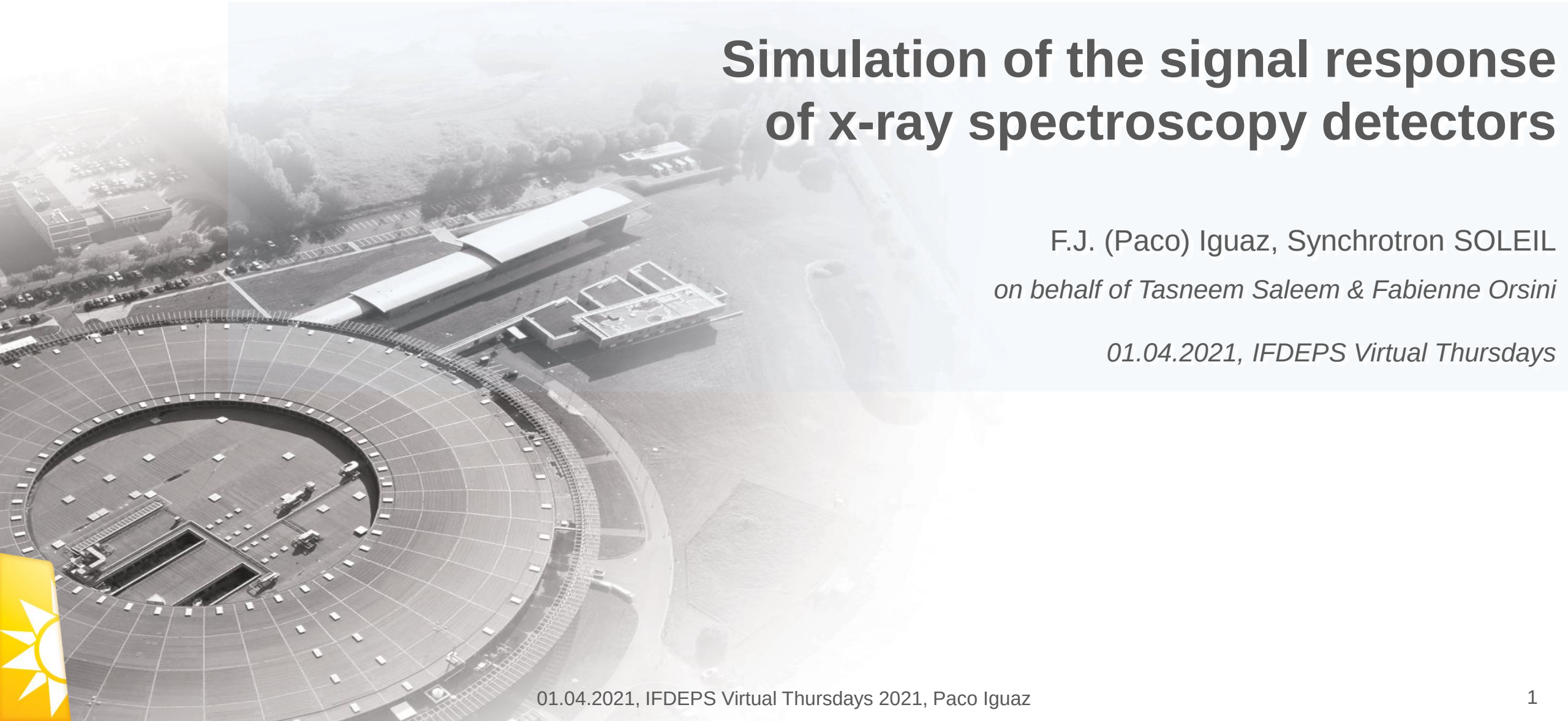

Simulation of the signal response of x-ray spectroscopy detectors

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on behalf of Tasneem Saleem & Fabienne Orsini

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Introduction

Goals:

- ***Optimization of the design*** *of future x-ray spectroscopy detectors in the prototyping phase.*
- *Estimation of the* ***physics performance*** *(ex. signal-to-background ratio) in a real experiment.*
- *Actual application:* ***multi-element germanium detectors for XAFS.***

ALLPIX2 framework:

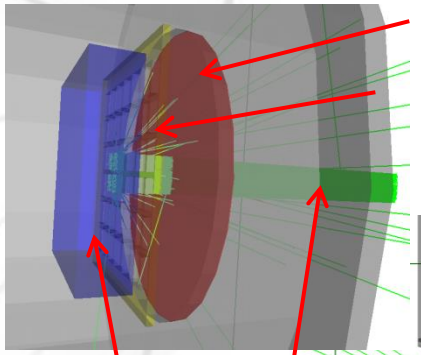
- *Initially developed for pixelated silicon detectors for* ***HEP physics at CERN****.*
- *Simulation of photon/matter interaction made by* ***Geant4 library****.*
- *Module to simulate* ***charge carrier transport in semiconductors*** *using an imported* ***3D field map****.*

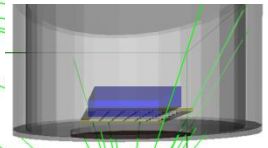
https://project-allpix-squared.web.cern.ch/project-allpix-squared/
https://gitlab.cern.ch/allpix-squared/allpix-squared

New features included:

- *Transport properties for* ***germanium*** *sensors.*
- ***Beam polarization****.*
- ***Detector geometry*** *(collimator, hexagonal pixels) &* ***beamline sample environment****.*
- *3D electric field map from* ***COMSOL Multiphysics® - Semiconductor module****.*
- ***Digital Pulse Processor*** *features (noise model, dead-time, pile-up effect).*

Overview of ALLPIX² simulation chain





Geometry (*Beam, target & detector*)

GEANT 4 *Photon-matter interaction*

Photon distribution (*Vertex, Energy, direction, polarization*)

Charge generation

Charge drift

Signal induction

ALLPIX² *C++ based framework*

Digital electronics
XMAP, FalconX, Xspress3
- *Input & Output count rate*
- *Pile-up effects*

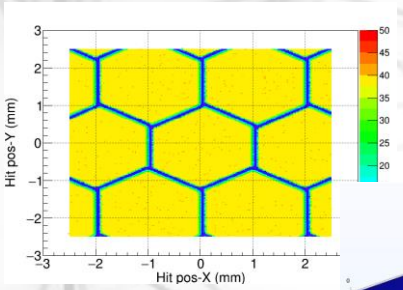
COMSOL *3D electric field program*

RESULTS ⟷ **REAL DATA**

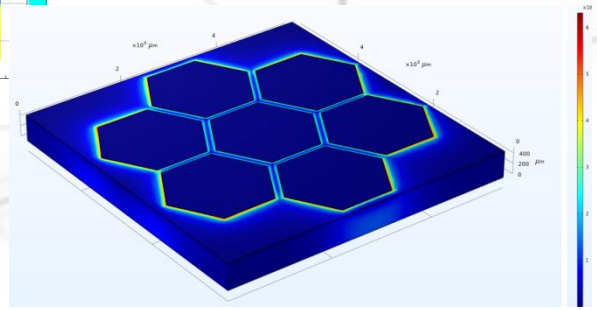
Energy spectrum

Input and Output count rate Dead Time

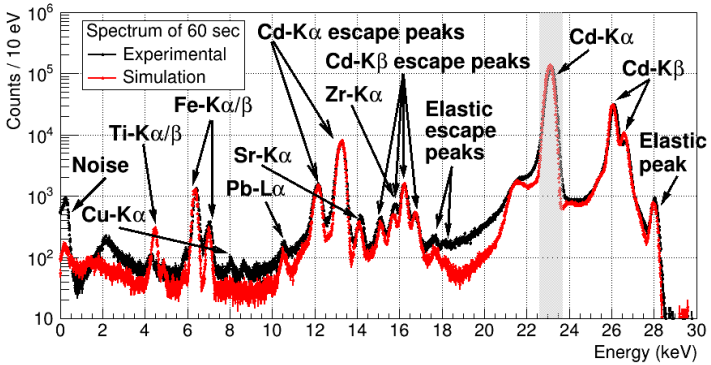
Preamplifier signals



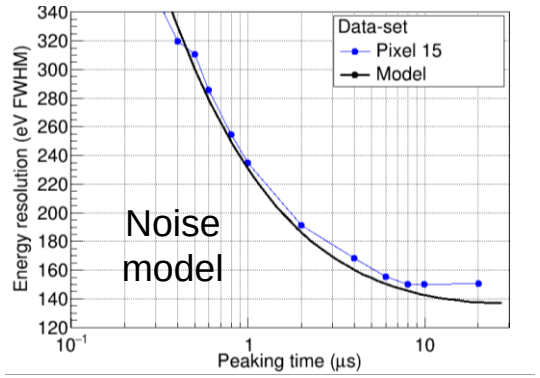
Hit map of hexagonal pixels

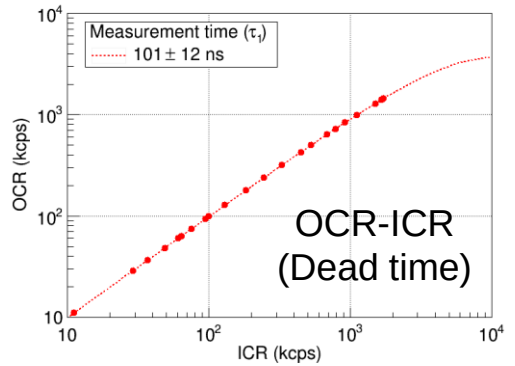


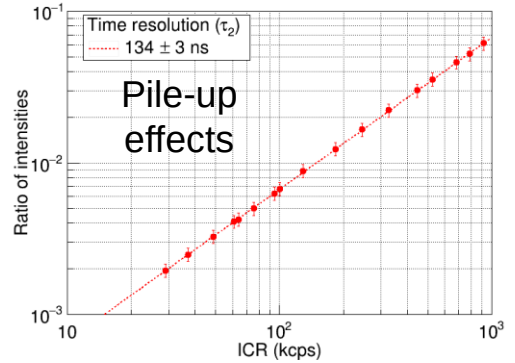
3D electric field map of 7 hexagonal pixels in germanium by COMSOL Multphysics®



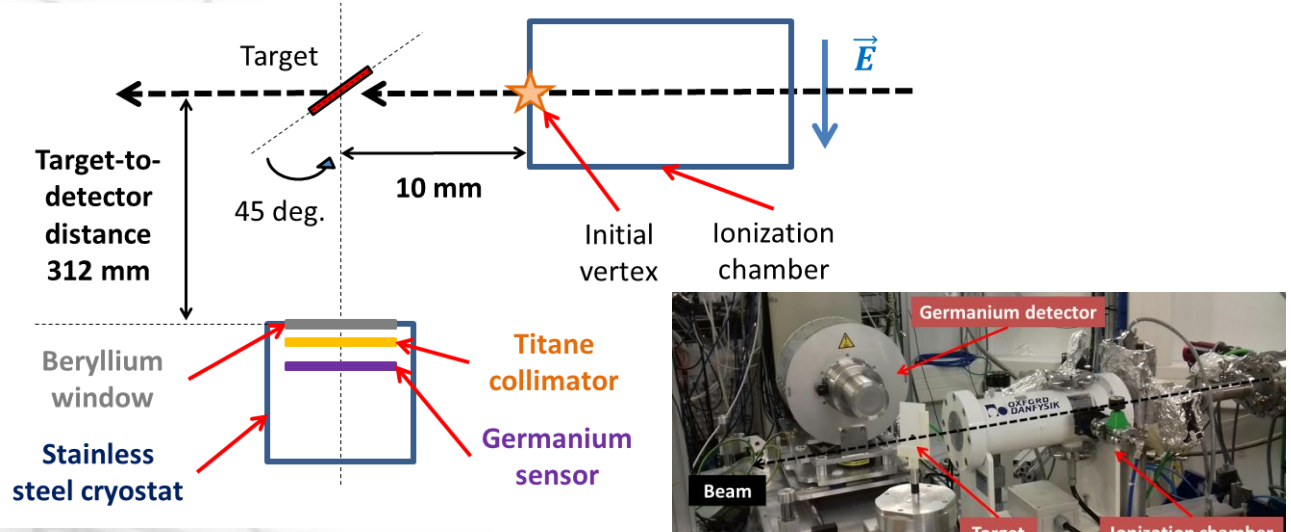
Energy spectrum during a XAFS experiment

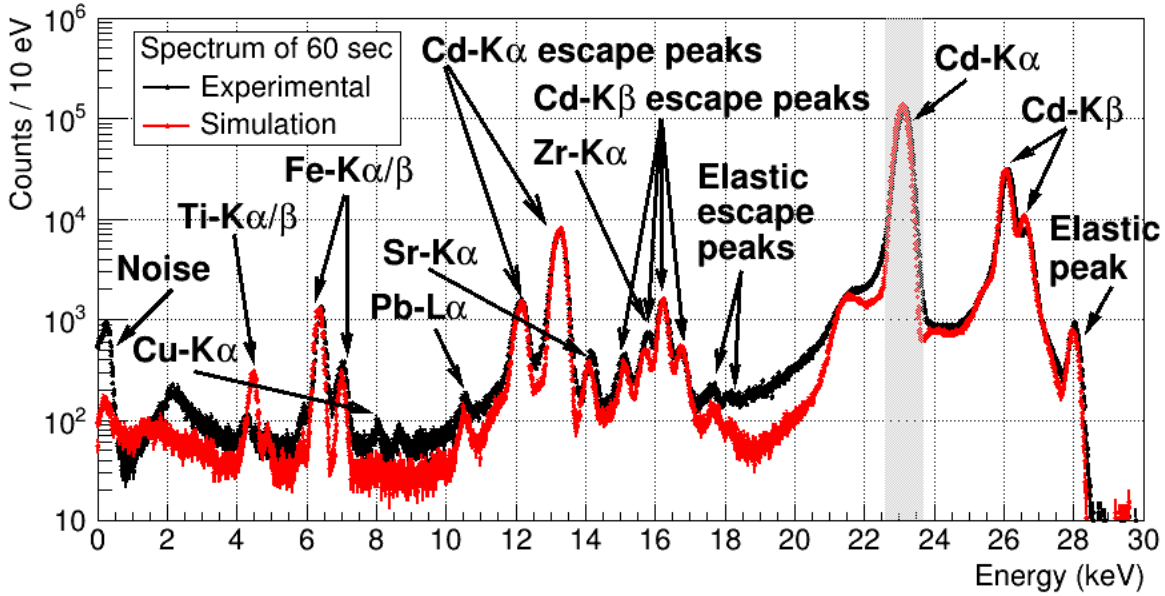






Validation of simulated model

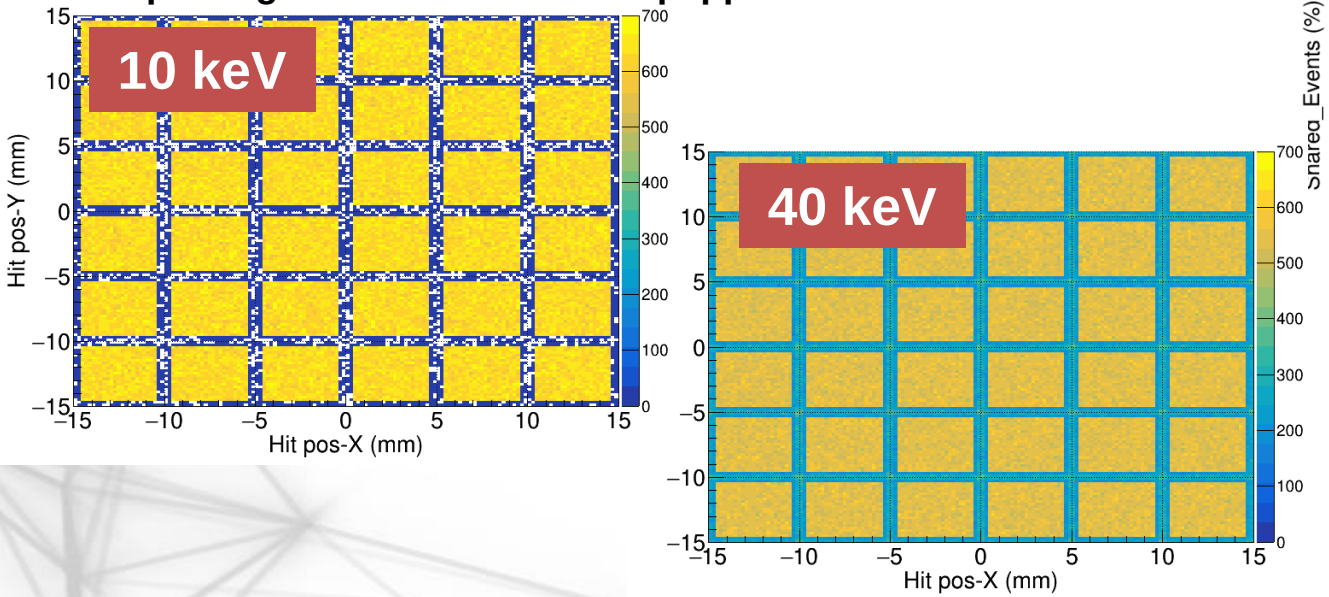


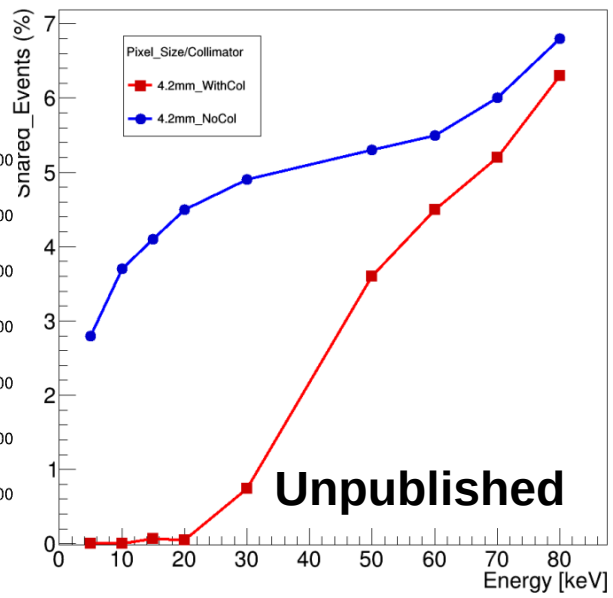


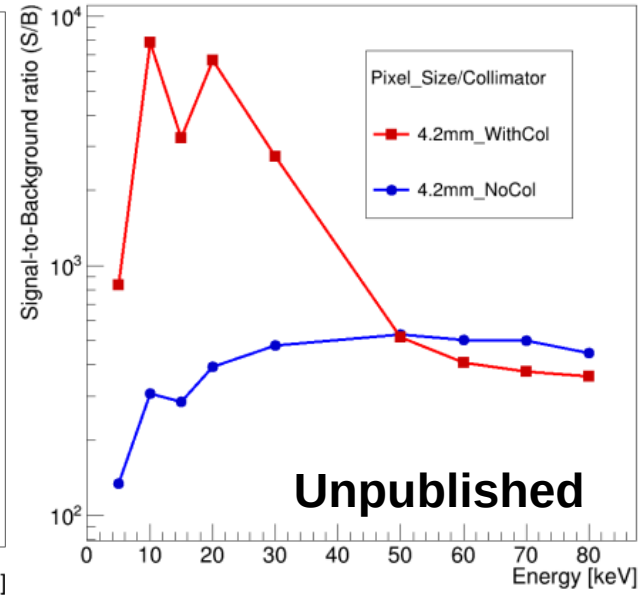
- *ALLPIX² simulation chain calibrated by XAFS experimental data provided by SAMBA beamline.*
- ***Detector**: commercial 36 element germanium detector + XIA-XMAP DPP.*
- ***Experimental data:** organic soil sample rich in cadmium, fixed energy (28 keV), 60 sec spectra.*
- *Comparison of simulated and experimental spectra:*
  - ***Fair agreement except Compton levels** -> Electronics origin & dispersion along the sensor surface.*
  - ***Beam is not fully (99%) linear polarized** -> Study of beamline polarization to be done.*

S/B ratio of a multi-element germanium detector

Hit map of a germanium detector equipped with a titanium collimator







- *Commercial detectors are equipped by a collimator* ***to reduce the charge sharing*** *&* ***to improve the signal-to-background (S/B) ratio***, ***reducing the detection area*** *(i.e.* ***solid angle****).*
- *However, collimators are* ***transparent at x-ray high energies****, increasing the background level.*
- ***On-going study of S/B ratio & charge sharing for future multi-element germanium detectors****:*
  - *With or without collimator.*
  - *Square/Hexagonal pixel shapes, different pixel sizes.*
  - *Xspress4 DPP (cross-talk rejection feature) & guard ring.*