ELLIPTICAL CAVITIES PRODUCTION TECHNOLOGIES

Marco Garlasche'
On behalf of FCC SRF Work Package and CERN EN-MME Group

FCC SRF WP : Towards 400 MHz Manufacturing

End goal is to **provide cavities conform to CDR baseline** requirements. In order to do this:

- **Identify the best manufacturing strategy** in view of *RF performance*, *400MHz design*, *series production*
- **Supporting R&D** of all stakeholders involved

Fabrication Program *[..2022→2023..]*

1.3 GHz	• Provide substrate for RF & coating studies • Benchmark fabrication processes uninfluenced by the size of the cavity	…internal EB welding, machining of RF surfaces, spinning, deep drawing …
400 MHz	• Provide substrate for RF & coating studies • Validate best manufacturing strategy in view of series	…Cost reduction studies Industrialization of cutoffs…

- **1.3 GHz** : Design Of Tests defined. Few activities finished/ongoing
- **400 MHz** :
  - Studying options for cavity fabrication process (seamless,…)
  - Industrialization strategy for Cut-Offs production

Monoblock 1.3 GHz Cavity

CERN Ref. : Karol SCIBOR

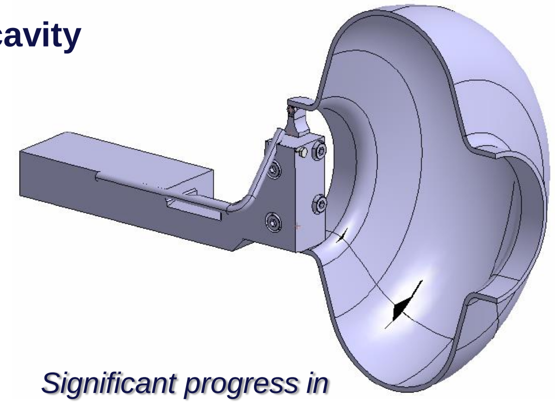
Proposed and implemented first of kind mono-block cavity

Specific process definition for bulk machining

- Tool holder design & manufacturing
- CAM programming, Diamond finishing

Metrology

- Roughness **Ra ~ 0.15 µm**
- **internal shape deviation < 20 µm**
- Wall thickness variations < 20 µm



Significant progress in Nb/Cu ELL

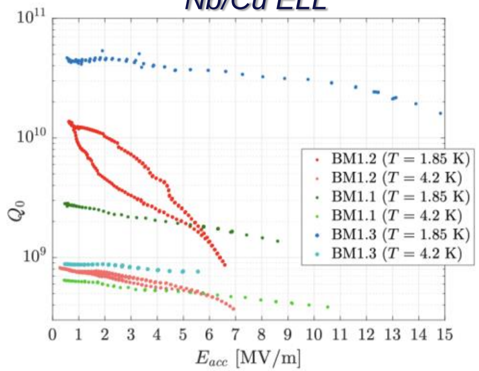


Figure 3: Quality factor (Q_0) vs accelerating field (E_{acc}) of the tested BM1 coatings at normal and superfluid LHe.

Courtesy Walter VENTURINI

Best Performance in terms of coating & RF results !

Monoblock = Reference component for Fabrication studies

Electron Beam Welding : Internal with Deflector

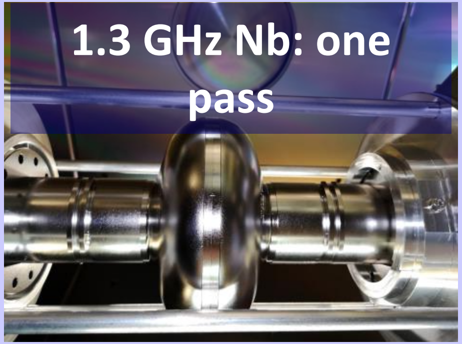
Successfully done

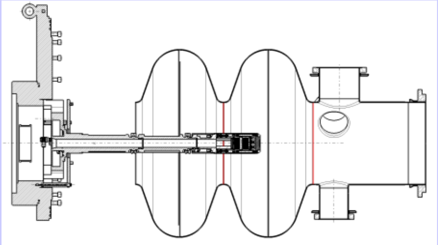
- ✓ **1.3 GHz Nb** cavity: fully welded from inside using deflector
- ✓ **1.3 GHz Cu** cavity: equator welded using deflector

CERN Ref. : Gilles FAVRE

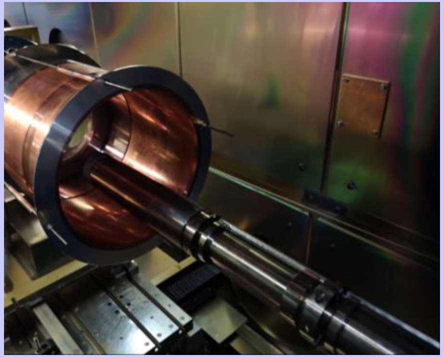
Keyhole 1st pass

Cosmetic pass





400 MHz Cu



Ongoing & future work

- ✓ Development or local repair strategy using deflector (lack of fusion, undercuts & repair of holes)
- ✓ Optical vision system to ease joint localization (400 MHz only)
- ✓ Development of parameters for 400 MHz Cu cavities welding:

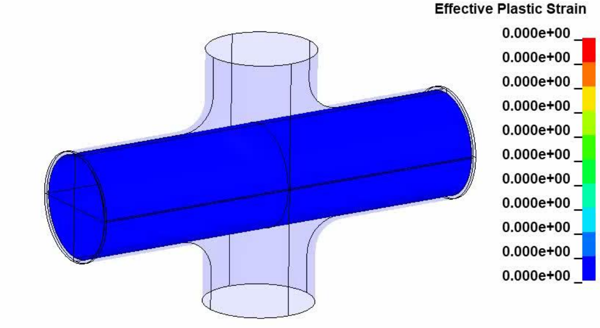
  → Feasibility study to add focusing coil to minimize the beam divergence at long distance

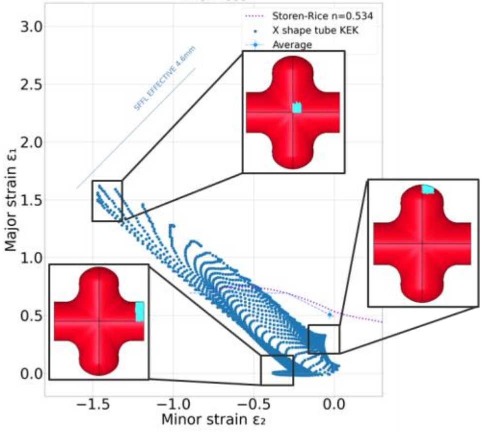
Hydroforming 1.3 GHz Cavity

Single-step Hydroforming

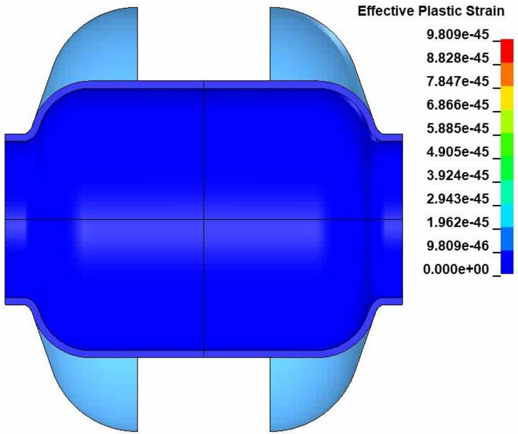
1) Hydro-form
2) Measure
   - *3D Shape & deformed mesh*
   - *Thickness, Roughness*
3) Benchmark with numerical simulations

Collaboration with KEK
A. Yamamoto, M. Yamanaka





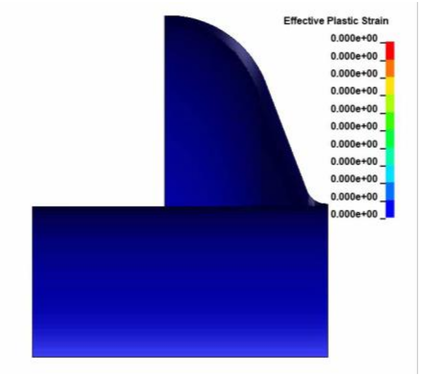
Necking + Hydroforming

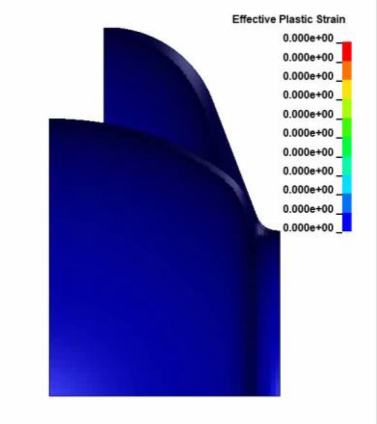


Hydroforming 400 MHz Cavity

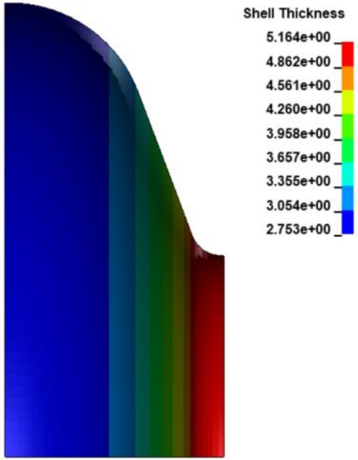
Our target: from tube to cavity in minimum # steps
Always aiming at the industrially feasible

- Initial tube, standard from industry :
  - OD 311 mm, thck. 5.5 mm
  - L ~ 600mm
  - **LIMIT**
- **Hydroforming ONLY**
- From tube to final geometry **in two steps**
- Intermediate annealing





Thinning ~ 50%



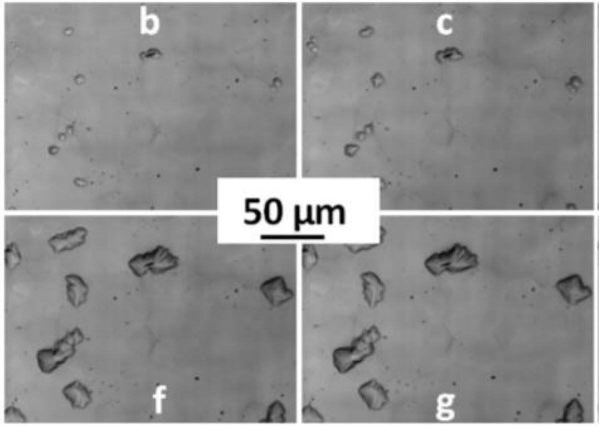
Manufacturing R&D

- **More "Fundamental" R&D** is also ongoing
- Studying the **influence of fabrication processes on material properties/features of interest for (S)RF**
- Mostly embedded within current activities in ongoing Fabrication Program

Hydrogen content:

Aim: Check the potential **impact of** several **manufacturing processes** (spinning, machining, hydroforming, electro-hydraulic forming,...) on the **hydrogen content**.

Concern: Nb hydrides

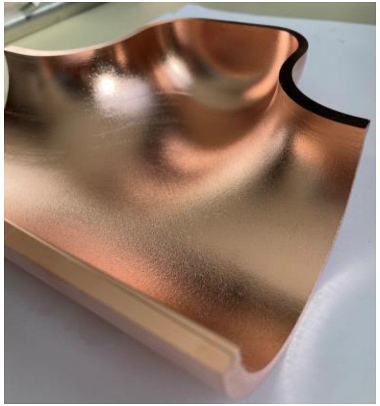


Barkov, F., et al. "Precipitation of hydrides in high purity niobium after different treatments." *Journal of Applied Physics* 114.16 (2013): 164904.

Roughness amelioration:

Aim: Check if roughness can be reduced by chemical treatments.

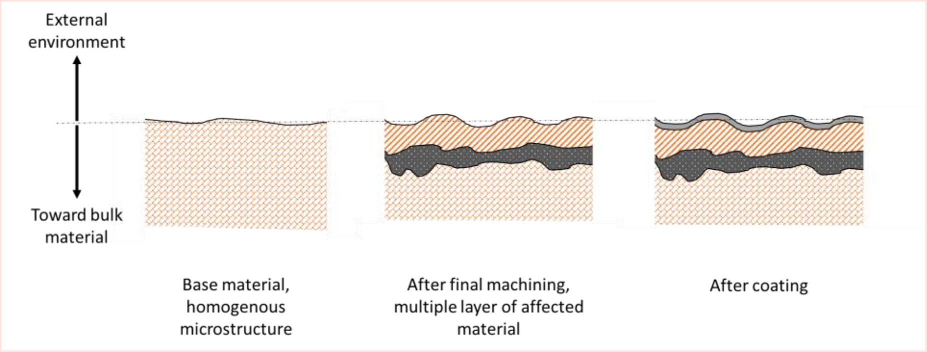
Question: Is there a lower **limit?** Is there a difference in terms of roughness improvement **between machined vs. deformed surfaces**?

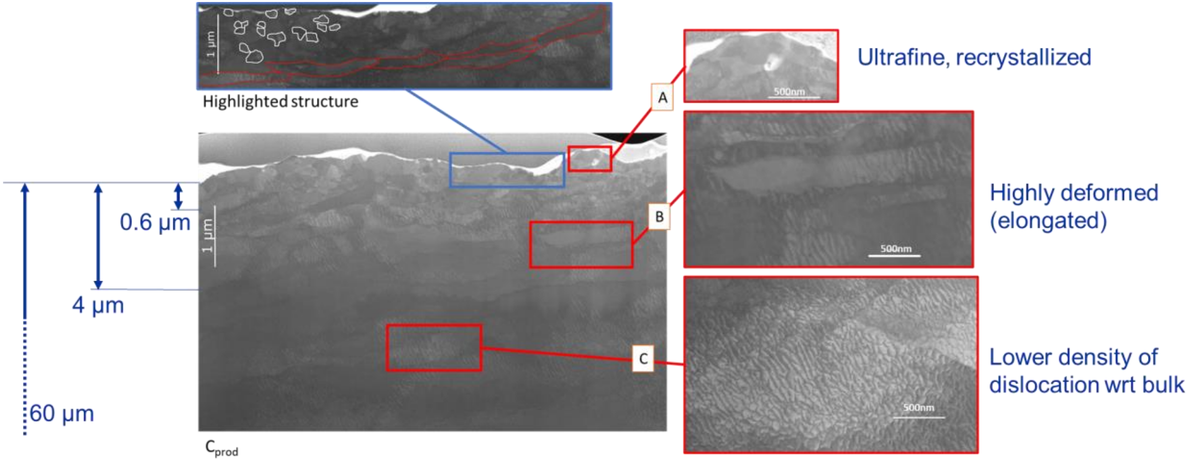


Collab. : TE/VSC – EN/MME
CERN Ref. : Adria GALLIFA, Guillaume ROSAZ

R&D: Machining & Affected Surface Layer

CERN Ref. : Pierre NAISSON





https://www.sciencedirect.com/science/article/pii/S092401362100443X

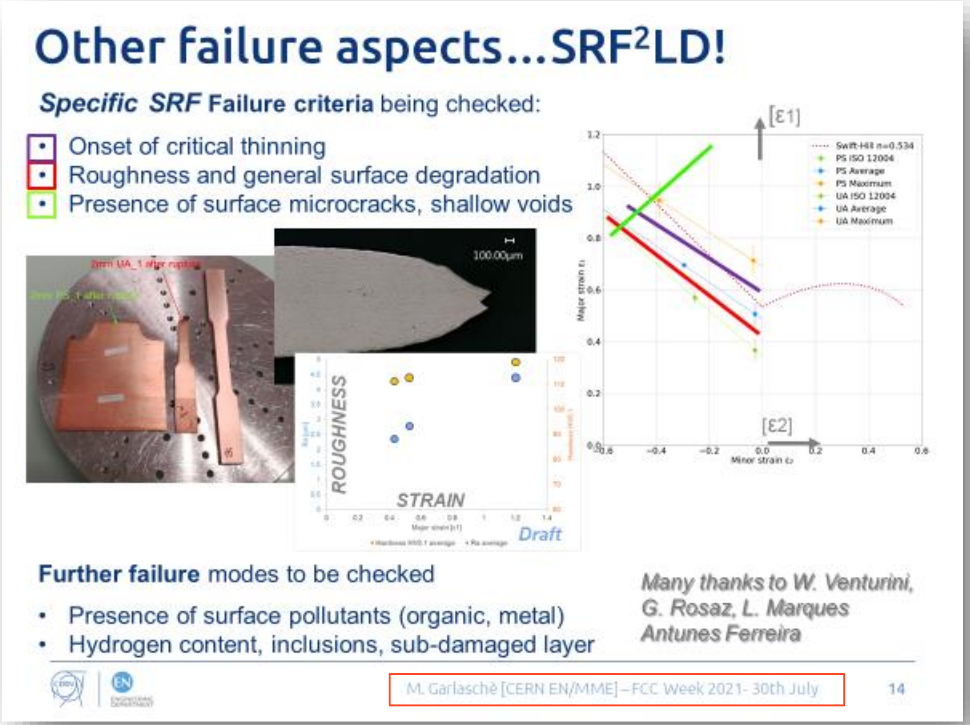
<u>Aim</u>: master the **impact of machining on the surface layer**; and its influence on later coating performance

Study finalized for finishing conditions in **turning**:

- Influence on substrate limited to 60 µm in optimal machining condition
- Highly modified subsurface limited to only 5 µm

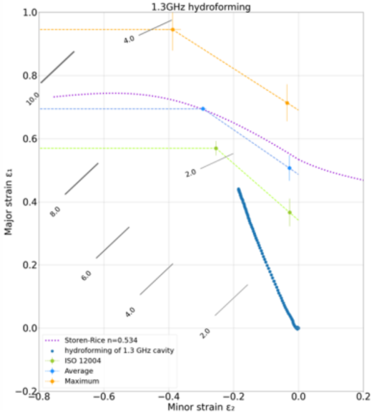
Parallel activity just started for **milling**

R&D : Copper Formability

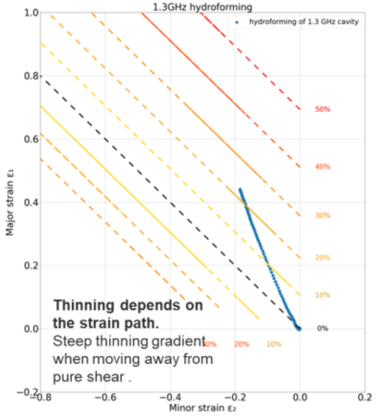


- **Evolving Forming Limit Diagram** to incorporate features of interest for SRF
- Quick prediction of multiple factors (failure, process yield)

SRFLD with Ra prediction



SRFLD with thickness prediction



Thank you
for your attention

Additional Activities

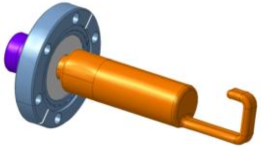
Ceramic Feedthroughs for SRF

Initial Campaign Finalized:

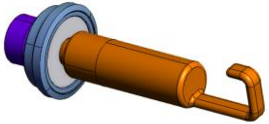
- **Design** to resist more rugged mounting and cryogenic conditions
- Comprehensive **Tests** to validate design:
  - Thermal Shocks (LN_2)
  - NDT: Leak Test, µCT
  - DT: Penetrant (ceramic surface), Metallurgic Examinations

HL-LHC CRAB Antenna

old design: "Full Ti-flange"



new design: rotatable Ti-Flange (with ss-ring)



Significant cracks after mount and thermal shocks

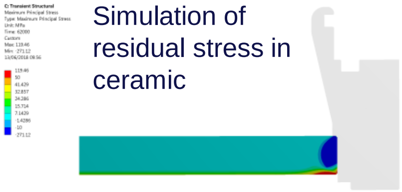
No development of cracks after 5 mounts and thermal shocks

Ongoing & future work

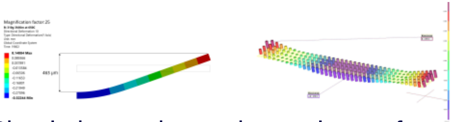
Numerical simulation of brazing assemblies. Predict residual stresses and deformation after brazing of dissimilar materials.

- ➢ Strong reduction of time and resources for testing of assembly design
- ➢ Design optimization through simulations rather than practical trial and error

Establishment of sound material models & failure criteria for ceramic components



Simulation of residual stress in ceramic

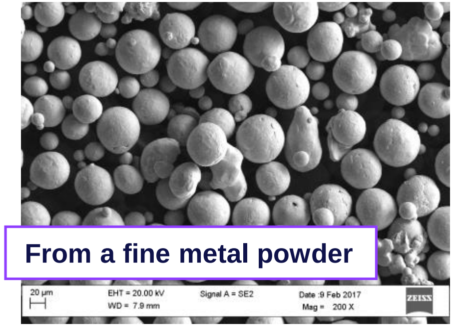


Simulation and experimental test of creep in copper samples (flexural beam)

Collab. SY/RF - EN/MME
CERN Ref. : Eric MONTESINOS, Fritz MOTSCHMANN

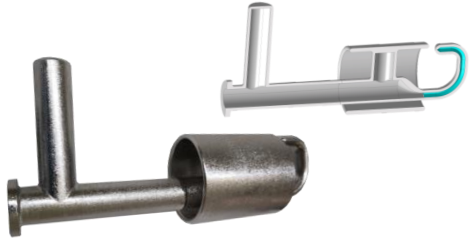
Additive Manufacturing for SRF Applications

CERN Ref. : Romain GERARD



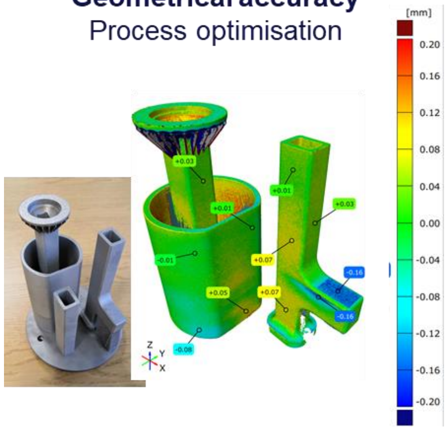
From a fine metal powder

Fused only where material is needed



To produce complex components

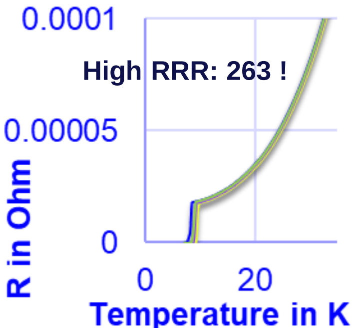
Geometrical accuracy
Process optimisation

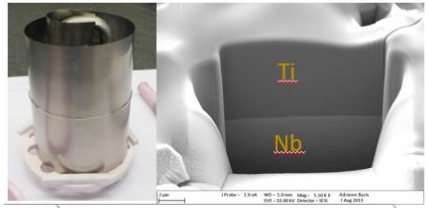


Post-processing treatments to meet SRF Requirements

Purity
Purification of the components by titanium gettering

High RRR: 263 !





Surface roughness and cleanliness
Tribofinishing and chemical etching