ATS-KT Innovation Day

Development of copper electroformed NEG coated vacuum chambers

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Outline

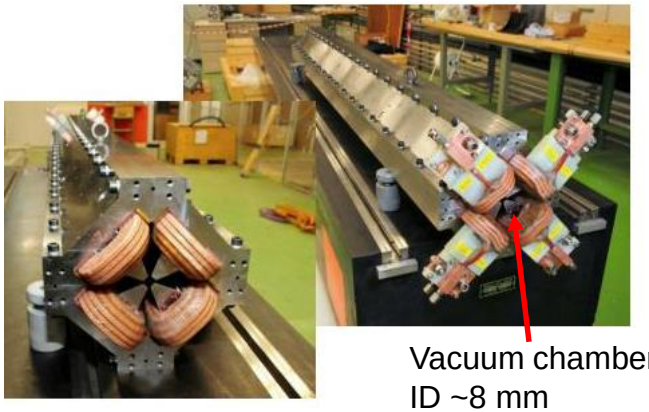
1. Motivation
2. Idea
3. Prototypes
4. Next steps
5. Applications

Why? New generation light source accelerators and CLIC

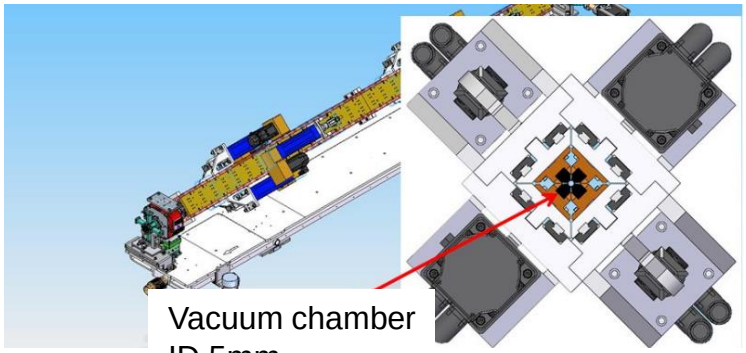
Next generation synchrotron light sources and CLIC (beam focussing) demand the use of small-aperture beam pipes: magnetic poles closer to the beam.

- Big impact on the vacuum system: low conductance vacuum chambers.
- Distributed pumping , as getter coating, is needed to keep gas density low.

M. Modena et al. (2014)
CLIC MB quadrupole [1]



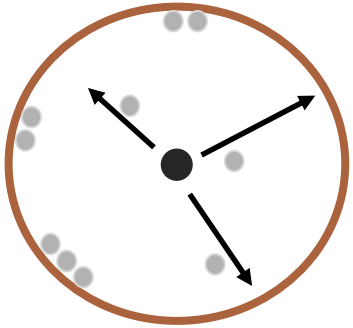
H. D. Nuhn et al., Presentation at FLS (2012),
Delta undulator, SLAC



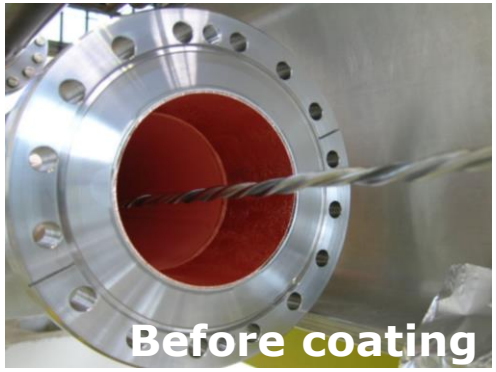
[1] http://clic-study.web.cern.ch

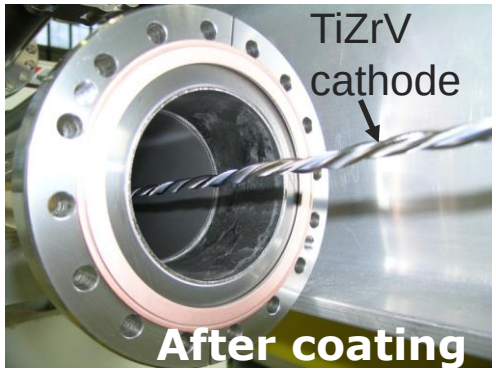
Why? NEG thin film coating

NEG thin film coating, developed at CERN, is usually performed by DC magnetron sputtering from a twisted Ti, Zr, V wire cathode that is positioned in the vacuum chamber centre.



Vacuum chamber





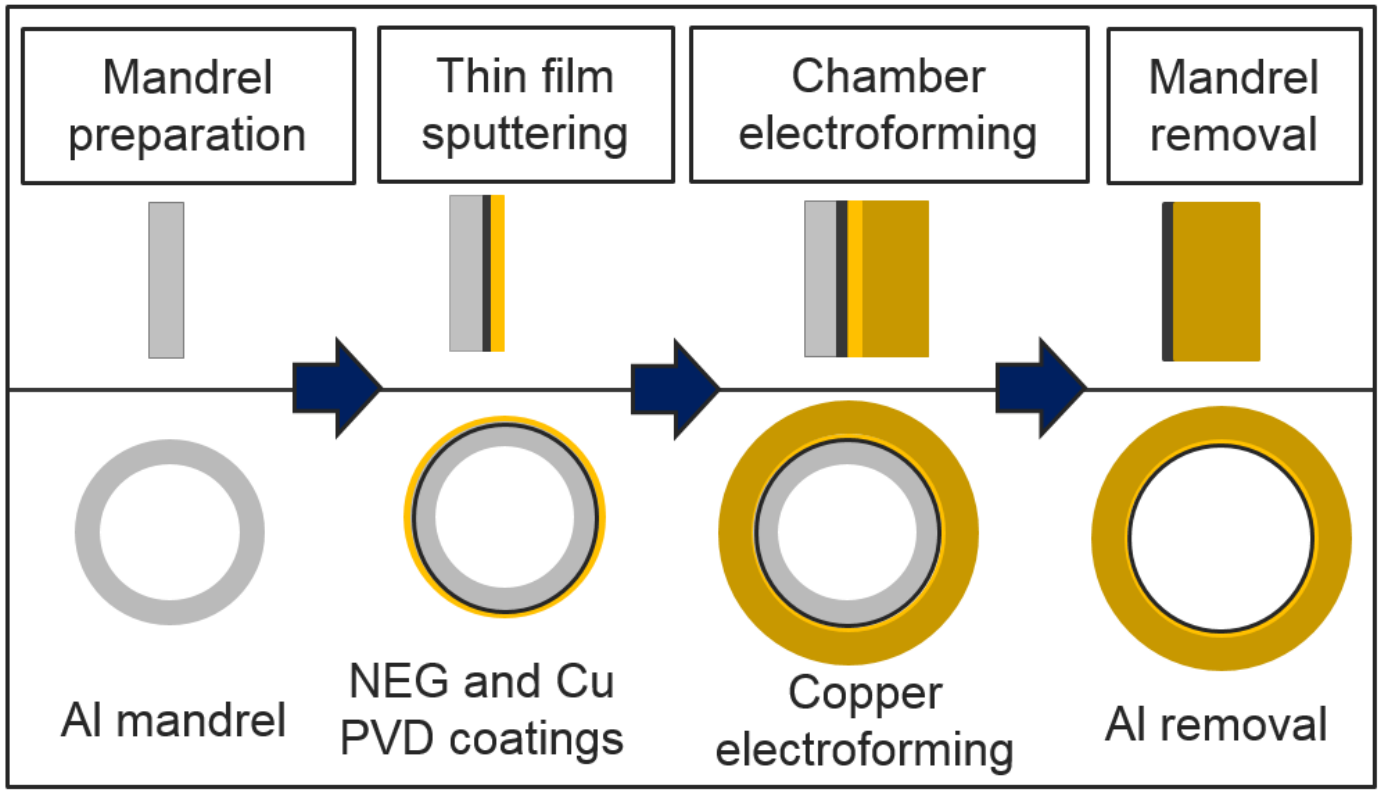
Physical vapor deposition techniques are difficult to apply to few-mm diameter pipes that are several meter long.

Vacuum chamber

°?

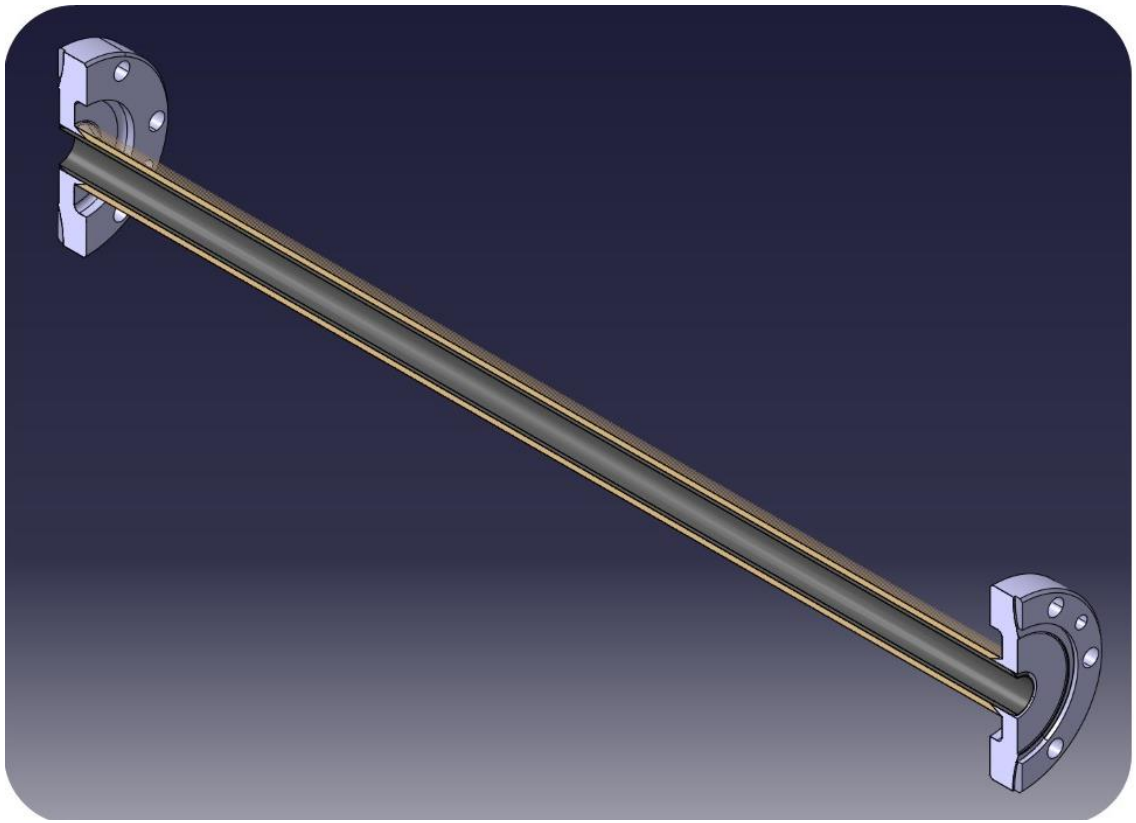
Production/coating technique based on mandrel technology

The vacuum chamber is produced by copper electroforming around a sacrificial aluminium mandrel which is pre-coated with a NEG thin film.



Production/coating technique based on mandrel technology

During the electroforming, the stainless steel flanges are assembled to the chamber without any welding/brazing.



Production/coating technique based on mandrel technology

Advantages of this technique:

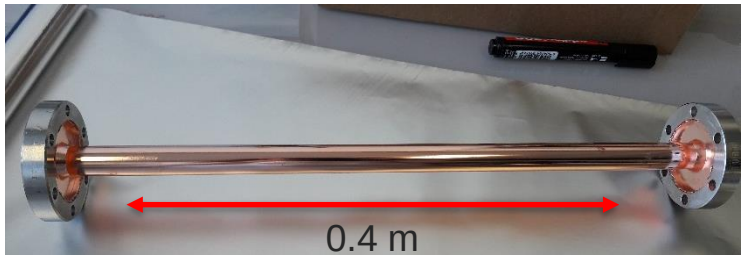
- Stainless steel joining is produced without EB welding or brazing step.
- Uniform coating (composition + thickness) is obtained along the length of the chamber.
- Coating reproduces the mandrel topography: If mandrel is polished, coating is very smooth.
- Very complex shapes can be coated if a mandrel can be machined.

Prototypes

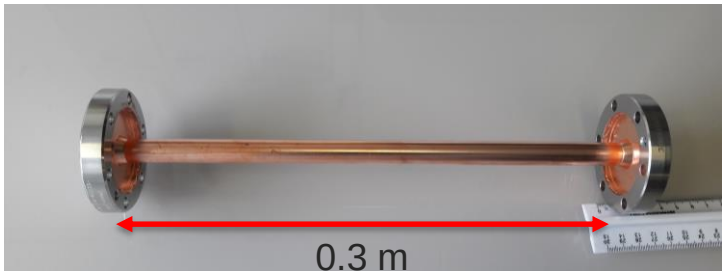
TiZrV coated chamber

Diameter constraint?

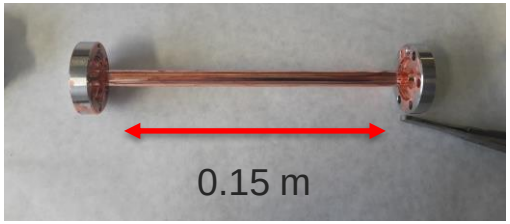
Chamber 16 mm diameter



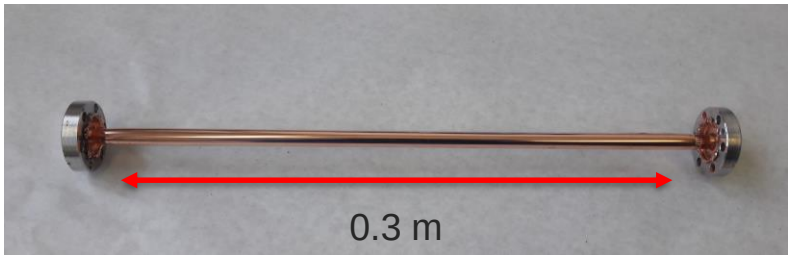
Chamber 12 mm diameter



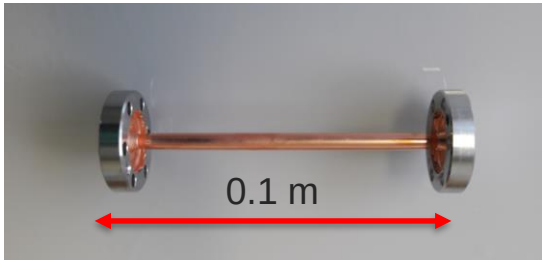
Chamber 6 mm diameter



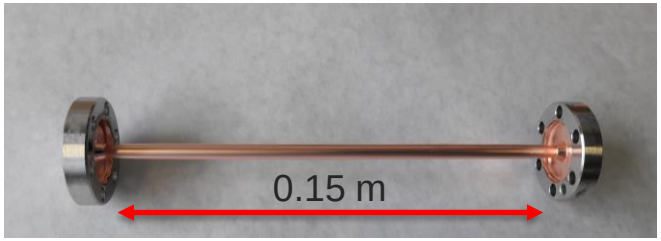
Chamber 5 mm diameter



Chamber 4 mm diameter



Chamber 3 mm diameter



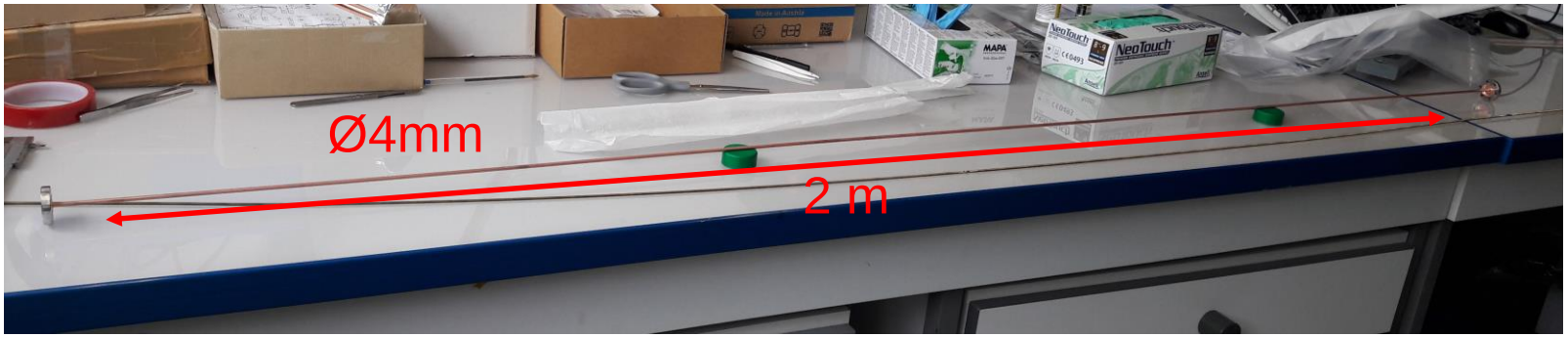
Lowest diameter ever NEG coated tube

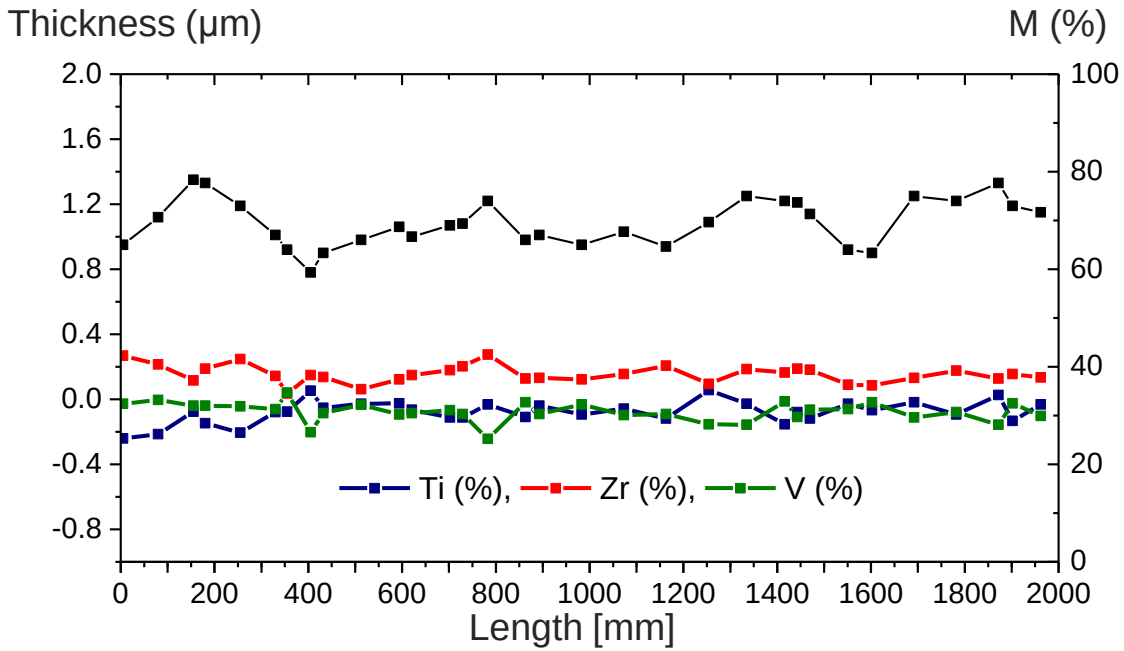
Prototypes

TiZrV coated chamber

Length constraint?

4mm internal diameter, 2 m length TiZrV coated chamber



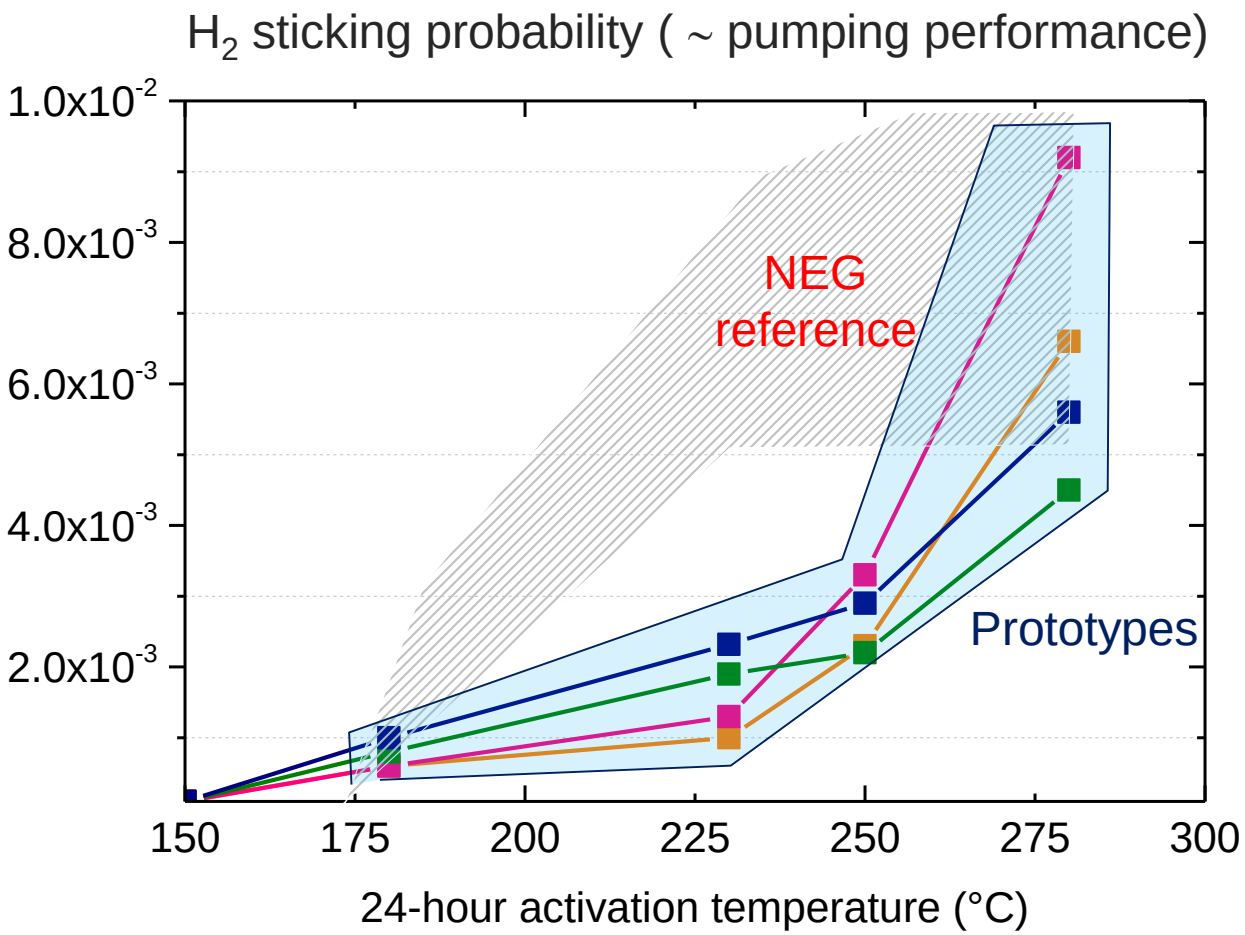


Limited only by the depth of the plating bath.

Prototypes

TiZrV coated chamber

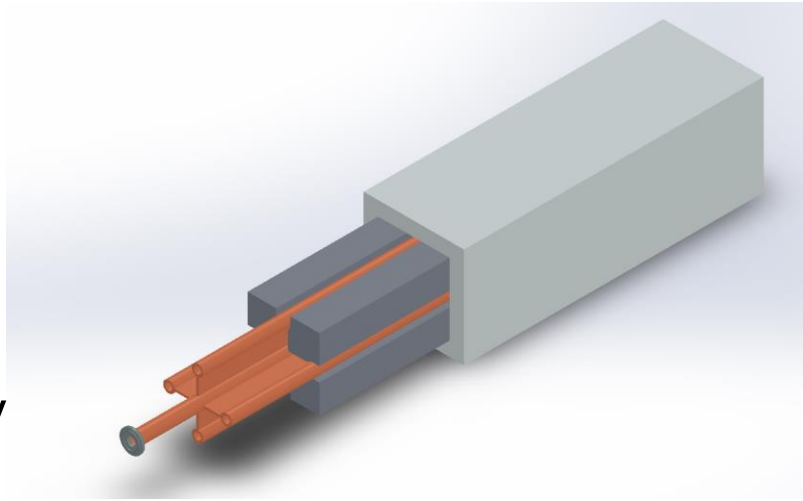
Pumping performance



H_2 sticking factor reaches reference values (standard coating method), but there is a delay in activation temperature.

Further steps

- Transfer of the technology to non circular and/or complex geometries.



- Joining stiffeners and/or cooling lines by the electroforming process.

- Optimization of plating procedures at CERN. Reverse pulse plating to optimize thickness distribution.

- Decrease the in-situ activation temperature of the coating.

Origin of the idea

- Vacuum in the beampipes of CLIC quadrupoles
- The idea has been pursued as a PhD work at CERN, in collaboration with the Université de Franche Comté.

Interest in HEP community

- High interest is shown from Berkeley Lab (US) and PSI (Zurich) for vacuum chambers of wigglers.
- Industrial companies that manufacture vacuum chambers for HEP have also shown interest

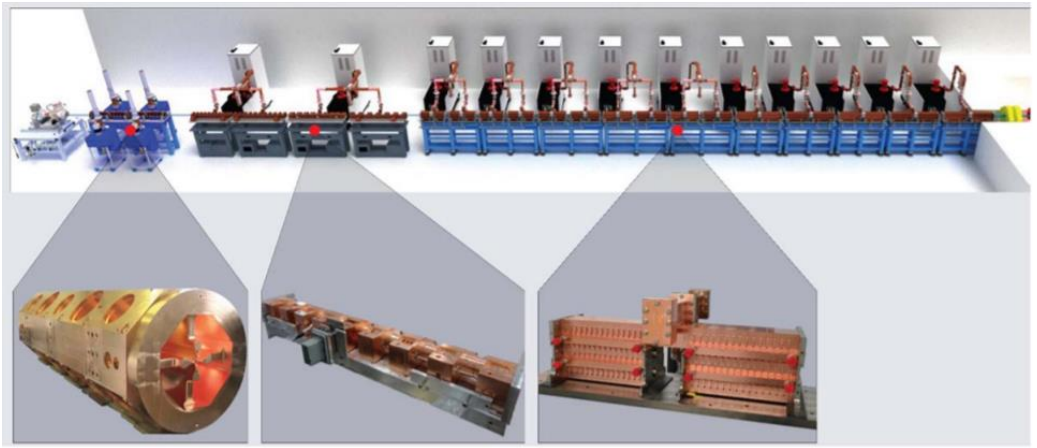
Other applications outside CERN and HEP

TiZrV coated beampipes

Advanced onco-therapy beam-pipes // accelerator for medical research

A. Degiovanni et al. Proceedings of NAPAC2016, Chicago, IL, USA

LIGHT (LINAC for Image Guided Hadron Therapy)



Free Electron Lasers

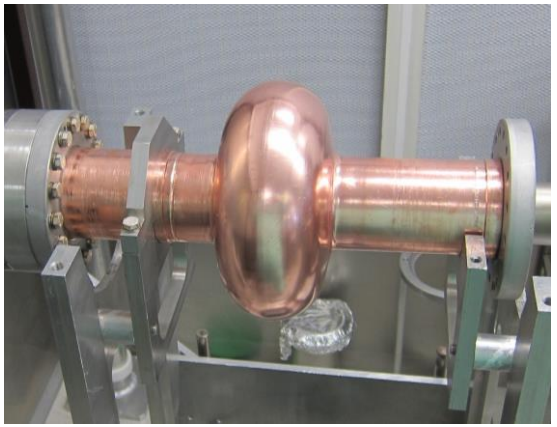
General idea: thin-film coated copper electroformed assembly

Applications can be expanded to other thin film coatings in complex and/or small geometries.

Other applications

RF cavities (to be tested)

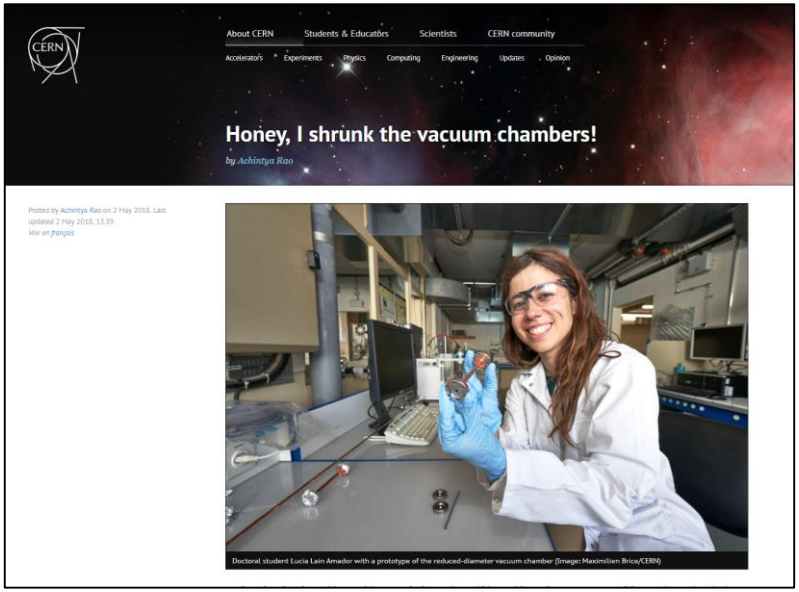
- Aluminium mandrel polished
- No EB welding in the process
- High RRR for electroformed copper
- Cu cavities made with Cu PVD layer
- Nb/Cu cavities made by deposition of Nb and Cu PVD layers on the mandrel



1.3 GHz cavity

LHC cavity

Thank you very much for the attention!



More info:

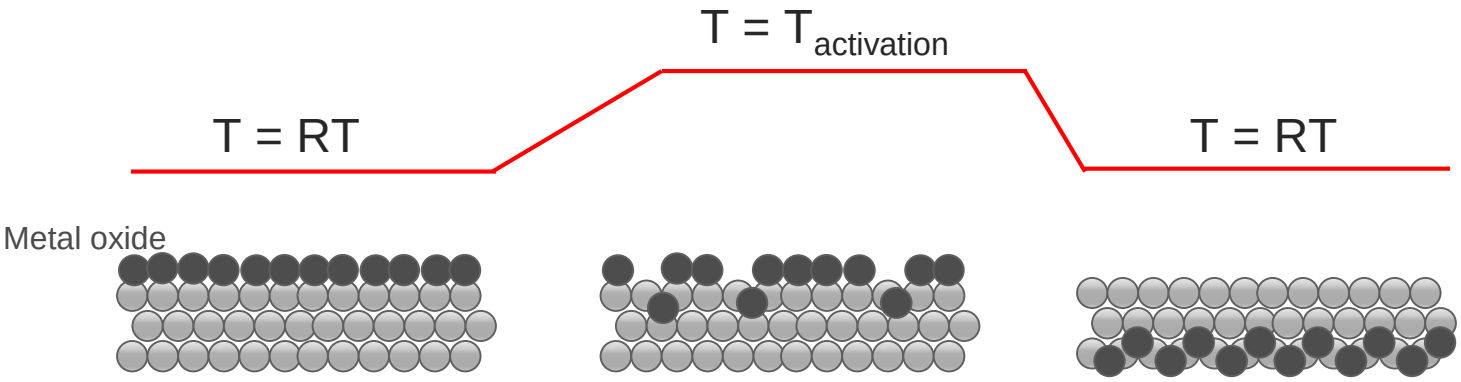
https://home.cern/about/updates/2018/05/honey-i-shrunk-vacuum-chambers

L. Lain Amador, P. Chiggiato, L. M.A Ferreira, V. Nistor, A. T. Perez Fontenla, M. Taborelli, W. Vollenberg, M-L Doche, J-Y Hihn,J. Vac. Sci. Technol. A, 36, 021601 (2018)

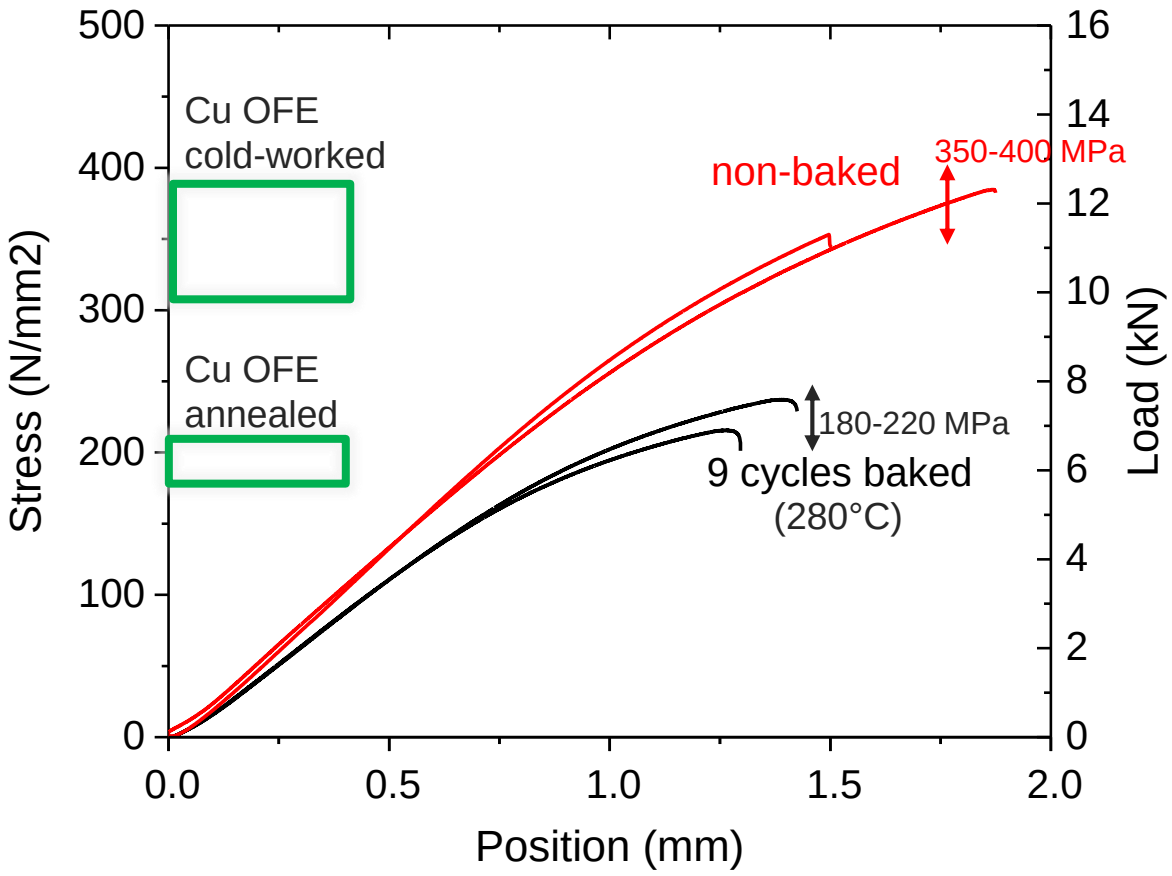
Non evaporable getter (NEG)

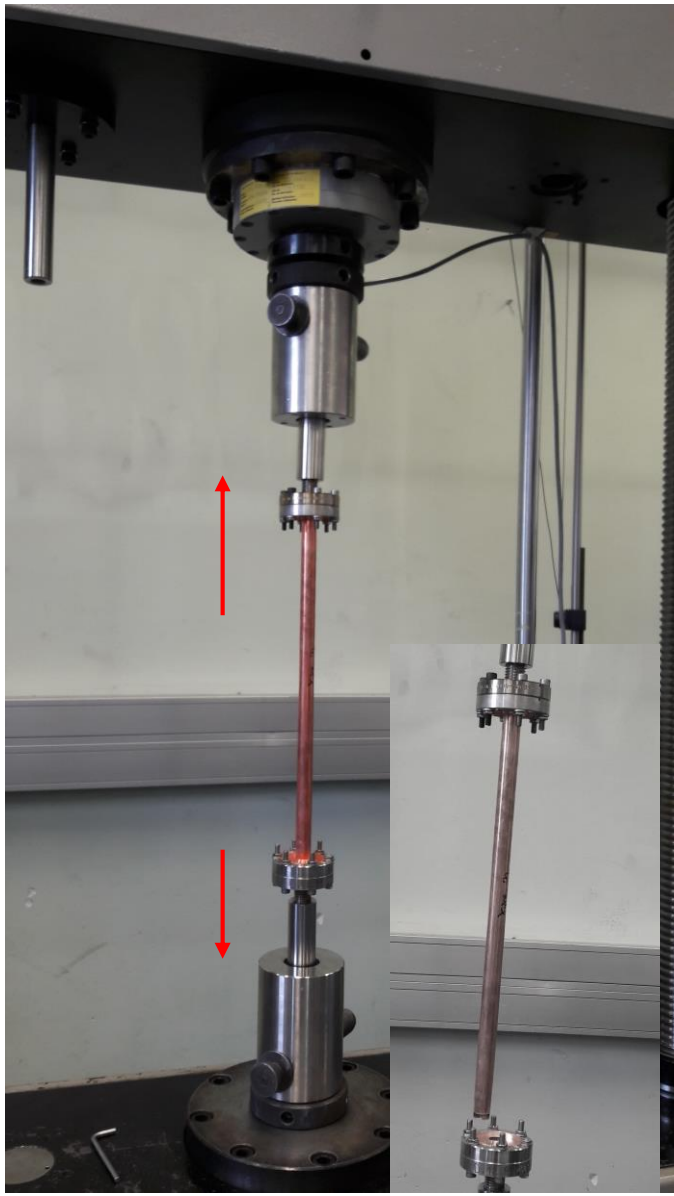
Non Evaporable Getter are materials than can pump residual gaseous molecules after thermal activation in vacuum.

During the activation, the surface oxygen diffuses inside the bulk.



Mechanical performance





Chambers before and after bake-out exhibit a tensile strength comparable to Cu OFE