History and potential of Non Evaporable Getter (NEG) technology

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www.cern.ch

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EIROforum
Science-Business WAMAS

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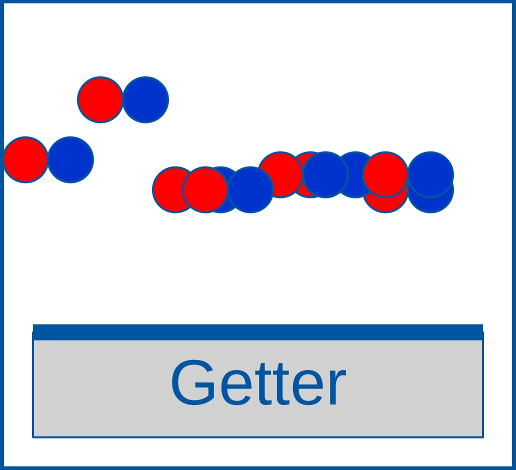
OUTLOOK

1. Evaporable and Non Evaporable Getters
2. Brief history of Getters
3. NEG technology at CERN
4. Potential of NEG coatings
5. Summary

❶ Evaporable and Non Evaporable Getters

Getters are materials capable of chemically adsorbing gas molecules (by chemisorption). To do so, their surface must be clean.

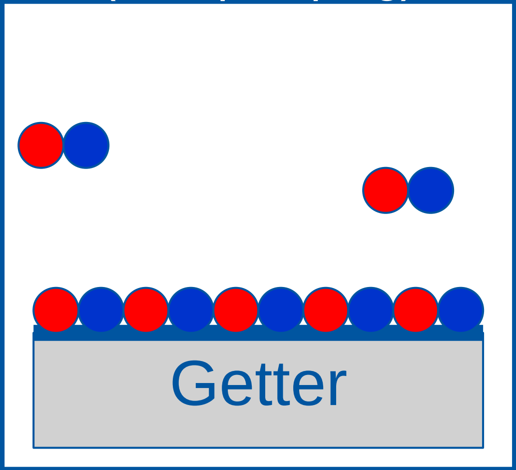
Chemisorption
(surface pumping)



Limited to 1 monolayer(~10^{15} molecules/cm^2)

Reactive gases are pumped:
CO, O_2, H_2O, N_2, H_2, CO_2
noble gases and methane are not pumped.

Diffusion
(bulk pumping)



Very large capacity!

At room temperature only H_2 diffuses
Other reactive gases require higher temperature

❶ Evaporable and Non Evaporable Getters

Getters are materials capable of chemically adsorbing gas molecules (by chemisorption). To do so, their surface must be clean.

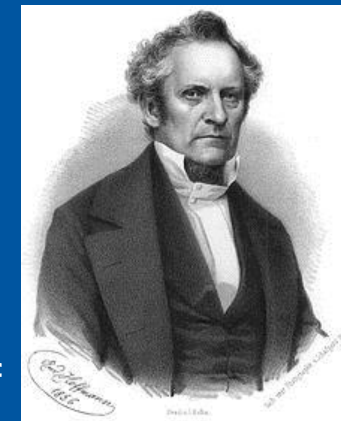
Getters can be classified by the way the clean surface is obtained:

In situ deposition of a fresh getter film (under vacuum) ⇨ ***Evaporable Getters***

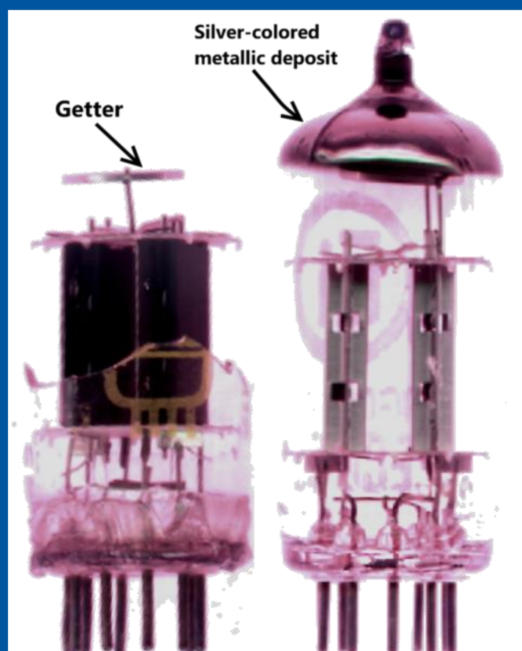
Diffusion of the oxide layer into the bulk (usually by heating in vacuum) ⇨ ***Non Evaporable Getters (NEG)***

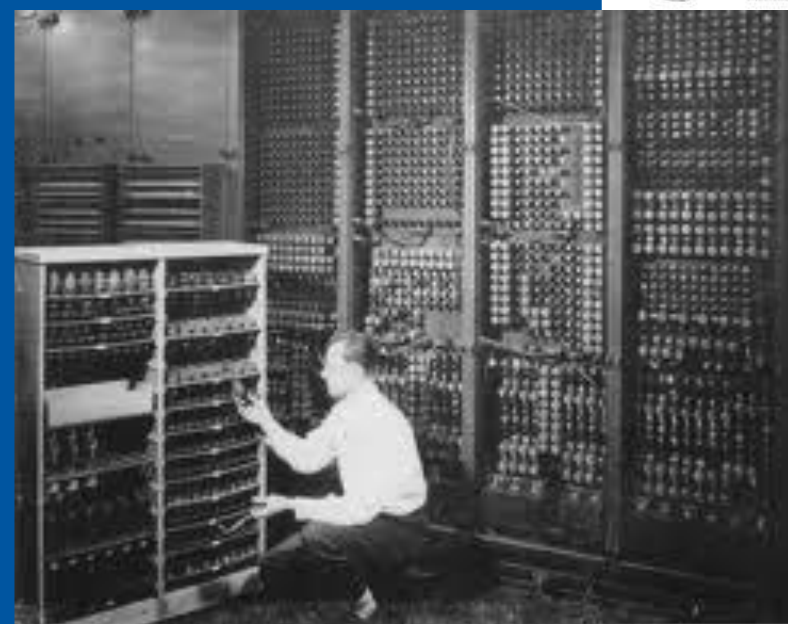
❶ Evaporable and Non Evaporable Getters / Brief history of getters

Getter pumping was reported for the first time in 1858 by Plucker. When working with gas discharges in vacuum he noticed that *“certain gases react with the cathode and the platinum deposited in the walls”*.



By the 1940s, industrialization of evaporable getters for vacuum tubes. (first phosphorous and then barium alloys). => reliability of electronics.





Replacing a bad tube meant checking among ENIAC's 19,000 possibilities.

2 Brief history of getters

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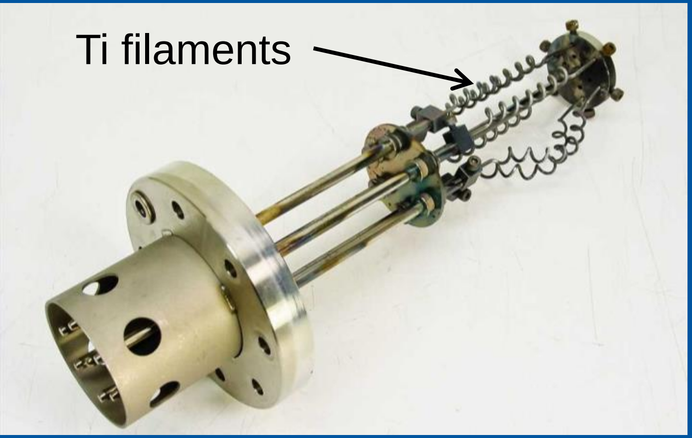
In 1953 Herb invented the titanium sublimation pump (and in 1958 Hall invented the sputter ion pump, combining getter and ion pumping). => improve vacuum technology



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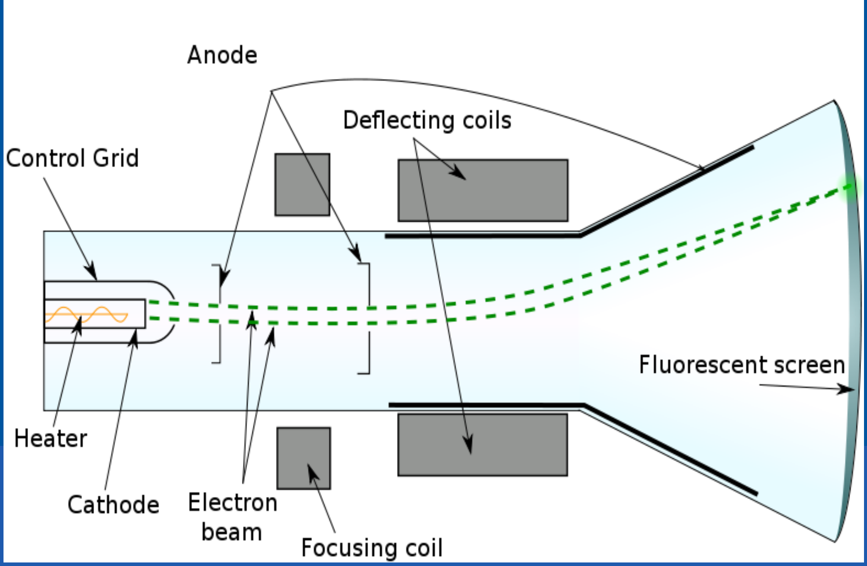
1966 The Total Yield Flash Getter extended the life of color tv tubes from 300 to 10 000 hours. (SAES Getters)



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NEG technology at CERN / Brief history of getters

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NEG technology at CERN

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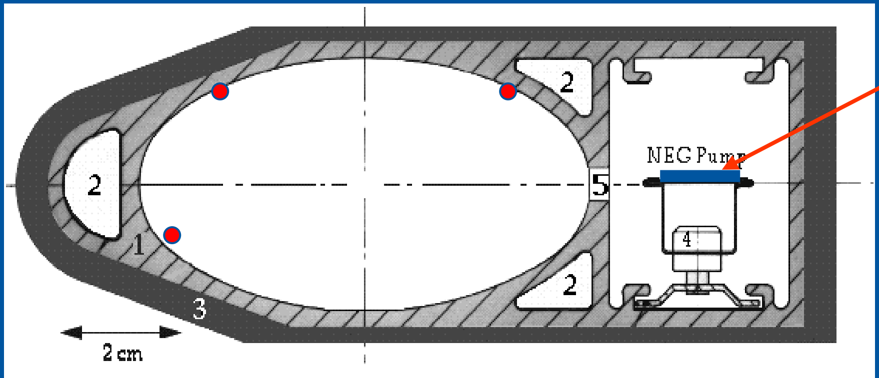
Cross section of the LEP dipole vacuum chamber



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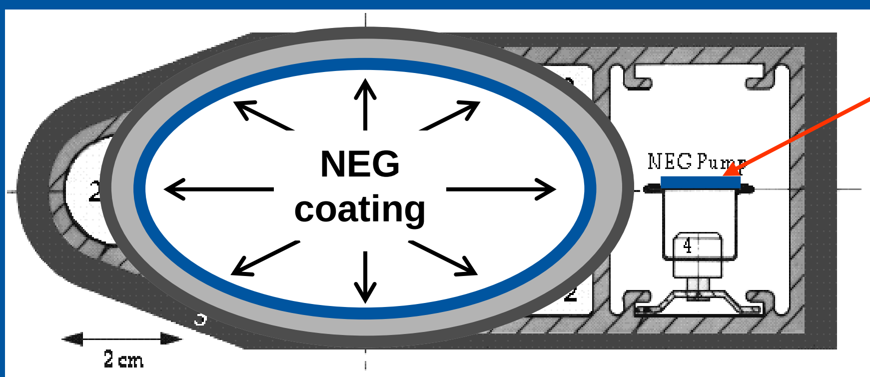
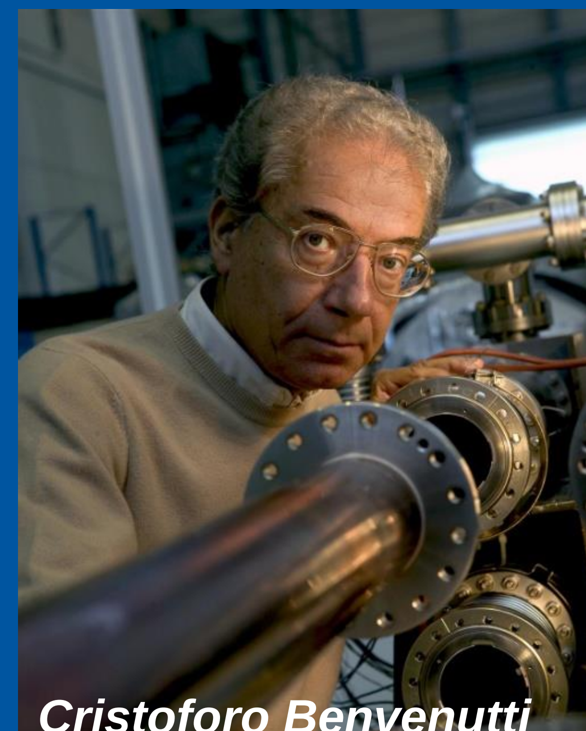
1998 Low activation temperature NEG coatings,(Ti-Zr-V), developed at CERN for the LHC.

Cross section of the LHC warm dipole vacuum chamber
Cross section of the LEP dipole vacuum chamber





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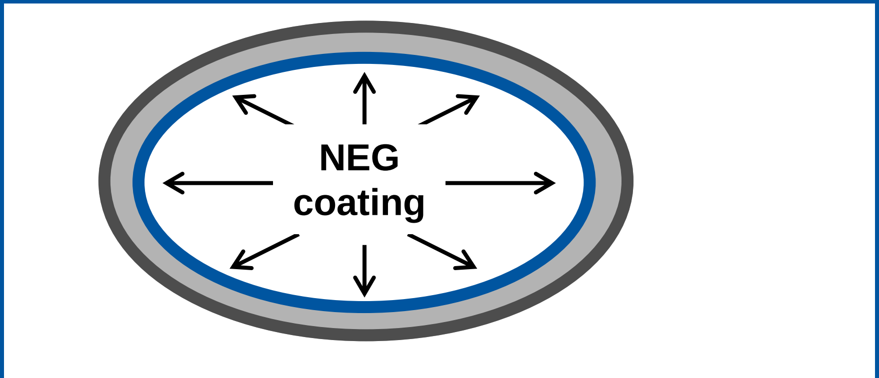
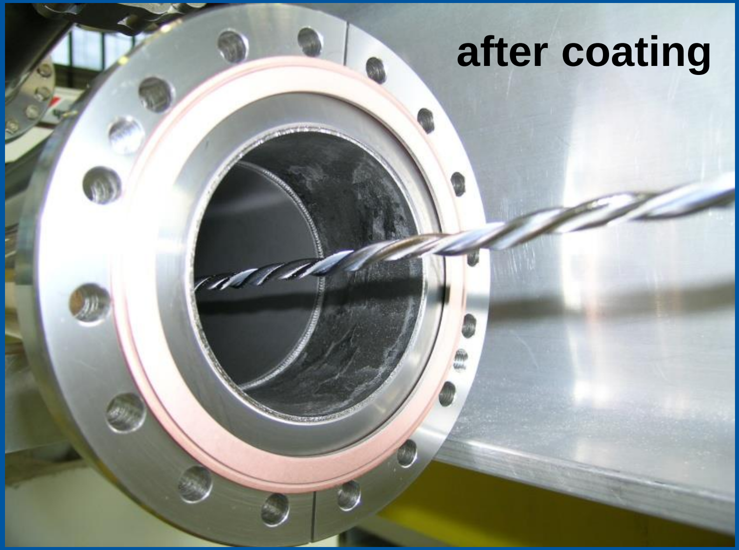


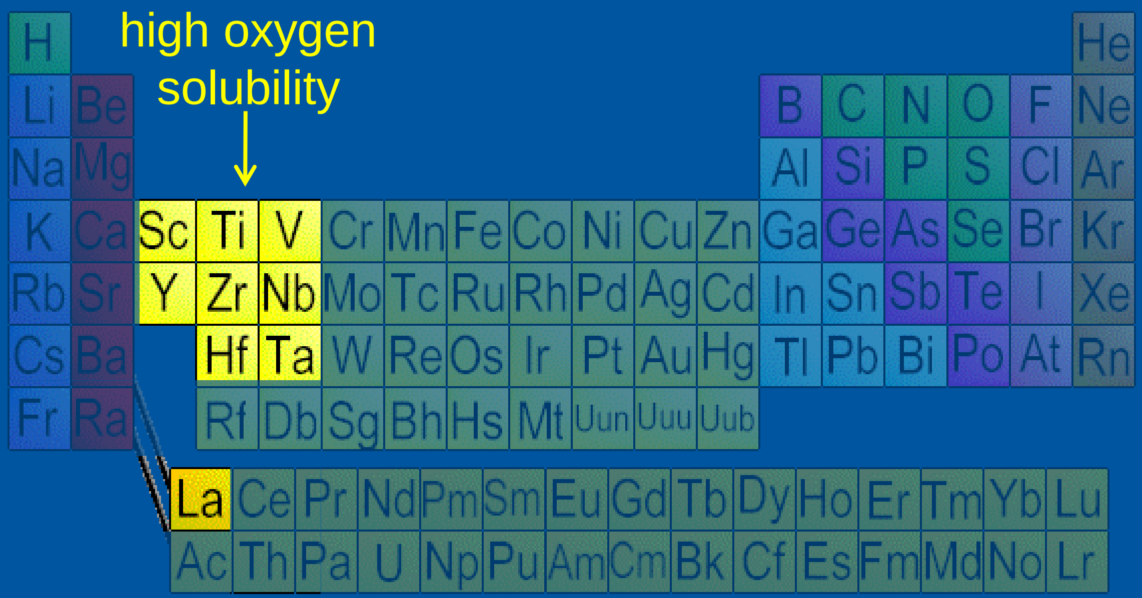


❸ NEG technology at CERN

Known NEGs required very high activation temperatures (>> 350ºC): Zr, Ti, Zr-Al, Ti-Al, Zr-V-Fe, Th-Ce-Al) (Usually as sintered powders or compressed in strips, pellets, rings)

CERN goal: find a NEG with low activation temperature. (compatible with the technical materials used for UHV: <400ºC for stainless steel, <250ºC for Cu, <200ºC for Al)

More than 20 materials were investigated by combining 2 or 3 of this elements in the form of thin films. (Produced by DC Magnetron Sputtering)



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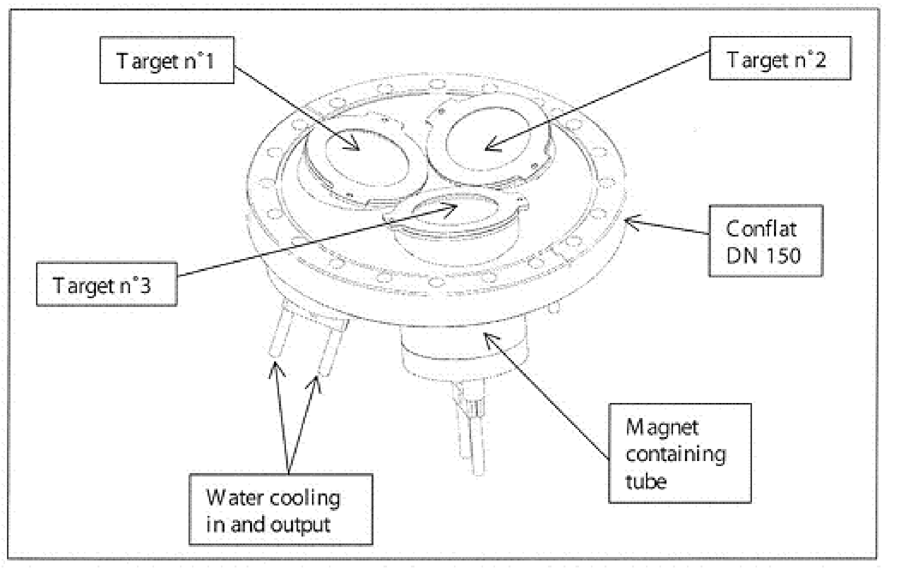

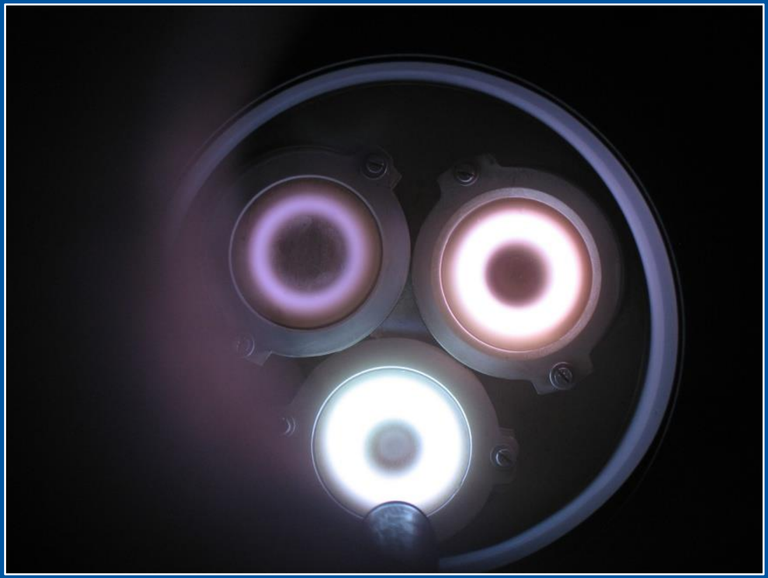

NEG technology at CERN

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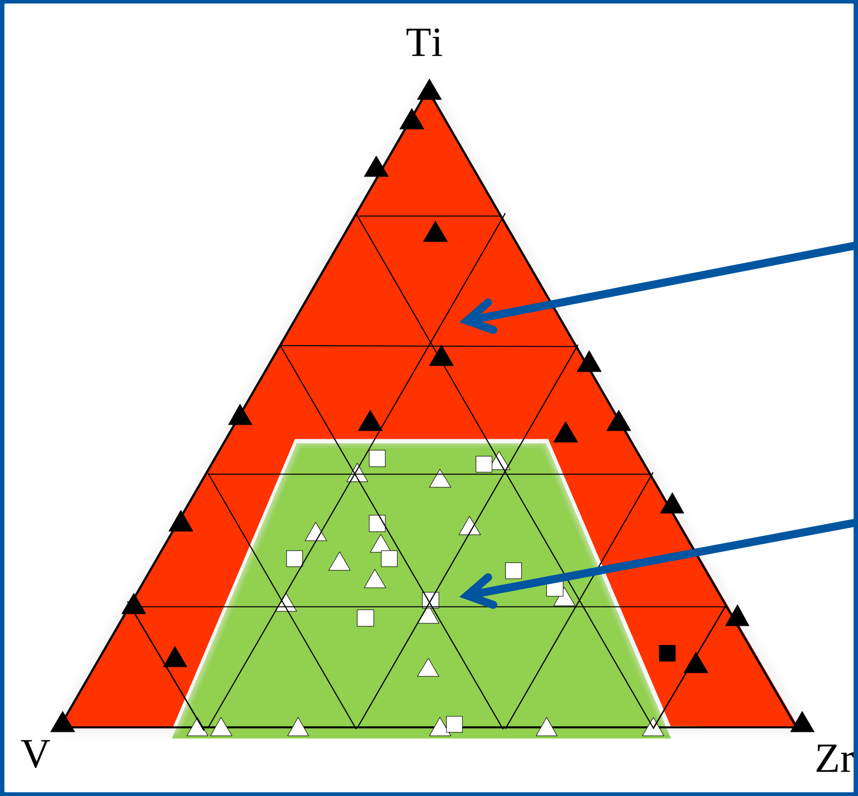
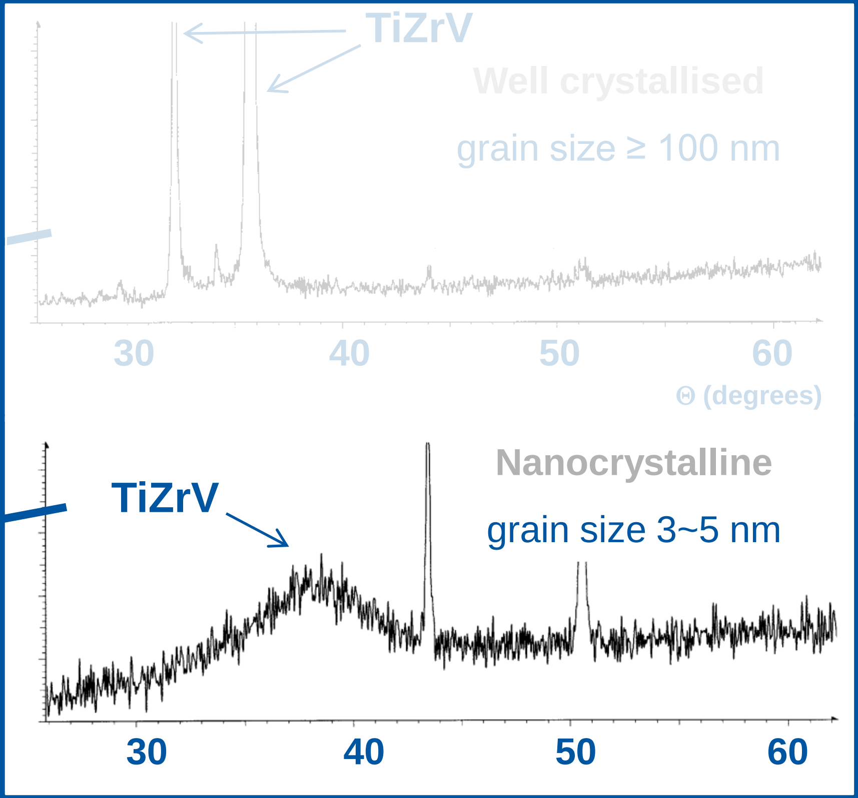
The ***Ti-Zr-V*** NEG coating can be activated at 180ºC for 24 hours.

Crystallographic structure (XRD)





NEG technology at CERN

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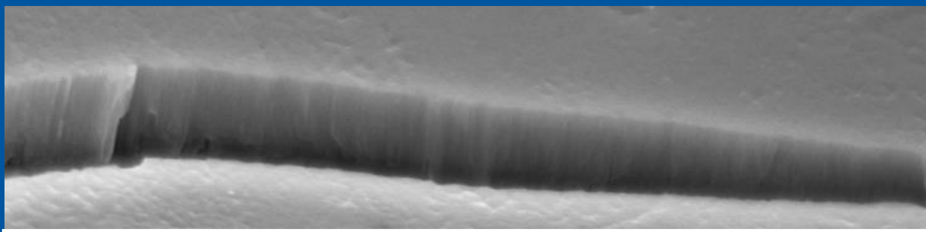
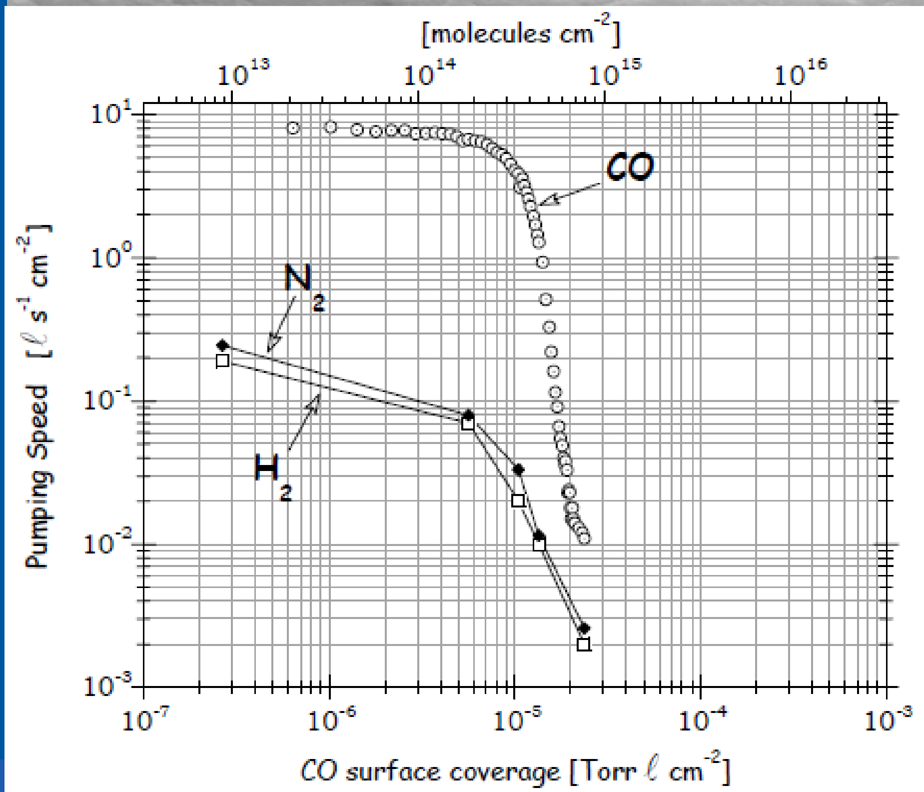
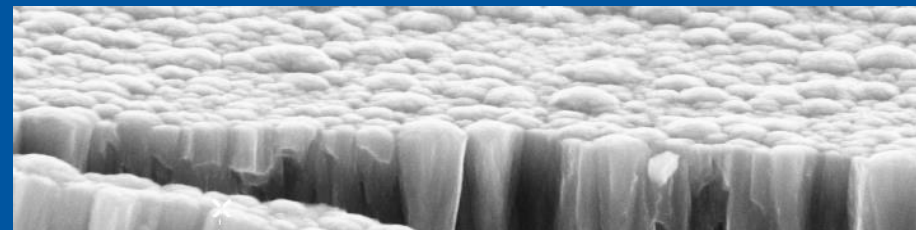
Vacuum properties 1: pumping speed versus coverage.

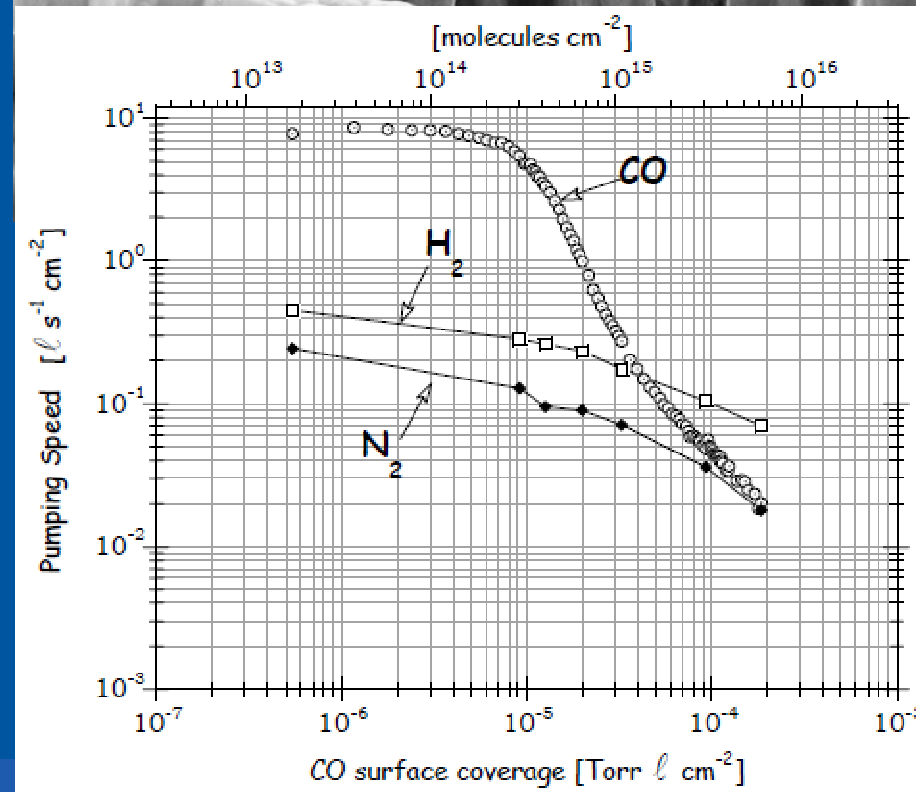
Smooth (coated at 100ºC)





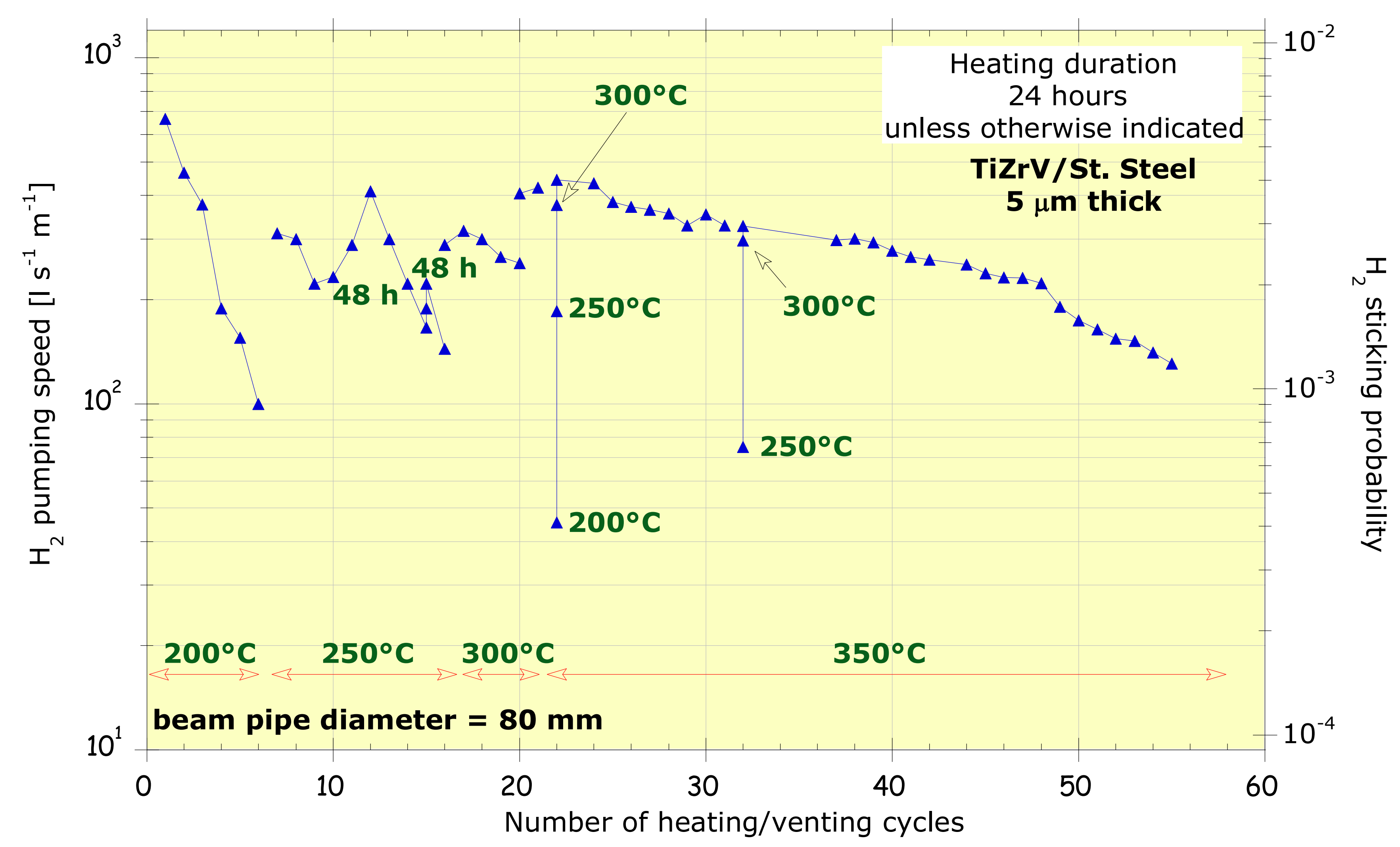
Rough (coated at 300ºC)





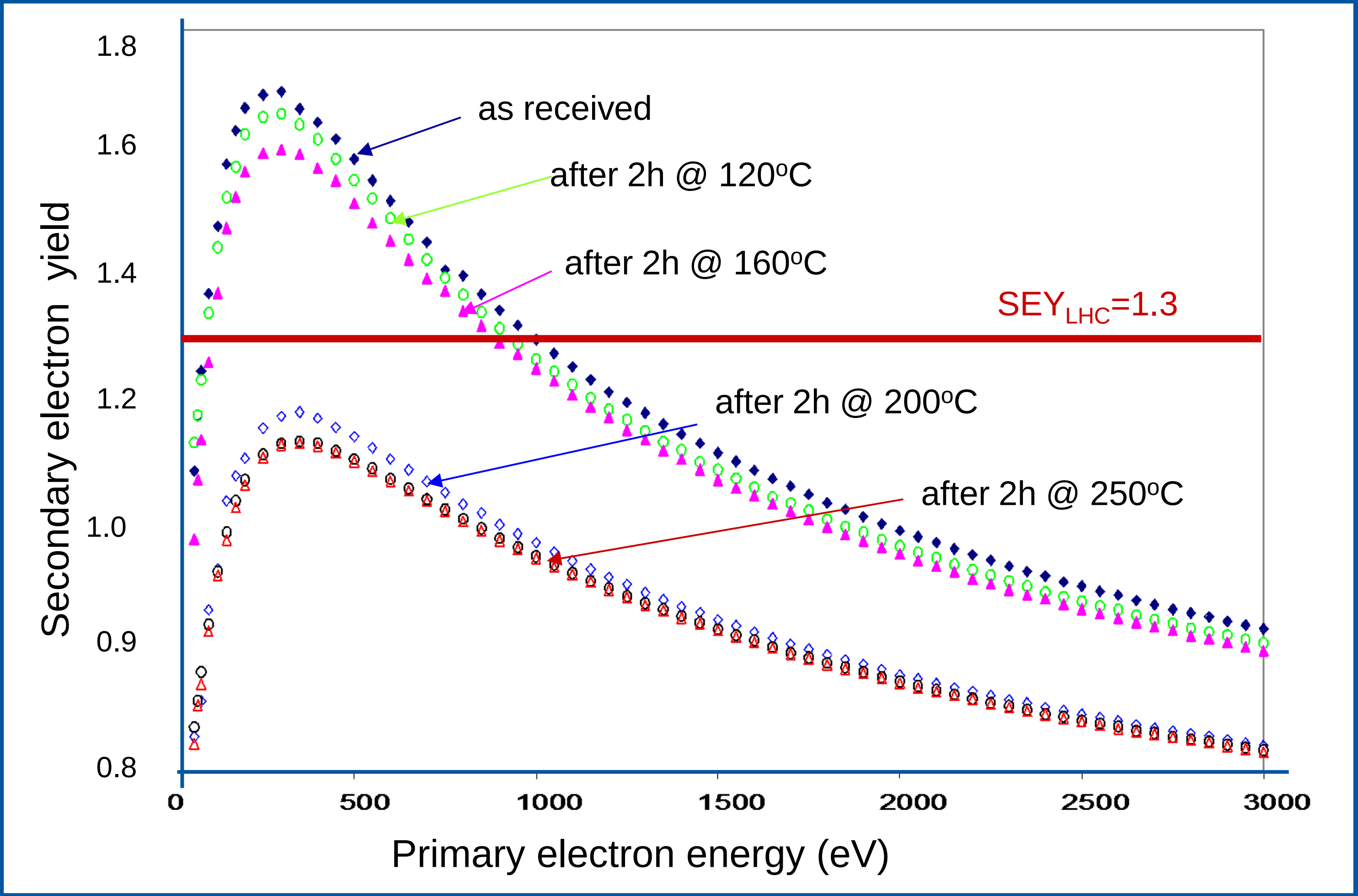
❸ NEG technology at CERN

Vacuum properties 2: ageing (recovery after air venting)



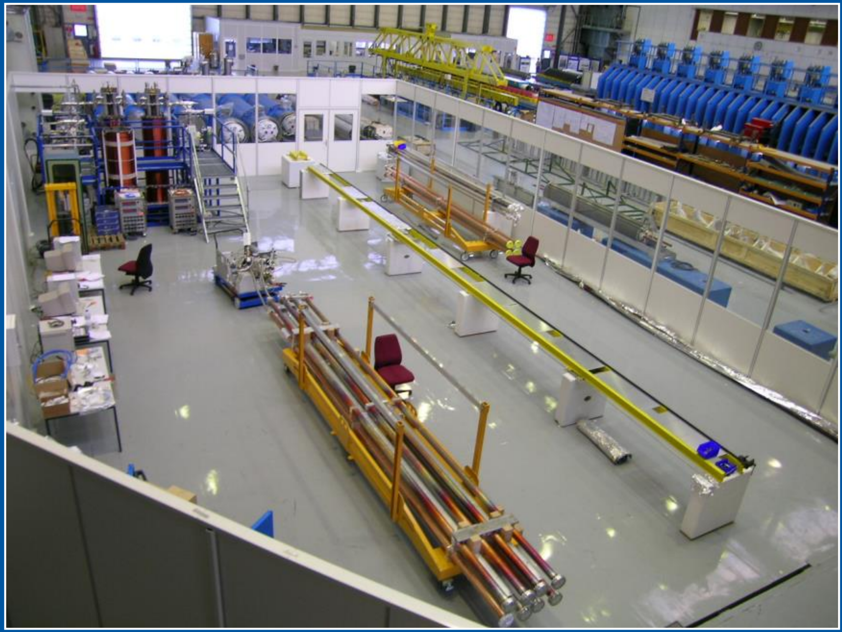
❸ NEG technology at CERN

Anti electron multipacting properties 1: low Secondary Electron Yield (SEY).



3 NEG technology at CERN

At CERN, large scale production for the LHC and experiments by DC Cylinder Magnetron sputtering (DCCM) from a target of Ti, Zr and V wires (more than 1300 chambers).



4 Potential of NEG coatings / NEG technology at CERN

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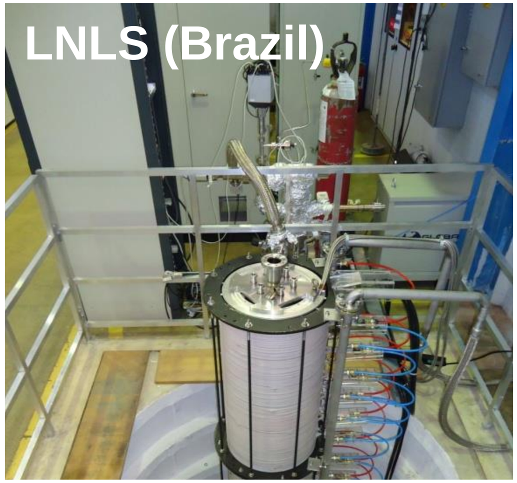

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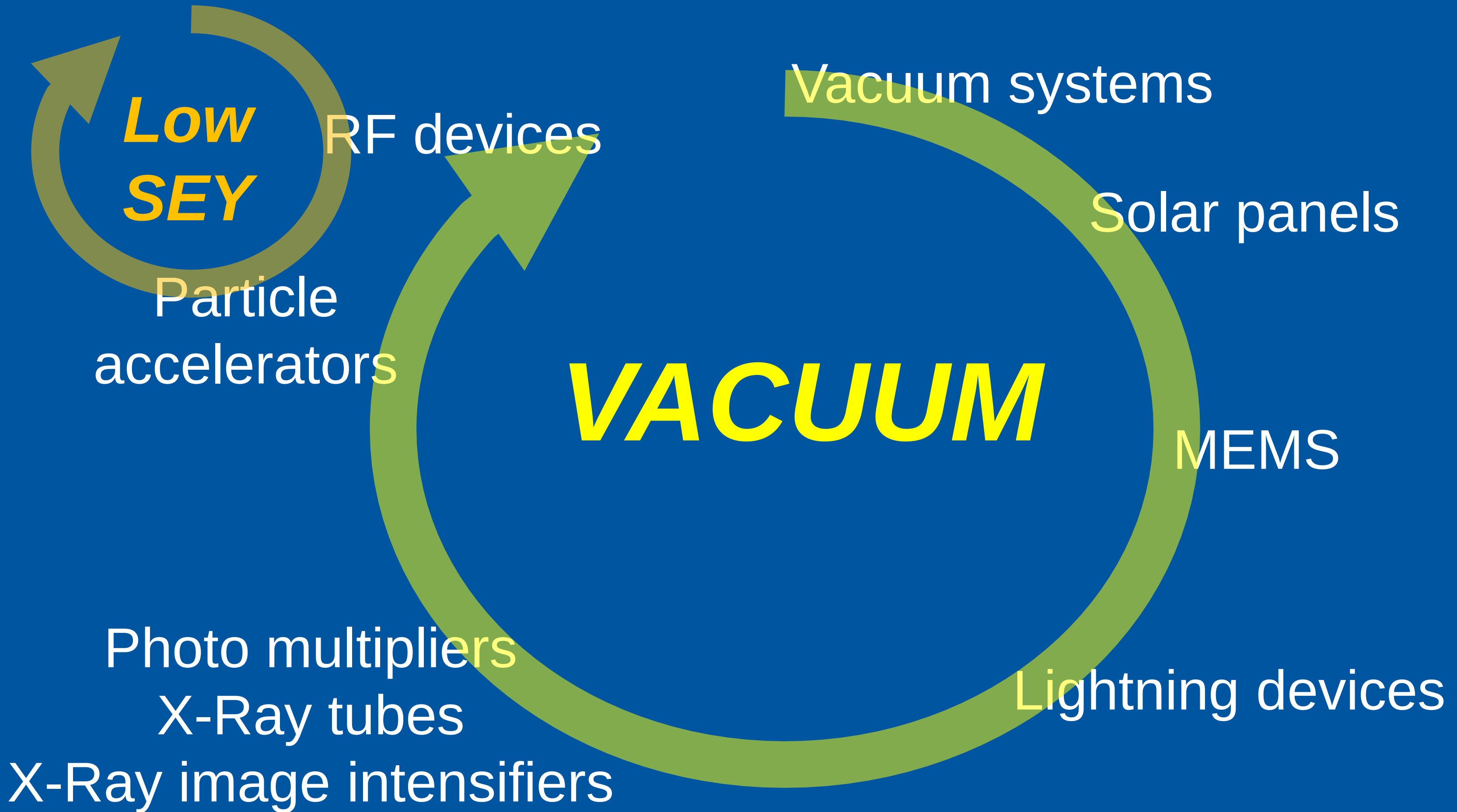
Potential of NEG coatings

At CERN, large scale production for the LHC and experiments by DC Cylinder Magnetron sputtering (DCCM) from a target of Ti, Zr and V wires (more than 1300 chambers). AND WORLD WIDE: ***users***, ***in design/study***

4 Potential of NEG coatings

Applications of NEG coatings other than in particle accelerators:



5 Summary and future

Due to their pumping properties, getters and NEGs became unavoidable in vacuum sealed devices.

The development of particle accelerators pushed the development of NEGs with low activation temperature and in the form of thin film coatings.

The anti electron multipacting properties, (low SEY), of NEG coatings became of major importance for positive particle accelerators and can potentially be applied to waveguides and RF devices.

These coatings are applied in more and more accelerators but also in other technology devices (solar panels, MEMS, X-Ray imaging, etc)

Future developments targets lowering the activation temperature (150ºC), deposition in small aperture devices (beam pipes) and integration in new assembly techniques.

Thank you for your attention.

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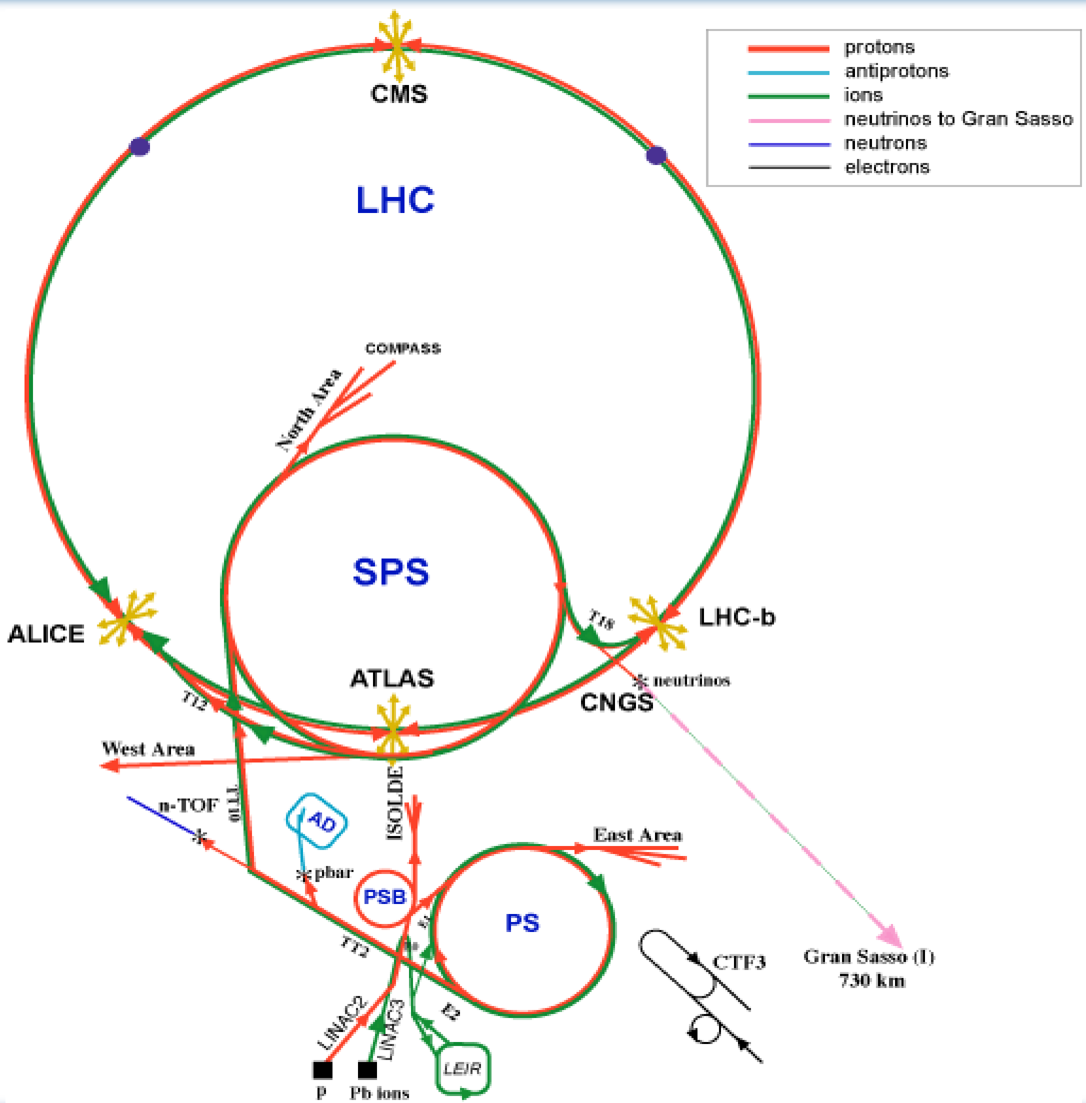
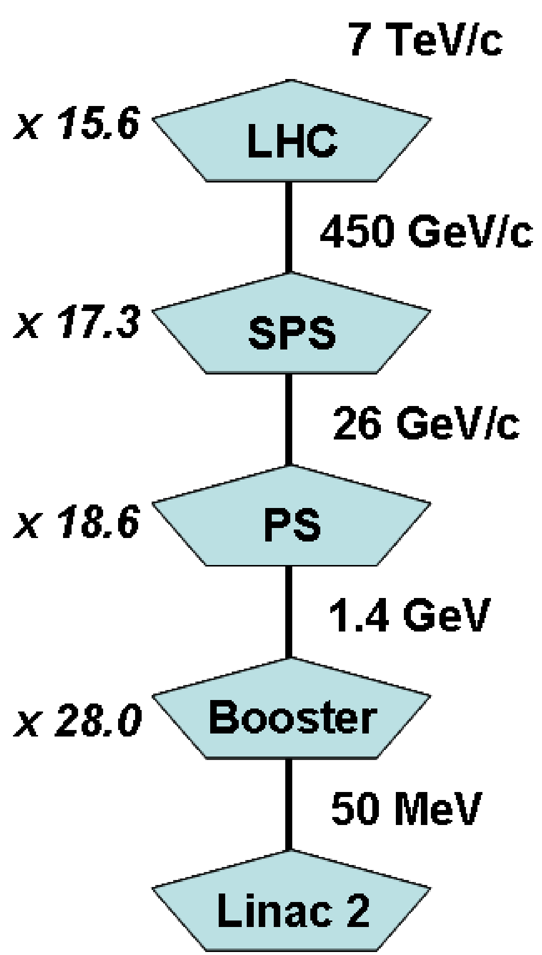
Introduction to CERN

1

CERN European Organization for Nuclear Research: *supplies particle accelerators and detectors to the scientific community to probe the fundamental structure of the universe*





❷ Why do we need NEG and Carbon coatings

- Vacuum required to minimize interaction of particles with the residual gas.

- Long beam pipes => low conductance => requires ***distributed pumping.***

- To avoid electron multipacting, the internal walls of the beam pipes must have ***Low Secondary Electron Yield (SEY).***

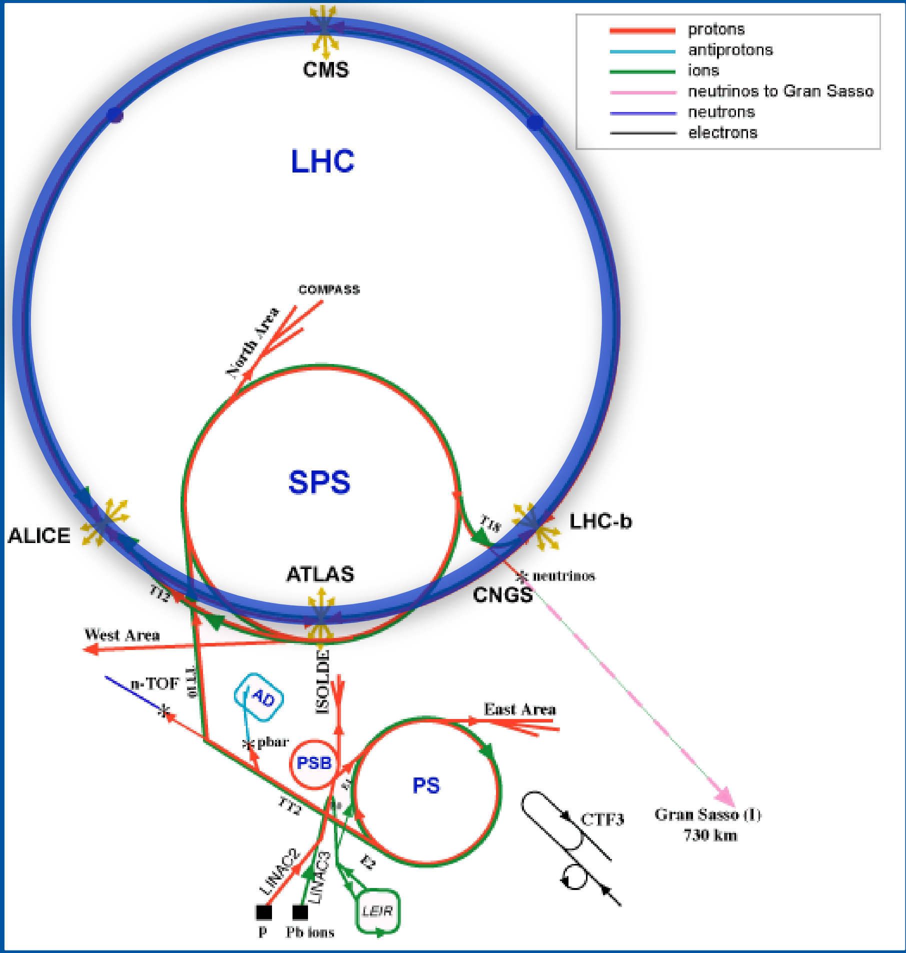
❷ Why do we need NEG and Carbon coatings

Motivation to develop NEG coating

Long Straight Sections (LSS) of the Large Hadron Collider (LHC)

- Low pressure in long beam pipes
- Multipacting threshold SEY_{max}=1.3
- Bakeable Beampipes (T>180ºC)

CERN accelerators complex



❷ Why do we need NEG and Carbon coatings

Motivation to develop NEG coating

Long Straight Sections (LSS) of the Large Hadron Collider (LHC)

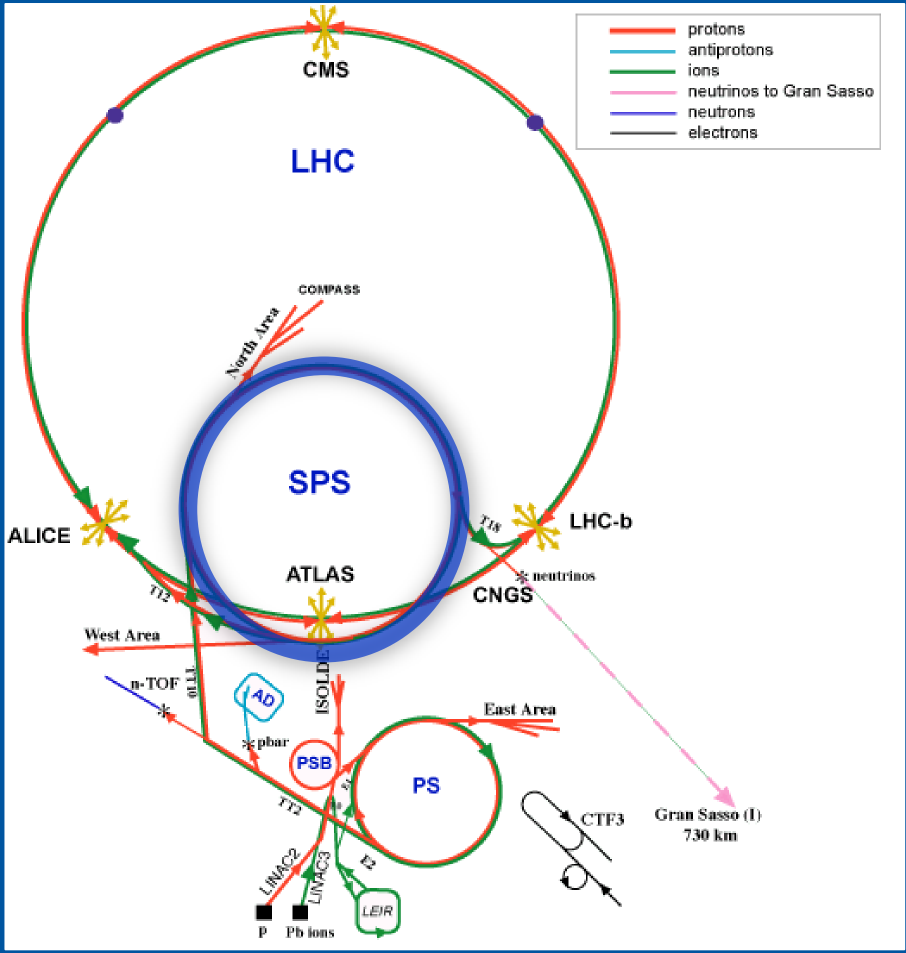
- Low pressure in long beam pipes
- Multipacting threshold SEY_{max}=1.3
- Bakeable Beampipes (T<350ºC)

Motivation to develop Carbon coatings

Upgrade the Super Proton Synchrotron (SPS)

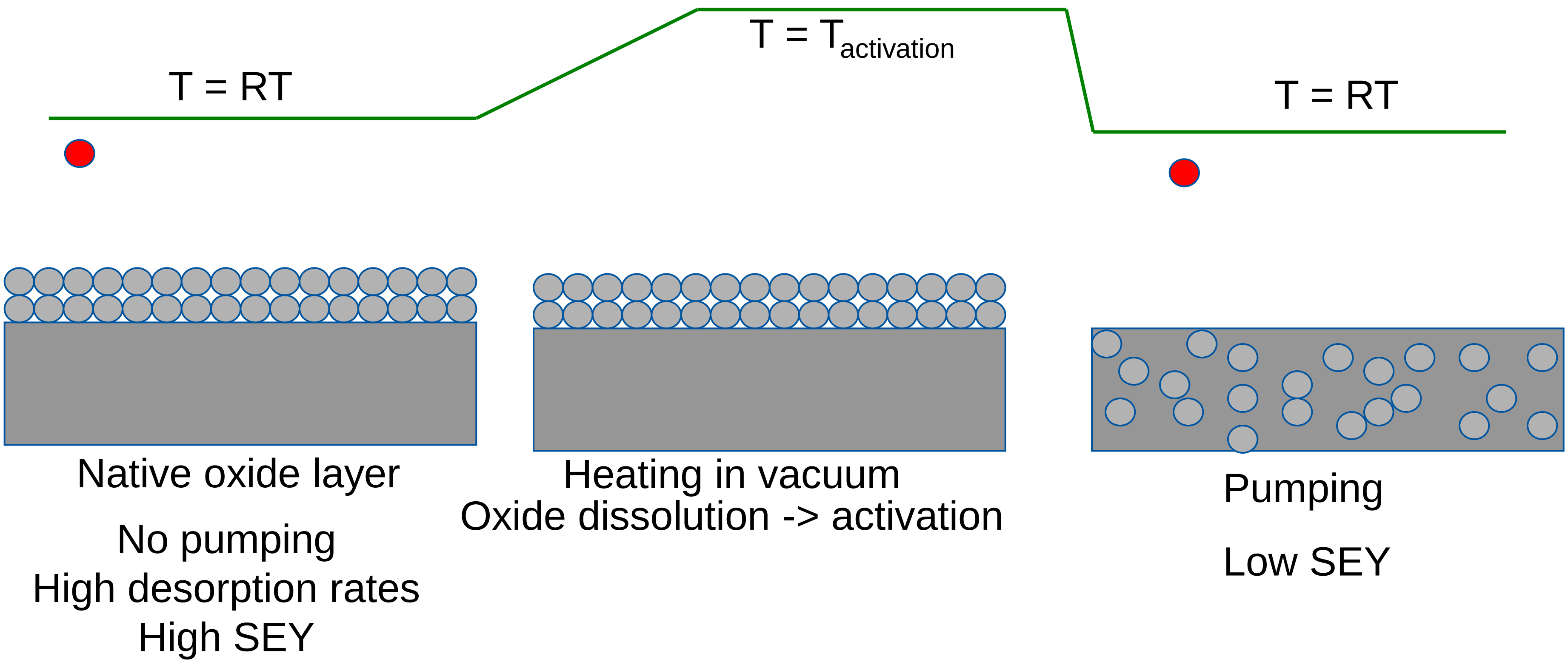
- Multipacting threshold SEY_{max}=1.3
- **Non Bakeable Beampipes**

CERN accelerators complex



3 NEG coatings

Getters are materials capable of chemically adsorbing gas molecules. To do so their surface must be clean. For Non-Evaporable Getters a clean surface is obtained by heating to a temperature high enough to dissolve the native oxide layer into the bulk.



NEGs pump most of the gas except rare gases and methane at room temperature

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NEG coatings

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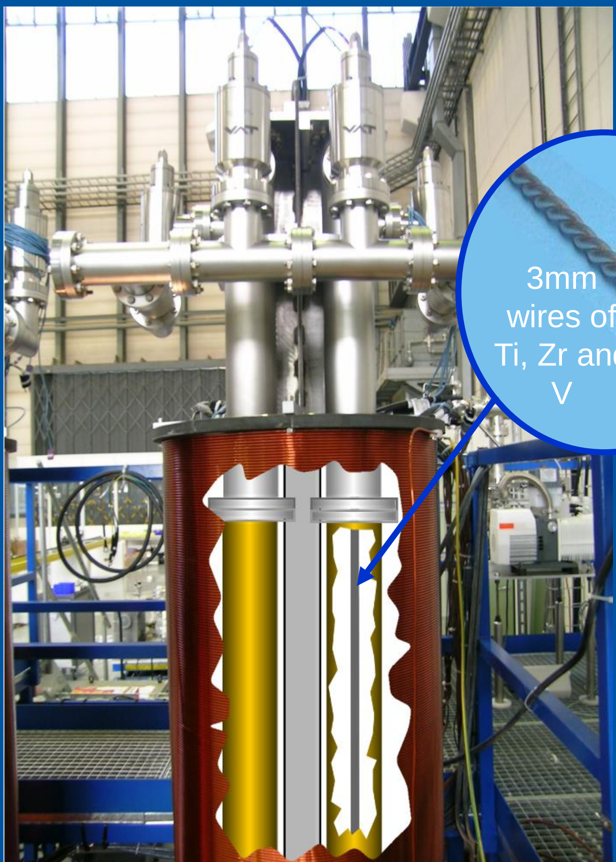

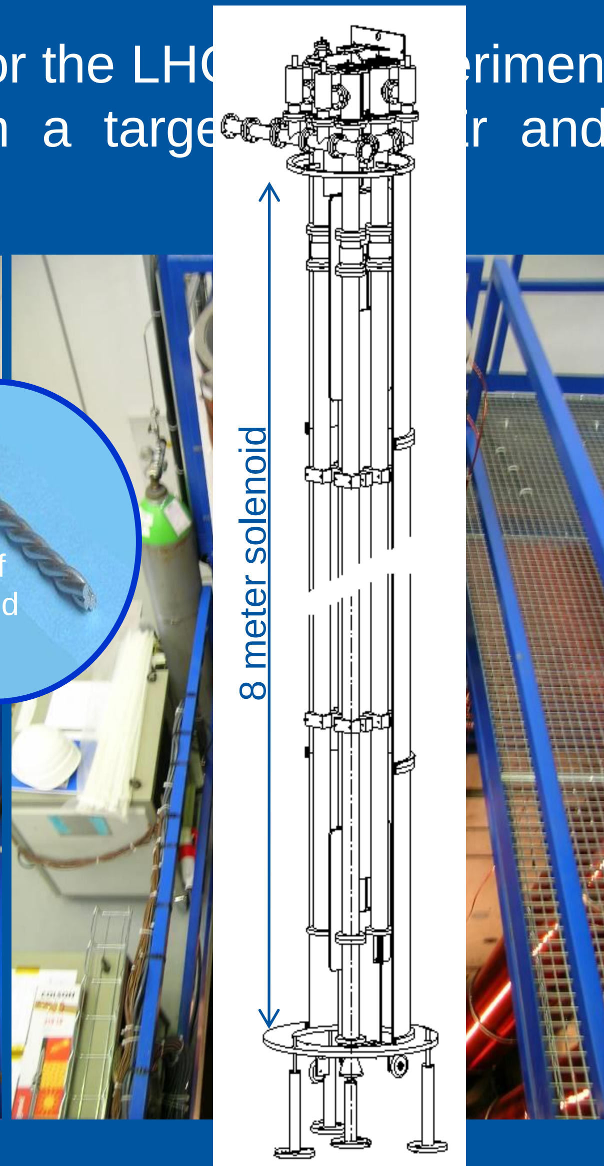

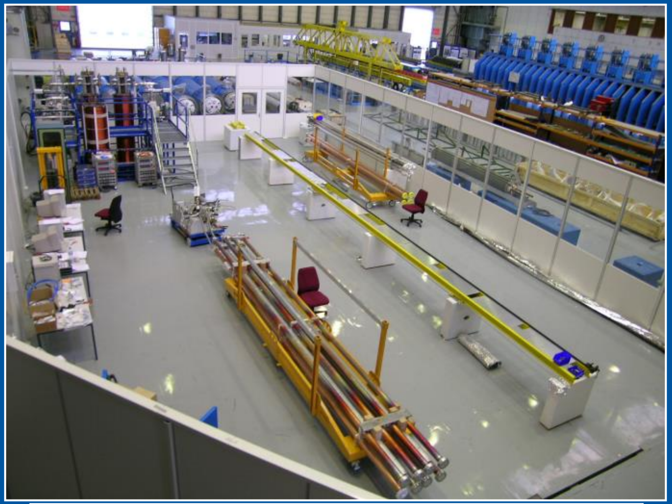

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➢Vacuum required to minimize interaction of particles with the residual gas.

➢Long beam pipes => low conductance => requires ***distributed pumping*** instead of localized pumping

➢To avoid electron multipacting, the internal walls of the beam pipes must have *Low Secondary Electron Yield (SEY).*

NEG coatings

3

Multipacting properties 2: Electron Multipacting.