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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

Metro RADON

trace Radon

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New developments in metrology: From MetroRADON to traceRadon

EURADOS-AM2021 WG3-S3 on 29th January 2021

This project 19ENV01 traceRadon has received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme.

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

Stefan Röttger, PTB, Ionizing Radiation, Radioactivity, Alpha and Gamma Spectrometry

Story

- EMPIR
- MetroRADON
  - new metrology
- traceRadon
  - new metrology
- perspective

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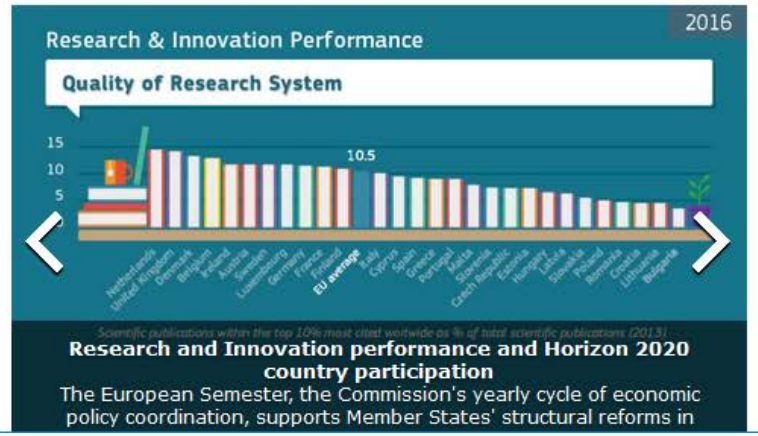

Project Stories

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BACK

Horizon 2020 is the biggest EU Research and Innovation programme ever with nearly €80 billion of funding available over 7 years (2014 to 2020) – in addition to the private investment that this money will attract. It promises more breakthroughs, discoveries and world-firsts by taking great ideas from the lab to the market.

History

Horizon 2020EU

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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.

The inclusion of capacity-building activities in EMPIR is helping to bridge the gap between countries with emerging metrology systems and those with more developed capabilities.

To take part in EMPIR, please visit the EMPIR F

- see the current plan for calls in EMPIR
- submit ideas for metrology research in re
- submit project proposals in response to a
- register as an expert to help EURAMET
- read guides to the call, evaluation, negoti

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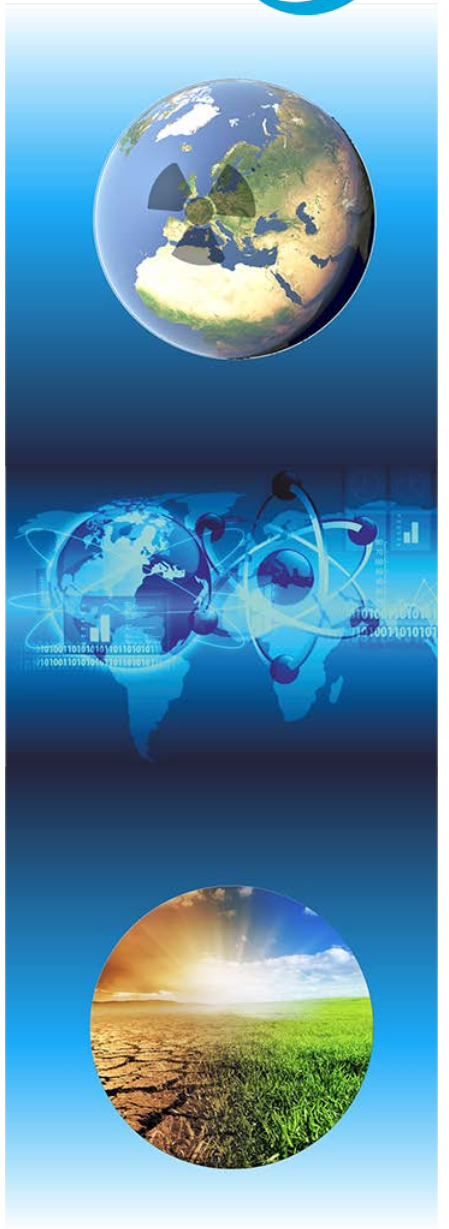
- Calls:
  - Health
  - Energy
  - Environment
  - Industry
  - Fundamental Metrology
  - Standardisation
  - Capacity Building
  - Dissemination



MetroRADON

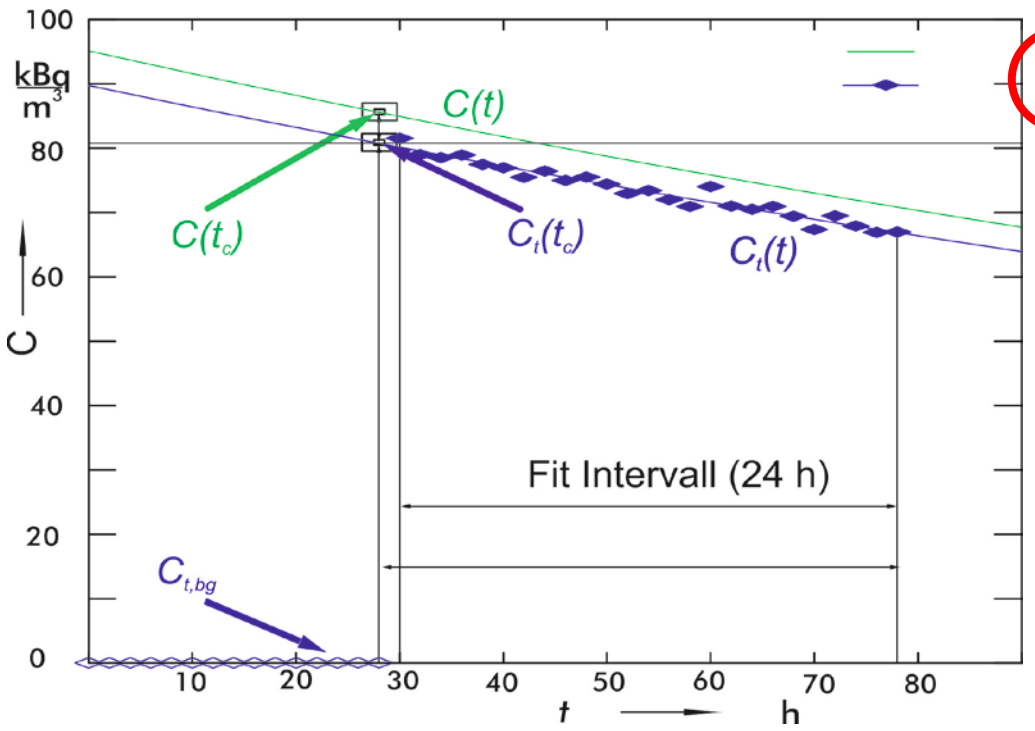
Welcome to metroRADON

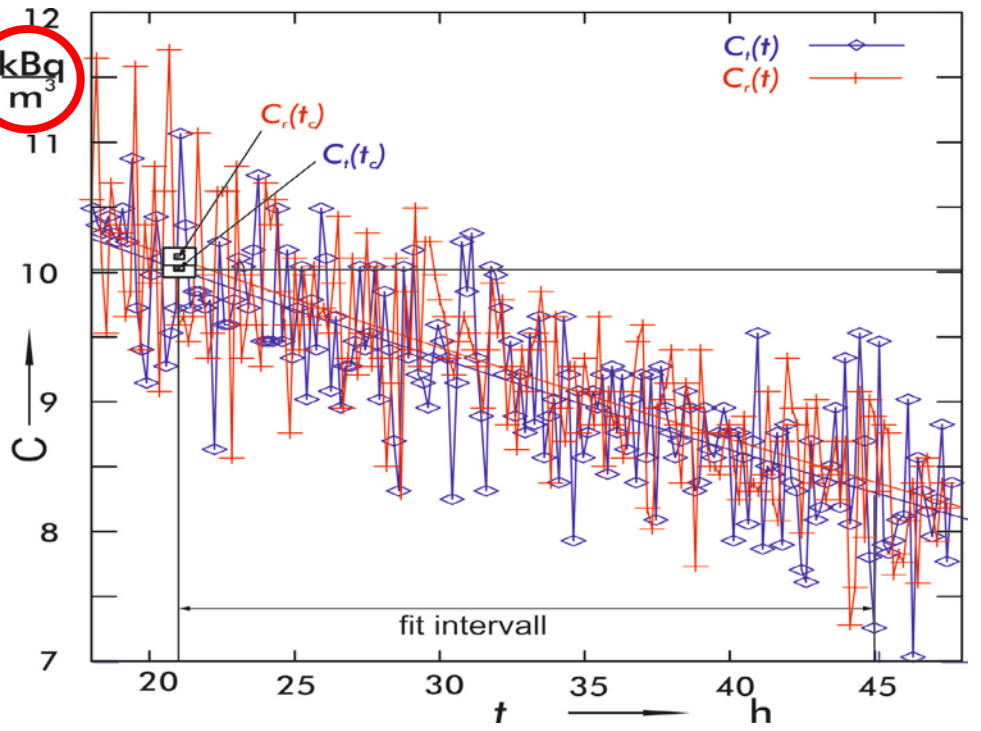
The European Council Directive 2013/59/EURATOM (EU-BSS) evokes new challenges for the metrology of radon measurements and calibrations in Europe. For the first time, the exposure of the public caused by radon will be part of legal metrology in Europe. Since the EU member states' levels of relevant activity concentration that are laid down in the EU-BSS shall not exceed 300 Bq/m³, new calibration procedures for existing commercial radon monitors with their limited counting statistics have to be developed.

metroRADON events

- 1st Progress Meeting

MetroRADON





$$C_r(t) = C_{r,tc} \cdot e^{(-\lambda \cdot t)} + C_{r,bg} \qquad C_t(t) = C_{t,tc} \cdot e^{(-\lambda \cdot t)} + C_{t,bg} \qquad k_t = \frac{k_r (C_r(t_c) - C_{r,bg})}{C_t(t_c) - C_{t,bg}}$$

$$C_r(t) = C_{r,tc} \cdot e^{(-\lambda \cdot t)} + C_{r,bg} \qquad C_t(t) = C_{t,tc} \cdot e^{(-\lambda \cdot t)} + C_{t,bg} \qquad k_t = \frac{k_r (C_r(t_c) - C_{r,bg})}{C_t(t_c) - C_{t,bg}}$$

The representation of the activity concentration in the range of 300 Bq·m^{-3} is a challenge to metrology!

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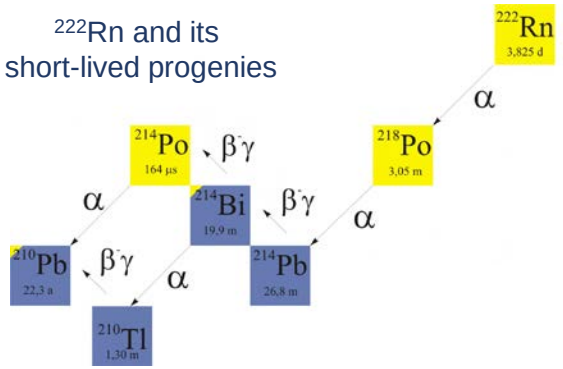
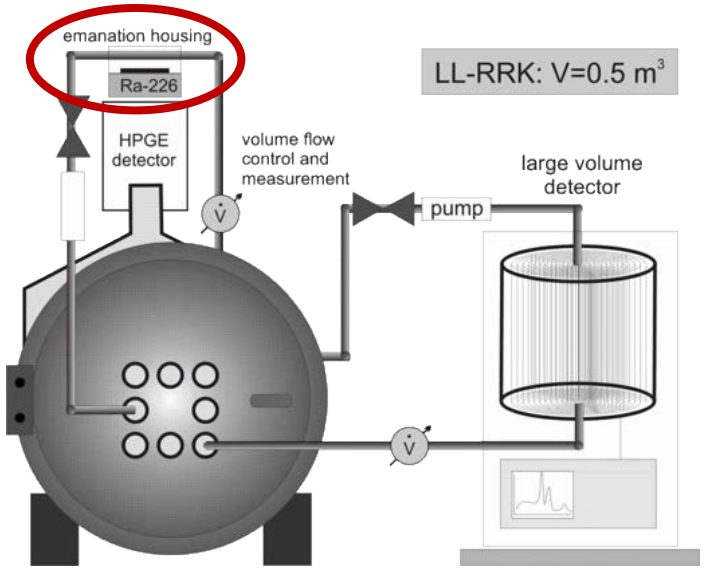
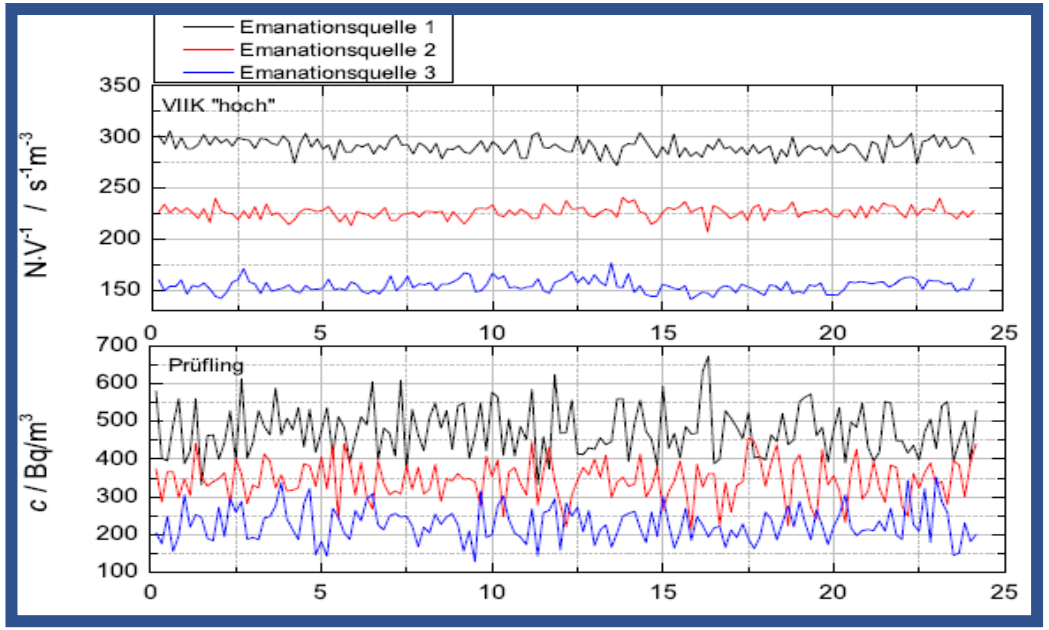
^{222}Rn and its
short-lived progenies



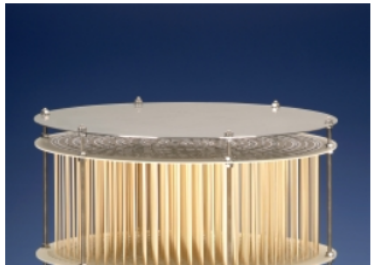
Preparation of EU-BSS by
PhDs of Diana Linzmaier and Florian Mertes





Low radon activity concentration measured precisely for the first time

Neues Messverfahren aus der PTB rechtzeitig zur Verschärfung der EU-Strahlenschutzrichtlinie



[PTB/es] **Man sieht es nicht, man riecht es nicht, man schmeckt es nicht – aber es kann in hohen Dosen tödlich sein: Das natürliche radioaktive Edelgas Radon tritt vor allem dort aus dem Boden aus, wo der Untergrund aus Granit besteht. Es kann aber auch in Baumaterialien vorhanden sein. Dass Radon in hohen Dosen Lungenkrebs verursacht, ist längst bekannt – viele Arbeiter aus den Uran-Minen der Wismut-Werke der DDR sind daran gestorben. Inzwischen schätzen aber Wissenschaftler, dass Radon auch in niedrigen Konzentrationen eine Gefahr sein kann, und haben die Strahlenwirkung darum offiziell hochgestuft: Das Gas**

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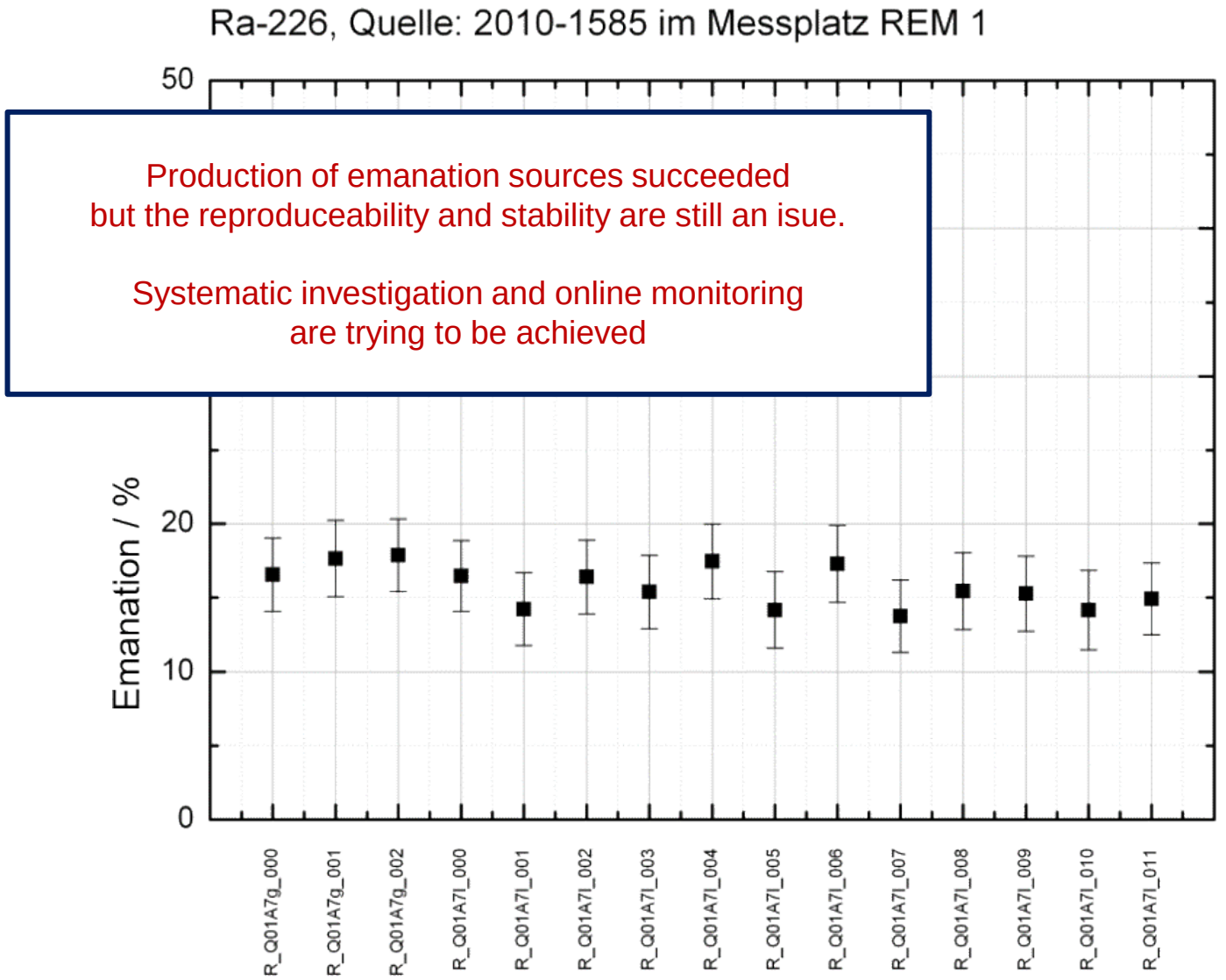
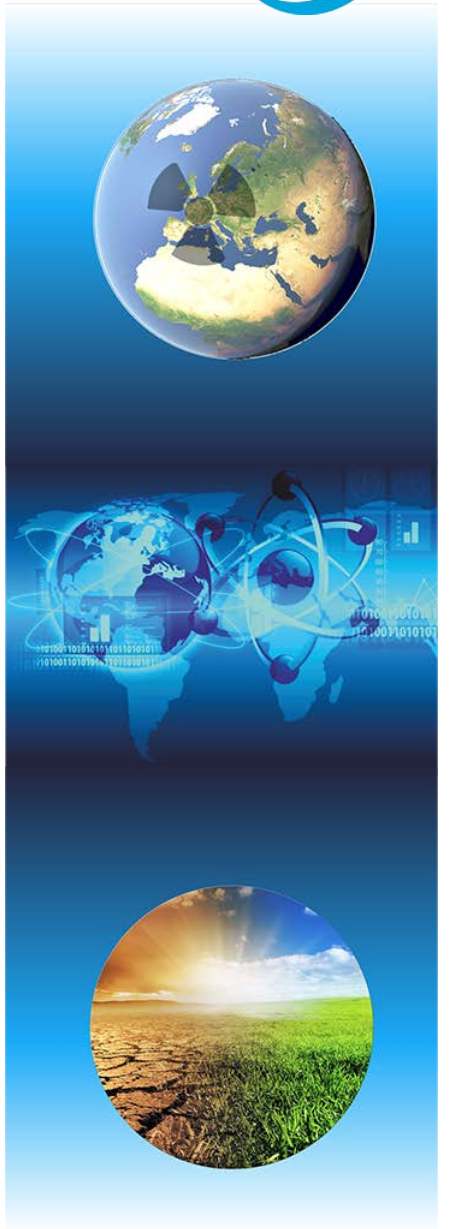


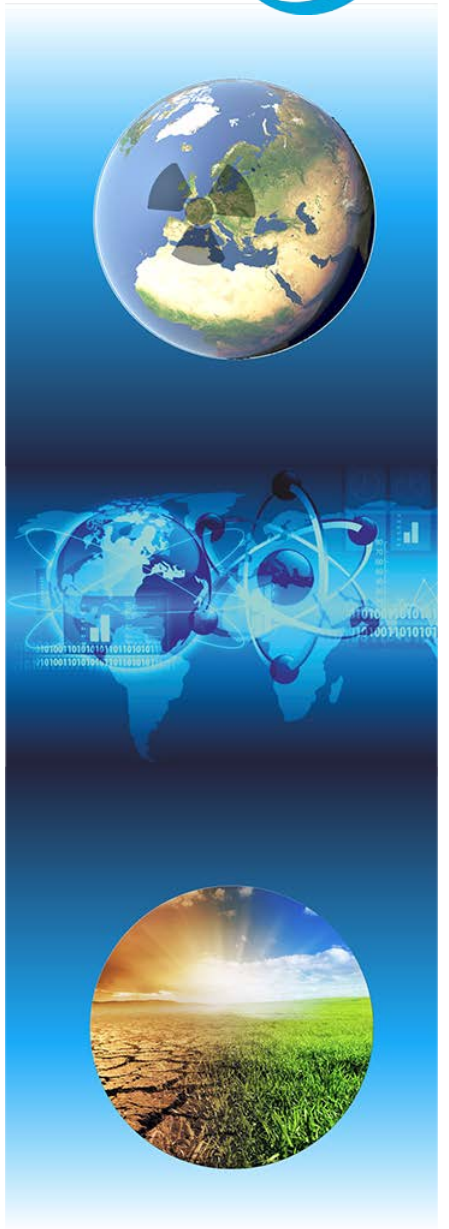
Production of emanation sources succeeded
but the reproduceability and stability are still an isue.

Systematic investigation and online monitoring
are trying to be achieved



MetroRADON

- Effective separation on ^{226}Ra from inactive Ba carrier in solution
  - ^{226}Ra electrodeposition
  - ^{226}Ra chemisorption
  - ^{226}Ra implantation after accelerator mass separation
- Electrodeposition of a thin film of ^{226}Ra on a metal deposit
- Quantification of the ^{226}Ra activity via α-spectrometry with defined solid angle
  - Absolut activity of ^{226}Ra
- Continuous measurement of the ^{222}Rn-losses- / emanation coefficient via γ-spectrometry
  - Comparison of ^{214}Pb and ^{226}Ra count-rate-ratios of an emanating an a sealed ^{226}Ra source of identical geometry



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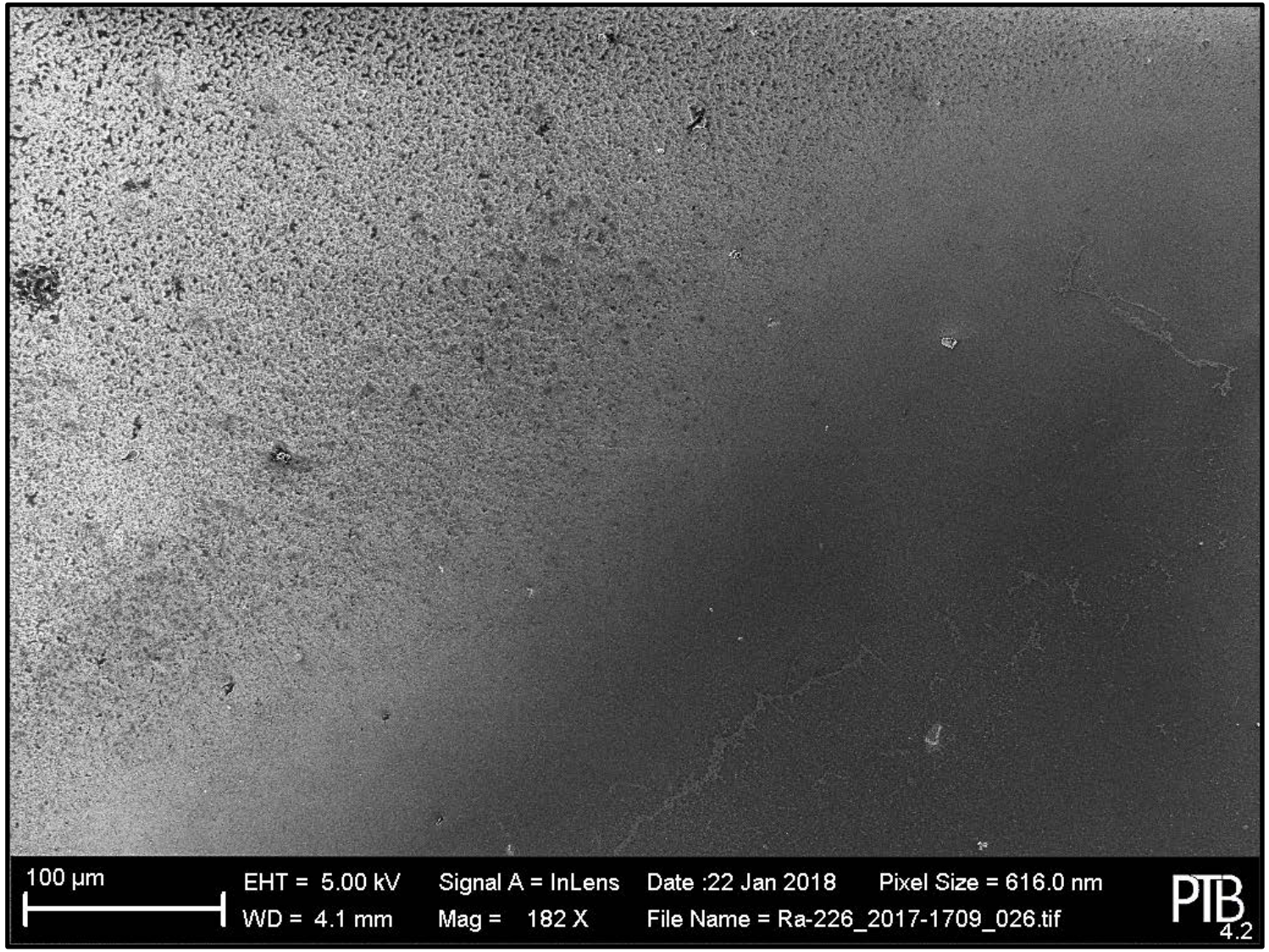
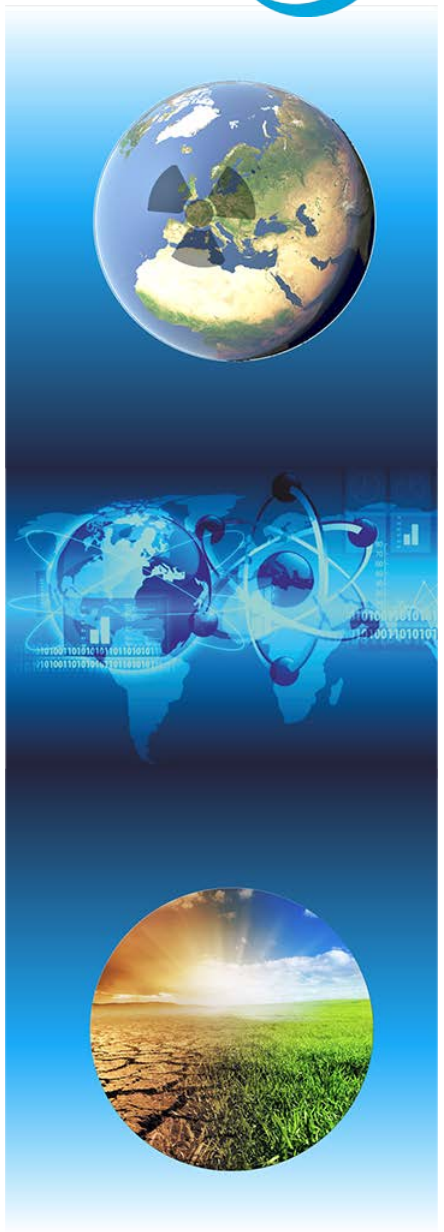
MetroRADON





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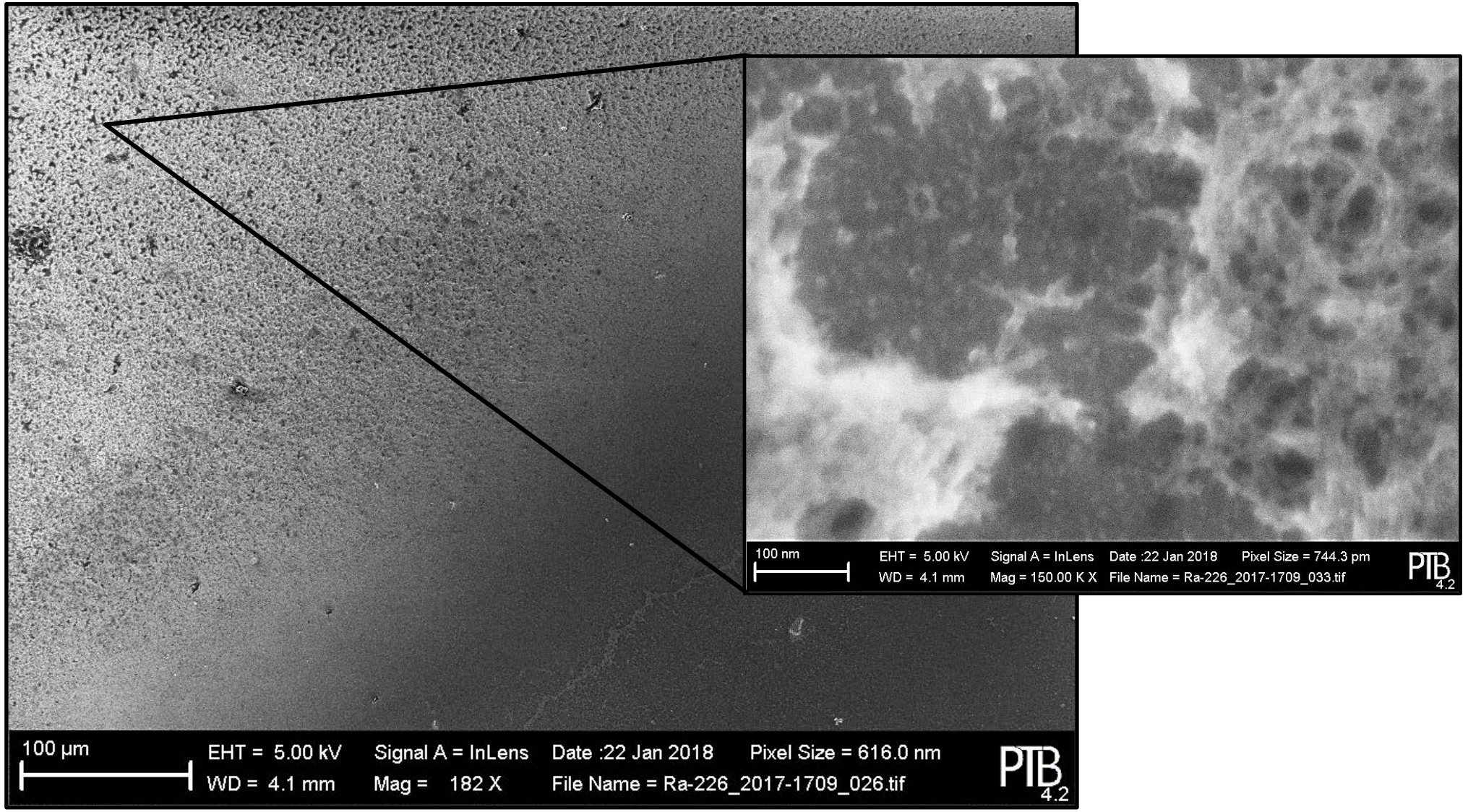
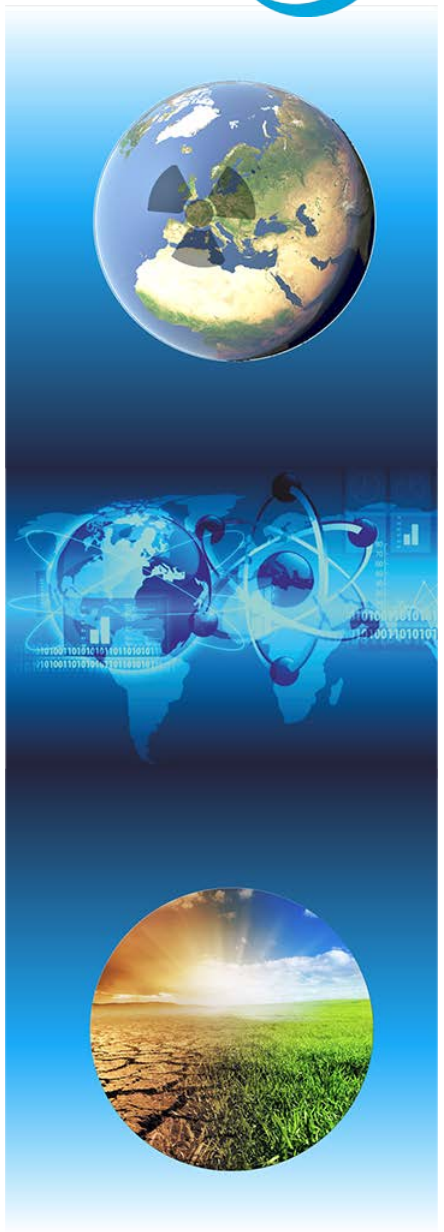
MetroRADON





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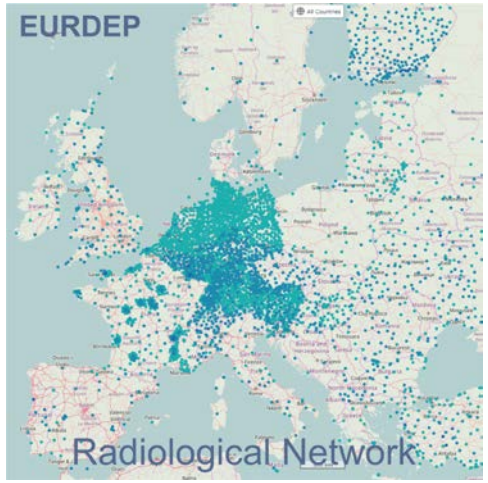

Climate change is one of the greatest challenges of our time.

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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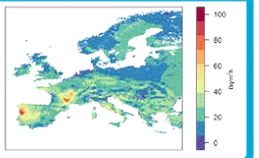
Traceability to the SI system

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

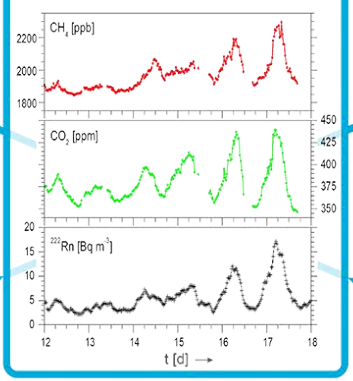
- Identification of RPA
- Quantifying the radon wash-out peak
- Data accessibility and public engagement



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

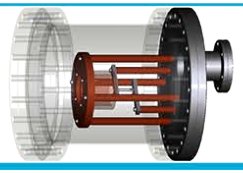
- Radon flux maps in GHG and climate change studies
- Inclusion of data from radiological early warning systems
- Validation of radon flux maps using radon flux measurements and outdoor radon activity concentrations

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



Traceable measurements of outdoor radon activity concentrations — WP1

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

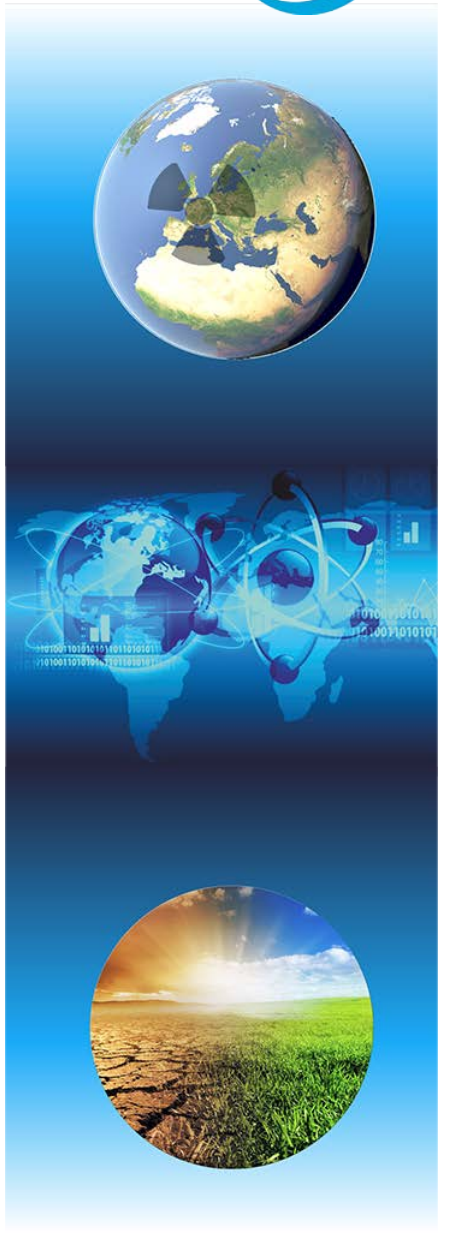


Radon flux measurements — WP2

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

Management and coordination — WP6

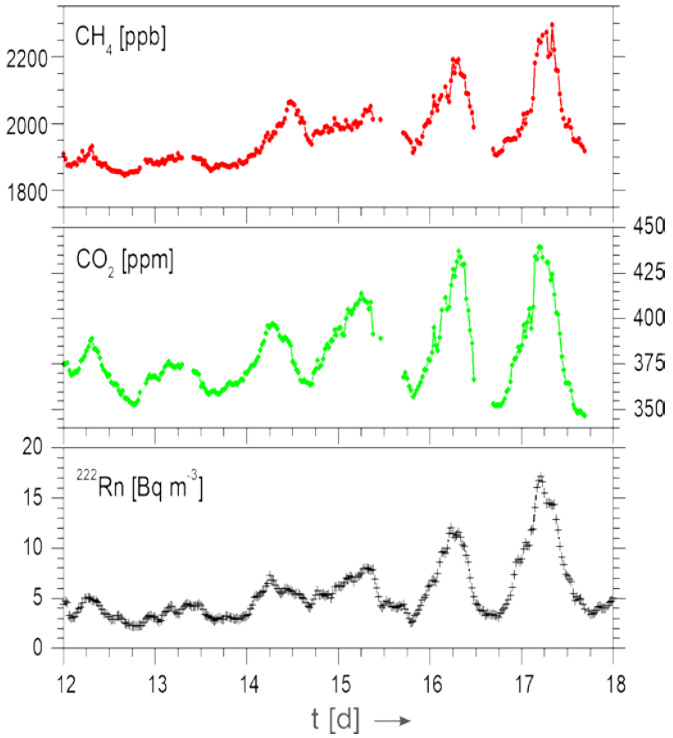
Seven leading European NMI/DI in the field of climate observation and ionising radiation. ICOS, JRC and other stakeholders directly involved as JRP-partners. Sufficient further external partners with high-level expertise to cover the broad spectrum of two scientific communities. High interest by stakeholder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



EMPIR 19ENV01 traceRadon

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

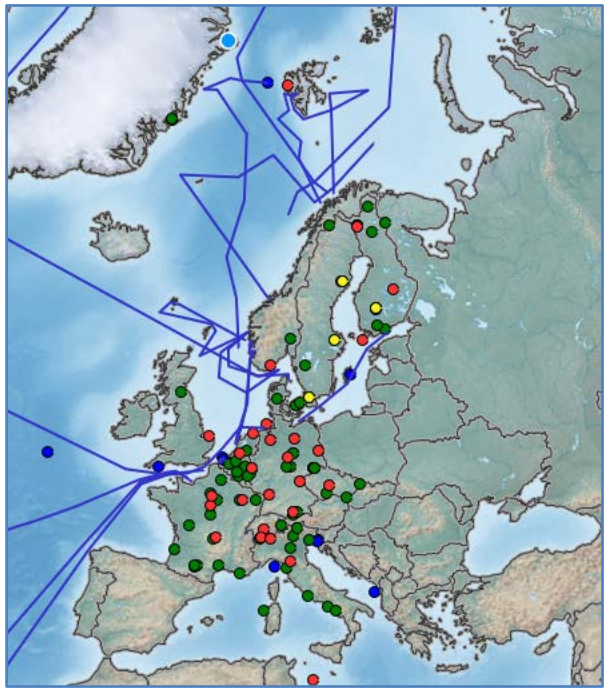
- GHG **flux measurements** are difficult though GHG concentration measurements are established.
- With radon activity concentration and radon flux measurements GHG fluxes can be **traced**!

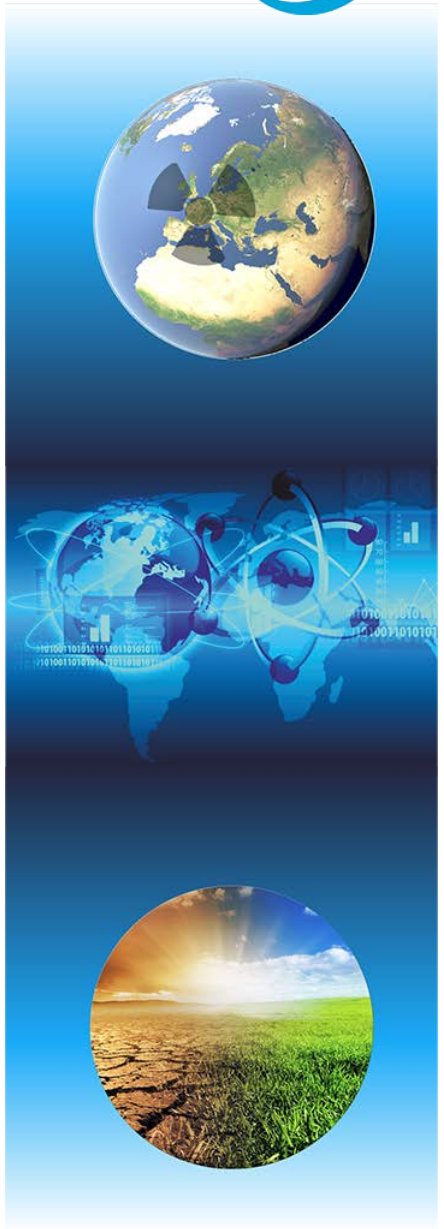


ICOS Atmospheric Station Specifications:

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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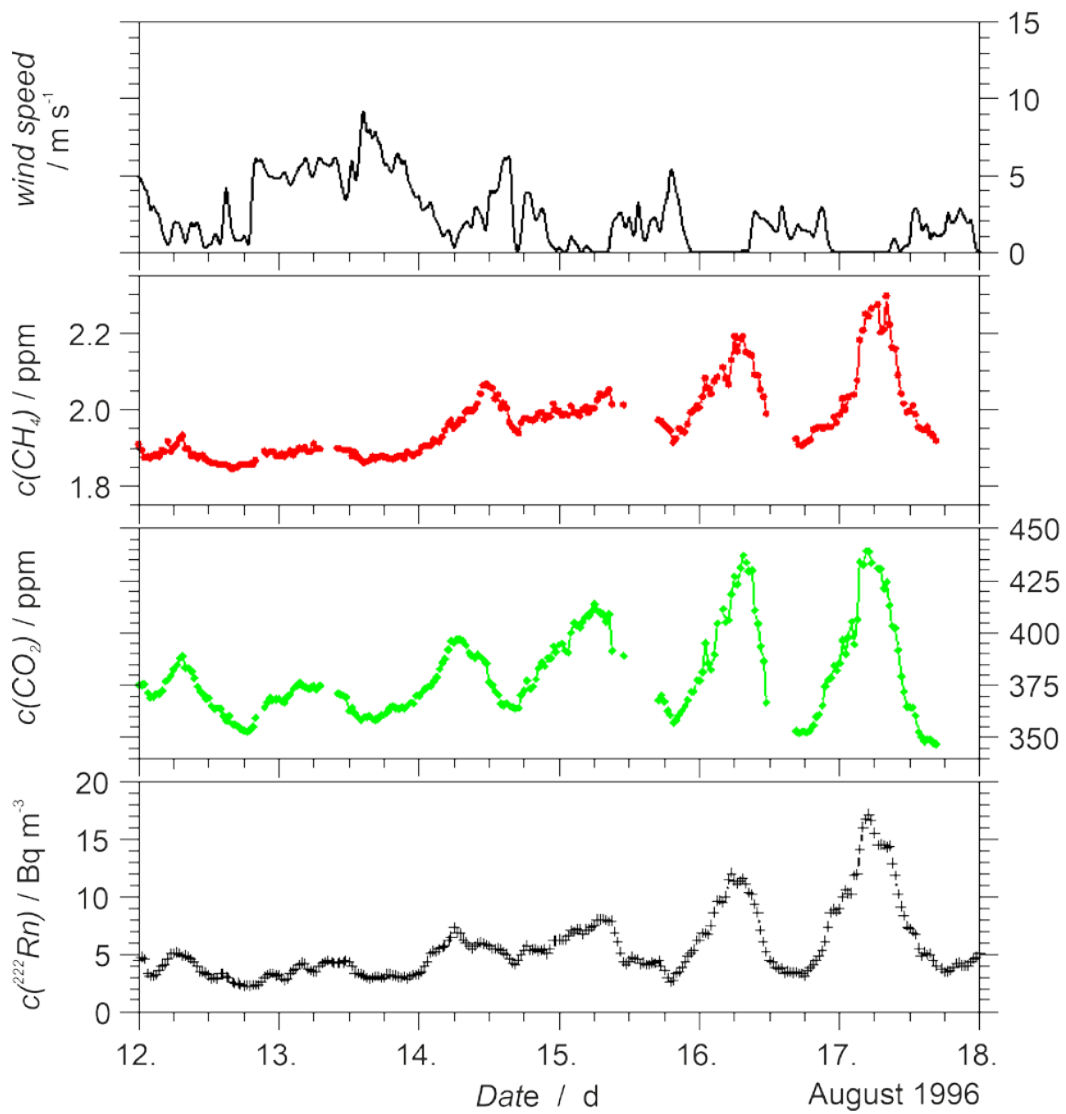

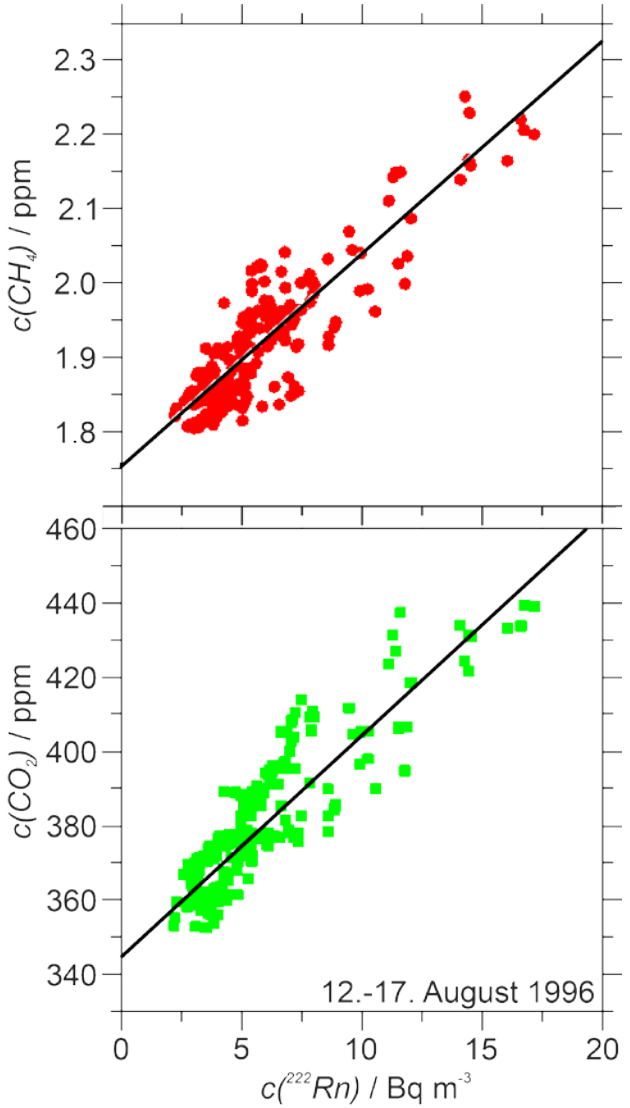

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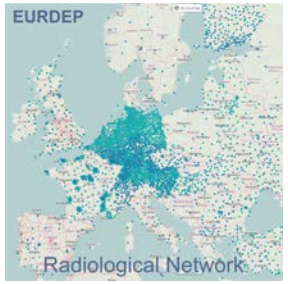
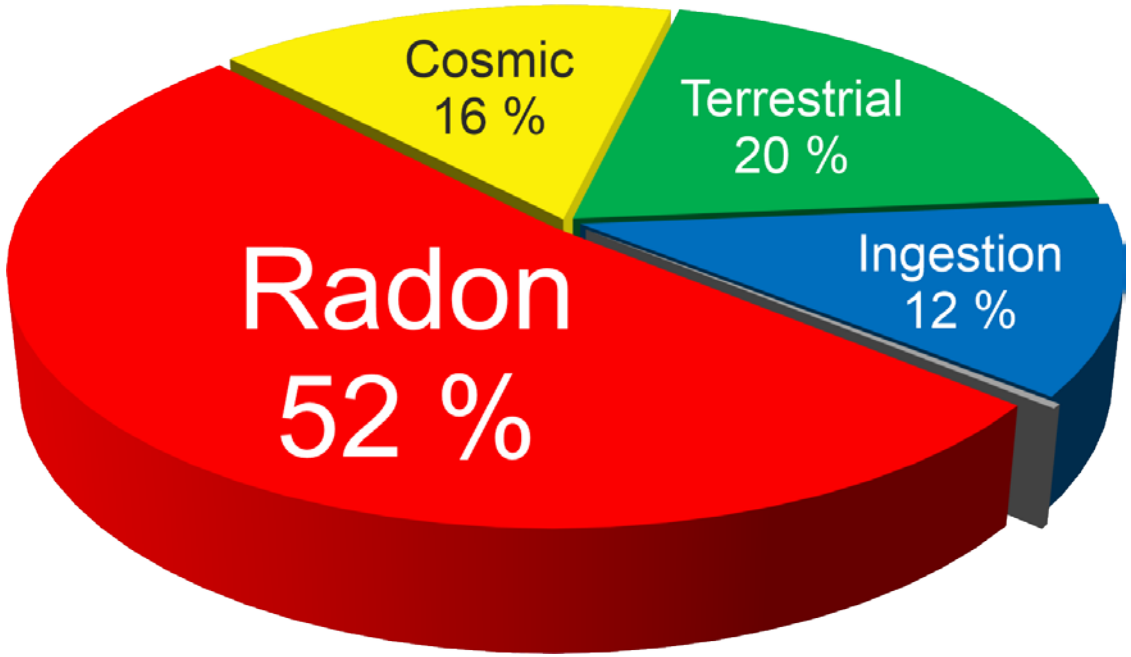


1. To develop traceable methods for the measurement of **outdoor low-level radon activity concentration** in the range of **1 Bq m^{-3} to 100 Bq m^{-3}**, with uncertainties of **10 % for k = 1**, to be used in climate monitoring (…).
2. (…).
3. (…) To support the validation with dosimetric and spectrometric 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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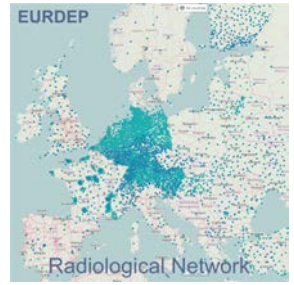
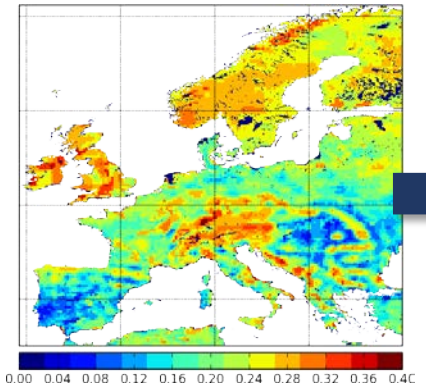
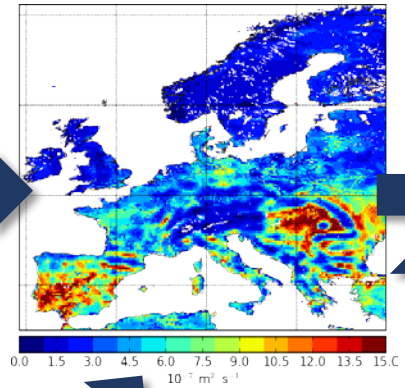
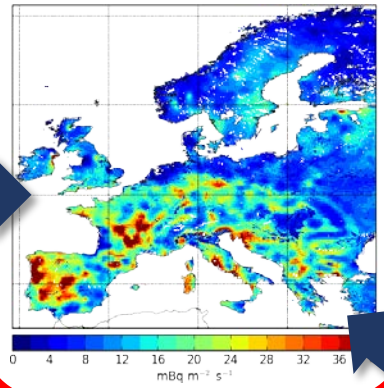
Our task: Joining forces in the field of radon



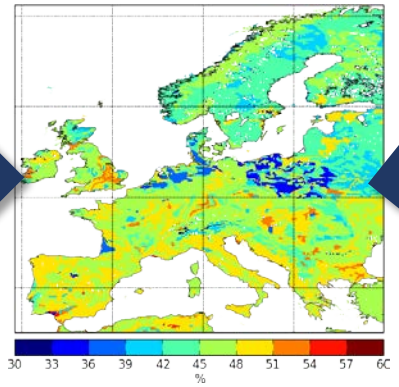


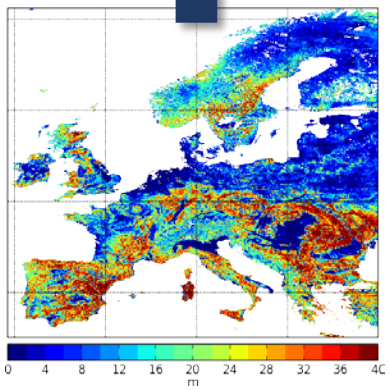


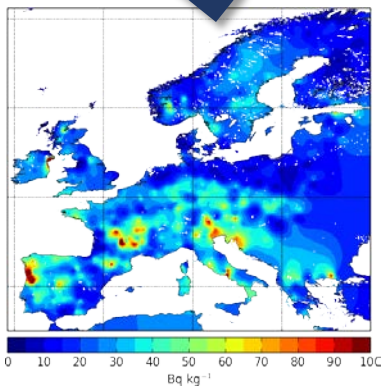


soil texture
% clay
% sand
% slit

bulk density





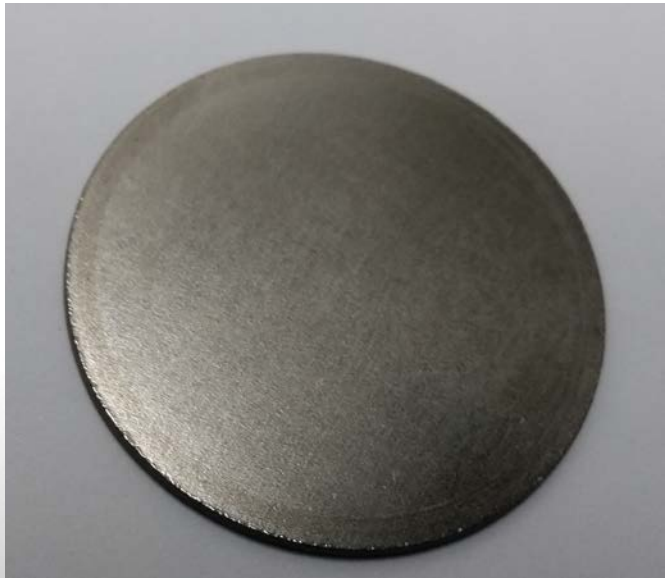


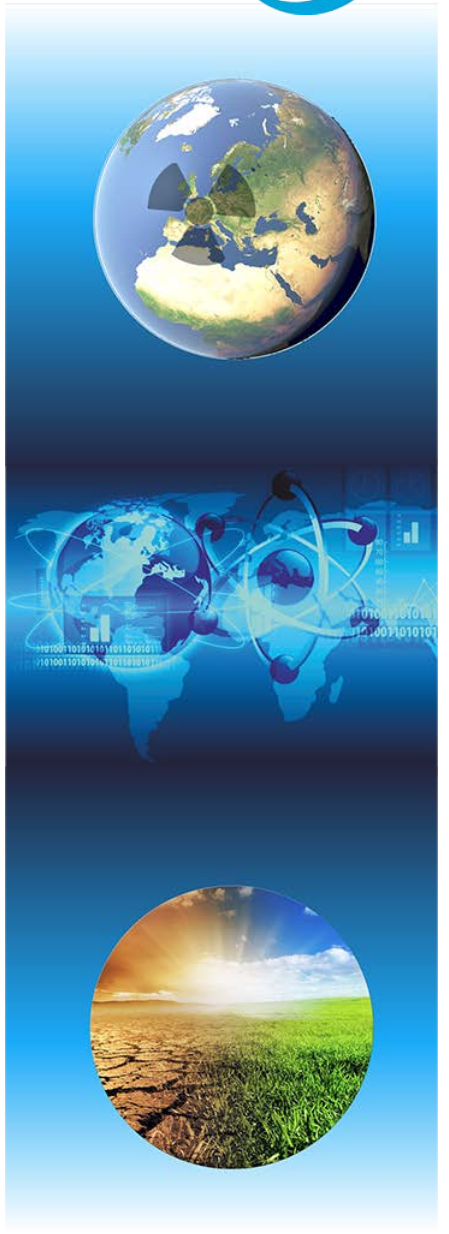
traceRadon

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





traceRadon

Characterisation of the new sources

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

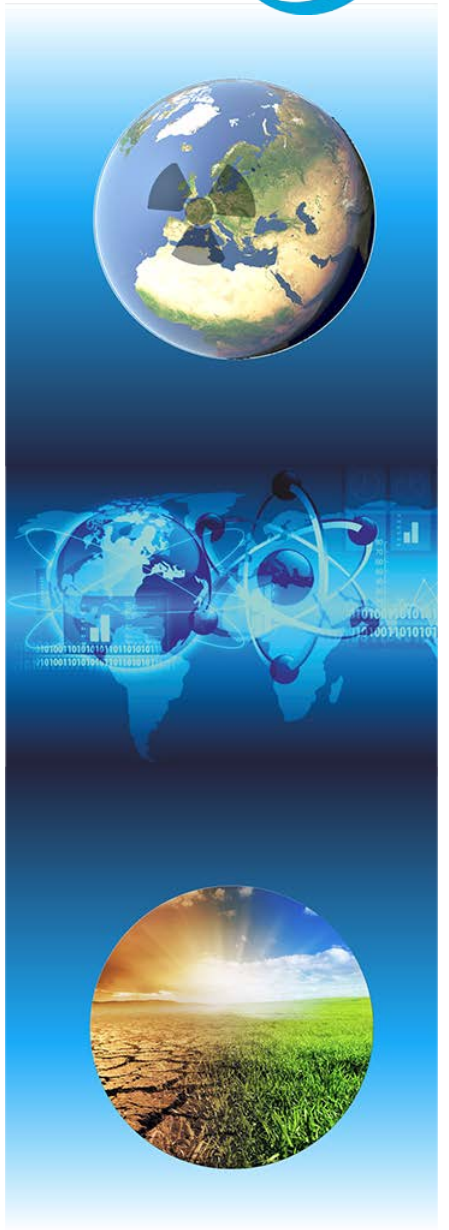
Ra-226 Activity:

- 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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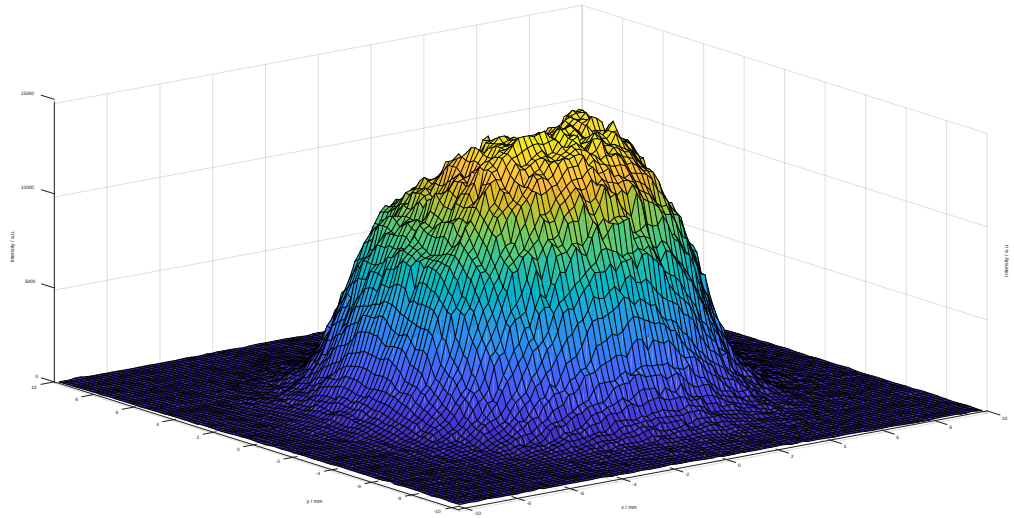
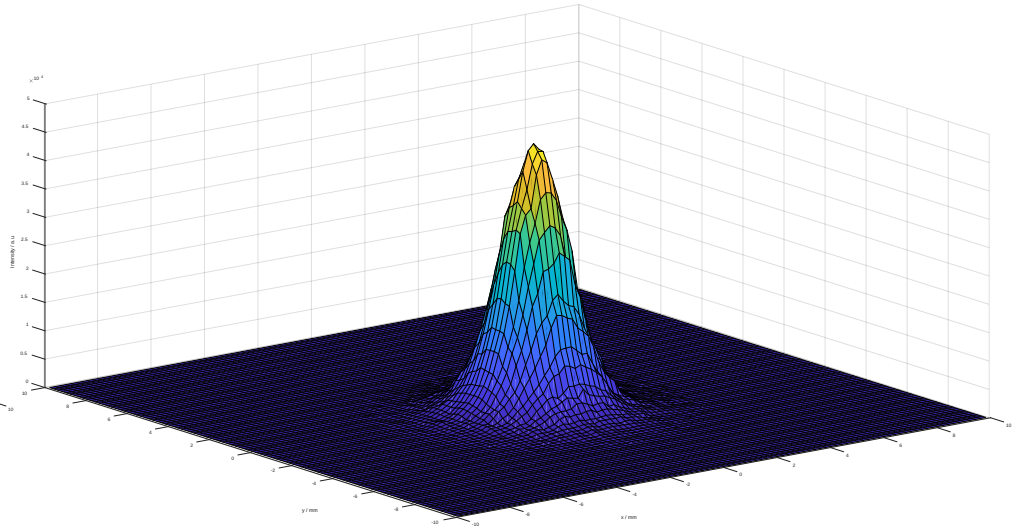
Implantation produces very defined Distribution (3D-Gaussian)

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

Electrodeposition

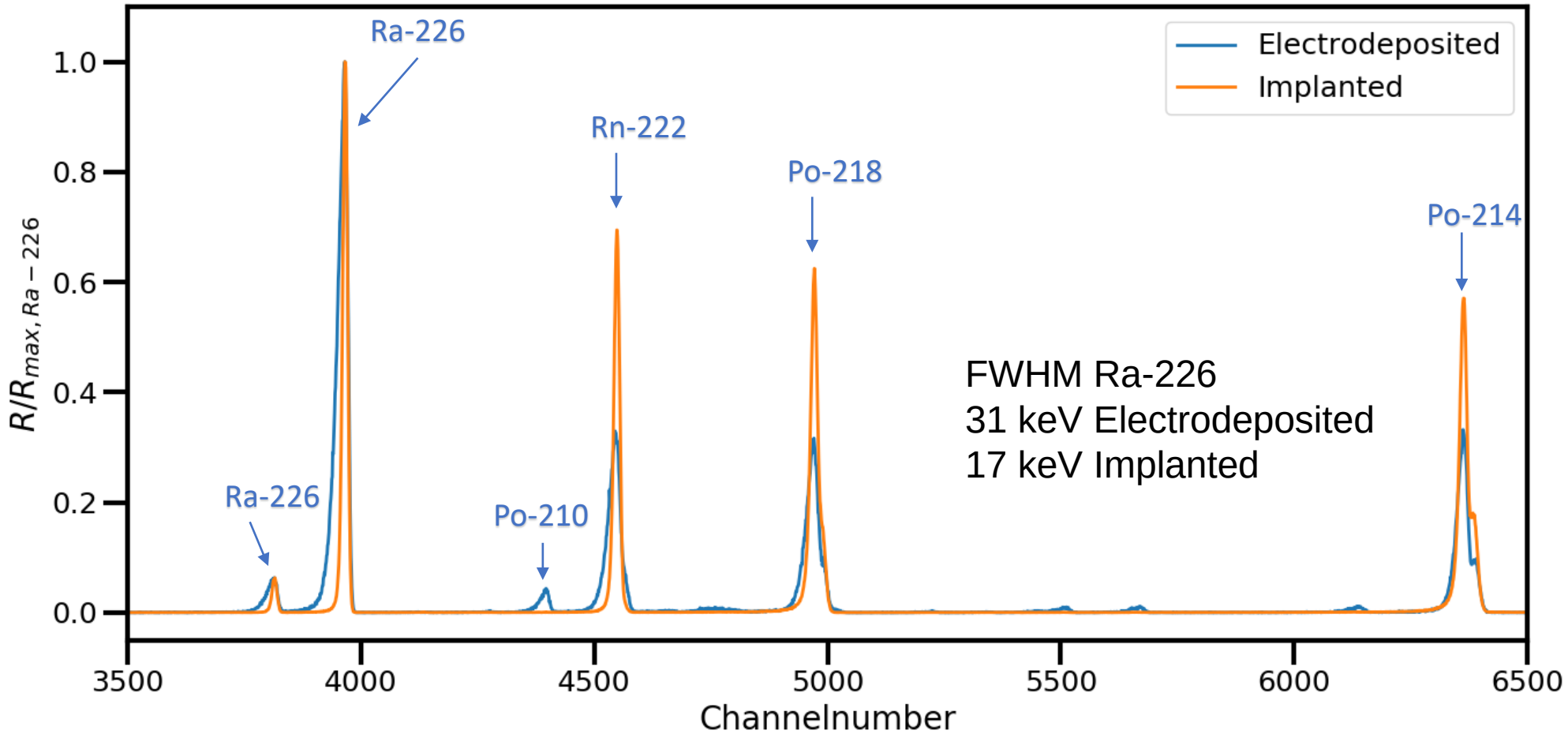


Implantation

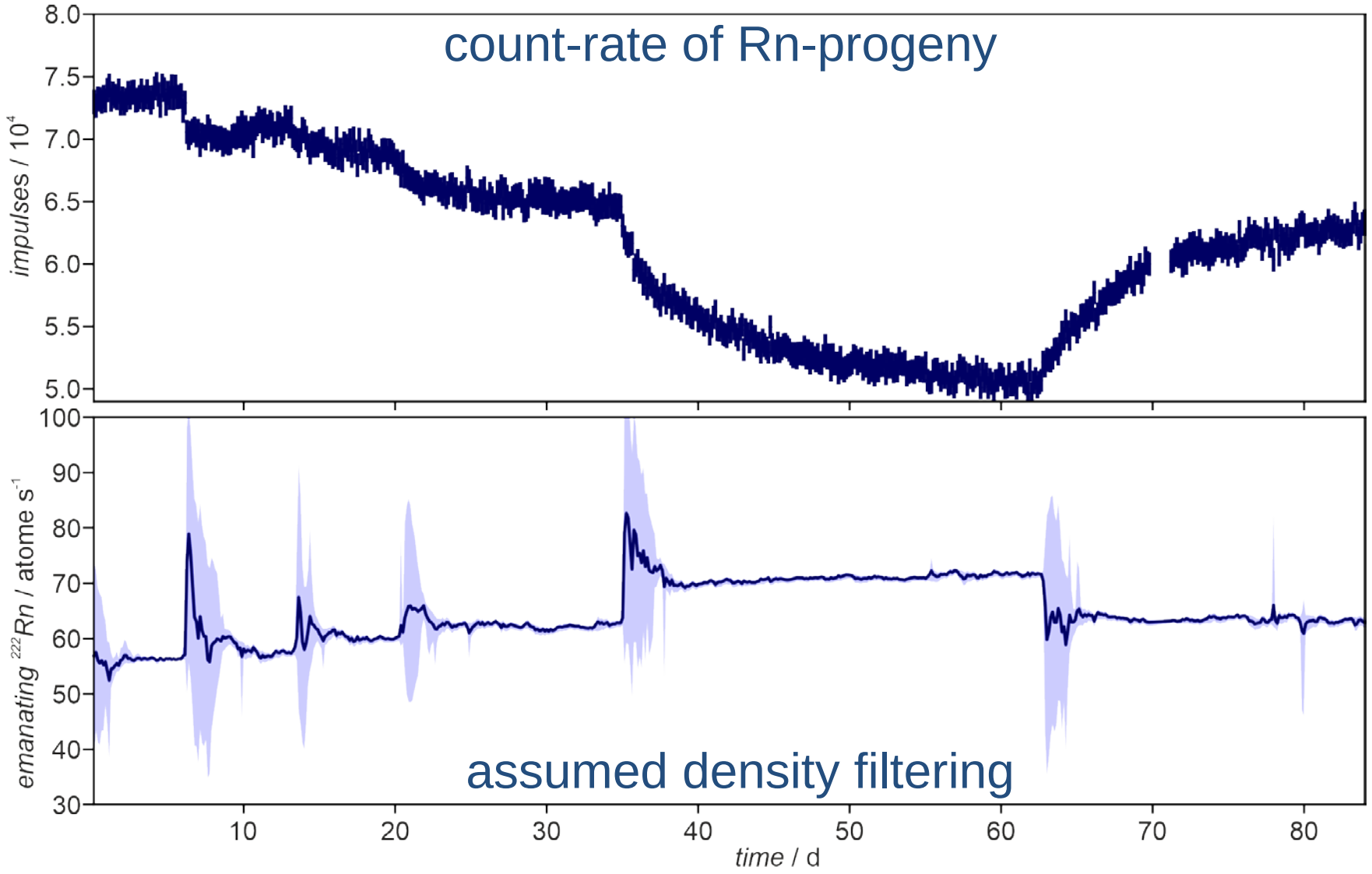


traceRadon

α-Spectra - Comparison



traceRadon – Kalman filter

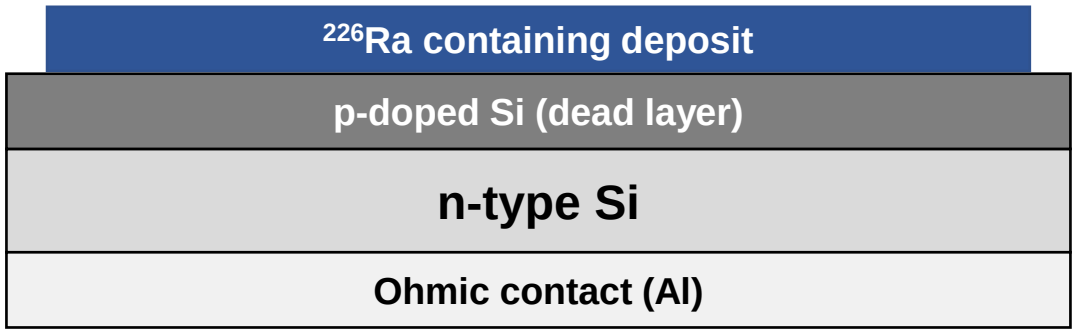


traceRadon – new idea

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

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

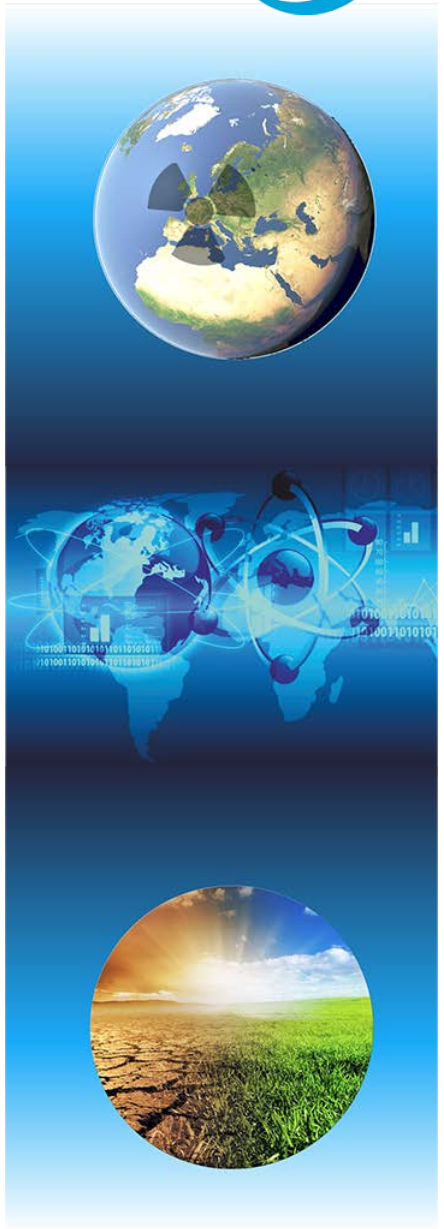
close to 2π sr : ca. 50 % detection efficiency of all α

[1]: SRIM calculation

traceRadon – new idea

Benefits of this design:

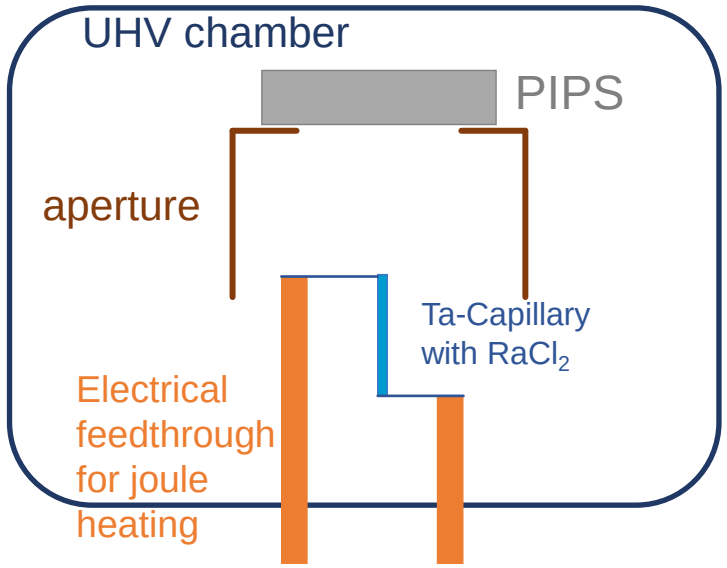
- High efficiency to detect residual ^{222}Rn: Possibility to estimate emanation behaviour on-line and with comparably high temporal resolution (1000 s)
  - Possibly absolute measurements, to be investigated
- Low background
- Relatively rugged and cheap detectors (1 k€ for bare detector)
- Emanation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

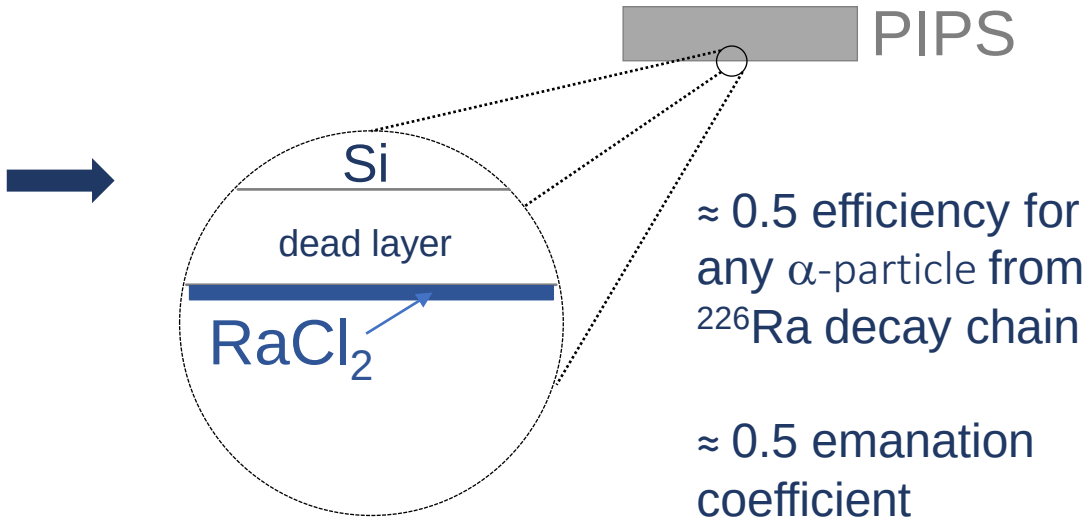


traceRadon – new idea

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

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



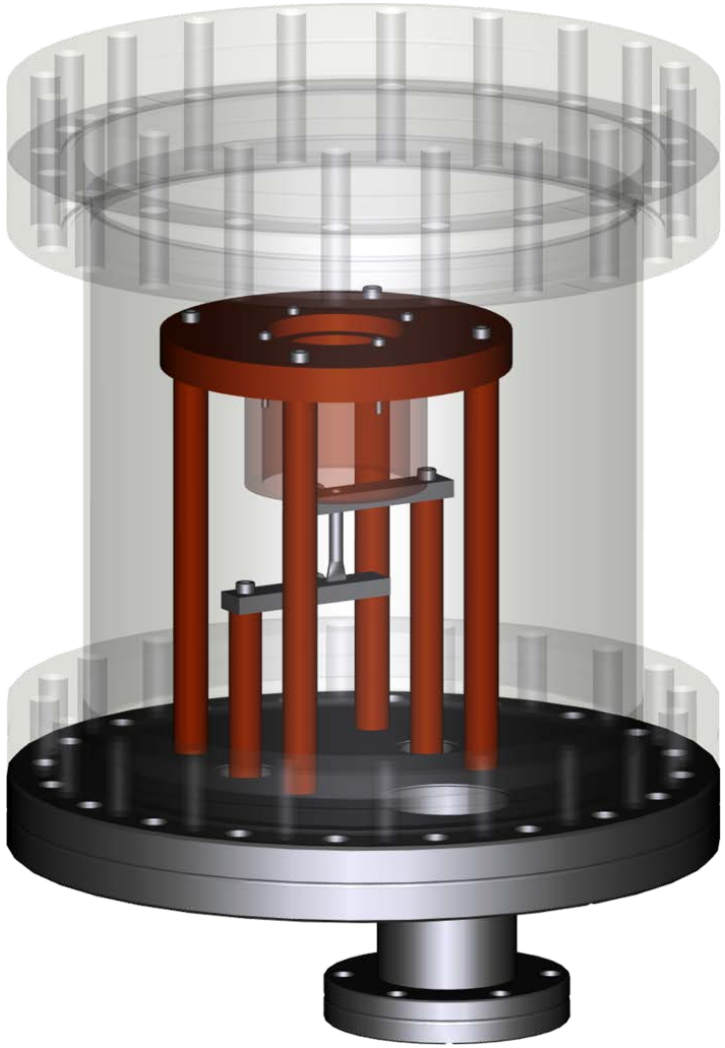


≈ 0.5 efficiency for any α-particle from ^{226}Ra decay chain

≈ 0.5 emanation coefficient

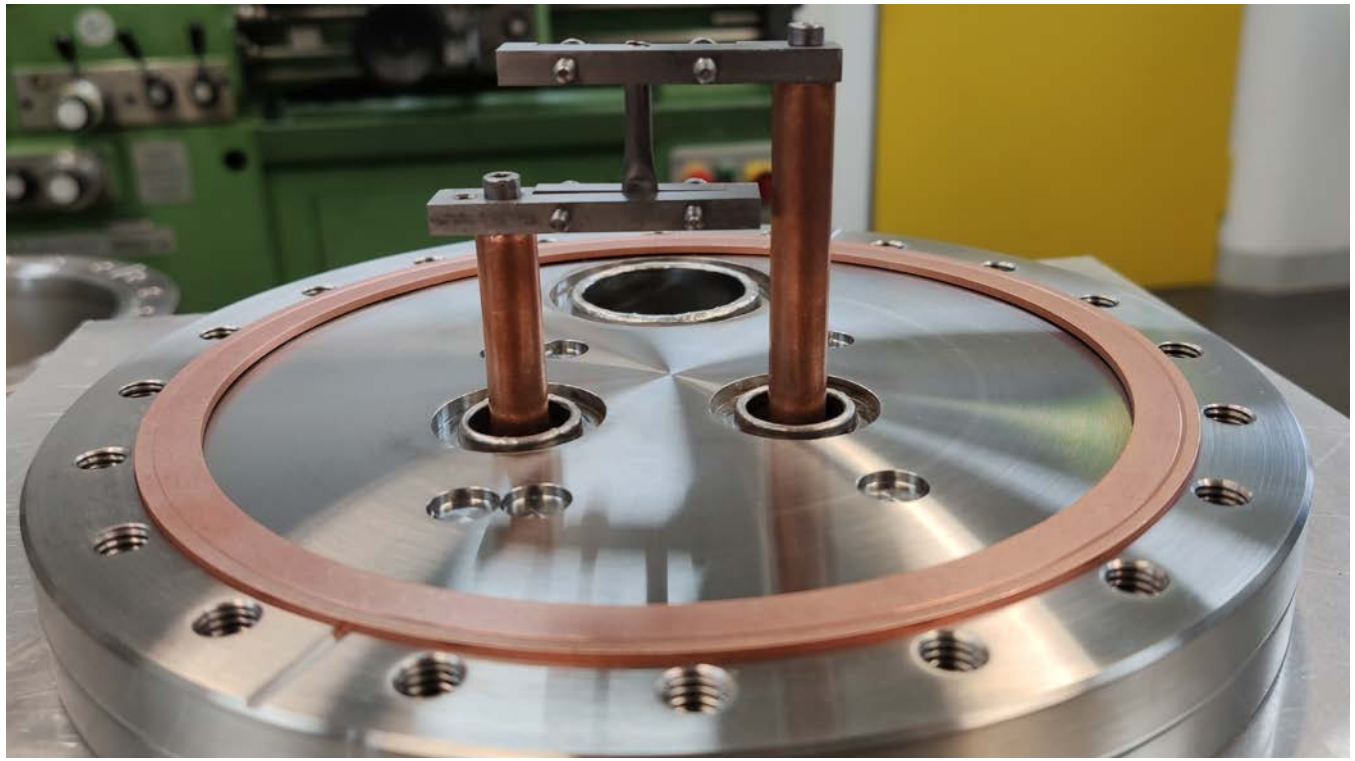
traceRadon – new idea

Primary, on-line emanation sources model and simulation

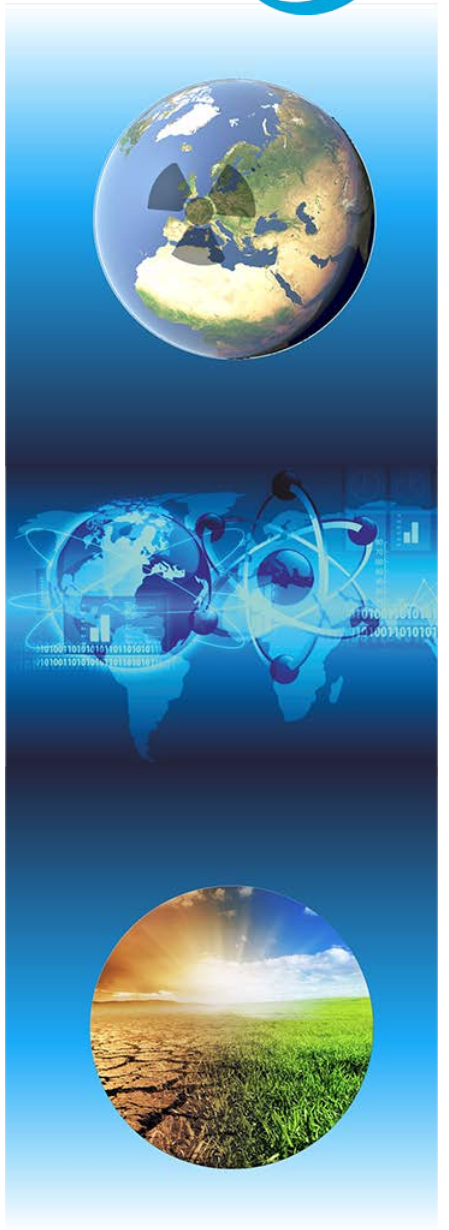


traceRadon – new idea

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

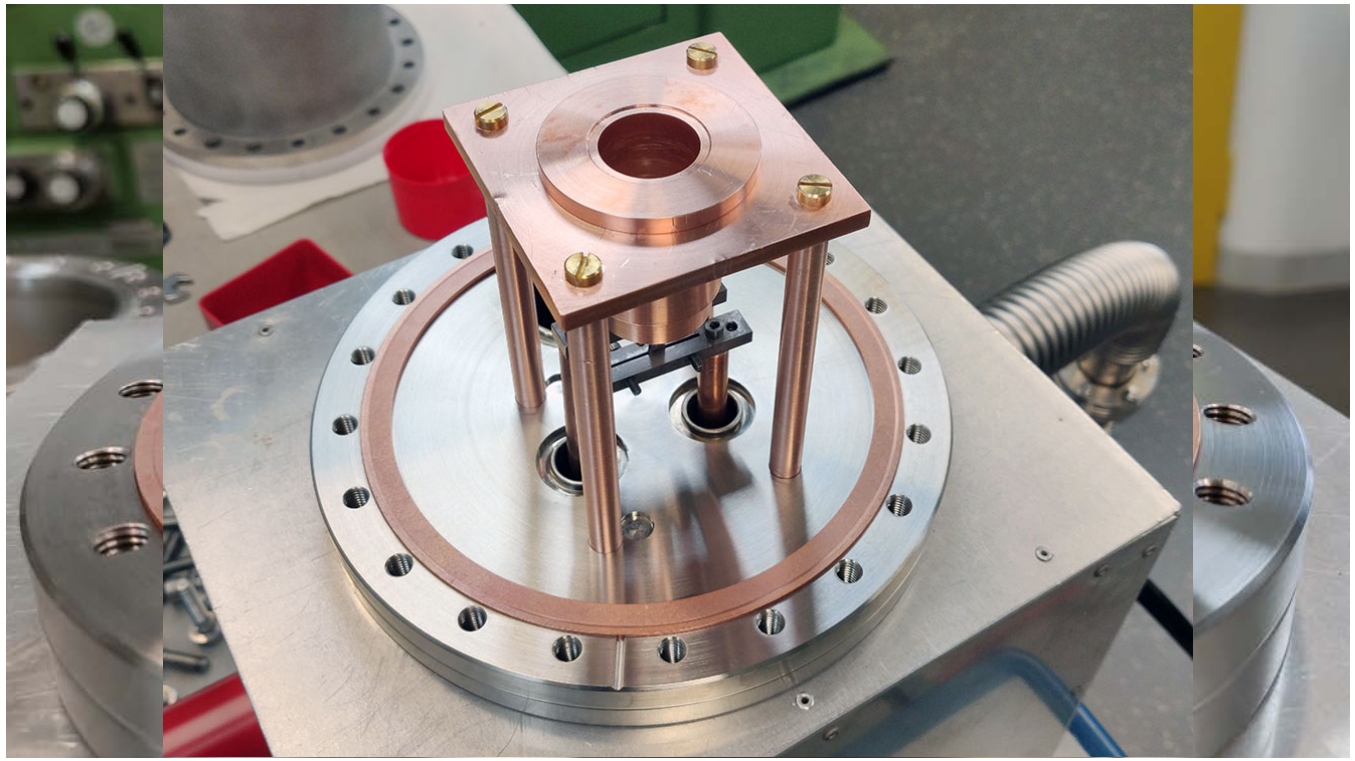


- < 10^{-6} hPa
- Low vapor-pressure materials (Ta)
- est. up to 2000 °C



traceRadon – new idea

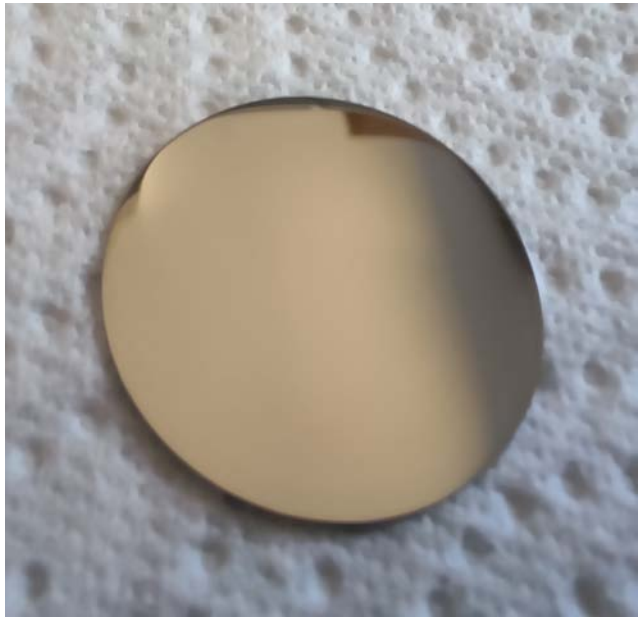
Primary, on-line emanation sources first realisation of suitable thermal PVD setup



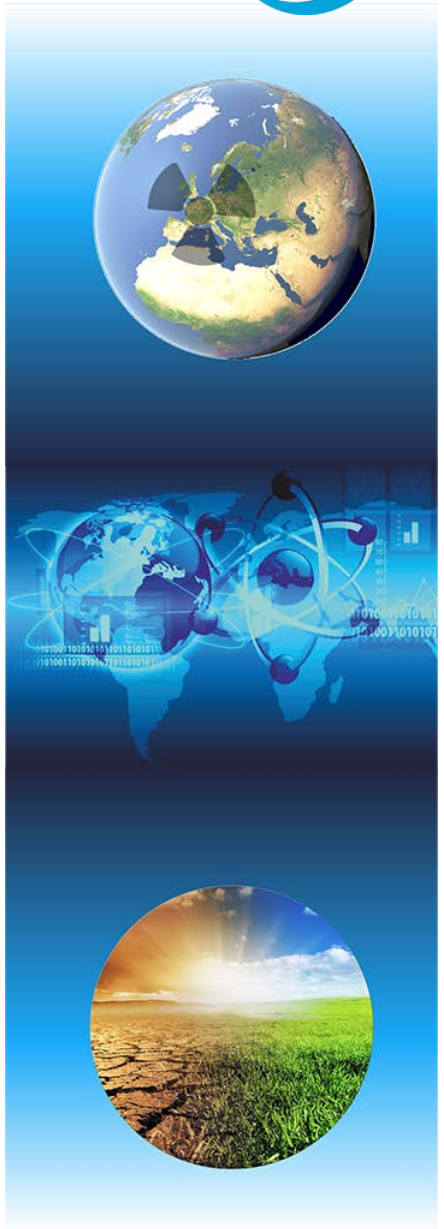
- < 10^{-6} hPa
- Low vapor-pressure materials (Ta)
- est. up to 2000 °C

traceRadon – new idea

Deposition of ^{226}Ra from $Ra(NO_3)_2$ onto stainless steel and p-type Silicon

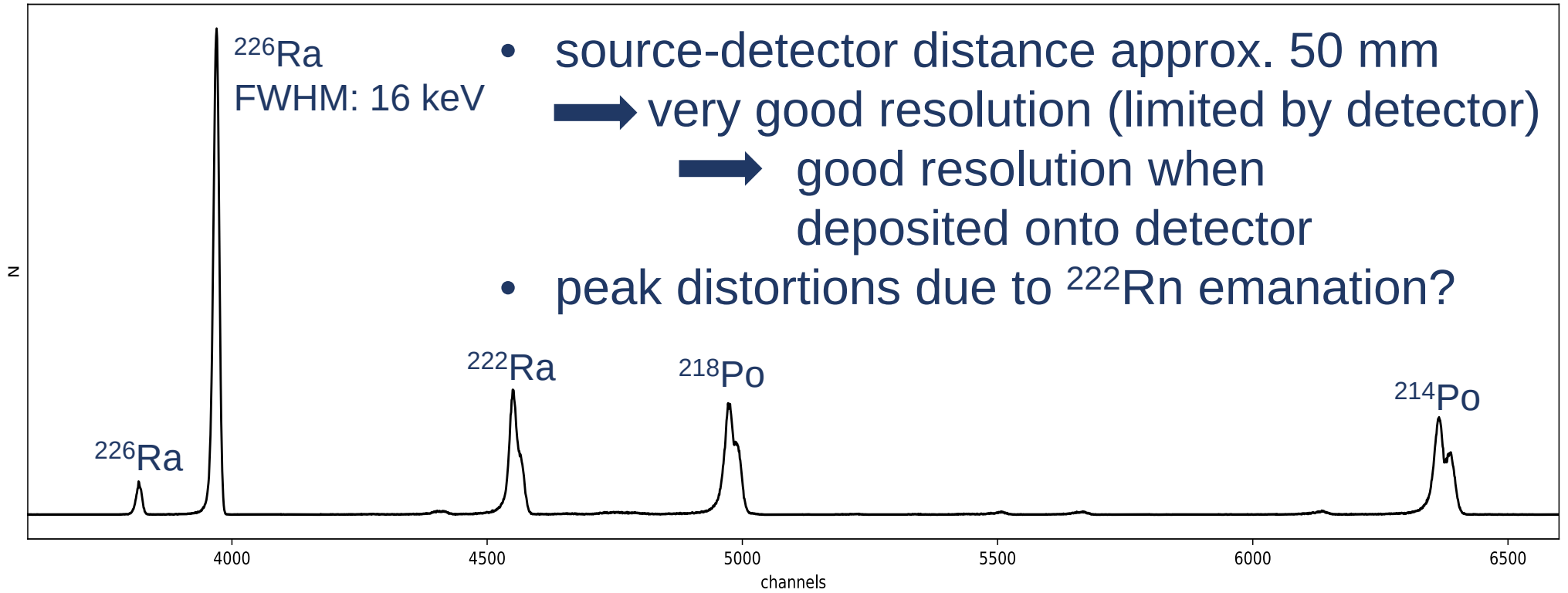


- 1” p-type Si-wafer with approx. 30 Bq ^{226}RaO
- Deposition efficiency < 10 %
- Deposit invisible to the bare eye



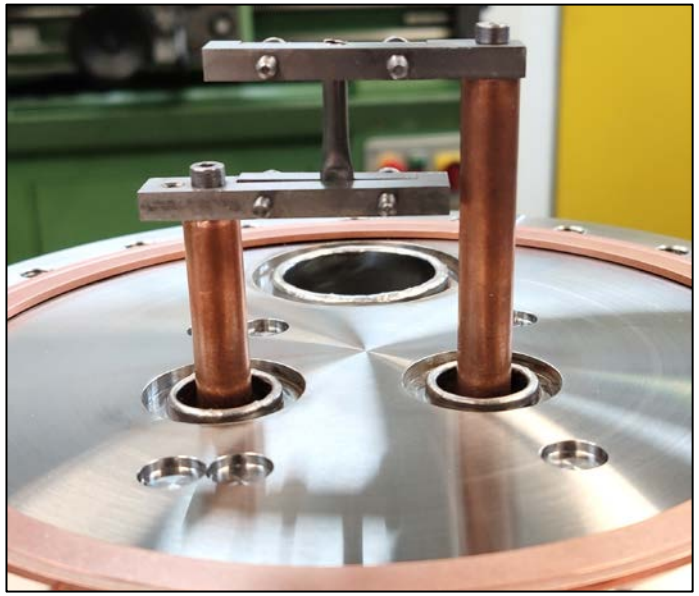
traceRadon – new idea

α-Spectrum: 1” p-type Si-wafer with approx. 30 Bq ^{226}RaO



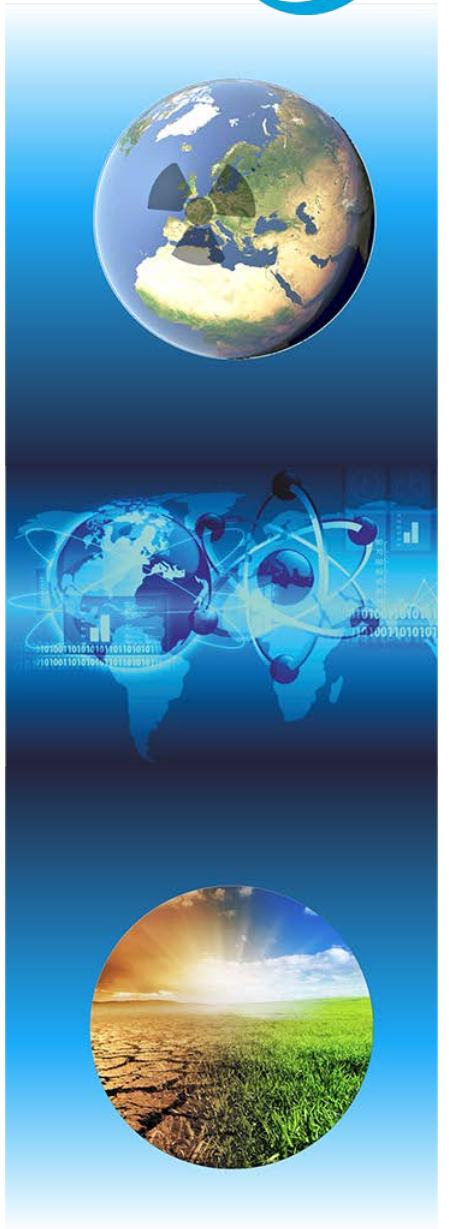
- source-detector distance approx. 50 mm
  ➡ very good resolution (limited by detector)
  ➡ good resolution when deposited onto detector
- peak distortions due to ^{222}Rn emanation?

traceRadon – new idea

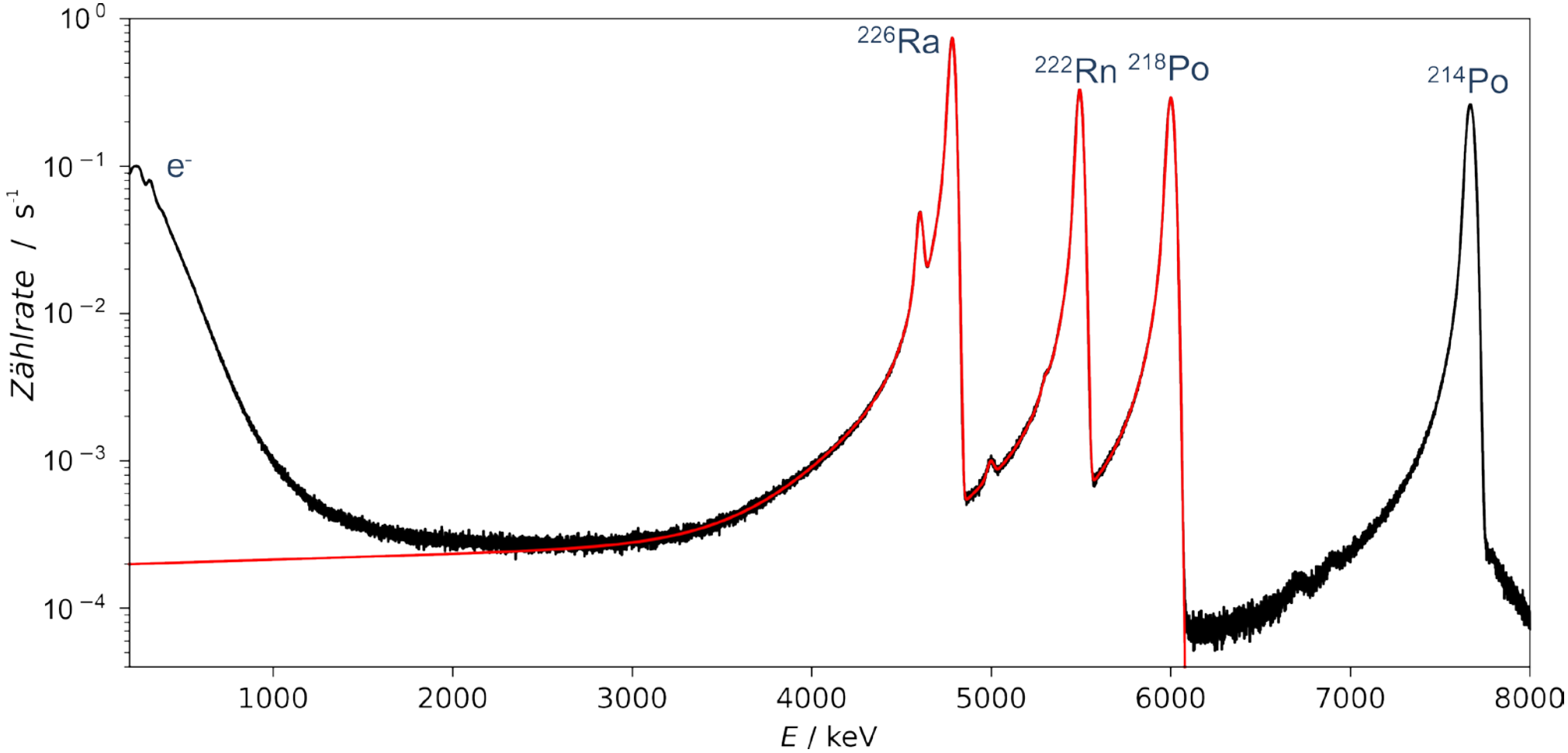


ca. 15 % yield (35 mm distance)
120 W, 15 min
$<10^{-6}$ hPa

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



traceRadon – new idea



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

➡ Model with mixtures of Exponentially modified Gaussians

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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Thanks for you attention!

Thanks to the MetroRADON-project partners:

EMPIR

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Thanks to the traceRadon-project partners:

- Homepage: http://traceRadon-EMPIR.eu/
- researchgate: https://www.researchgate.net/project/19ENV01-traceRadon
- twitter: @traceRadon ; https://twitter.com/traceradon

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