Calibration of A Small Anode Germanium Well Detector

NKS GammaSpec 2017

DTU Nutech, Roskilde, Denmark

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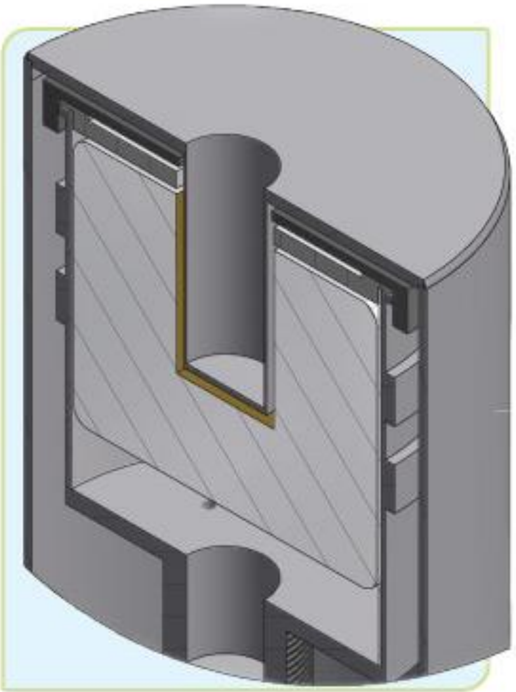
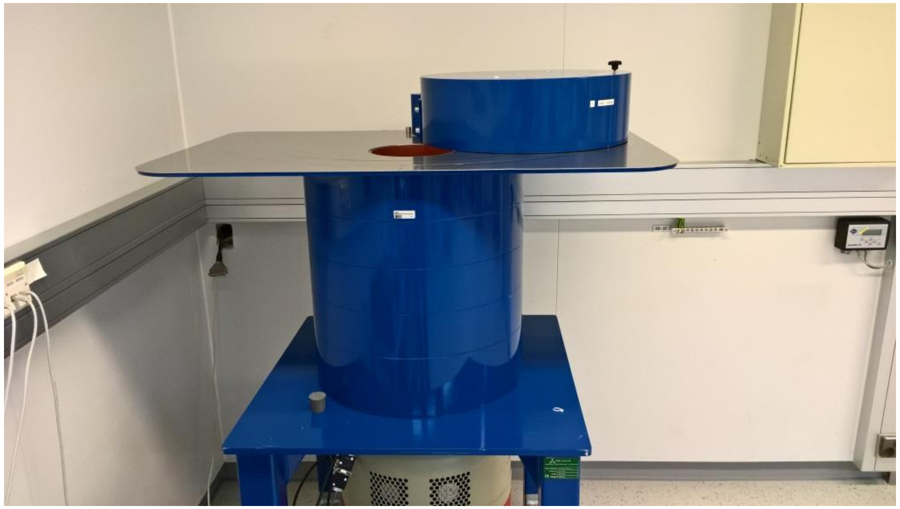
Introduction

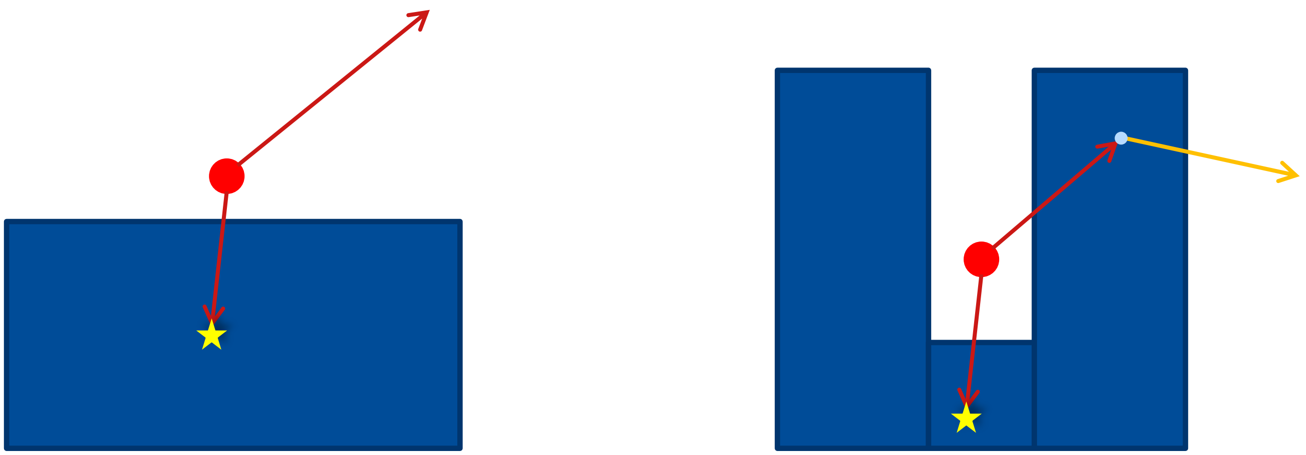
- Small anode germanium (SAGe) well detector manufactured by Canberra/Mirion
- Measurements possible both on top of the detector and inside the well
- High detection efficiency inside the well
  - Detection down to 20 keV
  - Complications arising from true coincidence summing (TCS)
- New type of detector at STUK
- Calibration the topic of Master's thesis





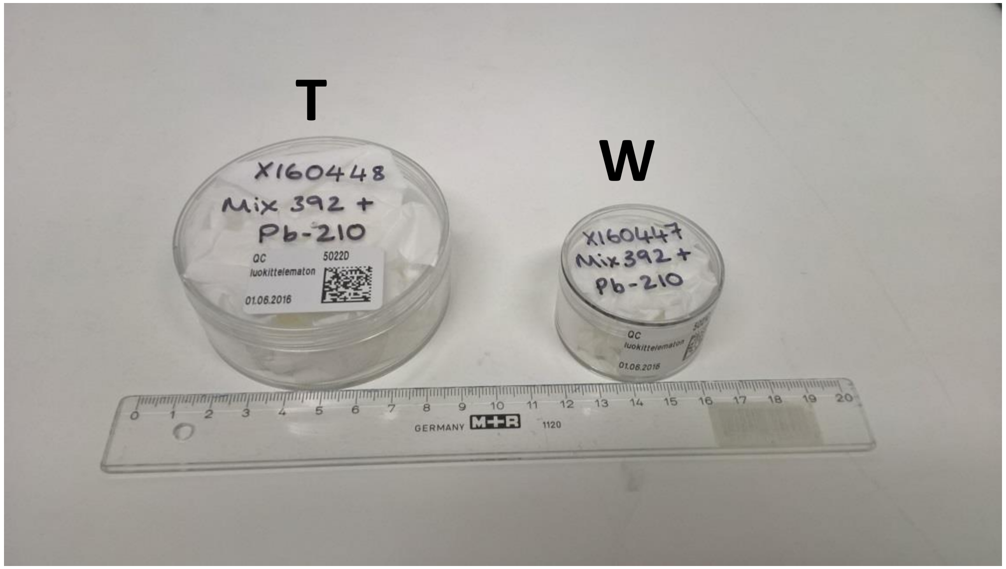
True coincidence summing

- TCS is dependent on the decay scheme of the nuclide, the full energy peak efficiency (FEPE) and the total efficiency
- Higher efficiencies cause more TCS
- The effect corrected with a TCS correction factor c_{TCS}
- Large c_{TCS} → Uncertainties in the total efficiency calibration become more important



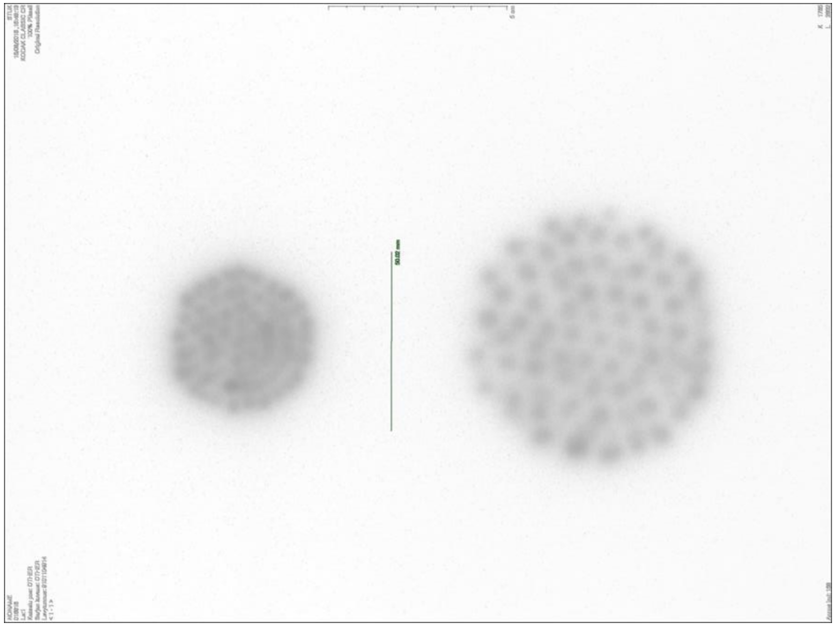
Measurement Geometries

- Standard containers at STUK: W and T containers (left)
  - Variable sample height and material
  - Measurements on top of the detector
- Test tube sample (right)
  - Inside the well
  - Constant filling height (40 mm), only water samples (for now)



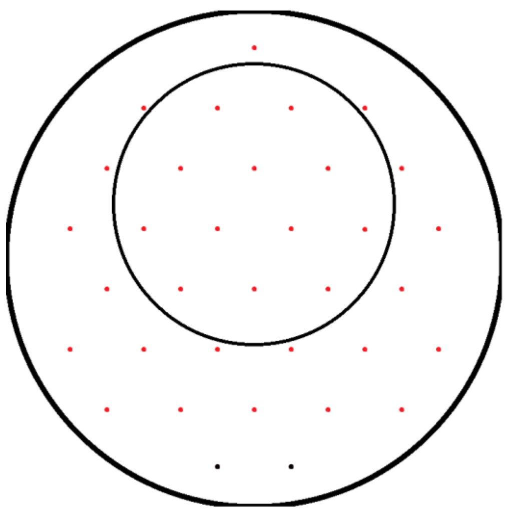
FEPE calibration samples

- Standard samples ordered from NPL
- Thin filters on bottom of W and T containers
- Radionuclide solution diluted in the test tube
- About 20 gamma lines, energies from 46 keV to 1.8 MeV
- Multiple nuclides with TCS correction



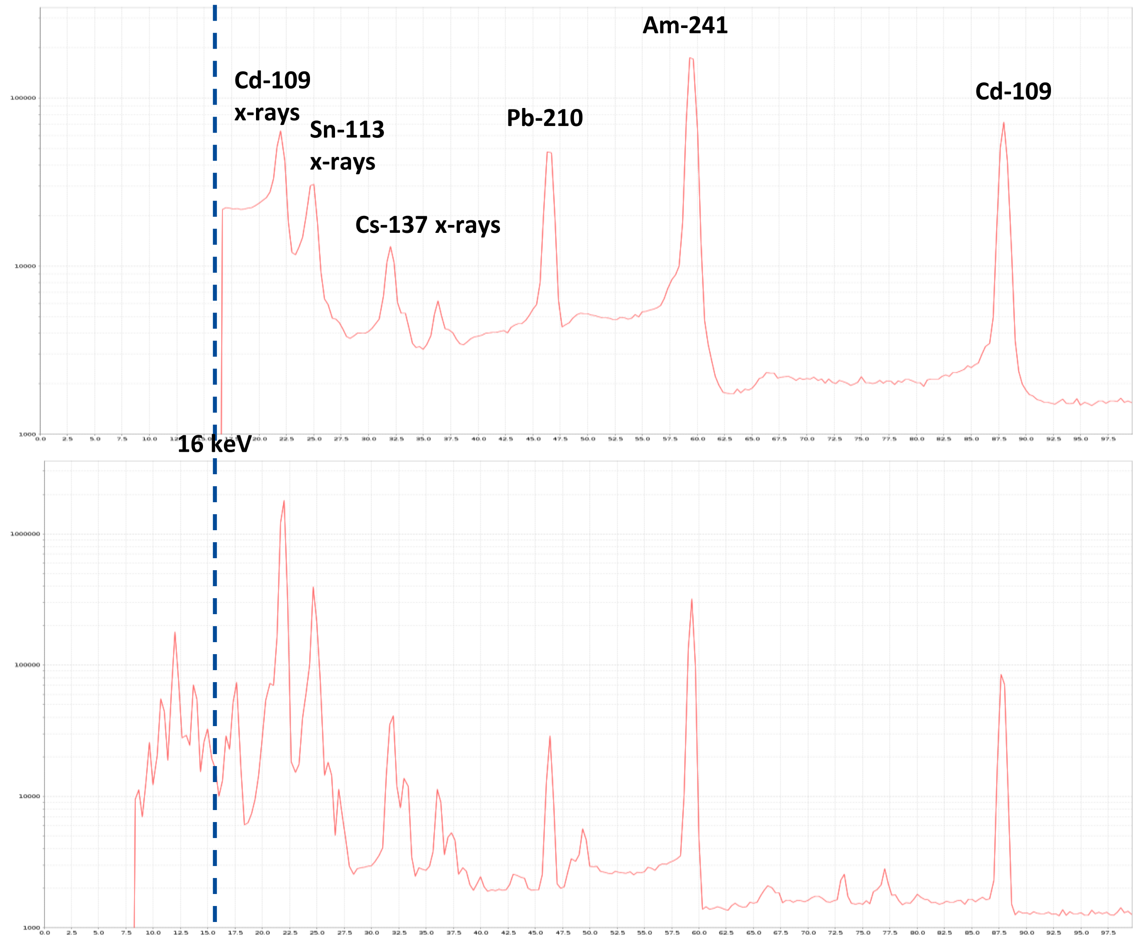
Total efficiency calibration samples

- Radioactive solution on thin filters and diluted into test tubes
- One nuclide in a sample
  - Only one gamma line, other gamma or x-rays should not cause a significant percentage of pulses
  - Very few suitable nuclides
- Nuclides used: Pb-210 (46.5 keV), Am-241 (59.5 keV) and Cs-137 (661.7 keV)



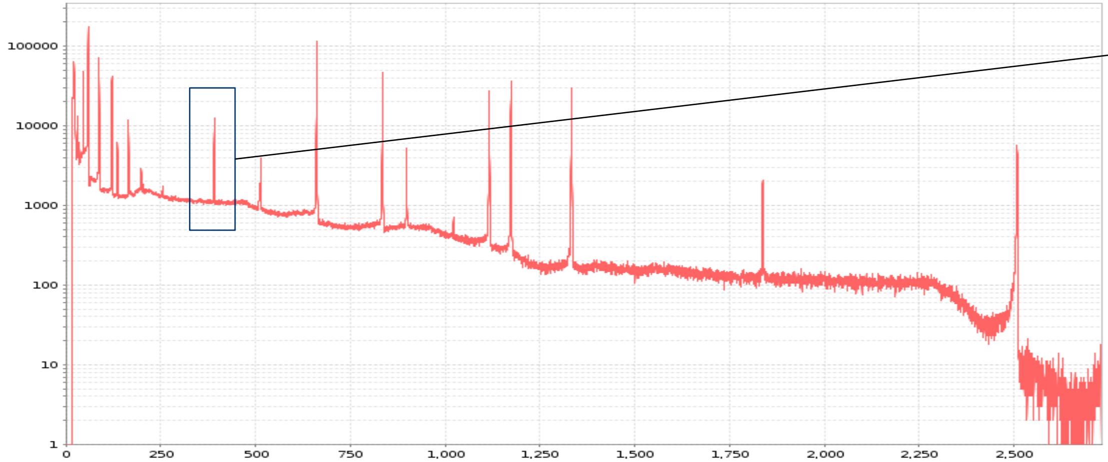
Low energy spectrum with SAGe and BEGe

- Sometimes low detection efficiency is not a bad thing



Measurements

- The time constants were optimised to ensure as good a resolution as possible
    - FWHM 0.75 keV at 46.5 keV and 1.75 kev at 1332.5 keV
- Measurements long enough to ensure good statistics for the peaks
- Analysis done with UniSampo Shaman



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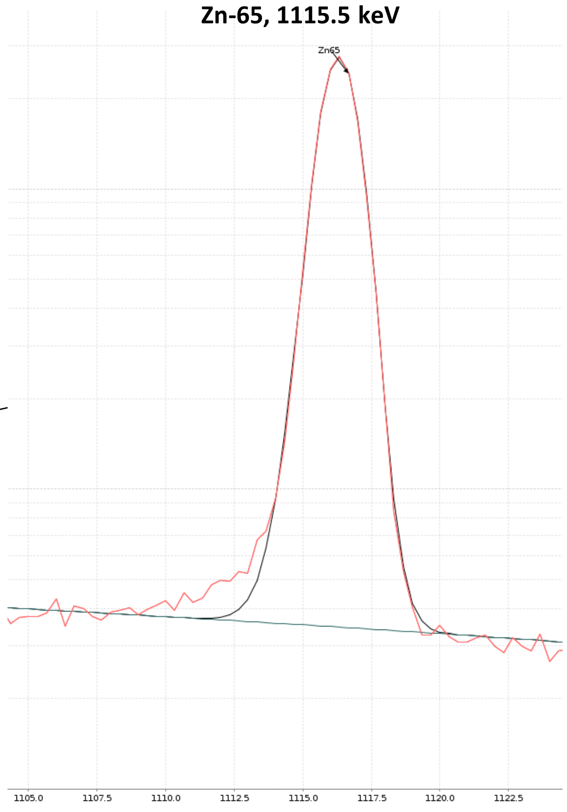
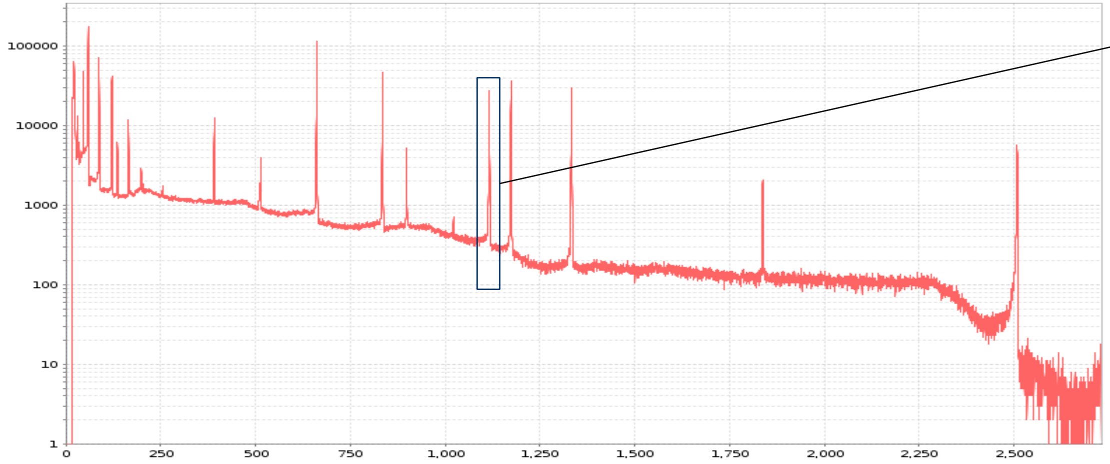
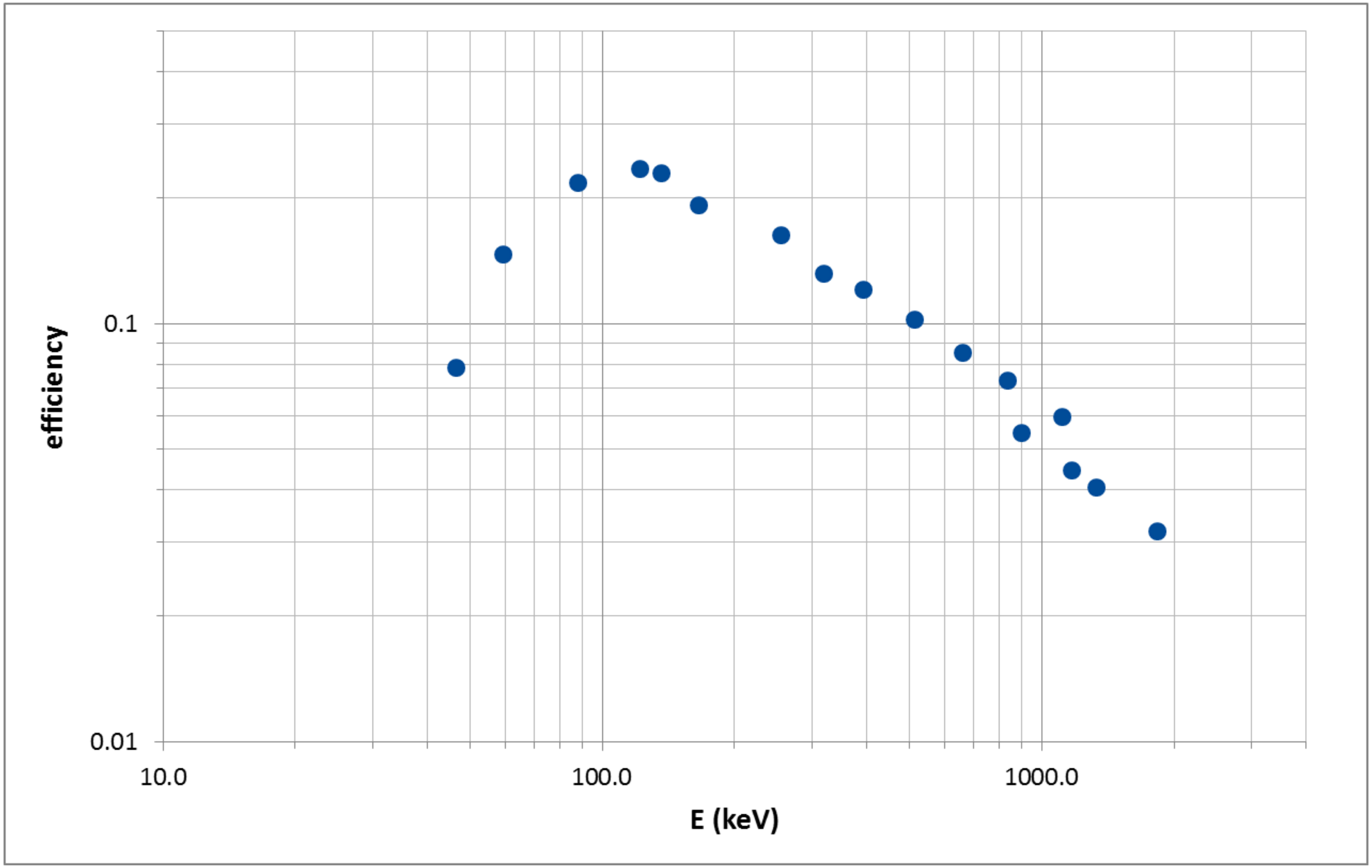
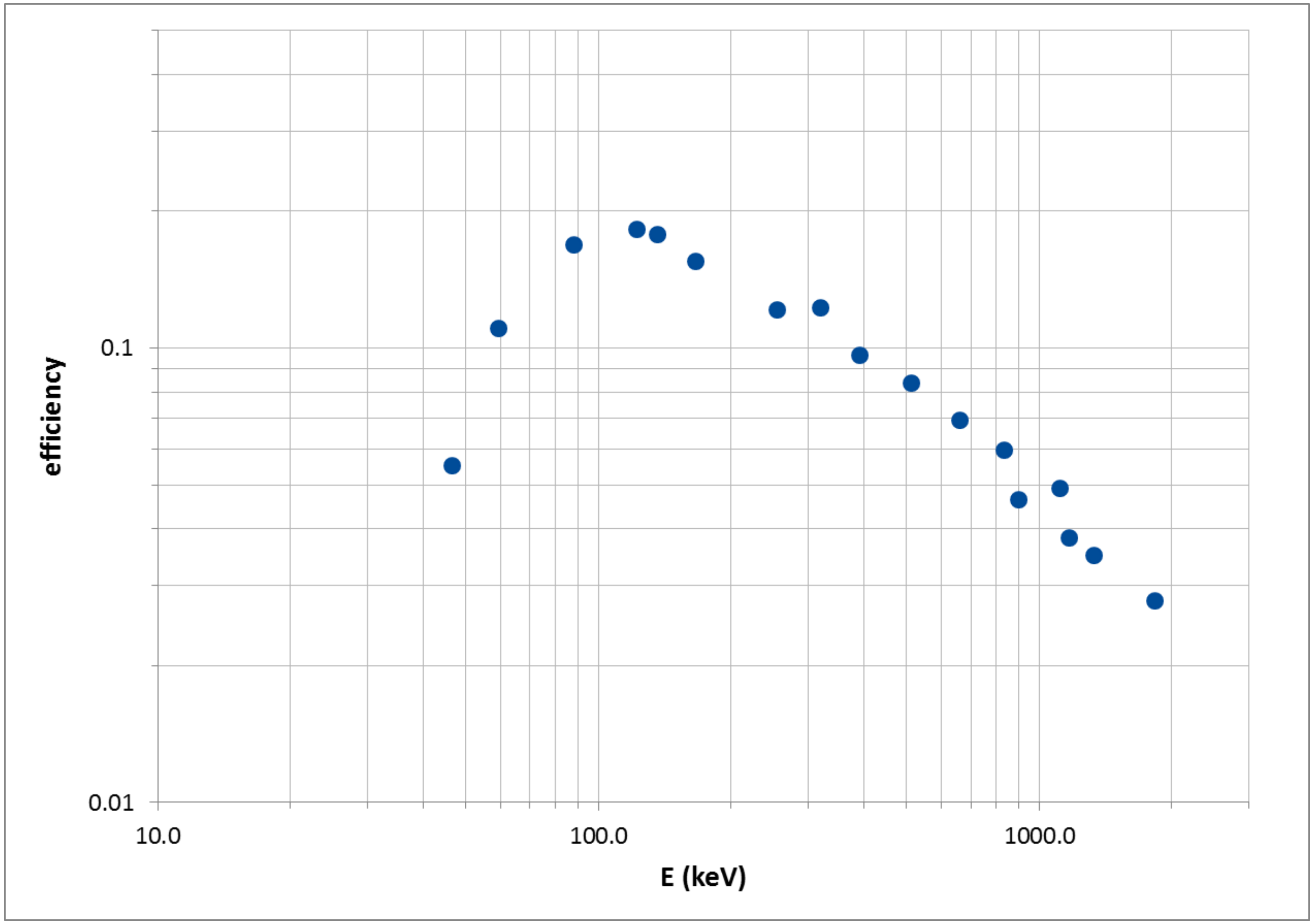




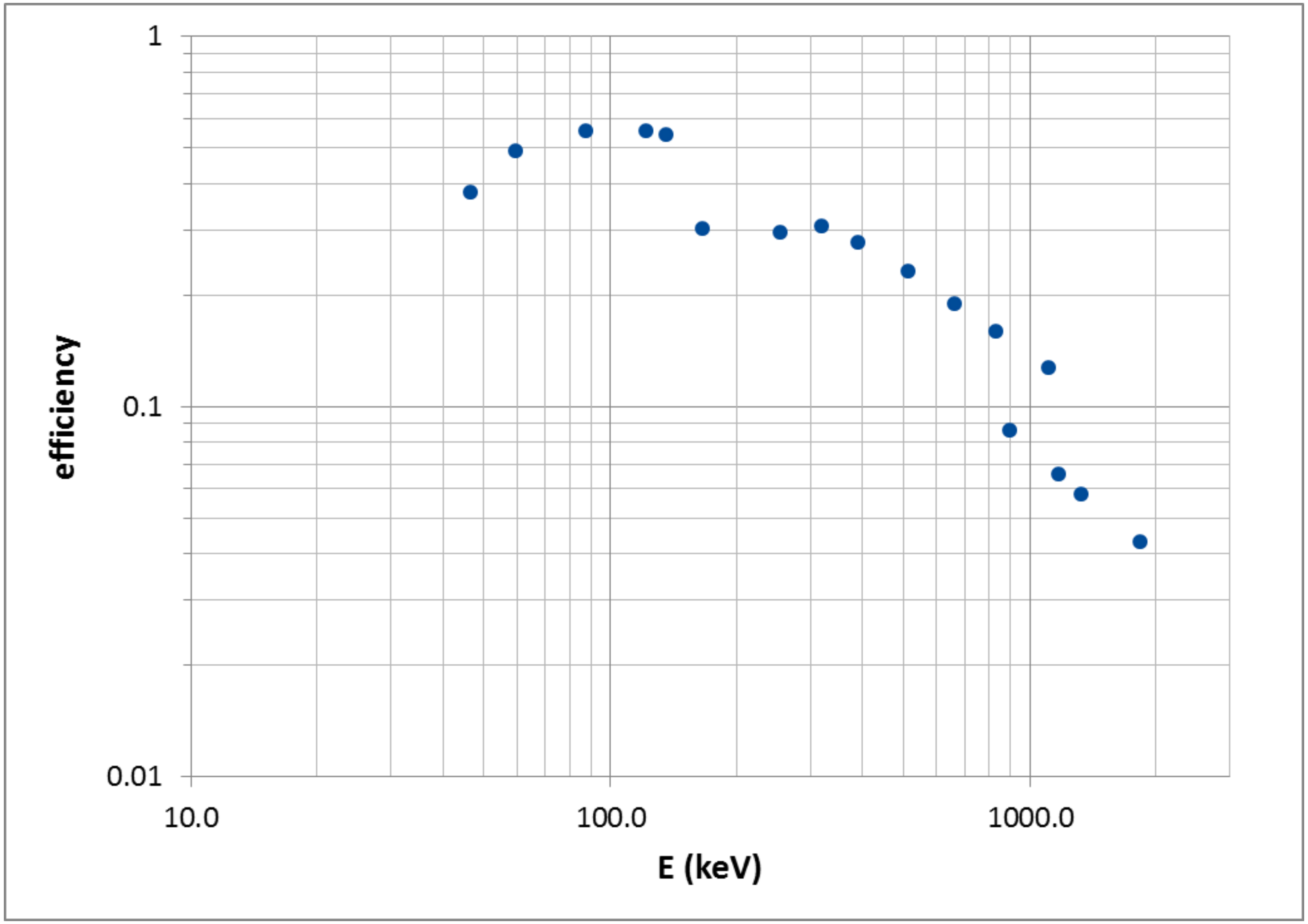
FEPE curve for the W geometry without TCS correction



FEPE curve for the T geometry without TCS correction

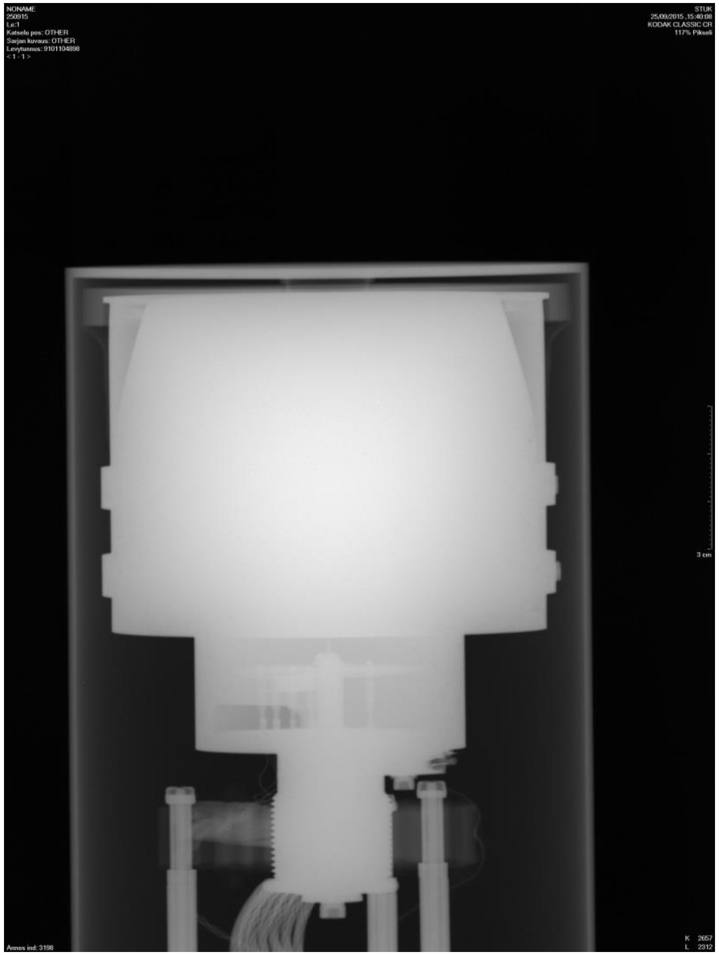


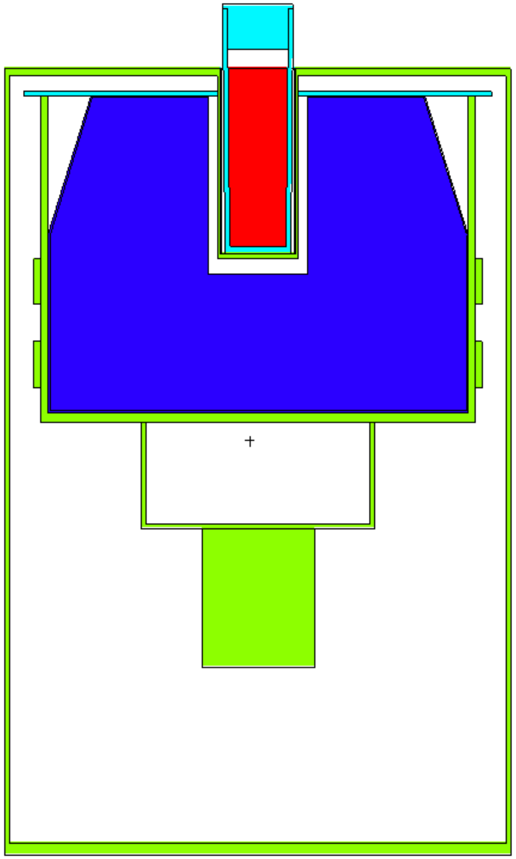
FEPE curve for the test tube geometry without TCS correction



Simulations

- Simulations needed for two purposes: uncertainty estimates and total efficiency curve
- MCNP was used in the simulations
- Statistical uncertainty small with reasonable simulation times
- Reliable modeling of physics and the geometry the main sources of uncertainty
- Unknowns: dead layer, crystal-window distance, window thickness…



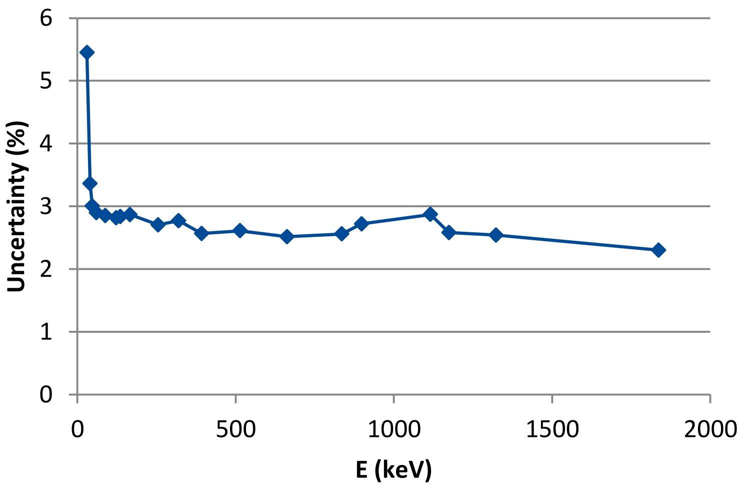


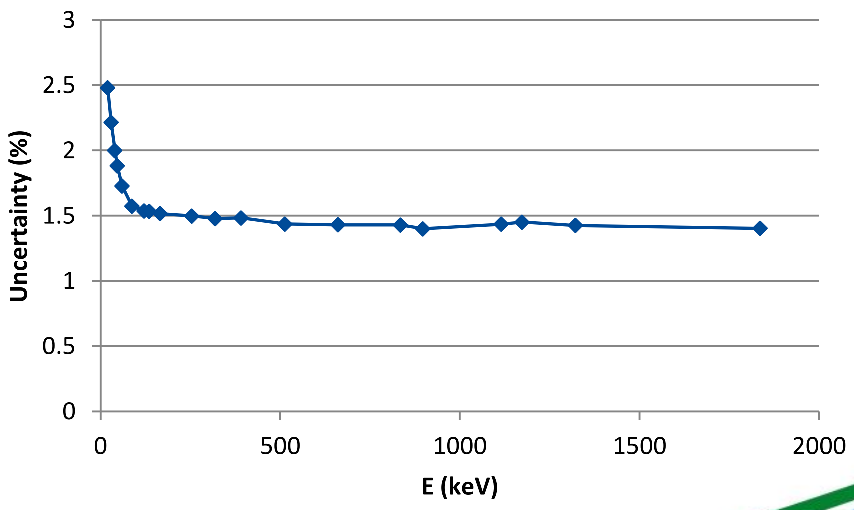
Constructing the MC model

- 1. Best guess for the detector shape
- 2. Adjustment to match experimental results
  - Mainly dead layer thickness but also crystal-window distance and window thickness
  - The model has to work with all the sample geometries
- Different dead layers for FEPE and total efficiency
  - 0.2 mm and 0.4 mm on top
  - 0.05 mm and 0.16 mm in the well
  - 0.3 and 3 mm on sides and bottom

Simulated uncertainty estimates

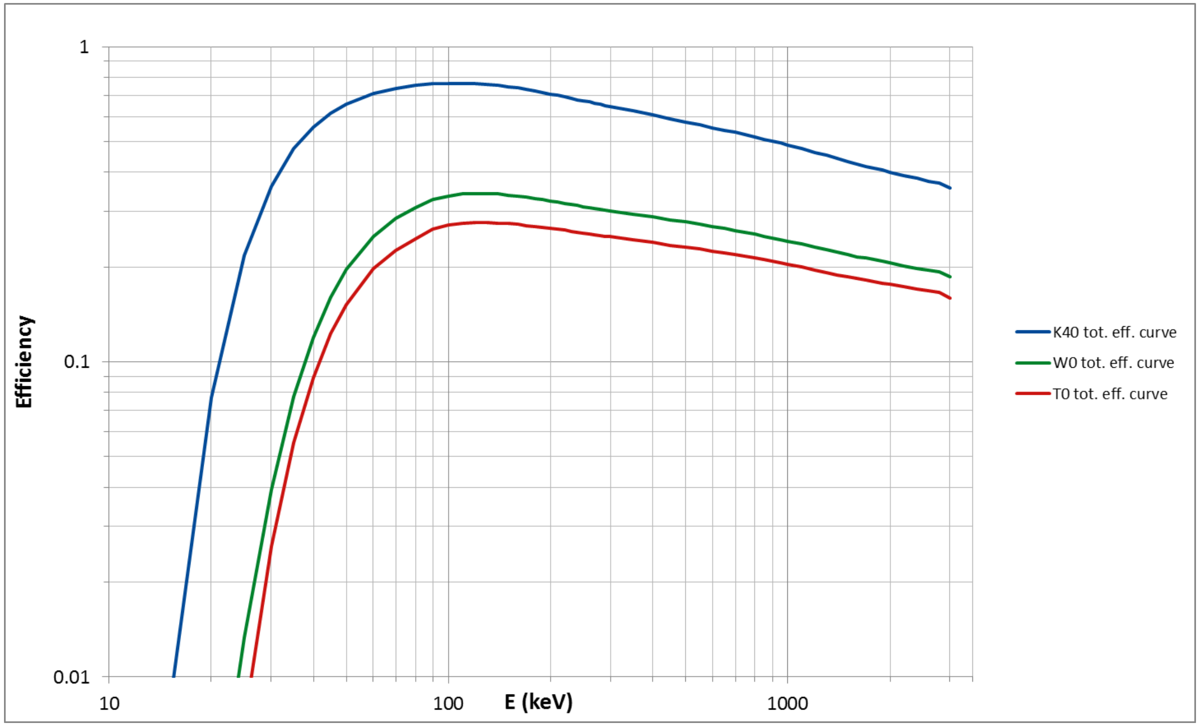
- Effects of container dimension uncertainties, positioning uncertainty, sample material and sample height related uncertainties were estimated with simulations
- Parameters were varied and the change in the efficiency was taken as the uncertainty
- Sample related uncertainties for W (left) and test tube containers (right):





Simulation of the total efficiency curves

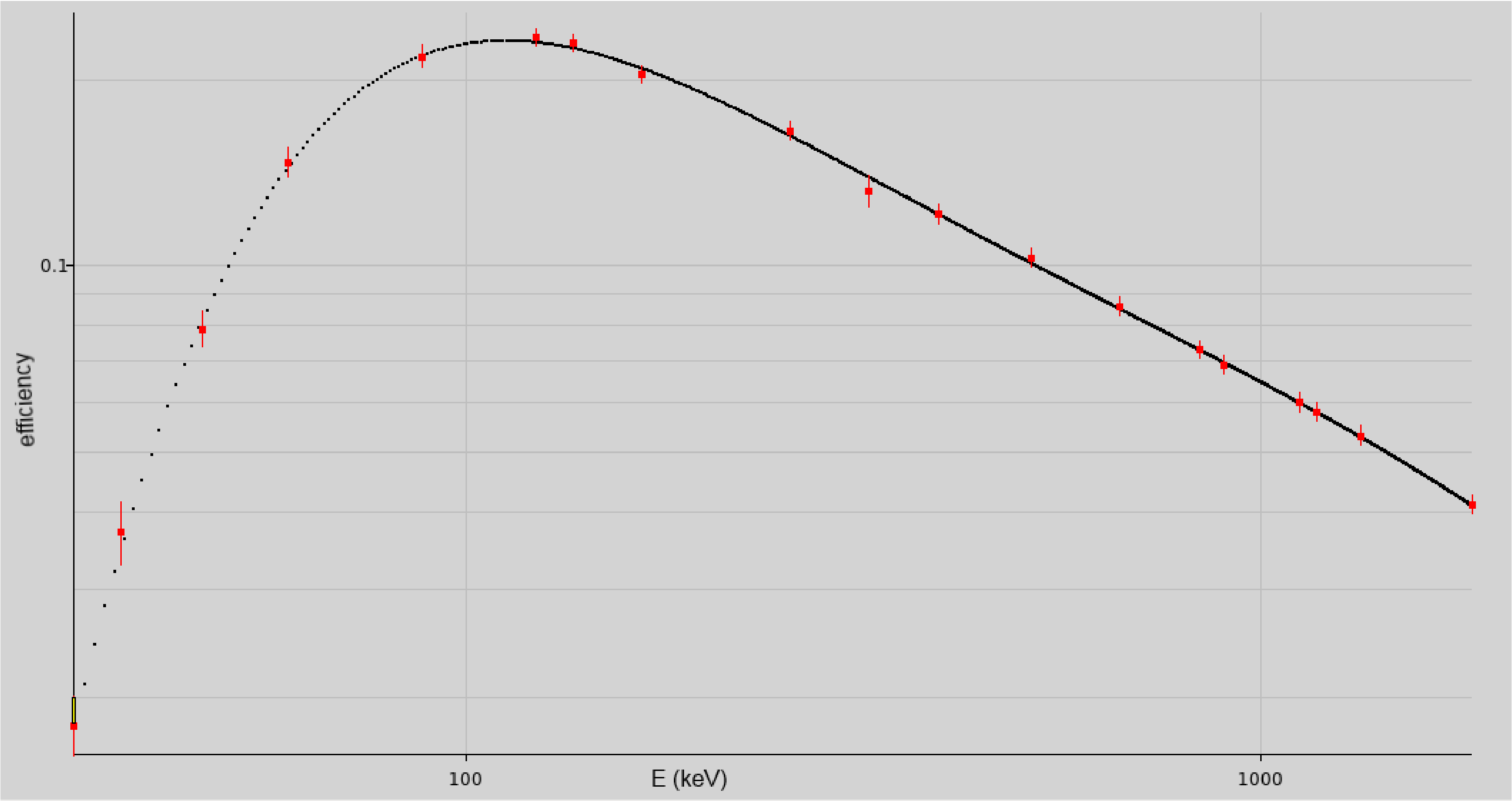
- Total efficiencies and uncertainties calculated from experimental data for the Pb-210, Am-241 and Cs-137 samples
- The MC model was modified so that the simulated total efficiency curves matched the experimental values



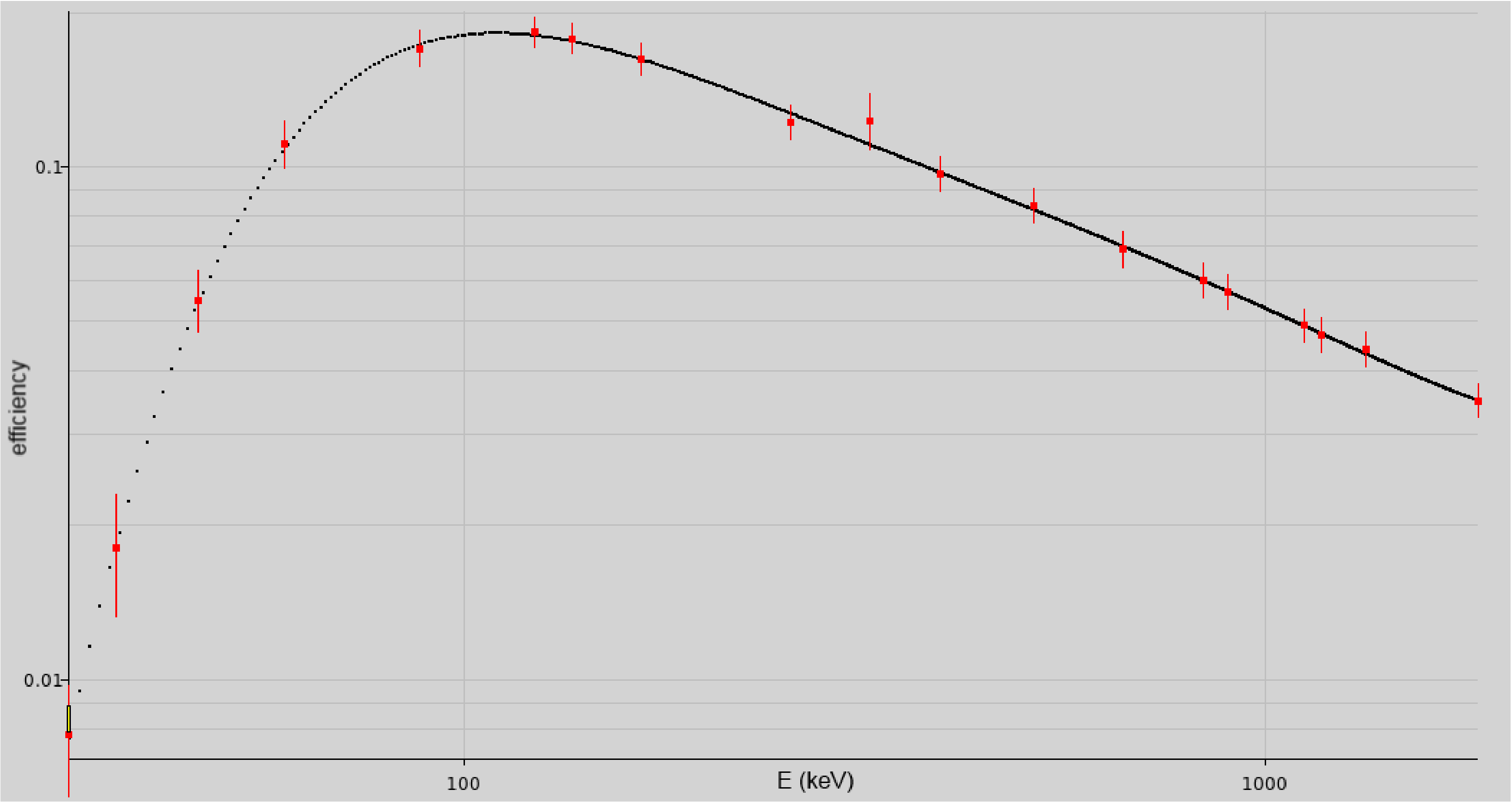
TCS correction factors

- The FEPE values without TCS correction and the simulated total efficiency curves were fed to UniSampo Shaman
- c_{TCS} calculation → new FEPE values
- New c_{TCS} calculation with the new FEPE values → same correction factors as with the first calculation
  - Iteration if they had differed
- Fifth order logarithmic polynomial fit

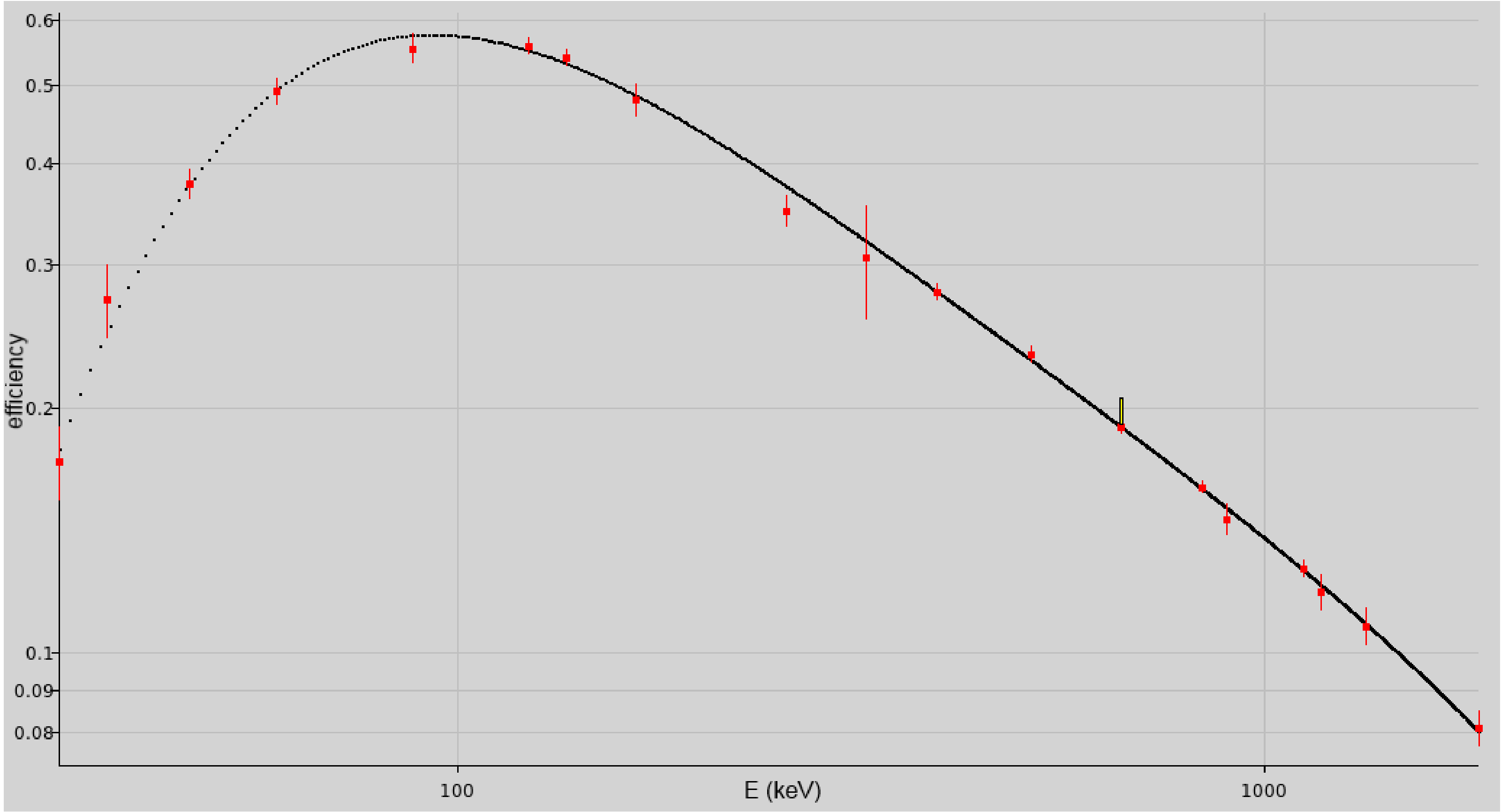
FEPE curve for the W geometry



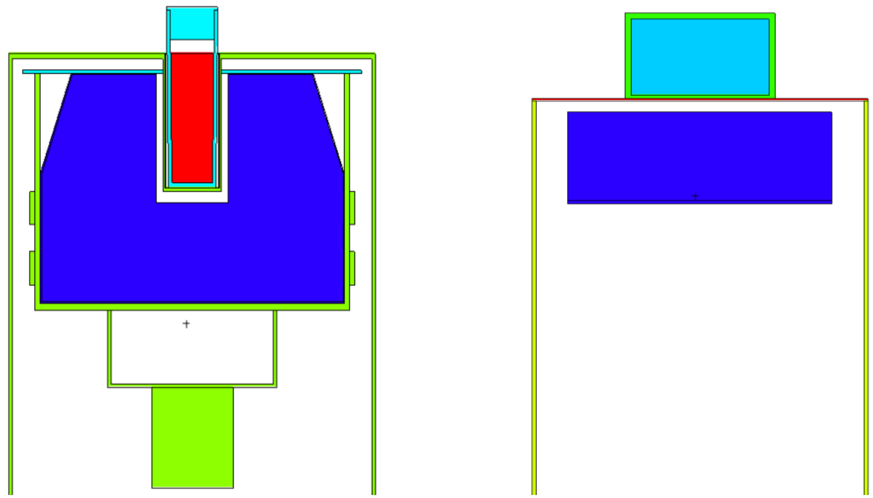
FEPE curve for the T geometry

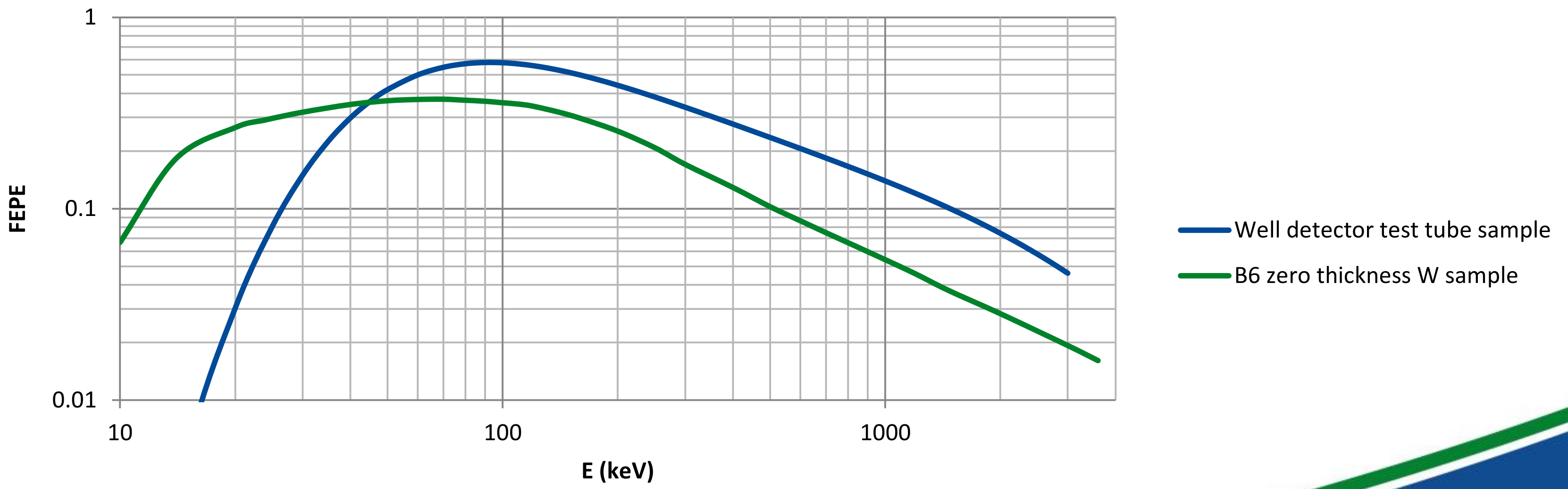


FEPE curve for the test tube geometry



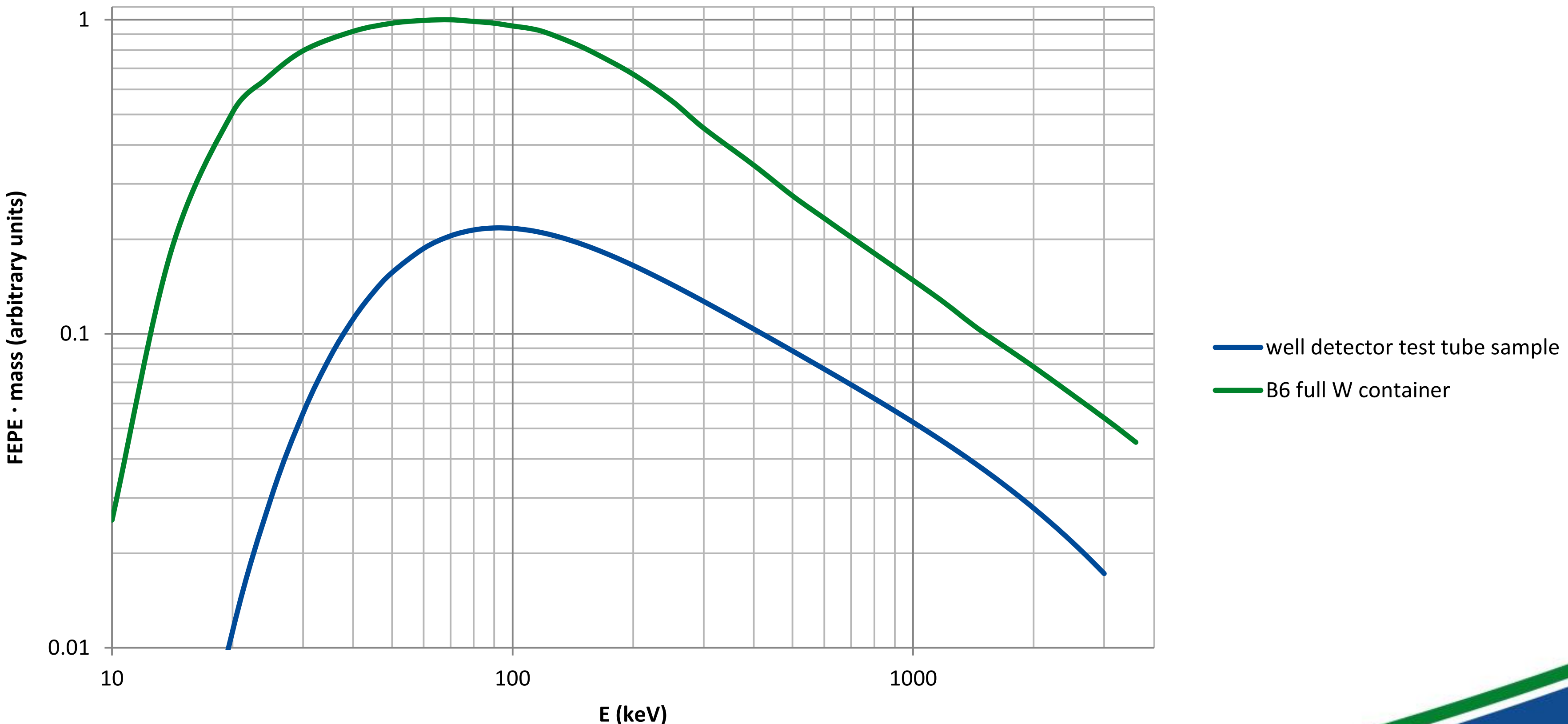
Comparison with a BEGe detector B6 at STUK





The comparison of actual peak count rates

- Larger volume, more activity in the sample
- Full W container vs. test tube sample:



Conclusions

- Good resolution and uncertainties were achieved
  - Better self absorption correction methods should be developed
- BEGe detectors better for W and T samples but the well detector is adequate
- Superior detection efficiency inside the well
- The actual peak count rates limited by sample size
- Good sample types
  - Small volume
  - Heavily concentrated water samples