SPIRAL 2

RESONATORS

SPIRAL 2 Linac

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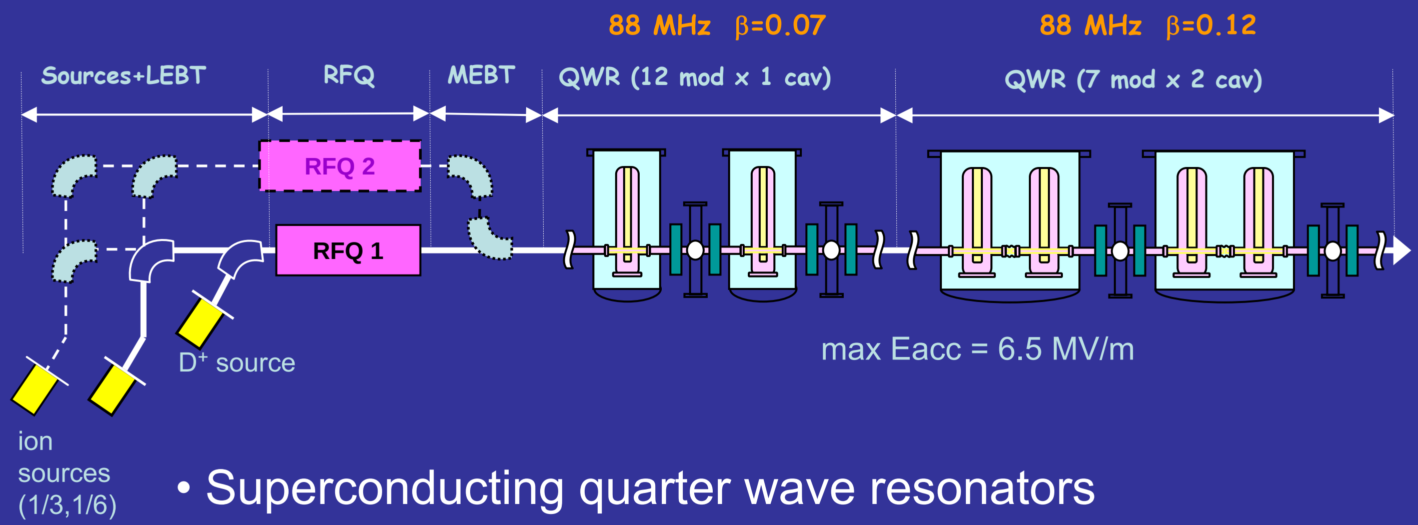

- Superconducting quarter wave resonators
  - β = 0.07 88MHz QWRs CEA/SACLAY
  - β = 0.12 88MHz QWRs IPN/ORSAY
- options : warm quadrupoles instead of SC solenoids / short cryostats

- RF optimization , RF coupling
- mechanics / RF
- 4K tests
- cryomodule overview

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Quarter-wave resonators (λ/4)

Requirements for SPIRAL 2 :

- bulk niobium technology
- 4K operation
- 88 MHz frequency
- minimum beam pipe diameter 30 mm
- separation of cavity vacuum and isolation vacuum
- RF losses < 7 W @ 6.5 MV/m
- specifications on maximum surface field:
  - Ep < 40 MV/m
  - Bp < 80 mT (at 8 MV/m)
- accelerating field definition adopted for the project

$$E_{acc} = \frac{V_{acc}}{\beta \lambda}$$

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Quarter-wave resonators (λ/4) optimization

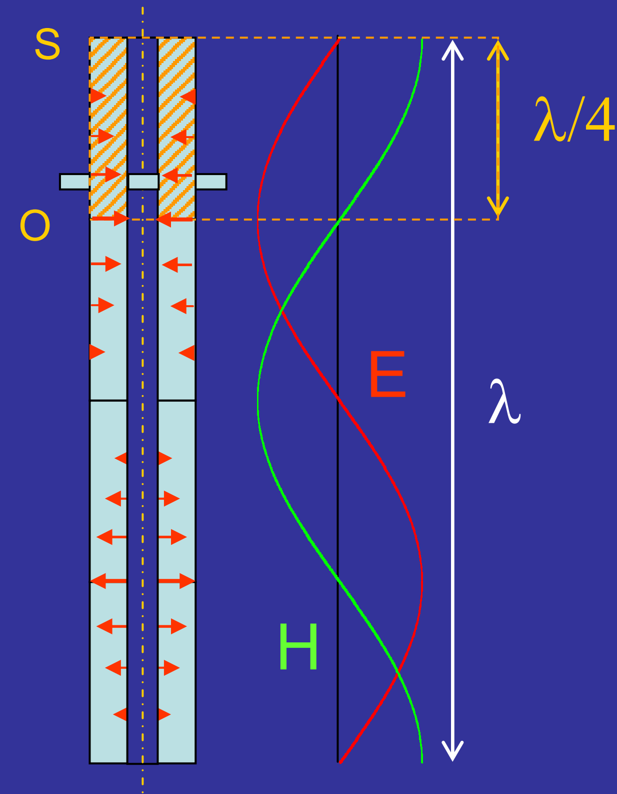
Cavity RF design:

❖ basic starting geometry : coaxial guide of length ≈ λ/4 of the TEM mode

one Open end (electric region),
one Short-circuit (magnetic region)

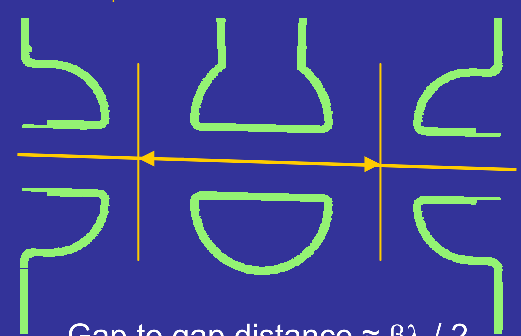
transverse electric field : the beam has to travel across the cavity on a radial path, through the stem➔ 2 accelerating gaps

❖ optimal β mainly dependant on the distance between gap centers: β_{opt} varies with cavity diameter and drift tube lengths



❖ The main objectives of the design were

- to achieve high accelerating voltages
- to reduce Ep/Eacc and Bp/Eacc
- to ease chemistry and HPR



Gap to gap distance ≈ βλ / 2

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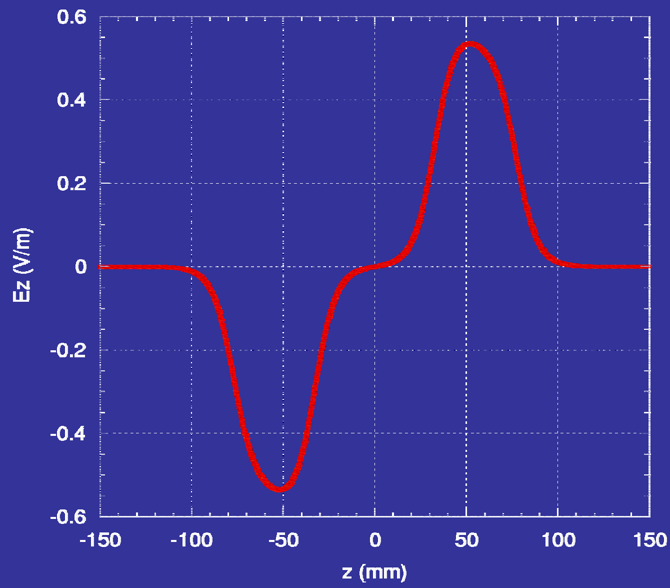
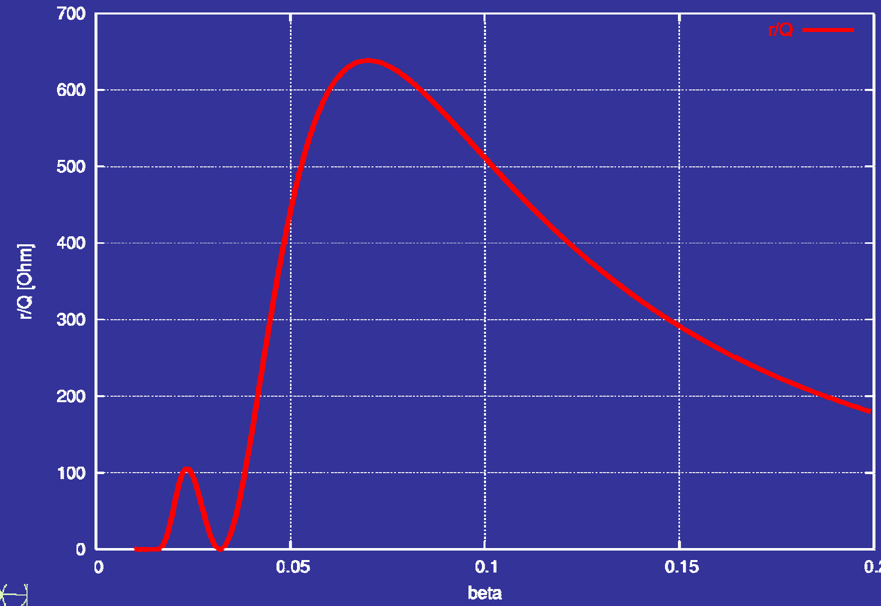
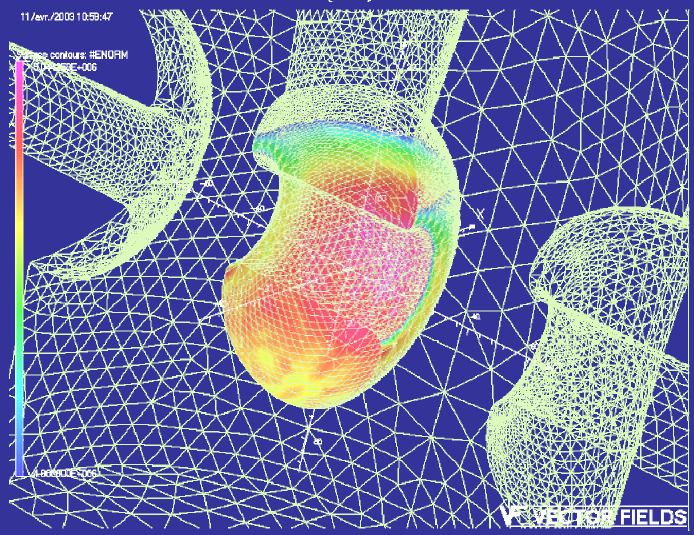
β = 0.07 cavity RF parameters







Frequency (MHz)	88
Optimal β	0.07
r/Q (Ω) @ optimal β	632
Ep/Eacc	5.0
Bp/Eacc (mT/MV/m)	8.75
Q_0 @ R_s = 10 nOhms)	2.2 10^9

β = 0.07 cavity RF coupling

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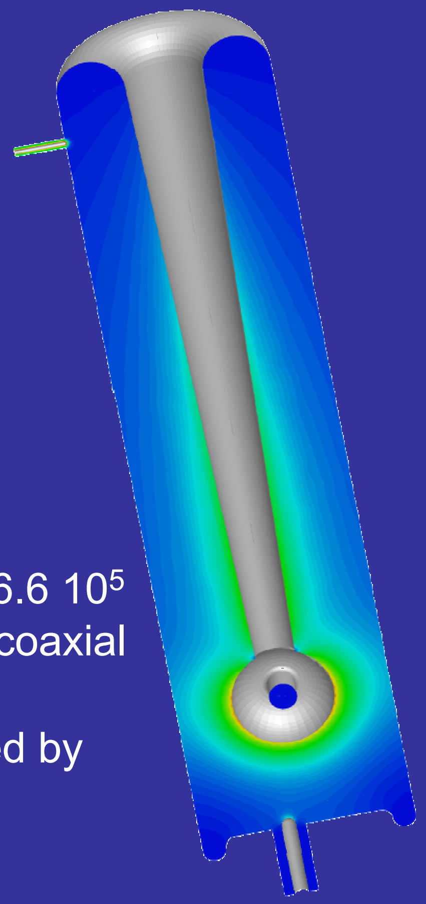
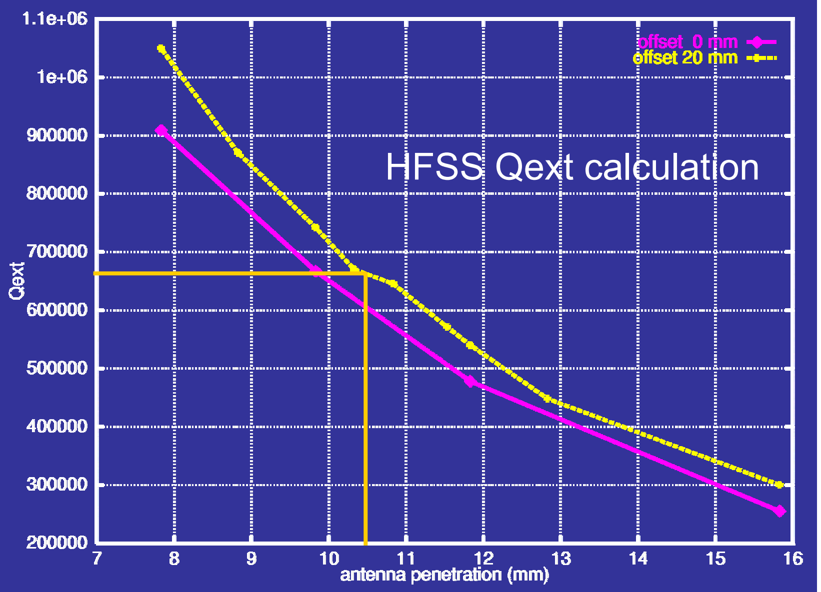
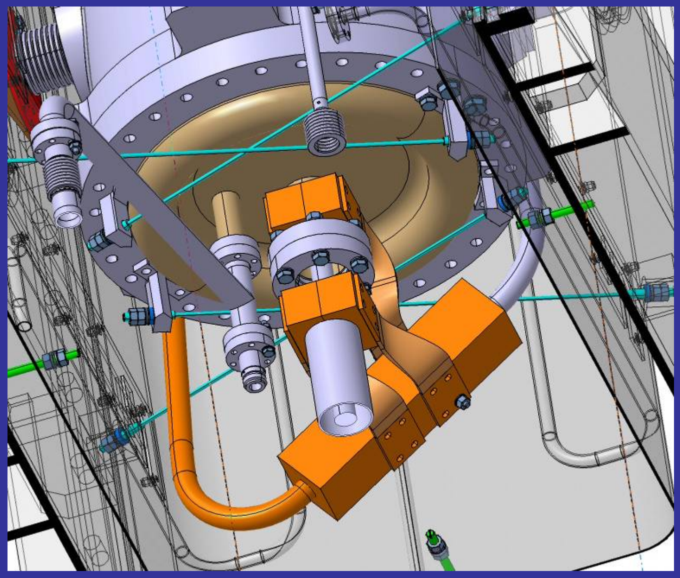


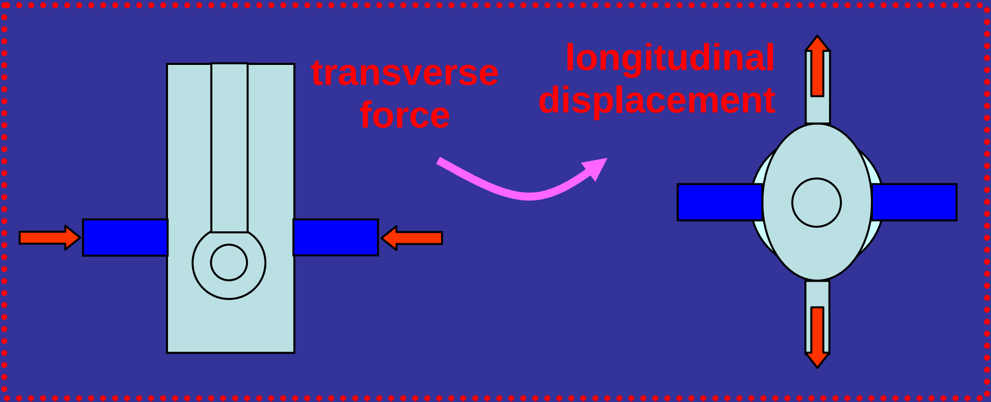


- nominal Qext= 6.6 10^5
- Ø 36 mm 50 Ω coaxial line
- coupler designed by LPSC Grenoble



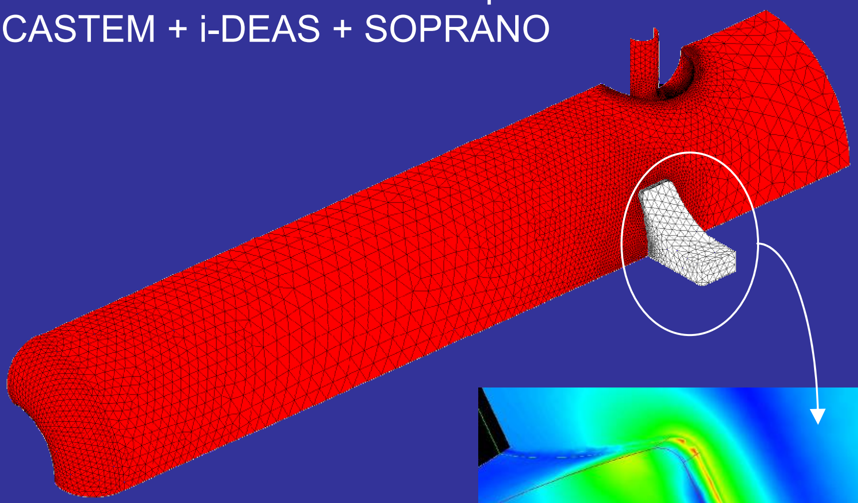
- *antenna in a low H area*
- *no extra opening in He tank*

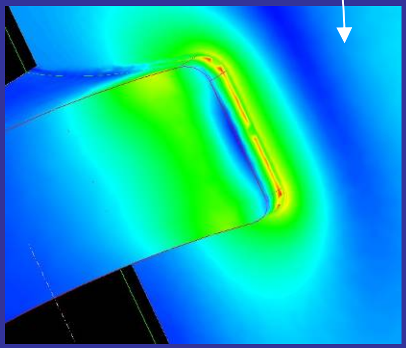
β = 0.07 cavity tuning



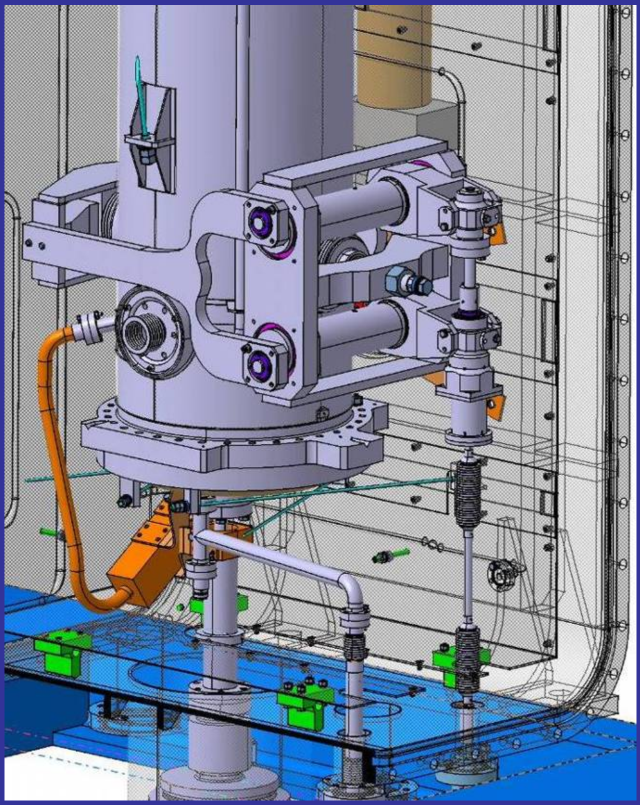
- transverse CTS
- saves longitudinal space
- low stress on drift tube welds
- computed tuning range ± 24 kHz at 4 K

Mesh for mechanical/RF coupled calculations
CASTEM + i-DEAS + SOPRANO





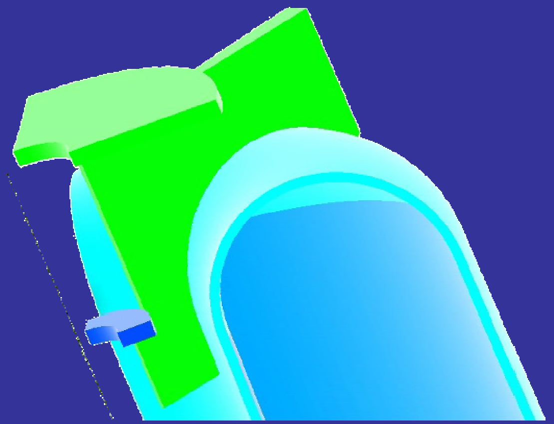
Von Mises stress



β = 0.07 cavity frequency stability

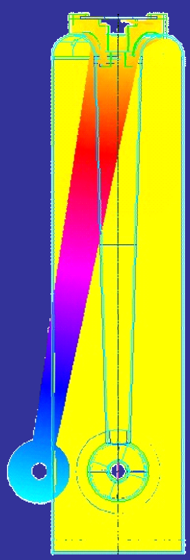
He bath pressure variations

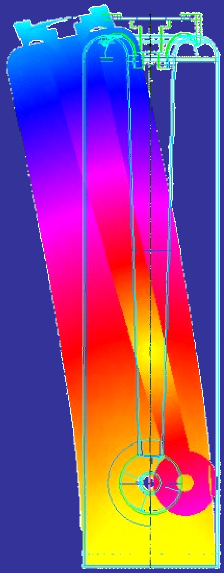
Expected $\Delta P \sim 10$ mbar
cavity BW =132 Hz :
$\Delta f_{pressure}$ < BW/10 $|\Delta f/\Delta P|$ = 1 Hz/mbar
80 % of $\Delta f_{pressure}$ due to vertical stem displacement
With 4 mm thickness $\Delta f/\Delta P$ = -2.5 Hz/mbar
adding a stiffener $\Delta f/\Delta P$ = -1 Hz/mbar



Mechanical modes

Mode 1 @ 43 Hz with stiffener
High sensitivity :
Transverse : 500 kHz/mm
Longitudinal : 650 kHz/mm



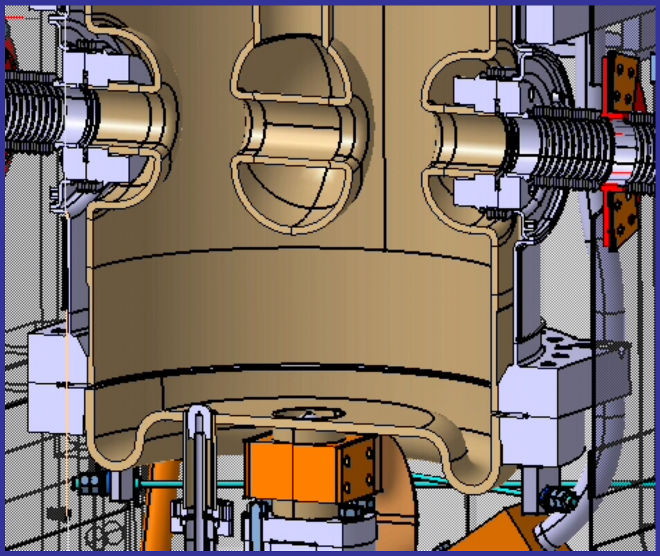


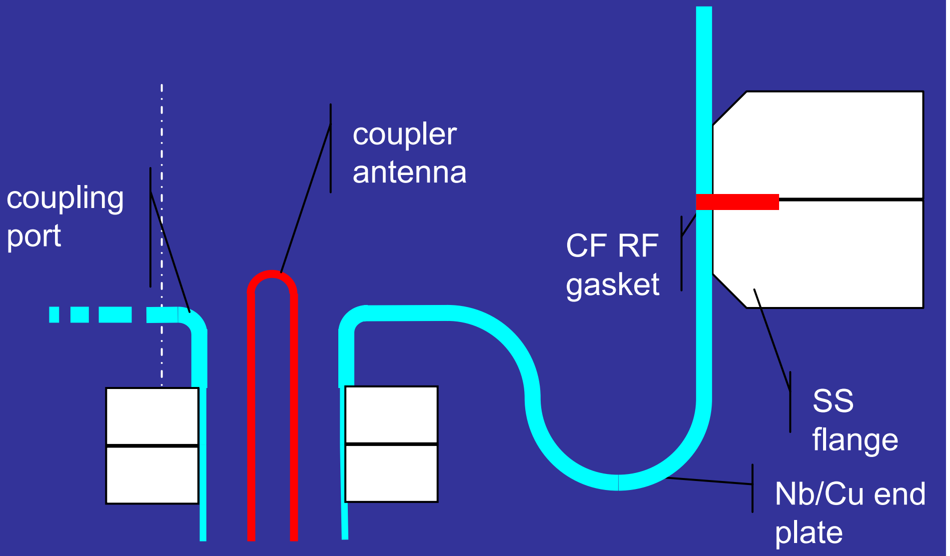
Mode 2 @ 126 Hz with stiffener

If needed, room is provided to include a Legnaro type damper

β = 0.07 cavity bottom plate

- Large opening for High Pressure Rinsing
- Nb sputtered copper plate
- H field very low in the cavity low end region : the plate can be cooled by conduction due to high thermal conductivity of copper
- Stainless steel He vessel -> 316LN flange brazed on the cavity
- Copper RF gasket position should be as low as possible
- S-shape :
  - mechanical compliance (differential shrinkage)
  - reduced coupler antenna penetration for required Q_{ext}
  - passes pressure qualification tests at 2.5 bars (vertical cryostat test)





β = 0.07 cavity Prototype cavity

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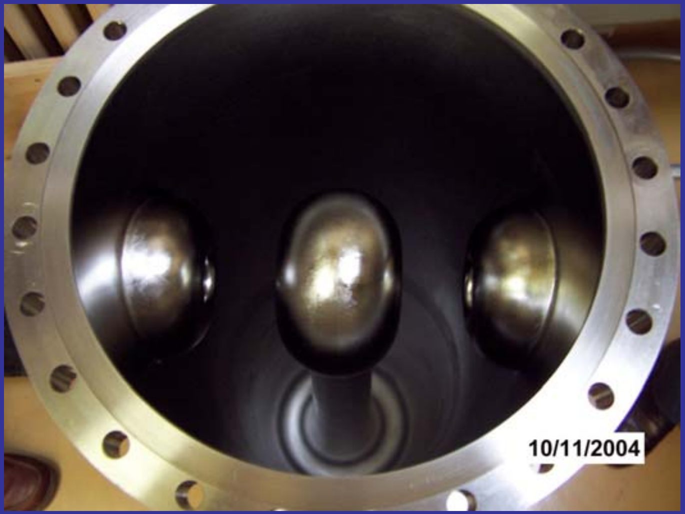
- Manufactured by ACCEL
- Differs from the final cavity :
  - NbTi end-plate and flange
  - vacuum tightness : copper ring + indium seal
  - 3 mm Niobium



Cavity preparation at Saclay

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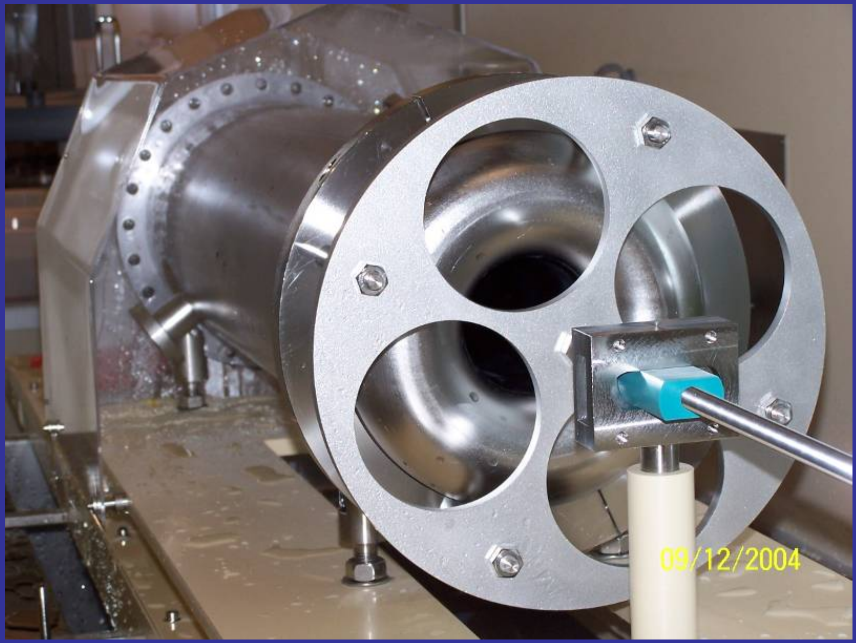
Chemical polishing

High pressure rinsing



β = 0.07 cavity vertical cryostat test

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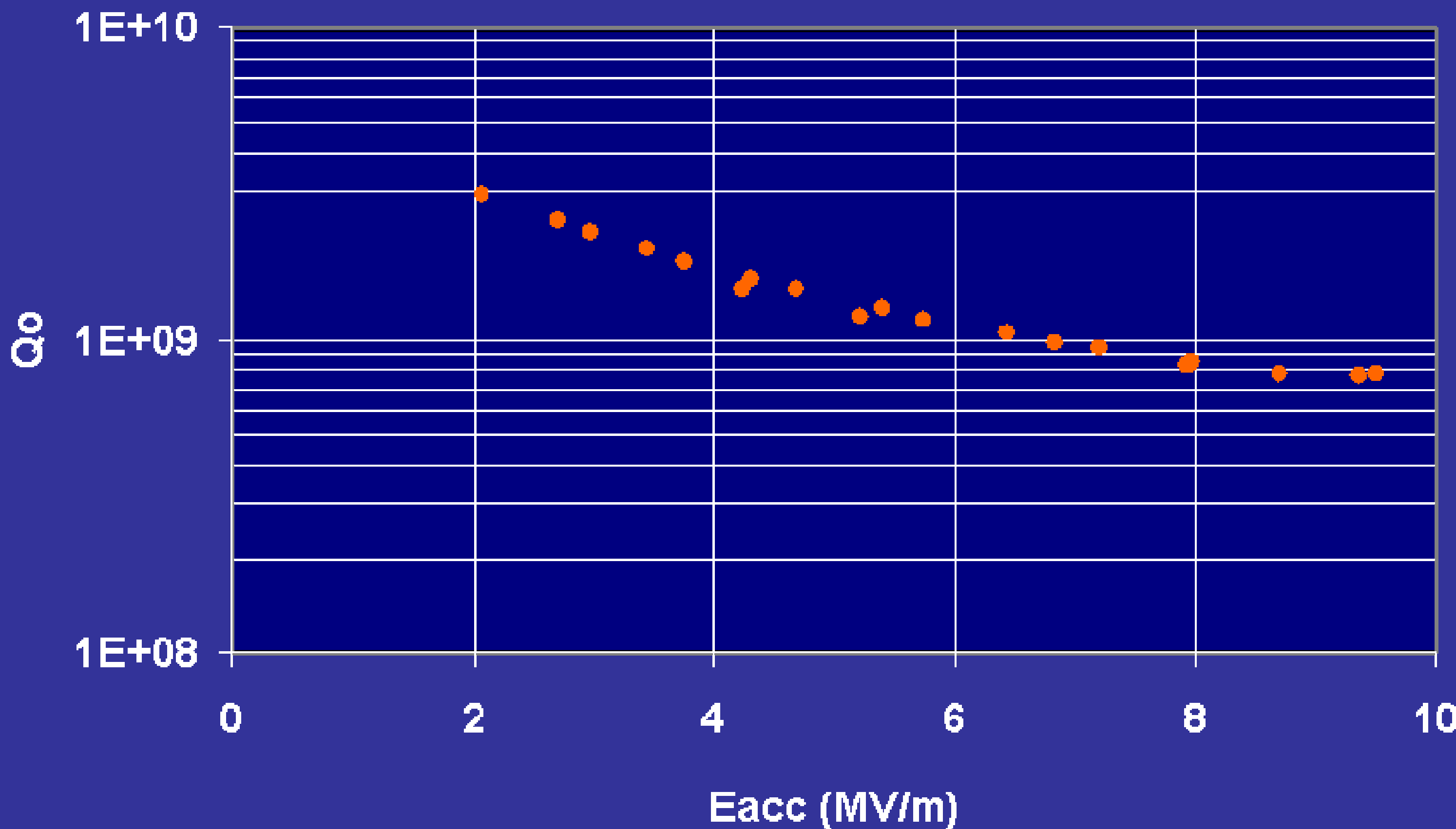

- ❖ Limited by partial quench at 9.5 MV/m
- ❖ Tests at 4.2 K and 1.8 K with same overall behavior. Extra test done in June with a SC Nb/Cu gasket with the same behavior at high field
- ❖ Quench attributed to thermal runaway in NbTi bottom plate ($\lambda_{NbTi} \approx 0.3$ W/m.K + defect ?). The stem region is not thermally affected
- ❖ Q0 = 10^9 @ 6.5 MV/m Pwall = 3.8 W < Maximum specified losses of 7 W

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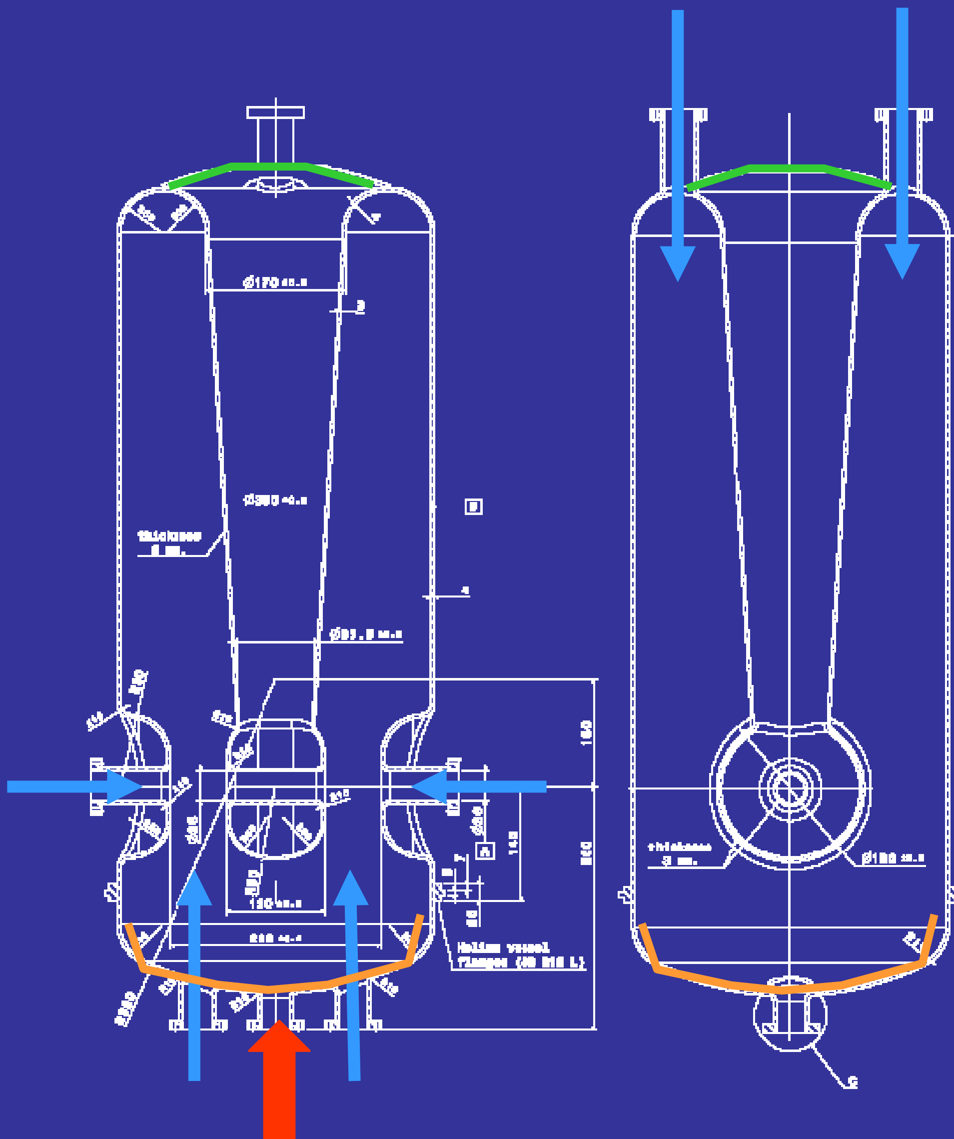
β = 0.12 QWR Mechanical Design



- ❖ Welded bottom plate
- ❖ Nb thickness: 4 mm (except the stem: 3 mm)
- ❖ Beam tubes aperture: Ø36 mm
- ❖ RF coupling by Ø36 mm port
- ❖ Stiffening plate on top-torus
- ❖ 6 ports for HPR
- ❖ Ø418 mm SS flange brazed on cavity bottom allows to weld the He tank

β = 0.12 cavity RF parameters

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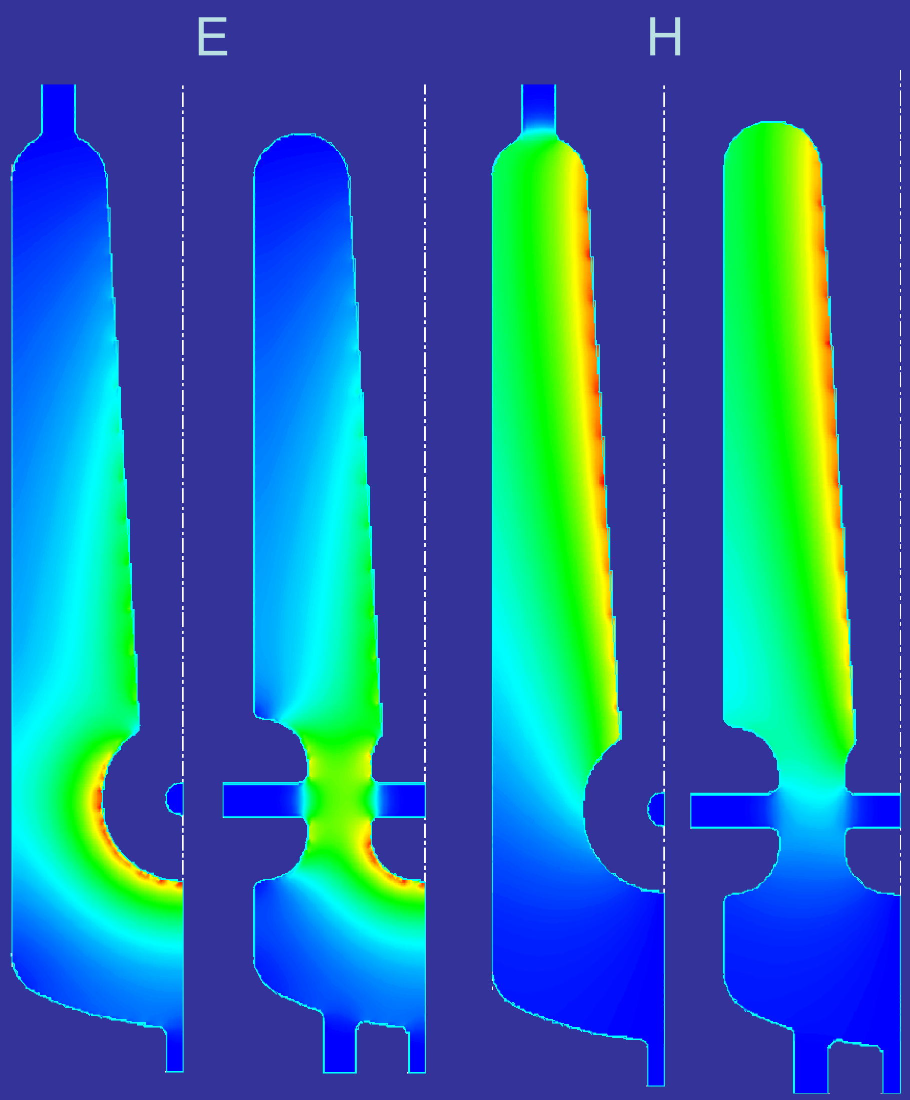
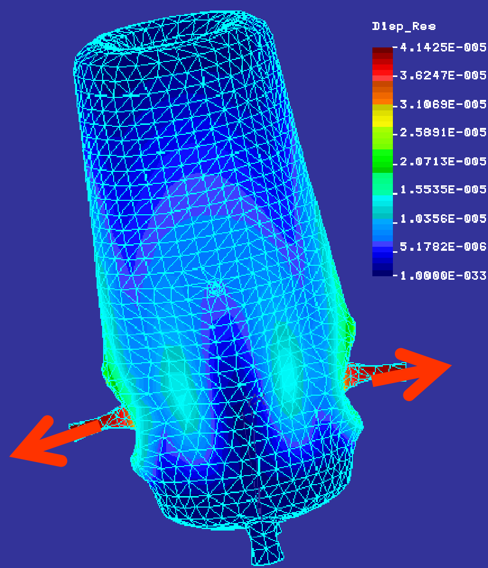


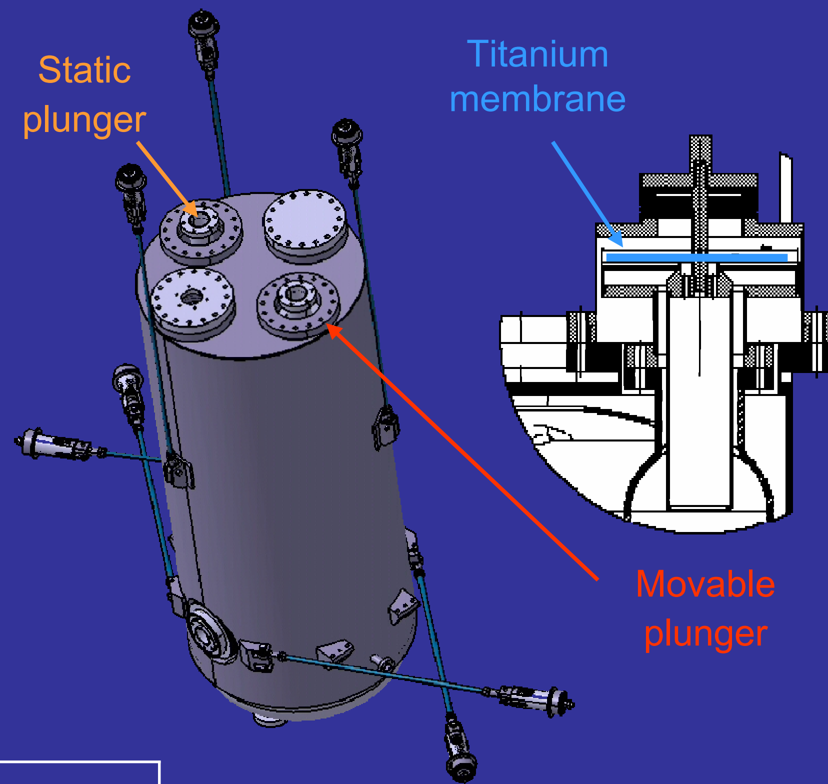
Frequency (MHz)	88
Optimal β	0.12
r/Q (Ω) @ optimal β	518
Ep/Eacc	5.6
Bp/Eacc (mT/MV/m)	10.2
Q_0 @ R_s = 12.5 nOhms	3.0 10^9

β = 0.12 cavity tuning

2 systems are studied



Tuning by pulling the beam tubes



Tuning using SC plungers

COSMOS & MICAV calculations	
Maximum stress for 1 bar [MPa]	**< 36**
Stiffness [kN/mm]	**16**
Tuning sens. using beam tubes [kHz/mm]	**31**
Tuning sens. using one Ø30 plunger [kHz/mm]	**1.2**

β = 0.12 prototype

- ❖ Manufactured by Zanon
- ❖ Includes the stainless steel flange needed to attach the He tank

Stiffening
on top torus

β = 0.12 Vertical cryostat test

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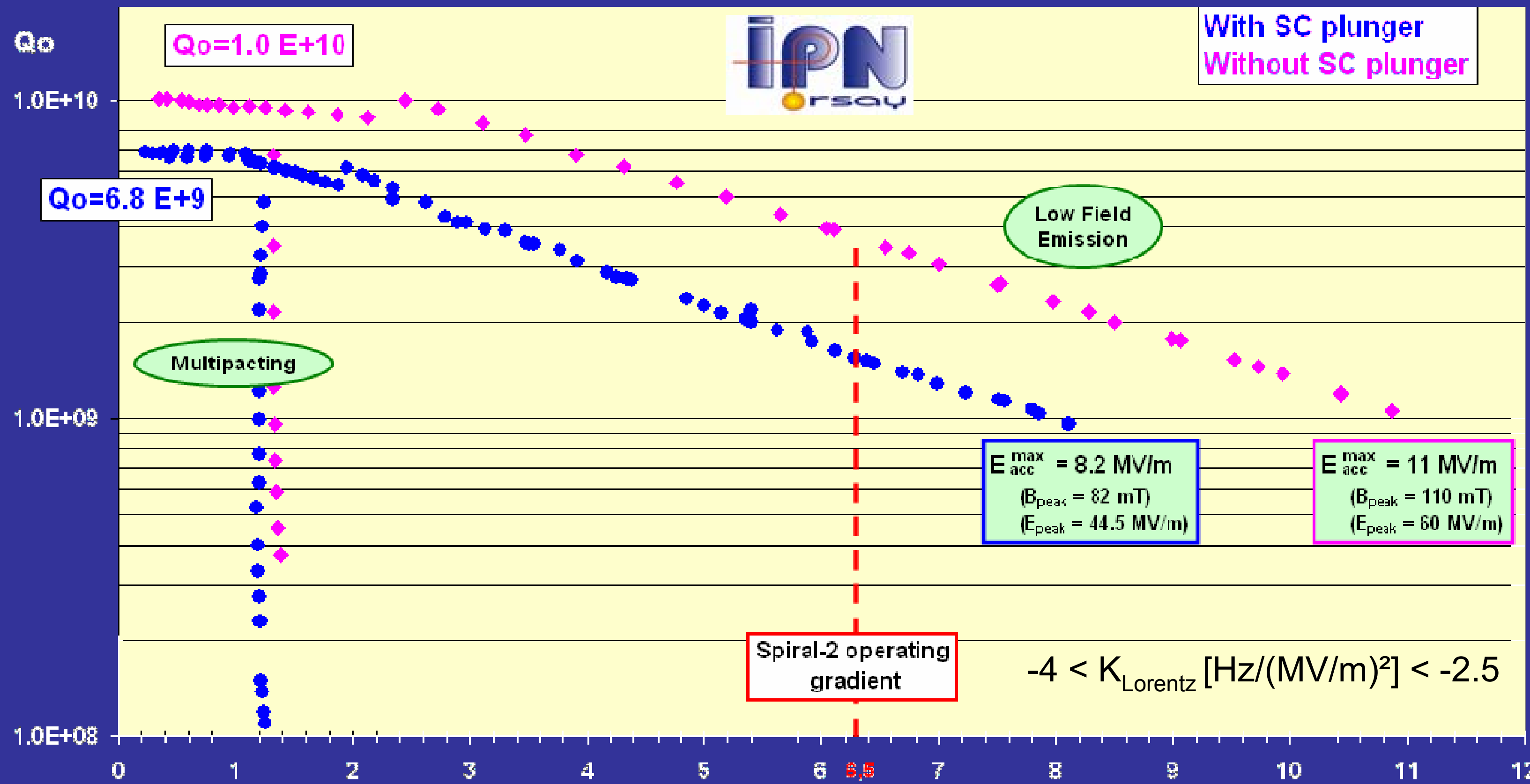

- ❖ Limited by power source at 11 MV/m.
- ❖ Limited by quench with SC plunger (Δf ≈ 65 kHz)
- ❖ Q0 = 1.5 10^9 @ 6.5 MV/m Pwall = 4 W < Maximum specified losses of 10 W

Cryostats overview

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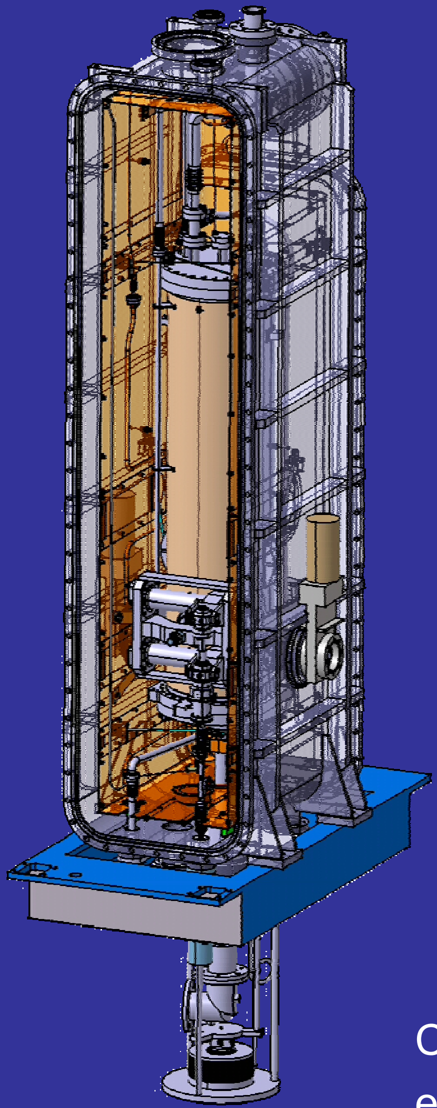
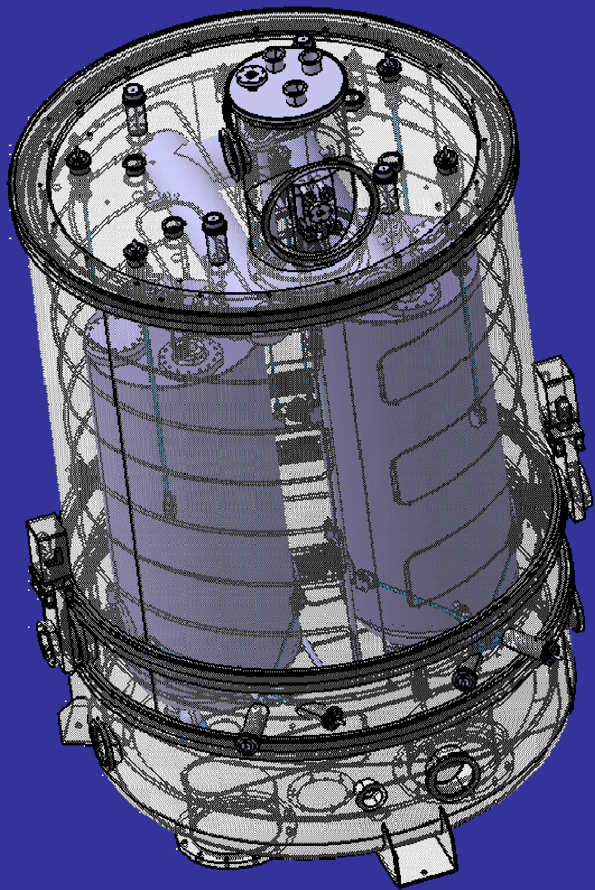
High β



Low β



Construction of a fully equipped cryostat for each β starting in 2005