2nd I.FAST WP10 meeting on 17 Jan 2023

Oleg B. Malyshev (UKRI)

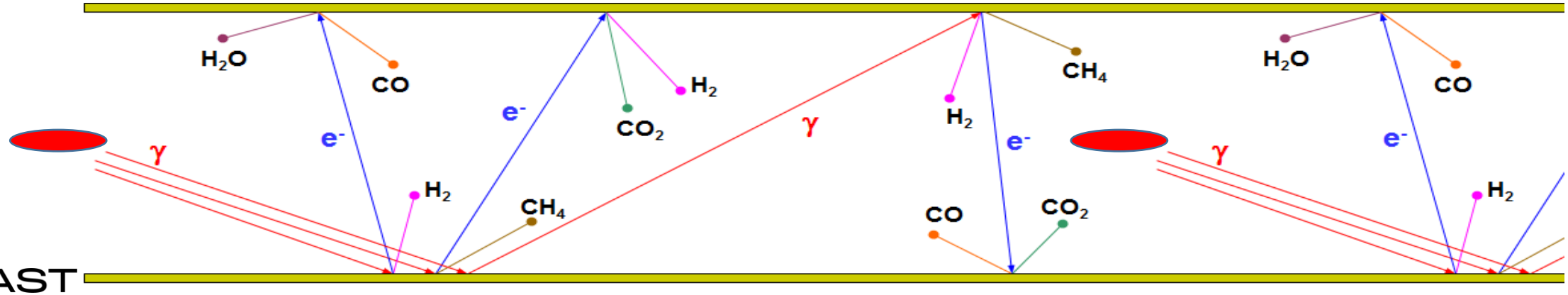
Task 10.5 leader

Vacuum in particle accelerators

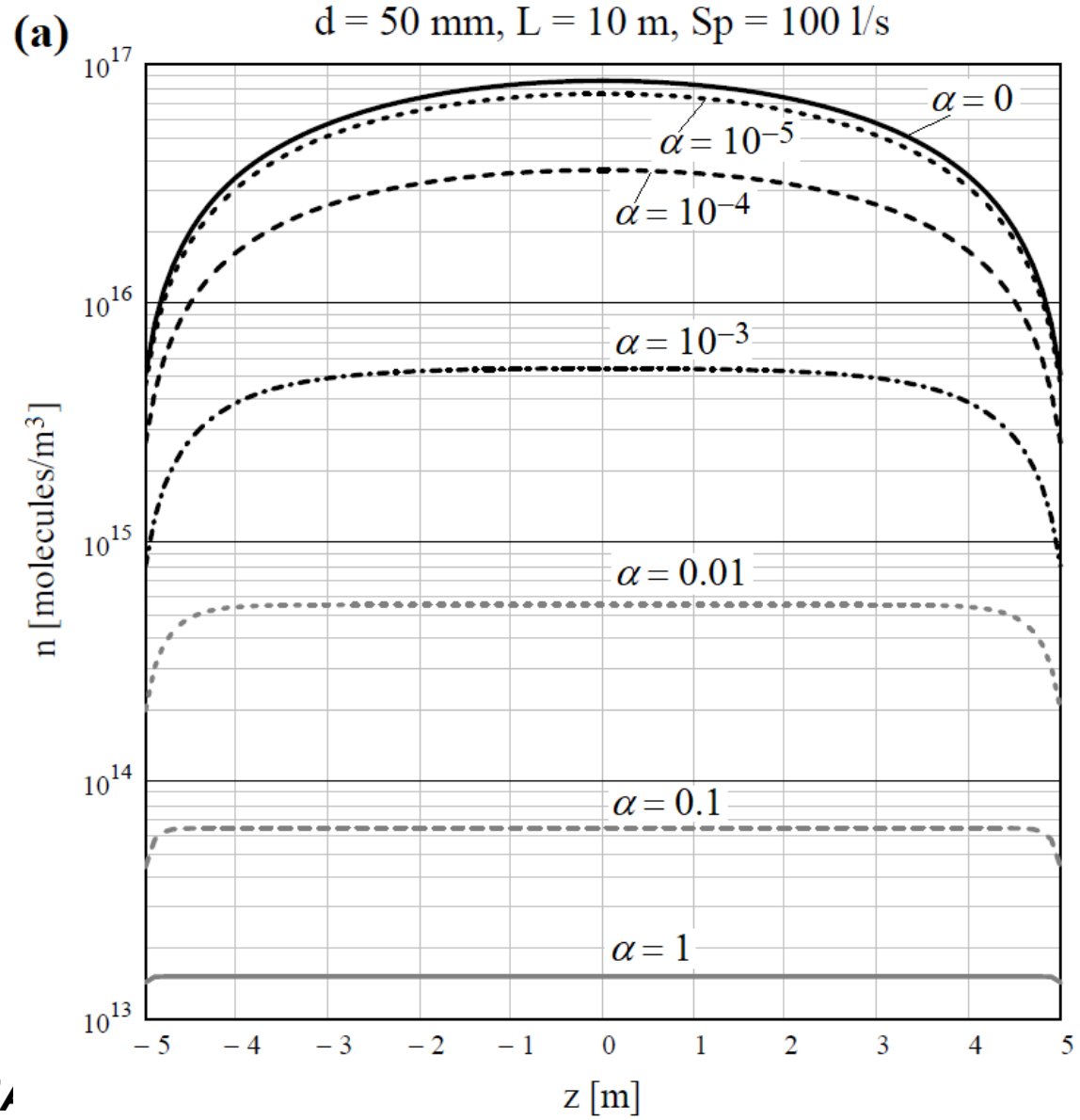
All particle accelerators need vacuum. The main reason is beam-gas interaction leading to a beam quality degradation:

- Increases beam size (emittance)
- Reduces beam lifetime
- Increases radiation hazard
- Encourages recombination

- **Photon stimulated desorption (PSD)** is one of the most important sources of gas ***in the presence of synchrotron radiation (SR)*** *or any photons with E > 5-10 eV.*
- PSD can be considered as a two-step process:
  - first, photons with energy > 5-10 eV cause the photoelectron emission,
  - then the photoelectron stimulate gas desorption.



Why a NEG coated chamber required?



To minimise unwanted collisions between accelerated particles and residual gas molecules to a tolerable level, the specified nas density must be met.

1) Effect of distributed pumping
   (a) A gas density *n* as a function of coordinate *z* for various **sticking probabilities *α***
   (b) Efficiency of lump pumps at the ends of vacuum chamber is low for **narrow vacuum chambers**

2) Average gas density *n* reduces proportionally with **PSD yields, *η*.**

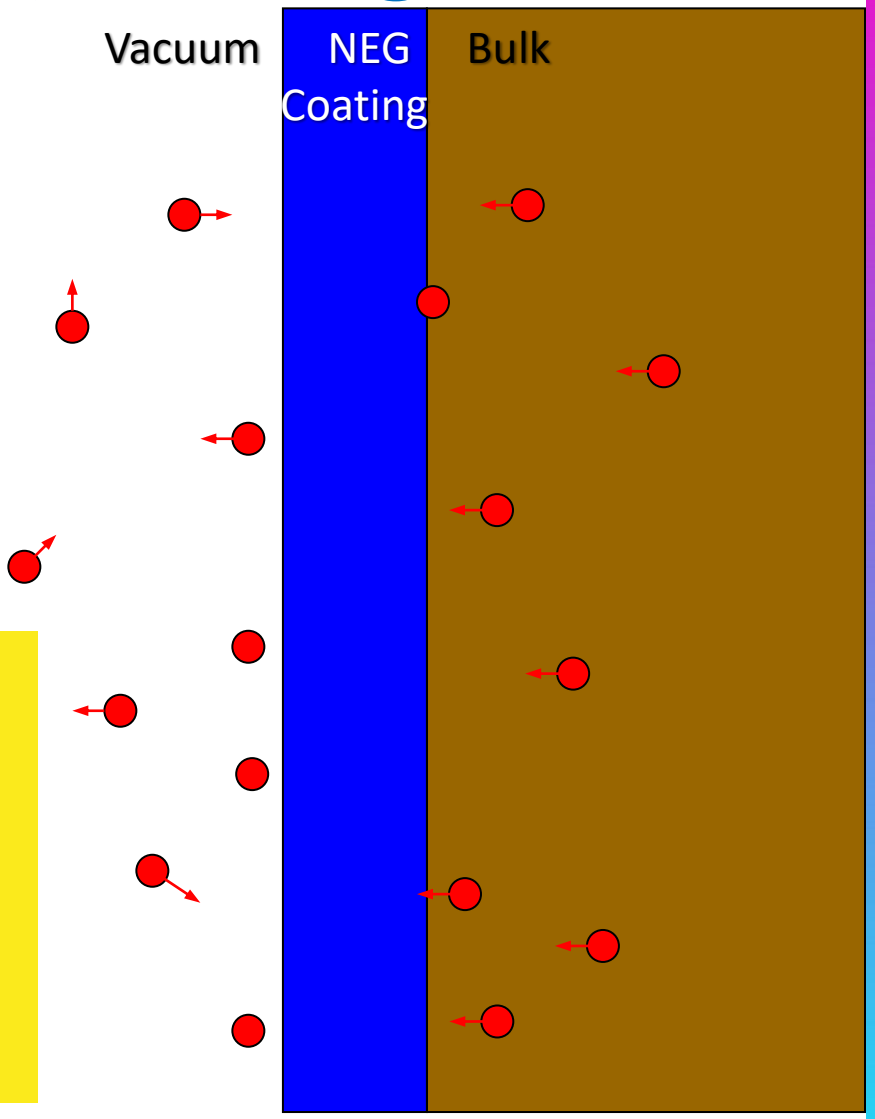
O.B. Malyshev. Vacuum in Particle Accelerators: Modelling, Design and Operation of Beam Vacuum Systems. (2019)

What non-evaporable getter (NEG) coating does?

1) **Reduces gas desorption:**
   - **A pure metal or metal alloy (Ti, Zr, V, Hf, etc.) film 0.5-3-μm thick without contaminants.**
   - **A barrier for molecules from the bulk of vacuum chamber.**
2) **Increases distributed pumping speed, *S*:**
   - **A sorbing surface on whole vacuum chamber surface**

providing a pumping speed of $S = \alpha \cdot A \cdot v/4$;

where α – sticking probability, A – surface area, v – mean molecular velocity



Main benefits of NEG coating:

- Can be activated at low temperature of 150-160 °C
- Meeting challenging vacuum specification at UHV or XHV
- Lower cost of vacuum system
  - ✓ Less number of pumps, thus less controllers and cables
  - ✓ Smaller size of the pumps, thus lower cost per unit
- The only solution for narrow vacuum chambers

What is really need for vacuum system design

- There are not enough PSD data for various NEG coatings.
  - A future machine vacuum deign can't be done properly without these data.
- What information have to be obtained:

- **Experimentally measured PSD yields, η, and sticking probabilities, α,** for H_2, CH_4, CO, CO_2 (*for modelling future machines*)
  - for various types of NEG coatings (composition and structure),
  - as a function of photon dose,
  - as a function of activation temperature and duration,
  - as a function of film thickness,
  - for shapes similar to vacuum chamber of future machines,
  - *etc*.

- **Practical knowledge and experience** on what happens in case of various operation issues:
  - SR induced activation, recovery rate after a vacuum accident,
  - SR induced pumping,
  - a leak during NEG activation,
  - SR beam alignment fluctuation,
  - non-uniform temperature during activation: overheated NEG, underheated NEG,
  - not uniformly coated and partially coated chambers (a chamber with an antechamber),
  - effect of storage in vacuum, in nitrogen, in argon, in air, ...,
  - NEG lifetime,
  - *other questions from machine operation experience*.

Task 10.5 objectives

- Building facilities for photon stimulated desorption (PSD) yield measurement on beamlines
  - at DLS and Soleil
- Obtaining and analysing the photon stimulated gas desorption (PSD) experimental data from Non-Evaporable Getter (NEG) coated prototypes under conditions similar to future light sources
  - Surface preparation at DESY
  - Coating with NEG at UKRI, later at DESY and Soleil
  - Pumping property testing of NEG coated samples in all partners labs

Samples for pumping properties evaluation

- It was agreed that a project *standard sample* for pumping properties evaluation is
  - made of OFHC or OFS copper samples
  - ID = 20 mm
  - L = 500 mm
  - equipped with two CF40 flanges

Courtesy of L. Lilje and R. Sirvinskaite (DESY)

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  - ID = 20 mm
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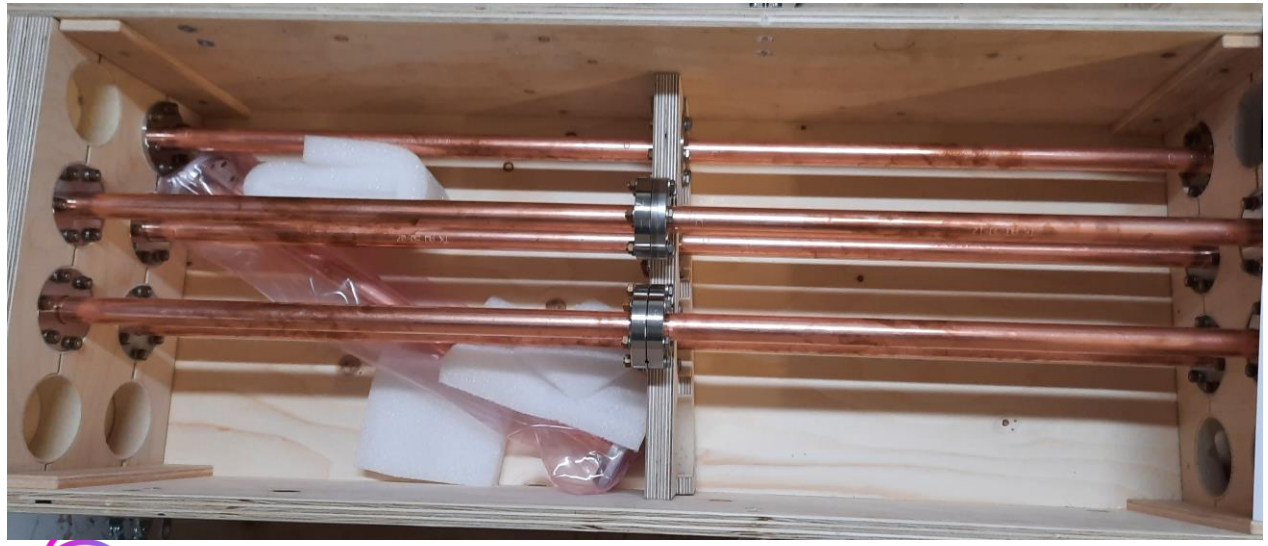
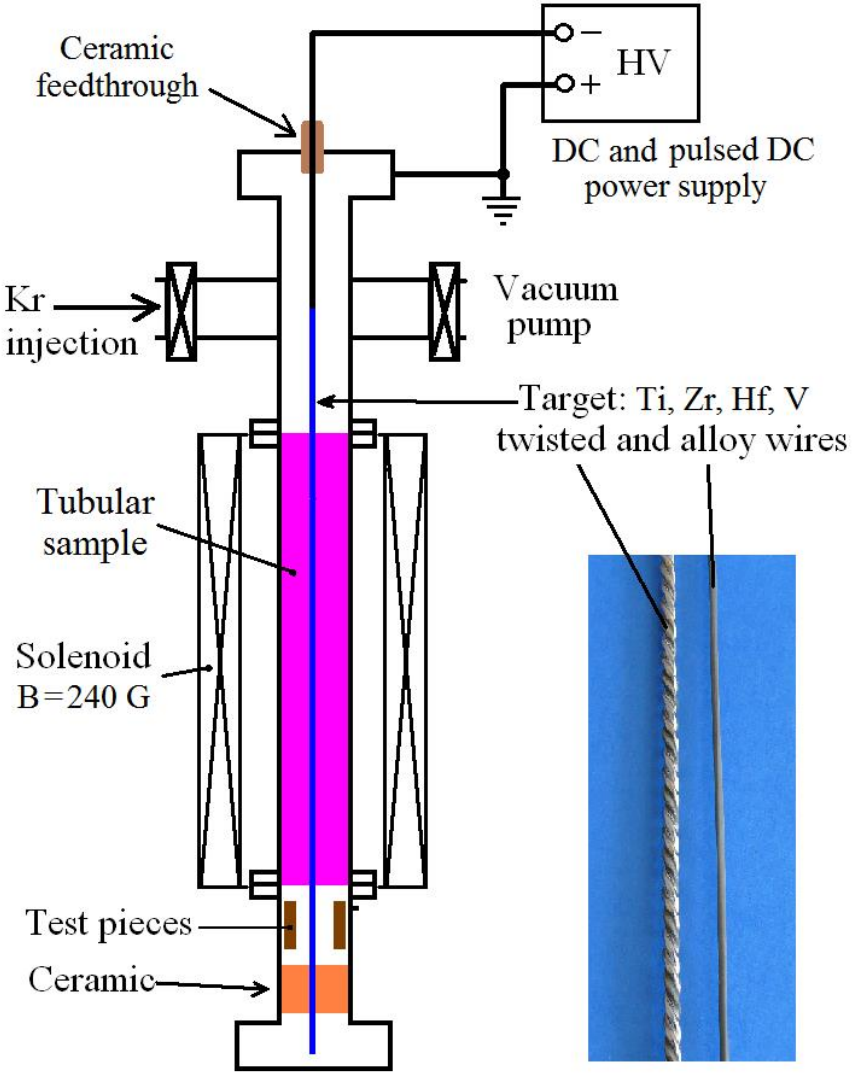
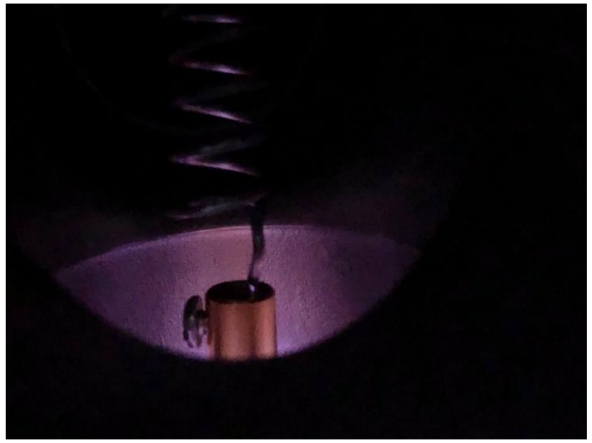
  - equipped with two CF40 flanges
- 11 samples have been provided by DESY in March 2022.



- 3 samples were used for comparison of cleaning/etching procedures
  - After arriving the samples to the UKRI
  - an inner surfaces of the samples found to have some black coverage. It was found that this is a silver oxide.
  - Thermal outgassing was a factor 2-3 higher than a reference sample cleaned at UKRU
  - The cause of this was found and the DESY cleaning procedure has been changed to address this issue.
- 8 ***identical samples*** will be
  - coated at UKRI
  - then tested in 4 labs for comparing (cross-verifying) the results obtained on different facilities

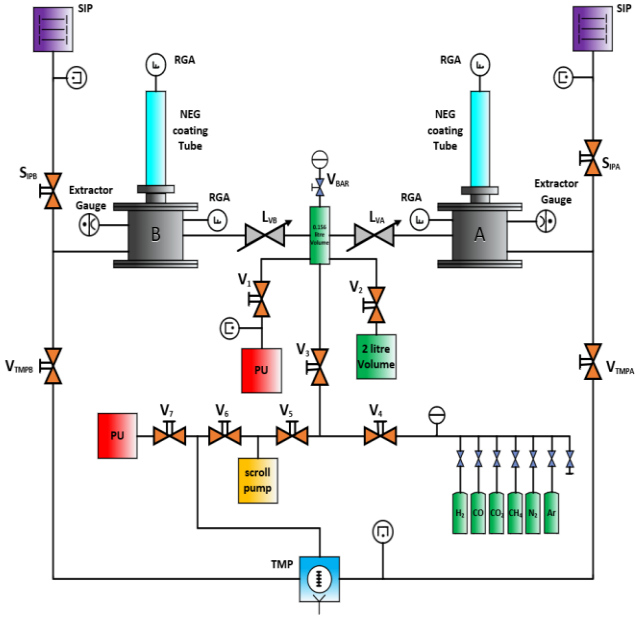
NEG deposition facility at UKRI (Daresbury Laboratory)





- The updated facility is used for a routine coating of tubes with
  - a length of 0.5 - 1 m
  - Inner diameter 5-100 mm
  - CF16-CF150 flanges
- Presently a final testing coating is ongoing on a tube with ID = 20 mm and L = 1 m then for PSD **a standard PSD sample** will be coated with NEG

Facilities for pumping properties evaluation at UKRI (DL)

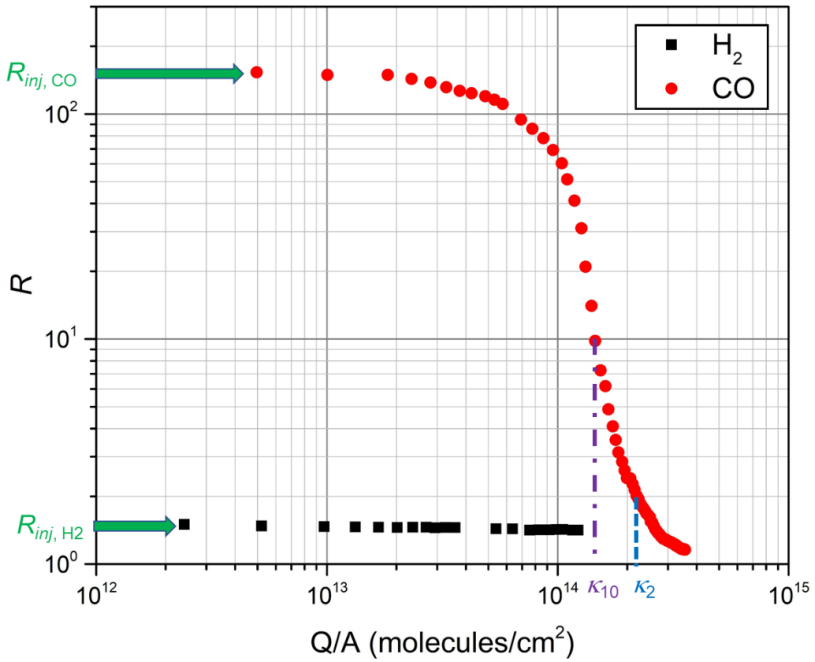


Key:

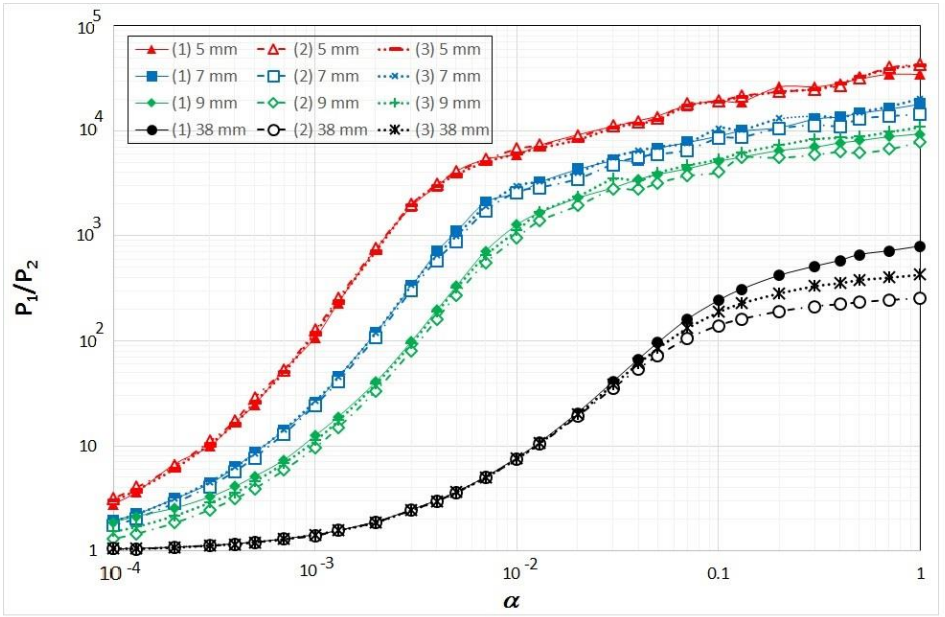
- Turbomolecular Pump (TMP)
- Sputter Ion Pump (SIP)
- Pump Unit (PU, TMP+piston pump)
- Inverted Magnetron Gauge (IMG)
- Membrane Gauge (MG)
- Residual Gas Analyser (RGA)
- Extractor Gauge (EG)
- Fine Leak Value

- The pumping properties evaluation facilities are used for a routine measurements of initial sticking probability α and sorption capacity κ.
- Up to 4 samples can be tested at the same time.

Typical result:
$R = P_{bot}/P_{top}$



Pressure ratio $R = P_{bot}/P_{top}$ as a function of sticking probability α *obtained with TPMC modelling*



Facilities for pumping properties evaluation at Soleil

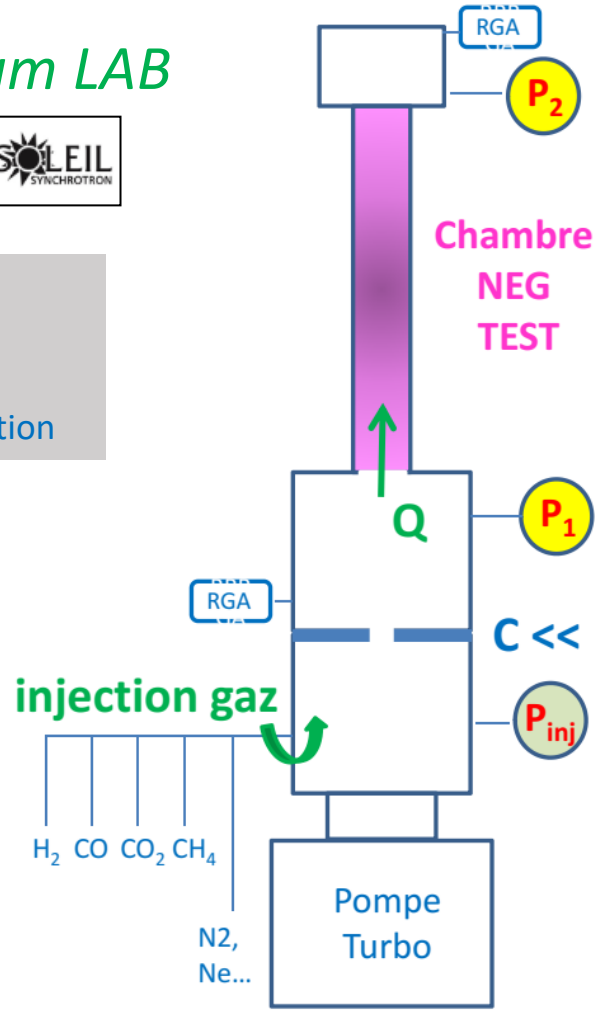
@ Vacuum LAB

- Sticking factor α
- Sorption capacity
- Activation optimization

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

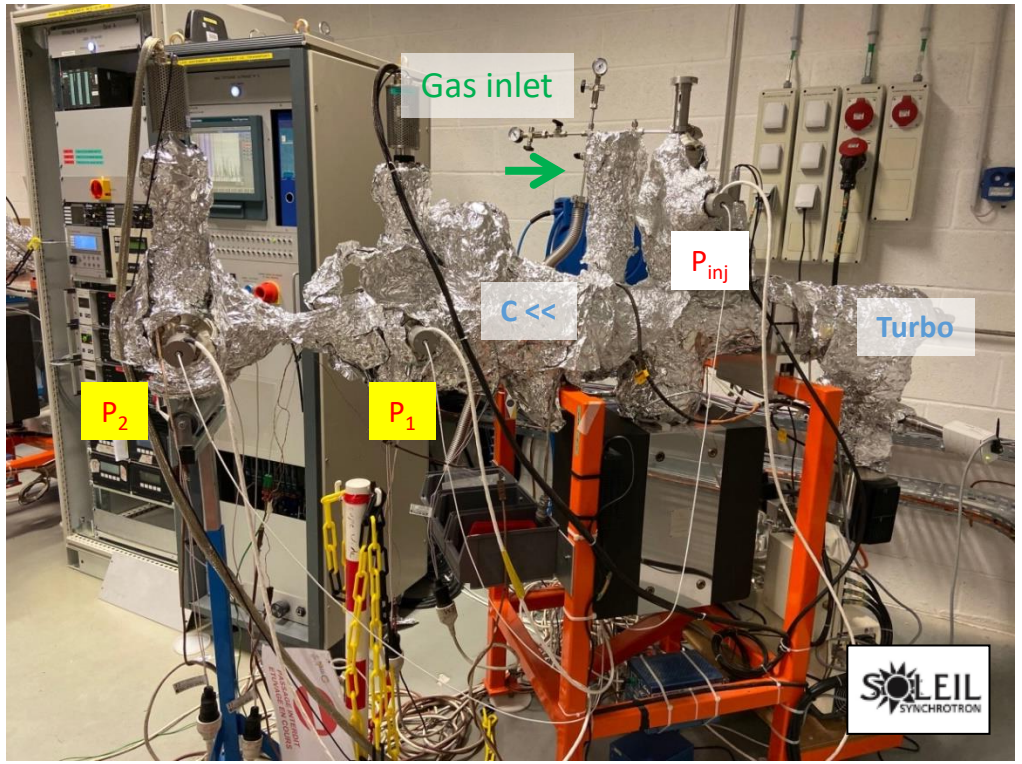
Courtesy of C. Herbeaux (Soleil)

- **Facility is in operation and it is ready for IFAST Task 10.5 samples**
- **2 samples has been coated at UKRI and sent to Soleil**



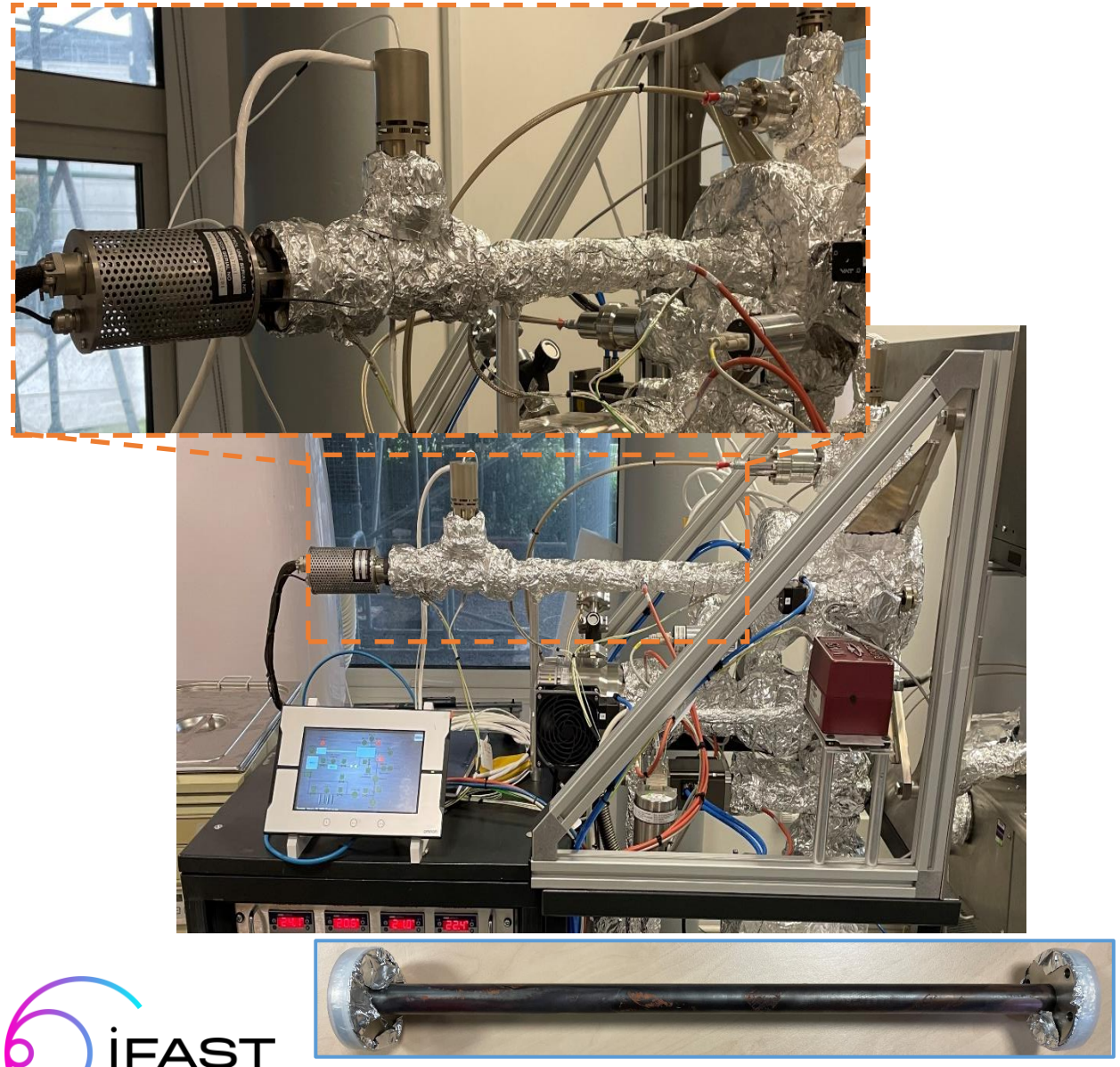
Transmission Method

2 Transmission Method Test Benches for NEG coating characterization



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

Facility for pumping properties evaluation at DSL



Pumping speed measurement system completed and ready for operational testing:

- RGA-based or extractor gauge pressure ratio method to estimate sticking probability
- Pumping provided by a 300 l/s TMP and a 150 l/s SIP
- Gas injection through dedicated system based on expansion volumes
- Four gases (H_2, CO, CO_2, CH_4) let through regulated leak valve, expected operating pressures up to 10^{-5} mbar
- System to be controlled by PLC

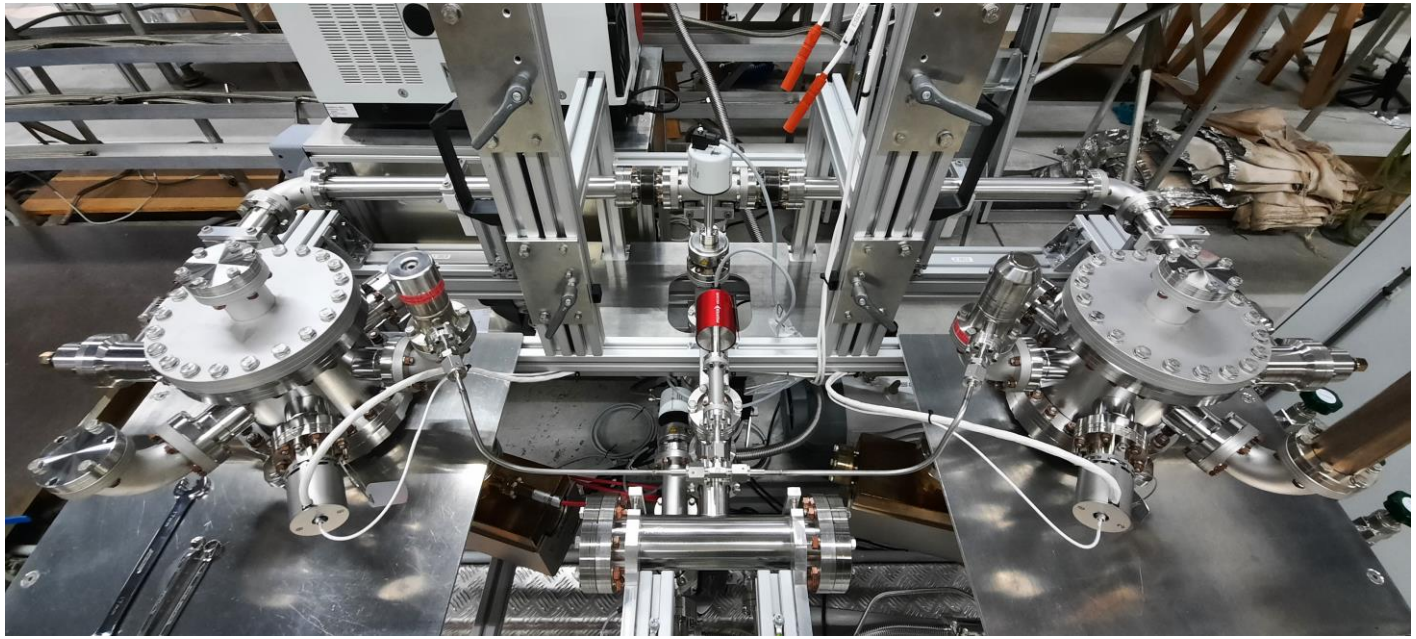
Status:

- First coated (Zr) test vessel supplied by Daresbury Laboratories (UKRI, UK)
- System currently in commissioning (to be ready for samples by summer 2023)

Courtesy of C. Burrows (DSL)

Facility for pumping properties evaluation at DESY

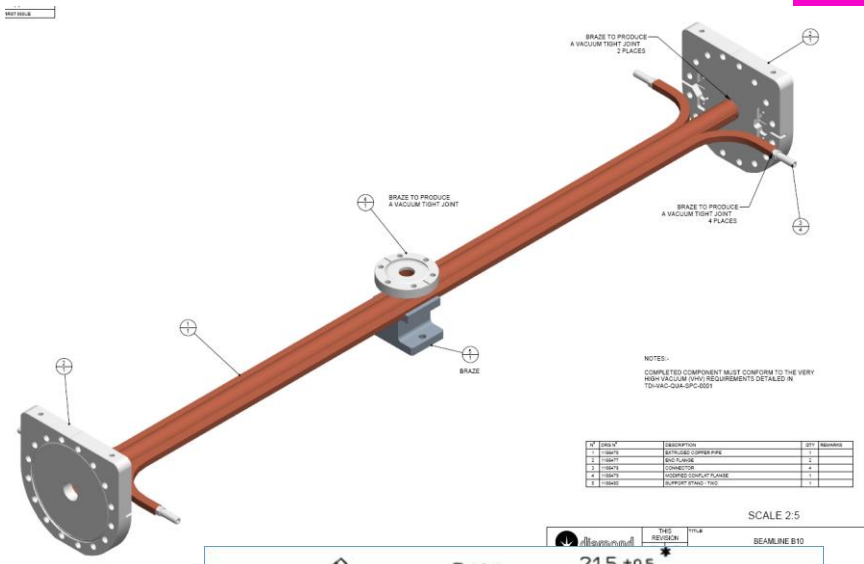
- **Pumping test setup is in operation**
- RGA or extractor gauge-based pressure ratio measurements
- Another mirroring system is lacking RGAs
- ESD setup (one of the two mirroring chambers) is ready for commissioning and pumping tests

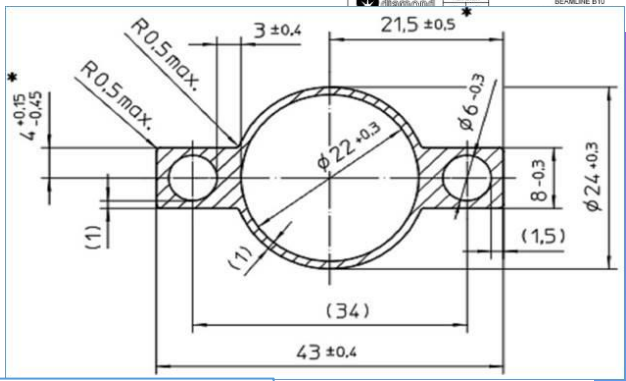


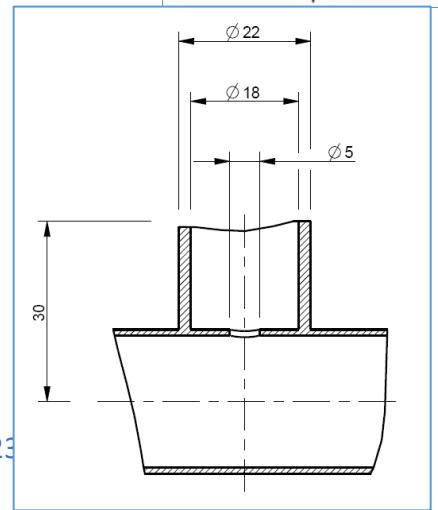
Courtesy of R. Sirvinskaite (DESY)

Sample for PSD measurements

- Samples jointly designed by Soleil and DLS
  - Central port is circular with ID = 18 mm and with 5-mm hole to vessel body
  - Central and end flanges are brazed
- 9 samples has been provided by Soleil in Oct. 2022.
    - 4-month delay by the industrial manufacturer SAES REAL
    - More samples can be produced in a future.
  - Initially, samples have been or will be cleaned by a manufacturer
  - Later, samples will be cleaned at DESY following a procedure being developed in an ongoing research
  - First two samples will be coated with Zr at UKRI (DL) in January and February 2023
    - so *identical samples* will be initially tested in DLS and Soleil for comparing (cross-verifying) the results obtained on different facilities

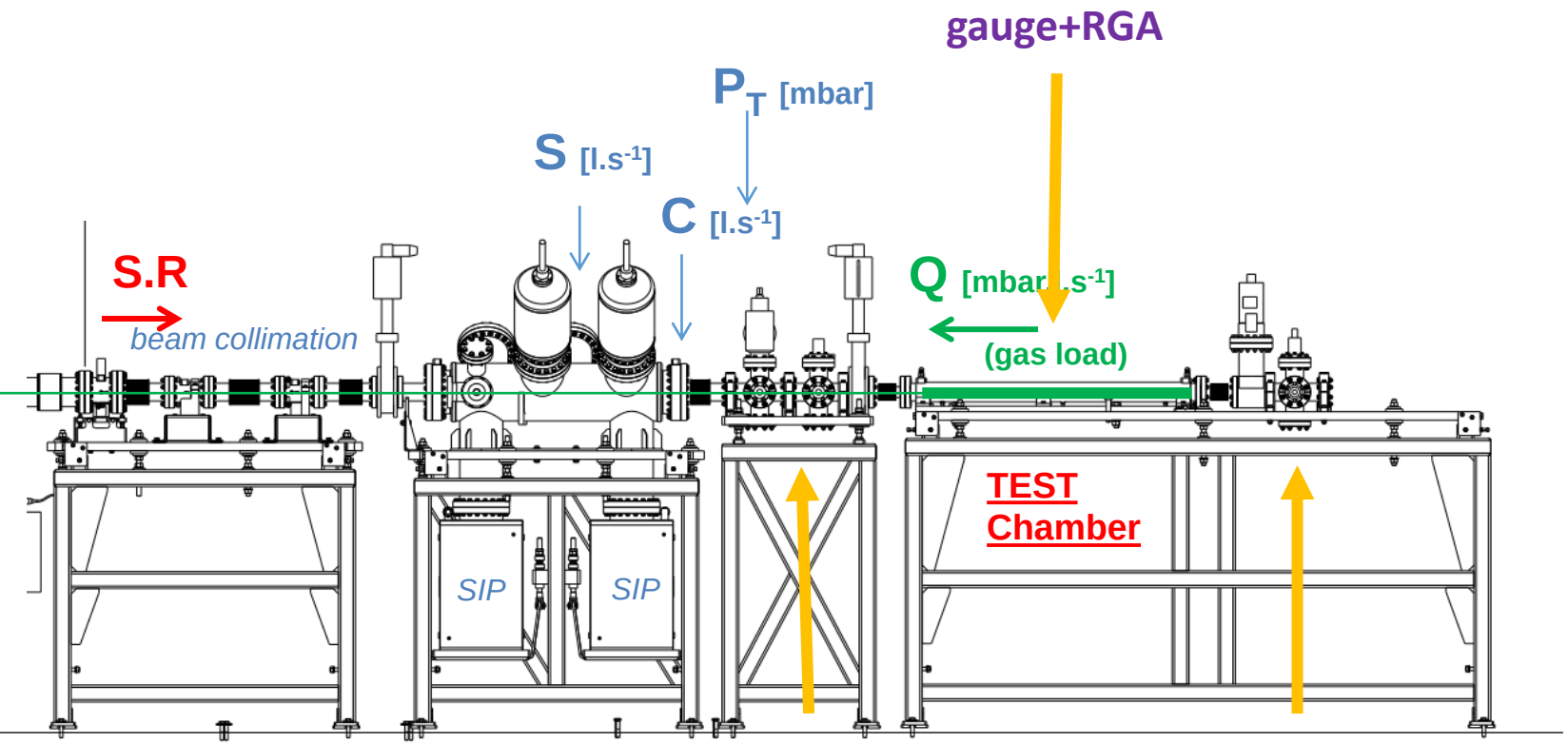






Courtesy of C. Burrows (DSL)

An updated facility for PSD studies on SR beamline at Soleil



Turbo molecular pump + gauge+RGA

Turbo molecular pump + gauge+RGA

Courtesy of C. Herbeaux (Soleil)

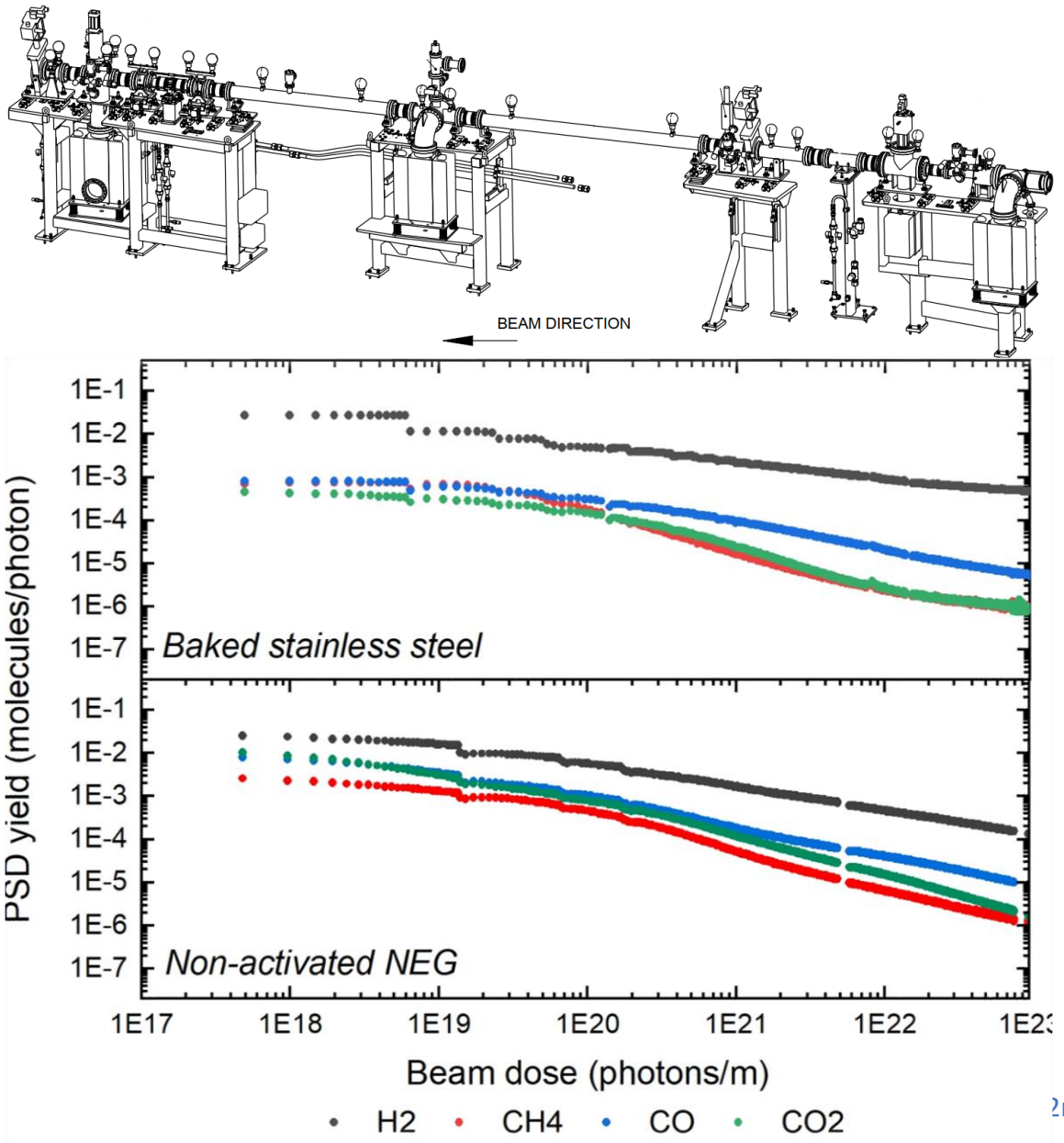
Overview

- Typical Soleil dipole front-end:
  - Photon flux: 3.4×10^{14} photon/(s·mrad·mA)
  - Critical energy: 8.379 keV
- Beam width at test piece 1-50 mm
- Test vessel angular range of up to 30 mrad (1.8°)

Status

- Front-end section: reconditioned during 2020
- Experimental end-station: operated in 2022 with samples coated with NEG at SAES getters
- The samples will be NEG coated at UKRI (DL) and installed during a Soleil shutdown in Aug 2023
  - Soleil is under shutdown till 15th March 2023 because the electricity cost

A facility for PSD studies on SR beamline at DSL



- DLS dipole front-end (FE10B):
  - installed November 2020
  - photon flux: 3.86 x 10^{14} photon/(s·mrad·mA)
  - critical energy: 8.379 keV
  - test vessel angular range of up to 60 mrad (3.5°)

Status

- Experimental end-station: under post-installation conditioning with a stainless steel DLS type uncoated sample till Feb 2022
- Stainless steel DLS type sample NEG coated at UKRI (DL) was installed during a DLS shutdown in March 2022 and remain under SR till present
  - PSD data collected for uncoated and non-activated coated vessels
  - Activation trials started on NEG coated (TiZrV) vessel and initial PSD measurements performed
  - Analysis ongoing for comparison to previous behaviours
- 1st copper sample coated with NEG could be installed during a following DLS shutdowns starting on the 26th May 2023.

Summary

- Task 10.5 team works in full capacity according its plan
- All necessary capabilities exist at least with two partners
  - Deposition facilities are operational at UKRI and DESY, in conditioning at DSL, can be used at Soleil
  - Pumping property evaluation facilities are operational at UKRI, DESY and Soleil, in conditioning at DSL.
- SR beamlines
  - Both PSD facilities have been commissioned with NEG coated samples and are ready for IFAST Task 10.5 samples
    - in Soleil from summer 2023
    - at DLS from 26th May 2023
- Samples:
  - 11 samples for pumping property measurements have been produced:
    - 3 samples has been used at UKRI for comparing copper cleaning procedures by TD measurements
    - 8 samples have to be re-cleaned at DESY and sent to UKRI for NEG coating and testing in 4 labs
  - 9 samples for PSD measurement have been designed and produced
    - delivered to UKRI for NEG coating in October 2022 and
    - to be installed on SR beamlines in May-Aug 2023
- Milestone MS48 report, Y1 and P1 contributions submitted on time

Acknowledgment (Task 10.5 team)

DLS

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- Chris Burrows
- Hugo Shiers
- Ryan Russell

DESY

- Lutz Lilje
- Ruta Sirvinskaite
- Nils Plambeck
- Ralph Böspflug
- Sven Lederer

Soleil

- Christian Herbeaux
- Nicolas Béchu
- Vincent Le Roux
- Jonathan Gaudio

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- Reza Valizadeh
- Eleni Marshall
- Adrian Hannah
- James Conlon

iFAST

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