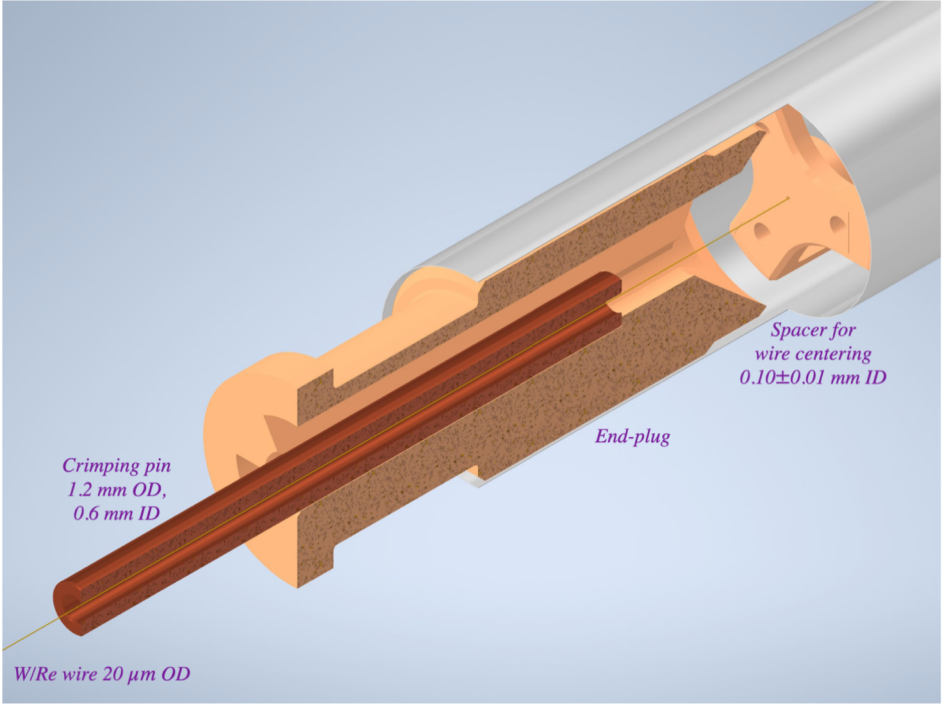


# Test of straw components at CERN

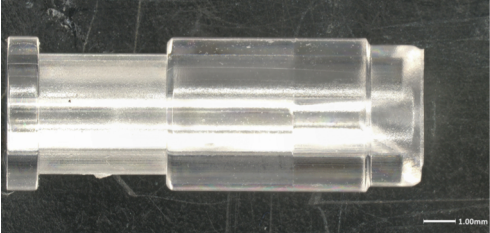
STT working group, 07/08/2024

Katie Buchanan, EN/MME/MM

# Introduction- New samples



## 1- End plug



Hold the pin and allowing gas flow: transparent PC, manufactured using injection molding

- Dimensional assessment
- Comparison of the batch

## 2- Crimping pin



Fix to the wire, made of Cu-DHP with 99.90 gold plated 0.05 μm

- Coating assessment
- Surface roughness
- Dimensional control

## 3- Spacer for wire centering



Spacer to center the wire with respect to the straw, made with black PC, manufactured using injection molding

- - External diameter on the plane of the central hole (nominal 4.88+0.0-0.03 mm)
- - Smoothness of the external surface (for the 3 "legs"), which will be in contact with the straw (nominal 0.25 μm)
- - Diameter, centering, and smoothness of the edge for the central hole (nominal diameter 0.10+-0.010 mm)

## 4- Straw material and welds

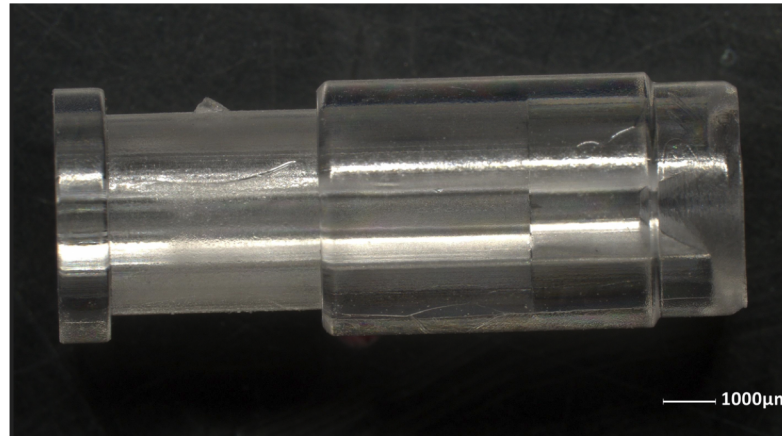


The straw film has a base Hostaphan RNK19, 19 μm thick with double coating with 70 nm of Al on each side, ultrasonically welded

- Raw material assessment
  - Green vs red
- Weld assessment

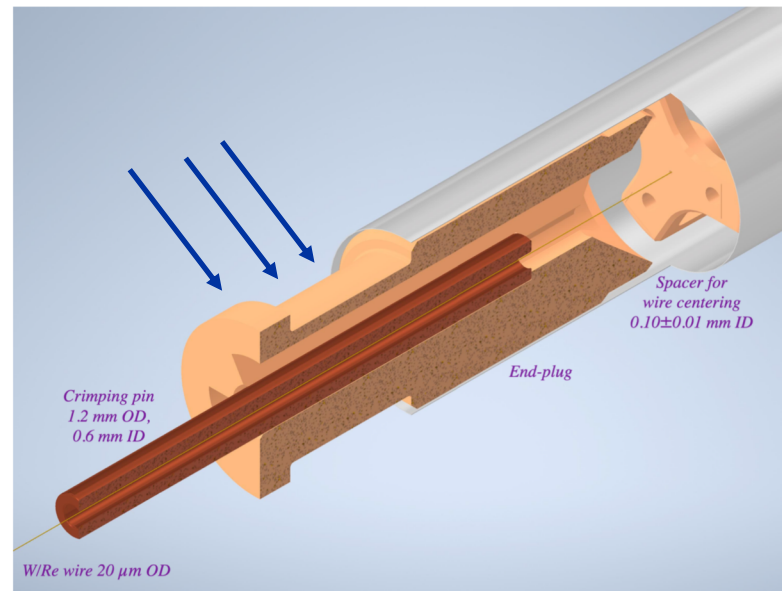


# 1. End plug

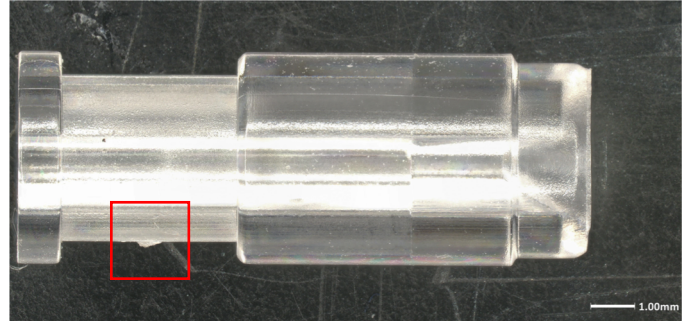
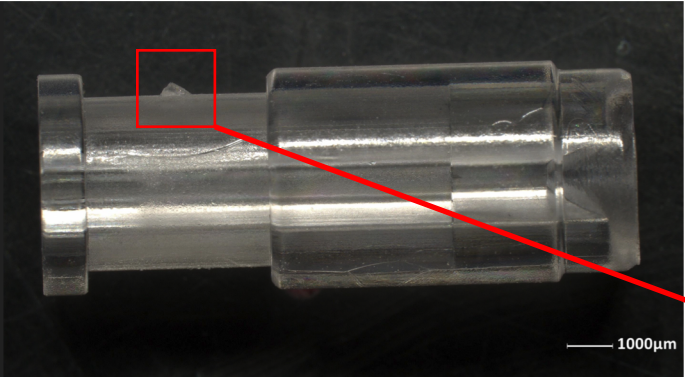


Hold the pin and allowing gas flow: transparent PC, manufactured by injection molding

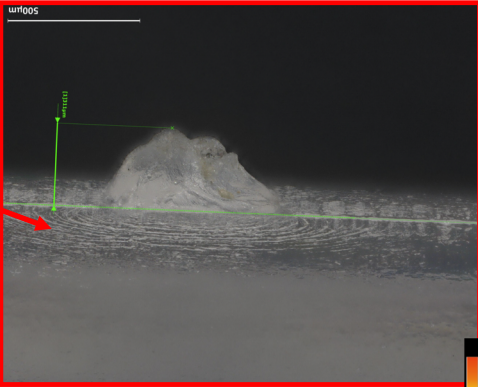
- Dimensional assessment
- Comparison of the batch



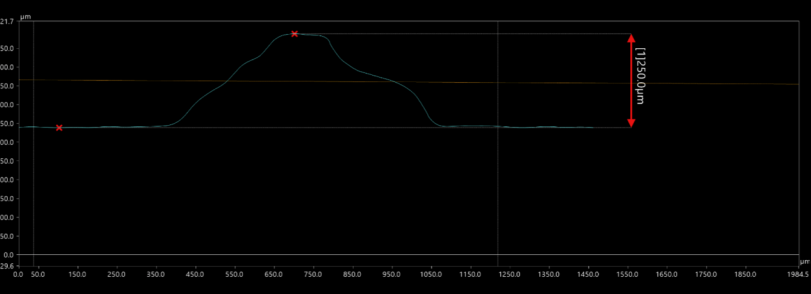
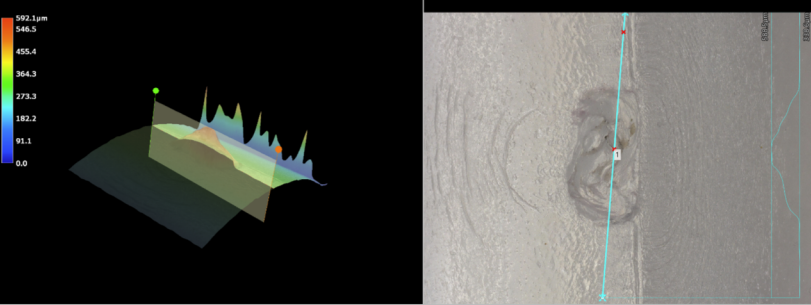
# 1- End plug- Visual inspection



- Small sharp nodule noted on all of the supplied end plugs, remaindered of the injection molding?
- Of the inspected, non of the sharp edges exceed the outer thickness of the part



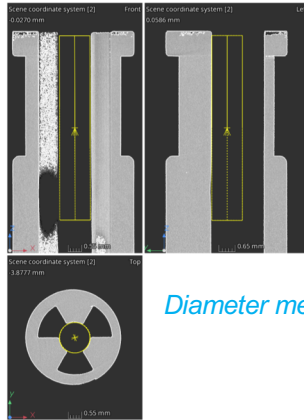
- The largest height of the imperfection measured was + 0.311 mm measured on the Keyence, due to the surface this measurement is to be taken as a maximum.
- This imperfection needs to be monitored due to the tolerance of the step being 1 mm.



# 1- End plug- Metrology inspection

## Sample 1

Project name: ...OTHERS/EDMS.3140304 [3093575 - 2x wire placers/4] VG files/2x wire placers.vgl  
 Scene path: ROI from volume - Part 1 - Coordinate measurement  
 Section: Geometry element images

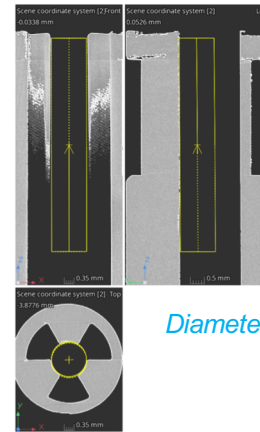


Date:	8/1/24 11:13 AM
Serial number:	2x wire placers AFC
Object evaluation state:	No tolerance
Scene evaluation state:	No tolerance
Name: Geometry element focused image	
Rule name:	n/a
View type:	Orthographic projection
Type:	Detail zoom
Creation reason:	Manual
Name: Cylinder 2	
Status:	OK
Type:	Cylinder
Position x [mm]:	0.2586
Position y [mm]:	-0.0270
Position z [mm]:	-3.8777
Radius [mm]:	0.6114
Construction method:	Maximum-inscribed fitted

Diameter measured = 1.22 mm

## Sample 2

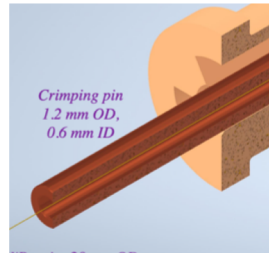
Project name: ...OTHERS/EDMS.3140304 [3093575 - 2x wire placers/4] VG files/2x wire placers.vgl  
 Scene path: ROI from volume - Part 2 - Coordinate measurement  
 Section: Geometry element images



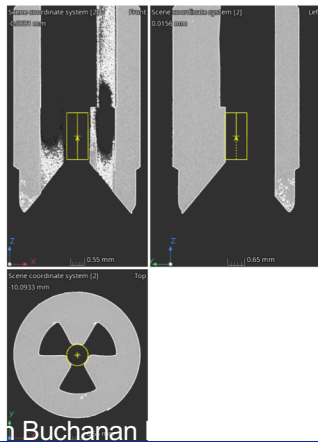
Date:	8/1/24 11:28 AM
Serial number:	2x wire placers AFC
Object evaluation state:	No tolerance
Scene evaluation state:	No tolerance
Name: Geometry element focused image	
Rule name:	n/a
View type:	Orthographic projection
Type:	Detail zoom
Creation reason:	Manual
Name: Cylinder 2	
Status:	OK
Type:	Cylinder
Position x [mm]:	0.0526
Position y [mm]:	-0.2338
Position z [mm]:	-3.8776
Radius [mm]:	0.6067
Construction method:	Maximum-inscribed fitted

Diameter measured = 1.21 mm

Outer diameter of Cu pin set to be 1.2 meaning the tolerance of the diameter of the hole  $\geq 1.22$  mm with a very small  $\pm$  tolerance



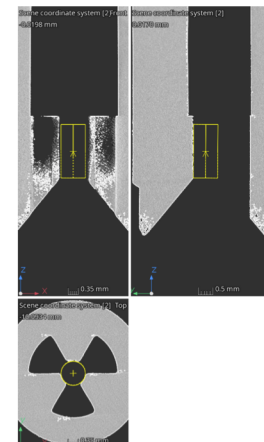
Project name: ...OTHERS/EDMS.3140304 [3093575 - 2x wire placers/4] VG files/2x wire placers.vgl  
 Scene path: ROI from volume - Part 1 - Coordinate measurement  
 Section: Geometry element images



Date:	8/1/24 11:13 AM
Serial number:	2x wire placers AFC
Object evaluation state:	No tolerance
Scene evaluation state:	No tolerance
Name: Geometry element focused image	
Rule name:	n/a
View type:	Orthographic projection
Type:	Detail zoom
Creation reason:	Manual
Name: Cylinder 3	
Status:	OK
Type:	Cylinder
Position x [mm]:	0.0156
Position y [mm]:	-0.0281
Position z [mm]:	-10.0933
Radius [mm]:	0.4104
Construction method:	Maximum-inscribed fitted

Diameter measured = 0.82 mm

Project name: ...OTHERS/EDMS.3140304 [3093575 - 2x wire placers/4] VG files/2x wire placers.vgl  
 Scene path: ROI from volume - Part 2 - Coordinate measurement  
 Section: Geometry element images

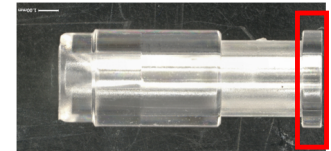
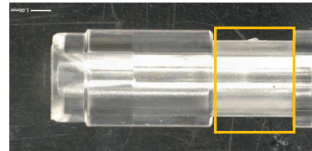
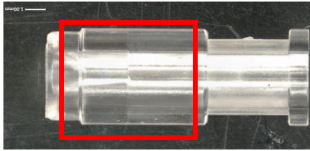


Date:	8/1/24 11:28 AM
Serial number:	2x wire placers AFC
Object evaluation state:	No tolerance
Scene evaluation state:	No tolerance
Name: Geometry element focused image	
Rule name:	n/a
View type:	Orthographic projection
Type:	Detail zoom
Creation reason:	Manual
Name: Cylinder 3	
Status:	OK
Type:	Cylinder
Position x [mm]:	0.0170
Position y [mm]:	-0.0198
Position z [mm]:	-10.0934
Radius [mm]:	0.4070
Construction method:	Maximum-inscribed fitted

Diameter measured = 0.81 mm



# 1- End plug- Metrology inspection



Diameter of 4.88  
+0.0-0.03 mm as  
per the data sheet  
is expected for the  
spacer therefore  
the same  
tolerance are  
used for the larger  
diameter of the  
end plugs



Sample 1

Sample 2

Project name: ...OTHERS/EDMS3140304/2003075 - 2x wire placers[4] VG Rlec2x wire placers.vg  
Scene path: RCI from volume - Part 1 - Coordinate measurement  
Section: Feature images

Date: 8/1/24 11:13 AM  
Serial number: 2x wire placers A/C  
Object evaluation state: No tolerance  
Scene evaluation state: No tolerance

Name	Feature Image
Rule name	rlc
View type	Right
Type	Detail
Creation reason	Manual

Name: Feature 1  
Type: Diameter  
Source A: Cylinder 1  
Actual value [mm/deg]: 4.8420 mm

Project name: ...OTHERS/EDMS3140304/2003075 - 2x wire placers[4] VG Rlec2x wire placers.vg  
Scene path: RCI from volume - Part 1 - Coordinate measurement  
Section: Feature images

Date: 8/1/24 11:13 AM  
Serial number: 2x wire placers A/C  
Object evaluation state: No tolerance  
Scene evaluation state: No tolerance

Name	Feature Image
Rule name	rlc
View type	Right
Type	Detail
Creation reason	Manual

Name: Feature 3  
Type: Diameter  
Source A: Cylinder 3  
Actual value [mm/deg]: 3.8115 mm

Project name: ...OTHERS/EDMS3140304/2003075 - 2x wire placers[4] VG Rlec2x wire placers.vg  
Scene path: RCI from volume - Part 1 - Coordinate measurement  
Section: Feature images

Date: 8/1/24 11:13 AM  
Serial number: 2x wire placers A/C  
Object evaluation state: No tolerance  
Scene evaluation state: No tolerance

Name	Feature Image
Rule name	rlc
View type	Right
Type	Detail
Creation reason	Manual

Name: Feature 5  
Type: Diameter  
Source A: Cylinder 5  
Actual value [mm/deg]: 4.8825 mm

Project name: ...OTHERS/EDMS3140304/2003075 - 2x wire placers[4] VG Rlec2x wire placers.vg  
Scene path: RCI from volume - Part 2 - Coordinate measurement  
Section: Feature images

Date: 8/1/24 11:28 AM  
Serial number: 2x wire placers A/C  
Object evaluation state: No tolerance  
Scene evaluation state: No tolerance

Name	Feature Image
Rule name	rlc
View type	Right
Type	Detail
Creation reason	Manual

Group: Feature 1  
Name: Diameter  
Coordinate system: Scene coordinate system  
Actual value [mm/deg]: 4.8663 mm  
Nominal value [mm/deg]:  
Tolerance [H] [mm/deg]:  
Tolerance [h] [mm/deg]:

Project name: ...OTHERS/EDMS3140304/2003075 - 2x wire placers[4] VG Rlec2x wire placers.vg  
Scene path: RCI from volume - Part 2 - Coordinate measurement  
Section: Feature images

Date: 8/1/24 11:28 AM  
Serial number: 2x wire placers A/C  
Object evaluation state: No tolerance  
Scene evaluation state: No tolerance

Name	Feature Image
Rule name	rlc
View type	Right
Type	Detail
Creation reason	Manual

Group: Feature 5  
Name: Diameter  
Coordinate system: Scene coordinate system  
Actual value [mm/deg]: 3.8235 mm  
Nominal value [mm/deg]:  
Tolerance [H] [mm/deg]:  
Tolerance [h] [mm/deg]:

Project name: ...OTHERS/EDMS3140304/2003075 - 2x wire placers[4] VG Rlec2x wire placers.vg  
Scene path: RCI from volume - Part 2 - Coordinate measurement  
Section: Feature images

Date: 8/1/24 11:28 AM  
Serial number: 2x wire placers A/C  
Object evaluation state: No tolerance  
Scene evaluation state: No tolerance

Name	Feature Image
Rule name	rlc
View type	Right
Type	Detail
Creation reason	Manual

Group: Feature 6  
Name: Diameter  
Coordinate system: Scene coordinate system  
Actual value [mm/deg]: 4.8740 mm  
Nominal value [mm/deg]:  
Tolerance [H] [mm/deg]:  
Tolerance [h] [mm/deg]:

Average diameter = 4.855 ± 0.0165 mm

Average diameter = 3.8175 ± 0.008 mm

Average diameter = 4.8688 ± 0.074 mm

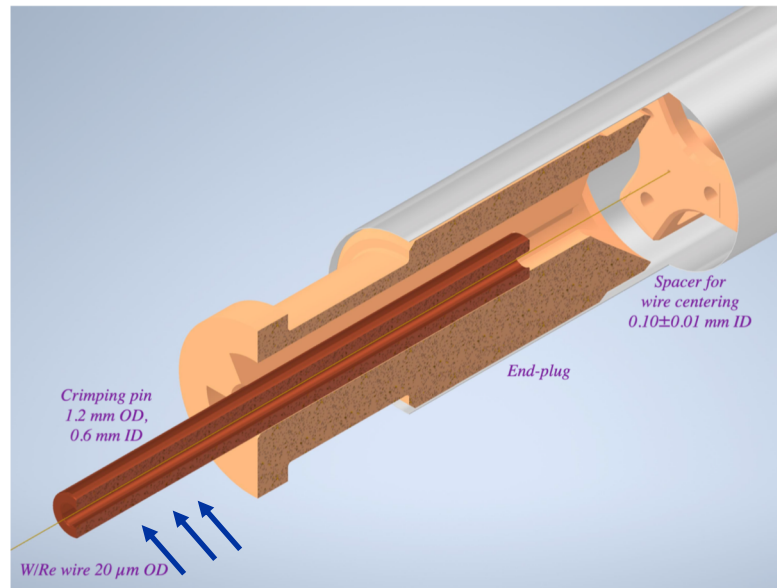




## 2. Crimping pin

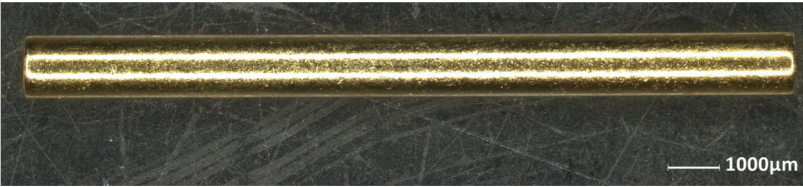
Fix to the wire, made of Cu-DHP with 99.90 % gold plated 0.05  $\mu\text{m}$

- Coating assessment
- Surface roughness
- Dimensional control



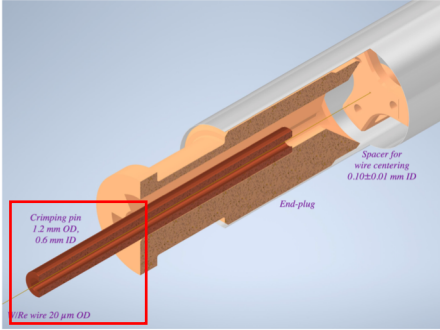
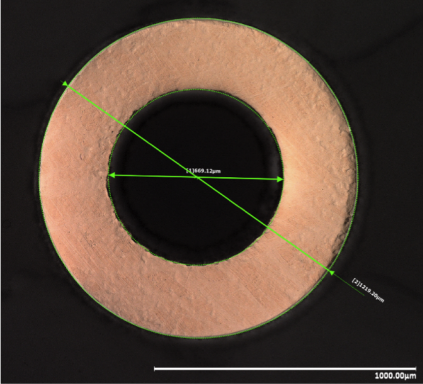
# 2- Crimping pin

## Geometry

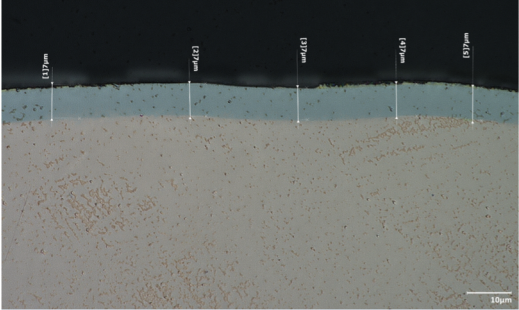


**External diameter**  
 Internally measured =  $1.211 \pm 0.0125 \text{ mm}$   
 Expected value =  $1.2 \text{ mm}$

**Internal diameter**  
 Internally measured =  $0.671 \pm 0.003 \text{ mm}$   
 Expected value =  $0.6 \text{ mm}$

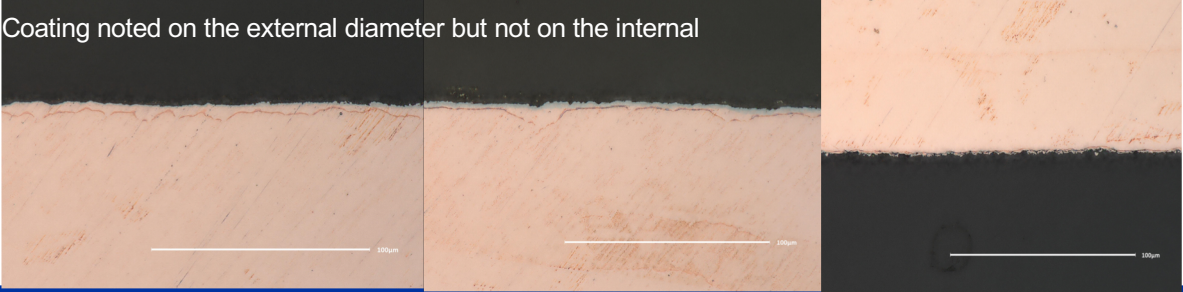


## Coating



**Coating**  
 Coating internally measured =  $0.671 \pm 0.003 \text{ mm}$   
 Expected value =  $0.6 \text{ mm}$

Sample coating has a very smooth homogeneous finish on the external diameter.



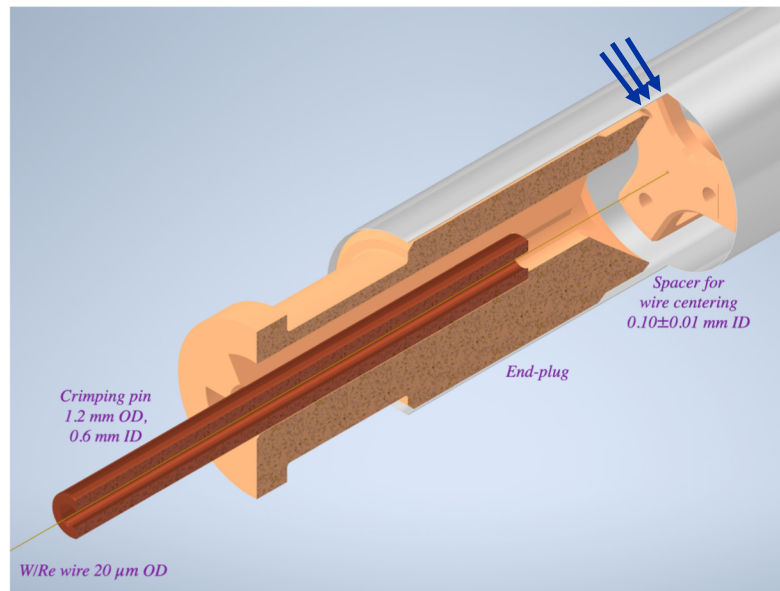


# 3. Spacer

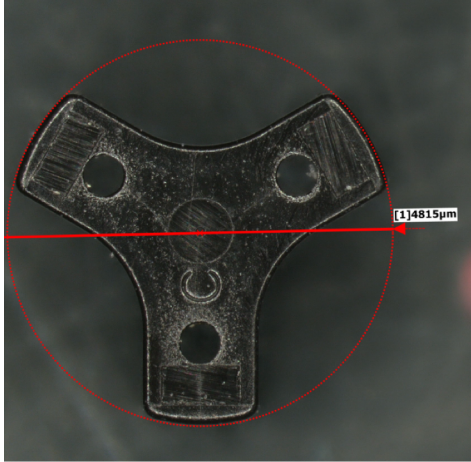


## Spacer to center the wire with respect to the straw, made with black PC

- - External diameter on the plane of the central hole (nominal  $4.88+0.0-0.03$  mm)
- - Smoothness of the external surface (for the 3 "legs"), which will be in contact with the straw (nominal  $Ra = 0.25$  µm)
- - Diameter, centering, and smoothness of the edge for the central hole (nominal diameter  $0.10+0.010$  mm)

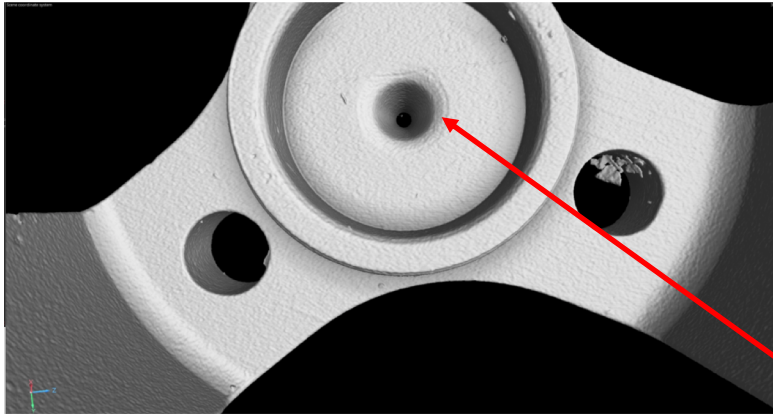
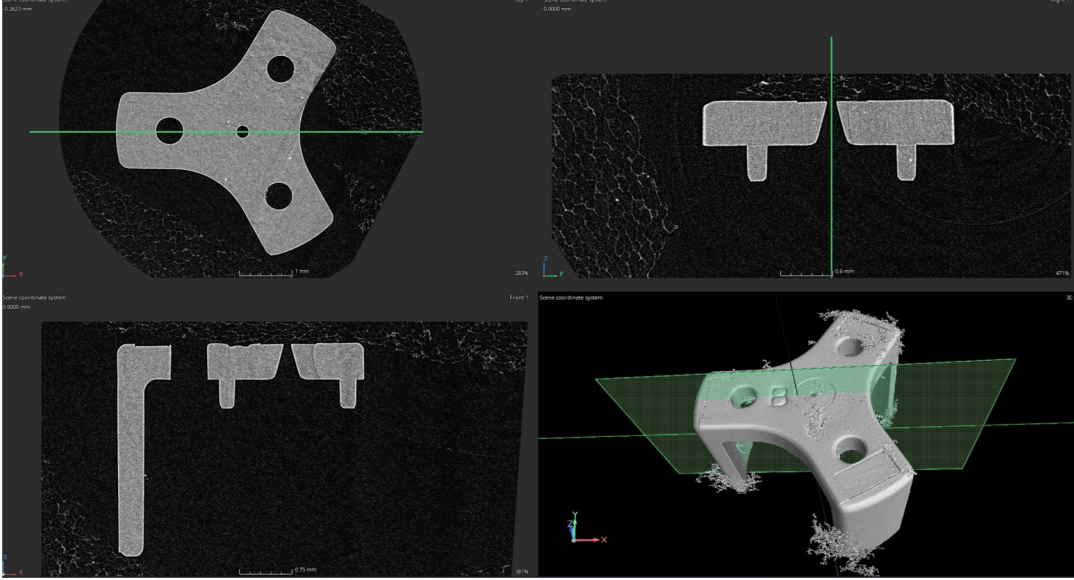


### 3- Spacer for wire centering



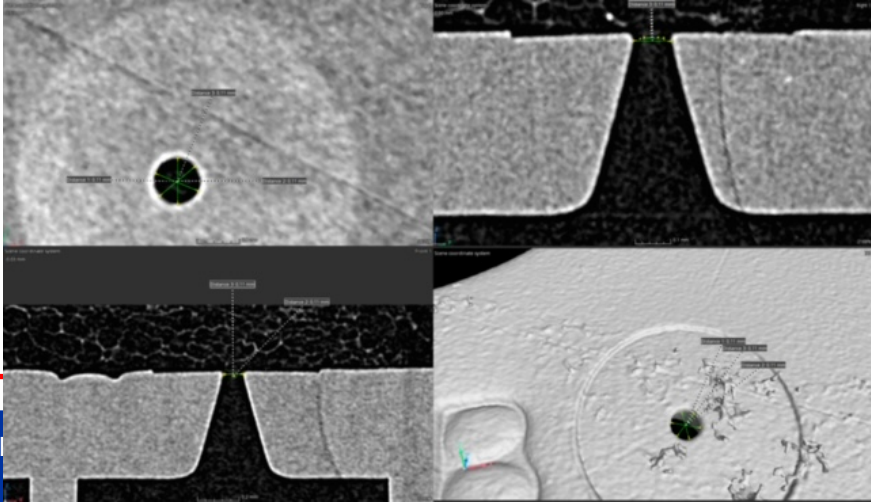
**Acceptance criteria:**  
 External diameter on the plane of the central hole (**nominal 4.88+0.0-0.03 mm**)

**Measured value:**  
 4.82 mm, other measuring technique needed to confirm the acceptance



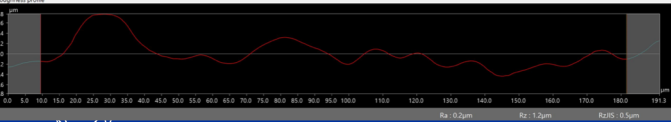
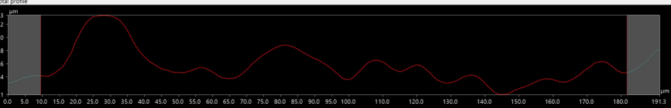
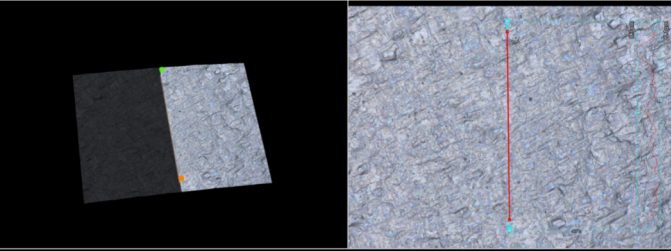
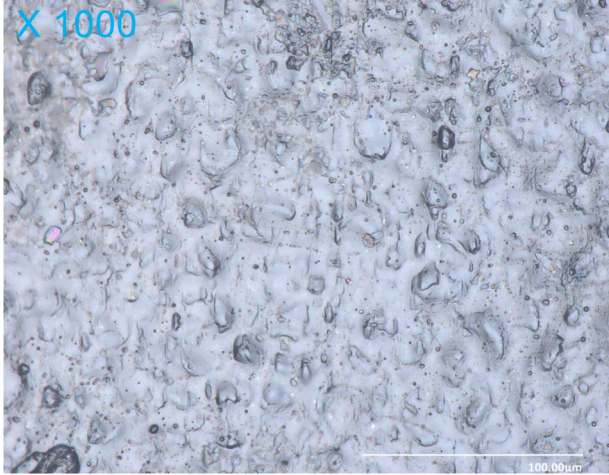
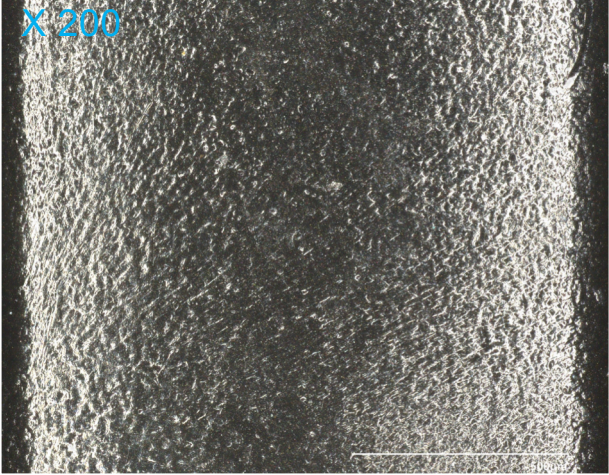
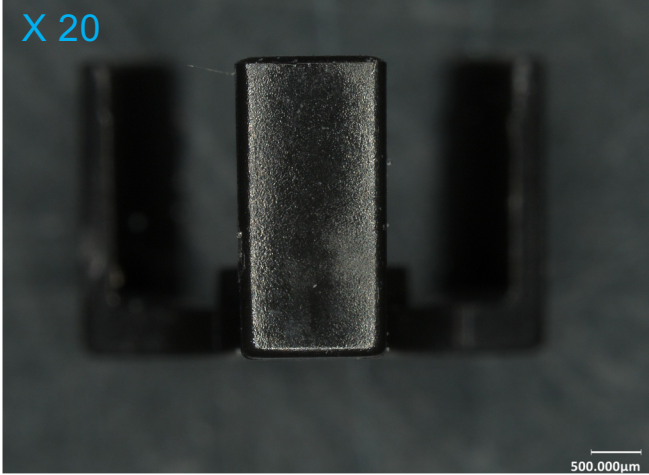
**Acceptance criteria:**  
 Diameter, centring, and smoothness of the edge for the central hole (**nominal diameter 0.10+0.010 mm**)

**Measured values:**  
 Central hole diameter = 0.11 mm, acceptable to standard  
 No sharp angled edges noted at the interfaces





# 3- Spacer for wire centering



Roughness values measured using Keyence VHX 7000, with a resolution of 0.1 µm

All leg roughness measurements had a value of **Ra = 0.2 µm**  
 Expected value from the data sheet was **0.25 µm, therefore acceptable**

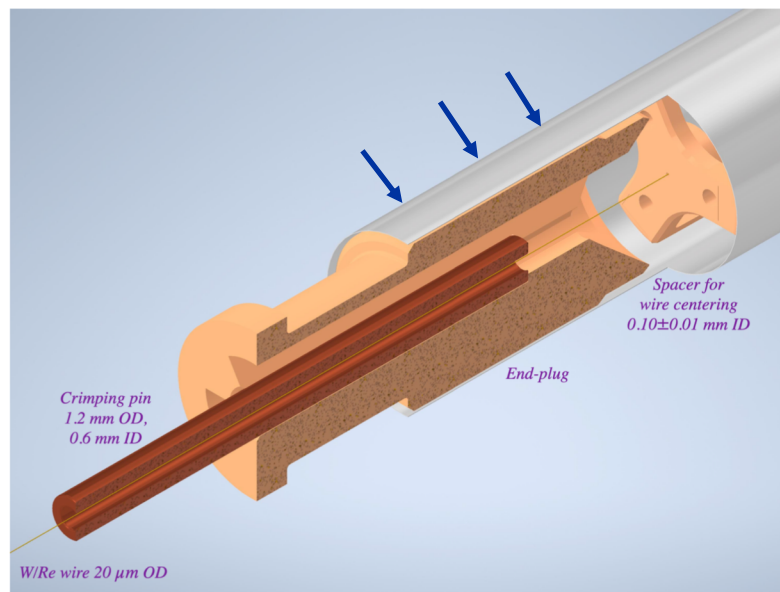
*(Other techniques are available for a higher resolution of results)*

# 4. Straw material & weld



The straw film has a base Hostaphan RNK19, 19  $\mu\text{m}$  thick with double coating with 70 nm of Al on each side, ultrasonically welded

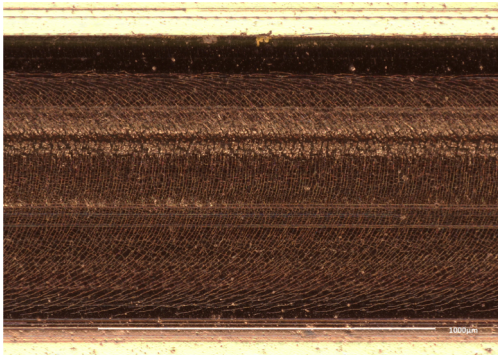
- Raw material assessment
  - Green vs red
- Weld assessment





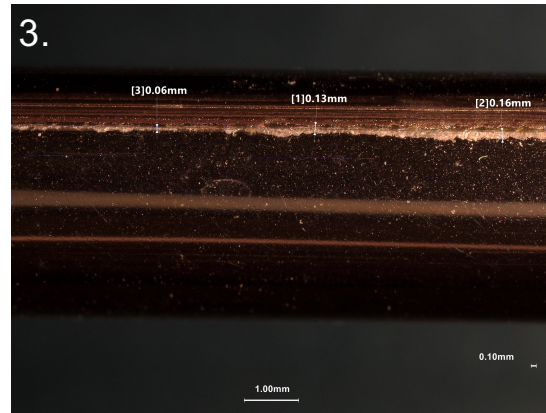
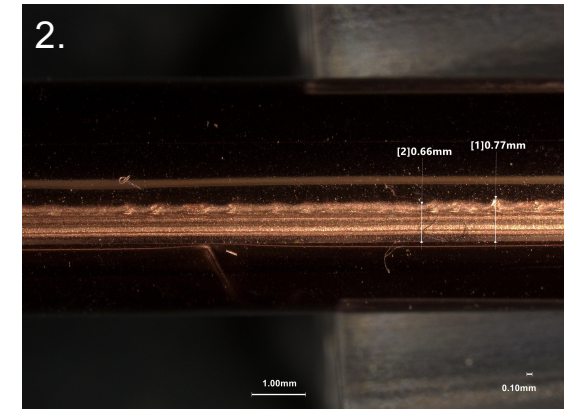
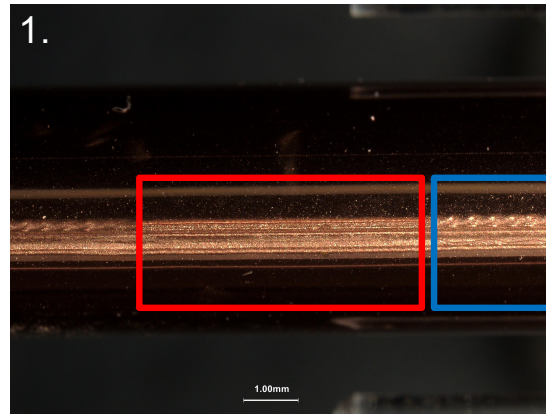
## 4. Welds (examples from NA 62)

### Successful weld



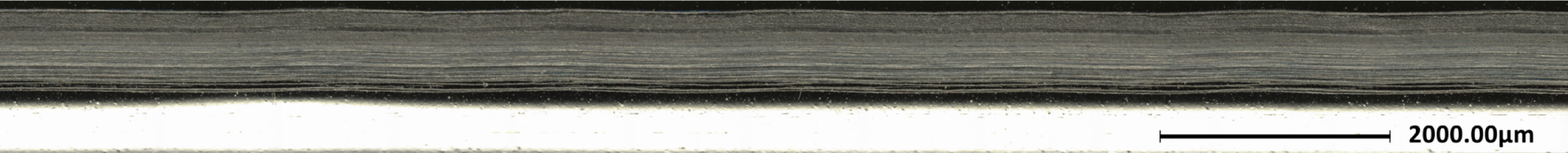
1. Strong consistent weld
2. No changes in the weld appearance/metallization

### Imperfections in weld

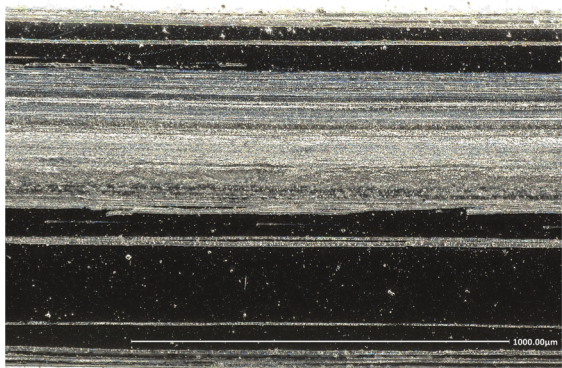
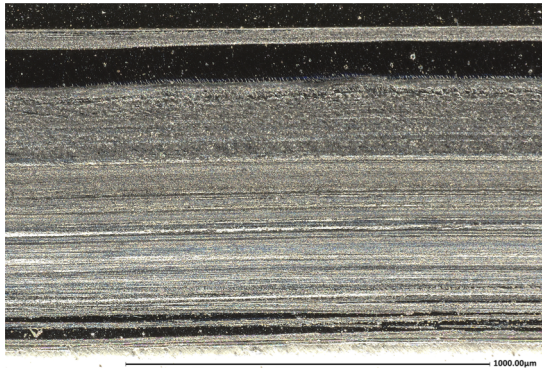
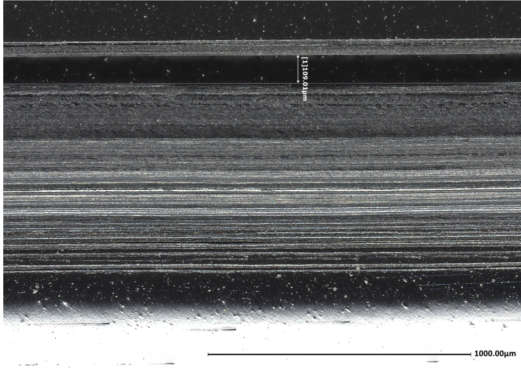


1. Different weld texture noted. Area has both straight (red box) and wave (blue box) like finishes
2. Welding width varies across the sample (660  $\mu\text{m}$  – 770  $\mu\text{m}$ )
3. Welding interfaces vary in thickness/height (60  $\mu\text{m}$  – 160  $\mu\text{m}$ )

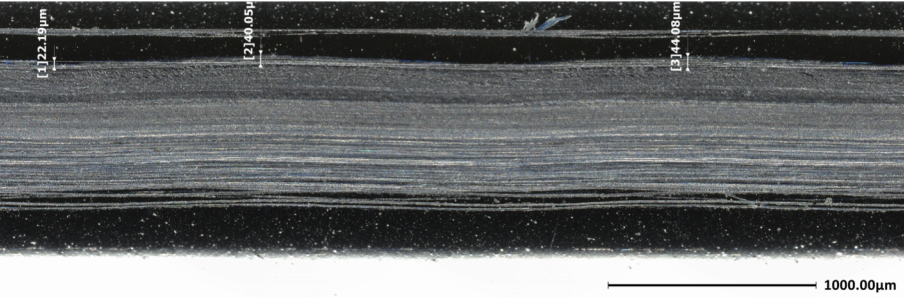
# 4. Welds- exterior



Good strong consistent weld with homogeneous and straight weld boundary's



Tooling marks noted neighboring the weld face



The average weld width measured to be 686.6 µm.

Slight wave noticed on the weld, ranging from +44 µm and - 22 µm of the mid point.



# 4. Welds- Cross section

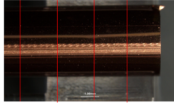
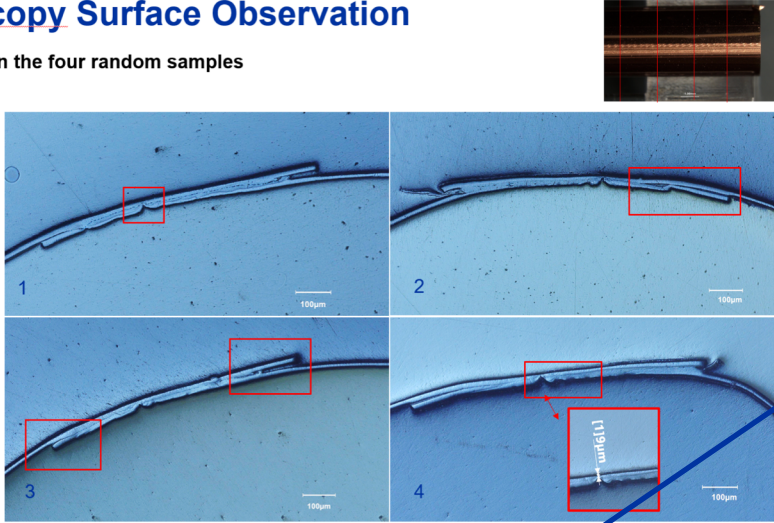
Acceptance and failure criteria based on the standard set on the NA 62 project

## Critical imperfections

### Digital Microscopy Surface Observation

Types of features found on the four random samples

- 1. Indented marks
- 2. Not enough contact at weld interface / Lack of binding
- 3. Unbonded extremities
- 4. Indented marks results in critical points

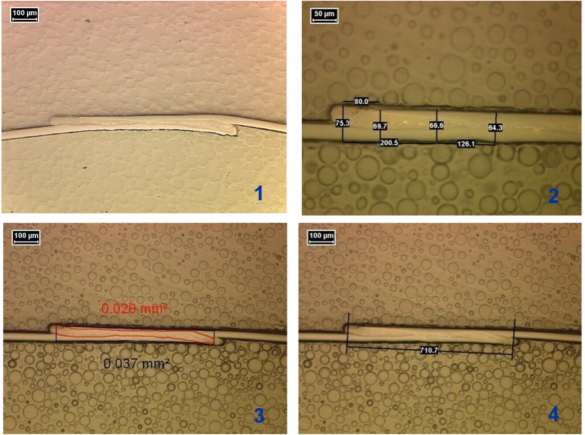


## Acceptance criteria

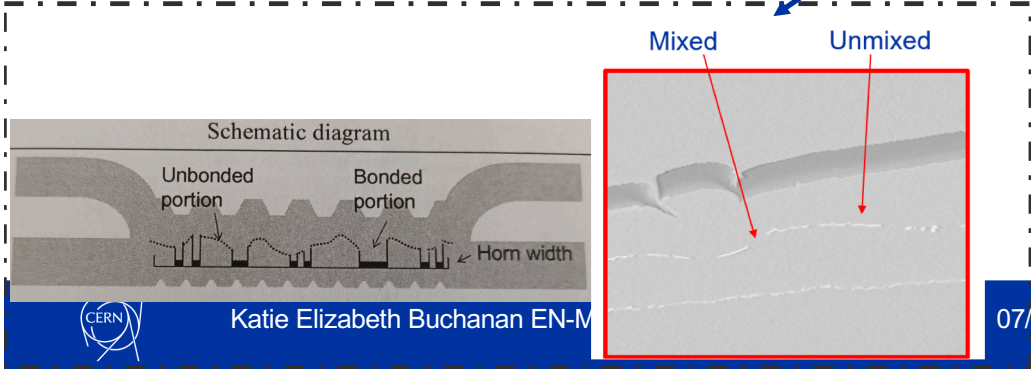
### Digital Microscopy Surface Observation

Criteria for a good weld from the previous study

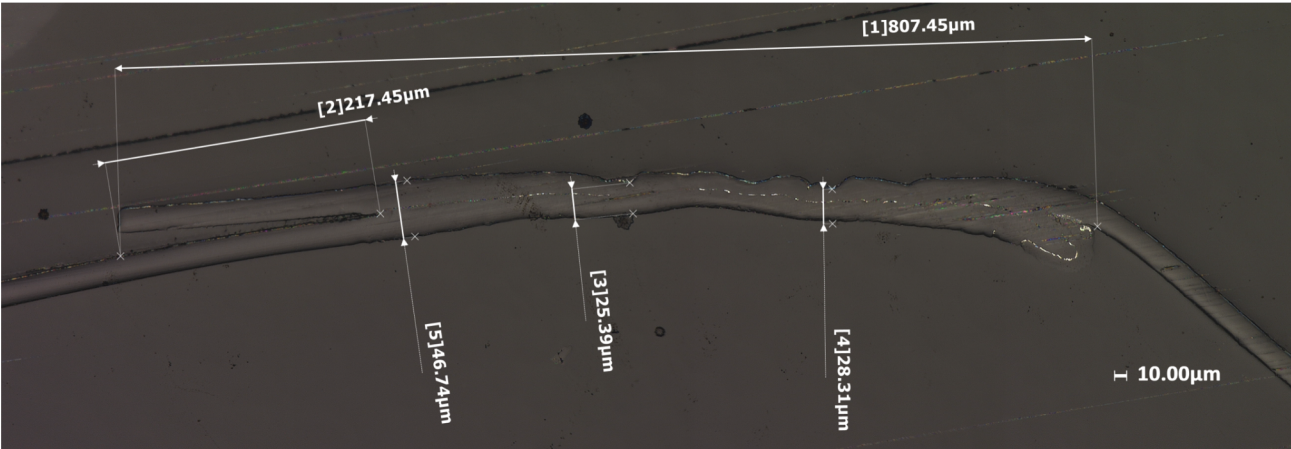
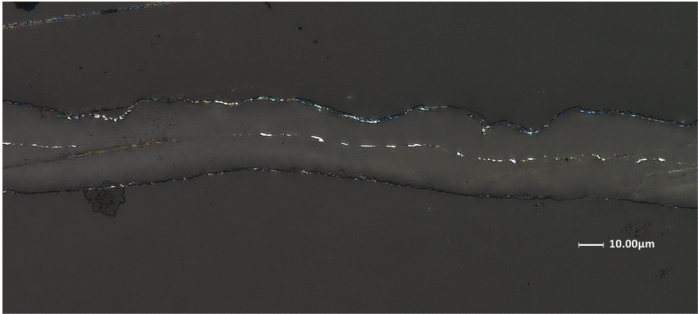
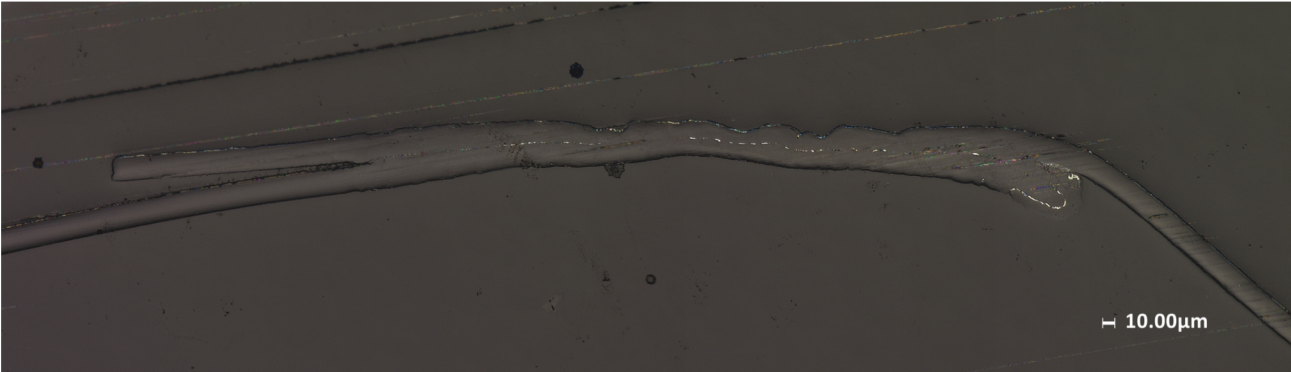
- For the 19 µm:
  - 1. No indented marks or critical points or damage to the substrate material
  - 2. Weld thickness > 36 µm
  - 3. Complete weld interface (> 50% contact)
  - 4. The entire weld nugget of the ultrasonic bonded area under the sonotrode > 600 µm



USW Teranology used was taken from relevant scientific publications published by the 'GM research & development centre'



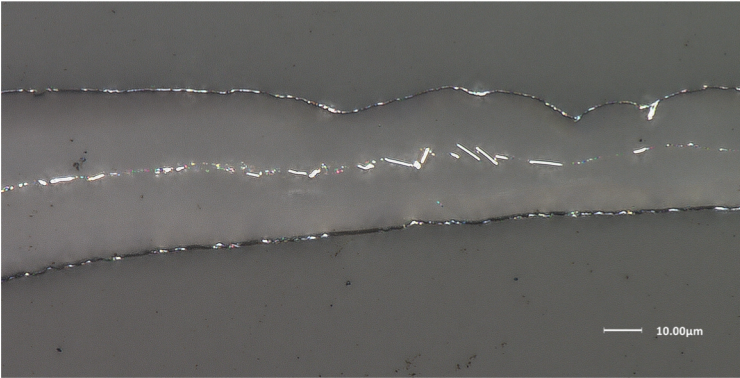
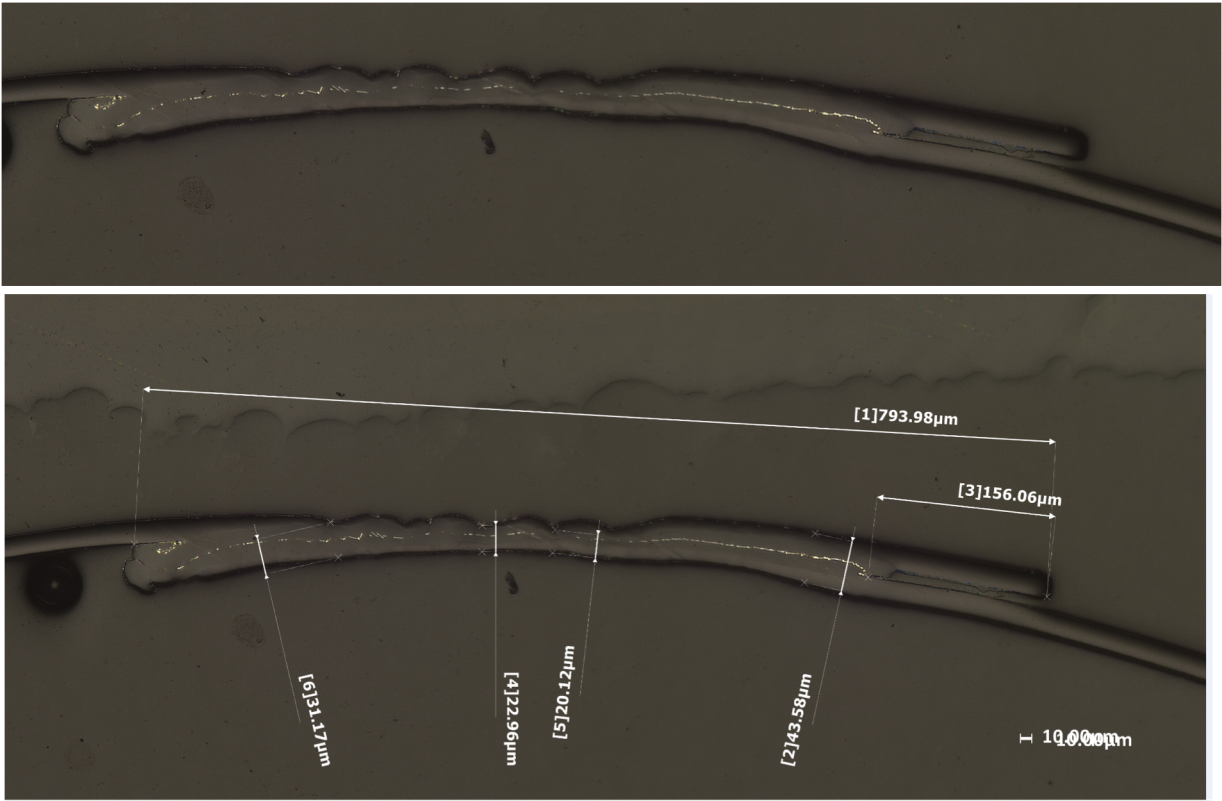
# Weld cross sections -1



- Slight indications of critical marks, reducing the thickness to **28 μm** but not completely critical
- Average weld thickness measured at **33.48 μm**.
- Completed weld interface ~ **75 %**, being **590 μm**, slightly under **600 μm**

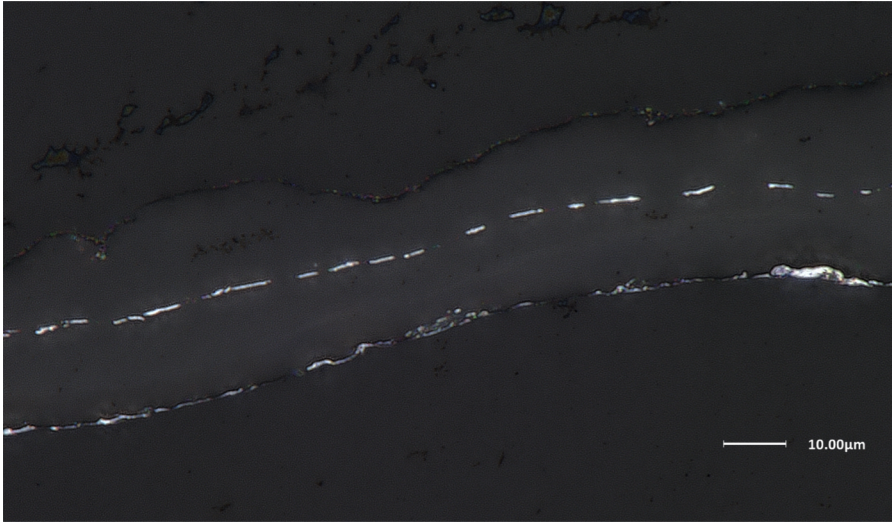
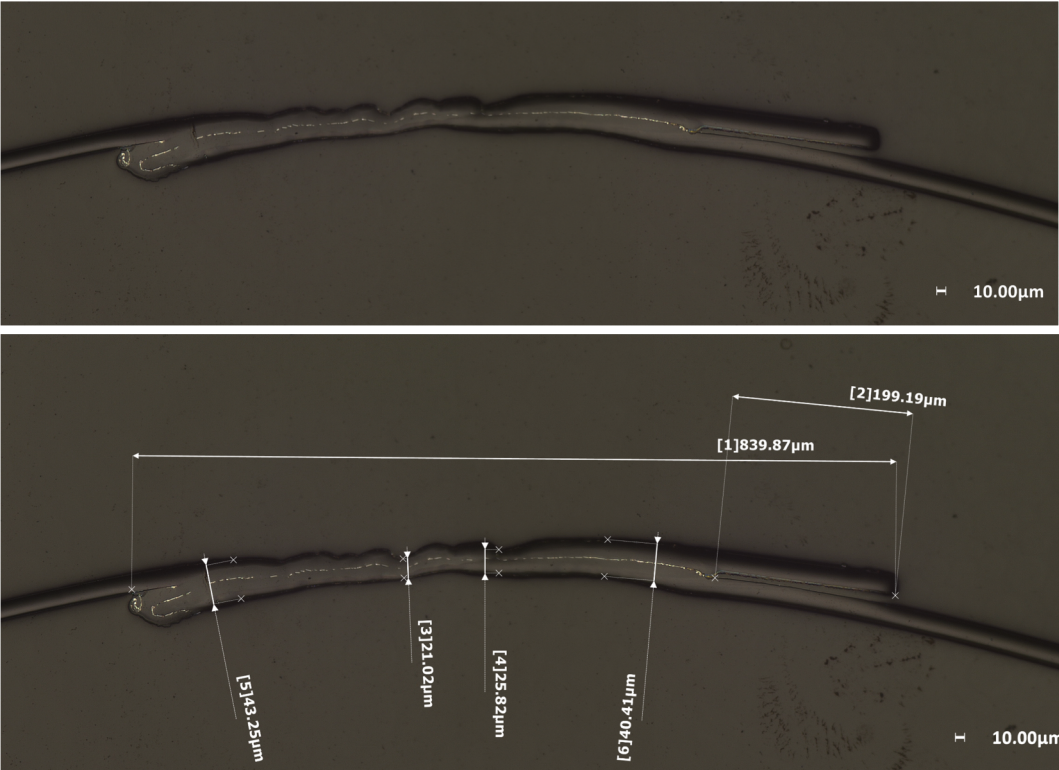


# Weld cross sections -2



- Slight indications of critical marks, reducing the thickness to **20 μm**
- Texture on the top surface
- Average weld thickness measured at **29.01 μm**.
- Completed weld interface ~ **80 %**, being **637 μm**, accepted as over **600 μm**

# Weld cross sections -3

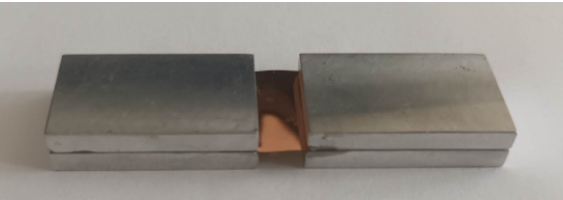
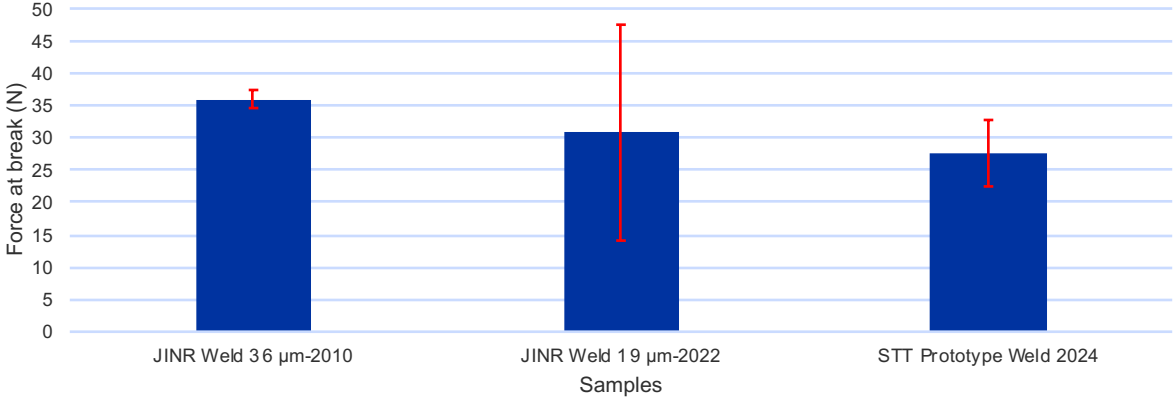


- Slight indications of critical marks, reducing the thickness to **21 µm**
- Texture on the top surface
- Average weld thickness measured at **32.63 µm.**
- Completed weld interface ~ **77.3 %**, being **640 µm**, accepted as over **600 µm**

# Weld mechanical testing

	JINR 2010 (36µm)	JINR 2022 (19µm)	DUNE 2024 (19µm)
Stress at break $\sigma_t$ (MPa)	103.5 ± 0.9	102.2 ± 20.8	95.99 ± 19.64
Force at break (N)	36.0 ± 1.4	31.0 ± 16.7	27.62 ± 5.14
Force at break per unit length (N/mm)	2.40	2.06	1.82 ± 0.37

### CERN Straw analysis



Parameters			
Gauge Length:	Machine Grip to Grip Length	Speed:	Strain Measurement:
6 mm	16 mm	1 mm/min	Video-extensometer (stickers on aluminium grip)



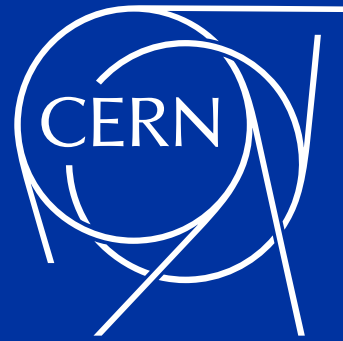
# Conclusion

- Manufactured parts all are fitting to the specifications and limits set.
- Area of concern on the end plugs will require monitoring for sharp edges.
- Welds look sound and homogeneous on the external face with no significant issues noted.
- Slight texture on the top surface of the weld cross section noted, could lead to critical points within the weld which is one of the leading cause of pre-failure.

# Upcoming

- Full assessment of the raw material

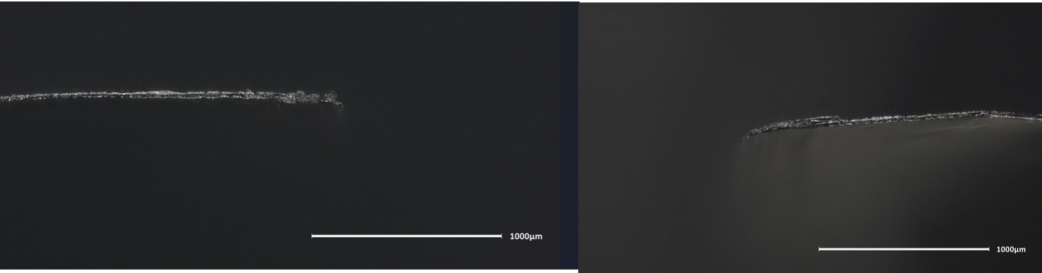




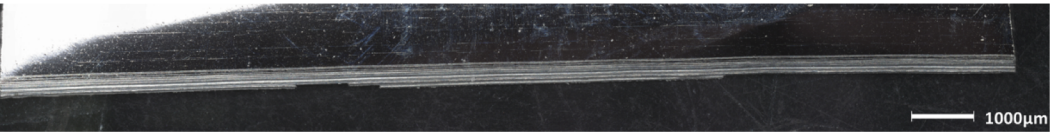
**Questions**

# Fracture analysis

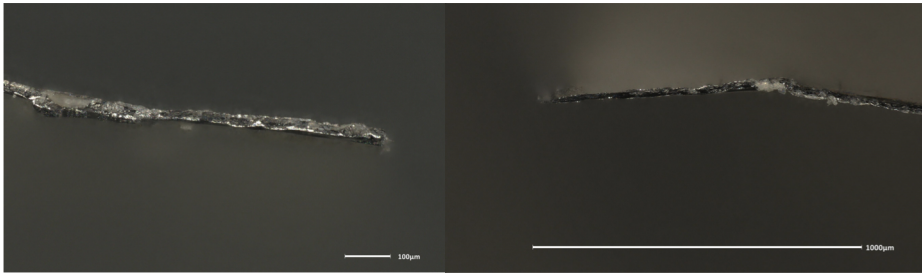
Sample 1- 1.28 N/mm



Fracture looks to be of shear type, with one side showing the weld edge



Sample 3- 2.21 N/mm



Fracture appearing to be in tension between the weld edges

