Development of a background model for coincidence gamma-ray spectrometry measurements in radionuclide monitoring

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INTRODUCTION AND MAIN RESULTS

This poster presentation provides insights related to the development of a realistic source background model using Geant4 simulation toolkit which is aimed to play a key role in optimizing the minimum detectable activity of coincidence gamma-ray spectrometers for detection of CTBT-relevant radionuclides. Measurements with a single-crystal HPGe detector were used to characterize background contributions from the detector environment, air filter materials, and air borne radionuclides. These measurements were used to build and validate simulation models that replicate the observed background spectra.

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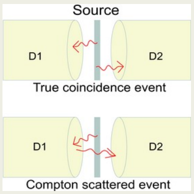
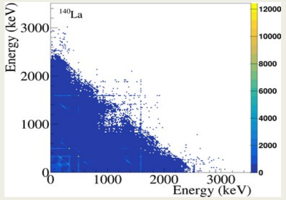
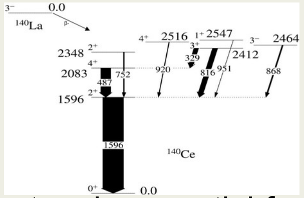
Introduction

Radionuclide particulate monitoring is a key method for nuclear explosion detection. The use of gamma-ray coincidence spectrometry can suppress background drastically and improves sensitivity to certain radionuclides (coincidence emitters) relevant to CTBT verification.

Source : www.ctbto.org







The design and optimization of detectors is essential for obtaining good sensitivity, i.e. a low Minimum Detectable Activity (MDA)

- MDA depends on efficiency and background!
- Background caused by true coincidences as well as scatter cross talk of single gamma-rays

Scope of present work

Development of a background model for sensitivity optimization in coincidence spectrometry. The background model will be used in parameter optimization studies and needs to be computationally non-expensive

- La-140 is target nuclide in optimization

Background source model

Three components of the gamma ray background obtained experimentally with single crystal HPGe system:

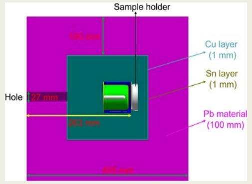
A) Nuclides in **filter material** and **air exposure**

- Reproduced well with simulations

Monte Carlo simulation (Geant4)

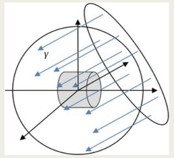
Simulated geometry:

- Detector (HPGe)
- Lead shield



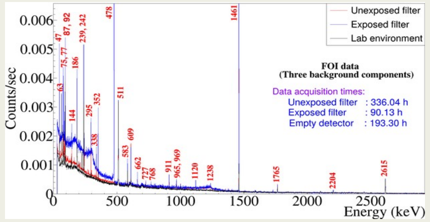
B) Radiation from **detector environment**

- Computationally efficient source model is needed, and in turn well-founded approximations
- Simulation of gamma-rays from ambient sources including cosmic origin (computationally expensive)
  - In cosmic background, at low energies, gamma ray component has been found to dominate, other species are therefore neglected
- Phenomenologically obtained through de-convolution of the response function from the measured single-detector pulse-height spectrum
- Validation was performed via dual-detector coincidence measurements where the source was modeled to yield a uniform and isotropic radiation environment across the detector system

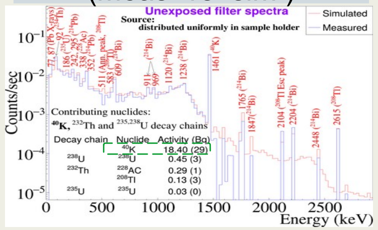


Results

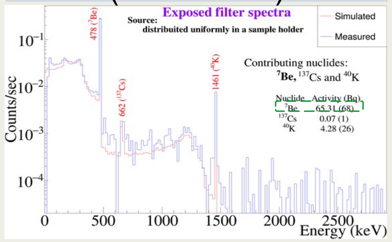
Three background components from measurements



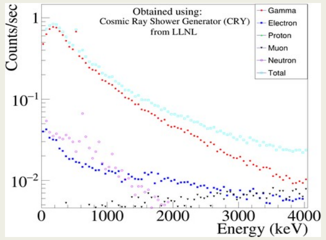
Unexposed filter spectra (meas. vs. sim.)



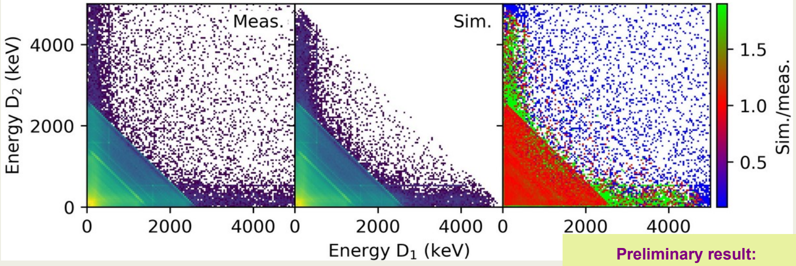
Exposed filter spectra (meas.+sim)



Cosmic ray induced background



Estimation of background from lab environment.



Preliminary result:
(unshielded HPGe dual-detector)

Simulated 2D histogram:

- Source spectrum unfolding of simulated response function from experimental 1-d background spectrum
- Approach validated with experimental 2-d background spectrum (so far with preliminary results from unshielded detector)

Conclusions

1. Gamma emitting nuclides in sample (filter and exposure) can be reproduced satisfactorily
2. Background from detector environment, dominated by gamma-rays, is well modelled using a source that generates a uniform and isotropic radiation field, with reduced computational costs by omitting shield transport

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