LEReC RF Commissioning during Run-17

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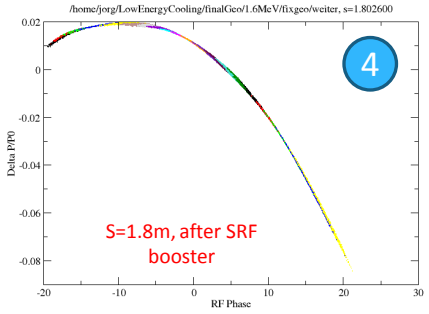
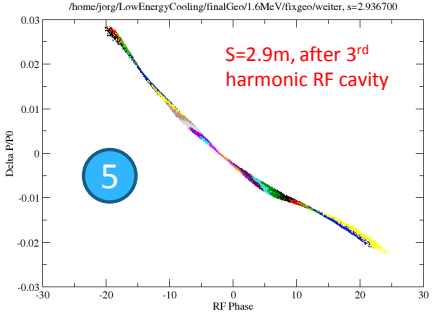
Outline

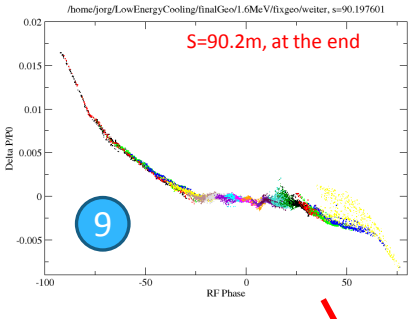
* Quick review of (or introduction to) LEReC RF systems
* What is scheduled to be installed this shutdown
* What we are planning for Run-17
* Beyond Run-17

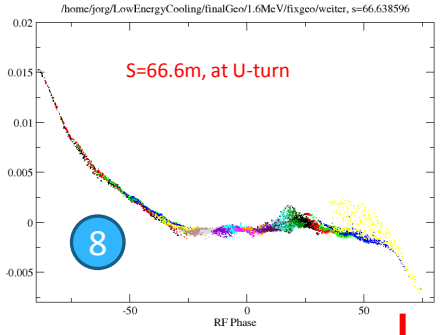
LEReC RF Systems

* We have four RF systems for accelerating and controlling the energy and energy spread of the electron beam used for cooling:
  * 704 MHz SRF Booster Cavity
    * Acceleration to desired beam energy (+ a bit more).
    * Produces an energy chirp to stretch the electron bunches (to reduce space charge effects).
  * 2.1 GHz Warm Cavity (3rd Harmonic)
    * Provides RF curvature correction to compensate 704 MHz curvature.
  * 9 MHz Warm Cavity
    * Provides a linear energy kick which varies along the macro-pulse bunch train.
    * Compensates the “linear” periodic transient beam loading, i.e. the energy loss in the cavity from the first to the last bunch of a macropulse.
  * 704 MHz Warm Cavity
    * Removes the energy chirp impressed by the 704 MHz Booster Cavity.

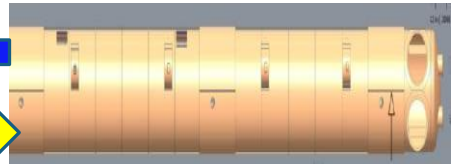








"Map" of longitudinal phase space evolution vs location.
(J. Kewisch, M. Minty)
(Further edited by KSS & KJM)



704 MHz SRF Booster

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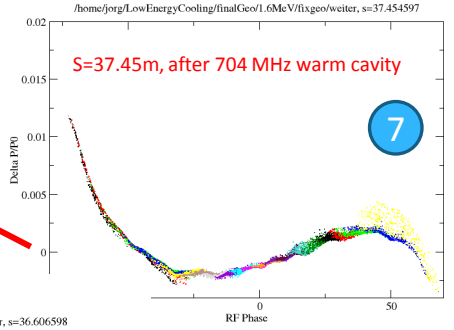
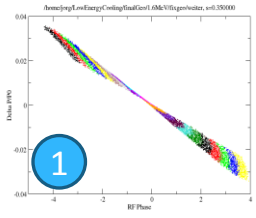
DC Gun

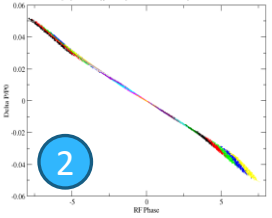
2.1 GHz Warm Cavity

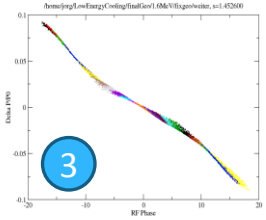
9 MHz Warm Cavity

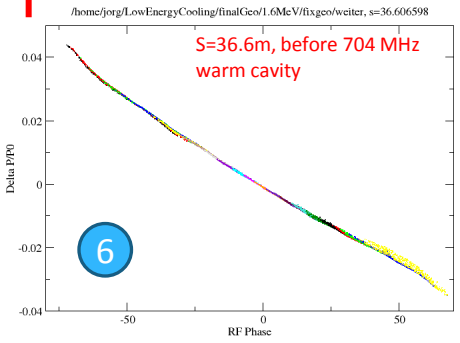
704 MHz Warm Cavity





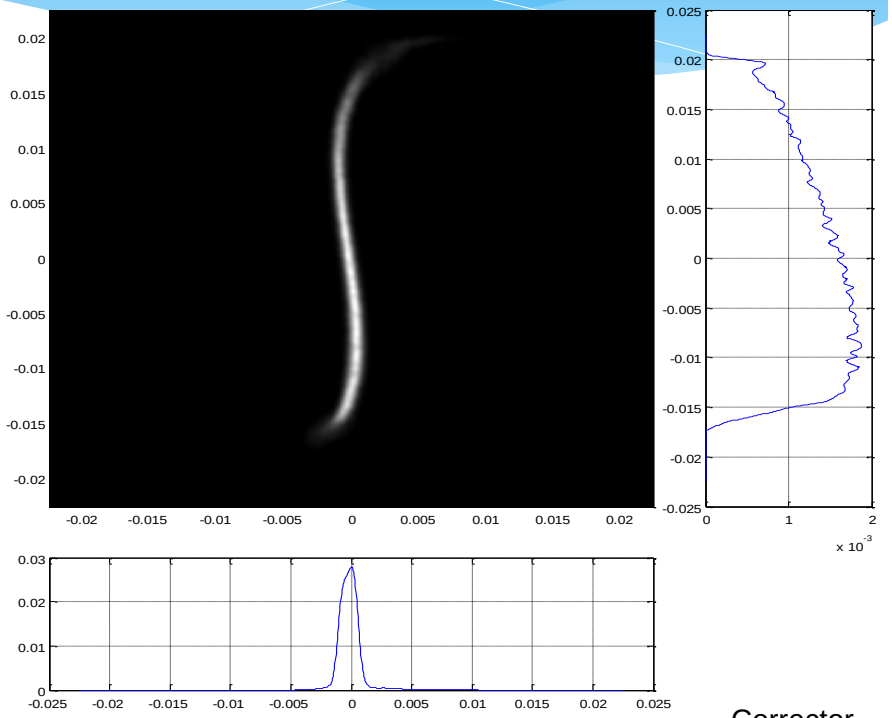


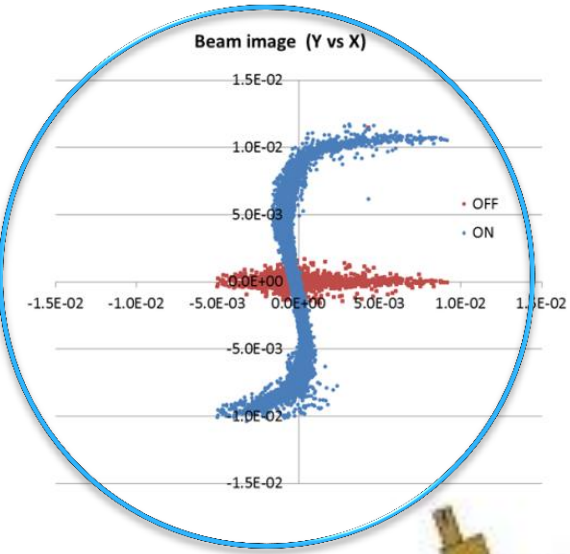


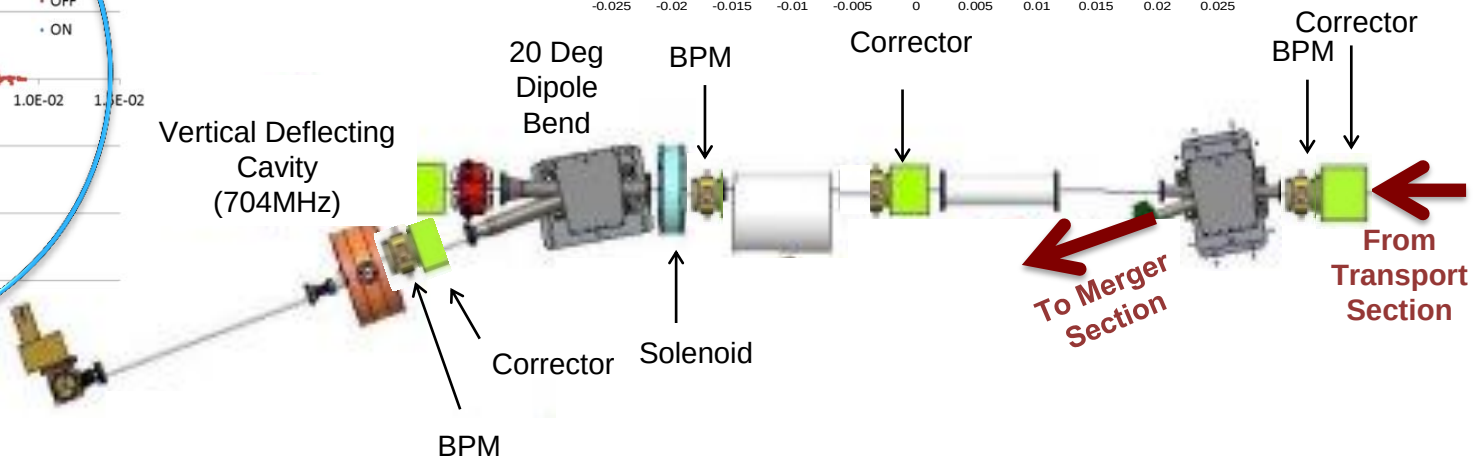


LEReC RF Systems

* We have one additional cavity:
  * 704 MHz Vertical Deflecting Cavity
    * Used in the diagnostic beamline for measuring longitudinal phase space.
    * Produces a vertical kick that depends on RF phase to streak beam on YAG screen. Dispersion from dipole provides (relative) energy measurement.





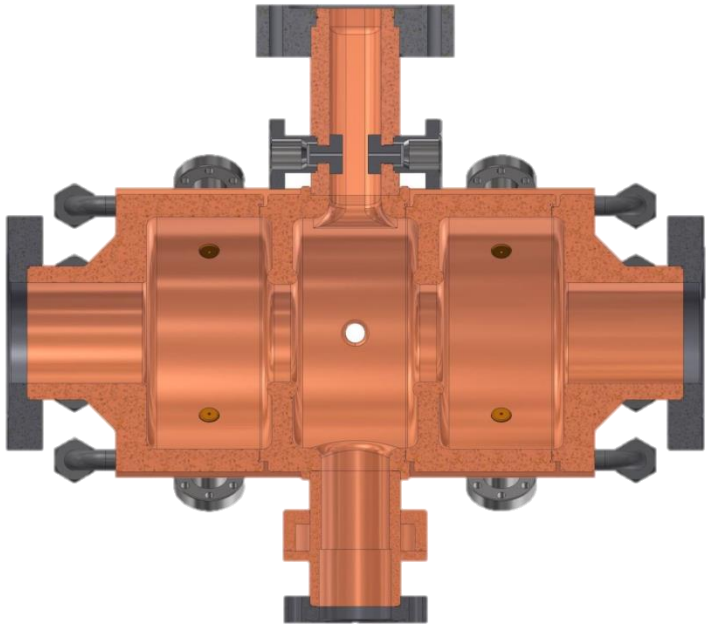


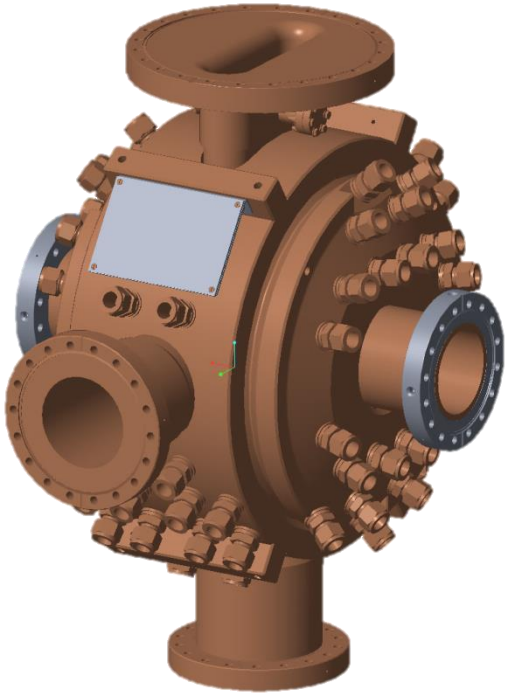
LEReC RF Systems

* Additional system functions:
  * Provide timing references for Instrumentation and Controls
  * Provide laser oscillator reference, laser macro-bunch structure timing, measure laser phase
  * Measure beam phase (relative to booster cavity RF) in the gun-to-booster transport, feedback to stabilize
  * Beam energy feedback based on absolute energy measurement from 3 BPMs around 180° dipole
  * Machine protection (MPS) interface

2016 Installations

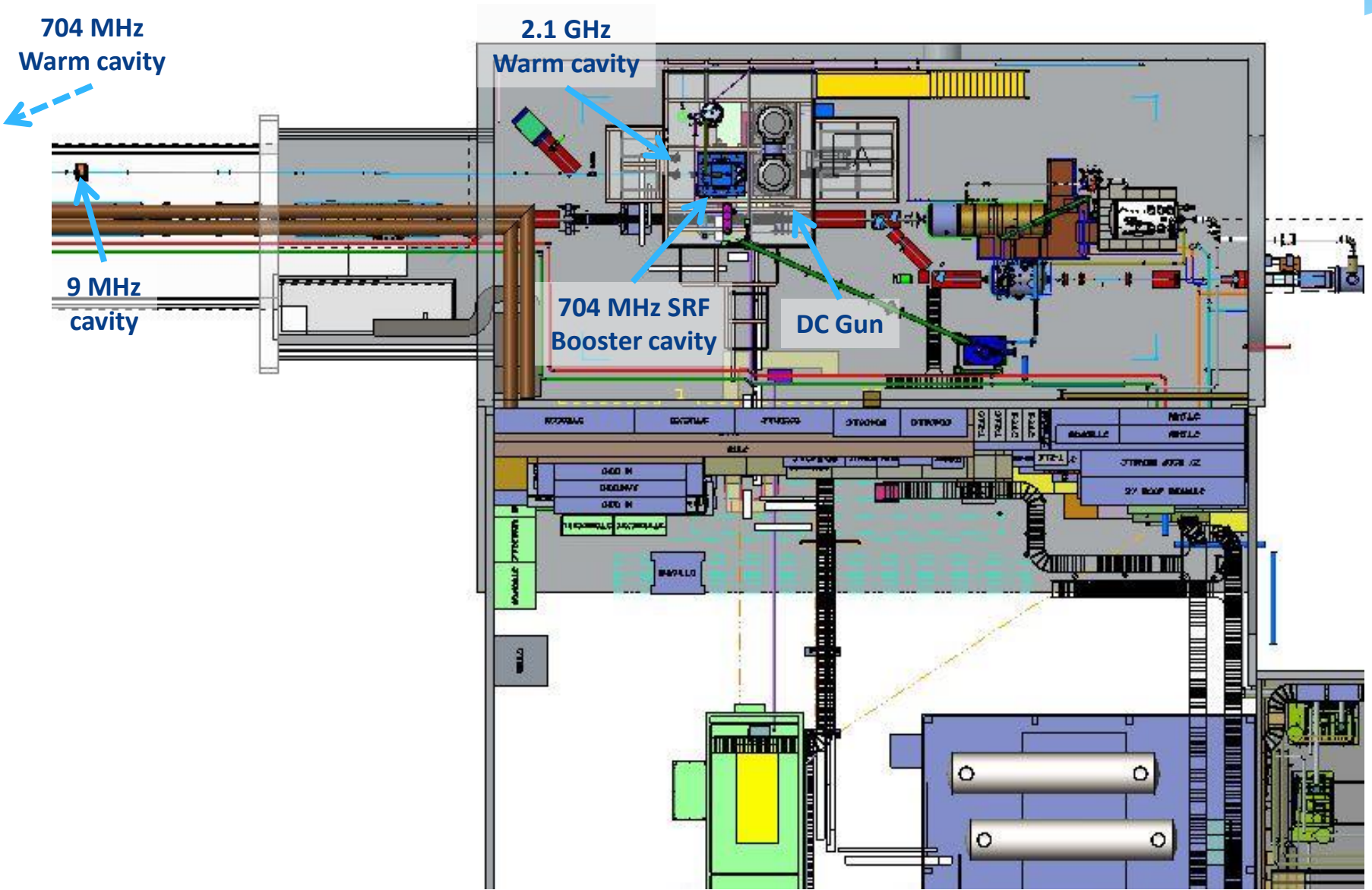
* Two of the RF cavities will be installed in IR2 this shutdown – the 2.1 GHz cavity and warm 704 MHz cavity





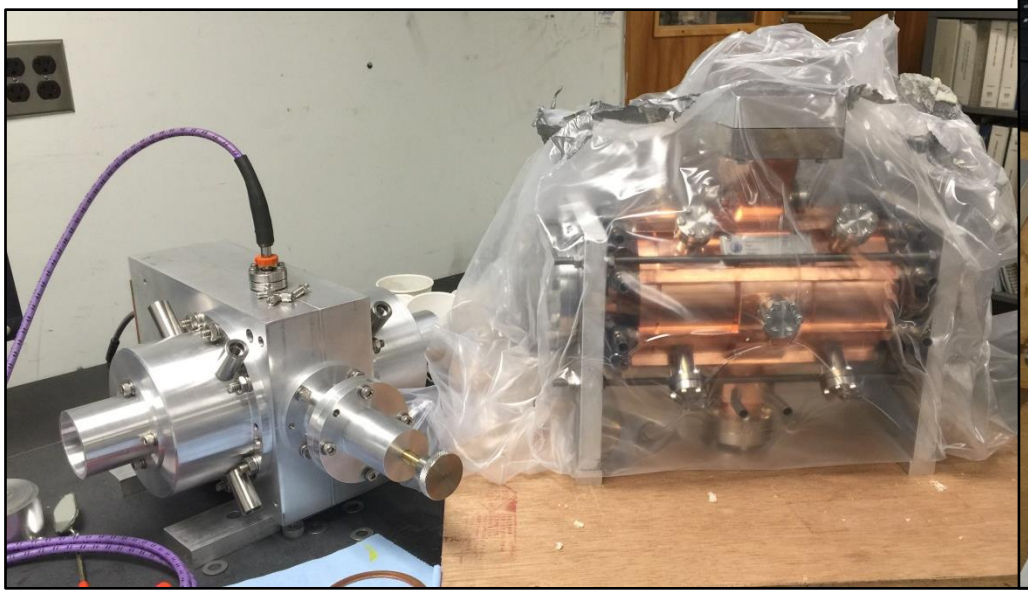
* Also installing two of the new 9 MHz RHIC (ion) cavities in sector 3 (see Alex's talk)

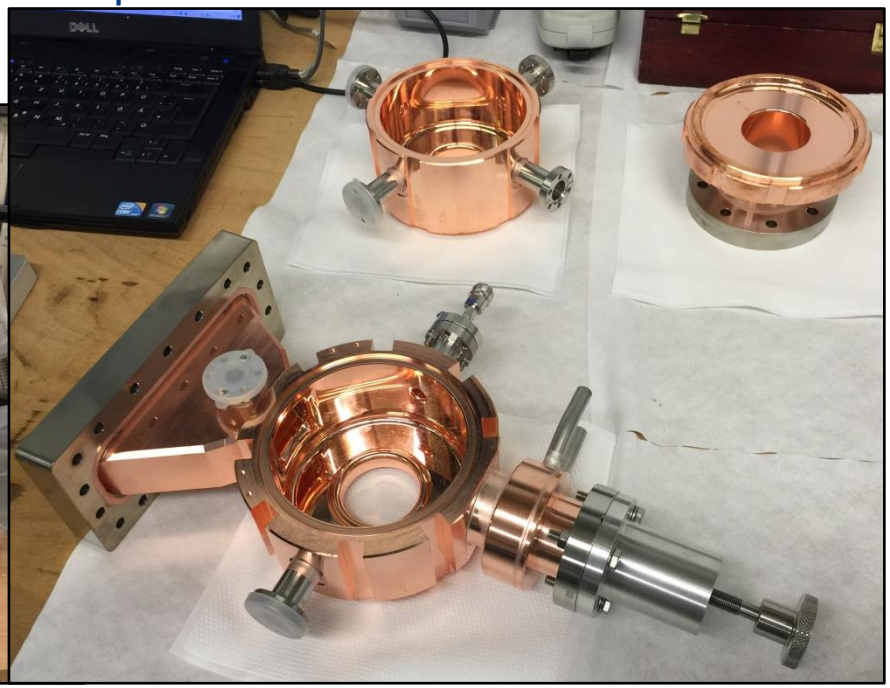
2016 Installations



2.1 GHz Cavity

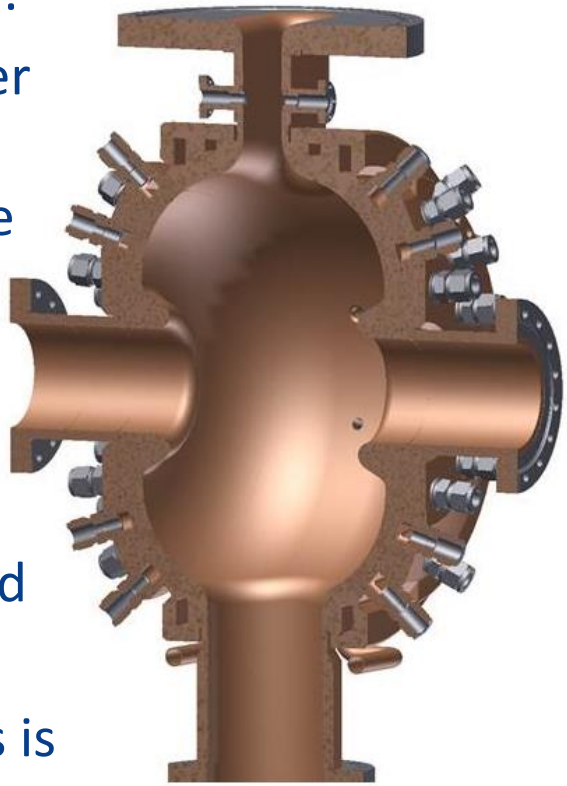
* A significant amount of testing was already performed on an aluminum “cold model” of the cavity.
* The production copper cavity was fabricated by RI Research Instruments (RI) in Germany and received last week.
* The power amplifier should be received from Microwave Amplifiers Ltd soon.
* The amplifier will be used to condition the vacuum window for the waveguide, and then the cavity, window, waveguide and amplifier will be installed in IR2 and 1002B.





704 MHz Warm Cavity

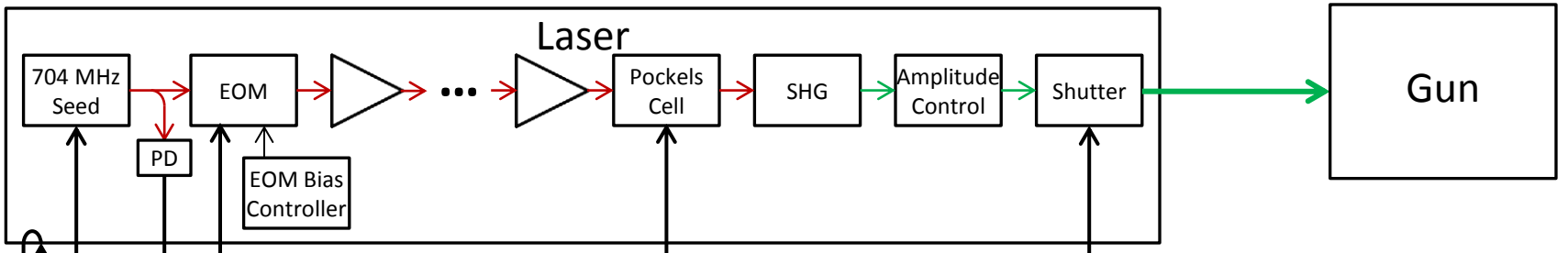
* RI is building the cavity. We expect delivery in the fall.
* We are also expecting delivery of two 704 MHz power amplifiers for the booster cavity by this fall. They are not needed for the booster cavity until Run-18, so we will use one for running the 704 MHz warm cavity during Run-17.
* The initial plan for the warm 704 MHz was to retune the amplifier that is currently being used for the CeC 500 MHz. However, due to the overlap of the CeC and LEReC schedules, that is no longer an option.
* Another new 704 MHz amplifier will be ordered. This is a better option for performance, but complicates the physical layout of equipment in 1002B and the waveguide routing.

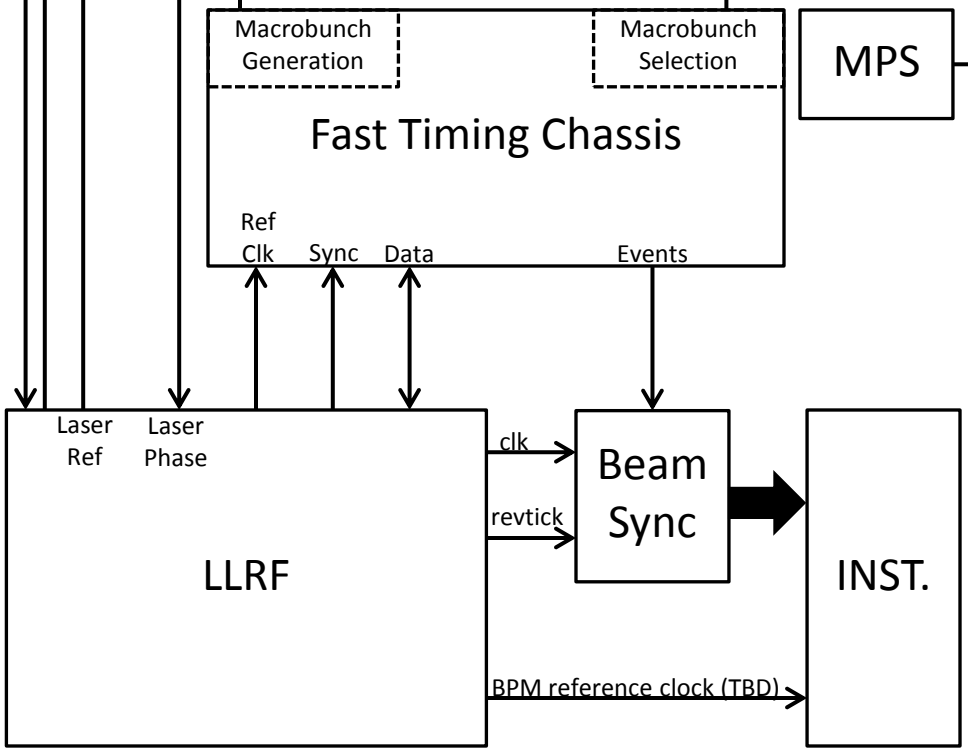


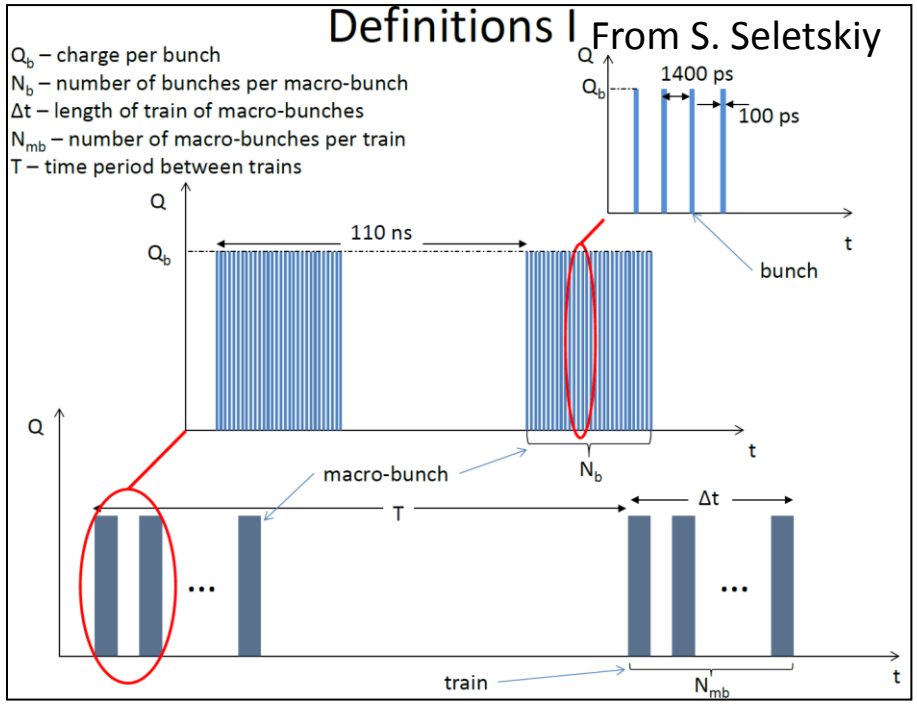
Run-17 Plans

- Major task that ties into RHIC operation is cavity conditioning and commissioning of the LLRF for the two warm cavities that will be installed.
  - Condition cavities to full voltage to verify cavity design and HLRF – this requires IR2 to be swept and locked up
  - Testbed for development and testing of new or modified LLRF hardware, firmware and software
    - Up/Down conversion HW (planning to use modified version of Fermilab LCLS-II design)
    - Firmware support for HW I/Q loop (feedback loop for stabilizing amplitude and phase, building off development of the Linac LLRF)
    - Firmware support for adaptive feed-forward compensation of transient beam loading
- Support DC gun and laser testing by providing the necessary laser timing signals.
- Other efforts are happening in parallel, but are not tied to the RHIC schedule.

Timing System

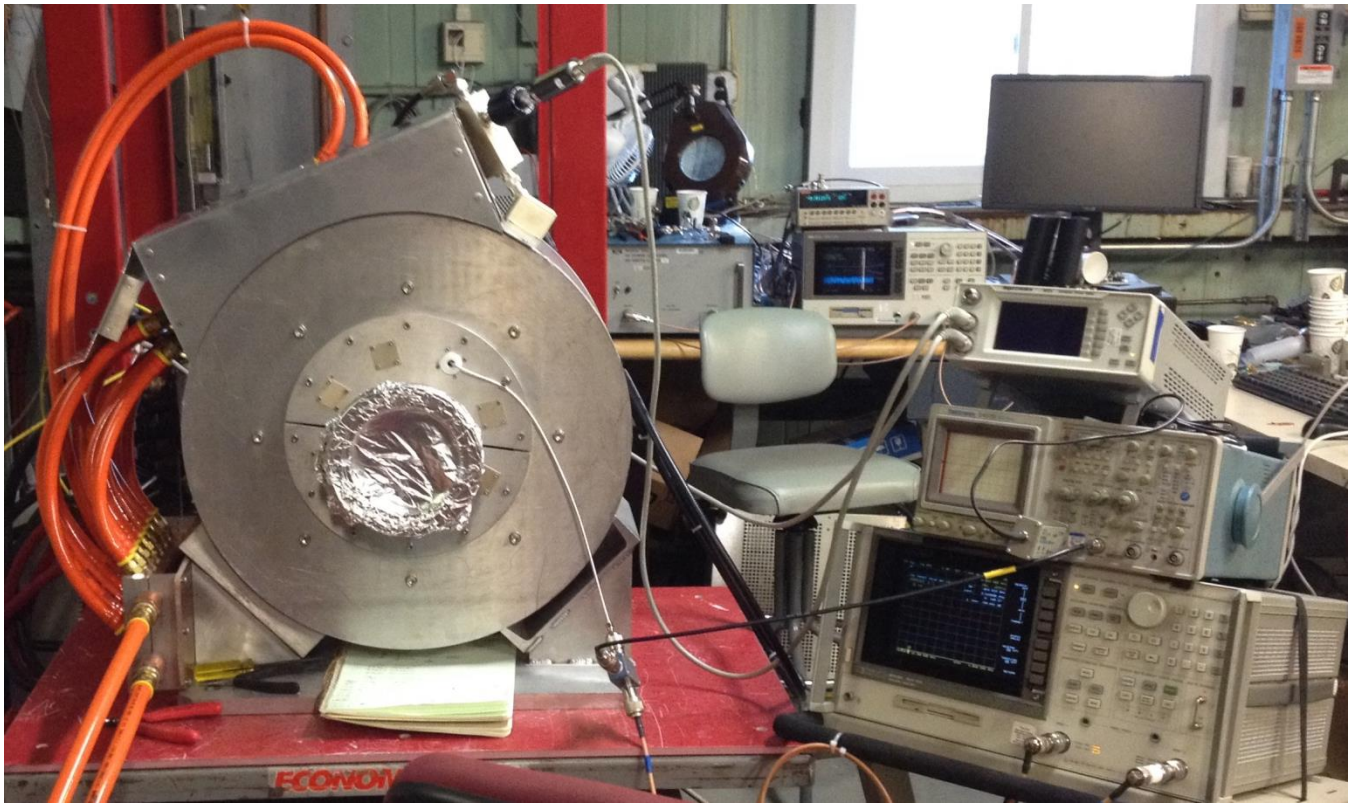






Run-17 Parallel Efforts

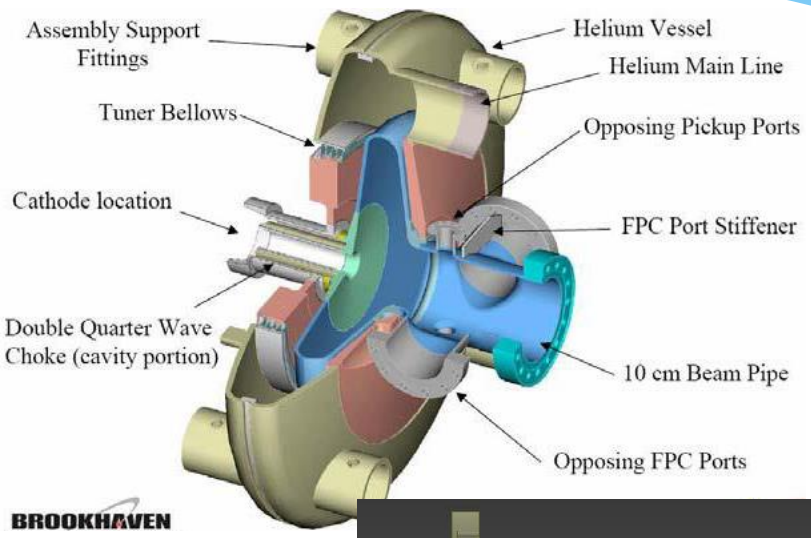
* The 9 MHz cavity is being tested in 925. It is a copy of the existing RHIC bouncer cavity design and operates at low enough voltage to do all testing outside the RHIC tunnel.



Run-17 Parallel Efforts

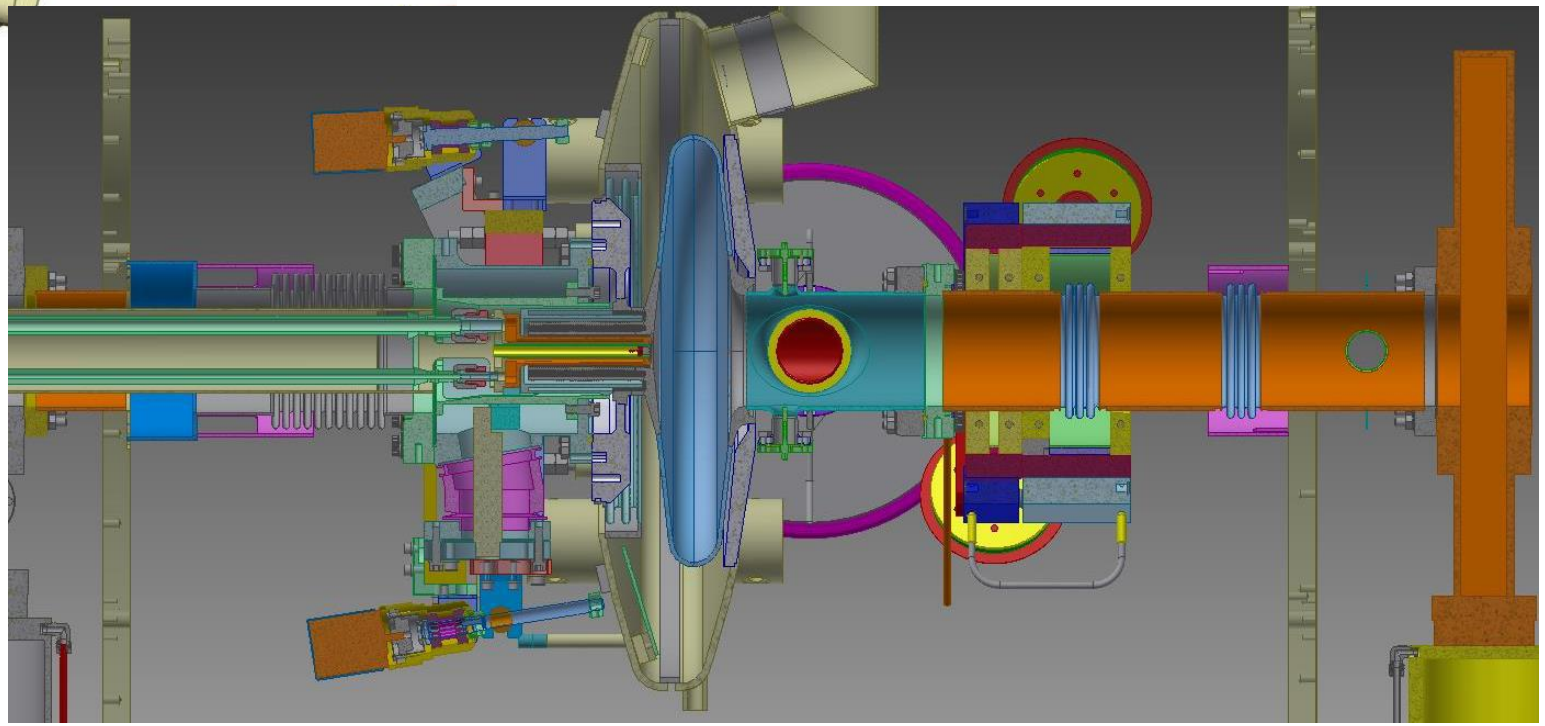
* The ERL Gun is being repurposed as the 704 MHz SRF Booster cavity for LEReC. This is a major effort that has been going on since at least last fall and will continue through the next year.
  * Cryomodule was removed from ERL cave, cryomodule disassembled and cavity removed, cavity shipped to Argonne for modifications and cleaning (last winter/spring).
  * Modifications are ongoing at Roark (ANL subcontractor), due back to ANL for cleaning (light BCP and HPR) in August. Then cavity goes to J-Lab for vertical test before coming back to BNL (due here in the fall).
  * The cavity will be reassembled into the cryomodule with new upstream and downstream inserts and modified spacing of the FPCs. The cryomodule will be reinstalled in the ERL cave for testing (winter).
  * SRF booster cavity will be moved to IR2 and installed next shutdown.

SRF Booster Cavity Modifications

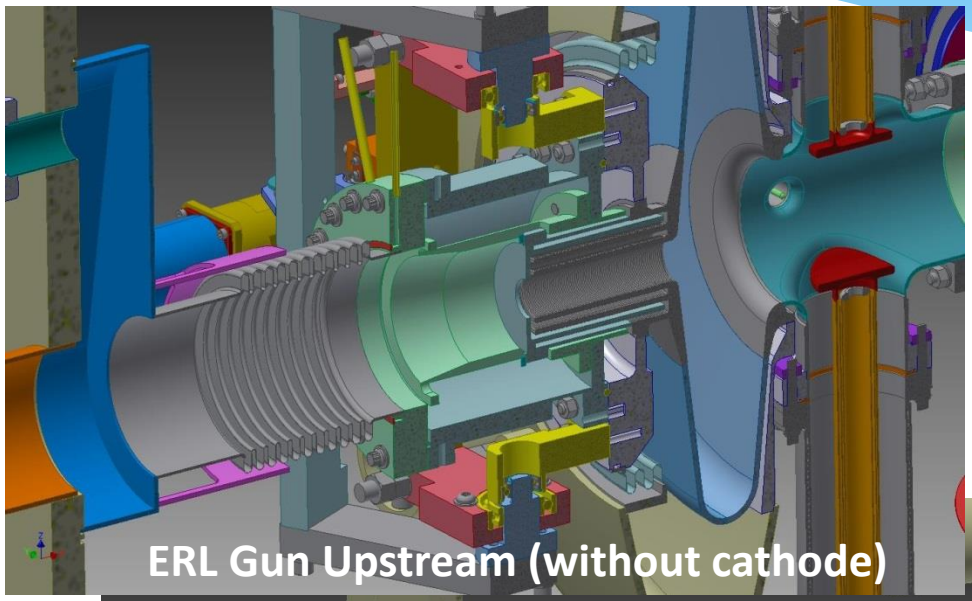


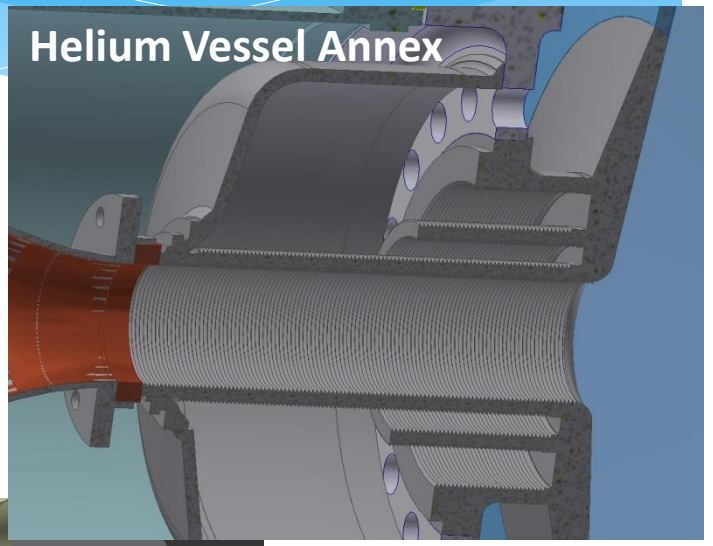
BROOKHAVEN

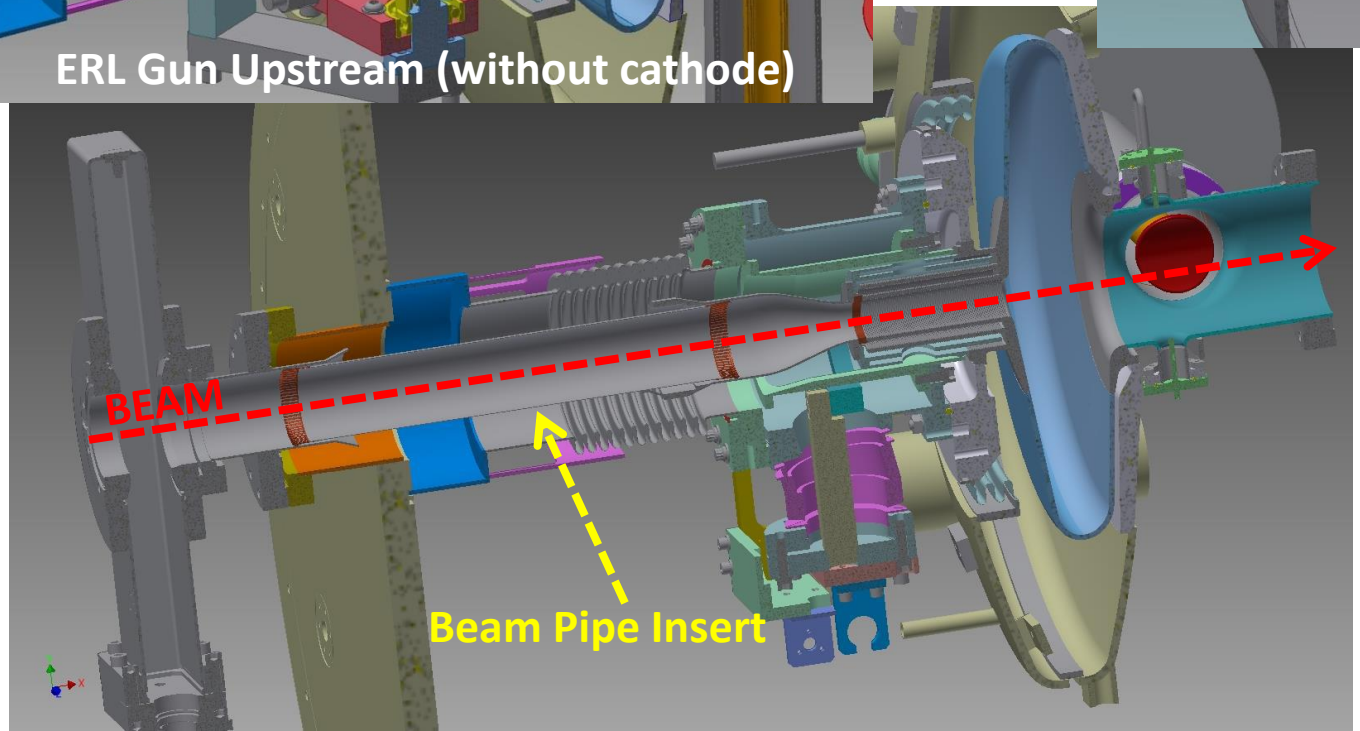
ERL SRF Photocathode Gun Configuration



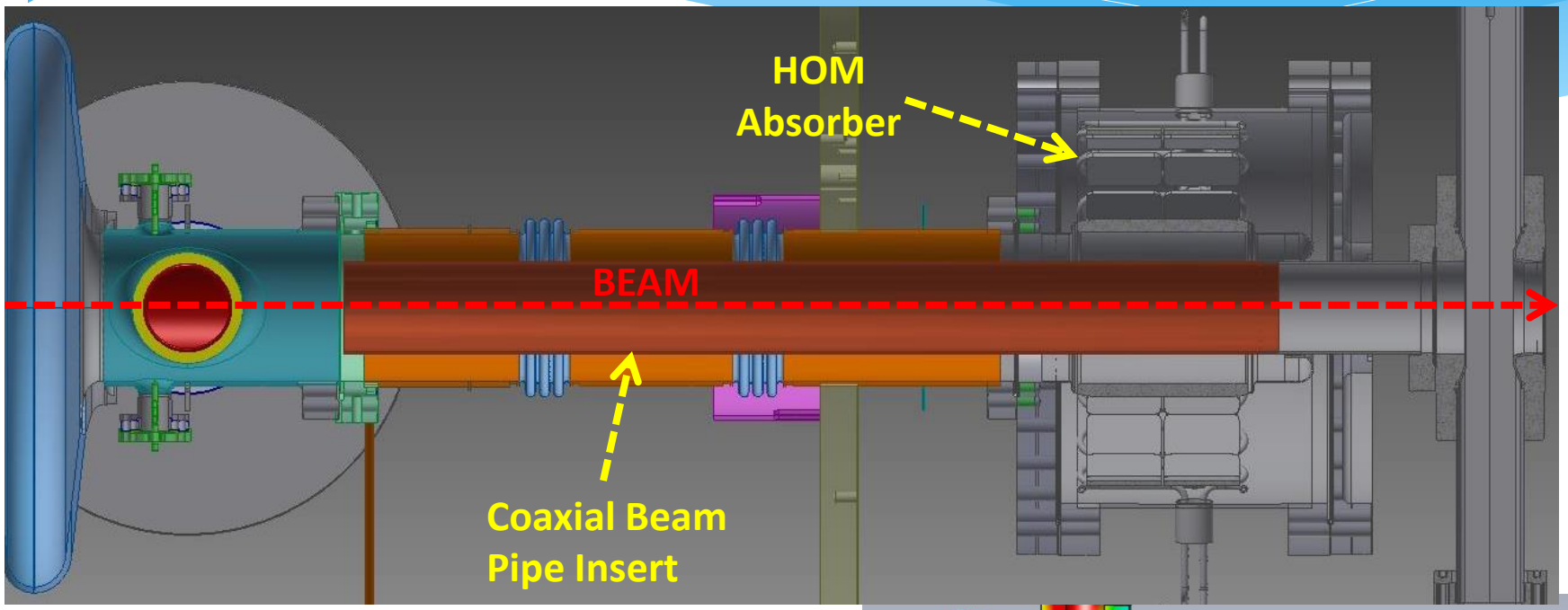
Booster Cavity Upstream Modifications

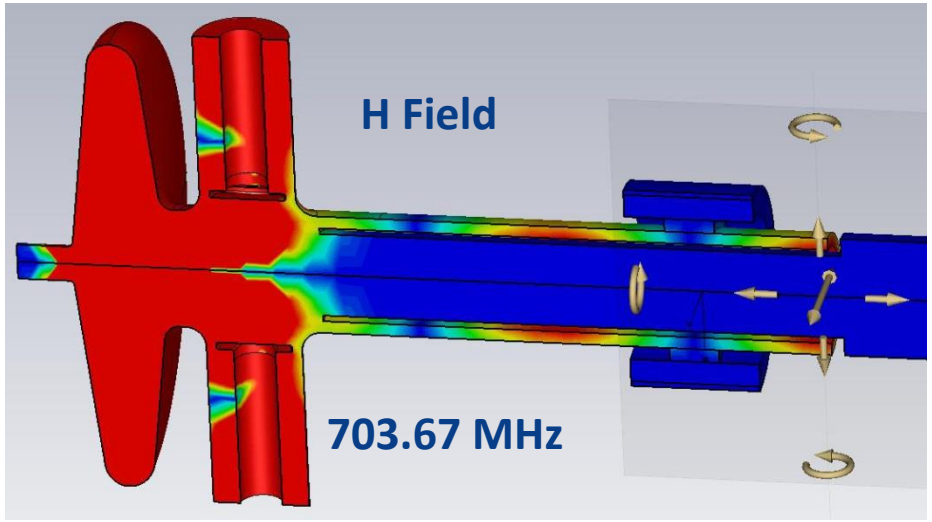


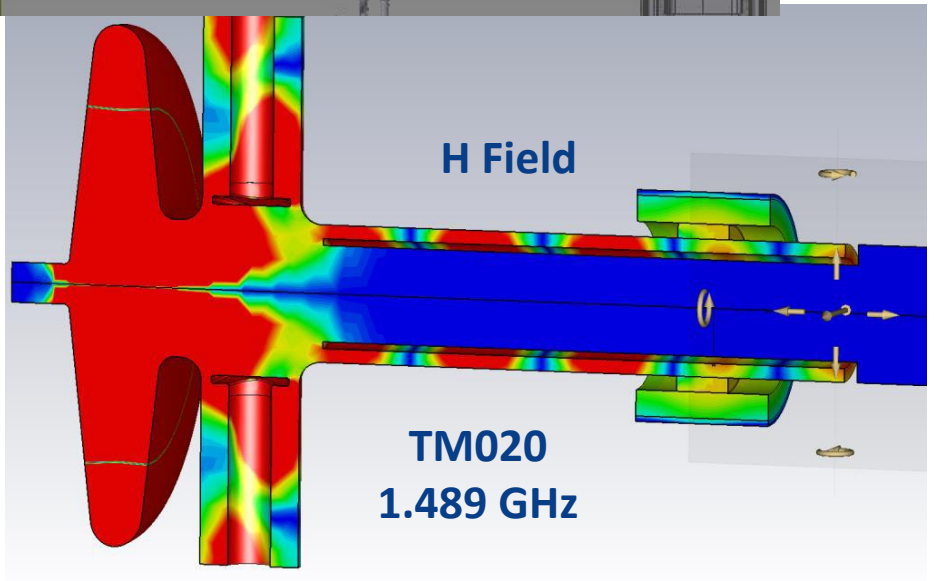




Booster Cavity Upstream Modifications







2017 Shutdown and Run-18

* Major efforts for the 2017 shutdown are:
  * Installation of SRF Booster cavity
  * Installation of deflecting cavity and diagnostic line
  * Installation of remaining (four) ion beam 9 MHz cavities in sector 3
  * Continued development and testing of LLRF (to meet energy stability requirements, any issues found in Run-17, etc.)
* Run-18 efforts will be focused on commissioning of electron beam

Acknowledgements

This presentation is a very brief summary of a lot of work by many people:

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My apologies to anyone who I forgot.