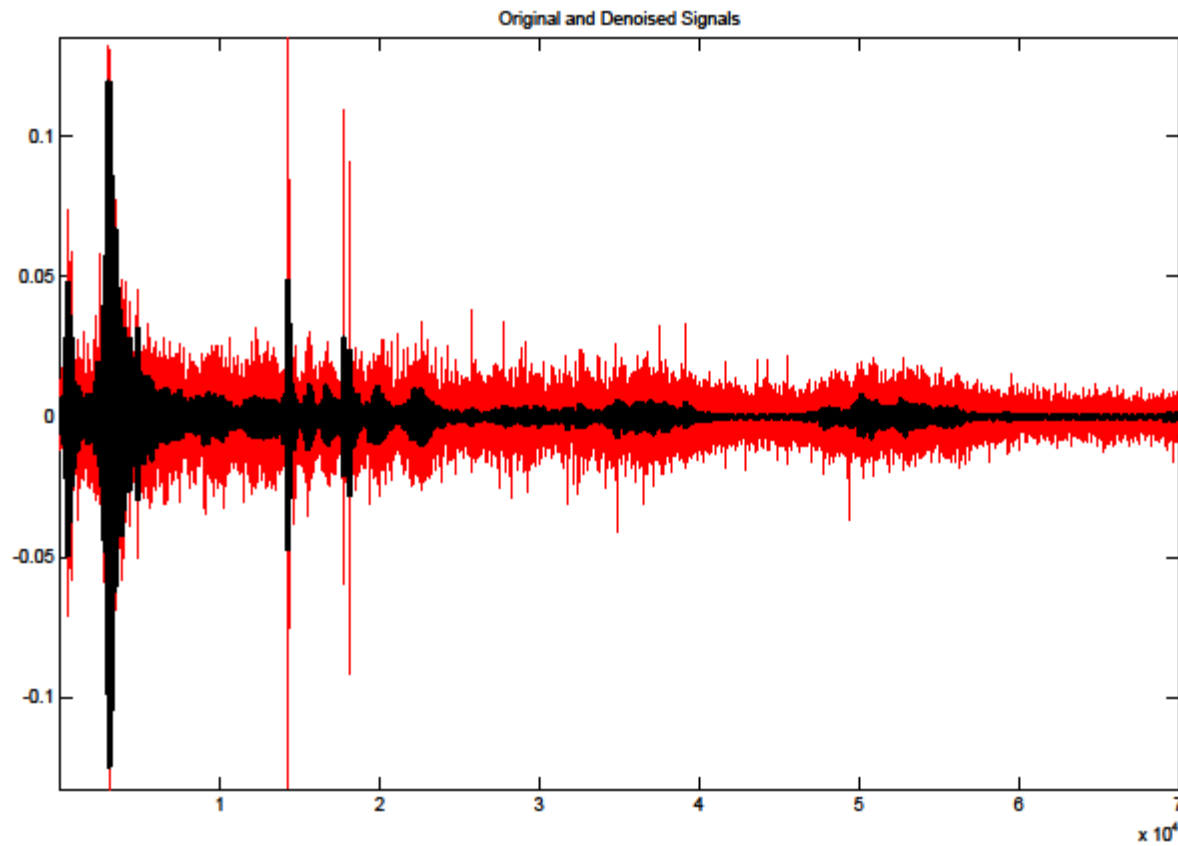


Analisi di Antonello Ortolan

Tolta la parte sotto 2 mHz con un metodo di wavelet

Curva nera fatta isolando la parte spettrale con maggior segnale

19 ore



Denoised Signal

Original Signal

Close

X-	Y+	XY-
X	Y	XY

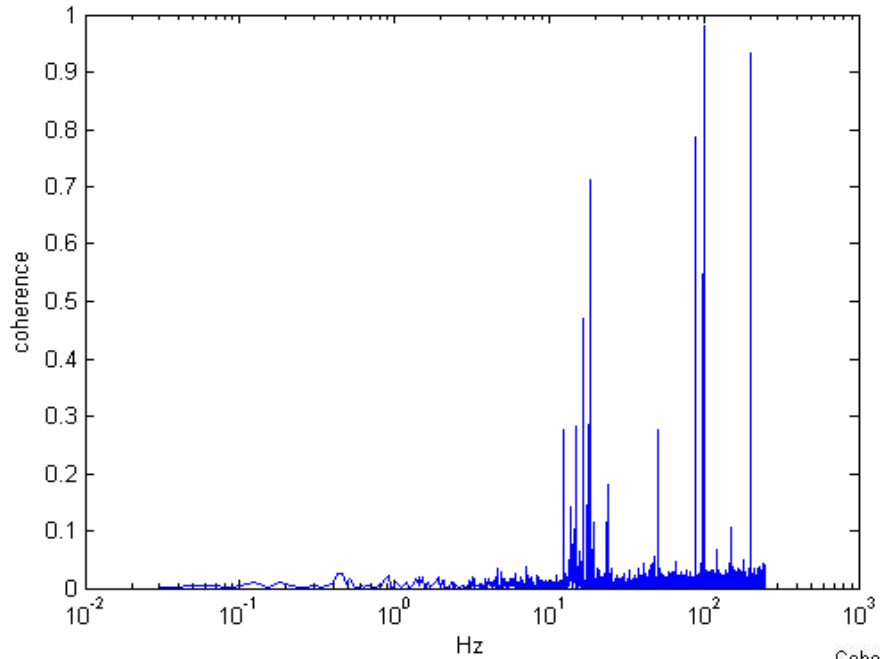
Center	X	Y
C1		

Fit	X=
	Y=

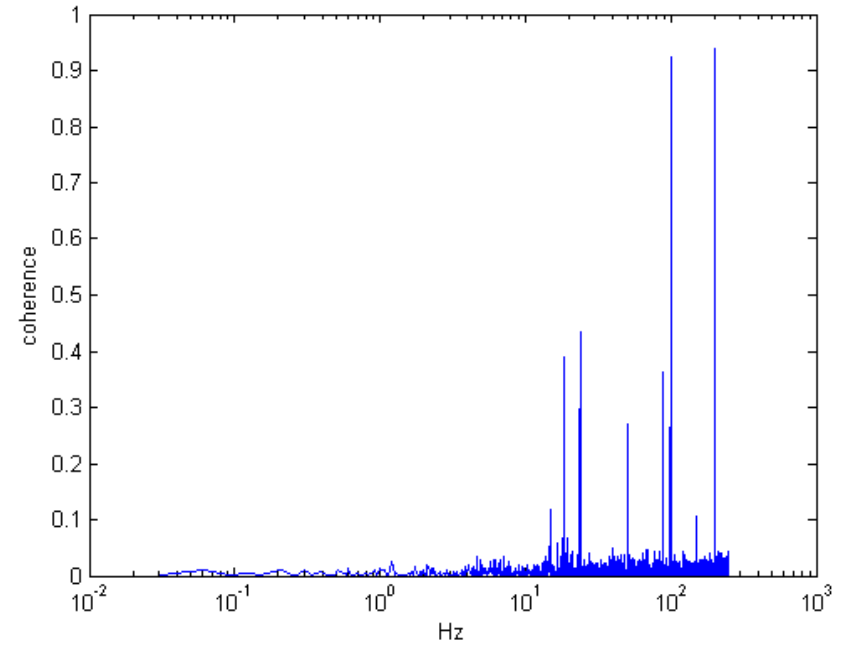
Fullscreen	<	>
	<<	>>

Coerenza con la Dark Fringe

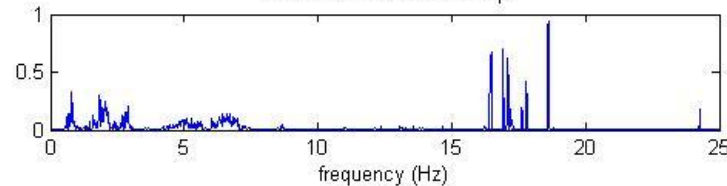
coherence Pr B1p q2 DChCorr
2 hour of data



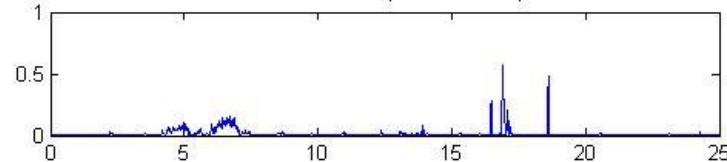
coherence Pr B1p q1 DChCorr
2 hour of data



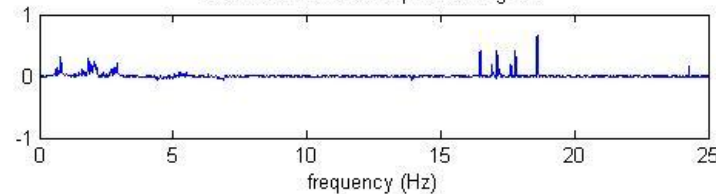
Coherence G-Pisa PrB1Acp



Coherence microphone PrB1Acp

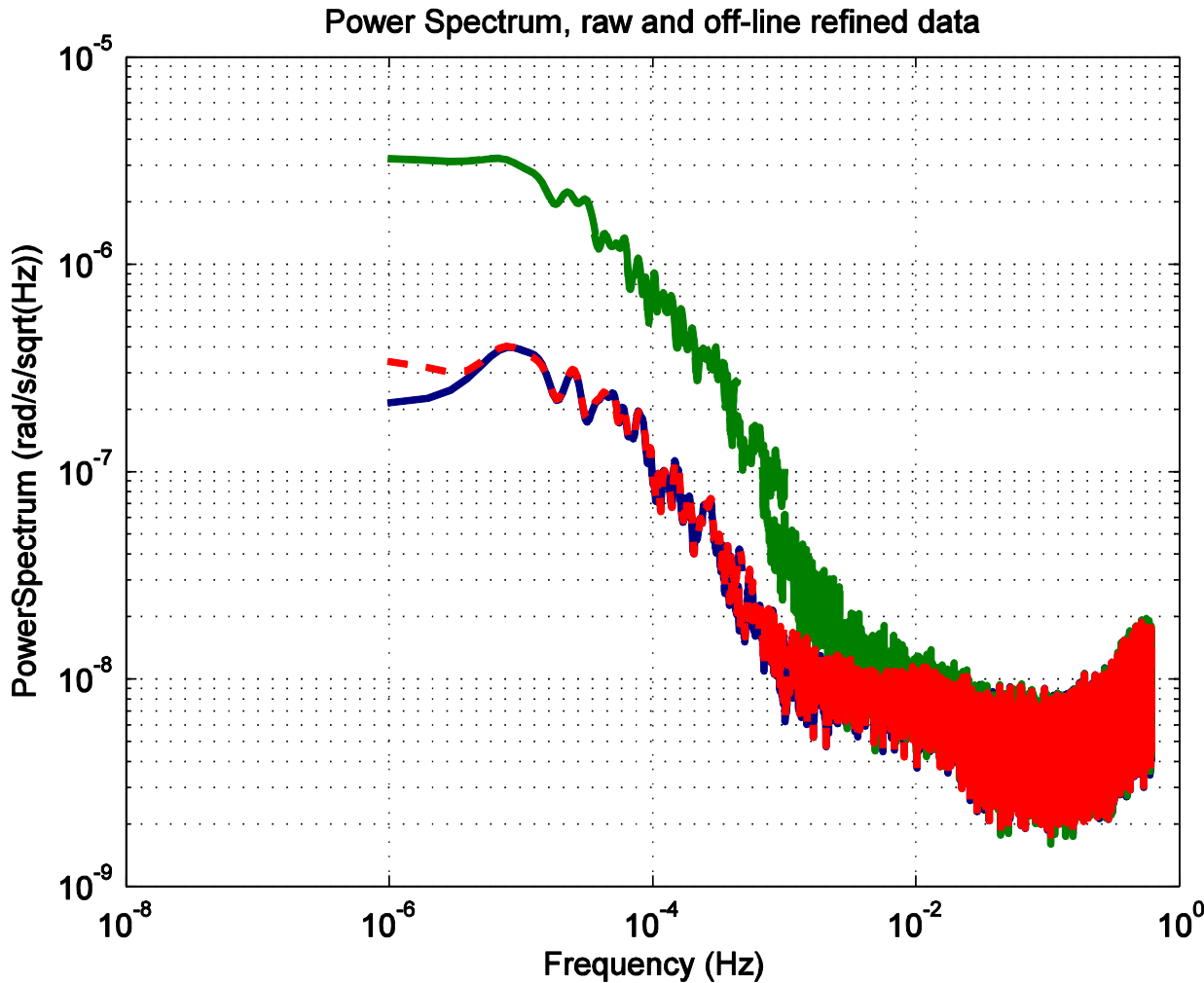


Subtraction of the two previous signals



Puo' aiutare per il data quality
e il commissioning in genere?
Saremo in grado di dare una
Risposta entro la fine dell'anno,
Dopo VSR5

Sensibilità di G-Pisa



Sotto i mHz domina
Il backscattering
Non abbiamo
evidenziato
sostanziali differenze
della sensibilità di G-
pisa nei due
orientamenti

Sensibilità sotto il 1mHz

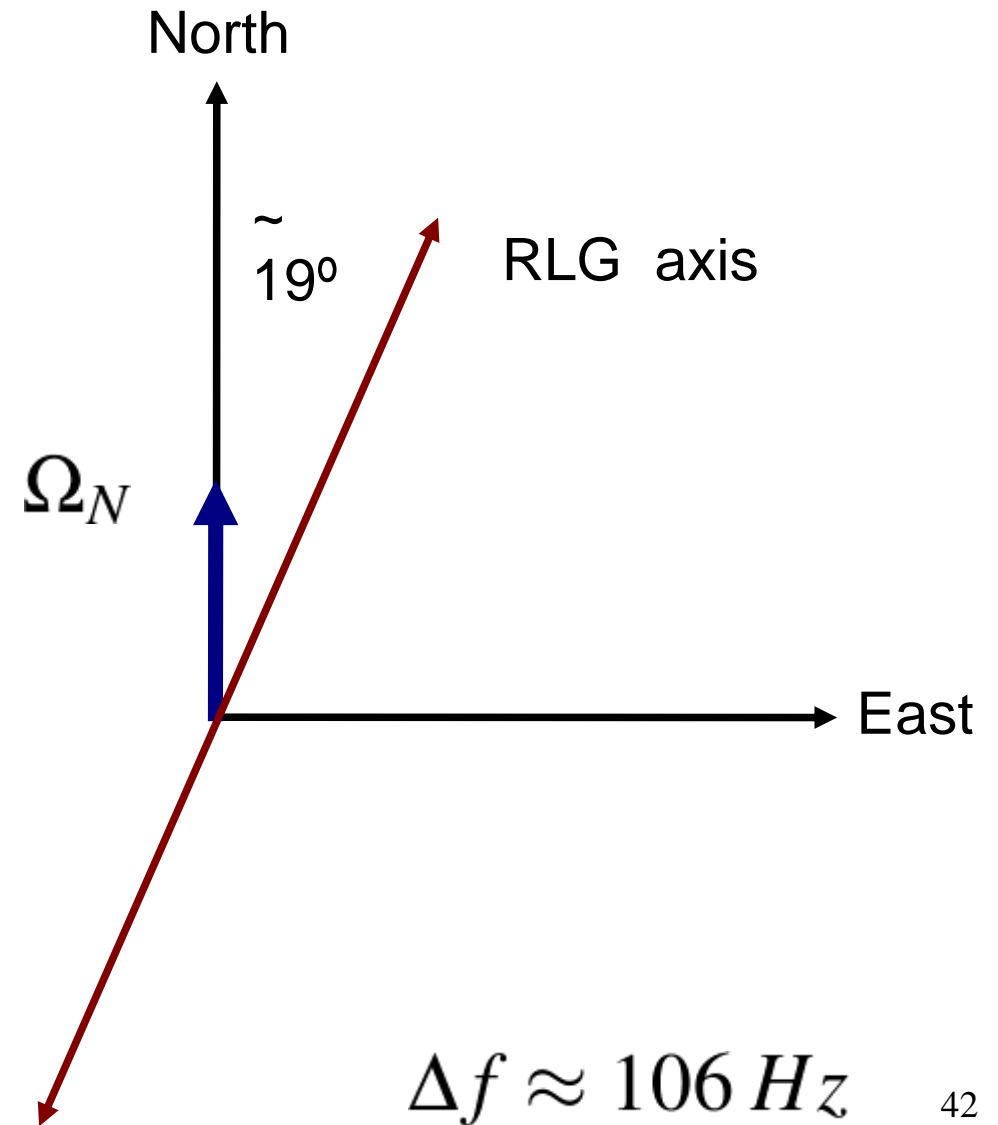
Sotto 1 mHz domina il rumore di backscattering

Siamo in grado di cancellare parte di questo rumore stimando un 'discriminante' usando la modulazione creata dal backscattering sulle uscite singole (non di battimento) dei due beam

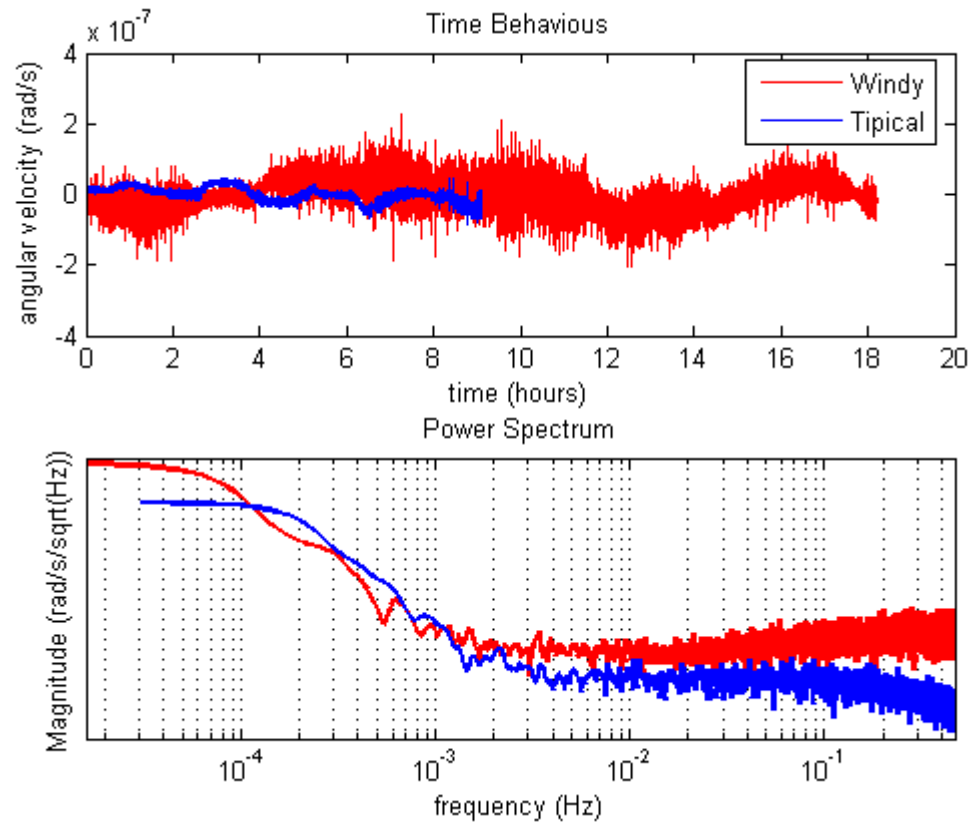
Stiamo studiando la riduzione di questo rumore sfruttando filtri kalman e la conoscenza delle equazioni che regolano il laser stesso: problema non lineare

G-PisVirgo a e il vento

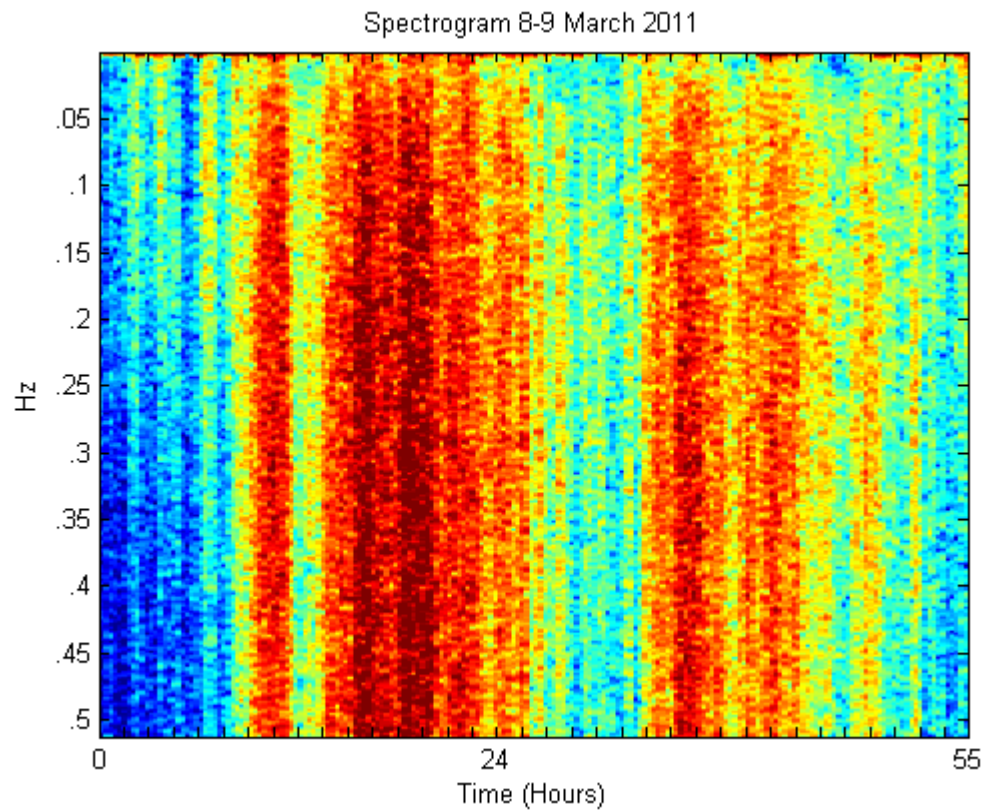
G-Pisa



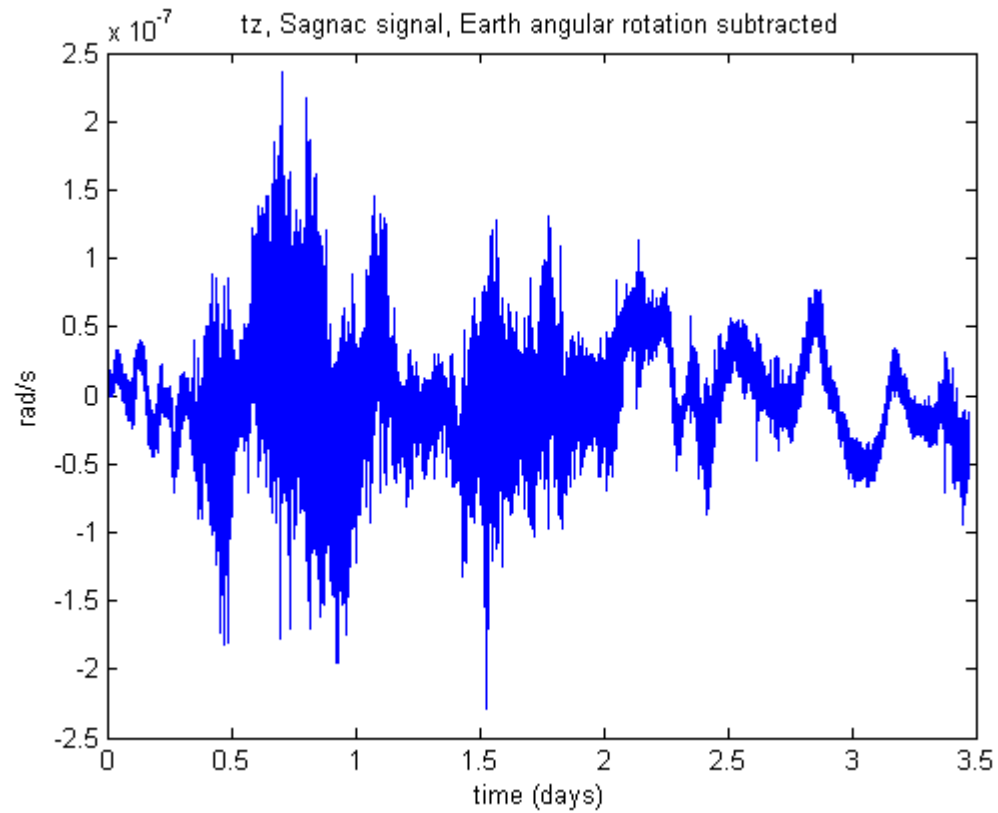
Confronto: condizioni tipiche o in presenza di vento forte



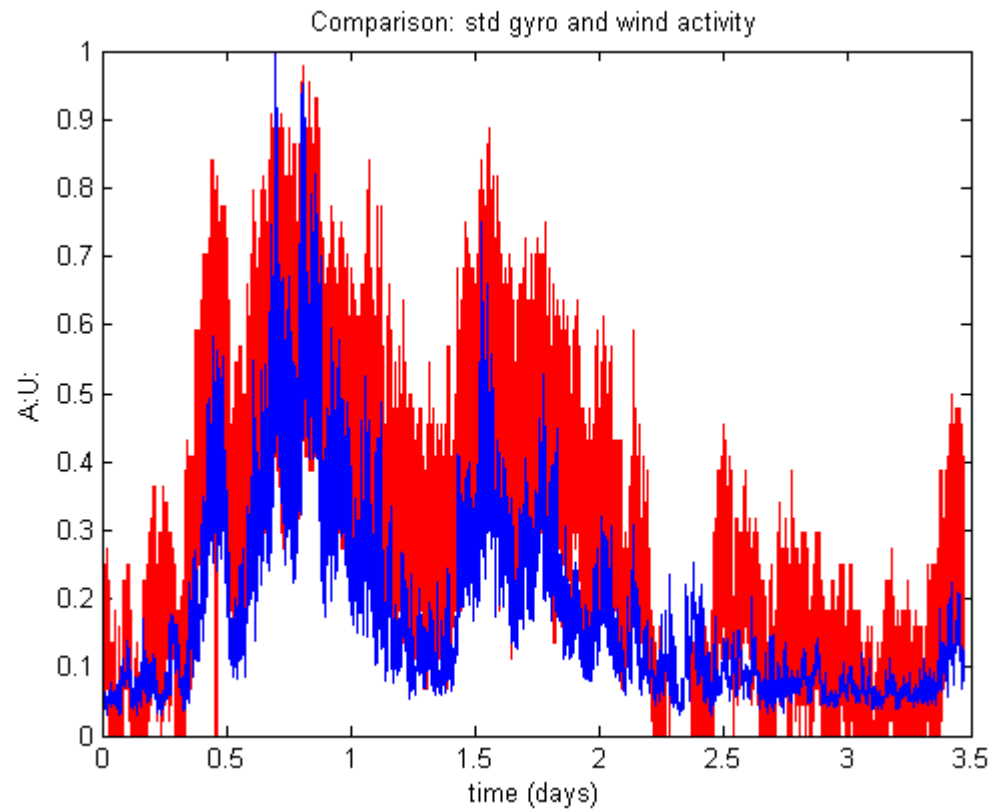
Giorni piu' o meno ventosi



Velocità angolare indotta dal vento

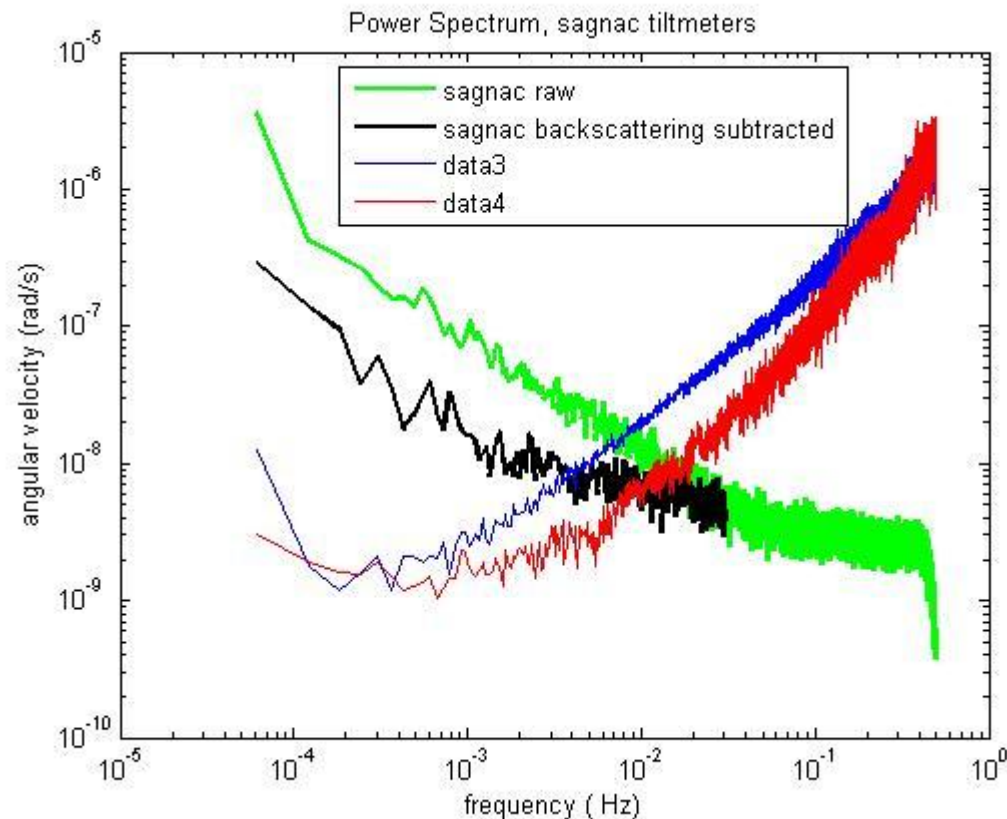


Pargone G-Pisa e anemometro



nanoTiltmeter

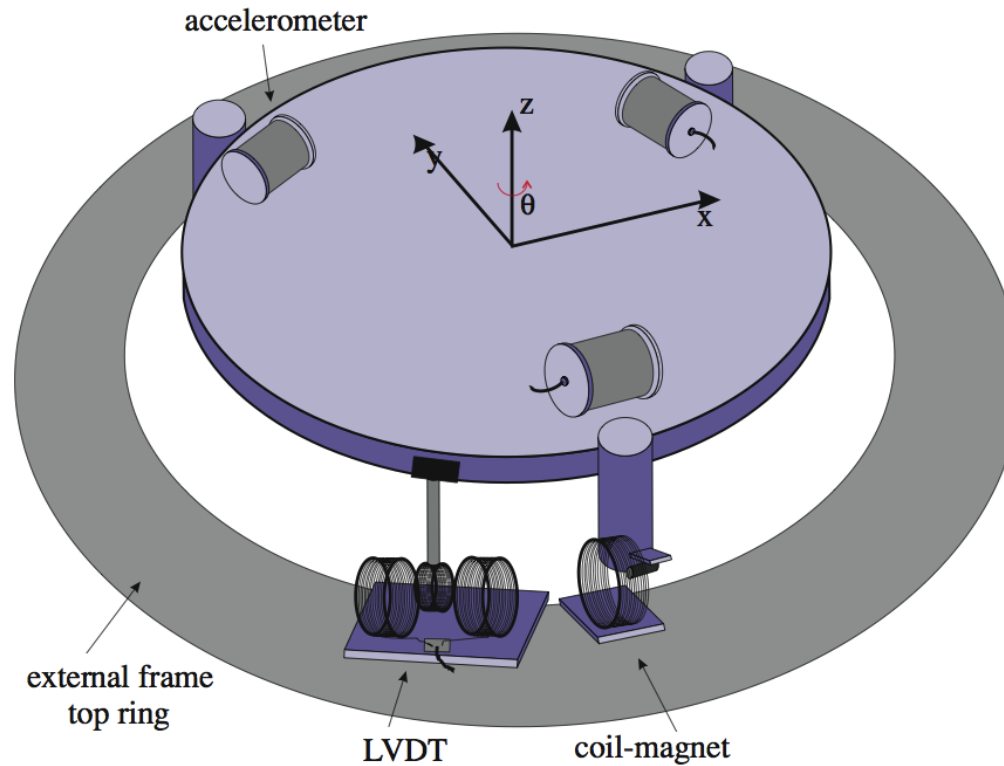
Possiamo paragonare i nostri risultati con un nano tiltometro, che ci è stato 'donato' da Erich Lippmann



Filtri Kalman

Stiamo studiando come sottrarre il rumore del backscattering, che influenza le frequenze sotto le decine di MHz, utilizzando filtri Kalman

Può G-Pisa aiutare nell'annoso problema dell'effetto culla degli accelerometri?



Test sperimentale

Controllo del Pendolo Invertito

Diego Passuello sta inserendo l'algoritmo necessario a ricostruire il segnale in velocità di G-Pisa nel DSP di Virgo. Appena sarà pronto, potremo fare test per vedere se il segnale del ringlaser può essere inserito nel loop del Pendolo Invertito, che inserisce rumore nella catena durante le giornate ventose

inoltre

Un articolo in press su App. Phys. B (Springer)

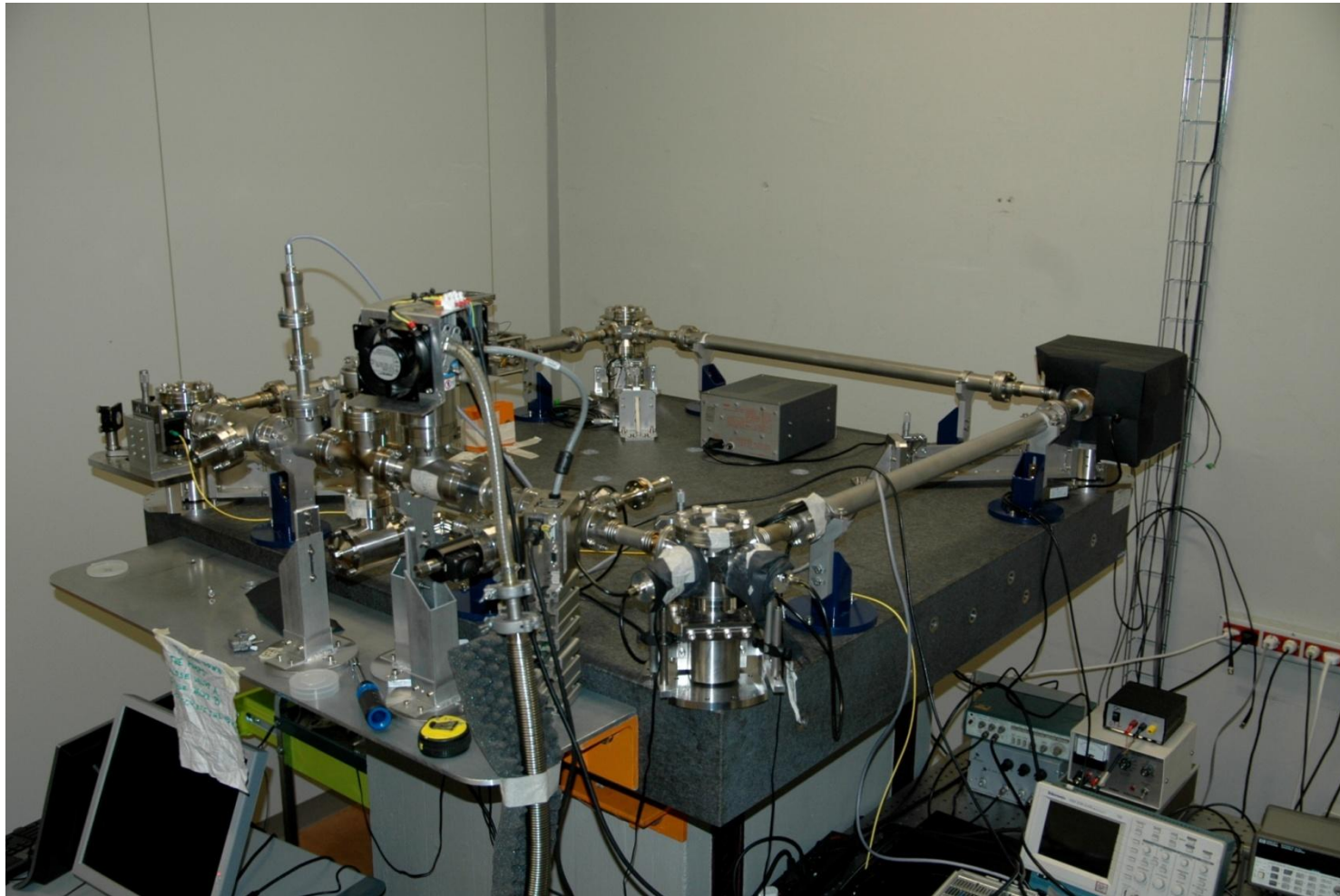
2 articoli in preparazione: terremoto del Giappone
e G-Pisa in posizione verticale

2 proceedings : Moriond e Neutel

G-GranSasso *draft pronto*

We propose an under-ground experiment to detect the general relativistic effects due to the curvature of space-time around the Earth (de Sitter effect) and to rotation of the planet (dragging of the inertial frames or Lense-Thirring effect). It is based on the comparison between the IERS value of the Earth rotation vector and corresponding measurements obtained by a three-axial laser detector of rotation. The proposed detector consists of six large ring-lasers arranged along three orthogonal axes. With shot noise limited square rings of 6 m side, which can achieve a sensitivity of $20 \text{ prad/s}/\sqrt{\text{Hz}}$ and 2 years integration time, the 1% sensitivity required for the measurement of the Lense-Thirring drag can be reached. The multi-gyros system, composed of rings whose planes are perpendicular to one or the other of three orthogonal axes, can be built in several ways. Here, we consider cubic and octahedron structures. The symmetries of the proposed configurations provide mathematical relations that can be used to study the stability of the scale factors, the relative orientations or the ring-laser planes, very important to get rid of systematics in long-term measurements, which are required in order to determine the relativistic effects.

G-Pisa è basato su un disegno meccanico in acciaio molto duttile e flessibile, ma necessita del controllo del perimetro per garantire un funzionamento costante



Il grande ring G di Wetzell, monolitico, realizzato in Zerodur, garantisce 'per costruzione' un funzionamento costante del laser



