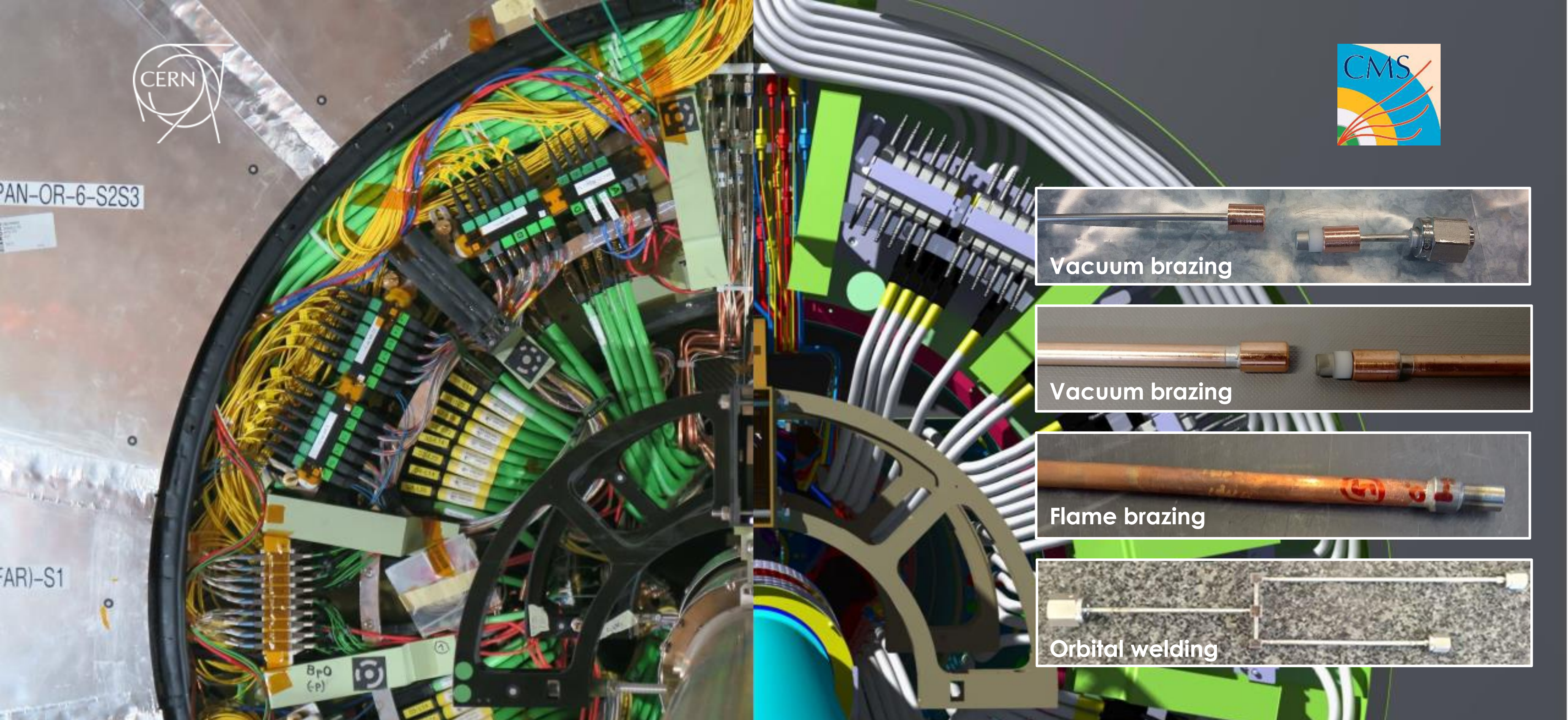


Joining Techniques used in Pixel Phase 1

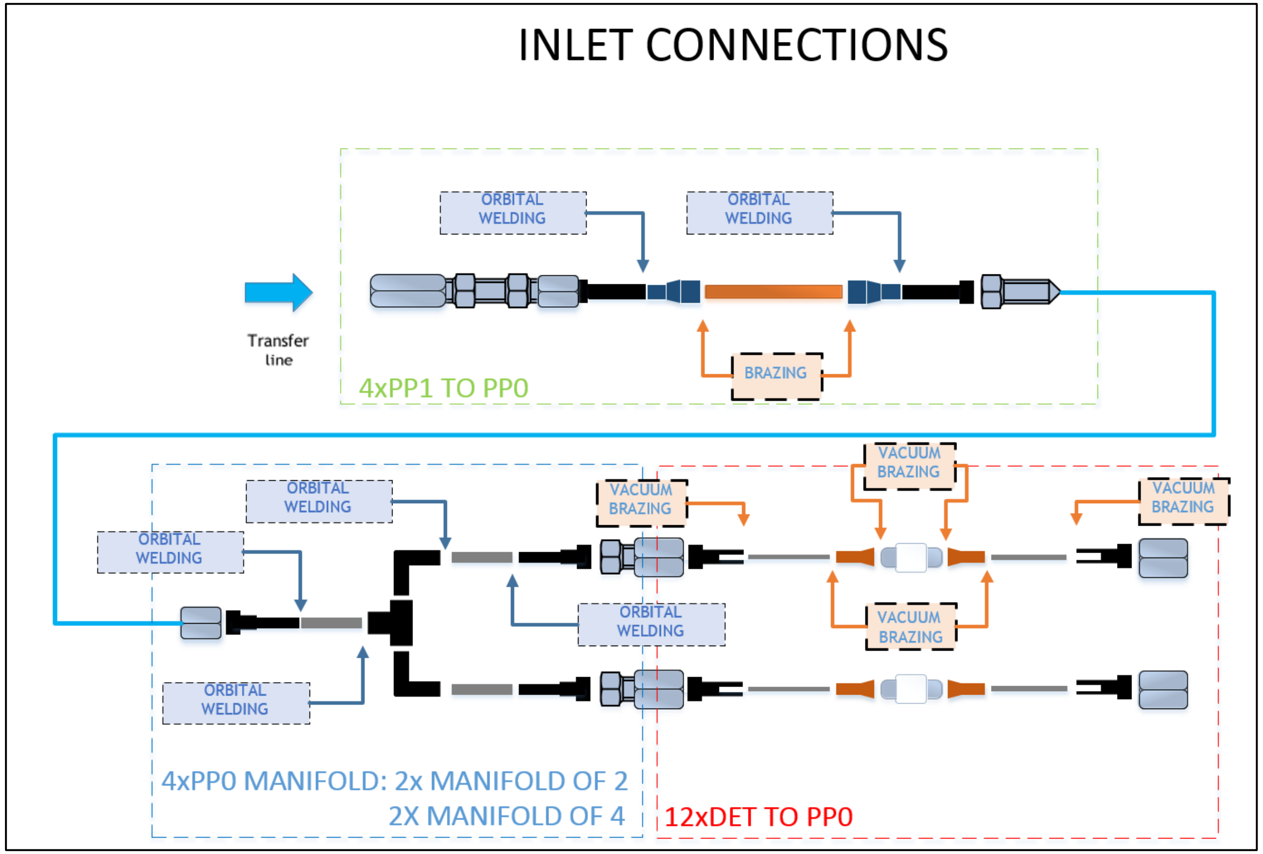
Karol RAPACZ, Jerome DAGUIN, Nicola Bacchetta, Hans POSTEMA, Fritz MOTSCHMANN, Thibaut COIFFET, Gonzalo IZQUIERDO

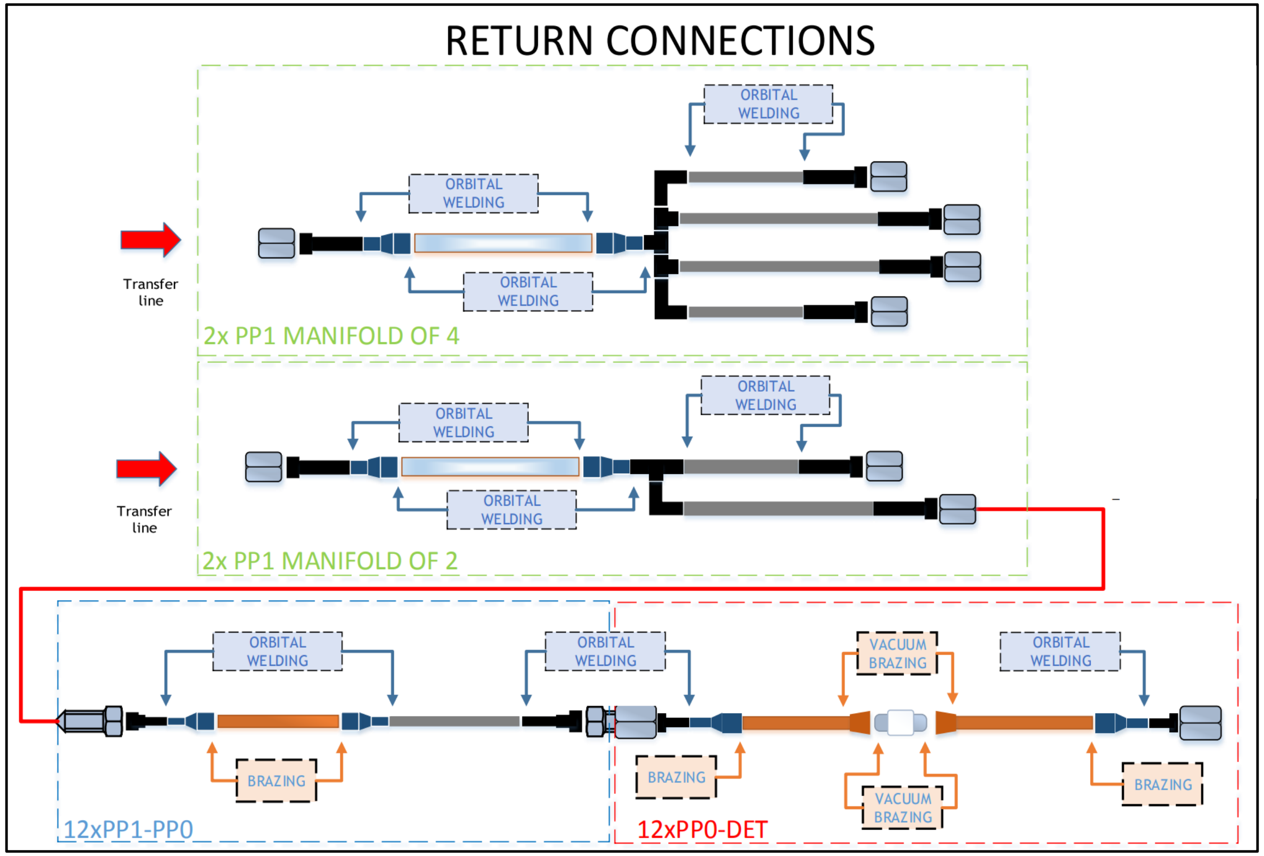
This presentation concerns joining techniques used in Pixel Phase 1 project from PP1 to BPIX and FPIX detectors. It doesn't describe joining techniques used inside FPIX and BPIX tracking volumes

Overview of Joining techniques used in Pixel Phase 1

For all removable connections Swagelok VCR connectors were used (1/4'' and 1/8'').
Material used for pipes - stainless steel (manifolds, capillaries) and copper (return lines)
To make non-removable joints, the following techniques were used:

1. Orbital welding
2. Flame brazing
3. Vacuum brazing



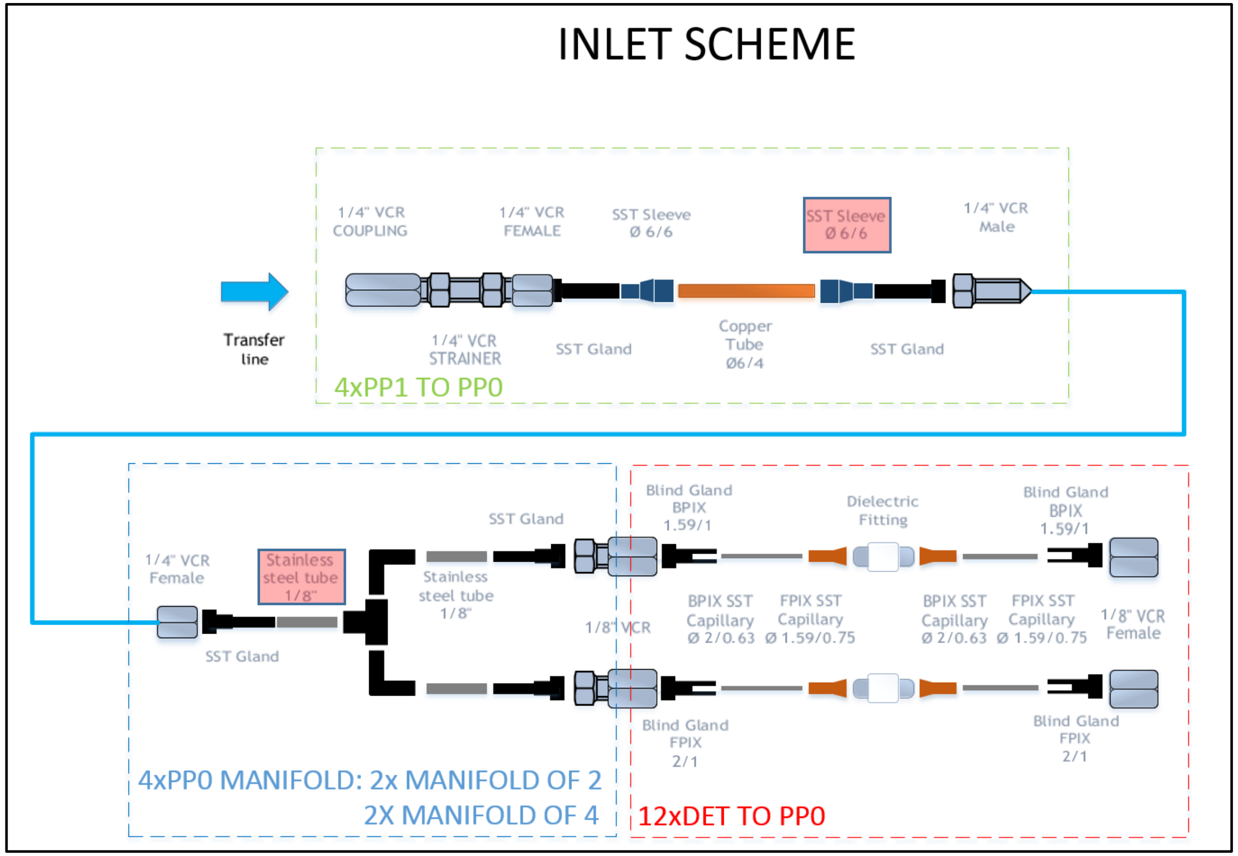


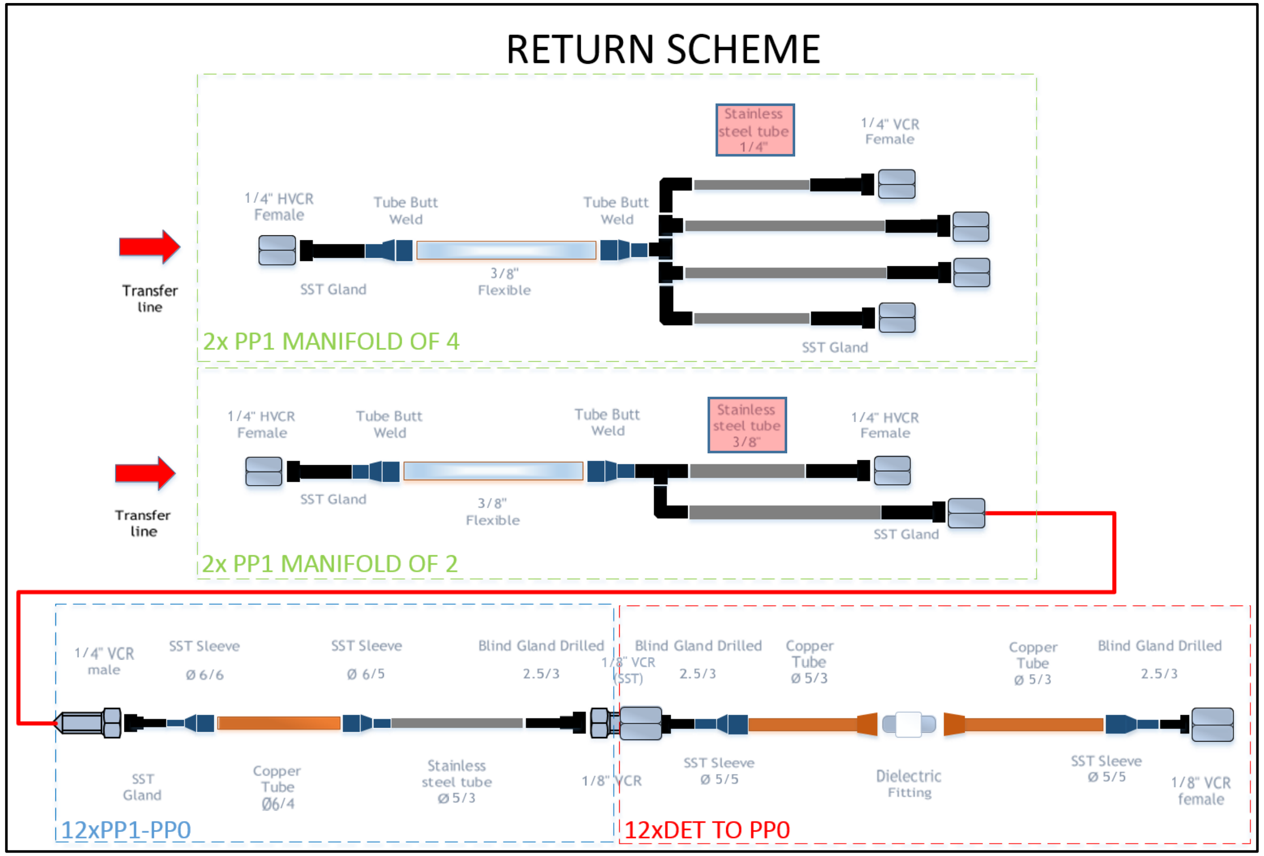
karol.jozef.rapacz@cern.ch

Orbital welding

Orbital welding was performed for 4 different pipe sizes:
1/8''
1/4''
6 [mm]
3/8''

Swagelok orbital welding heads were used to perform all the welding. All assembly parts were ordered from Swagelok except transition sleeves which were custom made.
For 1/8'' piping a micro welding head was used due to the complexity of the pipes



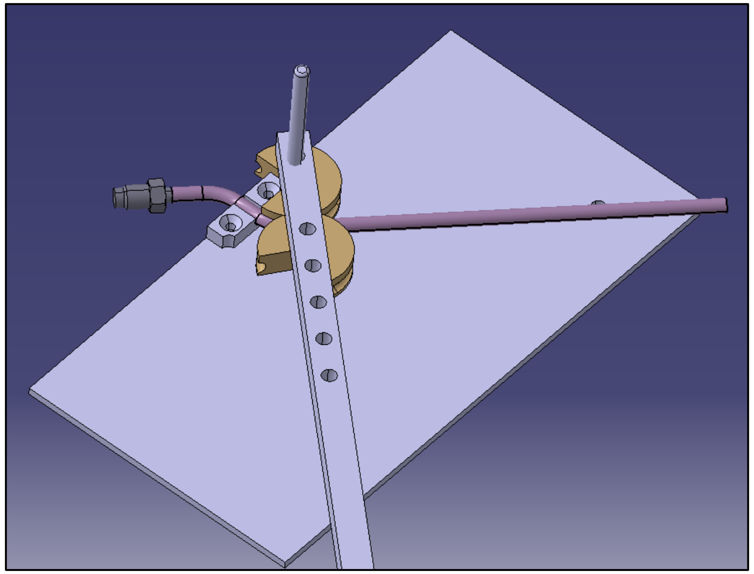


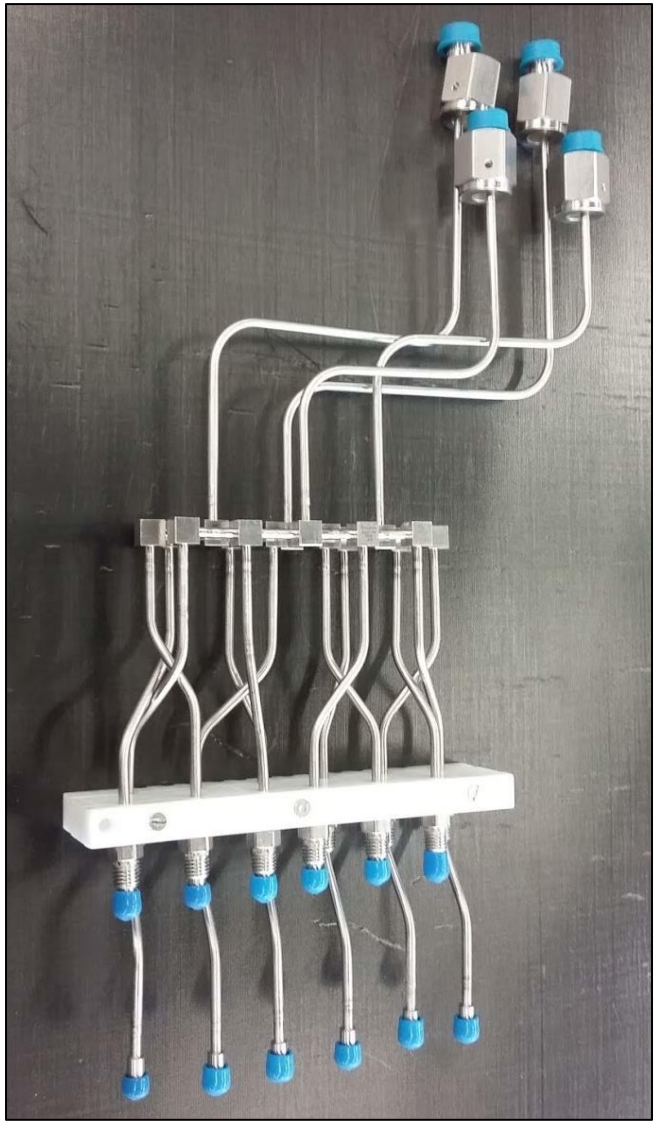
karol.jozef.rapacz@cern.ch

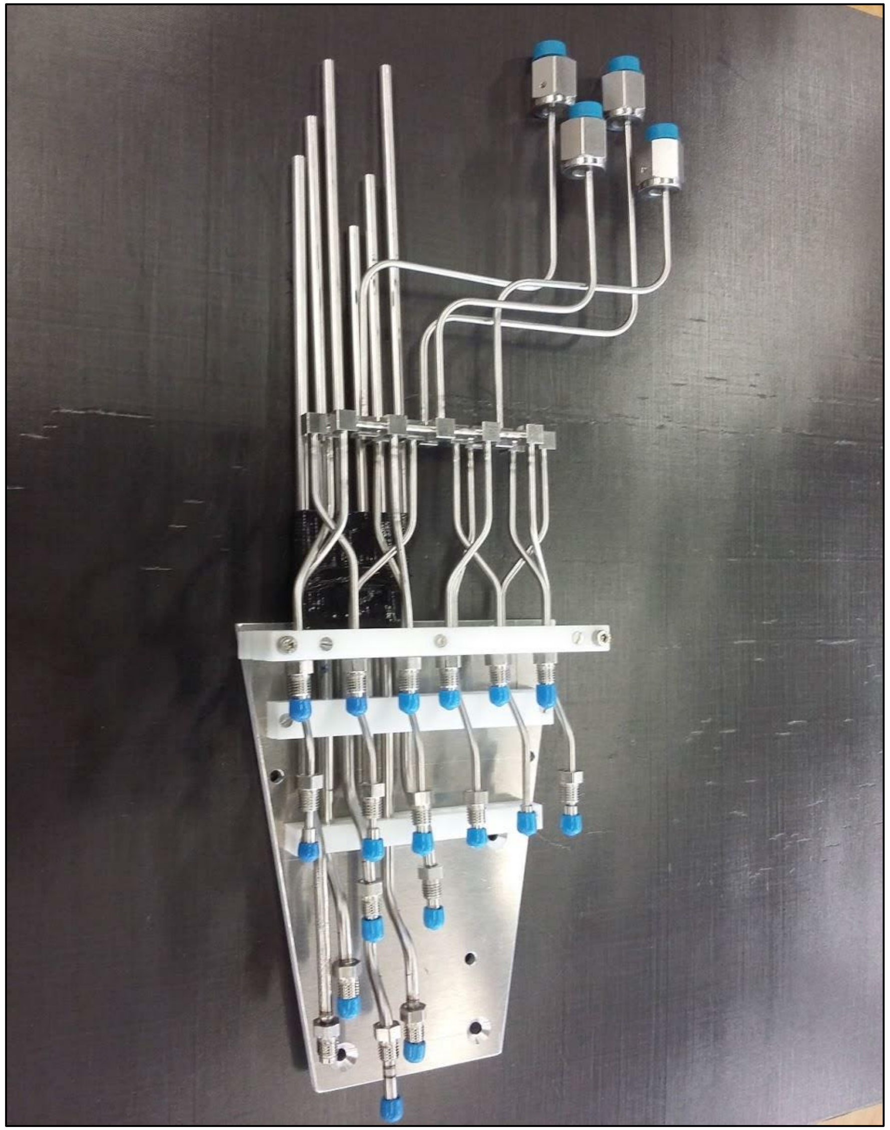
Orbital welding

Manifold design had to be adjusted to meet space requirements to perform orbital welding.
Some pipes had to be bent after orbital welding was done.
All the welds went through visual and radiographic inspection to guarantee highest-possible quality joints

Roughly 700 welds done – all passed leak and pressure test





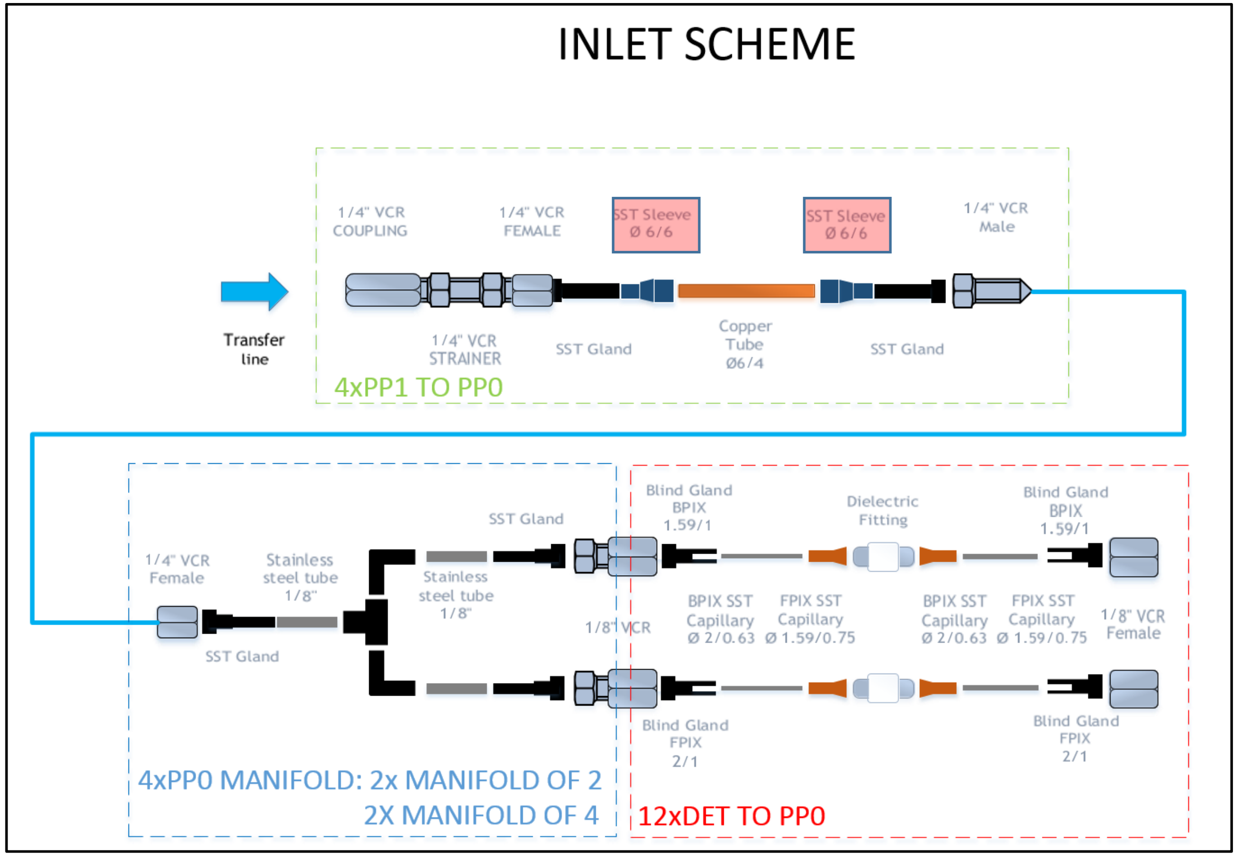


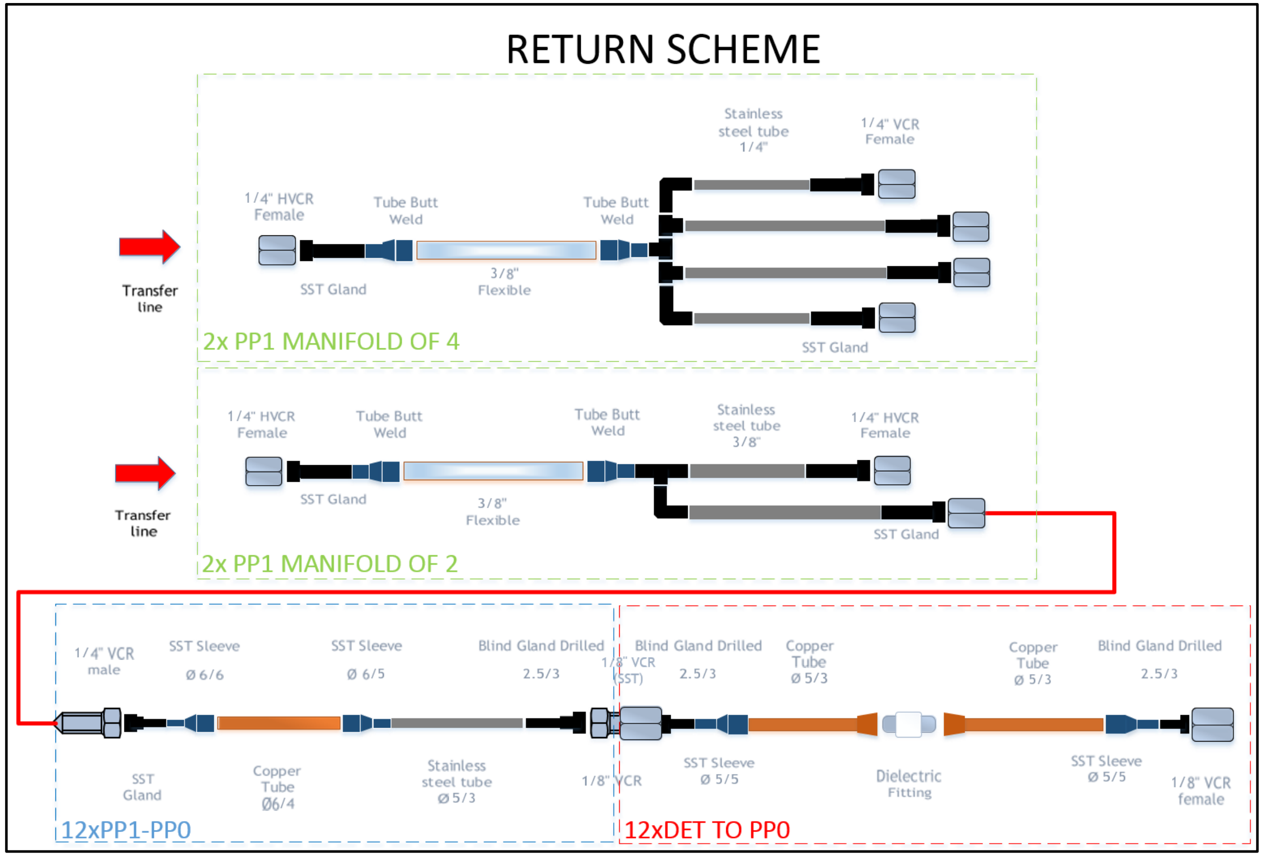
karol.jozef.rapacz@cern.ch

Flame brazing

Flame brazing was performed to join Stainless steel sleeves to 6 [mm] OD copper tube to make transition from stainless steel VCR connections to copper piping.

Filler: CASTOLIN 1800 (DIN 8513: L-Ag55Sn)
Flux: CASTOLIN 1802N ATMOSIN

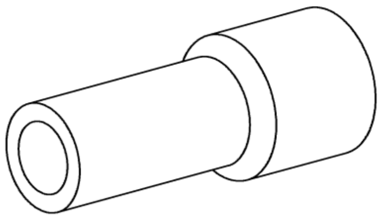


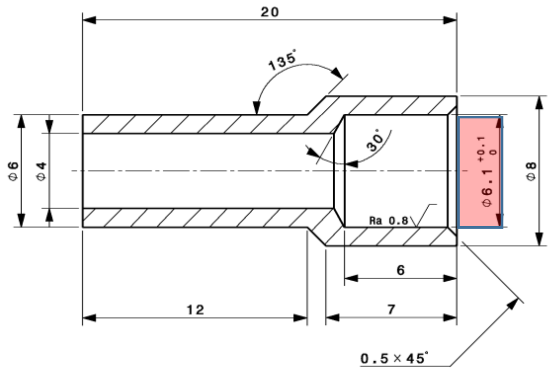


karol.jozef.rapacz@cern.ch

Flame brazing

To adjust gap for flame brazing ultrasonic inspection was done for each iteration of the sleeve design in order to optimize the design





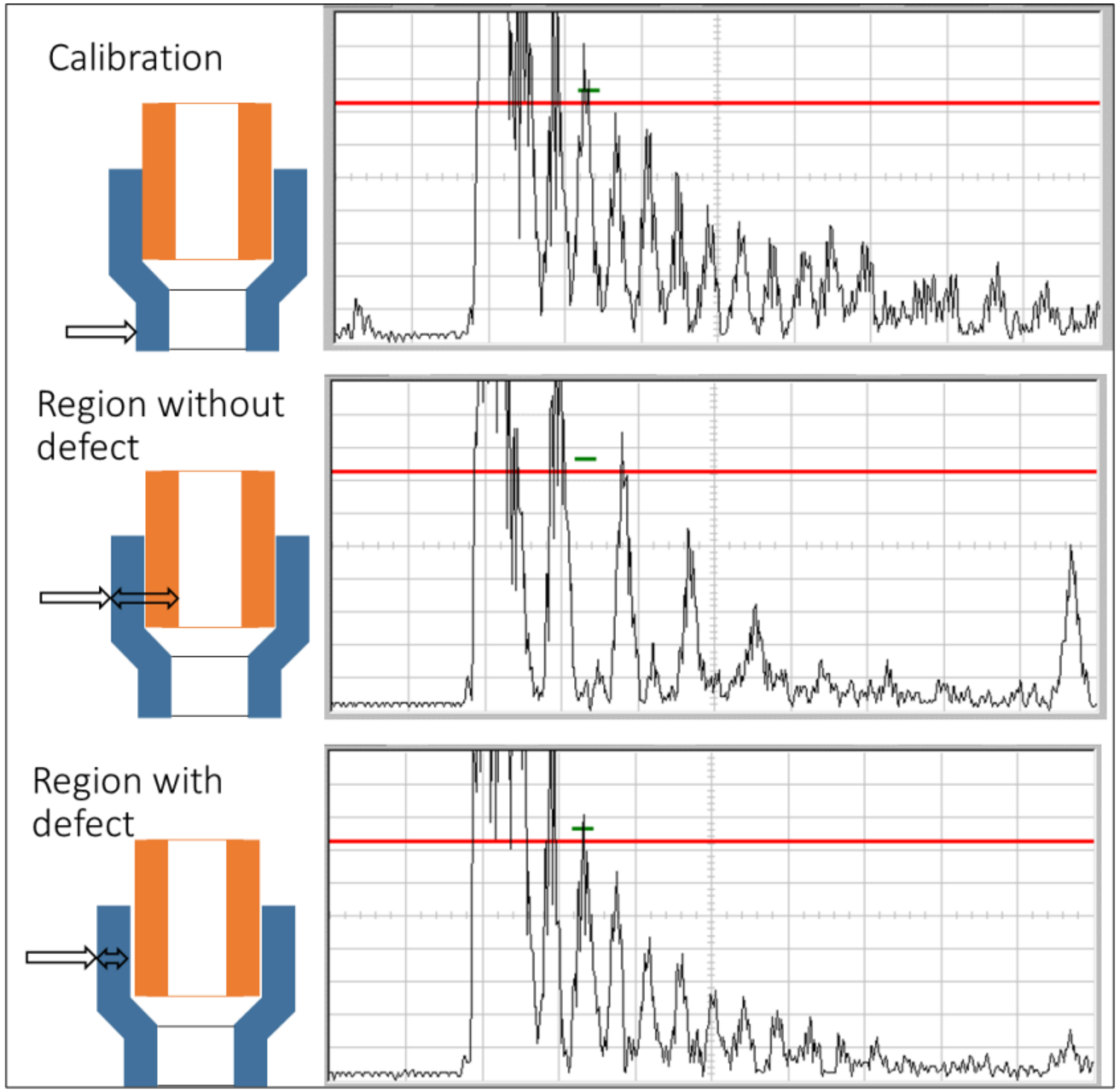
Device	Krautkramer USPC 2100			
Probe	Harisonic I3 1006T H10M (Ø9.5 mm, 10 MHz) + 2 m cable			
Wave:	**Type**	**Frequency**	**Angle**	**Gain**
	Longitudinal	10 MHz	0°	See Table 2
Couplant	Water column 67 mm			
Scanning	From the outside. Polar with 1° and 0.2 mm steps			
Calibration	On the prolongation of the stainless steel sleeve. In order to avoid interference with the entrance echo and with the backwall echoes in the regions with good brazing, the 3rd order echo (2nd repetition) is used for the C-scan, see Figure 1.			
Specification or acceptance criteria:				
EN ISO 18279 Annex B. Quality level B, stringent: 80 % or more of the projected area filled with braze metal. Gas cavities, pockets or pores max 20 % of the projected area. Absence of continuous leaking path through the axial length.				

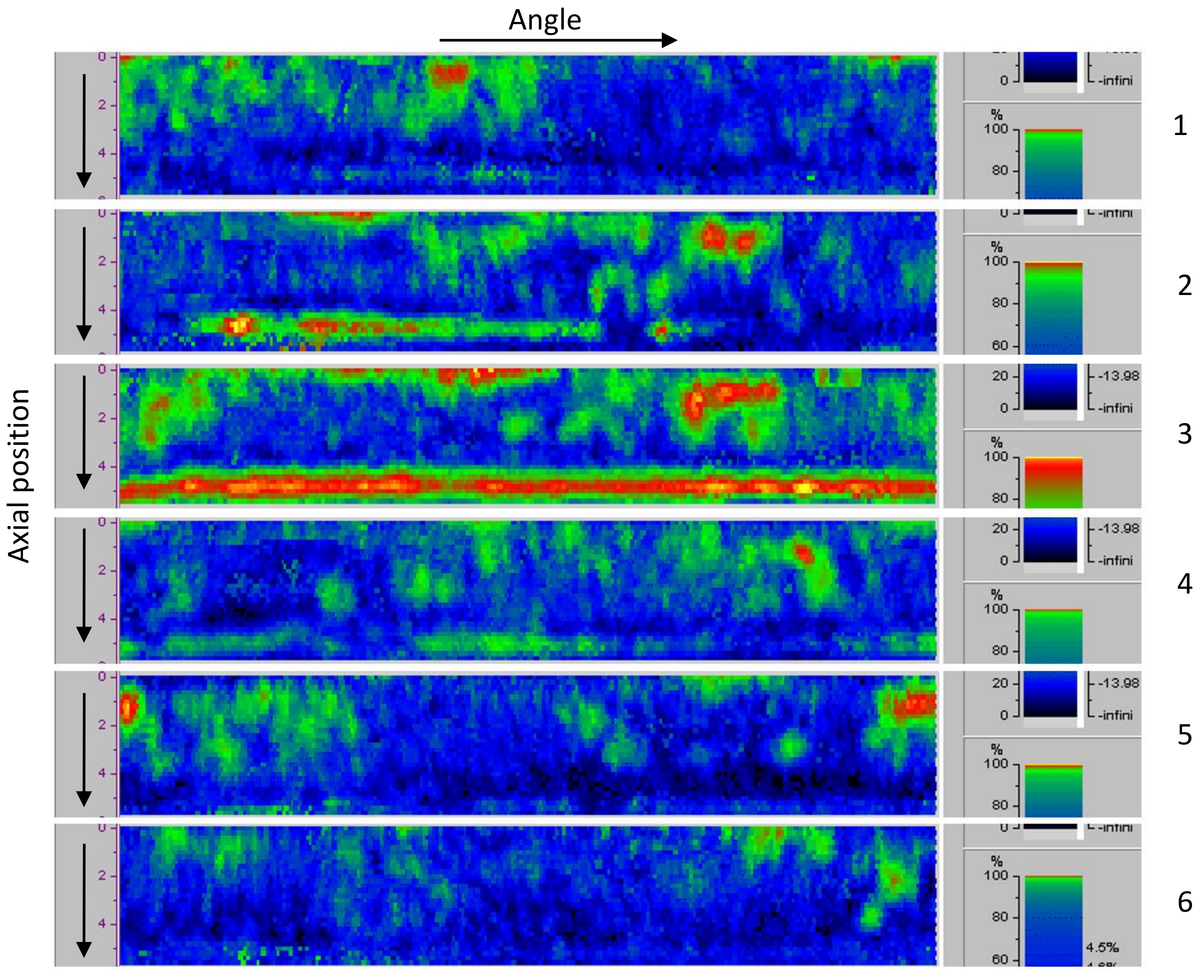
G. Arnau Izquierdo, EDMS 1799840

Flame brazing

Witness samples of each produced batch went through ultrasonic inspection as well (8 witness samples out of 80 produced pipes)

Roughly 200 brazed joints done – final design passed leak and pressure tests without failure



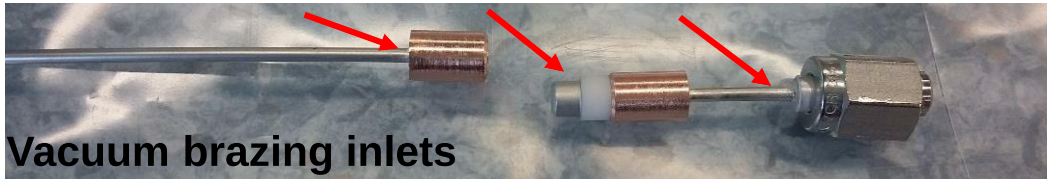


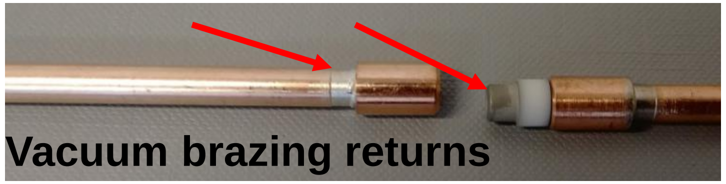
G. Arnau Izquierdo, EDMS 1799840

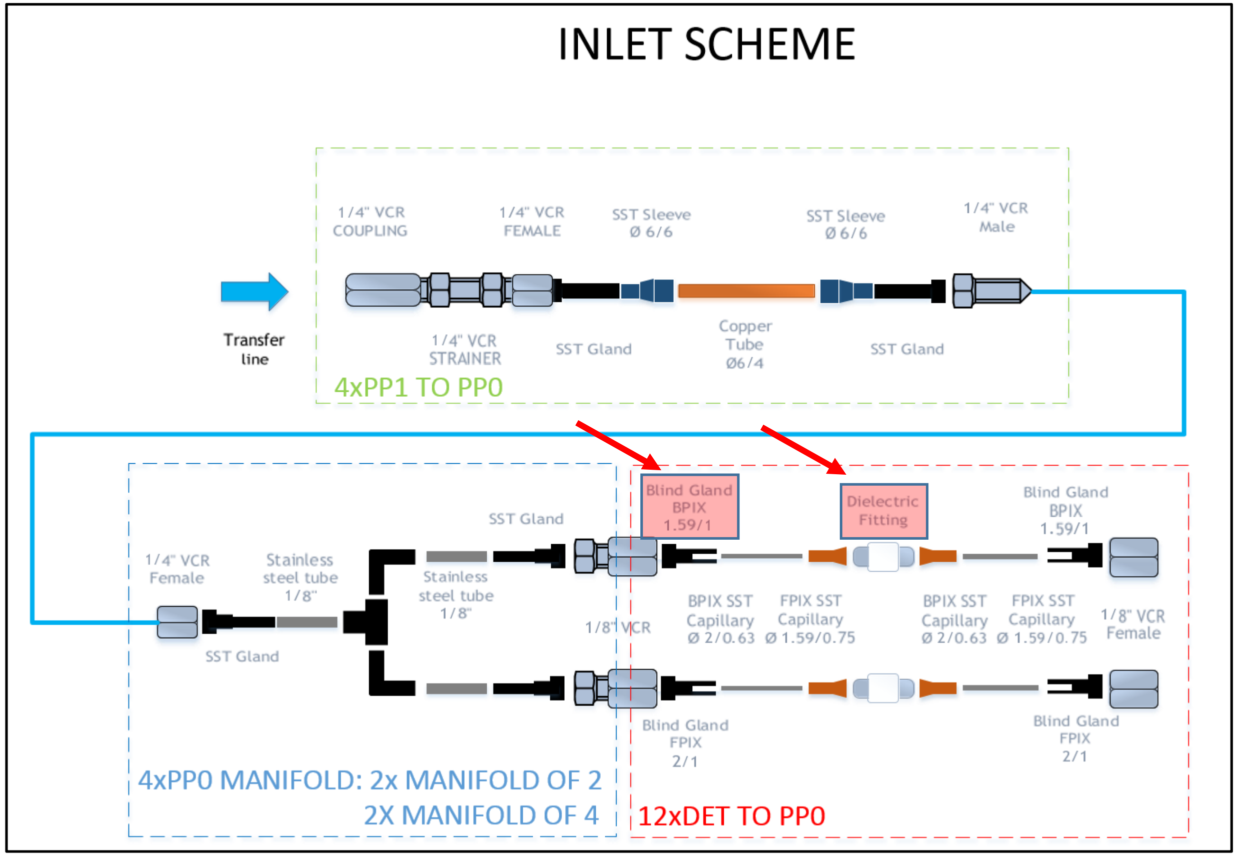
karol.jozef.rapacz@cern.ch

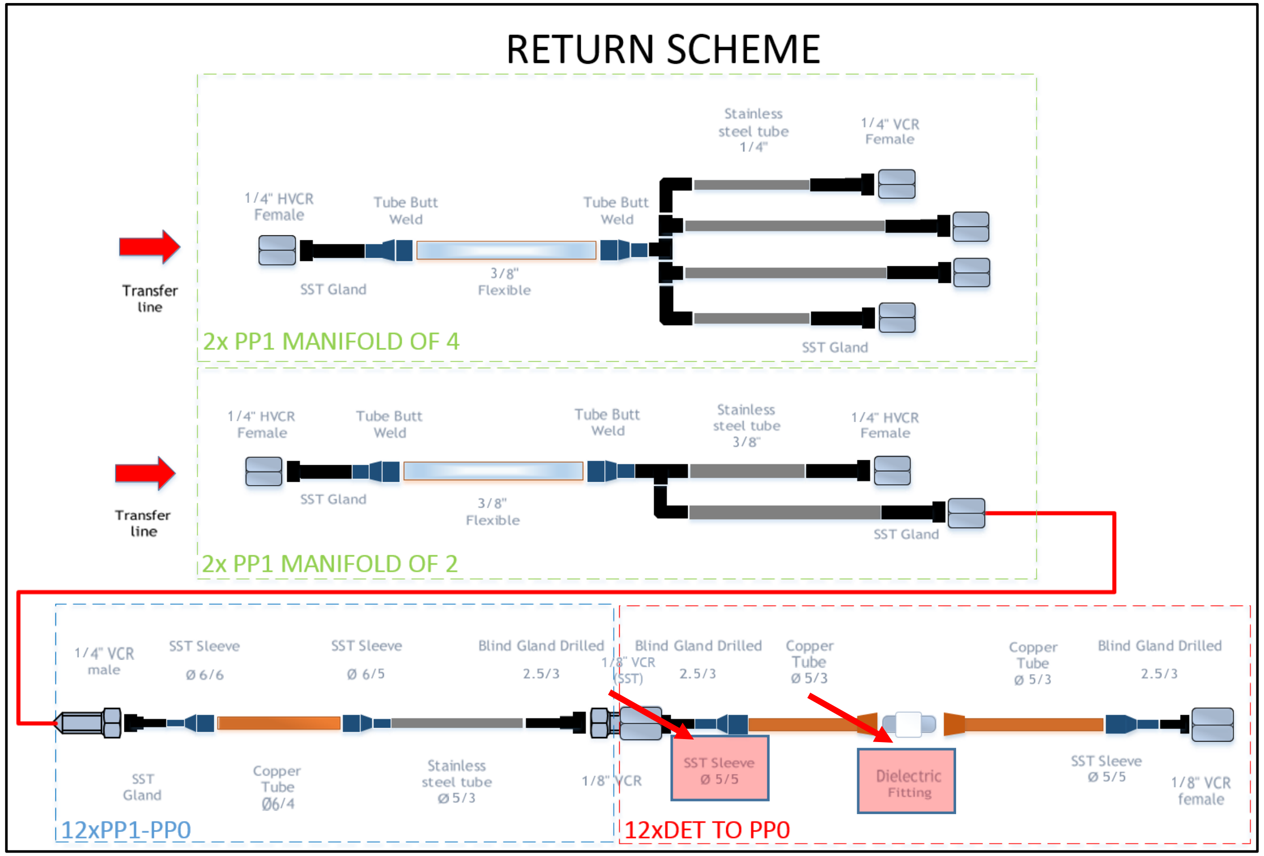
Vacuum brazing

Vacuum brazing was chosen as the only sophisticated joining technique for metal/ceramic transition. Also VCR fittings were vacuum brazed to the capillaries as it guaranteed high leak-tightness and introduced minimal distortion to the capillary's diameter.









karol.jozef.rapacz@cern.ch

Vacuum brazing – dielectric fitting

Dielectric (Al_2O_3) was metallized by Mo/Mn+Ni-deposition for the ceramic-metal transition.
Since ferromagnetic material like Dilver/Kovar was not suitable for our application, the dielectric joint was designed to have gaps kept during all the brazing cycles. Filler AWS BVAg-30 (B-Ag68CuPd-805/810, SCP1) at max 815 C was used.

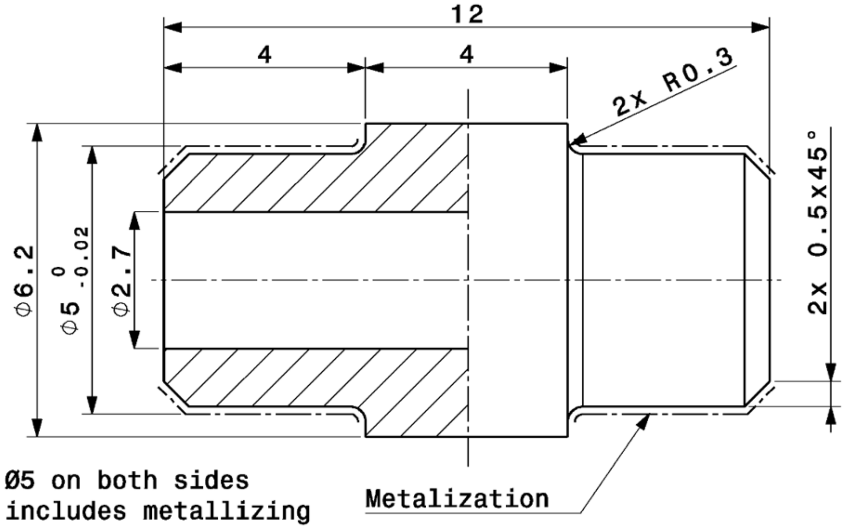


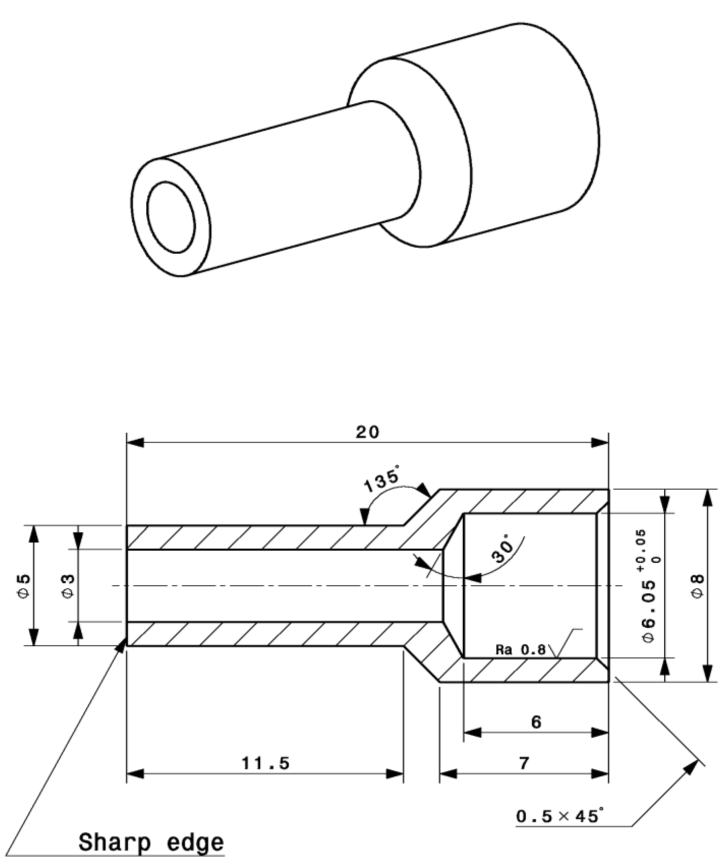
Table 1 - Brazing gap for ceramic copper brazing (max 0.1 mm on diameter)

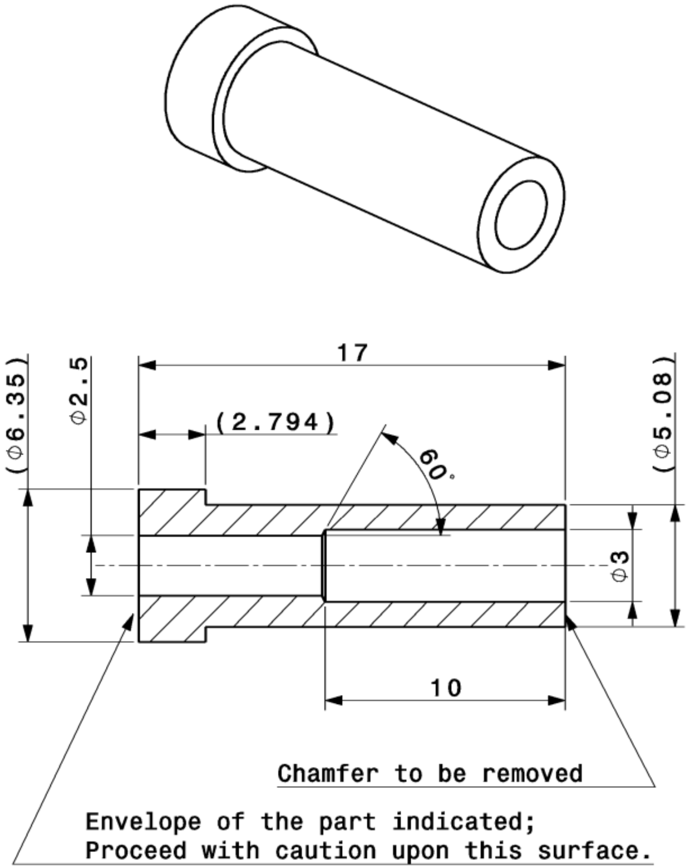
	RT	$T_{brazing}$ = 815°C
$Ø_{min}$ ceramic	4.98	5.01
$Ø_{max}$ fitting (Cu)	5.01	5.09
gap	0.03	0.08

Fritz Motschmann, EDMS 1799157

Vacuum brazing capillaries/outlets – 1/8’’ VCR gland

Since capillaries and return pipes had to be detachable, they had to be equipped with VCR connectors.
In order to do that for the return pipes, transition sleeves were used (design very similar to one used for flame brazing)
For capillaries Swagelok blind glands were used which were drilled to suit the outer diameter of a given capillary type with adequate tolerances.
To perform gland to capillary vacuum brazing, nickel based filler was used (~1050 C)
For returns pipes, silver based filler was used (~850 C)





Fritz Motschmann, EDMS 1799157

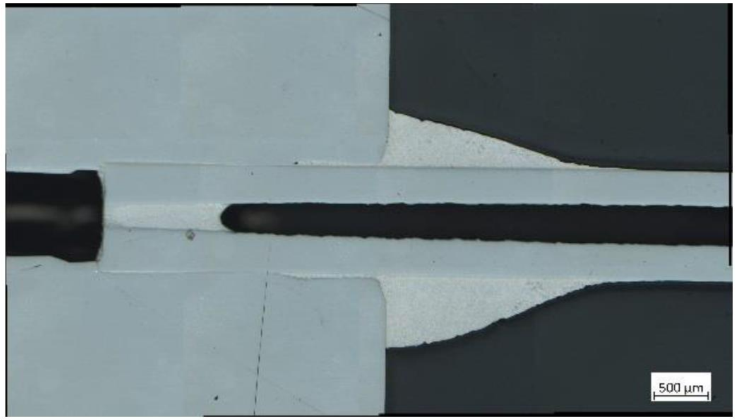
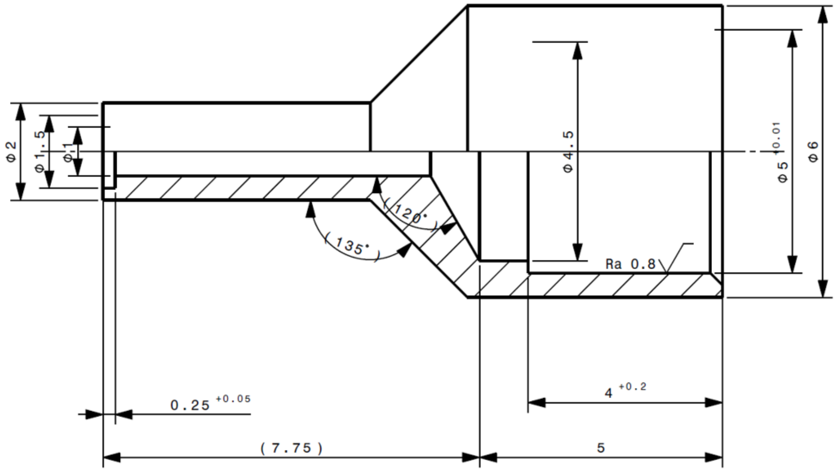


Figure 7 – Stainless steel capillary/gland brazing (with step)

karol.jozef.rapacz@cern.ch

Vacuum brazing – dielectric sleeve initial design

Initial material used for the dielectric sleeve design was stainless steel which would have allowed laser welding of the capillaries after vacuum brazing. Unfortunately, the low tendency for plastic deformation of stainless steel introduced high stresses resulting in micro-cracks appearing in the dielectric fitting. Also laser welded joints turned out to be too fragile to cope with installation procedures (3D bending), thus decision to change dielectric sleeve design was made.



Fritz Motschmann, EDMS 1799157

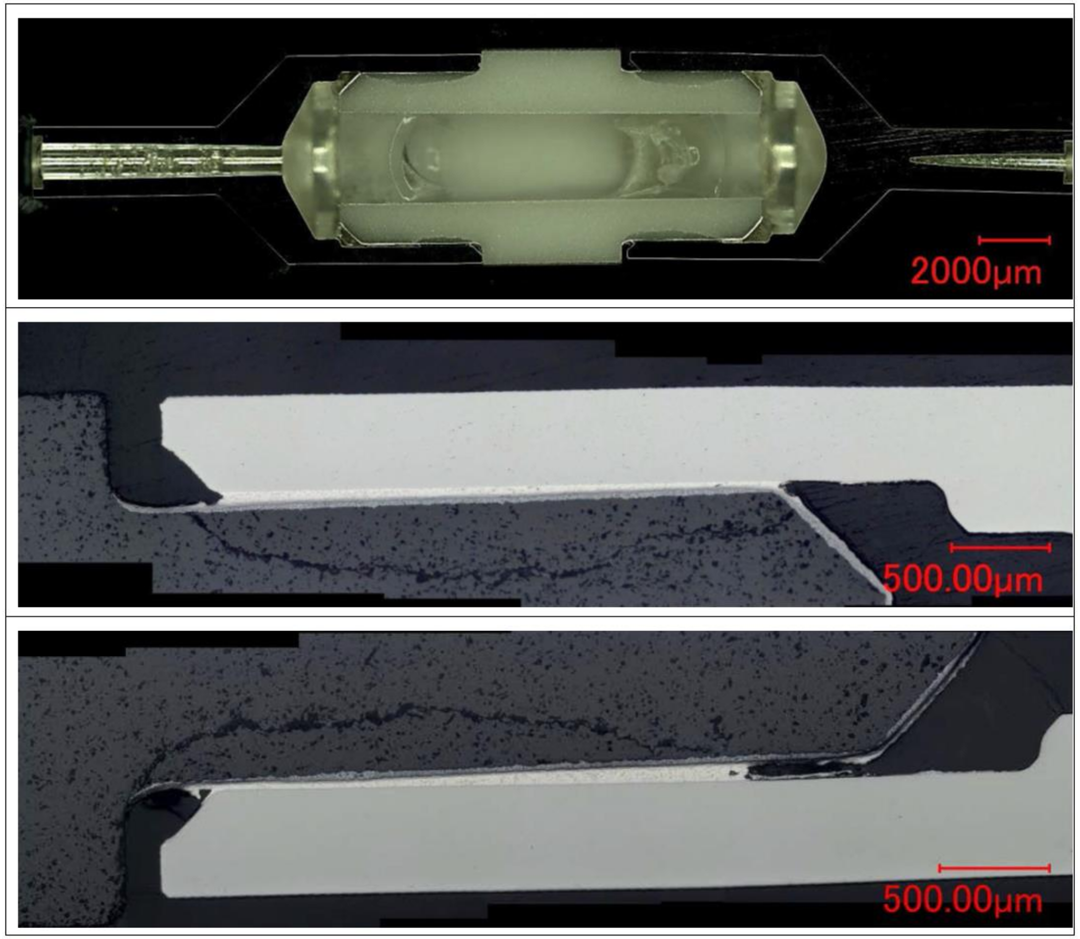
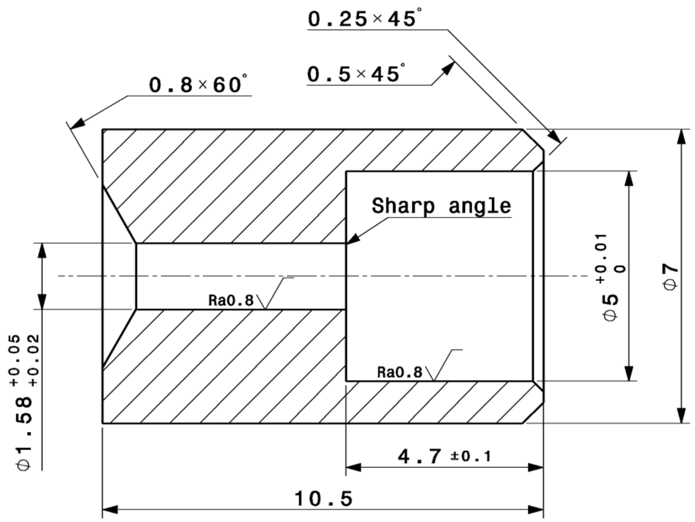


Figure 4 – Microscopic examination of stainless steel/ceramic joint (M. Crouvizier, EN-MME-MM)

karol.jozef.rapacz@cern.ch

Vacuum brazing – dielectric fitting final design

To avoid problems with the dielectric fitting cracking, the sleeve material was changed from stainless steel to copper and redesigned. These capillaries were inserted inside the sleeve itself to perform vacuum brazing instead of laser welding.



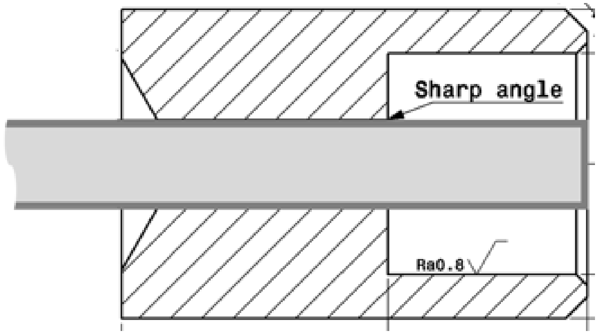


Figure 8 – Position of capillary in copper fitting

Fritz Motschmann, EDMS 1799157

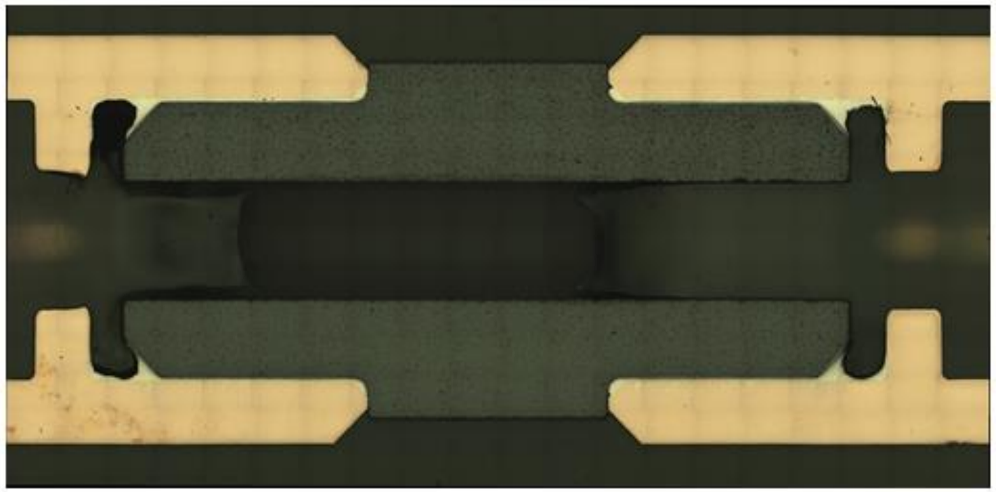


Figure 6 - Microscopic examination of copper/ceramic joint (M. S. Meyer, EN-MME-MM)

Vacuum brazing/dielectric fittings – problems

1. Since VCR female nut threads are plated with silver, special attention has to be paid to filler choice in order not to exceed melting point of silver. If possible, male nuts should be used (no silver plating).

2. Some of the dielectric fittings received were not brazed at all due to issues with the placement of brazing filler material (figure 14).

3. Due to the high stresses introduced by 3D bending, dielectric fittings were considered too fragile and stainless steel reinforcements were added later on.

Fritz Motschmann, EDMS 1799157

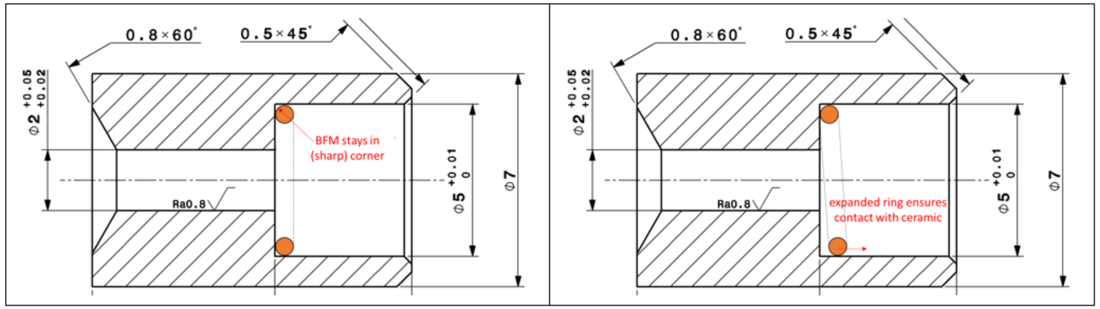
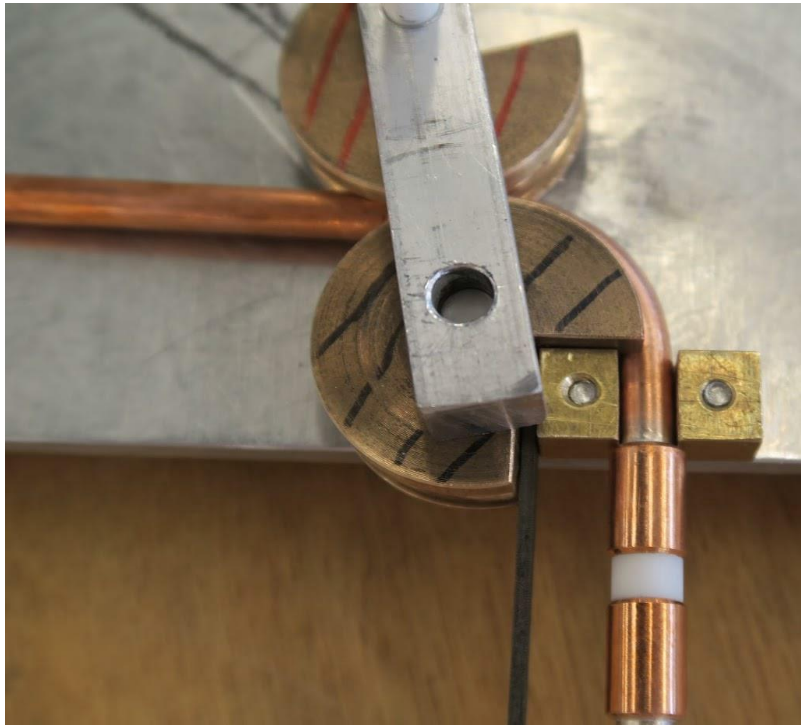
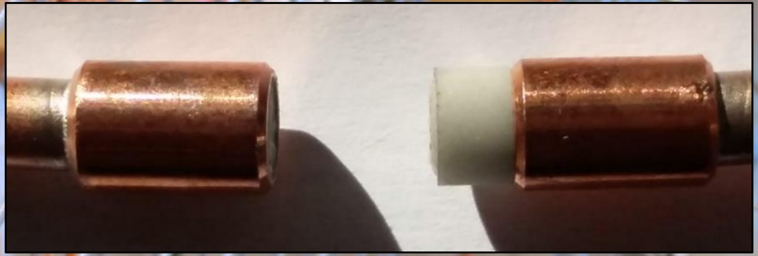


Figure 14 – placement of brazing filler material (BFM) in copper fittings for ceramic brazing – left: initial condition, right: improved placement

Roughly 400 brazed joints done
6 capillaries rejected from initial batches due to the leaky joints on ceramic pieces.
After solving the problem with filler placement, all passed leak and pressure test





Dielectric fittings reinforcements

To reinforce dielectric fittings, stainless steel sleeves were manufactured which were put on copper sleeves to hold the dielectric. In-between thin (100 microns) kapton foil was placed and low viscosity glue was poured from the top to fix reinforcements in place.

This was only applied for the return pipes as capillaries were flexible and didn't introduce high stresses to the dielectric fittings during manipulation.

Conclusions

<u>Orbital welding:</u>

In hands of well qualified welder:
+ very reliable
+ robust
+ fairly fast from the manufacturing point of view (no special pipes treatment required)

- On-site welding limited to the sizes of the welding heads
- Limitations for thin-walled tubing

<u>Flame brazing:</u>

In hands of well qualified technician:
+ reliable
+ robust
+ less space required to make connection

- requires very high cleanliness
- requires more prototyping than orbital welding (tuning tolerances)
- on-site brazing limited due to the high temperatures
- requires pipe preparation

<u>Vacuum brazing:</u>

+ can be applied for more demanding and exotic joints (e.g. ceramic – metal)
+ can be fast (batch brazing)

- requires highly specialized staff
- a lot of prototyping needed
- requires special pipe preparation (often machining)
- expensive
- can't perform on-site

Useful links:

Pixel Phase 1 overview:

https://edms.cern.ch/document/1774100/1

Ultrasonic inspection:

https://edms.cern.ch/document/1799840/1

Vacuum brazing report

https://edms.cern.ch/document/1799157/1

karol.jozef.rapacz@cern.ch