News from structure production task force – T18_CERN

G. Riddone on behalf of the
task force team

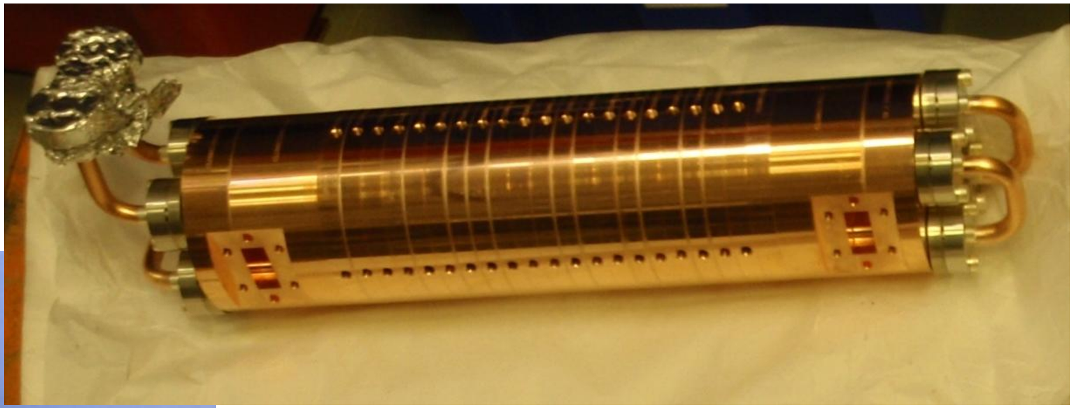
20.03.2009

Content

- Introduction and task force motivation
- T18_CERN: Fabrication history and results from CERN investigations
- Differences from other CERN/SLAC/KEK/Fermilab structures
- Actions for future structures
- Conclusions

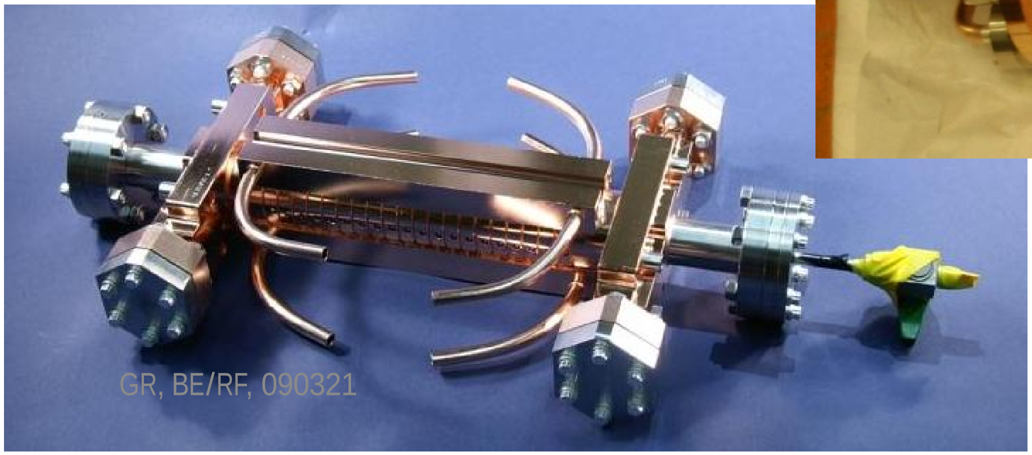
Introduction to T18

- T18 structures: 5 manufactured
  - 4 KEK/SLAC (2 tested: 1 at SLAC and 1 at KEK)
  - 1 CERN (tested at SLAC)
- All T18 have the same RF design
- *It is the first time that the test results of a CERN structure can be compared with those from the same structure made at KEK/SLAC*

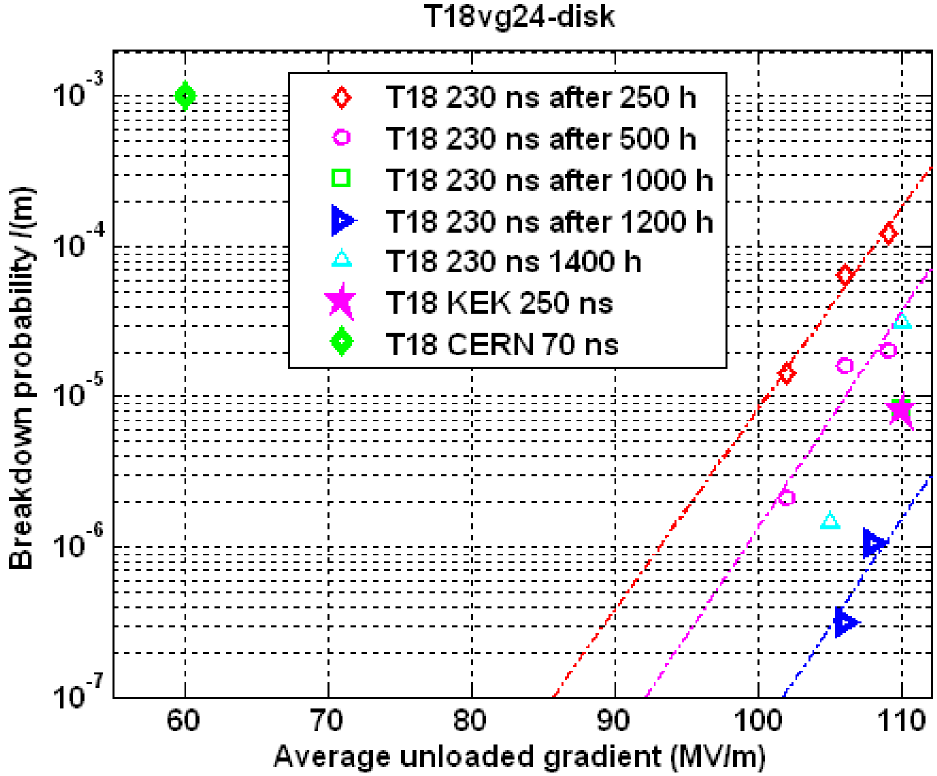


T18_CERN

T18_KEK/SLAC



T18 high power test results



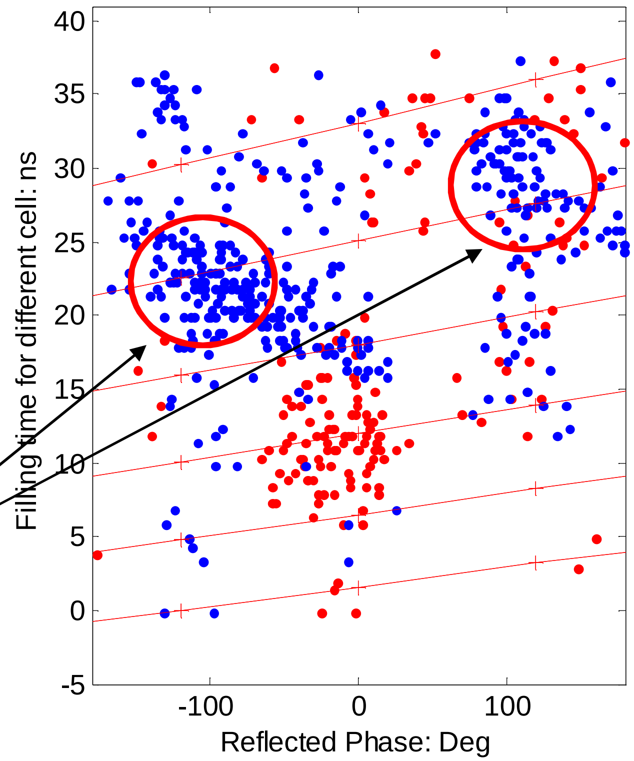
Breakdown distribution of

T18Disk_SLAC (red, last 500hrs),

210~230 ns,110~120 MV/m

T18Disk_CERN (Blue,40hrs).

180 ns,45~49 MV/m



'Hot' cells 13 +15

C. Adolphsen, S. Doebert

Task force program

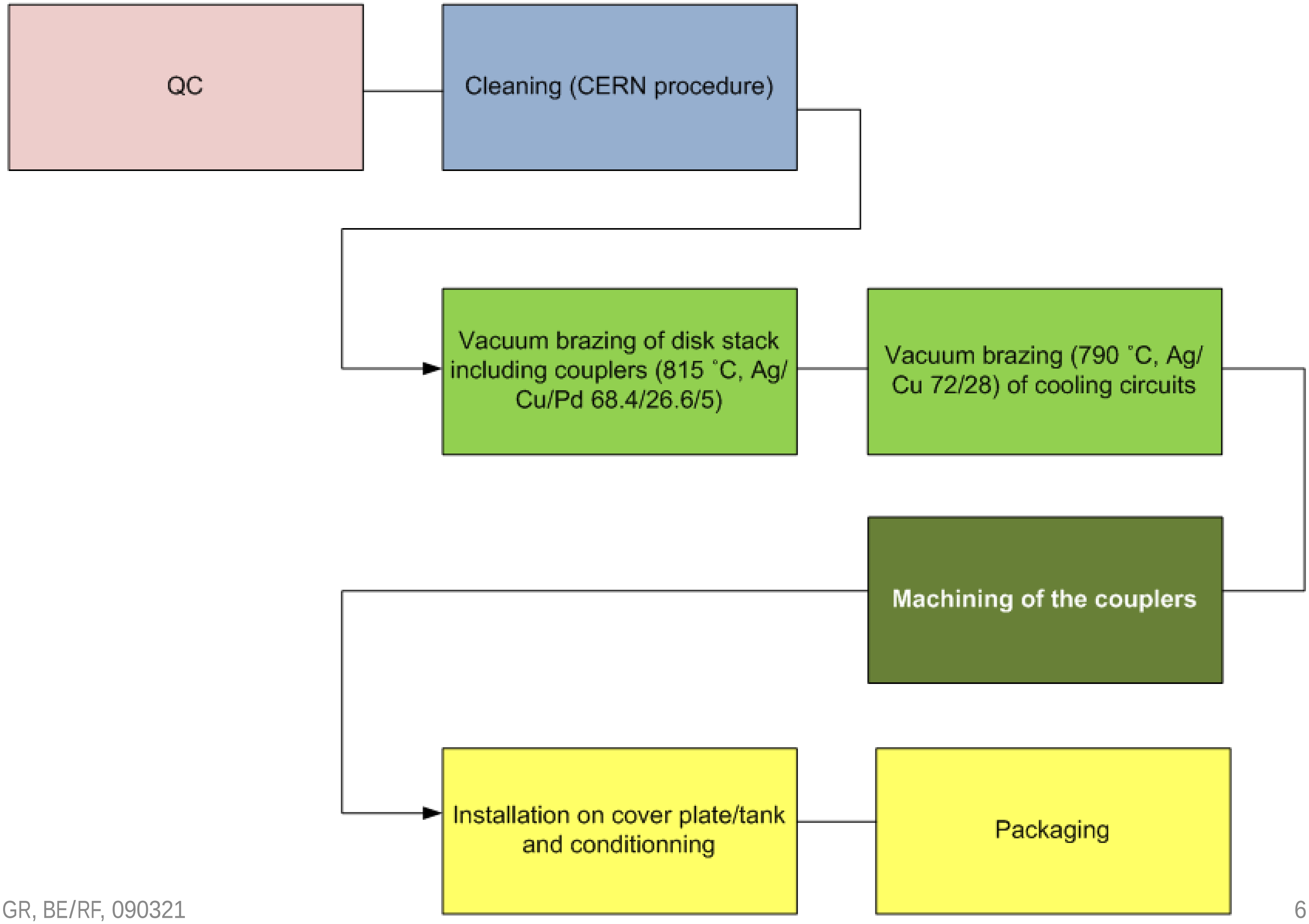
- Following the test results of the T18_CERN a "Task Force" has been set-up to understand the cause (isolated problem or general problem of CERN structures) and to define the actions for the future structures.

- Program
  - Review the fabrication and preparation of the T18_CERN
  - Cut and inspect the T18_CERN
  - Compare the T18 preparation other structures made at CERN, KEK, SLAC and Fermilab and identify the differences
  - Define actions for future structures

- *Participants: C. Adolphsen (SLAC), G. Arnau Izquierdo, S. Atieh, S. Calatroni, S. Doebert, M. Gerbaux, A. Grudiev, T. Higo (KEK), T. Pieloni, G. Riddone, M. Taborelli, R. Zennaro, I. Syratchev, W. Wuensch*

- *Contributions from C. Achard, M. Aicheler, A. Cherif, J. Kovermann, M. Polini, A. Toerklep, ...*

CERN assembly cycle



T18_disk_CERN
Fabrication history

Accelerating structure CLIC vg1 disk undamped G. Riddone, BE/RF, last update: 20090116

Drawings: CLIAAS110111...118

Date	Steps	Specification	Procedure	Report	Remarks	What might have gone wrong	Future actions for this structure	Future actions for future structures
08.04.2008	Shipping of raw material (21.02.2008 order)	790779			Material Cu OFE	different material although Kugler confirmed in written that used CERN material	1. Test on the witness piece	1. Comparison with KEK Cu 2. Build a structure with KEK Cu
15.03.2008	Fabrication - Kugler (new firm)			903943	Prototype for qualification: disk 10		1. SEM inspections on prototype disk 10	
May-June 2008					First full structure During fabrication, use of "isopropanol + air" or "ethanol + air" as cutting fluid		1. SEM inspection after cutting (particular attention in remachined zones check for steps on the iris)	
14.07.2008	Reception at CERN			982939	1/ Several scratches and rabbles on the couplers 2/ Deep non-acceptable scratches on CLIAAS11007/ disks 5 & 10			
16.07.2008	Dimensional control	913748		937998	iris dimensions not correct, D (2A) error ~ -30 um			
	Repair				Remachining at Kugler			
18.08.2008	Reception at CERN				New disks #5 and 10 + repaired discs			
20.08.2008	Dimensional control			937998	D (2A) error + 0 /- 7 um			
22.08.2008	Assembly tests				- coupler external diameter not correct- smaller by 200 um (error during rough machining) - decision to put spacers on brazing assembly to compensate for the error			
23.08.2008	Cleaning		823258		- no etching step - cleaning is only by solvents - the cleaning is repeated twice for each part	Not appropriate cleaning procedure (previous cleaning procedure included etching)		1. Use different (previous) cleaning procedure (see EDMS# 983346)
		863211			T=820 C, wire SCP1 (AgCuPa)			
				965148	Qualification of brazing			
29.08.2008	Brazing disks			982945	Brazing of the full structures After brazing: the error in diameter of the coupler not fully compensated by the spacers	Bad quality of the oven Not correct brazing cycle Gaps between cells		1. Test cycle to check the quality of the oven before brazing (Bodycote confirmed possibility to do a cycle up to 1200 C for cleaning the oven (outgassing) 2. Addition step of vacuum firing of the cells before brazing (see FNAL procedure) [tbc]
02.09.2008	Brazing#1 cooling plugs				Brazing of the 8 cooling plugs, T=780 C			
13.09.2008	Leak test				3/8 cooling plugs were leaky			
24.09.2008	Machining of couplers		982950			Particles falling inside the structure		1. study coupler configuration not needing remachining
25.09.2008	RF check		826376	982966	bead pulling indications of mismatching of the output matching cell			
08.10.2008	Brazing#2 cooling plugs				T= 795 C			
28.10.2008	RF check		826376	982966	confirmation of previous results			
19.11.2008	Leak test			979326				
20.11.2008	Shipping to SLAC		874513		- Structure wrapped in "papier de soie" + Al foil + bubble protection - tilt and shock indicators turned to red (50 G) - when unpacked, no visible damage	Microparticles inside the structures during transport	1. Procedure for shipping from SLAC	1. New procedure (whenever possible transport under vacuum or overpressure of N2)
05.12.2008	Replacement in tank		981475		Done at SLAC			

Fabrication NC (ID, OD) ➔ remachining needed

3 brazing cycles (1 additional)

Mismatch output matching cell

No special packaging

T18_CERN followed the nominal CERN assembly cycle

CERN investigations

- Cutting of the structure (S. Atieh)
- Material analysis (A. Toerklep)
- SEM inspections (A. Toerklep, G. Arnau): focus on brazing joints and presence of craters

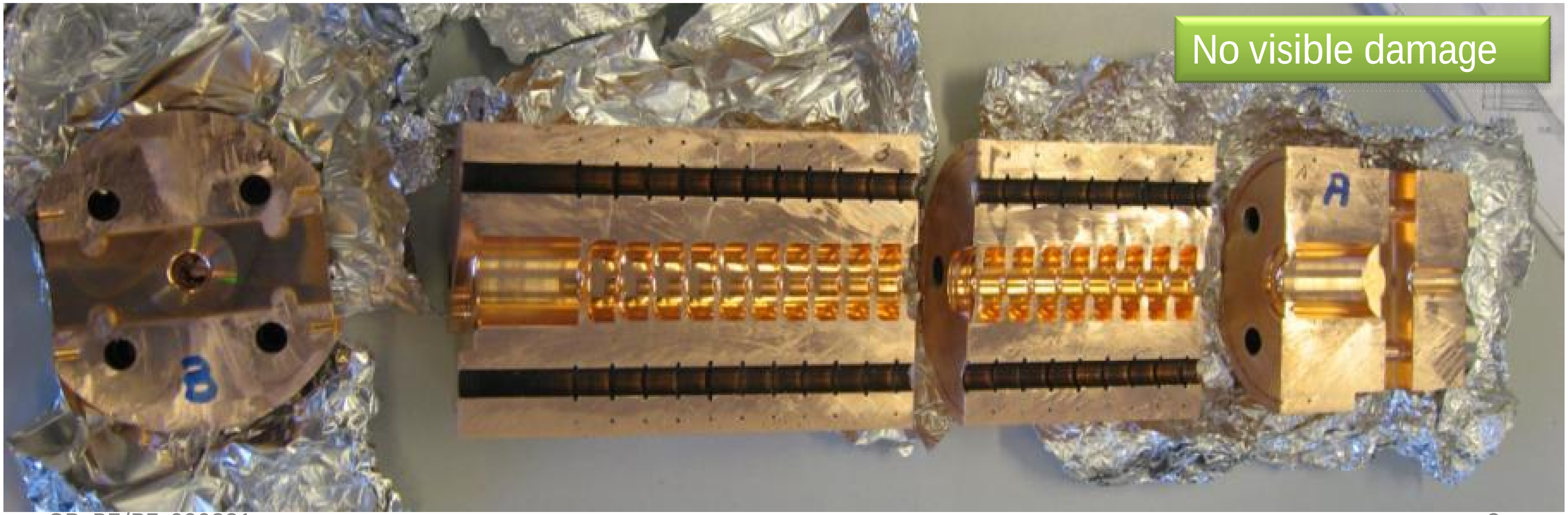


Photo S. Atieh

Analysis of raw material supplied to Kugler

- See report EDMS 988683.
  A. Toerklep

Material property and impurity content within the specification

- Grain size

Technical specification:	Testing Results:
-*In accordance with the standard ASTM E112-96(2004)e1*	- *Standard Test Methods for Determining Average Grain Size E112*
Grain size ≤ 90	Average diameter = 89.8μm

- Hardness

Technical specification:

R_p 0.2%	

Testing Results:

-*With Brinell hardness test.* Hardness $HBS_{2.5/62.5/15}$

Temper state estimated from 106 is between H04 and H08

- H04: (tensile=345MPa, yield=310MPa, Elongation at break A5=6%)
- H08: (tensile=380MPa, yield=345MPa, Elongation at break A5=4%)

- Electro conductivity

Technical specification:	Testing Results:
-Conductivity (as per ASTM B193) in annealed condition states:	-Testing with a conductivity meter (Foerster Instruments, SIGMATEST 2.069, Uncertainty +/- 1%)
minimum of 101 % IACS	100.6 % IACS

- Composition

Technical specification:

The reference publications are standards ASTM F68-93 and B170-93. Cu min: 99.99%

The impurities shall be in accordance with ASTM F170-93 except:

O2 traces: Maximum 5 ppm

Impurities:

Element	Grade 1
Copper min.	99.99
Cadmium max.	0.0001
Phosphorus max.	0.003
Sulphur max.	0.0018
Zinc max.	0.0001
Mercury max.	0.0001
Lead max.	0.001
Selenium max.	0.001
Tellurium max.	0.001
Bismuth max.	0.001

- Arsenic, Antimony, Bismuth, Selenium, Tellurium Tin and Manganese is in total not to exceed 40 ppm

Testing Results:

From external lab: Metalor Technologies SA

O2 traces: All measurements: ≤ 2 ppm

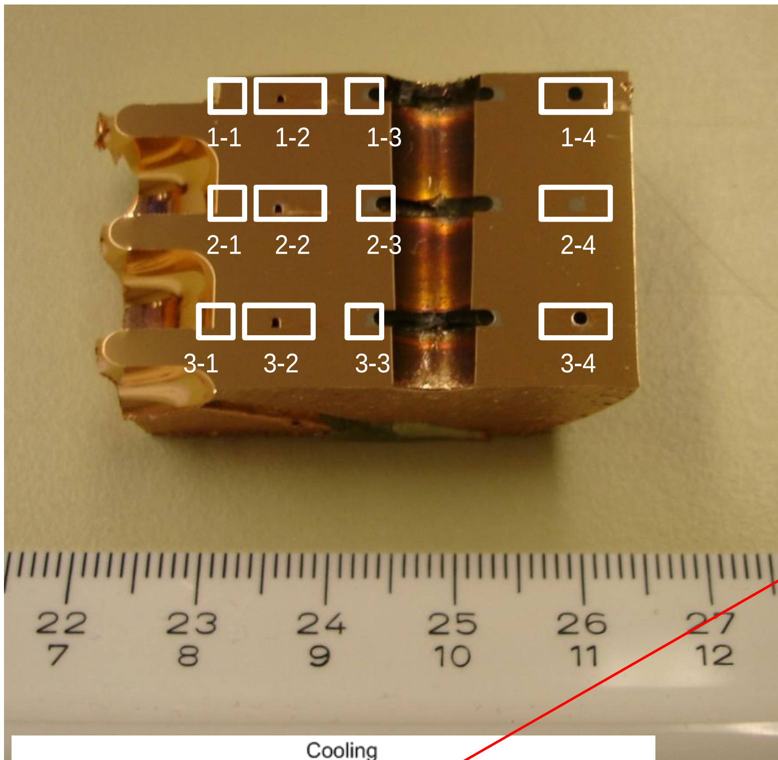
The following metallic impurities were found (in ppm):

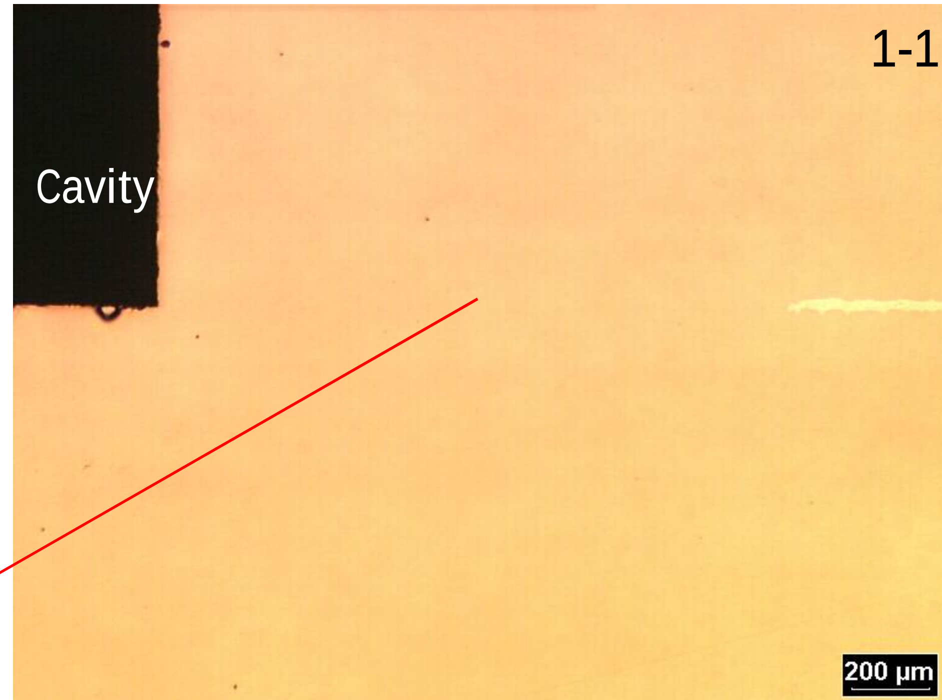
Ag: 5
Mg: 2
Ca: 1
Ni: 1
Fe: 2
Se:1

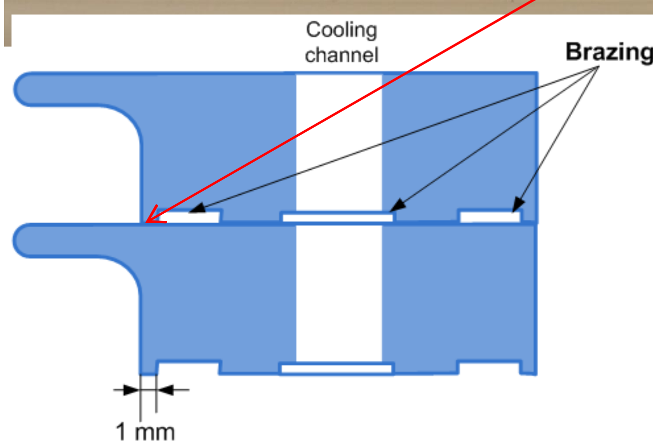
All other metal components are analyzed below the detection Limit (1 ppm)

Total of metallic impurities: 12 ppm

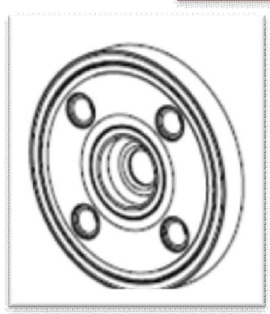
Inspection of brazing joints





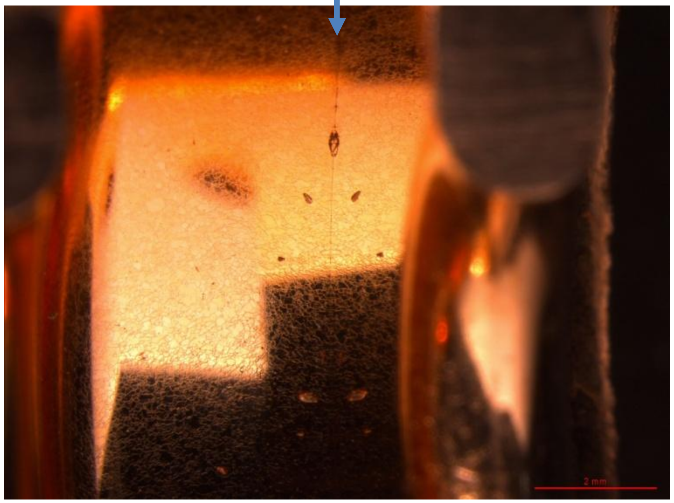


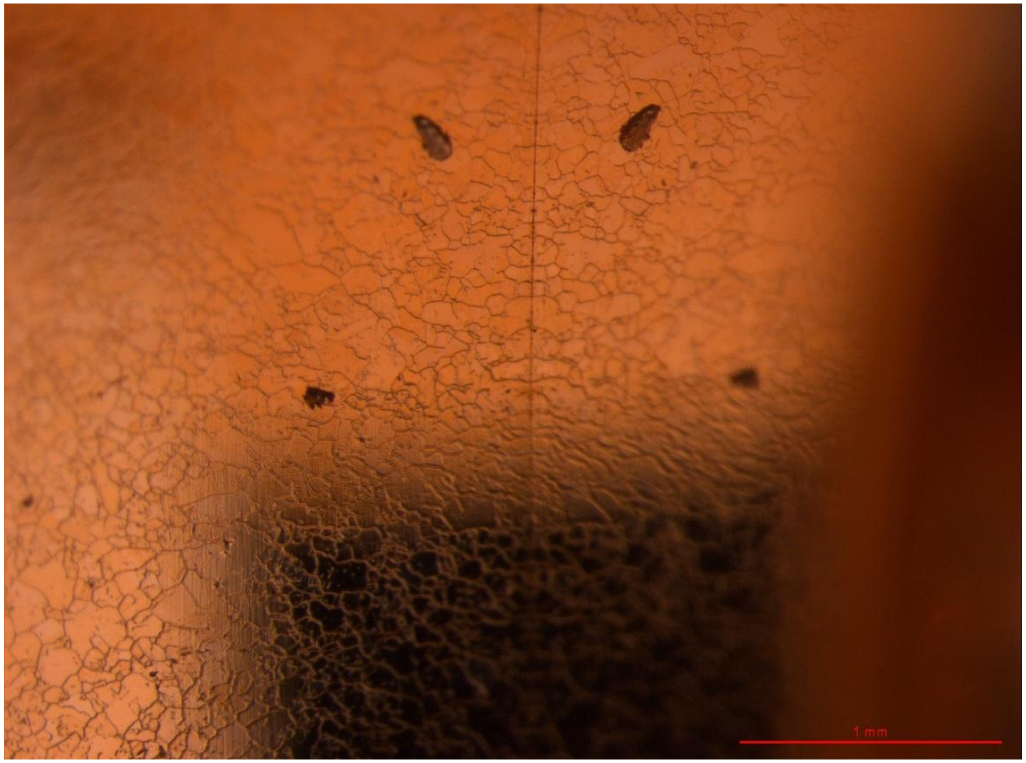
Good bonding without gaps



Inspection of brazing joints

Joint

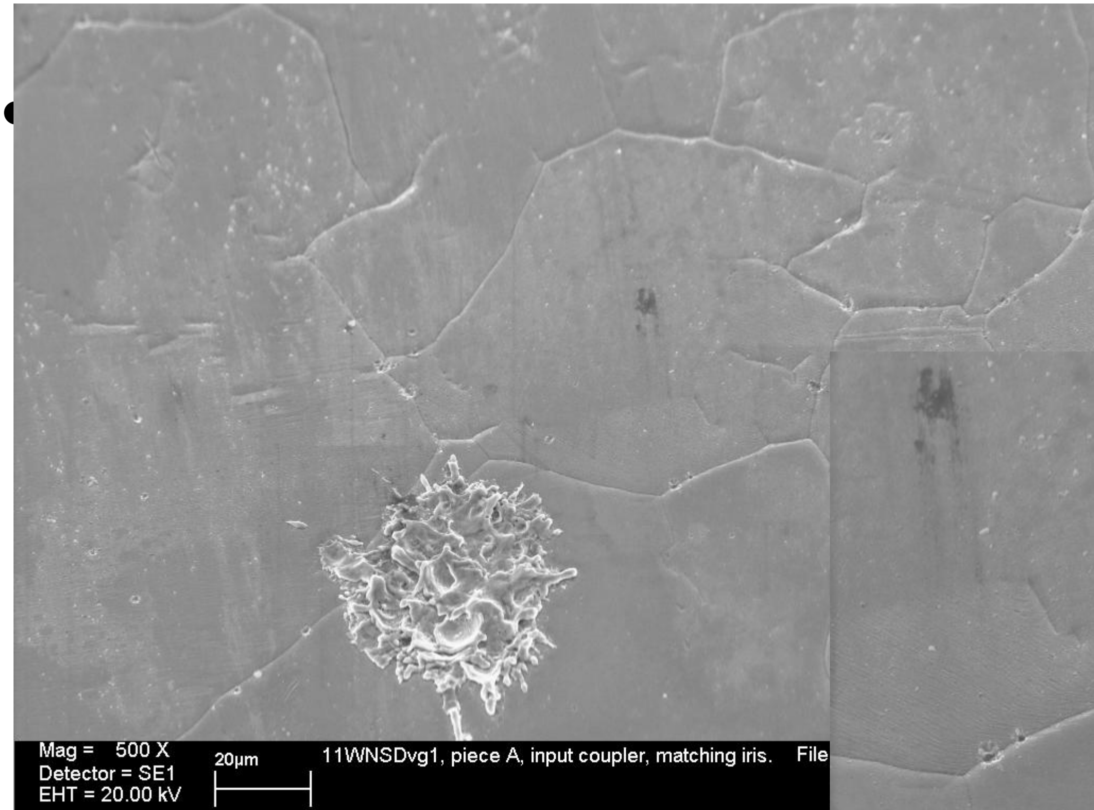


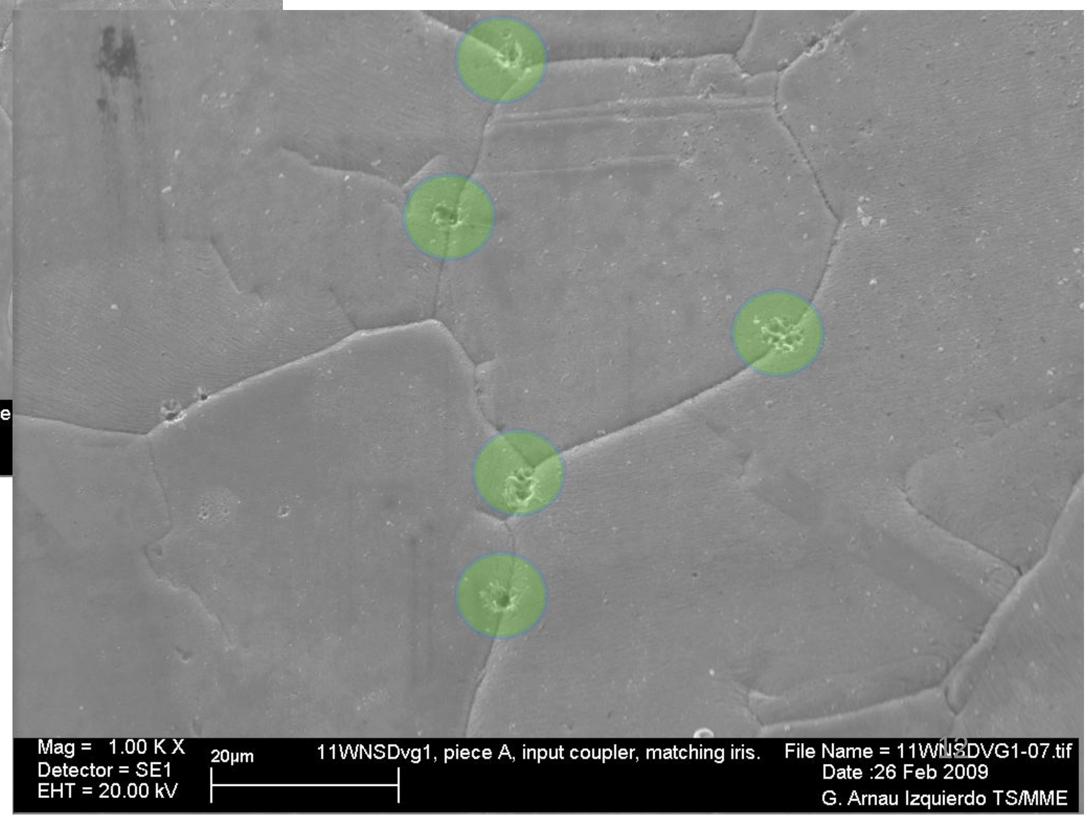


No brazing alloy coming inside the cells

Craters at grain boundary

Piece A, input coupler, matching iris

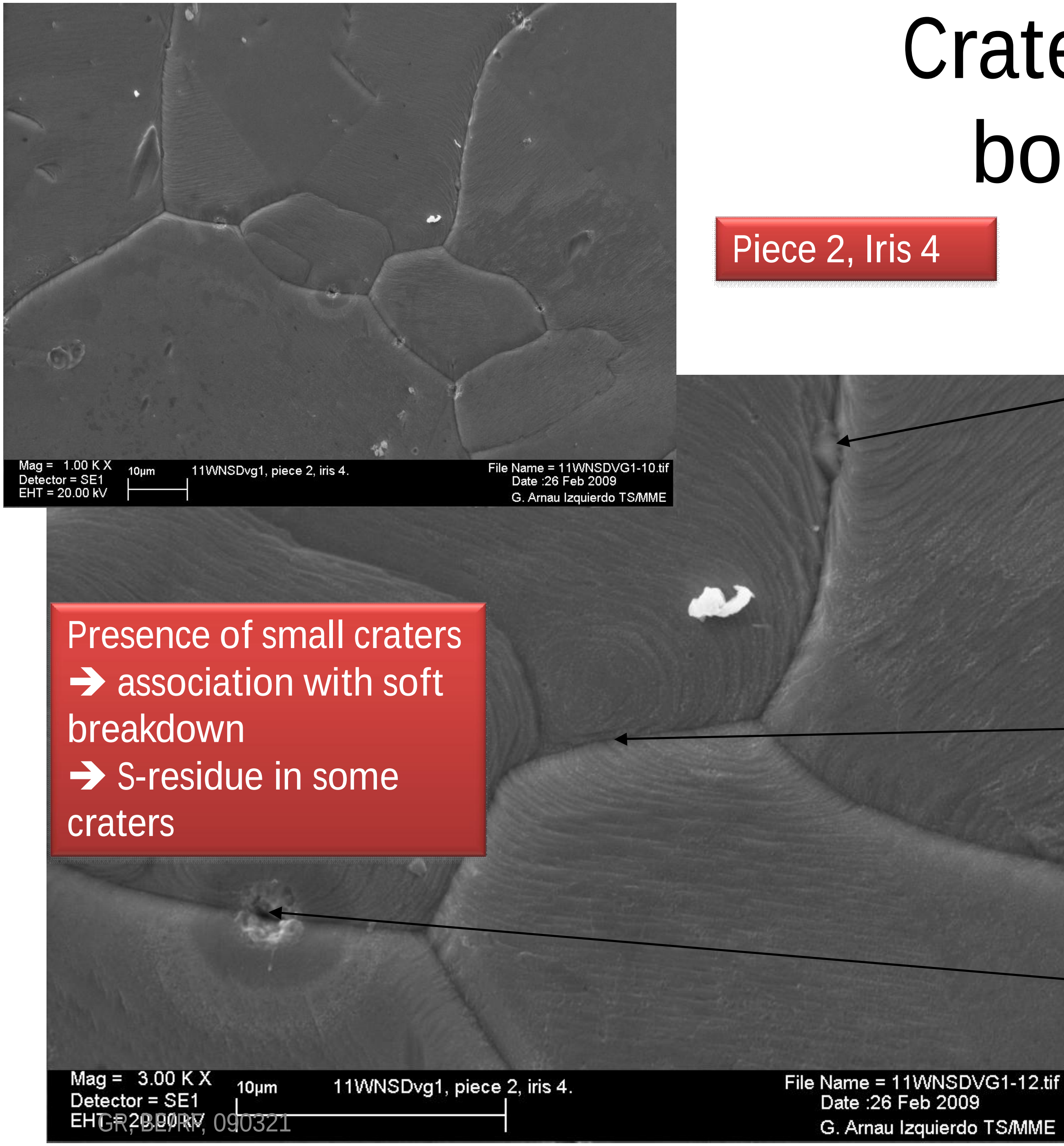




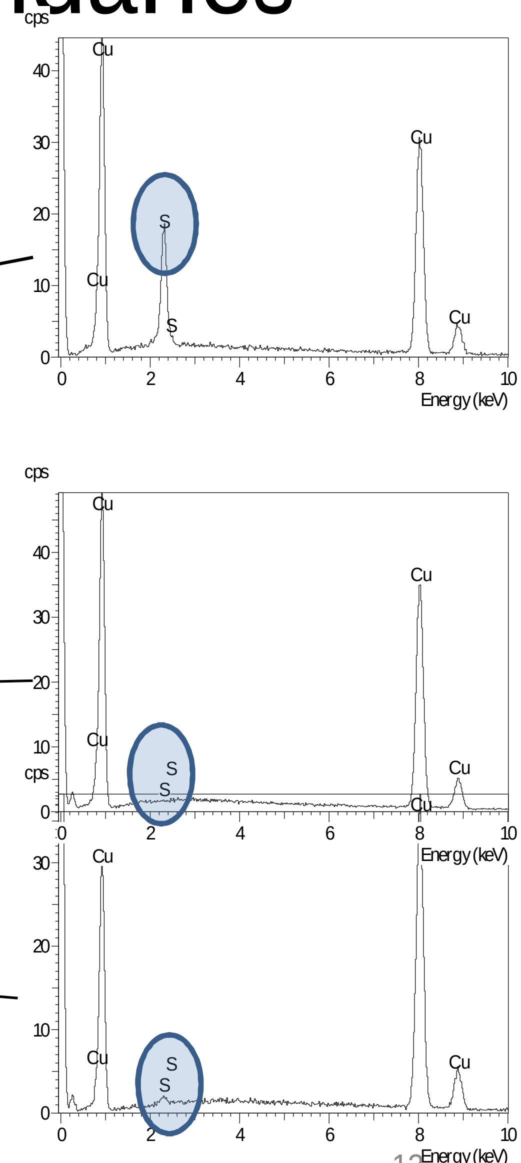
- Frequent small craters
- Question on grain size (interesting to cut other T18 and compare)

Craters at grain boundaries

Piece 2, Iris 4

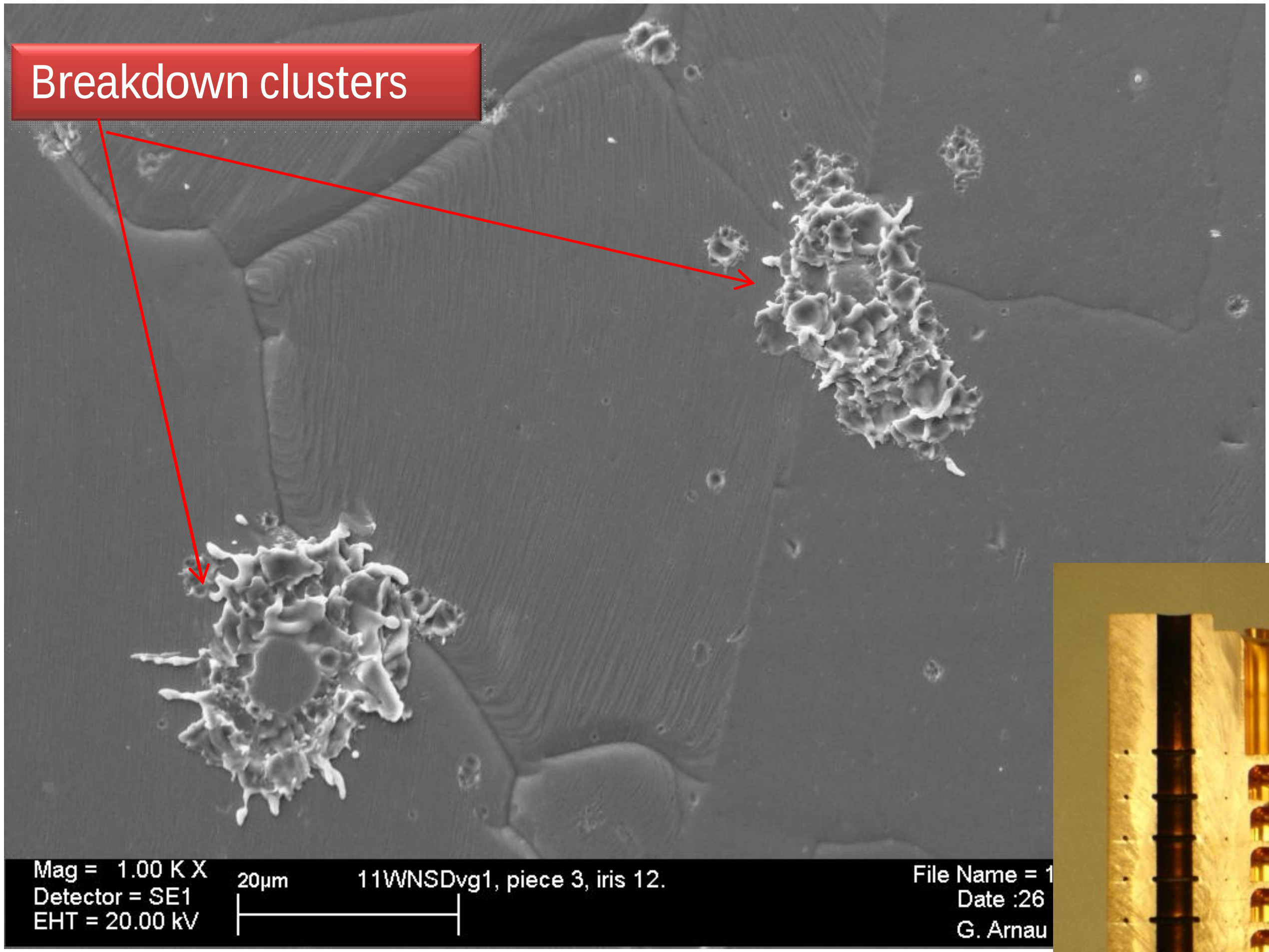


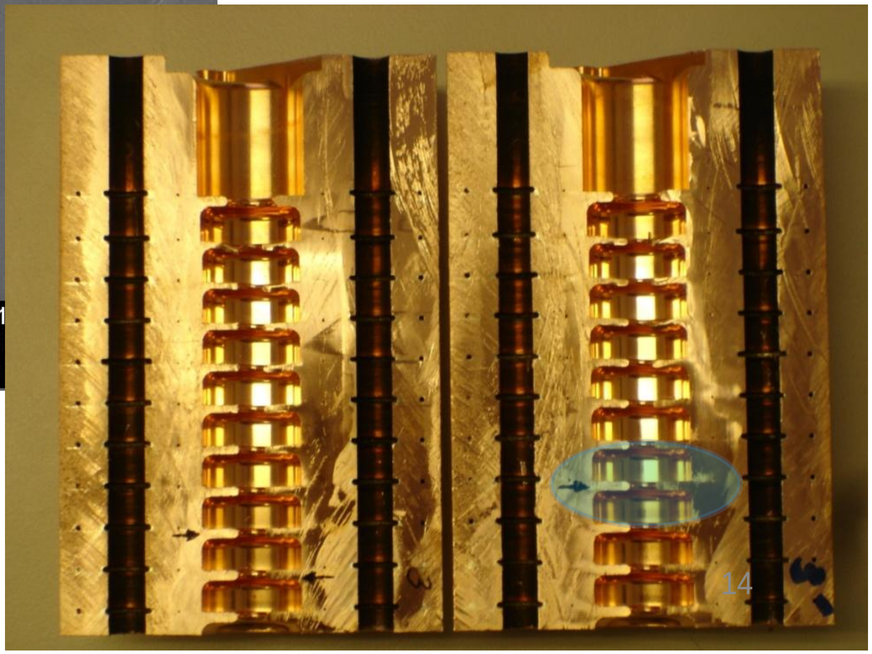
Presence of small craters
➔ association with soft breakdown
➔ S-residue in some craters



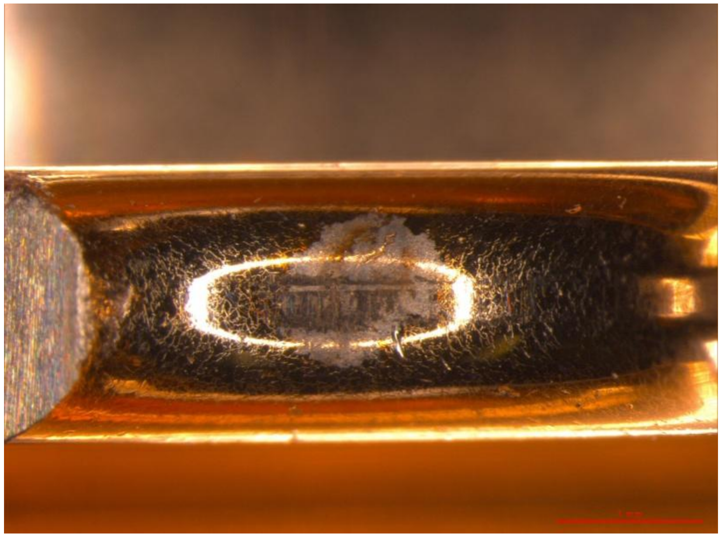
Inspection on iris 12

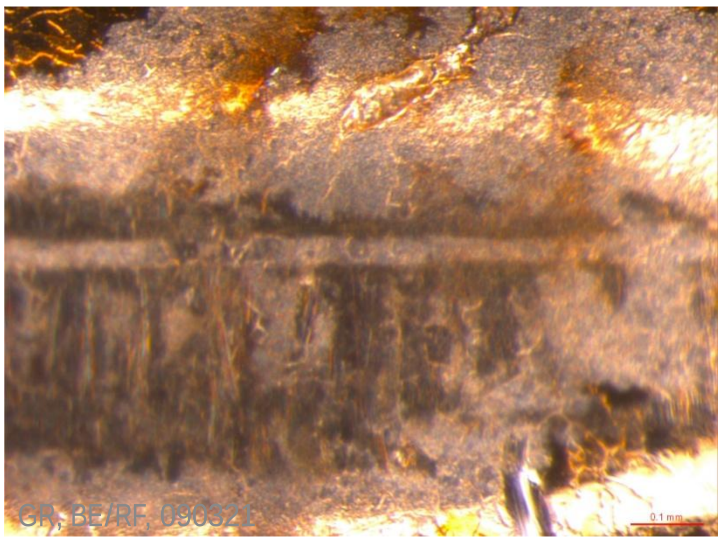
Piece 3, Iris 12

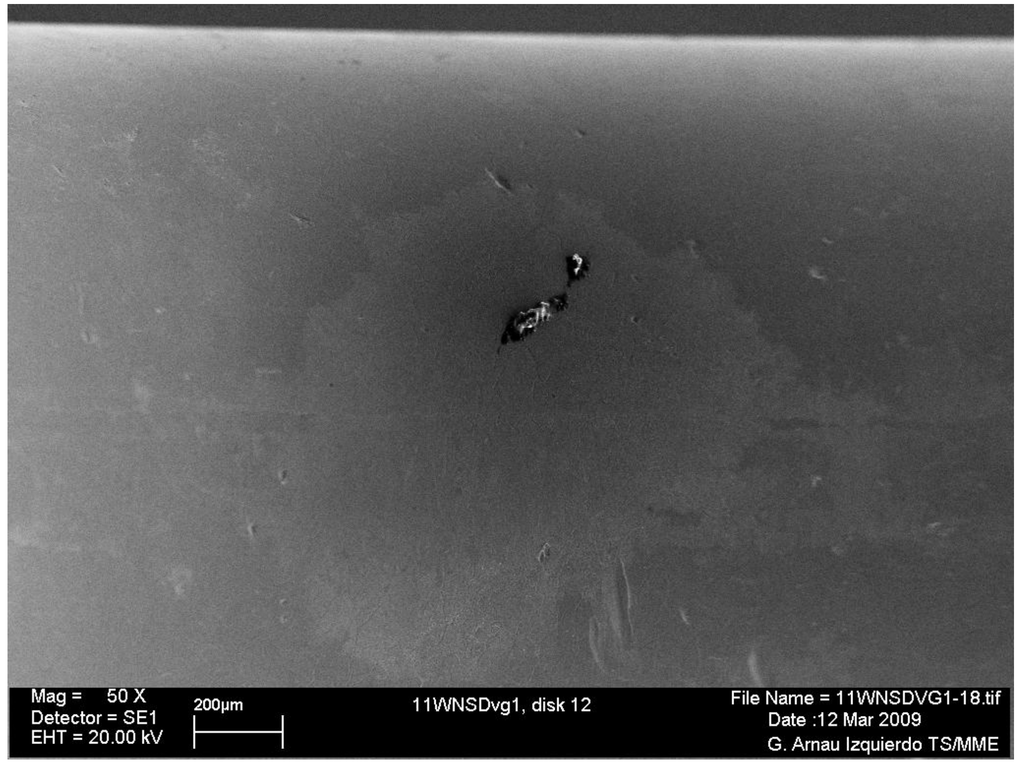




Inspection on iris 12 (special case)

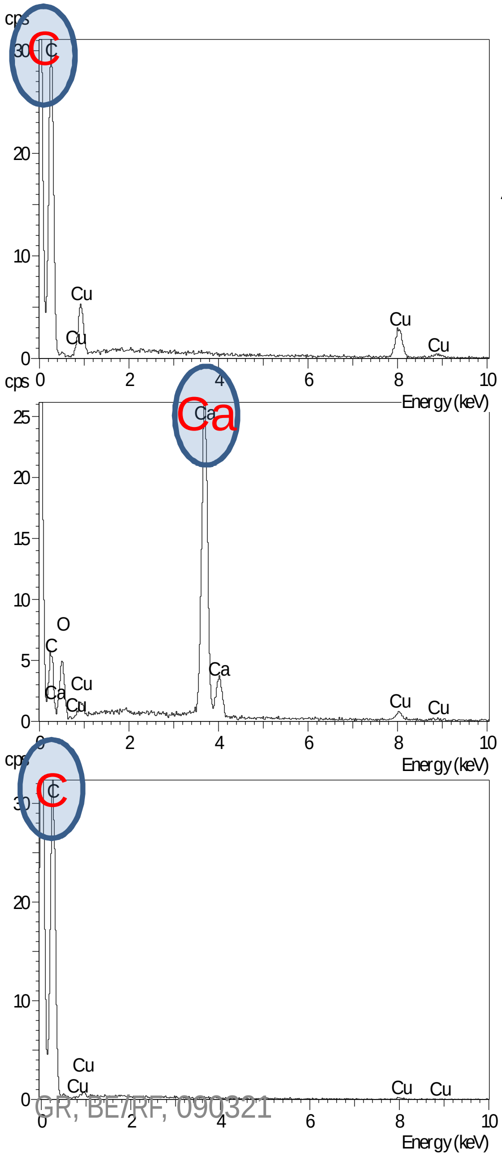


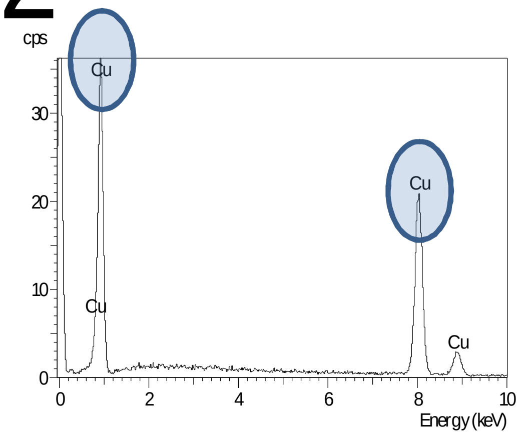


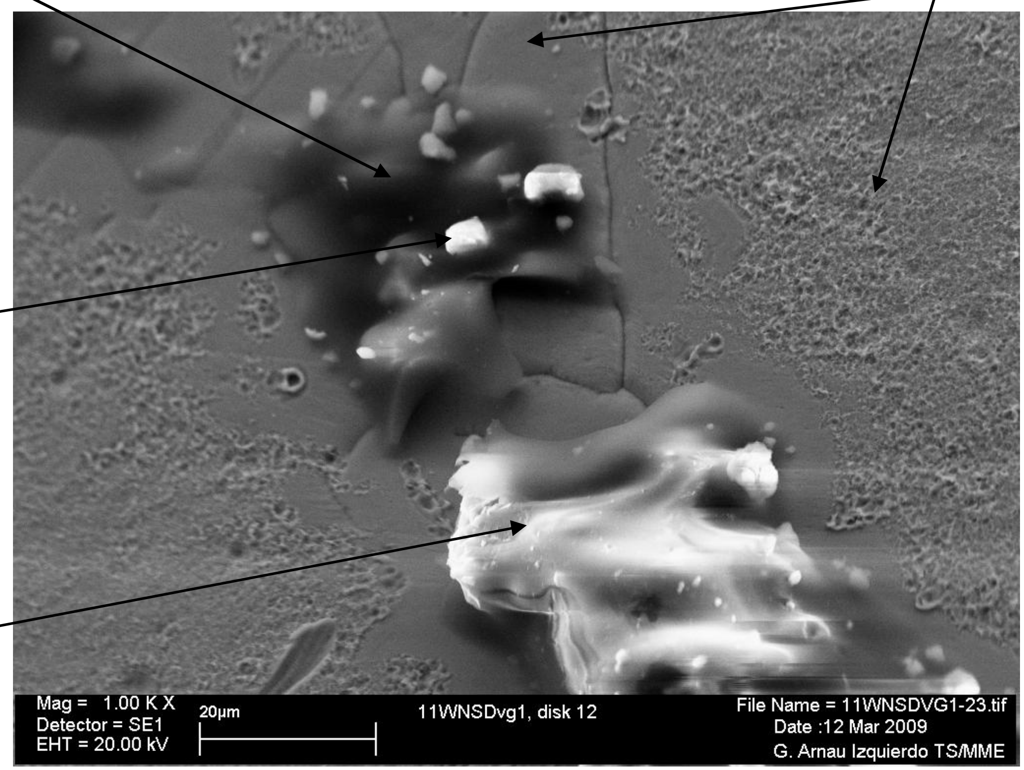


Inspection on iris 12

Contamination between brazing and testing



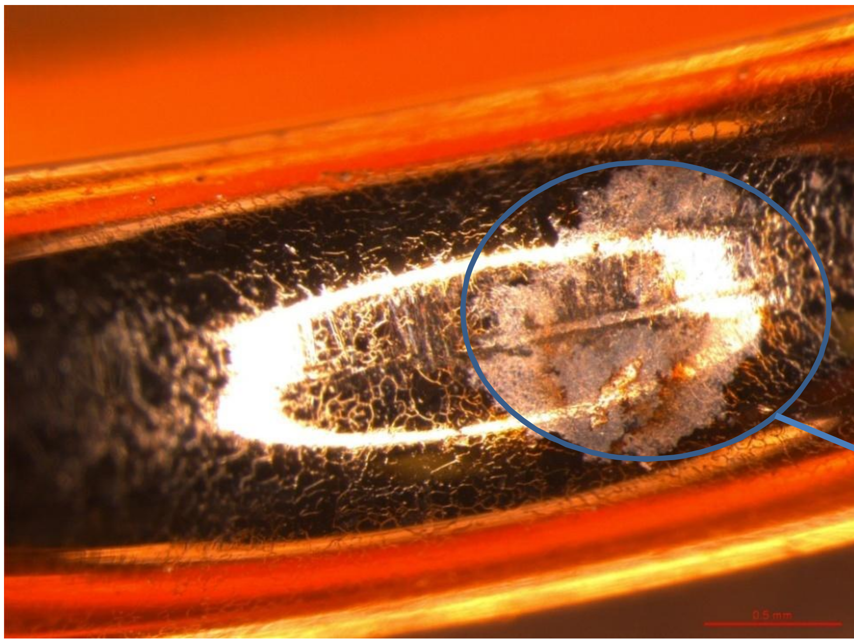


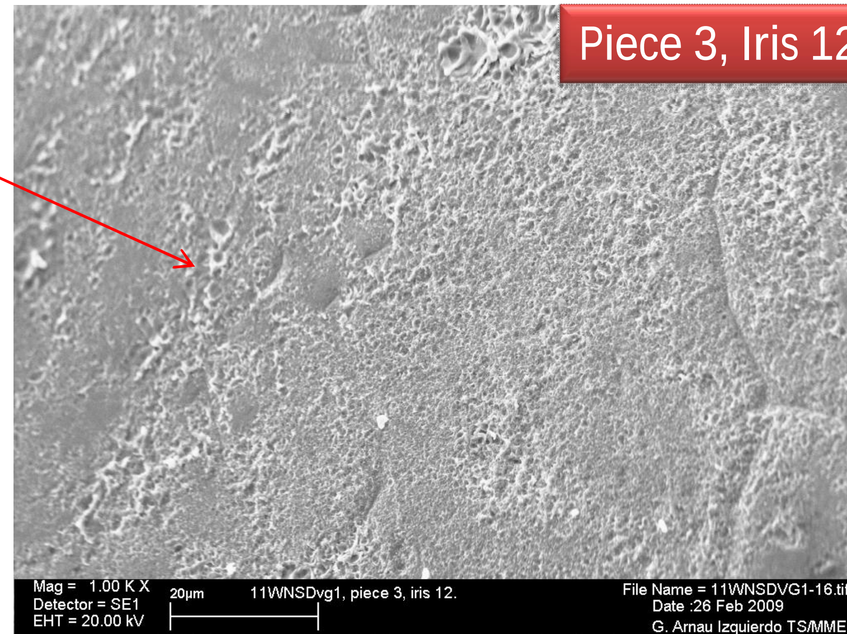


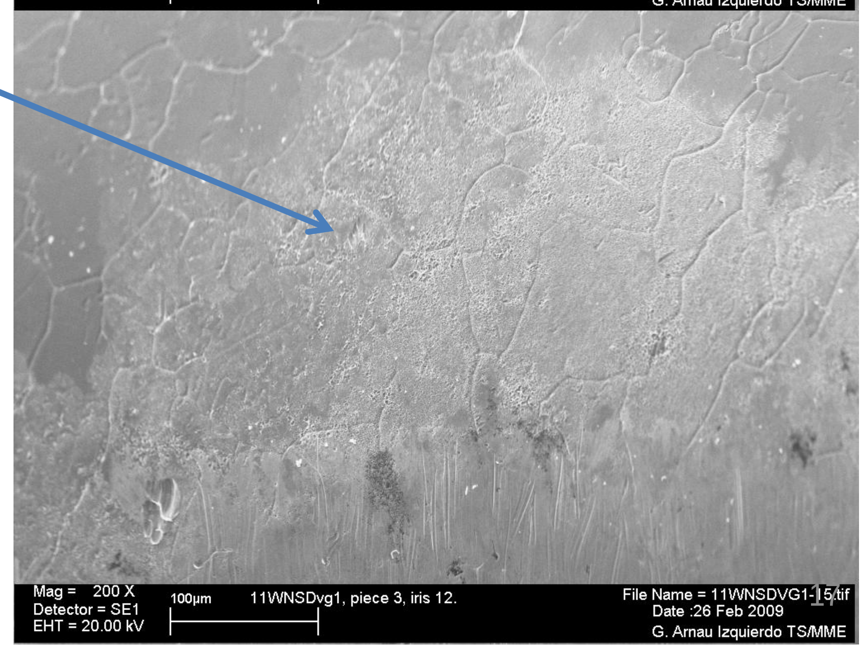
Inspection on iris 12

Region of craters

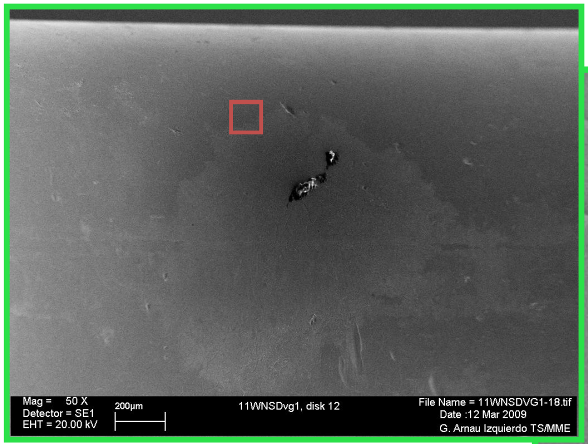
Piece 3, Iris 12

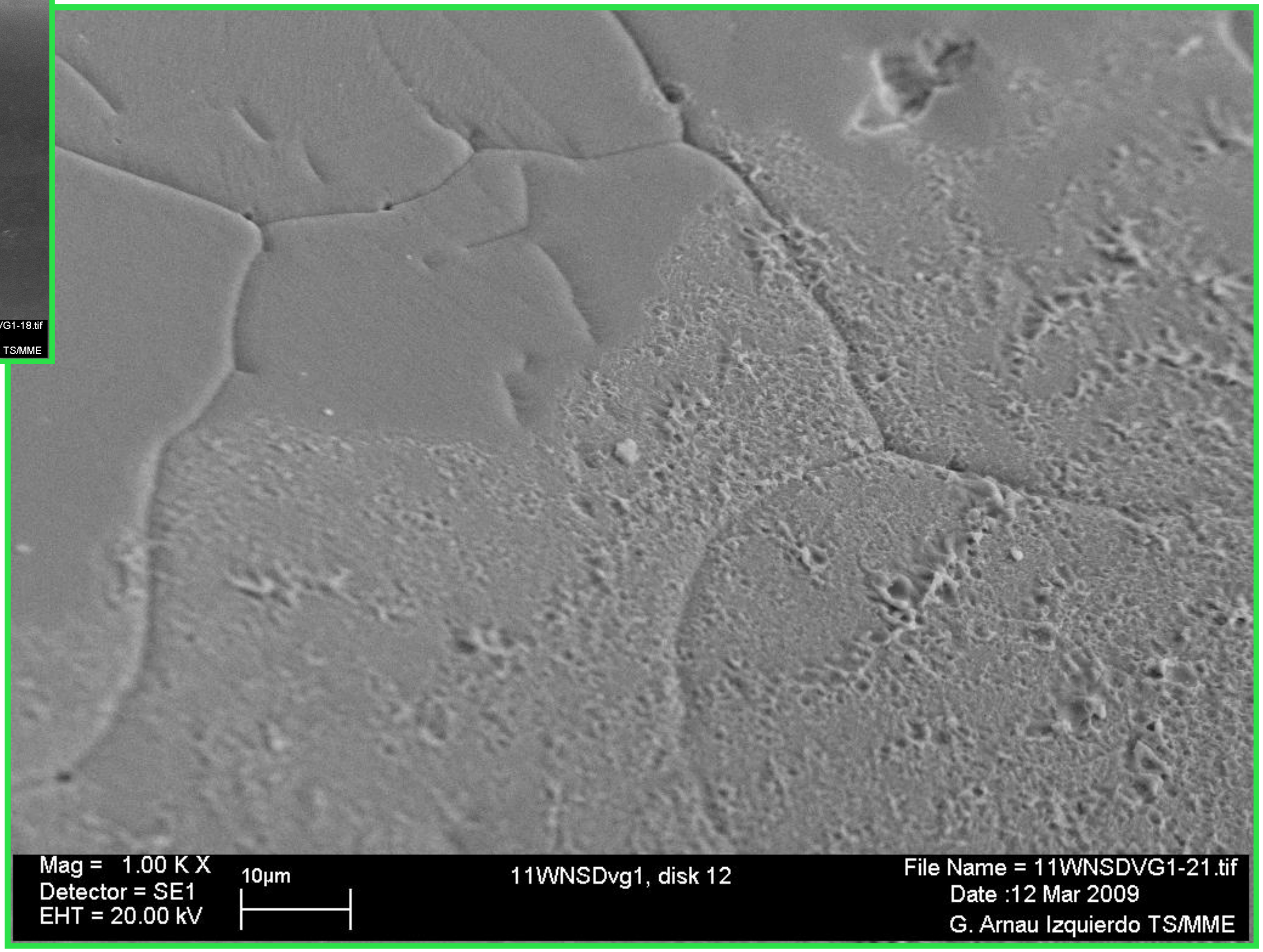






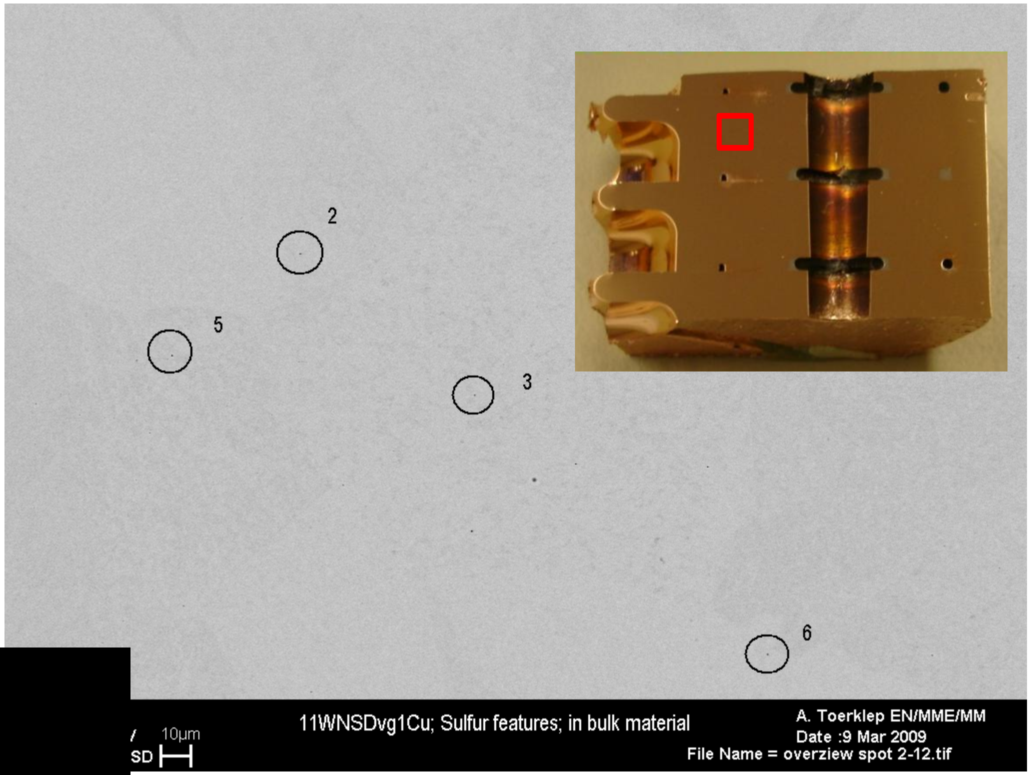
Inspection on iris 12

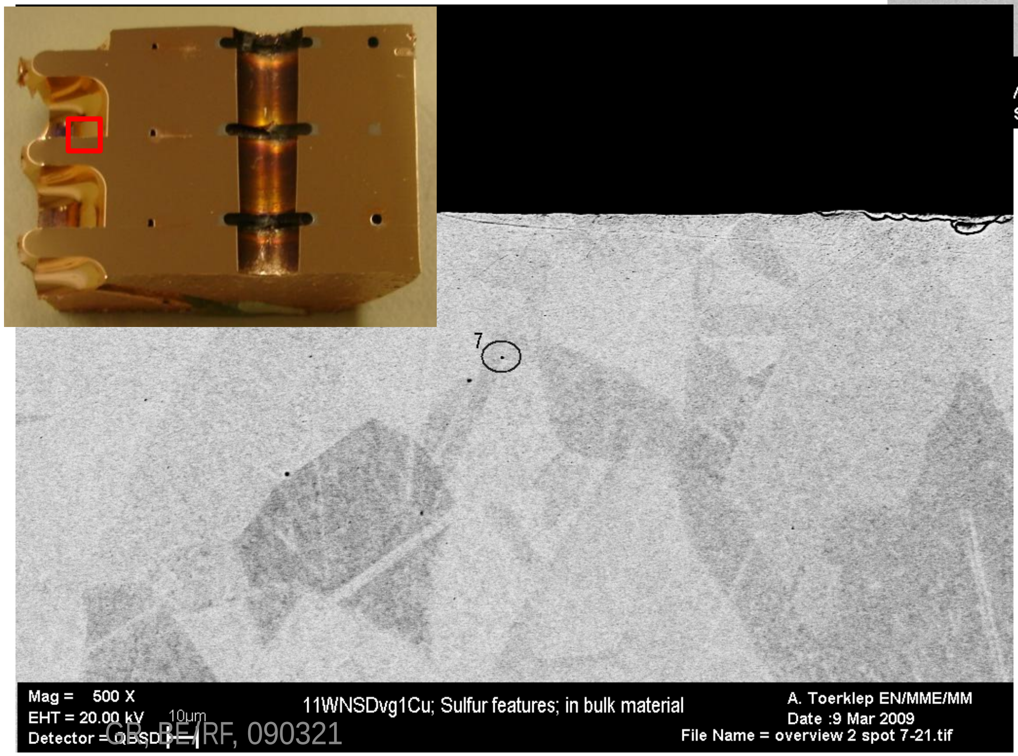


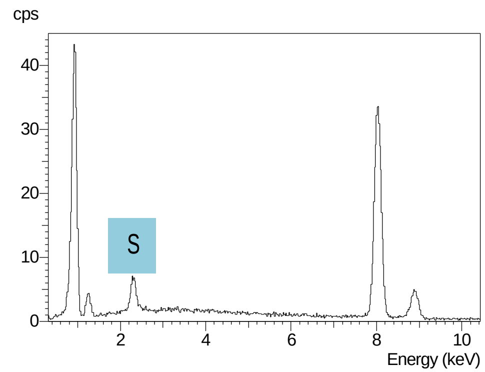


Sulfur features also in bulk material

In agreement with technical specification







Summary of observations

- Material composition according to CERN specification
- No sign of defects or activities in brazing region
- Frequent small craters in the grain boundaries
- S-rich particles in the grain boundaries
  - S-residue found in craters
- S-rich particle also in bulk
- Grain size raises questions, but issue to be followed in future
- Special case, iris 12
  - Region of iris 12 with intense activity, evidence of contamination ➔ coherent with test results

What we learned

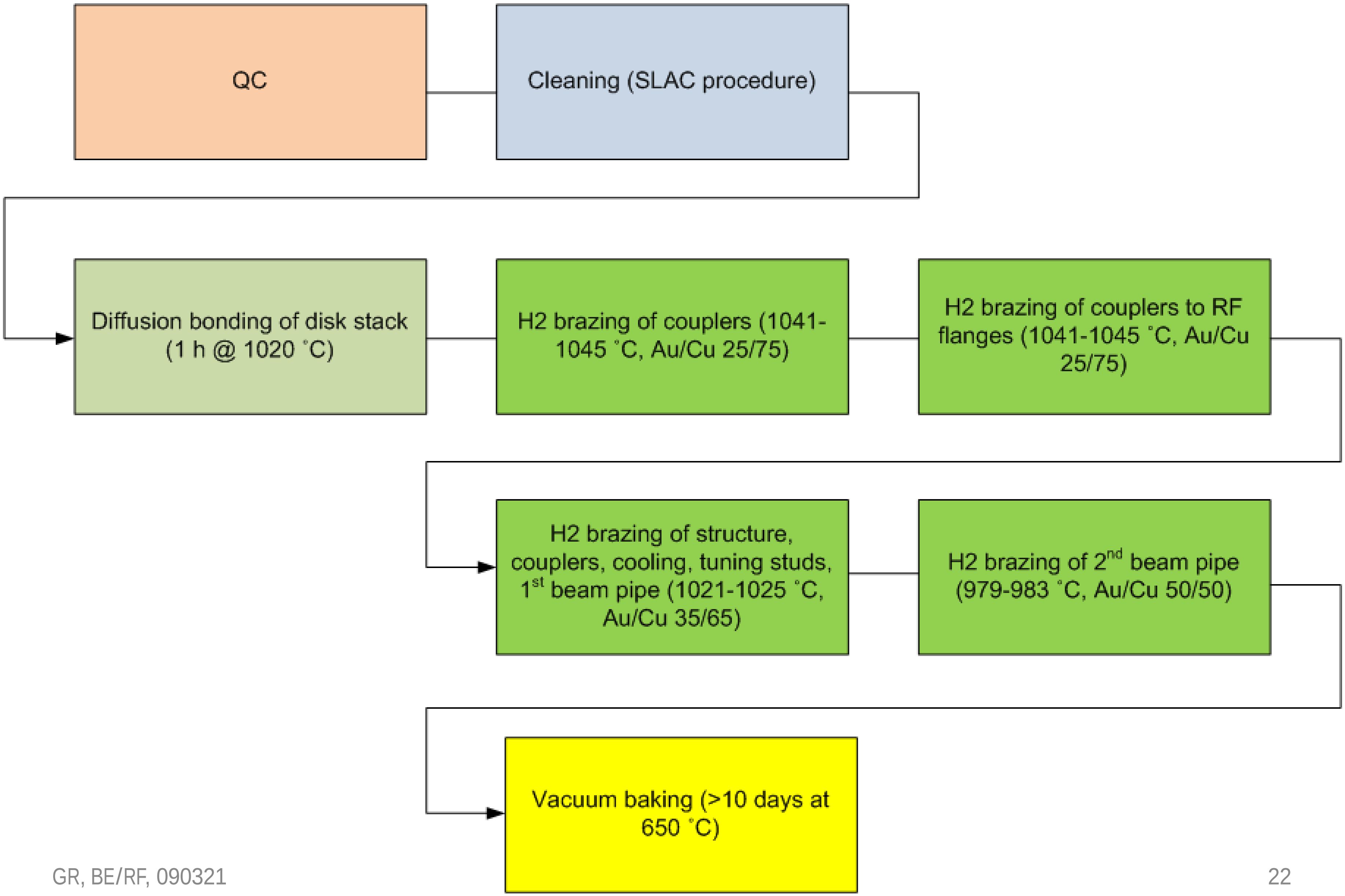
- S-rich particles in the grain boundaries
  - association with soft breakdown
  - S can be present in Cu-OFE up to 18 ppm ➔ completely soluble above 750 °C but in equilibrium – slow cooling – forms Cu_2S at room temperature
- Grain size could be an issue

Dedicated program with heat treatments and material origin

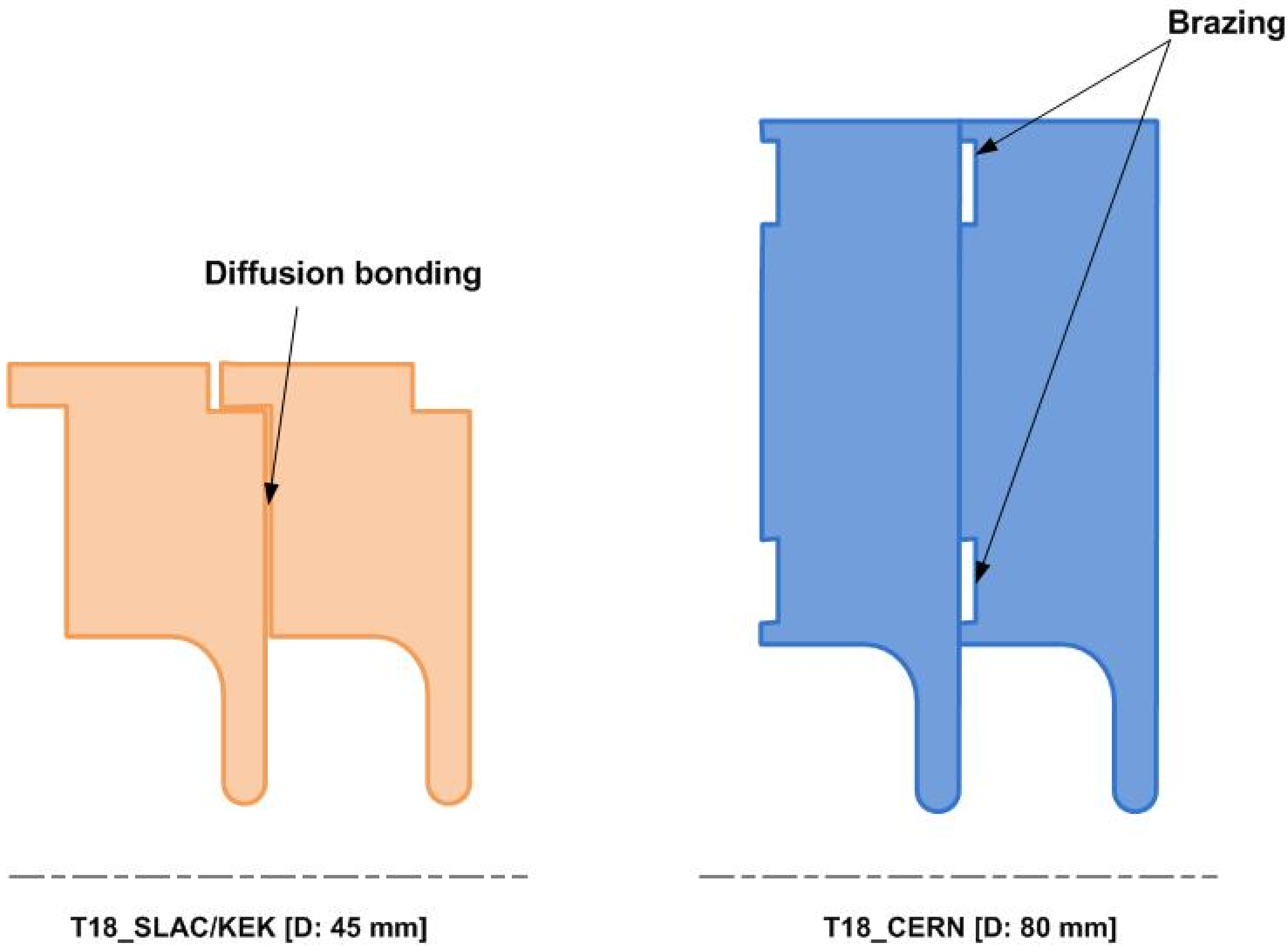
Comparison with assembly cycles at KEK/SLAC and Fermilab

- Cleaning/handling procedures shall be improved
- Additional steps on dimensional control and SEM are required during preparation

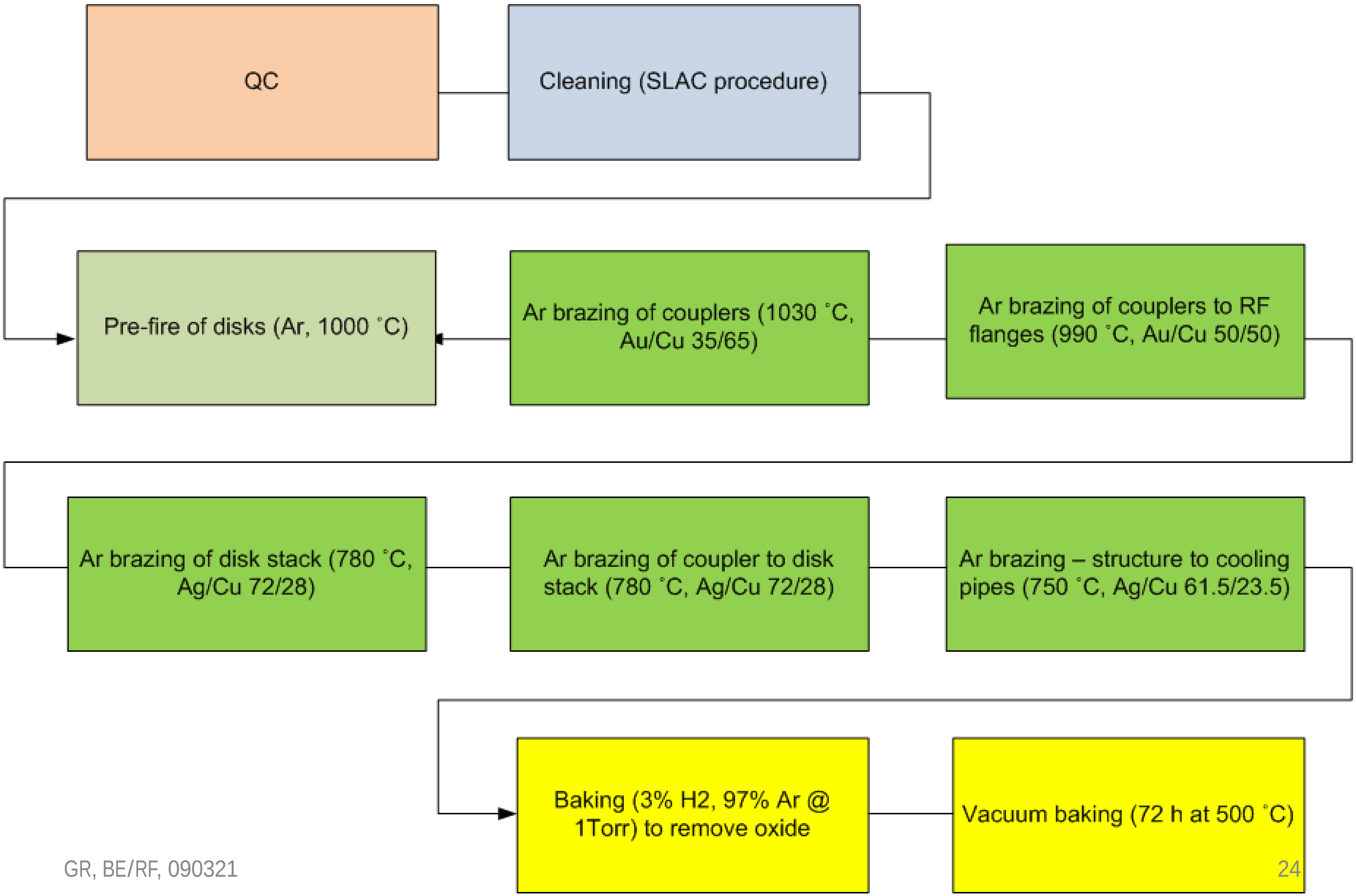
SLAC/KEK assembly cycle



CERN and SLAC/KEK bonding



Fermilab assembly cycle



Investigation on S-presence and grain size

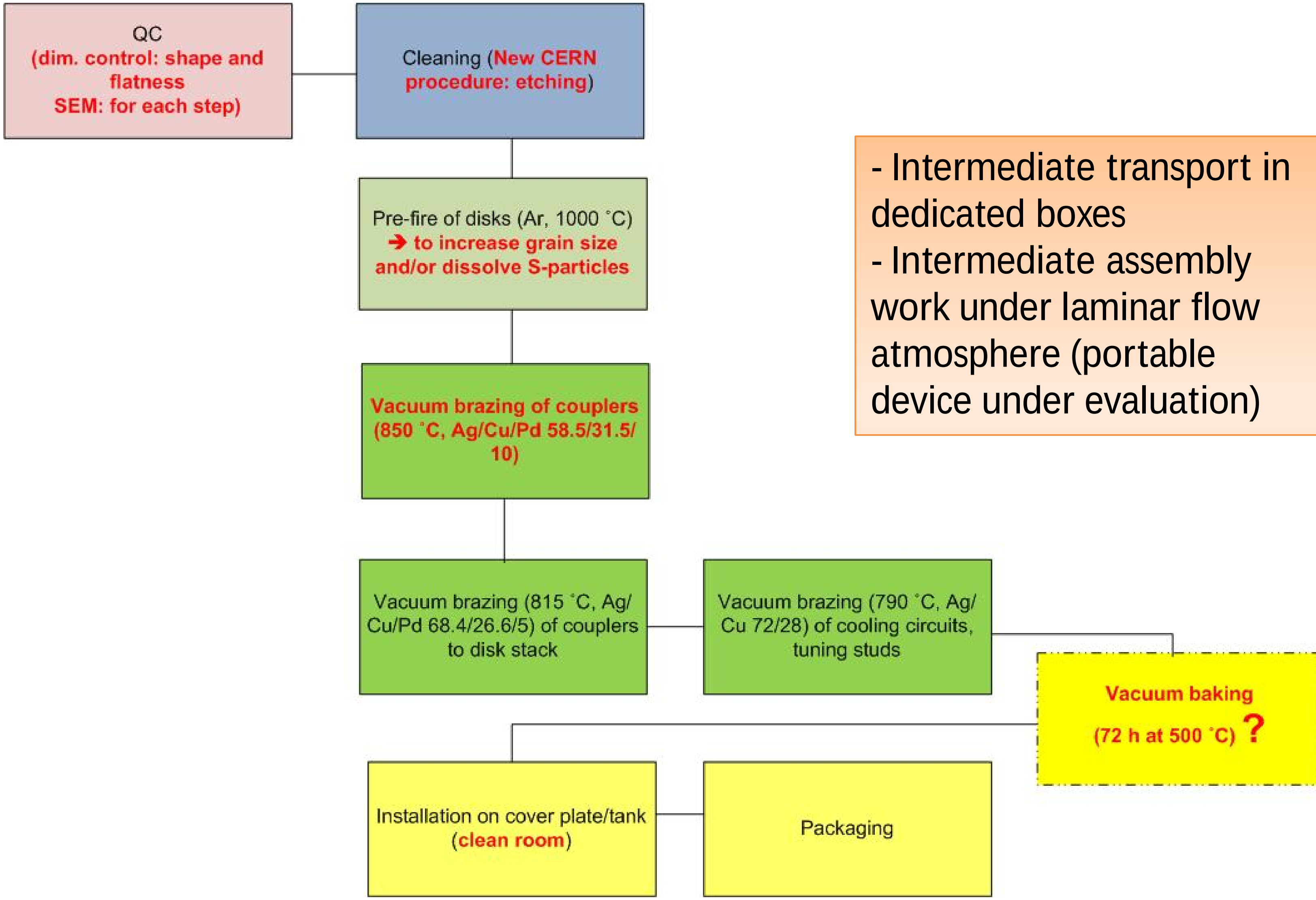
	CERN Cu OFE (fly cutting Ra 0.008) 50 mm	KEK Cu OFE (fly cutting Ra=0.008) 55 mm
0	As machined and cleaned	As machined and cleaned
1 (4 samples)	Vacuum Brazing 820 C (Bodycote)	Vacuum Brazing 820 C (Bodycote)
2	Vacuum Brazing 820 C (CERN)	Vacuum Brazing 820 C (CERN)
3	Vacuum Diffusion bonding 1045 C (Bodycote)	Vacuum Diffusion bonding 1045 C (Bodycote)
4	H2 Brazing 820 C (Bodycote)	H2 Brazing 820 C (Bodycote)
5-6-7-8	As machined (annealing)	As machined (annealing)
6-7-8	H2 Diffusion bonding 1050 C (Bodycote)	H2 Diffusion bonding 1050 C (Bodycote)
7-8	H2 Brazing 1000 C (Bodycote)	H2 Brazing 1000 C (Bodycote)
8	Vacuum baking after H2 brazing (Bodycote)	Vacuum baking after H2 brazing (Bodycote)

SEM inspections after each step

Future short-term structures

- T24 undamped (disks for tank version at CERN) ➔ new assembly procedure
- T24 undamped x2 ➔ fabricated by KEK/SLAC
- T24 undamped D = 45 mm (under mechanical design) x2 ➔ new design and new assembly procedure
- T18 KEK/SLAC design x2 (under tendering) ➔ SLAC/KEK assembly procedure
- TD18 (already brazed) ➔ cleaning

CERN new assembly cycle



- Intermediate transport in dedicated boxes
- Intermediate assembly work under laminar flow atmosphere (portable device under evaluation)

Dimensional control

- Present situation
  - Machine with an accuracy of +/- 3 um ➔ insufficient with respect to needs ➔ subcontrating to outside institutes
  - General rule for machine accuracy: 3-4 times better than required accuracy on pieces
  - Serious problem of probe: too high forces ➔ marks on pieces
  - Machine Veeco: good for roughness and topography measurement
  - Room adapted for this machine and required tolerance

- To be improved
  - Low force probe: 15 kCHF
  - New machine +/- 0.3-0.4 um (3 suppliers) [High Priority]
    - Needed personnel
    - Needed adaptation of existing room

Meeting S. Atieh, A. Cherif, M. Polini, G. Riddone 06.03.2009

Mag: 2.6 X

Mode: VSI

Surface Data

Date: 11/03/2009

Time: 13:22:29

Surface Statistics:

Ra: 820.66 nm

Rq: 968.11 nm

Rz: 11.61 um

Rt: 17.67 um

Set-up Parameters:

Size: 2695 X 2314

Sampling: 13.10 um

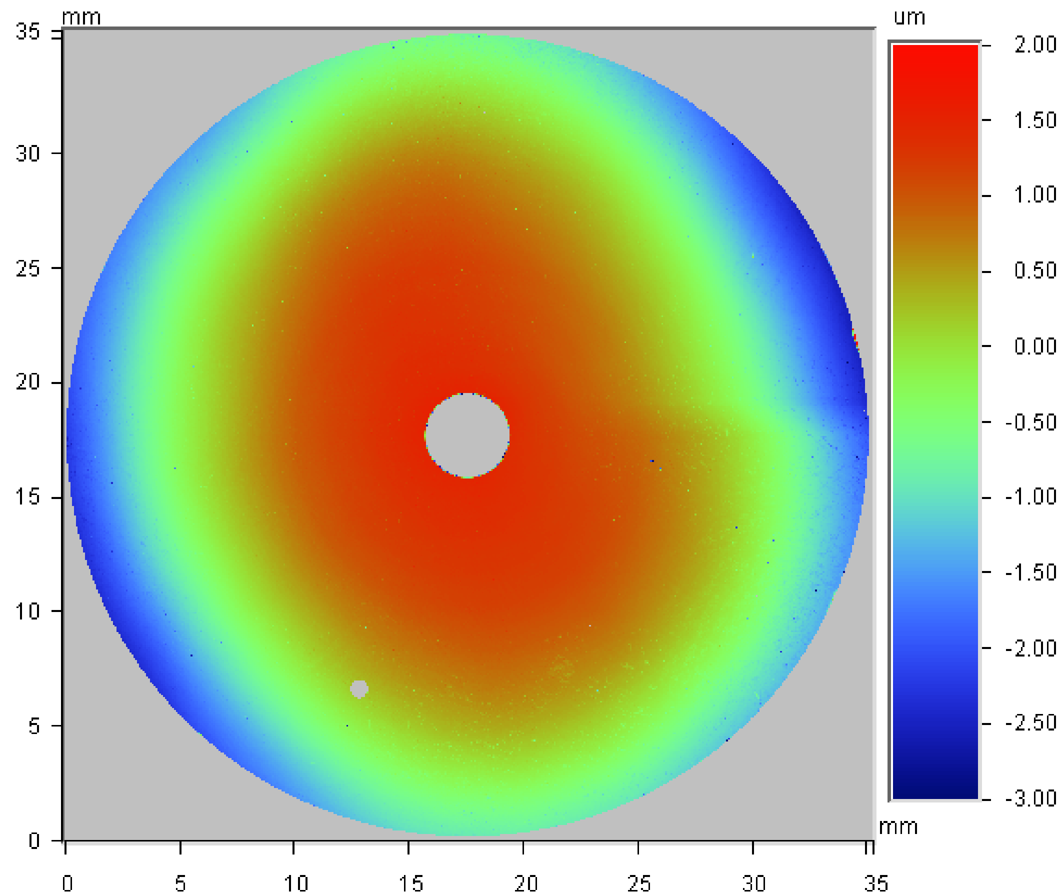
Processed Options:

Terms Removed:

Tilt

Filtering:

None



Title:

Note: PLANEITE MESUREE SUR CELLULE 35 mm SUR MACHINE VEECO

Veeco

Vue 3D

Date: 03/03/2009

Time: 10:23:16

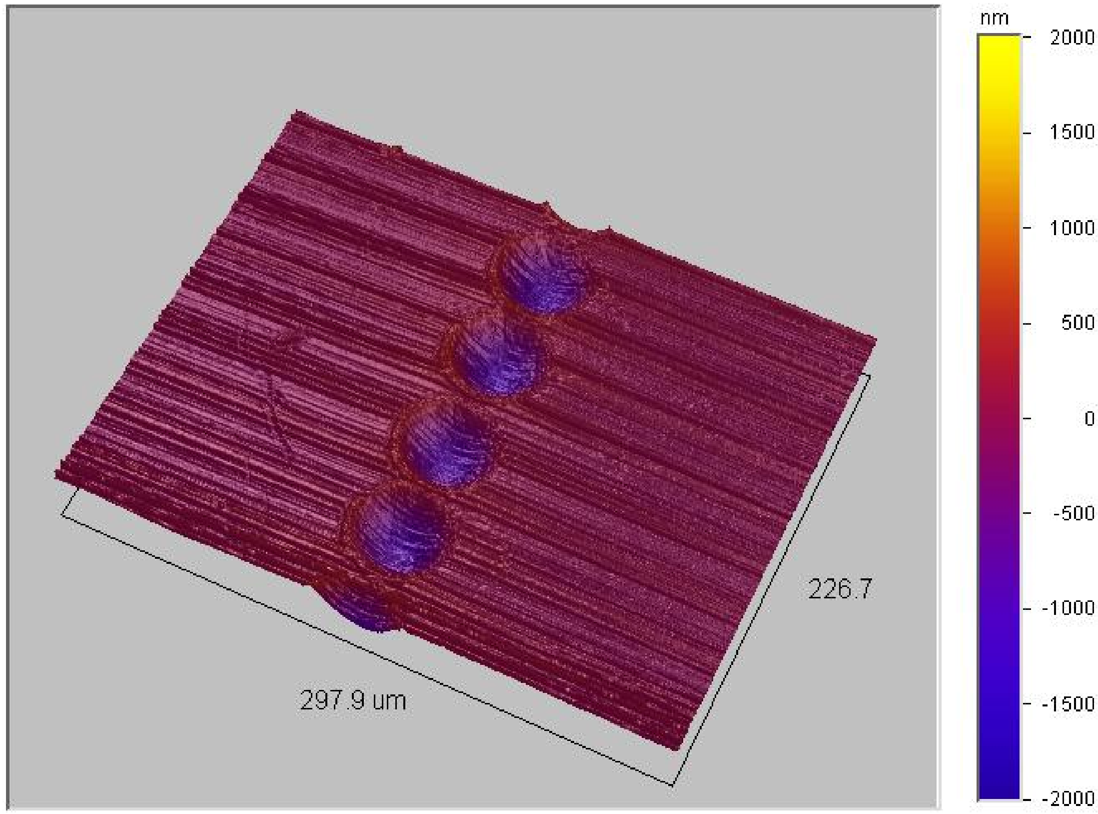
Information sur la mesure

Magnification: 20.75

Measurement Mode: VSI

Sampling: 0.40 um

Array Size: 736 X 480



Title: Extremity cell B

Note: Piece 2 (11WNSDVG1.8)

<u>Marques dues au palpeur</u>

Fabrication

- Present situation
  - VDL, Kugler (only turning)
  - LT Ultra under qualification

  - Promising Kaleido, Engineering and TNO

- To be improved
  - New firms in Europe
  - New firms in Japan
  - New firms in USA

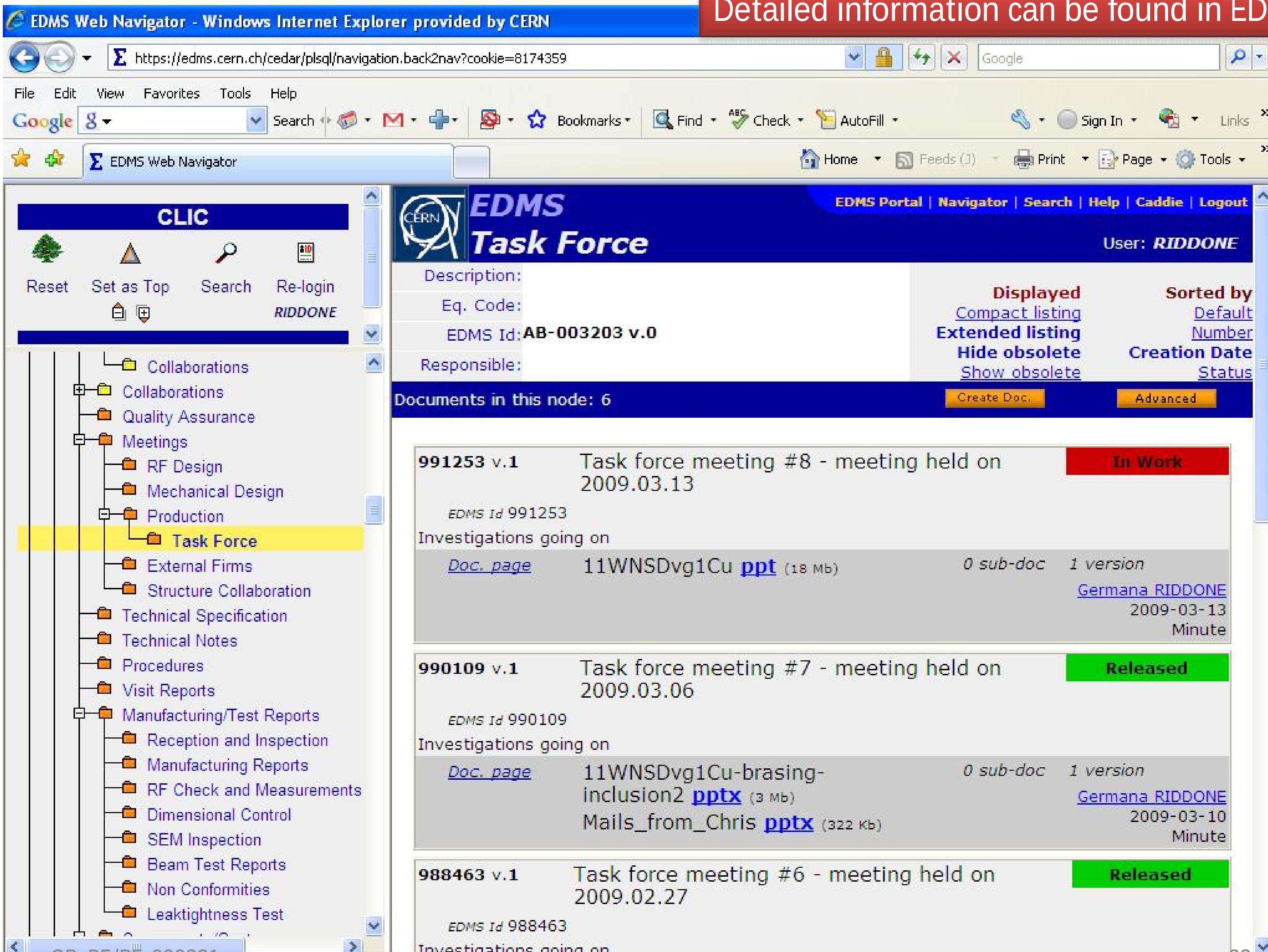
  - Development work in collaboration with firms (very difficult with VDL) and other institutes
  - Procurement of combined machine at CERN [prototyping phases, special pieces, pre-qualification for series, fall-back solution]
    - qualified people (1 Eng. + 1 Tech) to be trained [Priority 2]

Meeting S. Atieh, A. Cherif, M. Polini, G. Riddone 06.03.2009

Conclusions

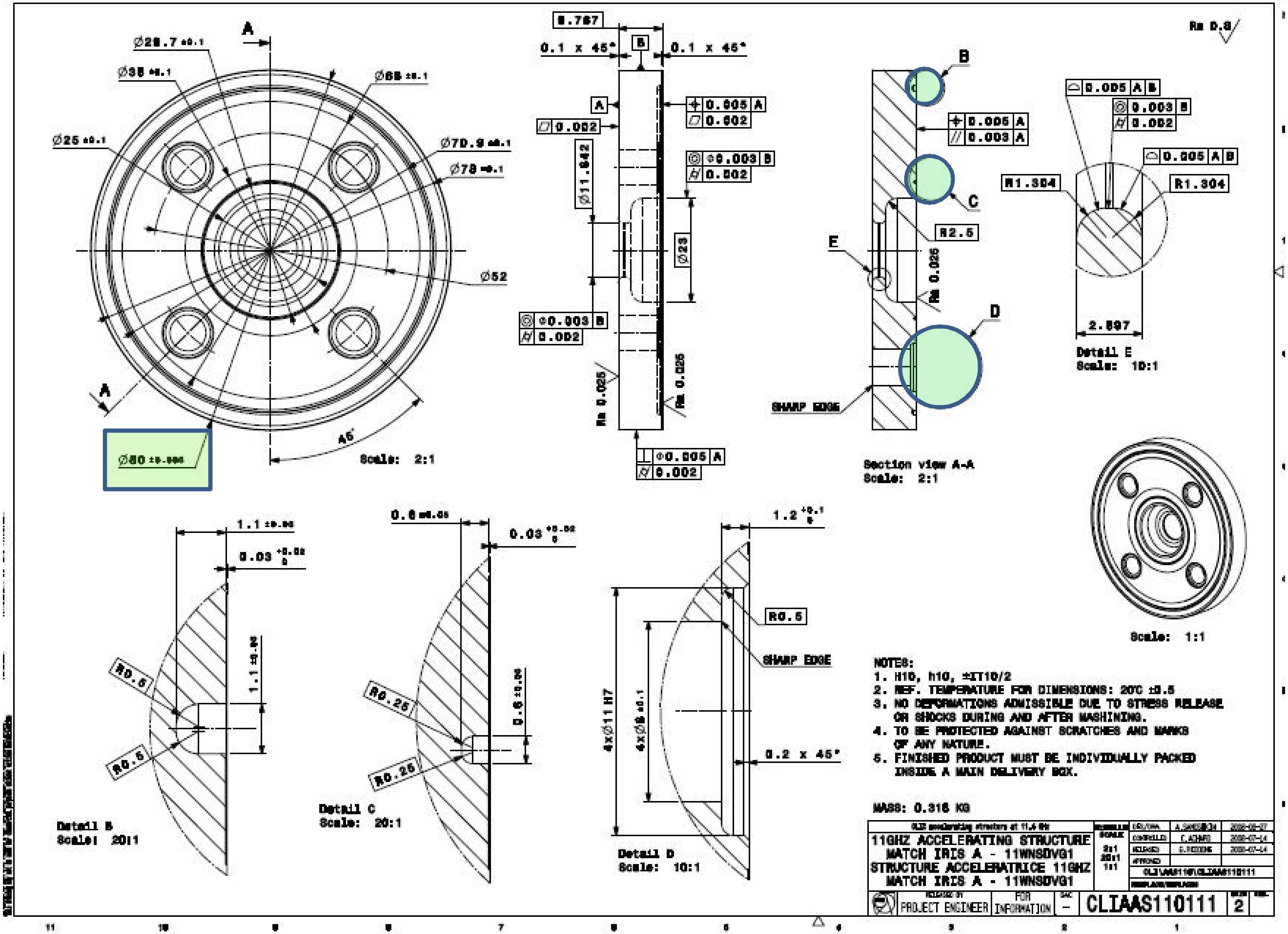
- T18_CERN showed bad test results (same structures made at KEK/SLAC showed good results, demonstrating nominal CLIC performance)
- Investigations on T18_CERN, showed that iris 12 is a special case: contamination and evidence of high activity region
- Program to investigate S-presence and grain size launched
- New assembly procedure established: *pre-fire at 1000 °C, cleaning procedure, separate preparation of RF couplers*
- Additional QC steps identified
- Fabrication of T18 with SLAC/KEK design launched

Detailed information can be found in EDMS



Extra slides

T18_CERN


Ra 0.8
Scale: 2:1
Section view A-A
Scale: 2:1
Detail E
Scale: 10:1
Scale: 1:1
SHARP EDGE
Detail B
Scale: 20:1
Detail C
Scale: 20:1
Detail D
Scale: 10:1
NOTES:
1. H10, h10, ±IT10/2
2. REF. TEMPERATURE FOR DIMENSIONS: 20°C ±0.5
3. NO DEFORMATIONS ADMISSIBLE DUE TO STRESS RELEASE OR SHOCKS DURING AND AFTER MACHINING.
4. TO BE PROTECTED AGAINST SCRATCHES AND MARKS OF ANY NATURE.
5. FINISHED PRODUCT MUST BE INDIVIDUALLY PACKED INSIDE A MAIN DELIVERY BOX.
MASS: 0.316 KG
11GHZ ACCELERATING STRUCTURE MATCH IRIS A - 11WNSDVG1
STRUCTURE ACCELERATRICE 11GHZ MATCH IRIS A - 11WNSDVG1
PROJECT ENGINEER
FOR INFORMATION
CLIAAS110111
2

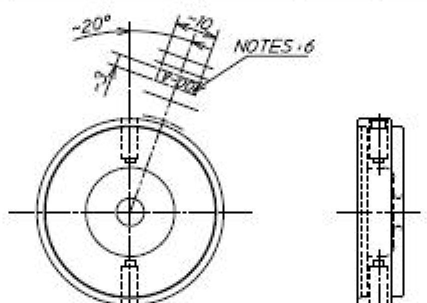
3rd ANGLE PROJECTION

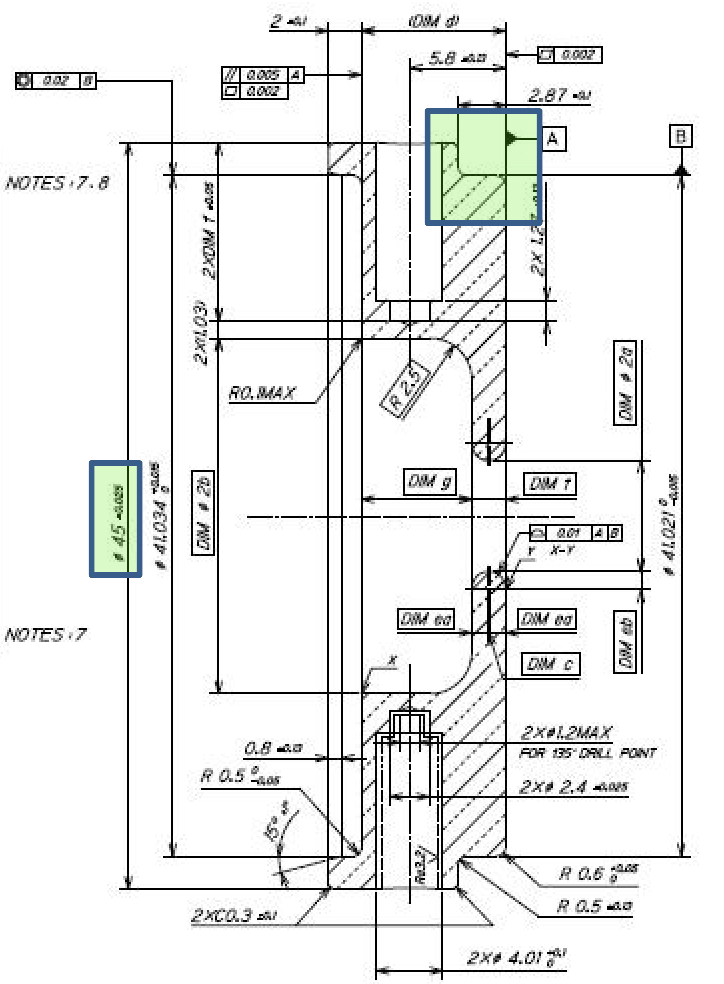
Ra0.2 (Ra3.2)

CLIC_VG1 PARAMETER

No.	2a	2b	i	g	ea	eb	c	(d)	f
0	11.839	22.996	2.897	6.870	1.300	1.300	0.297	9.766	
1	8.119	22.859	2.794	5.850	1.257	1.517	0.280	8.644	10.04
2	8.036	22.142	2.750	5.975	1.238	1.492	0.274	8.725	10.40
3	7.872	22.042	2.663	6.041	1.198	1.442	0.267	8.704	10.45
4	7.707	21.944	2.576	6.128	1.159	1.392	0.258	8.704	10.50
5	7.542	21.850	2.489	6.215	1.120	1.342	0.249	8.704	10.54
6	7.378	21.758	2.402	6.302	1.081	1.292	0.240	8.704	10.59
7	7.213	21.671	2.315	6.389	1.042	1.242	0.231	8.704	10.63
8	7.048	21.586	2.228	6.476	1.003	1.193	0.222	8.704	10.68
9	6.884	21.505	2.141	6.563	0.963	1.143	0.215	8.704	10.72
10	6.719	21.426	2.054	6.650	0.924	1.094	0.206	8.704	10.76
11	6.554	21.351	1.967	6.737	0.885	1.045	0.197	8.704	10.79
12	6.390	21.280	1.880	6.824	0.846	0.995	0.188	8.703	10.83
13	6.225	21.211	1.793	6.911	0.807	0.946	0.179	8.703	10.86
14	6.060	21.146	1.705	6.998	0.768	0.897	0.170	8.703	10.90
15	5.895	21.084	1.618	7.085	0.729	0.849	0.161	8.703	10.93
16	5.731	21.025	1.531	7.172	0.689	0.800	0.154	8.703	10.96
17	5.566	20.970	1.444	7.259	0.650	0.752	0.145	8.703	10.98
18	5.401	20.918	1.357	7.346	0.611	0.703	0.136	8.703	11.01
19	5.319	20.869	1.314	7.411	0.591	0.679	0.132	8.725	11.03
20	10.450	21.596	2.157	7.433	0.950	0.950	0.257	9.589	10.67

NOTES:7.8 (row 0) — NOTES:7 (row 20)





NOTES:
1. DIMENSIONS IN THIS DRAWING ARE AT 20℃, WHILE OPERATION TEMPERATURE IS 30℃.
2. LUBRICANT BASED ON CHLORINE OR SULFUR SHOULD BE AVOIDED, NO POLISHING IS ALLOWED.
3. POSITIVE CORNERS ARE CHANFERED C0.2 UNLESS SPECIFIED.
4. NEGATIVE CORNERS ARE R<0.2 UNLESS SPECIFIED.
5. NO HARMFUL BURRS NOR SCRATCHES ARE ALLOWED.
6. NUMBERING IS INSCRIBED.
   nn(CELLNo.00-20)-x (LOTNo.A-E) ex. (00-A)
7. IRIS CROSS SECTION IS CIRCULAR.
8. NO TUNING HOLE.
7. ANNEALING AT 500℃ FOR 2HOURS IS APPLIED BEFORE FINAL CUTTING.

No.	Part Name	Material	Unit Quantity	Total Quantity	Remarks
01	45mm DIA STD CELL	C1011	21		

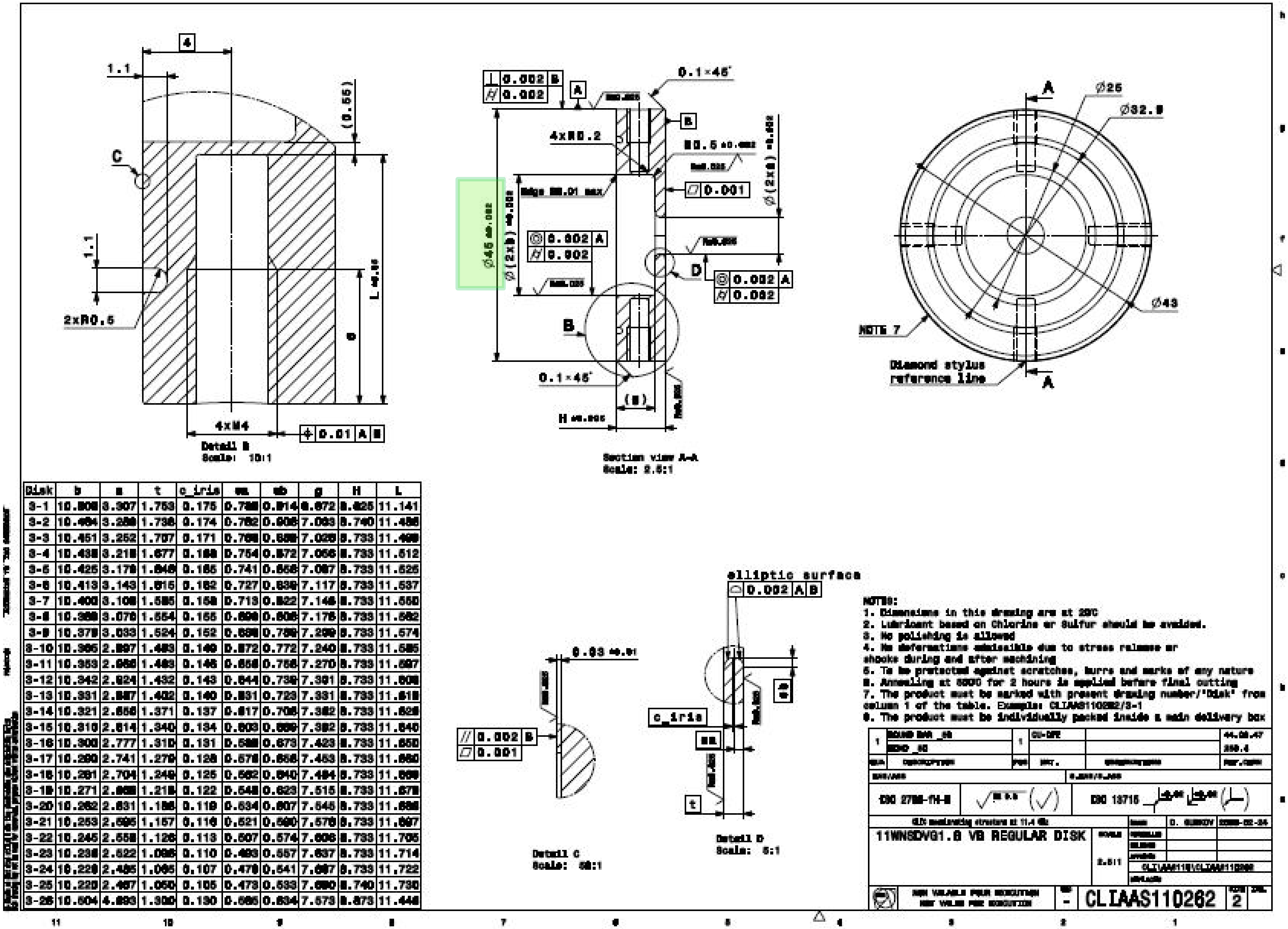
Rev.2		Designed	Drawn	Checked	Approved	Scale
Rev.1		Takatomi	Takatomi		Higo	4:1
Date	2007/10/10					

Drawing Name: CLIC 11WNSDvg1 45mm DIA STD CELL

High Energy Accelerator Research Organization
1-1 Oho,Tsukuba,Ibaragi,305-0801,Japan

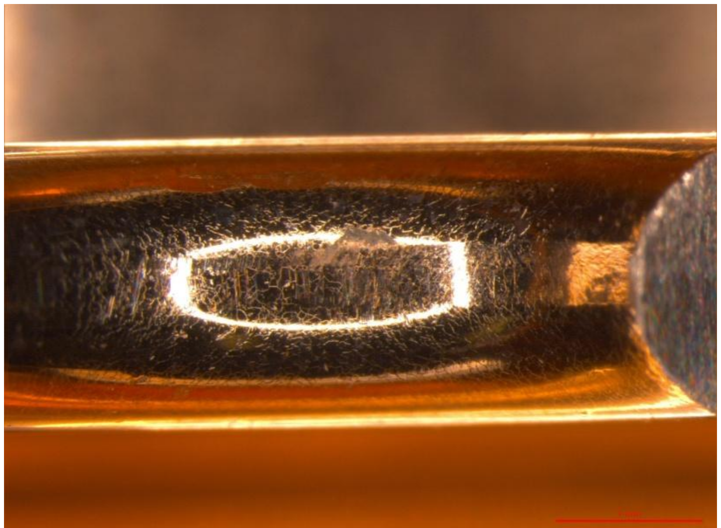
Drawing Number: CLICVG1-02-01E — Rev. A

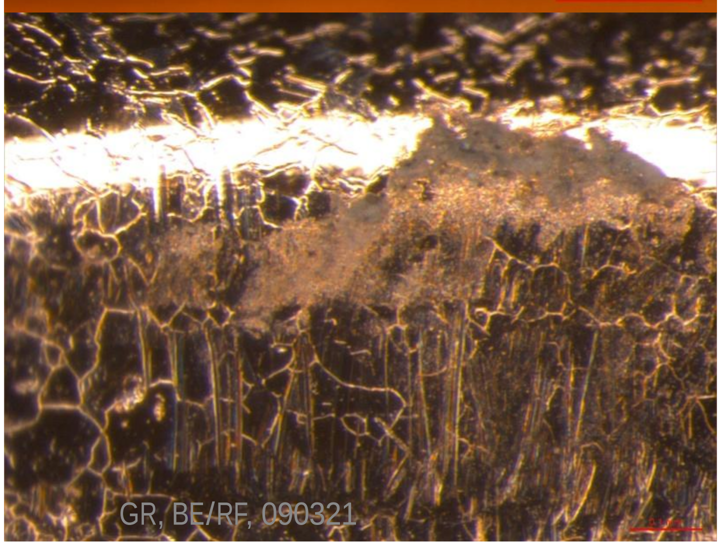
T24 undamped D = 45 mm

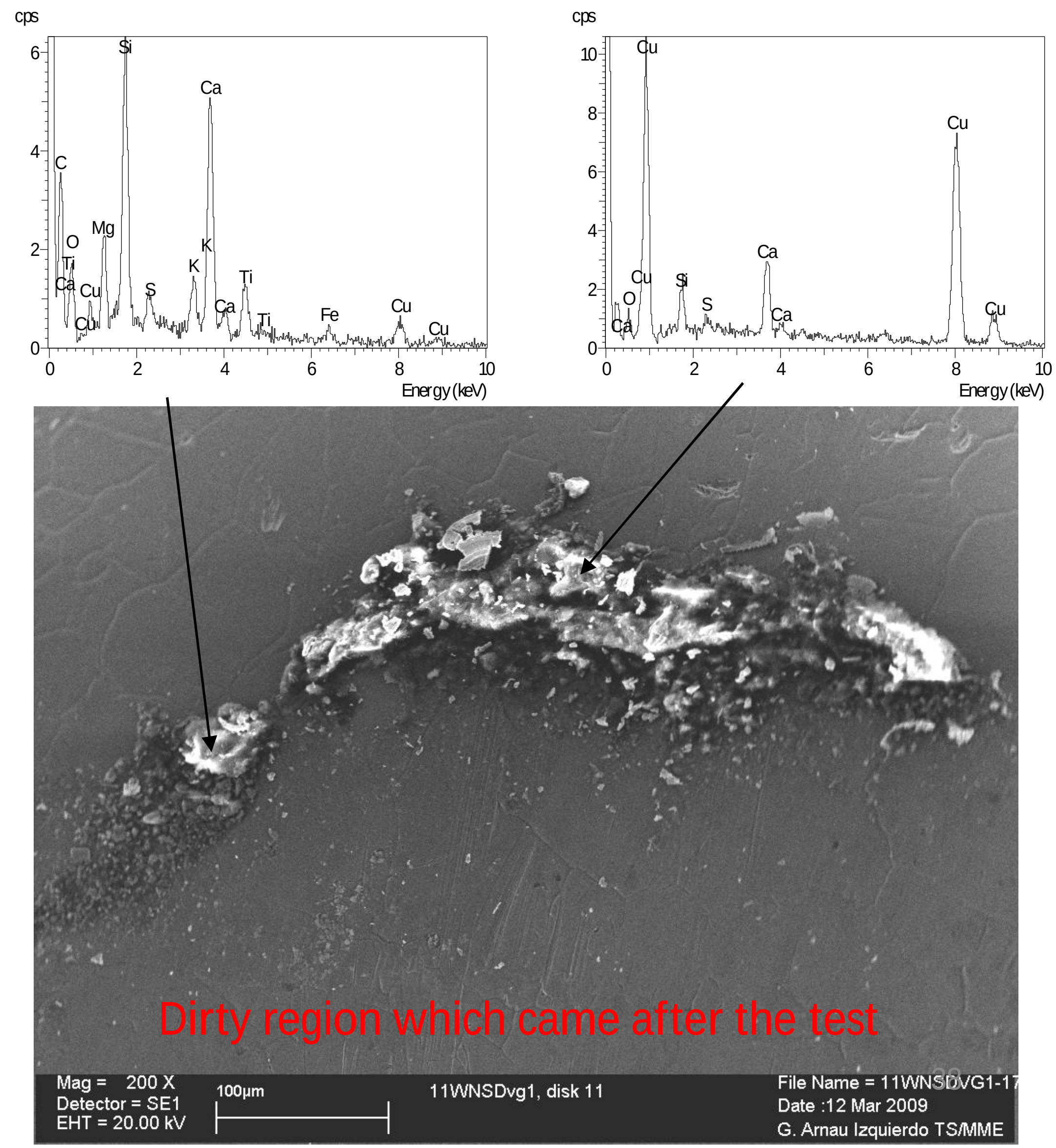


Disk	b	a	t	c_iris	wa	wb	g	H	L
3-1	10.508	3.307	1.753	0.175	0.788	0.914	6.972	8.825	11.141
3-2	10.484	3.289	1.738	0.174	0.782	0.906	7.003	8.740	11.488
3-3	10.451	3.252	1.707	0.171	0.768	0.889	7.026	8.733	11.499
3-4	10.438	3.218	1.677	0.168	0.754	0.872	7.056	8.733	11.512
3-5	10.425	3.178	1.646	0.165	0.741	0.856	7.087	8.733	11.525
3-6	10.413	3.143	1.615	0.162	0.727	0.839	7.117	8.733	11.537
3-7	10.400	3.108	1.585	0.158	0.713	0.822	7.148	8.733	11.550
3-8	10.389	3.070	1.554	0.155	0.699	0.806	7.178	8.733	11.562
3-9	10.379	3.033	1.524	0.152	0.686	0.789	7.209	8.733	11.574
3-10	10.365	2.997	1.493	0.149	0.672	0.772	7.240	8.733	11.585
3-11	10.353	2.960	1.463	0.146	0.658	0.756	7.270	8.733	11.597
3-12	10.342	2.924	1.432	0.143	0.644	0.739	7.301	8.733	11.608
3-13	10.331	2.887	1.402	0.140	0.631	0.723	7.331	8.733	11.618
3-14	10.321	2.850	1.371	0.137	0.617	0.706	7.362	8.733	11.629
3-15	10.310	2.814	1.340	0.134	0.603	0.689	7.392	8.733	11.640
3-16	10.300	2.777	1.310	0.131	0.589	0.673	7.423	8.733	11.650
3-17	10.290	2.741	1.279	0.128	0.576	0.656	7.453	8.733	11.660
3-18	10.281	2.704	1.249	0.125	0.562	0.640	7.484	8.733	11.669
3-19	10.271	2.668	1.218	0.122	0.548	0.623	7.515	8.733	11.679
3-20	10.262	2.631	1.188	0.119	0.534	0.607	7.545	8.733	11.688
3-21	10.253	2.595	1.157	0.116	0.521	0.590	7.576	8.733	11.697
3-22	10.245	2.558	1.126	0.113	0.507	0.574	7.606	8.733	11.705
3-23	10.236	2.522	1.096	0.110	0.493	0.557	7.637	8.733	11.714
3-24	10.228	2.485	1.065	0.107	0.479	0.541	7.667	8.733	11.722
3-25	10.220	2.457	1.050	0.105	0.473	0.533	7.680	8.740	11.730
3-26	10.504	4.993	1.300	0.130	0.666	0.834	7.573	8.873	11.448

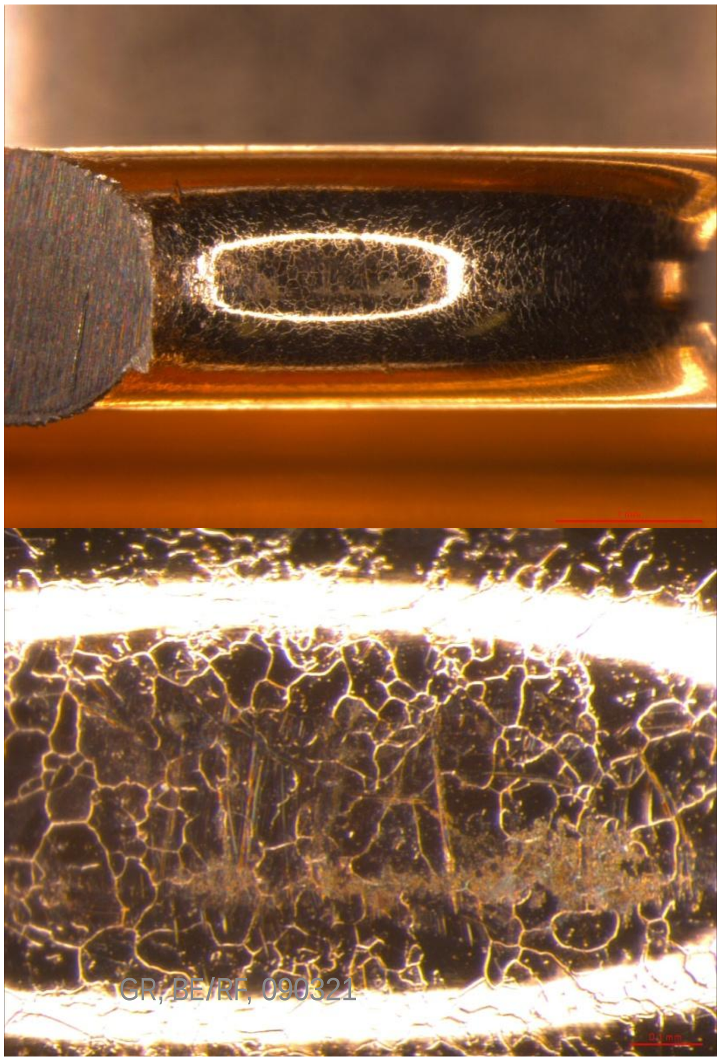
Inspection on iris 11

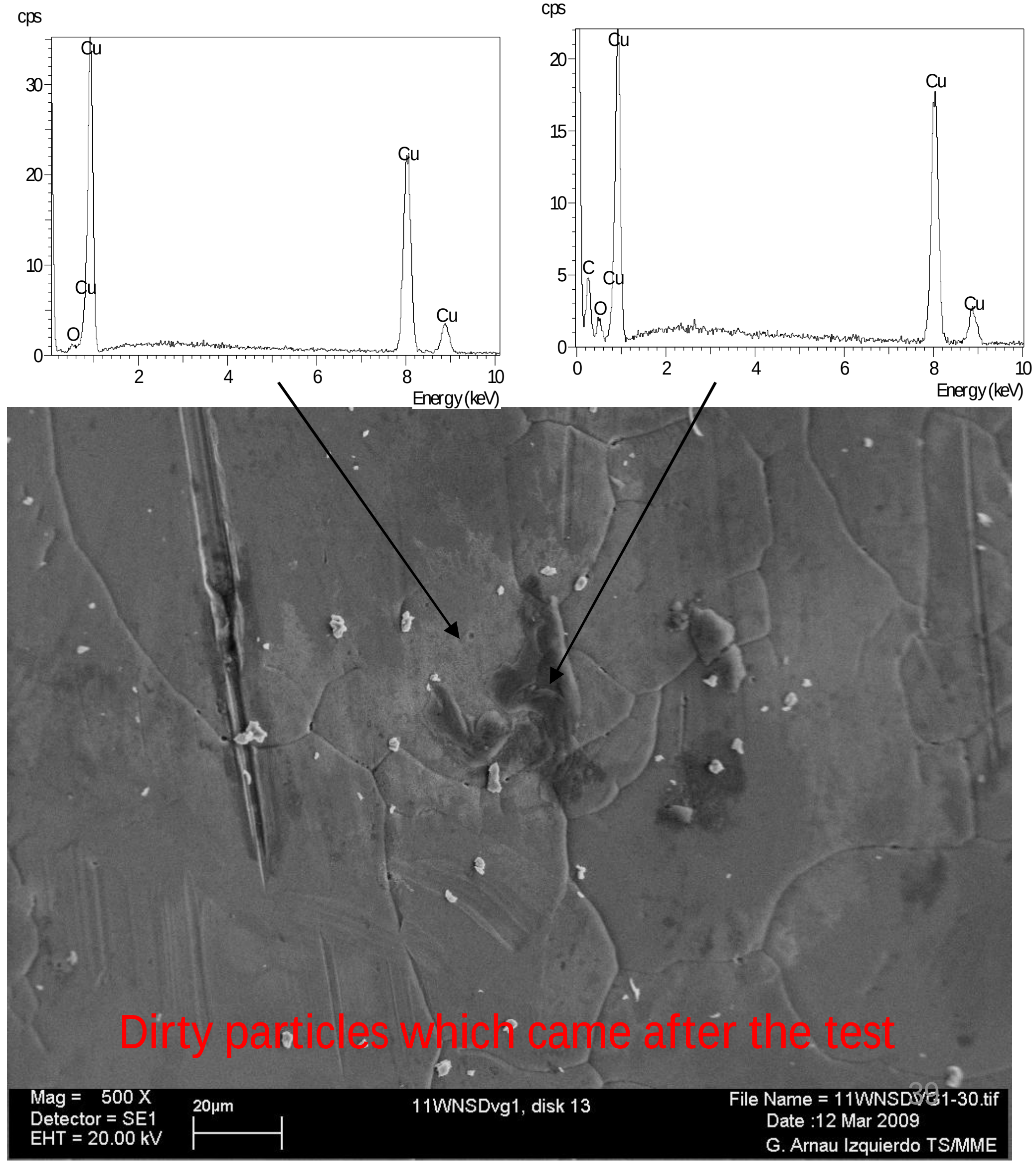




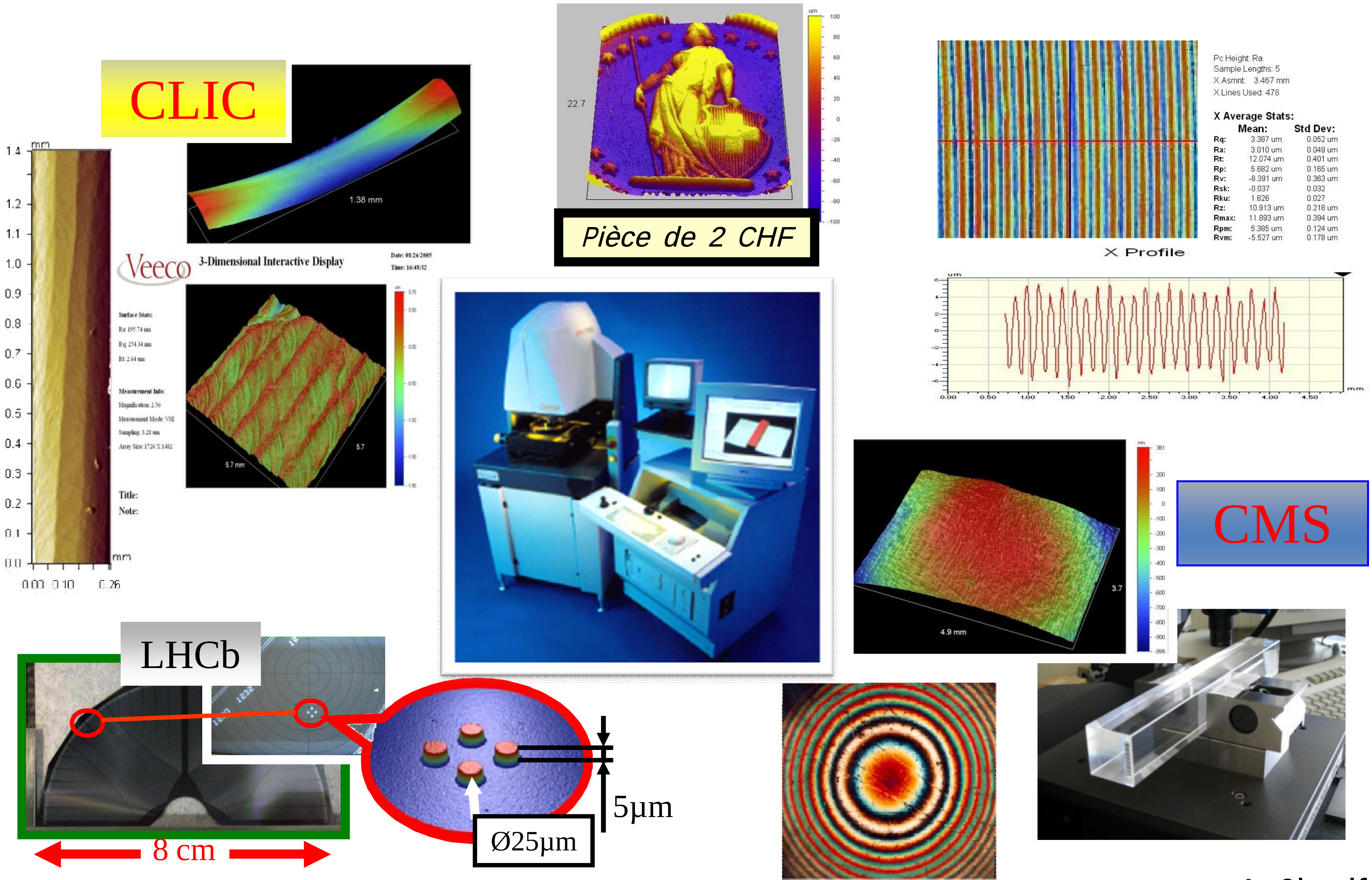


Inspection on iris 13





Rugosimètre – profilomètre optique VEECO NT3300



A. Cherif

3-Dimensional Interactive Display

Date: 11/03/2009

Time: 13:22:29

Surface Stats:

Ra: 820.66 nm

Rq: 968.11 nm

Rt: 17.67 um

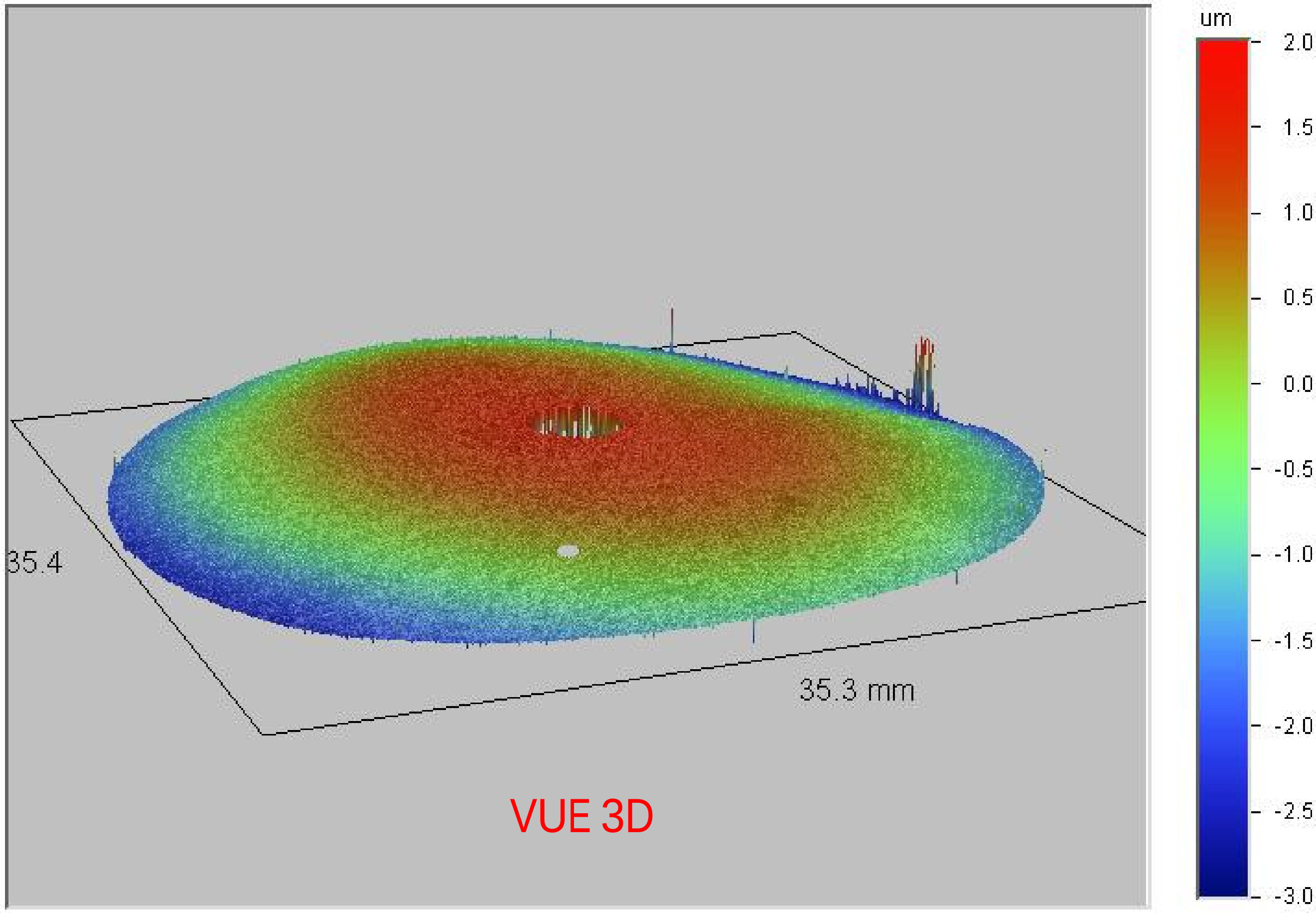
Measurement Info:

Magnification: 2.56

Measurement Mode: VSI

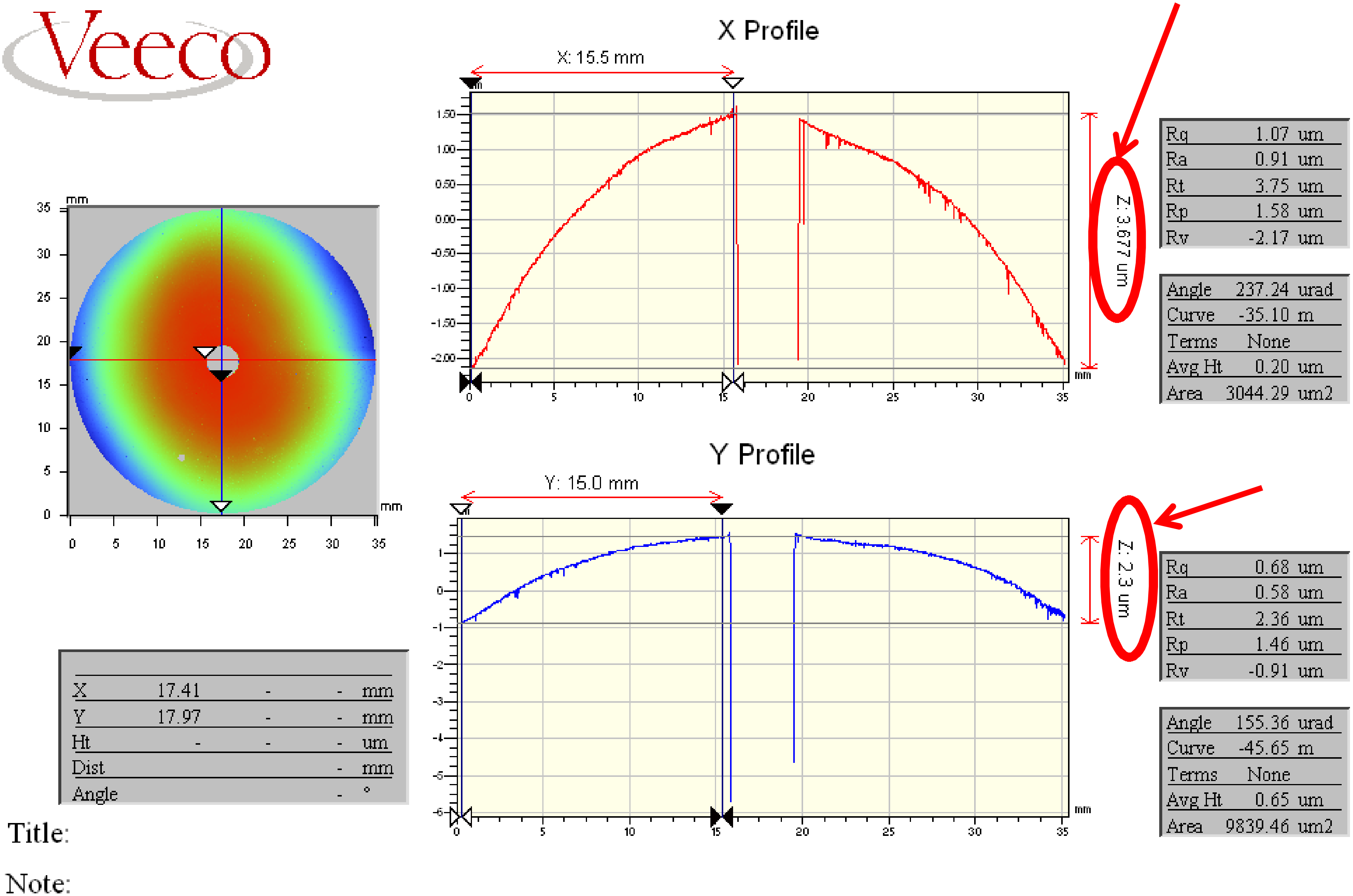
Sampling: 13.10 um

Array Size: 2695 X 2314

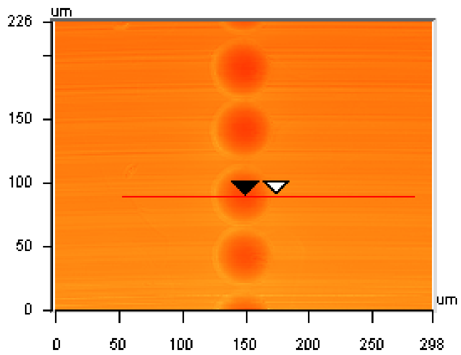


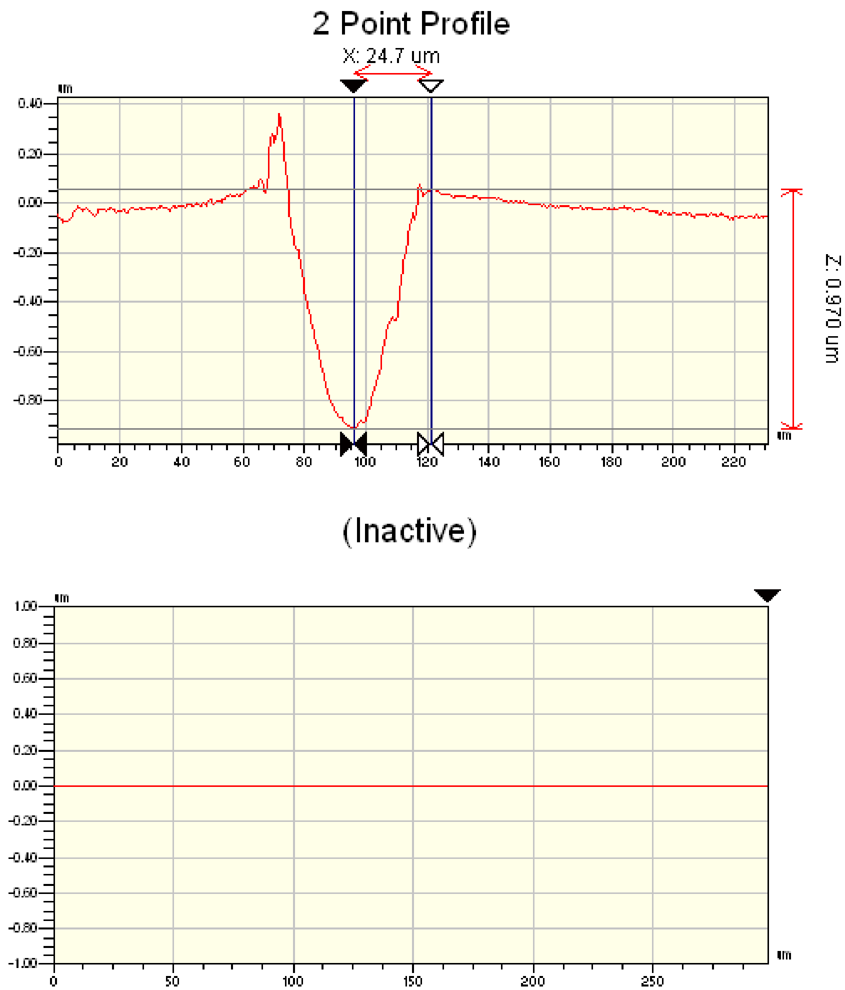
Title:

Note:


Veeco
X Profile
X: 15.5 mm
Z: 3.677 um
Rq 1.07 um
Ra 0.91 um
Rt 3.75 um
Rp 1.58 um
Rv -2.17 um
Angle 237.24 urad
Curve -35.10 m
Terms None
Avg Ht 0.20 um
Area 3044.29 um2
Y Profile
Y: 15.0 mm
Z: 2.3 um
Rq 0.68 um
Ra 0.58 um
Rt 2.36 um
Rp 1.46 um
Rv -0.91 um
Angle 155.36 urad
Curve -45.65 m
Terms None
Avg Ht 0.65 um
Area 9839.46 um2
X 17.41 - - mm
Y 17.97 - - mm
Ht - - - um
Dist - mm
Angle - °
Title:
Note:

A. Cherif





Title: Extremity cell B

Note: Piece 2 (11WNSDVG1.8)

Marques dues au palpeur

A. Cherif