Half-Wave Resonator Cryomodule Status

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DOE Independent Project Review of PIP-II
15 November 2016
Outline

• Scope of Work

• Half-Wave Resonator (HWR) Cryomodule Overview

• Deliverables:
  – FY17 Deliverables
  – FY18 Deliverables (aka the cryomodule)

• Current Status:
  – Cryomodule Assembly Preparation
  – Half-Wave Resonator Processing

• Schedule to Finish HWR Cryomodule
Scope of Work

• ANL will design, fabricate and make ready for FNAL a HWR cryomodule for the acceleration of 2 mA H⁻ beams from 2.1 to ≥10.3 MeV.
  – Comply with the Functional Requirements Specifications.
  – Satisfy both Argonne and Fermilab safety requirements. For example:
    • The solenoids have ASME U stamps.
    • The cavity safety review at Argonne with FNAL participation was passed on May 17, 2012. The design was approved.
    • The cryomodule safety review at Argonne with FNAL participation was held on August 30, 2012. The design was approved.
    • Our approach to safety was used as the basis for the IFMIF HWR cryomodule analyses and fabrication.

• ANL is committed to delivering a working, high-performance HWR cryomodule to FNAL.
HWR Cryomodule

- Conduction Cooled Leads (FNAL)
- Helium Manifold
- Helium Relief Port
- Sub-Atmospheric HTXG Output
- Cooldown Manifold
- Ti Strong-Back
- Slow Tuner Gas Heat Exchanger
- Half-Wave Resonator
- SC Solenoid
- Vacuum Manifold

2.2 m X 2.2 m X 6.2 m
## FY16 Deliverables

<table>
<thead>
<tr>
<th>Deliverables</th>
<th>Status</th>
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</thead>
<tbody>
<tr>
<td>1 Complete fabrication of magnet assemblies.</td>
<td>Finished</td>
</tr>
<tr>
<td>2 Complete fabrication of sub-systems (RF couplers, slow tuners and BPMs)</td>
<td>Finished</td>
</tr>
<tr>
<td>3 Engineering cool down of the cryomodule to 80 K.</td>
<td>Finished</td>
</tr>
<tr>
<td>4 Complete RF surface processing of 7 production cavities.</td>
<td>In Progress</td>
</tr>
<tr>
<td>5 Testing of 7 production cavities individually in the test cryostat.</td>
<td>In Progress</td>
</tr>
</tbody>
</table>

## FY17 & FY18 Deliverables

<table>
<thead>
<tr>
<th>Deliverables</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Assembly of the cryomodule.</td>
<td>Started</td>
</tr>
<tr>
<td>2 Vacuum and cryogenic testing of the cryomodule.</td>
<td>Not started</td>
</tr>
<tr>
<td>3 Delivery and installation at FNAL.</td>
<td>Not started</td>
</tr>
</tbody>
</table>
Current Status – Select Sub Systems

- BPM
- Beam Spool
- Cavity w/ Slow Tuner
- HWR, Solenoid, BPM & Cabling
- Beam Line Gate Valve
- Cavity Pick-Up Probe
- 2/5 K Heat Exchanger
Current Status – Coupler Development

- 10 kW Forward Power, 50 \( \Omega \), \( \phi \)50 mm Variable Co-Axial Coupler
- Coupler Comprised of 4 Regions With Separate Functions:
  - Warm RF Vacuum Window
  - Thermal Transition
  - Cold RF Vacuum Window
  - 2 – 5 – 70 K Variable Bellows

Coupler “Cold” Component Testing
Engineering Cool-Down Results

Cryomodule Alignment

Alignment Measurements

Cryomodule Assembly

Cool Down Data
Current Status – Cryomodule Preliminary Assembly

- Cooldown Manifold
- Helium Relief Port
- Ti Strong-Back
- Sub-Atmospheric HTXG
- Half-Wave Resonator
- Helium Manifold
- SC Solenoid

11/15/2016
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Half-Wave Resonator Processing & Testing

- Remaining tasks to finish the HWR processing and testing:
  - QTY = 3 of 9 half-wave resonators remain to be finished.
  - Hydrogen degas the half-wave resonators.
  - Light (~20 μm) electropolish after hydrogen degassing.
  - Resonators cleaning and assembly for testing.

- Finished pre-bake of the half-wave resonator baking frame parts on 26 October 2016.

- The next half-wave resonator hydrogen degassing is scheduled for the week of XX November 2016.

- We expect to finish all of this work by the end of February 2017.
Clean facilities for HPR & Assembly

1.3 GHz Cavity Electropolishing, 325 MHz BCP

325 MHz Spoke Cavity BCP

650 MHz Cavity Electropolishing

162 MHz Cavity Electropolishing
Half-Wave Resonator Testing

Goal: 2 W, Cavity Power

Diagram with plots showing accelerating gradient vs. E_{pk} (MV/m) and B_{pk} (mT) with V_{gain} (MV) on the axes.
Schedule to Finish – FY17

• Q2FY17:
  – Finish the cryomodule preliminary assembly.
  – Finish the hydrogen degassing and surface processing of the remaining 3 half-wave resonators.

• Q3FY17:
  – Finish testing of the 3 half-wave resonators.
  – Disassemble the preliminary cryomodule assembly.
  – Begin cleaning of all beam line components for the final cryomodule assembly.

• Q4FY17:
  – Finish cleaning all beam line components for the final cryomodule assembly.
  – Start cryomodule clean assembly.
Schedule to Finish – FY18

- Q1FY18:
  - Finish the cryomodule clean assembly.
  - Finish the cryomodule assembly.

- Q2FY18:
  - Final testing of the cryomodule at Argonne.
    - Leak test of all systems,
    - Operation of all sub-systems, and
    - Possible cold testing if time permits.
  - Transfer cryomodule to FNAL.
Argonne Personnel Working on This Project

• Senior Physicists:
  – M.P. Kelly (PHY).
  – P.N. Ostroumov (PHY).

• Physicist:
  – Z. Conway (PHY).
  – S.-h. Kim (PHY).

• Many thanks to FNAL for:
  – HWR Hydrogen Degassing
  – Cryomodule Hardware
  – Engineering Advice

• Engineers:
  – M. Kedzie (PHY).
  – T. Reid (HEP).
  – B. Guilfoyle (HEP).
  – A. Barcikowski (NE).
  – K. Wood (HEP).
  – F. Skrzecz (HEP).
  – W. Jansma (APS).

• Designers:
  – G. Cherry (NE).

• Technicians:
  – TBD.
Summary

• We are performing a preliminary assembly of the cryomodule now.

• Targeting a delivery sometime in the second quarter of FY18.