RADICAL – New Research Project at STUK

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GammaRay 2018, Reykjavik, 25.-26.9.2018

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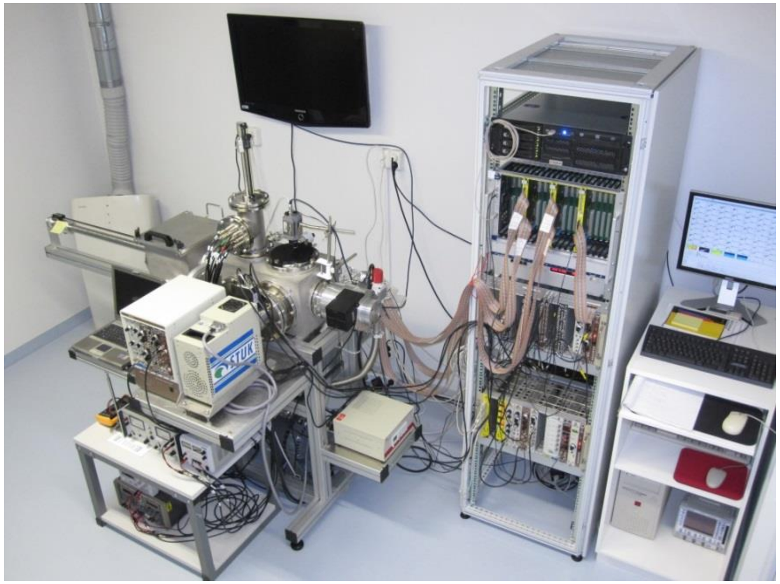
Introduction

- Objective of the RADICAL project is to increase the sensitivity of the radiation measurement systems used in STUK.
- The main themes and keywords associated with the research are: multi-parameter data acquisition, digital electronics, list-mode data standardization and analysis algorithms and techniques.
- RADICAL has three distinct but synergetic work packages.
- RADICAL continues the research done at STUK approx. 2007-2014.

Introduction

- RADICAL is a collaborative research project between STUK and the University of Jyväskylä.
- Three and a half year project (2018-2021).
- Transfer of knowhow and people between institutes (STUK, University of Helsinki, University of Jyväskylä).
- Two postdoc researchers from two institutes (University of Jyväskylä and University of Helsinki).
- Existing and new measurement setups will be used.



Past research activities (leading to RADICAL)

- The past work presented here was mainly carried out in STUK’s Security Technology laboratory (defunct) approx. 2007-2014.

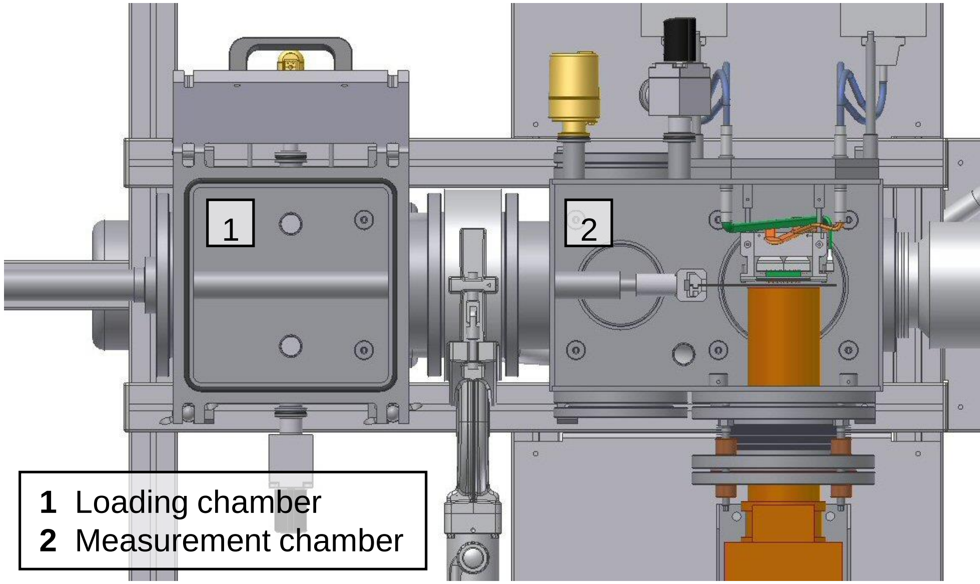
- A key part and the main product of a four year long NDA: Non-Destructive Analysis project was the PANDA device (Particles And Non-Destructive Analysis).

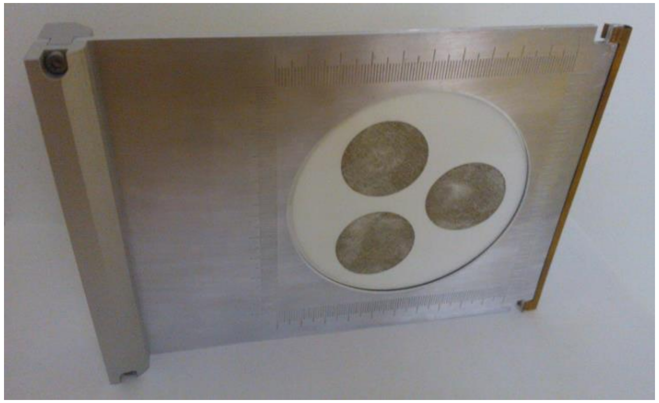
The PANDA device

- When designing PANDA the goal was to make an instrument that could serve as a permanent setup for sample measurements and also as a development platform to test new ideas and techniques.
- Methods used in basic research, such as list-mode data acquisition, position-sensitive detectors and coincidence techniques are applied in the PANDA device.
- Main focus was on hard-to-detect alpha-decaying nuclides.

The PANDA device

- Two vacuum chambers
  - Loading chamber
  - Measurement chamber
- Chambers separated with a gate valve.
- Samples are transported from the Loading chamber to the Measurement chamber using a linear feedthrough.
- Measurement chamber has two Measurement Positions (MP1 and MP2) for different detector setups.
- Vacuum made using a turbomolecular pump and two scroll pumps.
- Precision valves are used to control pumping and venting speeds.





Sample holder (for air filter)

PANDA: Measurement Position 1

Detectors

- HPGe detector (BEGe = Broad Energy Germanium) for gamma- and X-rays

  - crystal diameter 70 mm and thickness 21 mm
- Position-sensitive DSSSD (Double-Sided Silicon Strip Detector) for alpha particles

  - Area $(64\ mm)^2$, thickness 300 µm

  - 32 vertical and 32 horizontal strips

    -> 1024 “pixels” with size $(2\ mm)^2$
- The detectors are facing each other

  - Distance adjustable, typically 8 mm

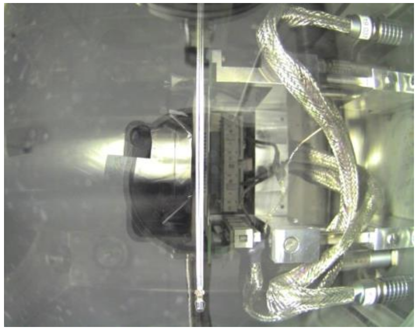
  - Samples measured between the detectors

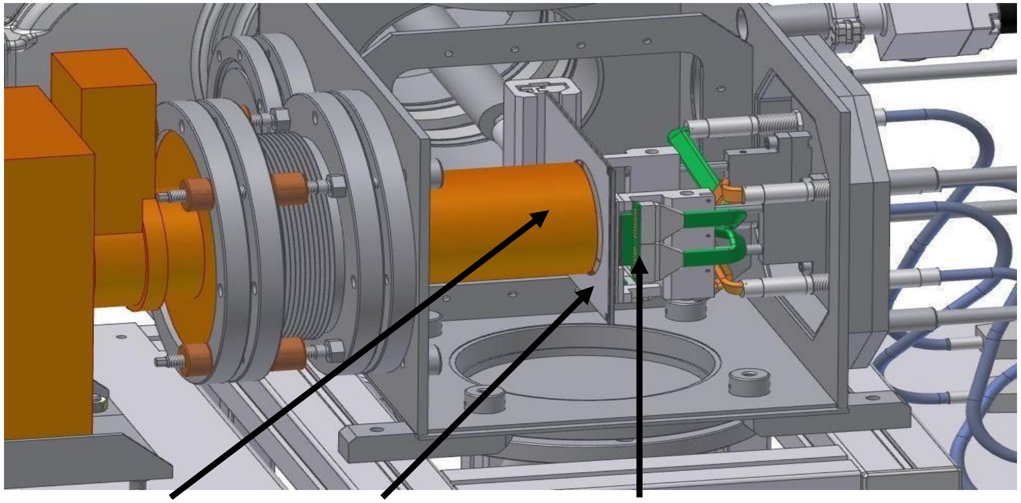
Data acquisition

- List-mode data acquisition

-> events registered individually and time stamped

- Spectra can be created afterwards





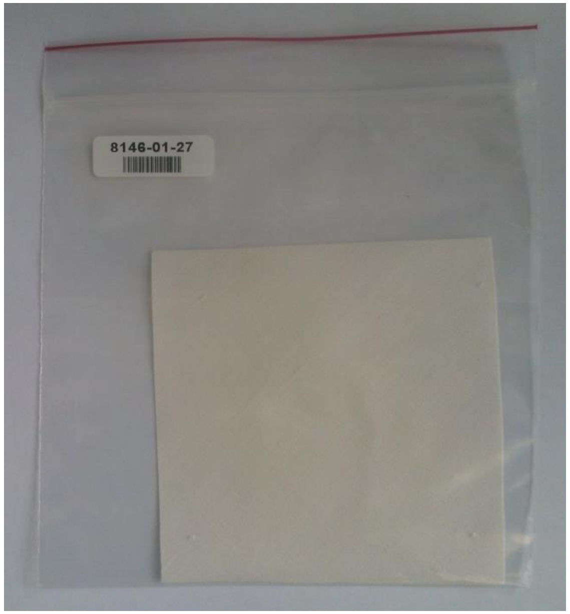
PANDA: Measurement Position 1

Example 1: Swipe sample

- Different kinds of swipes are commonly used to collect samples from surfaces.
- IAEA provided STUK reference and unknown swipe samples for the testing of the coincidence setup of MP1.

- Analysis of a reference swipe is presented here.
- The swipe contained 10 ng of Pu and 1 µg of U (and also ^{241}Am).
- The Pu-240/239 ratio was 0.132.
- Swipe area approximately 10 cm x 11 cm.

- Swipe sample measured twice with in MP1.
- In the second measurement a 300 µm thick Ti foil was placed between the swipe and the BEGe detector.

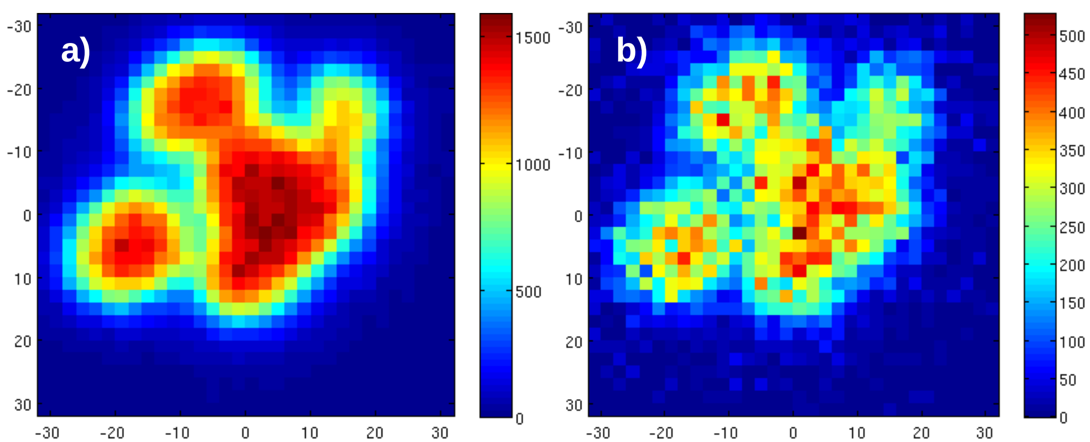


J. Turunen et al., Novel spectrometric approach to non-destructive characterization of safeguards samples, ESARDA Bulletin 45 (2010) 23-28

PANDA: Measurement Position 1

Example 1: Swipe sample, alpha particle hit map

- The position-sensitive DSSSD detector can be used to make alpha particle hit maps showing the distribution of radioactive materials in the sample.
- In this case, we can see that the radioactive material is spread on a large area in the swipe and it is not, for example, a single particle.
- Setting a gate to the 59.5 keV gamma-ray peak of ^{241}Am we get the alpha hit map for this nuclide alone. This shows that the distribution of ^{241}Am in the sample follows the overall distribution.

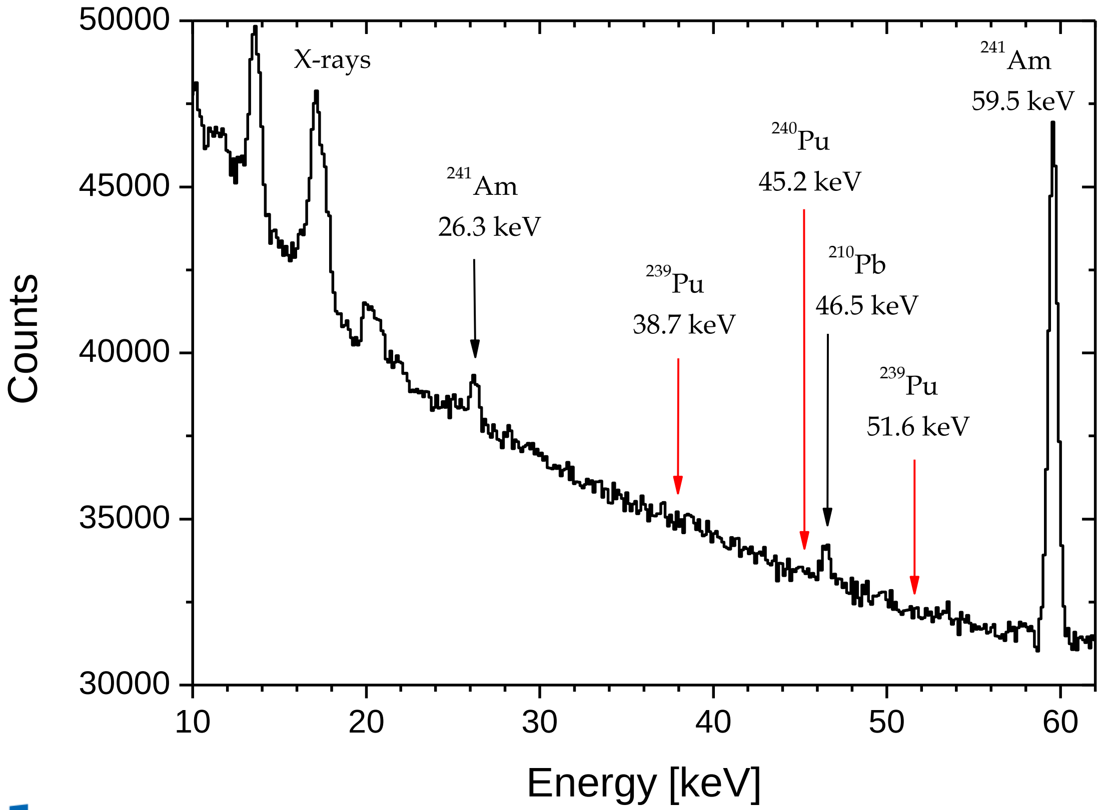


a) Alpha particle hitmap of a swipe sample.
b) 59.5 keV (^{241}Am) gamma-gated alpha particle hitmap.

PANDA: Measurement Position 1

Example 2: Determination of Pu isotope ratio from a nuclear bomb particle

- Comparison of singles gamma-ray and alpha-gated gamma-ray spectra



PANDA: Measurement Position 1

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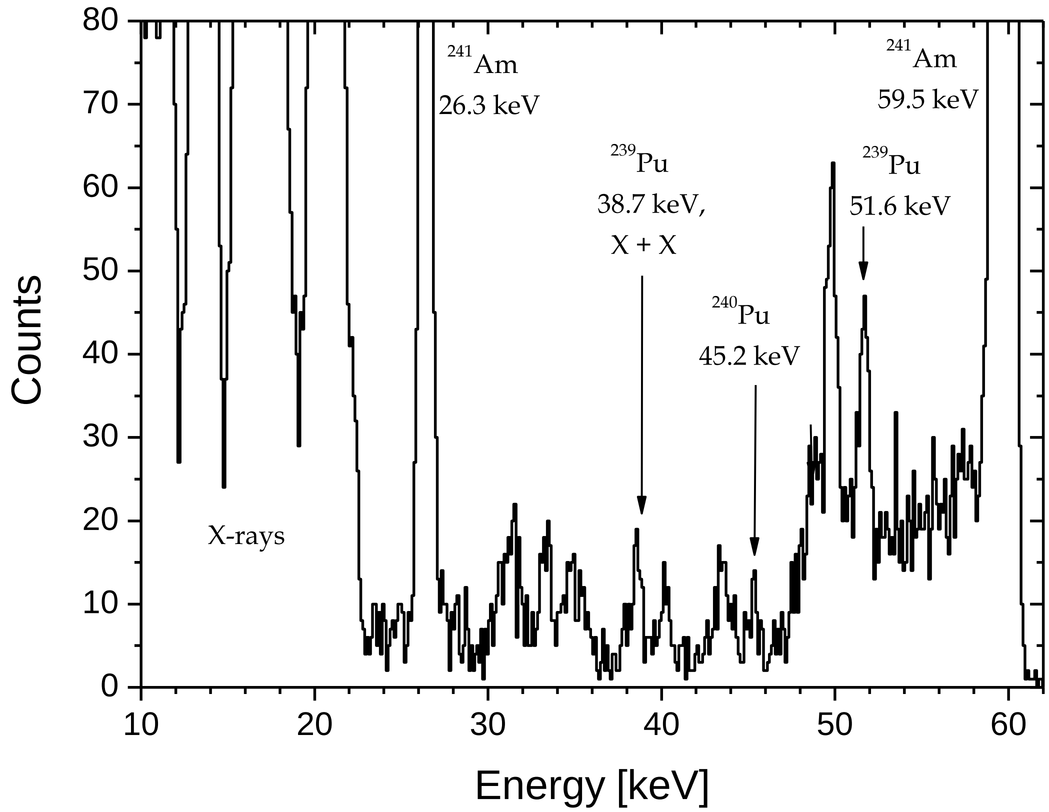
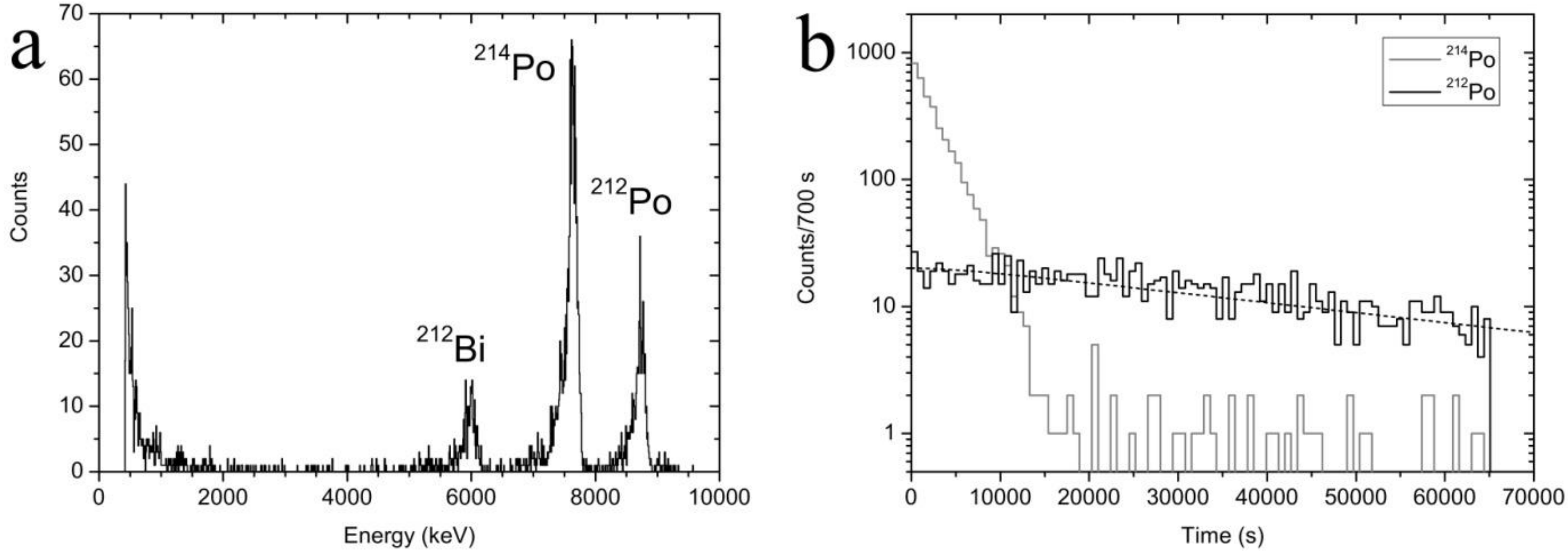


PANDA: Measurement Position 1

Example 3: Time behaviour of different nuclides

- Aerosols from indoor air collected on thin foils. These aerosols contained radon progenies.
- It was studied that the radon progenies remain in the surface of the foils even in vacuum conditions if the foil is not manipulated.

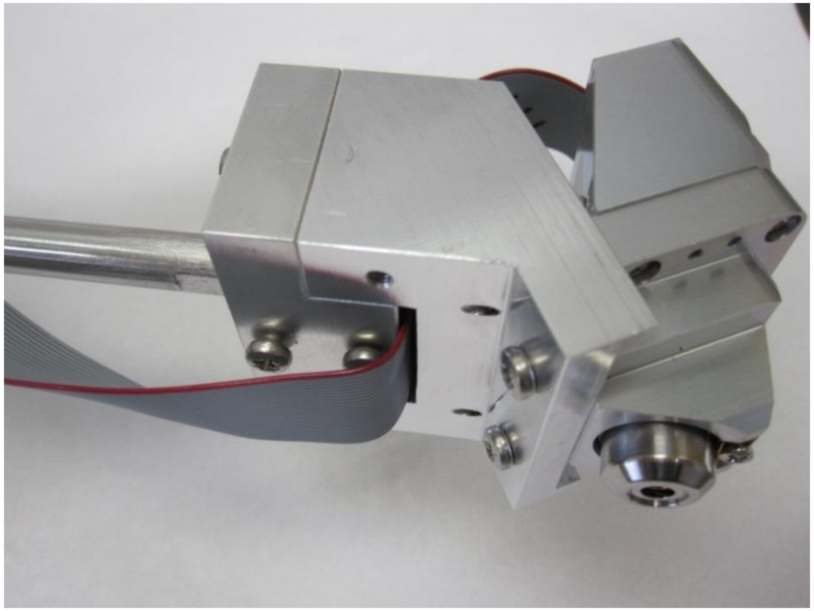


J. Turunen et al., Collection and behaviour of radon progenies on thin Mylar foils, Radiation Measurements 46 (2011) 631

PANDA: Measurement Position 2

SDD detector

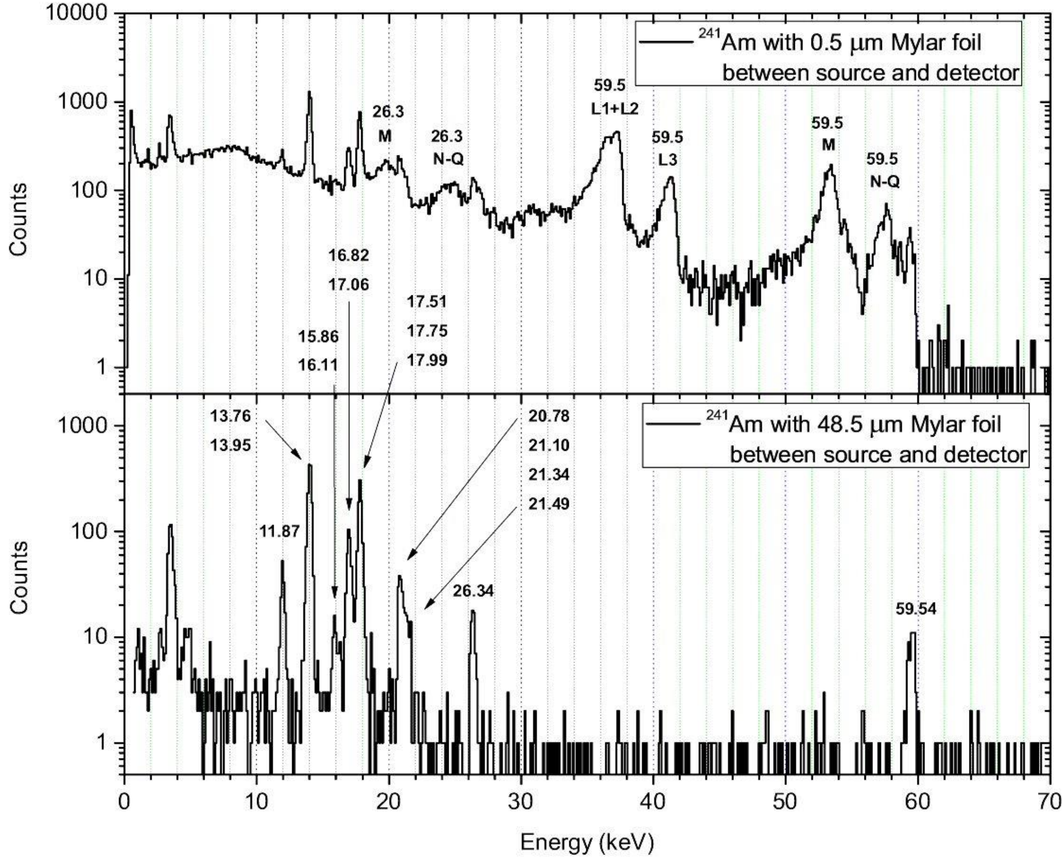
- MP2 hosts a prototype silicon drift detector (SDD)
  - Area 10 mm^2 (7 mm^2 when collimated)
  - Thickness 450 µm
- Can be used to detect conversion electrons and low energy X-rays
- Operates at -10 °C temperature
  - Does not need LN cooling
- Excellent energy resolution
  - 150 eV @ 5.9 keV Mn K(α)
- Useful energy range approx. 0.3-30 keV



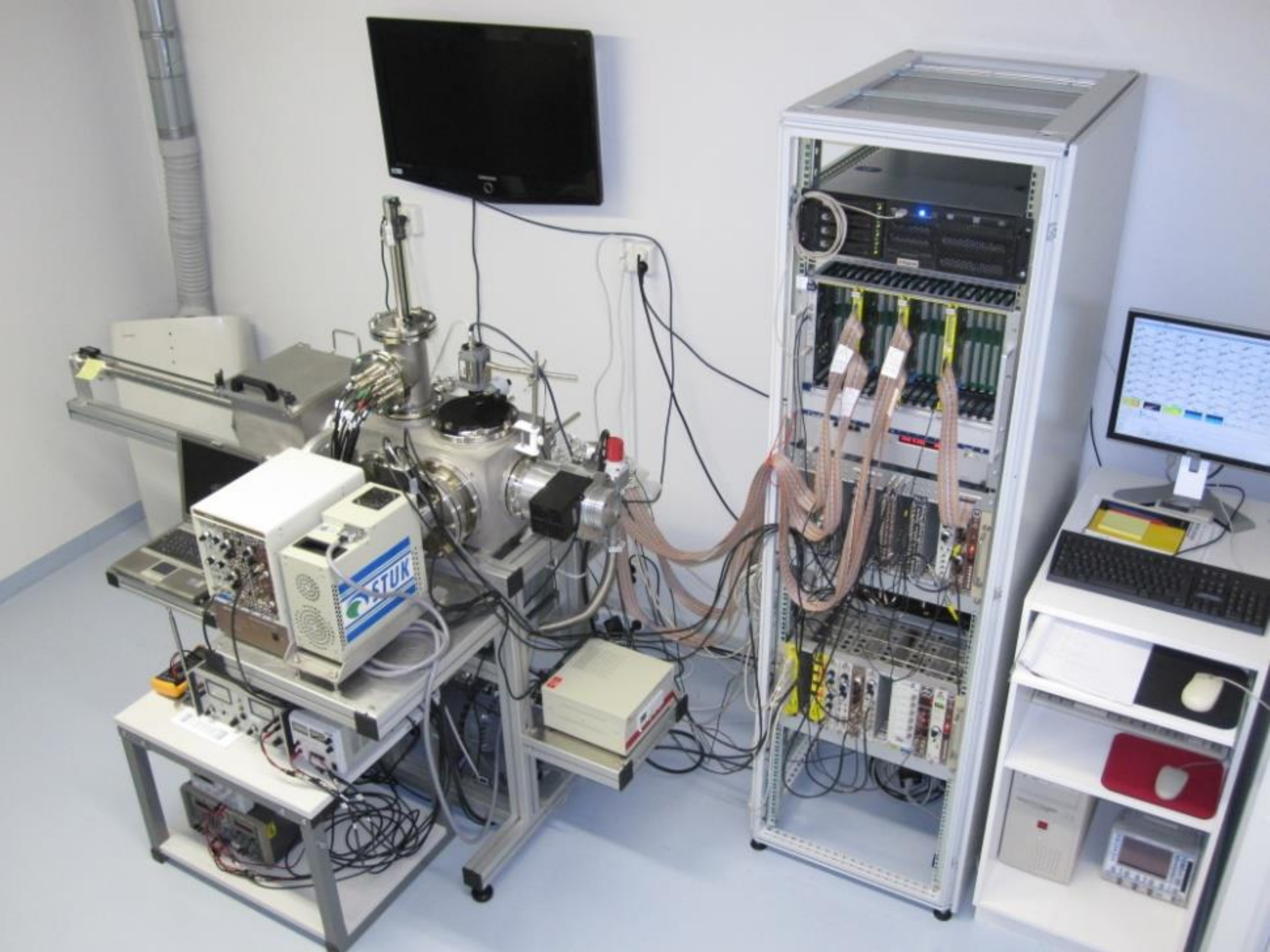
PANDA: Measurement Position 2

Example 4: Measurement of a ^{241}Am sample with the SDD

- A thin ^{241}Am sample measured twice in MP2.
- Difference in the two measurements was the thickness of Mylar foil between the sample and detector (0,5 µm and 48,5 µm).
- If only the X-rays (photons) are of interest the conversion electrons and beta background can be removed.
- The energy resolution of the SDD:n is much better than of the BEGe detector (FWHM 272 keV vs. 595 keV @ 13.9 keV).



J. Turunen et al., Comprehensive radioassays of samples using the PANDA device, Nuclear Instruments and Methods in Physics Research A 678 (2012) 78-82

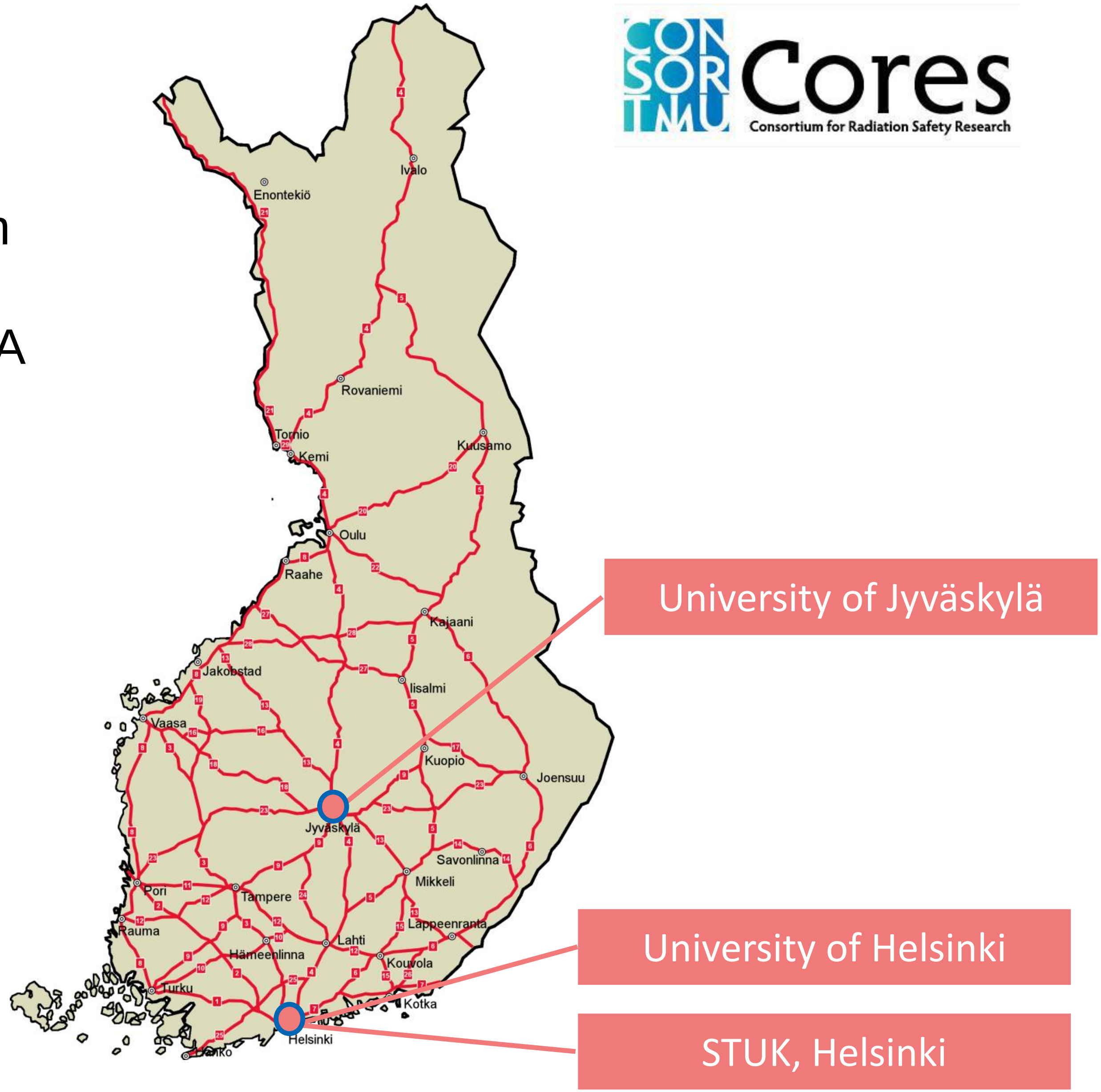

STUK

MiniPANDA

- Based on the experiences gained with the PANDA device a simplified measurement setup ”MiniPANDA” was constructed.
- Measurement geometry similar as in PANDA: BEGe detector and Si detector face-to-face.
- Samples measured at normal air pressure and inside a lead castle.
- At first coincidence data collection done using hardware. Updated to digital system later.

Cores
Consortium for Radiation Safety Research

- After the big cuts in STUK's research funding, the PANDA device was moved from STUK to the University of Jyväskylä



SÄTEILYTURVAKESKUS
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RADIATION AND NUCLEAR SAFETY AUTHORITY

RADICAL

- RAdiation Detection In Coincidence And List mode

RADICAL: WP1

- Development of analysis and QA/QC tools, performing detector simulations and integration of multi-parameter state-of-the-art data acquisition systems based on digital nuclear electronics

RADICAL: WP1

- Literature evaluation and selection of digital electronics solution – (specifications, cost, support from manufacturer and possibility to modify pulse-filtering firmware)
- Experimental testing and final selection of digital electronics solution – testing resolution/linearity/threshold levels etc. with germanium and silicon detectors
- Implementation of time-stamped data acquisition system – incorporation of digital electronics into measurement setups
- Conversion of output list-mode data into standardized format if not already in it
- Implementation of metadata production and incorporation into data stream or storage

RADICAL: WP1

- Evaluation and selection of simulation and calibration tools to be used
- Procurement of needed software licences
- Detector simulations
- Review of commercial off-line analysis and data sorting-software
- Purchase and development of optimal off-line data sorting algorithms and analysis routines (traceability of sorting conditions is also important), development of QA/QC tools is part of this task
- Integration of final results into STUK’s data management systems

RADICAL: WP2

- Position- and radiation-type sensitive analysis and imaging of environmental samples

RADICAL: WP2

- Construction and testing of current PANDA at JYFL-ACCLAB
- Addition and testing of beta particle detectors
- Addition and testing of new conversion electron detectors
- Test measurements of archived aerosol filters and other environmental samples
- Imaging of archived aerosol filters with the Helium Ion Microscope at JYU
- Possible upgrade of electronics and data acquisition system (WP1)
- Measurements, analysis and dissemination of results with final system

RADICAL: WP3

- Active suppression and multi-parameter data acquisition in low-background sample analysis

RADICAL: WP3

- Simulation and optimization of detector geometry for new low-background measurement system (WP1)
- Procurement and testing of scintillator (active shield) detectors
- Building of the complete low-background setup
- Integration of electronics and data acquisition system to new setup (WP1)
- Update and calibration of Mini-PANDA device (data acquisition part in WP1)
- Investigation of use of silicon detector coincidence and effect on MDA (test measurements with updated PANDA and Mini-PANDA devices)
- Measurements, analysis and dissemination of results with PANDA, Mini-PANDA and final low-background system

RADICAL – current status

- First postdoc researcher Timo Hildén started to work on the RADICAL project 1.8.2018.
- The second one Hussam Badran will join the project on 1.10.2018.

- Testing of the PANDA device has already started at JYU.
- Currently part of WP3 equipment already procured and assembled at STUK's gamma laboratory.
- Simulation tools are being built.

Conclusions

- The RADICAL project started summer 2018 and it should be completed by the end 2021.
- The objective of the project is to improve the sensitivity of various radiation measurement systems used in STUK.
- The goal is to get fully operational laboratory systems that can be used in normal routine operation.
- After the project it will be evaluated can the techniques and methods be used to improve other measurement systems at STUK.