Universität Zürich[UZH]

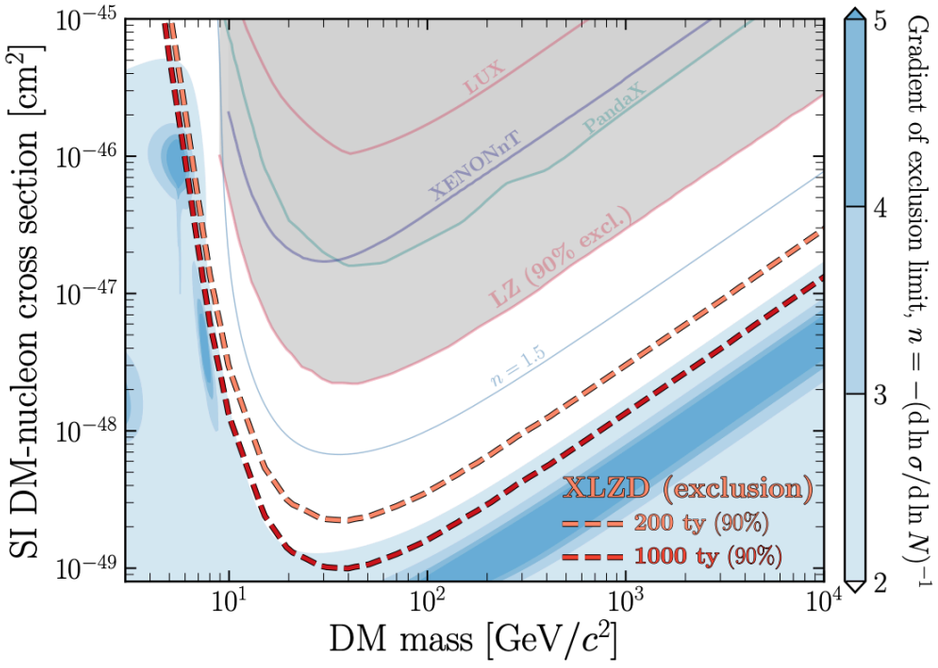
Swiss National Science Foundation

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

Margherita Noia, on behalf of the Xenoscope team at UZH

Low Radioactivity Techniques, 21-24 September 2026, York

XLZD - The next generation liquid xenon observatory



- **WIMP** search down to the neutrino fog
- Competitive sensitivity to **neutrinoless double beta decay**
- Neutrino physics and rare events observatory

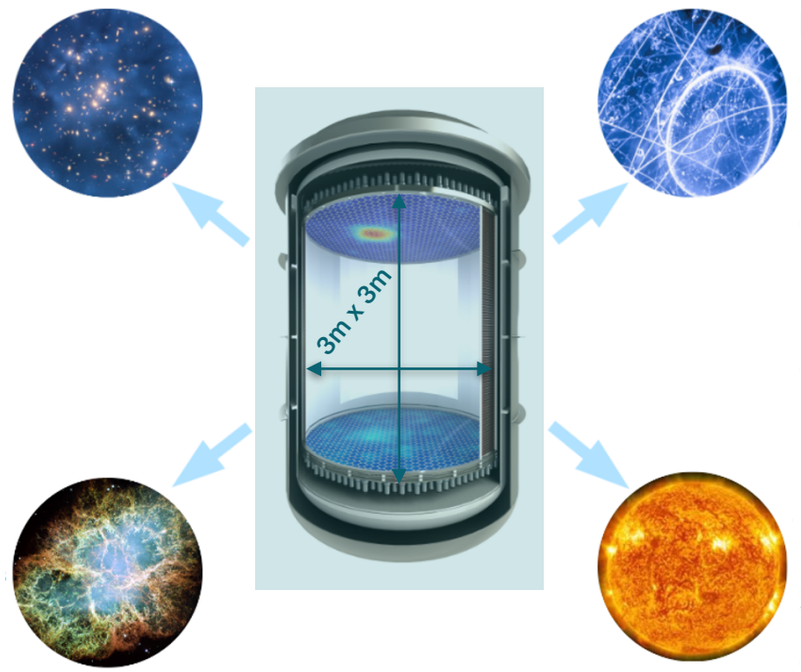
- A **3m x 3m** dual phase TPC
- Active volume with **60 up to 80 tons** of LXe

Dark Matter

- WIMPS
- Sub-GeV
- Inelastic
- Axion-like particles
- Plank mass
- Dark photons

Supernovae

- pp neutrinos
- Early alert
- Supernovae neutrinos
- Multi-messenger astrophysics



Neutrinos nature

- Neutrinoless double beta decay
- Neutrino magnetic moment
- Double electron capture

Sun

- pp neutrinos
- Solar metallicity
- ^7Be, ^8B, hep

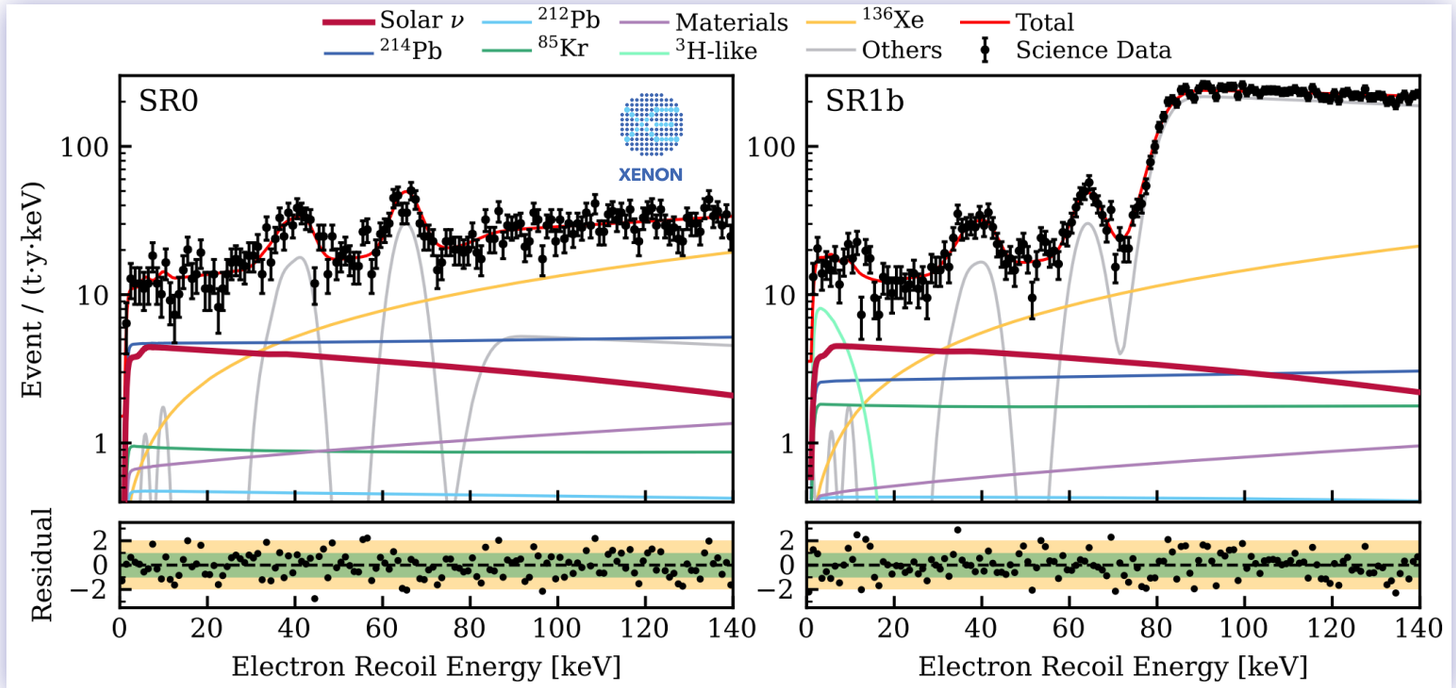
XENON + LZ + DARWIN

XLZD Collaboration, Eur. Phys. J. C 85, 1192 (2025)

Radon is the main contribution to background

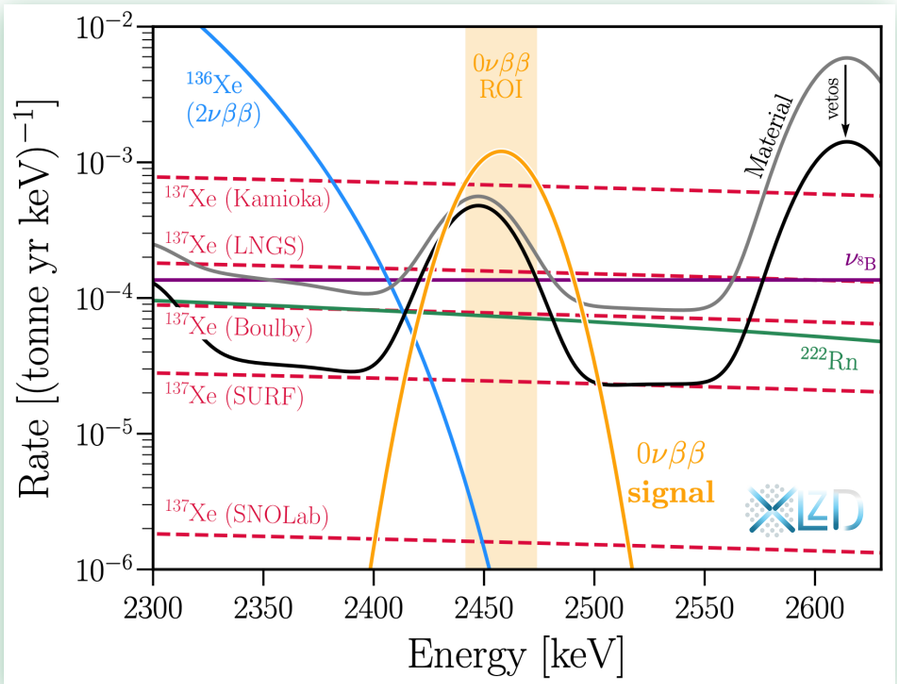
First Measurement of Solar Neutrinos through Elastic Neutrino-Electron Scattering at the keV Scale (2026)

arXiv:2608.29450

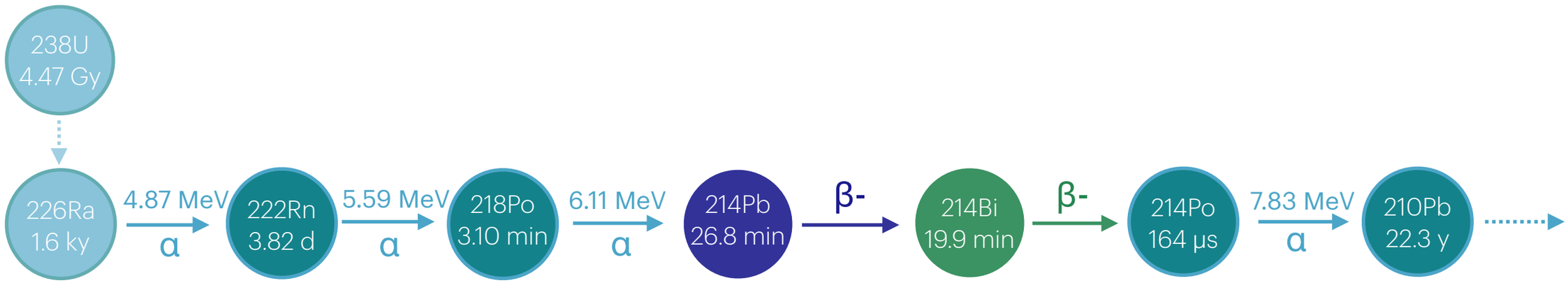


Electronic recoil background

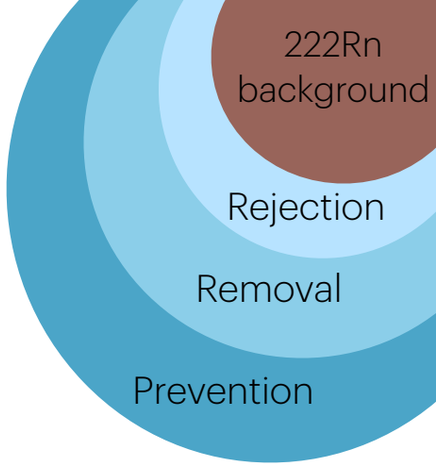
The XLZD Design Book (2025)



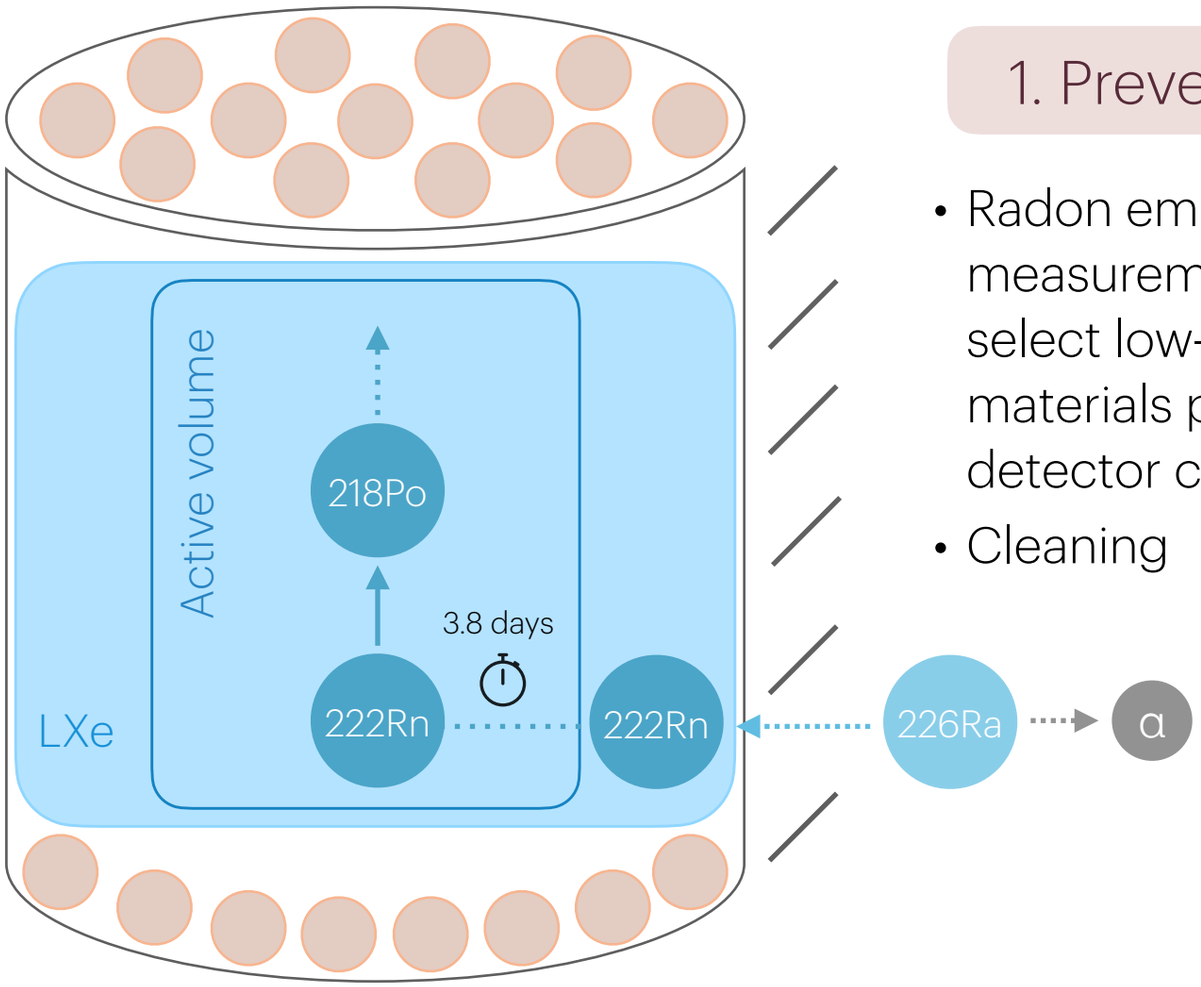
γ line at the $Q_{\beta\beta} = 2458\ keV$



Where does radon come from?



- ^{222}Rn is part of the primordial ^{238}U decay chain and can therefore be found in any material
- Due to its relatively long half life it can reach the active volume of the detector where it decays



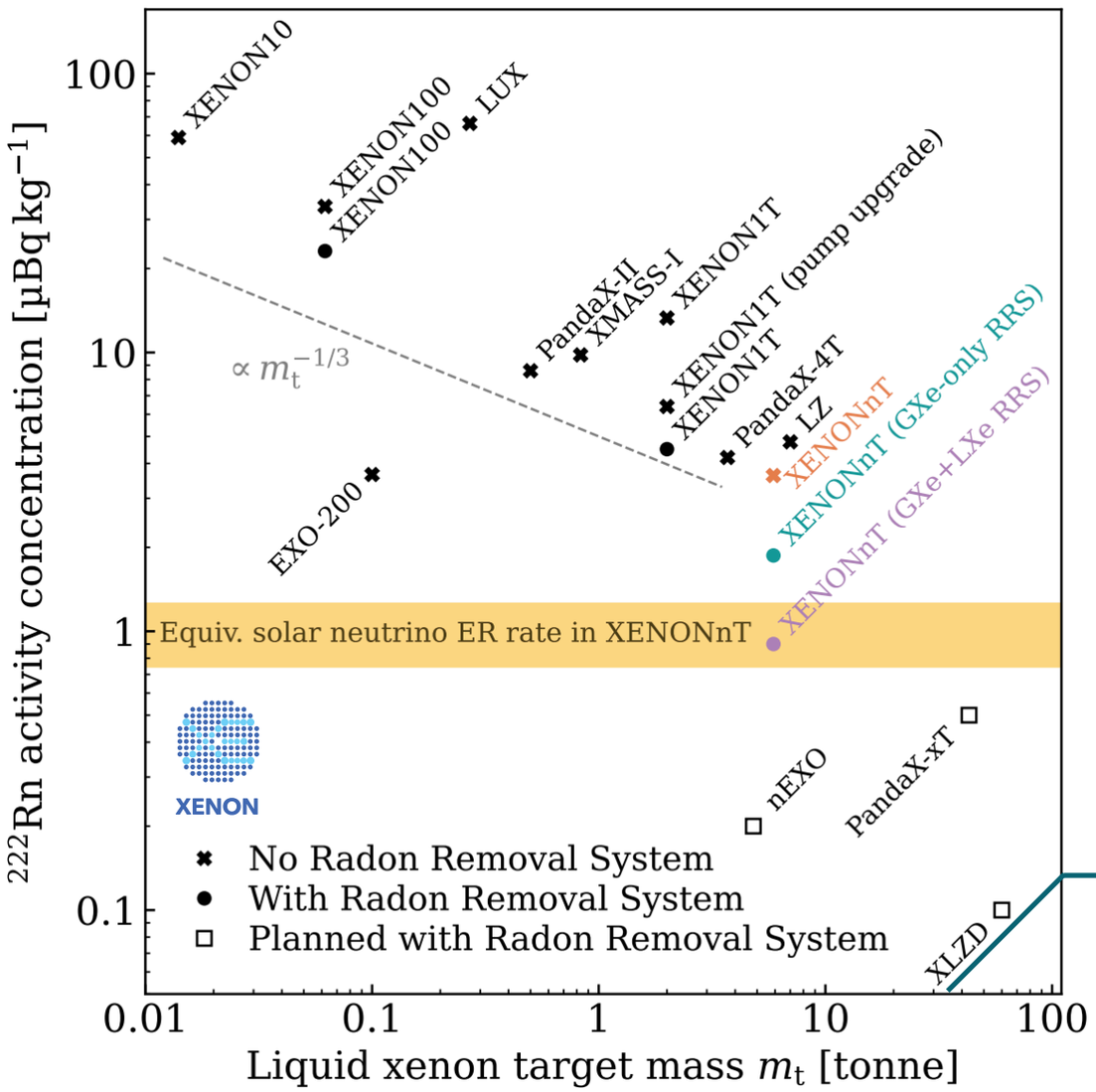
Radon mitigation strategy

1. Prevention	2. Removal	3. Rejection
• Radon emanation measurements to select low-radioactivity materials prior to detector construction • Cleaning	• Cryogenic distillation • Absorption	• Convection and diffusion models to reconstruct the spatial distribution of radon progeny

Reaching extremely low radon concentration

Radon Removal in XENONnT down to the Solar Neutrino Level (2025)

Phys. Rev. X 15, 031079



- ^{222}Rn activity concentration generally decreases with decreasing surface-to-volume ratio
- XENONnT experiment has reached unprecedented low concentrations of ^{222}Rn achieving a level of < 1 μBq/Kg
- XLZD goal is to reach 0.1 μBq/Kg so that ER solar neutrinos become dominant

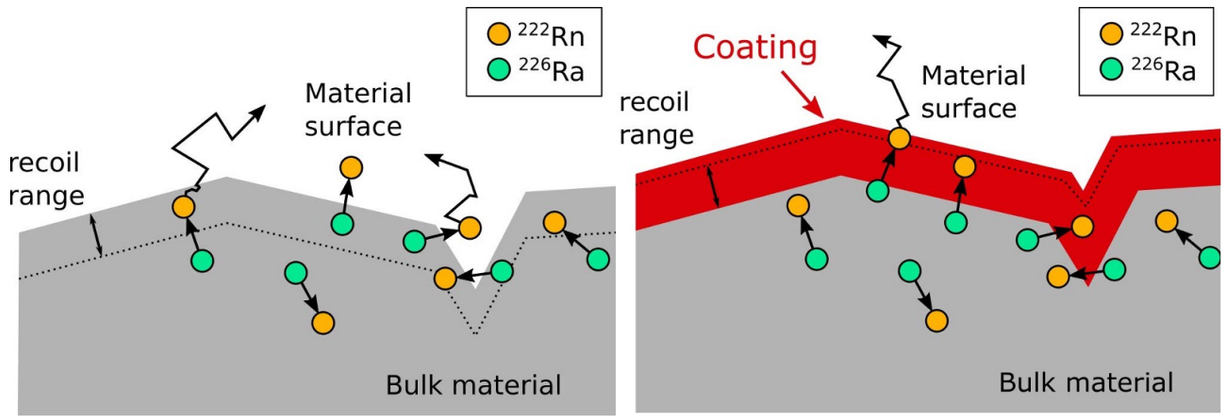
Challenge

Need for new radon mitigation techniques!

A new mitigation technique: surface coating

Idea

Application of a thin coating layer to reduce radon emanation from the surface



F. Jörg, G. Eurin, H. Simgen

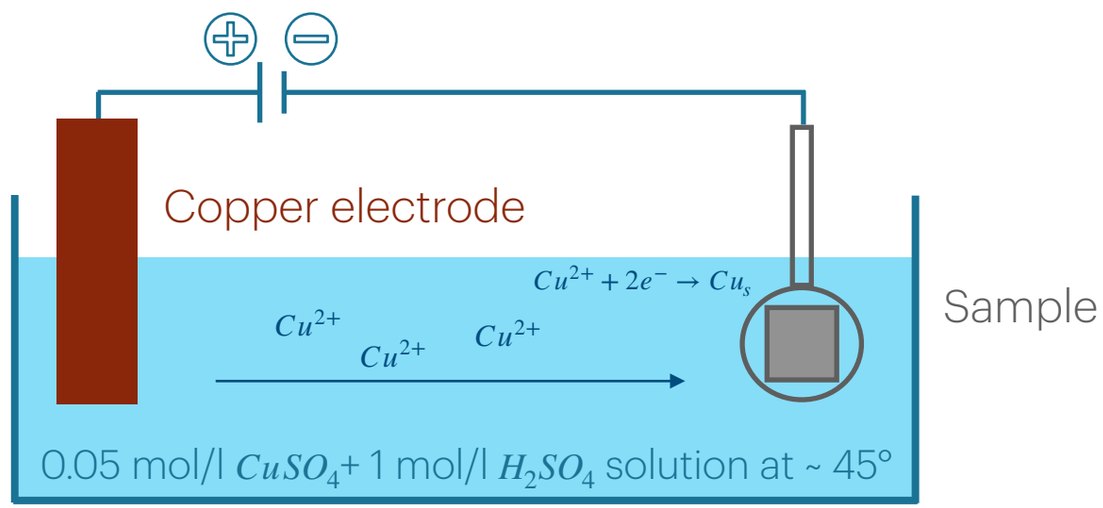
arXiv:2606.26190

Requirements

- ✓ THICK enough to contain radon recoil O(10 nm) for 86.2 keV recoil energy
- ✓ THIGHT enough to prevent radon diffusion
- ✓ HIGH RADIOPURITY

Electrochemical plating

- $CuSO_4$ dissociate in the electrolyte: $Cu^{2+} + SO_4^{2-}$
- By application of voltage copper ions migrate towards the sample and deposit on its surface
- Copper electrode continuously replenishes Cu^{2+} in the solution

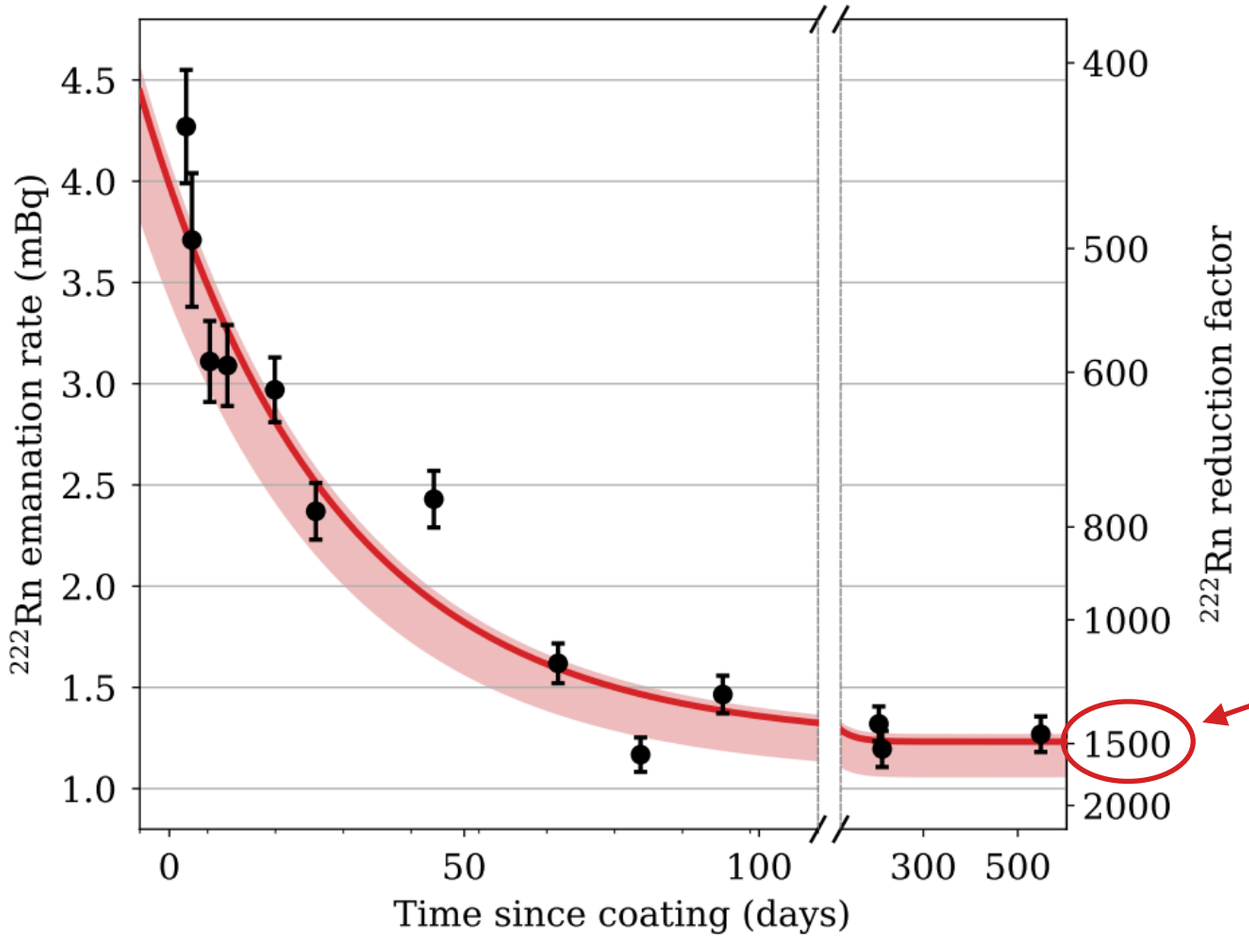


stirring and heating

See talk from Sophie Armbruster, MPIK

Achieved a thousandfold reduction factor!

$$\text{Reduction factor} = \frac{^{222}Rn \text{ Activity before coating}}{^{222}Rn \text{ Activity after coating}}$$



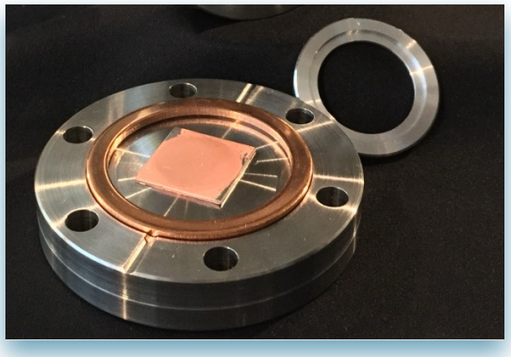
- ^{226}Ra implanted stainless steel sample with **initial radon emanation of 2 Bq**
- Decrease of emanation likely due to room temperature self-annealing of the copper layer

Reduction factor of 1500!

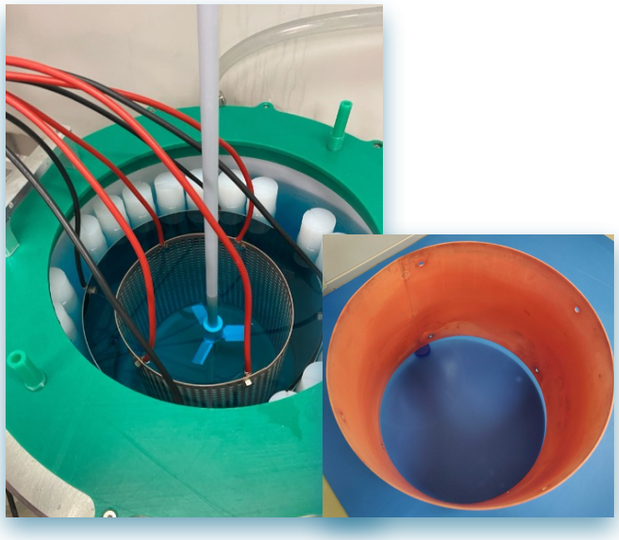
Check new paper from F. Jörg, G. Eurin, H. Simgen

Towards coating at larger scales...

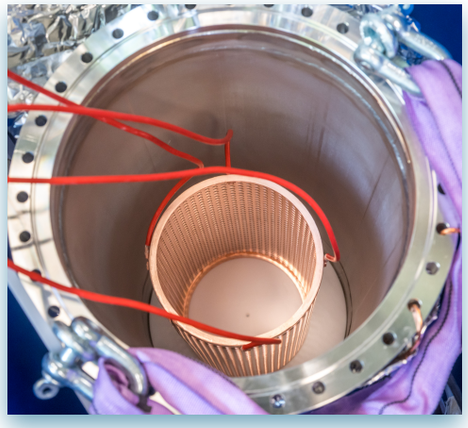
Sophie Armbruster, MPIK
Florian Jörg, UZH
Teresa Marrodan Undagoitia, MPIK
Margherita Noia, UZH
Giovanni Volta, MPIK
Hardy Simgen, MPIK



Successfully coated 2 cm^2 sample



Successfully coated 0.14 m^2 cylinder shell



Successfully coated vessel like geometry of 0.56 m^2

Xenoscope facility at the University of Zurich

Today....

Towards coating at larger scales...

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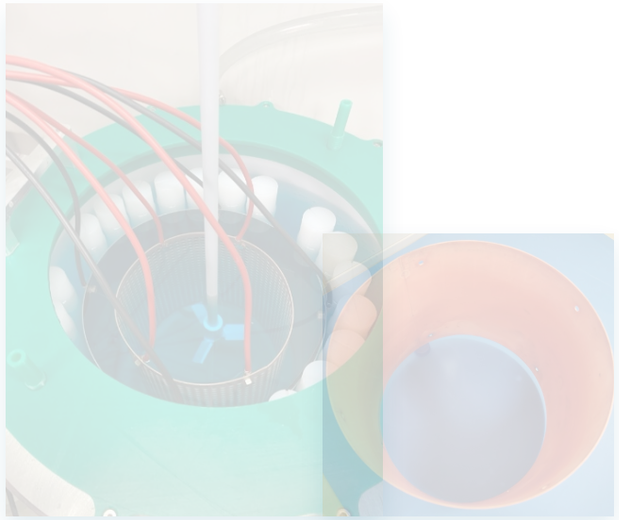


Successfully coated 0.14 m^2 cylinder shell

Successfully coated vessel like geometry of 0.56 m^2

Xenoscope facility at the University of Zurich

Today....

Xenoscope: a 2.6 m tall dual phase TPC

Goals

- Demonstrate electron drift over 2.6 m
- Measure electron cloud transversal and longitudinal diffusion
- Study optical properties of Xe
- **Test radon mitigating surface coatings**

THIS TALK

L. Baudis et al 2021 JINST 16 P08052

Spring 2022 — Purity monitor

L. Baudis et al., Eur. Phys. J. C 83, 717 (2023)

July-August 2024 — Commissioning run

M. Adrover et al 2025 JINST 20 P04013

April - June 2025 — First science run

Completed

March - May 2026 — Second science run

Analysis ongoing!

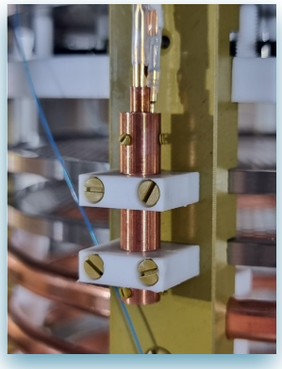
The Xenoscope team at UZH:

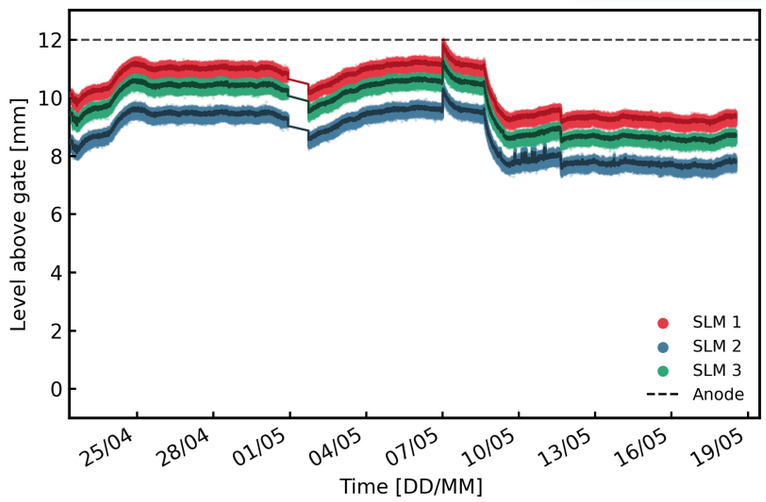
Nicolas Angelides, Marta Babicz, Erin Barillier, Laura Baudis, Harvey Birch, Chiara Capelli, Paloma Cimental, Jose Cuenca García, Sebastian George, Rebecca Hampp, Miguel Hernandez, Luisa Hötzsch, Florian Jörg, Knut Morå, Margherita Noia, Sana Ouahada, Björn Penning, Francesco Piastra

Xenoscope TPC

Liquid level monitoring

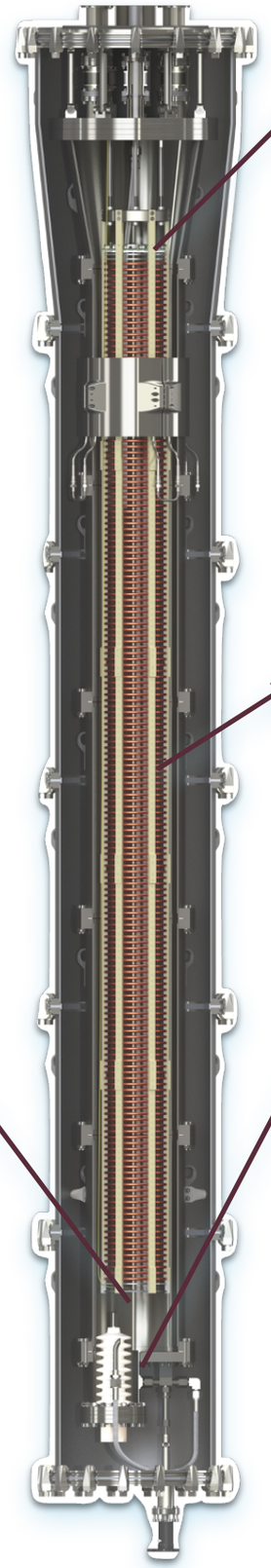
- Monitoring done using short and long level meters (resp. SLM and LLM)





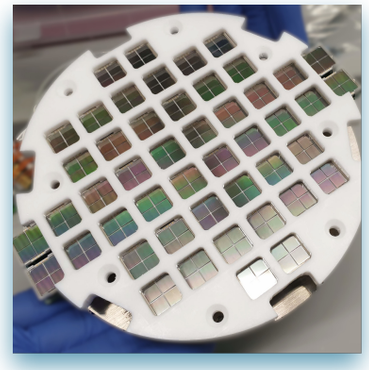
Photocathode

- Gold coated photocathode (50 nm thickness) on a quartz substrate (2 mm thick)
- Xe flash lamp pulse transmitted through optical fibre (10^6 electrons/pulse at 1 Hz)



SiPM array

- SiPMs: Hamamatsu S13371
- 12 tiles with 12 mm x 12 mm each
- Readout in parallel: 12 channels

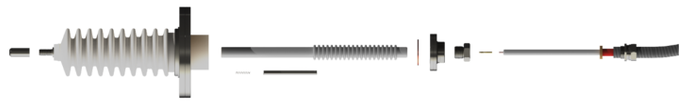


Field cage

- Field cage with 173 OFHC copper rings

High voltage feedthrough

- Custom made air-to-vacuum feedthrough and in house designed connection to the cathode



Demonstrated 2.35 m drift!

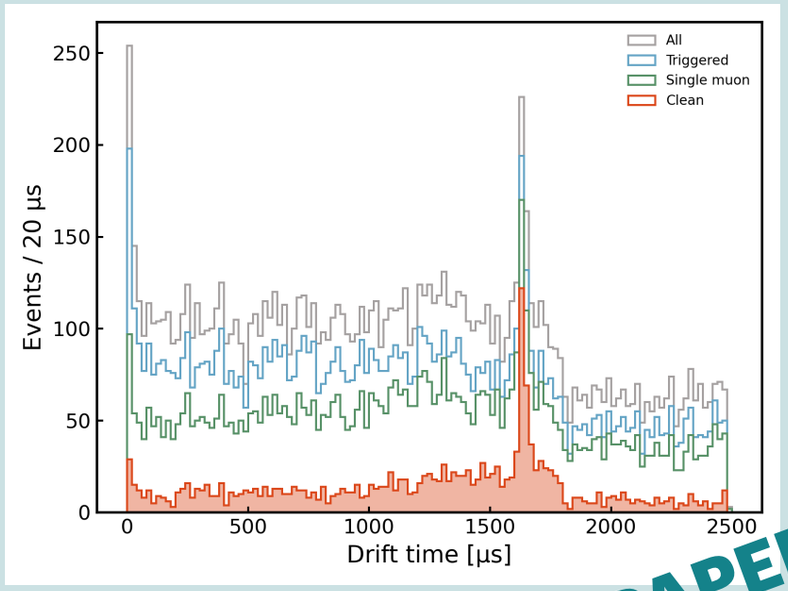
Plots by Rebecca and Sana

Science Run 2

- Drift field: 95 V/cm
- Extraction field : 8 kV/cm

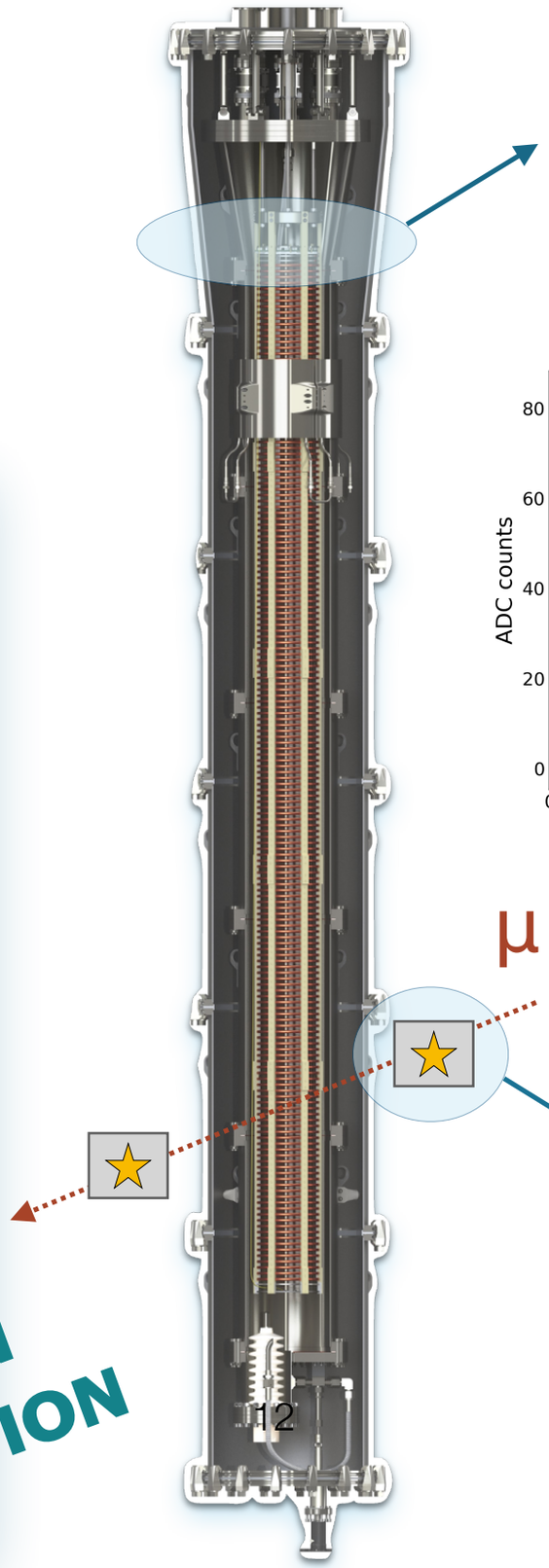
Preliminary results

- First measurement of electron drift in LXe over more than 2 m!

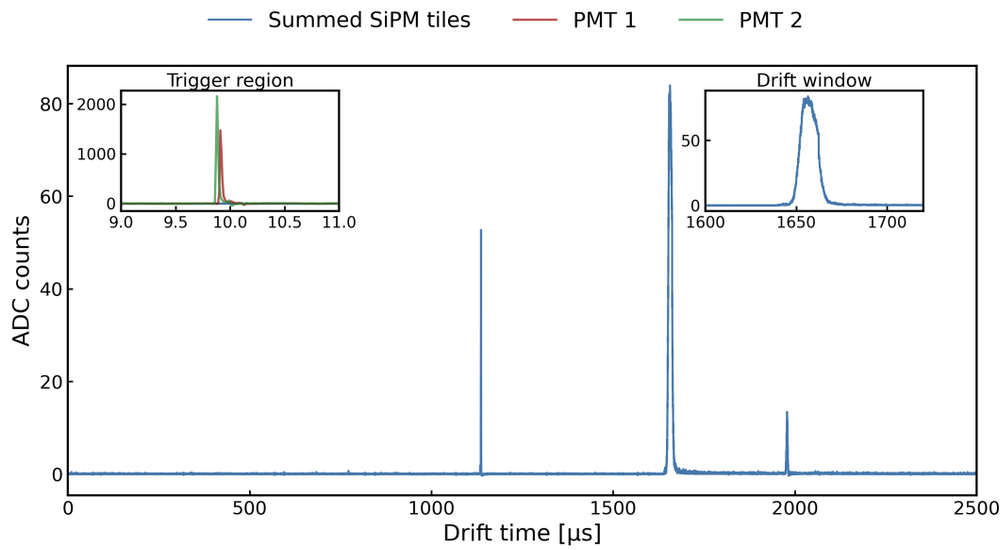


Drift time distribution

PAPER IN PREPARATION



- Recording signals on the **SiPMs array** within 2.6 ms in case of coincidence



Example event

- Detecting signals from **interactions with cosmic muons**
- 2 **plastic scintillators** coupled to 3'' PMT used as trigger in case of coincidence

Demonstrated 2.35 m drift!

Plots by Rebecca and Sana

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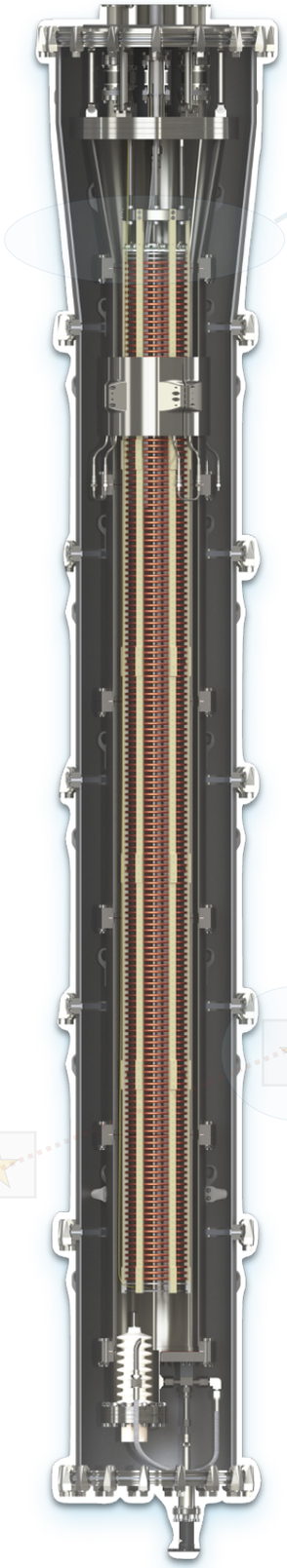

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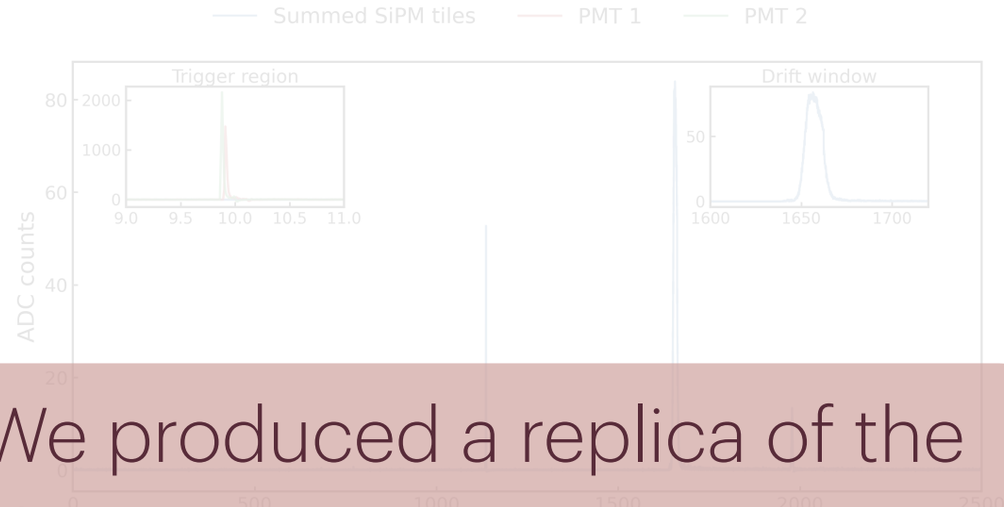


Example event

We produced a replica of the Xenoscope cryostat to coat it!

- Detecting signals from **interactions with cosmic muons**
- 2 **plastic scintillators** coupled to 3'' PMT used as trigger in case of coincidence

Shipping Xenoscope cryostat to Heidelberg

University of Zurich, physics department

- Replica of Xenoscope cryostat disassembled
- 5 stainless steel segments 550 mm x 250 mm

306 km

Max Planck Institute for Nuclear Physics , Heidelberg

Assembled the cryostat and performed a **radon emanation measurement** before the coating

Radon emanation result

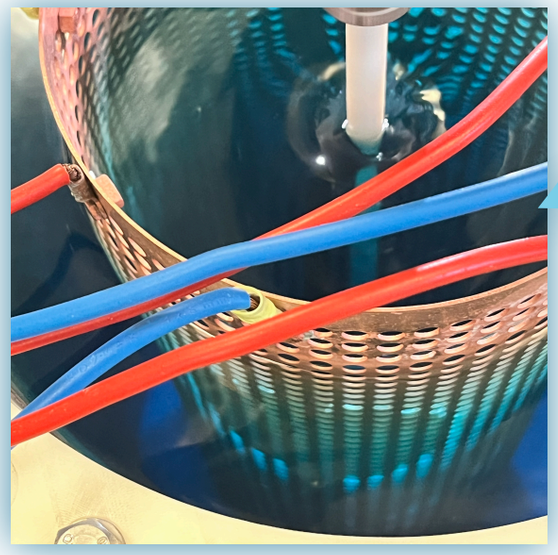
- Measured an emanation rate of $441 \pm 28\ \mu Bq$ for $2.16\ m^2$ total surface

Upscaling the coating setup

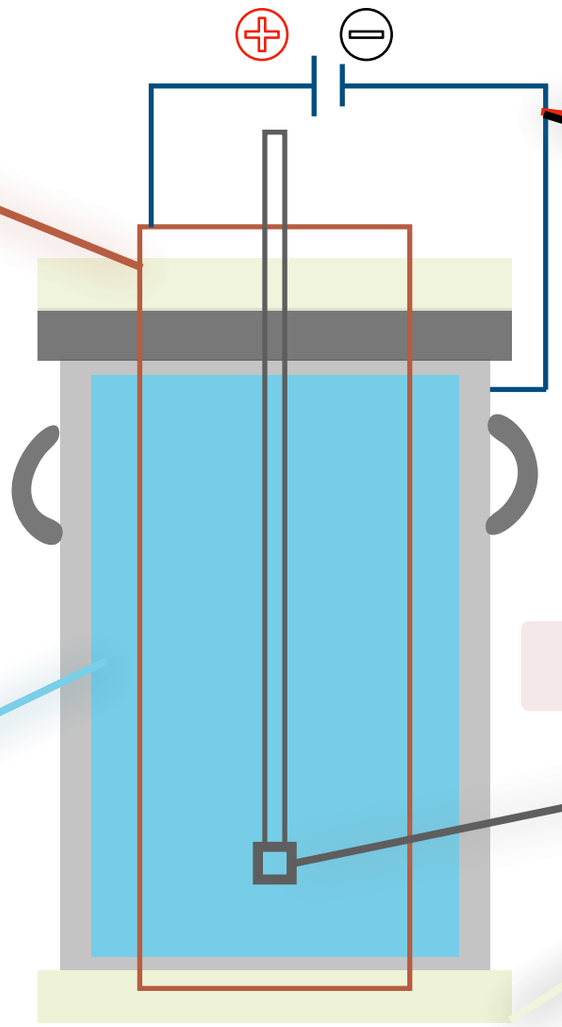
- Upscaled the setup to coat a 550 mm height x 250 mm diameter vessel in one go

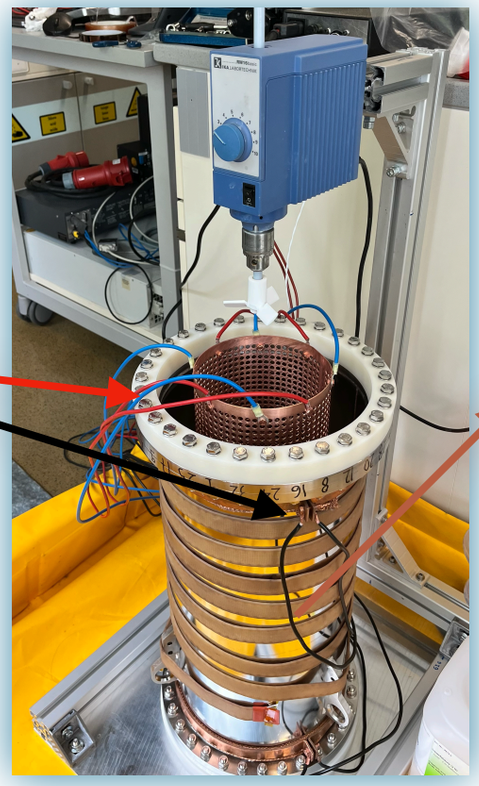
600 mm height copper electrode

Electrolyte
- Pre heated at 50° in the oven



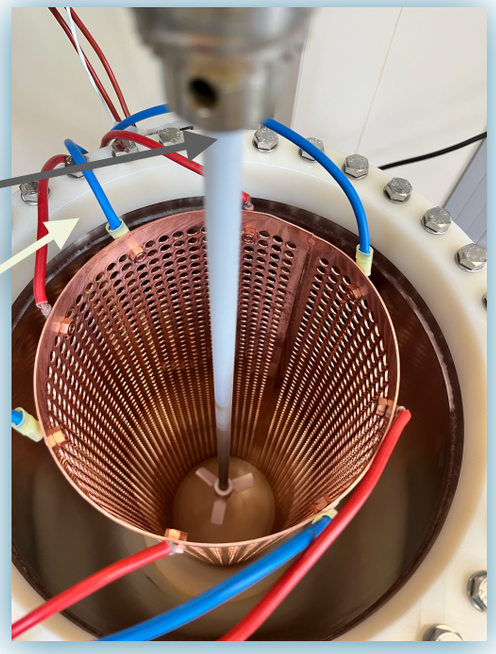
Positive and **negative** connections
- 216 A current for first 1 µm layer
- 43 A current for following 4 µm





Heating tapes 60°

Stirrer



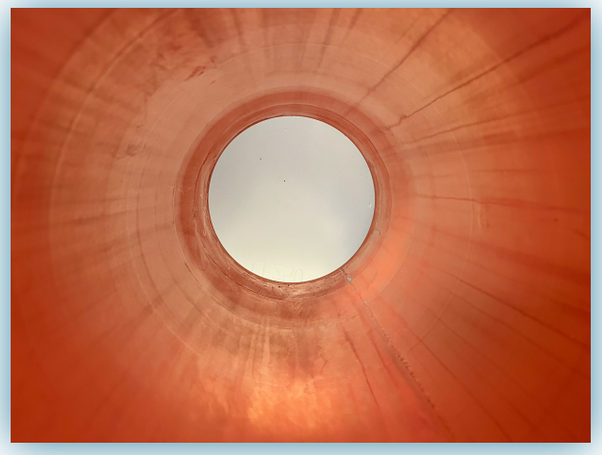
HDPE extension and bottom CF 250 flanges

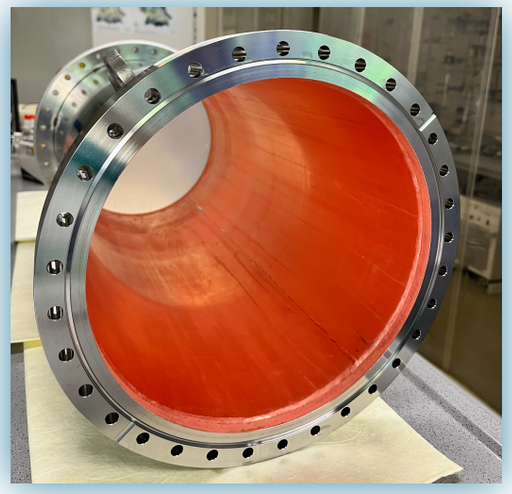
We successfully coated the 5 Xenoscope segments

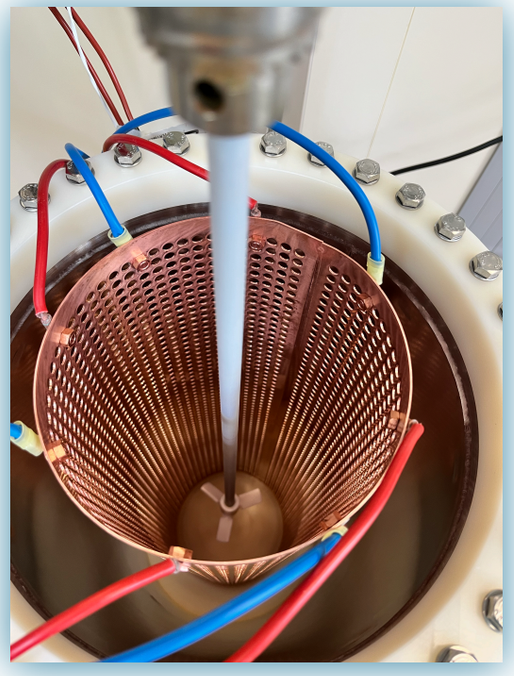
Coated $5 \times 4320\ cm^2$ vessels = $21600\ cm^2$ surface in total

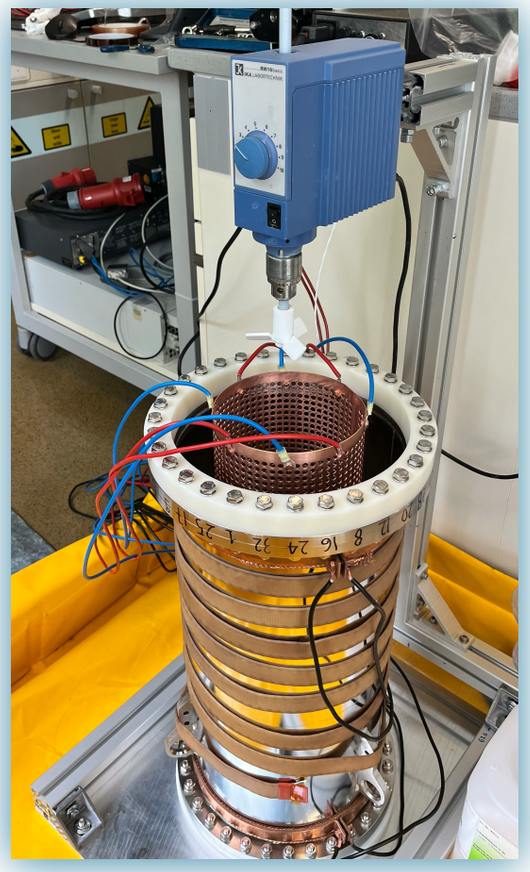
LAST WEEK

MPIK laboratory









Summary and next steps

Radon **emanation measurements before the coating** ✓

Coating of the 5 segments ✓

DONE !

Radon **emanation measurements after the coating**

ON GOING

Test in LXe in the next Xenoscope run to check purity requirements

FIB/SEM electron microscopy inspection after run for stability checks

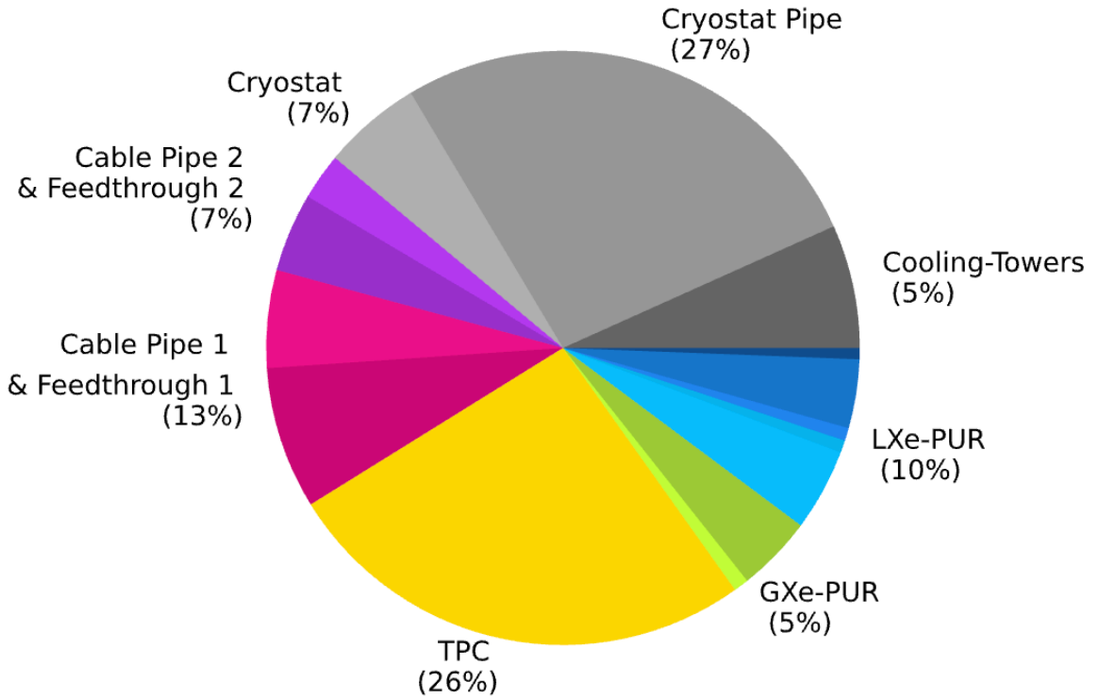
TO DO...

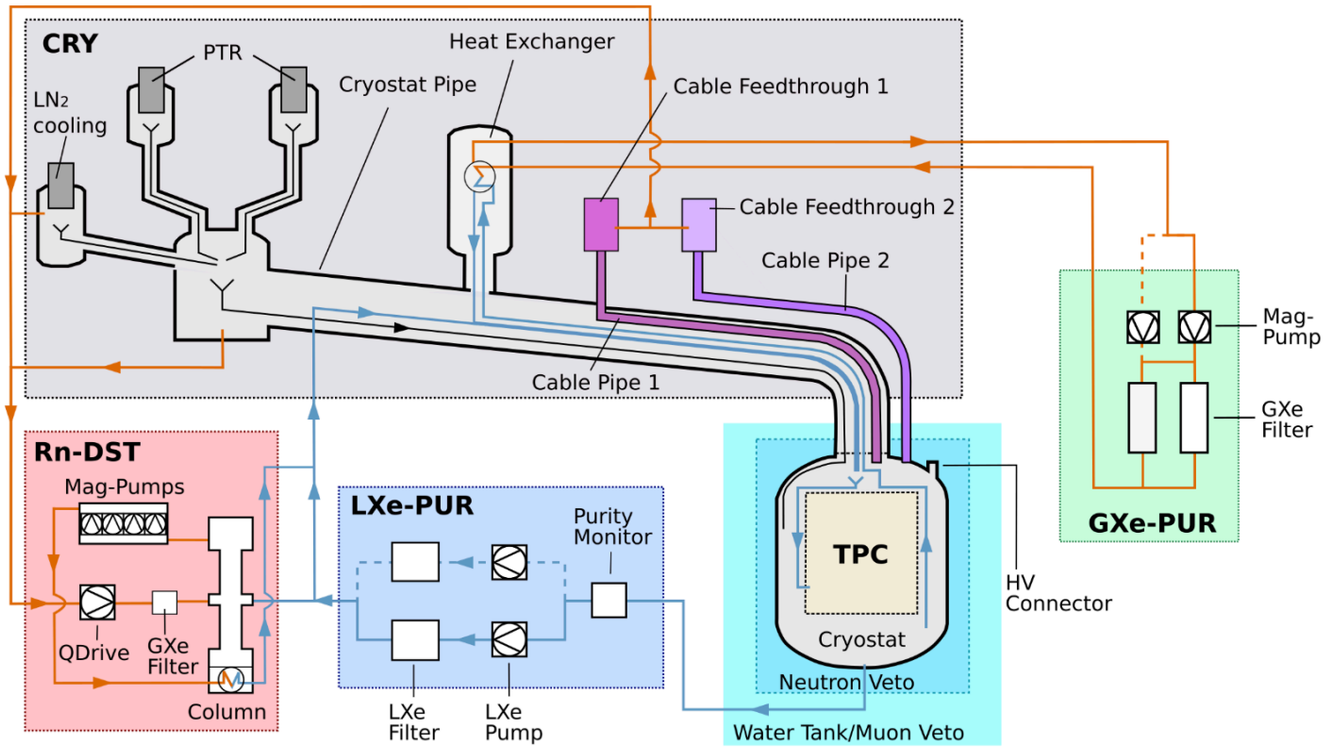
THANK YOU FOR YOUR ATTENTION!

Backup slides

Radon emanation in XENONnT

The different subsystem contributions to the overall ^{222}Rn emanation rate in XENONnT



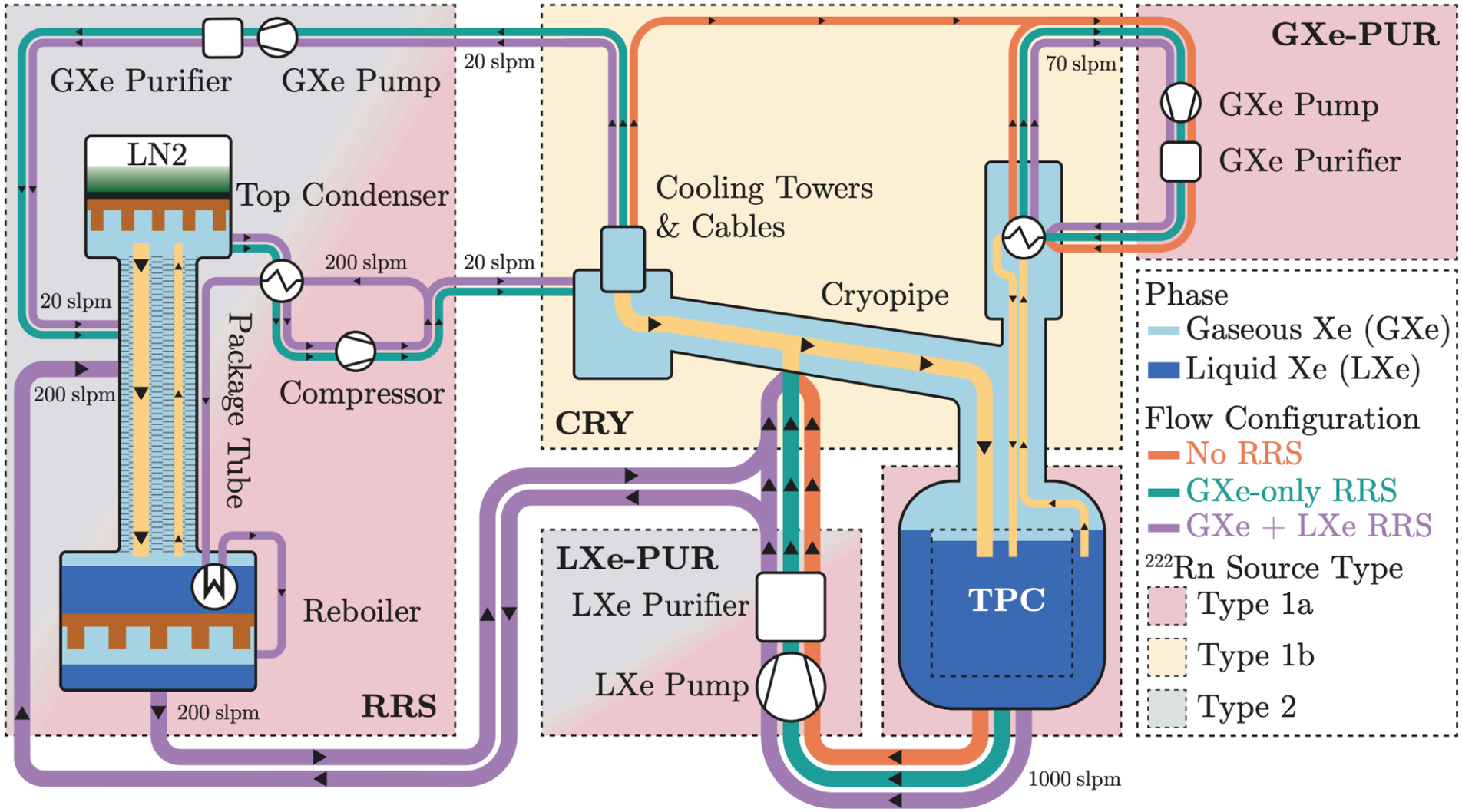


Final TPC emanation rate = 9.3 mBq.

- Emanation from 494 PMTs ~2.2 mBq
- Emanation from cables running inside the inner cryostat add additional ~ 3mBq

Material radiopurity control in the XENONnT experiment

XENONnT Radon distillation column

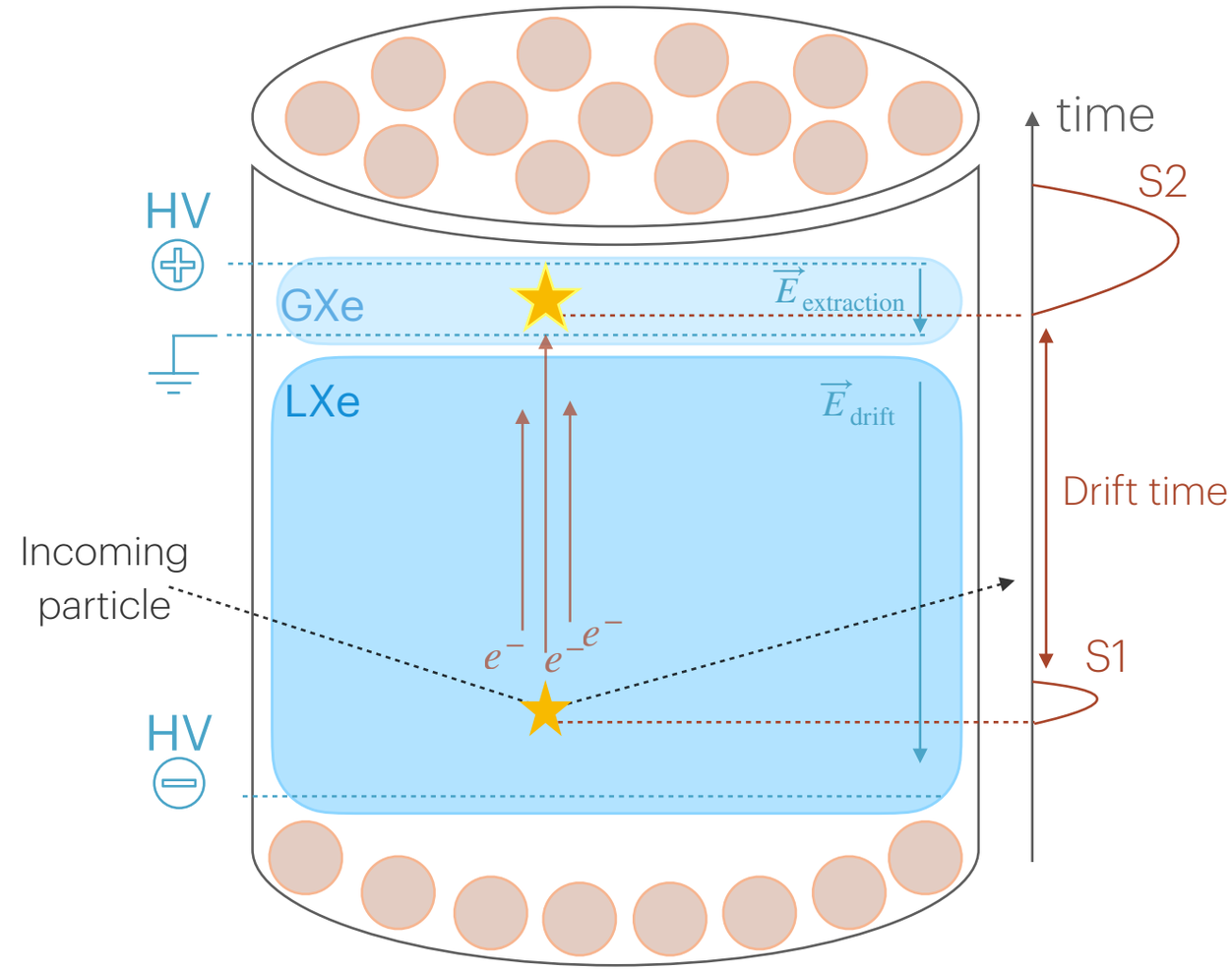


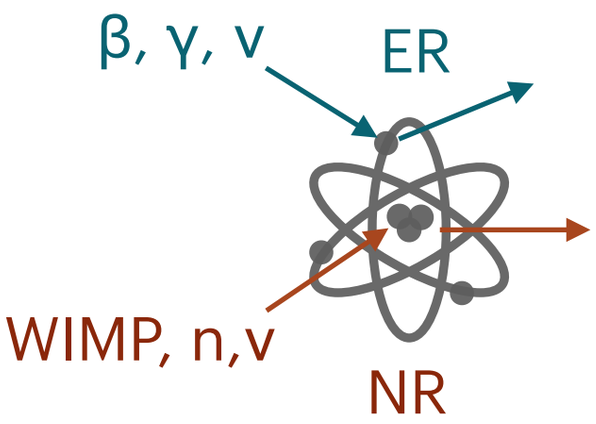
Radon Removal in XENONnT down to the Solar Neutrino Level (2025)

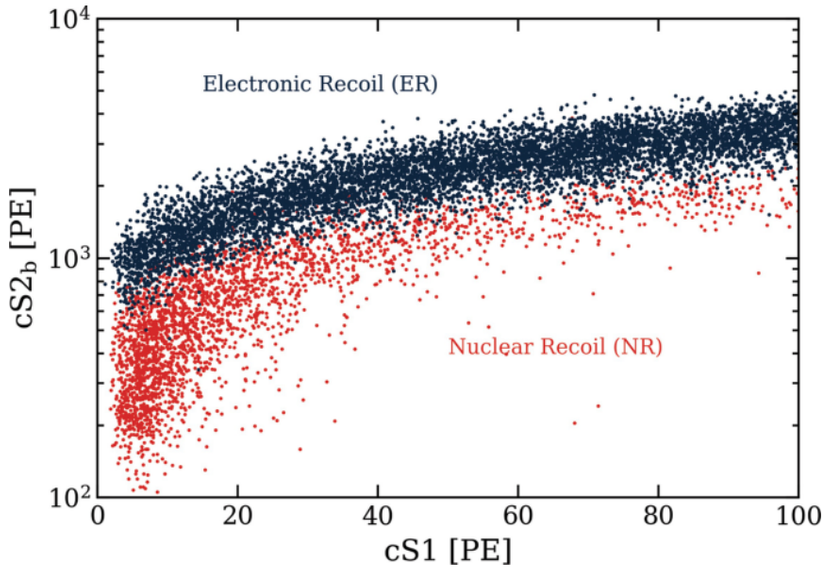
LXe dual phase TPCs

Working principle

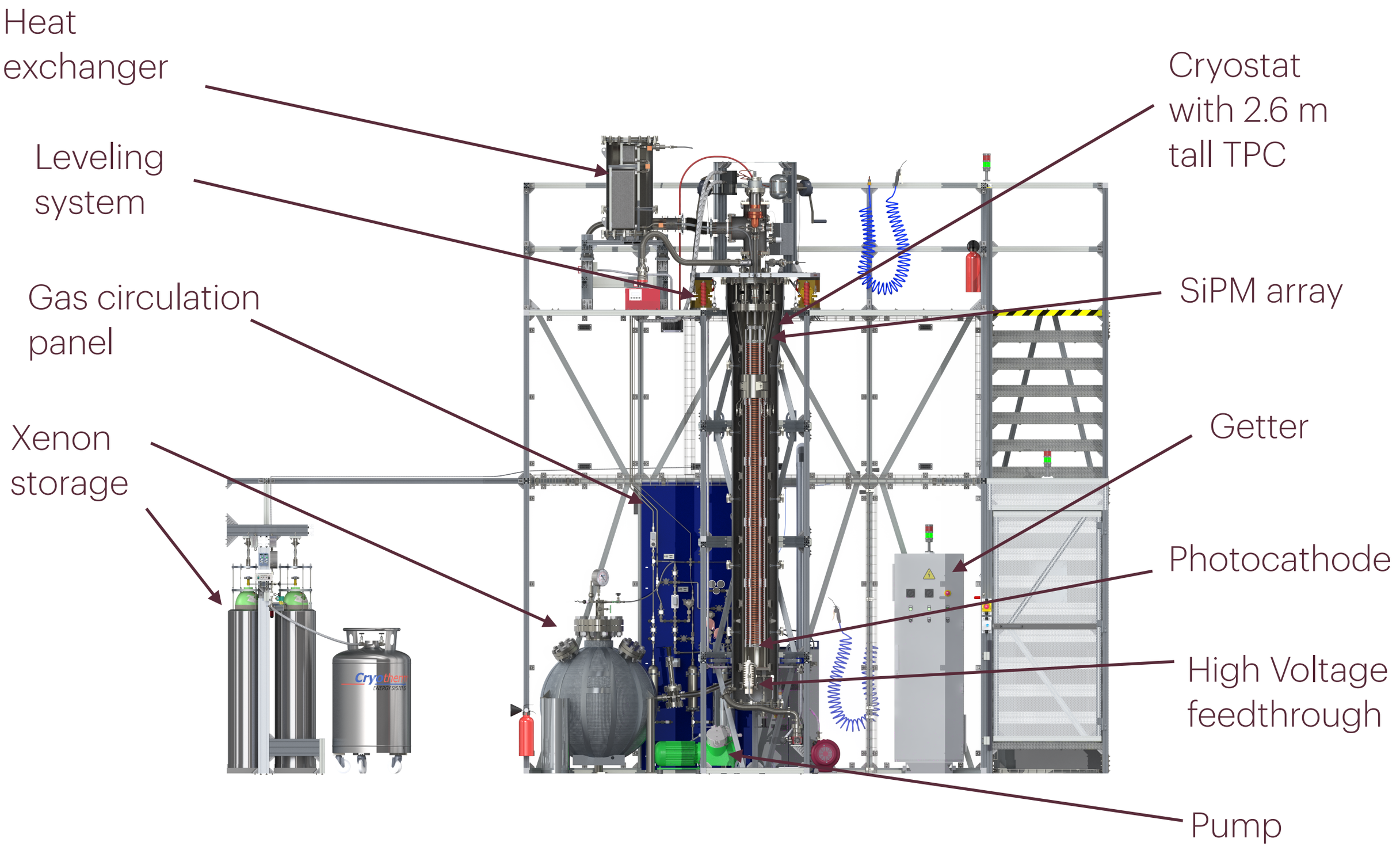
- Dual-phase time projection chamber (TPC) with **liquid xenon** (LXe) and **gaseous xenon** (GXe)
- S1: prompt scintillation light
- S2 : Ionisation electrons
- S2 & drift time : 3D position reconstruction
- S1/S2: **Electronic recoil** (ER) and **Nuclear recoil** (NR) discrimination







The Xenoscope facility

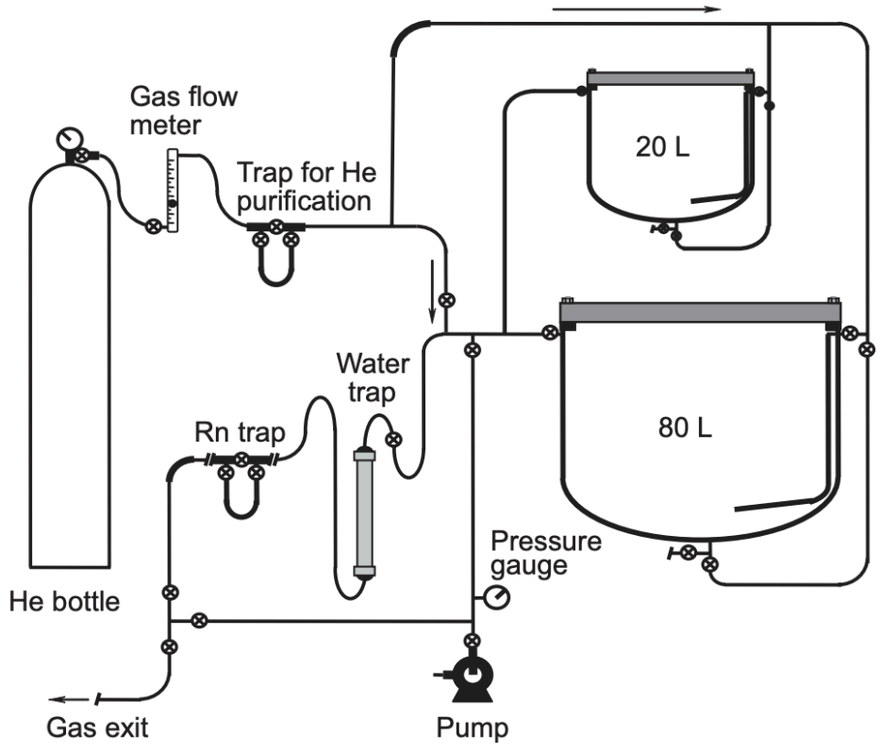


Miniaturized proportional counters

Used for radon emanation measurements

- Hand made by ultra pure quartz
- Active volume about $1 cm^3$
- Using gas mixture of 90% Ar, 10% CH4
- Possible to perform 222Rn emanation measurements for extremely low activities of $40\ \mu Bq$ with 20% uncertainty

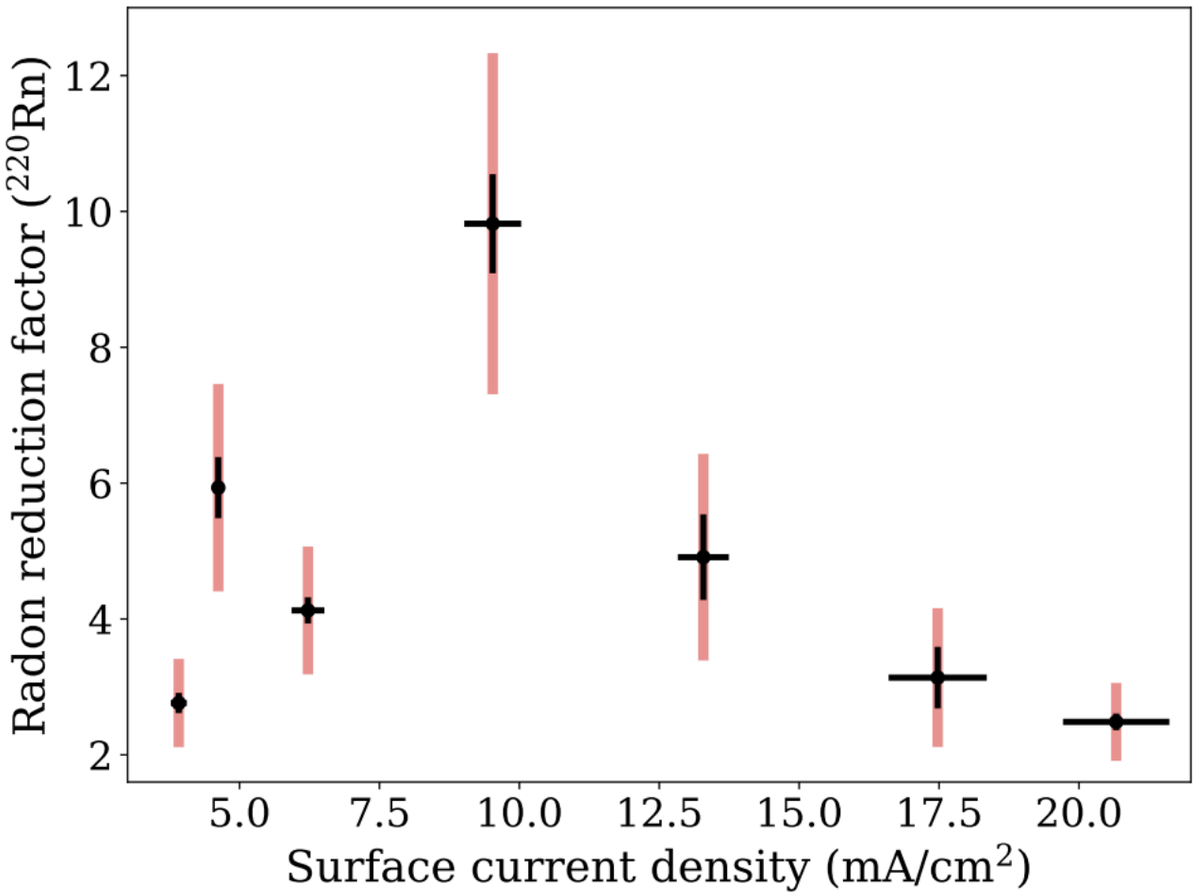
Picture from MPIK



G. Zuzel, H. Simgen, High sensitivity radon emanation measurements

Surface current density study

- Study of reduction factor of ^{220}Rn emanation as a function of the current density
- A maximum reduction is obtained for a current density of $10\ mA/cm^2$



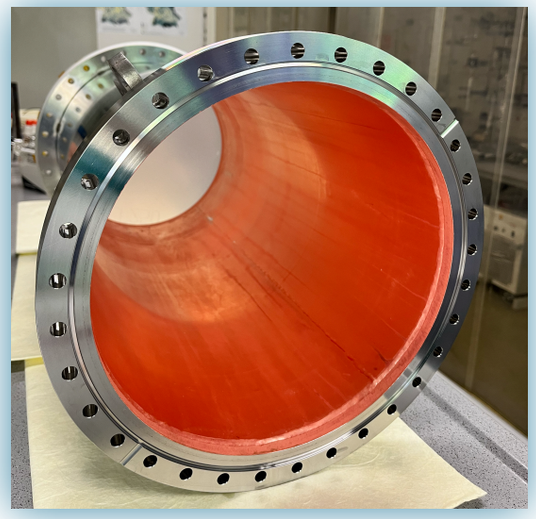
F. Jörg, G. Eurin, H. Simgen
arXiv:2606.26190

Used recipe: first layer at a larger surface current density ($50\ mA/cm^2$), second step with standard recipe

Tests after application of coating layer

Cleaning

- Rinse with water 2-3 times
- Passivated with citric acid to prevent oxidation



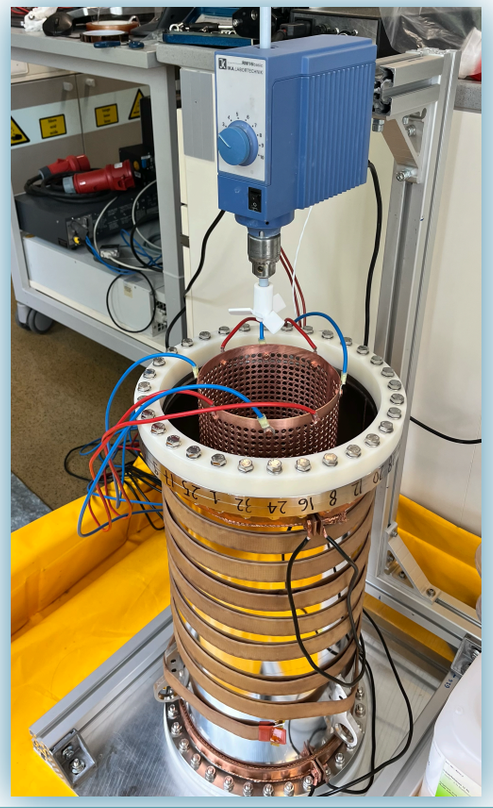
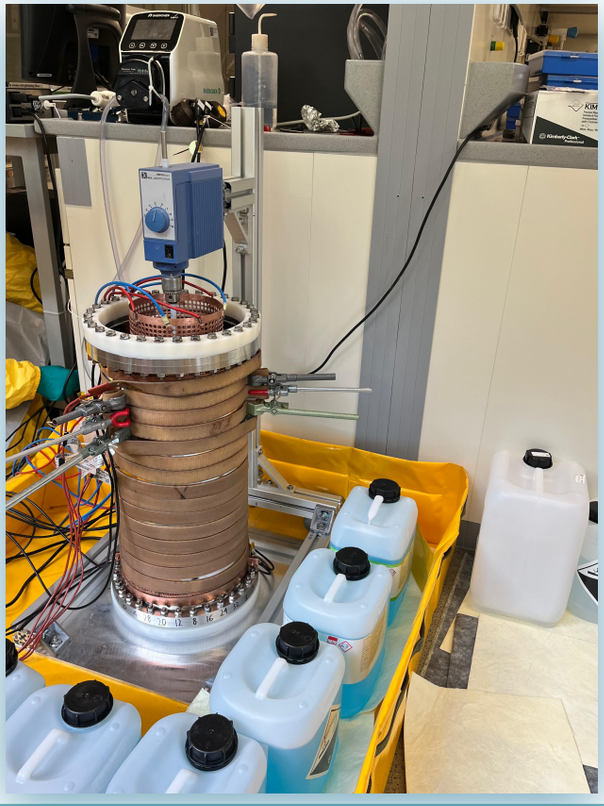
Tests

- Check surface roughness by wiping
- Test layer adhesion by scratching with a PVC hose

Improvements

- Improve heating using 2 heating tapes
- Increase temperature of electrolyte
- Adjust stirrer position

First heating configuration



Improved heating configuration