Non-destructive sample analysis using coincidence technique with the upgraded PANDA device

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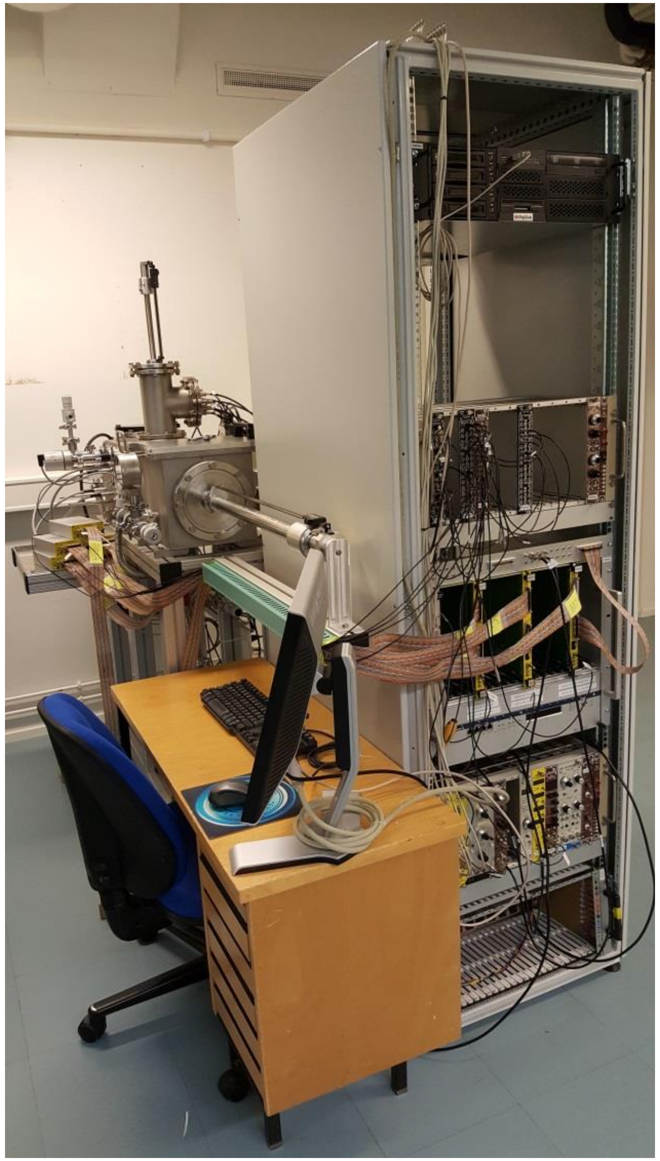
PANDA

- PANDA (Particles And Non- Destructive Analysis) was developed for the analysis of radioactive samples related to nuclear safety, security and safeguards (3S).

- PANDA was designed, constructed and tested in a collaboration of STUK and the Accelerator Laboratory of the University of Jyväskylä (JYFL-ACCLAB).

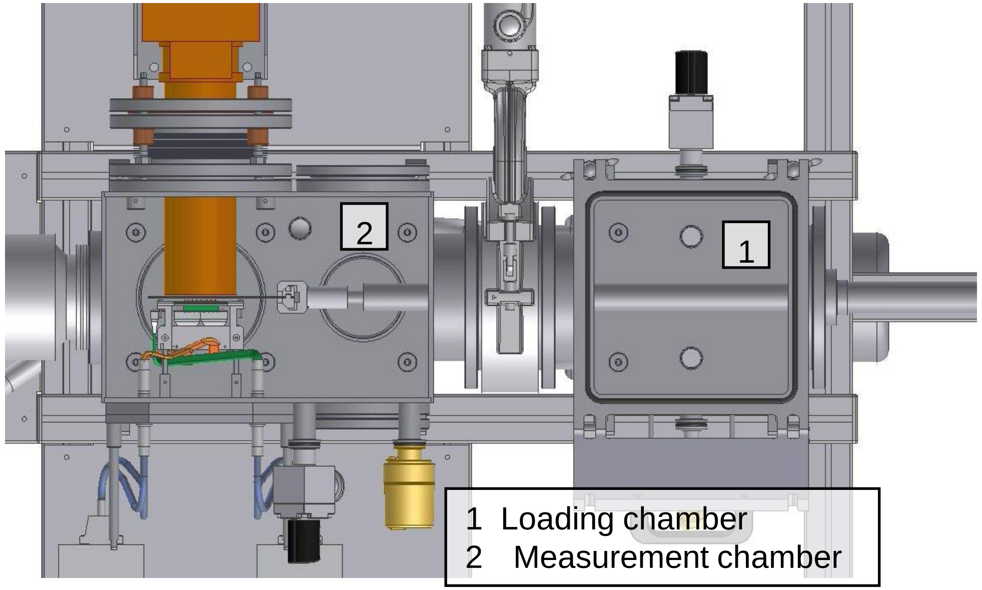
- The PANDA device has been employed in measurements for both research and operational use and presented in several articles.
  - J. Turunen et al, Nucl. Instrum. Methods Phys. Res. A 613 (1) (2010) 177–183.
  - J. Turunen et al, Radiat. Meas. 46 (6–7) (2011) 631–634.
  - K.A. Peräjärvi et al, Environ. Sci. Technol. 45 (4) (2011) 1528–1533.
  - J. Turunen et al, Nucl. Instrum. Methods Phys. Res. A 678 (2012) 78–82.
  - J. Turunen, Univ. Jyväskylä (2013).

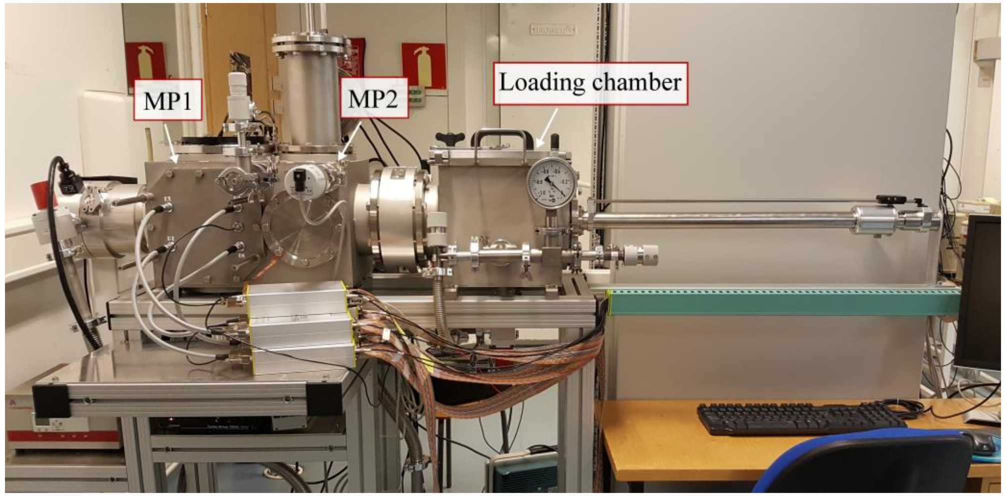
- The PANDA device was re-located from STUK to JYFL-ACCLAB.



PANDA

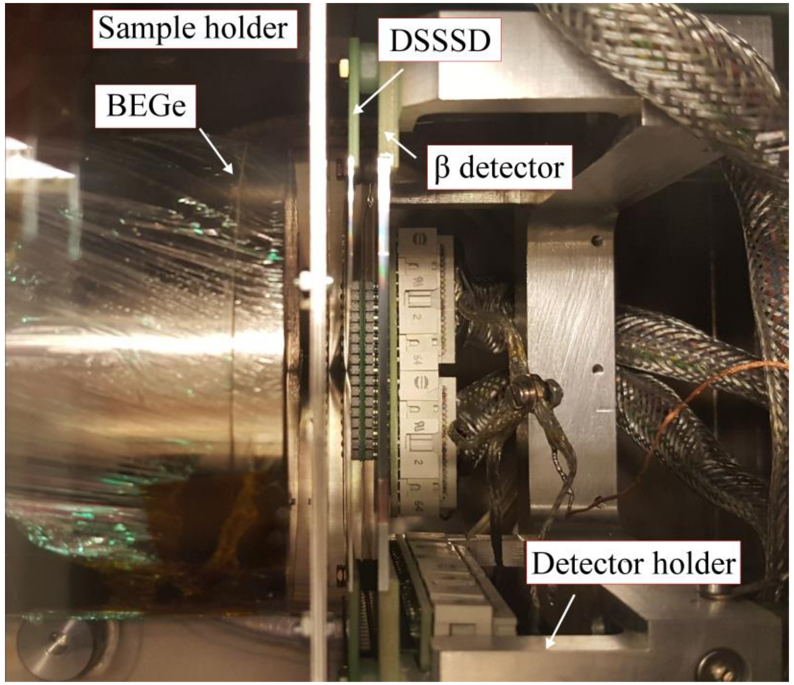
- Two vacuum chambers separated with a gate valve.
  - Loading chamber
  - Measurement chamber
- Samples are transported from the Loading chamber to the Measurement chamber using a linear feedthrough.
- Vacuum made using a turbomolecular pump and two scroll pumps and precision valves are used to control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





Detection setup of the measurement position MP1

- Broad Energy Germanium detector (BEGe) for γ- and X-rays detection
  - Crystal diameter 70 mm, thickness 21 mm
  - 0.5 mm carbon epoxy entrance window
- Position-sensitive Double-Sided Silicon Strip Detector DSSSD for α particles detection
  - Active area of 64 × 64 mm^2 and thickness of 311 µm
  - 32 horizontal (x side) and 32 vertical (y side) strips, yielding 1024 individual pixels with size 2 mm^2
- The detectors are facing each other
  - DSSSD – BEGe distance is adjustable, typically 10 mm
  - Samples measured between the detectors
- Additional thick silicon detector added behind the DSSSD for β particles detection.
  - Thickness 1500 µm
  - Distance between the DSSSD and the β detector is adjustable, set to 3 mm



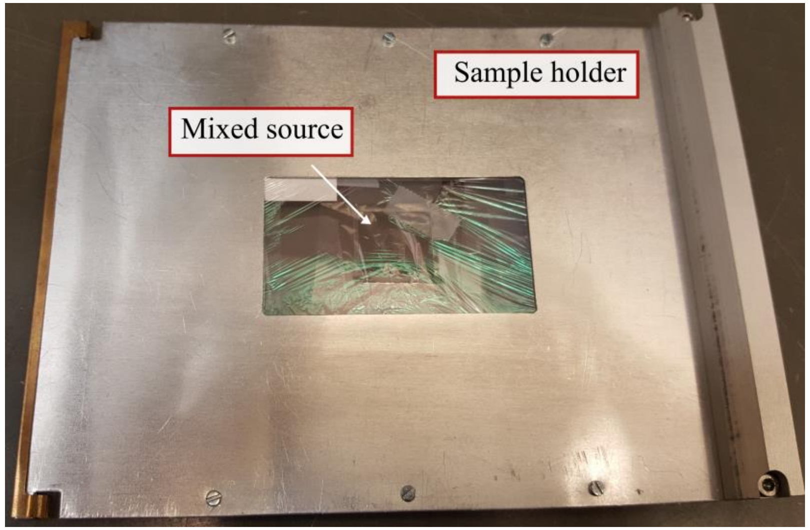
Data acquisition

- List-mode data acquisition
  - Events registered individually and time stamped.
- Spectra can be created afterwards using VISSY software.

Coincidence measurement

- Testing the capabilities of the measurement position MP1 of the PANDA device to perform α−γ and β−γ coincidence measurement.

- Sample:
  - Mixed ^{134}Cs & ^{226}Ra source (decay chain contains both α and β decaying nuclides).
  - Small droplets of radioactive solutions deposited on 8µm thick Mylar foil and cover with 0.5 µm.



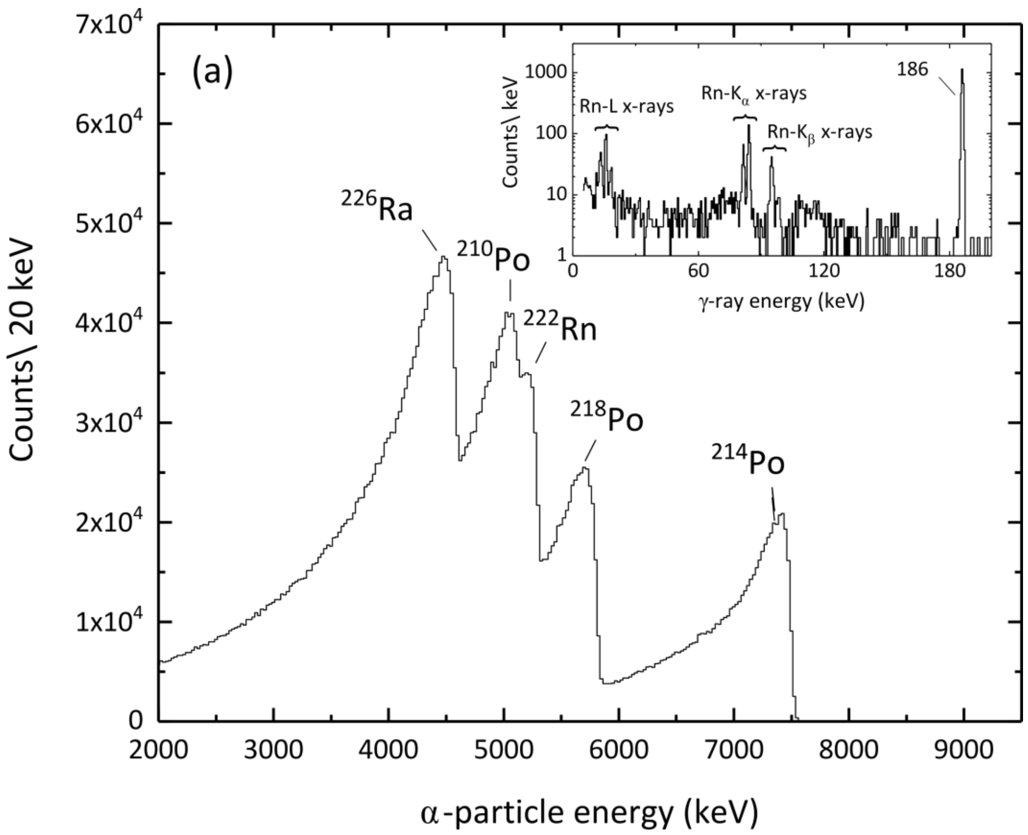


Fig1: (a) Energy spectrum of α-particles detected in the horizontal strips of the DSSSD. The inset shows γ-ray energy spectrum in coincidence with the α-particles energy of ^{226}Ra

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Coincidence measurement

- The sensitivity of the upgraded PANDA device to detect β particles using the DSSSD was improved.
- Testing the performance of the β detector:
  - β − γ coincidence technique.
  - DSSSD - β-detector coincidence measurement.
- Samples:
  - Air filter sample contained ^{137}Cs (used to calibrate the β-detector).
  - Mixed ^{134}Cs & ^{226}Ra source.
- β spectrum can be used to discriminate nuclides with high β-particles energy.

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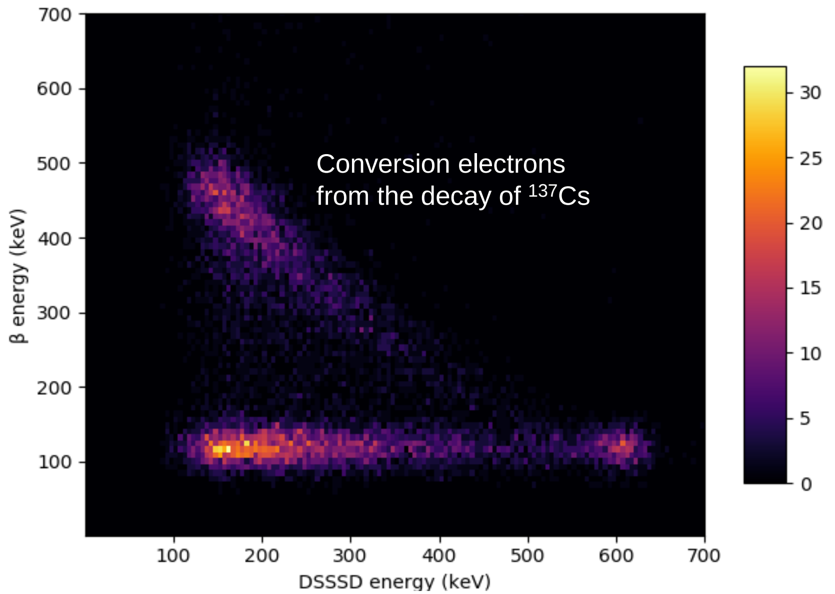


Fig2: DSSSD - β-detector coincidence energy

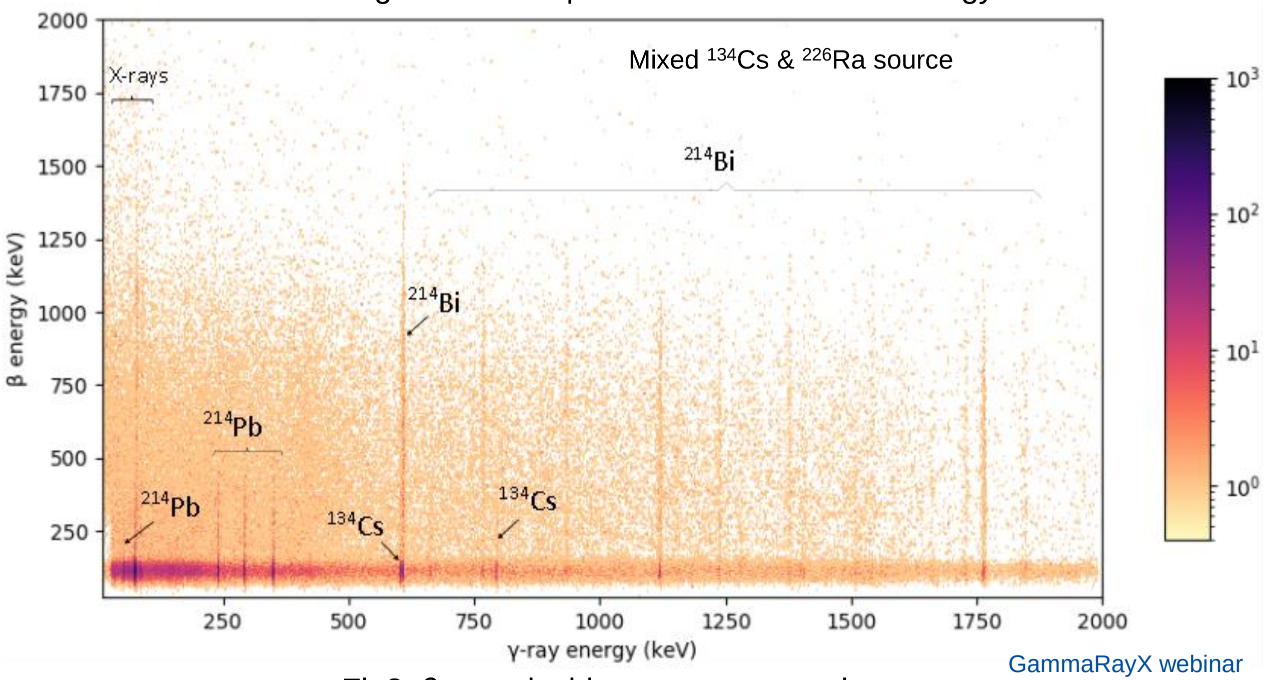


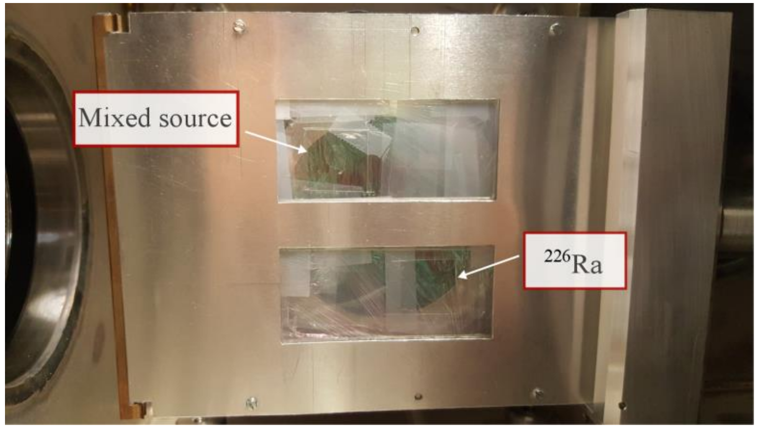
Fig3: β - γ coincidence energy matrix

Position sensitivity

- The position sensitivity of the PANDA device for β particles can be demonstrated with help of the β detector using β - γ coincidence technique.

- Combined sample:
  - Mixed ^{134}Cs & ^{226}Ra source
  - Pure ^{226}Ra source.

- Upgraded PANDA device can now be used for simultaneous position-sensitive α - γ and β - γ coincidence measurements of samples.



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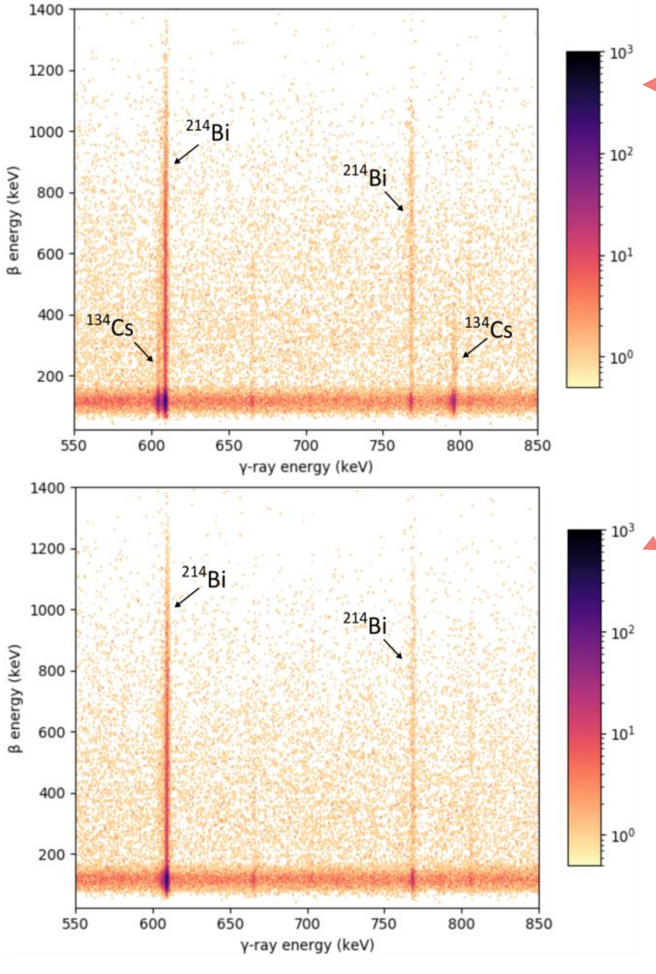


Fig4: β - γ coincidence energy matrix

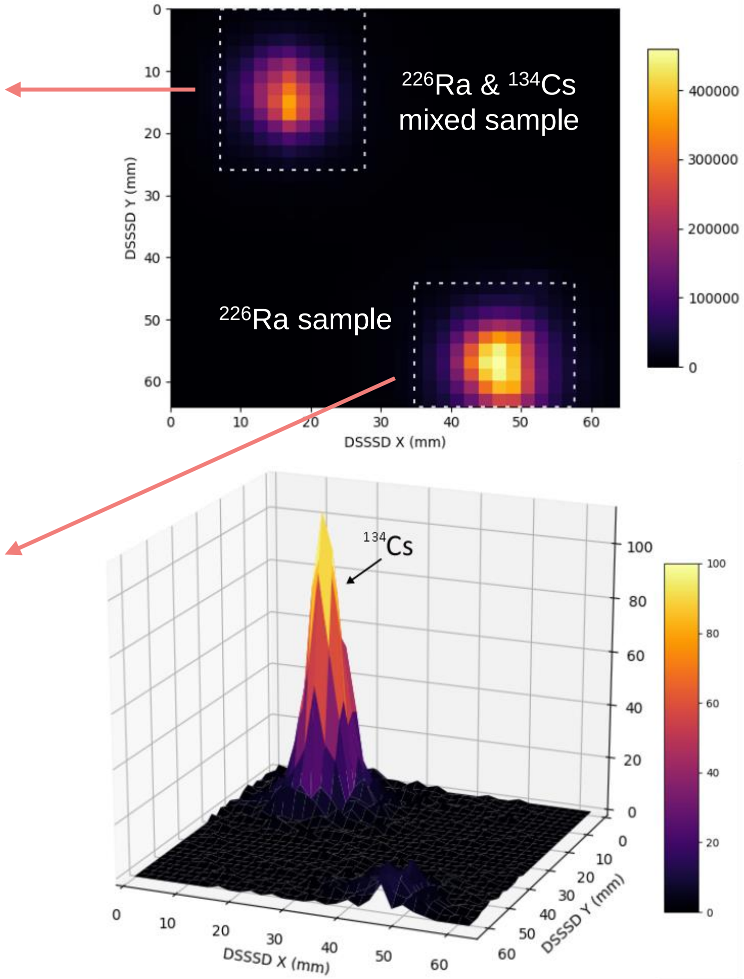


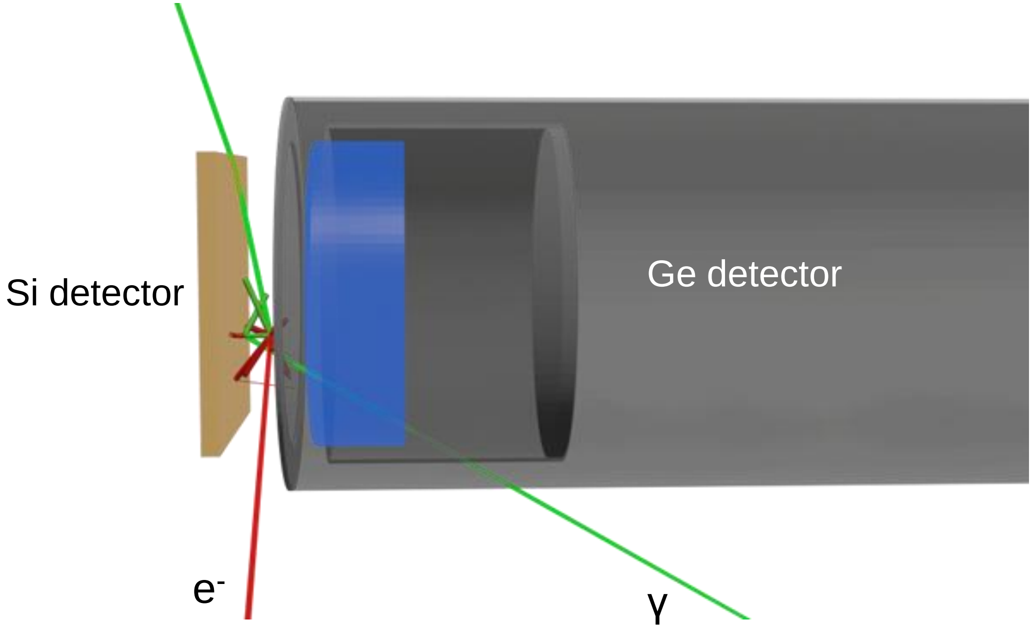
Fig5: X-Y position co-ordinate DSSSD hitmap

Geant4 simulations

- The goal of the Geant4 simulation:
  - To achieve as close as possible to the realistic scenario.
  - To reproduce the experimental situation in detail.
  - To guide in decisions on possible upgrades for the detection system and data analysis techniques in the future.

- The current PANDA setup was modelled using Geant4 based simulation package to explore the full capabilities of the device.

- The simulated PANDA setup includes:
  - All the active elements: DSSSD, BEGe and β detector.
  - All the necessary inactive parts in which the charged particles and gamma rays could interact: BEGe entrance window, dead layers of the silicon detectors, sample material, sample holder and some other vacuum parts etc …



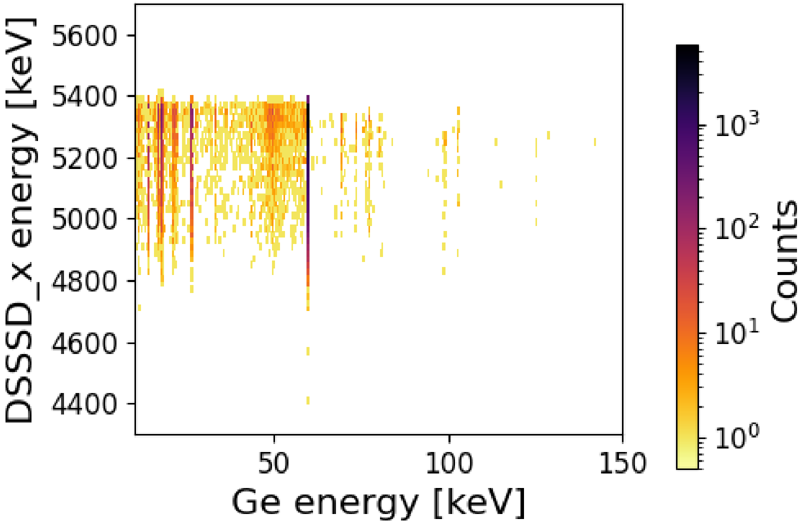


Fig3: Simulated α - γ coincidence energy matrix for ^{241}Am point-like source

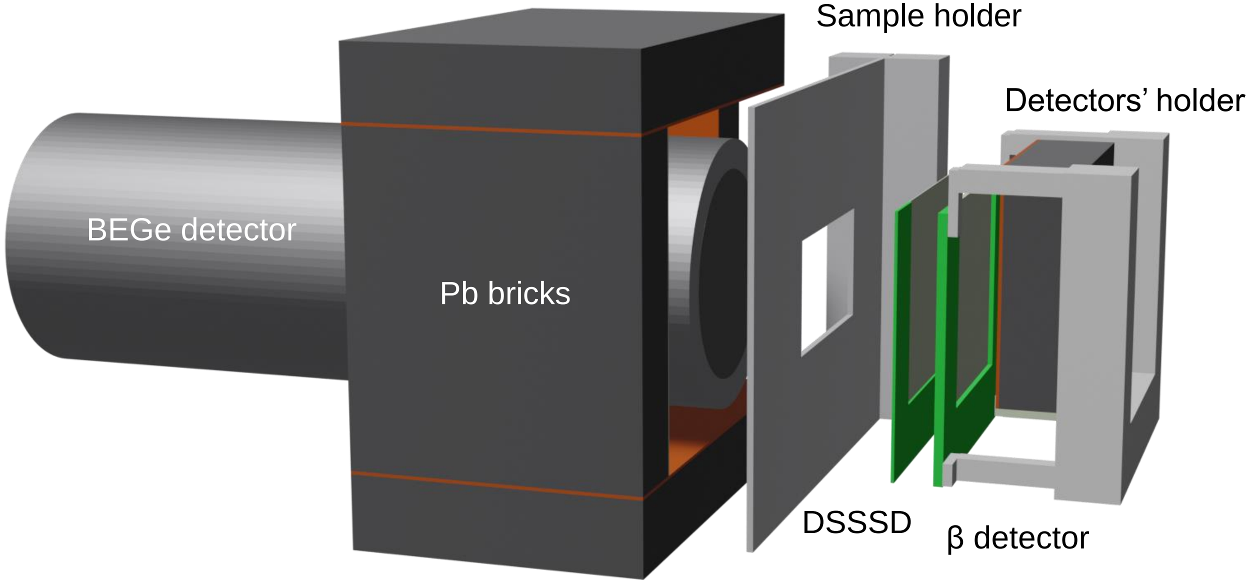
Geant4 simulations

- The Geant4 model of the PANDA device was used:
  - To deduce the characterization properties of MP1 detectors and compared it to the measured data.
  - To plan the future upgrade for the PANDA device.

- MP1 passive shield:
  - Not possible to have a fully shielded PANDA device.
  - Several passive-shielding configurations were explored.
  - The final thicknesses, distances and positions of the passive shield components were optimized.
  - Results were compared to the measured data.

- Preliminarily results from the simulation are in good agreement with the measured data.

- Will be submitted to a scientific journal.



Thank you!