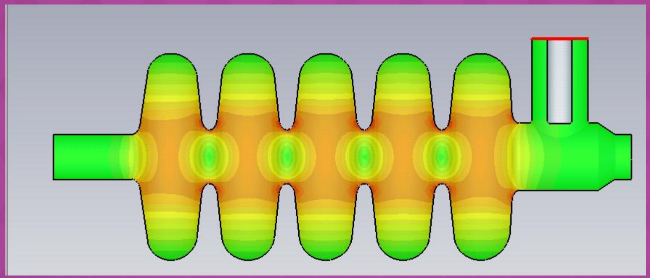
STATUS OF THE BETA=0.65 CAVITY FOR SPL LINAC

G. Olry, *CNRS-IPN Orsay*



4th SPL collaboration meeting, 01/07/2010, Lund

OUTLINE

- Requirements

Since November 2009 (last SPL coll. meeting), studies in 2 phases

- Nov ‘09 – March ‘10: first design
  - 2D (Superfish™) and 3D (CST Microwave Studio™) calculations on:
    - Cell-to-cell coupling factor
    - Adjustments and shape sensitivity for field flatness
    - Positioning of the power coupler (external Q)
  - Mechanical design
    - Static load (2 bars @300K), Lorentz forces detuning
  - Helium tank design

- April ‘10-nowadays (still on-going): new design
  - New parameters for vacuum load: 1.5 bars@300K
  - Proposal for another design: new end-groups (same as β= 1 CEA)

- Conclusion & Planning

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

GOALS

Epeak/Eacc < 2.6

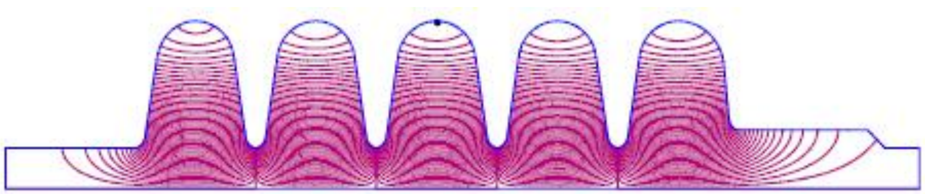
Bpeak/Eacc < 5.2 mT/(MV/m)

+

Cell-to-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

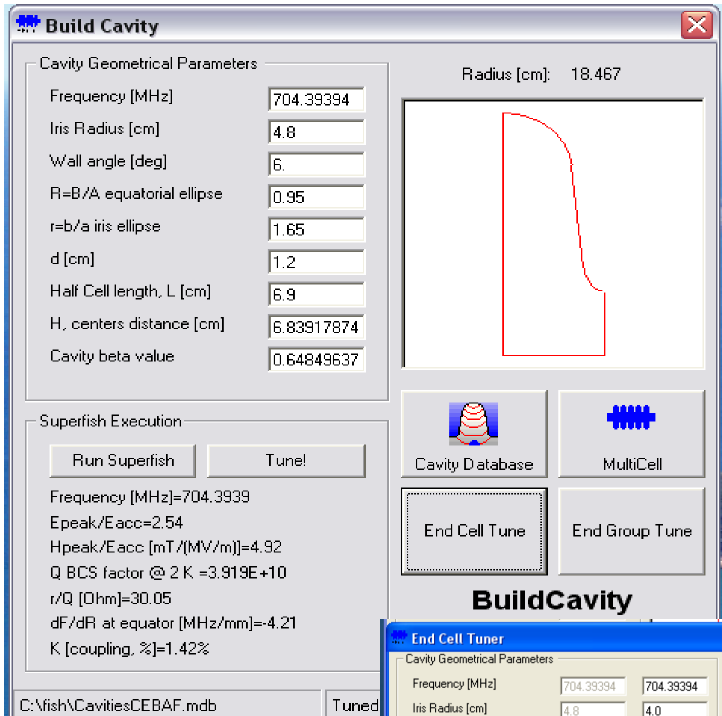
J-Luc Biarrotte, PhD Thesis, 2000, Orsay

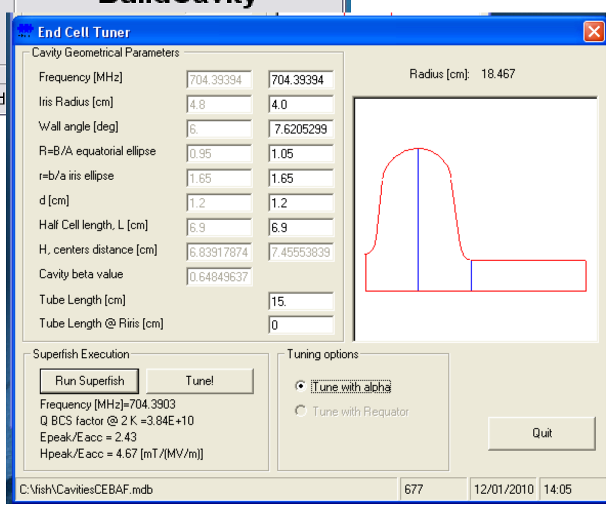
NOV '09 – MARCH '10: FIRST DESIGN

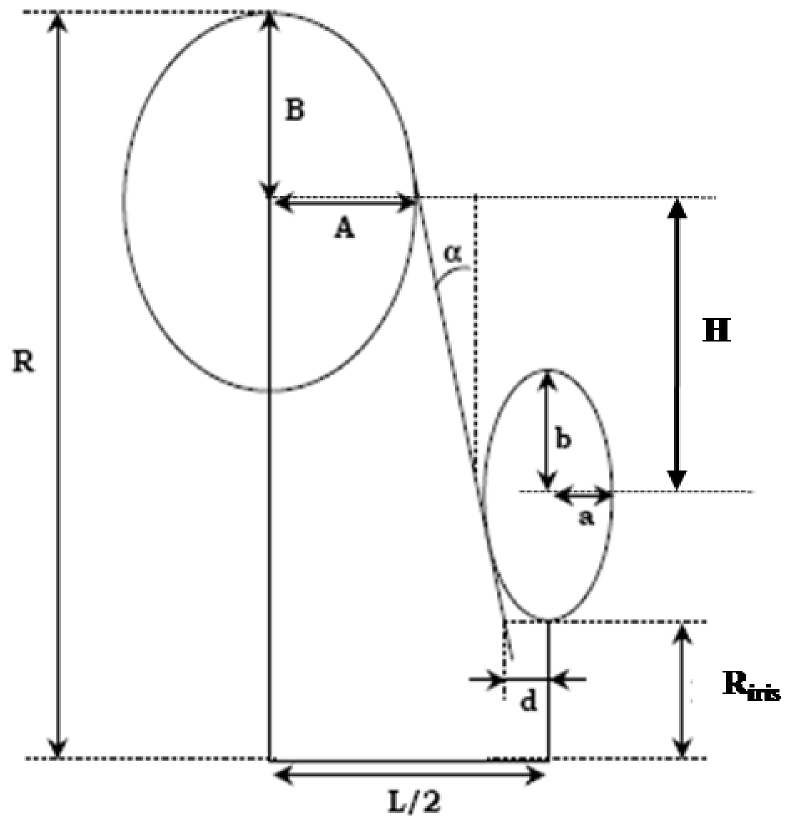
2D STUDY (SUPERFISH)

Designed with <u>Build cavity</u> (Paolo Pierini, INFN Milano)
Poisson Superfish Interface for multi-cell cavity design.

<u>Parameterisation :</u>
The different parameters were iteratively optimised & the frequency readjusted by retuning the cell radius "R".

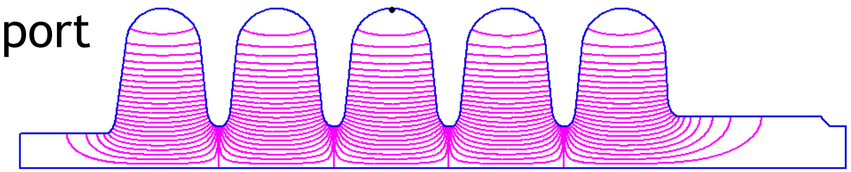






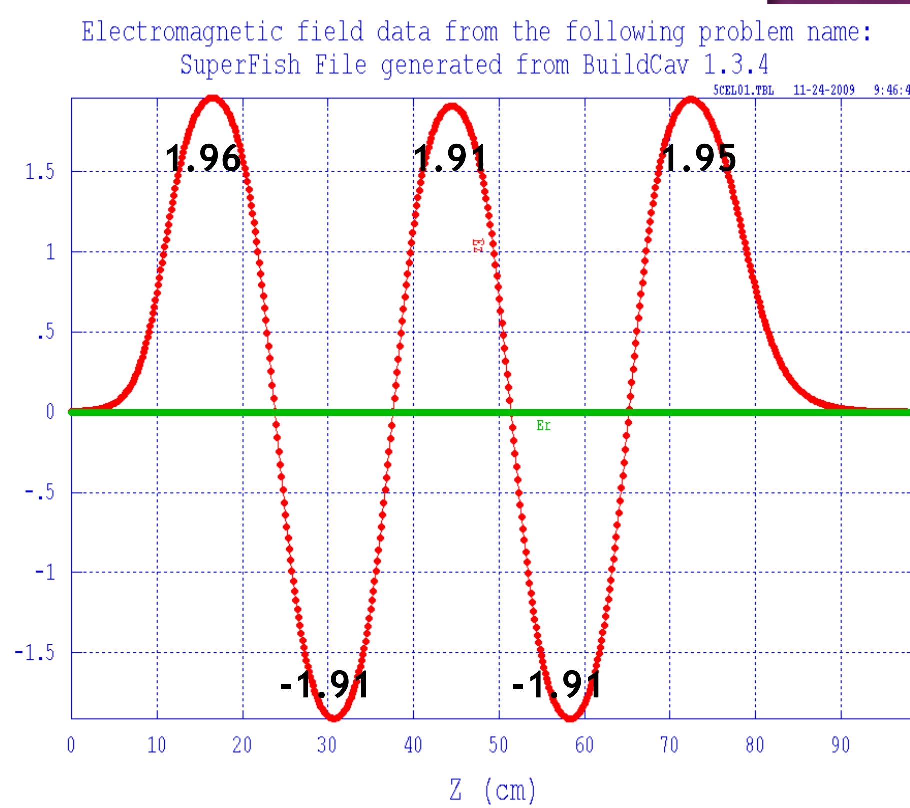
2D STUDY (SUPERFISH)

→Design of the cells
→Input for 3D calculations with RF coupler port



	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

F. Bouly (IPNO)



Field Flatness : 2.55%

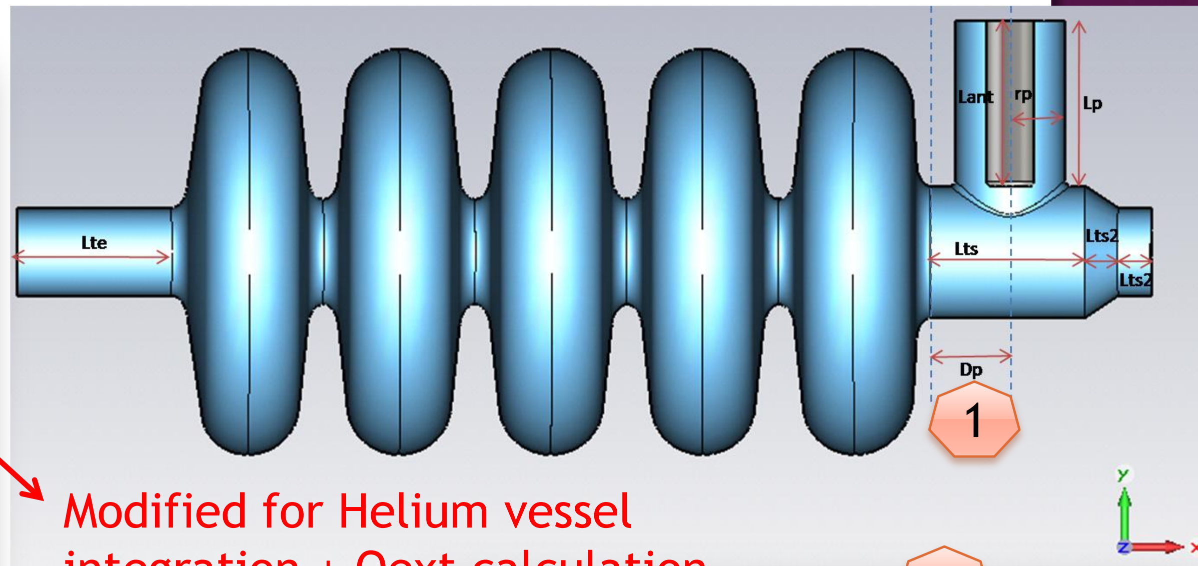
Frequency = 704.407 MHz
Q0 (@ 2K) = $3.9\ 10^{10}$

<u>At β_g = 0.65</u>
r/Q = 299
Epeak/Eacc = 2.5
Bpeak/Eacc = 4.9 mT/(MV/m)

OK

3D CALCULATIONS (MWS)

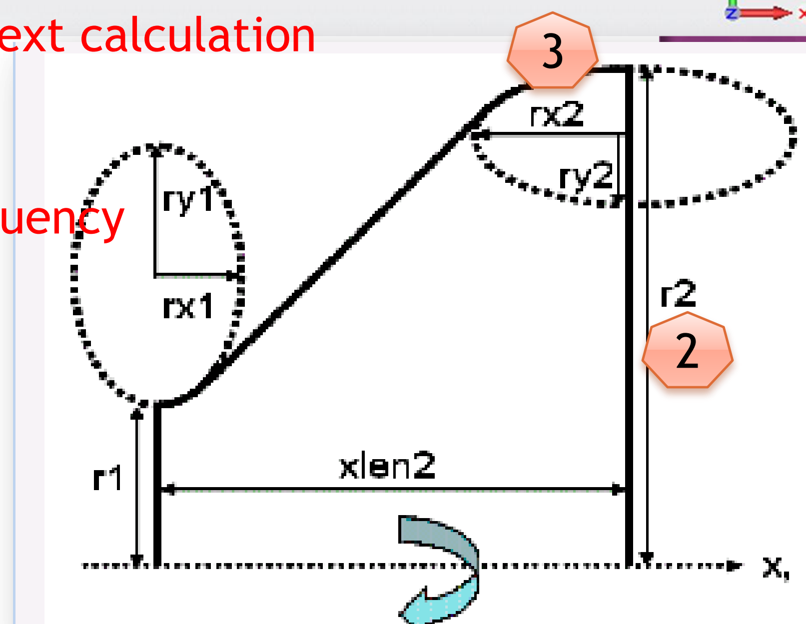
Name	Value	Description
Dp	72	Distance port-cellule
Lant	151	Longueur antenne
Lcone	30	Longueur cone
Le	Lm	Demi cellule d'entrée
Lm	69	Demi cellule intermédiaire
Lp	150	Longueur port
Ls	Lm	Demi cellule de sortie
Lte	140	Longueur tube d'entrée
Lts	140	Longueur tube de sortie
Lts2	30	Longueur tube 2
beta	.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



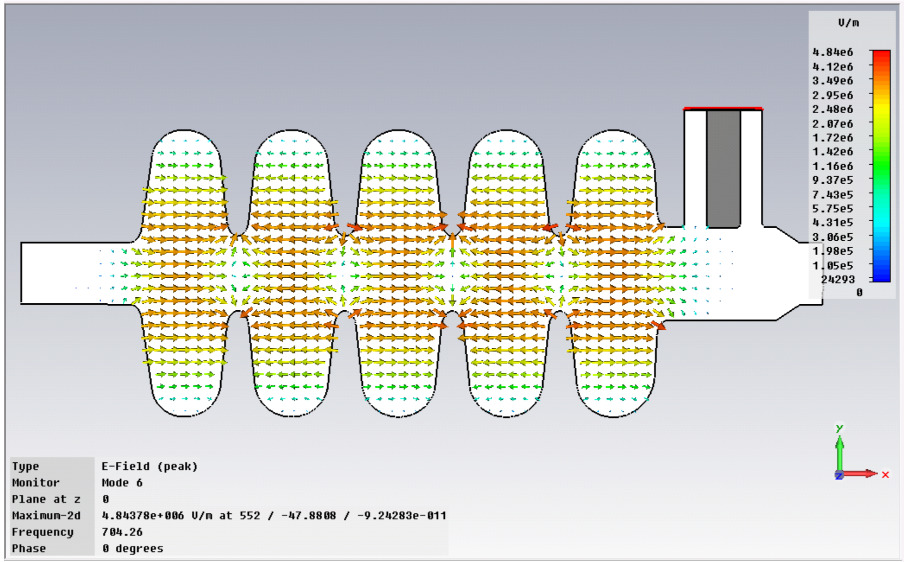
Modified for Helium vessel integration + Qext calculation

Retuned for frequency adjustment

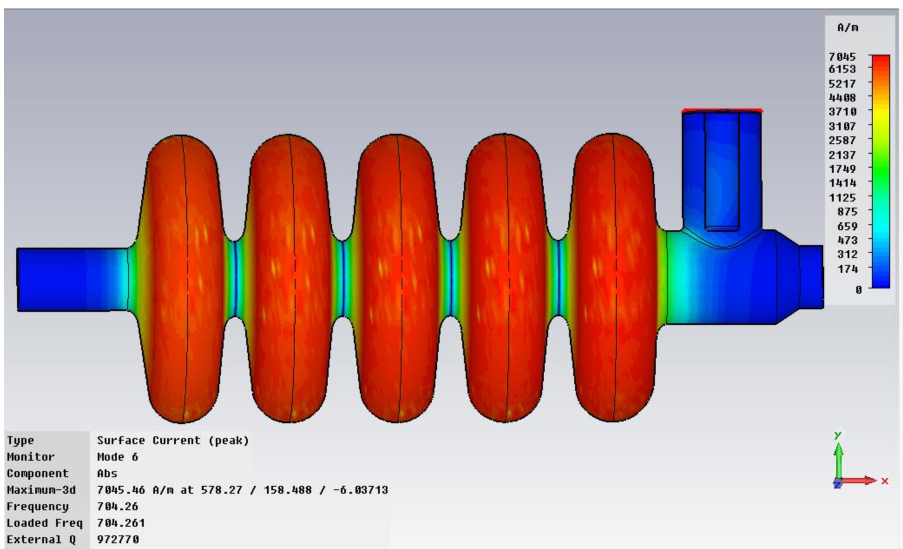
Adjusted for field flatness



3D CALCULATIONS: FIELDS & QEXT

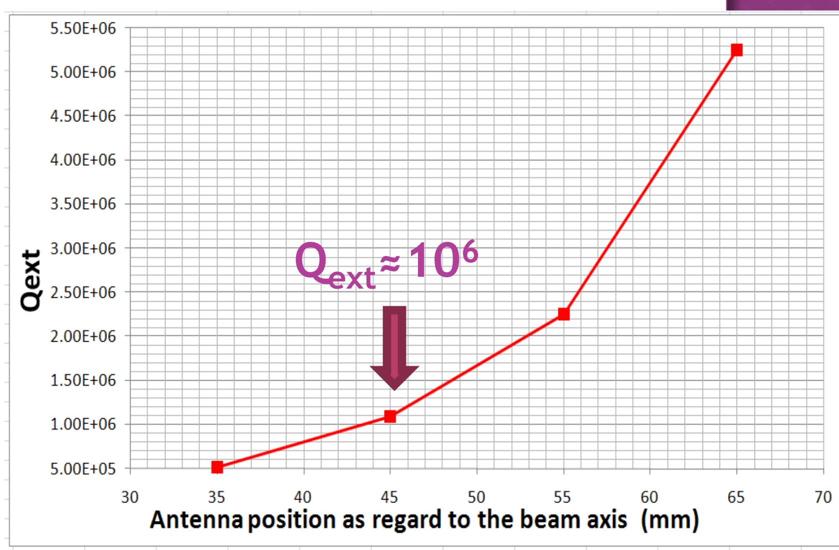


F. Bouly & D. Longuevergne (IPNO)



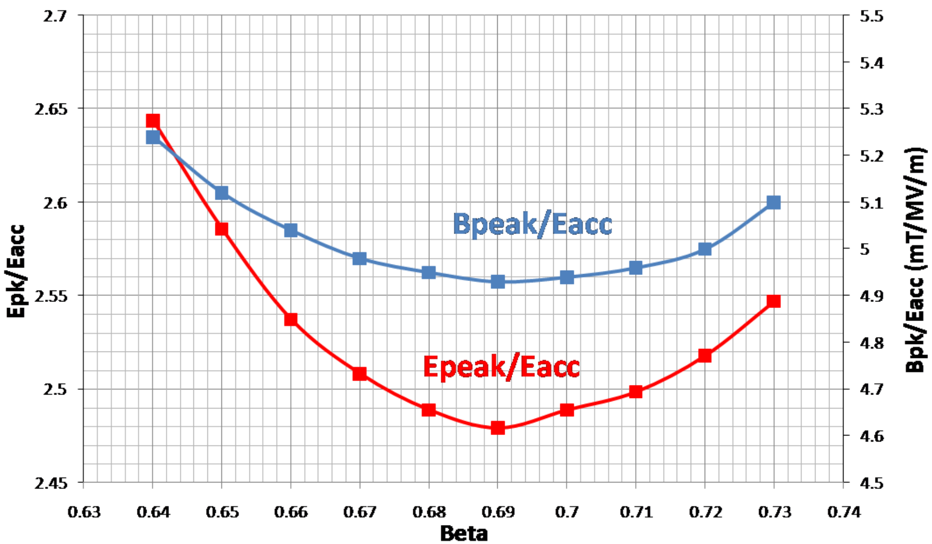
Freq = 704.3 MHz
Q_{ext} = 1.09 10^6
Q0 (@ 2K) = 2.8 10^{10}
K = 1.47 %

External coupling adjusted with the penetration length of the antenna

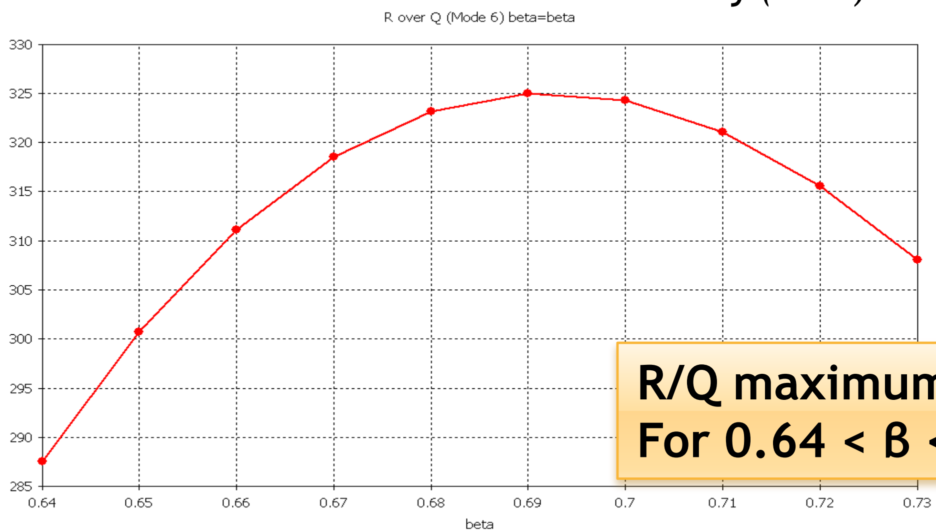


3D CALCULATIONS: RF PARAMETERS

Evolution of the peak fields ratios as function of the reduced velocity β



F. Bouly (IPNO)



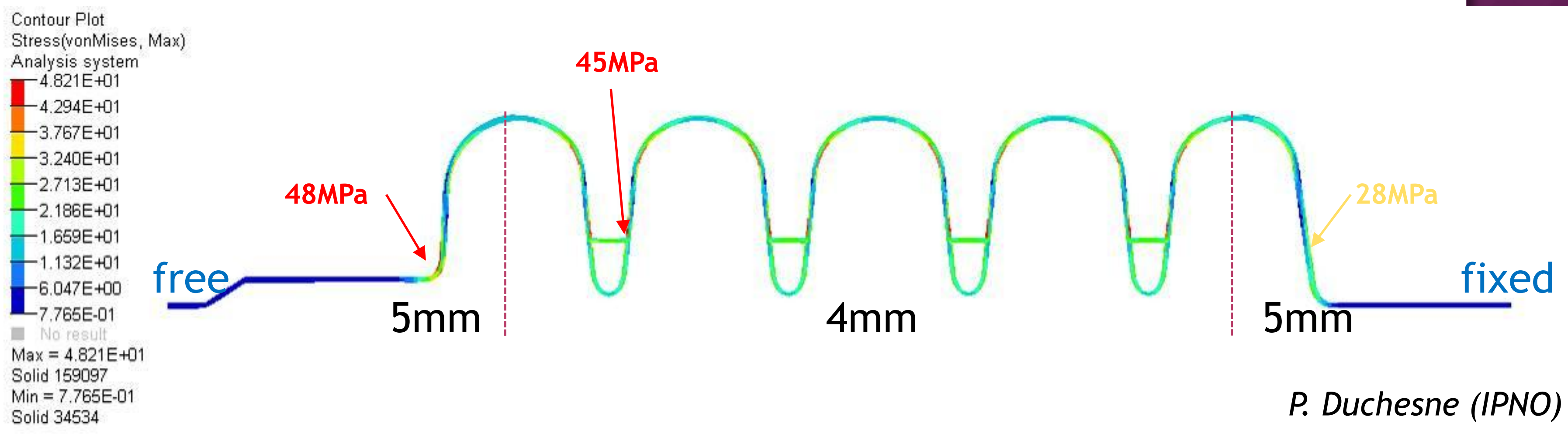
At βg = 0.65
Bpk/Eacc = 5.1 mT/(MV/m)
Epk/Eacc = 2.6
r/Q ≈ 300

At βopt = 0.69
Bpk/Eacc = 4.9 mT/(MV/m)
Epk/Eacc = 2.5
r/Q ≈ 325

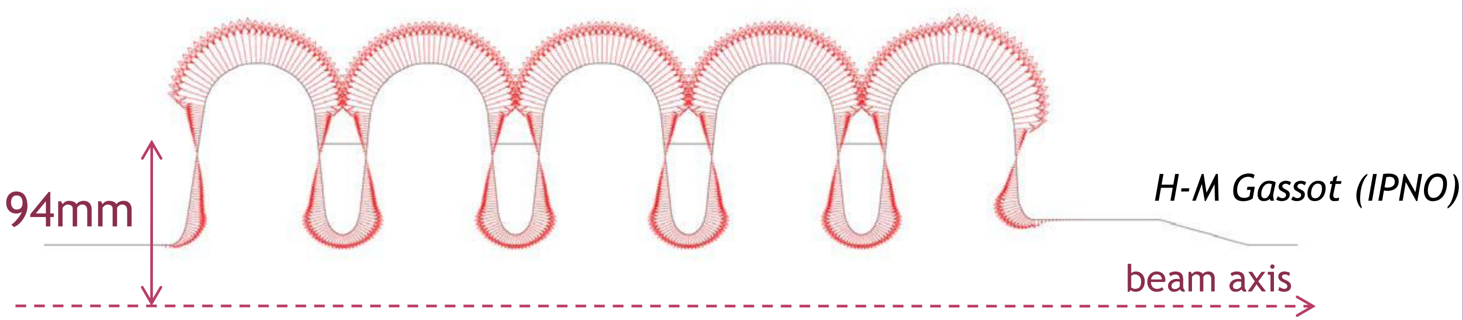
R/Q maximum for βopt.
For 0.64 < β < 0.73 → 285 < r/Q < 325

MECHANICAL CALCULATIONS

- Main pb: Von Mises stresses > 50 MPa for 2 bar @ 300K with only 4 mm → end-cell thickness increased to 5mm

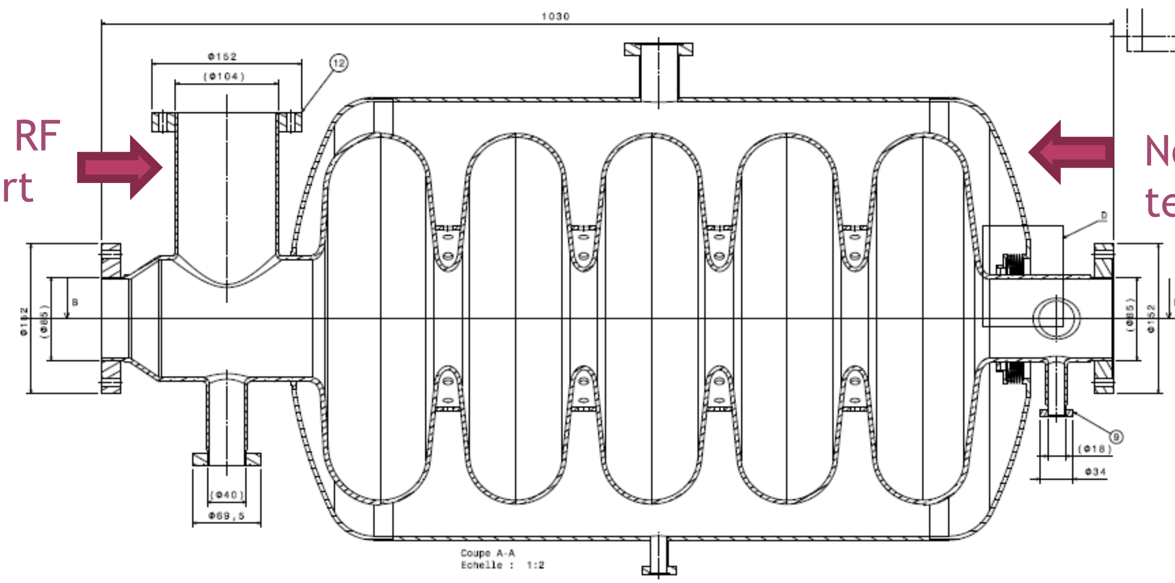


- Lorentz forces detuning with 1 stiffening ring between cells: $K_L < -1\ Hz/(MV/m)^2$



HELIUM VESSEL INTEGRATION

No-cooling RF coupler port



No tuning system test ability

Influence of the thermal contraction 300K→4K

Volume decrease : V 0.99857

→ **Cavity frequency shift: +1 MHz**

Influence of the chemical etching

Assumption : 100µm removed uniformly from the cavity walls

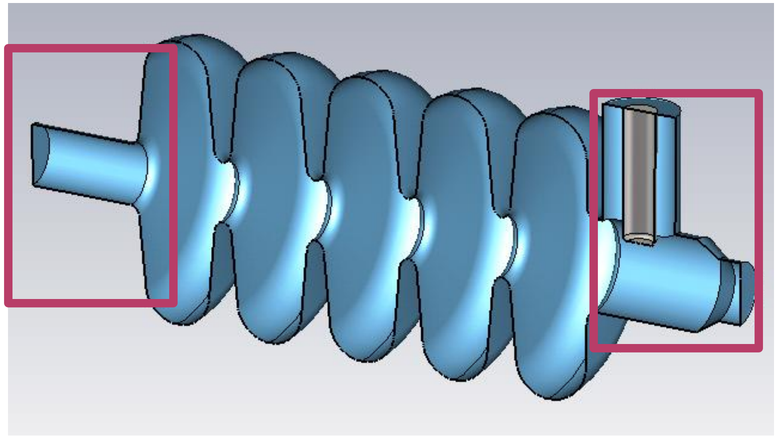
→ **Cavity frequency shift: - 0.4 MHz**

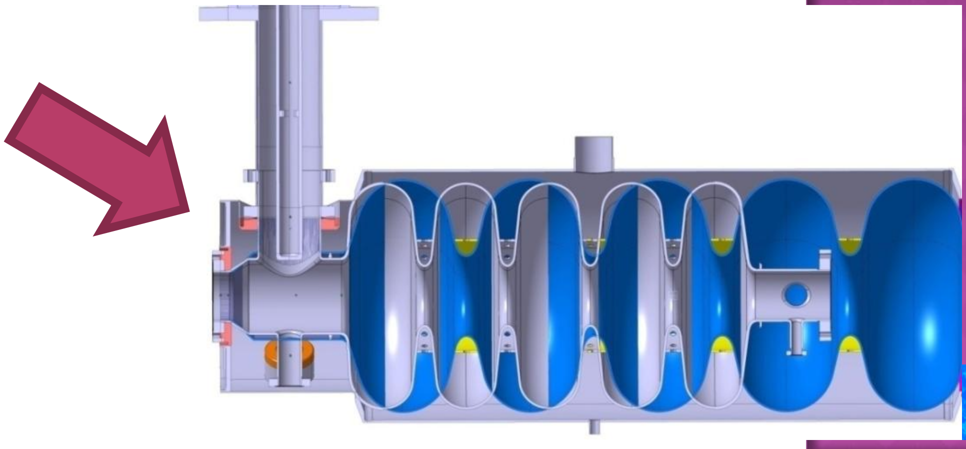
APRIL ’10 -...: NEW DESIGN

NEW DESIGN: NEW OPTIONS

Starting point: discussions with CERN & CEA → get the same end-groups than those designed for the β=1 ➡ <u>SAME INTERFACES</u>

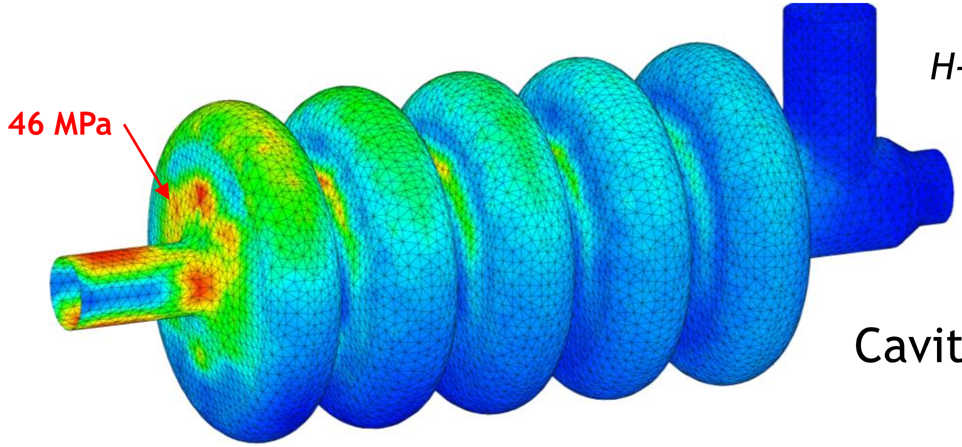
Main changes:
→Bigger beam tubes apertures on both sides
→New design of the 2 external half cells (field flatness)
→New helium vessel (including the tuning system interface)
→New position of the power coupler (Qext)
+
→ New parameters for vacuum load: 1.5 bar @300K





MECHANICAL CALCULATIONS

- Von Mises stresses for 1.5 bar @ 300K < 50 MPa with 4mm (3.5mm should be ok for the inner cells)



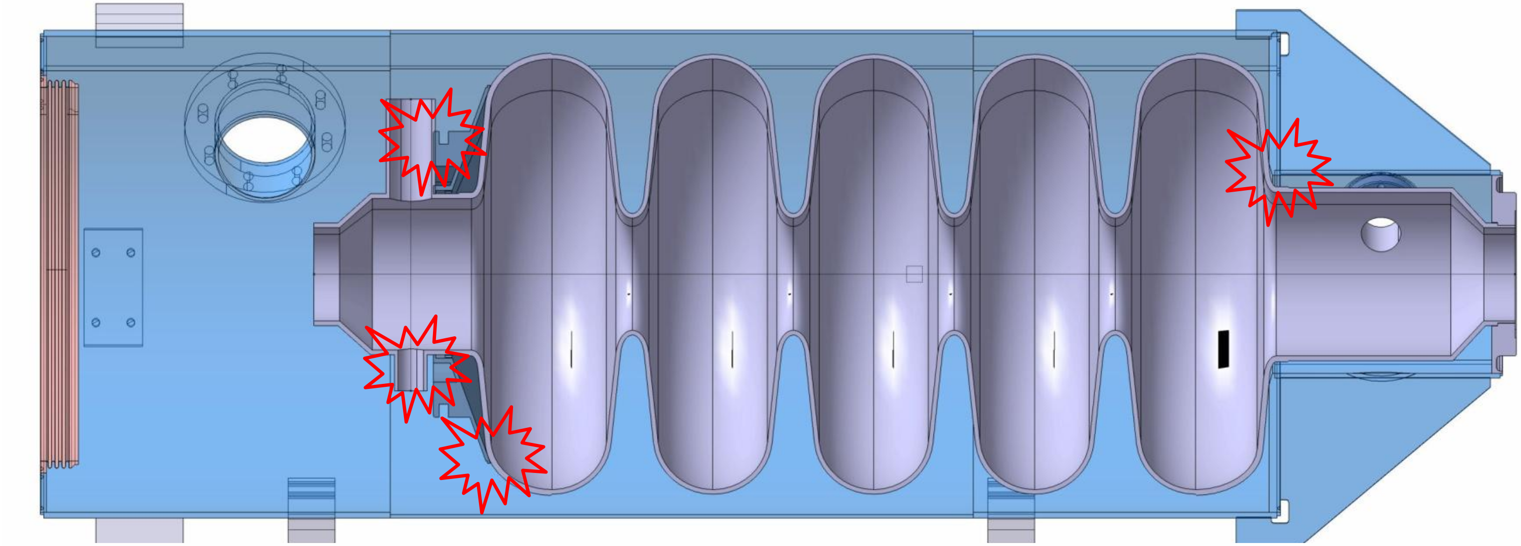
H-M Gassot (IPNO)

Cavity walls = 4mm

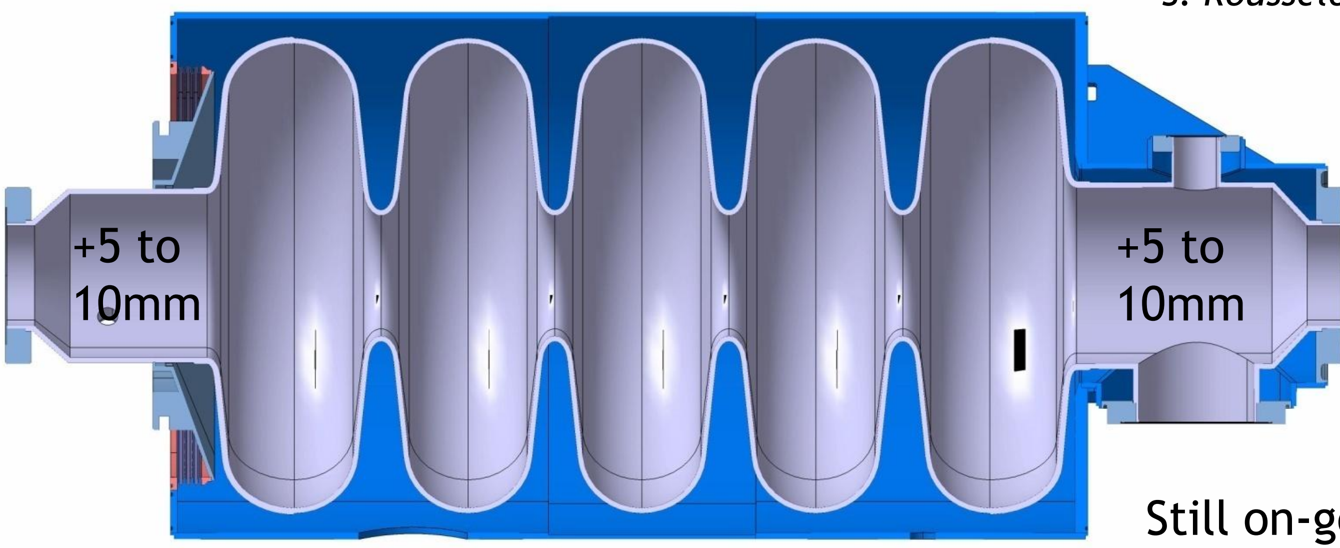
- Lorentz forces detuning (still 1 ring) : K_L~ -1.6 $Hz/(MV/m)^2$

CAVITY INTEGRATION

- beta=0.65 cavity inside beta=1 helium vessel



S. Rousselot (IPNO)



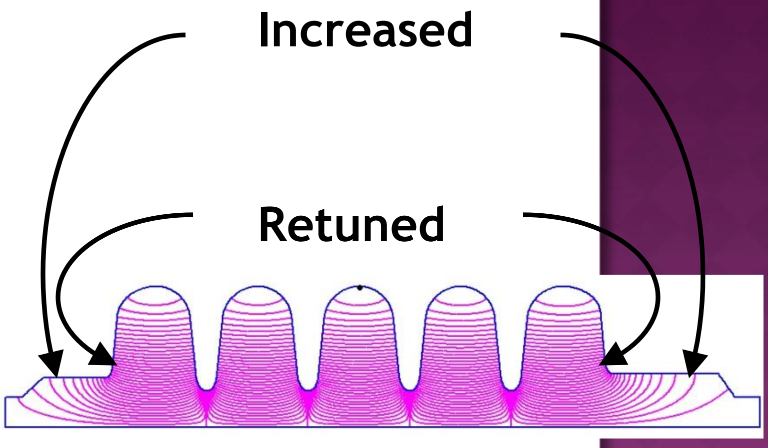
Still on-going...

RF DESIGN

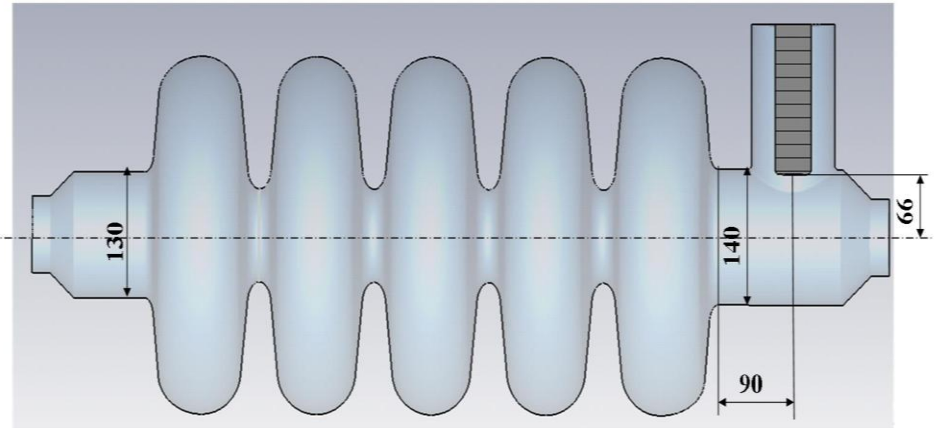
2D and 3D studies

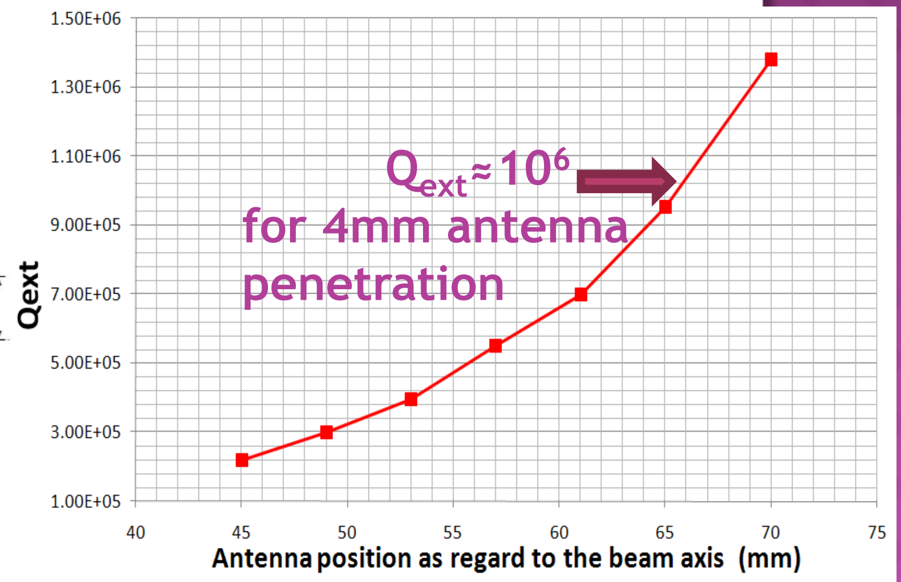
	Left Cell [tuning system side]	Inner Cell	Right Cell [coupler side]
R	184.6	184.6	184.6
L	69	69	69
Riris	65 (40)	48	70 (60)
A	52.2	47.1	53.0
B	41.8	44.75	37.1
a	10.7	14.3	10.7
b	19.3	23.5	21.5
L_tube	85 (before conical reduction)		150 (before conical reduction)

No changes



F. Bouly (IPNO)





RF PARAMETERS…STILL OK

First Design

f (MHz)	704.3
Epk/Eacc	2.58
Bpk/Eacc (mT/MV/m)	5.10
K (%)	1.47
r/Q (Ohm)	301
G (Ohm)	200
Vacc @βg & 1 Joule (MV)	1.16
Qo (@2K, Rres=2nΩ)	$3.8\ 10^{10}$
Transit Time Factor	0.7

Second Design with new end-groups

f (MHz)	704.0
Epk/Eacc	2.63
Bpk/Eacc (mT/MV/m)	5.12
K (%)	1.45
r/Q (Ohm)	275
G (Ohm)	197
Vacc @βg & 1 Joule (MV)	1.11
Qo (@2K, Rres=2nΩ)	$3.9\ 10^{10}$
Transit Time Factor	0.65

CONCLUSIONS

- RF Design: best compromise to fulfil requirements, especially adjusting k% & Epeak/Eacc.
- Mechanical calculations: OK
- 2 designs of cavity + tank

<u>Planning</u>

- July-Aug'10: Technical drawings & call for tender preparation (cavity + Niobium)
- Sept-Oct'10: Call for tender
- Nov'10: Choice of the manufacturer
- Dec'10: Start of the fabrication
- Sept'11: Cavity delivery (w/o tank)
- Oct'11: Field flatness
- Nov'11: Cavity + tank delivery
- Dec'11: Preparation (BCP + HPR) and test (Vertical cryostat)

Thank you for your attention