Cavity Integration

H. Hayano

(A) Cavity Integration Work Packages

ID	Title	Description
1.2.1	Tuner	Development of slow tuner for resonance stabilization and fast tuner for Lorentz detuning compensation
1.2.2	Input Coupler	Development of coupler designs, including evaluation of fixed/variable coupling, port diameter, heat load, etc.
1.2.3	Magnetic Shield & He-Vessel	Determination and test of magnetic shielding method, inside/outside He-vessel. Vessel material, bi-metallic junctions, Pressure Vessel regulation, and alignment method.
1.2.4	Integration/Test	system integration into cryomodule and performance test
1.2.5	Cost & Industrialization	Cost estimate and pre-industrialization value engineering

(B) Plug-compatibility concept development

Specifications for plug-compatibility
Definitions of boundary for plug-compatibility

(A) Cavity Integration Work Packages

1.2.1 Tuner development status

(1) Blade-tuner status

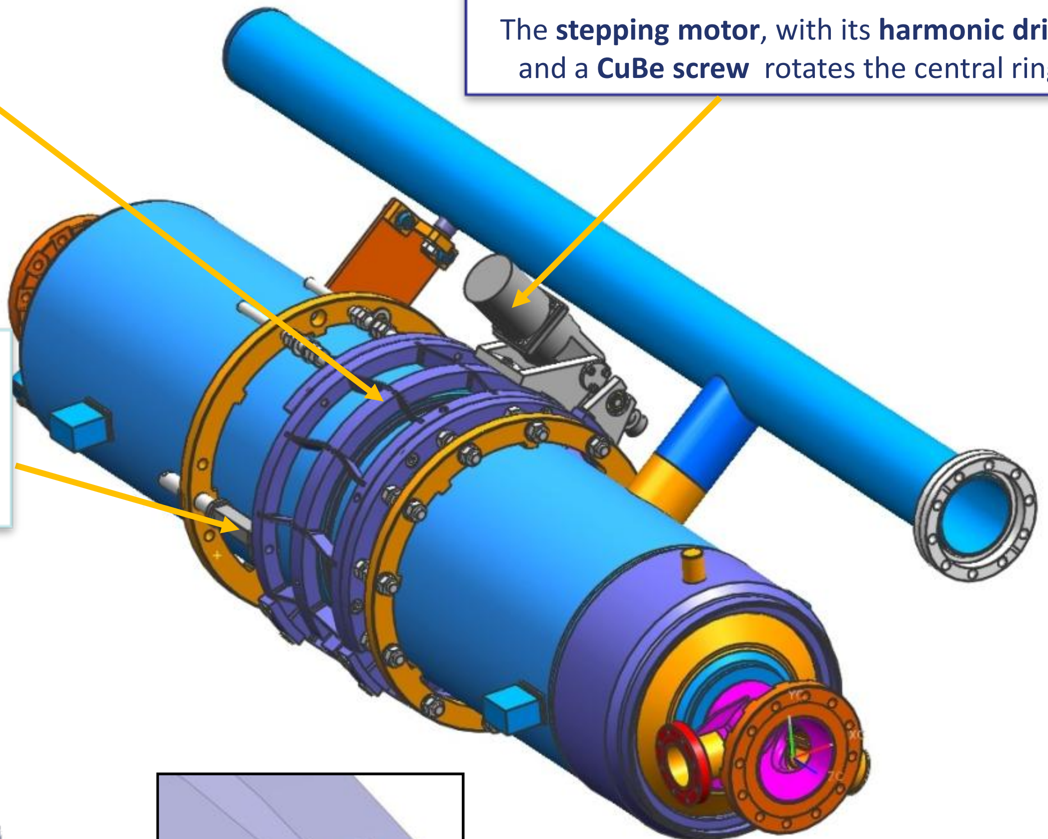
Blade Tuner "Slim" Prototype

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.

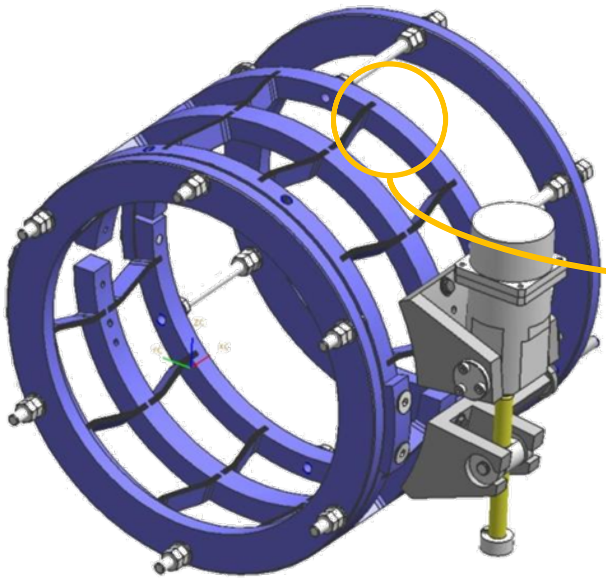
The movement system

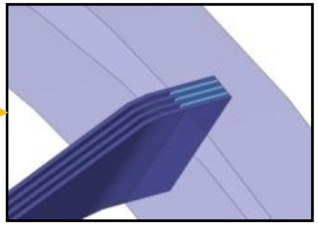
The **stepping motor**, with its **harmonic drive** and a **CuBe screw** rotates the central ring



The Piezo Actuators

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





Lighter,

Cheaper,

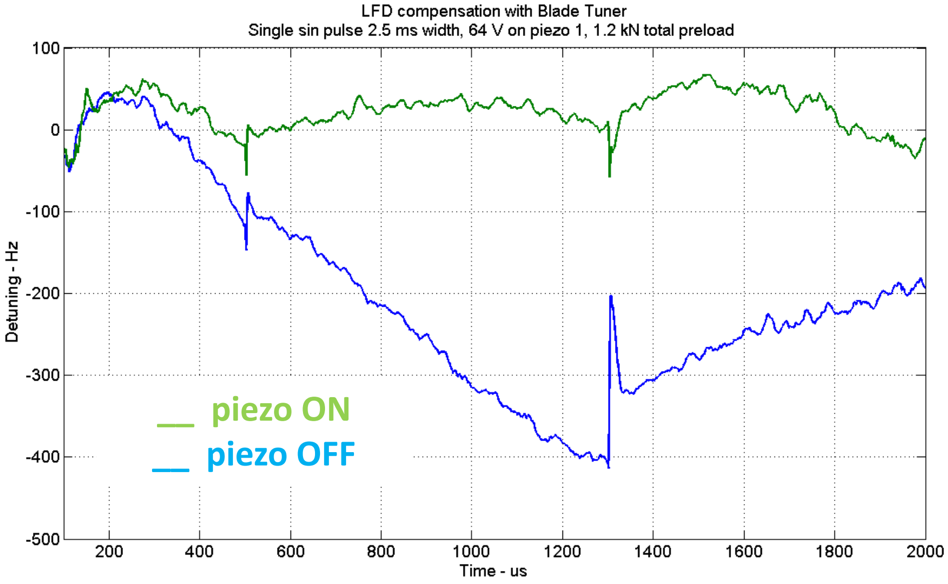
New driving mechanism,

Wider tuning range,

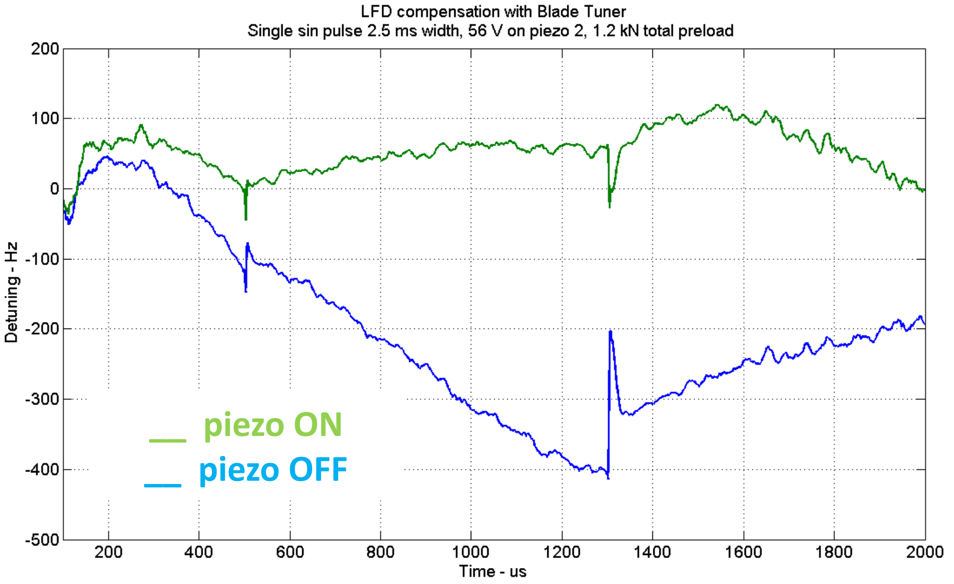
Ready for future SS tank

Blade Tuner tests at CHECHIA – Results

- LFD exhibited by Z86 cavity, about 300 Hz, has been compensated:
  - Actuating each piezo alone (see plots)
  - Actuating both piezo in parallel



64 V on piezo #1

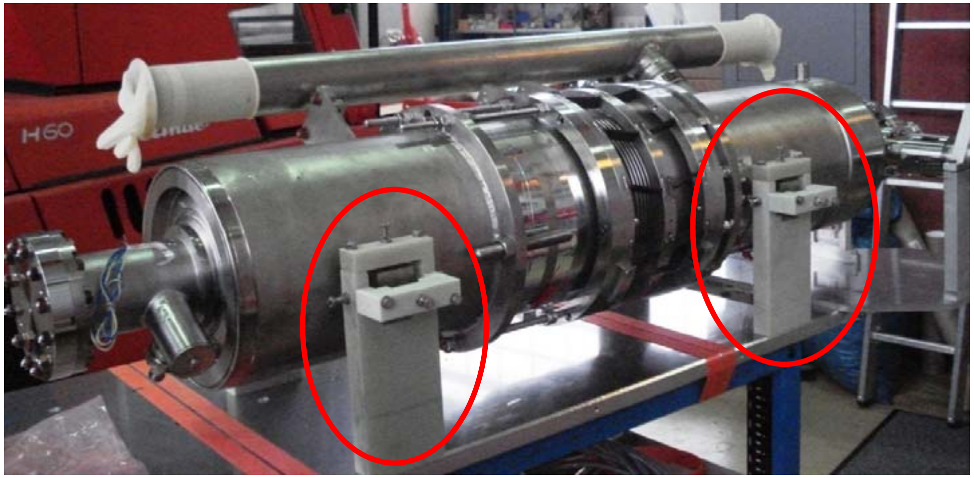


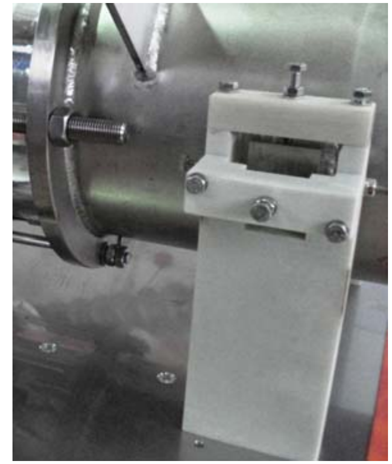
56 V on piezo #2

Nominal piezo pulse amplitude for this level of LFD is 60 V +/- 7%

Eacc ~24MV/m

Test setup at HoBiCat - BESSY





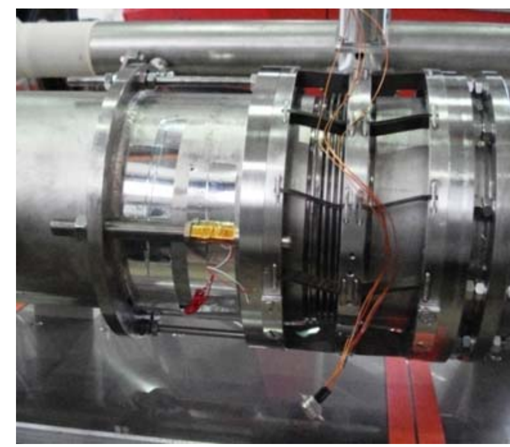
The cavity package is installed on a table

- Each pad is clamped in a Teflon pillar that can slide on the SS table

The table hosting the cavity and its ancillaries is then moved into the HoBiCat cryostat

Feb. 2008 in the HoBiCaT horizontal cryostat, BESSY

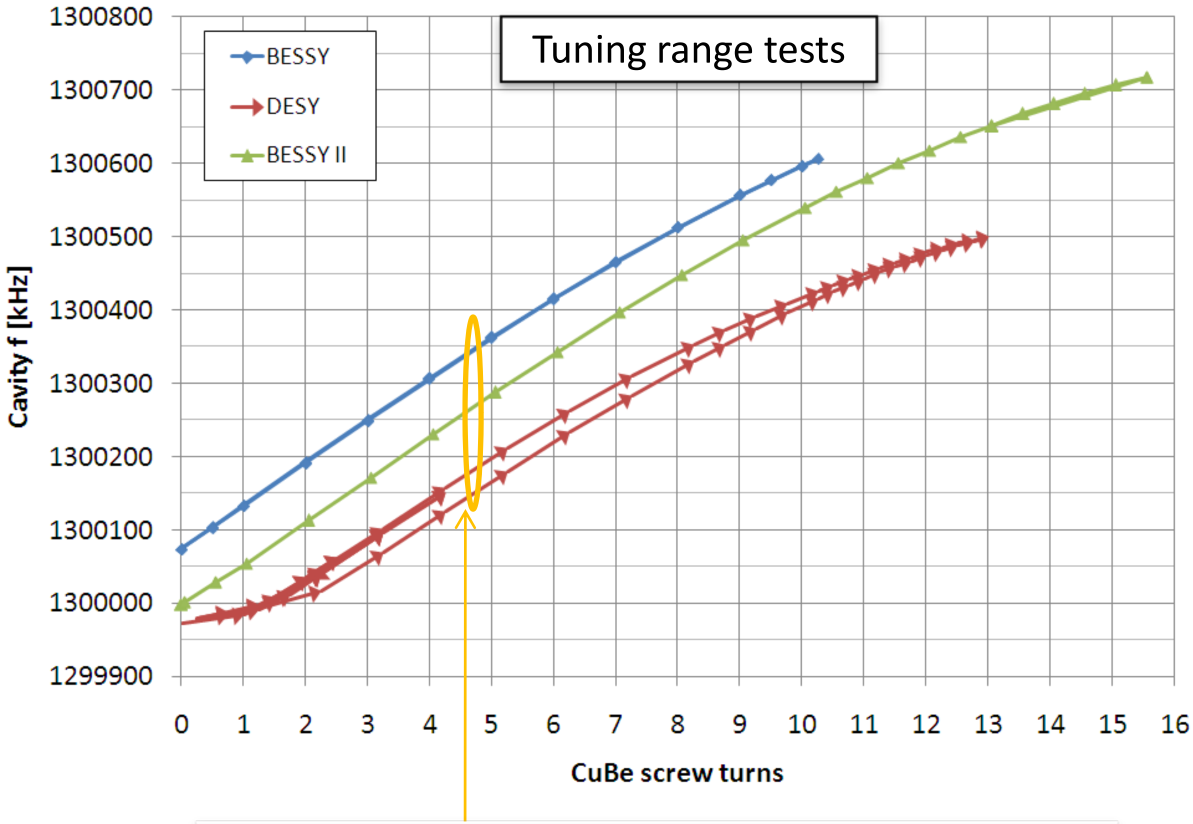
The same assembly but equipped with a prototype of a possible alternative driving unit: **Phytron stepper motor + Planetary Gear**



- Blade Tuner cold tests, February and April 2008
  - Stainless steel + Inconel Blade Tuner (same as CHECHIA test)
  - 40 mm Noliac piezo (same as CHECHIA test)
  - Phytron stepper motor, 200 steps/turn
  - Phytron VGPL planetary gear, 1:100 reduction ratio **<10 nm/step**
  - therefore 20000 steps each spindle turn (CuBe spindle screw, 1.5 mm/turn)

HoBiCaT Tests – full tuning range

600 kHz tuning range has been confirmed with margin.
The hysteresis has been almost cancelled.



Mechanical hysteresis almost cancelled over the full range after a few cycling

Tests were performed with different piezo preloads.

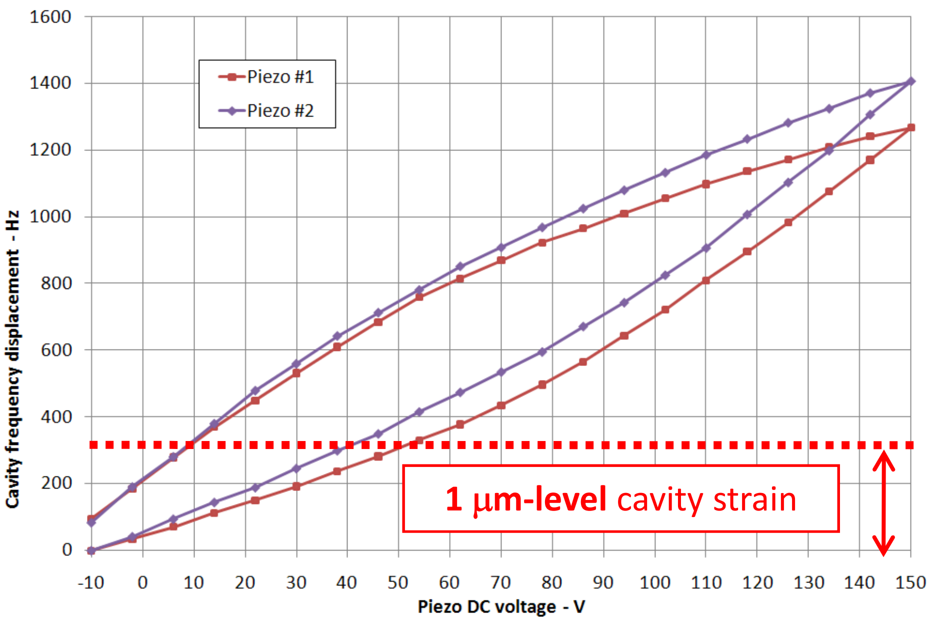
The correct value cancels the piezo unloading effect and enhances tuning sensitivity.

Tuning resolution met expectations, about **1.5 Hz/half-step** confirmed.

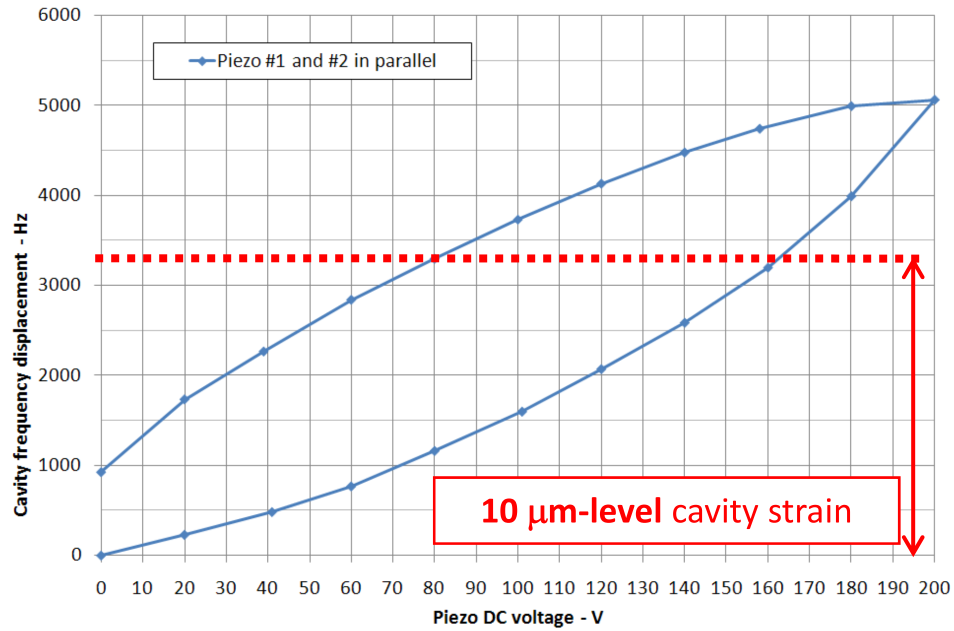
Blade Tuner piezo tests at HoBiCaT

- Each piezo actuator alone and also both in parallel have been driven with a DC voltage, the cavity frequency is locked by a PLL and measured.
- No deviation observed from the hysteresis curves expected from piezoelectric properties: no obstacles to the movement of piezo.
- Looking at plots a sub-micron resolution can be observed: 10 V step in piezo driving voltage corresponds to about 0.1 μm at low absolute voltage (where slope is lower)

Each piezo alone up to 150 V:
1.3 kHz +/- 10 % tuning range



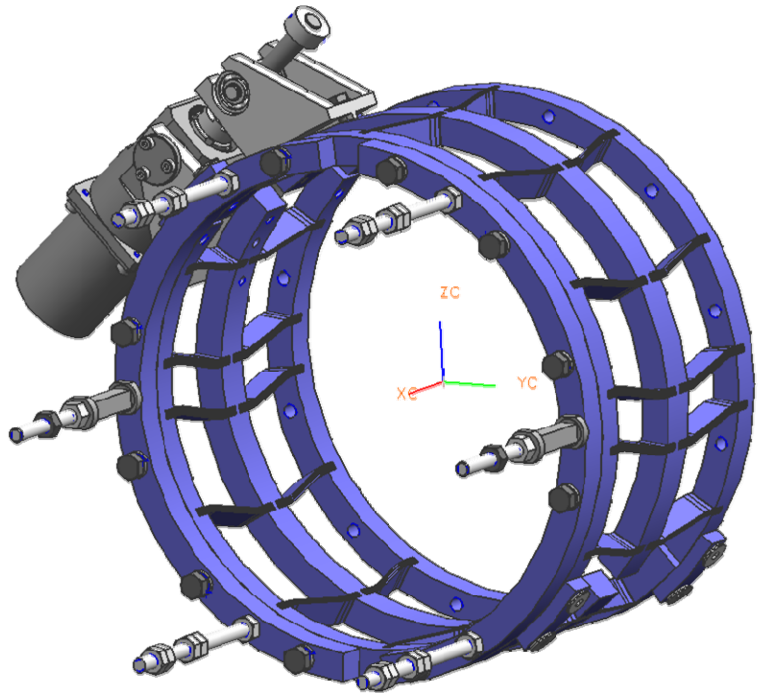
Both piezo together up to 200 V:
5 kHz tuning range

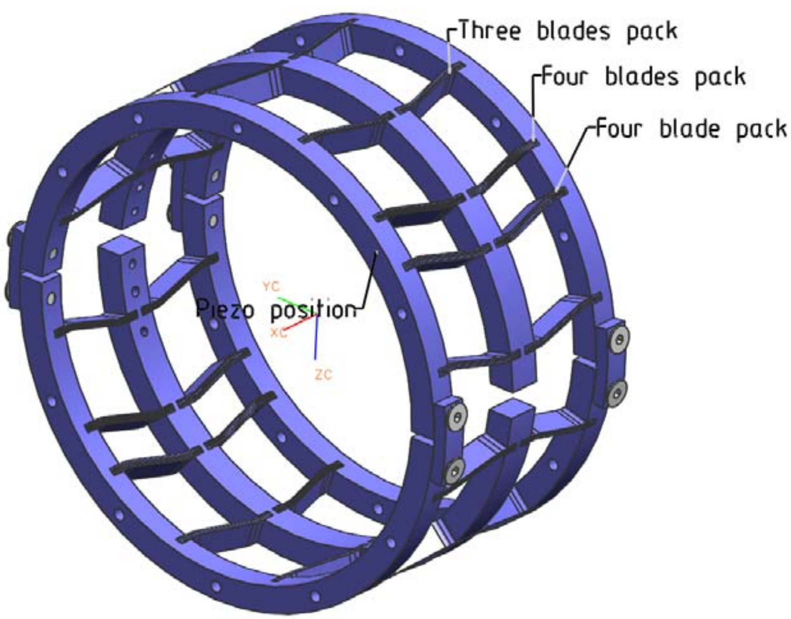


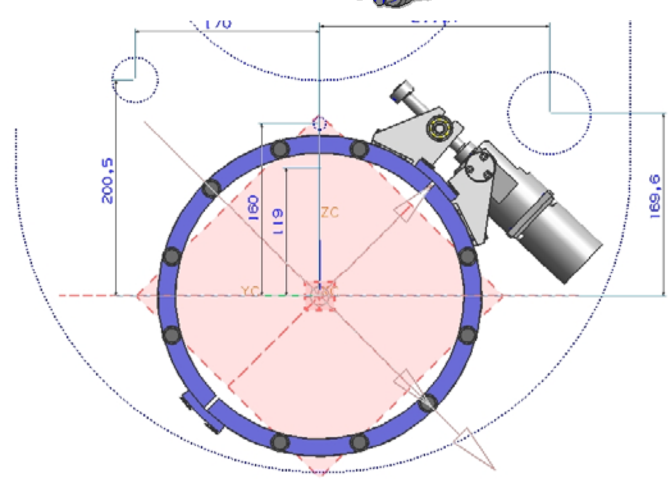
The ILC Blade Tuner

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

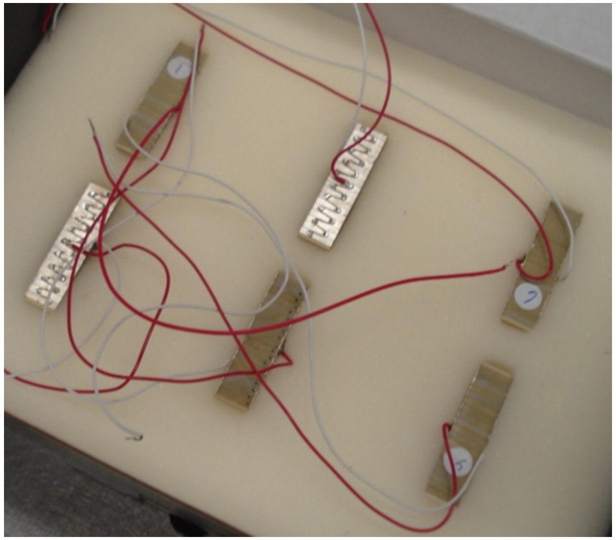
The experience gained with the cold tests on the prototype has been used for the final revision of the Blade Tuner.







Manufacturing

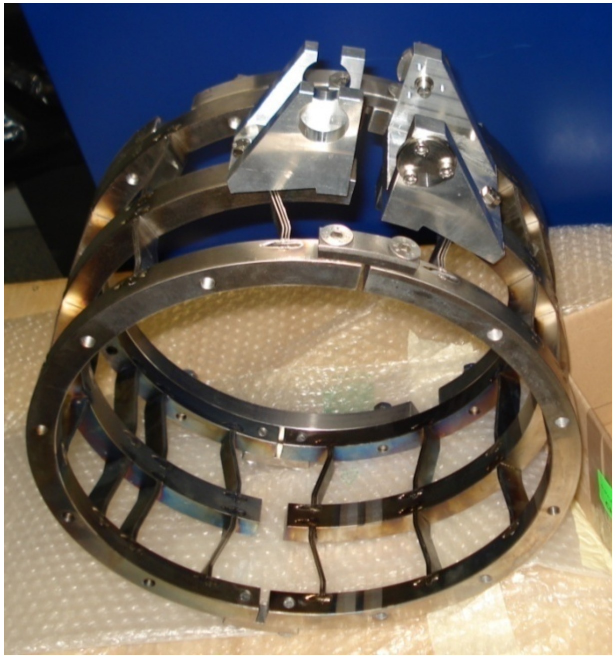


Important installations to come in short times:

•Cryomodule 2 (CM2) of **ILCTA** facility at New Muon Lab, FNAL, US: 8 units

•**S1-Global** facility at KEK, Japan: 2 units

•**ILC-HiGrade** of EU FP7 is also on the way: 24 units

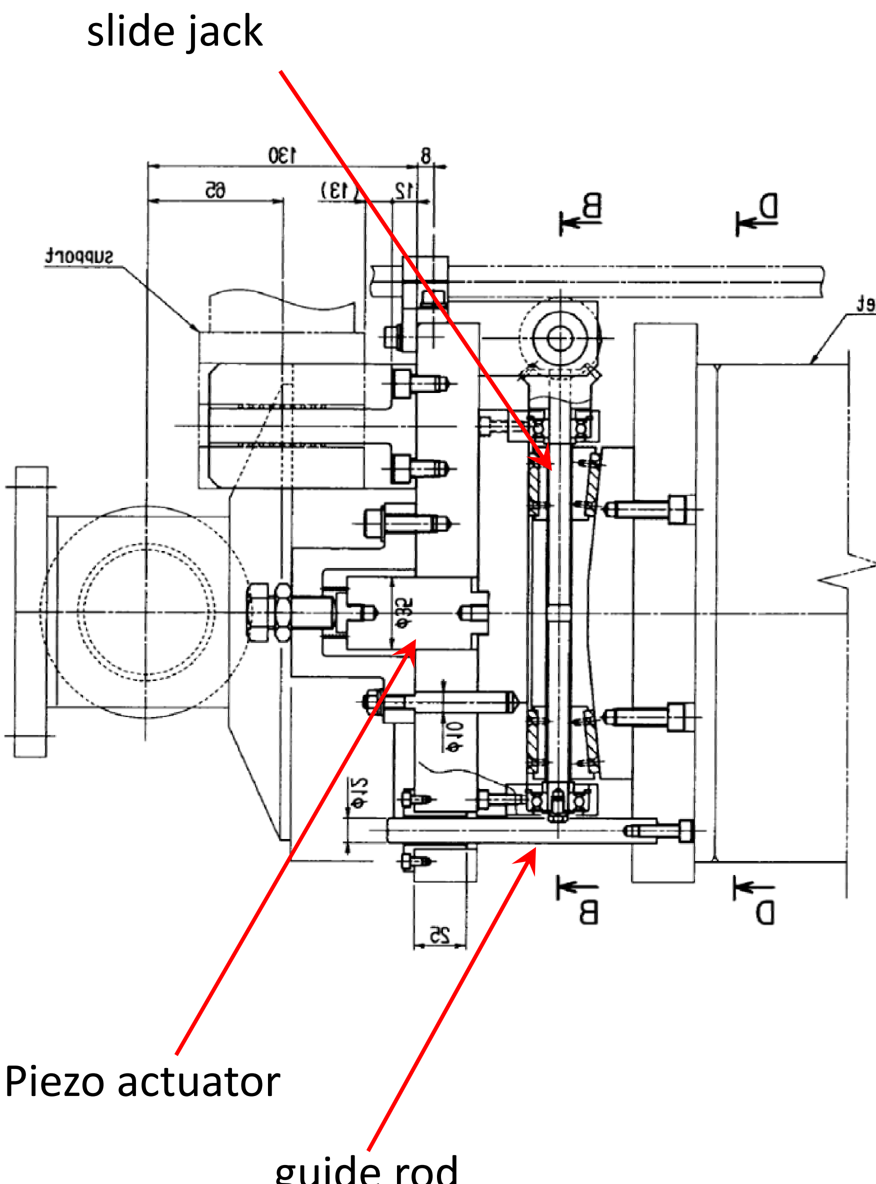


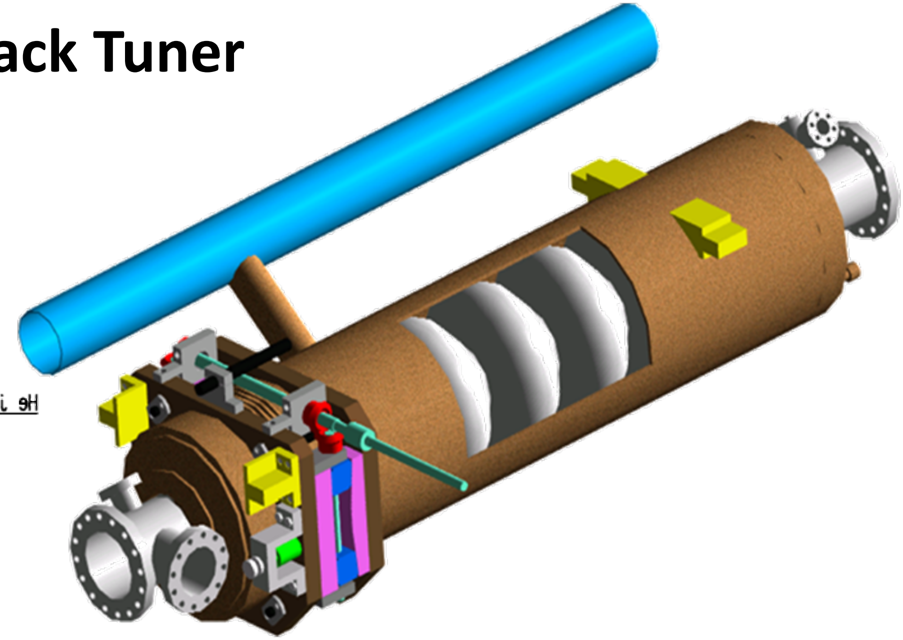
(A) Cavity Integration Work Packages

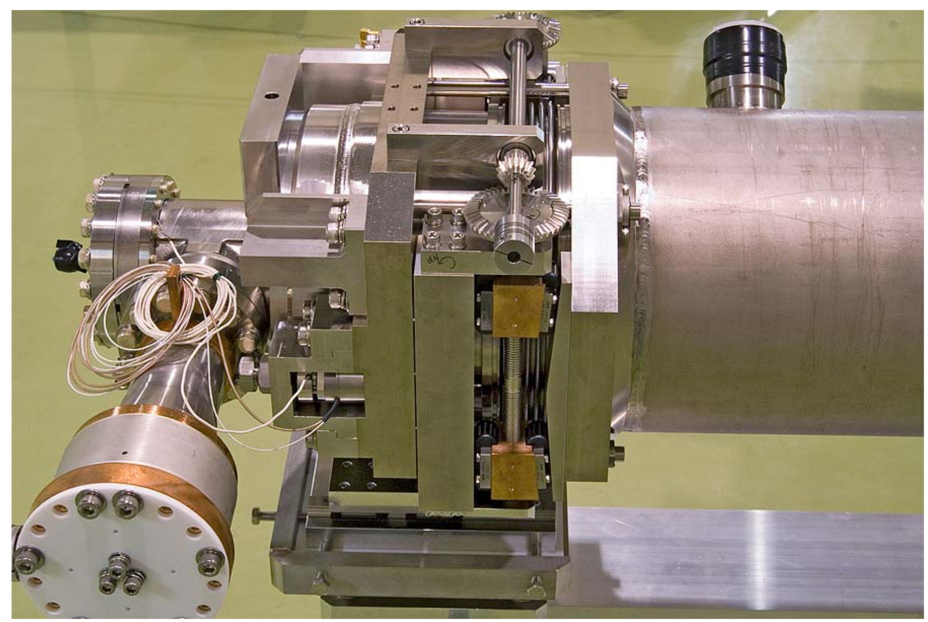
1.2.1 Tuner development status

(2) Slide-jack tuner status

KEK Slide-Jack Tuner



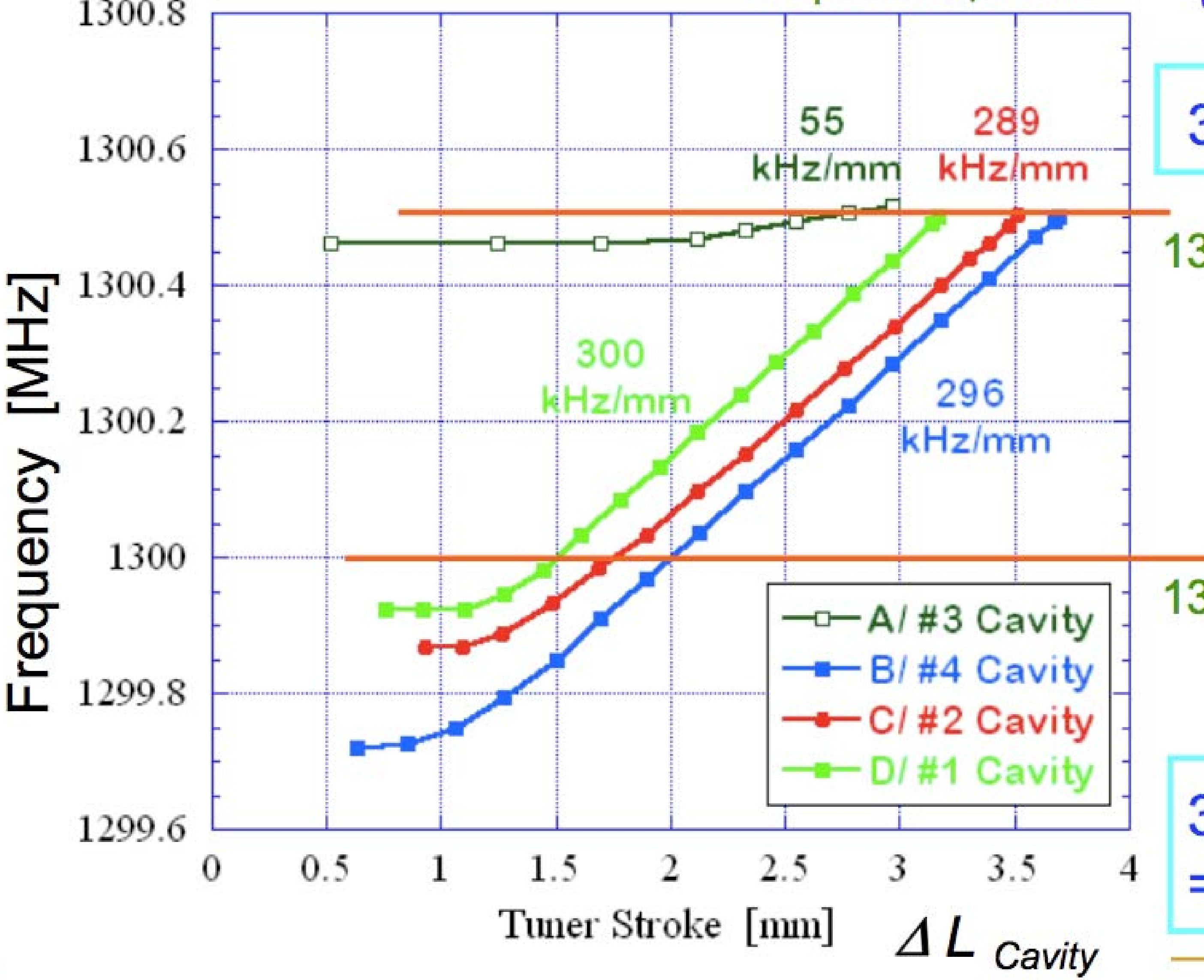




Tuner Stroke in STF Phase-1.0

September, 2008

at 2 K

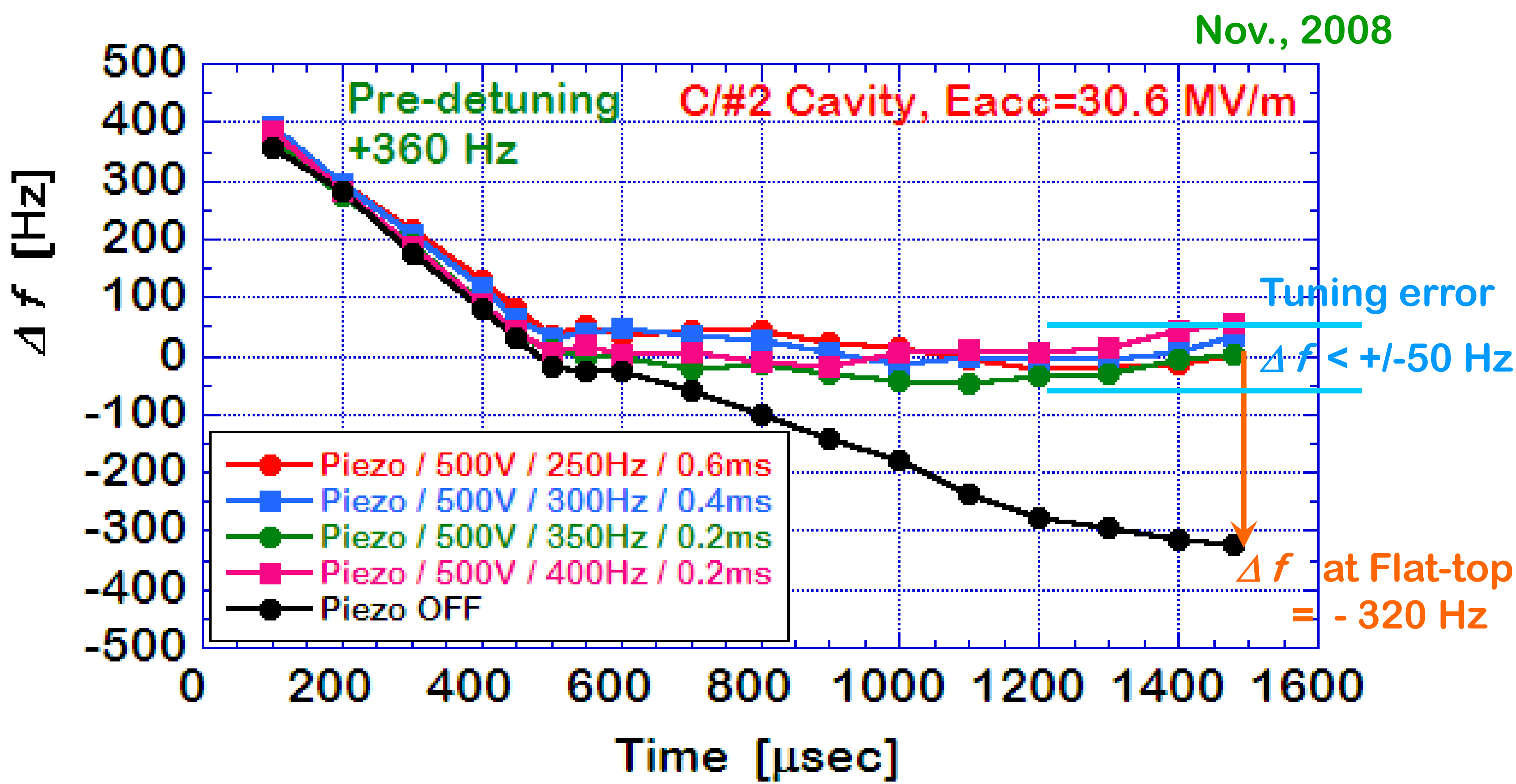


300 Hz/μm

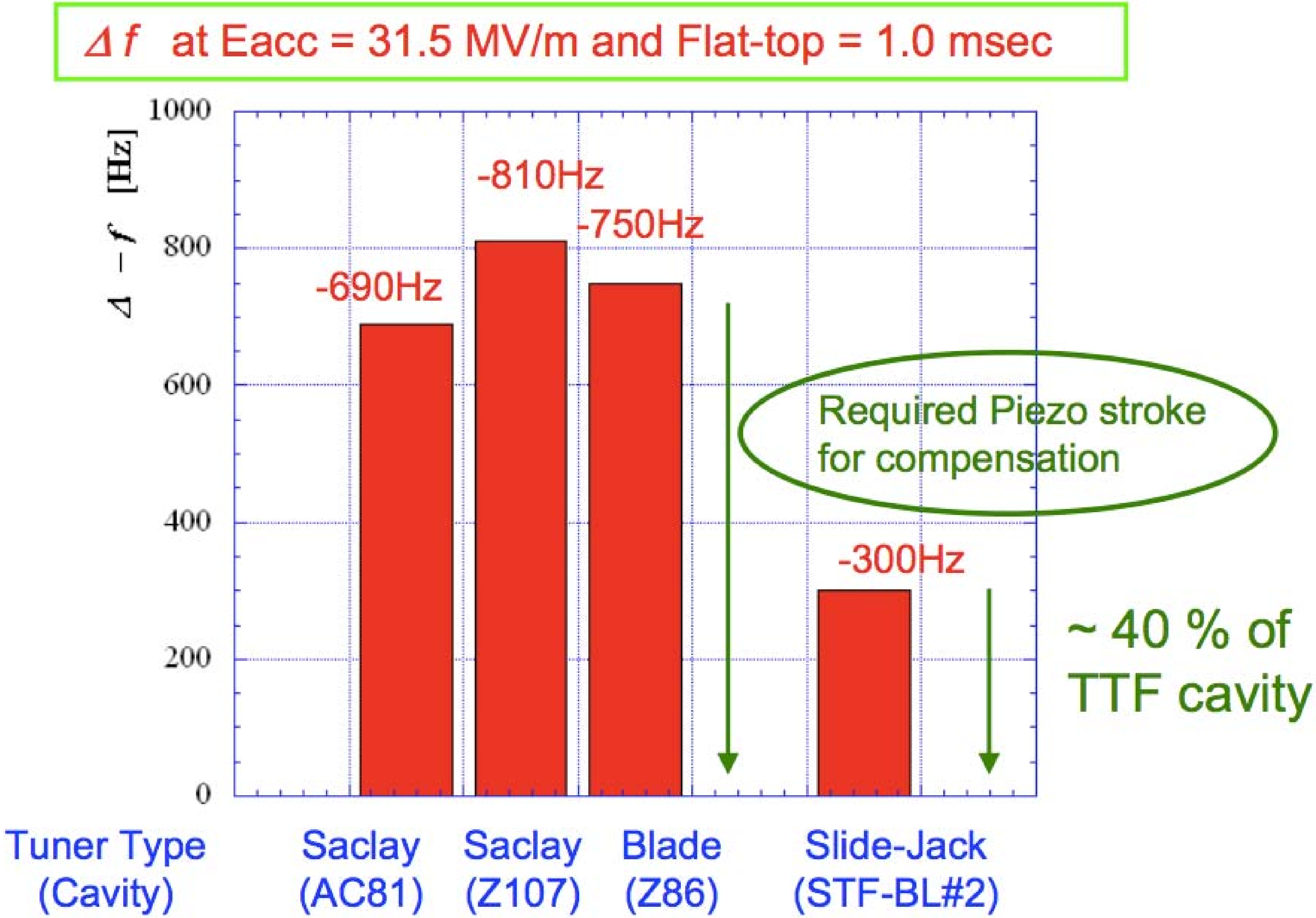
300 kg/mm
= 300 g/μm

STF Cryomodule Tests (5)

Compensation of Lorentz-detuning by Piezo Tuner

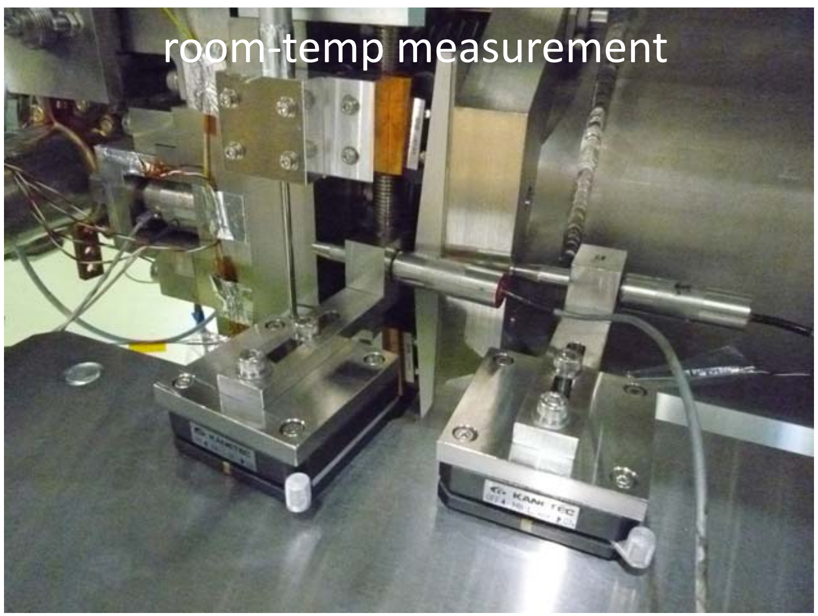


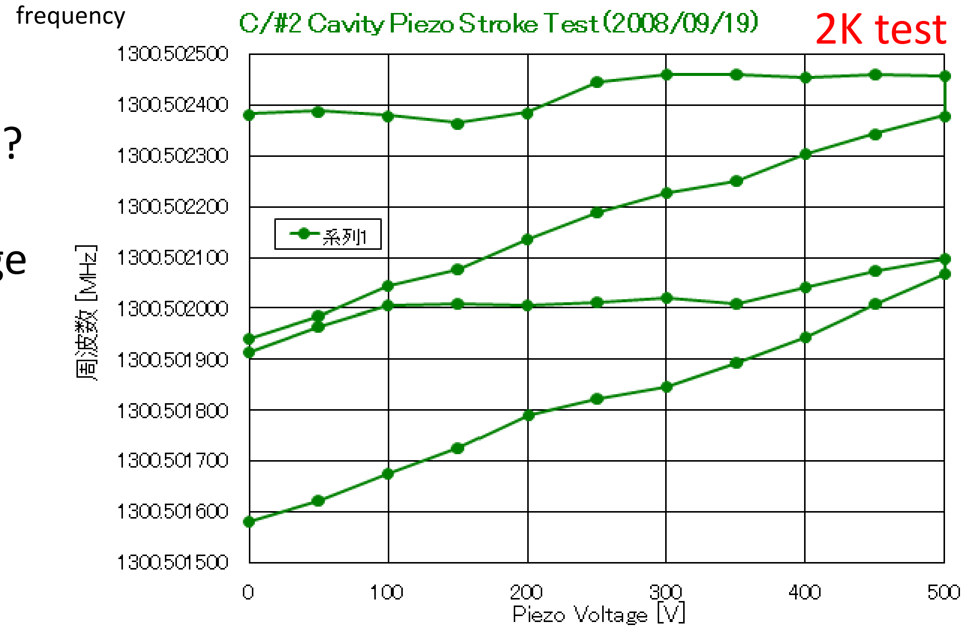
Comparison of Lorentz force detuning

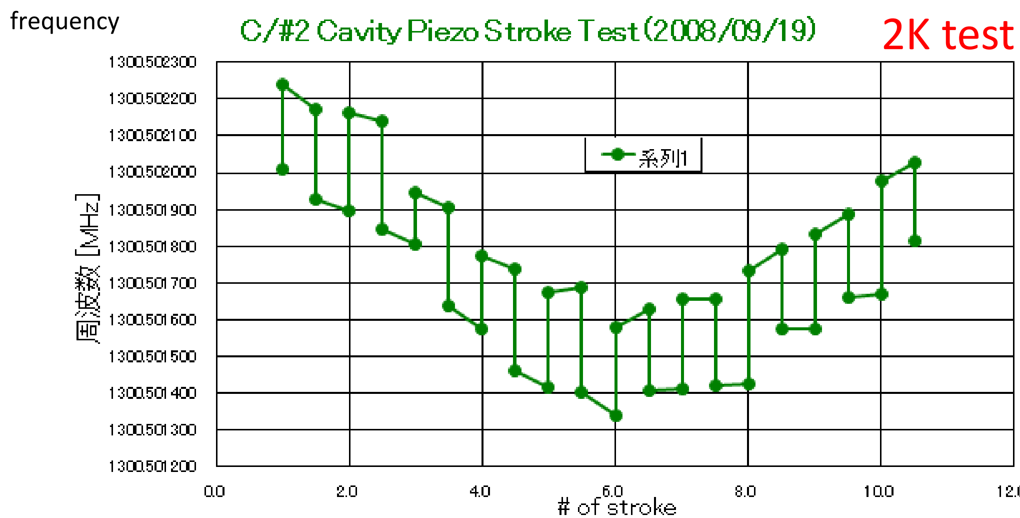


No repeatability for piezo response at 2K (STF1.0 experiment)

support tab friction for piezo drive??
or
other effect, like a drift by temp. change??
→ confirmation by room-temp meas.
and, consideration of tuner design change are underway.

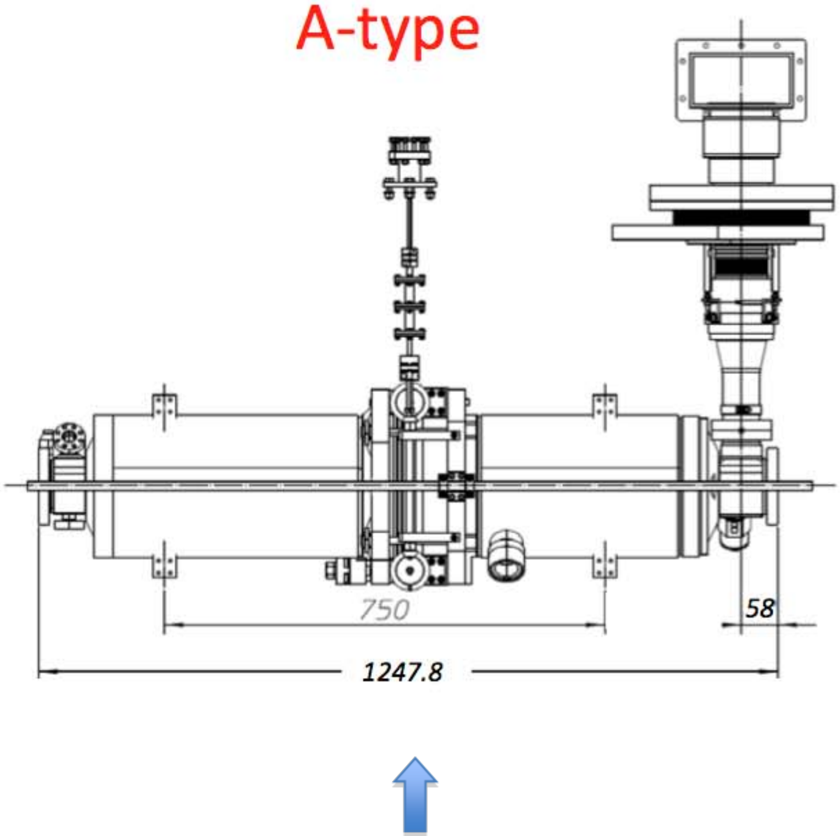


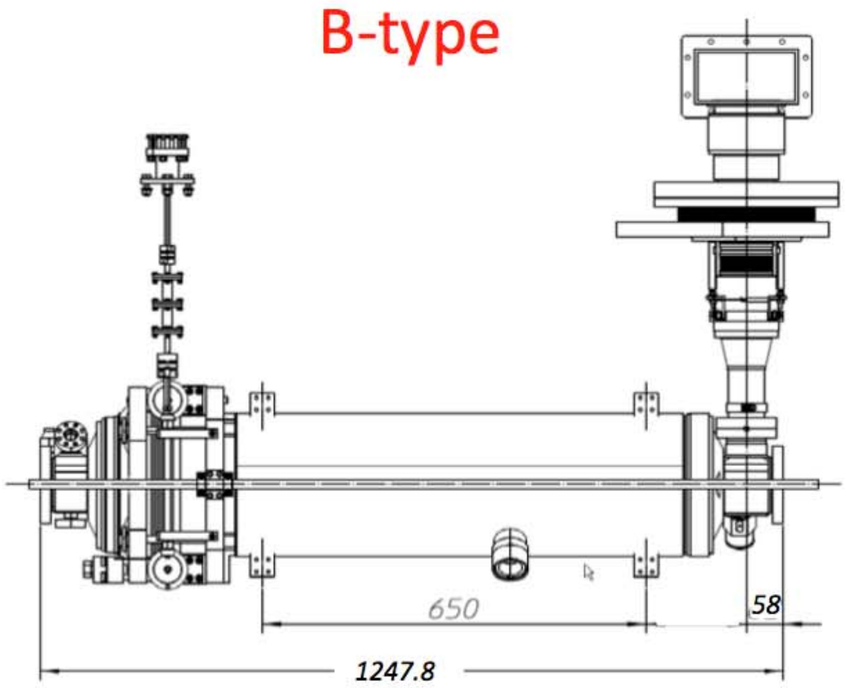




Tuner location and He vessel supports study

KEK evaluates two tuner locations and two support locations.
(in S1G module and phase-2 1st cryomodule)





4 supports are plug-compatible

(A) Cavity Integration Work Packages

1.2.2 Input Coupler development status

(1) TTF-III coupler industrialization study results

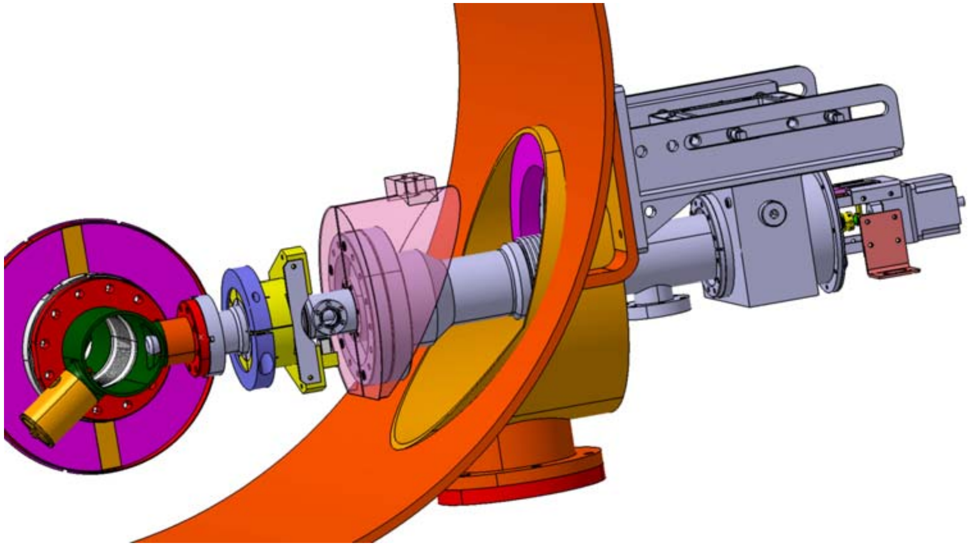
Status report on "Industrialization studies" at LAL
on power couplers for XFEL

______

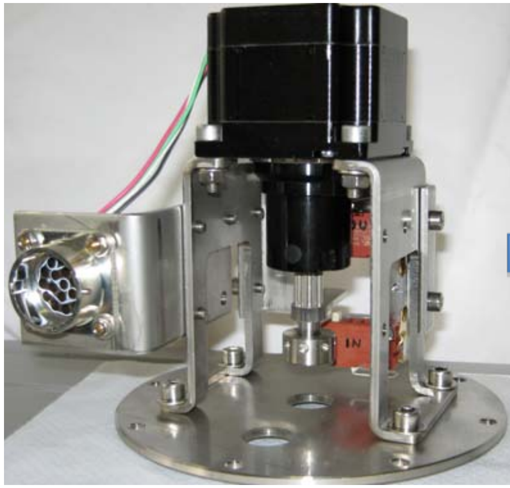
SCRF Meeting

Fermi Lab

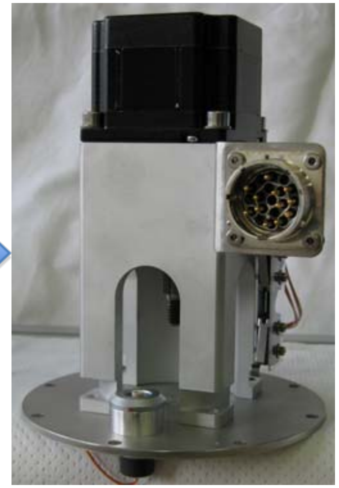
21-25 April 2008



Example of systems engineering result

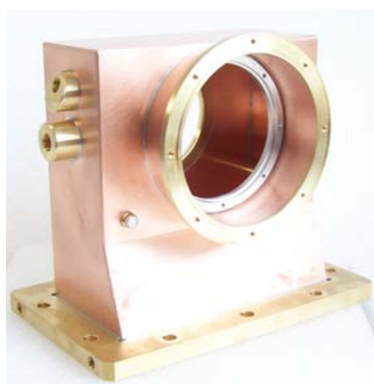


Prototype design for motorized tuning



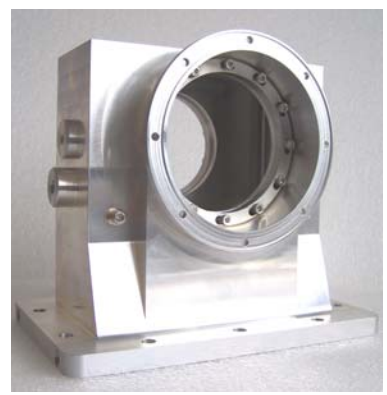
Industrial design

Design to minimize assembly time (chain clamp)



Copper + stainless steel + brass: 13 parts

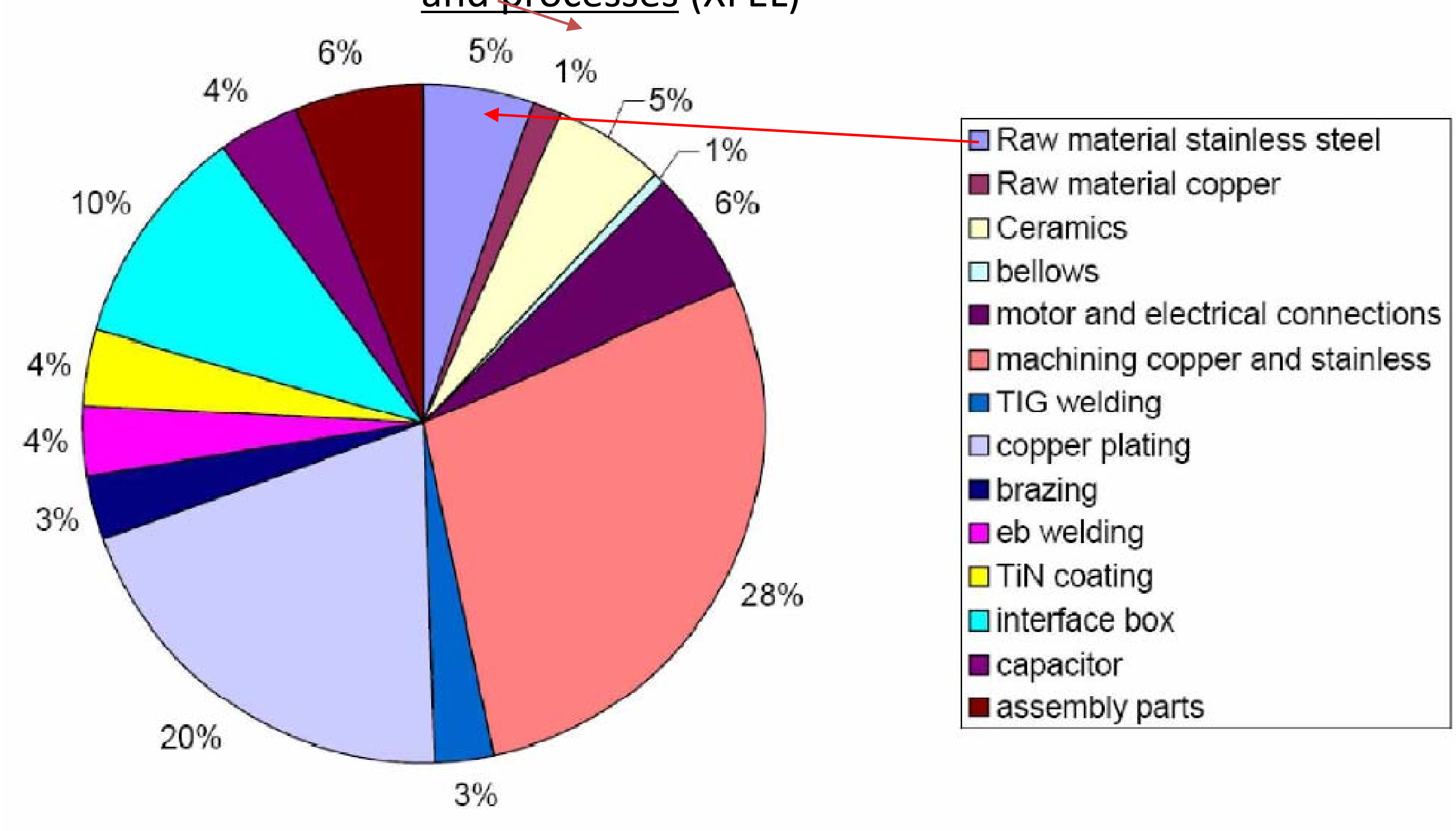
brazed and soldered



Al alloy: 1 single part

- Prototypes: machined from single block
- Mass production: casting

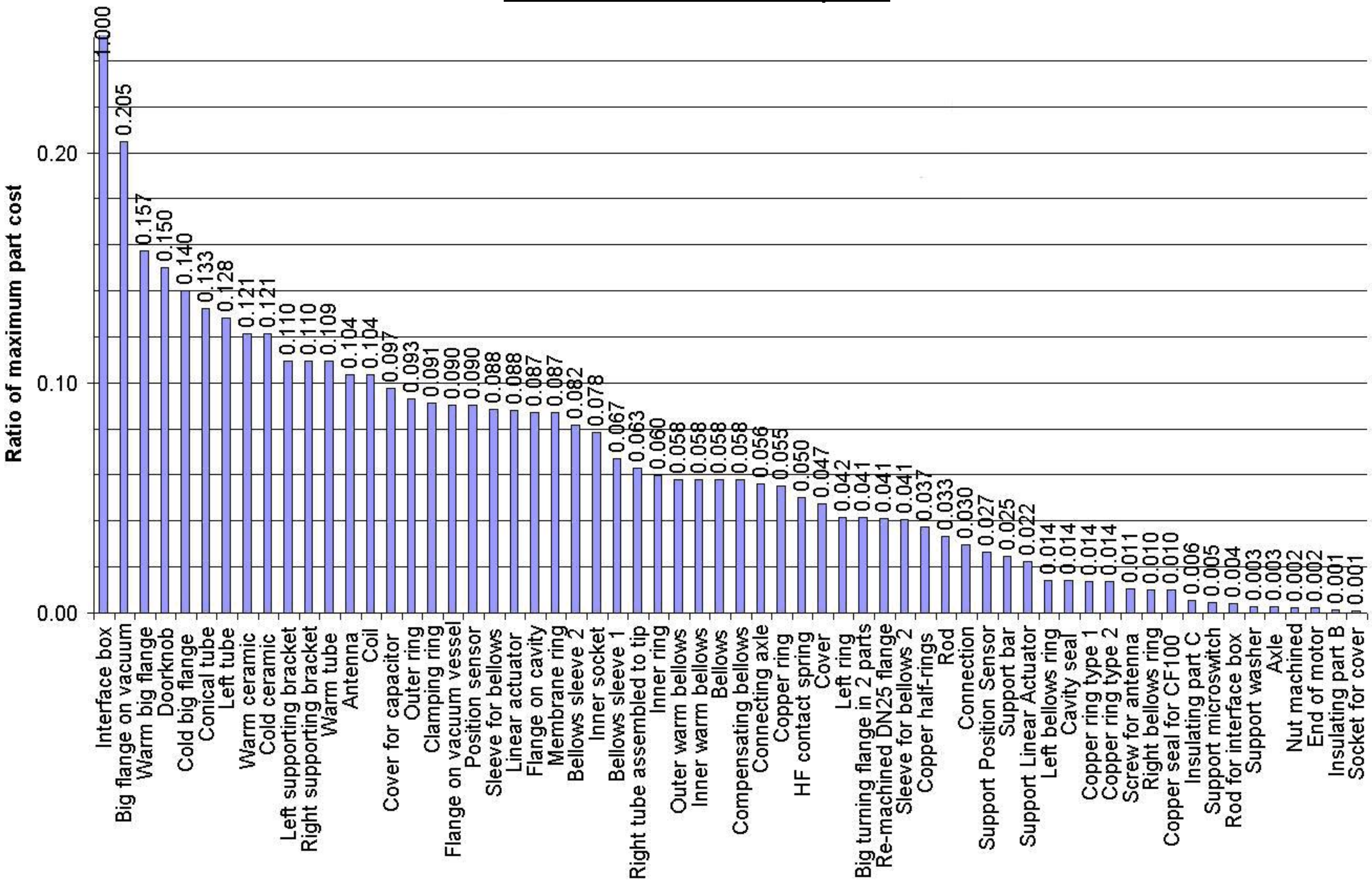
Manufacturing cost breakdown for materials and processes (XFEL)



Total raw material cost ~ 20 %

~ 11% - **Savings for fixed Qext**

Bar chart for each part



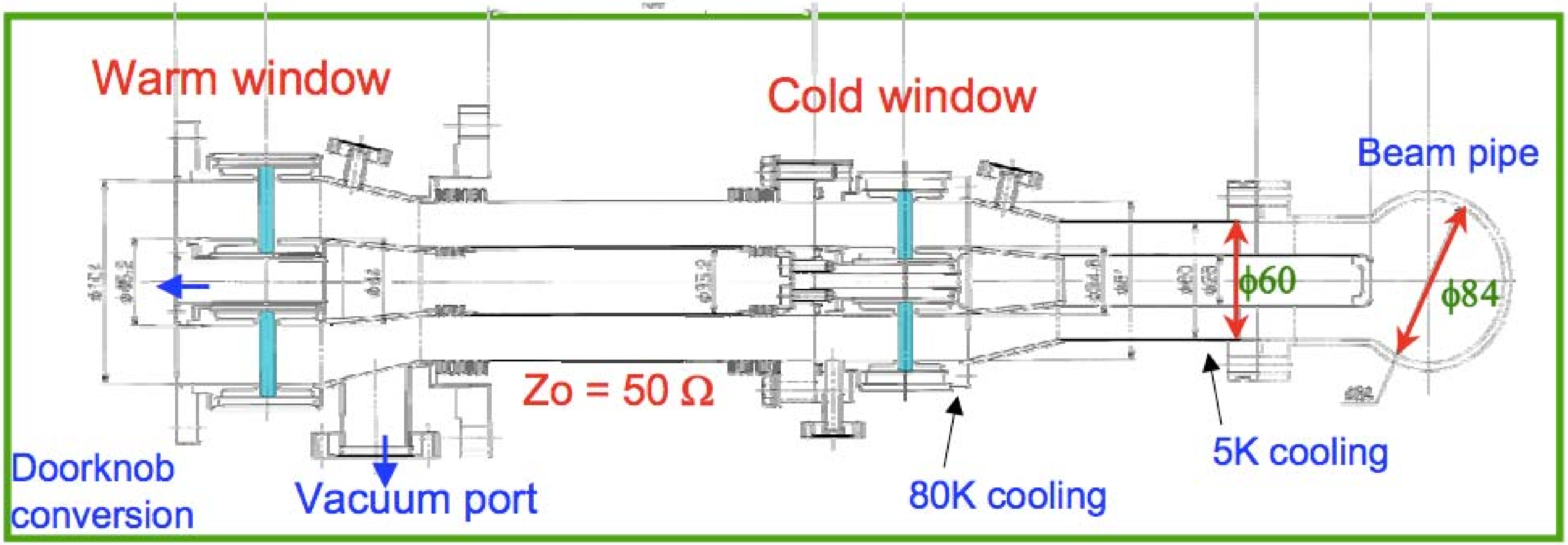
This is the basis for future round of cost reduction: → concentrate efforts on expensive items

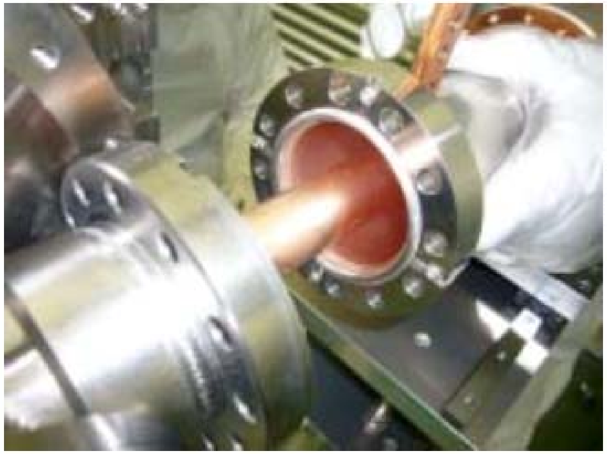
(A) Cavity Integration Work Packages

1.2.2 Input Coupler development status

(2) STF fixed coupler study results

Fixed Coupler for STF Phase-1.0

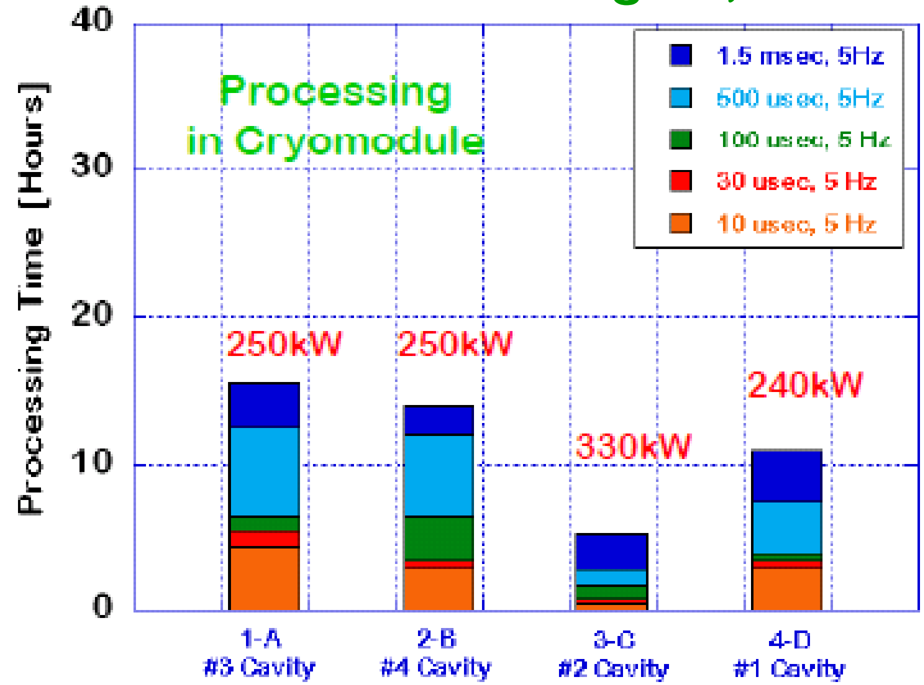




Processing of Input Couplers in Cryomodule ; STF Phase-1.0

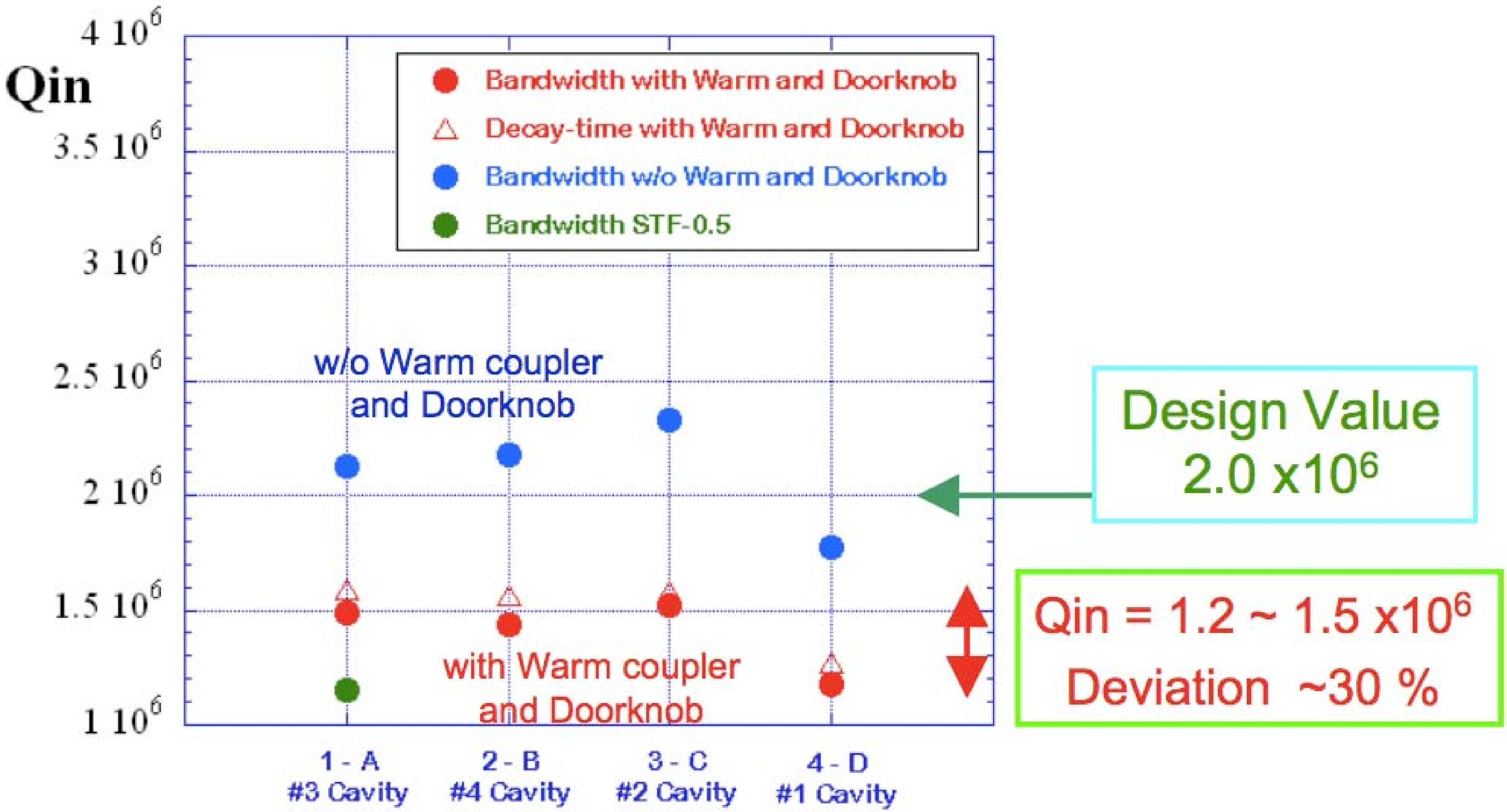
August, 2008

Four STF-BL Cavities



Processing time
up to 240~330 kW
for 5 ~ 15 hours
at Cryomodule

Qin of Fixed Input Couplers in Cryomodule



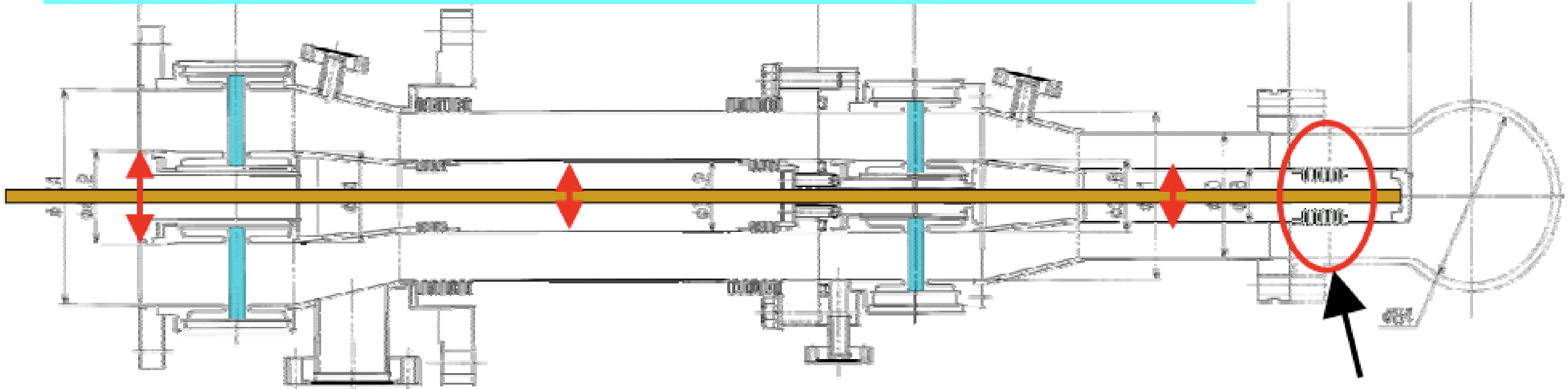
Large difference of Qin between with / without Warm & Doorknob

-> maybe insufficient assembly precision

New Variable Input Coupler for S1 Global and STF Phase-2

Present Fixed Input Coupler

ϕ 45.2	ϕ 35.2	Zo = 50 Ω	ϕ 26



Large diameter of an inner conductor and Low impedance

Bellows of Inner Conductor

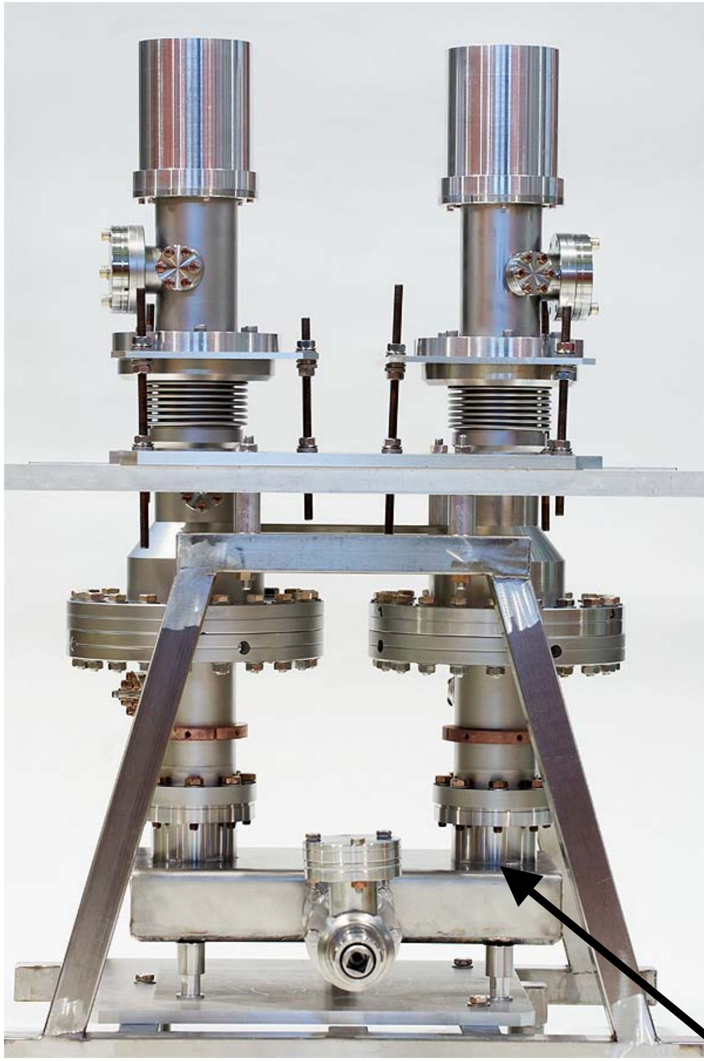
New

ϕ 52	ϕ 41	Zo = 41.5 Ω	ϕ 30

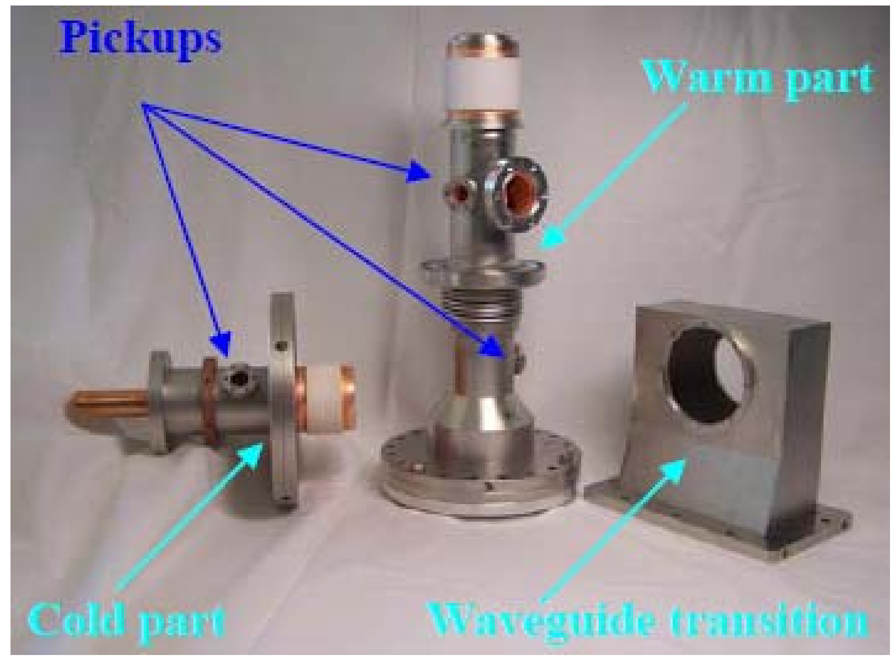
Variable Antenna Length → +/- 2.5 mm

Tune-ability of Qin → +/- 30 %

Power test of TTF-V Couplers at LAL and KEK



FJPPL Collaboration
between KEK and LAL
(H. Jenhani, P. Lepercq, M. Lacroix, A. Variola)



The TTF-V is a LAL design based on the TTF-III coupler design at DESY, and they were fabricated by ACCEL.

ϕ62 for more power capability

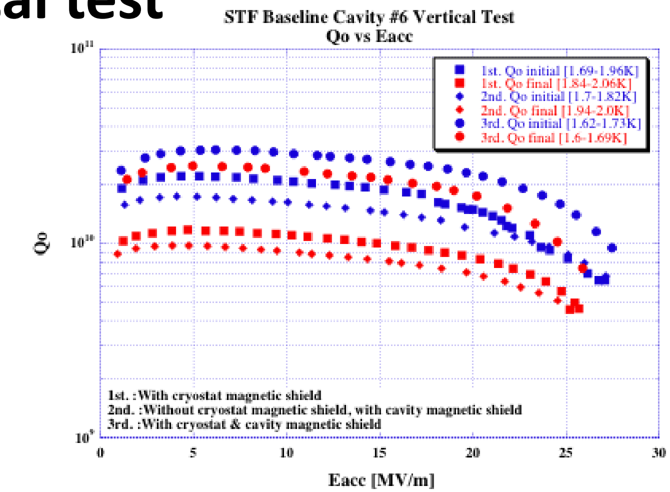
(A) Cavity Integration Work Packages

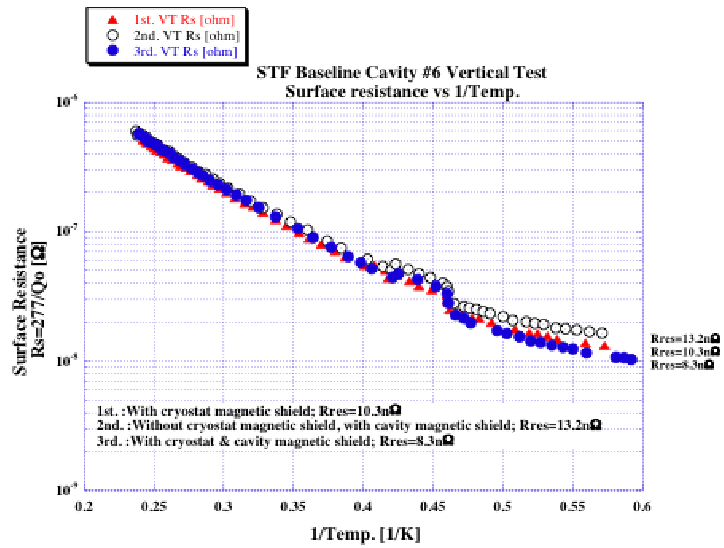
1.2.3 Magnetic Shield study status

STF studies for magnetic shield

Magnetic shield evaluation in vertical test

magnetic shield (same as for cryomodule installation)





MHI-06 cavity were vertical tested in December 2008, January 2009.

MHI-06 : no cavity mag-shield, cryostat mag-shield: Rs=10.3nΩ ← usual vertical test

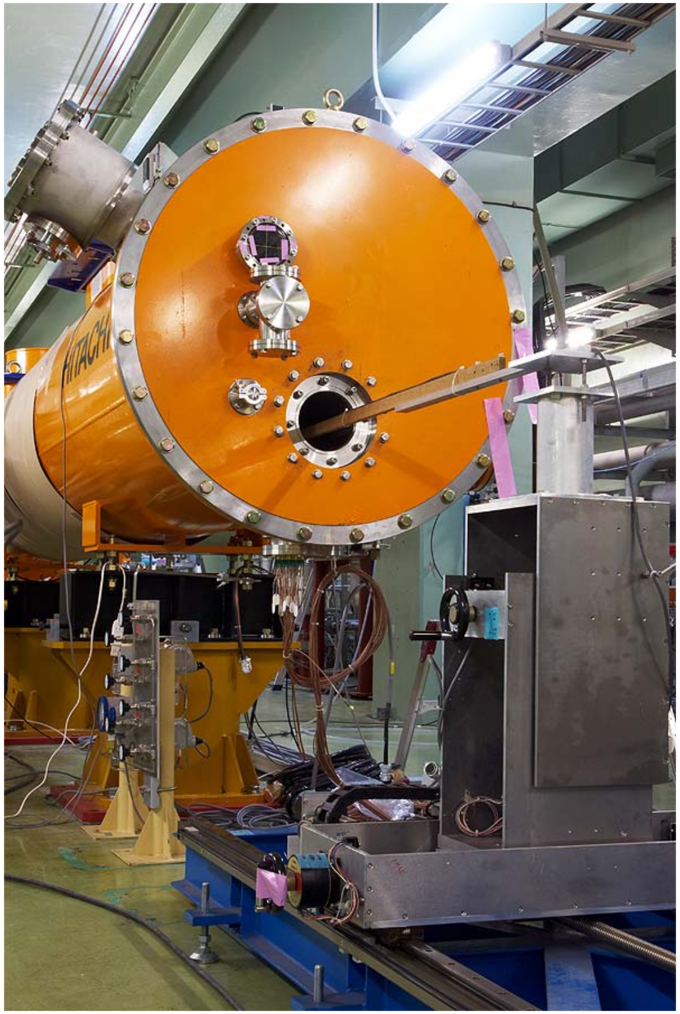
cavity mag-shield, no cryostat mag-shield: Rs=13.2nΩ ← cryomodule installation

cavity mag-shield, and cryostat mag-shield: Rs=8.3nΩ

Magnetic shield evaluation in STF cryomodule

cavity magnetic shield
(one end is open for probe scan)

direct magnetic field measurement
inside of the cavity magnetic shield,
in the cold state.
Measurement is now underway.



magnetic probe is inserted from outside
and the mapped field can be measured.

(B) Plug-compatibility concept development

(1) Specifications for plug-compatibility

(2) Definitions of boundary for plug-compatibility

Why and How Plug-compatibility ?

- **Cavity**
  - Necessary "extended research" to improve field gradient,
  - Keep "room" to improve field gradient,
  - Establish common interface conditions,
- **Cryomodule**
  - Nearly ready for "system engineering"
  - Establish unified interface conditions,
  - Intend nearly unified engineering design
  - Need to adapt to each regional feature and industrial constraint

Plug-compatibility in
R&D and Construction Phases

- **R&D Phase**
  - Creative work for further improvement with keeping replaceable condition,
  - Global cooperation and share for intellectual engagement
- **Construction Phase**
  - Keep competition with free market/multiple-suppliers, and effort for const-reduction, (with insurance)
  - Maintain “intellectual” regional expertise base
  - Encourage regional centers for fabrication/test facilities with accepting regional features/constraints

(1) Specification Profile Tables

The purpose of table:

to understand specification of function, specification of physical dimensions.
to understand what is fixed, what is not fixed, for item by item.
to facilitate ‘Plug compatibility’ concept.

Tables visualize the specifications for;

Cavity
Tuner
Coupler

We had the discussion

at Cavity Kick-off meeting in DESY (Sep. 2007),
at ML-SCRF meeting in DESY (Jan. 2008),
at GDE meeting in Sendai (Mar. 2008),
at ML-SCRF meeting in FNAL (Apr. 2008)
at GDE meeting in Chicago (Nov.2008)

Updated tables are followings;

cavity	specification item	specification	unit and comments	further comments
RF properties	Frequency	1.30	GHz	
	Number of cells	9.00	cells	
	Gradient	31.50	MV/m	operational
		35.00	MV/m	Vertical test
	Q0	0.80	10^10	at 35
		1.00	10^10	at 31.5
	HOM damping		Q	decide later
			R/Q	decide later
	Short range wake			decide later
	Operating temperature	2.00	K	
Physical properties	Length	1247	mm	TESLA-short length
	Aperture		mm	must be compatible with beam dynamics
	Alignment accuray	300.00	um	rms
	Material	Niobium		
	Wall thickness	2.80	mm	
	Stiffness			decide later
	Flange/Seal system		Material	decide later
	Maximum overpressure allowed	2	bar	
	Lorentz force detuning over Flat-top at 35 MV/m	1.00	kHz	maximum
	Outer diameter He vessel	230.00	mm(inner diameter)	Mag shield outside, decide later for precise number
		230.00	mm(inner diameter)	KEK Mag shield inside, decide later for precise number
	Magnetic shielding		inside/outside	decide later

* yellow boxes indicate ‘not fixed’

tuner	specification item	specification	unit and comments	further comments
Slow tuner	Tuning range	>600	kHz	
	Hysteresis in Slow tuning	<10	µm	
	Motor requirement	step-motor use, Power-off Holding, magnetic shielding		
	Motor specification	ex) 5 phase, xxA/phase, …	match to driver unit, match to connector pin asignment,…	decide later
	Motor location	insdie 4K? / outside 300K? / inside 300K accessible from outside?	need availability discussion, MTBF	decide later
	Magnetic shielding	<20	mG at Cavity surface, average on equater	
	Heat Load by motor	<50	mW at 2K	
	Physical envelope	do not conflict with GRP, 2-phase line, vessel support, alignment references, Invar rod, flange connection,…		cable connection, Mag shield
	Survive Frequency Change in Lifetime of machine	~20 Mio. steps	could be total number of steps in 20 years,	

* yellow boxes indicate ‘not fixed’

Fast tuner	Tuning range	>1	kHz over flat-top at 2K	
	Lorentz detuning residuals	<50	Hz at 31.5MV/m flat-top	(LD and microphinics? or LD only?) :decide later
	Actuator specification	ex) low voltage piezo 0-1000V, …	match to driver unit, match to connector pin asignment, …	decide later
	Actuator location	insdie 4K?/inside 4K accessible/inside 100K? accesible / inside 300K accessible from outside?		decide later
	Magnetic shielding	<20	mG at Cavity surface average	
	Heat Load in operation	<50	mW	
	Physical envelope	do not conflict with GRP, 2-phase line, vessel support, alignment references, Invar rod, flange connection,…		
	Survive Frequency Change in Lifetime of machine	$>10^{10}$	number of pulses over 20 years, ($2x10^9$:operational number)	

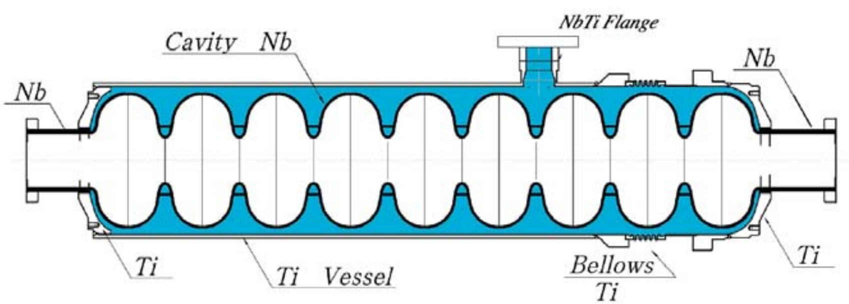
* yellow boxes indicate ‘not fixed’

Coupler	condition	specification	unit and comments	further comments
Power requirements	Operation	>400	kW for 1600 us	
	Processing	>1200	kW upto 400 us	need after vac break, cool-down
		>600	kW larger than 400 us	need after vac break, cool-down
	Processing with reflection mode	>600	kW for 1600us	in Test stand
Processing time	warm	<50	hours	after installation, definition of power/pulse_width target are the same as 'Power Requirement' above.
	cold	<30	hours	after installation, definition of power/pulse_width target are the same as 'Power Requirement' above.
Heat loads /coupler	2K static	< 0.063	W	
	5K static	< 0.171	W	depend on tunability
	40 K static	< 1.79	W	
	2K dynamic	< 0.018	W	
	5K dynamic	< 0.152	W	
	40K dynamic	< 6.93	W	
Cavity vacuum integrety	# of windows	2		
	bias capablity	yes		
RF Properties	Qext	Yes/No	tunable	decide later
	Tuning range	1-10	10^6 if tunable	
Physical envelope	Position		compatible to TTF-III	decide later
	Flange		compatible to TTF-III	decide later (to cavity, to cryostat)
	waveguide		compatible to TTF-III	decide later
	support		compatible to TTF-III	decide later
Instrumentation	vacuum level	>= 1		
	spark detection	0	at window	
	electron current detection	>= 1	at coax	
	temperature	>= 1	at window	

* yellow boxes indicate ‘not fixed’

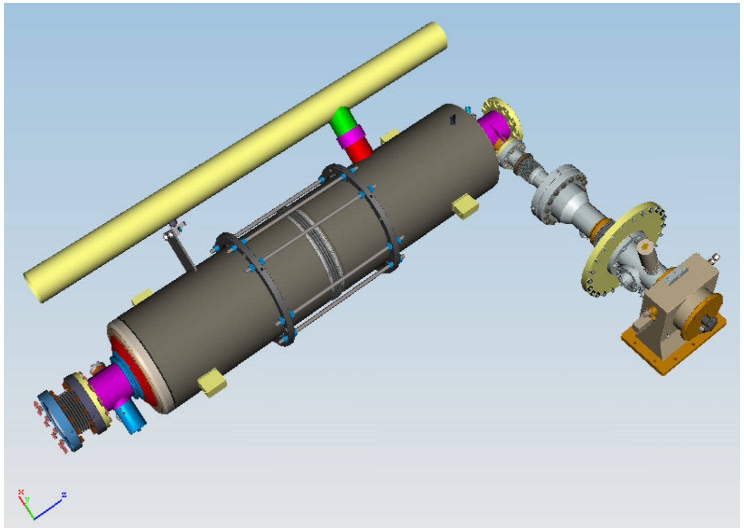
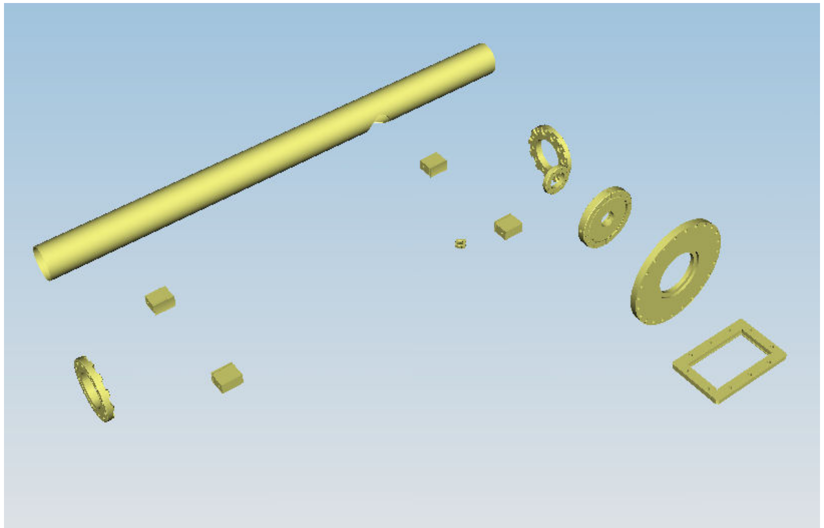
(2) Definitions of boundary for plug-compatibility

Plug compatible conditions at Cavity package (in progress)



Item	Can be flexible	Plug-compatible
Cavity shape	TESLA /LL /RE	
Length		Required
Beam pipe dia		Reuuired
Flange		Required
Tuner	TBD	
Coupler flange		Required
He –in-line joint		Required
Input coupler	TBD	TBD

Cavity package boundary details

(1) cavity port flange (beam pipe)
(2) 4 support tubs
(3) He supply pipes
(4) input coupler port flange
(5) cryostat vessel flange for input coupler
(6) waveguide flange for power input

The points of boundary discussion

(A) Baseline Design and specifications are exist, but not for all.
discussion continue for tuner design and other item which is not yet fixed.

(B) keep boundary conditions for other designs (not BCD),
or
prepare interface pieces to keep boundary conditions in the next.

(C) cavity and input coupler can be thought as a cavity package,
as plug-compatible component, however the boundary must
be satisfied.

(D) ….

Summary of 'Cavity Integration Work package'

(A) Work Package progress

1. Blade tuner study is well in advance. 8 units will be installed FNAL CM2, 2 for S1G.
2. Slide-jack tuner was demonstrated of small LD. Further study is underway.
   Two install location will be evaluated in S1G.
3. TTF3 coupler is going into the mass production. Cost studies were done.
4. STF fixed couplers were evaluated in cryomodule,
   and is going to install variable coupling capability.
5. TTF-V couplers are in power test at LAL and KEK.
6. Magnetic shield evaluations are in progress.

*system integrations into cryomodule: FNAL and KEK has integration experience.
*cryomodule performance tests are done in DESY, KEK.
(This is not yet mentioned in this talk.)

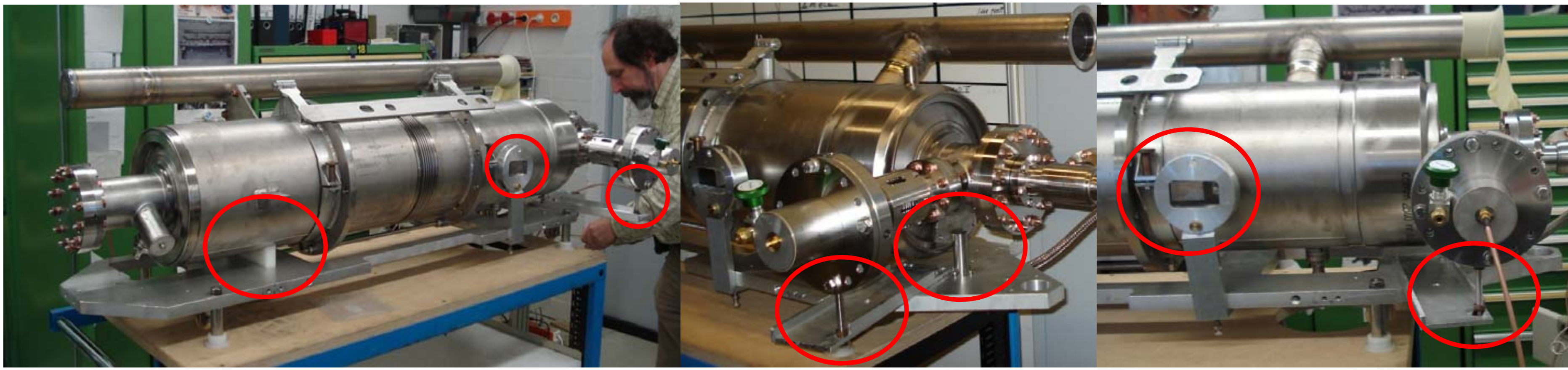
(B) Plug-compatibility concept development

Specifications profile for plug-compatibility are on a way (still several are not fixed).
Definitions of boundary for plug-compatibility are almost done
(still some discussion left).

end

spare slides

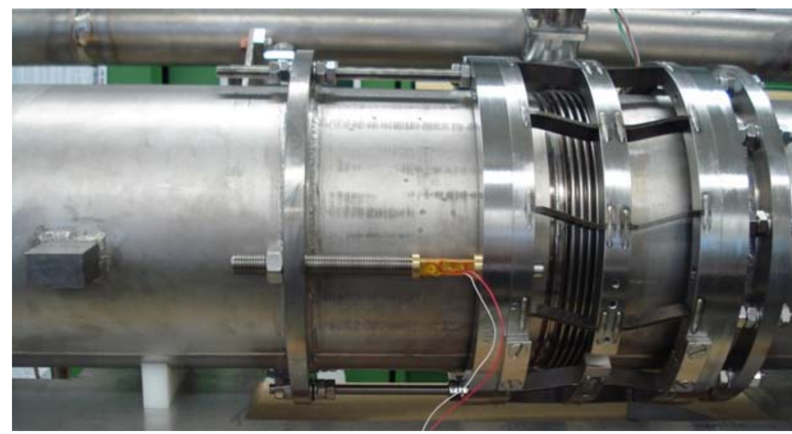
Test setup at CHECHIA - DESY



The cavity package is installed on a table

- 2 pads fixed by supporting clamps
- helium tank sliding on a Teflon support,
- beam pipe and coupler supported

The table hosting the cavity and its ancillaries is then moved into the CHECHIA cryostat

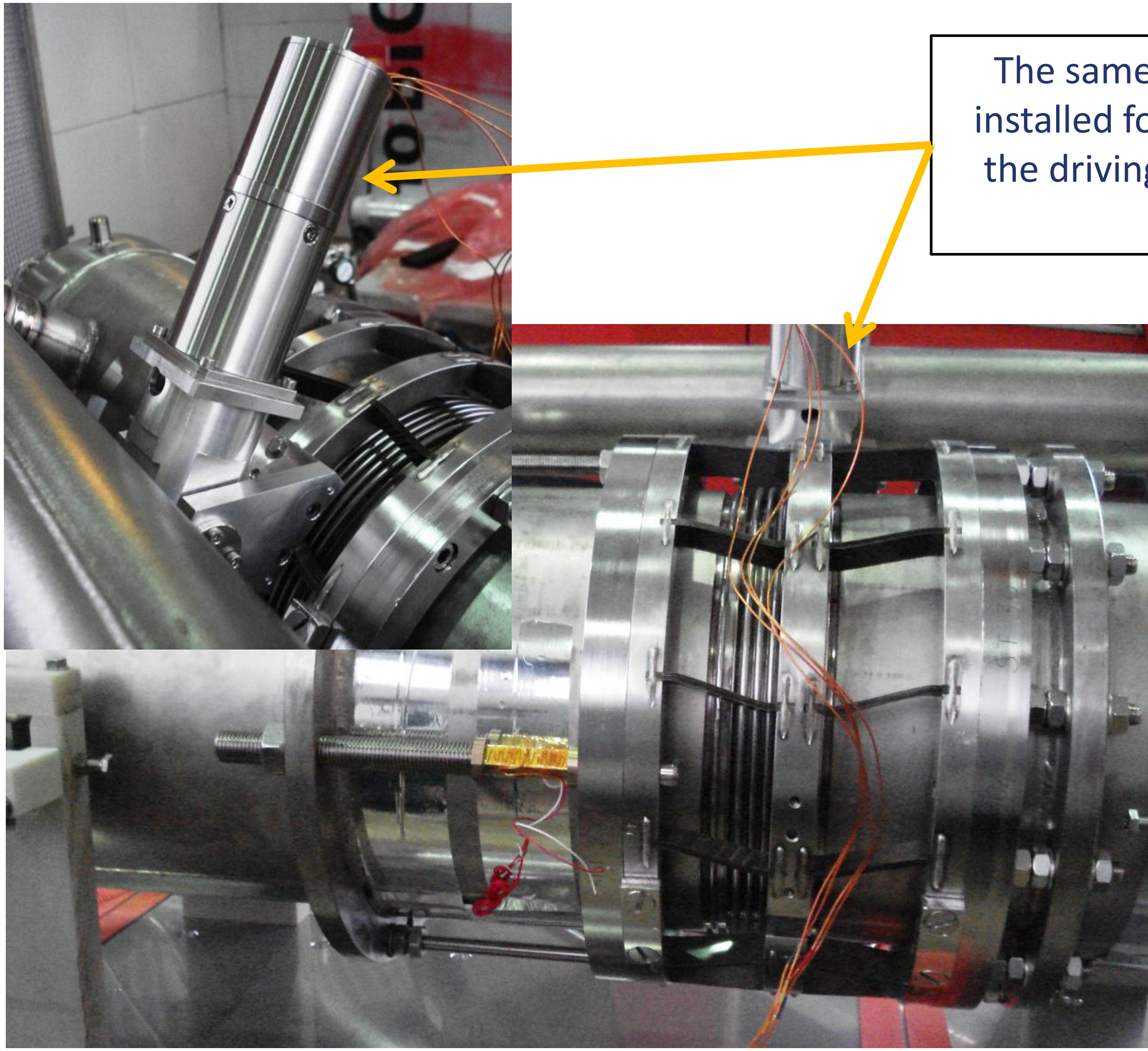


- Blade Tuner cold tests on September 2007
  - Stainless steel + Inconel Blade Tuner
  - 40 mm Noliac piezo (10 x10 mm^2)
  - Sanyo-Denki stepper motor, 200 steps/turn
  - HD drive unit, 1:88 reduction ratio
  - therefore 17600 steps each spindle turn (CuBe spindle screw, 1.5 mm/turn)

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 + Harmonic Drive gear**
2 Noliac 40 mm standard piezoelectric actuator installed

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

Considerations about friction

Superstructure Test setup

Ti pad on rolling needles (Cry 3), 40 kg preload force, T = 77 K:

- Static friction coefficient : **0.0043**
- Dynamic friction coefficient : **0.0022**

D. Barni, M. Castelnuovo, M. Fusetti, C. Pagani and G. Varisco
FRICTION MEASUREMENTS FOR SC CAVITY SLIDING FIXTURES IN LONG CRYOSTATS
Advances in Cryogenic Engineering, **Vol. 45A**, Plenum Publishers, 2000, 905-911

CHECHIA setup

PTFE Teflon on Titanium

- Static friction coefficient : **0.17** (40 times larger than Type 3)

Friction Data Guide (Linden, NJ: General Magnaplate Corp., 1988

HoBiCat setup

PTFE Teflon on Steel

- Static friction coefficient : **0.04** (9 times larger than Type 3)

Friction Data Guide (Linden, NJ: General Magnaplate Corp., 1988

Blade Tuner tests at CHECHIA

The piezo assisted blade tuner performed as expected

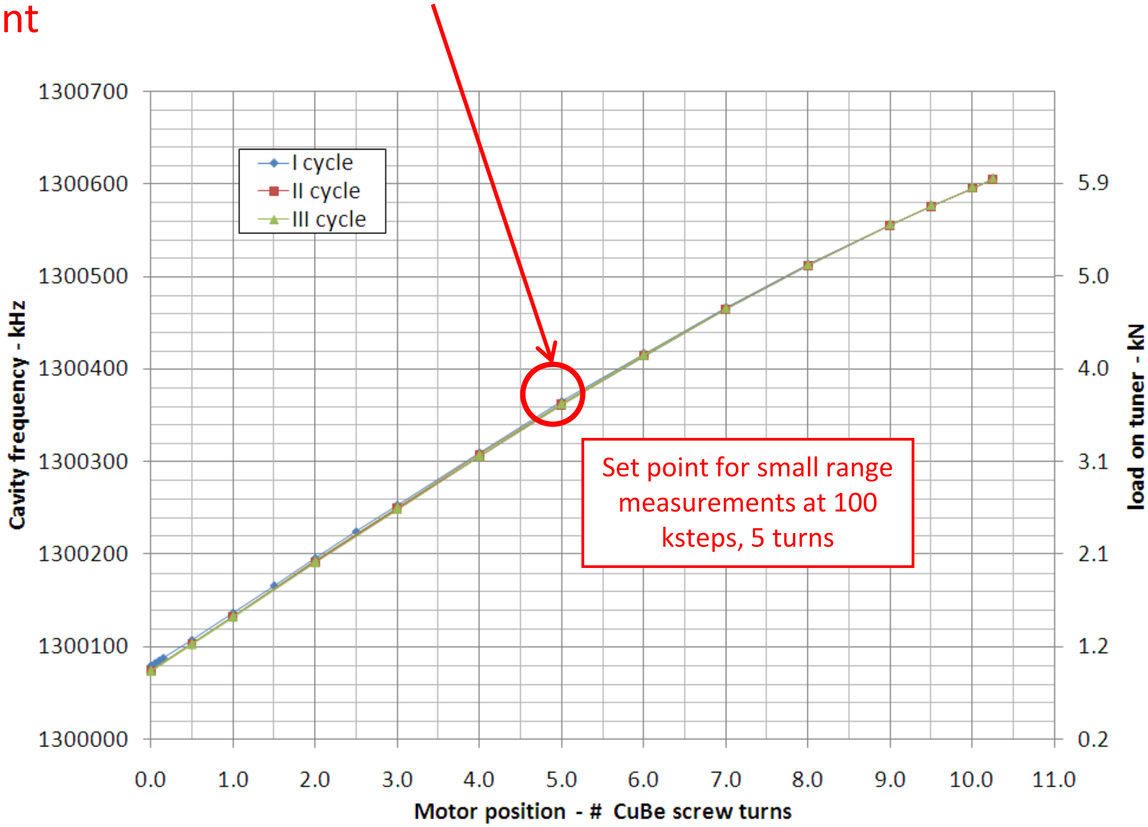
Simulations are confirmed by experimental data

	Only one piezo acting
Nominal RT stroke at 200 V (max voltage)	60 μm
Stroke at 60 V	12 μm
Residual stroke at 25 K	3 μm
Blade Tuner efficiency	40 % +/-10%
Static-to-Dynamic ratio	1.2
Resulting stroke at the cavity	1 μm +/- 10%
Expected resulting dynamic cavity frequency variation	280 - 350 Hz
Measured resulting dynamic cavity frequency variation	300 Hz

HoBiCaT tests – small tuning range

Data about frequency tuning on a μm-scale come from:

- Piezo actuators static tuning range measurements. Piezo are driven with DC voltage
- Drive unit small range measurements. Stepper motor is driven in a small range around a working point



Blade Tuner piezo tests at HoBiCaT

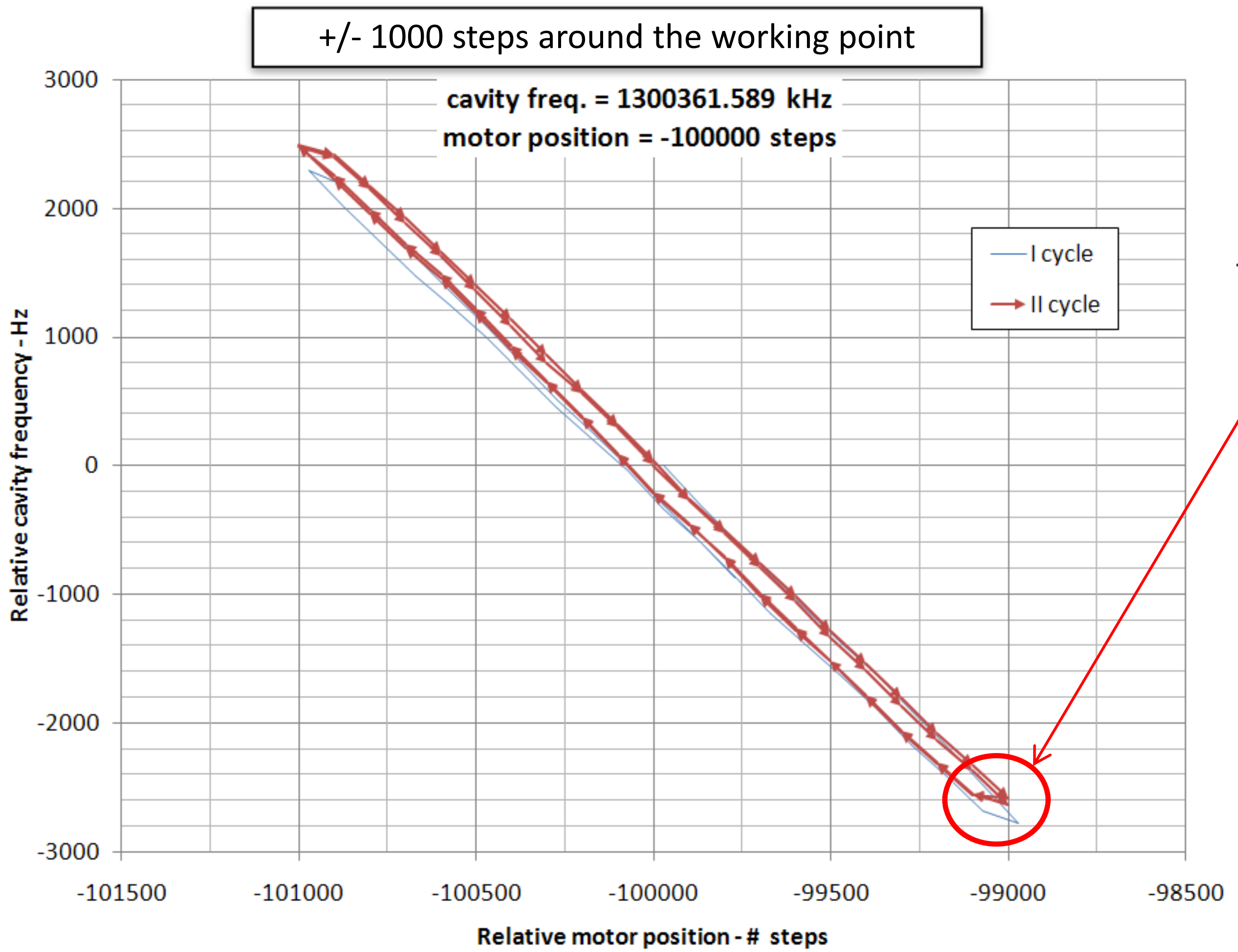
The HoBiCaT piezo tests confirm that the entire stroke expected to be transmitted to the cavity by piezo actuators is achieved:

Consider for example the test with both piezo operated in parallel up to 200 V (table):

	Both piezo acting
Nominal RT stroke at 200 V (max voltage)	60 μm
Residual stroke at working T (25%)	15 μm
Blade Tuner efficiency	83 %
Resulting stroke at the cavity	**13 μm**
Expected resulting static cavity frequency variation	4.1 – 5.2 kHz
Measured static cavity frequency variation	**5 kHz**

HoBiCaT motor 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**

Design analysis - conclusions

Tuner under construction (3.9.4)	Tuner characteristics	Required value	Margin factor
Tuning range - nominal (no hysteresis)	0 – 500 kHz		
Tuning range – max. (some hysteresis[1])	0 – 600 kHz		
Max compression strength[2]	7800 + 3100 N	7800 + 1.1 * 2840 N	1.0
Max traction strength	16000 N	13771 N	1.16
Compression stiffness	15 – 100 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	5.2
	25 Nm - devoted 1:200 gear -		10.4

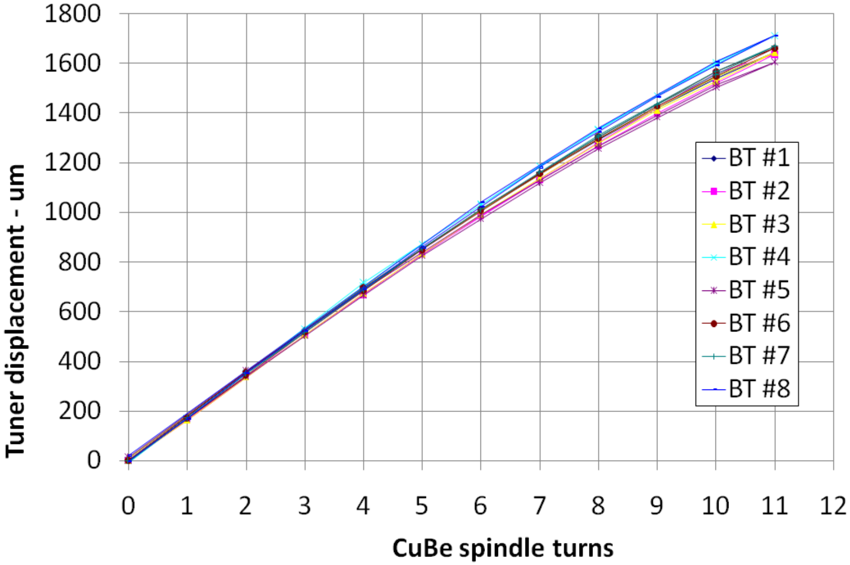
1 With some plastic deformations at worm, limited to the blade packs near the motor

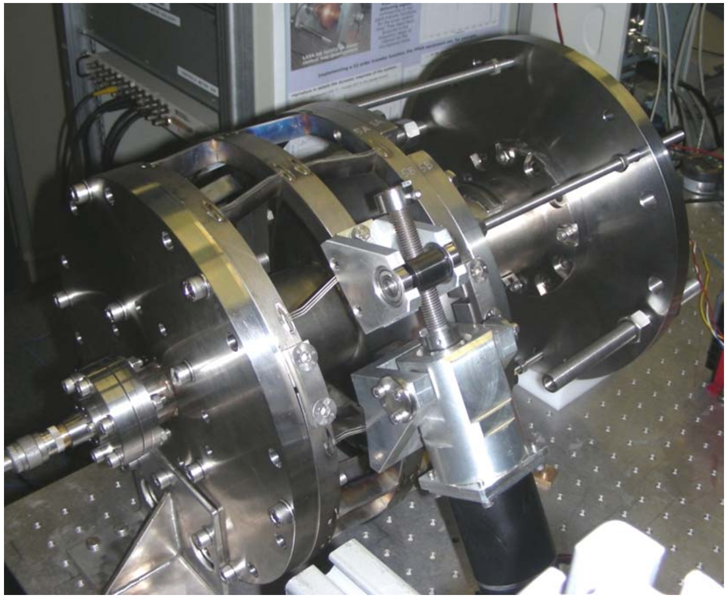
2 This is composed of the fixed part due to the cavity deformation and a variable part due to external pressure

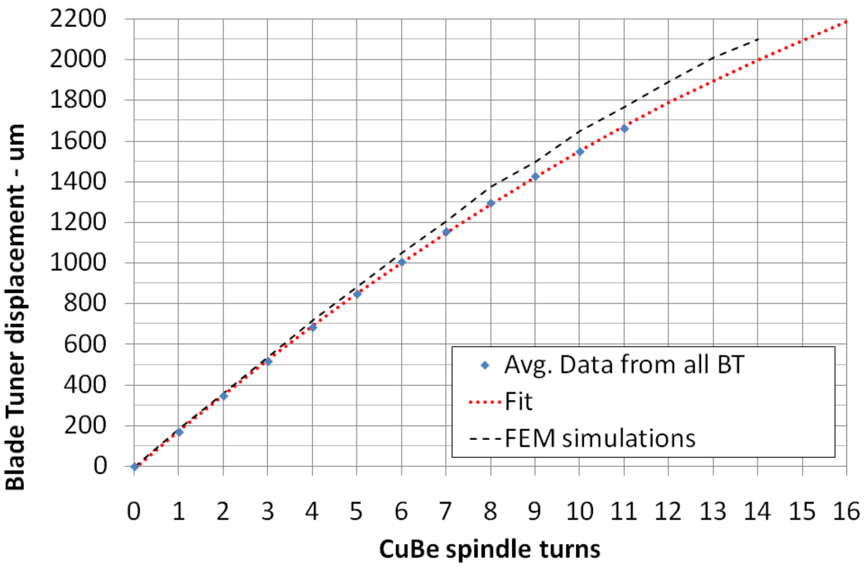
Room Temperature Qualification

The first 8 units produced have been tested for qualification at room temperature on a devoted single cell test facility

Results meet expectations in terms of **homogeneity** and **predictions** (tolerable 5 % full-scale discrepancy)





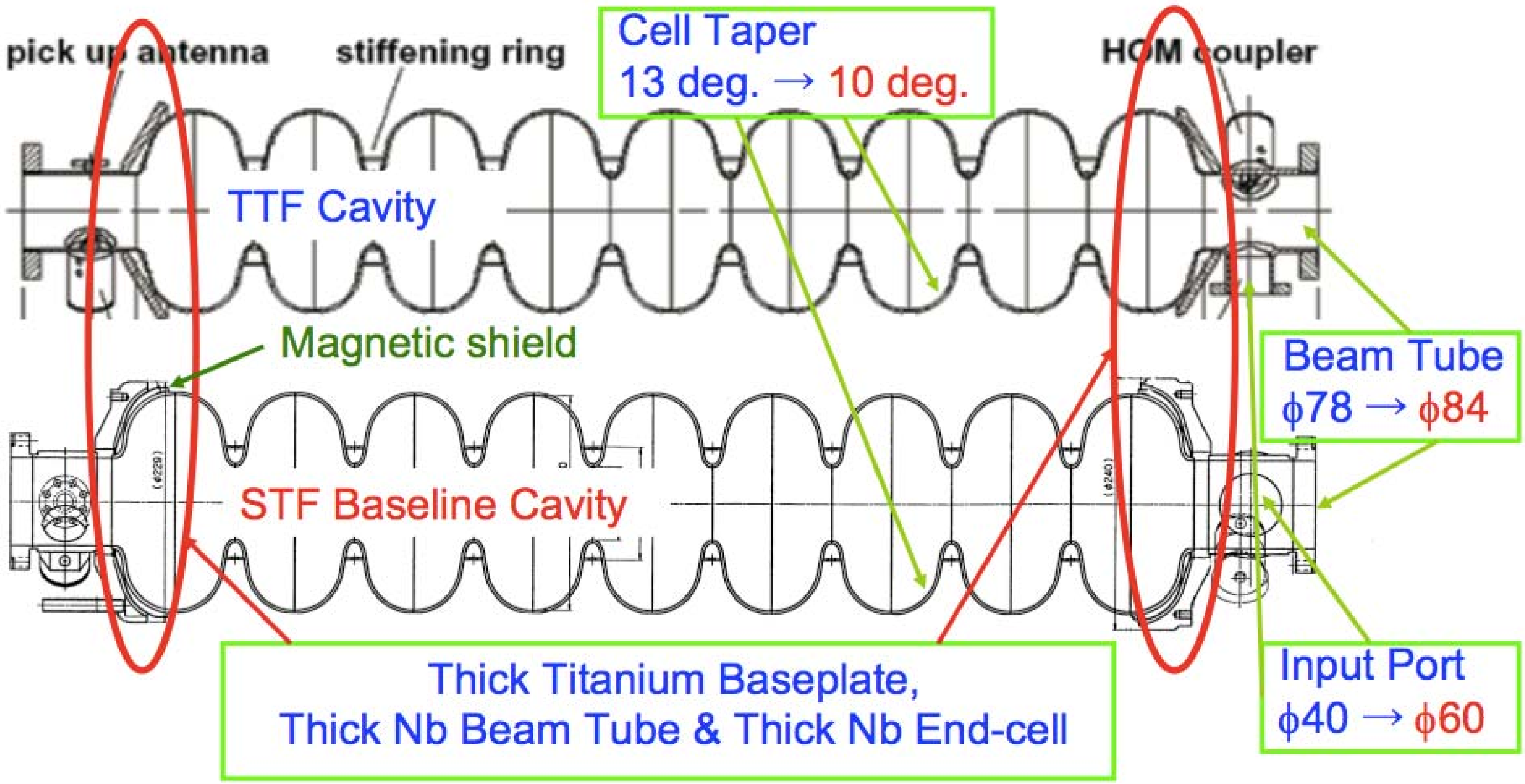


Revised Blade Tuner - conclusions

- Production and room temperature qualification of first 8 units of revised Blade Tuner satisfactorily completed.
  - 2 complete tuner system now shipping to Fermilab. INFN group will now join FNAL team for installation and cold test of first units in horizontal cryostat.
  - Shipment of remaining 6 assemblies will shortly follow in view of the CM2 commissioning.
  - 4 additional Blade Tuner units have already been required by Fermilab. Production expected by this year.

- The revised Blade Tuner will be also involved in the existing collaboration with BESSY
  - Several research topics related CW and small BW application of SC cavities (ERL etc.): microphonics active compensation, ultra-small fast tuning range improvement (nm level)
  - Further horizontal cold tests planned from March 2009.

STF Baseline Cavity ; Improved Stiffness



	STF Baseline Cavity	TTF Cavity	
Stiffness of Cavity Sys.	72 kN/mm	22 kN/mm	
Lorentz Detuning at flat-top	Δf = - 150 Hz	Δf = - 500 Hz	Estimation at 31.5 MV/m

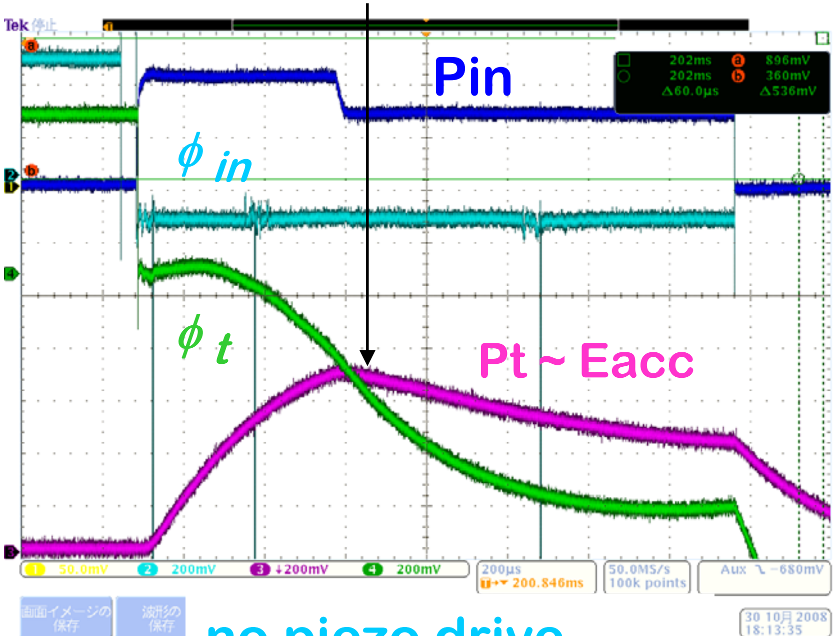
STF Cryomodule Tests (2)

Best Result ; obtained Eacc,max in #2 Cavity

1.5 msec, 5 Hz operation

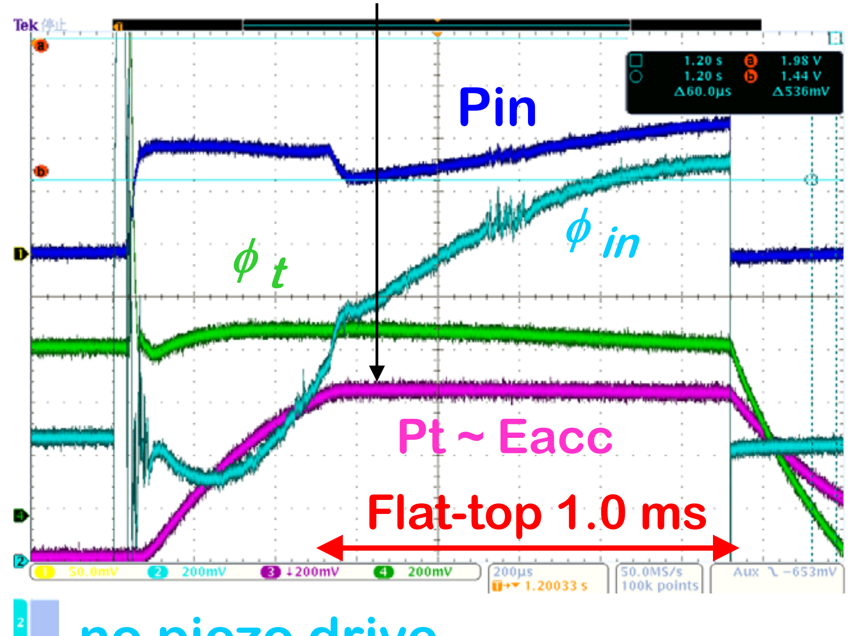
November, 2008'

RF Feedback / OFF
32.7 MV/m



no piezo drive
no pre-detuning

RF Feedback / ON
32.0 MV/m



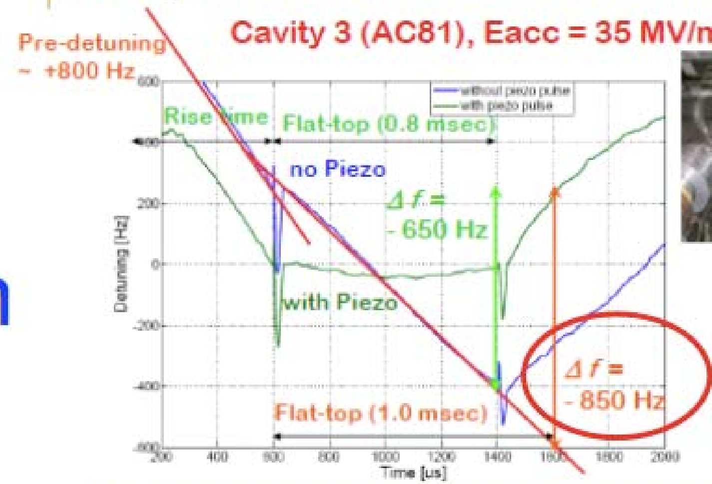
no piezo drive
pre-detuning (Δf = +300 Hz)

Lorentz force detuning in TTF Cavities with a different tuner system

Δf at Eacc = 31.5 MV/m,
Flat-top = 1.0 msec

Saclay Tuner tested in Module 6 (by L. Lilje)

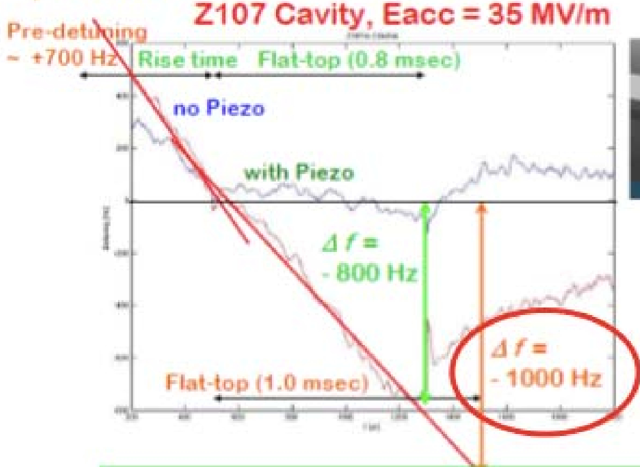
Cavity 3 (AC81), Eacc = 35 MV/m

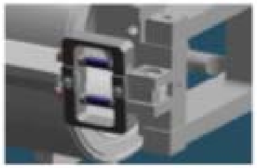


Δf = - 690 Hz (Eacc = 31.5 MV/m, Flat-top = 1.0 msec)

Saclay Tuner tests for XFEL (by L. Lilje)

Z107 Cavity, Eacc = 35 MV/m

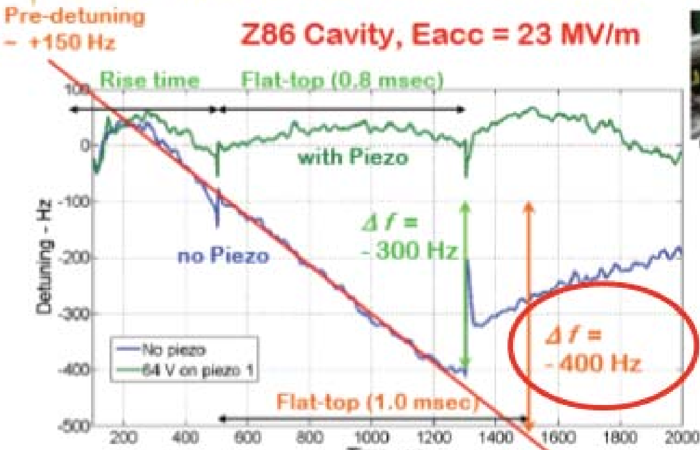




Δf = - 810 Hz (Eacc = 31.5 MV/m, Flat-top = 1.0 msec)

Blade Tuner tested in CHECHIA (by L. Lilje)

Z86 Cavity, Eacc = 23 MV/m



Δf = - 750 Hz (Eacc = 31.5 MV/m, Flat-top = 1.0 msec)

Scenario for couplers production – XFEL

Principles:

- 2 industrial contracts: each for 400 couplers
- Separate production at each industry
- Responsibility of industry includes RF conditioning

Limit of responsibility for industry

Type 1 → Type 1

Type 2 → Type 2

Manufacturing

Assembly

4 pairs/week

Orsay

(LAL)

1 RF Conditioning station

- 1.3 GHz tuning
- RF conditioning
- acceptance tests
- dismount
- pack (double bag)
- ship or store

Saclay

(IRFU)

Cryomodules assembly

- **Cavity string assembly**
- **Cryomodules assembly**

Ship 1/week

DESY

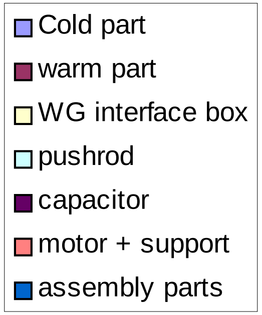
Cryomodule test

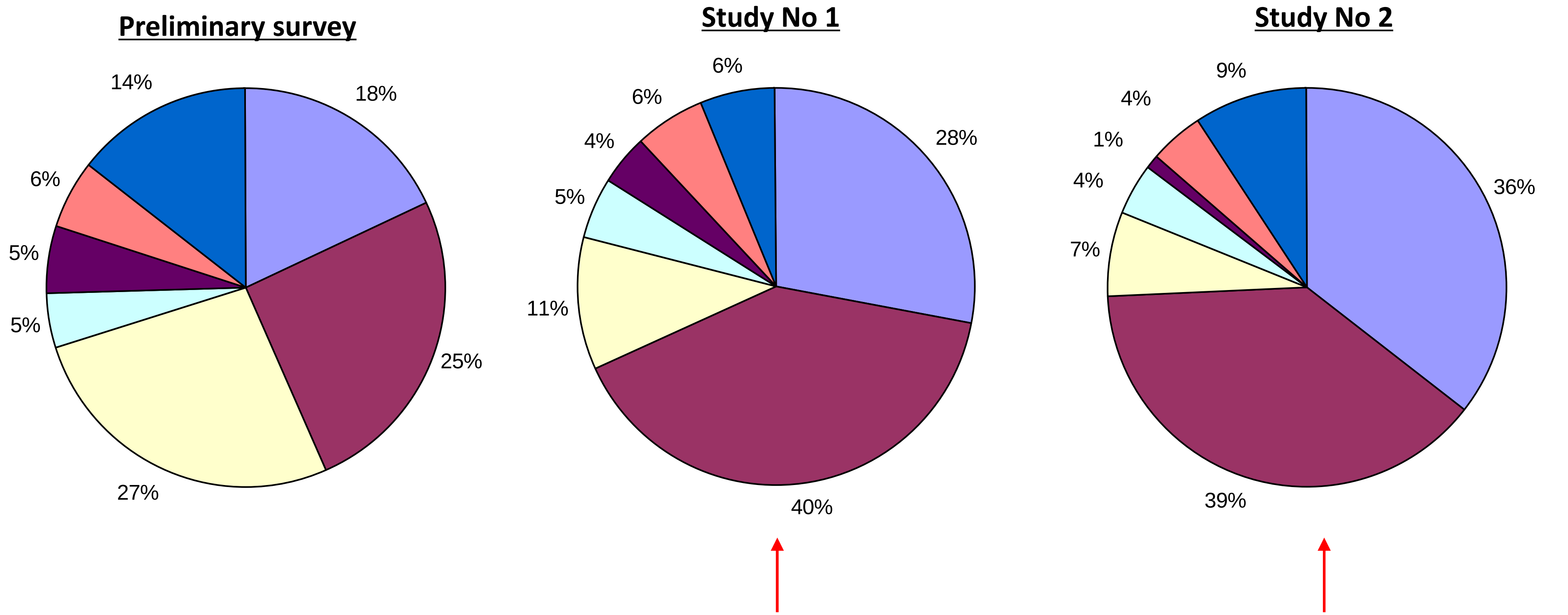
At each industry:

Clean rooms operations:

- wash
- rinse
- dry
- assemble
- vacuum pumping
- He leak test
- bake

Cost breakdown for subassemblies (XFEL)





11% - Savings for fixed Qext - 8%

~ 5 to 6% of total contract price (without electronics, cabling, plugs)

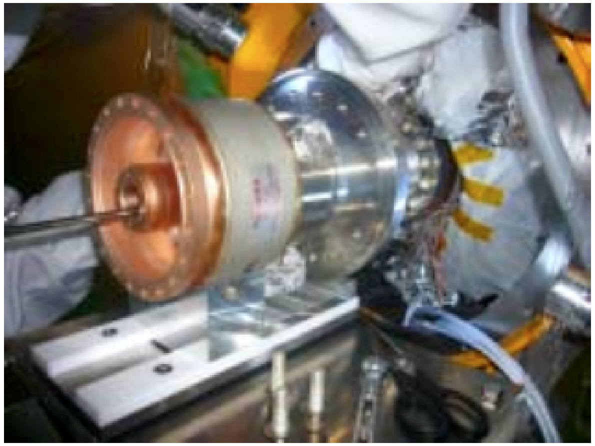
~ 7 to 10% - - - (including electronics, cabling, plugs)

Installation of Warm Couplers and Doorknobs into Cryomodule

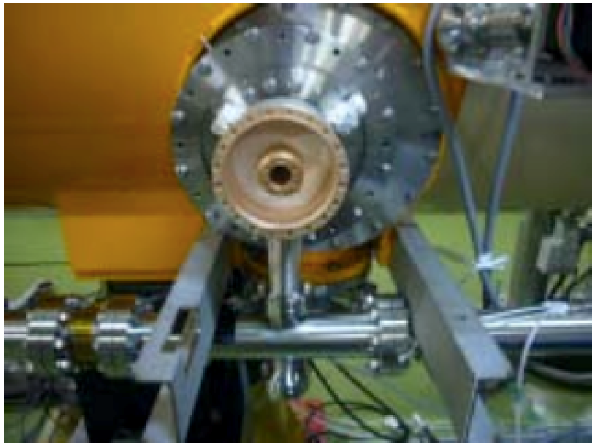
June, 2008

Coaxial - N Transition

Warm Coupler



Connection of Inner Conductor



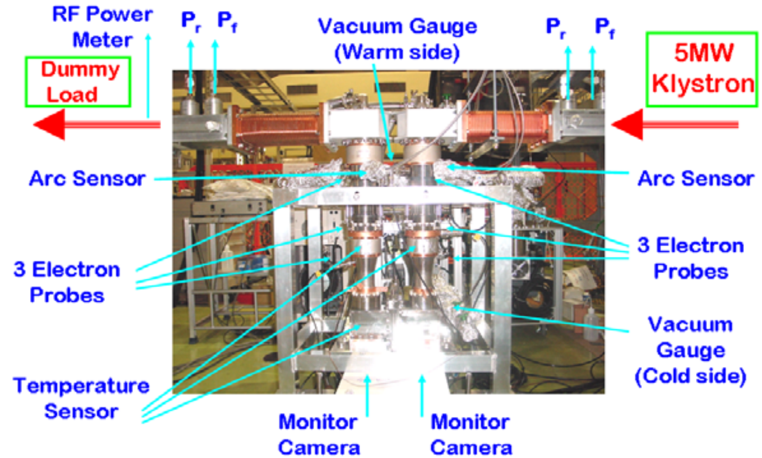
Vacuum Pumping Tube

Clean Booth for Assembly

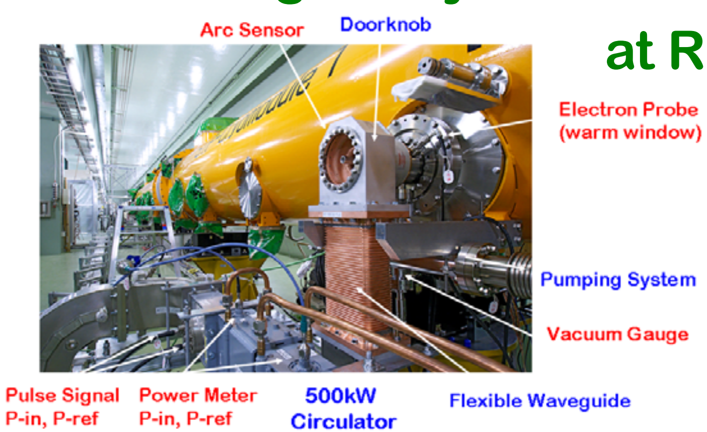
Doorknob-type Transition

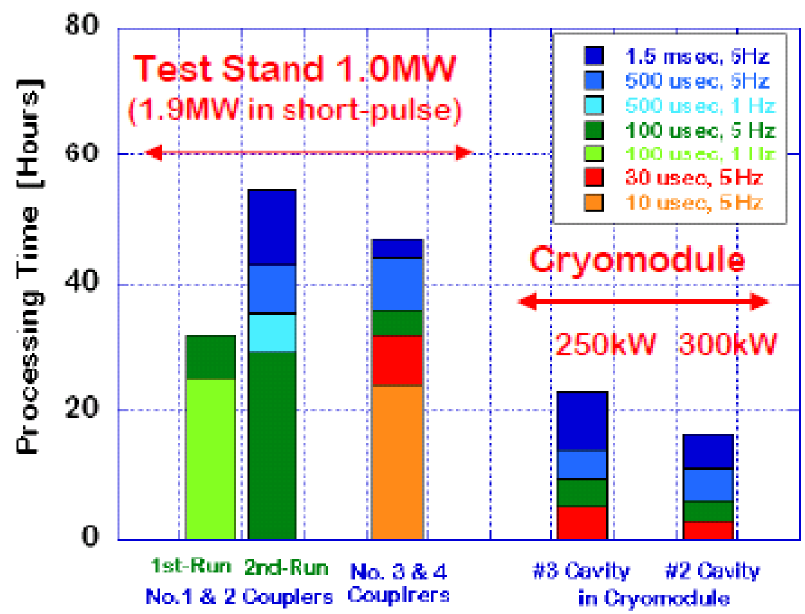
Component Test ; Input Couplers

Processing in Test Stand

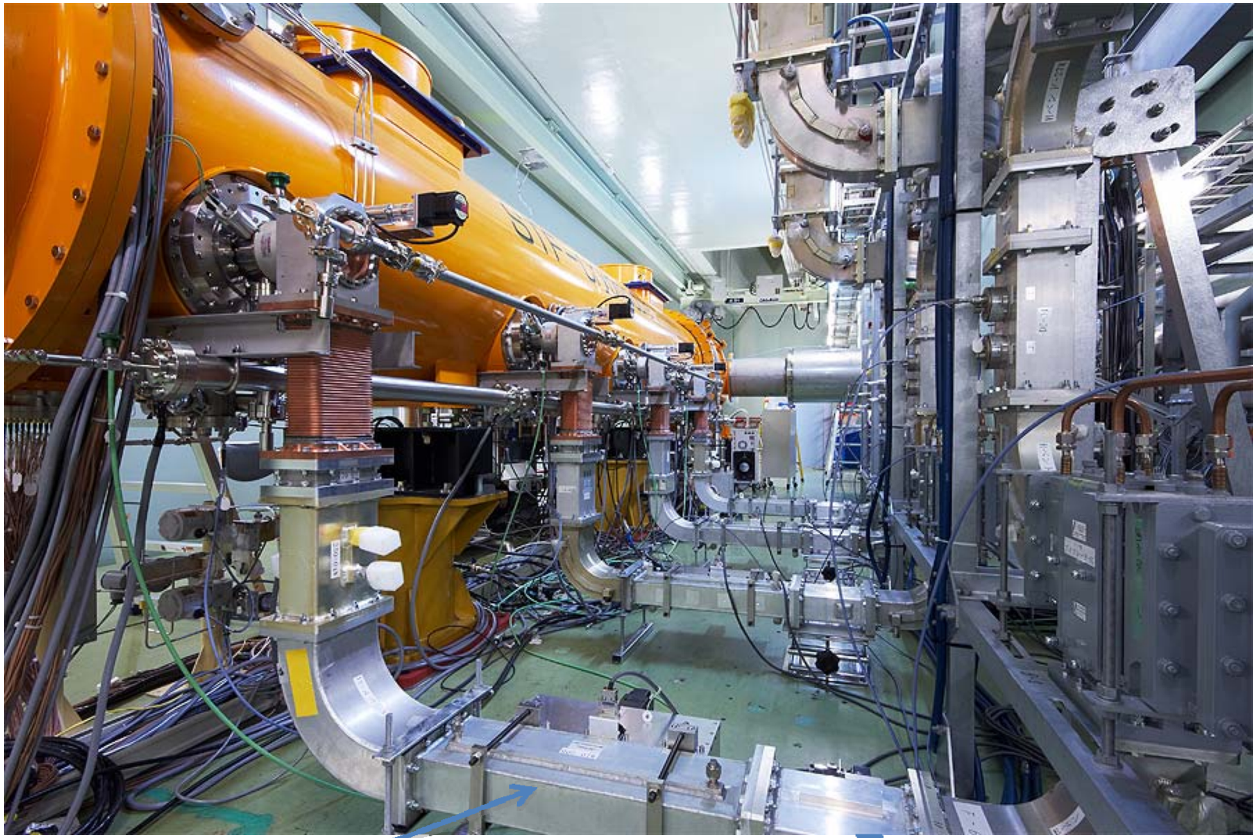


Processing in Cryomodule at R.T.





QL control test by WG phase shifter and reflector



phase shifter

reflector

high power test, 4 cavities combined,
using external phase shifters and variable reflectors.
QL can be set +/- 15%.