# Vibration measurements on the LHC cryo-magnets and their jacks

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DESY

# LHC Alignment Jacks

- Alignment jacks have been designed for 3-axis precise positioning of the LHC cryomagnets
- Long term static stability and easy installation (no girder)
- Motorized version available for IP quadrupoles
- Dynamic performance untested so far
- Low cost
- It may be an attractive solution for supporting the ILC cryomodules on the tunnel floor.

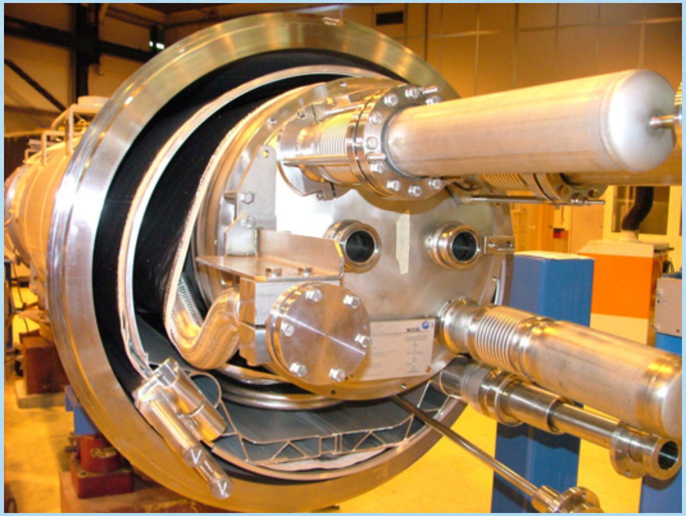
# LHC Cryo-Dipoles

LHC standard cryo-dipole installed in the 3-4 arc section. Note the small concrete interface between the jack and the tunnel floor as compared with low beta quads (next slide).

Fiberglass cold mass supports

| | |
|---|---|
| Length | 17 m |
| Weight | 32 tons |
| Cryostat diameter | ~ 1 m |
| No.of jacks | 3+1 at center for sagitta compensation |
| Cold mass support | 3 fiberglass posts on the bottom |

Characteristics of LHC standard dipoles



Cold mass view

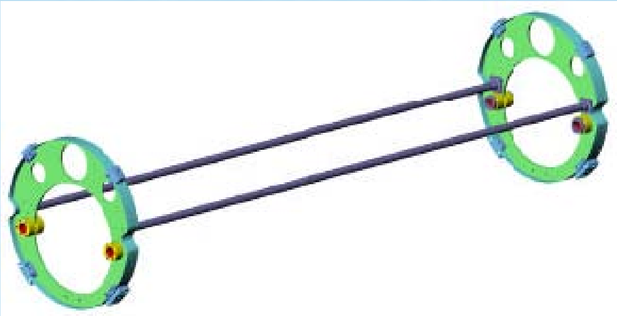
# LHC Low ß Quadrupole


LHC low beta quadrupole near ALICE interaction region

View of the alignment jacks. Note the enlarged contact plate between the jacks and the concrete slab for better surface contact, and hence stability.

| | |
|---|---|
| Length | ~ 9 m |
| Weight | 17 tons |
| Cryostat diameter | ~ 1 m |
| No.of jacks | 3 with enlarged footing section |
| Cold mass support | Full cross section collars |

Characteristics of LHC low beta quadrupoles



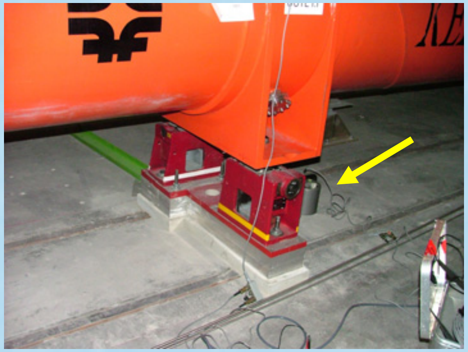
Composite spider-like cold mass support, designed for better support .

Reference: ´LHC interaction region quadrupole cryostat design and fabrication´. T.H.Nicol, C. Darve, Y. Huang, T.M. Page

# Methodology

**Sensors used: two tri-axial Güralp seismometers (CMG-6TD) together with vertical and horizontal geophones (SENSOR SM-6)**

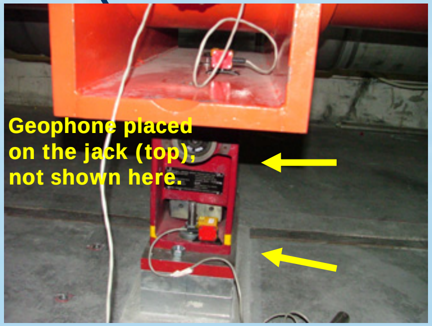
**Sensor positions: To study stability of cryo-dipole jacks, one seimometer was positioned on the most stable position on the vessel top, and the other, on the tunnel floor directly underneath the module. Data taking period: ~ 1 hr for each configuration.**

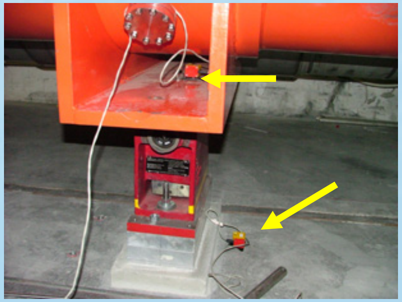


**Standard FFT techniques were used to deduce power spectrum density (psd) and integrated spectra resulted in the displacement (in nm) at f > 1 Hz.**
**For more information, please click on:**

http://vibration.desy.de/documents/index_eng.html

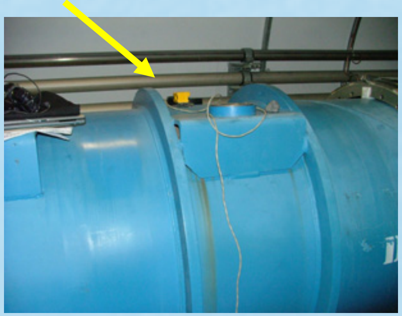
**To study the stability of the jacks, geophones were placed on the module socket, on the jacks (both top and the base of the jacks) and on the tunnel floor for both vertical and horizontal transverse (transverse to the beam) directions.**

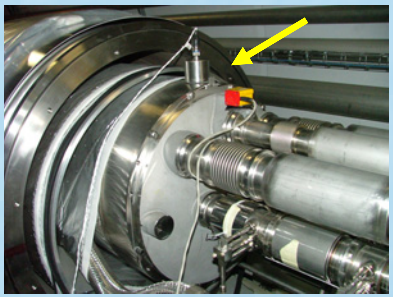


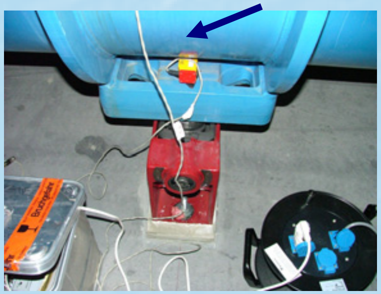



# Methodology

**To study stability of the cold mass, geophones were placed on the vessel top, directly on the cold mass and on the socket of the module.**







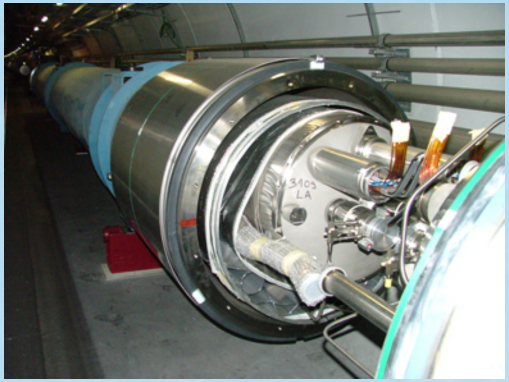
**Measurements on the stability of the jacks were performed on 4 modules in total: 2 stand-alone cryo-dipoles (for reproducibility checks), one connected to the other modules in the ring and one low beta cryo-dipole (ALICE interaction point).**

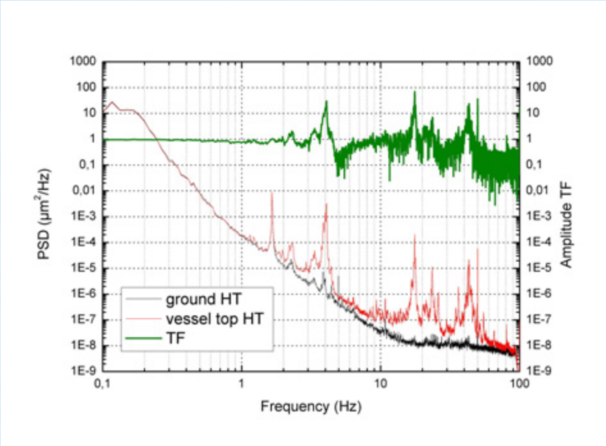
**Two stand alone modules (sector 2):**
- **Dipole number: HCLBALA000-IN003109**
- **Dipole number: HCLBALA000-IN002352**

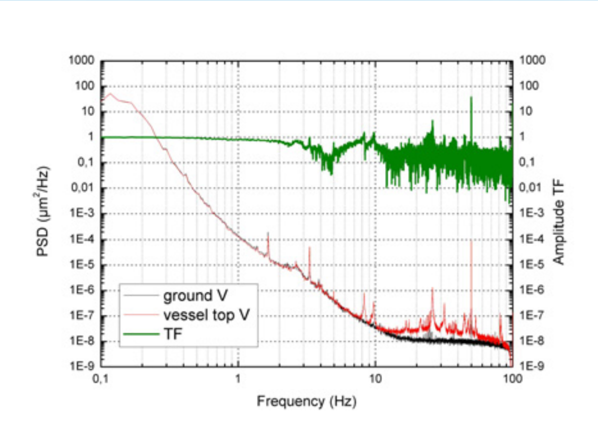


**One connected module (sector 4):**
- **Dipole number: HCLBBLA000-IN003198**

# LHC Cryo-Dipoles **Stand-alone configuration**

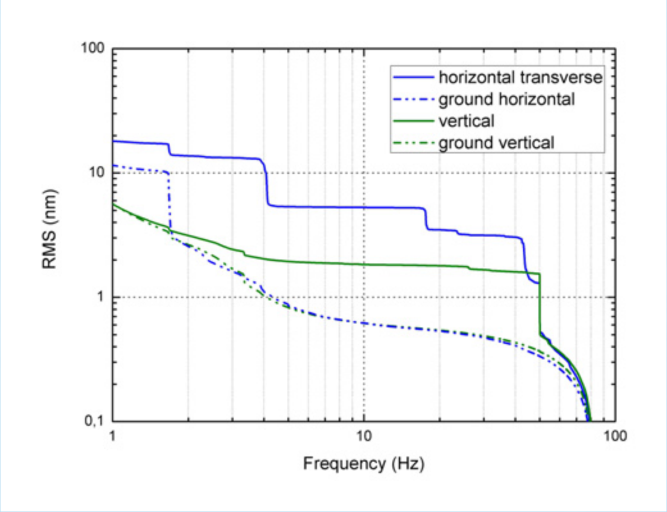





**Comparison of ground spectra vs. vessel top in both horizontal transverse and vertical directions (seismometer measurements).**

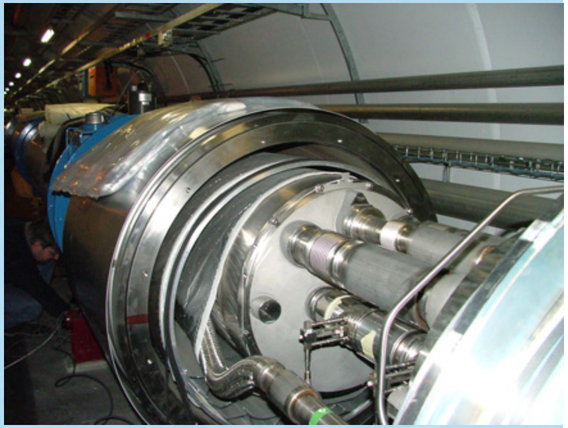
- **Low frequency resonance at 4 Hz (amplification of TF ~30) in the horizontal transverse direction. This resonance is pushed further in the low beta quads to 10 Hz (slide 11).**
- **Other large amplitude modes at 17 (amplification of TF ~80) and 42 Hz (amplification of TF ~30).**
- **Very stable in vertical, no visible resonances, motion dominated by facility noise.**
- **in this sector, the strongest peak (~1.7 Hz) in the spectrum comes from the facility.**

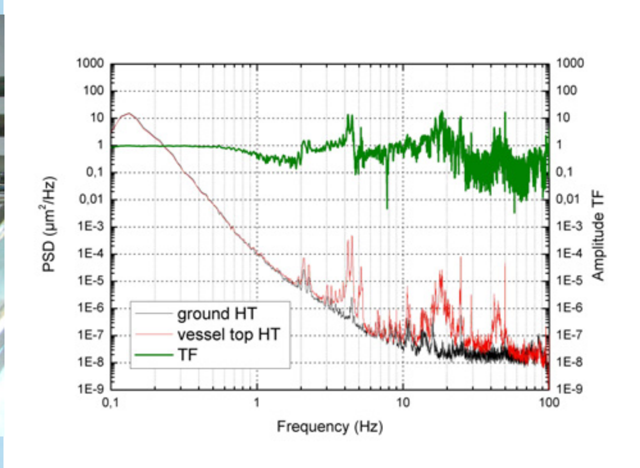


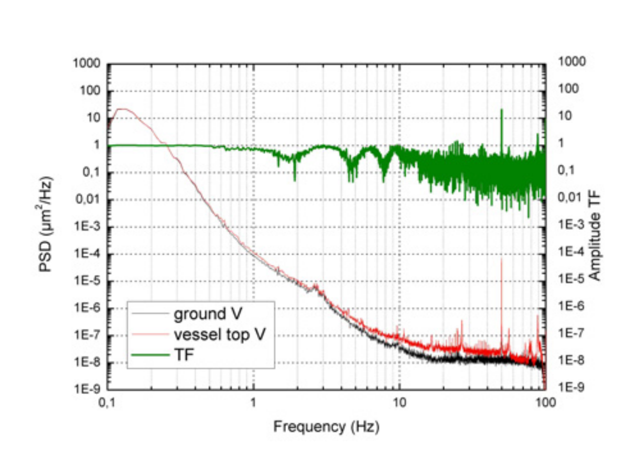

RMS comparison of ground and vessel top in both vertical and horizontal transverse.

**Vertical is more stable than horizontal transverse, however LHC tunnel is a very quiet site, in the order of only a few nm rms @ f > 1 Hz.**

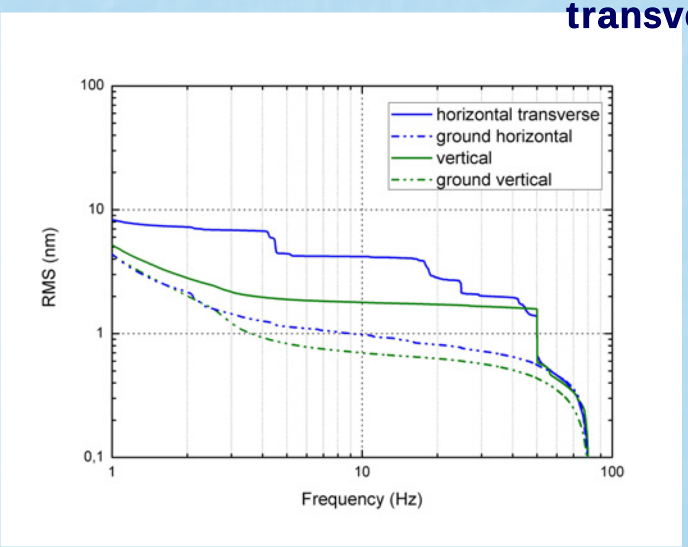
# LHC Cryo-dipoles **Connected configuration**





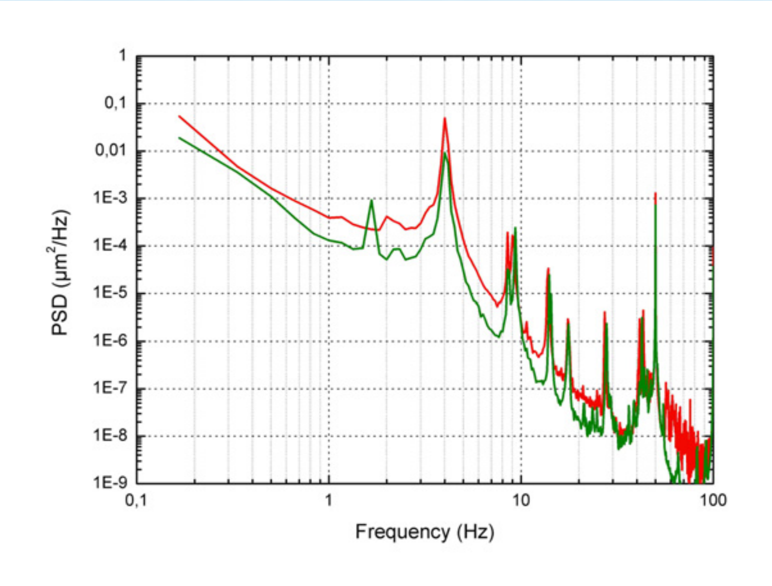

**Comparison of ground spectra vs. vessel top in both horizontal transverse and vertical directions (seismometer measurements).**



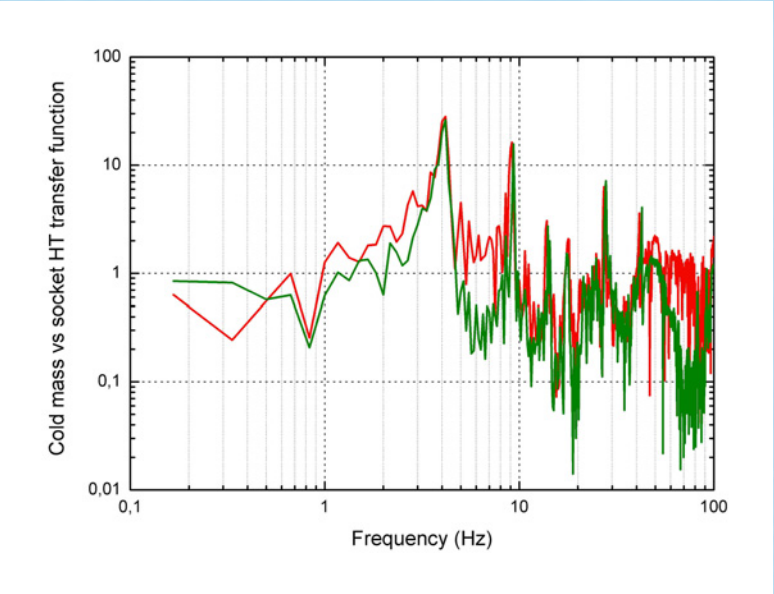

- **Frequency response almost identical to the stand alone case but with some damping of the resonances as seen from the amplification of the resonances shown in the transfer function (in green) in the case of the horizontal transverse.**
- **For the vertical case, both stand alone and connected cryo-dipoles have almost the same rms motion of ~ 5 nm @ 1 Hz.**
- **large amplification of the ground motion from the support @ 4 Hz, but taking advantage of the CERN site, the resulting RMS motion amplitude is absolutely safe for the LHC operation.**

# LHC Cryo-dipoles

**Stand-alone: comparison between two unconnected dipoles**




**Cold mass spectra (horizontal transverse) of two dipoles**



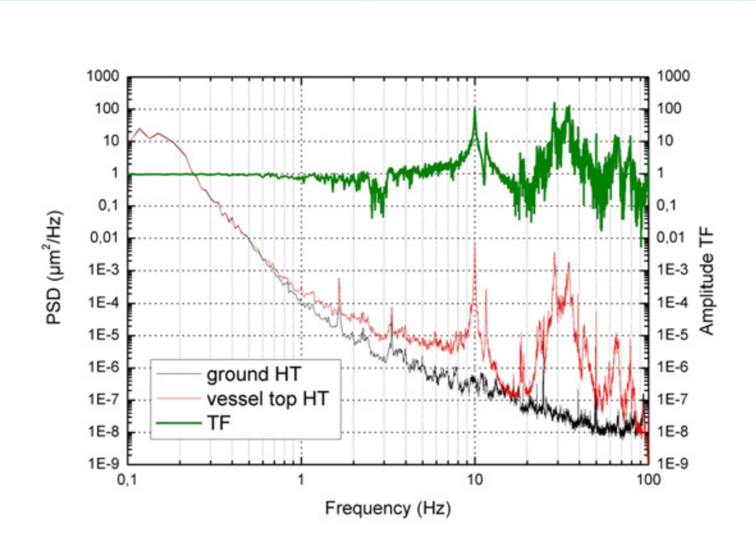

**Cold mass transfer function (horizontal transverse) comparison**

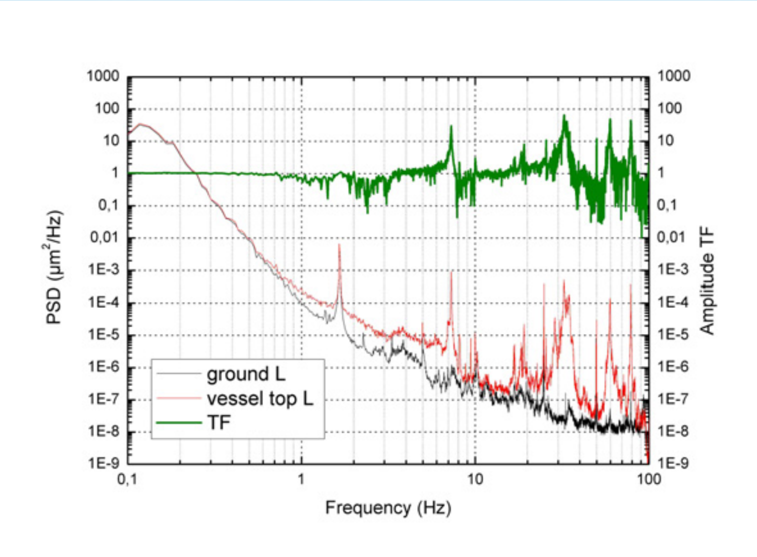
**Two stand alone modules (sector 2):**

- **Dipole number: HCLBALA000-IN003109**
- **Dipole number: HCLBALA000-IN002352**

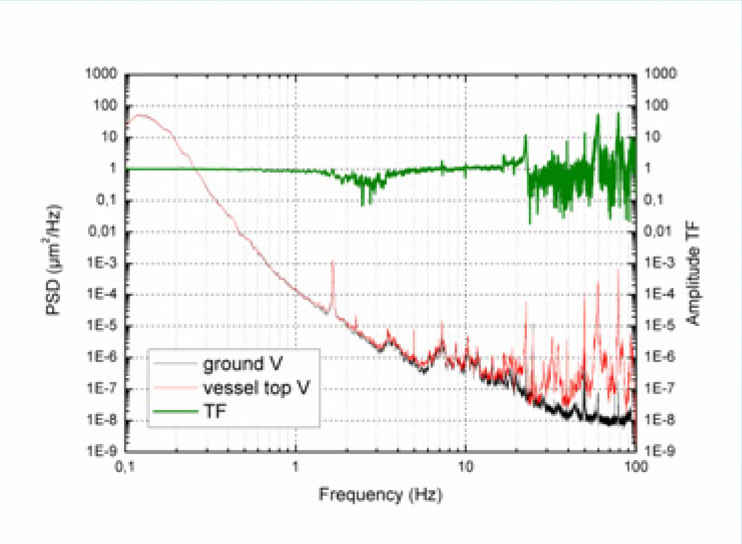
**Conclusion: The two stand-alone dipoles measured are very similar, i.e. both have similar resonance peaks.**

# LHC Low ß Quadrupole Ground to vessel top transfer function



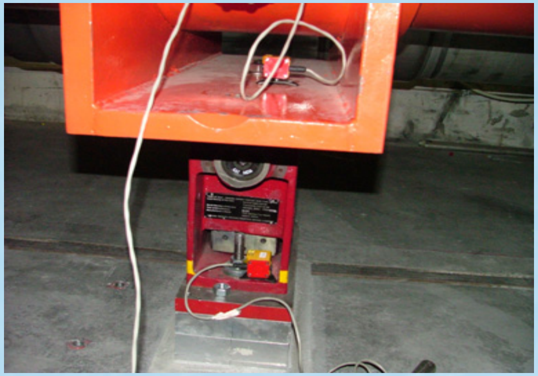




**Comparison of ground spectra vs. vessel top in horizontal transverse, longitudinal and vertical directions clockwise (seismometer measurements) for the low beta modules.**



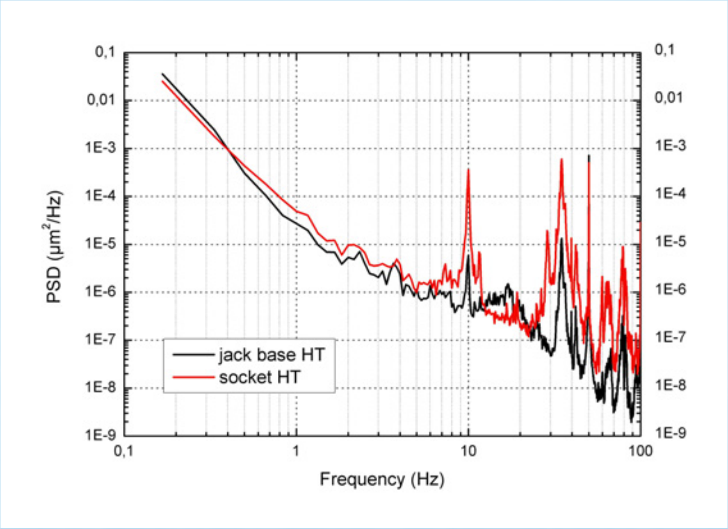

- **Better stability than the dipoles along the transverse direction with the first mode at 10 Hz, but larger (amplification of TF ~100.**
- **Soft in the longitudinal axis with a 7.3 Hz mode.**
- **Stable along the vertical direction.**

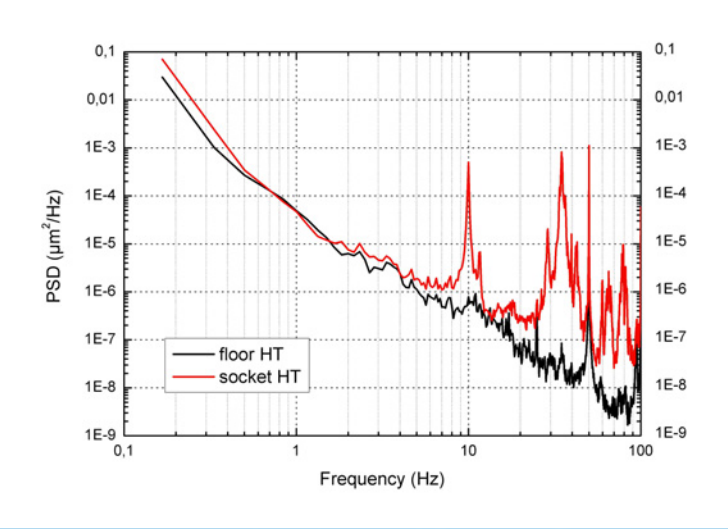
# LHC Low ß Quadrupole Effect of the support foundation



Vessel socket vs jack base

Vessel socket vs tunnel floor



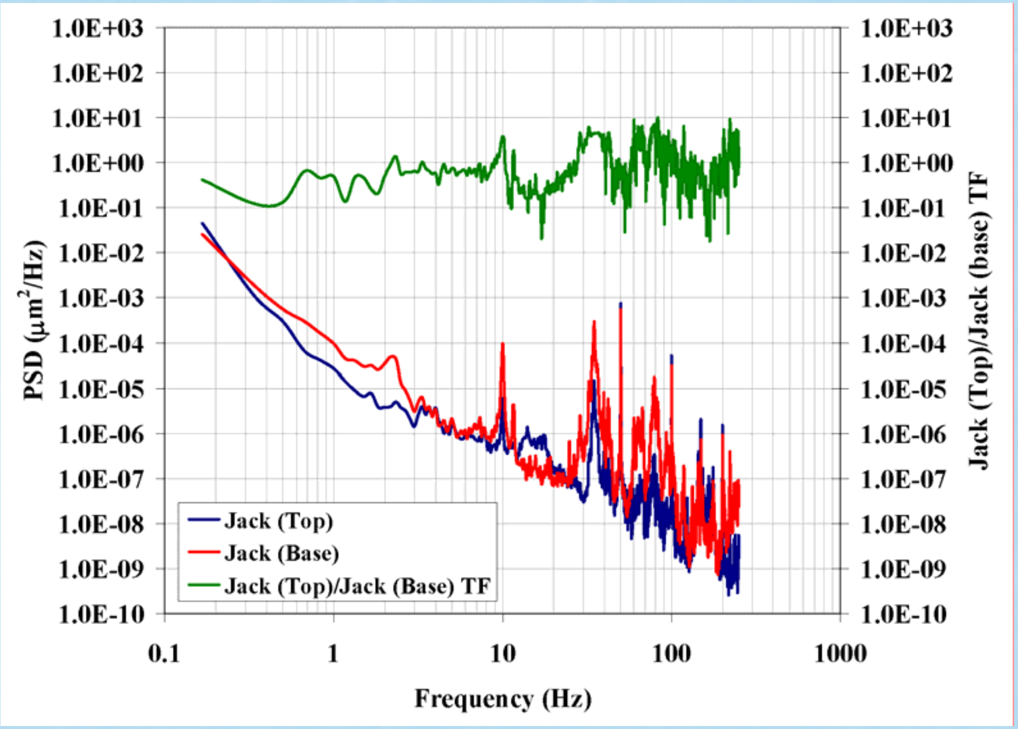




**• Transverse mode structure is already visible at the interface between the jack and the concrete pad, but not on the tunnel floor. Our investigation of the spectra between the base of the jack and the floor shows that the concrete pad induces resonances @ 10 and 42 Hz.**

**• The enlarged contact surface produces significant benefits on the dynamic stability of the module.**

# Cryo-magnet Jacks

**Measurement of the Transfer Function (TF) in the horizontal transverse direction of the cryo-magnet jacks, at the top and the base of the jacks, shows that the jacks have no internal resonances in the frequency range measured (1.7-250 Hz, geophone measurements).**

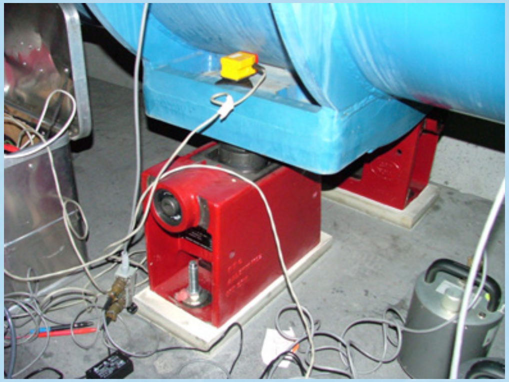


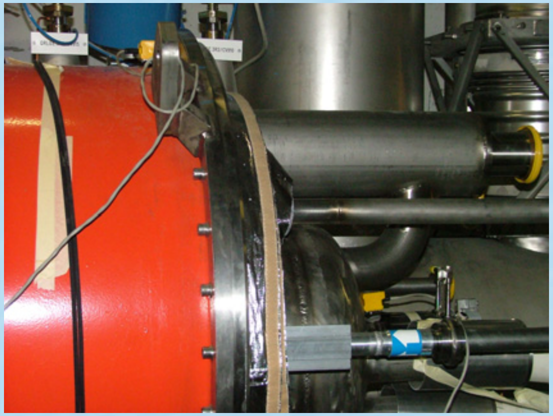

**Conclusion: For the ILC supports, one should concentrate on the optimization of the interface between the tunnel floor and the jacks.**

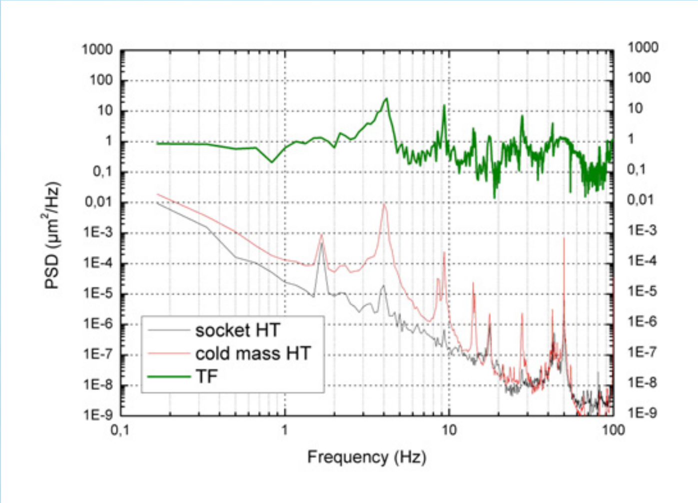
**Low frequency resonances seen @ 4 Hz in the case of the cryo-dipoles and 10 Hz in the case of low beta dipoles, may affect the stability of the nanometer-sized beams in both the ILC and the XFEL.**

# LHC Magnets-cold mass

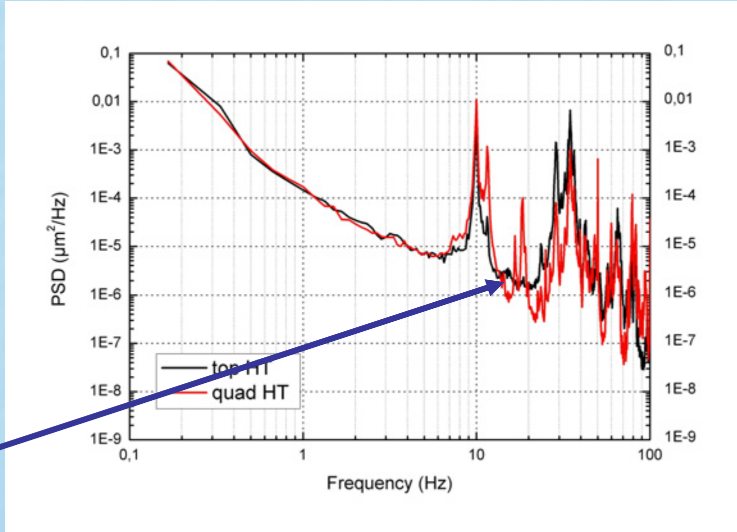
Measurement on the standing alone dipole and quadrupole








**the cold mass motion is dominated by the large amplitude module rocking modes. In dipoles seems not very well supported internally: two modes at 8 and 14 Hz are visible in the cold mass PSD only. In the case of the low beta quadrupole, the lowest modes are seen at 16 and 18 Hz.**



# LHC Magnets- Summary

• We have investigated the dynamic stability of standard LHC arc section dipoles in both stand-alone and connected to the beam-line configurations
• The support design with no girder and short leveling jacks has been evaluated
• We have found low frequency mechanical resonances (4 Hz, the lowest) that largely amplifies the floor motion in the horizontal transverse direction.
• However this will not affect the LHC operation because of the low level of ground motion in the tunnel.
• the alignment jacks look ‘undersized’ to guarantee proper vibrational stability for the 32 ton dipoles.
• The results of the measurements on the short low beta quadrupole cryostat look promising for the use of the alignment jacks for the ILC linacs, after suitable modifications (properly sized footing).

# Special Thanks to: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