R&D Activities in the ESRF RF group

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Current Increase

- Short term: 300 mA
  - Tests with existing Cavity T° regulation: negative
    - 250 mA attained but not reliable due to longitudinal HOM driven instabilities
  - Development of a new HOM detector
    - Analysis of HOM signals from each of the 30 cavity cells, using FPGA processing → easier identification of cavity to be de-tuned
  - Task force on fast multibunch feedback
    - Benefit from corresponding developments on several machines
    - Easier implementation thanks to progress in fast digital signal processing: FPGA

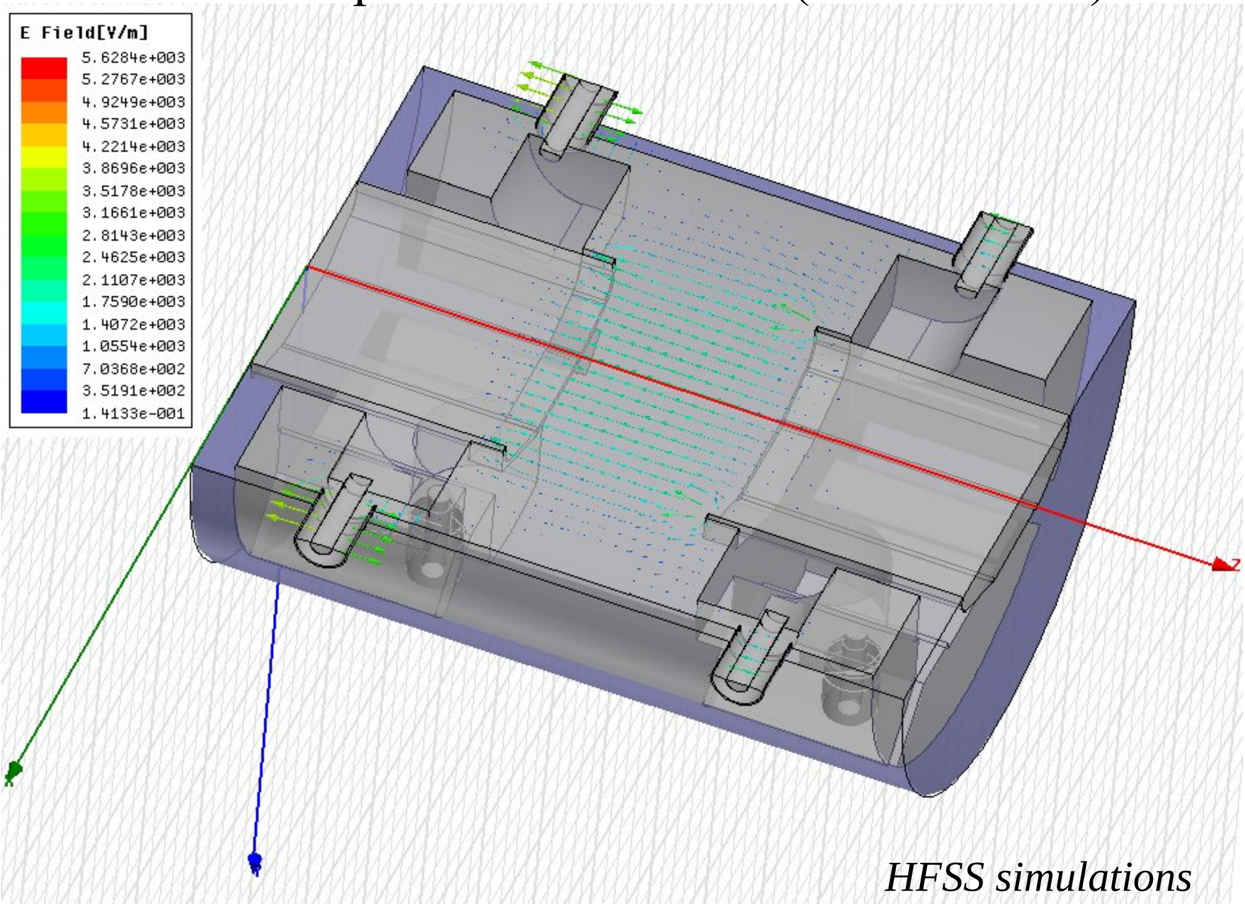
➢ Longitudinal feedback – LFB 🕔 1 year R&D

- Feasibility study completed, now design phase
- Expected damping: 5-6 times natural damping rate (sufficient to master longitudinal HOM driven instabilities with existing cavities up to 300 mA)
- Longitudinal kicker based on SLS design, being adapted to the ESRF: $3.75\ f_{rf} = 1321\ MHz$
- Low level RF front ends to be developed
- Solid state Amplifier (4 x 50 W) being ordered
- FPGA for broadband digital processing : potential suppliers being evaluated

➢ Transverse feedback – TFB : planned after LFB

Longitudinal kicker optimization

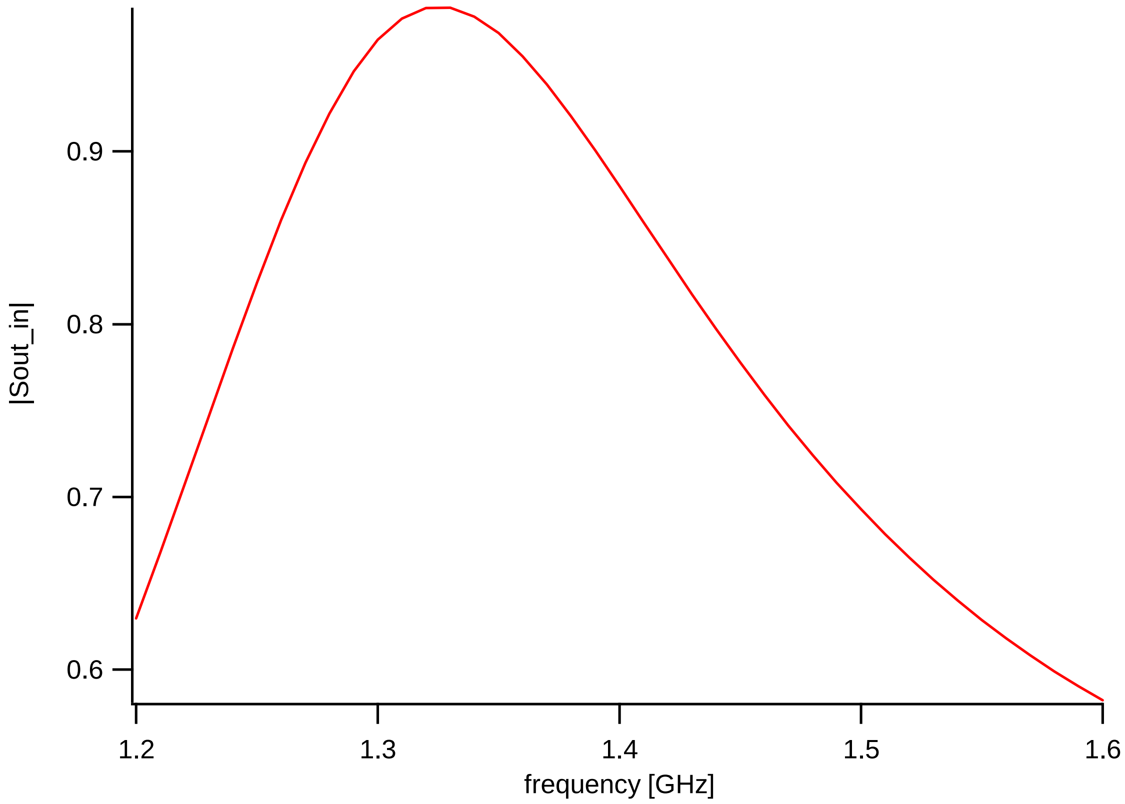
- Geometry based on the SLS longitudinal kicker
- Specification:
  - center frequency at 3.75*f_{RF}=1321 MHz
  - bandwidth > f_{RF}/2=176 MHz
  - impedance maximized (SLS: 1500 Ω)



HFSS simulations

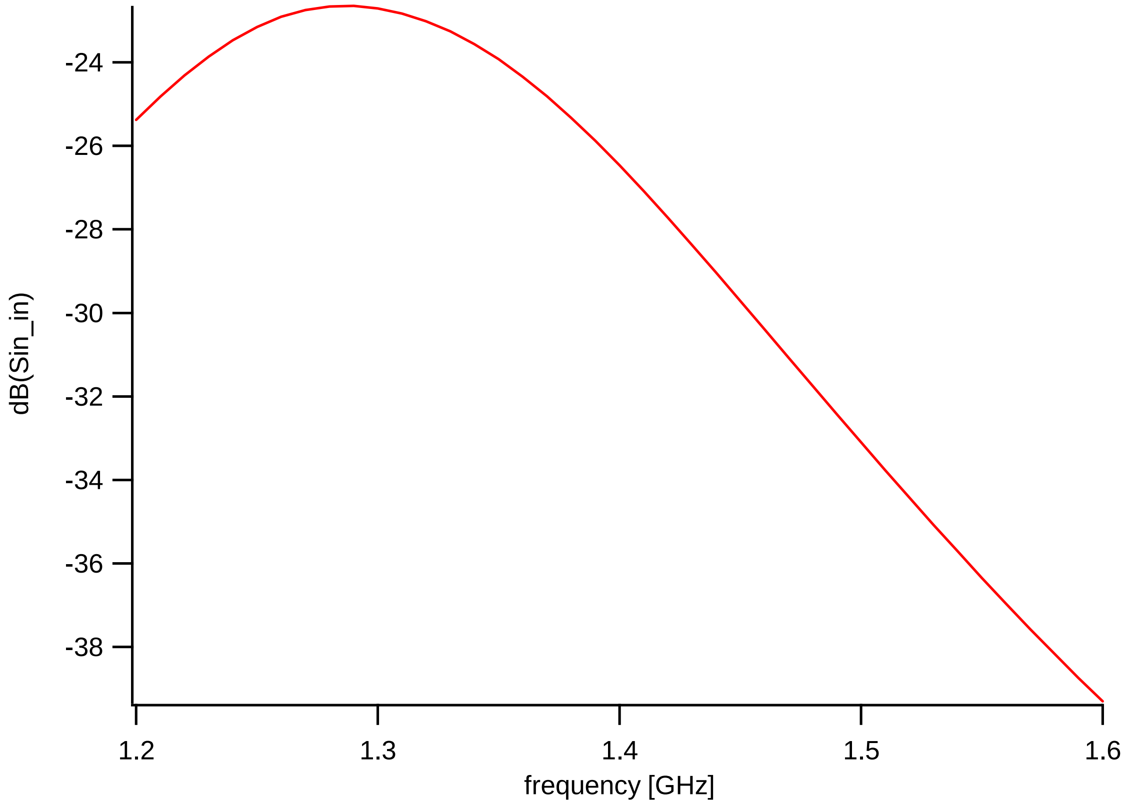
Longitudinal kicker - overall transmission

We need 4 input and 4 output coupleurs for a large bandwidth



- center frequency: f_{RF} = 1322 MHz
- bandwidth: F_{rf} = 270 MHz
- impedance: 1700 Ω

Longitudinal kicker - overall input reflection



Geometry of the ridge optimize to have an overall reflection below -23 dB

- Long term: 500 mA
  - Follow up of strongly HOM damped EU cavity
    - see presentation by E. Weihreter
    - Basis for a design study for the ESRF [PhD thesis at ESRF]
  - LFB & TFB possibly sufficient for 500 mA
    - Reconsider non damped cavities with T°-regulation (like e.g. Elettra Cavity)

HOM Damped Cavities for I > 500 mA

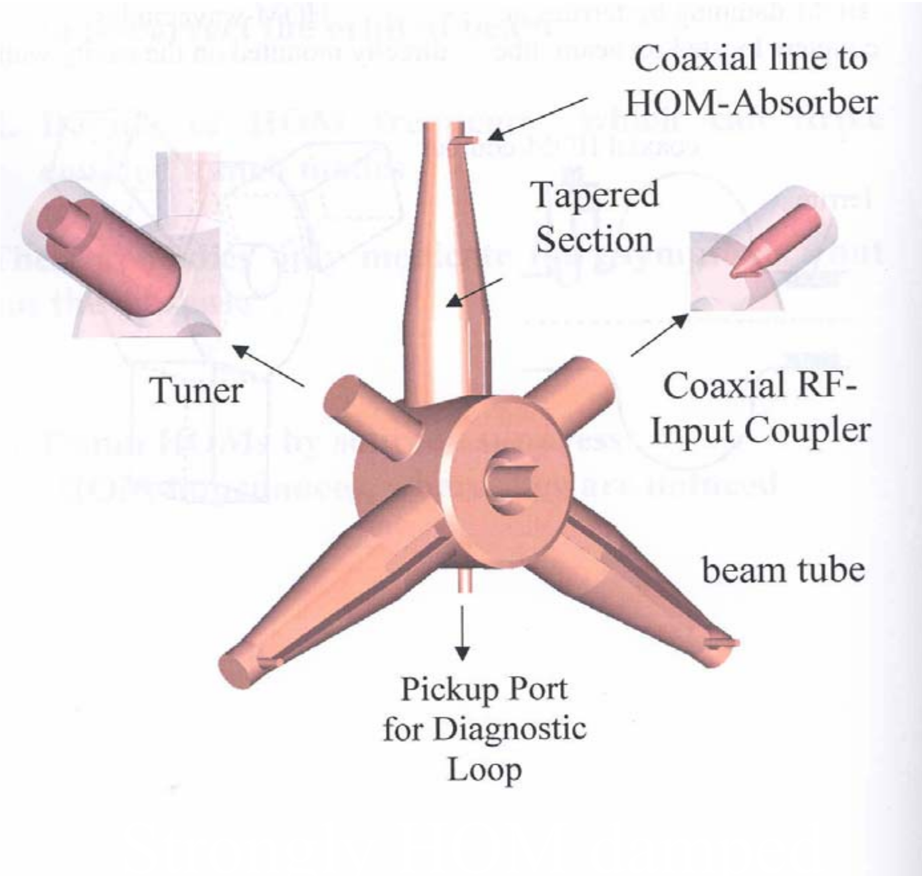
- Problem (present ESRF parameters):
  - E_0 = 6 GeV
  - U_0 = 5 MeV/turn

    ⇒ Beam loading:

I_{beam}	300 mA	500 mA	1 A
P_{beam}	1.5 MW	2.5 MW	5.0 MW

  - V_{acc} = 9 MV: very modest

HOM Damped NC Cavity
- e.g. EU Cavity -

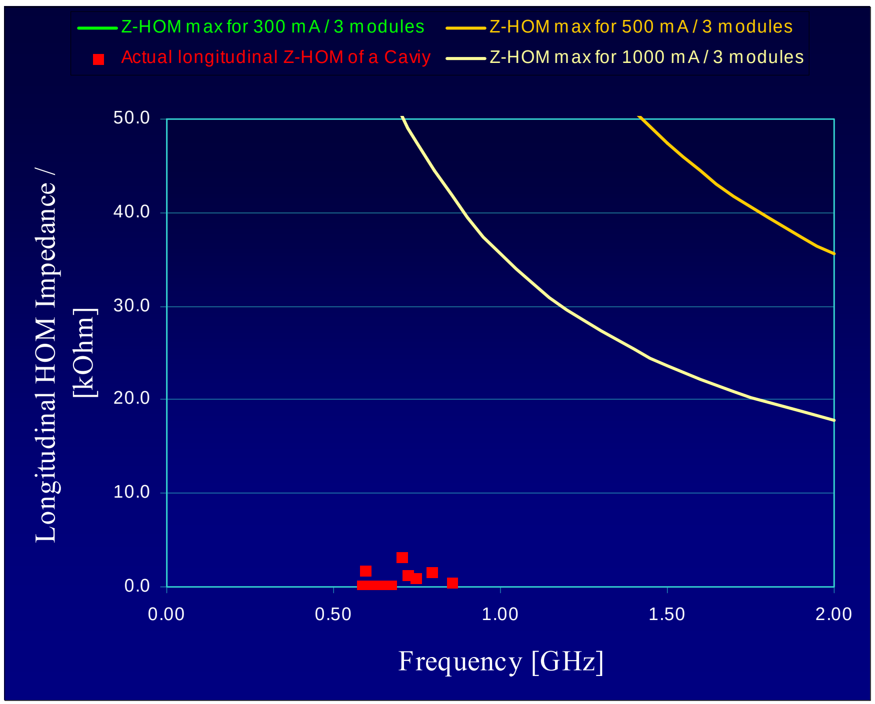


- Basis for planned R&D of an ESRF cavity at 352 MHz
- Reasonable assumption:
  - 18 cells at ESRF
  - 3 times less Power/coupler than SC solution
  - BUT: more HOM impedance than SC cavity

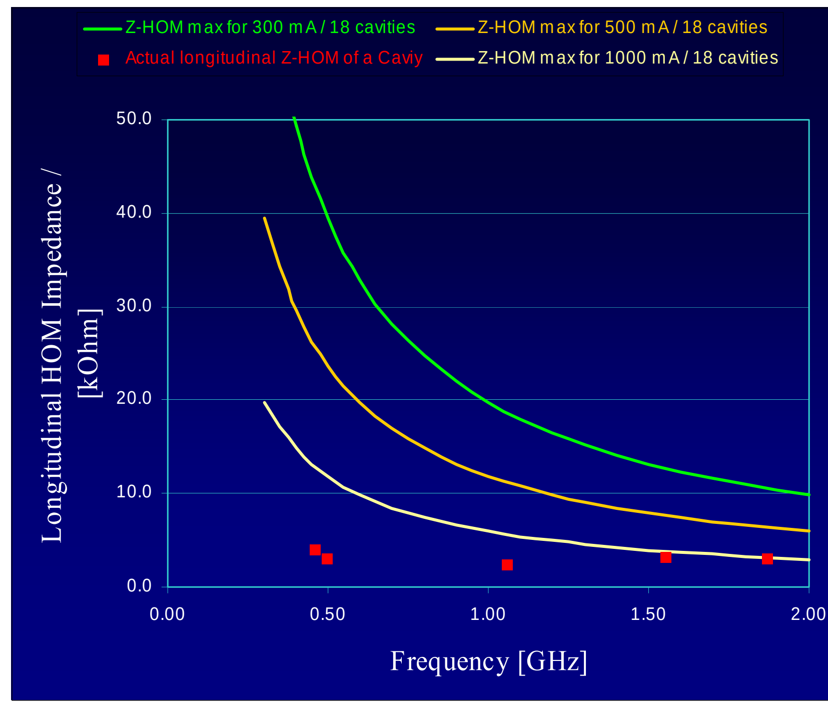
J. Jacob

Check of Stability HOM / LCBI

3 SC SOLEIL modules

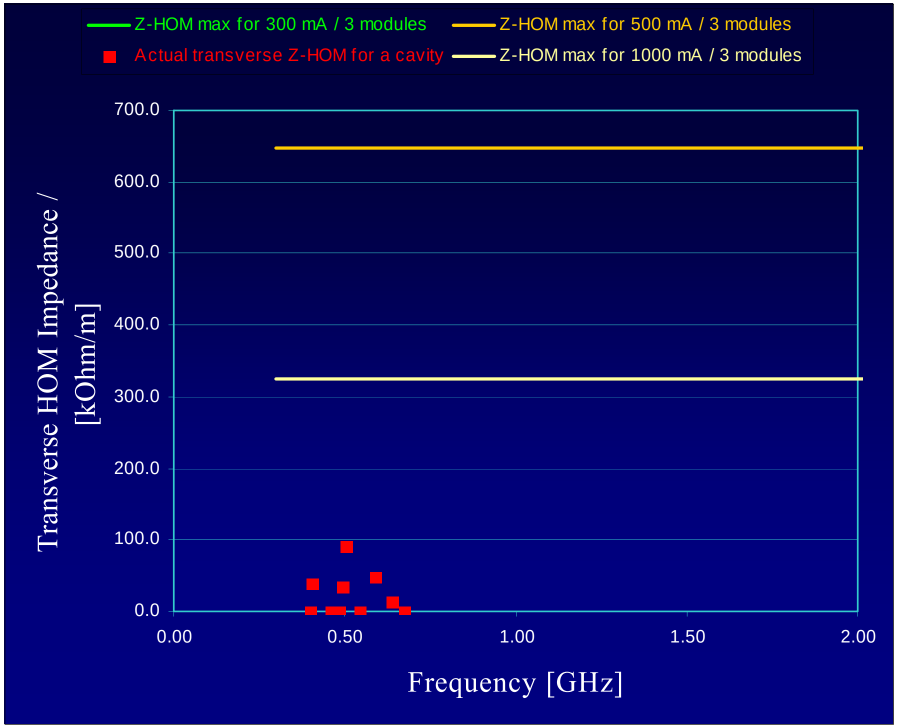


18 NC EU-type cavities



Check of Stability HOM / TCBI

3 SC SOLEIL modules



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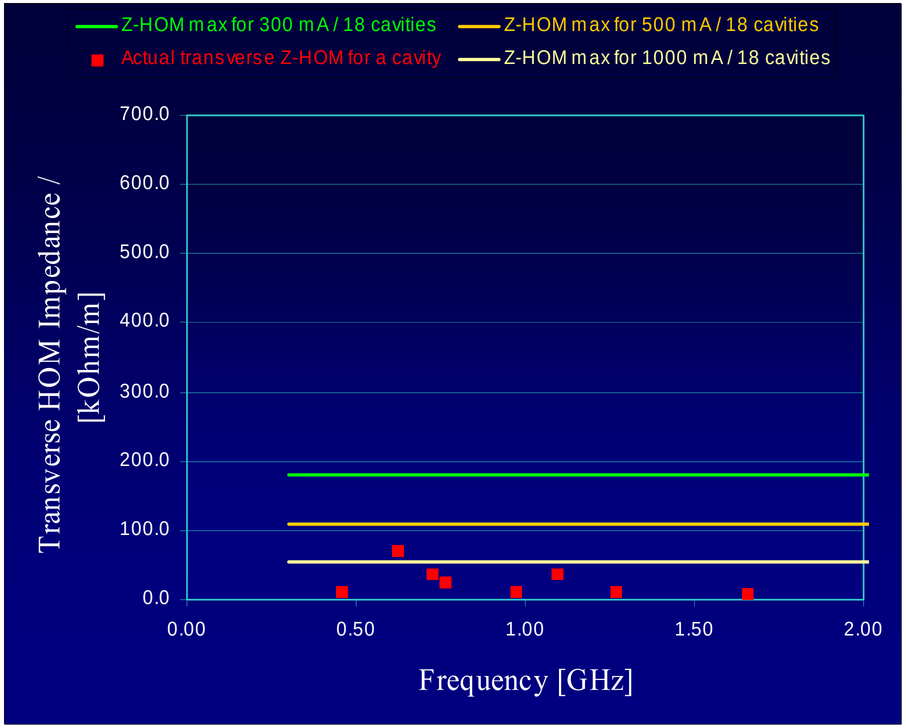


Typical RF Parameters with 18 NC Cavities

V_{acc}	9 MV		
R_s at 352 MHz	3.2 MΩ		
N_{cav}	18		
V_{acc} / Cavity	0.5 MV		
P_{copper} / Cavity	39 kW		
I_{beam}	300 mA	500 mA	1 A
P_{beam}	1.5 MW	2.5 MW	5 MW
P_{beam} /Cavity	83 kW	139 kW	278 kW
P_{total} /Cavity	122 kW	178 kW	317 kW
β_{opt}	3.13	4.56	8.13
Total RF power	2.2 MW	3.2 MW	5.7 MW
Mains power	4.8 MW	7.0 MW	12.5 MW

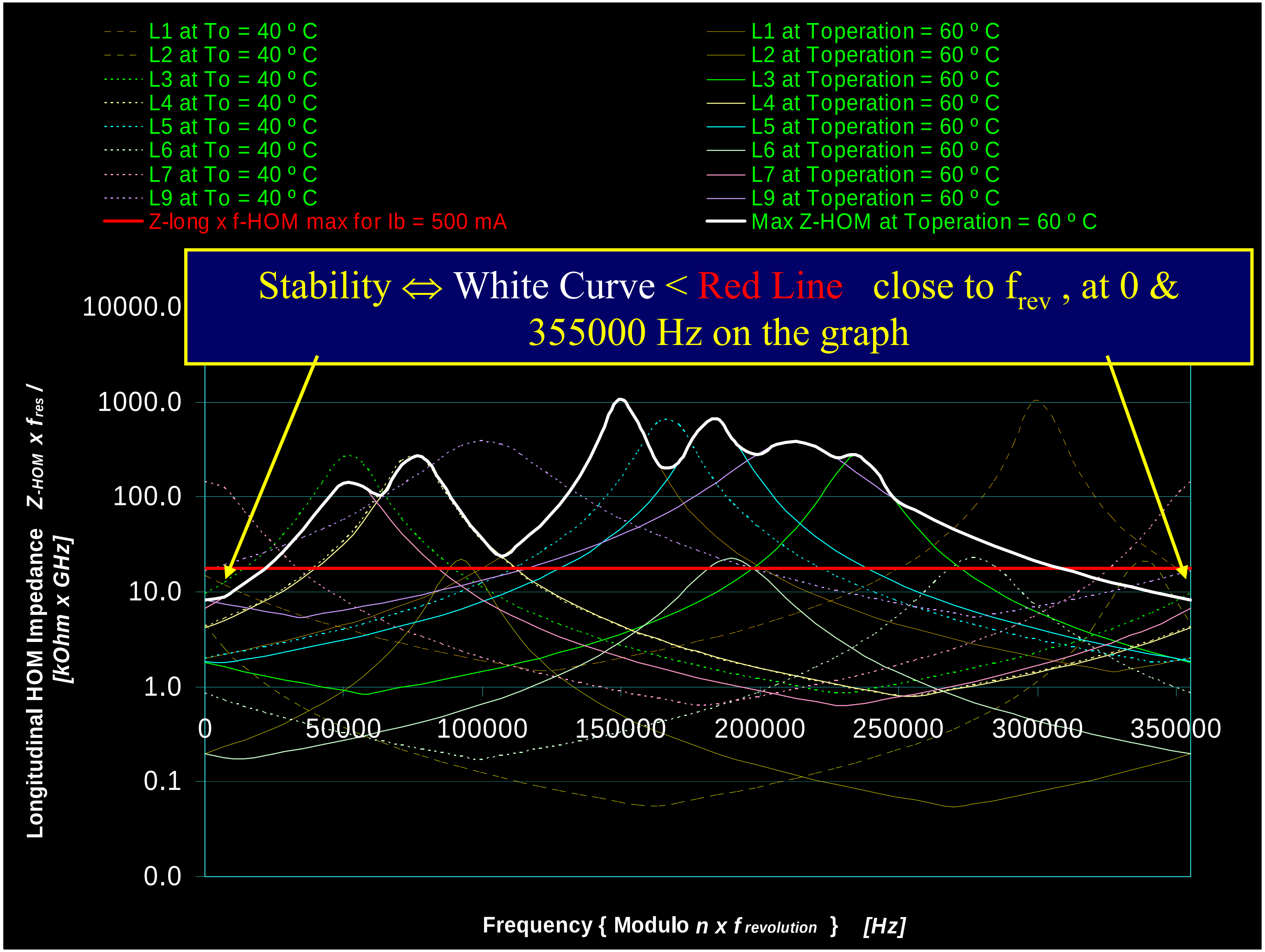
- Conservative figures
- Achievable with existing 3 RF transmitters

Alternative: Elettra type Single Cell Cavity with HOM detuning

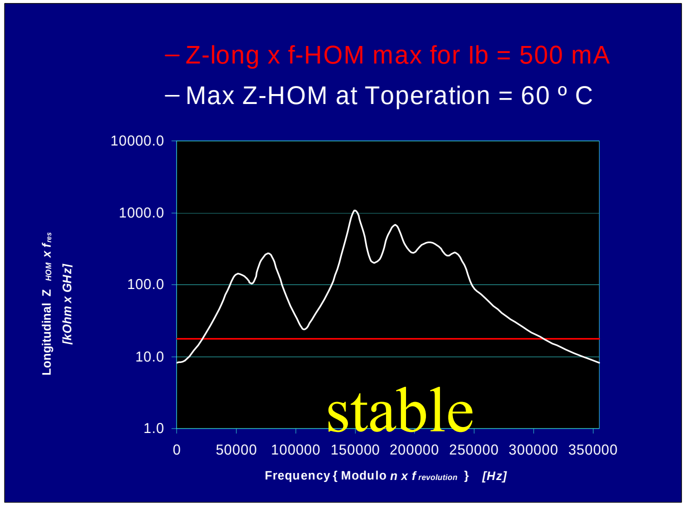
First simulations carried out:

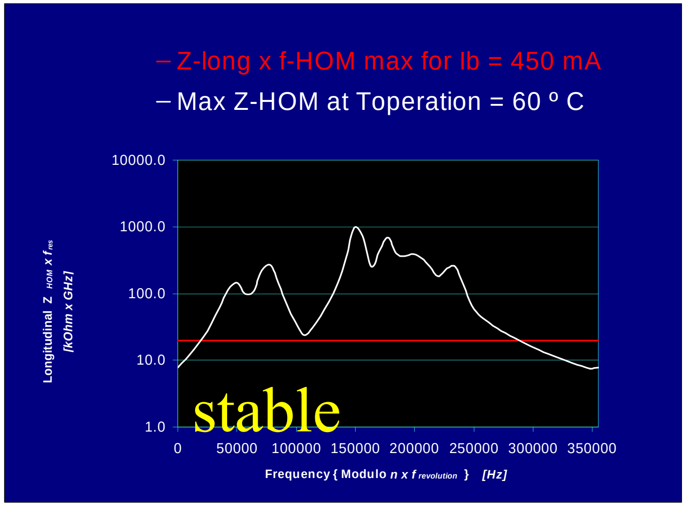
- Using typical measured values of a real recent Elettra cavity *[M. Svandrlik]*
- Including:
  - Effect of Temperature on HOM frequencies,
  - Main tuner motion to compensate reactive beam power in the fundamental mode and its effect on HOM (i.e. HOM frequency shift as a function of I_{beam})
  - Additional mechanical HOM tuner: not used here
- Scaling from 500 MHz Elettra to 352 MHz ESRF main RF
- Assuming the smallest possible number of cavities: $N_{cav} = 12$
- Assuming that all cavities are identical, which is in contradiction with mechanical tolerances, however, assumed here for ease of computation. It is believed that random starting frequencies would not make it easier to park all the HOMs off $n \times f_{rev}$.

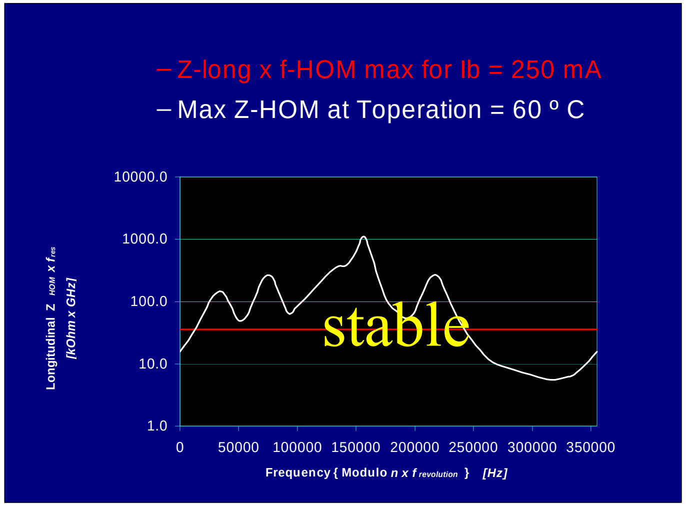
Stable working point found for 500 mA with 12 Elettra cavities
Only Longitudinal CBI's with Longitudinal HOMs L1,…,L9 considered here

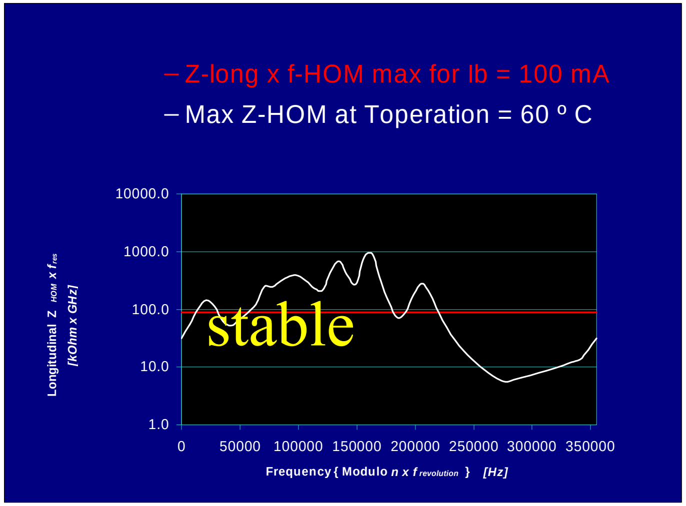


- Working point stable during the decay from 500 mA down to 0 mA
- HOM frequencies = $f(I_{beam})$ $\Rightarrow$ *Z-HOM* increases at f_{rev} as beam decays, but remains smaller than increased threshold value

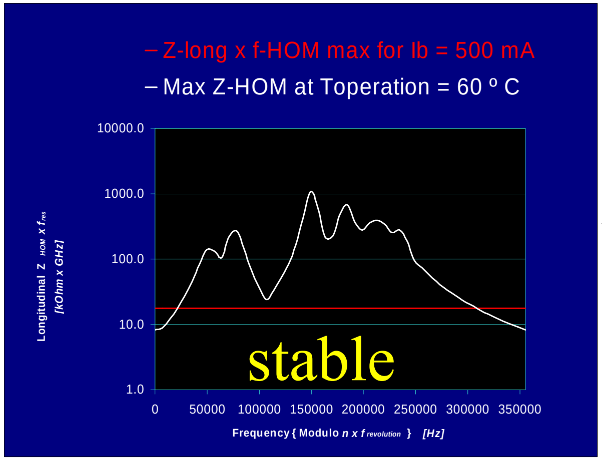




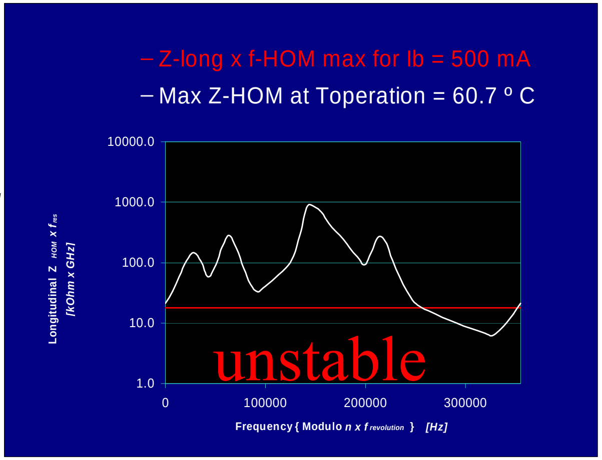




- Working point sensitive to small variations: here $T_{stability} \pm 0.7\ °C \Rightarrow unstable$

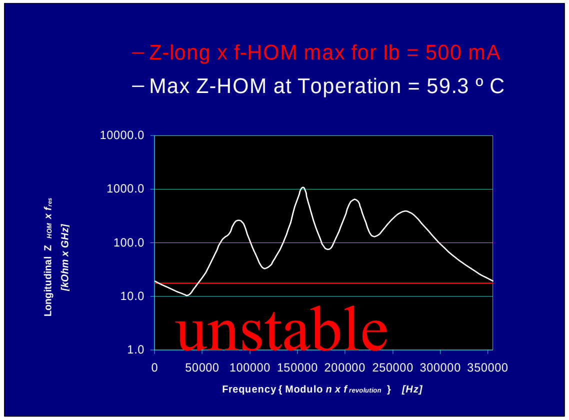


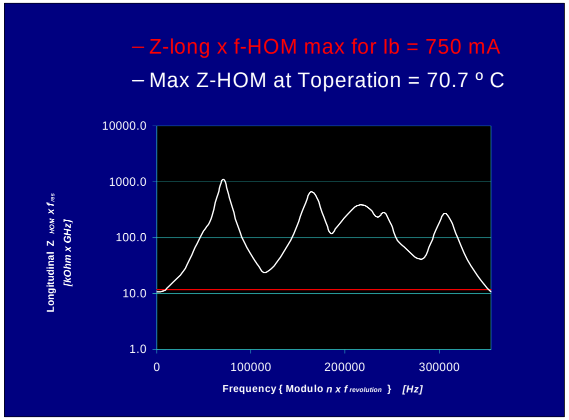
$\Delta T = +\ 0.7\ °C$



$\Delta T = -\ 0.7\ °C$

- Highest LCBI threshold achieved: 750 mA





- Among 3 different approaches:
  - HOM damped NC Cavity:
    - Presently preferred solution
    - Conservative operation conditions for 500 mA at ESRF
  - Elettra type single cell undamped cavities with HOM detuning:
    - First calculations indicate that an Elettra-like solution has to be considered as simple alternative
    - Transverse HOMs need to be checked
    - Not taken into account here: T = 60 … 70 °C ⇒ decrease of conductivity, broader resonance curves, increase of required RF power, …
  - HOM damped SC Cavity:
    - Not excluded, but lower priority solution
    - Would require Coupler R&D to allow for high beam loading
  - Multibunch Feedback:
    - In any case useful to damp remaining CBI in case of NC cavities (HOM damped or detuned)

- Status of the R&D
  - –First simulations of BESSY cavity using GdfidL under way
    - Goal: Crosscheck with MAFIA results obtained at BESSY
  - –First simulations of HOM dampers using HFSS
    - Goal: Crosscheck with Microwave Studio results / BESSY
  - –Simulation with ANSYS of new ferrite loaded HOM damper
    - Goal: Thermal and mechanical check of BESSY design
  - –This year’s goal: setting up the numerical tools allowing to define a new ESRF cavity

Acknowledgments

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