NATIONAL ACCELERATOR LABORATORY

SLAC Work Status for the CLIC High Gradient Accelerator Structure R&D

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CLIC 09

October, 2009

SLAC NATIONAL ACCELERATOR LABORATORY

Outline

1. Introduction
2. Work in the Past
3. Structure Fabrication Technology
4. Ongoing Work
5. Scope for Future Work

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1. Introduction

We've Been Working Together Successfully Toward Our Goal

Statement from CLIC07 Workshop

- Our urgent priority is to produce X-band test structures based on optimized X-band designs.

One of our most important feasibility demonstrations is operating a fully featured accelerating structure at 100 MV/m and the full pulse length with an appropriate breakdown rate.

- To speed up this process, and to benefit from all the development work made by NLC/JLC, SLAC and KEK are also producing test structures.
- In the coming year, all testing which could lead to a feasibility demonstration will occur at SLAC and KEK.
- We hope that our colleagues at SLAC and KEK get good support from their management!

What we are contributing

- 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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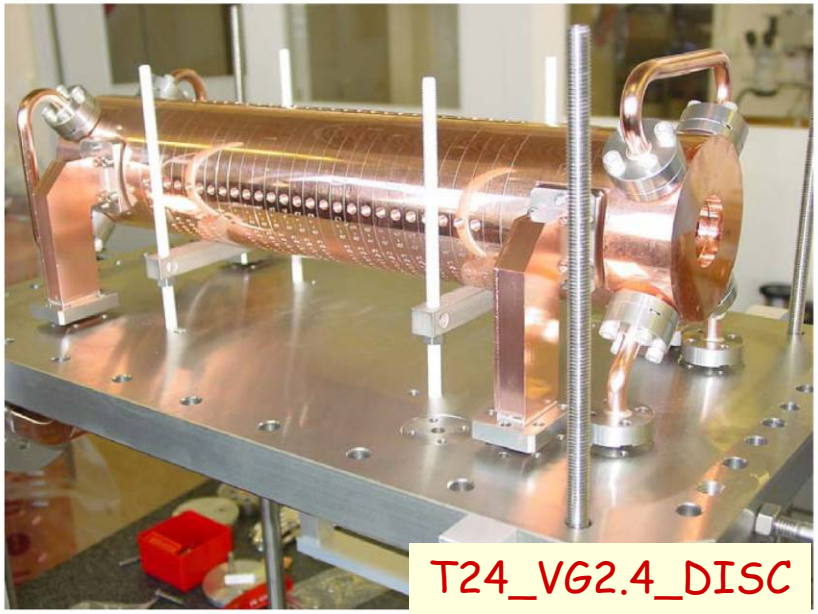
2. Work in the Past

Work Done Since the Collaboration

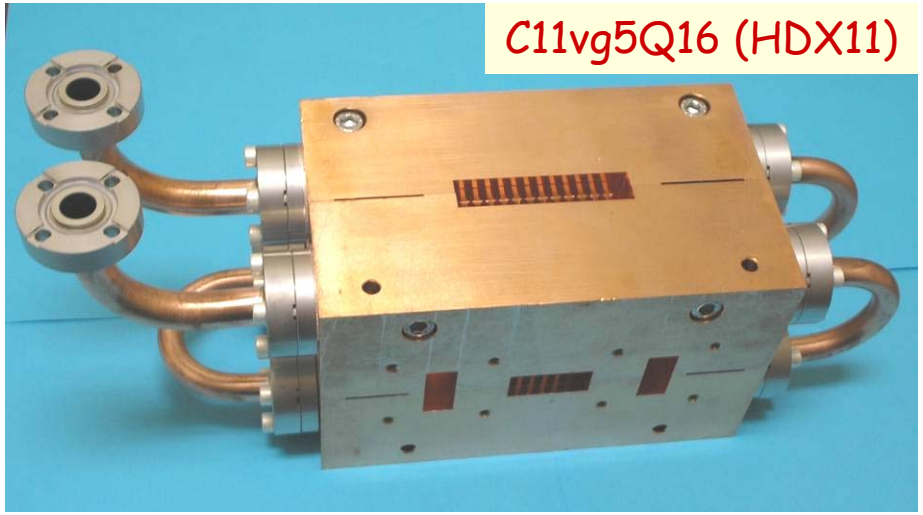
1. Eleven structures have been made and five high power tested
   - 1 x T28_vg2.9 (T26) Structure
     Used T53VG3MC components and completed by the end of May, 2008
     High power tested in the NLCTA since June 2008.
   - 4 x T18_VG2.4_DISC Structures #1, #2, #3, #4
     Two with SLAC flanges, high 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
     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
   - HDX11 Cu Structure and 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

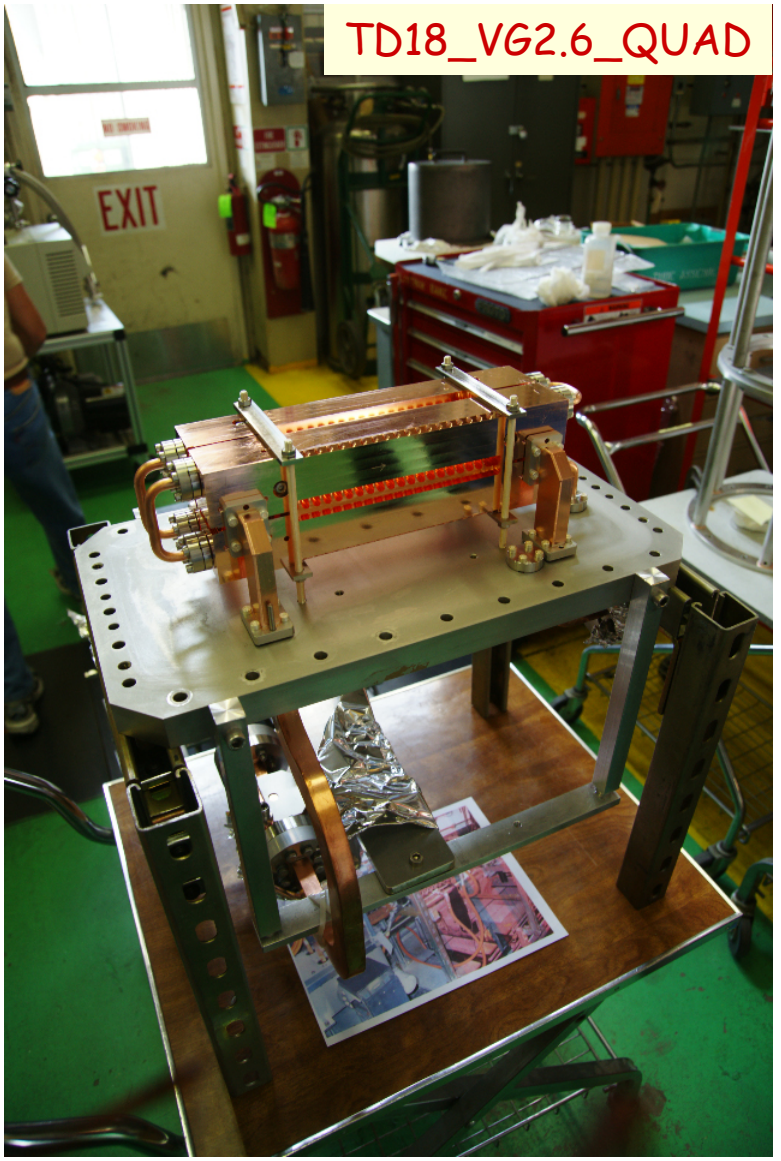
Some CERN made Structures Tested at SLAC



T24_VG2.4_DISC



C11vg5Q16 (HDX11)



TD18_VG2.6_QUAD

2007-09 CERN/CLIC Made Structures Tested at SLAC

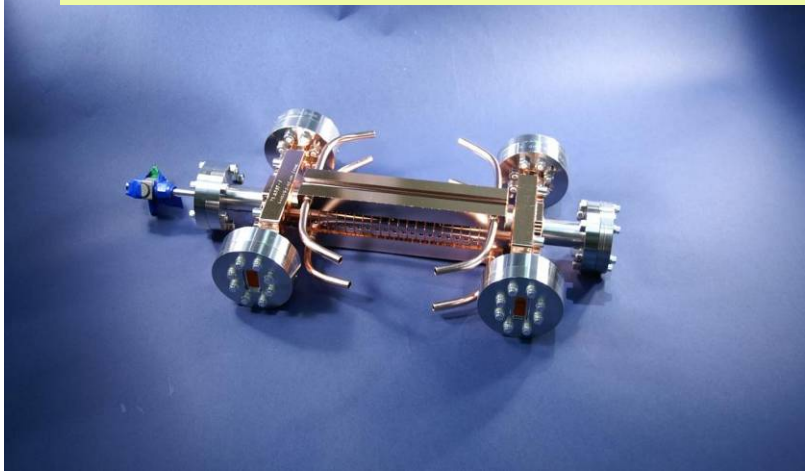
(Yellow = Quad Cell Geometry, Green = Disk Cell Geometry)

In Beamline	Structure	Note	Performance
11/06 – 2/07 NLCTA	C11vg5Q16 (HDX11)	First X-band Quad - Irises Slotted	Poor: 57 MV/m, 150 ns, 2e-5 BDR – grew whiskers on cell walls
2/08 - 4/08 NLCTA	C11vg5Q16 (HDX11)	Refurbished	Initially good (105 MV/m, 50 ns,1e-5 BDR) but one cell degraded
4/07 – 10/07 NLCTA	C11vg5Q16-Mo (HDX11)	Molybdenum Version of Above	Poor: 60 MV/m, 70 ns, 1e-6 BDR
10/08 – 12/08 NLCTA	TD18vg2.6_Quad	No Iris Slots but WG Damping	Very Poor: would not process above 50 MV/m, 90ns – gas spike after BD
12/08 – 2/09 NLCTA	T18vg2.6-Disk	CERN Built, Operate in Vacuum Can	Very Poor: very gassy with soft breakdowns at 60 MV/m, 70 ns
8/09 – 8/09 NLCTA	T24vg2.4-Disk	CERN Built, Operate in Vacuum Can	Very poor: 40 MV/m, 100 ns, breakdown uniformly throughout the structure

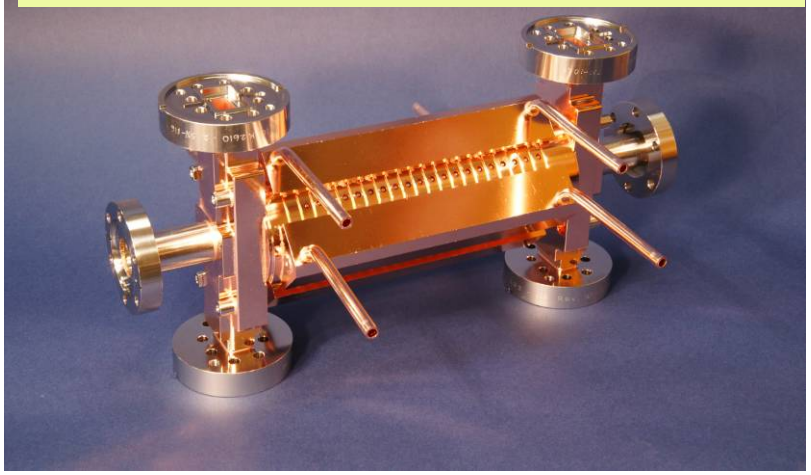
Even though the gradients were not satisfactory,
but a lot of knowledge and experiences have been obtained.

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

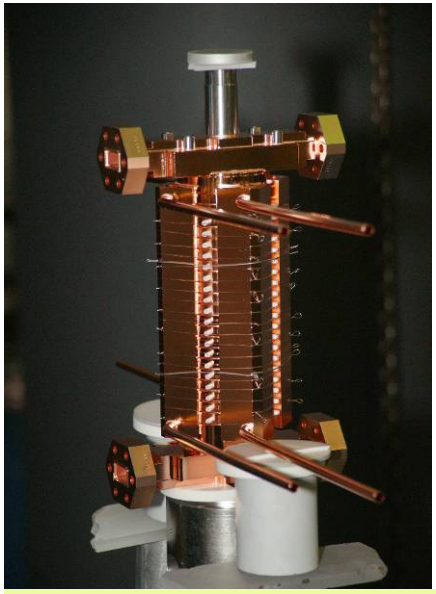
T18_VG2.4_DSC with SLAC Flanges



TD18_VG2.4_DISC with SLAC Flanges



T28_VG2.9 (T26) with SLAC Flanges



TD18_VG2.4_DISC with KEK Flanges

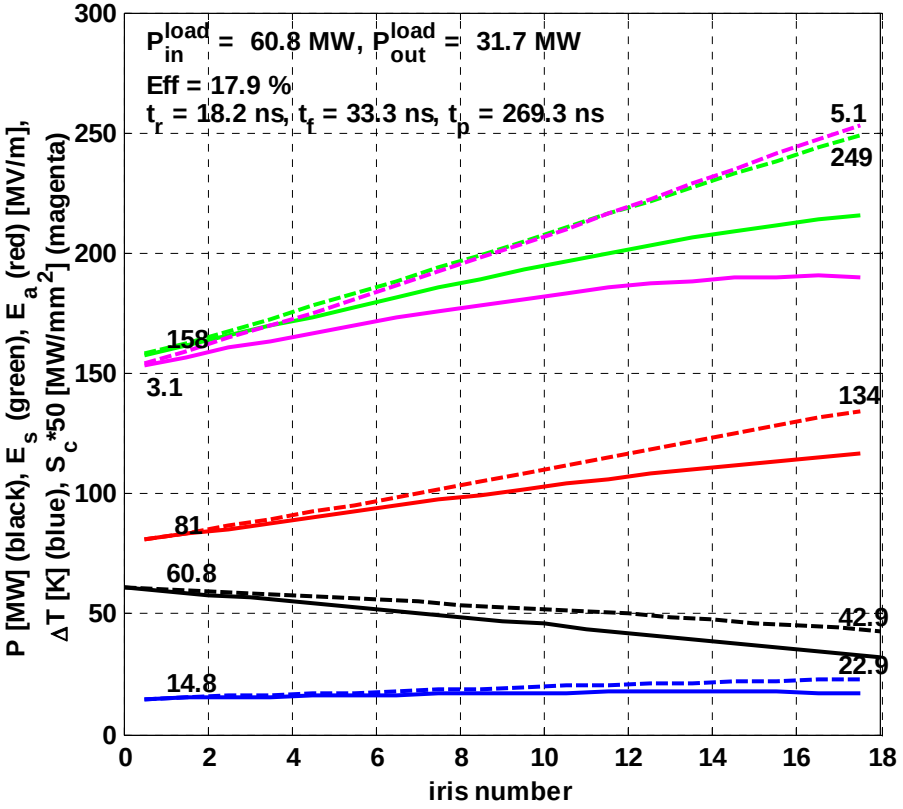
2008-09 Tested KEK/SLAC Made Structures

(Yellow = Quad Cell Geometry, Green = Disk Cell Geometry)

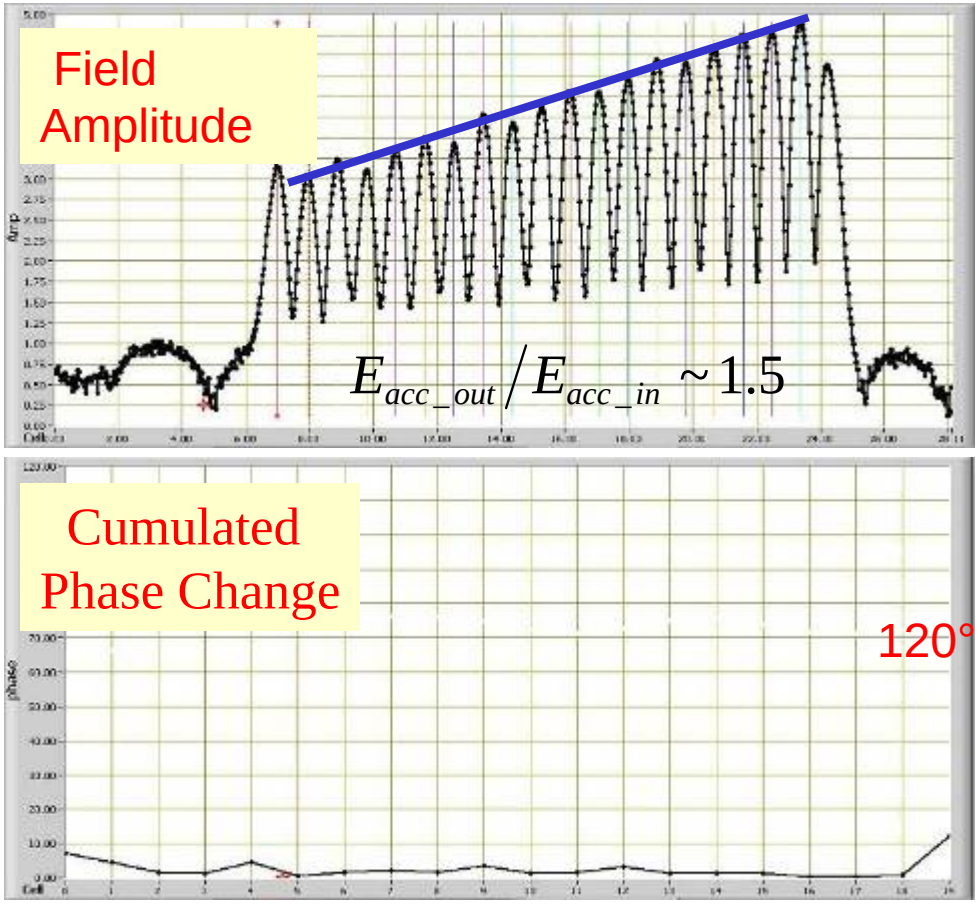
In Beamline	Structure	Note	Performance
4/08 – 7/08 NLCTA	T18_VG2.4_DISK-I	Cells by KEK, Assembled at SLAC	Good: 105 MV/m, 230 ns at LC BDR spec of 5e-7/pulse/m but hot cell developed
7/08 – 10/08 NLCTA	T18_VG2.4_DISK-I	Powered from Downstream End	Good: 163 MV/m, 80 ns, 2e-5 BDR in last cell.
10/08 – 8/09 KEK	T18_VG2.4_DISK-II	Cells by KEK, Assembled at SLAC	Good: 105 MV/m, 250 ns at BDR of 2e-6/pulse/m with 4000 hours processing
6/09 – 9/09 NLCTA	T18_VG2.4_DISK-III	Cells by KEK, Assembled at SLAC	Good: Still under testing. Similar like T18vg2.6-Disk-I with low breakdown rate at 110 MV/m, 230 ns after 400 hours

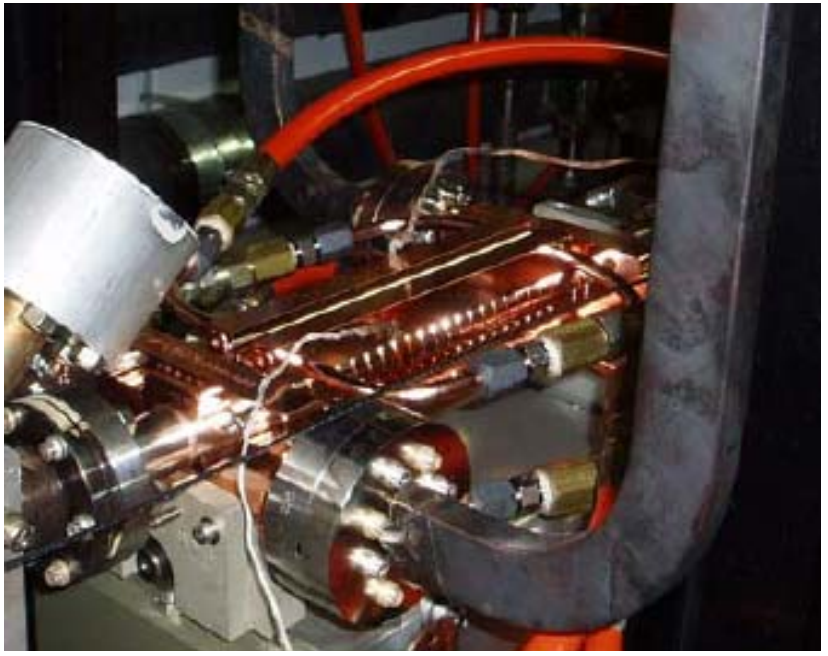
T18_VG2.4_DISC Structures

Frequency.	11.424GHz
Cells	18+input+output
Filling Time	36ns
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



T18_VG2.4_DISC Structure Test

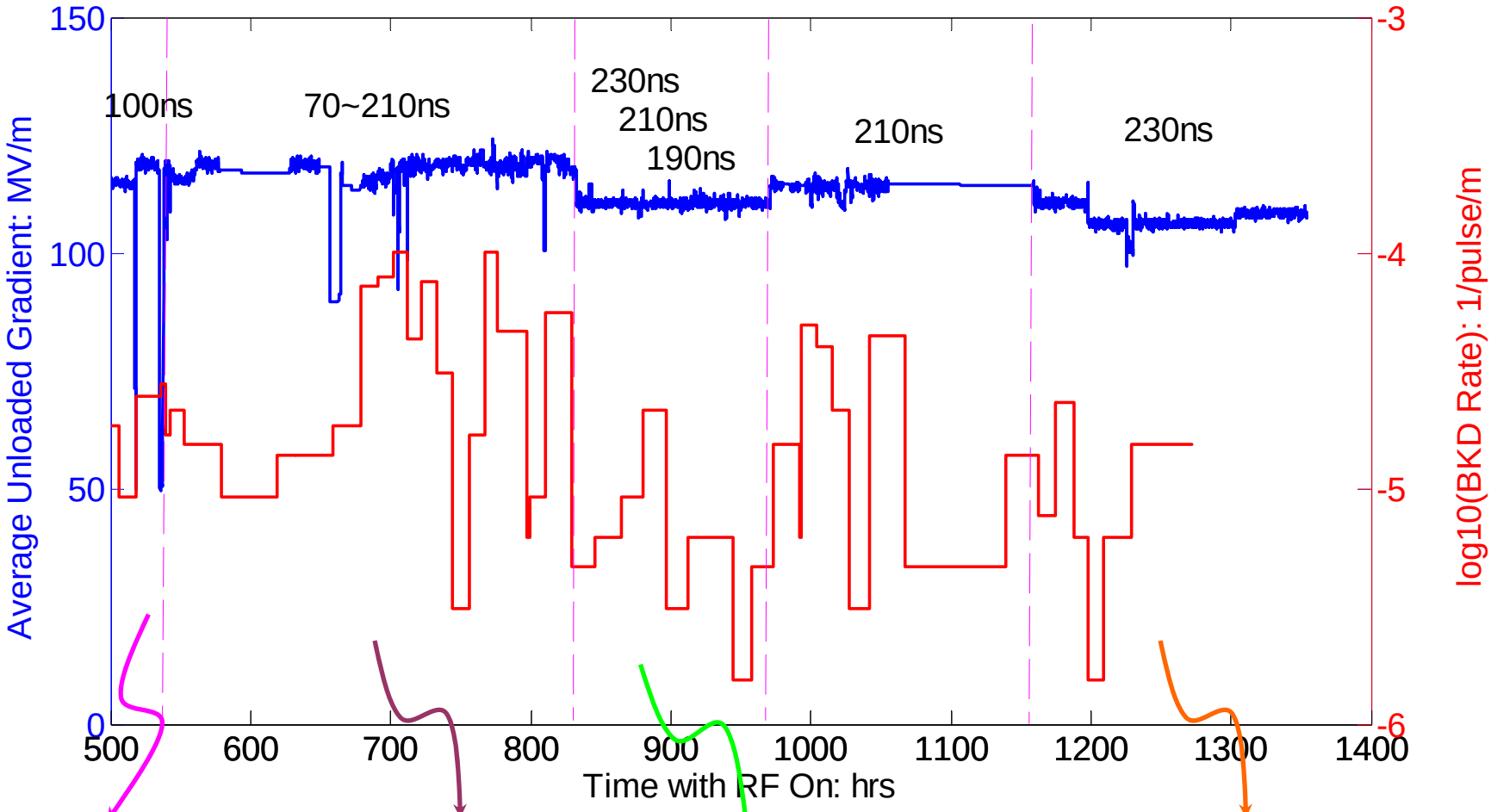




Microwave Tuning and test

High power test set-up

The following 900hrs, maximum unloaded gradient is 120MV/m



Short pulse higher gradient condition

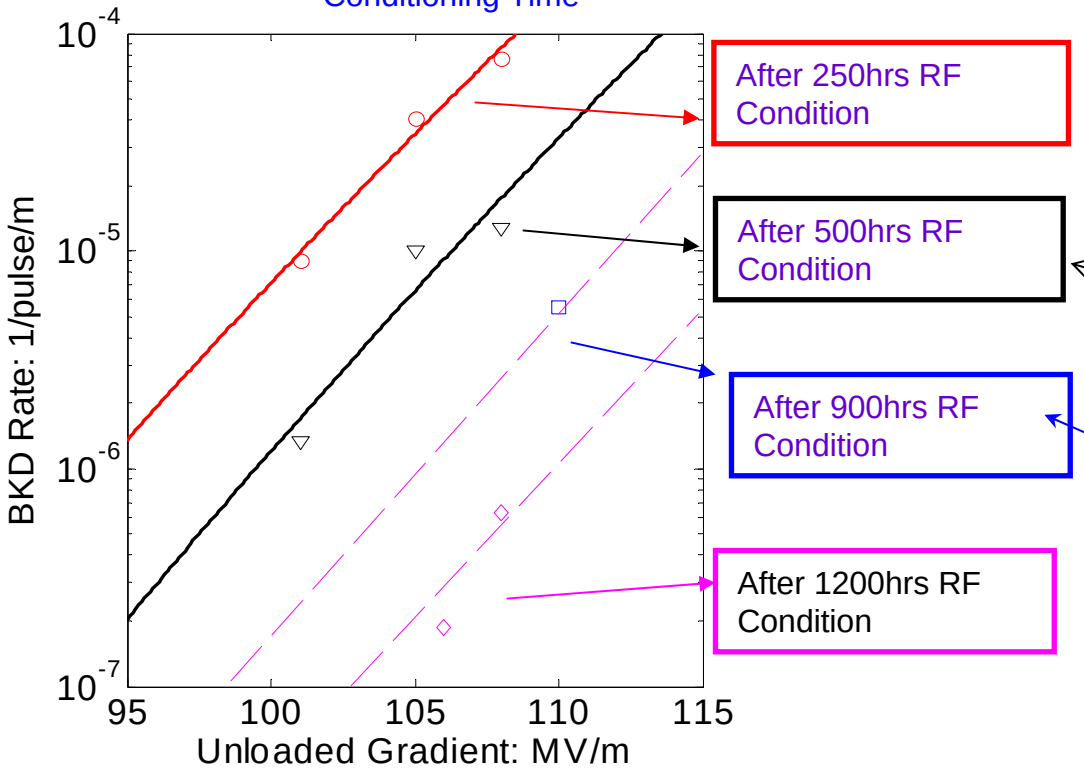
Pulse shape dependence BKD study.

BKD pulse width dependence study at 110MV/m.

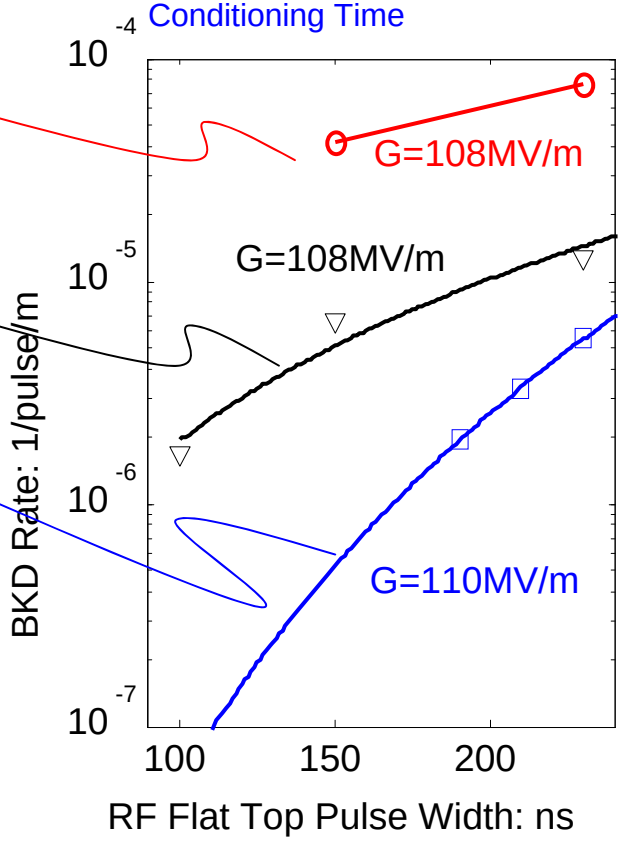
BKD gradient dependence study at 230ns pulse width

Breakdown Rate Characteristics at Different Conditioning Time

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

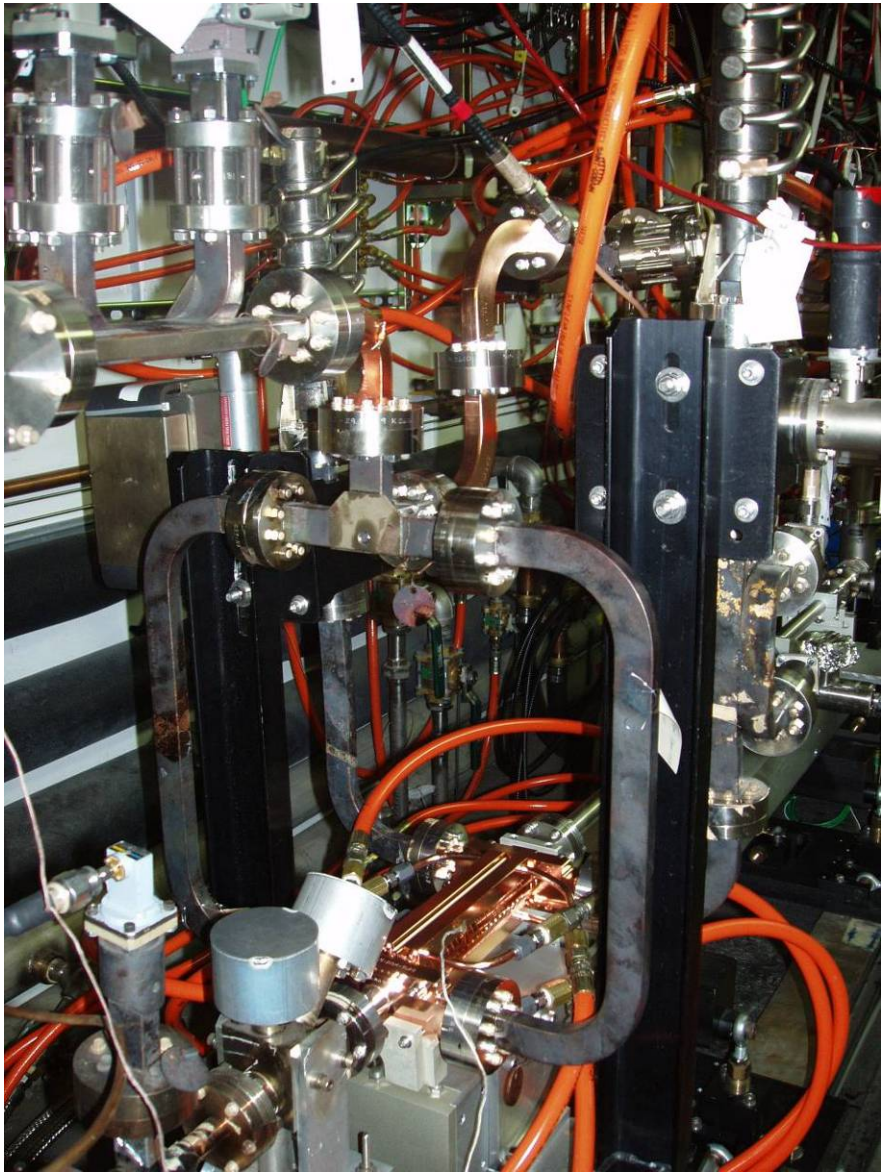


RF BKD Rate Pulse Width Dependence at Different Conditioning Time



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

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



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3. Structure Fabrication Technology

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

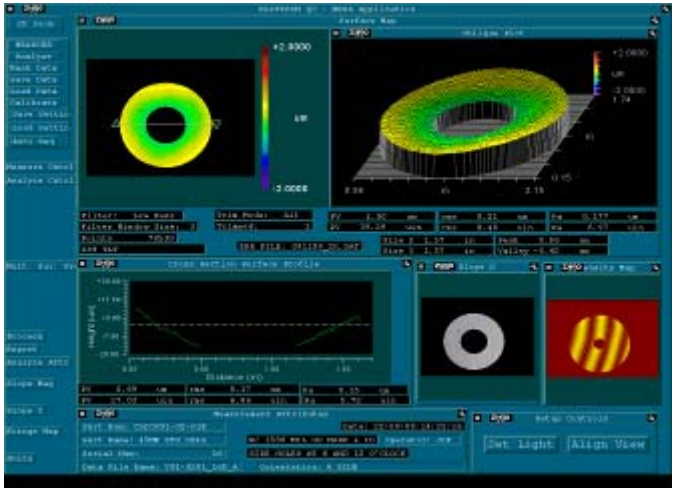
7. Cold tap water rinse for minimum of 2 minutes until the film on part disappears.
8. Ultrasonic in DI Water for 1 minute.
9. Ultrasonic in new, clean alcohol for 1 minute.
10. Final Rinse to be done in new, clean alcohol.
11. Hold in clean alcohol in stainless steel containers.
12. Dry in a clean room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

For accelerator structure parts with regular machining surfaces:

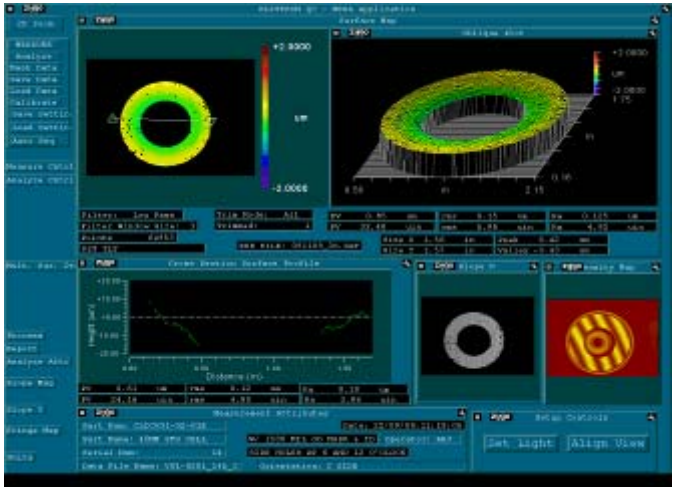
6. Immense in the following solution for maximum of 30-60 seconds depending on the surface finish required:

ZYGO Surface Flatness Measurement for a Typical Cup of T18_VG2.4_DISC #3 and #4

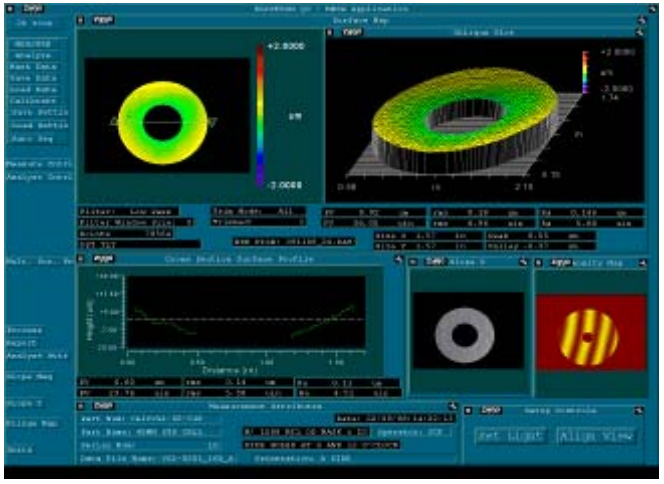
Both sides show less than 1 micron concaved



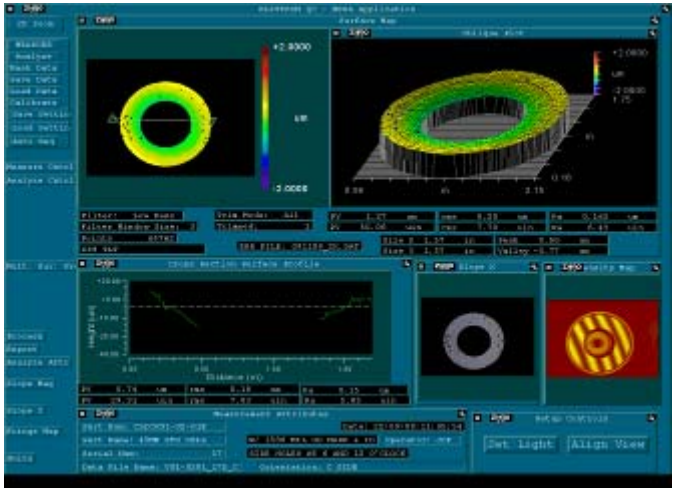
16D-A



14D-C



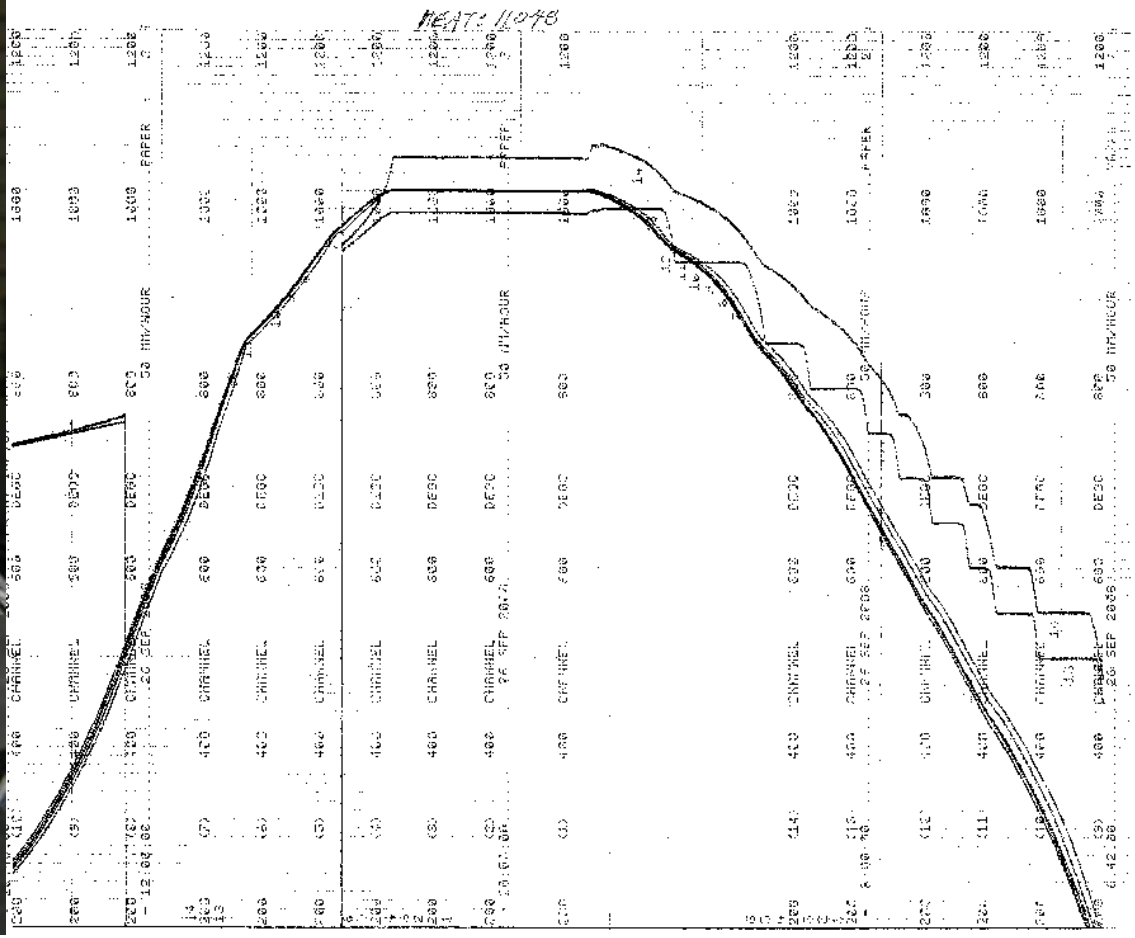
17D-A



17D-C

Stacking for Body Bonding of T18_vg2.4_DISC

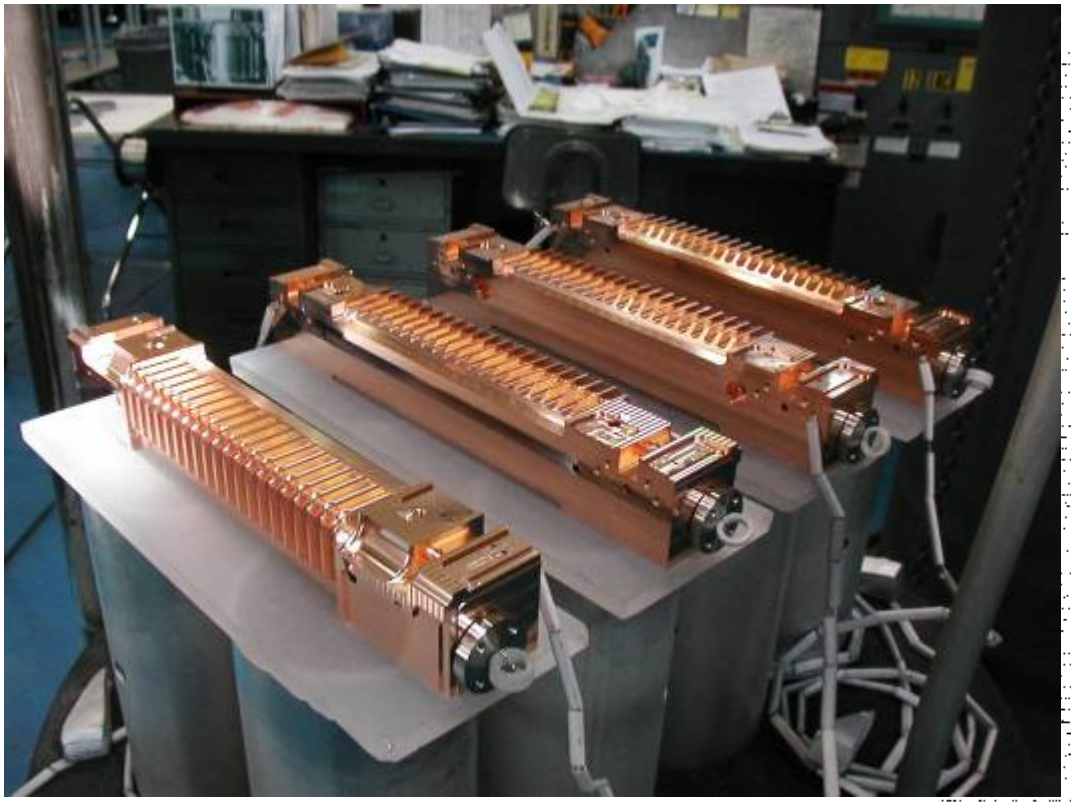
Diffusion Bonding of T18_vg2.4_DISC

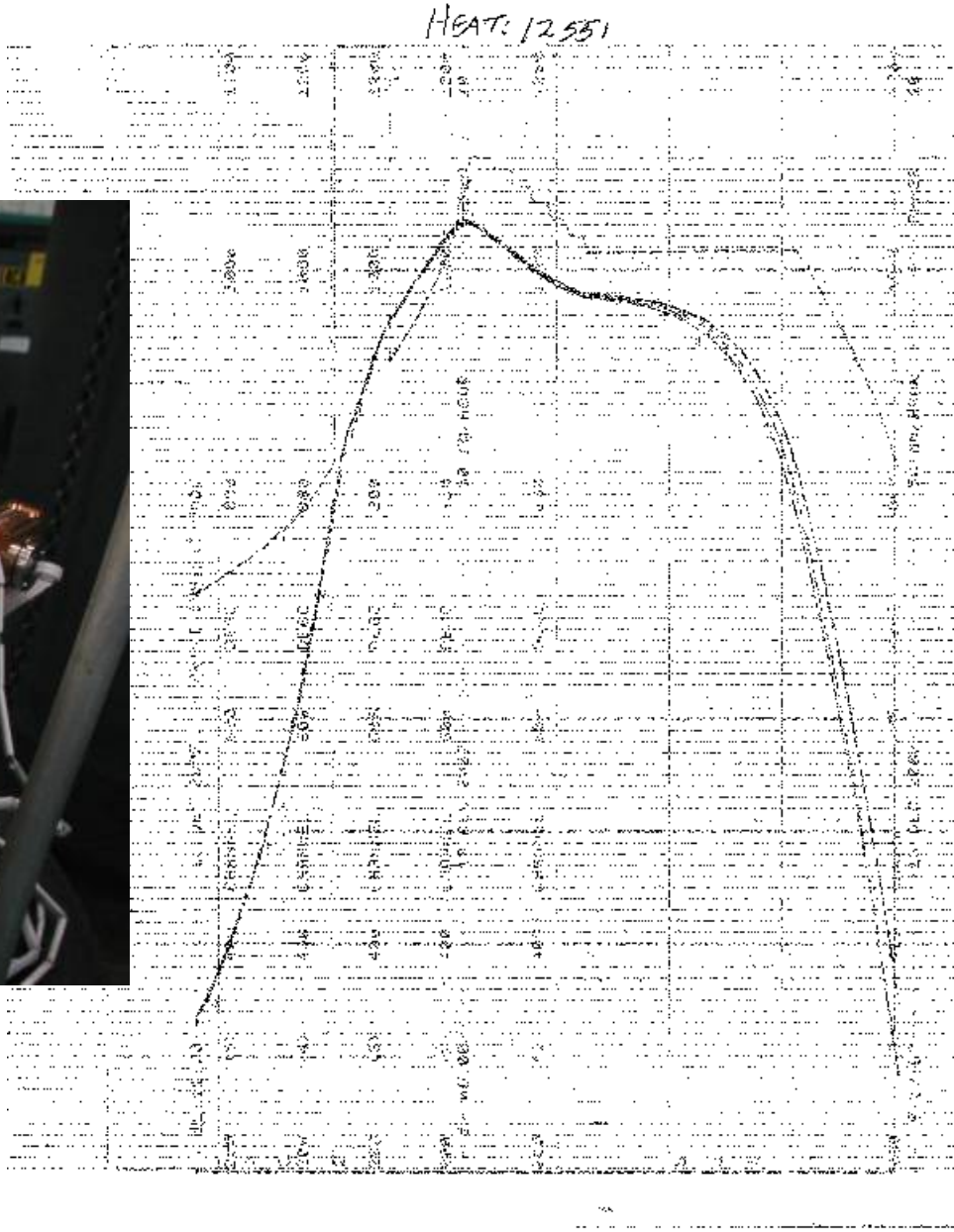


Pressure: 60 PSI (60 LB for this structure disks)

Holding for 1 hour at 1020º C

Brazing of QUAD with Water Flange

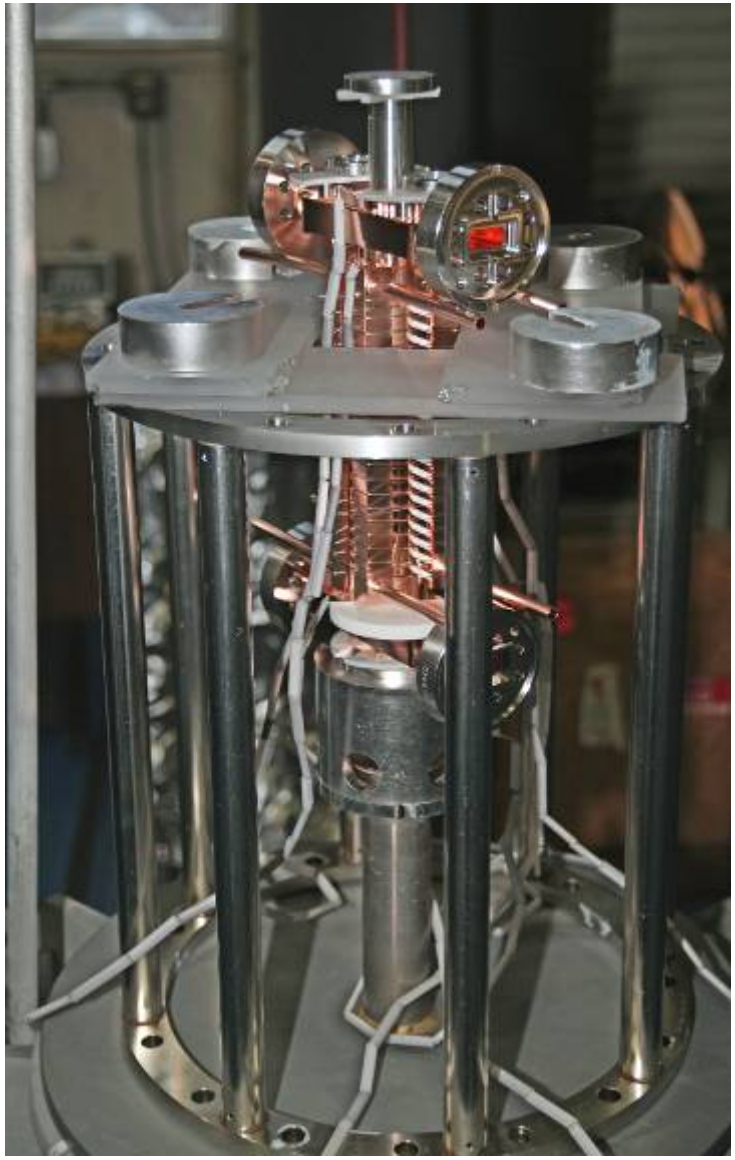




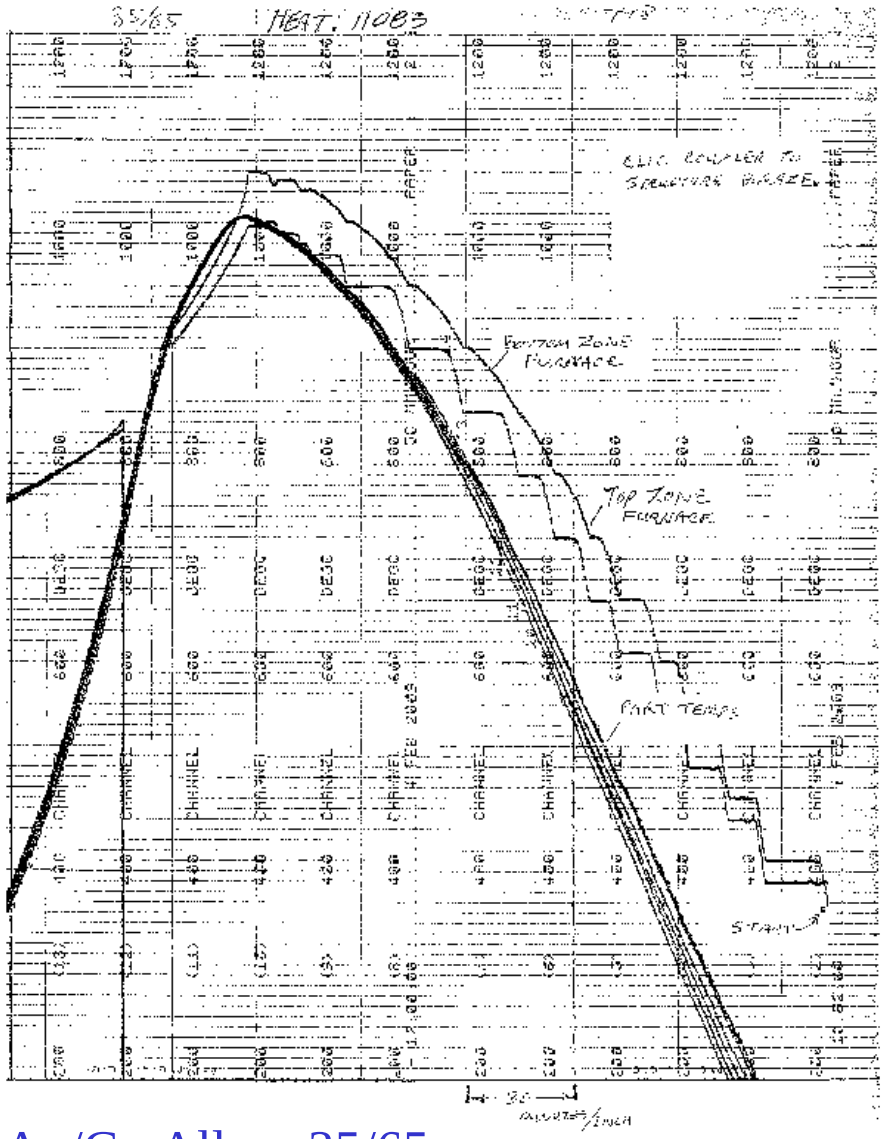
Au/Cu Alloy: 25/75

Brazing temperature: 1041-1045° C

First Assembly Brazing of T18_vg2.4_DISC

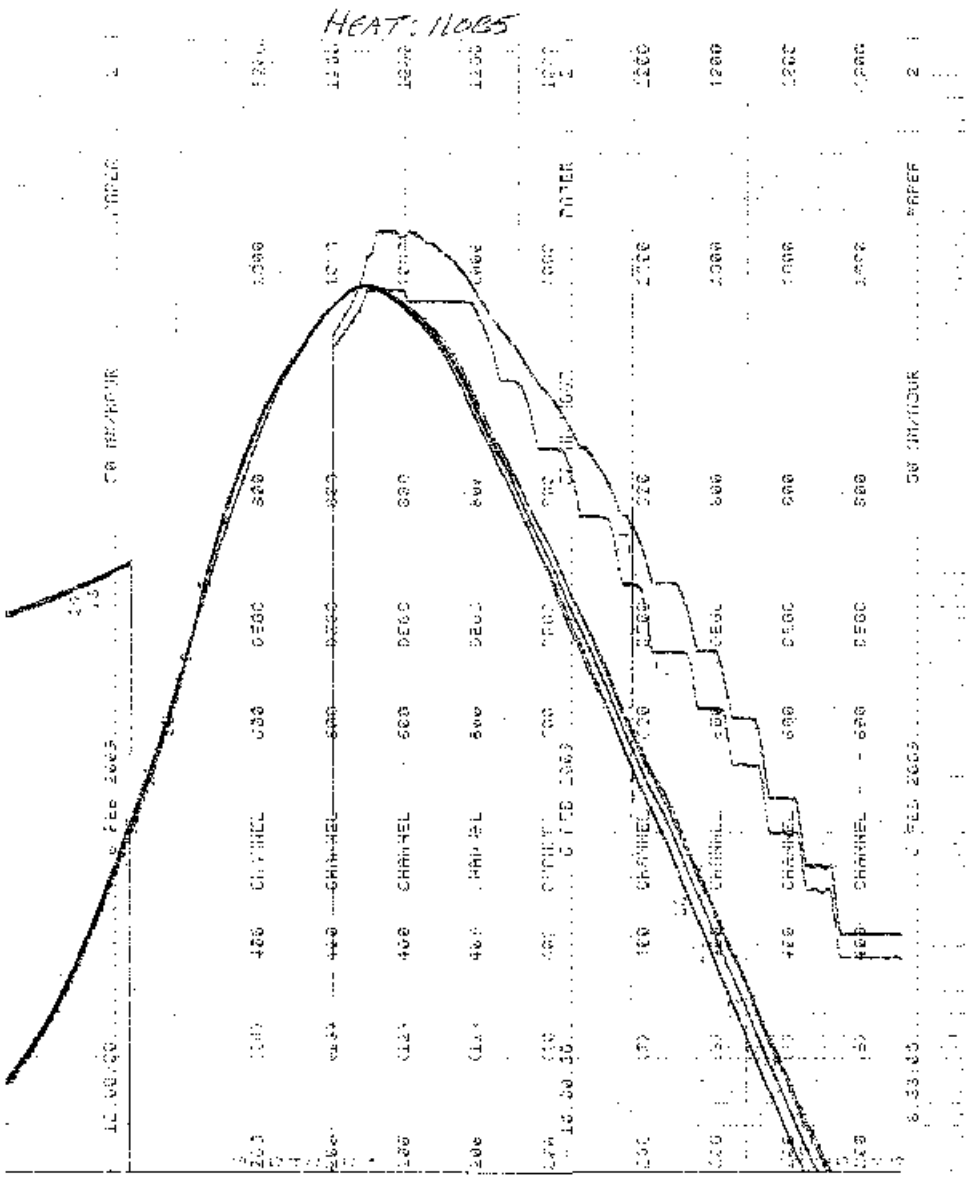


Body / Two Coupler Assemblies / Cooling/One Beam Pipe / Tuning Studs



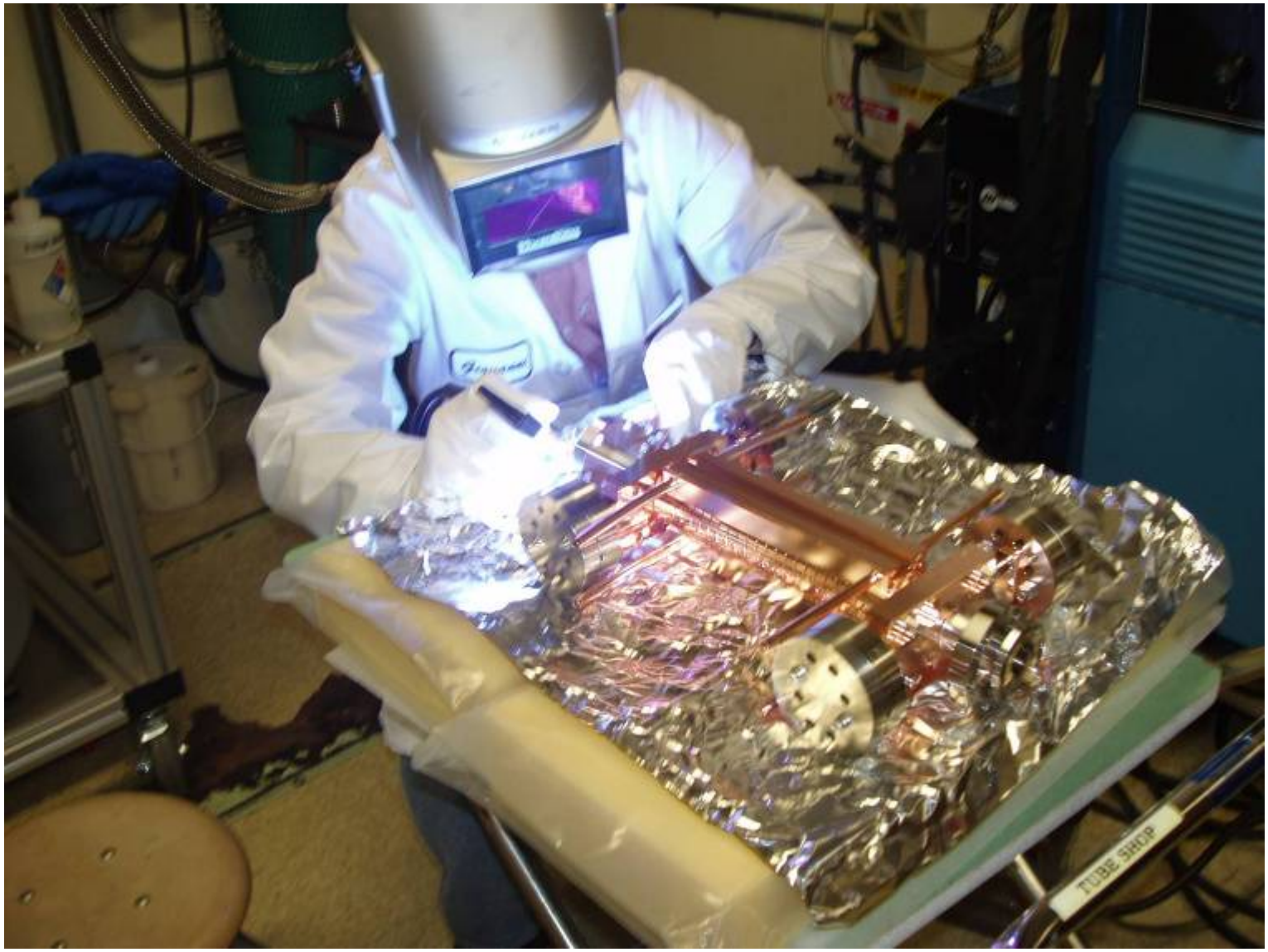
Au/Cu Alloy: 35/65
Brazing temperature: 1021-1025º C

Final Brazing of T18_vg2.4_DISC

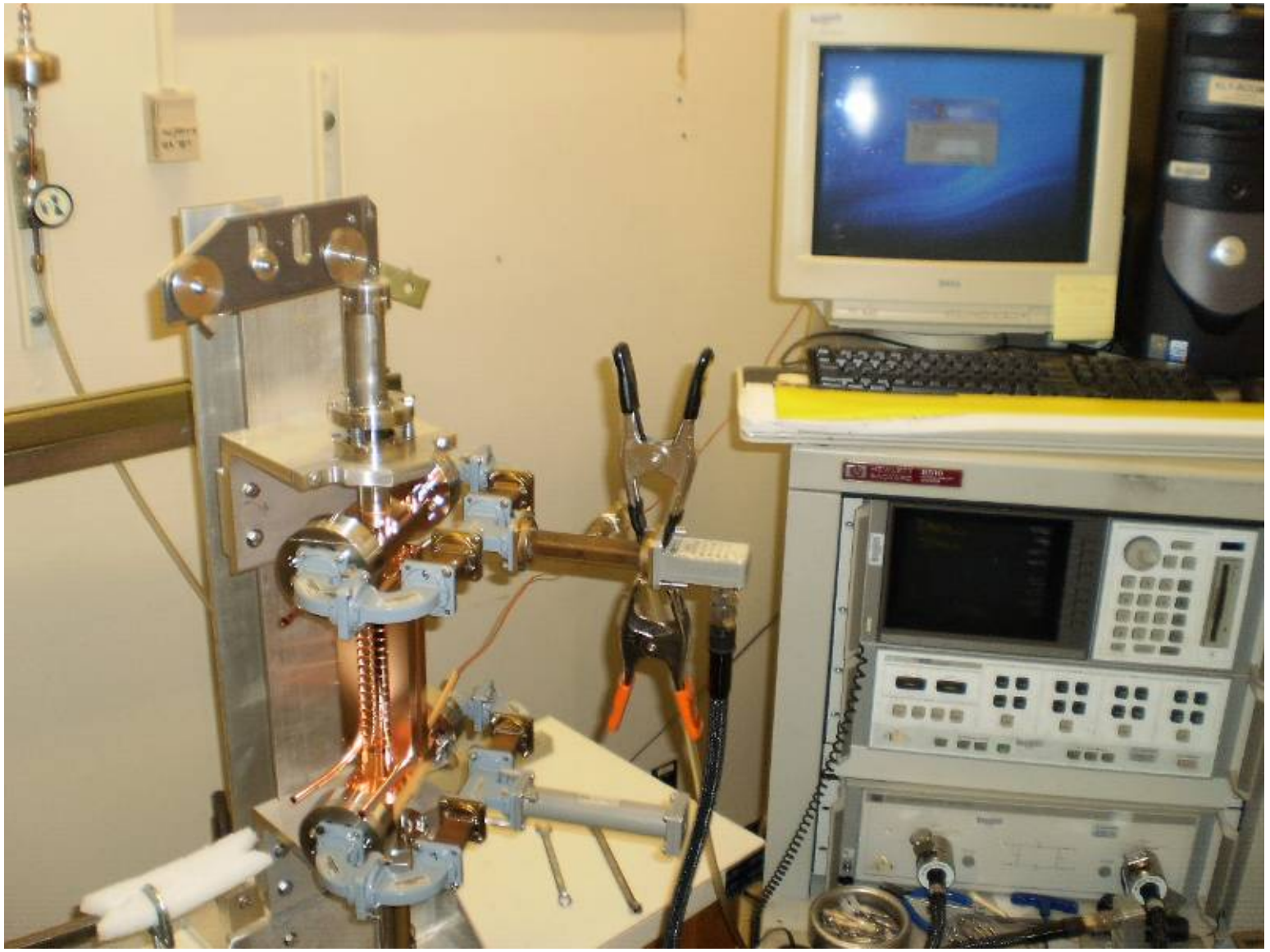


Au/Cu Alloy: 50/50
Brazing temperature: 979-983º C
Adding One Beam Pipe

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

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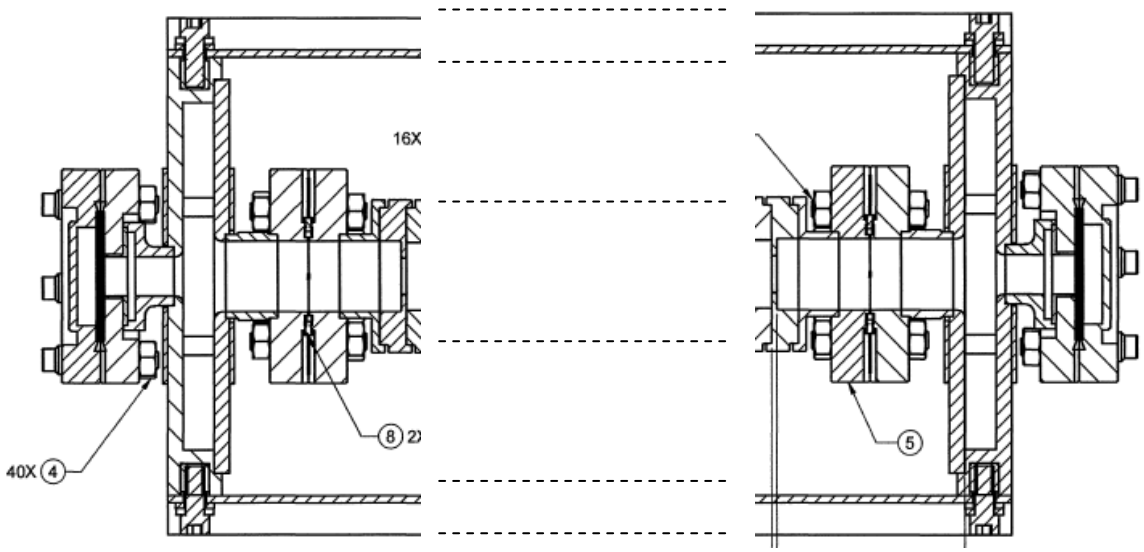
5. Ongoing Work

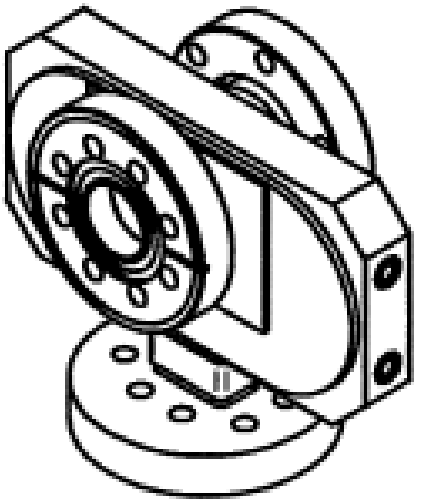
Ongoing Program for Structures

1. C10 Structures: 2 x C10_VG 1.35 #1, #2 and 2 x C10_VG 0.7 #1, #2
   - All four assemblies are completed
   - One VG1.35 in preliminary high power test with problem in RF feed
   - More testing after resolving the problems in circular waveguide junction
2. TD18_VG2.4_DISK #2, #3
   - Microwave tuning both structures completed
   - Vacuum baking underway
   - Shipping #3 with KEK flanges to KEK
   - Assembly of the structure with SLAC flanges in preparation
   - High power test in October
3. Plan to retest TD18_VG2.4_QUAD
   - Chemical cleaning done
   - Planning to have hydrogen firing and Vacuum baking
   - Reassembly and microwave check in March.

Schematic View for C10 Structures - I

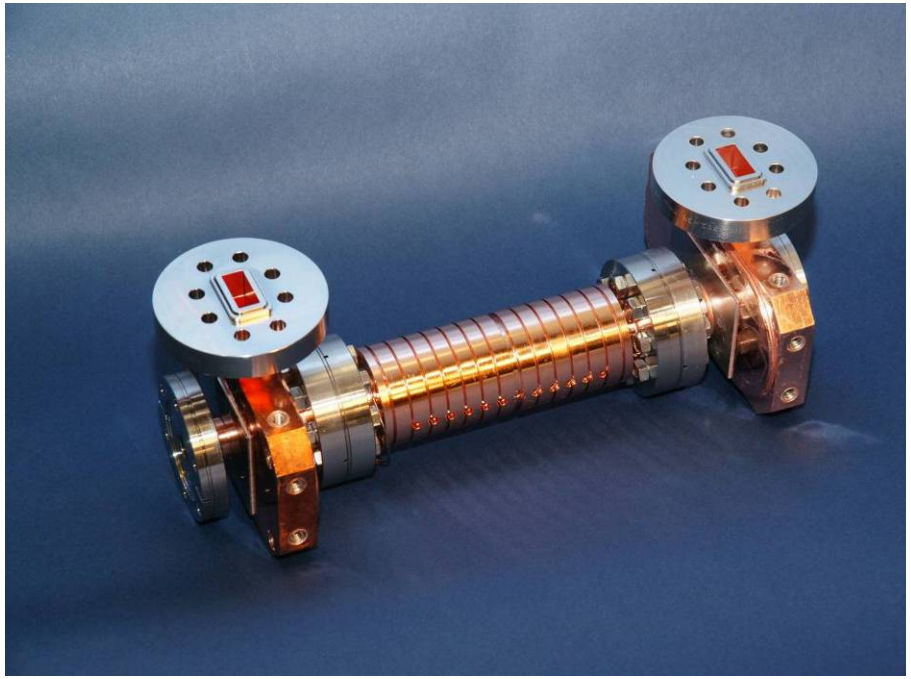


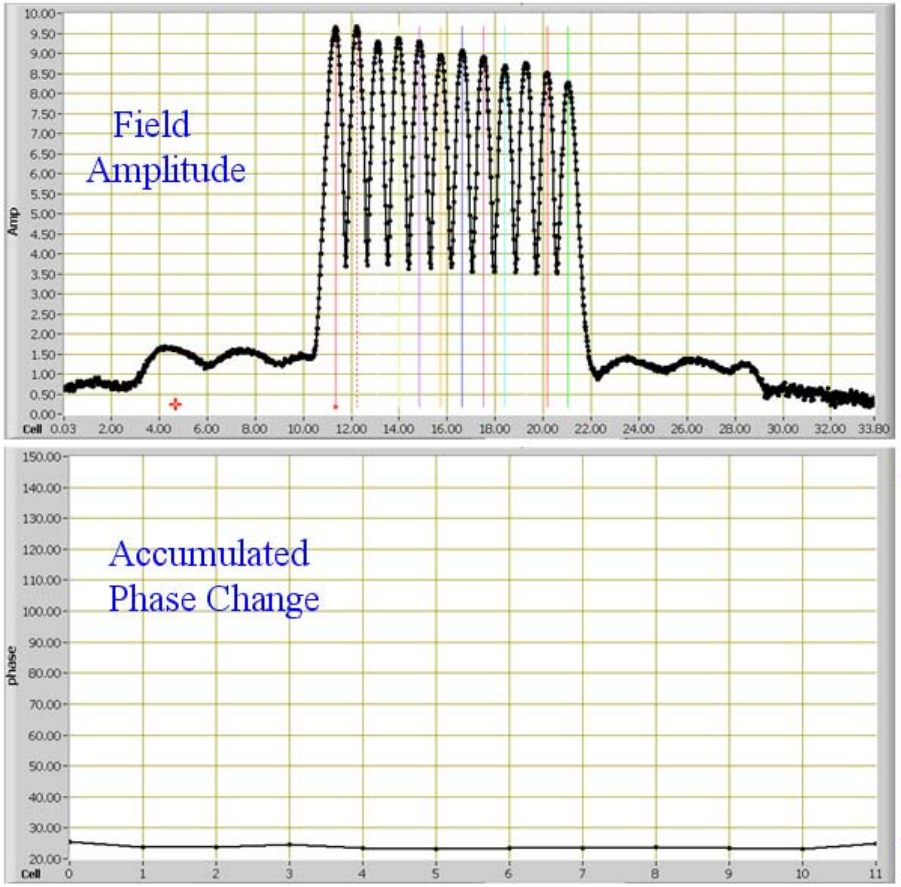
Structure Assembly



TM01 Mode Launcher

First C10_VG1.35 Structure

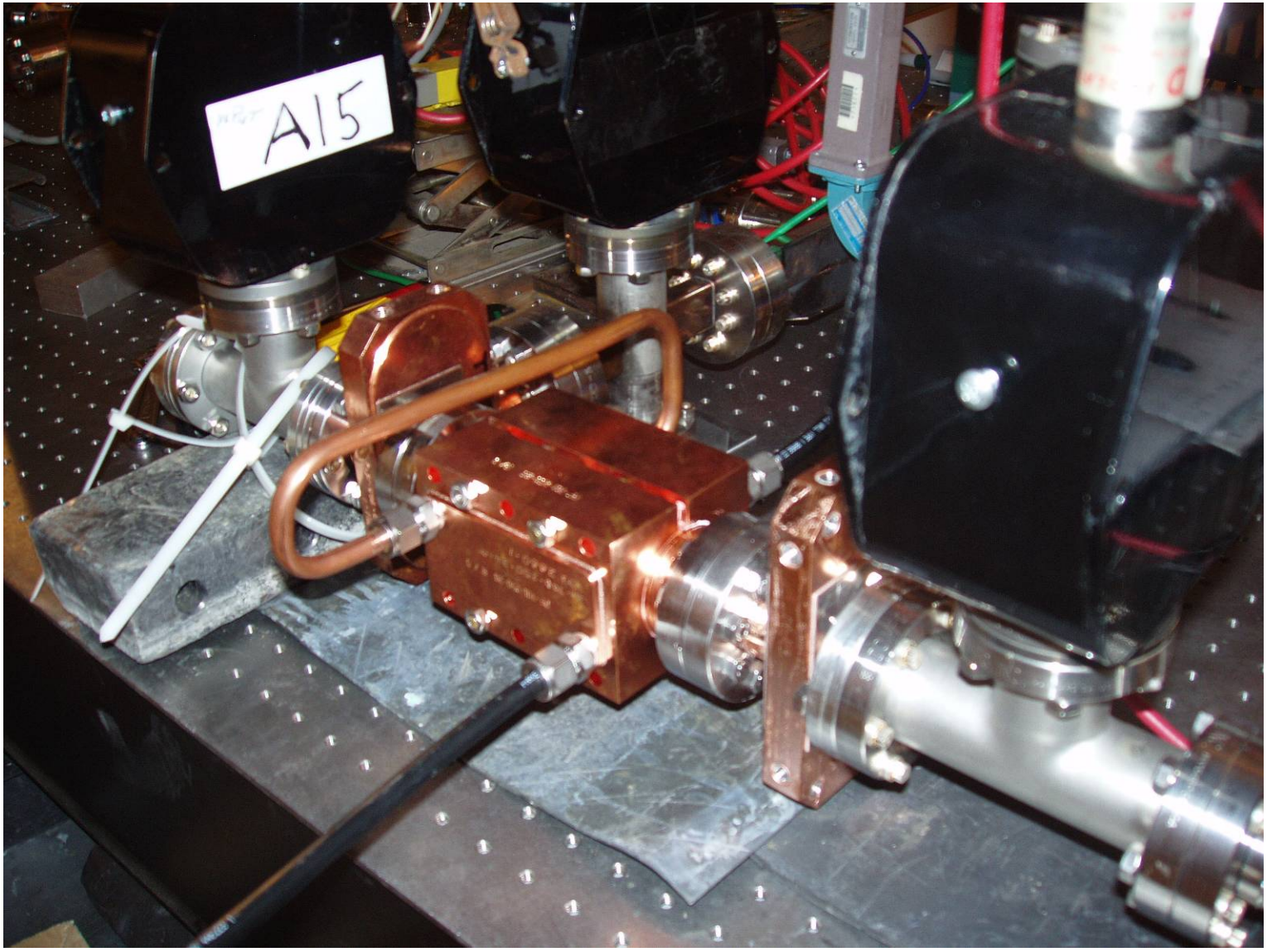




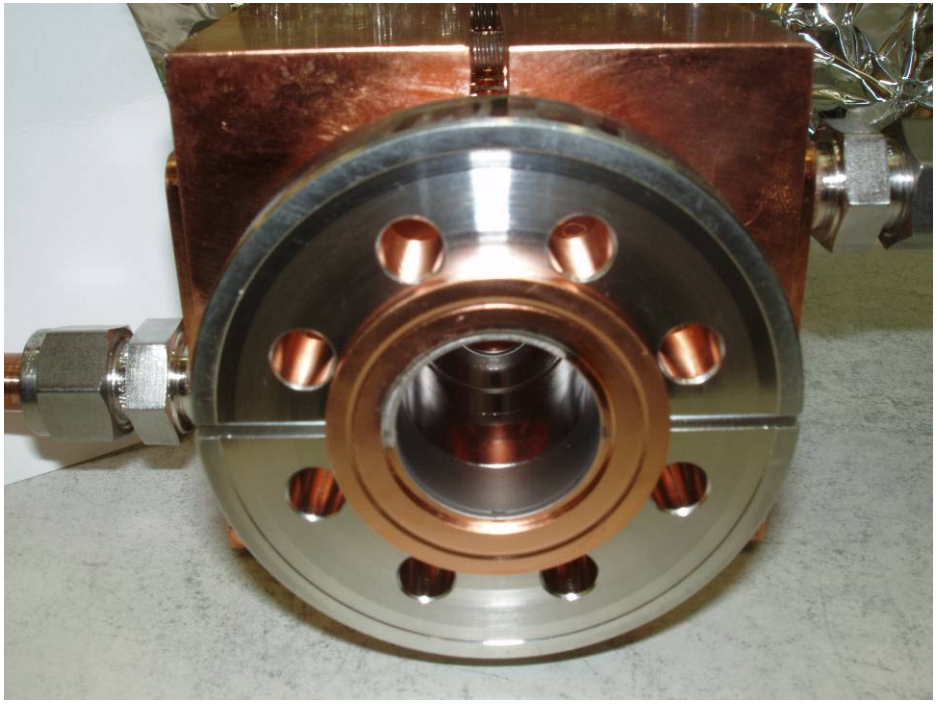
Average Eacc=100 MV/m at Pin=48 MW

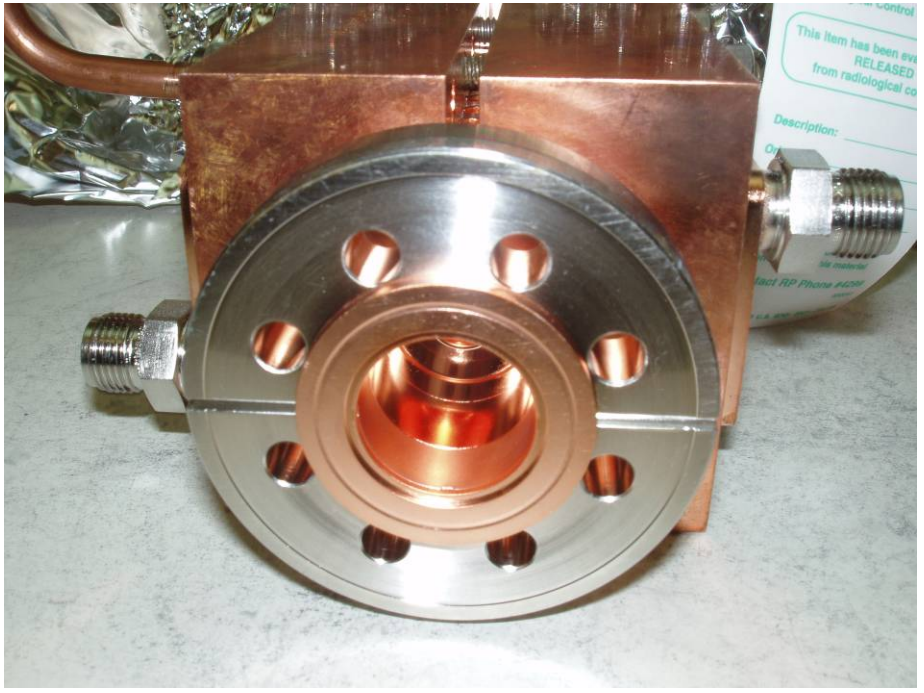
Microwave measurement after tuning

First C10_VG1.35 Structure Under High Power Test



First C10_VG1.35 Structure after High Power Test

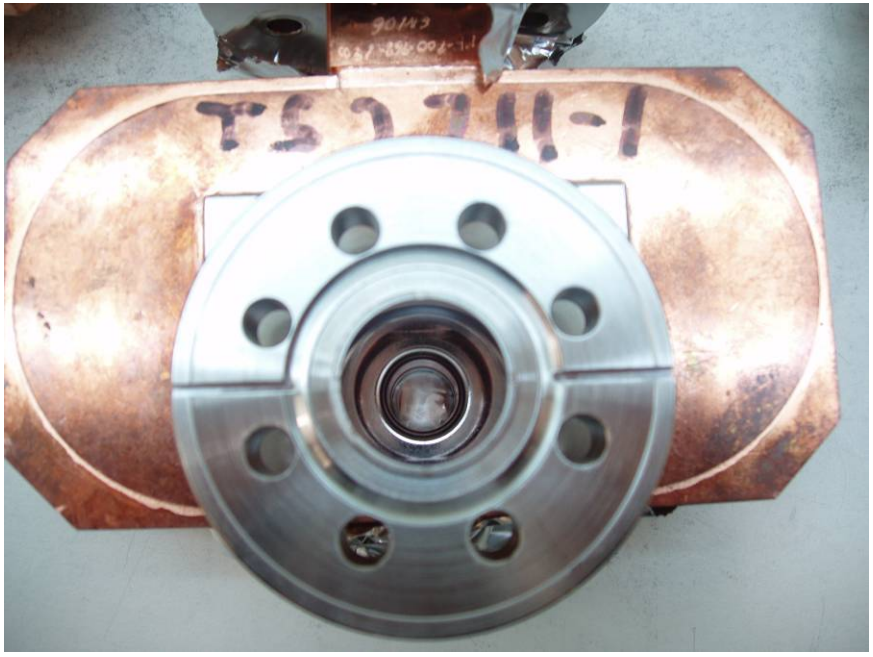




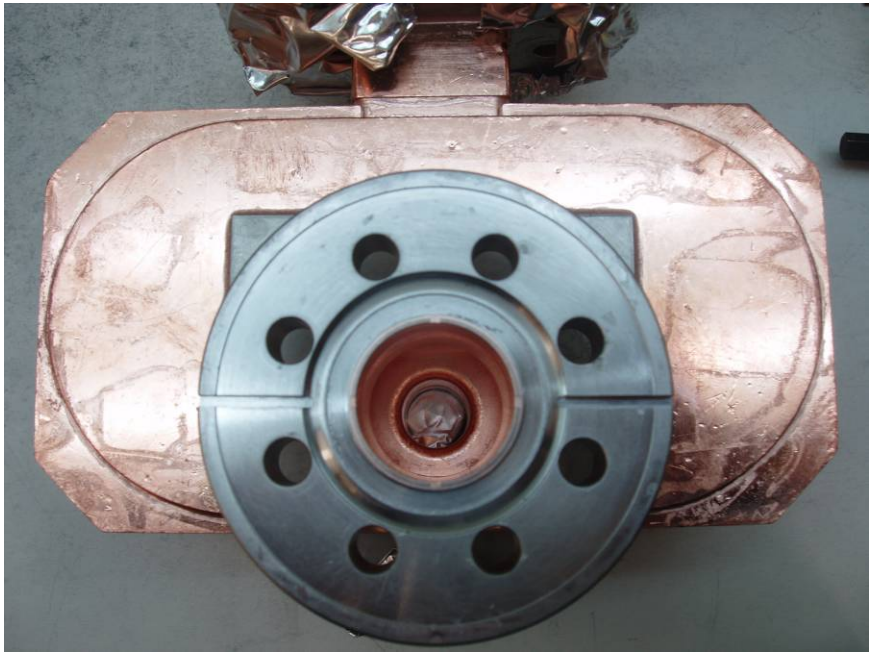
Input Side

Output Side

Mode Launcher for First C10_VG1.35 Structure after High Power Test

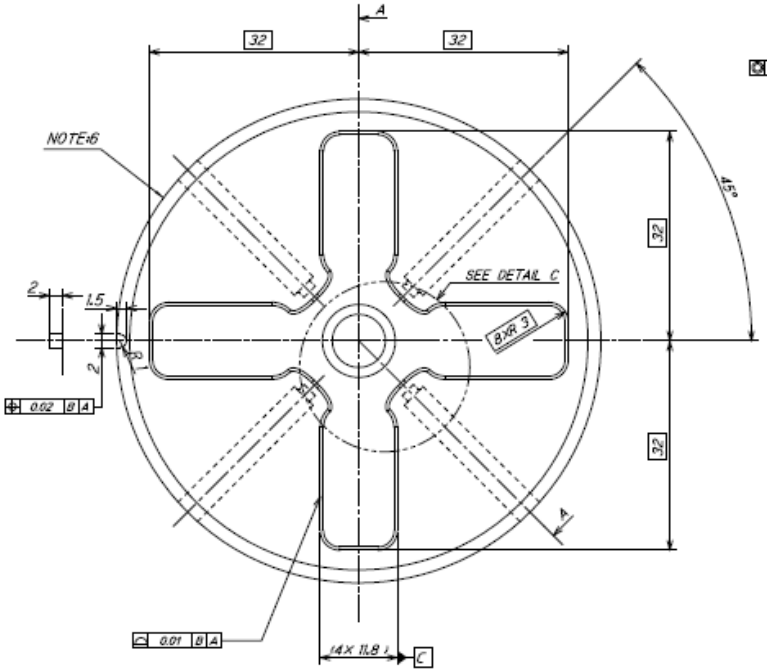


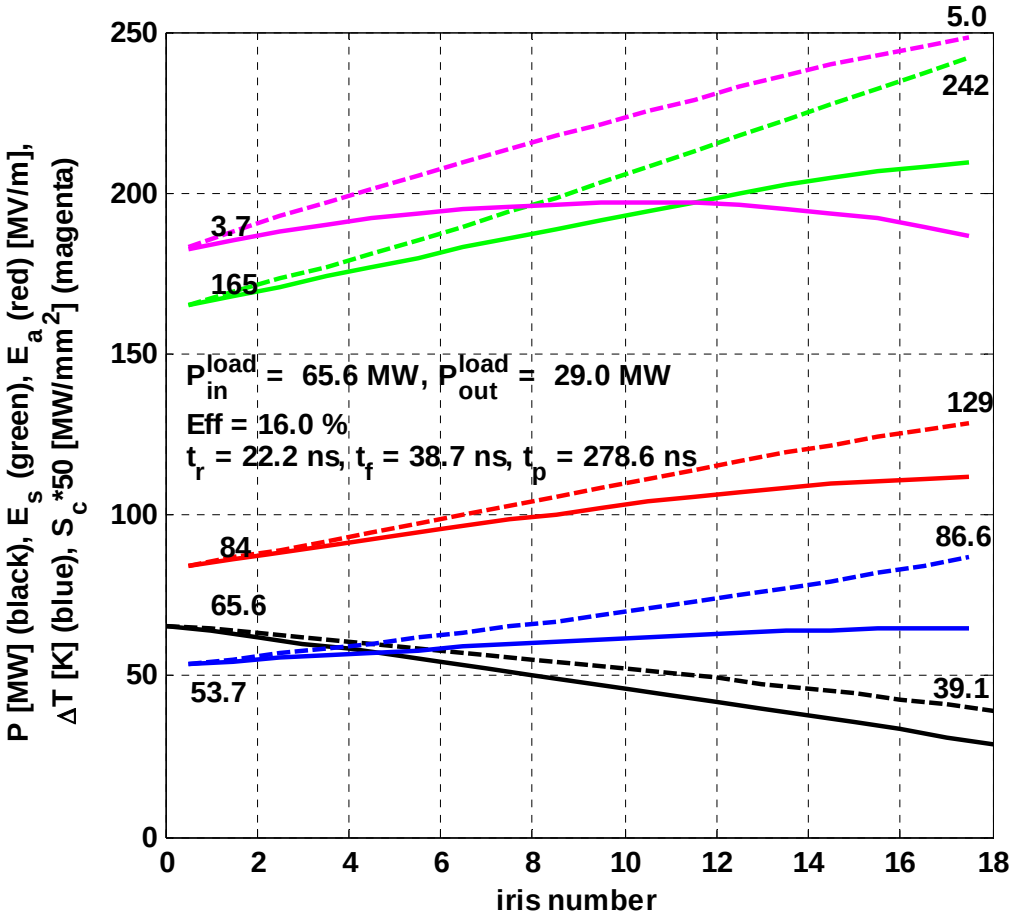
Input Side



Output Side

Characteristics of TD18_VG2.4_DISK Structures





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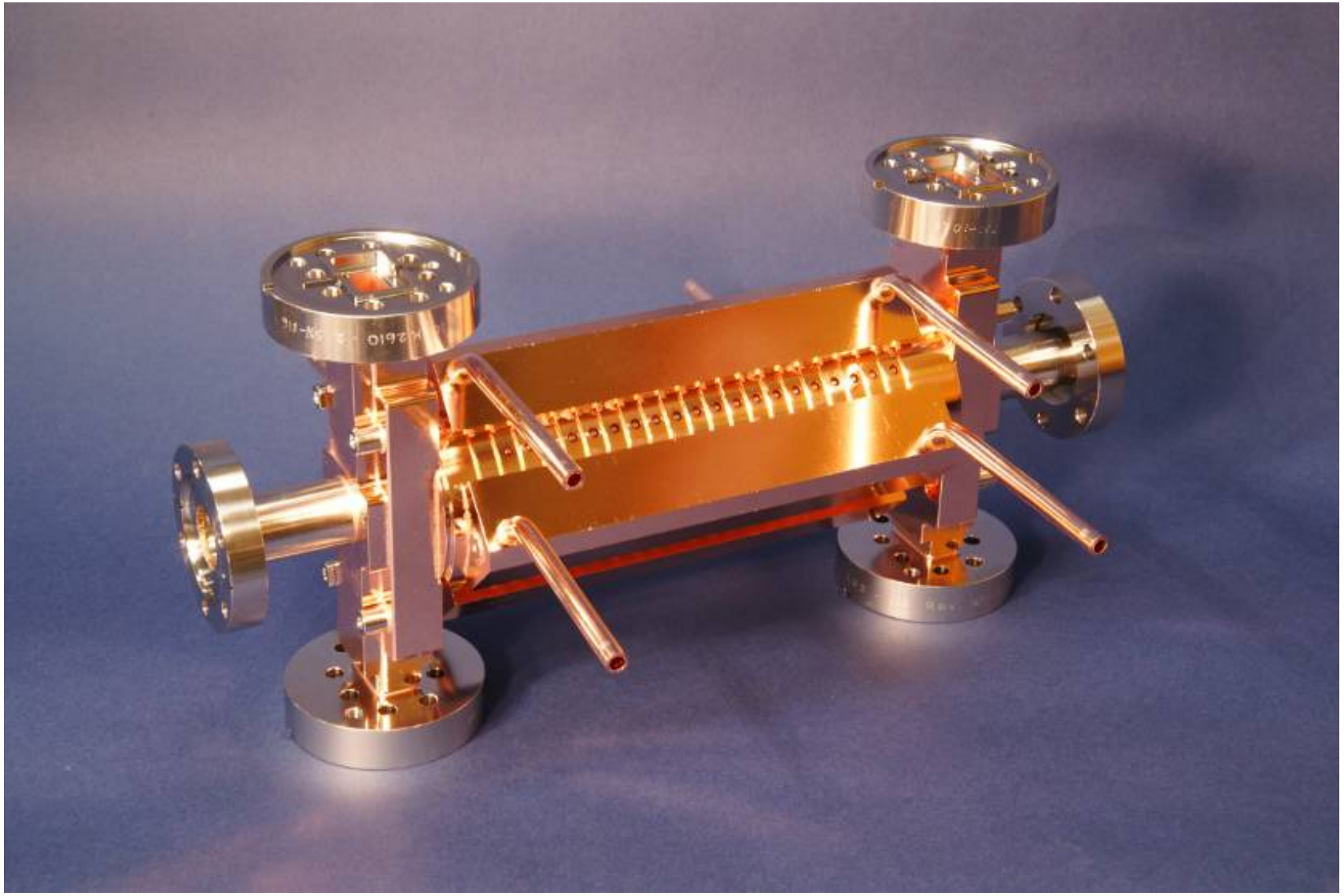
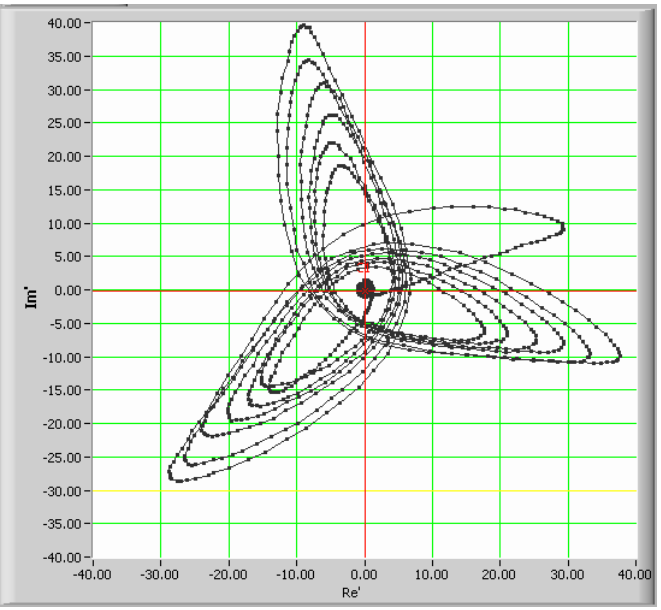
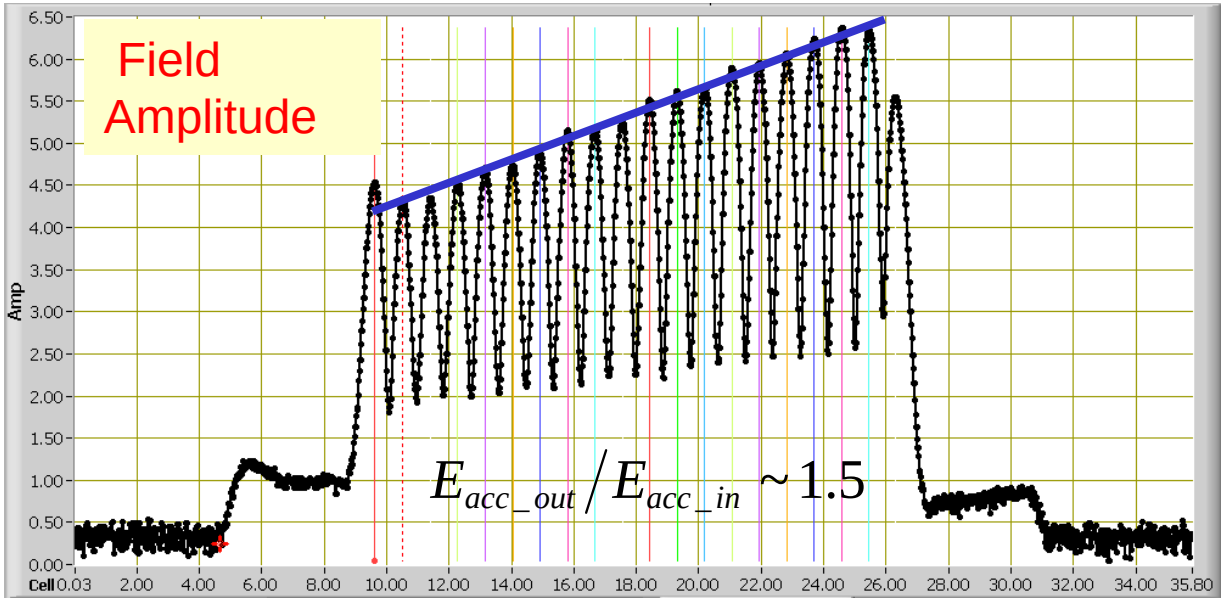
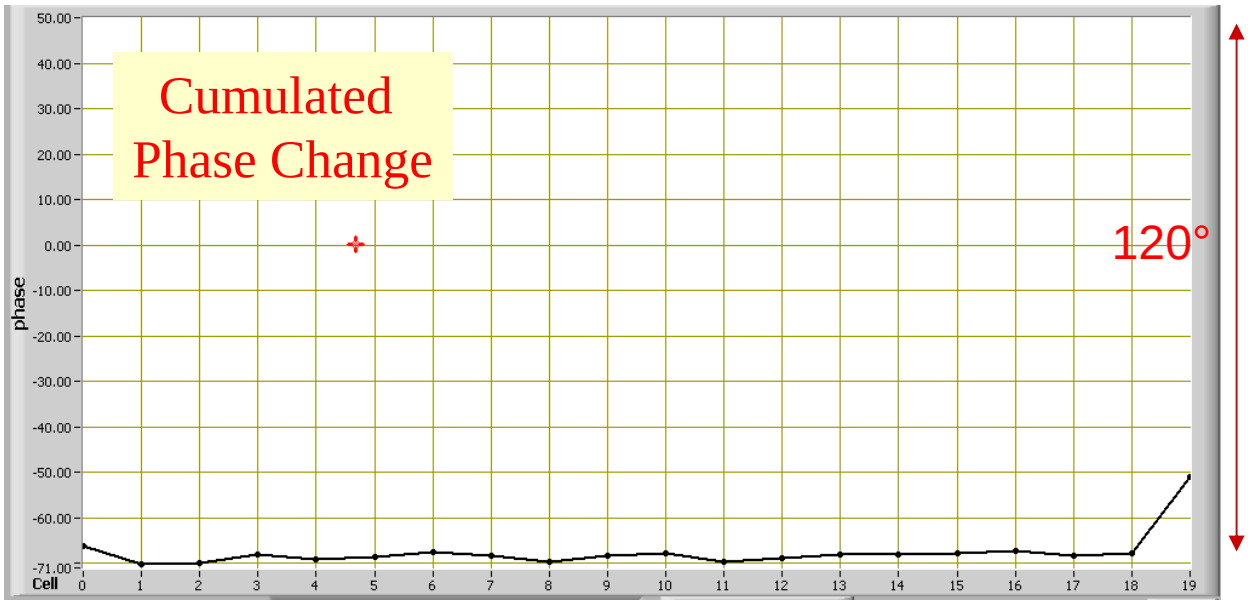
Recent TD18_VG2.4_DISK Structures



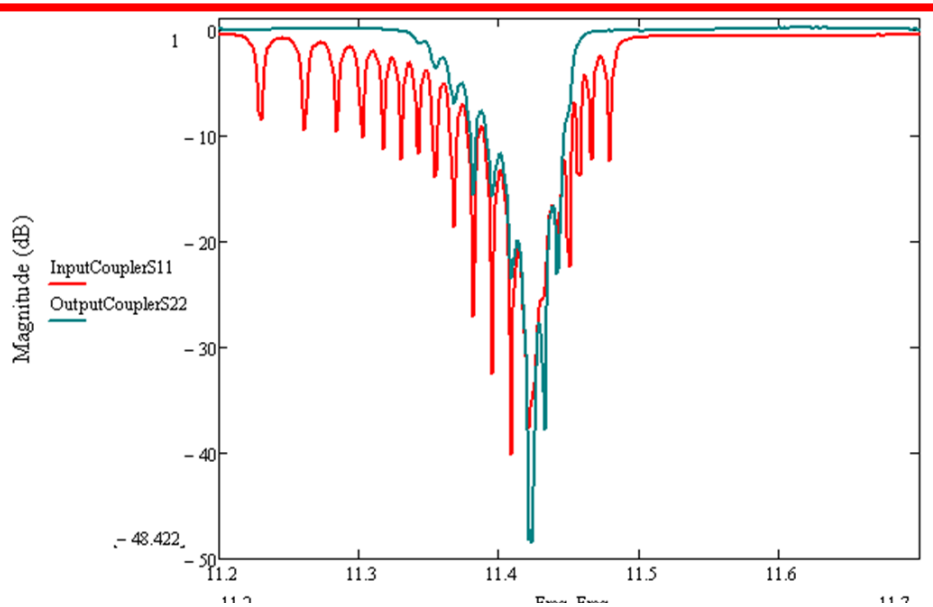
Tuning Results for TD18_VG2.4_DISK





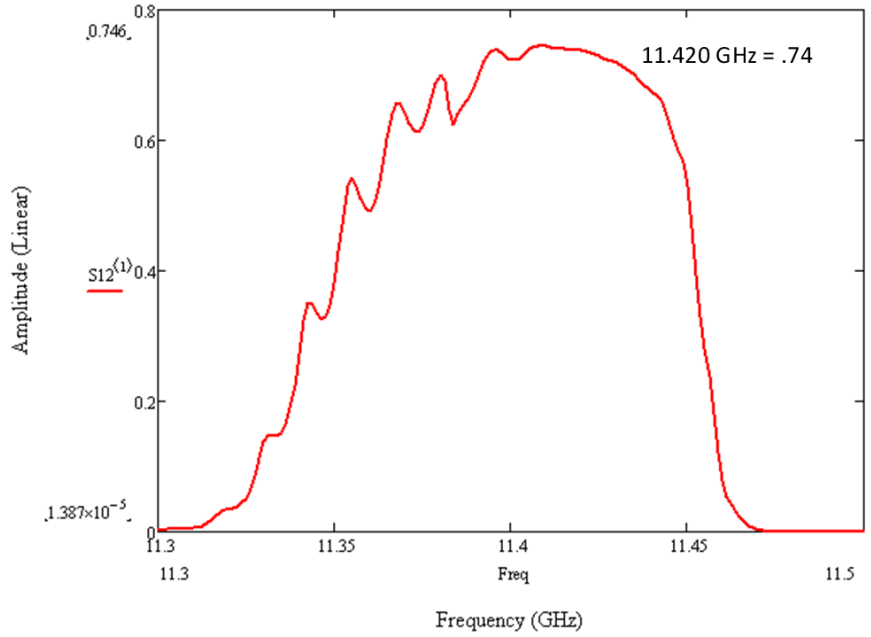


S Parameters of TD18_VG2.4_DISK #3



$S_{11} = 0.015$

$S_{22} = 0.006$



$S_{12} = 0.74$

6. Scope for Future Work

Work in the Near Future

1. TD18_VG2.4_DISK #2, #3
   - After baking, High power testing at SLAC and KEK
2. Three more C10 Structures 1xVG1.35 and 2xVG0.7
   - Microwave tuning and High power testing
3. Four more C10 Structures 2xVG2.25 and 2xVG3.3
   - All parts ordered
   - SLAC Assembly, tuning and High power testing
4. TD18_VG2.4_DISK #1
   - CERN made in a can
   - High Power Testing at SLAC
5. TD24_VG1.8_DISK #1
   - CERN made
   - High power testing at SLAC
6. CD10 2 x VG1.35 #3
   - CERN made
   - High power testing at SLAC
7. CD10 2 x VG1.35#1, #2
   - KEK machining
   - Assembly, Tuning art SLAC and High power testing at SLAC/KEK
8. T-500GeV
   - CERN made and High power testing at SLAC