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Recent Results on NEG Coating Characterisation

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Outline

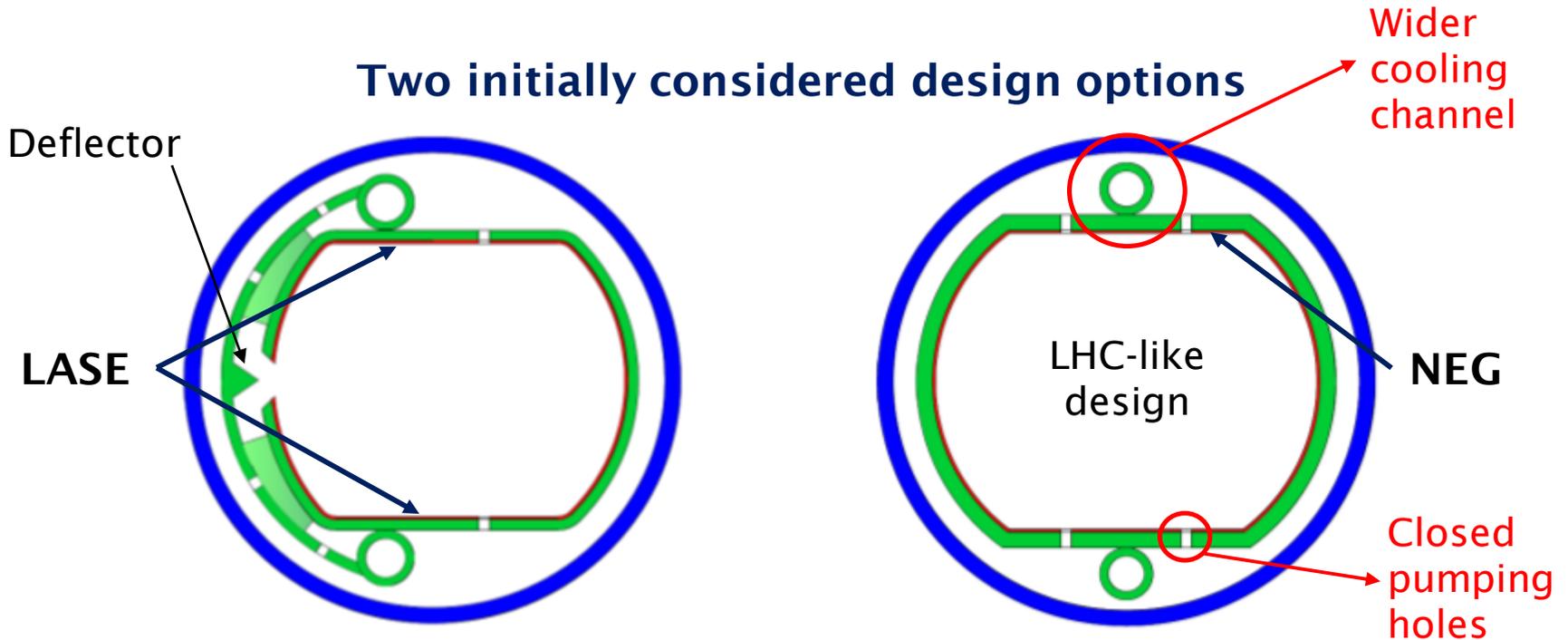
1. NEG coating and its properties
2. Tested samples and their morphology
3. NEG characterisation system
4. Experimental procedure
5. Sticking probability at room temperature
6. Cooling a non-activated sample
7. ESD at room temperature before and after activation
8. ESD during cooling
9. Sticking probability at cryogenic temperatures
10. ESD at 90 K
11. Conclusions and future experiments



NEG Coating

- One of two surface treatments considered in EuroCirCol WP 4 Task 4 to mitigate e-cloud and ion instabilities

Two initially considered design options



Ultimately, the deflector design was proposed



NEG as candidate material

Advantages:

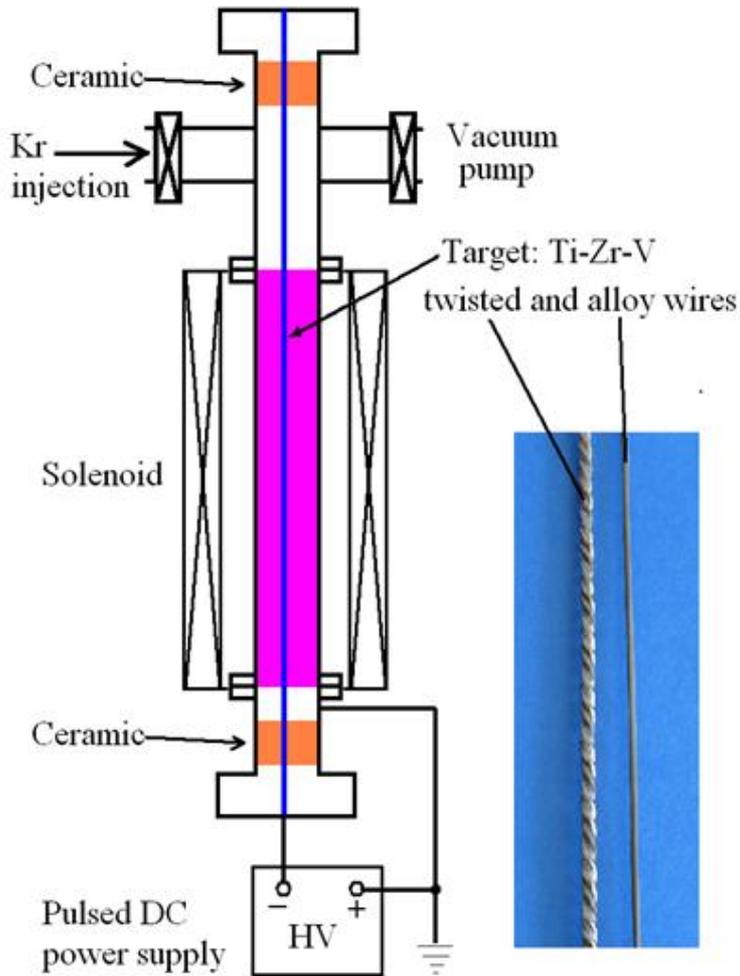
- **Distributed pumping** – no pumping holes needed, beam and insulation vacuum can be separated
- Reduced **electron-, photon- and ion-stimulated desorption** (ESD, PSD and ISD) yields
- Secondary Electron Yield **SEY < 1**
- **SR activation @ RT** – avoid heating of the tube (challenging at any temperature)

Main question:

Can these properties be kept at cryogenic temperatures?



Tested samples



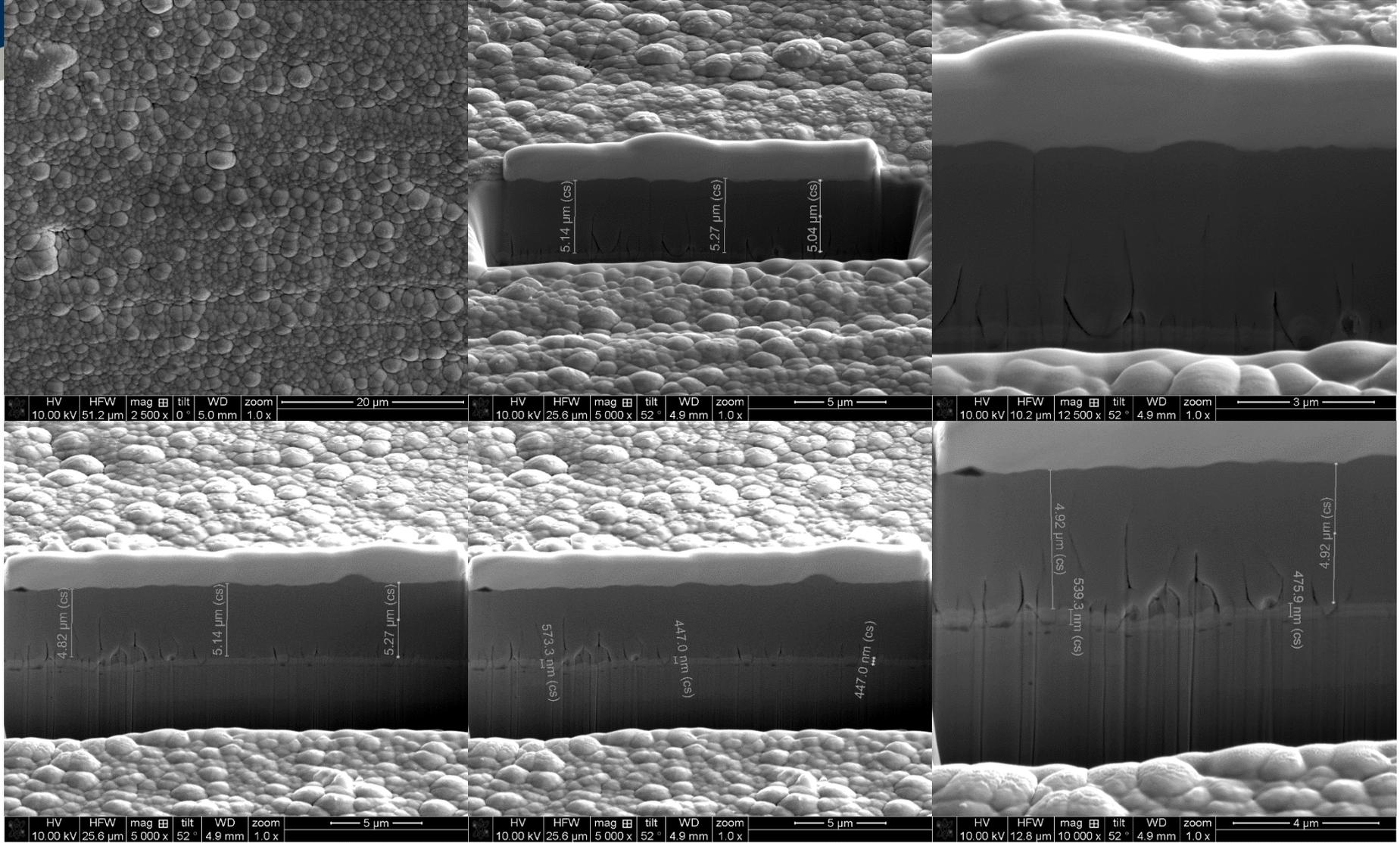
| Parameter | Dense | Columnar |
|--------------|----------------|-----------|
| Gas | Kr | Kr |
| Pressure | 10^{-3} mbar | 0.1 mbar |
| Power supply | Pulsed DC | DC |
| Temperature | 90-110 °C | 90-110 °C |

Two tubular samples

- TiZrV coating deposited from alloy wire
- Tube length – 50 cm
- Tube diameter – 3.8 cm
- Columnar structure

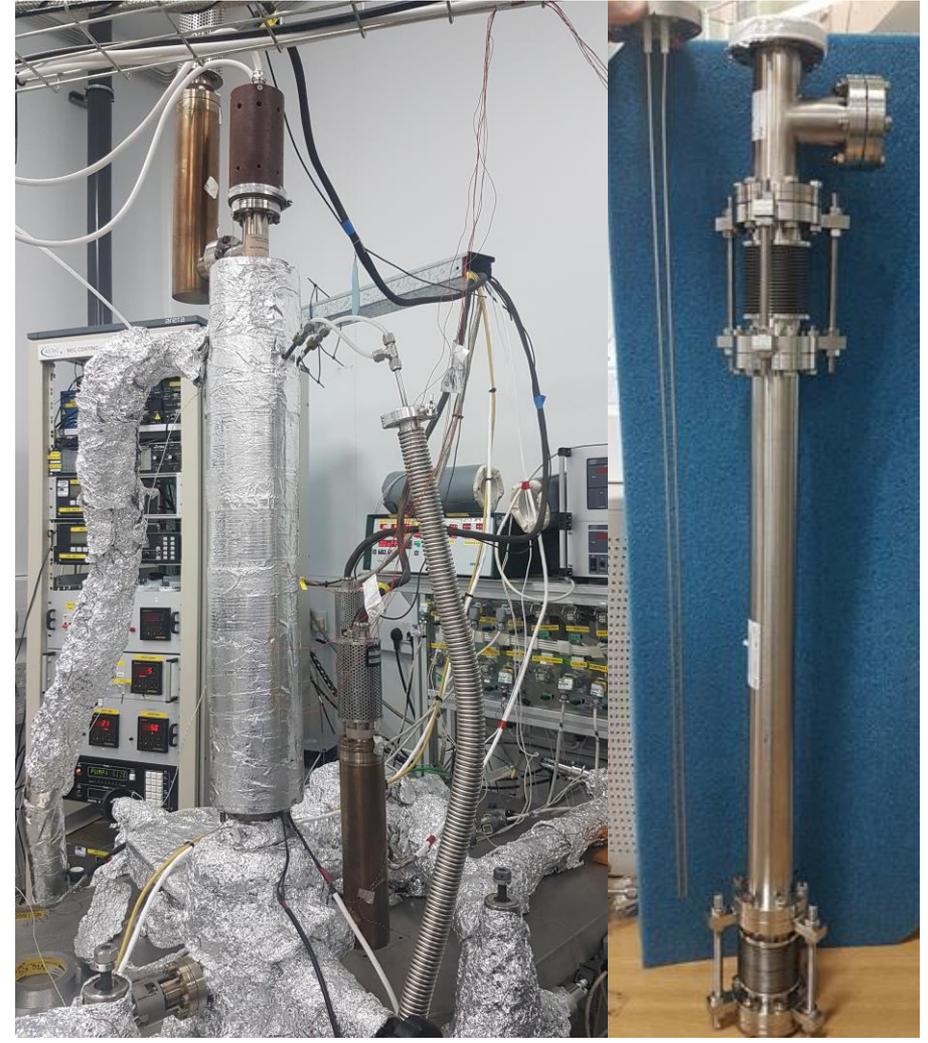
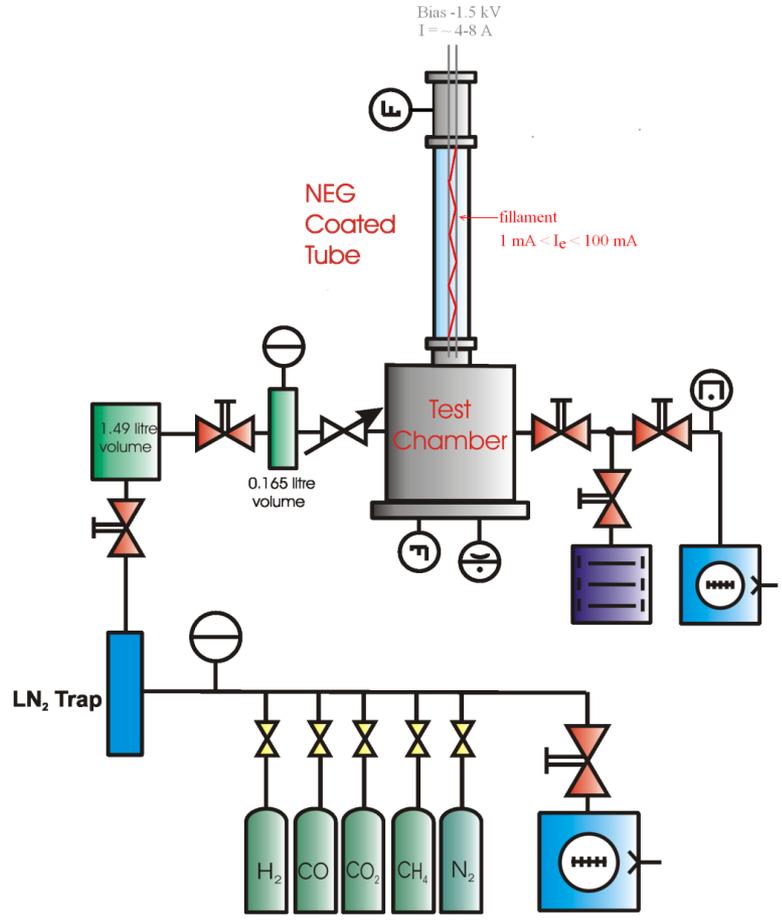


Sample morphology



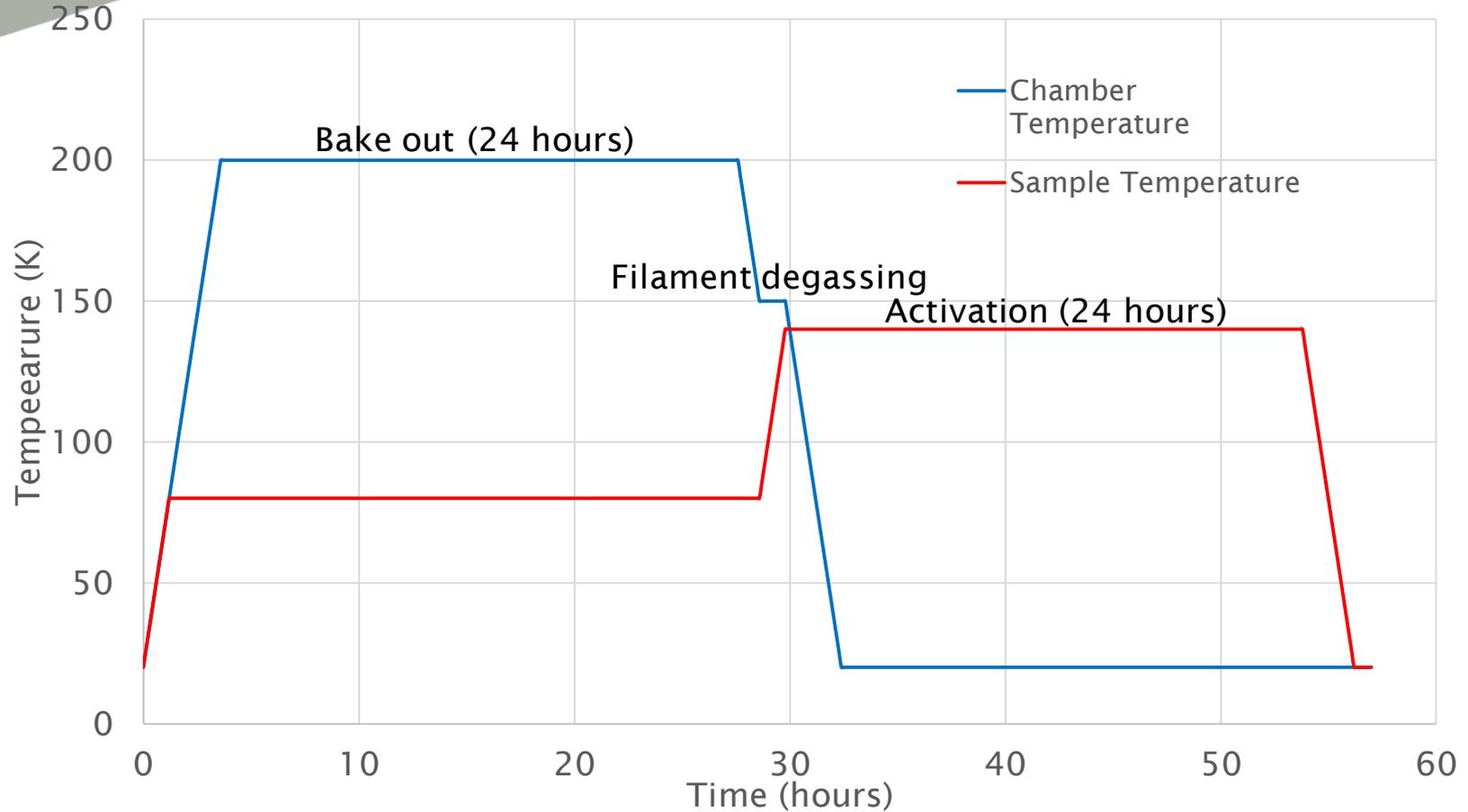


NEG vacuum properties evaluation at cryogenic temperatures





ASTeC activation procedure



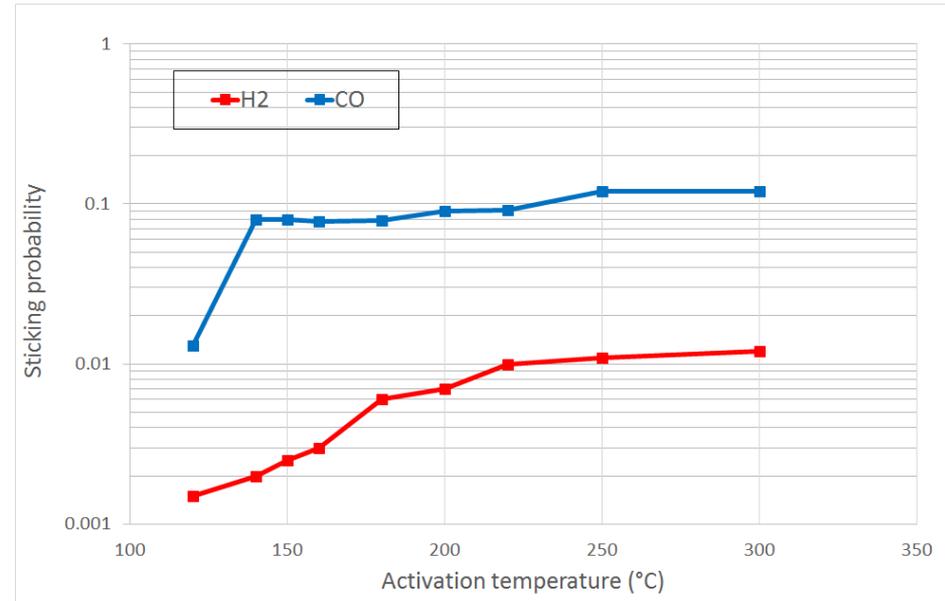
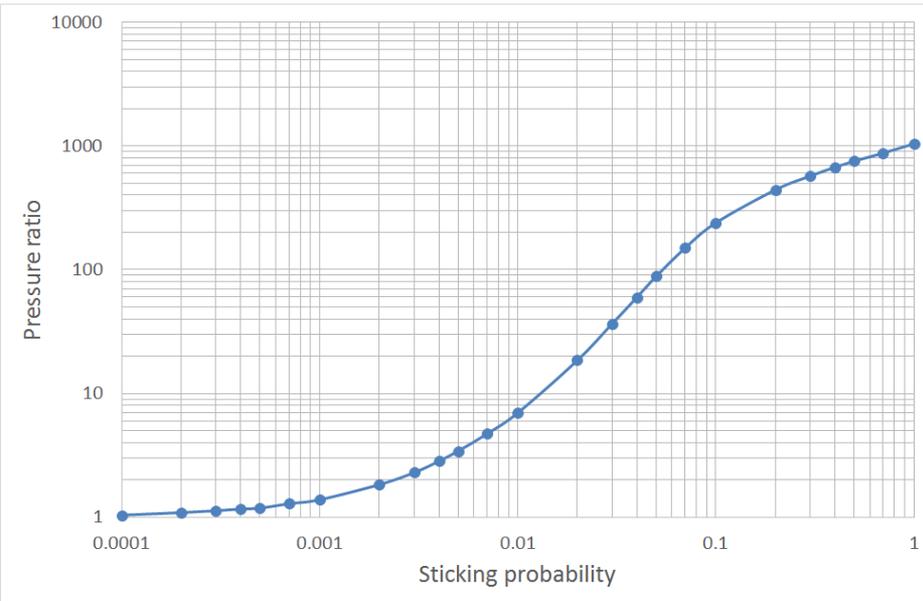
To re-activate the NEG, sample has to be heated again



Sticking probabilities at room temperature

Vacuum chamber modelled in Molflow, the data used to convert pressure ratio to sticking probability of NEG coating

Activations to 120, 140, 150, 160, 180, 200, 220, 250 and 300 °C – pressure ratios recorded



CO nearly fully pumped after activation to 180 °C

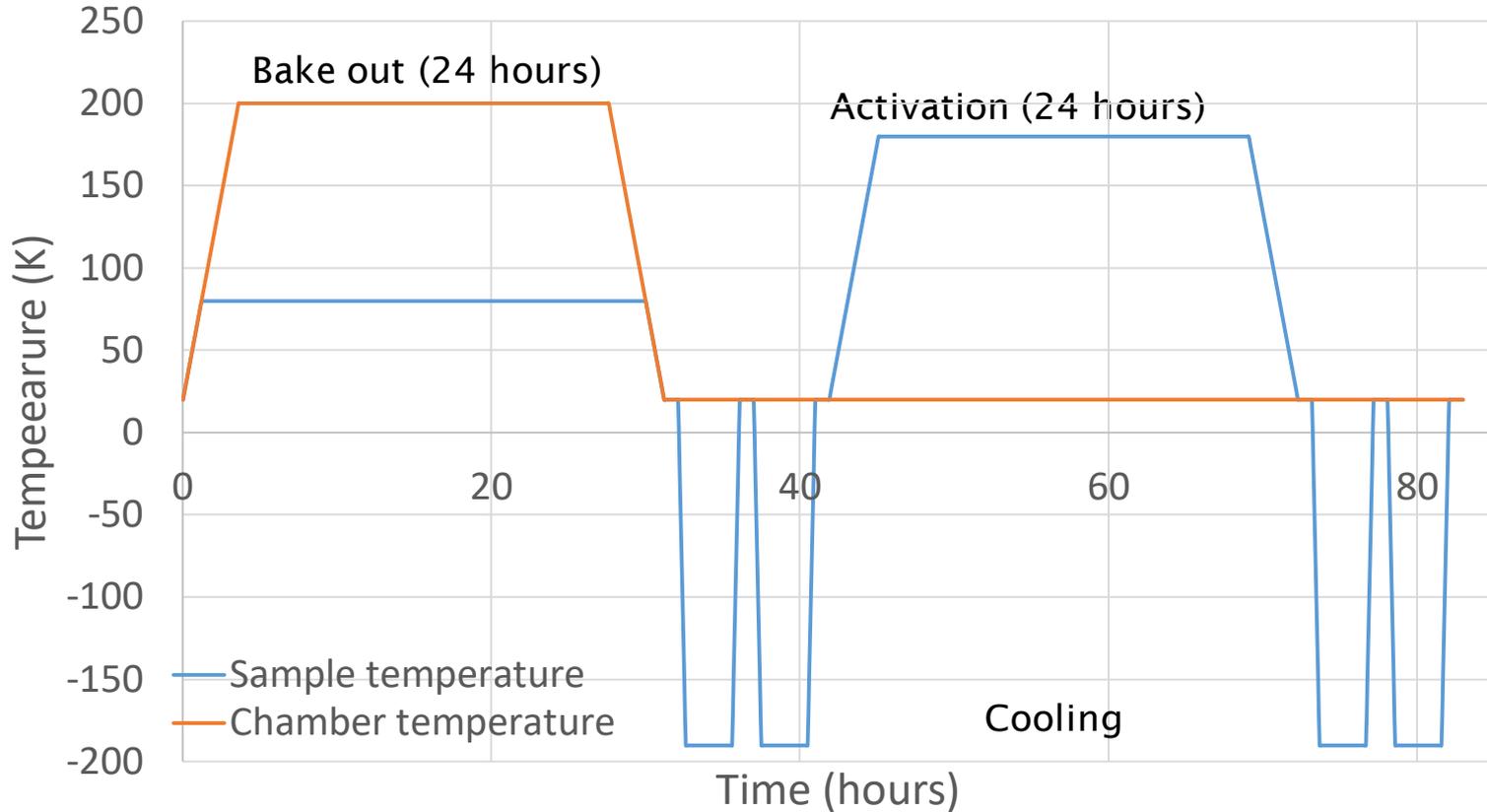


List of completed experiments

| Sample | Description of the experiment | Pump | Activation | Cooling | Result |
|--------|---|-------|------------|---------|-------------------------------------|
| 1 | H ₂ &CO injections | None | 120-190 | No | α vs T _{activation} |
| 2 | ESD | TMP | None | Yes | Activation with ESD? |
| 2 | Desorption from hot filament | TMP | None | Yes | Cryosorption |
| 2 | ESD | TMP | 180 | No | η @ RT |
| 2 | ESD | TMP | 180 | Yes | η and η' @ CT |
| 2 | H ₂ +CO injections | SIP | 180 | No | α @ RT |
| 2 | Desorption from hot filament | TMP | 180 | Yes | $\alpha(T)$ |
| 2 | Ar, CO ₂ , CO, CH ₄ , H ₂ injections | TMP | None | Yes | Cryosorption of diferent gases |
| 2 | ESD | TMP/N | None | Yes | Activation with ESD? |
| 2 | ESD | TMP/N | 180 | Yes | η and η' @ CT |
| 2 | H ₂ &CO injections | TMP | 180 | Yes | $\alpha(T)$ |



Experimental procedure for cryogenic measurements



Sample was activated to 180 °C again after these experiments

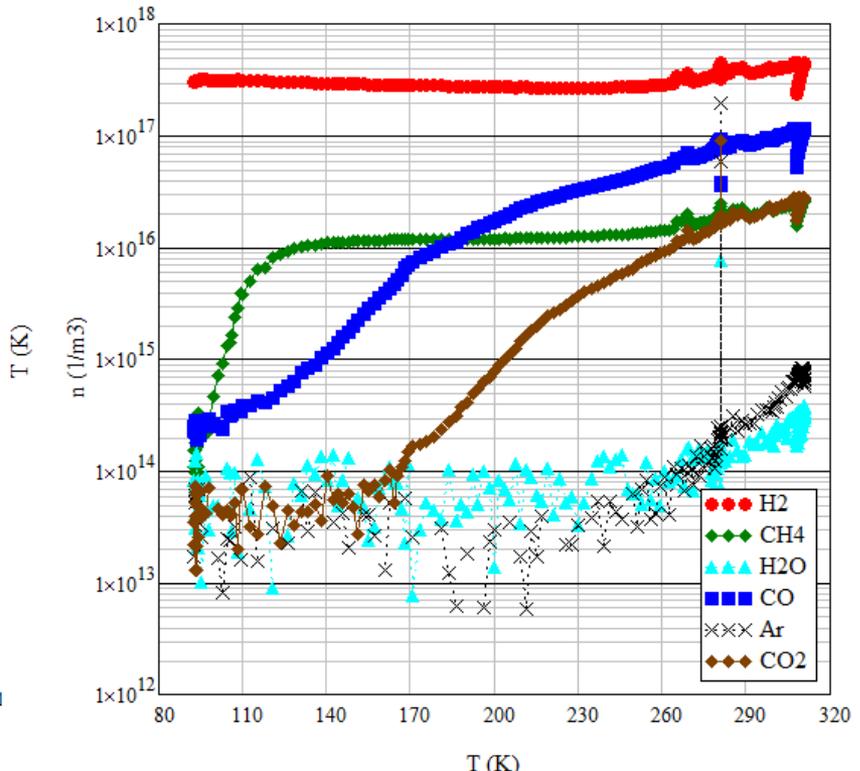
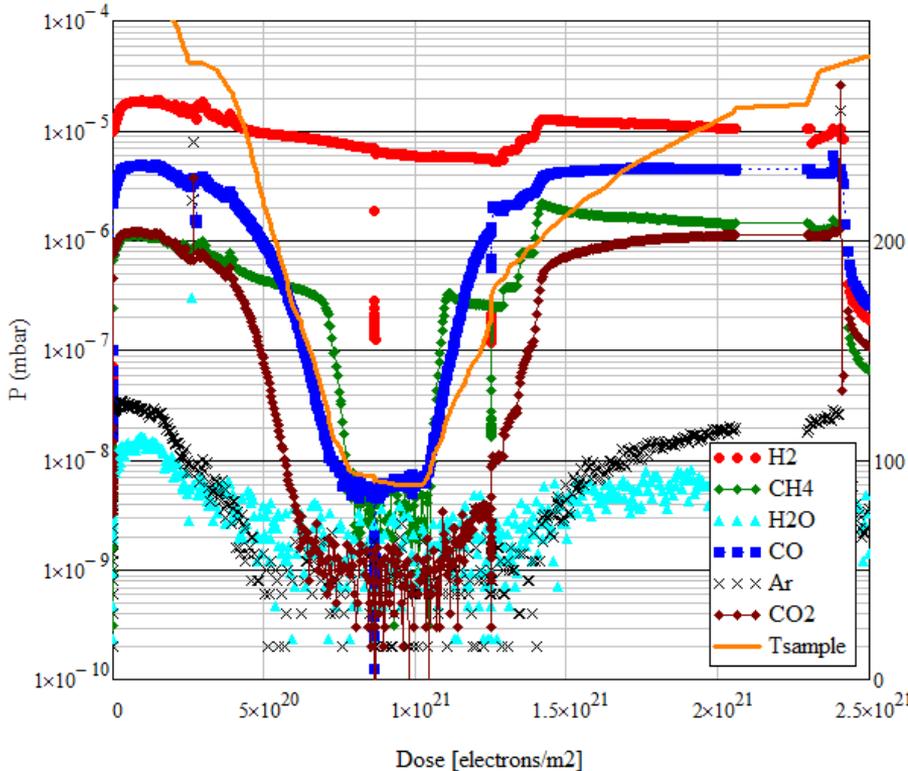


Cooling a non-activated sample

Pressure inside the NEG-coated chamber during cryogenic ESD experiments

Gas density inside the NEG-coated chamber as a function of temperature during ESD

$$n_t = n_{RGA} \frac{\overline{v_{RT}}}{v_t} = \frac{P_{RGA}}{k_B \sqrt{T_{RT} T_t}}$$



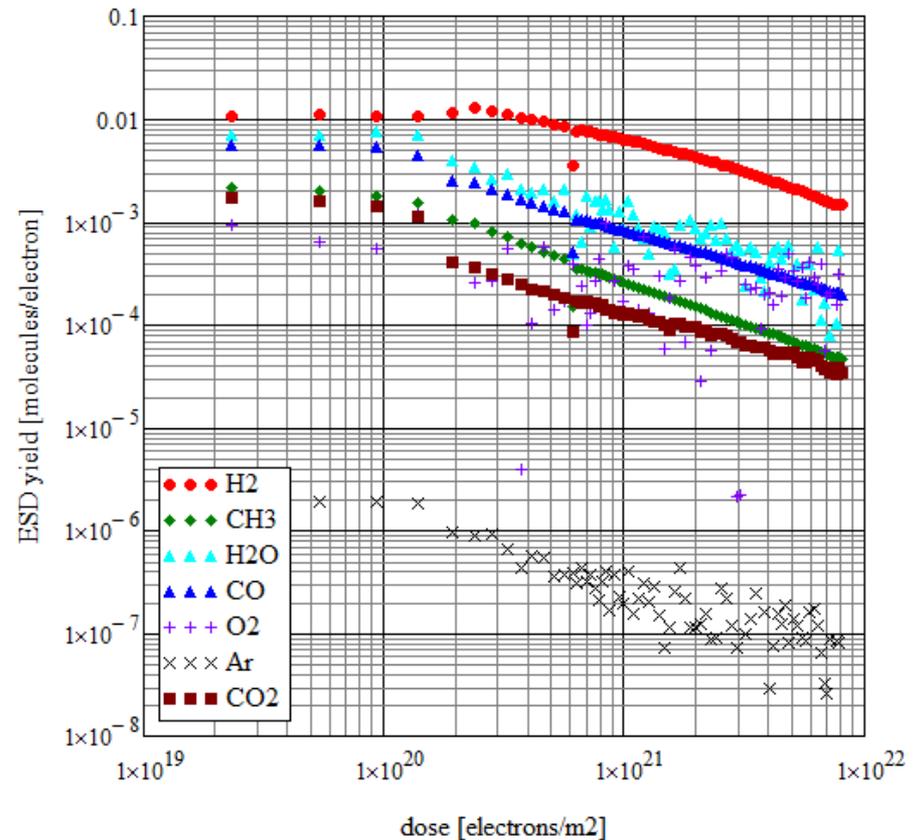


Initial ESD yields before and after NEG activation

Comparison of initial ESD yields (molecule/electron) before and after NEG activation

| Gas | Before activation | After activation |
|-----------------|--------------------|----------------------|
| H ₂ | 0.2 | 0.01 |
| CH ₄ | 6×10 ⁻³ | 2×10 ⁻³ |
| CO | 0.025 | 5×10 ⁻³ |
| Ar | 2×10 ⁻⁴ | 2×10 ⁻⁶ |
| CO ₂ | 6×10 ⁻³ | 1.5×10 ⁻³ |

ESD yield after NEG activation as a function of dose

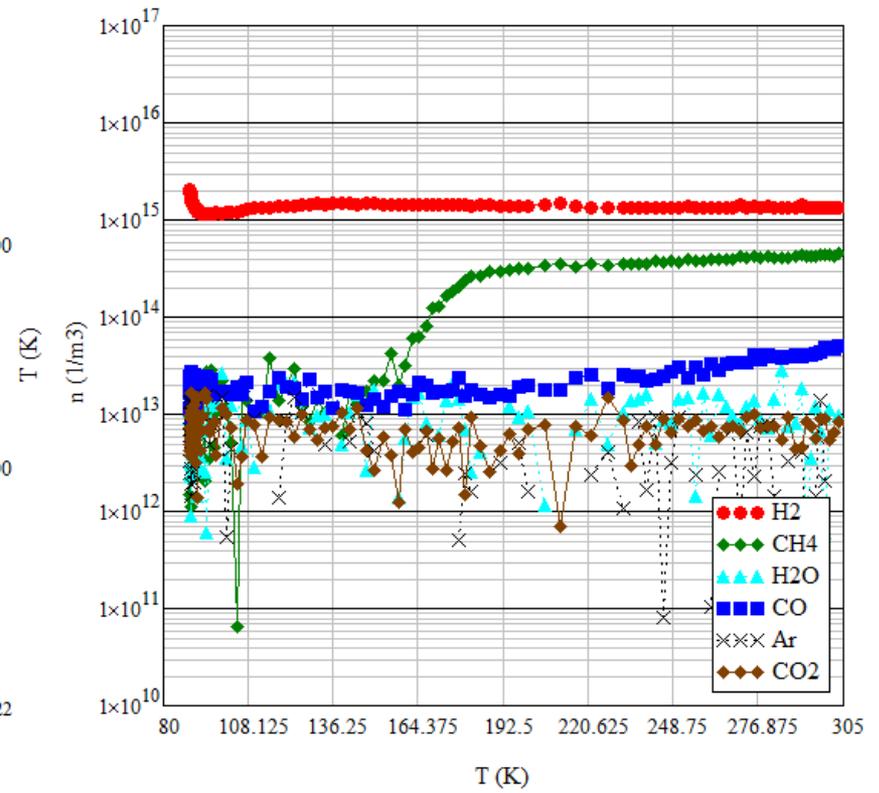
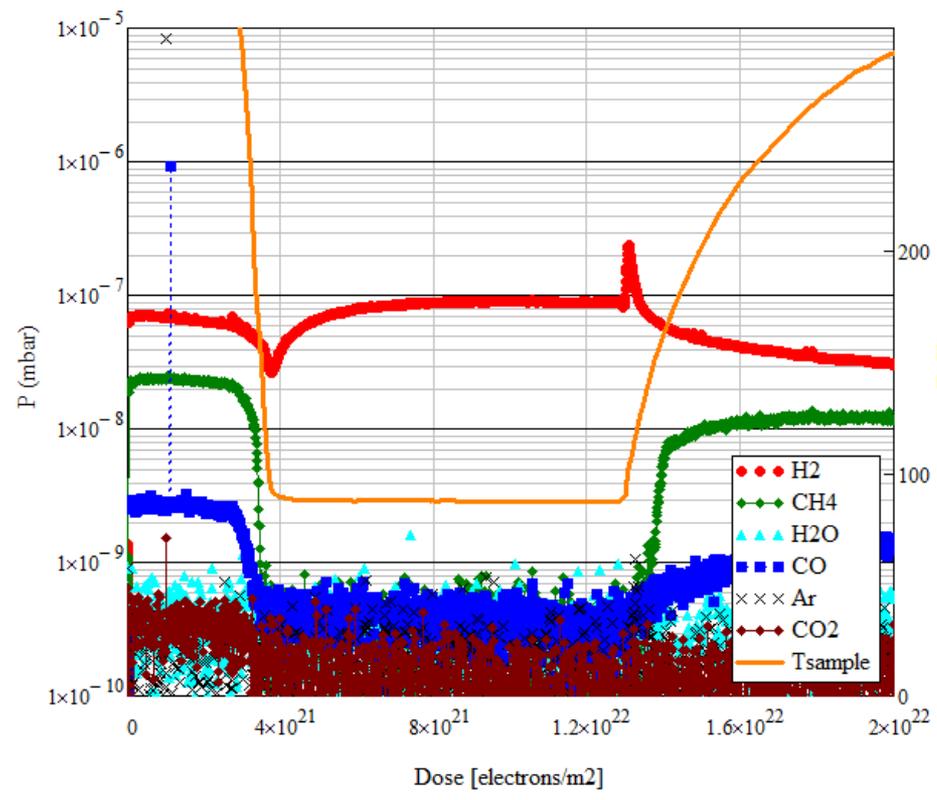




ESD from activated NEG coating at cryogenic temperatures

Pressure inside the NEG-coated chamber during cryogenic experiments

Gas density inside the NEG-coated chamber as a function of temperature



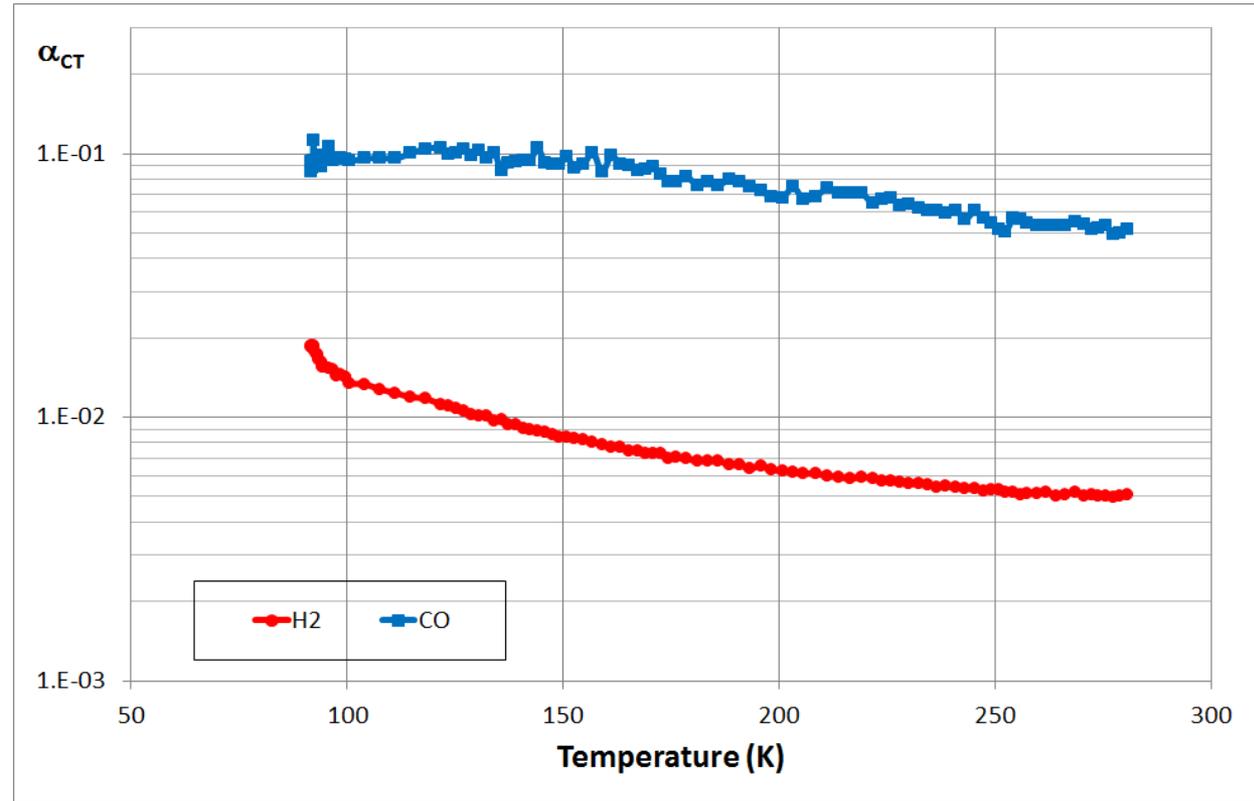


Sticking probability measurements at cryogenic temperatures

1. The source of gas – hot filaments placed along the test tube

$$\alpha_{CT} = \alpha_{RT} \frac{P_{RT}}{P_{CT}}$$

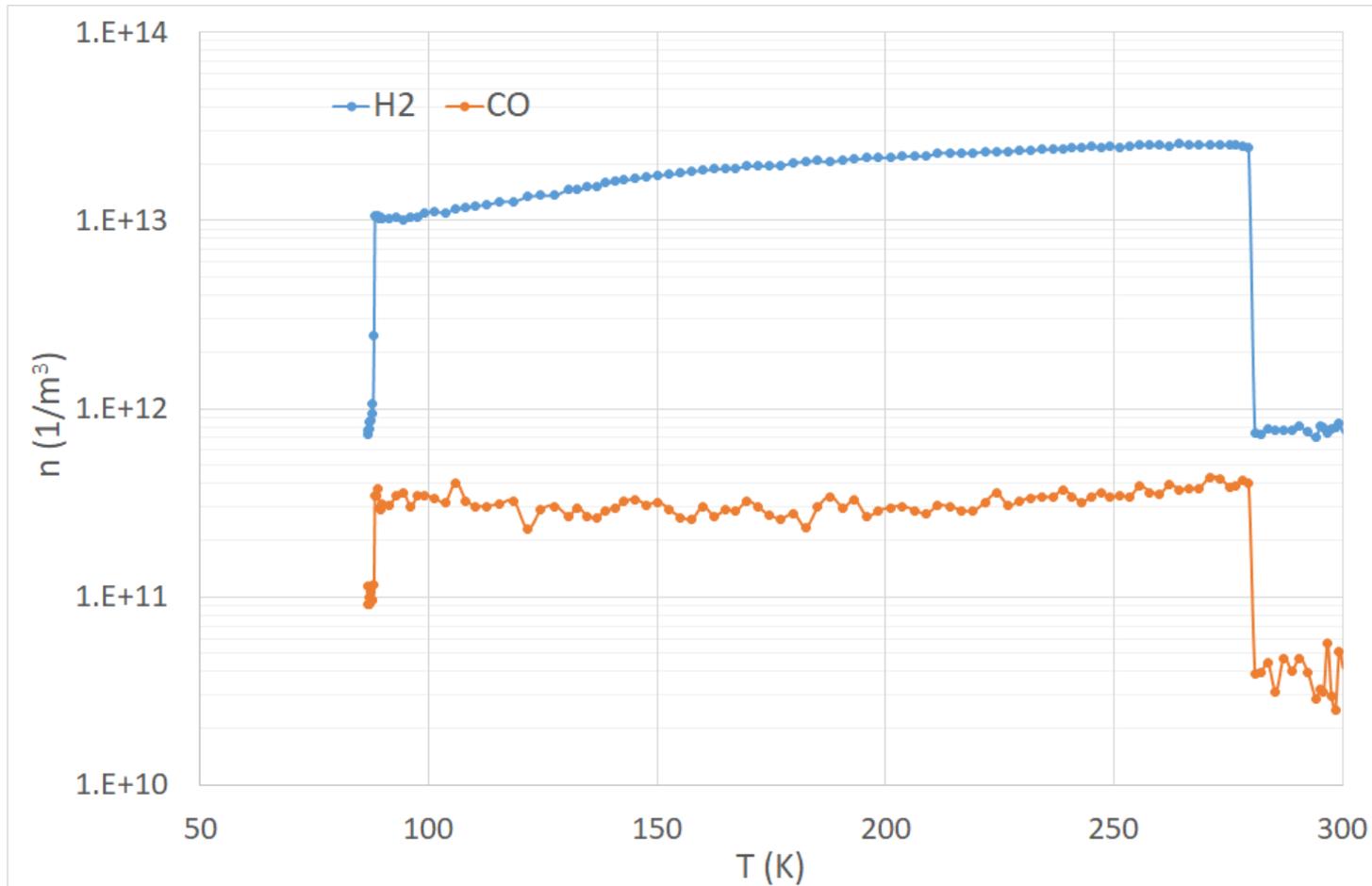
2. 12 hours activation, then gas injection + TPMC



| Gas | α at 300 K | α at 85 K |
|----------------|--------------------|--------------------|
| H ₂ | 4×10^{-3} | 4×10^{-2} |
| CO | 5×10^{-2} | 0.1 |



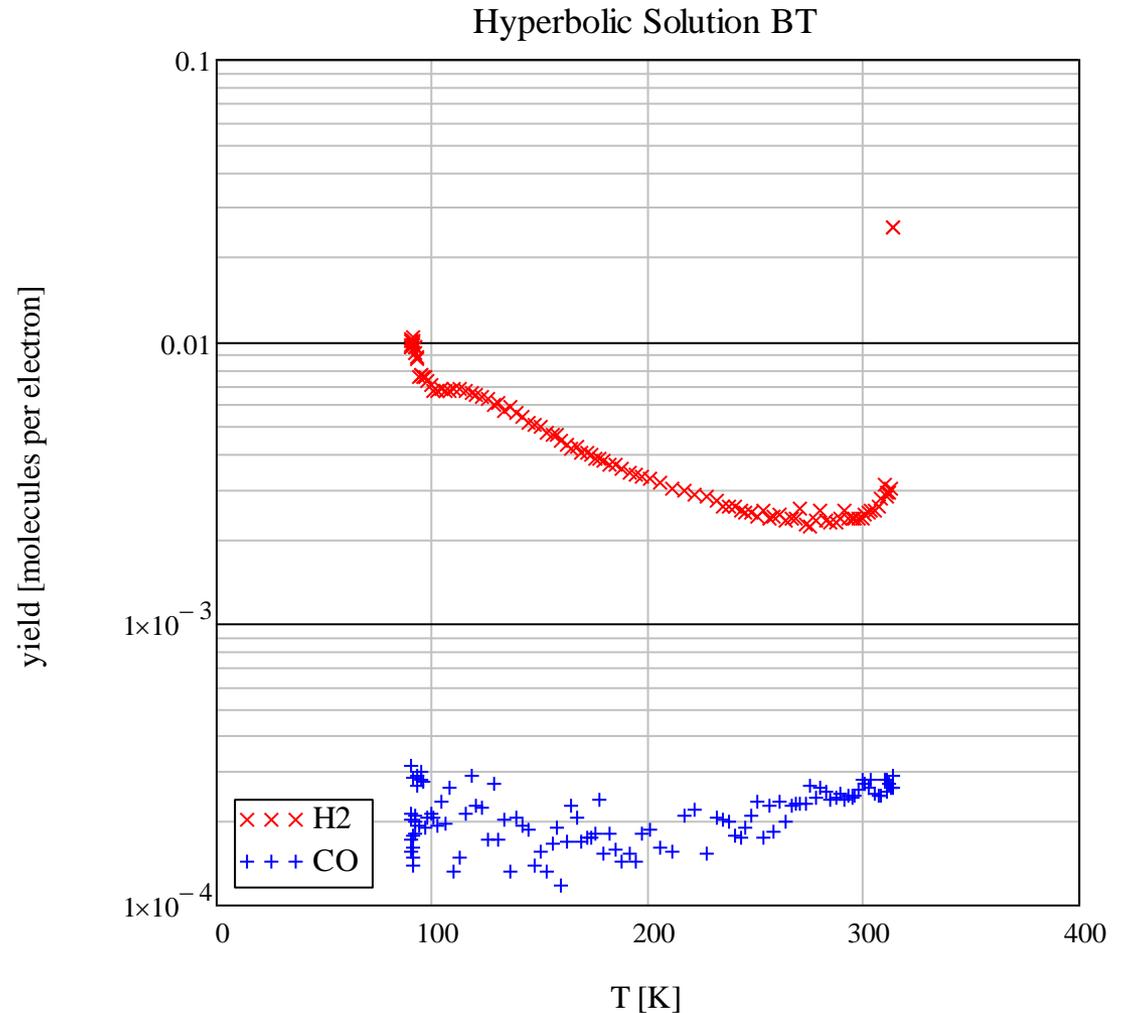
Gas density inside the NEG-coated chamber during cooling down





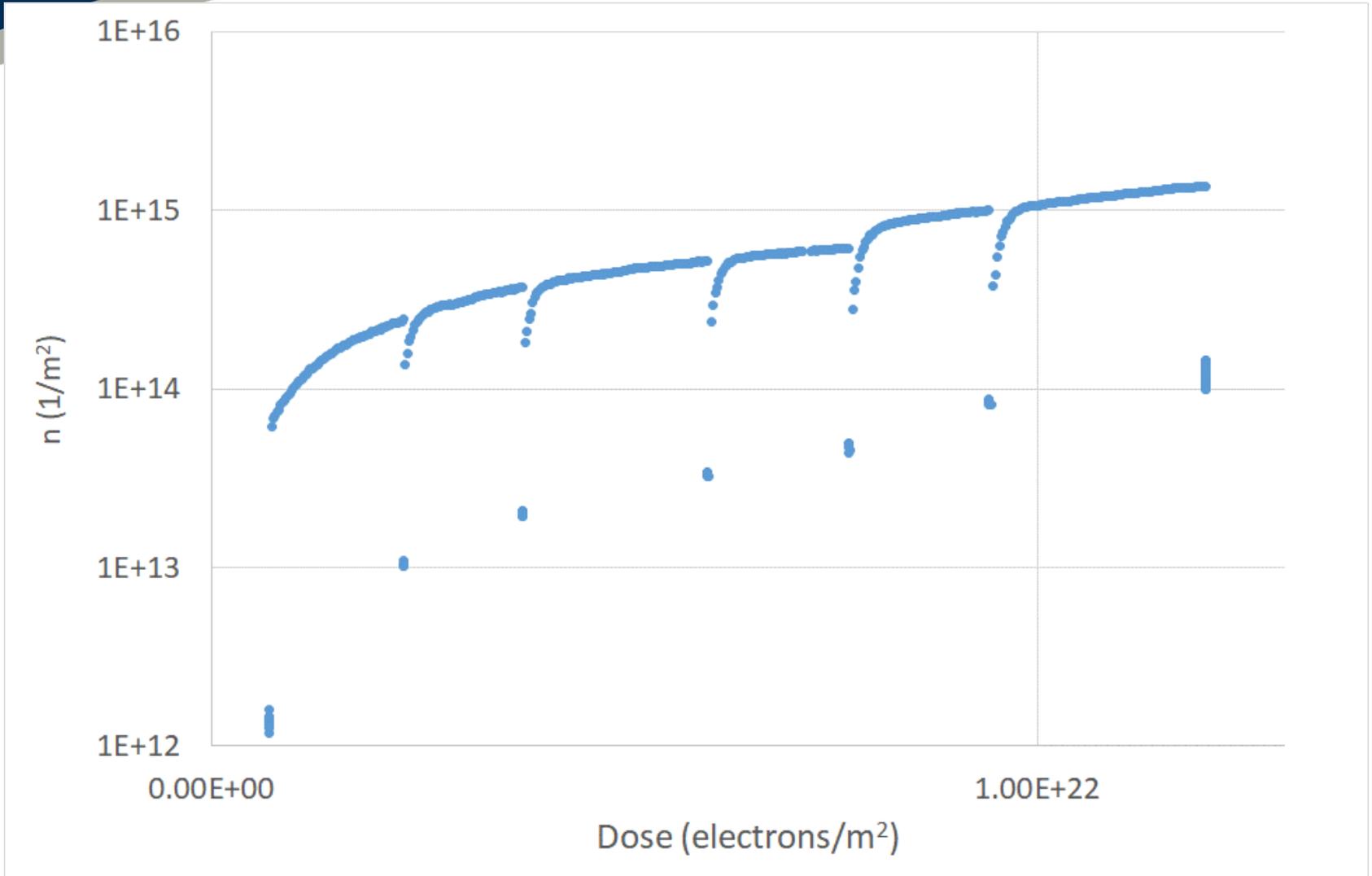
ESD yield as a function of temperature during cooling down

ESD yields were calculated using data for sticking probabilities and measured gas density; however, ESD yield cannot increase at low temperature





ESD at 85 K

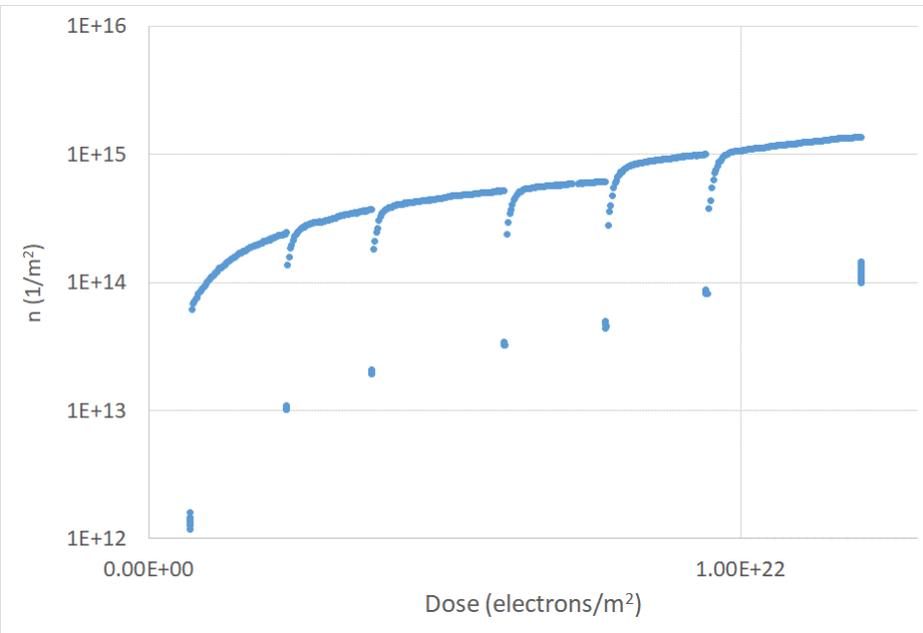




H₂ ESD and PSD

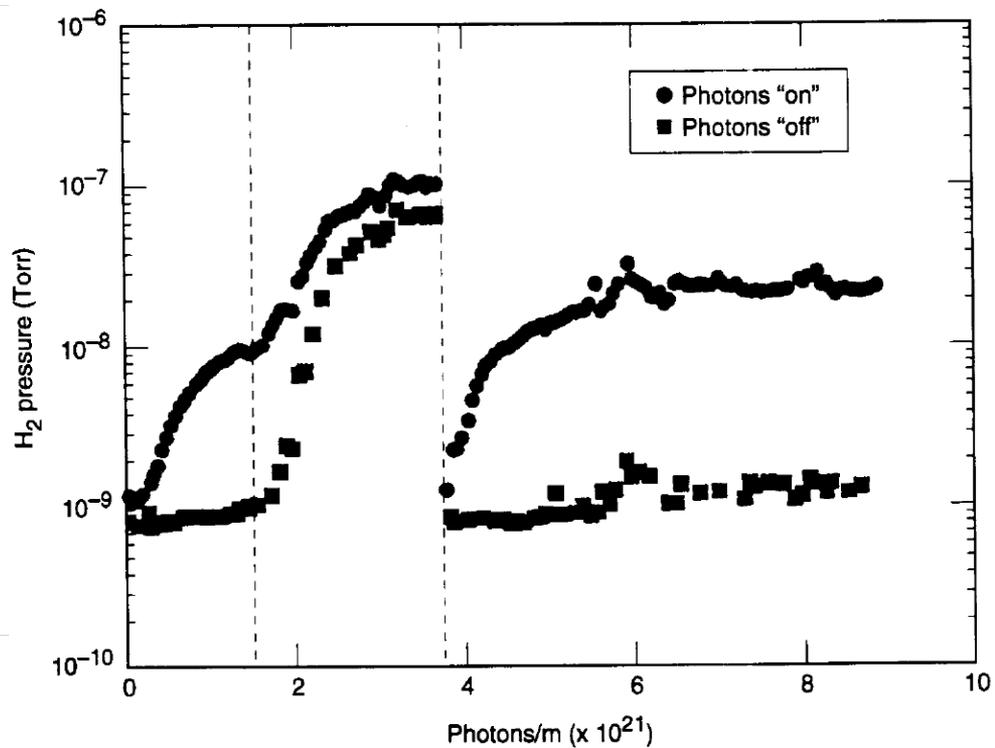
H₂ pressure increase during photo desorption measurements from copper.

ESD at 85 K (2019)



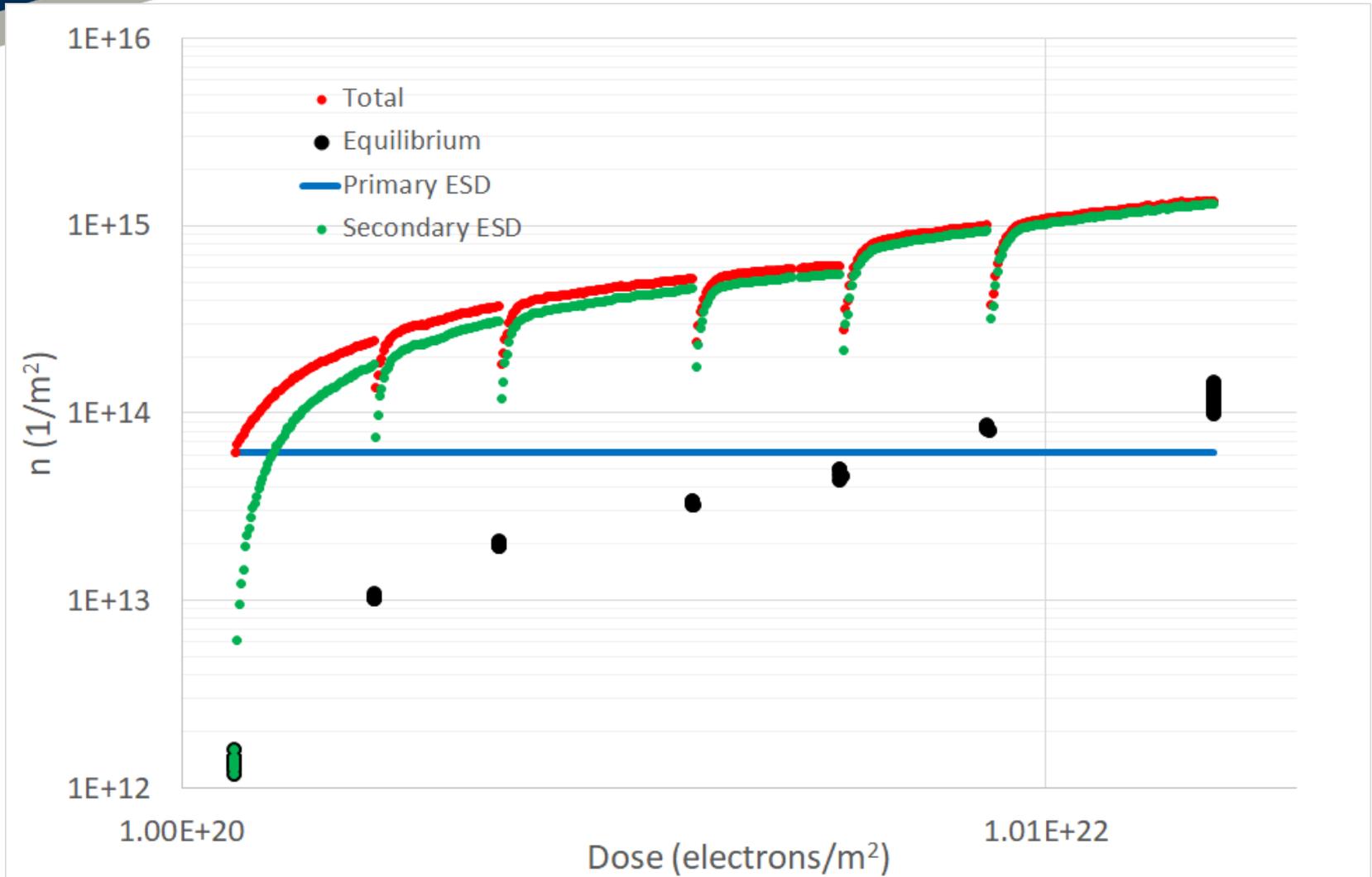
PSD at 4.2 K

(V. Anashin et al., 1994)





ESD at 85 K – gas density





Conclusions and future experiments

| Task | Problem | Solutions |
|---------------------------|---|---|
| ESD and pumping | Does NEG coating work at cryogenic temperatures? | For CO: <ul style="list-style-type: none">• η reduces and α increases For H ₂ : <ul style="list-style-type: none">• η and α - small change,• η' effect (like at 4.2 K) is observed on activated NEG surface |
| NEG activation with SR | Would SR induced activation of NEG coating be possible at cryogenic temperatures (like it is observed at RT)? | No such effect observed at cryogenic temperature |
| New types of NEG coatings | Different composition, morphologies | <ul style="list-style-type: none">• Columnar and dense films of Ti-Zr-Hf-V, Ti-Zr-V and Zr films have been studied |



Acknowledgements

- The European Circular Energy-Frontier Collider Study (EuroCirCol) project has received funding from the European Union's Horizon 2020 research and innovation programme under grant No 654305. The information herein only reflects the views of its authors and the European Commission is not responsible for any use that may be made of the information.
- The target was funded by the National Key Research and Development Program of China under grant No 2016YFA0402004.
- Many thanks to the EuroCircol WP4 participants and staff at Daresbury laboratory, most importantly Adrian Hannah and James Conlon