Thinking Outside the Box

A different approach to the LHC crab cavity problem - still a work in progress !

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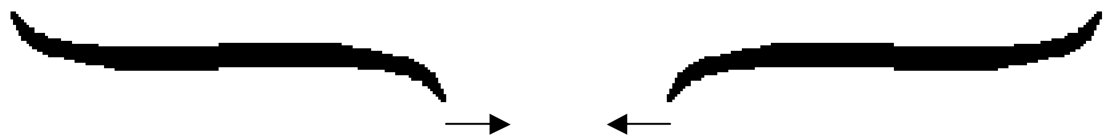
Basic parameter issues

The LHC design parameters introduce some specific problems for crab cavity design - which are known to us all:

1. Very close beam spacing
2. Relatively long bunches (compared to say, the ILC)
3. Multi-pass colliders usually need very heavily damped cavities

There is a luminosity loss when the bunch length becomes comparable to cavity frequency by c because $\sin x \neq x$



This has been studied for the LHC bunch length and going to frequencies as high as 800MHz is deemed acceptable if not optimal - issue is fitting the cavities in the inter-beam space which is not that big.

I try going down to 200MHz (lowest frequency I think is practical) and sending both beams through the same cavity

I say 200MHz is the lowest feasible frequency because

$$V = c\, E\, \Theta_C \,/\, (4\pi\, f\, R_{12})$$

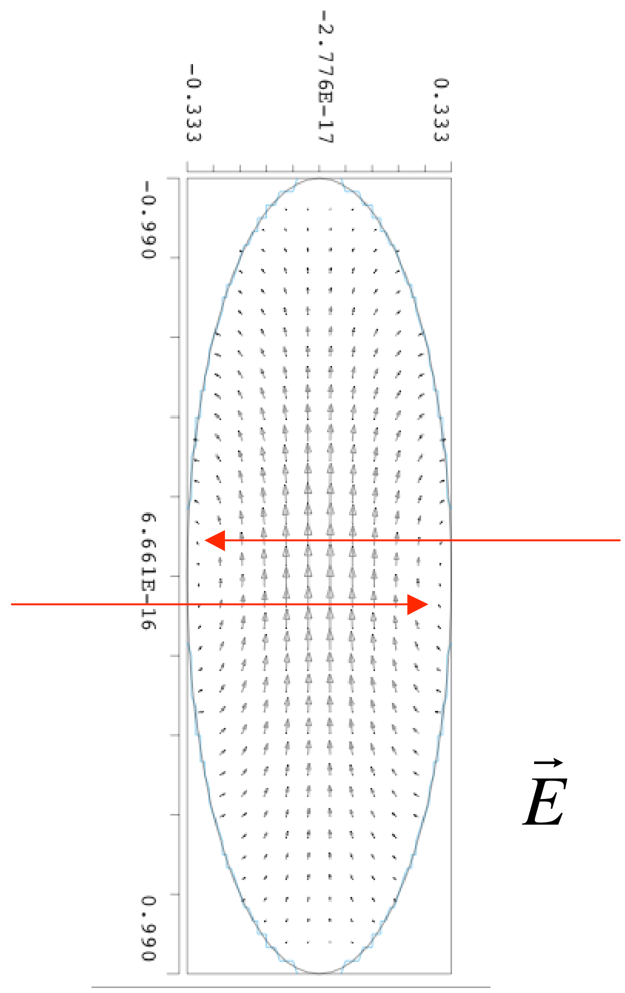
and from Frank I've learned that Θ_C ~400μrad and R_{12} ~30m. That puts V at 11.1MV for 200MHz, which (Derun can correct me) is the sort of result that has been obtained in the mu-cool cavities at 201MHz. As long as $E_{PEAK}/E_{DEFLECTION}$ stays small!

One cavity shape with small $E_{\mathrm{PEAK}}/E_{\mathrm{DEFLECTION}}$ is the sphere - to maintain polarization, would want ellipsoid.

To have both beams come through at zero crossing introduces a z position constraint of 1/2 cycle

Beam-beam effect, minimized by high aspect ratio & bunches passing through 1/2 cycle apart - I have not worked out exactly how high the ratio can go and still give the kick needed

Short-range transverse wakes go up as a power of the bunch length and can cause banana-shaping. The effect is reduced by not having irisis. There is a fixed effect due to the asymmetry seen by the beam - maybe one can compensate for that in the beampipe to cavity junction



The problem so far...

- This, or any cavity, will need tremendous damping of L/S/HOM modes.

$$\theta_{bunch\ off\ desired\ line} \propto \left(\frac{q_{bunch}}{E_b}\right)\frac{R}{Q}F_I(\delta, d)$$

where $F_I(\delta, d)$ is the multiplication effect due to accumulated wakes from previous bunches. $F_I(\delta, d)$ depends on the frequency of the mode relative to the bunch spacing (δ) and the damping (d). Just to keep $F_I \sim 1$ requires

$$d \equiv \frac{\omega \Delta T_{bunch}}{2Q} \leq \ln\left(\frac{1+\sqrt{5}}{2}\right)$$

depending what frequency you think your mode is at, or how far over 1 you are willing to let F_I go, you could be wanting Q_{EXT} on the order of 100.

The problem so far...

- This cavity in particular has modes that are very highly coupled to the beam - similar to the operating mode but with the electric field along the beam z axis. These are like the traditional TM_{010} modes of an elliptical cavity. There will also be modes like TM_{110} in an elliptical cavity, and higher index modes also

- A more 'elegant' solution to damping: just stay off these modes. That is, tune the main and one or two particularly bad modes to have frequencies with nice phase relationships to the beam so as to control $F_I(\delta, d)$ by controlling δ rather than d.

...suggestions solicited!

- Given the geometric symmetry of the cavity, I'm thinking of plungers that could move the surface in or out at specific spots that would be on nodes of the Slater field quantity

$$\delta f \propto \mu_0 \frac{H^2}{2} - \varepsilon_0 E^2$$

for one or more of the important nodes

But I'm having trouble figuring out how these devices might actually be designed for a superconducting cavity. For Cu they might be small cylinders that form the cavity wall and move in and out but for Nb/Cu I think there would be electrical connectivity issues