



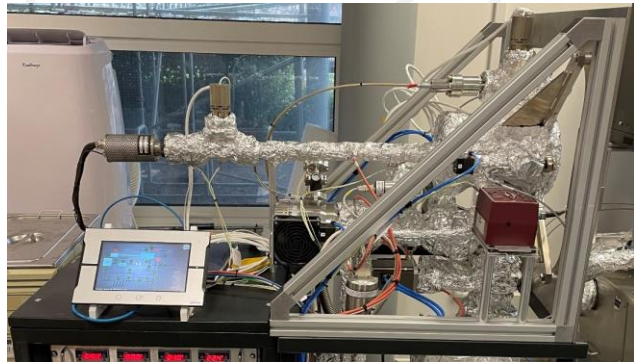
Update on PSD and pumping property measurements at DLS

C. Burrows, M.P. Cox and Z. Mei

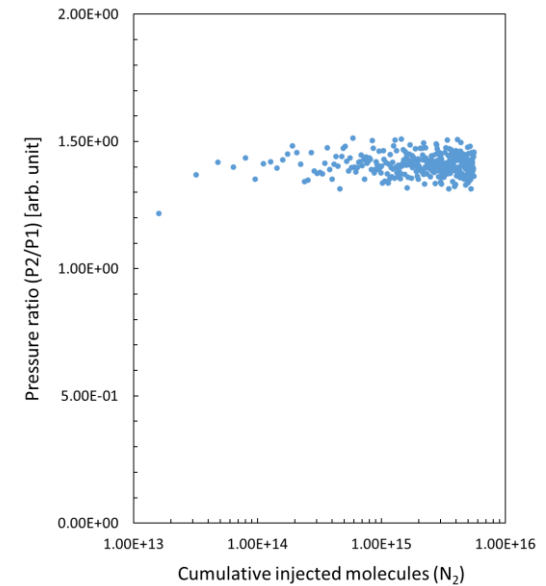
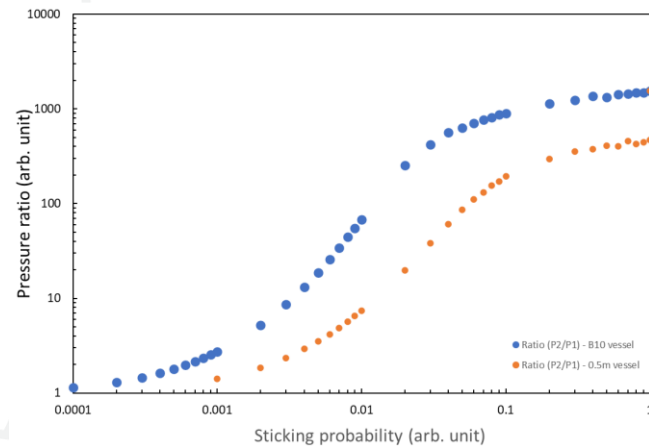
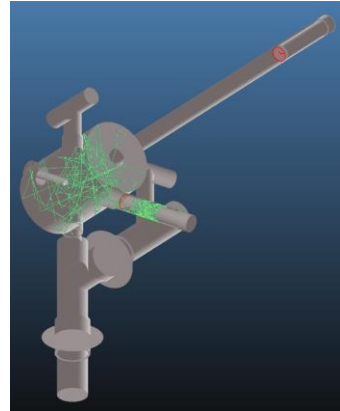
24th September 2024

Pumping property measurements - uncoated

- Initial testing completed on simple, non-NEG coated, 0.5 m DN40 vessel
 - $\alpha < 0.001$ for N_2



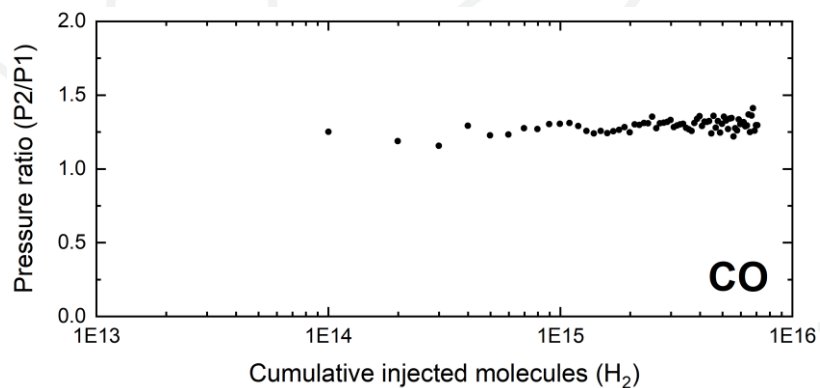
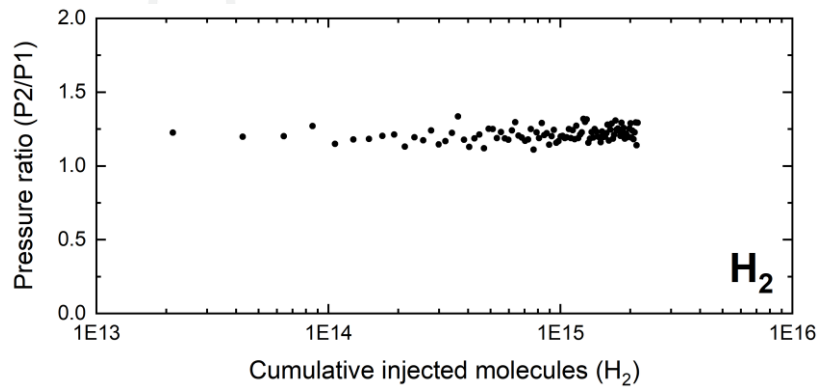
Pumping speed measurement system (0.5 m DN40)



Total pressure measurement – extractor gauges

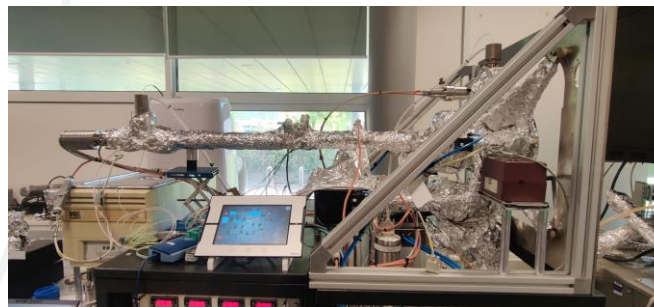
Pumping property measurements – NEG coated

- Non-coated stainless-steel vessel (DN40, 500 mm) – *no pumping*
- NEG-coated stainless-steel vessel from PSD beamline (DN40, 1000 mm) – *no pumping?*



- No pumping seen for H₂ or CO ($\alpha < 0.001$) in first activation
- Previous attempts to activate on PSD beamline saw **no PSD yield changes**
- Pumping behaviour seen at UKRI (E Marshall) after 160 °C activation:
 $\alpha_{\text{H}_2} = 6\text{E-}4$
 $\alpha_{\text{CO}} = 0.013$

Bakeout method issues? Currently attempting **4th activation trial at 180 °C**



L: System with mounted PSD vessel, R: PSD vessel

Pumping property measurements – NEG coated

Bakeout method issues? Currently attempting 4th activation trial at 180 °C

Previous pumping behaviour:

$$\alpha_{\text{H}_2} = 6\text{E-}4$$

$$\alpha_{\text{CO}} = 0.013$$

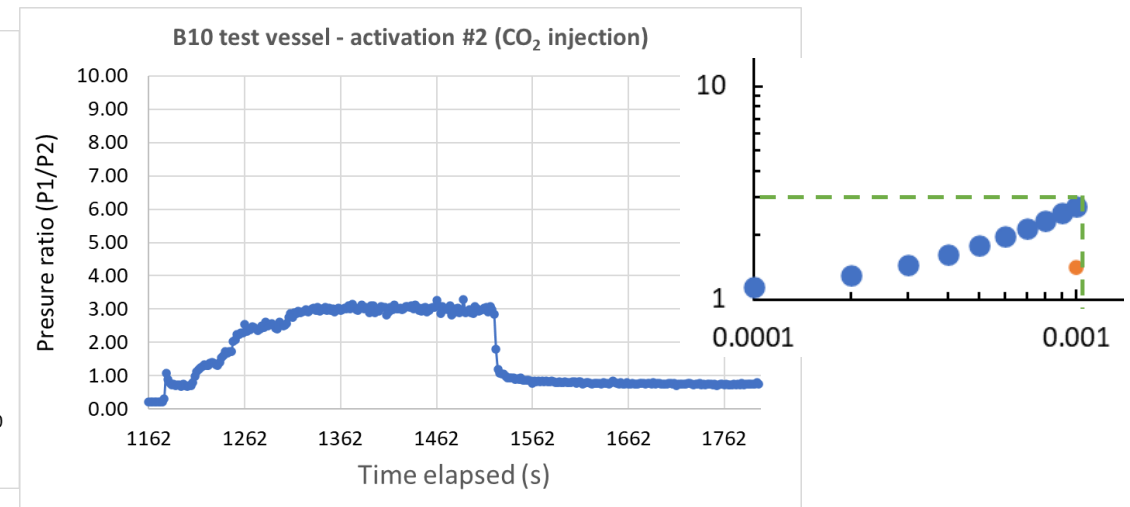
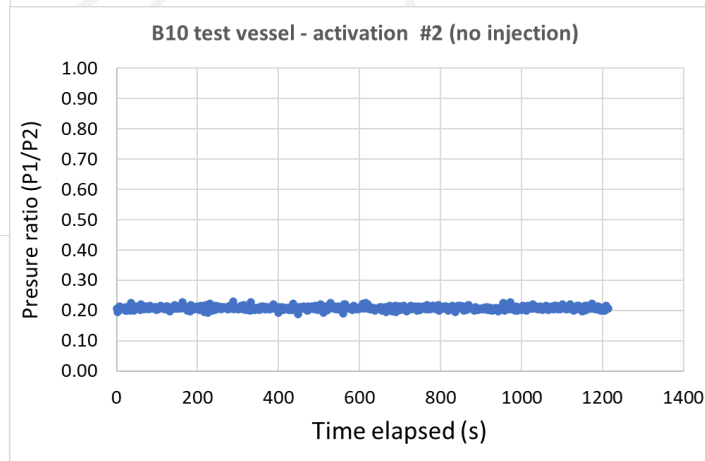
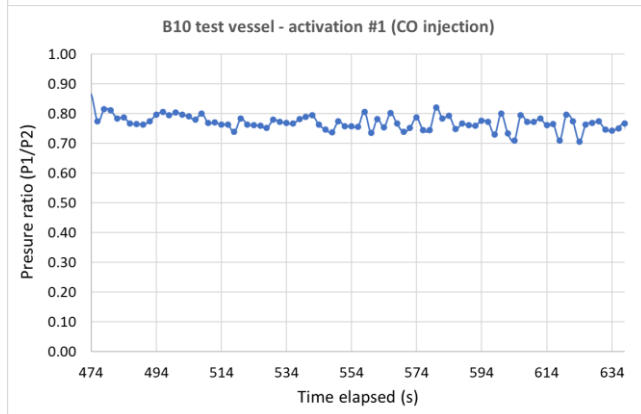
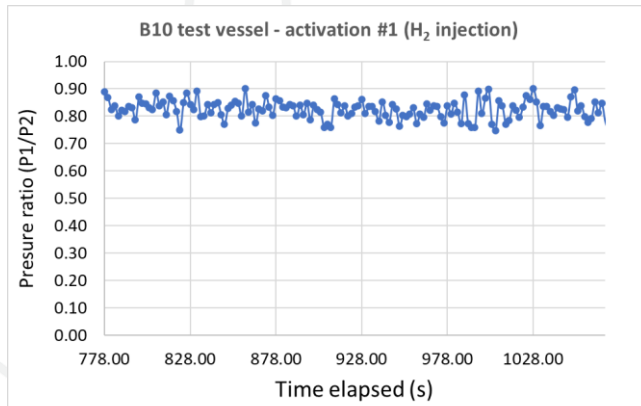
New pumping behaviour?

$$P1/P2 \sim 3$$

$$\alpha_{\text{CO}_2} = \sim 0.001$$

Not significant but step in the right direction...

Hot off the press...

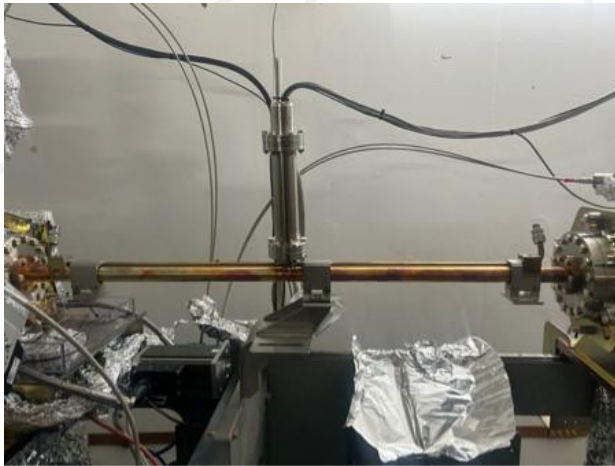


PSD status & update

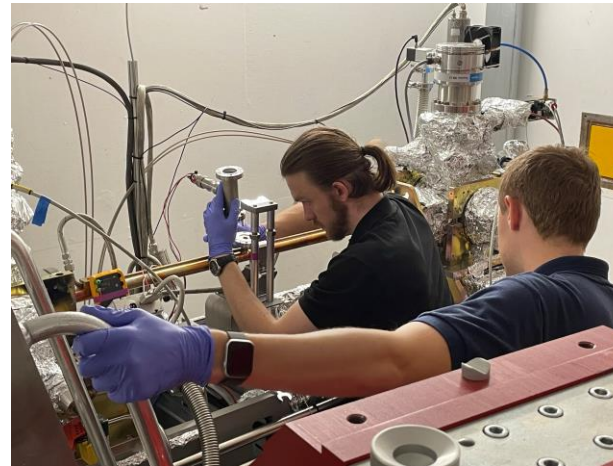
Previous: Data collected from [DN40 stainless-steel vessel](#) and presented at EVC/NEG workshop

Current status:

- March 2024 – installed [new \$\varnothing\$ 20mm Cu-vessel](#) (I.FAST-type) coated at UKRI
- August 2024 – installed [upgraded central-port conditioning assembly](#)
 - full end-station bake to 180 °C with NEG vessel at 80 °C
- September 2024 – [initial beam exposure](#) on non-activated (but baked) vessel



March 2024 – installed vessel, no conditioning assembly

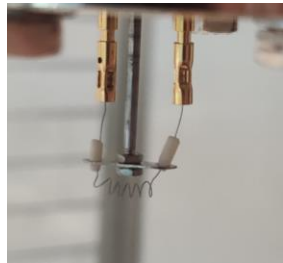
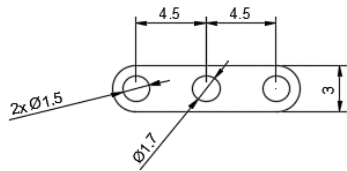


August 2024 – conditioning assembly installation



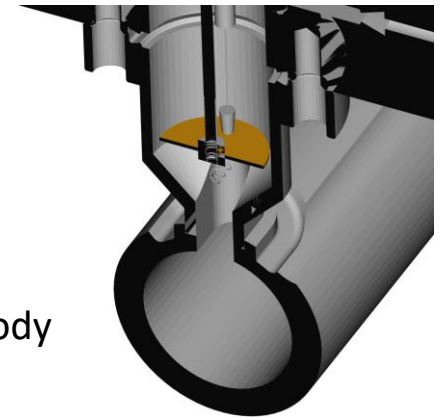
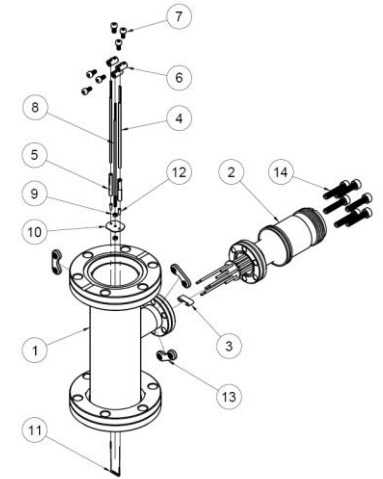
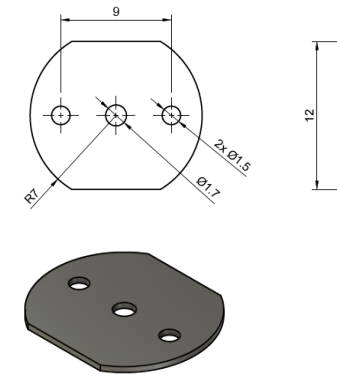
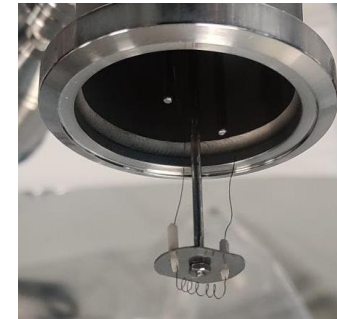
PSD beamline – conditioning assembly I

- Updated conditioning assembly for new central port geometry
- V4 conditioned offline until no effect from bombardment



Above: First revision (V3) - intended to fit directly into racetrack profile

▸ Narrow profile results in line-of-sight into RGA port



Right: Second revision (V4) – located in DN16 body

Able to condition racetrack section efficiently, some line-of-sight beyond plate

PSD beamline – conditioning assembly II

- Two designs of plate: **with** and **without** chamfered edges
 - Chamfered disc installed for improved conductance
- Net effect is small change in area that is not easily conditioned by electron bombardment

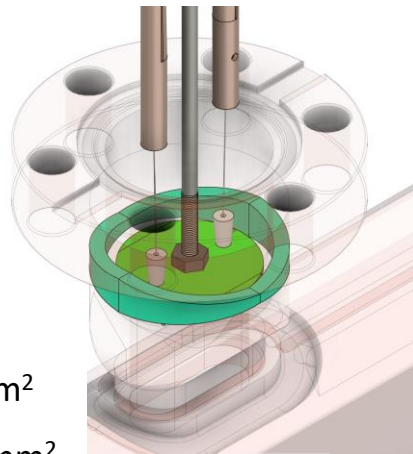
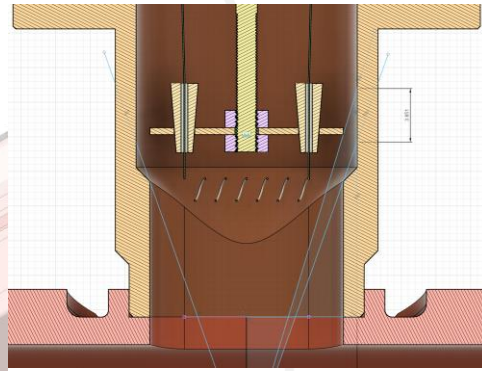
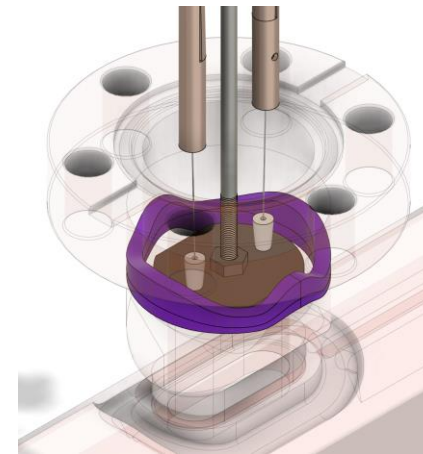


Plate area = 148 mm²

PSD cup area = 123 mm²



Full disc



Chamfered disc

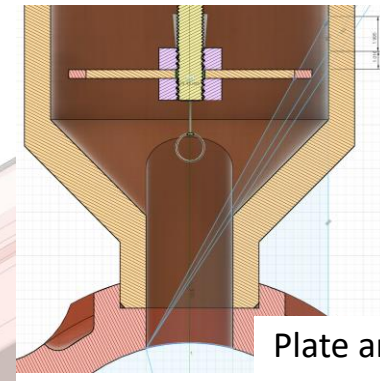


Plate area = 138 mm²

PSD cup area = 141 mm²

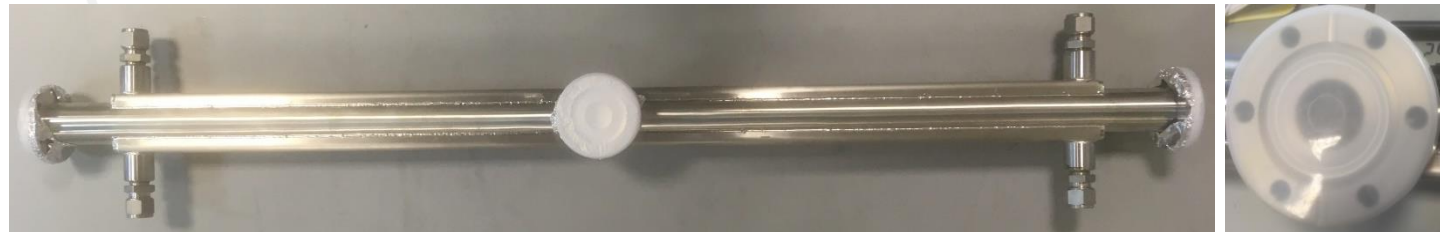
- Chamfer reduces plate surface area by ~10 mm² and increases exposed vessel surface by ~18 mm²
- Total illuminated vessel area is 53410 mm², **unconditioned area is 0.26% total vessel area**

PSD – stainless-steel vessel

Two 304L stainless-steel ($\varnothing 34.9$ mm, 1 m long) vessels exposed to dipole light

- A. **Uncoated** stainless-steel vessel
- B. **NEG-coated** stainless-steel vessel [coated at UKRI by R. Valizadeh: TiZrV coating, nominal 1.0 μm thickness]

DN40 PSD test vessel #1: stainless steel, uncoated & NEG-coated



Four cases considered:

- 1. **Uncoated vessel** (stainless-steel) - **baked** at 180 °C for 110 hours
- 2. **NEG-coated (not activated)** - **unbaked**
- 3. **NEG-coated (bake-out)** - **baked** at 190 °C for 24 hrs
- 4. **NEG-coated, saturated** with high-purity N₂ - **unbaked**

Results presented at
EVC-17 (Harrogate, UK) &
NEG workshop (York, UK)

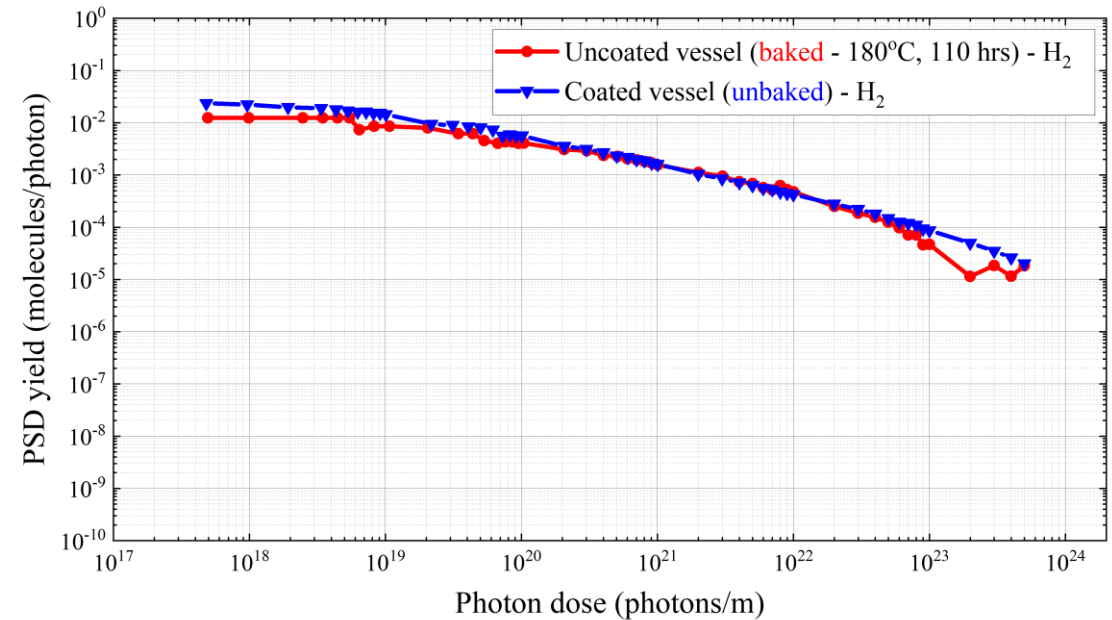
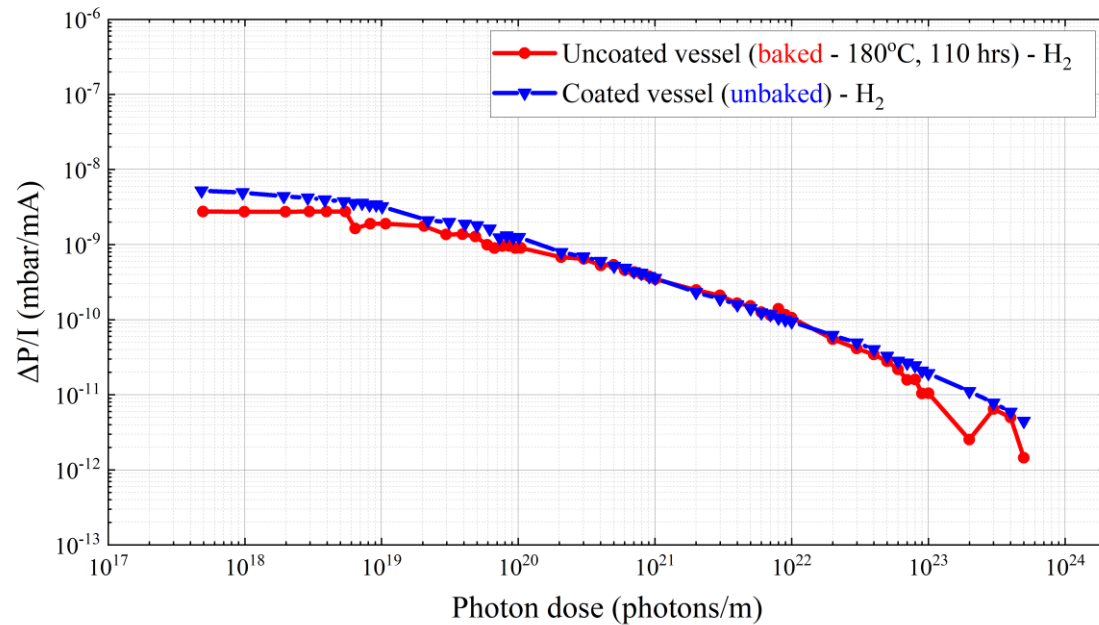
Partial pressures & PSD yields

- Three-gauge method data, preliminary PSD yields for H_2 , CH_4 , CO , CO_2 in the [non-pumping case](#)
- Also shown is dynamic pressure data from mid-vessel RGA during illumination
 1. Compare **baked** stainless-steel vessel with [unbaked NEG-coated](#) vessel
 2. Compare **baked** NEG-coated vessel and subsequent [N₂ vent](#)

Hydrogen (H₂)

Uncoated vessel **baked** [180 °C, 110 hrs]
NEG-coated unbaked

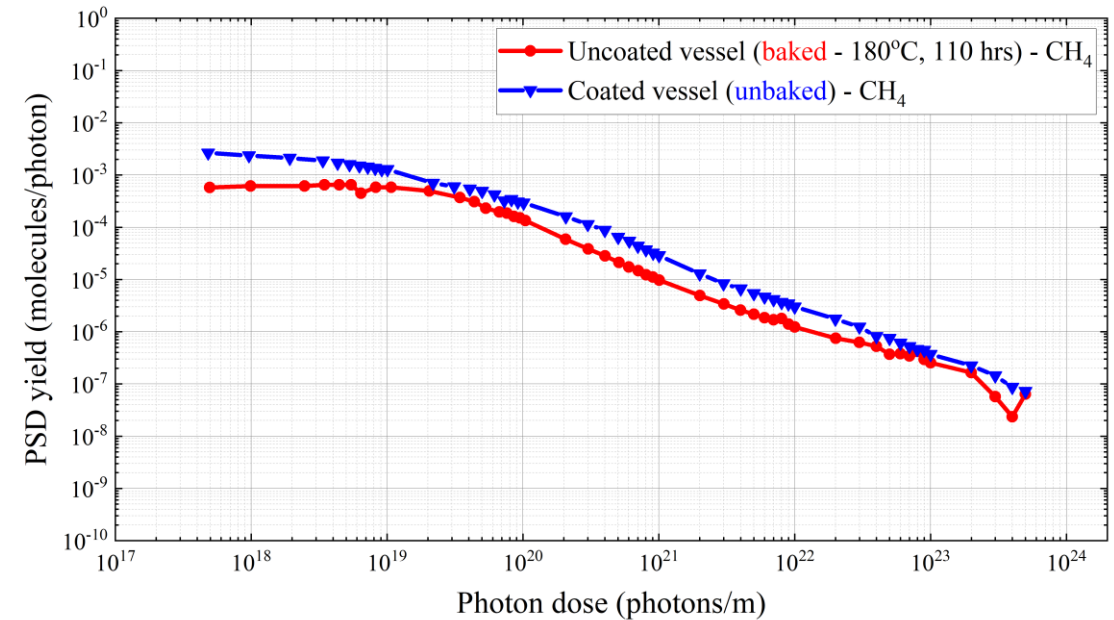
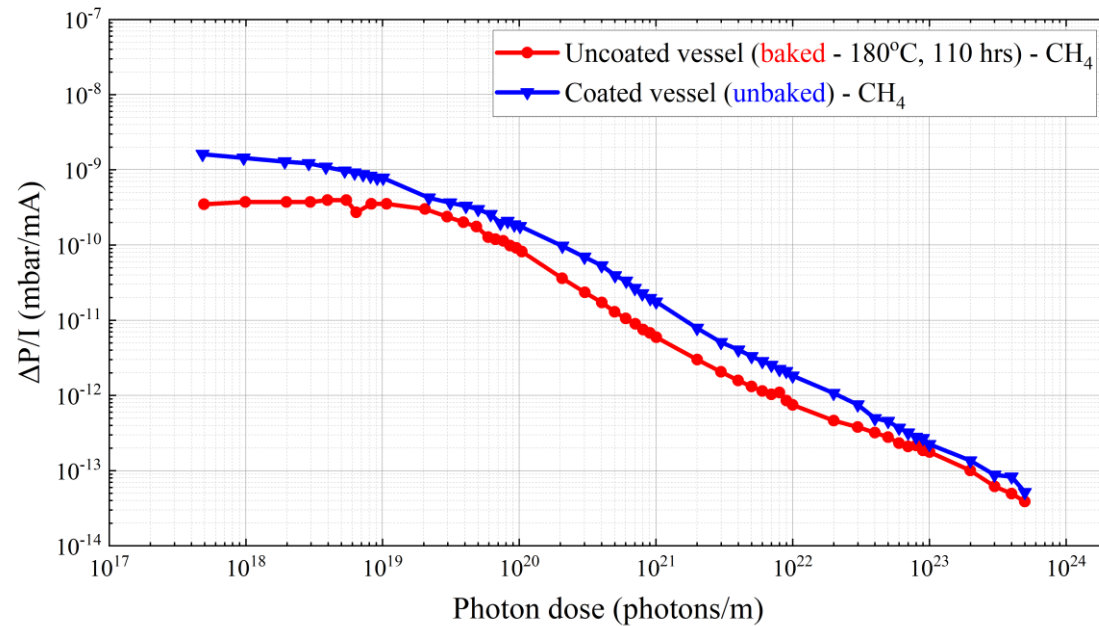
- Dynamic pressures similar between uncoated and NEG-coated cases
- PSD yields are similar between NEG-coated and uncoated vessels
- H₂ has small effect on stored electron beam properties



Methane (CH₄)

Uncoated vessel **baked** [180 °C, 110 hrs]
NEG-coated unbaked

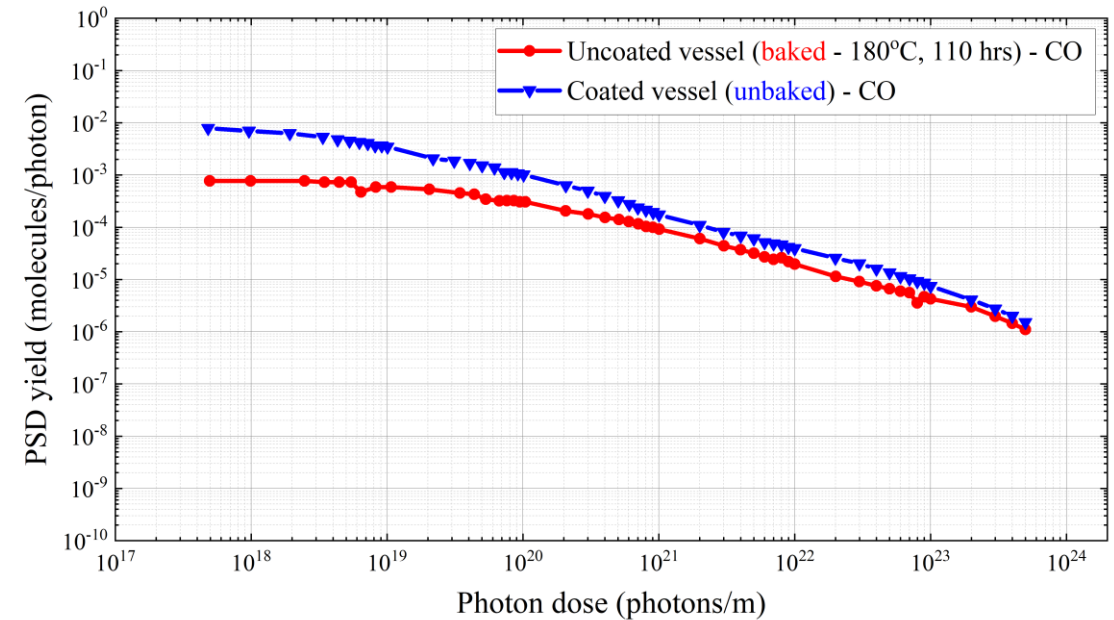
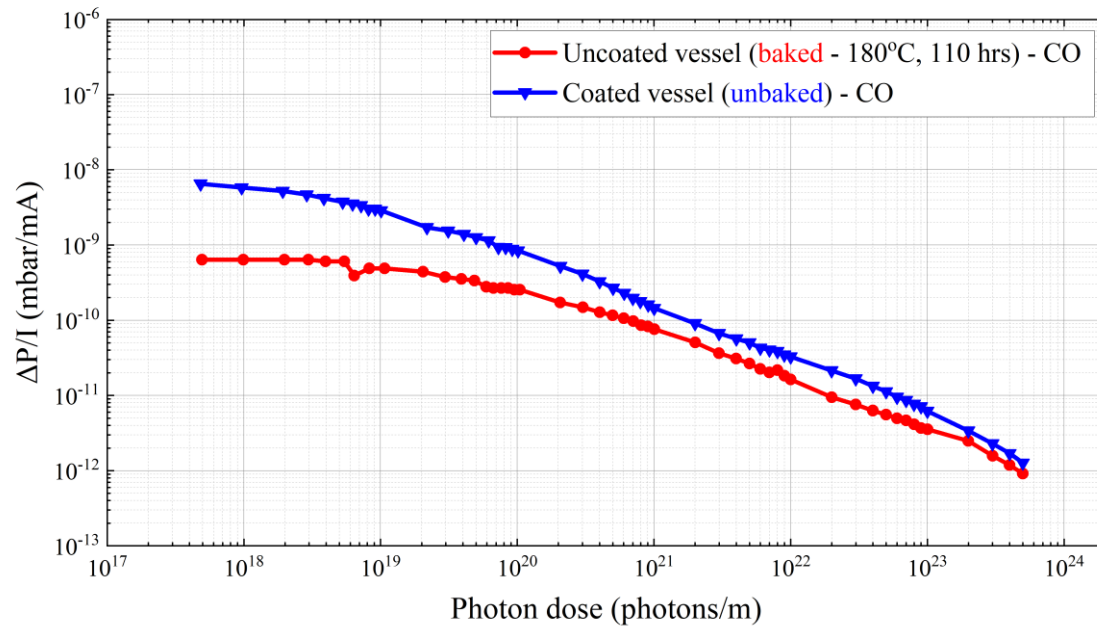
- Dynamic pressure and PSD yields derived from CH₃ signal
- Dynamic pressure is higher for unbaked NEG-coated vessel in dose range investigated
- PSD yield is 2–5x reduced for the non-coated vessel, yields comparable at high doses



Carbon monoxide (CO)

Uncoated vessel **baked** [180 °C, 110 hrs]
NEG-coated unbaked

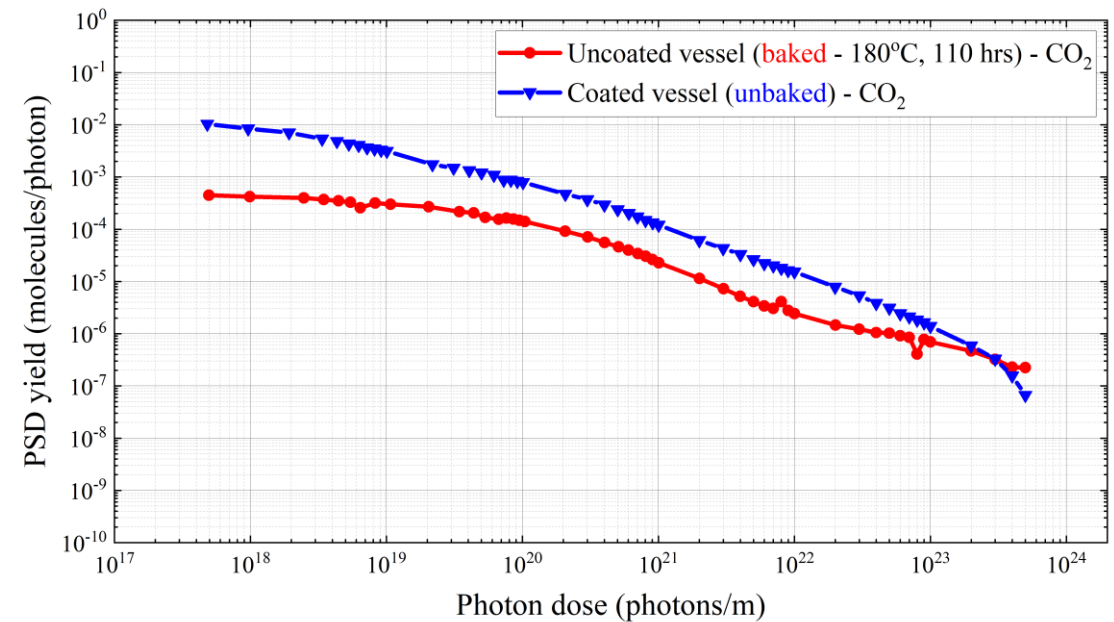
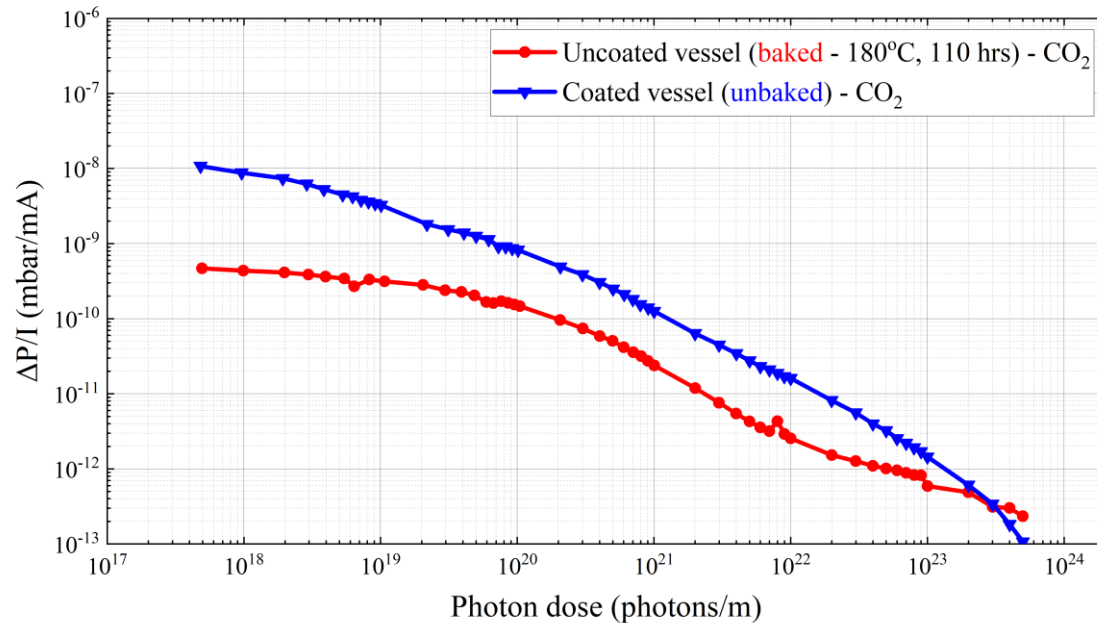
- Dynamic pressure differs by 2-10x over photon dose range investigated
- PSD yield is 2-10x higher for the NEG-coated vessel
- Yields become similar towards higher doses ($>5 \times 10^{23}$ photons/m, ~ 400 A.h)



Carbon dioxide (CO₂)

Uncoated vessel **baked** [180 °C, 110 hrs]
NEG-coated **unbaked**

- PSD yield is up to a factor 25 lower for uncoated vessel compared to non-coated vessel
- As for other gases, at high doses PSD yields become comparable
- Of PSD yields determined, CO₂ has strongest effect on beam



PSD yield - summary

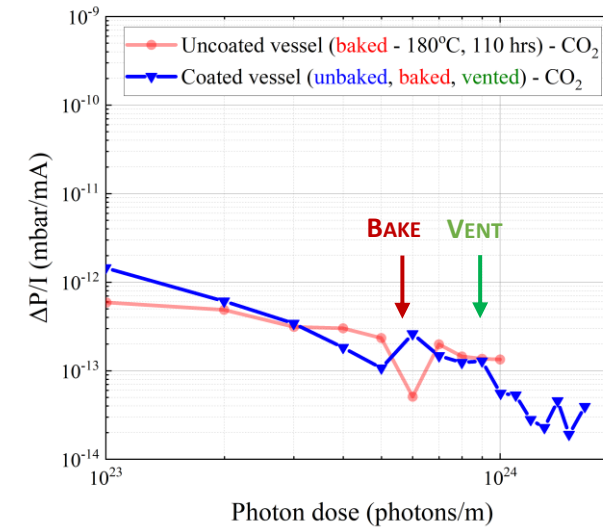
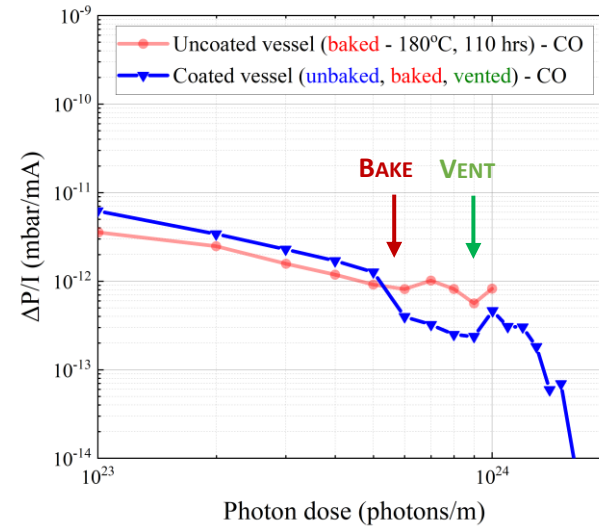
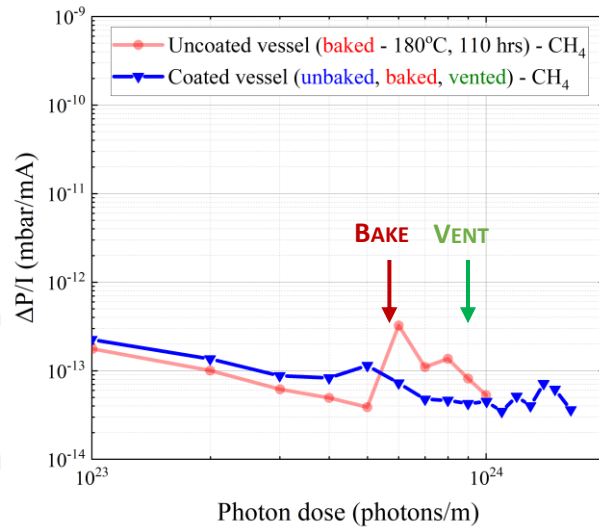
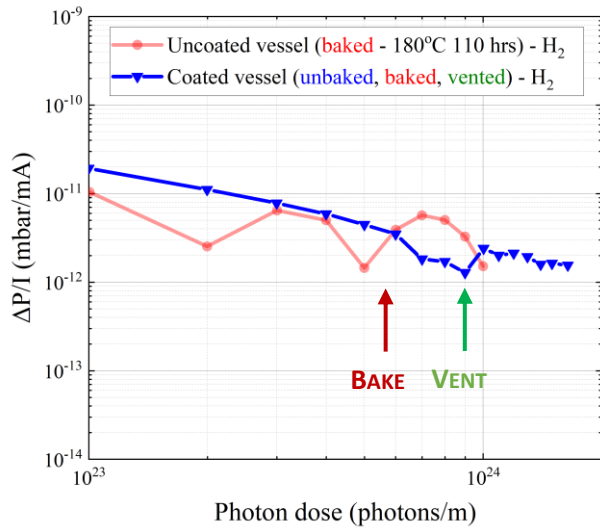
- PSD yield for H₂ is similar between vessels, yields for CH₄, CO and CO₂ are higher for the NEG-coated vessel
- At higher doses, PSD yields are comparable between uncoated and NEG-coated vessels
 - High photon dose equivalent to ~400 A.h at Diamond

	Uncoated vessel		NEG-coated vessel	
	PSD yield (mol./photon)		PSD yield (mol./photon)	
	Low dose (1x10 ¹⁸ γ/m)	High dose (5x10 ²³ γ/m)	Low dose (1x10 ¹⁸ γ/m)	High dose (5x10 ²³ γ/m)
H₂	1.2E-02	1.8E-05	2.2E-02	2.0E-05
CH₄	6.1E-04	6.4E-08	2.4E-03	7.2E-08
CO	7.7E-04	1.1E-06	7.0E-03	1.5E-06
CO₂	4.2E-04	2.2E-07	8.4E-03	6.6E-08

NEG coating bake-out & saturation

Uncoated vessel	baked [180 °C, 110 hrs]
NEG-coated	unbaked
NEG-coated	baked [190 °C, 24 hrs]
NEG-coated	vented [N ₂ , 1 atm., 30 mins]

- After 5×10^{23} photons/m dose, NEG-coated vessel **baked** to 190 °C for 24 hours
- Observe a reduction in dynamic pressures



- Following this, NEG-coated vessel **vented** to 1 atm. high-purity N₂ for 30 minutes
- Dynamic pressure behaviour recovered after further ~ 300 A.h dose

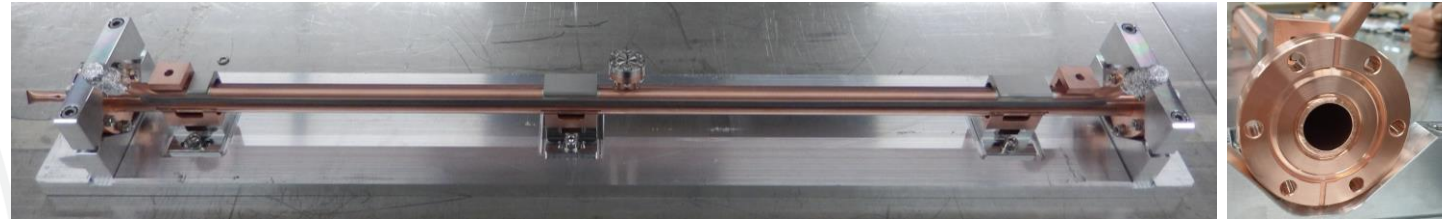
PSD behaviour – stainless-steel vessels

- PSD yields within 1 decade of previously reported values for:
 - Stainless-steel (J. Vac. Sci. Technol. A **17**(2), 1999, p635; Vacuum **33**(7), 1983, p397)
 - Non-activated NEG coating (IPAC'15, 2015, pp.3123-3126)
 - Preliminary data omits gas-specific RGA corrections
- Yields are consistent between **baked** stainless-steel and **unbaked** NEG-coating after a dose of 5×10^{23} photons/m (~400 A.h at Diamond)
 - Non-baked start-up of NEG-coated accelerators may be viable, depending on required dose
- Dynamic pressures from NEG-coated vessel reduced after baking - following N₂ vent, vessel pressures recovered within 7 weeks of user operation

PSD measurements at Diamond – copper vessel

- One OFS-Cu ($\varnothing 20$ mm, 1 m long) vessel exposed to dipole light
- A. **NEG-coated** vessel [coated at UKRI: dense TiZrV coating, nominal 1.0 μm thickness]

DN20 PSD test vessel #2: OFS-Cu, NEG coated
Diamond-II compatible

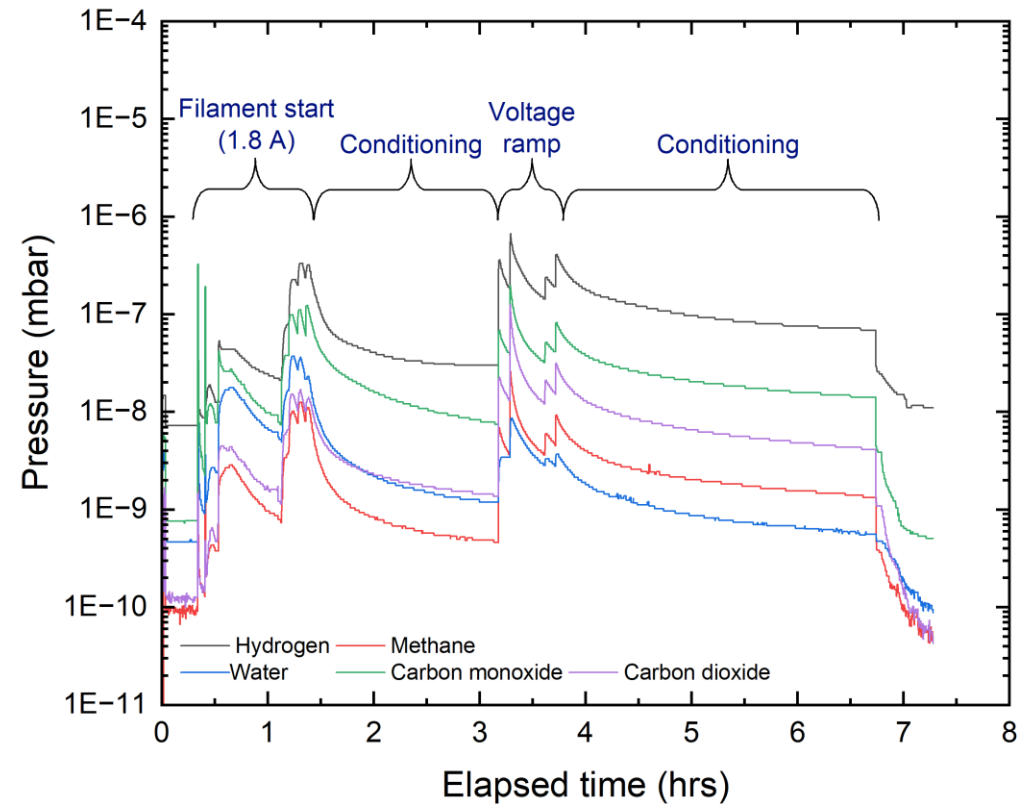
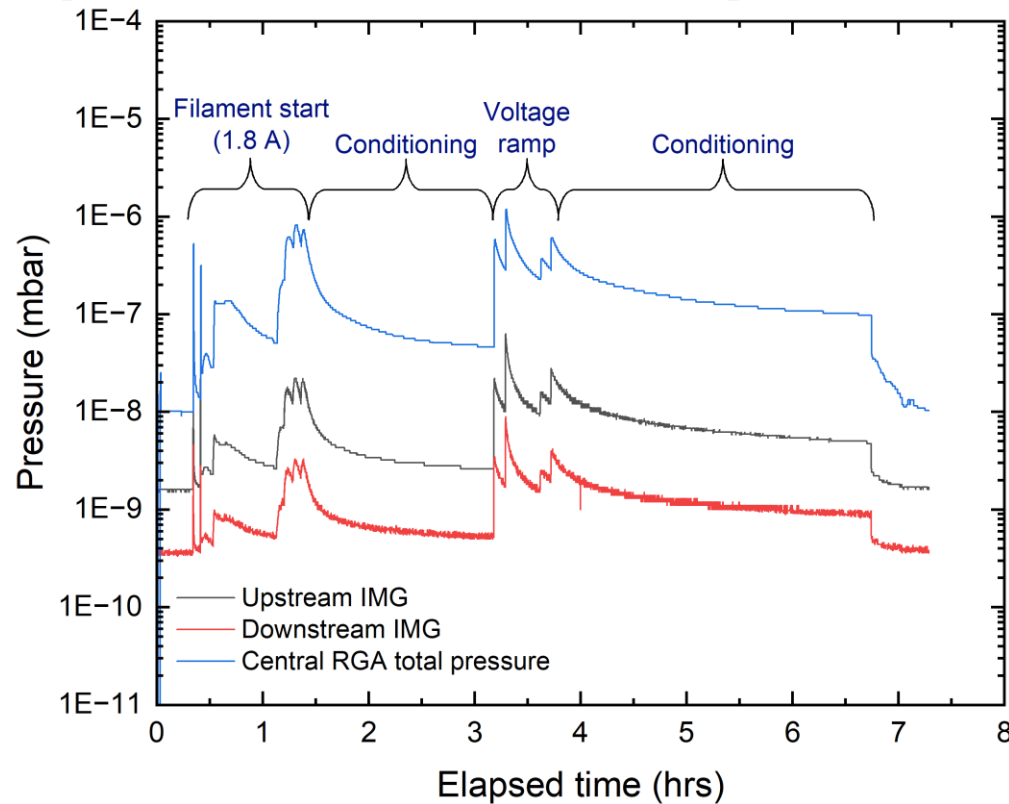


- **NEG-coated vessel baked** at 80 °C for 88 hours
- **Stainless-steel components baked** at 180 °C for ~72 hours (total bake for 88 hours)
- Vessel tested by E Marshall at UKRI, shown to pump (**right**)

	α (180 °C)
H ₂	0.001
CO	0.009
CO ₂	0.02 (RGAs noisy)
Ratio=10 Capacity for CO $\approx 4.8 \times 10^{18}$ CO/m ²	

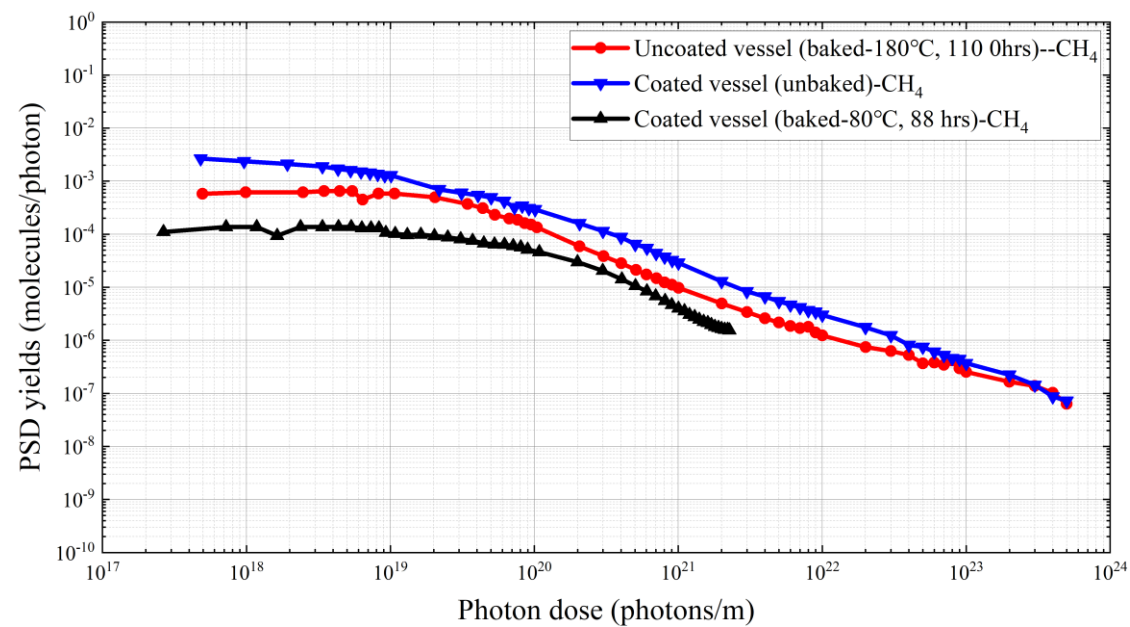
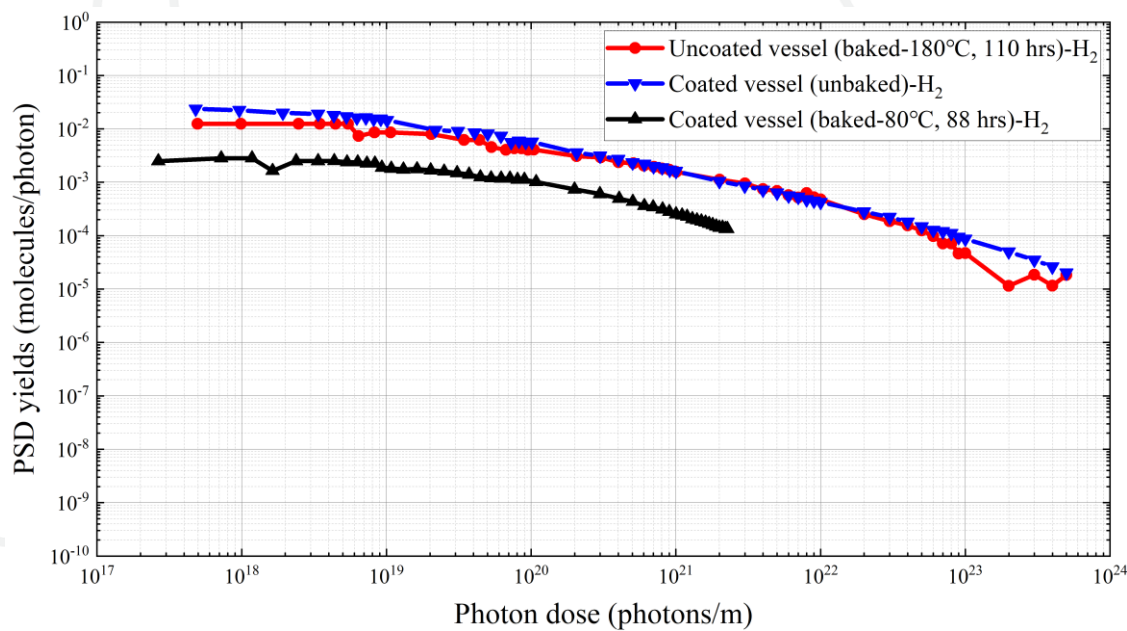
PSD – OFS-Cu port conditioning

- Example conditioning of central port plate and DN16 central port
- Plate previously run offline for >48 hours)



PSD – OFS-Cu Hydrogen & methane

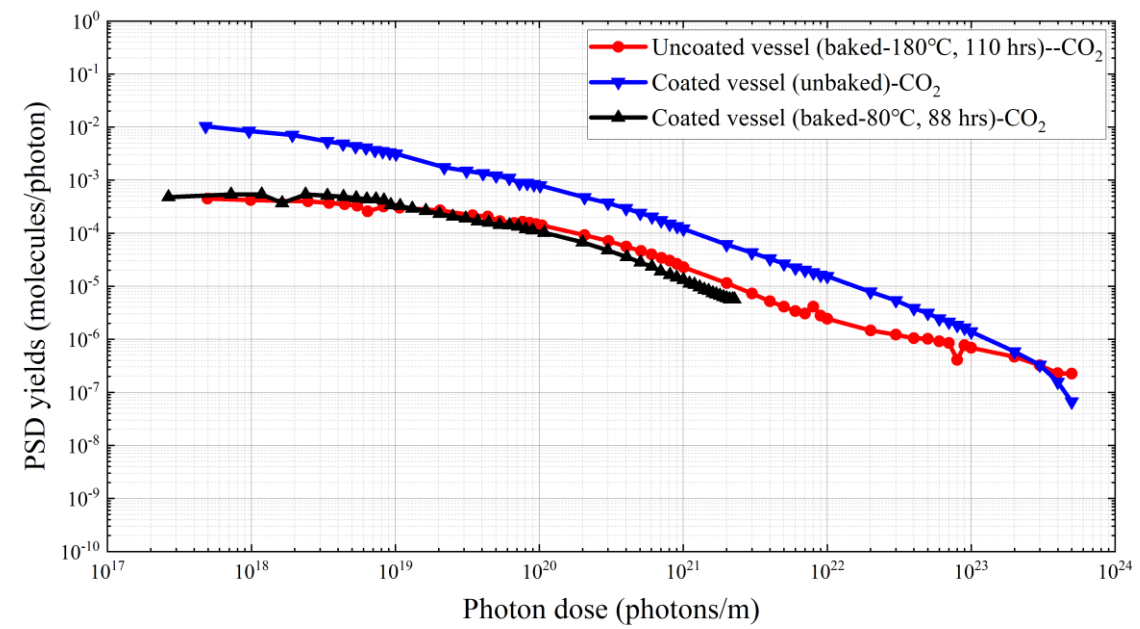
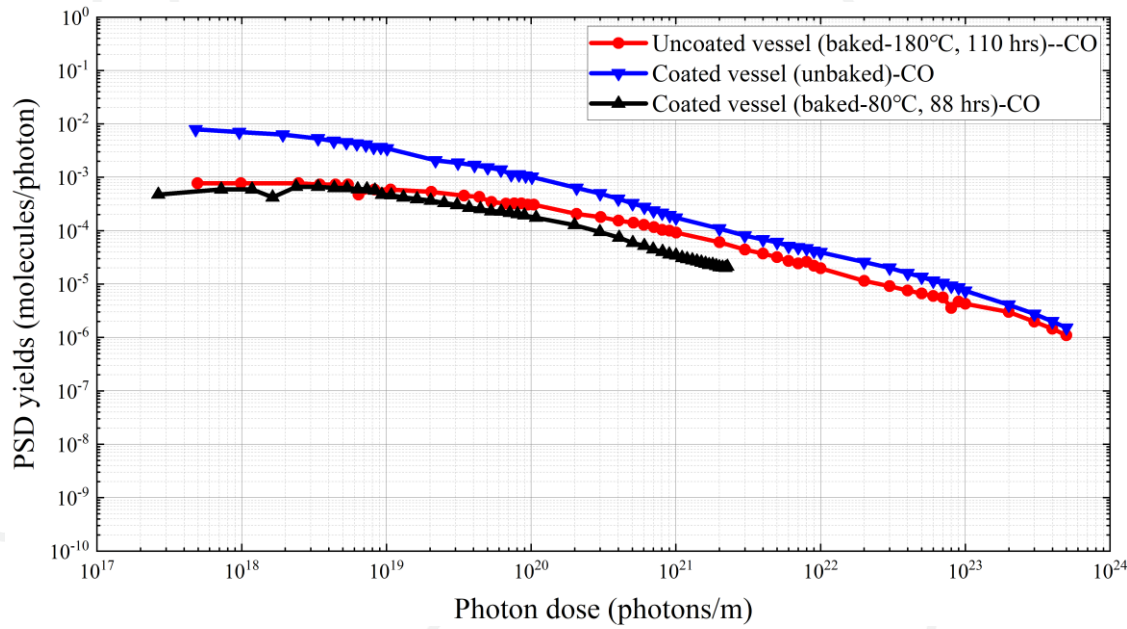
- PSD yields for H₂ and CH₄ **reduced** for baked NEG-coated vessel compared to unbaked
- Yields also lower than for baked stainless-steel (no copper data to compare with from FE10B)



Red stainless-steel vessel – baked
Blue NEG-coated vessel – not baked
Black NEG-coated vessel – baked

PSD – OFS-Cu Carbon monoxide & carbon dioxide

- PSD yields for CO and CO2 are **similar** to baked uncoated vessel
- Yields also lower than for unbaked NEG-coated vessel (no copper data to compare with)



Red stainless-steel vessel – baked
Blue NEG-coated vessel – not baked
Black NEG-coated vessel – baked

PSD – OFS-Cu summary

- PSD yields are reduced compared to non-baked NEG-coated vessel (as might be expected)
- Values are lower or similar to baked non-coated vessel (bakeout conditions similar)

Next Steps:

- Activation of NEG coating is main goal

Next DLS shutdown: 11th October – 3rd November (testing/Diamond-II upgrades will limit access)

Following shutdown is 18th December – 10th January (small opportunity here in New Year)