Low Loss ILC Cavity

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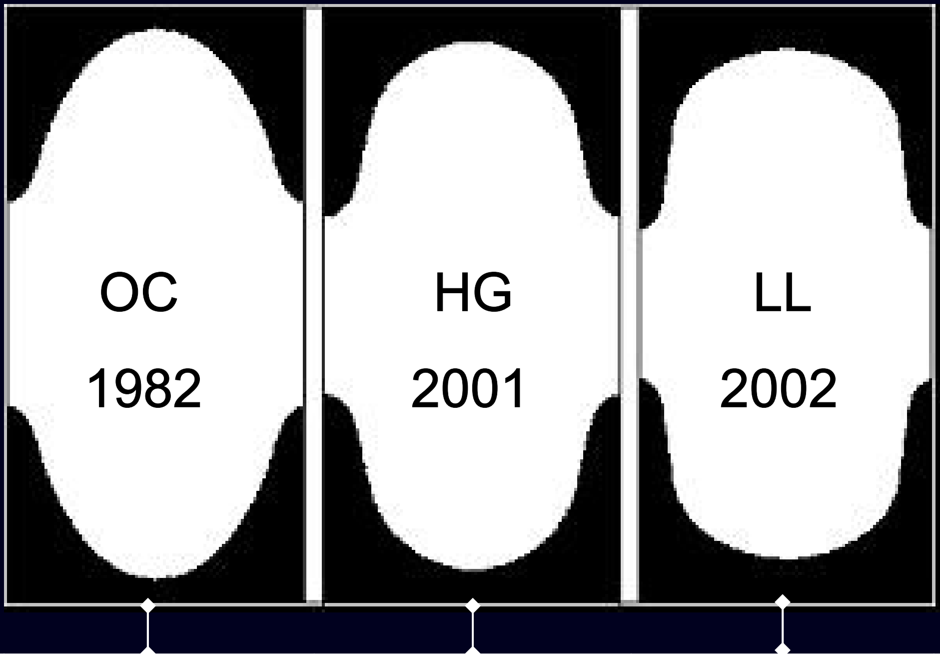
1. Introduction
2. FM passband
3. HOMs
4. Multipacting and the Lorentz force detuning
5. Summary and the next steps

1. Introduction: Evolution of the elliptical cavities

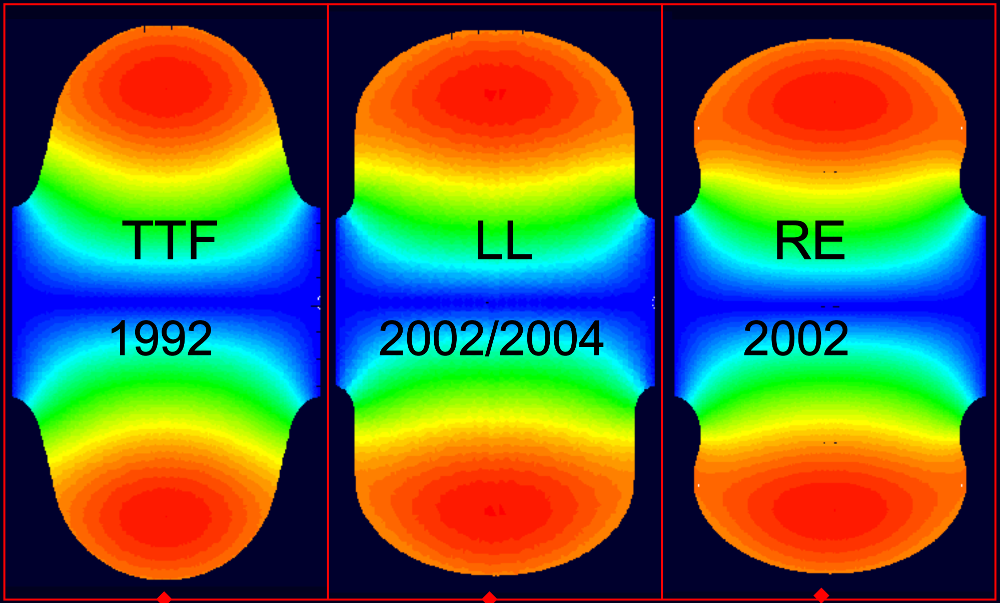
Example: 1.5 GHz inner cells for the CEBAF accelerator



k_{cc}	[%]	3.29	1.89	1.49	field flatness
E_{peak}/E_{acc}	-	2.56	1.96	2.17	max gradient (E limit)
B_{peak}/E_{acc}	[mT/(MV/m)]	4.56	4.15	3.74	max gradient (B limit)
R/Q	[Ω]	96.5	112	128.8	stored energy
G	[Ω]	273.8	266	280	dissipation
R/Q*G	[Ω*Ω]	26421	29792	36064	dissipation (Cryo limit)

1. Introduction: Evolution of the elliptical cavities cont.

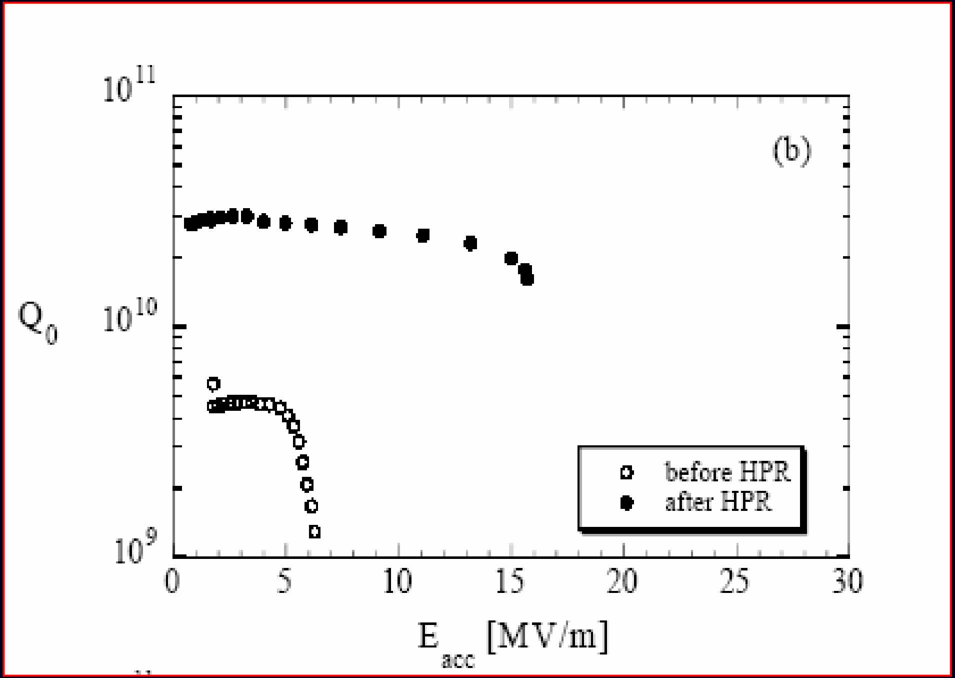
Example: 1.3 GHz inner cells for TESLA and ILC



r_{irisb}	[mm]	35	30	33	
k_{cc}	[%]	1.9	1.52	1.8	field flatness
E_{peak}/E_{acc}	-	1.98	2.36	2.21	max gradient (E limit)
B_{peak}/E_{acc}	[mT/(MV/m)]	4.15	3.61	3.76	max gradient (B limit)
R/Q	[Ω]	113.8	133.7	126.8	stored energy
G	[Ω]	271	284	277	dissipation
R/Q*G	[Ω*Ω]	30840	37970	35123	dissipation (Cryo limit)

1. Introduction: Criteria

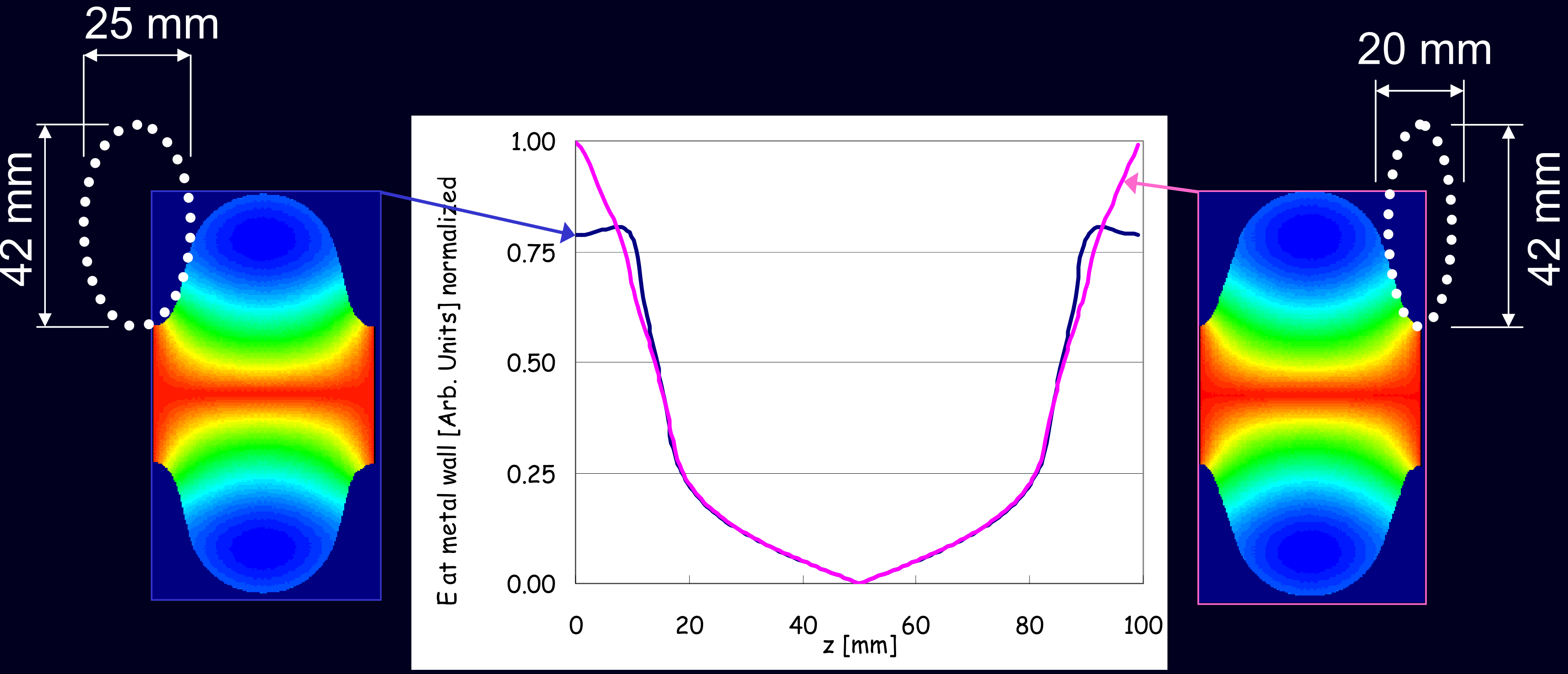
In 1991/1992 the common agreement was that the field emission is the limitation in the performance of sc cavities.



Conclusion was that E_{peak}/E_{acc} must be low

1. Introduction: Criteria E_{peak}/E_{acc}

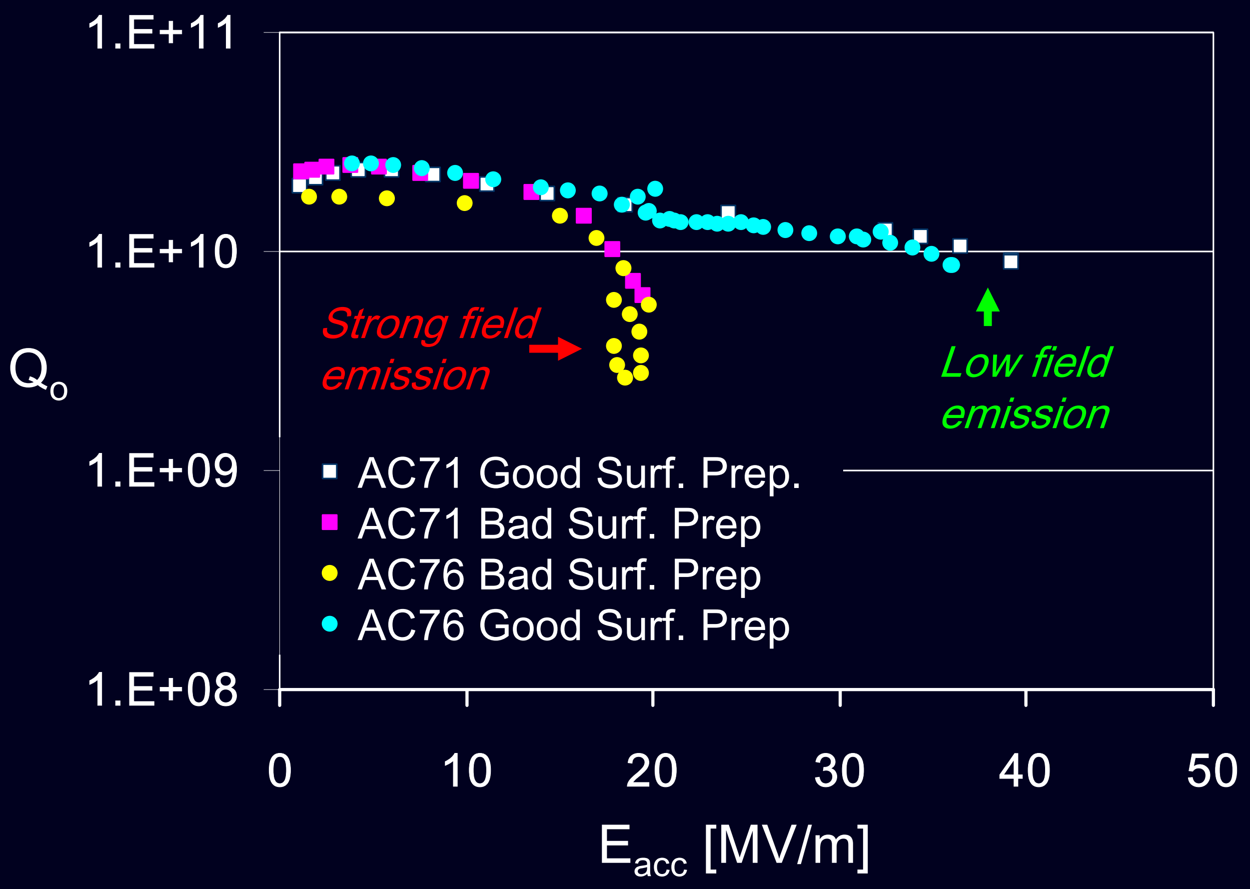
Both cells have the same: f, (R/Q), and iris radius



E on the Nb wall

1. Introduction: Criteria cont.

Some examples: 2002/2005

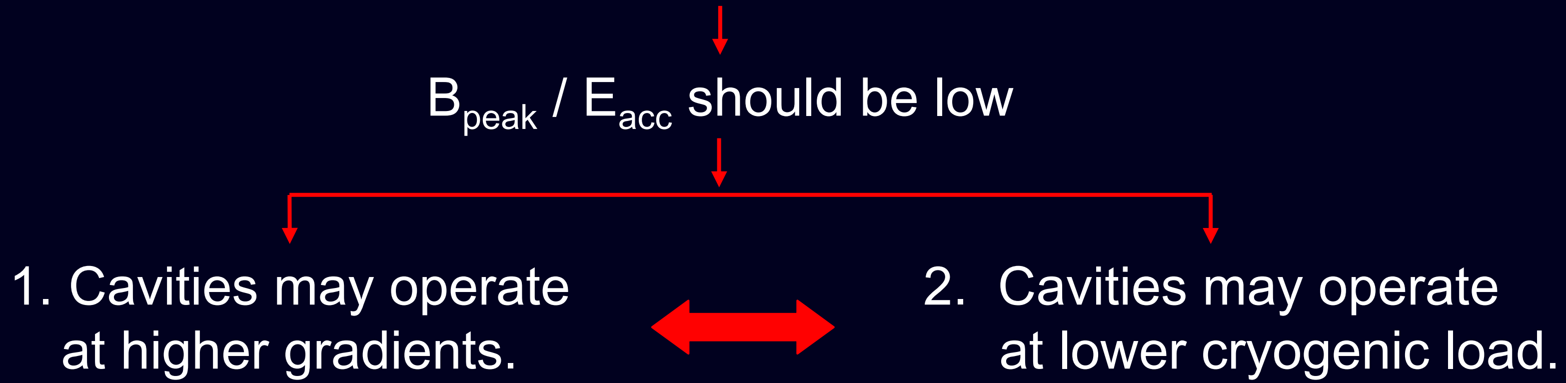


1. Introduction: Criteria, cont.

Kenji Saito (KEK) proposed (PAC2003, TESLA Meeting 2003) to verify our criteria for the cavity design.

Kenji argues that:

- The field emission is not a hard limit in the performance of sc cavities if the surface preparation is done in the right way.
- Unlikely this, magnetic flux on the wall limits performance of a sc cavity (Qo decreases or/and quench). Hard limit 180 mT for Nb



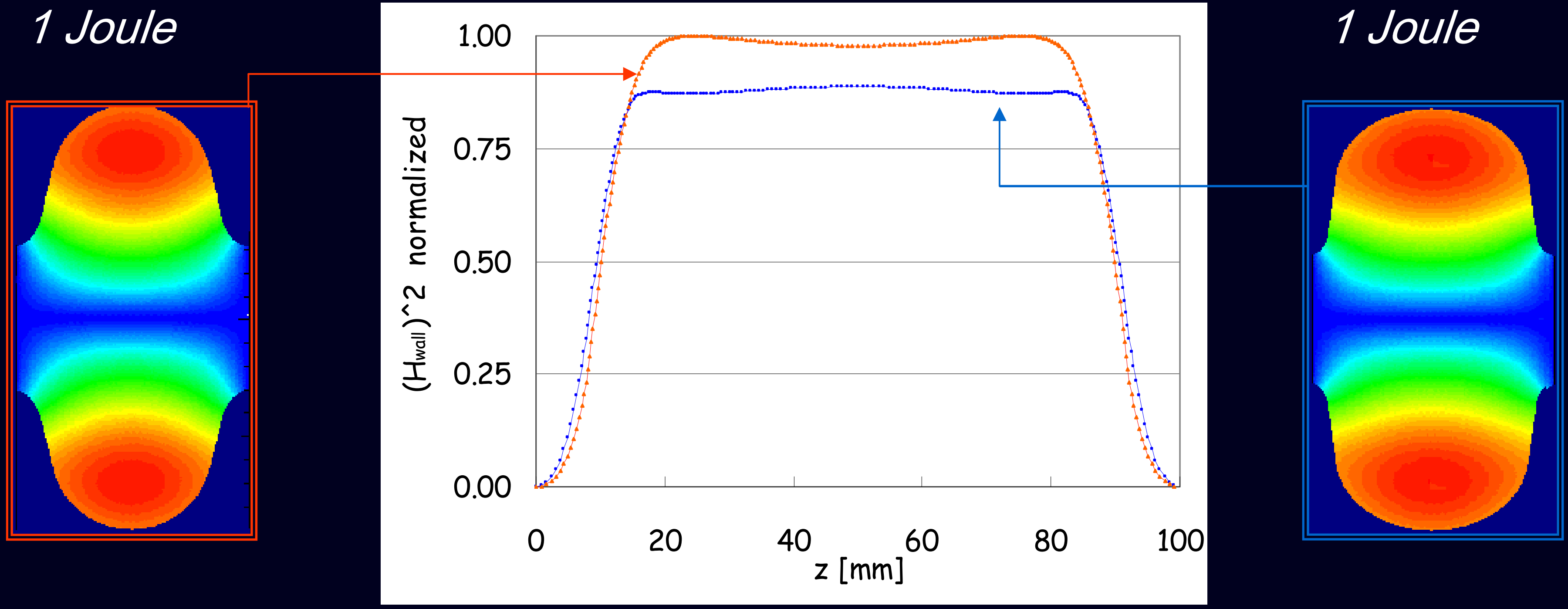
B_{peak} / E_{acc} should be low

1. Cavities may operate at higher gradients.

2. Cavities may operate at lower cryogenic load.

1. Introduction: Criteria, cont.

“Hunting” for high gradients goes together with “hunting” for low cryogenic loss.



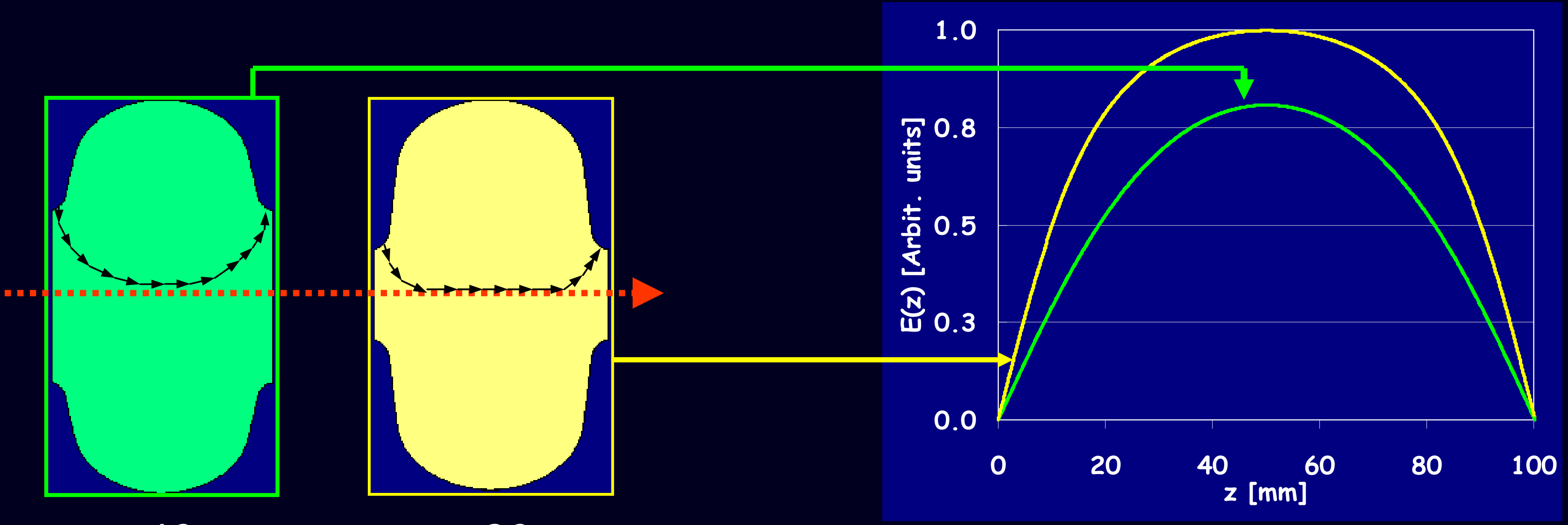
H^2 on the Nb wall

1. Introduction: How to get E_{peak}/E_{acc} , B_{peak}/E_{acc} low.

The most effective "knob to turn" is to make radius of the iris (r_i), smaller :

- (R/Q) is bigger
- E_{peak}/E_{acc} , B_{peak}/E_{acc} is lower

Closing iris we make E_{acc} higher at the same stored energy in the cell, but this is not for free.

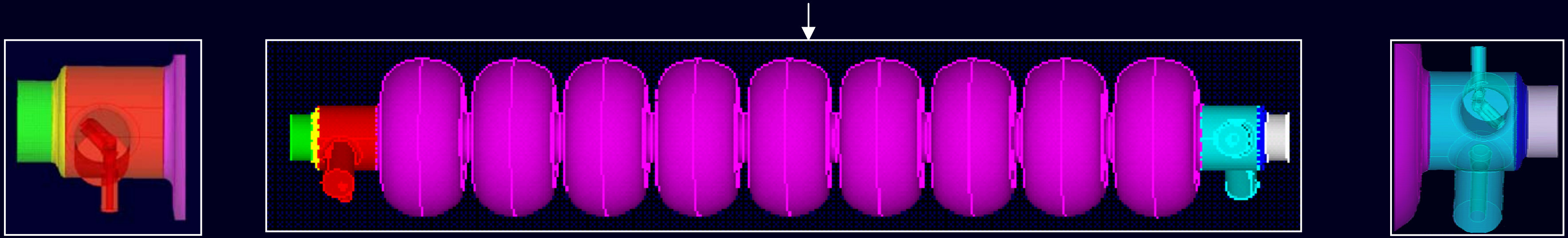


r_i = 40 mm *r_i = 20 mm*

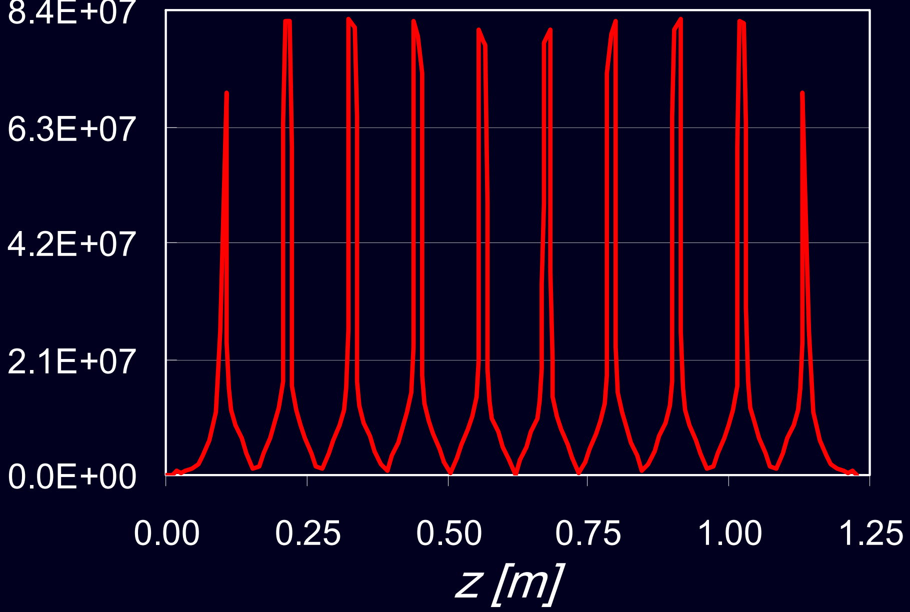
E_z (z) for small and big iris radius

2. Low Loss cavity: Fundamental Mode

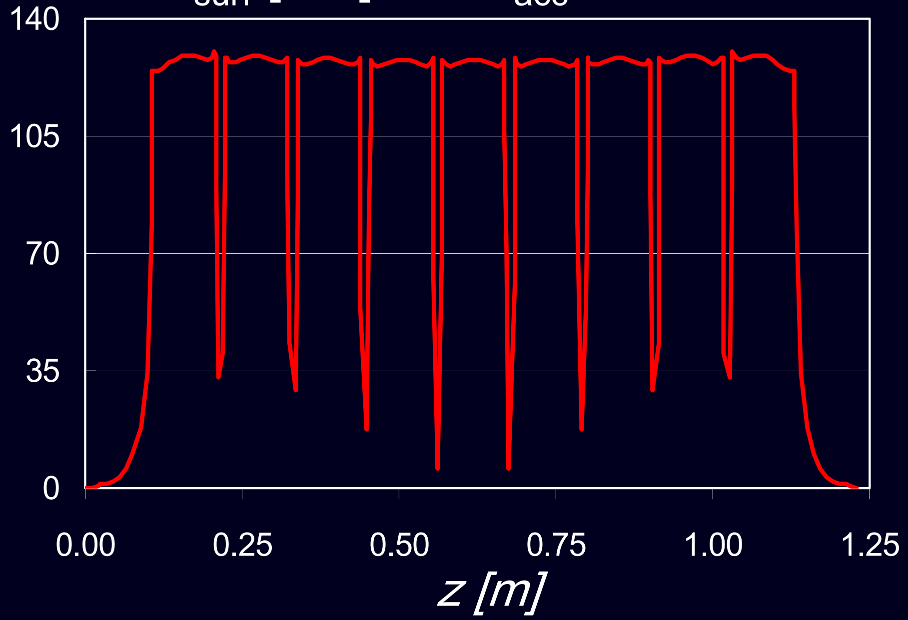
DESY (2D) , SLAC (3D)



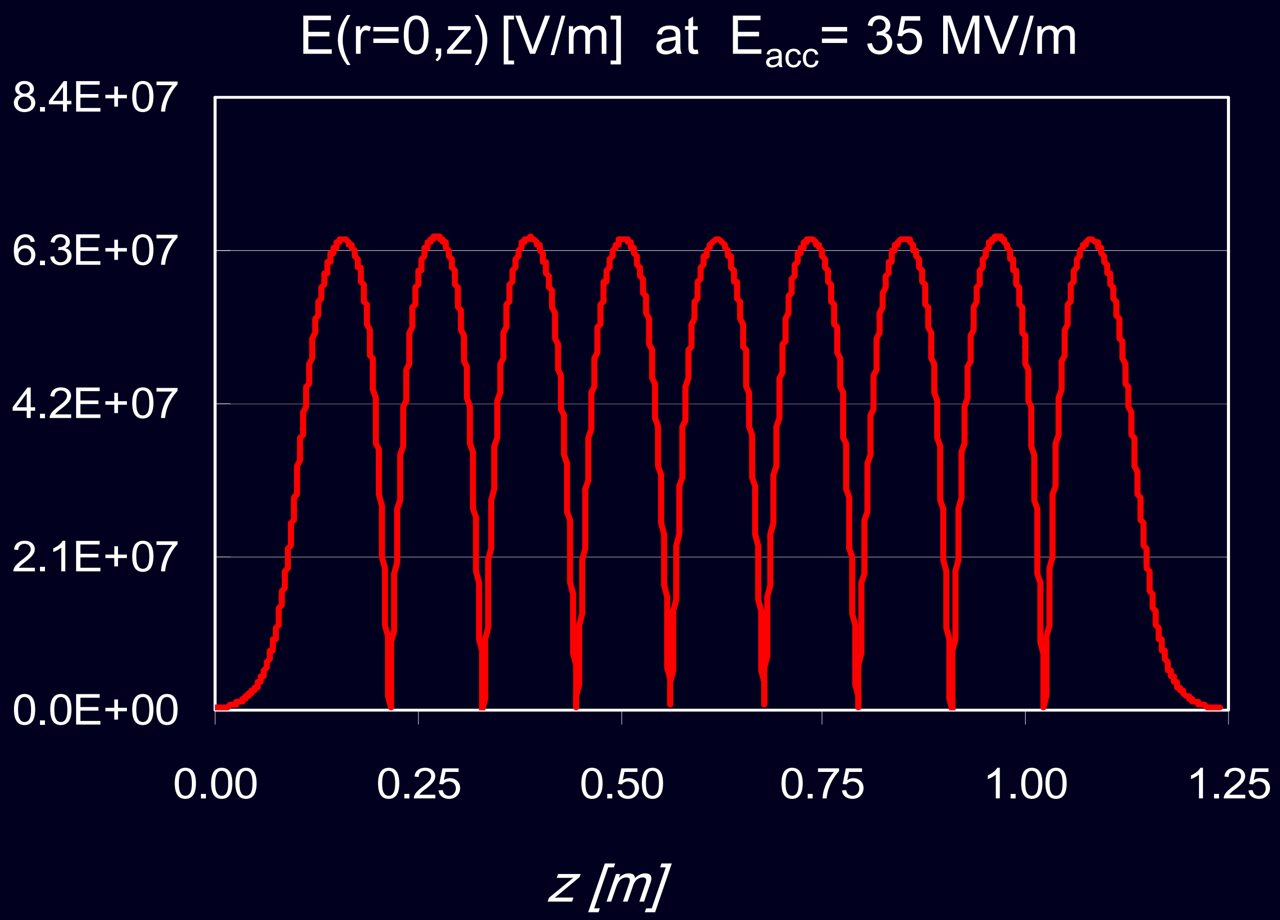
E_{surf} [V/m] at E_{acc}= 35 MV/m



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



2. Low Loss cavity: Fundamental Mode



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

2. Low Loss cavity: Fundamental Mode, cont.

		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

2. Low Loss cavity: Fundamental Mode, cont.

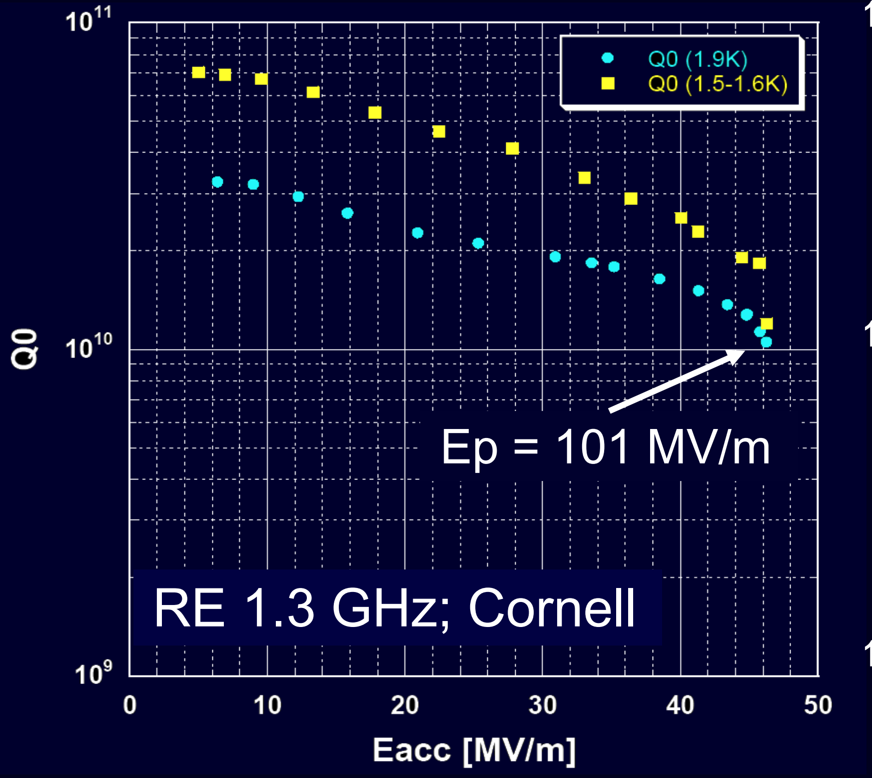
k_{cc} = 1.52% and Nc = 9

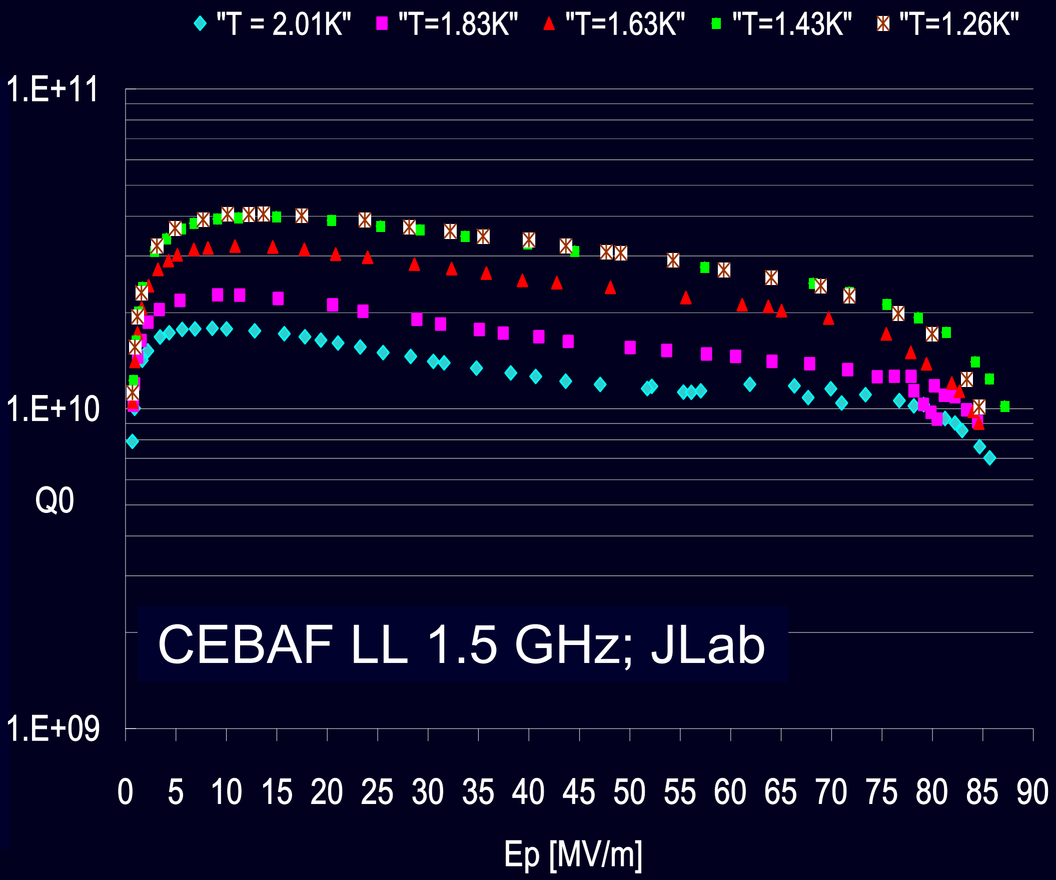
The measure of the field flatness sensitivity to frequency errors in a multi-cell cavity is: $a_f = (Nc)^2 / (ß \cdot k_{cc})$

	OC Nc = 5	LL CEBAF Nc =7	TESLA Nc =9	SNS ß=0.61 Nc =6	SNS ß=0.81 Nc =6	RIA ß=0.47 Nc =6	LL ILC Nc =9
a_f	1489 *in 1982*	3288	4091 *in 1992*	3883	2924	5040 *in 2003*	*5329* *in 2008*

2. Low Loss cavity: Fundamental Mode, cont.

$E_{peak}/E_{acc} = 2.36$ → E_{peak} = 83 MV/m at Eacc = 35 MV/m





3. Low Loss cavity: Higher Order Modes.

SLAC (Ωmega 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

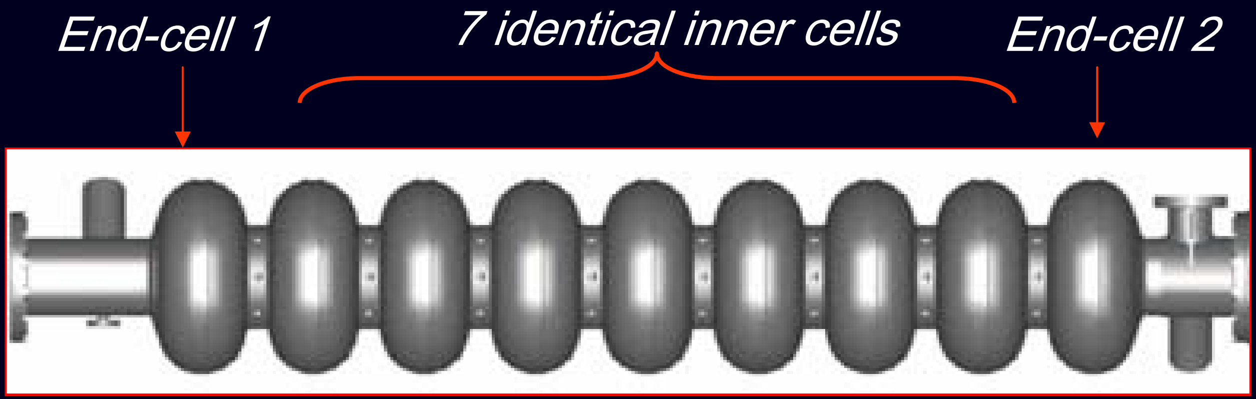
Compensation for increased $k_\perp$ will demand better cavity alignment

~230 µm instead of 300 µm

3. Low Loss cavity: Higher Order Modes, cont.

- Multi-bunch: Spec for Q_{ext}

Asymmetry of TTF structures



End-cells have slightly different geometry for better TE121 damping (this mode was trapped in the LEP cavities).

3. Low Loss cavity: Higher Order Modes, cont.

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

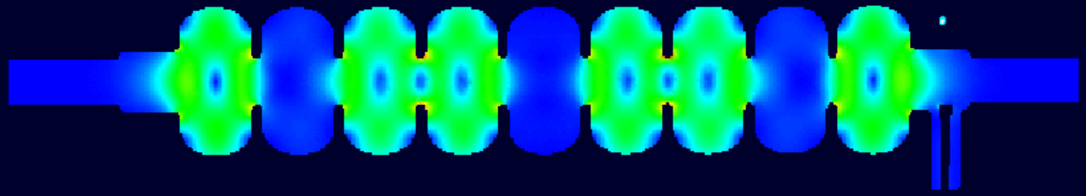
Damping of monopoles and dipoles; SLAC-ACD, FNAL

Boundary conditions

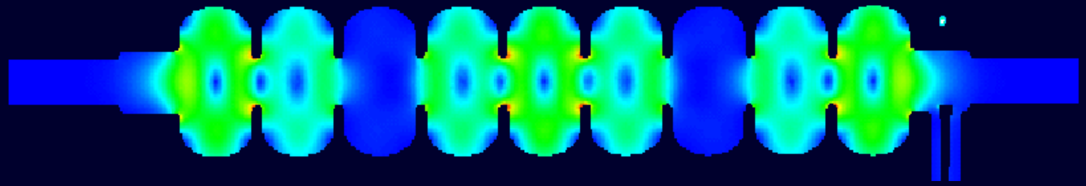
- SLAC: In full 3D model, all ports are OPEN and MATCHED.
- FNAL: In 2D model, beam pipes are terminated with ELECTRIC / MAGNETIC SHORT. Beam tubes with Ø82mm, no step.

3. Low Loss cavity: Higher Order Modes, cont.

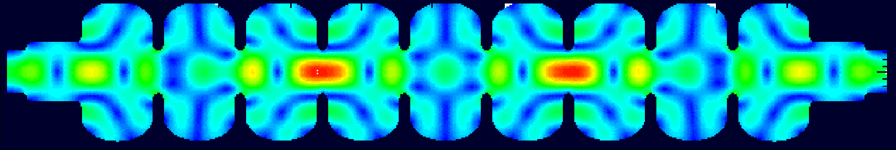
Monopoles	F range [MHz]	Highest (R/Q) [Ω]	k_{cc} [%]	Q_{ext} for the highest (R/Q) modes
TM011-like	2149-2188	192 and 199	1.8	$\sim 10^4$
TM021-like	2784-2872	1.7	3.1	$< 10^4$
TM022-like	3426-3497	44	2.1	not computed yet



F= 2.177482E+09
(R/Q)= 192 [Ω]



F= 2.182806E+09
(R/Q)= 199 [Ω]



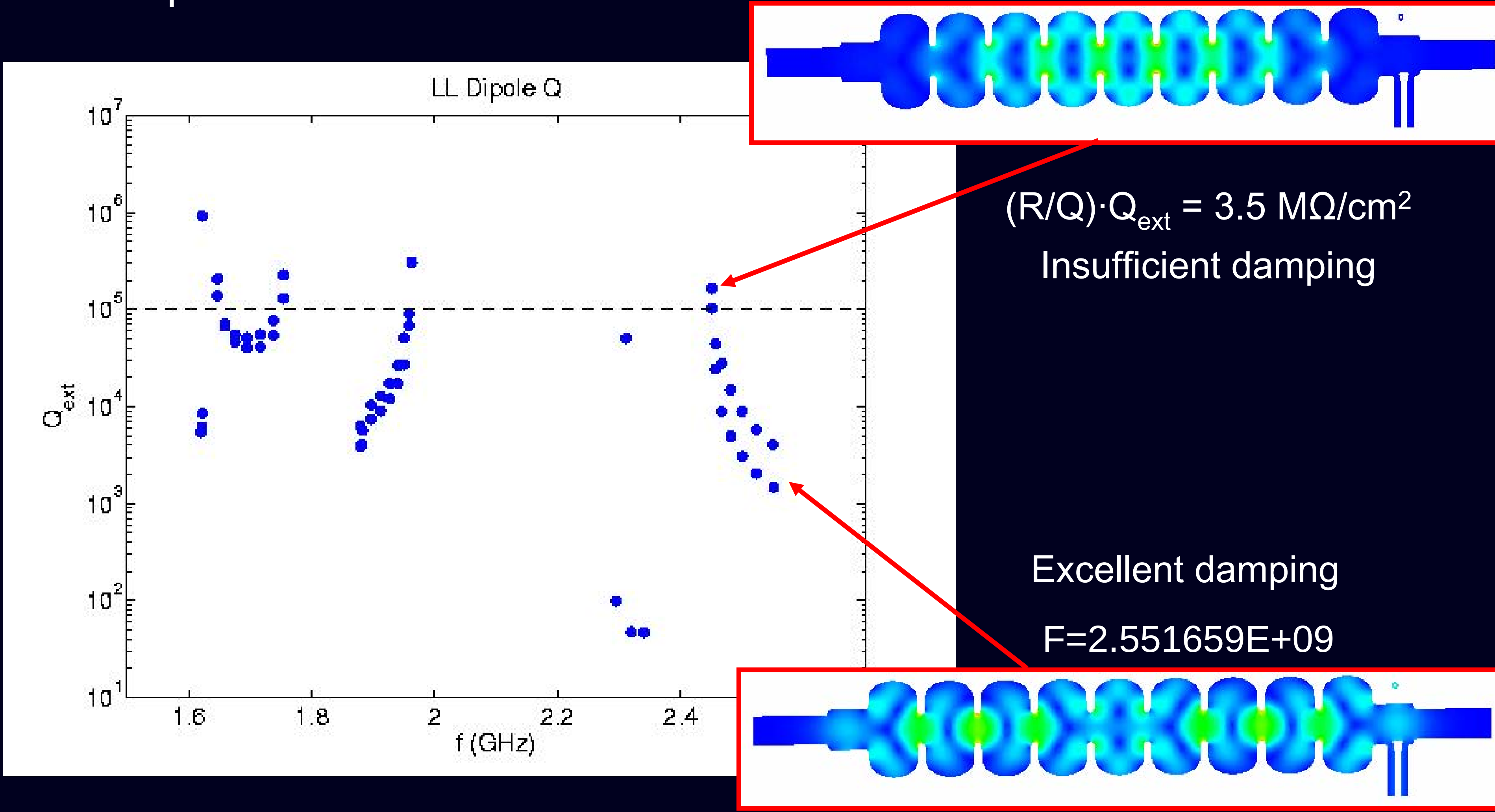
F= 3.473066E+09
(R/Q)= 44 [Ω]

3. Low Loss cavity: 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	$3\cdot10^4$	
TM110-like	1879 - 1963	14 and 10	4.3	$< 5\cdot10^4$	
3-rd passband ?	2451 - 2552	18	4	$< 2\cdot10^5$	$< 5\cdot10^3$
4-th passband	2657 - 2973	0.2	11		$< 5\cdot10^2$
5-th passband ?	3049 - 3068	0.3	0.6		$< 5\cdot10^4$
6-th passband	3293 - 3354	2.3	1.8		$< 4\cdot10^3$

3. Low Loss cavity: Higher Order Modes, cont.

3-rd passband ??



F=2.451071E+09

$(R/Q)\cdot Q_{ext}$ = 3.5 MΩ/cm²

Insufficient damping

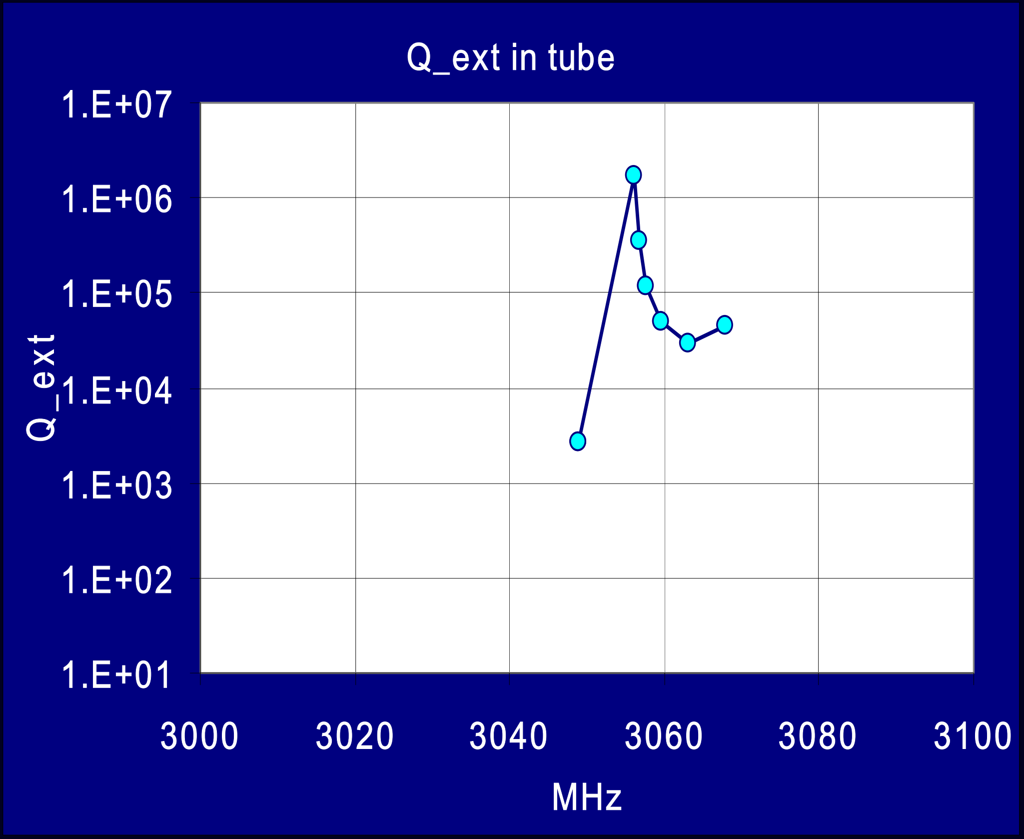
Excellent damping

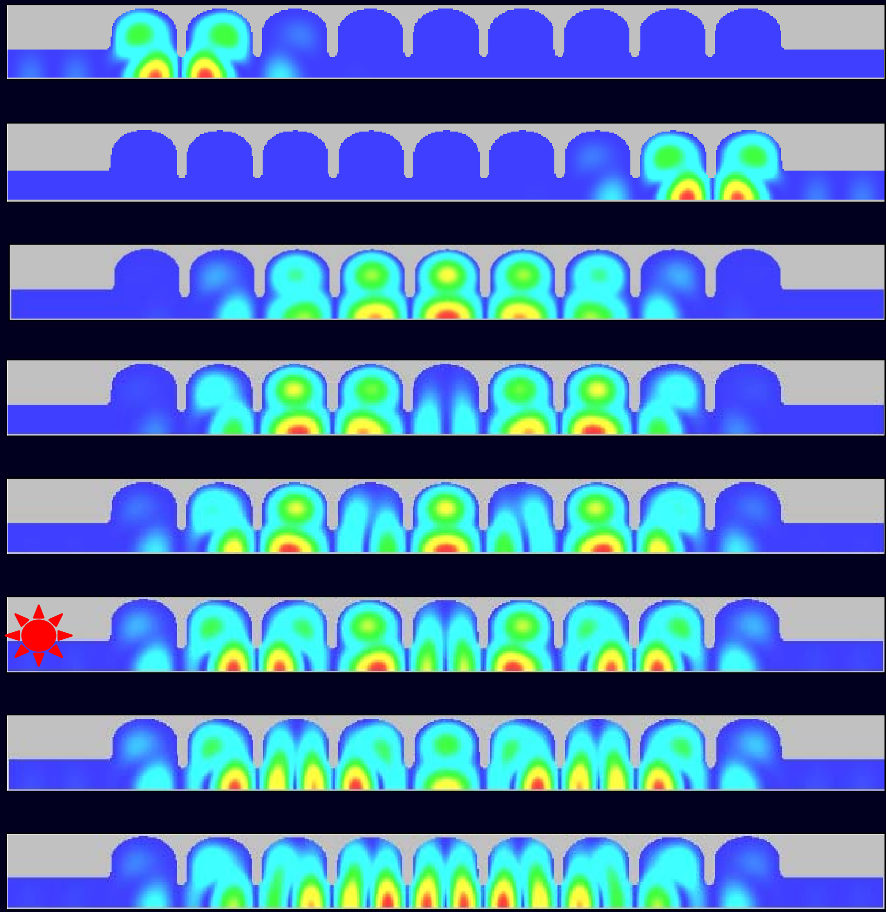
F=2.551659E+09

3. Low Loss cavity: Higher Order Modes, cont.

5-th passband ?

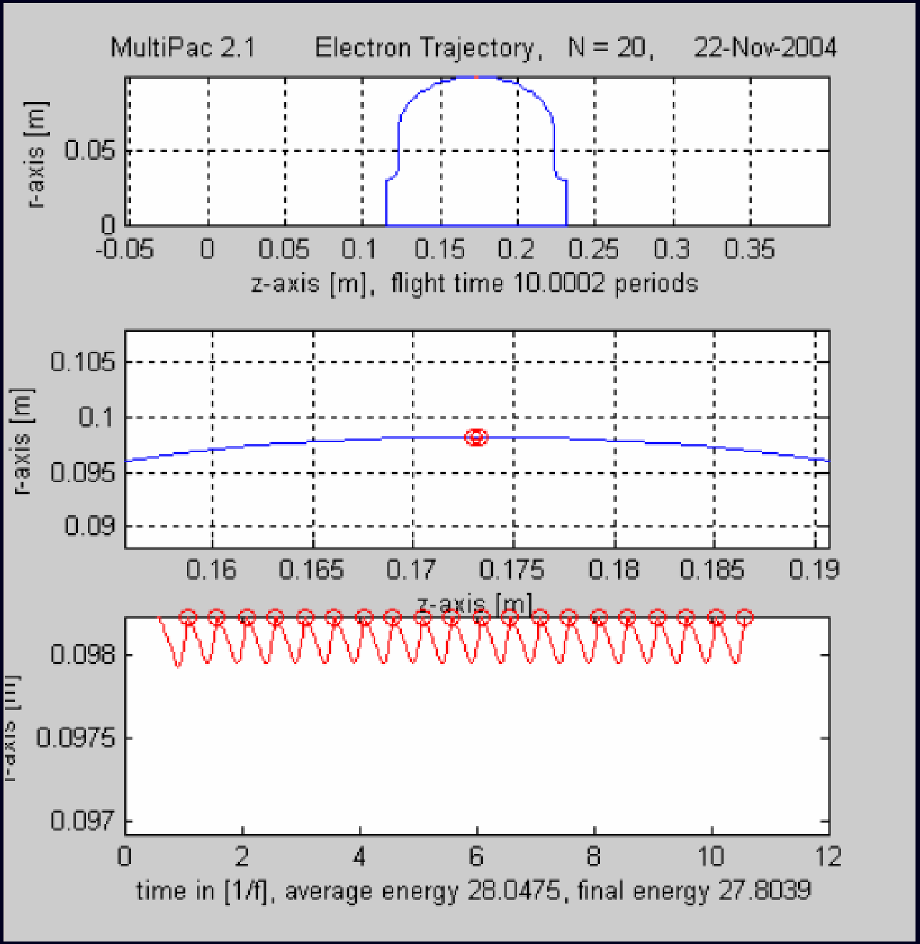
Data from FNAL, we need 3D SLAC calculation to see if there is a problem.





4. Multipacting and the Lorentz force detuning (FNAL Group)

Multipacting

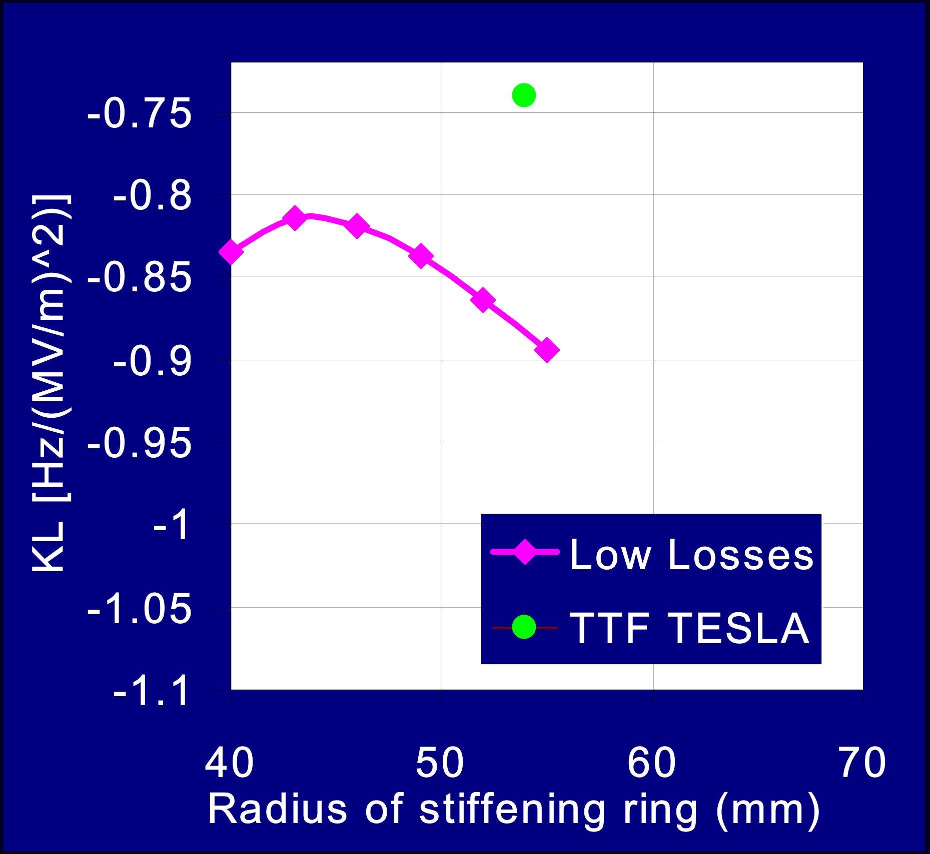


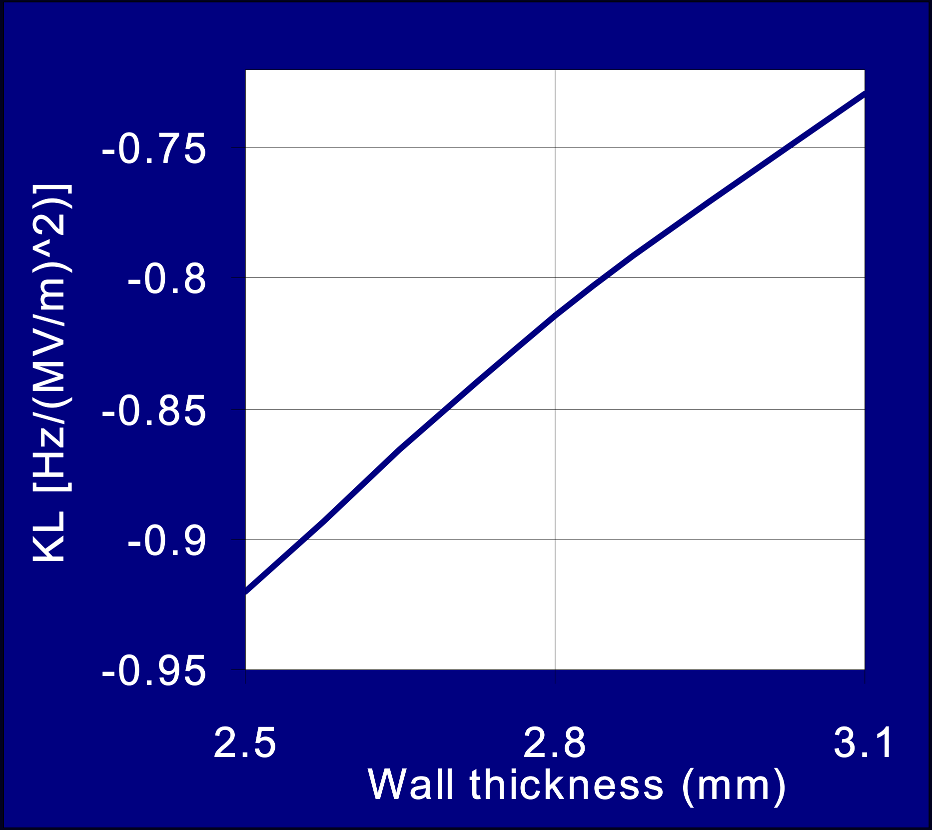
At the equator one resonance trajectory was found, but impact energy is too small, to create enough secondary electrons.

4. Multipacting and the Lorentz force detuning (FNAL Group)

Lorentz force detuning at 35 MV/m:

- TTF TESLA -908Hz
- LL -998 Hz





5. Summary and the next steps

What is good about this structure ?

- Lower cryogenic loss by ~20% (as compared to TTF structure).
- Shorter rise time by 13% due to higher (R/Q) (as compared to TTF structure).
- 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 %.

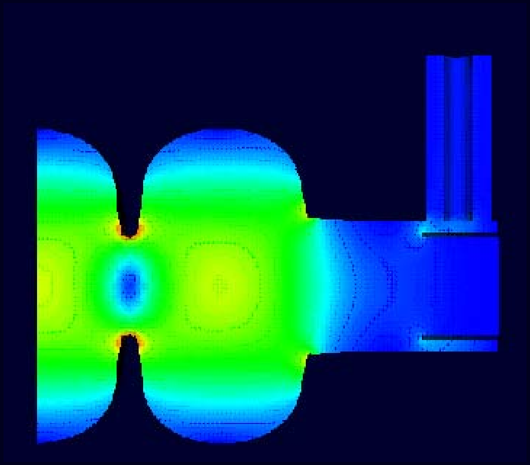
Open questions:

- Vibrations ?
- Preparation and cleaning ?

5. Summary and the next steps

Next steps:

- end-cells tuning to improve damping of 3-rd and 5-th dipole passbands or/and make asymmetry (more dyes needed to build prototypes).
- Implementation of alternative coupling methods both for FM and HOMs.



Computer modeling by ACD-SLAC and copper model of similar device built at DESY by MHF-SL group agree very good.

- Qext of FM coupler covers range $2 \cdot 10^5$ to $8 \cdot 10^6$.
- Can we build HOM coupler based on the same idea?

- KEK plans to build four 9-cell LL structures by the end of September 2005.