3.9 GHz, 3rd Harmonic 4-Cavity Module Status

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Fermilab

TTC meeting at LAL

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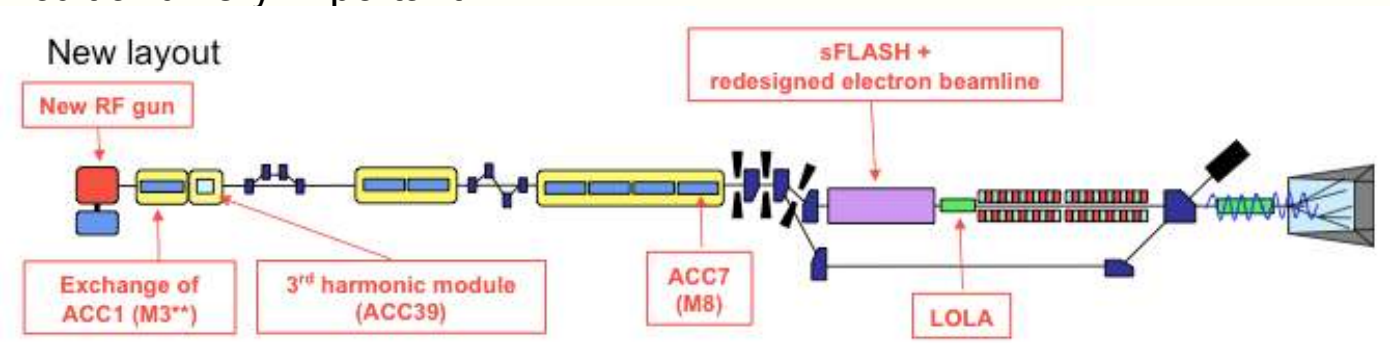
Outline 3.9GHz Module

- What is it and what will it do?
- Why do it & What has it done for Fermilab?
- Progress, Accomplishments, History
  - Technical progress
    - The steps: Design, Fabrication, Process, Vertical test, Dress, Horizontal test, Module assembly, Infrastructure
- Lessons Learned and Problems encountered
- Schedule - Looking Forward
- Conclusion

The 3.9GHz cavity module -What is it -what will it do?

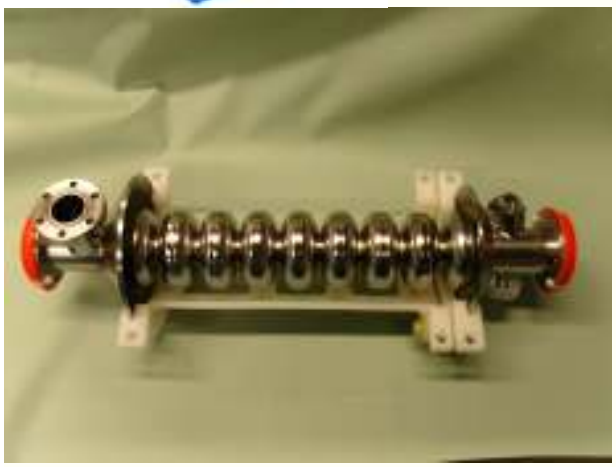
- The 3.9GHz module, ACC39, will be installed in the DESY FLASH injector just after the 1.3GHz ACC1 (first) cryomodule.
- It will be used in conjunction with this module in order linearize the bunch energy vs. time over the bunch length.
- This in turn should make “bunch compression” to very short bunches with high peak currents more efficient, or a more controlled longer bunch charge distribution.
- The SASE FEL operation should become more efficient and stable seeded operation (sFlash) possible.
- This is an important proof of principle not only for FLASH and XFEL but also for accelerator-photon physics, and a learning experience.
- The control of the phase and amplitude of the 1.3-3.9 GHz module pair will be difficult and very important.



Why Do It & What Has It Done for Fermilab?

- The 3.9GHz effort is part of a collaboration with DESY.
- In this collaboration DESY has advised Fermilab on many of the aspects of SRF development and has supplied design and assembly information.
- In 2007, DESY provided for Fermilab a 1.3GHz Type 3+ module kit. This module was assembled at FNAL by the FNAL personnel with the assistance of DESY experts. The module is being installed in the NML facility.
- The 3.9GHz module has been/will be a learning experience for FNAL in all aspects of beta=1 SRF cavity and module design through commissioning.
- Successful completion will clearly show Fermilab's growing competence and abilities in SRF technology.
- It is important that we learn and benefit for our experiences and "Lessons Learned".

3.9GHz Overview Photos



Infrastructure

- Some old and some new
  - Old - A0 SRF R&D Infrastructure:
    - Modest, built up over the years
      - Soft wall clean room
      - UV water & Ultrasonic bath
      - High Pressure Rinse
      - Vertical test (short dewar)
      - RF systems (1.3 & 3.9)

  - New - set up for 1.3GHz & also used for 3.9GHz
    - Horizontal Test Stand (HTS) at Meson (MDB)
    - String and Cold mass assembly at Cryomodule Assembly Facility (CAF)

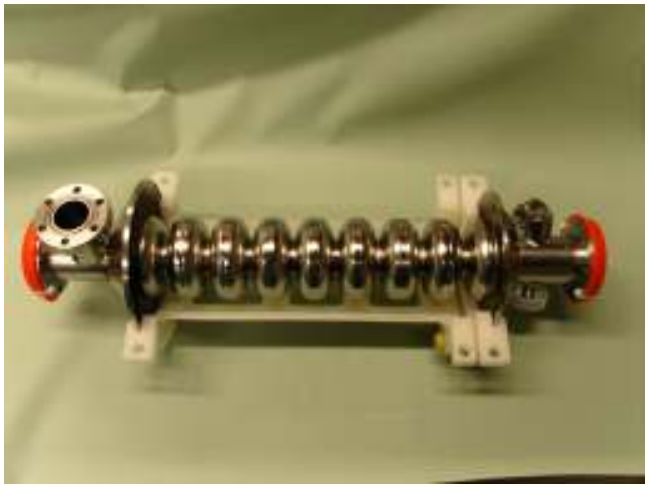
Cavity Fabrication Steps

- Documents on Cavity and Helium Vessel Fabrication and Welding by M. Foley, et al
  - 3.9GHz Cavity Fabrication Specification
    - Material
    - Blanks for half cells
    - Fabrication of Components
    - End Assemblies
    - Welding of Cavity
    - Final Test of Cavity
  - Procedures for Welding Helium Vessels to 3.9 GHz Cavities
    - Preparation for Electron Beam welding
    - Electron Beam Welding
    - Preparation for TIG Welding
    - Final TIG welding
    - E-beam Weld Parameters
    - TIG Weld Parameters

Fabrication and Processing Steps

- Table of processing steps by A. Rowe, et al
  - About 200 steps after fabrication
- Outline
  - Preliminary Processing Sequence
    - Preliminary Preparation
    - External Surface Preparation
    - Internal Bulk Surface Preparation
    - Hydrogen Degasification
    - RF tuning
  - Vertical Test Processing Sequence
    - Internal Surface Preparation
    - 1st Vertical Test
    - 2nd Vertical Test
  - Titanium Helium Vessel Welding
  - Horizontal Test Processing Cycle

Cavity fabrication,BCP, HPR, Vertical Test



Bare 3.9 cavity

Weld

BCP etch

Hi Press Rinse

Vertical test & dewar

Vertical test control area

Helium vessel welding
Dressed Cavity to HTS

String and Module Assembly Steps

- Assembly Travelers by T. Arkan, M. McGee, D. Olis, et al
  - Assembly QA Traveler
  - Cavity String Assembly
  - Cold Mass Assembly Parts 1-3
  - Final Assembly Traveler
  - Shipping Document
  - Warm Coupler Assembly Document

3.9GHz Module Assembly

Assembled cavity string

Various group working on the cold mass assembly

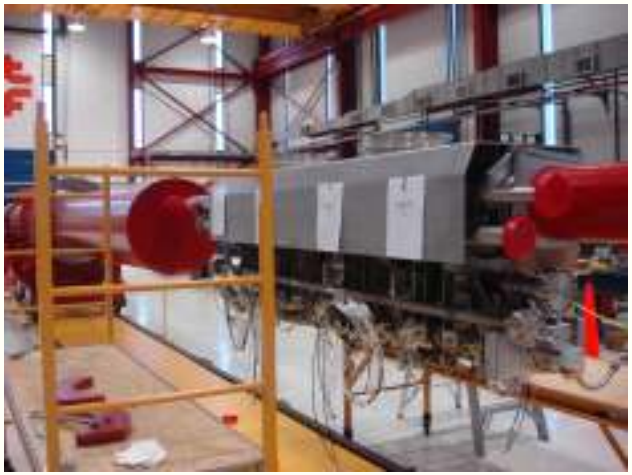
Cold Mass being prepared for transport

Cold Mass transport

3.9GHz Module Assembly

Cold mass to Big Bertha

Completed Cold Mass

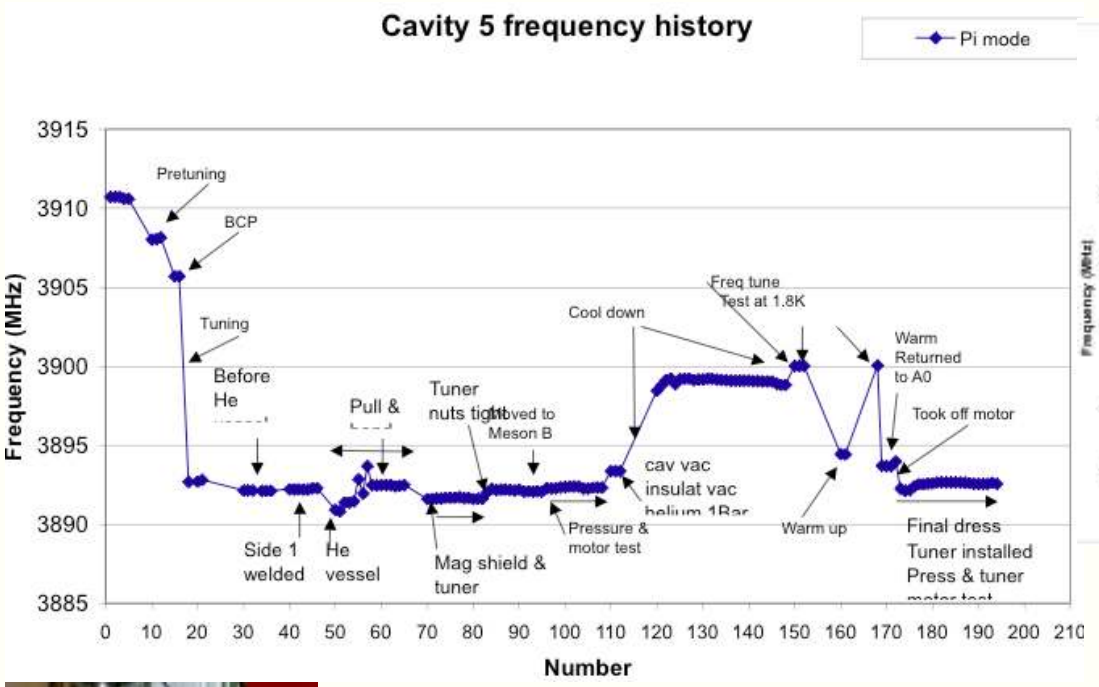


Cold Mass at Big Bertha

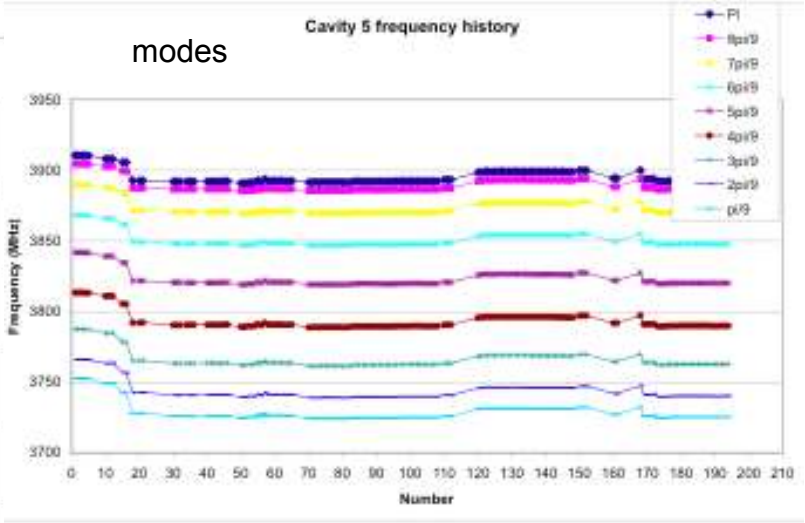
Cold Mass to the Vacuum Vessel assembly

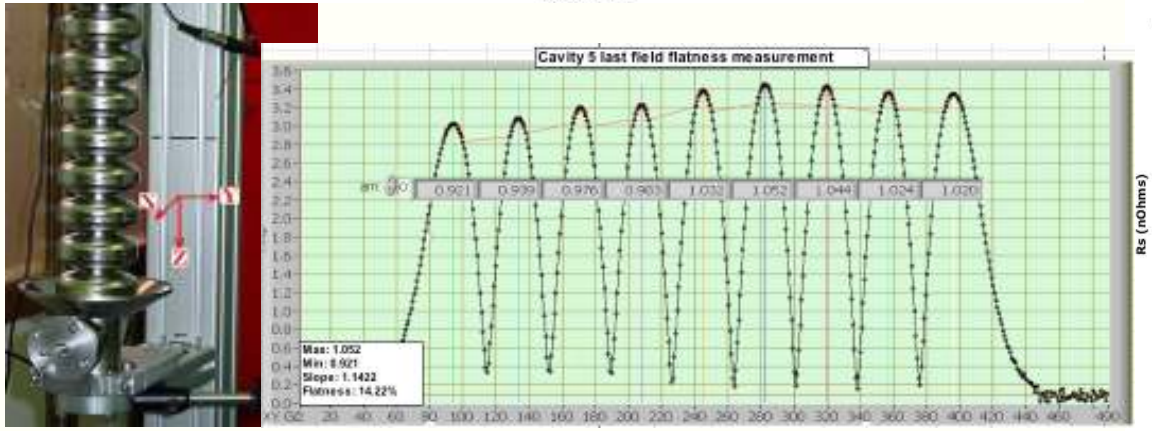
Warm/Low power RF Measurements

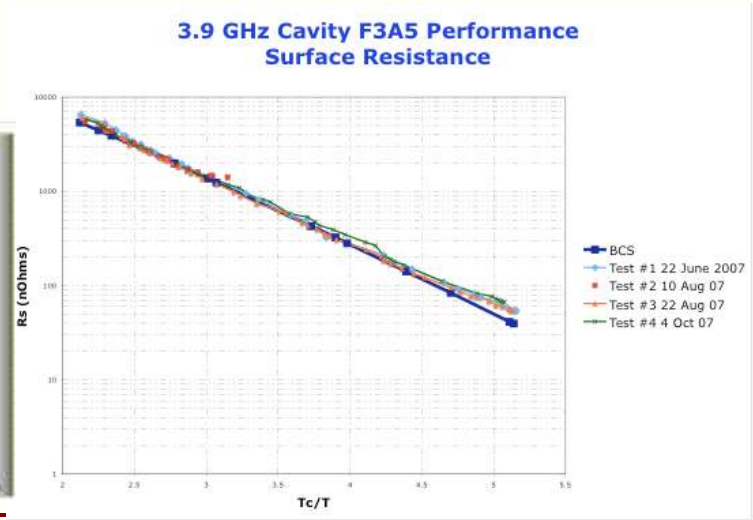
T. Khabiboulline



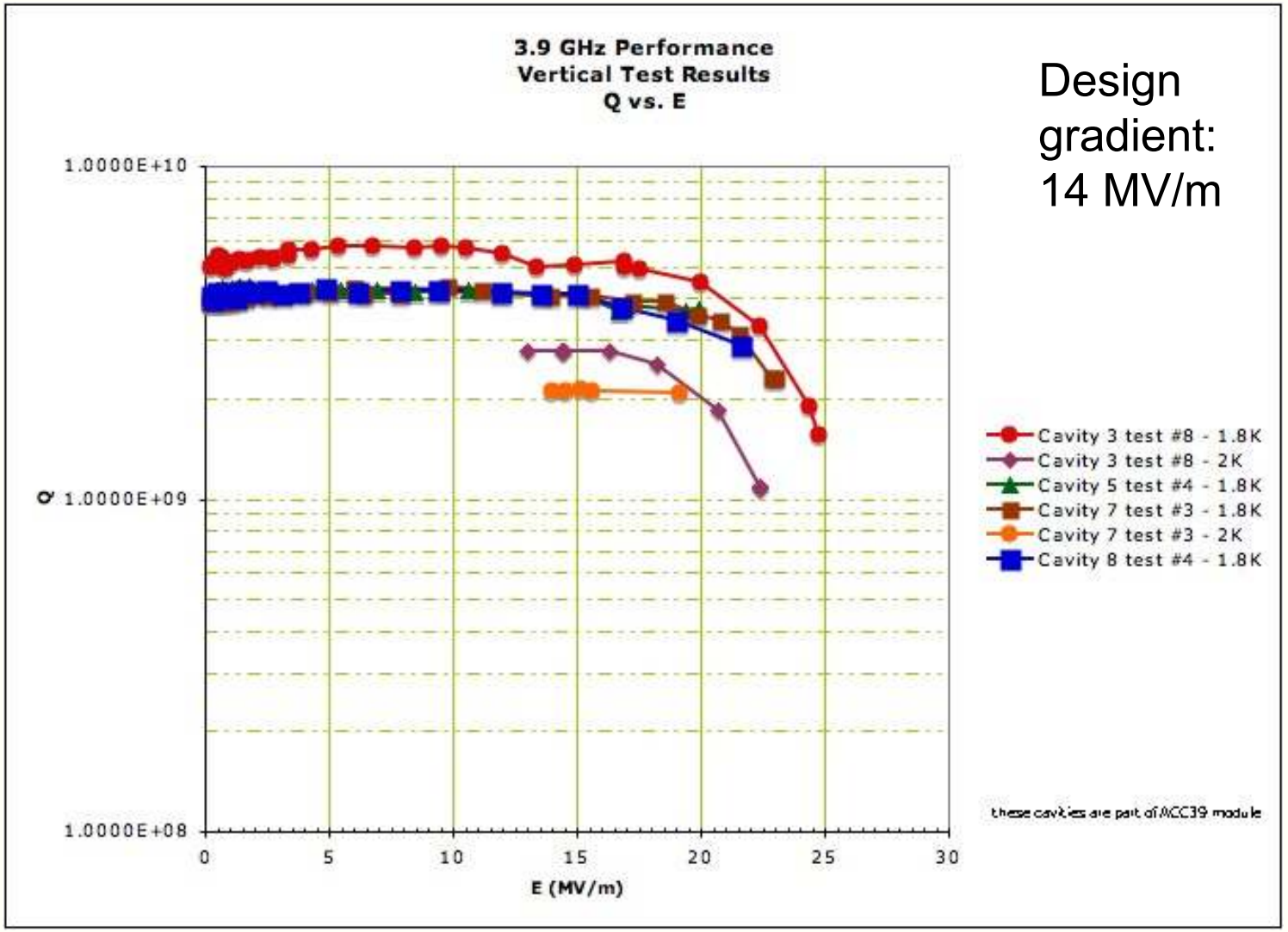
modes







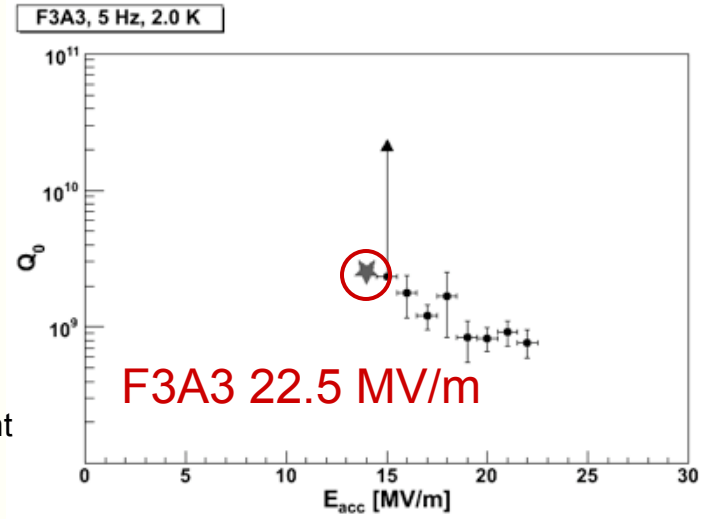
3.9GHz Cavity Vertical Tests

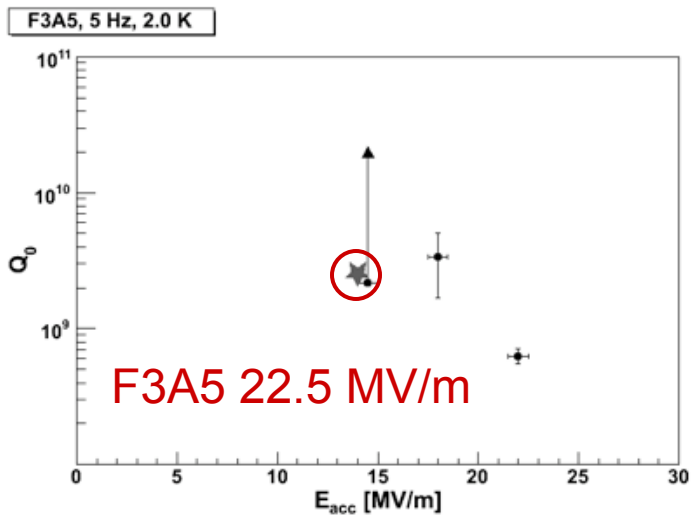


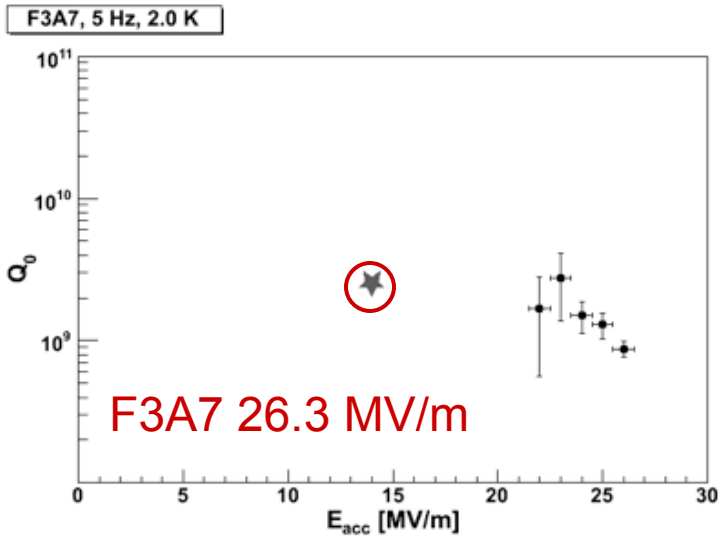
Design gradient: 14 MV/m

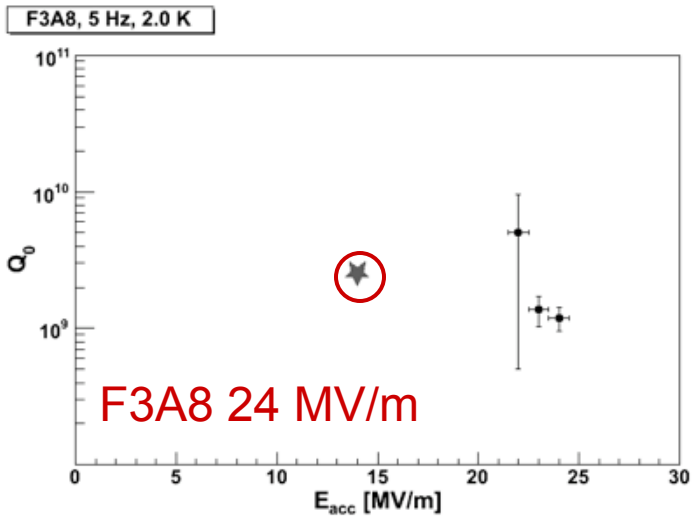
Cav 3,5,7,8 Horizontal Test Results at HTS

Design Gradient
14MV/m









Schedule Highlights - past

- 2002 — TESLA Facility Phase 2 Report with 3.9 GHz module for bunch compression (TESLA-FEL 2002-01)
- 2002-3 — Cavity design documents (TESLA-FEL 2002-05, 2003-01/FNAL TM 2210)
- 2005 — DESY-FNAL MOU on 3.9 module
- 2006, 03-06 — C1,C2 failures, Multipacting & HOM wall thickness
- 2006, 08 — F3A3 fabrication finished- first usable cavity
- 2007, 05 — F3A3 good vertical test after HOM formteils cut, 24MV/m
- 2007, 10 — F3A5 vertical tests with HOM feed-throughs complete 19MV/m
- 2008, 02-09 — F3A5 in horizontal test stand (HTS)
- 2008, 04 — F3A5 achieved 22.5MV/m in HTS
- 2008, 12 — F3A8 last cavity of four removed from HTS
- 2009, 01 — String assembled in CAF-MP9 Clean Room
- 2009, 02 — Cold mass to CAF-ICB
- 2009, 04 — Module finished and shipped to DESY

2002 to 2009 - start to ship - for module tests at DESY

Problems & Lessons Learned

- Technical issues
  - HOM design and multipacting - 1-post redesign for F3A7, F3A8
  - HOM antennae feed-throughs: followed JLab type design
  - Titanium Helium vessel weld design, welding and Titanium pipe welding
- Infrastructure issues
  - e- Beam welder availability
  - BCP etch availability, FNAL & ANL
  - HTS commissioning
  - Maintenance of effective CR, HPR, and Cryo systems at A0
- Procedural issues
  - Pressure vessel testing and Engineering note, ORC:
    - Fermilab is learning to deal with the safety aspects of SRF testing (non-ASME materials, etc.). The 3.9GHz effort, especially the HTS step, played a pioneering role in the format and content of Engineering notes and approval to cooldown and power test SRF cavities. At times a frustrating process (~6 months for HTS approval), but the need is also understood. Organizationally, Fermilab is now better poised and taking strategic steps for future operations.

Still to Do

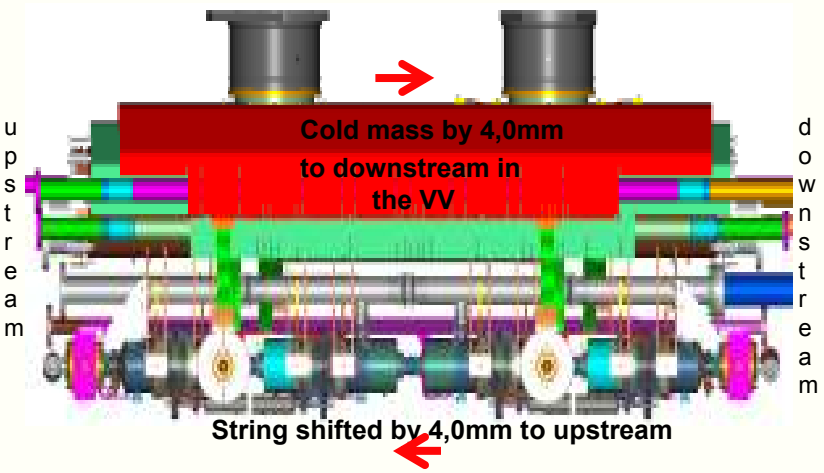
- Spare cavities
  - Qualify F3A4 & F3A6 as spares
  - Complete F3A9 fabrication and subsequent steps
- Summary Report of RF tests and measurements for each cavity (in progress)
  - History overview for assembly, process, measure and test
  - Warm and mechanical measurements
  - Vertical test summary
  - Horizontal test summary
  - Final tests
- Summary Report of Technical Designs (in progress)
  - Accelerator physics use of 3.9 GHz module
  - RF design of cavities, input couplers, HOM couplers,
  - Thermal analysis
  - Cavity assembly and processing steps.

Update on Module after Arrival at DESY-1

- Transportation shock log data good, maximum 1.2 g differential.
- Vacuum was maintained during transport. String is leak-tight (10^{-8} Torr at pump).
- One heat shield interference found and corrected (80K coupler shield to 4K module shield).
- Survey comparison FNAL->DESY excellent:
  - Cavity targets as a group comparison, max difference 0.16mm
  - Relative to cold mass max difference 0.28mm
  - Measurement accuracy ~0.15mm
- One warm-end input coupler piece was test fitted by DESY and FNAL people.
- Instrumentation and cavity frequency checks are ok.

Update on Module after Arrival at DESY-2

- Some cavity support bearing housings, “C channels”, were found out of position, others not accessible in the module to check. Likely occurred during alignment of the cavities.
- Cold Mass assembly was removed at DESY and moved ~4mm upstream. C-channels now all in position.
- Cold Mass is back in vacuum vessel as of 10-06-09. FNAL personnel assisted DESY colleagues during re-assembly.
- Coupler installation planned for week of 22 June with DESY and FNAL personnel.



3.9GHz Schedule Highlights – Future

May-June '09	Module fix and coupler installation
May - Sept '09	Preparation of Cryo Mod Test Bench (CMTB) at DESY for 3.9 test
Oct - Nov '09	Installation and check out of module at CMTB
Oct - Dec '09	Test ACC39 at CMTB
Sept 09 - Feb '10	FLASH shutdown
Dec 09 - Feb '10	ACC39 installation in FLASH
March '10	Technical commissioning of ACC39 in FLASH
Apr - June '10	Beam commissioning in FLASH
Summer '10	User operation

We must still show that the cavities work in the module at DESY test facility and TTF/FLASH.

Conclusions

- The 3.9 module has been an important and fundamental learning experience for FNAL in all areas of SRF technology.
- This is the 1st 3.9 GHz module built anywhere.
- Cooperation across the Fermilab organization was vital to accomplish this. New players have been recruited and trained.
- Successful lasing results from FLASH will be an important step of R&D to the accelerator field in general and illustrates the importance of accelerator developments & applications across different end user facilities. (e.g. Hi Energy, Nuclear, Materials,…)