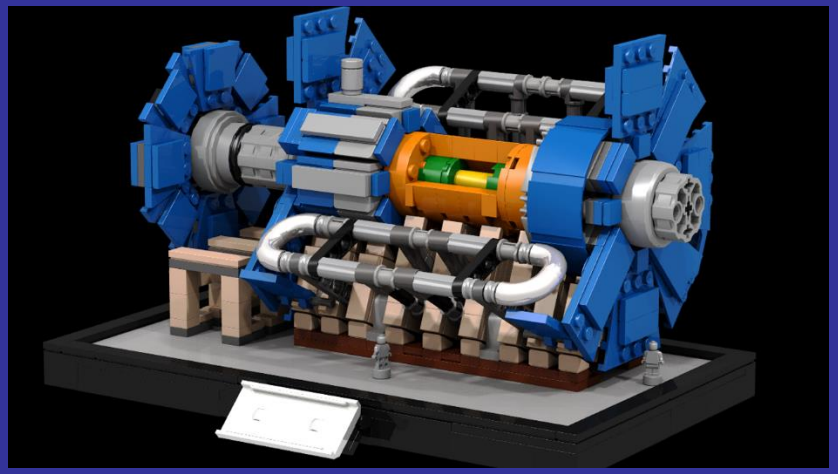
Coatings voor toepassingen binnen het CERN

Wil Vollenberg
TE-VSC-SCC-thin films lab

- Introductie
- Wat zijn coatingen
- Hoe maken we coatingen
- Belangrijke toepassing: NEG

Cern is een onderzoekscentrum voor deeltjes fysica



Cern is een onderzoekscentrum voor deeltjes fysica

Materiaalkunde onderzoek en ontwikkeling ter ondersteuning van versnellers en detectoren

Materiaalkundige ondersteuning:

- Keuze van materialen
- bewerken van materialen (warmte / chemisch / mechanisch)
- Coaten van materialen

Van Dale: Coaten is het aanbrengen van een deklaag.

Meeste gevallen is dat een dunne laag.

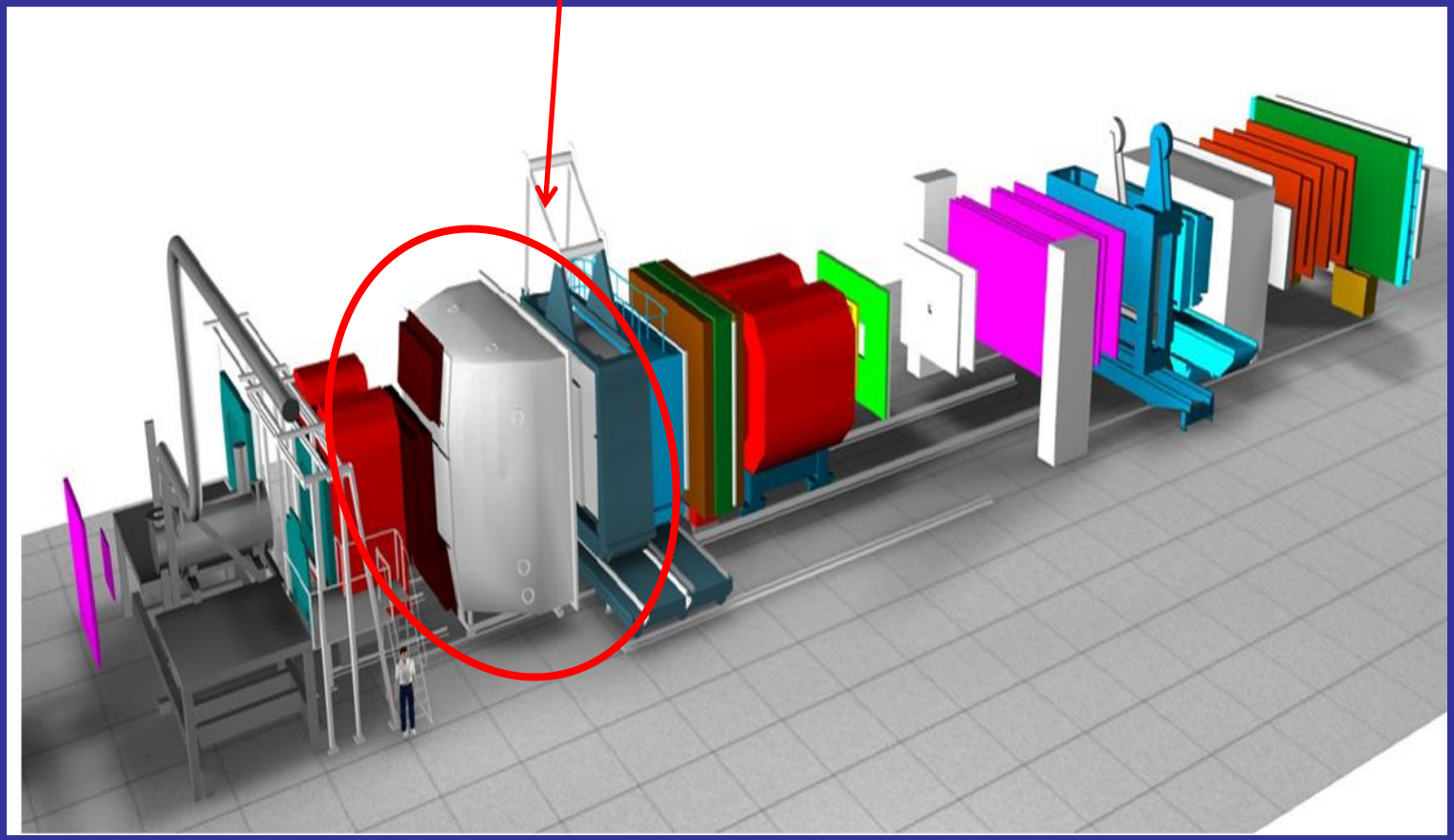
Voor onze toepassingen: 10 nm – 5 µm (haar: 50 µm)

M.b.v. coaten veranderen we de oppervlakte eigenschappen van een materiaal.

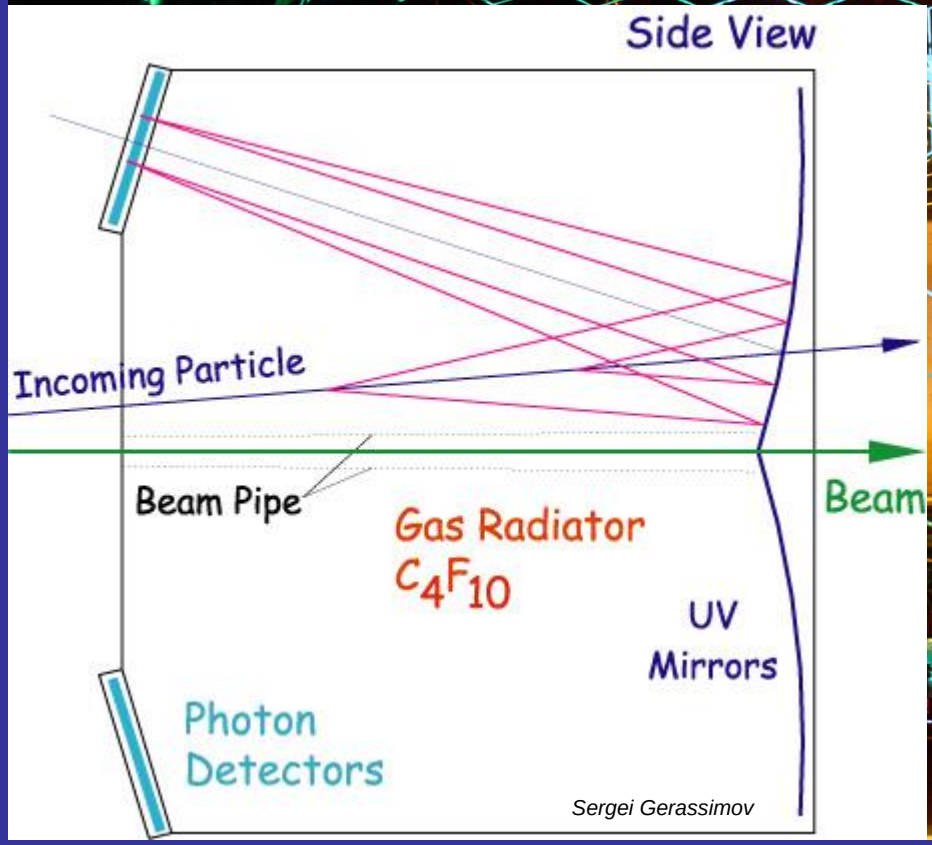
80 nm Al
+
30 nm MgF_2

Reflectiviteit:
90 – 95 %

COMPASS RICH

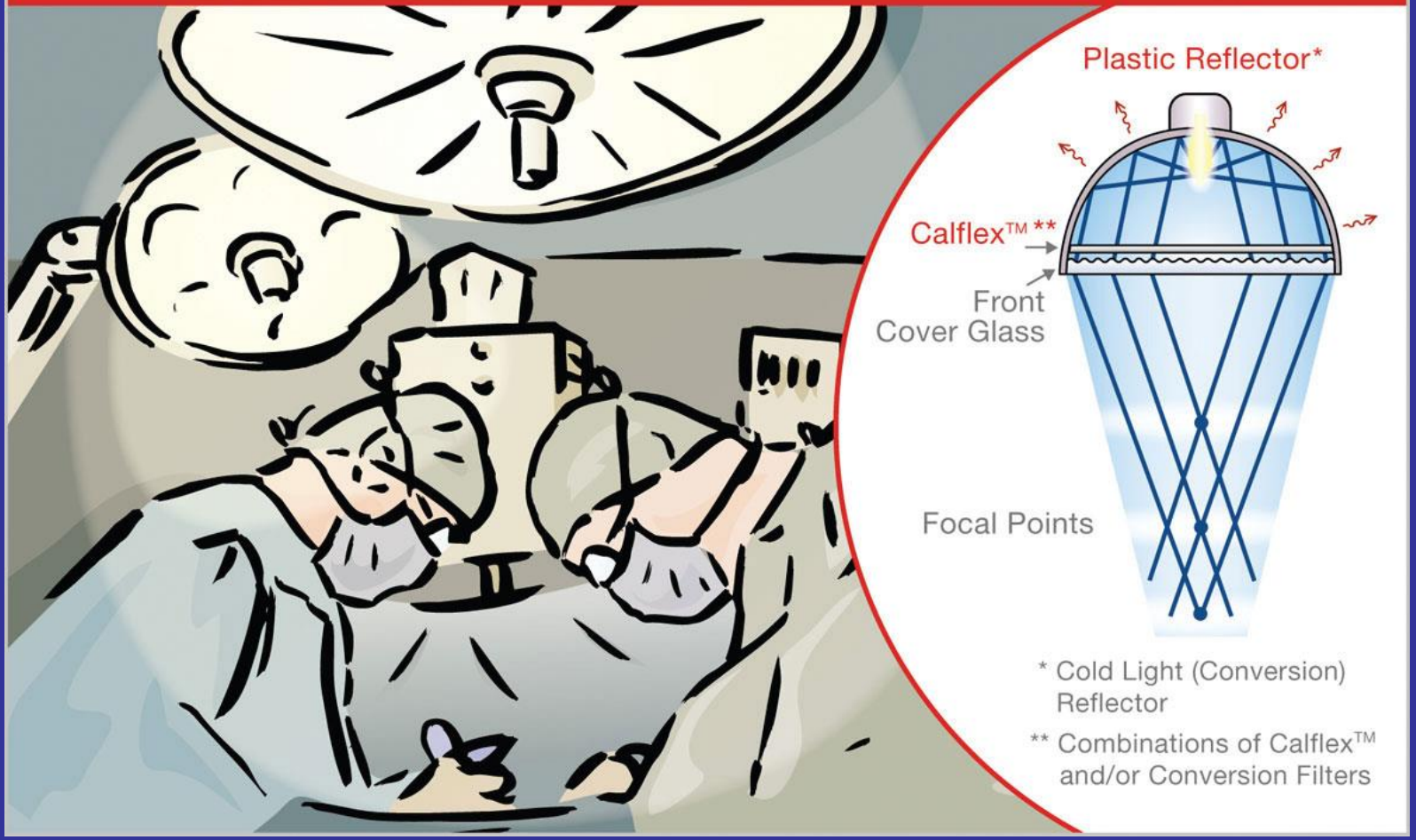


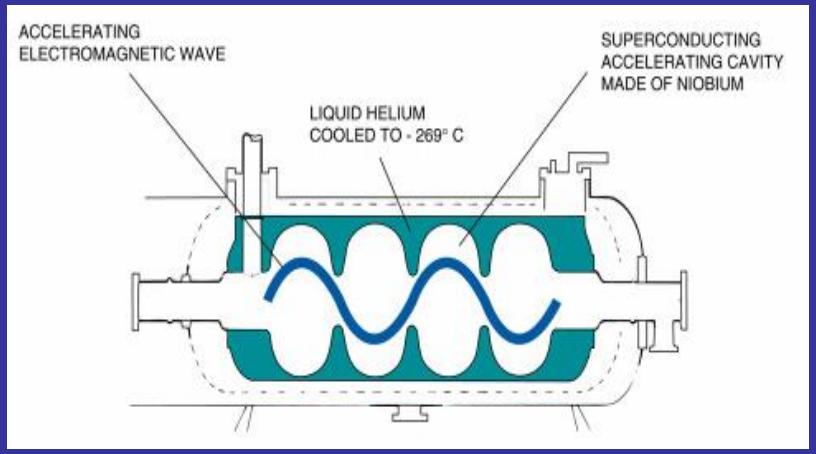
COMPASS RICH

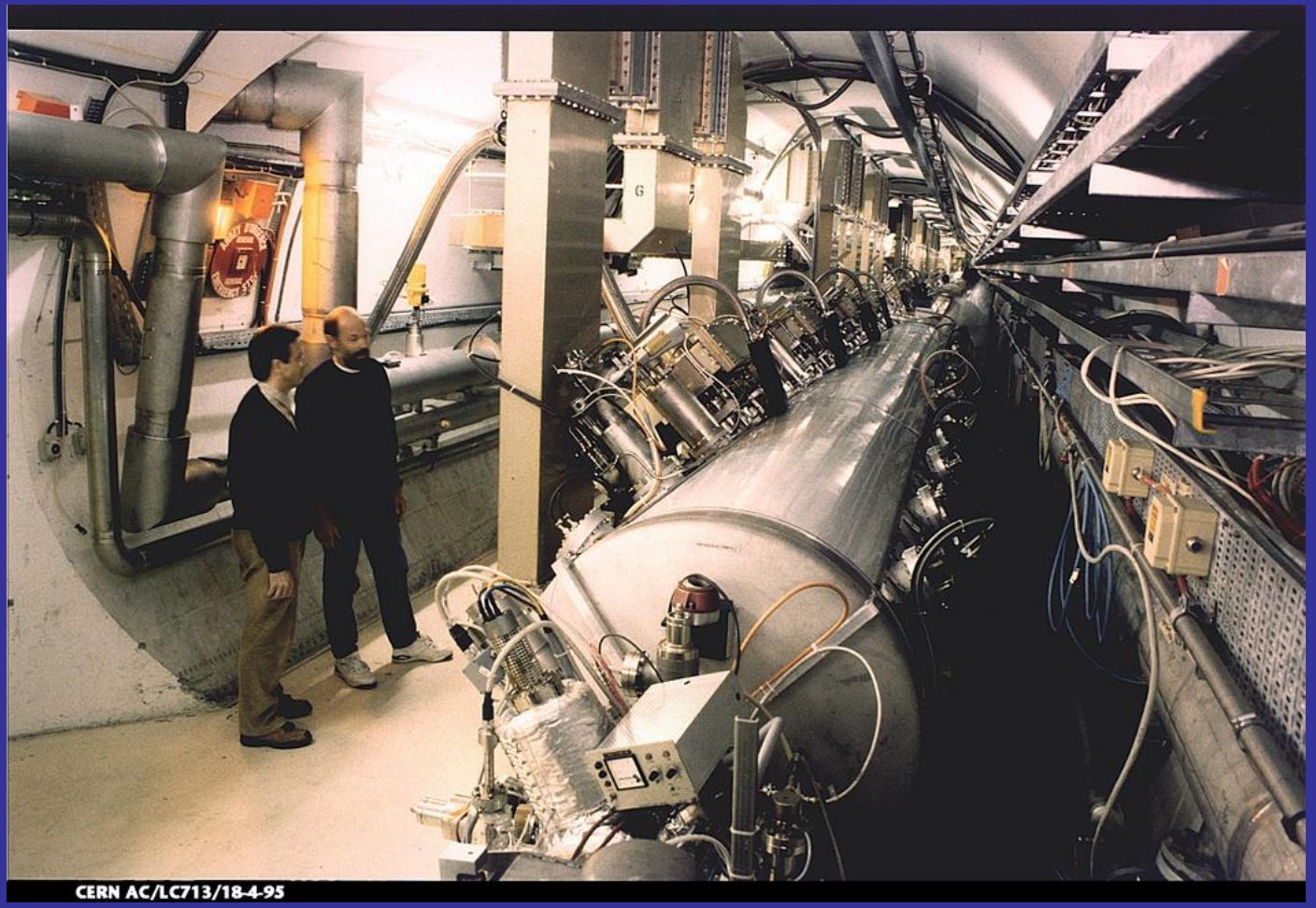


Medical Lighting

www.oerlikon.com/optics



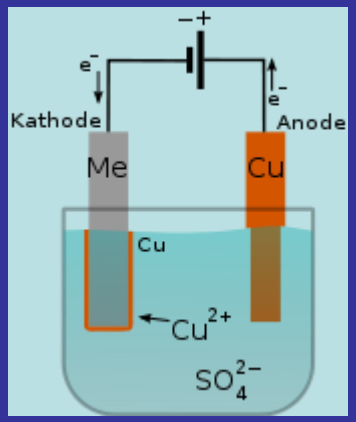

ACCELERATING
ELECTROMAGNETIC WAVE
SUPERCONDUCTING
ACCELERATING CAVITY
MADE OF NIOBIUM
LIQUID HELIUM
COOLED TO - 269° C


CERN AC/LC713/18-4-95

Hoe maken we coatingen

- Galvanisch,
- CVD ,

Silicium
Half-geleiders



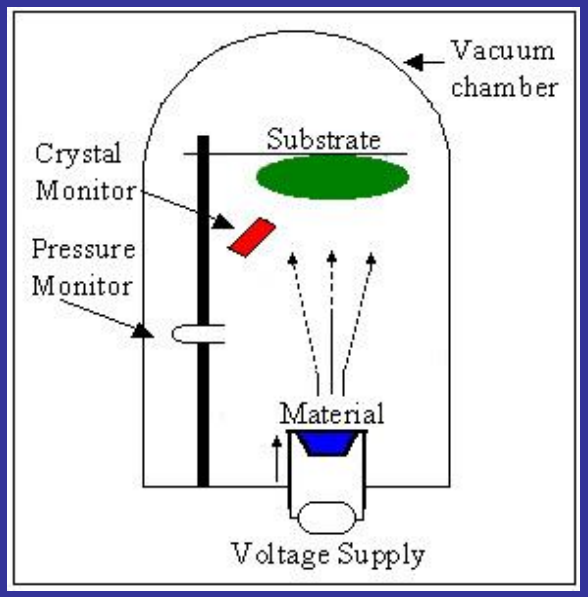
Redox-reactie

Toelichting:

- opdampen
- Plasma coaten

VACUUM

Thermisch opdampen

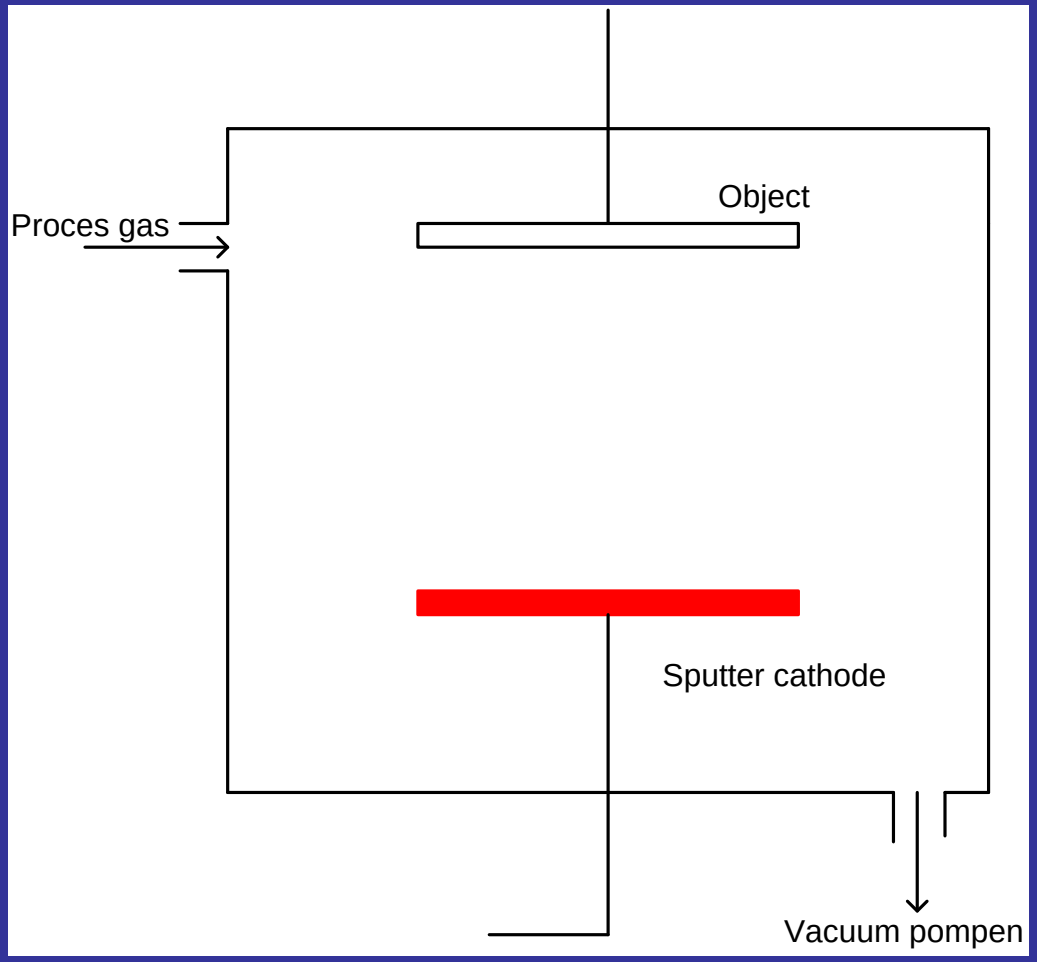


Opdampen: vaste stof → vloeibaar → damp

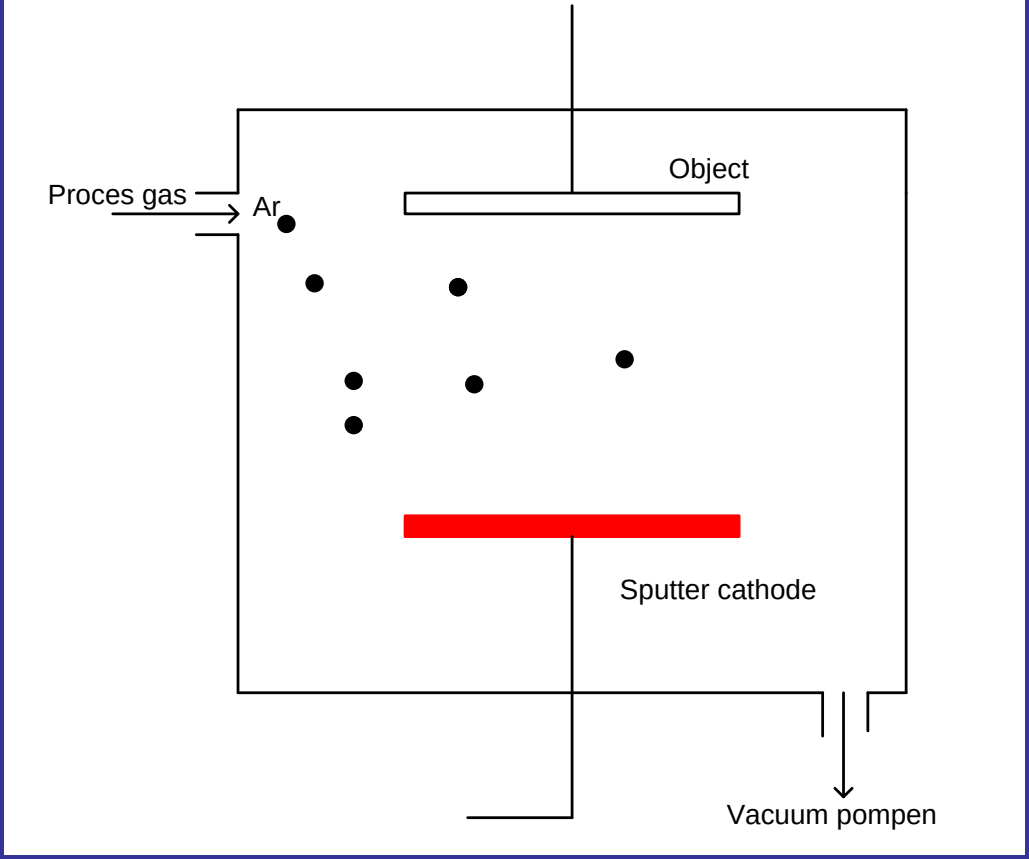
condensatie geeft coating

Waarom onder vacuum?

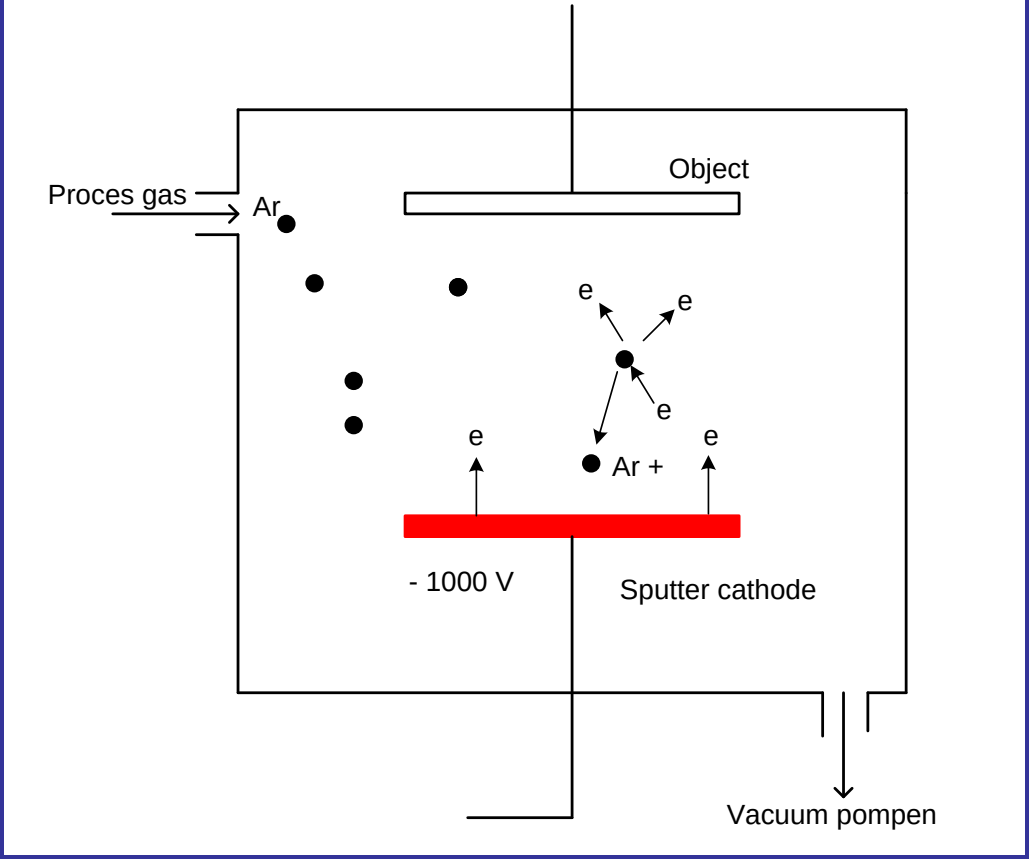
Plasma coaten (sputter process)



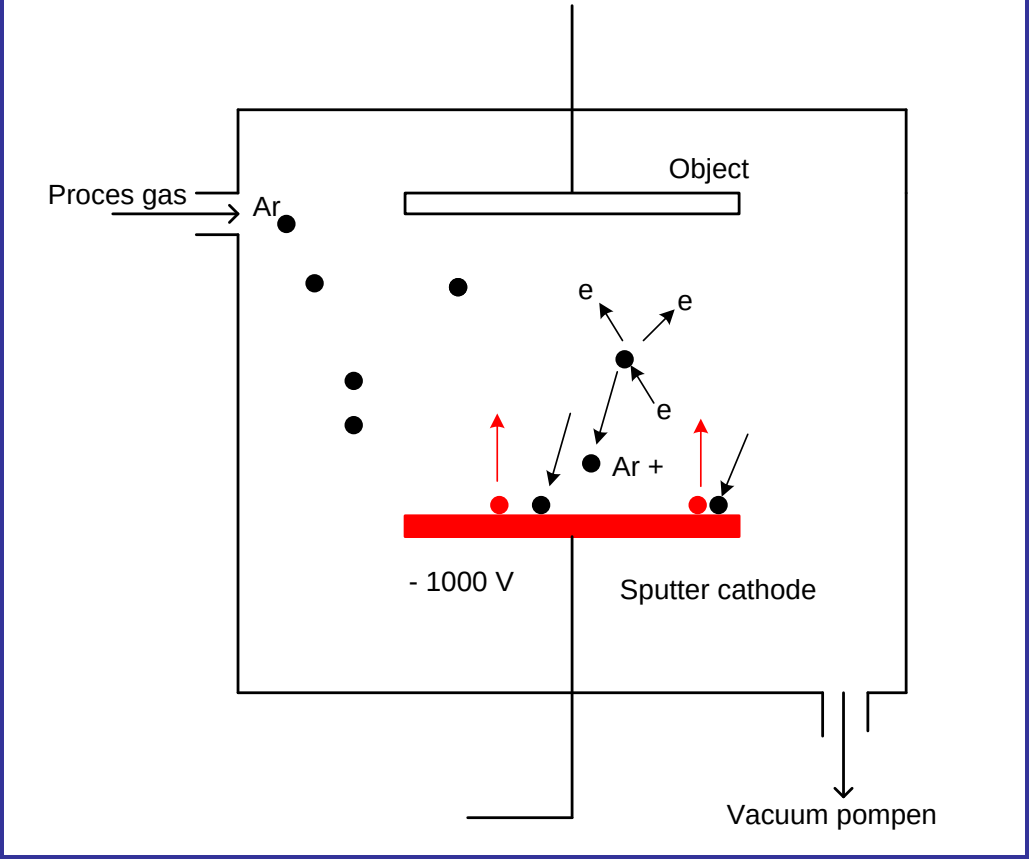
Plasma coaten (sputter process)



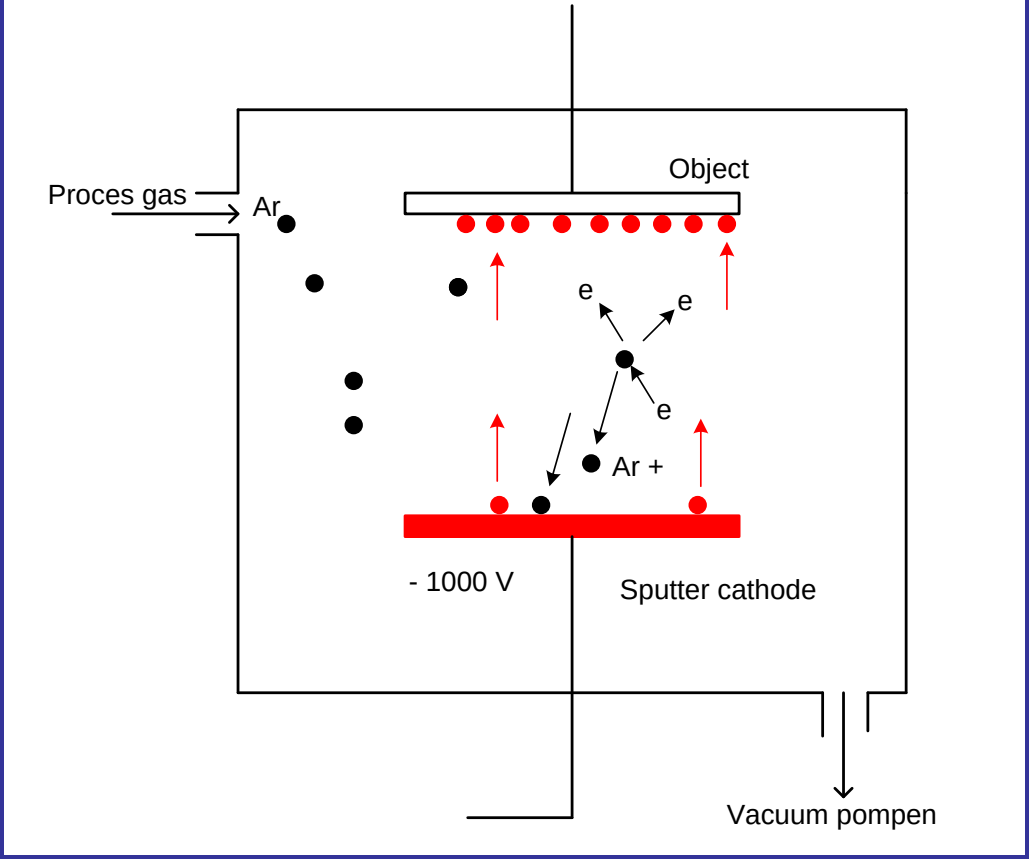
Plasma coaten (sputter process)



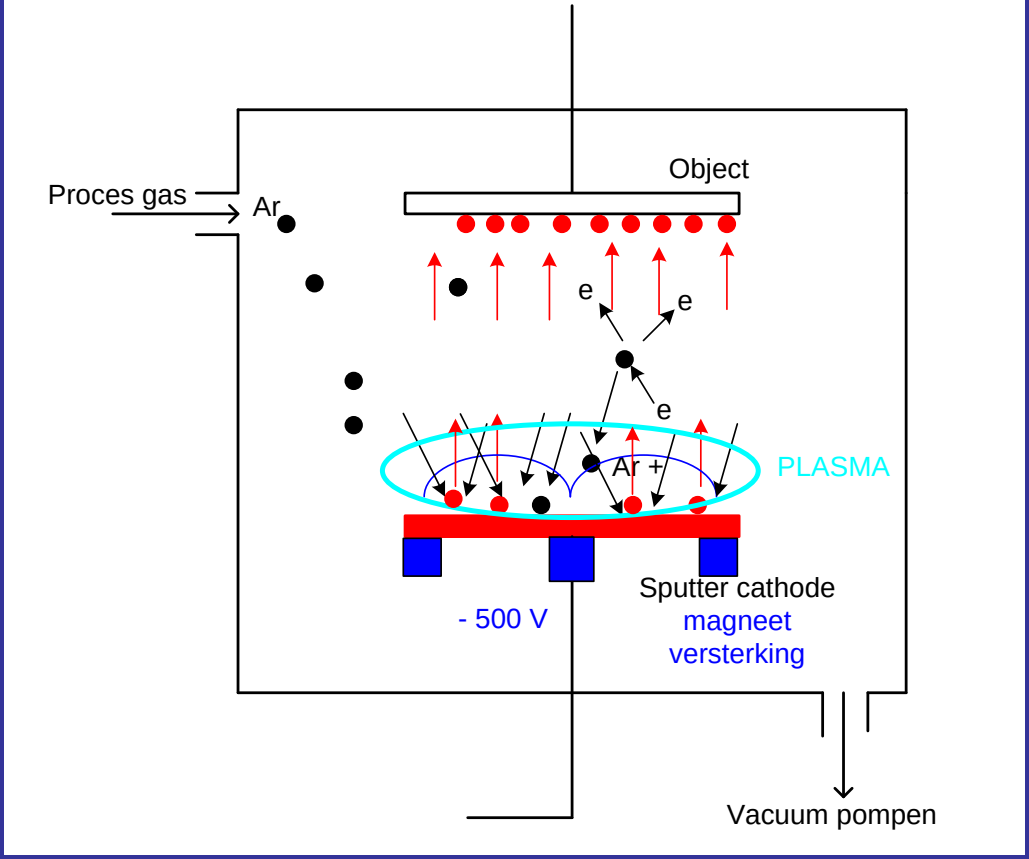
Plasma coaten (sputter process)



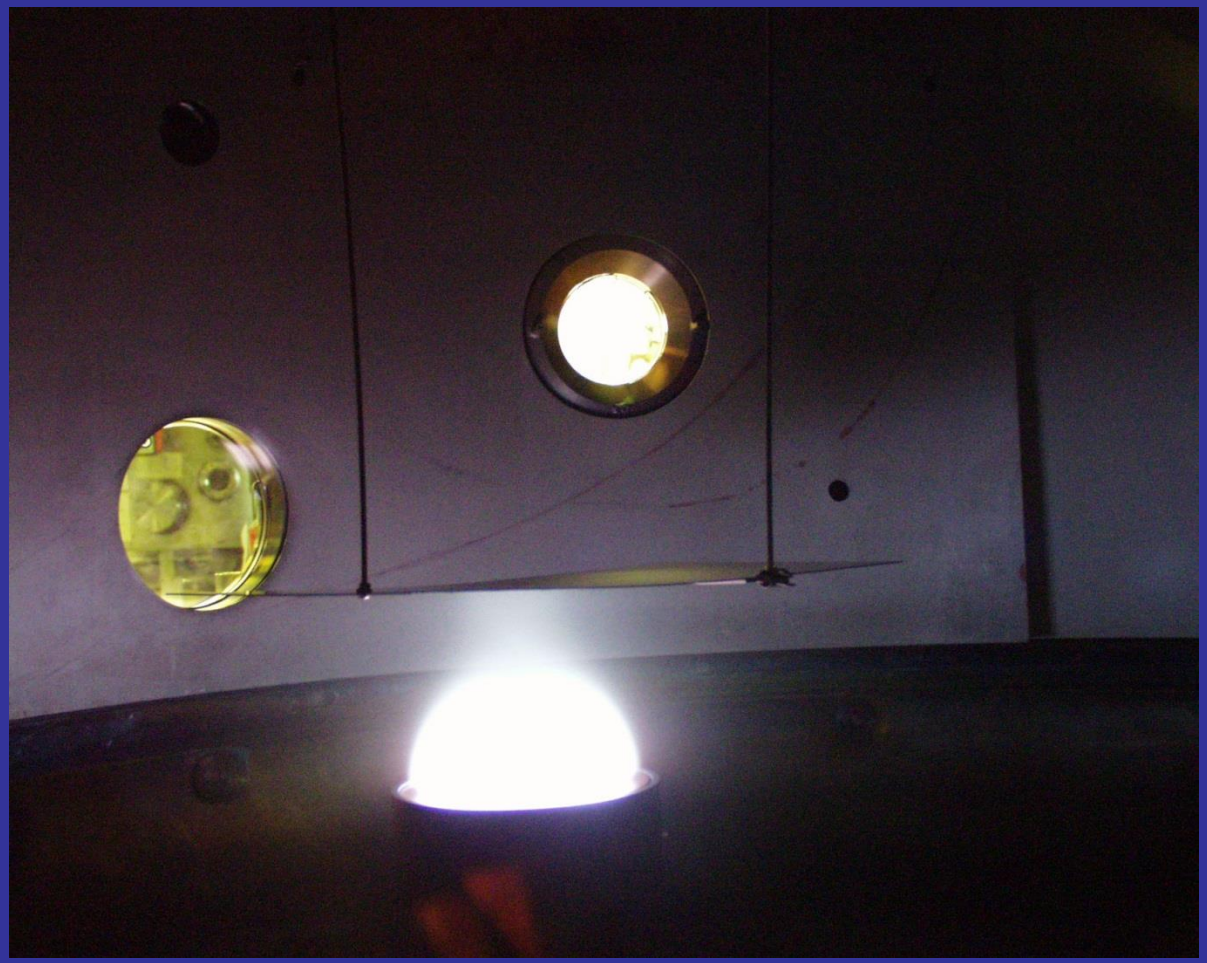
Plasma coaten (sputter process)



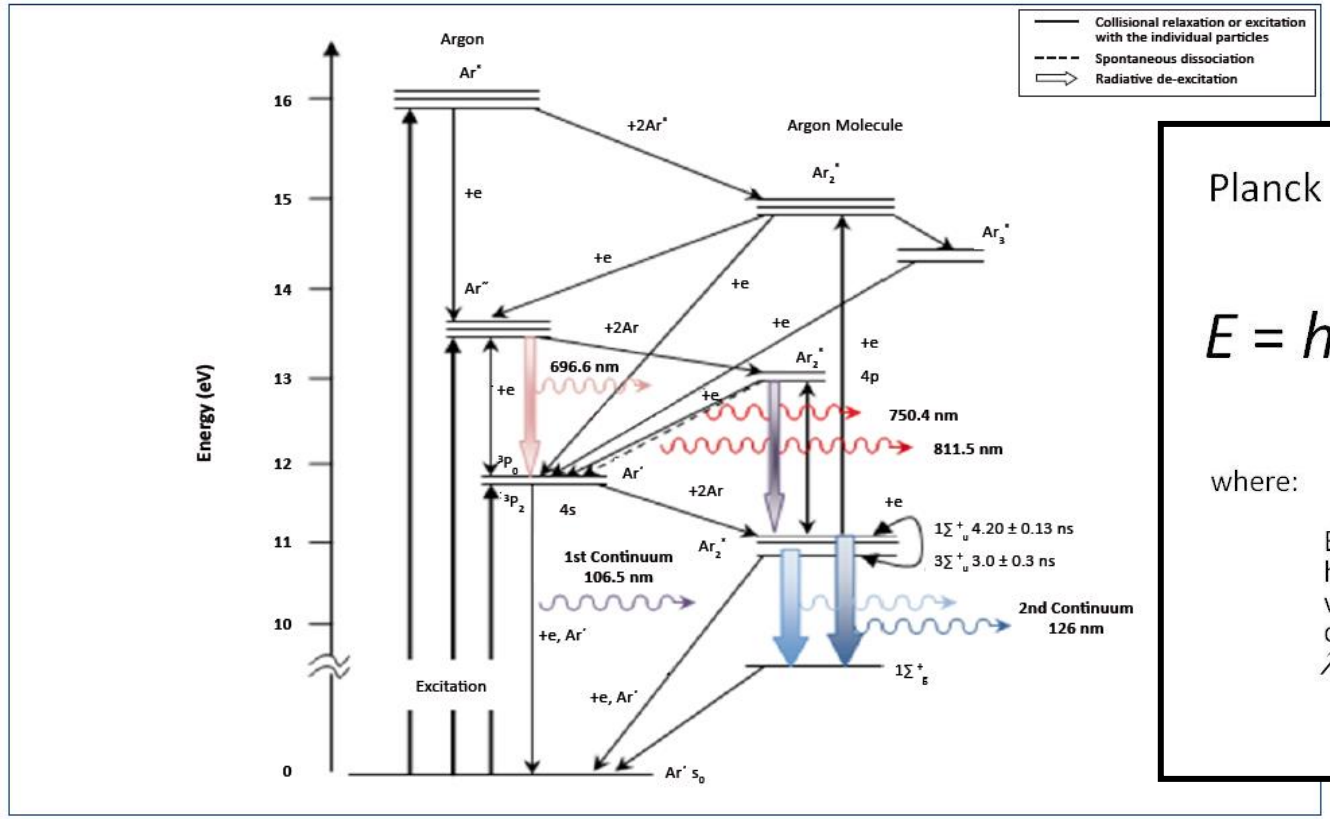
Plasma coaten (sputter process)
met magneet versterking



Plasma coaten (sputter process)
met magneet versterking



Aangeslagen toestand → foton emissie



The $3p^5 4s$ level is drawn as a doublet, with the non-metastable members ignored.

FIGURE 1: Energy level for atomic and molecular argon excited by a dielectric barrier discharge, showing transitions leading to the 126 nm, 750.4 nm and 811.5 nm emissions.

Planck relation:

$$E = h\nu = \frac{hc}{\lambda}$$

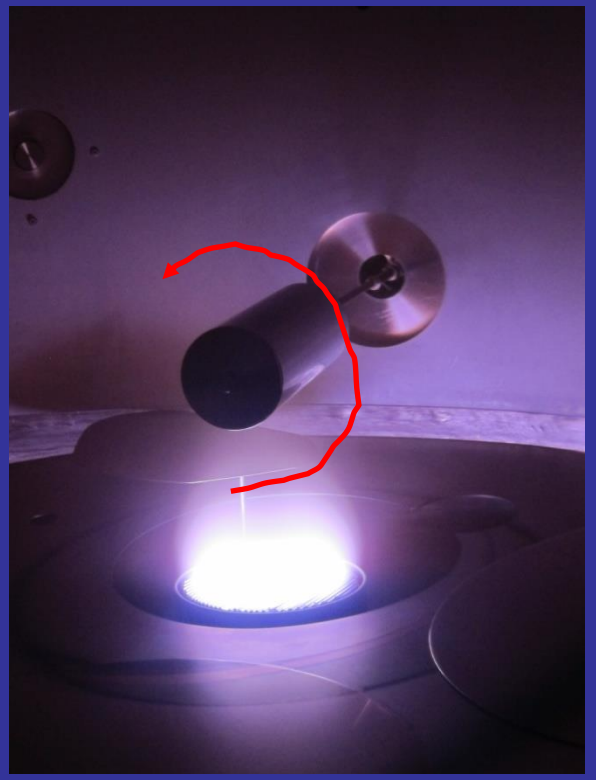
where:

E = energy
h = Plank constant
v = frequency
c = speed of light
λ = wavelength

Erosie van kathodes

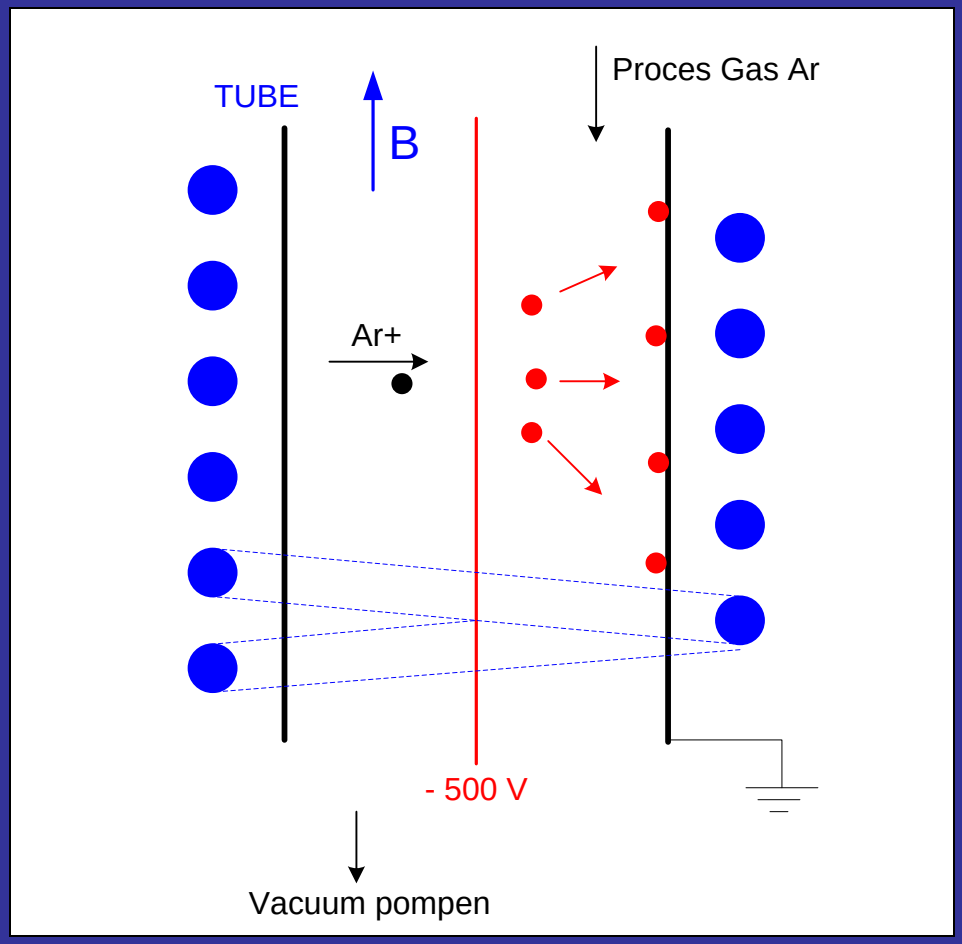
Niet vlakke objecten

3 D objecten



Uitwendig coaten van cylinder

Plasma coaten in cylindrische configuratie: coaten van binnenkant cylinder

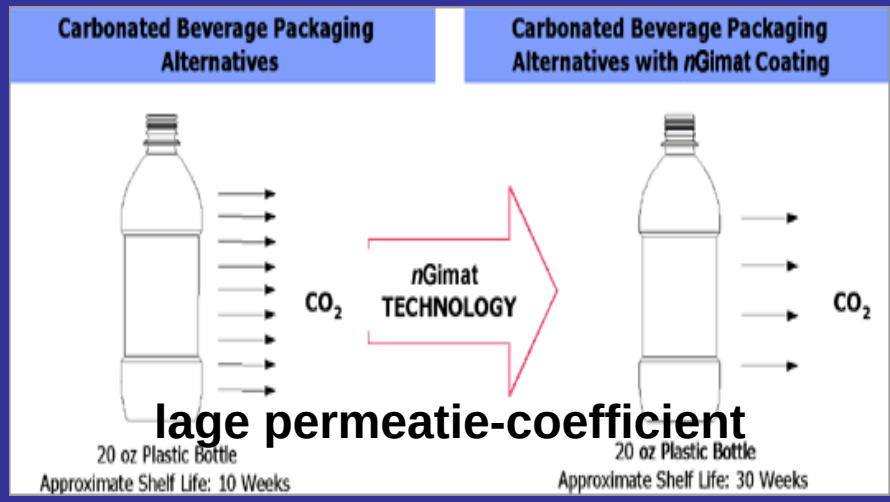


Voorbeelden van coatingen in industrie: WELKE EIGENSCHAPPEN?

Harde / slijtvaste coating

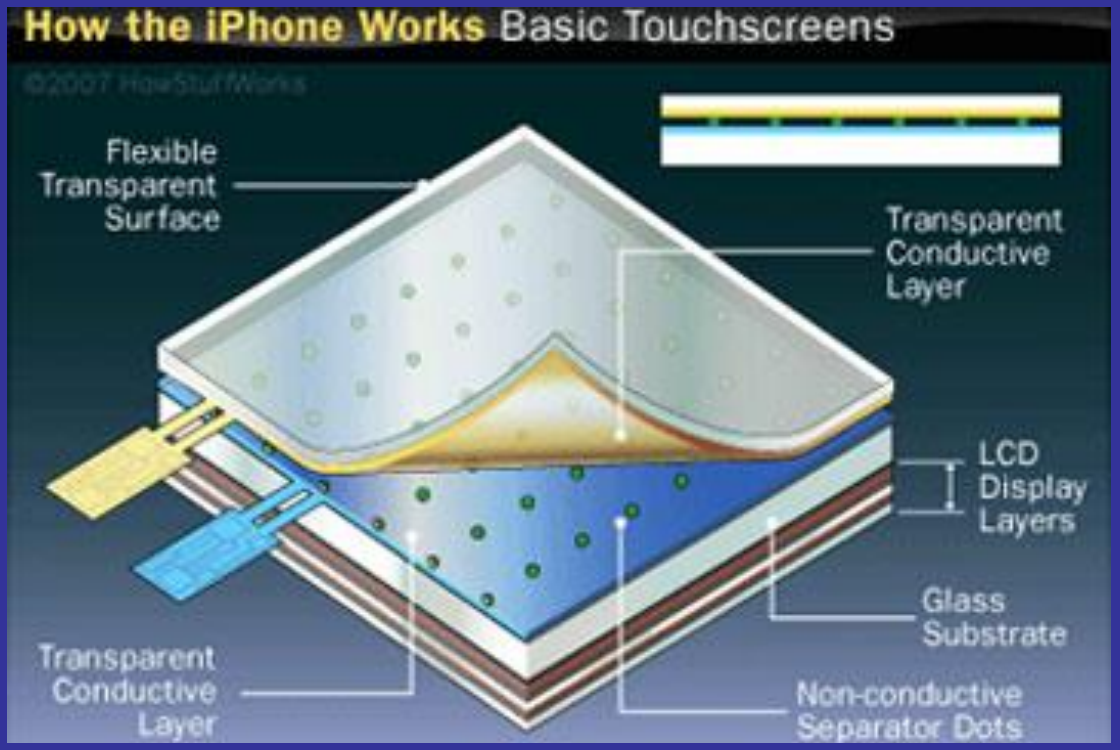
lage wrijvings-coefficient

lage transmissie



lage permeatie-coefficient

Voorbeelden van coatingen in industrie



Een ander toepassing op CERN :

NEG COATING: pompende coating

LHC: Beam pipe: Pressure < $1*10^{-11}$ mbar ($1*10^{-9}$ Pa)

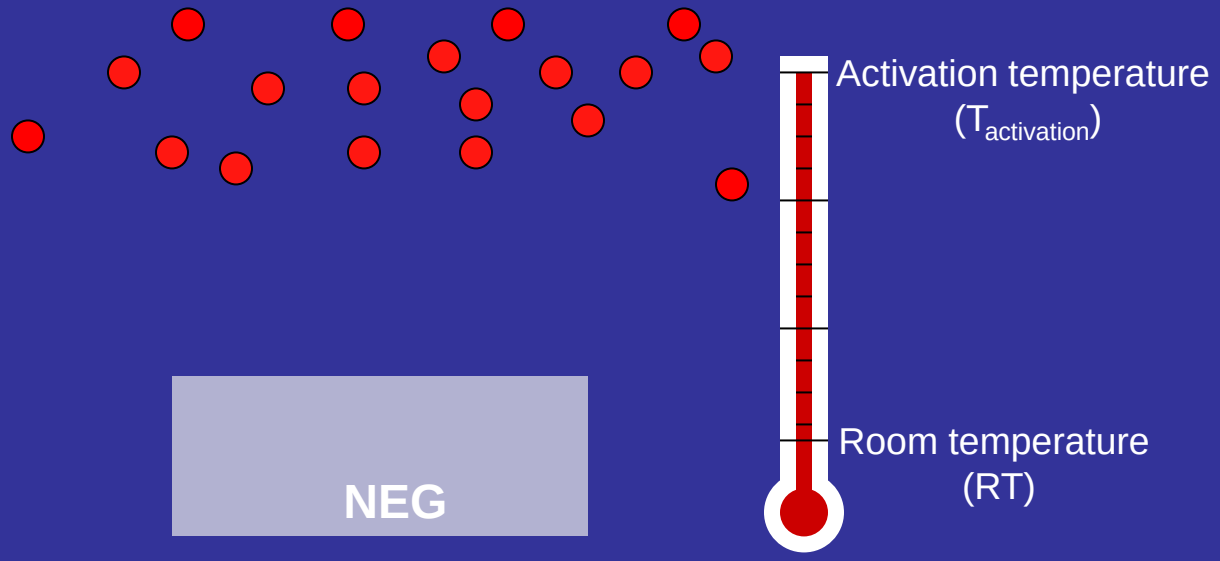
Materiaalkunde

What is a Non Evaporable Getter (NEG)?

A NEG material presents a reactive surface to some gas species, adsorbing (*gettering*) impinging molecules.

Once saturated, the *gettering* activity ceases and no more gas is pumped.

The NEG can than be regenerated by heating to its activation temperature during a certain time.

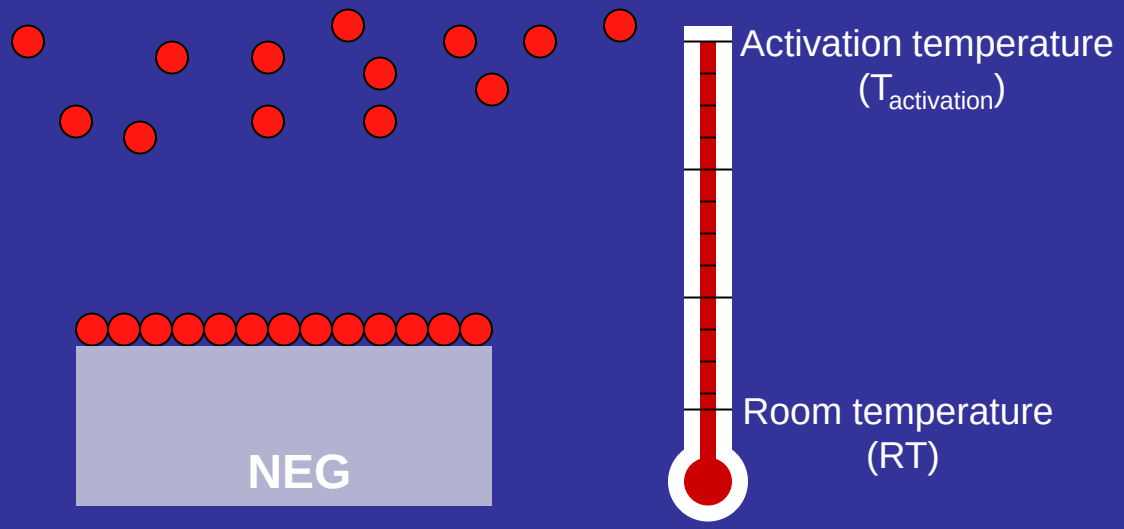


What is a Non Evaporable Getter (NEG)?

A NEG material presents a reactive surface to some gas species, adsorbing (*gettering*) impinging molecules.

Once saturated, the *gettering* activity ceases and no more gas is pumped.

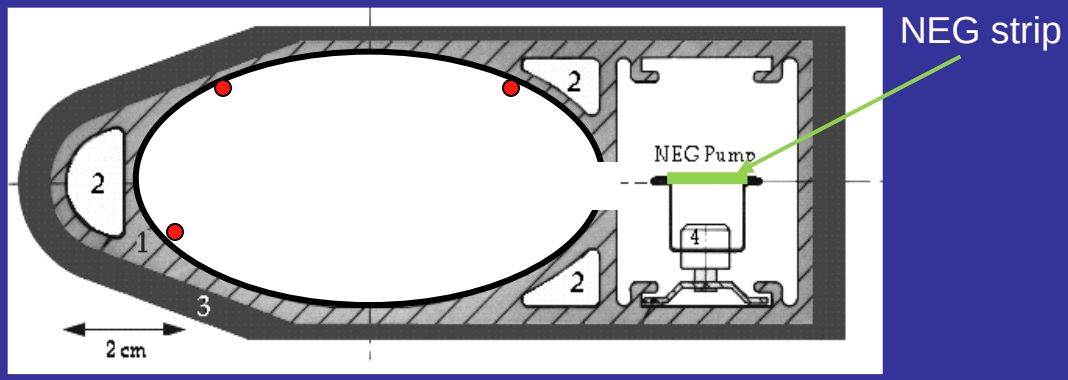
The NEG can than be regenerated by heating to its activation temperature during a certain time.



Back to room temperature (RT) the NEG recovers its pumping capabilities.

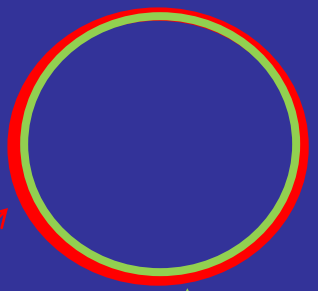
The solution was to integrate the vacuum pump in the beam pipes by inserting a strip of NEG. This NEG strip could be activated by resistive heating and pump molecules desorbed all along the beam pipe.

Cross section of the LEP dipole vacuum chamber

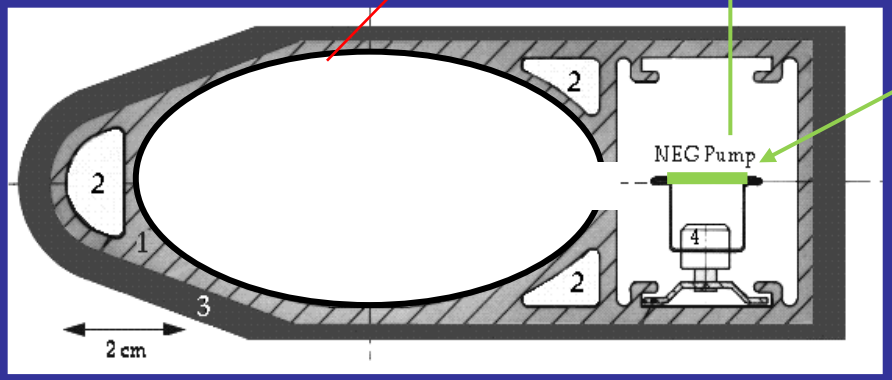


The solution was to integrate the vacuum pump in the beam pipes by inserting a strip of NEG. This NEG strip could be activated by resistive heating and pump molecules desorbed all along the beam pipe.

VOOR LHC



Cross section of the LEP dipole vacuum chamber



R & D

Research:

- legering met een “lage” activatie temperatuur.

De laagste activatie temperatuur is gevonden in een ruim gebied van composities met:

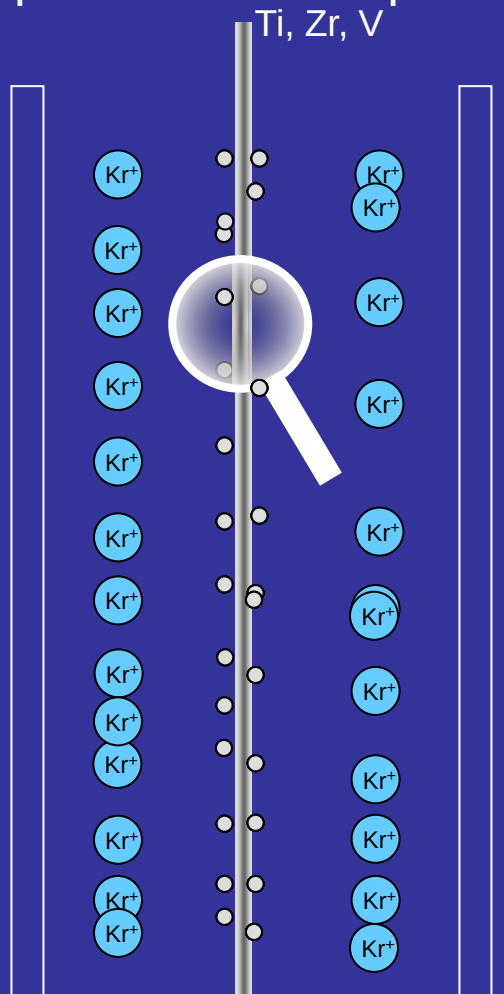
Titanium, Zirconium en Vanadium

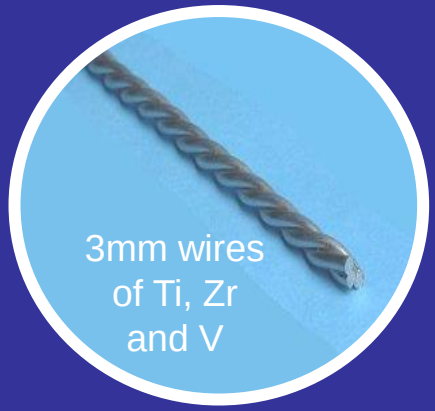
en is 180 ºC ; 24 uur

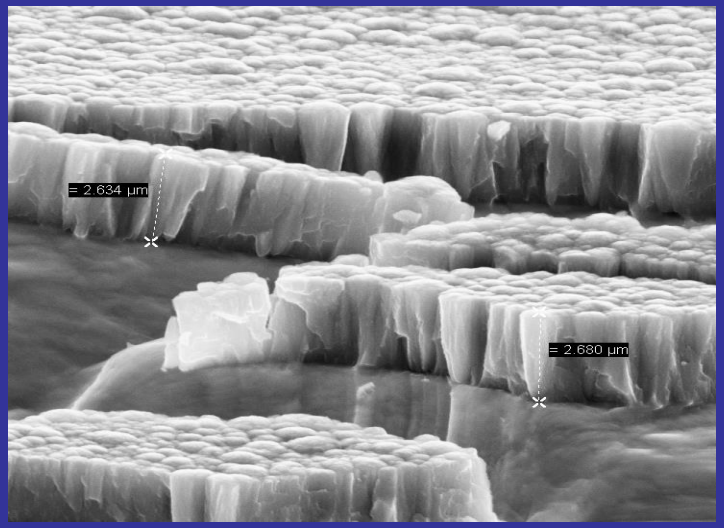
- onderzoek naar coating parameters (T , Power, Gasses)

- Lange termijn effecten (activatie cycli)

This NEG thin film is obtained by bombarding a target made of inter twisted wires of titanium, zirconium and vanadium, with ions. The atoms of the target are then sputtered and deposited in the beam pipe walls.







Totale project:

van Research tot installatie

10 jaar
5 mensen

Wat nu :LHC werkt

"upgrade" van LHC: diverse onderdelen

Onderdrukking van Electronen emissies van pijpwanden in voor versnellers (SPS: 1976 , 6.9 km)

R & D 2012-2016: aangetoond:

Koolstof coating

1. Introduction / Motivation; why?

The formation of electron clouds in particle accelerators.

Proton bunch (charge +)

Gas molecule

Electron (charge -)

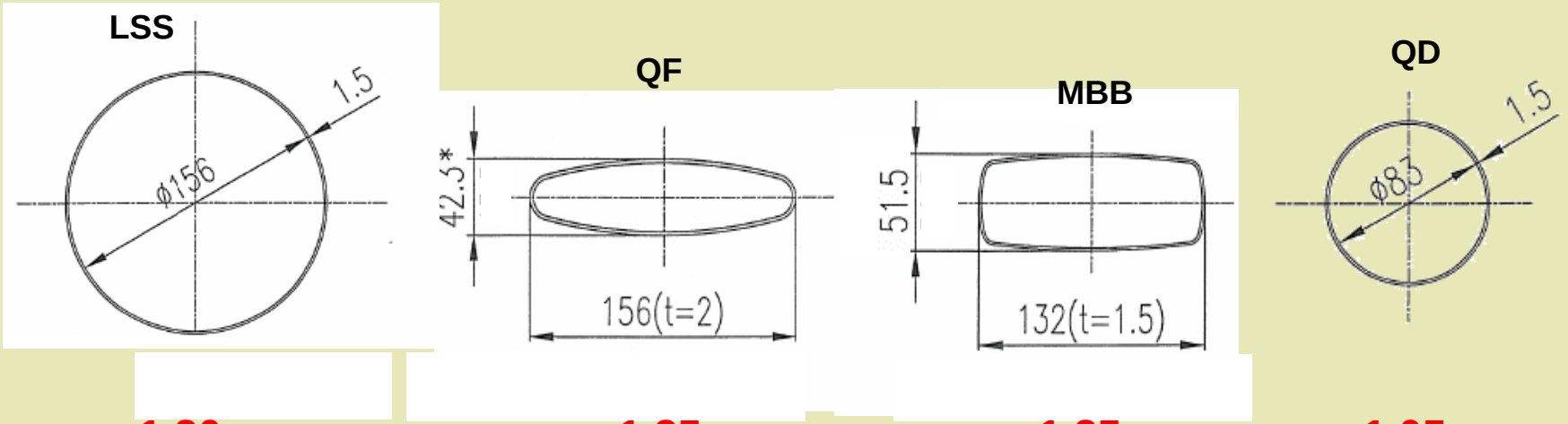
Secondary electron Yield (SEY) = $\frac{\text{Number of emitted electrons}}{\text{Number of impinging electrons}}$

1. Introduction / Motivation; why?

Threshold for SEY for e-cloud:

Depending of geometry, and energy

For SPS different geometries



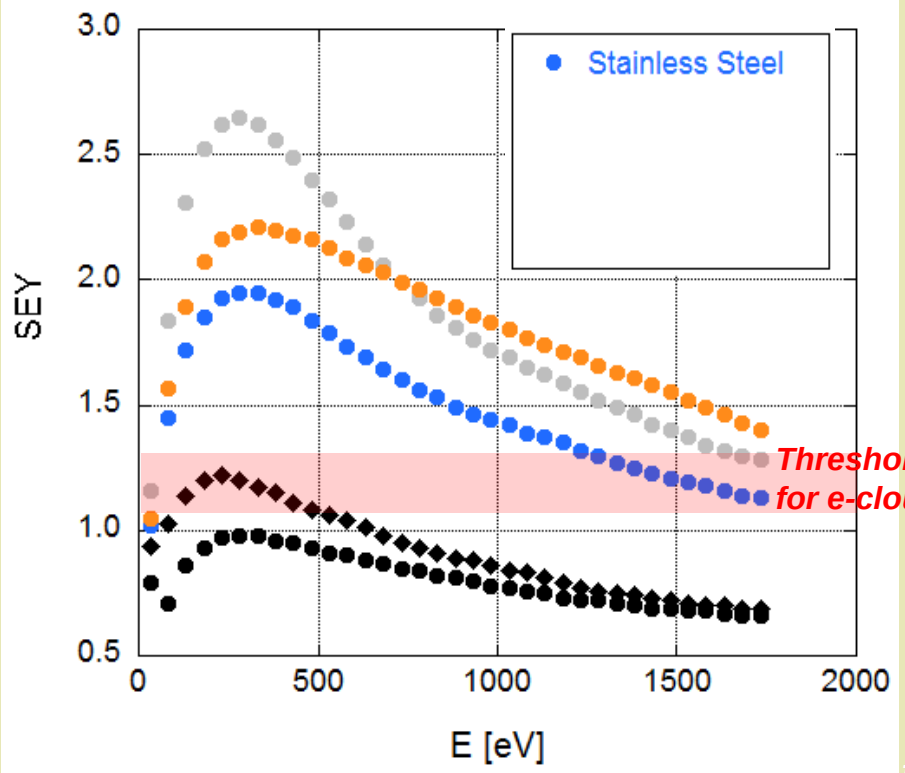
1.20 **1.25** **1.25** **1.05**

*: Giovanni Iadarola: LIU SPS scrubbing review; 8-9 September 2015, values for “worst” case scenario

2. Method: How?

Development of carbon coatings (from 2007)

Why carbon? → **Graphite has a low SEY (secondary electron yield)**



Alternatives:

- **Clearing electrodes**
- **LESS**

(Laser Engineered Surface Structures)

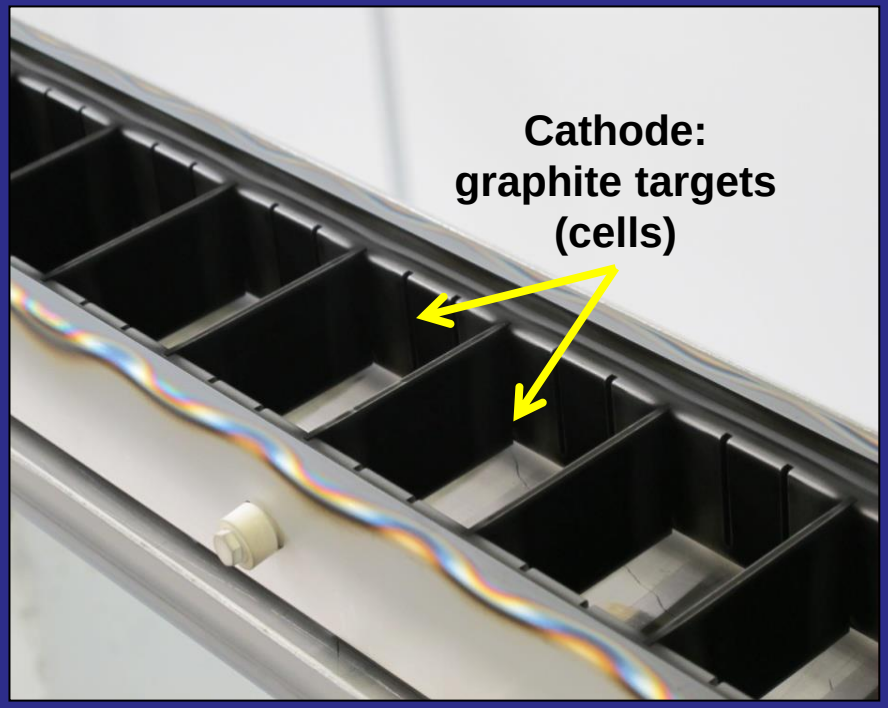
Threshold for e-cloud

Ontwikkeling van Carbon coatings in vacuum pijp

Test opstelling in lab: 2013-2016

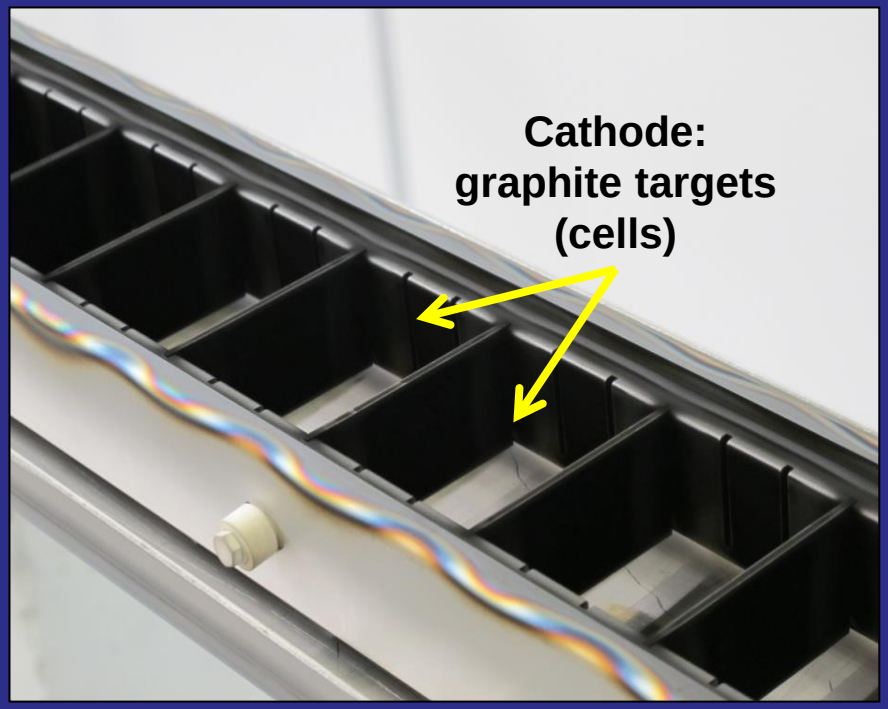
Ontwikkeling van Carbon coatings in vacuum pijp

Test opstelling in lab: 2013-2016



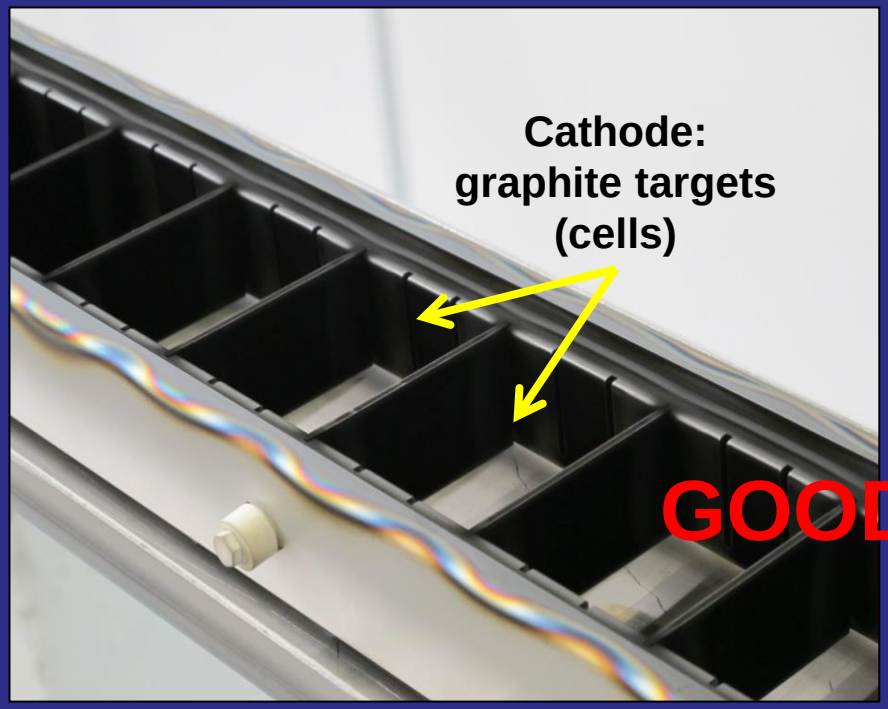
Ontwikkeling van Carbon coatings in vacuum pijp

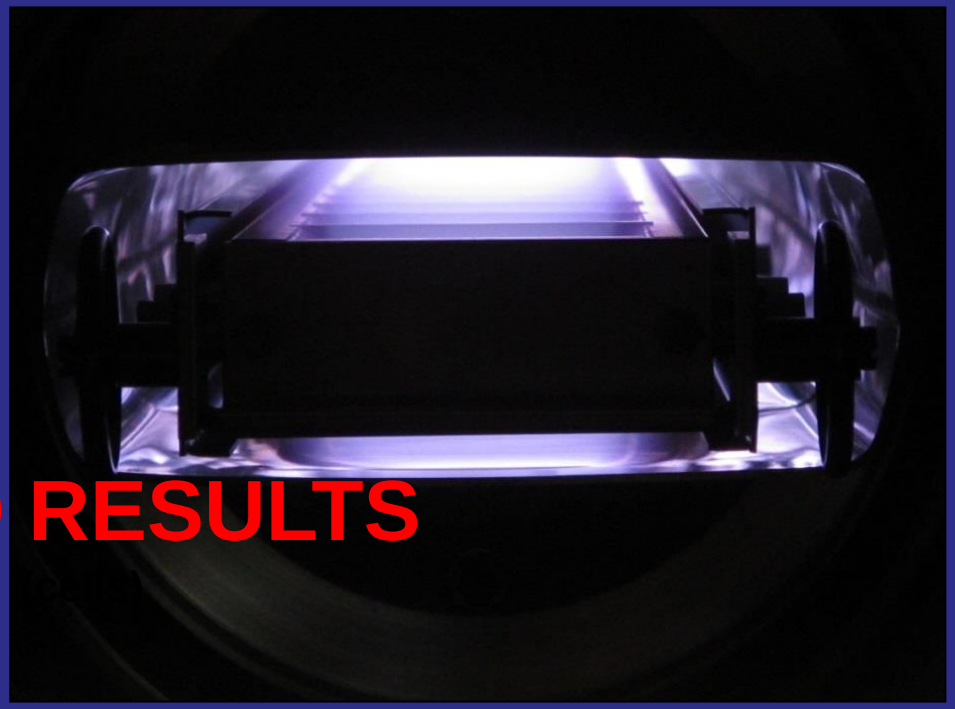
Test opstelling in lab: 2013-2016



Ontwikkeling van Carbon coatings in vacuum pijp

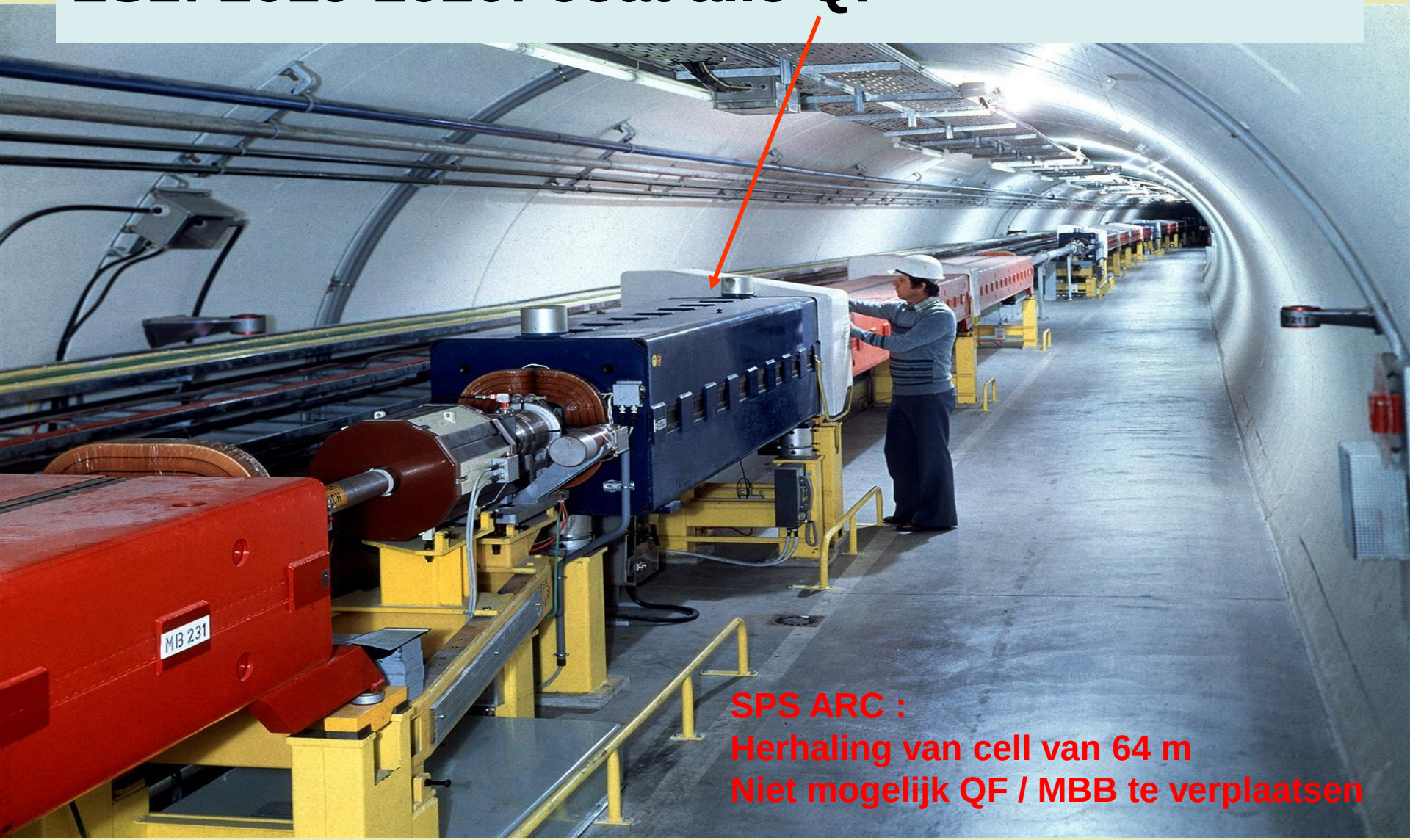
Test opstelling in lab: 2013-2016



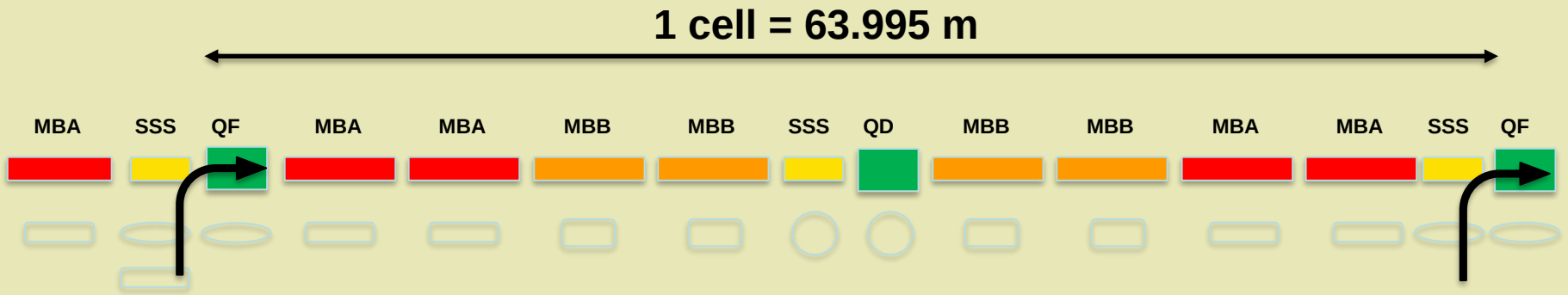


GOOD RESULTS

LS2: 2019-2020: coat alle QF



LS2: coating of alle QF + small magnets



Coating lab in surface building

+ drifts to 181

Insitu Carbon coatings in SPS

2017/2018 TEST:

11 MBB

9 QF

LS2, 2019-2020:

- 88 QF
- 102 magn. in lab.

SPS operationeel sinds 2022: goede resultaten mbt electronen-wolk reductie