Superconducting Cavity activities within HIPPI

CARE '08

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CEA/Saclay

Outline

- Objectives of HIPPI - WP3
- Cavities parameters
- Tests
- Conclusions

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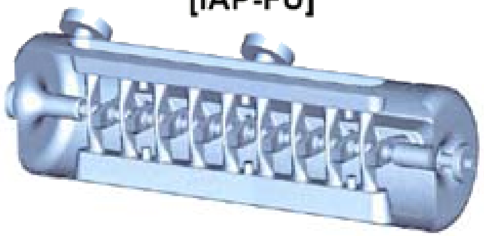
Objectives of the HIPPI-WP3

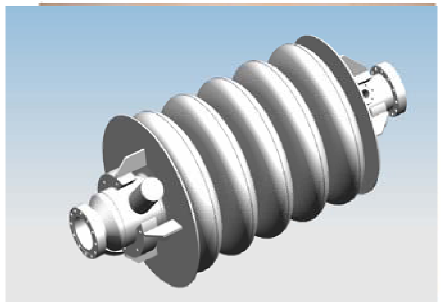
- Characterization of superconducting (SC) RF structures for use in a pulsed proton linac
- Investigation of different type of structures ; prepare for comparative assessment
- Realization of a high power 704 MHz RF test place with cryogenic infrastructure

Spoke (low beta)
[FZJ, Orsay]

CH (low/medium beta)
[IAP-FU]



Multi-cell elliptical (medium/high beta)
[CEA, INFN]



Objectives : gradient > 7 MV/m with Q > 10^{10} in the energy range 100-200 Mev, at a construction cost comparable to normal-conducting structures ; development of efficient superconducting structures down to beam energies around 5 Mev ; availability of a 704 MHz high power RF test place for SC cavities.

From R. Garoby in CARE kick off meeting – 20,21 Nov. 2003

The HIPPI – WP3 program

Lab.	Type	In the frame of HIPPI	β-design	Gaps	Freq. (MHz)
INFN	Elliptical	Tuning system + He tank + RF tests	0.47	5	704
CEA	Elliptical	Cavity + Tuning system + He tank + coupler + RF tests	0.47	5	704
FZJ	3 Spoke	Cavity + coupler (IPN)	0.48	4	352
FZJ	3 Spoke	Tests	0.2	4	760
IPNO	1 Spoke	Cavity + coupler + He tank + Tuning system	0.15	2	352
IAP	CH	Tuning system	0.1	19	352

All the cavities have been fabricated...

Elliptic A / β = 0.47 / INFN

Elliptic B / β = 0.47 / CEA

3-Spoke / β = 0.48 / FZJ

3 Spoke / β = 0.2 / FZJ

1 Spoke / β = 0.15 / IPNO

CH / β = 0.1 / IAP

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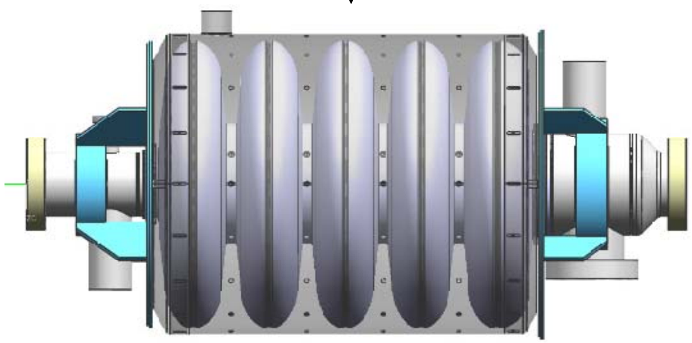
Design parameters (RF)

	Elliptical A INFN	Elliptical B CEA	3 - Spoke FZJ	Spoke IPNO	CH IAP - FU
Number of gaps	5	5	4	2	19
Frequency [MHz]	704	704	352	352	352
geometrical β	0.47	0.47	0.48	0.15	0.1
Bpk/Eacc [mT/(MV/m)]	5.88	5.59	10.97	11.94	7.28
Epk/Eacc	3.57	3.36	4.65	3.97	6.56
G [Ohm]	160	161	101	67	56
r/Q [Ohms]	180	173	420	88	3220
Beam diameter aperture [mm]	80	80	50	56	28
Lacc = Ngap.β.λ/2 [mm]	500	500	818	128	810
Operating Temperature (O.T.)	2 K	2 K	4.2 K	4.2 K	4.2 K
R_{BCS} @ O.T. (theoretical)	3.2 nΩ	3.2 nΩ	39 nΩ	39 nΩ	39 nΩ
Q_0 @ O.T. for R_{BCS}	$5*10^{10}$	$5*10^{10}$	$2.6*10^9$	$1.7*10^9$	$1.4\ 10^9$

Miscellaneous

cavity	Elliptic A	Elliptic B	3 Spoke	1 Spoke	CH
Nominal wall thickness [mm]	4	4	4	3	2-3
Overall length of the cavity [mm]	870 mm	832 mm	780 mm	450 mm	1050 mm
Flanges material	NbTi	St. Steel	St. Steel	St. Steel	
Helium tank material	Ti	St. Steel	N/A	St. Steel	N/A
Magnetic shield	Yes	Yes	supplied by cryostat	No	supplied by cryostat

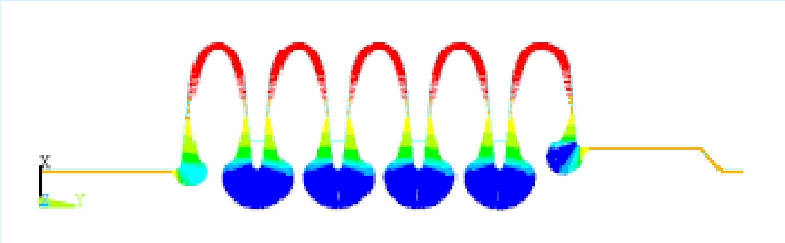


Inner magnetic shield (inside the He tank)

Outer magnetic shield

Mechanical simulations

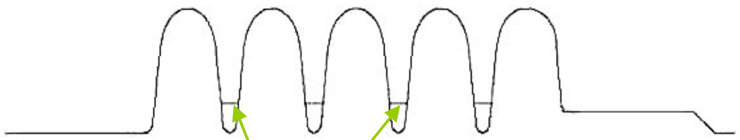
- Calculations of mechanical parameters have been carried out for all the cavities in order to evaluate :
  - the influence of the ***Lorentz Force Detuning*** (LFD) during the tests
  - the influence of the ***Helium pressure***
- Main parameters are :
  - ***cavity stiffness*** [kN/mm]
  - ***He pressure sensitivity*** [Hz/mbar]
  - ***Lorentz coefficient*** K_L [Hz/(MV/m)²] (frequency detuning due to Lorentz forces)
    - K_L depends strongly on the external stiffness, which is not easy to evaluate
    - Meaningful informations must contain the ***extreme values of*** K_L ***(free/fixed ends),*** and the theoretic curve between these points



- Calculations on the ***dynamical parameters*** (mechanical modes) have also been performed (EllA, EllB, CH), but their comparison is of poor interest because they strongly depend on the cavity surroundings ⇨ ***not presented here***

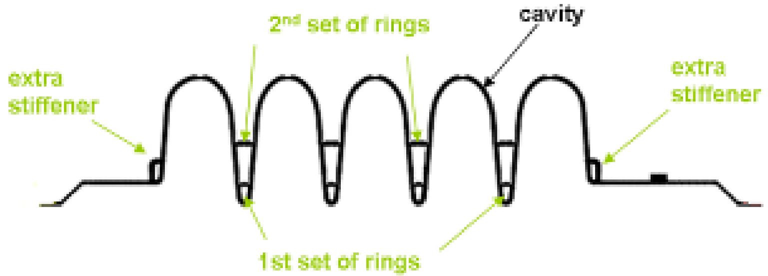
Stiffening systems

Elliptic A (INFN)

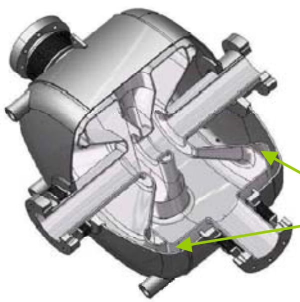


stiffening rings

Elliptic B (CEA)

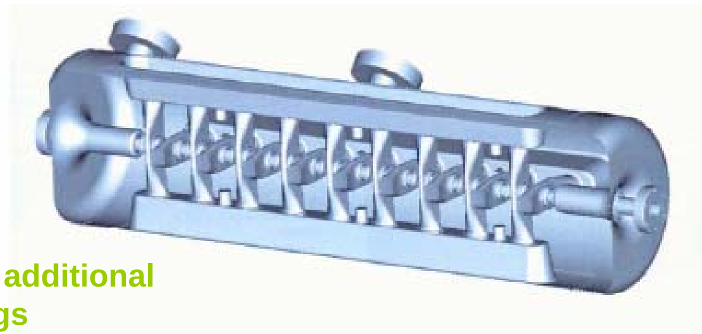


1 Spoke (IPNO)



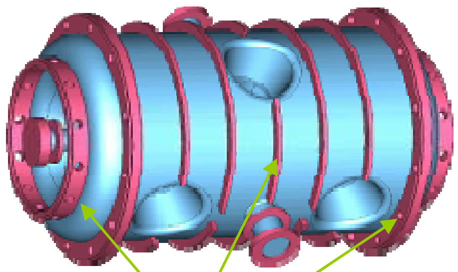
stiffeners

CH (IAP)



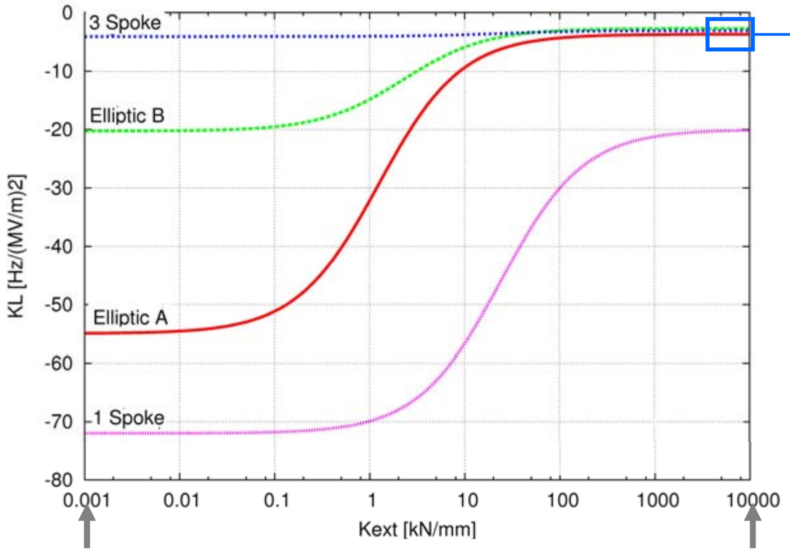
stiffening ribs – additional stabilization rings

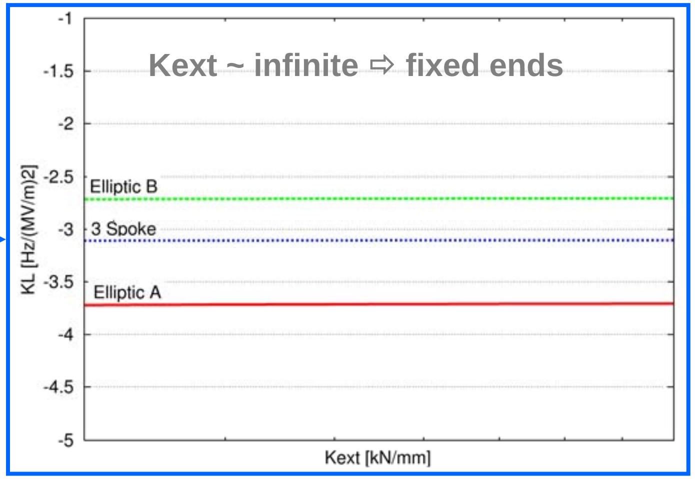
3 Spoke (FZJ)



(in red) stiffening rings

Curves K_L/Kext





Kext ~ 0⇨ free ends

Kext ~ infinite ⇨ fixed ends

The value for |K_L@fixed ends| determines the minimum Lorentz detuning expected on the cavity (external stiffness is infinite)

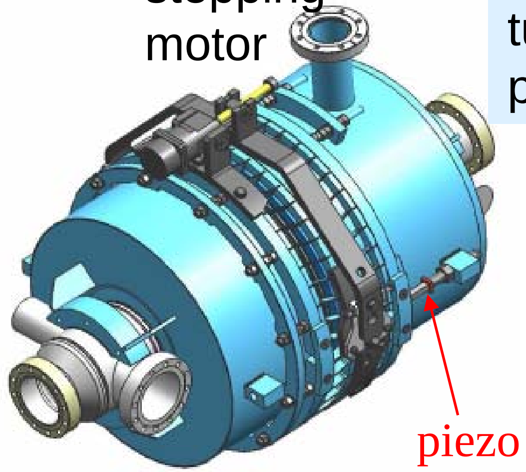
If |ΔK_L(free ends/fixed ends)| is small : the external stiffness is not a critical value to have a small Lorentz detuning

If |ΔKL(free ends/fixed ends)| is high : the external stiffness (stiffness of the tuner) has to be high enough : ~100 kN/mm

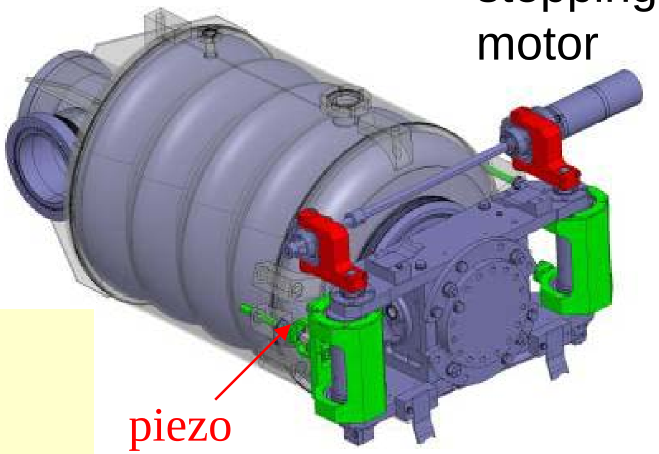
Mechanical parameters

cavity	Elliptic A	Elliptic B	3 Spoke	1 Spoke	CH
Cavity stiffness K [kN/mm]	1.25	2.25	22.4	24	6.5
Tuning sensitivity $\Delta F/\Delta l$ [kHz/mm]	353.4	295	182.7	964	400
Pressure sensitivity [Hz/mbar] (fixed ends	84.7	29.2	21.4	41	250
K_L with fixed ends [Hz/(MV/m)²]	-3.7	-2.7	-3.1	-20	-8
K_L with free ends [Hz/(MV/m)²]	-54	-20.3	-4.1	-72	
K_L measured during cold tests (range)	[-47 ; -20] (several tests)	-3.8 ± 0.4	-5.5	[-55 ; -47] (several tests)	

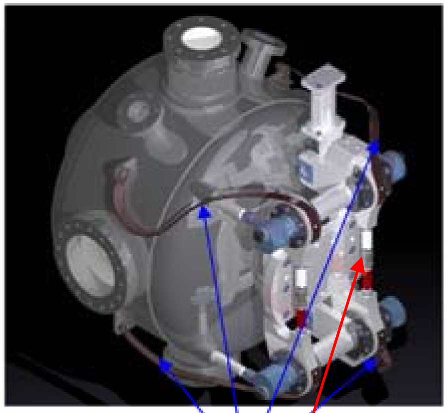
Tuners



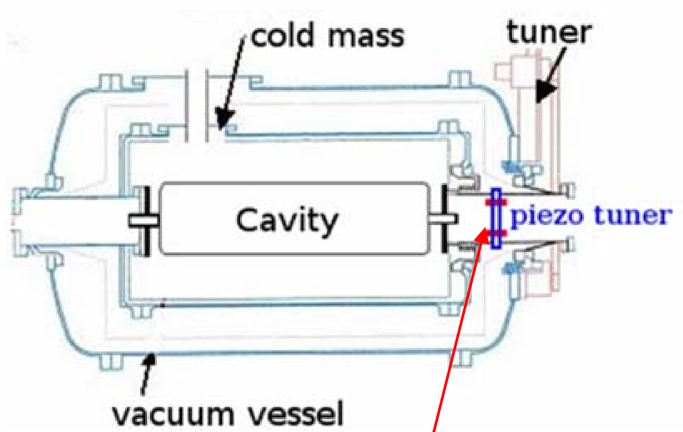
Elliptic A : blade tuner, between two parts of the He tank



Elliptic B : tuner between the He tank and the cavity flange



1 Spoke : tuner between the He tank and the cavity flange



CH structure : tuner between the inner cold mass containing the helium and the outer vacuum vessel.

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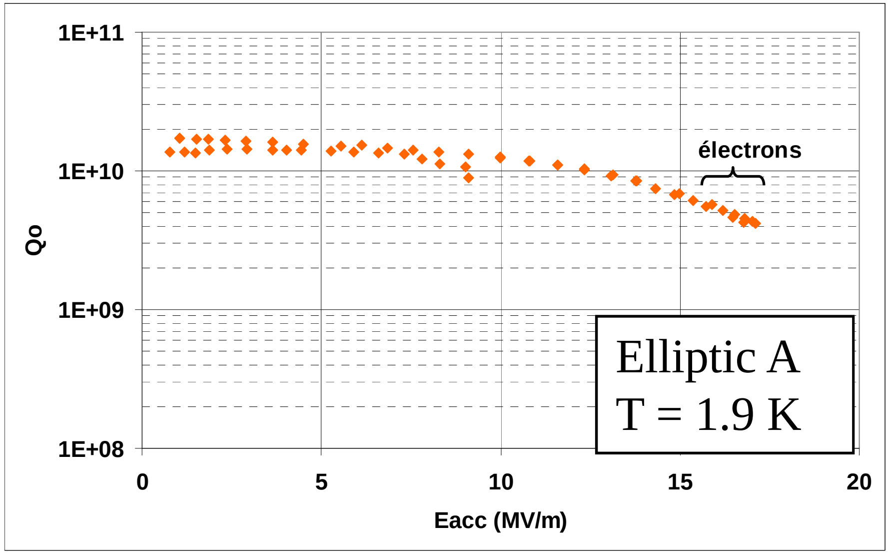
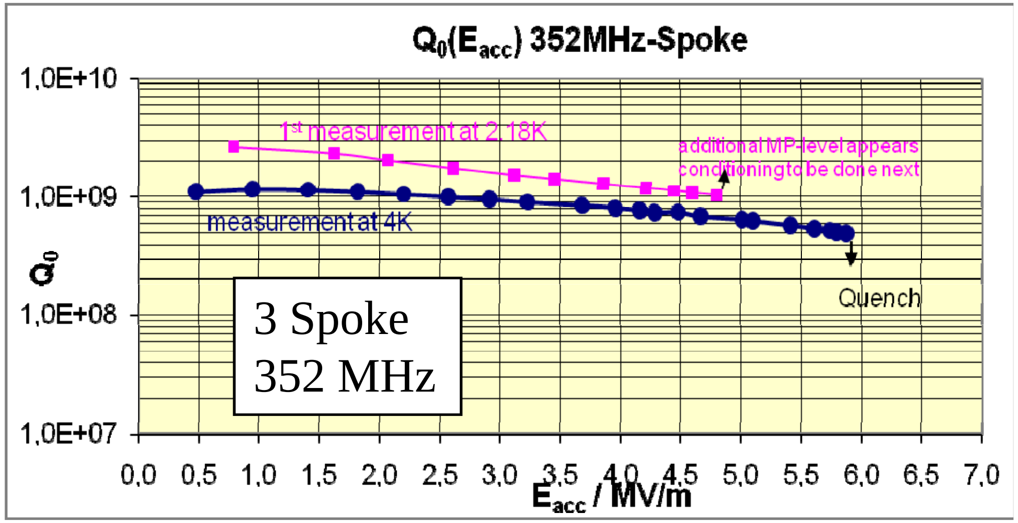
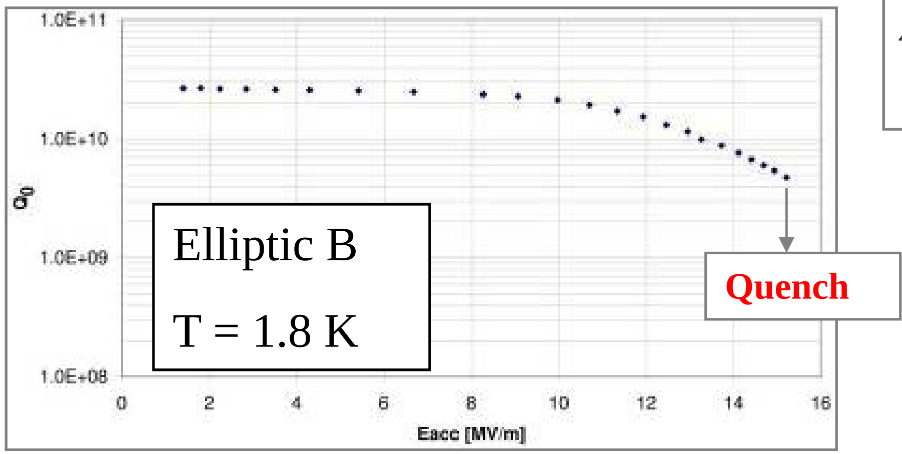
Low power RF tests - 1

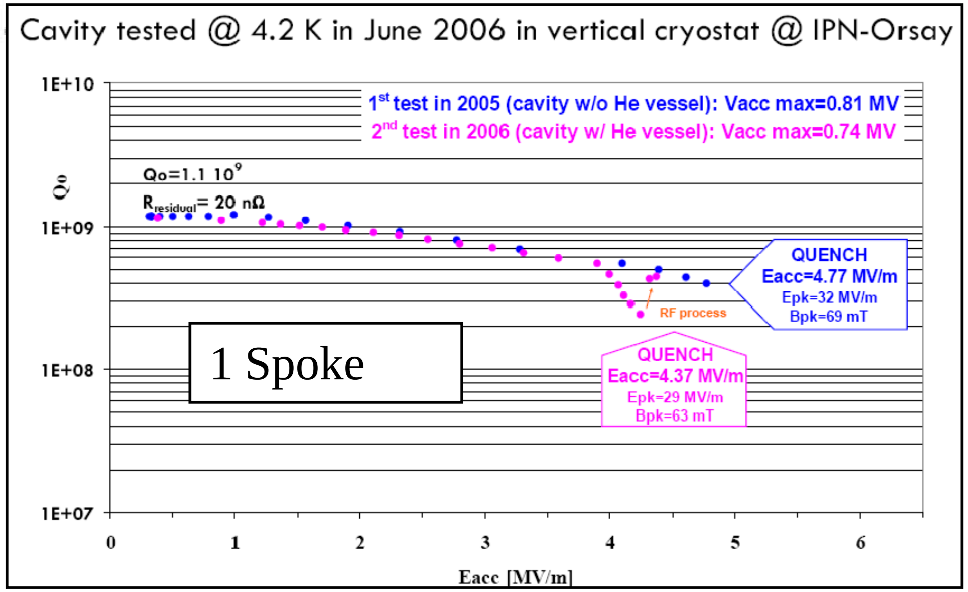
β ~ 0.5



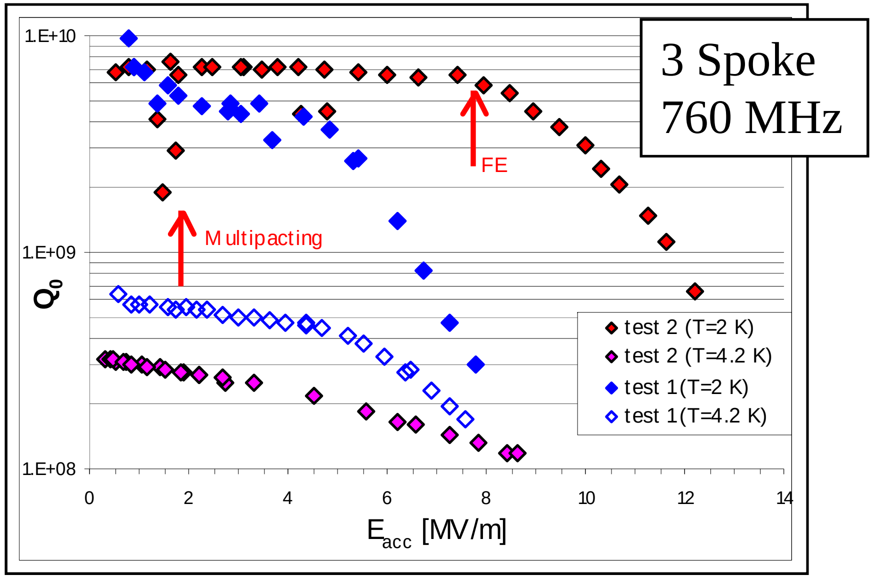


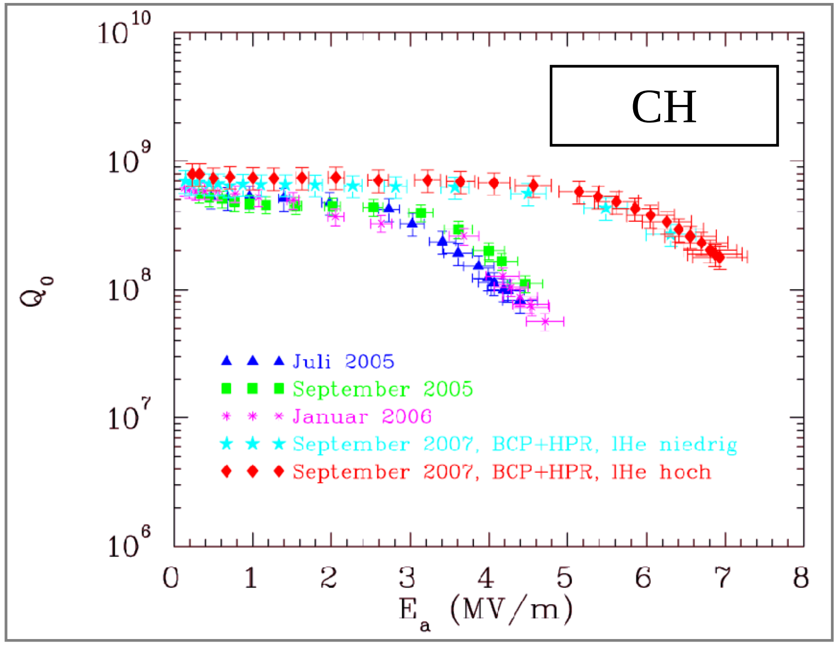


Low power RF tests - 2



β ~ 0.1-0.2





Eacc summary

$Lacc = Ngap*\beta*\lambda/2$

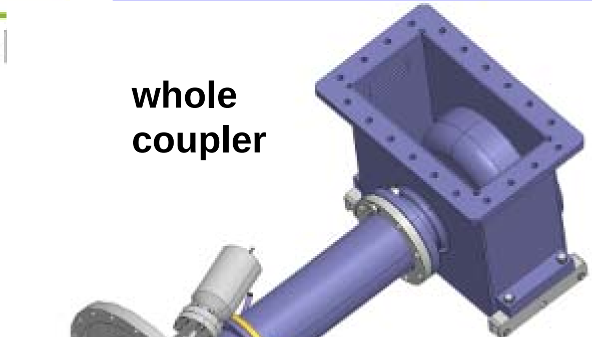
$Eacc = |\Delta U|/(q.Lacc) = Vacc/Lacc$

ΔU is the energy received by a particle while crossing the cavity

cavity	Elliptic A	Elliptic B	3 Spoke	1 Spoke	CH
Eacc max	17 MV/m	15 MV/m	5.8 MV/m	4.77 MV/m	7 MV/m
Lacc	500 mm	500 mm	818 mm	170 mm	810 mm
|ΔU|	8.5 MeV	7.5 MeV	4.7 MeV	0.81 MeV	5.7 MeV
Lcav	870 mm	832 mm	780 mm	450 mm	1050 mm
Vacc/Lcav	9.7 MV/m	9 MV/m	6 MV/m	1.8 MV/m	5.4 MV/m

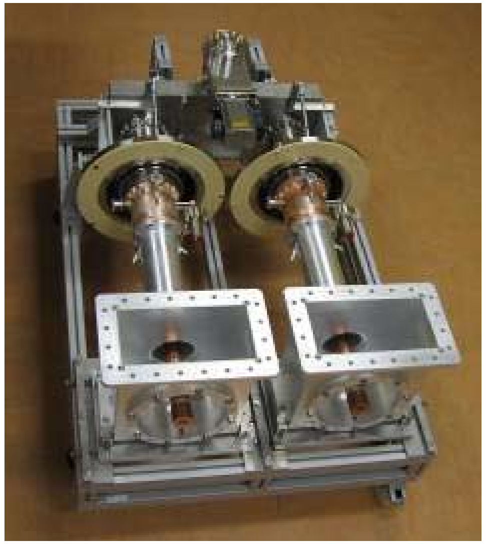
This Vacc/Lcav doesn't take into account the intermediate space between the cavities depending on the accelerator and cryomodule design.

Couplers



whole coupler

copper plating of the outer conductor



test bench

Elliptic B

250 kW peak power

duty cycle 10 %

To be tested and conditionned very soon in the high power 704 MHz RF place at Saclay

1 Spoke

20 kW cw

RF windows

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Comparative assessments

- Most of a the cavities developed in the frame of the program have performances as good as expected.
- The work achieved through the HIPPI-WP3 has given very significant elements about the design, the construction, and the experimental tests about SC structures, which can lead to comparative assessment.
- A further comparison should involve parameters external to the cavities themselves, and cryogenic technology.
- Exhaustive results will be presented in the final HIPPI-WP3 report. The results will be classified in two groups by beta families : β=0.5 & β = 0.1-0.2