3.9GHz Wakefields

Calculation of wakefields in 3.9GHz cavities:
what if we had to do without dampers?
(a work in progress)

Status report of FNAL effort

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HOMs in SCRF Workshop
DESY, 22-23 Jan 2007

Calculation Method

- Long-range wakefield calculation originally developed for 3.9GHz TM_{110} mode cavity: FNAL-TM-2356.
- Started with formalism of R. Wanzenberg, TESLA 2001-33.
- Used R/Q values of Khabibouline, Solyak and Wanzenberg in FNAL-TM-2210 / TESLA-FEL 2003-01.

Calculation Method

$$R^{(n)}/Q \equiv \frac{2}{\omega_n} \frac{\left\{ V_n(\vec{r})/r^m \cos[m(\phi-\phi_n)] \right\}^2}{4U_n}$$

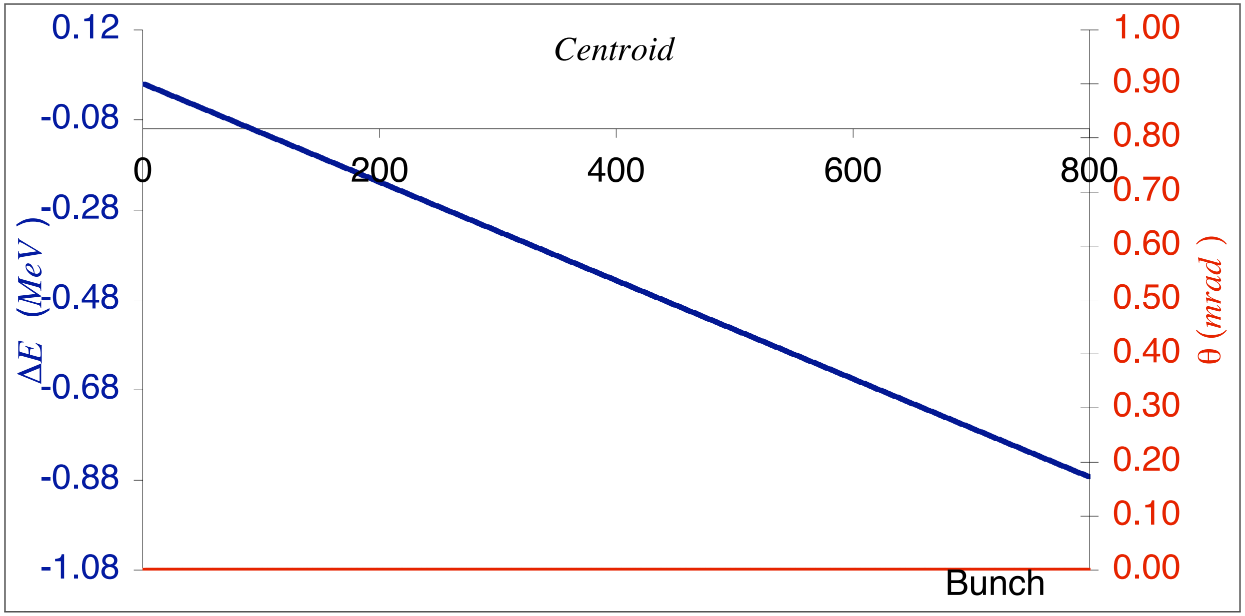
$$W_{//}^{(n)}(s) = \frac{R^{(n)}}{Q}\omega_n \cos\left(\frac{\omega_n s}{c}\right)\exp\left(-\,s/c\tau_n\right) \qquad W_{\perp}^{(n)}(s) = c\frac{R^{(n)}}{Q}\sin\left(\frac{\omega_n s}{c}\right)\exp\left(-\,s/c\tau_n\right)$$

m	f (MHz)	$R^{(m)}/Q$ (Ω-m^{2m})	Q_{TOT}
0	3900.00	0.000E+00	6.54E+09
0	7506.00	2.322E+01	5.05E+09
1	4834.00	5.070E+05	5.47E+09
1	5443.00	2.090E+05	7.23E+09
1	7669.00	2.950E+05	4.84E+09
2	9133.00	1.119E+09	3.11E+09

Bunch spacing	1000.00 *ns*
Bunch charge	1.00E-09 *Coulomb*
Bunch length	1 *ps*
E_{BEAM}	130 *MeV*
R_{BCS}(3.9*GHz*)	20.0 $n\Omega$
R_0(3.9*GHz*)	20.0 $n\Omega$
Beam offset	1 *mm*

Easy to repeat with different values…

Calculation Result

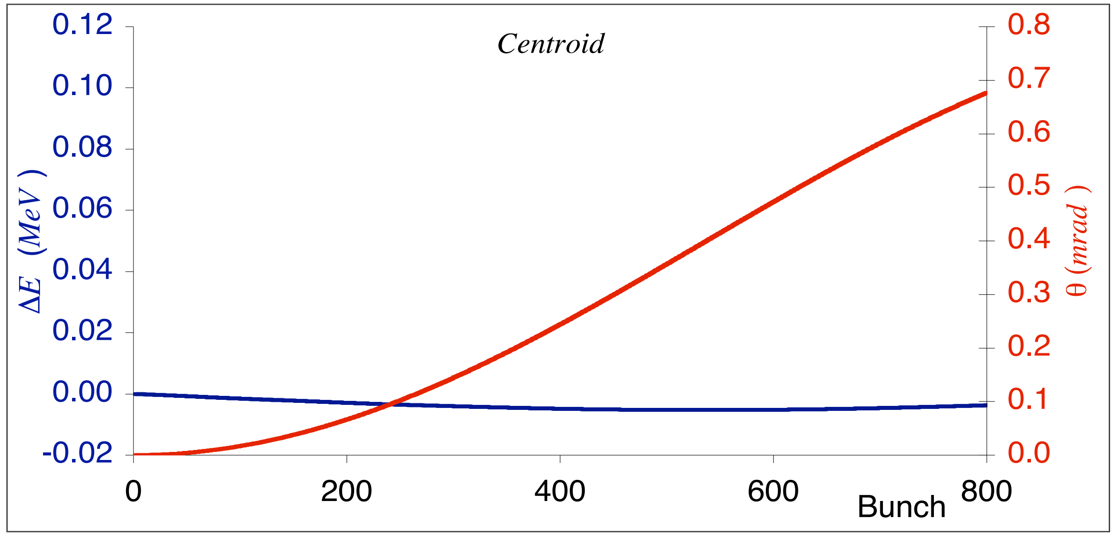


If monopole at 7506MHz lands on resonance and is not damped, beam energy changes ~800keV (for a single 9-cell)

Excel/VBA code - runs reasonably quickly

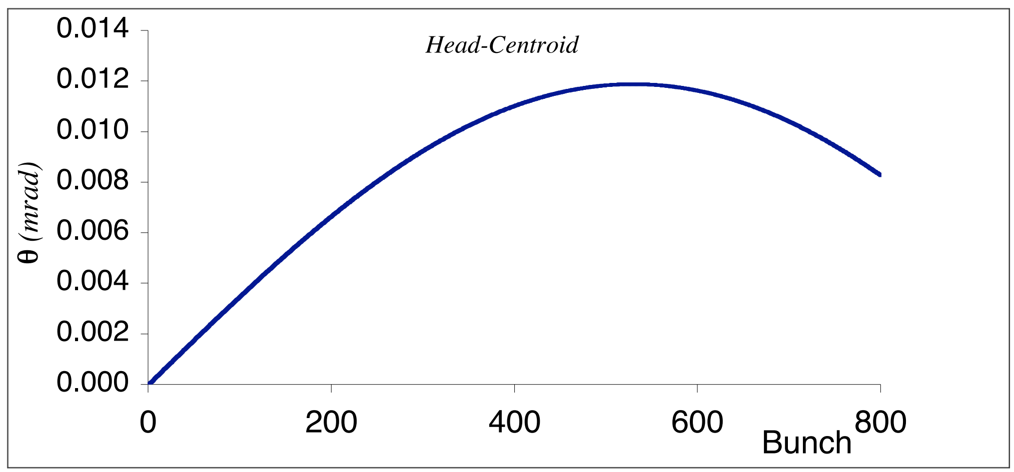
Calculation Result

For dipole modes worst case is f_{cavity} ~468Hz off (integer) f_{beam}



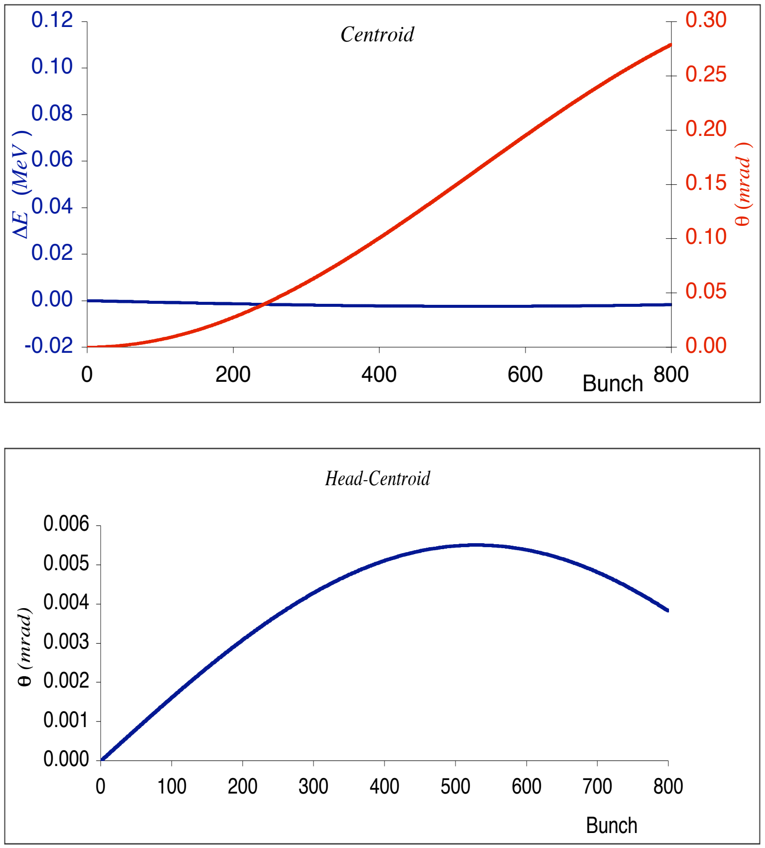
Here is that case for 4834MHz mode, 1 cavity

There is also crabbing - the angular deflection 1σ in front of bunch center ≠ deflection at bunch center

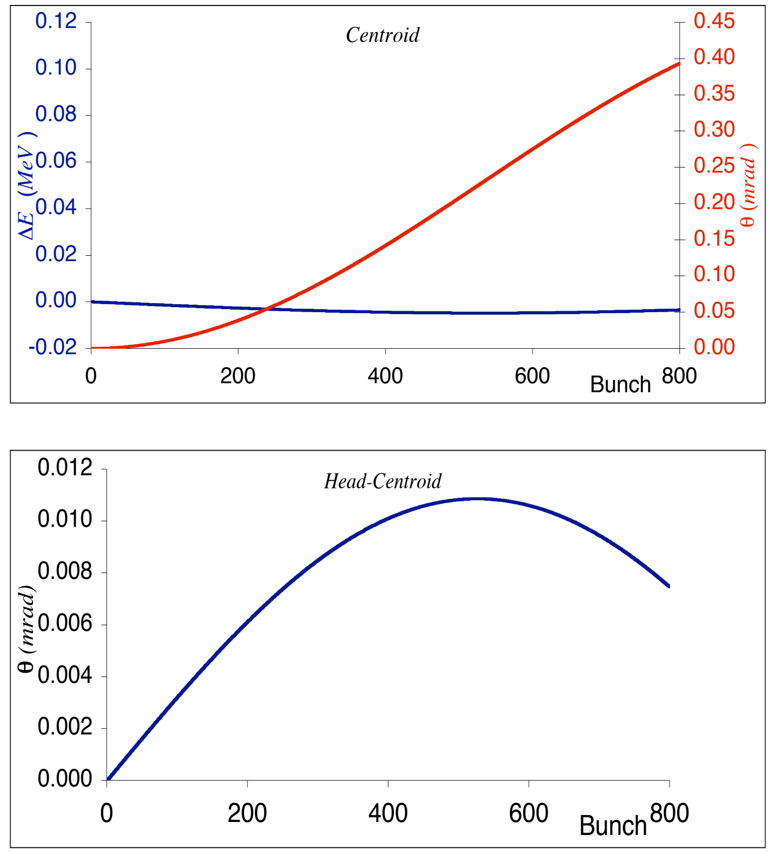


Calculation Result

5443MHz mode



7669MHz mode



Same shape, scaled (almost) by R/Q

9133GHz m=2 mode smaller

Calculation

1) Note that with intrinsic damping only, decay time of the beam-excited modes is $\mathcal{O}$[1/3sec] and for rep rates over a Hz or so, there will still be fields left in the cavities from earlier trains

2) I've started to look at the typical, rather than the worst case - not really ready to show it

The numbers are typically much smaller, however…

I believe that for a critical subsystem that contains a small number of components, worst-case analysis rather than typical-case analysis is appropriate.

Status

A detailed report of the 3rd Harmonic coupler redesign was given by N. Solyak for the whole 3rd Harmonic team at the KEK meeting of the TTC in Sept 25-28th 2006

https://indico.desy.de/conferenceDisplay.py?confId=92

(scroll down to find his talk / Tuesday at 16:35)

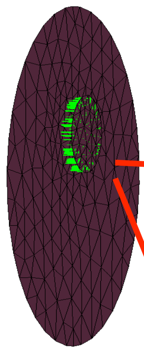
From the relative field levels in $\pi/9$ vs π modes and observed temperature spikes, it is clear that we are quenching in the HOM coupler at 12-14 MV/m.

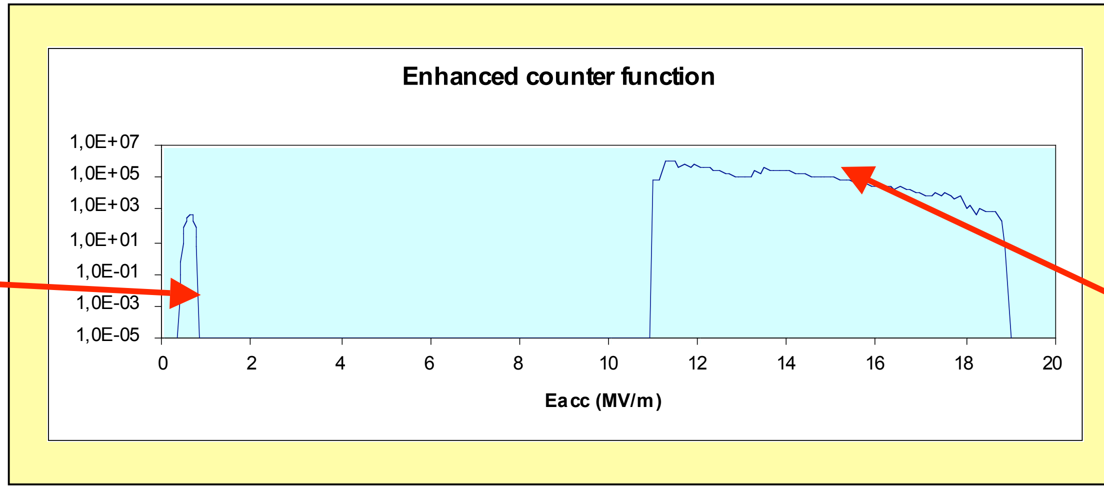
We have a simulation that says that multipacting should happen at about this level

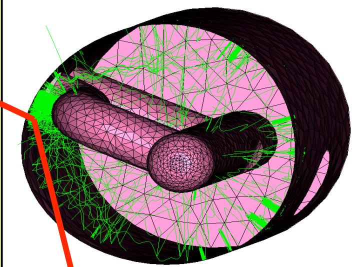
MP in current HOM design at F=3.9GHz

3D simulation

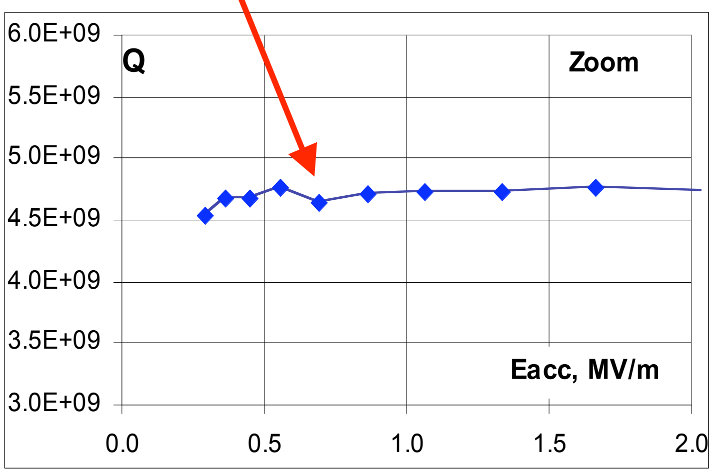
Omega 3P(Analyst)



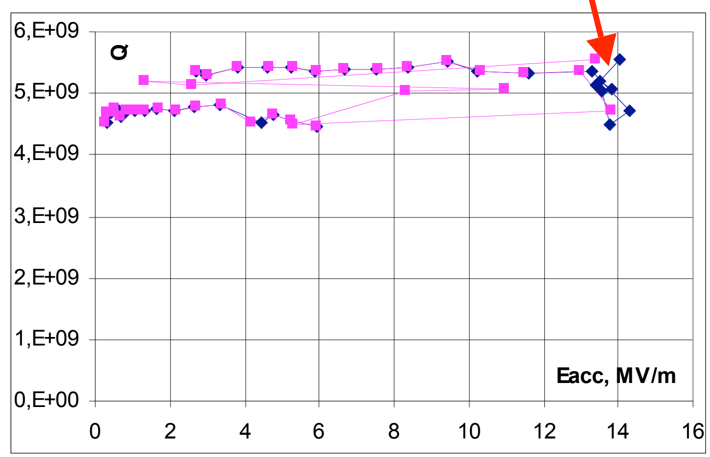




MP in notch gap 0.6 mm



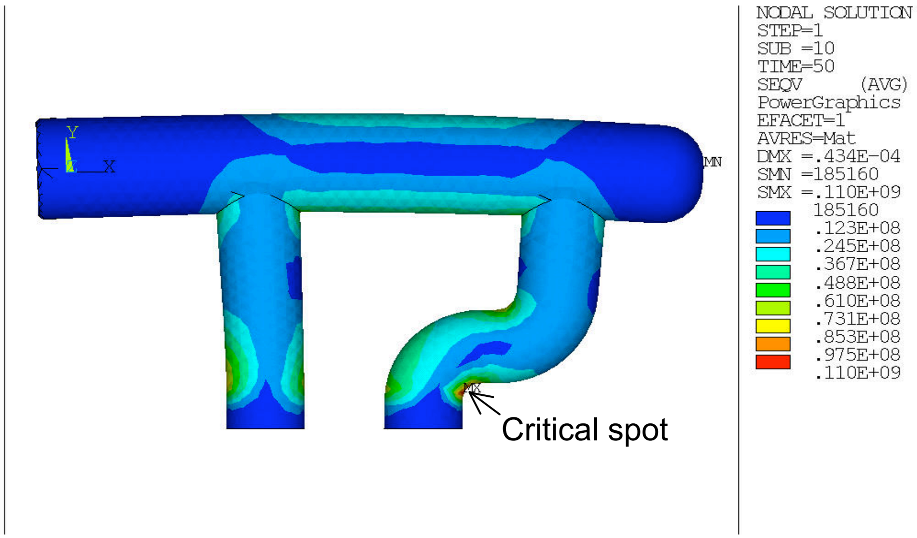
MP in 2 mm Leg-wall gap



Results of vertical test MP observed at Eacc~0.7MV/m (Q drop). Quench at Eacc~14MV/m. Second resonance frequency of HOM was tuned higher than designed value.

Status

Almost all ways of heating the formteil cause large stresses in the same place, for the same reason - and this is where we saw fractures in cavity 2.

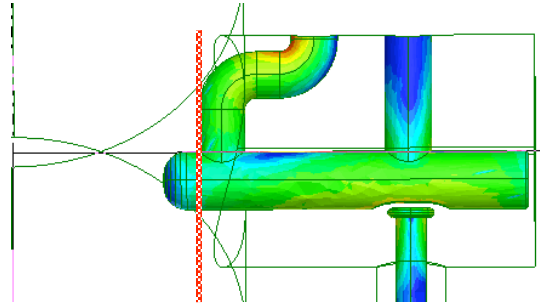


3-pronged attack on the problem

Status

1) a cut here should reduce
fields in multipacting area
by a factor of 2 - moving
the barrier out of way

Can be applied retroactively



Cavity 4 now in fabrication at JLab with this modification

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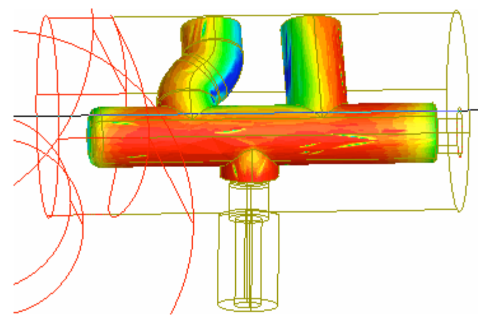
2) a less-sharp dogleg and rounded end at
the tuning notch, combined with thicker
material should be more robust



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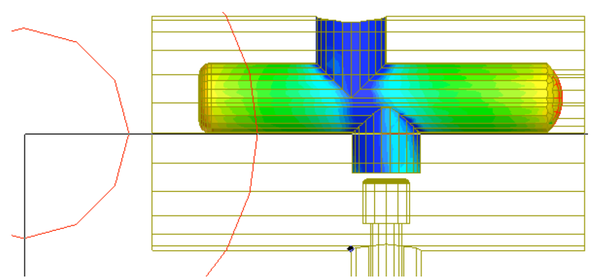
3) a single, straight-legged design
which should have low fields; like
(2) has 2.5mm tuning gap - less
sensitive



credit: T.Khabibouline

Status

- 1-post and new 2-post prototypes were built in Cu and tested
- Weld tests are now underway in Nb
- We have 9 pick-up antennas from one vendor - 3 need rework
- 3 pick-up antennas from a 2nd vendor for evaluation due any day now
- Horizontal test stand, mockup ass'y of cold mass on track for this spring.

Conclusion

- If you run a 3rd Harmonic cavity without dampers, you *could* see
  - $\Delta E \sim$ 800keV $\Delta\Theta \sim$ 0.7mrad $\Theta_{\mathrm{CRAB}} \sim$ 12mrad

- This does not allow for high rep-rate effects

- We have a consistent & likely explanation for the failure of the HOM coupler, and are implementing several proposed fixes