3rd PBC technology mini workshop: vacuum, coating and surface technologies

Thin film coating facilities at CERN/TE

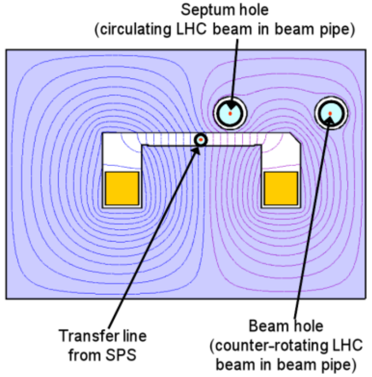
Pedro Costa Pinto CERN/TE-VSC-SCC

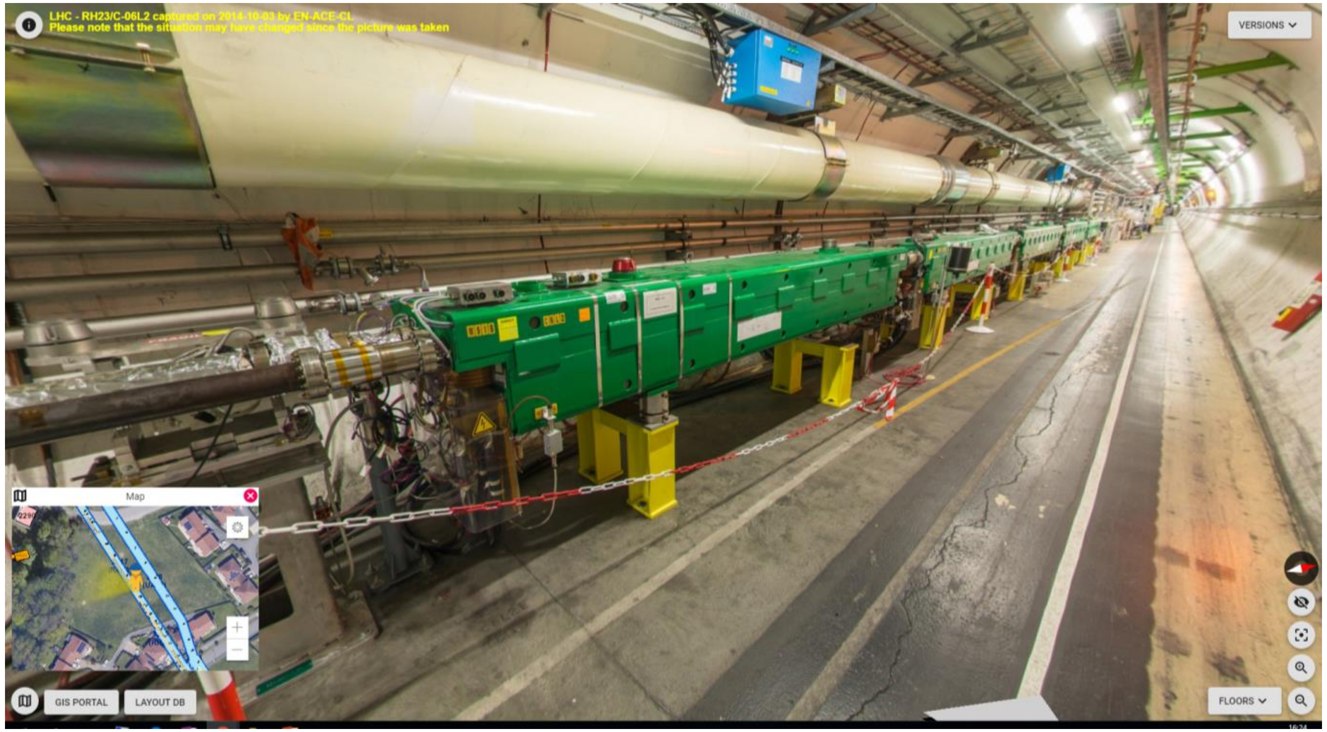
1. Thin films for particle accelerators (why, what & how)
2. CERN/TE coating facilities and examples
3. Summary

1. Thin films for particle accelerators (why, what & how)

Thin film coatings are used mainly to change the surface properties of accelerators components

Example: beam pipes for the septa magnets for the LHC (injection kickers)





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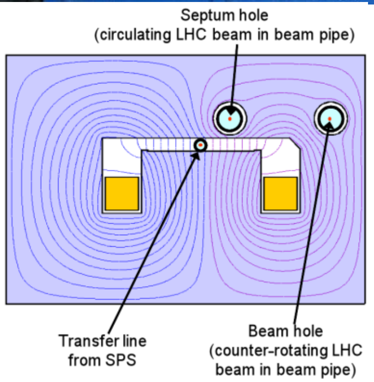
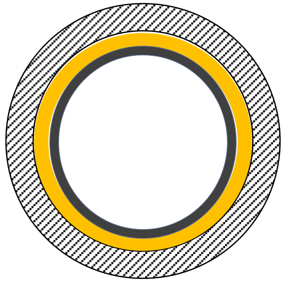




- **Mumetal tubes (0.9 mm thick)** ⇨ magnetic shielding + mechanical stability
- **Cu electroplating (0.4 mm thick)** ⇨ increase conductivity
- **Ti-Zr-V thin film coating (1 µm thick)** ⇨ distributed pumping + low secondary electron emission (e-cloud mitigation)

1. Thin films for particle accelerators (why, what & how)

Most common applications of thin films to accelerator components at CERN:

Ti films to prevent charge build up and electron multipacting in RF devices

Superconductive coatings for RF cavities (Nb)

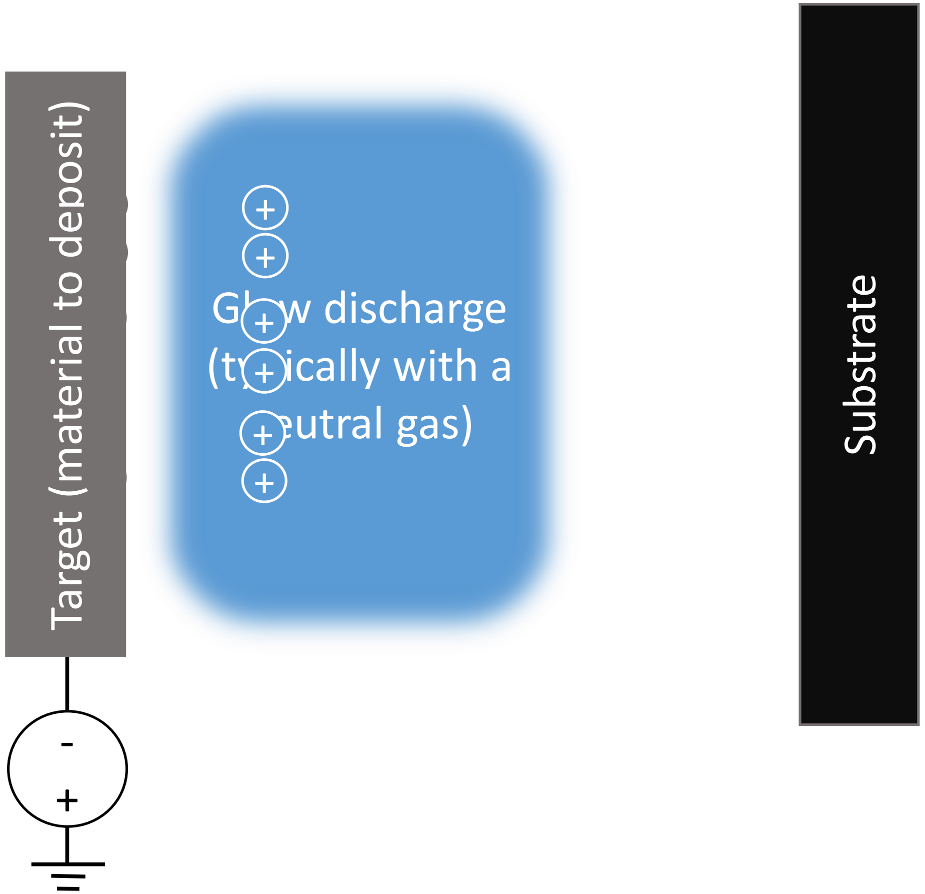
Conductive coatings on absorber blocks for collimators (Cu, Ti, Mo)

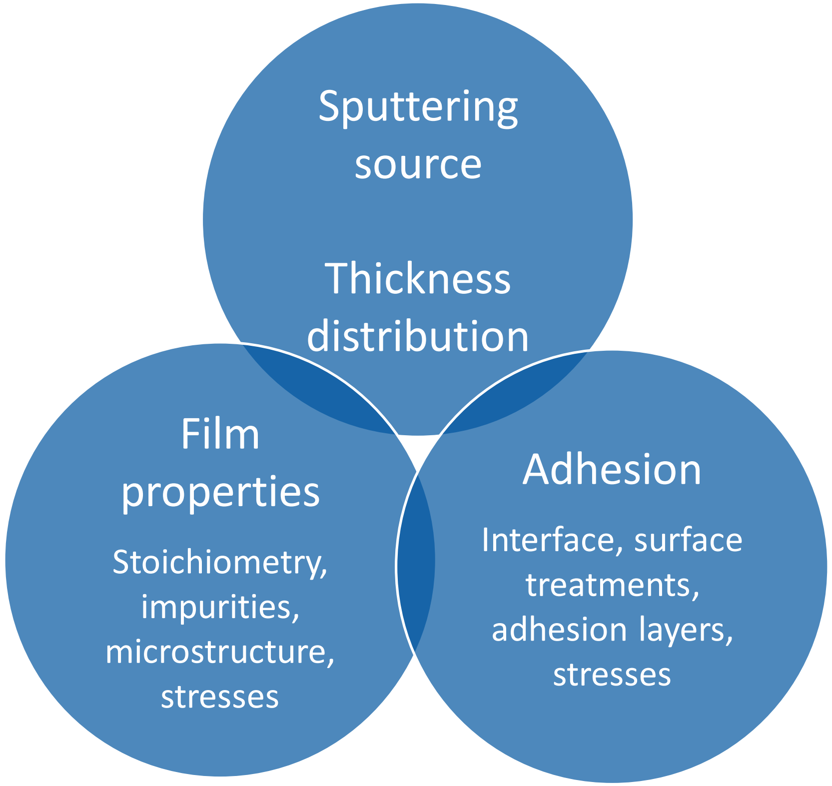
NEG coatings for vacuum pumping and e-cloud suppression (Ti-Zr-V)

Carbon coatings for e-cloud suppression

1. Thin films for particle accelerators (why, what & how)

Coating processes: Physical Vapor Deposition –> Glow Discharge Sputtering

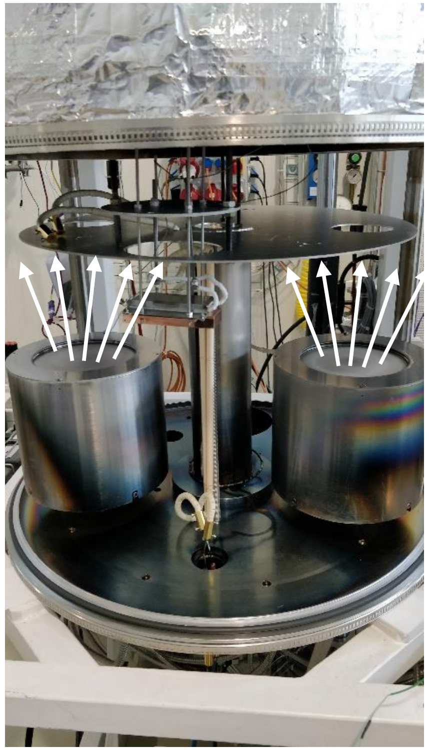




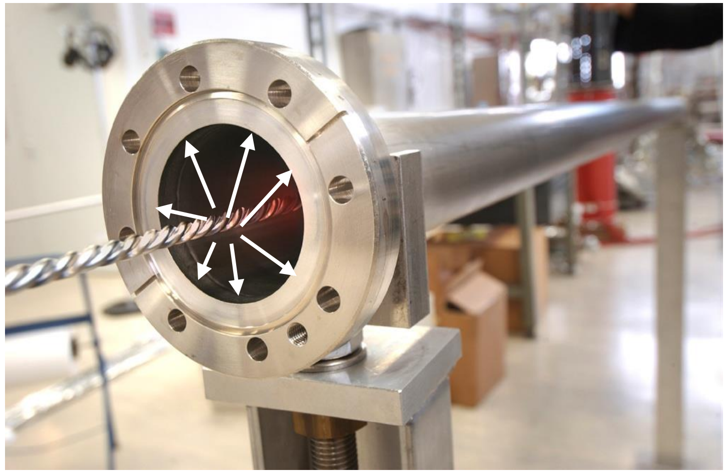
1. Thin films for particle accelerators (why, what & how)

Coating processes: Physical Vapor Deposition –> Glow Discharge Sputtering

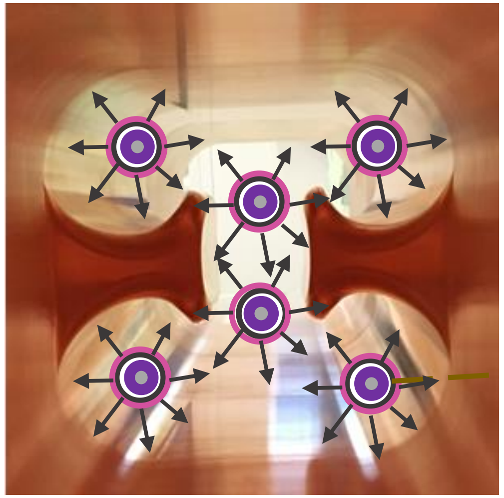
Flat substrates
planar targets



Tubular substrates
cylindrical targets



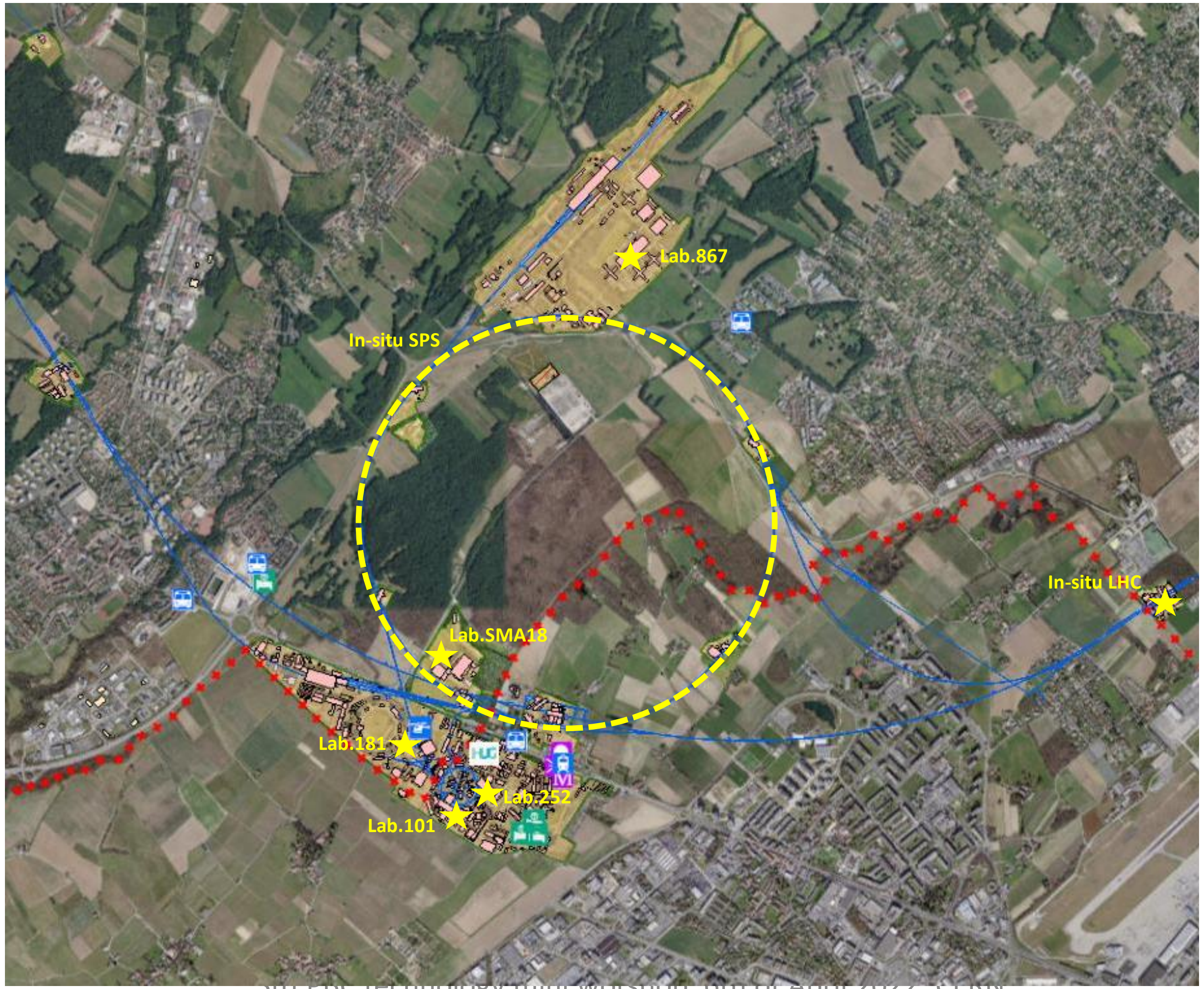
High complexity
Multiple targets



F. Avino et al, TTC, 05.02.2020, Geneva

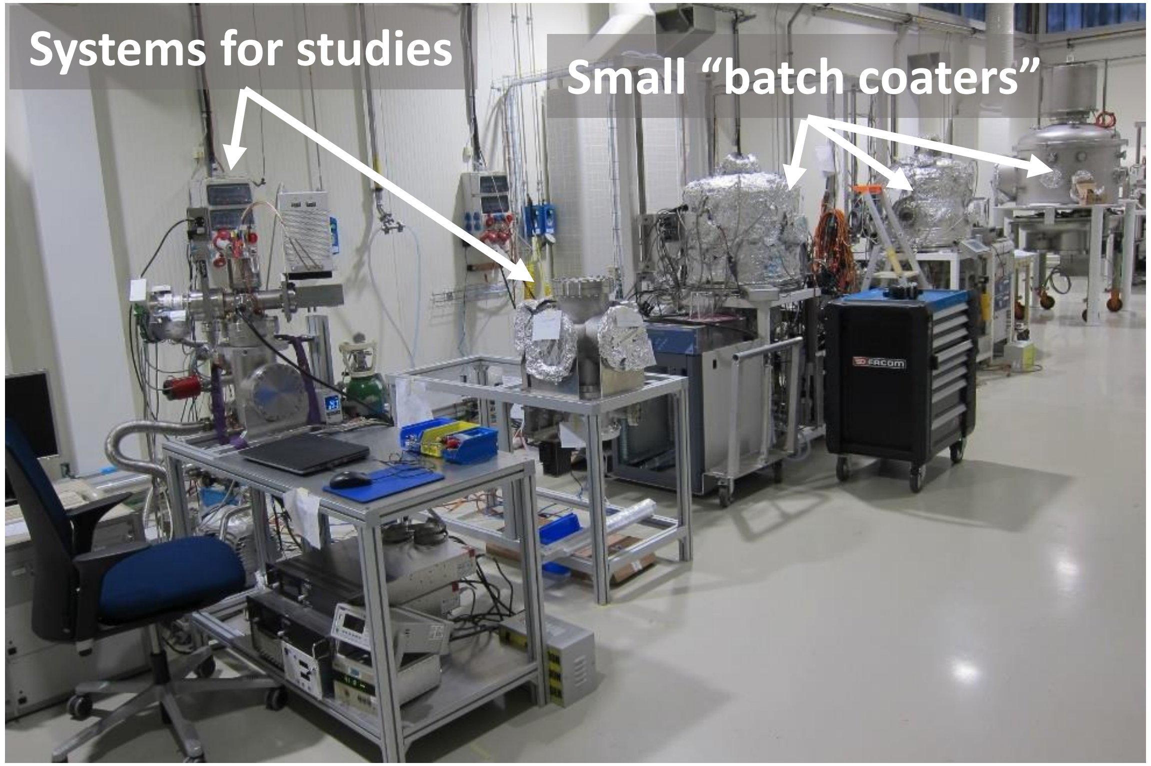
2. CERN/TE coating facilities and examples

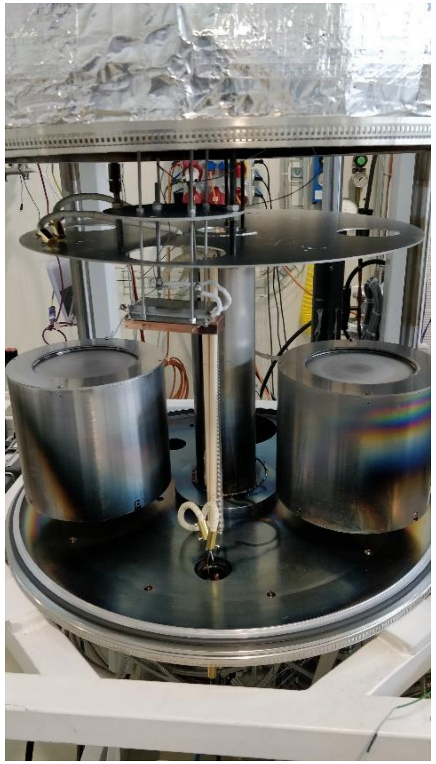
Coating facilities at CERN/TE:



2. CERN/TE coating facilities and examples

General purpose coating lab. in B.101:





Development of Nb_3Sn superconducting films for RF acceleration.

Challenges: precise stoichiometry, crystallography, diffusion of Cu from the substrate.

Deposited materials: Cu, Ti, Mo, Au, Ag, Al, a-C, Nb, Nb_3Sn, Ti-Zr-V, ZrB_2, etc.

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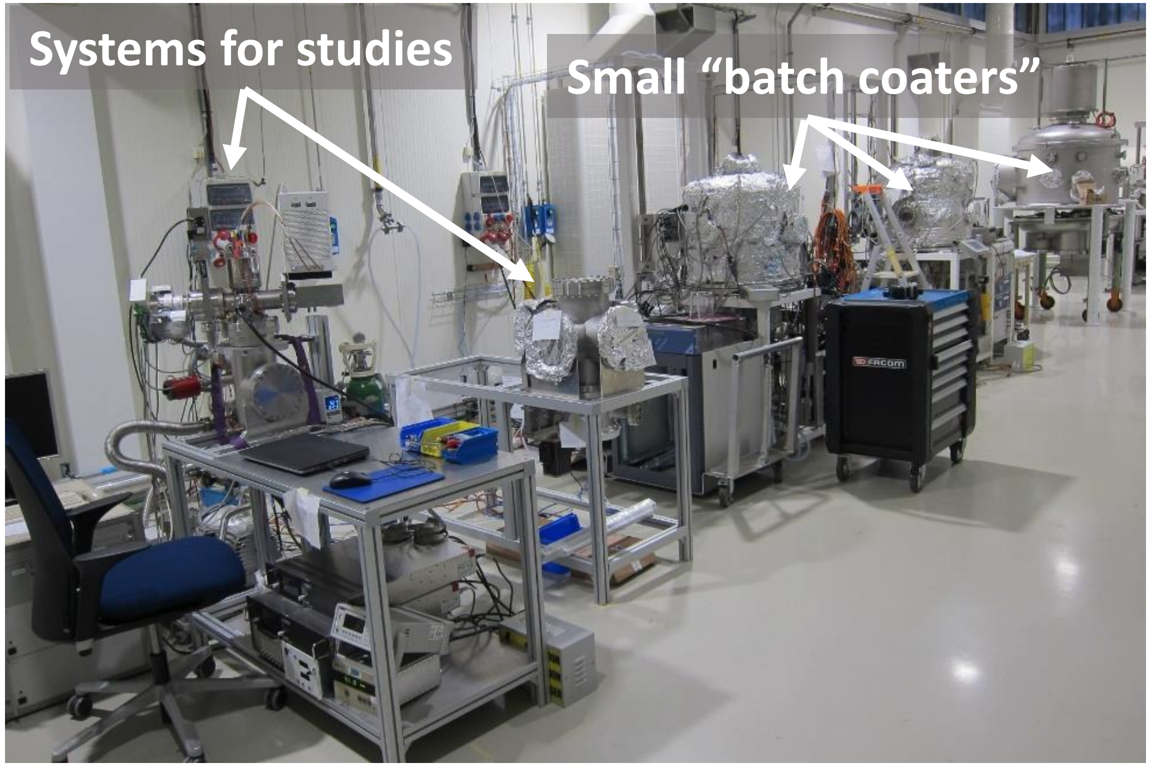

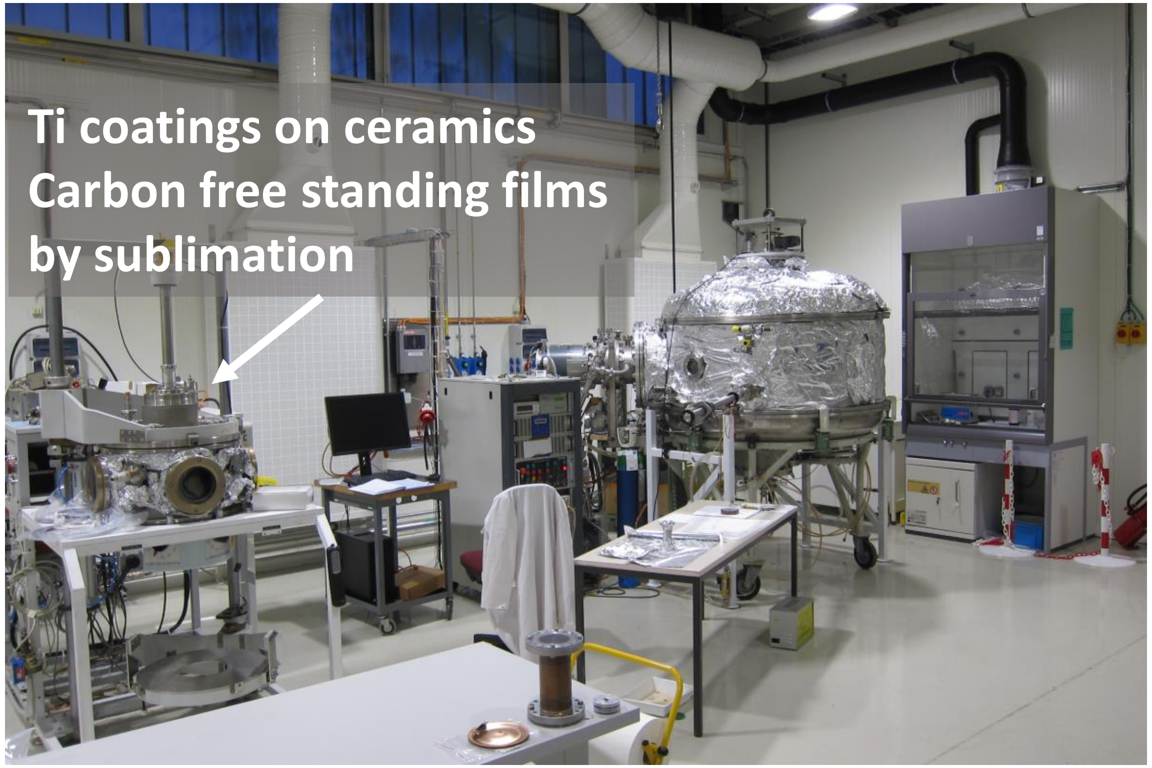

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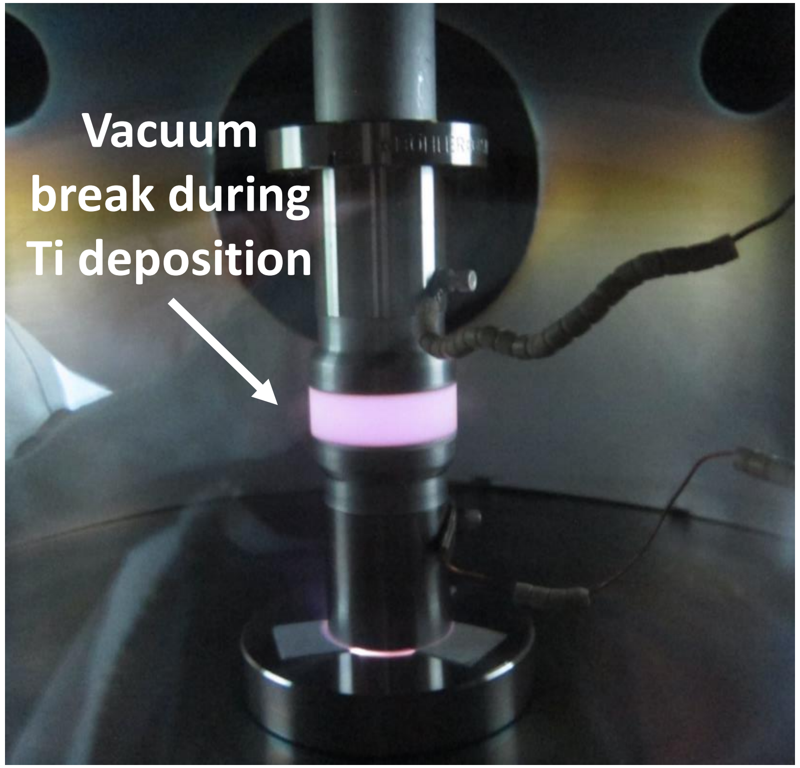

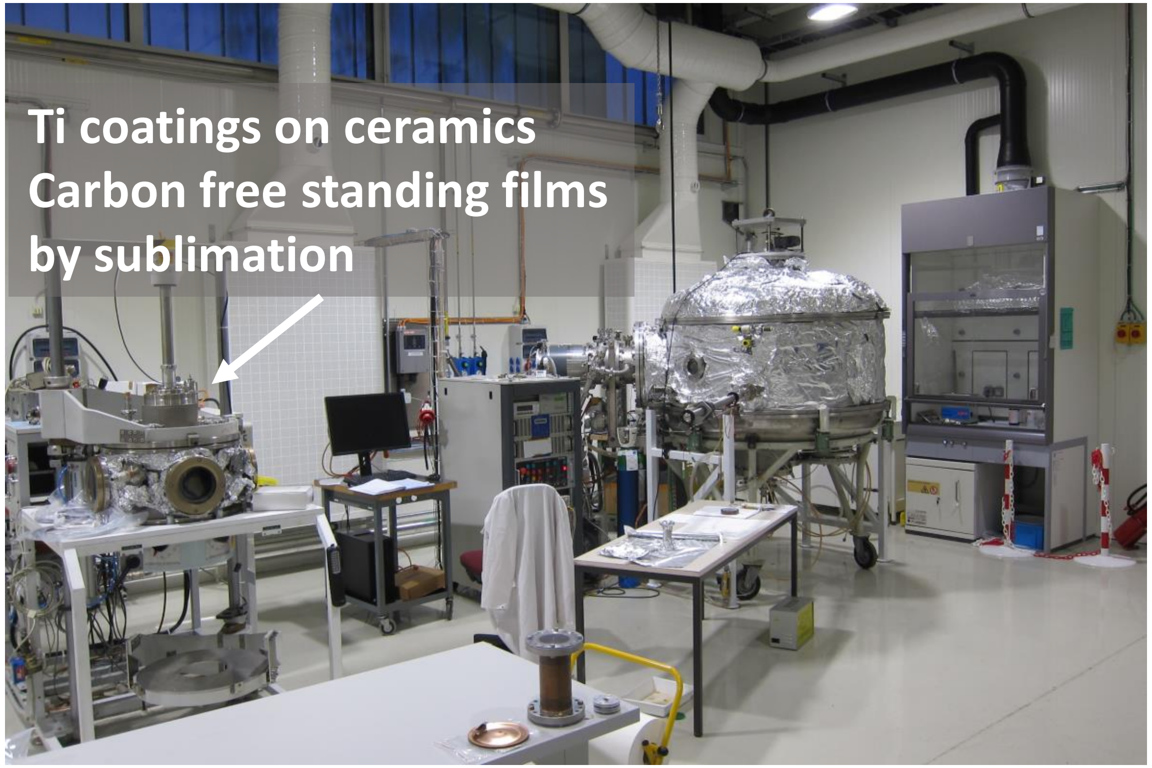

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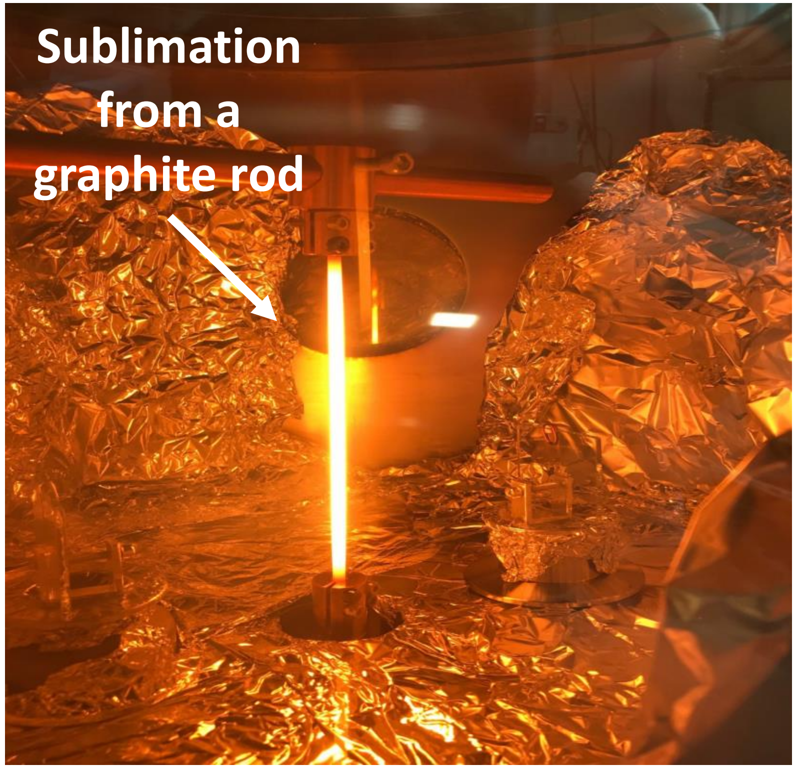

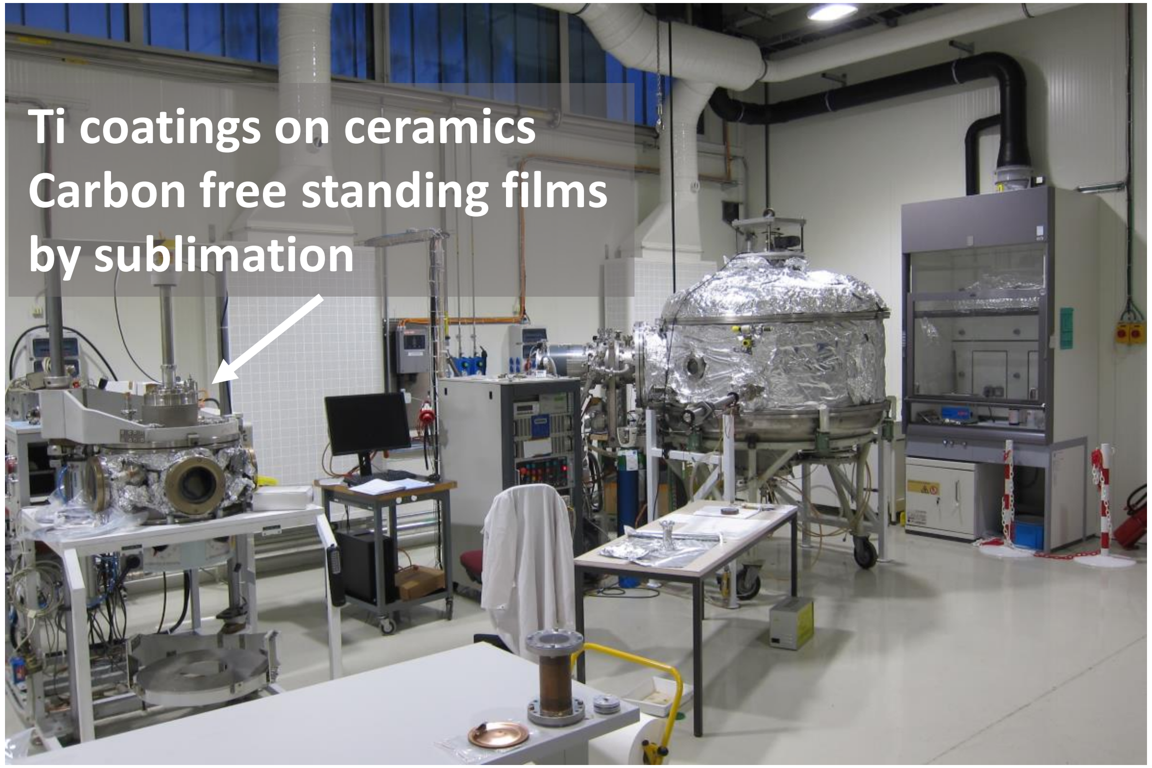

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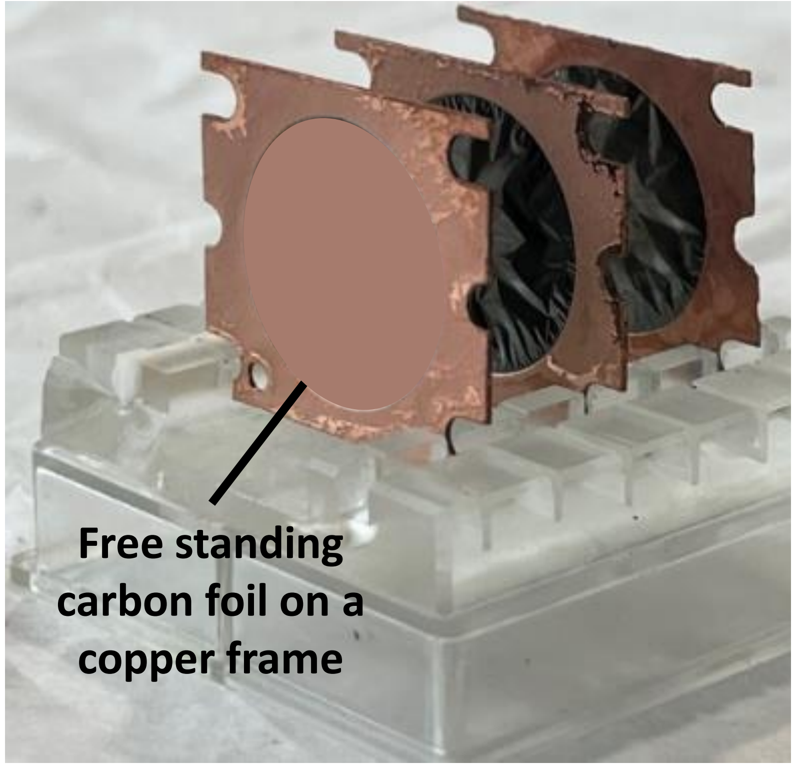
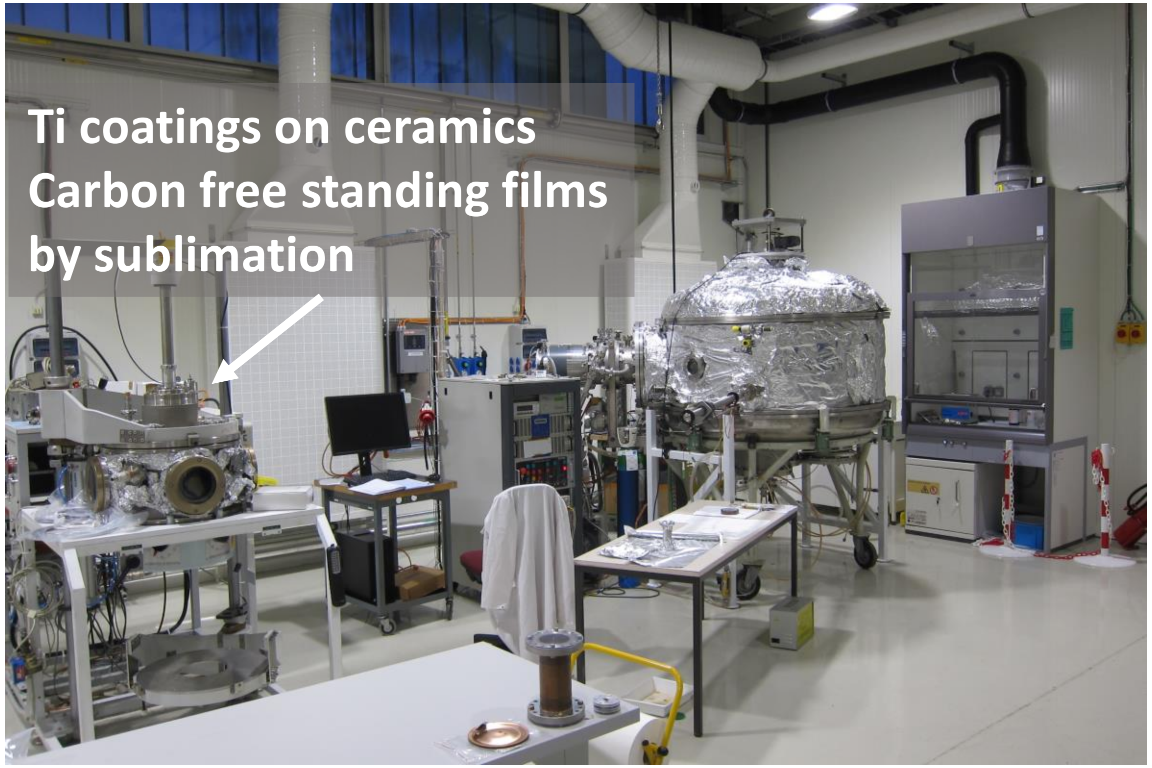
2. CERN/TE coating facilities and examples

General purpose coating lab. in B.101:

After removing the copper from the central part of the copper frame by chemical etching





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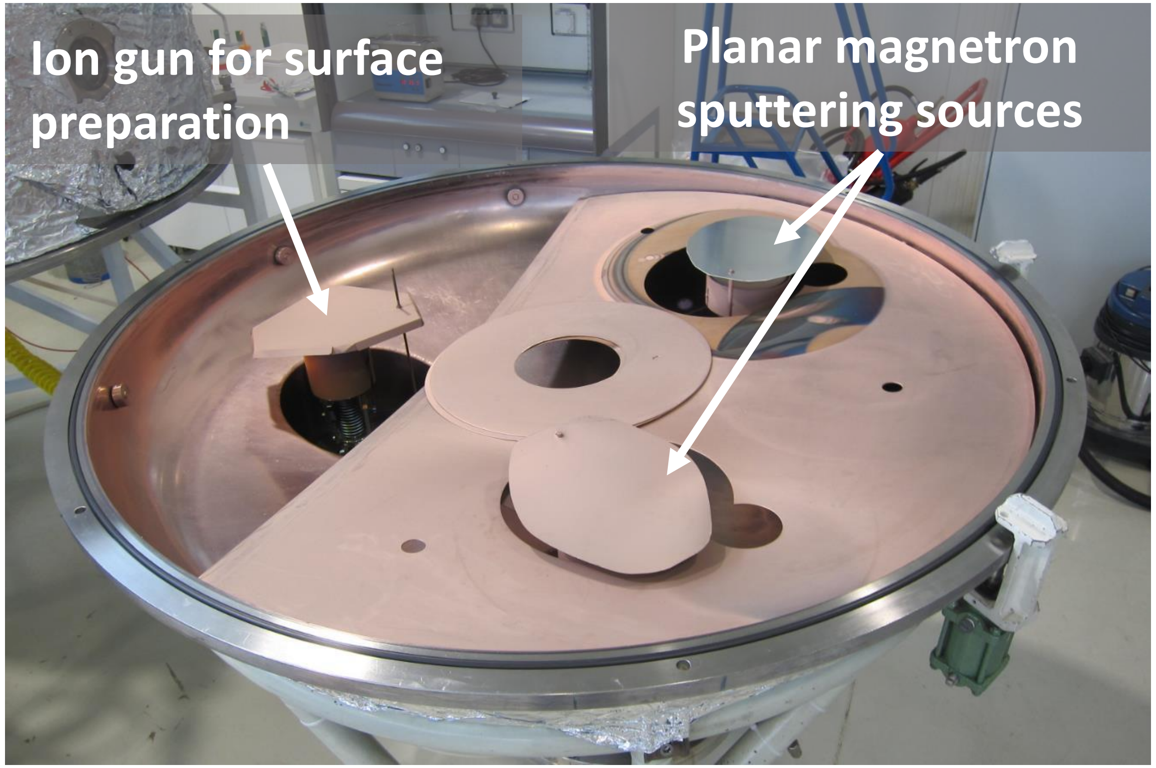

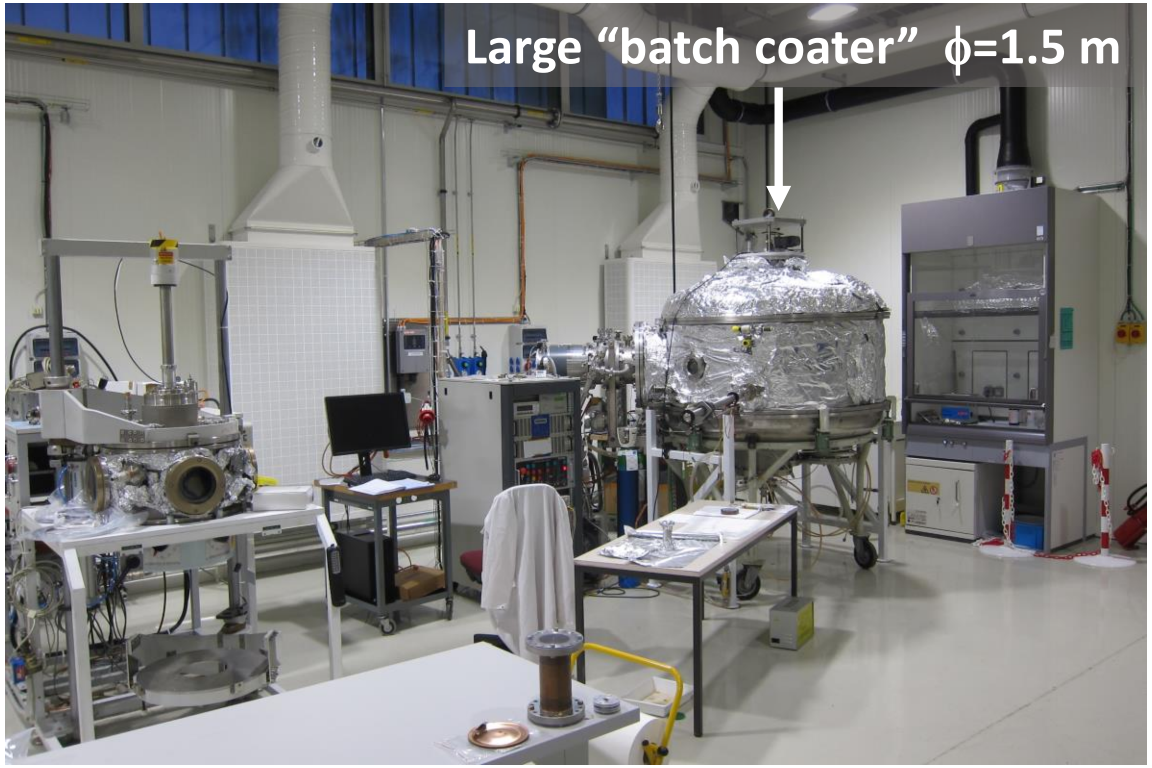

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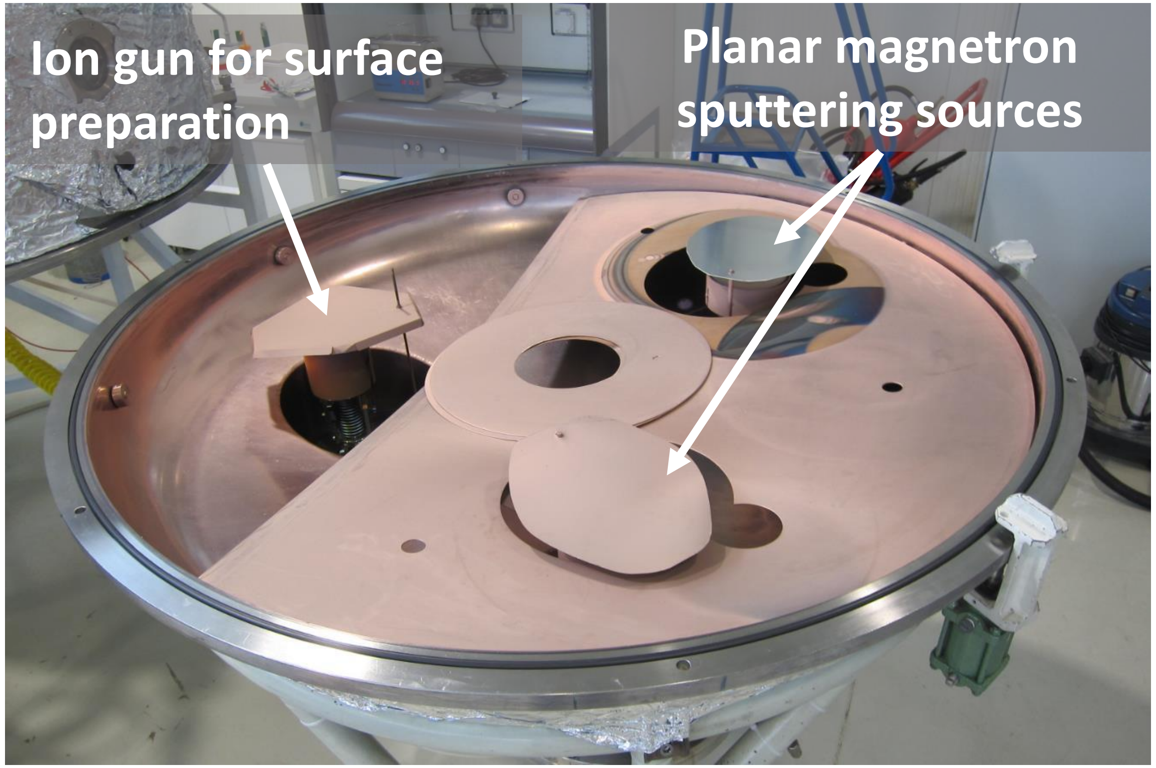

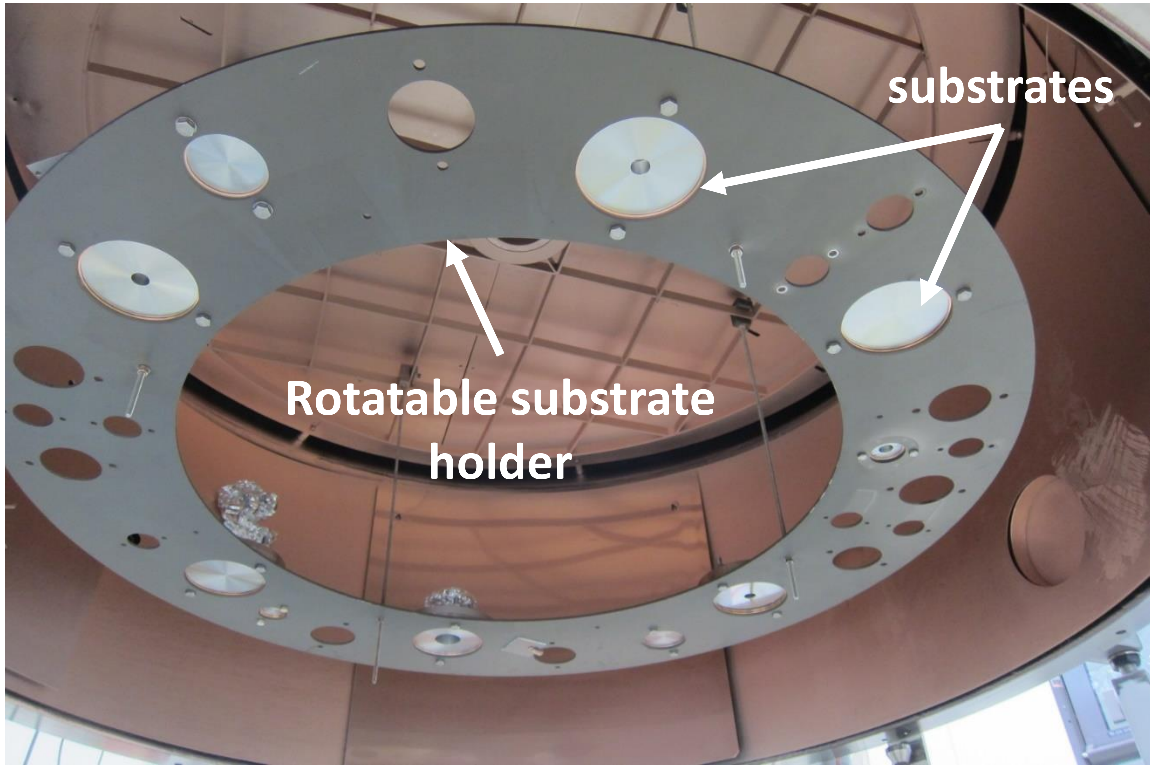

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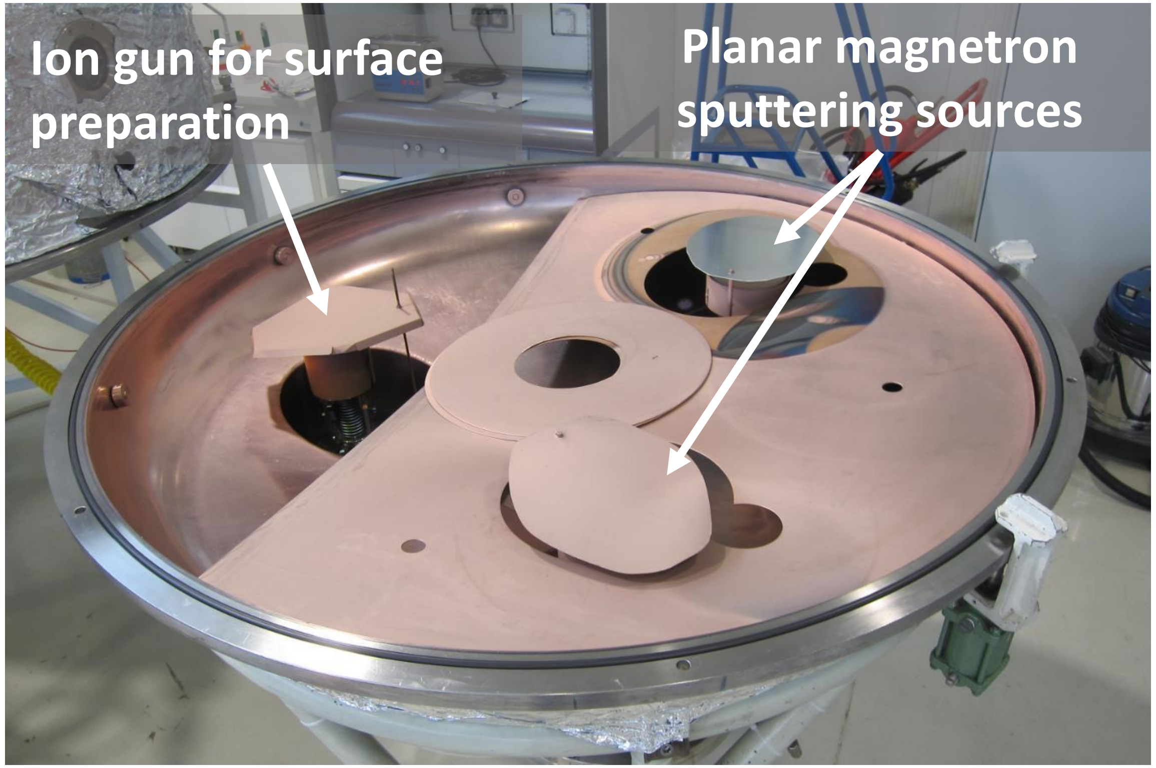
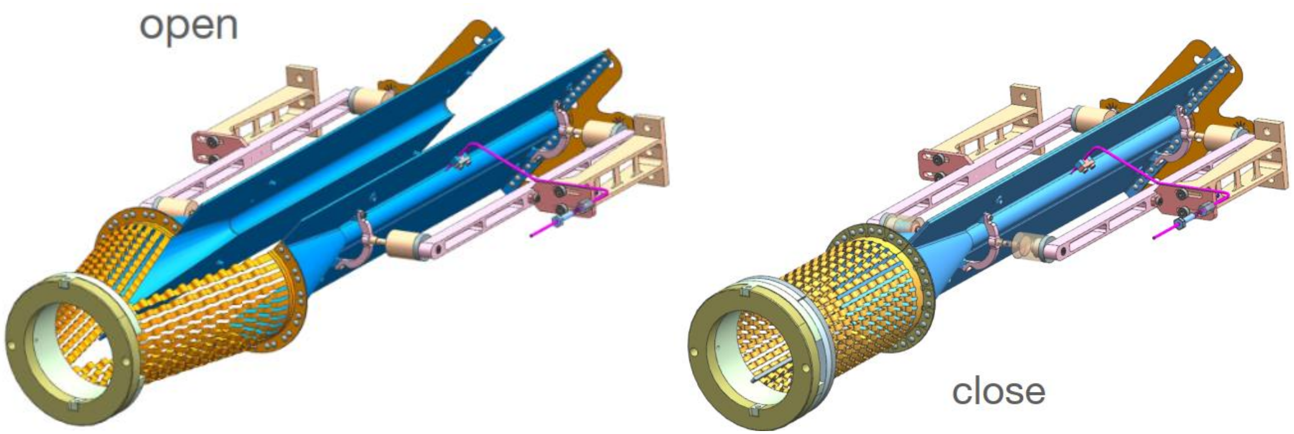
2. CERN/TE coating facilities and examples

General purpose coating lab. in B.101: coating the SMOG 2 cells with carbon coating





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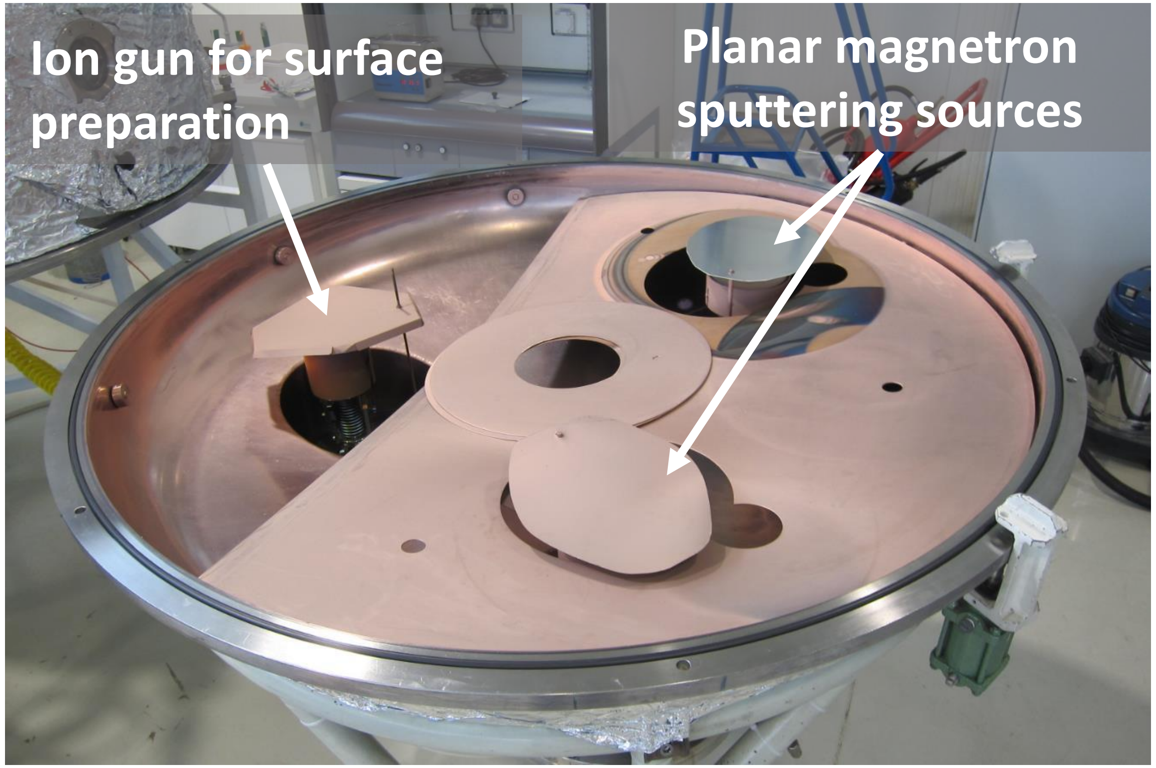

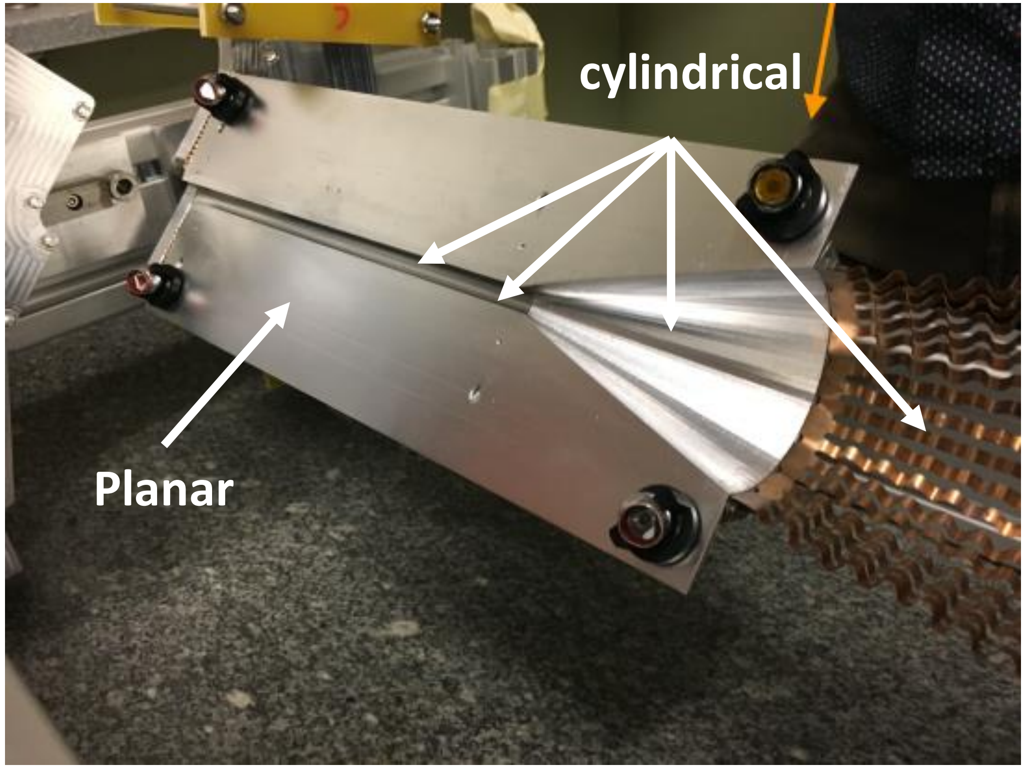

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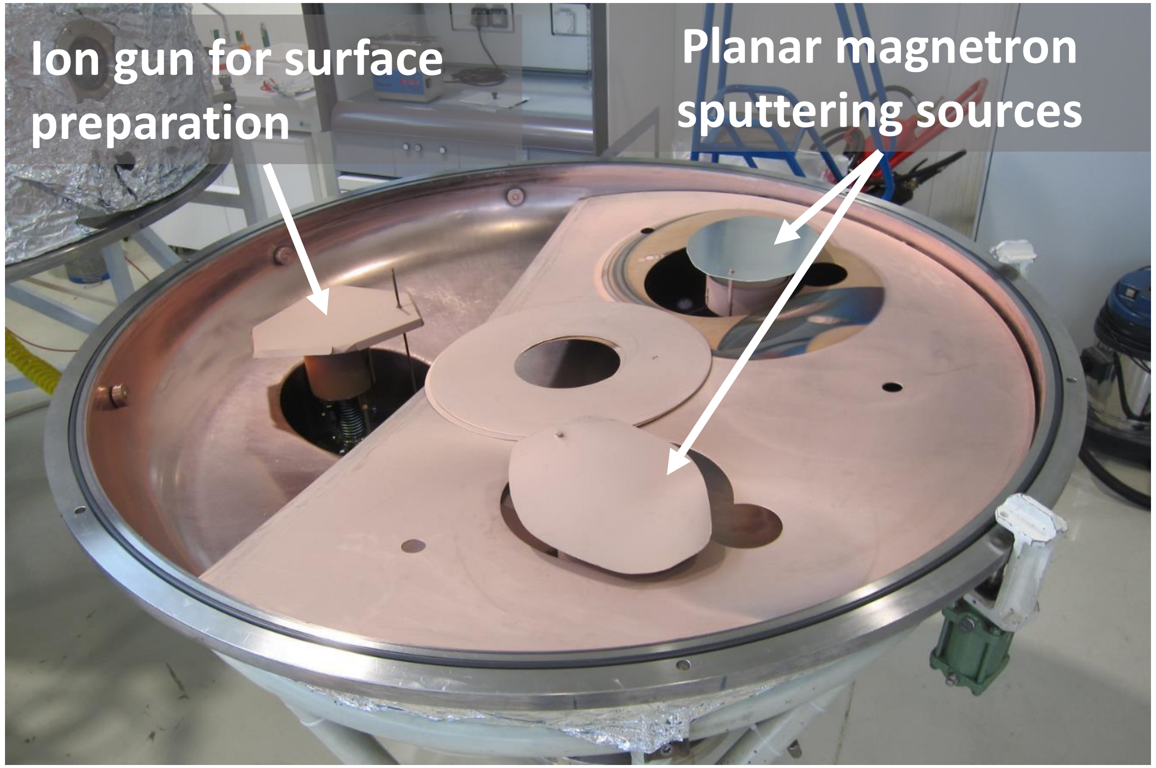

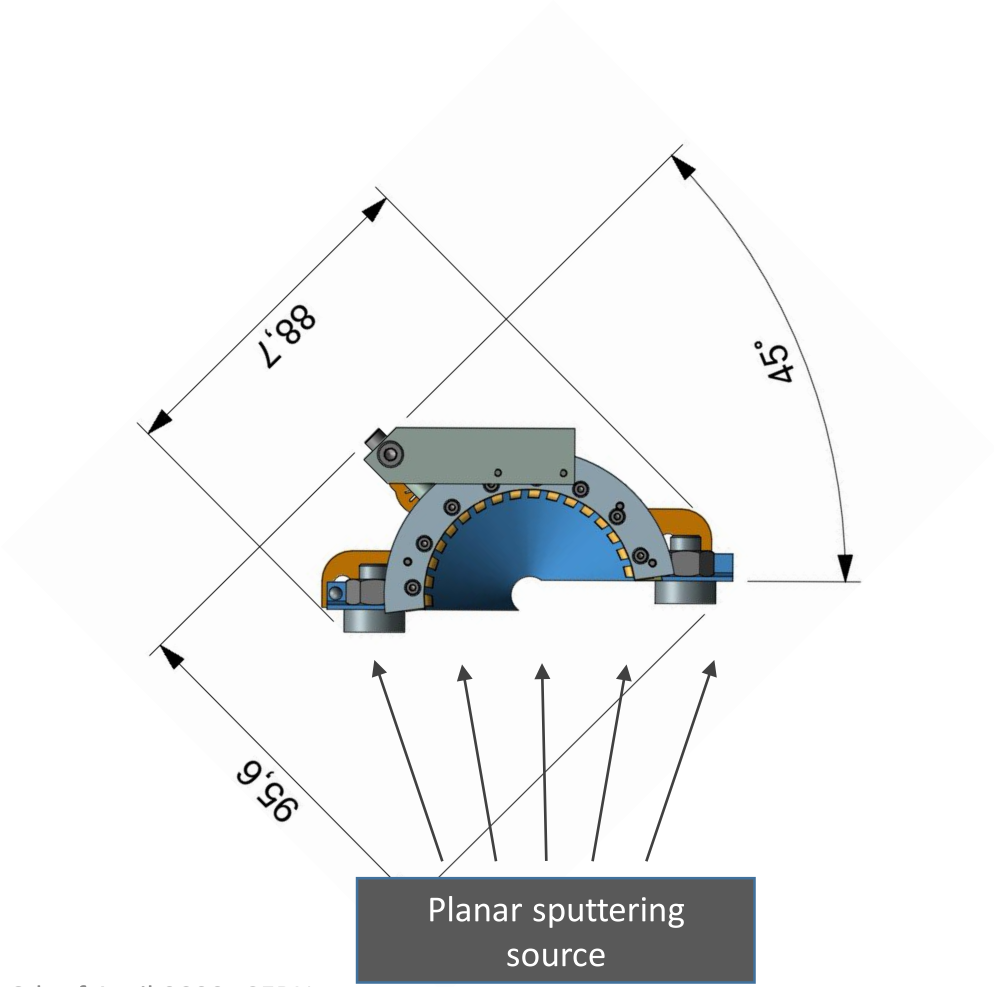

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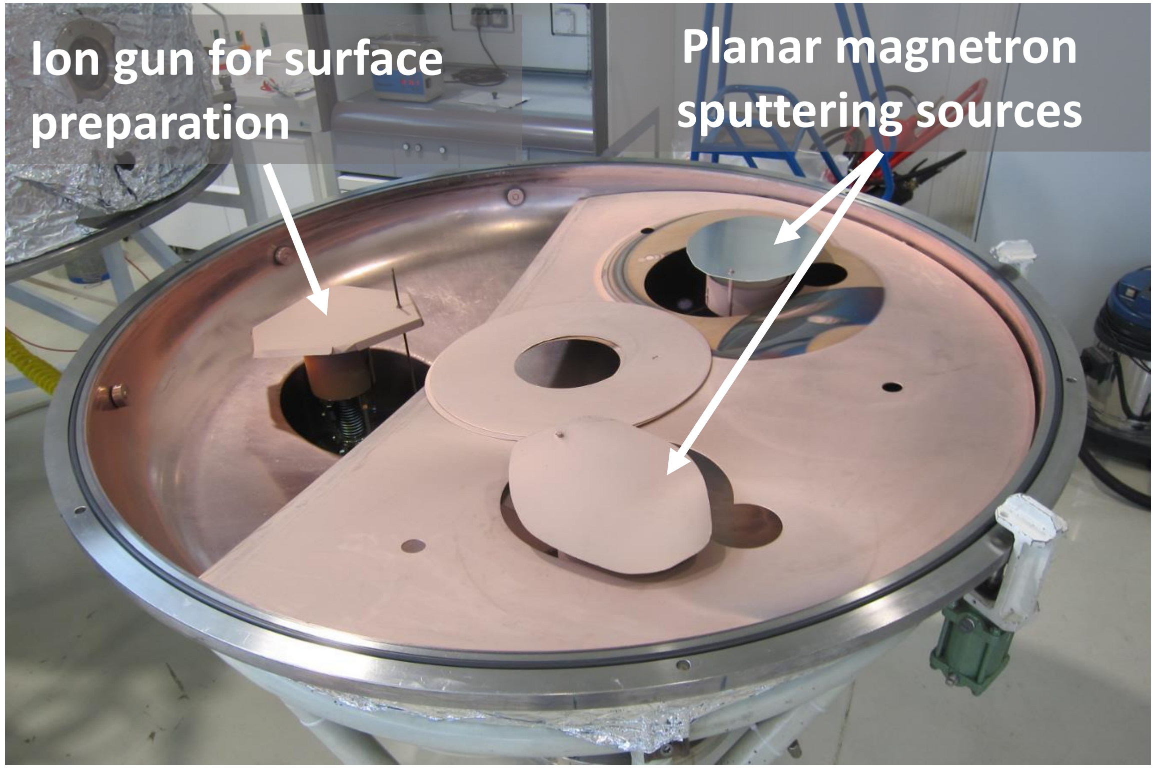
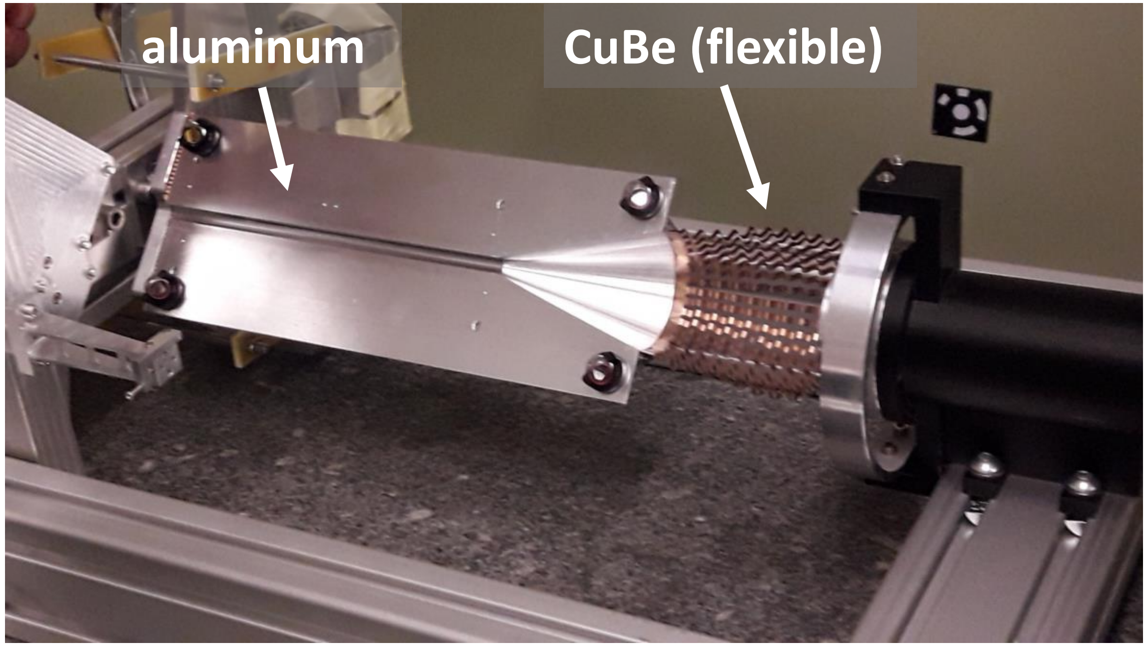


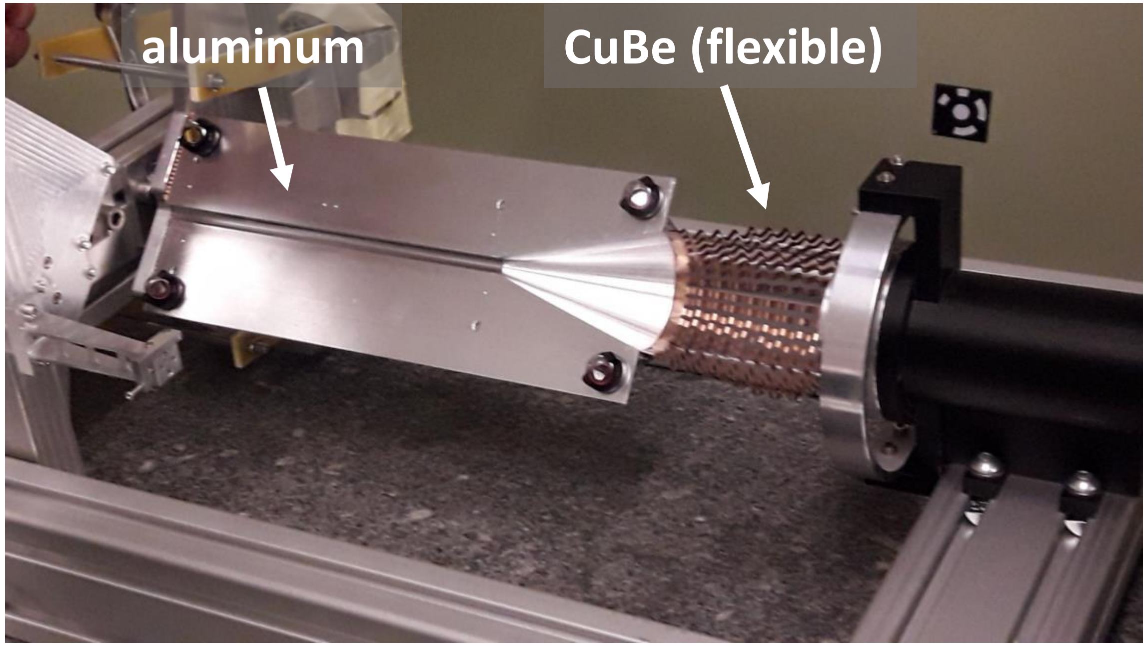


2. CERN/TE coating facilities and examples

General purpose coating lab. in B.101: coating the SMOG 2 cells with carbon coating

Al surface preparation:
- Degreasing
- Ion etching before deposition
- Ti sublayer (~50 nm)

CuBe surface preparation:
- Chemical etching + passivation with chromic acid
- Ion etching before deposition
- Ti sublayer



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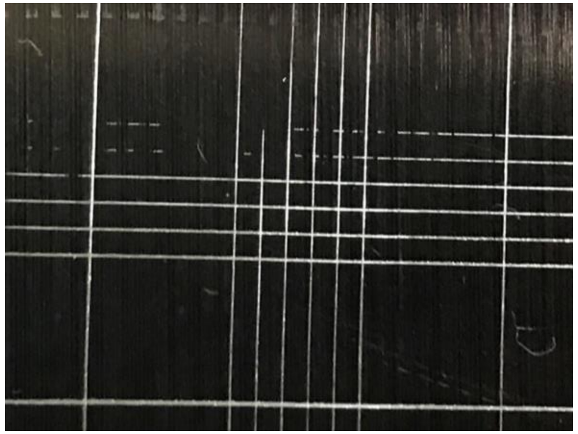
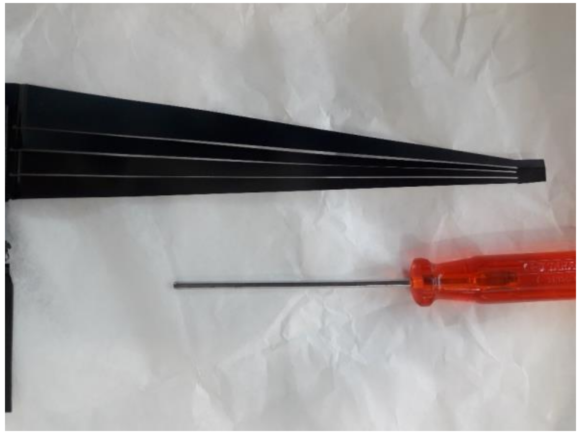
- Ti sublayer

Cross-hatch tests (Al)



“bending tests” (CuBe)



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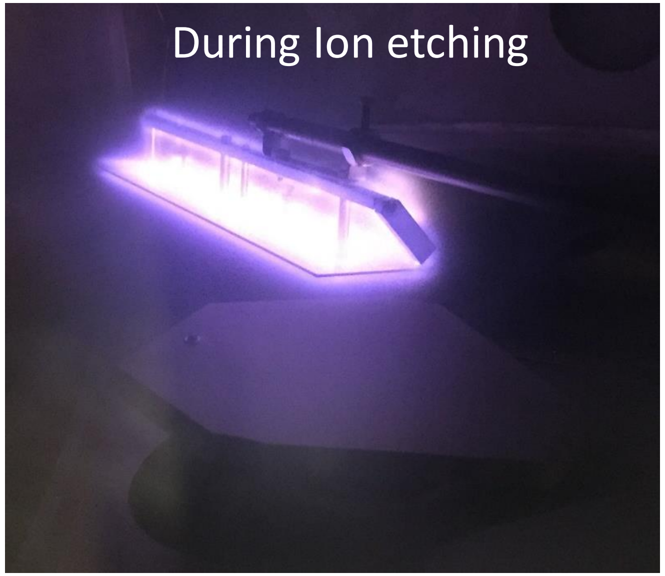

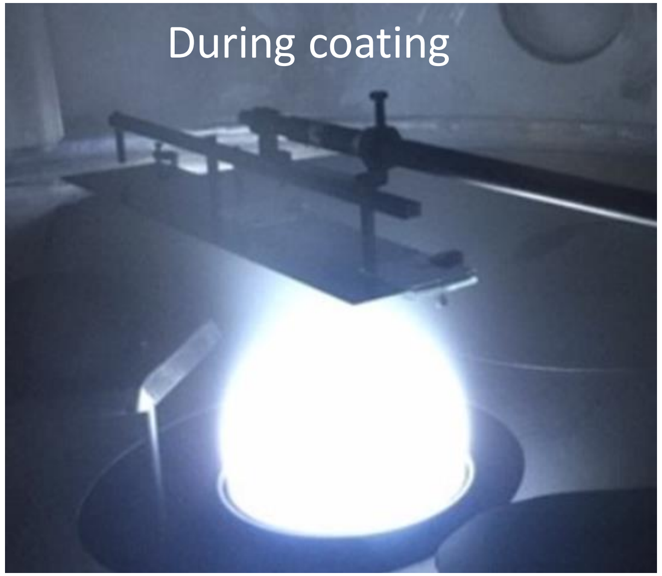

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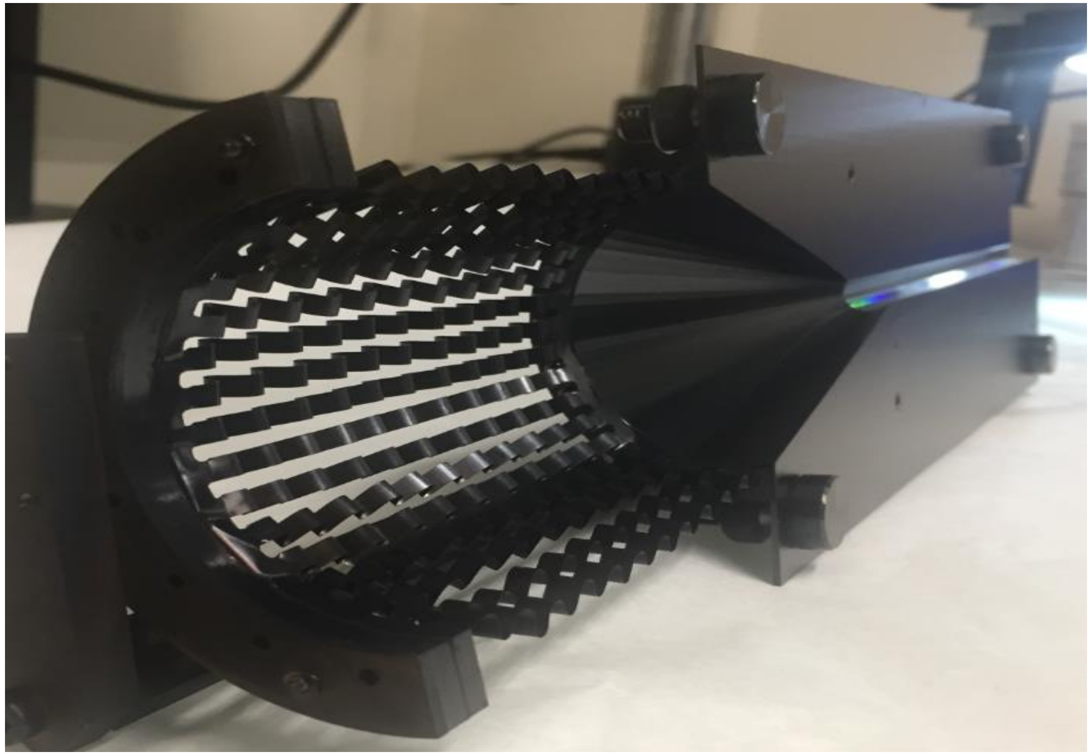
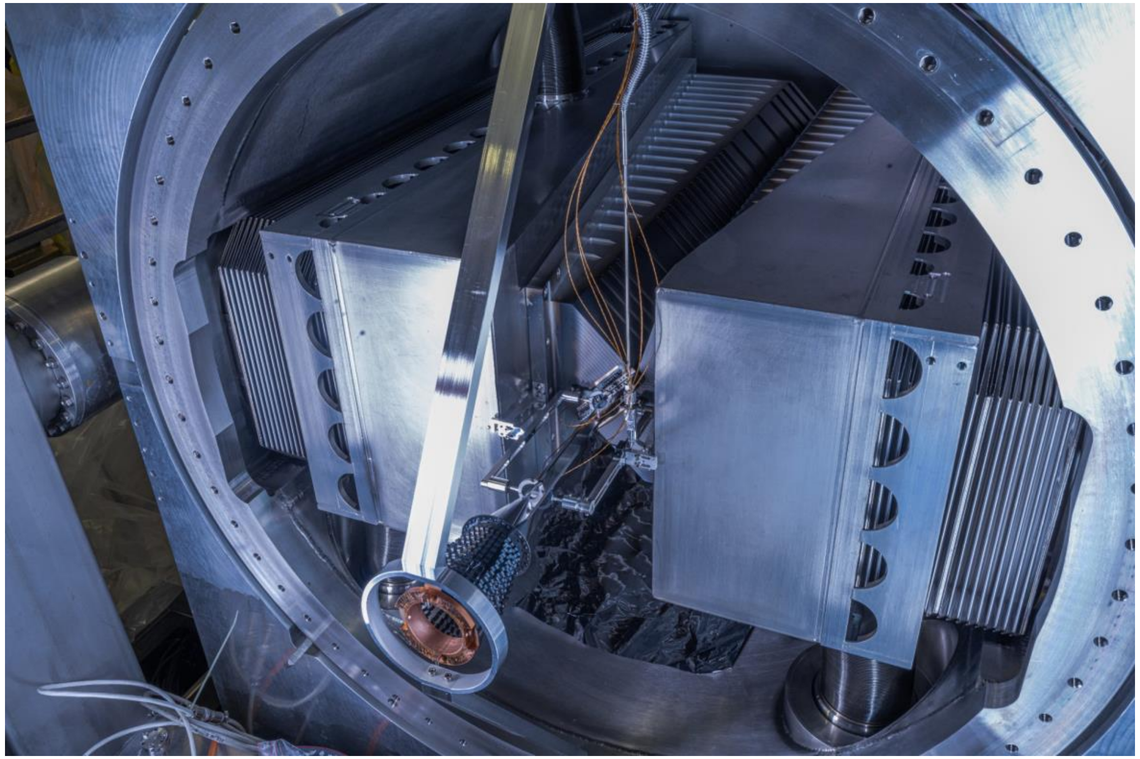
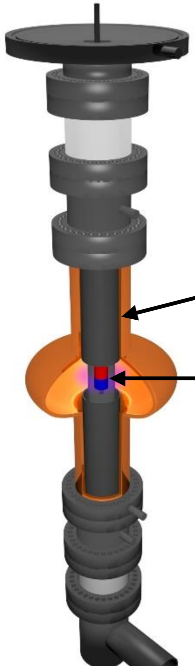




2. CERN/TE coating facilities and examples

Superconducting RF cavities R&D lab. in B.101: Nb

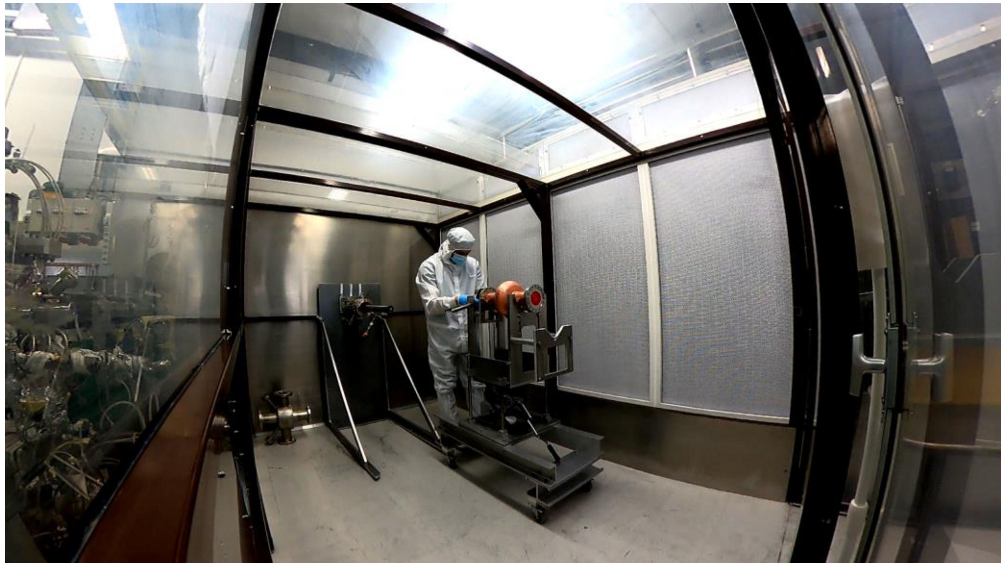


2. CERN/TE coating facilities and examples

Superconducting RF cavities R&D lab. in B.101: Nb

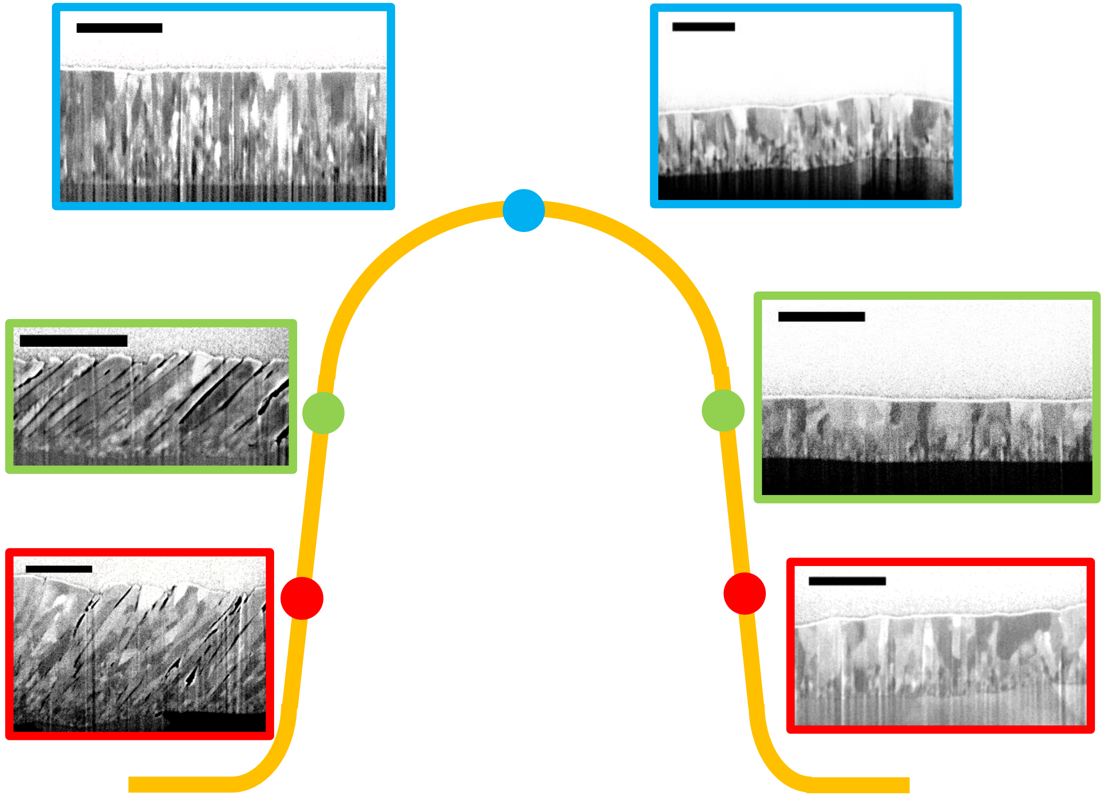
1.3 GHz cavity (Nb/Cu)

ISO5 clean room for assembly



DC magnetron sputtering

High Power Impulse Magnetron Sputtering



G. Rosaz, 1st PBC mini workshop: superconducting RF

2. CERN/TE coating facilities and examples

Superconducting RF cavities production lab. in B.252: Nb

ISO5 clean room for assembly

Coating system for LHC cavities

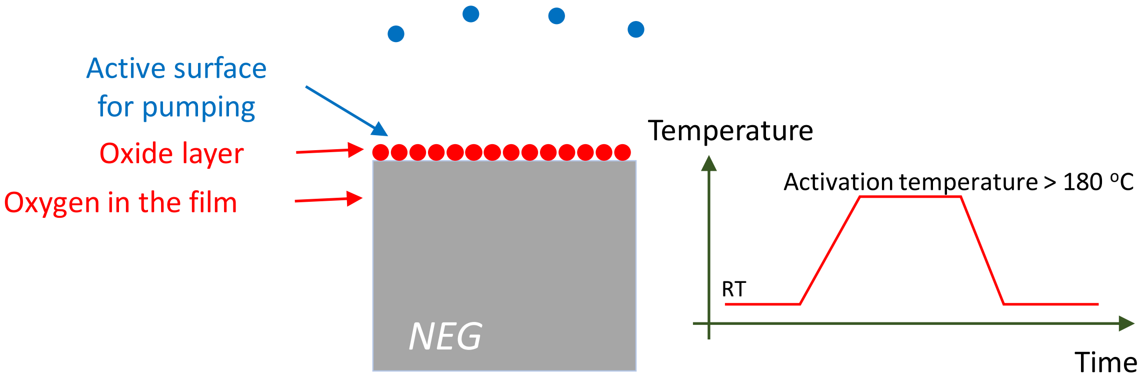
2. CERN/TE coating facilities and examples

Coating lab. for long beam pipes in B.181: Ti-Zr-V (Non Evaporable Getter), a-C (low secondary electron emission)

Up to 7 meter long and diameter 0.6 meter.

Non Evaporable Getters (NEG): Ti-Zr-V

Diffusion of the oxide layer into the bulk
(by heating in vacuum to ***the activation temperature***)



Pumped gases: CO, O_2, H_2O, CO_2, N_2, H_2 => distributed pumping

Not pumped: noble gases and CH_4 (at room temperature)

Low secondary electron emission => prevent e-cloud

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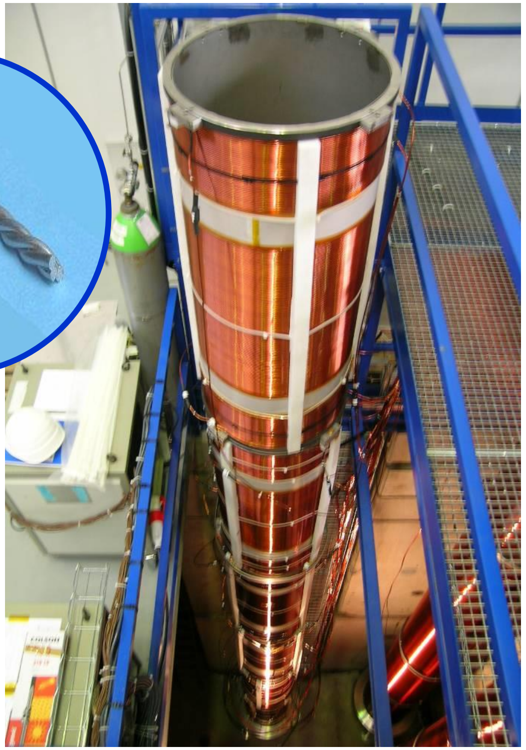
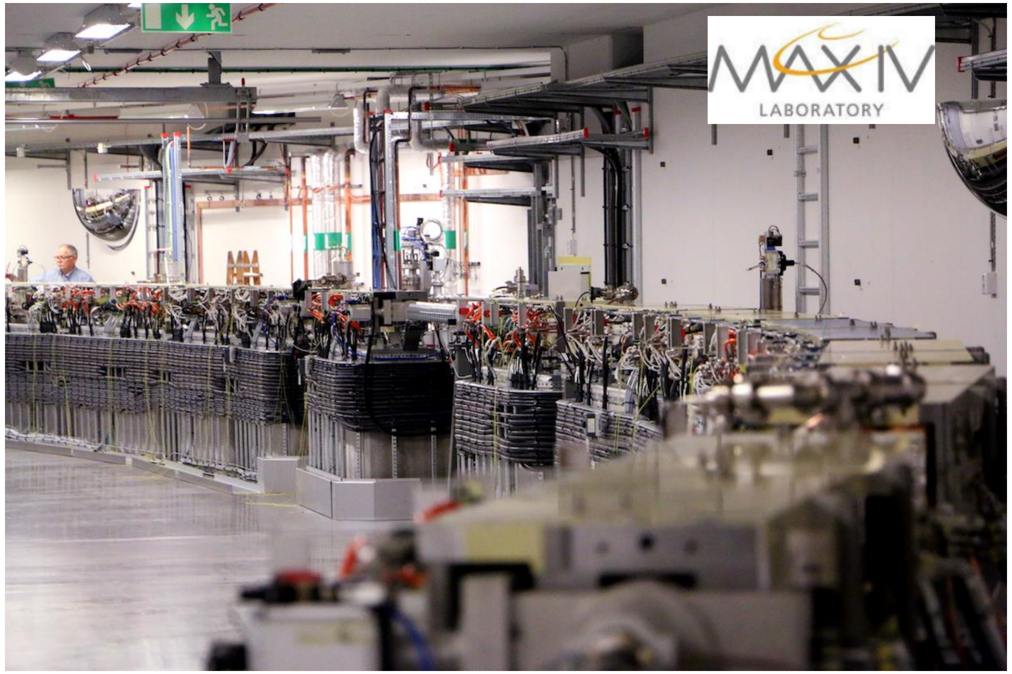


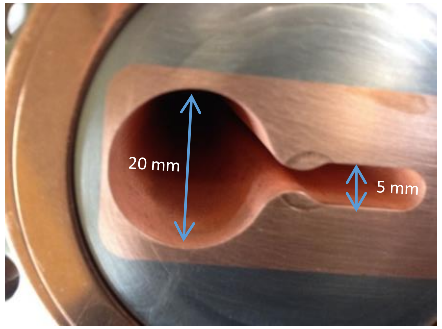
More than 3 km of coated beam pipes in the LHC

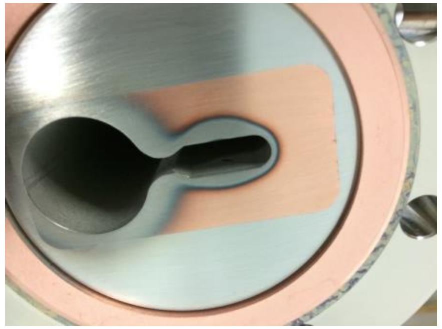
2. CERN/TE coating facilities and examples

Coating lab. for long beam pipes in B.181: Ti-Zr-V (Non Evaporable Getter), a-C (low secondary electron emission)

4th generation synchrotron light source => fully coated with Ti-Zr-V. Partially coated at CERN, partially at industry





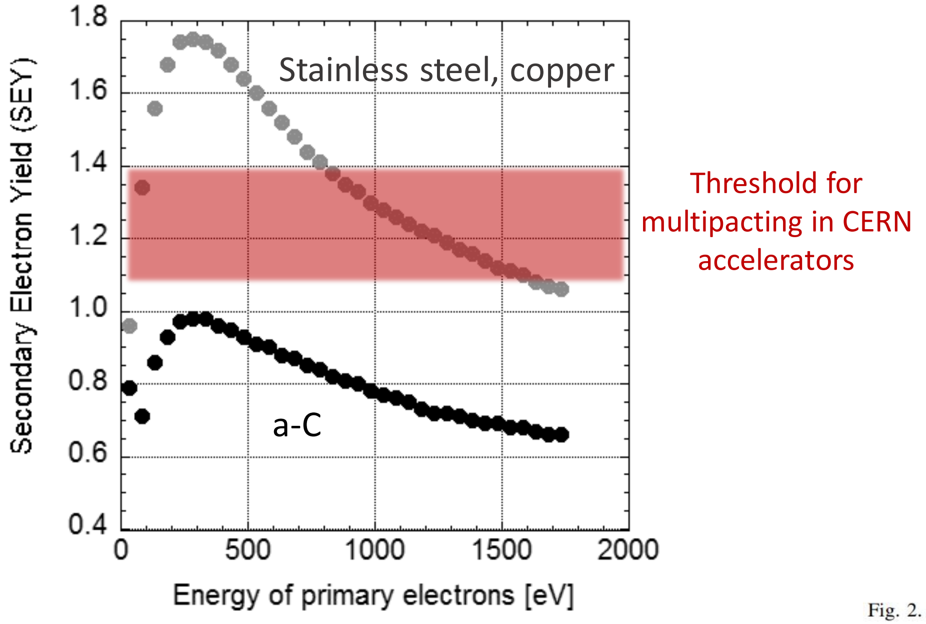


2. CERN/TE coating facilities and examples

In-situ coatings in the SPS tunnel: amorphous carbon, a-C (low secondary electron emission)

Electron multipacting in bempipes => heat loads, pressure rise, beam instabilities

Reduce the secondary electron emission from the walls of the beam pipes



Carbon thin films

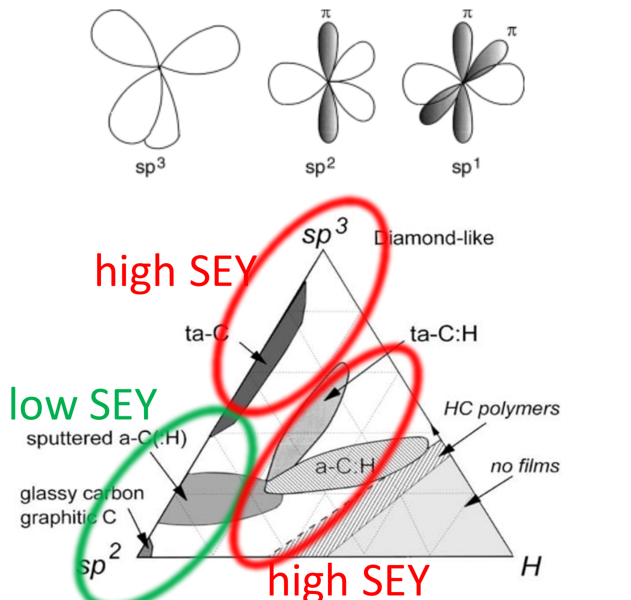
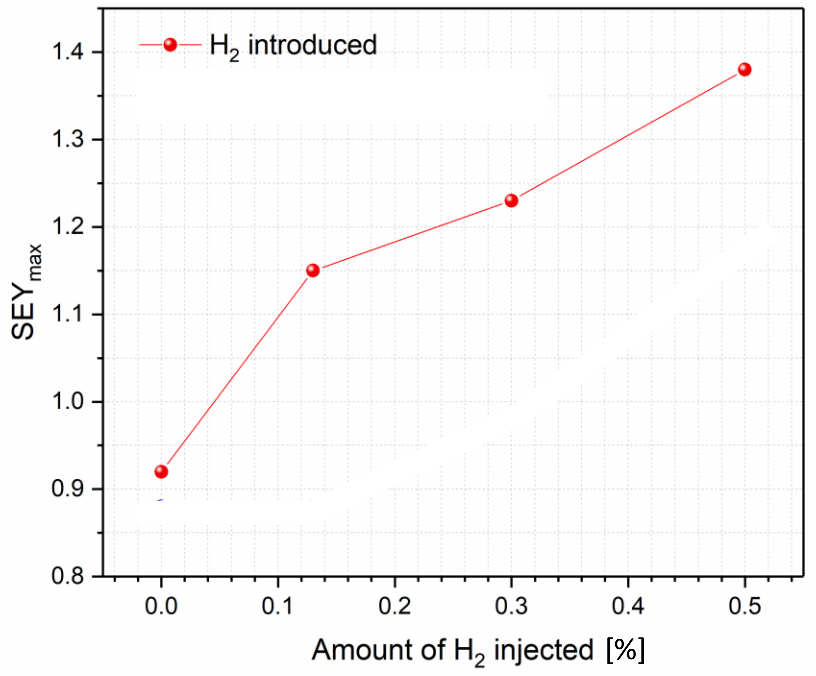


Fig. 2. Ternary phase diagram of bonding in amorphous carbon–hydrogen alloys.

J. Robertson / Materials Science and Engineering R 37 (2002) 129–281

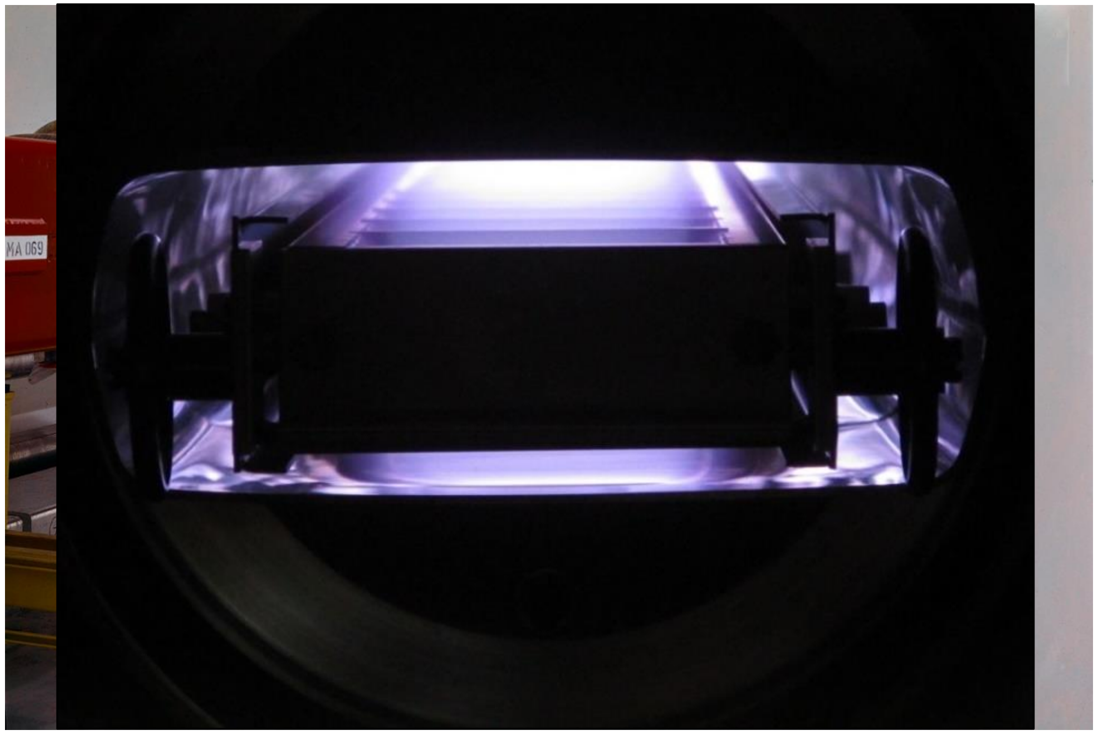
SEY in function of the H_2 and N_2 injected in the discharge



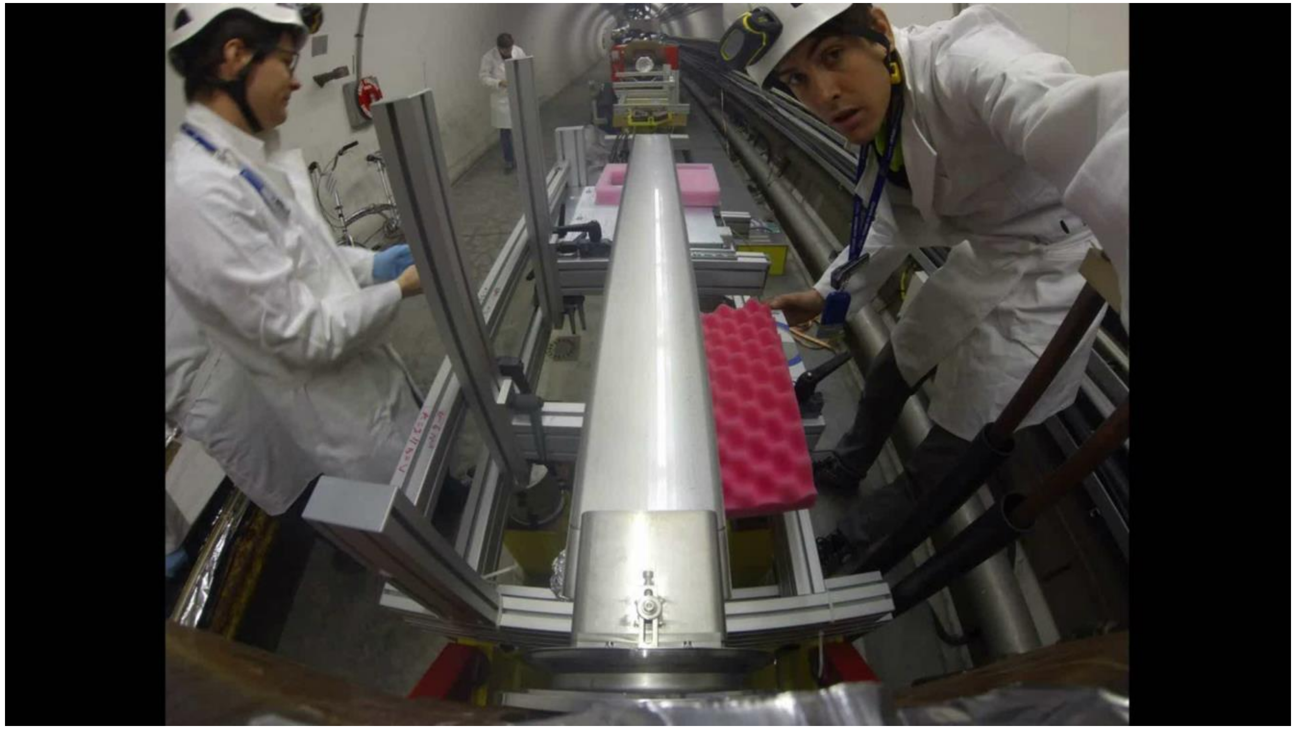
2. CERN/TE coating facilities and examples

In-situ coatings in the SPS tunnel: a-C (low secondary electron emission)

The Super Proton Synchrotron tunnel



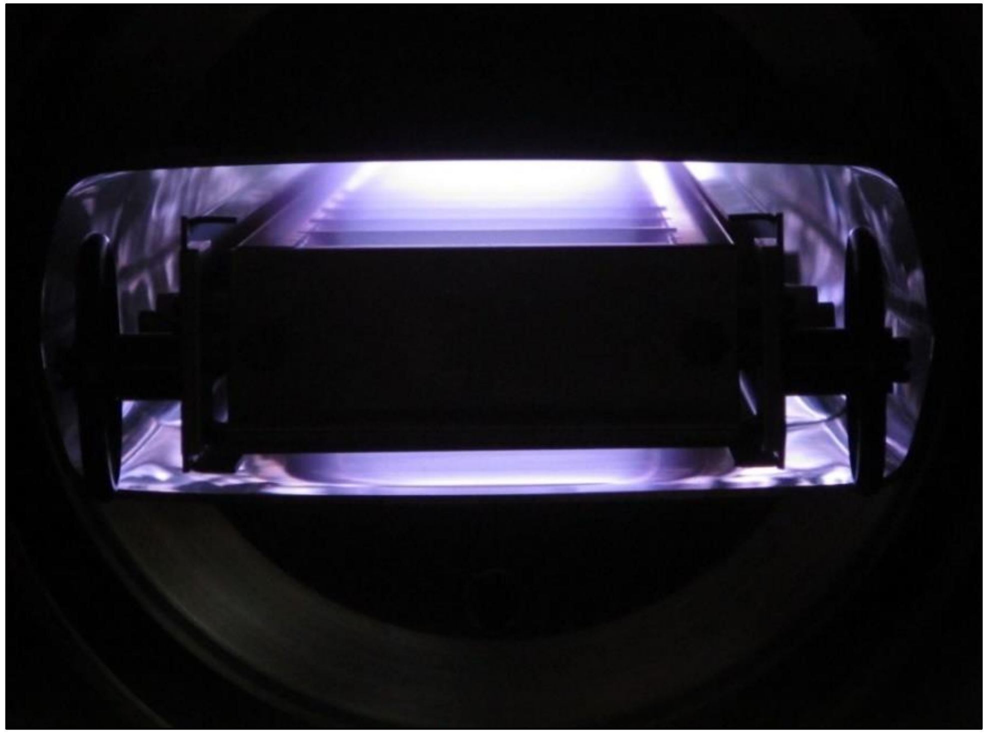
Assembling coating setup in the tunnel



2. CERN/TE coating facilities and examples

In-situ coatings in the SPS tunnel: a-C (low secondary electron emission)

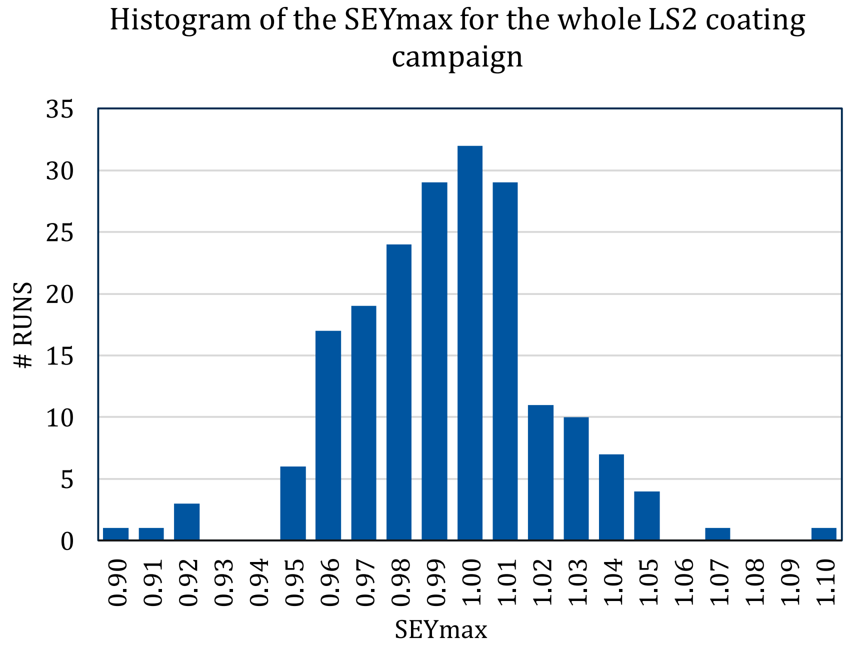
The first large scale production in the SPS during the CERN Long Shutdown (**212 coating runs**):



88 QF quadrupole magnets (294 m) coated in-situ 2 runs / week with 2 systems

110 Short straight Section elements (104 m) coated ex-situ 2 runs / week with 2 systems

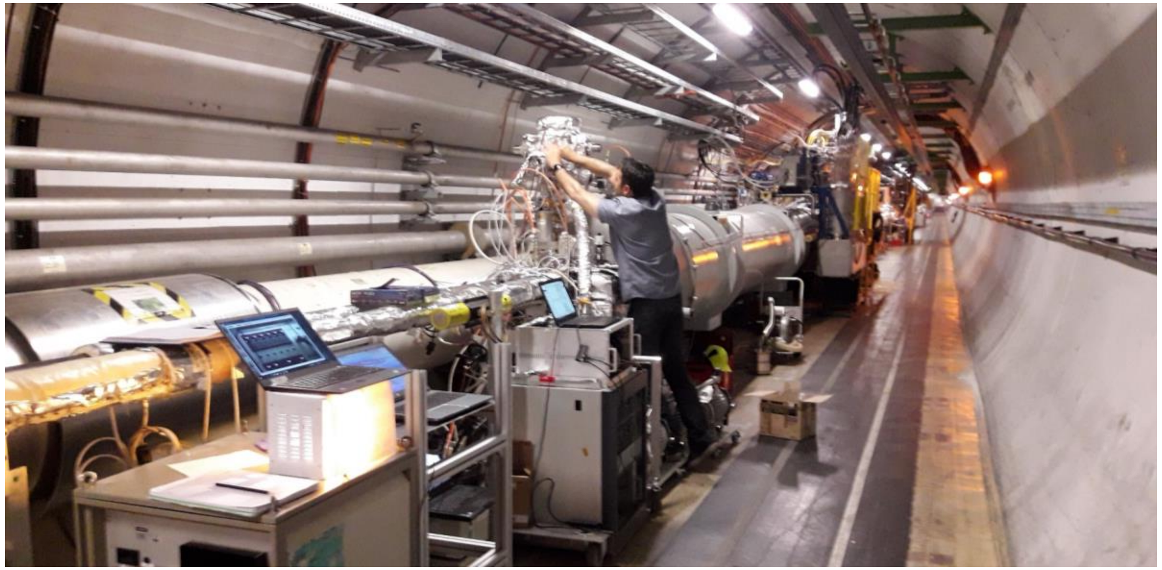
29 Drift vacuum chamber (80 m) coated ex-situ 2 runs / week with 2 systems



2. CERN/TE coating facilities and examples

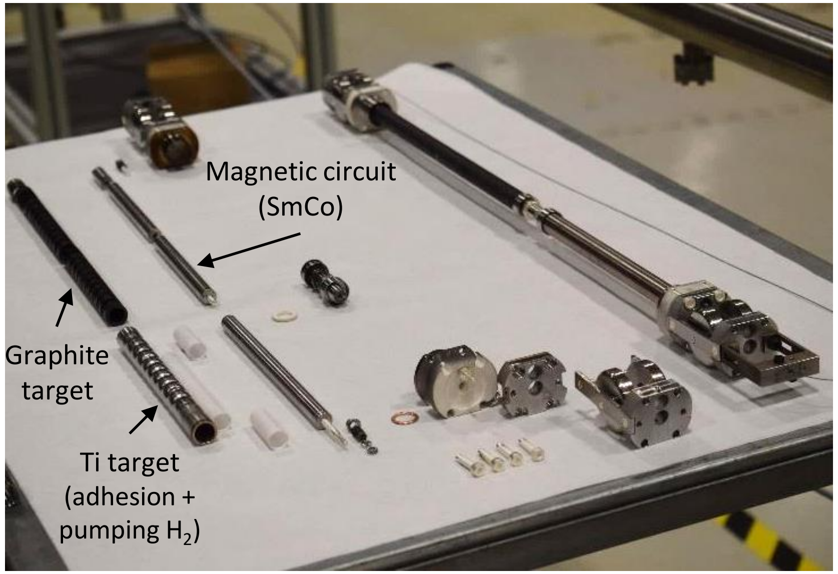
In-situ coatings in the LHC tunnel: a-C (low secondary electron emission to mitigate electron multipacting)

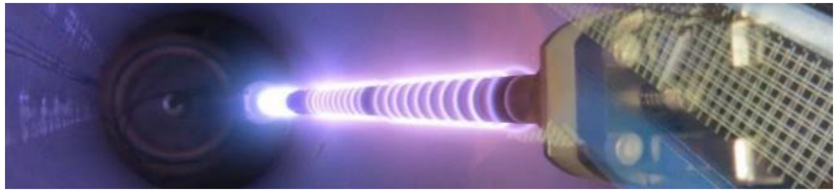
Length to be coated ~12 meter



Limited space to insert coating device < 250 mm

Modular sputtering source displaced by cables

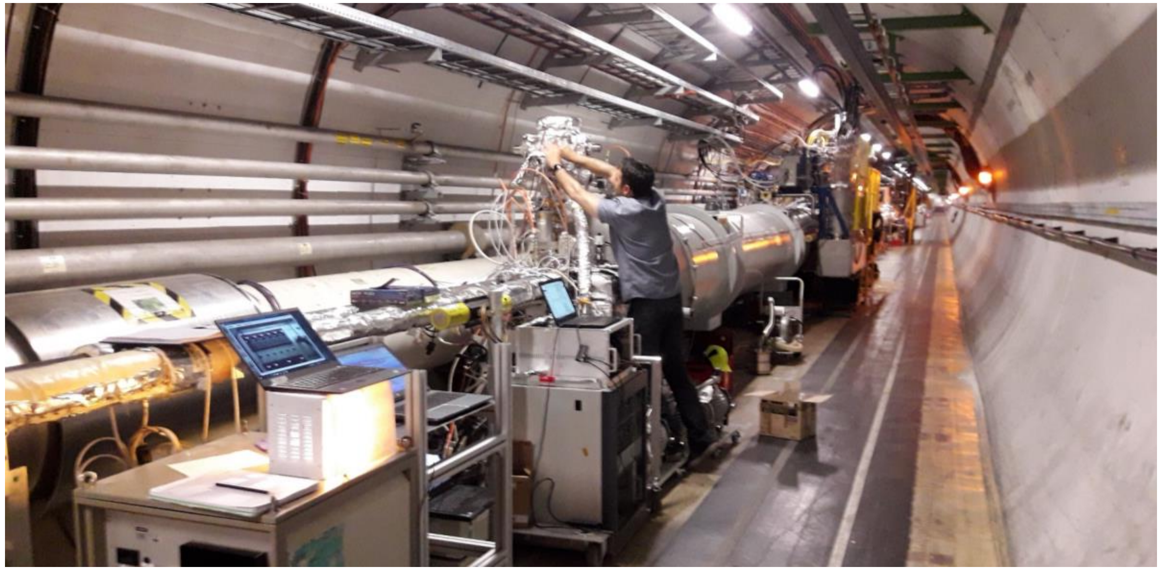




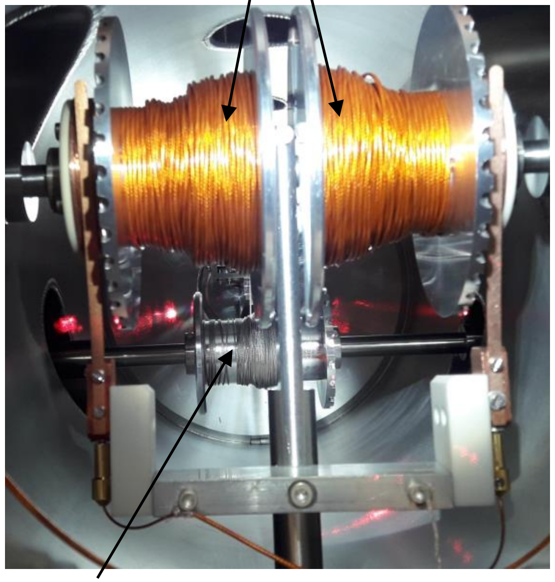
2. CERN/TE coating facilities and examples

In-situ coatings in the LHC tunnel: a-C (low secondary electron emission to mitigate electron multipacting)

Length to be coated ~12 meter

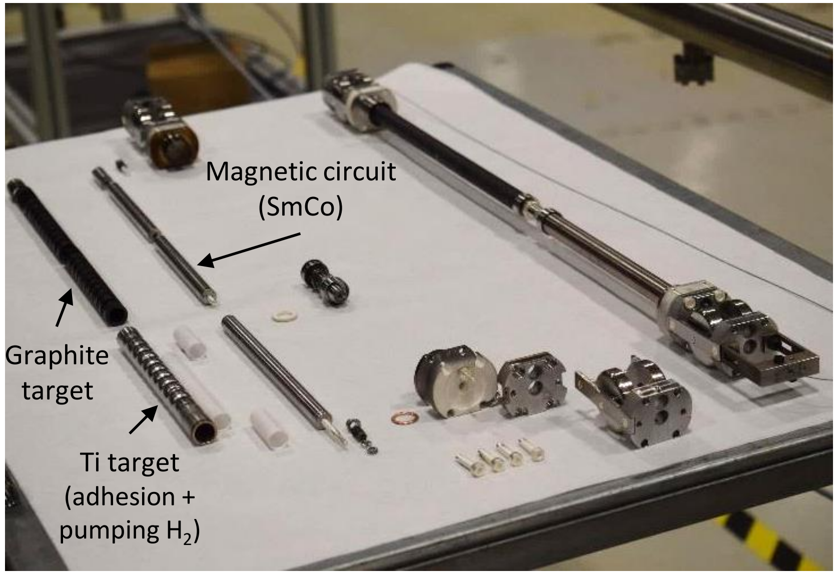


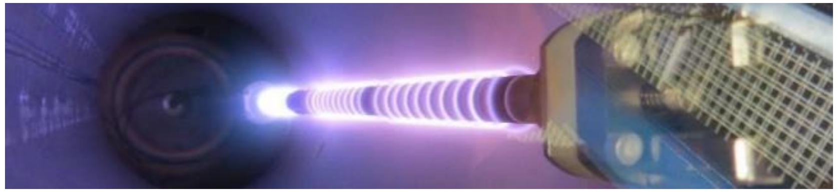
Electrical cables



Mechanical cable

Modular sputtering source displaced by cables





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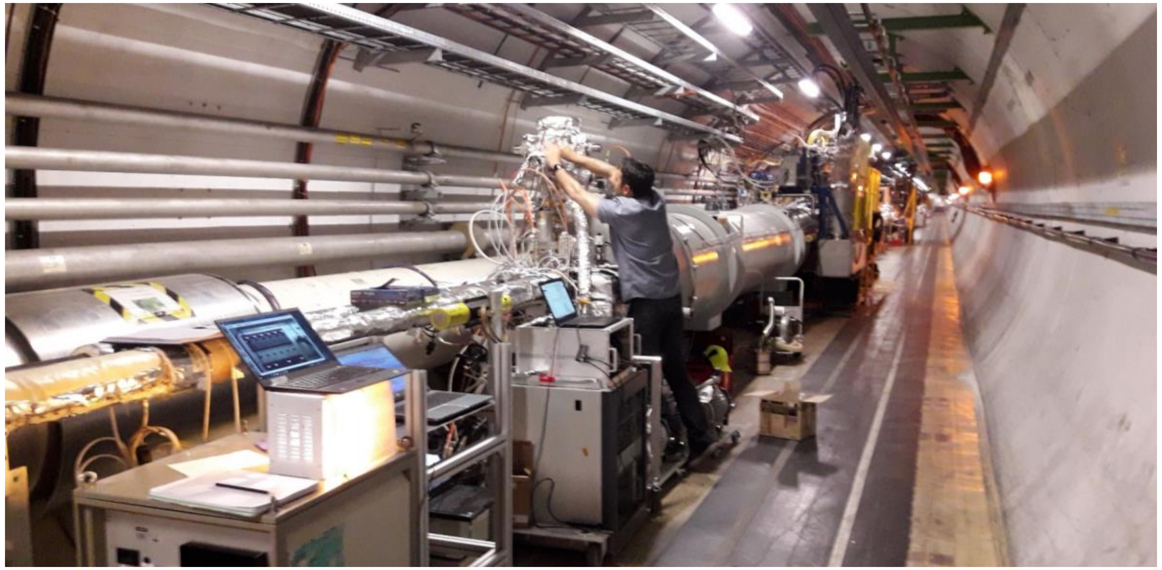
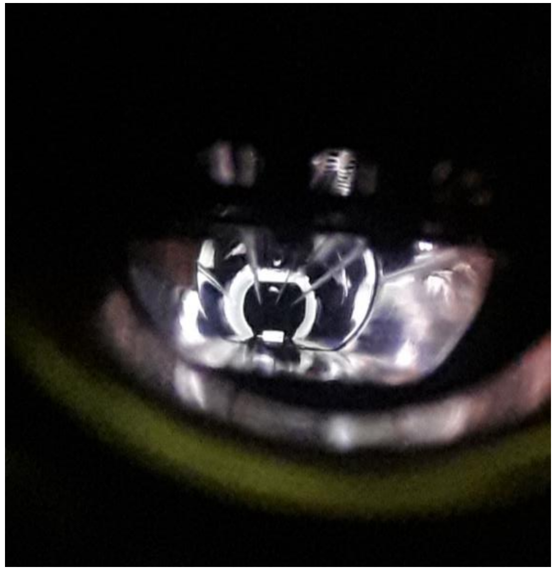
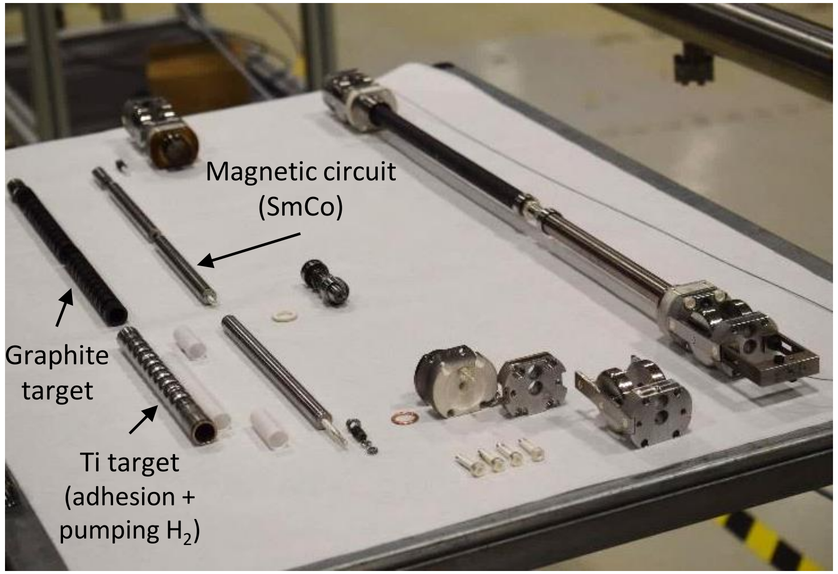
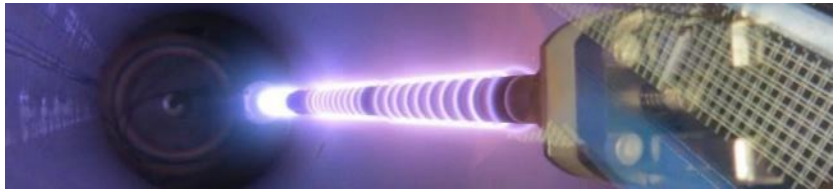




Modular sputtering source displaced by cables





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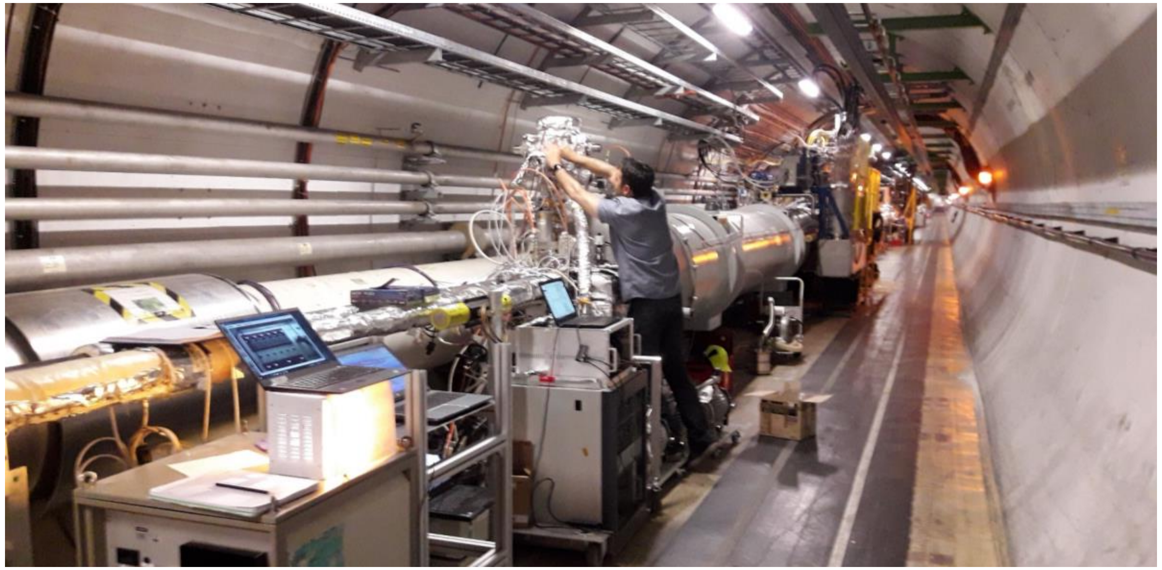
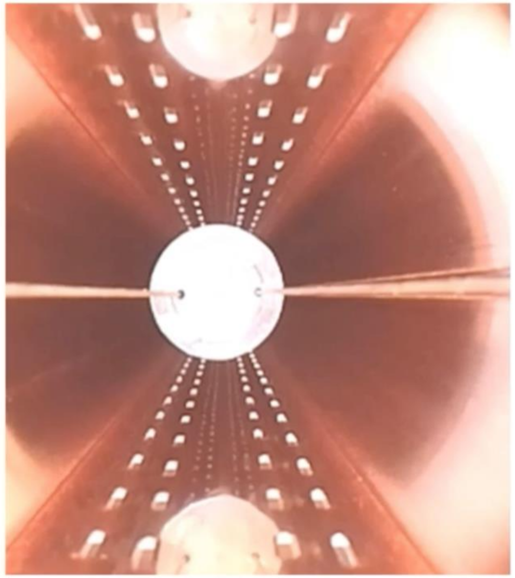
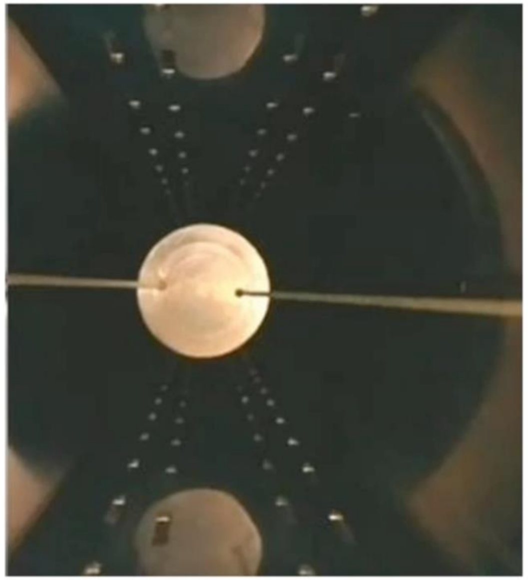


Before coating



After coating



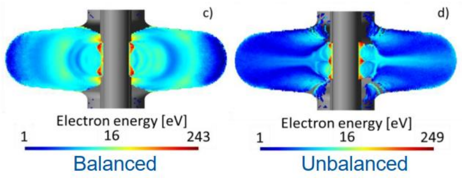
3. Summary

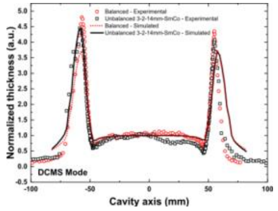
CERN/TE have a wide expertize on thin film coatings, mainly oriented to particle accelerators.

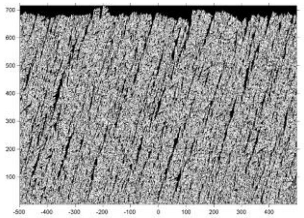
From R&D to large scale production: choice of materials, adapting the PVD technology to the constrains (hollow cathode discharges, HIPIMS, displace sputtering sources in vacuum for more than 10 meters, etc), surface preparation (wet chemistry, ion etching, adhesion layers, diffusion barrier layers…)

Integration of simulations on the R&D process (not tackled here) have been increasing in the last years.

Simulation of the glow discharge → Transport of species from target to substrate → Film microstructure







Thank you for your attention