SRF $\frac{1}{2}$ - CELL GUN & ISSUES

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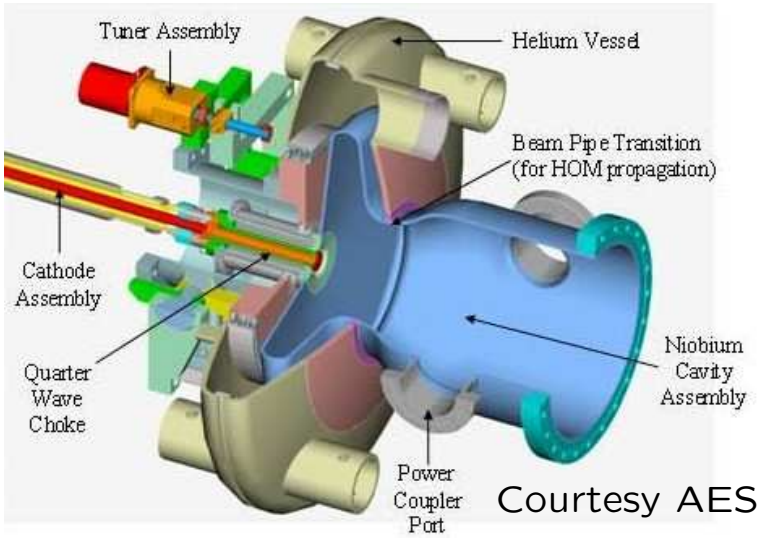
BNL

May 25, 2006

$\frac{1}{2}$ Cell SRF Gun

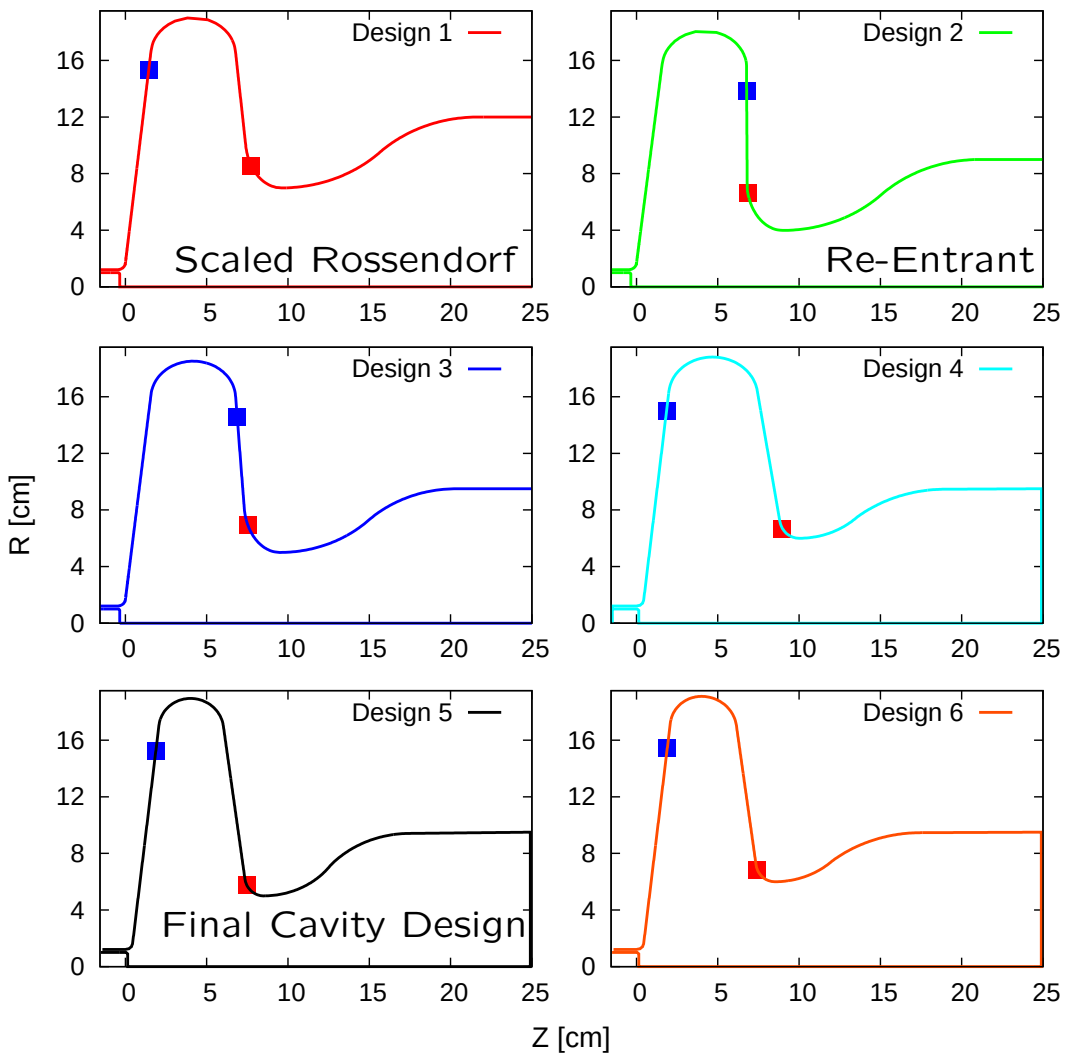


Courtesy AES

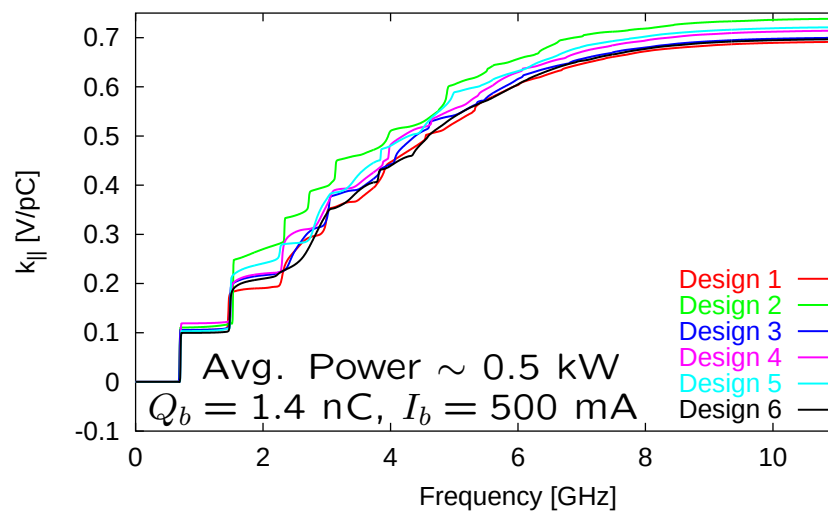
Cavity Design	Right Cell
Frequency	703.75 MHz
Iris Radius, R_{iris}	5.0 cm
Wall Angle, α	6.5°
Equatorial Ellipse, $R = \frac{B}{A}$	1.1
Iris Ellipse, $r = \frac{b}{a}$	1.2
Cav. wall to iris plane,	1.0 cm
Active cavity Length, L	8.5 cm
Center to equator end	18.95 cm
Avg. Beta, $< \beta = \frac{v}{c} >$	0.587

- Generation of ampere class CW beam
- $\beta < 1$ and varying
- Low $\epsilon_{x/y}$ & $\delta E/E$
- E_z at the cathode
- Strong Coupling $Q_{ext} \sim 10^4$
- Coupler Kicks
- Multipacting
- HOMs & Stability Criteria
- Cathode Issues and Isolation

Gun Shapes

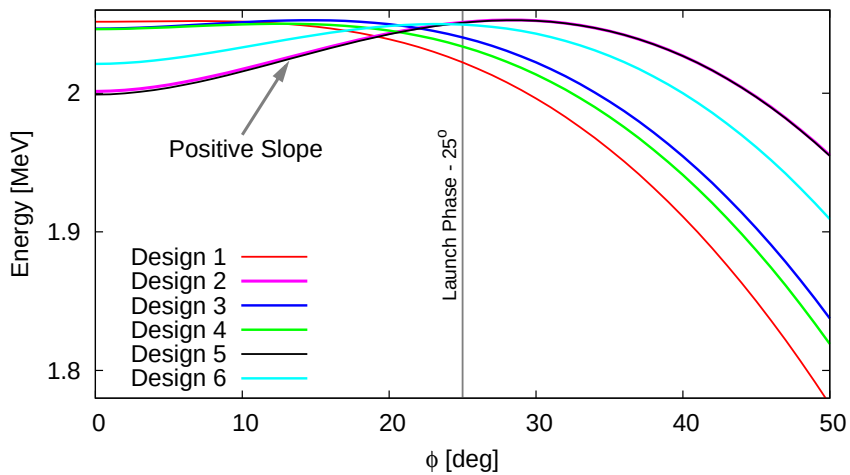


Shape	r/Q [Ω]	E_p/E_a	B_p/E_a [$\frac{mT}{(MV/}$
Design 1	101	1.14	2.73
Design 2	105	1.39	2.97
Design 3	103	1.20	2.81
Design 4	112	1.33	2.69
Design 5	95	1.42	2.96
Design 6	92	1.42	2.87

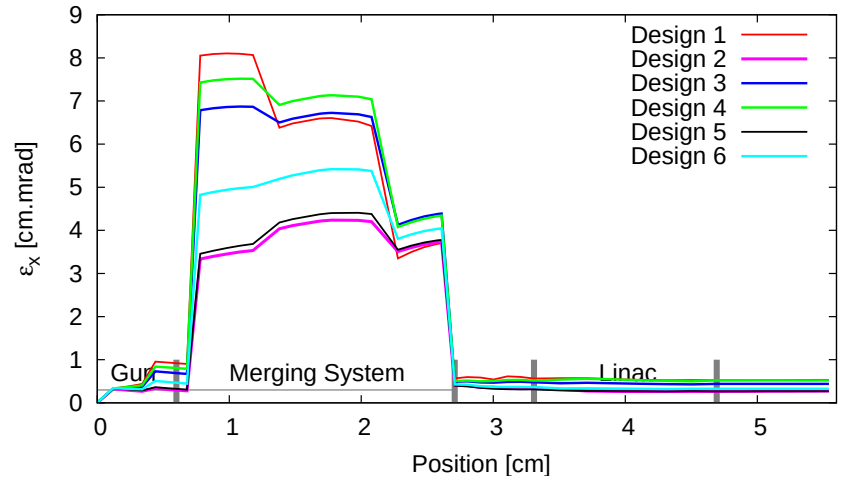


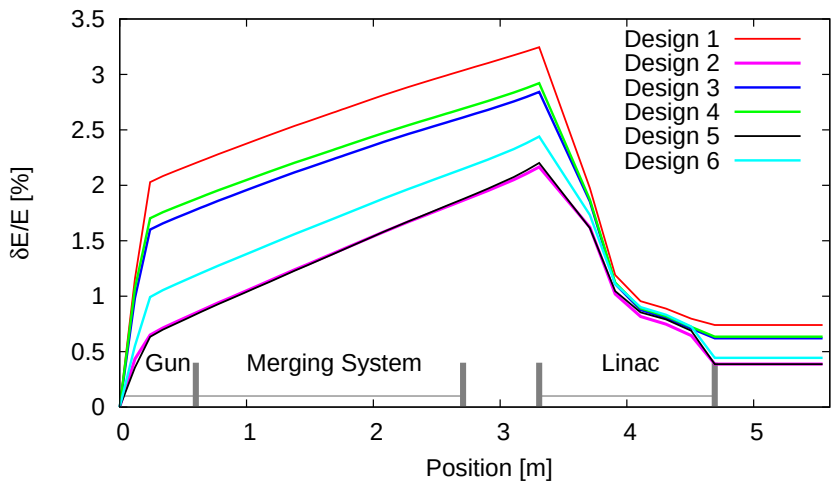
Energy Spread & Emittance

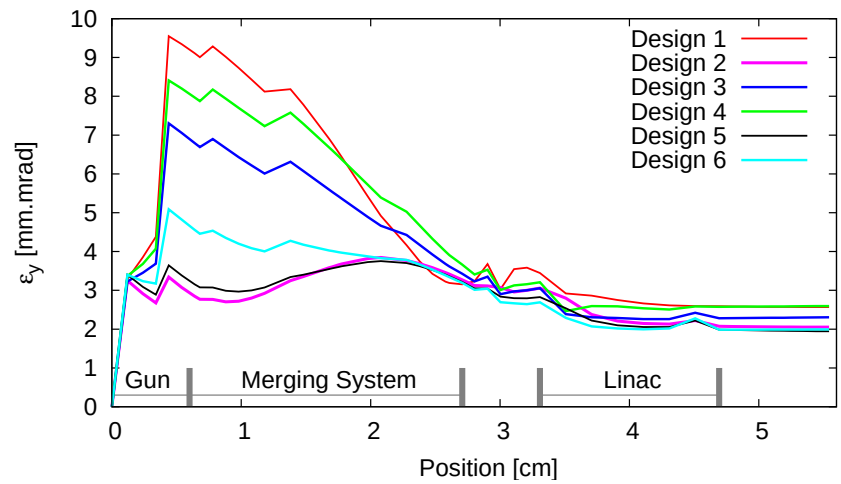
Longitudinal



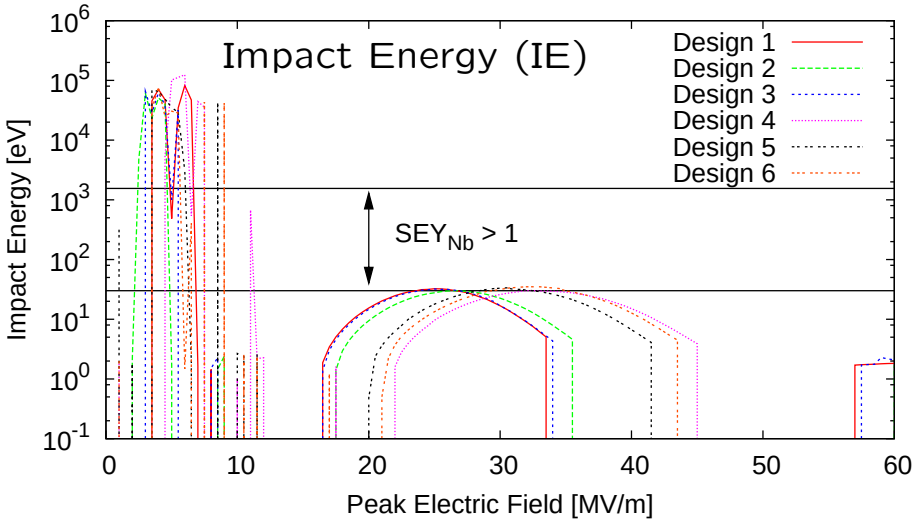
Transverse

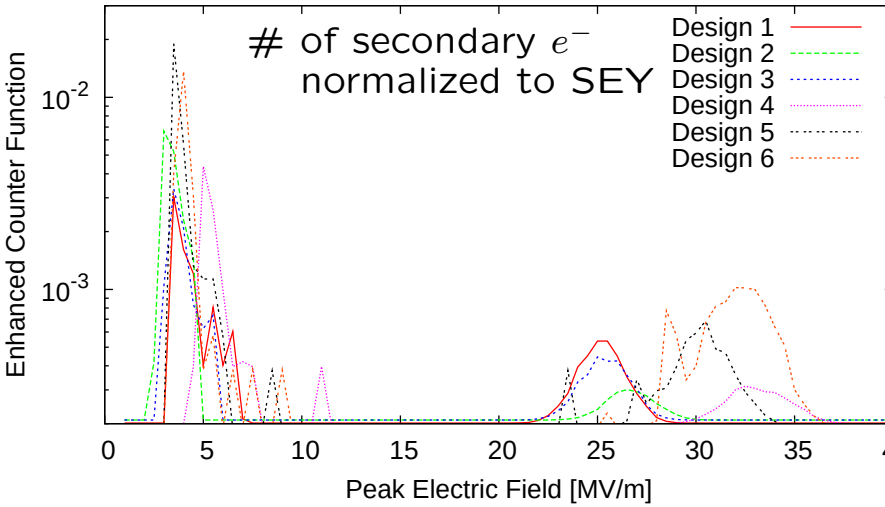


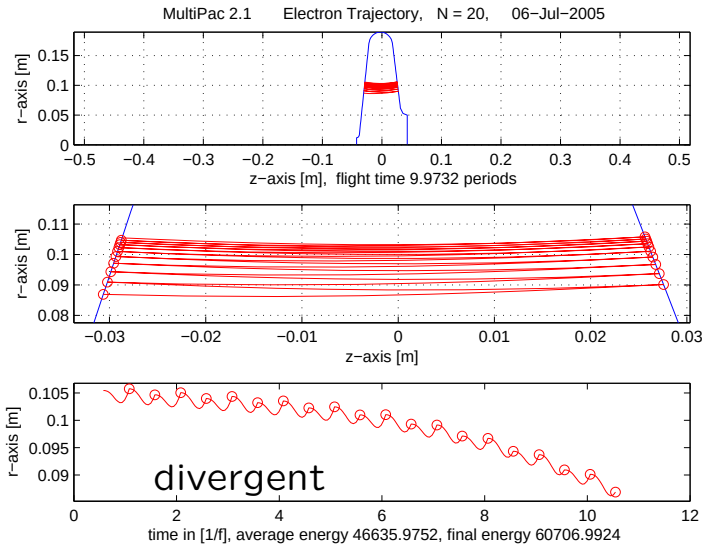


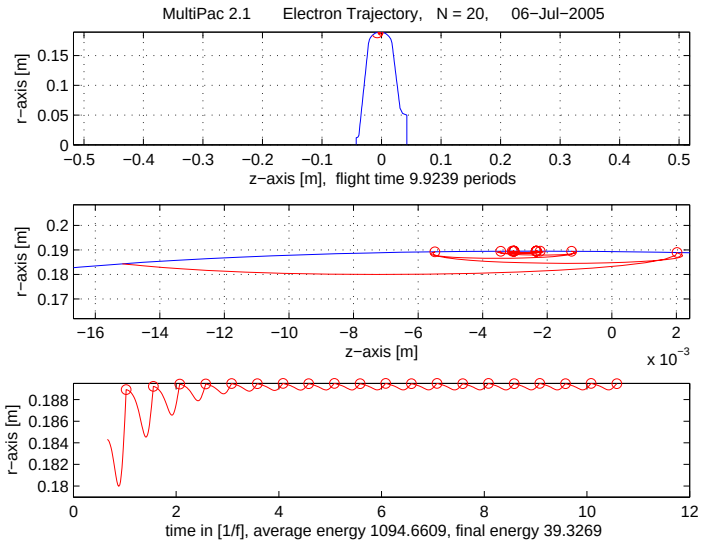


Multipacting

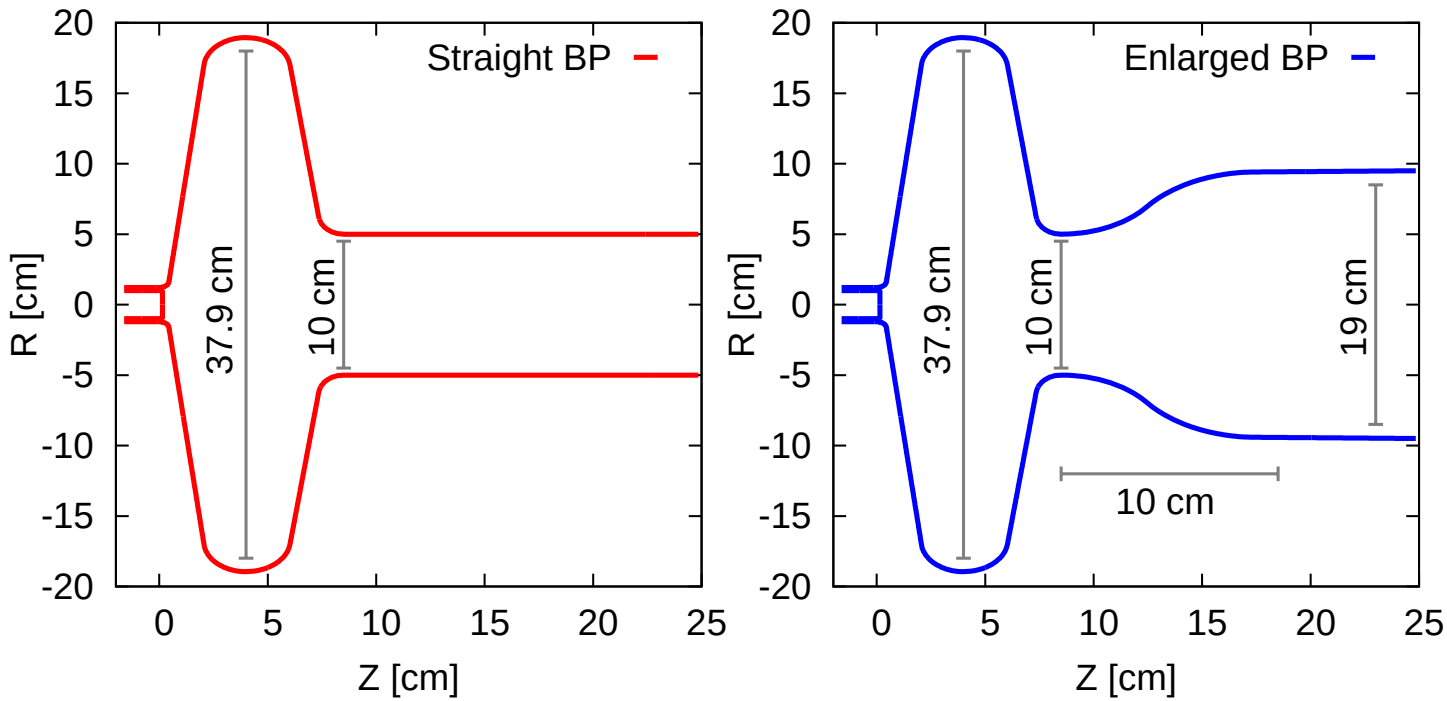






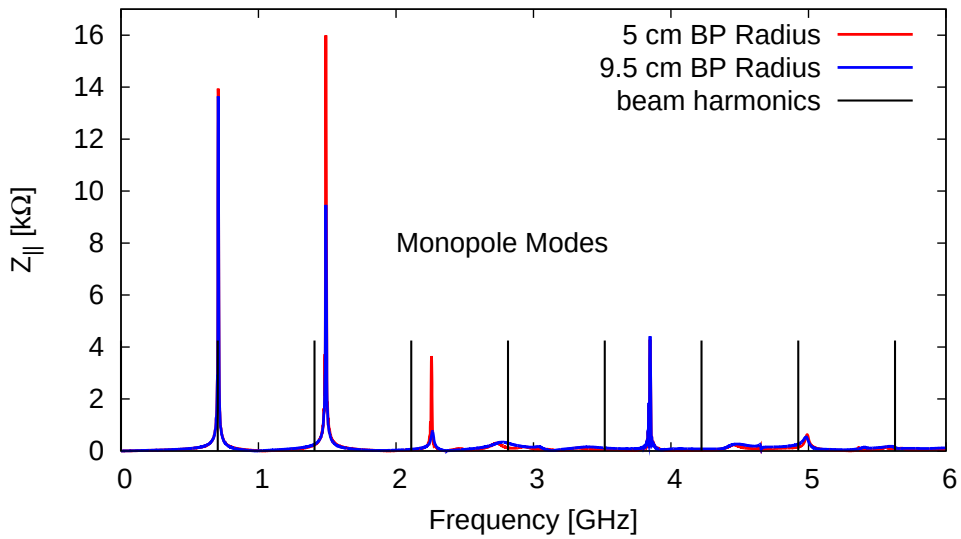


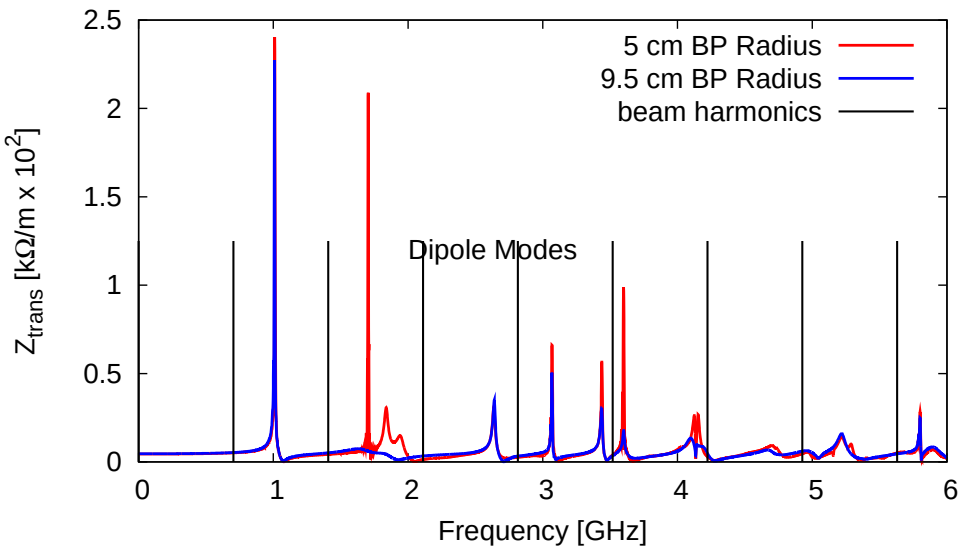
Beam Pipe Transition



- HOM Damping ☺
- FPC Coupling (field level $< 10^2 \rightarrow$ 10 cm away) ☹
- Mechanical Design (manufacturing, valves etc..) ☹

Impedance Spectrum & Laser Stability





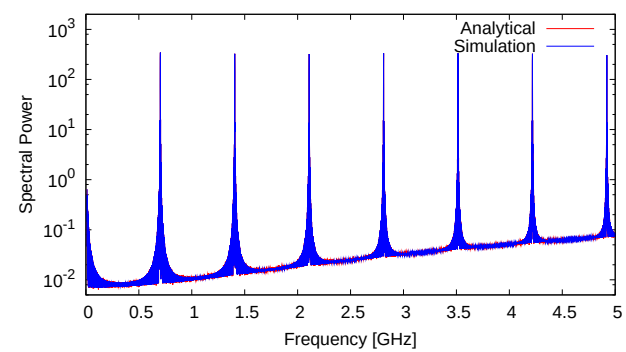
Phase Modulation:

$$I(t) = \sum_{n=-\infty}^{\infty} a_n \delta(t - nT_0 - \epsilon_n)$$

Spectral Power Density:

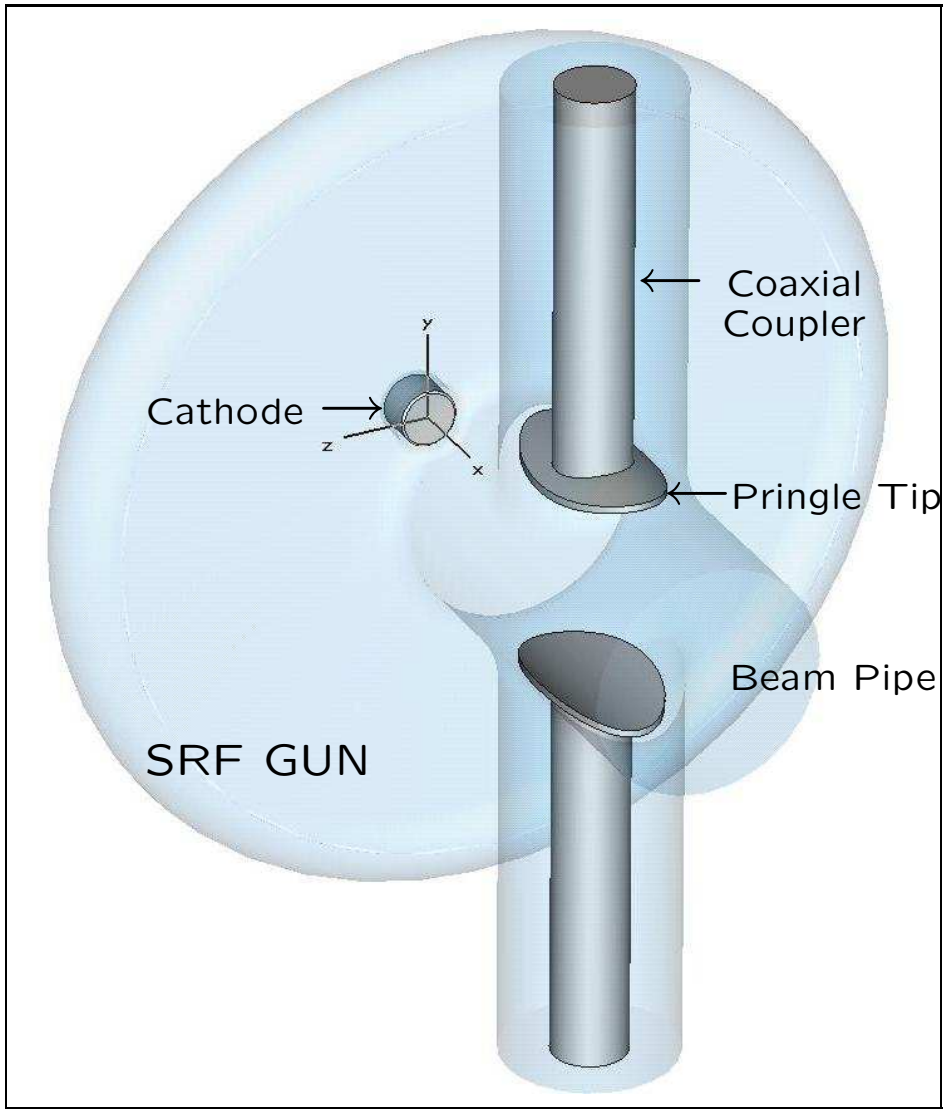
$$P(\omega) = \frac{2\pi}{T_0^2} \underbrace{\left[\frac{\sin(\sqrt{3}\omega\sigma_\epsilon)}{(\sqrt{3}\omega\sigma_\epsilon)}\right]^2}_{envelope} \sum_{m=-\infty}^{\infty} \underbrace{\delta\left(\omega - \frac{2\pi m}{T_0}\right.}_{harmonics}$$

$$+\frac{1}{T_0} \underbrace{\left[\left(1 - \left[\frac{\sin(\sqrt{3}\omega\sigma_\epsilon)}{(\sqrt{3}\omega\sigma_\epsilon)}\right]^2\right) + \sigma_a^2\right]}_{baseline}$$



$\frac{V_{HOM}}{V_{acc}} \approx 9 \times 10^{-3}$ ($\sigma_a = 1\%$, $\sigma_\epsilon = 1$ ps)

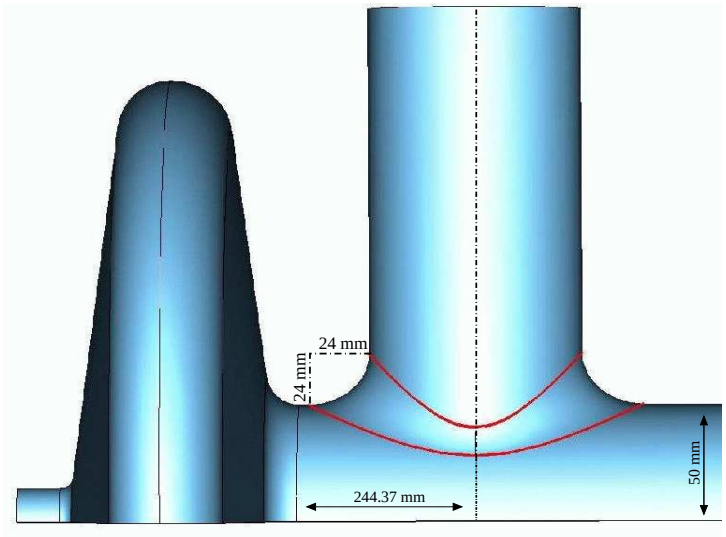
Coupling Fundamental Power



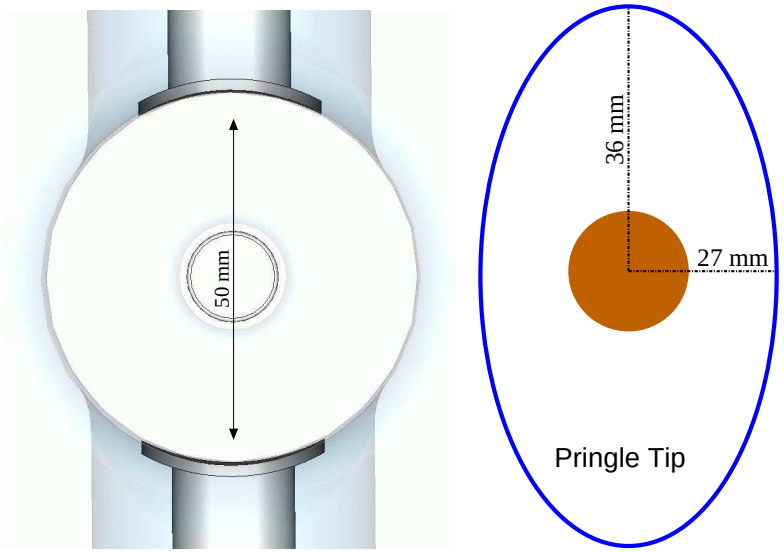
- Couple strongly: $Q_{ext} \sim 5 \times 10^4$
- Coupler kicks
- Reduce wakefields
- Engineering, alignments, etc..

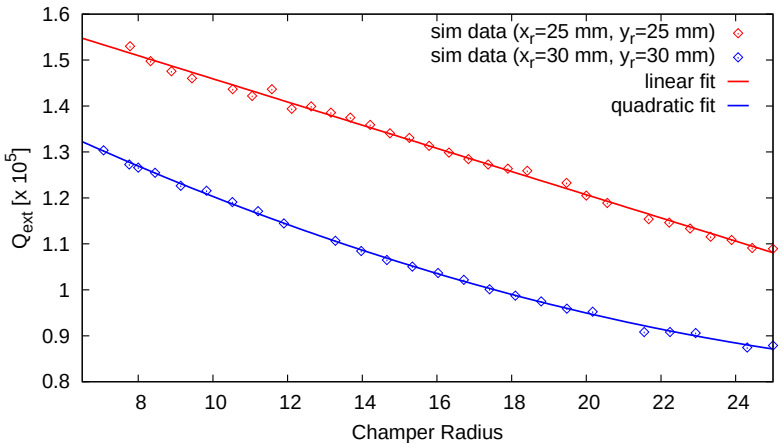
FPC Optimization

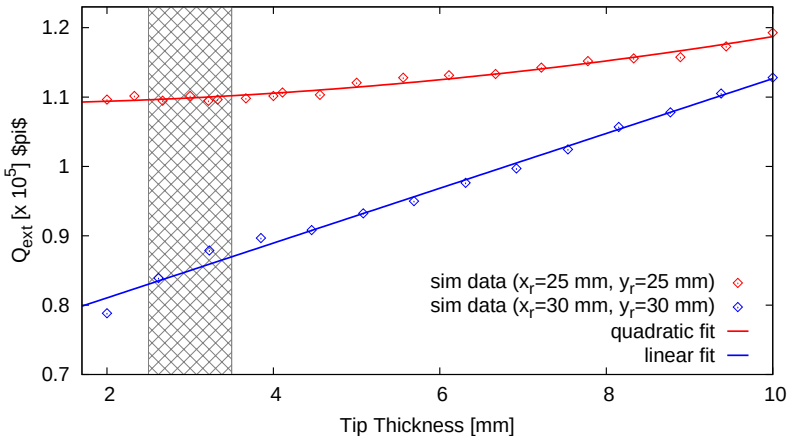
FPC - Beam Pipe Edge



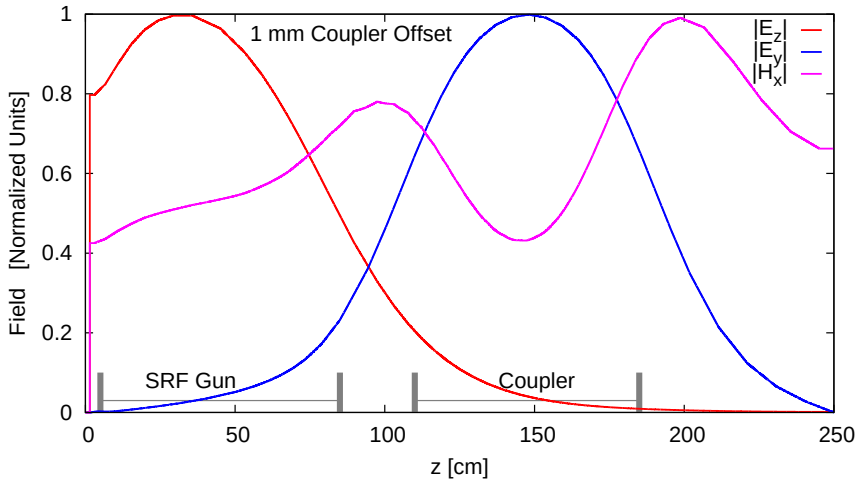
Pringle Tip Thickness

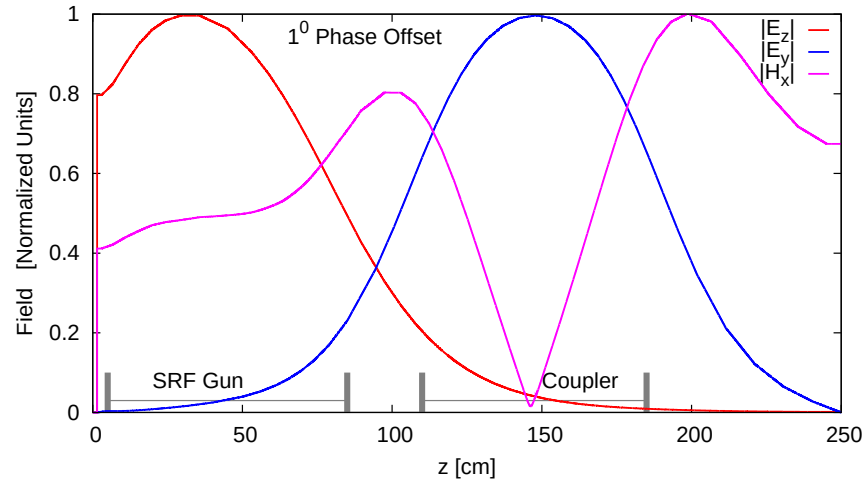






Coupler Kicks



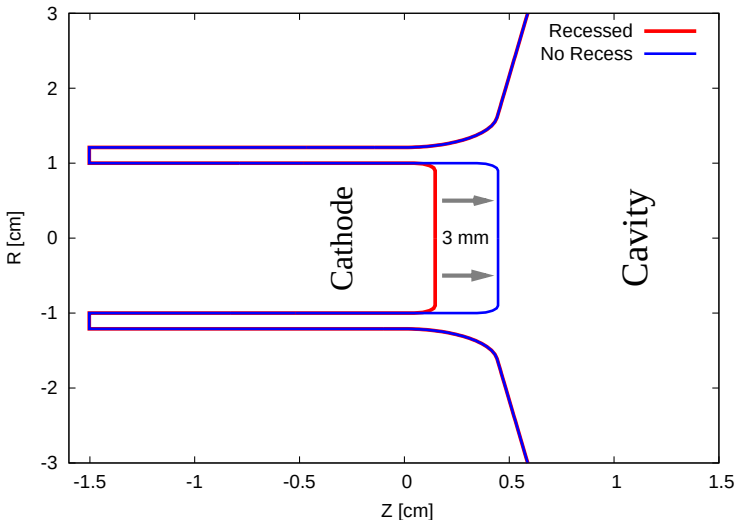


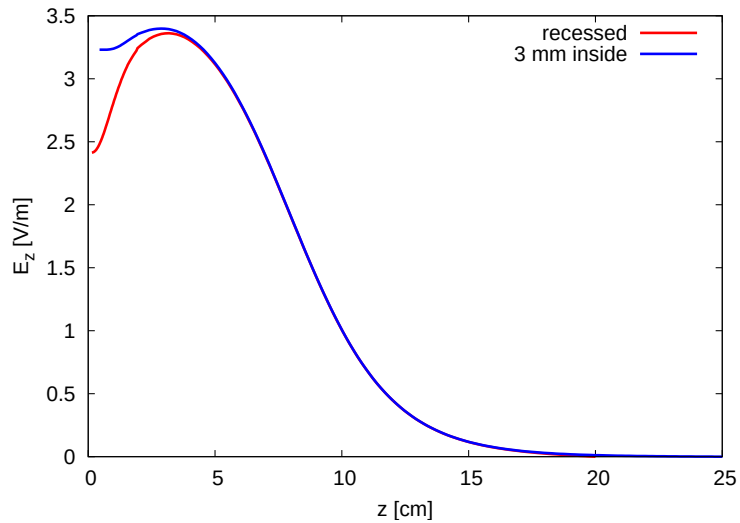
$$\delta_t = \frac{\int (E_y + v_z B_x) dz}{\int E_z dz}$$

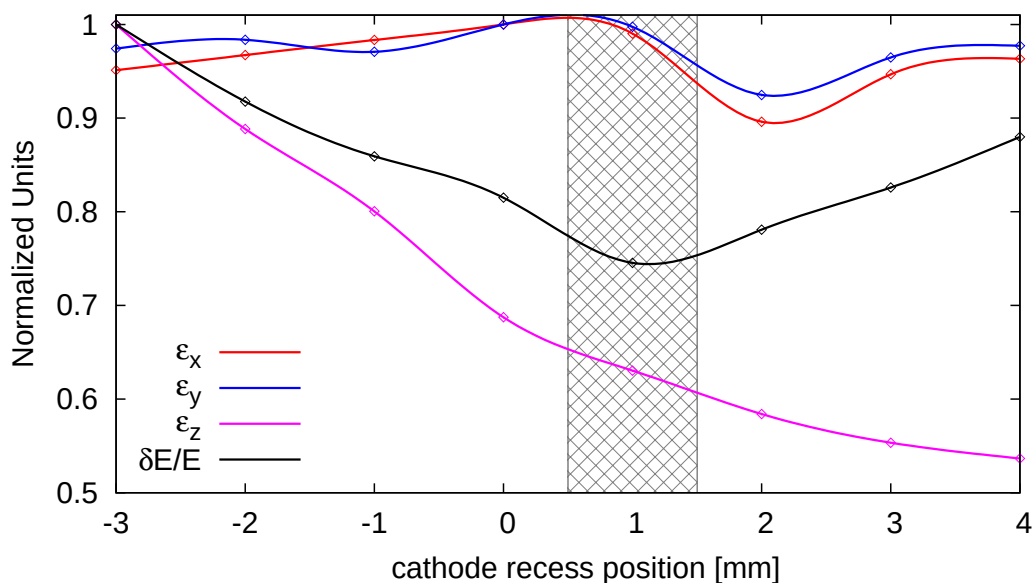
$$d\epsilon_n = \sigma_t \frac{2\pi\sigma_z}{\lambda_{RF}} \frac{eV_{acc}}{E_0} \left| Re(\delta_t) \sin\phi_0 + Im(\delta_t) \cos\phi_0 \right|$$

Asymmetry	Kick	$d\epsilon_n/\epsilon_n$
Tip Penetration	(-6.1 - 5.0i)$\times 10^{-5}$ mm^{-1}	$<$ 3%
Phase Offset	(8.4 - 5.9i)$\times 10^{-5}$ deg^{-1}	$<$ 3%

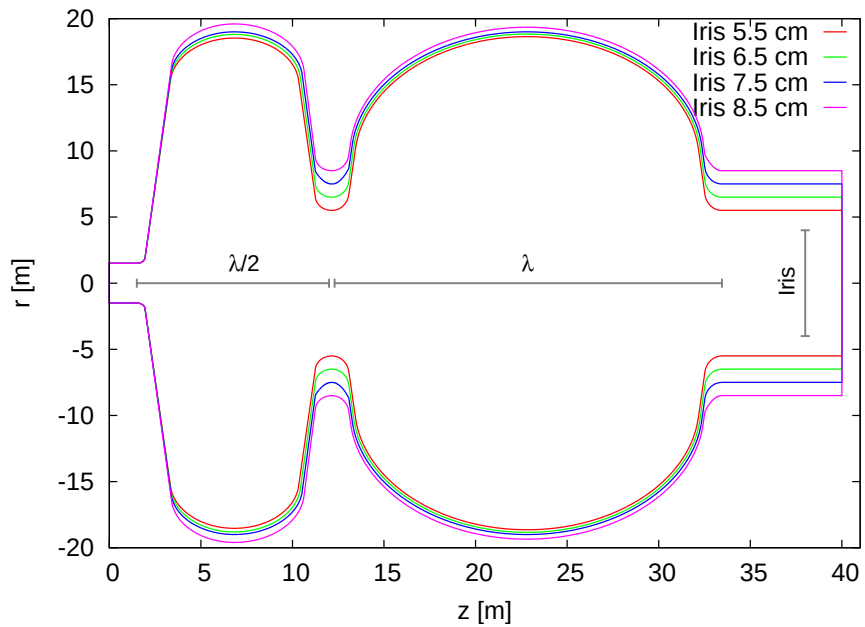
Cathode Recess







eCooling 1.5 Cell Gun



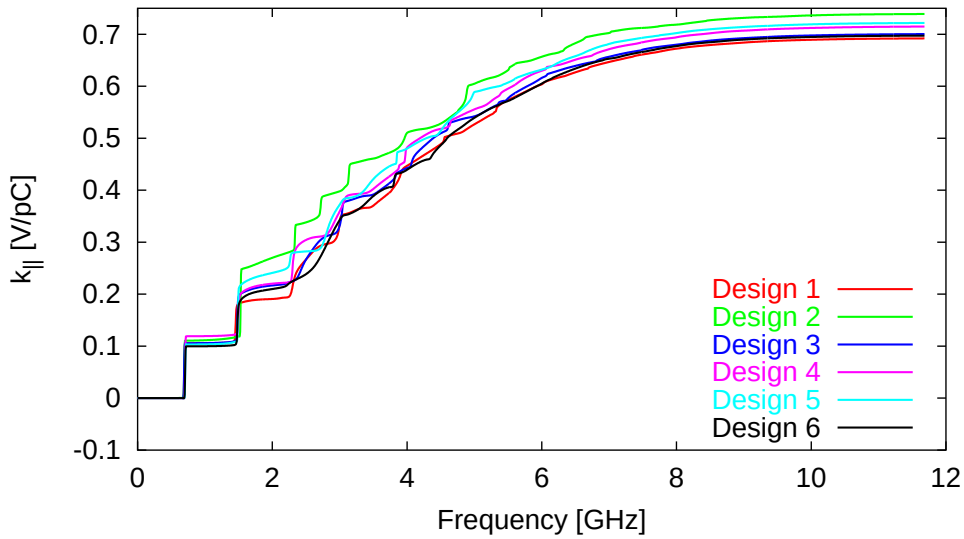
- Optimize Iris Radius
  - f_{HOMs} & $f_{cut-off}$
  - Trapped Modes
- Beam pipe transition
  - HOM damping
  - FPC Coupling
- Optimize L_1 & L_2
  - Energy Vs. Phase Slope
  - Longitudinal Emittance
  - Transverse Emittance
- Optimize cavity ellipses
  - Peak fields, R/Q, etc...

Some Open Issues

- PIC Simulations and emmittance calculations
- BBU (high charge case)
- Low repetition rate (a few MHz)
- HOM Damping from FPC
- HOM Tuners, etc ...

Extra Slides

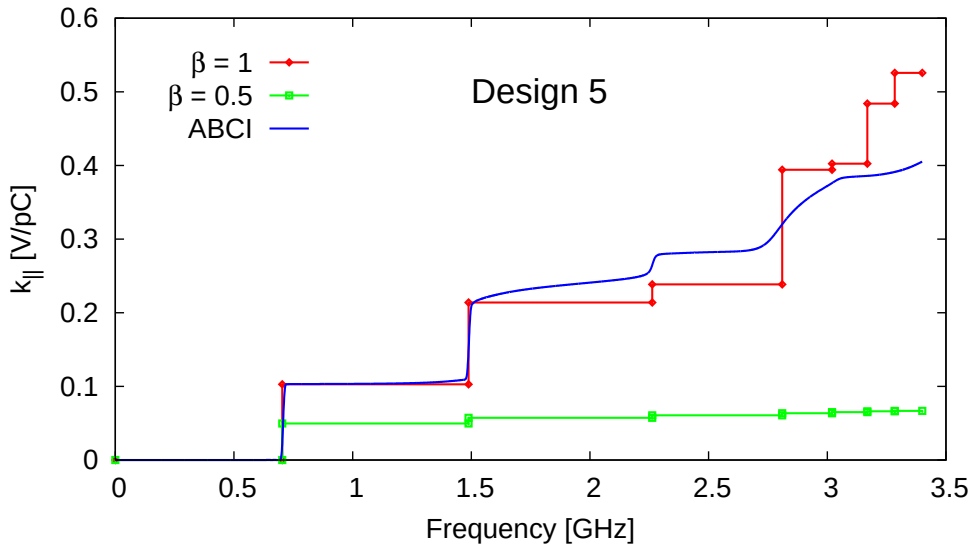
Average HOM Losses



$$\boxed{P_{HOM} = k_{||} Q_b I_b}$$

For $\beta = 1$:

$$k_{||} = \int_{-\infty}^{\infty} Z(\omega) d\omega$$



For $\beta < 1$:

$$k(\beta, \sigma) = \sum_{n=1}^{n} \frac{\omega R_s(\beta)}{2Q_n} \, e^{-(\frac{\omega\sigma}{\beta c})^2}$$

Avg. Power $\sim$ 0.5 kW

($Q_b = 1.4$ nC, $I_b = 500$ mA)