A COLD TUNER SYSTEM WITH MOBILE PLUNGER

ESS-BILBAO, IFMIF, MYRRHA AND SPIRAL2
OUTLINE

- Mobile plunger System presentation
- ESS-Bilbao System
- IFMIF System
- MYRRHA 325MHz CH Cavity
- SPIRAL2 System
- CONCLUSION
EXAMPLES OF TUNING SYSTEMS

By deformation (most used)

By insertion

Variable reactance

Spiral2 tuner.
Scissors Jack tuner
Blade tuner.

Isac2 tuner, Triumf.

ESS- Bilbao tuner
ATLAS upgrade

ESS Spoke tuner
ReA3 tuner
Spiral2 tuner.
MYRRHA CH cavity tuner.

26/09/2013 – Longuevergne David
## PROS AND CONS

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

\[ \beta = 0.39 \text{ Double Spoke} \]
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.
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.
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.
2 Niobium bellow tuners
- Sensitivity ~ 125 kHz/mm
- Fast tuner $\Delta F=130$Hz, slow tuner $\Delta F=130$kHz
- Optimized to limit multipacting in bellow
- Cavity and tuners have been built
- To be tested at 4K
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
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 only if
Surface treatment of plunger = Surface treatment of cavity
## SPIRAL2 TUNER (3)

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Static detuning (kHz)</th>
<th>Dynamic detuning (Hz)</th>
<th>Additional losses (%) @ 6.5 MV/m</th>
<th>Magnetic field at flange (mT)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min (10mm)</td>
<td>Max (50 mm)</td>
<td>+/- (4 mm)</td>
<td></td>
</tr>
<tr>
<td>Φ = 20 mm</td>
<td>5</td>
<td>25</td>
<td>1900</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.05</td>
</tr>
<tr>
<td>Φ = 25 mm</td>
<td>8</td>
<td>39</td>
<td>3000</td>
<td>4.7</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>0.11</td>
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<tr>
<td>Φ = 30 mm</td>
<td>11</td>
<td>50</td>
<td>4300</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.25</td>
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Quench problematic:

Cavity is strongly overcoupled
⇒ Quenched cavity has a $Q_0$ close to $Q_{ext}$
⇒ Significant RF power dissipated ~ 500W
⇒ If plunger is quenched, temperature increases very quickly.
⇒ Can be destructive if power not stopped within seconds.
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