Thomas Jefferson National Accelerator Facility

UPGRADE AND HIGH CURRENT CAVITY DEVELOPMENTS

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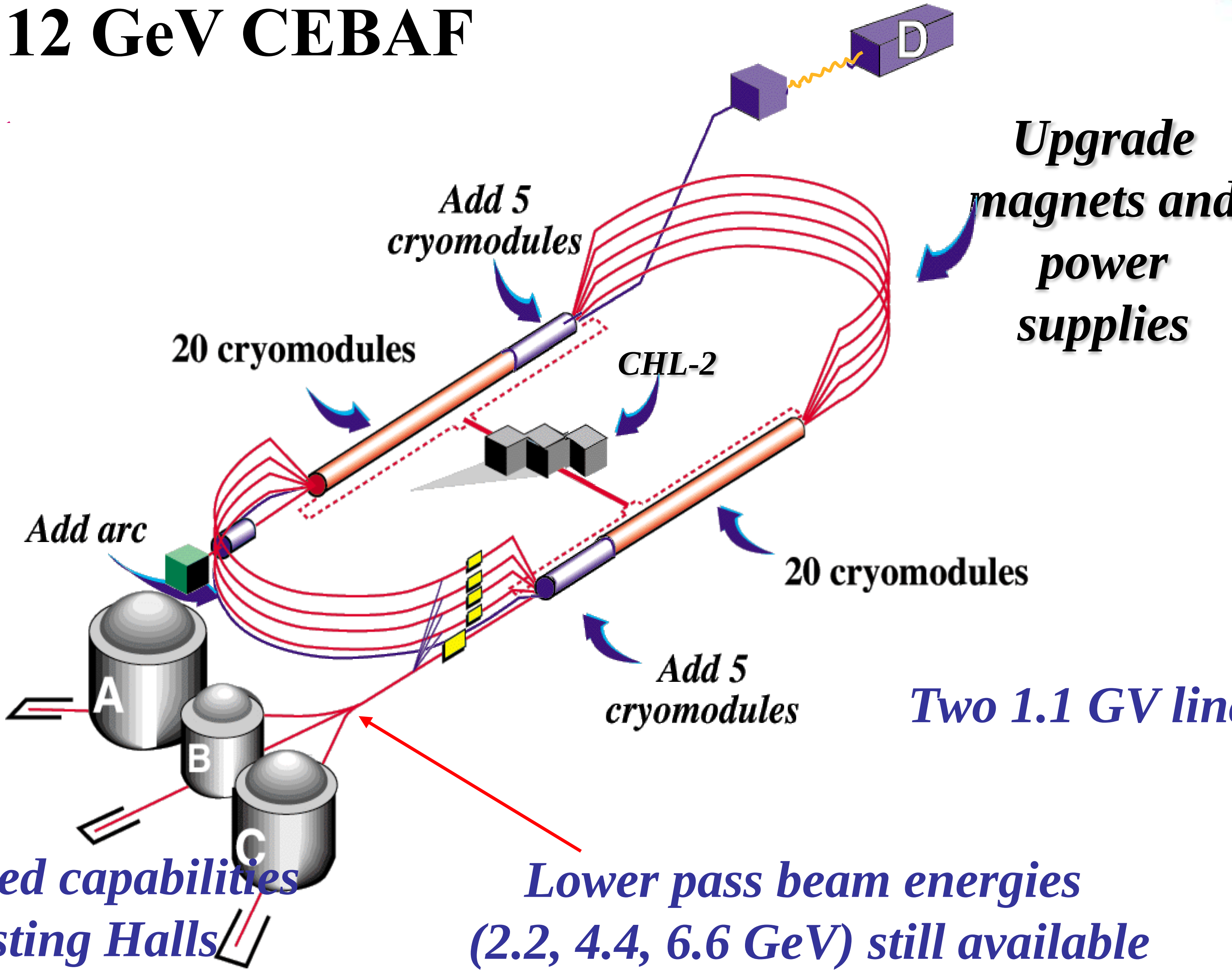
Outline

- Jefferson Lab CEBAF Upgrade
  - Cryomodule/Cavity Requirements
  - Cavity Solution
  - **Cavity Performance**
  - **HOM Issues**
  - **Future Activities**
- Jefferson Lab High Current Program
  - Background
  - **Cryomodule Concept**
  - **Cavity and Critical Component Status**
  - **Future Activities**

12 GeV CEBAF



Two 1.1 GV linacs

Enhanced capabilities in existing Halls

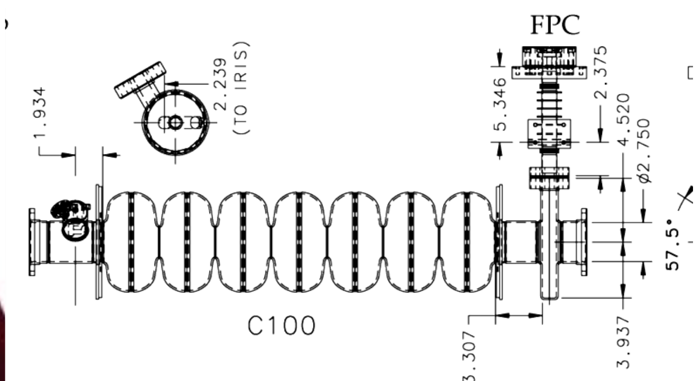
Lower pass beam energies (2.2, 4.4, 6.6 GeV) still available

Requirements Overview

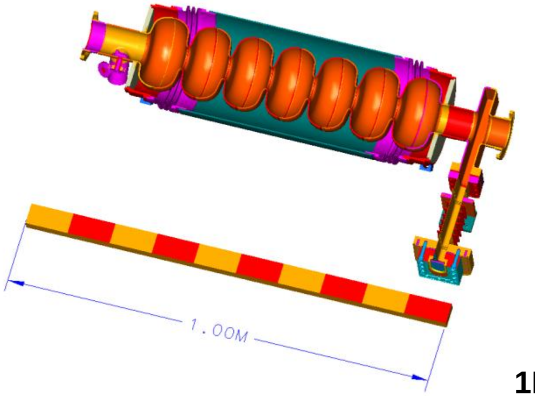
- Add 1 GV, 0.5 GV per Linac
- 1497 MHz CW
- 10 Cryomodules (CM), 100 MV each
- CM has 5.6 m active length, 8ea 7 cell cavities
- Eacc ~19 MV/m includes operational overhead
- 400 μA injected current (up to 6 passes)

Parameter List

Cryomodule	
Total active length	5.6 m
Voltage	108 MV
2 K heat load	≤300 W
50 K heat load	≤300 W
Cryomodule length	~8.5 m

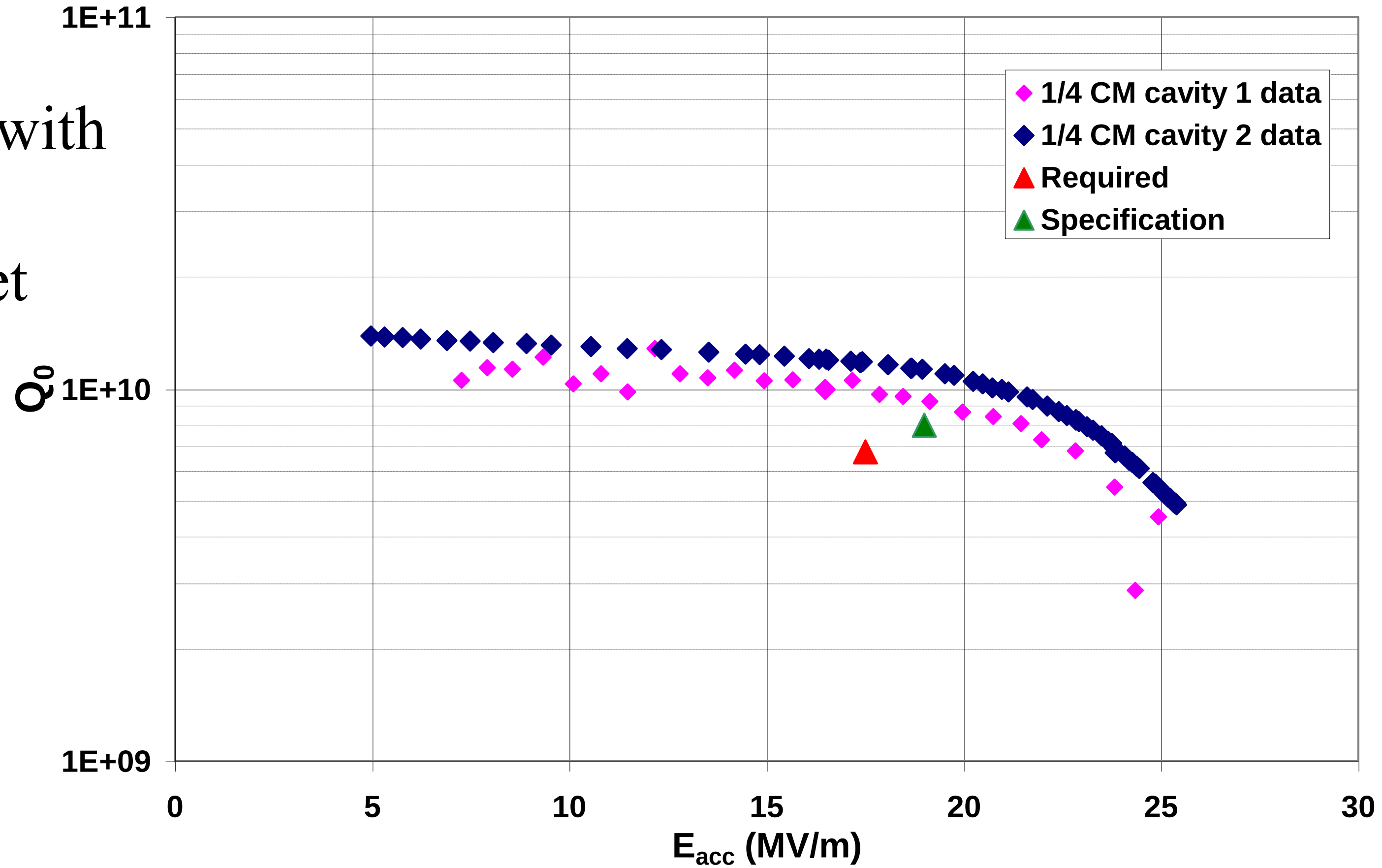


Cavity	
Frequency	1497 MHz
Cavity active length	0.7 m
Geometry Factor	280 Ω
Ep/Eacc	2.17
Hp/Eacc	3.74 mT/(MV/m)
Gradient	19.2 MV/m
Qext Fundamental Power Coupler (FPC)	$3.2 * 10^7$
FPC power rating	13 kW
Dipole mode damping	$< 1 * 10^{10}$ Ω/m



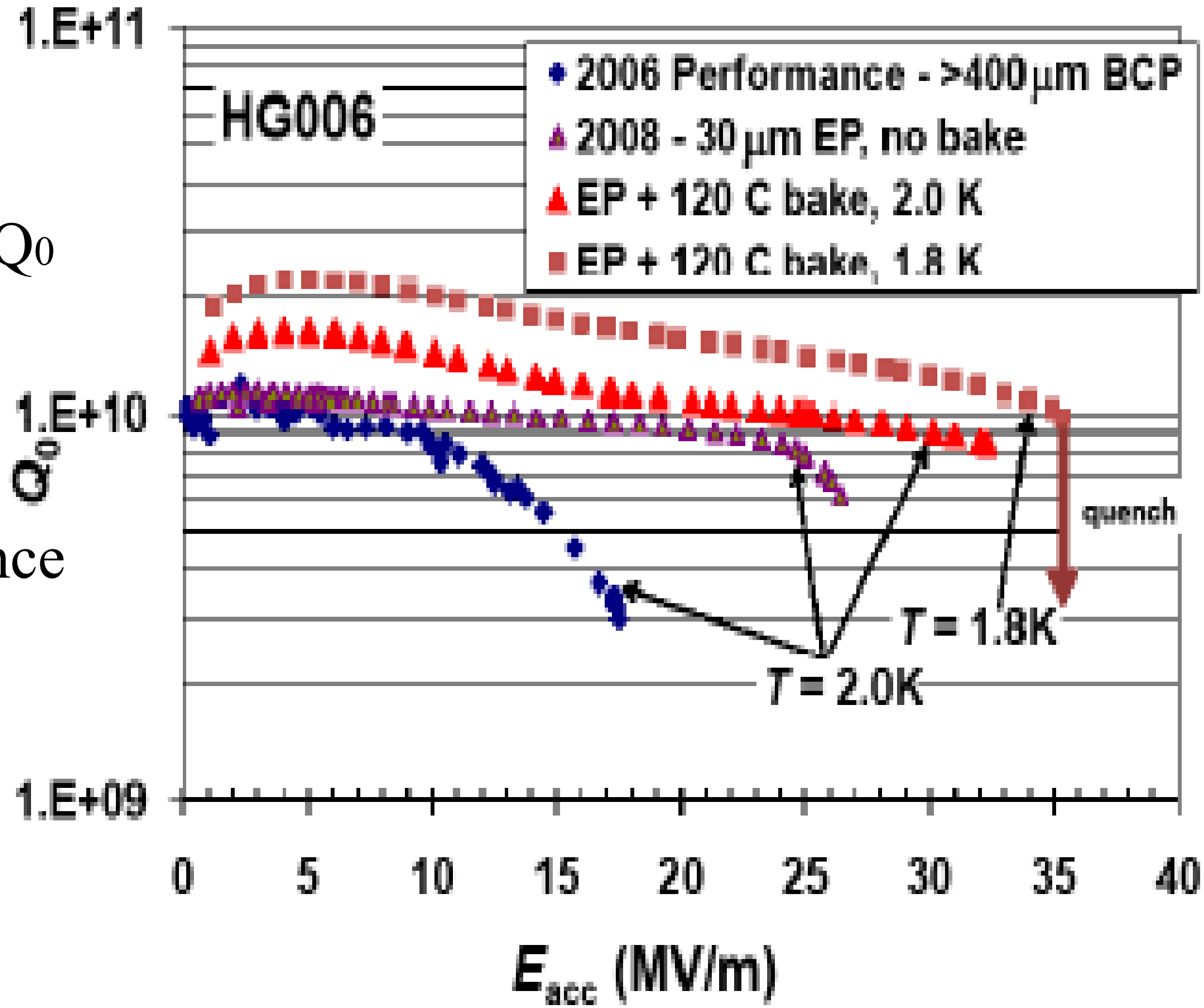
Cavity Performance Upgrade Baseline Plan

- C100 Cavities with standard BCP processing meet project requirements



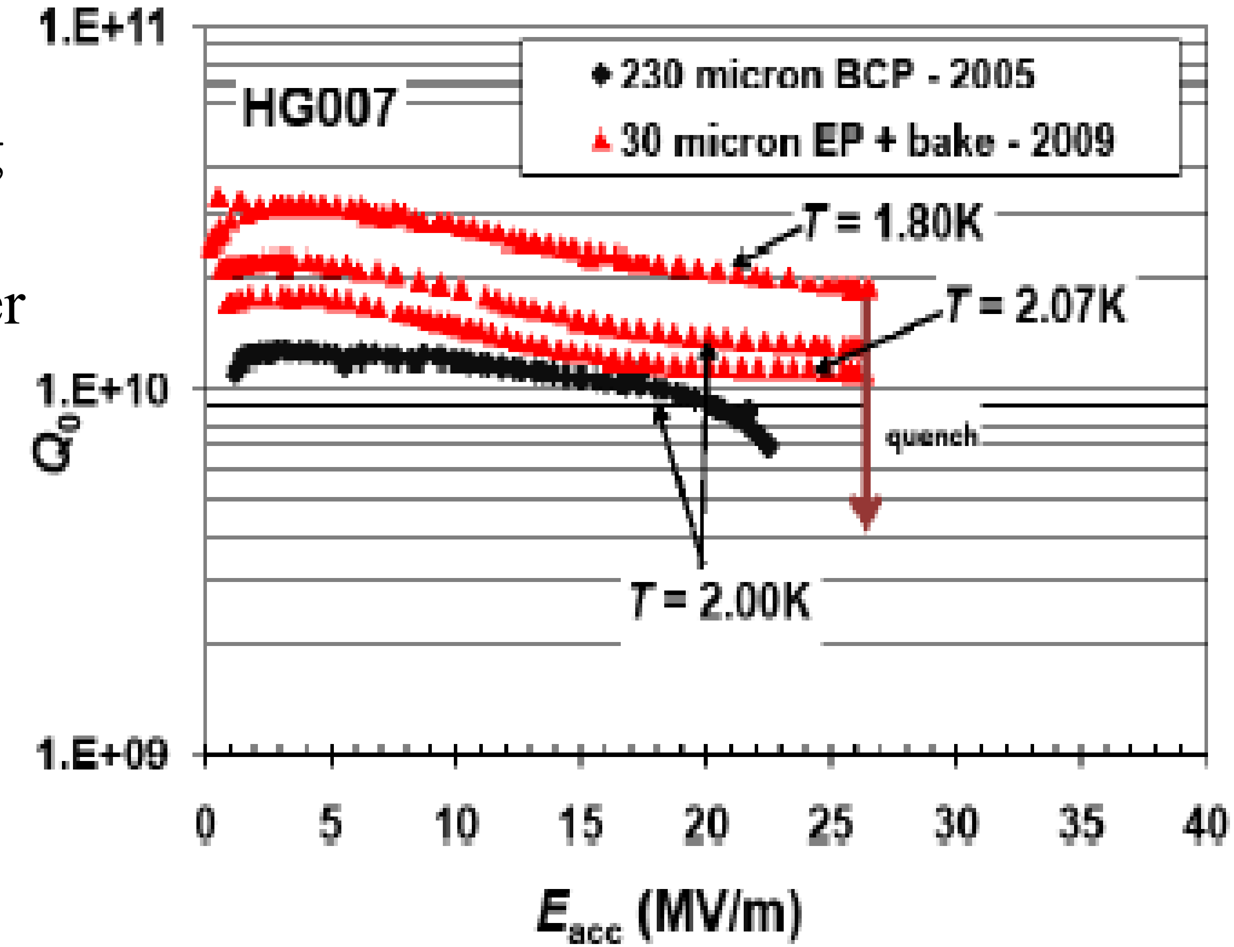
Cavity Performance with electro-polishing processing

- Aggressive BCP polishing had degraded Eacc and Q_0 performance
- EP processing recovers and improves performance



Cavity Performance with electro-polishing, promising results

- Light EP processing improves Eacc and Q_0 performance after normal BCP processing

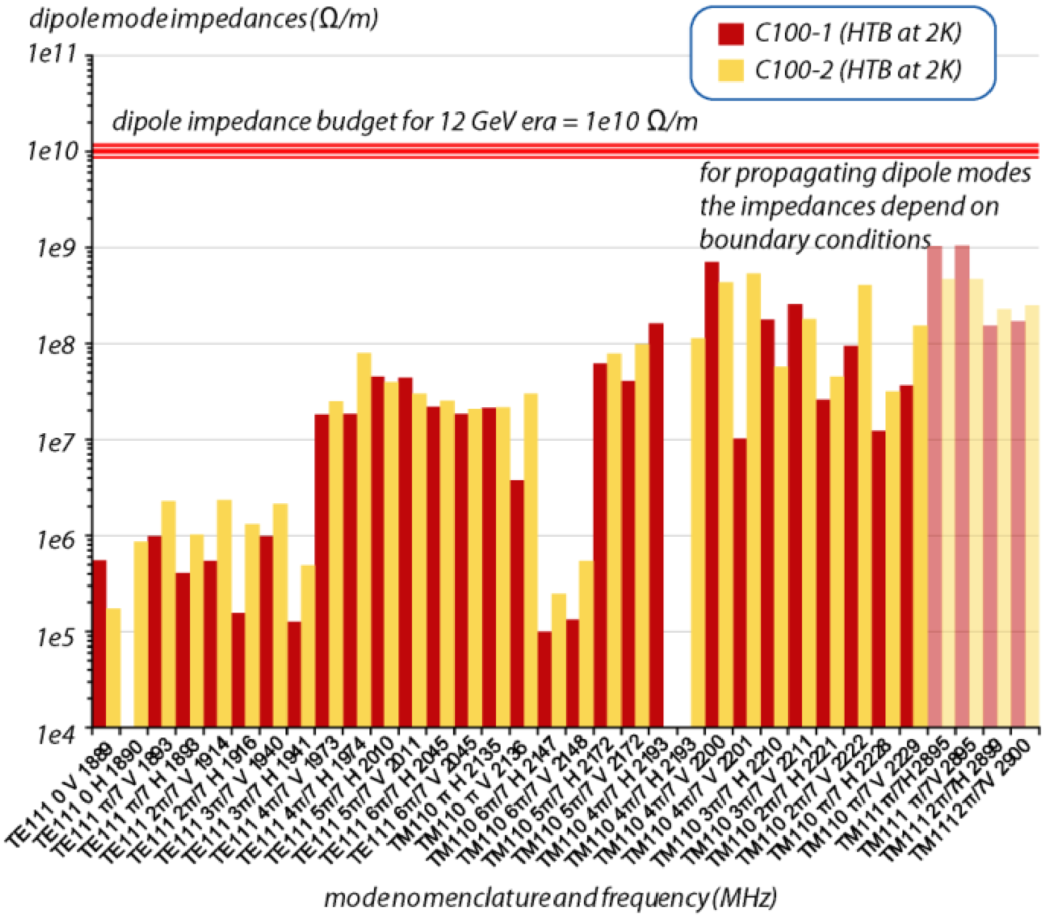


HOMs

- Requirement for injected beam current was increased, 100 → 400 μA
- Dipole mode damping < 1 $*10^{10}$ Ω/m
- All requirements are met by existing design but …..
- Concern over cavity performance prompted extensive simulations and measurements
- End effects (including cavity to cavity) are critical for coupling at the beamline HOM couplers
- FPC coupling and HOM damping in the warm waveguide network is required

C100 cavity dipole impedance

Order of magnitude margin for more stringent requirements



Dipole shunt impedances for C100-1 and C100-2 respectively as derived from measured Ql values.

C100 Cavity Future

- Continue to investigate EP as an alternative to BCP (possibly a combination of both, BCP with a final EP)
- We will make a few, ~8, more C100 cavities in house
- Production order for 86 cavities has been placed
- Start receiving cavities next spring
- Finalize production processes and documentation before the cavities start to arrive

High Current Program

High Current Program

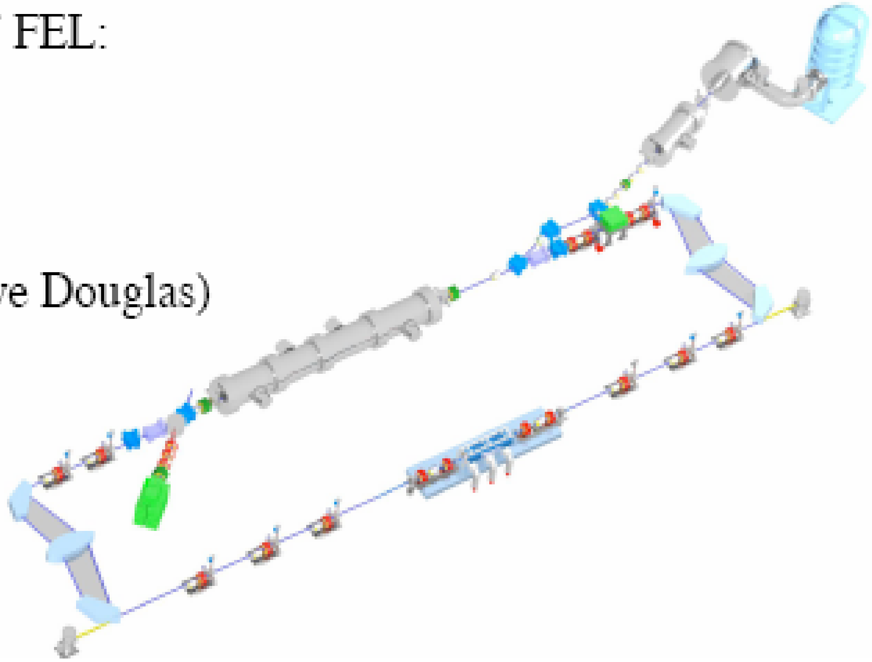
- JLAB has been in the business of FELs and ERLs for a long time using CW SRF linacs
- Existing Jefferson Lab designs are ok for ~ 10 mA and are in routine use at the existing JLAB FEL
- Beam current requirements have gone from ~ 1mA to ~10 mA to ~100 mA and talk of ~1 A
- Design and fabrication of 1 Amp and 100 mA cavities, 748.5 and 1497 MHz respectively, are complete (748.5 scaled to 1497 MHz)
- Conceptual designs for 1 A and 100 mA cryomodules is complete and design work continues on the 100 mA cryomodule

High Current Application, 1 Example

High-average power ERL's face many challenges on the "current" frontier. Some similar to storage ring e+e- colliders, e.g. HOM damping, RF power.

Typical "industrial-strength" FEL:

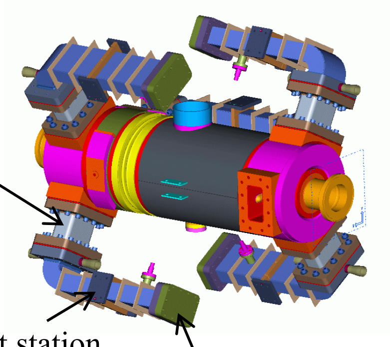
- ~100MeV beam energy,
- ~100kW+ optical power
- ~100mA+ beam current
- Compact layout (e.g. Dave Douglas)
- High real-estate gradient
- CW
- Low cryogenic load
  - Low wall losses
  - Warm HOM loads

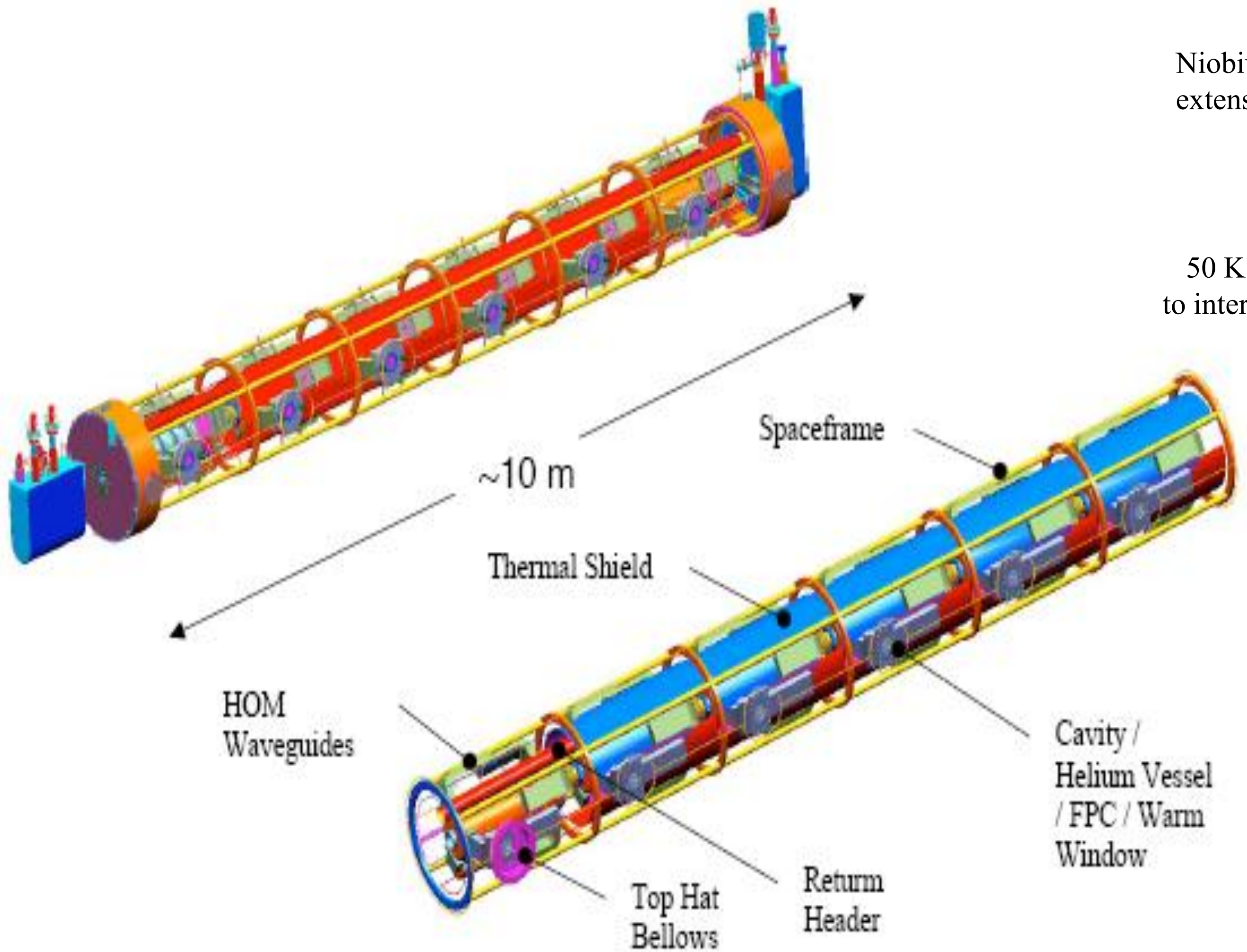


1 Amp Cryomodule

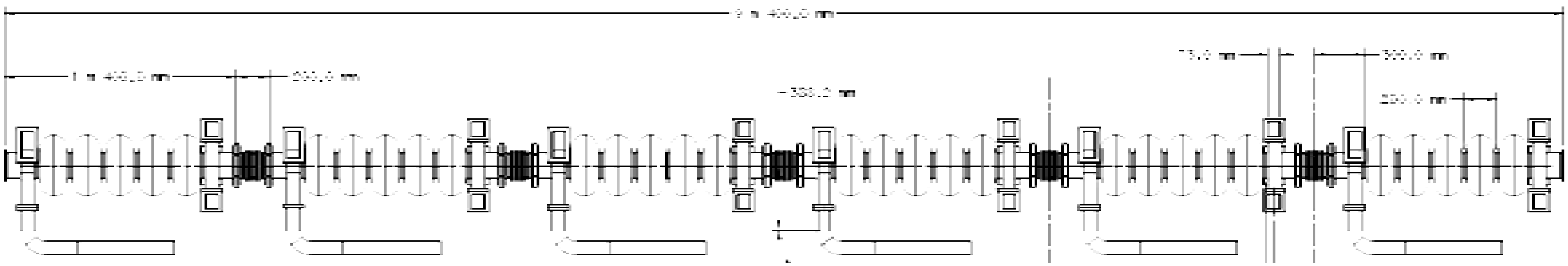
- Requirements
  - Voltage 100-120 MV
  - Length ~10m
  - Frequency 750 MHz
  - Beam Aperture >3” (76.2mm)
  - BBU Threshold >1A
  - HOM Q’s $<10^4$
  - Beam power 0-1MW
- Other concerns:
  - Low cryogenic losses
  - Maintainability, flexibility, cost.

1 Amp Cryomodule Concept
6 each, 5 cell cavities

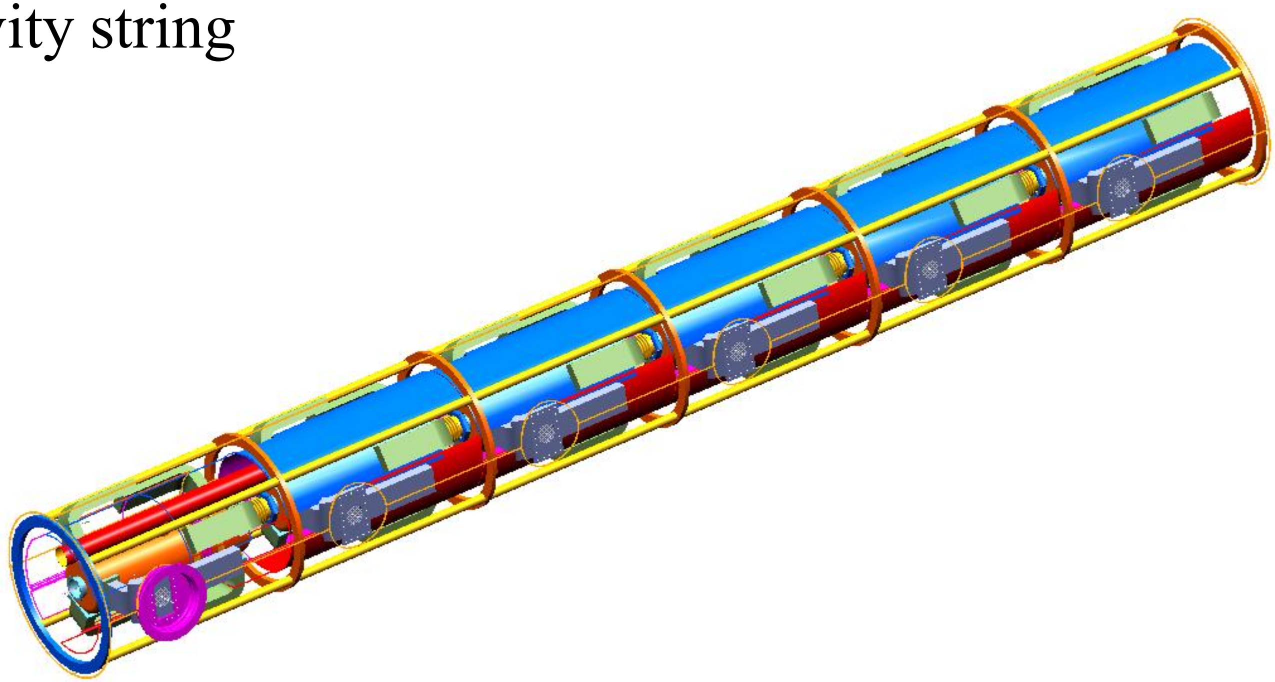




1 Amp Cryomodule Concept



6 cavity string



Spaceframe / Thermal Shield Assembly

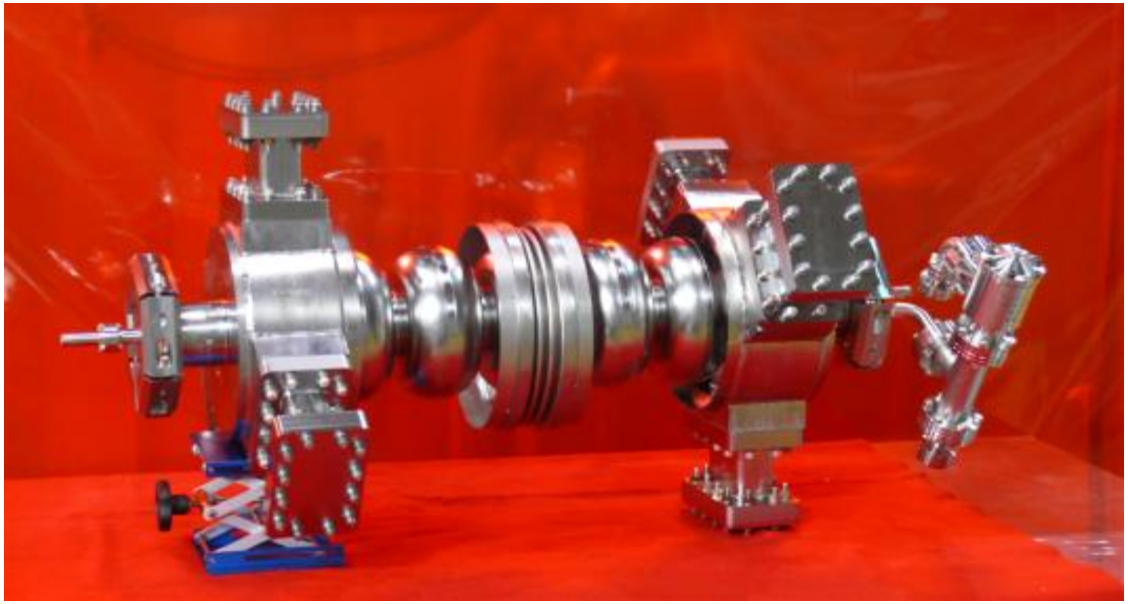
1 Amp CM Cryogenic Heat Load

- Dynamic Heat Load @ 2K ~ 400 W
  - **Cavity Dissipation = 55 W per cavity**
    - Eacc = 16.7 MV/m, Qo=8E9, R/Q = 636
  - **HOM Dissipation ~ 8 W per cavity**
    - 4 kW Power, 1.5 GHz
- Dynamic Heat Load @ 50 K ~ 190 W
  - Due to heat-stationed HOM waveguides
  - FPC waveguides are gas-cooled
    - 200 kW operation requires 4x SNS-flow per coupler
      - 0.15 g/sec/coupler
- **Totals with Static Heat Load**

2K ~455 W **50K ~550 W**

High Current Cavities

- Design considerations
  - Keep trapped modes away from beam resonances avoiding extremely large HOM power
  - Good HOM damping
  - Avoid multipacting barriers

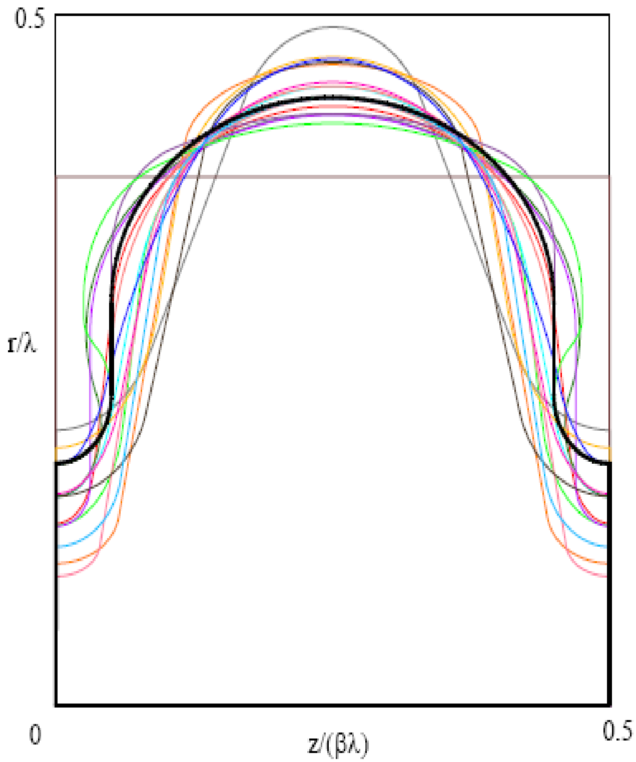


1497 MHz 5 cell HC (100 mA) cavity

Prototype 1497 MHz cavity with endgroups

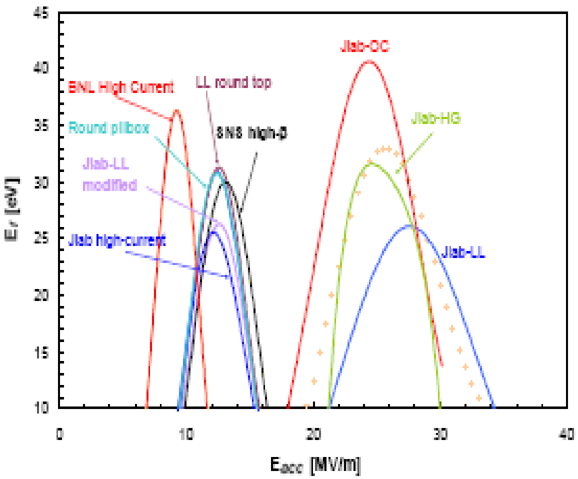
Cavity design

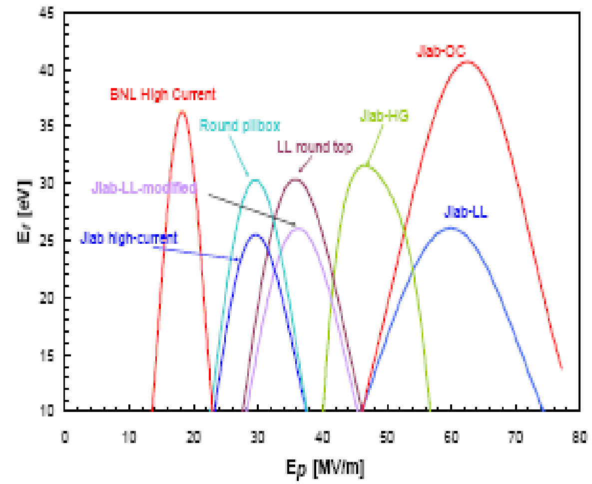
- Cell shape
  - Comparison with other SRF projects
  - JLAB uses a single geometry or center and end cells, end cells trimmed differently

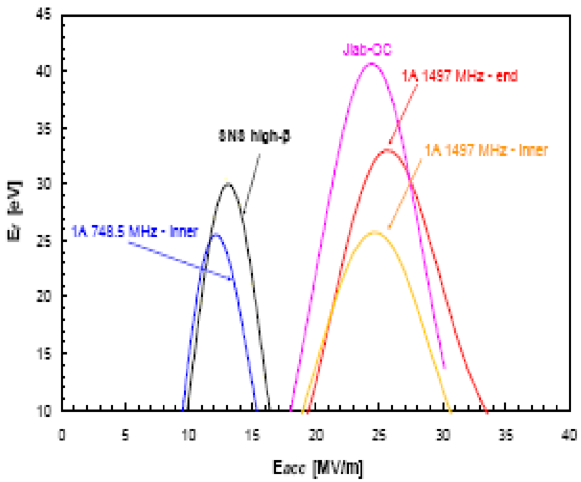


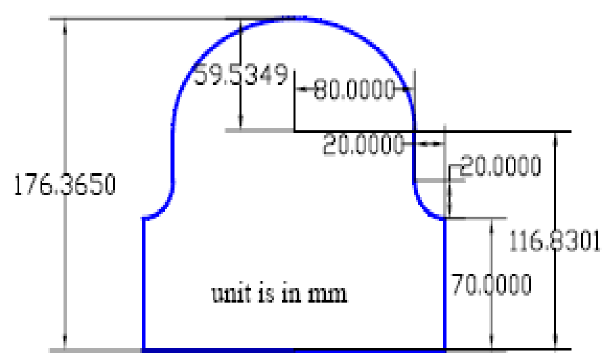
Cavity design

- Multipacting simulation using FishPact







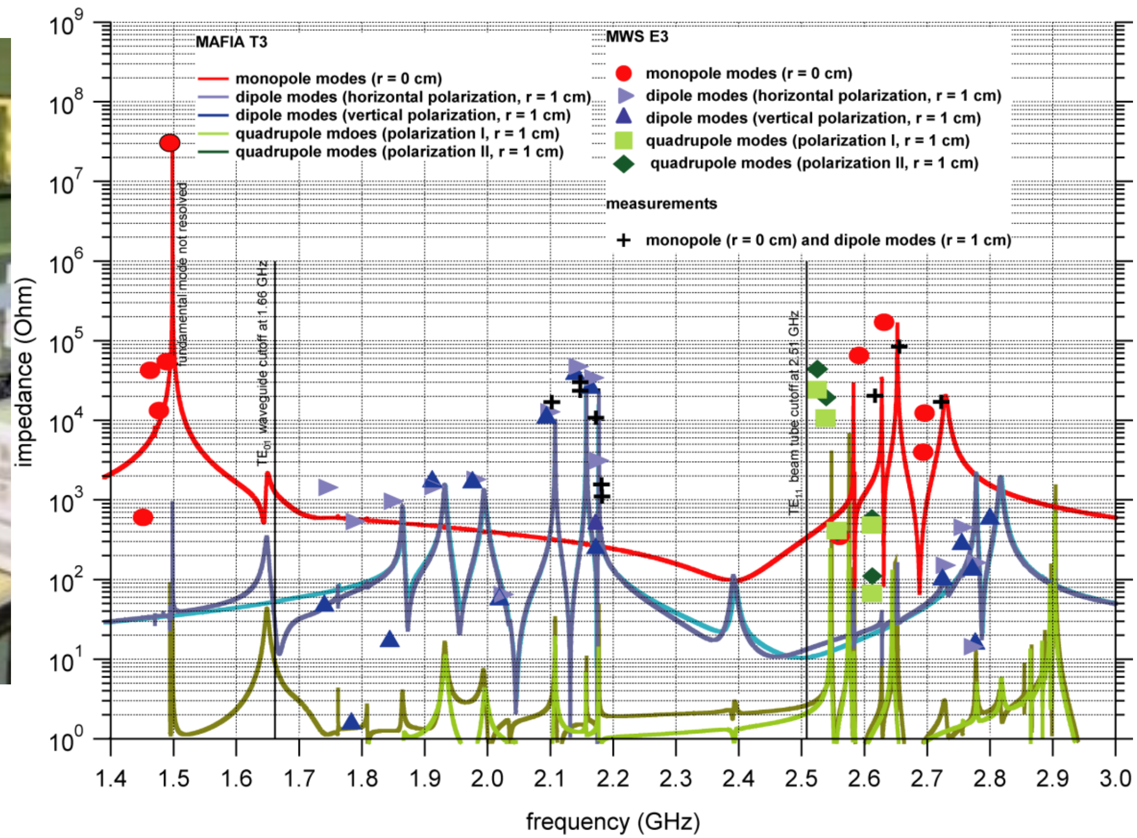


Final JLab High Current cavity cell shape design

Cavity Performance

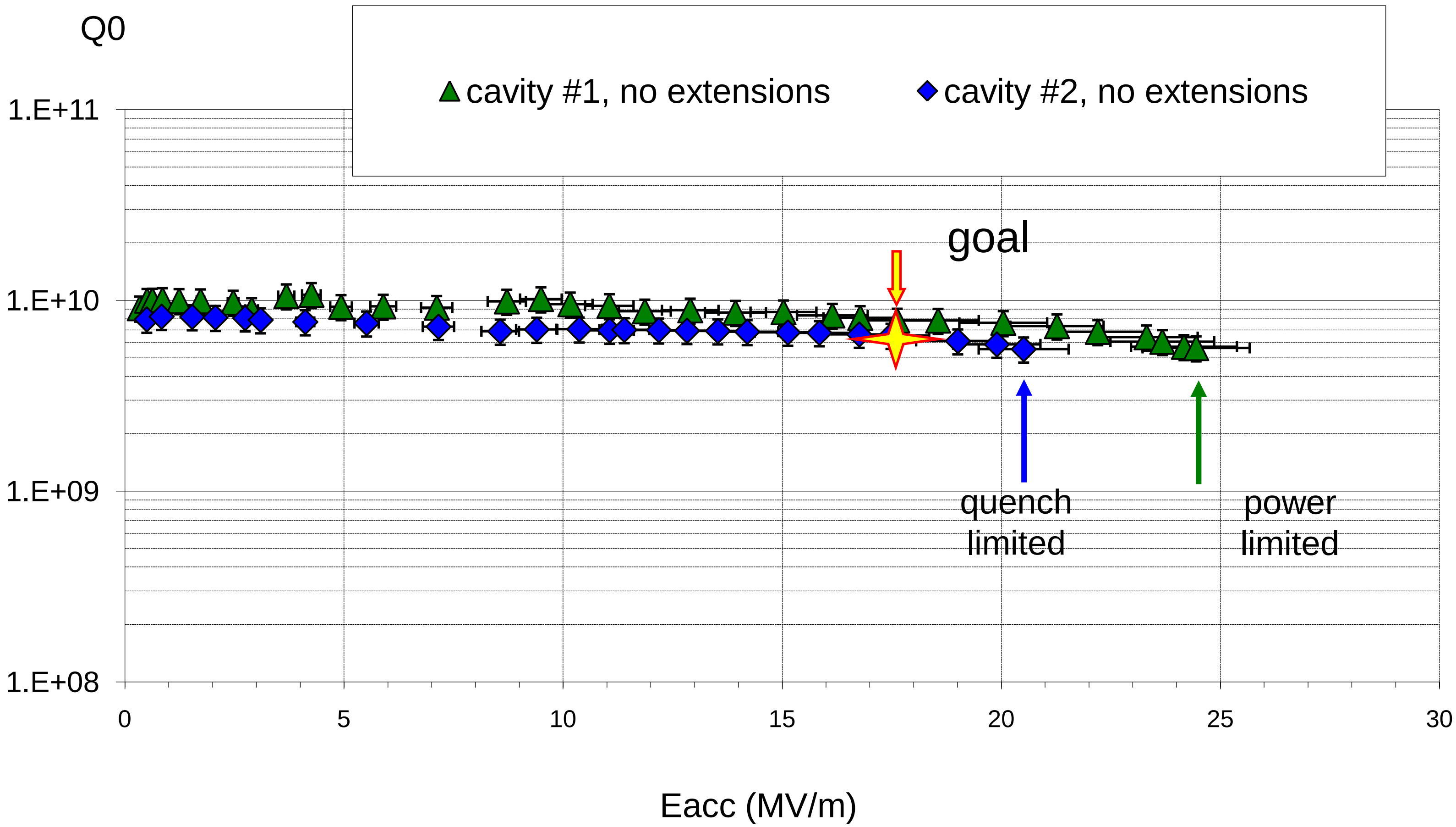
- Extensive bench testing of Copper and Niobium single cell and multi cell cavities

Bead-pull HOM measurement setup



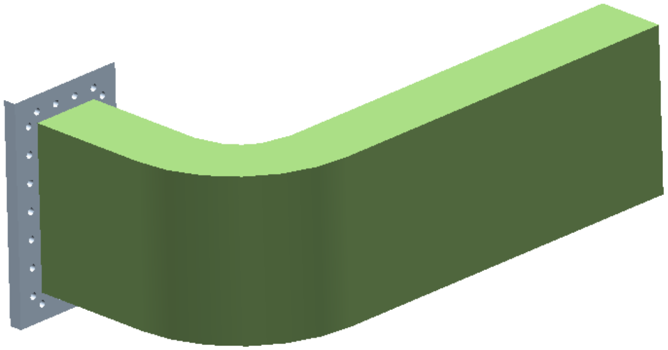
Cavity Performance

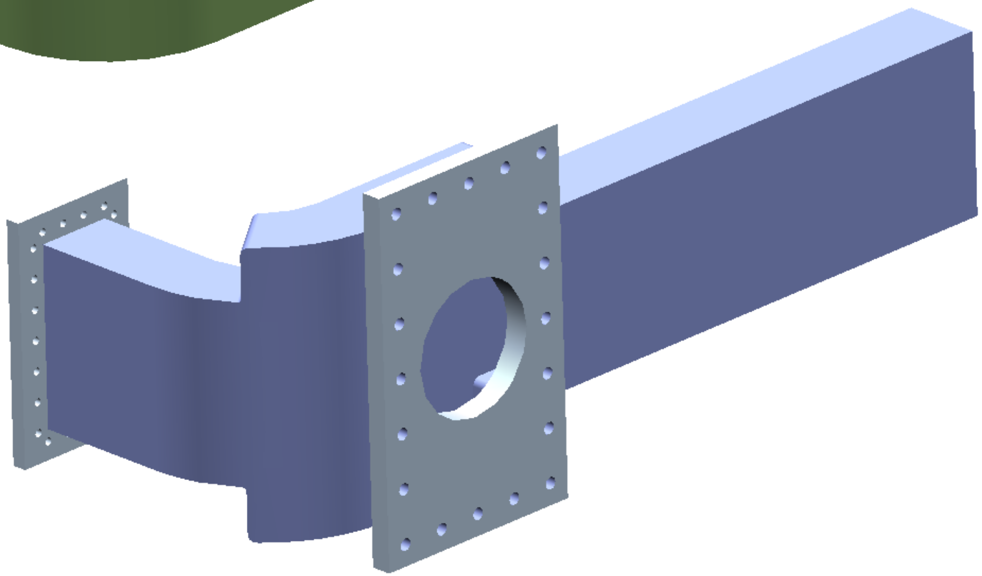
- 1497 MHz Vertical Test Data

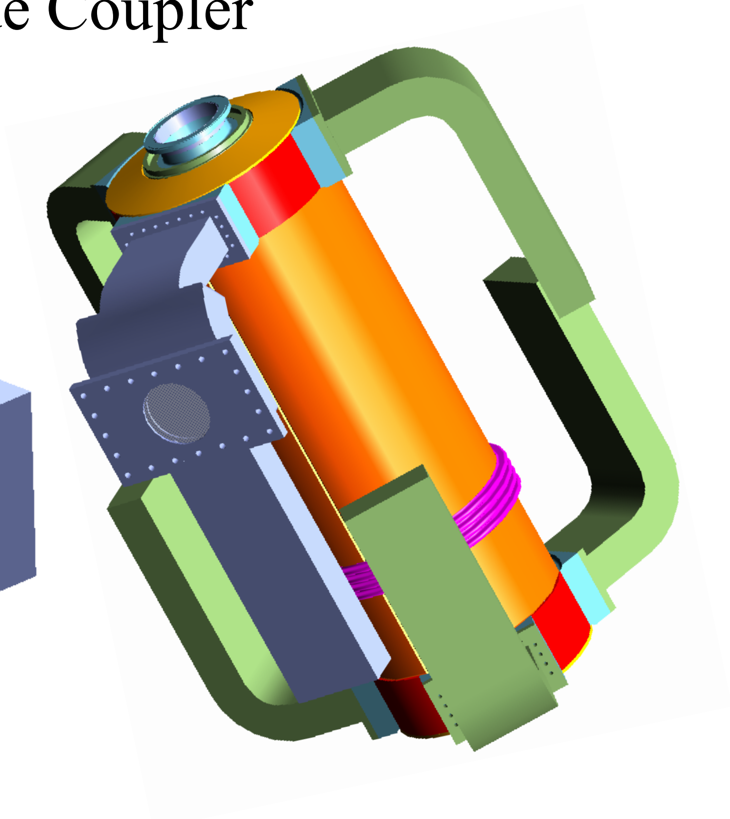


Components

- HOM Waveguide Coupler
- Combination HOM/FPC Waveguide Coupler

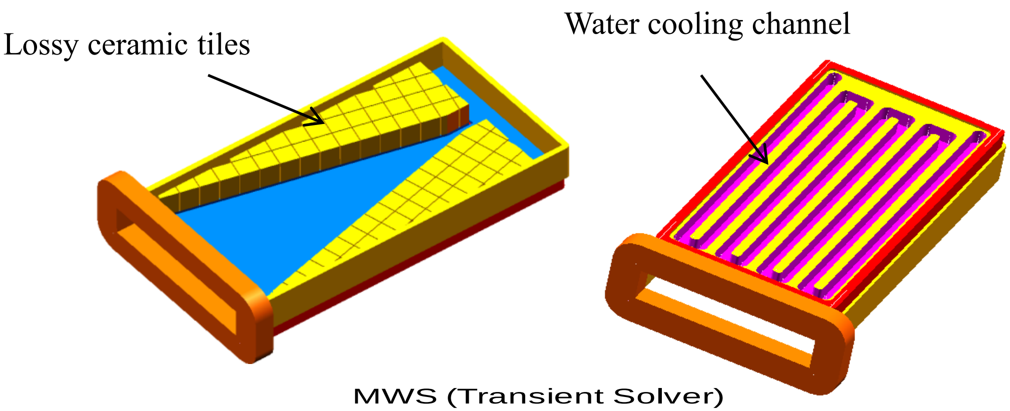


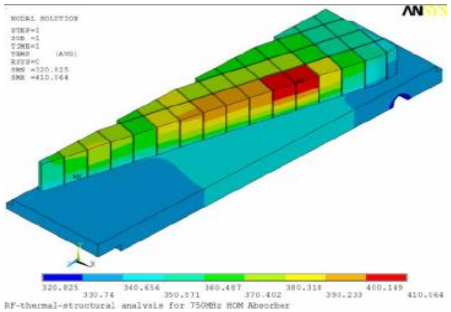




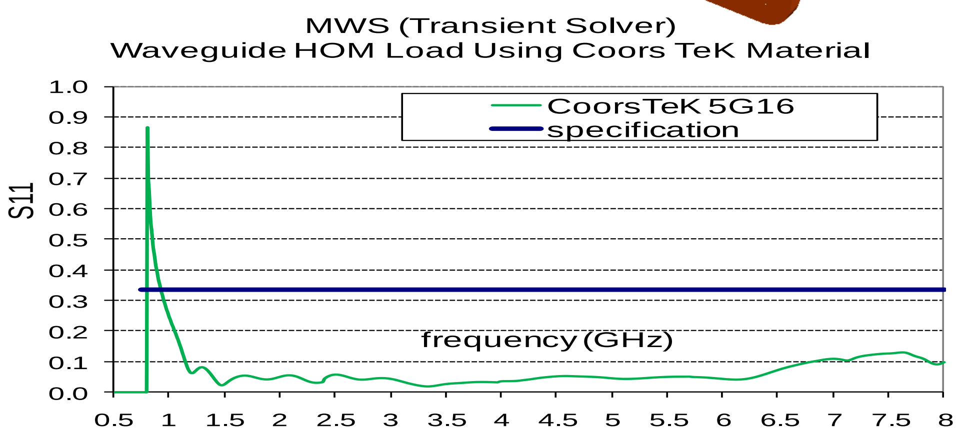
Components

- HOM Load, 4 kW
- RF planar window, M. Stirbet THPPO056





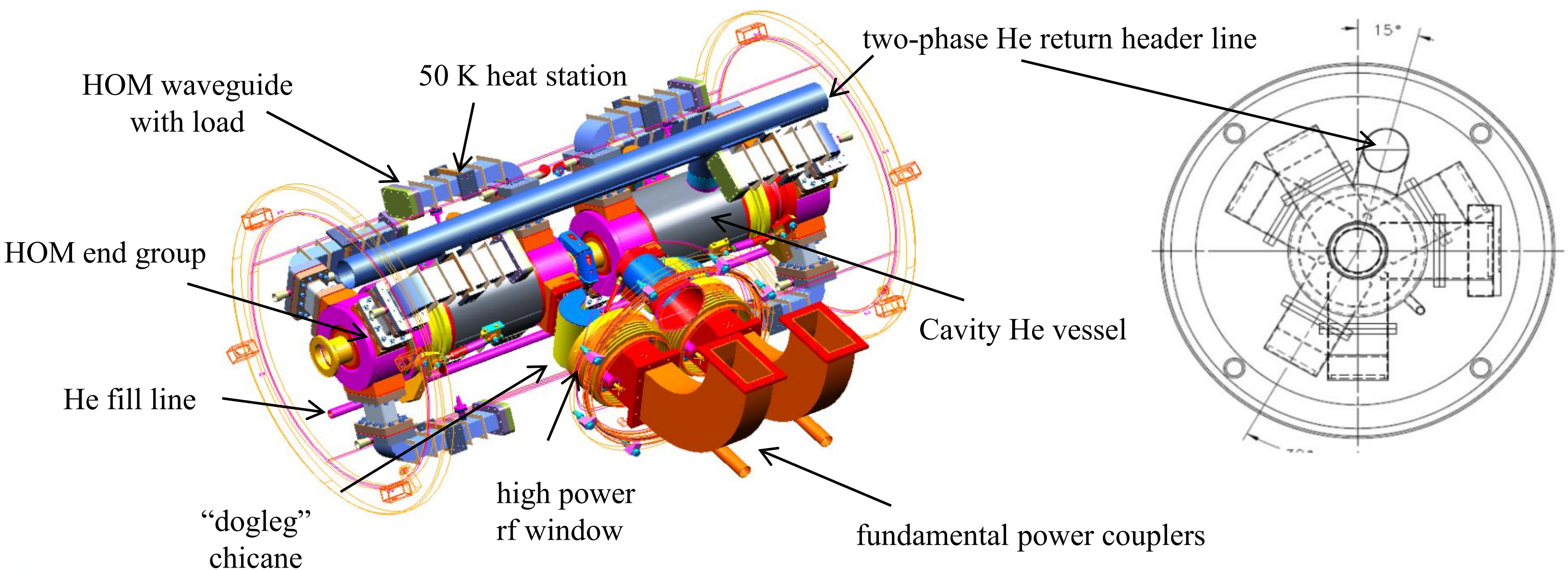
Temperature distribution



High power load design and simulation results

100 mA Cryomodule Design

- Use existing 1497 MHZ cavities
- Use existing horizontal test bed cryostat
- Complete designs of “critical” components, FPC, HOM couplers and loads, RF window



Conceptual design of a cavity-pair cryomodule

100 mA Cryomodule Plans

- Complete design, fabrication, and assembly
- Tests in FY10
  - Acceptance testing in the Cryomodule Test Facility
  - Beam tests in the FEL

High Current Program

- Actively prototyping and testing critical components
  - Cavities
  - RF couplers, FPC and HOM
  - RF windows
  - HOM loads
- Cryomodule designs going forward existing components as much as possible
- Beam test in FY10

Summary

- 12 GeV Upgrade cavity work is in good shape and the order for 86 cavities has been placed
- Work continues on improving processes for best cavity performance

- High current program at Jefferson Lab in alive and well
- Design, prototype, and testing of components is ongoing
- Design work for a beam test cryomodule has started
- Beam test is planned for FY10