SSR2 beta 0.47 and 0.51 comparison

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### Table of main parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>SSR2 FNAL</th>
<th>SSR2 for RISP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimal beta</td>
<td>0.471</td>
<td>0.5149</td>
</tr>
<tr>
<td>Aperture [mm]</td>
<td>40</td>
<td>50</td>
</tr>
<tr>
<td>Frequency [MHz]</td>
<td>325</td>
<td>325</td>
</tr>
<tr>
<td>Effective length $2\beta \lambda/2$ [m]</td>
<td>0.4348</td>
<td>0.4753</td>
</tr>
<tr>
<td>$E_{peak}/E_{acc}$</td>
<td>3.45</td>
<td>3.53</td>
</tr>
<tr>
<td>$B_{peak}/E_{acc}$ [mT/(MV/m)]</td>
<td>6.107</td>
<td>6.25</td>
</tr>
<tr>
<td>$G$ [Ohm]</td>
<td>112.98</td>
<td>118.65</td>
</tr>
<tr>
<td>$R/Q$ [Ohm]</td>
<td>289.94</td>
<td>275.93</td>
</tr>
<tr>
<td>$Q_0 @ Rs=10$ nOhms</td>
<td>1.129E+10</td>
<td>1.186E+10</td>
</tr>
<tr>
<td>$P_d$ [W] @ Max en. gain</td>
<td>6.5</td>
<td>8.6</td>
</tr>
<tr>
<td>Max $E_{peak}$ [MV/m]</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Max $B_{peak}$ [mT]</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>Max energy gain [MeV]</td>
<td>4.98</td>
<td>5.32</td>
</tr>
<tr>
<td>Max gradient [MV/m]</td>
<td>11.47</td>
<td>11.2</td>
</tr>
</tbody>
</table>
Transit time factor

- SSR2 cavity will be used from 38 to 180 MeV corresponding to a beta range from 0.276 to 0.544 (H-). The picture below compares SSR2 40 mm aperture FNAL and SSR2 50 mm aperture for RISP TTF. TTF is lower for the latest version but the achievable energy gain is higher (see previous slide).
- SSR2 beta 0.51 requires higher energy in the cavity to maintain acceleration in the first part of the beta range.
Number of cavities in PIP-II

- The total number of SSR2 needed for PIP-II section has been estimated with a simple model, it predicts 38 cavity for the actual design (35 SSR2 beta 0.51 are currently used in the lattice).
Field asymmetry vs beta

- Field asymmetry in the whole beta domain of PIP-II are shown below for both SSR2 designs having beta optimal 0.47 and 0.51.
- The higher beta design shows more quadrupole asymmetry, increasing the accelerating gaps does not help reducing transverse fields components.
MP Simulations

- Multipacting simulations in CST particle studio show that the two designs behave similarly, MP could be an issue and the EM design should take that into account.
- SSR2 beta 0.47 shows some very narrow MP barrier after 10.7 MV/m but the max operating gradient is set to 11.47 MV/m, so they do not seem to interfere with operation.
Two SSR2 designs have been developed:

- **SSR2-v0**: $\beta = 0.47$. The resonator was designed to be part of Project X under design at Fermilab.
- **SSR2-Korea**: $\beta = 0.51$. SSR2-v0 was modified to meet requirements of Project X and RISP (Korea)

**RF volume of SSR2-v0**

- Beam pipe aperture 40 mm
- 4 coupler ports
- 541.4 mm inside diameter

**RF volume of SSR2-Korea**

- Beam pipe aperture 50 mm
- 2 coupler ports
- 560.8 mm inside diameter
- 2.8 mm RRR Nb shell
- 2 stiffening rings on each endwall (reactor grade Nb)
- 6 beam pipe ribs on each side (reactor grade Nb)
- 4 mm thick RRR Nb collar at the spoke
SSR2-v0 Endwall stiffness:

- Endwall sensitivity to axial deformations: \( \frac{df}{dL} = 300 \text{ kHz/mm} \)
- Endwall stiffness for an axial load applied to the beam pipes: \( 20.5 \text{ kN/mm} \)
- Required coarse tuning range: 135 kHz

\[
F_{\text{tuning}} = \frac{k}{\text{sensitivity range}} \approx 9.5 \text{ kN}
\]
SSR2-v0 Dressed Cavity:

Helium vessel made of 316L 6 mm thick
Design aimed to reduce the system sensitivity to pressure fluctuations of the He bath \((df/dp)\)
No detailed design at the moment

The interfaces between the Helium Vessel and the cavity are:
- 2 beam pipes
- 4 coupler ports
- 1 transition ring

A bellows is introduced to improve the \(df/dp\) performance of the dressed resonator and to allow tuning.
- 2.8 mm RRR Nb shell
- 1 stiffening rings on each endwall (reactor grade Nb)
- 6 beam pipe ribs on each side (reactor grade Nb)
- 4 mm thick RRR Nb collar at the spoke
SSR2-Korea Endwall stiffness:

- Endwall sensitivity to axial deformations: \( \frac{df}{dL} = 228.7 \text{ kHz/mm} \)
- Endwall stiffness for an axial load applied to the beam pipes: 19.5 kN/mm
- Required coarse tuning range: 135 kHz

\[
F_{\text{tuning}} = \frac{k}{\text{sensitivity \ range}} \approx 12 \text{ kN}
\]
SSR2-v0 Dressed Cavity:

Helium vessel made of 316L 6 mm thick
Design aimed to reduce the system sensitivity to pressure fluctuations of the He bath \( \frac{df}{dp} \)

The interfaces between the Helium Vessel and the cavity are:
- 2 beam pipes
- 4 coupler ports
- 1 transition ring

A bellows improves the \( \frac{df}{dp} \) performance of the dressed resonator and to allow tuning.

\[
\frac{df}{dp} \quad [\text{Hz/mbar}]
\]

5.6

-8.4 Hz/mbar

* This is old design of Helium Vessel with flanges with blind holes, further design changed them with through holes.
Conclusions

<table>
<thead>
<tr>
<th></th>
<th>SSR2 0.47</th>
<th>SSR2 0.51</th>
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</thead>
<tbody>
<tr>
<td>EM parameters</td>
<td>Slightly better</td>
<td>Slightly worse</td>
</tr>
<tr>
<td>Quadrupole Field</td>
<td>Slightly better</td>
<td>Slightly worse</td>
</tr>
<tr>
<td>Multipacting</td>
<td>Need to mitigate</td>
<td>Need to mitigate</td>
</tr>
<tr>
<td>Acc.Eff.(TTF@38-180 MeV)</td>
<td>Slightly more uniform</td>
<td>Less effective at low $\beta$</td>
</tr>
<tr>
<td>Mechanical design</td>
<td>Need to be changed (MP)</td>
<td>Need to be changed (MP)</td>
</tr>
<tr>
<td>Sensibility to tuning (df/dl)</td>
<td>Slightly better</td>
<td>Slightly worse</td>
</tr>
</tbody>
</table>

- Preliminary decision pends towards lower beta cavity design (0.47).
- MP still needs to be mitigated (cavity shape changes), start working on low beta (0.47).
- Final choice will be done later.