Spoke development status and single spoke test program @ FREIA

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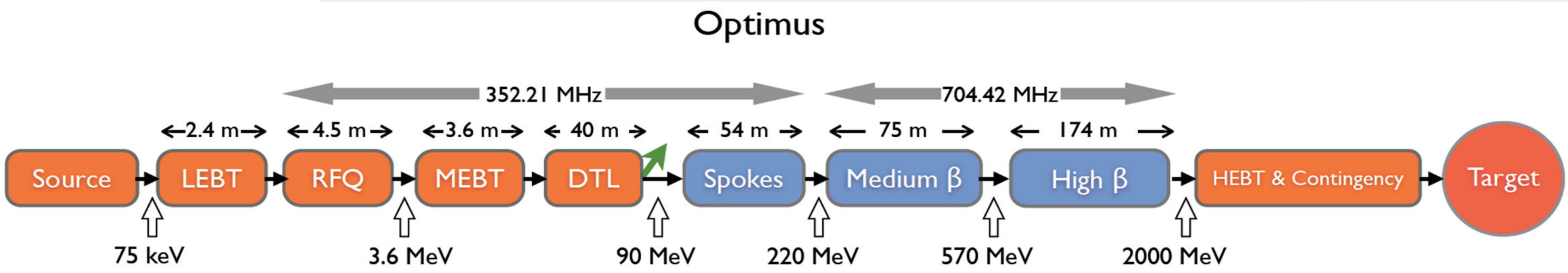
ESS WP 4 leader

Workshop on spoke cavity and RF test program, 20th-21st November 2013

ESS Spoke section

Latest version of the ESS Linac: Optimus



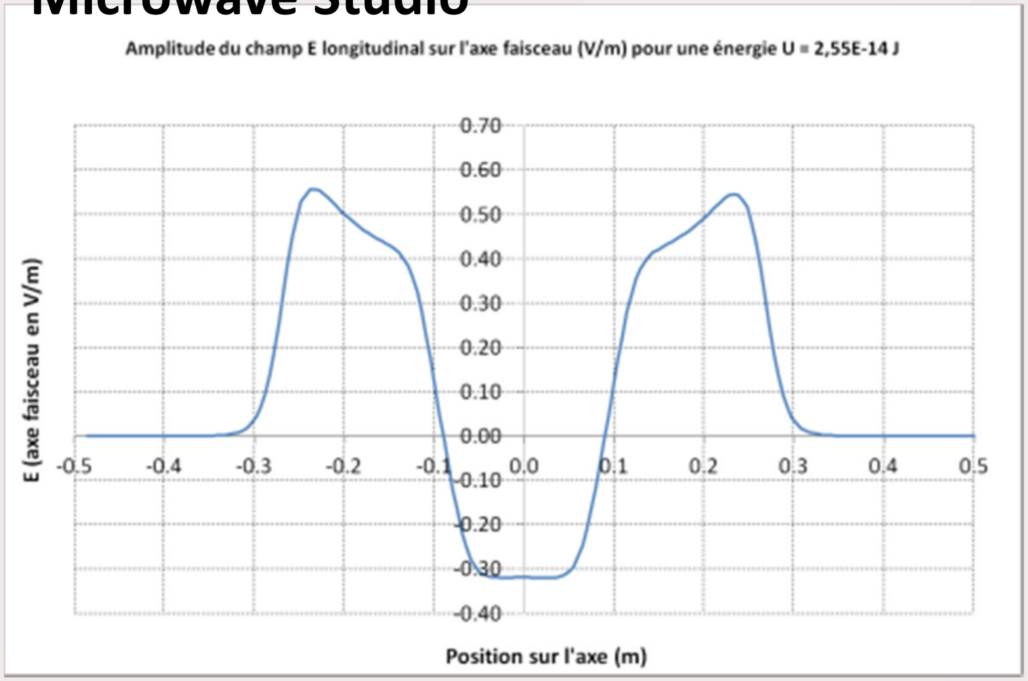
Section	Cavity β	Total number of Modules	Cavity frequency	# Cavity per module	# Cavity per section	Section length
Spoke	0.50	13	352.21 MHz	2	26	54 m

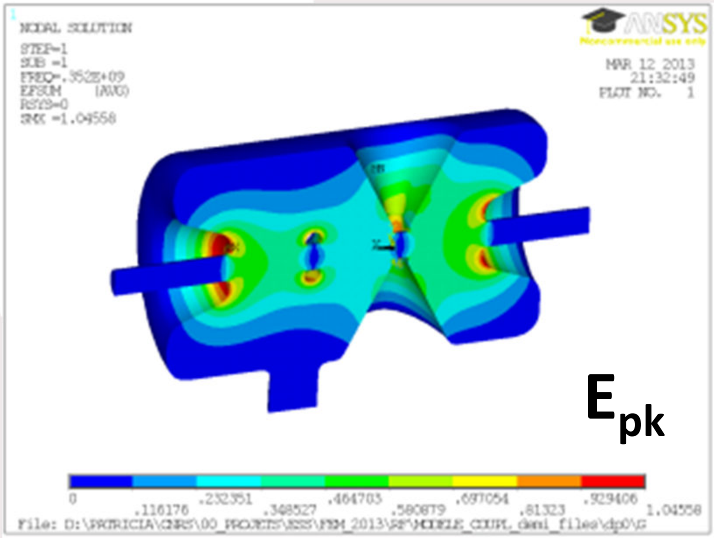
Main consequences for the spoke coming from the cost reduction effort (-> Optimus design) is the increased gradient and increased power to be transmitted to the beam

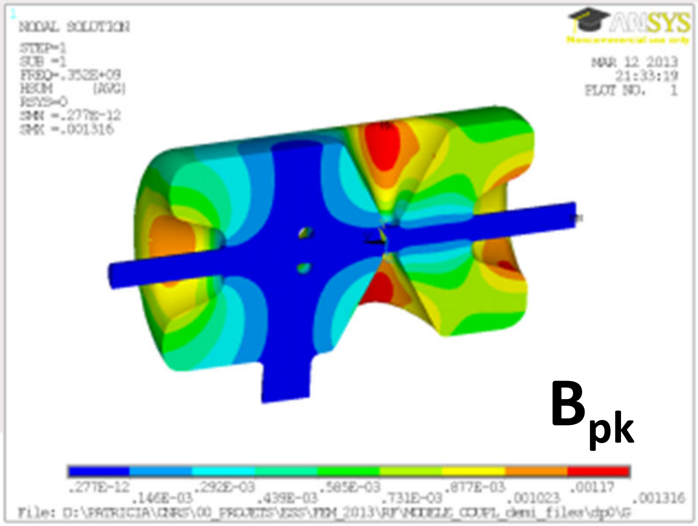
ESS Spoke section

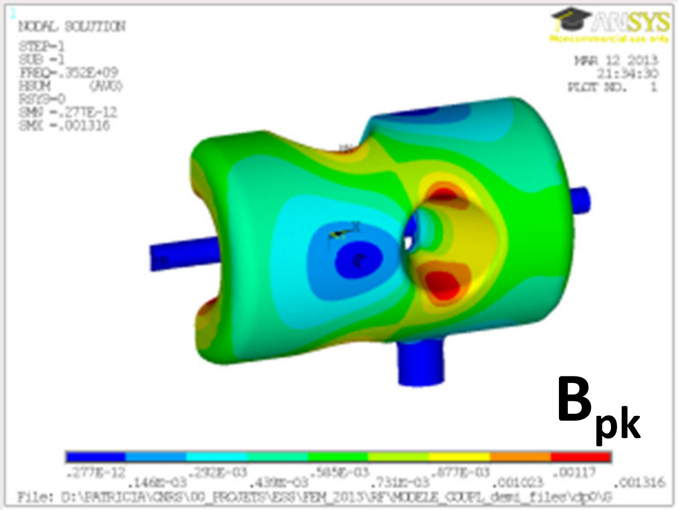
DOUBLE-SPOKE CAVITY	
Frequency [MHz]	352.21
Beta_optimum	0.50
Operating gradient [MV/m]	9.0 (8.8)
Temperature (K)	2
Bpk [mT]	61
Epk [MV/m]	38
G [Ohm]	133
r/Q [Ohm]	427
Lacc (=beta optimal x nb of gaps x λ /2) [m]	0.639
Bpk/Eacc [mT/MV/m]	6.8
Epk/Eacc	4.3
P max [kW]	335

Cavity RF design performed with CST Microwave Studio







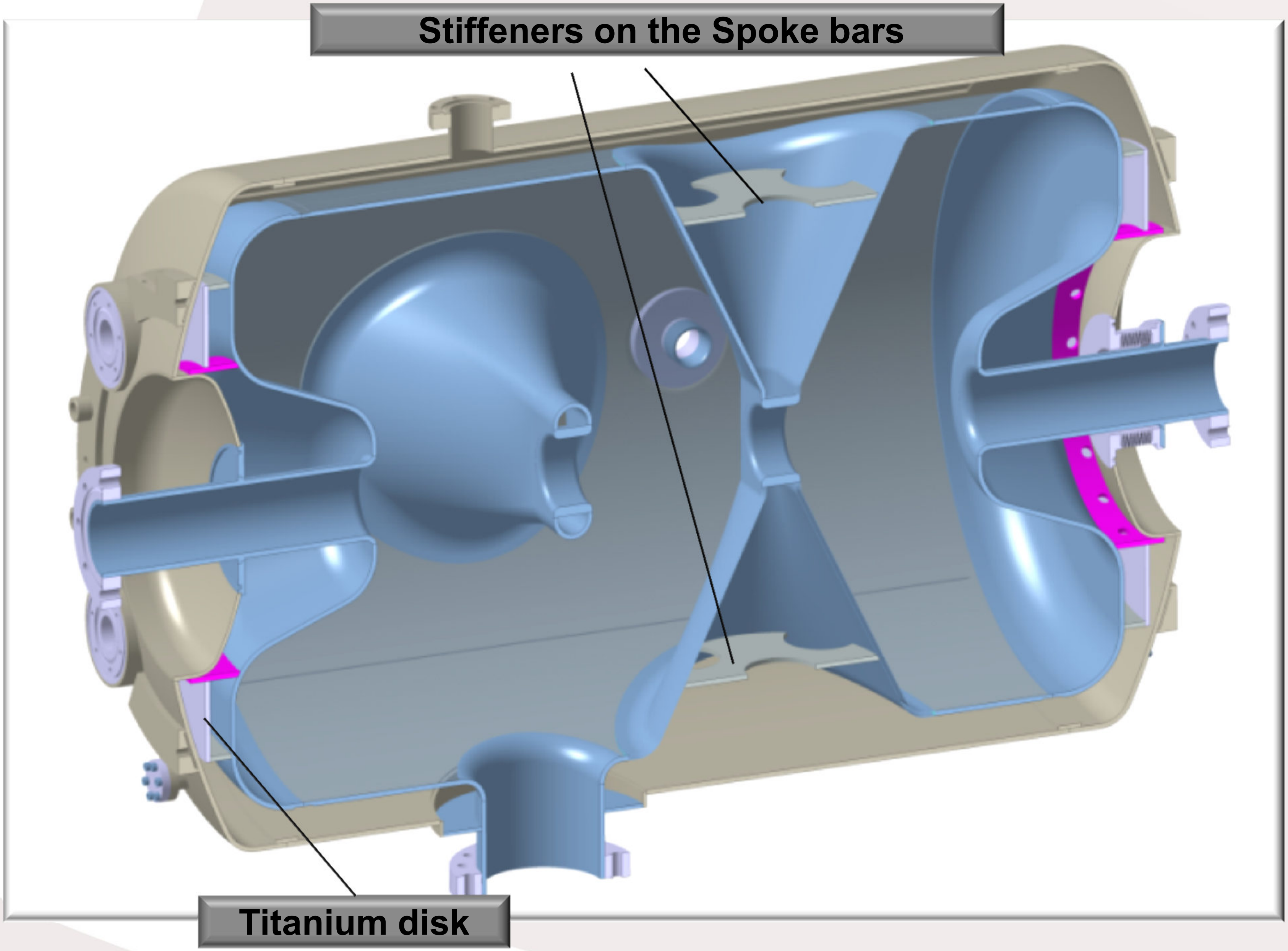


ESS Spoke section

DOUBLE-SPOKE CAVITY	
Qo at low field	**6.3 10^9**
assuming a Rres (nΩ)	**20**
and op. temperature (K)	**2**
Qo @ nominal gradient	**1.6 10^9**
i.e. assuming a Qo drop of a factor	**4**
r/Q [Ohm]	**427**
Operating gradient [MV/m]	**9.0 (8.8)**

This gives a dynamic heat load per cavity (Eq. in CW) : 2.0 W

ESS Spoke section



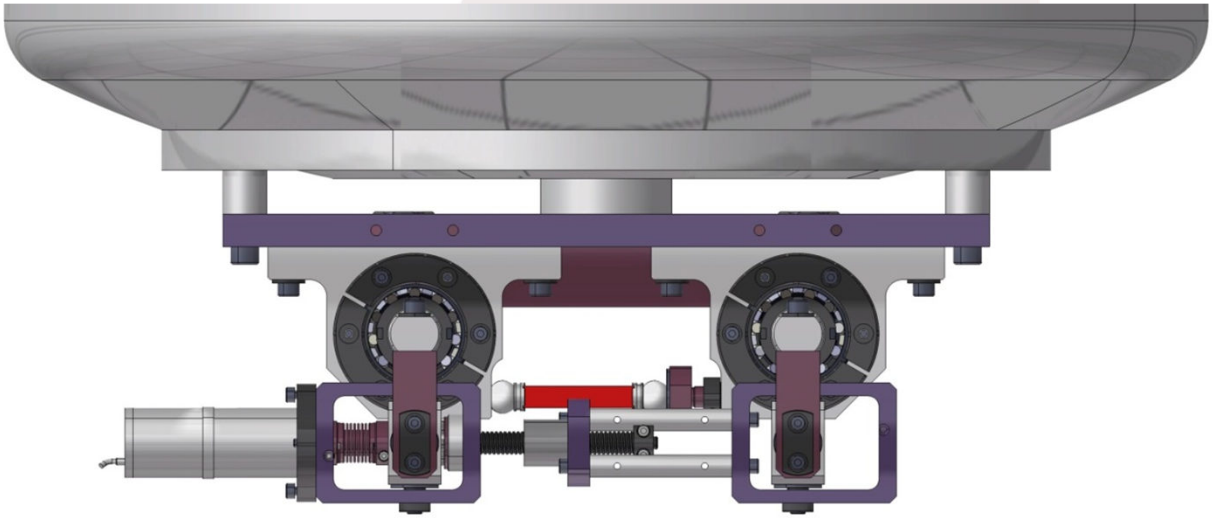
ESS Spoke section

Main mechanical parameters of the prototype cavity			
	Initial design		**Final optimization**
Thickness of the cavity walls	**4 mm**		**4 mm**
Critical pressure	**1.47 bar**		**2.77 bar**
Stiffness of the cavity	**20 kN/mm**		**20 kN/mm**
Tuning sensitivity $\Delta f/\Delta z$	**135 kHz/mm**		**128 kHz/mm**
Sensitivity to helium pressure fluctuation K_P without CTS with CTS	**+16.5 Hz/mbar** **+26.0 Hz/mbar**		**+ 15.5 Hz/mbar** **+ 23.9 Hz/mbar**
Lorentz forces detuning factor K_L without CTS with CTS	**-5.13 Hz/(MV/m)^2** **-4.4 Hz/(MV/m)^2**	**For 9 MV/m:** **Δf = - 415 Hz** **Δf = - 356 Hz**	**~ id.**

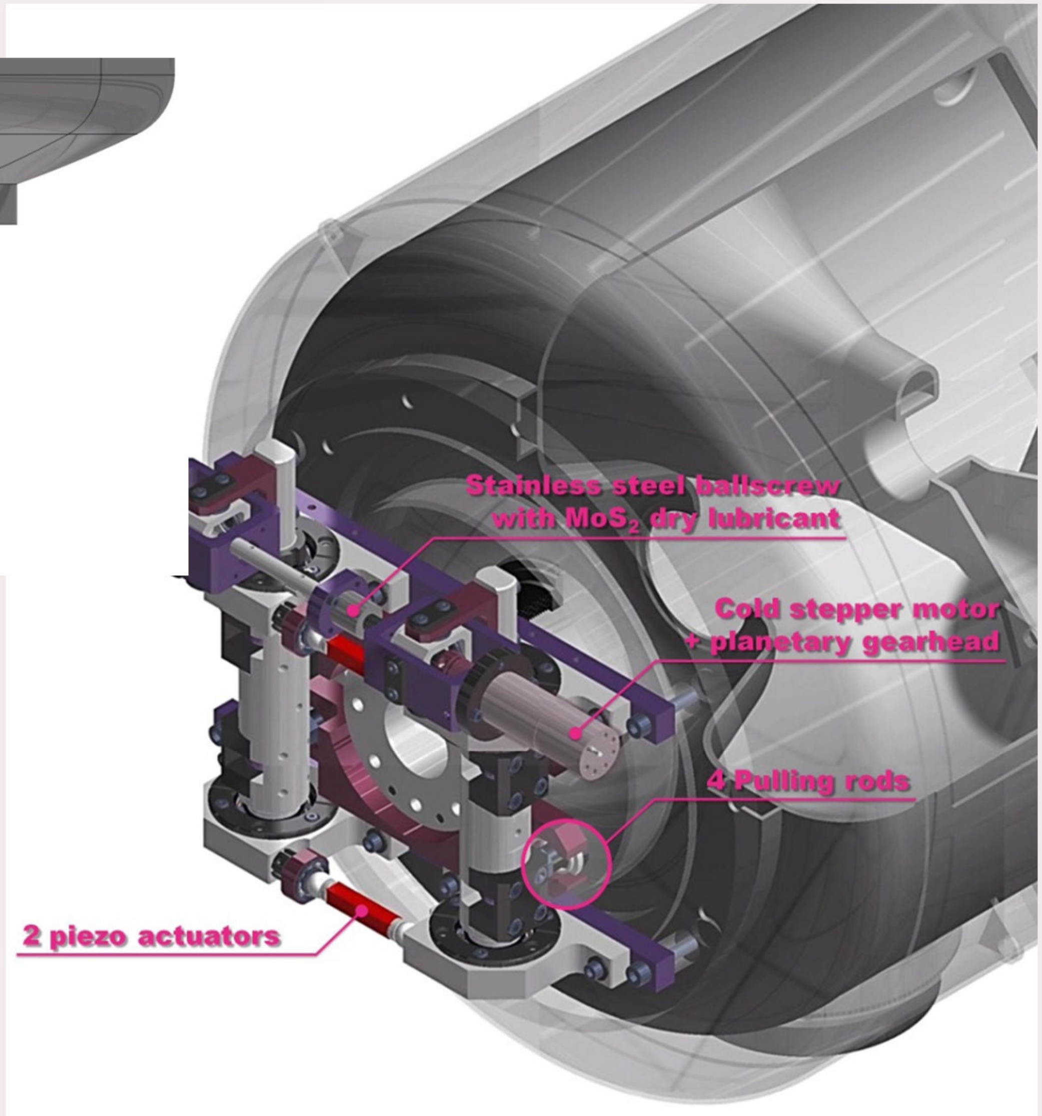
Cavity bandwidth = 1530 Hz (Ql = 2.3 10^5) at nominal

(and 1990 Hz for Ql = 1.77 10^5, max value)

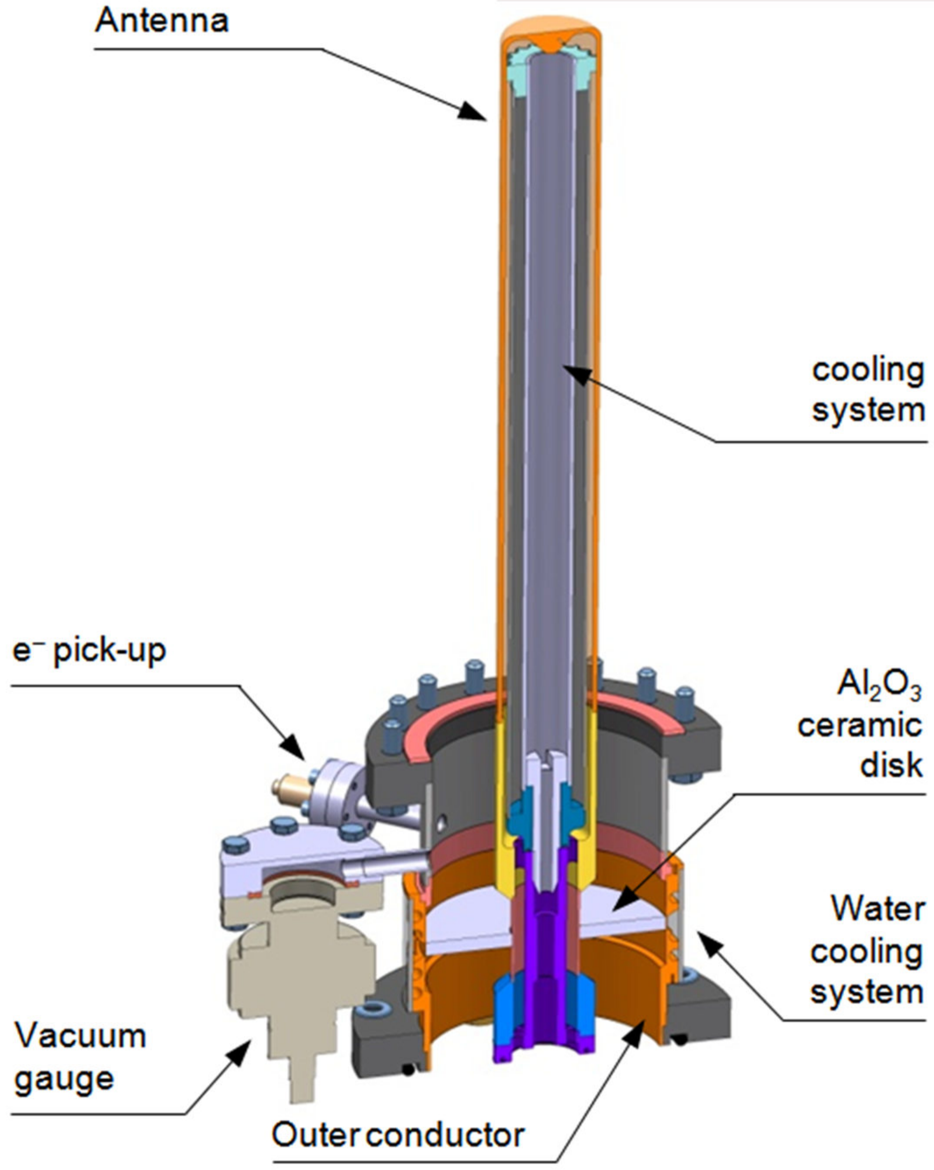
ESS Spoke section

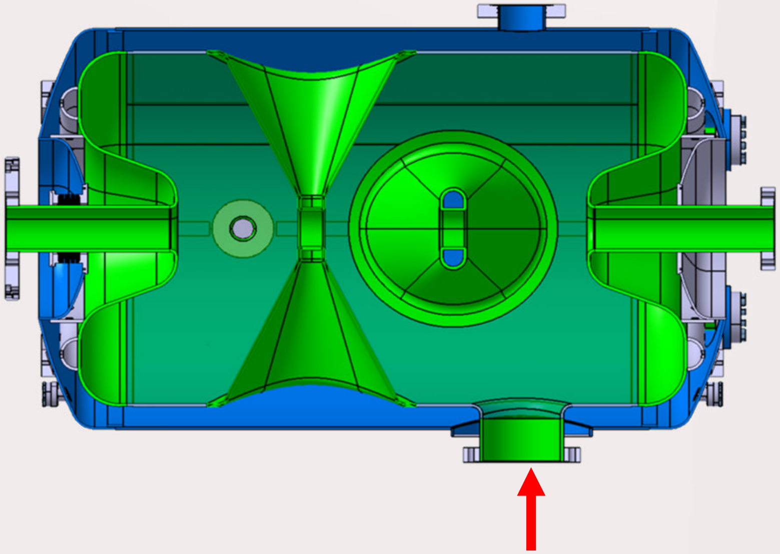


CTS parameters / results	
Cavity sensitivity	128 kHz/mm
Cavity stiffness	20 kN/mm
Max cavity deformation	1.28 mm
Course / Tuning range	1.28 mm / 160 kHz
Resolution	1 Hz/step
Piezo tuning range	~ 1.5 kHz *(tbc)*

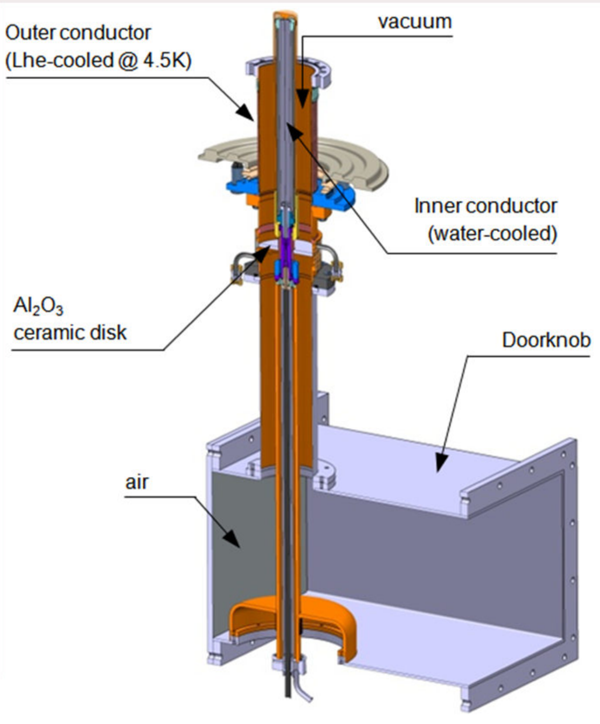


ESS Spoke section

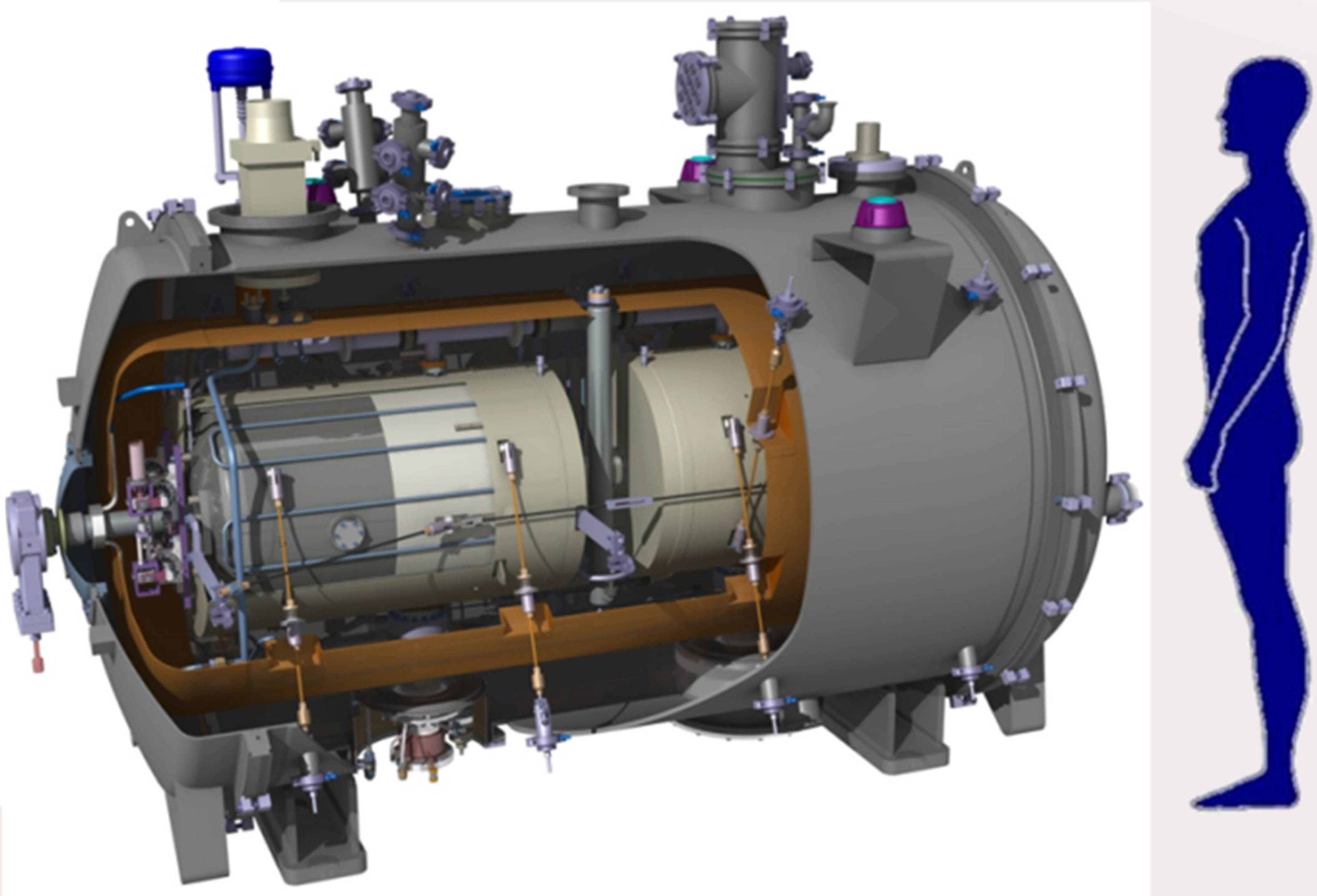




Power coupler port 100 mm diameter

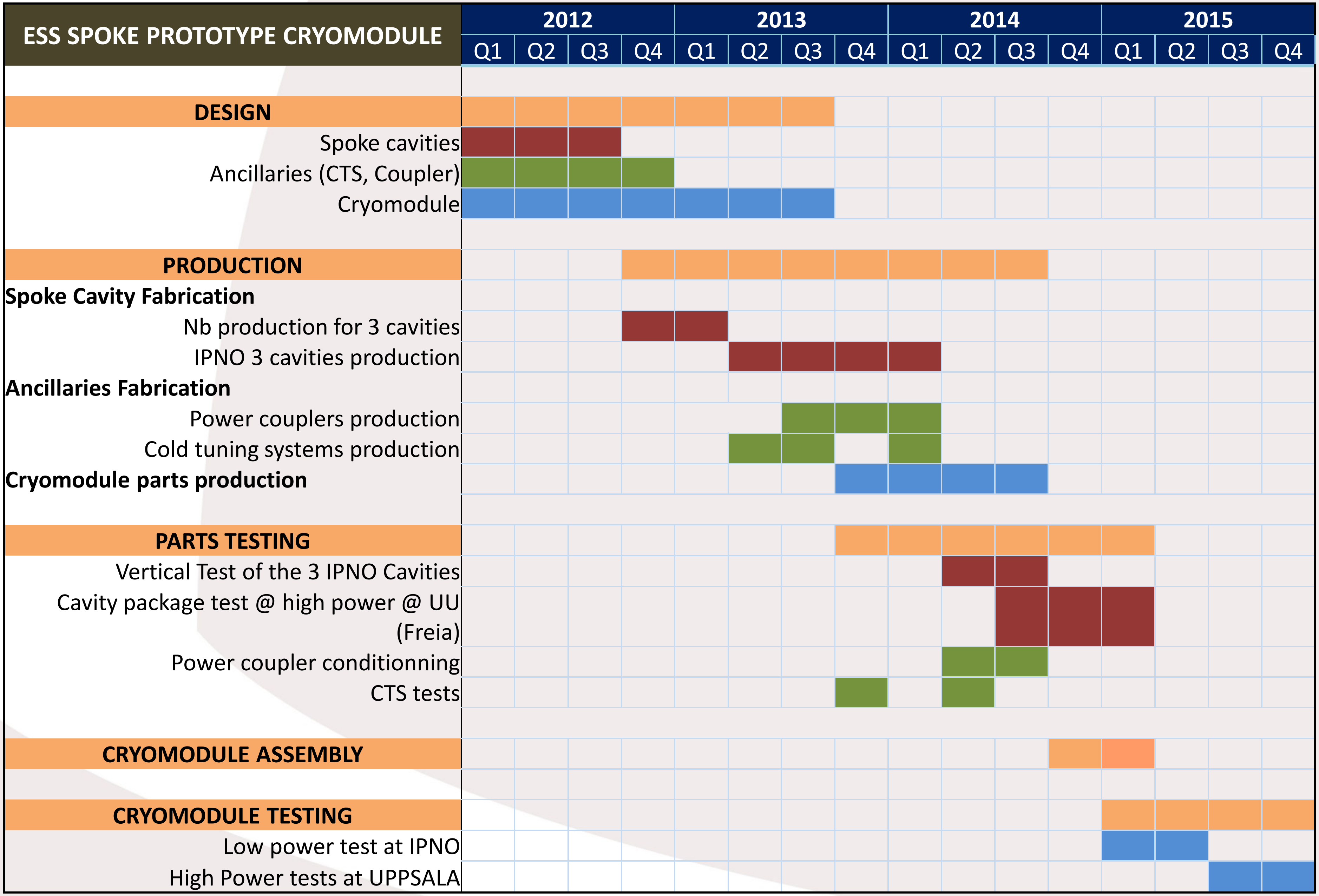


ESS Spoke section



Prototyping strategy & Schedule

Prototyping of each components before series production



Purpose of the test plan

What to test all over the spoke test program ?

Easy answer: all numbers listed in the EssSyrAccSpklEmrL4 document (level 4 requirements) and in the corresponding RF and cryo requirement document as well.

Global spoke test program: a 3 stages program on 4 components

5 components:

- cavity
- power coupler
- cold tuner
- cryomodule
- LLRF

3 stages:

- individual tests
- horizontal cryostat tests
- integrated tests in the cryomodule

Component #1 : cavity

1. Individual test in vertical cryostat @ IPNO

- **Qo = f(Eacc) curve**
  - ✓ **Qo at low field**
  - ✓ **Qo at nominal Eacc**
  - ✓ **Max achievable gradient**
  - ✓ **Check the benefit of some specific preparation treatment** *(H degazing, in-situ baking, …)*

- **Check for MP barriers,** *assess how difficult/easy it is to process*
- **Characterized field emission activity** *(onset, levels, …)*
- **Qt calibration** *(and also Qi but far from nominal case)*
- **Lorentz detuning coefficient** *("not nominal" case)*
- **Sensitivity to helium pressure fluctuation Kp** *(also in "not nominal" case)*

Component #1 : cavity

2. Test in HNOSS@ FREIA (in the nominal configuration: with a fully dressed cavity)

- **Qo = f(Eacc) curve**
  - ✓ **Qo at low field** *(low accuracy measurement)*
  - ✓ **Qo at nominal Eacc** *(low accuracy measurement)*
  - ✓ **Max achievable gradient**
  - ✓ **Check the benefit of some specific preparation treatment** *(H degazing, in-situ baking, …)*
- **Check for MP barriers,** *assess how difficult/easy it is to process with the power coupler*
- **Characterized field emission activity** *(onset, levels, …)*
- **Qt and Qi calibration**
- **Lorentz detuning coefficient** *(closer to "nominal" case)*

Component #1 : cavity

2. Test in HNOSS@ FREIA (in the nominal configuration: with a fully dressed cavity)
   - **Sensitivity to helium pressure fluctuation Kp** *(also closer to "nominal" case)*
   - **Assess the impact of the power coupler on the intrinsic cavity performances**

One remark: intermediate test of a spoke cavity in HNOSS@ FREIA in the β=1 configuration (no power coupler) could be of interest

- **HNOSS facility validation** *(magnetic shielding efficiency, for a simpler cryo test w/o the complexity of the RF but with a real cryogenic load)*
- **Still perform valuable experiments even in case of planning or technical issues with RF amplifier or power couplers**

Component #2 : cold tuner

1. Individual test in vertical cryostat @ IPNO

It might be possible to assemble the CTS on the spoke cavity and still fit in Orsay vertical cryostat

- **Measure the tuning range** *(motor & piezo)*
- **Measure the tuning sensitivity** *(motor & piezo)*
- **Hysteresis characterization (if any)**
- **…**

Component #2 : cold tuner

2. Test in HNOSS@ FREIA (in the nominal configuration: with a fully dressed cavity)

- **Overall cold tuner operation with the final LLRF:** *test of the whole RF chain, all the feedback/feed-forward algorithms for frequency regulation*
- **CTS operation in a almost final operating conditions:** *temperature, mechanical environment,…*
- **Perform reliability tests: long term operation ?** *How long ?*

Component #3 : power coupler

1. RF conditionning @ IPNO (CEA)

- Surface conditioning by "RF cleaning"
- Several configurations (SW, TW)
- Possibly: determine the maximum power that could be sustained -> failure test (with the limit of available RF power)
- …

Component #3 : power coupler

2. Test in HNOSS@ FREIA (in the nominal configuration: with a fully dressed cavity)

- **Measure parameters linked to the cavity coupler coupling:**
  - **Qi**
  - **Impact on cavity performances and on cryo load**
  - **Cooling circuit efficiency**
  - **Pollution ?**
- **Whole RF chain operation with the final LLRF:** *from RF source to cavity, test all the feedback/feed-forward algorithms for amplitude and phase control*
- **Perform reliability tests: long term operation ?** *How long ?*