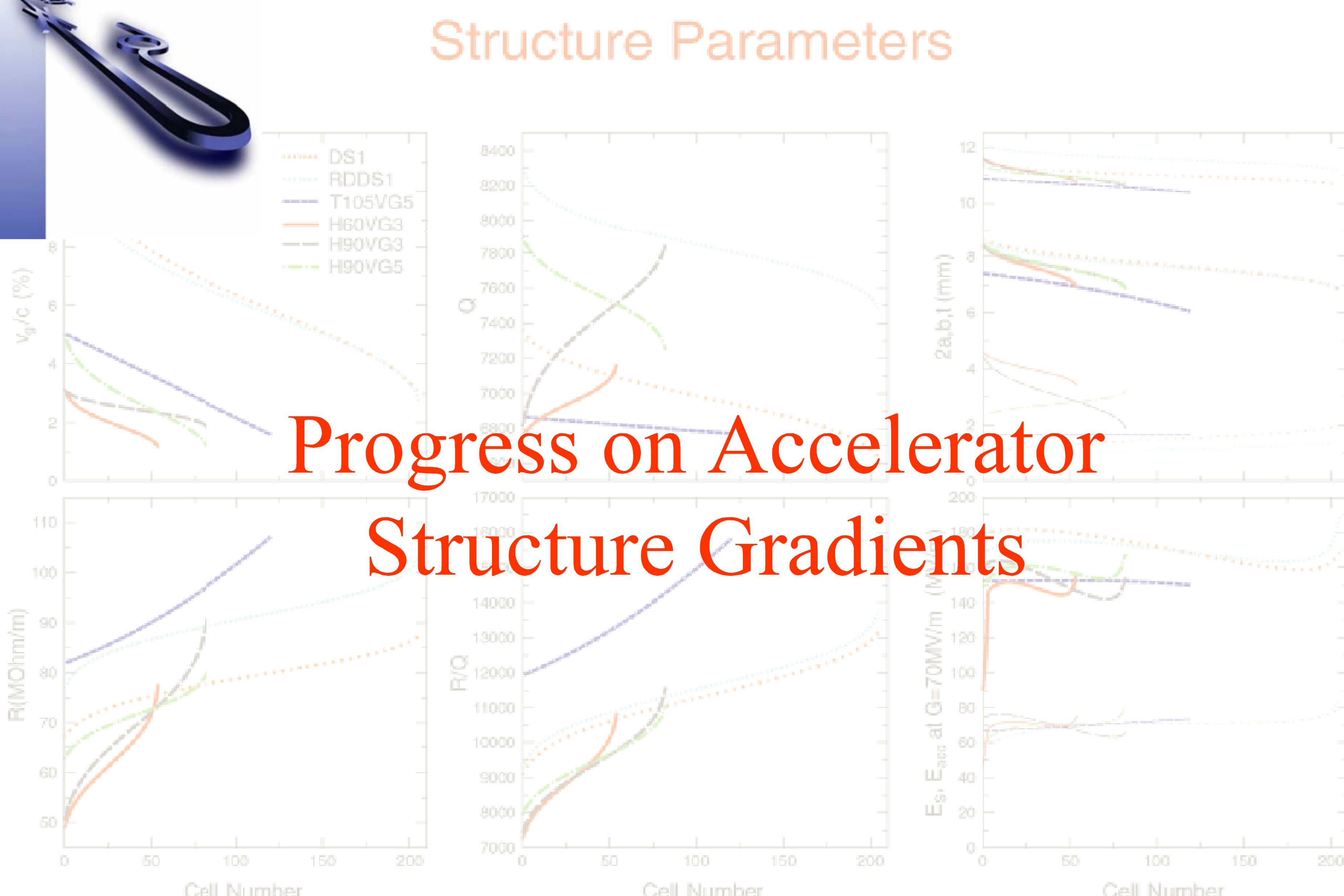

Progress on Accelerator Structure Gradients

Chris Adolphsen

High Gradient Studies at the NLC Test Accelerator (NLCTA)

Contributors

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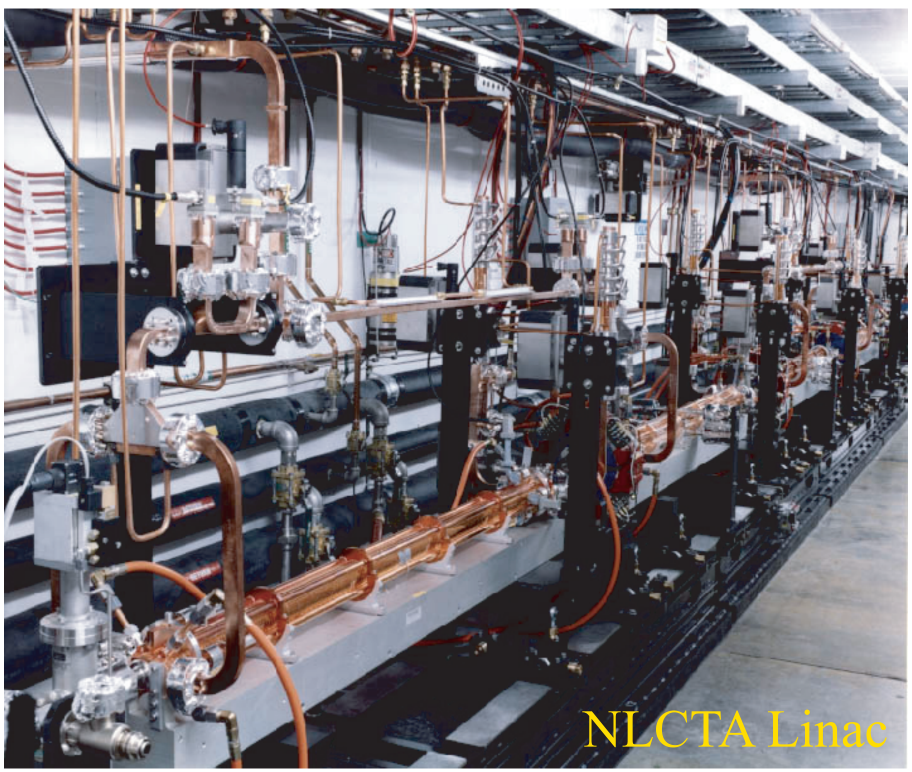
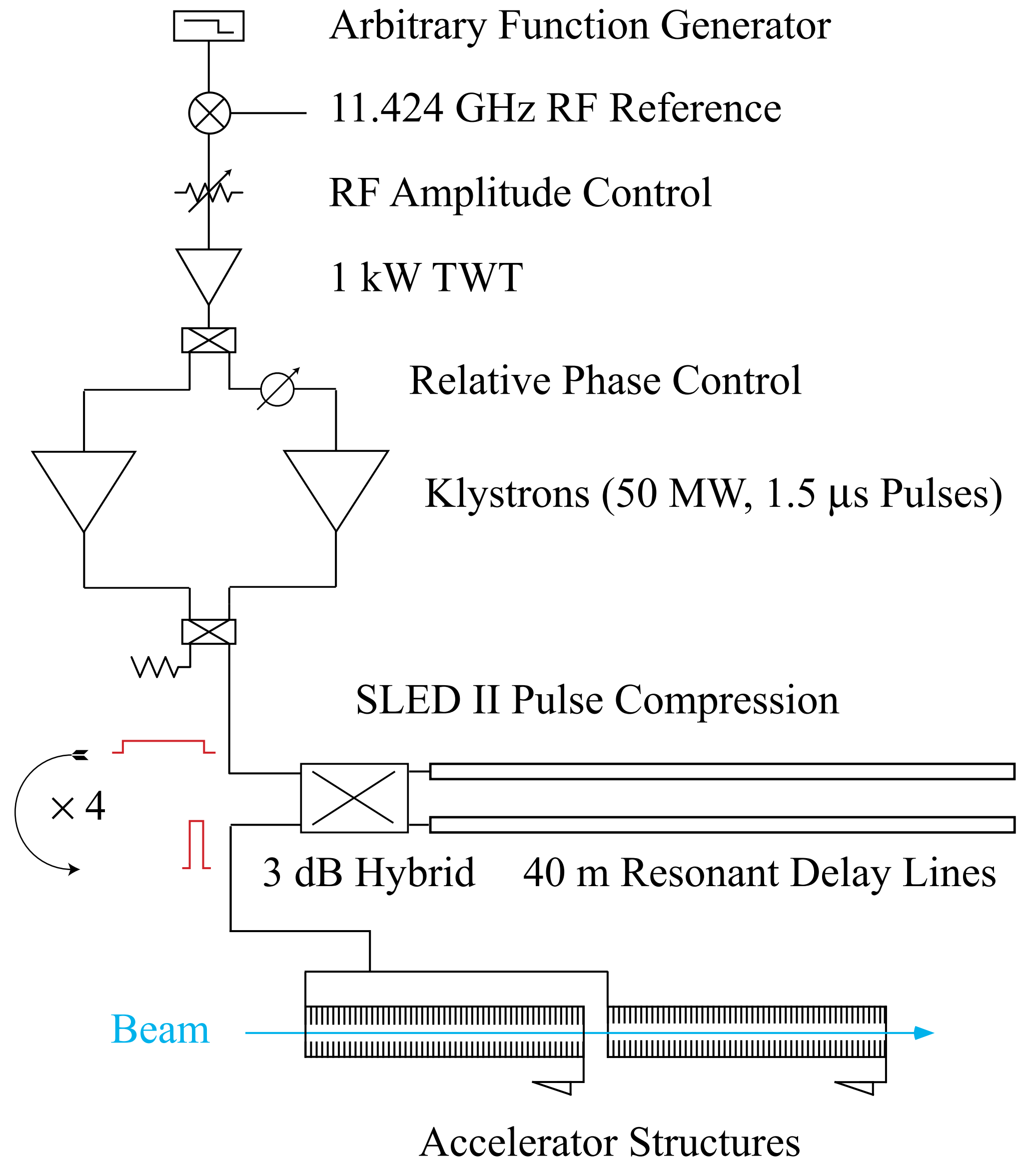
J. Nelson, C.K. Ng, M. Ross, R. Ruth,
T. Smith, S. Tantawi, J. Wang and P. Wilson



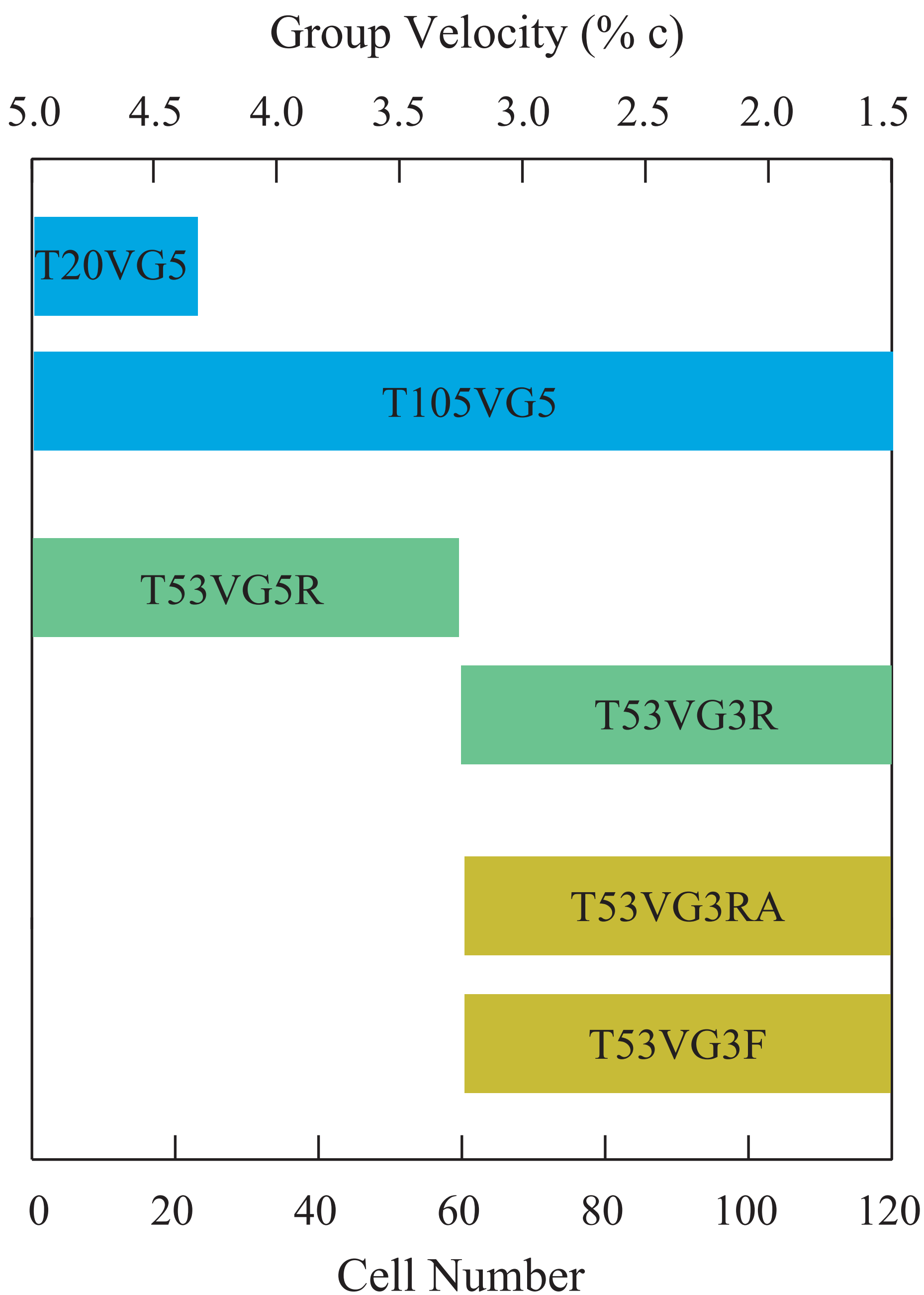
NLCTA Linac RF Unit (One of Two)



Structure Development Overview

- After improvements to the rf processing capabilities at NLCTA in 2000, realized nominal NLC/JLC 1.8 m long structures were being damaged during processing and would not meet performance requirements at 65 MV/m.
- Launched aggressive R&D program
  - Build/Test low group velocity traveling wave structures and standing wave structures.
  - Improve structure handling, cleaning and baking methods.
  - Study characteristics of rf breakdown in structures, cavities and waveguides.
  - ⇘ Thus far have tested 20 structures (over 10 khr operation at 60 Hz).
- T-Series Structures
  - Essentially the downstream (low group velocity end) portions of the 1.8 m structures. Chosen because this region of the 1.8 m structures showed little damage.
  - Produced structure with acceptable trip rate at gradients up to 90 MV/m.
- H-Series Structures
  - Developing low group structures with acceptable iris sizes to limit short-range wakefields and slots in cells to damp long-range wakefields.

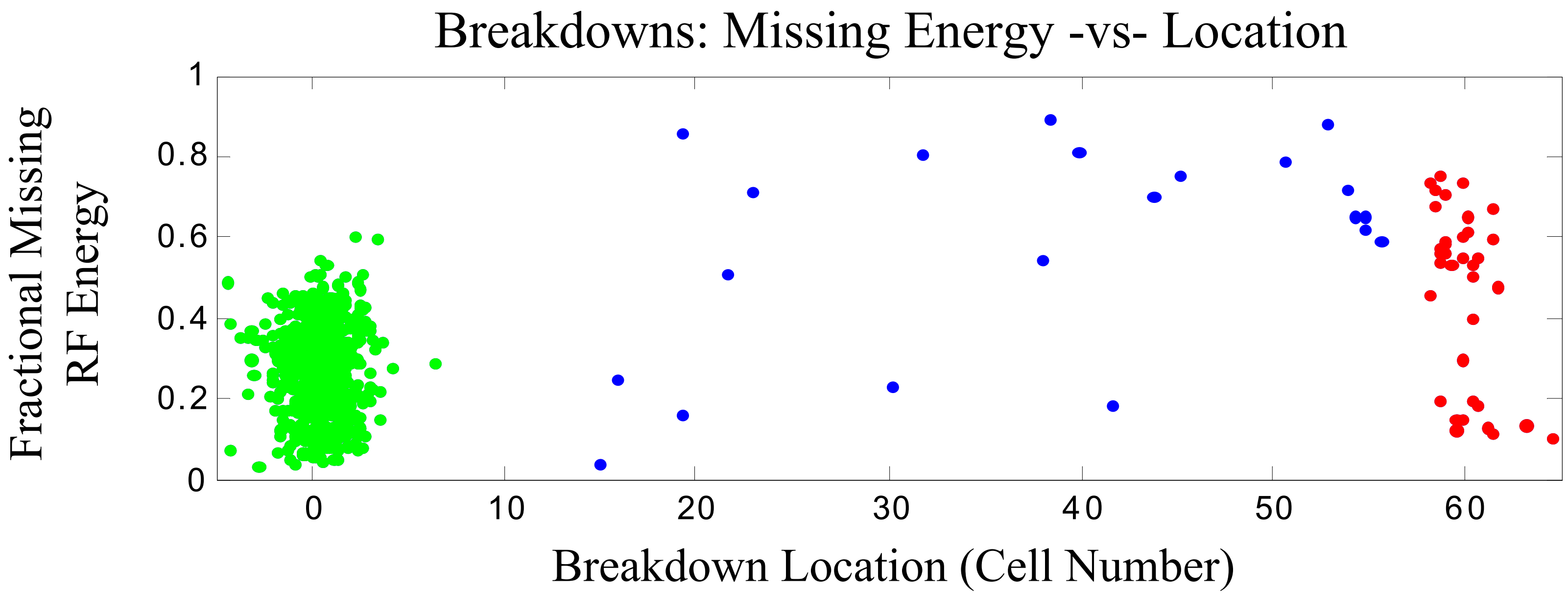
T-Series Structures Tested



Cell Machining	Etch Depth for Cell Cleaning	Input Coupler
Diamond Turned	0.3 microns	Standard
Conventionally Machined	3 microns	Standard
Conventionally Machined	1.5 microns	Low Field/ Low Impedance
Diamond Turned	No Etch	Standard

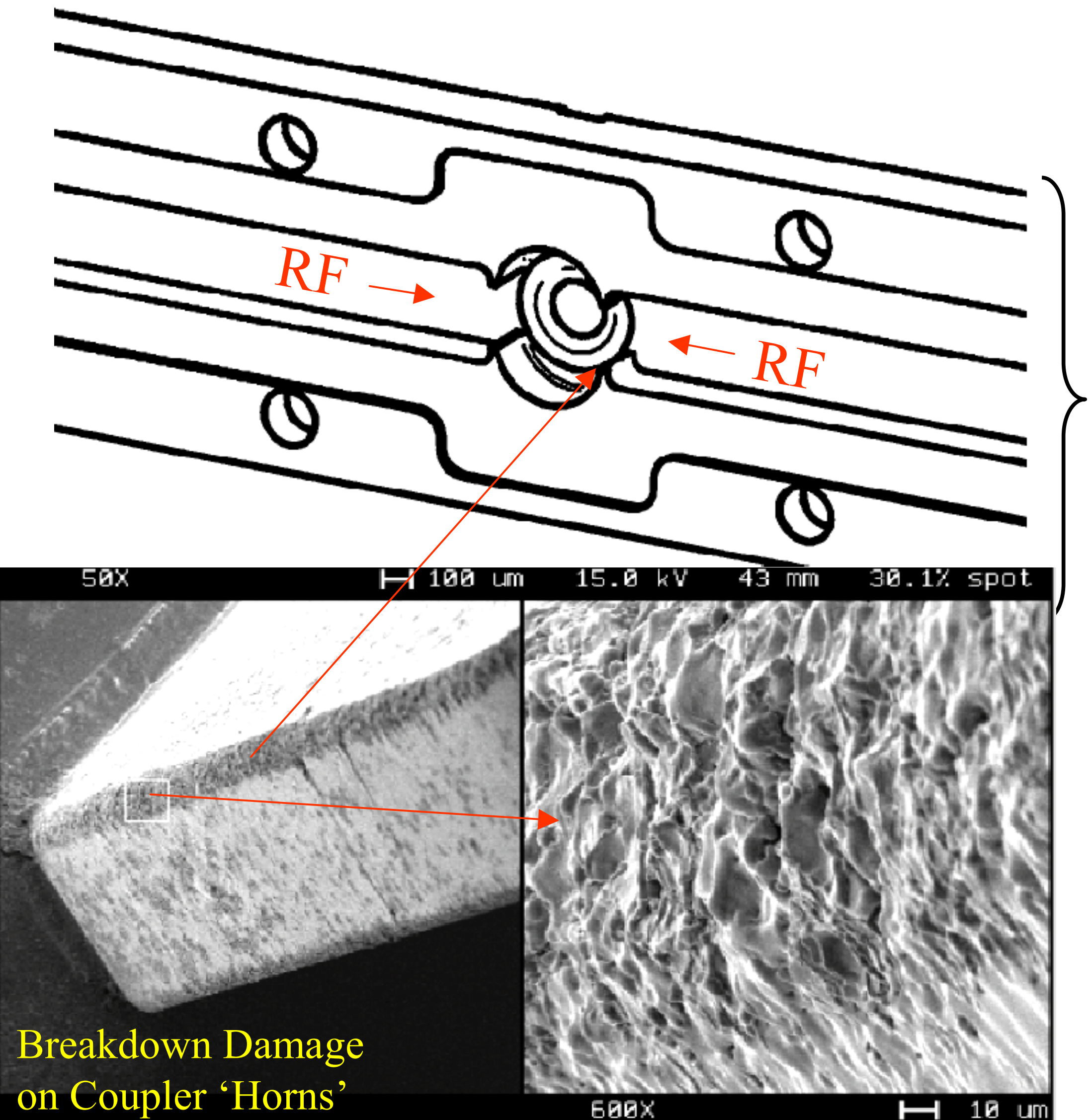
Example of Low Group Velocity Structure Performance at 70 MV/m

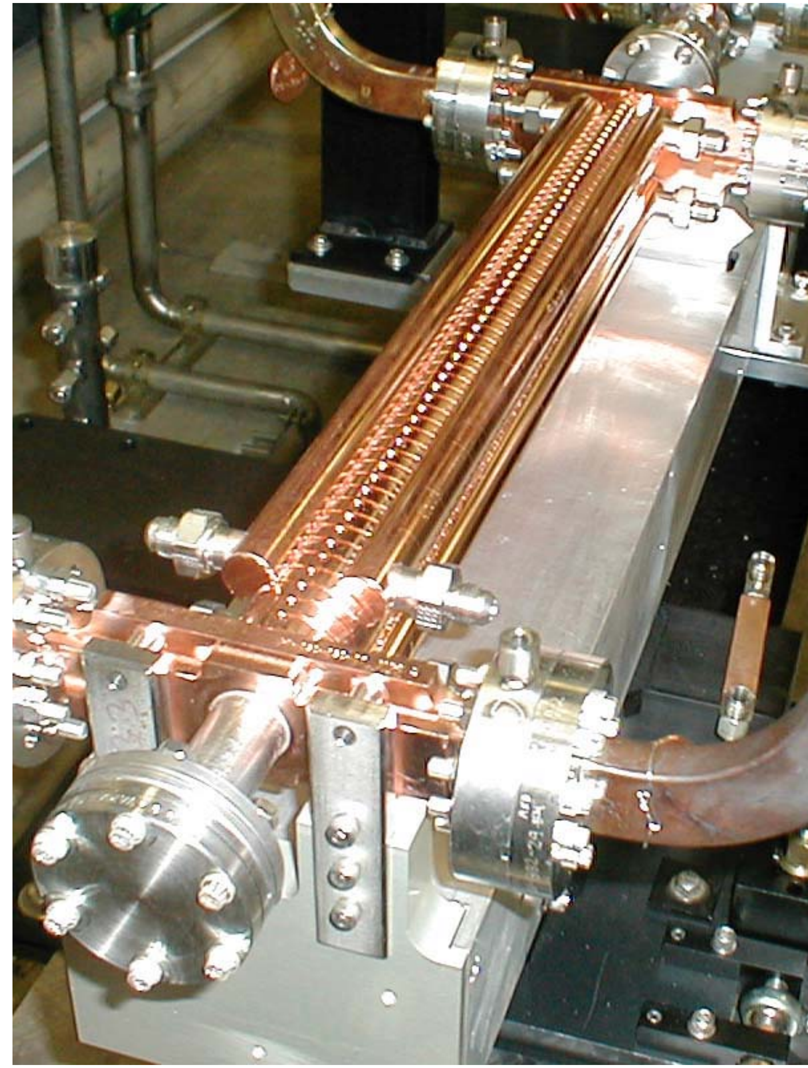
(120 Hours of Operation at 60 Hz with 400 ns Pulse Widths)



- Breakdown rate in structure body (blue events) = 0.2 per hour or about <u>one in a million pulses</u>.
  - NLC goal is < 0.1 per hour: measure from < 0.1 to 0.3 per hour in five structures.
- Breakdown rate in the two coupler cells (green and red events) = 5.5 per hour
  - Rates in other structure couplers vary from 0.1 to 5 per hour → suspect pulse heating at the coupler waveguide openings as the root cause.

Input Coupler with Upstream Cover Removed

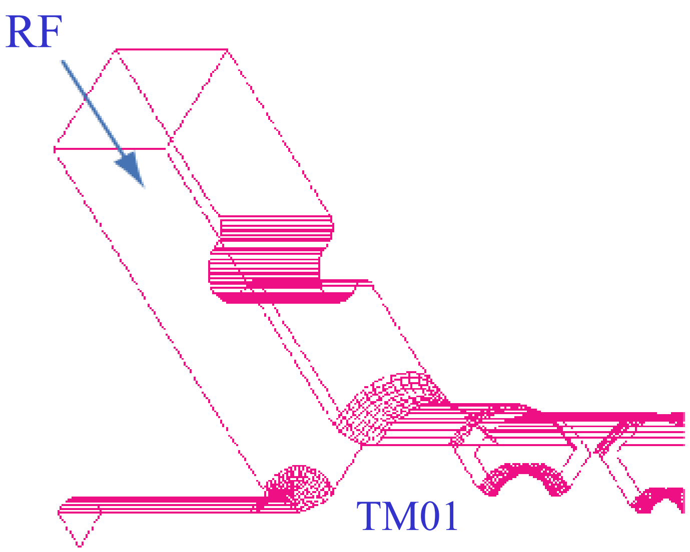




T53VG3 Structure

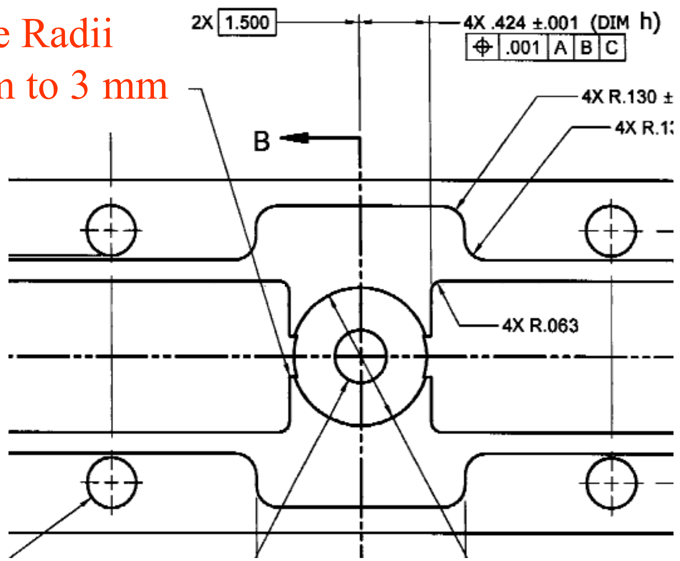
Coupler Improvements to Lower Pulse Temperature Rise from > 130 °C to < 40 °C

Mode Converter Coupler
(¼ Cutaway View)



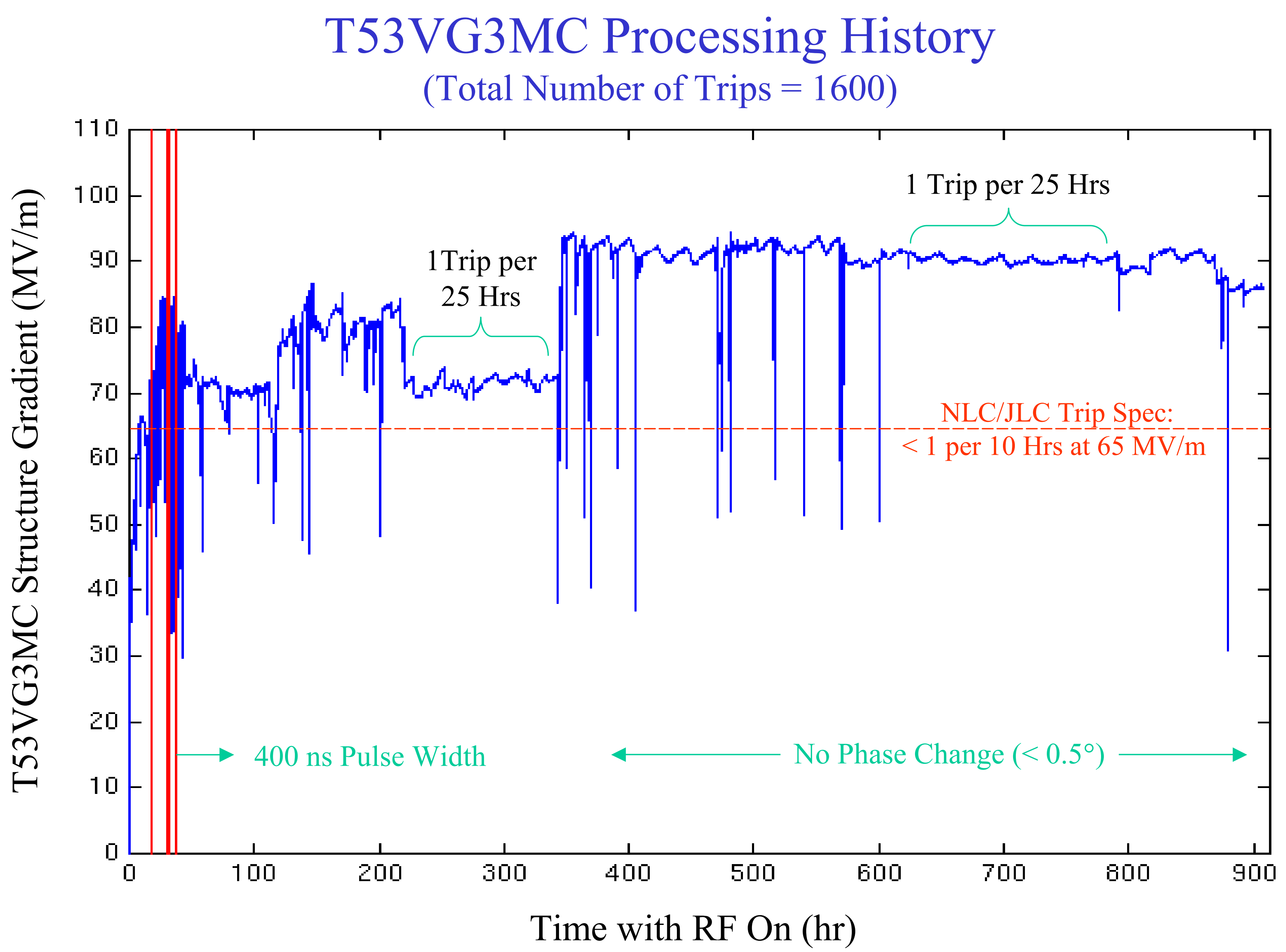
Fat Lip Coupler
(Round Horn Edges)

Increase Radii
from 76 µm to 3 mm



Build T53VG3MC Structure to Test Low Pulsed Temperature Rise Designs

- T53VG3 Body Design
- Mode Converter Input Coupler
- Fat Lip Output Coupler



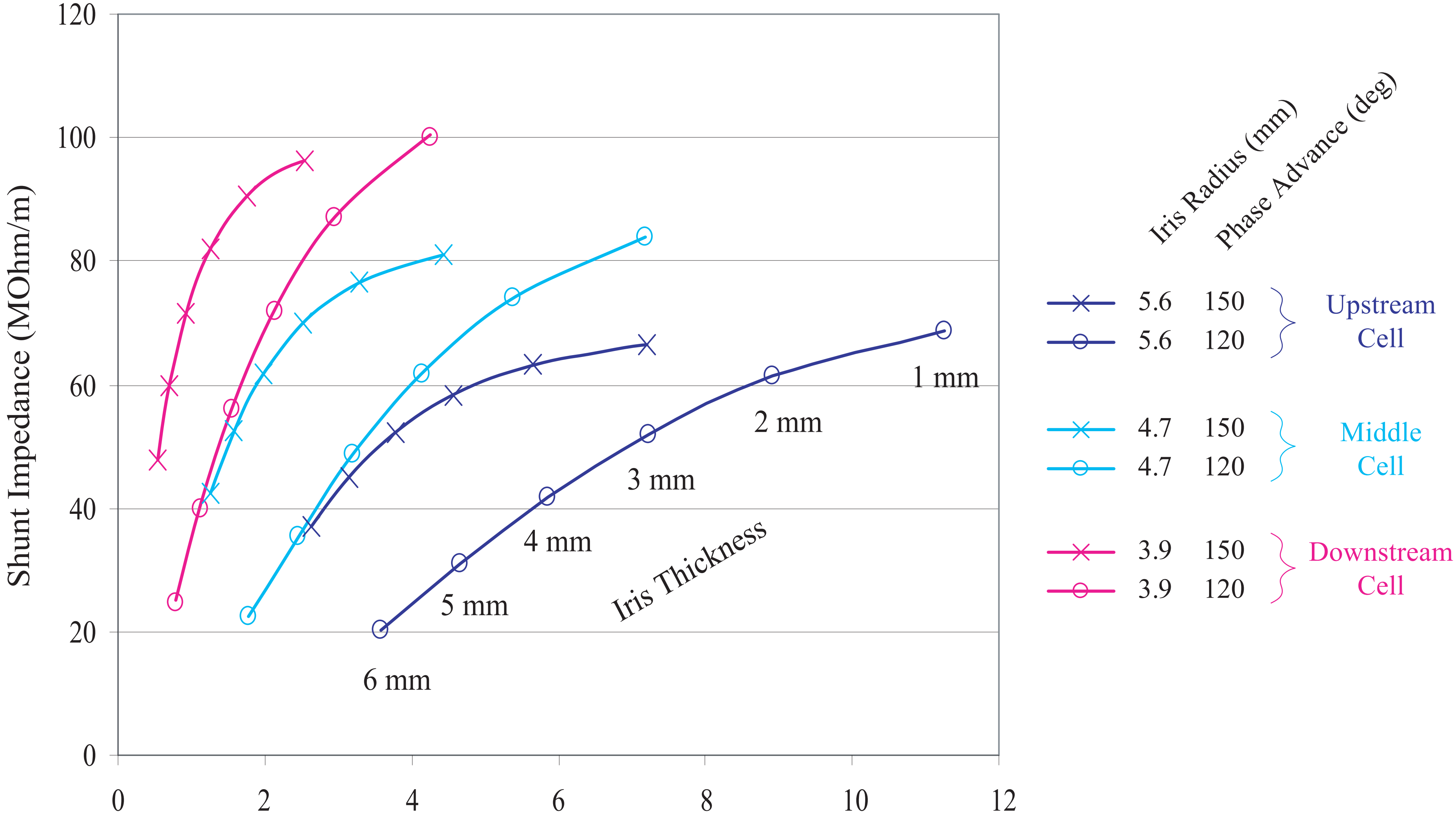
T53VG3MC Processing History
(Total Number of Trips = 1600)
T53VG3MC Structure Gradient (MV/m)
Time with RF On (hr)
1Trip per
25 Hrs
1 Trip per 25 Hrs
NLC/JLC Trip Spec:
< 1 per 10 Hrs at 65 MV/m
400 ns Pulse Width
No Phase Change (< 0.5°)
0
10
20
30
40
50
60
70
80
90
100
110
0
100
200
300
400
500
600
700
800
900

H-Series Structures

- Although the structure with the improved couplers (T53VG3MC) performed very well, it cannot be used in the NLC/JLC.
  - The average iris radius, <a/λ>, is smaller (0.13) than desired (0.18), yielding a transverse wakefield three times larger than considered acceptable.
- As the next step toward an 'NLC/JLC-ready' structure, 150 degree phase advance designs with <a/λ> = 0.18 & 0.17 (called H-Series structures) are being developed.
  - Pay twice in loss of shunt impedance → input power/length 50% larger than T-Series
  - Five <a/λ> = 0.18 structures have been tested so far:
    - H90VG5: Sharp-edge couplers prevented full processing.
    - H60VG3: Sharp-edge couplers slowed processing – body breakdown rate OK at 65 MV/m.
    - H60VG3(FXB2): FNAL first full length structure – would not process above 70 MV/m.
    - H90VG3: Meets trip rate specs at 60 MV/m.
    - H60VG3(6C): Contains six slotted cells – close to acceptable trip rate at 65 MV/m.

Designing an ⟨a/λ⟩ = 0.18 Structure with Low Group Velocity

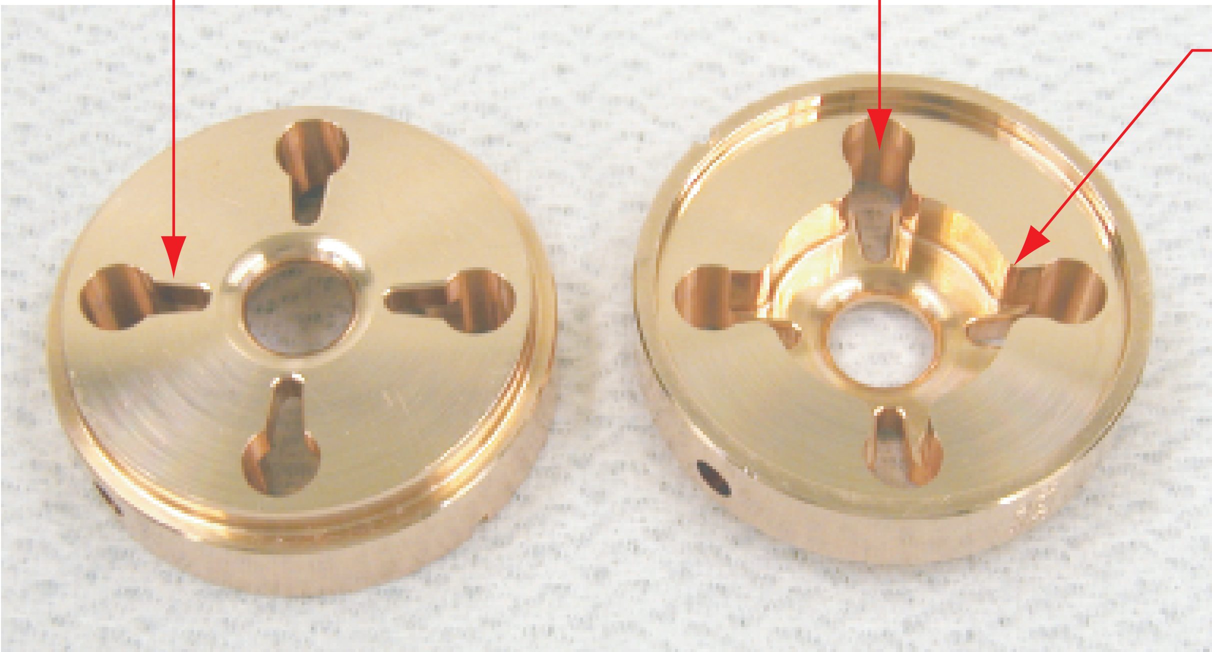
Parameters of Upstream, Middle and Downstream Cells -vs- Phase Advance and Iris Thickness



Zenghai Li

Prototype Cells to Damp the Long-Range Wakefield

- Modified earlier designs to lower pulse heating.
- Expect ~ 50 °C temperature rise at 70 MV/m, 400 ns.

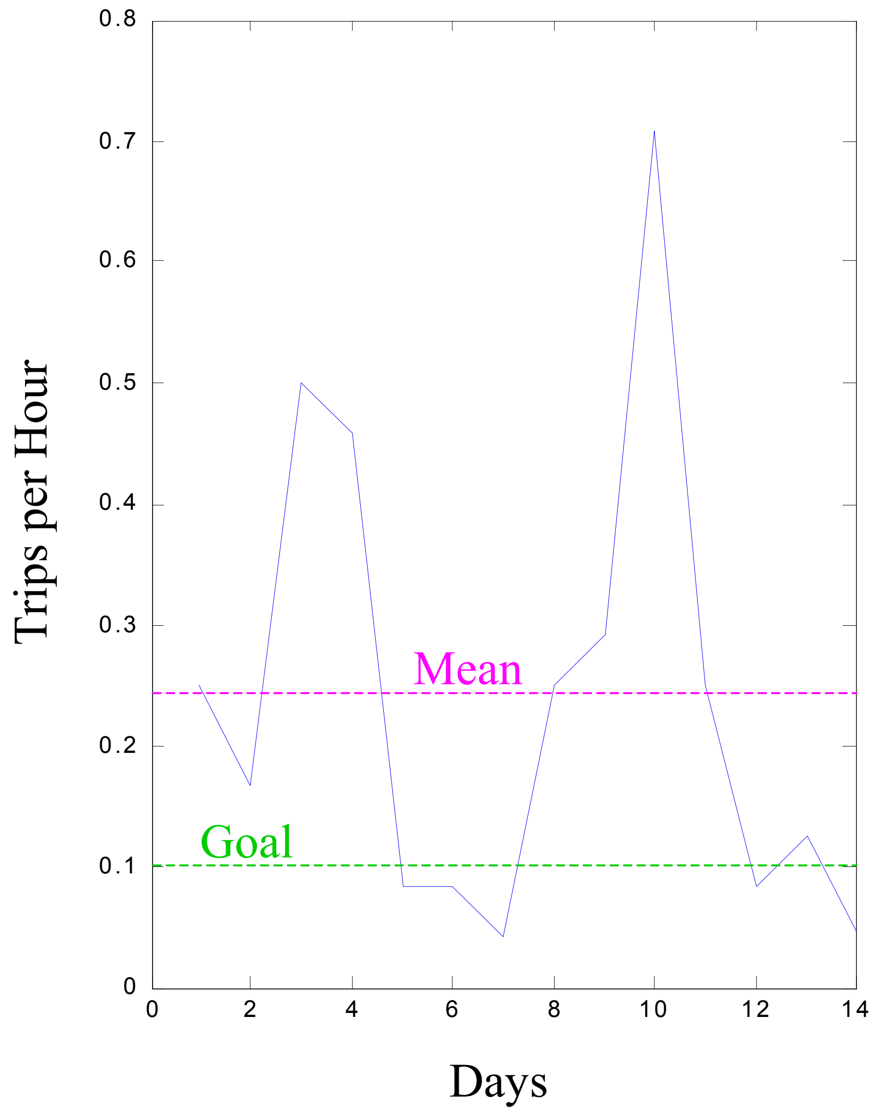


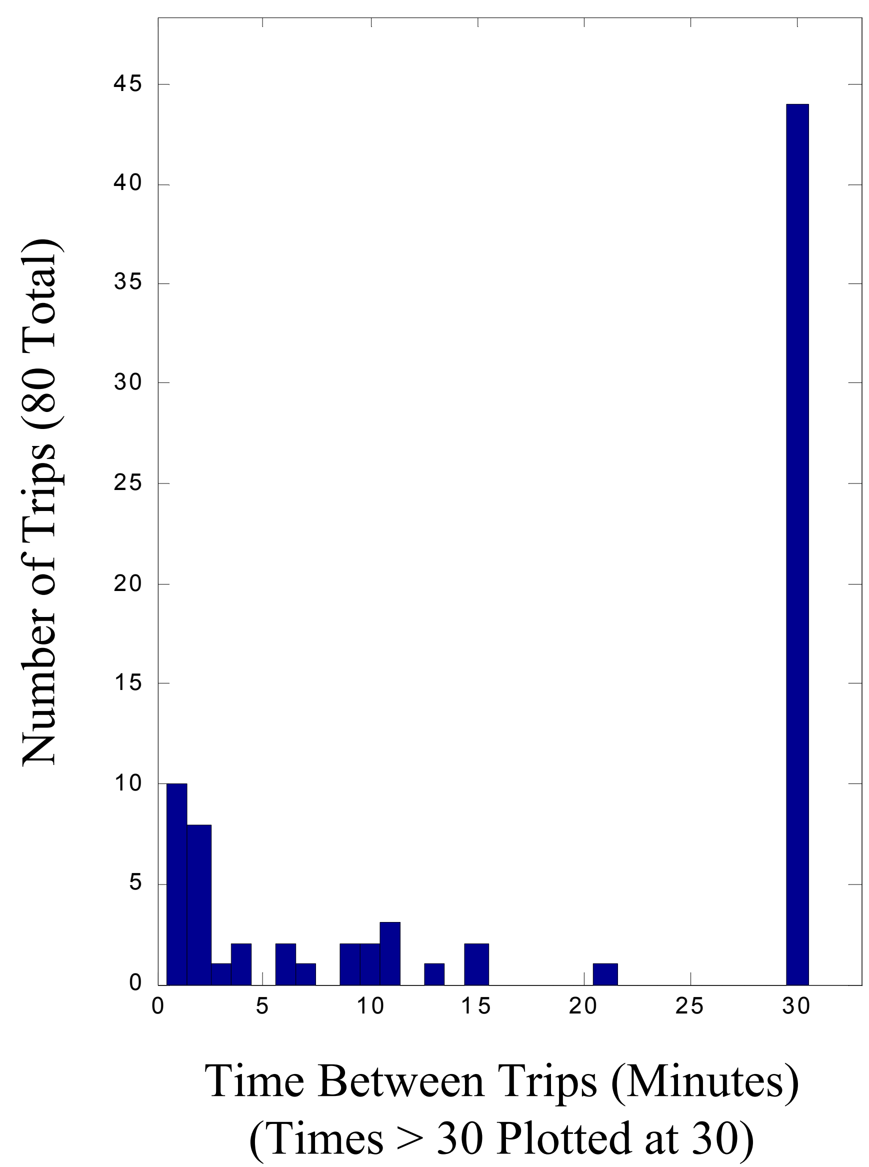
- High Gradient Tests of Slotted Cells:

  Currently Testing H60VG3(6C) that Includes 6 Slotted Cells.

  First Test of Fully Slotted H60VG3 Structure in June 2003

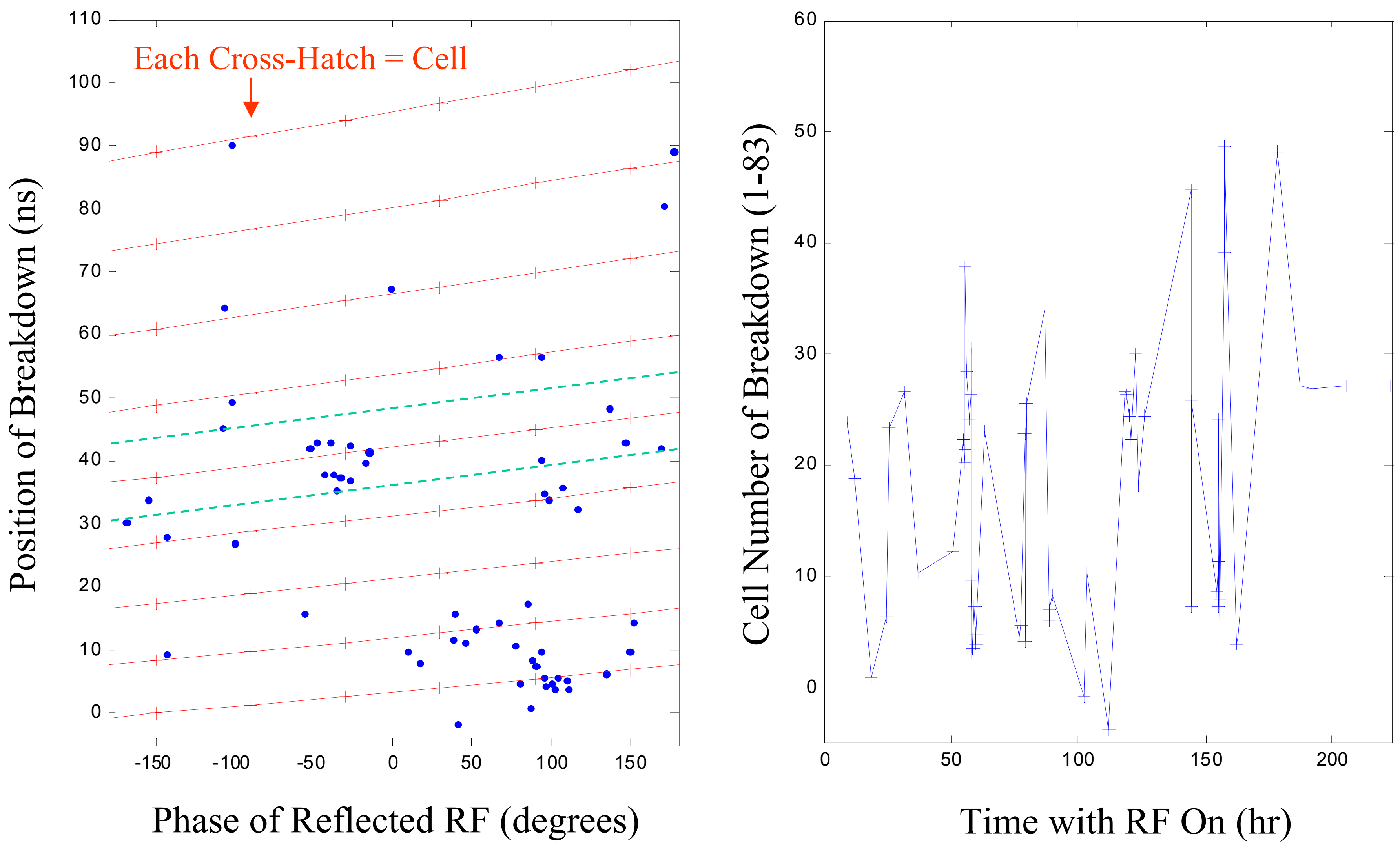
Breakdown Statistics for H60VG3(6C) at 65 MV/m, 400 ns



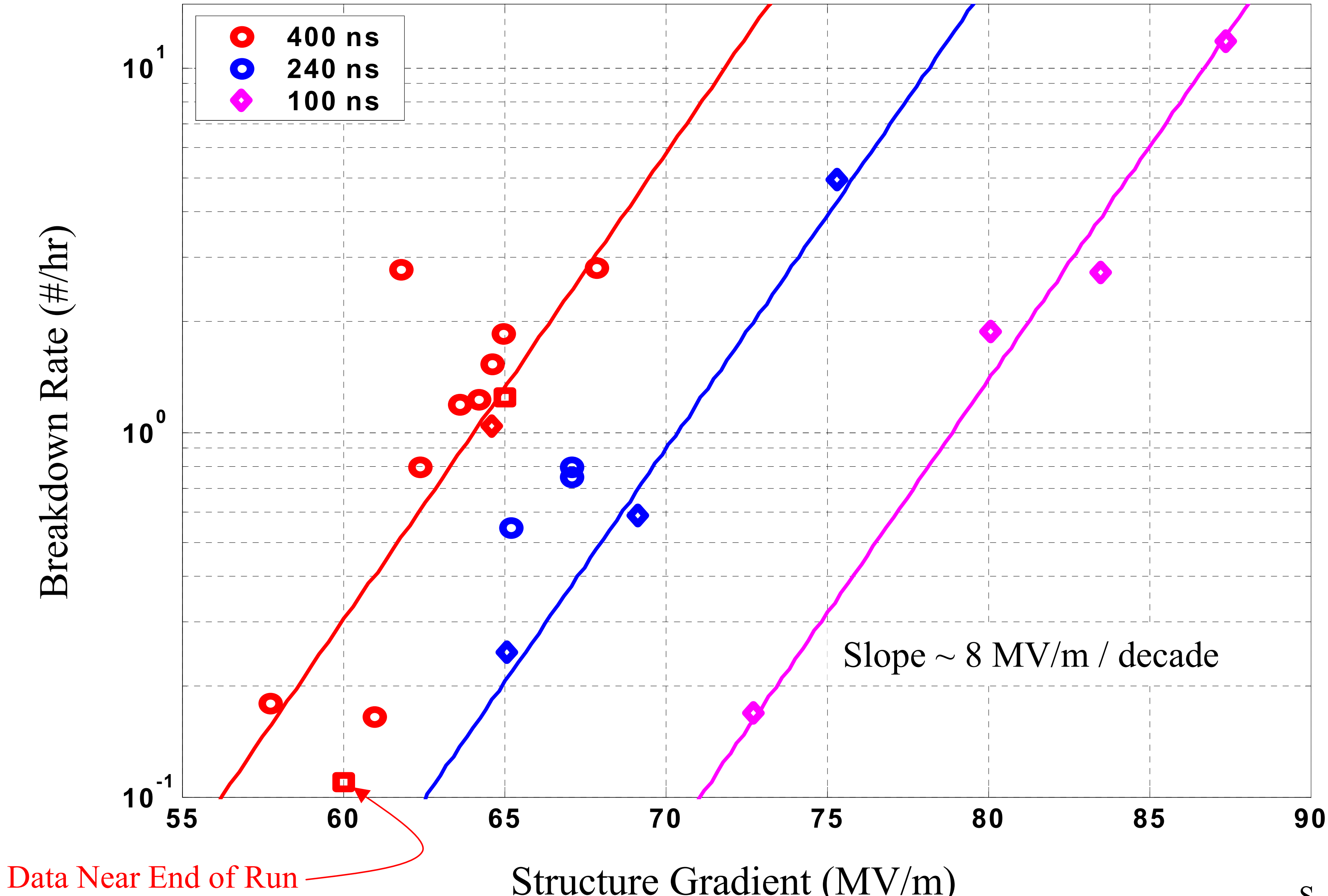


H60VG3(6C) Breakdown Locations at 65 MV/m, 400 ns Pulse Width Inferred from Reflected and Transmitted RF

(Slotted Cells Between Dashed Green Lines)

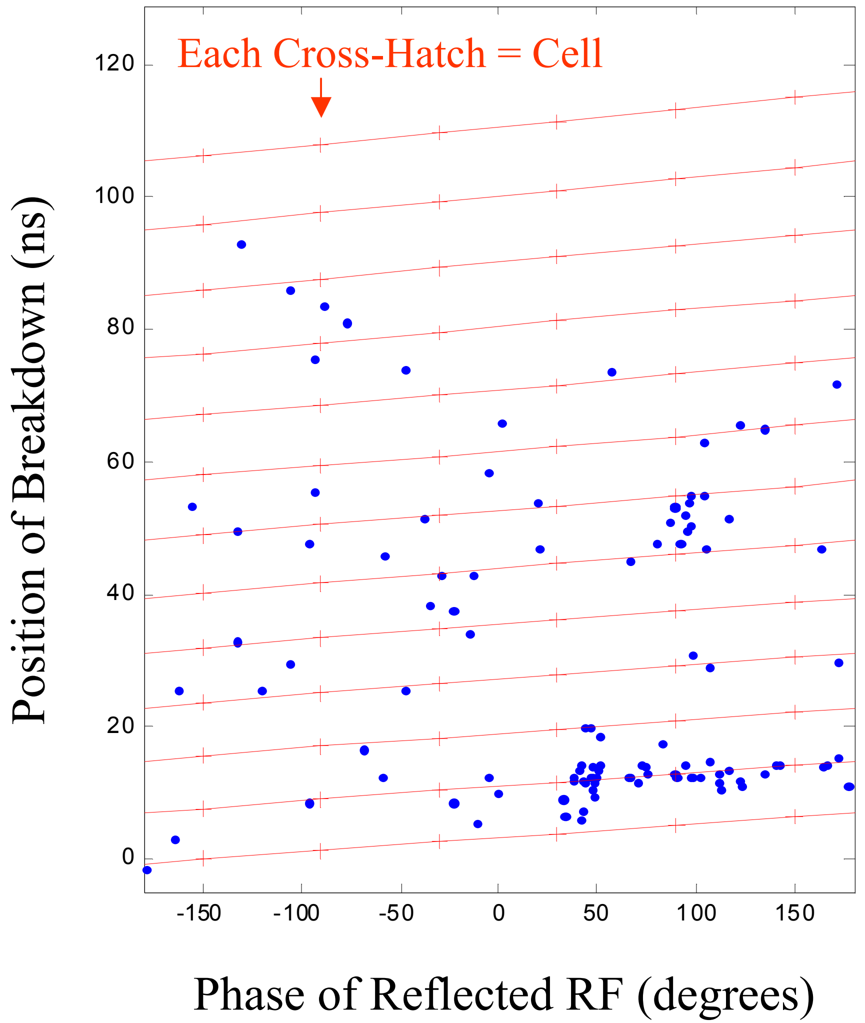


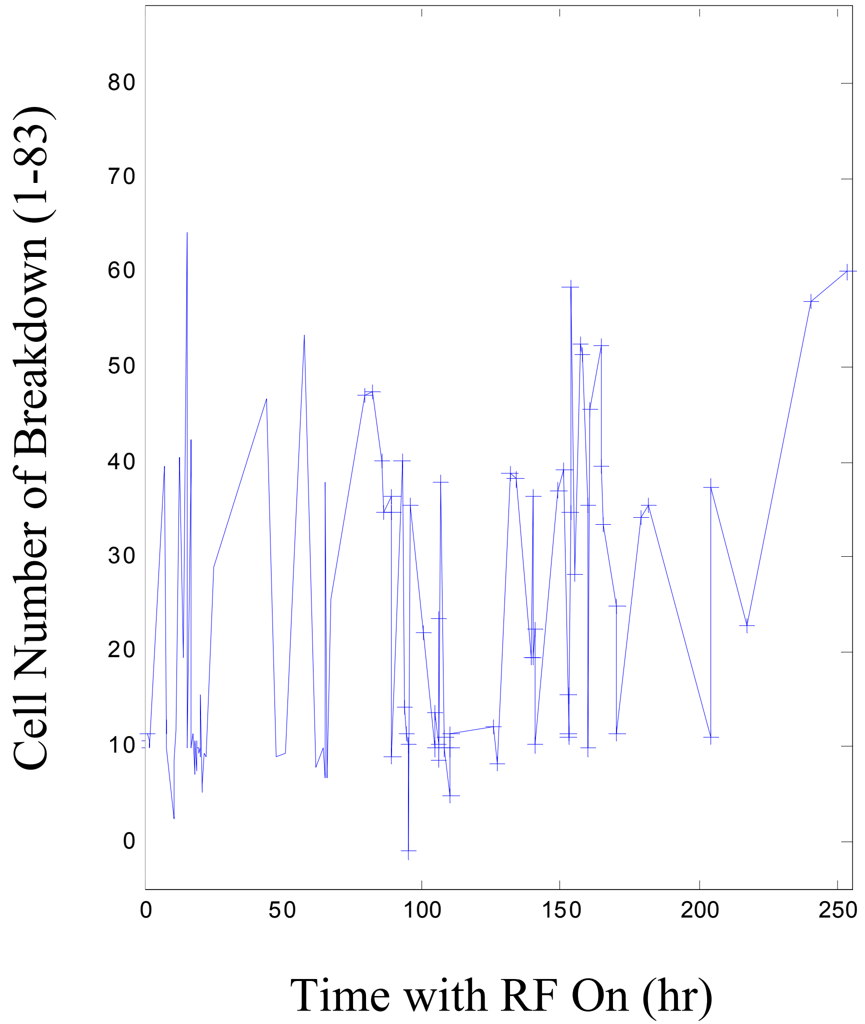
H90VG3 Breakdown Rate -vs- Gradient for 3 Pulse Lengths



S. Doebert

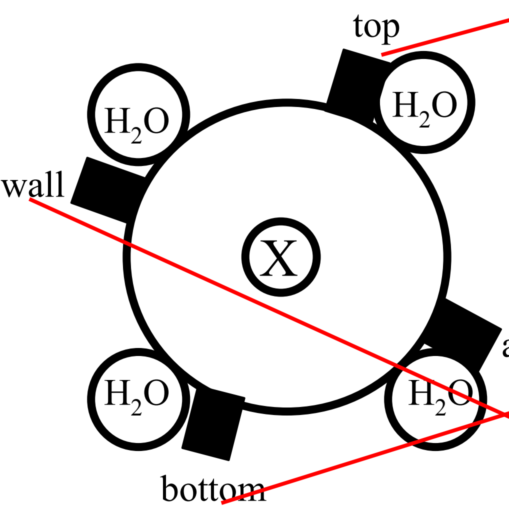
H90VG3 Breakdown Locations at 60-68 MV/m, 400 ns Pulse Width Inferred from Reflected and Transmitted RF



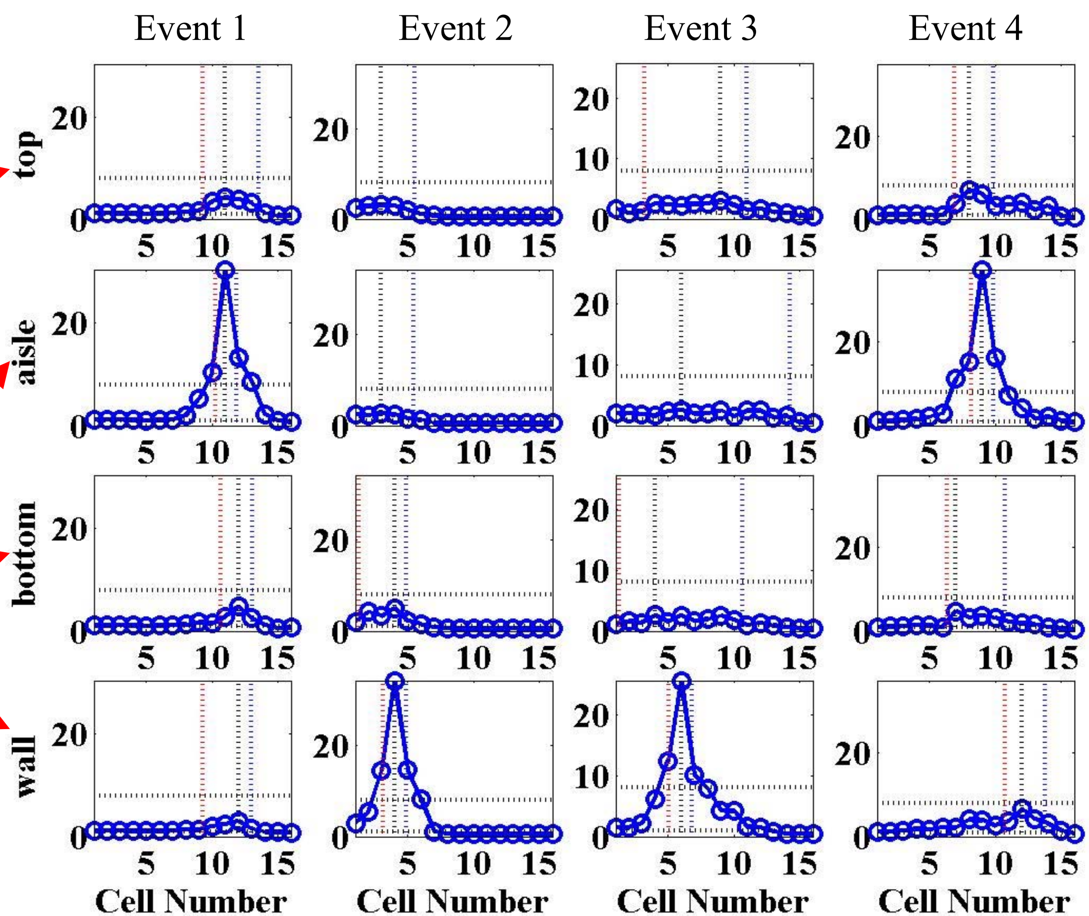


Breakdown Analysis Using Acoustic Sensors

Cross Sectional View of Structure with Sensors Attached

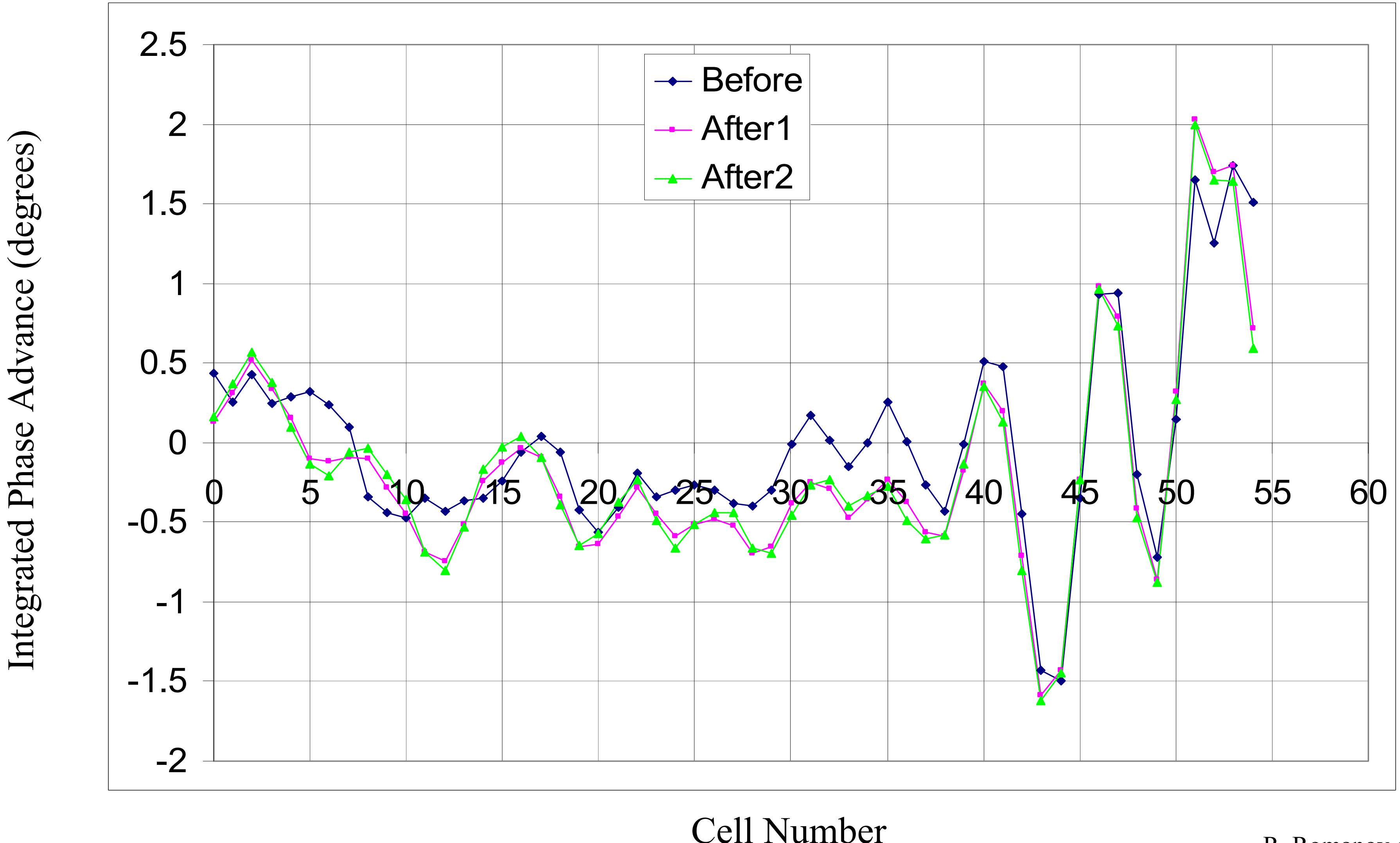


Signal -vs- Cell Number for Four Events with Clearly Discernable Azimuthal Asymmetry



J. Nelson, NLCTA Ops, et. al.

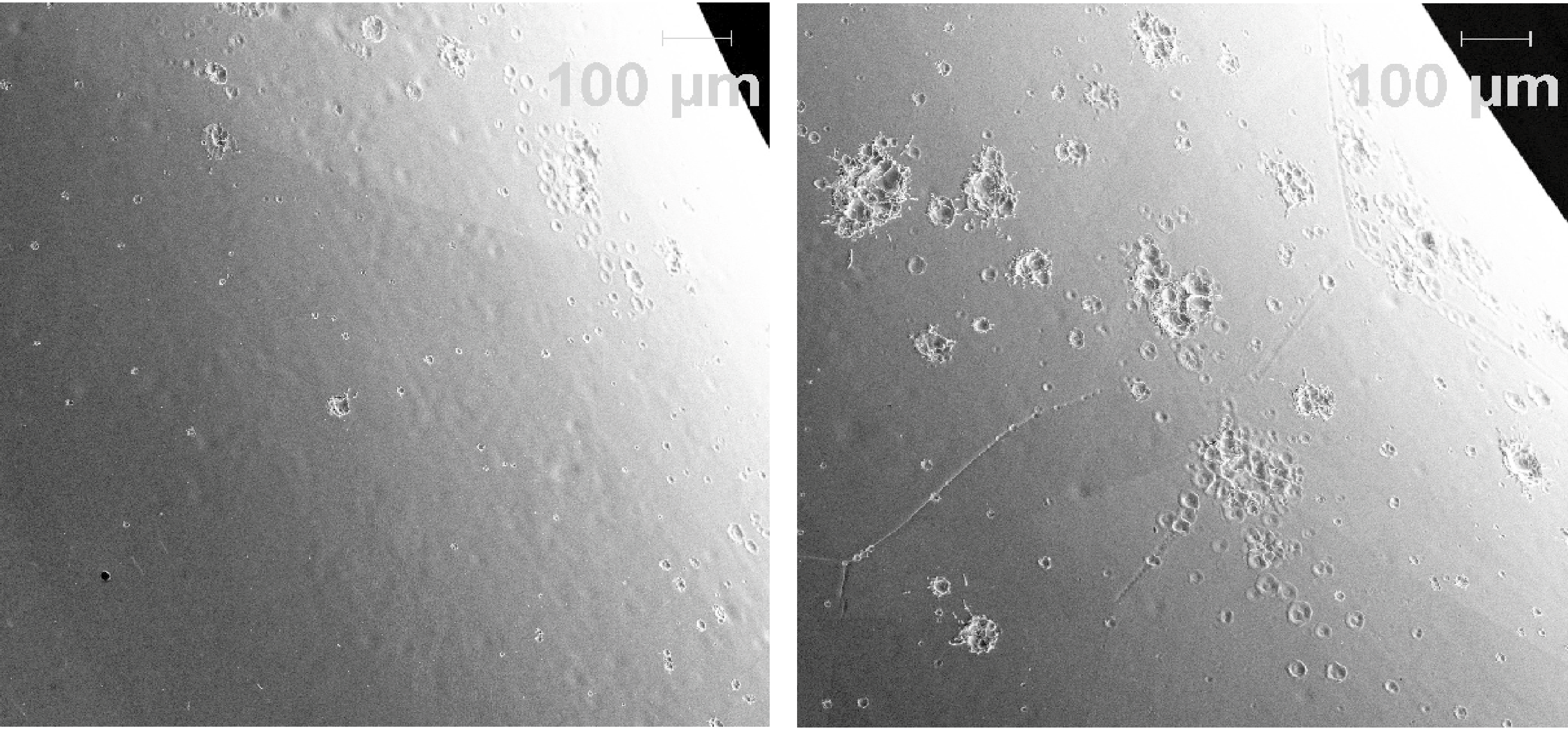
Bead-Pull Phase Advance Measurements of H60VG3 (FXB2) Before Processing and After 300 Hours of Processing to 70 MV/m During Which It Incurred About 7000 Breakdowns



R. Romanov et al

H90VG5 Cell 13 Iris After RF Processing

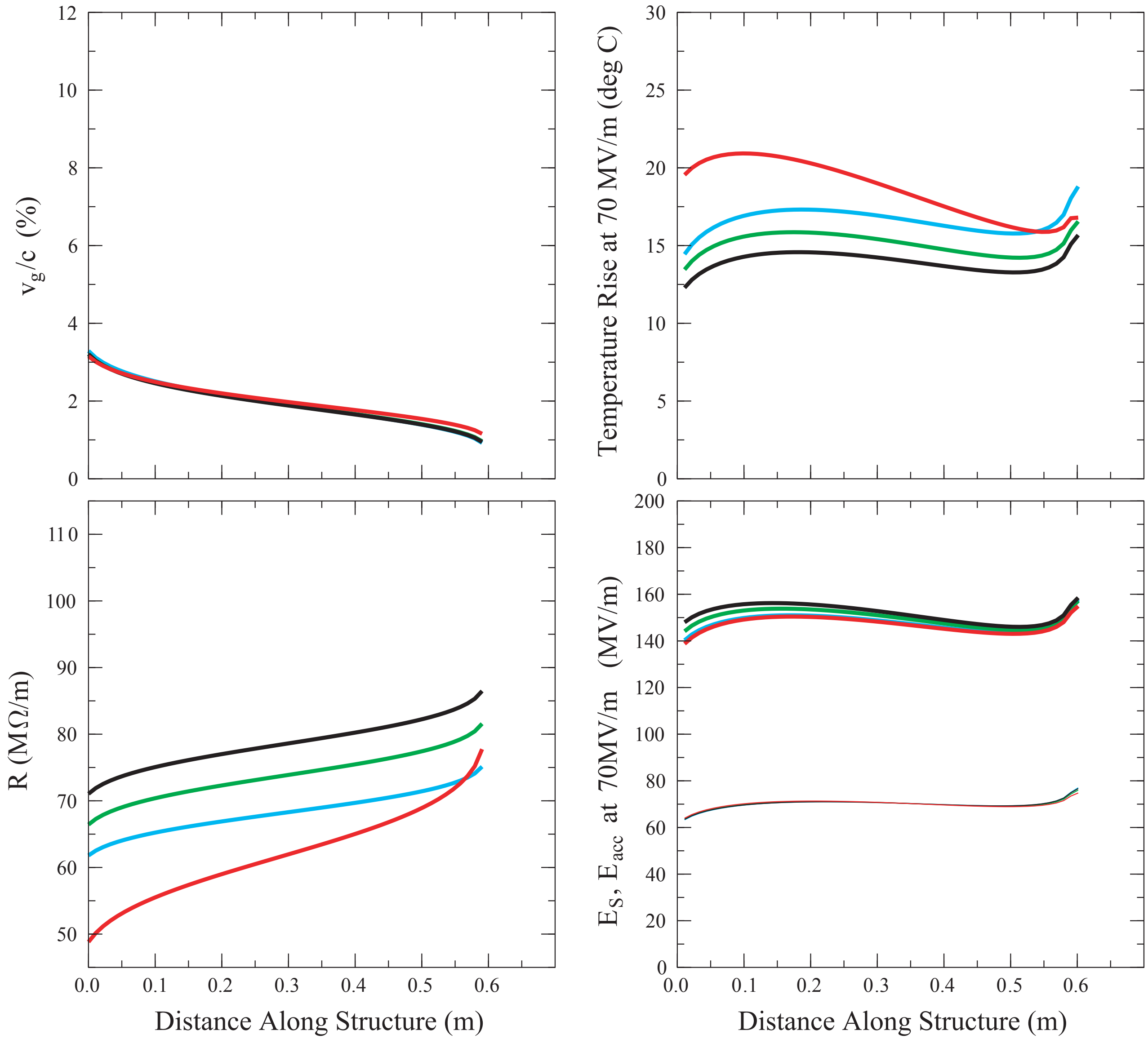
(Worse Than Neigboring Cells Due to Al Inclusion)



Development and Schedule Overview

- The current H60VG3(6C) has the essential features of an NLC/JLC structure and basically meets performance requirements.
- To improve efficiency and perhaps provide more operating overhead, an $a/\lambda = .17$ version of this structure (H60VG3S17) has been adopted for the NLC baseline design.
- The main goal for the next year is to have eight of these structures operating for > 2000 hr at 65 MV/m in the NLCTA Linac, powered by the 8-Pack Source.
  - FNAL and KEK will fabricate these structures.
- Structure development will also continue, including tests of:
  - Several H60VG3's ($a/\lambda = .18$) built by FNAL.
  - A fully slotted version of H60VG3 (H60VG3S18).
  - A longer H-type structure (H75VG4S18) .
  - An $a/\lambda = .17$ version of H60VG3 without slots (H60VG3A18).
  - A pair of standing wave structures with low pulse temperature rise couplers.
  - CERN test structures with Mo and/or W irises (SLAC studying Mo tipped irises)

H60VG3 Structure Parameters -vs- a/λ

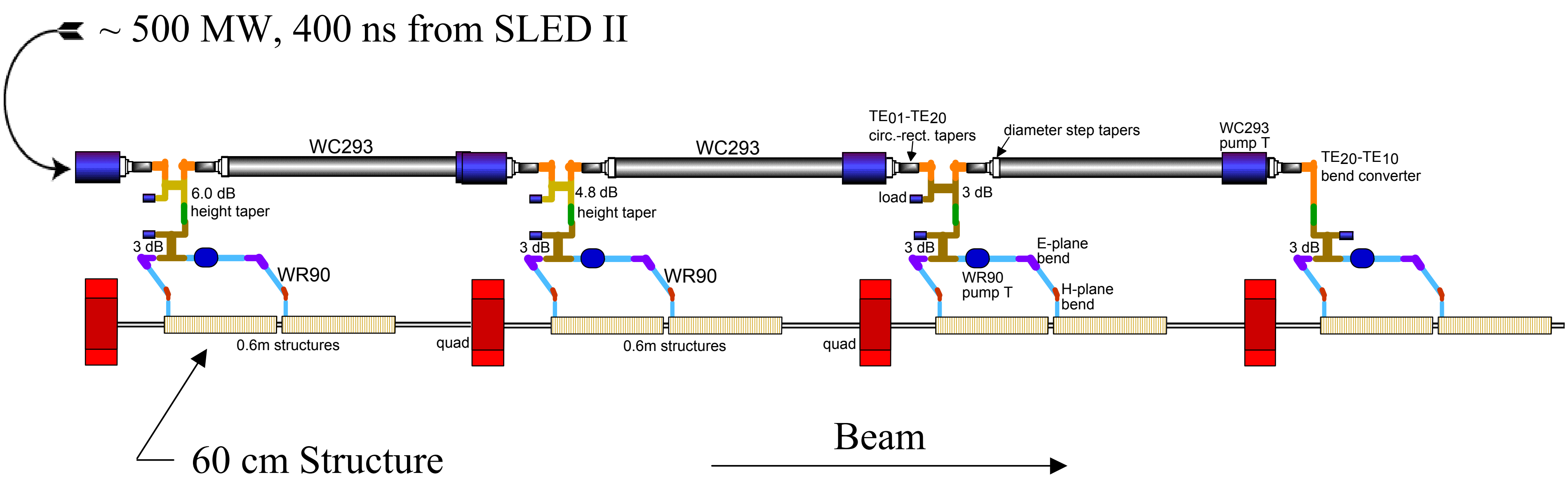


Input Power (MW) for 70 MV/m

a/λ = 0.180	73.2
a/λ = 0.170	64.7
a/λ = 0.165	60.8
a/λ = 0.160	57.5

Z Li

Possible Scheme for Powering Eight H60VG3 Structures in NLCTA Using the Eight-Pack Power Source

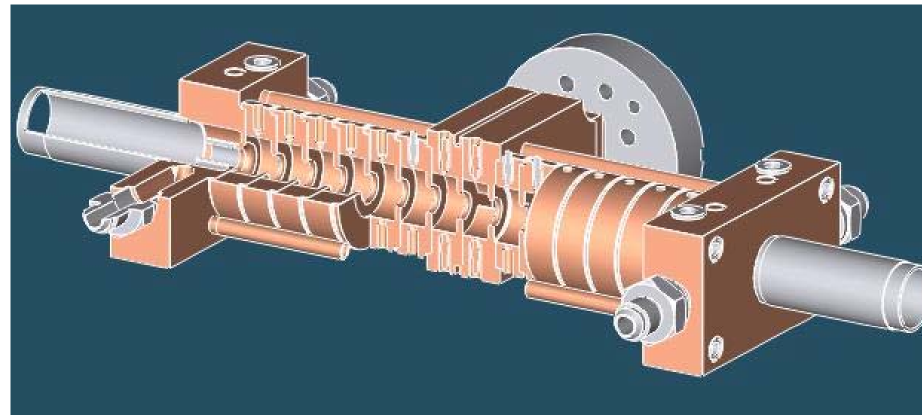


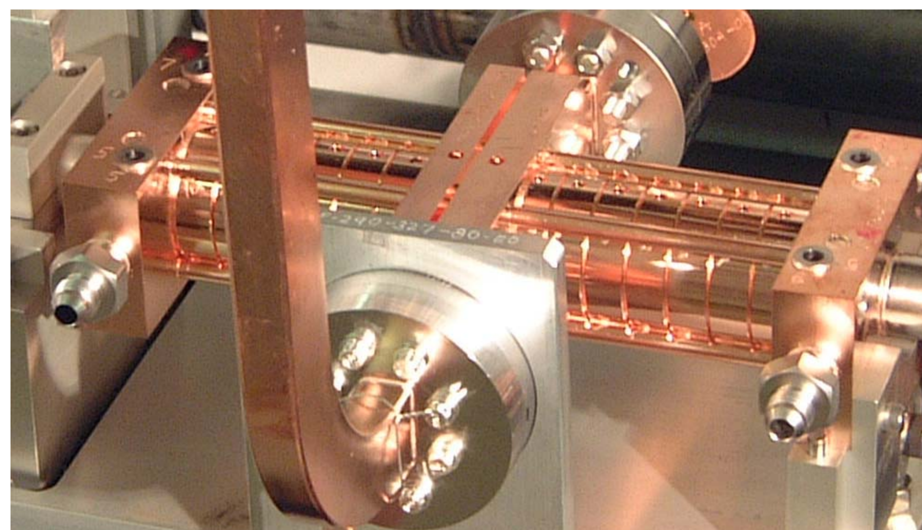
C. Nantista

Standing-Wave Structures

- In NLC, standing-wave structures would operate at the loaded gradient of 52 MV/m.
- Of three pairs tested, one pair had breakdown rates of < 1 per 8 million pulses at 55 MV/m and no discernable frequency change after 600 hrs of operation.
- Pulse heating in coupler likely limiting higher gradient operation – will be reduced for next test in June, 2003.

15 Cell, 20 cm Standing-Wave Structure





Structure Testing Schedule

2003

Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.

H90VG3N (0.18, 150°, no slots) — KEK/SLAC
H60VG3(FXB2) (0.18, 150°, no slots) — FNAL

H60VG3(6C) (0.18, 150°, 6 slotted) — KEK/SLAC
H60VG3(FXB3) (0.18, 150°, no slots) — FNAL

SW20a375 (Standing Wave Structure Pair) — KEK/SLAC
H60VG3S18 (0.18, 150°, slots) R1 DEMONSTRATION — KEK/SLAC

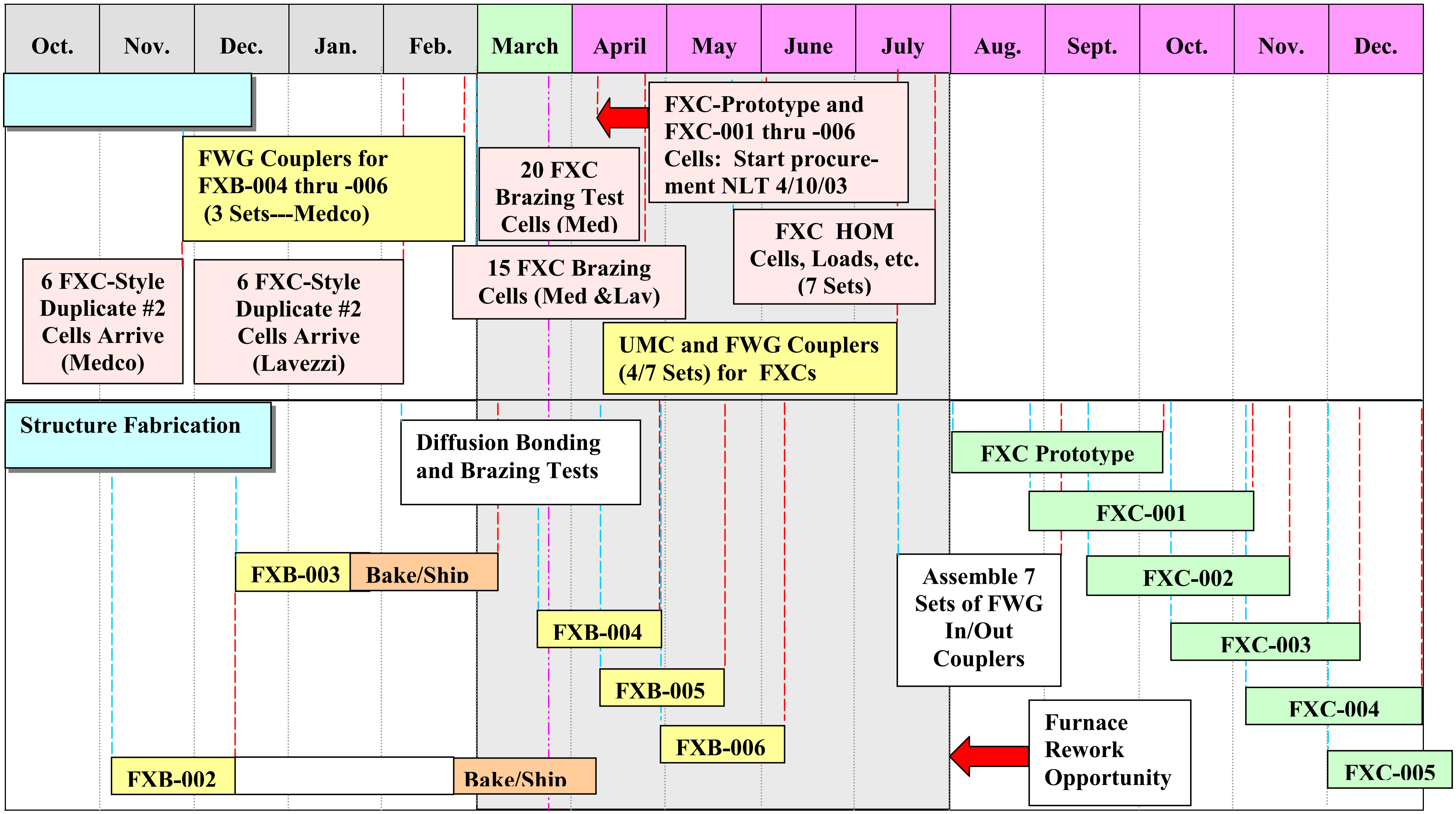
CERN Test Structures (W and/or Mo irises) — CERN

H75VG4S18 (0.18, 150°, slots) — KEK/SLAC
H60VG3(FXB4) (0.18, 150°, no slots) — FNAL

H60VG3A17 (0.17, 150°, no slots) — SLAC
H60VG3(FXB5) (0.18, 150°, no slots) — FNAL

Up to Four H60VG3S17 (0.17, 150°, slots, HOM output) starting in November — KEK
Up to Five H60VG3S17(FXC) (0.17, 150°, slots, HOM output) starting in November — FNAL

FNAL 2003 Structure Fabrication Plan



H. Carter

High Gradient Summary

Making Steady Process Toward an ‘NLC/JLC – Ready’ Structure

- Produced a T-Series structure that reliably operated at 90 MV/m.
- Developing structures with acceptable average iris radii:
  - H60VG3_6C has essential features of an NLC/JLC structure and basically meets performance requirements.
  - Have adopted a lower a/λ design to improve efficiency and performance at the cost of somewhat larger wakefields.
- Pulse heating in slotted cells does not appear to be a problem – will test fully slotted structure in June 2003.
- Will operate 4.8 m of structures with Eight-Pack power source for system test and to improve performance statistics.