ILC European Regional Meeting and ILC-BDIR

Royal Holloway, University of London, 20-23 June 2005

Tuner Issues: Lateral and Coaxial

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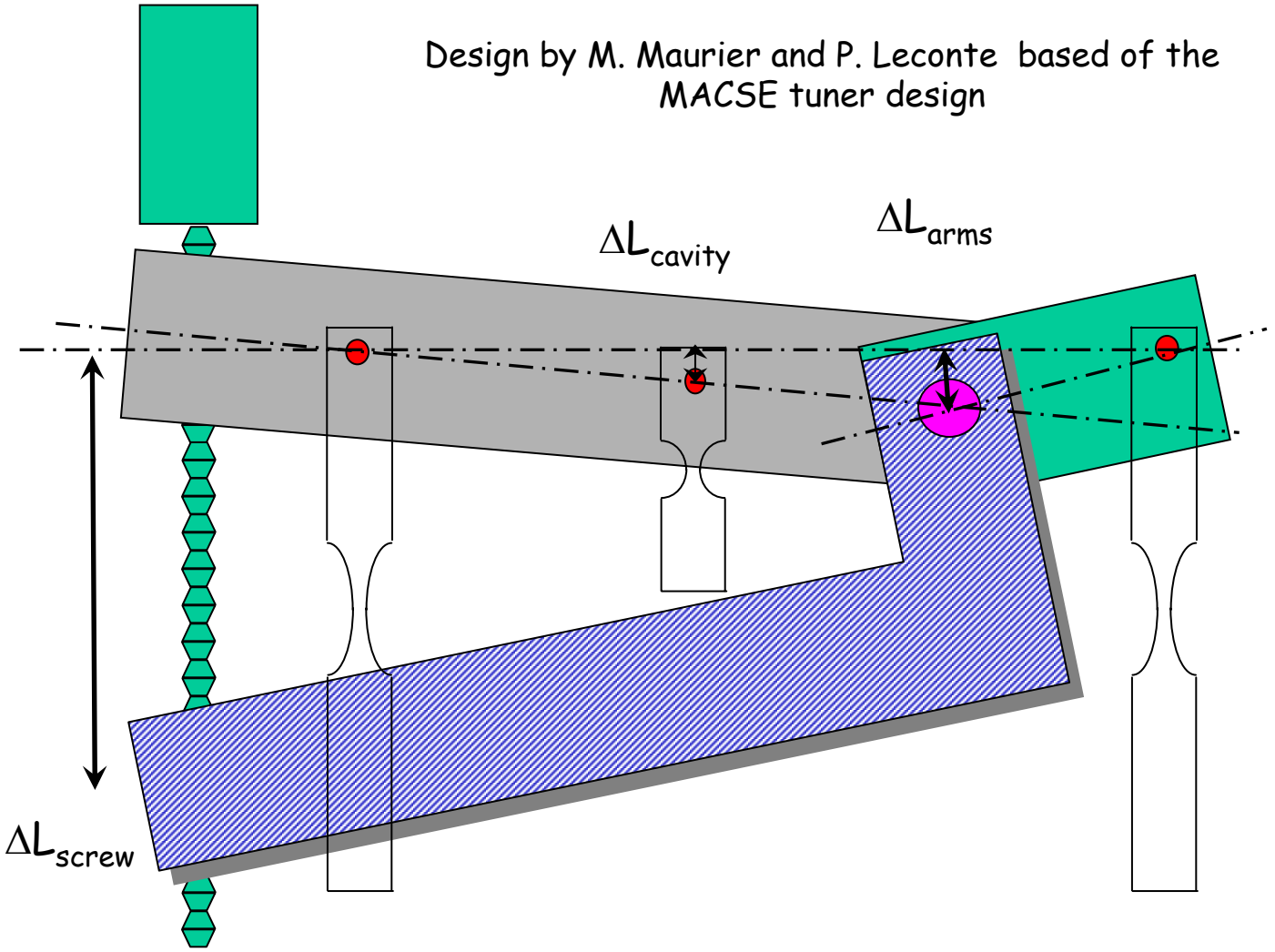
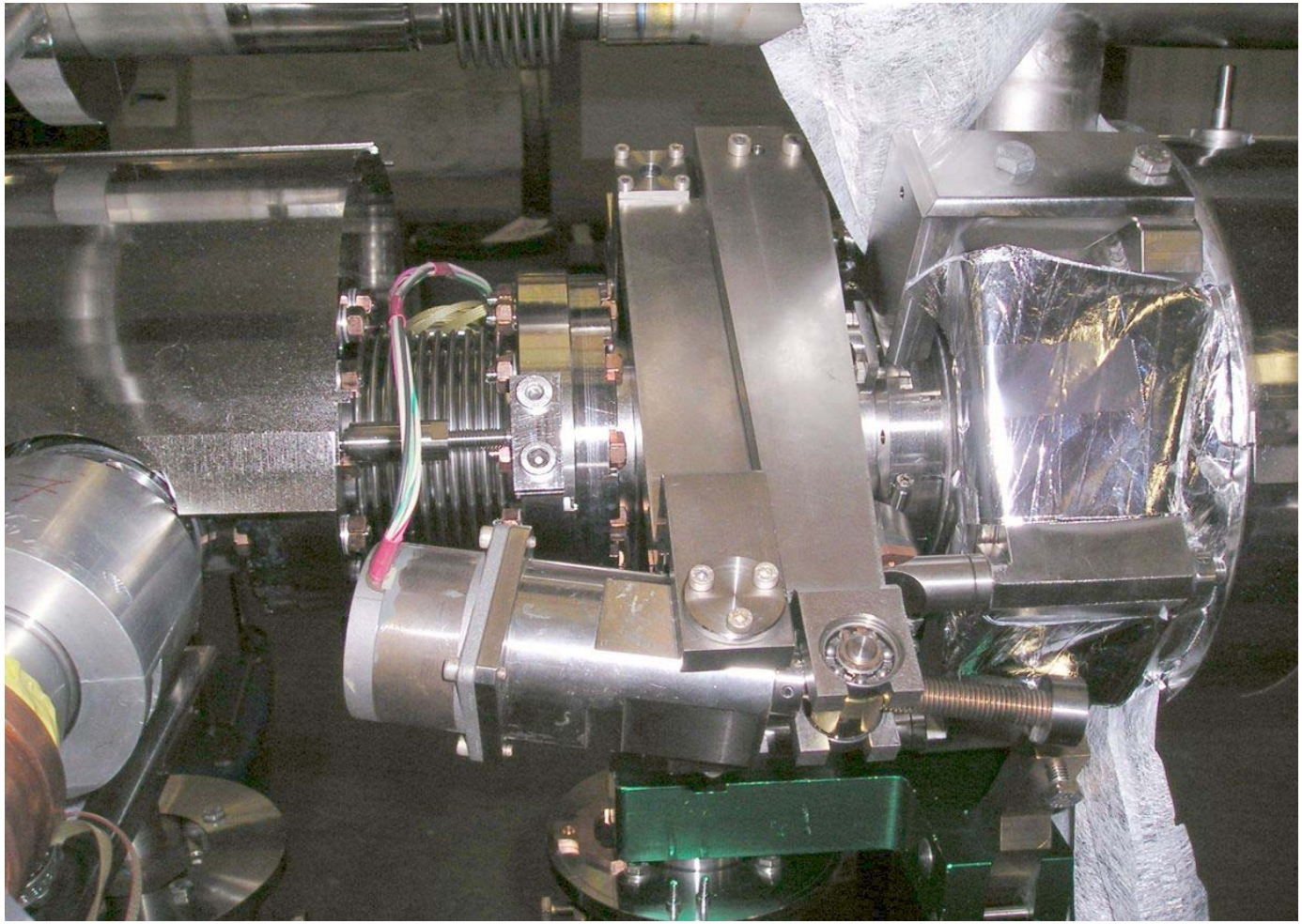
INFN Milano and DESY

On leave from University of Milano

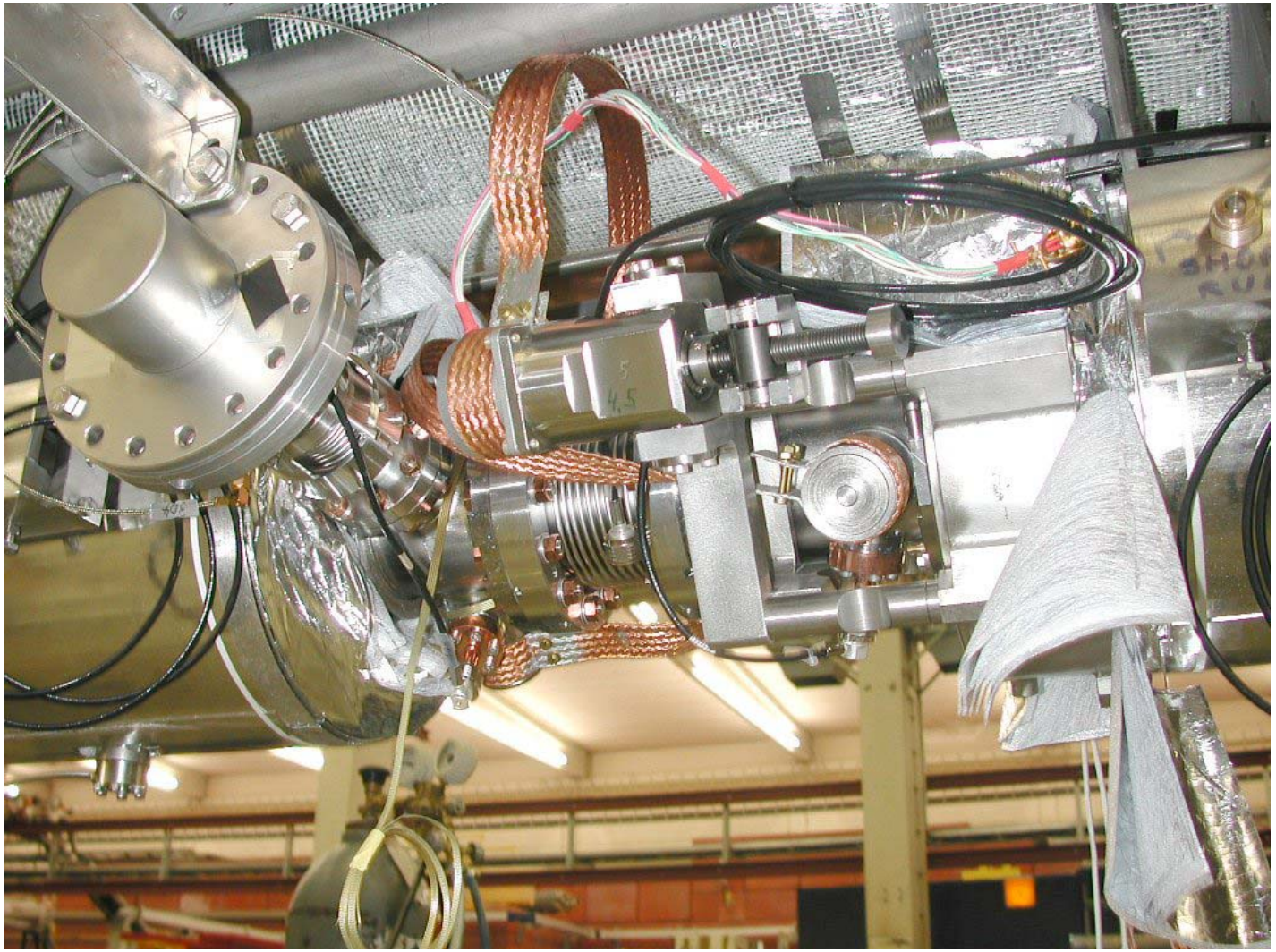
The TTF Saclay Tuner: Operation Principle



The TTF Saclay Tuner - 1

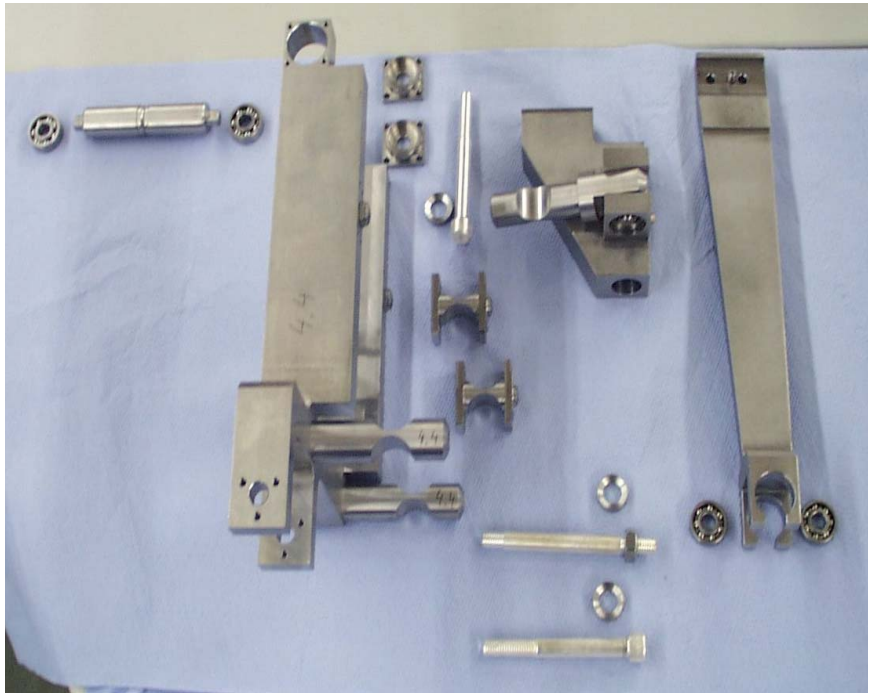


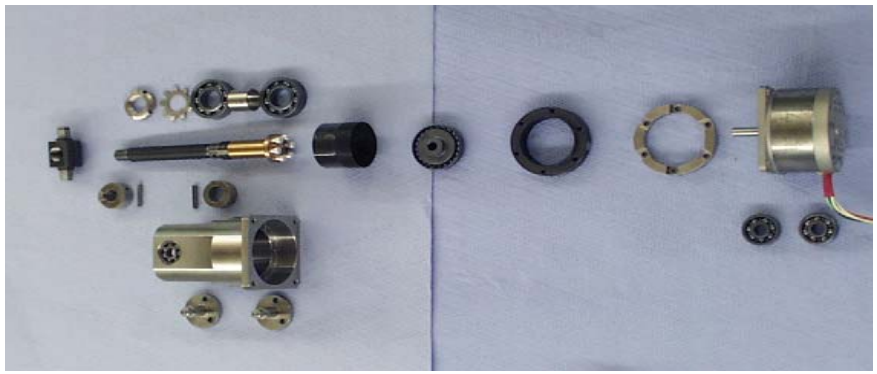
The TTF Saclay Tuner - 2



Tuner parameters and Details

- Double lever system: ratio ~ 1/25
- Stepping motor with Harmonic Drive gear box
- Screw – nut and gearbox system: surface coating (balzers Balinit C coating) for working at cold and in vacuum
- ball bearings with lubricant Lamcoat
- Δz_{max}= 2 mm
- ΔF_{max} = 830 kHz
- theoretical resolution: Δz = 1.5 nm or 0.74 Hz
- calculated stiffness: 180 kN/mm (measured : 100 kN/mm)





Long Term Experience in TTF

total amount in million motor steps - averaged per module

Status: 15-Mar-05 R. Lange MKS

Module cycl. c/w months c	M1 5 17	M2 3 44	M3 1 35	MSS 3 14	M1* 2+(1) 8+(12)	M2* (1) (12)	M3* 1+(1) 3+(12)	M4 1+(1) 3+(12)	M5 1+(1) 3+(12)
add carry steps	0.0	0.0	0.0	0.0	9.9 M1	9.3	6.1	0.0	0.0
prepare at 300 K	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.2	0.2
CHECHIA 4K/2K	3.8	3.8	3.8	2.8	0.0	0.0	0.0	2.8	2.8
module assembly	0.2	0.2	0.2	0.5	0.2	0.2	0.2	0.2	0.2
TTFLinac 4K/2K	5.7	5.1	1.9	0.5	5.7	0.8	2.3	1.9	2.1
total steps	9.9	9.3	6.1	4.0	15.9	10.4	8.7	5.1	5.3

expected lifetime:> 48 million motor steps from long term tests

Summary of TTF Experience

By Rolf Lange

Tests , installations and operations with standard cold tuners from Saclay type have not caused problems and have worked fine from 1997 until autumn 2004.

But

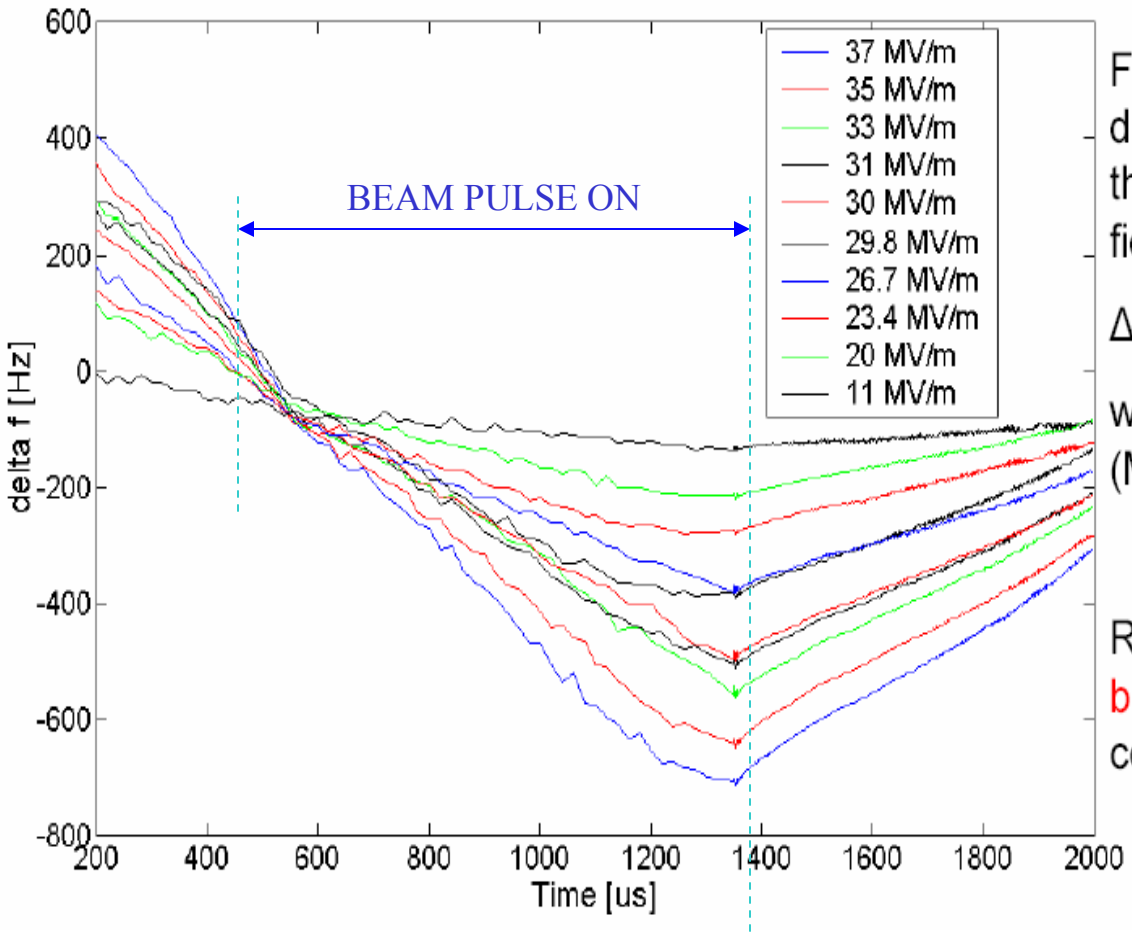
Oct-04 Module 3* tuner cavity 4 after many years operation does't work!
Motor coils o.K. Problem not understood!

Nov-04 Module 5 tuner motors had been connected to other wrong old spare driver electronic components in a typical Friday afternoon/week-end action. The components had not been checked!!!

➔DC and holding current for 3 days
4 motor coils (C1-C4) destroyed, motor not working
4 motor coils (C5-C8) damaged, but motors still working

Although these problems the tuner itself is the most reliable component in the TTF Cryomodules during the last 8 years of TTF operation.

Lorentz Force Detuning



Frequency detuning due Lorentz forces of the electromagnetic field in the cavities:

$\Delta f = K \cdot E_{acc}^{2}$

where $K \approx 1\ Hz / (MV/m)^2$

Remember: Cavity bandwidth with main coupler is ≈ 300 Hz

Possible Cures

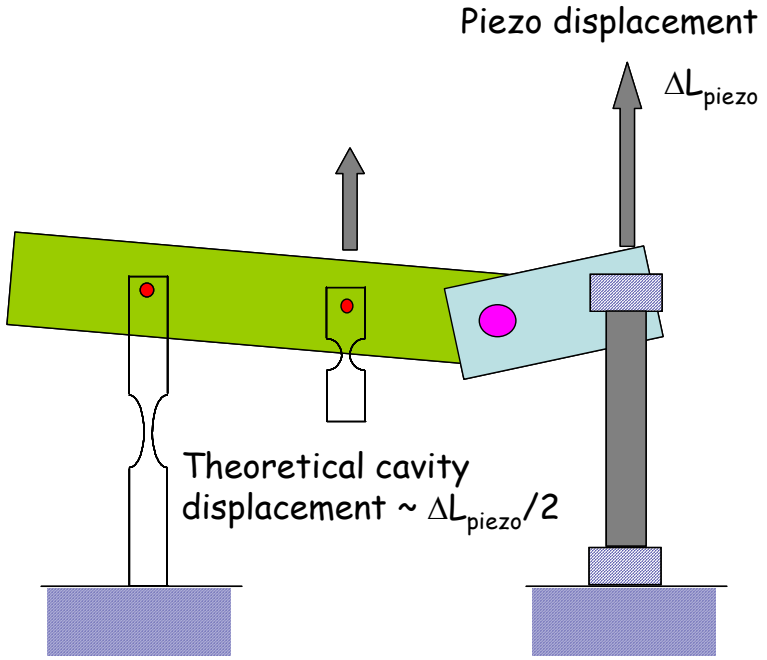
- Additional RF power

  for field control

- Active tuning system in the millisecond pulse

  with piezoelectric and/or magnetostrictive devices

Operation Principle



Important note:
The strength applied on the cavity shall always be set in the state of compression in order to avoid the neutral point (equilibrium between pushing and pulling)

1. If the cavity elasticity response is much lower than the piezo displacement speed then the tuner will be in the neutral point.

2. The compression force applied to the piezo element depends on the step motor position.
To guarantee 10 years lifetime of piezostacks the preload force need to be set around 1.2 kN (±300N)

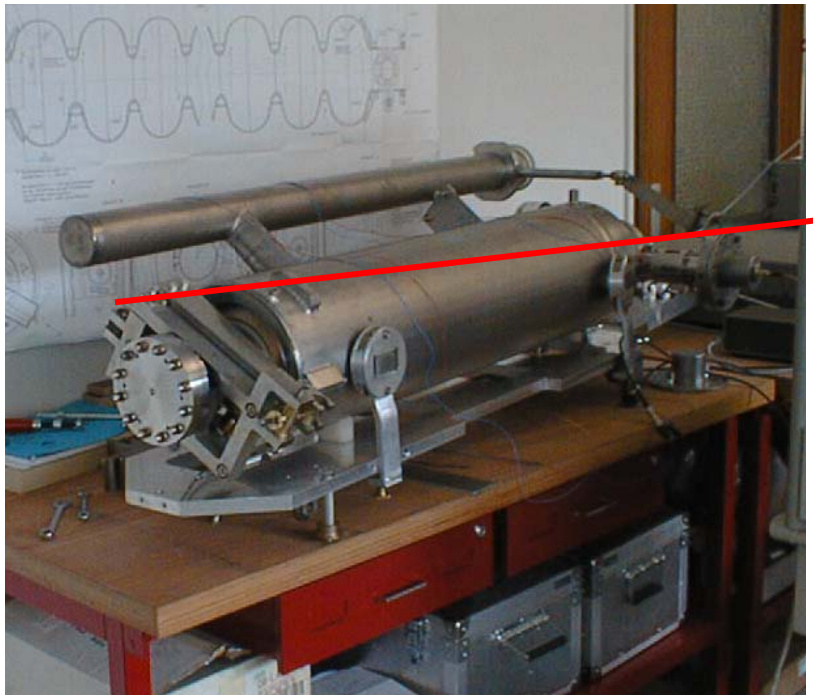
Piezo-assisted Tuner on AC73

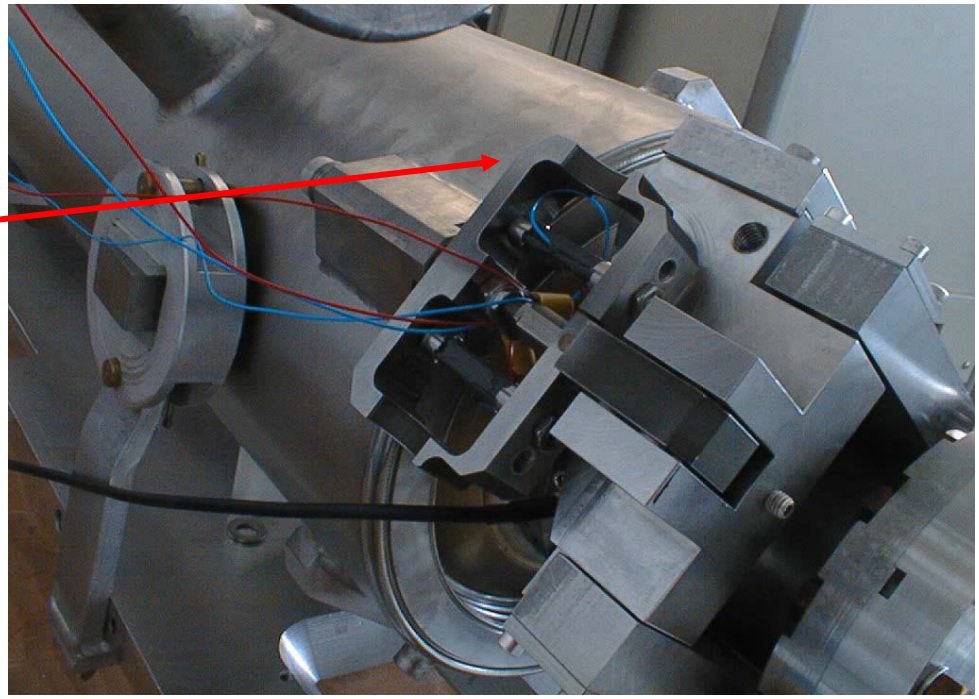
- To compensate for Lorentz force detuning during the 1 ms RF pulse

  Feed-Forward

- To counteract mechanical noise, "microphonics"

  Feed-Back

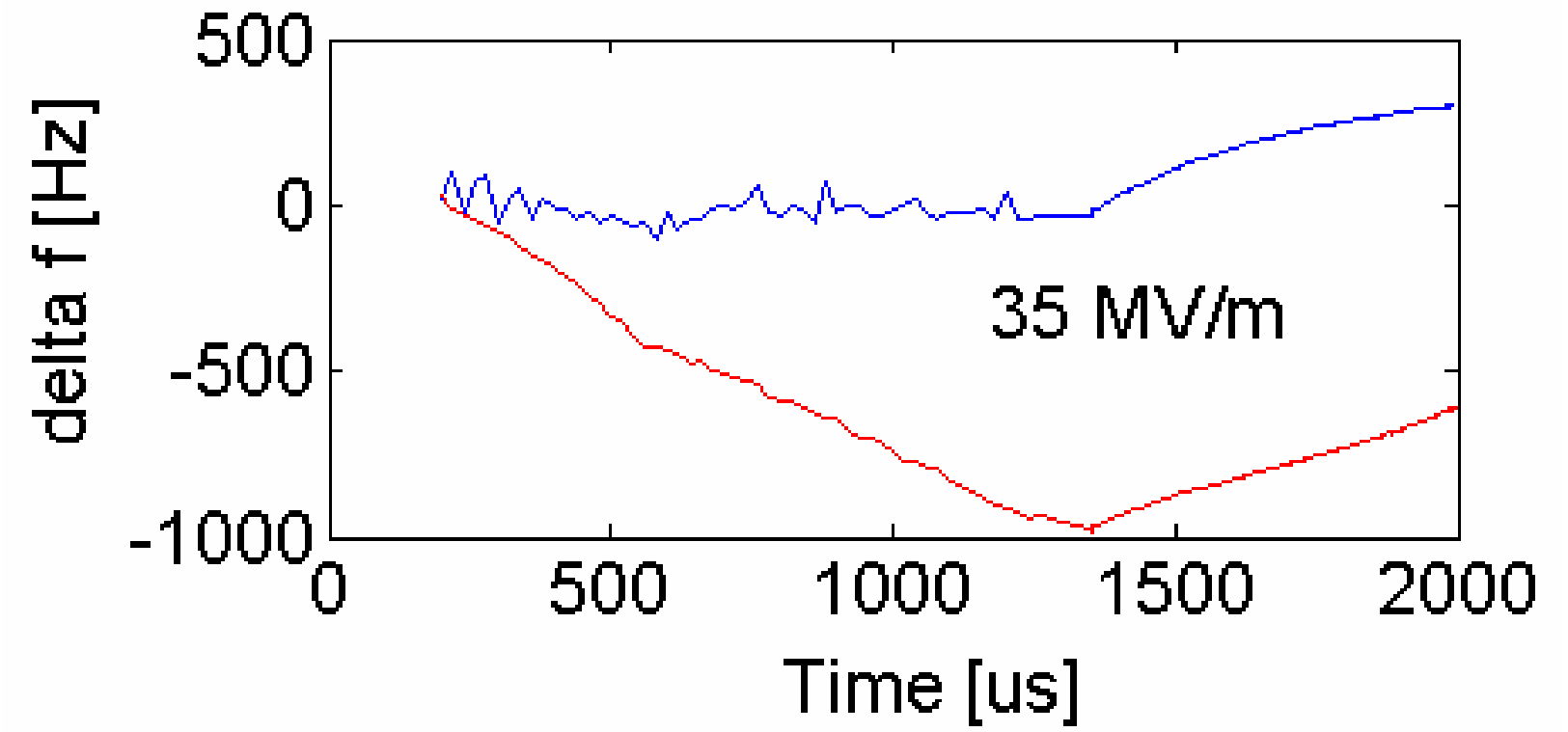




Successful Compensation @ 35 MV/m

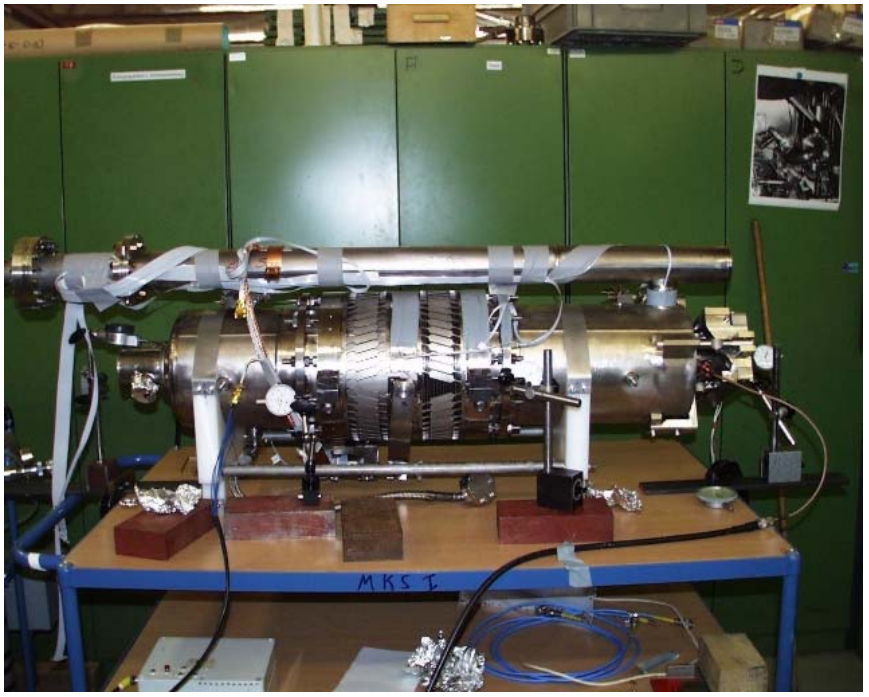
Cavity detuning induced by Lorentz force during the tests performed in Chechia at **TESLA-800 specs**

- Piezo-compensation on: just feed-forward resonant compensation
- Piezo-compensation off



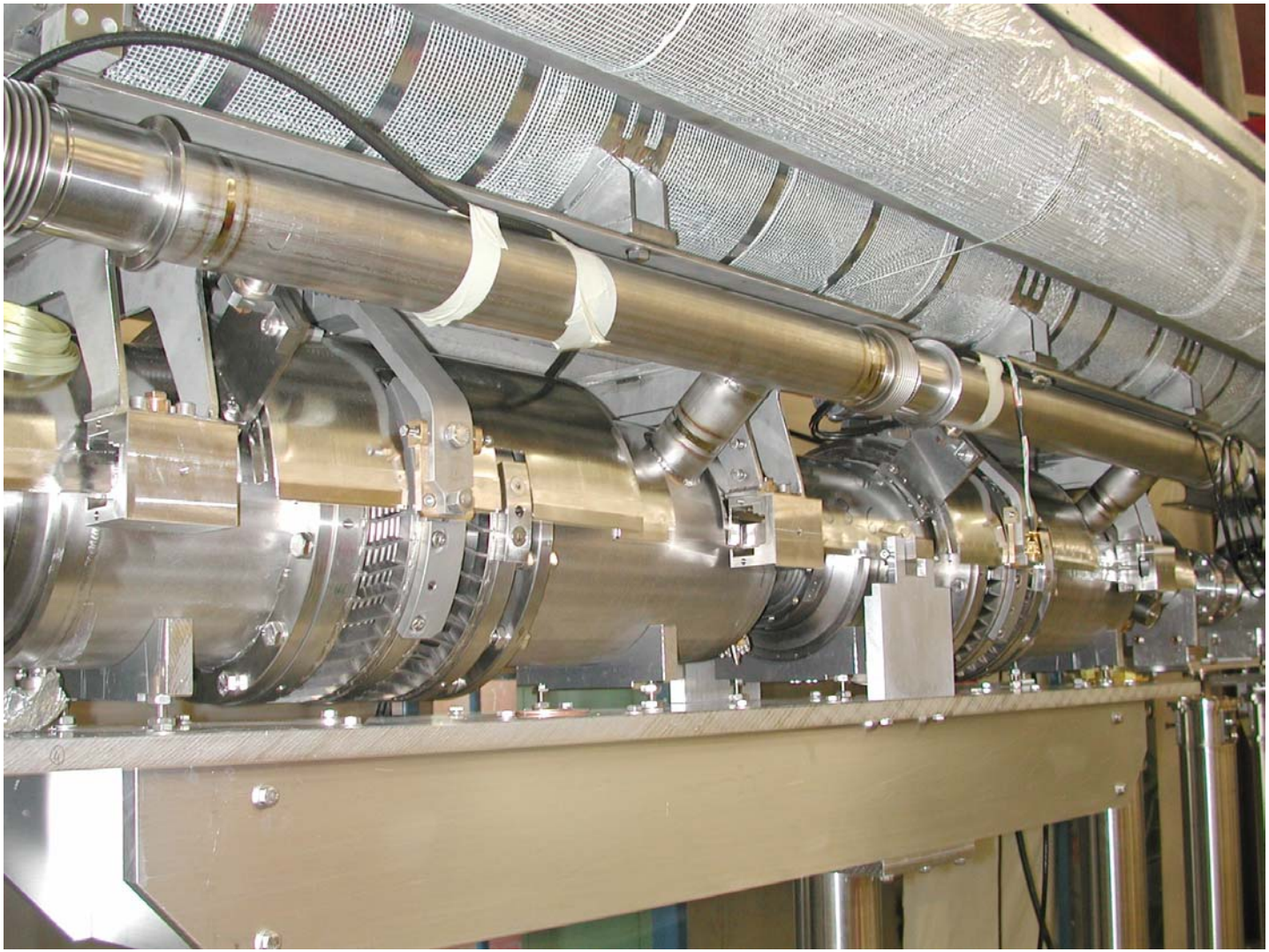
Coaxial tuner prototypes at DESY

H. Kaiser



H.-B. Peters

INFN Blade-Tuners on Superstructures



CARE – JRA1 WP8

- The development of active tuner systems is imperative for operation of SC cavities at high gradient.
- WP 8 is to provide tuners based on piezoelectric and magnetostrictive effects,
- We aim to develop tuners capable of compensation of 1 kHz detune, allowing the cavities to operate stably at 35 MV/m.
- Long lifetime is also a major issue - we aim to develop tuners allowing for 10 years of operation.

Involved Laboratories

DESY - *S. Simrock, L. Lilje, C. Albrecht*
Deutsches Elektronen-Synchrotron

TUL-DMCS - *A. Napieralski, P. Sekalski, M. Grecki*
Department of Microelectronic and Computer Science,
Technical University of Lodz, Poland

INFN – *A. Bosotti, R. Paparella*
Italian National Institute for Nuclear Physics, Milan, Italy

IN2P3 – *M.Fouaidy*
Institut National de Physique Nucléaire et de Physique des Particules,
Orsay, France

CEA Saclay – *P. Bosland*
Commissariat à l'Energie Atomique

WP8 Main Tasks

8.1 UMI (coaxial) tuner

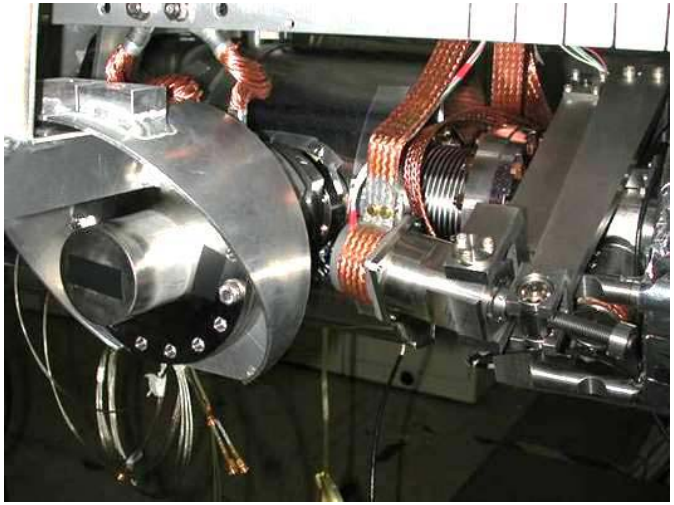
8.2 Magnetostrictive tuner

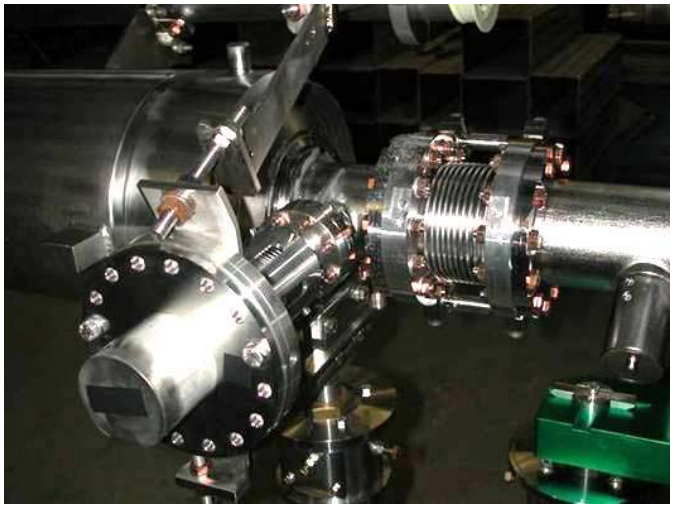
8.3 CEA tuner

8.4 Piezo characterization

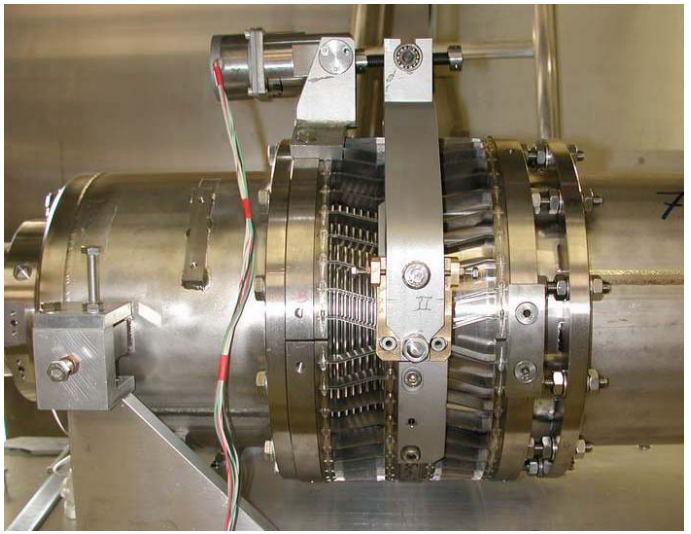
References for the New Tuner Designs

The Saclay Tuner in TTF

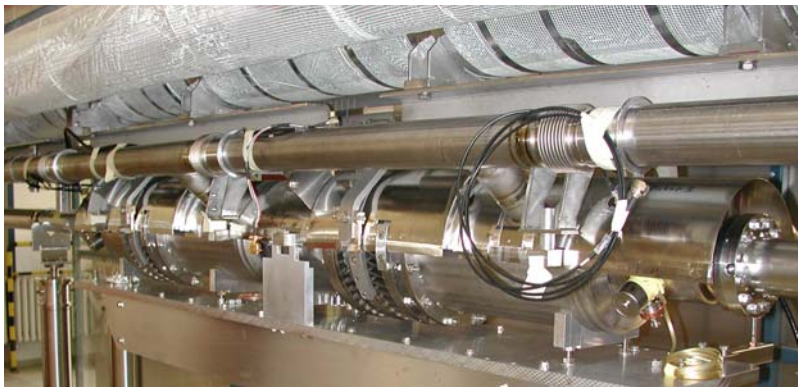




The INFN Blade-Tuner

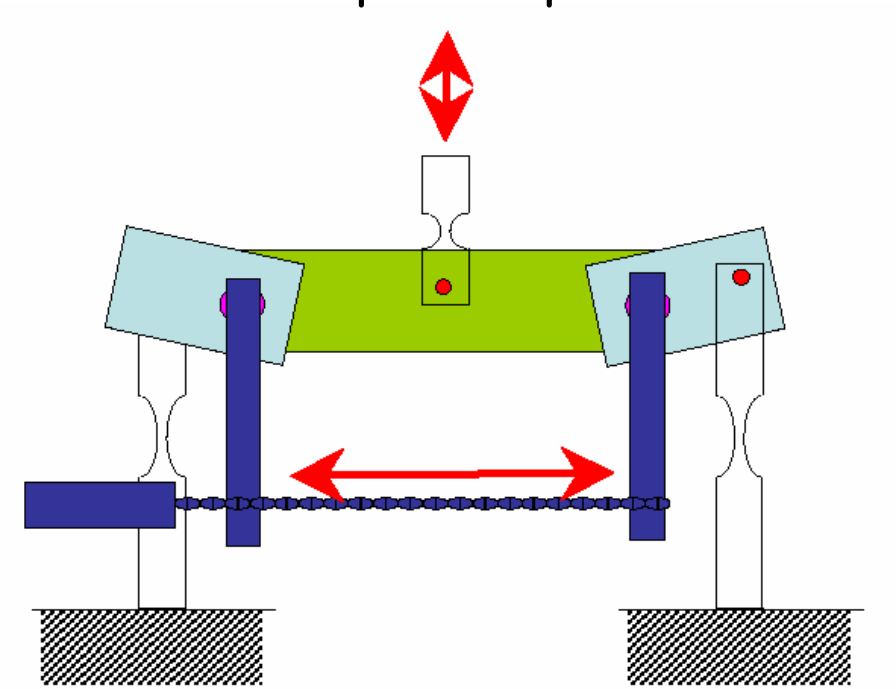


Successfully operated with superstructures



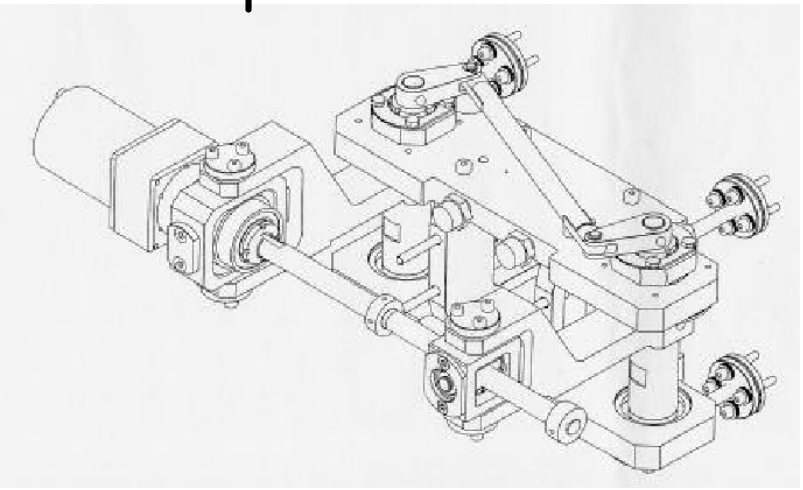
CEA Experience on Tuner Design

Principle of operation

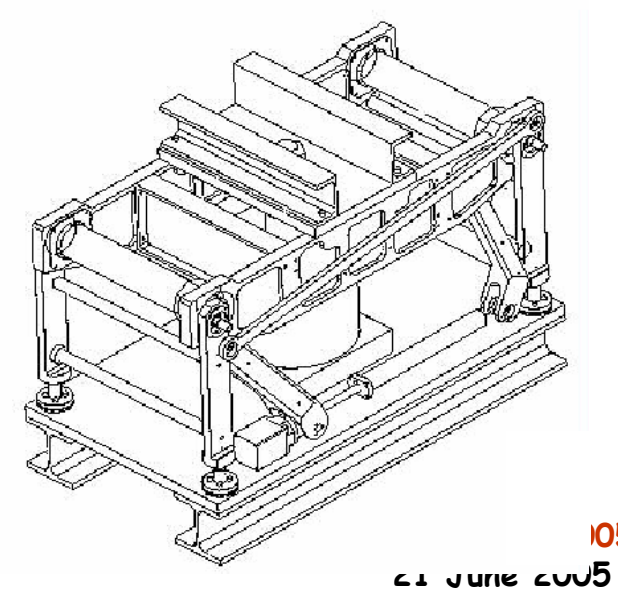


The tuner will never be in the neutral point.

Super 3HC tuner



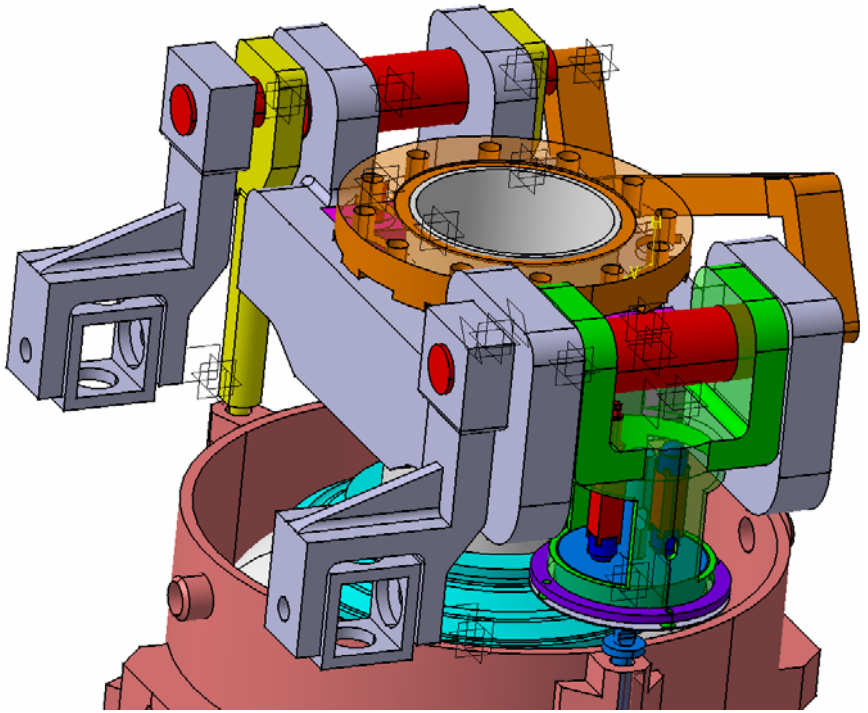
SOLEIL tuner



The New Saclay Tuner for XFEL

New design with piezos

- **CARE/JRA-SRF**
- **SOLEIL upgrades**
- **larger rigidity**



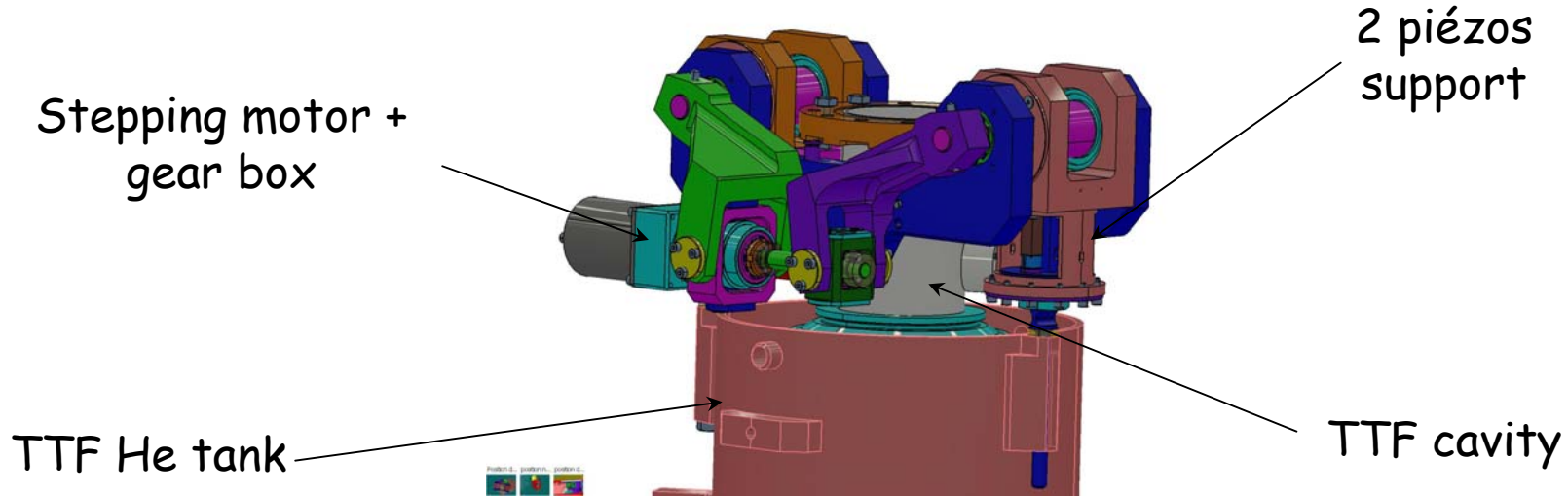
- Fabrication of 2 tuners since beginning of 2005
- 12 NOLIAC piezos, 2 PHYTRON stepping motors ordered
- Coll. with IPN Orsay: CEA send NOLIAC piezos to IPN for characterization, and IPN send P.I. piezos for tests on tuners
- Coll. with INFN-Milano for measurement with stress sensors @ 2K

The New Piezo assisted Saclay Tuner

Principle of the Super-3HC tuner with 3 fixations on the TTF helium tank

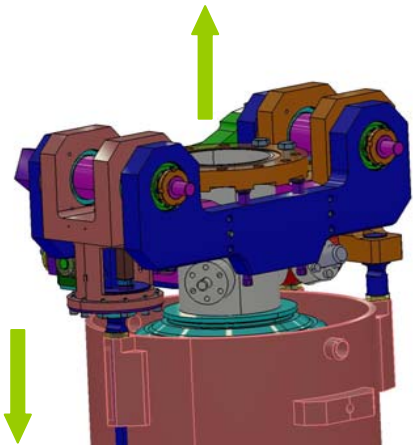
Full tuning range: ± 460 kHz

Resolution ~ present TTF tuner (~ 4 nm)

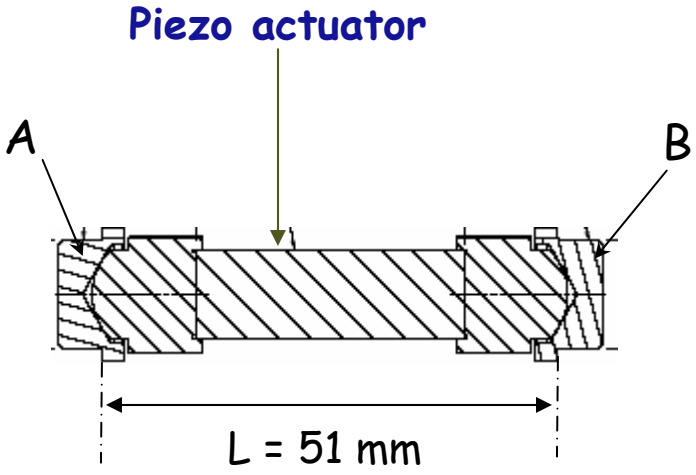


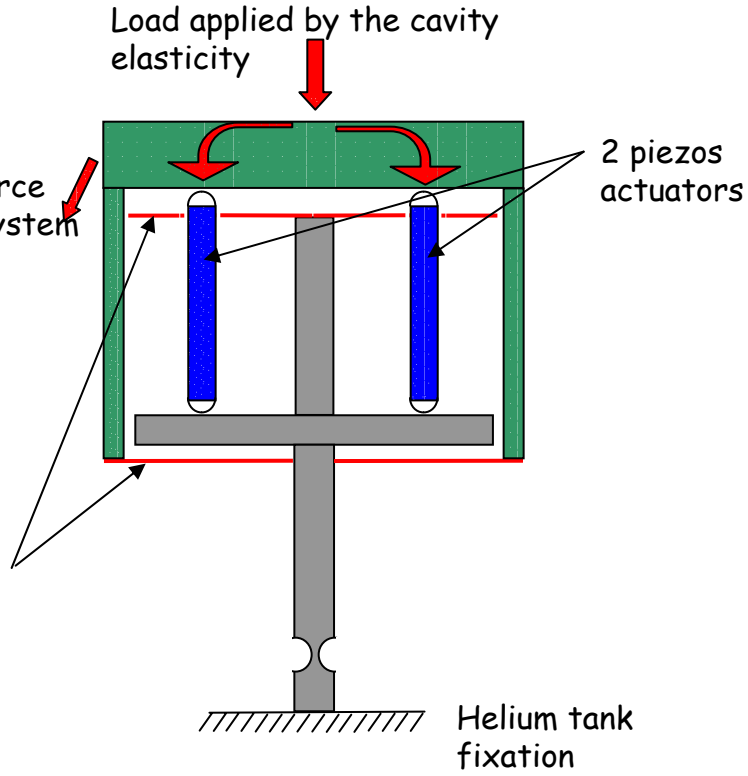
Piezo Support Principle

The cavity is stretched



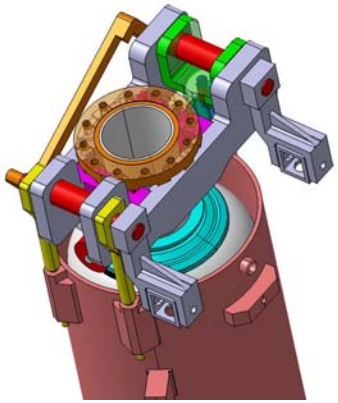
Piezo support is compressed by the cavity elasticity

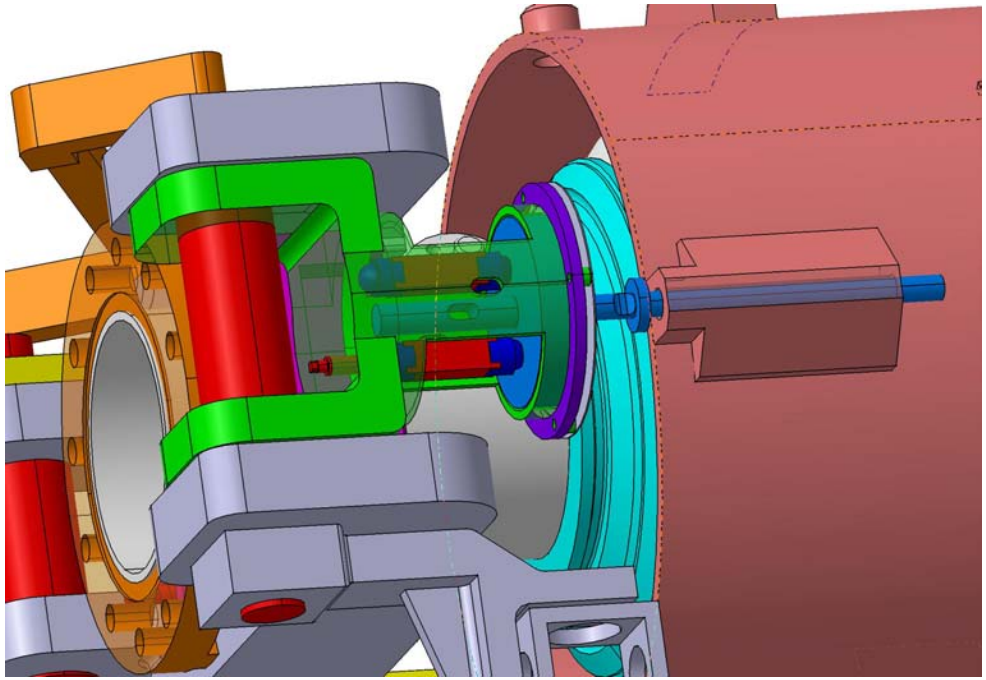


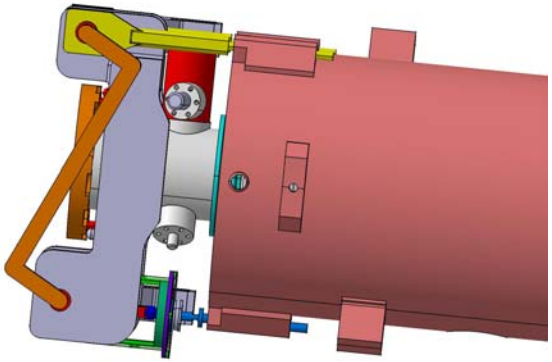


A and B pieces have to be machined in order to adjust the length L for the 2 piezos

CEA Tuner Details

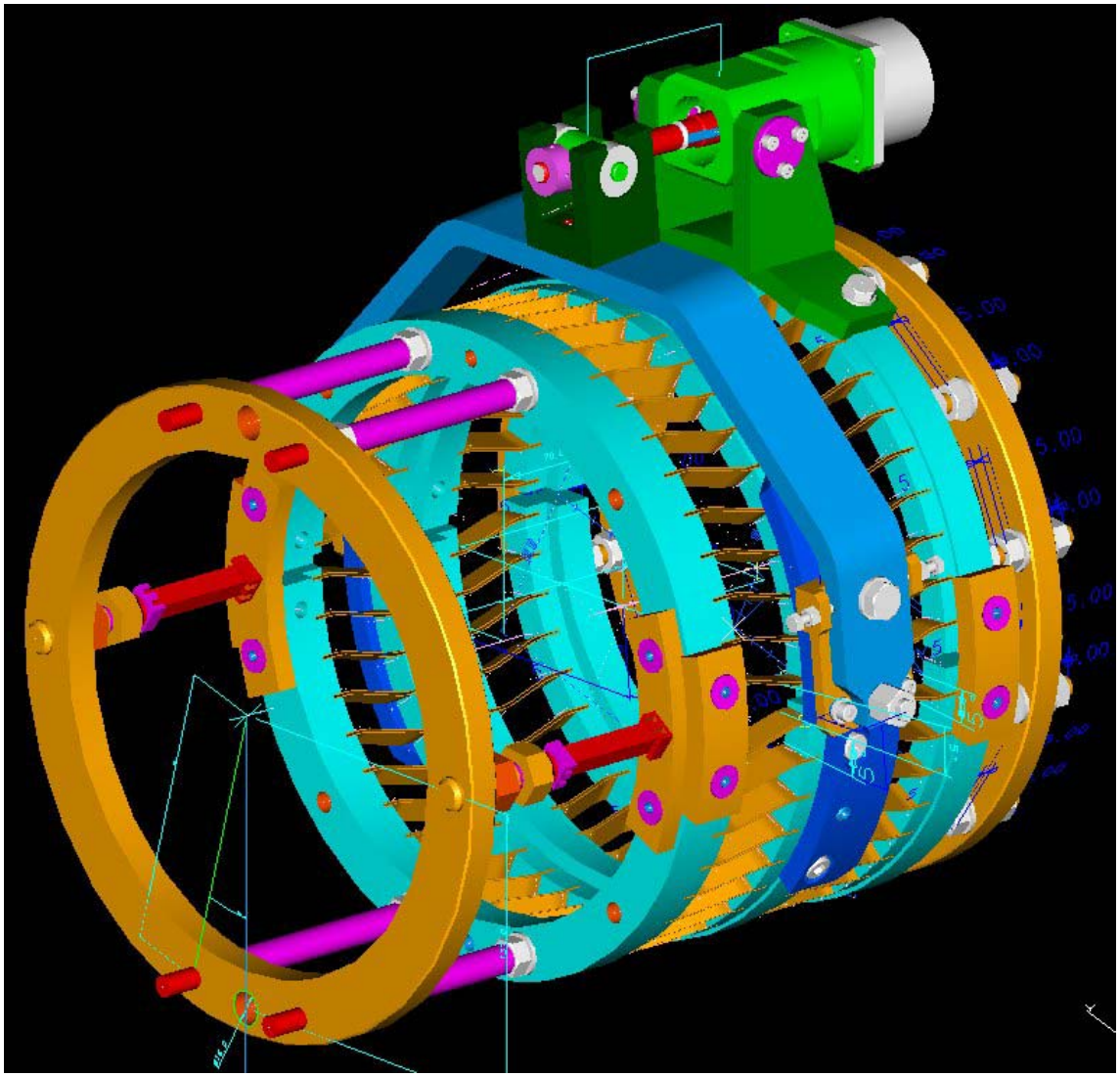




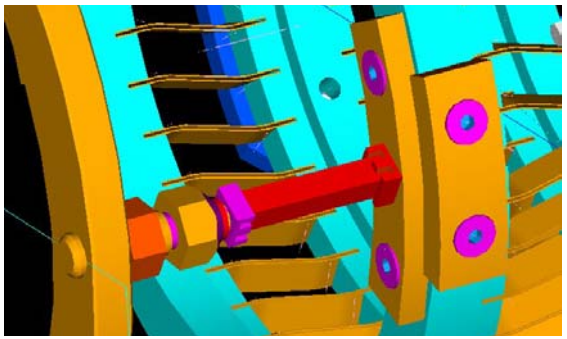


This tuner will be available in autumn 2005

The New INFN Blade-Tuner

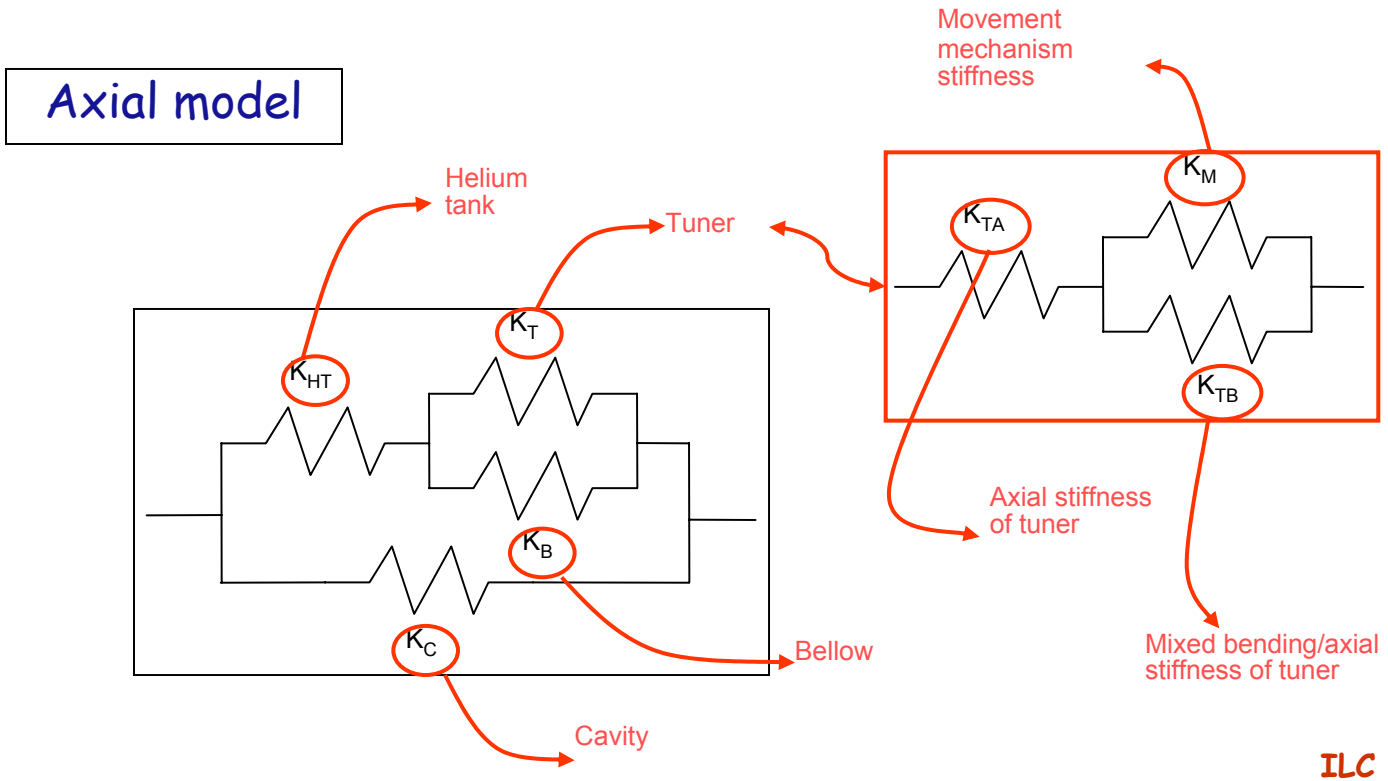


- Integration of piezos for Lorentz forces and microphonics completed.
- Final Drawing delivered for fabrication.
- Two prototype, including the modified helium tank, expected by end of September 2005
- Cold tests results by fall 2005 (DESY, BESSY, Cornell?)



Simplified structural model

- Tuner – Cavity – Helium tank system:
  - Axial behavior has been investigated in quasi static conditions
  - Bending behavior is being investigated
  - The most complicated part is the tuner: axial, bending and shear stiffness have to be considered

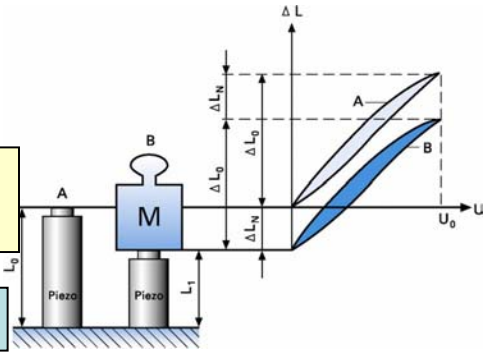


Blade Tuner Details

Requirements from the cavity point of view

± 1 mm fine tuning (on cavity) → ΔF on all piezo (sum) ≈ 3.5 kN

This value has to be considered as a preload variation and, if lower than the maximum characteristic force of piezo, acts as an offset

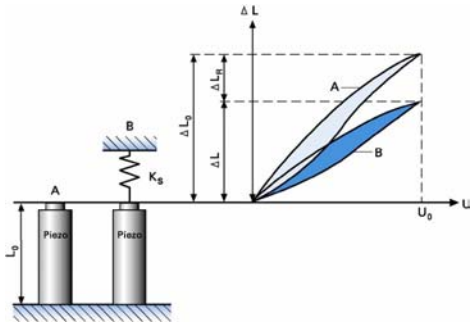


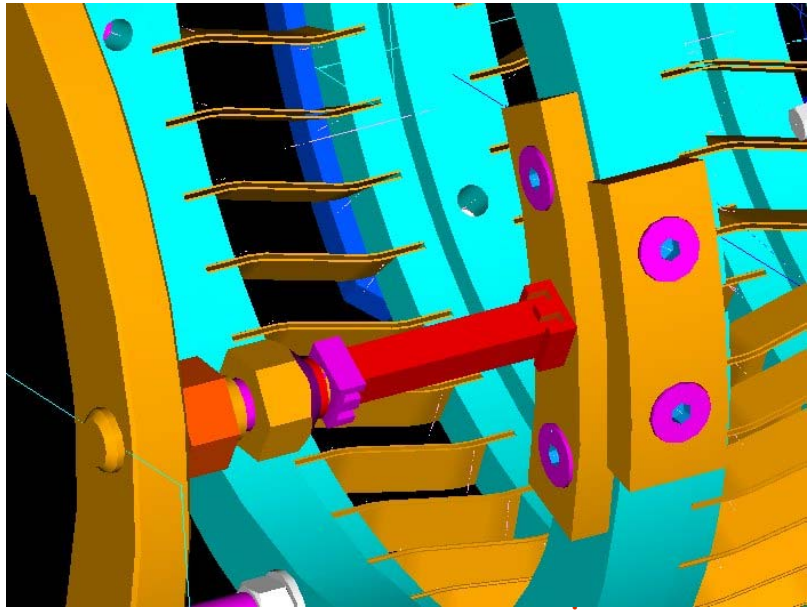
1 kHz fast tuning → ≈ 3 μm cavity displacement → ≈ 4 μm piezo displacement

This value has to be guaranteed at the temperature of 2 K, we expect to need a 40 mm long piezo

4μm piezo displacement → ≈ ΔF on all piezo ≈ 11.0 N

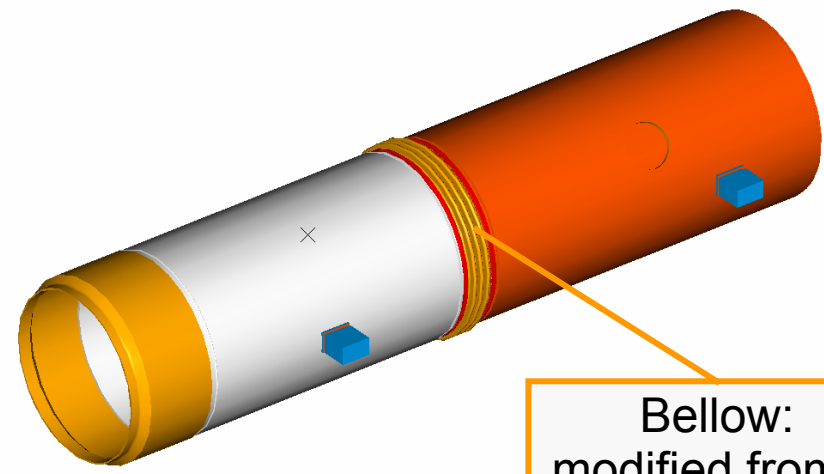
This value has been obtained in quasi-static conditions: no dynamic forces were considered



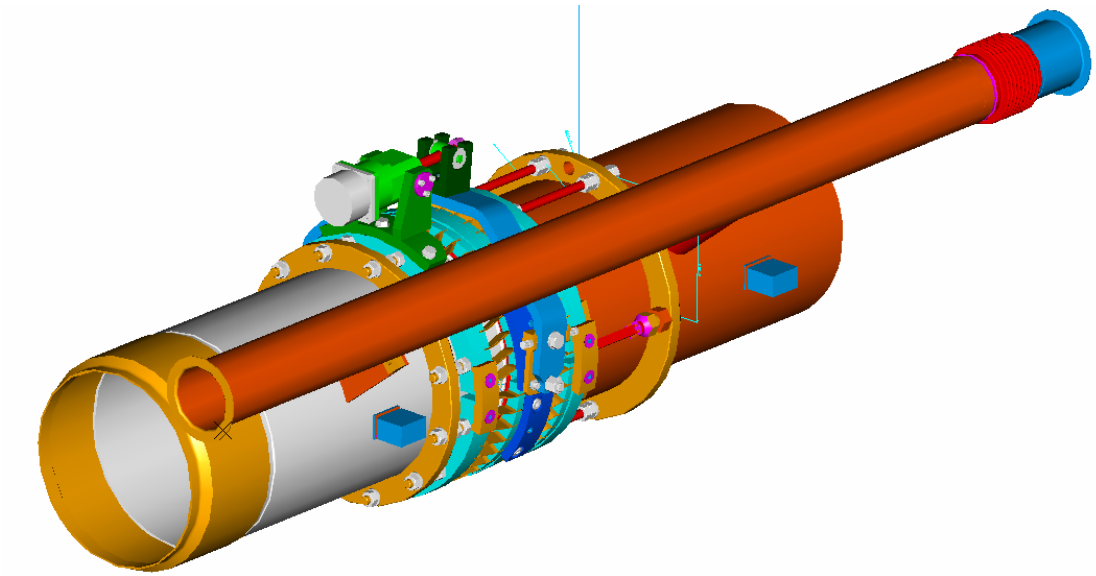


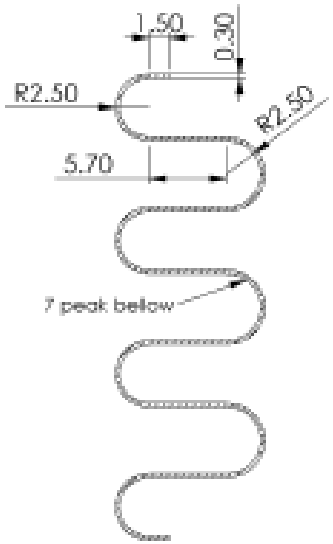
Revised He Tank

- Now the He tank needs to be split in two parts, with a bellow in between to allow the cavity elongation
- Magnetic shield assembly should probably be modified



Bellow: modified from 4 to 7 peaks





Status of Blade-Tuner

Completed…

- It is a simple configuration;
- Low part number;
- The cavity elasticity is used to provide the piezo preload;
- Piezo capabilities seem to satisfy the requirements;
- Different piezo with different lengths and cross sections can be used (up to 72 mm length)
- Open possibility to use one piezo as actuator and the other one as measurement device. Is the stroke sufficient in this case?

Still to investigate…

- Piezo cannot sustain shear or bending forces, the system should avoid these excitation;
- With respect to the superstructure configuration, the tuner has no bending and shear stiffness due to the presence of the piezo actuators;
- Equilibrium and continuity of the helium tank has to be guaranteed by the cavity and the bellow;
- The assembling procedures are being revised in order to minimize the forces on the piezo.

Piezo characterisation

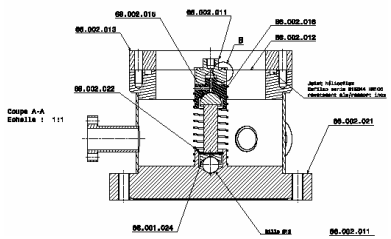
Displacement (stroke) vs. applied voltage

Force vs. applied voltage

Capacitance vs. temperature and preload force

Impedance vs. temperature and preload force

Blocking force

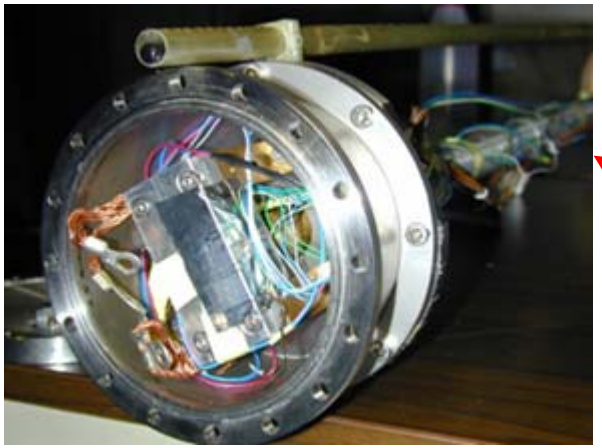


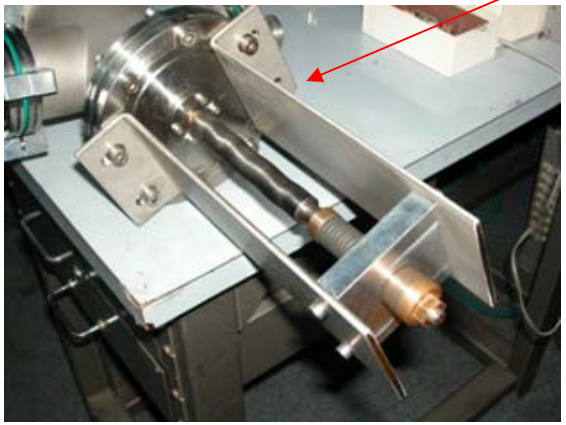
IPN, Orsay

DESY, Hamburg

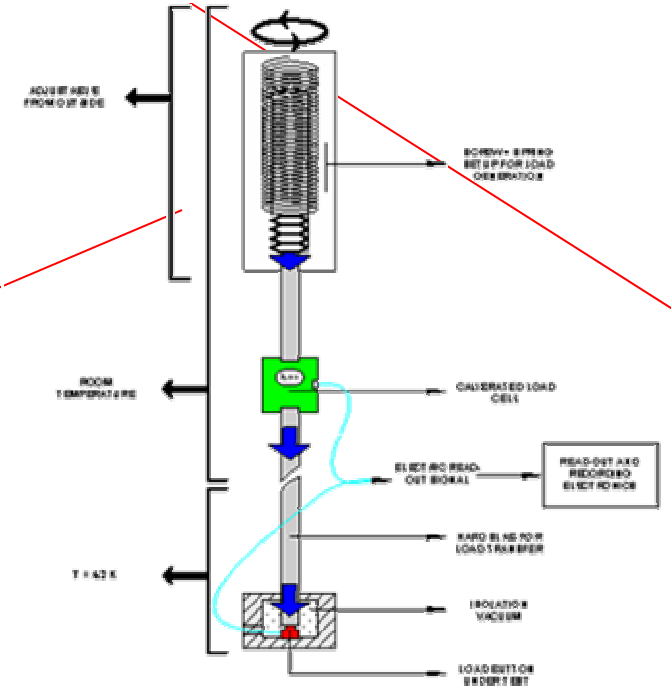
INFN, Milan

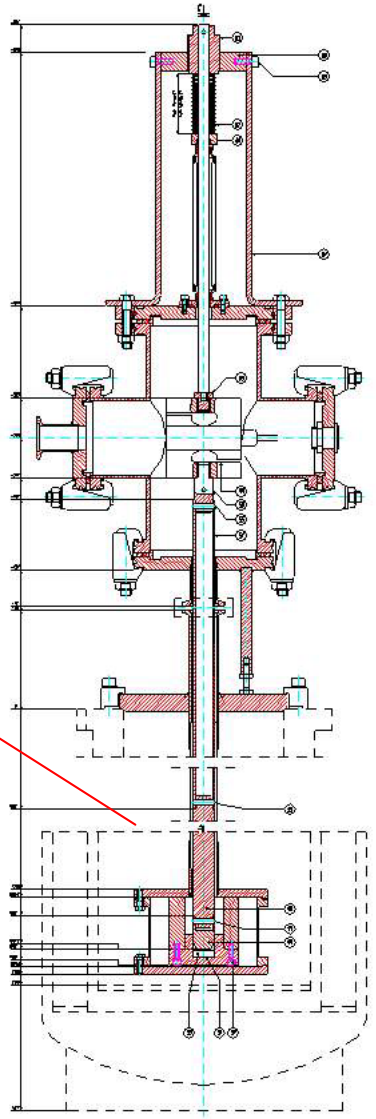
Devices calibration "facility"





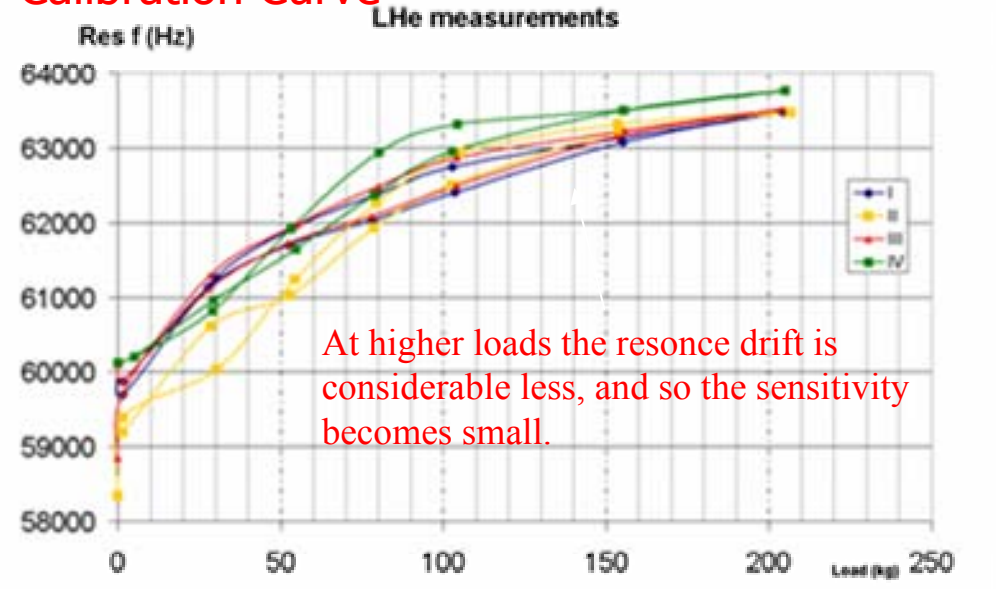
Insert Drawing



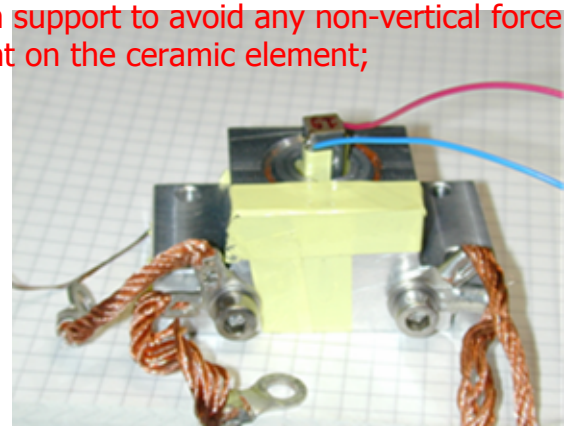


Piezo frequency response vs applied load

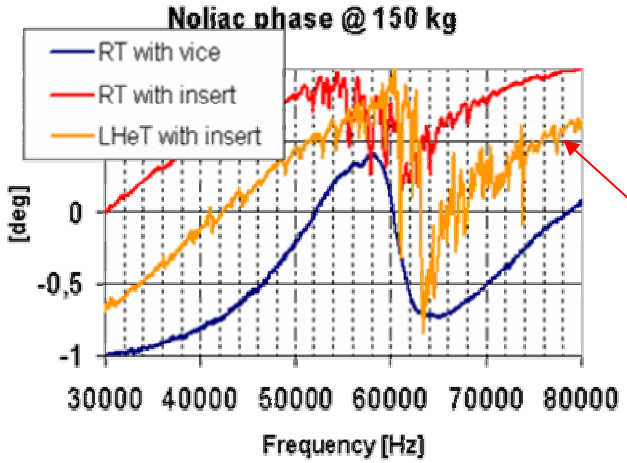
Calibration Curve

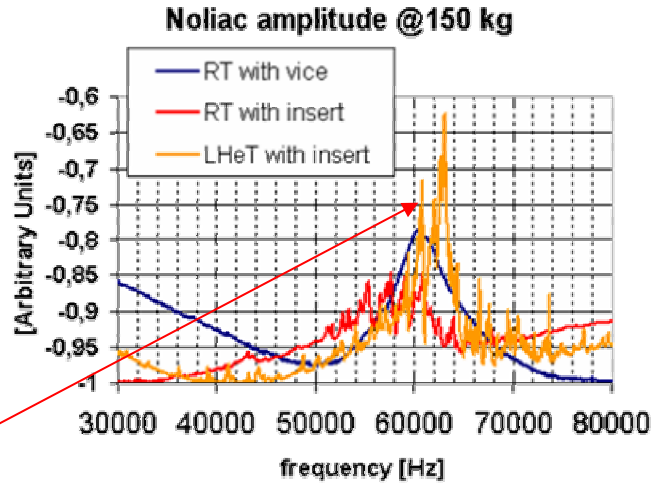


Each piezo to be tested is hosted in a properly shaped aluminium support to avoid any non-vertical force component on the ceramic element;



the support element is then fixed inside the cold box

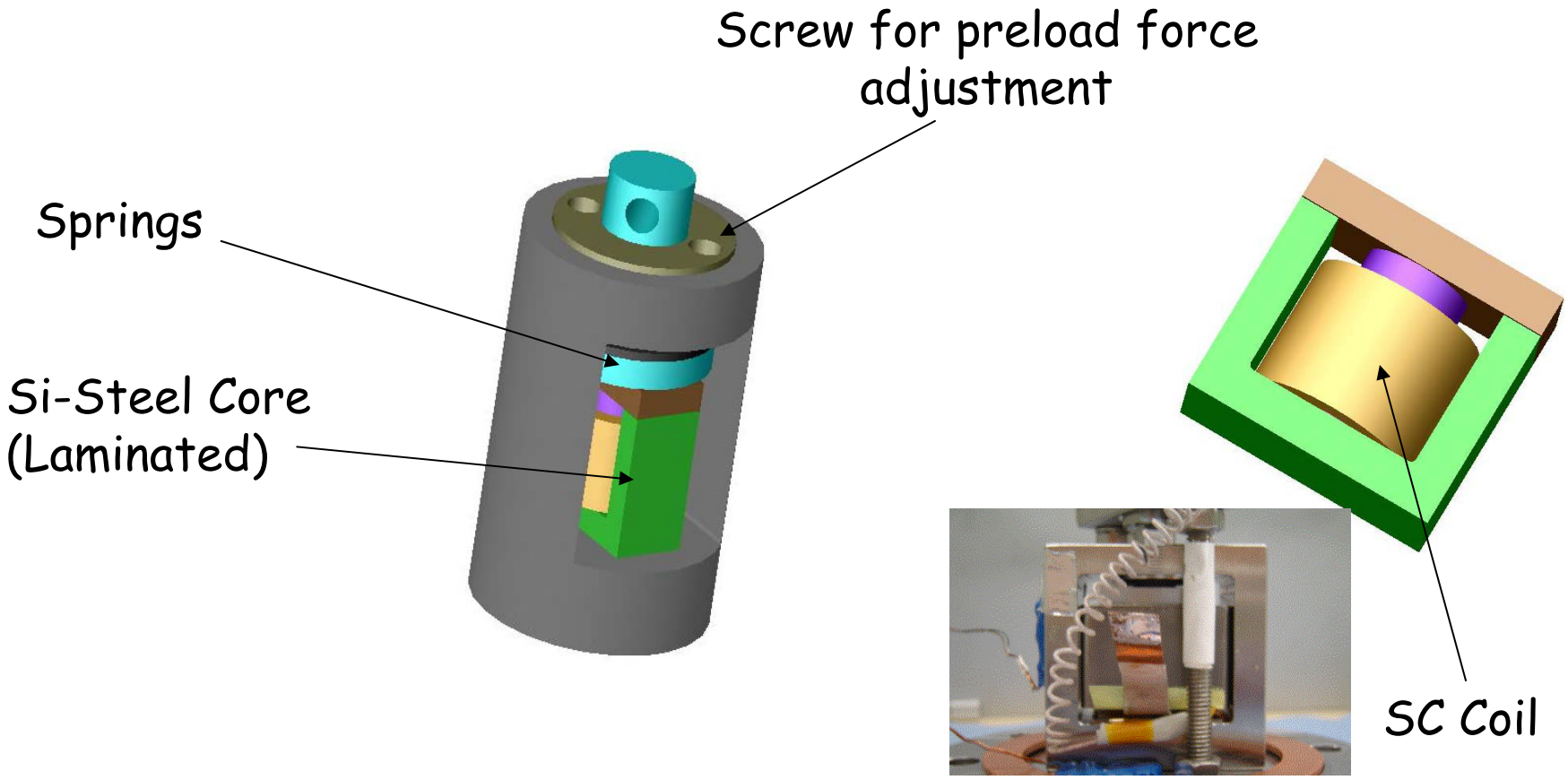




A noise is superimposed on the response when the piezo is placed into the insert and loaded

Magnetostrictive Actuators

Magnetostrictive actuators could be compatible with existing tuner concepts: Linear and Coaxial



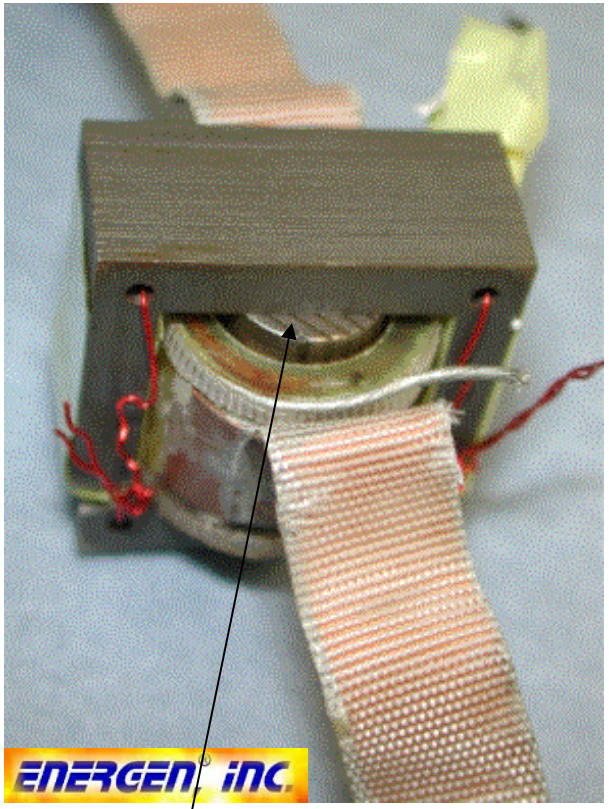
Prototype under Test at DESY

Build by ENERGEN Inc.

Springs

Active elements
with ferrite,
S.C. Coil
and thermal connectors

Cover



Magnetostrictive rod

Conclusions

- Two piezo assisted tuner designs are in the fabrication stage to be extensively tested in fall this year.
- Both should work reliably being based on established experience
- Cold motorization and annexed ball-bearing components are the ones extensively qualified on TTF.
- Comparative unity tuner cost will be performed
- For ILC the evaluation of the cost impact of the slight reduction of the cavity filling factor (real estate gradient) will possibly be the driving criteria for the tuner choice.