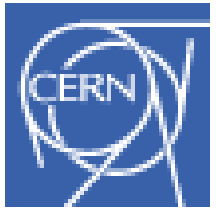


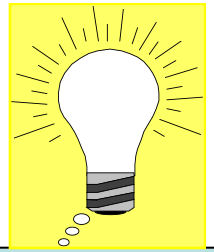
... where the NEG film was born in 1996!

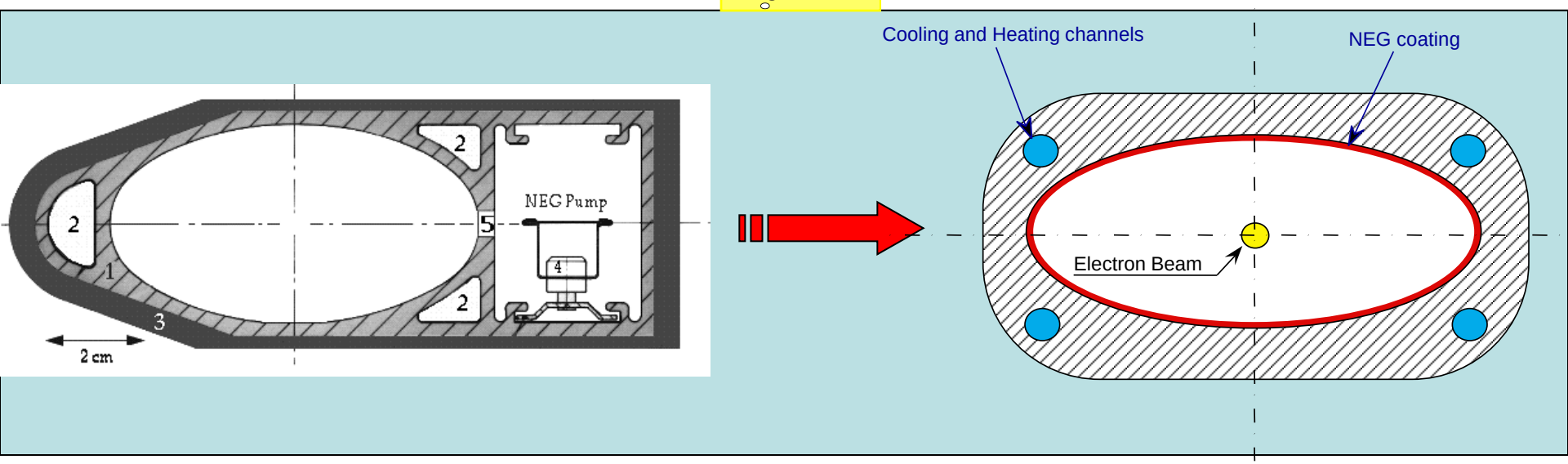
NEG thin film coatings

Paolo Chiggiato

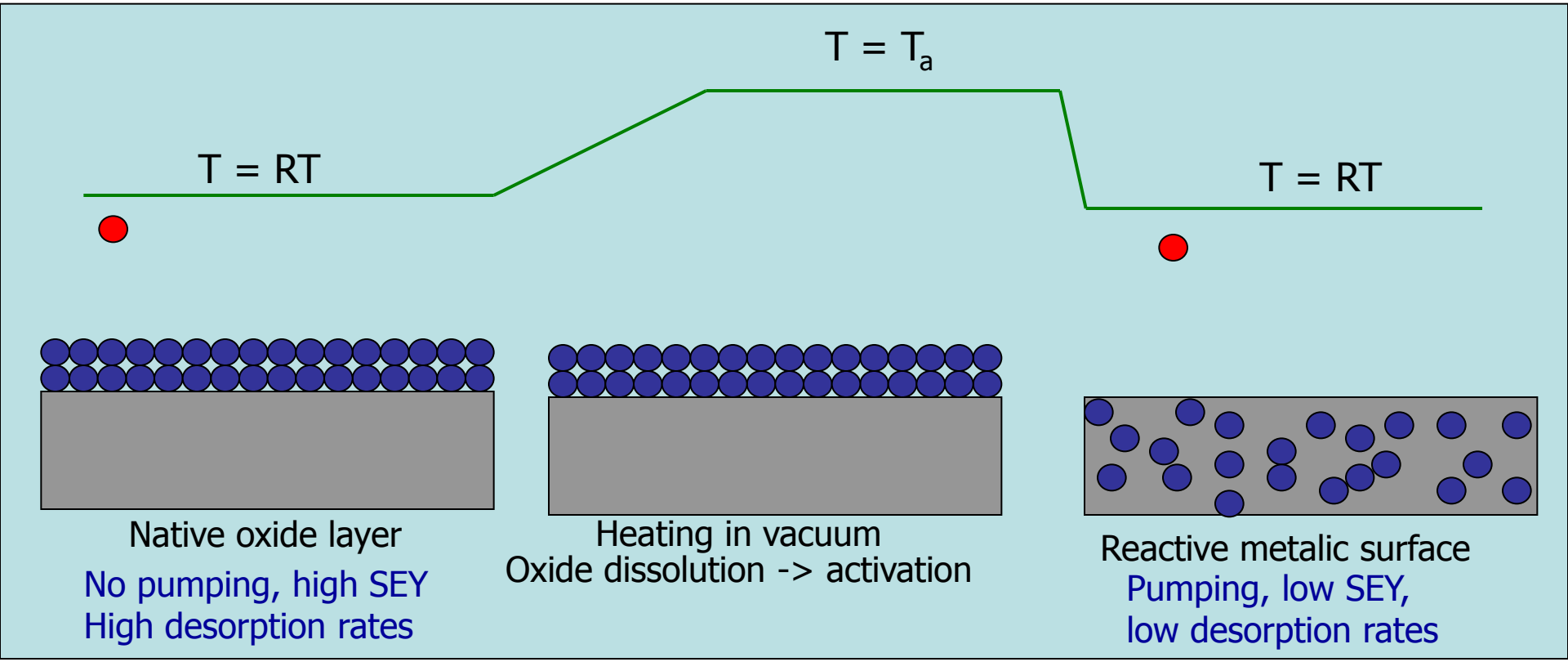
How a pumping vacuum chamber can be obtained:

…by sputter coating its inner wall with a non-evaporable getter film before the installation in the accelerator.





Getters are materials capable of chemically adsorbing gas molecules. To do so they need to be activated



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

The activation temperature has to be compatible with the substrate materials:

St. steel < 400 °C

Copper alloys < 250°C

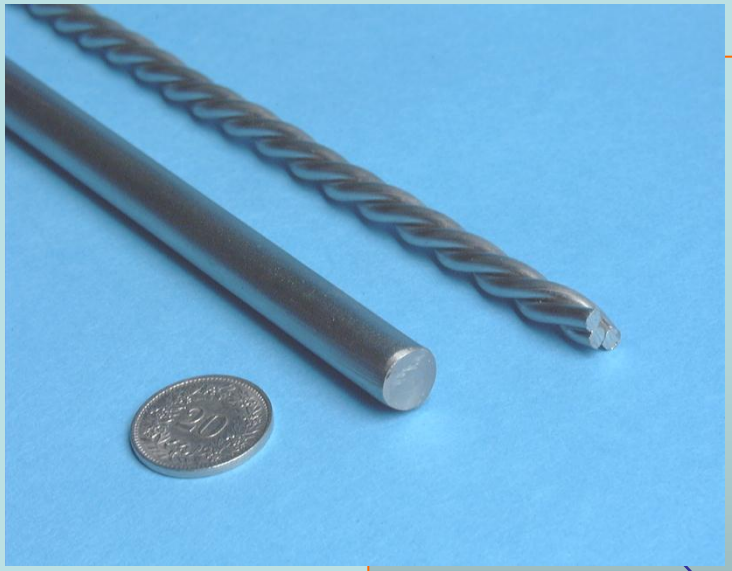
Aluminum alloys < 200 °C

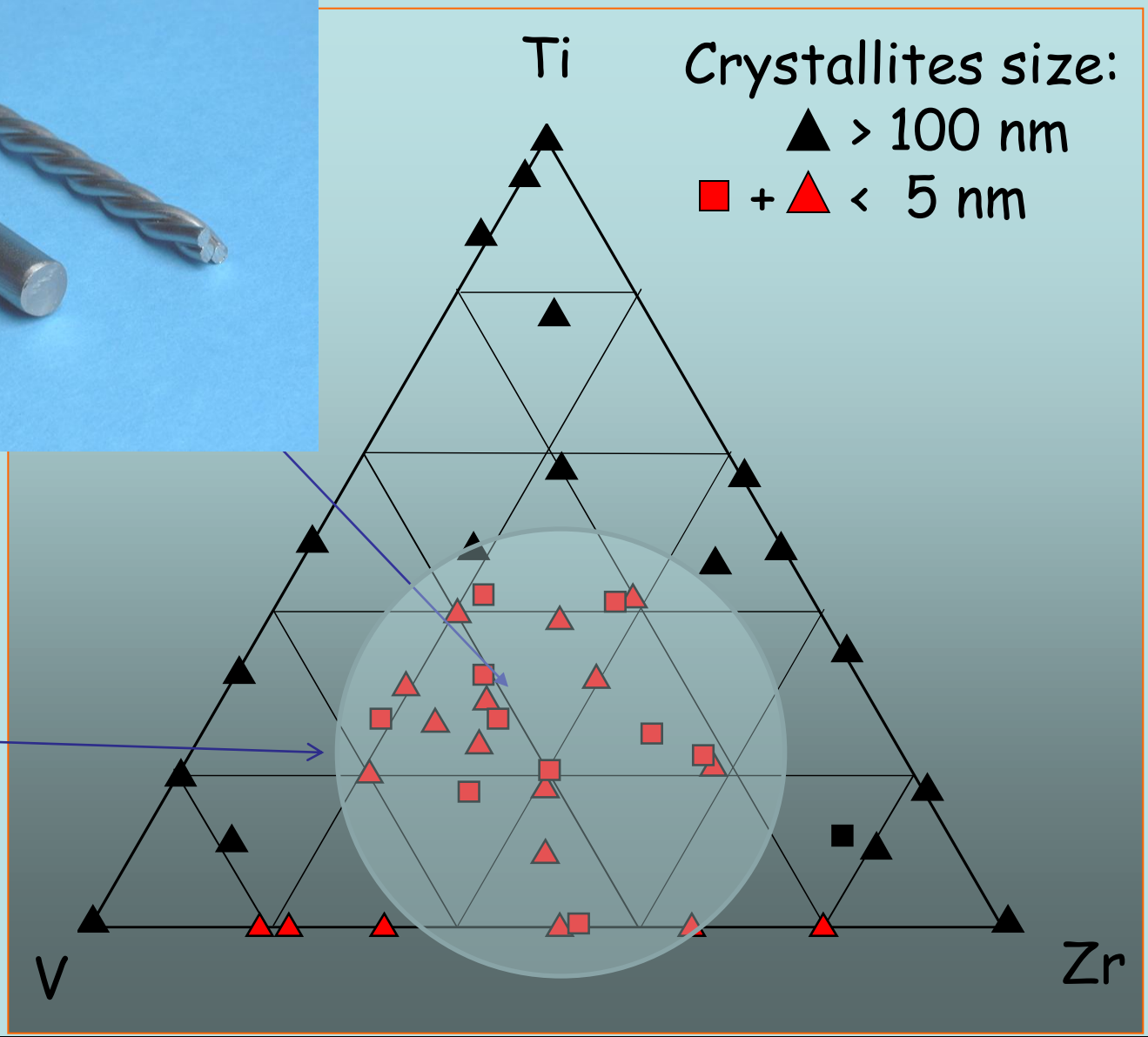
Lowest activation temperature found up to now:

180 °C

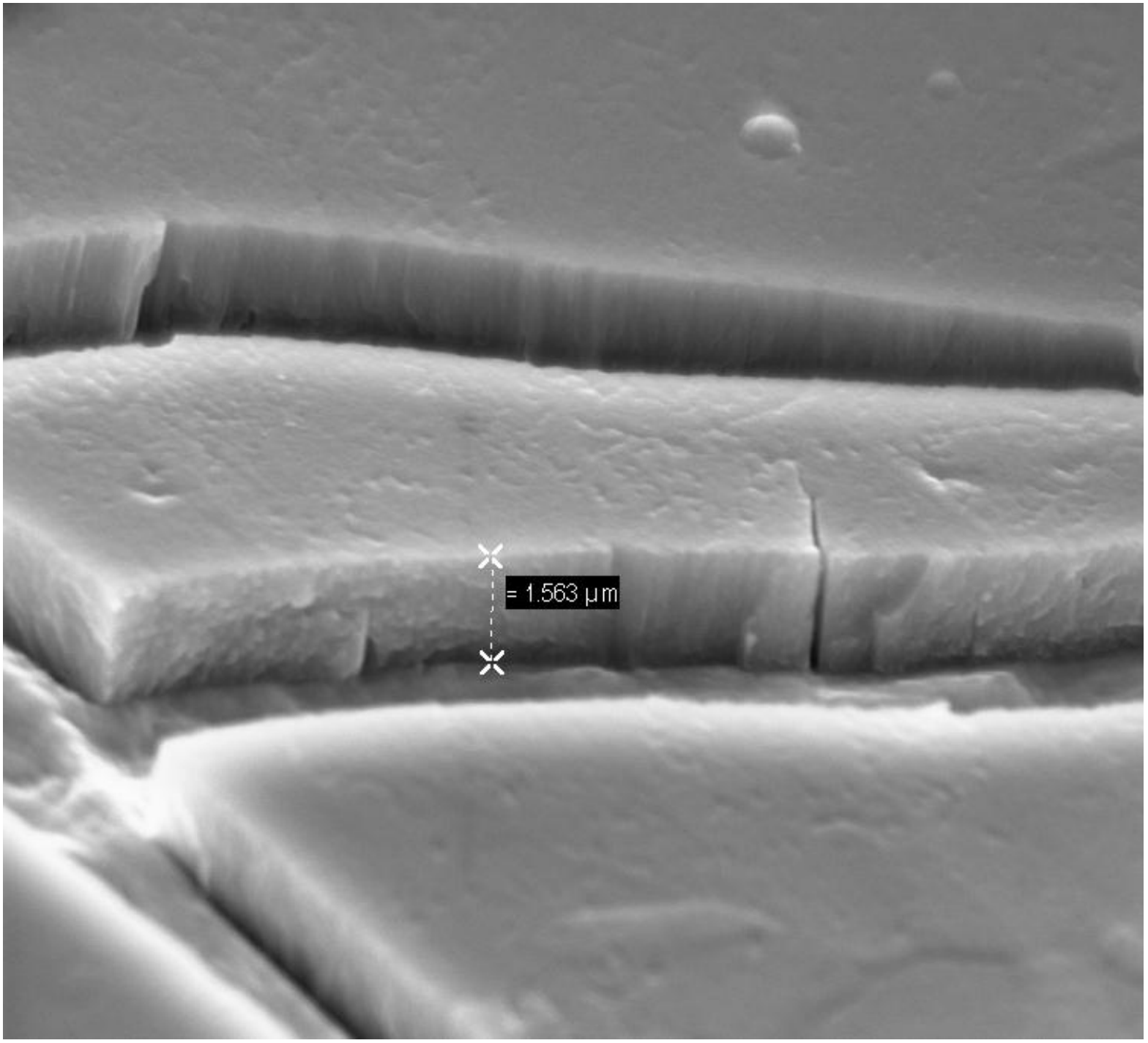
(24 hours heating in vacuum)

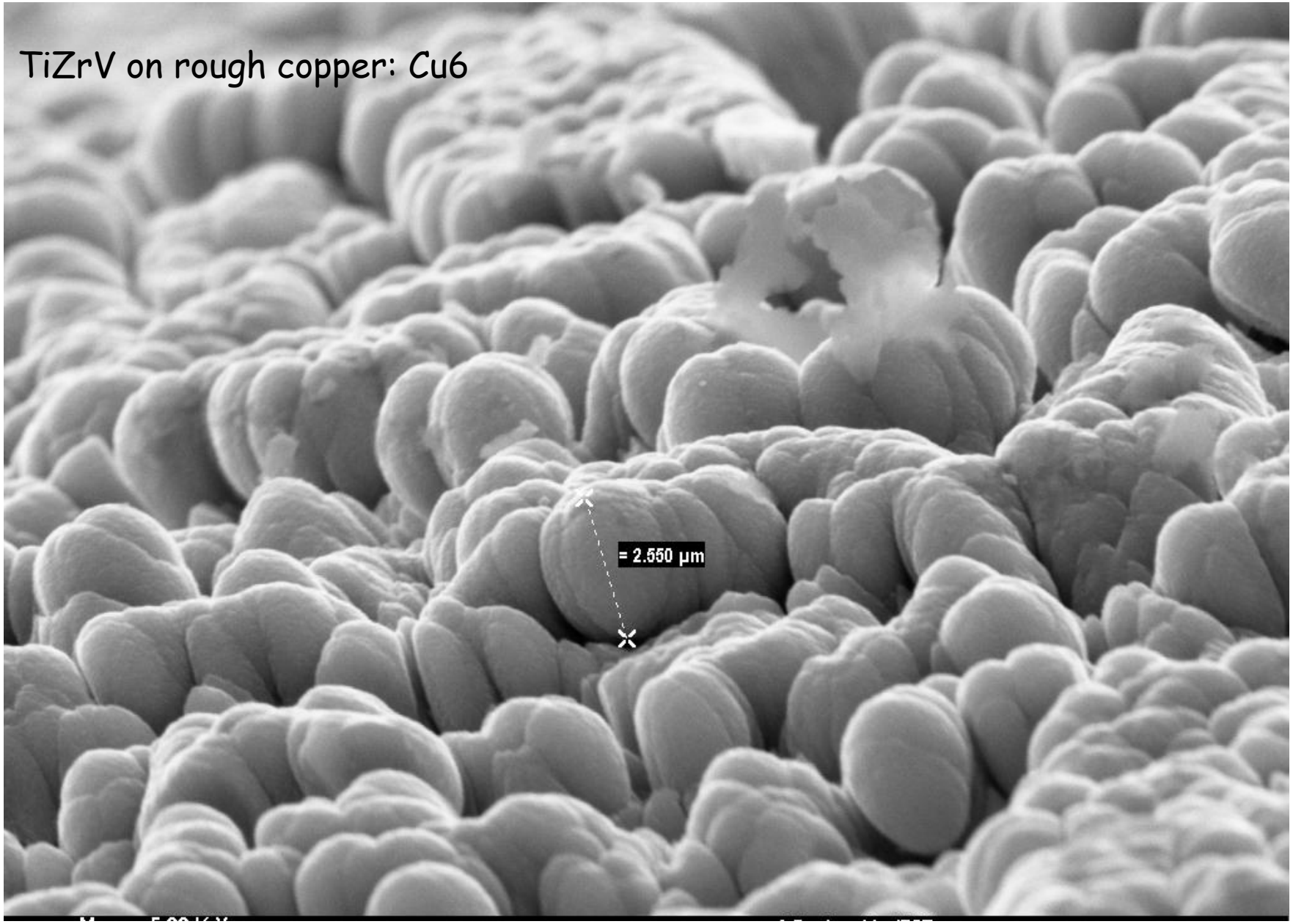
in a large range of composition in the Ti-Zr-V system

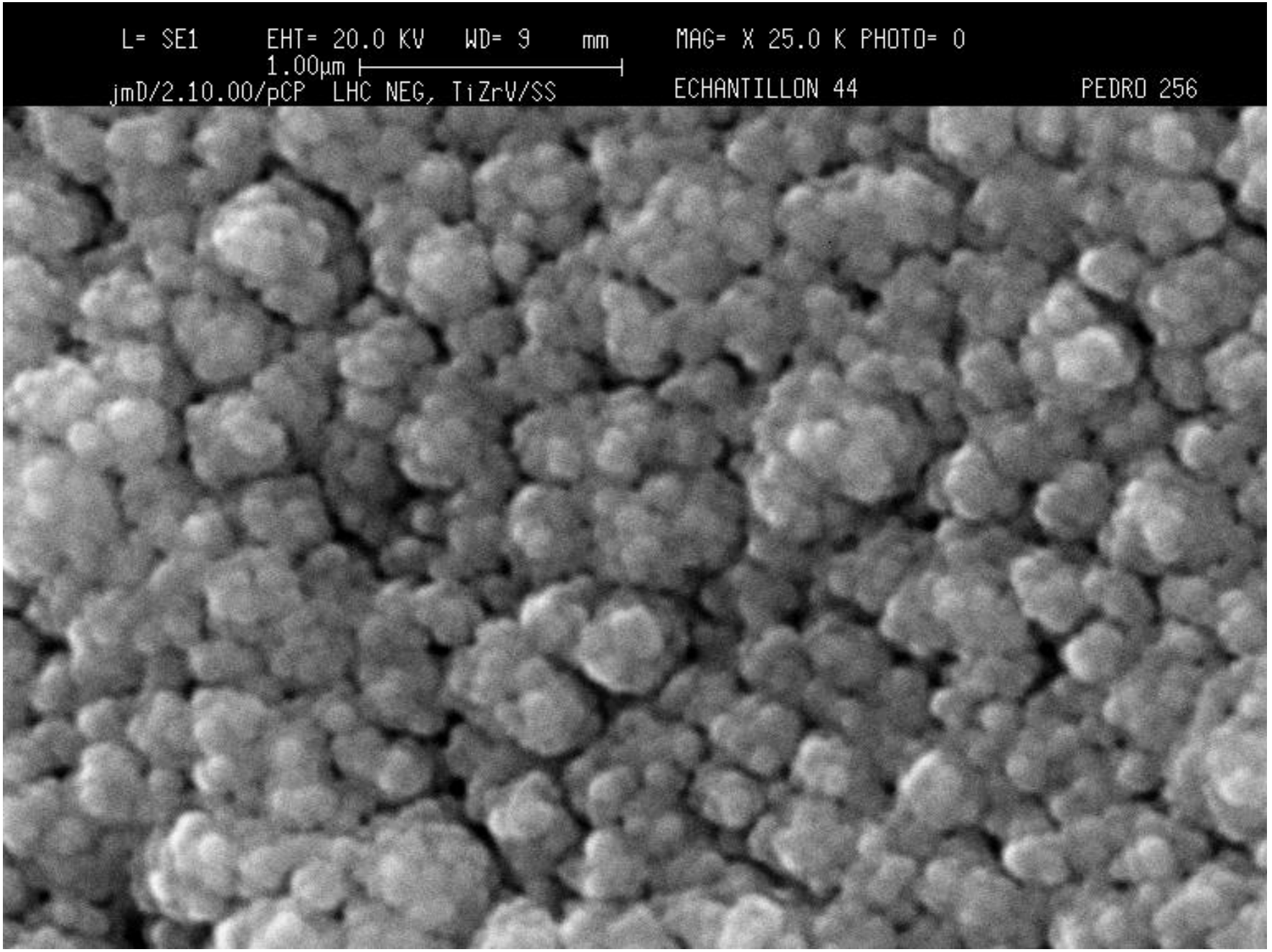


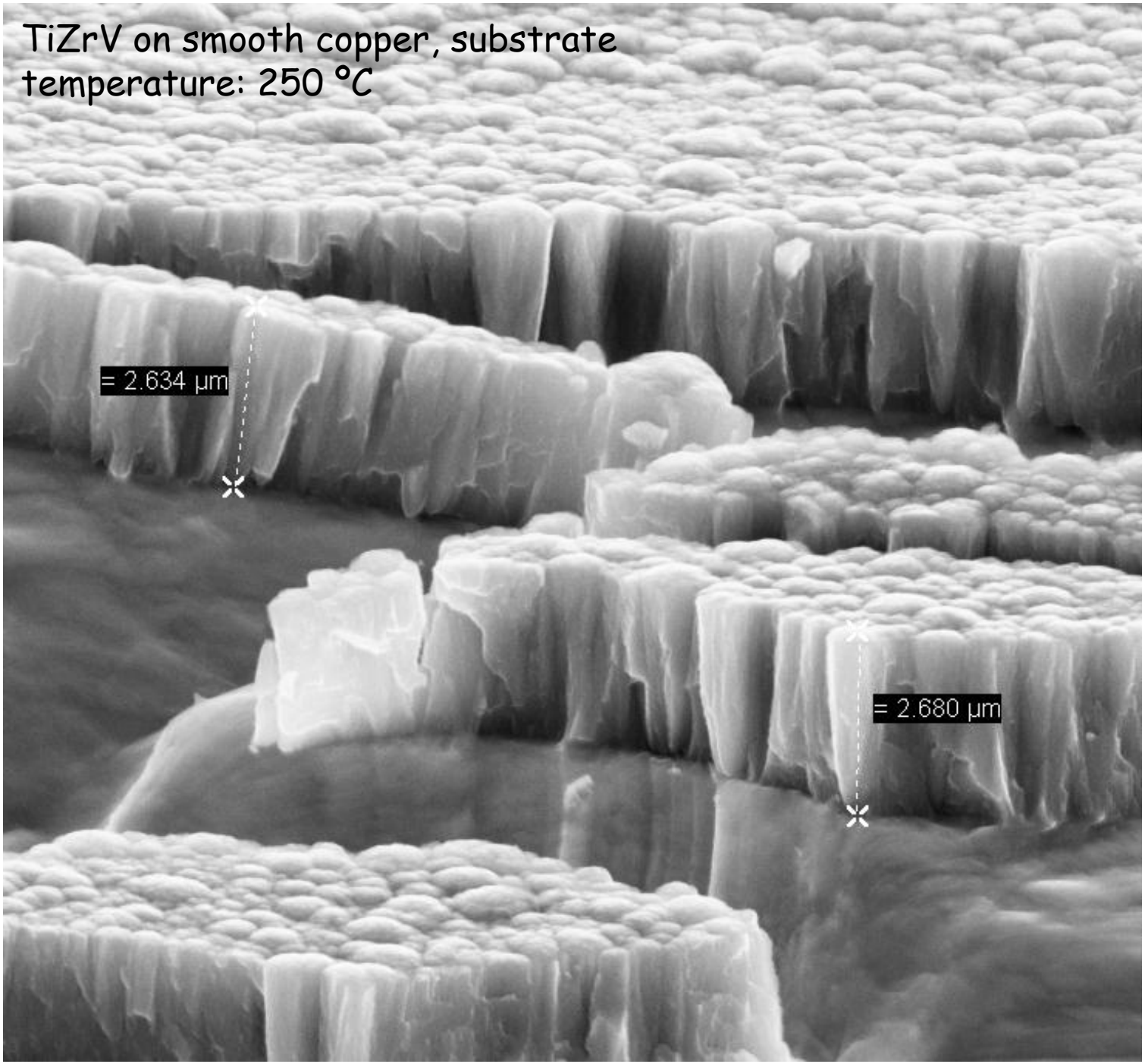


Low activation temperature


= 1.563 µm


TiZrV on rough copper: Cu6
= 2.550 µm


L= SE1 EHT= 20.0 KV WD= 9 mm MAG= X 25.0 K PHOTO= 0
1.00µm
jmD/2.10.00/pCP LHC NEG, TiZrV/SS ECHANTILLON 44 PEDRO 256


TiZrV on smooth copper, substrate temperature: 250 °C
= 2.634 µm
= 2.680 µm

✓ Role of the substrate material on the activation process and on the film morphology.

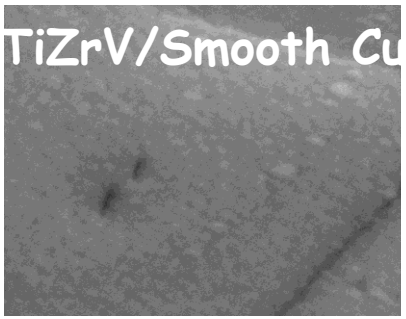
Does not affect the film crystallinity

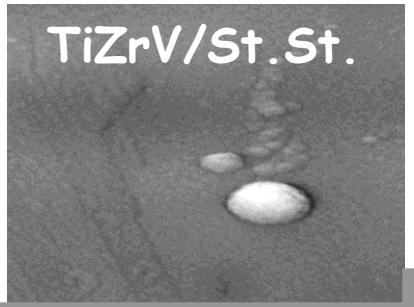
Does not affect the activation process

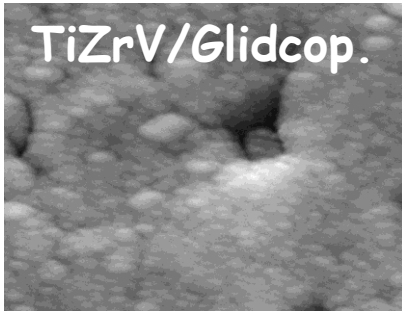
Affects the film morphology

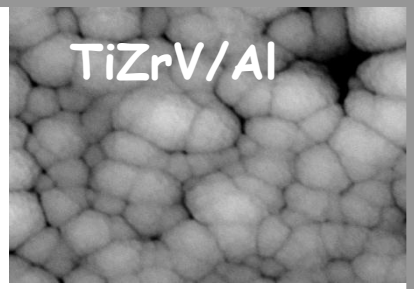
Substrates studied

Glass
Stainless steel
Copper
Aluminium
Glidcop
Beryllium
Al-Be







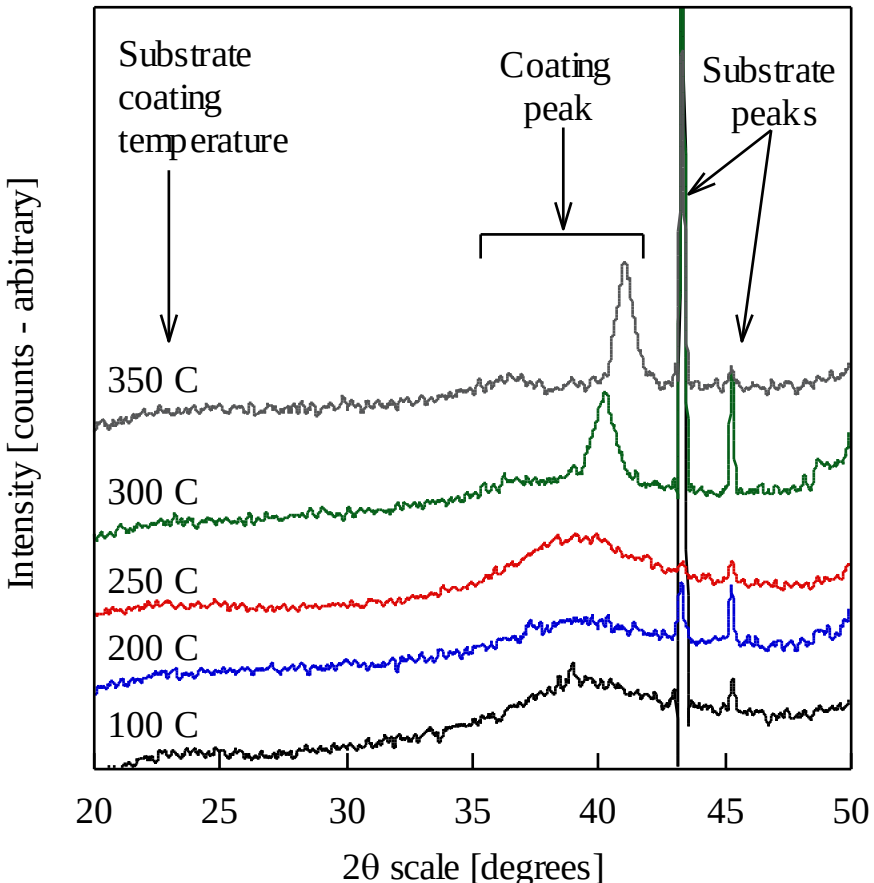


✓ Influence of the substrate temperature during coating.

Influence of the substrate temperature

On film crystallinity: increased grain size for T≥ 300°C

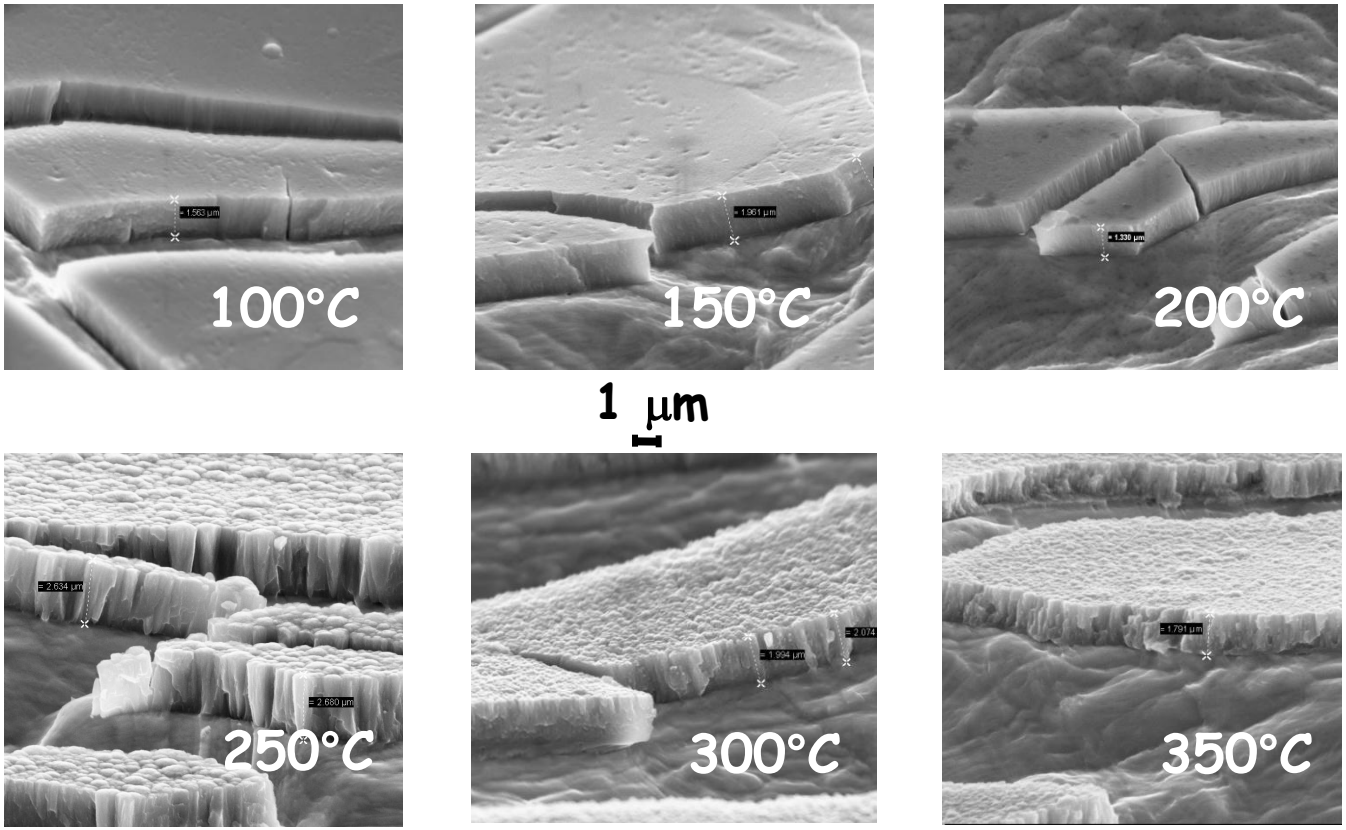
250 °C is the highest substrate temperature at which a grain size below the threshold value of 5 nm is still preserved.
For T>300°C the activation process is delayed



✓ Influence of the substrate temperature during coating.

Influence of the substrate temperature

On film morphology:
increased roughness for T> 200°C



✓ Functional properties:

Large and uniformly distributed pumping speed for most of the residual gases: ≈0.5 l $s^{-1}cm^{-2}$ for H_2 and ≈5 l $s^{-1}cm^{-2}$ for CO .

Monolayer surface capacity for CO (about 10^{15} molecules cm^{-2}).

Photon and electron desorption yields lower than those for standard vacuum materials.

Extremely low CH_4 and Kr outgassing rate: ≤10^{-17} Torr l $s^{-1}cm^{-2}$ (Kr desorption energy = 21±1 Kcal mol^{-1})

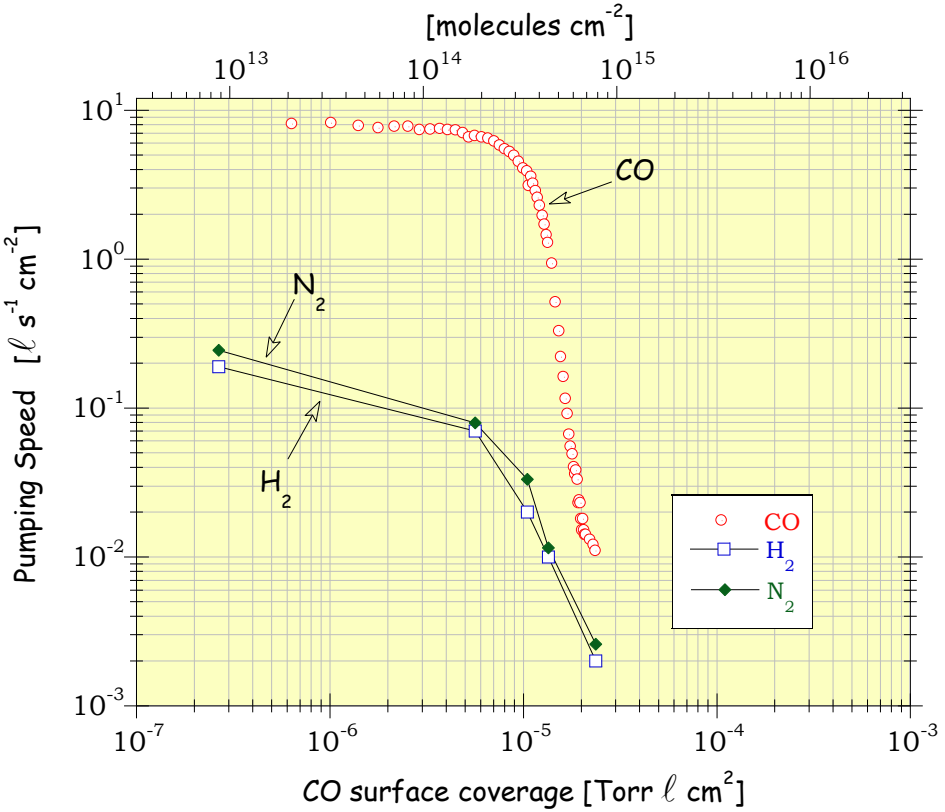
Typical initial H content of the order of 10^{-3} at. fraction. Dissociation pressure negligible at room temperature; 10^{-10} Torr at 180°C, 10^{-8} Torr at 250°C.

Safe H charging limit at room temperature: 10 Torr l g^{-1} (≈ $2x10^{17}$ H_2 molecules cm^{-2} μm^{-1}).

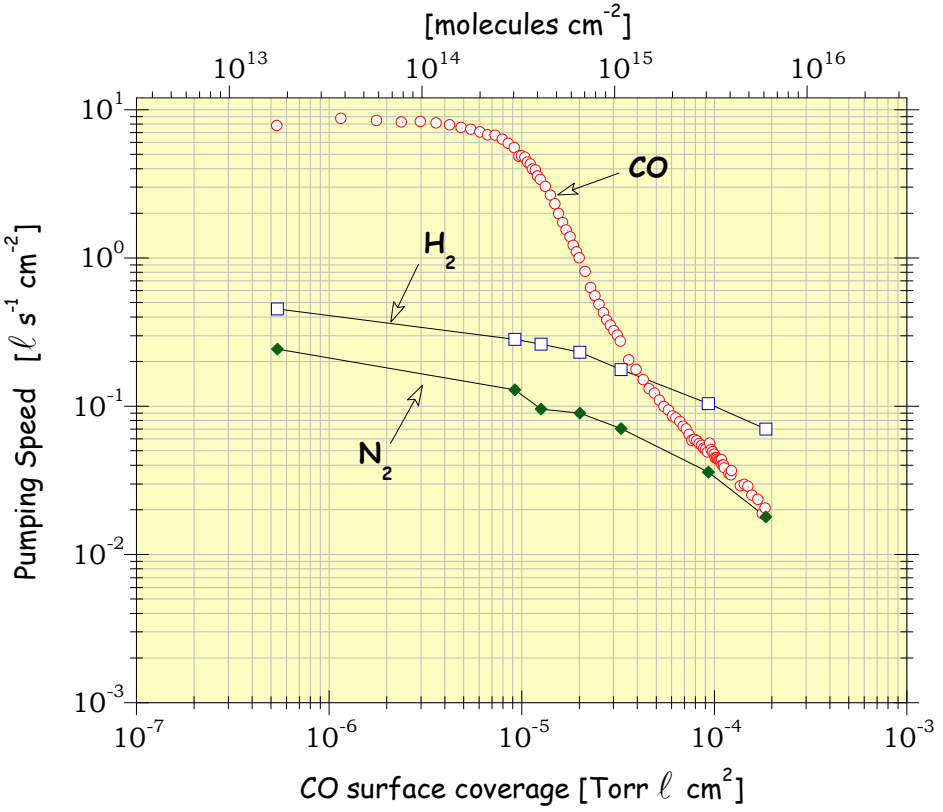
Low SEY (≈1.1 at peak value)

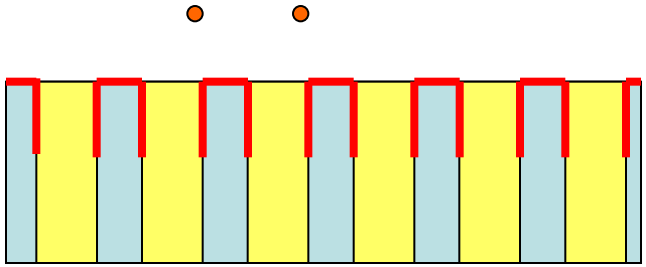
TiZrV functional properties: pumping speed

Smooth coating

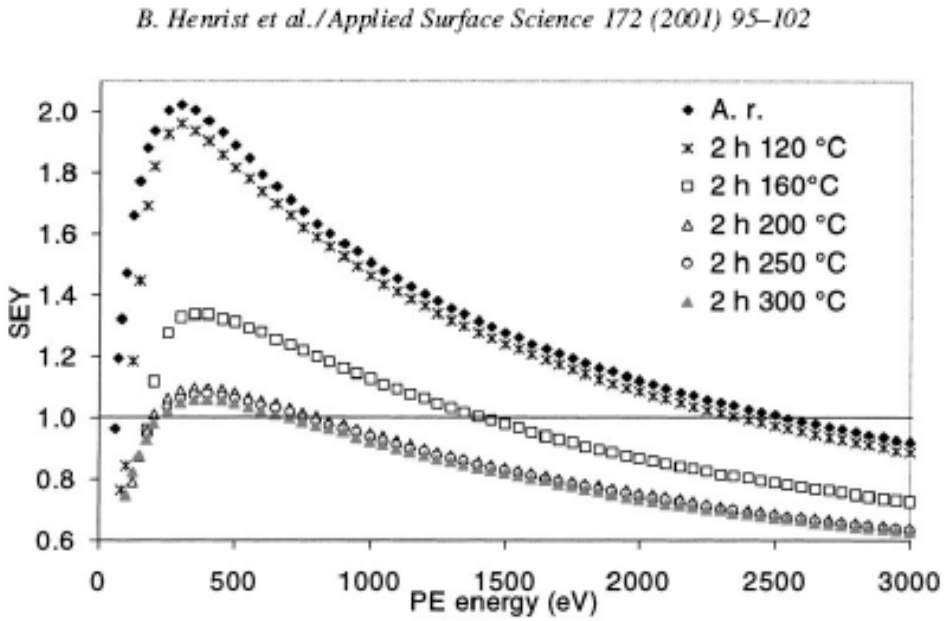


Rough coating

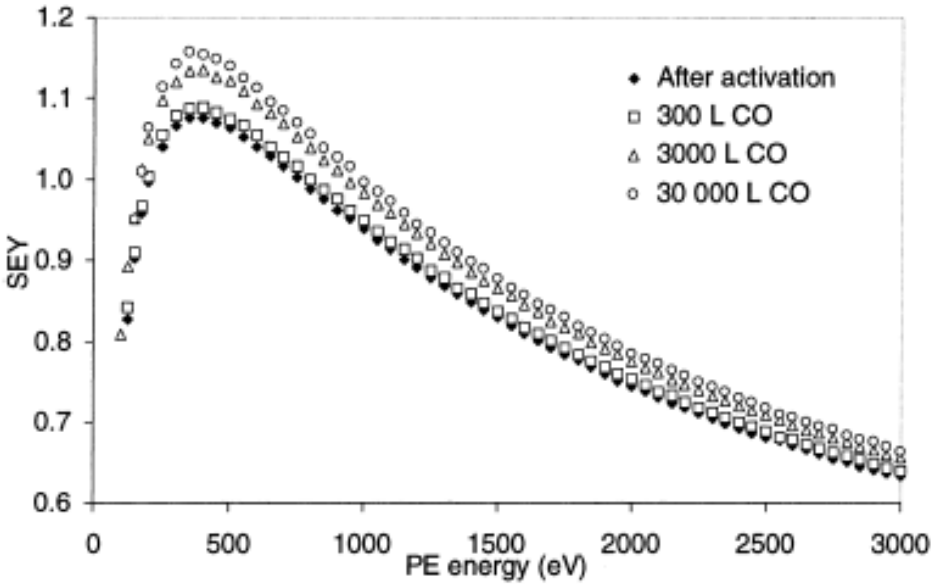




TiZrV functional properties: secondary electron yield



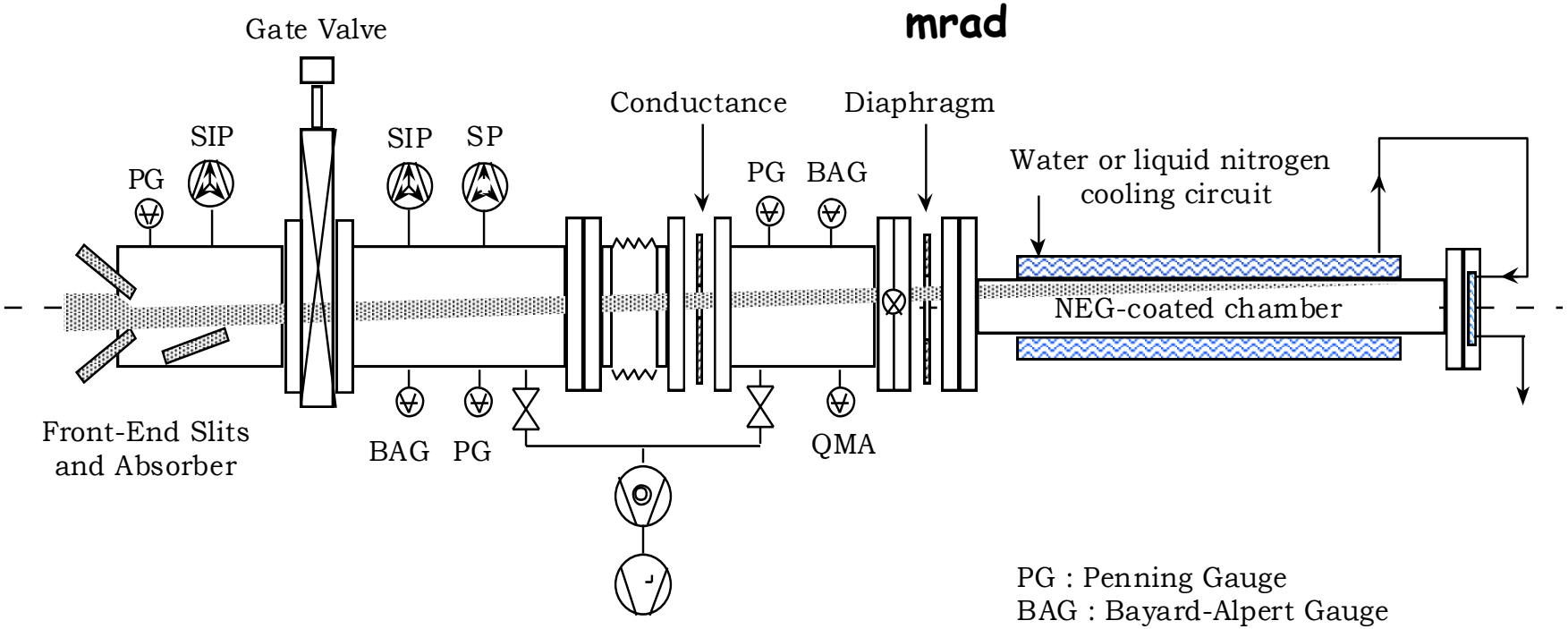
SEY versus PE energy of the TiZrV NEG coating:
as received and after 2h heating at 120, 160, 200, 250 and 300 °C.



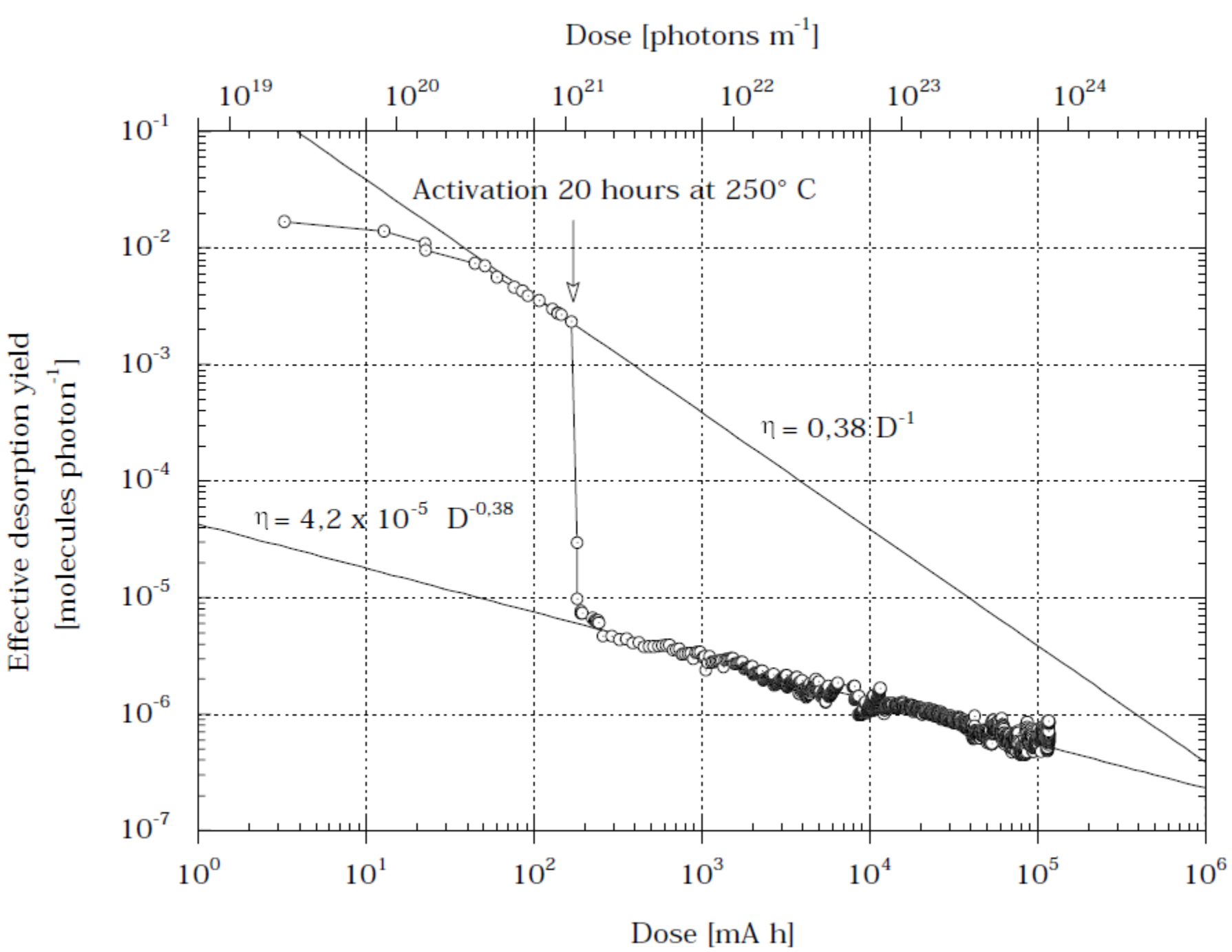
Influence of CO exposure on the SEY of a TiZrV coating activated 2 h at 300 °C and cooled at 60°C before CO exposure

TiZrV: synchrotron radiation induced desorption

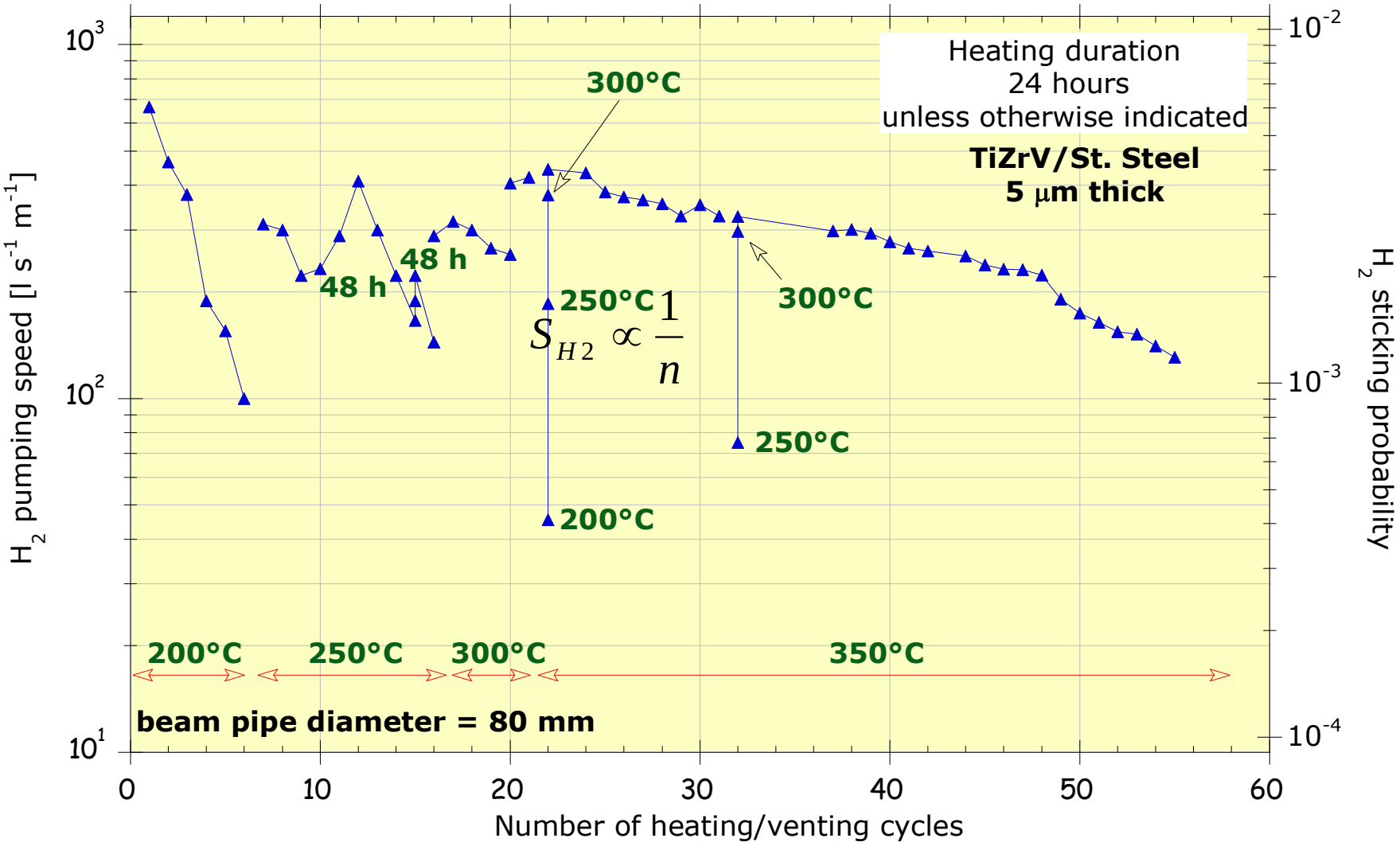
Angle of incidence = 25 mrad



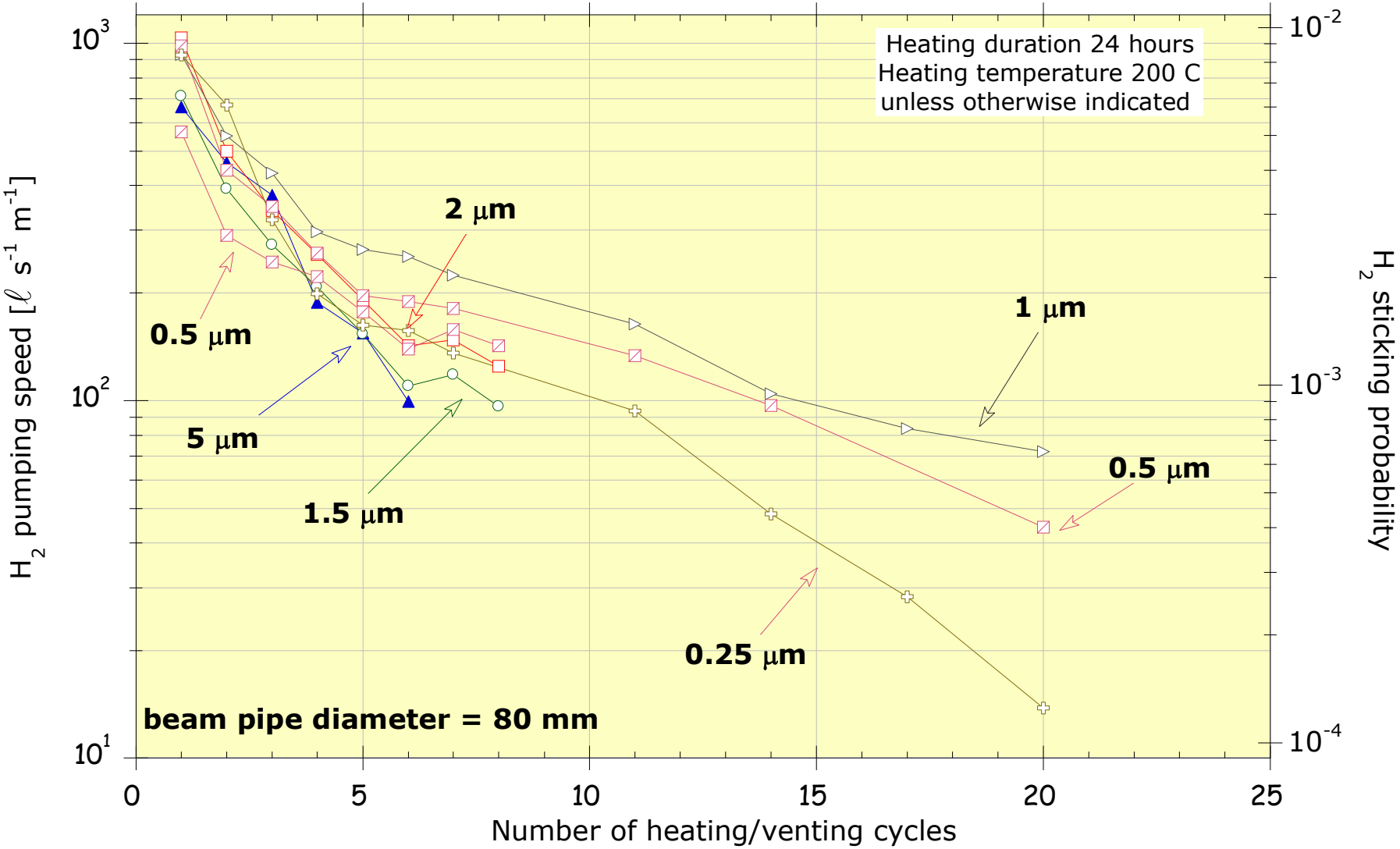
PG : Penning Gauge
BAG : Bayard-Alpert Gauge
QMA : Quadrupole Masss Analyser
SIP : Sputter Ion Pump
SP : Sublimation Pump


Dose [photons m^{-1}]
10^{19}
10^{20}
10^{21}
10^{22}
10^{23}
10^{24}
Activation 20 hours at 250° C
$\eta = 0{,}38\ D^{-1}$
$\eta = 4{,}2 \times 10^{-5}\ D^{-0{,}38}$
Effective desorption yield
[molecules photon^{-1}]
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
10^{6}
Dose [mA h]

✓ Performances deterioration:



Performances deterioration: ageing



✓ Performances deterioration:

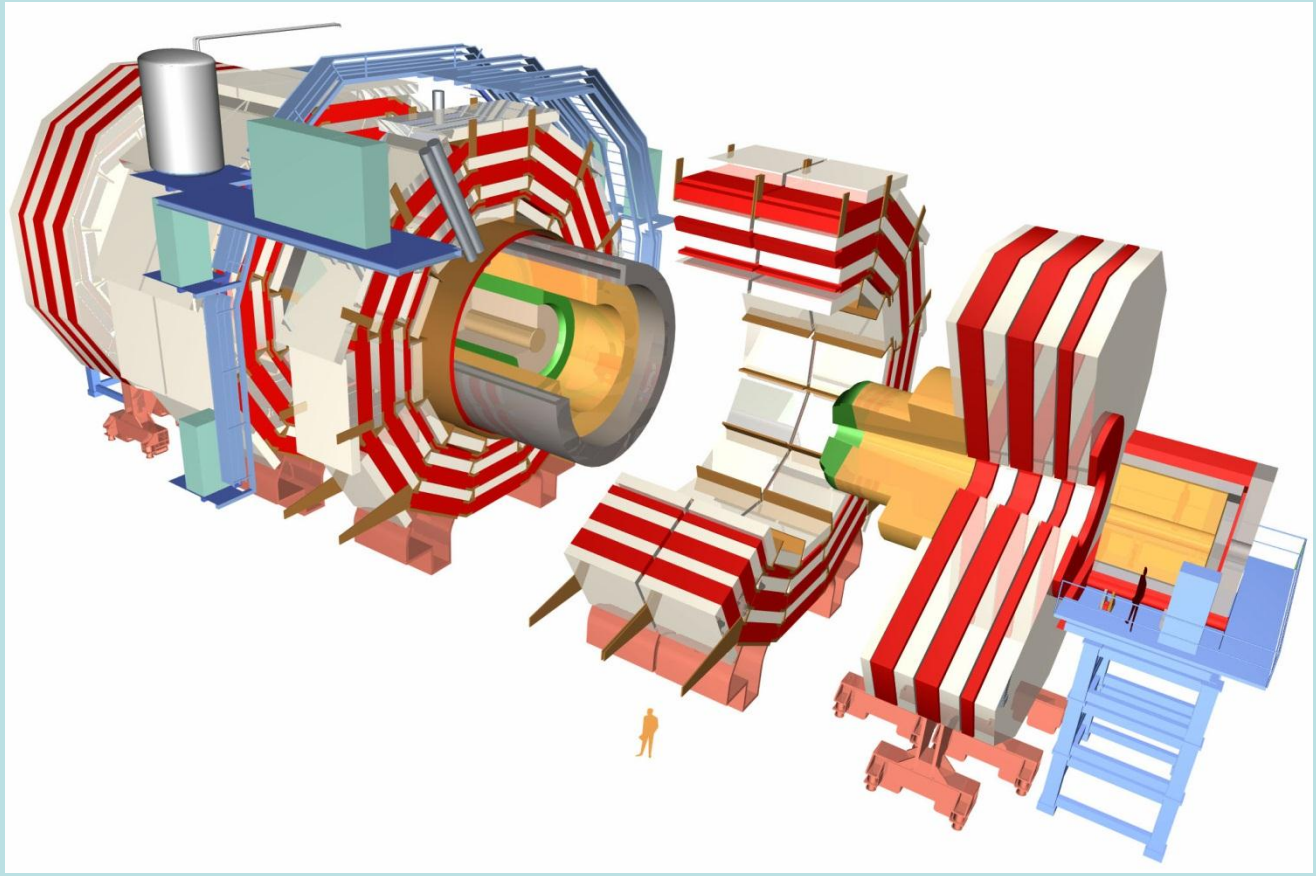
- The pumping speed shows a gradual decrease after each venting-activation cycle.
- The decrease of performance depends on the heating temperature; higher the temperature, lower the loss. For a heating cycle of 200°C x 24h, for the first 10 cycles, in the worst case:

$$S_{H2} \propto \frac{1}{n}$$

- When the activation cycle is carried out at temperatures lower than 250°C, pumping speed can be partially recovered by increasing the heating temperature.
- The loss of performance recorded along the first 10 cycles does not depend on the thickness of the film, for thickness higher than 0.25 μm.

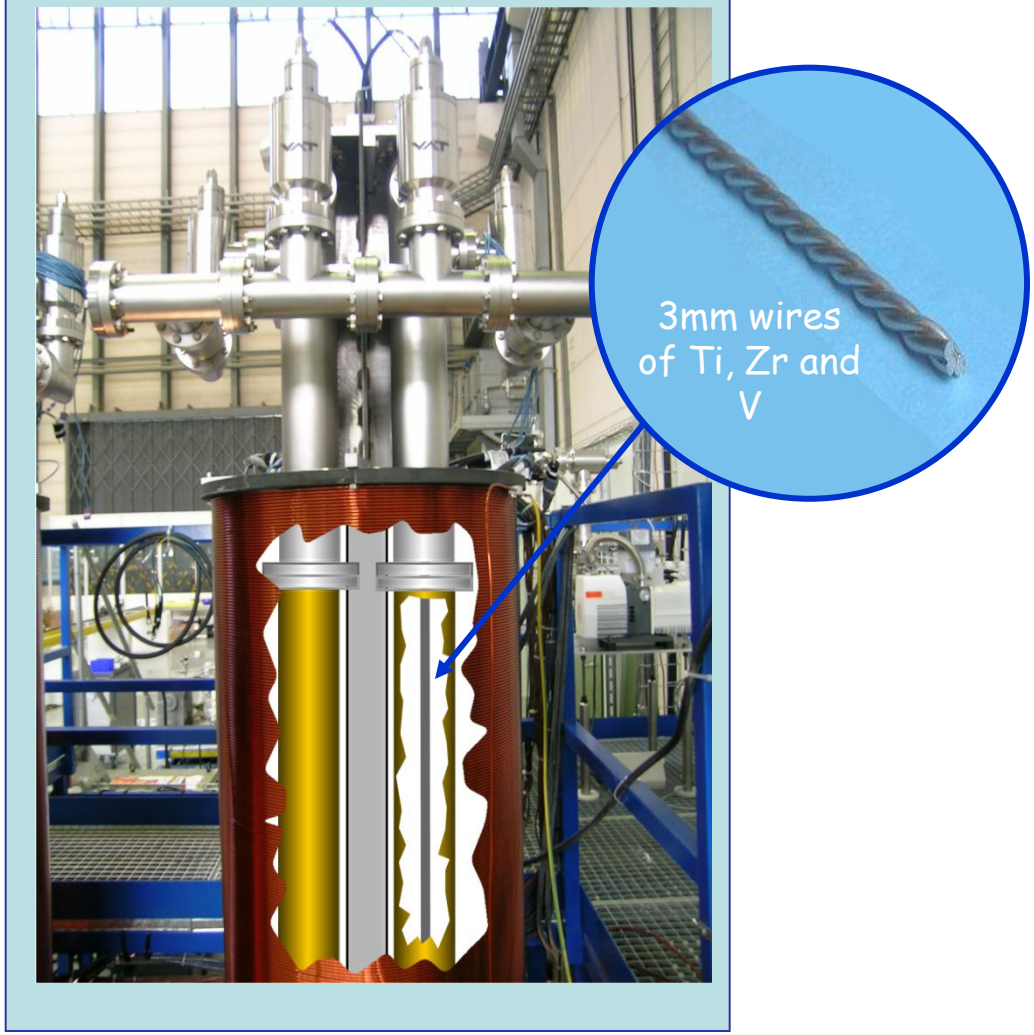
About 1 Kg of Ti-Zr-V will be spread over the LHC to coat about 1200 vacuum chambers of roughly 6 Km of long straight section beam pipe.

Most important vacuum chambers are in the proximity and in the centre of the 4 gigantic experiments.



A dedicated coating facility is available at CERN since 2004:

- ✓ 3 independent magnetron sputtering systems
- ✓ maximum length: 7.5 m; maximum diameter: 60 cm
- ✓ maximum production rate: 20 chambers per week.


3mm wires
of Ti, Zr and
V