
# A COLD TUNER SYSTEM WITH MOBILE PLUNGER

## ESS-BILBAO, IFMIF, MYRRHA AND SPIRAL2

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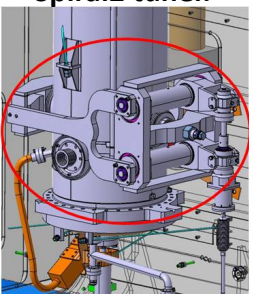
# OUTLINE

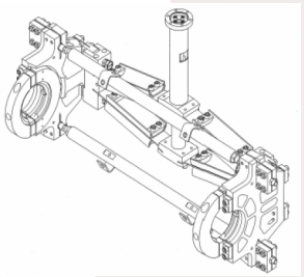


- Mobile plunger System presentation
- ESS-Bilbao System
- IFMIF System
- MYRRHA 325MHz CH Cavity
- SPIRAL2 System
- CONCLUSION

# EXAMPLES OF TUNING SYSTEMS

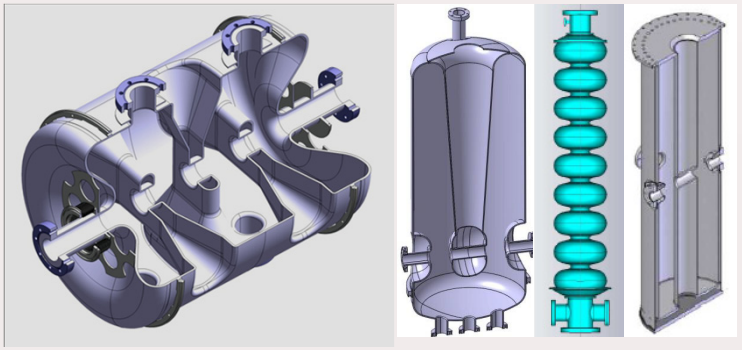
Spiral2 tuner.

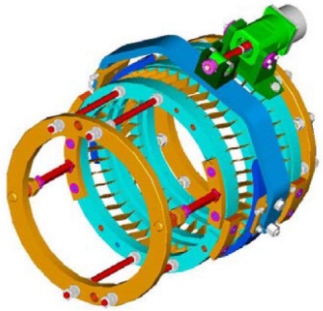




Scissors Jack tuner

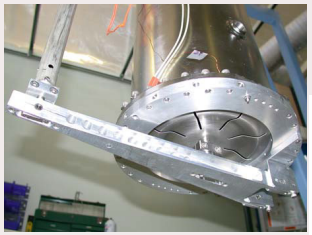
**By deformation (most used)**



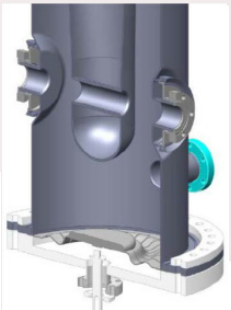


Blade tuner.

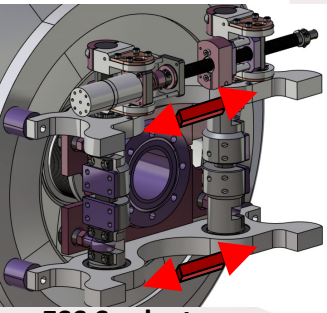
**By insertion**



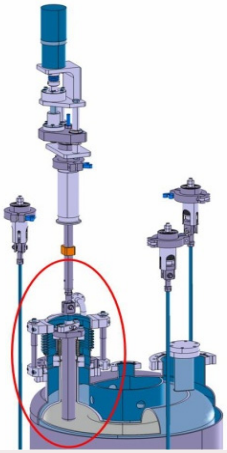
Isac2 tuner, Triumf.



ReA3 tuner

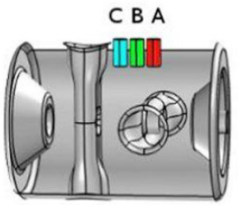


ESS Spoke tuner

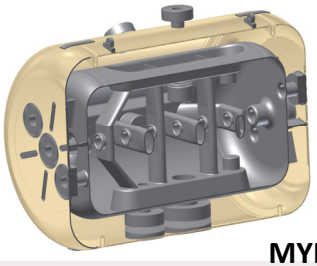


Spiral2 tuner.

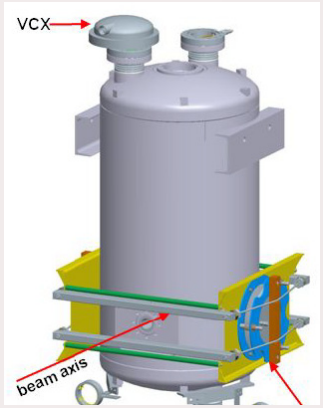
**Variable reactance**




ESS- Bilbao tuner



MYRRHA CH cavity tuner.




ATLAS upgrade

# PROS AND CONS



| | By deformation | By insertion |
|---|---|---|
| **Pros** | - Reliable<br>- A lot of experience<br>- No direct interactions in cavity RF space<br>- Easy maintenance | - Low force needed<br>- No risks of plastic deformation<br>- Tuning range not limited by Niobium<br>- Several tuners in parallel.<br>- More compact |
| **Cons** | - Possible irreversible damages (plastic deformation)<br>- Massive (difficult to cool down)<br>- High forces involved<br>- Tuning range limited by limit of elasticity of Niobium<br>- Only one tuner per cavity | - Lack of experience<br>- Inserted in cavity volume (problems of cleanliness, possible RF limitations)<br>- Has to be integrated in LHe loop<br>- Complexity of cleaning procedure and maintenance (dust generation?)<br>- Quench problems |

# PROS AND CONS



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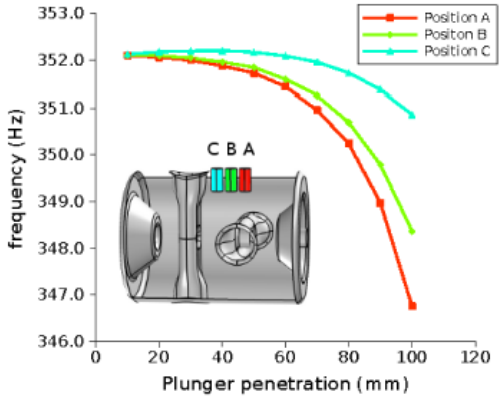
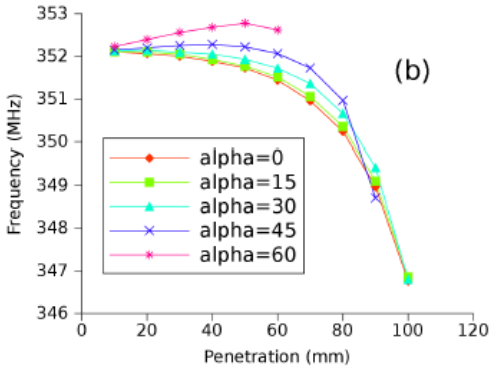
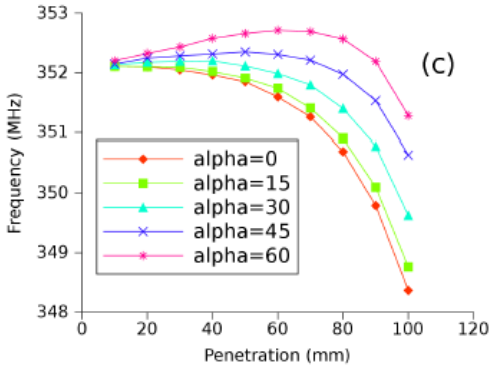
| **Cons** | - Possible irreversible damages (plastic deformation)<br>- Massive (difficult to cool down)<br>- High forces involved<br>- Tuning range limited by limit of elasticity of Niobium<br>- Only one tuner per cavity | - Lack of experience<br>- Inserted in cavity volume (problems of cleanliness, possible RF limitations)<br>- Has to be integrated in LHe loop<br>- Complexity of cleaning procedure and maintenance (dust generation?)<br>- Quench problems |

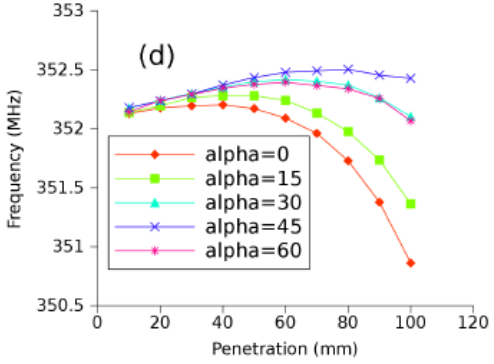
**Complementary solution : good where the other fail**

# ESS-BILBAO TUNER (1)

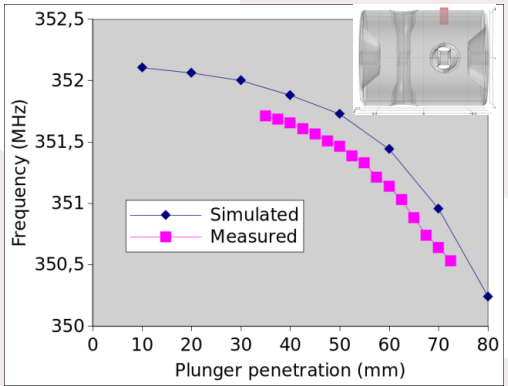


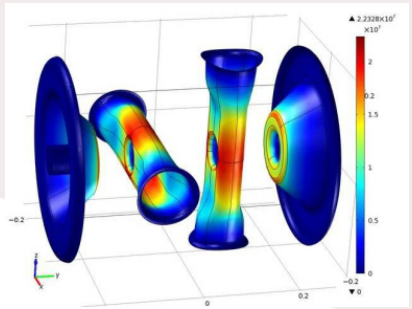



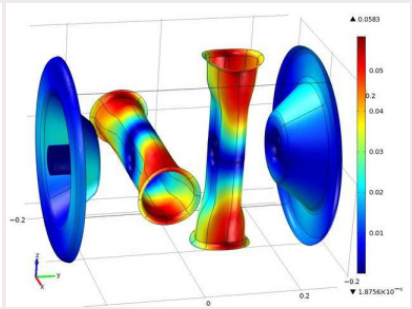




- RF simulations done for different plunger position and orientation (diameter of 35mm)
- Most favorable is perpendicular and aligned with spoke.
- Aluminium prototype built to validate simulations
- Good agreements between simulations and prototype measurements

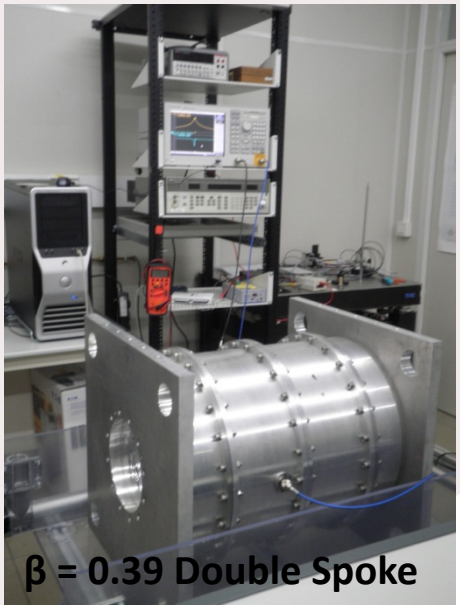


Electric field



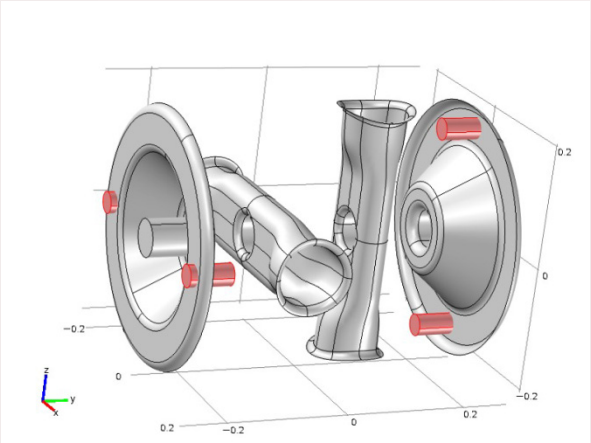
Magnetic field



**β = 0.39 Double Spoke**

# ESS-BILBAO TUNER (1)

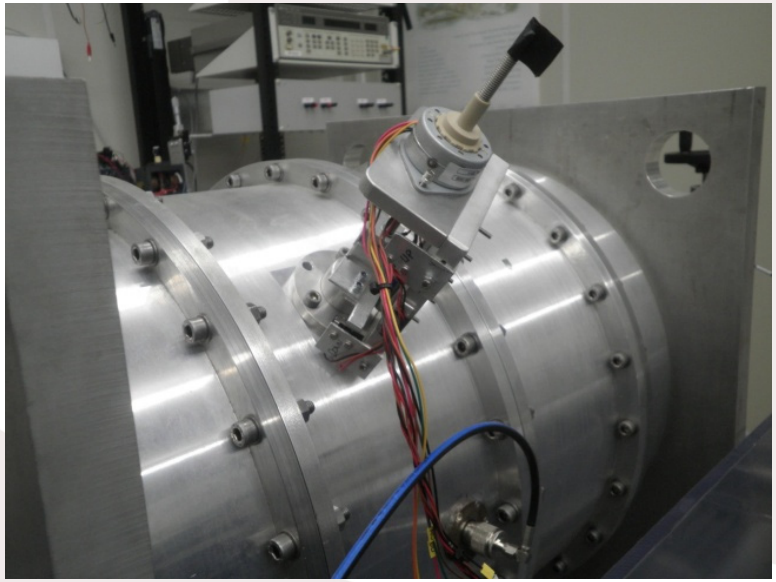


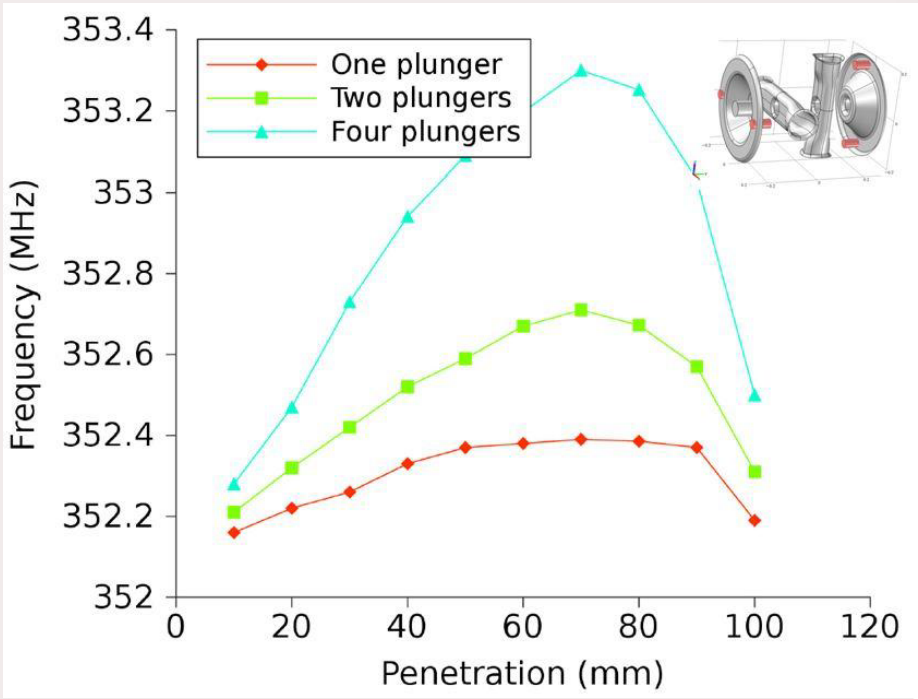


➢ Alternative position studied through end covers (positive shift).

➢ To be done :

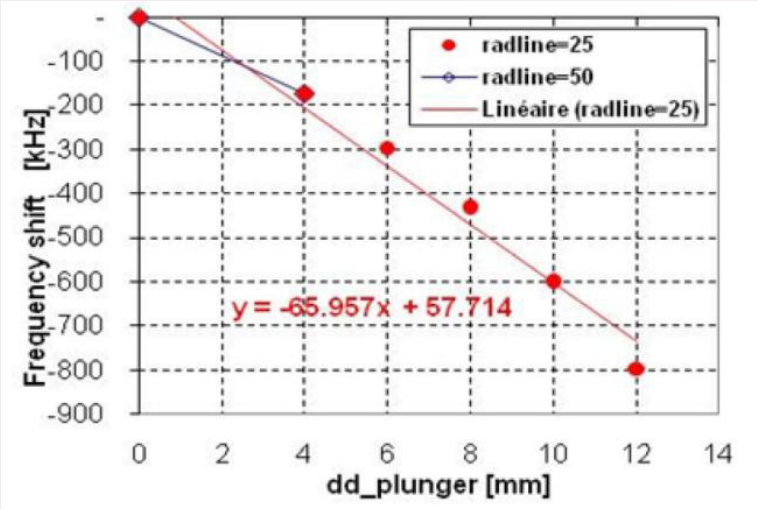
- Mechanical design
- LHe loop design
- Additional RF analyses : perturbation of electric field on beam axis.

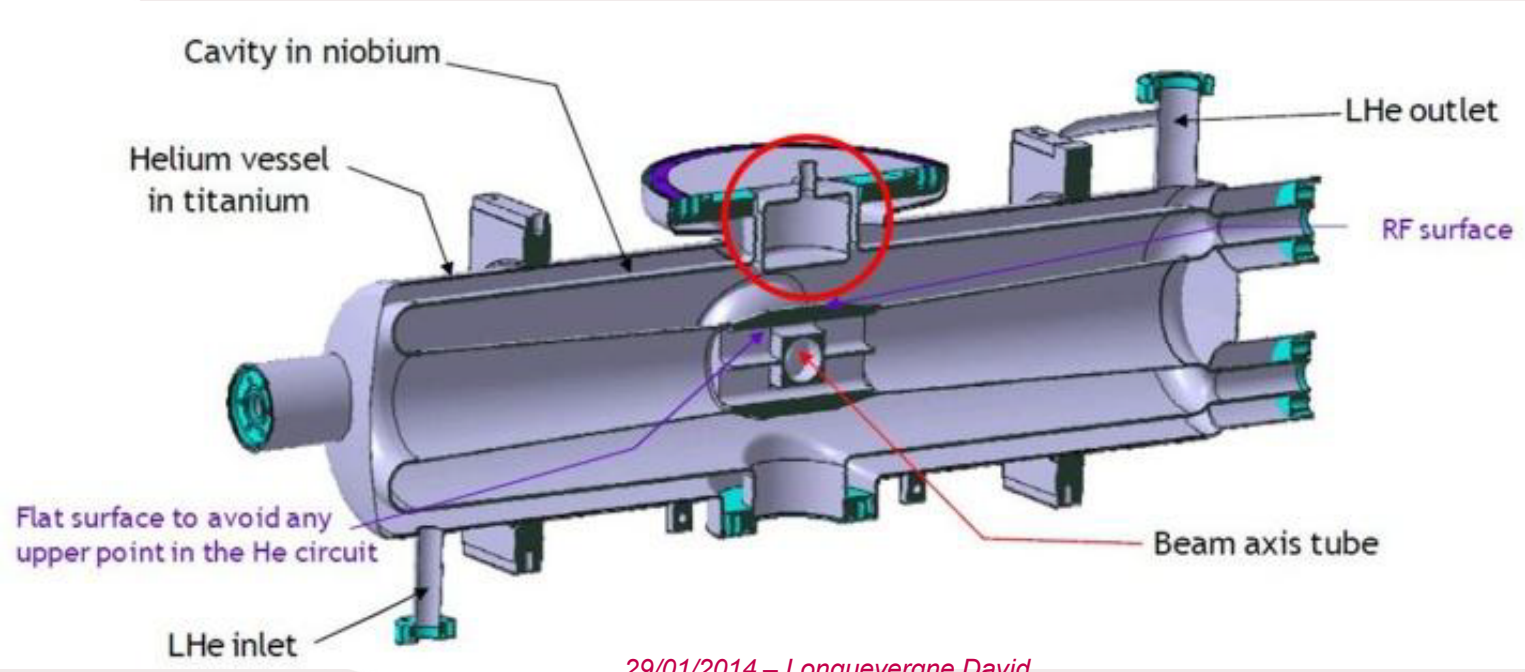




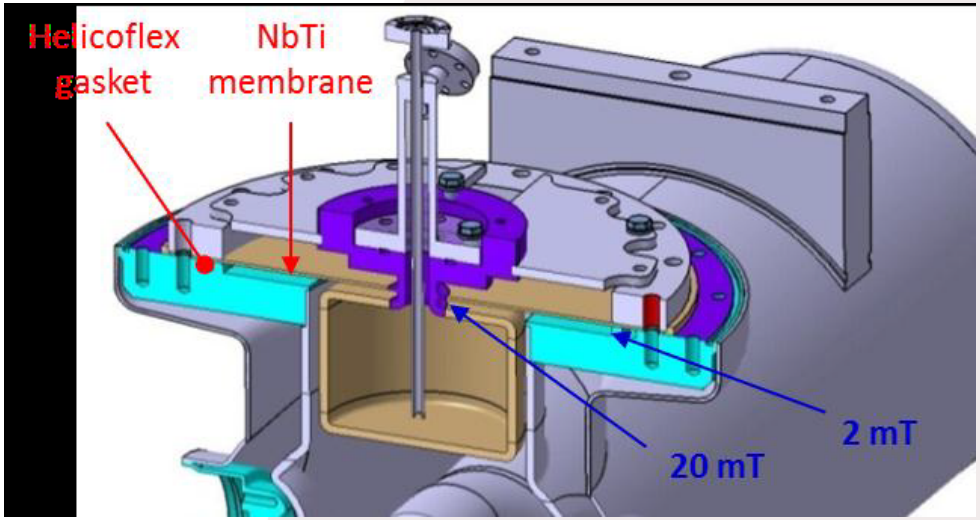
# IFMIF TUNER (1)

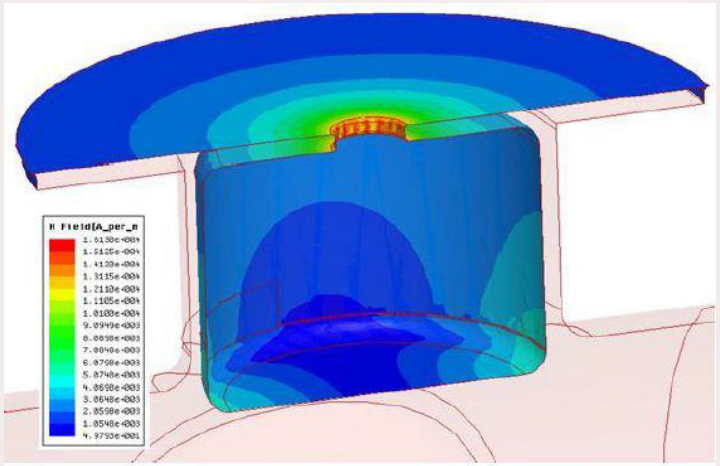
- Plunger solution envisaged for compactness and because of stiffness of cavity
- Ø = 100mm, bulk Nb.
- Membrane in NbTi : ± 1 mm => ± 50 kHz
- Design well advanced and prototyping done
- Cold test revealed premature quench at 1 MV/m and low Qo.

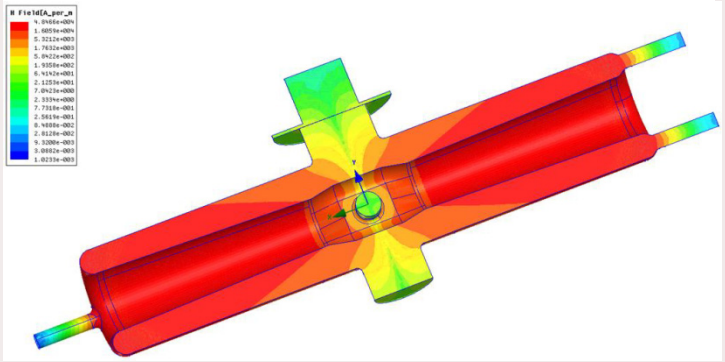


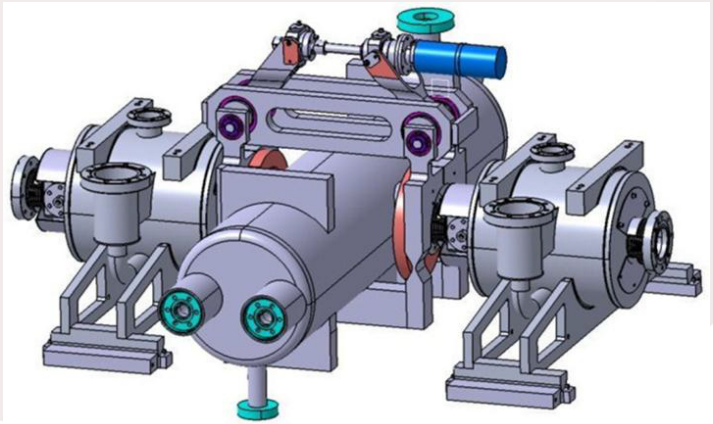



# IFMIF TUNER (2)



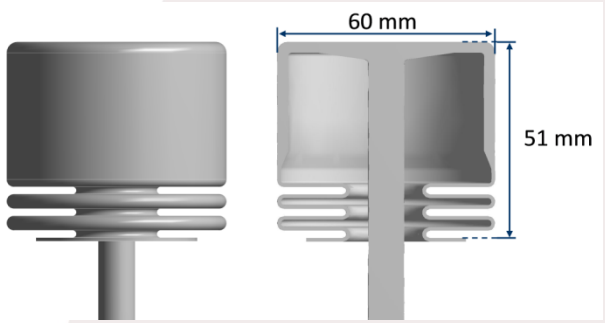



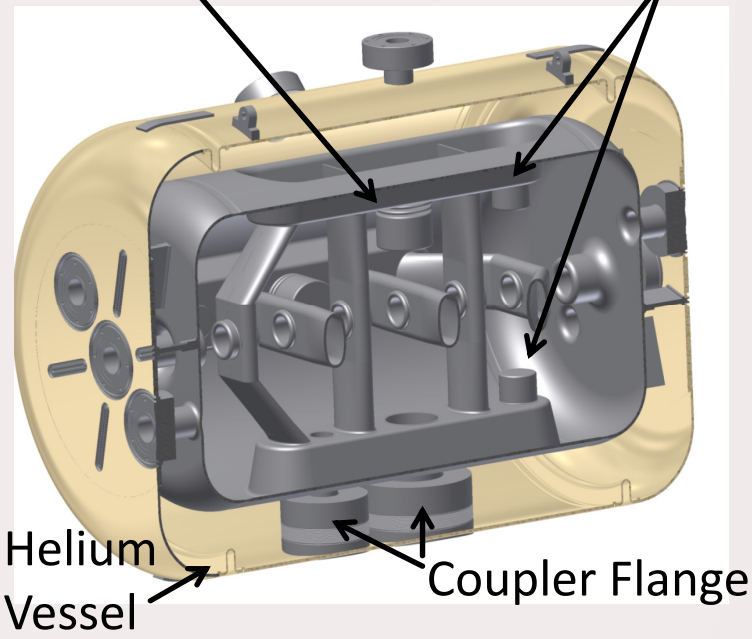




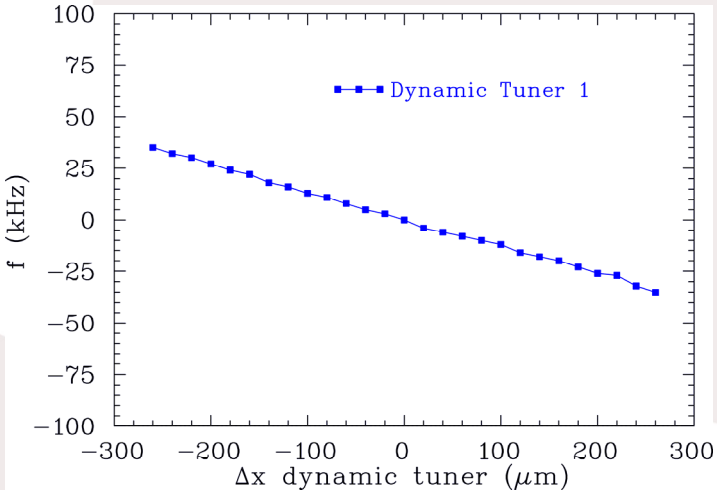
- Additional RF simulation showed a significant magnetic field on plunger neck (NbTi) and on Helicoflex gasket.
- Tests done to localize quench :
  - NbTi parts replaced by Nb parts
  - ⇒ Quench field increased but Qo still low
  - Nb plunger inverted (field reduction on gasket)
  - ⇒ Qo and quench field increased
- Plunger solution abandoned for more conservative tuner system by deformation due to tight schedule.

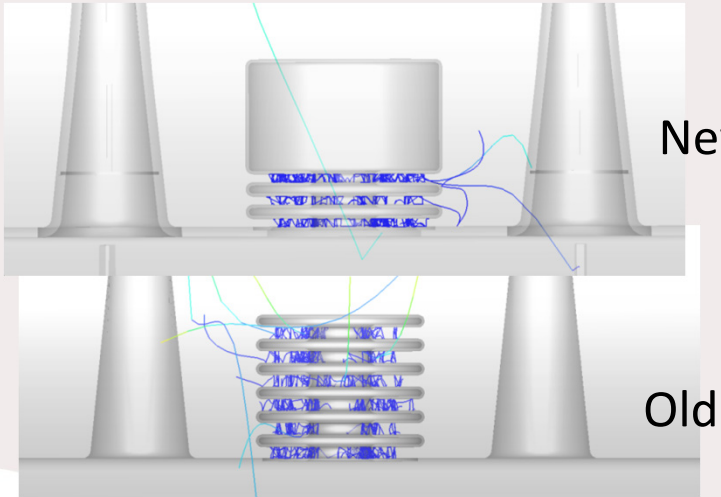
# MYRRHA 325 MHZ CH CAVITY TUNER



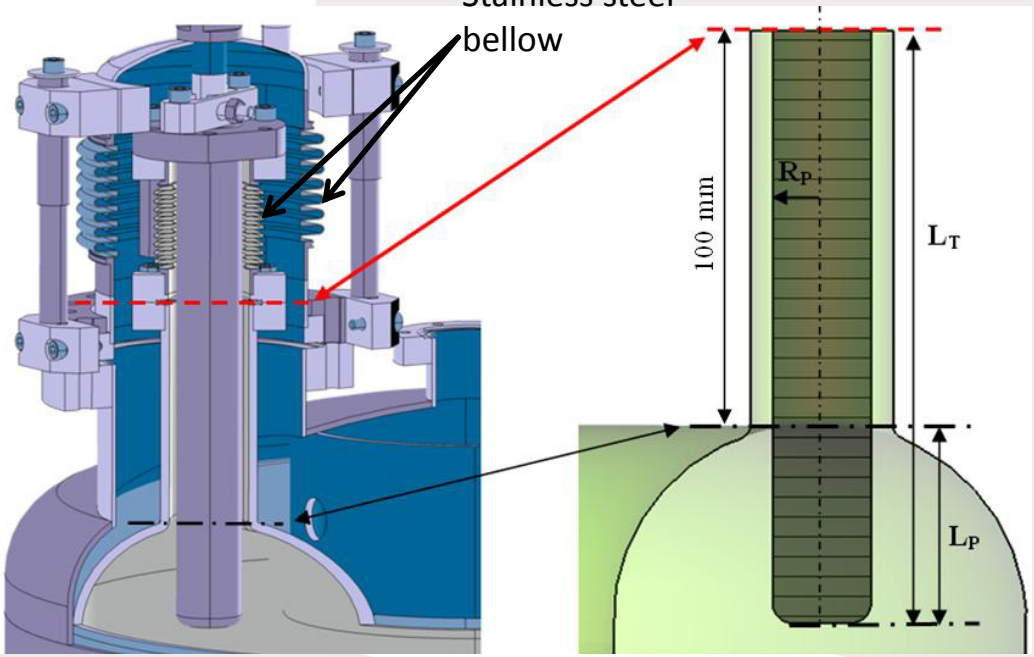

- 2 Niobium bellow tuners
- Sensitivity ~ 125 kHz/mm
- Fast tuner ΔF=130Hz, slow tuner ΔF=130kHz
- Optimized to limit multipacting in bellow
- Cavity and tuners have been built
- To be tested at 4K

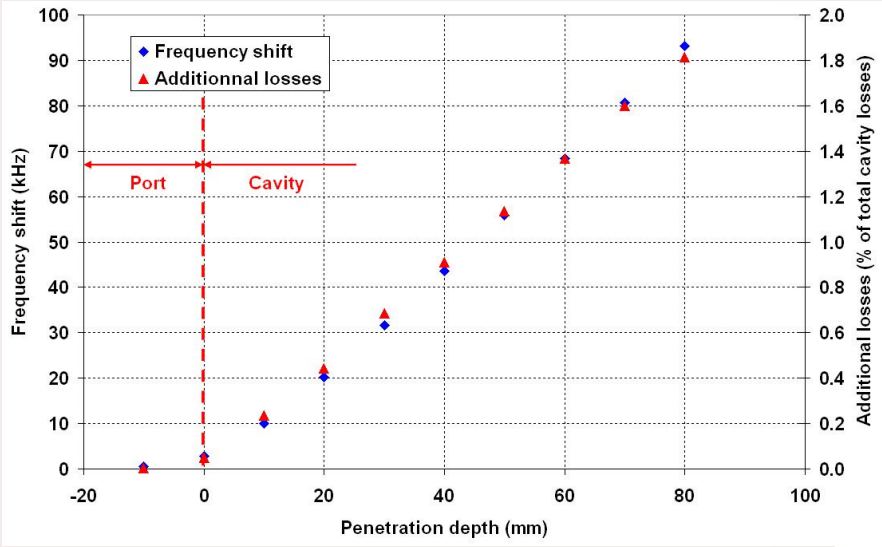


# SPIRAL2 TUNER (1)

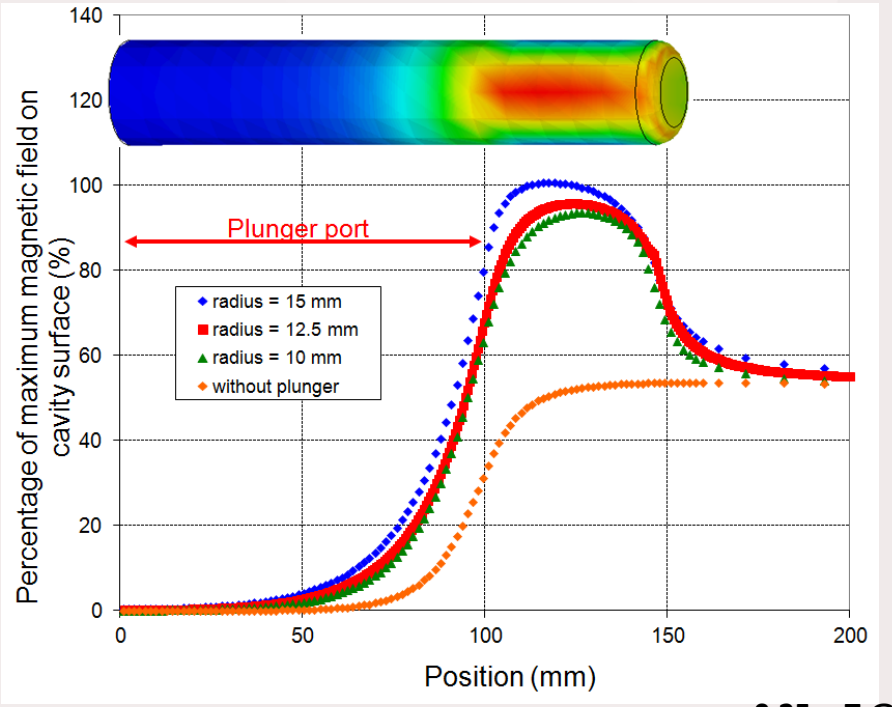
- Most advanced system already validated at 4K on 14 cavities (RF validation).
- Validated on cryomodule (RF + mechanical validation)
- Ø = 30mm, bulk Nb, stainless steel bellow
- Sensitivity ~ 1kHz/mm, Range : ± 4mm
- Static penetration ~ 50mm in cavity

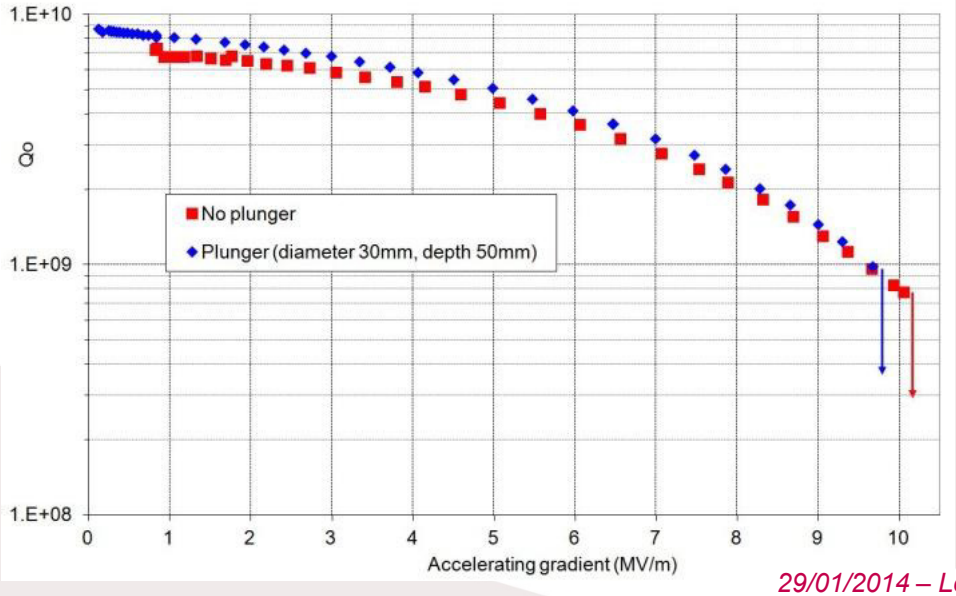


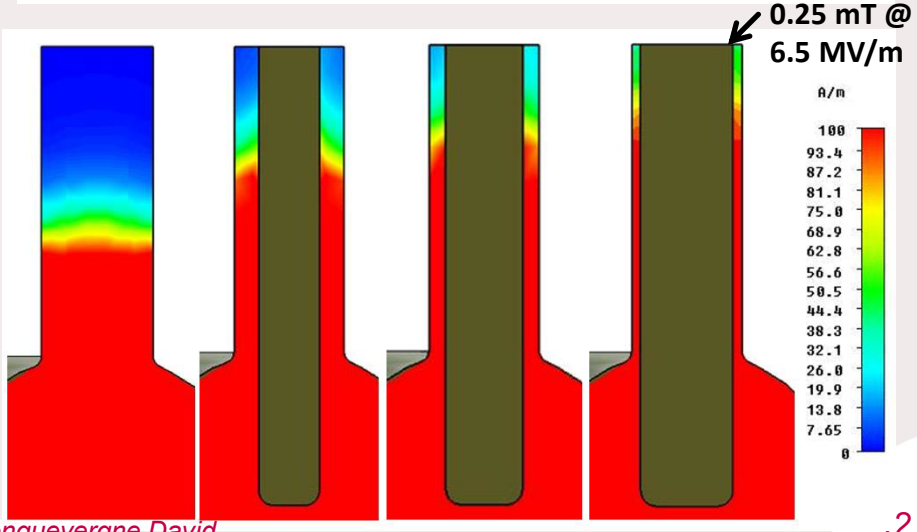



# SPIRAL2 TUNER (2)

- RF simulations done to ensure :
  - Surface magnetic field on plunger not greater than in cavity
  - Residual magnetic field at cavity flange below 1 mT
  - Losses not above 1W.
- RF tests showed no limitations <u>only if</u>
  Surface treatment of plunger = Surface treatment of cavity



# SPIRAL2 TUNER (3)

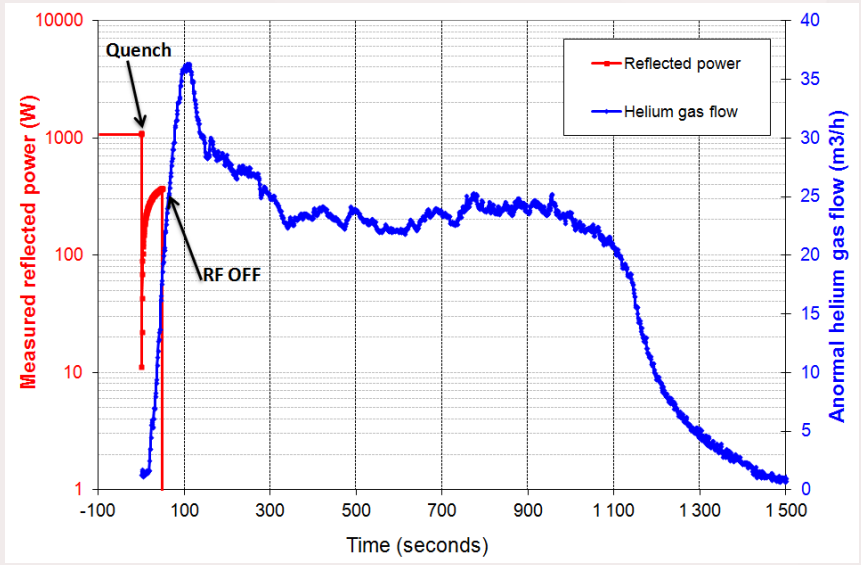


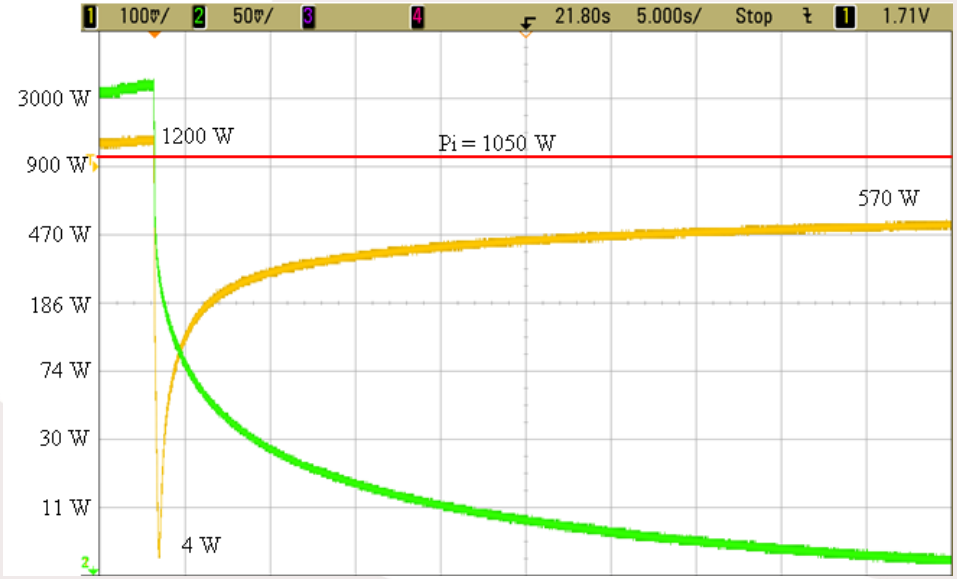
| Diameter | Static detuning (kHz) | | Dynamic detuning (Hz) | Additional losses (%) @ 6.5 MV/m | Magnetic field at flange (mT) |
|---|---|---|---|---|---|
| | Min (10mm) | Max (50 mm) | +/- (4 mm) | Max (50mm) | |
| Φ = 20 mm | 5 | 25 | 1900 | 2.2 | 0.05 |
| Φ = 25 mm | 8 | 39 | 3000 | 4.7 | 0.11 |
| Φ = 30 mm | 11 | 50 | 4300 | 11 | 0.25 |

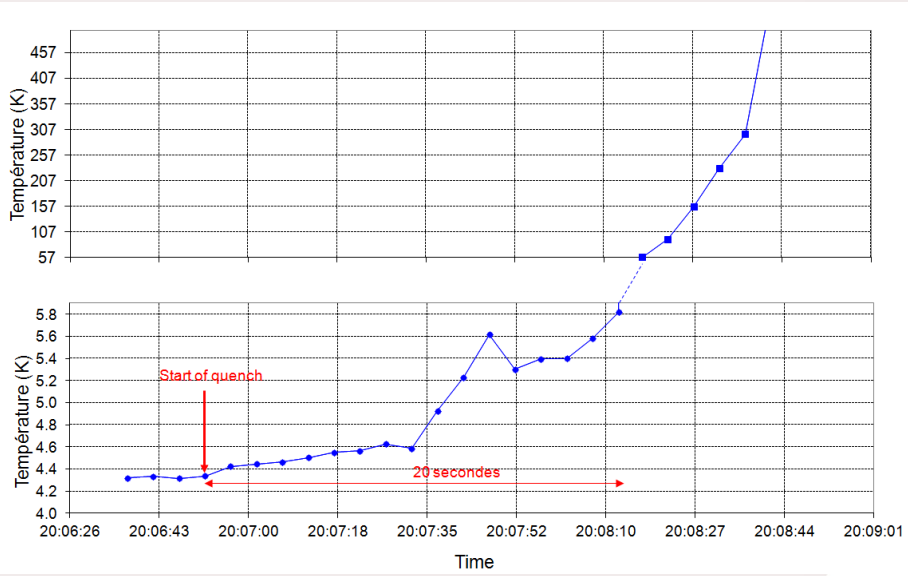
# SPIRAL2 TUNER (4)

➢ **Quench problematic :**

Cavity is strongly overcoupled
⇒ Quenched cavity has a Qo close to Qext
⇒ Significant RF power dissipated ~ 500W
⇒ If plunger is quenched, temperature increases very quickly.
⇒ Can be destructive if power not stopped within seconds.




**Temperature in plunger during a quench**

# SPIRAL2 TUNER (3)



➢ **Mechanical problem observed :**

Significant overshoot (~ 100 Hz) and hysteresis (< 200 Hz) when direction of motion is changed

⇒ frequency regulation impossible as bandwidth ~ 88 Hz.

Difficulty to identify and localize the problem.

⇒ Need to develop a technique to measure small frequency deviation at room temperature to ease troubleshooting

➢ Swing motion of plunger because of plays

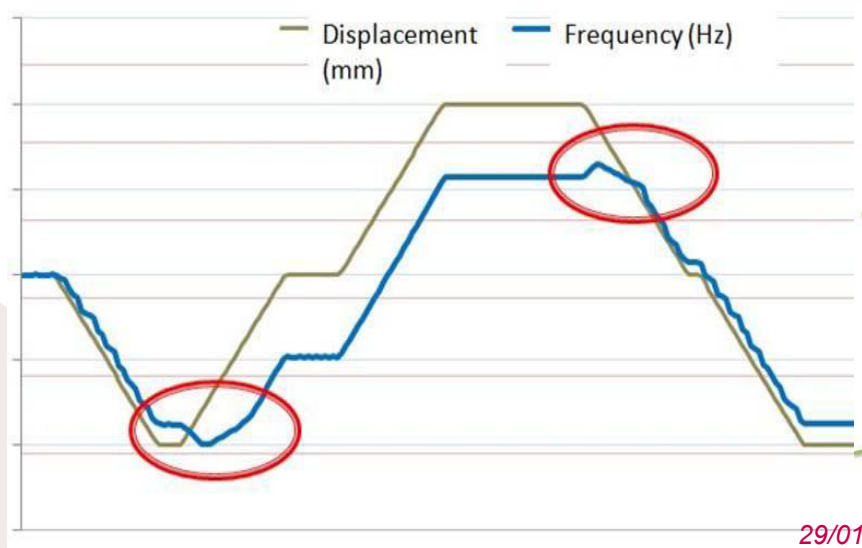
➢ Impossible to redesign the whole mechanism and annulate plays !

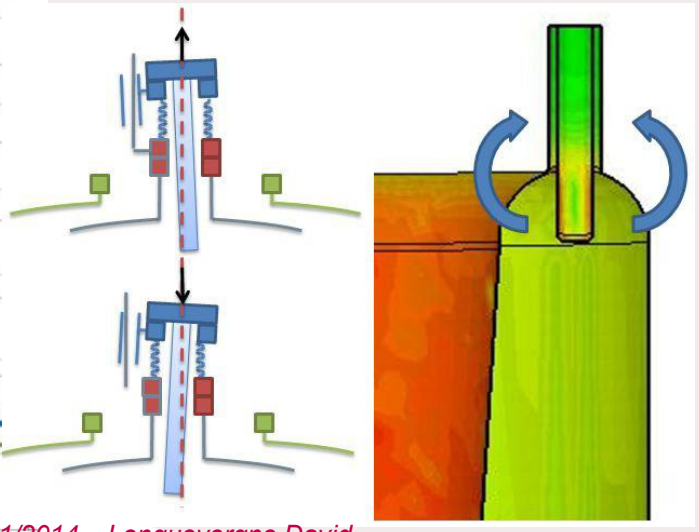
➢ Trick : force swing motion along field lines to avoid frequency change (Slater Th.)

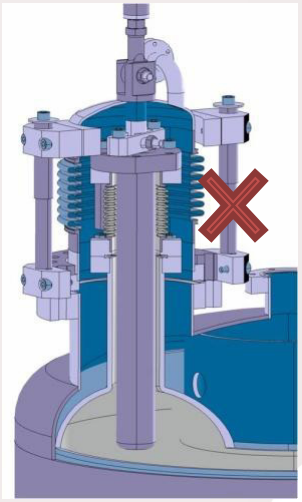
➢ Reduce hyperstatism.

⇒ Overshoot < 5 Hz.

⇒ Hysteresis < 20 Hz.



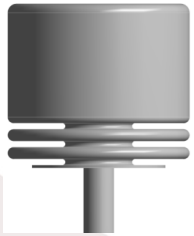


# CONCLUSION



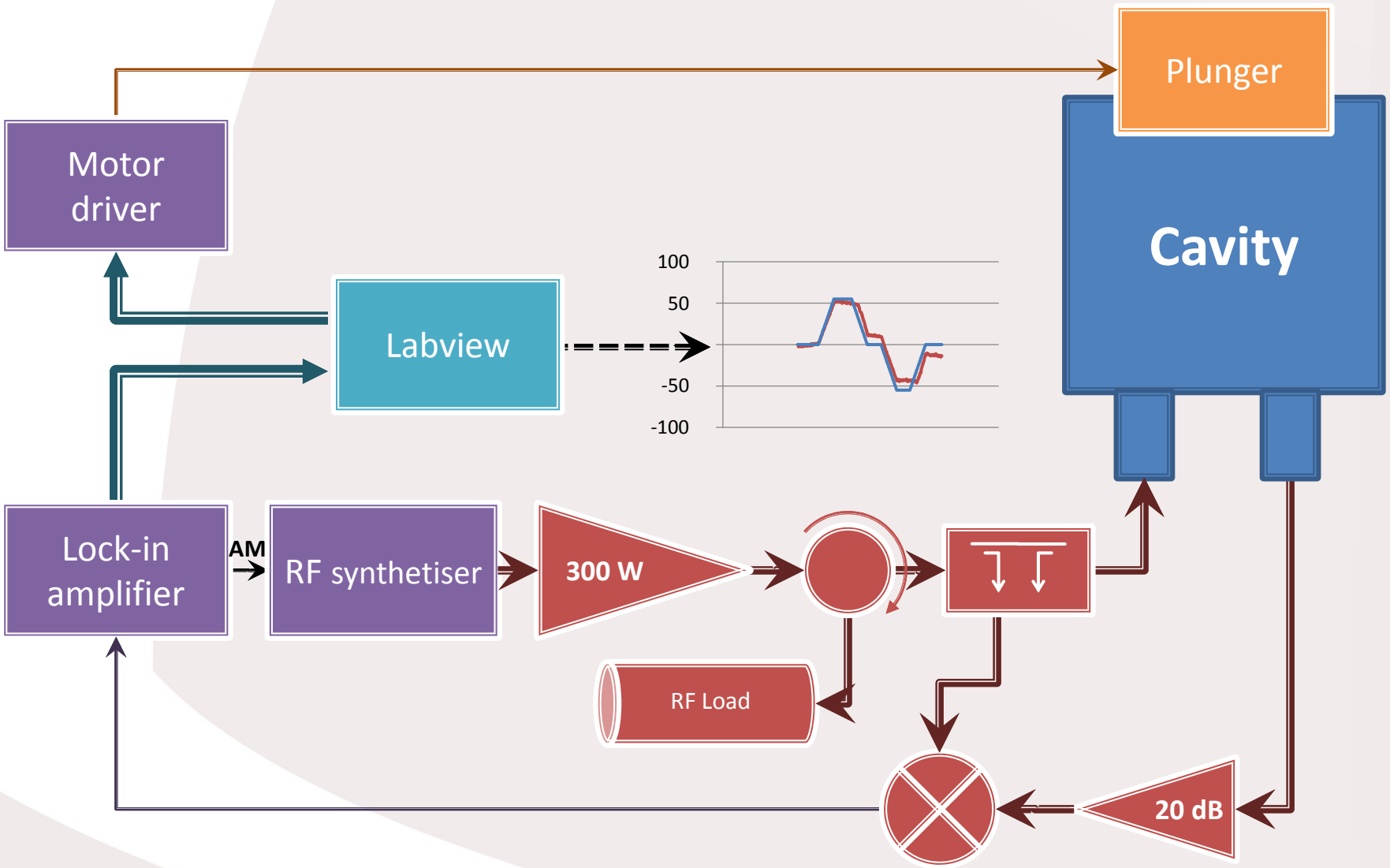
- ESS-Bilbao system offers many alternative
- IFMIF system abandoned but unfortunately lack of time
- MYRRHA system to be validated at 4K
- SPIRAL2 system is now successful !

- Moving plunger is a good alternative solution when
  - ⇒ Cavity is too stiff (QWR, HWR, Spoke, …)
  - ⇒ Compactness is required
  - ⇒ Flexibility is needed (capacitive or inductive, multiplicity)
- **BUT :**
  - ⇒ Lack of experience (dust generation ?)
  - ⇒ Require additional RF simulation (maximum field, residual field, losses, …)
  - ⇒ Require surface conditioning at the same standards as the cavity
  - ⇒ Maintenance more complicated (clean room required)
  - ⇒ Translation mechanism has to be well adjusted and very reliable



**Many Thanks to J.L Munoz (ESS-Bilbao), Guillaume Devanz (CEA-IRFU) and H. Podlech (IAP) for the material.**

# Thank you for your attention


Plunger
Motor driver
Cavity
Labview
100
50
-50
-100
Lock-in amplifier
AM
RF synthetiser
300 W
RF Load
20 dB