ILC-HiGrade Kick-Off Meeting

DESY, Hamburg 29 August 2008

WP8 Tuner

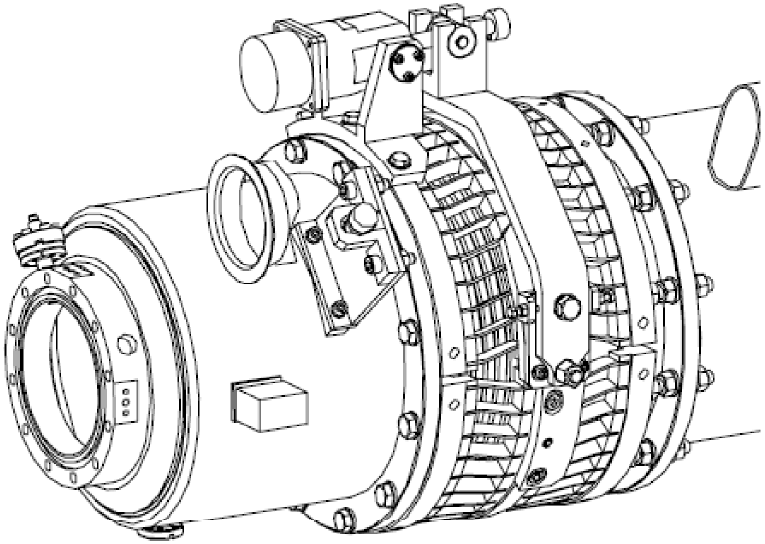
Status & Perspective

Carlo Pagani

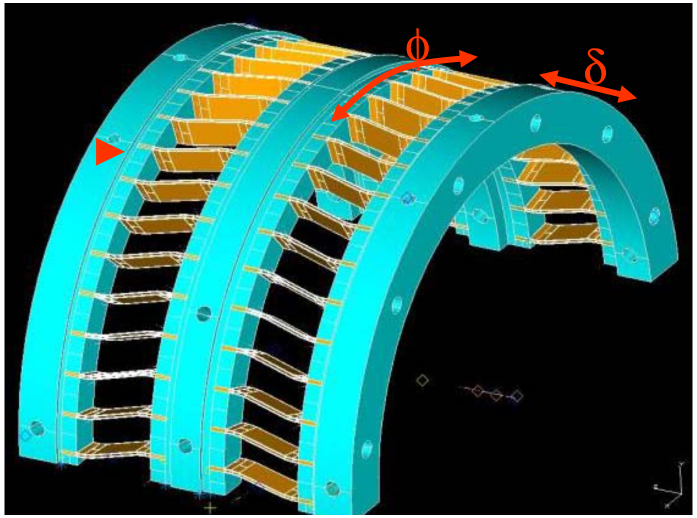
University of Milano & INFN Milano - LASA

Material prepared by: Rocco Paparella, Angelo Bosotti and Nicola Panzeri

The Superstructure Blade Tuner

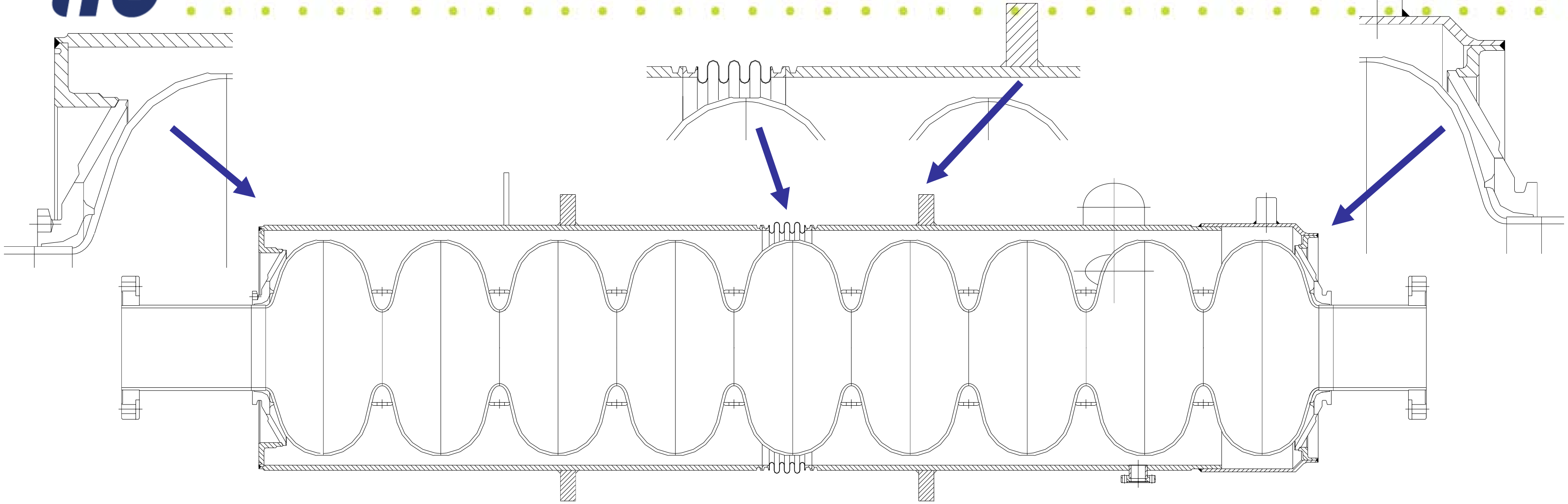


INFN Milano - LASA & DESY



Transforms the central ring rotation in a longitudinal axial motion that change the length of the cavity, i.e. its frequency

Modified Standard TTF He Tank



So far the Blade Tuner has been mounted on tanks/cavities adapted from the TTF design. ILCTA will develop new tank design.

Blade Tuner prototype for the ILC

Lighter

The redesign of rings allowed an important **weight reduction** (about 40%) maintaining the full symmetry with collinear blades.

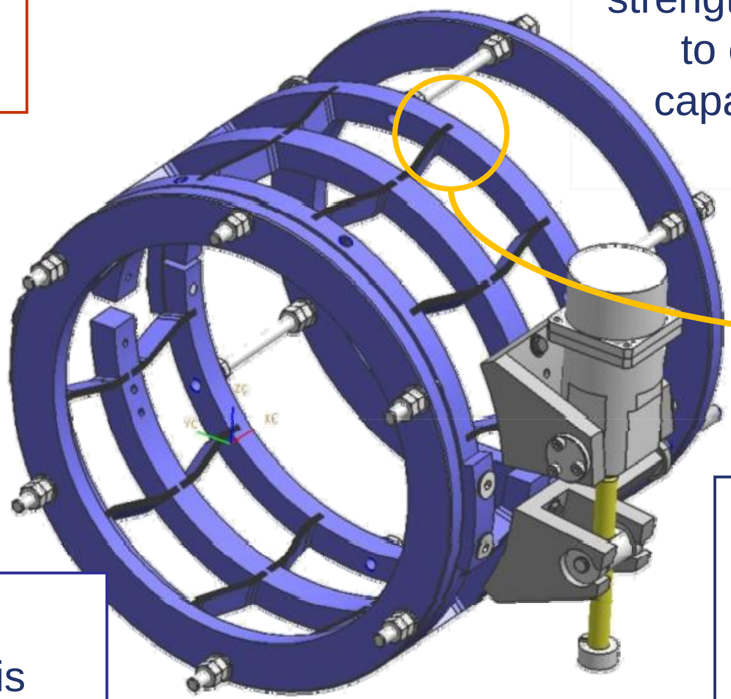
Cheaper

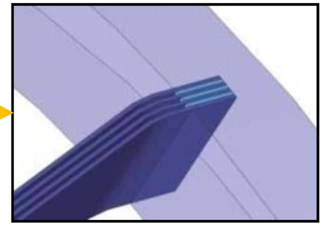
The new geometry and mechanism lead to an **important reduction of costs**.

New driving mechanism

The new driving mechanism is simpler, **cheaper and more compact**, simplifying the installation of an external **magnetic shield**.

2 units produced





Ready for future SS tank

The tuner can be **built both with titanium or stainless steel rings**. The use of an high strength alloy for blades allows to exploit the full tuning capabilities without plastic strains.

Wider tuning range

The different blade geometry adopted **improve the slow tuning capabilities** to more than 1.5mm at the cavity level.

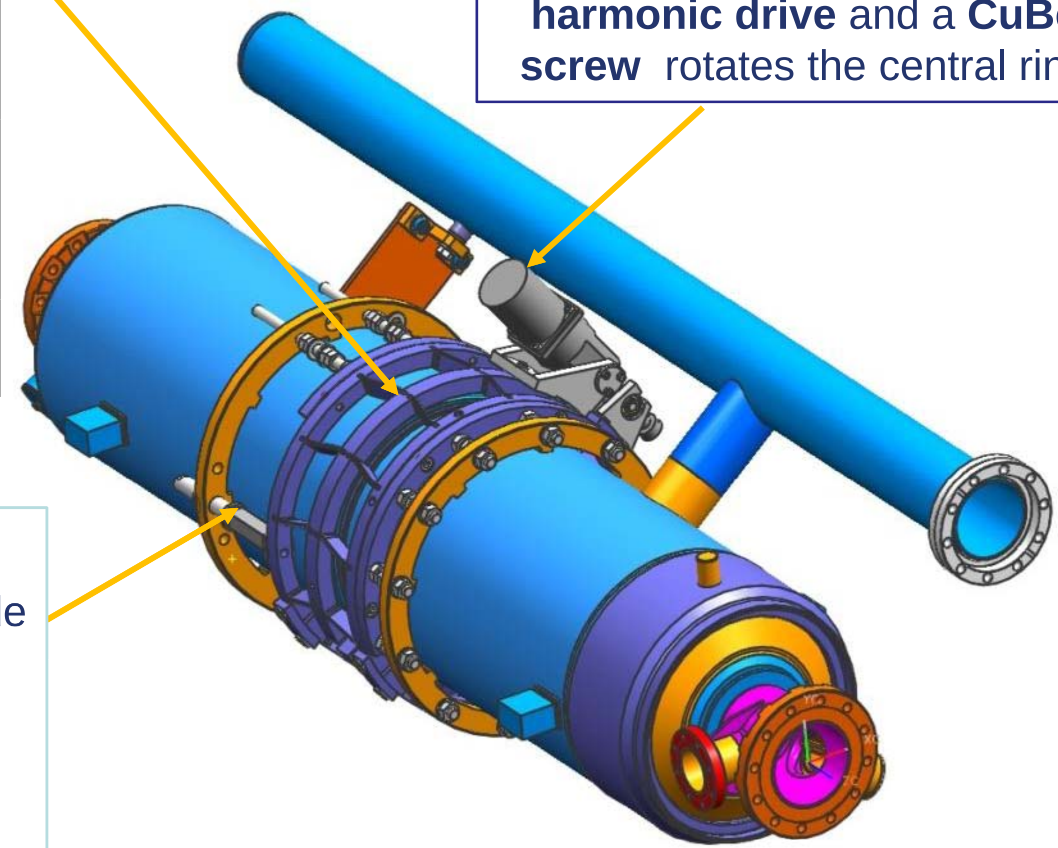
The Tuning Actions

The bending rings

The bending system consists of **three different rings**: one of the external rings is rigidly connected to the helium tank, while the central one is divided in **two halves**. The **rings are connected by thin plates, the blades**, that by means of an imposed azimuthally rotation bend and elastically change the cavity length.

The movement system

The **stepping motor**, with its **harmonic drive** and a **CuBe screw** rotates the central ring



The Piezo Actuators

2 piezo actuators in parallel provide fast tuning capabilities needed for **Lorentz Force Detuning** (LFD) compensation and **microphonics** stabilization.

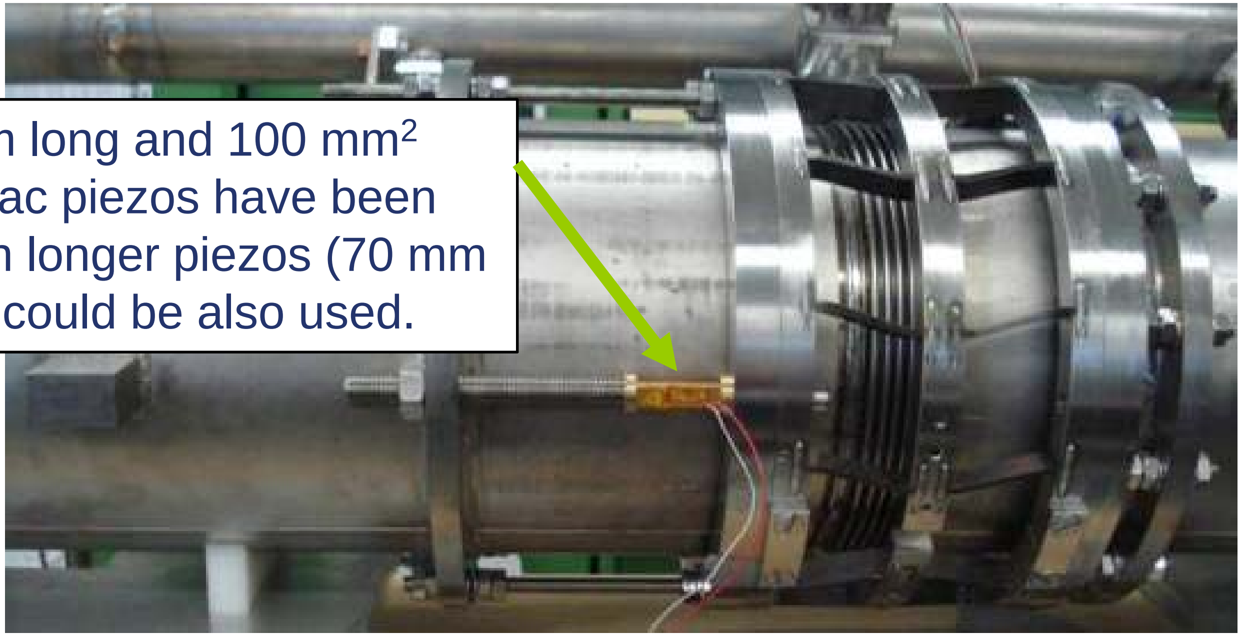
Blade Tuner prototype cold tests

- **The Stainless Steel + INCONEL prototype has been tested at cold:**
- **Sept. 2007 in the CHECHIA** horizontal cryostat, DESY
  - Installed on the **Z86 TESLA cavity** equipped with a standard modified He vessel
  - Equipped with a standard TTF unit: **Sanyo stepper motor + HD gear**
  - **2 Noliac 40 mm** standard piezoelectric actuator installed
- **Feb. 2008 in the HoBiCaT** horizontal cryostat, BESSY
  - The same assembly but equipped with a prototype of a possible alternative driving unit: **Phytron stepper motor + Planetary Gear**

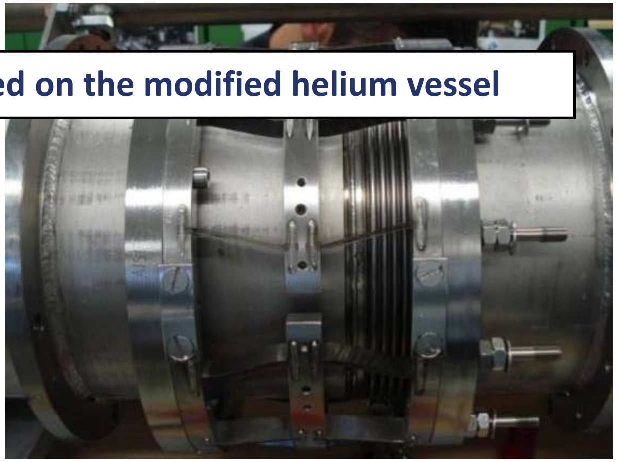
Stainless Steel + Inconel model

Blade Tuner installation – Halle III, DESY

Two 40 mm long and 100 mm^2 section Noliac piezos have been inserted. Much longer piezos (70 mm and more) could be also used.



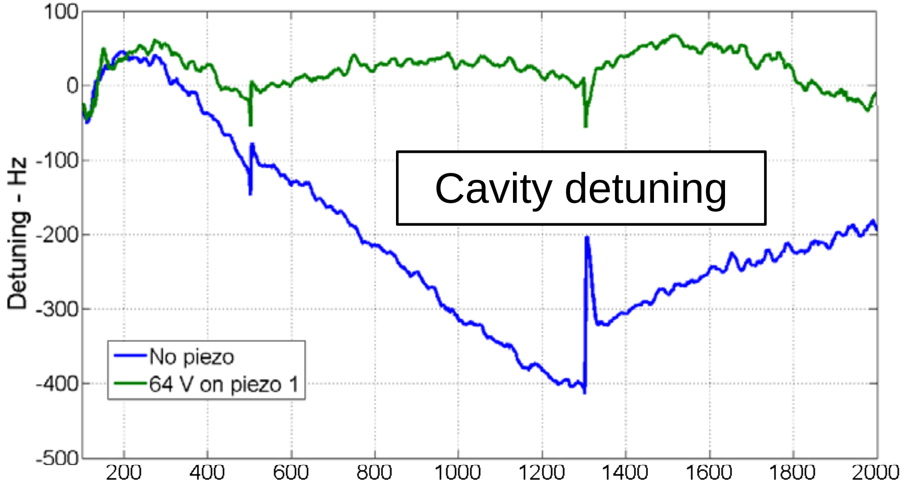
The tuner installed on the modified helium vessel

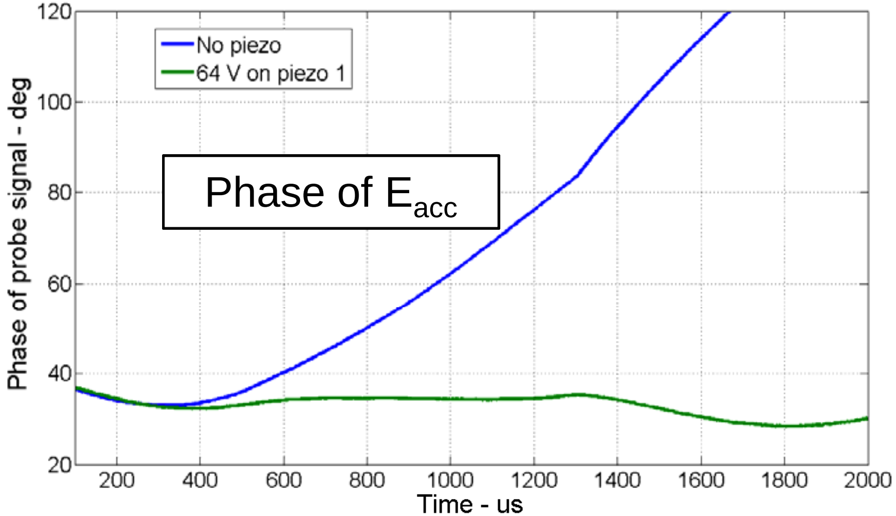


Driving motor installed

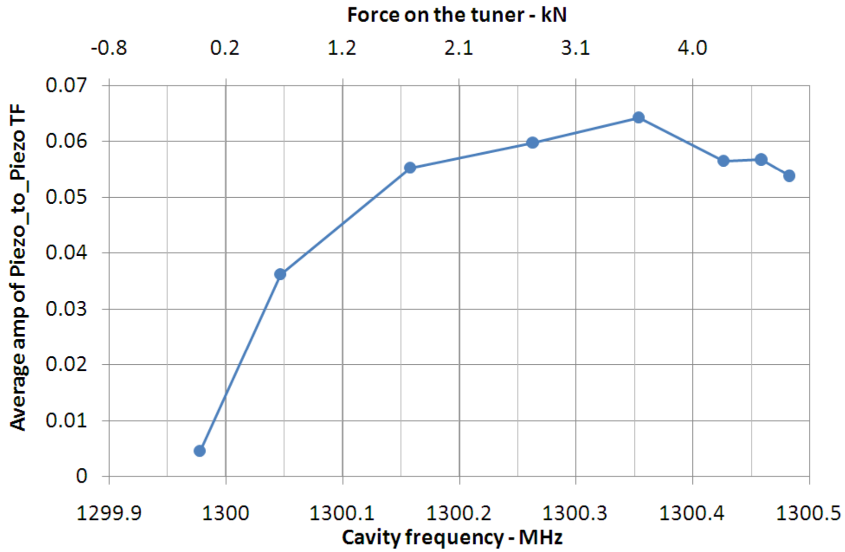
Cold test in CHECHIA – LFD compensation

single half-sine pulse, 2.5 ms long, 0.95 ms in advance with respect to RF



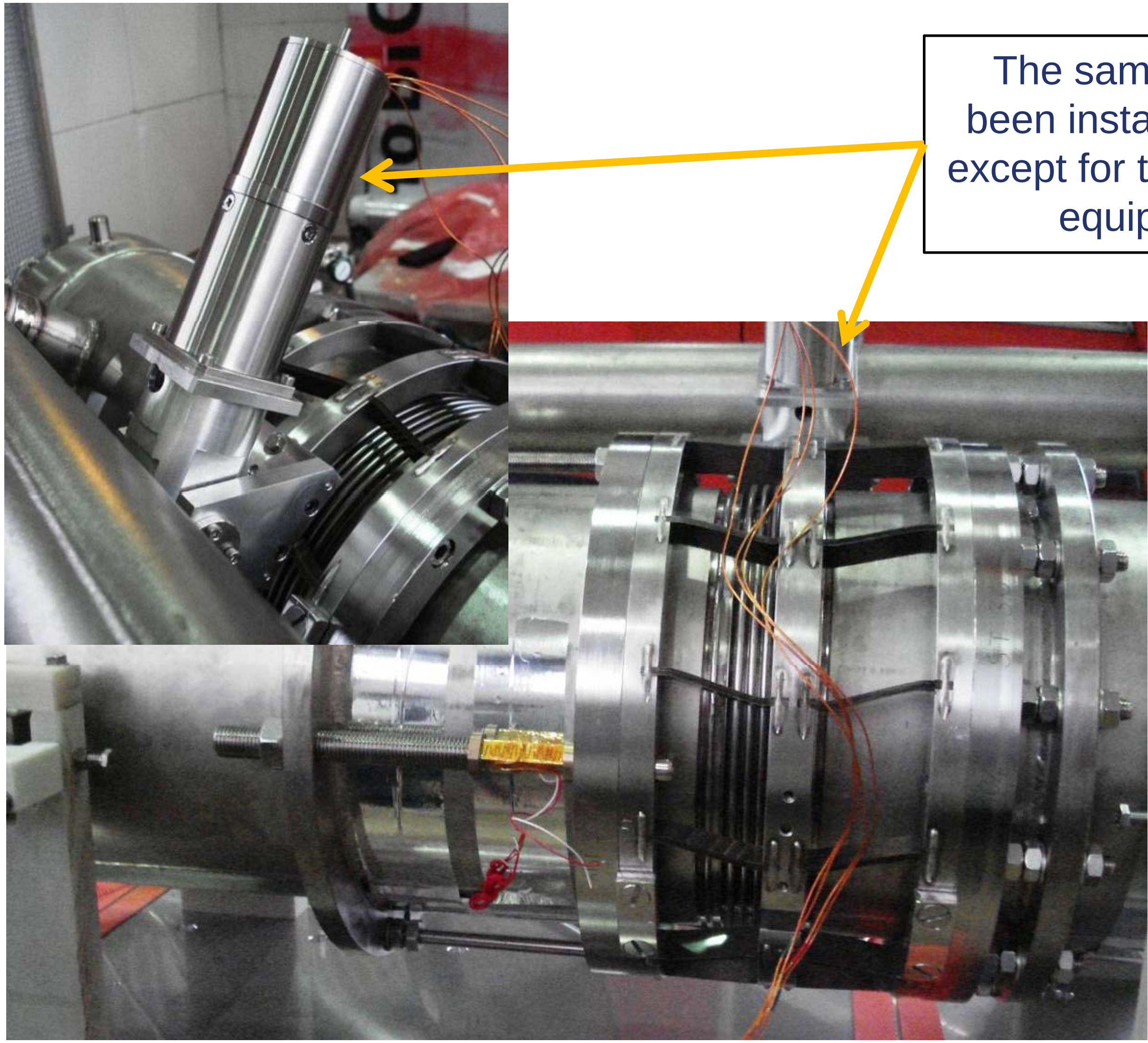


Piezo to cavity coupling strength



300 Hz of LFD, during the RF pulse flat top, have been compensated at E_{acc} = 23 MV/m, driving only one of two installed piezo actuators with 64 V, less than 1/3 of the nominal maximum driving voltage (200 V @ RT).

Blade Tuner installation in HoBiCaT, BESSY

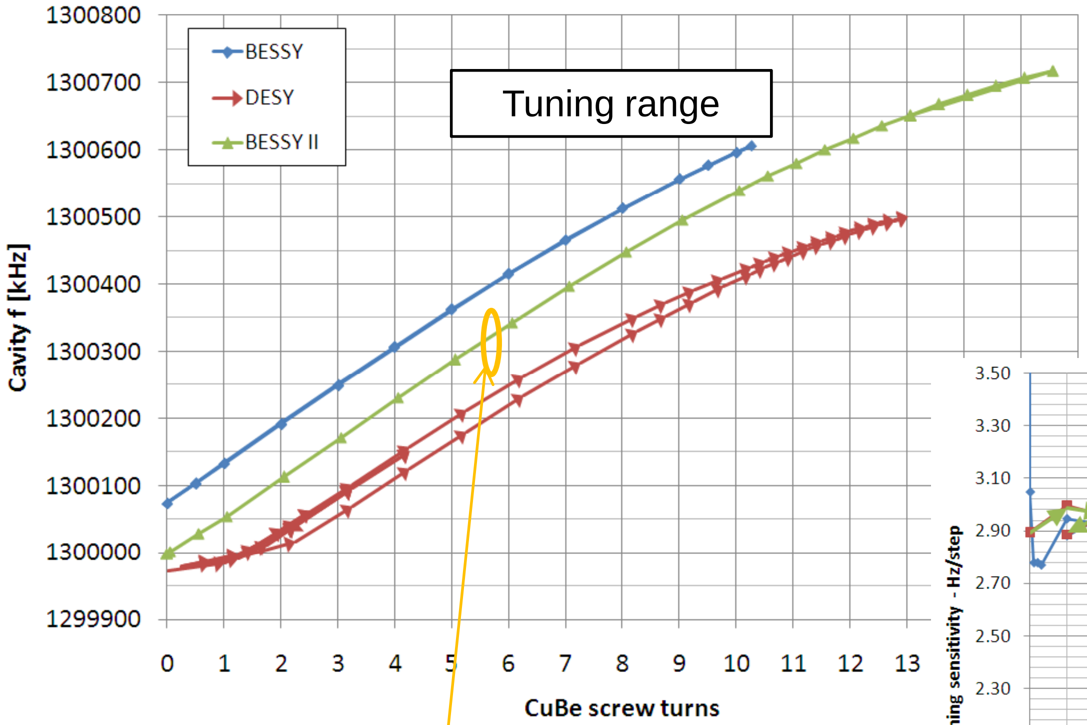


The same Blade Tuner assembly has been installed for cold testing at BESSY, except for the driving unit, a stepper motor equipped with **planetary gear**

HoBiCaT at BESSY

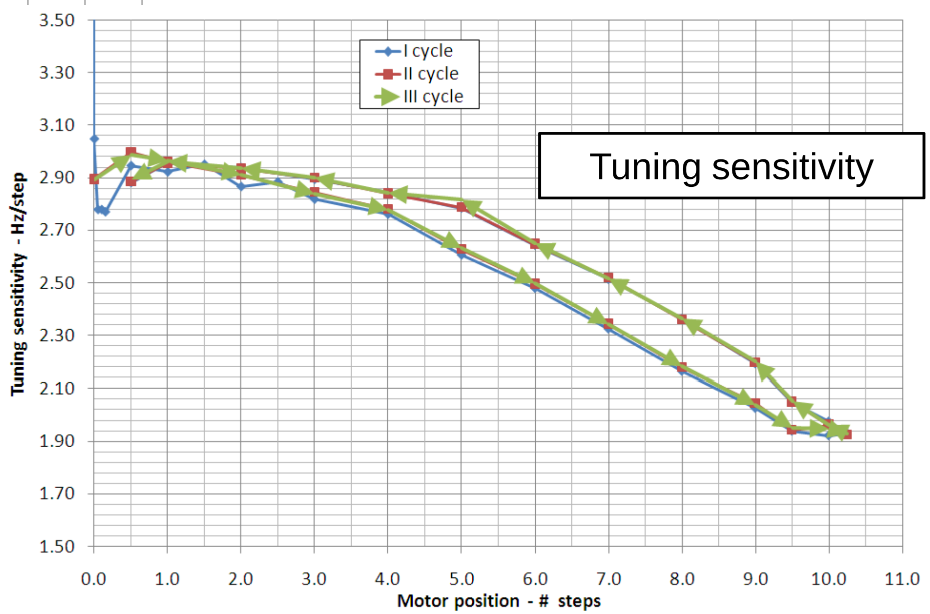
HoBiCaT Tests – full tuning range

A full tuning range of 720 kHz has been achieved
The hysteresis has been almost cancelled.



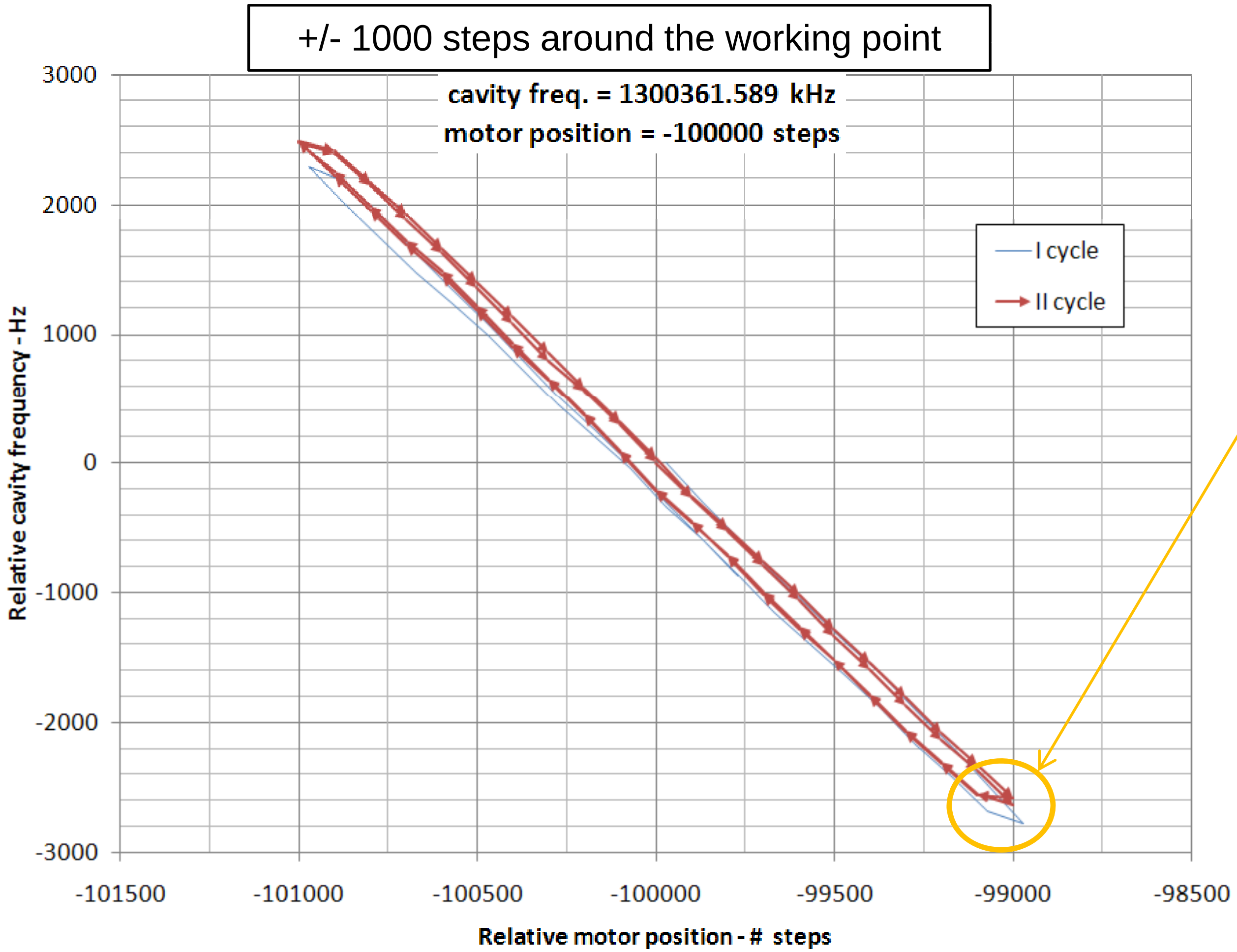
This time an **higher piezo preload** than CHECHIA test has been set. As a consequence **the piezo unloading effect is no more visible** in the sensitivity plot

Hysteresis shown in the first cycle has been almost cancelled after a few tuning range cycling



HoBiCaT Tests – close to the working point

tuning characteristics around a specific working point



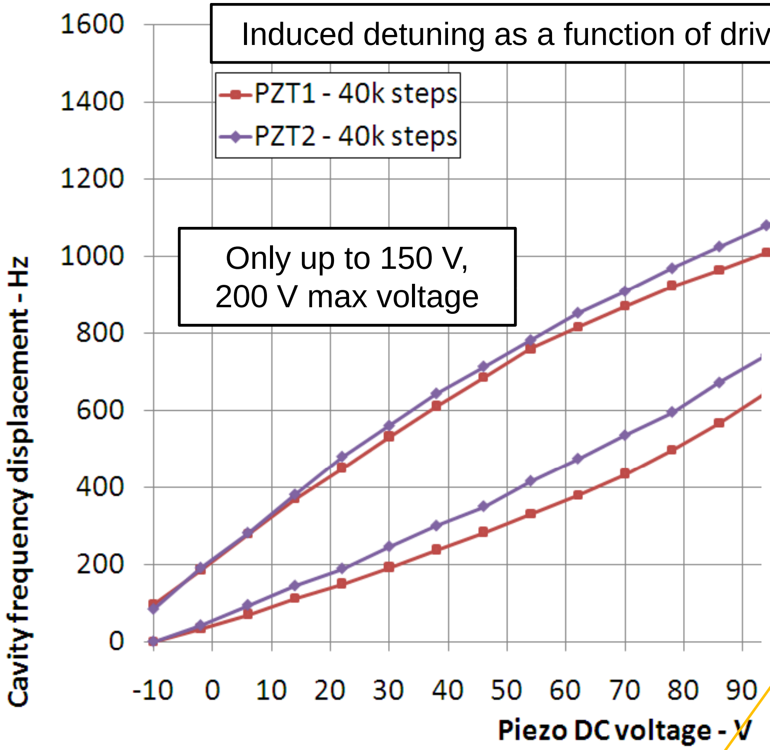
The frequency positioning behavior and the amount of **backlash, about 85 steps**, is slightly higher than the one usually experienced with TTF tuner.

But the **planetary gear** installed, here tested for the first time, actually introduces a significantly **higher backlash if compared to HD gear, about 20 times higher**

HoBiCaT Tests – DC piezo characterization

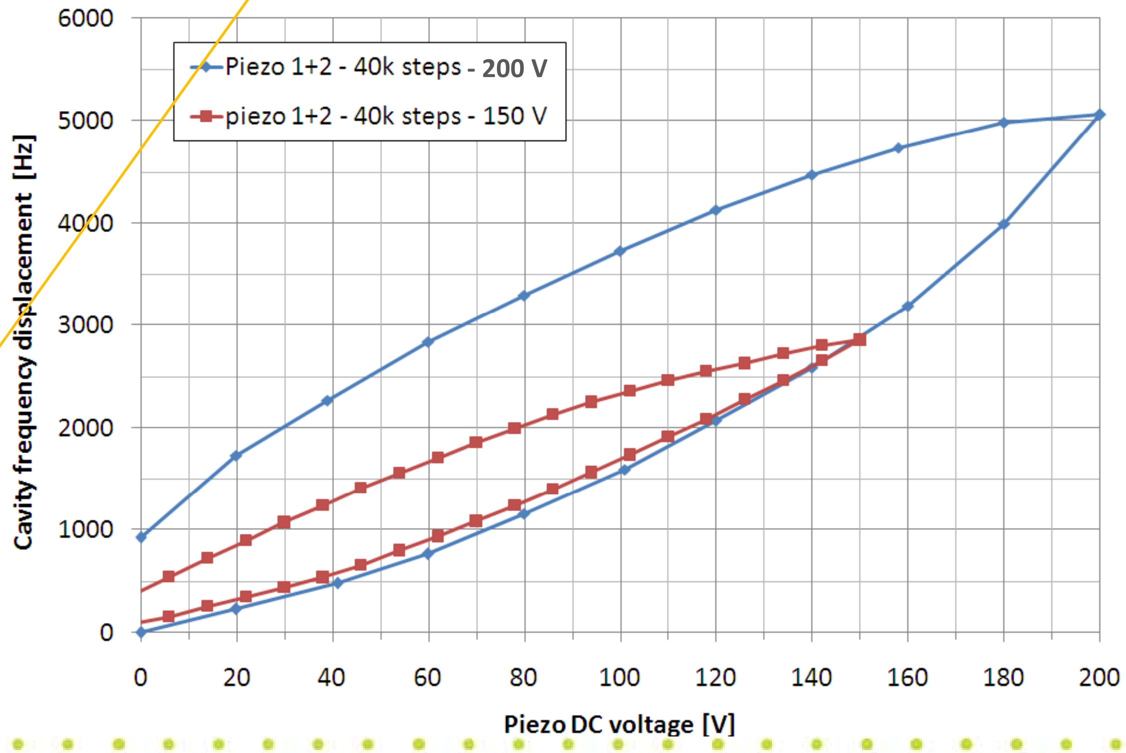
piezo fast tuning performances in terms of induced static detuning

Induced detuning as a function of driving DC voltage for each piezo



Only up to 150 V,
200 V max voltage

Induced detuning as a function of driving DC voltage for both piezo in parallel and up to the maximum voltage



Only a limited difference (expected by design) has been measured for the performances of the two piezo.
Improved in the FNAL tuners

Blade Tuner prototype cold tests - conclusions - 1

- **The coaxial Blade Tuner prototype has been successfully cold tested.**

- **Installation, assembling and robustness**
  - The whole Blade Tuner assembly safely withstands all the cooldown, warm-up and operating procedures at DESY and BESSY.

- **Tuning range**
  - The static tuning capacity fully meets expectations and requirements.
  - A full tuning range of **720 kHz** has been achieved.
  - The observed hysteresis after the first measure has been nearly cancelled after a few successive load cycles.
  - The current **tuning sensitivity is of about 1.5 Hz per motor half-step**, already a reasonable value. Eventual further improvement can be easily achieved by increasing the reduction ratio of the gear.
  - Apart from the different tuning sensitivity, **the behavior for the shortest tuning range reveals a level of settling and uncertainty in the frequency positioning that is comparable to the one experienced with the TTF tuners.**

Blade Tuner prototype cold tests - conclusions - 2

- **Piezoelectric performances**
  - The dynamic detuning compensation capabilities has large performance margins for LFD and microphonics compensation, even in view of ILC goal gradient.
  - 5 kHz of max static tuning range achieved in HoBiCaT operating the two piezo in parallel with only 1 kN preload each and 200 V maximum voltage. According to TTF experience, this would lead to about **2.5 kHz dynamic detuning** compensation range with TTF pulses
  - The Blade Tuner assembly has higher dynamic Lorentz coefficient, as expected, if compared to average TTF. This has been anyway easily compensated by the higher fast tuning efficiency and it is fully explained by the provisional assembly for this test
    - For HiGrade we should develop a stiffer He Tank assembly dedicated to the Blade Tuner assembly, and not an adaptation to the current!
    - Stiffer cavity end-cones would also improve performance

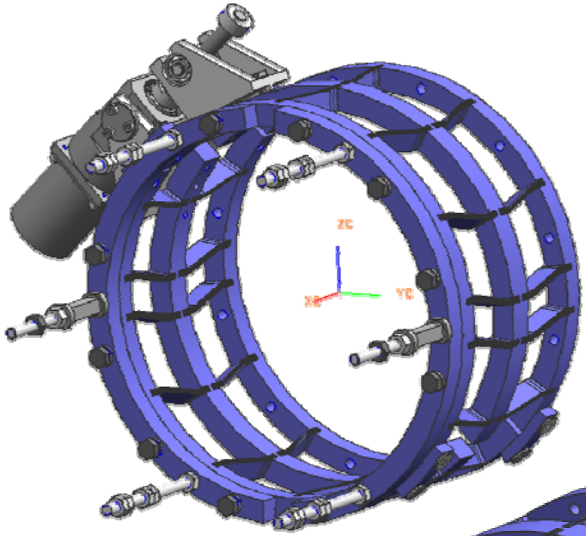
Motor position / total load [# steps] / [kN]	**Voltage range** [V]	**Cavity Δf Piezo 1** (motor side) [kHz]	**Cavity Δf Piezo 2** [kHz]	**Cavity Δf Piezo 1+2** [kHz]	**Piezo 1 to total** [%]
0 / 1	0 – 150	0.79	1.11		42
- 40000 / 2	0 – 150	1.27	1.41	2.86	47
- 40000 / 2	0 – 200			**5.06**	

The ILC Blade Tuner

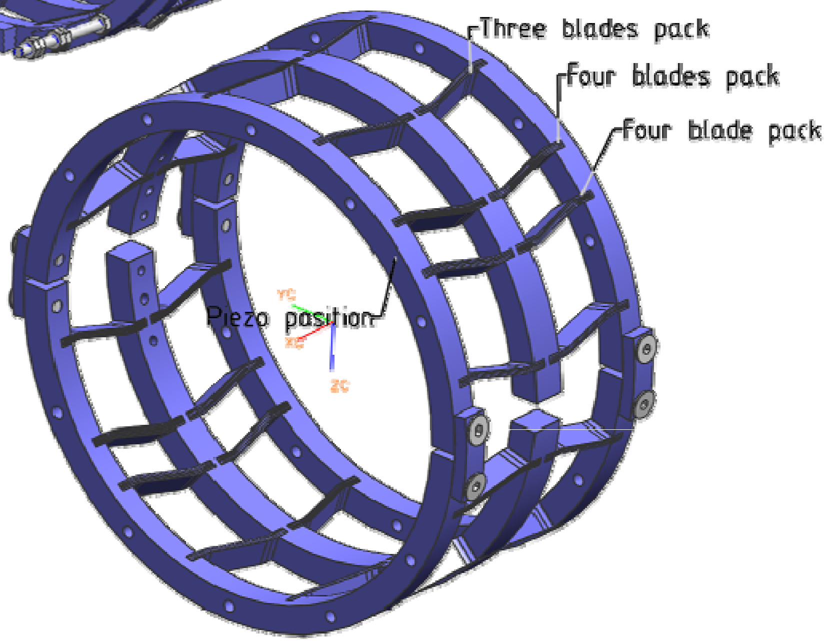
On the basis of the test results here presented the ILC Blade Tuner prototype is already close to fulfill all the ILC specifications.

The experience gained with the cold tests on the prototype has been used for the final revision of the Blade Tuner.

The production of the first 8 units has been completed on July 2008. They will be delivered to Fermilab in order to equip the second ILCTA cryomodule.



The piezo positions correspond to the **double blade packs**: these packs withstand an higher load

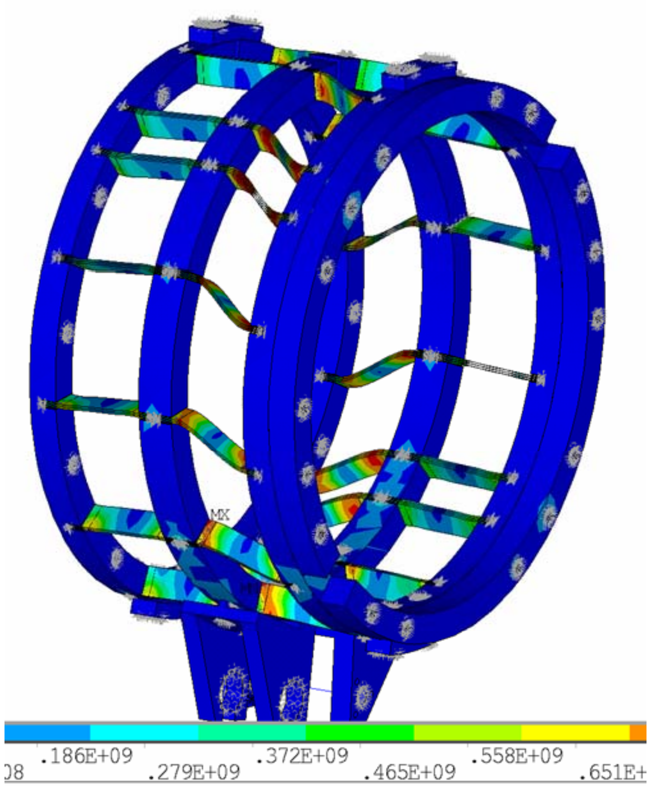


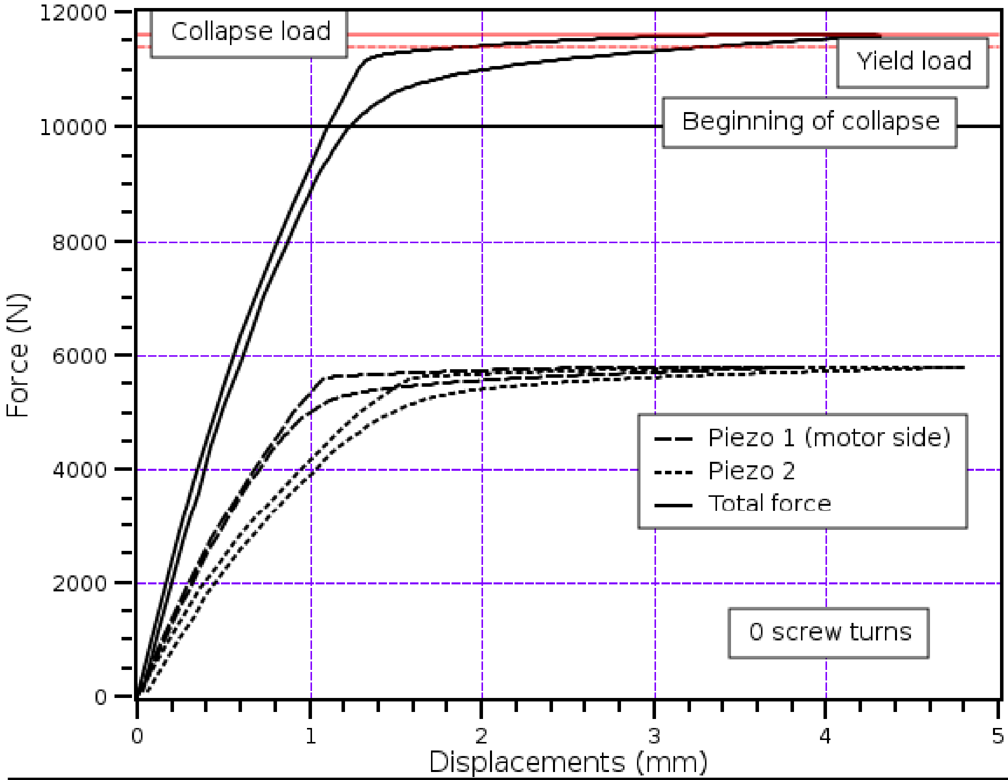
Design analysis – whole tuner

Possible failure modes for the titanium revised Blade Tuner have been studied through a complete 3D FE model in order to evaluate its limit loads.

In this analysis the tuner is at 0 screw turn position

Collapse at 12 kN





Displacements and force distribution at the piezo positions with the tuner at the **0 screw** turns position

Revised Blade Tuner - conclusions

ILC revised Ti Blade Tuner	Tuner characteristics	Reference value (includes operating conditions, transients, pressure vessels codes etc)
Tuning range – max.	0 – 600 kHz	
Max compression strength	12 kN	11 kN
Max traction strength	16 kN	14 kN
Compression stiffness	15 – 100 kN/mm	35 kN/mm
Mean freq. sensitivity	1.5 Hz/half-step - XFEL standard drive unit -	0.75 Hz/half-step - actual TTF I tuner sensitivity -
	0.75 Hz/half-step - devoted 1:200 gear -	
Max. torque at the CuBe screw	12.5 Nm - XFEL standard drive unit -	2.4 Nm
	25 Nm - devoted 1:200 gear -	

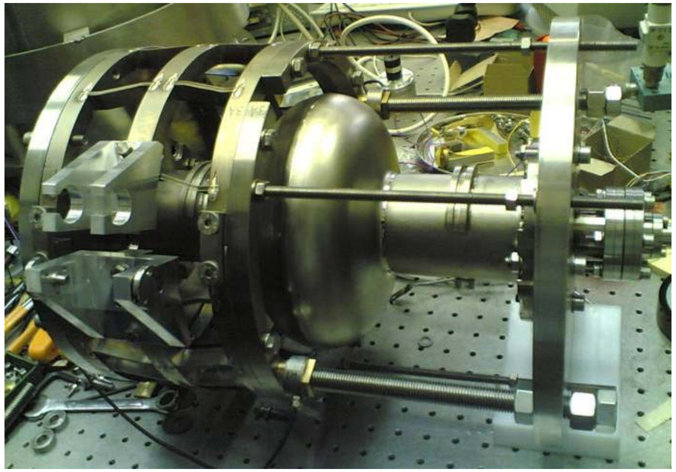
This is the chosen design for the ILC-HiGrade WP8 tuners, that can be fabricated

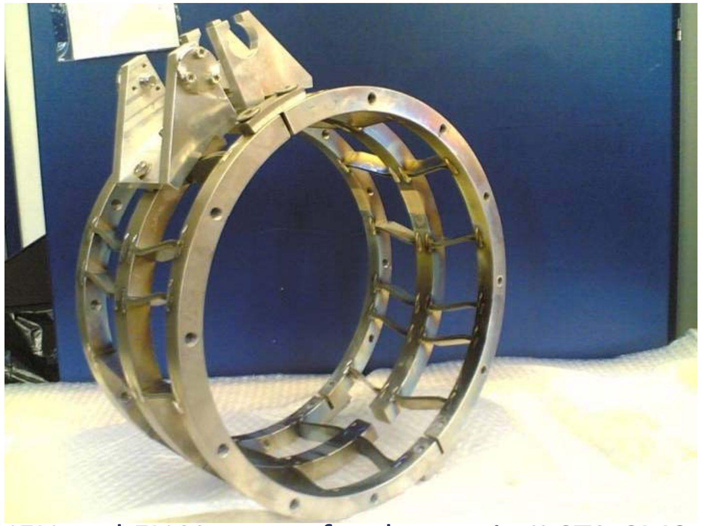
Moreover, this is the design used for the 8 tuners for ILCTA CM2 at FNAL

ILCTA CM2 Hardware…

The first 8 ILC revised Blade Tuner have been produced (July 2008)

As of today, (warm) RF test are being performed with a single cell at INFN Milan in order to measure the kinematic performances and the load bearing capabilities of each unit.





The full compatibility has been granted by the joint effort of INFN and FNAL teams for the use in ILCTA CM2

Delivery of complete, double piezo equipped, Blade Tuner units is foreseen for October 2008.

WP8 Plan

Objectives Demonstrate suitability of tuner design in tests. Establish a cost-effective tuner production of 24 tuners.

Description of work

Long-term frequency drifts of the cavities e.g. due to changes in helium pressure have to be compensated by a slowly operating mechanical system. Such tuners have been developed in Milan. Under RF load cavities undergo mechanical deformation due to the Lorentz force such that the frequency of the cavity is detuned during the RF pulse. Given the high Q-value of superconducting RF cavities, the efficiency of the acceleration is immediately affected. It is hence mandatory to counteract the Lorentz force with a fast piezoelectric tuner. The integration of the fast actuators is being pursued and needs to be validated at the gradient levels of the ILC. One of the biggest challenges is to operate and control the tuner in the vacuum at temperatures of 2°K and to maintain a cost-effective design.

A sufficient number of tuners to support power tests of cavities in a cryostat will be procured.

Deliverables

8.2	Tuner Report	Report on tuner fabrication	24
8.3	Tuner Fabrication	Tuners fabricated	42

WP8 Work/Deliverables/Interfaces

- Work
  - Tuner design is there, we also have the 8 prototypes which are under test NOW (mechanical, RF on single cell at warm)
  - Will possibly have cold tests within HiGrade at FNAL
  - Experience with FNAL tuners: 8 months from tender to delivery (includes tooling)
- Deliverables
  - INFN can launch soon CFT for the series production of X (=24-30?) tuners
- Interfaces
  - Keep present XFEL CM mechanical compatibility
    - Distance Coupler/Pads on He Tank
  - With cavity WP
    - Helium tank design, requires a ILC prototype tank, not an adaptation which affects LFD performances
    - Possibly also the right moment to redesign for stiffer end groups