Third Harmonic Cavity Status

- General parameters
- Cavity design
- Main coupler calculation
- HOM analysis and HOM coupler design
- Lorentz Forces and Stress analysis
- Summary
Third harmonic cavity (3.9GHz) was proposed to compensate nonlinear distortion of the longitudinal phase space due to cosin-like voltage curvature of 1.3 GHz cavities.

Parameter List for 3.9 GHz 9-cell cavity:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of cavities</td>
<td>4</td>
</tr>
<tr>
<td>Active Length</td>
<td>0.346 m</td>
</tr>
<tr>
<td>Gradient</td>
<td>14 MV/m</td>
</tr>
<tr>
<td>Phase</td>
<td>-179 deg</td>
</tr>
<tr>
<td>R/Q</td>
<td>778(750) Ω</td>
</tr>
<tr>
<td>$E_{\text{peak}}/E_{\text{acc}}$</td>
<td>2.26</td>
</tr>
<tr>
<td>$B_{\text{peak}}$ ($E_{\text{acc}}=15$ MV/m)</td>
<td>0.0727 T</td>
</tr>
<tr>
<td>Q_{ext}</td>
<td>9.5e+5</td>
</tr>
<tr>
<td>BBU limit for HOM, Q</td>
<td>&lt;1.e+5</td>
</tr>
<tr>
<td>Total energy</td>
<td>20 MeV</td>
</tr>
<tr>
<td>Beam current</td>
<td>9 (12) mA</td>
</tr>
</tbody>
</table>

**Steps to build 3rd harmonic cavity:**

- Cu model
- Main Coupler
- HOM coupler
- Nb model
- He vessel with tuner
- Cryostat
Cavity with increased end-cell iris (30→40mm)

<table>
<thead>
<tr>
<th></th>
<th>mid</th>
<th>end</th>
<th>end1</th>
</tr>
</thead>
<tbody>
<tr>
<td>h</td>
<td>19.217</td>
<td>same</td>
<td>same</td>
</tr>
<tr>
<td>a</td>
<td>15</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>b</td>
<td>35.787</td>
<td>same</td>
<td>same</td>
</tr>
<tr>
<td>ry</td>
<td>6</td>
<td>same</td>
<td>same</td>
</tr>
<tr>
<td>rz</td>
<td>4.5</td>
<td>same</td>
<td>same</td>
</tr>
<tr>
<td>Ry</td>
<td>15</td>
<td>same</td>
<td>same</td>
</tr>
<tr>
<td>Rz</td>
<td>13.6</td>
<td>12.08</td>
<td>14.4</td>
</tr>
</tbody>
</table>

Axis E_z-field

Surface E-fields
Cups production and QC measurements

- Dies for mid-cell (Rutgers Univ)
- Coin for iris shaping
- Dies for end-cell (delayed)
- 2+6 (+24) Cu cups
- 4 (+2) Nb cups
- Mechanical and RF QC done on each step
Produced 4 Nb cups 2.8mm thickness for welding test (Oct, 2002)
Blanks for 2 more cups to check profile and RF QC, then anneal and re-stamp.
Mechanical and RF quality control

Copper Cups  
#A,#B, #1-6  
1. Stamped and coined  
2. Mechanical and RF QC  
3. #1-6 Annealed, re-stamped, re-coined  
4. Mech and RF QC, facing  
5. Brazed 2 dumbbells: (1-2) and (4-5)

Results of RF measurements

Design  
F₀=3742.4  Fₚ=3900

#B Stamped, Coined  
F₀=3749.3  Fₚ=3916.1

HFSS calculation  
F₀=3749.5  Fₚ=3914.1

#1 Annealed St&Co  
F₀=3726.4  Fₚ=3887.8

HFSS calculation  
F₀=3724.9  Fₚ=3885.8

Brazed dumbbells:

(#1-#2)  
F₀=3724.9  Fₚ=3885.8

(#4-#5)  
F₀=3721.0  Fₚ=3880.4

(1-2)+(4-5)  
F₀=3723.1  Fₚ=3883.2

Repeatability ±(2-2.5) MHz (6 pcs)
Dumbells

Two dumbells brazed in vacuum furnace (65Cu/35Au)

Carbon support is used for aligning and brazing of cups
RF and mechanical QC

**RF set-ups**

- Cups and dumbell RF QC, (fundamental and HOM modes)
- Plunger measurement and cavity tuning (CKM set-up upgrading)
- Bead-pull measurements (NLC set-up)
Main Coupler Design

P = 46 (7.5) kW

DESY type window in coax 30mm/13mm

S11 = 0.01

S11 = 0.03

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Status of 3rd harmonic cavity
Coaxial coupler (HFSS simulation)

Designed \( Q_{\text{ext}} = 9.5 \times 10^5 \)

- Coax geometry: \( \varnothing=30\text{mm}, Z=50\ \Omega \), antenna -5mm inside tube. Second antenna (from right) is used as pick-up.
- Most calculations have done for 3cell geometry. After optimization was checked for 9-cell. \( (Q_{9\text{cell}} = 3 \times Q_{3\text{cell}}) \).
- To provide needed \( Q_{\text{ext}} \), coupler should be placed very close to cavity (25mm) for geometry on the top picture. Increasing end-cell iris from 15mm to 20mm (bottom geometry) allow move coupler away from the cavity (35mm).
Waveguide type coupler

HFSS model

\( dW_{opt} = 20\text{mm} \)

\( 9\text{cells } dW = 20, dL = 30 \)

\( 9\text{cells } dW = 32, dX = 20 \)

\( 3\text{cells } dW = 32.33, dX = 10 \text{mm} \)

\( 3\text{cells } dW = 20, dL = 10 \text{mm} \)

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High Order Modes (HFSS simulation)

Transverse (R/Q) (HFSS)

- EE-boundaries
- MM-boundaries

Graph showing R/Q (Ohm/cm²) versus frequency (MHz) with peaks at different frequencies and boundaries indicated.
HOM coupler design proposed by J. Sekutowich (scaling of TTF design). We re-calculated and optimized this design (Initial design had 3.32 rejection frequency)

Rejection 3.9GHz
Cavity excited by the beam (2mm off-set)

F = 3900
Q_{ext} = 1 \times 10^6

2^{nd} dipole band
Q_{ext} < 1 \times 10^4

3^{nd} dipole band
Q_{ext} < 1 \times 10^4

Tube

F = 5520.1
Q = 25000

Monopole, Q = 2.5 \times 10^4

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Status of 3^{rd} harmonic cavity
Frequency shift due to Lorentz forces

<table>
<thead>
<tr>
<th>Thickness (mm)</th>
<th>∆F (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td>200</td>
</tr>
<tr>
<td>2.8</td>
<td>90</td>
</tr>
</tbody>
</table>

Displacement of the cell wall due to Lorentz force. Wall thickness T=1.5 mm.

• HFSS simulation of half cell
  - $P = \frac{(\mu_0 H^2 - \varepsilon_0 E^2)}{4}$
  - data exchange (HFSS-ANSYS)

ANSYS simulation of stresses in half cell
  - different wall thickness
  - Young modulus, Poisson’s ratio

• Frequency shift due to Lorentz force (Slater’s Theorem)
  - $\Delta F = \frac{1}{4W} \int \frac{F dV_{HE}}{\Delta V}$

$\Delta F$ is the frequency shift due to Lorentz forces, $F$ is the force, $W$ is the width of the cell, $\Delta V$ is the change in volume, and $dV_{HE}$ is the differential volume of the higher-order mode.
Summary

- **Cavity design**
  - Start production of cups, dumbells, tubes, couplers
  - Mechanical and RF QC for production feed-back
  - Tooling and RF set-ups in progress

- **Main coupler**
  - Calculation done
  - Design in progress

- **HOM analysis and HOM coupler design**
  - HOM analysis in progress
  - HOM coupler design is finished, Cu model is ordered (delivery Nov, 2002)

- **Lorentz Forces and Stress analysis** done.

**team:**

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**help:** V.Yarba, D.Finley, L.Bellantoni, D.Snee, T.Arkan, H.Carter, B.Smith, A.Rowe.