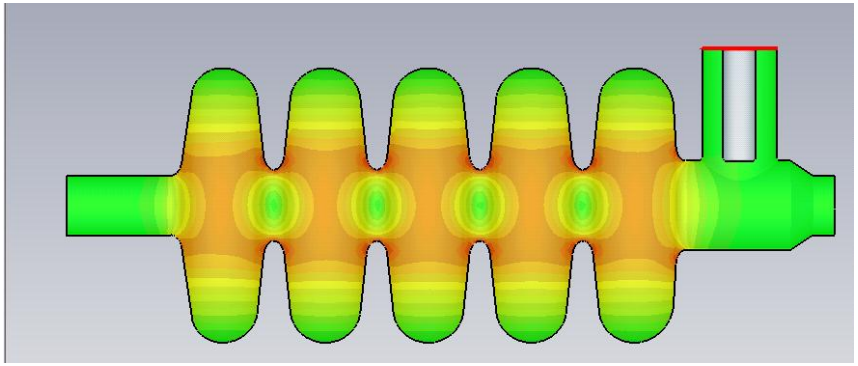
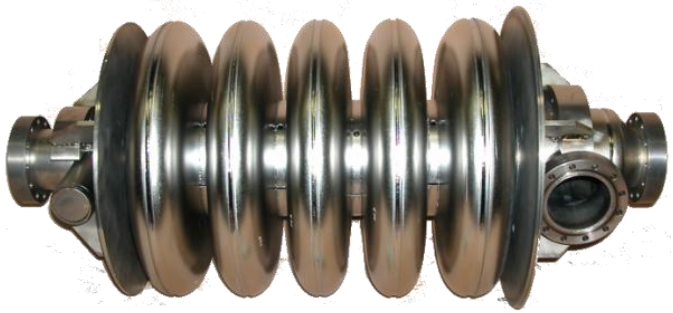
RF design of the β=0.65 5-cells superconducting cavity for the SPL Program





SPL Group meeting
Video conference

Monday, February 8th 2010

F.Bouly, D. Longuevergne
(IPNO)

Needs/ Requirements

Table 4.11: SPL superconducting linac design parameters

Maximum peak surface electric field	50 MV/m
Maximum peak surface magnetic field	100 mT
Cavity quality factor at 2 K	$\geq 10^{10}$
Accelerating gradient ($\beta = 0.65$)	19 MV/m
Accelerating gradient ($\beta = 1.0$)	25 MV/m
R/Q ($\beta = 0.65$)	290 Ω
R/Q ($\beta = 1.0$)	570 Ω
Frequency	704.4 MHz
Number of cells	5

Conceptual design of the SPL II, CERN-2006-006

Epeak/Eacc < 2.63

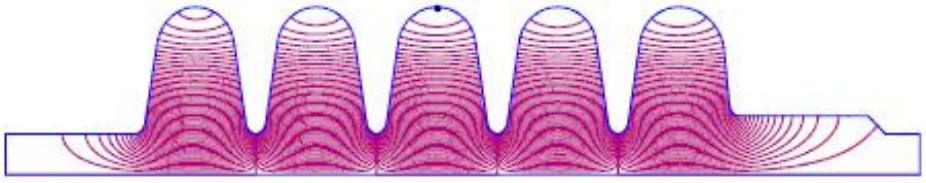
Bpeak/Eacc < 5.26 mT/(MV/m)

+

Cell coupling factor k ≈ 1.5 %

Starting point :

1999, EUROTRANS cavity β= 0.65

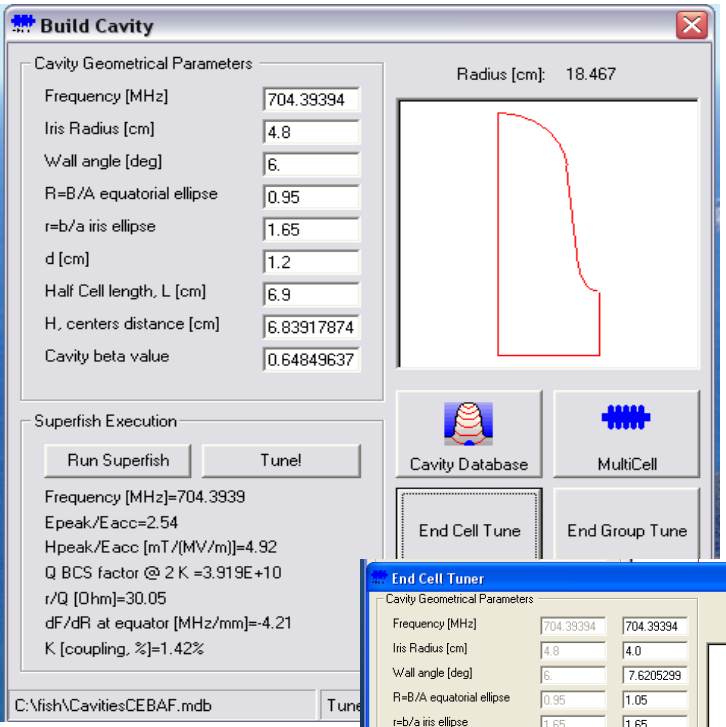


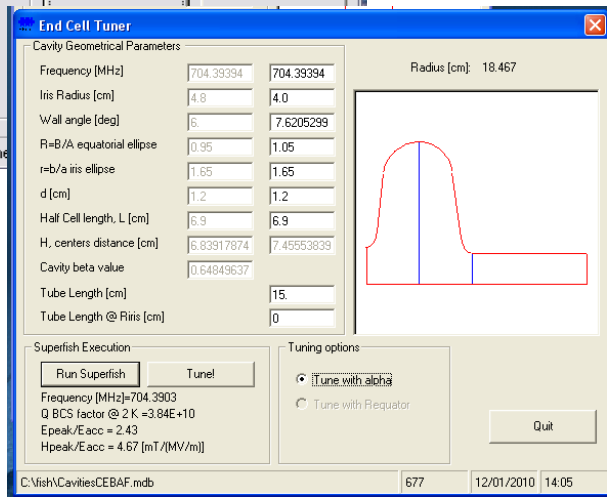
	Cavité β_g=0,47	Cavité β_g=0,65
$[B_{pk}/E_{acc}]_{ref}$ (mT/MV/m)	5,88	4,88
$[E_{pk}/E_{acc}]_{ref}$	3,58	2,61 !!
G (Ω)	152,7	194,1
$[r/Q]_{ref}$ (Ω)	79,5	157,5
K (%)†	1,35	1,11 !!
plat de champ (%)	1,3	1,3
$f_{SUPERFISH}$ (MHz)	704,42	704,42

J-Luc Biarrotte, PHD Thesis, 2000, Orsay

2D Preliminary study

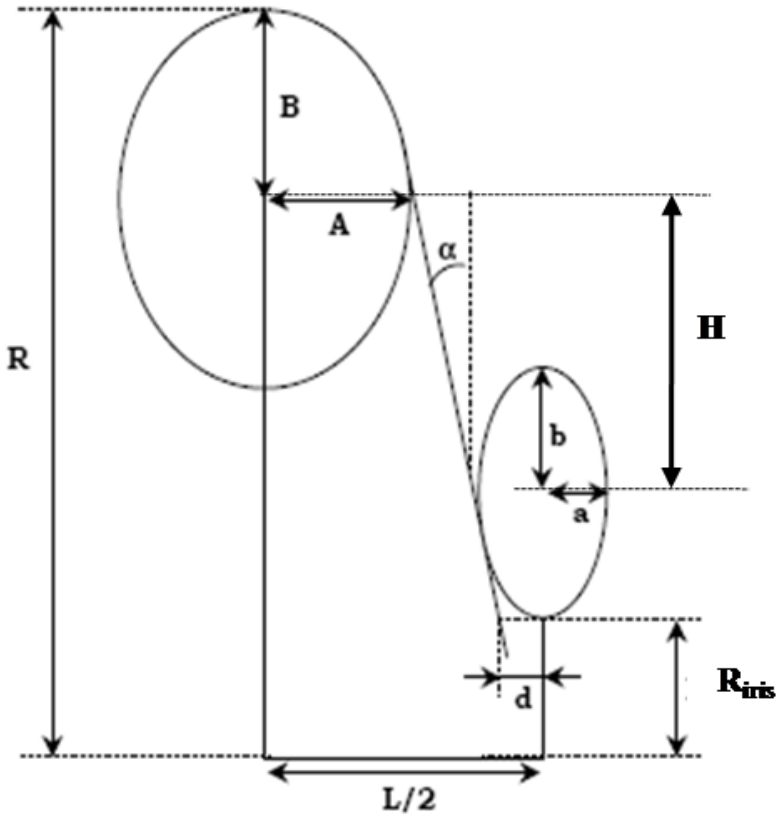
Using of Build cavity (Paolo Pierini, INFN Milano) :
Poisson Superfish Interface for multi-cel cavity design.





Parameterisation :

The frequency is retuned thanks to “R” each time one of the other parameters is changed.

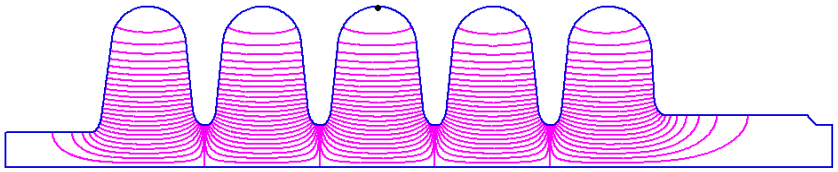


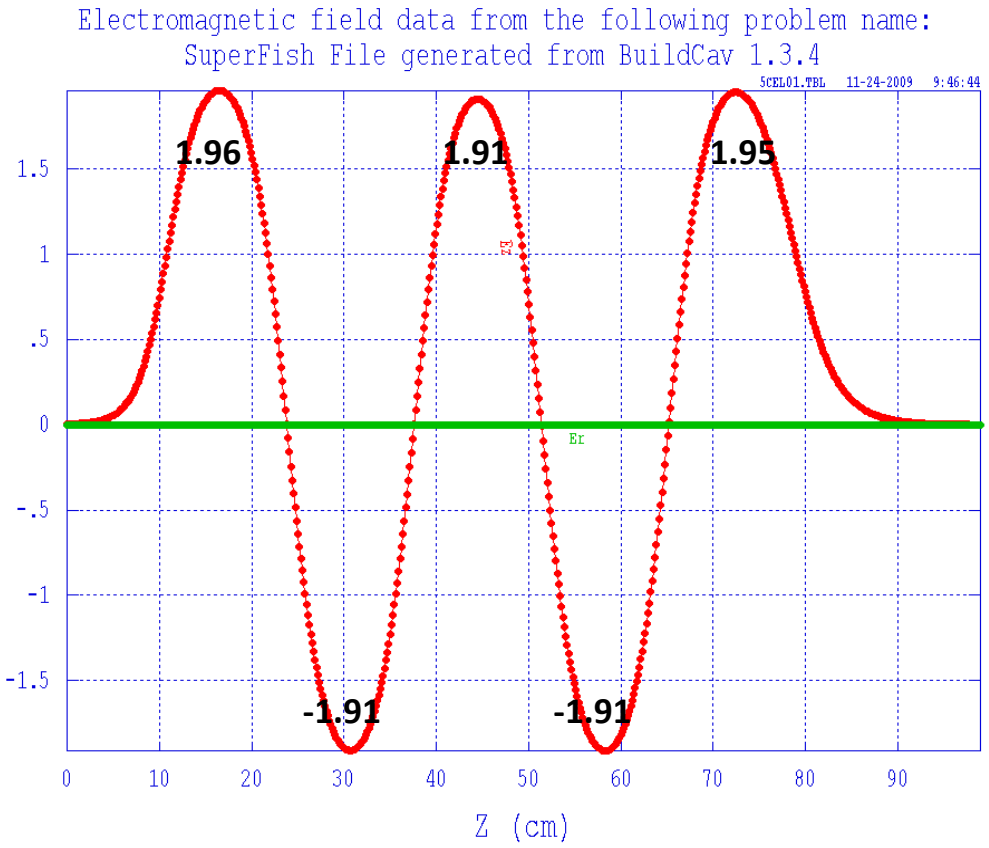
2D Preliminary study - Results

Calcul 2D sans port coupleur

	Left Cel	Internal Cel	Right Cel
R	184.67	184.67	184.67
L	69	69	69
Riris	40	48	60
A	41.62	47.10	53.02
B	39.53	44.75	55.67
a	15.15	14.26	13.17
b	25.0	23.53	21.73
L_tube	150		170 before shrinking

Fréquence = 704.407 MHz
Q0 (@ 2K) = 3.9 10^{10}
A βg = 0.65
r/Q = 298.5
Epeak/Eacc = 2.57
Bpeak/Eacc = 4.96 mT/(MV/m)



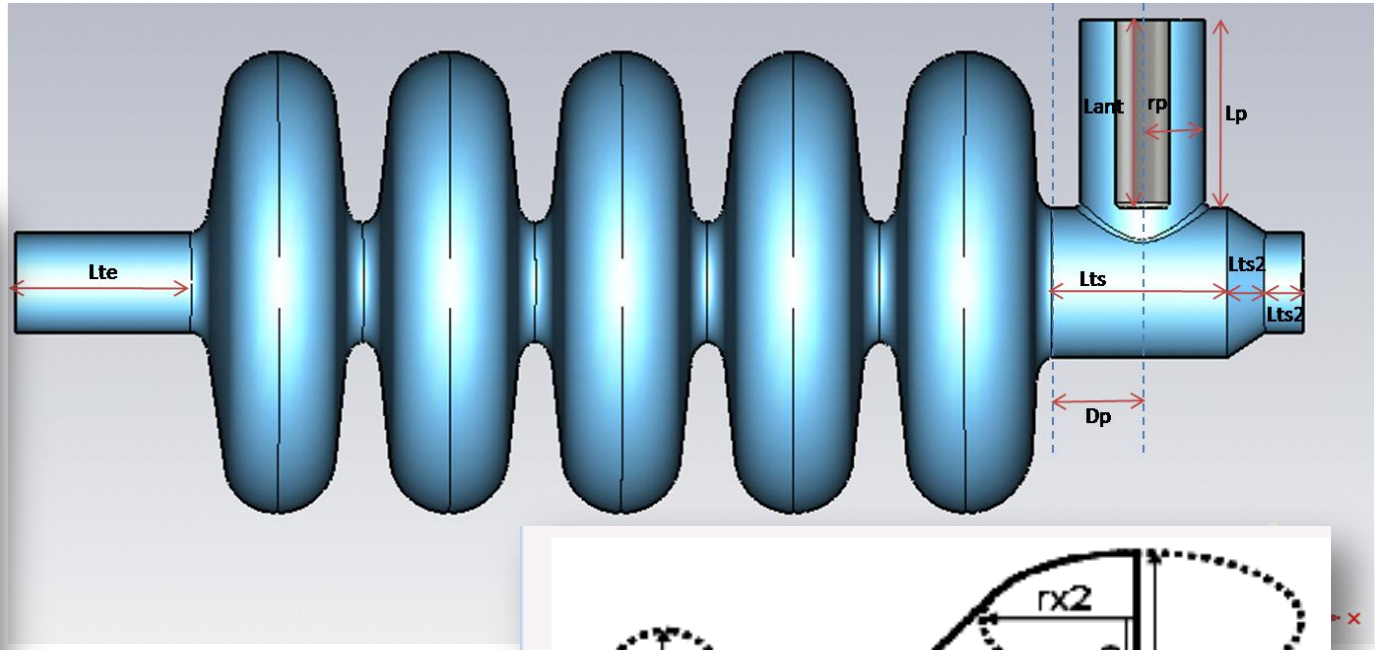


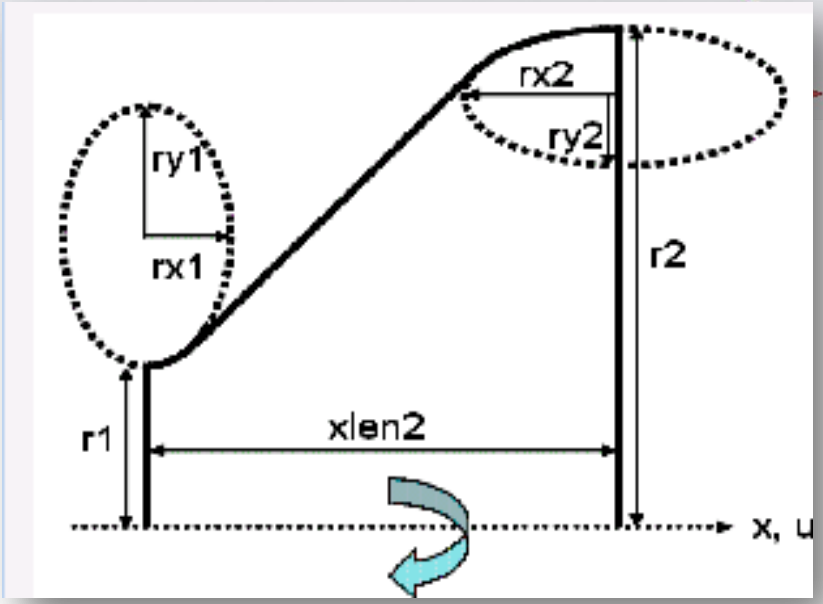
Field Flatness : 2.55%

3D calculations

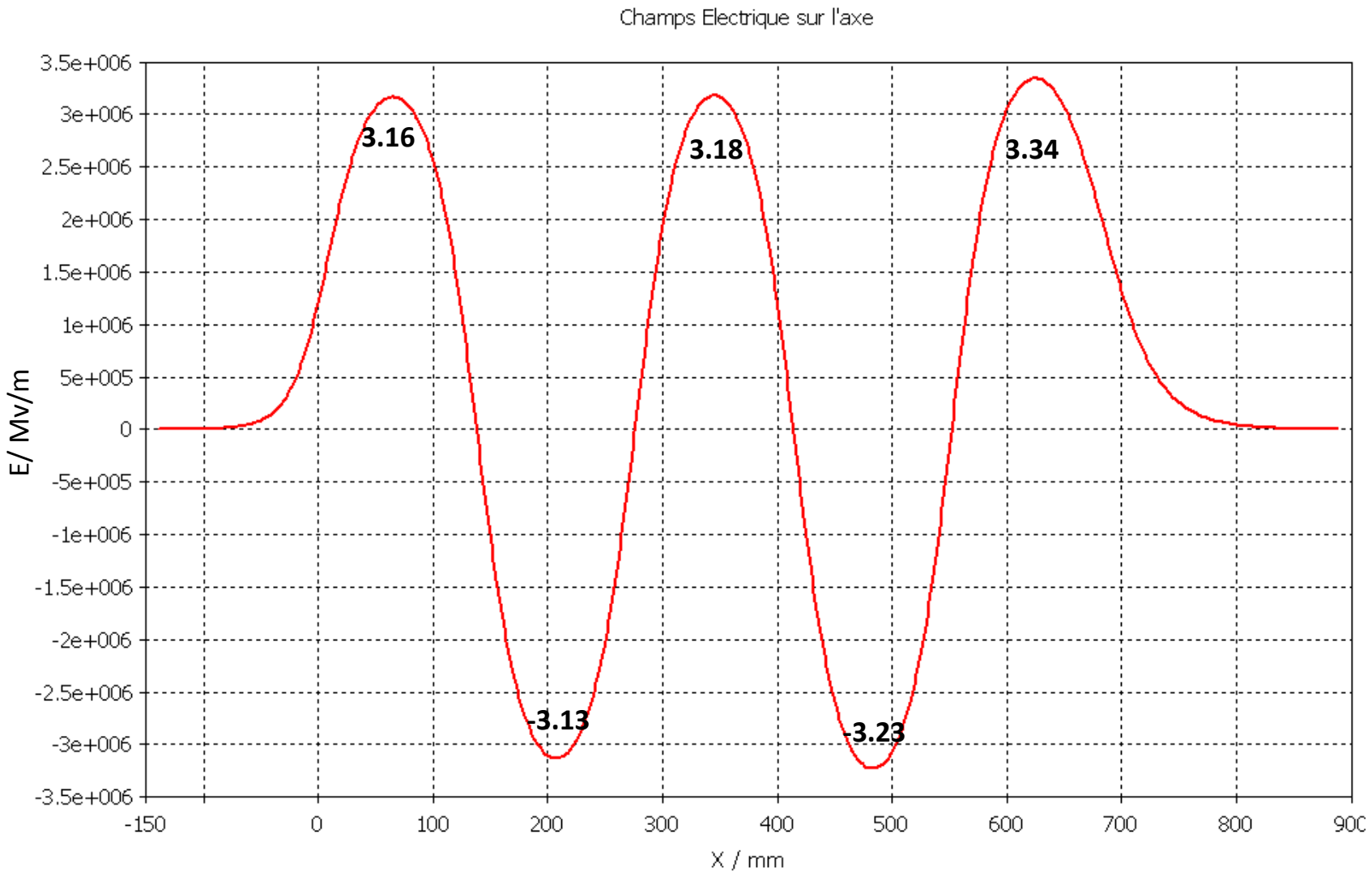
3D design in CST Microwave studio

Name	Value	Description
Dp	72	Distance port-cellule
Lant	151	Longueur antenne
Lcone	30	Longueur cone
Le	Lm	Demi cellule d'entrée
Lm	69	Demi cellule intermédiaire
Lp	150	Longueur port
Ls	Lm	Demi cellule de sortie
Lte	140	Longueur tube d'entrée
Lts	140	Longueur tube de sortie
Lts2	30	Longueur tube 2
beta	.65	
r1e	40	Demi cellule d'entrée
r1m	48	Demi cellule intermédiaire
r1s	60	Demi cellule de sortie
r2e	r2m	Demi cellule d'entrée
r2m	184.5	Demi cellule intermédiaire
r2s	r2m	Demi cellule de sortie
rant	21.7	Rayon antenne
rp	50	Rayon port coupleur
rx1e	15.2	Demi cellule d'entrée
rx1m	14.3	Demi cellule intermédiaire
rx1s	13.2	Demi cellule de sortie
rx2e	41.6	Demi cellule d'entrée
rx2m	47.1	Demi cellule intermédiaire
rx2s	53	Demi cellule de sortie
ry1e	25	Demi cellule d'entrée
ry1m	23.5	Demi cellule intermédiaire
ry1s	21.7	Demi cellule de sortie
ry2e	39.5	Demi cellule d'entrée
ry2m	44.7	Demi cellule intermédiaire
ry2s	55.7	Demi cellule de sortie





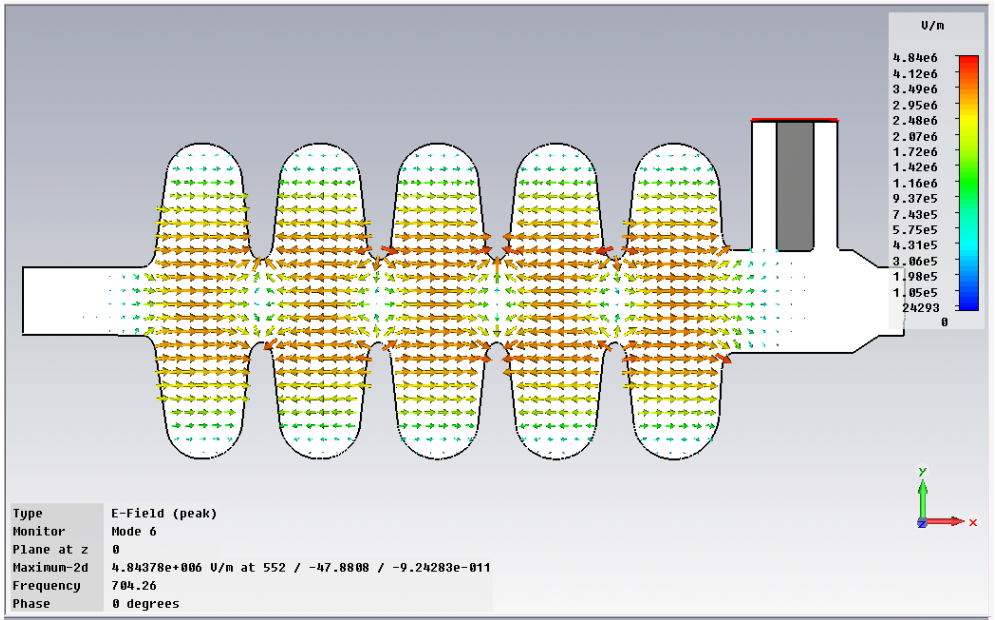
3D calculations – Field Flatness

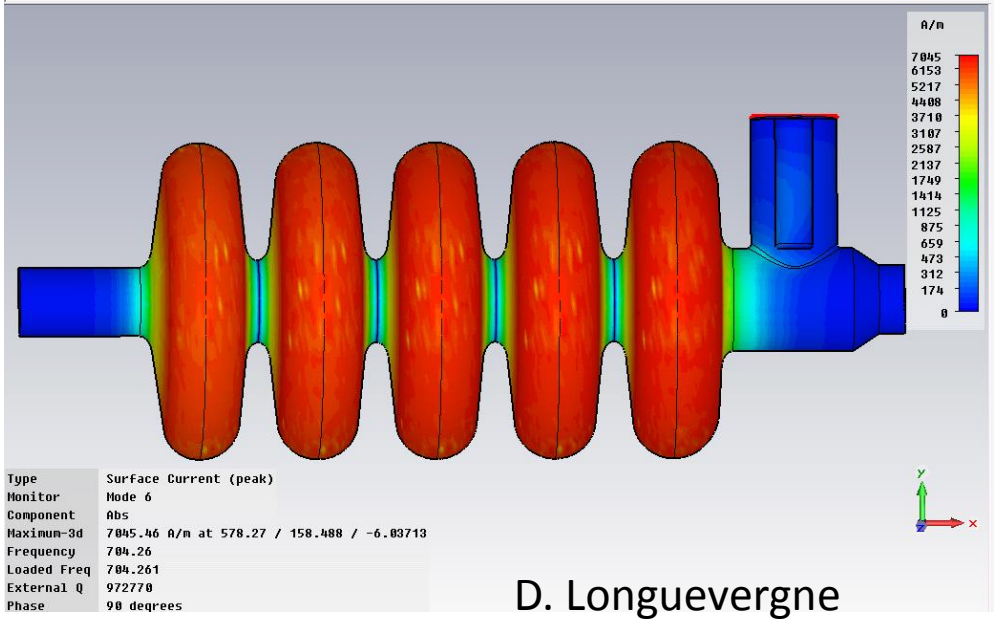


Field Flatness: 6.3%

D. Longuevergne

3D calculations - Results



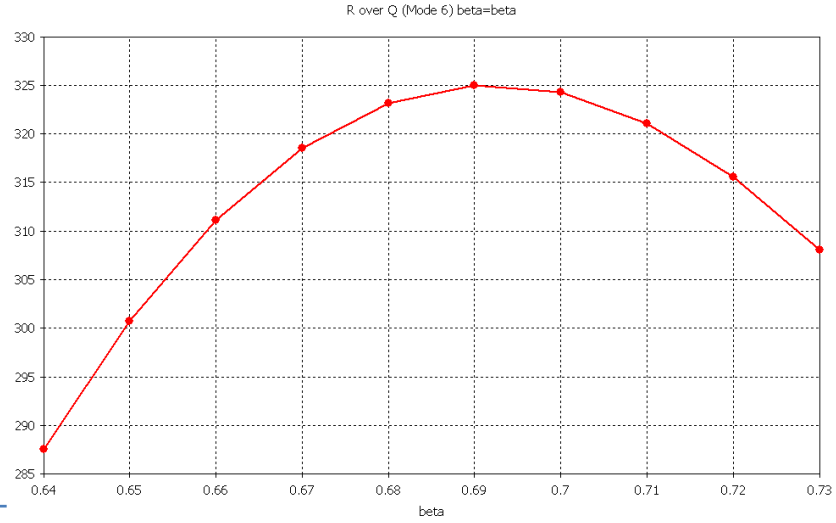


D. Longuevergne

Freq = 704.3 MHz
Q_{ext} = 1.09 10^6
Q0 (@ 2K) = 3.8 10^{10}
K = 1.47 %

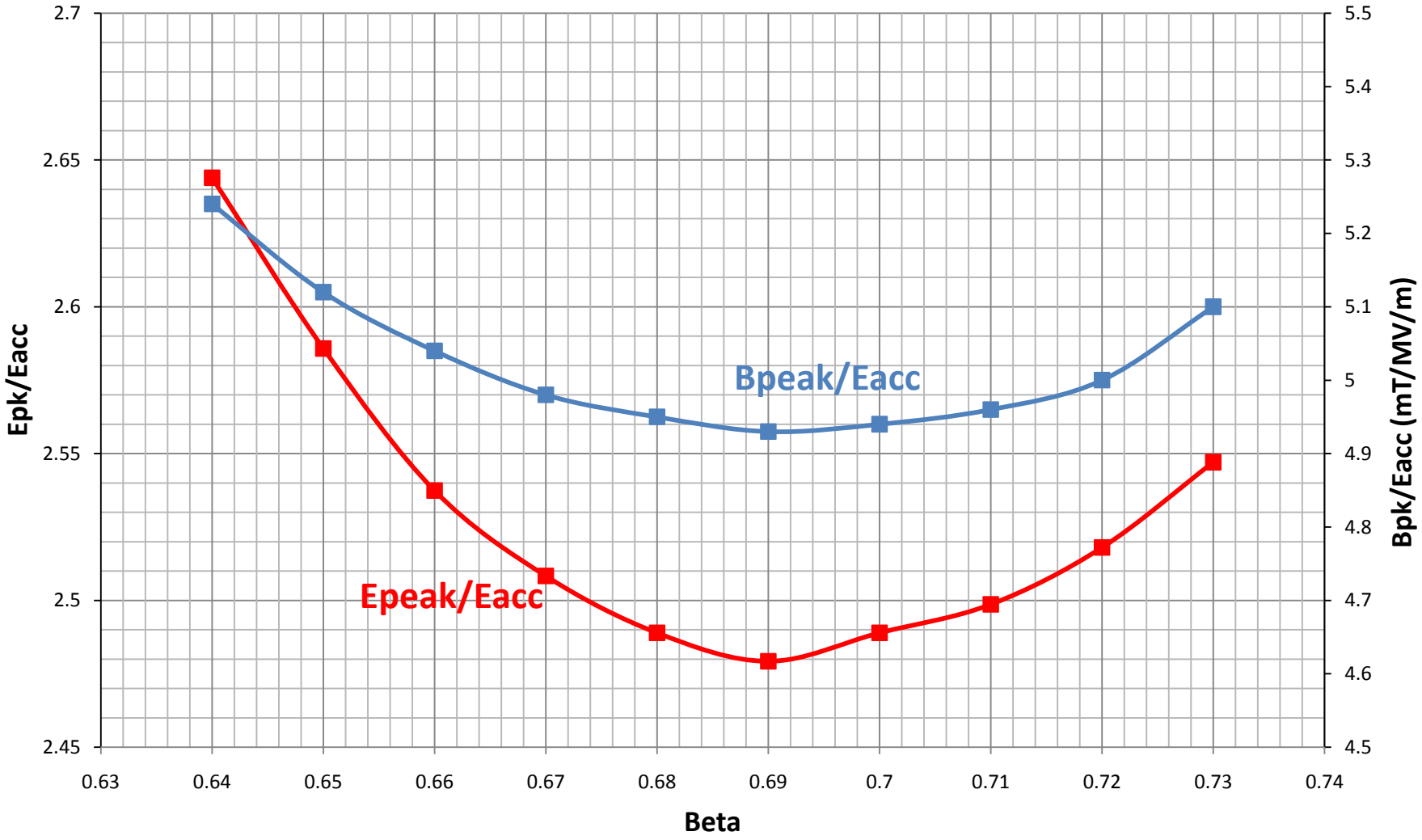
A βg = 0.65
Bpk/Eacc = 5.1 mT/(MV/m)
Epk/Eacc = 2.58

A βopt = 0.69
Bpk/Eacc = 4.92 mT/(MV/m)
Epk/Eacc = 2.47



3D calculations - Results

Evolution of the peak fields ratios as function of the particles velocities



First overview of the HOMs

_ First 100 HOM- 3D calculation using CST MS

_ TM & TE Not identified

Solver Results:

Mode	Frequency	Accuracy |(Ax-x)/x|	max(e)	div(e)
1	450.231248631	2.96e-011	1.62e-002	3.76e-007
2	694.942413476	2.55e-011	4.27e-002	1.08e-006
3	697.464924391	3.09e-012	3.99e-002	1.02e-006
4	700.574415904	1.24e-011	4.07e-002	1.11e-006
5	703.080763885	1.42e-011	3.84e-002	1.04e-006
6	704.044649143	1.92e-012	6.02e-002	1.22e-006
7	1008.3245498	6.25e-012	1.34e-002	1.07e-006
8	1008.40606963	1.76e-012	1.34e-002	1.07e-006
9	1012.6993262	9.11e-012	1.21e-002	1.07e-006
10	1012.87449441	2.60e-012	1.25e-002	1.07e-006
11	1019.87937605	4.28e-012	1.31e-002	1.13e-006
12	1020.09994471	2.99e-012	1.25e-002	1.11e-006
13	1029.12207929	2.04e-011	1.25e-002	1.06e-006
14	1029.25304921	5.96e-012	1.26e-002	1.06e-006
15	1036.85680442	3.19e-012	1.33e-002	1.02e-006
16	1036.94438518	4.87e-012	1.33e-002	1.02e-006
17	1211.27113527	5.58e-012	6.16e-003	1.32e-006
18	1218.1099024	6.55e-012	5.55e-003	1.34e-006
19	1250.4336455	2.67e-012	6.47e-003	1.51e-006
20	1253.11276318	2.72e-012	5.29e-003	1.45e-006
21	1303.17367359	1.09e-011	6.84e-003	1.58e-006
22	1306.46582241	1.26e-011	5.80e-003	1.58e-006
23	1329.45374319	9.02e-012	2.16e-003	8.53e-007
24	1359.35702044	5.05e-012	3.67e-003	1.46e-006
25	1371.65487163	1.47e-012	5.66e-003	1.50e-006
26	1380.66917739	2.38e-012	6.05e-003	1.01e-006
27	1381.06013818	6.91e-013	6.79e-003	1.06e-006
28	1381.66880622	3.45e-012	6.29e-003	1.01e-006
29	1381.97439701	7.96e-012	6.50e-003	1.08e-006
30	1382.99680163	1.07e-012	6.02e-003	9.85e-007
31	1383.29822031	3.87e-012	7.03e-003	1.10e-006
32	1384.29857372	1.07e-012	5.97e-003	1.01e-006
33	1384.62765699	1.90e-012	6.20e-003	1.05e-006
34	1385.17228005	6.38e-013	6.45e-003	1.03e-006
35	1385.5585008	3.09e-012	6.71e-003	1.03e-006
36	1389.51433161	2.20e-012	2.87e-003	1.44e-006
37	1420.2657088	7.04e-012	4.70e-003	1.46e-006
38	1421.45377161	5.60e-013	5.35e-003	1.56e-006
39	1484.0035404	1.37e-012	1.46e-003	5.14e-007
40	1516.92015375	6.79e-013	5.55e-003	1.09e-006
41	1524.42574293	7.49e-013	5.44e-003	1.19e-006
42	1536.42087116	5.89e-013	5.90e-003	1.16e-006
43	1549.29952949	4.78e-013	5.27e-003	1.22e-006
44	1558.43649318	4.29e-013	5.64e-003	1.17e-006
45	1614.35322921	4.95e-013	3.41e-003	1.02e-006
46	1616.38125507	5.00e-013	1.93e-003	9.05e-007
47	1643.71030289	3.58e-013	2.46e-003	7.55e-007
48	1644.26226721	4.12e-013	2.79e-003	9.55e-007
49	1686.9315093	1.08e-012	3.14e-003	1.19e-006
50	1687.66704278	7.70e-013	3.73e-003	1.51e-006
51	1692.63964805	8.31e-013	3.02e-003	1.04e-006
52	1693.33847238	7.72e-013	3.55e-003	1.33e-006
53	1698.37126061	1.00e-012	3.01e-003	1.17e-006
54	1699.03340911	4.57e-013	3.41e-003	1.49e-006
55	1703.57908617	5.29e-013	3.38e-003	8.43e-007
56	1714.72459302	8.08e-013	1.96e-003	5.48e-007
57	1714.8959182	2.83e-012	2.05e-003	5.45e-007
58	1715.98128761	3.00e-010	2.93e-003	1.05e-006
59	1716.07613619	4.23e-010	2.93e-003	9.71e-007
60	1716.30681888	3.63e-010	2.94e-003	7.56e-007
61	1716.38728624	9.17e-009	2.87e-003	7.62e-007
62	1716.53644654	9.73e-010	2.89e-003	8.44e-007
63	1716.61640451	1.37e-009	2.82e-003	8.61e-007
64	1716.99524316	3.56e-010	2.82e-003	1.37e-006
65	1718.65995013	1.94e-011	2.50e-003	1.37e-006
66	1718.89238918	2.52e-012	2.76e-003	1.06e-006
67	1719.43573435	1.10e-011	2.34e-003	7.59e-007
68	1719.56022002	9.30e-012	2.08e-003	5.51e-007
69	1735.00049115	1.68e-013	2.07e-003	7.29e-007
70	1735.7045156	2.76e-013	2.42e-003	9.31e-007
71	1740.28441667	3.01e-013	4.63e-003	1.21e-006
72	1747.67470249	1.21e-012	2.92e-003	1.49e-006
73	1749.50114782	4.06e-013	2.61e-003	1.46e-006
74	1751.83598171	6.09e-013	4.68e-003	1.15e-006
75	1758.23916625	2.23e-013	2.88e-003	1.45e-006
76	1759.57693115	2.75e-012	2.85e-003	1.22e-006
77	1760.9187767	3.99e-012	2.83e-003	1.45e-006
78	1761.84189445	1.50e-012	4.26e-003	1.17e-006
79	1776.50077717	5.90e-013	3.06e-003	1.53e-006
80	1777.90671333	1.24e-012	2.68e-003	1.46e-006
81	1782.88466403	2.79e-013	2.18e-003	1.27e-006
82	1795.46620791	1.29e-011	2.86e-003	1.39e-006
83	1795.74303473	3.16e-011	2.84e-003	1.40e-006
84	1797.65948798	1.16e-011	1.91e-003	8.51e-007
85	1799.44452722	2.38e-012	2.93e-003	7.54e-007
86	1805.35091124	2.69e-013	1.99e-003	8.73e-007
87	1860.05260416	4.88e-012	1.83e-003	8.52e-007
88	1860.18384631	8.65e-012	1.81e-003	8.60e-007
89	1879.56137424	3.14e-011	3.14e-003	1.16e-006
90	1880.12432291	1.37e-010	3.37e-003	1.07e-006
91	1881.49756026	5.29e-011	1.90e-003	1.04e-006
92	1886.25403927	7.48e-008	1.45e-003	7.62e-007
93	1886.33239811	6.94e-008	1.52e-003	7.53e-007
94	1888.50122912	2.11e-008	3.06e-003	1.21e-006
95	1888.68957817	8.64e-009	3.03e-003	1.22e-006
96	1899.62094795	9.12e-009	2.83e-003	1.23e-006
97	1899.96111538	1.29e-009	2.81e-003	1.23e-006
98	1919.3199373	5.58e-007	2.12e-003	1.02e-006
99	1919.63661772	1.12e-006	2.12e-003	1.02e-006
100	1929.11883885	2.29e-004	2.40e-002	1.21e-006

Optimum guess for the highest eigenfrequency would be: 1929.12.

Solver Statistics:

	Peak memory used (kB) Physical	Virtual	Free physical memory (kB) At begin	Minimum
Matrices calc.	533388	652244	22047068	21633392
Solver run total	1306664	1384636	22069512	20687796

Mesh generation time : 128 s
(= 0 h, 02 m, 08 s)
Solver time : 84358 s (= 23 h, 25 m, 58 s)
Total time : 84486 s (= 23 h, 28 m, 06 s)

summary

f (MHz)	704.3	Ok
Ep/Eacc	2.58	Ok
Bpk/Eacc (mT/MV/m)	5.10	Ok
K (%)	1.47	Ok
r/Q (Ohm)	301	Ok
G (Ohm)	200	Ok
Vacc @βg & 1 Joule (MV)	1.16	Ok
Qo (@2K, Rres=2nΩ)	$3.8\ 10^{10}$	Ok