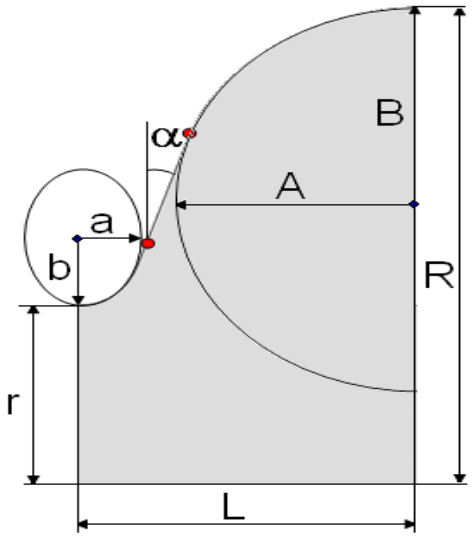
PIP-II
650 MHz, beta = 0.92
Cavity and Cryomodule Parameters

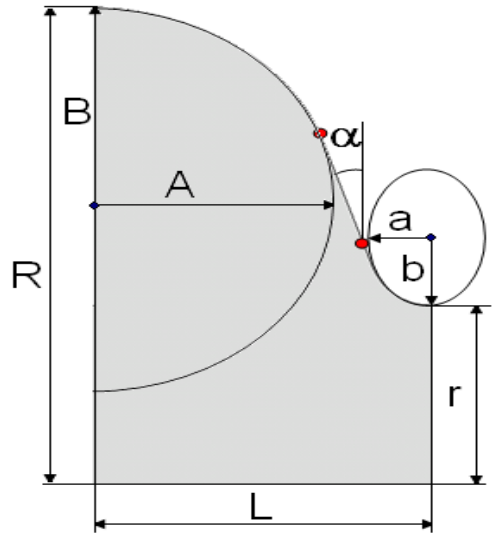
650 MHz, beta=0.92, 5 –cell cavity geometry

Left cell



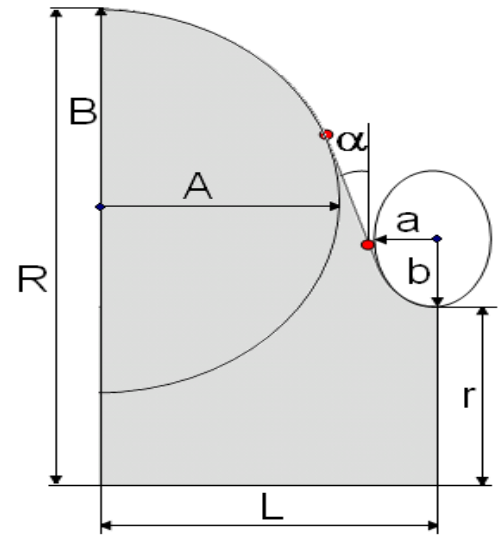
r	59
R	200.052
L	97.555
A	84.0
B	90.0
a	13.0
b	28.0
α	1.3°

Regular cell



r	59
R	200.052
L	106.08
A	85.0
B	78.0
a	20
b	33
α	1.9°

Right cell



r	59
R	200.052
L	97.555
A	84.0
B	90.0
a	13.0
b	28.0
α	1.3°

All dimensions are in mm.

Cavity Parameters	**FNAL 118 mm**
β_G	0.92
β_{opt}	0.97
Effective Length ($5*\beta_{opt}\ \lambda/2$), [m]	1.1185
$R/Q(\beta_G)$, [Ω]	576
$R/Q(\beta_{opt})$, [Ω]	610
G, [Ω]	260
Nominal Energy Gain at β_{opt}, [MeV]	19.9
Nominal Gradient at β_{opt}, $E_{acc}(\beta_{opt})$, [MeV/m]	17.8
Cavity Surface E_{peak}, [MV/m]	38.9
$E_{surf}/E_{acc}(\beta_{opt})$	2.185
Cavity Surface B_{peak}, [mT]	73.1
$B_{surf}/E_{acc}(\beta_{opt})$, mT/MeV/m	4.106
Dressed Cavity Length (flange to flange), [m]	1.4002

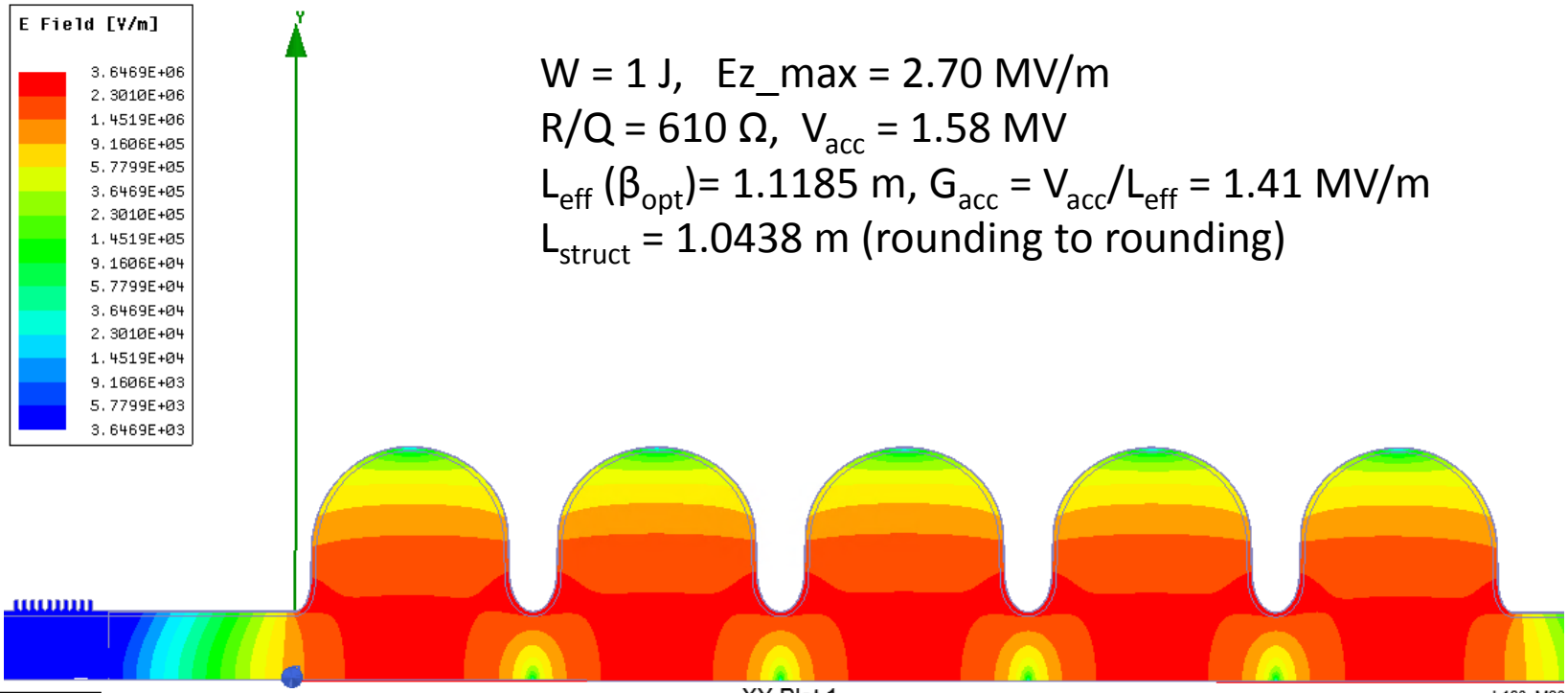
650 MHz 5-cell beta=0.92 PIP-II cavity

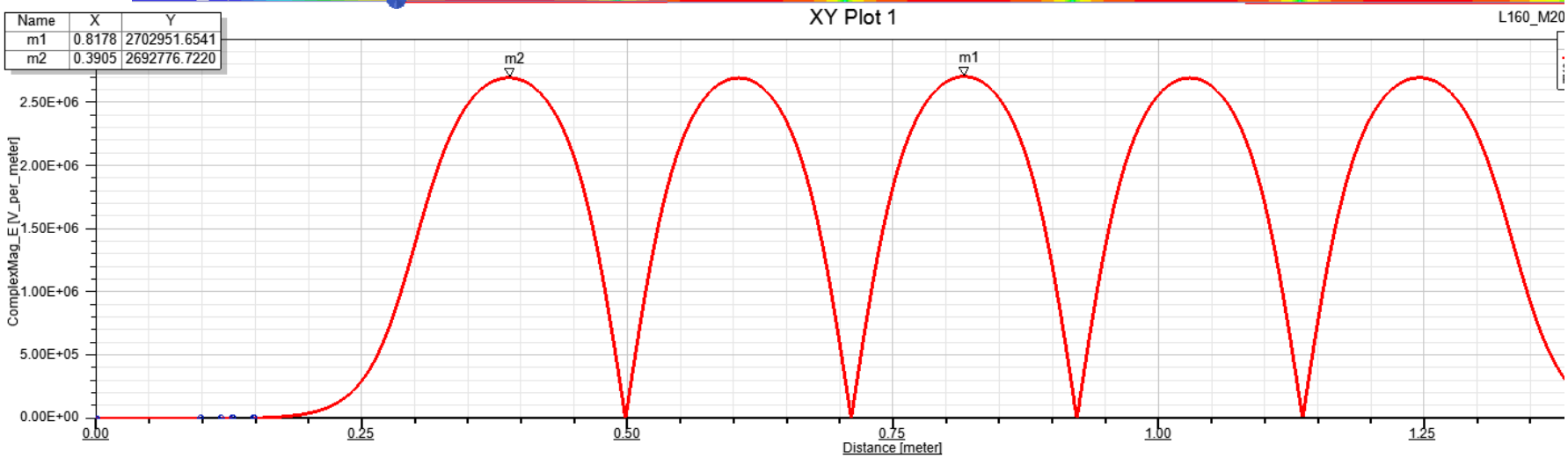
W = 1 J, Ez_max = 2.70 MV/m

R/Q = 610 Ω, V_{acc} = 1.58 MV

L_{eff} (β_{opt})= 1.1185 m, $G_{acc} = V_{acc}/L_{eff}$ = 1.41 MV/m

L_{struct} = 1.0438 m (rounding to rounding)





Pulsed Transient Process

$f0 = 6.5\times10^{8}$ $\quad QL0 := 11.5\cdot10^{6}$ $\quad T0 := \frac{1}{f0}$ $\quad frep := 20$ $\quad Q0 = 3\times10^{10}$ $\quad U1 := 1.58\cdot10^{6}$ $\quad U0 := 19.9\cdot10^{6}$

$N_CAV := 6$

$$P0 := \frac{\omega0\cdot\left(\frac{U0}{U1}\right)^{2}}{Q0} = 21.595534086051$$

$$\delta0 := \frac{-1}{2\cdot T0}\cdot\ln\left(1-\frac{2\cdot\pi}{QL0}\right) = 177.568328929618 \qquad \tau0 := \frac{1}{\delta0} = 0.005631634909 \qquad t_fill := 1\cdot\tau0\cdot\ln(2) = 0.003903551859$$

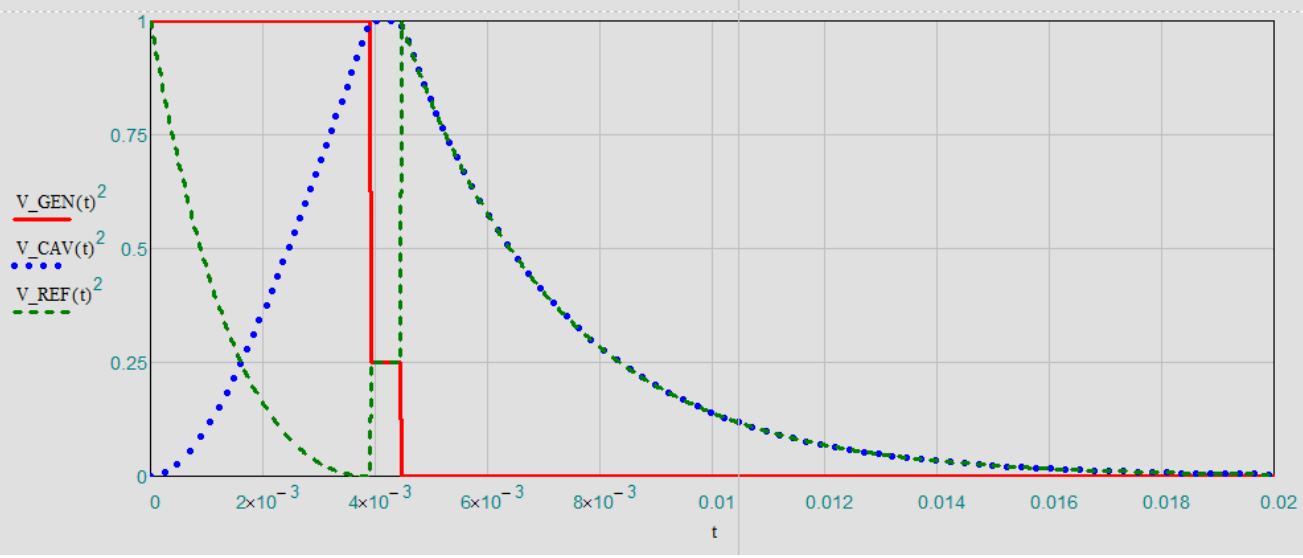
$t_ftop := 550\cdot10^{-6}$ $\quad t_end := 20\cdot10^{-3}$

$$V_FILL := 2\cdot\left(1-e^{\frac{-t_fill}{\tau0}}\right) \qquad V_TOP := 2\cdot\left(1-e^{\frac{-t_ftop}{\tau0}}\right) = 0.186090247963 \qquad \tau0 = 0.005631634909$$

$$V_GEN(t) := \begin{cases} x \leftarrow 1 & \text{if } t \le t_fill \\ x \leftarrow 0.5 & \text{if } t_fill < t \le t_fill + t_ftop \\ x \leftarrow 0 & \text{otherwise} \\ x \end{cases}$$

$$V_CAV(t) := \begin{cases} x \leftarrow 2\cdot\left(1-e^{\frac{-t}{\tau0}}\right) & \text{if } t \le t_fill \\ x \leftarrow V_FILL + (1-V_FILL)\cdot\left[1-e^{\frac{-(t-t_fill)}{\tau0}}\right] & \text{if } t_fill < t \le (t_fill + t_ftop) \\ x \leftarrow \left[V_FILL + (1-V_FILL)\cdot\frac{V_TOP}{2}\right]\cdot e^{\frac{-[t-(t_fill+t_ftop)]}{\tau0}} & \text{otherwise} \\ x \end{cases}$$

$$V_REF(t) := V_CAV(t) - V_GEN(t)$$



$$\frac{\int_0^{t_end} V_GEN(t)^2\,dt}{\int_0^{t_end} V_REF(t)^2\,dt} = 1.003061230776$$

$$\eta := \frac{frep}{V_CAV(t_fill)^2}\cdot\int_0^{t_end} V_CAV(t)^2\,dt = 0.0978$$

$$P_CM := P0\cdot\eta\cdot N_CAV = 12.673557166749$$

Energy Balance

$$E_inp := 1\cdot t_fill + t_ftop\cdot 0.25 = 0.004041051859$$

$$E_out := \int_0^{t_end} V_REF(t)^2\,dt = 0.004028158894$$

Pulsed Transient Process with Fast Discharge

$$vdis(x) := \left[V_FILL + (1 - V_FILL)\cdot\frac{V_TOP}{2}\right]\cdot e^{\frac{-[x-(t_fill+t_ftop)]}{\tau 0}} - 2\left[1 - e^{\frac{-[x-(t_fill+t_ftop)]}{\tau 0}}\right]$$

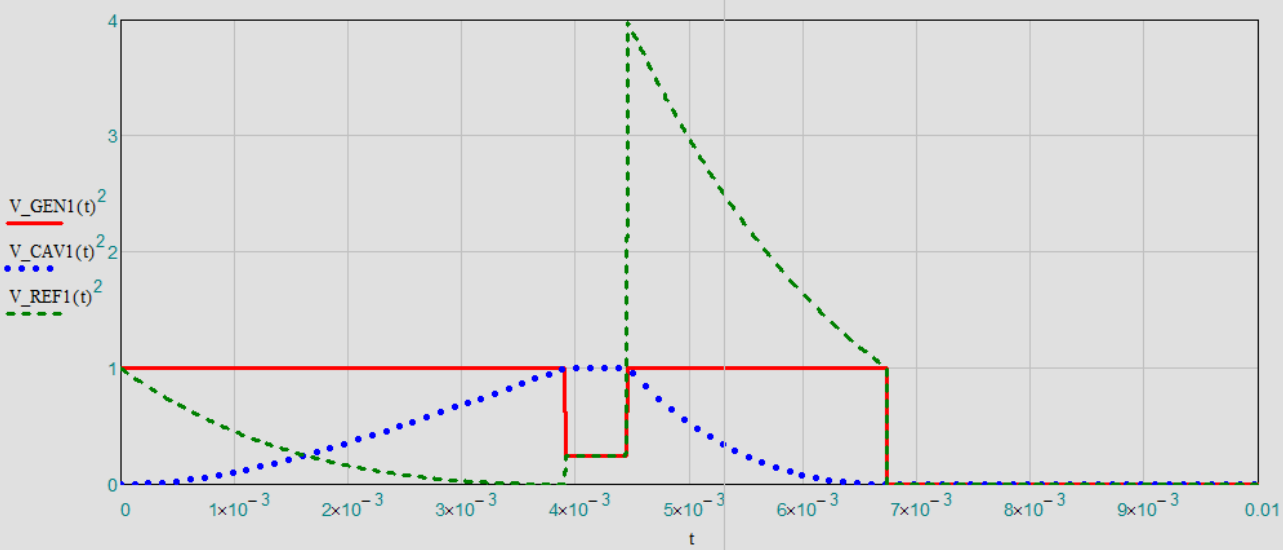
$$x := t_fill + t_ftop = 0.004453551859$$

$$t_off := root(vdis(x), x) = 0.006736983312$$

$$V_GEN1(t) := \begin{cases} x \leftarrow 1 & \text{if } t \le t_fill \\ x \leftarrow 0.5 & \text{if } t_fill < t \le t_fill + t_ftop \\ x \leftarrow -1 & \text{if } t_fill + t_ftop < t \le t_off \\ x \leftarrow 0 & \text{otherwise} \\ x \end{cases}$$

$$V_CAV1(t) := \begin{cases} x \leftarrow 2\cdot\left(1 - e^{\frac{-t}{\tau 0}}\right) & \text{if } t \le t_fill \\ x \leftarrow V_FILL + (1 - V_FILL)\cdot\left[1 - e^{\frac{-(t-t_fill)}{\tau 0}}\right] & \text{if } t_fill < t \le (t_fill + t_ftop) \\ x \leftarrow \left[V_FILL + (1 - V_FILL)\cdot\frac{V_TOP}{2}\right]\cdot e^{\frac{-[t-(t_fill+t_ftop)]}{\tau 0}} - 2\left[1 - e^{\frac{-[t-(t_fill+t_ftop)]}{\tau 0}}\right] & \text{if } t_fill + t_ftop < t \le t_off \\ x \leftarrow 0 & \text{otherwise} \\ x \end{cases}$$

$$V_REF1(t) := V_CAV1(t) - V_GEN1(t)$$



$$\eta 1 := \frac{frep}{V_CAV1(t_fill)^2}\cdot\int_0^{t_off} V_CAV1(t)^2\,dt = 0.055426$$

$$P_CM1 := P0\cdot\eta 1\cdot N_CAV = 7.181747426859$$

Energy Balance

$$E_inp := 1\cdot t_off - t_ftop\cdot(1 - 0.25) = 0.006324483312$$

$$E_out := \int_0^{t_end} V_REF1(t)^2\,dt = 0.006324891703$$

Parameters of SC HB650 Cryomodule	FNAL HB650 CM
Cavity Nominal Stored Energy, [J]	158.6
Q_0 at 2K, [x10^{10}]	3
Cavity Power Dissipation at CW, [W]	21.6
Cavities per Cryomodule	6
CM Dynamic Load at CW, [W/CM]	129.6
Pulsed Operation Repetition Rate, [Hz]	20
Cavity Loaded Q_L , [x10^6]	11.5
Nominal Cavity Feeling Time, [ms]	3.90
Beam Pulse Duration, [ms]	0.55
Fast Discharge Time, [ms]	2.28
Cryo-duty Factor (normal discharge), [%]	9.78
Cryo-duty Factor (fast discharge), [%]	5.54
CM Dynamic Load (normal discharge), [W/CM]	12.67
CM Dynamic Load (fast discharge), [W/CM]	7.18