FCC
— **RF** —
Considerations

FCC-RF-Working Group
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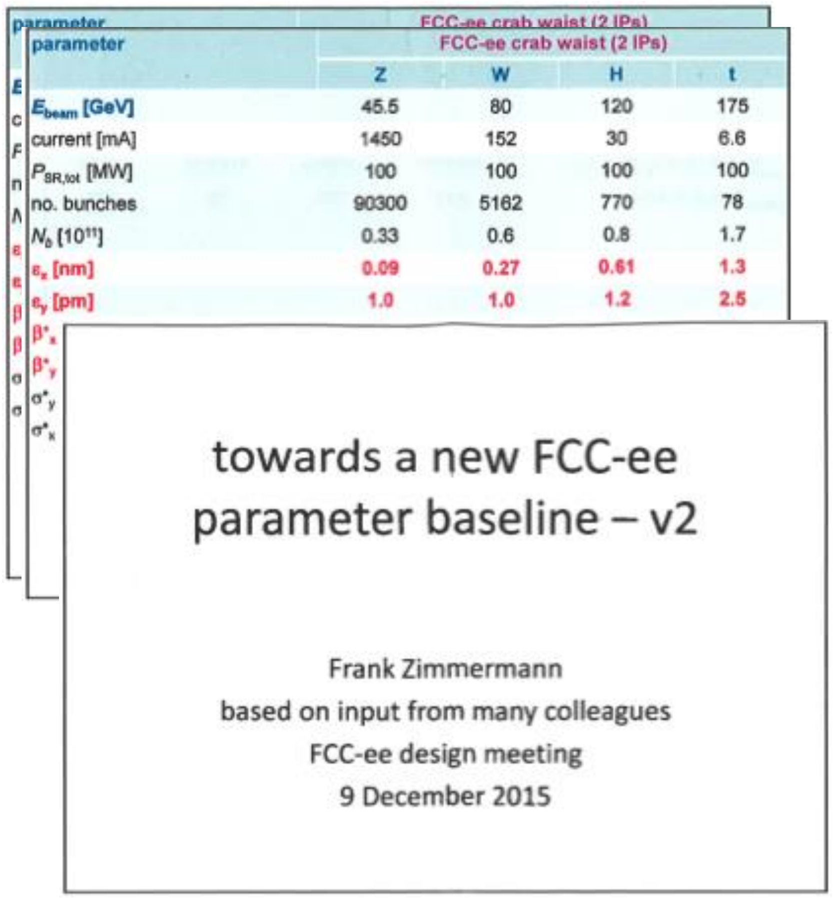


	V_tot	n_bunch	I_beam	E_turnloss
Z	0.08	90300	1450	0.034
W	0.8	5162	152	0.33
H	5.5	770	30	1.67
t	10	78	6.6	7.55

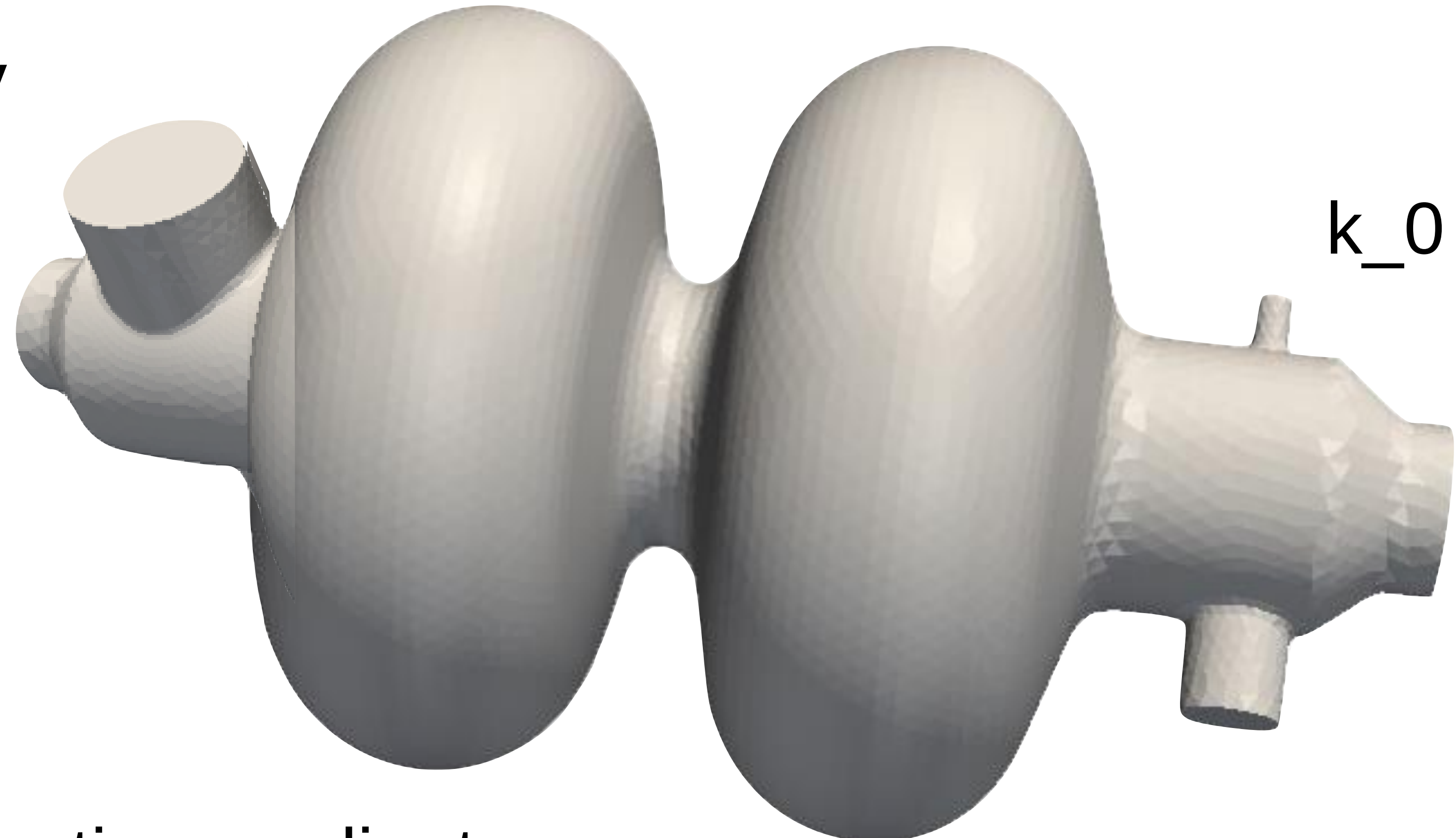
Input

Machine Parameters

G : Geometry factor

R_s : Surface Resistivity

f : Frequency



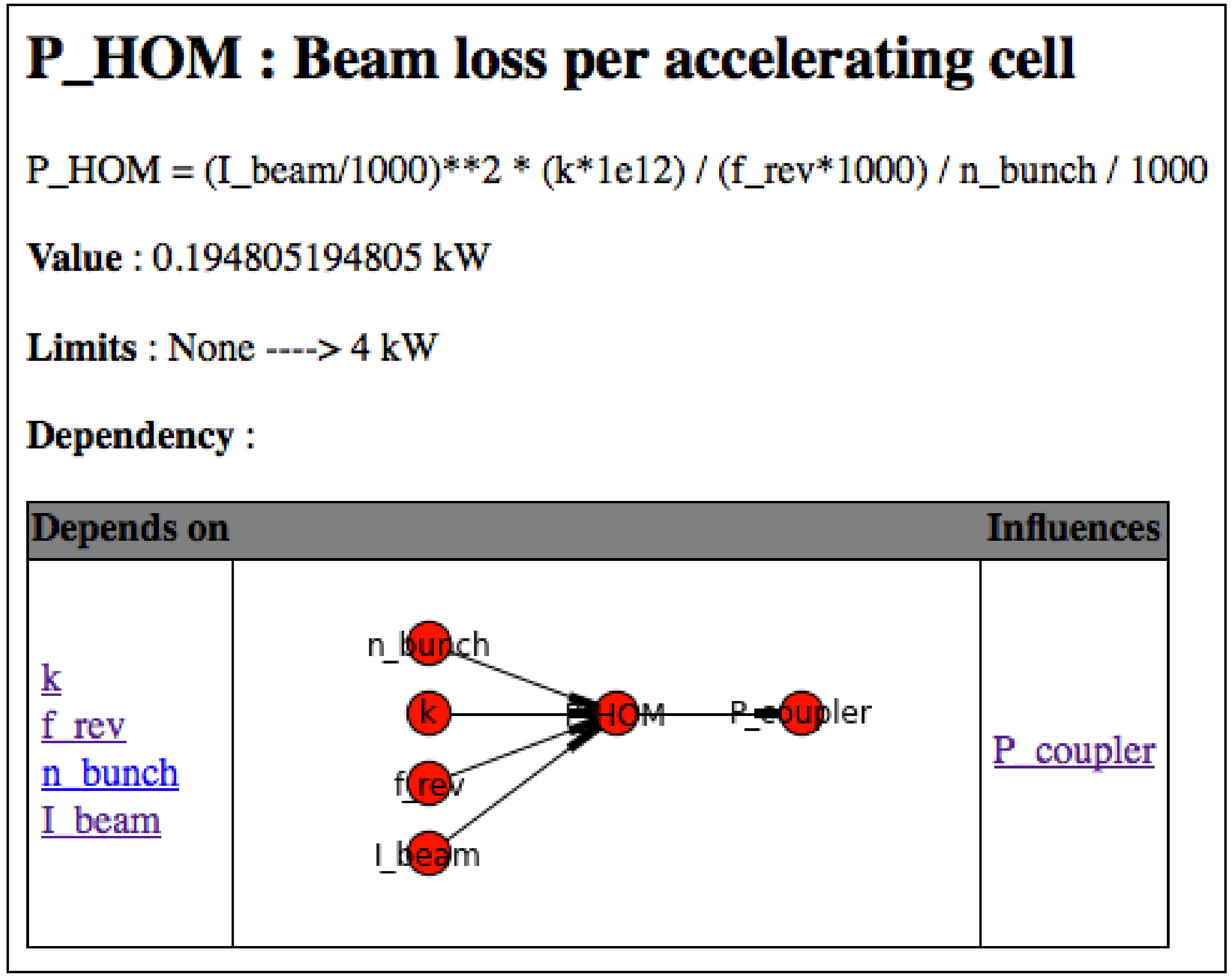
k_0 : Loss factor

E_acc : Accelerating gradient

n_cells : Number of cells

Design and Technology

Choices



P_HOM : Beam loss per accelerating cell

P_HOM = (I_beam/1000)**2 * (k*1e12) / (f_rev*1000) / n_bunch / 1000

Value : 0.194805194805 kW

Limits : None ----> 4 kW

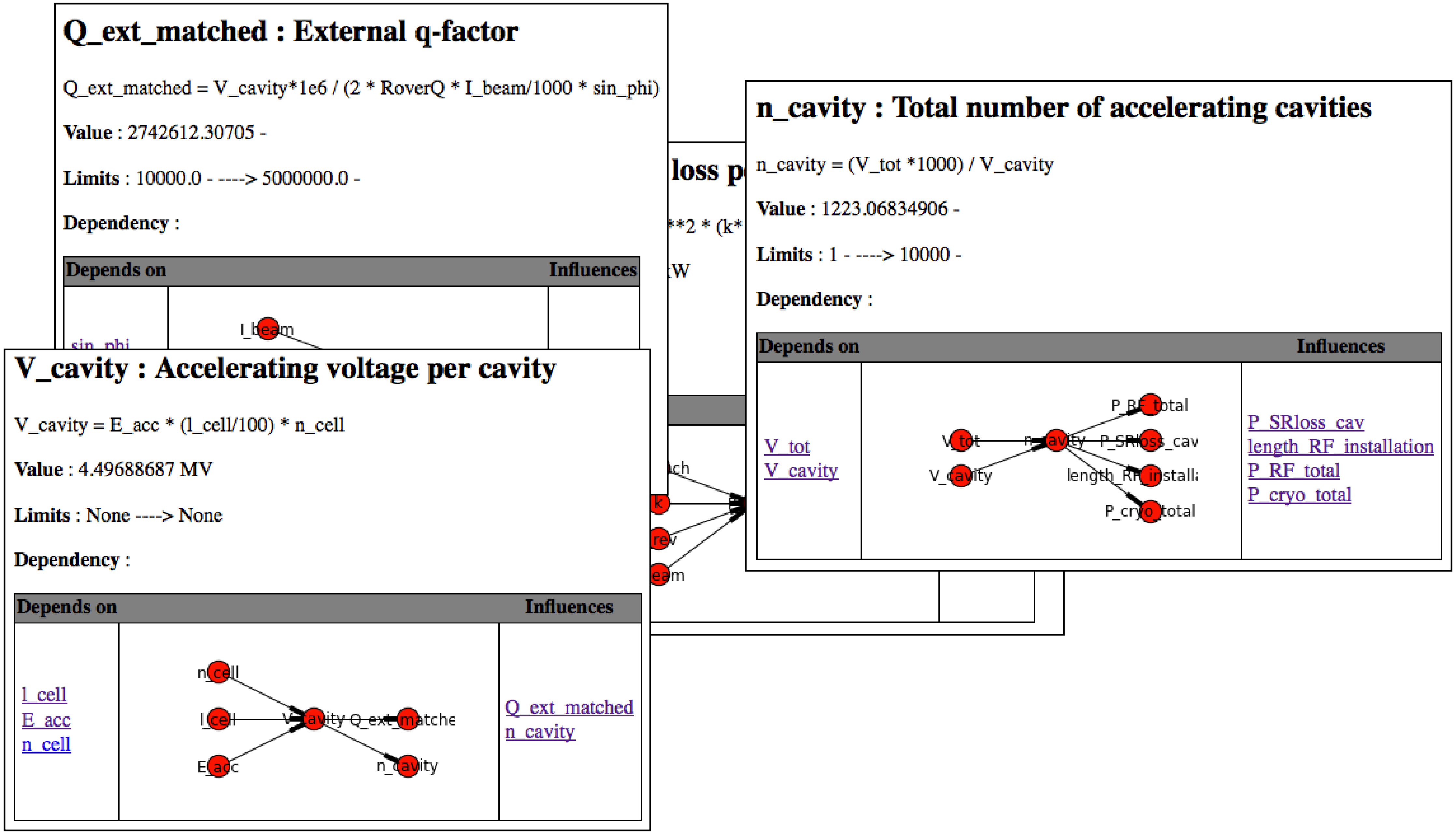
Dependency :

Depends on		Influences
k f_rev n_bunch I_beam		P_coupler

Interrelationships

and

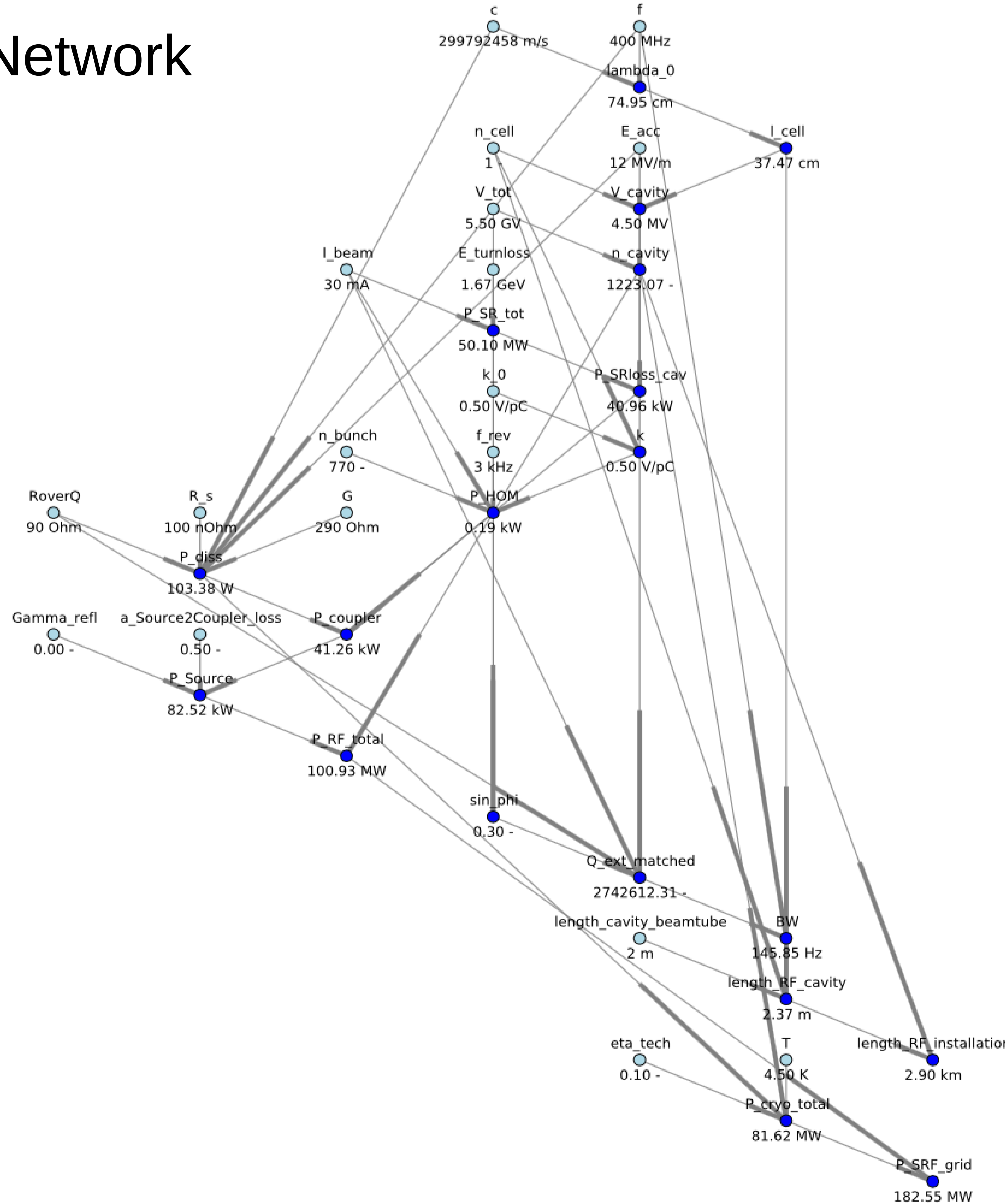
Limits

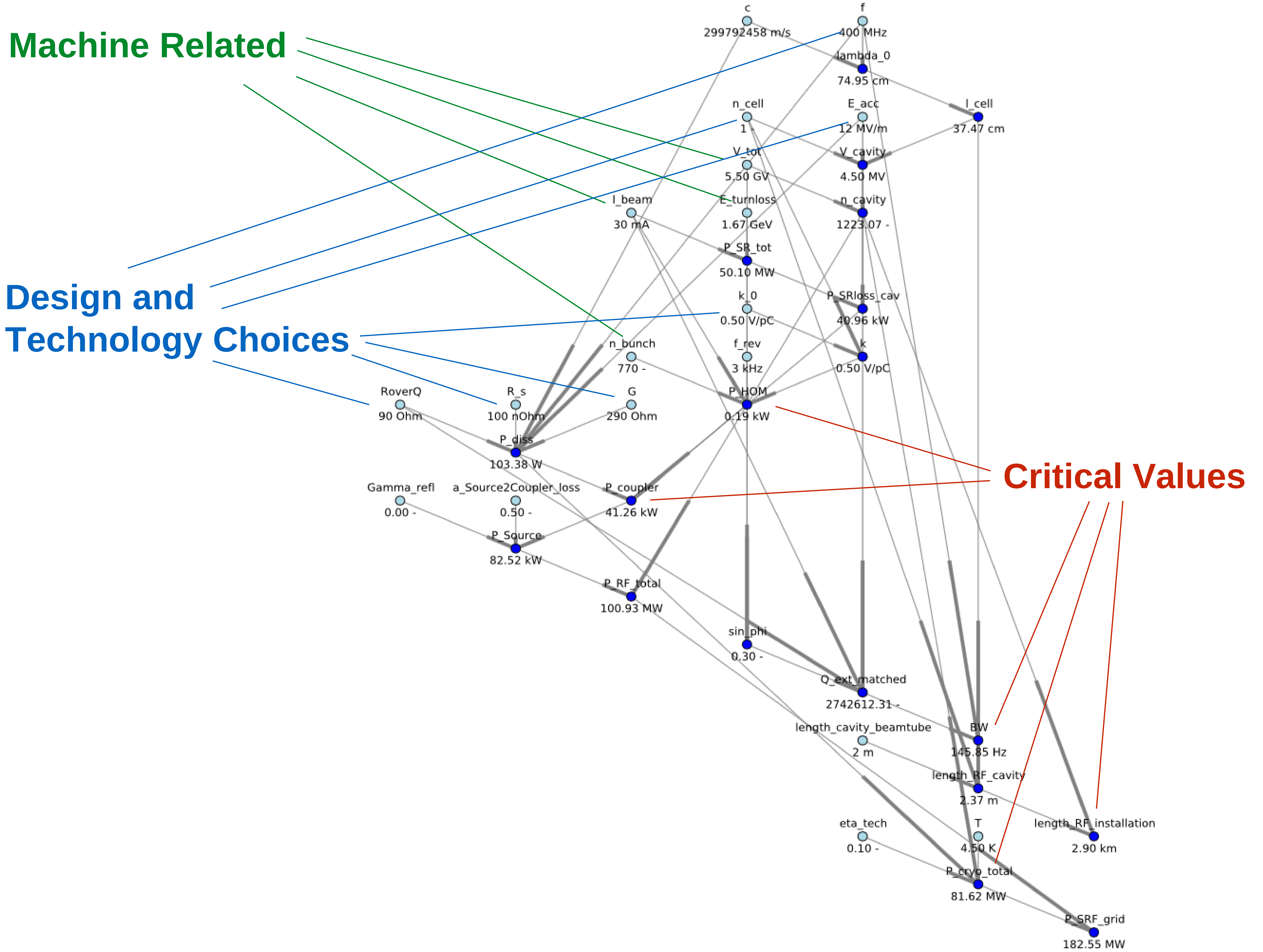


Interrelationships

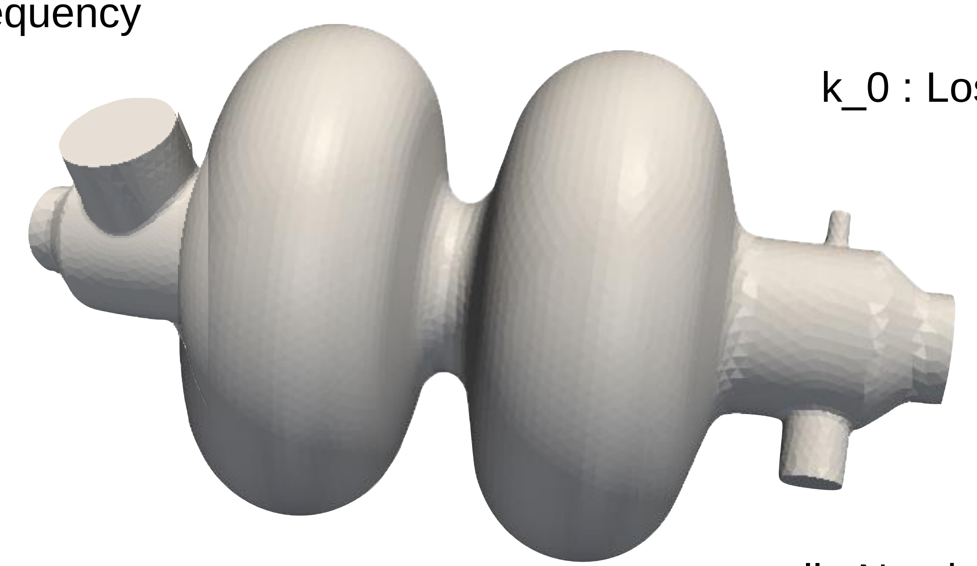
Collection of Quantities

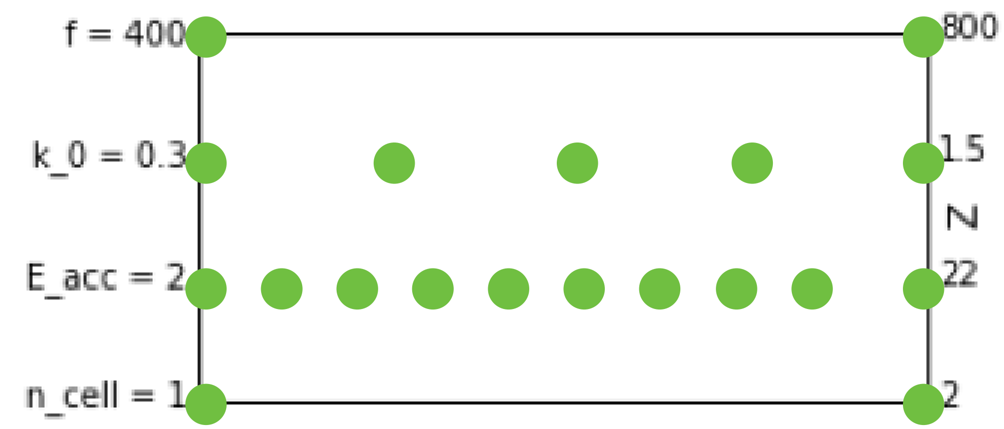
Interrelationship Network





Machine Related
Design and Technology Choices
Critical Values
c
299792458 m/s
f
400 MHz
lambda_0
74.95 cm
n_cell
1 -
E_acc
12 MV/m
l_cell
37.47 cm
V_tot
5.50 GV
V_cavity
4.50 MV
I_beam
30 mA
E_turnloss
1.67 GeV
n_cavity
1223.07 -
P_SR_tot
50.10 MW
k_0
0.50 V/pC
P_SRloss_cav
40.96 kW
n_bunch
770 -
f_rev
3 kHz
k
0.50 V/pC
RoverQ
90 Ohm
R_s
100 nOhm
G
290 Ohm
P_HOM
0.19 kW
P_diss
103.38 W
Gamma_refl
0.00 -
a_Source2Coupler_loss
0.50 -
P_coupler
41.26 kW
P_Source
82.52 kW
P_RF_total
100.93 MW
sin_phi
0.30 -
Q_ext_matched
2742612.31 -
length_cavity_beamtube
2 m
BW
145.85 Hz
length_RF_cavity
2.37 m
eta_tech
0.10 -
T
4.50 K
length_RF_installation
2.90 km
P_cryo_total
81.62 MW
P_SRF_grid
182.55 MW





Test all possible combinations

Design and Technology

Parameter Variation

Machine Parameters

	V_tot	n_bunch	I_beam	E_turnloss
Z	0.08	90300	1450	0.034
W	0.8	5162	152	0.33
H	5.5	770	30	1.67
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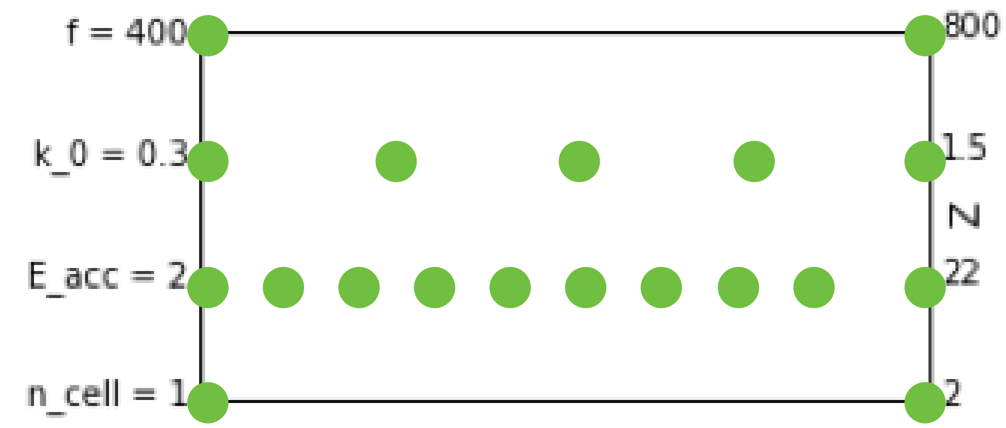
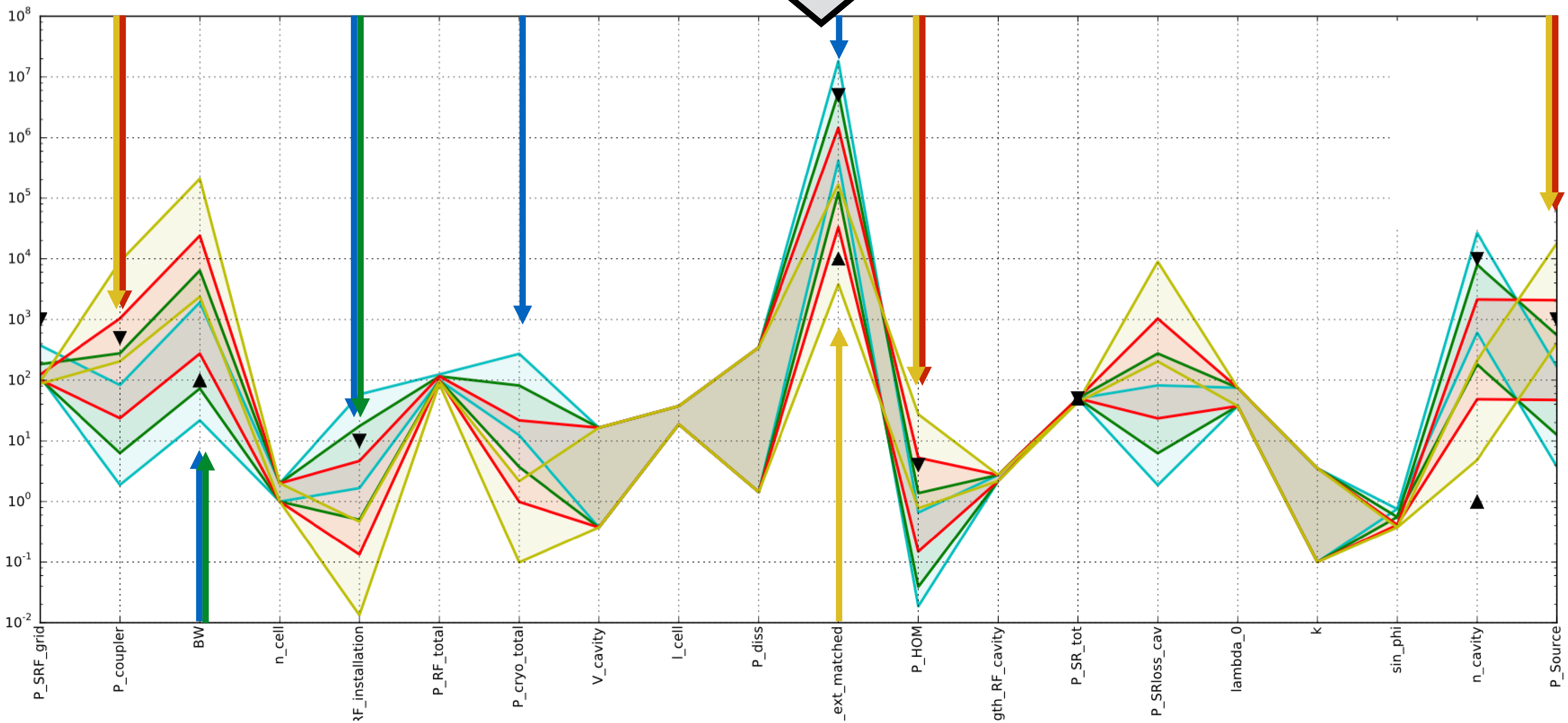
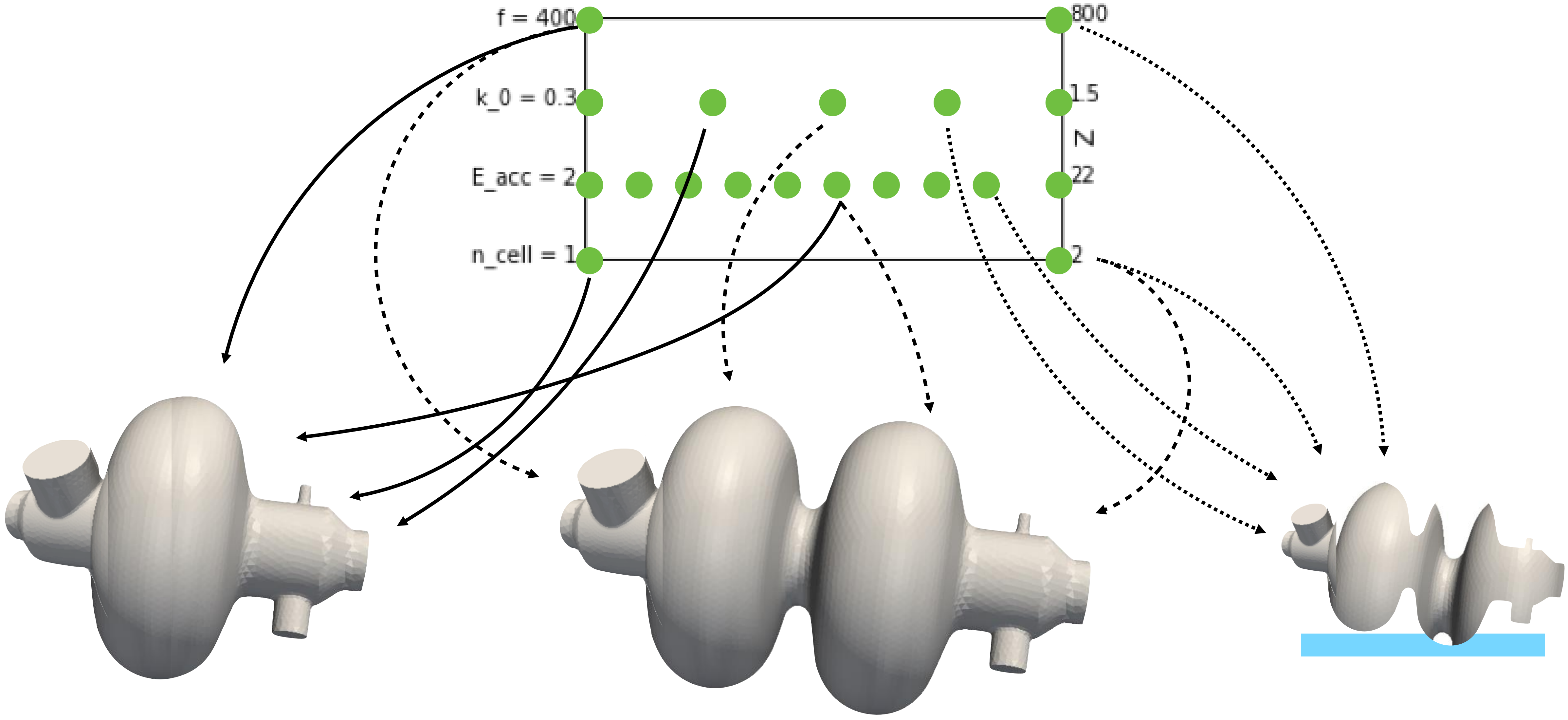
Design and Technology Choices







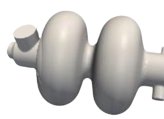
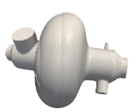
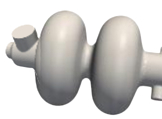
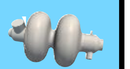
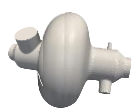
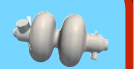
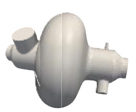
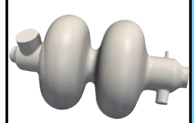
	f [MHz]	# cells	Vcell [MV/m]	R/Q [Ohm]	G [Ohm]	k// [V/pC]	Rs [nOhm]	Operating T [K]	Pmax/FPC [kW]
1 cell, 400MHz	400	1	10.0	90	290	0.50	100	4.5	500
2 cells, 400MHz	400	2	10.0	90	290	0.70	100	4.5	500
2 cells, 800MHz	800	2	20.0	90	290	1.00	80	2.0	400

Design and Technology

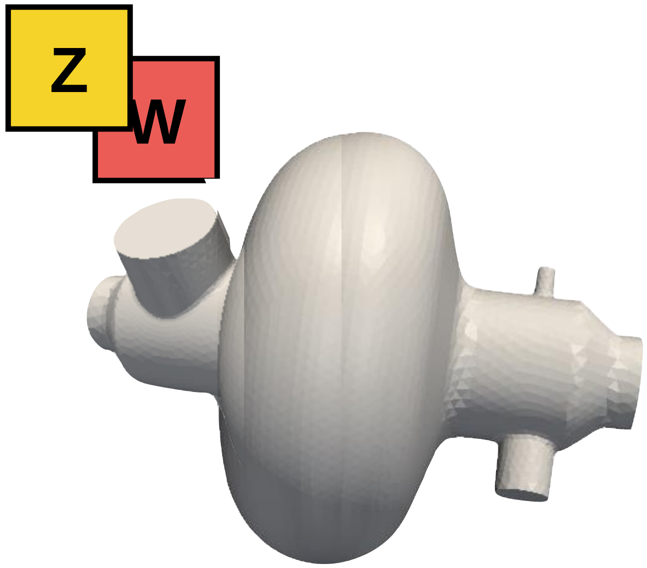
Testing 3 Different Designs

Design and Technology

3 Different Designs
4 Machines

	Z			W			H			t		
Technology&design												
cavity choice	**1 cell, 400MHz**	**2 cells, 400MHz**	**2 cells, 800MHz**	**1 cell, 400MHz**	**2 cells, 400MHz**	**2 cells, 800MHz**	**1 cell, 400MHz**	**2 cells, 400MHz**	**2 cells, 800MHz**	**1 cell, 400MHz**	**2 cells, 400MHz**	**2 cells, 800MHz**
frequency [MHz]	400	400	800	400	400	800	400	400	800	400	400	800
Nb cells/cavity	1	2	2	1	2	2	1	2	2	1	2	2
Eacc [MV/m]	**2.1**	**1.05**	**1.65**	**10.0**	**10.0**	**20.0**	**10.0**	**10.0**	**20.0**	**10.0**	**10.0**	**20.0**
R/Q [Ohm]	90	90	90	90	90	90	90	90	90	90	90	90
k// [V/pC]	0.50	0.70	1.00	0.50	0.70	1.00	0.50	0.70	1.00	0.50	0.70	1.00
Pfpc max [kW]	0.50	0.70	1.00	0.50	0.70	1.00	0.50	0.70	1.00	0.50	0.70	1.00
G [Ohm]	290	290	290	290	290	290	290	290	290	290	290	290
Rs [nOhm]	100	100	80	100	100	80	100	100	80	100	100	80
Operating Temp [K]	4.5	4.5	2.0	4.5	4.5	2.0	4.5	4.5	2.0	4.5	4.5	2.0
RF system parameters												
Cell length [m]	0.375	0.375	0.1875	0.375	0.375	0.1875	0.375	0.375	0.1875	0.375	0.375	0.1875
Active length/cavity [m]	0.375	0.75	0.375	0.375	0.75	0.375	0.375	0.75	0.375	0.375	0.75	0.375
Vcell [MV]	0.79	0.39	0.31	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75
Pbeam loss [MW]	49.3	49.3	49.3	50.16	50.16	50.16	50.1	50.1	50.1	49.83	49.83	49.83
Qext matched	7.1E+03	7.1E+03	5.6E+03	3.3E+05	6.6E+05	6.6E+05	2.3E+06	4.6E+06	4.6E+06	4.2E+06	8.4E+06	8.4E+06
BW	56343	56343	143418	1204	602	1204	175	87	175	96	48	96
Nb cells	102	203	259	213	213	213	1467	1467	1467	2667	2667	2667
Nb cavities	**102**	**102**	**129**	**213**	**107**	**107**	**1467**	**733**	**733**	**1333**	**667**	**667**
Pdiss/cav [W]	**3**	**1**	**1**	**72**	**72**	**115**	**72**	**72**	**115**	**72**	**72**	**115**
RF system active length [m]	38	76	48	80	80	40	550	550	275	500	500	250
RF system length [m]	**180**	**218**	**165**	**379**	**229**	**136**	**2603**	**1577**	**935**	**1183**	**717**	**850**
Pcryo tot [MW]	**0**	**0**	**0**	**10**	**5**	**18**	**68**	**34**	**123**	**62**	**31**	**112**
PRF/cell [kW]	**485**	**485**	**381**	**235**	**470**	**470**	**34**	**68**	**68**	**37**	**75**	**75**
Phom [kW]	3.9	5.4	7.8	0.7	1.0	1.5	0.2	0.3	0.4	0.1	0.1	0.2
max "allowable" k// [V/pC]	[illegible]			[illegible]			[illegible]			[illegible]		

R’n’D Topics



400 MHz (1 cell) x 90

RF Power up to 500 kW

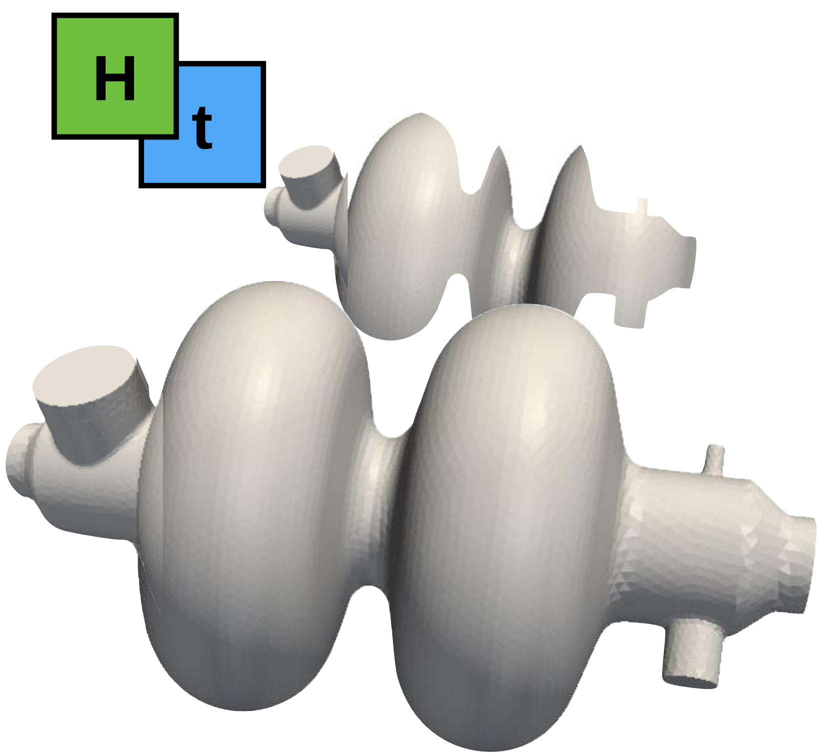
HOM Power up to 4 kW

Niobium on Copper @ 4.5 K

Fundamental Power Coupler

Loss factor

HOM Damping



400/800 MHz (2 cells) x 700

RF Power below 80 kW

Cryo Losses 170 kW

Niobium on Copper @ 4.5 K
Bulk Niobium @ 2 K

Solid-State Amplifier

R_s and E_acc

End

— Discussion and Comments —

Interrelationship Table

NAME	TITLE	MATH	VALUE	UNIT	LOWER_LIMIT	UPPER_LIMIT	SOURCE
f	frequency	-	400	MHz	-	-	-
c	speed of light	-	299792458	m/s	-	-	https://en.wikipedia.org/wiki/Speed_of_light
lambda_0	wave length	c/(f*1e6) * 100	74.95	cm	-	-	-
l_cell	RF cell length	lambda_0/2	37.47	cm	-	-	-
E_acc	maximum accelerating gradient	-	12	MV/m	-	-	-
n_cell	number of cells per cavity	-	1	-	-	-	-
V_cavity	accelerating voltage per cavity	E_acc * (l_cell/100) * n_cell	4.50	MV	-	-	-
V_tot	total RF voltage for the machine	-	5.50	GV	-	-	Machine type specific
n_cavity	total number of accelerating cavities	(V_tot *1000) / V_cavity	1223.07	-	1	10000	-
E_turnloss	synchrotron loss per turn OR WHAT EVER	-	1.67	GeV	-	-	-
I_beam	beam current	-	30	mA	-	-	-
P_SR_tot	power loss due to synchrotron radiation	(E_turnloss * 1e9) * (I_beam / 1000) / 1e6	50.10	MW	49.50	50.50	-
P_SRloss_cav	beam loss per accelerating cavity	P_SR_tot / n_cavity * 1000	40.96	kW	-	-	-
k_0	HOM loss factor constant	-	0.50	V/pC	-	-	Plot by Rama Calaga
k	HOM loss factor	k_0 * n_cell**0.5	0.50	V/pC	-	-	Plot by Rama Calaga
f_rev	revolution frequency	-	3	kHz	-	-	-
n_bunch	number of bunches	-	770	-	-	-	-
P_HOM	beam loss per accelerating cell	(I_beam/1000)**2 * (k*1e12) / (f_rev*1000) / n_bunch / 1000	0.19	kW	-	4	-
G	Geometry factor	-	290	Ohm	-	-	[Padamsee, pp. XX]
R_s	surface resistance	-	100	nOhm	-	-	[Padamsee und Sarah, pp. XX]
RoverQ	R upon Q	-	90	Ohm	-	-	LHC standard
P_diss	dissipated power per cell	(E_acc*1e6)**2 * c * (R_s*1e-9) / ((4 * f*1e6) * G * RoverQ)	103.38	W	-	-	[Padamsee, pp. XX]
P_coupler	total RF power per cavity going through the power coupler FPC	P_HOM + P_SRloss_cav +	41.26	kW	-	500	-