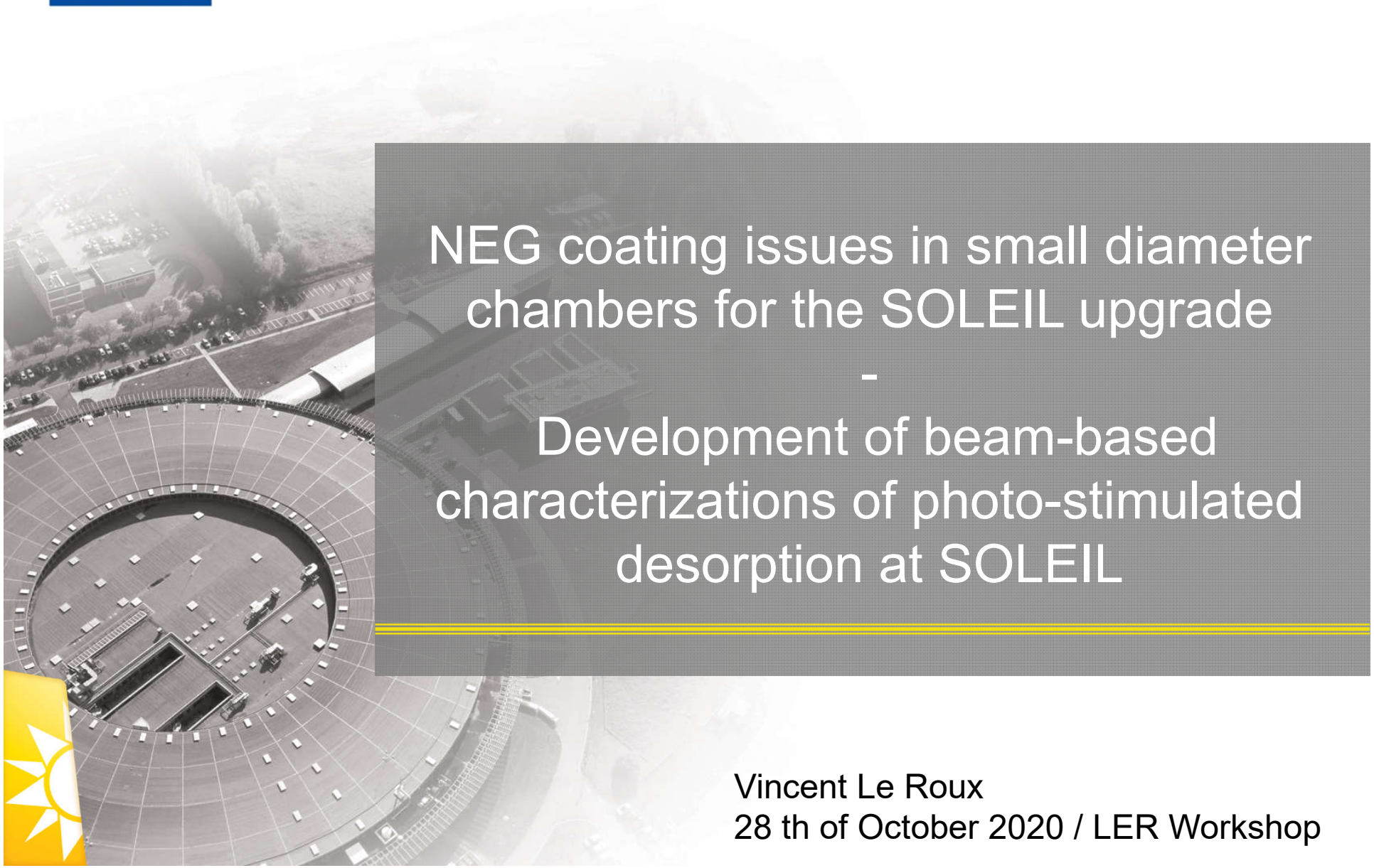


NEG coating issues in small diameter chambers for the SOLEIL upgrade
-
Development of beam-based characterizations of photo-stimulated desorption at SOLEIL

Vincent Le Roux
28 th of October 2020 / LER Workshop

INTRODUCTION

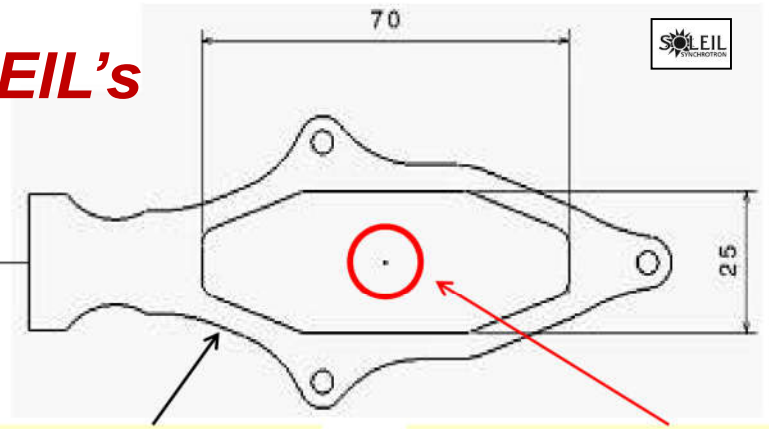
SOLEIL UPGRADE
Vacuum System performance requirements

- **Vacuum** : < 10^{-9} mbar @ 500 mA - Integrated dose 100 A.h
- **Heat Load Management** : Power Handling / Heat dissipation of Bending Magnets - Insertion Device Radiation
- **Low Impedance Budget design** :
  - Geometric effects : lowering gaps/steps/transitions, RF bellows
  - Resistive wall effects: surfaces roughness/resistivity

ONE Main Key Feature for SOLEIL's Upgrade lattice

Drastic reduction of the size of the vacuum chambers

10 mm Int. Diam. chambers
(not only on straight section)



INTRODUCTION

SOLEIL, MAX IV and SIRIUS opened up the way :

'NEG coating can be extensively used and *Pumping in conductance limited system can be partly compensated with* ***NEG coating***'

SOLEIL Upgrade will push this trend to a new limit:

→ Vacuum level and quality mostly « NEG dependant »
→ Only few discrete standard pumping (SIP…)

Vacuum pressure profile along the lattice will rely on the NEG performances

- Sticking factors
- Saturation threshold (sorption capacity)
- « Dynamic pumping » under SR irradiation
  (balance between pumping and PSD)

NEG issues for the Pre-conception strategy

Vacuum System Main Features and Targets

- Full distributed **Ti-Zr-V NEG coating / 1 µm** average thickness
- **Ex-situ bakeout** to protect the permanent magnets of the lattice and simplify the initial conception. Back-up by "**Neon venting**" for vacuum intervention which preserves NEG activation.
- Extensive use of Cu-OFS (Ag-0,02/0,12 %) for chambers/absorbers
  → combination of mechanical, magnetic, conductive and thermal properties
- Direct power absorption of Dipole photons along the vessels walls

Strategy

- Development of NEG coating characterization ***@ SOLEIL***
  - 2 **Transmission Factor** test benches: sticking factor, sorption capacity
  - 1 **PSD measurements** Beamline on the D08-1 photon exit
- Collaboration for NEG coating in "small tubes" (< ∅ 20 mm) :
  - **SAES Getter / SOLEIL** *[CONV-19-014]*
    "downscaling the NEG coating properties with or without SR beams"
  - **Berkeley Lab (ALS) / SOLEIL** *[CV-20-012]*
    "PSD studies of ∅ 6 mm NEG-coated tubes"

BACKGROUND

Few milestones …

CERN – ESRF

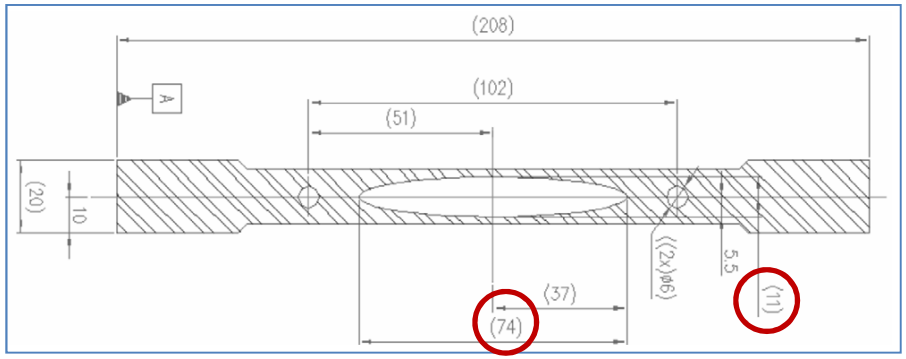
- Early work of C. Benvenuti / P. Chiggiato on NEG thin films : « end of the 90's »

*C. Benvenuti, P. Chiggiato, **J. Vac. Sci. Technol. A 16** (1) Jan/Feb 1998*

*C. Benvenuti et al. / **Vacuum 53** (1999) 219—225*

- Development of NEG coating for Synchrotron: "**ID chambers**" for ESRF

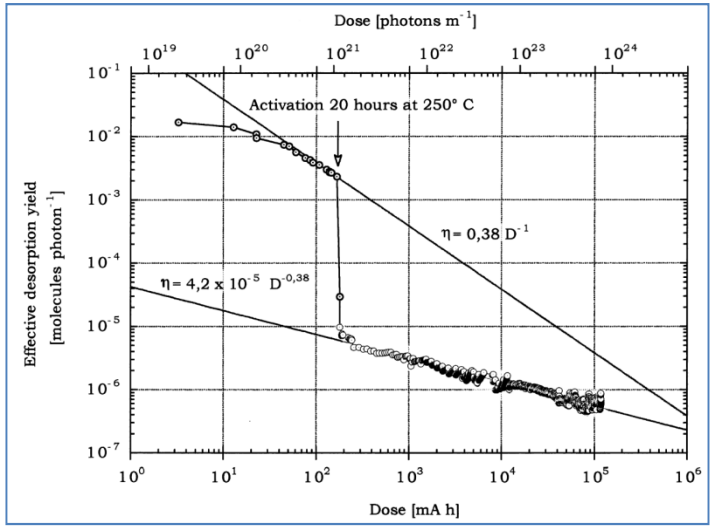
*R. Kersevan, **Proc. EPAC-2000** Conference, Vienna, June 2000, page 2289-2291*



ESRF chamber CV5073
(L=5073 mm, 11 mm x 74 mm)

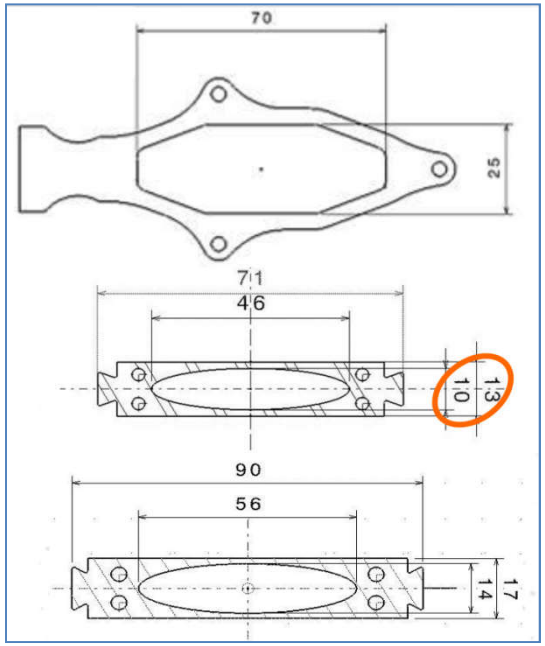
- First *PSD* studies on NEG-coated chambers (Ti-Zr-V)

*P. Chiggiato, R. Kersevan / **Vacuum 60** (2001) 67-72*



BACKGROUND

Few milestones …



SOLEIL

First extensive use of NEG coating (TiZrV)
All the straight vessels (Q/S-pole + ID)
56 % of the ring circumference

C. Herbeaux , N. Béchu, J-M. Filhol
***Proceedings of EPAC08**, Genoa, Italy (**2008**)*

MAX IV

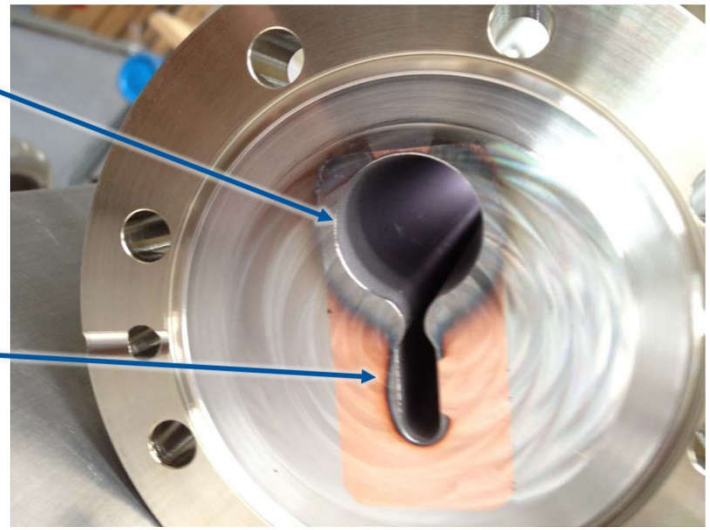
"Full" NEG-coated ring (TiZrV)
"Chamber walls as distributed absorbers "

Al-Dmour, E., Ahlback, J., Einfeld, D., Tavares, P. F. & Grabski, M.
J. Synchrotron Rad. 21, 878–883. (2014)

*S. Calatroni, P. Chiggiato, P. Costa Pinto, M. Taborelli, **CERN**, M. Grabski, J. Ahlbäck, E. Al-Dmour, P. Fernandes Tavares, **MAX IV***

Electron chambers:
- ID22 mm
- L=300 (435) mm
- Pressure 0.06 mbar
- Magnetic field 180 Gauss
- Power Density 25 W/m

Photon chambers:
- From 6x11 mm to 7x34 mm
- L=300 (435) mm
- Pressure 0.66 mbar
- Magnetic field 500 Gauss
- Power Density 25 W/m



Proceedings of IPAC2013, Shanghai, China (2013)

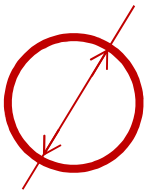
BACKGROUND

Few milestones …

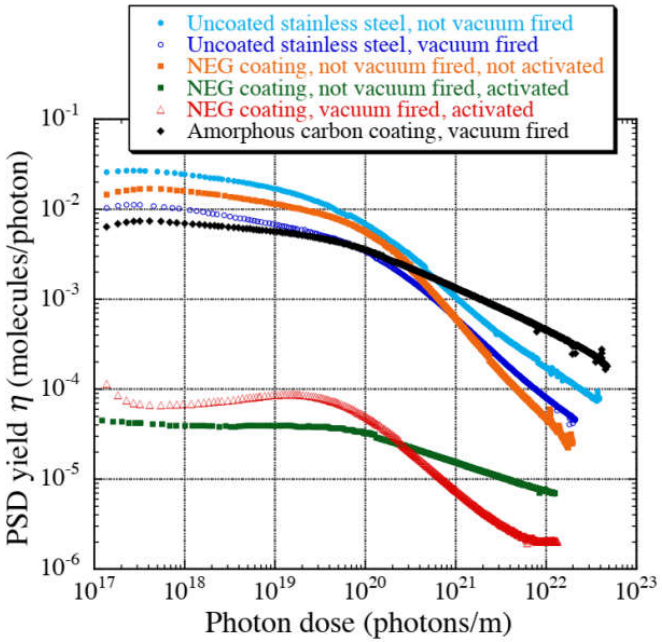
CERN – KEK

Extensive studies of PSD and secondary electron yields on NEG-coated chambers (TiZrV)

*M. Ady, P. Chiggiato, R. Kersevan, **CERN**,*
*Y. Tanimoto, T. Honda, **KEK***
***IPAC2015**, Richmond, VA, USA (**2015**)*
+
"Vacuum Properties of NEG and Carbon Coatings Exposed to Synchrotron Radiation "
***"VSC Seminar"**, CERN, 25 September 2015*



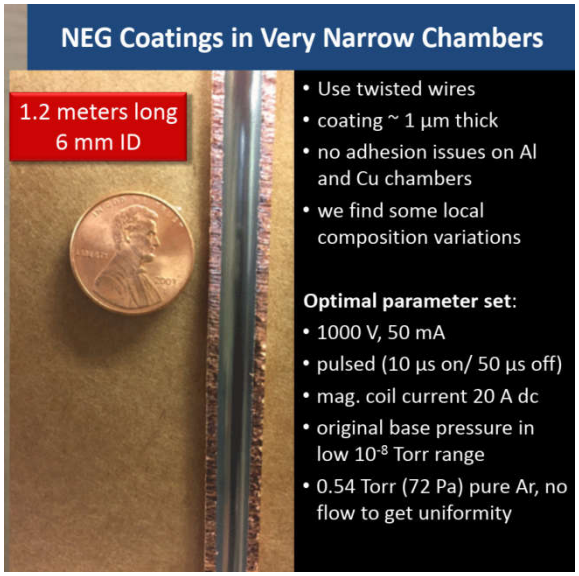
61 mm Int. Dia.



ALS-U

NEG coatings in very narrow chambers, **ID 6 mm**

André Anders, Csaba Toth, Yuchen Yang, Charles Swenson,
Thomas Oliver, Christoph Steier, Wim Leemans
***80th IUVSTA Workshop,** NSRRC, Hsinchu, Taiwan (2016)*



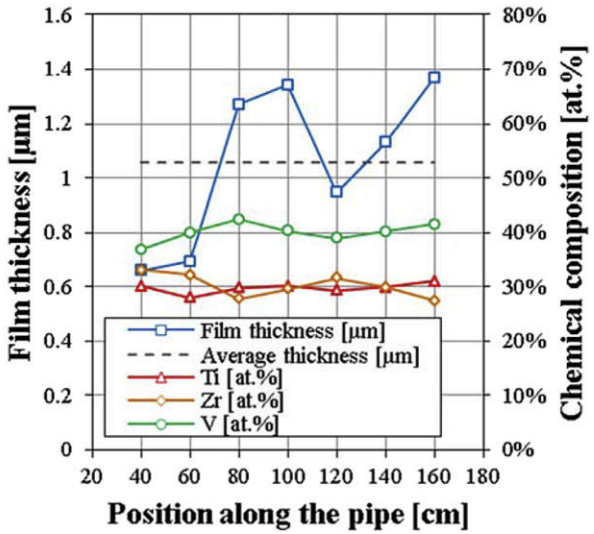
BACKGROUND

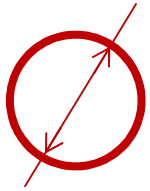
Few milestones …

SAES Getter S.p.A

NEG coating in ID 10 mm, 8 mm, 6 mm… 4 mm

*T. Porcelli et al. / **Vacuum 138** (2017) 157-164*



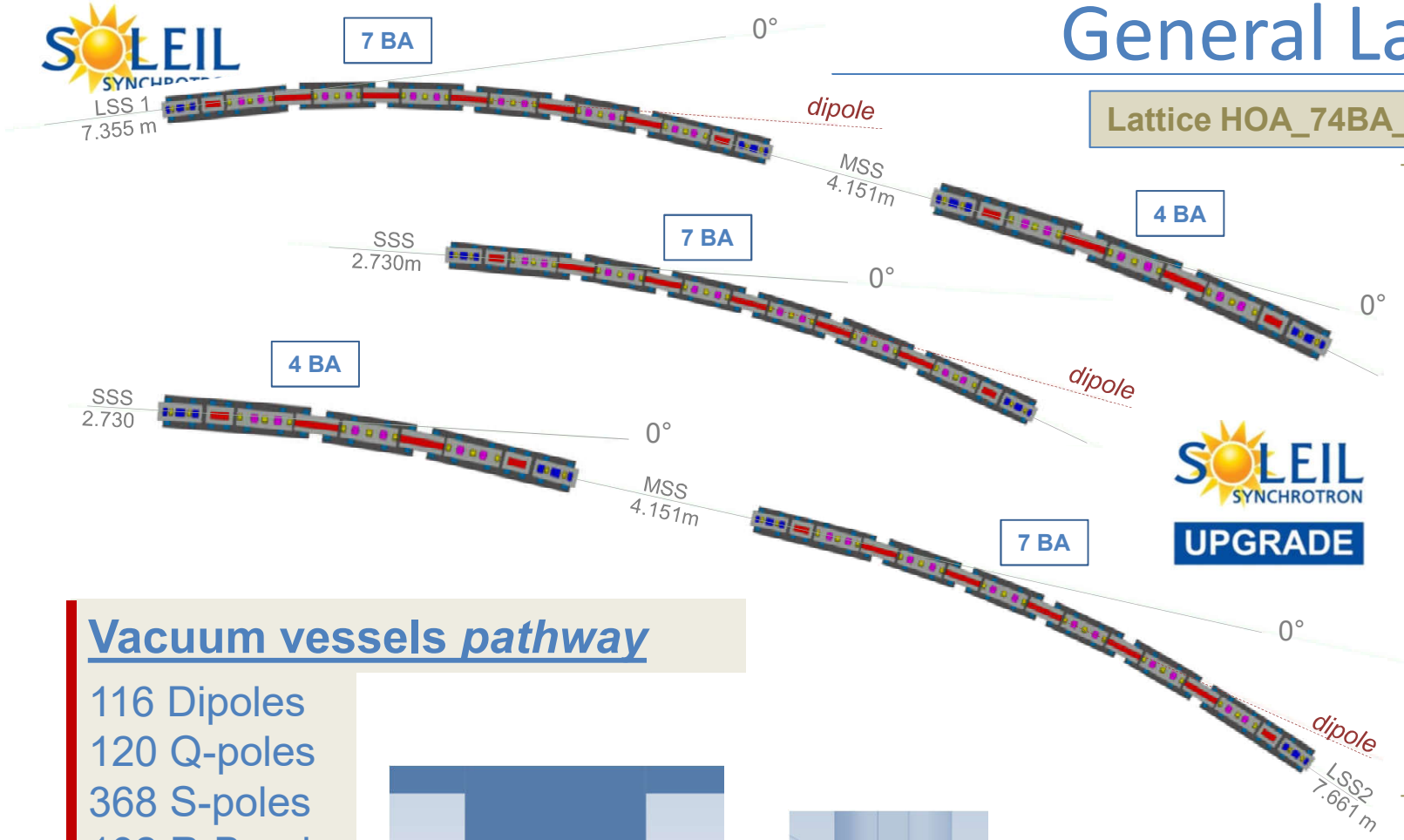


10 mm Internal Diameter

For NEG coating in small tubes, **we need data** on their pumping characteristic (*Sticking, Sorption Capacity*) and behavior under photon beam irradiation (*PSD, "dynamic pumping"*)

General Lay-out

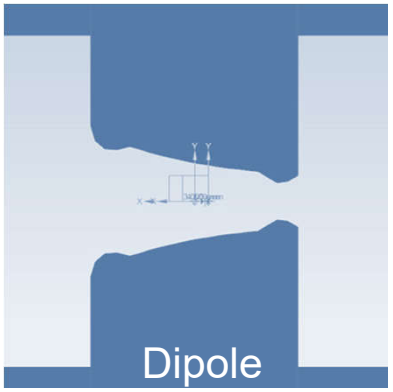
Lattice HOA_74BA_SYM4_V0313

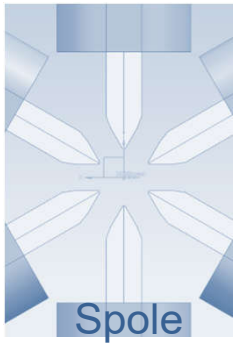


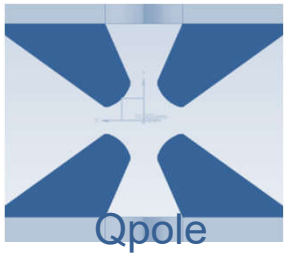
Vacuum vessels *pathway*

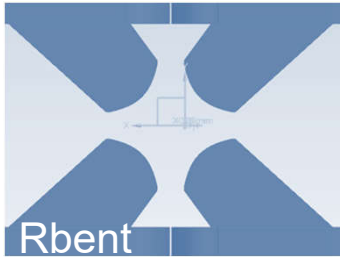
116 Dipoles
120 Q-poles
368 S-poles
192 R-Bends
176 O-poles

Minimum Magnetic Bore of 16 mm



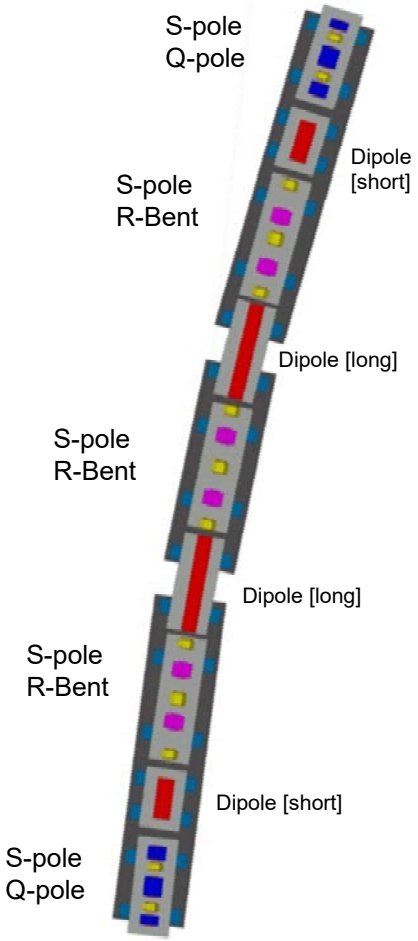


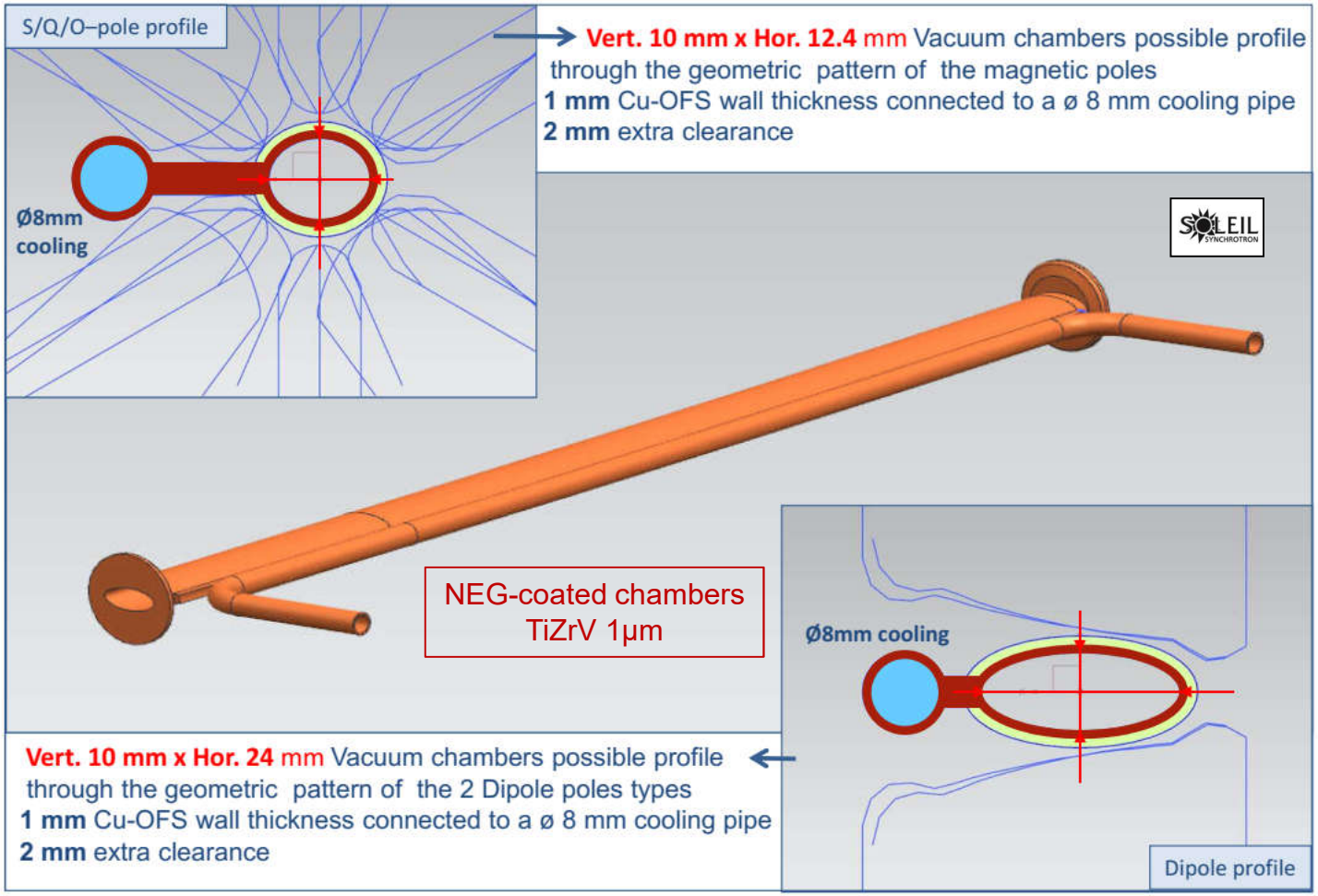




Vacuum chamber pre-design

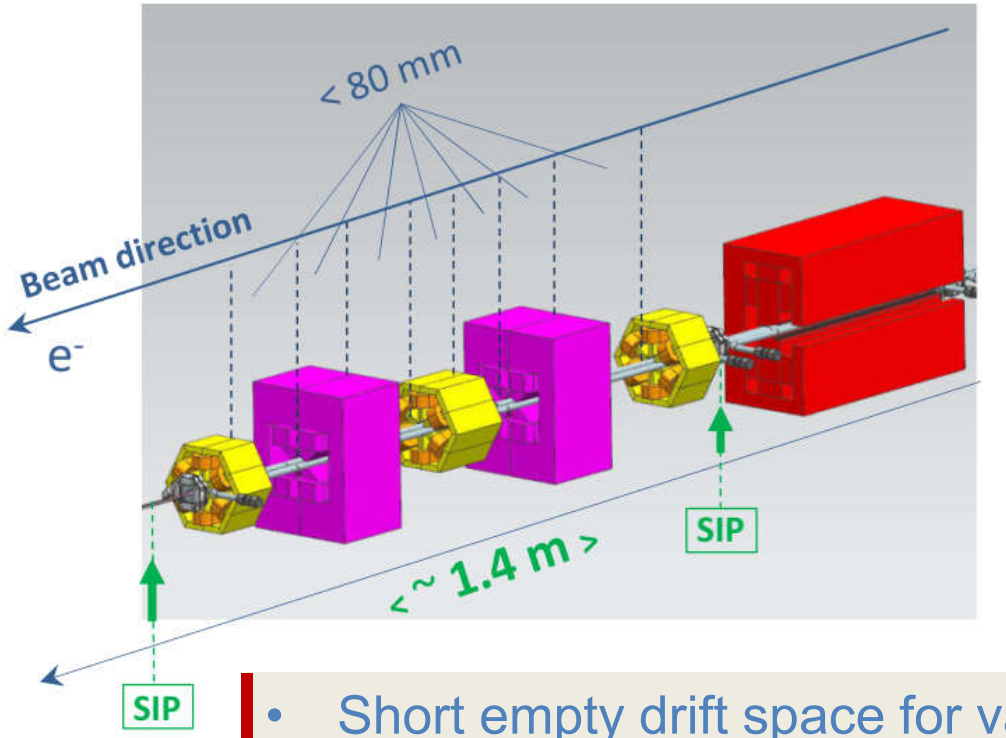
2 generic shapes with distributed cooling





for **7 BA** or **4 BA**

Vacuum chamber pre-design



Ultra Compact magnetic lattice

- Short empty drift space for vacuum components (valves, flanges, pumps etc…)
- Ultra low Conductance configuration (pumping speed through a 10 mm hole is 9 l/s !)
- An average of 1 small standard ***SIP*** pump every 1.4 m is possible to pump extra PSD gas load

Preliminary Vacuum Simulations

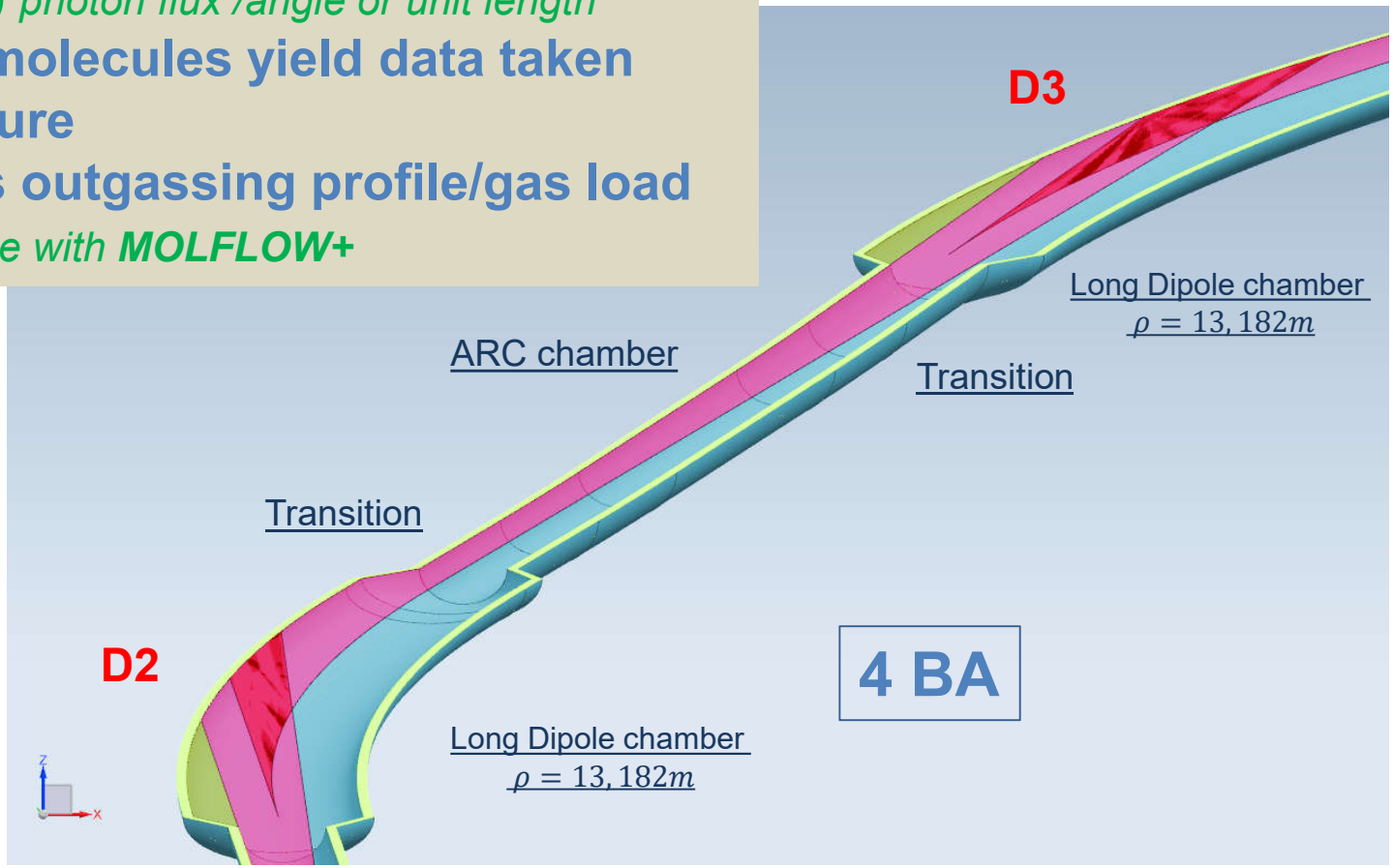
"Classical" three steps approach

- **Conventional CAD-assisted ray tracing**

→ $N_\theta(s)/N_l(s)$ *photon flux /angle or unit length*

- **Photon to molecules yield data taken from literature**
- **SR induces outgassing profile/gas load**

→ *Pressure profile with* ***MOLFLOW+***



Preliminary Vacuum Simulations

η : Photon to molecule yield data

Standard values of η for Stainless Steel and TiZrV NEG-coating

Dose @SOLEIL	η *Stainless Steel*
0.01 A h $[2.2x10^{20}\ ph/m]$	$10^{-2}\ mol/ph$
1 A h $[2.2x10^{22}\ ph/m]$	$5.10^{-4}\ mol/ph$
100 A h $[2.2x10^{24}\ ph/m]$	$\sim 10^{-5}\ mol/ph$

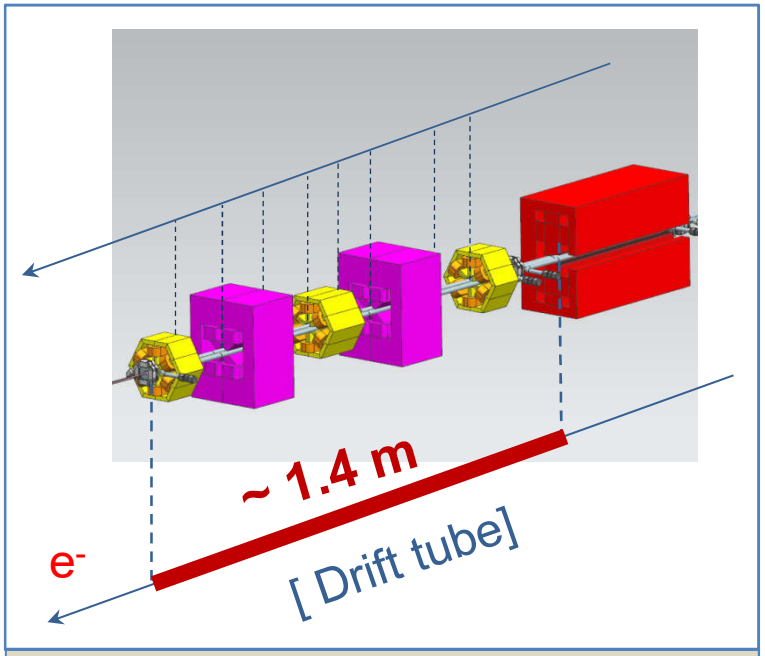
Dose @SOLEIL	η *Activated NEG-coating [Ti-Zr-V]*
0.01 A h $[2.2x10^{20}\ ph/m]$	$5.10^{-5}\ mol/ph$
1 A h $[2.2x10^{22}\ ph/m]$	$7.10^{-6}\ mol/ph$
100 A h $[2.2x10^{24}\ ph/m]$	$8.10^{-7}\ mol/ph$

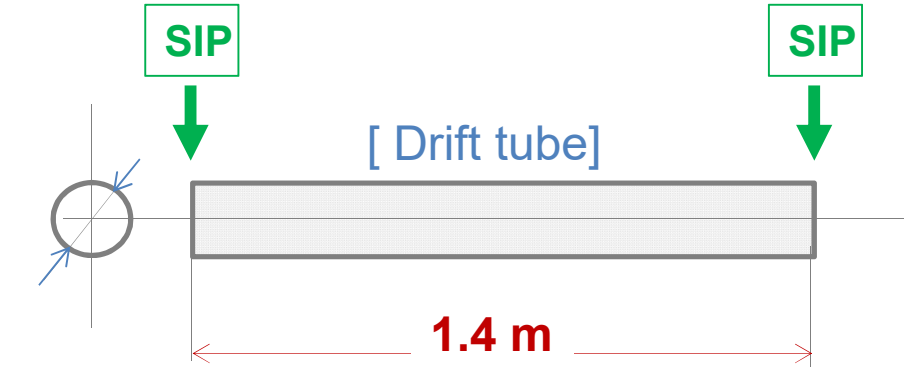
C. L. Foerster et al. J. Vac. Sci. Technol. A, Vol. 8, No.3, 1990
O. Gröbner et al. J. Vac. Sci. Technol. A 12(3), 1994
C. Herbeaux et al. J. Vac. Sci. Technol. A, Vol. 17, No. 2,1999
P. Chiggiato, R. Kersevan / Vacuum 60 (2001) 67}72
Y. Tanimoto, T. Honda, M. Ady, R. Kersevan, P. Chiggiato VSC Seminar, CERN 09/25/2015

Data taken on « standard » dimension pipes *i.e ID100, ID 61…*

Preliminary Vacuum Simulations

Simplified Model representative of the lattice





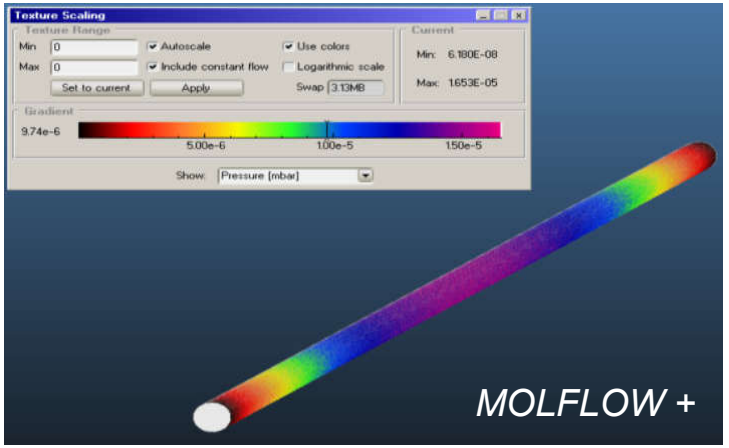
SR irradiation

$\sim 5.10^{18}$ ph $s^{-1}m^{-1}$

@ 500 mA

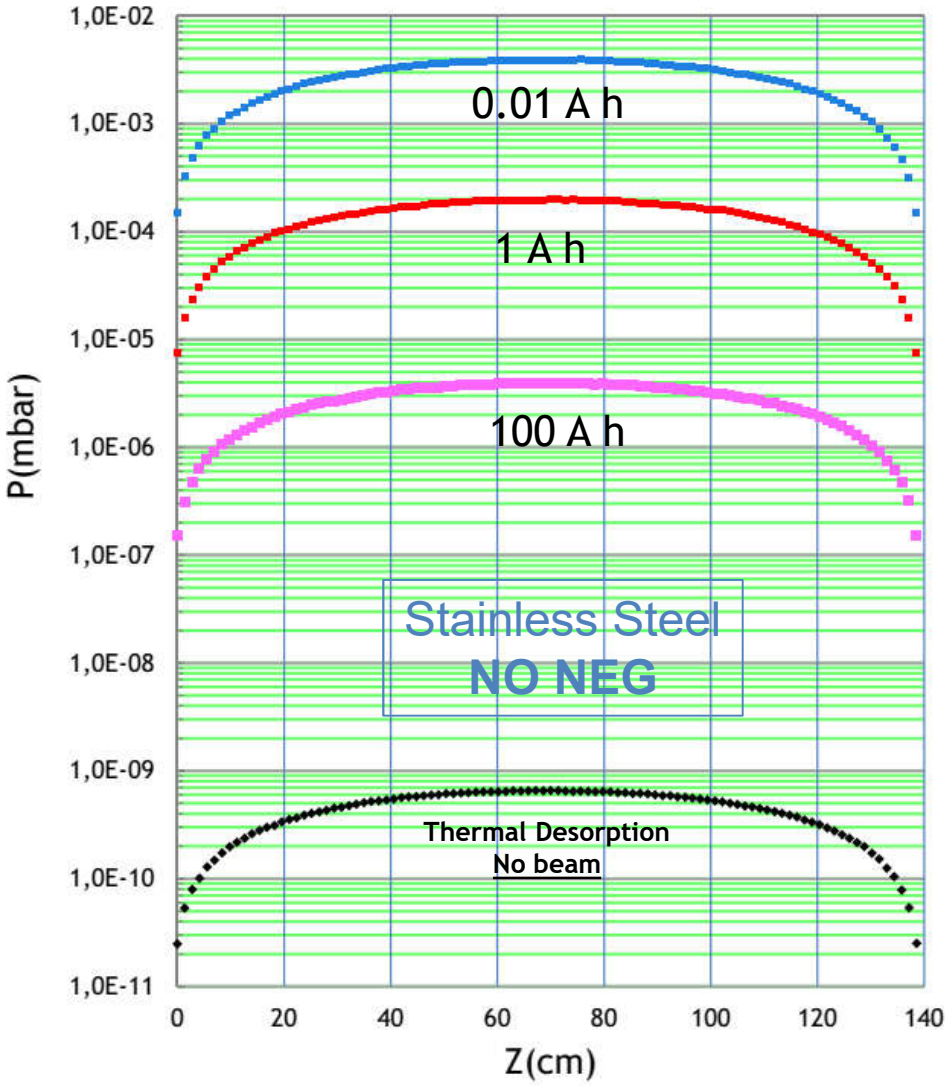
$\mathbf{Q}\ [\mathrm{mbar.l}.s^{-1}.m^{-1}]$

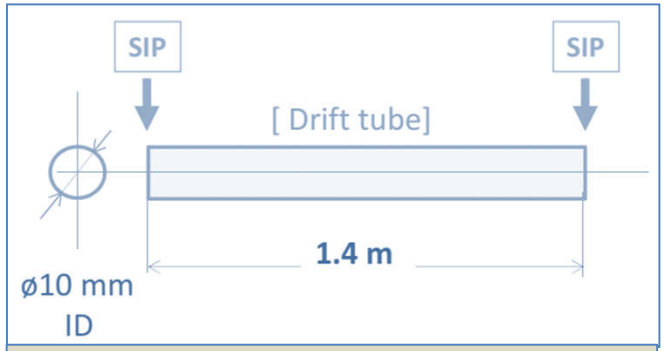
« Optimistic Scenario »
No photon scattering



Preliminary Vacuum Simulations

Total Pressure for Stainless Steel with NO NEG





SR irradiation

$\sim 5.10^{18}$ ph $s^{-1}m^{-1}$

@ 500 mA

Total Pressure for
3 different accumulated doses
0.01 Ah / 1 Ah / 100 Ah
No NEG coating

No Commissioning Scenario

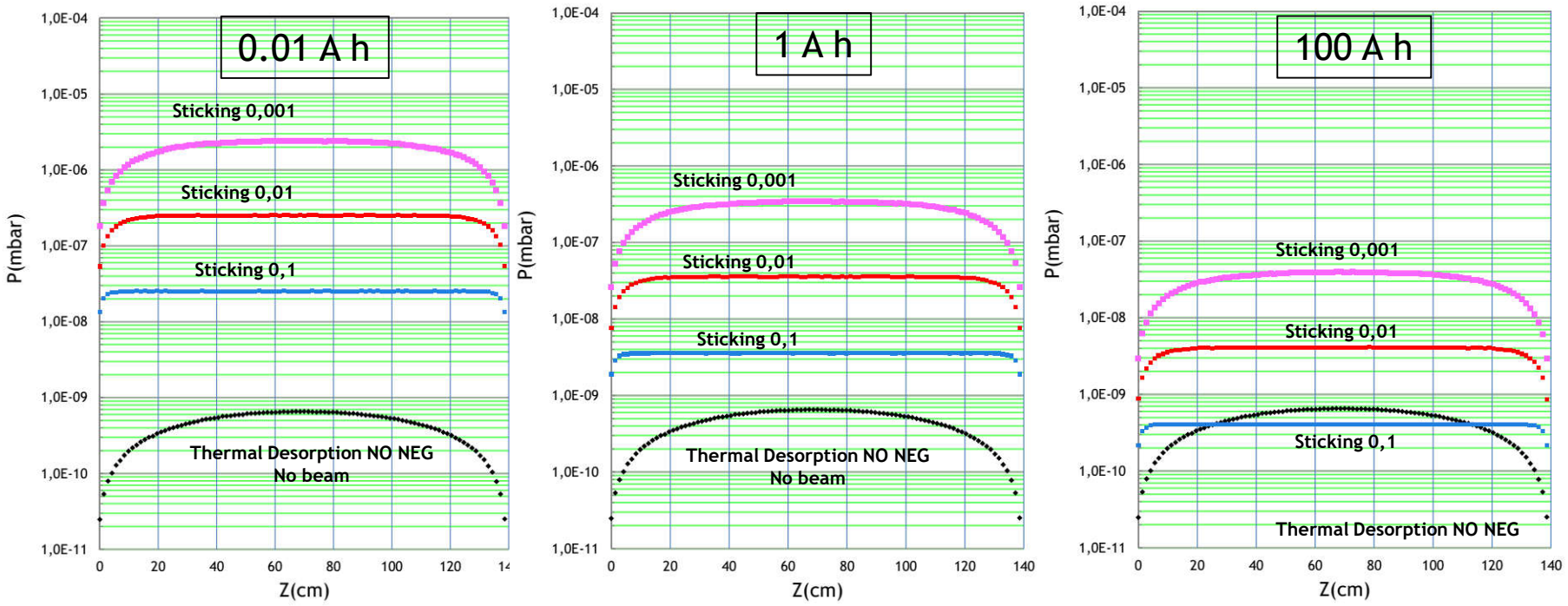
Preliminary Vacuum Simulations

Total Pressure for NEG-coated chambers

Total Pressure for
3 different accumulated doses
0.01 Ah / 1 Ah / 100 Ah
on NEG coating

NEG *"sticking"* variation
0.1 / 0.01 / 0.001

SR irradiation
$\sim 5.10^{18}$ ph $s^{-1}m^{-1}$ @ 500 mA

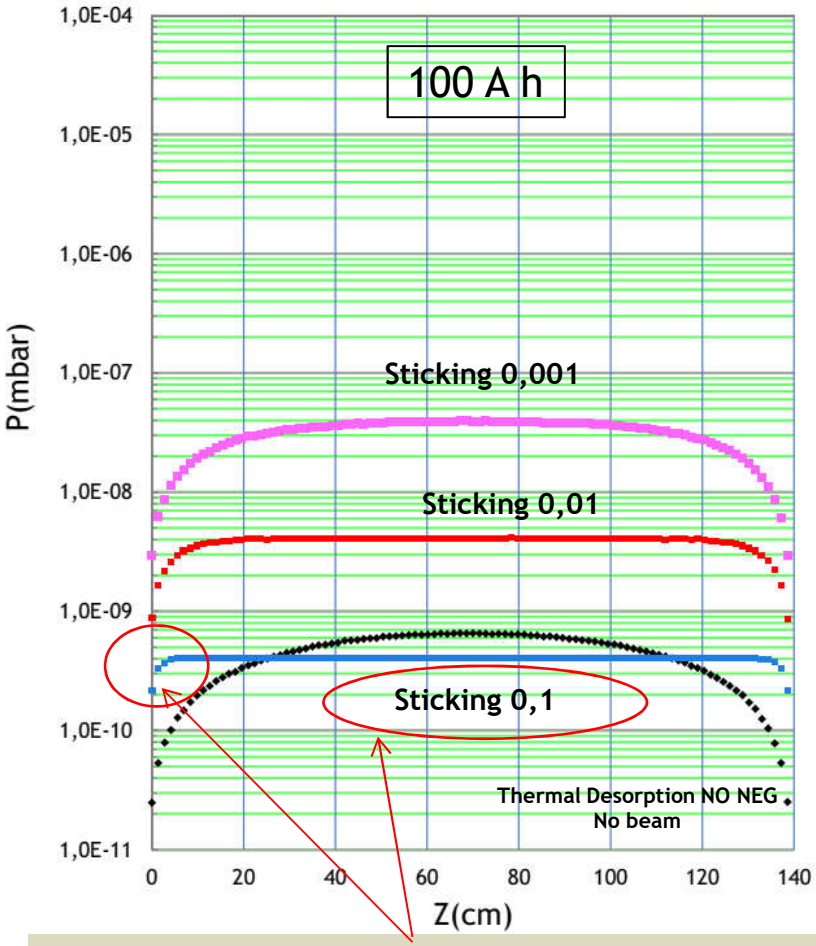


Preliminary Vacuum Simulations

Total Pressure for NEG-coated chambers

@ 100 Ah

SR irradiation
$\sim 5.10^{18}$ ph $s^{-1}m^{-1}$ @ 500 mA



Substantial Residual Sticking Probability of the NEG **is Necessary**

Commissioning target
< 10^{-9} mbar @ 100 A.h

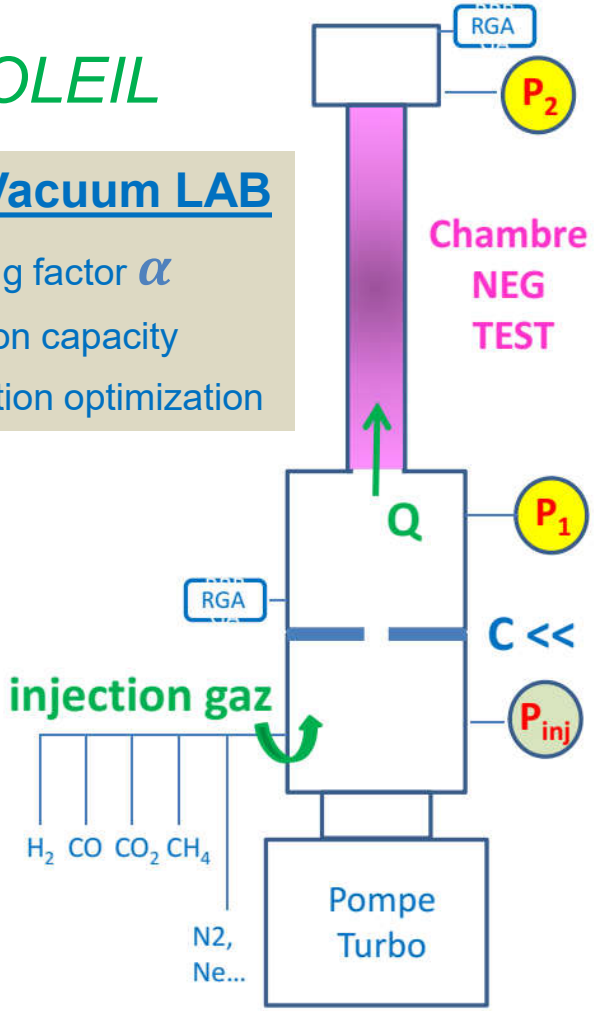
NEG coating Characterization

…of small diameter chambers

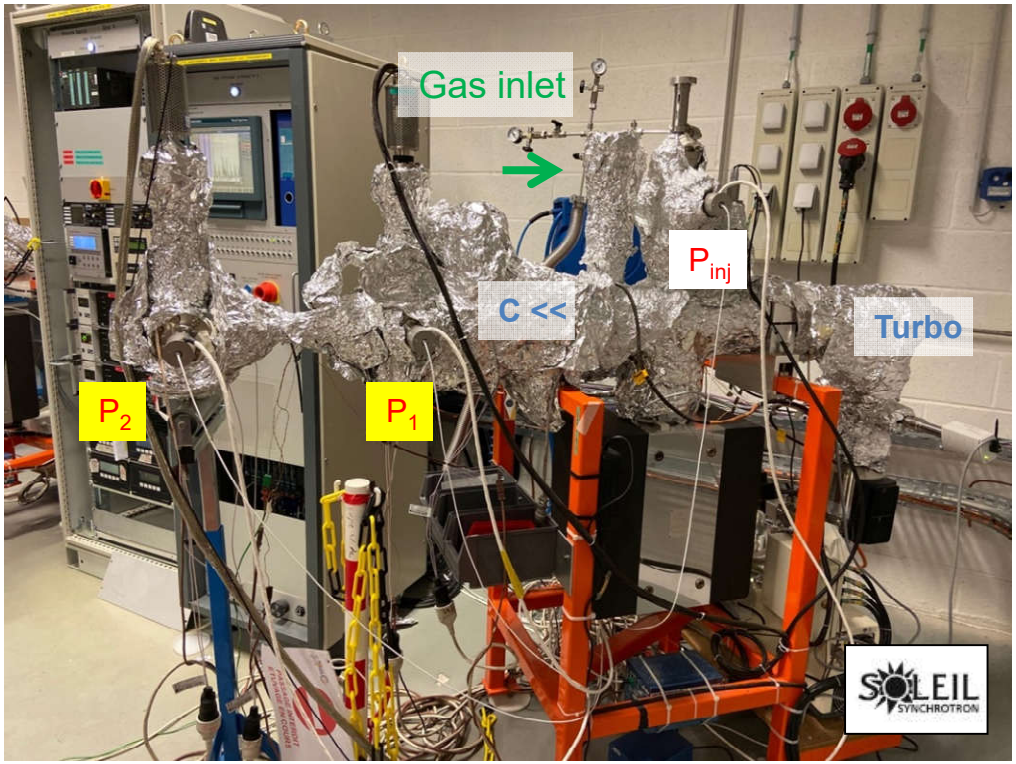
@ SOLEIL

In the Vacuum LAB

- Sticking factor α
- Sorption capacity
- Activation optimization



NEG coating intrinsic properties



Transmission Method

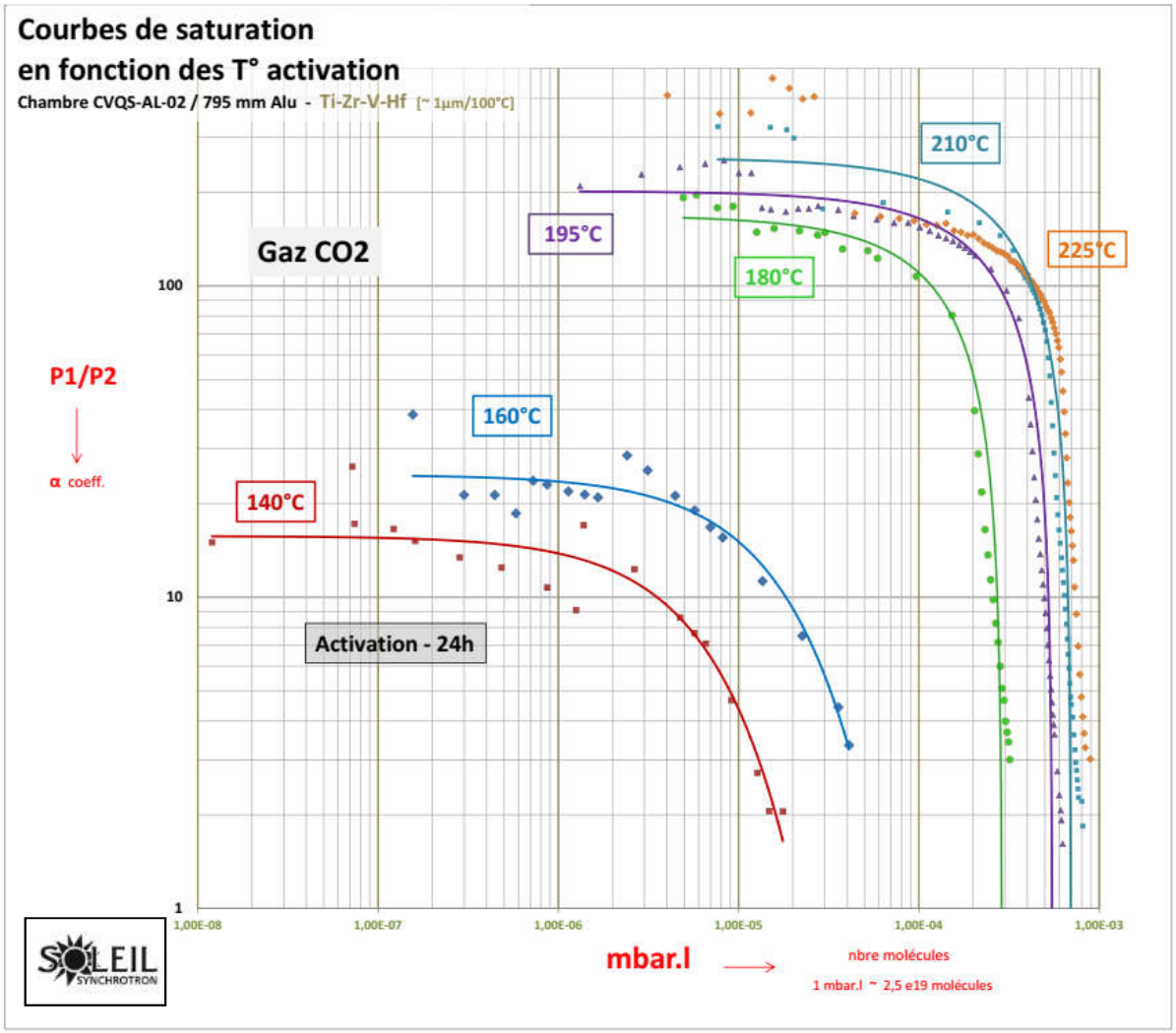
P. Costa Pinto, P. Chiggiato, A. Sapountzis, T. Sinkovits, M. Taborelli,
CERN
80th IUVSTA Workshop, NSRRC, Hsinchu, Taiwan (2016)

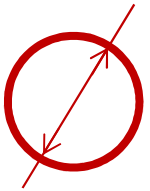
P_1/P_2 is calibrated with **MOLFLOW+** to find α

NEG coating Characterization

…of small diameter chambers

NEG-coated pipes made @ SOLEIL





ID 63 → ID 40 → ID 20
(in mm)

Ti-Zr-V
~1 µm

Select the correct activation protocol

Typical Sorption Capacity curves for Increasing activation T°

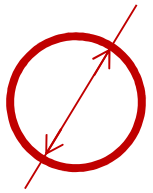
24h / 200°C:
A good compromise for Ex-situ Bakeout

NEG coating Characterization

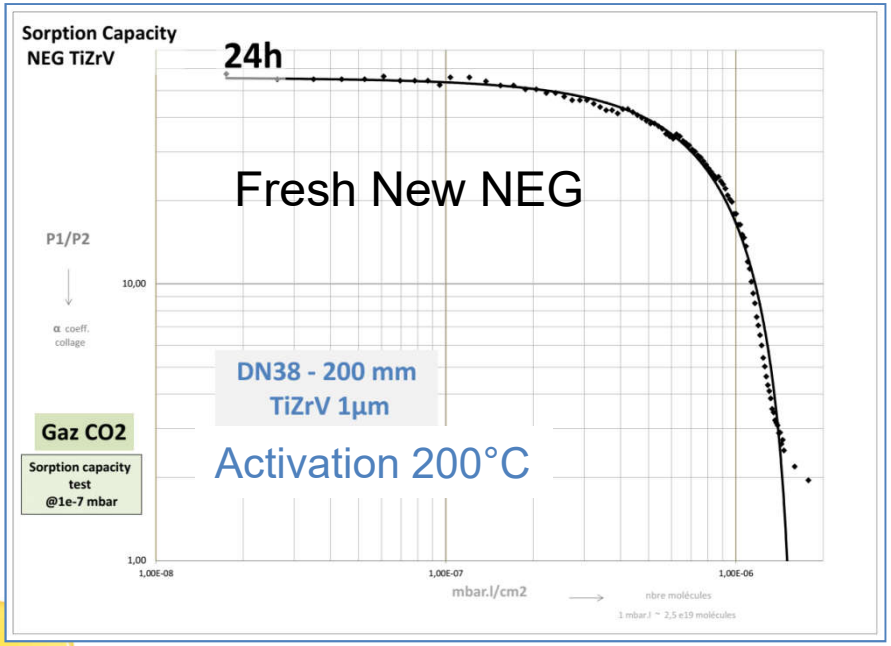
…of small diameter chambers

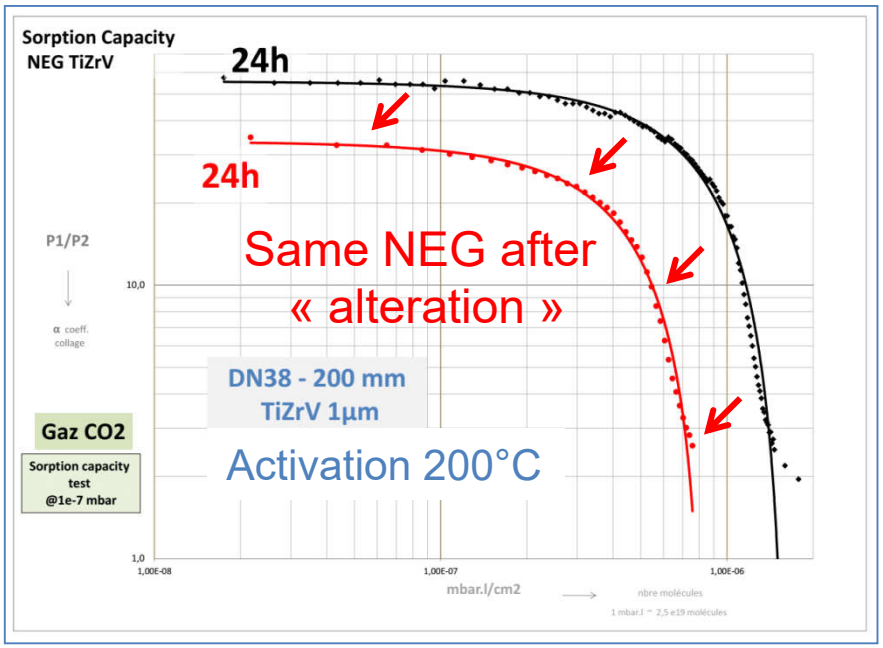
NEG-coated pipes made @ SOLEIL

One example of activation optimization of the NEG
→ Recovering of some properties of a NEG after
"Alteration" / Multiple cycling / Ageing



ID 63 → ID 40 → ID 20
(in mm)





Initial sorption capacity with 24h activation/200°C

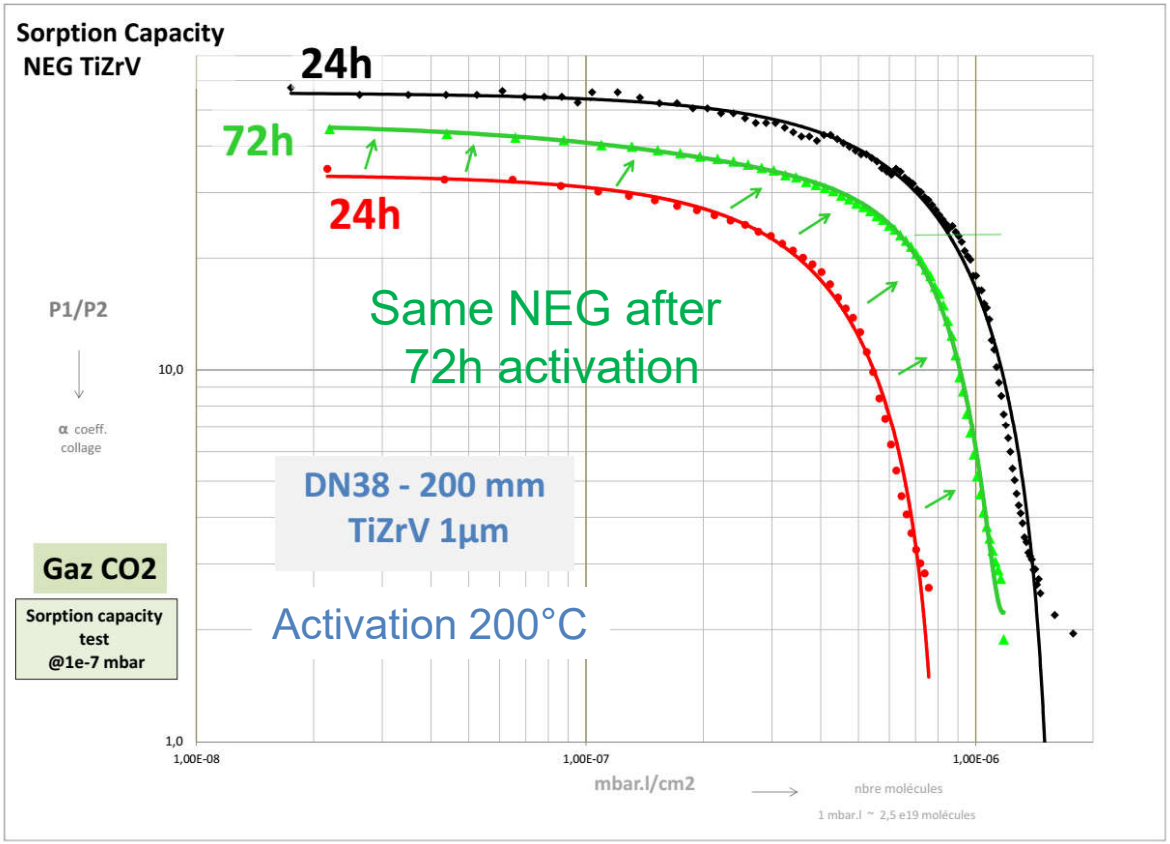
Decrease of the capacity after some « Alteration » / « Ageing » (same 24 h activation/200°C)

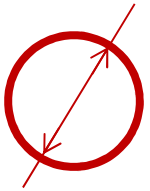
NEG coating Characterization

…of small diameter chambers

NEG-coated pipes made @ SOLEIL

One example of activation optimization of the NEG
→ Recovering some properties of a NEG after
"Alteration" / Multiple cycling / Ageing





ID 63 → ID 40 → ID 20
(in mm)

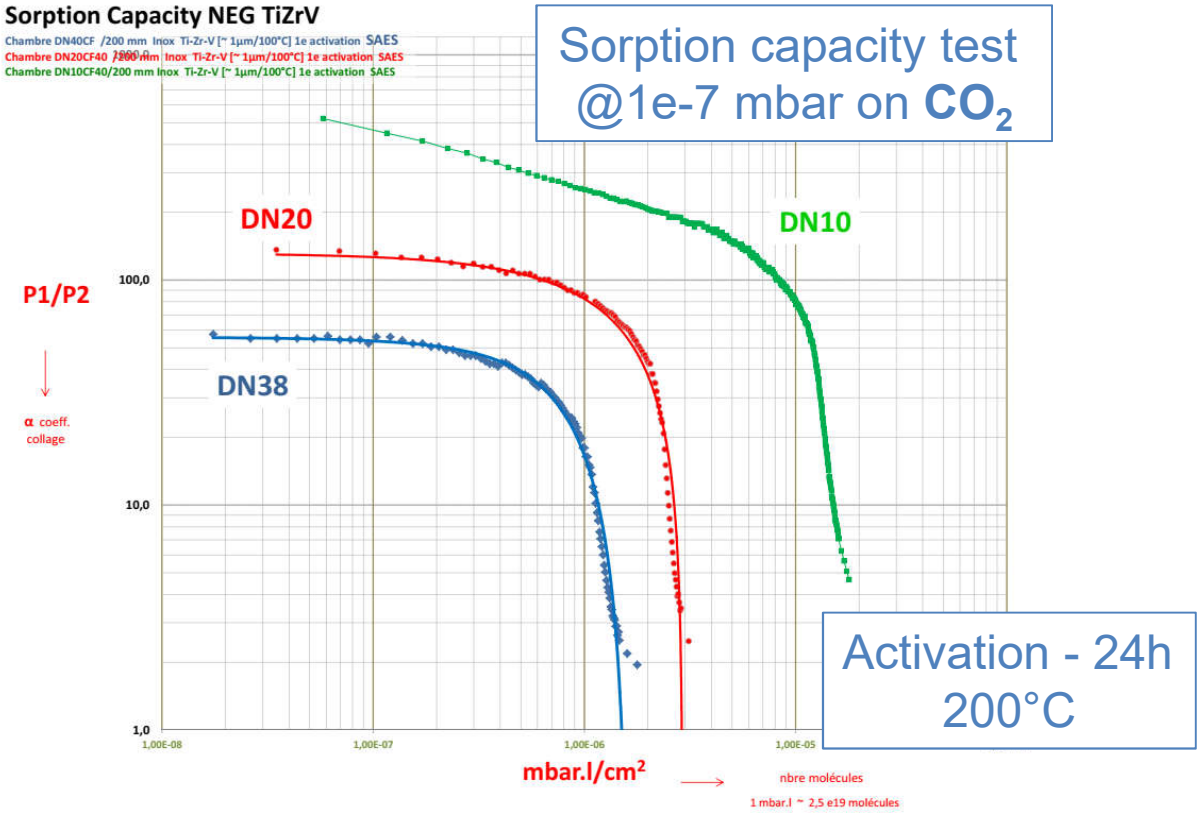
Recovering some NEG sorption capacity by increasing the activation time to 72 h but keeping the T° at 200°C

Interesting feature for the operation of the future ring

NEG coating Characterization

…of small diameter chambers

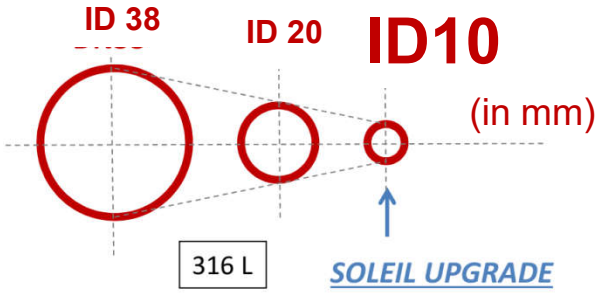
NEG-coated pipes made @ SAES Getter



Sorption capacity test @1e-7 mbar on CO_2

Activation - 24h 200°C

TESTS on TiZrV 1µm NEG-coated pipes
Sorption capacity and Sticking factor

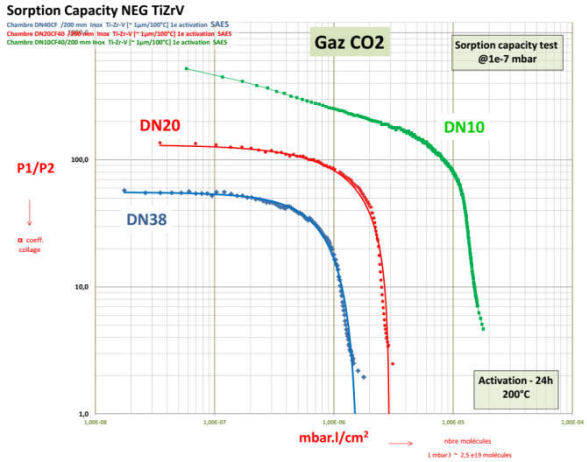


200 mm Pipes

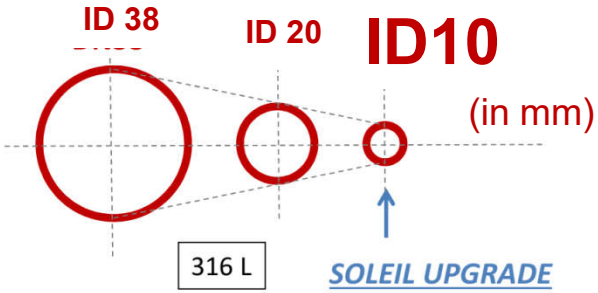
Initial sticking probability > 0,1 [CO2]
Sorption capacity > 10^{-6} mbar.l/cm^2
Similar behavior found on ID38 / ID20 / ID10

NEG coating Characterization

…of small diameter chambers



TESTS on TiZrV 1µm NEG-coated pipes
Sorption capacity and Sticking factor



200 mm Pipes

- **The Steeper P1/P2 trend on ID10** when the NEG starts to saturate on CO2 could be attributed to:

? Effect of the small conductance itself?

?Generation of CH4 which distort the pressure measurements

Experiments on CO and Hydrogen are underway and may help in the understanding

- **Higher capacity on ID10 is also under investigation**:

? Morphology of the NEG film → the more « columnar » - the higher is the capacity

May be a result of different interaction between the tube's volume, the Kr pressure and plasma ignition conditions during the deposition process

NEG coating Characterization

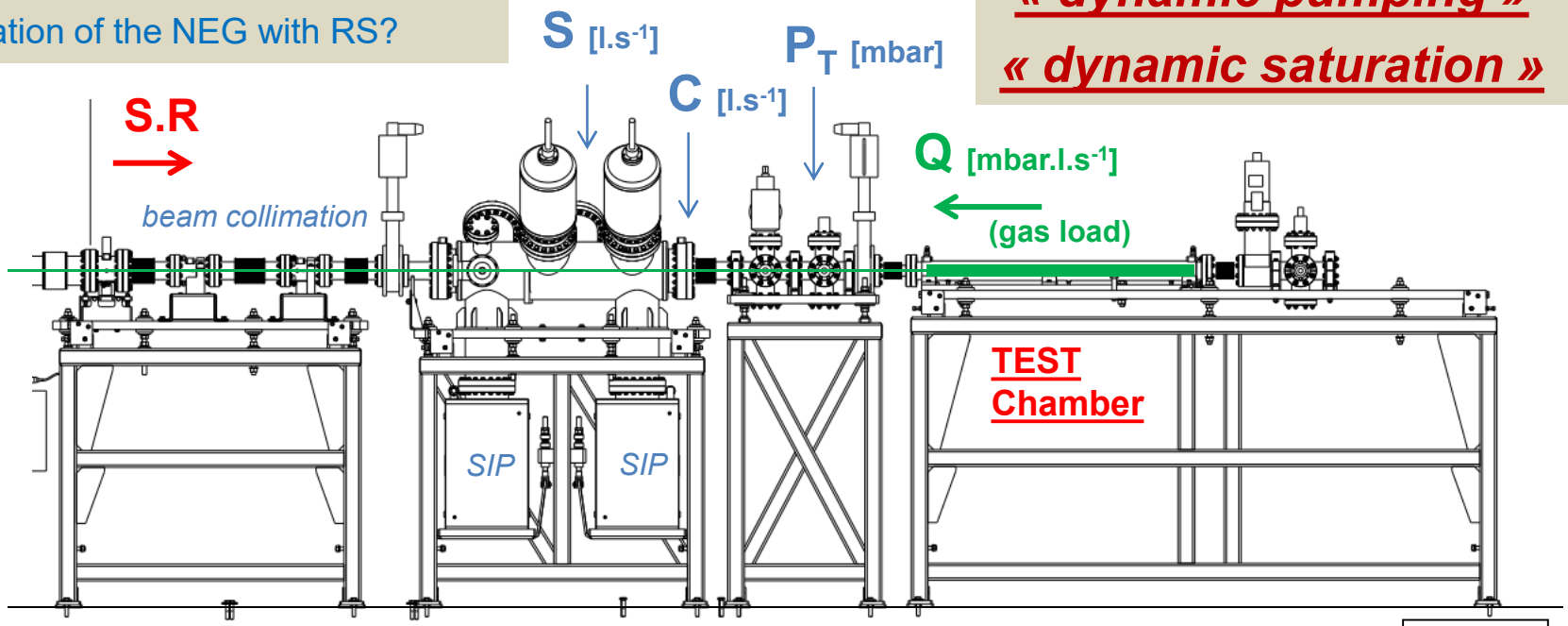
Ongoing phase : Installation of a *PSD* beamline

[August 2020]

On the SOLEIL Ring
→ *photon exit D08-1*

- Evolution of the PSD yield with the photon dose
- Activation of the NEG with RS?

NEG
« dynamic pumping »
« dynamic saturation »



Photon to molecule yield η

$$\eta \propto \frac{Q}{8{,}17.10^{20}.E[GeV].I[A]}$$

Q ~ C x P_T
C << S

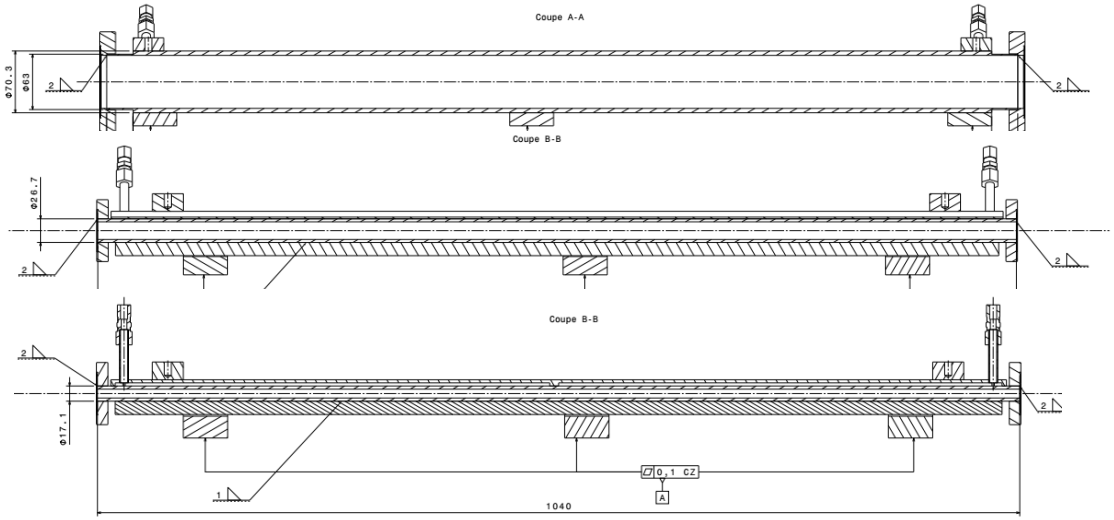
NEG coating Characterization

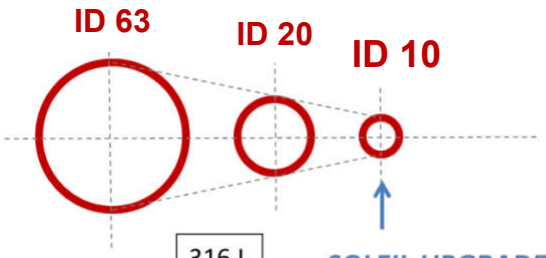
TEST PLAN

[→ mid 2021]

TESTS on TiZrV 1µm NEG-coated pipes
PSD yield

NEG-coated,
Water cooled chambers
from SAES





316 L

Cu-OFS

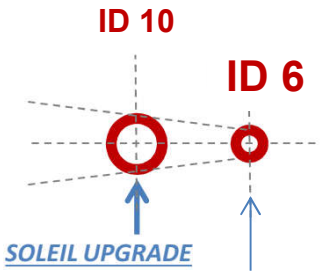
SOLEIL UPGRADE

1 m long

TESTS on TiZrV 1µm NEG-coated pipes
PSD yield

NEG-coated at ALS-U

Cu-OFS

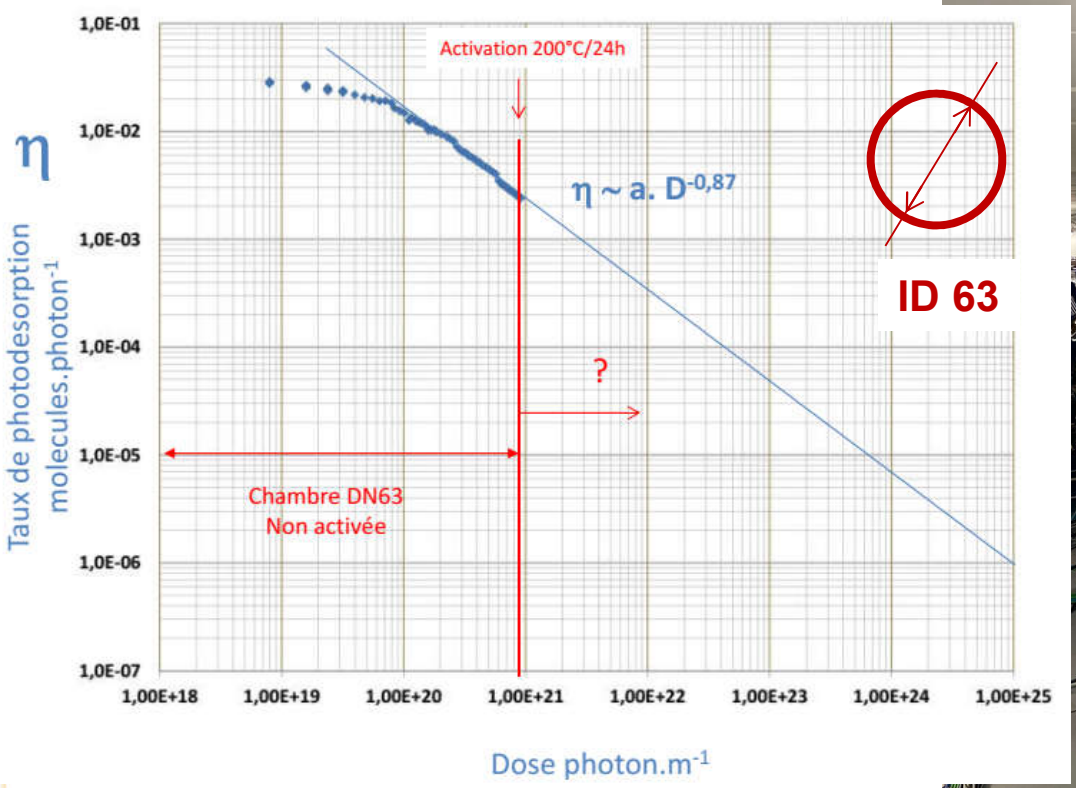


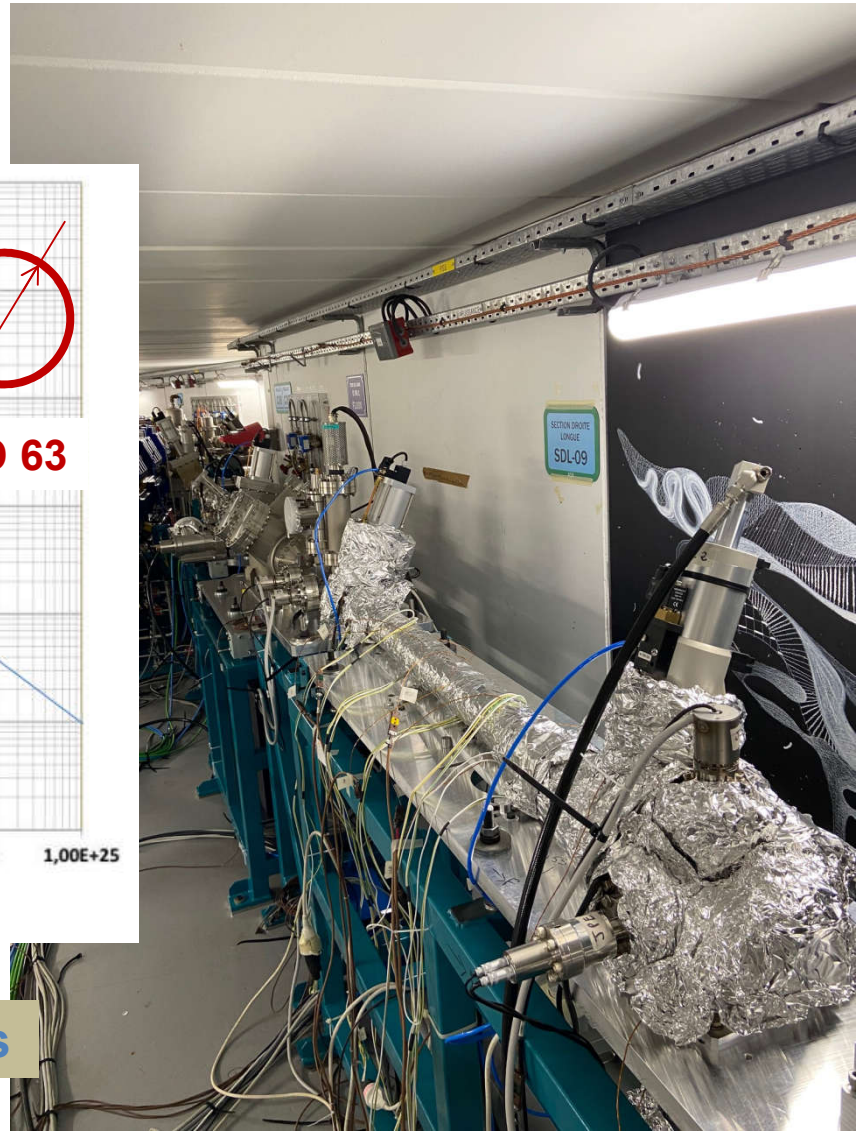
Only for Insertion Device chambers

NEG coating Characterization

Ongoing phase : First beam and data collect

Last week-end (24_Oct._2020) !





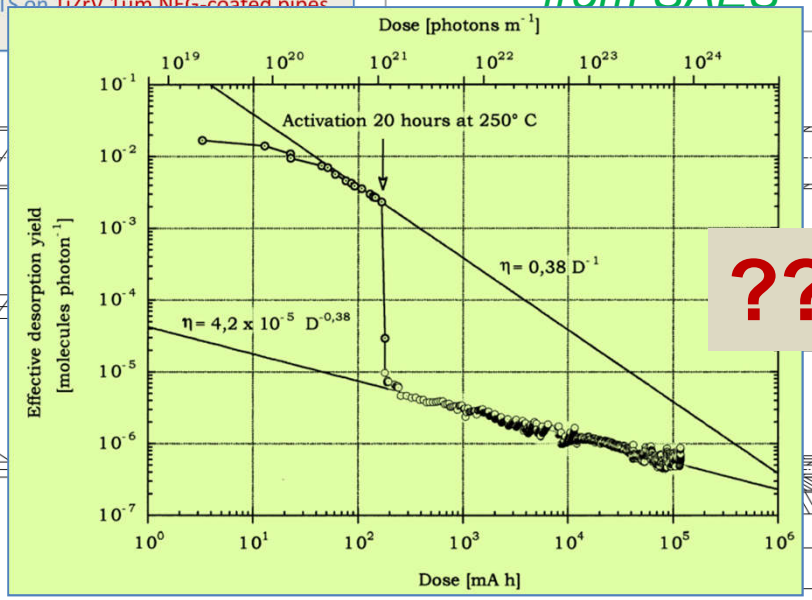
Beamline Ok for PSD measurments

NEG coating Characterization

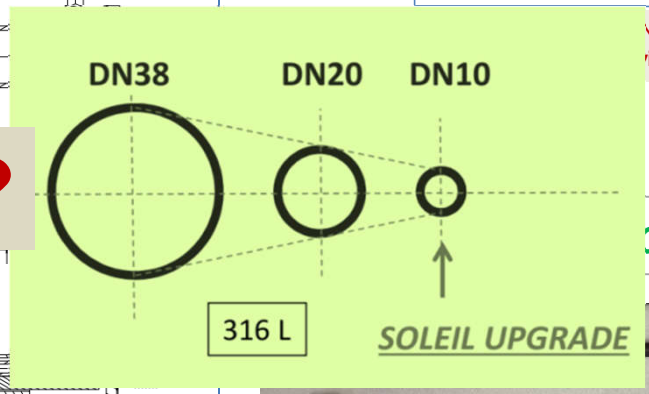
…of small diameter chambers

TESTS on Ti7rV 1µm NEG-coated pipes

NEG-coated, Water cooled chambers from SAES

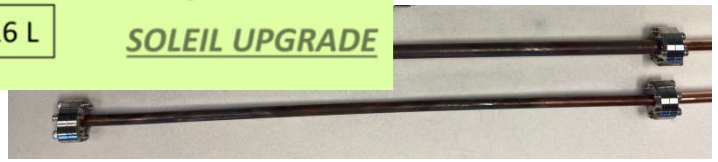


??

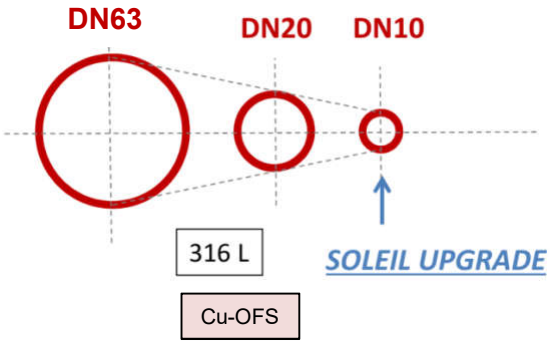


NEG-coated pipes
Yield

d at ALS-U



DN10



+ « Residual Sticking » <u>after Irradiation</u>

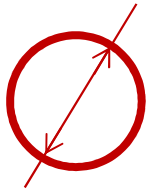
How the NEG is affected by the Dose?

→ '*Use the PSD beamline as a Transmission Method bench*' (with no SR beam)

CONCLUSION

…We are on our way to get answers

→ TiZrV 1µm NEG coating shows encouraging behavior in 10 mm ID pipes
→ *PSD* measurements will be soon fully operational and need to prove a favorable *Dynamic Pumping* efficiency in such geometry and back up our first preliminary vacuum simulations



10 mm ID

1 µm TiZrV

Crucial importance of NEG pumping characteristics

Continued characterization is needed

→ Confirm parameters for 10 mm ID pipes pumping

→ Get data on "Dynamic Pumping" → PSD yield

NEG deposition in narrow and complex geometries →

Collaborations

? CERN ? saes group


SOLEIL
SYNCHROTRON
UPGRADE