

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

Thin film coating facilities at CERN/TE

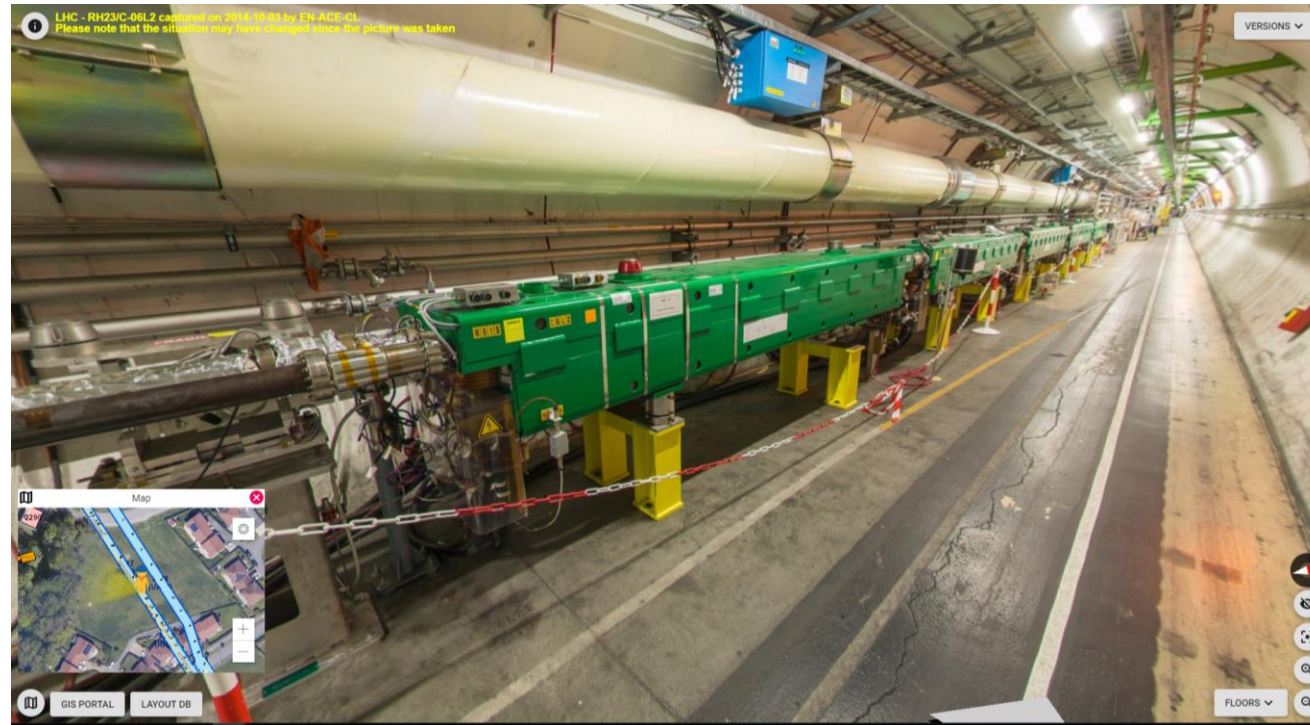
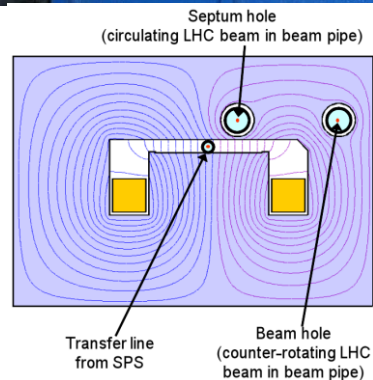
Pedro Costa Pinto CERN/TE-VSC-SCC

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

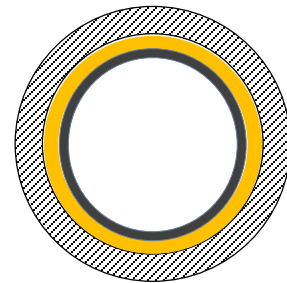
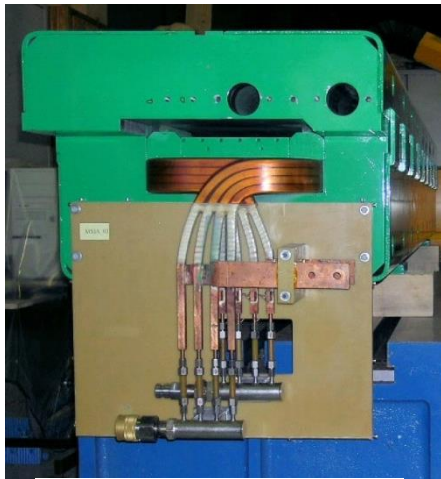
Example: beam pipes for the septa magnets for the LHC (injection kickers)



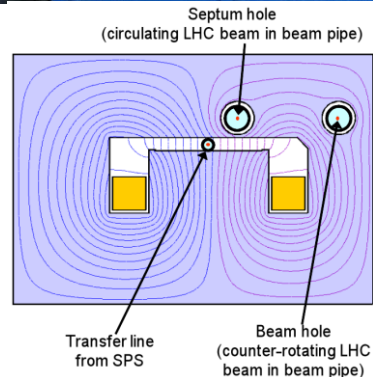
1. Thin films for particle accelerators (why, what & how)

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)



- **Mumetal tubes (0.9 mm thick)** \Rightarrow magnetic shielding + mechanical stability
- **Cu electroplating (0.4 mm thick)** \Rightarrow increase conductivity
- **Ti-Zr-V thin film coating (1 μm thick)** \Rightarrow 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)

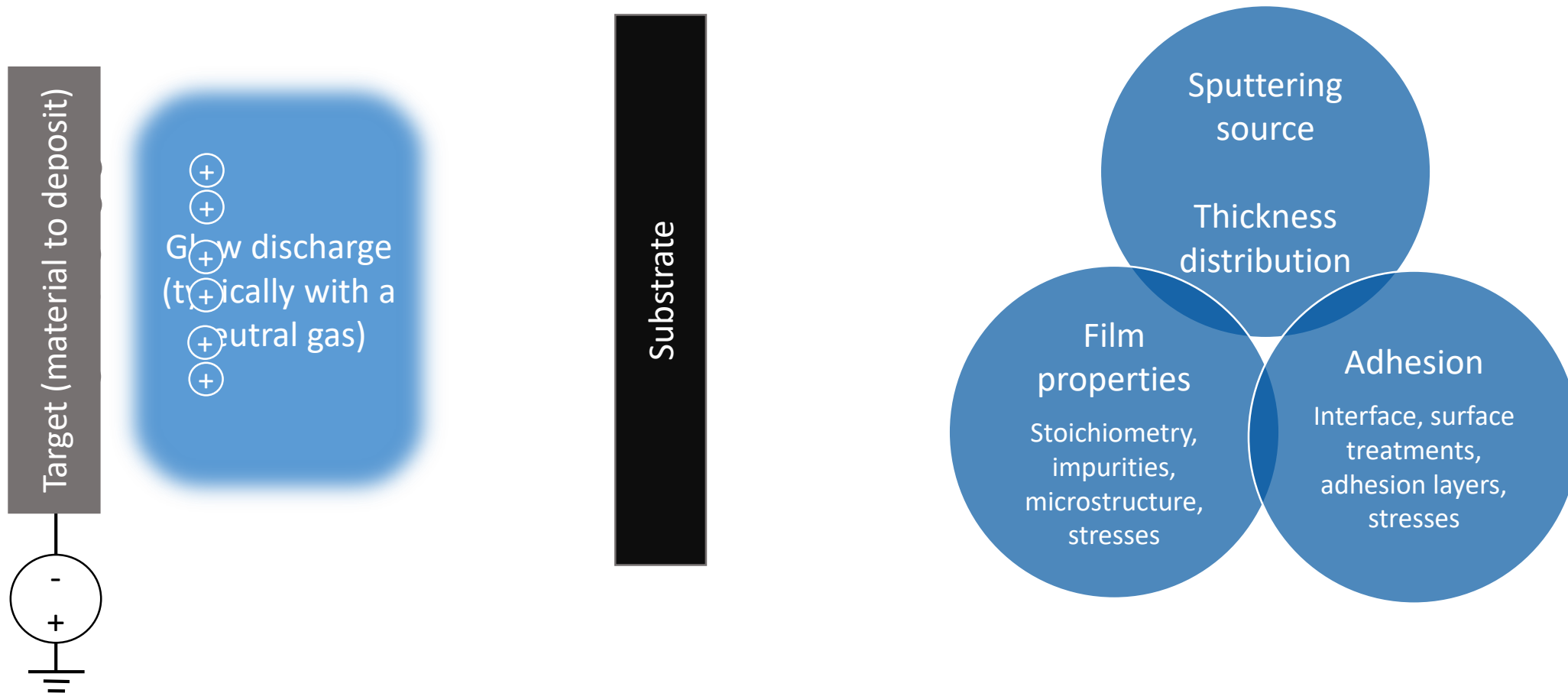


Carbon coatings for e-cloud suppression



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

Coating processes: Physical Vapor Deposition → Glow Discharge Sputtering



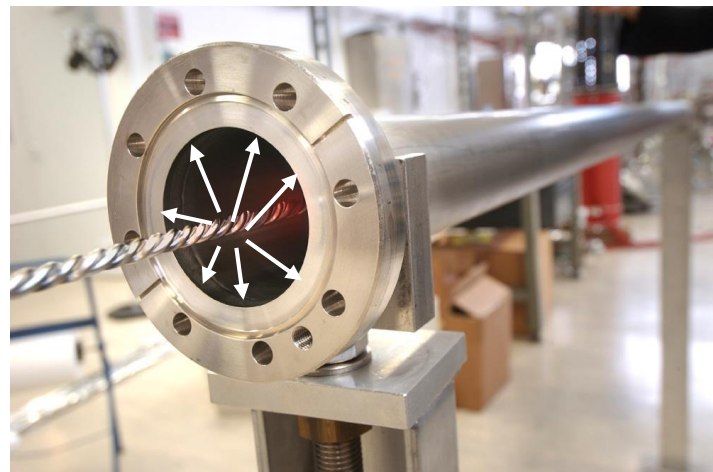
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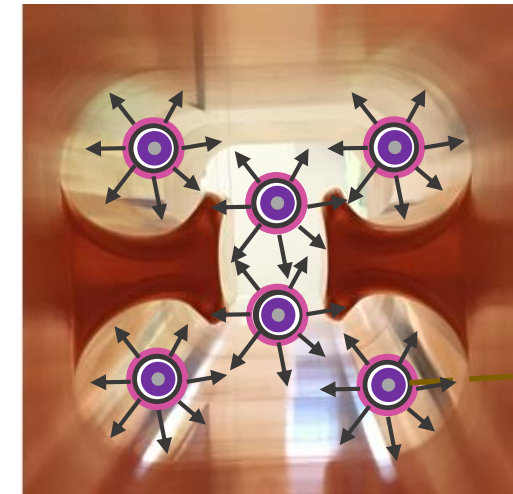
Flat substrates
planar targets



Tubular substrates
cylindrical targets



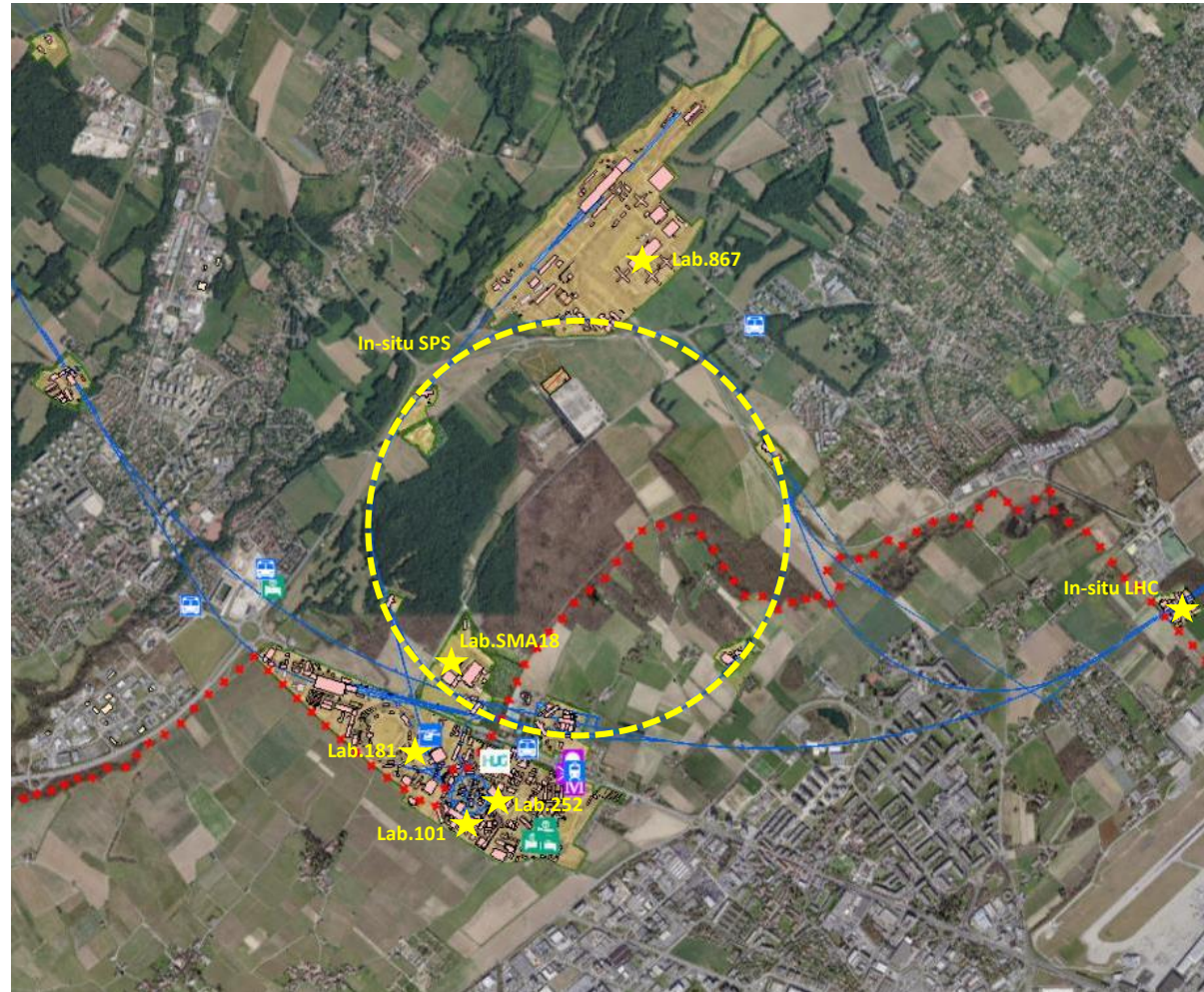
High complexity
Multiple targets



F. Avino et al, TTC, 05.02.2020, Geneva

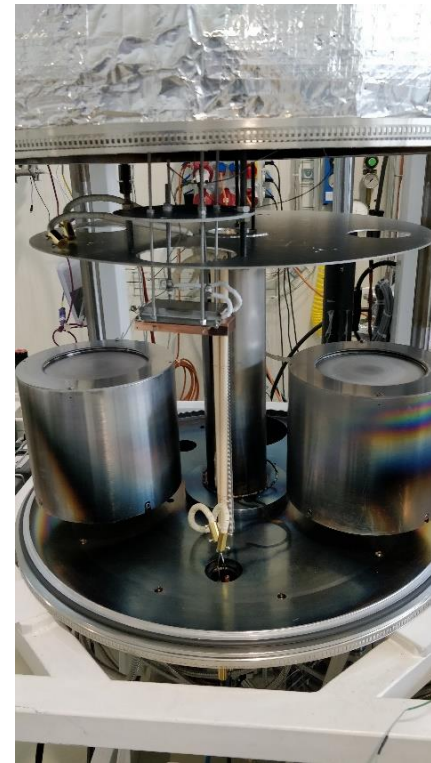
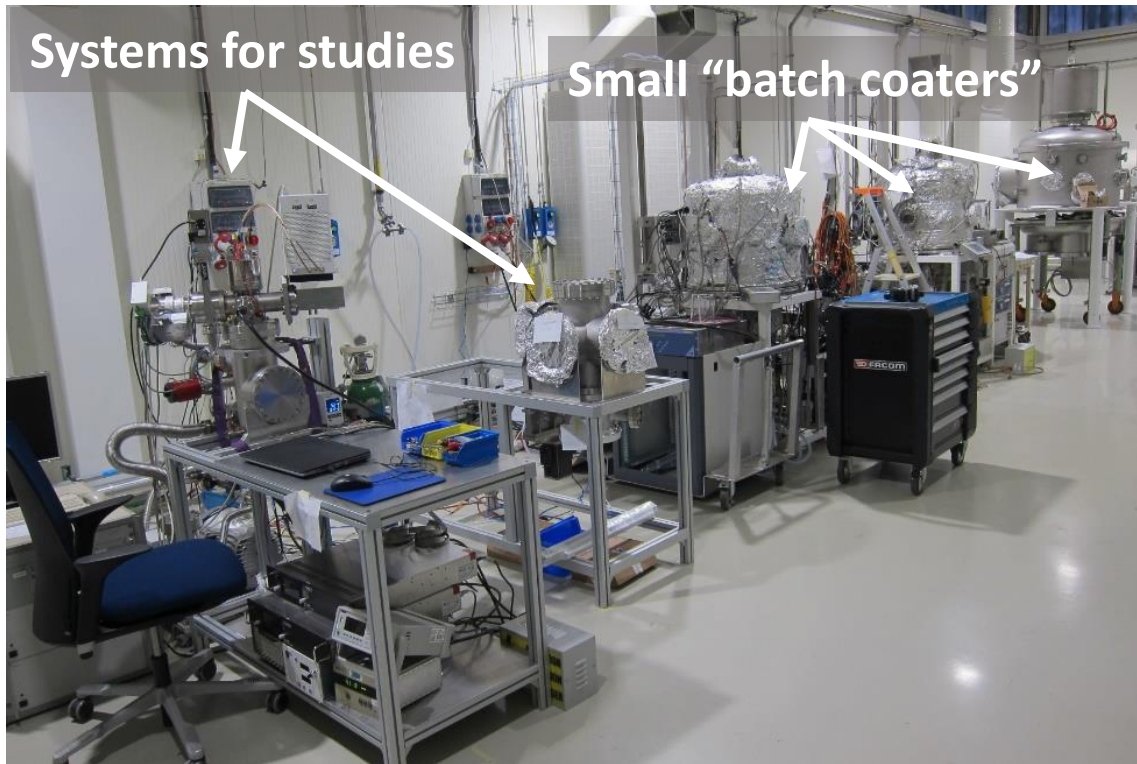
2. CERN/TE coating facilities and examples

Coating facilities at CERN/TE:



2. CERN/TE coating facilities and examples

General purpose coating lab. in B.101:



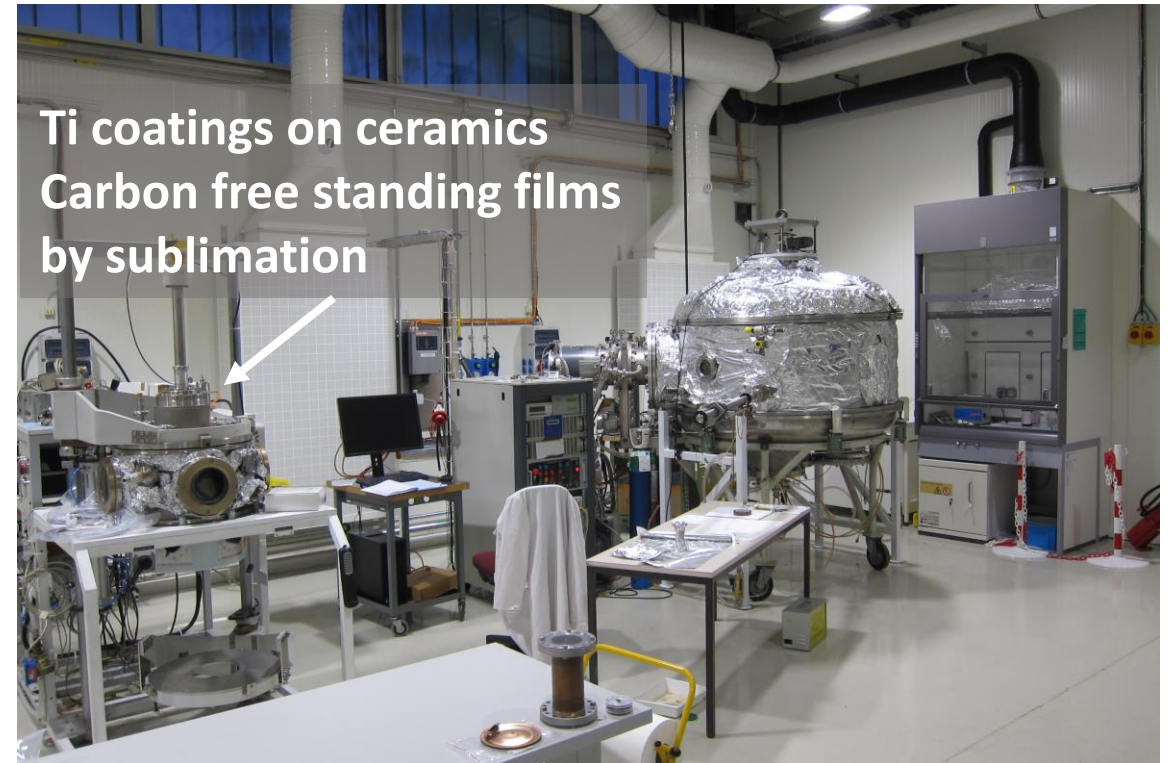
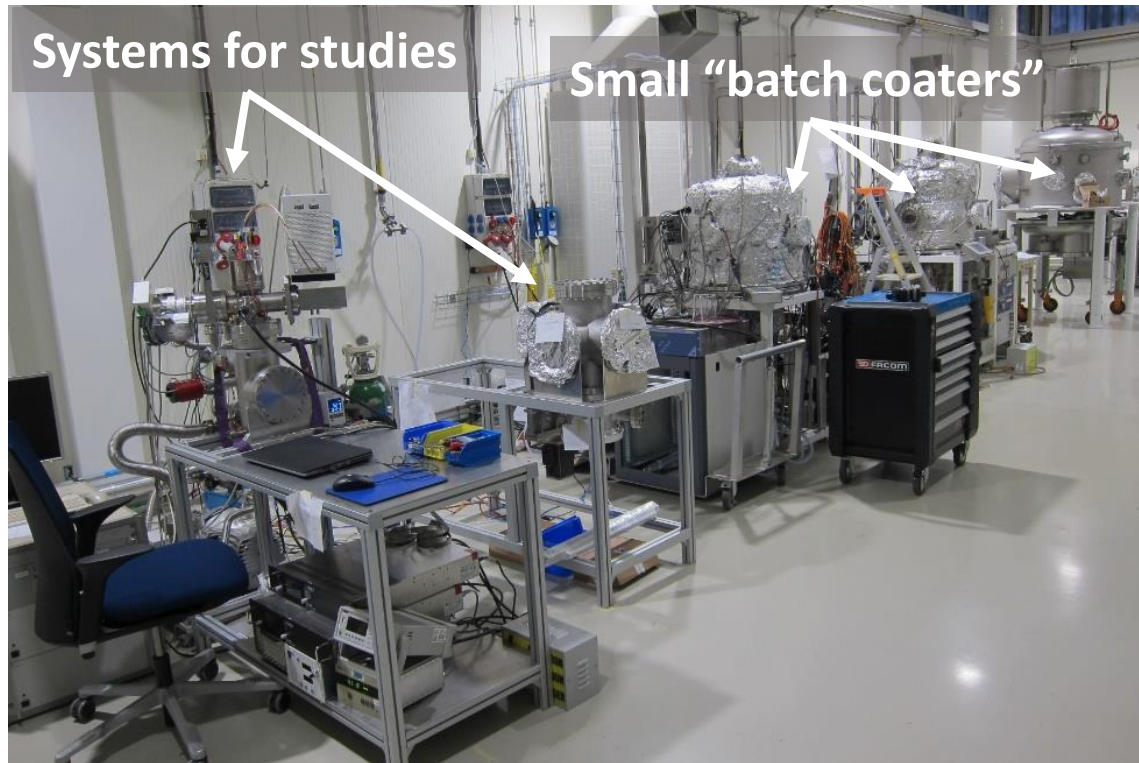
Development of Nb_3Sn superconducting films for RF acceleration.

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.

2. CERN/TE coating facilities and examples

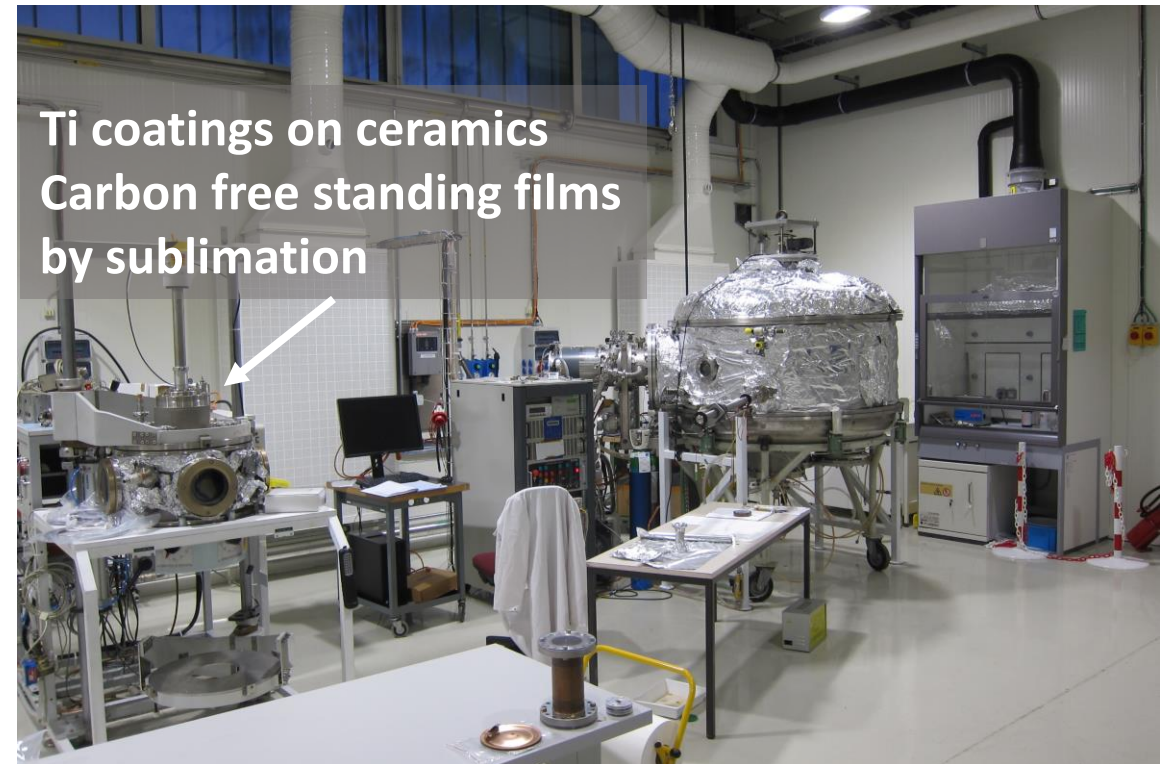
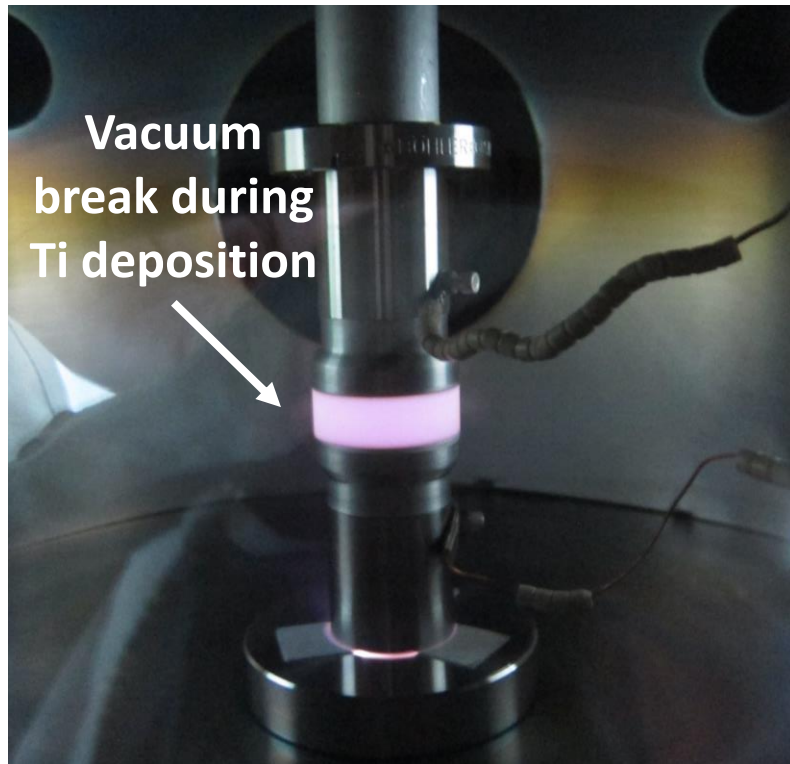
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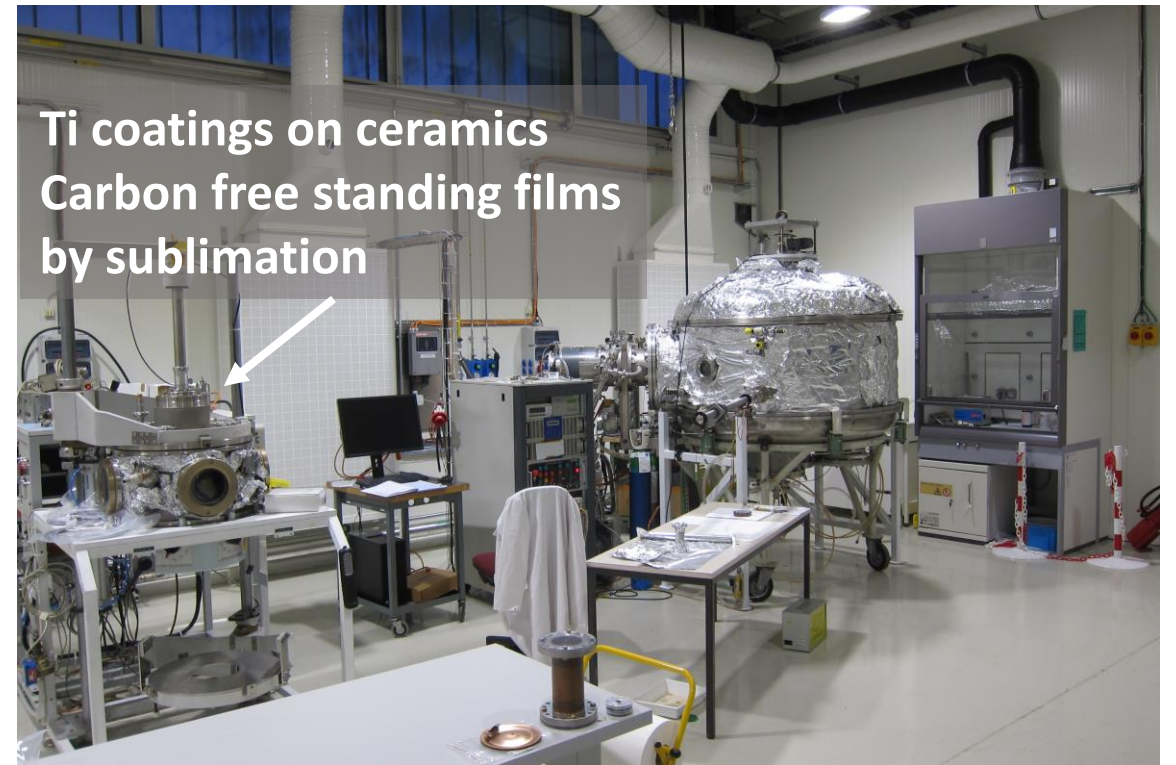
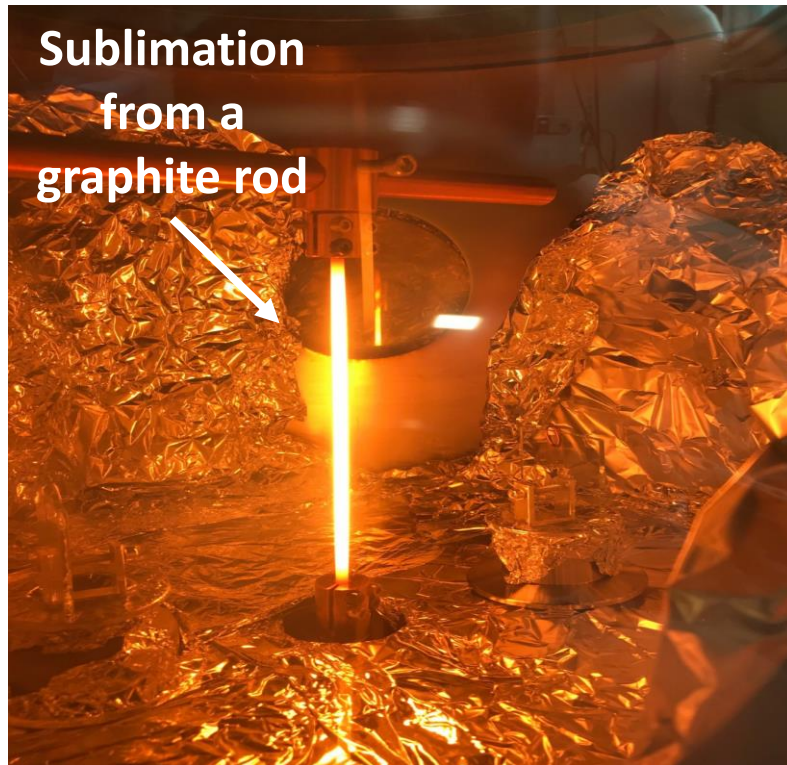
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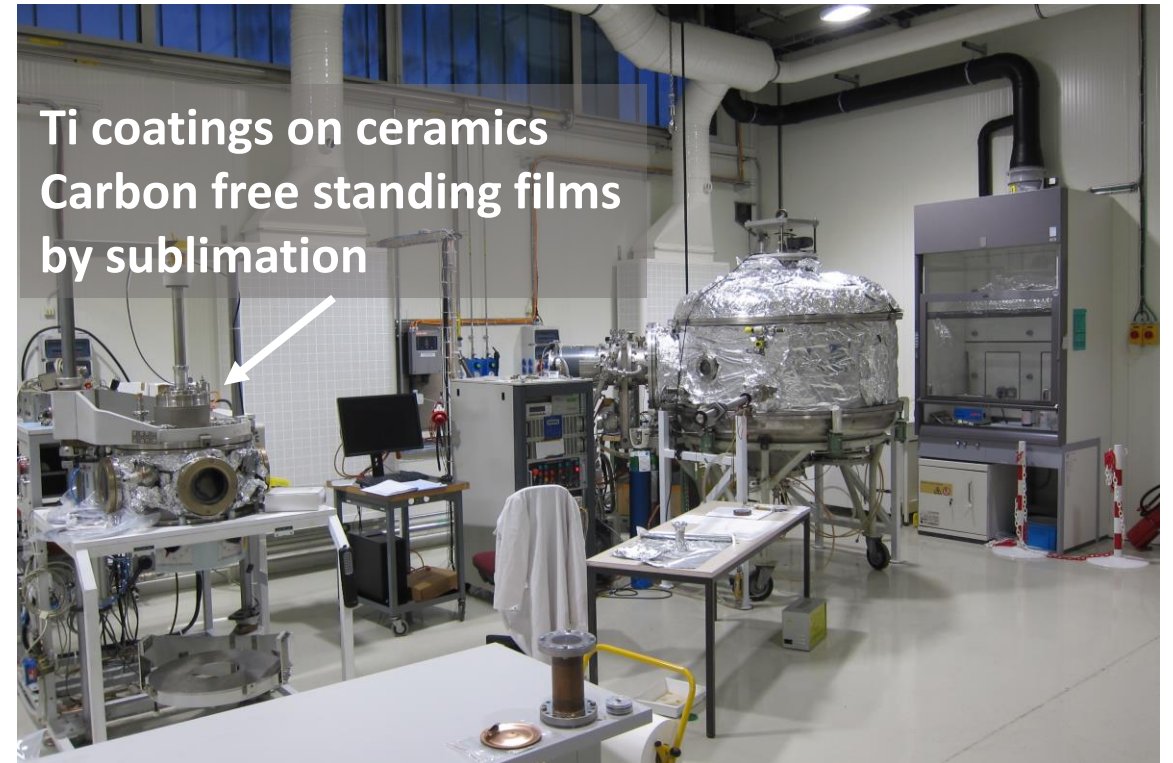
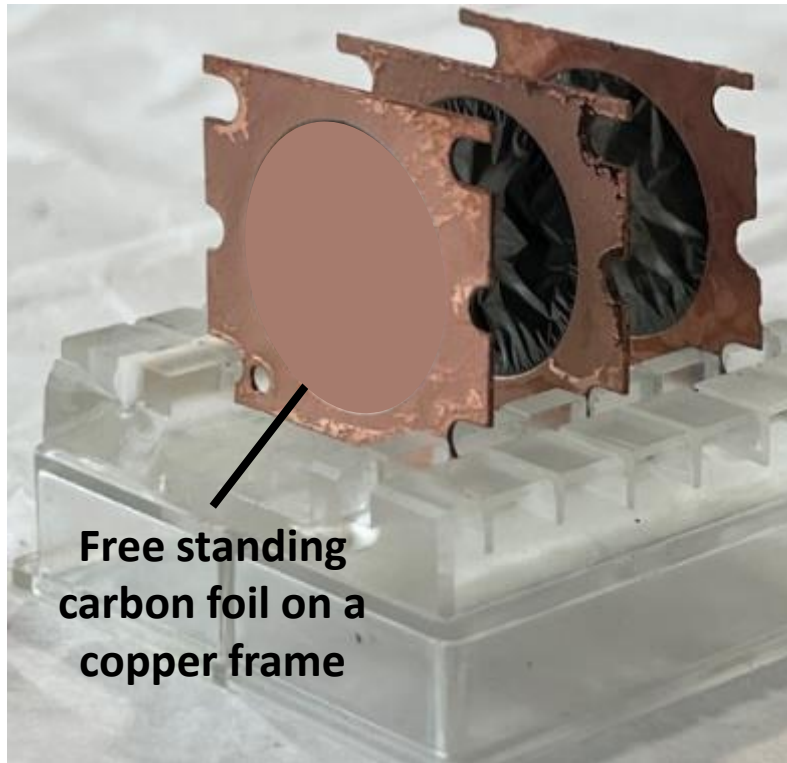
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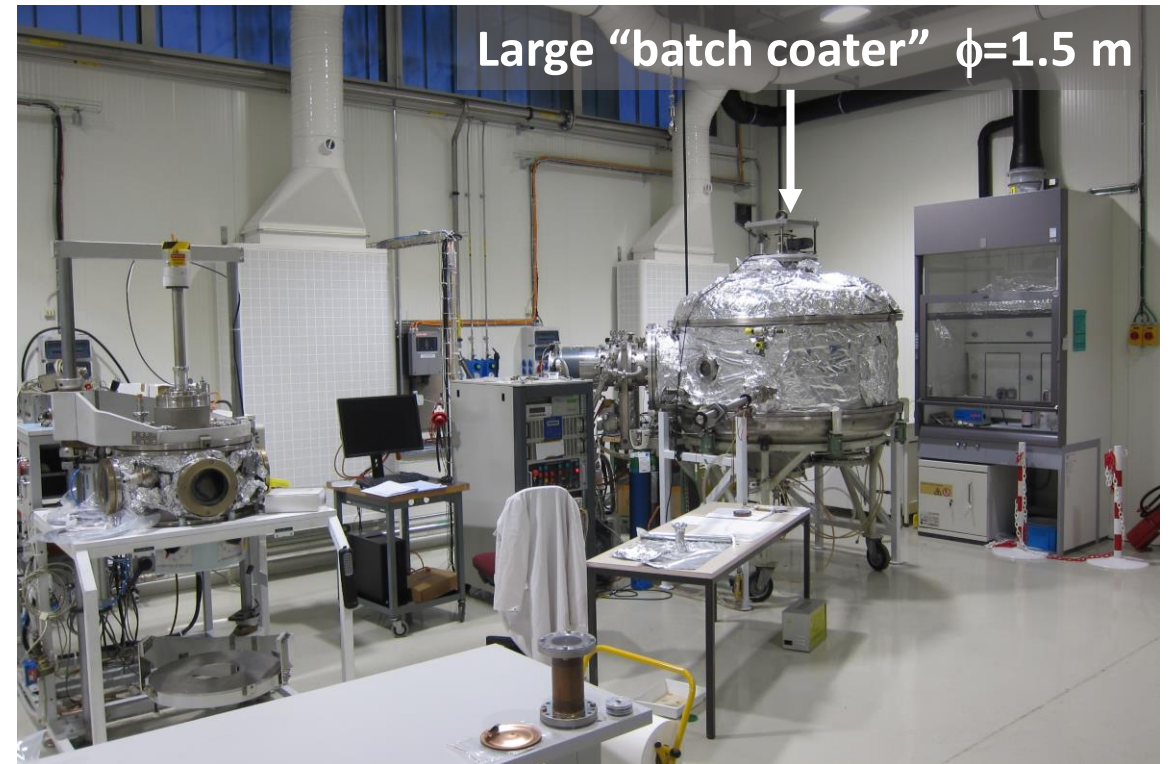
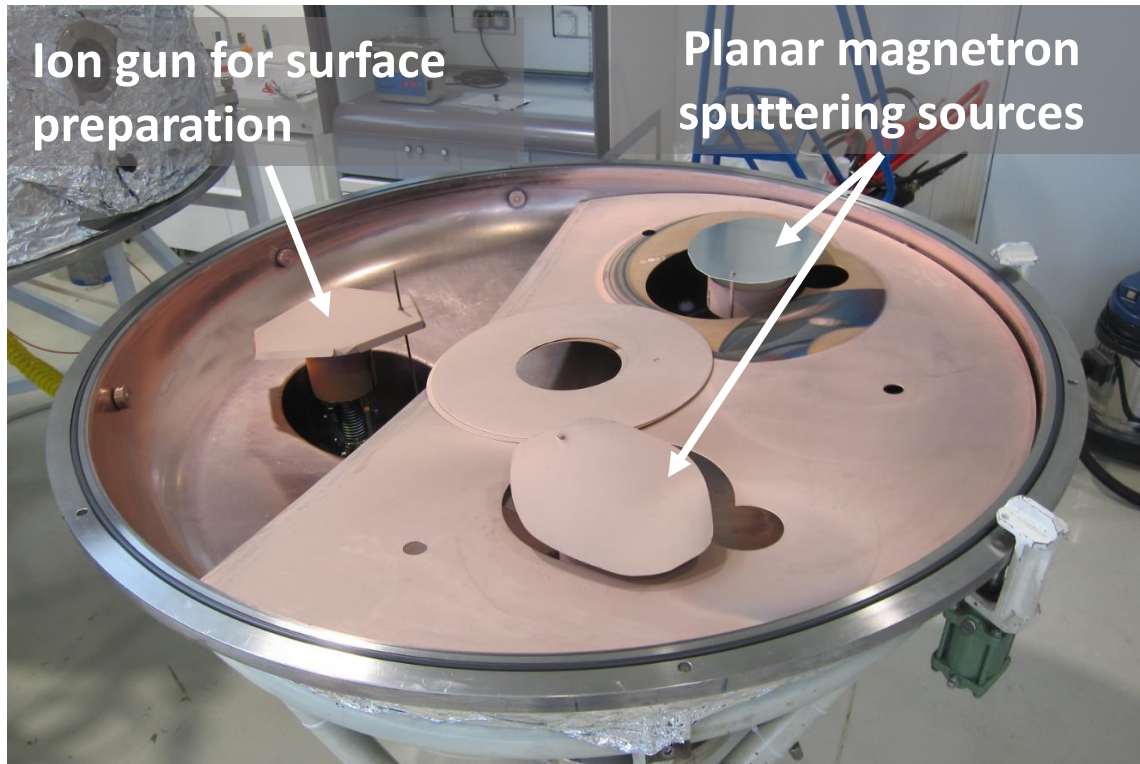
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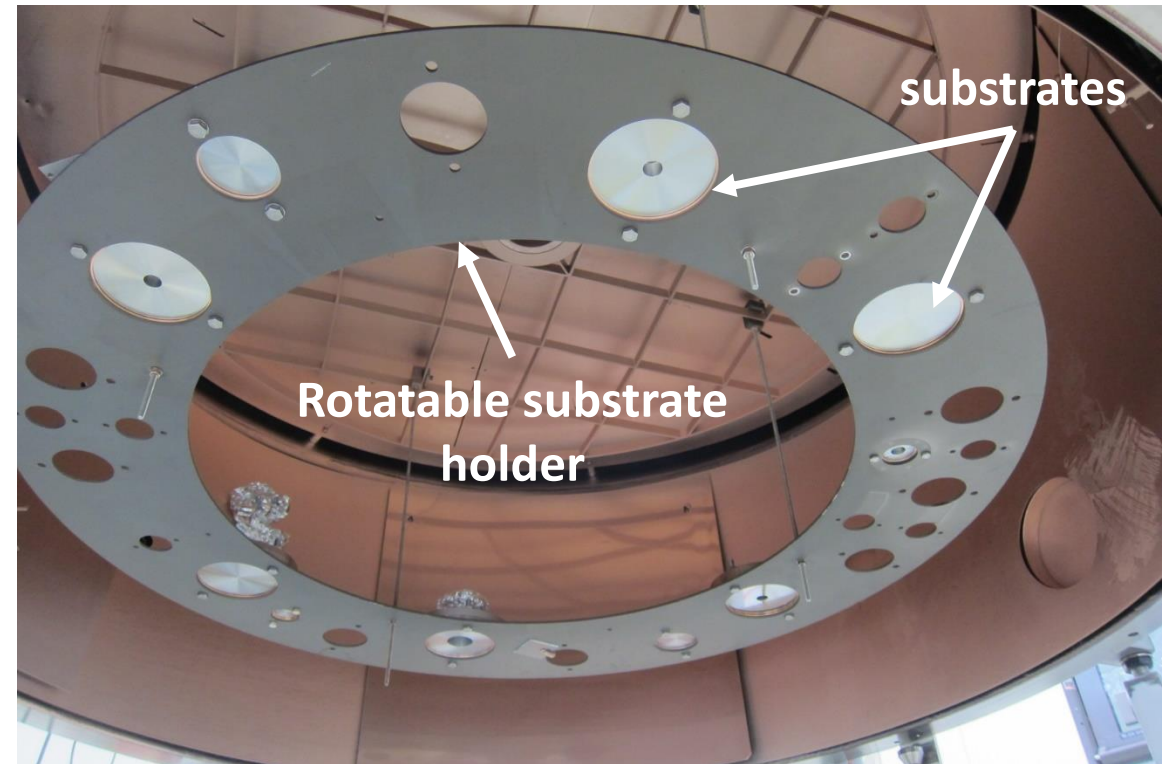
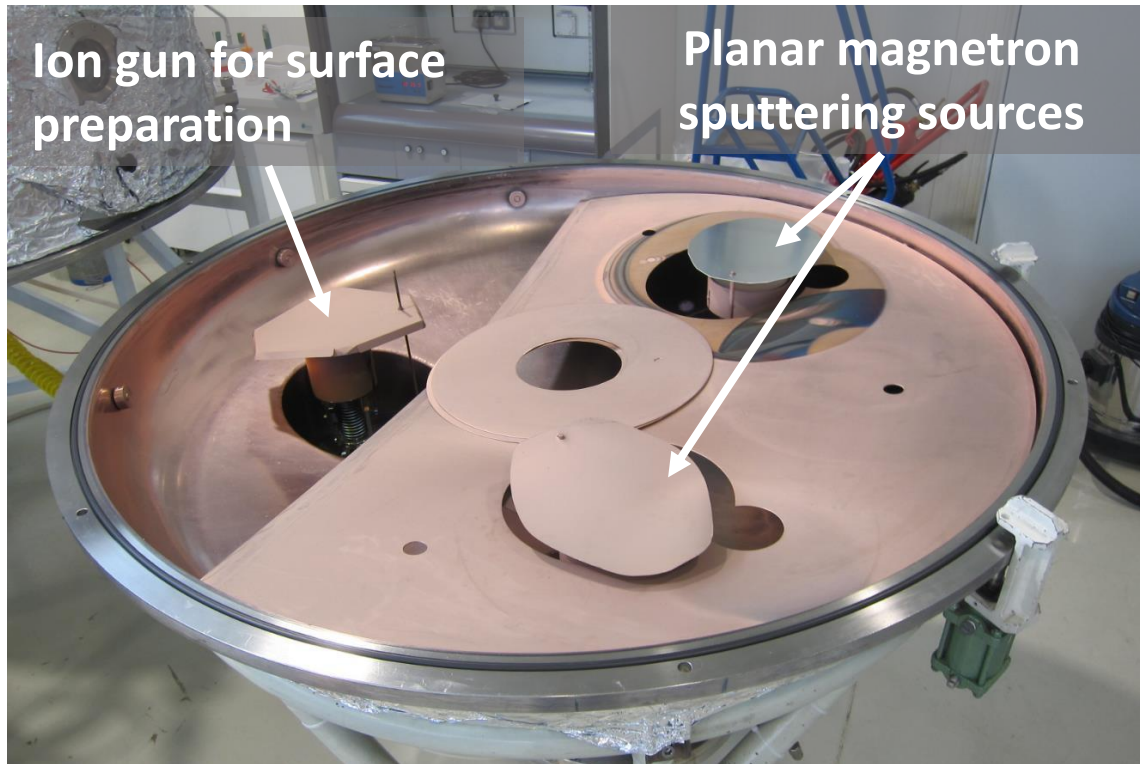
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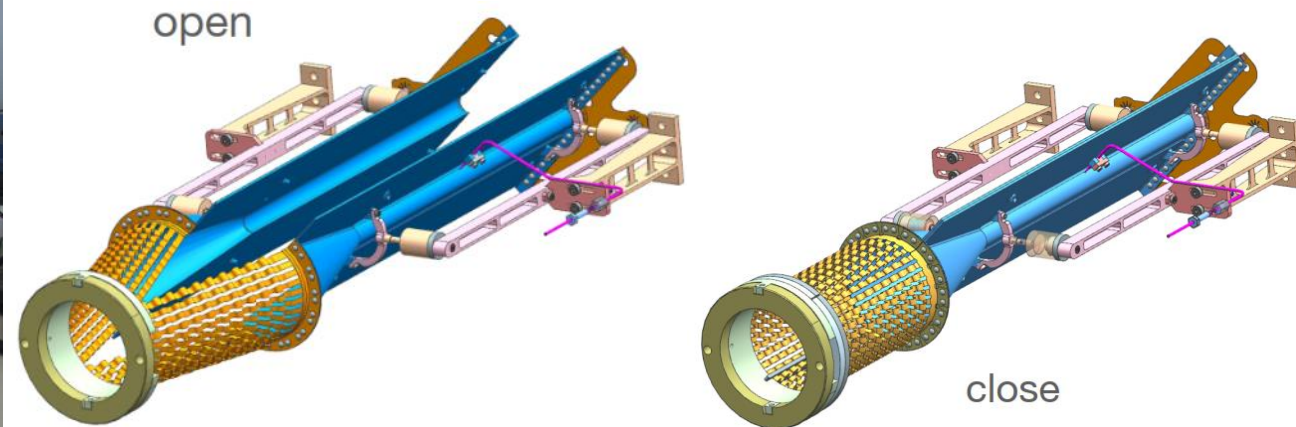
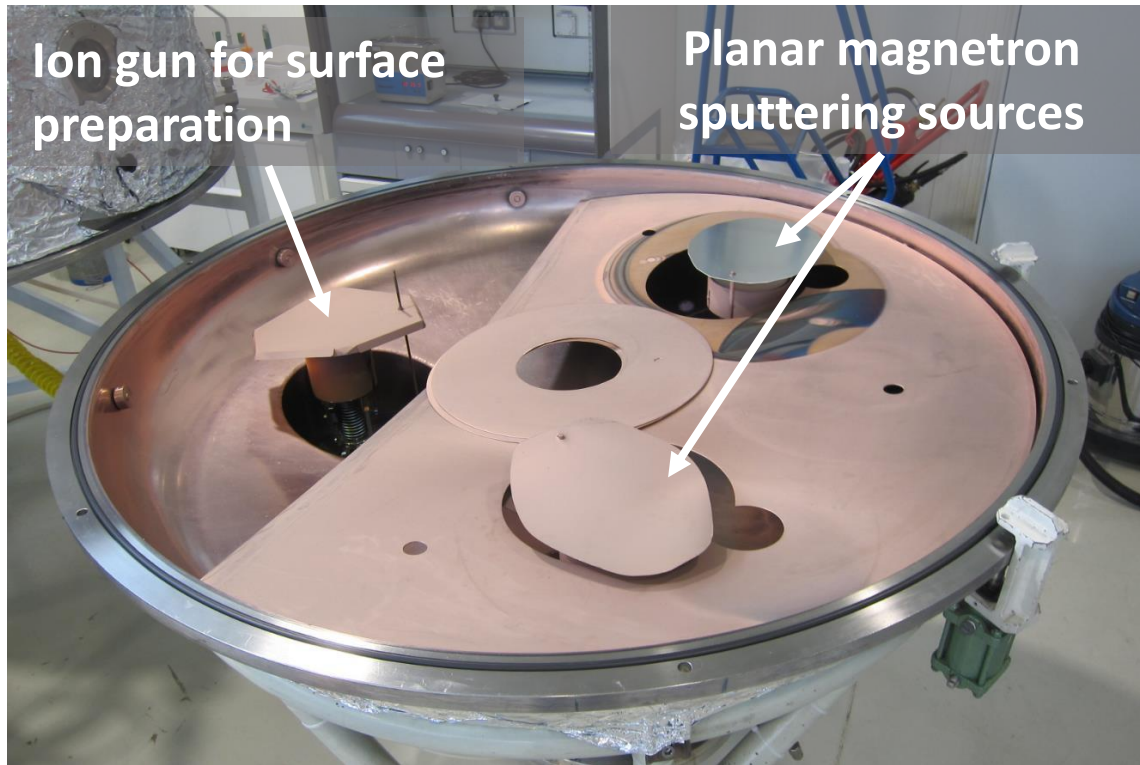
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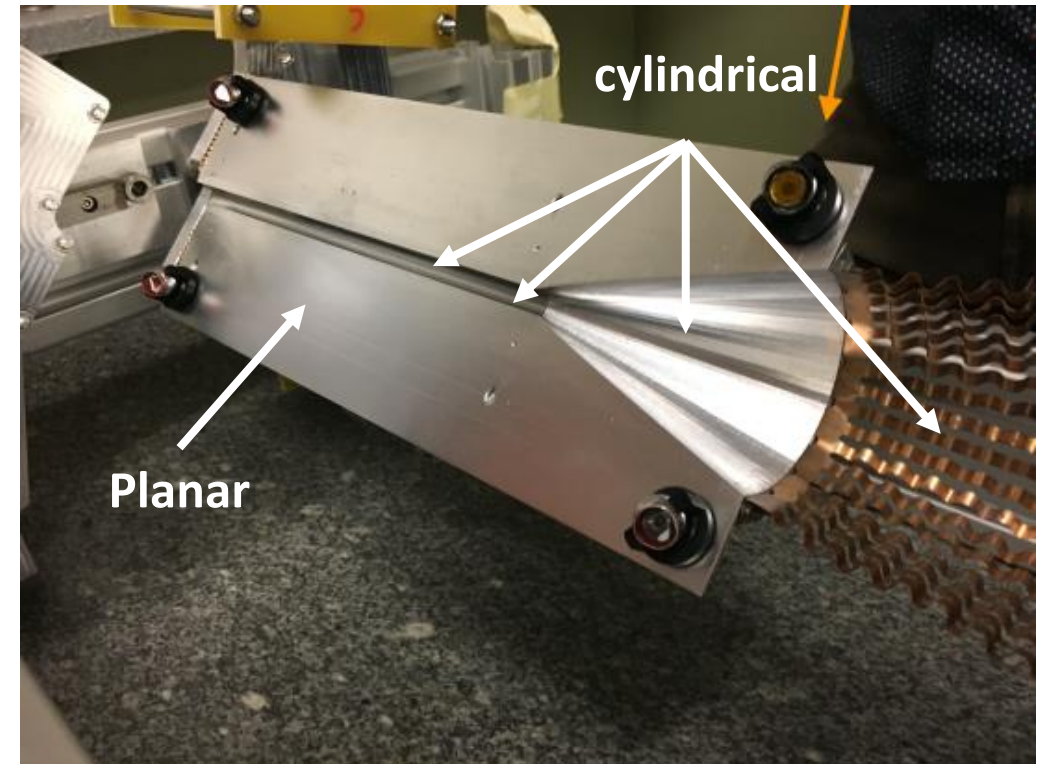
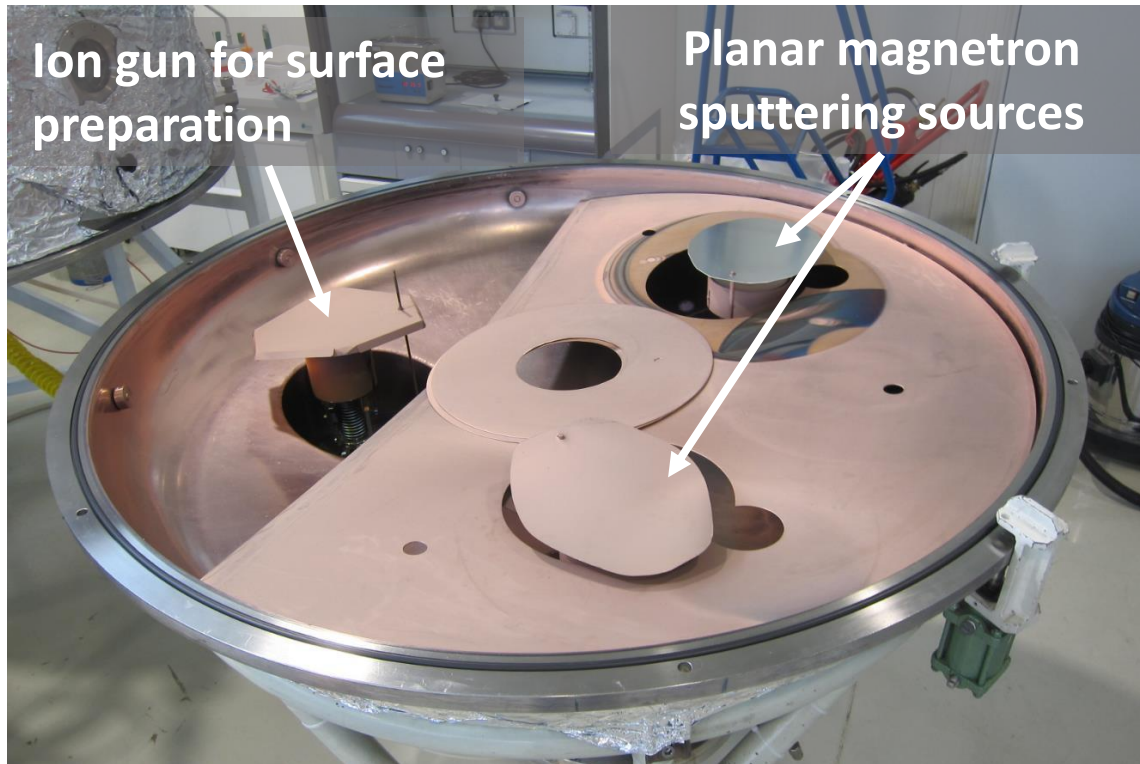
2. CERN/TE coating facilities and examples

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



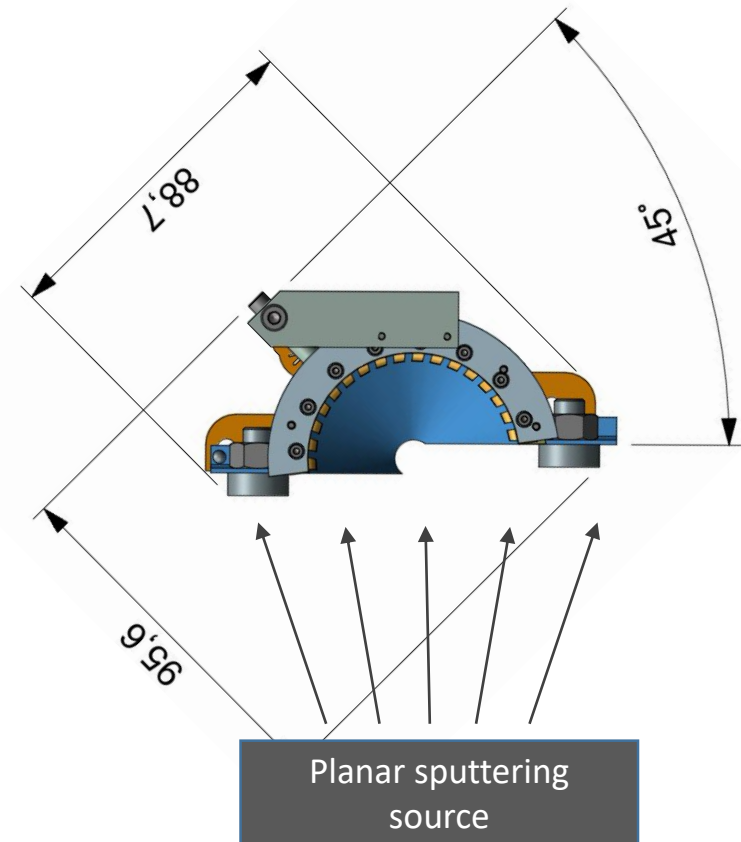
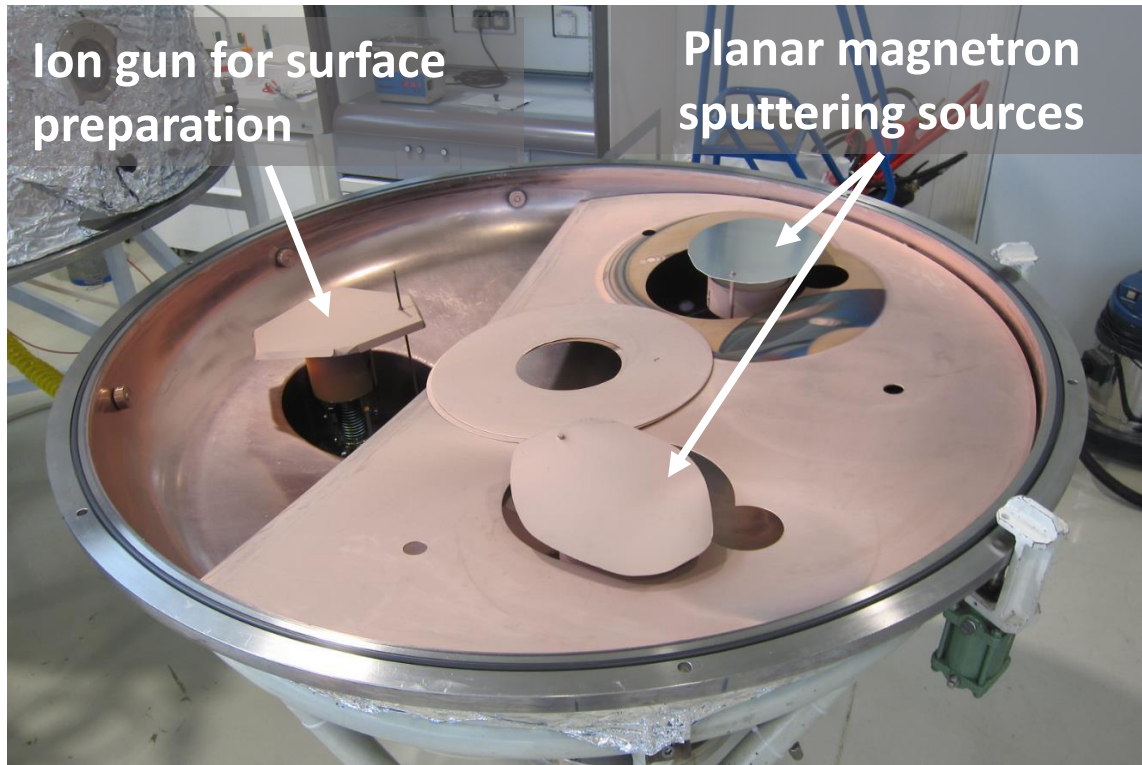
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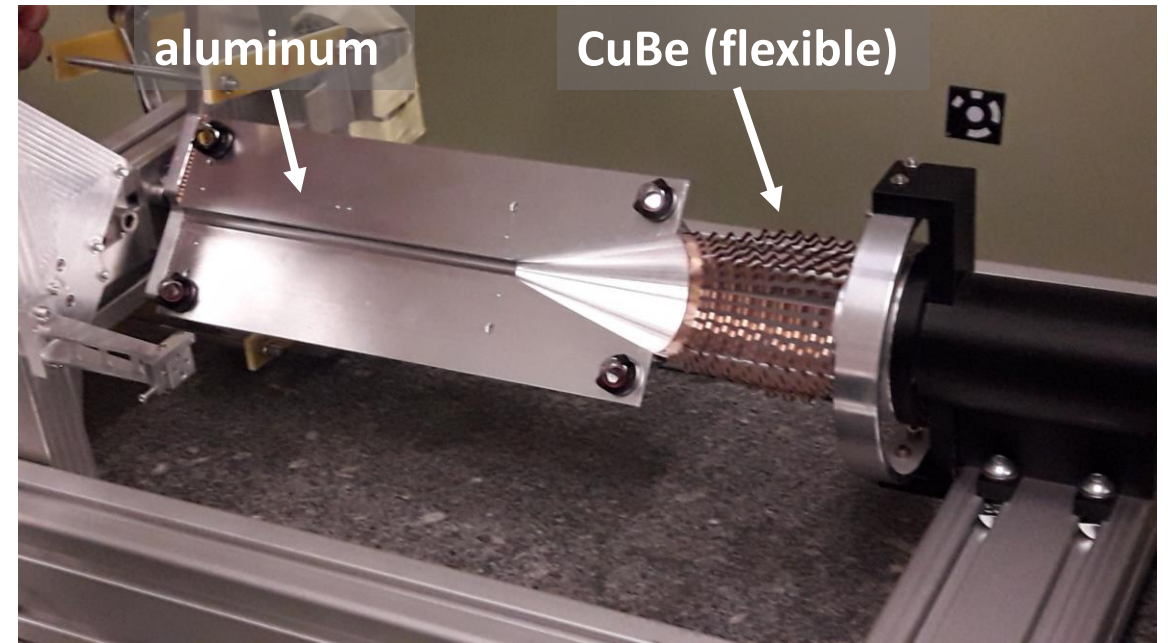
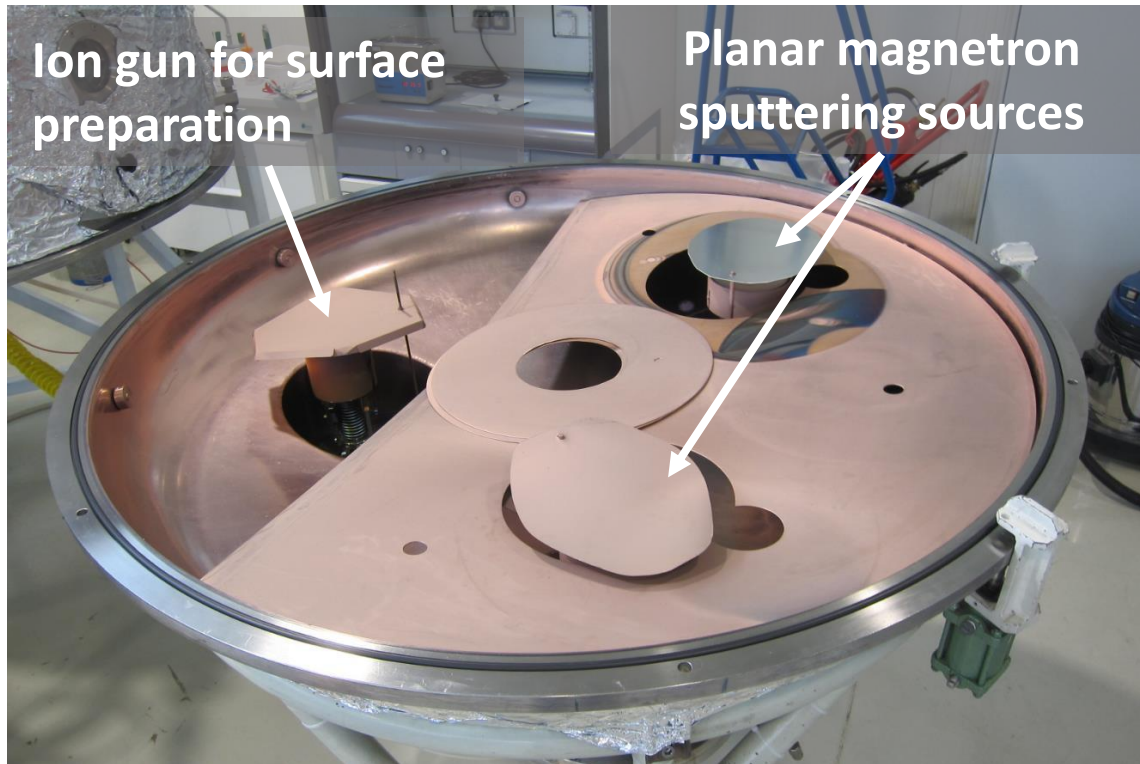
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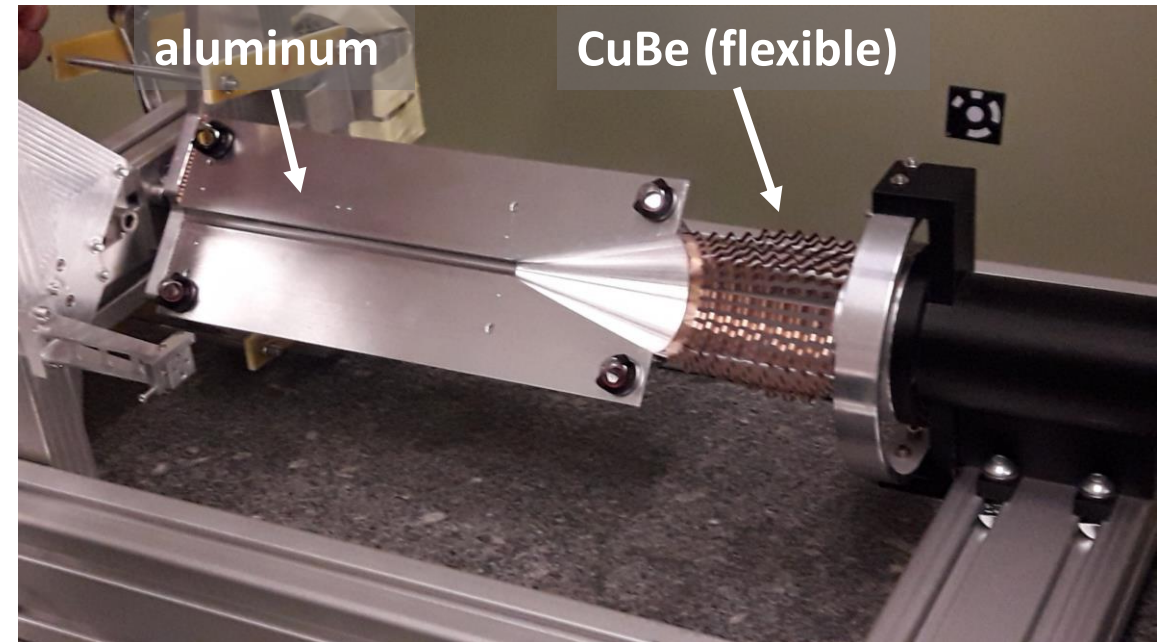
General purpose coating lab. in B.101: coating the SMOG 2 cells with carbon coating

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



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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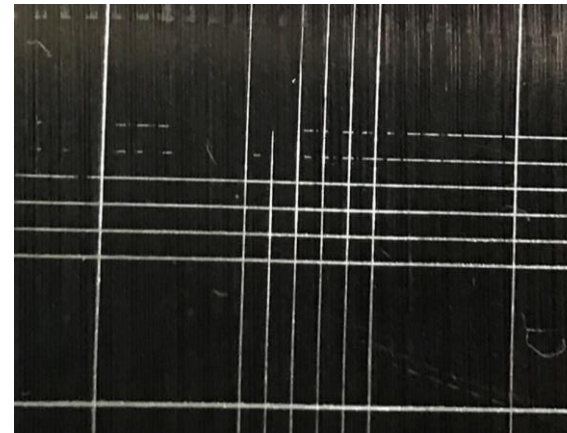


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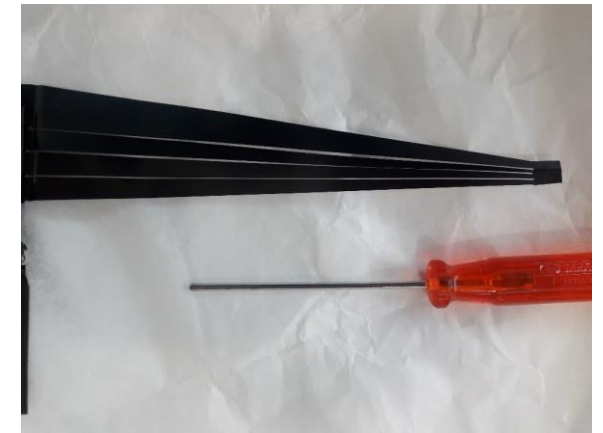
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Cross-hatch tests (Al)



“bending tests” (CuBe)



2. CERN/TE coating facilities and examples

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

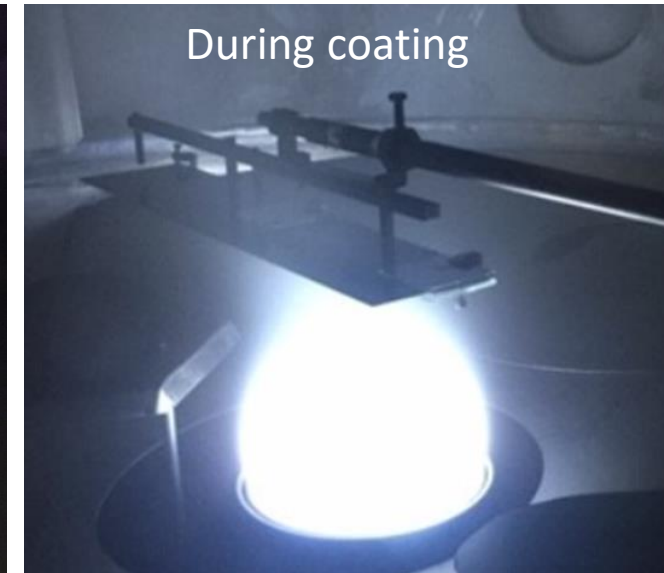
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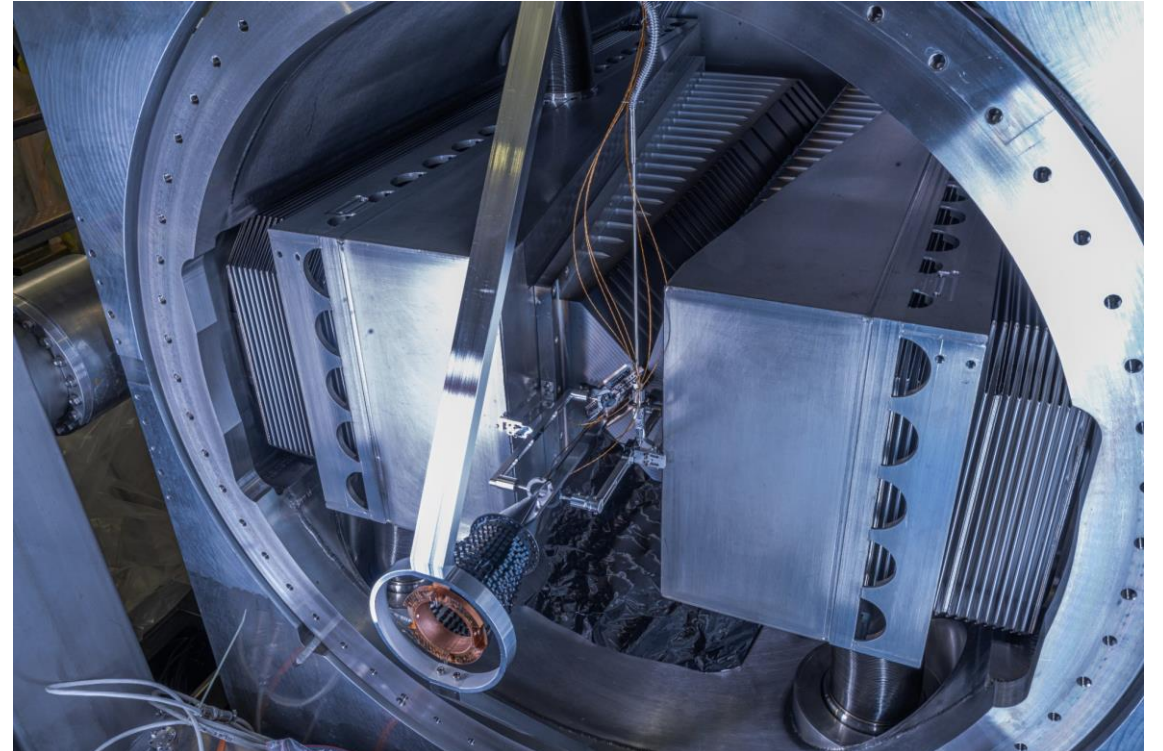
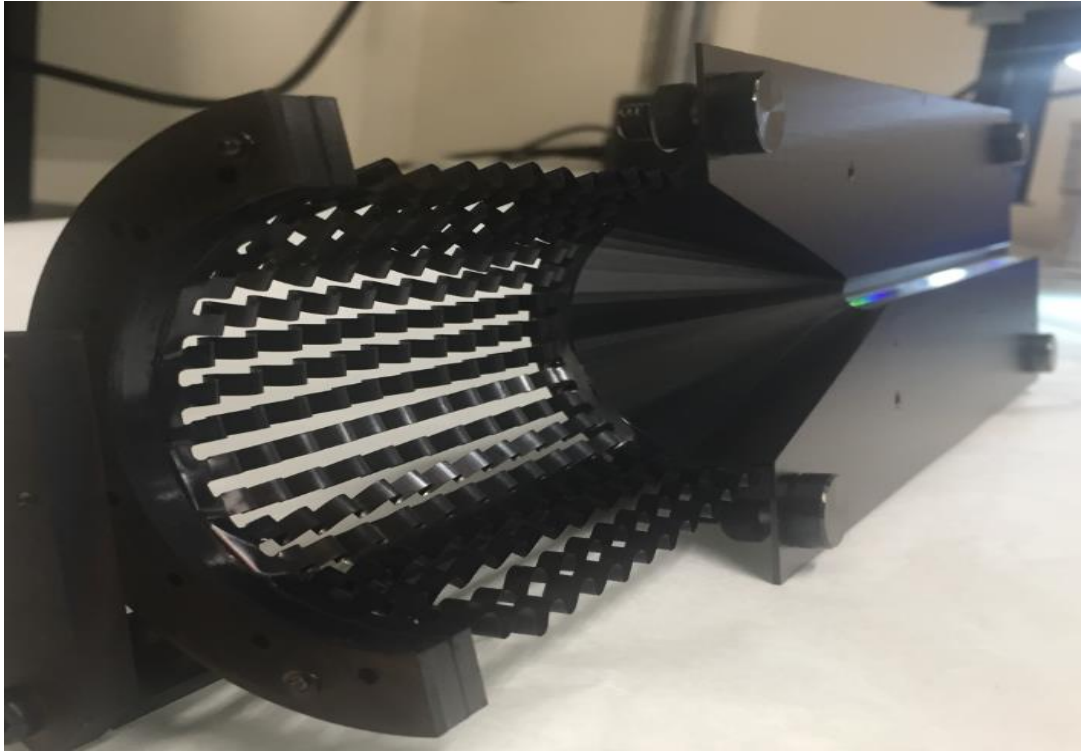
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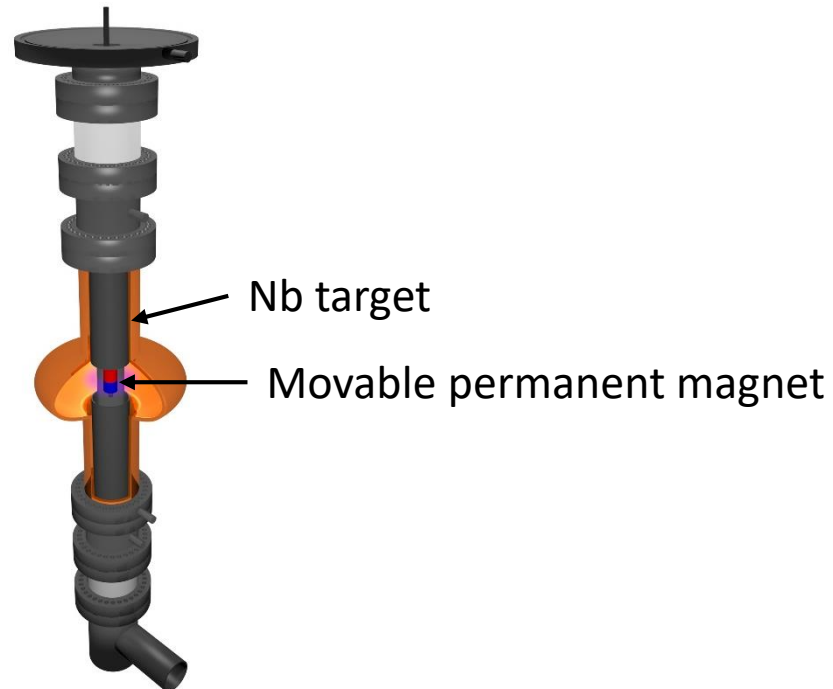


2. CERN/TE coating facilities and examples

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



1.3 GHz cavity
(Nb/Cu)



2. CERN/TE coating facilities and examples

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

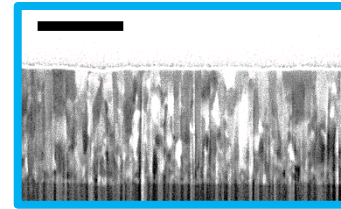


1.3 GHz cavity
(Nb/Cu)

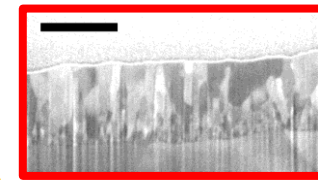
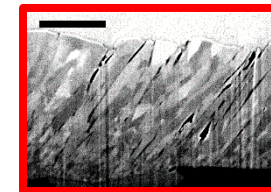
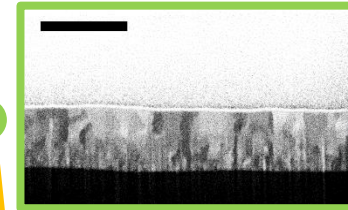
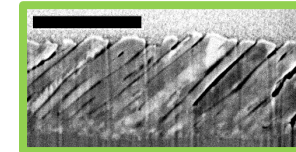
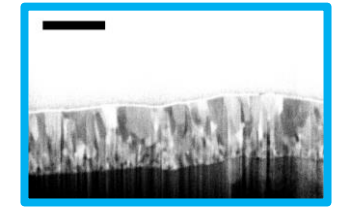
ISO5 clean room for assembly



DC magnetron sputtering



High Power Impulse Magnetron Sputtering



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

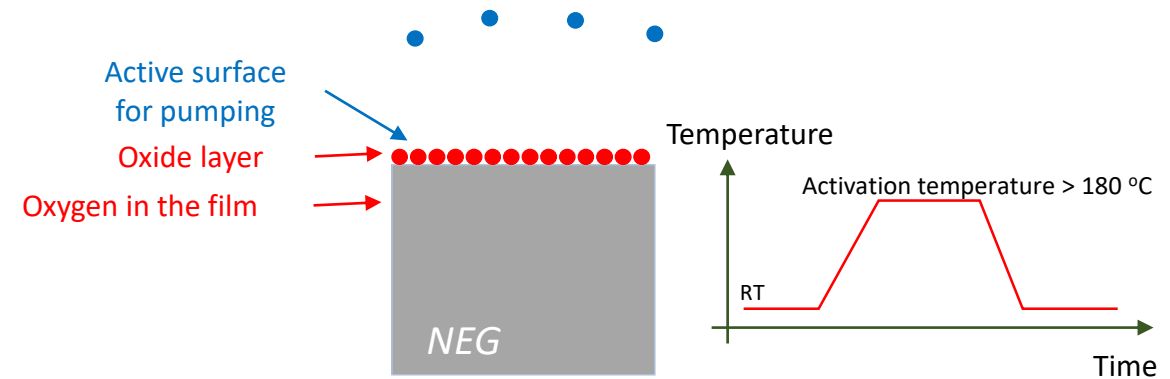
Coating lab. for long beam pipes in B.181: Ti-Zr-V (Non Evaporable Getter), a-C (low secondary electron emission)

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, O₂, H₂O, CO₂, N₂, H₂ => distributed pumping

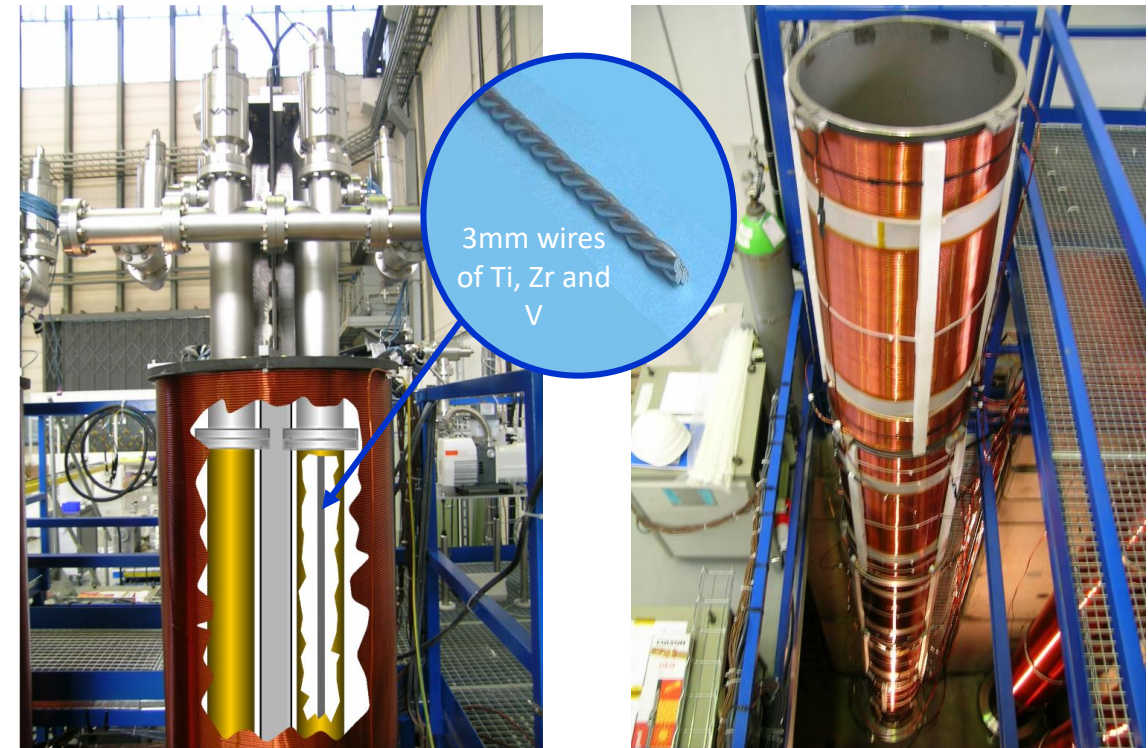
Not pumped: noble gases and CH₄ (at room temperature)

Low secondary electron emission => prevent e-cloud

2. CERN/TE coating facilities and examples

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

Up to 7 meter long and diameter 0.6 meter.

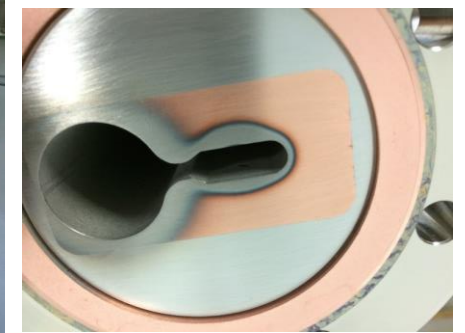
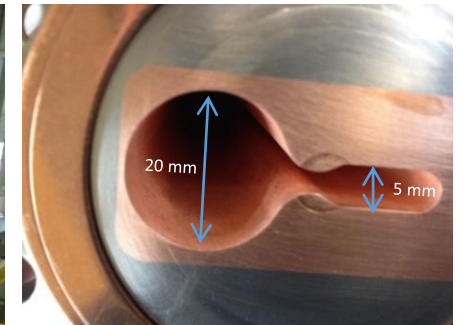


More than 3 km of coated beam pipes in the LHC

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

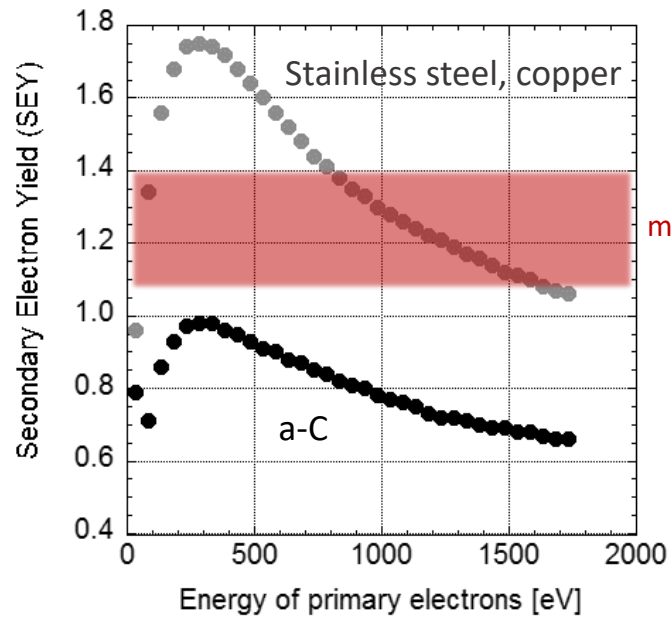


2. CERN/TE coating facilities and examples

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



Threshold for multipacting in CERN accelerators

Carbon thin films

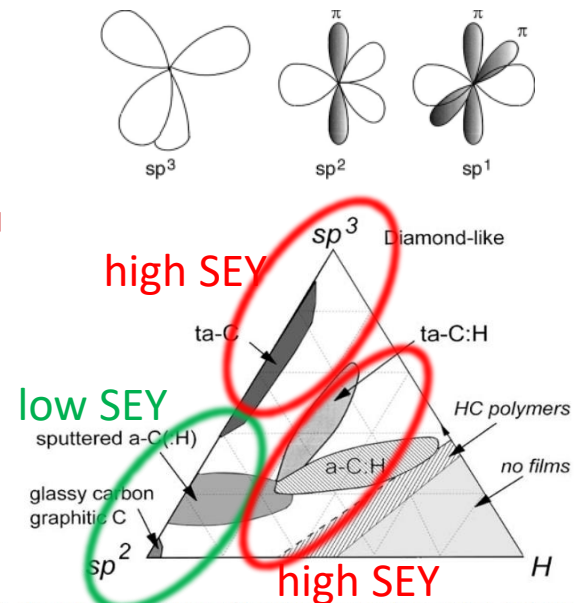
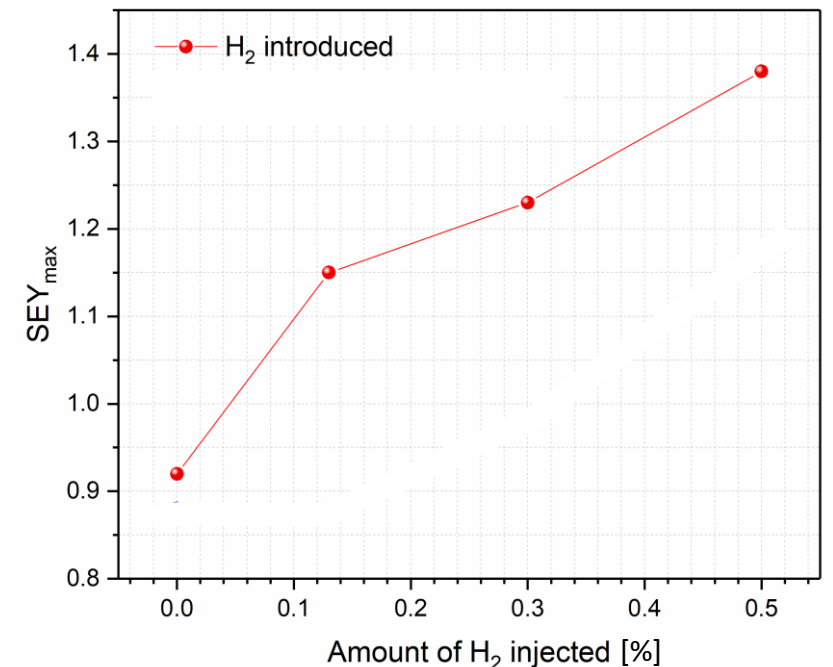


Fig. 2. Ternary phase diagram of bonding in amorphous carbon-hydrogen alloys.
J. Robertson / Materials Science and Engineering R 37 (2002) 129-281

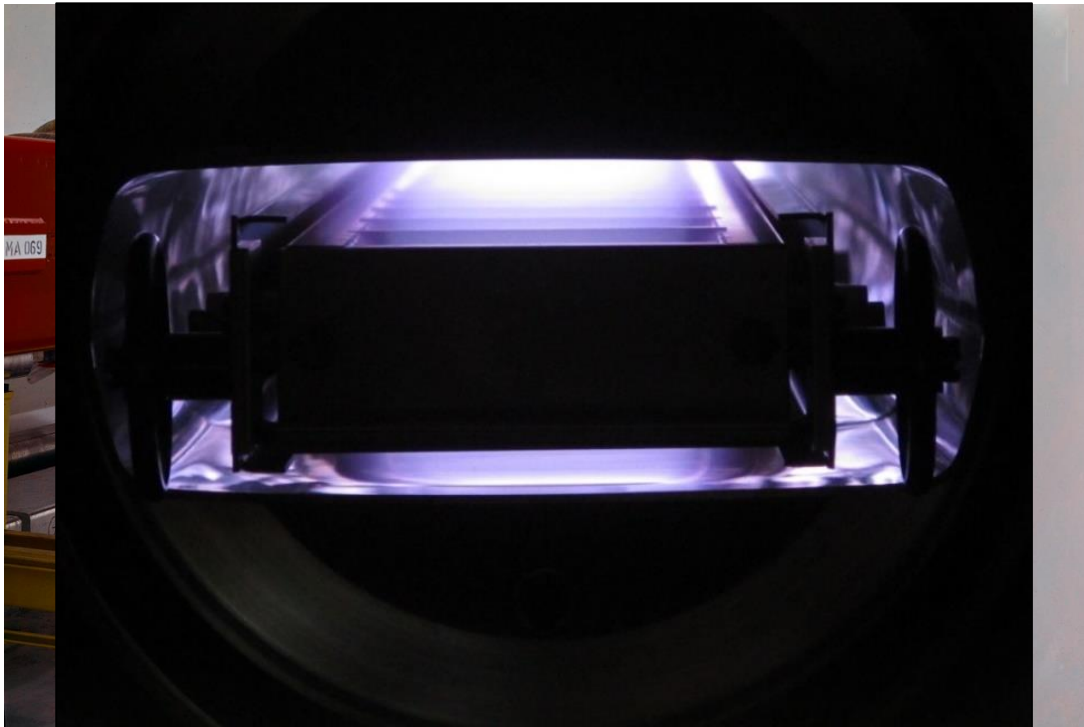
SEY in function of the H₂ and N₂ injected in the discharge



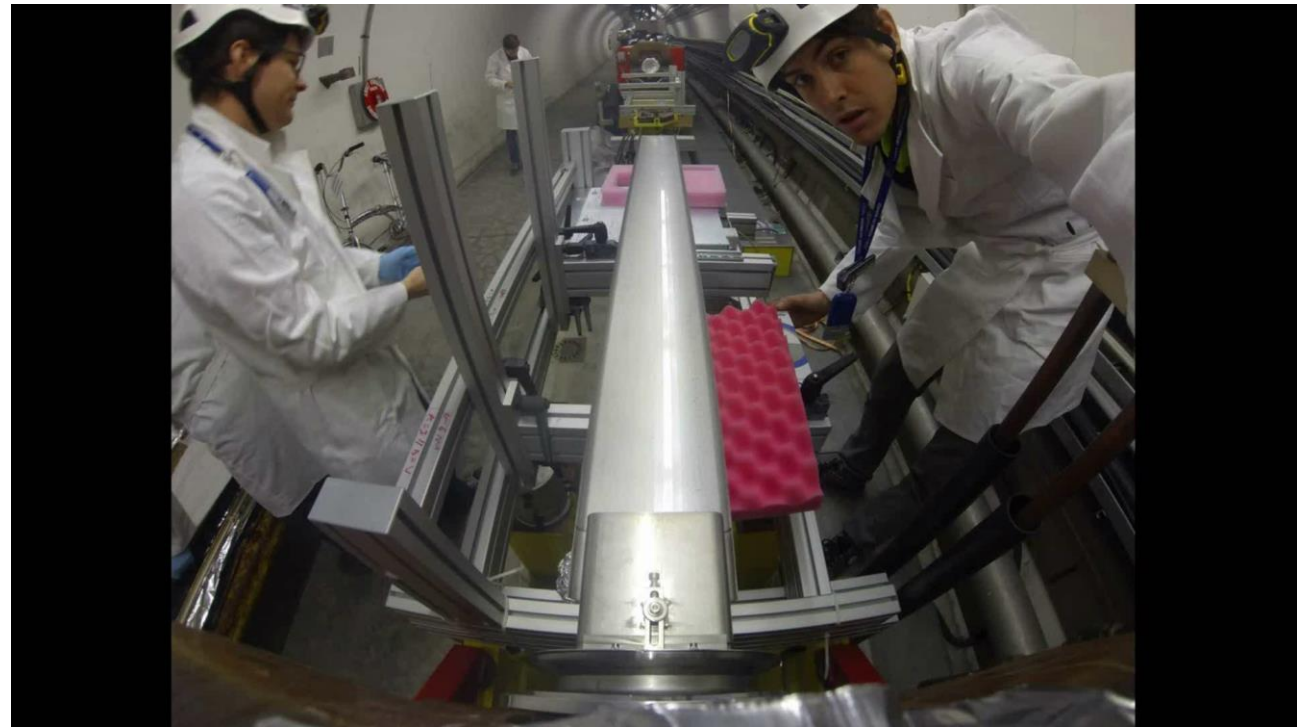
2. CERN/TE coating facilities and examples

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

The Super Proton Synchrotron tunnel



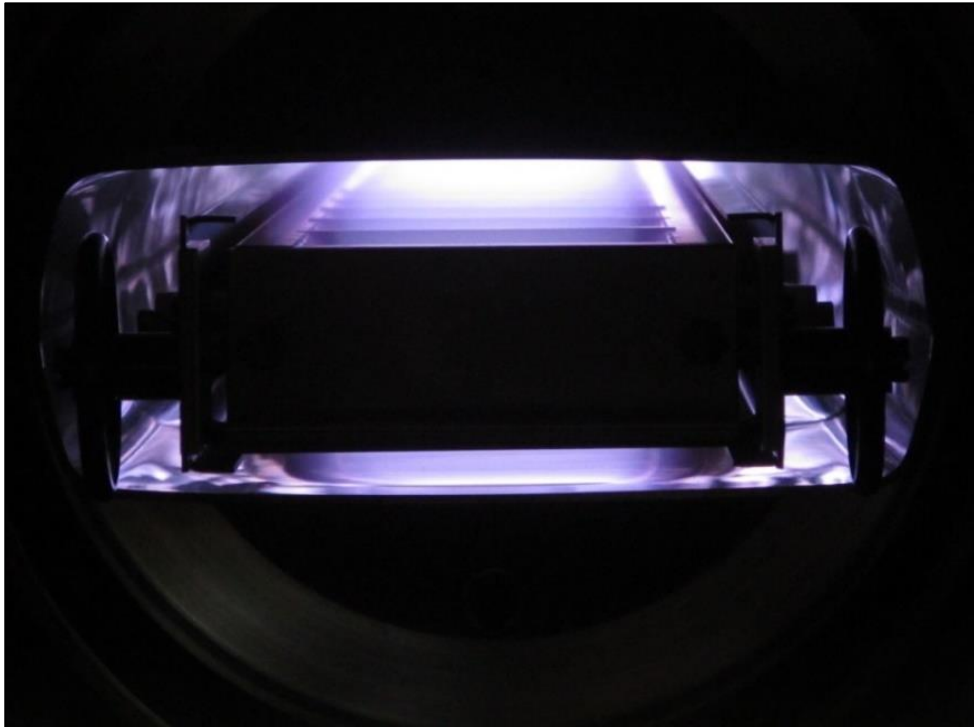
Assembling coating setup in the tunnel



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**):

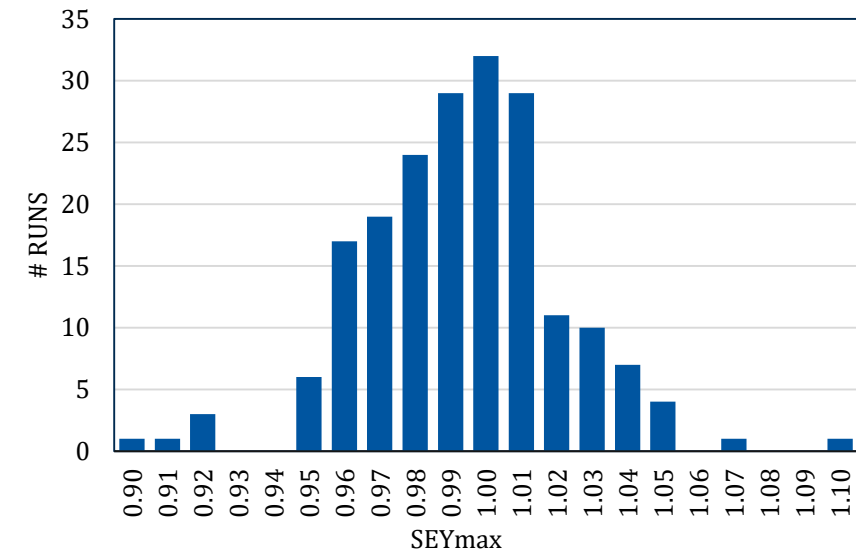


88 QF quadrupole magnets (294 m)
coated in-situ 2 runs / week with 2
systems

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

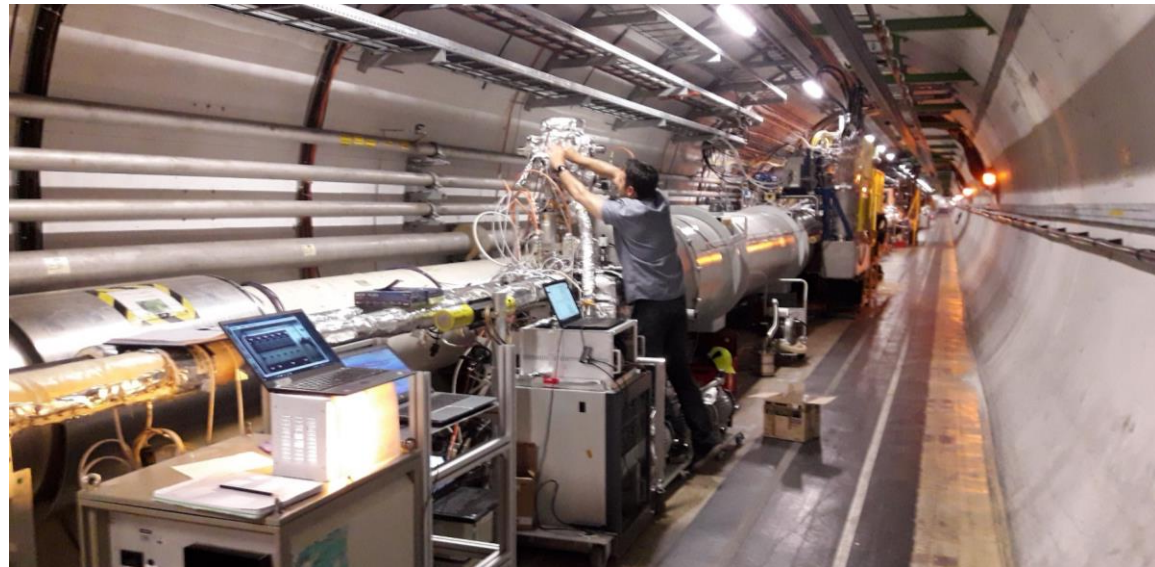
Histogram of the SEY_{max} for the whole LS2 coating campaign



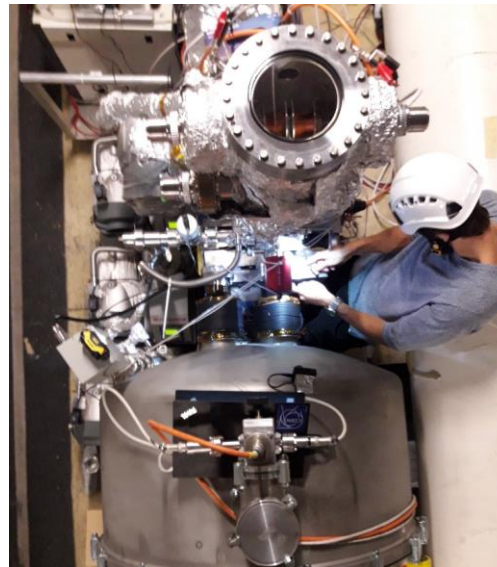
2. CERN/TE coating facilities and examples

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

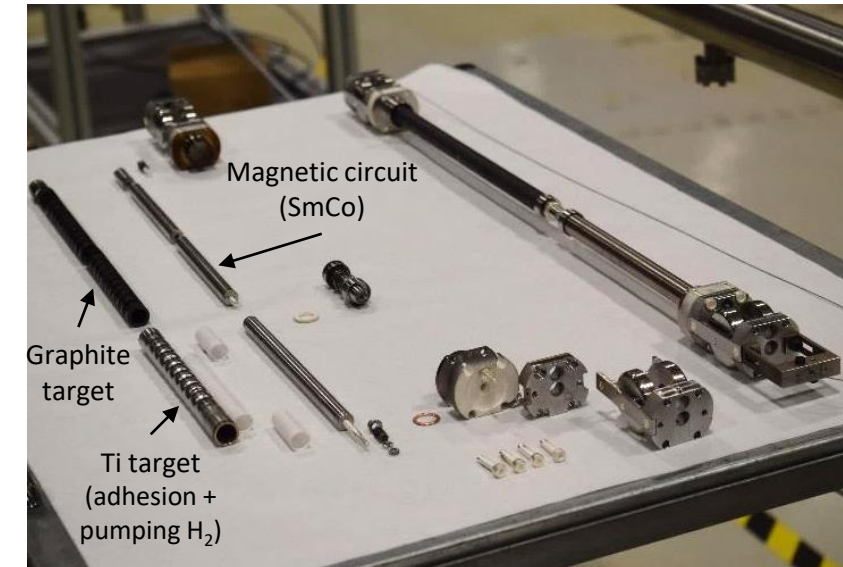
Length to be coated ~ 12 meter



Limited space to insert coating device < 250 mm



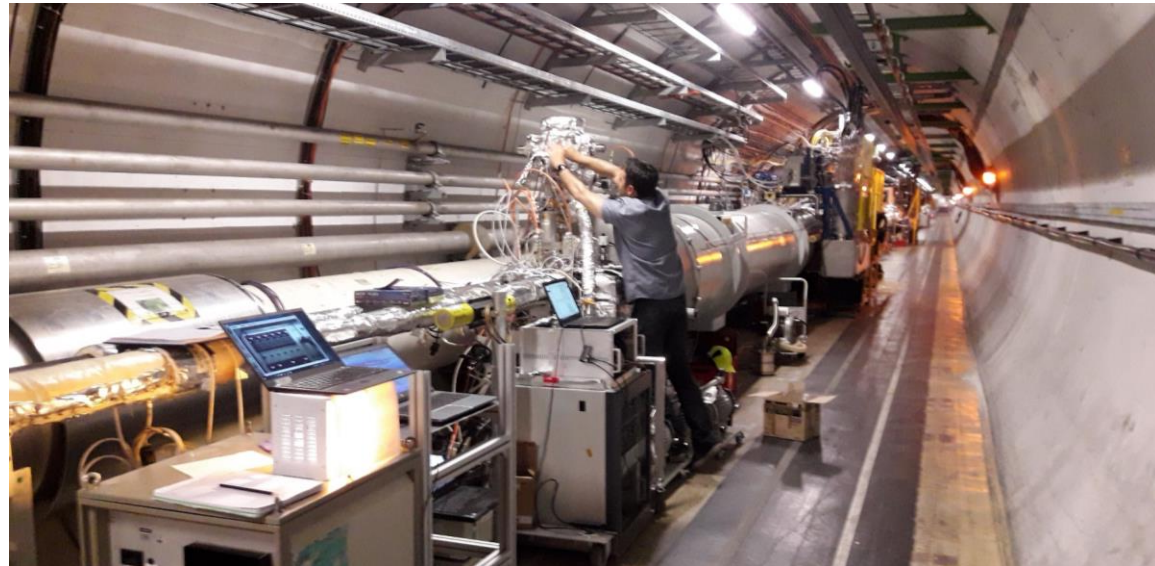
Modular sputtering source displaced by cables



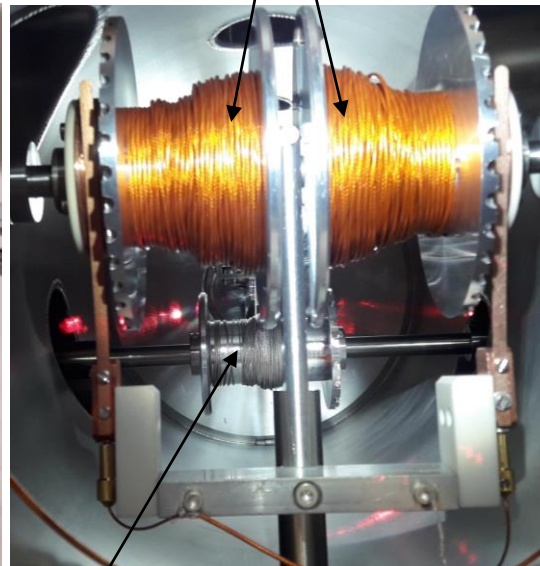
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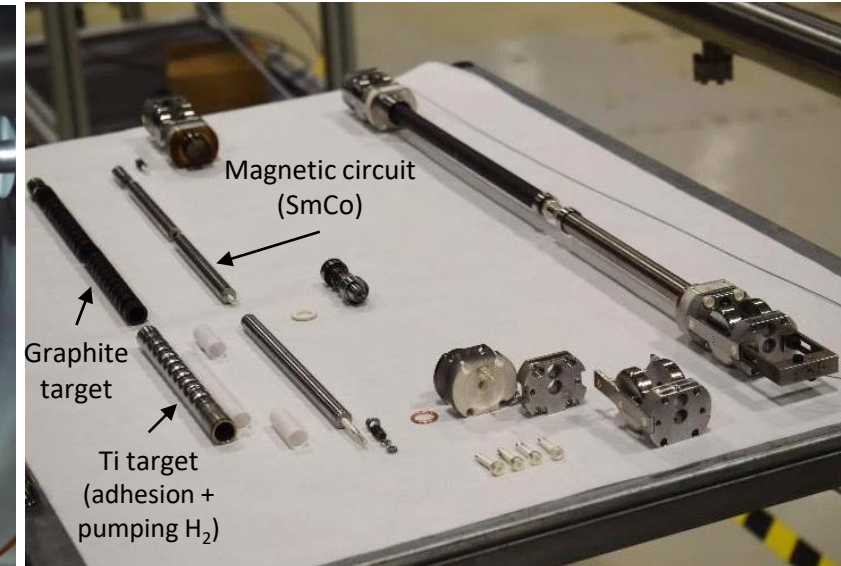
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Electrical cables



Modular sputtering source displaced by cables



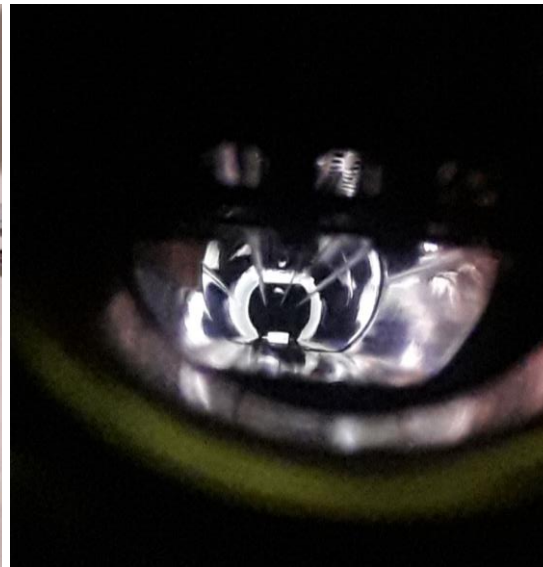
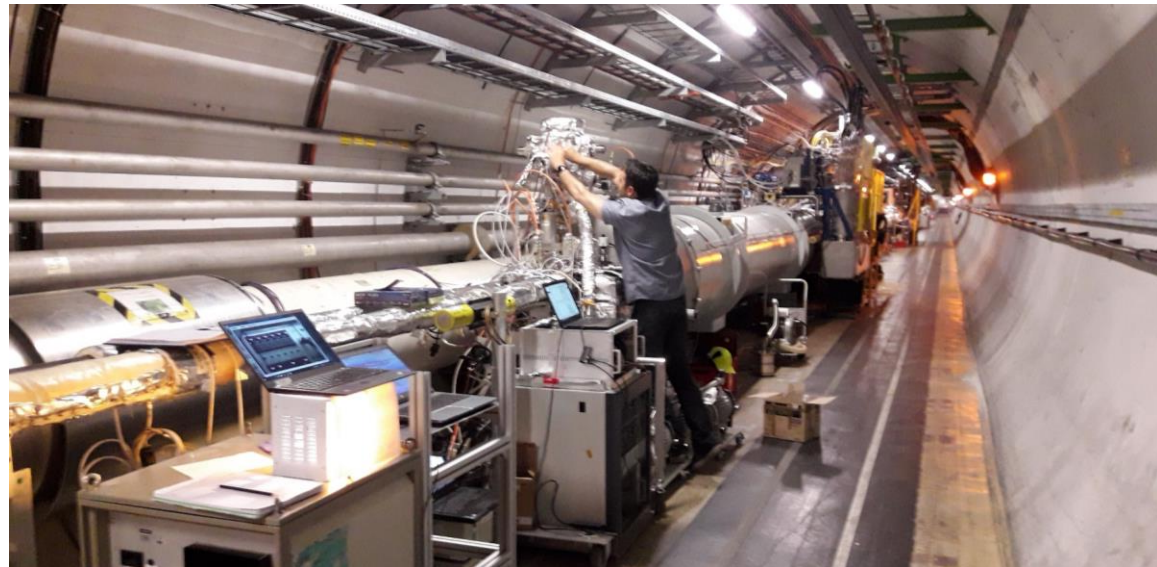
Mechanical cable



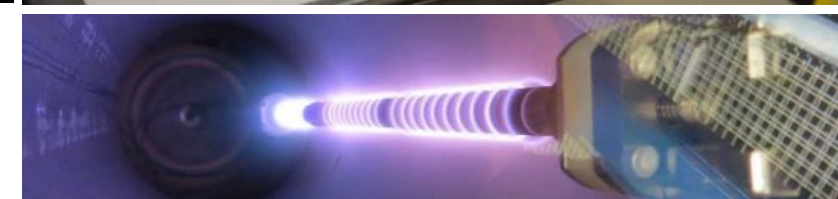
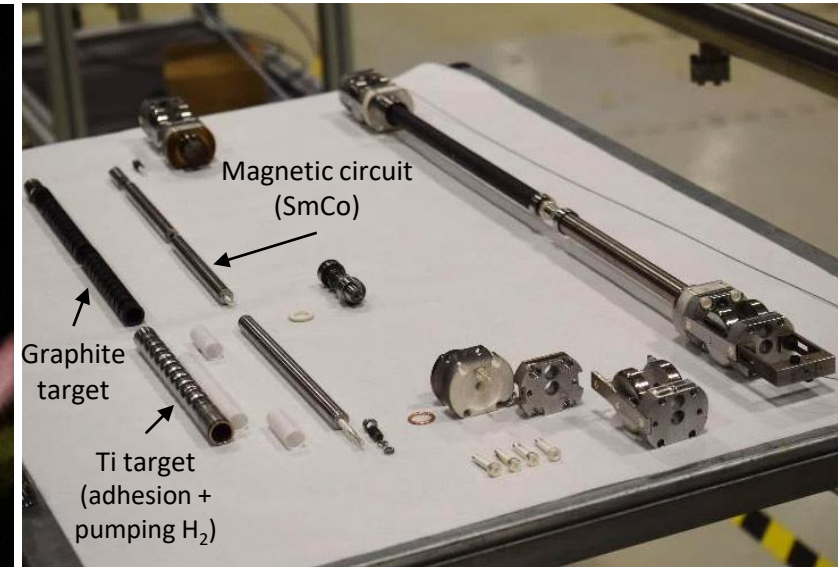
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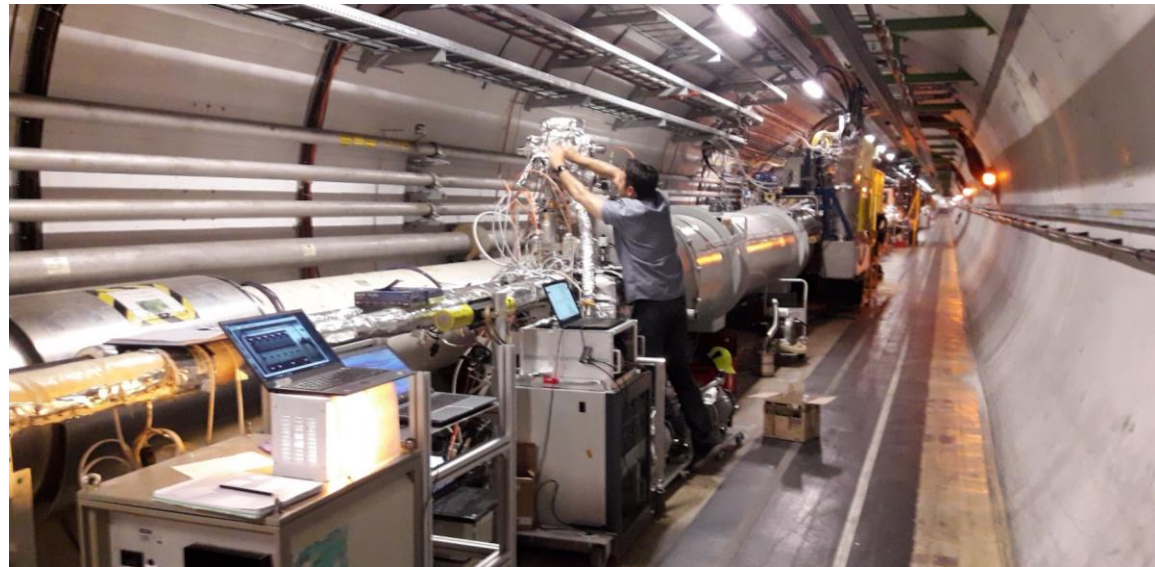
Modular sputtering source displaced by cables



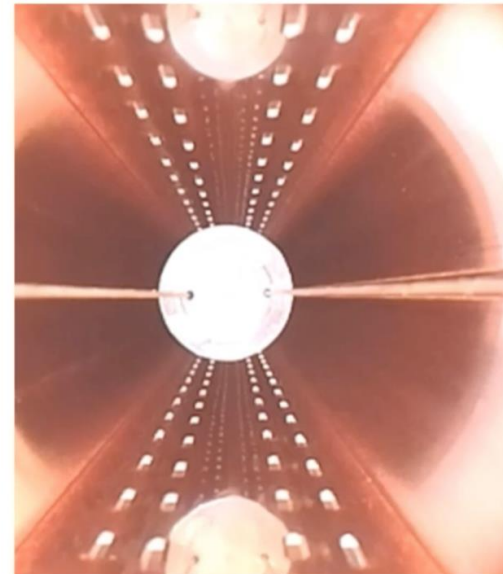
2. CERN/TE coating facilities and examples

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

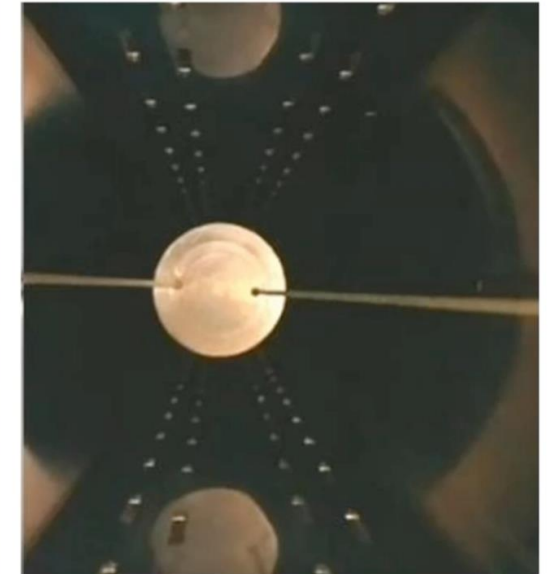
Length to be coated ~12 meter



Before coating



After coating

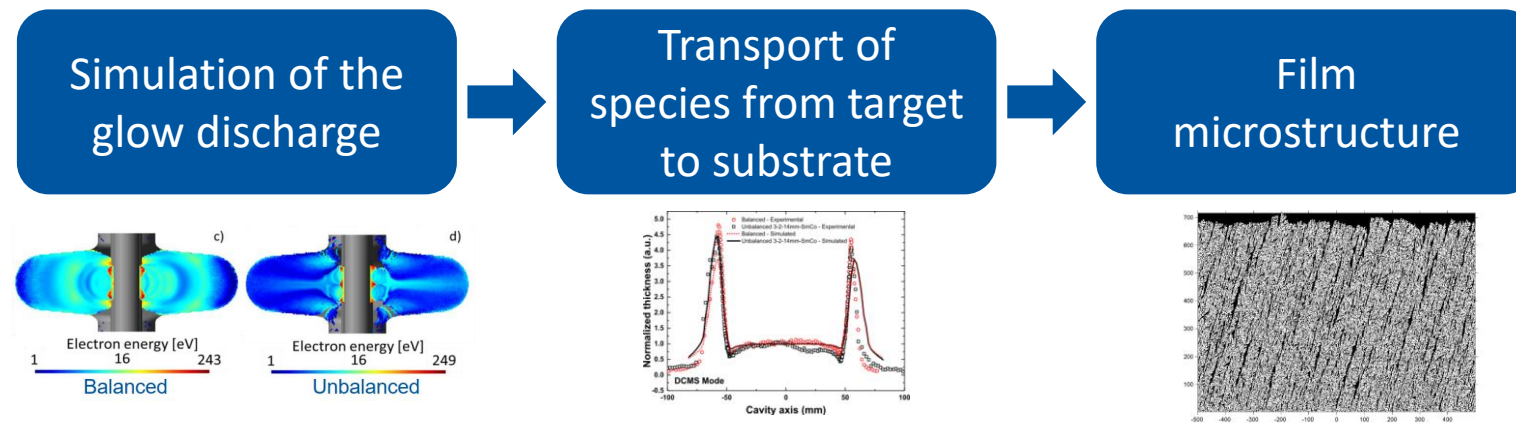


3. Summary

CERN/TE have a wide expertise 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 constraints (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.



Thank you for your attention