Low Loss ILC Cavity

DESY

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1. Introduction

2. FM passband

3. HOMs

4. KEK and JLab activities

1. Introduction: Criteria

- Field emission is not a hard limit in the performance of sc cavities:

  optimization (1992) → $E_{peak}/E_{acc} = 2$ limits E_{acc} to ~43 MV/m

- Magnetic flux of ~180 mT is the hard limit in the performance:

  optimization (2004) → $B_{peak}/E_{acc} = 3.61$ mT/(MV/m) limits E_{acc} to ~50 MV/m

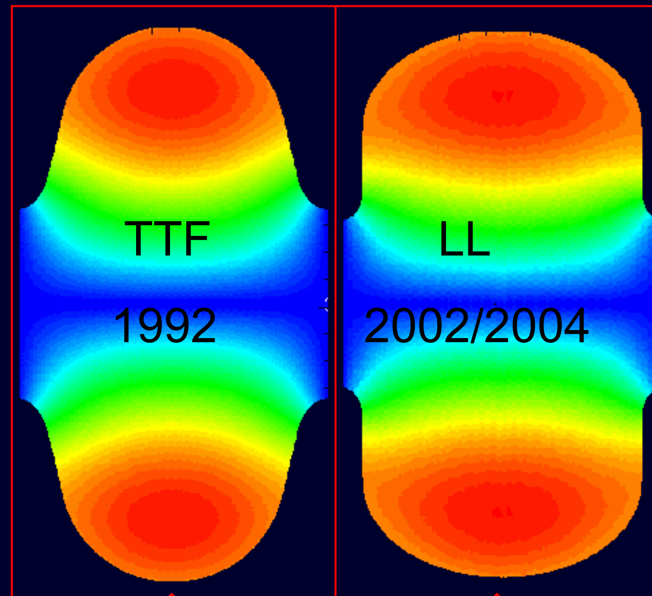
B_{peak} / E_{acc} should be low

↓

1. operation at higher gradients. ⟷ 2. operation at lower cryogenic load.

2. Fundamental Mode: Inner cells.

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

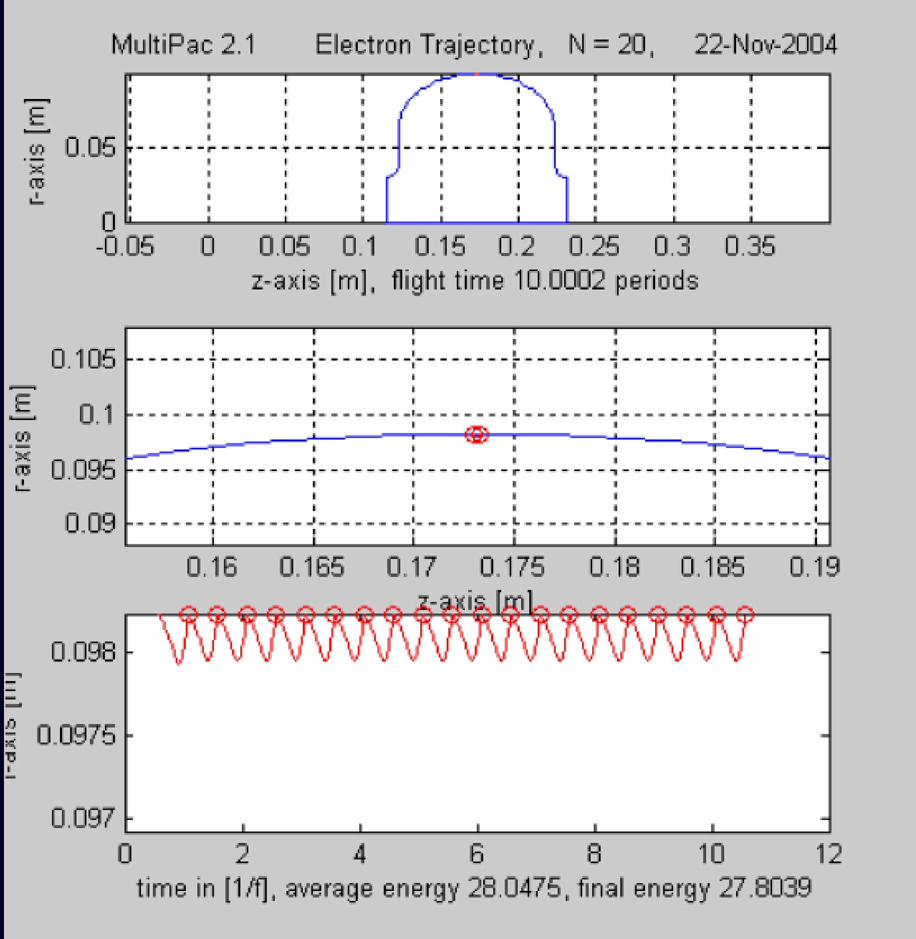


Optimized for minimum: B_{peak}/E_{acc}

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)

2. FM: Multipacting and the Lorentz force *(FNAL Group)*

Multipacting

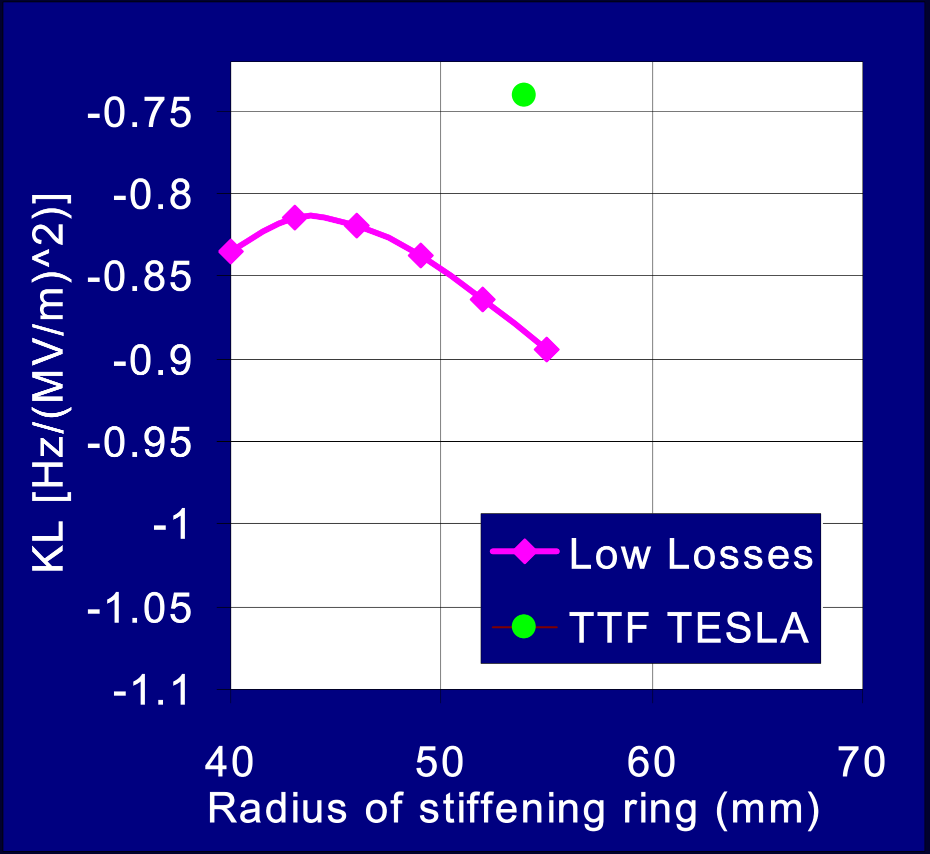


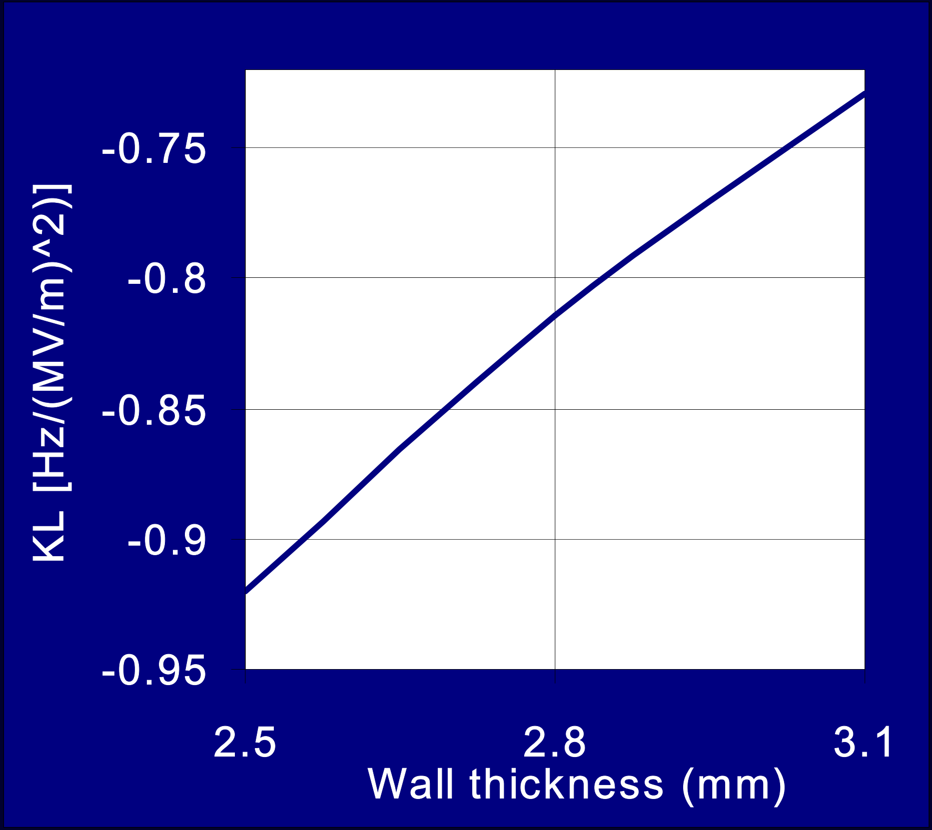
At the equator one resonance trajectory was found, but impact energy is too small, to create enough secondary electrons.

2. FM: Multipacting and the Lorentz force *(FNAL Group)*

Lorentz force detuning at 35 MV/m:

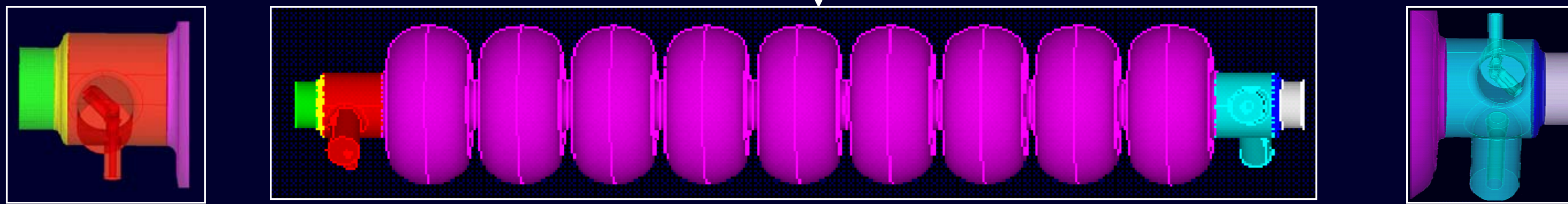
- TTF TESLA -908Hz
- LL -998 Hz



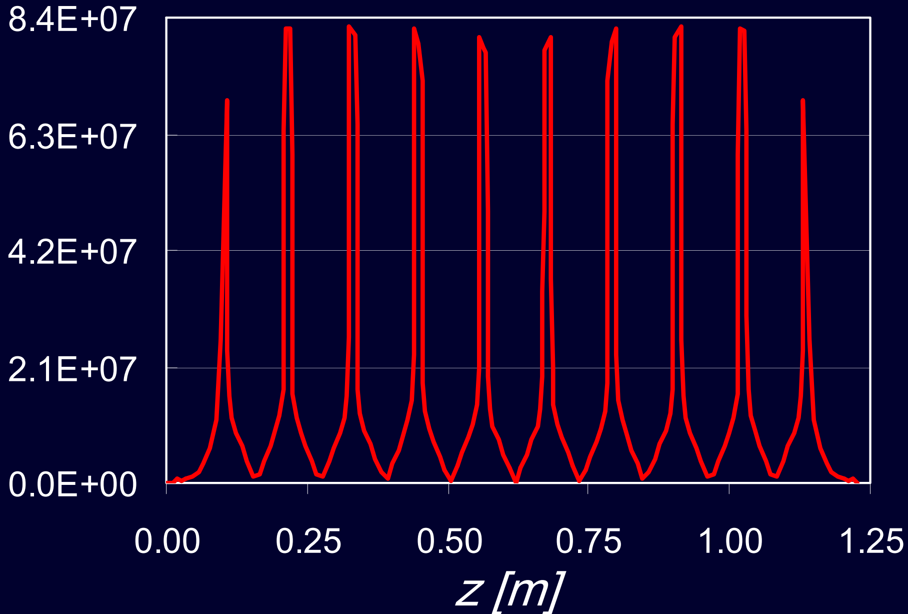


2. Fundamental Mode: 9-cell.

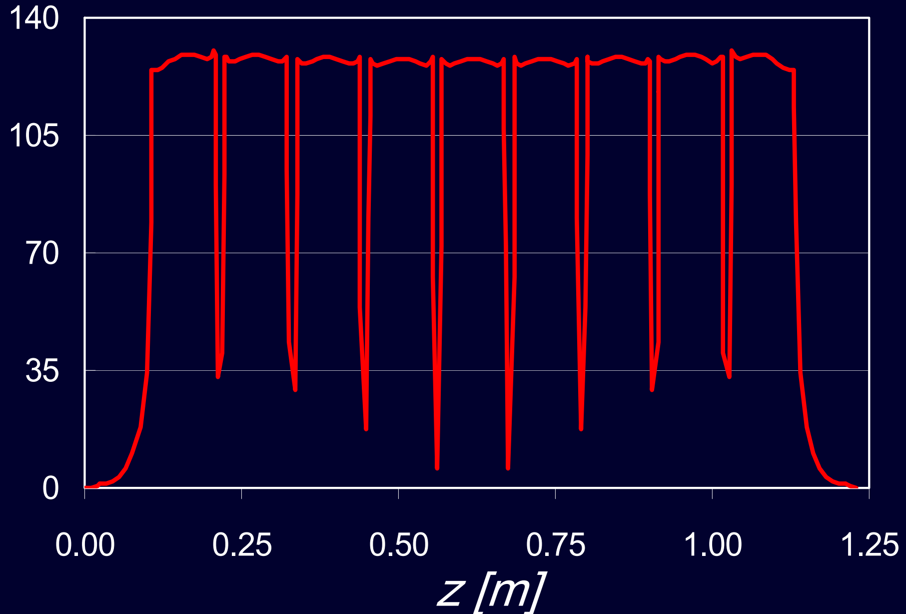
DESY (2D) , SLAC (3D)



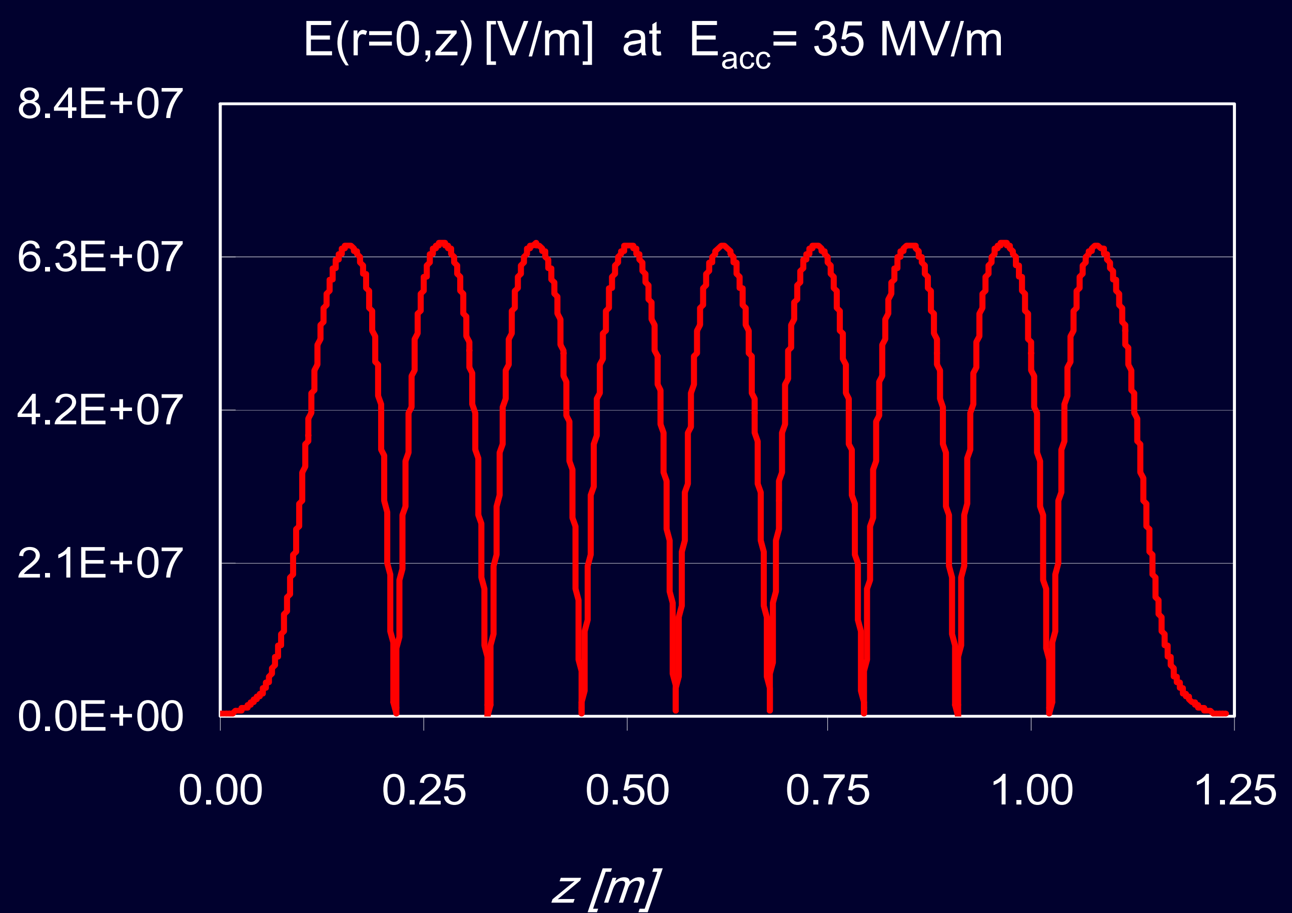
E_{surf} [V/m] at E_{acc}= 35 MV/m



B_{surf} [mT] at E_{acc}= 35 MV/m



2. Fundamental Mode: 9-cell.



FM frequency of both end-cells is matched to π-mode frequency of 7 inner cells.

2. Fundamental Mode: 9-cell.

		LL	TTF
Type	-	symmetric	asymmetric
f_{π}	[MHz]	1300.0	1300.0
Number of cells, Nc	-	9	9
k_{cc}	[%]	1.52	1.9
E_{peak}/E_{acc}	-	2.36	1.98
B_{peak}/E_{acc}	[mT/(MV/m)]	3.61	4.15
R/Q	[Ω]	1166.5	1012
G	[Ω]	284.8	271
(R/Q*G) / Nc	[Ω*Ω]	36913	30472

3. Higher Order Modes: 9-cell

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]	<u>0.38</u>	0.23
$k_\parallel$ (σ_z=1mm) single inner cell	[V/pC]	1.72	1.46

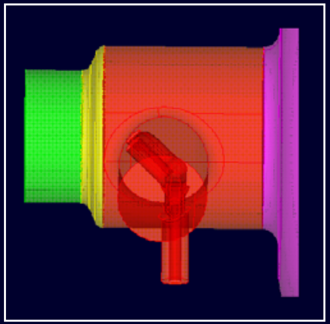
Better cavity alignment must compensate for increased $k_\perp$

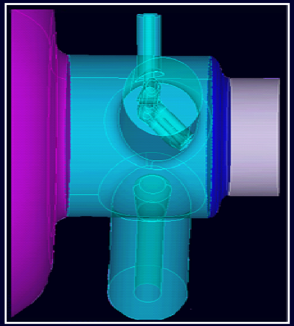
~230 μm instead of 300 μm

3. Higher Order Modes, cont.

- The first version of LL structure is symmetric (December 2004).
- We can make it asymmetric if needed.
- TDR spec for TTF cavities is: $(R/Q)\cdot Q_{ext} \leq 1\ M\Omega/cm^2 = 10\ G\Omega/m^2$

Damping of monopoles and dipoles; SLAC-ACD, FNAL





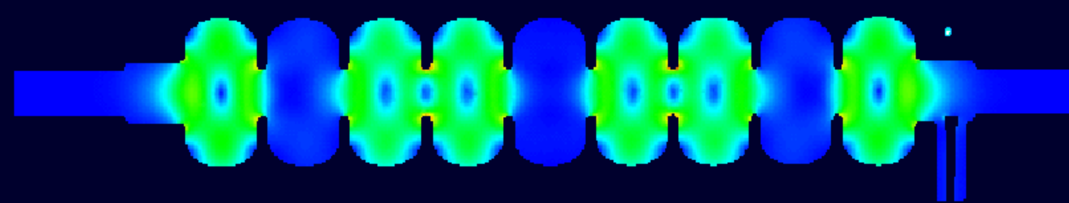
Boundary conditions

- SLAC: In full 3D model, all ports are OPEN and MATCHED.
- FNAL: In 2D model, beam pipes are terminated with ELECTRIC / MAGNETIC SHORT. Beam tubes with Ø82mm, no step.

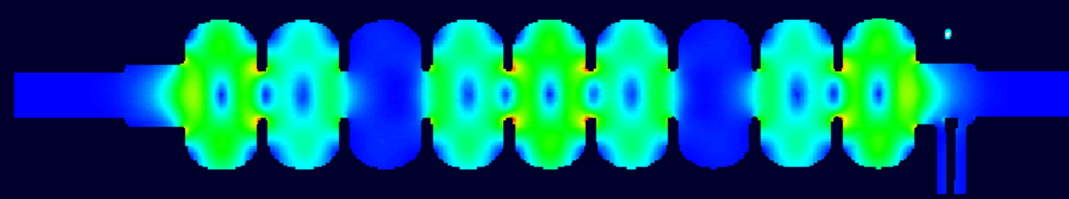
3. Higher Order Modes, cont.

Monopoles	F range [MHz]	Highest (R/Q) [Ω]	k_{cc} [%]	Q_{ext} for the highest (R/Q) modes
TM011-like	2149-2188	192 and 199	1.8	$\sim 10^4$
TM021-like	2784-2872	1.7	3.1	$<10^4$
TM022-like	3426-3497	44	2.1	not computed

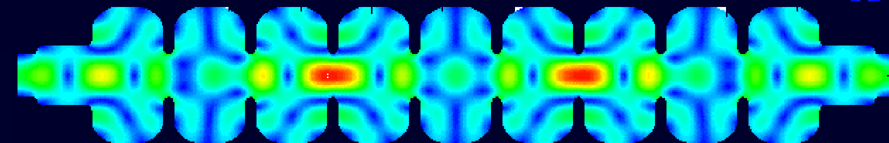
F= 2.177482E+09
(R/Q)= 192 [Ω]



F= 2.182806E+09
(R/Q)= 199 [Ω]



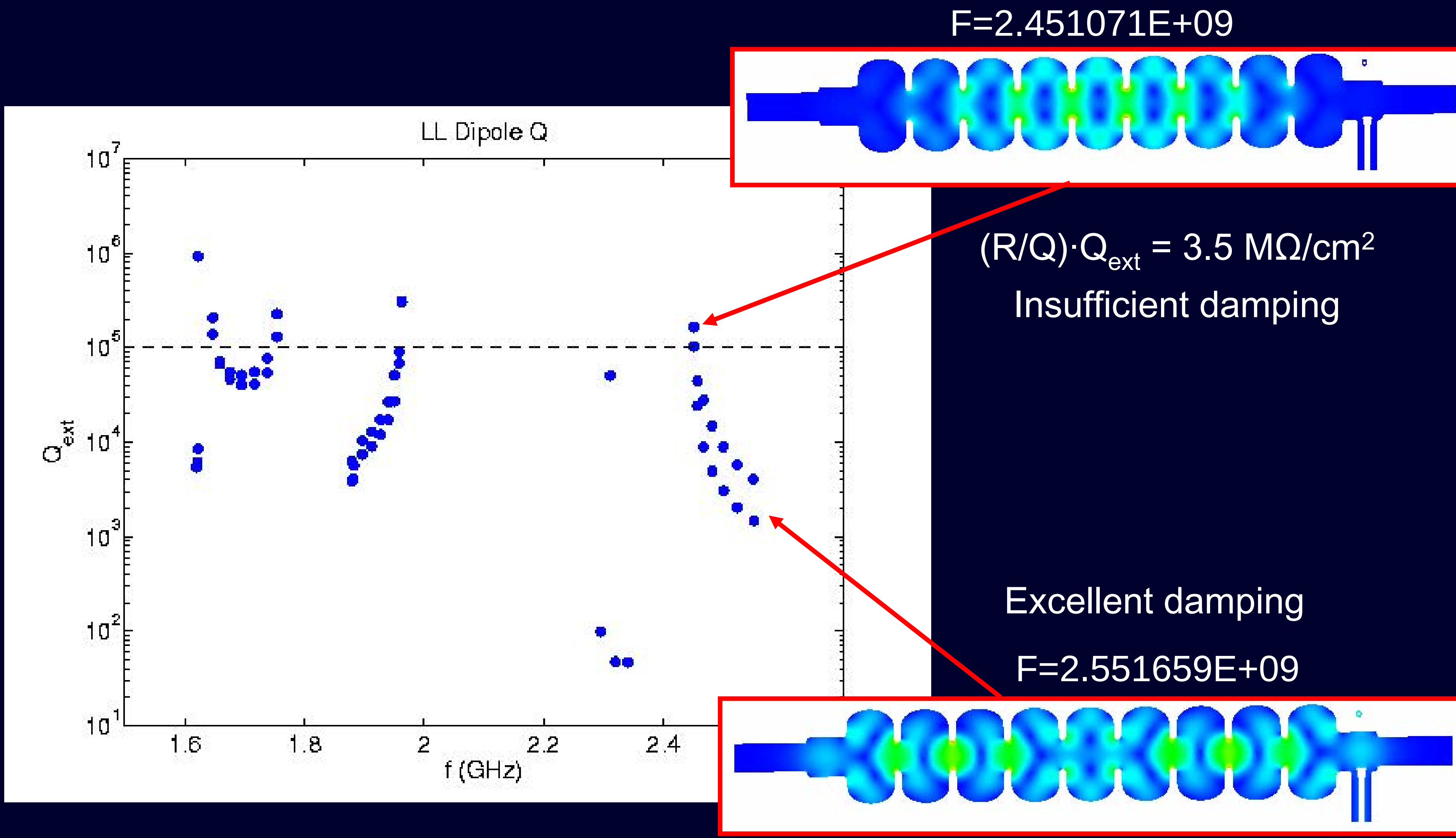
F= 3.473066E+09
(R/Q)= 44 [Ω]



3. Higher Order Modes, cont.

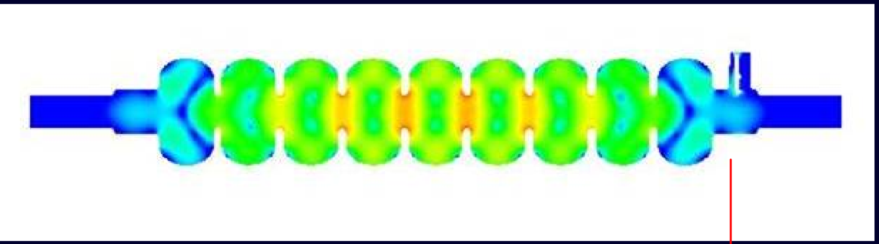
Dipoles	F range [MHz]	Highest (R/Q) [Ω/cm^2]	k_{cc} [%]	Q_{ext} for the highest (R/Q) modes SLAC	FNAL
TE111-like	1620 - 1755	7	8	$4\cdot10^4$	
TM110-like	1879 - 1963	16 and 12	4.3	$< 2\cdot10^4$	
3-rd passband ?	2451 - 2552	32	4	$< 2\cdot10^5$	$< 5\cdot10^3$
4-th passband	2657 - 2973	0.2	11	$< 2\cdot10^4$	
5-th passband	3049 - 3068	0.5	0.6	$< 10^6$	
6-th passband	3293 - 3354	2.3	1.8		$< 4\cdot10^3$

3. Tuning of end-cells for 3rd passband.

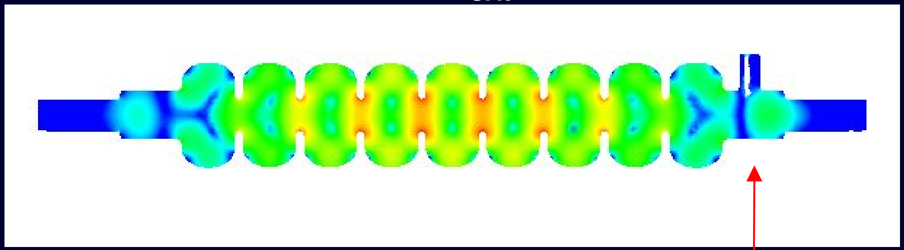


3. Tuning of end-cells for 3rd passband *(ACD SLAC+DESY)*

2451.2 MHz, $Q_{ext}=1.6\cdot10^5$



2451.0 MHz, $Q_{ext}= 6\cdot10^4$



Ø82mm→Ø92mm + HOM coupler shifted by few mm's

The price is less damping of 5-th passband $Q_{ext} <10^6$ is $< 3\cdot10^6$

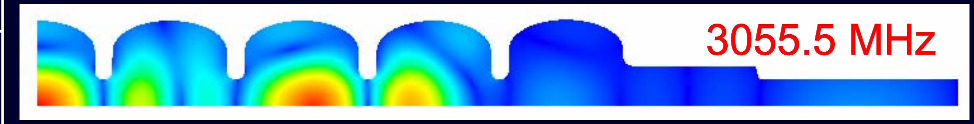
Percentage of stored energy in the end cells.

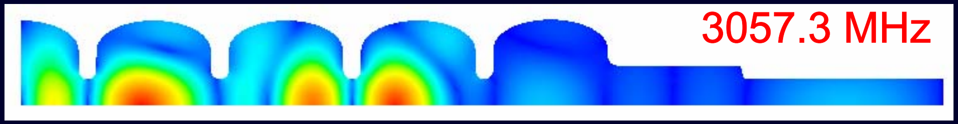
Original Model

F (MHz)	U (%)
3055.6	0.76
3057.5	1.60

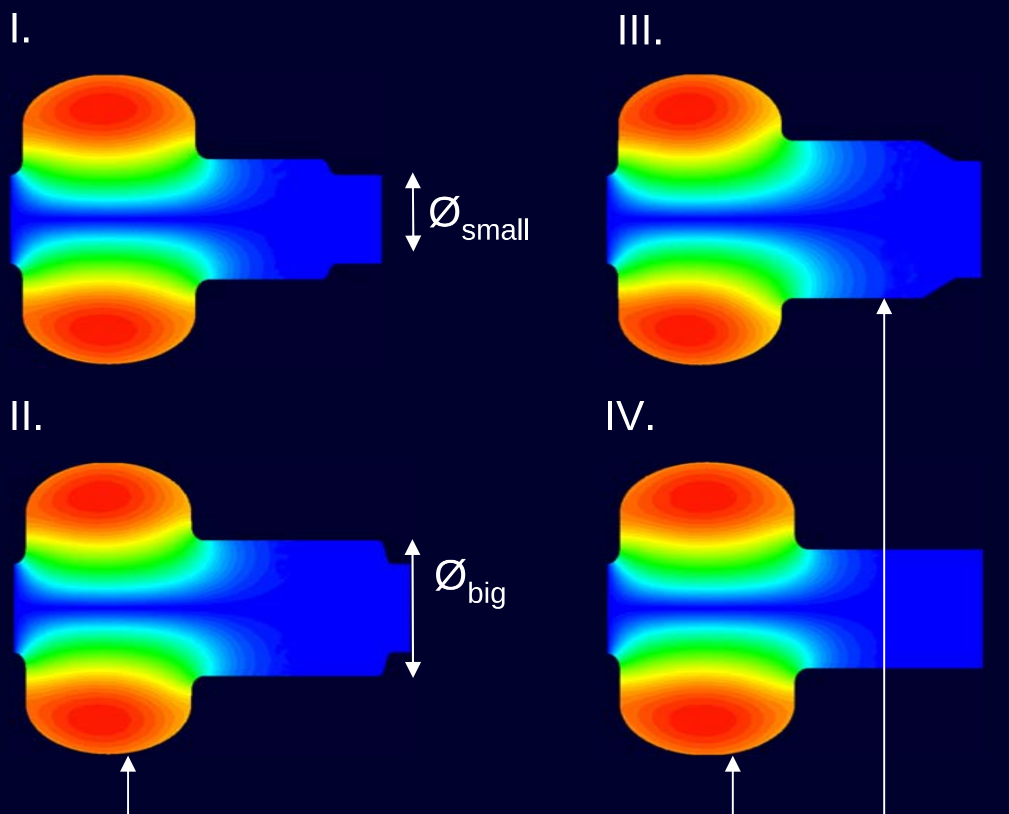
Modified Model

F (MHz)	U (%)
3055.5	0.27
3057.3	0.70





3. HOMs; End-cells summary



Improved end-cell proposed by SLAC/DESY/JLab

3rd-passband "confined"

End-cells proposed at KEK

3rd-passband propagates

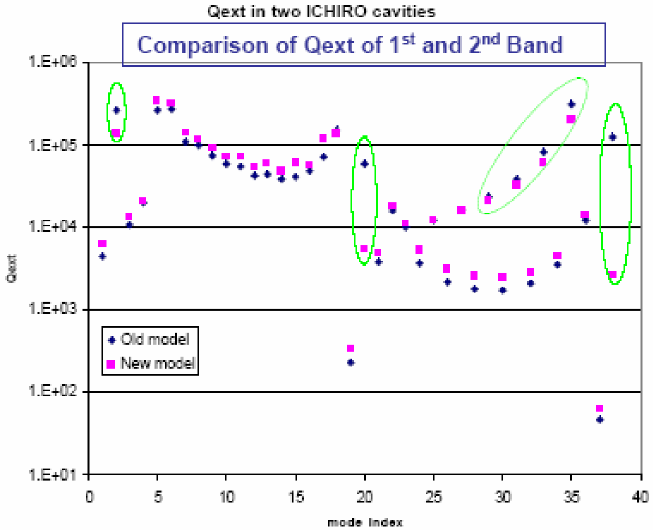
	Unit	I	II	III	IV
$\varnothing_{big}$	[mm]	82	92	108	80
$\varnothing_{small}$	[mm]	60	60	80	80
R/Q	[Ω]	123.3	115.5	103.1	124.7
G	[Ω]	288.4	291.5	297.5	287.6
R/Q·G	[Ω·Ω]	35560	33668	30672	35864

All end-cells are OK to proof the RF-performance for the accelerating mode.

2nd LL structure

Completed ICHIRO 2nd 9-cell cavity on June 2 @ Kuroki Industrial corporation

Damping of TE111 and TM110 dipoles
as modeled by ACD at SLAC



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

Pre-tuning after annealing on May 21-24

Electropolishing @Nomura Plating on May 27

EP surface

120^{O}C baking on May 29-31

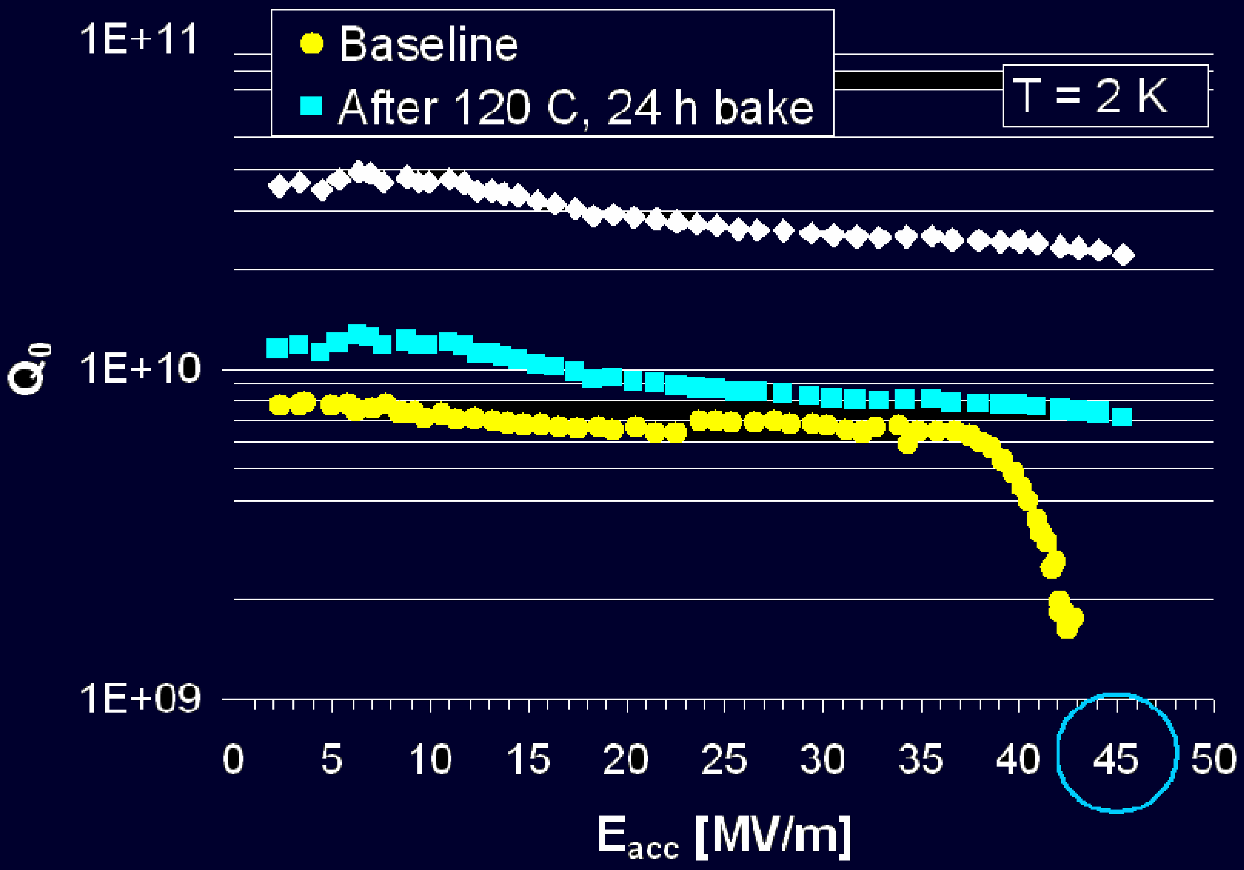
Cavity assembly on May 28

HPR @ KEK on May 27-28

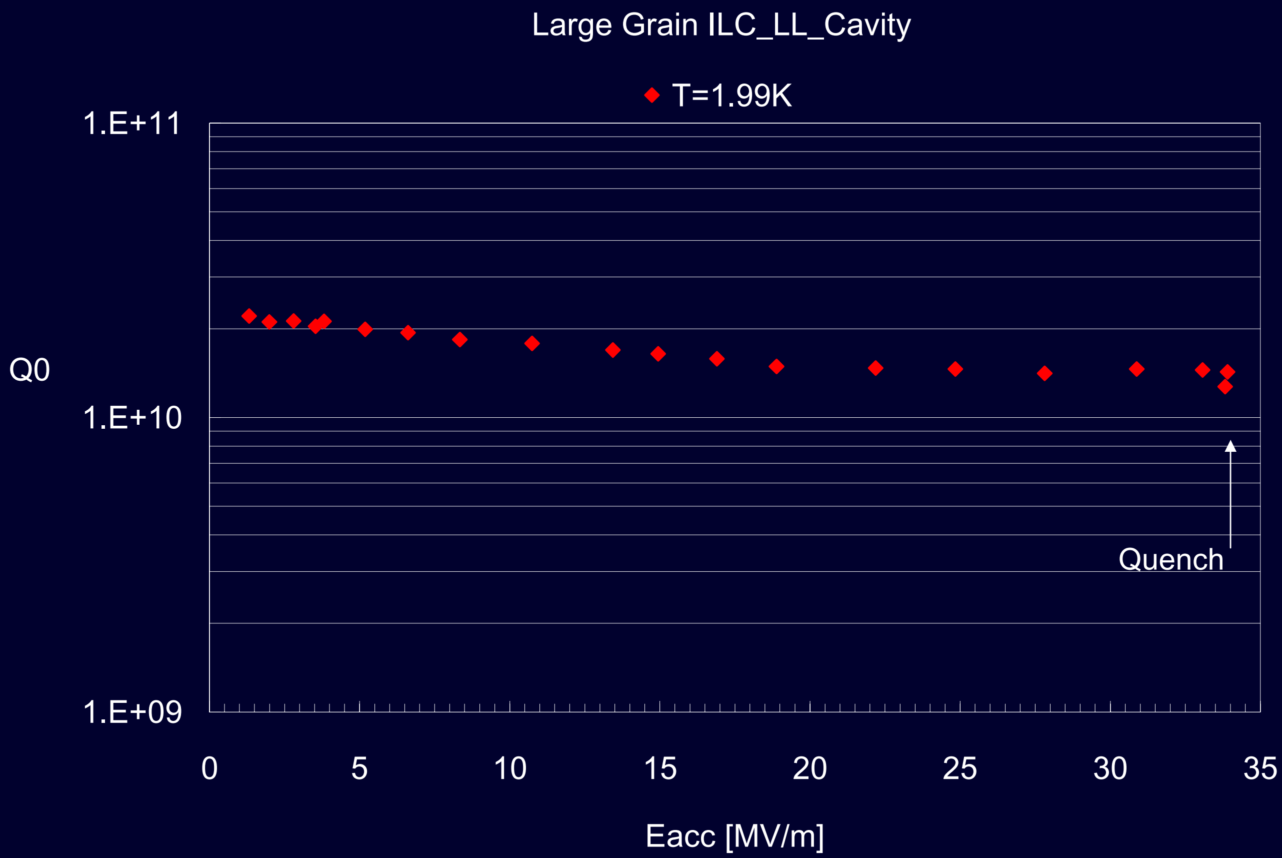
3. Activities: JLab 2.3 GHz LL single cell cavity *(P. Kneisel)*

LL 2.3 GHz; JLab

Material with low Tantalum content < 500 ppm



3. Activities: JLab 1.3 GHz ILC-LL single cell cavity



Material with high Ta content ~ 1500 ppm

In this test strong Lorentz force detuning was observed ~18 kHz at 34 MV/m ??

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

What is good about this structure ?

- 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.

What is critical for this structure ?

- 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 %.

Open questions:

- Vibrations ?
- Preparation and cleaning ?