

Surface treatments for vacuum applications at CERN

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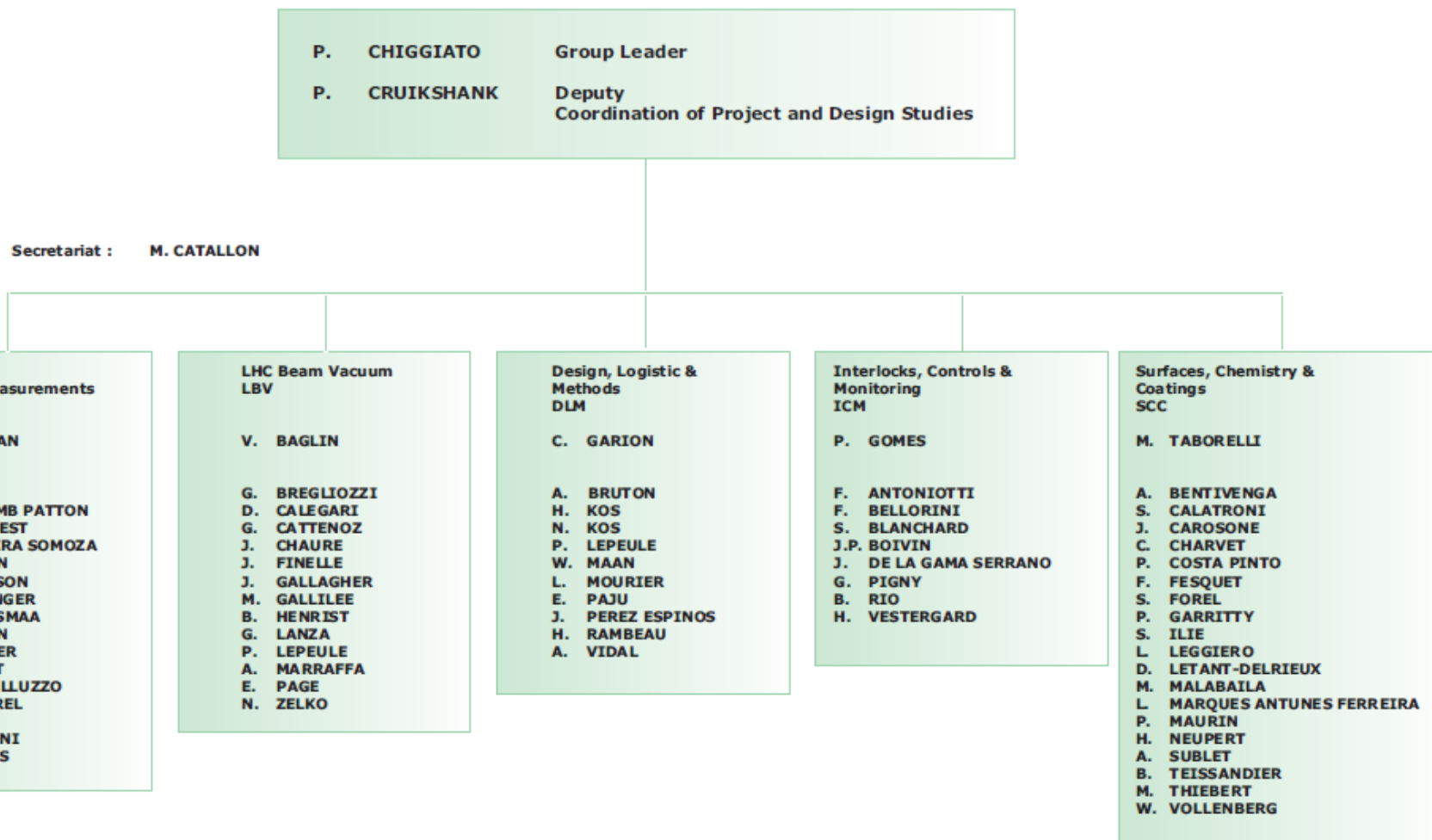
Technology Department
Vacuum, Surfaces & Coatings



JRC-CERN collaboration workshop, CERN, January 27th, 2014

Vacuum, Surfaces and Coatings

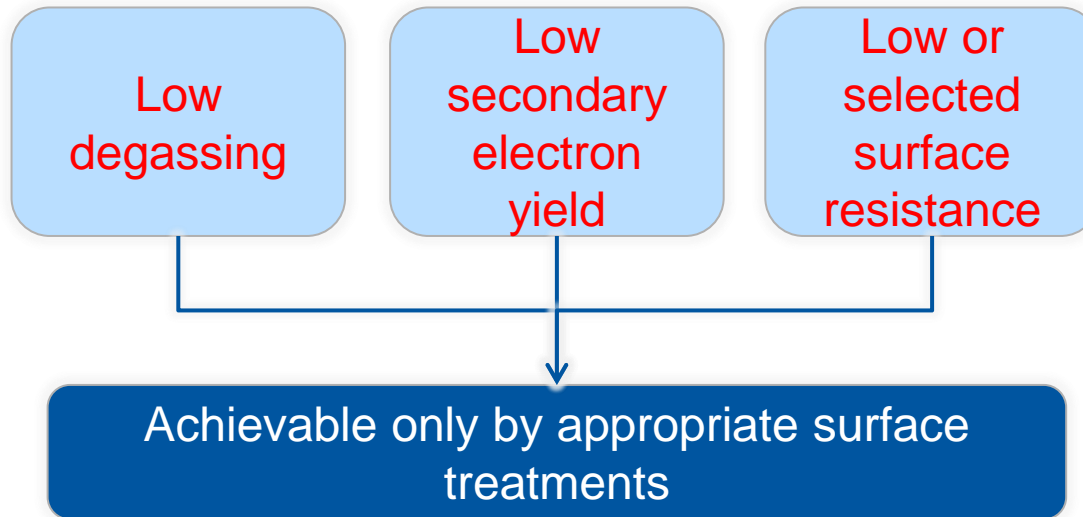
Staff Members



Outlook

- 1 Vacuum materials require surface treatments**
- 2 Chemical surface treatments**
- 3 Coatings**
- 4 Future developments**

Vacuum materials require surface treatments



Surface treatments

Any deliberate modification of the surface properties of vacuum materials to cope with the accelerators' requirements.

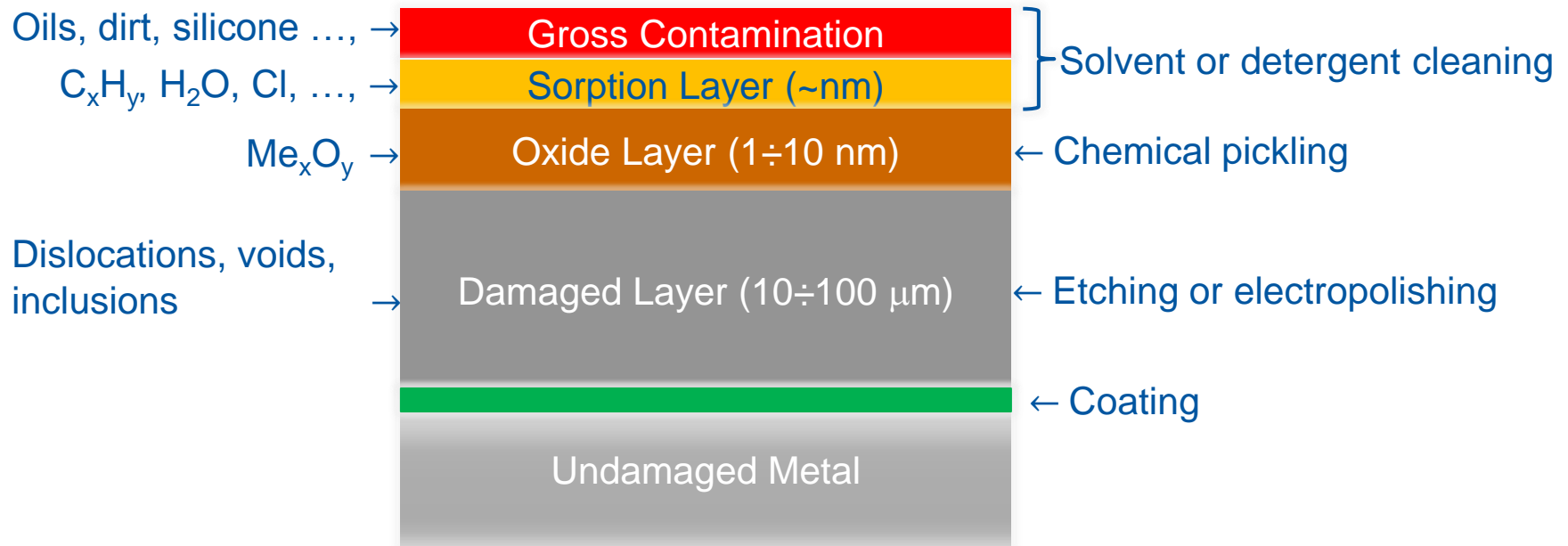
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Surface treatments are strategic for accelerator operation and new projects

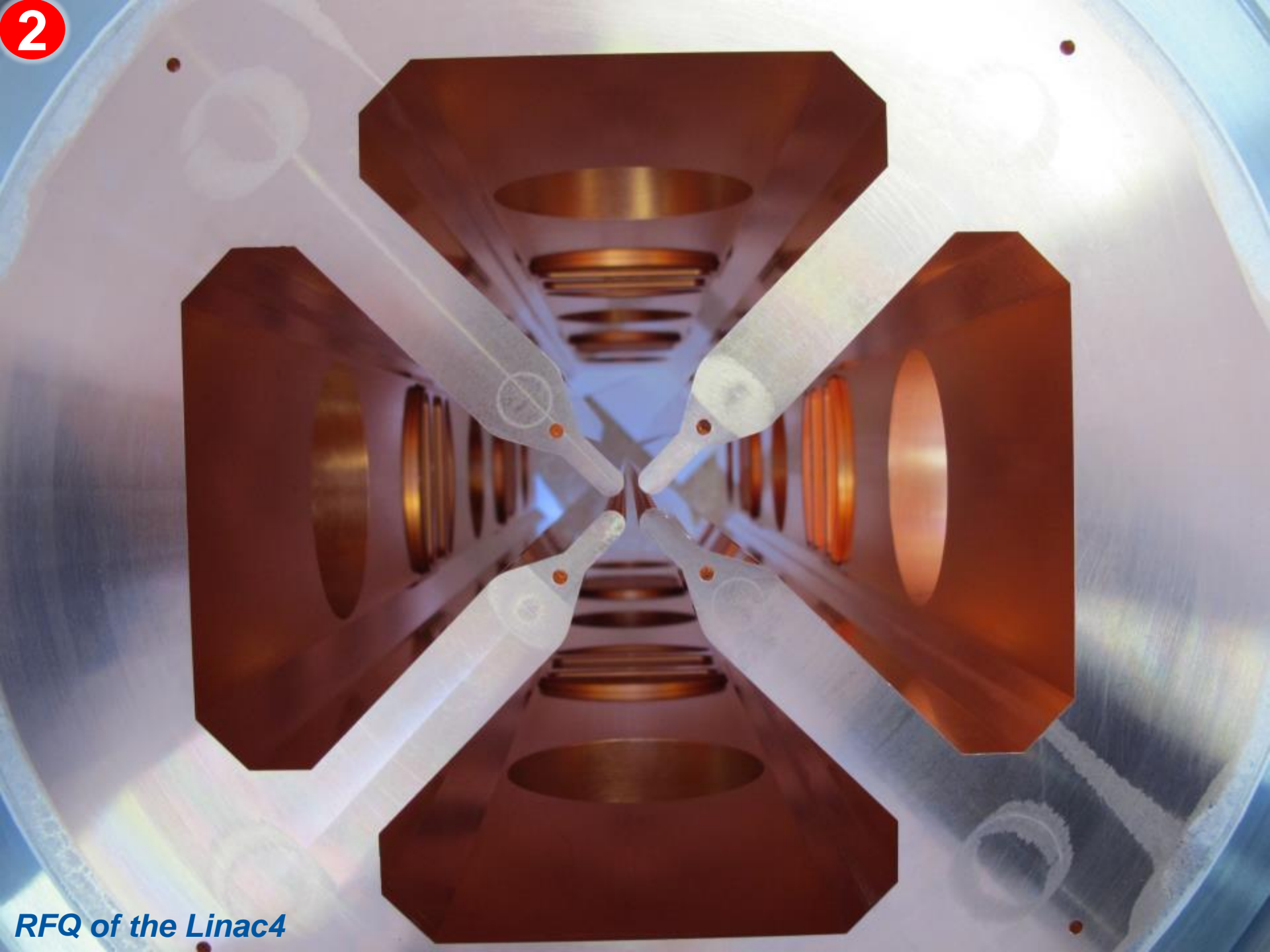


CERN investment: new building for chemical surface treatments (and special printed circuits)

Vacuum materials require surface treatments

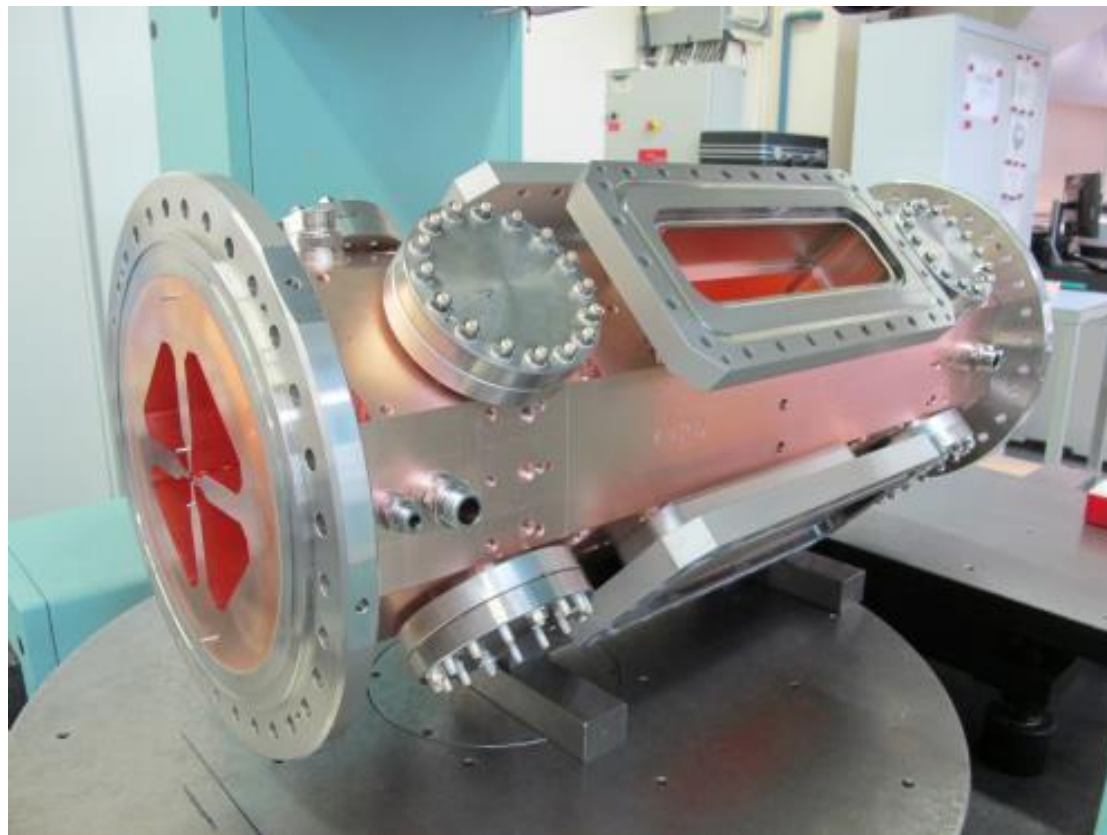


2



RFQ of the Linac4

2



Radio Frequency Quadrupoles (RFQ) for the Linac4

2



LHC beam screens with cooling capillaries

2



LHC RF cavities



HIE-ISOLDE RF cavities

Electropolishing of Cu

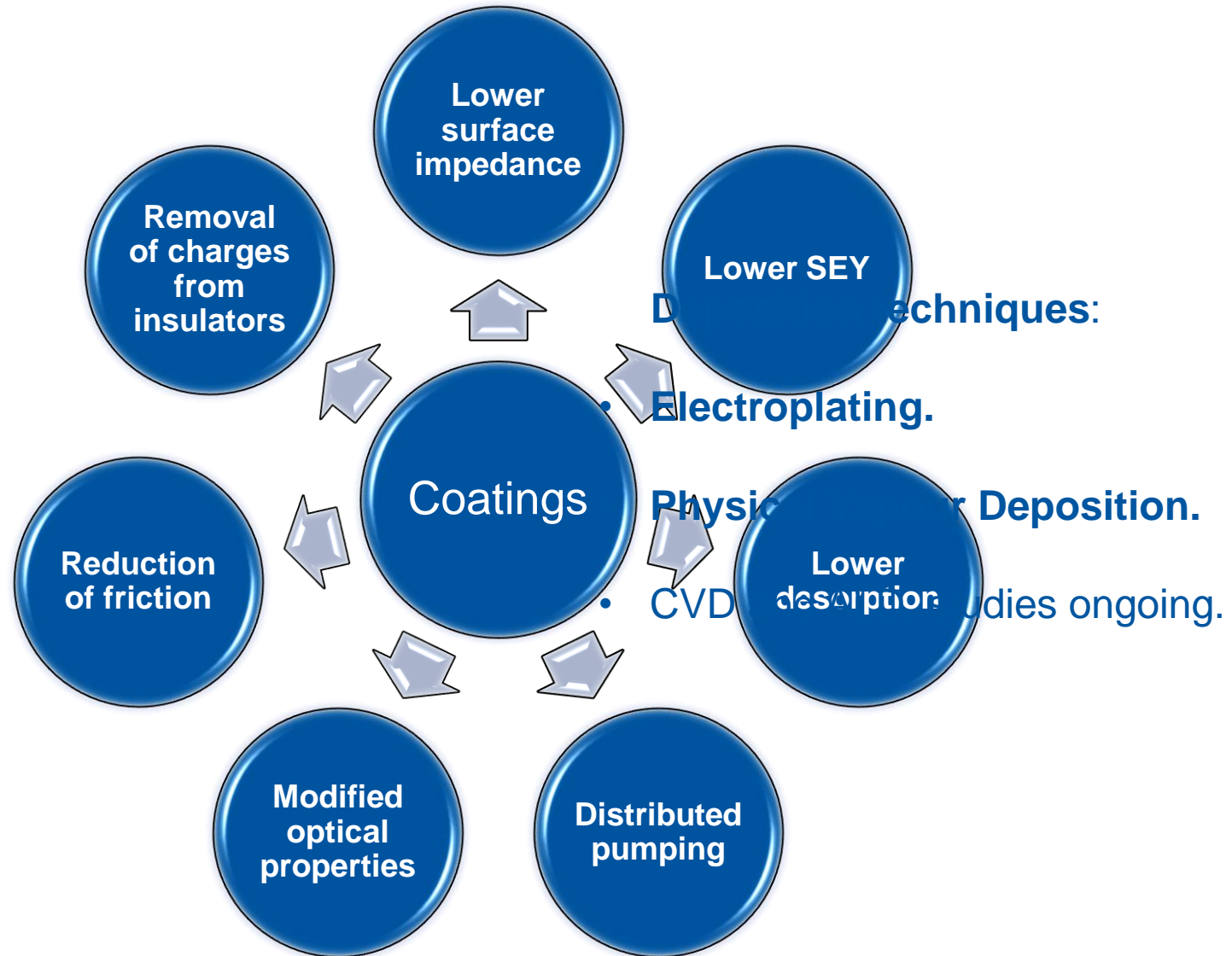


Chemical polishing of Cu



Courtesy of Serge Forel

Coatings modify the surface properties



3

Coatings: Cu electroplating



Electroless deposition of *LHC's* VCTYB



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JRC-CERN collaboration workshop19th,

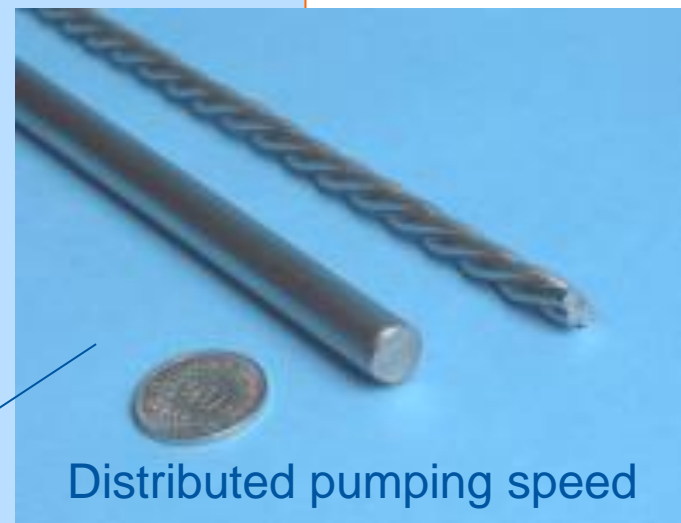
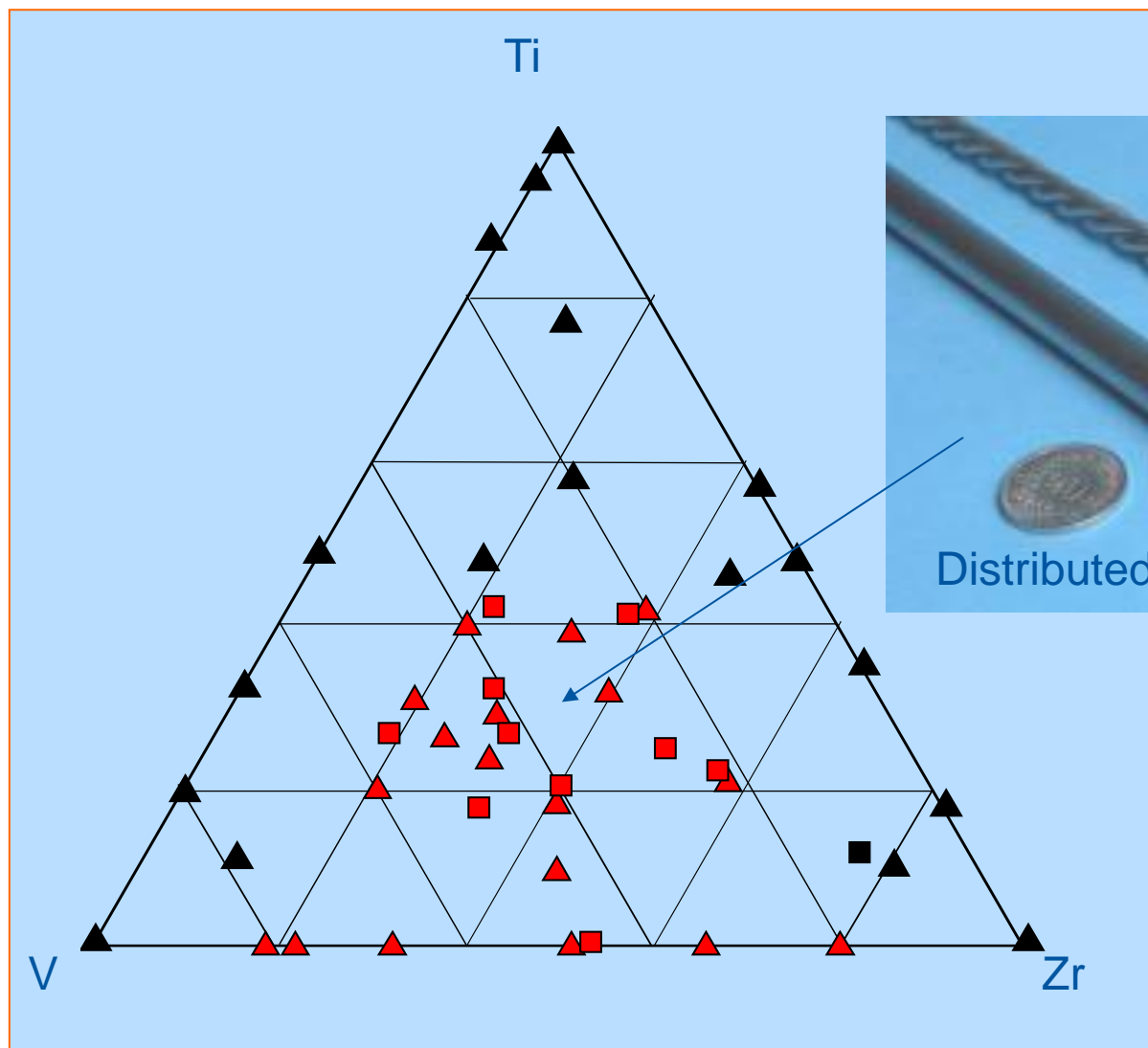
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Coatings: Cu electroplating



Electroless deposition of *LHC's* VCTYB

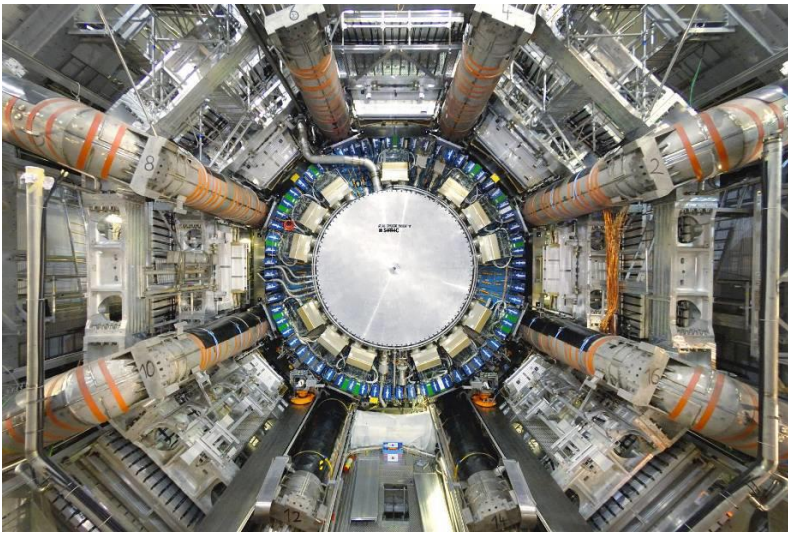


Nominal composition:

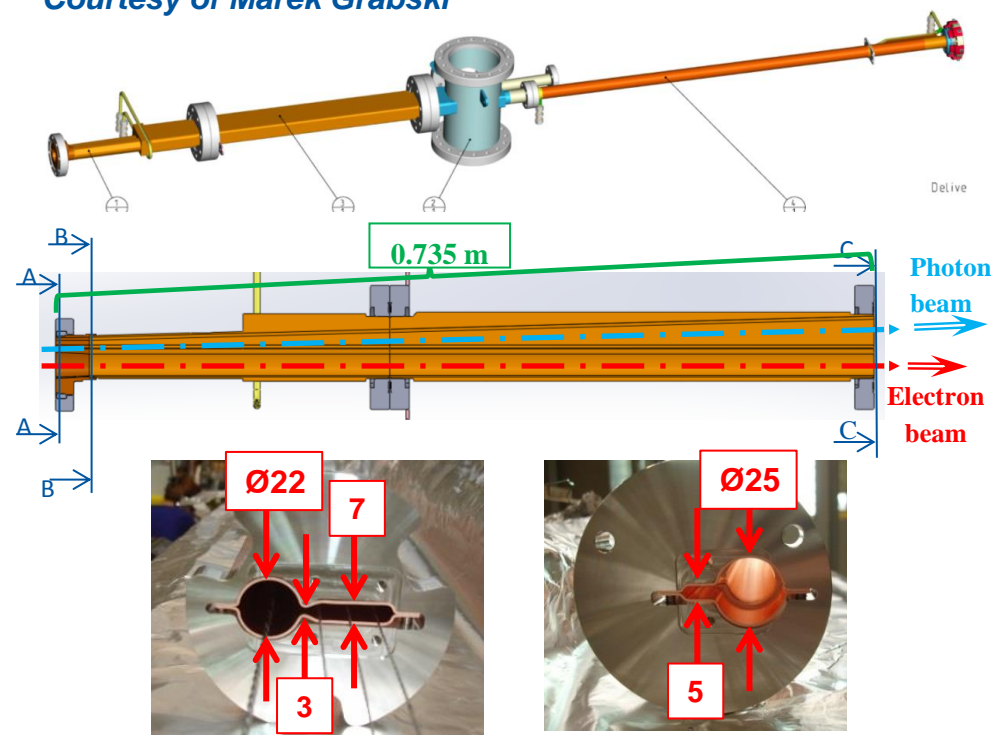


**Activation
temperatures:
180°C for 24 h**

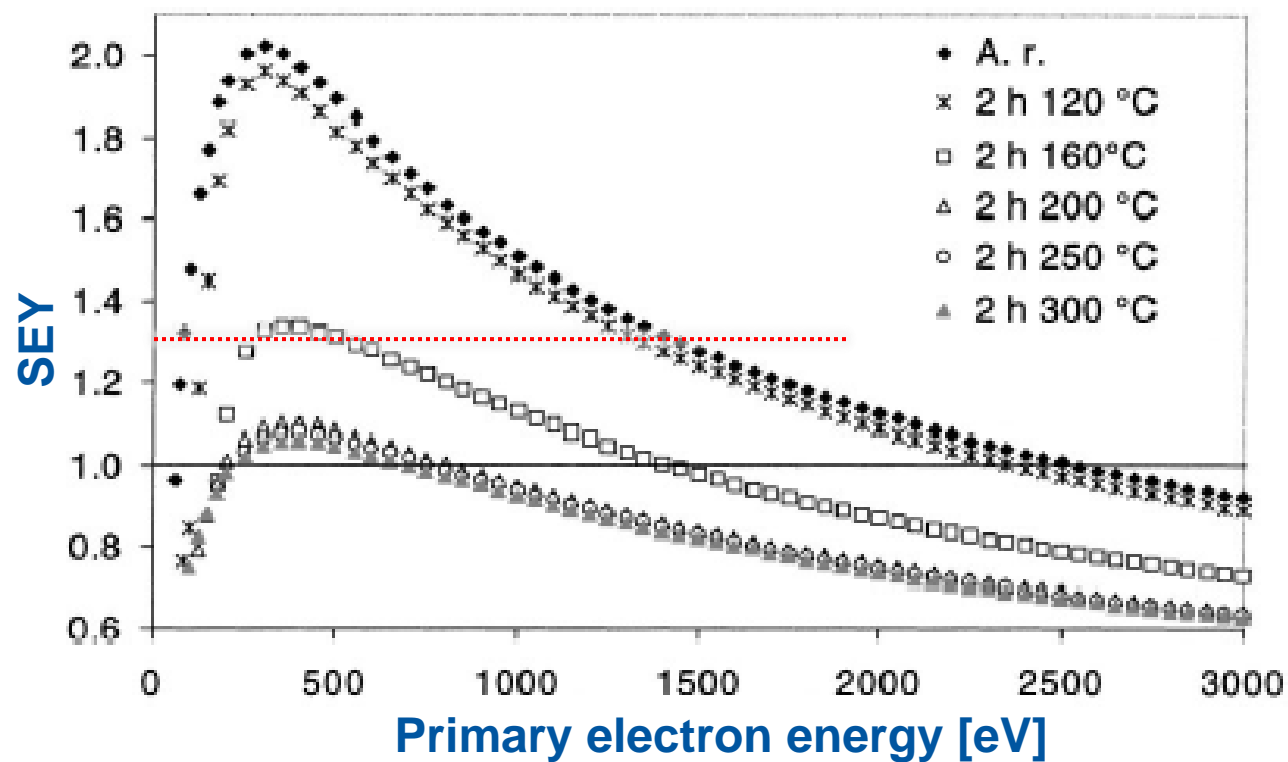


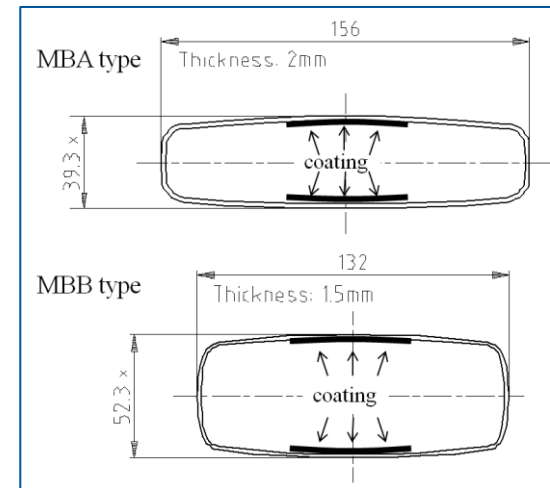
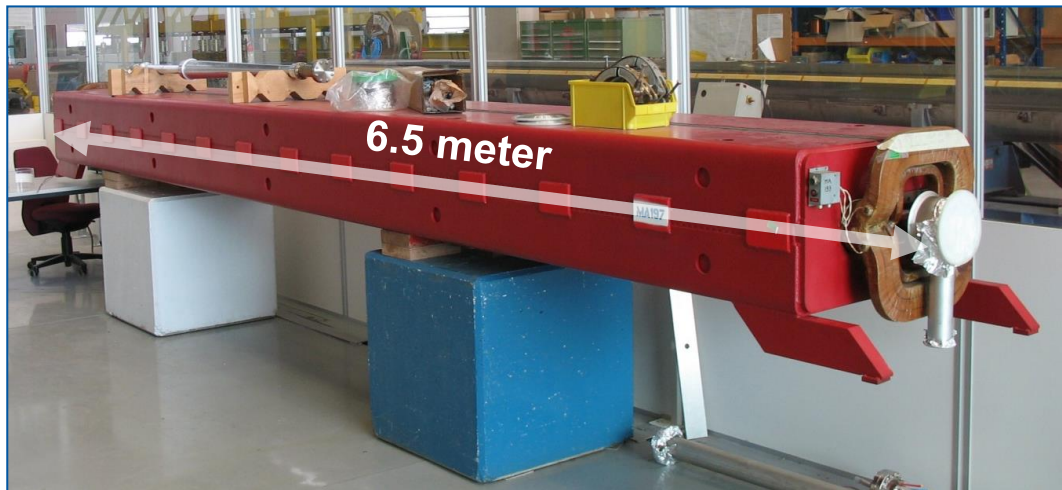


Courtesy of Marek Grabski

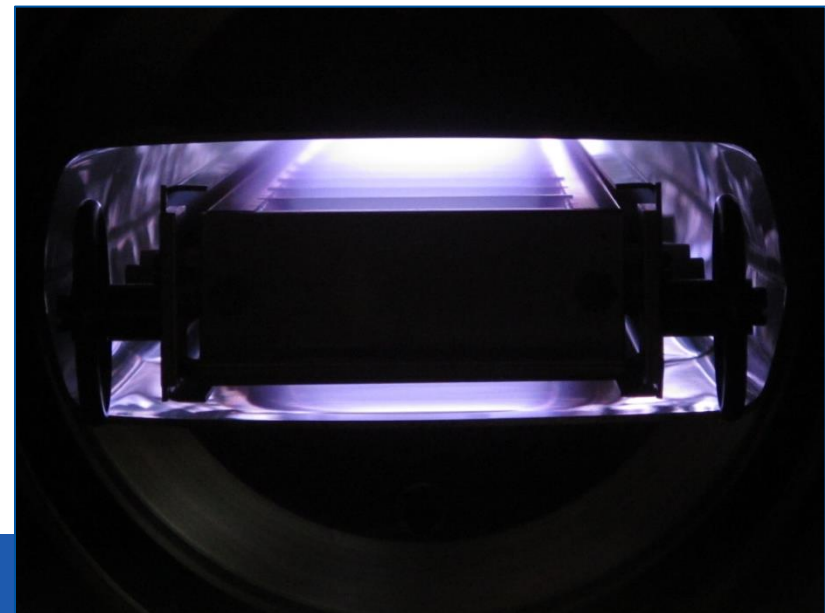
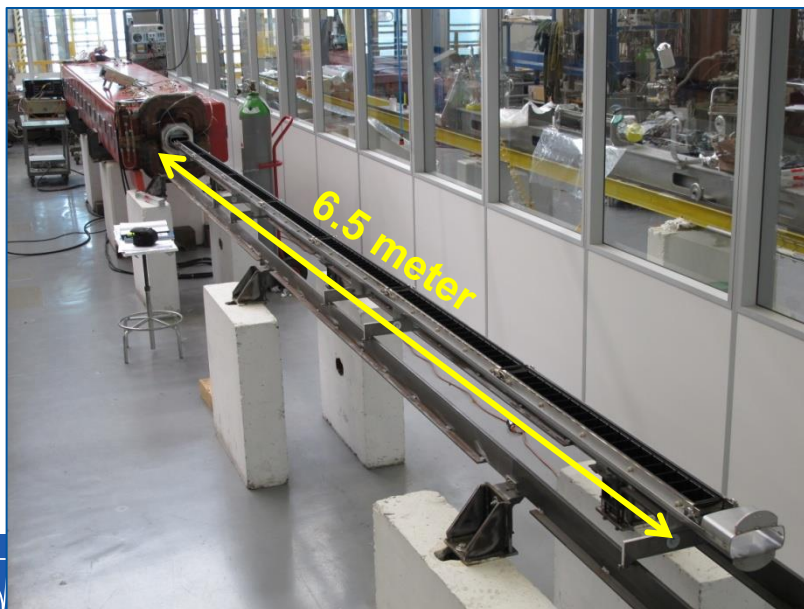


B. Henrist et al./Applied Surface Science 172 (2001) 95–102





Coating by hollow cathode sputtering



Coating: Niobium for superconducting RF cavities



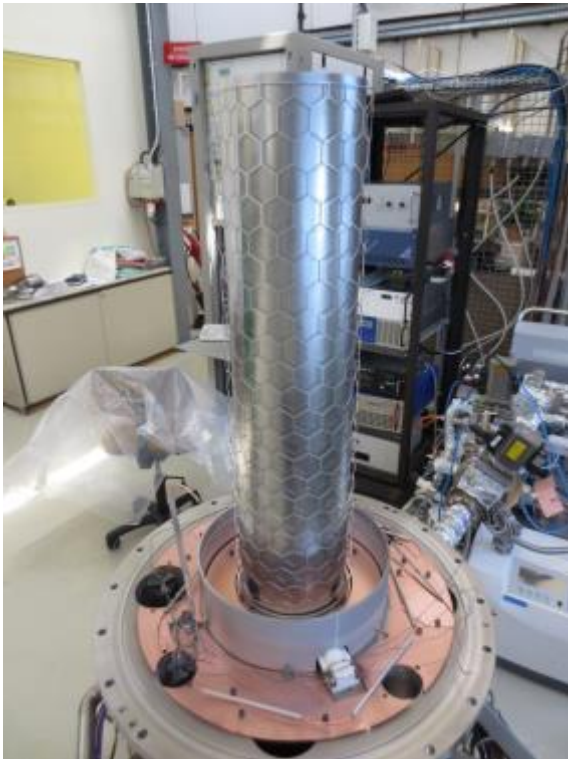
LEP 350 MHz
> 250 pieces:
Industrial collaboration



LHC 400 MHz
30 pieces
Industrial collaboration

- DC Magnetron, Nb ($1\text{--}2\ \mu\text{m}$)
- Purity (vacuum!) and substrate preparation (electro polishing or chemical polishing) are crucial.
- Developed at CERN in the 80's, presently applied to HIE-ISOLDE cavities

Coating: Niobium for superconducting RF cavities



HIE-ISOLDE 100 MHz
20 pieces high beta, production started
12 pieces low beta, design phase

- **Less harmful** chemical products for cleaning and electropolishing.
- NEG coatings in **confined structures (we have requests for coatings of 4-mm diameter beam pipes)**.
- Understanding of the role of **coating parameters on the SEY** of carbon films.
- Applications of **alternative coating** techniques: ALD and HiPIMS.

Acknowledgements

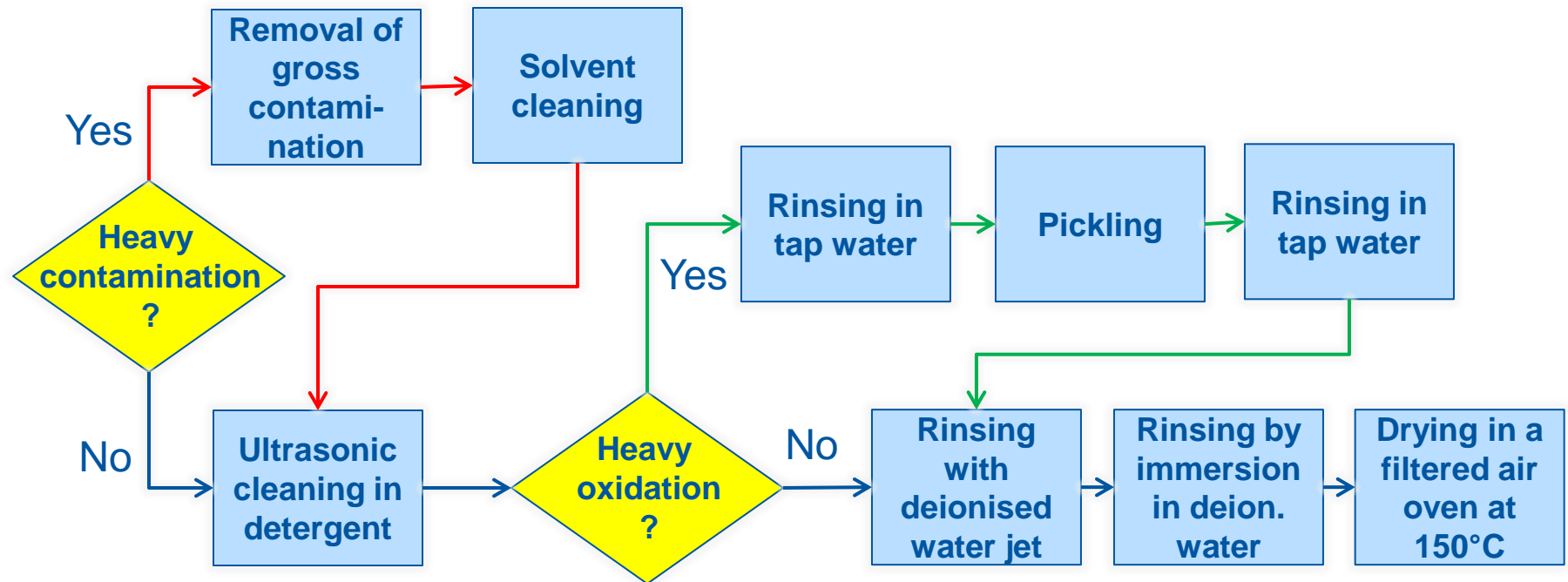
I wish to thank all my colleagues of the Vacuum, Surfaces and Coatings group of the Technology Department at CERN, including students and visitors.

The VSC group has become a centre of excellence in Europe encompassing all aspects of vacuum technology, from surface treatments to computation, operation and control of unique facilities.



Additional slides

Cleaning Procedure



St. Steel

CERN standard:

Solvents

- perchlorethylene vapour (121 °C)

Detergent

- Stainless steel: P3-ALMECO 18 (ph=9.7) at 65°C
- Al and Cu: NGL 17.40 sp ALU at 45 °C

Pickling

- St. steel: HF+HNO₃ solut.

Deionised water

resistivity ≥ 1 M Ω cm.

- Applied at CERN for hazardous materials: beryllium.

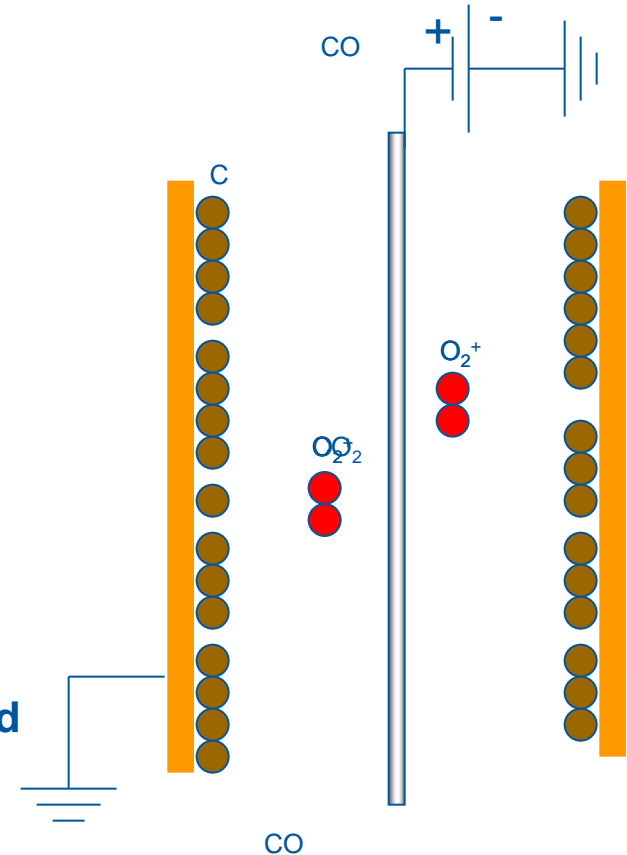
In situ pure O₂ plasma removes carbon from the substrate without hazardous waste.

- ❖ Standard magnetron-sputtering assembling
- ❖ Injection of O₂ (about 10⁻²Torr)
- ❖ The central wire is polarized positive relative to the chamber
- ❖ “Reverse sputtering” is started
- ❖ $O_2^+ + C \rightarrow CO + CO_2$
- ❖ Key issues:

Chemical sputtering yield >> physical sputtering yield

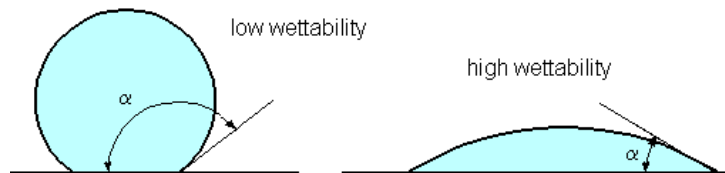
maximize evacuation of CO and CO₂

O₂⁺ energy about 100eV



Successfully applied to the LHCb Be chamber

- Wettability test
- Surface sensitive techniques (for example AES, XPS, FTIR...)
- Radiotracers
- Functional characterization: outgassing rate, ESD yields and SEY
- In-situ measurements



Removal of the Damaged Layer

Dislocations, voids,
inclusions



Damaged Layer (10÷100 μm)

← Etching or electropolishing

Undamaged Metal

The damaged layer is removed to:

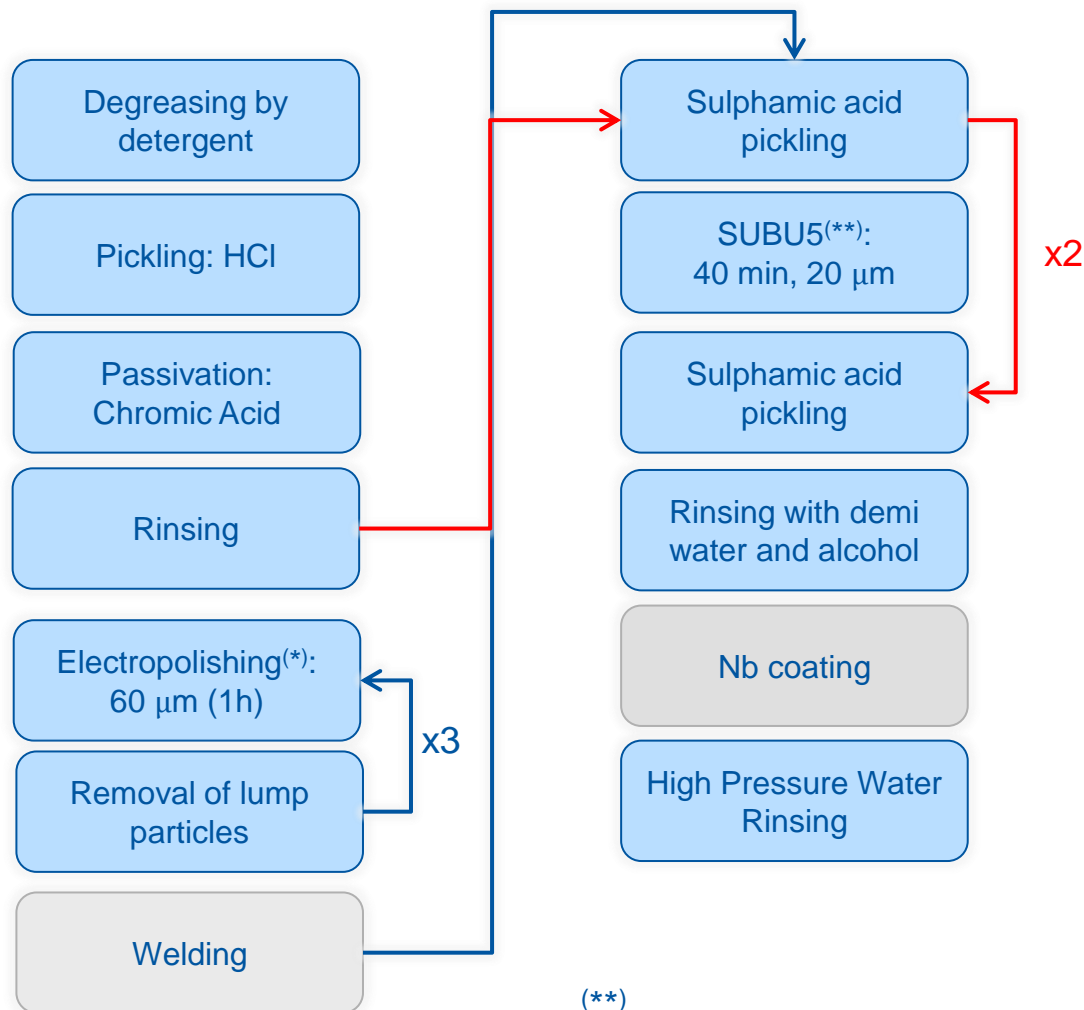
- Reduce surface roughness
- Eliminate inclusions and embedded contaminations.

Two methods:

- Electropolishing
- Chemical attack or chemical polishing

3 Removal of the Damaged Layer: Cu for SC RF Cavities

Preparation for Electropolishing



(*)

- H_2SO_4 (96% mol): 90 % vol.
- HF (40% mol): 10 % vol.

(**)

- Sulfamic acid (H_3NSO_3): 5g/l
- Hydrogen peroxide (H_2O_2): 5% vol.
- Butanol ($\text{C}_4\text{H}_9\text{OH}$): 5% vol.
- Ammonium citrate: 1g/l



Courtesy of Serge Forel

4

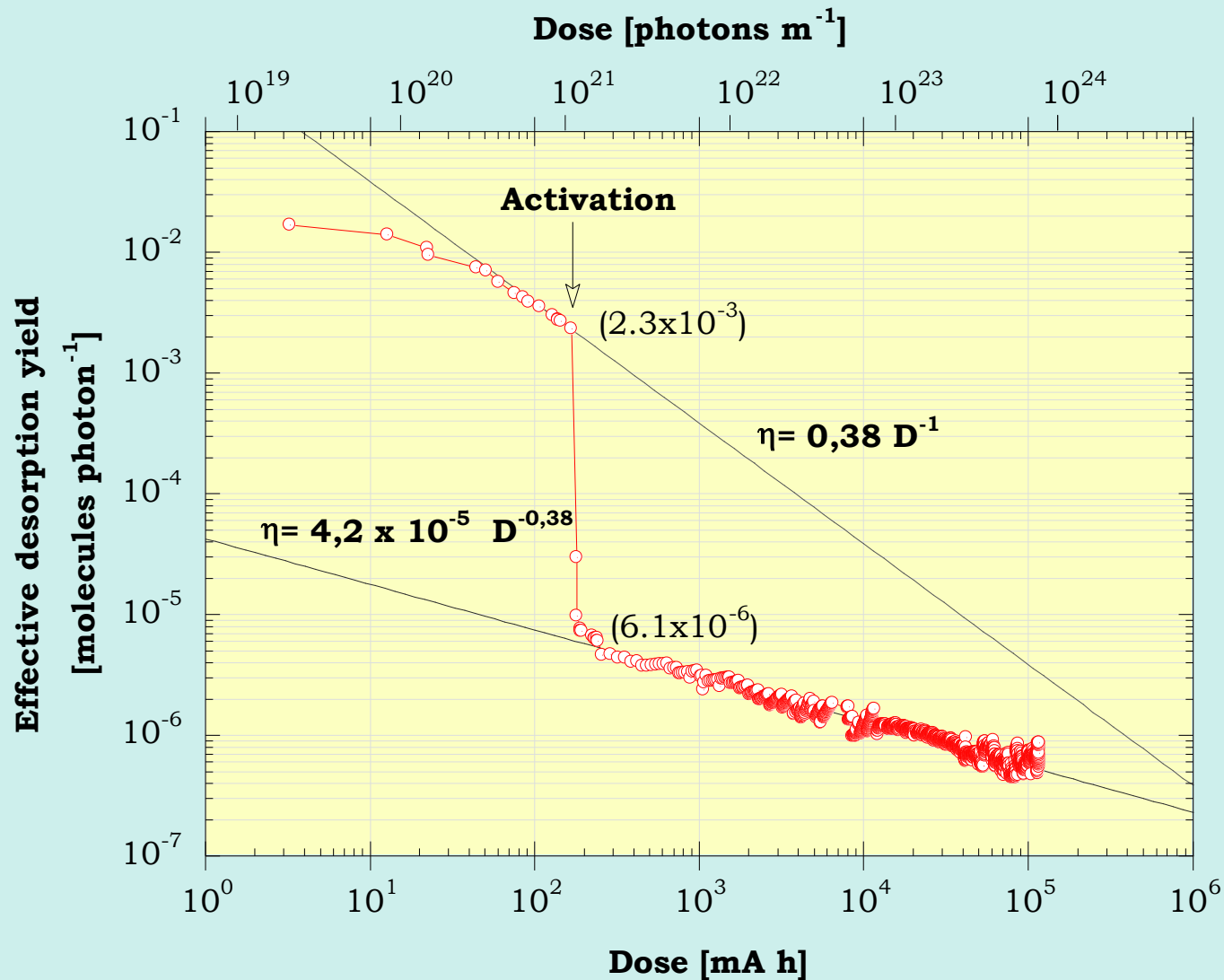
Pickling

Rinsing

Electroplating

Degreasing





Photon desorption
at the ESRF.



Coating: Sputtered Carbon

- Ti-Zr-V film coating have $\delta_{\max} \approx 1.1$ after activation at temperature higher than 180°C (24h).
- But they cannot be applied to **unbaked vacuum** chambers like those of the LHC's injectors and LHC's beam pipes at cryogenic temperatures.
- **Carbon coatings** deposited by sputtering are a valid solution.

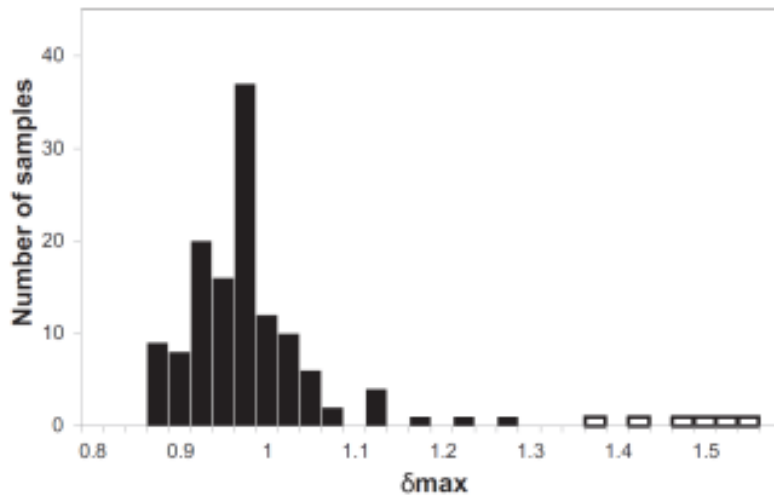


Fig. 2. Histogram of δ_{\max} , with 119 samples deposited by MS (filled black columns) and 6 samples deposited by PECVD (empty columns).

