

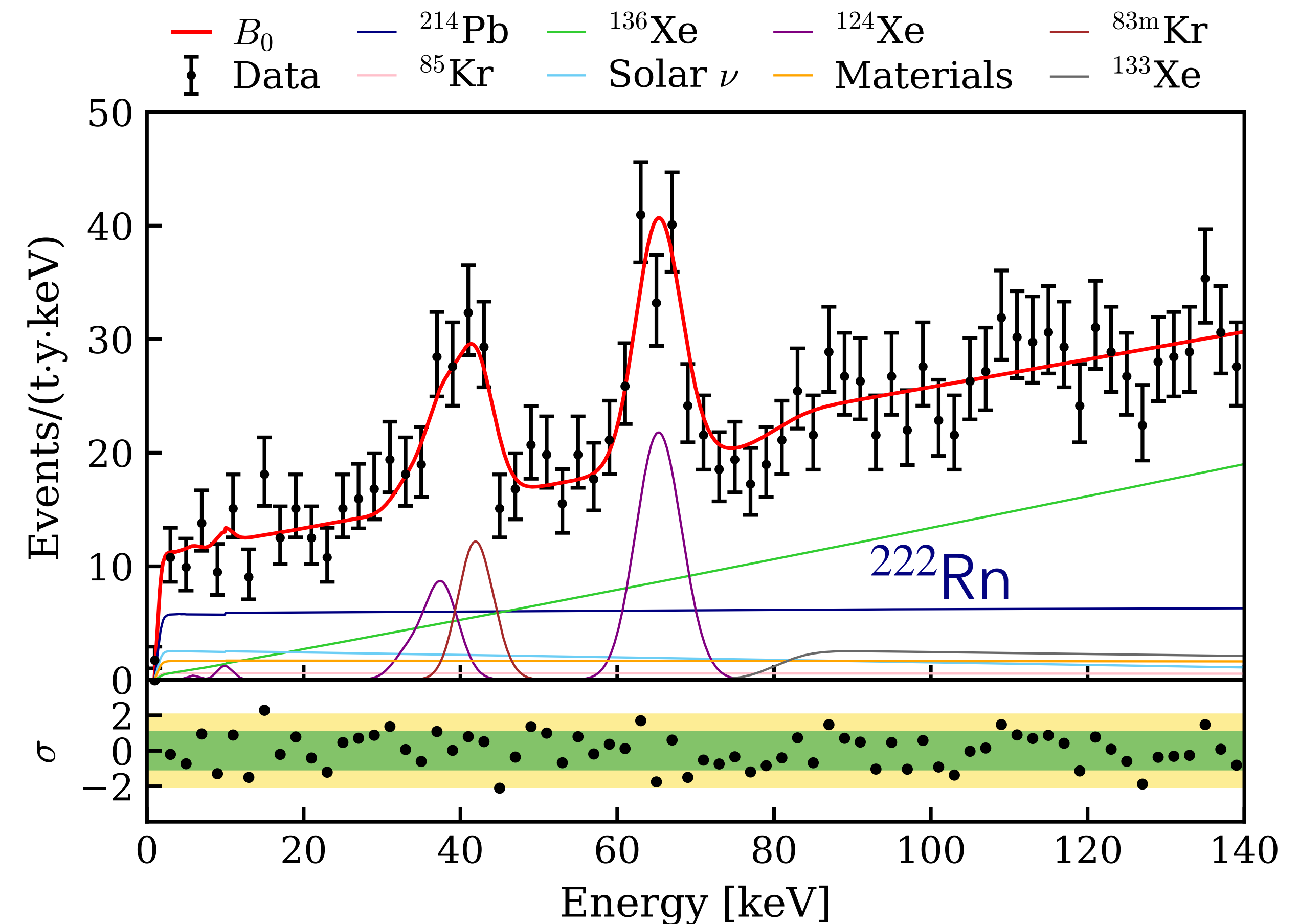
Coating based radon barriers for future liquid xenon detectors

LRT 21.09.2026

Why do we care about radon?

Radon background in liquid xenon detectors

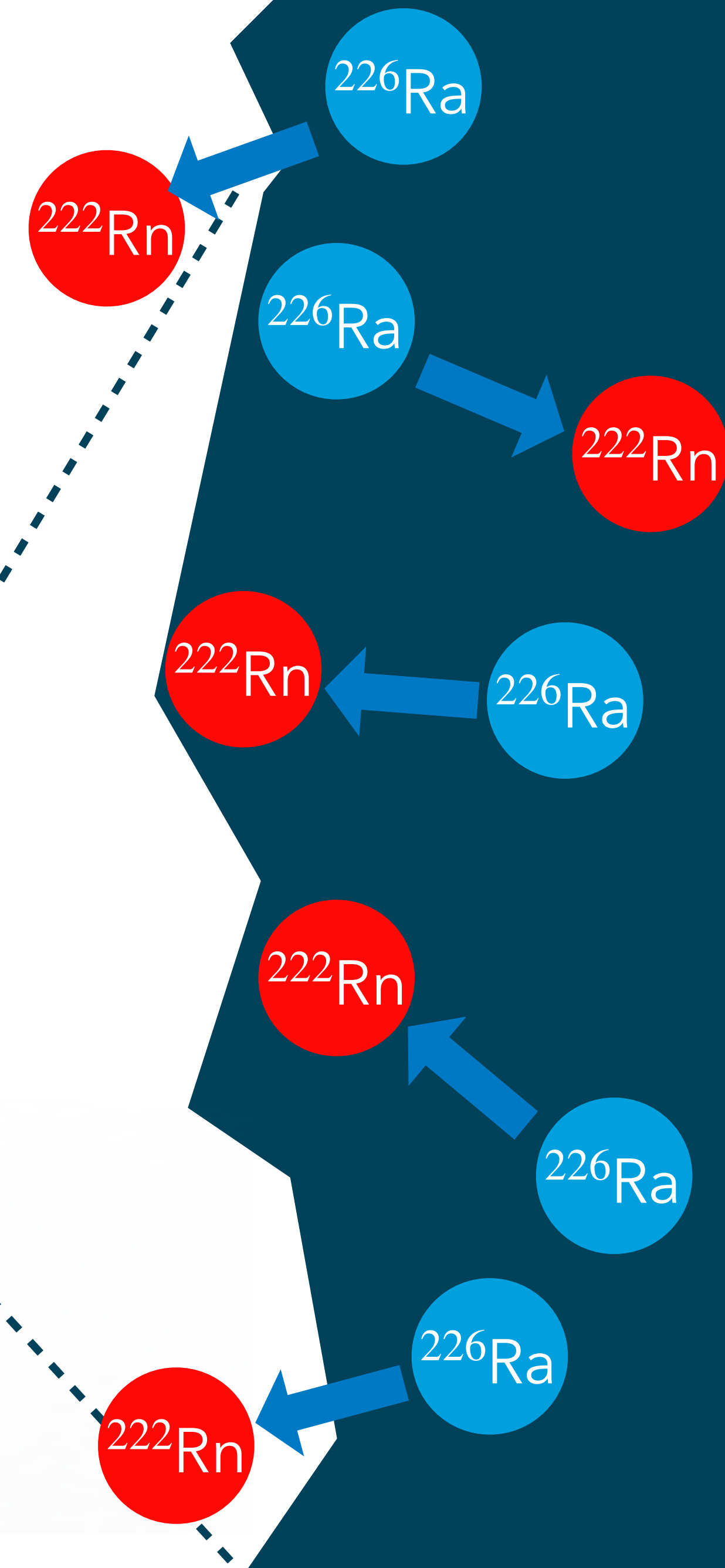
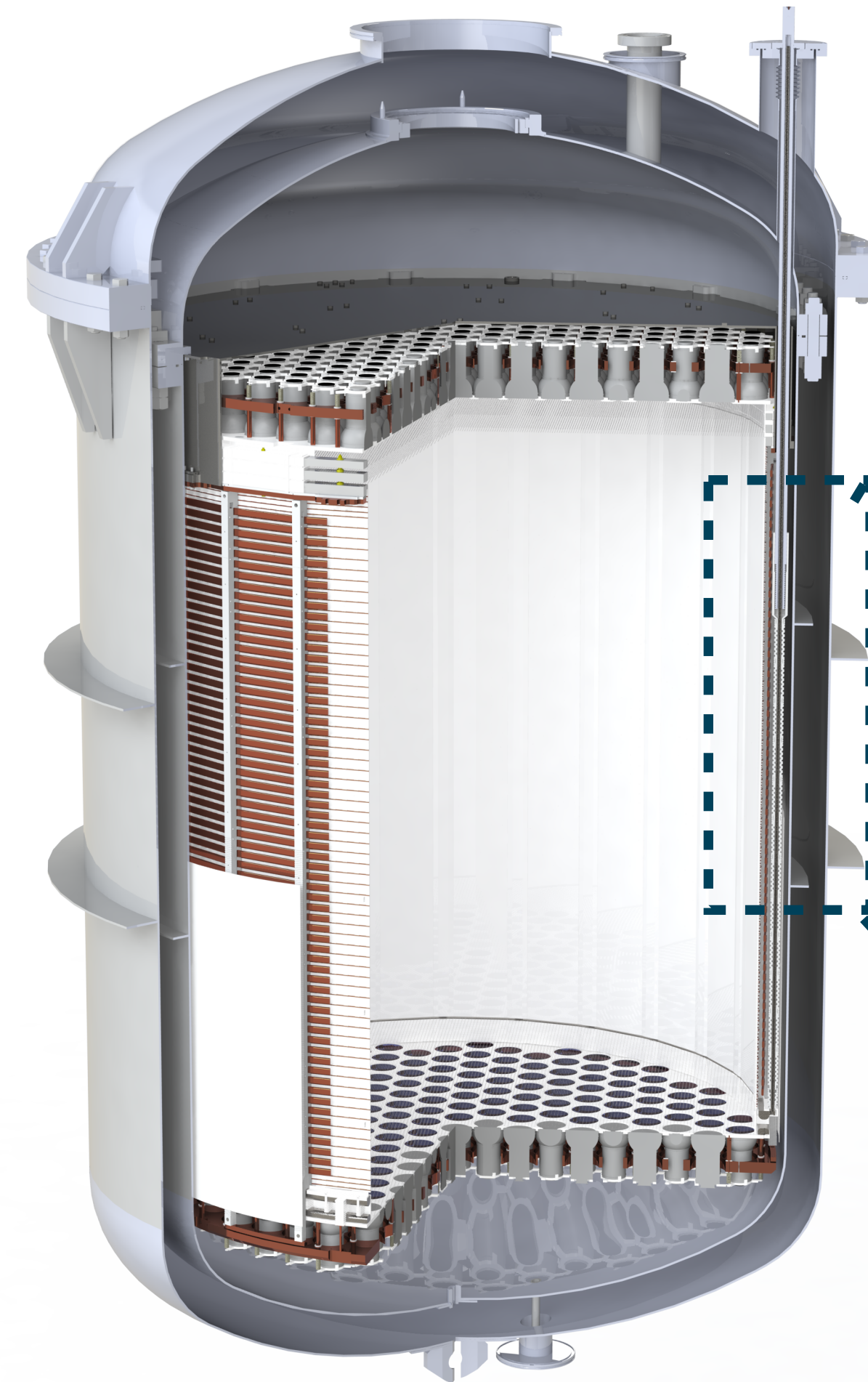
- Low signal expectations require extremely low background rates
- ^{222}Rn and the subsequent low energy β decay of ^{214}Pb is a significant background for WIMP search
- ^{222}Rn distributes homogeneously in detector: No suppression via fiducialization!



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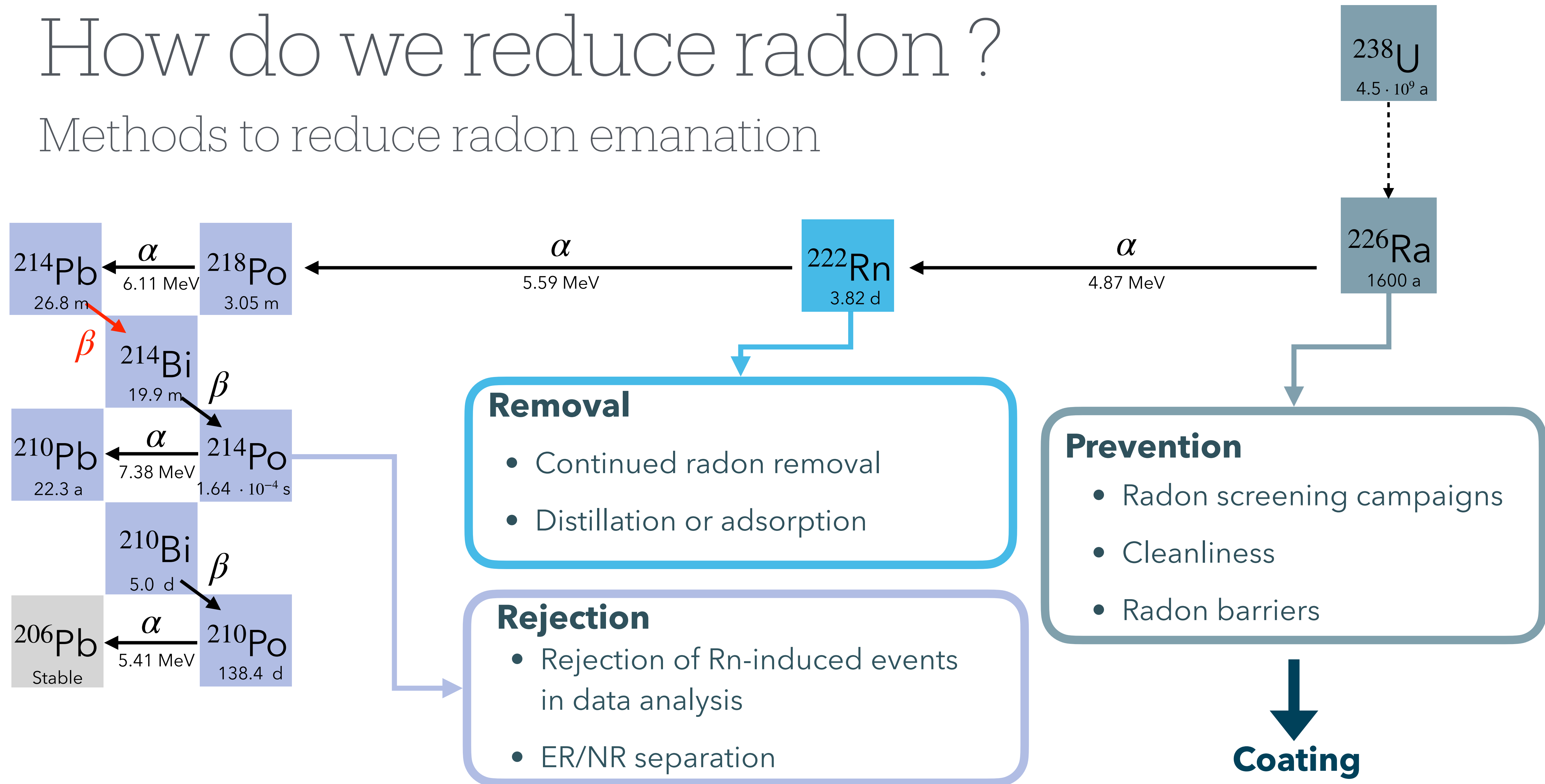
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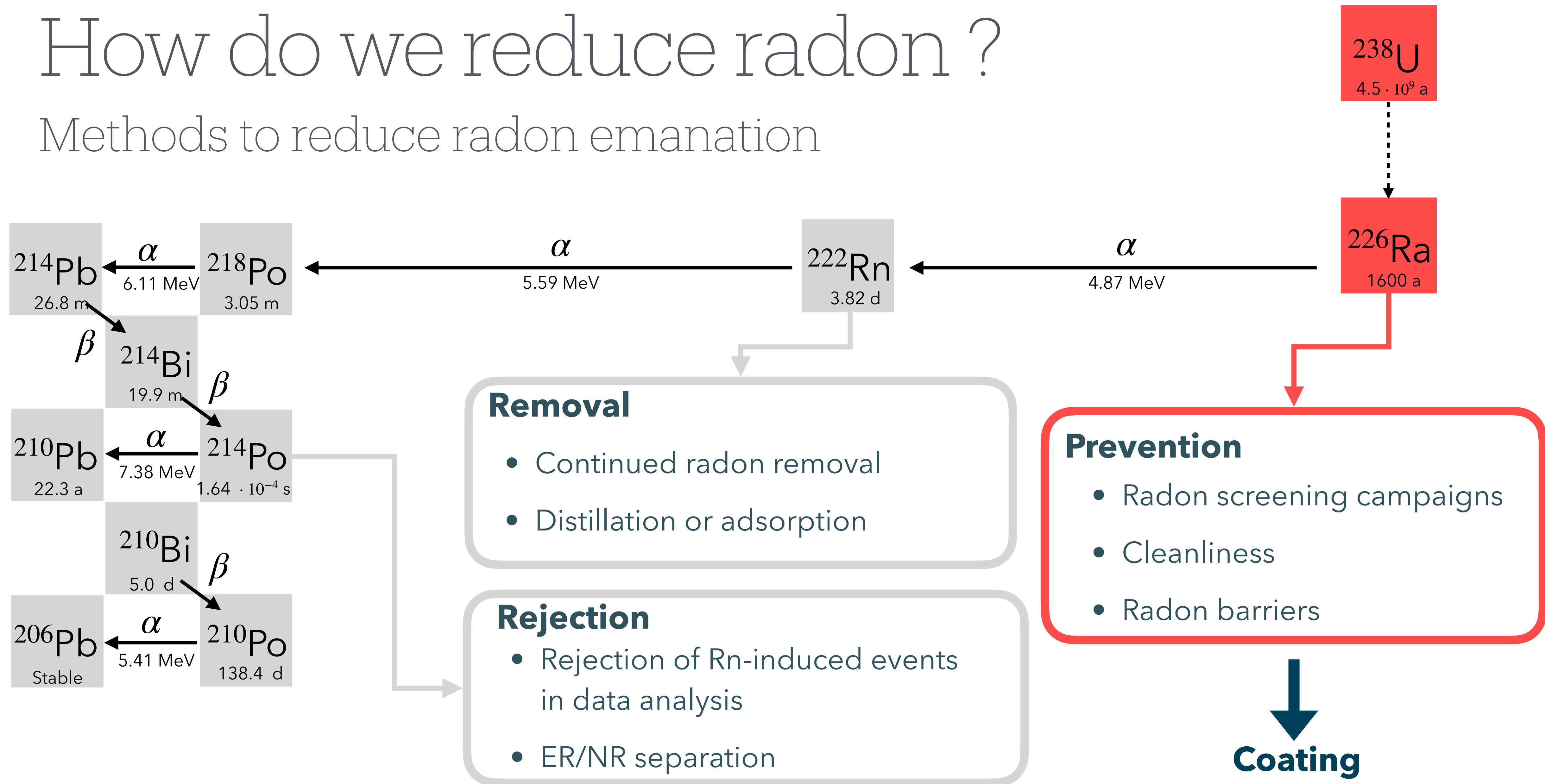
How do we reduce radon ?

Methods to reduce radon emanation



How do we reduce radon ?

Methods to reduce radon emanation

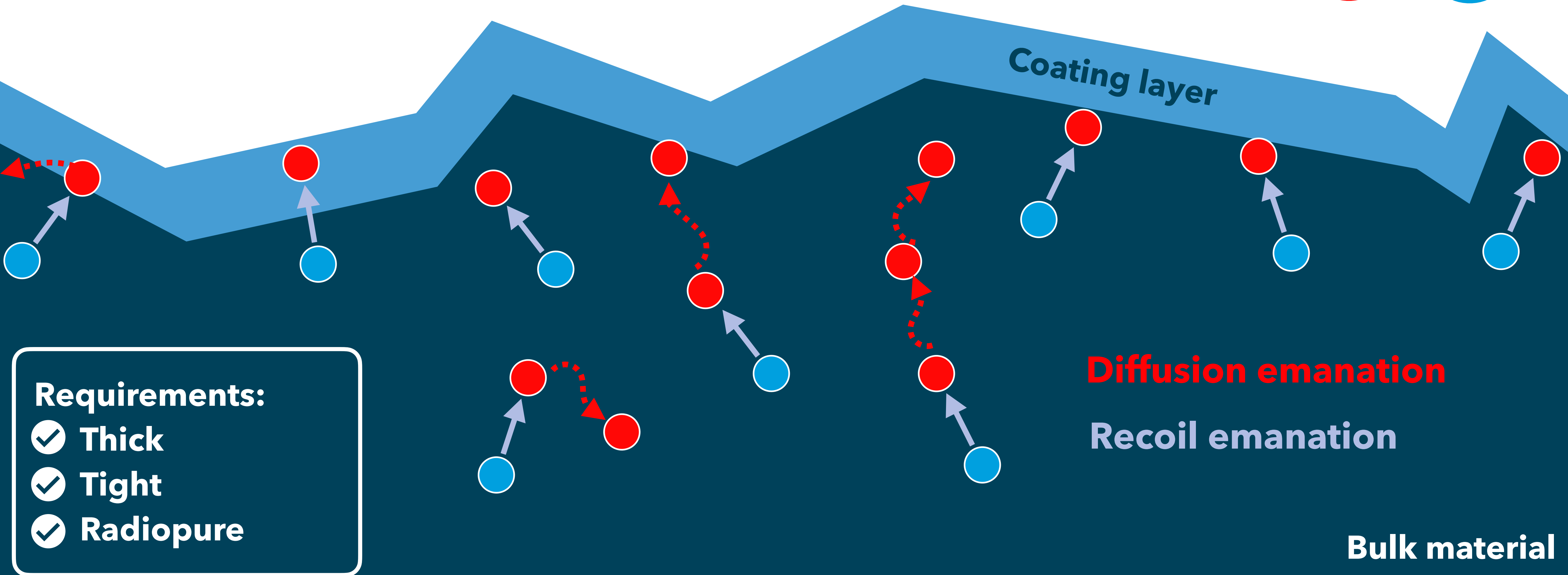


How do we reduce radon ?

Basic concept of coating

^{222}Rn

^{226}Ra



Explored coating methods

Method	Material	Thickness	Reduction factor	
			^{220}Rn	^{222}Rn
Sputtering	Titanium	0.4 - 0.8	4.5	2.1 ± 0.7
Plasma spraying	Copper	3	22	-
Epoxy resin	Stycast	≈ 200	≥ 74	-
Chem. Vapor deposition	Carbon	1	3	1.4 ± 0.4
Electrochemical plating	Copper	5	130	1500 ± 70



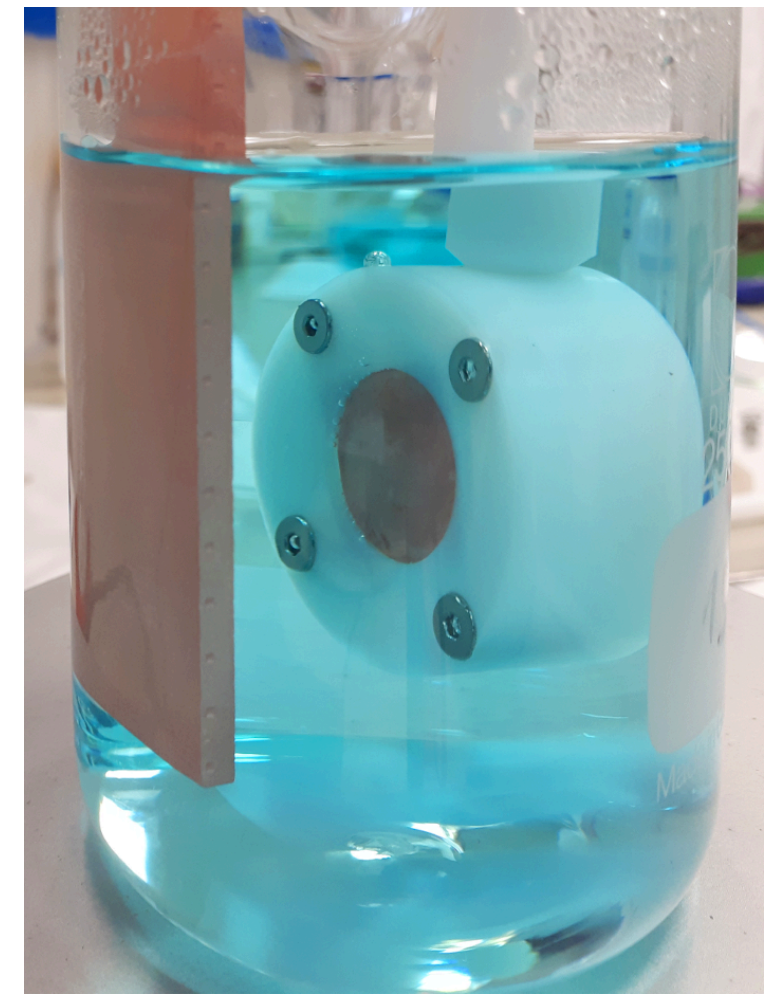
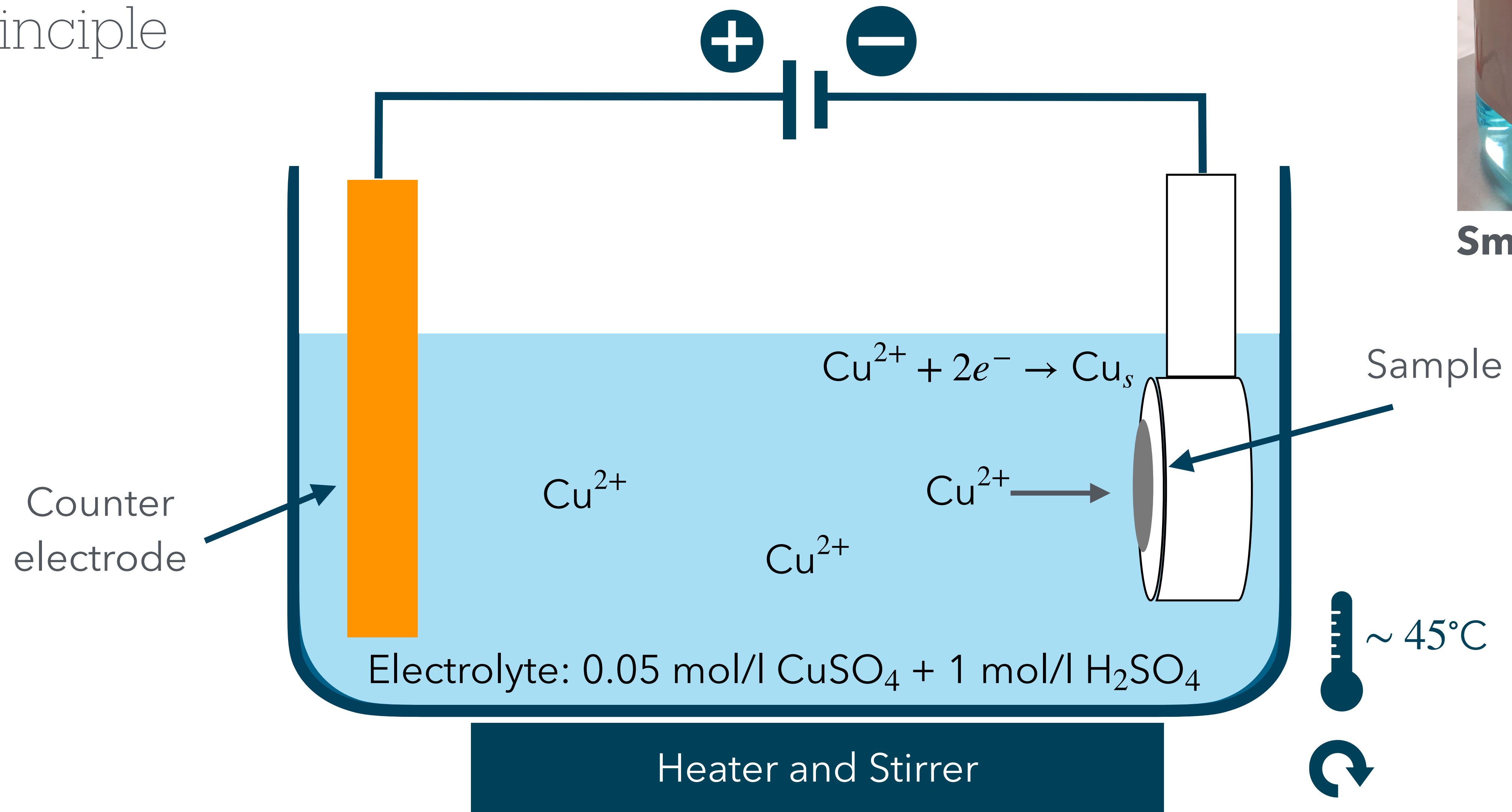
Best results for ECP !

„Application of surface coating for radon mitigation in rare-event searches.“ by Jörg, et al (2026)



Electrochemical plating (ECP)

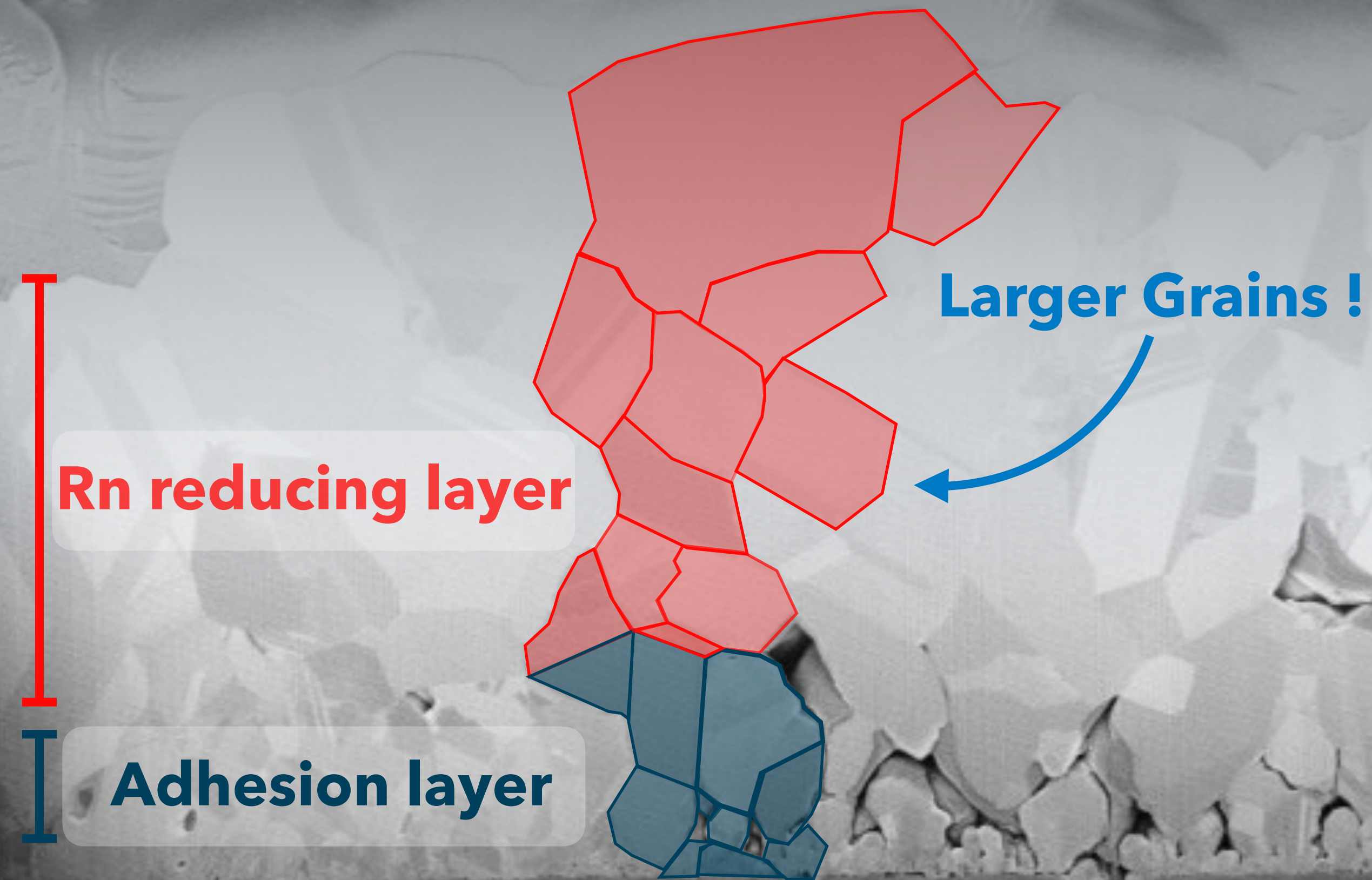
Principle



Small setup

Electrochemical plating (ECP)

2-step procedure



Recipe:

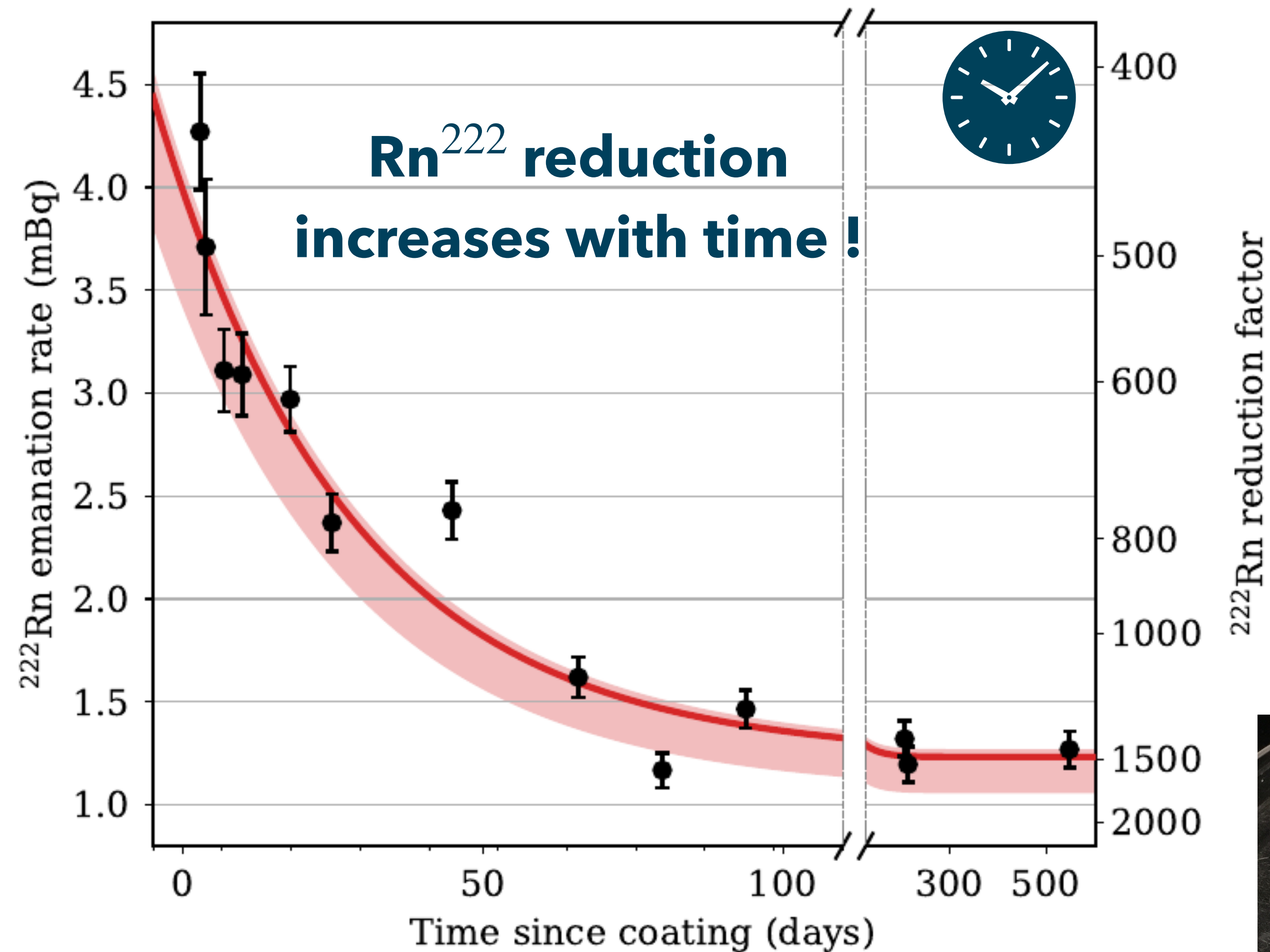
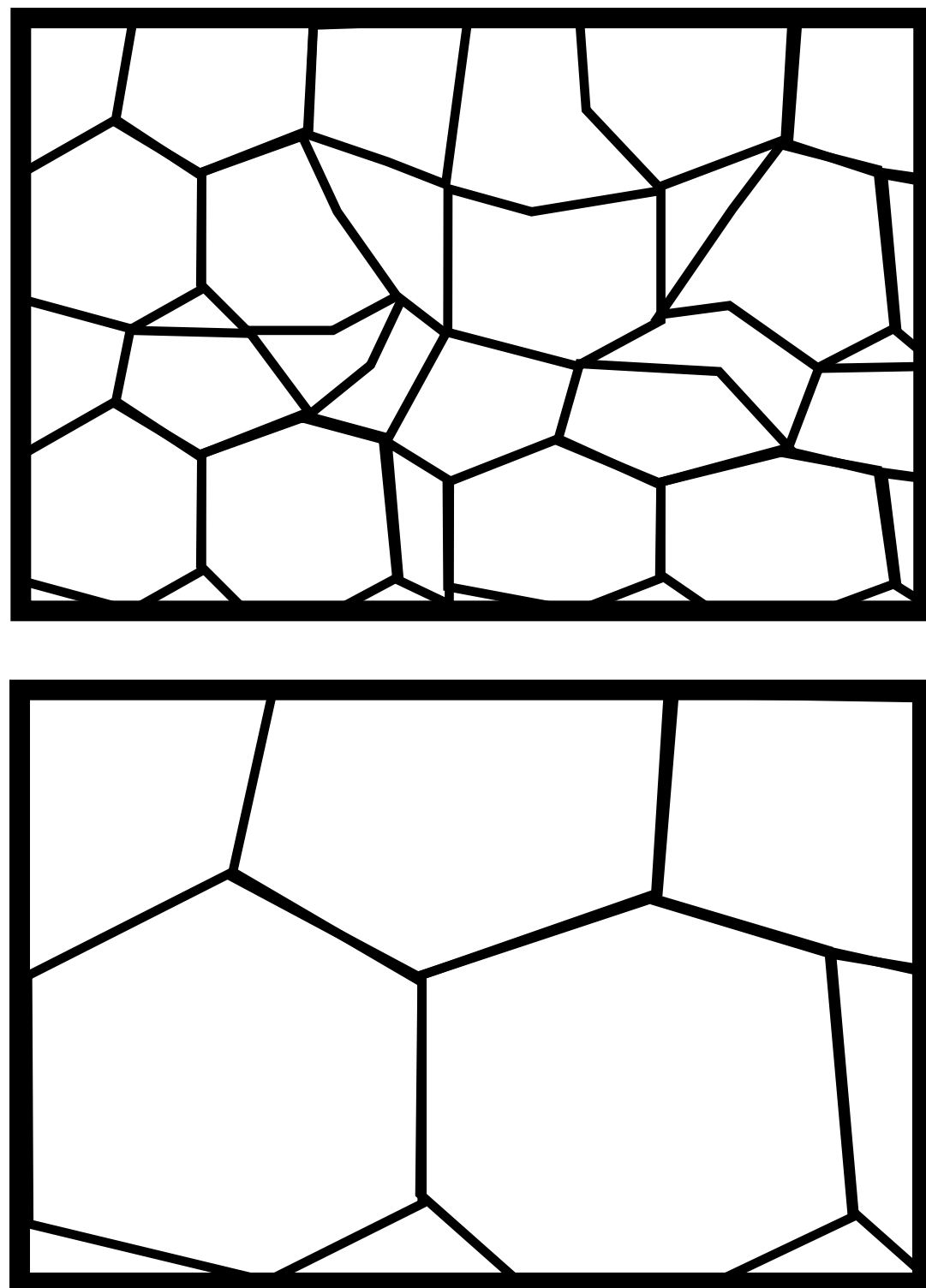
- 1 μm at 50 mA/cm²
- 4 μm at 10 mA/cm²

Jörg, F., Eurin, G. & Simgen, H. (2026). Application of surface coating for radon mitigation in rare-event searches. arXiv:2606.26190.

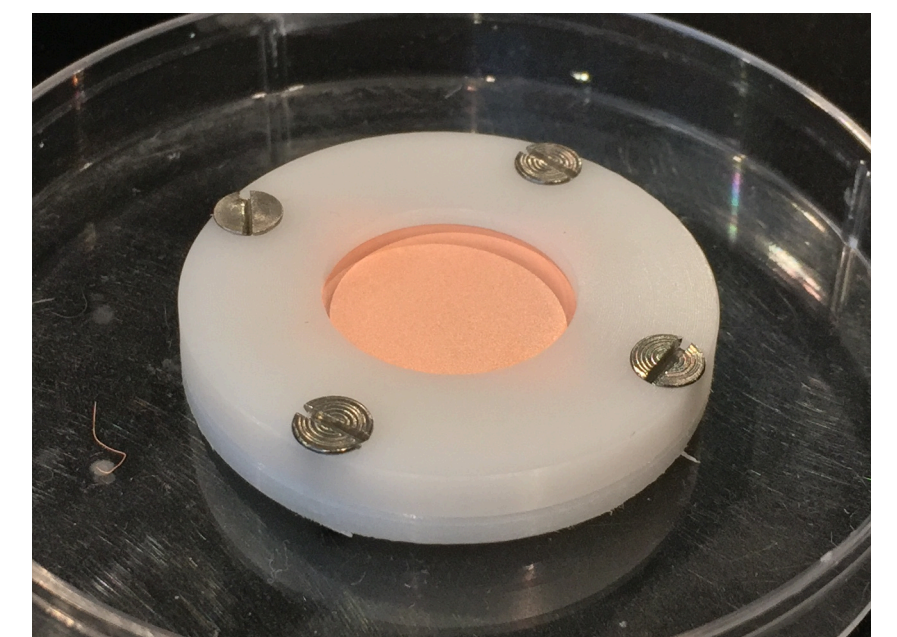
Electrochemical plating (ECP)

Annealing

Self-annealing



²²⁶Ra sample with
2 Bq of ²²²Rn
emanation



Upscaling

Upscaling

$\sim 2.8 \text{ cm}^2$ $\xrightarrow{\times 500}$ $\sim 0.14 \text{ m}^2$ $\xrightarrow{\times 4}$ $\sim 0.56 \text{ m}^2$

Small setup



Medium setup



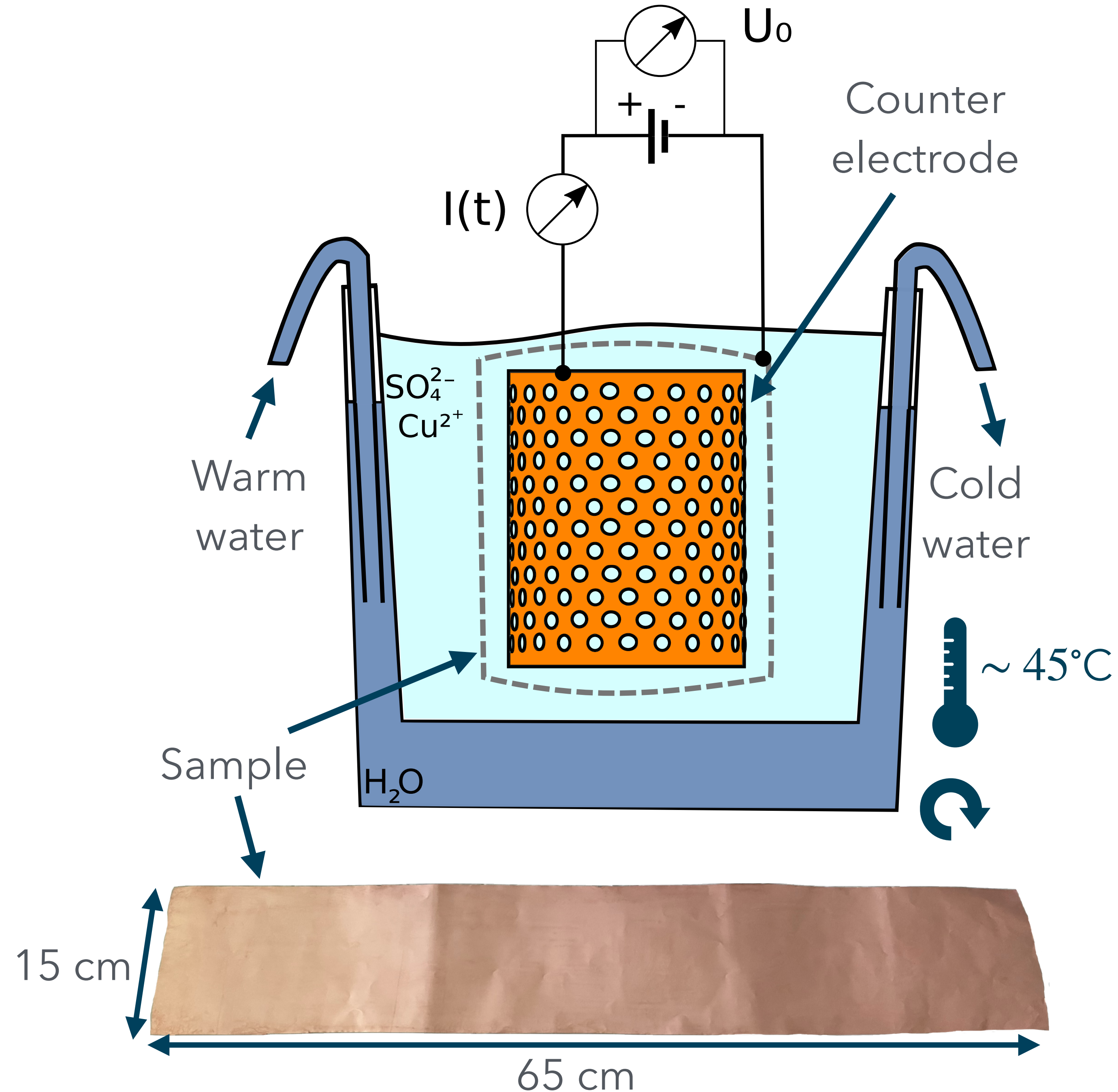
Large setup



Upscaling

Medium setup at MPIK

- SS foil with a thickness of $50\ \mu\text{m}$
- ECP on both sides
- High mechanical resistance and stability under extreme temperatures, from heating to liquid nitrogen



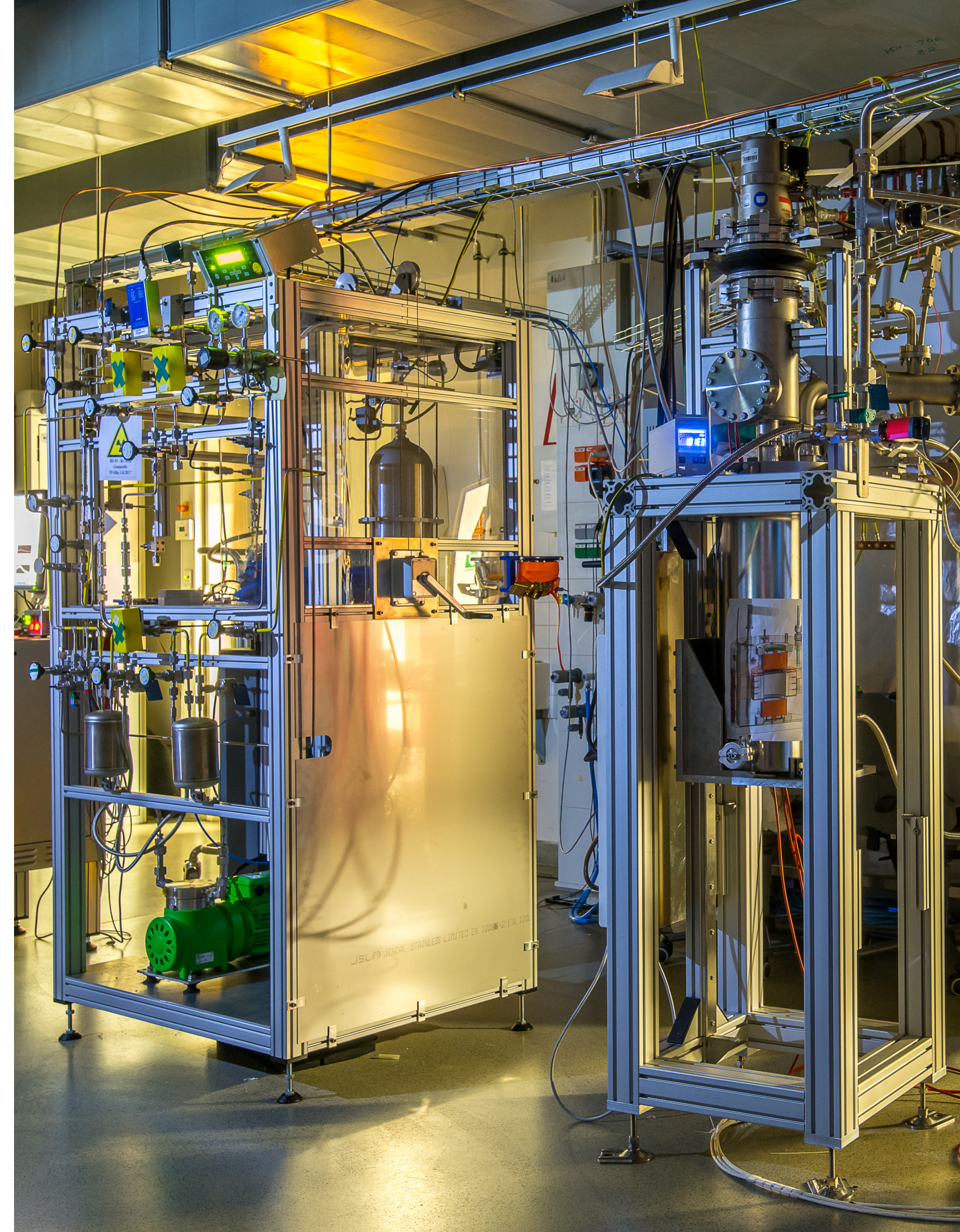
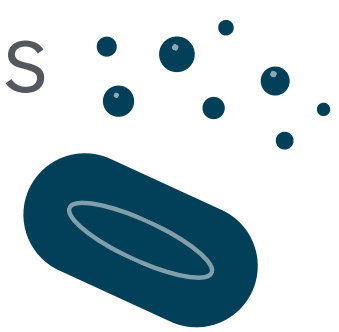


Performance test

Performance test

The Heidelberg Xenon detector (HeXe)

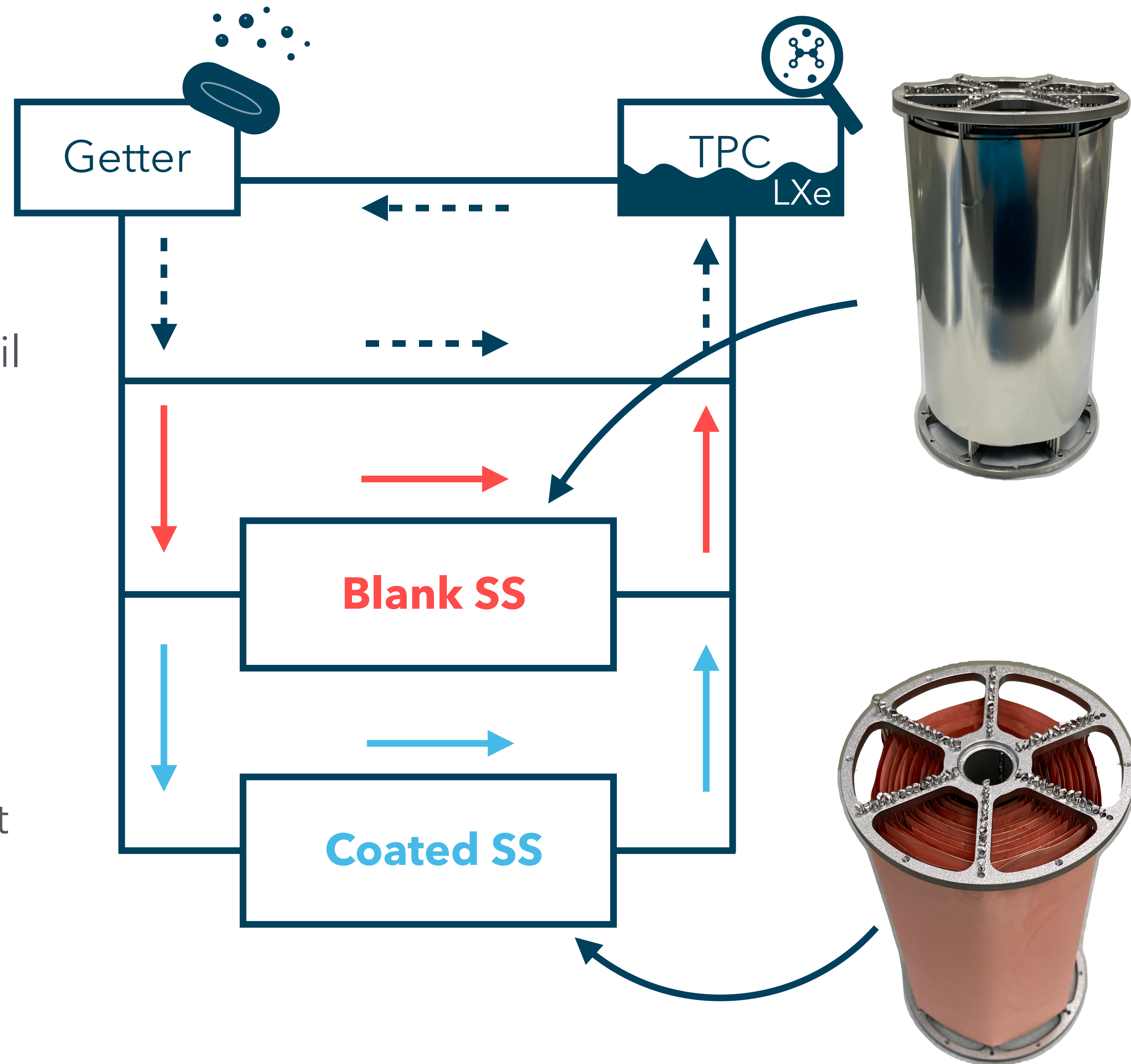
- Local liquid xenon (LXe) detector at MPIK
- Dual phase xenon time projection chamber (TPC) containing **345 g of LXe**
- Getter continuously removes impurities :•••• in gaseous xenon (GXe)



Performance test

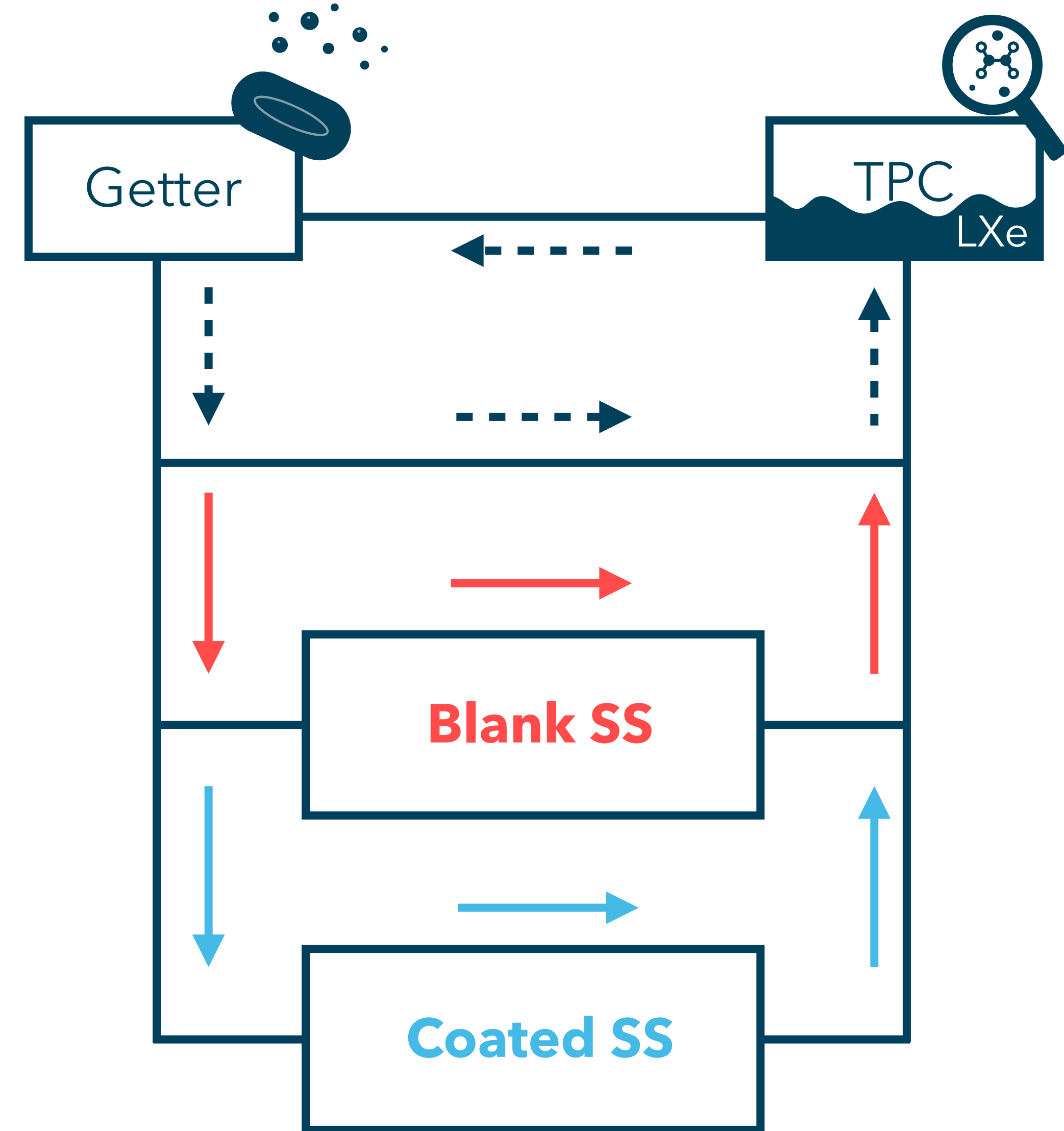
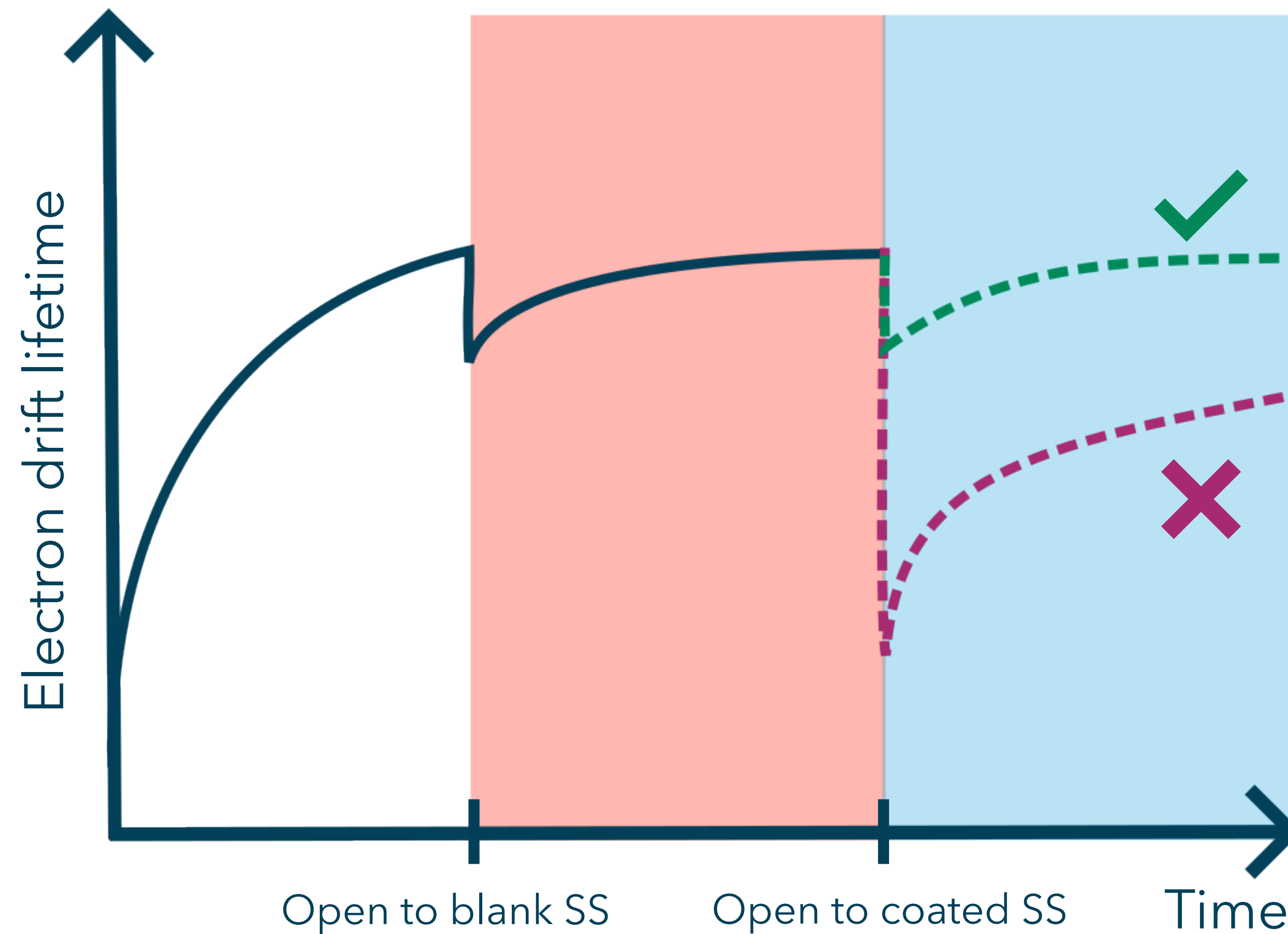
The sample

- Sample: Dual-sided copper-coated SS foil
- 0.8 m² of electroplated/blank SS foil in **gas system**
- 2 vessels: One blank SS and one coated SS foil
- Performance evaluated with electron drift lifetime



Performance test

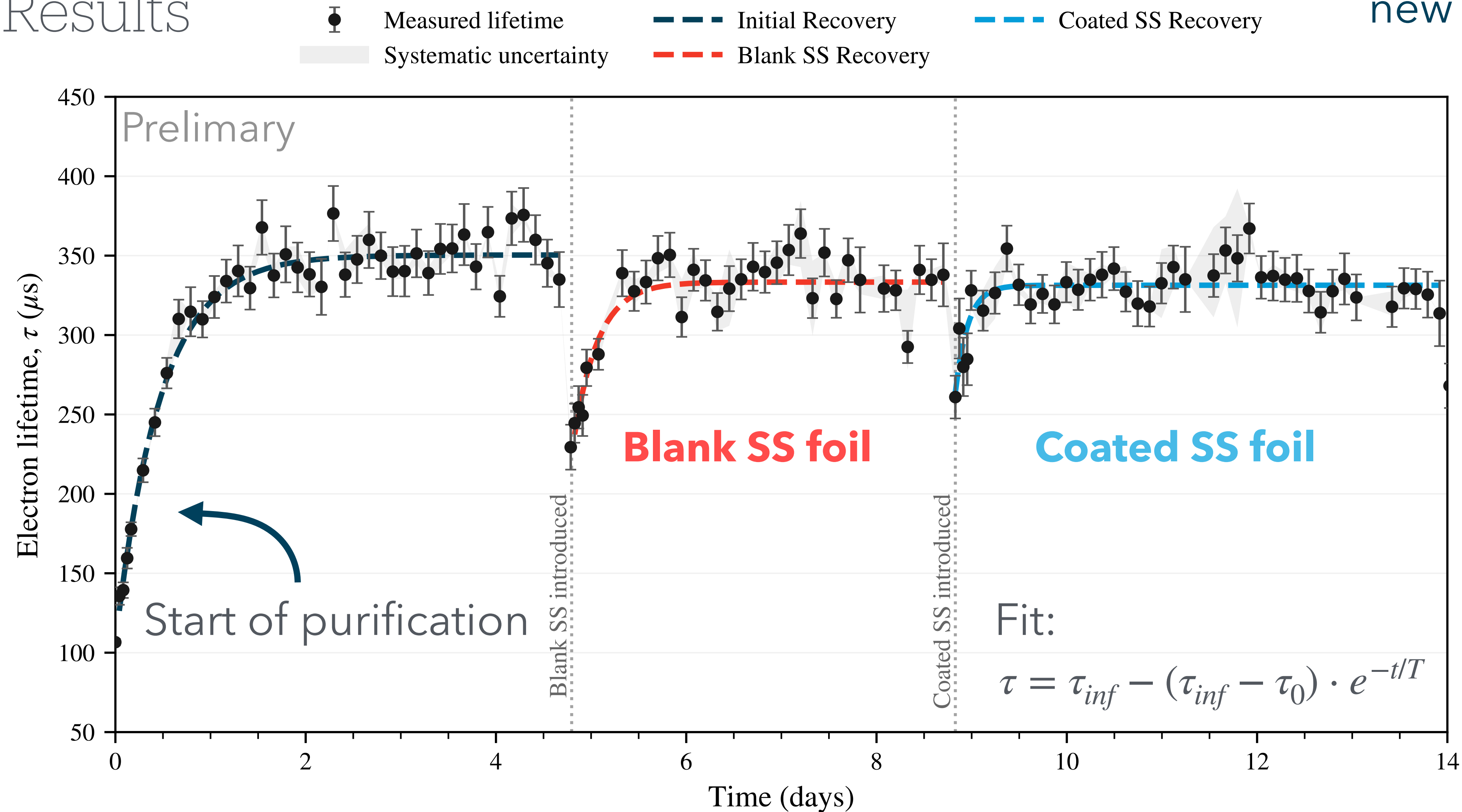
The test



Performance test

Results

Plateau drops due to new surfaces included



**Coated sample
performs similar to
SS sample !**

Outlook

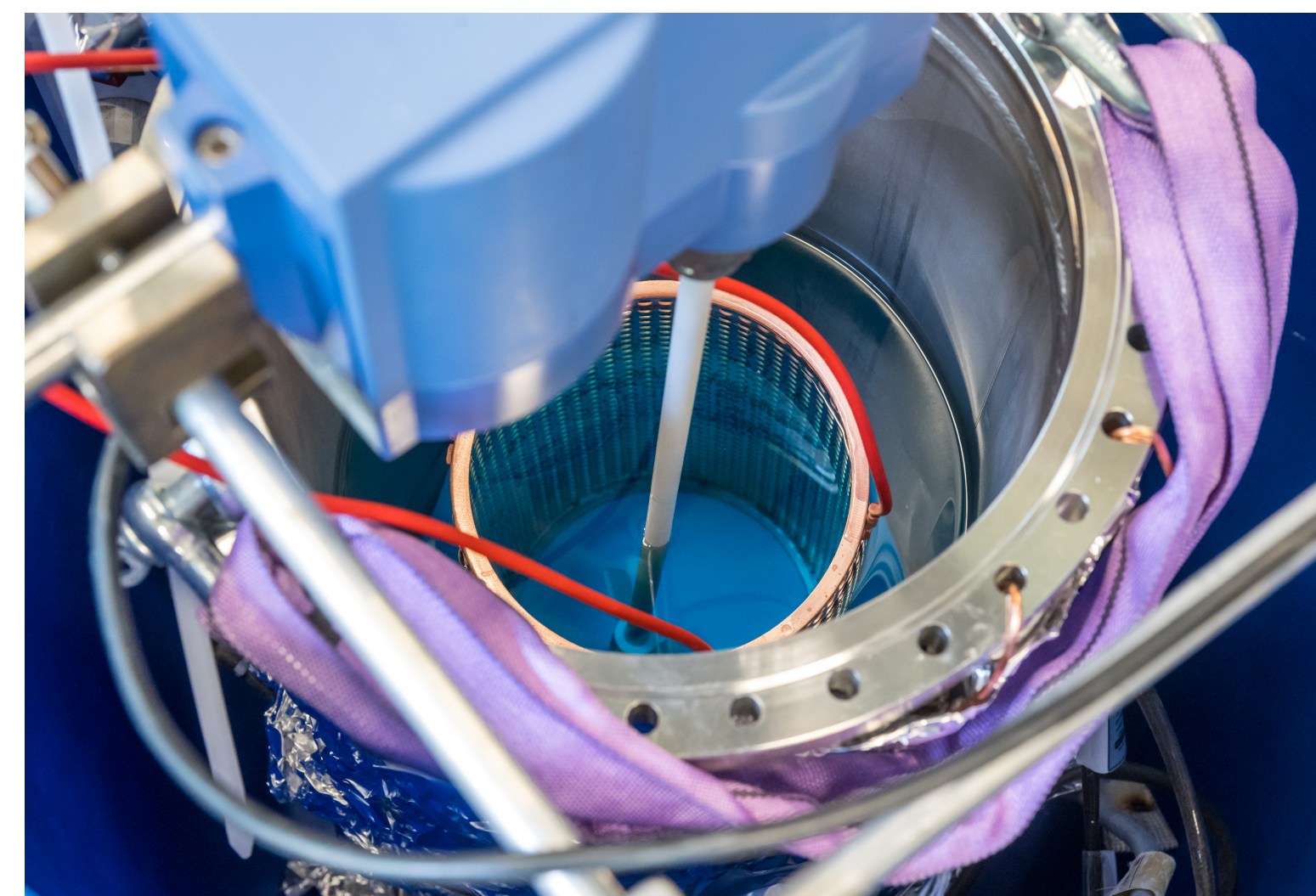
- Can we reduce Rn^{222} ? → Yes, ECP of copper leads to a reduction **factor of 1500**

- Can we upscale ECP ? → Yes !

**Paper in
preparation!**

- Is the ECP layer stable ? → Yes, also under **GXe** !

Current goal: Can we ECP even larger vessels ? → Yes !



Test in **LXe** with
University of Zürich

See M. Noia's talk on Wednesday:

„Testing radon mitigating surface coatings in
Xenoscope - a 2.6 meter long liquid xenon TPC“



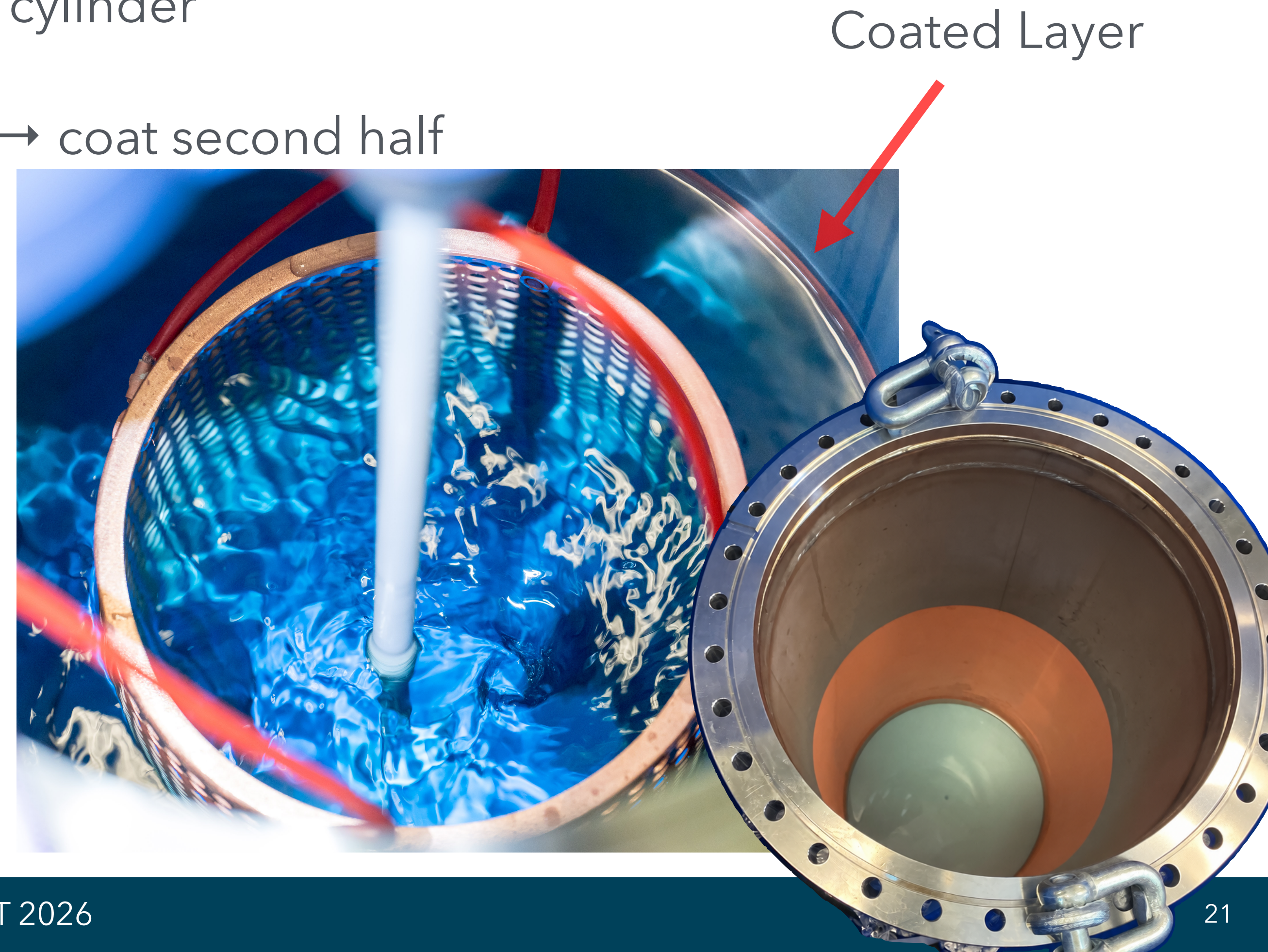
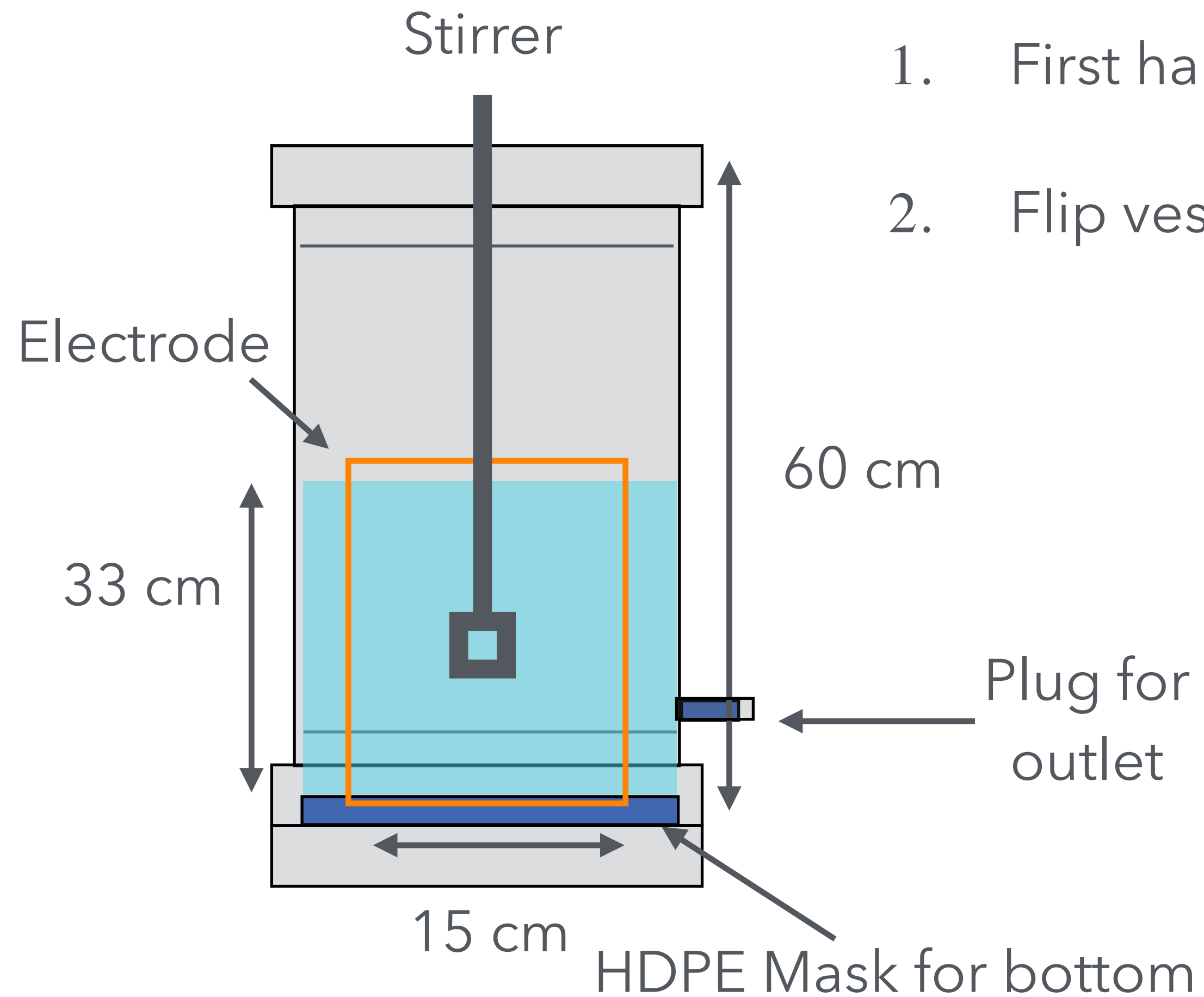
Backup

How can we safely ECP large vessels ?

Mantle

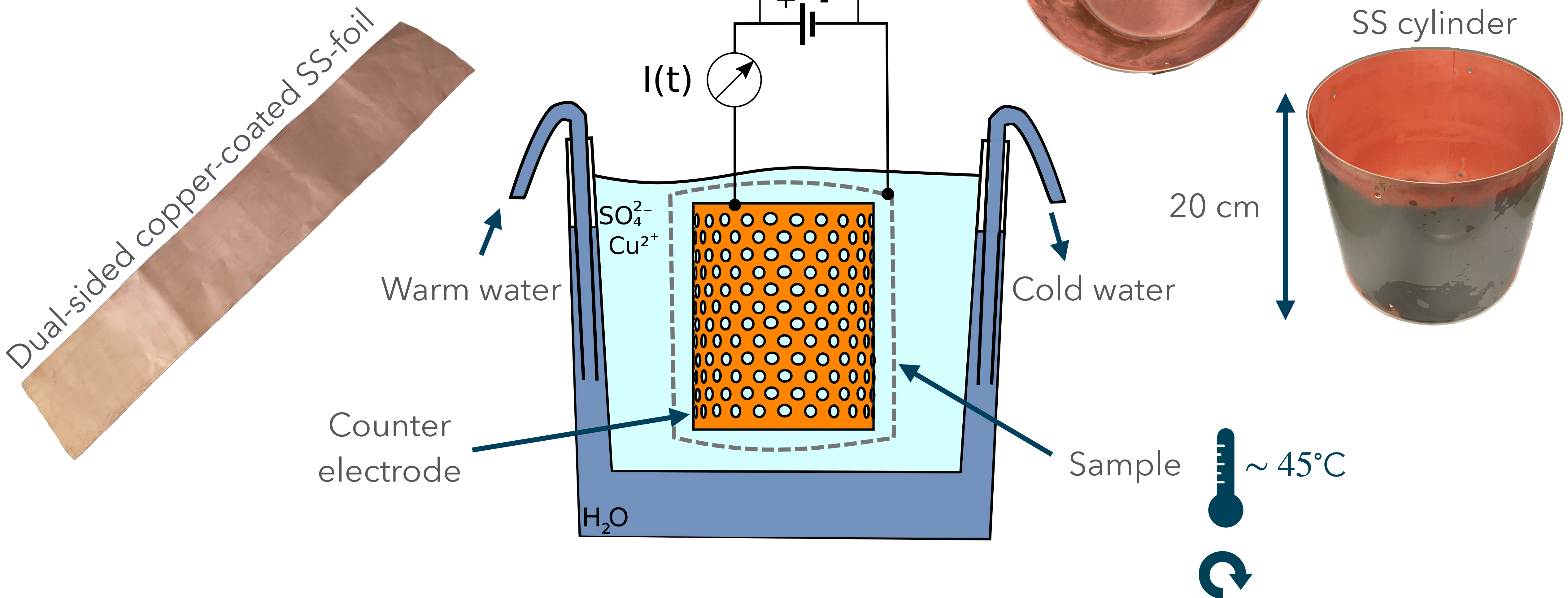
Coating sequence:

1. First half of cylinder
2. Flip vessel → coat second half



Upscaling

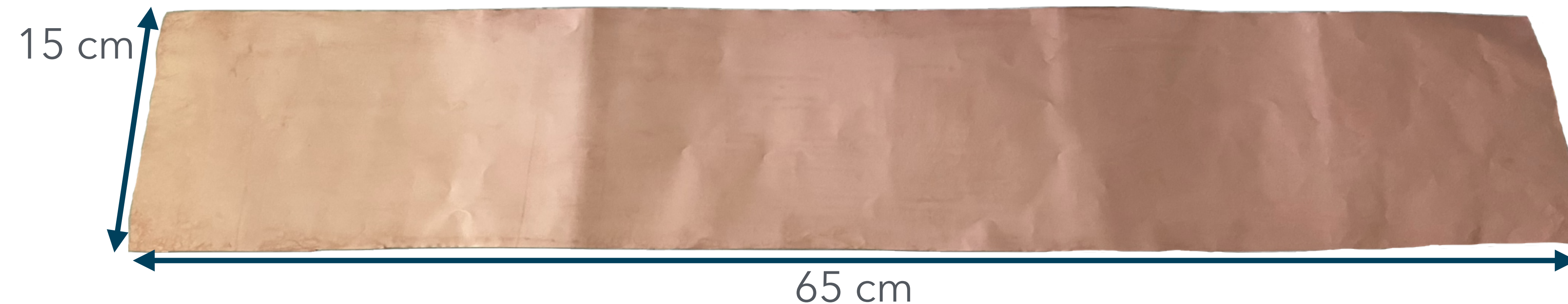
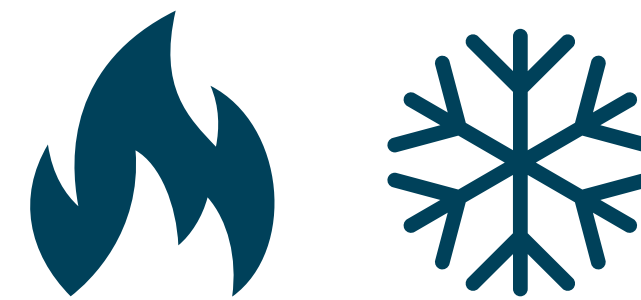
Medium setup at MPIK



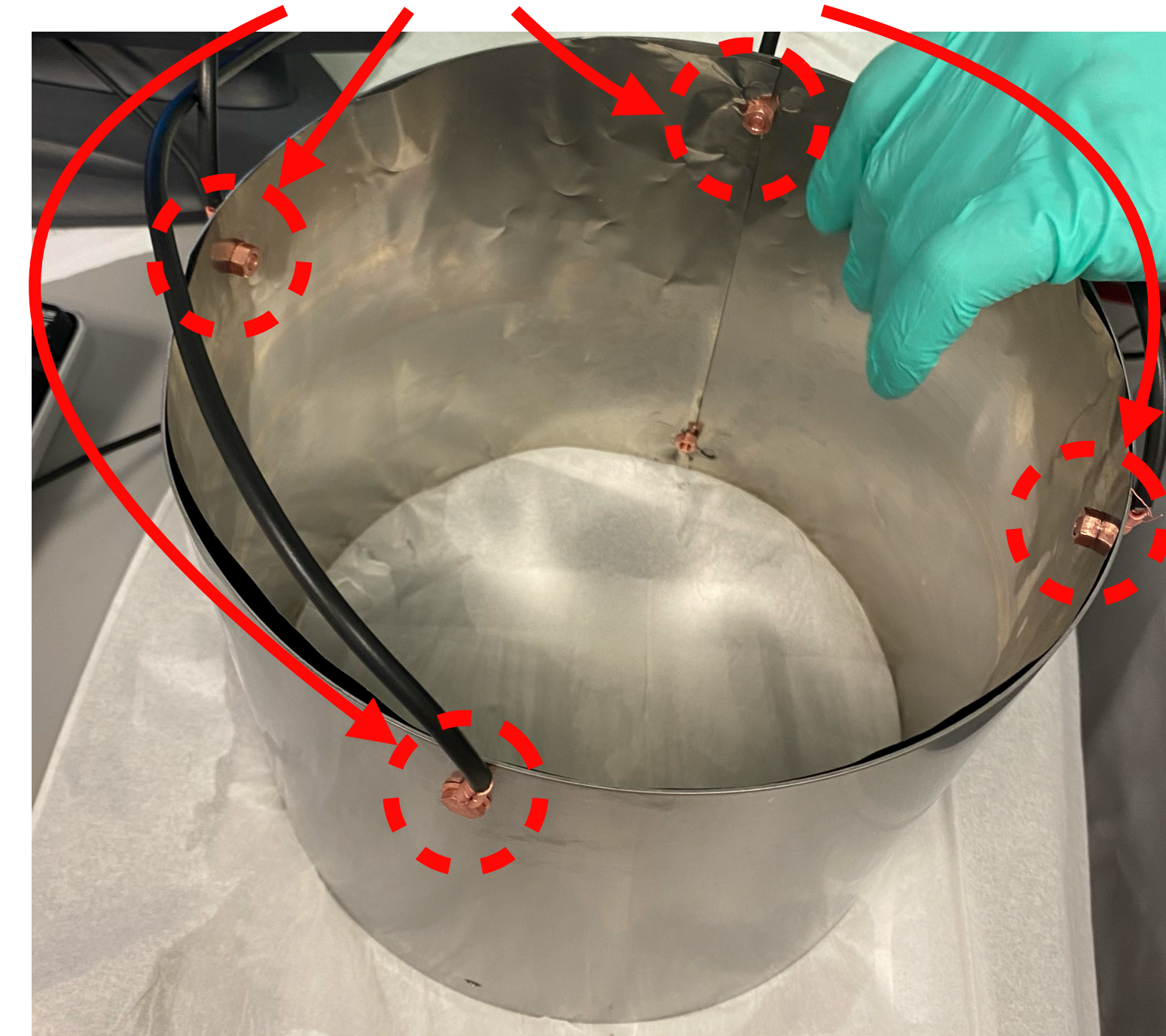
Upscaling

Dual-sided copper-coated SS-foil

- 68 x 20 cm SS foil with a thickness of 50 μm
- Coated on both sides
- High mechanical resistance and stability under extreme temperatures, from heating to liquid nitrogen



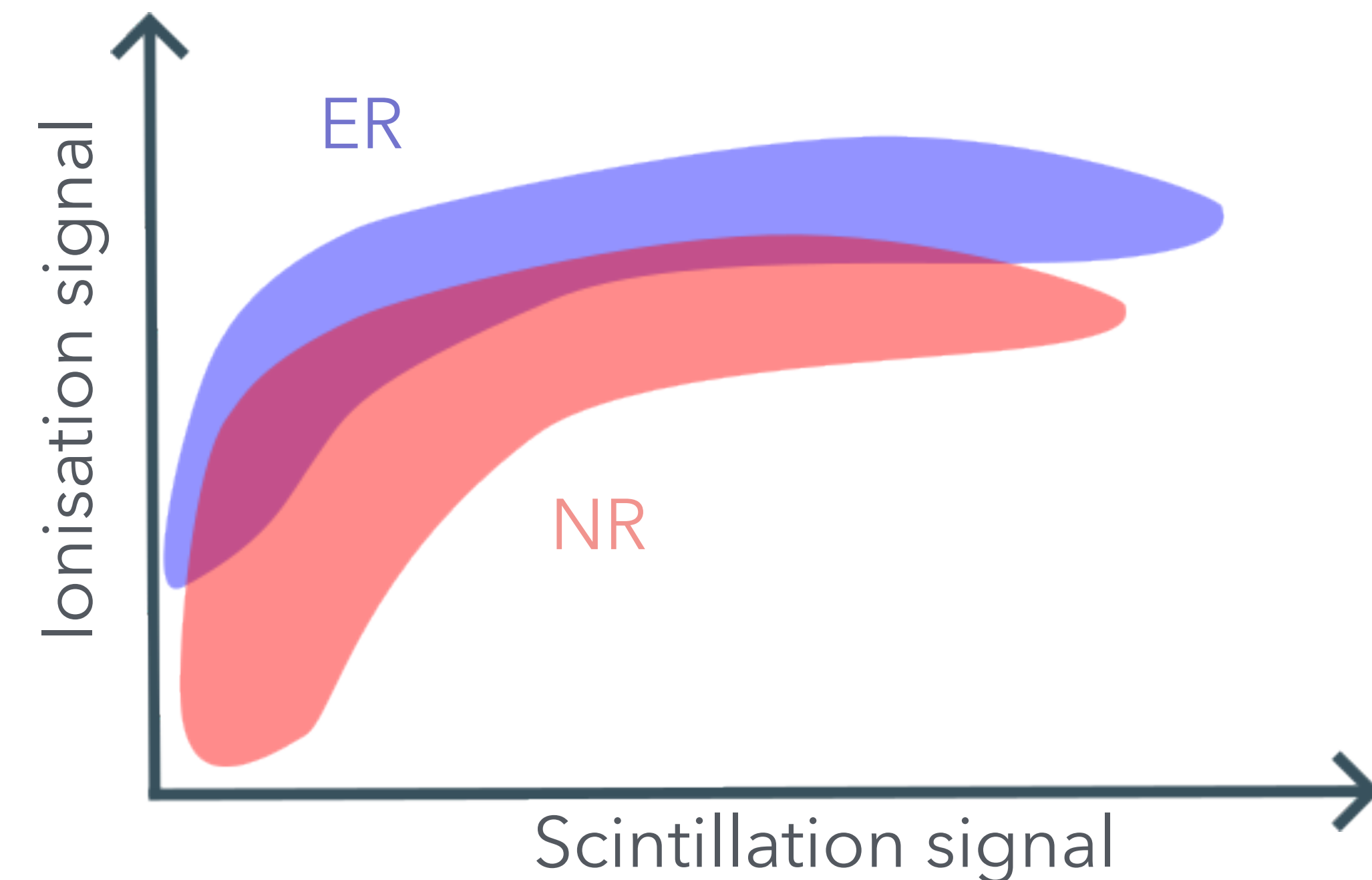
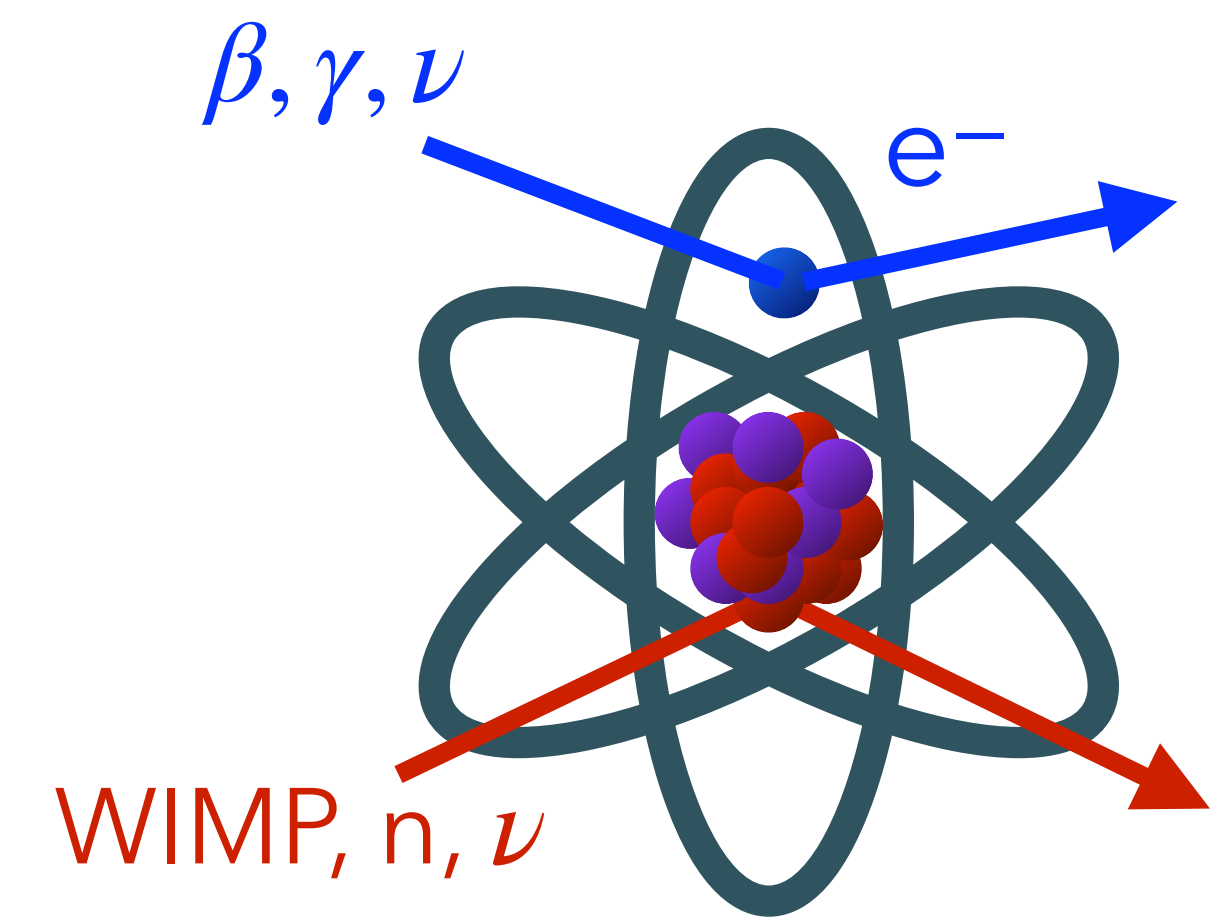
Electrode connections



Why do we care about radon ?

Radon background in liquid xenon detectors

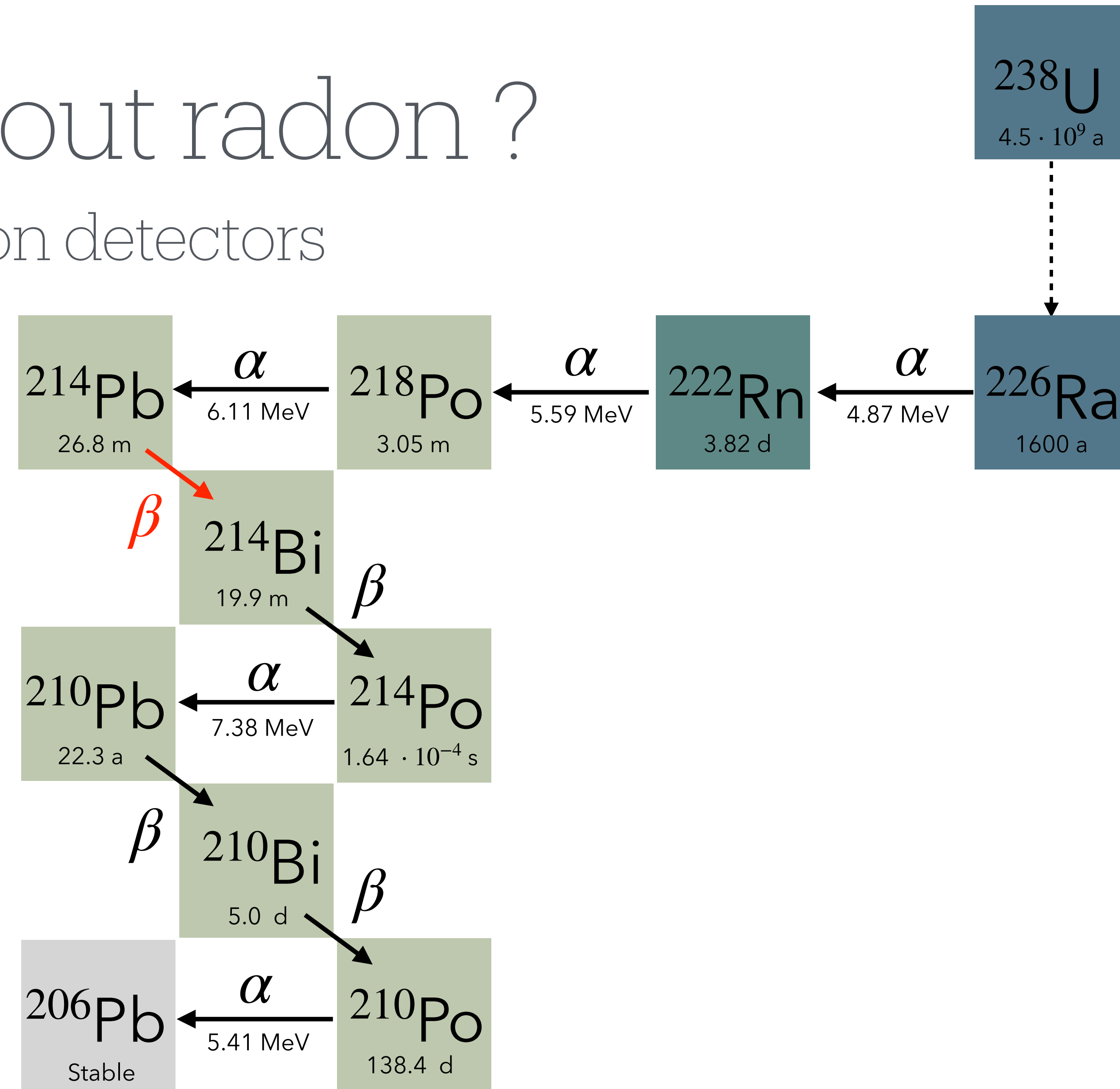
- WIMP are expected to transfer small recoil energies via elastic scattering of the Xenon nuclei (**NR**)
- Gamma and beta particles scatter elastically on electrons producing electronic recoils (**ER**)
- Distinguished in LXe TPC due to their dE/dx resulting in different scintillation and ionisation yields



Why do we care about radon?

Radon background in liquid xenon detectors

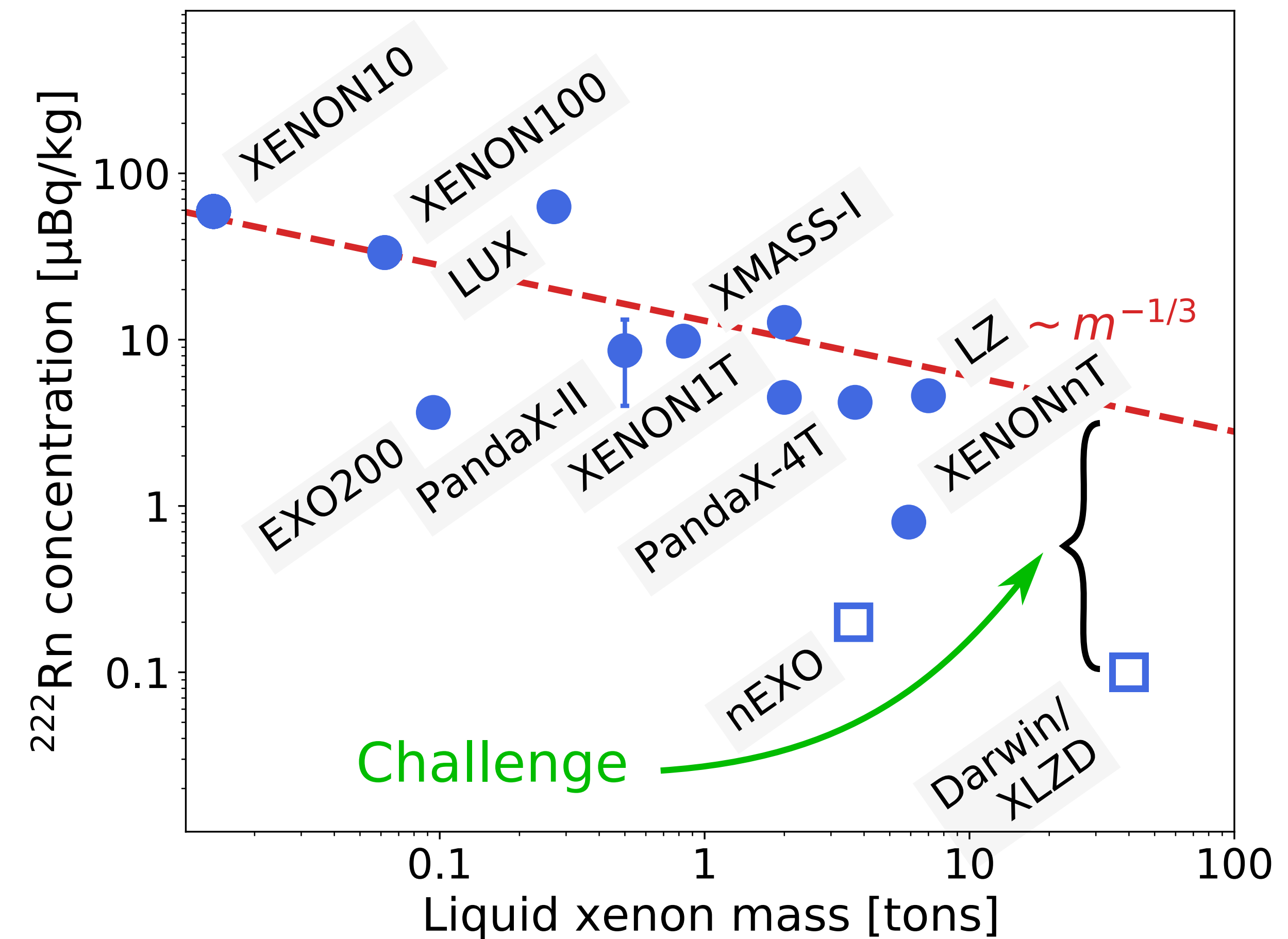
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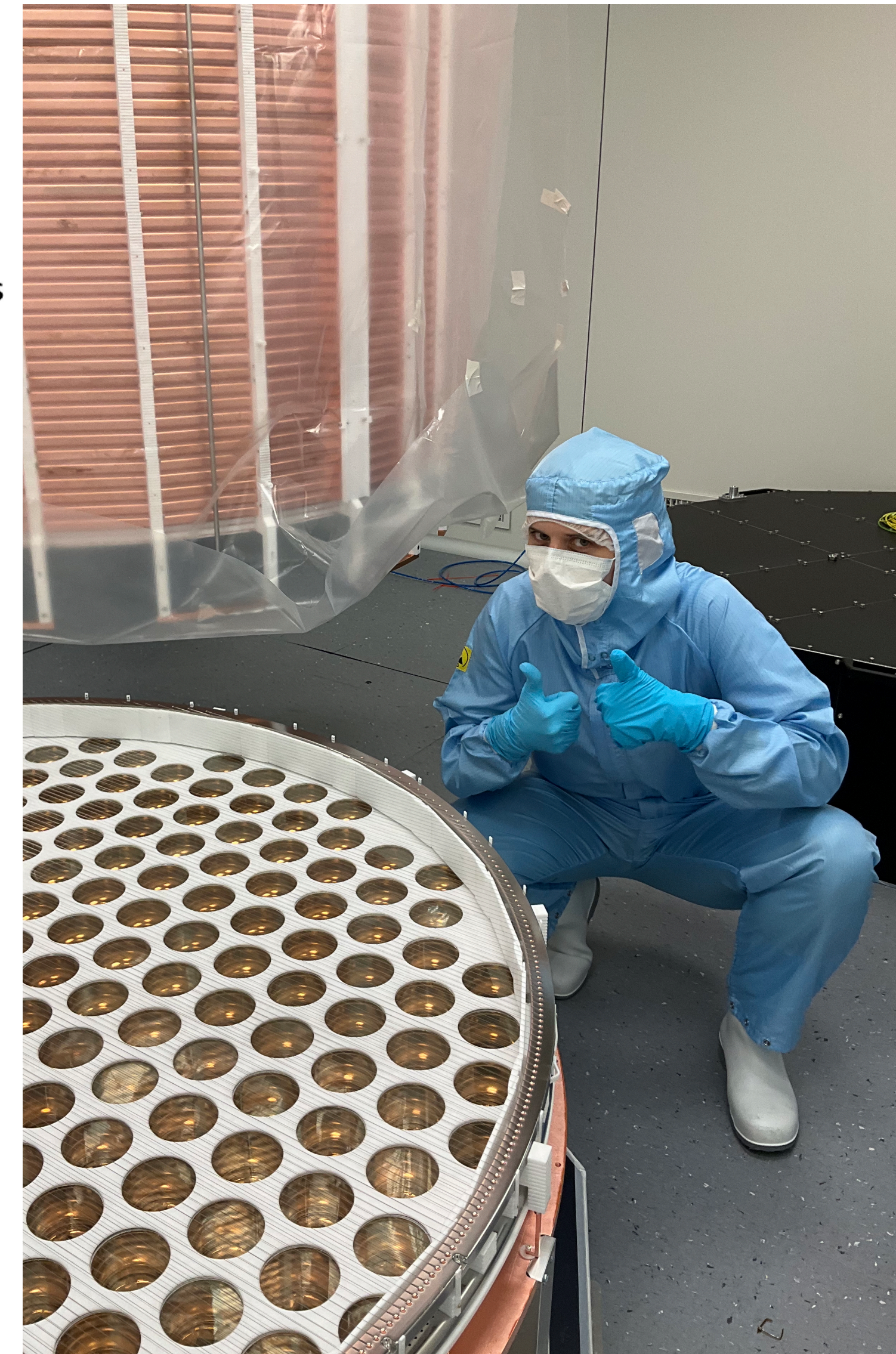
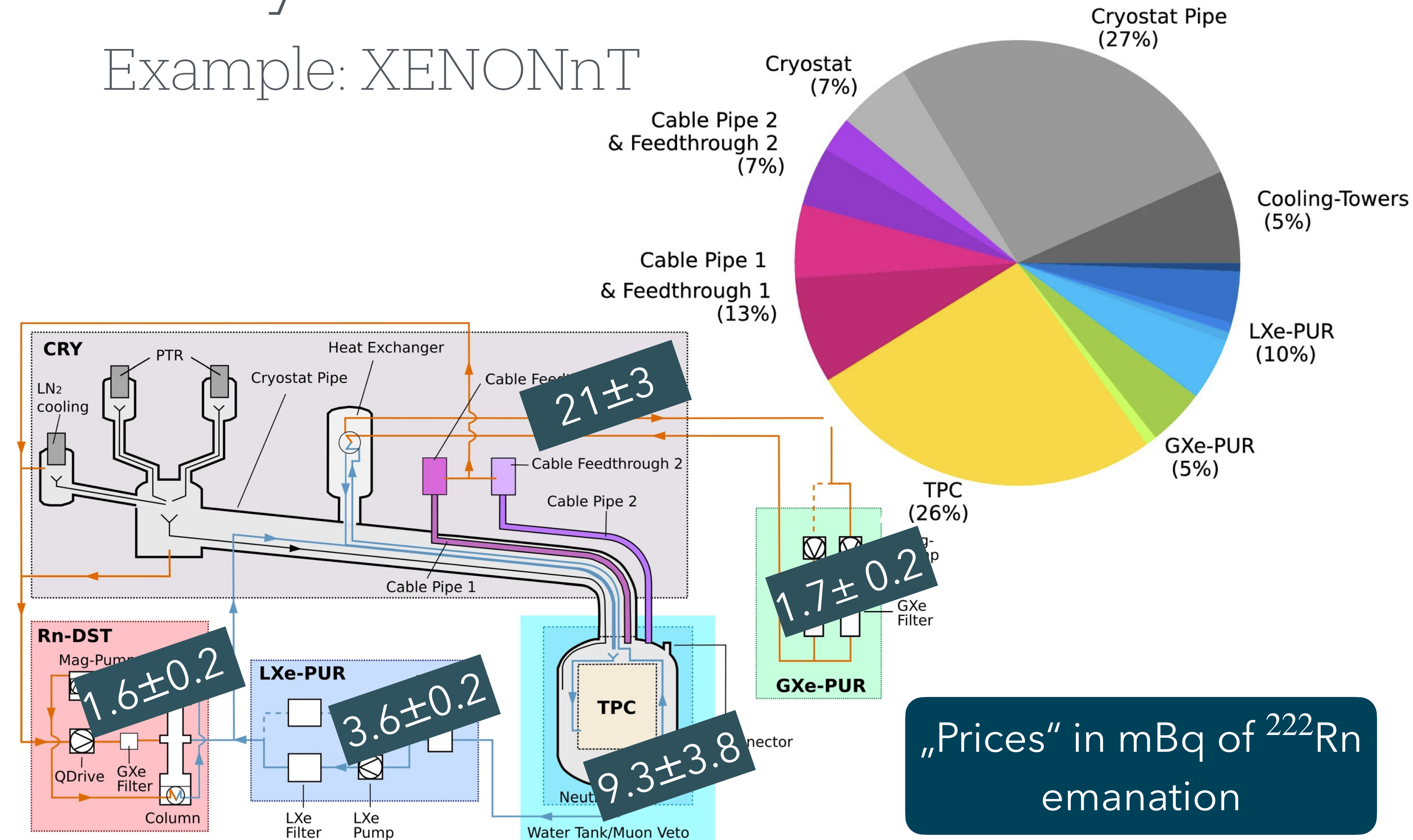
Requirement for future Xe-based detectors

- Radon concentration is proportional to its internal surface area $\rightarrow \propto m^{-1/3}$
- In XLZD mass scaling will be insufficient to reach required radon concentration
- Radon mitigation strategies must be improved

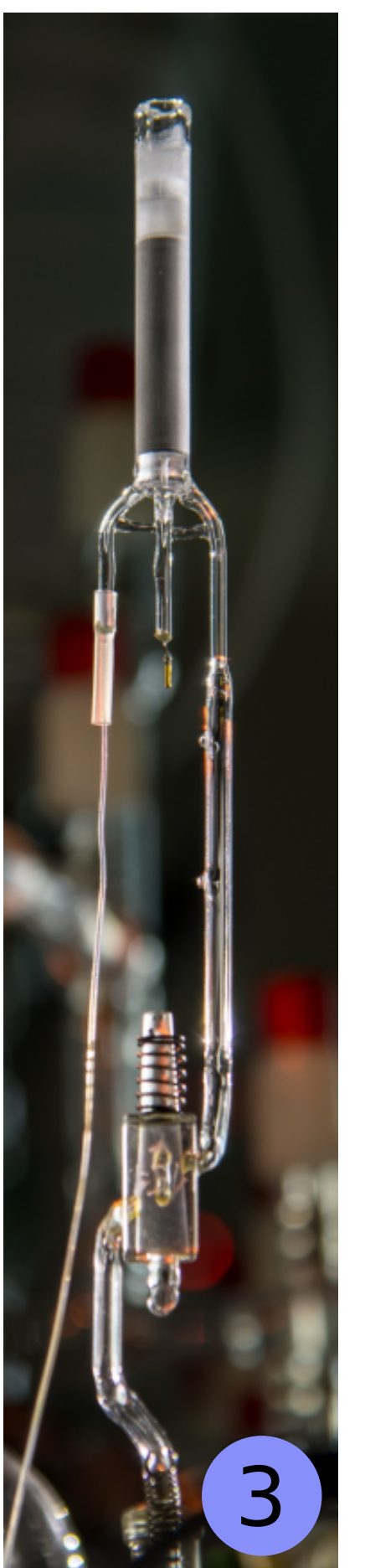
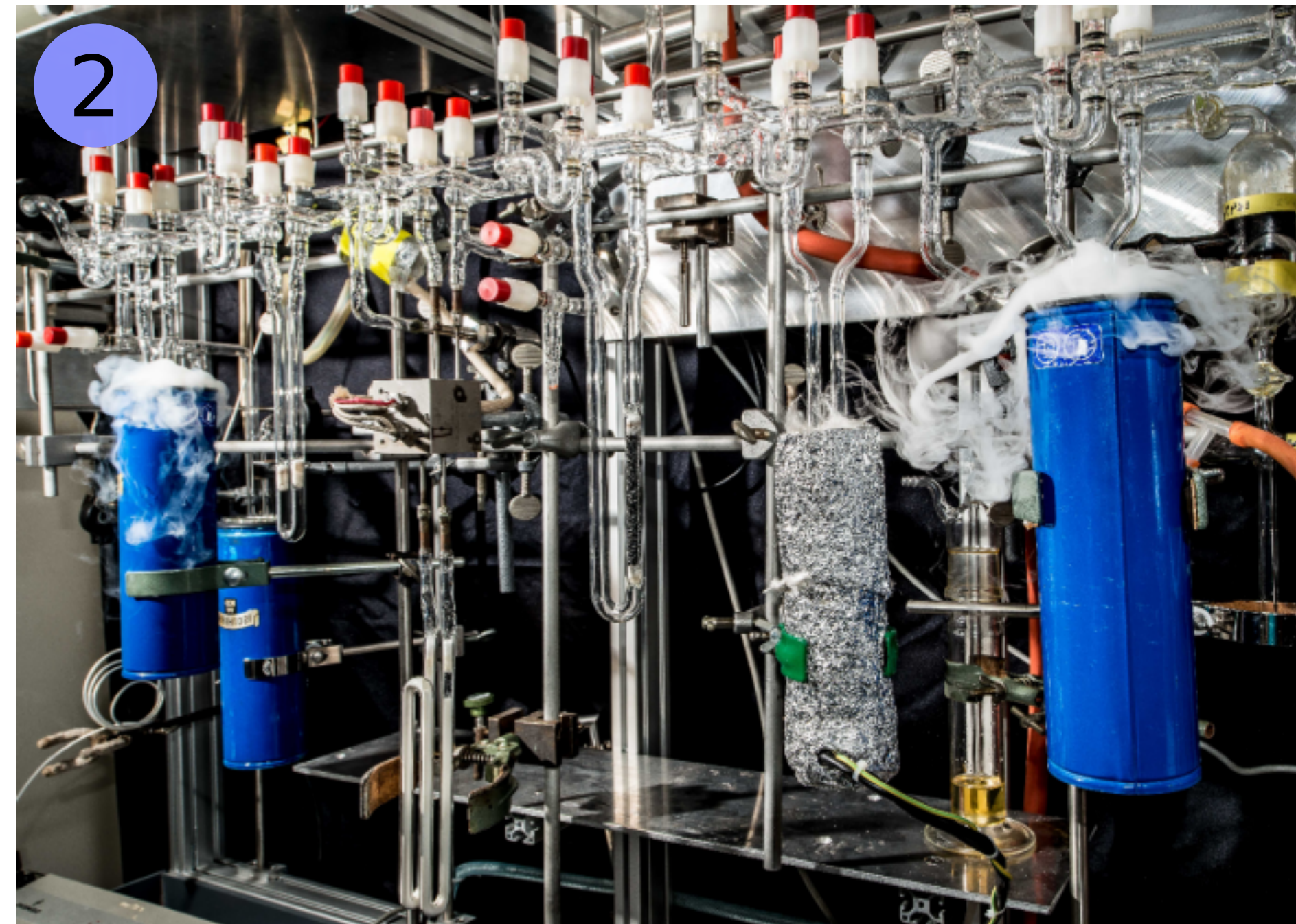
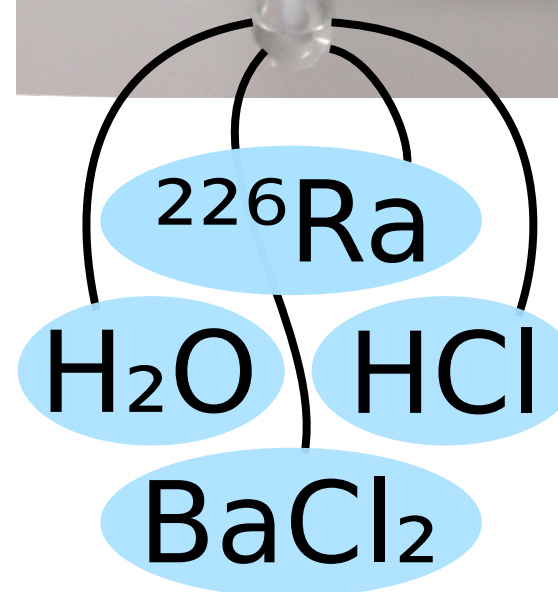


Why do we care about radon?

Example: XENONnT



Measurement of radon

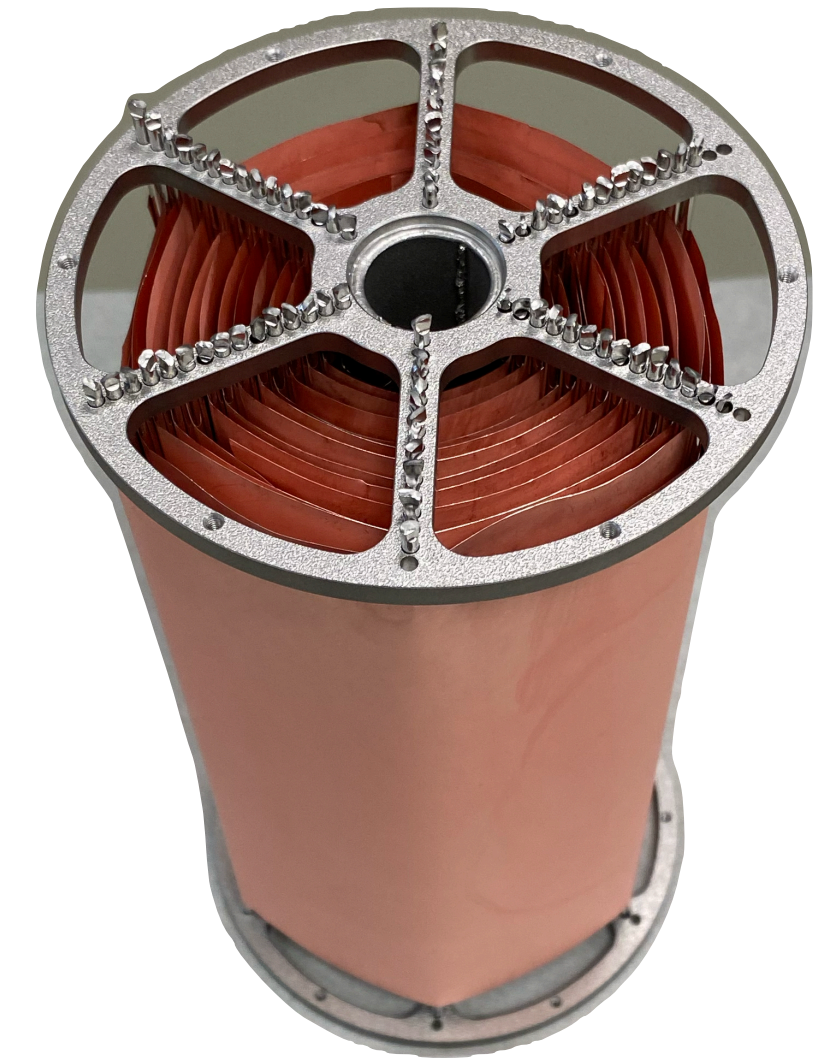


1. ^{222}Rn trapped in carbon trap cooled with liquid nitrogen
2. Transfer and purification of the sample
3. ^{222}Rn emanation measured with proportional counter

Performance test

Cleaning

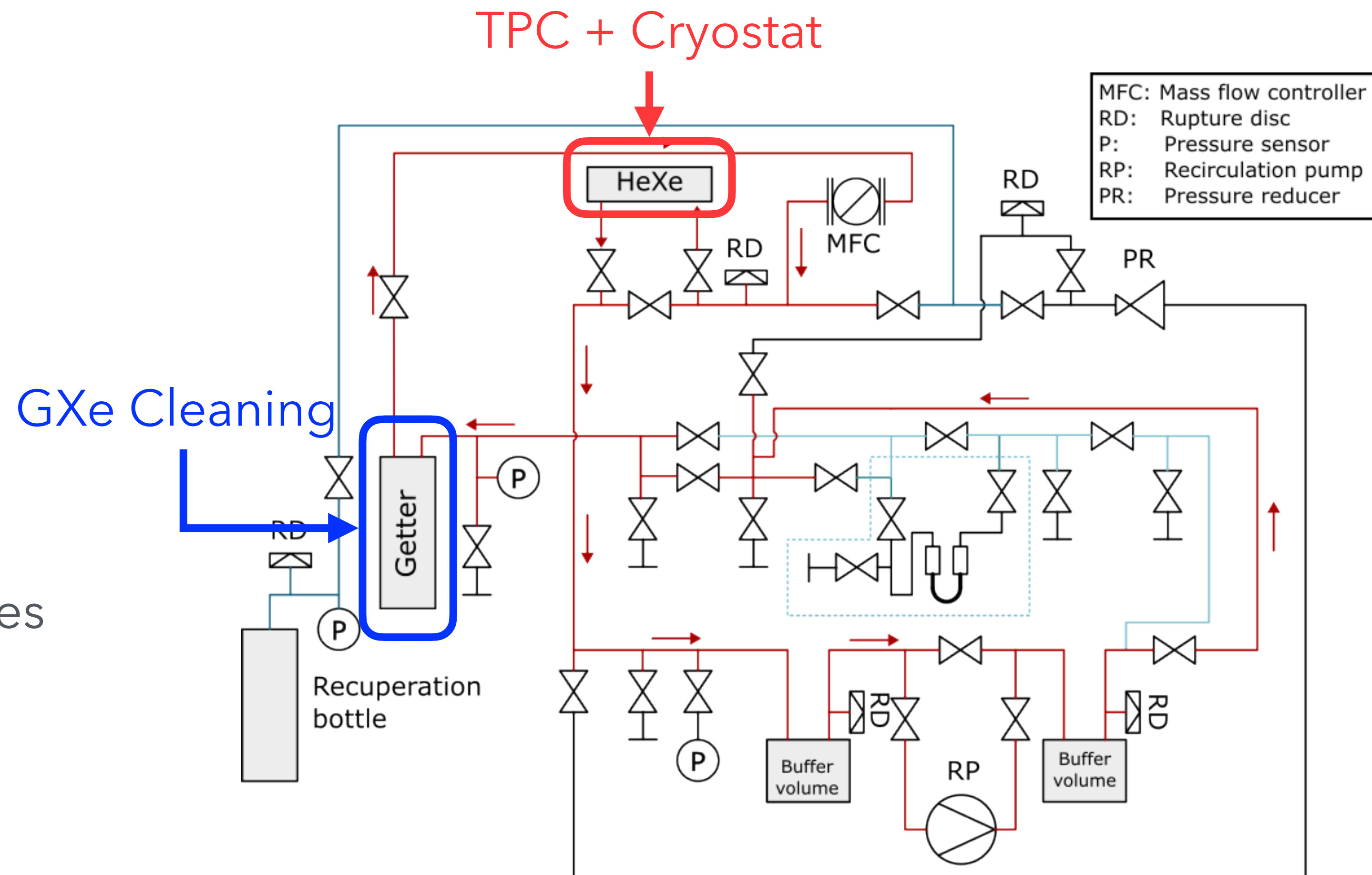
	Blank SS	Coated SS
	US bath with 5% Deconex 20ns	US bath with 5% Deconex 20ns
After coating	-	US bath in 5% ELMA acid intense +3% citric acid
After coiling	US bath in 5% Deconex 20ns	Dip cleaned 10% ELMA 65, + 3% citric acid
After first HeXe runs	US bath in 99.8% ethanol	US bath in 99.8% ethanol
Baking	10 days	10 days
Flushing at 2.75 slpm GXe	26 days	27 days



Performance test

The Heidelberg Xenon detector (HeXe)

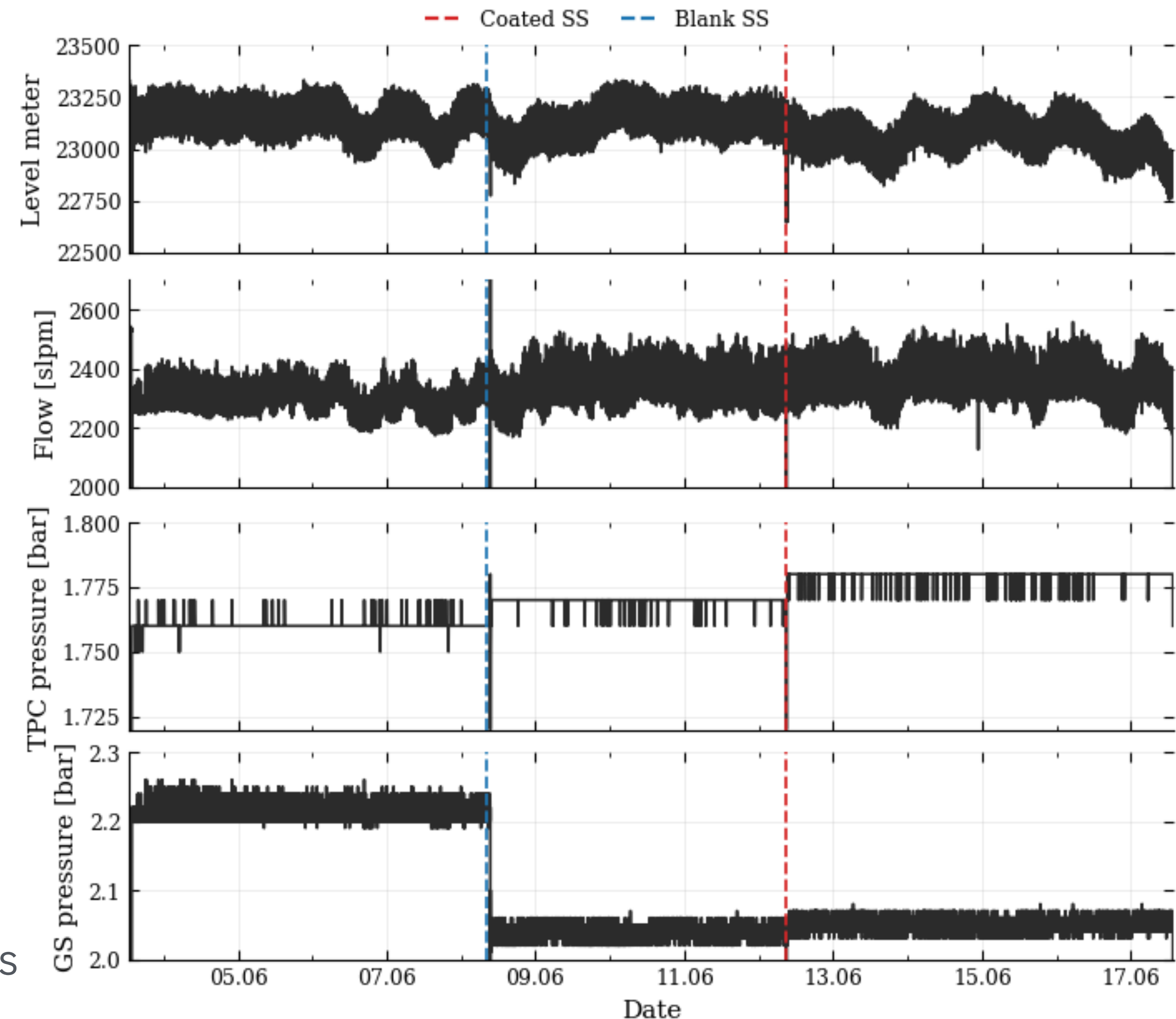
- Local liquid xenon (LXe) detector at MPIK
- Dual phase xenon time projection chamber (TPC)
- TPC contains 345 g of LXe
- Getter continuously removes impurities in gaseous xenon (GXe)



Performance test

Detector conditions

- HeXe was kept at stable conditions during measurement
 - Stable liquid level
 - Stable GXe flow at 2.3 slpm
 - Stable TPC and GS pressure
 - Stable TPC temperature
- Drift field was 50 V/cm → Drift time of $45\mu\text{s}$



Performance test

Electron drift lifetime

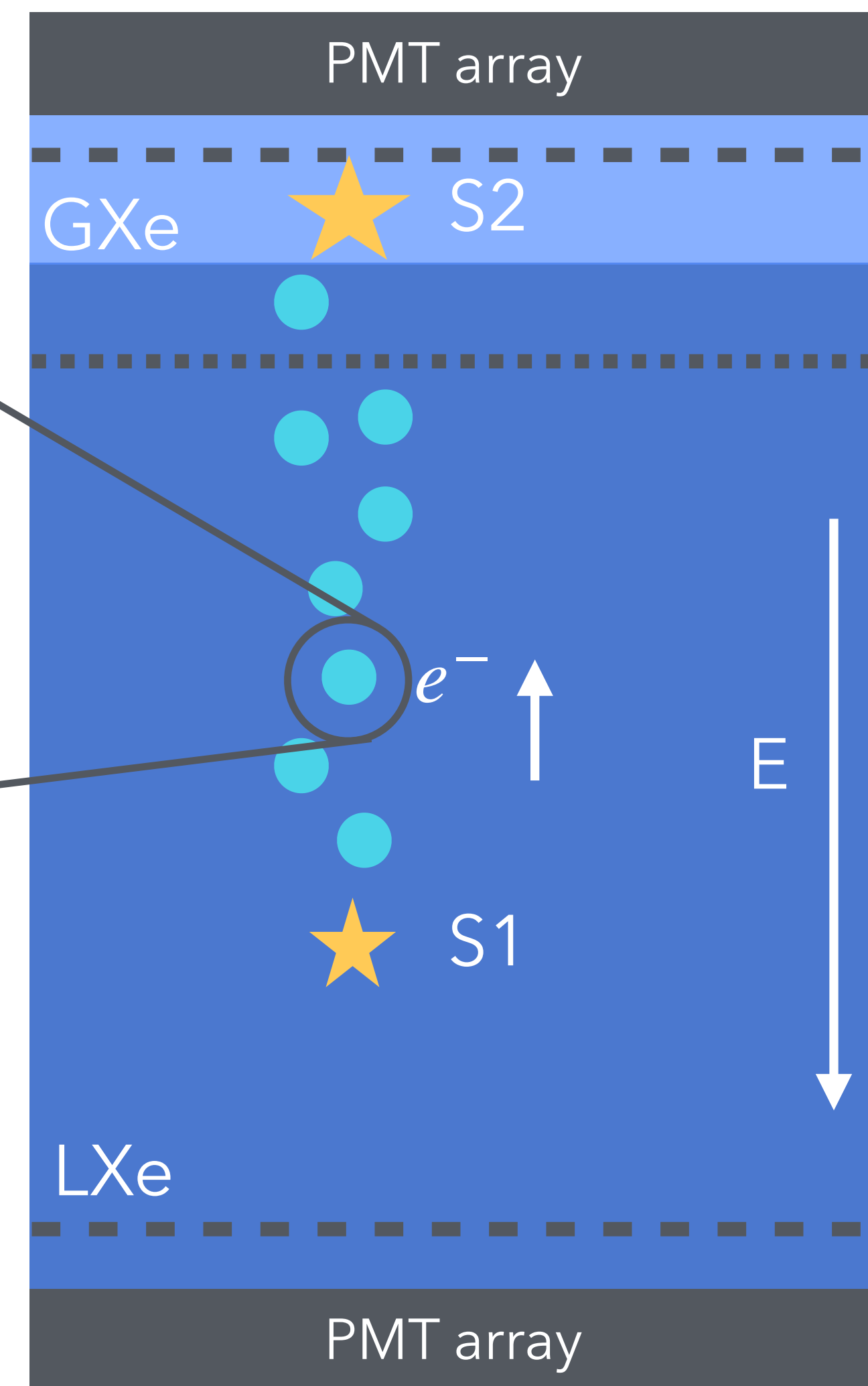
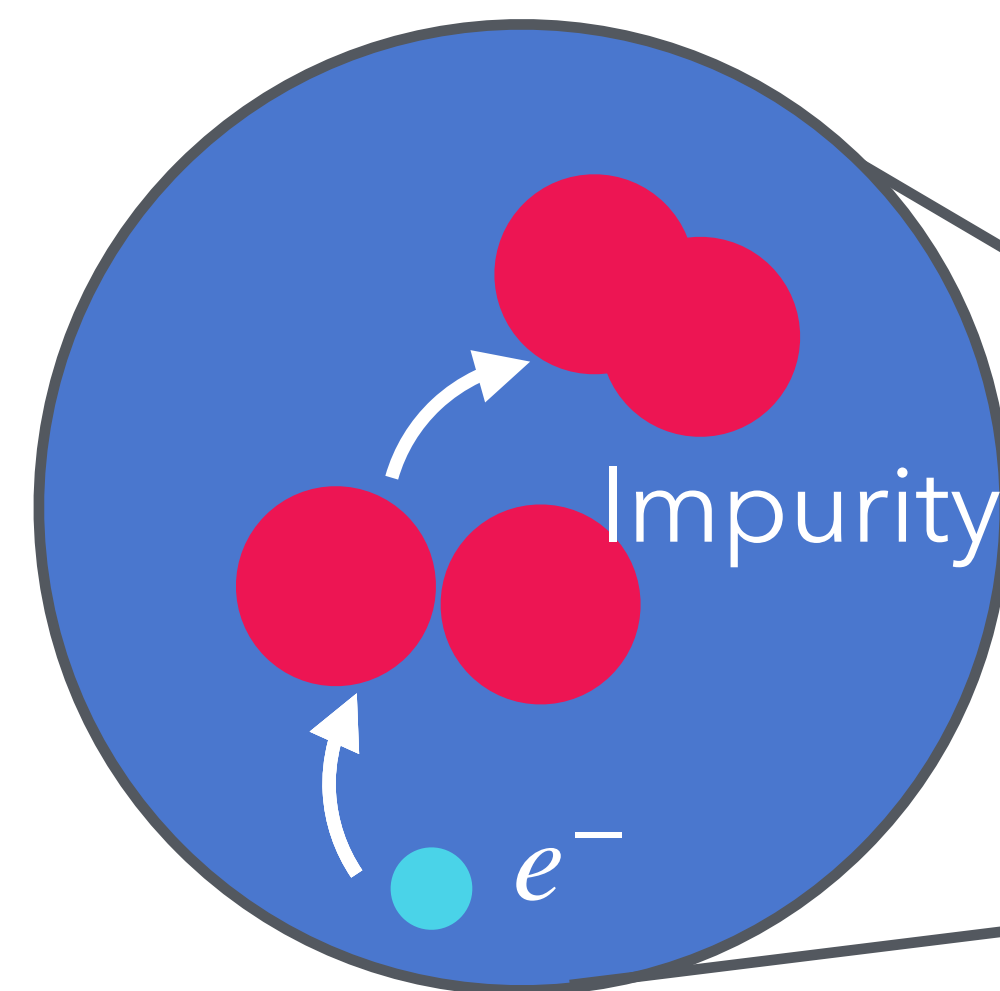
- Xenon contains trace impurities of $O_2, N_2, H_2O \dots$
- We used the internal calibration source of ^{83m}Kr
- Comparing the number of electrons before $N_e(0)$ and after drift $N_e(t)$ provides an indirect measurement of the electronegative purity concentration in the LXe

$$N_e(t) = N_e(0) \cdot e^{-t/\tau}$$

$$\tau = \frac{1}{N_S \cdot k_S}$$

With impurity concentration N_S and k_S the impurity attachment rate

Capture by electronegative impurities



Performance test

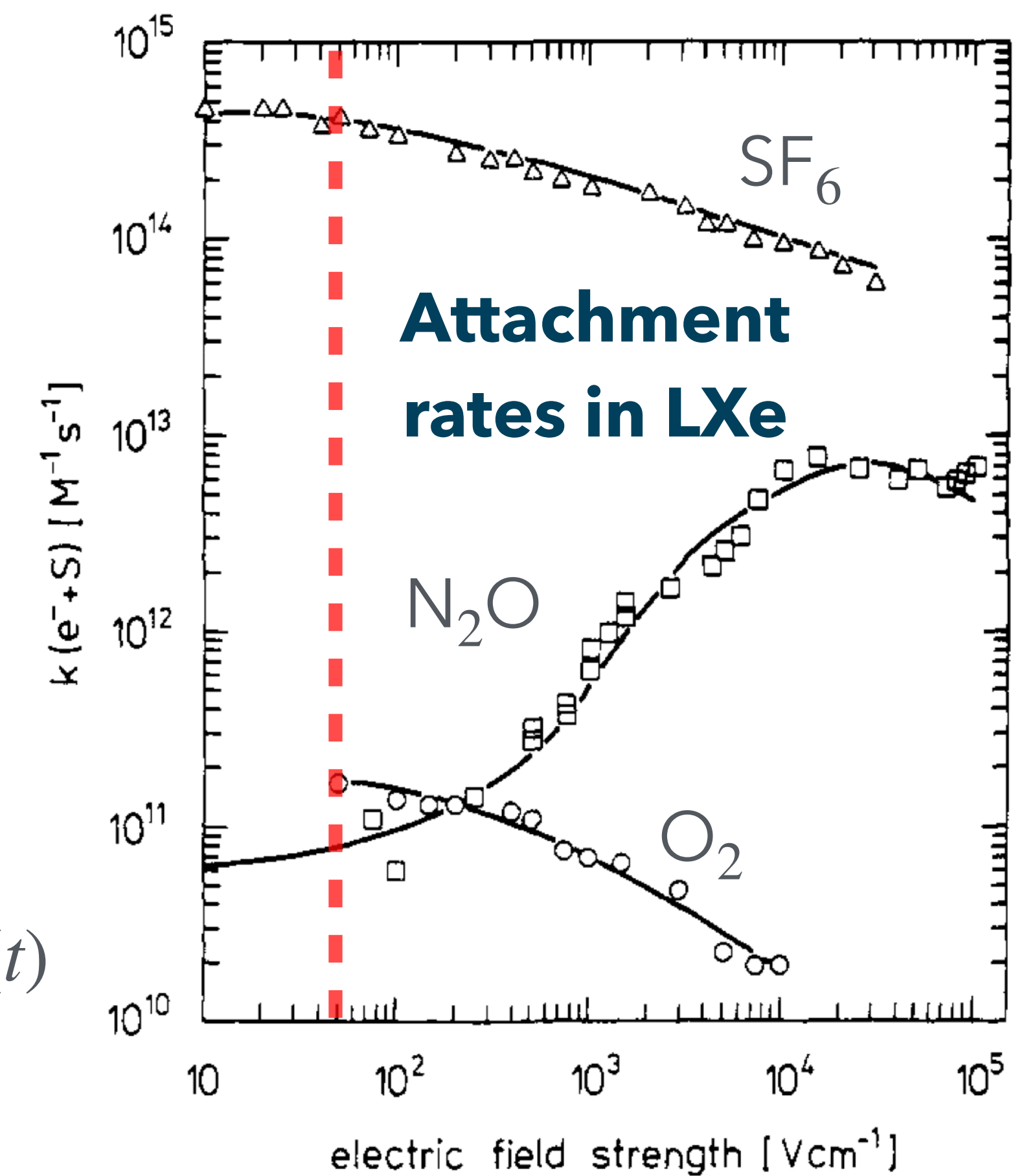
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Bakale et al., J. Phys. Chem. 80 (1976) 2556

Performance test

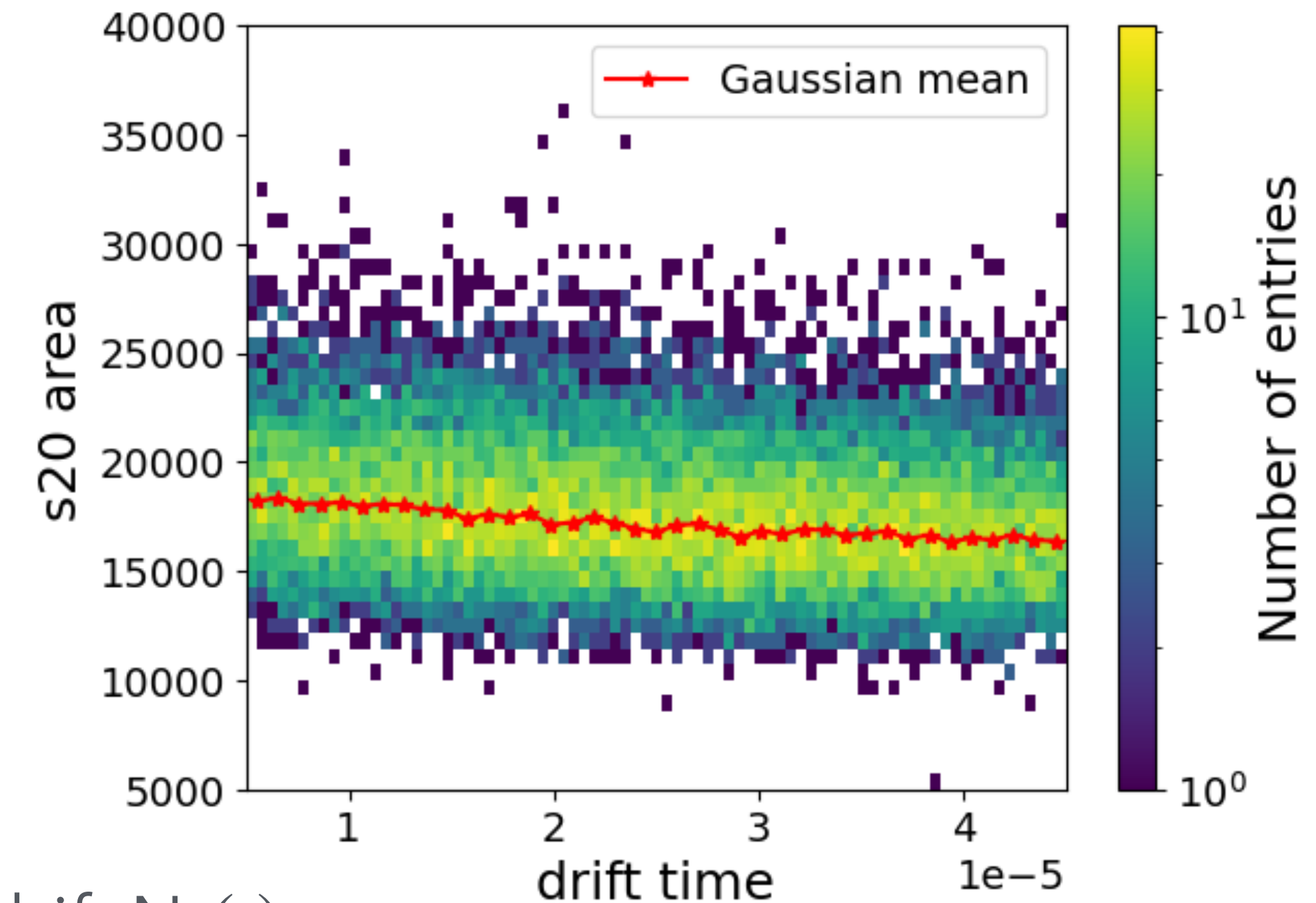
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Performance test

Results

E-life can be translated into a O_2 outgassing rate R

$$N_{O_2}(ppb) = \frac{V_{Mol(Xe)}}{\tau_{inf}(\mu s) \cdot k_{O_2}}$$

$$V_{Mol(Xe)} = 0.046 \text{ [liter/mol]}$$

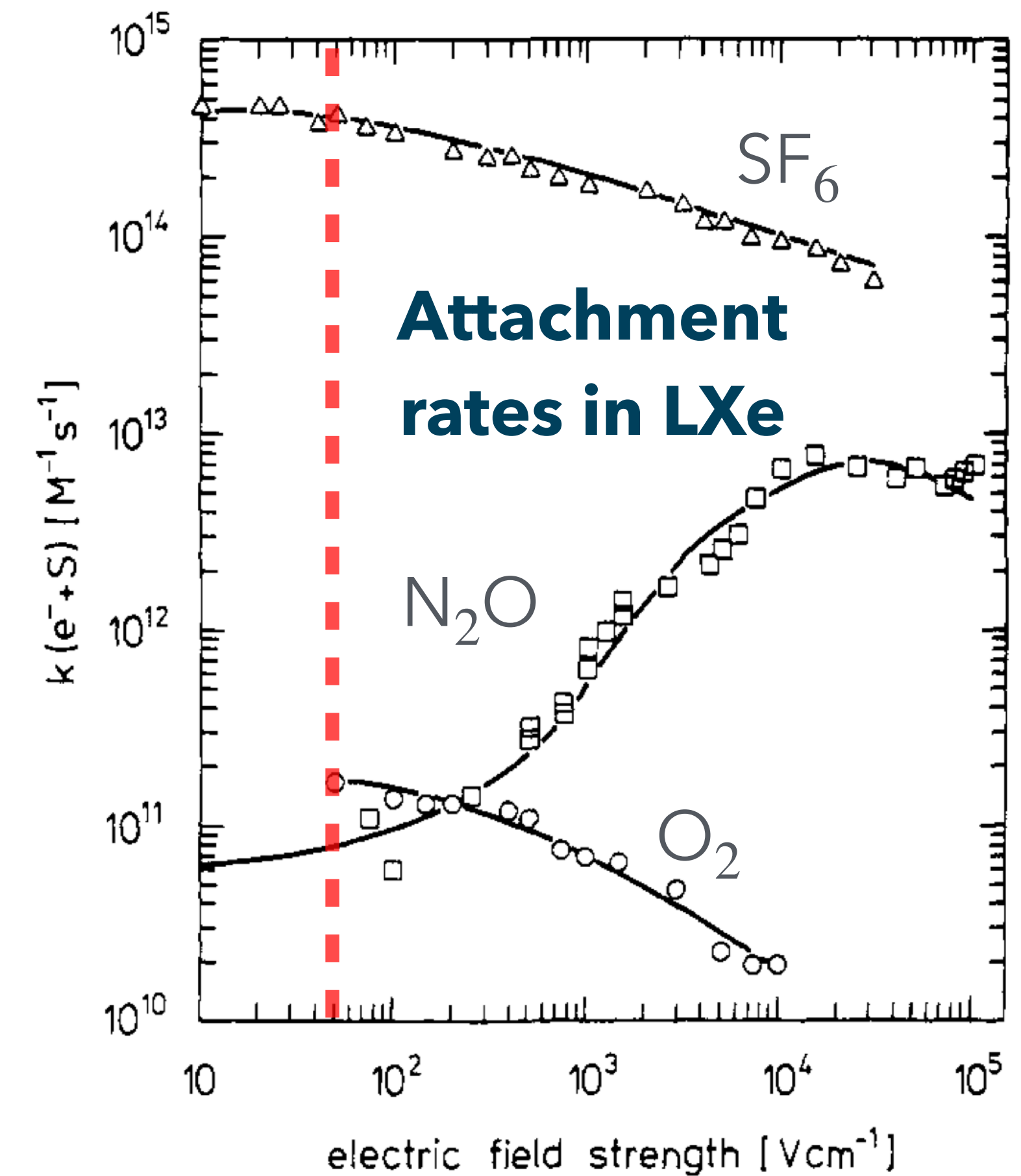
$$N_{O_2}(ppb) = \frac{271 \text{ [ppb liter]}}{\tau_{inf}(\mu s)}$$

$$k_{O_2} = 1.7 \cdot 10^5 \text{ [/mol/}\mu s\text{]}$$

$$R = F_M \cdot N_{O_2}$$

$$F_M = F \cdot \frac{\rho_{GXe}}{M_{Xe}} = 2.270 \text{ [slpm]} \cdot \frac{5.894 \text{ [g/liter]}}{131.29 \text{ [g/mol]}} = 0.1019 \text{ [mol/liter/minute]}$$

$$R \text{ [mol } O_2\text{]} = 0.1019 \text{ [mol/liter/minute]} \cdot \frac{271 \text{ [ppb liter]}}{\tau_{inf}(\mu s)}$$



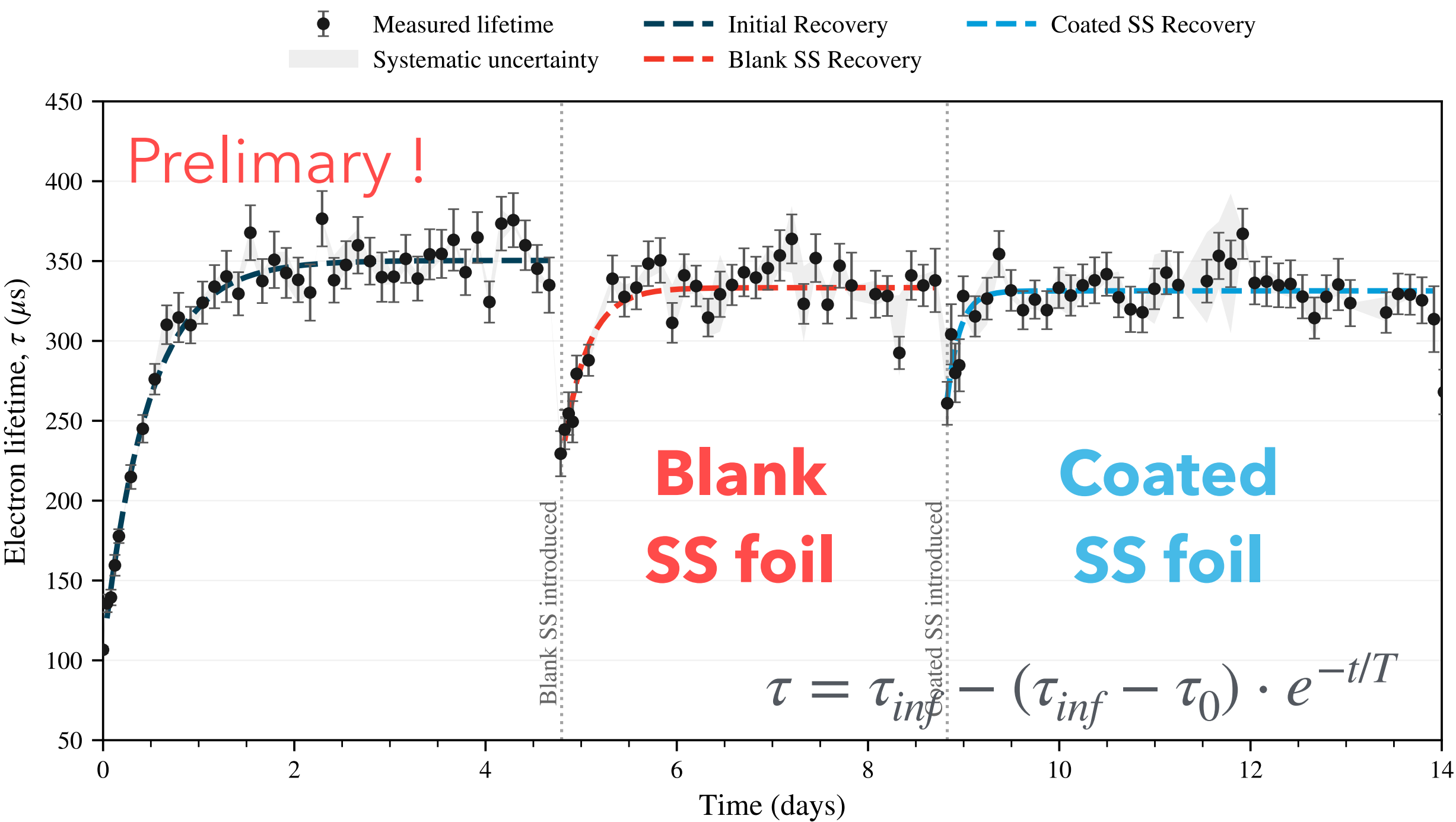
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Performance test

Results

Preliminary results !

E-life τ_{inf} can be translated into a O₂ outgassing rate:



Type	$\tau_{inf} [\mu\text{s}]$	Impurity Conc.NO2 [ppb]	Outgassing Rate R [e-11 (mol O2)/min]
Start	$350 \pm 3 \text{ (stat.) } ^{+5}_{-5} \text{ (syst.)}$	$0.772 \pm 0.007 \text{ (stat.) } ^{+0.012}_{-0.010} \text{ (syst.)}$	$7.87 \pm 0.07 \text{ (stat.) } ^{+0.12}_{-0.10} \text{ (syst.)}$
Blank SS	$333 \pm 3 \text{ (stat.) } ^{+10}_{-10} \text{ (syst.)}$	$0.812 \pm 0.007 \text{ (stat.) } ^{+0.024}_{-0.024} \text{ (syst.)}$	$8.27 \pm 0.07 \text{ (stat.) } ^{+0.24}_{-0.24} \text{ (syst.)}$
Coated SS	$331 \pm 2 \text{ (stat.) } ^{+8}_{-8} \text{ (syst.)}$	$0.817 \pm 0.006 \text{ (stat.) } ^{+0.021}_{-0.020} \text{ (syst.)}$	$8.32 \pm 0.06 \text{ (stat.) } ^{+0.21}_{-0.20} \text{ (syst.)}$