

Engineering developments towards seamless substrates ? Not so fast !

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On behalf of FCC SRF WP2 and CERN EN-MME group

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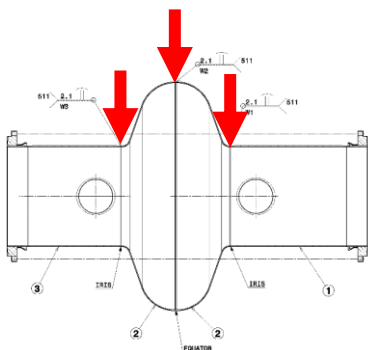
Looking for seamless substrates, but welding still needed for SRF cavities manufacturing

- **Elliptical cavities at CERN : past fabrication overview**
- **New welding strategy**
- **Copper welding test campaign**
- **Recent Applications / Next steps**
- **Joint conclusions**

Main quality requirements for SRF cavities welds:

- no porosity close to functional surface (risk of opening during chemical treatment)
- Smooth surface RF side (low roughness, no spatter, flat profile)

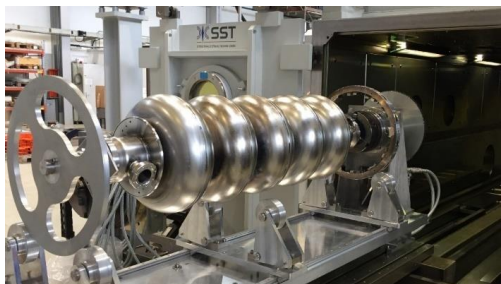
The last elliptical cavities welded at CERN (since 2015) were welded from **outside** (due to accessibility)



External welding gives better results on Niobium than copper (better surface roughness & compactness for Nb)

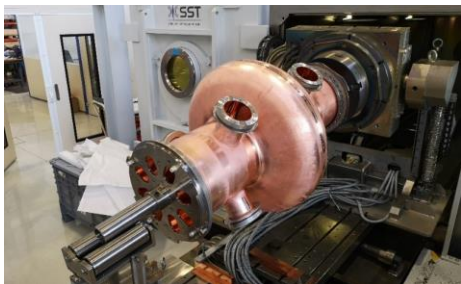
→ Copper welding procedures have to be improved for FCC

SPL (niobium)



Niobium SPL cavity weld
($Ra \sim 0.6\text{-}1\text{ }\mu\text{m}$)

LHC (copper)

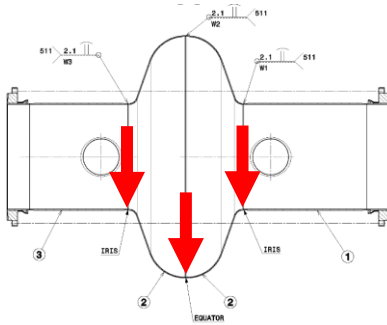


400 MHz LHC cavity
($R_a \sim 7\text{-}10\ \mu\text{m}$)

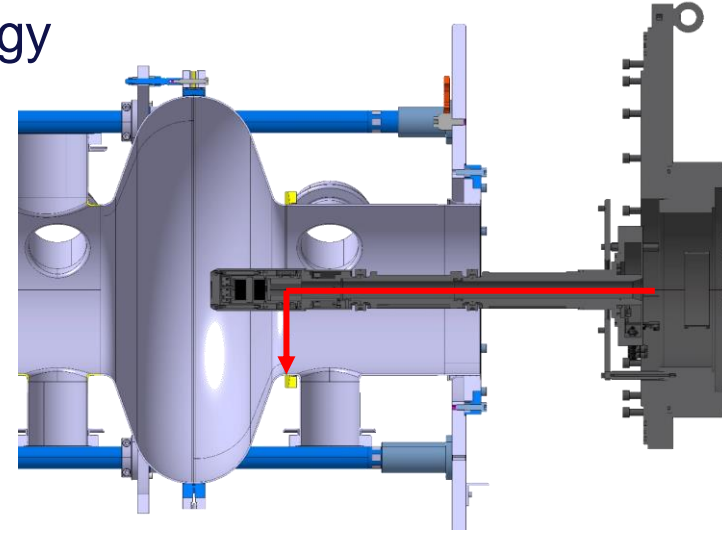
New welding strategy

Welding from inside to improve welds roughness RF side

- Direct beam access to RF side not possible for all welds
- Beam deflector needed to reach RF surface



→ Testing campaign ongoing to be performed to find optimal welding parameters and preparation minimize risk of defects



EB deflector characteristics :

- Purchased in 2020
- Bends the e- beam 90°
- Fits in a tube Ø78 mm
- Adjustable length : 400 – 1000 mm
- Beam power up to 15 kW (tested)

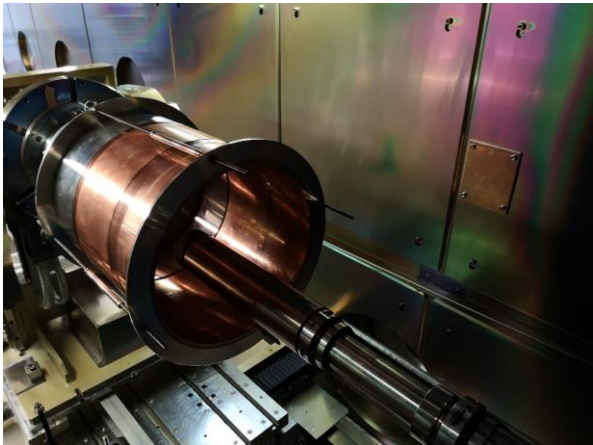


Copper welding test campaign

A test campaign was carried out on representative copper samples to develop welding parameters

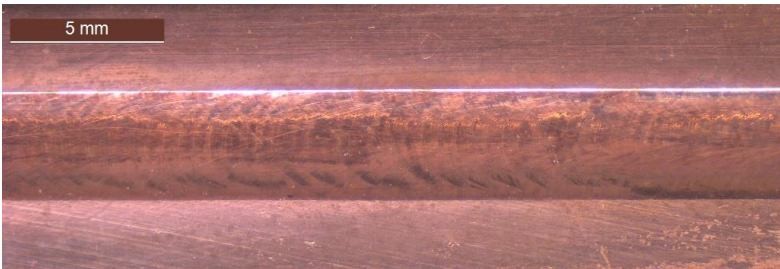
Main outcomes:

	External welding	Internal welding
RF Surface roughness (Ra)	7-10 μm	0.6-1 μm
Porosity content	0-12 pores/m	0-10 pores/m
Transversal shrinkage	0.6 mm	1-1.2 mm
spatter	Requires backing plate + mechanical polishing	no polishing required



Deflector test setup

→ Promising results, quality similar to niobium could be achieved on functional RF surface



RF side of internal weld test sample

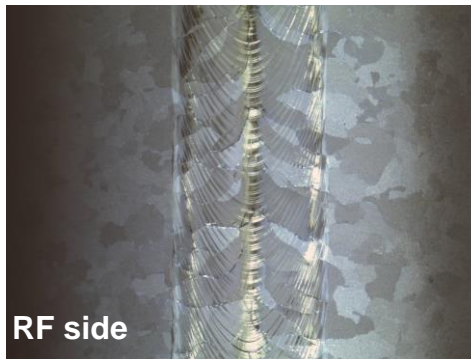


Cross section, welded thickness 2.3 mm
Courtesy M. Crouvizier

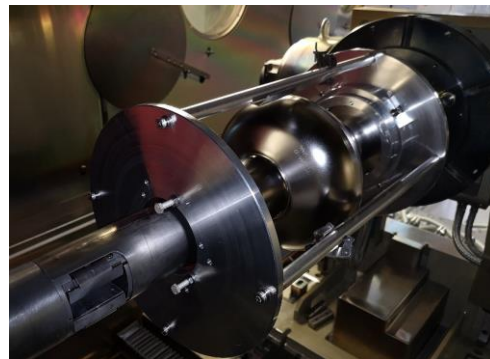
Recent applications using Deflector

- 2020 : 1.3 GHz Niobium cavity for KEK

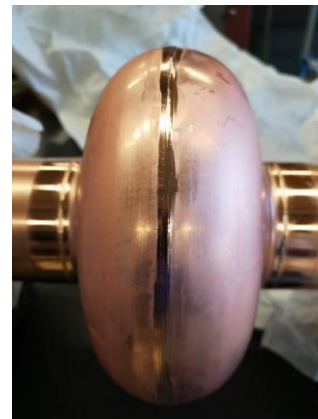
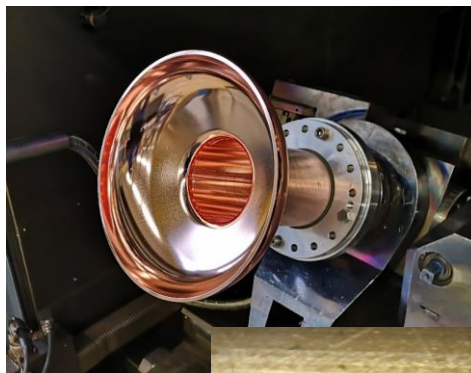
https://indico.desy.de/event/32219/contributions/116568/attachments/71263/90988/TTC2022_T.Dohmae_upload.pdf



Courtesy T. Dohmae, KEK

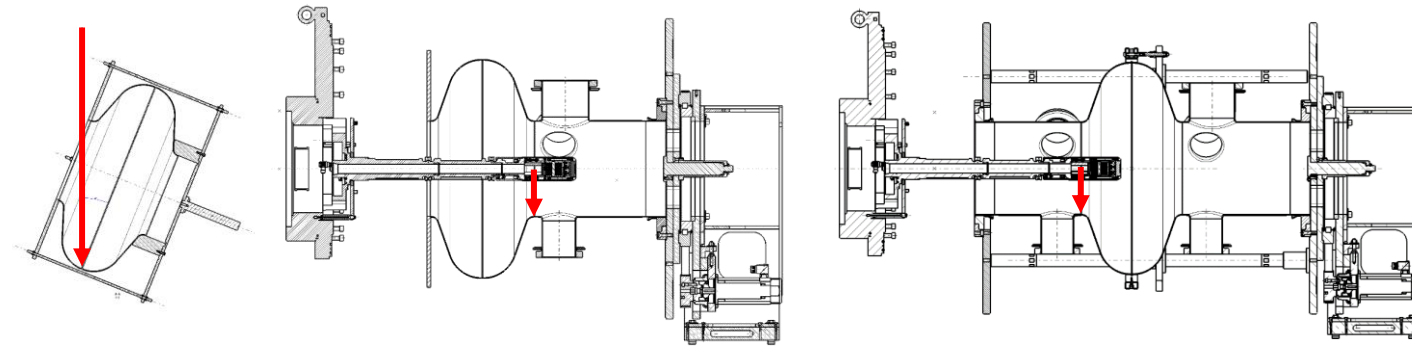


- 2021 : 1.3 GHz copper cavity (spun half-cells, equator welding only)



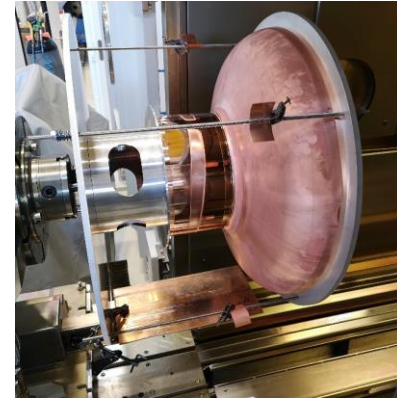
Next steps

- 2023 : 400 MHz LHC copper spare cavity



LHC cavity final assembly sequence

- From 2024 : FCC 400 MHz simplified test cavities with monocell (no equator welding)
 - 2 cavities with monocell machined from bulk
 - 2 cavities with hydroformed monocell



Half-cell to tube test setup



Internal Welding tooling

Conclusions

Abridged but coherent campaign ongoing, for **defining manufacturing route for FCC series cavities**

Seamless fabrication:

- 400 MHz bulk-machined will provide benchmark for downstream surface processes
- promising results from 1.3 GHz hydroforming campaign

Not forgetting **EB welding!** (400 MHz : ~ 2 Km of iris welds...)

- The EB deflector showed promising results on improving RF surface quality with respect to the old procedure (lower surface roughness, no polishing required)
- Experience gained during development for LHC spare cavities will be directly applicable to FCC
- Coming applications for LHC and FCC will be critical to determine if internal welding is a significant improvement for SRF performance

Fabrication R&D:

- CERN building know-how on main domains of interest for SRF mechanical fabrication
- ...advanced process simulations, material and failure characterization (SRFLD,..), impact of fabrication processes on SRF requirements (machining of RF surfaces, ...)

Thank you for your attention

Questions ?

Acknowledgements

All involved colleagues from SY-RF, TE-VSC, EN-MME, ... and many fruitful collaboration (KEK...)