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The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

Neue Entwicklungen in der Radonmetrologie: 19ENV01 traceRadon

82. Sitzung des GK 851 am 12. + 13.10.2021

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***19ENV01 traceRadon** denotes the EMPIR project reference.*

Coordinator: Annette Röttger

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EUROPEAN METROLOGY PROGRAMME FOR INNOVATION AND RESEARCH (EMPIR)

EMPIR is the main programme for European research on metrology. It coordinates research projects to address grand challenges, while supporting and developing the SI system of measurement units.

EMPIR follows on from the successful European Metrology Research Programme (EMRP), which issued its final call for projects in 2013. There is an increased focus within EMPIR on innovation activities to target the needs of industry and accelerate the uptake of research outputs.

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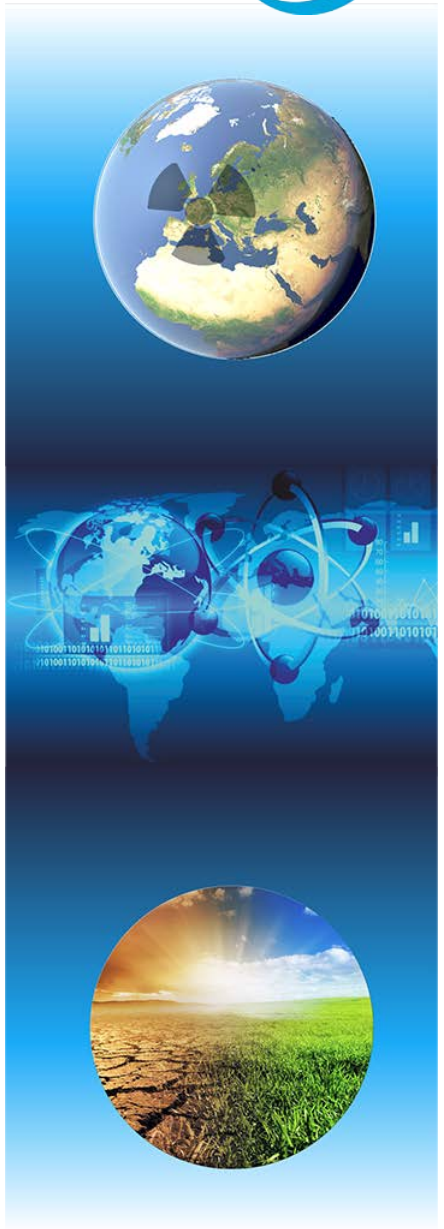

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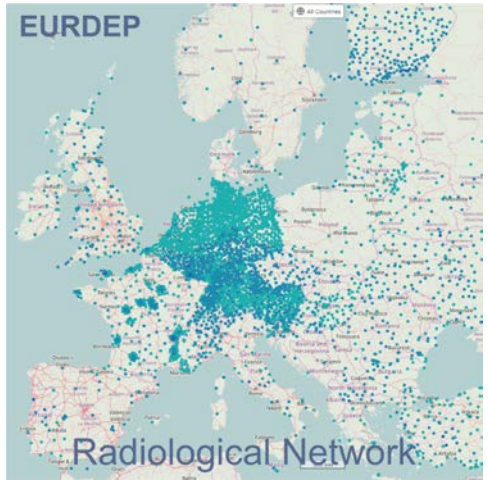

Climate change is one of the greatest challenges of our time.

The temperature rise of the atmosphere of our planet, due to the greenhouse effect, is caused by the increase of GHG emissions.

- ICOS: Monitoring of GHG emissions, the dispersion of GHGs and the resulting GHG concentrations in air, is of utmost importance for appropriate climate change mitigation measures.
- EURDEP: Collection and exchange of radiological monitoring data between participating countries of the radiation in the environment.

Both networks could profit from radon measurements at the outdoor level. But **traceability to the SI system** is not established yet.

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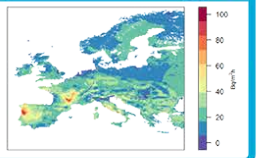
Traceability to the SI system

Radon and radon flux in maps for radiation protection issues — WP4

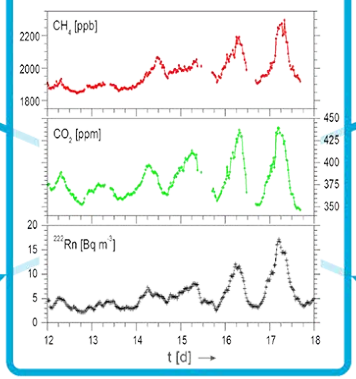
- Identification of RPA
- Quantifying the radon wash-out peak
- Data accessibility and public engagement



Validation of radon flux models and inventories using radon flux and terrestrial data — WP3

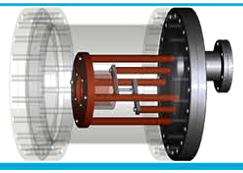
- Radon flux maps in GHG and climate change studies
- Inclusion of data from radiological early warning systems
- Validation of radon flux maps using radon flux measurements and outdoor radon activity concentrations

$$j_{CH_4} = j_{Rn} \cdot \frac{\Delta c_{CH_4}}{\Delta c_{Rn}}$$



Traceable measurements of outdoor radon activity concentrations — WP1

- Traceable low-level radon sources
- Development of a transfer standard
- Calibration and long-term stability



Radon flux measurements — WP2

- Development of a reference radon flux monitor
- Test under field conditions
- Measurement campaigns
- RTM application

Management and coordination — WP6

Seven leading European NMI/DI in the field of climate observation and ionising radiation. ICOS, JRC and other stakeholders directly involved as JRP-partners. Sufficient further external partners with high-level expertise to cover the broad spectrum of two scientific communities. High interest by stakeholder community, expressed by 65 letters of support and a large group of 34 potential collaborators.

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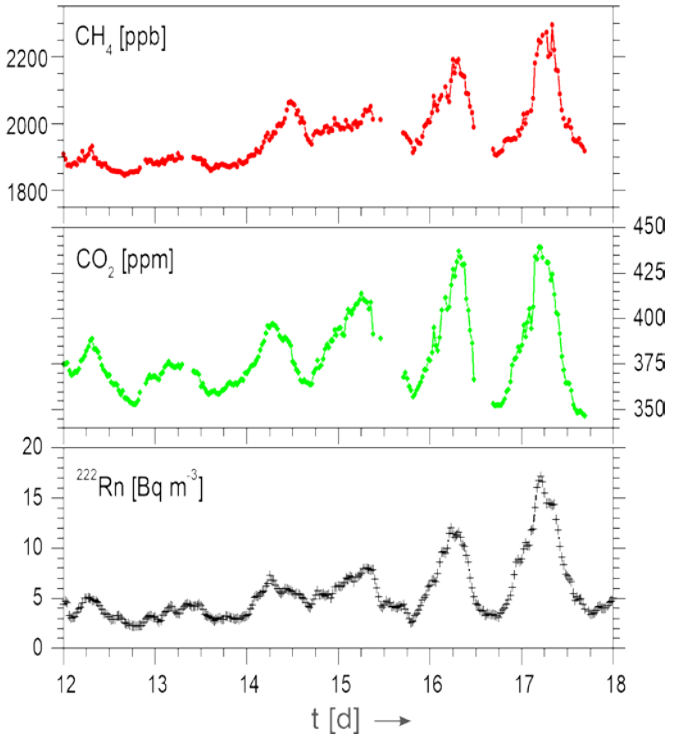
Why is Radon an issue in **climate observation**?

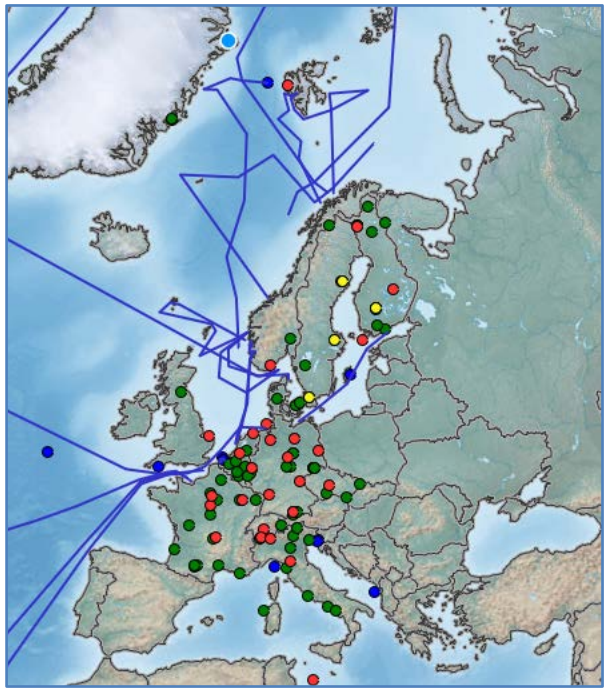
- GHG **flux measurements** are difficult though GHG concentration measurements are established.
- With radon activity concentration and radon flux measurements GHG fluxes can be **traced**!



ICOS Atmospheric Station Specifications:

Radon monitor: "At the present stage, Radon-222 measurements are not mandatory in ICOS. However, Radon-222 is recognized as a very valuable measurement, in particular for trace gas flux estimates."

- Determine source terms of GHG



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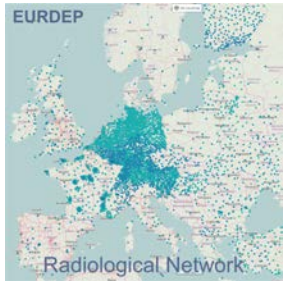
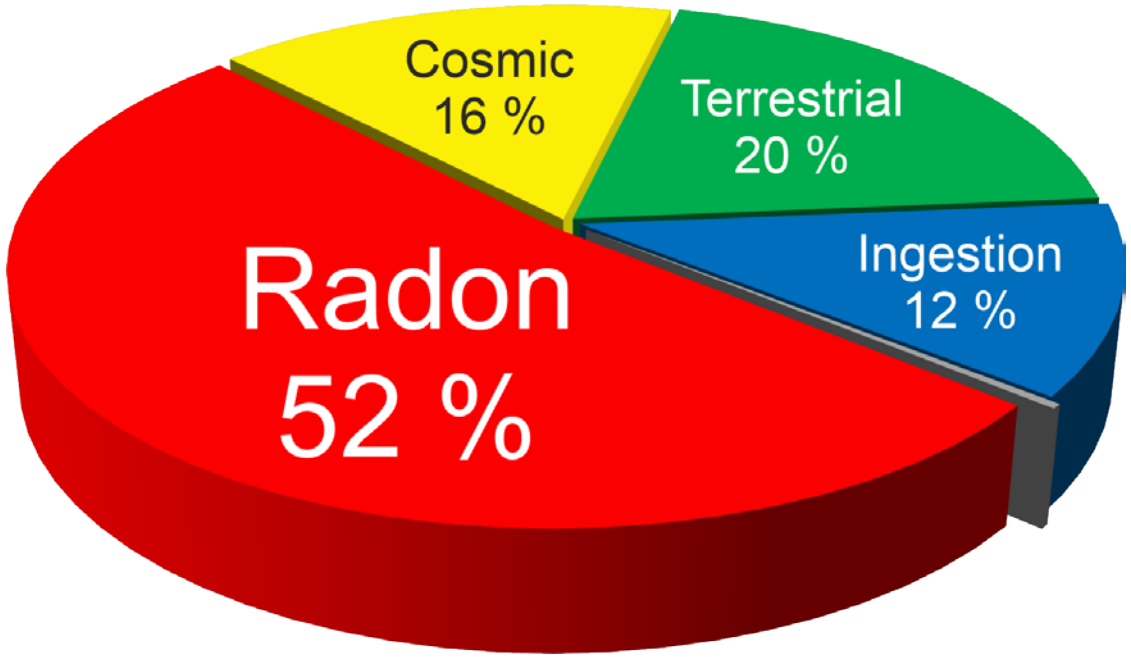


1. To develop traceable methods for the measurement of **outdoor low-level radon activity concentration** in the range of **1 Bq m^{-3} to 100 Bq m^{-3}**, with uncertainties of **10 % for k = 1**, to be used in climate monitoring (…).
2. (…).
3. (…) To support the validation with dosimetric and spectrometric data from the **radiological early warning networks in Europe** (…).
4. To provide **easy to use dynamic radon and radon flux maps** for radiation protection in line with Council Directive 2013/59/EURATOM, including their use to identify **RPA** and **radon wash-out peaks** (…).

UNSCEAR, 2008:
Radon and its progeny contribute about half of the natural radiation dose to the public.

Public exposure to natural radiation:
Total average individual dose:
3 mSv a^{-1}



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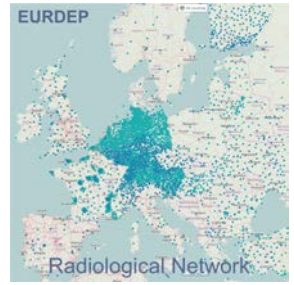
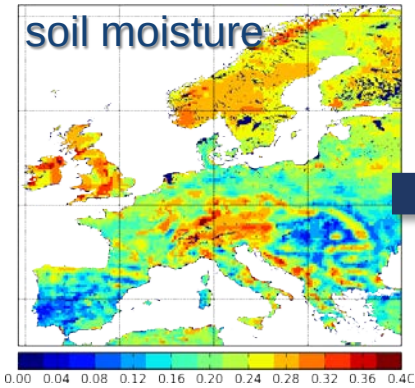
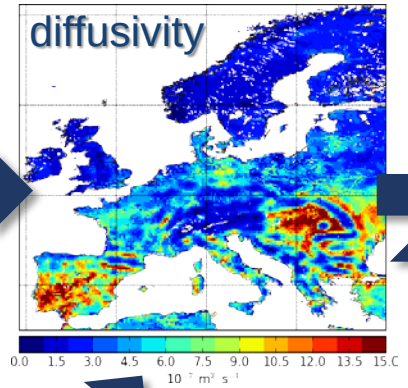
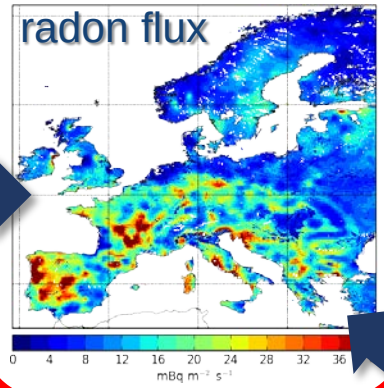
Our task: Joining forces in the field of radon



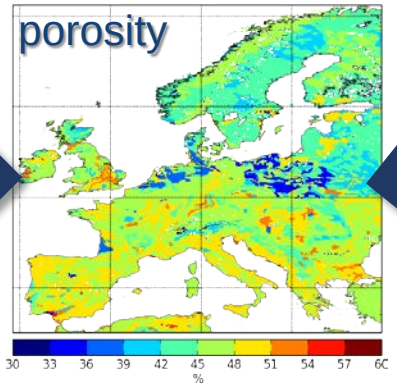


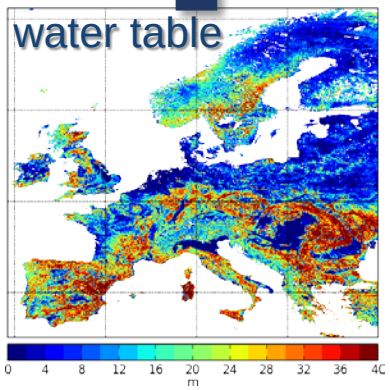


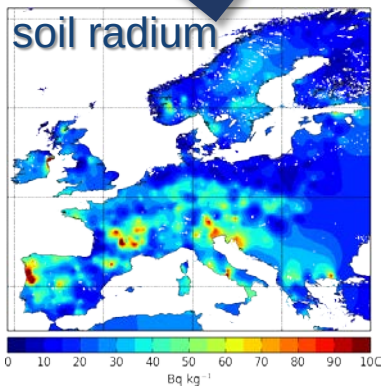


soil texture
% clay
% sand
% slit

bulk density







based on Karstens et.al. 2015

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traceRadon

What new metrology did traceRadon provide so far?

1. New sources

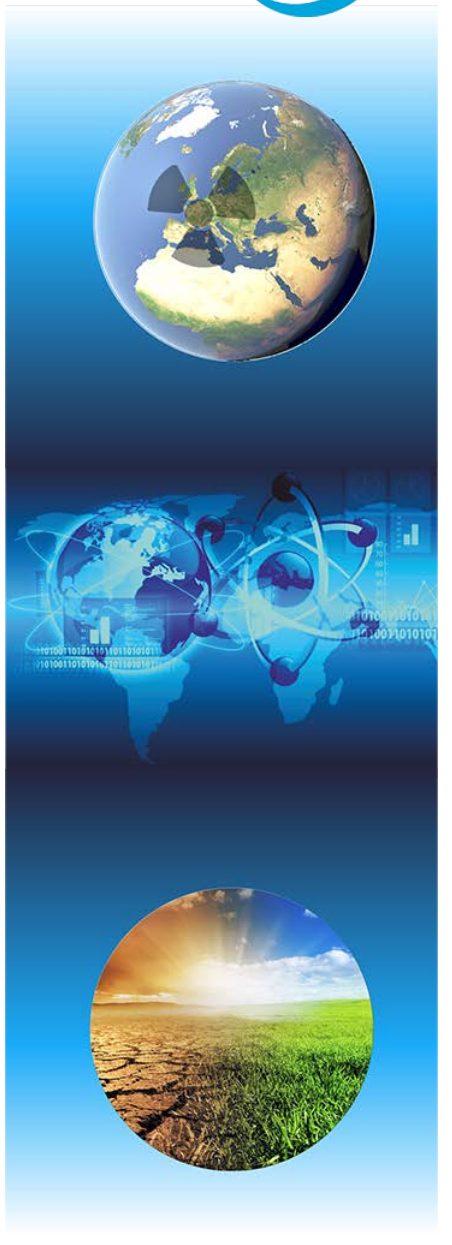
2. New calibrations

traceRadon

Old design
Polyester-Foil
Drop-cast Ra-226
wrapped in PE-Foil

Electrodeposited Sources
Deposition at
30 V < U < 200 V

Implanted
Implantation of Ra-226 into W / Al after mass separation



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Characterisation of the new sources

$$^{226}_{88}Ra \rightarrow ^{4}_{2}\alpha\,(4.87\ MeV) + {}^{222}_{86}Rn\,(86\ keV)$$

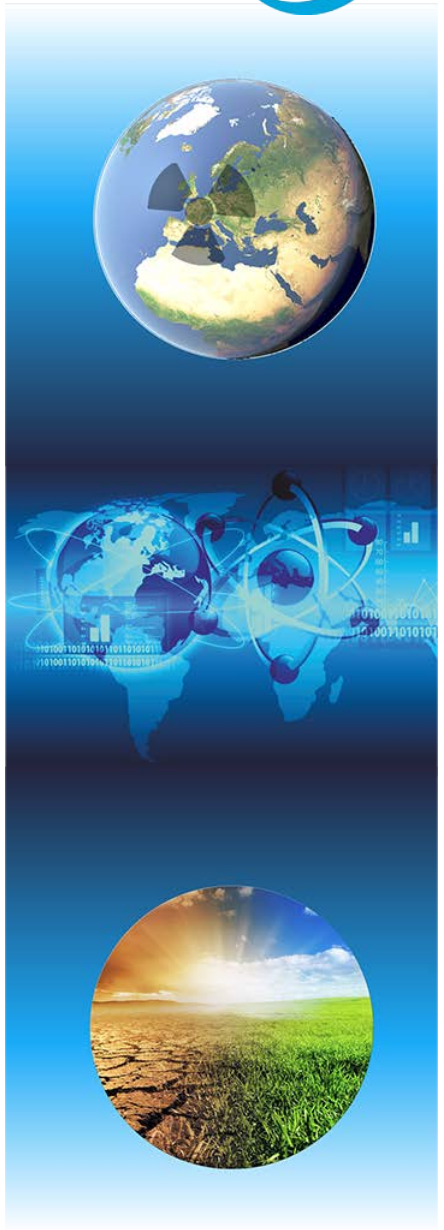
Ra-226 Activity:

- DSA α-Spectrometry
- Autoradiography

→ Primary Rn-222 Source

Emanation Power:

- γ-Spectrometry (HPGe, $LaBr_3$, $CeBr_3$, SrI_2)
  → Portable “on-line” measuring system
- Comparison with enclosed source of the same type



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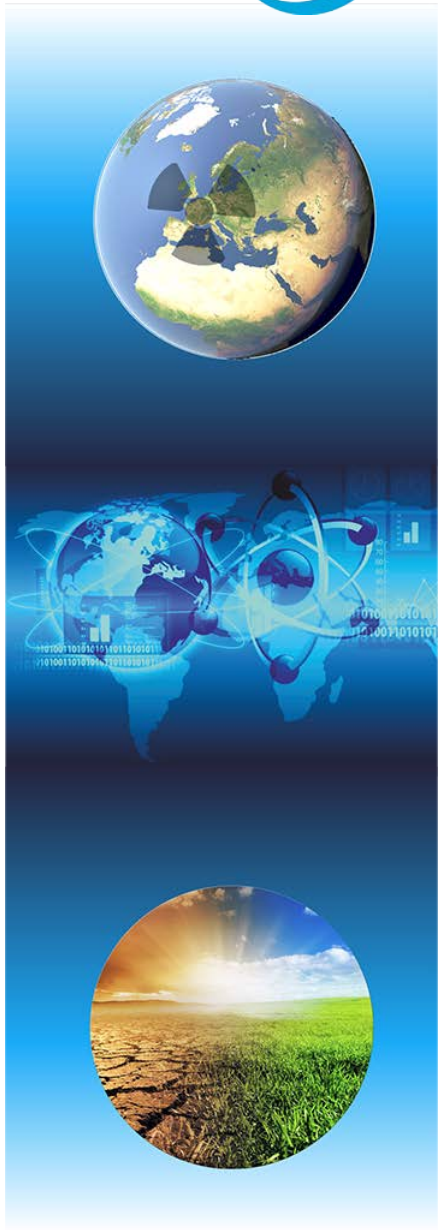
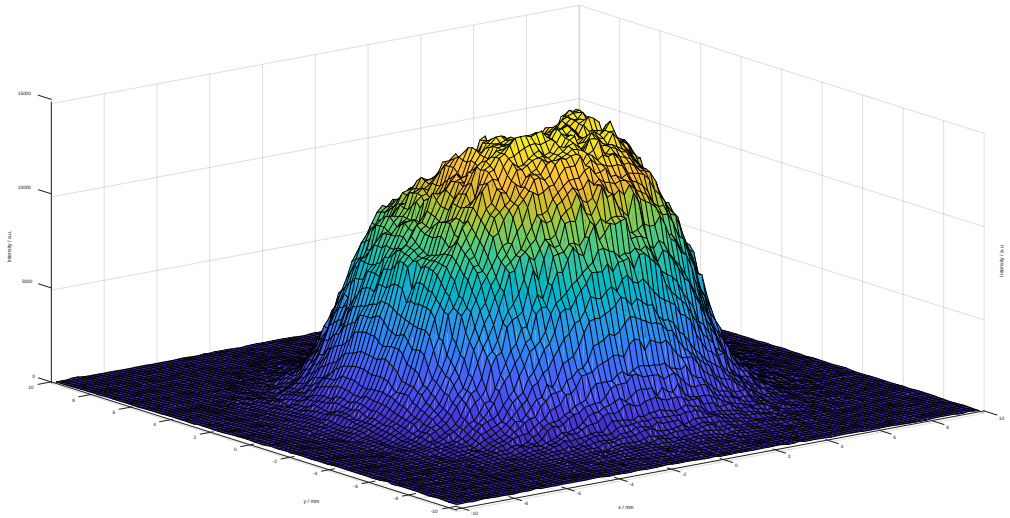


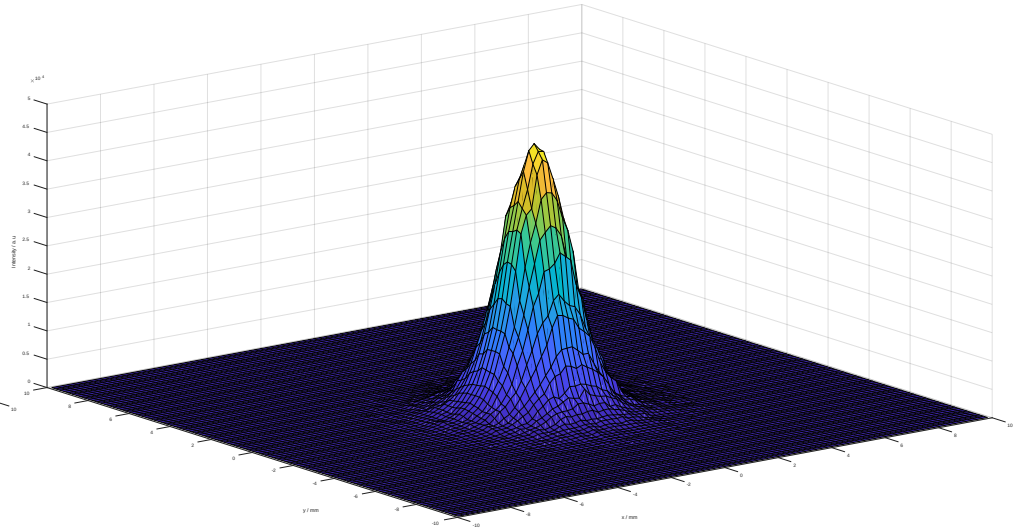
Implantation produces very defined Distribution (3D-Gaussian)

➡ Beneficial for α-Spectrometry (FWHM, MC-Calculations)

Electrodeposition



Implantation



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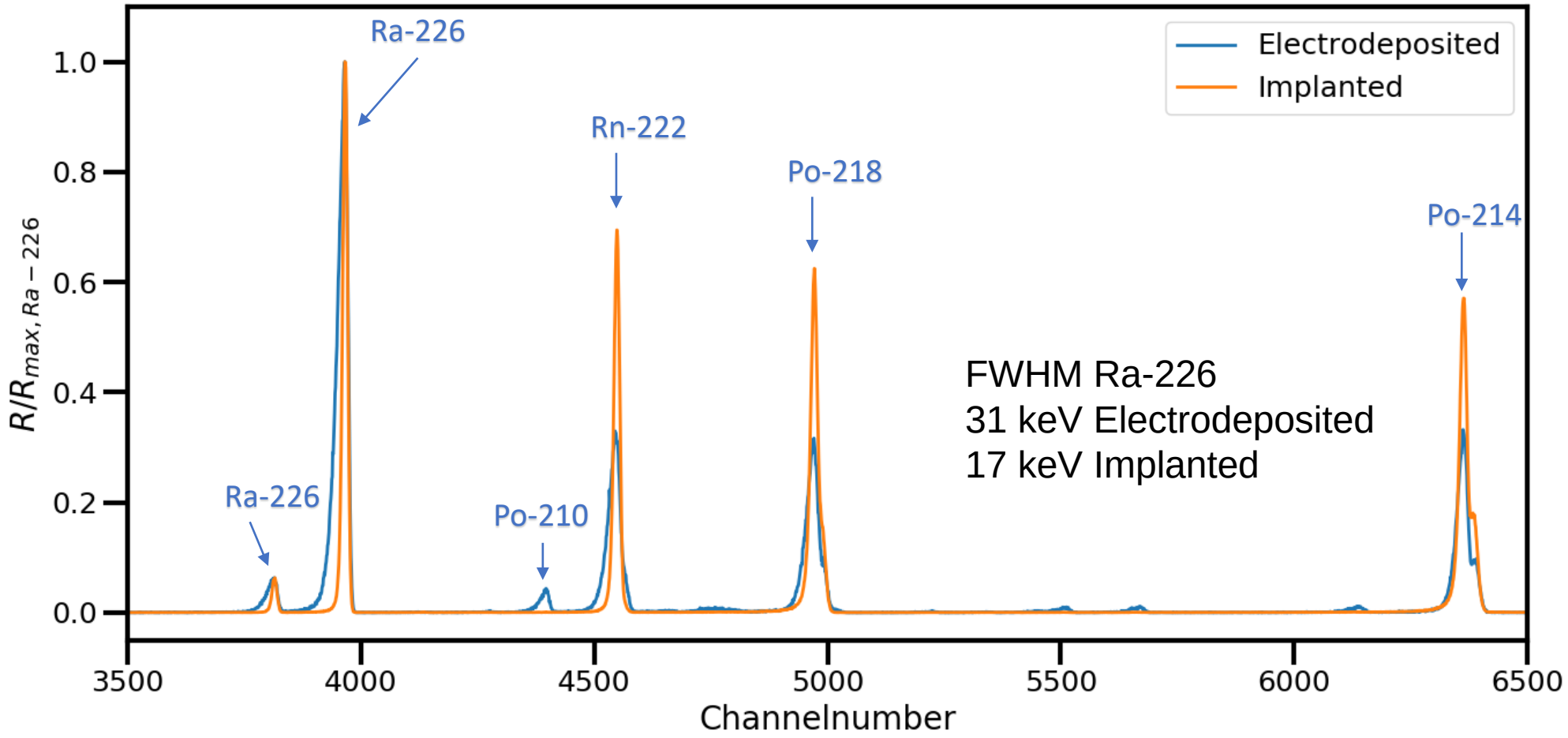
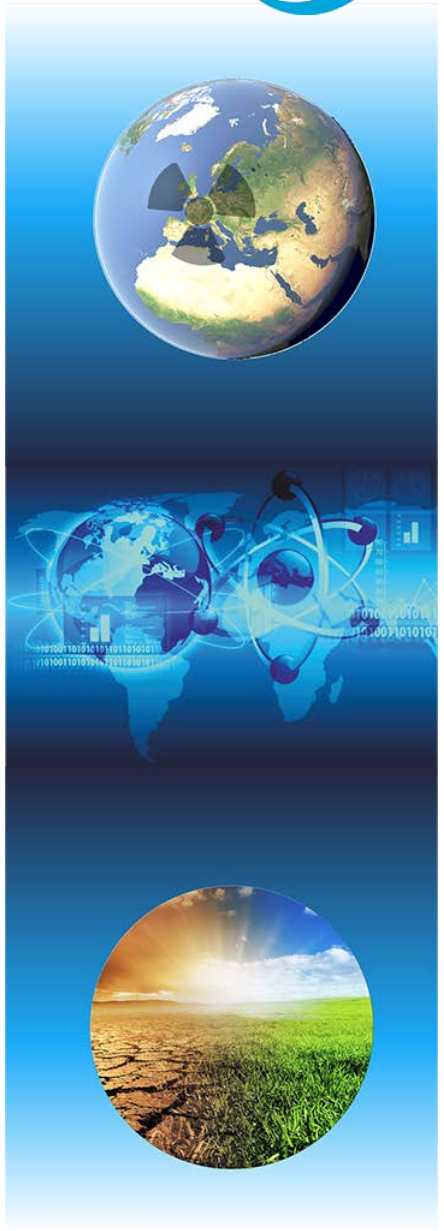
α-Spectra - Comparison





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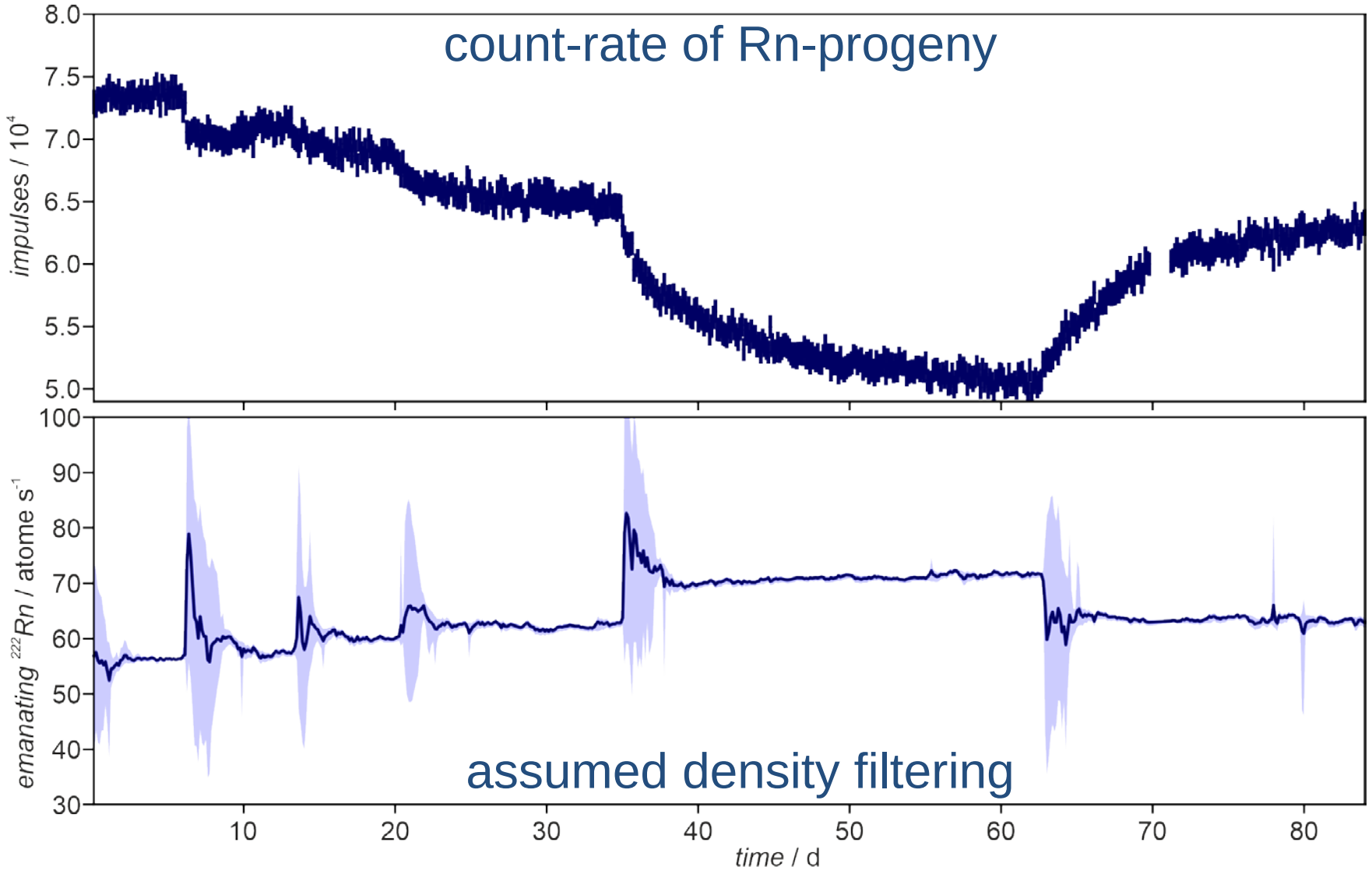
traceRadon – Kalman filter



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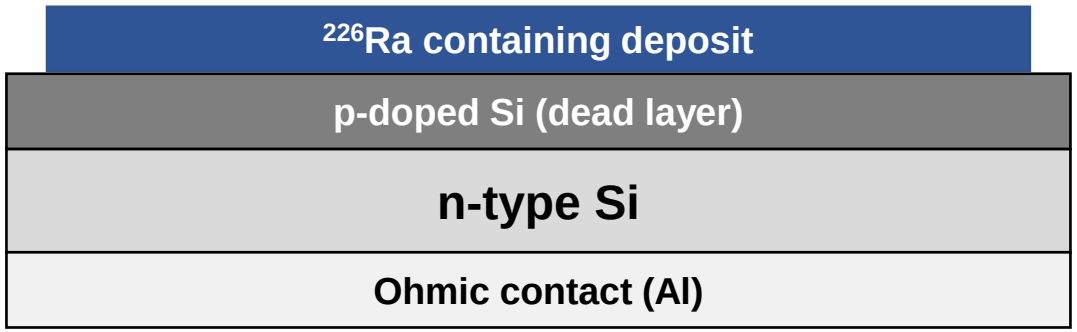
traceRadon – source & detector

$^{226}Ra \rightarrow {}^{222}Rn + \alpha$

E: 86 keV recoil
avg. range (Si): 40 nm [1]

E: 4.78 MeV
avg. range (Si): 23 µm [1]



few µg / cm²
50 nm
> 100 µm

thin layer ^{226}Ra : recoil emanation of ^{222}Rn

close to 2π sr : ca. 50 % detection efficiency of all α

[1]: SRIM calculation

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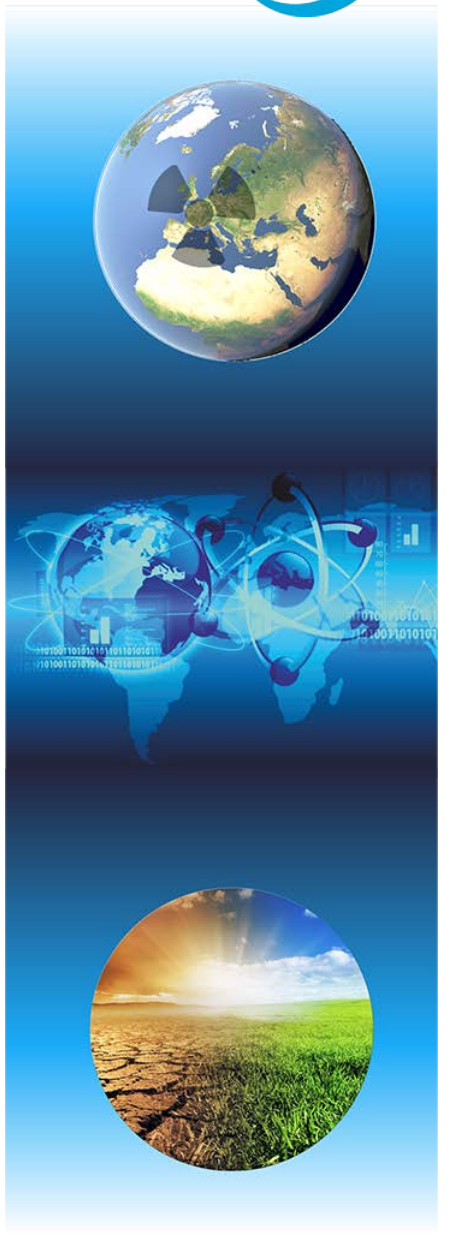
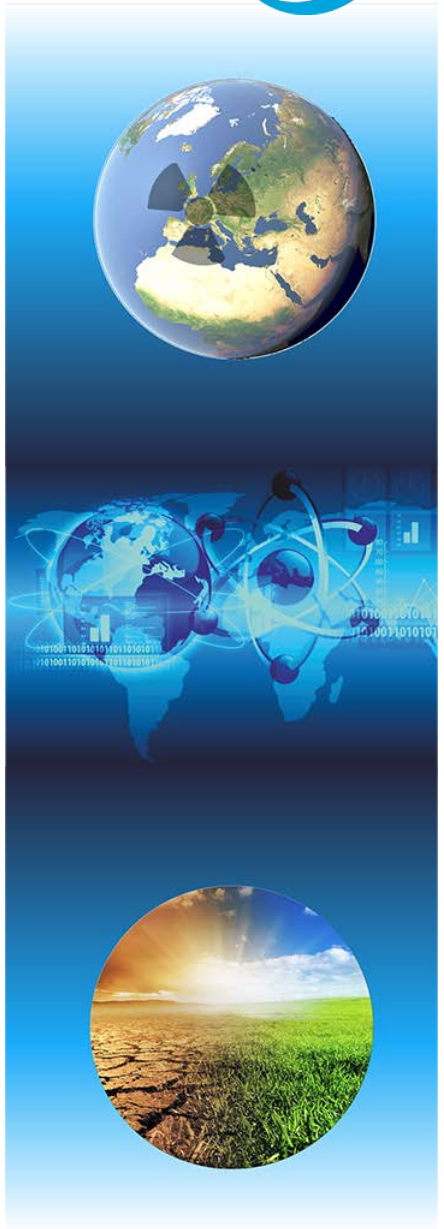


traceRadon – source & detector

Benefits of this design:

- High efficiency to detect residual ^{222}Rn: Possibility to estimate emanation behaviour on-line and with comparably high temporal resolution (1000 s)
  - Possibly absolute measurements, to be investigated
- Low background
- Relatively rugged and cheap detectors (1 k€ for bare detector)
- Emanation due to recoil (rather than diffusive processes)
  - Possibly diminished effect of environmental parameters



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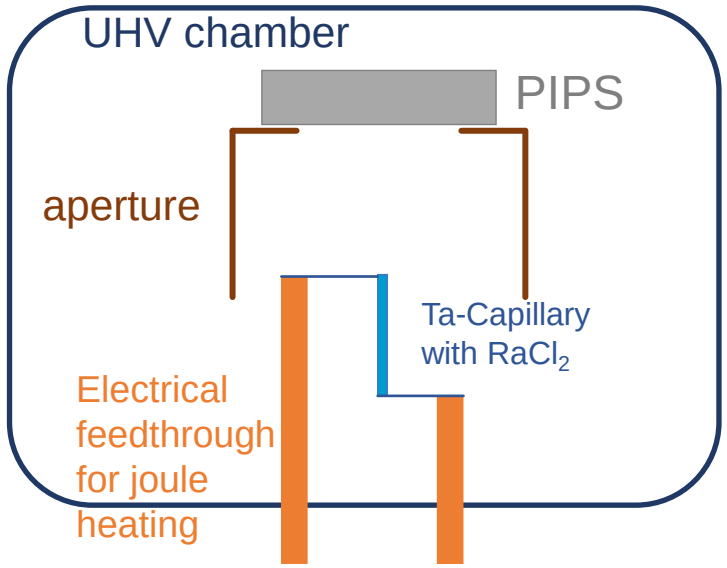
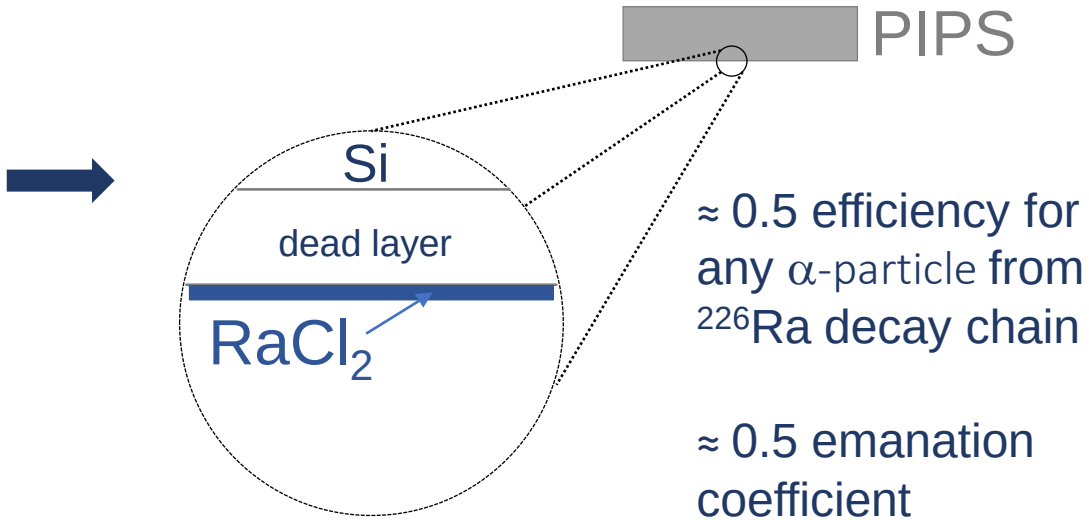
traceRadon – source & detector

Can α-spectrometry be used to make primary, extremely sensitive, on-line emanation source?

➡ *Modify PIPS with layer of $RaCl_2$ by **thermal-PVD***





≈ 0.5 efficiency for any α-particle from ^{226}Ra decay chain

≈ 0.5 emanation coefficient

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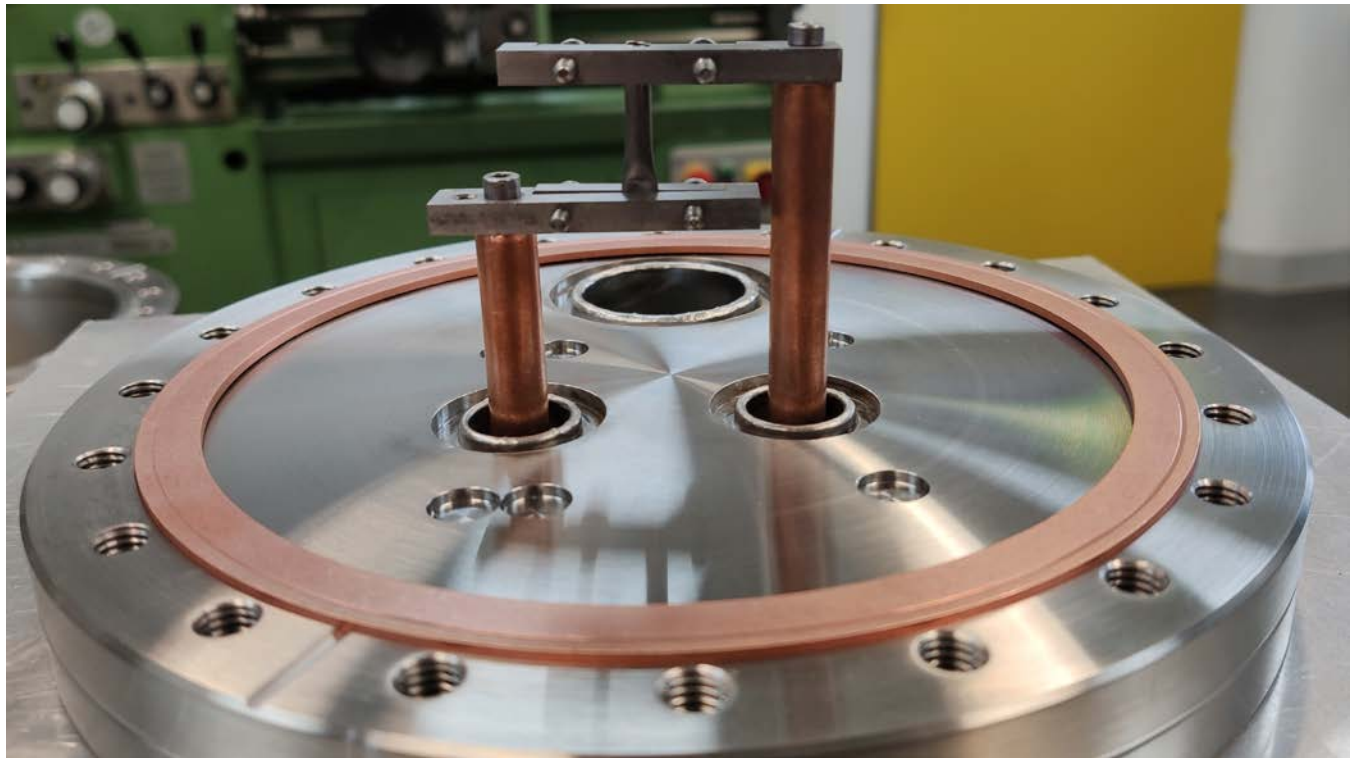
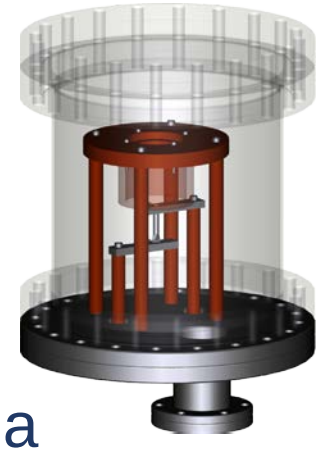
Primary, on-line emanation sources first realisation of suitable thermal PVD setup





- < 10^{-6} hPa
- Low vapor-pressure materials (Ta)
- est. up to 2000 °C

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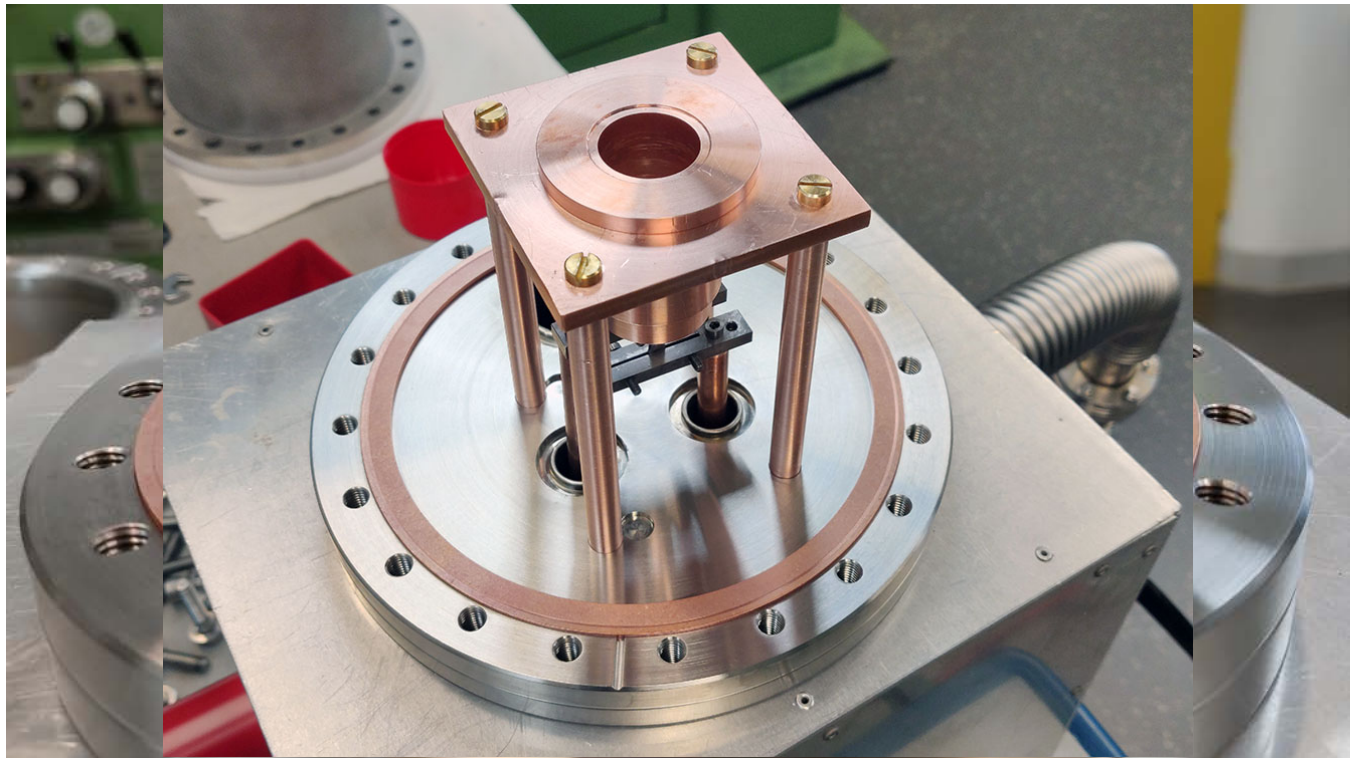
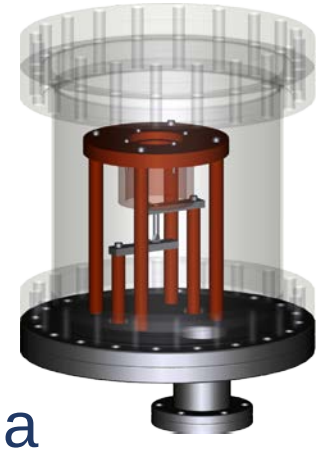
traceRadon – source & detector

Primary, on-line emanation sources first realisation of suitable thermal PVD setup





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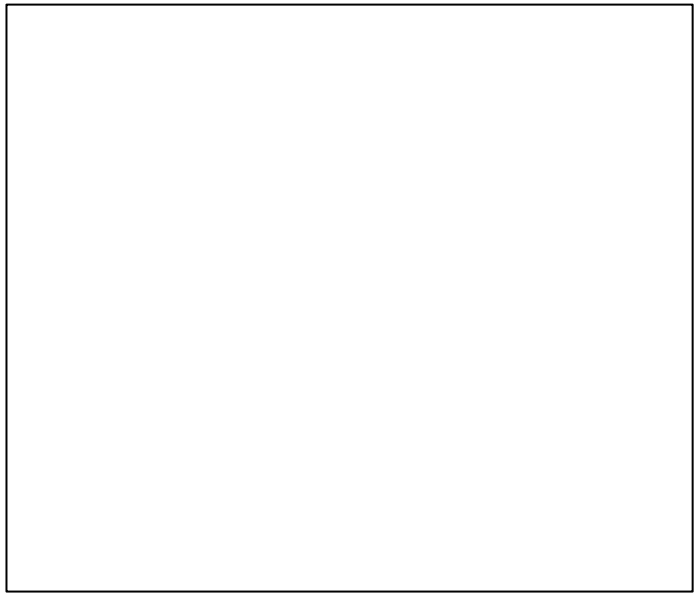
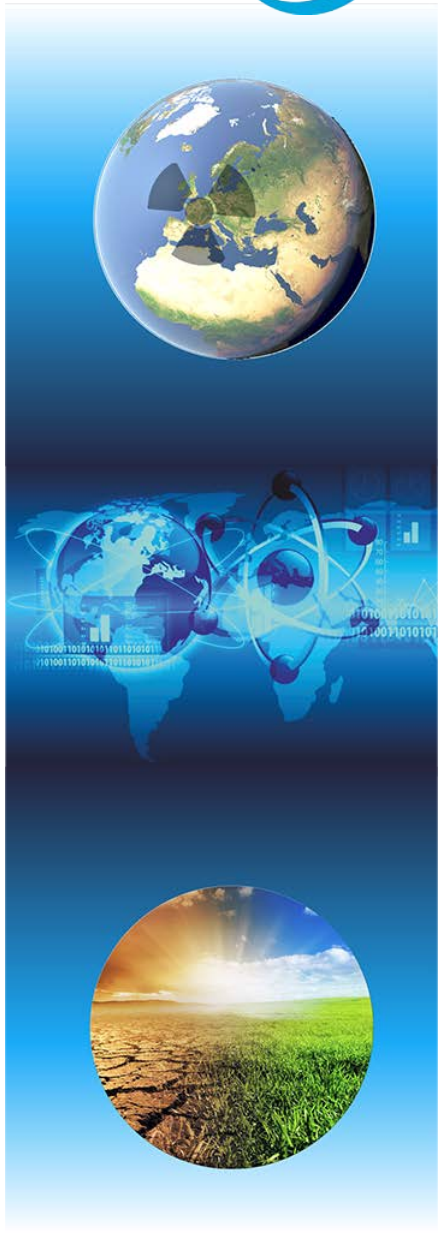


ca. 15 % yield (35 mm distance)
120 W, 15 min
$<10^{-6}$ hPa

PIPS 450 mm², 300 µm
with
150 Bq ^{226}Ra layer



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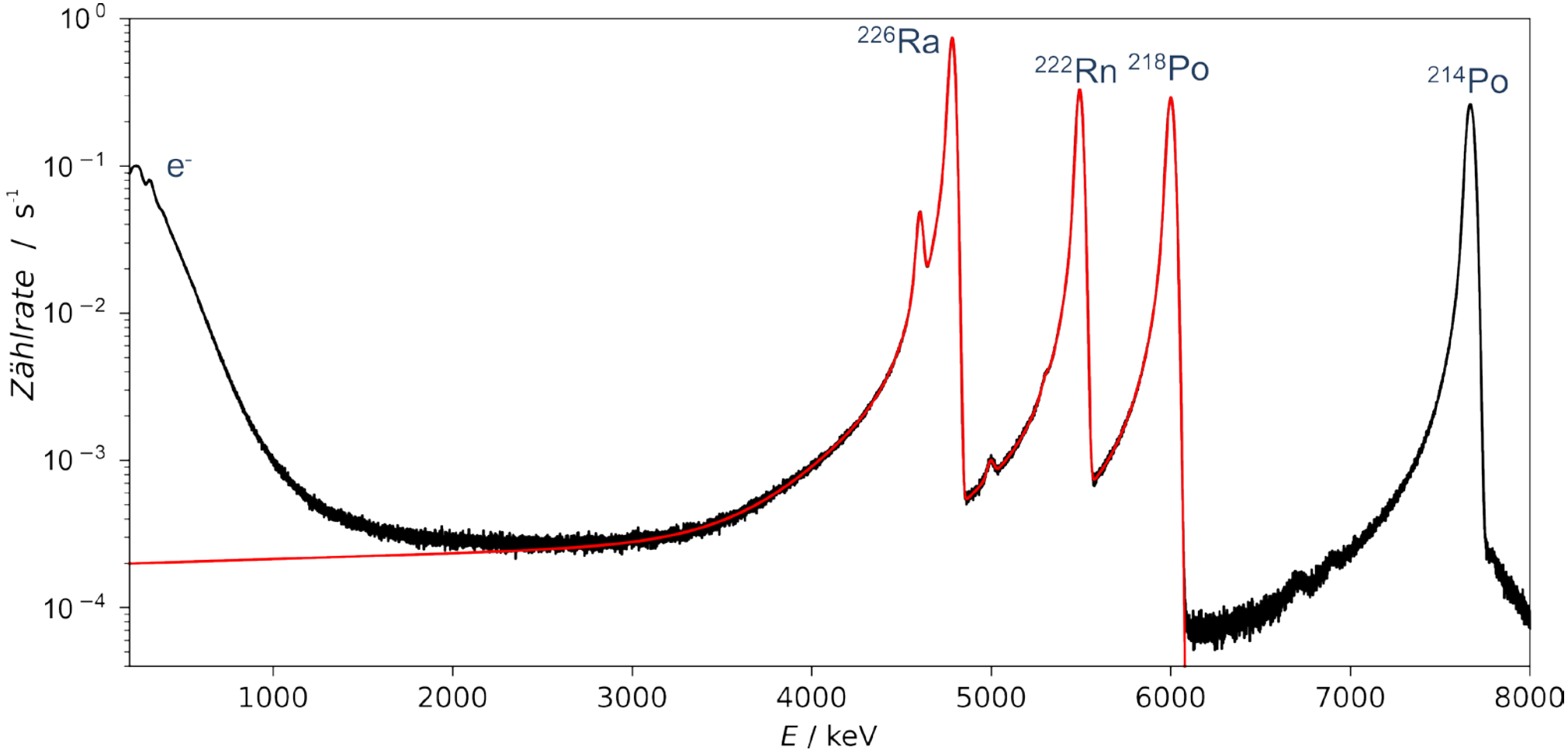
traceRadon – source & detector



Peaks are reasonably well resolved, still need to account for tailing contributions

➡ Model with mixtures of Exponentially modified Gaussians

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traceRadon – new traceability

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New metrology for radon at the environmental level

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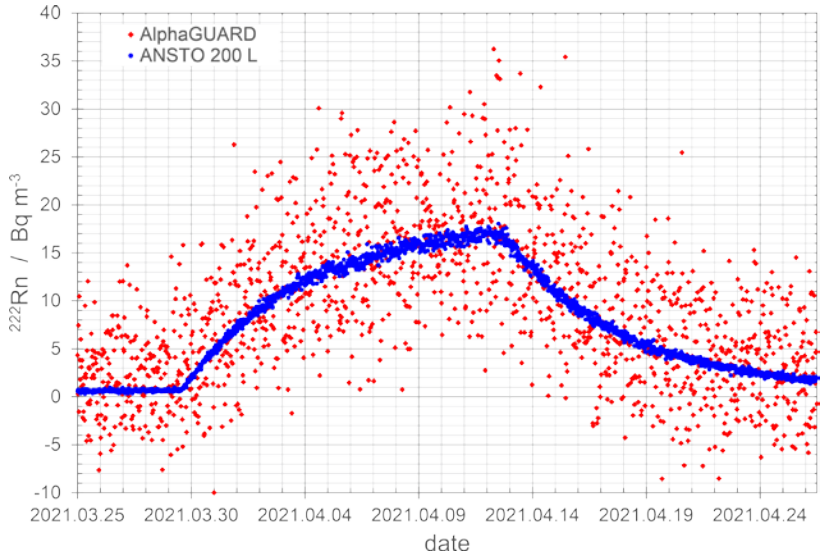

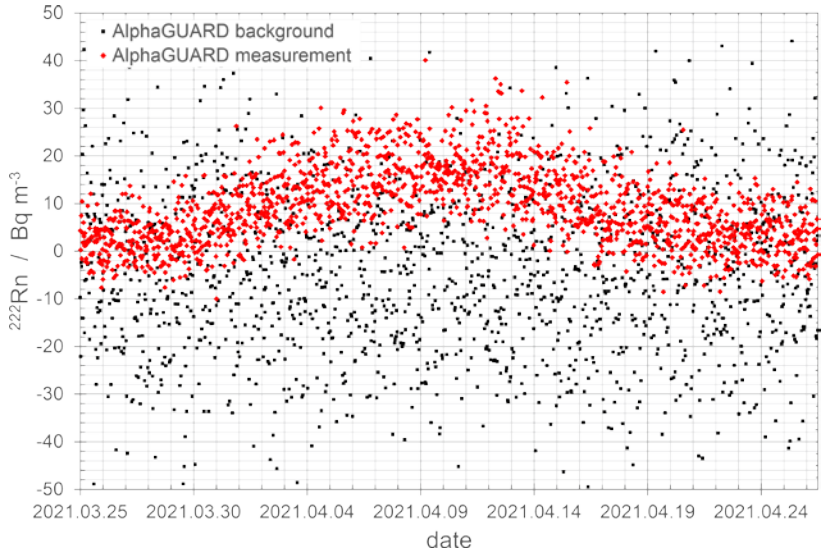

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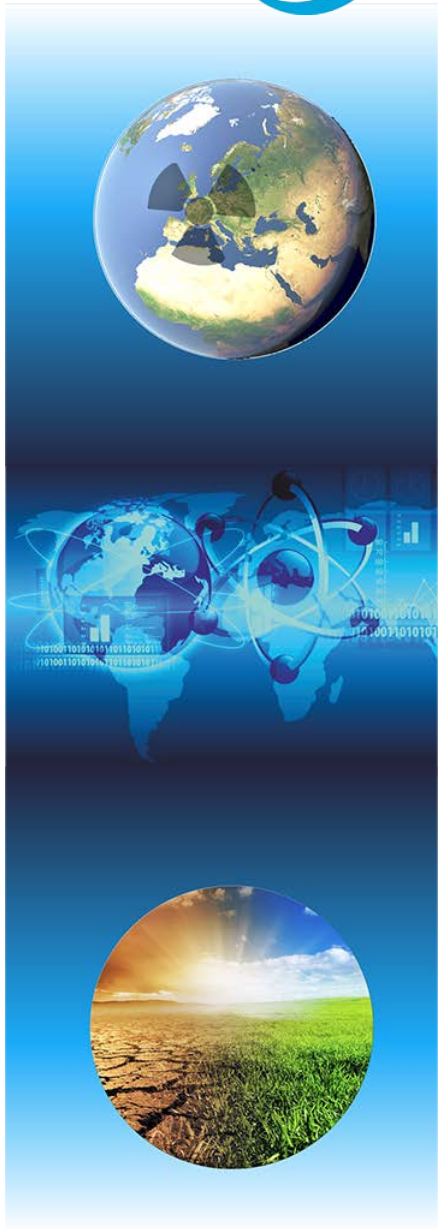
EMPIR 19ENV01 traceRadon

Bringing scientific achievements together for the benefit of two large Stakeholder groups:

- **Climate research** and **radiation protection research** needs support of traceable low-level outdoor radon measurements according to the needs of UNFCCC and the Council Directive 2013/59/Euratom.
- Radon and radon flux data is needed to estimate regional GHG emissions fluxes and radon priority areas (RPA) but the uncertainties are too large due to missing metrological capabilities.
- Working on the distinction from anthropogenic and natural GHG emissions!



This presentation includes material from publications / presentations from partners and collaborators of the EMPIR 19ENV01 traceRadon project.
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