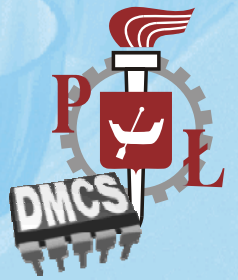
JRA1-SRF
Work Package 8
Tuners

presented by

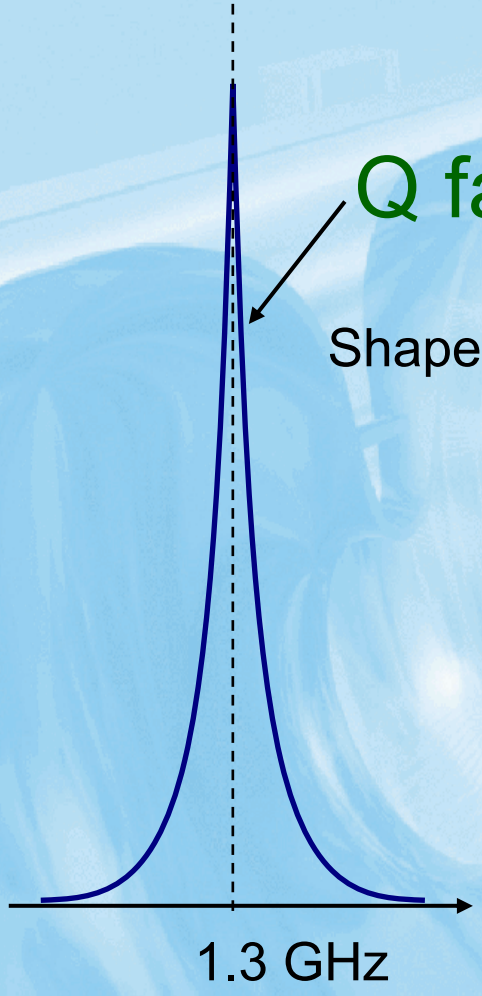
Przemek Sekalski



- Work Package overview
- Research done in 2005
- Results

Work Package overview

Each cavity must work on resonance



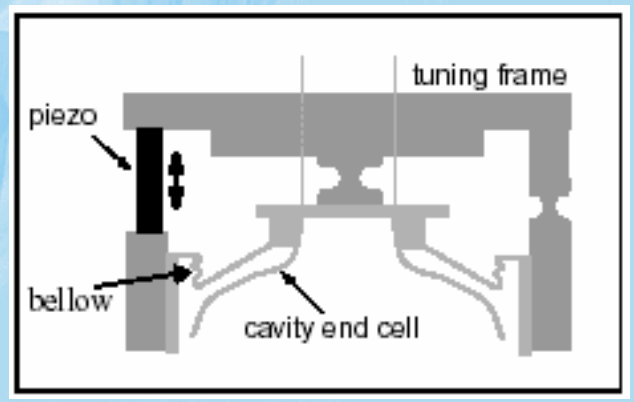
TESLA cavities

Q factor ~10^{10} ⇔ Bandwidth ~250Hz

Shape of cavity (length) determines its resonance frequency

1kHz ⇔ 1.88µm

Cavity length over 1 meter



High precise tuning system
is required to save RF power

Motivation

The development of active tuner systems is imperative for operation of SC cavities at high gradient

SLOW TUNER

Needed for pre-tuning stage to reach proper initial frequency

- **cavity length change in range of several mm (⇔ few MHz of detuning compensation)**
- **pre-tuning phase will be performed rare (i.e. once a week or even month)**

FAST TUNER

Needed for Lorentz force and microphonics compensation during the RF pulse

active tuning will be performed during each pulse

Microphonics

vibration of environment

- **Stochastic**
- **Feedback algorithm**
- **Δf < 20 Hz**

Lorentz Force

- **Repetitive and periodic**
- **Feed-forward algorithm**
- **($\Delta f_{static} \sim E_{acc}^2$)**
- **35MV/m ⇔ ~1 kHz ⇔ ~1.9 μm**

Main goals of WP 8

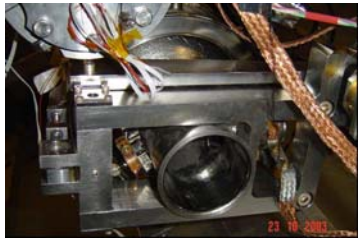
- Development of fast tuners based on piezoelectric and/or magnetostrictive elements
- Fast and slow tuners integration
- We aim to develop tuners capable of compensation of 1 kHz detune, allowing the cavities to operate stably at 35 MV/m
- Long lifetime is a major issue - we aim to develop tuners allowing for 10 years of operation

Description

Electromechanical systems for Lorentz force & microphonics compensation and for pre-tuning stage

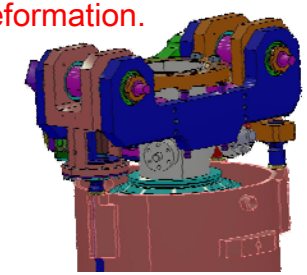
CEA-Saclay current design

- Double lever system
- Stepping motor PHYTRON with Harmonic Drive gear box
- ΔZ=±5mm, Δf=±2.6MHz
- Theoretical resolution 1.5nm
- Stiffness ~100kN/mm
- Ready for piezoelectric and magnetostrictive actuator



CEA-Saclay new design

- Double lever with a screw-nut system
- Stepping motor PHYTRON or SANYO with Harmonic Drive gear box
- Δf=±2MHz @RT, Δf=±460kHz @2K
- Ready for piezoelectric and magnetostrictive actuator
- The preload strength on the piezo is totally applied by the cavity elasticity deformation.



task 8.1

UMI Milan tuner Coaxial

- Three coaxial rings connected by blades
- Stepping motor for pre-tuning stage
- Piezos up to 72mm length
- Shorter dead zone between cavities 350→283mm (total accelerator length reduction by 5%)
- Expensive (factor of 2-3)
- Stiffer than others (easily upgradeable)

task 8.3

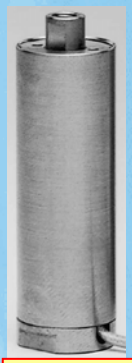
Description cont

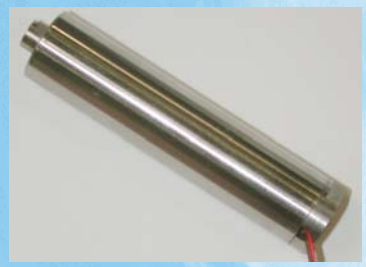
Piezoelectric actuators PZT

Dimensions: **10x10x36mm**
Manufacturer: **PI**

Dimensions: **10x10x30mm**
Manufacturer: **NOLIAC**

task 8.4





Dimensions: **7.5x7.5x50mm**
Manufacturer: **PiezoMechanik**

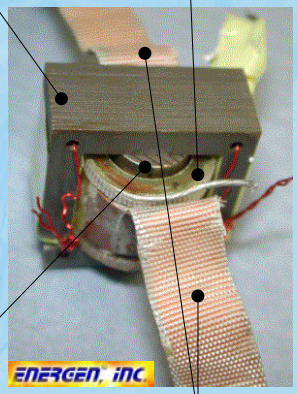
Dimensions: **7x7x30mm**
Manufacturer: **EPCOS**

Magnetostrictive actuators

Plunger & Belleville springs

Niobium Cover

Active magnetostrictive element with ferrite, s.c. coil and thermal connectors



Ferrite necessary to close magnetic circuit

Superconducting coil (Nb_3Sn)

Magnetostrictive rod (made of Kelvin ALL®)

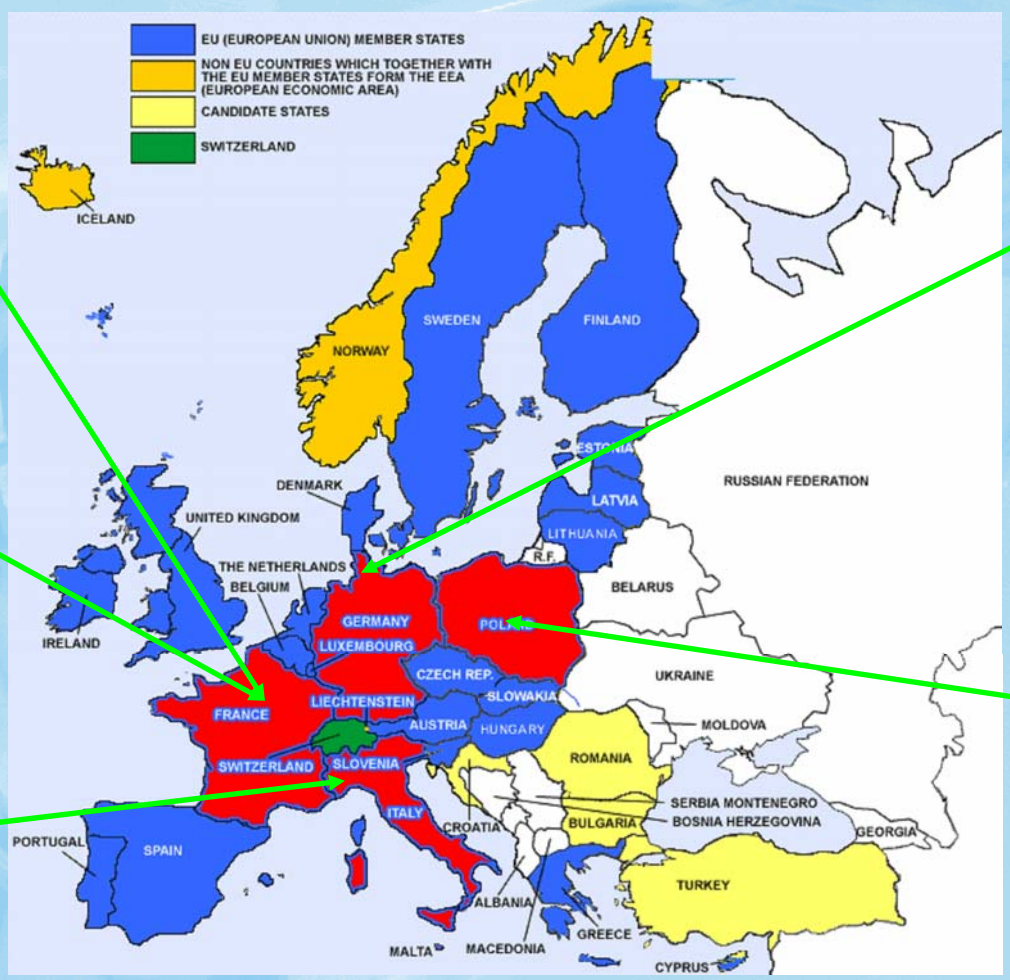
Thermal connectors

task 8.2

Dimensions: **Φ10x20mm**
Manufacturer: **ENERGEN**
Material: **KELVIN ALL®**

Dimensions: **6x6x20mm**
Manufacturer: **ETREMA**
Material: **GalFeNOL**

Partners


EU (EUROPEAN UNION) MEMBER STATES
NON EU COUNTRIES WHICH TOGETHER WITH THE EU MEMBER STATES FORM THE EEA (EUROPEAN ECONOMIC AREA)
CANDIDATE STATES
SWITZERLAND
ICELAND
NORWAY
SWEDEN
FINLAND
RUSSIAN FEDERATION
DENMARK
UNITED KINGDOM
IRELAND
THE NETHERLANDS
BELGIUM
LATVIA
LITHUANIA
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SLOVAKIA
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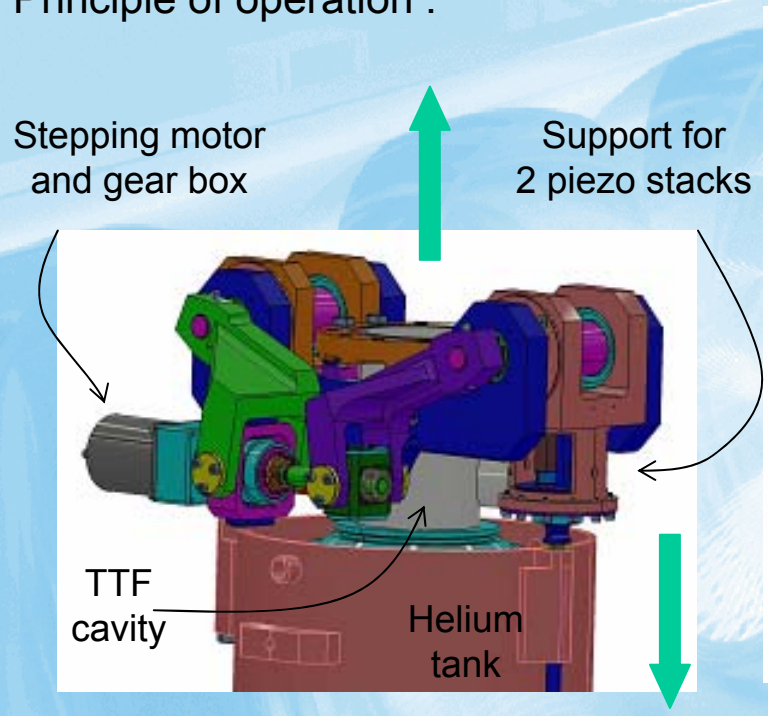
ROMANIA
ITALY
SERBIA MONTENEGRO
BOSNIA HERZEGOVINA
CROATIA
BULGARIA
GEORGIA
PORTUGAL
SPAIN
TURKEY
ALBANIA
GREECE
MALTA
MACEDONIA
CYPRUS

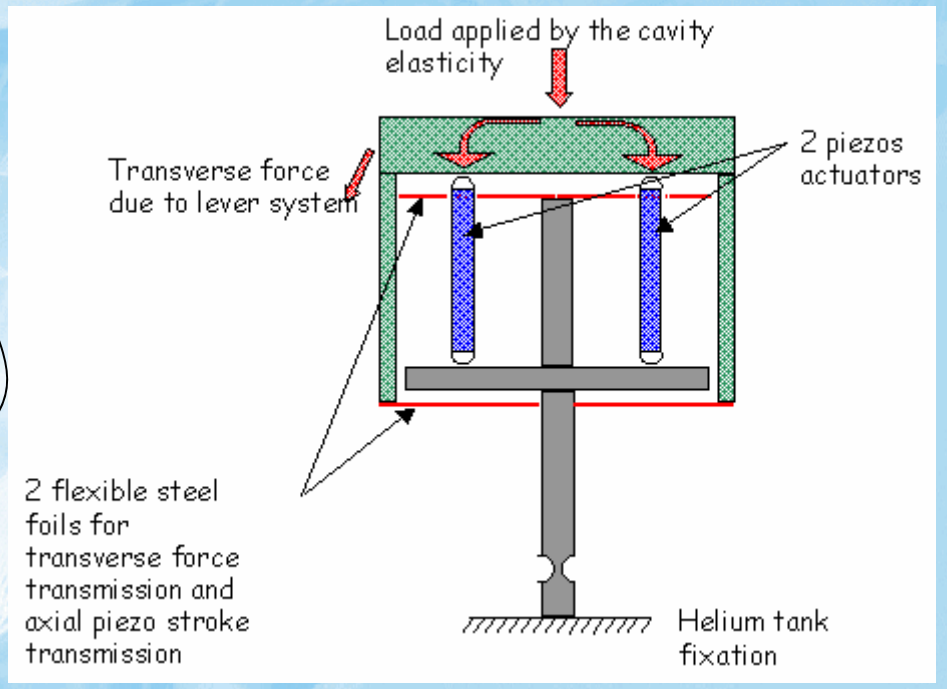
Research

Overview on the Saclay Piezo Tuner System (PTS)

Tuner designed in the framework of CARE SRF

Principle of operation :





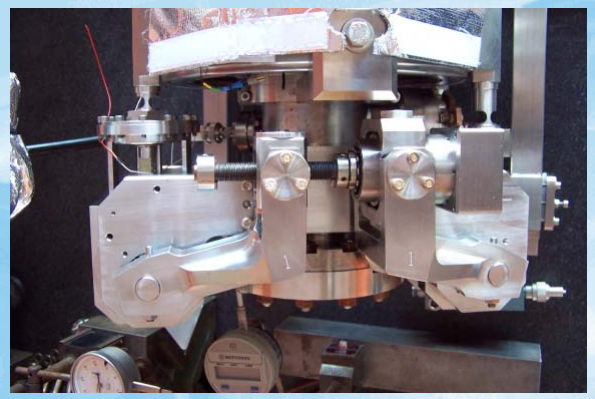
When the cavity is stretched, the piezo support is compressed by the cavity elasticity.
Full tuning range = ± 270 kHz, High displacement resolution of the order of a few nm.

For more details : pierre.bosland@cea.fr or guillaume.devanz@cea.fr

Piezo Tuning System

Ready for a Cold Test !
Scheduled before end of the year

Tuner mounted on the TTF cavity (1.3GHz) and measurements started at room temperature

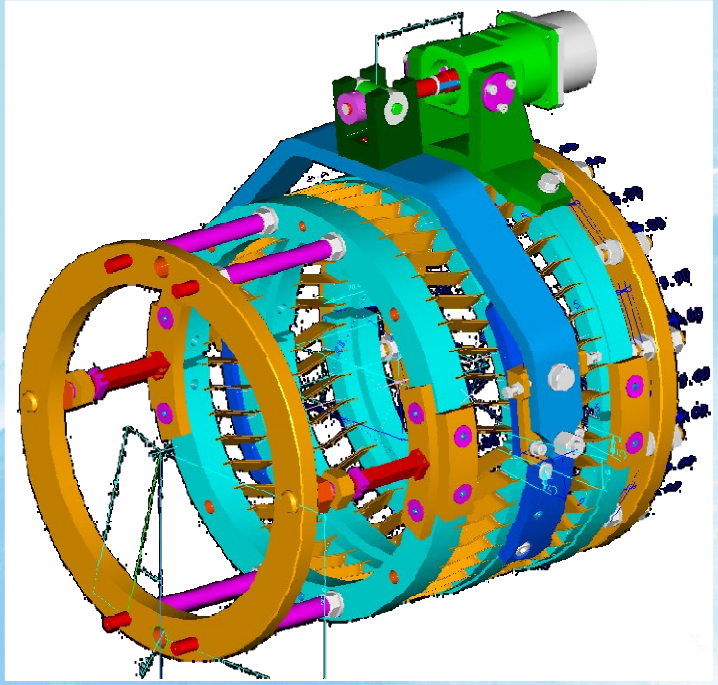


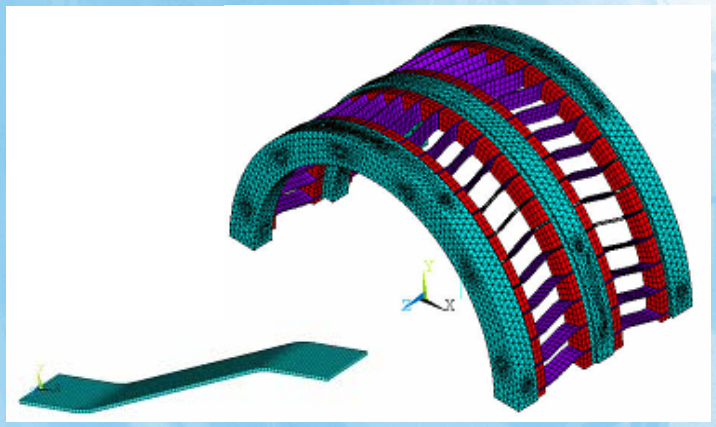
Eccentric arms and stepping motor support

Tuner on TTF 9-cells cavity

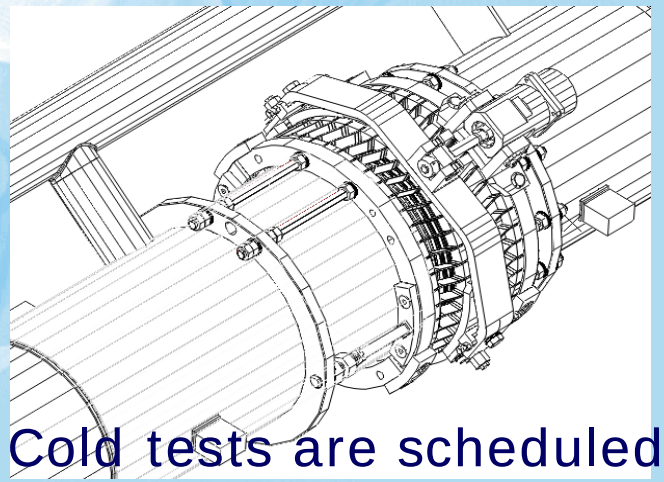
Cavity mounted in CryHolab with instrumentation

INFN blade tuner (coaxial)





- Integration of piezos for Lorentz forces and microphonics completed.
- All the parts have already been constructed by ZANON
- The assembling of two complete prototypes, including the modified helium tank, is well in progress at ZANON
- Two cold tests are preview at DESY and BESSY facilities.



Cold tests are scheduled for the beginning of the next year

For more details : angelo.bosotti@mi.infn.it

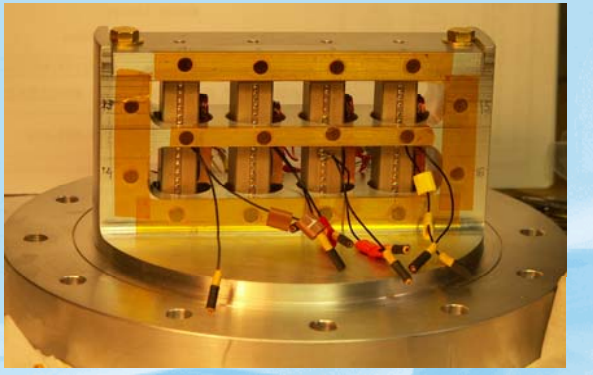
Piezostack characterization

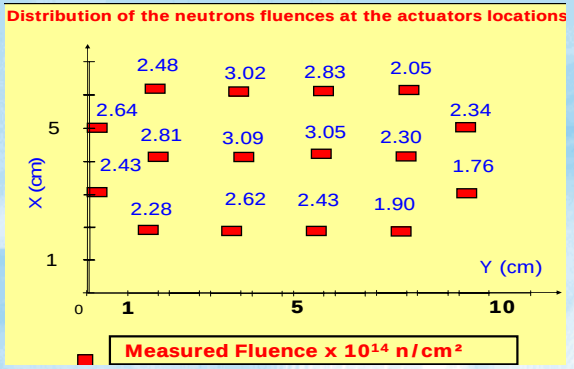
EXPERIMENTAL PROGRAM AT ORSAY

EXPERIMENT-TOPICS	MAIN GOAL
Characterization of different piezoelectric actuators at low temperature T in the range 1.8 K-300 K ✓	Displacement vs. Piezo Voltage @ different T Dielectric properties vs. T (Capacitance, dielectric constant, loss tangent, dielectric losses) Thermal behaviour (Heating, heat capacity, thermal resistance, time constant) ✓
Preparation of radiation hardness with fast neutrons at Liquid Helium (LHe, T=4.2 K) temperature experiment ✓	Development and validation of experimental set-up and procedure without neutrons beam; Set a reference test for piezoelectric actuator properties ✓
Radiation hardness tests with fast neutrons at Liquid Helium LHe temperature	Characteristics of piezoelectric actuators as function of neutron influence at LHe temperature
Measurement of the mechanical stiffness of piezoelectric actuators; Effect of preloading force on actuator properties; ✓ Validation test at room temperature	Determination of piezoelectric actuator stiffness; Development of a method and procedure for adjusting and precise measurement of the preloading force using the actuator as sensor ✓
Mechanical stiffness @ low temperature (LHe and LN2) ✓	Displacement vs. force at different temperature; Capacitance vs. force @ different temperatures; Deformation vs. force @ different temperatures; ✓
Resonance spectrum of piezoelectric actuator under various loading force at different temperature (RT, LN2, LHe) ✓	Effect of the preloading force on the electro-mechanical properties of piezoelectric actuator @ different T ✓

☛ Experimental program for task 8.4 is nearly completed

Radiation Hardness tests with fast neutrons at T=4.2 K

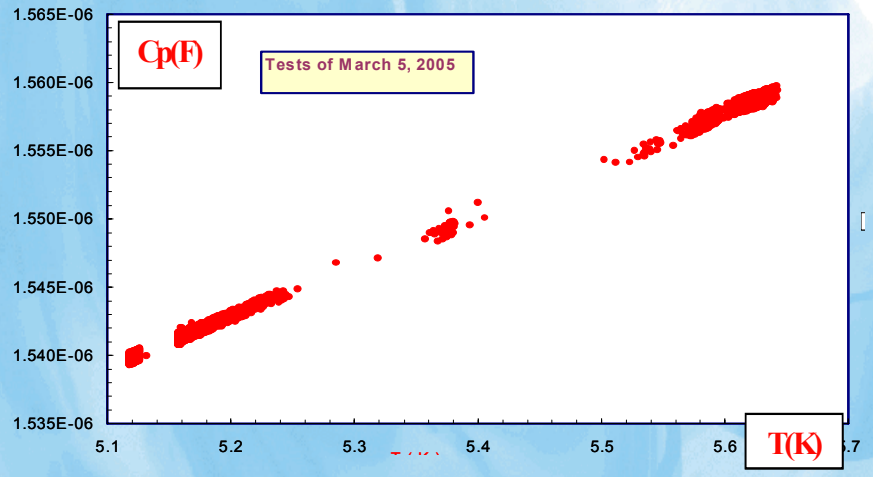




Test stand for 4 PICMA actuators and measurement of total dose distribution (x10^{14} n/cm²)

Irradiations insert in front of the beam-line

Total dose of ~ 2-3.10^{14} n/cm² in 8h exposure to beam



Radiation tests finished: 3 Runs performed, 11 actuators evaluated

No anomalous behavior, no damage observed during irradiations with fast neutrons in liquid helium (T=4.2 K)

Piezostack characterization - summary

Dimensions: **10x10x36mm**
Manufacturer: **PI**

Dimensions: **10x10x30mm**
Manufacturer: **NOLIAC**

Maximum displacement (stroke) at 1.8K >3μm

Actuators suited for **VUV-FEL**, **X-FEL** and even **ILC** (≈1kHz⇔~35MV/m)

No damage and no electrical breakdown observed during all tests

Lifetime at LN_2>1.5*10^9 cycles (INFN)⇔5Hz for 10 years of operation

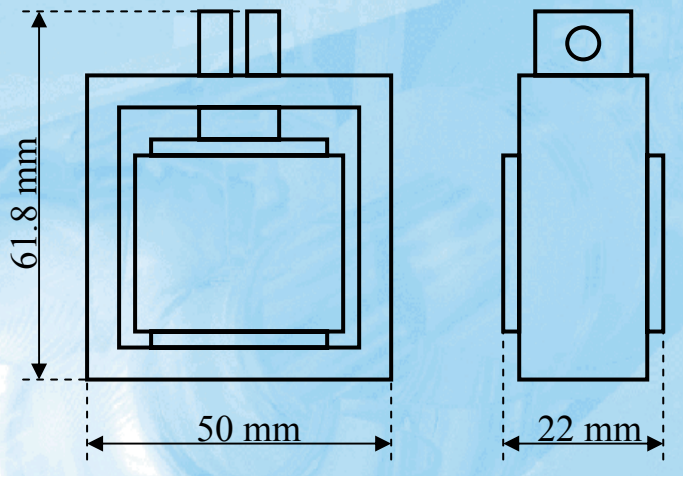
No damage caused by neutron irradiation, only heating observed

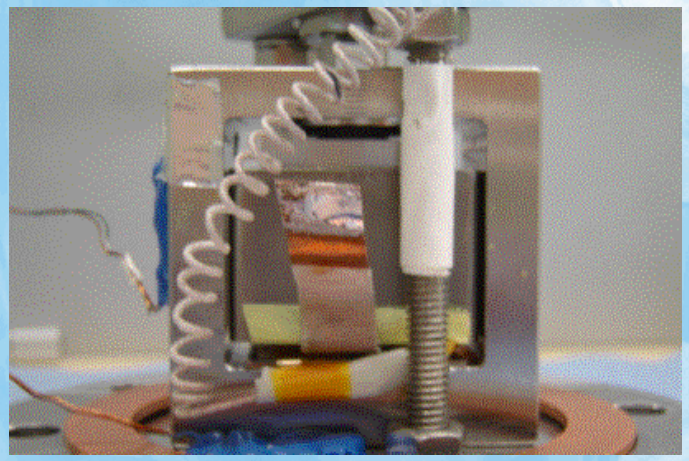
Dose of 2-3*10^{14} in 8h

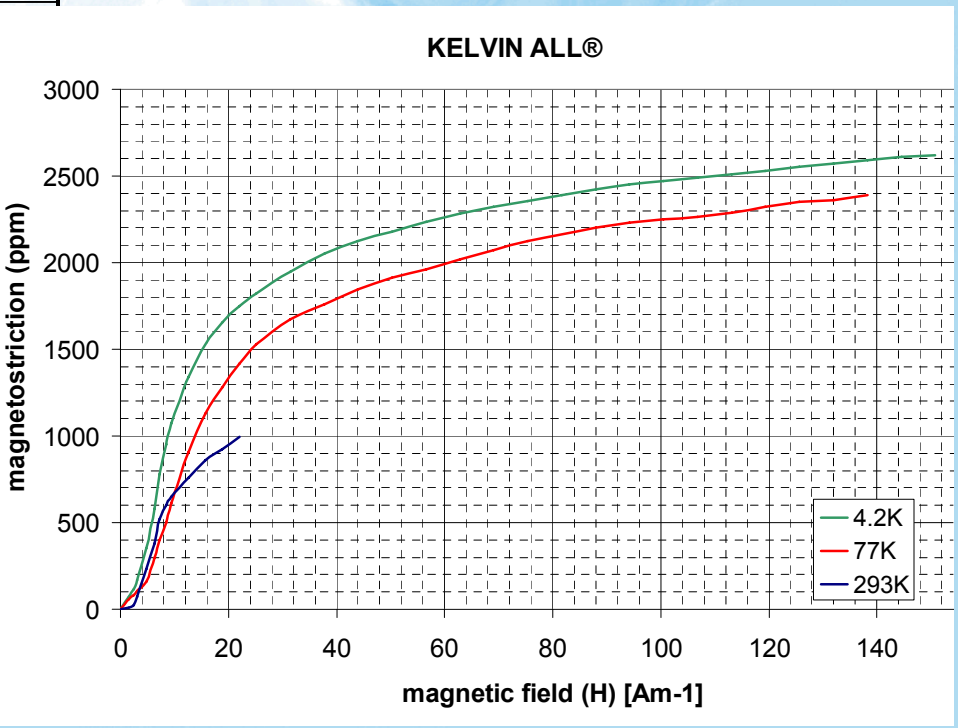
Facility for piezostack investigation is set in IPN Orsay and INFN Milan

Alternative: Magnetostrictive tuner specifications

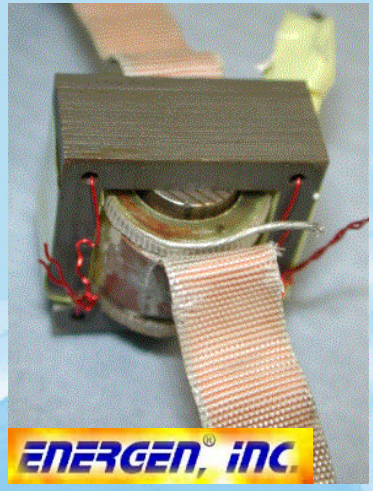
Parameter	Specification
Dimensions:	61.8 mm High x 50 mm Wide x 22 mm Deep
Stroke:	20 µm (preload 1500N)
Resolution:	better than 0.2 µm
Slew rate:	0.15 µm/ µsec
Operating Temp:	2.1 K
Load:	3 kN
Stray magnetic field:	< 25mG at 30 mm from actuator
Pulse Length:	1.6 ms
Repetition Rate:	60 per second
Heat Load to 2.1 K:	< 0.1 W
Lifetime:	5 x 10^{10} Cycles

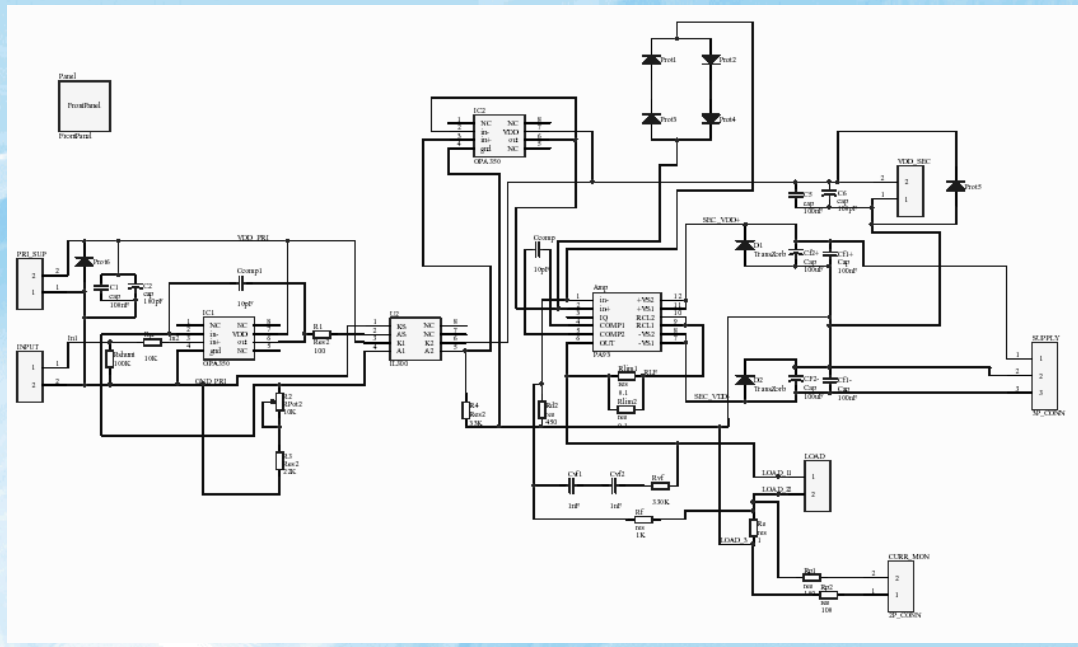




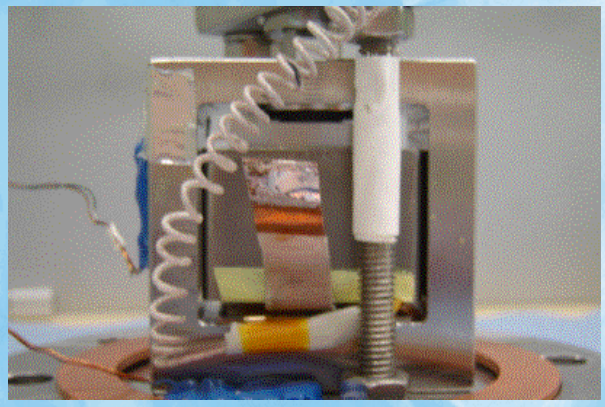


Alternative: Magnetostrictive tuner prototype

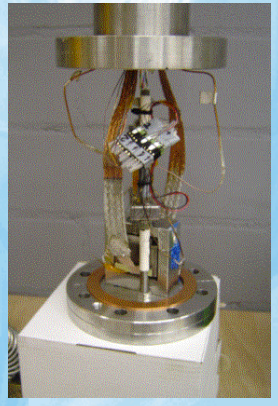




Power Transconductance Amplifier based on PA93 APEX Power Operational Amplifier



Fast tuner with Kelvin All rod from ENERGEN

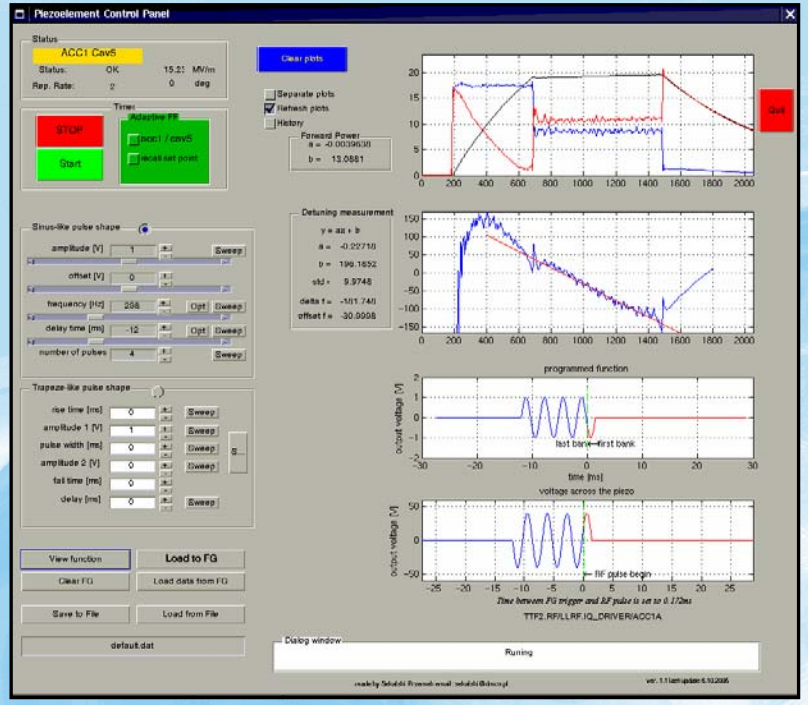


Experimental setup

GalFeNOL rod from ETREMA

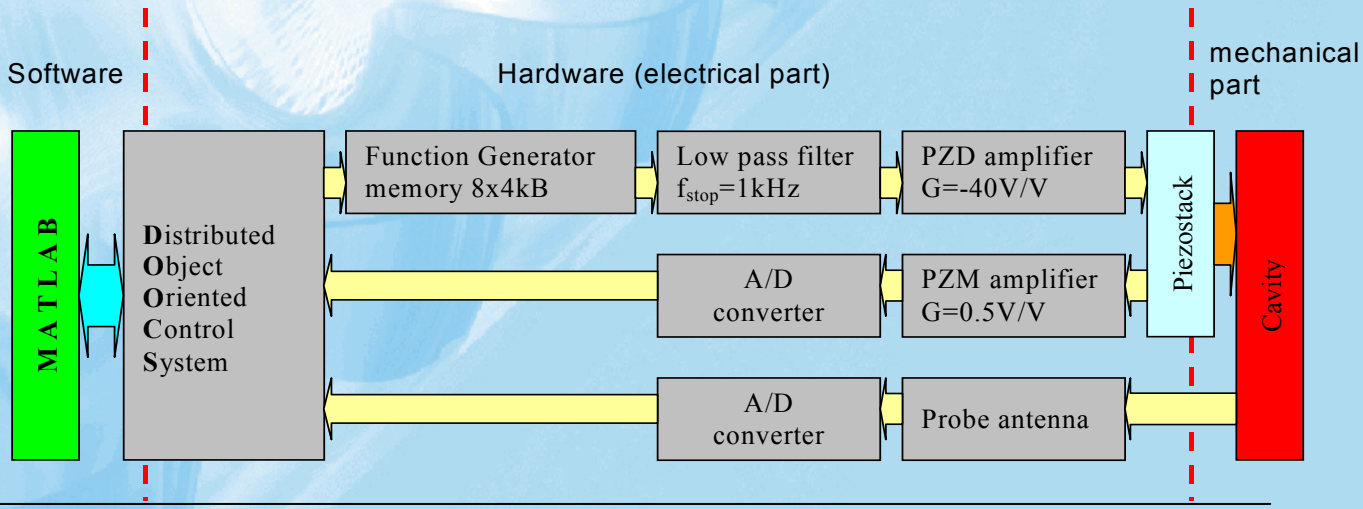
Current results
VUV-FEL experiments

Piezo Control Panel

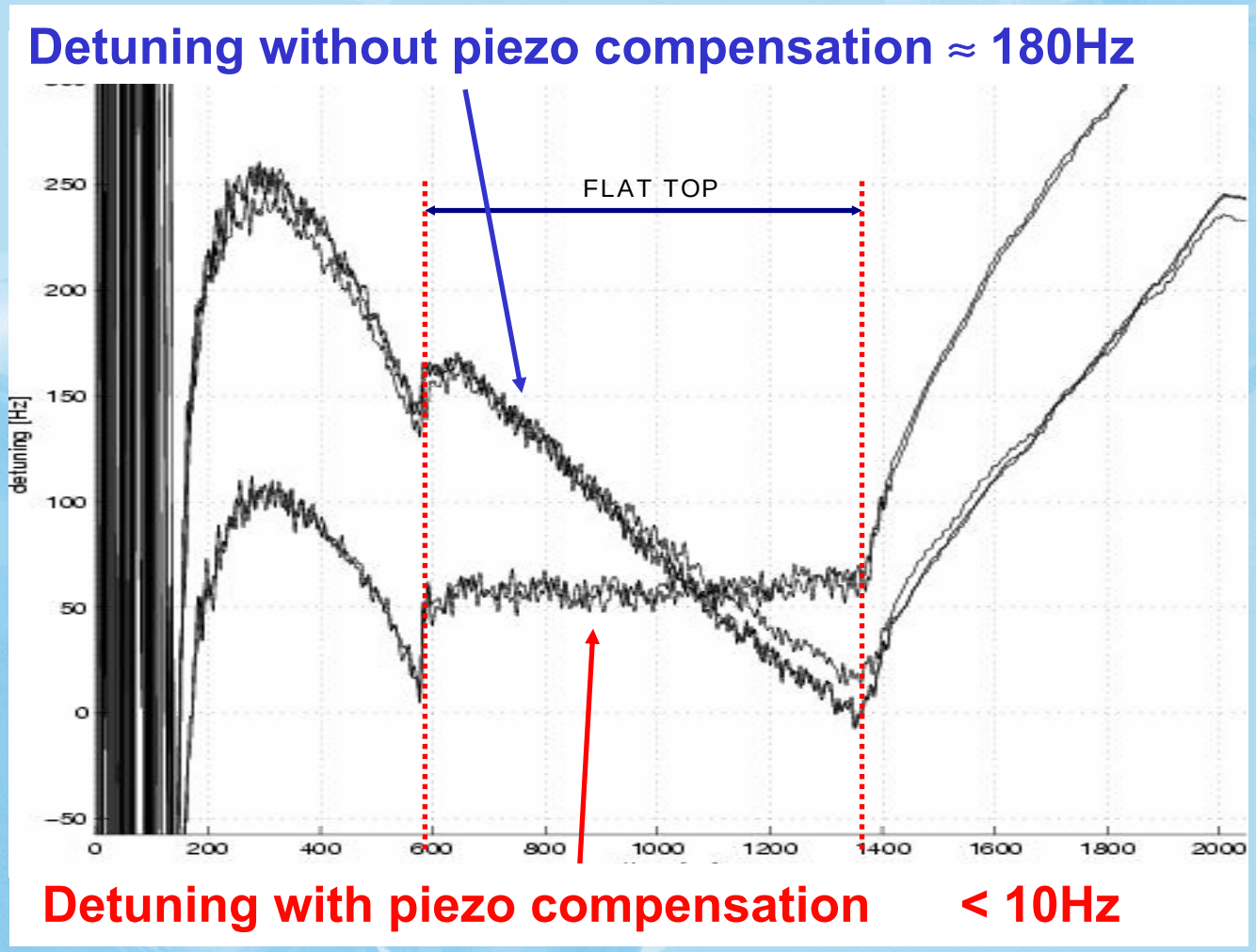


Control panel is now implemented in MATLAB

Final goal is to integrate the algorithms with LLRF system in FPGA or in DSP
(collaboration with WP9)



Results



Measurement done in cavity 5, ACC1 VUV-FEL

field gradient ~20 MV/m

Conclusions

Piezo Tuner System (CEA) and Blade Tuner (INFN) will be **ready** for cold test with cavities **in 2-3 months**.

Piezostack characterization is almost finished. Tested actuators are immune to radiation, might work for required lifetime and fulfils requirements for **VUV-FEL**, **X-FEL** and **ILC**.

The magnetostrictive tuner was run successfully at LHe temperature. Ready for test with the cavity in a month.

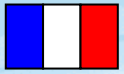
Automatic feed forward algorithm for piezostack-based system for Lorentz force compensation works correctly. It dumps detuning from 180Hz (15MV/m) down to below 10Hz in **2 iterations**.

Conclusions

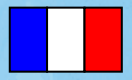
- 2 official WP 8 meetings since beginning of 2005,
- over 10 other meetings,
- 22 talks (TESLA Technology Meeting, SRF, PAC, etc),
- 11 conference papers,
- 2 journal paper,
- one CARE report (8.1.5 Milestone),
- **As of yesterday: gold medal on EUREKA 2005 exhibition.**

I would like to thank to the co-workers...

C. Pagani, A. Bosotti, P. Michelato, R. Paparella, N. Panzeri, P. Pierini, F. Puricelli, INFN Sezione di Milano LASA, Italy
G. Corniani, ZANON, Schio, Italy



Bo Wu, G. Devanz, P. Bosland, E. Jacques , S. Leducq, J.F. Denis, M. Luong, CEA-Saclay, France
and B. Visentin from the CryHolab Group



M. Fouaidy, G. Martinet, N. Hammoudi, F. Chatelet, A. Le Goff, A. Olivier, M. Saki, N. Gandolfo, H. Saugnac, L. Simonet, S. Blivet, F. Galet, S. Rousselot, S. Bousson, IPN-Orsay, France

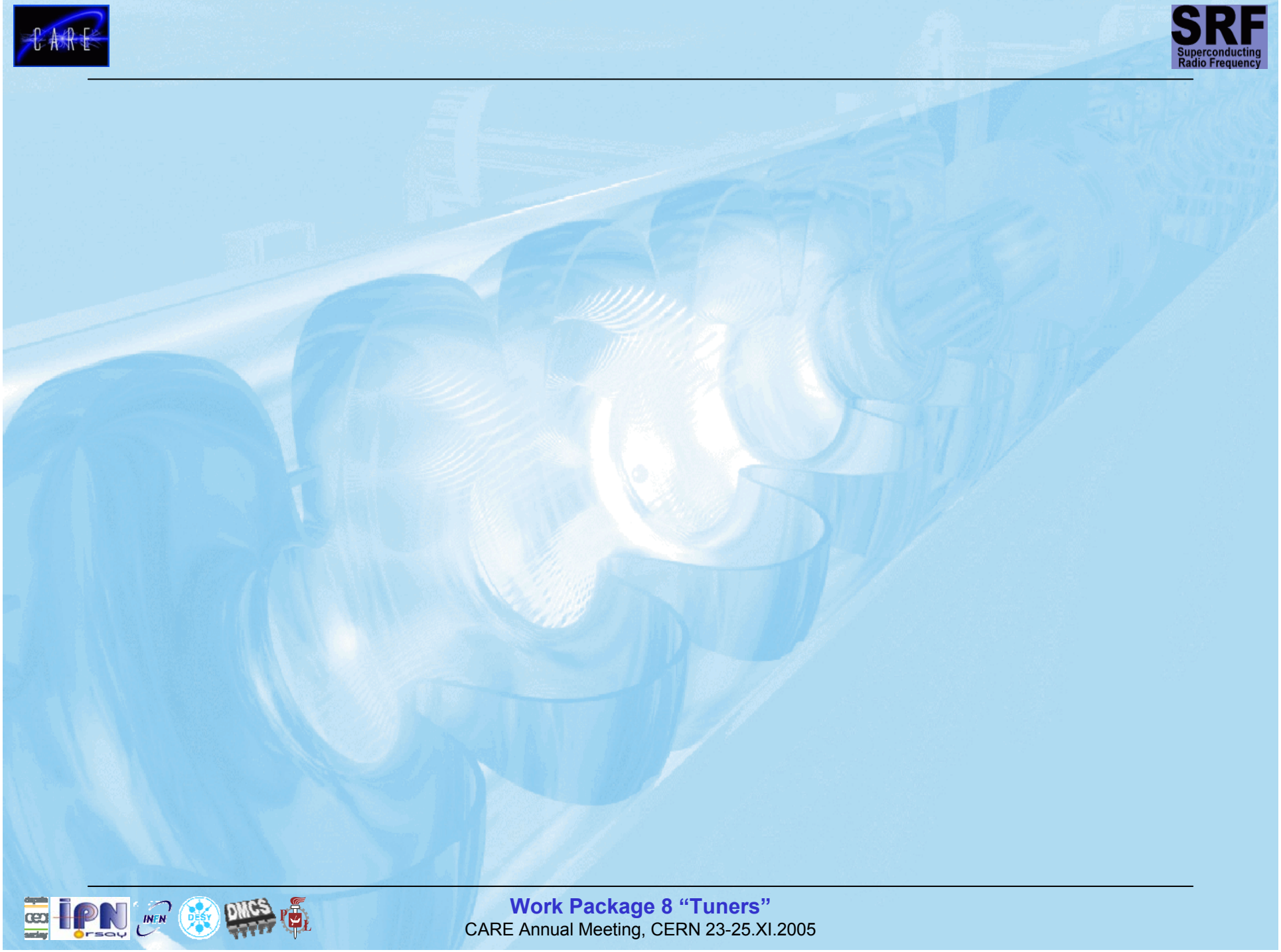
A. Napieralski, M. Grecki, G. Jablonski, DMCS-TUL, Poland

S. Simrock, L. Lilje, R. Lange, C. Albrecht, K. Gadow, J. Schaffran, A. Brandt, DESY-Hamburg

and many others...

Thank you for your attention

sekalski@dmcs.pl



Progress

No	Task	Begin of task	End of task	Apr 05	Jul 05	Nov 05
8	WP8 TUNERS	01.01.04	31.12.07	23%		
8.1	UMI TUNER	01.01.04	31.12.07	13%	30%	57%
8.1.1	Control electronics	01.01.04	02.07.04	**100%**		
8.1.2	Mechanical tuner design, leverage system/motor	03.01.05	29.09.05	20%	**100%**	
8.1.3	Integration piezo design	03.01.05	09.05.05	5%	**100%**	
8.1.4	Choice of transducer/actuator	09.05.05	10.08.05	0%	**100%**	
8.1.5	Report UMI tuner	10.08.05	10.08.05	0%	90%	**100%**
8.1.6	Tuner fabrication	10.08.05	07.02.06	0%	30%	70%
8.1.7	Piezo fabrication and bench tests	07.02.06	06.02.07	0%	0%	0%
8.1.8	Cavity-tuner-coupler integration	04.01.06	30.06.07	0%	0%	
8.1.9	Pulsed RF tests	02.07.07	31.12.07	0%	0%	
8.1.10	Evaluation of tuner operation	31.12.07	31.12.07	0%	0%	
8.2	Magnetostrictive Tuner	01.01.04	31.01.06	31%	55%	80%
8.2.1	Complete specification	01.01.04	30.01.04	**100%**		
8.2.2	Conceptual design	02.02.04	31.03.04	**100%**		
8.2.3	Prototype and performance evaluation	01.04.04	04.02.05	70%	85%	95%
8.2.4	Finalize tuner and drive electronics design	01.07.04	14.04.05	25%	50%	**100%**
8.2.5	Test of tuner	14.04.05	31.01.06	0%	10%	25%
8.2.6	Report on magnetostrictive tuner	31.01.06	31.01.06	0%	0%	

Progress

No	Task	Begin of task	End of task	Apr 05	Jul 05	Nov 05
8.3	CEA Tuner	05.01.04	01.06.05	63%	80%	93%
8.3.1	Design Piezo + Tuning System	05.01.04	18.06.04	100%		
8.3.2	Fabrication	21.06.04	31.03.05	50%	95%	100%
8.3.3	Installation RF	01.04.05	01.06.05	0%	95%	100%
8.3.4	Start of Integrated Experiments	01.06.05	01.06.05	0%	0%	70%
8.4	IN2P3 Activity	01.01.04	07.08.06	21%	50%	80%
8.4.1	Characterize actuators/piezo-sensors at low temperature	01.01.04	21.03.05	60%	85%	95%
8.4.2	Report on actuator/piezo sensor	21.03.05	21.03.05	0%	60%	70%
8.4.3	Test radiation hardness of piezo tuners	01.07.04	15.08.05	20%	100%	
8.4.4	Report on radiation hardness tests	15.08.05	15.08.05	0%	50%	70%
8.4.5	Integration of piezo and cold tuner	03.01.05	06.12.05	5%	20%	100%
8.4.6	Cryostat tests	06.12.05	03.02.06	0%	0%	20%
8.4.7	Tests with pulsed RF	03.02.06	07.08.06	0%	0%	0%
8.4.8	Report on IN2P3 tuner activities	07.08.06	07.08.06	0%	0%	30%

Meetings organized under JRA1

Date	Title / subject	Location	Number of Attendees	Website Address
January 24, 2005	Magnetostrictive tuner development	DESY, Hamburg, Germany	5	
March 11, 2005	Preparation of magnetostrictive test characterization	IPN, Orsay, France	5	
March 30 – April 1, 2005	TESLA Technology Meeting	DESY, Hamburg, Germany	117	tesla.desy.de
April 1, 2005	WP 8 Meeting	DESY, Hamburg, Germany	10	tesla.desy.de/~sekalski
May 16-20, 2005	PAC 2005	Knoxville,		http://www.sns.gov/pac05/
May 30-June 5, 2005	WILGA Symposium	Tennessee, USA	120	http://wilga.ise.pw.edu.pl/2005/eng/
June 22-25, 2005	12th International Conference MIXDES	Wilga, Poland	150	www.mixdes.org
July 10-15, 2005	SRF 2005 Workshop	Cracow, Poland	240	http://www.lns.cornell.edu/public/SRF2005/
August 28-September 2, 2005	SPIE Conference	Warsaw, Poland	100	http://spie.org/home.html
September 19-21, 2005	IMAPS 2005	Darlowo, Poland	90	http://imaps2005.man.koszalin.pl/
October 19-21, 2005	JRA1	Legnaro, Italy	50	

List of talks of JRA1 members

Subject	Speaker/Lab	Event	Date	Web site
Full Characterization at Low Temperature of Piezoelectric Actuators	M. Fouaidy, IPN Orsay	TESLA Technology Meeting	March 31	tesla.desy.de
Magnetostrictive tuner	P. Sekalski, TUL-DMCS	TESLA Technology Meeting	31.03.05	tesla.desy.de
Experiences and Reliability with Cold Saclay Frequency Tuner in CHECHIA and Cryomodules and with Cold Blade Frequency Tuner in CHECHIA and Superstructure Module	R. Lange, DESY	WP 8 Meeting	1.04.05	
New CEA Piezo tuning system	P. Bosland, CEA Sacley	WP 8 Meeting	1.04.05	
UMI tuner	A. Bosotti, INFN Milan	WP 8 Meeting	1.04.05	
Blade tuner	N. Panzeri, INFN Milan	WP 8 Meeting	1.04.05	
Full Characterization at Low Temperature of Piezoelectric Actuators Used for SRF Cavities Active Tuning	M. Fouaidy, IPN Orsay	WP 8 Meeting	1.04.05	
Magnetostrictive tuner and piezo control system	P. Sekalski, TUL-DMCS	WP 8 Meeting	1.04.05	
Mechanical Vibration Measurements on TTF Cryomodules	A. Bosotti (INFN/LASA)	PAC 05	May 20	http://www.sns.gov/pac05/
Full Characterization at Low Temperature of Piezoelectric Actuators Used for SRF Cavities Active Tuning	M. Fouaidy IPN-Orsay	PAC 05	May 20	http://www.sns.gov/pac05/
Variety of Electromechanical Lorentz Force Compensation Systems Dedicated for Superconducting High Field Resonant Cavities	P. Sekalski DMCS-TUL	Wilga Symposium	May 31	http://wilga.ise.pw.edu.pl/2005/eng/

List of talks of JRA1 members cont.

Subject	Speaker/Lab	Event	Date	Web site
Performance of Magnetostrictive Elements at LHe Environment	P. Sekalski DMCS-TUL	MIXDES	June 22	www.mixdes.org
Static and dynamic properties of piezoelectric actuators at low temperature and integration in SRF cavities cold tuning systems	M. Fouaidy IPN-Orsay	MIXDES	June 23	www.mixdes.org
Piezoelectric Stack Based System for Lorentz Force Compensation	P. Sekalski DMCS-TUL	SRF 2005	July 12	http://www.lns.cornell.edu/public/SRF2005/
Electromechanical, Thermal Properties and Radiation Hardness Tests of Piezoelectric Actuators at Low Temperature	M. Fouaidy IPN-Orsay	SRF 2005	July 14	http://www.lns.cornell.edu/public/SRF2005/
Cold Tuning System Dedicated To 700 Mhz Superconducting Elliptical Cavity For Protons Linac	M. Fouaidy IPN-Orsay	SRF 2005	July 14	http://www.lns.cornell.edu/public/SRF2005/
RRR of Copper Coating And Low Temperature Electrical Resistivity Of Material For TTF Couplers	M. Fouaidy IPN-Orsay	SRF 2005	July 14	http://www.lns.cornell.edu/public/SRF2005/
Application of multilayer piezoelectric elements for resonant cavity deformation in VUV-FEL DESY accelerator	A. Napieralski DMCS-TUL	IMAPS 2005	September 20	http://imaps2005.man.koszalin.pl/
Magnetostrictive tuner development and recent results with CTS tuner	P. Sekalski DMCS-TUL	JRA1, Legnaro	October 20	
Status of IPN Orsay activities : R&D on Fast Active Cold Tuning System for SRF cavities	M. Fouaidy IPN-Orsay	JRA1, Legnaro	October 20	
Development of a Piezoelectric Tuner Preliminary tests on C45 TTF Nine-cells Cavity	P. Bosland, CEA Sacley	JRA1, Legnaro	October 20	
Fast Piezo Blade Tuner (UMI Tuner) for SCRF Resonators Design and Fabrication	A. Bosotti, INFN Milan	JRA1, Legnaro	October 20	

Papers

List of papers	Title	Authors	Journal / Conf.
CARE- pub			
	Przegląd prac Politechniki Łódzkiej realizowanych w programie CARE Research overview realized by Technical University of Lodz in CARE framework	A. Napieralski, M. Grecki, P. Sekalski, D. Makowski, M. Wojtowski, W. Cichalewski, B. Koseda, B. Swiercz, **DMCS-TUL**	Elektronika 2/2005, ISSN 0033-2089
	Systemy elektromechaniczne do kompensacji odkształcenia wnęk rezonansowych stosowanych w technologii TESLA Electromechanical systems for shape compensation of TESLA technology based cavities.	P. Sekalski **DMCS-TUL**	Elektronika 7/2005, ISSN 0033-2089

Papers

CARE-Conf			
	Improvement of the Blade Tuner Design for Superconducting RF Cavities	C. Pagani, A. Bosotti, P. Michelato, N. Panzeri, P. Pierini **INFN**	PAC 05
	Performance of Magnetostrictive Elements at LHe Environment	M. Grecki, P. Sekalski, **DMCS-TUL** C. Albrecht **DESY**	12th International Conference MIXDES 2005, pp. 799-802, ISBN 83-919289-9-3.
	The Fast Piezo-Blade Tuner for SCRF Resonators	C. Pagani, A. Bosotti, P. Michelato, N. Panzeri, R. Paparella, P. Pierini **INFN**	SRF 05
	Electromechanical, Thermal Properties and Radiation Hardness Tests of Piezoelectric Actuators at Low Temperature	M. Fouaidy, G. Martinet, N. Hammoudi, F. Chatelet, A. Olivier, S. Blivet, H. Saugnac, A. Le Goff, **IPN**	SRF 05
	Cold Tuning System Dedicated To 700 Mhz Superconducting Elliptical Cavity For Protons Linac	M. Fouaidy, N. Hammoudi, N. Gandolfo, S. Rousselot, M. Nicolas, P. Szott, S. Blivet, H. Saugnac, S. Bousson, **IPN**	SRF 05
	RRR of Copper Coating And Low Temperature Electrical Resistivity Of Material For TTF Couplers	M. Fouaidy, N. Hammoudi, **IPN** S. Prat, **LAL**	SRF 05
	Piezoelectric stack based system for Lorentz force compensation caused by high field in superconducting cavities	P. Sekalski, A. Napieralski, **DMCS-TUL** S. Simrock, **DESY**	SRF 05
	CARE activities on superconducting RF cavities at INFN Milano	A. Bosotti, P. Pierini, P. Michelato, R. Paparella, N. Panzeri, L. Monaco, R. Paulon, M. Novati **INFN** C. Pagani, **DESY**	SPIE Conference, Warsaw, Poland
	Application of multilayer piezoelectric elements for resonant cavity deformation in VUV-FEL DESY accelerator	A. Napieralski, P. Sekalski **DMCS-TUL**	IMAPS 2005

Papers

CARE-Note			
	PI piezo Life Time Test Report	A. Bosotti, R. Paparella, F. Puricelli **INFN Milan**	
	Mechanical study of the “Saclay piezo tuner” PTS (Piezo Tuning System)	P. Bosland, Bo Wu, **DAPNIA - CEA Saclay**	
CARE Report			
	Report on Fast Piezo Blade Tuner (UMI Tuner) for SCRF Resonators Design and Fabrication **8.1.5 Milestone**	C. Pagani, A. Bosotti, P. Michelato, R. Paparella, N. Panzeri, P. Pierini, F. Puricelli **INFN Sezione di Milano LASA, Italy** G. Corniani, **ZANON, Schio, Italy**	
CARE/SRF Document			

Motivation

The cavities are pulsed at high field.

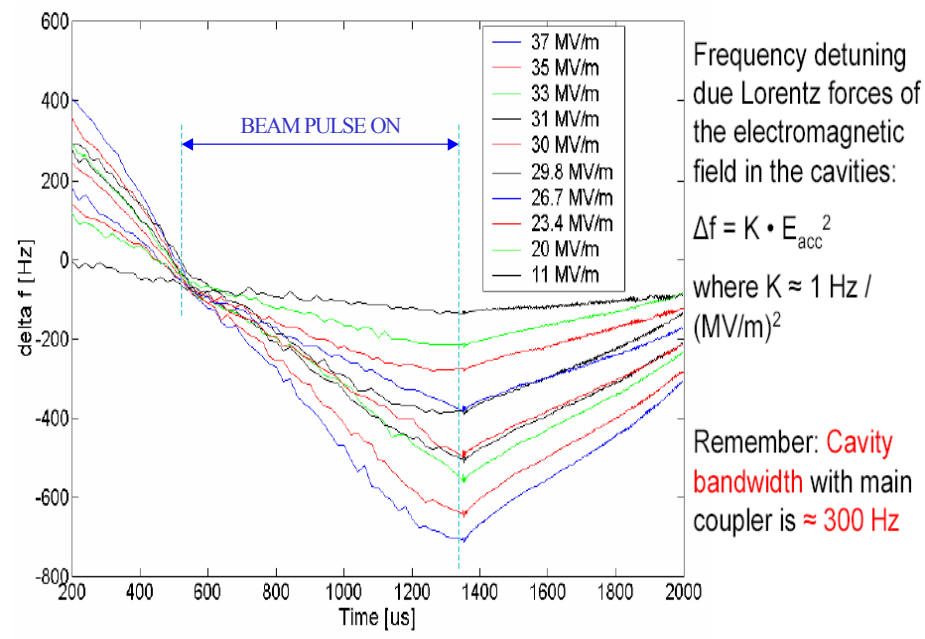
The field generates the radiation pressure, which interacts with cavity walls.

The cavity changes its dimensions,

The change of the resonant frequency of the cavity,

The master oscillator frequency is constant.

De-tuned cavity



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

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

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

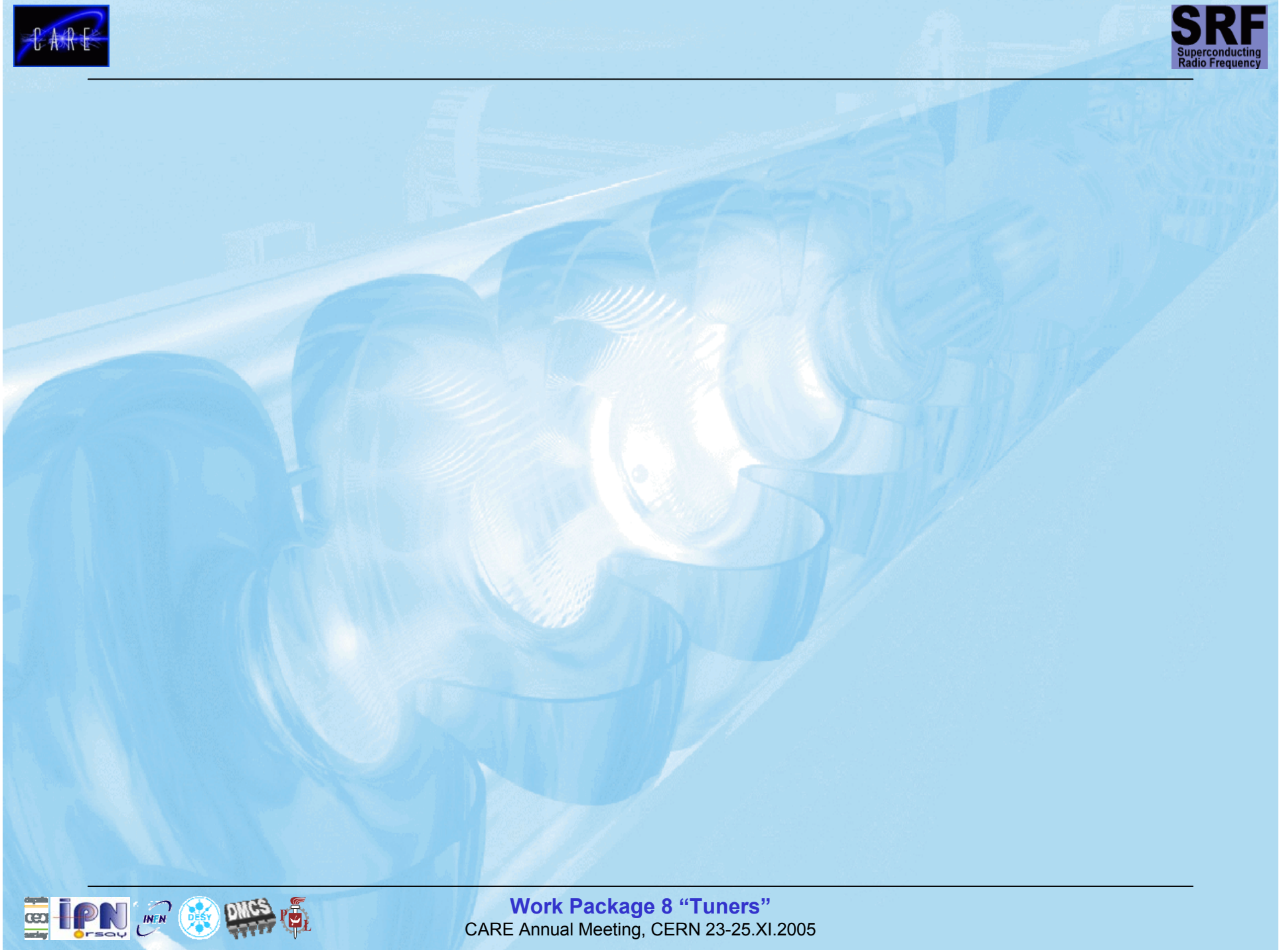
Remember: Cavity bandwidth with main coupler is ≈ 300 Hz

1. Additional RF power
   for field control could be used
2. Passive detuning system
   (stiffness rings, stiffer cavity, fixture) could be used
3. Active detuning system
   with piezoelectric and/or magnetostrictive device could be used

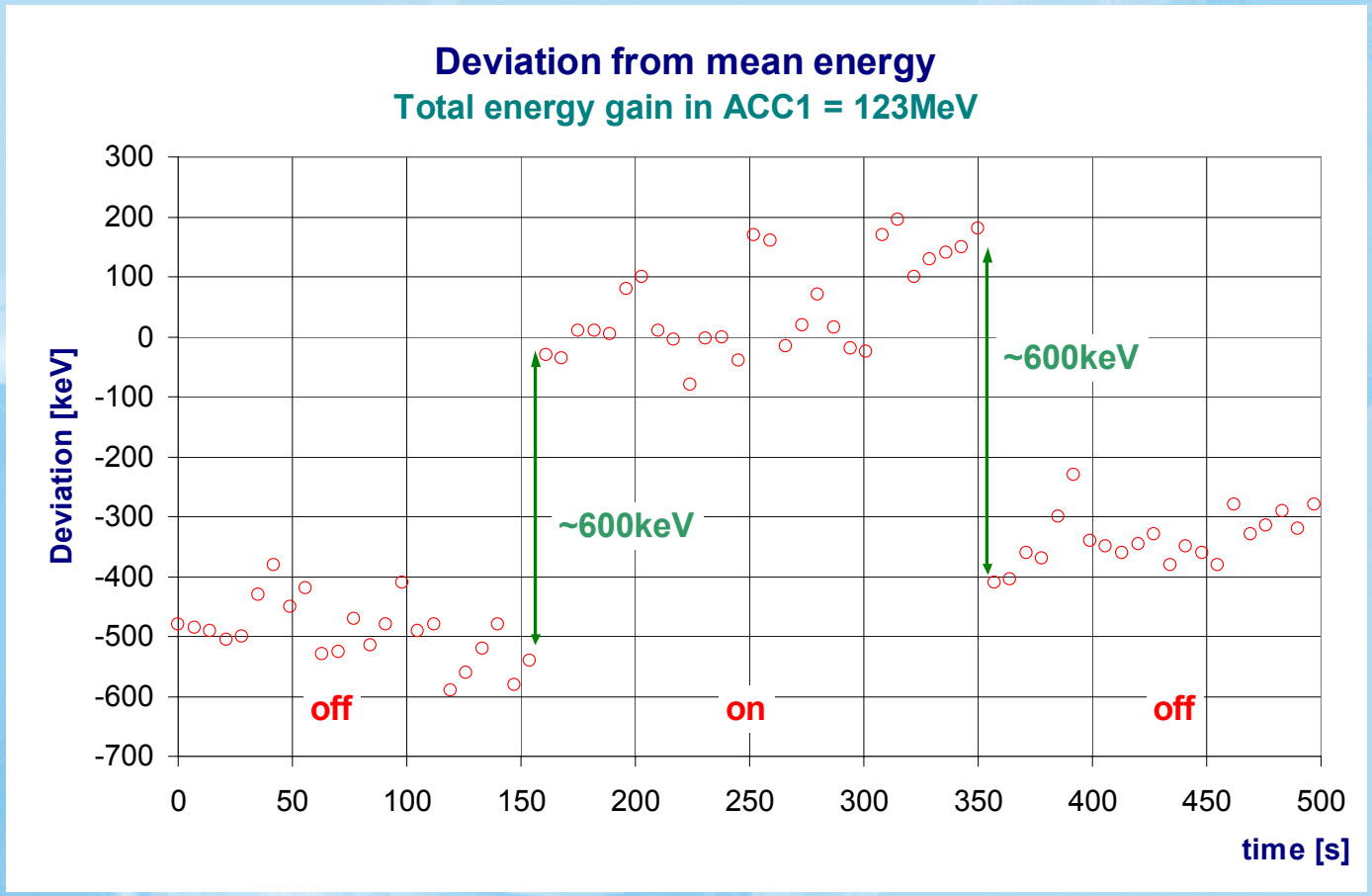
CARE JRA1

WP 8

TUNERS



Result of beam energy drift



The energy increases by almost **600keV** (**0.5%**) due to the fast tuner applied to **only one** cavity (cav5/ACC1)

The drift is caused by the klystron. Feedback in ACC1 was switched off.