ERL Cavity for High Currents

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Motivation: ecooling@RHIC

- Cooling $Au$ beams at 100 GeV requires $\sim 54$ MeV $e^-$
- High current ($> 200 mA$) and high bunch charge (10-20 nC)
- Replenish $e^-$ every cycle - energy recovery
BNL 5-Cell ERL Cavity

- 4" RF shielded gate valve
- HOM ferrite assembly
- Tuner location
- 2K main line
- Space frame support structure
- Cavity assembly
- Vacuum vessel
- 2K fill line
- Outer magnetic shield
- Thermal shield
- Inner magnetic shield
- He vessel
- Fundamental Power Coupler assembly
Criteria for Cavity Design

- **Fundamental Mode:**

  \[
  \frac{E_{\text{peak}}}{E_{\text{acc}}} (\downarrow), \quad \frac{H_{\text{peak}}}{E_{\text{acc}}} (\downarrow), \quad \frac{R_s}{(R/Q)G} (\downarrow)
  \]

- **Higher Order Modes:**
  - HOM Power & Kick \((k_{||}, k_{\perp})\)
    \[
    P_{\text{avg}} = 2k_{||}IQ
    \]
  - BBU - Trapped Modes \((k_{\text{cell-cell}}, N_{\text{cells}}, Q_{\text{ext}})\)
    \[
    I_{\text{thr}} = \frac{-2prc^2}{e \left( \frac{R}{Q} \right) Qe\omega_m} \left[ M_{12}sin(\omega_{mtr}) \right]
    \]
  - Efficient extraction of HOMs
Cavity Shape Optimization

- Iris Radius, $R_{iris}$: 8.5 [cm]
- Wall Angle, $\alpha$: 25 [deg]
- Equatorial Ellipse, $R = \frac{b}{A}$: 1.0
- Iris Ellipse, $r = \frac{b}{a}$: 1.1
- Cav. wall to iris plane, $d$: 2.5 [cm]
- Half Cell Length, $L = \frac{\lambda \beta}{4}$: 10.65 [cm]
- $H = D - (R_{iris} + b + B)$: 4.195 [cm]
- Cavity Beta, $\beta = \frac{v}{c}$: 1.0
Trapped Modes

Frequency Difference

\[ \Delta f = 30 \text{MHz} \quad (2.4 \text{ GHz}) \]

\[ \Delta f = 13 \text{MHz} \quad (1.4 \text{ GHz}) \]

Number of Cells

no e-m fields at HOM couplers positions

e-m fields at HOM couplers positions
Beam Pipe Transition

- Damping HOMs
  - Enlarged BP (KEK, BNL)
  - Loop couplers (TESLA, CEBAF)

- Minimize fundamental leakage (> 10 W).

- Minimize FPC kick
  - Enlarged BP (KEK, BNL)
  - Symm. couplers

- Cold to warm transition (Counter Flow of He)
HOM Extraction & Damping

Ferrite Absorbers
Broadband (300 K)

(Cornell Type)

Loop Couplers
Resonant Circuit (2 K)

(TESLA Type)
## BNL High Current Cavity

### Main Parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency RHIC Harmonic</td>
<td>703.75 MHz</td>
</tr>
<tr>
<td>Number of cells</td>
<td>5</td>
</tr>
<tr>
<td>Active cavity length</td>
<td>1.52 m</td>
</tr>
<tr>
<td>Iris Diameter</td>
<td>17 cm</td>
</tr>
<tr>
<td>Beam Pipe Diameter</td>
<td>24 cm</td>
</tr>
<tr>
<td>$G$ (Ω)</td>
<td>225</td>
</tr>
<tr>
<td>$R/Q$</td>
<td>403.5 Ω</td>
</tr>
<tr>
<td>$Q$ BCS @ 2K</td>
<td>$4.5 \times 10^{10}$</td>
</tr>
<tr>
<td>$Q_{ext}$</td>
<td>$3 \times 10^6$</td>
</tr>
<tr>
<td>$E_p/E_a$</td>
<td>1.97</td>
</tr>
<tr>
<td>$H_p/E_a$</td>
<td>5.78 [mT/MV/m]</td>
</tr>
<tr>
<td>cell to cell coupling</td>
<td>3%</td>
</tr>
<tr>
<td>Sensitivity Factor ($N^2/\beta$)</td>
<td>833</td>
</tr>
<tr>
<td>Field Flatness</td>
<td>96.5 %</td>
</tr>
<tr>
<td>Lorentz Detuning Coeff</td>
<td>1.2 [Hz/MV/m]</td>
</tr>
<tr>
<td>Lowest Mech. Resonance</td>
<td>96 [MHz]</td>
</tr>
<tr>
<td>$k_{</td>
<td></td>
</tr>
<tr>
<td>$k_{\perp}$ (σz – 1 cm)</td>
<td>3.1 [V/pC/m]</td>
</tr>
<tr>
<td>HOM Power (10-20 nC)</td>
<td>0.5-2.3 [kW]</td>
</tr>
</tbody>
</table>

![Field Flatness](image.png)
HOMs: Simulation & Measurements

**Frequency Domain**

- Monopole Modes
  - TM010
  - MAFIA Measurement

- Dipole Modes
  - MAFIA Measurement

**Time Domain**

- Monopole Modes
  - TM010
  - MAFIA Measurement

- Dipole Modes
  - MAFIA Measurement
Threshold Current > 2 Amps
BNL eCooling Configuration - 4 Cavities - 54 MeV
(Numerical Codes from JLAB)
Summary

- Design, fabrication and prototype testing is complete.

- Nb cavity is being prepared for surface chemical treatment.

- Cryomodule assembly at BNL (Dec. 2005) and horizontal testing to take place early next year.

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