Thoughts of Cavity Peripherals R&D in EDR phase

H. Hayano (KEK)

Cavity peripherals to be considered :

- Tuner (mechanical, piezo) <- Lorentz detuning compensation
- Magnetic shield <- acc. Gradient, easy handling
- He jacket with sliding support mechanism <- keep alignment
- Alignment method <- external alignment reference
- Input coupler <- heat load, tuning capability
- Beam pipe flange & vacuum seal <- vacuum-tight
- Feed-through connector <- RF heating, vacuum-tight
- Monitor cables <- heat load
- Thermal anchors <- heat load
- Bolts & nuts <- easy handling, contamination by lubrication

R&D goals in EDR phase

- Establishment of ILC design
  - unified design? -> yes
    - merit of unified design:
      - exchangeability world-wide
    - demerit of unified design:
      - no flexibility
- Cost reduction R&D
  - keep ILC performance.
  - keep maintenability.
- Industrialization
  - cavity peripherals is easy to industrialize.

How to achieve the goals

How to achieve these goals in 3 years (2007,8,9)

1st year: nomination of task team, start discussion

2nd year: discuss & collect required data to compare

3rd year: technology selection, then
make unified design, drawings, fabrication

Who will make selection of each technology

Task force by technical expert + PM

Chair person?

When will it be made?

After one cryomodule test experience in each region.

(DESY:done, FNAL:2007,2008, KEK:spring 2008)

New idea or new technology after selection?

->Same task force.

Status of cavity peripherals technologies

Tuners & He jacket (no BCD),

existing or planning:

TTF : Saclay 1 tuner, Saclay 2 tuner, Blade tuner (Ti jacket)
FNAL : Saclay 1 tuner, Blade tuner for 3.9GHz (Ti jacket)
STF : Slide jack tuner(Ti jacket), Ball screw tuner(SUS jacket)

Couplers (BCD : TTF III),

existing or planning:

TTF : TTF III, (TTF V, TW60)
FNAL : TTF III
STF : two disk windows coupler, capacitive coupling coupler

Others (no BCD),

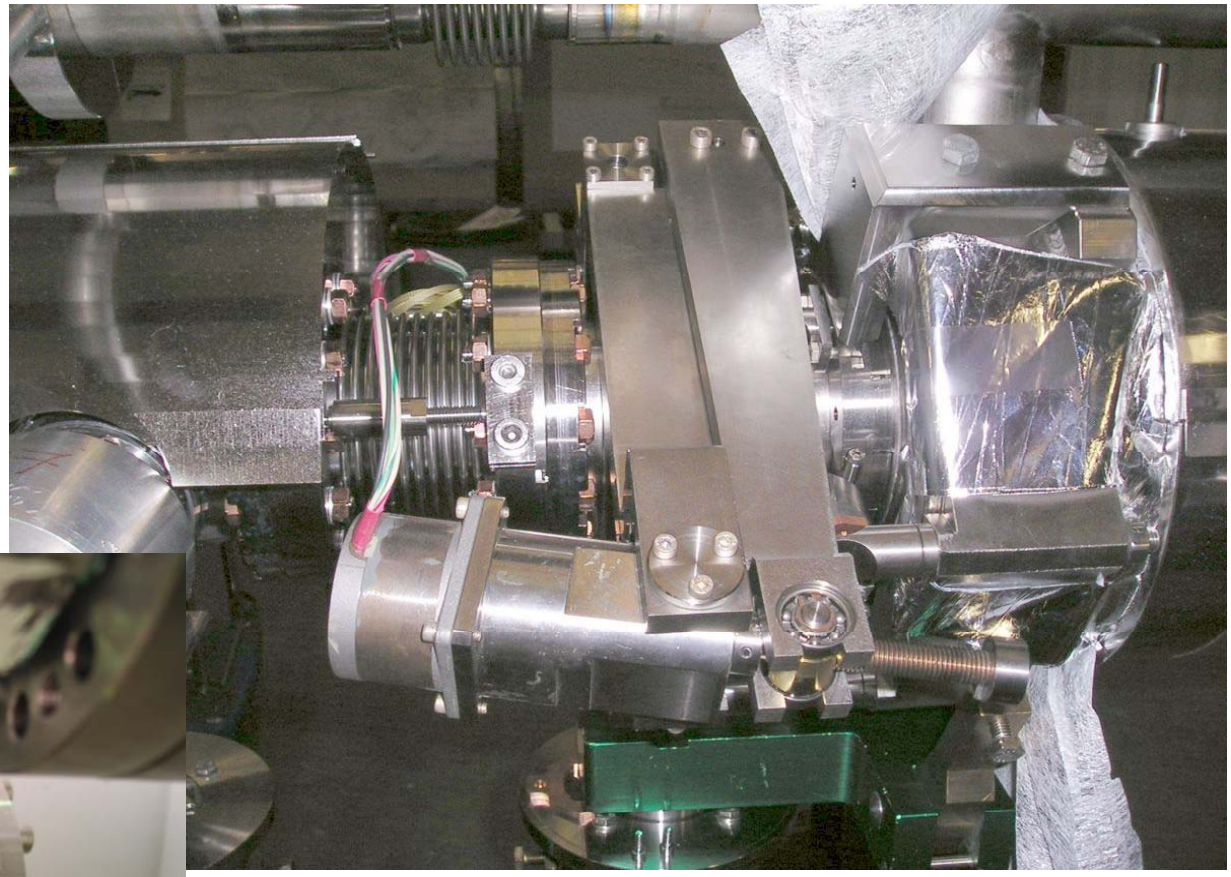
Magnetic shields: shield outside, shield inside of He jacket
Alignment method: reference at beam pipe flange, at jacket end plate
Etc.

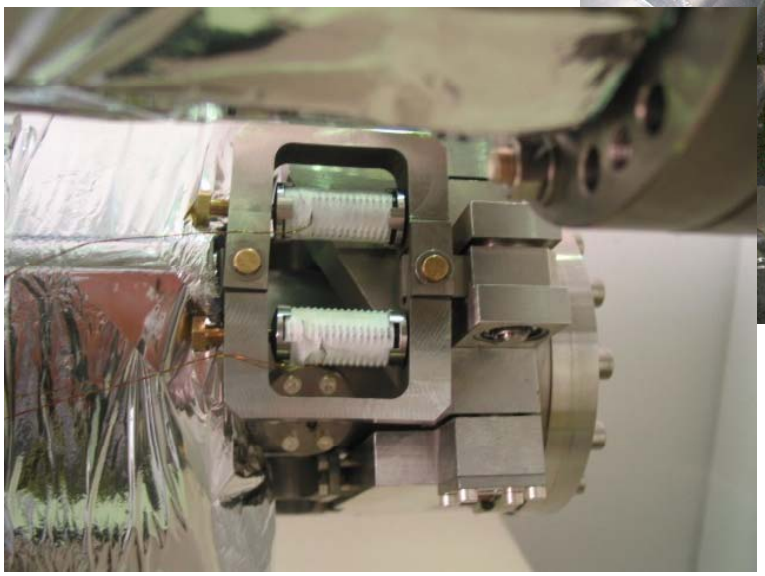
Engineering Points for Tuner & Jacket

The followings need to be compared :

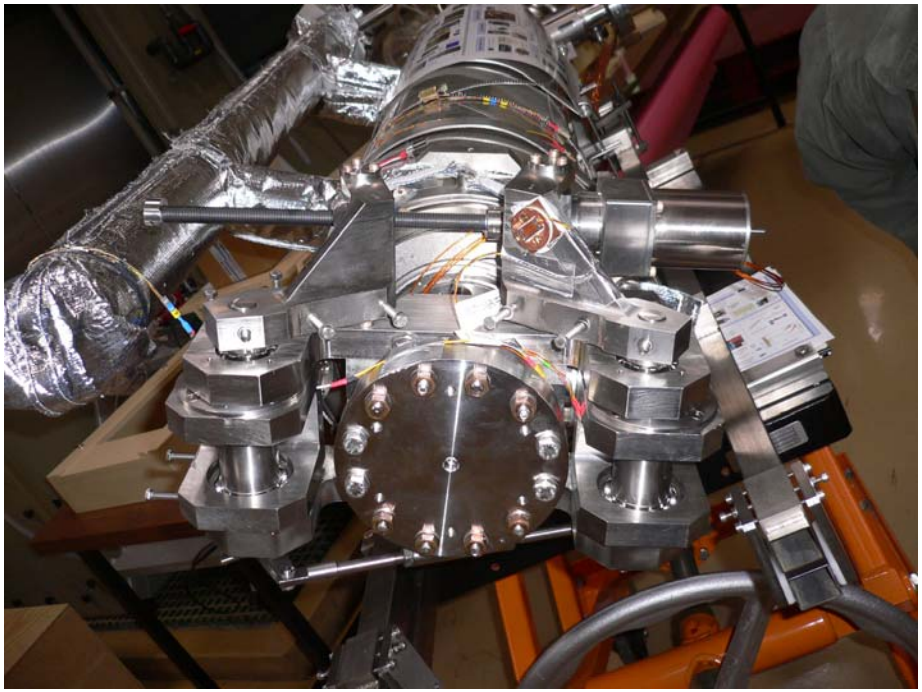
- **Margin of detuning compensation.**
- **Small stroke of piezo actuator.**
- **Piezo exchangeablity (fatigue of piezo actuator).**
- **Motor exchangeability (in case of accident).**
- **Easy installation of tuner.**
- **Easy access to alignment reference.**
- **Easy coverage of magnetic shield.**

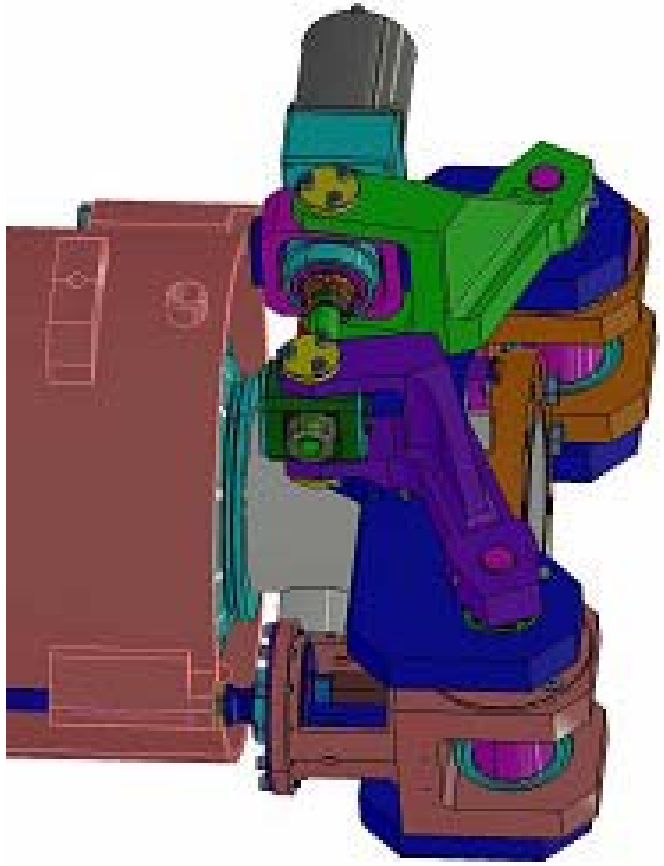
Saclay-1 Tuner (TTF)



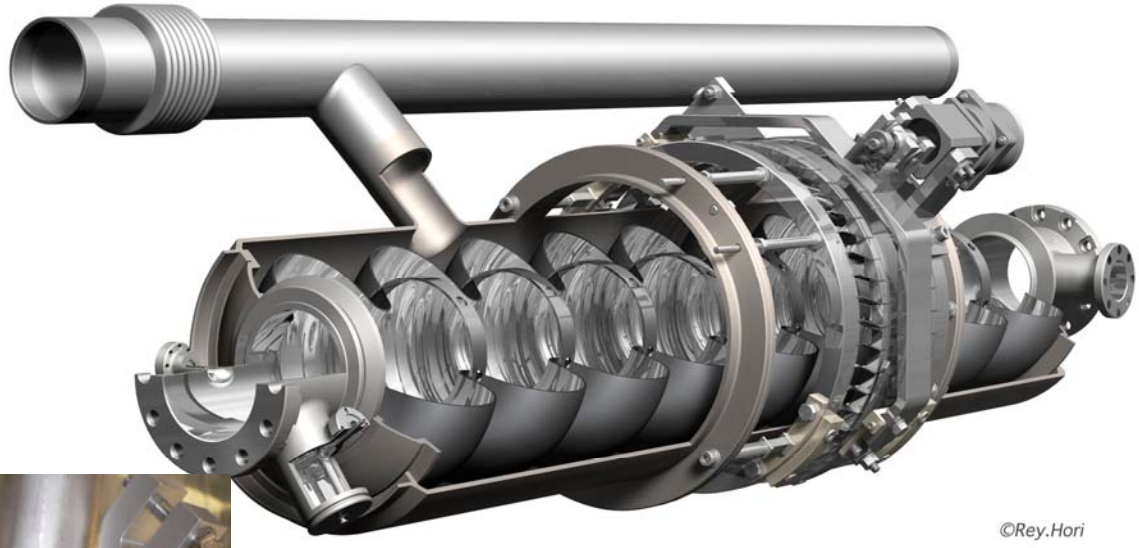


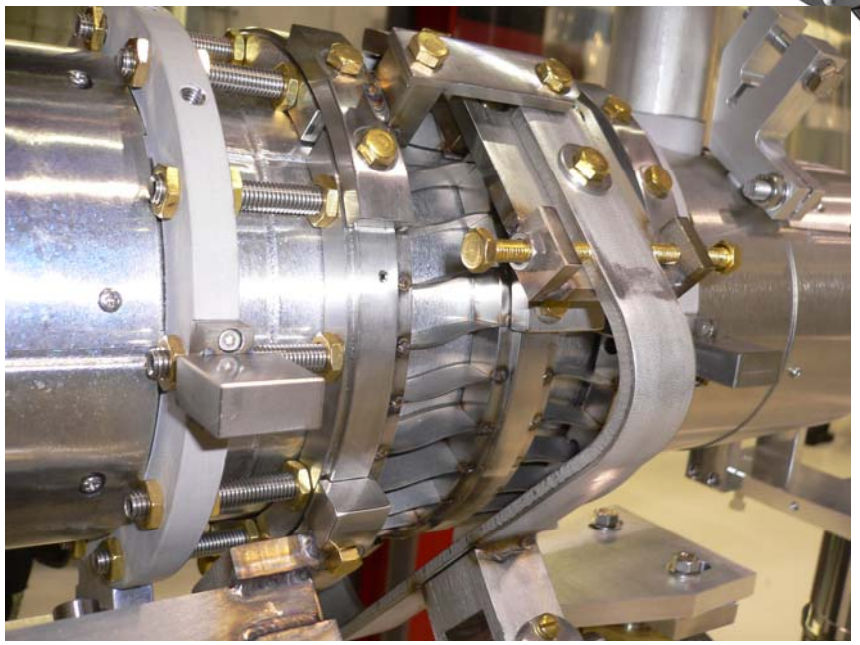
Saclay-2 Tuner



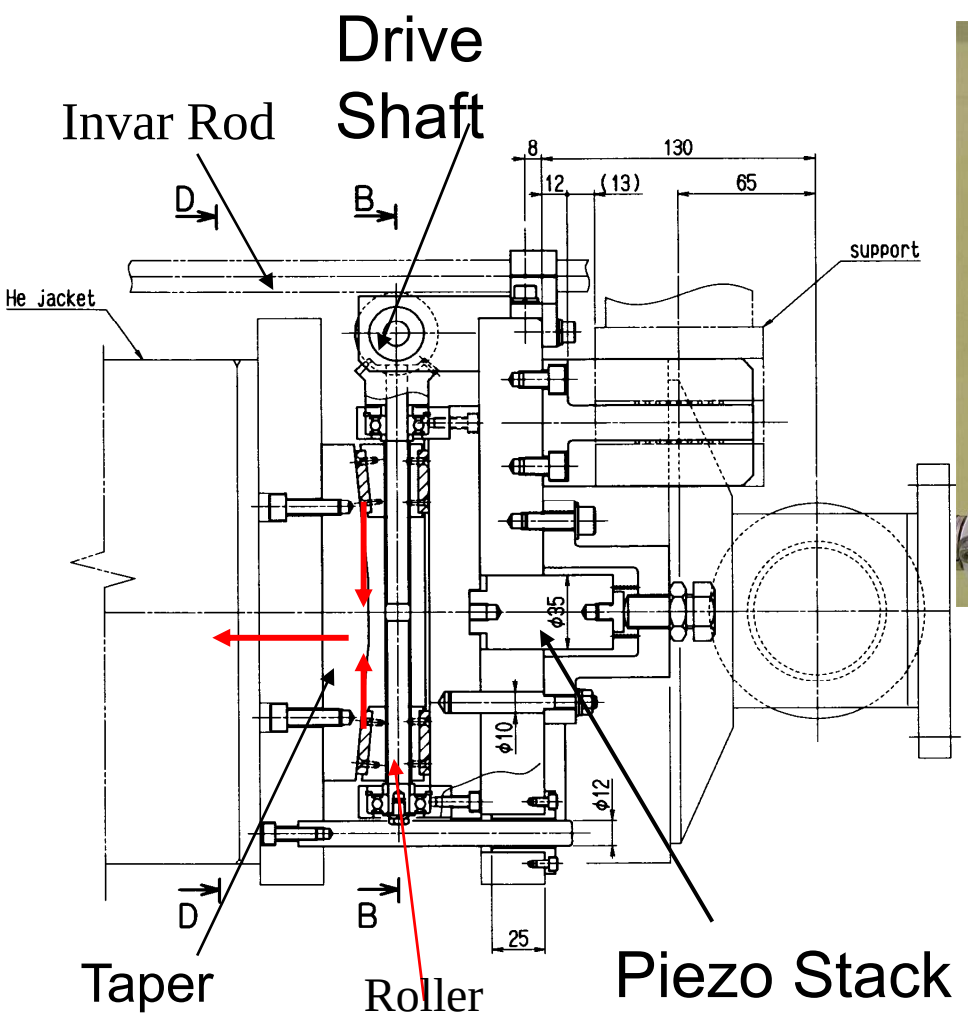


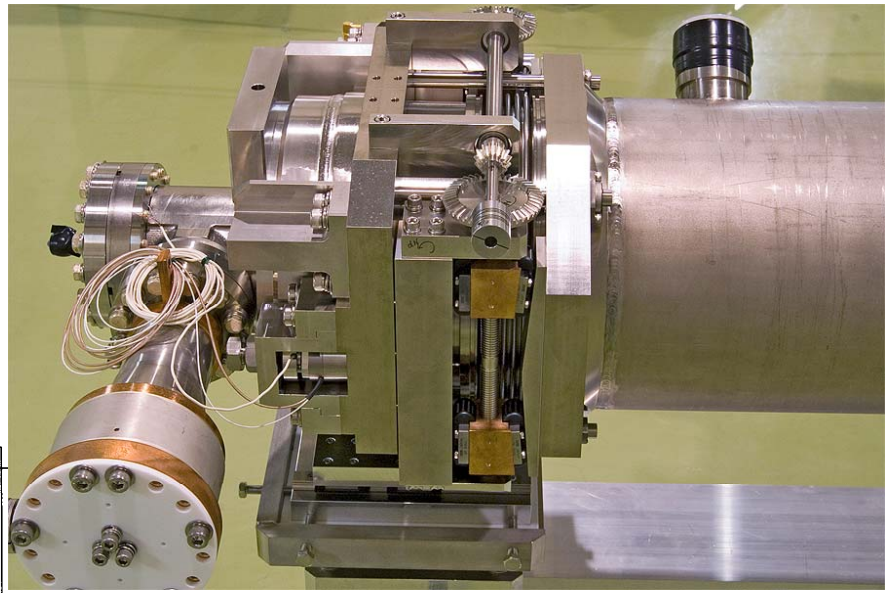
Blade Tuner

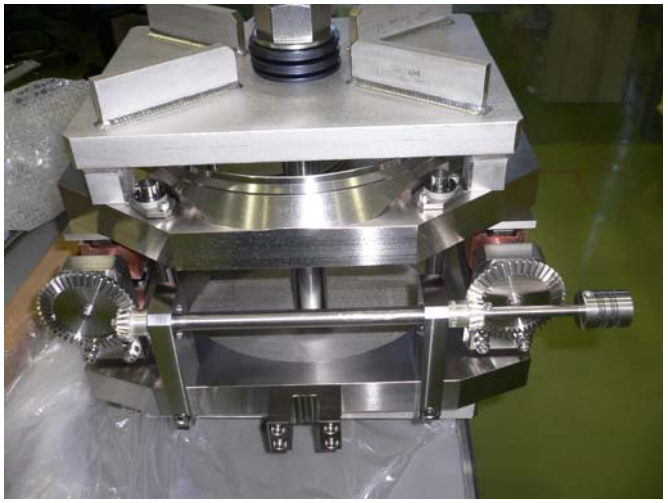




Slide Jack Tuner (STF-BL)







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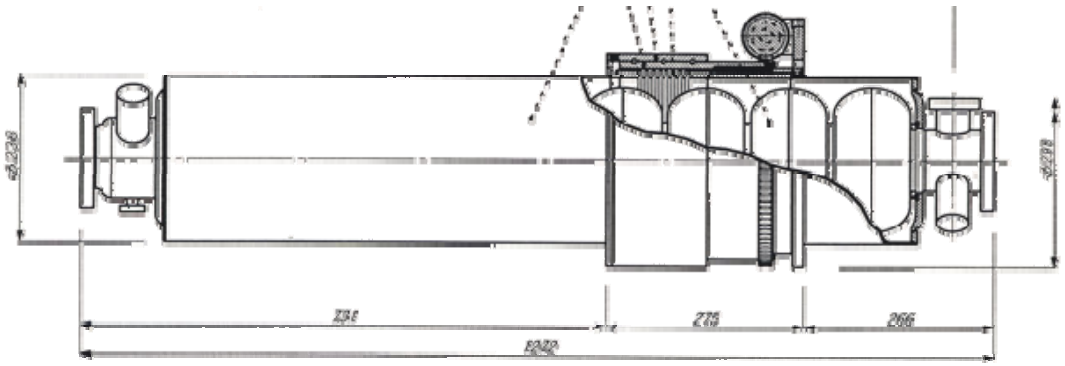
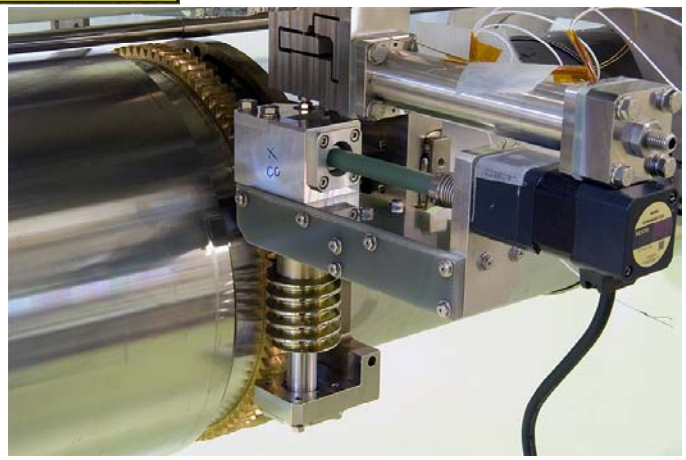
Ball screw tuner (STF-LL)





Dynamic Lorentz Detuning

Results at TTF

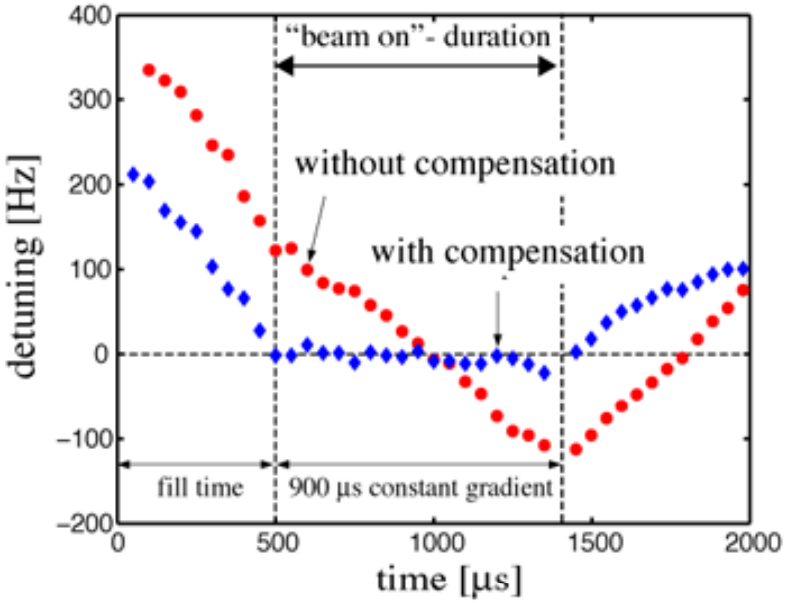


Fig. 5: Demonstration of active Lorentz force compensation with a PZT driven tuner (TTF 9-cell cavity at 23.5 MV/m flat-top gradient).

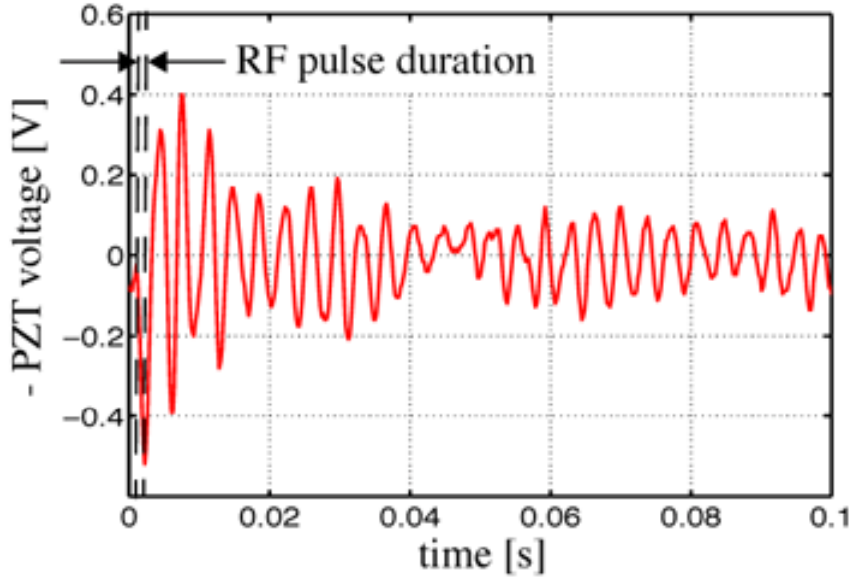
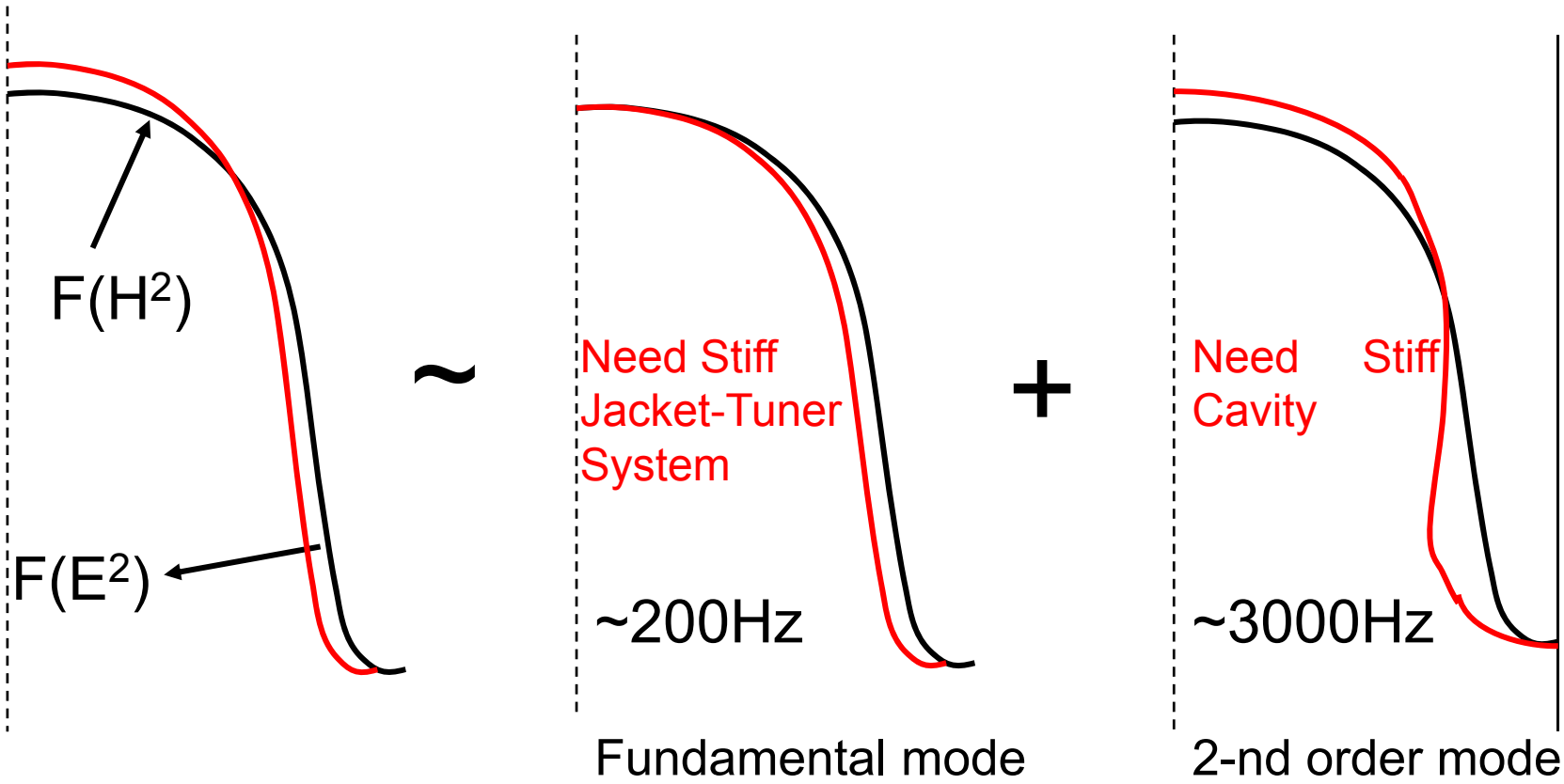


Fig. 3: Lorentz force excitation of mechanical modes during pulsed operation of a TTF 9-cell cavity, measured with the piezo-element (30 MV/m flat-top gradient 10 Hz repetition rate).

ΔPkly < 10 % $\rightarrow$ Detuning angle < 12 deg. , (Δf < 53Hz)

Two Dominant Mechanical Modes
Single –Cell



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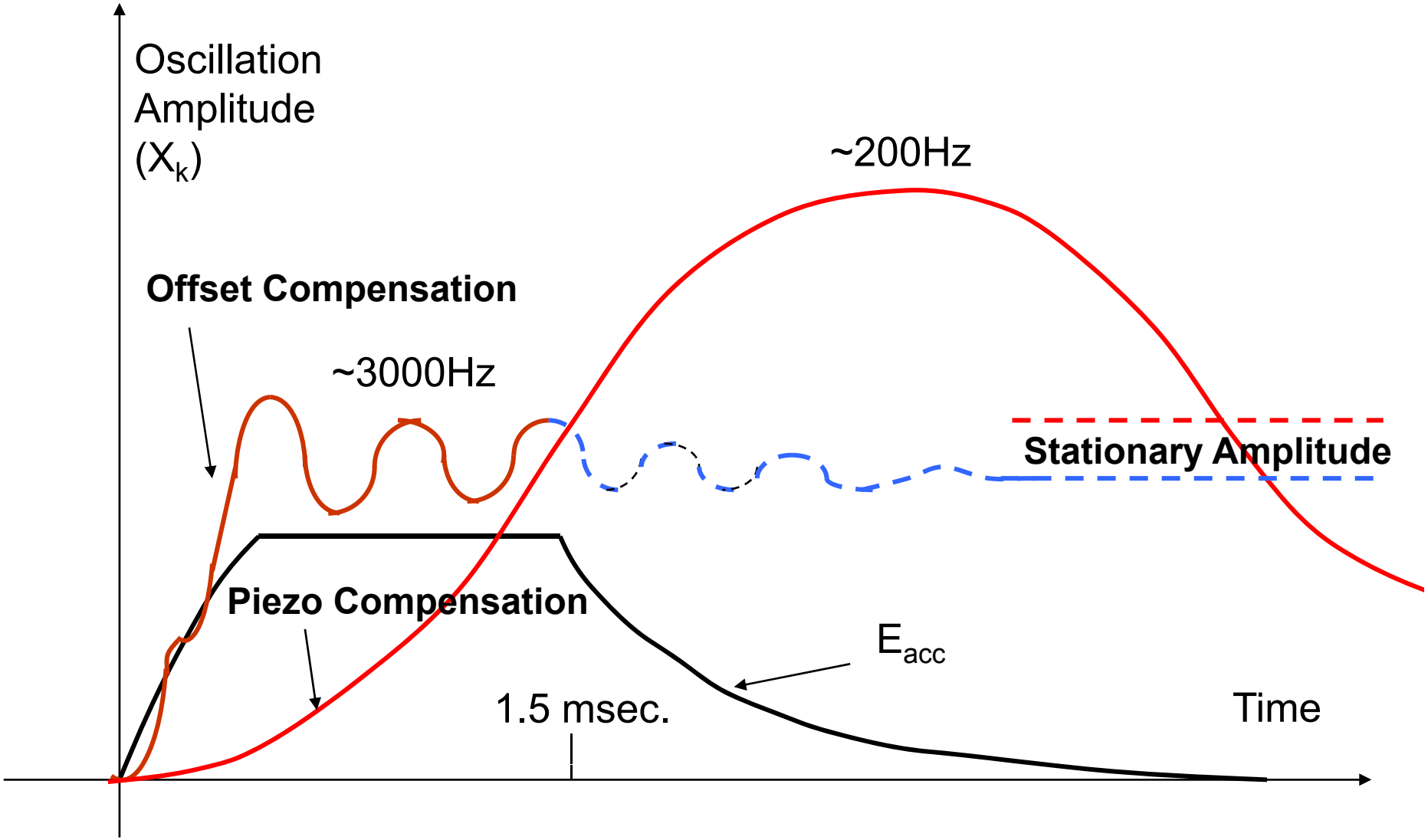
Mechanical Oscillation



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Good Approximation

$$x(s,t) \cong x_{\text{Fundamental modes}} + x_{\text{Second - order modes},0\pi}$$

$$\delta f(t) \cong \frac{df}{dx} x_{\text{Second - order modes},0\pi} \; ; \quad t \leq \text{Filling Time}$$

$$\delta f(t) \cong \delta f_{\text{Second - order modes}} + \frac{df}{dx} x_{\text{Fundamenral modes}} \; ; \quad t \geq \text{Filling Time}$$

$$\cong \delta f_{\text{Second - order modes}} + \frac{df}{dl} \delta l$$

$$\cong A E_{acc}^2 + \frac{df}{dl} \frac{dl}{dF} \left(B E_{acc}^2 \right)$$

$$\cong A E_{acc}^2 + \frac{df}{dl} \frac{B}{K_S} E_{acc}^2 \; ; \quad K_S : \text{Tuning System Stiffness}$$

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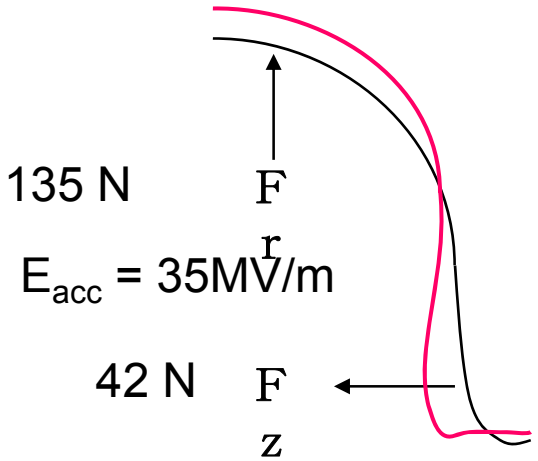
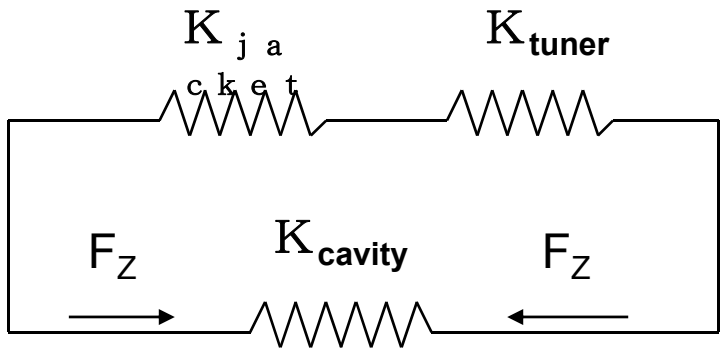
Lorentz Detuning Comparison





		TTF Saclay-I	STF Slide Jack	STF Ball Screw
A	Hz / (MeV/m)^2	0.37(TESLA)	0.37(TESLA)	1.2(LL)
B	N / (MeV/m)^2	0.034	0.034	0.05
df / dl	Hz /μm	320	320	370
K_S	N /μm	22	72	55
K_{jacket}	N /μm	50	95	61
K_{tuner}	N /μm	40	290	500
Stationary Δf (31.5 MV/m)	Hz	870	520	1540
Δf (Compensation)	Hz	500	150	1000
Fine Tuning Stroke	μm	1.5	0.5	2.7

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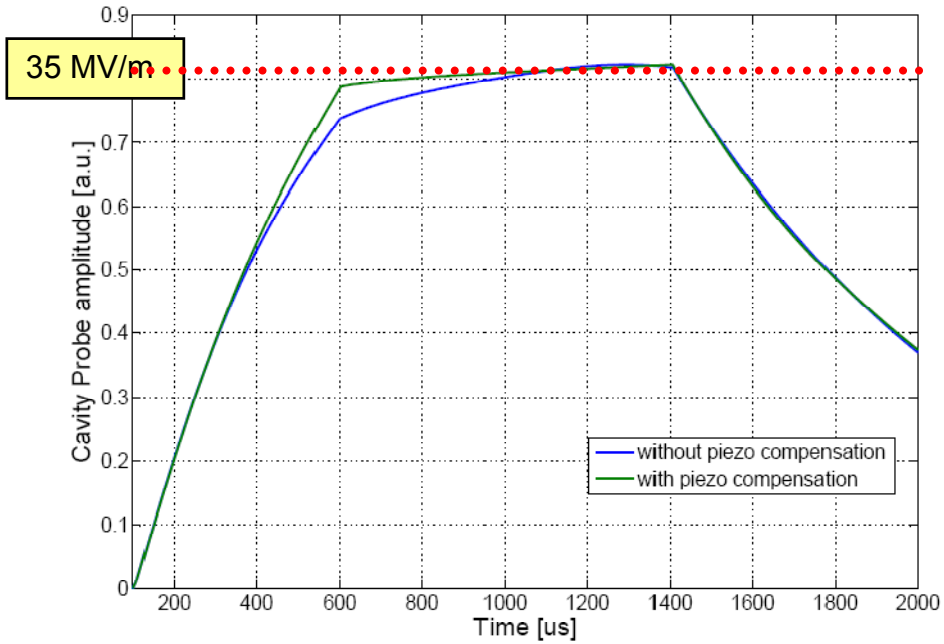
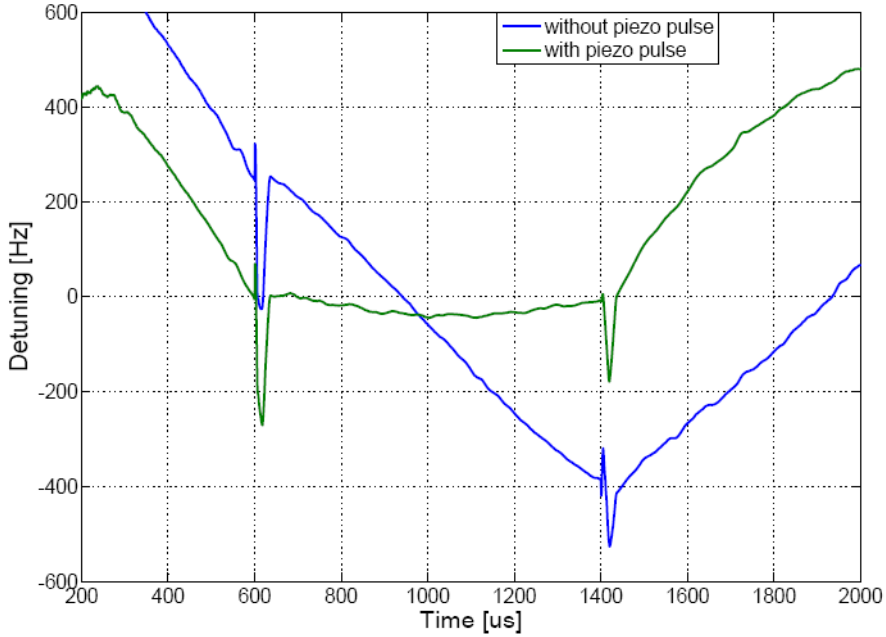
Module 6 Cavity 3

Gradient



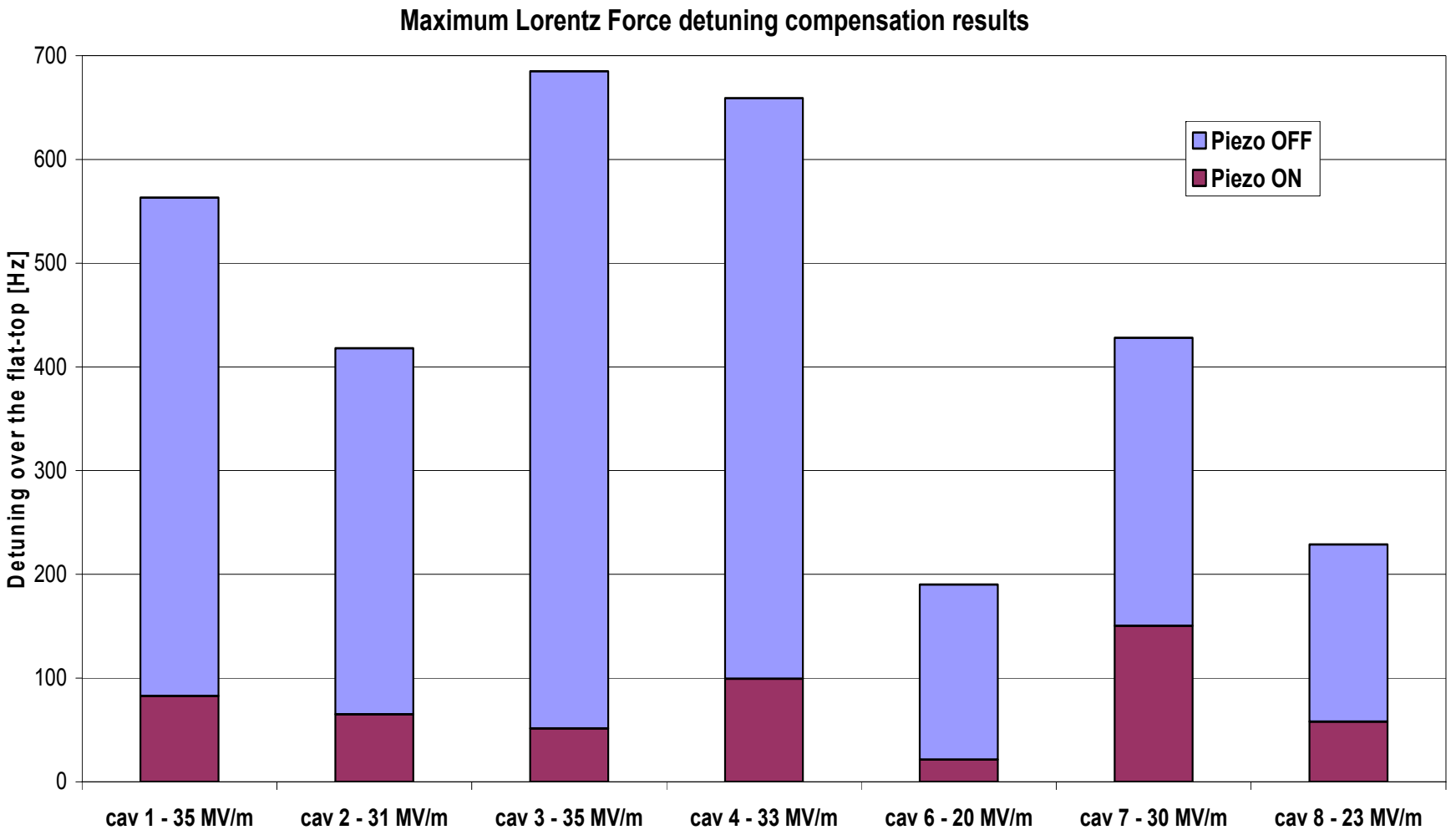
Detuning



Residual detuning: ~50Hz
with piezo on

L. Lilje

Maximum Compensation & Residual Error



L. Lilje

Operating Gradient Error Source

Error Source	Error	Effect on Energy Gain	
Input Coupling Geometric + Field Flatness	10%	+1.1, -1.4%	Fixed
Input Power	2%	+1.5, -1.6%	Fixed
Input Power Phase	3 deg.	-0.25%	Fixed
Lorentz Detuning Compensation Error	11 deg.	-2.1%	Need Precise Tuning

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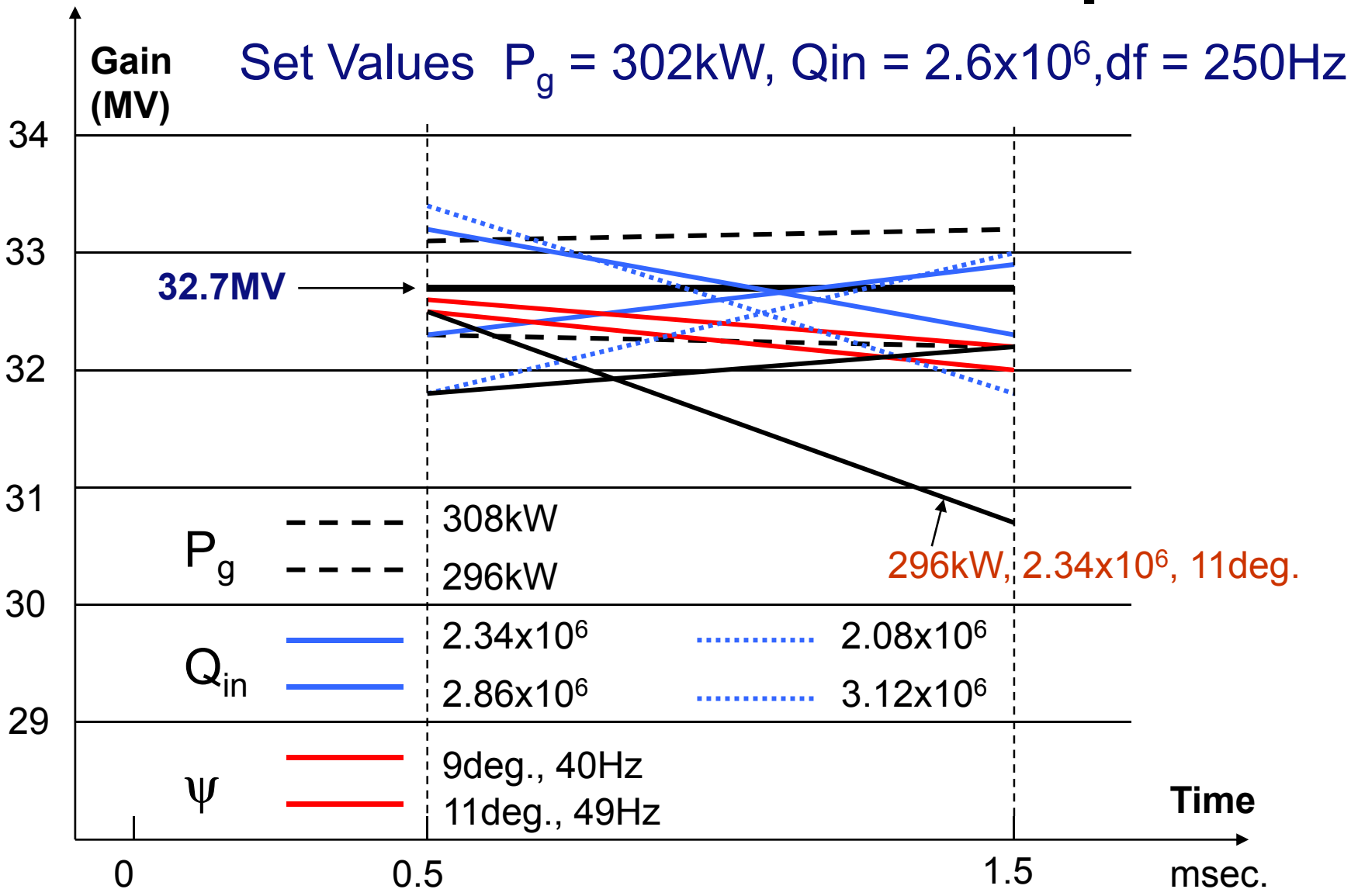
Gradient Error in flat-top



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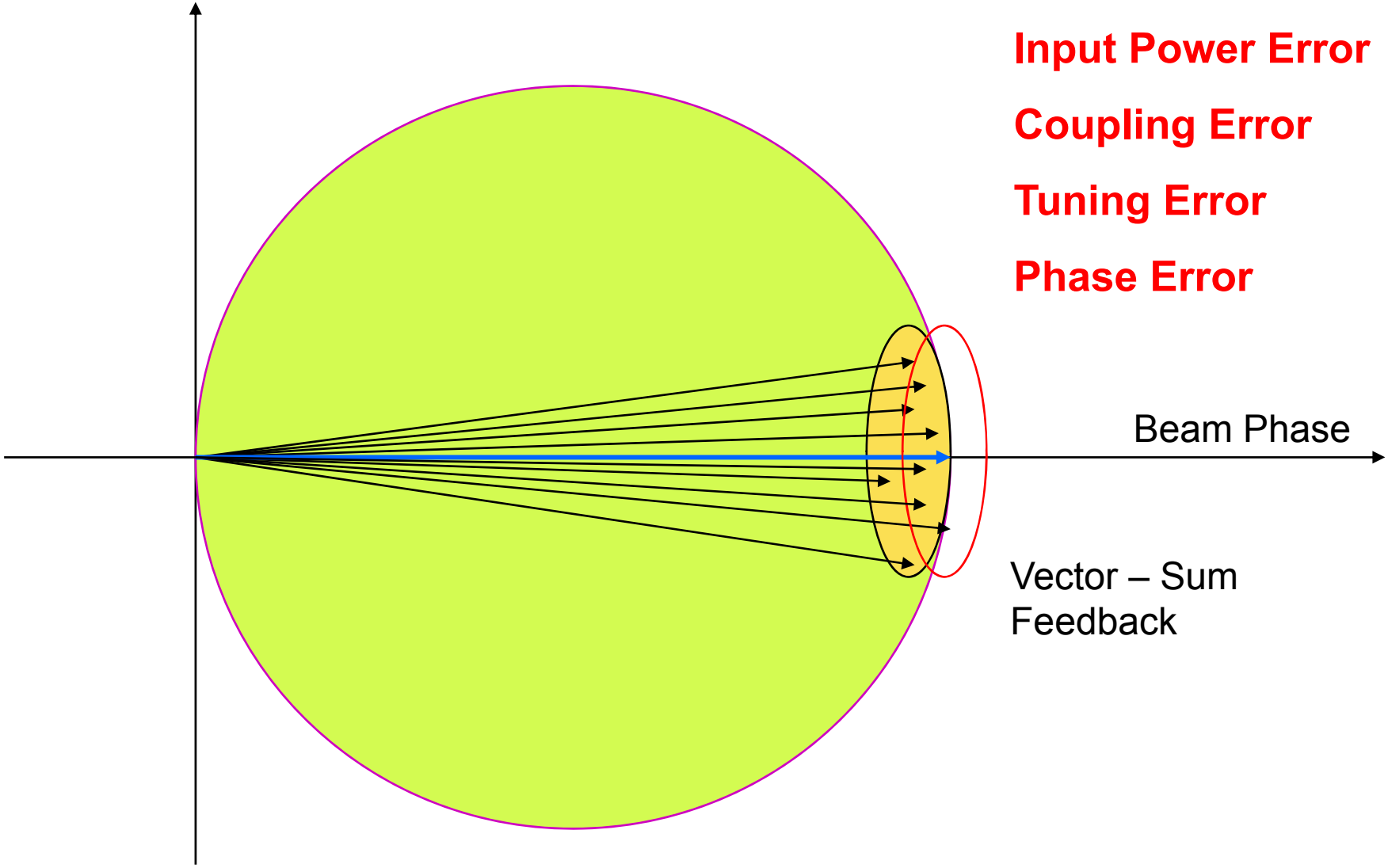
Cavity Voltage Error & Gain Reduction



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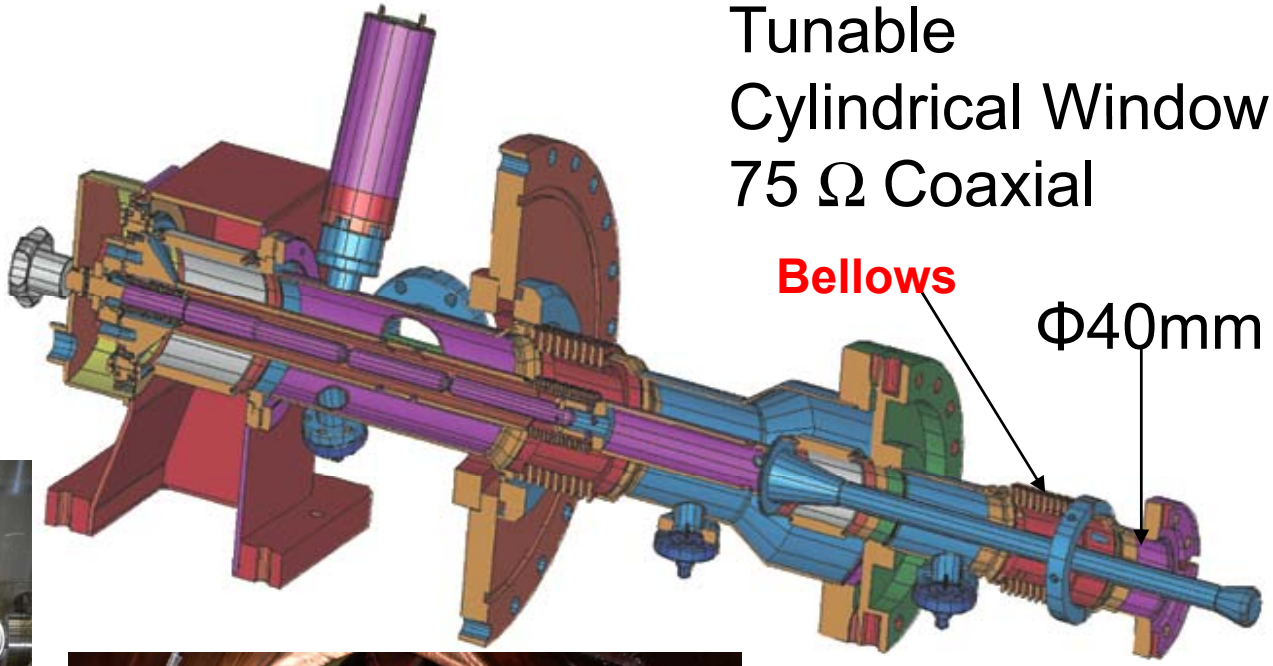
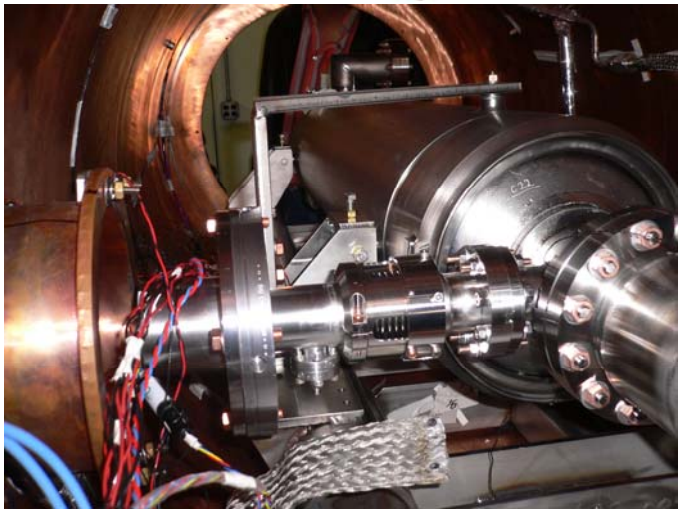
Engineering Points for coupler

The followings need to be compared :

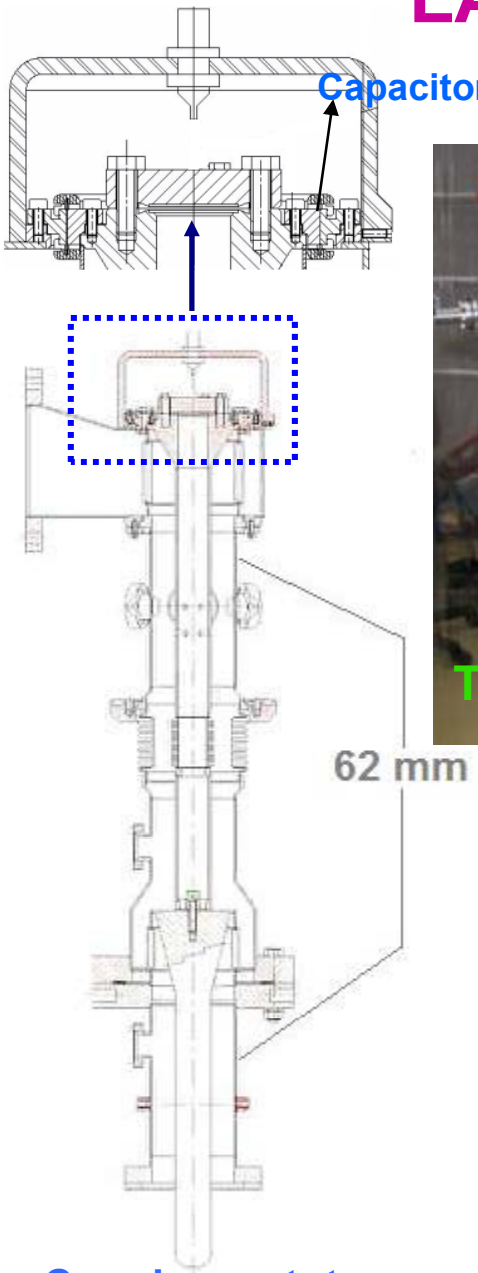
- **rf power capability**
- **low heat load**
- **easy installation**
- **tuning capability (fixed coupling, adjustable coupling)**
- **conditioning time**
- **window multipacting/breakdown**
- **leak tight vacuum seal**
- **no contamination during cold part assembly**

TTF-III Coupler

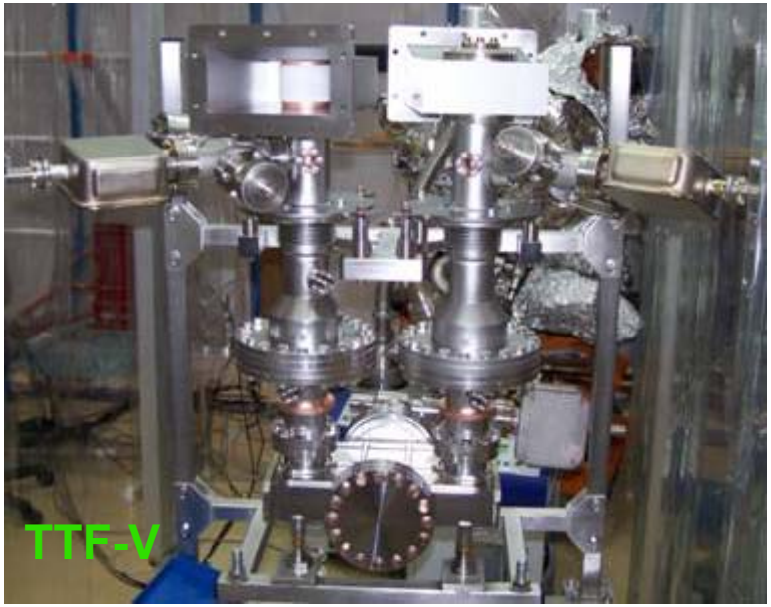


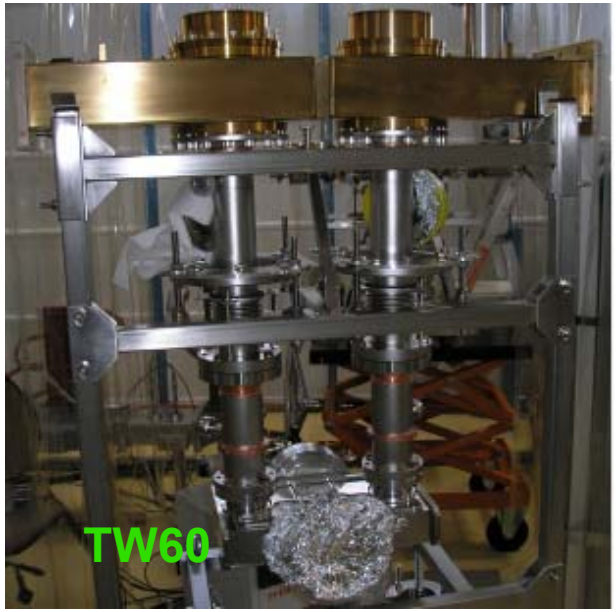


LAL prototypes: TTFV & TW60

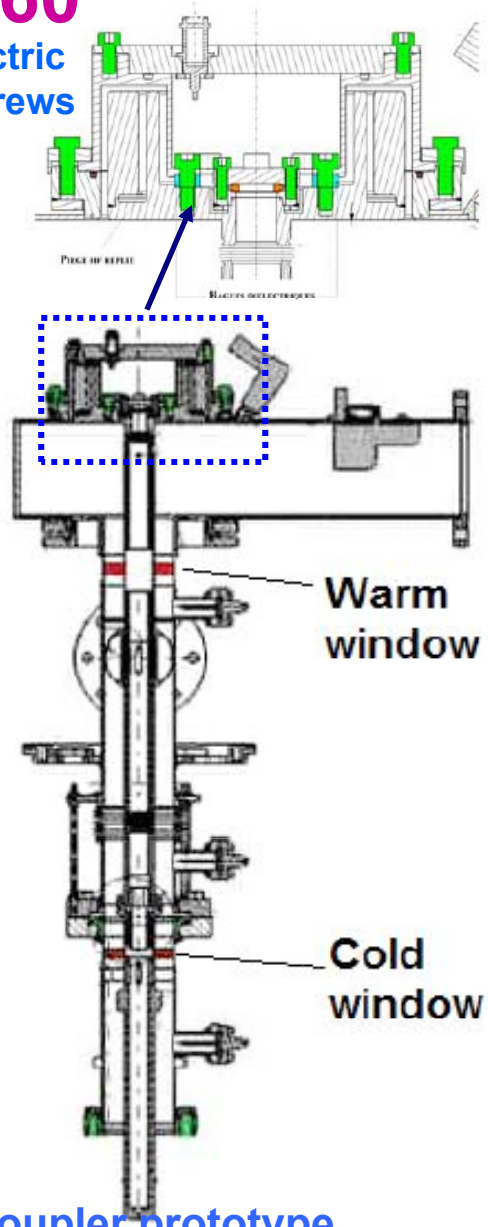


Coupler prototype
TTF-V





Insulation using dielectric ring and insulating screws



Coupler prototype
TW60

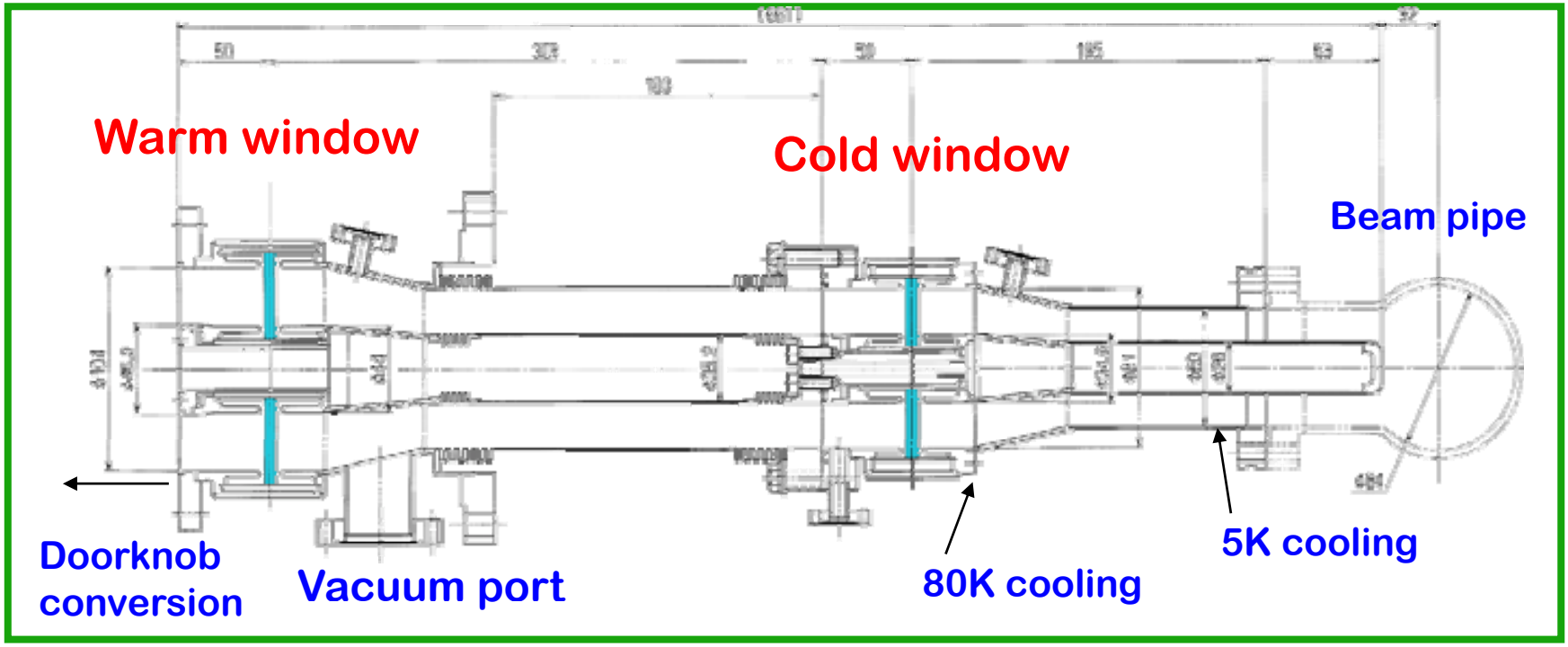
H. Jenhani

Input Coupler for STF Baseline Cavities

Improved design for simplicity with no tuning mechanism.

TRISTAN Type Coaxial Disk Ceramic ;

(KEKB 1 MW/cw, JPARC-ADS 2.2 MW/pulse)



	80 K	5 K	2 K
Static Loss	5 W	1.1 W	0.05 W
Dynamic Loss	3 W	0.2 W	0.03 W

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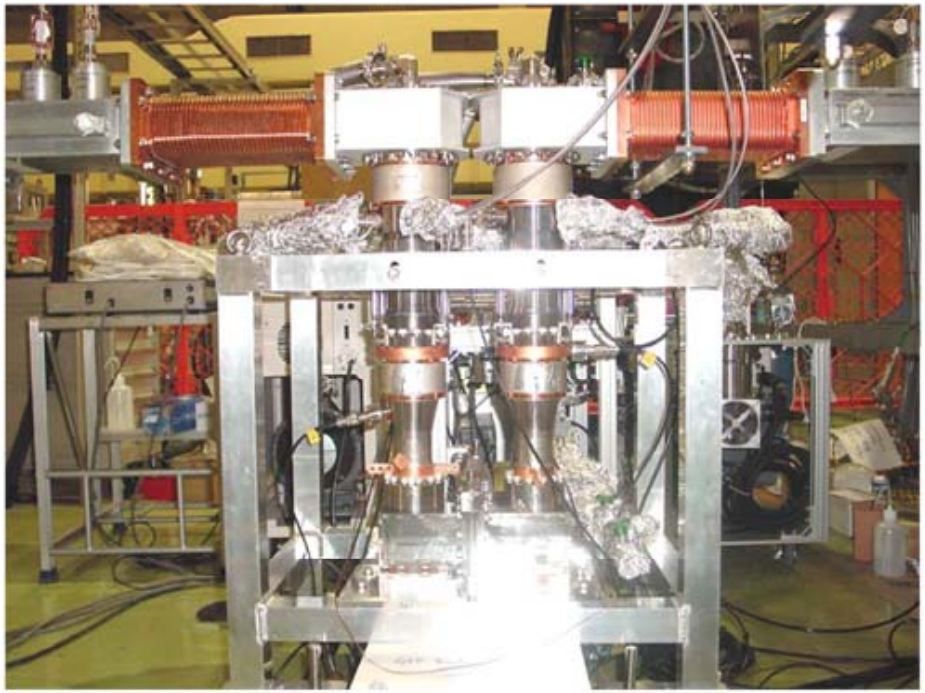
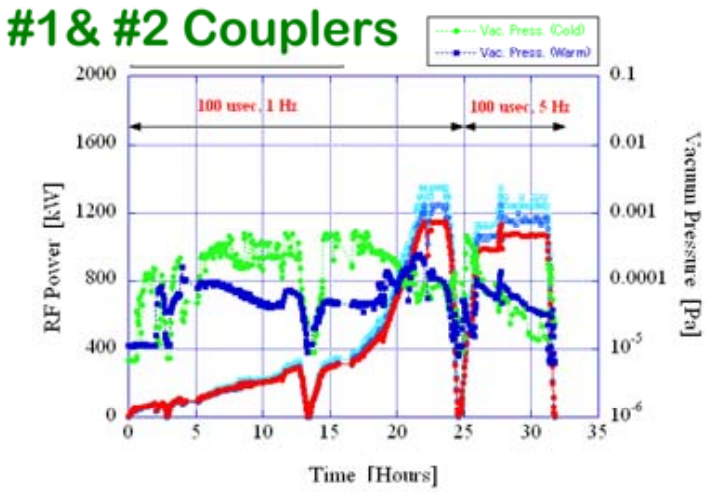
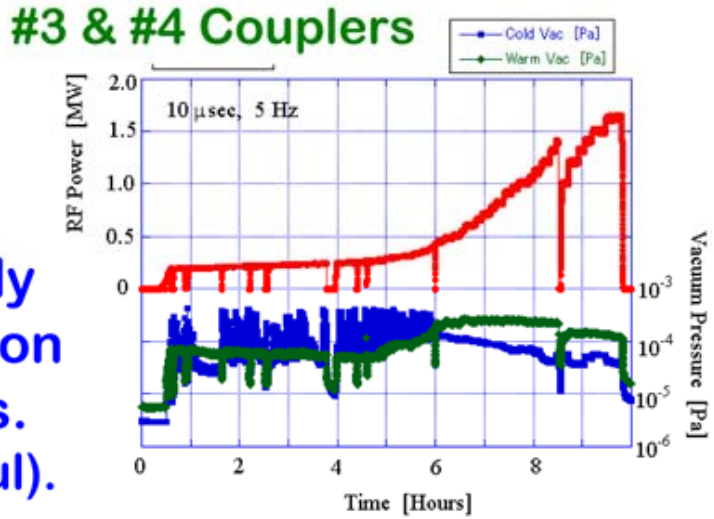
Power test of Two disk couplers







Four input couplers have been successfully processed up to 1.0 MW in a pulsed operation of 1.5 msec and 5 Hz, without any troubles. Total processing time is ~ 50 hours, (very careful).

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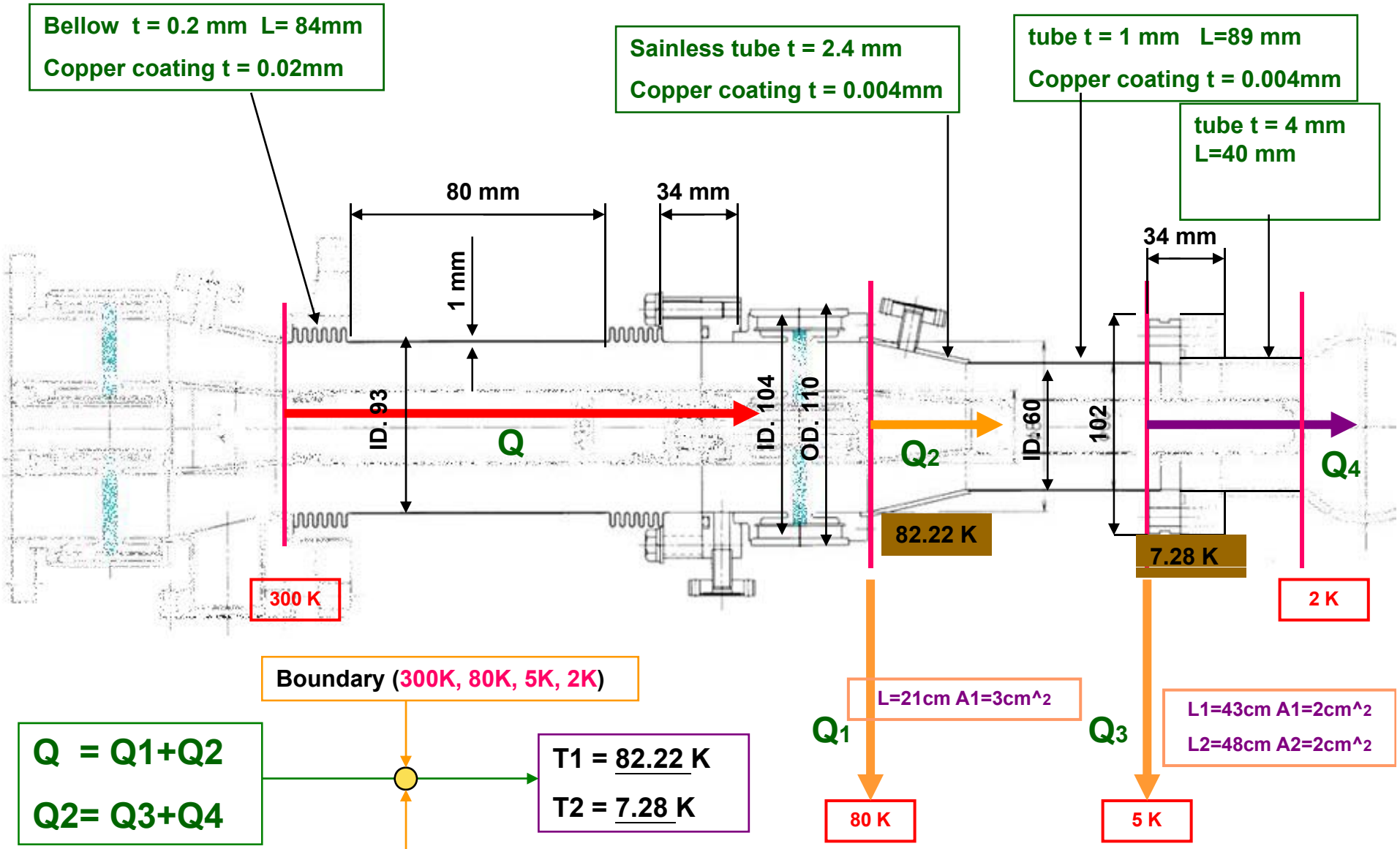
Heat load estimation of Two disk coupler



Boundary (300K, 80K, 5K, 2K)

$Q = Q1+Q2$

$Q2 = Q3+Q4$

T1 = 82.22 K

T2 = 7.28 K

Thermal characteristic are decided at average temperature of the sample

Tsai MingHsun

Total heat loss(static) of Two disk coupler

35 MV				
	Type of wire	Q 300K~80K	Q 80K~5K	Q 5K~2K
	C.C	0.20631672	0.068002944	0.000387168
Sensor wire	Cernox	0.4616128	0.6915028	0.0479688
	PtCo	0.577016	0.883536	0.0007584
	Area of thermal anchor	Q 300K~80K	Q 80K~5K	Q 5K~2K
Coupler Body	1X	2.778976164	1.036172719	0.054801882
	1/2X	2.759197429	1.285294939	0.105984042
		Q 300K~80K	Q 80K~2K	
RF Cable	X7	2.270865458	0.75363881	
		Q 300K~2K (W)		
Piezo	*RF cable*	0.1373436		
	wire	0.0016956		

Q at 80K (W)	Q at 5K (W)	Q at 2K (W)
6.294787142	2.679214463	0.99659426

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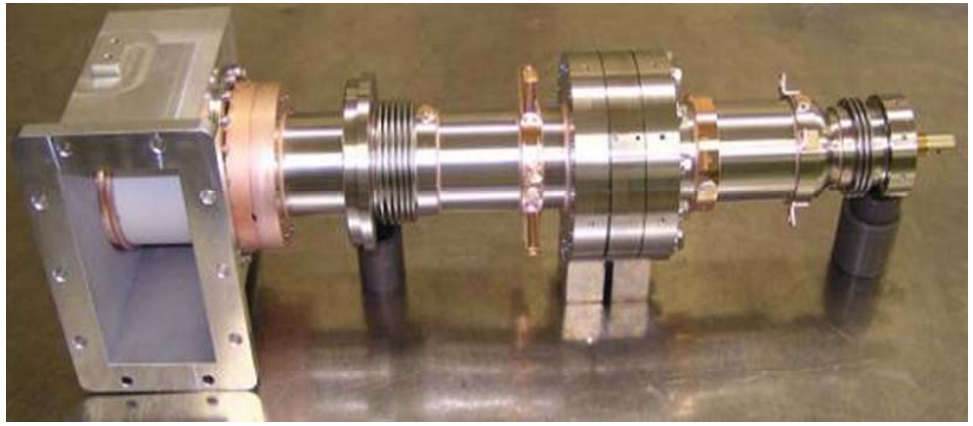
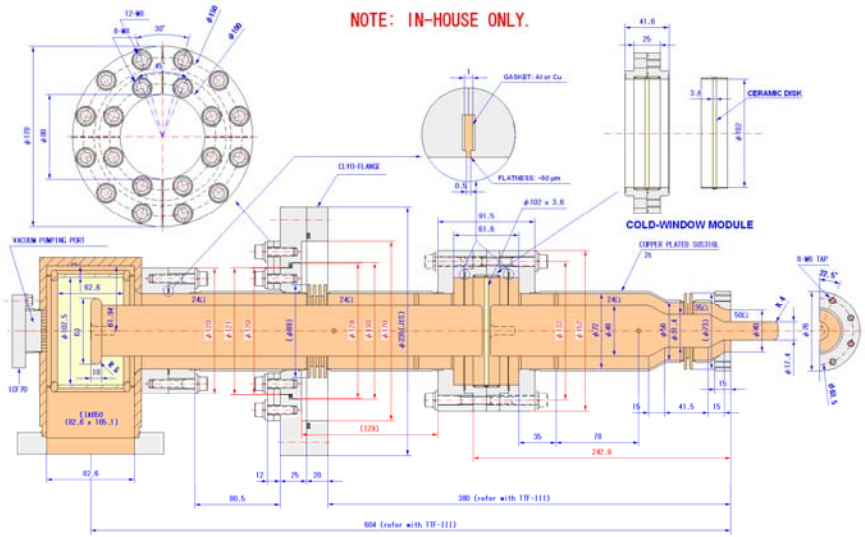
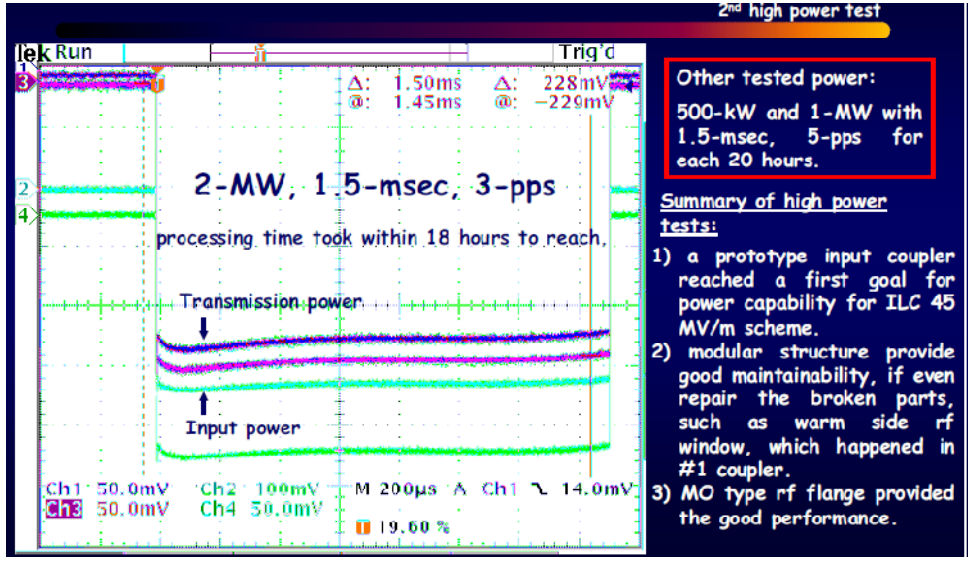
Capacitive coupling couplers

By H.Matsumoto and S.Kazakov







Successfully demonstrated the high power performance up to 2MW!

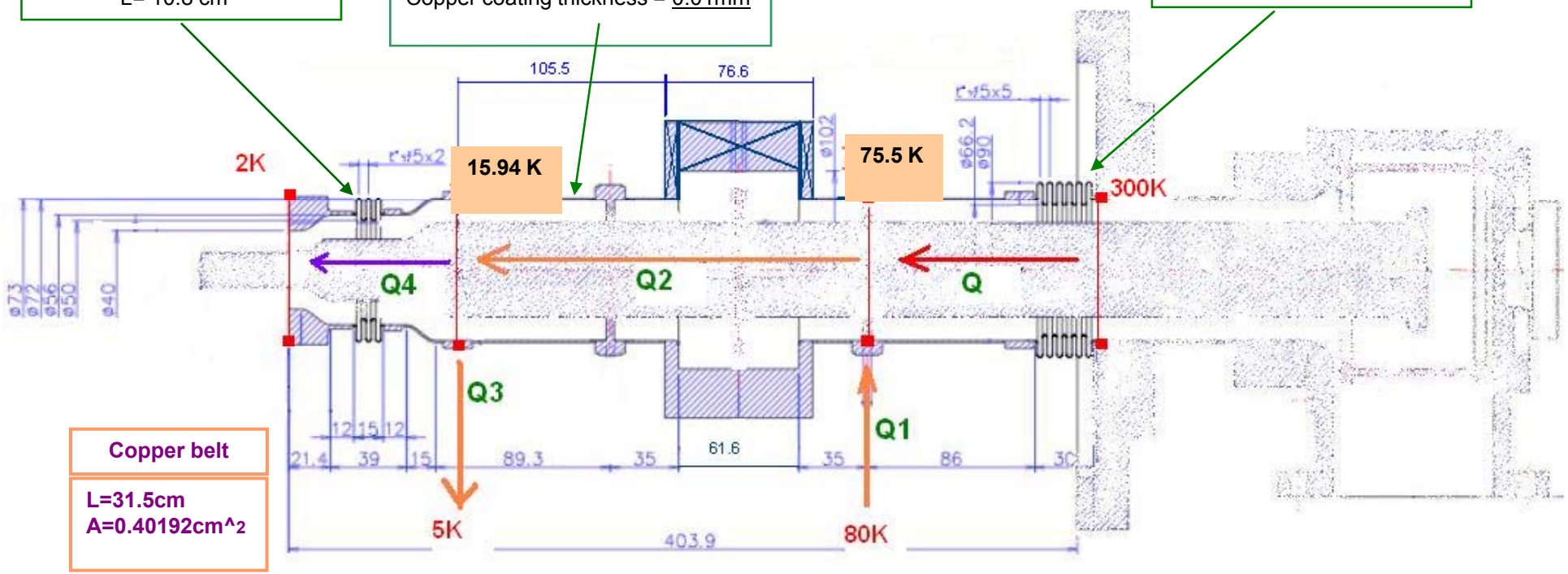
The specification: 500kW, 1.5msec, 5Hz @ 45MV/m operation

Heat load estimation of Capacitive coupling coupler

Bellows thickness = 0.1 mm
L= 10.8 cm

Stainless tube thickness = 0.5 mm
Copper coating thickness = 0.01mm

Bellows thickness = 0.1 mm
L= 26 cm



Boundary (300K, 80K, 5K, 2K)

$Q = Q1+Q2$

$Q2 = Q3+Q4$

T1 = 75.5 K

T2 = 15.94 K

Thermal characteristic are decided at average temperature of the sample

Tsai MingHsun

Total heat loss (static) of Capacitive coupling coupler

45 MV				
	Type of wire	Q 300K~80K	Q 80K~5K	Q 5K~2K
	C.C	0.18339264	0.068002944	0.000387168
Sensor wire	Cernox	0.4616128	0.7068288	0.0040448
	PtCo	0.577016	0.883536	0.0007584
	Area of thermal anchor	Q 300K~80K	Q 80K~5K	Q 5K~2K
Coupler Body	1X	1.174459296	1.49694252	0.172072772
	2X	1.168704707	1.654814307	0.104810419
		Q 300K~80K	Q 80K~5K	Q 5K~2K
	RF Cable	0.52954	0.406	0.0069237
		Q 300K~2K (W)		
	Thermal coupler		0.092399568	

Q at 80K (W)	Q at 5K (W)	Q at 2K (W)
4.094725443	5.216124571	0.381396827

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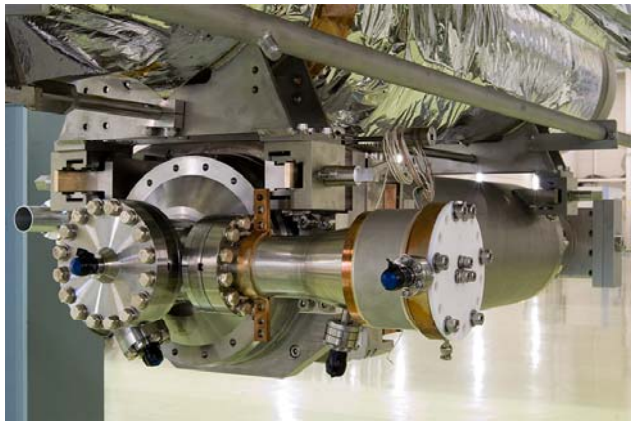
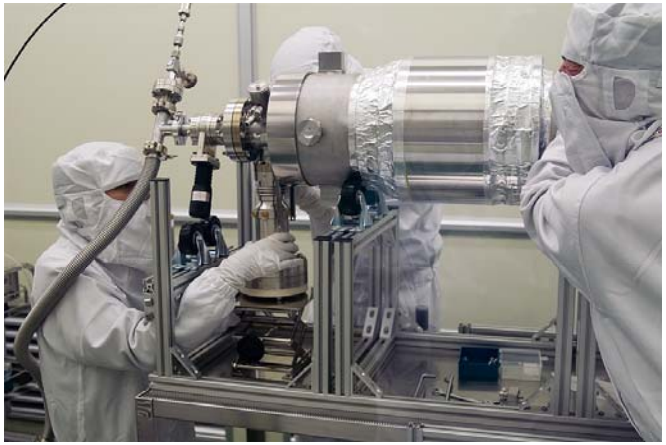
Coupler Installation to Cavity

Installation from side
with sliding stage



No fixing support



Installation from downside

with fixing
support
Because of
coupler bellows

Others

magnetic shield,
cavity alignment,
vacuum seals,
feedthrough, …

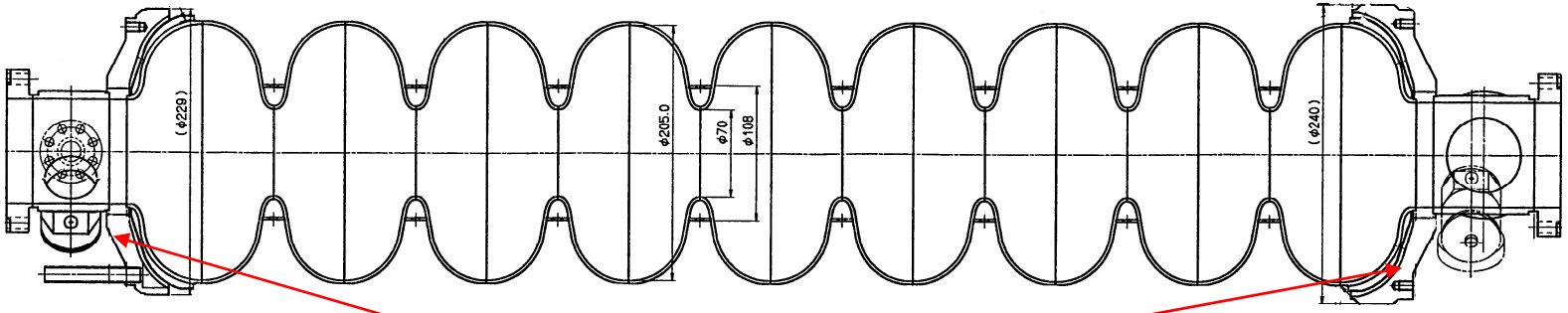
Three cavities (#1, #2, #4 Cavity) covered with He Jacket

Magnetic Shield Inside

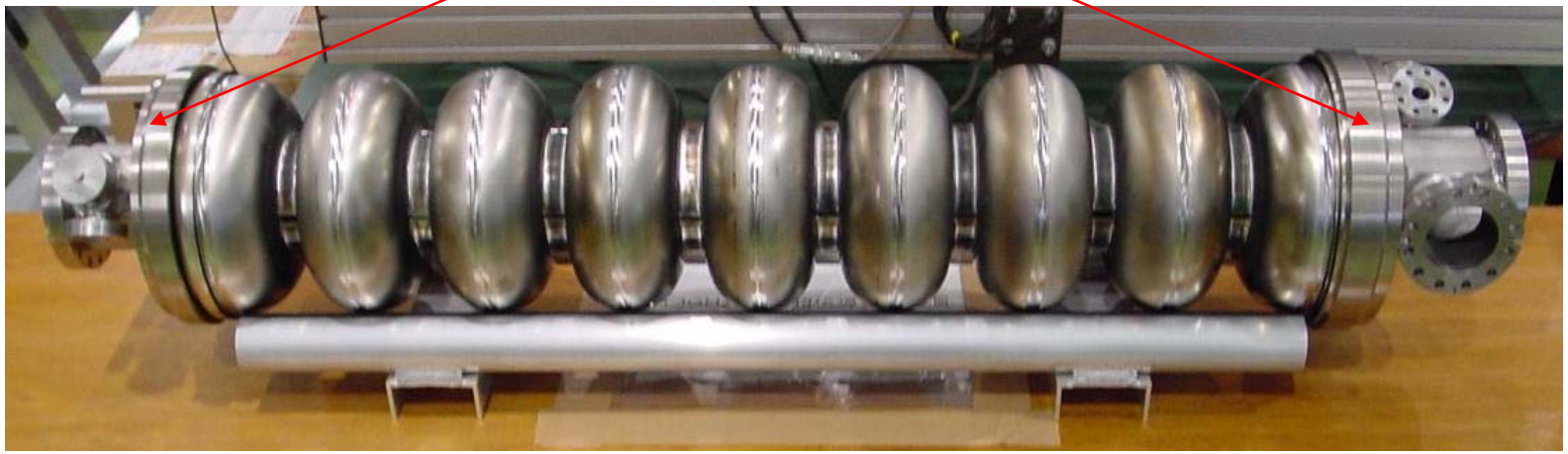
March, 2007'

S. Noguchi

Alignment reference of STF TESLA Cavity



Precisely machined thick endplates : alignment reference



vacuum seals

hexagonal cross-section Al gasket.
In-coated helico-flex.
Special helico-flex (Saclay)
Indium wire seal, …

feedthrough

Ceramic insulator.
Sapphire insulator.
Thermal anchor on it, …

summary

Cavity peripherals:

- Tuner (mechanical, piezo)
- Magnetic shield He jacket with sliding support mechanism
- Alignment method
- Input coupler
- Beam pipe flange & vacuum seal
- Feed-through connector
- Monitor cables
- Thermal anchors
- Bolts & nuts

They seems to be sub-component which are easy to get from industry.
Their technology can be compared, unified for ILC.
Need to wait until three region have some experience of them.

End of slides