Summary of the Superconducting RF WG

Lutz.Lilje@desy.de
DESY -MPY-
23.6.2005

- Overview on talks given
- List European Assets for the ILC
- Define necessary R&D and its benefits and needs

ILC SCRF I (08:30->10:00)

Chair: L. Lilje
Location: Arts
Room: ALT2--

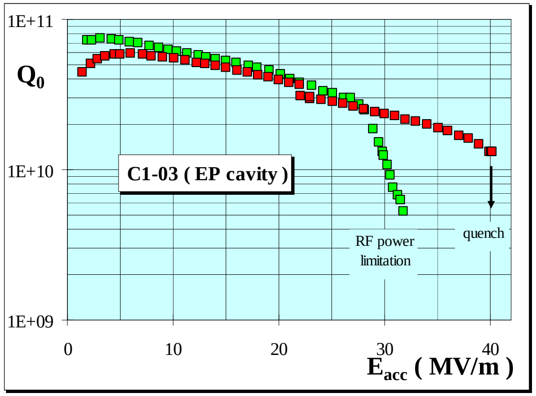
08:30	**Introduction to the WG** (15') Outline of the WG Agenda - Preparation for Snowmass	**Lilje, Lutz** *(DESY)*
08:45	**European Assets for the ILC** (30') (EU_SRF_infrastructures_20_6_05_xls.pdf transparencies) Review of European Research Infrastructures for the ILC - Collection of Information	**Proch, Dieter / Lilje, Lutz** *(DESY)*
09:15	**Optimization of the Baking Process for ILC** (20') (ILC_Baking_BV.pdf)	**Visentin, Bernard** *(CEA Saclay)*
09:35	**Electropolishing Issues** (20') (RD_EP_ju_05_LL.pdf)	**Antoine, Claire** *(CEA Saclay)*
10:00	coffee	

dapnia cea saclay

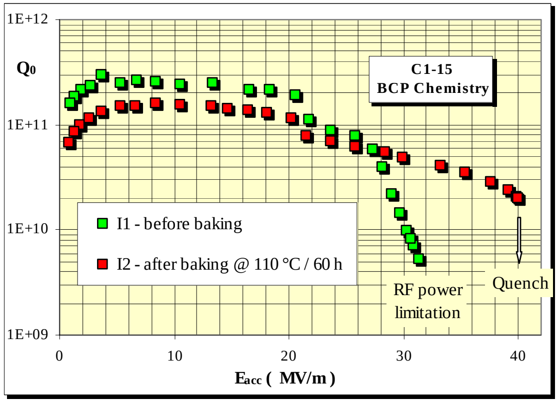
Baking ≡ *Recipe for high gradients*

T = 110 - 120 °C   t = 1 - 2 days

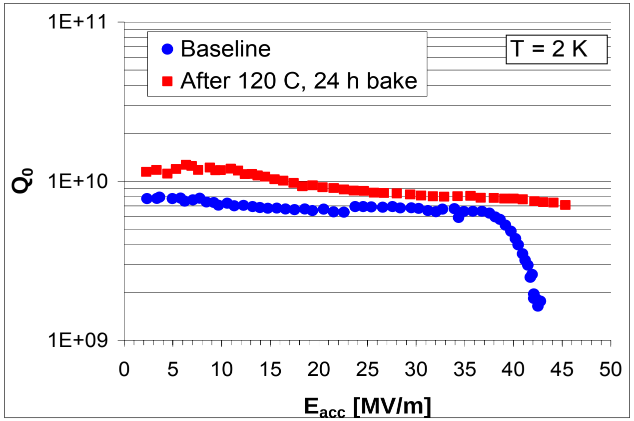
(Narrow Tuning Range)



1.3 GHz - Saclay / KEK
Electropolishing
Poly-crystal



1.3 GHz - Saclay
Chemical etching
Poly-crystal



2.2 GHz - JLab
Chemical etching
Single crystal

Whatever the niobium structure… (Single or Poly-crystal,)

Whatever the fabrication method…(EB Welding or Hydroforming, bulk Nb or clad Nb/Cu)

Whatever the chemical treatment… (Electropolishing or Buffered Chemical Polishing)

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cea
saclay

« In-Situ » Baking

unadapted to

Cavity Mass Production

Clean Room
(Class 100)

- High Pressure Rinse - 85 bars (FE)
- Air-Drying : **RT – 3 hours**
- Assembly + Helium Test

Test Stand
(Vertical Cryostat)

- (RF Test)
- « in-situ » Baking : **110 °C - ~~2 days~~**
- RF Test

save time:

<u>decrease</u> Baking Duration

risk of helium leaks ($\propto$ T)
for final RF test:

Baking <u>before</u> Assembly

save step:

Drying <u>with</u> Baking

Hot Air - Drying

well adapted to

Cavity Mass Production

Clean Room
(Class 100)

- High Pressure Rinse - 85 bars (FE)
- Hot Air-Drying : **T – 3 hours**
- Assembly + Helium Test

Test Stand
(Vertical Cryostat)

- RF Test

save time:

decrease Baking Duration

risk of helium leaks ($\propto$ T)
for final RF test:

Baking before Assembly

save step:

Drying with Baking

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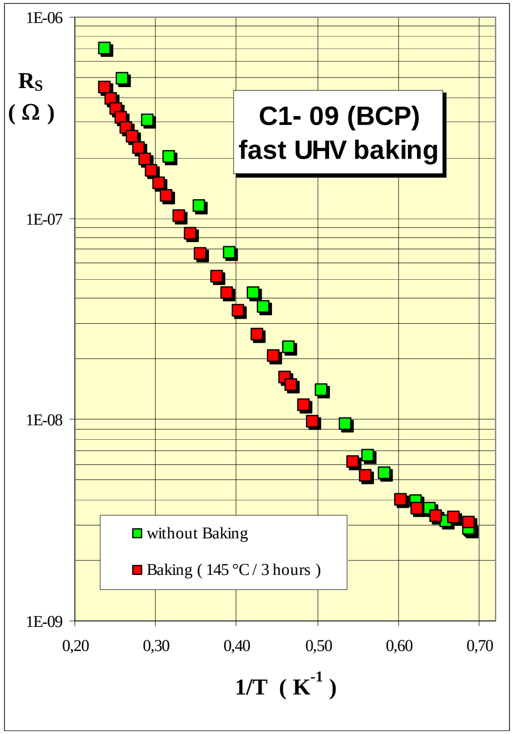
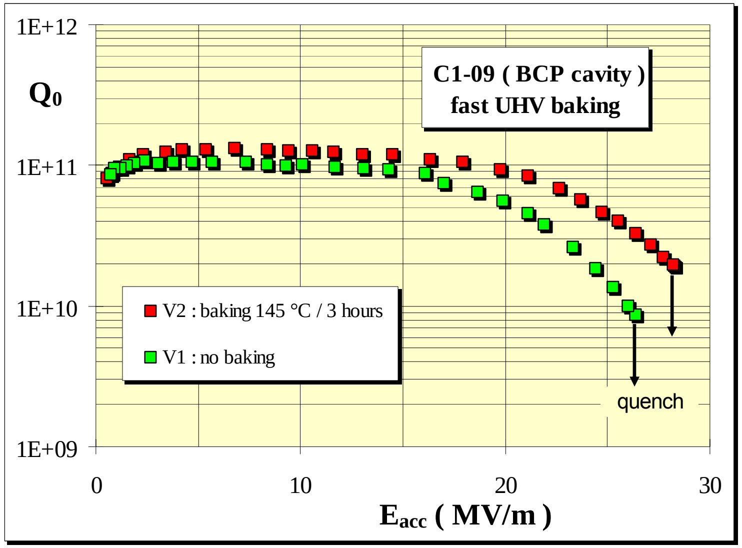
International Linear Collider

« Fast » Baking (UHV)

- Cavity pumped out (Ultra High Vacuum)
- Infra-Red emitters (T : short rise time)





145 °C - 3 hours

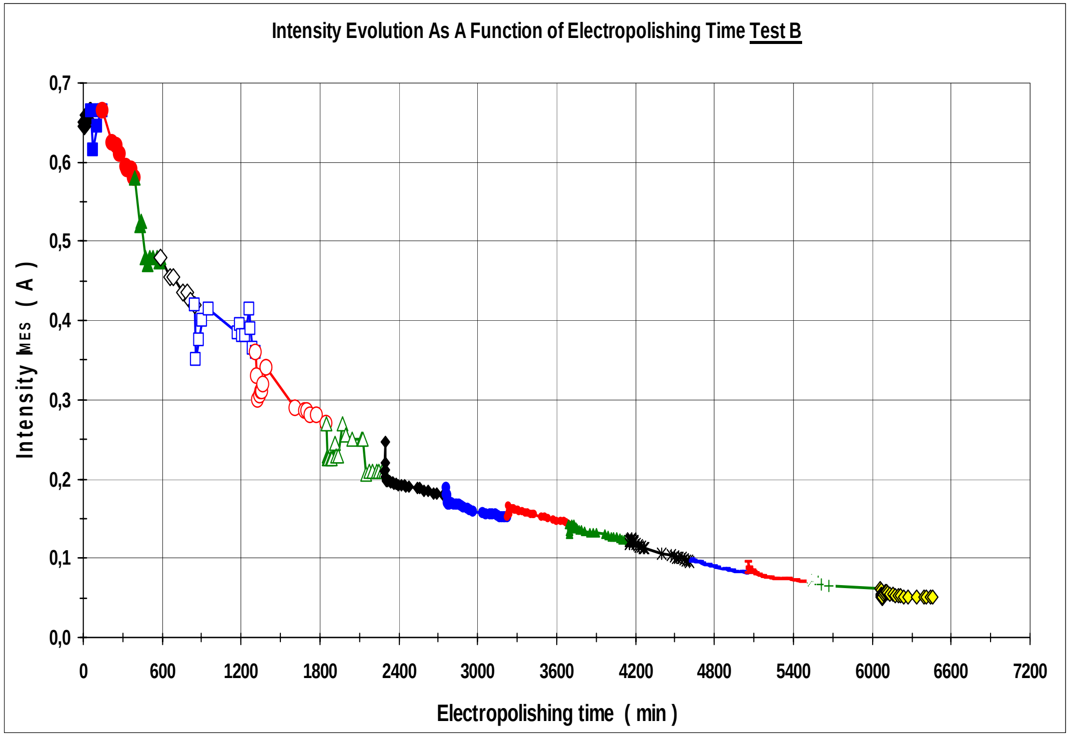
Right Hypothesis

Q-slope ↔ O diffusion

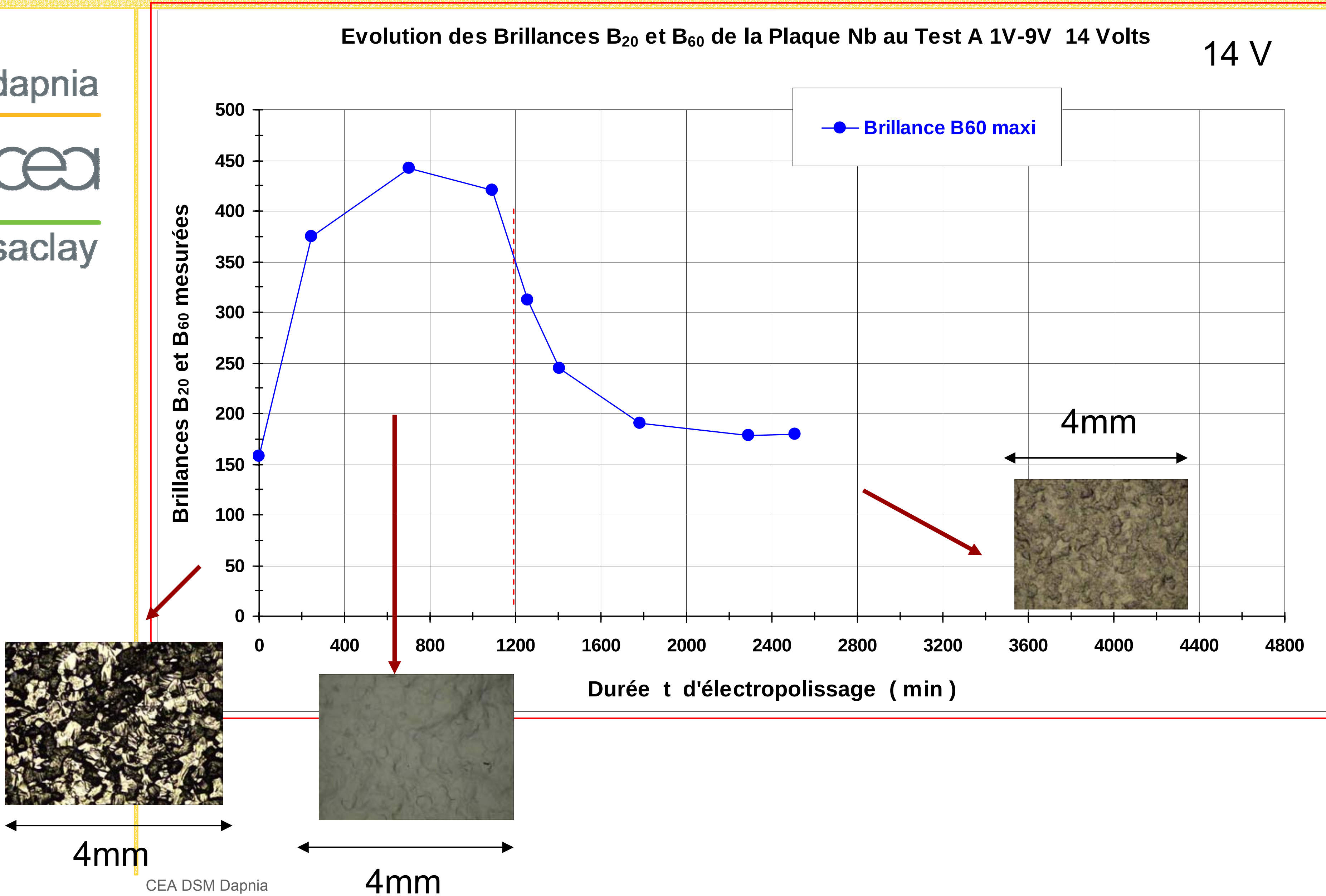
Aging Of The Bath

dapnia
cea
saclay

- Drop in the polishing speed.
- Deterioration of samples' surface.
- Changes in intensity oscillations.
- Aluminum corrosion, S and H_2S production



Aging effect on samples' surface



Aluminum corrosion, S and H_2S production

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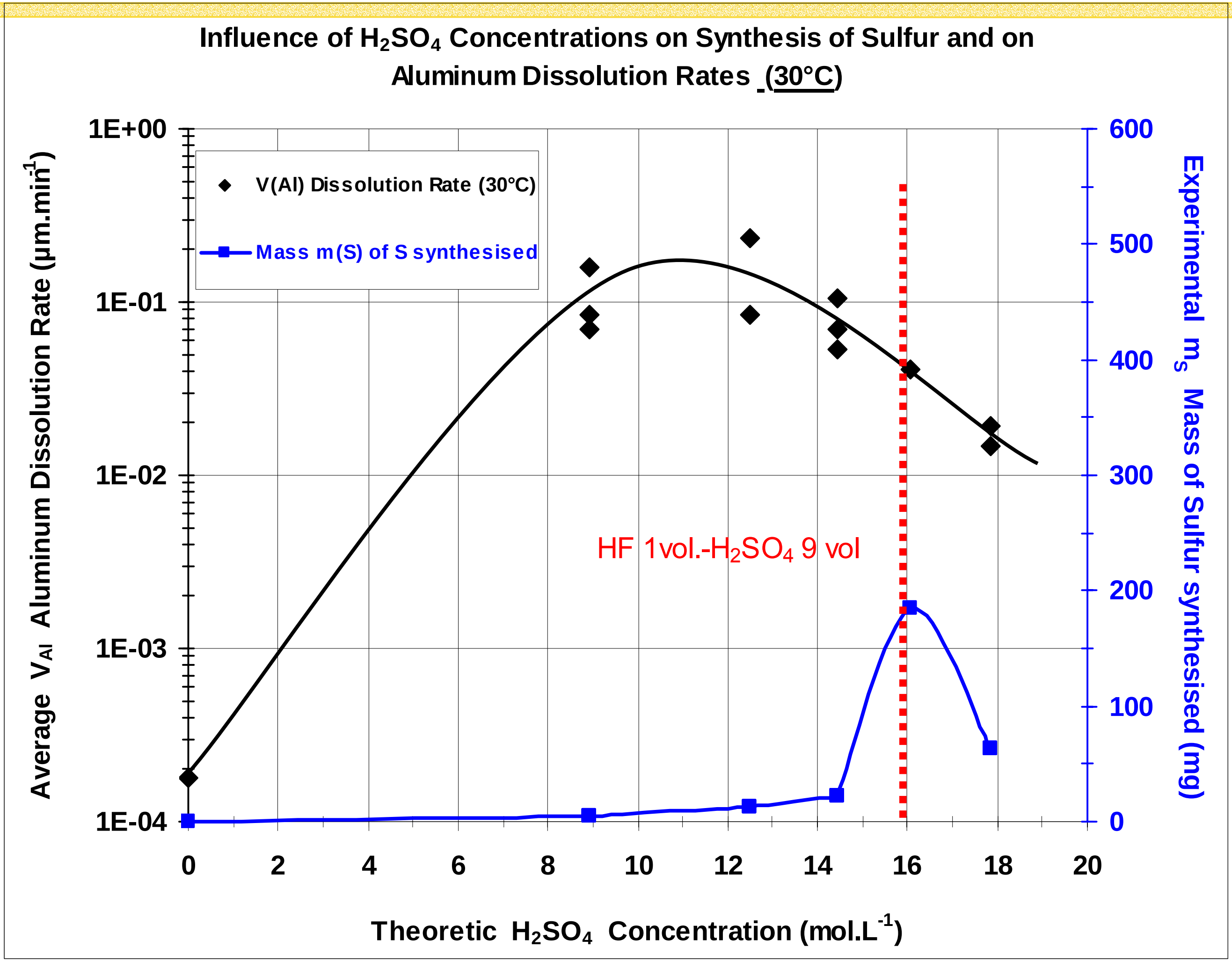
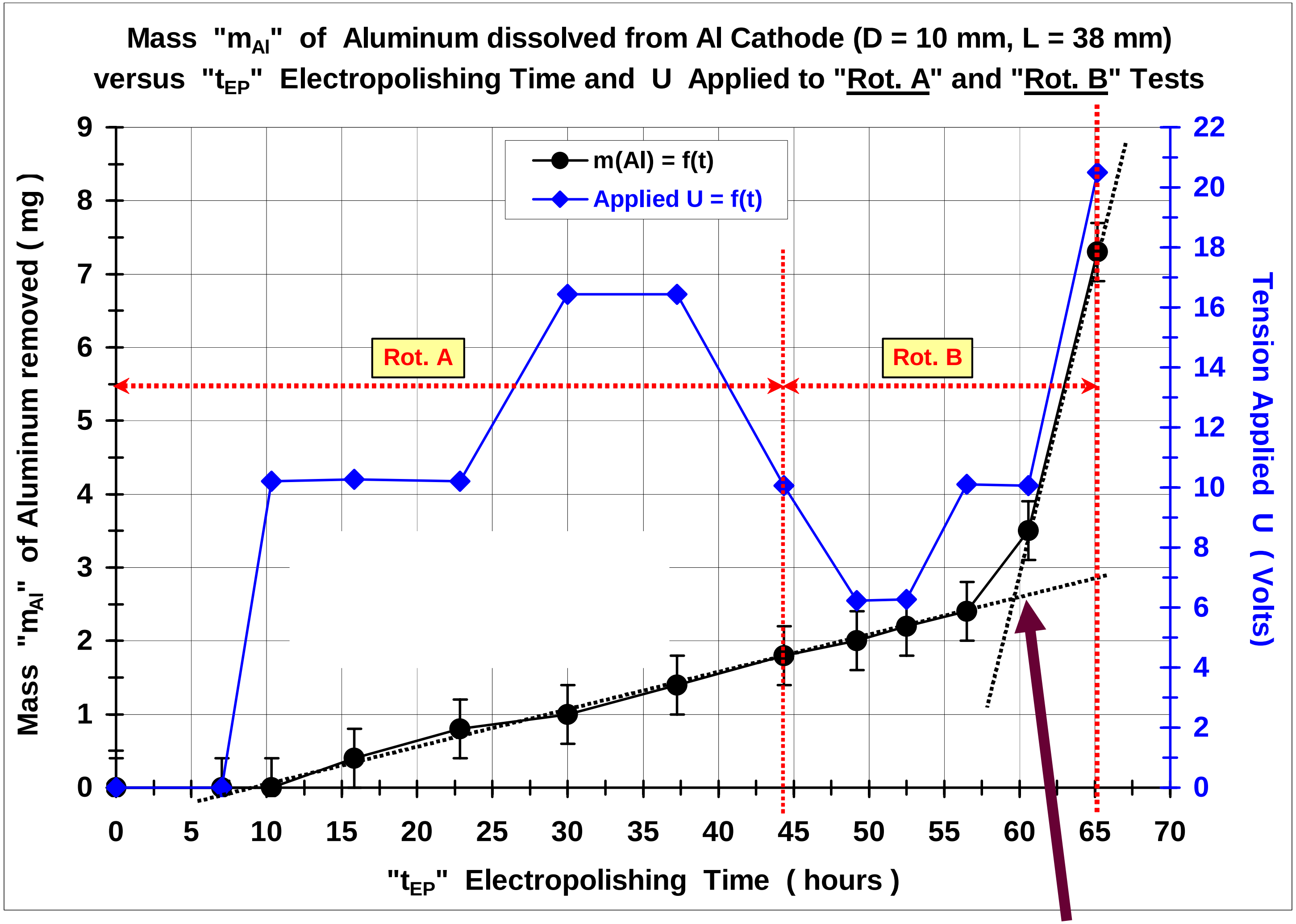


Lower content of H_2SO_4 reduces S production but increases Al corrosion (± acceptable !)

Cathode corrosion under bias



Corrosion becomes important when HF has reduced due to reaction + evaporation

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Without bias

- HF prevents S synthesis in presence of H_2SO_4
- H_2SO_4 hinders Al dissolution in presence of HF
- Active dissolution of Al and production of S when HF decreases (evaporation, reaction)

With bias:

- Synthesis of S and corrosion of aluminum cannot be hindered
- They can be reduced (↑ HF, ↑ H_2O,↓ H_2SO_4)

Conclusion 1

S is not soluble in H_2O : rinsing process

- works in ethanol, but not very effective
- is very effective in chloroform, but safety issues

Rinsing process must be improved

Aluminum :

- Is slightly dissolved in acidic mixture
- keeps in the form of Al^{3+} salts

Rinsing process must be improved

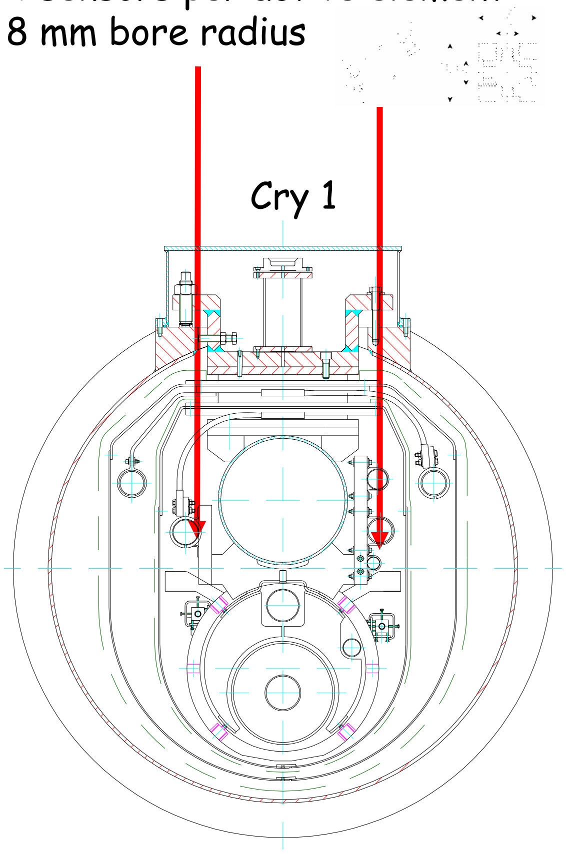
+ Change in EP bath composition : ↑ HF, ↑ H_2O

ILC SCRF II (10:30->12:00)			Chair: L. Lilje Location: Arts Room: ALT2--
10:30	Module Issues (20') (C.Pagani_ILC-EU_cryomodules.pdf)		Pagani, Carlo *(INFN)*
11:00	Coupler R&D for the ILC (20') (ILC_Royal_Holloway_Couplers.pdf)		Variola, Alessandro *(LAL Orsay)*
11:30	Tuner Issues (Lateral + Coaxial Tuner) (30') (C.Pagani_ILC-EU_tuner.pdf)		Pagani, Carlo *(INFN)*
12:00	lunch		

Wire Position Monitors

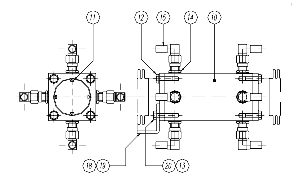
On line monitoring of cold mass movements during cool-down, warm-up and operation

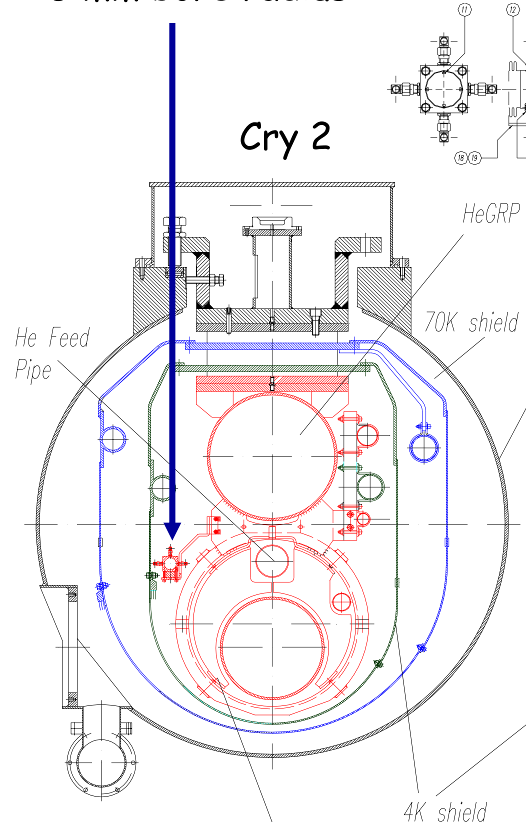
2 WPM lines with 2 x 18 sensors
4 sensors per active element
8 mm bore radius



Module 1

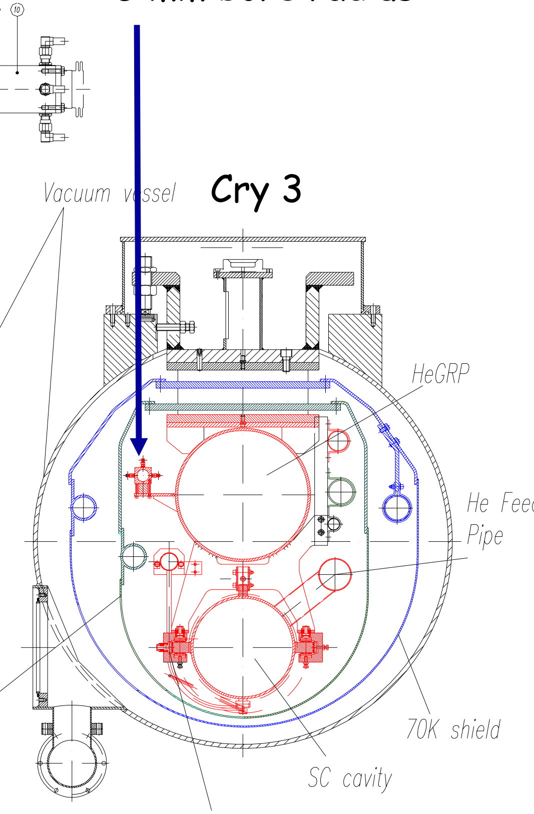
1 WPM lines
1 sensors per active element
25 mm bore radius





Module 2 & 3

1 WPM line
7 sensors/module
25 mm bore radius



Module 4 & 5

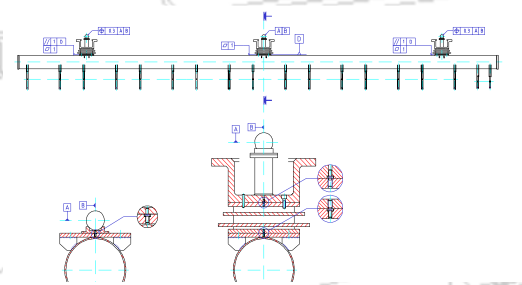
Performing Cryomodules

Three cryomodule generations to:

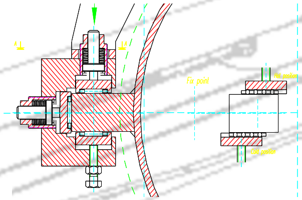
- improve simplicity and performances
- minimize costs

"Finger Welded" Shields

Reliable Alignment Strategy



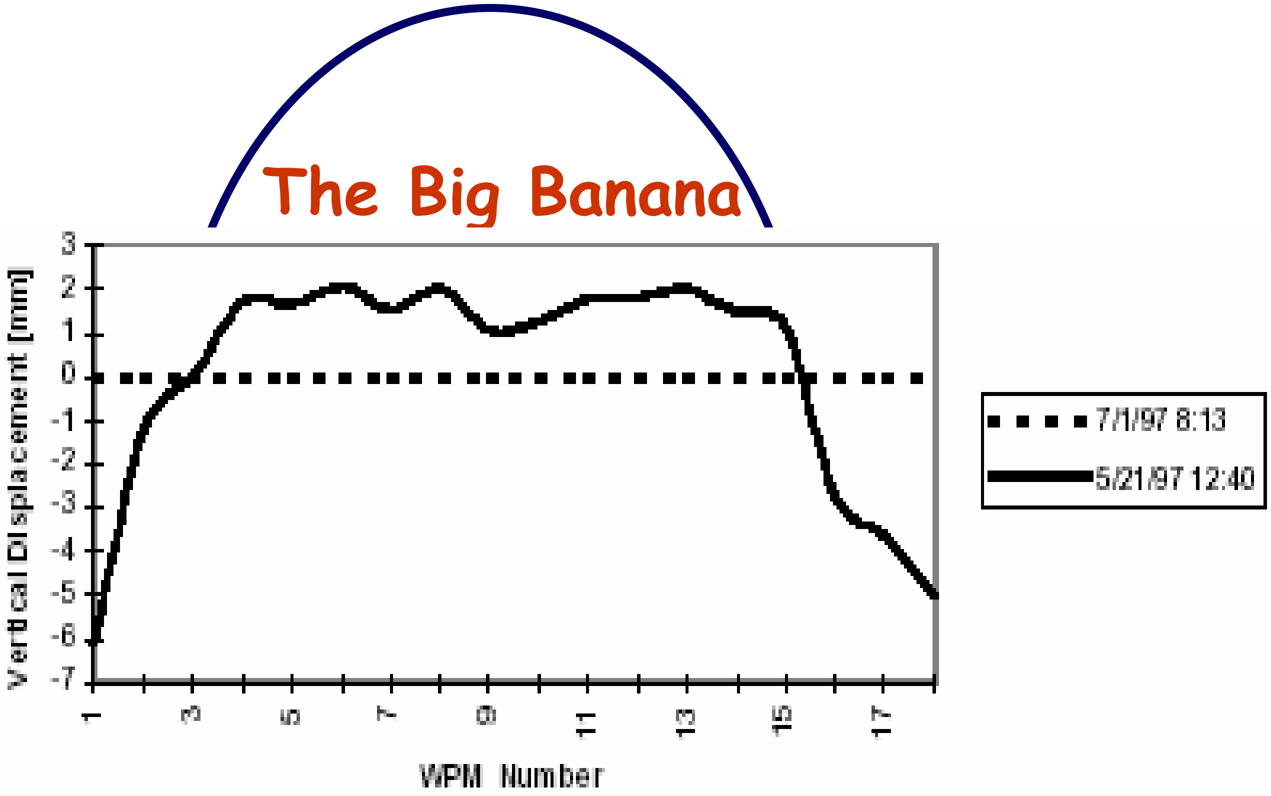
Sliding Fixtures @ 2 K



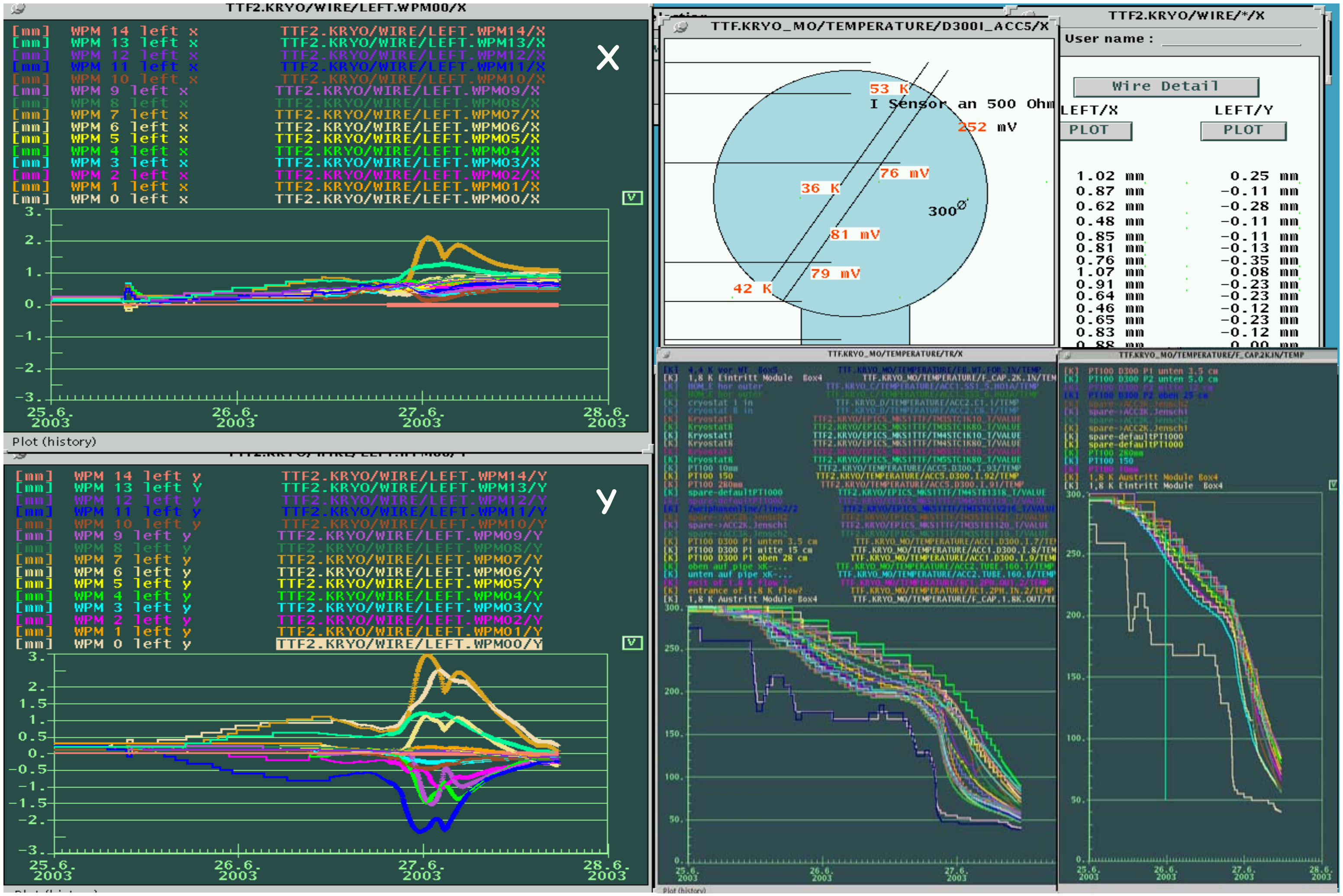
Required plug power for static losses < 5 kW/(12 m module)

Large Bending in First Cooldown

New Cooldown procedure suggested by the WPM's measurements during the first "fast" cooldown



Safe Cooldown of ACC4 and ACC5



TESLA Cryomodule Concept Peculiarities

Positive

- Very low static losses
- Very good filling factor: Best real estate gradient
- Low cost per meter in term both of fabrication and assembly

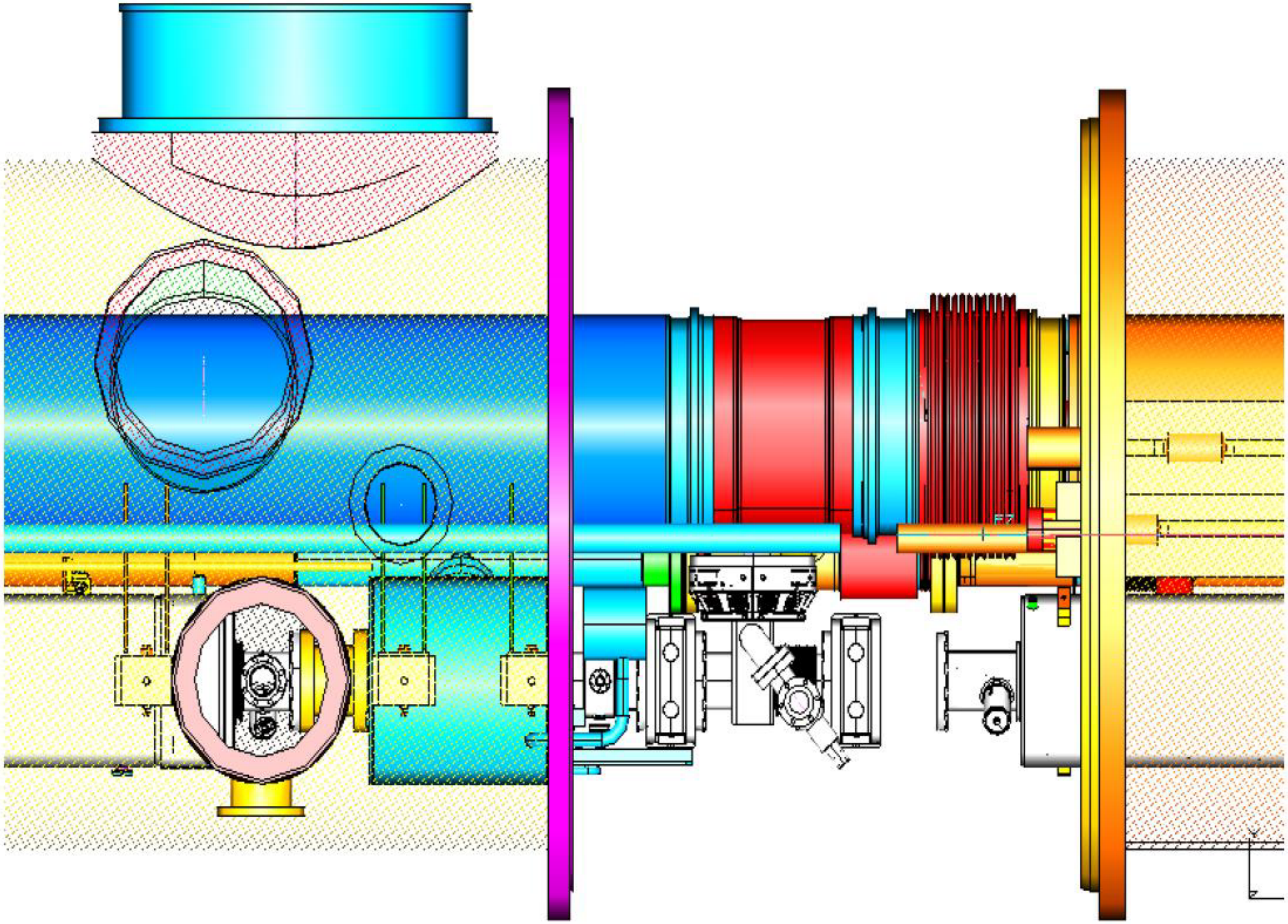
Project Dependent

- Long cavity strings, few warm to cold transitions
- Large gas return pipe inside the cryomodule
- Cavities and Quads position settable at ± 300 μm (rms)
- Reliability and redundancy for longer MTTR (mean time to repair)
- Lateral access and cold window natural for the coupler

Negative ?

- Longer MTTR in case of non scheduled repair
- Moderate (± 1 mm) coupler flexibility required

Cry3 adaptation in progress



- Manufacture of 30 TTF-III Couplers in Industry for VUV/FEL - Installation. This experimental set-up will be used for all the others activities

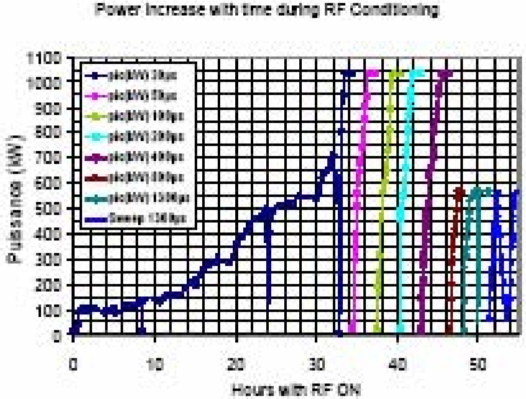
Class 10 clean room

Klystron/modulator

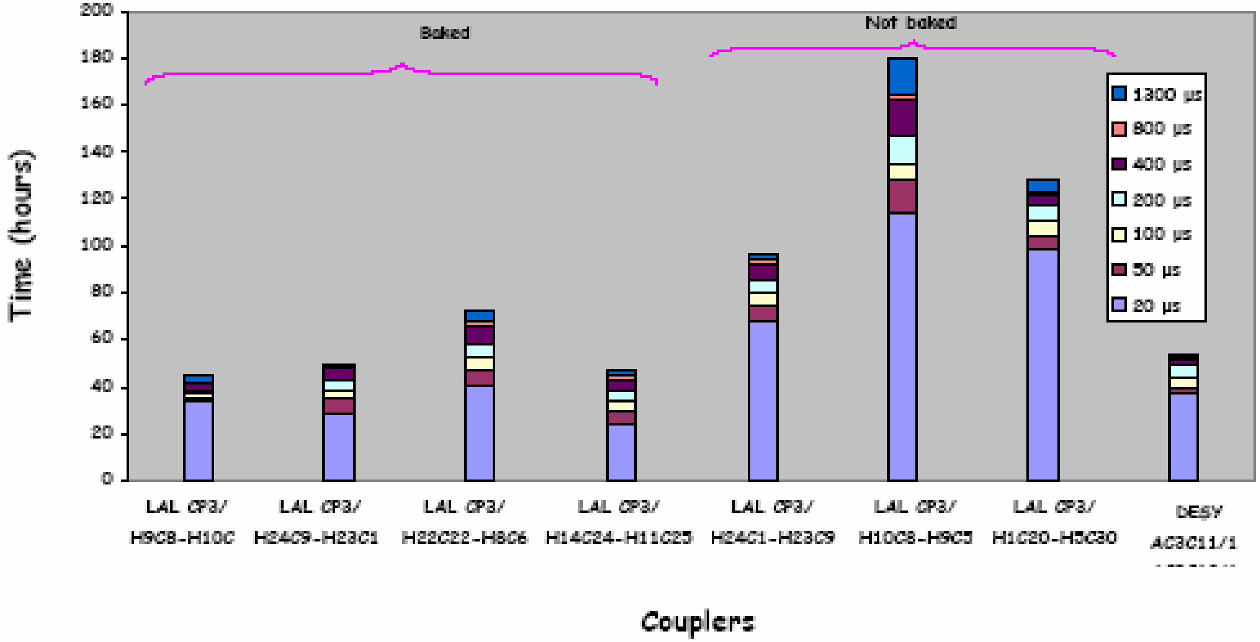
Vacuum furnace

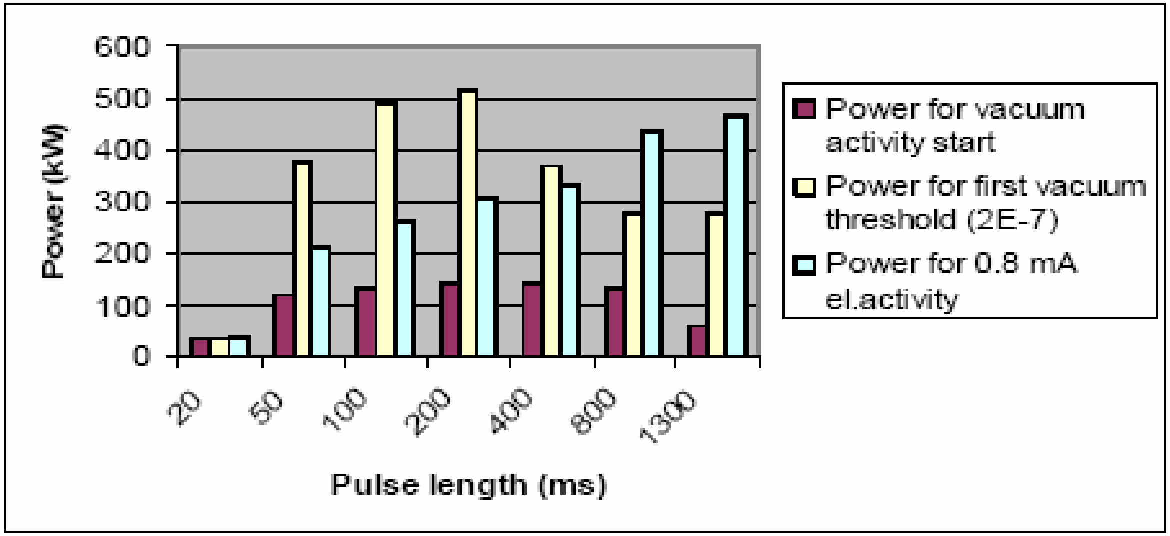
Ultra-pure water production

Reception, cleaning mounting
Conditioning and tests



Alessandro Variola, LAL-ORSAY
ILC European Regional meeting, OXFORD


Baked
Not baked
Time (hours)
1300 µs
800 µs
400 µs
200 µs
100 µs
50 µs
20 µs
LAL CP3/ H9C8-H10C
LAL CP3/ H24C9-H23C1
LAL CP3/ H22C22-H8C6
LAL CP3/ H14C24-H11C25
LAL CP3/ H24C1-H23C9
LAL CP3/ H10C8-H9C5
LAL CP3/ H1C20-H5C30
DESY AC3C11/1
Couplers

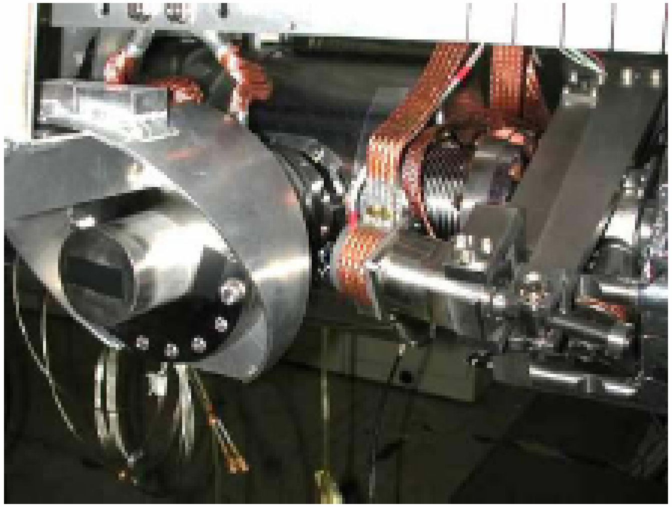

Power (kW)
Power for vacuum activity start
Power for first vacuum threshold (2E-7)
Power for 0.8 mA el.activity
20
50
100
200
400
800
1300
Pulse length (ms)

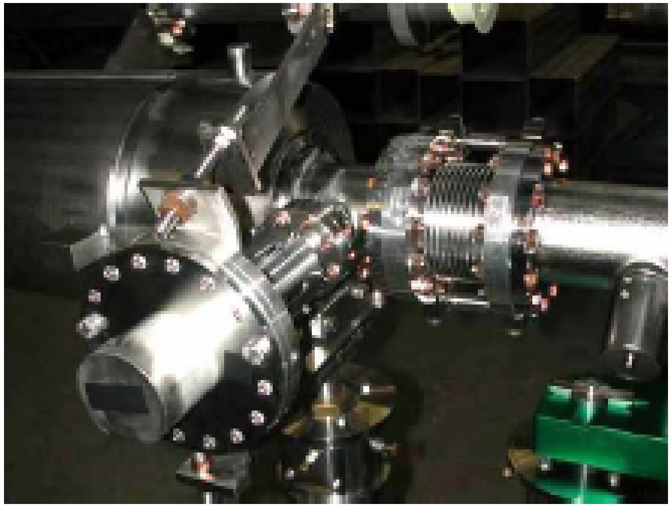
10 "spare" couplers for different measurements

- Some ideas for Conditioning Studies :
  - Memory effect (Couplers stored)
  - DC bias sweep to provoke multipactor
  - Argon discharge cleaning
  - Ceramics coated with Zi-Va-Ti
  - Fully Ti or TiN coated coupler (Couplers ready to be coated - Ti @ CERN if possible)
  - Effect of different environments on re-conditioning times (vacuum, N_2,….)
  - Establish maximum limits for interlock thresholds @ rep. rate
  - Effect of assembly of warm part in class 10 clean room
  - Central antenna as an e^- pick-up
  - And other ideas are discussed…………………………………….

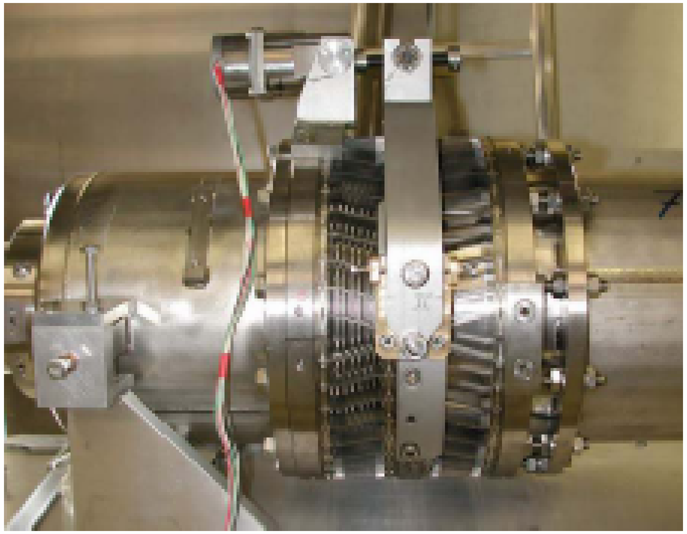
References for the New Tuner Designs

The Saclay Tuner in TTF

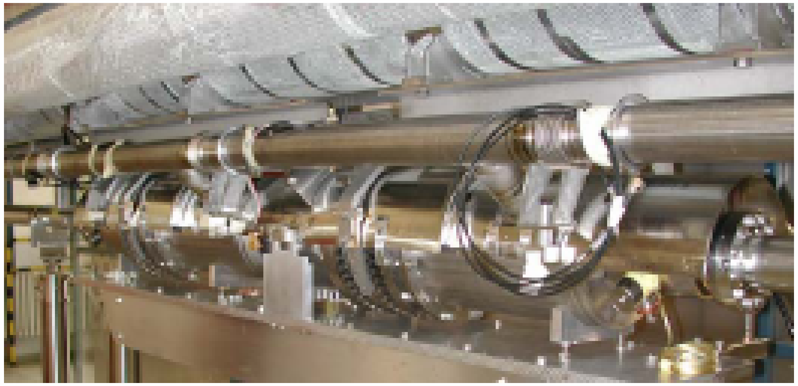




The INFN Blade-Tuner



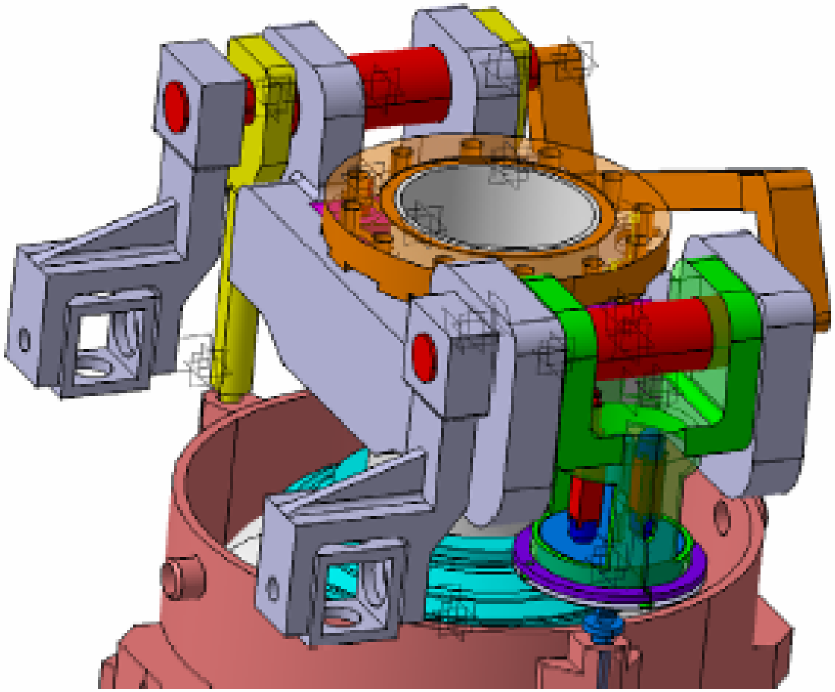
Successfully operated with superstructures



The New Saclay Tuner for XFEL

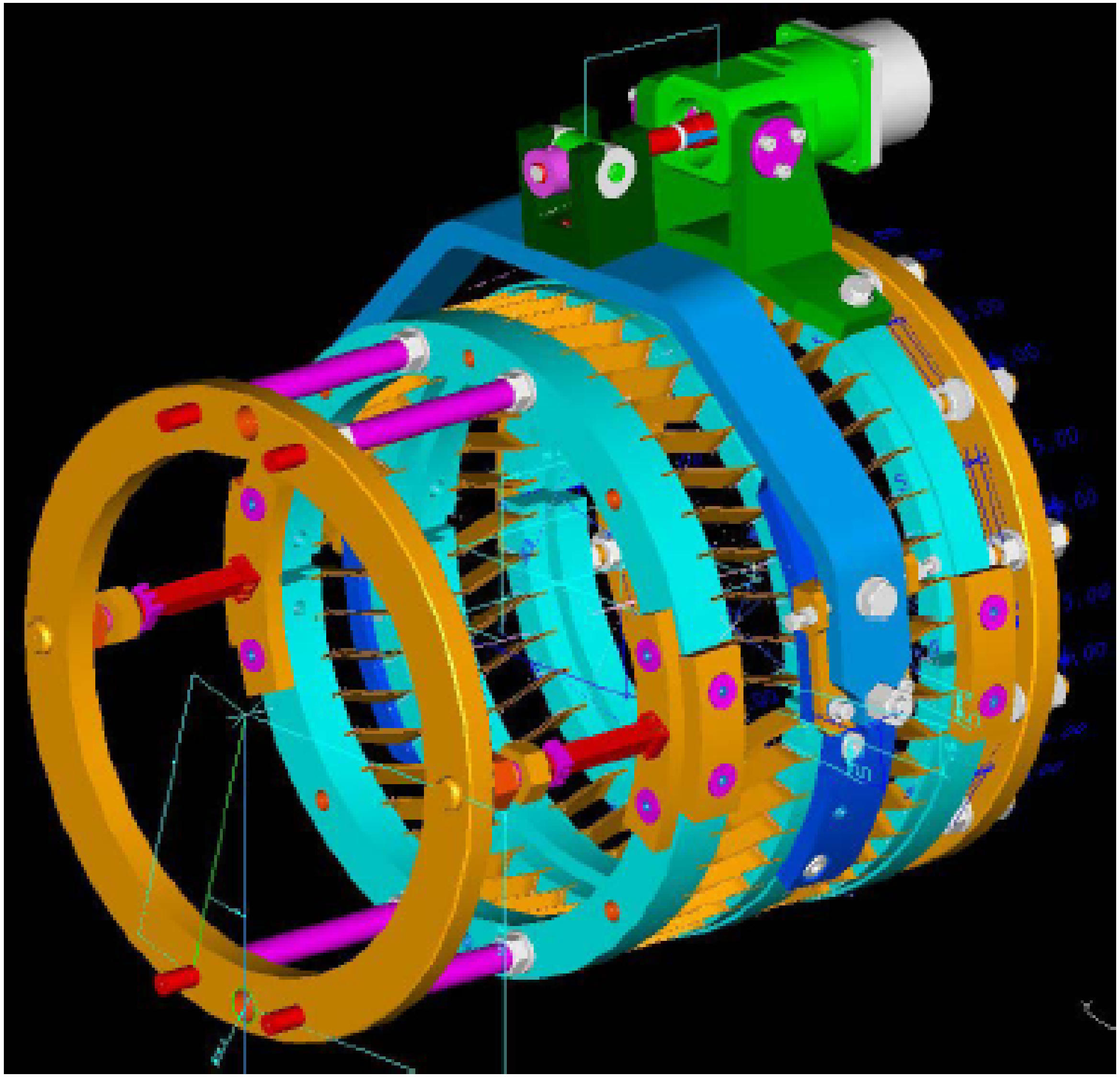
New design with piezos

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

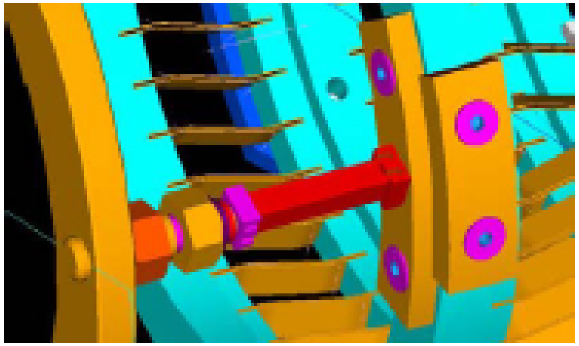


- Fabrication of 2 tuners since beginning of 2005
- 12 NOLIAC piezos, 2 PHYTRON stepping motors ordered
- Coll. with IPN Orsay: CEA send NOLIAC piezos to IPN for characterization, and IPN send P.I. piezos for tests on tuners
- Coll. with INFN-Milano for measurement with stress sensors @ 2K

The New INFN Blade-Tuner



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



Piezo characterisation

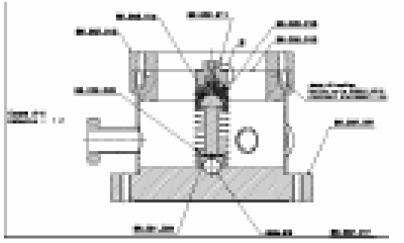
Displacement (stroke) vs. applied voltage

Force vs. applied voltage

Capacitance vs. temperature and preload force

Impedance vs. temperature and preload force

Blocking force

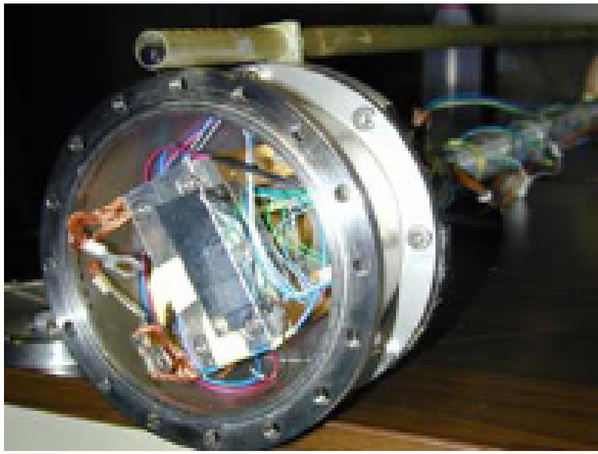


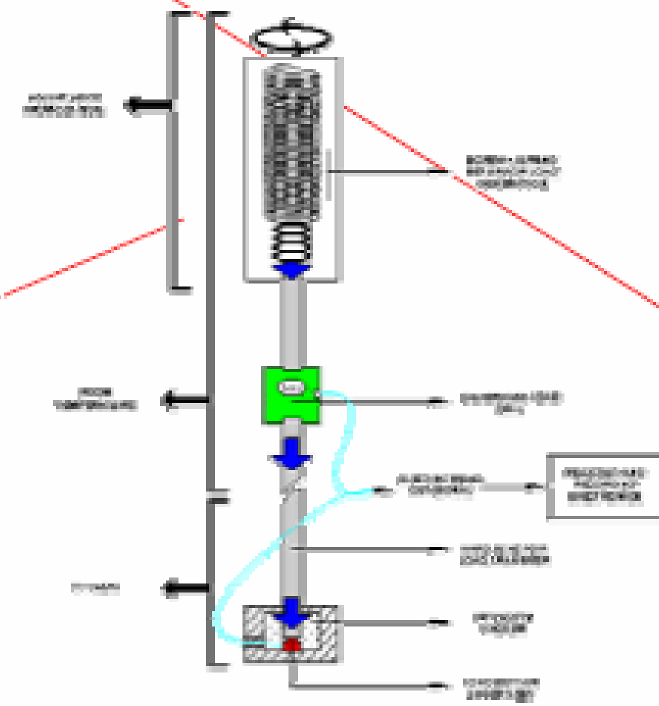
IPN, Orsay

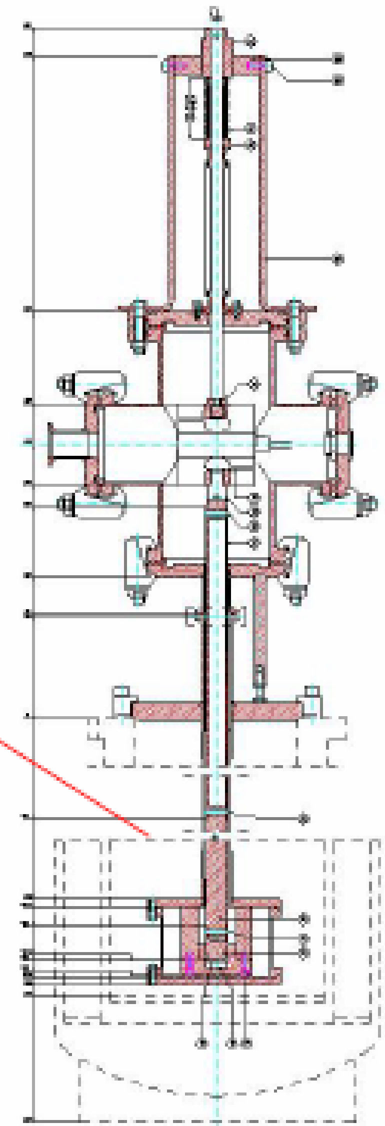
DESY, Hamburg

INFN, Milan

Devices calibration "facility"

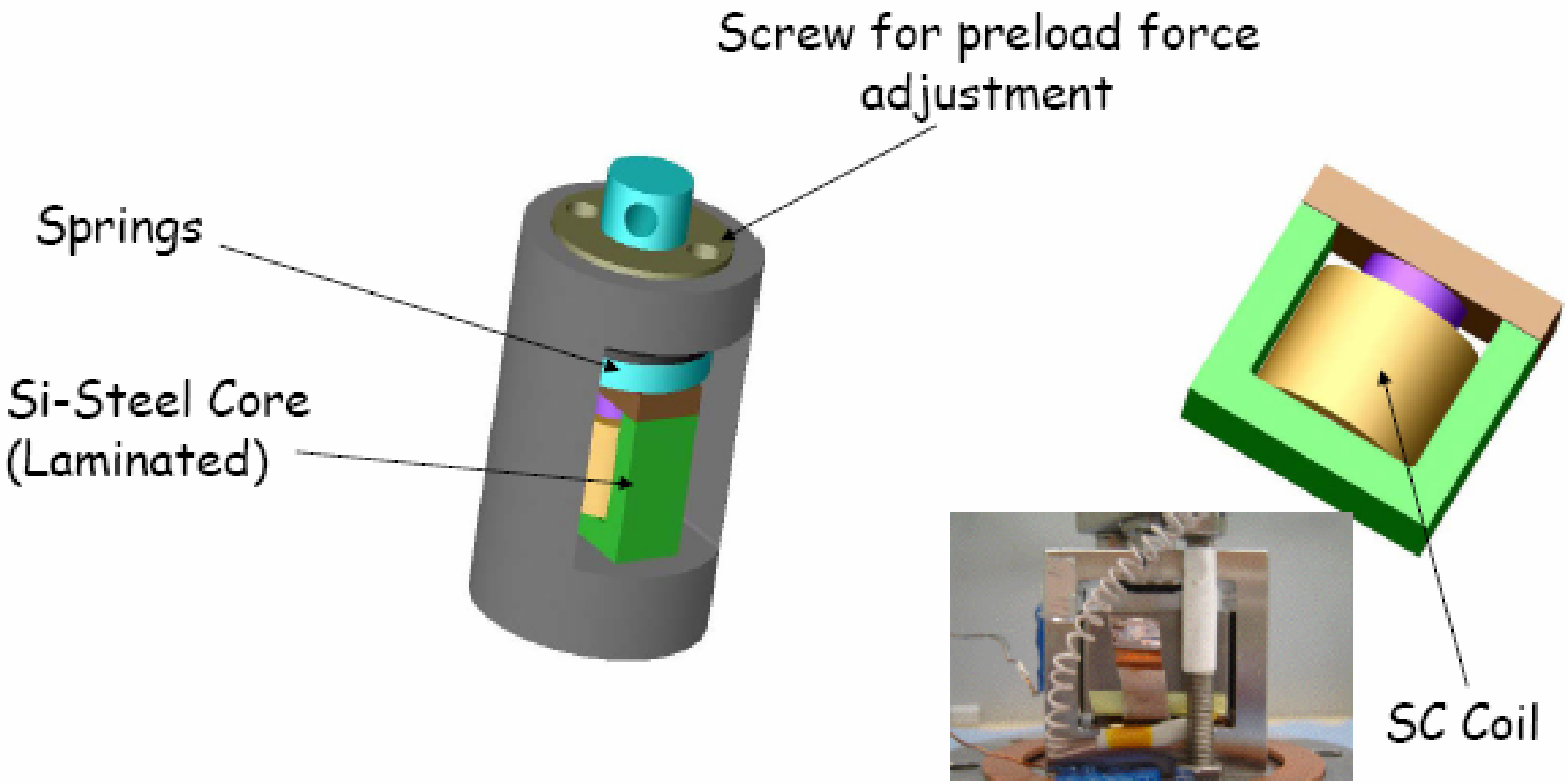






Magnetostrictive Actuators

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



ILC SCRF III (13:30->15:30)

Chair: L. Lilje
Location: Arts
Room: ALT2--

13:30	BPM design options for ILC (25') (Cold_bpms_Napoly_London.pdf)	Simon, Claire / Napoly, Olivier *(CEA Saclay)*
14:30	Status of the Low-Loss Cavity design (15') (2005_06_04_LL_Sekutowicz.pdf)	Sekutowicz, Jacek *(DESY)*
15:00	Crab Cavities (20') (BDIR_GB.pdf)	Burt, Graeme *(Lancaster University)*
15:30	coffee	

Cold BPM Options

OPTIONS

- Strip line
- Button
- Pill box RF cavity
- Re-entrant RF cavity
- Accelerating RF cavity

PROPERTIES @ 10-15 K

i. Positionning accuracy w.r.t. SC Quadrupole

ii. Resolution :
   - Single bunch
   - Bunch train: average
   - Bunch train: bunch to bunch

iii. Beam centering accuracy

Strip line

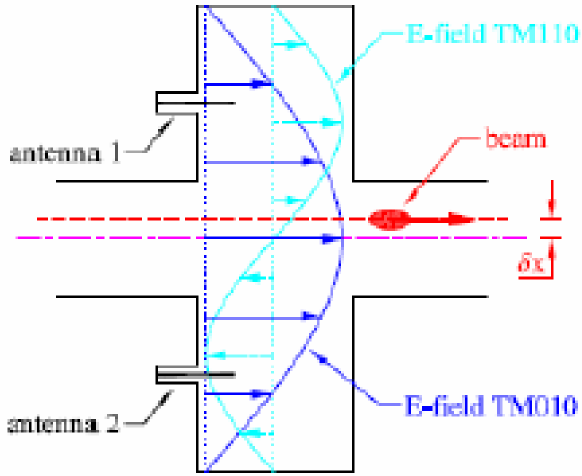
- Naturally broad band $\Delta\tau \sim cL$ $\Rightarrow$ single bunch / bunch to bunch BPM (directional)

- Submicron resolution achieved in SLC Final Focus and FFTB
  - Resolution $\propto$ beam pipe diameter or electrode separation

- Not advised in cold modules because of mechanical deformation during cool-down (*discussion with M. Wendt for the IR fast feedback BPM in SC doublet cryostat*): resolution > 10 µm

Pill box RF BPM

- Resonant cavity naturally narrow band ⇒ not a bunch to bunch BPM
- Resolution proportional to beam pipe diameter:
  resolution << sub-micron (cf Shintake, Balakin, KEK-ATF program).
- Robust in the cold
- Symmetrical and easy machining

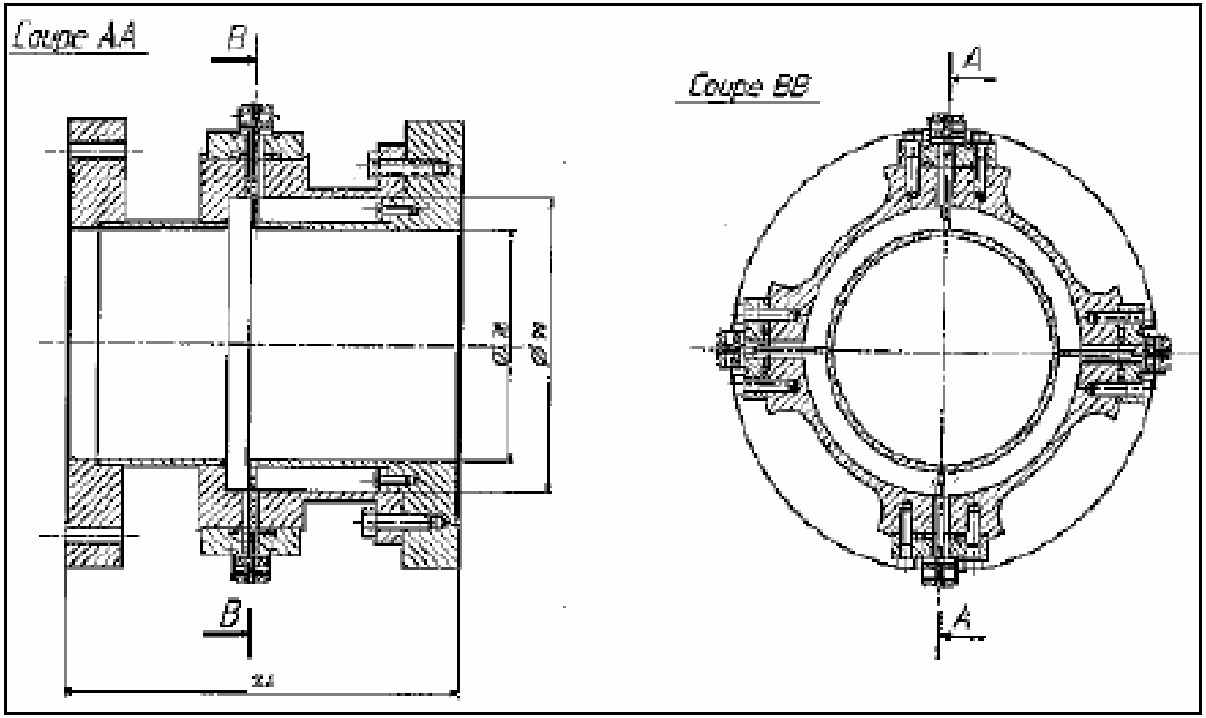


- Q_L << 1000 needed for bunch to bunch
  - TTF module BPM in Stainless Steel to reduce Q_0
  - Intercept @ 15K about 1 W from high frequency HOMs before the dedicated lossy ferrites (compared to 2 W for SC cavity @ 35 MV/m-5 10^9 and 10-50 mW from BPM cavity itself)
- Copper coated BPM with low Q_{ext} provided by different coupling antennas (*V. Sargsyan, TU Berlin*) ⇒ $\Delta\tau$ ~200 ns, not really bunch to bunch.

Re-entrant RF BPM

- Broad band cavity $Q_L = 50$, $\Delta\tau \sim 10$ ns
  ⇒ single bunch and bunch to bunch BPM
- Resolution proportional to beam pipe diameter:
  it can be ~1 µm (cf. M. Luong and C. Simon).
- Robust in the cold
- Symmetrical and easy machining

TTF-ACC1 prototype



Cold Re-entrant BPM

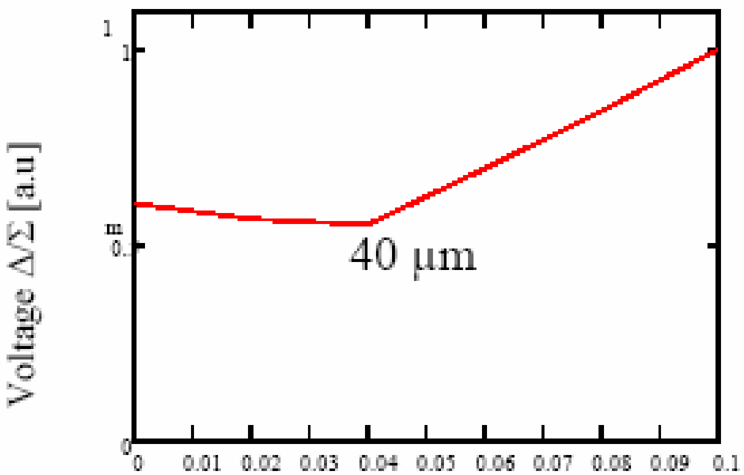
Linearity and **Centering Accuracy**

Old design

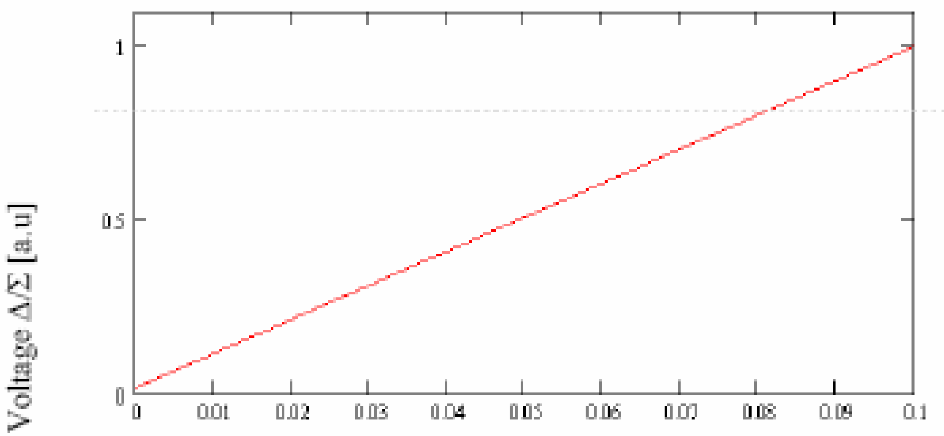
New design

Voltage Δ/Σ

[a.u]



Position of the beam (mm)



Position of the beam (mm)

Accelerating RF Cavity

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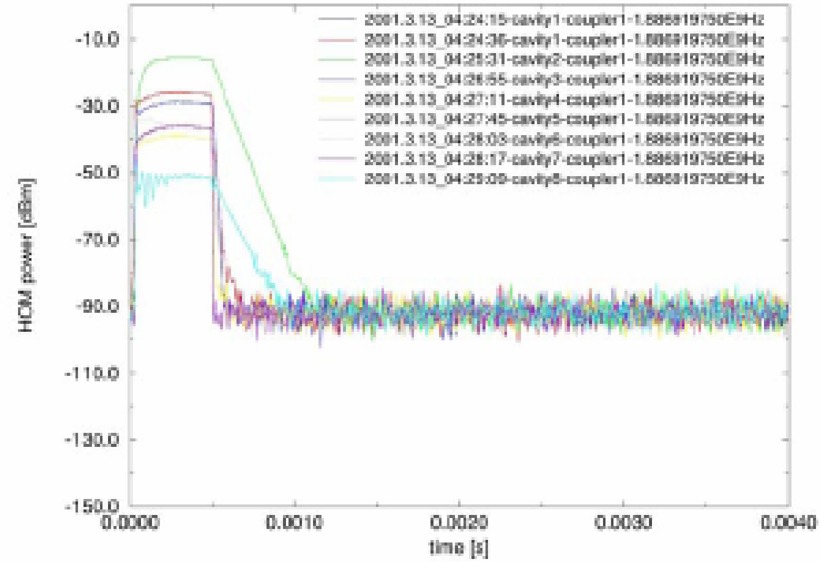
cea

saclay

- Naturally narrow band cavity : $Q_L \approx 10^4$, $\Delta\tau \sim 1$ µs

$\Rightarrow$ single bunch,

but not bunch to bunch BPM



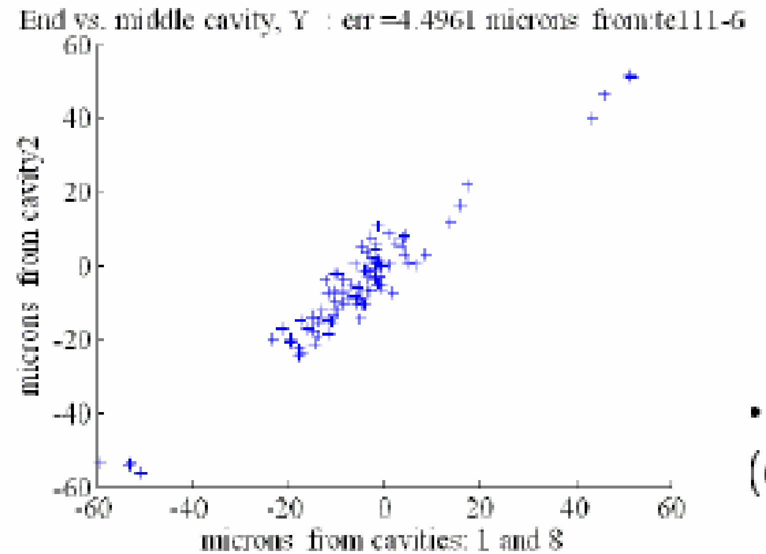
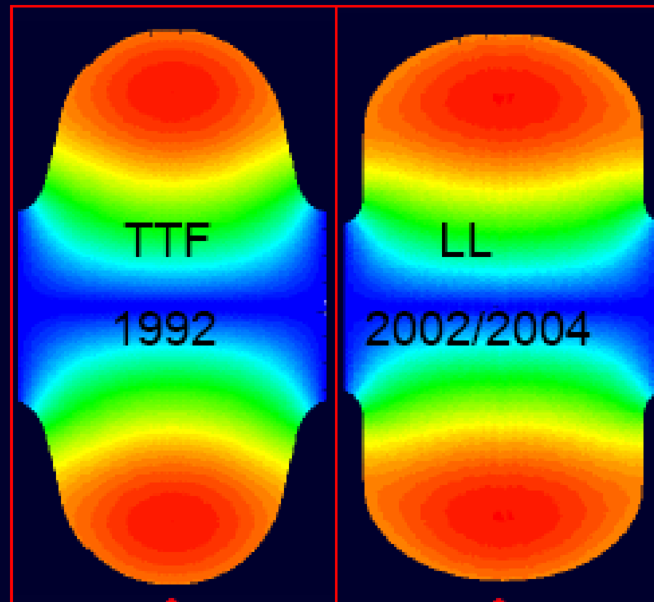


Figure 5: x predicted from the TE111-6 mode signals of cavity 2 vs that predicted from cavities 1 and 8 (at either end of the cryomodule). The width of the residual is approximately 4.5 microns, giving an estimate of the error associated with the measurement of a single cavity of about 3 microns.

- Relative position resolution ~ 4 µm (*cf. M. Ross and J. Frisch*).

2. Fundamental Mode: Inner cells.

Optimized for minimum: E_{peak}/E_{acc}



Optimized for minimum: B_{peak}/E_{acc}

r_{irisb}	[mm]	35	30	
k_{cc}	[%]	1.9	1.52	field flatness
E_{peak}/E_{acc}	-	1.98	2.36	max gradient (E limit)
B_{peak}/E_{acc}	[mT/(MV/m)]	4.15	3.61	max gradient (B limit)
R/Q	[Ω]	113.8	133.7	stored energy
G	[Ω]	271	284	dissipation
R/Q*G	[Ω*Ω]	30840	37970	dissipation (Cryo limit)

SLAC (Ω 3D, complex frequency), FNAL (2D), DESY (Fem2D, ABCI),

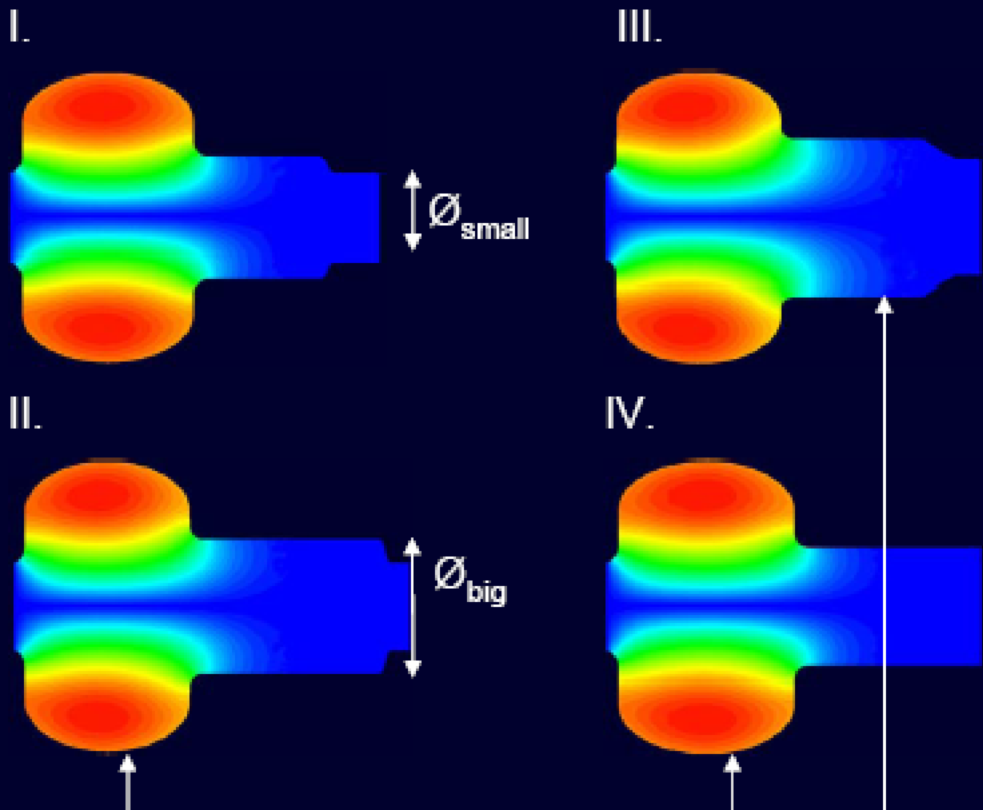
Loss factors of inner single cell

		LL	TTF
$k_{\perp}$ (σ_z=1mm) single inner cell	[V/pC/cm^2]	0.38	0.23
$k_{\parallel}$ (σ_z=1mm) single inner cell	[V/pC]	1.72	1.46

Better cavity alignment must compensate for increased $k_{\perp}$

~230 μm instead of 300 μm

3. HOMs; End-cells summary



Improved end-cell proposed by SLAC/DESY/JLab

3rd-passband "confined"

End-cells proposed at KEK

3rd-passband propagates

	Unit	I	II	III	IV
$Ø_{big}$	[mm]	82	92	108	80
$Ø_{small}$	[mm]	60	60	80	80
R/Q	[Ω]	123.3	115.5	103.1	124.7
G	[Ω]	288.4	291.5	297.5	287.6
R/Q·G	[Ω·Ω]	35560	33668	30672	35864

3. Activities: KEK *(Kenji bi-weekly report)*


Pre-tuning after annealing on May 21-24


Electropolishing @Nomura Plating on May 27


EP surface


120°C baking on May 29-31


Cavity assembly on May 28


HPR @ KEK on May 27-28

3. Activities: JLab

Aluminum model of 7-cells (9-cell) ILC-LL with optimized end-cells

Tuning and HOM damping measurements at DESY

Nb prototype of 7-cell ILC-LL will be ready before the Snowmass Workshop

Summary

<u>What is good about this structure ?</u>

- Lower cryogenic loss by ~20%.
- Shorter rise time by 13% due to higher (R/Q).
- Less sensitive to microphonics due to higher (R/Q) and thus lower Qext.
- Less stored energy by 13%.
- B_{peak}/E_{acc} lower.

<u>What is critical for this structure ?</u>

- Higher E_{peak}/E_{acc} = 2.36, (TTF structure 2).
- Weaker cell-to-cell coupling k_{cc}= 1.52% (TTF structure 1.9%).
- HOM loss factors are higher: $k_{\perp}$ by 65% , $k_{\parallel}$ by 18 %.

<u>Open questions:</u>

- Vibrations ?
- Preparation and cleaning ?

What is a crab cavity?

Head-on collision

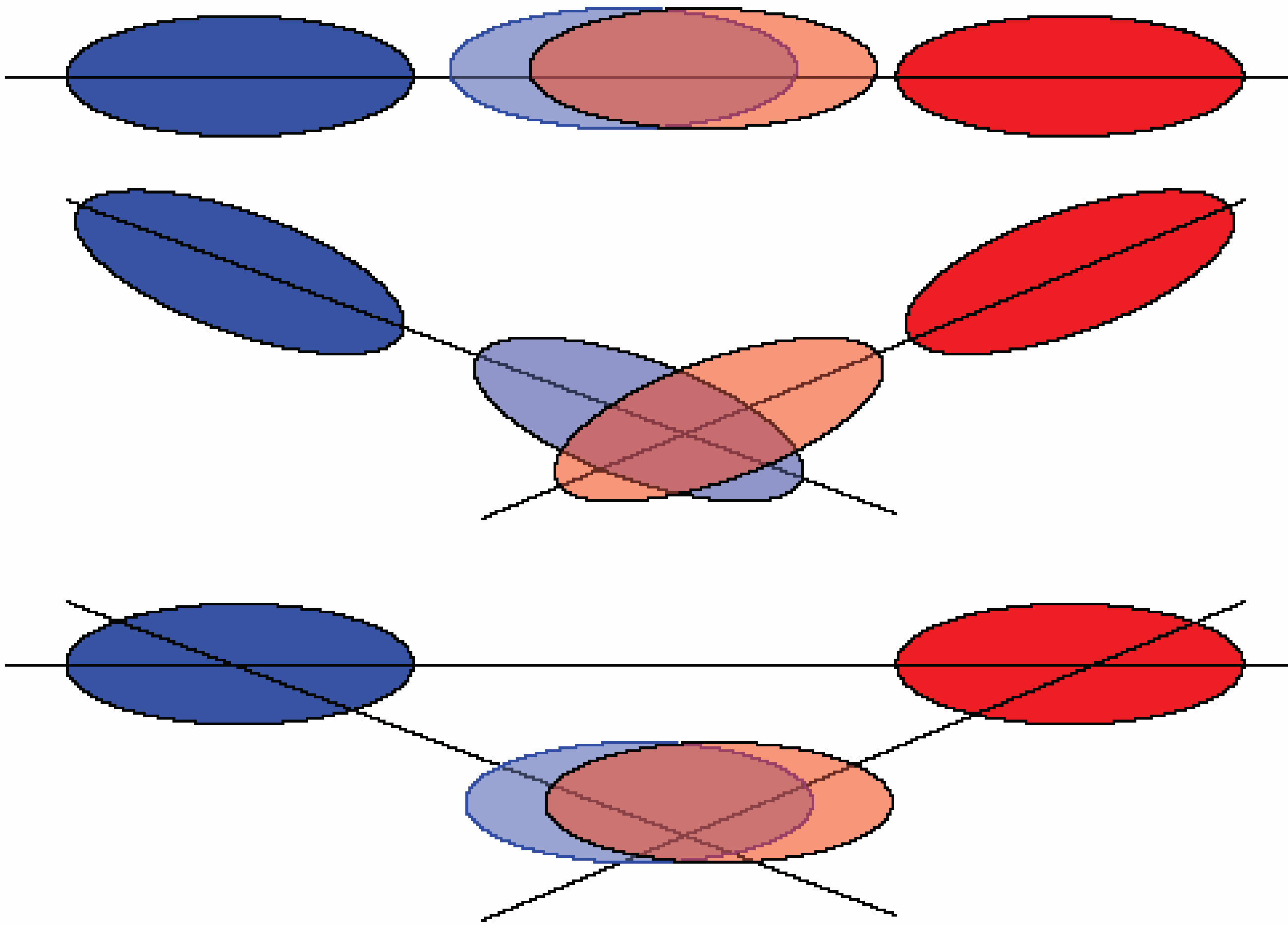
Maximum luminosity

Crossing angle introduced

Reduced luminosity due to crossing angle

Crossing angle with crab rotation

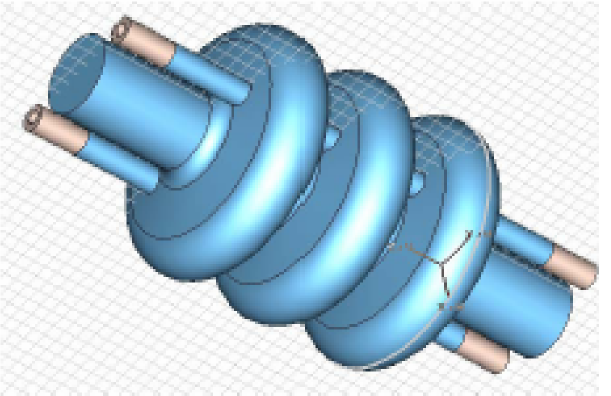
Effective head-on collision



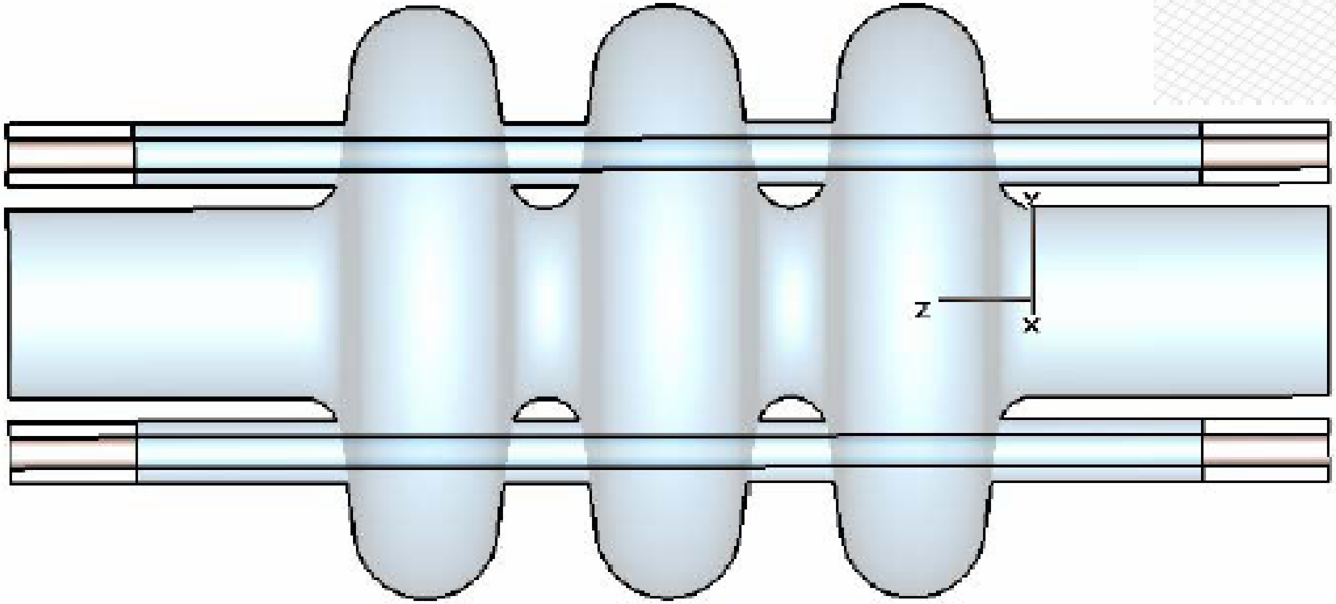
Conclusion

- Cavity should be very stable.
- Crab cavity should be superconducting.
- Cavity should have an elliptical cross section.
- LOM damping in multicell cavities will be a major consideration in the design.
- The optimum design should have as small a ratio as possible between the surface magnetic field and the magnetic field on axis.

Co-axial coupler for LOM

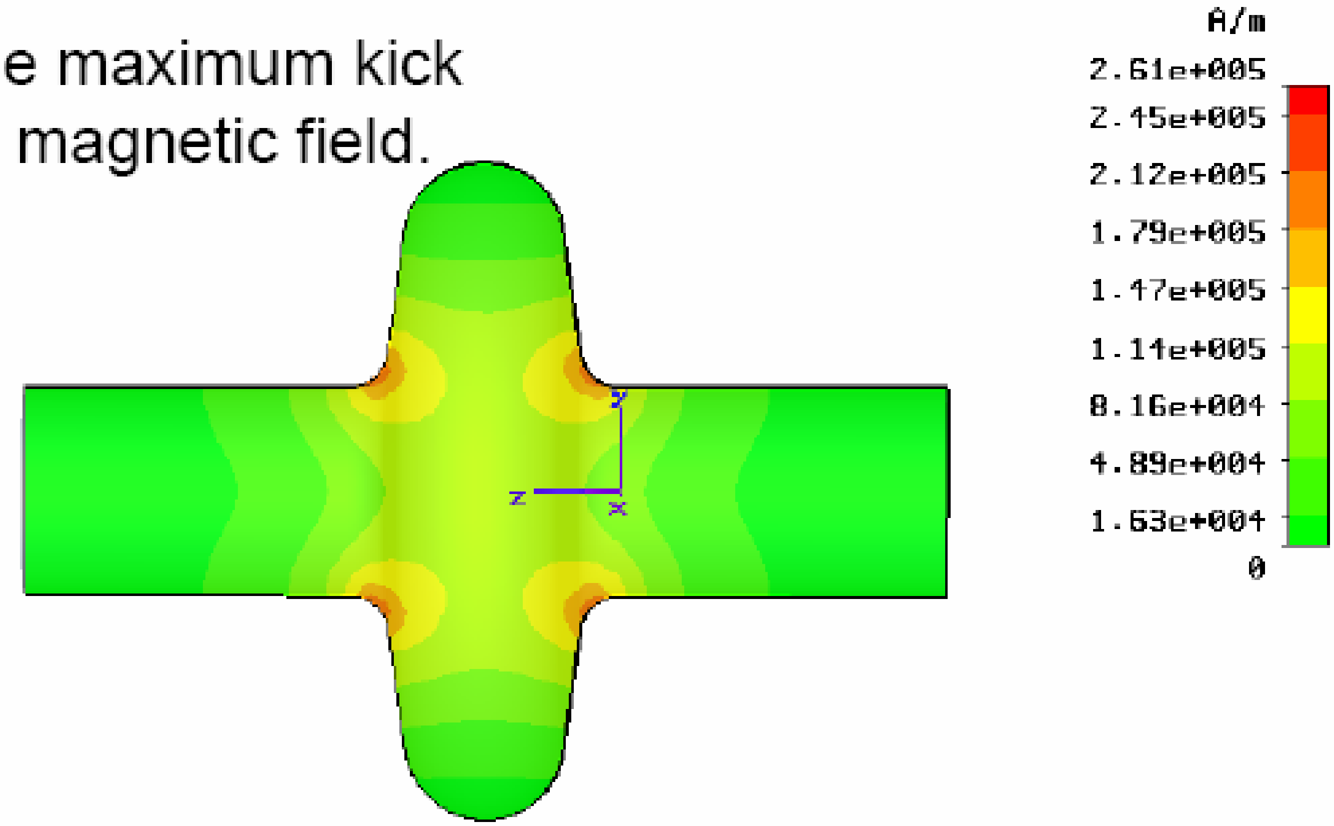


Design of multicell LOM couplers.



Maximum Magnetic field.

The limit to the maximum kick is the surface magnetic field.




```
Type          = H-Field (peak)
Monitor       = Mode 2
Component     = Abs
Plane at x    = 0
Frequency     = 3.97969
Phase         = 90 degrees
Maximum-2d    = 261057 A/m at 0 / -1.73706 / 0.272371
```

ILC SCRF IV (16:00->17:00)

Chair: L. Lilje
Location: Arts
Room: ALT2--

16:00 **Development of R&D issues presentation for Snowmass** (1h00') (Cryomodule-WBS.pdf) **All**

- Discussion on R&D issues
- Preparation for Snowmass

- Finalize European Assets list
- Discussion on cryomodule Work Breakdown Structure (WBS)

More detailed charge [for Snowmass]

- The Working Groups must work to agree upon the configuration of a large fraction of the collider design before and during the Workshop[Snowmass]. They should use the Workshop to develop paths to working decisions for the remaining critical issues with the expectation that these could be decided at one or two subsequent meetings during the fall of 2005.
- The Workshop should also be used to start the initial documentation of the BCD.
- Finally, the Working Groups should identify critical R&D topics and timescales for alternative solutions to the ILC Baseline Configuration that could have a significant impact on the performance or cost of the linear collider.

2 General Parameters

2.1 Gradient

2.1.1 requirements

2.1.2 baseline

35 MV/m (for 1TeV)

Defines maximum length of tunnel.

2.1.3 baseline justification

(1) **Proof-of existence**

2.1.4 baseline status

(1) **Reliability of preparation process is not yet sufficient**

(a) **Field emission is the major source**

(b) **Thermal conductivity needed is unclear**

2.1.5 foreseen/required baseline R&D

(1) Improved preparation needed

  (a) Reduction of field emission

  (b) Improved understanding of the (electro-)chemical process

(2) Understanding the Q-slope/bakeout effects

  (a) Basic research on superconducting properties of Nb needed

  (b) Improving process to be easily applicable

(3) XFEL cavity preparation

(4) Operability a gradients close to limit

3 Cavity Package

3.1 1 cavity

3.1.1 requirements

3.1.2 baseline

TESLA 9-cell

3.1.3 baseline justification

(1) Experience with operation in TTF

(2) Fabrication experience with ~100 cavities

(3) HOM experiments with beam

3.1.4 baseline status

3.1.5 foreseen/required baseline R&D

(1) 1000 will be built for XFEL

(2) Cost reduction

  (a) Large-crystal Nb material

3.1.6 options

low-loss

Potential European Contributions to ILC SRF R&D

Overview EU SRF Infrastructures, DRAFT version of 20.06.05, D.Proch			
Laboratory	Infrastructure	Installations	Remarks
Uni Wuppertal	Surface analysis	DC scanning	CARE EC support
		FEM microscope	
		FRT Micro Profilometer with AFM	
IN2P3, Orsay	High power Coupler	high power coupler teststand	CARE EC support
		cleanroom	
		clean water	
		clean bake out furnace	
Saclay/Orsay	Cryholab	horizontal cold tests	CARE EC support
CEA Saclay	Single cell infrastructure	BCP chemistry	
		EP chemistry	CARE EC support
		cleanroom/clean water	
		High pressure water	
		1200°C clean furnace	
		RRR, lambda measurement	
		RF klystron 1.5 MW -10 Hz-1ms	
		VT teststand	
INFN-Roma2	Thin film coating	Vacuum planar arc system	CARE EC support
		surface analytic	
		Tc, Hc measurement	
INFN-Milano	Tuner development	tuner warm test stand	CARE EC support
IPJ Soltan	Thin film coating lab	vacuum linear arc coating	CARE EC support
TU Lodz	Tuner development lab	Tuner development	CARE EC support
WUT-ISE	Low level RF lab	LLRF development	CARE EC support

Potential European Contributions to ILC SRF R&D

Overview EU SRF Infrastructures, DRAFT version of 20.06.05, D.Proch

Laboratory	Infrastructure	Installations	Remarks
(DESY)	X-FEL	X-FEL linac	installation will start in 2007
DESY	TTF linac	Linac measurements	
	TTF, 9-cell infrastructure	BCP chemistry	
		EP chemisty	CARE EC support
		cleanroom	
		High pressure water	
		VT cold teststands	
		high power coupler teststands	
		cavity tuning laboratory	
		1400°C clean furnace	
		800°C clean furnace	
	Chechia	horizontal cold teststand	
	Single cell infrastructure	High pressure water	
		cleanroom	
		CO2 cleaning	CARE EC support
		vertical teststand	
	RF lab laboratory	RF equippment	
		Eddy current & Squid scanning	CARE EC support
	Materials lab	Surface & bulk & metalurgical analyse	
		Tc, RRR, lambda measurement	
		hydroforming laboratory	CARE EC support
	Module test stand	*module processing*	*in preparation, EUROFEL EC supported*

Thanks for your attention!