Design and Fabrication of The RHIC Electron-Cooling Experiment High Beta Cavity and Cryomodule

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Outline

- Overview
- Cryomodule Configuration
- Superconducting Cavity Analysis, Design, Fabrication
- Cavity Testing
- Cavity Hermetic String Assembly
- Cryomodule Buildup
- Summary & Status
Overview & Design Features  

- **Electron Cooling Experiment Cavity – Test in BNL High Current ERL**
  - Cavity Physics Design done by Brookhaven. Cavity and cryomodule Engineering and Fabrication by AES
  - BBU Threshold > 1.8 Amps. Design Current of 500 mA
  - Large Cavity Bore & Beam Pipes ➔ No Trapped Modes
  - Ferrite Lined HOM Absorbers in Beamline Upstream and Down
  - Coaxial Fundamental Power Coupler ➔ <50 kW CW with Energy Recovery
Cryomodule Assembly Configuration

e-Cooling High $\beta$ Cavity & Cryomodule

Dimensions in inches

39,000 Diameter Vacuum Vessel

Beam Axis
Finite element models were used to evaluate the thermal, structural, and RF behavior thermal load, pressure load, and loads from the cavity tuner.

Cavity is inherently stiff due to large angle cell faces → no iris stiffeners, 3mm niobium thickness.

1st and 2nd mode 96.8 Hz

3rd mode 203.5 Hz

4th and 5th mode 213.6 Hz

ELECTROMAGNETIC ANALYSIS
LORENTZ FORCE DETUNING

Tuner Load and Frequency Shift

Load
Freq. shift

Cavity Displacement (in)

0 0.02 0.04 0.06 0.08 0.1 0.12 0.14 0.16 0.18

0 1000 2000 3000 4000 5000 6000 7000

0 -50 -100 -150 -200 -250 -300 -350 -400 -450
RF Analysis / Cavity Configuration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cavity Frequency</td>
<td>703.781 MHz</td>
</tr>
<tr>
<td>Energy Gain (E_{0TL})</td>
<td>15 MV</td>
</tr>
<tr>
<td>E_0 (Iris to Iris, L = 1.065m)</td>
<td>20.356 MV/m</td>
</tr>
<tr>
<td>Max Design E Field at Iris, E_{peak}</td>
<td>27.861 MV/m</td>
</tr>
<tr>
<td>Max Design H Field at Wall, H_{peak}</td>
<td>64870.6 A/m or 81.5 mT</td>
</tr>
<tr>
<td>Design Stored Energy</td>
<td>126,931 Joules</td>
</tr>
<tr>
<td>Residual Resistivity used in SUPERFISH</td>
<td>10 nOhms</td>
</tr>
<tr>
<td>Q_0 at 2K</td>
<td>1.51 \times 10^{10}</td>
</tr>
</tbody>
</table>

RF Parameters as calculated by SUPERFISH

- Nb55Ti Helium Vessel
- Dish Both Ends
- RF Pick-Up Port
- Nb55Ti End Flange Both Ends
- Gusset stiffeners
- Fundamental Power Coupler Port

Putting Accelerator Technology to Work
Low Power RF Test Cavities

- AES built two copper models for design verification & tooling development. Models formed and welded using same tools & techniques.
- BNL test program verified HOM performance and investigated potential “superstructure” configurations.

5-CELL 703.75 MHz COPPER LOW POWER RF TEST CAVITIES IN TUNING FIXTURE

~3.3 Meters
Niobium Cavity Fabrication

COMPLETED CAVITY ASSEMBLY IN TUNING FIXTURE AT AES

CAVITY PRE-WELD ASSEMBLY
Vertical Test Results (Done at JLAB)

\[ Q_0 \text{ vs. } E_{\text{acc}} \]

- Req'd Operational Performance
- Performance Goal

\[ 1.00 \times 10^9 \quad 1.00 \times 10^{10} \quad 1.00 \times 10^{11} \]

\[ 0 \quad 5 \quad 10 \quad 15 \quad 20 \quad 25 \]

Eacc (MV/m)
Cavity String Assembly I

Warm-to-Cold Beam Pipes

Helium Vessel Heads

Helium Vessel Cylinder

Fundamental Power Coupler
Cavity String Assembly II

Completed Hermetic String at JLAB

Putting Accelerator Technology to Work
Space Frame and Thermal Shield Installation

Magnetic shield assembly

Space frame/Thermal shield installation

Putting Accelerator Technology to Work
Space Frame and Thermal Shield Installation

e-Cooling High β Cavity & Cryomodule
Cryomodule Assembly

e-Cooling High $\beta$ Cavity & Cryomodule

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Putting Accelerator Technology to Work
Summary & Status

e-Cooling High β Cavity & Cryomodule

- A high-current SRF cavity for an Energy Recovery Linac has been designed by BNL and AES and fabricated by AES
- The cavity was cleaned and tested by JLAB with BNL personnel support
- Cavity performance exceeded goal of 20 MV/m at $Q_0 > 1 \times 10^{10}$ and far exceeded requirement of 15 MV/m at $Q_0 > 1 \times 10^{10}$
- Hermetic String assembled at JLAB with BNL personnel support and shipped to BNL
- BNL has recently completed Cryomodule assembly and unit is ready for installation in the ERL vault