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SLAC Activities for the CLIC X-Band Accelerator Structures

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Contributors in SLAC Side

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Outline

1. Introduction
2. Work in the Past
3. How the Structure Are Made
4. Some Test Results at SLAC
5. Scope for Future Work

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1. Introduction

CERN/SLAC/KEK Collaboration

For three years since early 2007, these three labs have collaborated in the R&D of CLIC high gradient RF structures including Main Linac Structure and Power Extraction and Transfer Structure.

One of the most important feasibility demonstrations is operating a fully featured accelerating structure based on optimized X-band designs at 100 MV/m and the full pulse length with an appropriate breakdown rate.

What We Are Contributing Based on Our 20 Years R&D in X-Band Accelerator Structures

- Experiences in accelerator electrical design.
- Experiences in accelerator mechanical design and fabrication technologies.
- Fabrication of test structures designed by CLIC, SLAC and KEK.
- Microwave tuning and characterizations of test structures.
- High power tests for test structures at 11424 MHz test stations.

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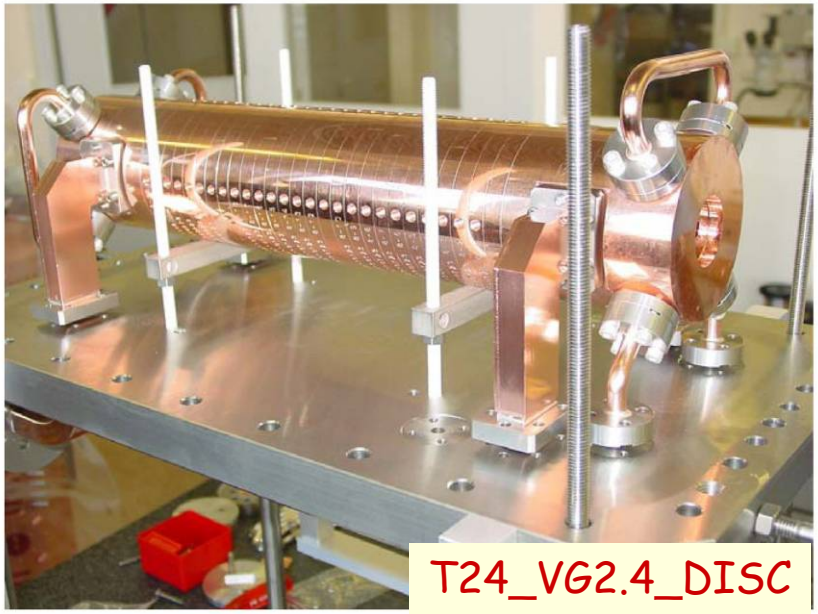
2. Work in the Past

Work Done Since the Collaboration

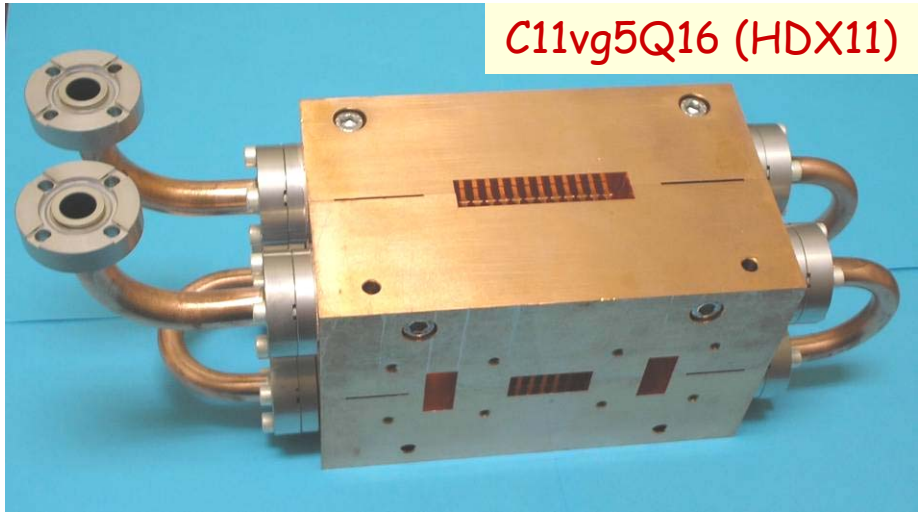
1. Eleven structures have been made and five high power tested
   - 1 x T28_vg2.9 (T26) Structure
     Used T53VG3MC components and completed by the end of May, 2008
     High power tested in the NLCTA since June 2008.
   - 4 x T18_VG2.4_DISC Structures #1, #2, #3, #4
     Two with SLAC flanges, high power tested successfully at NLCTA
     One with KEK flanges has also been successfully tested at KEK
   - 2 x TD18_VG2.4_DISC Structures #1, #2 and High Power Tested
     Fabrication completed (one with SLAC flanges, one with KEK flanges)
   - C10 Structures: 2 x C10_VG 1.35 #1, #2 and 2 x C10_VG 0.7 #1, #2
     Fabrication completed, one (VG1.35) of four structures preliminary tested
2. Five CERN made test structures high power tested

   SLAC Provided RF feed and related components for tank versions
   - One HDX11 Cu Structure and One HDX11 Mo Structure
     Electrical polishing and reassembly and Microwave evaluation
   - T18_VG2.6_QUAD
     Cooling tube flanges brazed at a hydrogen furnace with 25/75 Au/Cu alloy
     Four quadrant assemblies vacuum baked at 650°
   - T18_VG2.6_DISK Assembled in the tank at SLAC
   - T24_VG2.4_DISK Assembled in the tank at SLAC

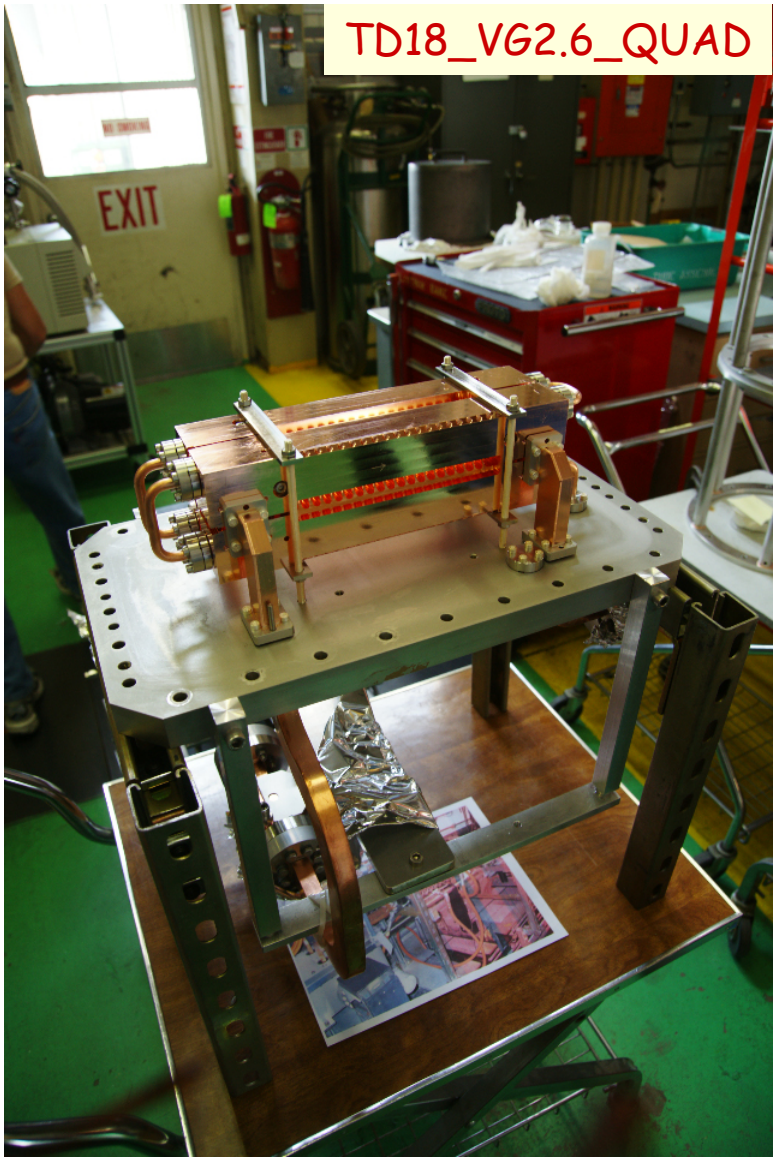
Some CERN made Structures Tested at SLAC



T24_VG2.4_DISC



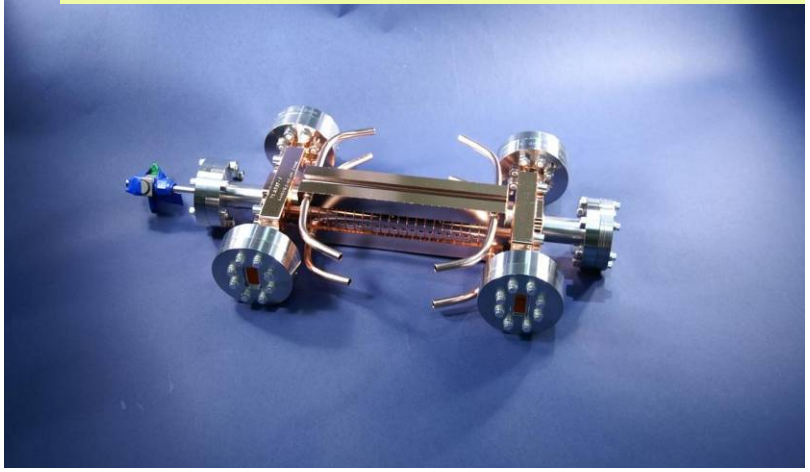
C11vg5Q16 (HDX11)



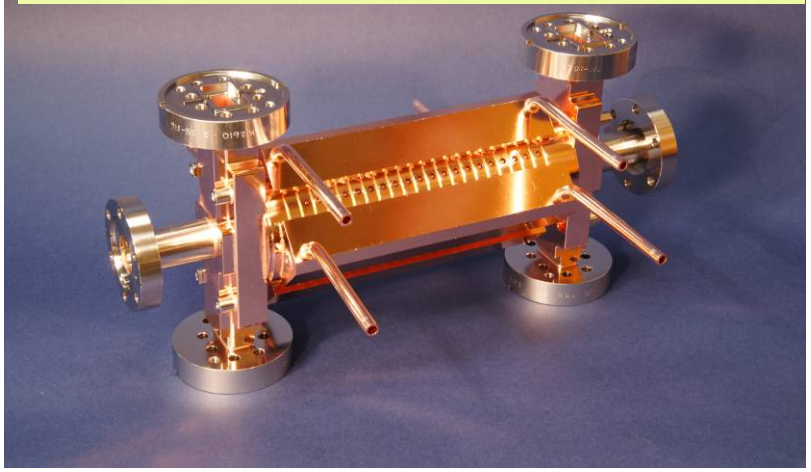
TD18_VG2.6_QUAD

Some of KEK/SLAC Made Accelerator Structures for Testing CLIC Main Linac Design

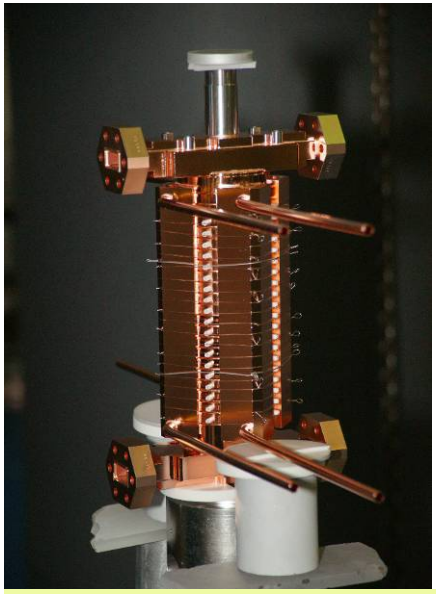
T18_VG2.4_DSC with SLAC Flanges



TD18_VG2.4_DISC with SLAC Flanges



C10_VG1.35 Structure



TD18_VG2.4_DISC with KEK Flanges

2008-10 Tested KEK/SLAC Made Structures

Test	Structure	Note	Performance
4/08 – 7/08 NLCTA	T18_VG2.4_DISK-I	Cells by KEK, Assembled at SLAC	105 MV/m, 230 ns at LC BDR spec of $5x10^{-7}$/pulse/m but hot cell developed
7/08 – 10/08 NLCTA	T18_VG2.4_DISK-I	Powered from Downstream End	163 MV/m, 80 ns, $2x10^{-5}$ BDR in last cell, consistent with forward operation
6/09 – 9/09 NLCTA	T18_VG2.4_DISK-III	Cells by KEK, Assembled at SLAC	Similar like T18vg2.6-Disk-I with low breakdown rate at 110 MV/m, 230 ns
12/09 – now NLCTA	TD18_VG2.4_DISK	Cells by KEK, Assembled at SLAC	100 MV/m, 200 ns at BDR of $3x10^{-5}$ /pulse/m with 4000 hours processing

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3. How the Structure Are Made

Fabrication of Accelerator Parts

1. National Laboratories
- SLAC
- KEK
2. Private Vendors
- US

Robertson Precision, Inc.
- Japan

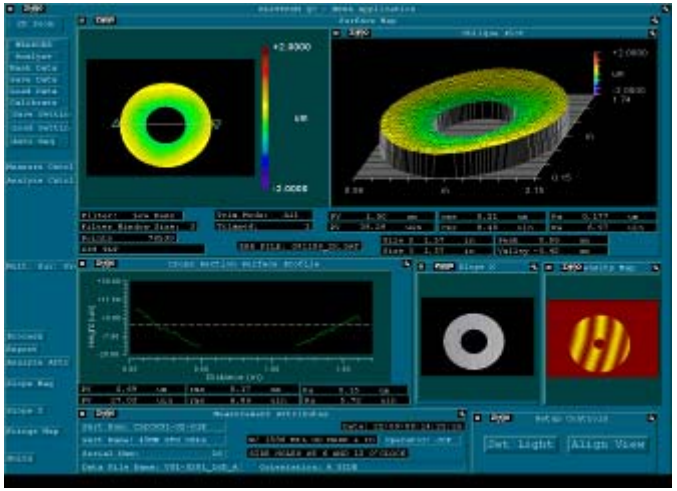
Morikawa co.
- Europe
- VDL Enabling Technologies Group (Netherland)

Lathe with Twin Spindles and Twin Turrets

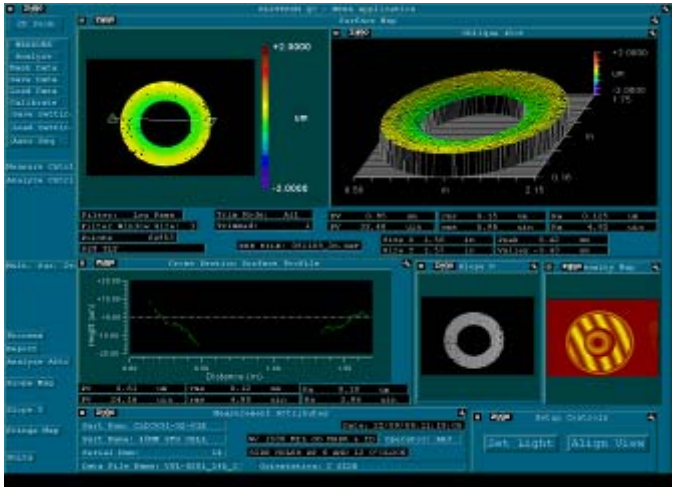
Profile tolerance 5 μm and Surface finishing 300 - 400 nm

ZYGO Surface Flatness Measurement for Typical Cups of T18_VG2.4_DISC

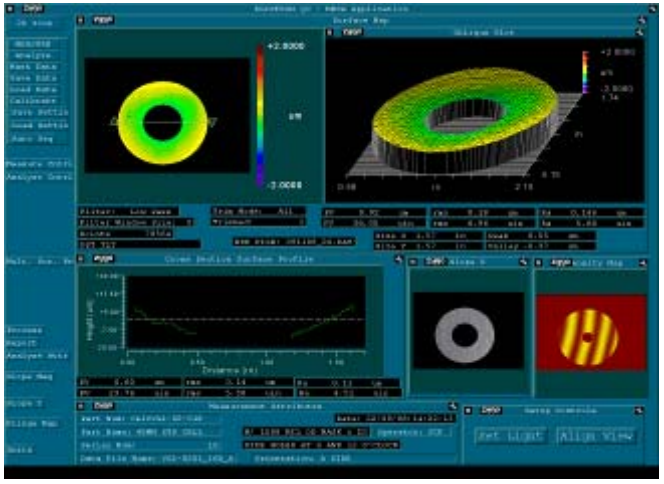
Both sides show ~ 1 micron flatness



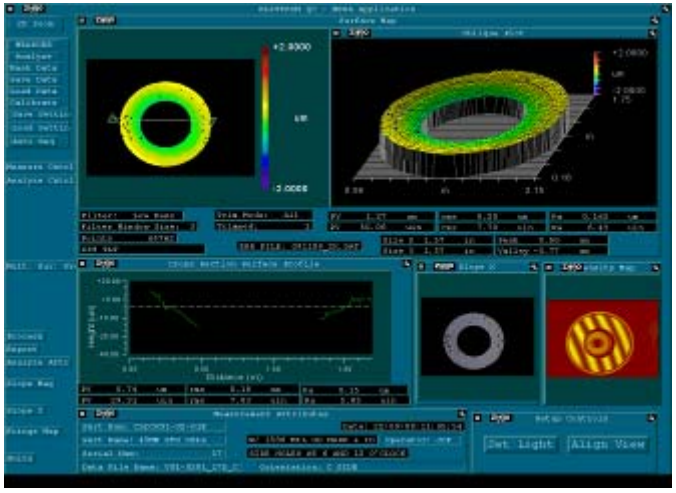
16D-A



14D-C



17D-A



17D-C

Cleaning of Accelerator Parts

For accelerator structure parts with single diamond tuning surfaces:

1. Vapor degrease in 1,1,1 trichloroethane or equivalent degreaser for 5 minutes.
2. Alkaline soak clean in Enbond Q527 for 5 minutes at 180ºF.
3. Cold tap water rinse for 2 minutes.
4. Immense in 50% hydrochloric acid at room temperature for 1 minutes.
5. Cold tap water rinse for 1 minute.
6. Immense in the following solution for maximum of 5 seconds depending on the surface finish required:

Phosphoric Acid, 75%	21 gallons
Nitric Acid, 42º Baume	7 gallons
Acetic Acid, Glacial	2 gallons
Hydrochloric Acid	12.6 fluid ounces
Temperature	Room

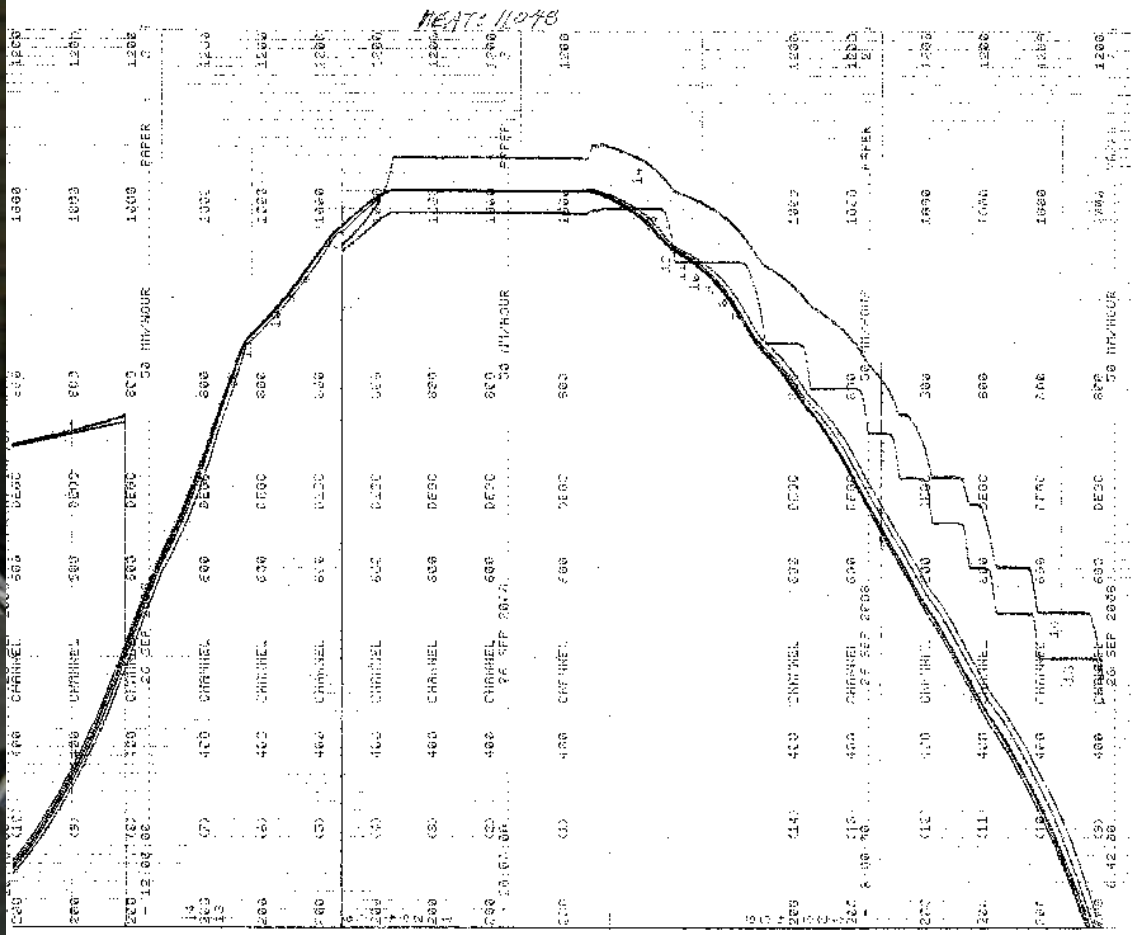
7. Cold tap water rinse for minimum of 2 minutes until the film on part disappears.
8. Ultrasonic in DI Water for 1 minute.
9. Ultrasonic in new, clean alcohol for 1 minute.
10. Final Rinse to be done in new, clean alcohol.
11. Hold in clean alcohol in stainless steel containers.
12. Dry in a clean room using filtered N2.

For accelerator structure parts with regular machining surfaces:

6. Immense in the following solution for maximum of 30-60 seconds depending on the surface finish required:

Stacking for Body Bonding of T18_vg2.4_DISC

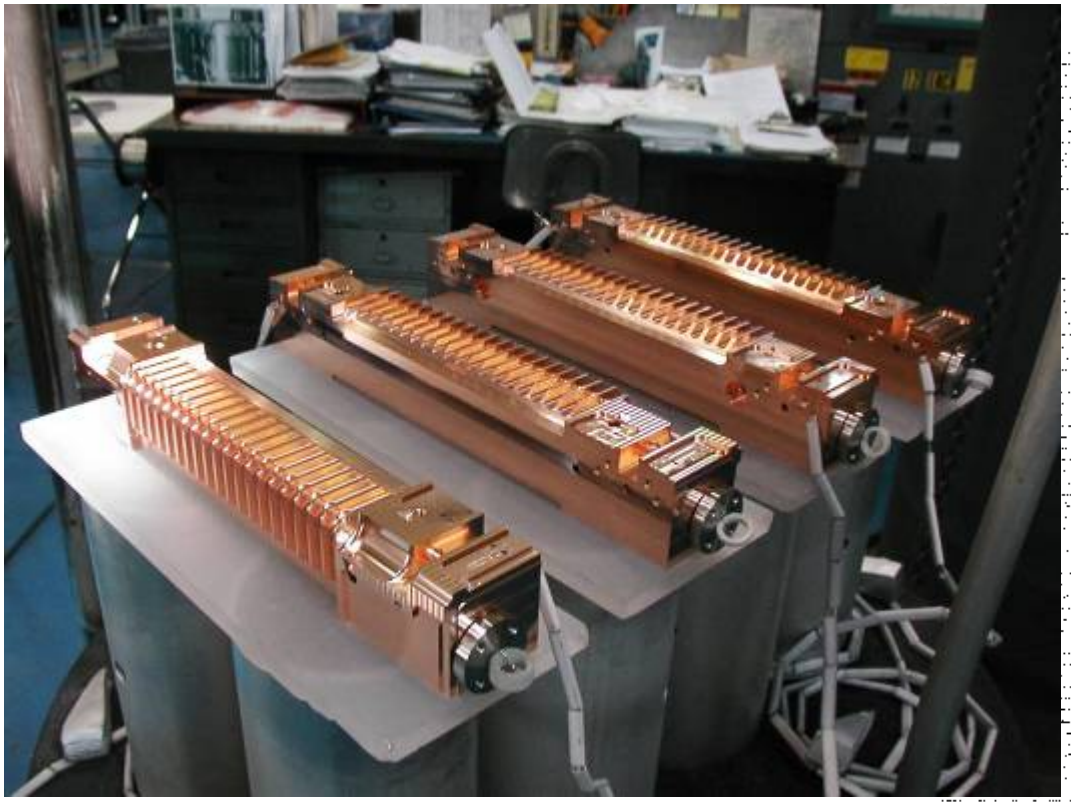
Diffusion Bonding of T18_vg2.4_DISC

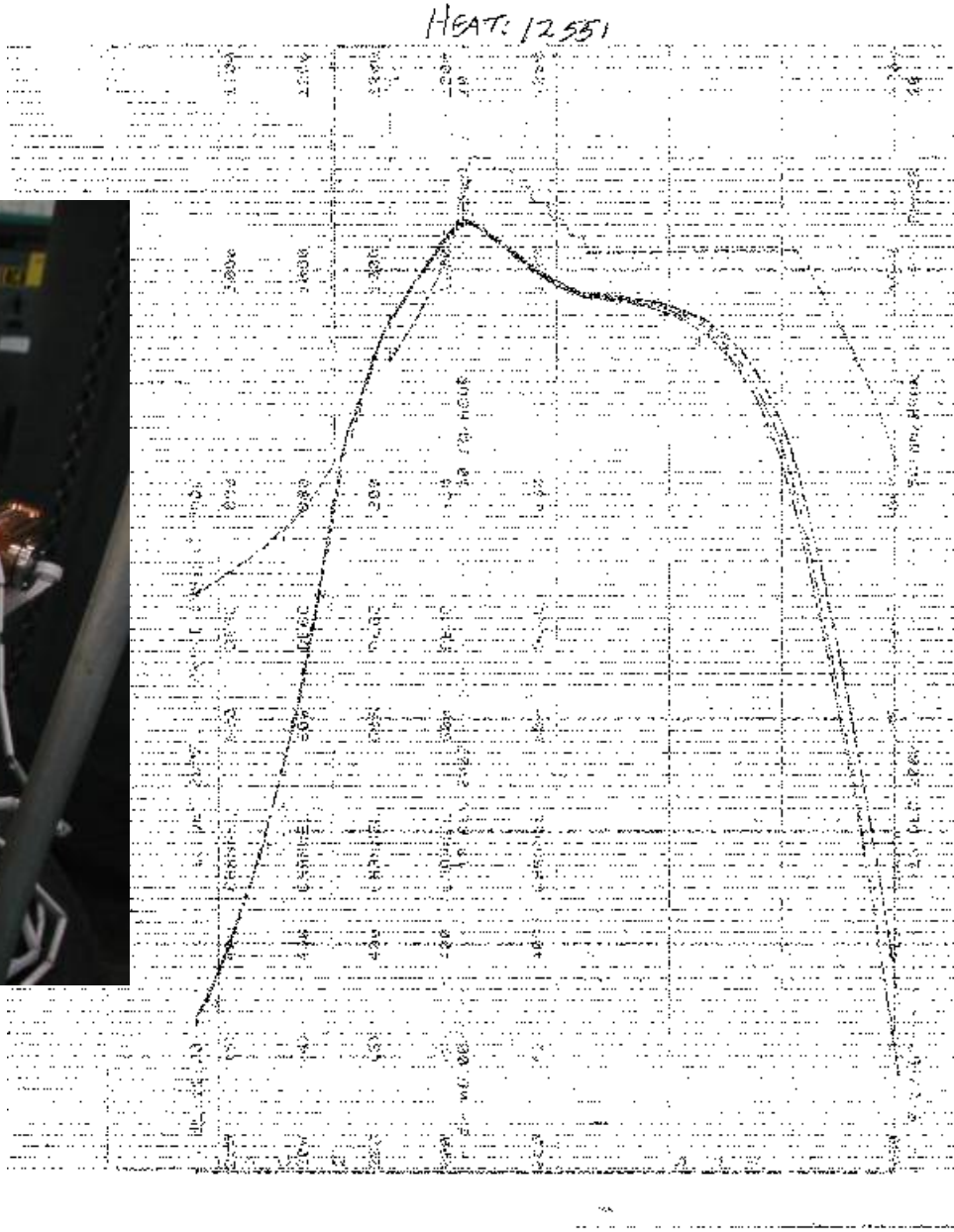


Pressure: 60 PSI (60 LB for this structure disks)

Holding for 1 hour at 1020º C

Brazing of QUAD with Water Flange

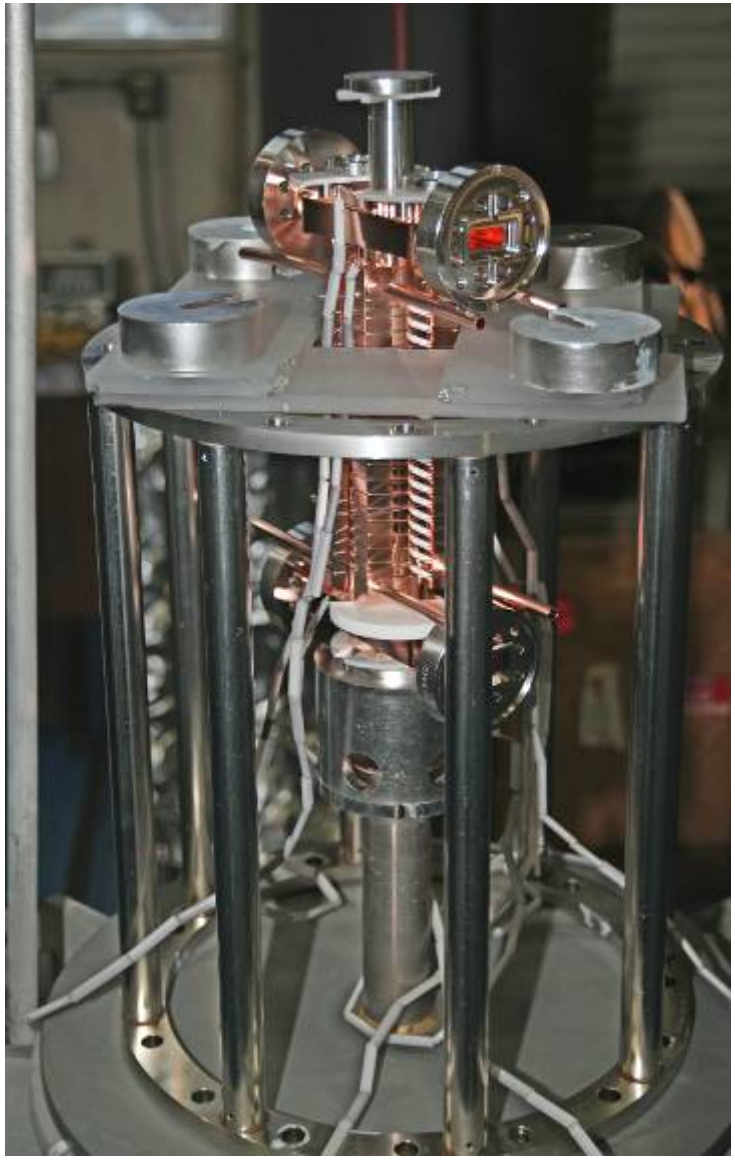




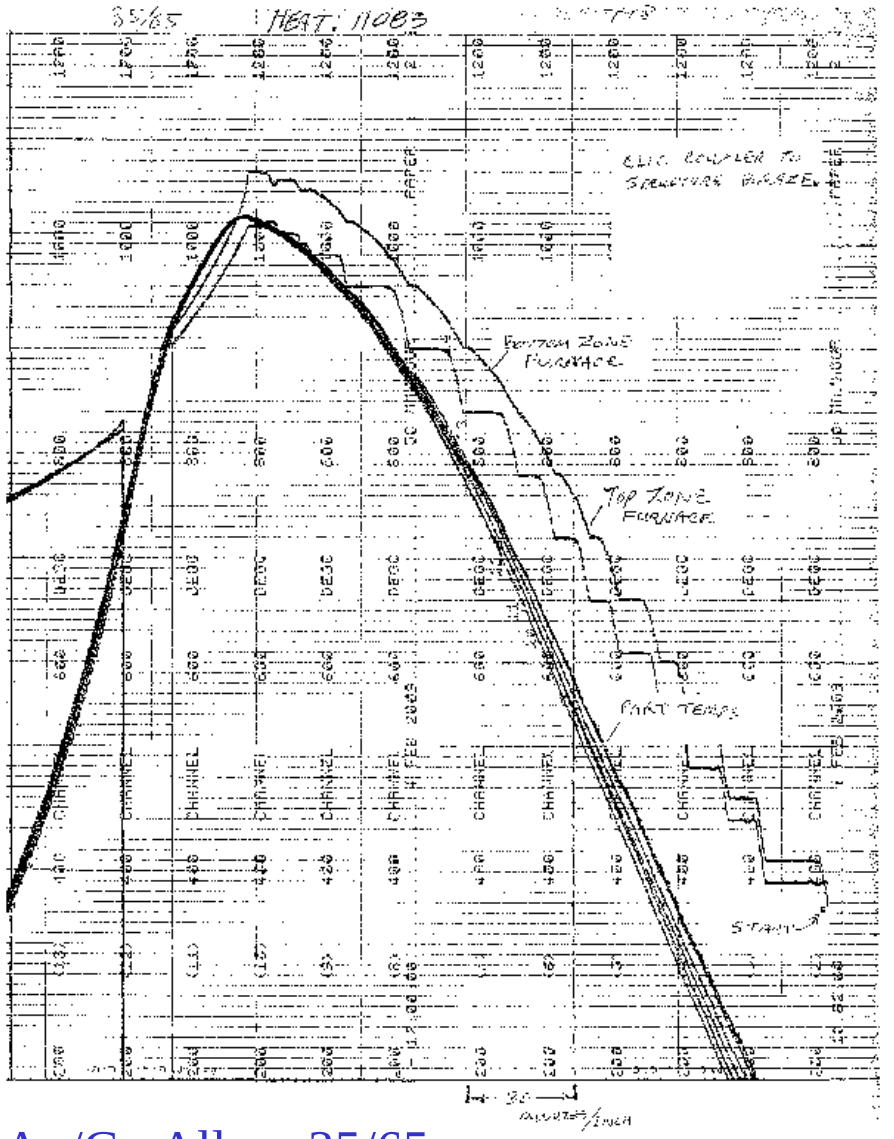
Au/Cu Alloy: 25/75

Brazing temperature: 1041-1045° C

First Assembly Brazing of T18_vg2.4_DISC

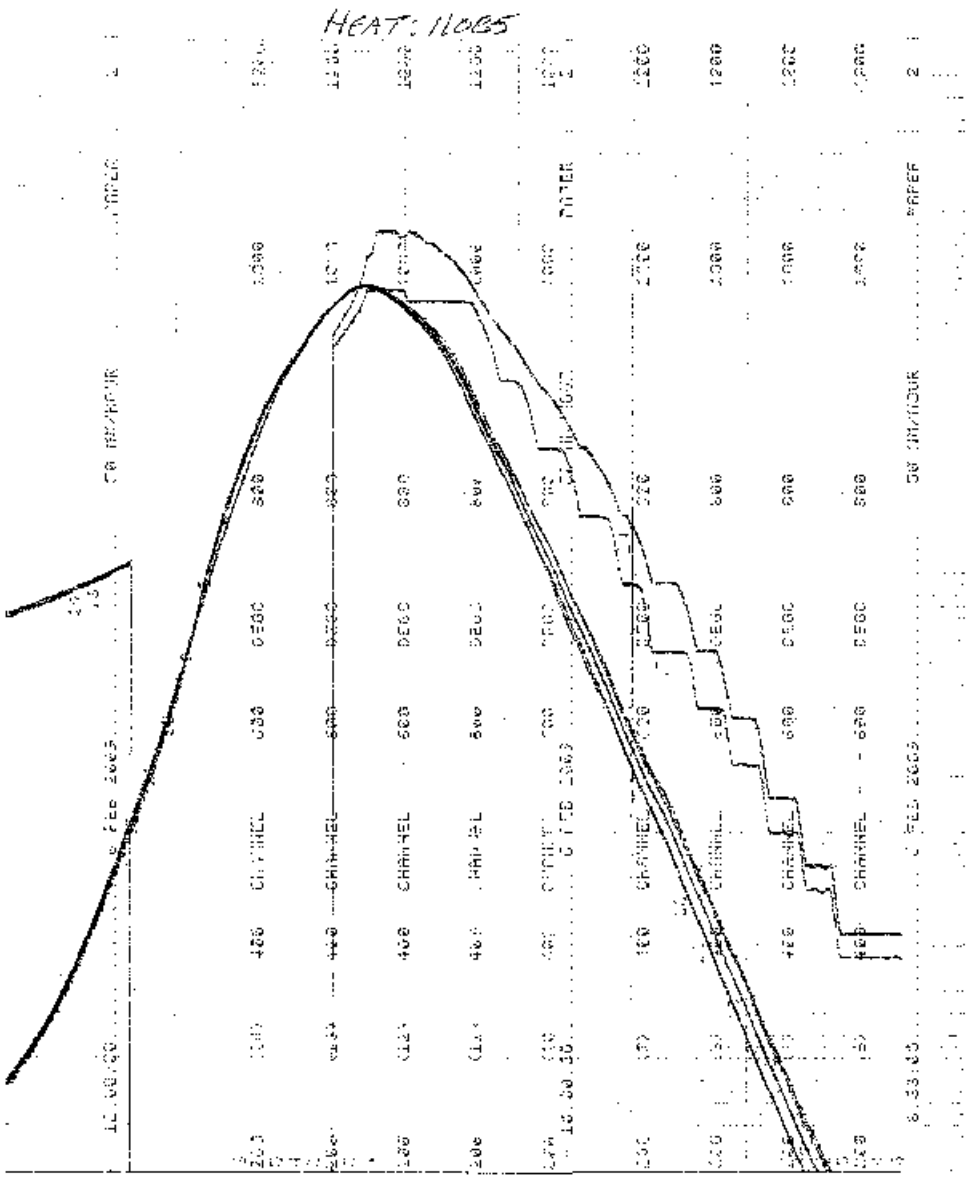


Body / Two Coupler Assemblies / Cooling/One Beam Pipe / Tuning Studs



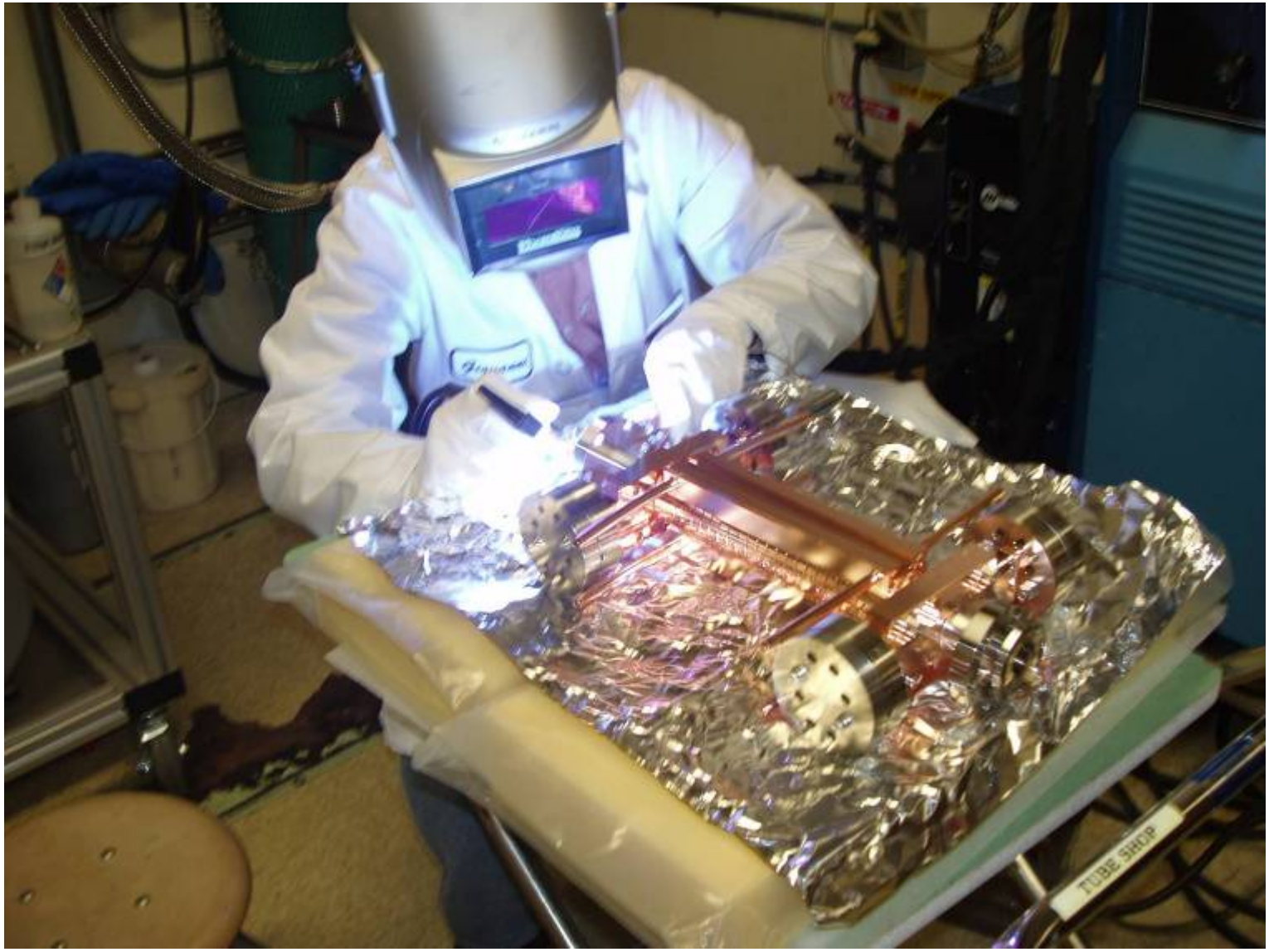
Au/Cu Alloy: 35/65
Brazing temperature: 1021-1025º C

Final Brazing of T18_vg2.4_DISC

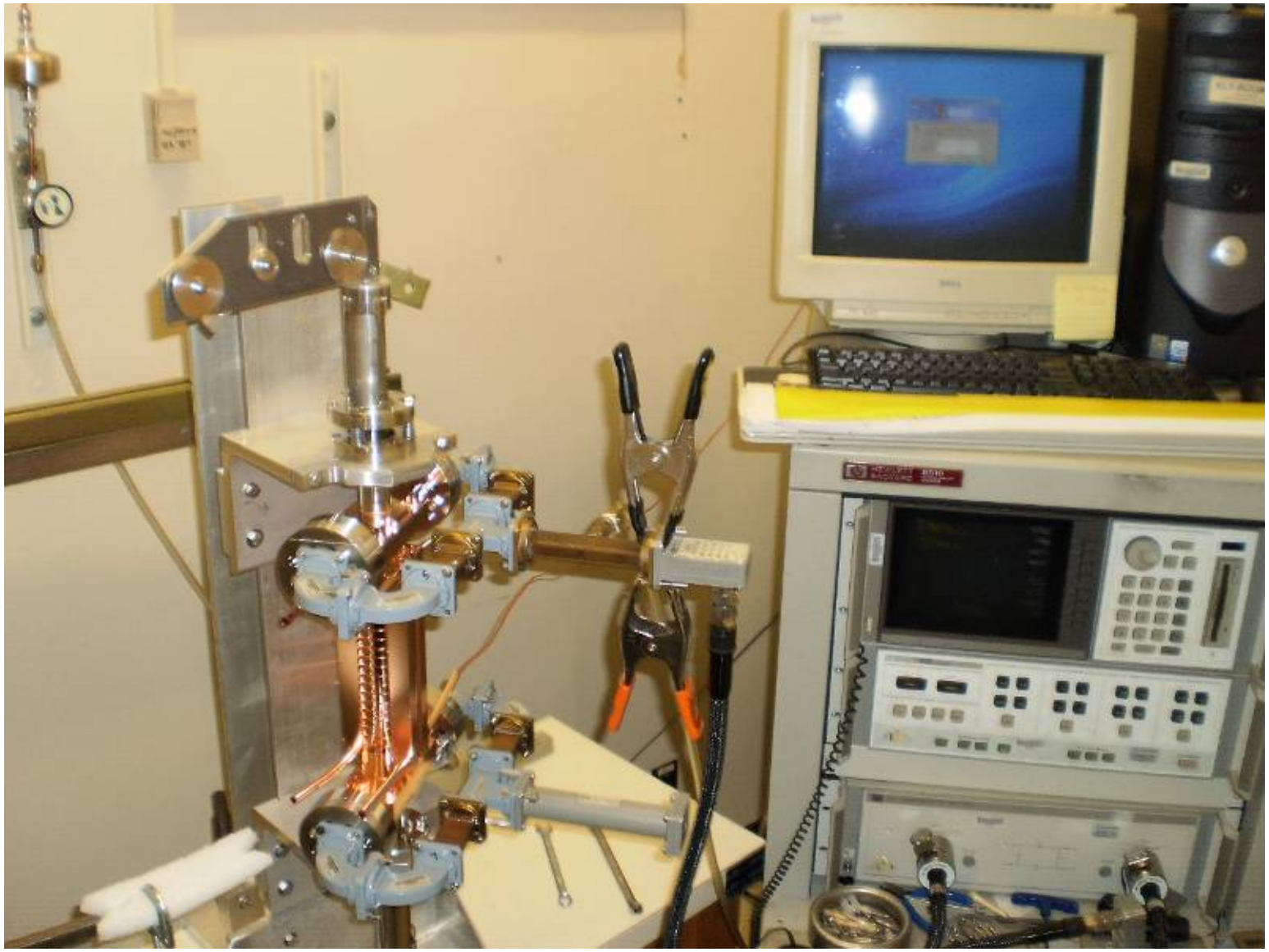


Au/Cu Alloy: 50/50
Brazing temperature: 979-983º C
Adding One Beam Pipe

Flange Welding for a T18_VG2.4_DISK Structure



Microwave Tuning and Characterization



J. Lewandowski

Vacuum Baking of T18_vg2.4_DISC

650° C

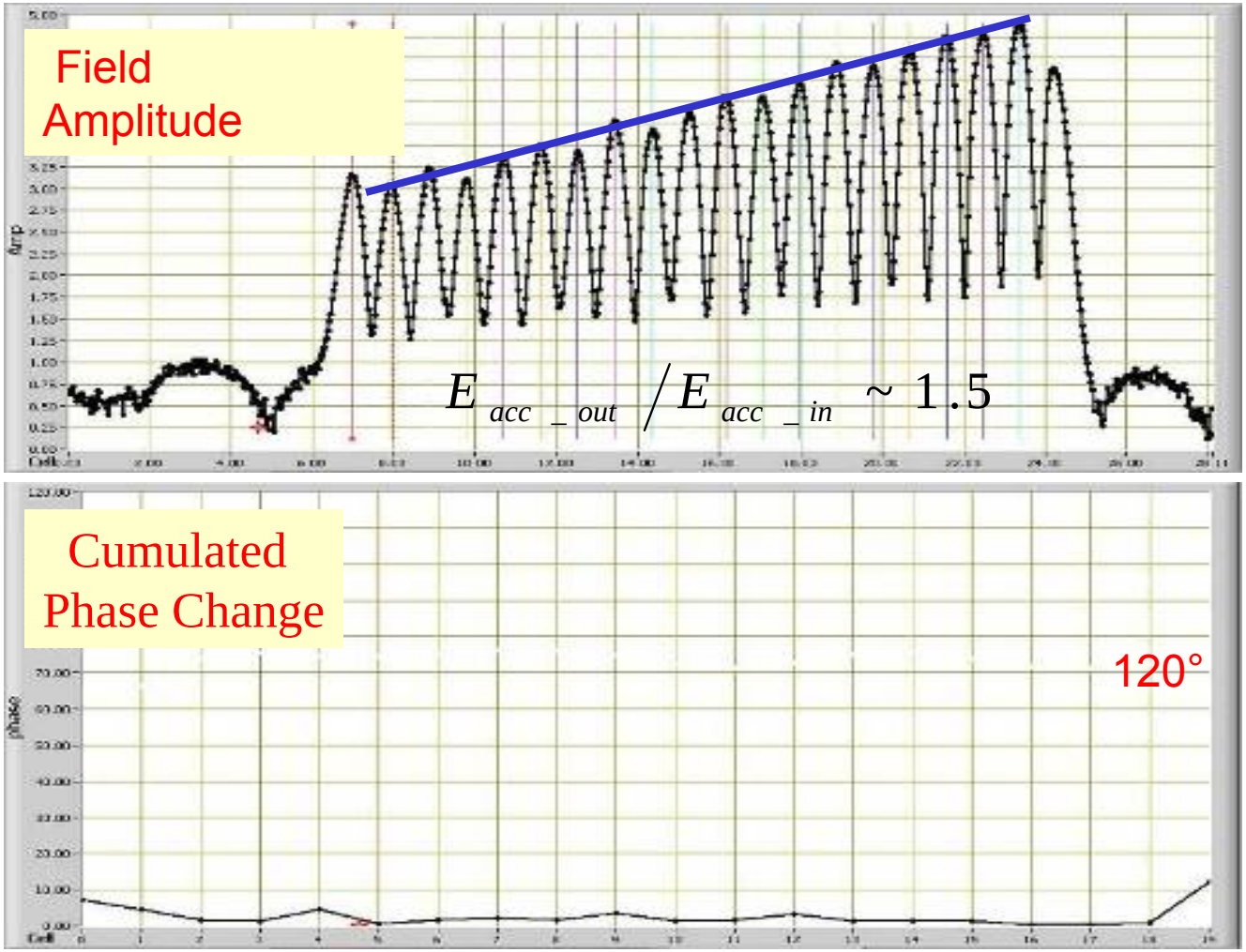
10 days

4. Some Test Results at SLAC

T18_VG2.4_DISC Structures

Frequency.	11.424GHz
Cells	18+input+output
Filling Time	36 ns
a_{in}/a_{out}	4.06 / 2.66 mm
Vg_{in}/Vg_{out}	2.61 / 1.02 (%c)
S_{11}	0.035
S_{21}	0.8
Phase	120Deg
Average Unloaded Gradient	55.5MW→100MV/m

Microwave Characterization of T18_VG2.4_DISC Structure



Microwave Tuning and test

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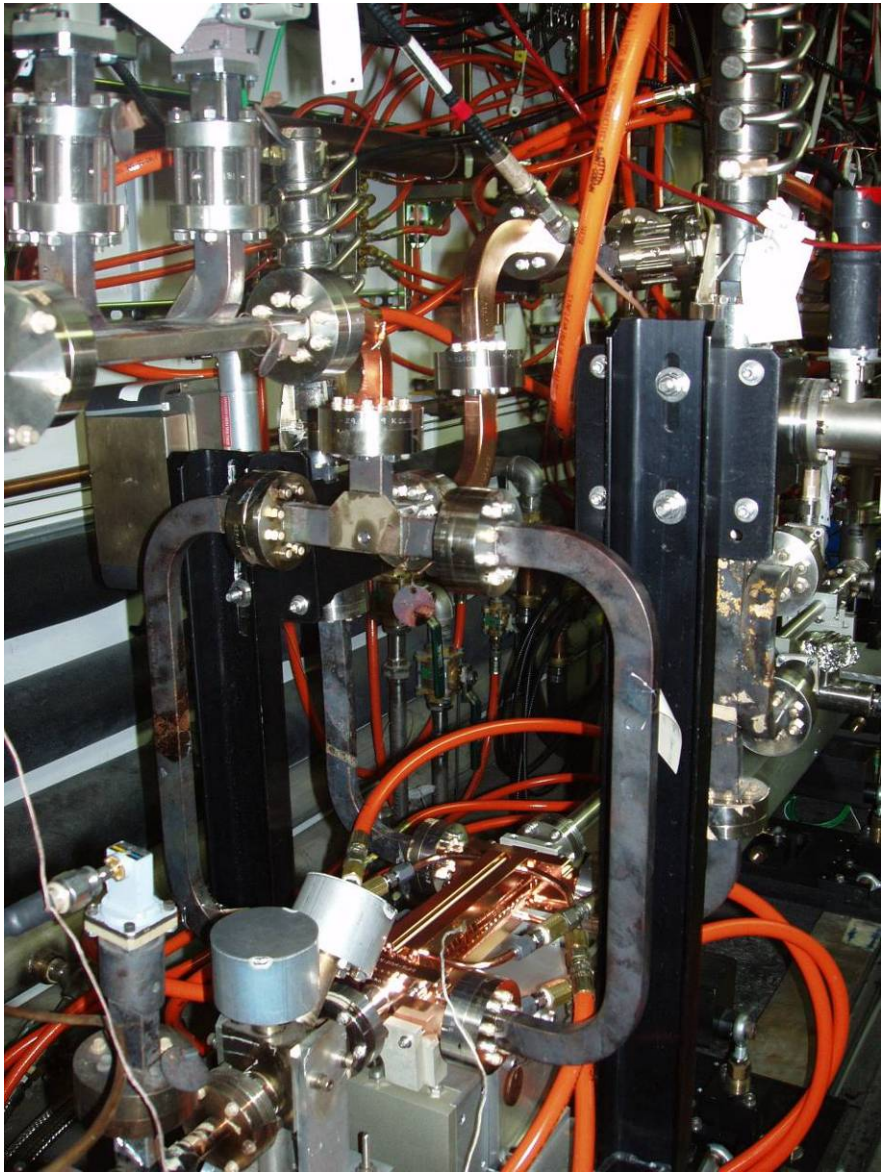
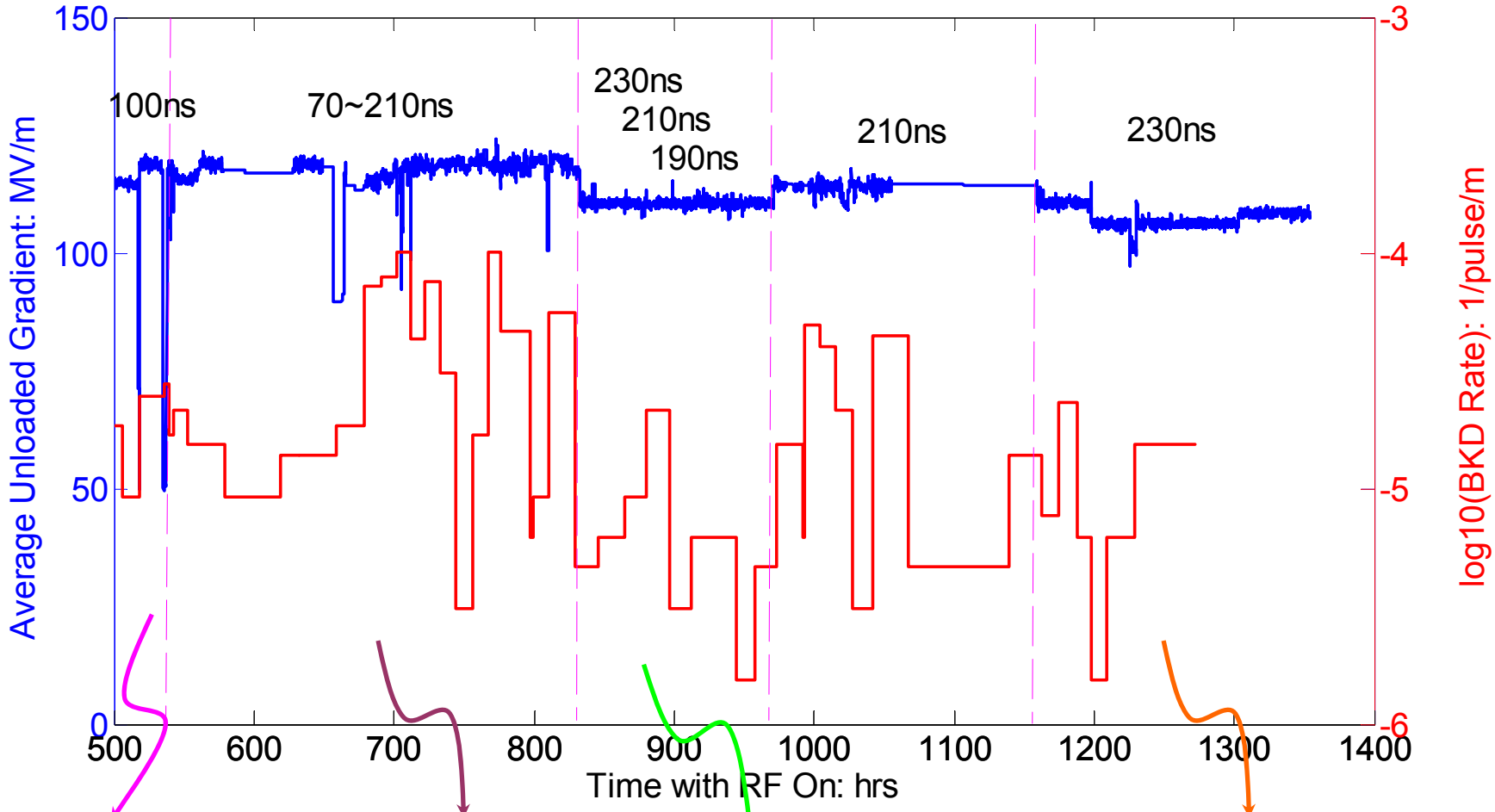
T18_VG2.4_DISC-III at NLCTA for High Power Test



T18_VG2.4_DISK
High Power Test



Short pulse higher gradient condition

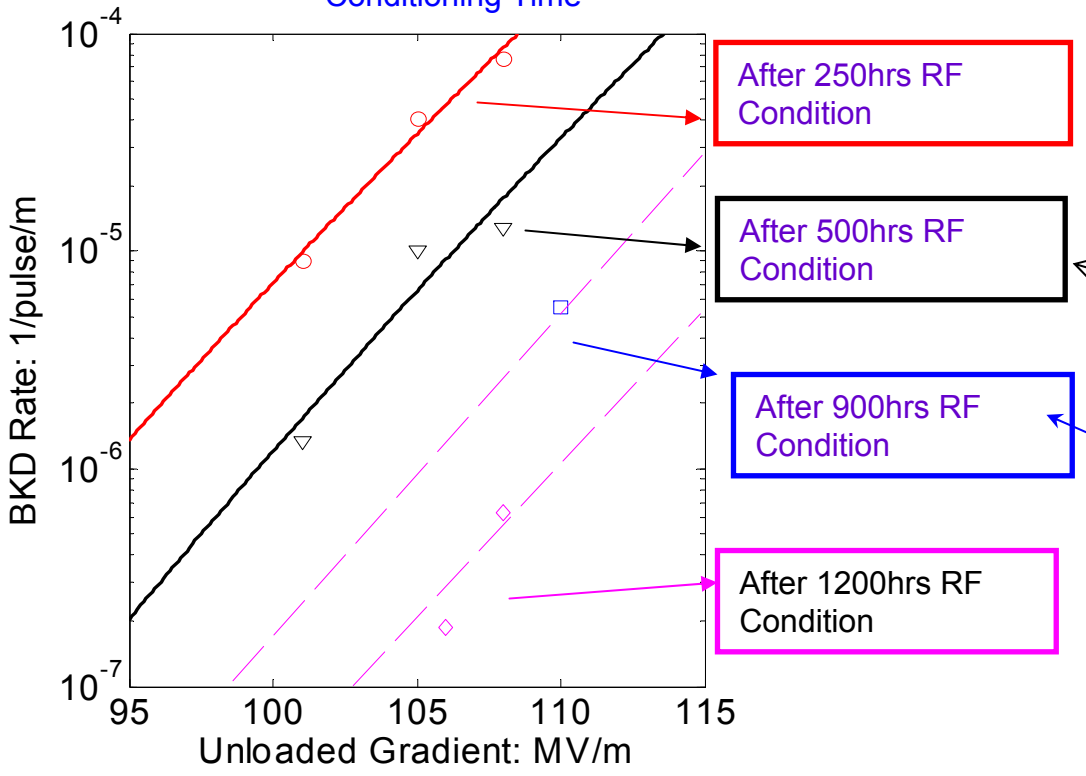
Pulse shape dependence BKD study.

BKD pulse width dependence study at 110MV/m.

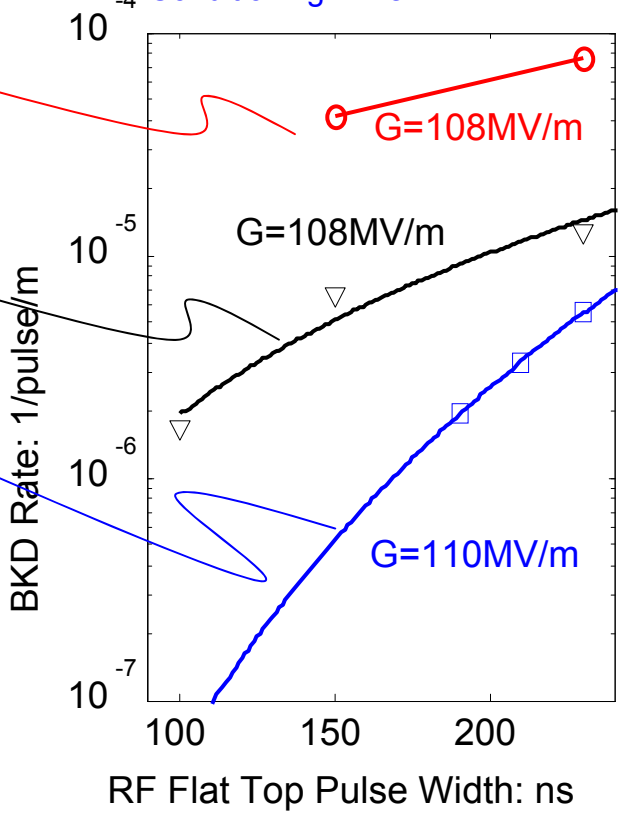
BKD gradient dependence study at 230ns pulse width

Breakdown Rate Characteristics at Different Conditioning Time

RF BKD Rate Gradient Dependence for 230ns Pulse at Different Conditioning Time

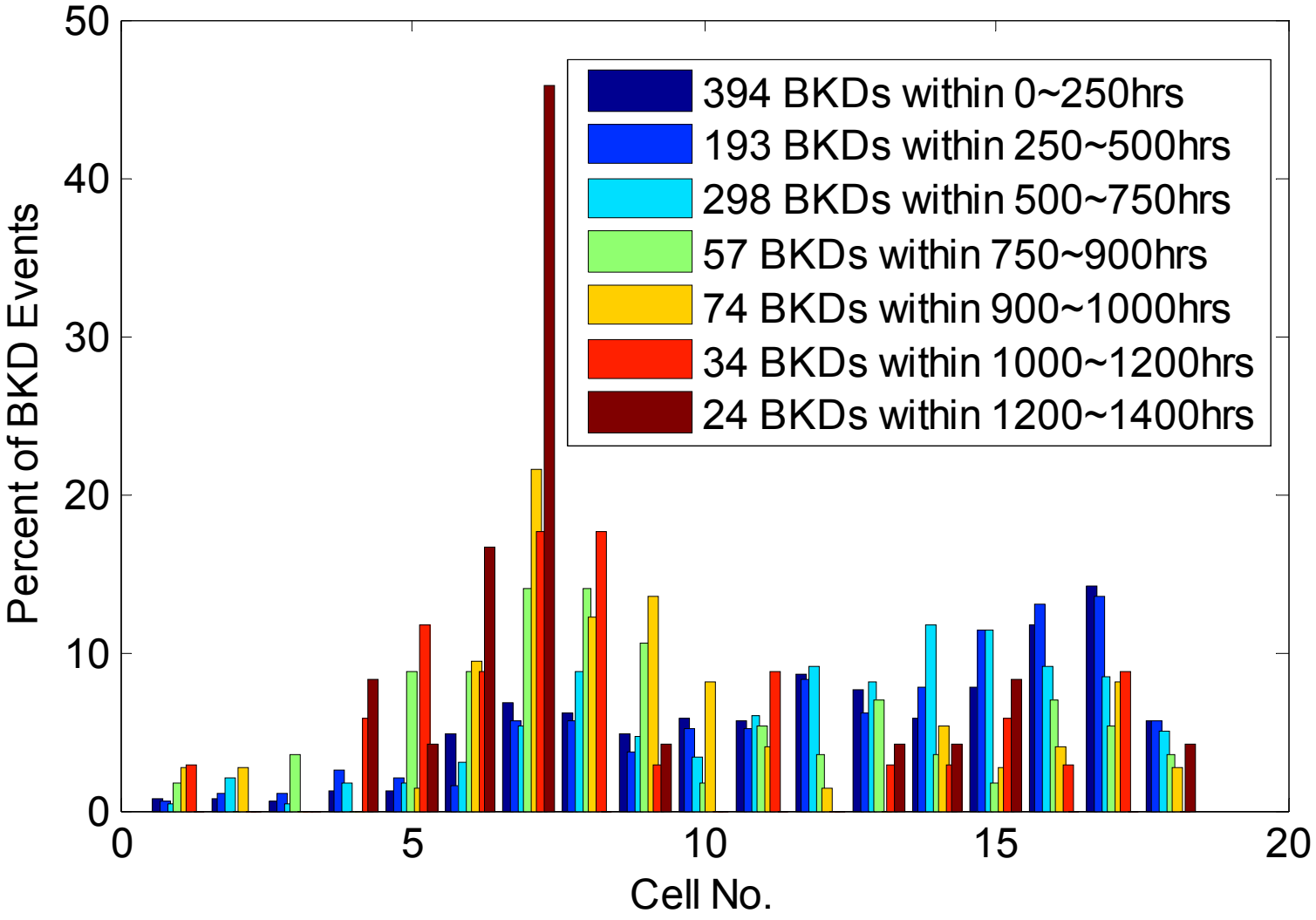


RF BKD Rate Pulse Width Dependence at Different Conditioning Time



This performance *maybe* good enough for 100MV/m structure for a warm collider, however, it does not yet contain all necessary features such as wake field damping. Future traveling wave structure designs will also have better efficiencies

Breakdown Distribution along Structure at Different Stages

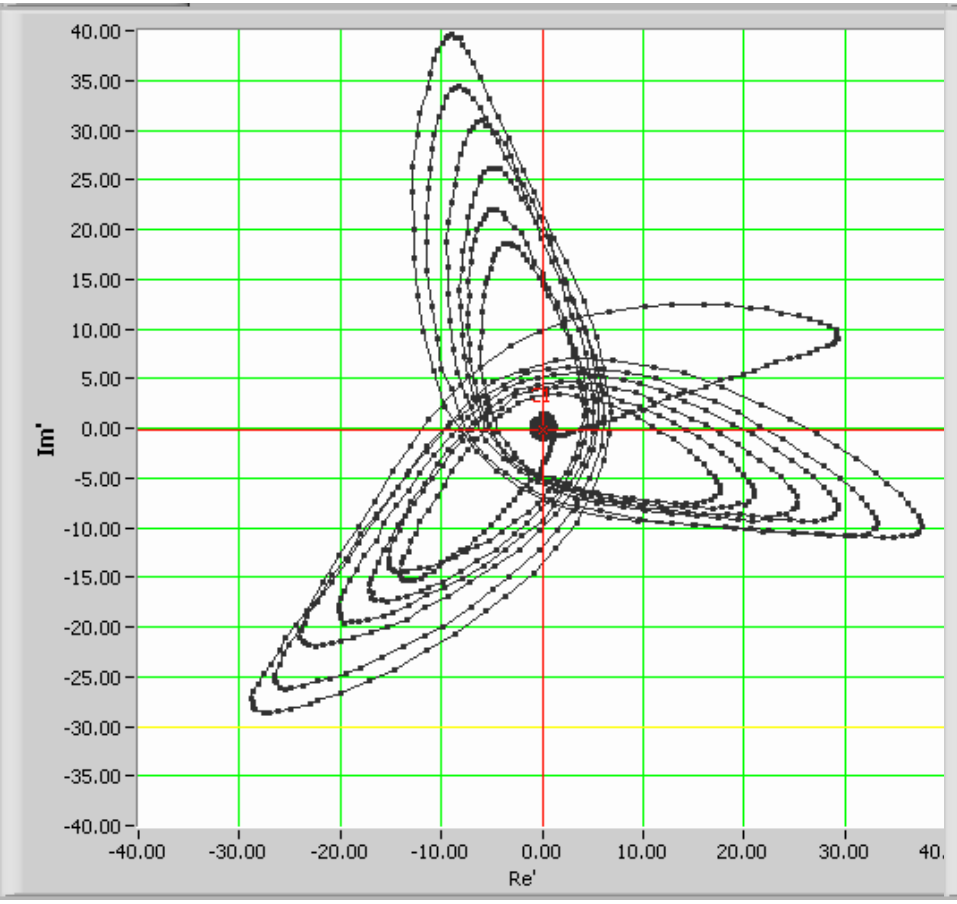


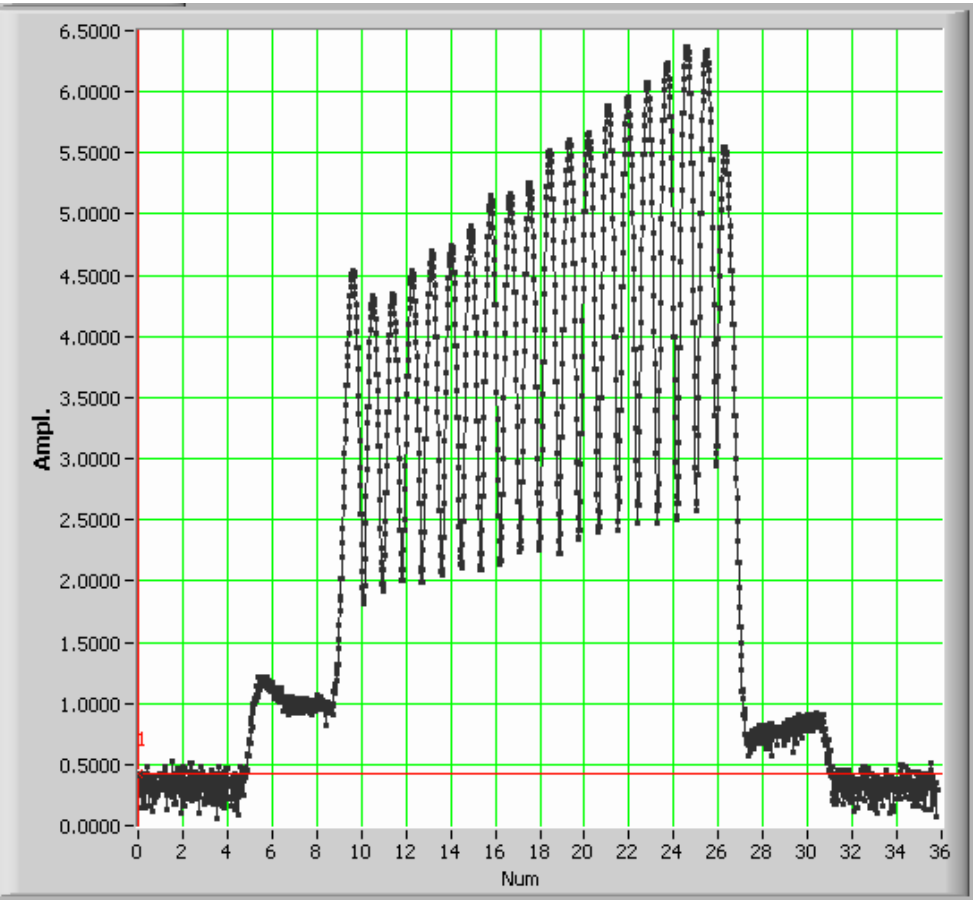
TD18_VG2.4_DISC Structures

Frequency.	11.424GHz
Cells	18+input+output
Filling Time	43 ns
a_{in}/a_{out}	4.02 / 2.66 mm
Vg_{in}/Vg_{out}	2.24 / 0.87 (%c)
S_{11}	0.02
S_{21}	0.74
Phase	120Deg
Average Unloaded Gradient	64.4MW→100MV/m

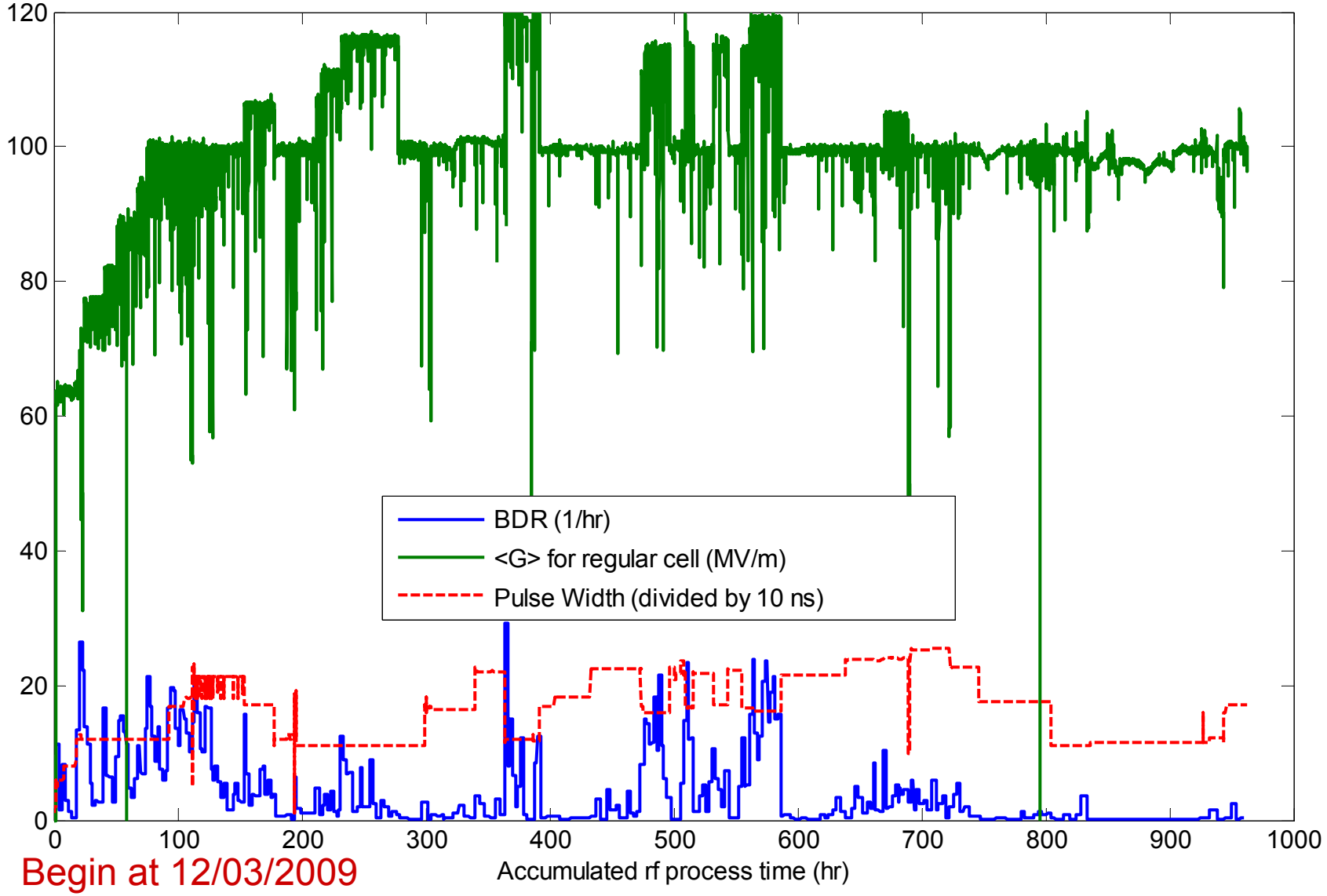
TD18_VG2.4_DISK Characterization

Frequency=11.42166 GHz 20.52°C, N_2



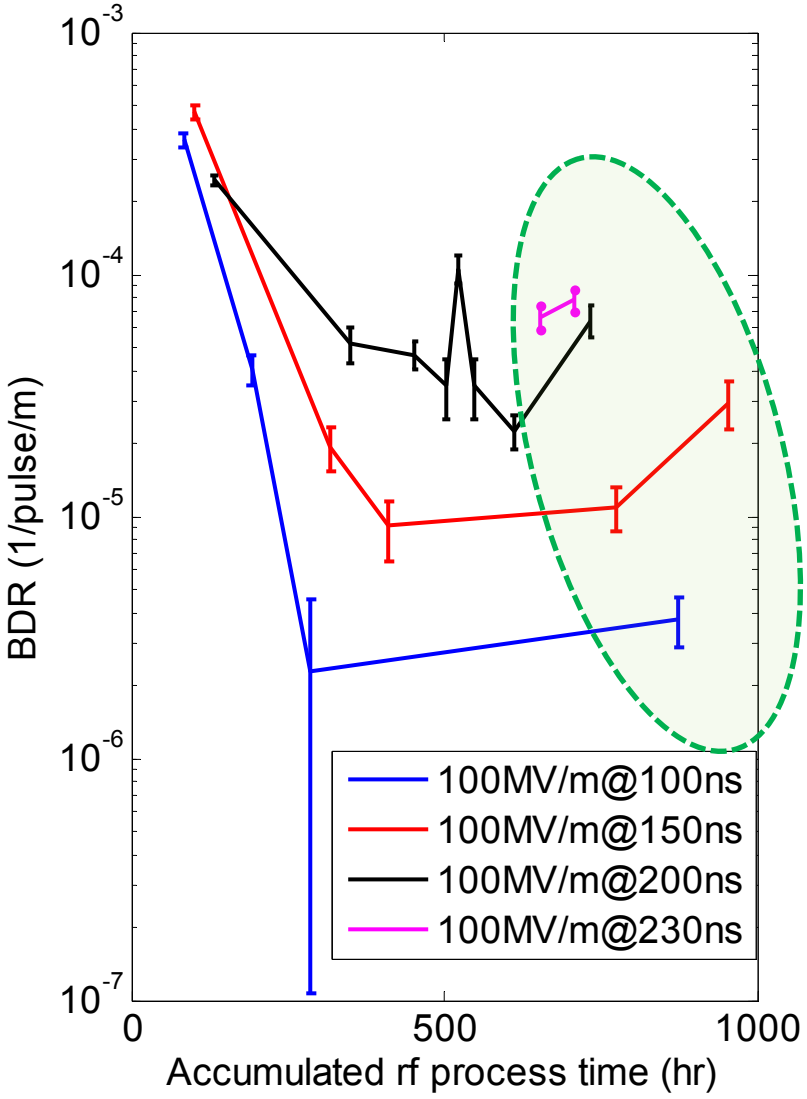


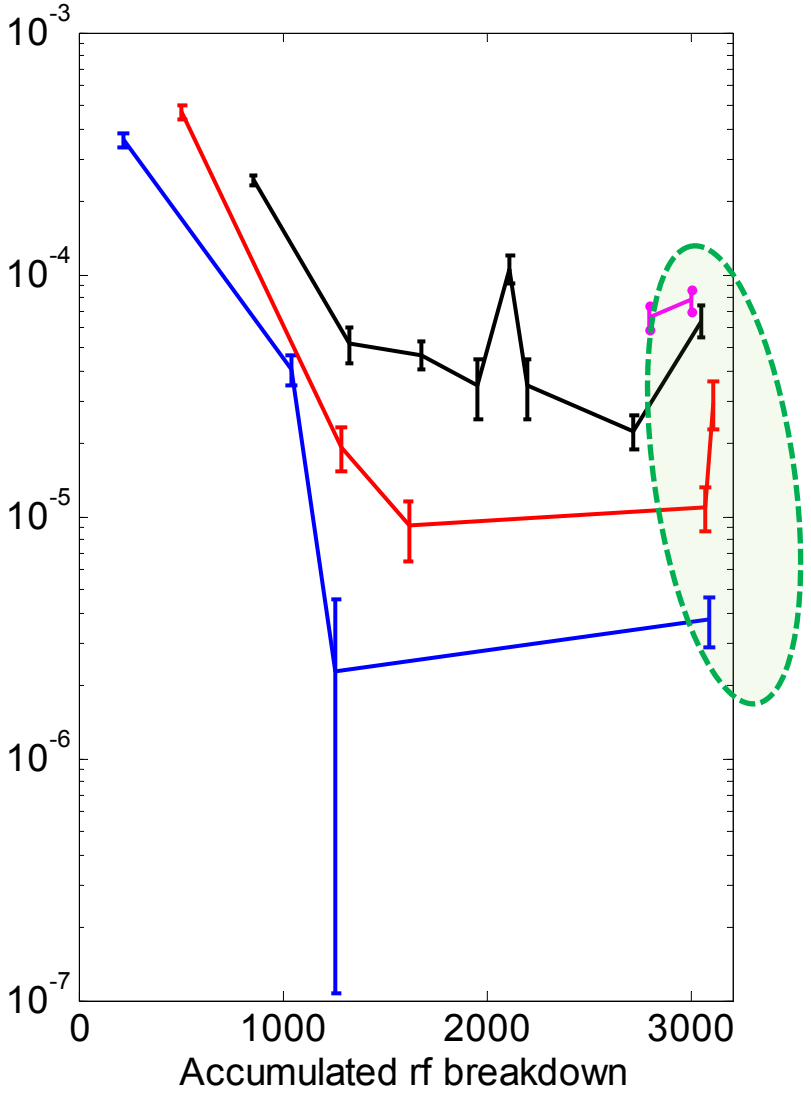
TD18_VG2.4_DISK
High Power Test



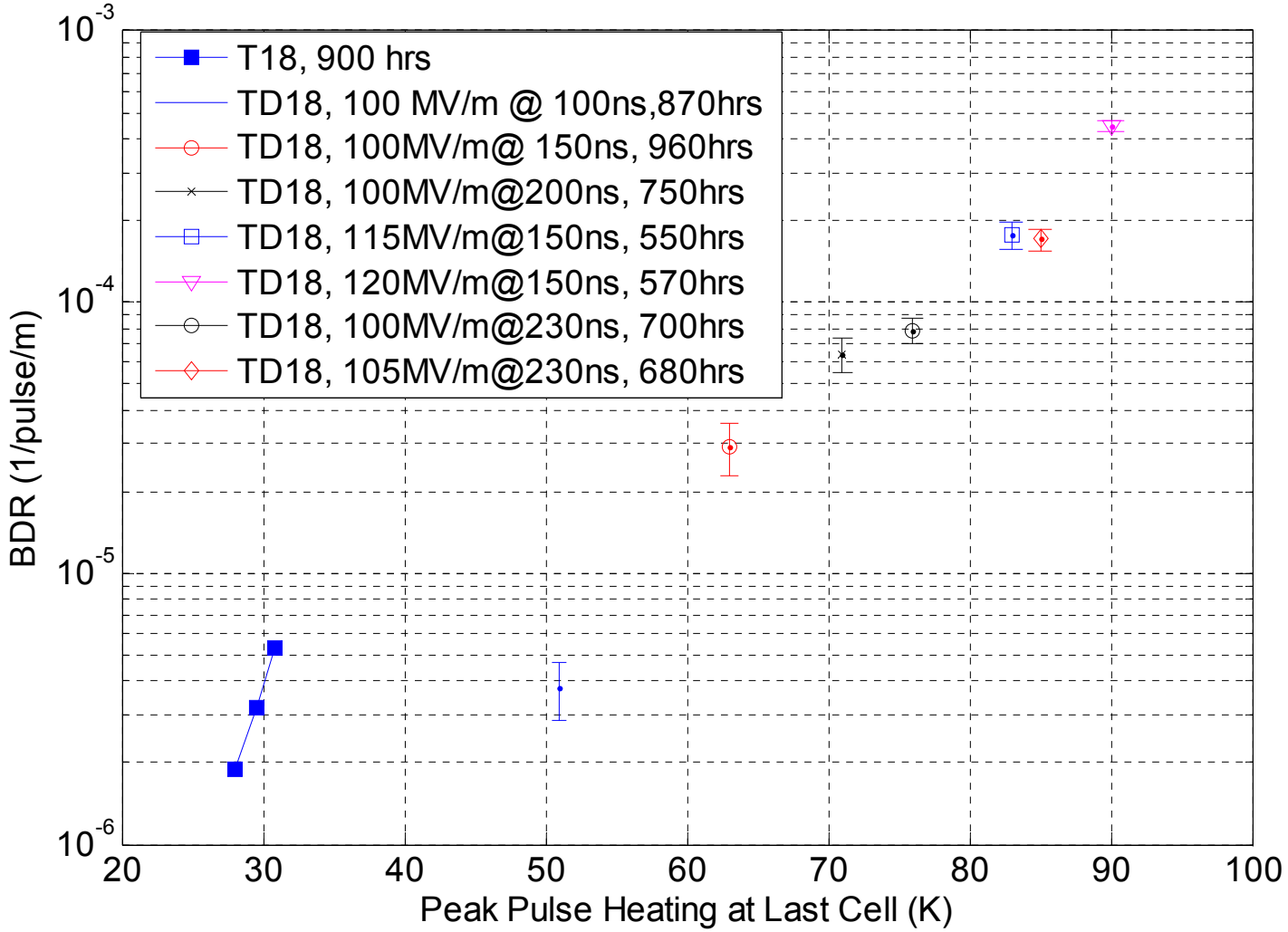
Begin at 12/03/2009

Breakdown Evolution with RF process

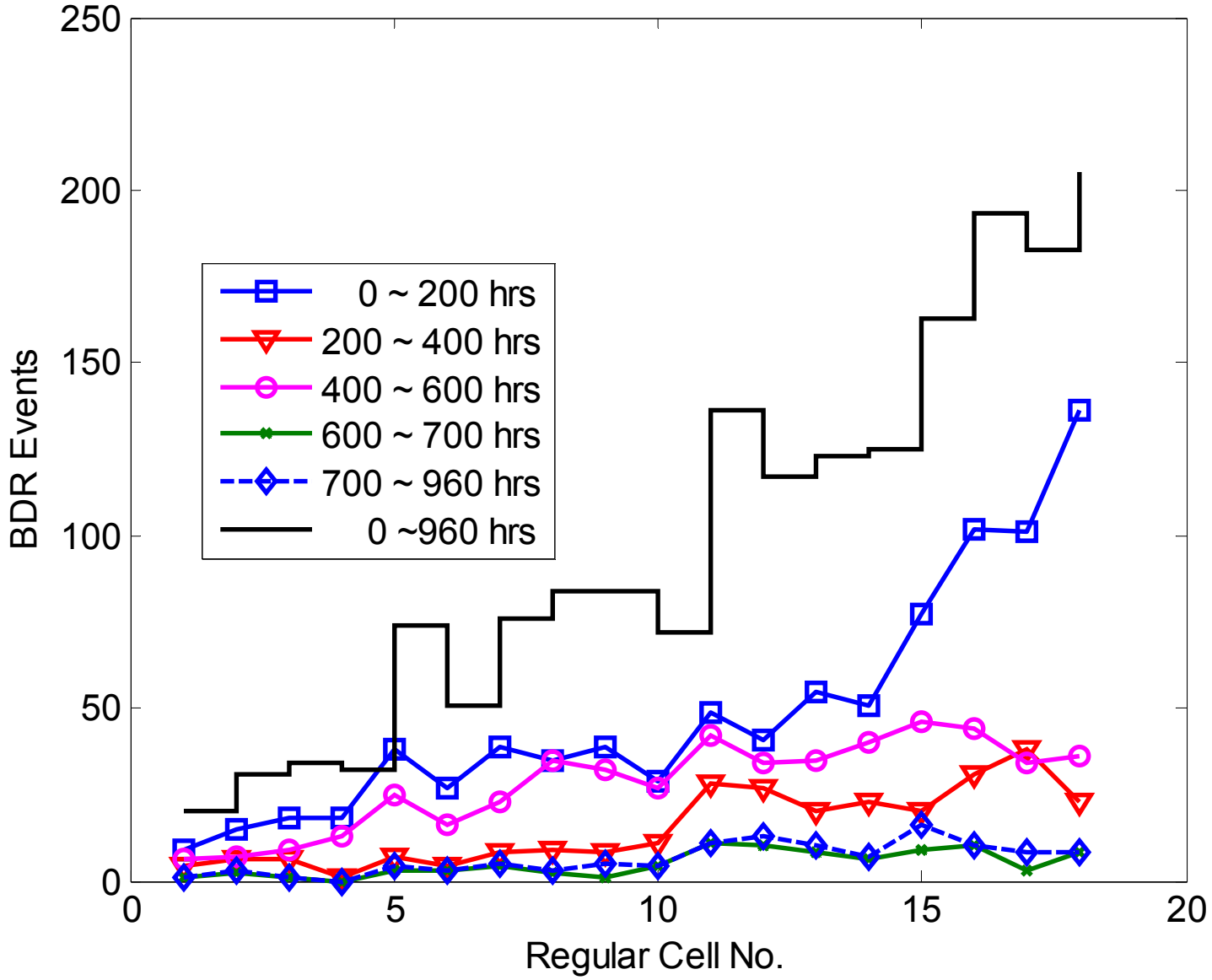




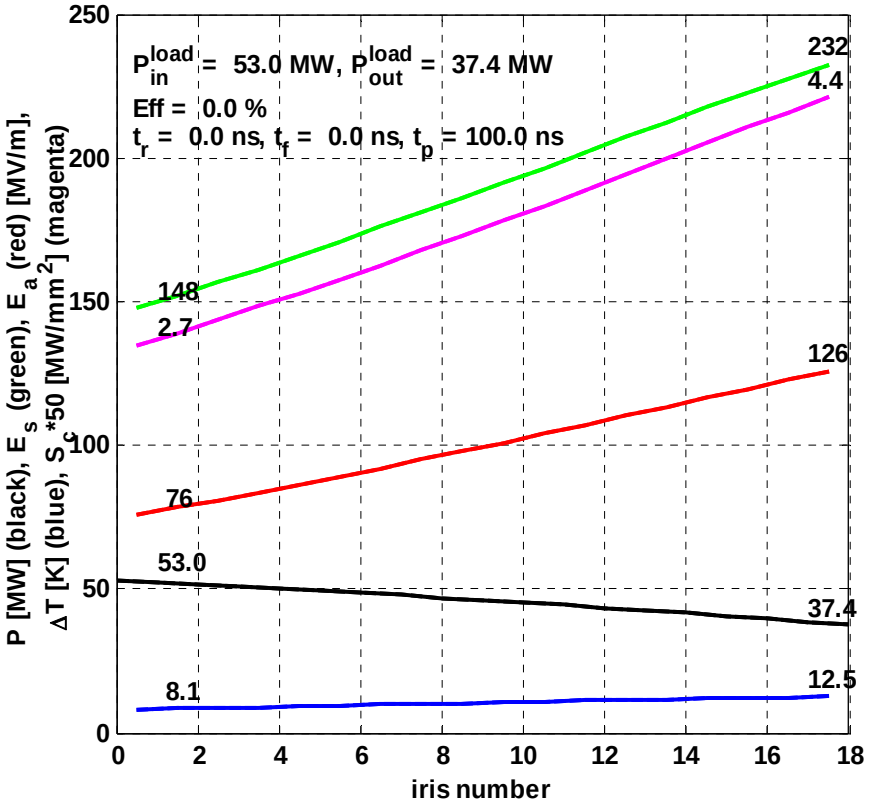
BDR Pulse Heating Dependence

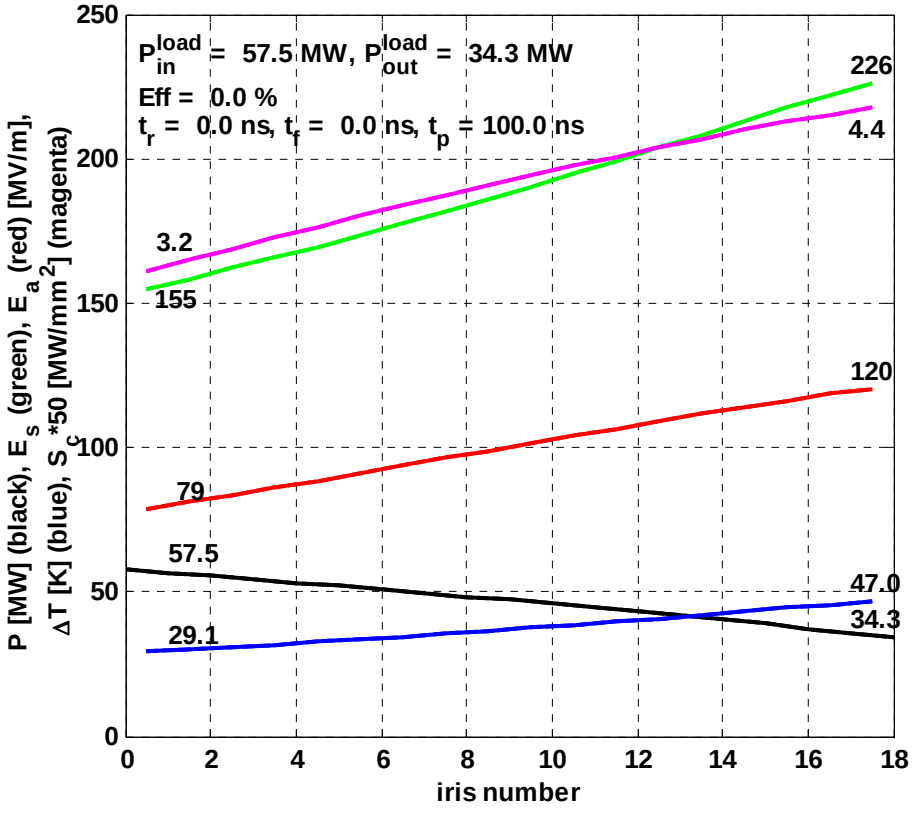


Breakdown distribution at different stage

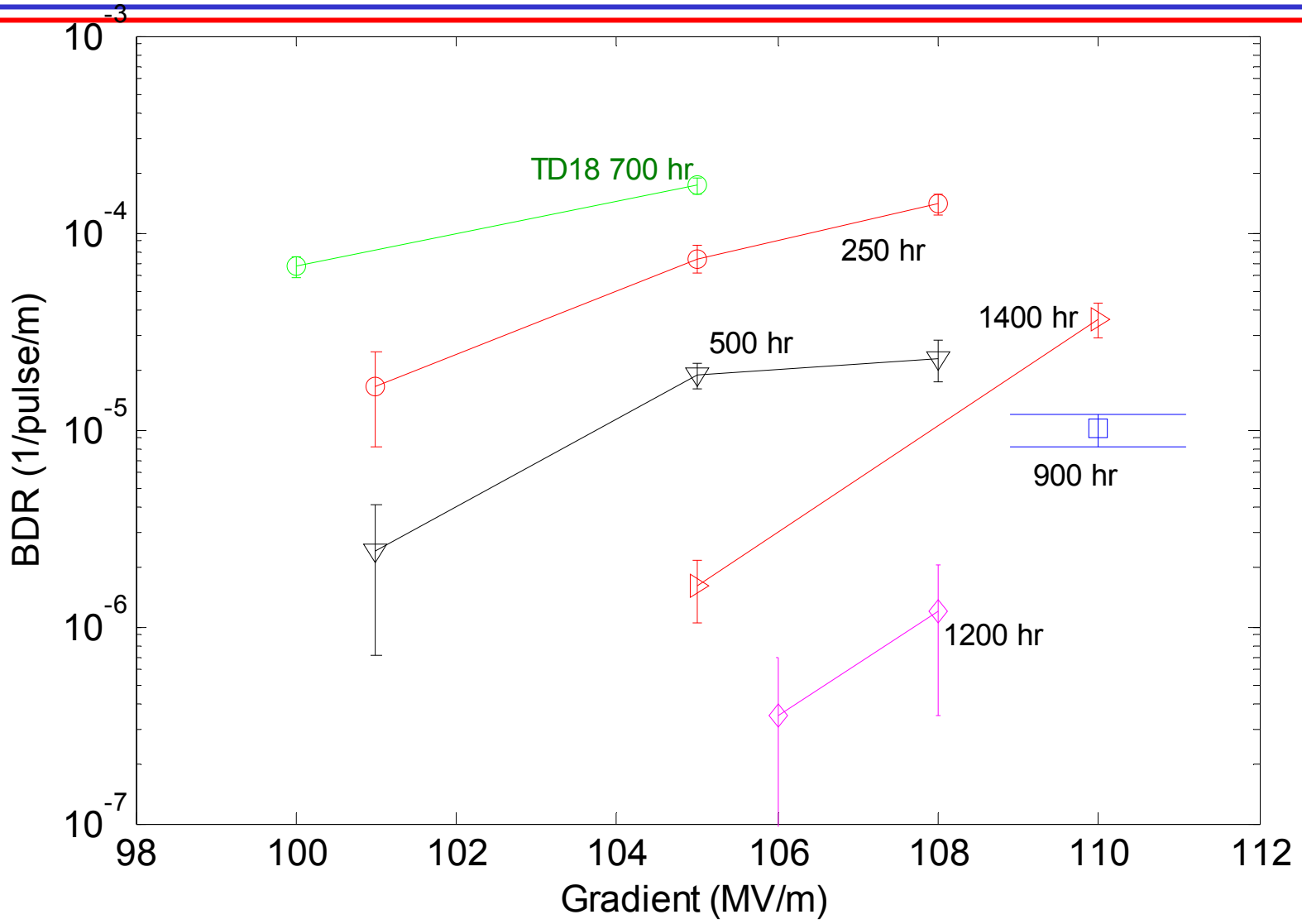


RF Properties Comparison for T18 and TD18





RF Process Results Comparison fot T18 and TD18



Pulse width 230ns, Green line for TD18, Others for T18

5. Scope for Future Work

Work in the Near Future

1. Three more C10 Structures 1xVG1.35 and 2xVG0.7
   - Microwave tuning and High power testing
2. Four more C10 Structures 2xVG2.25 and 2xVG3.3
   - All parts ordered
   - SLAC Assembly, tuning and High power testing
3. T24_VG1.8_DISK #3, #4
   - KEK made parts, assembly at SLAC
   - High Power Testing at SLAC and KEK
4. TD24_VG1.8_DISK #4, #5
   - KEK made parts, assembly at SLAC
   - High Power Testing at SLAC and KEK
5. T18_VG2.4_DISK #6
   - CERN made similar like KEK/SLAC fabrication
   - High power testing at SLAC
6. TD24_VG1.8_DISK
   - CERN made
   - High power testing at SLAC or CERN
7. C10 2 x VG1.35#1, #2
   - KEK fabrication with SLAC mode convertors
   - Assembly, Tuning art SLAC and High power testing at SLAC/KEK
8. CD10 2 x VG1.35#1, #2
   - KEK fabrication with SLAC mode convertors
   - Assembly, Tuning art SLAC and High power testing at SLAC/KEK