

AI-Based Advancements in Gamma Spectroscopy in Complex Environments

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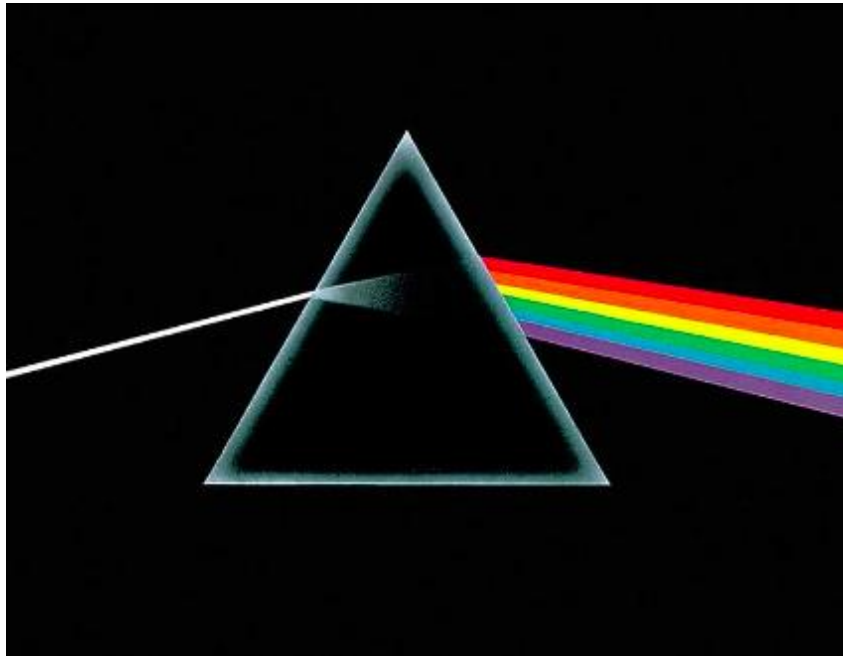
1. Recap Spectroscopy

Recap Spectroscopy

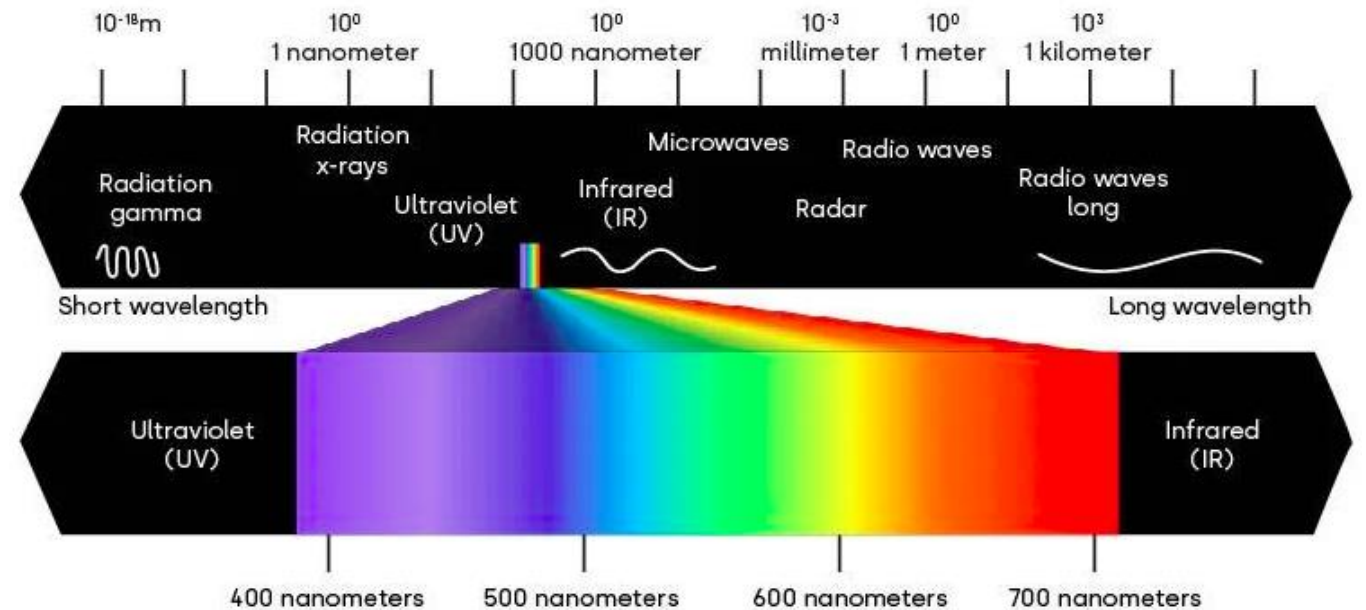
Google: investigation and measurement of spectra produced when matter interacts with or emits electromagnetic radiation.

Recap Spectroscopy

Google: *investigation and measurement of spectra produced when matter interacts with or emits electromagnetic radiation.*

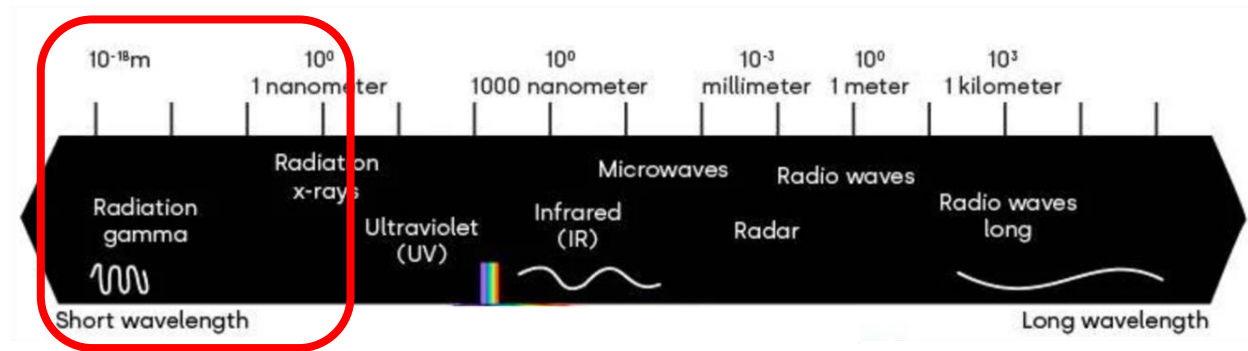


Visible spectrum



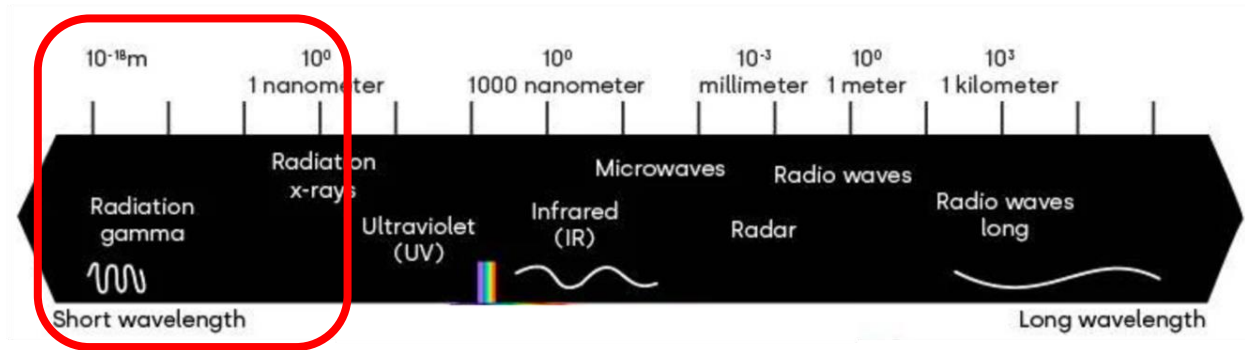
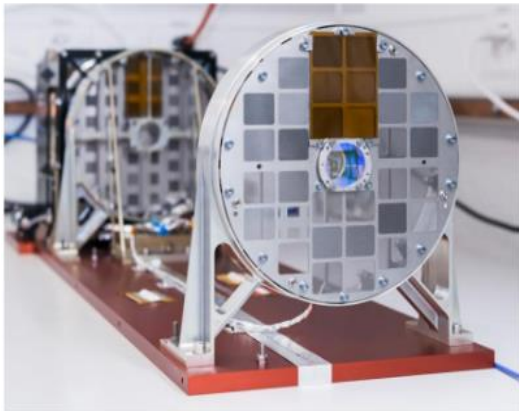
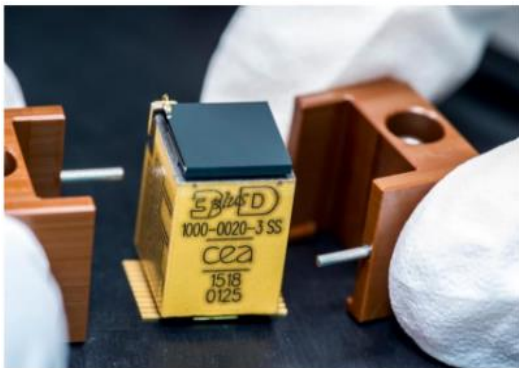
Recap Spectroscopy - X-ray and Gamma wavelength

Google: *investigation and measurement of spectra produced when matter interacts with or emits electromagnetic radiation.*



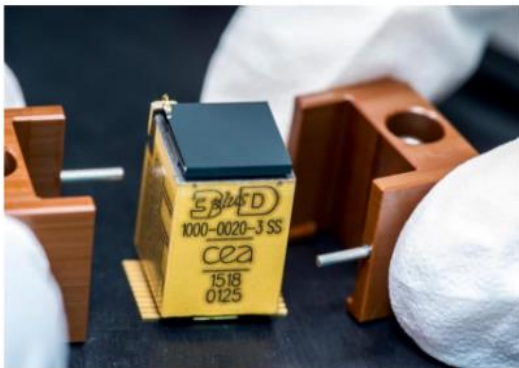
Recap Spectroscopy - X-ray and Gamma wavelength

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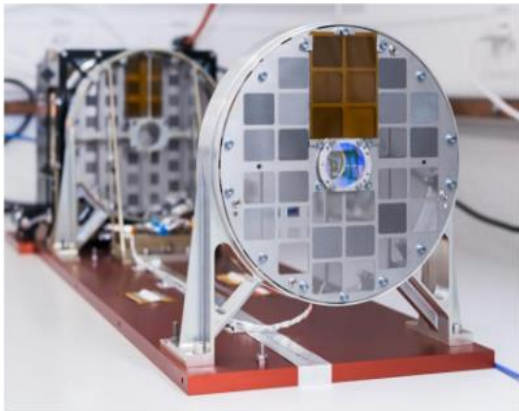


Recap Spectroscopy - X-ray and Gamma wavelength

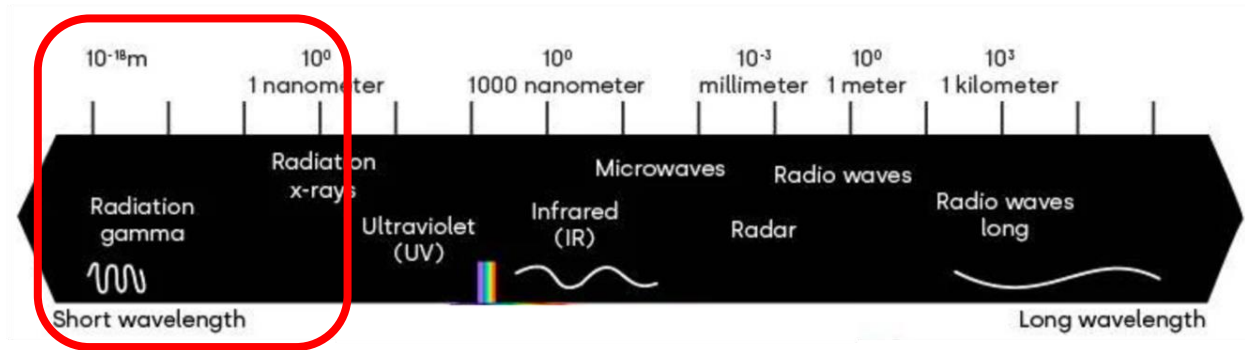
Google: investigation and measurement of spectra produced when matter interacts with or emits electromagnetic radiation.



Light-matter
interaction
Physics:

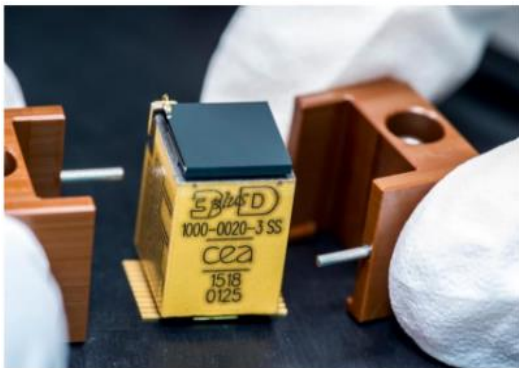


PE effect
Compton
scattering
Pair
creation

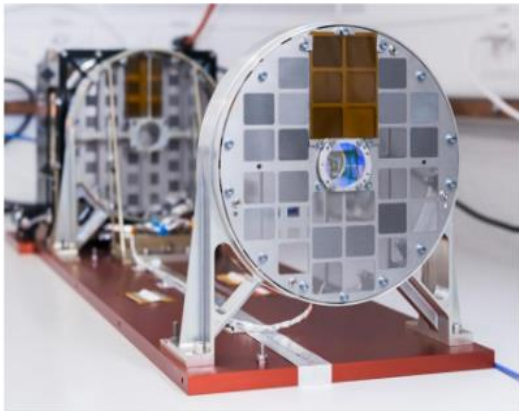


Recap Spectroscopy - X-ray and Gamma wavelength

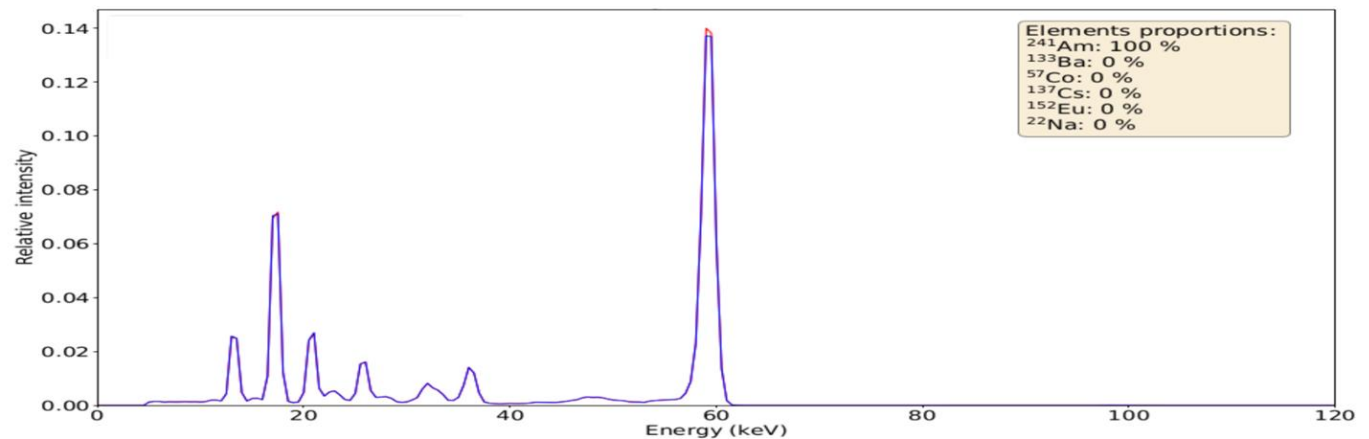
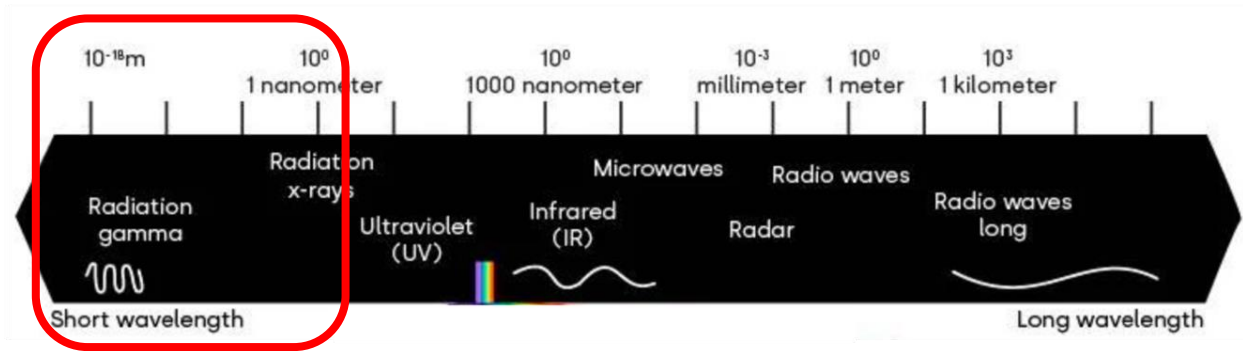
Google: investigation and measurement of spectra produced when matter interacts with or emits electromagnetic radiation.



Light-matter interaction
Physics:



PE effect
Compton scattering
Pair creation



felipe.fernandes@cea.fr



2. Why Gamma Spectroscopy?

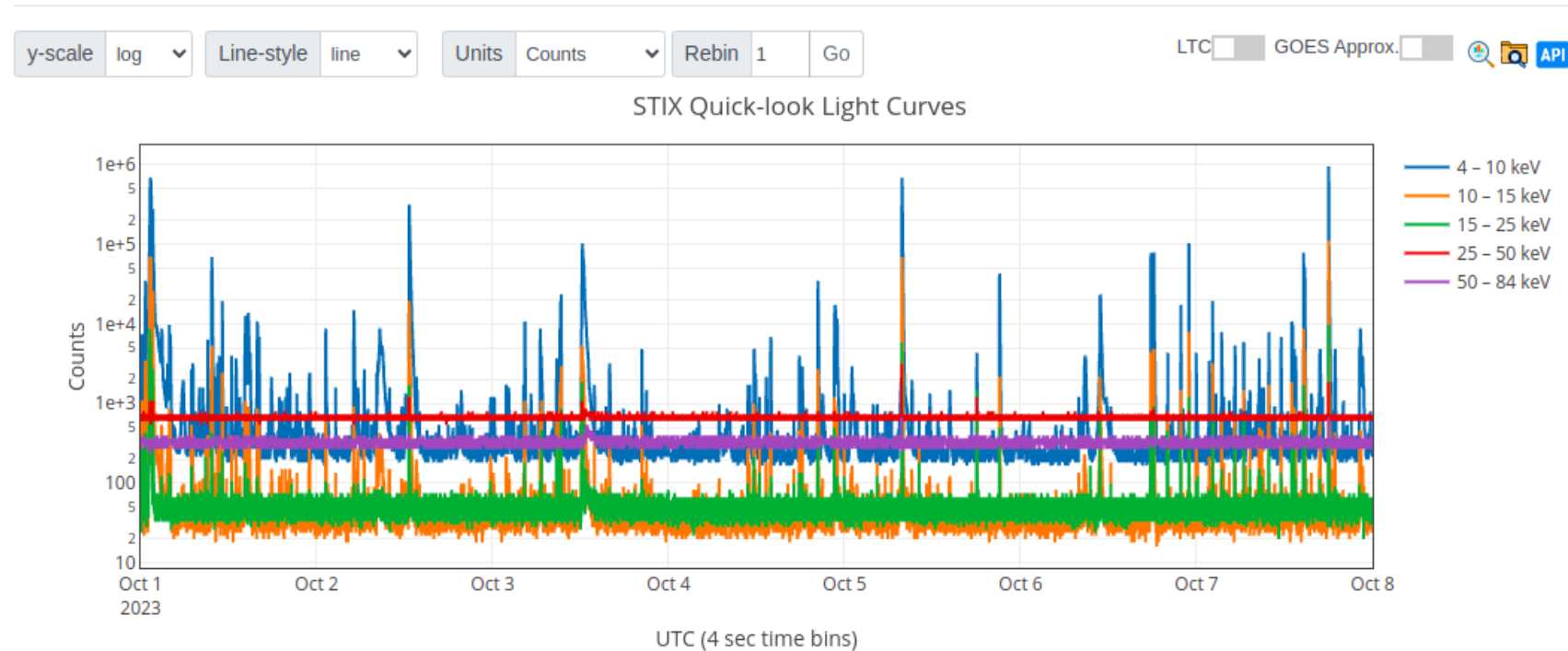
Detector and why Gamma Spectroscopy

- Caliste - CdTe semiconductor crystal
- First developments for astrophysical application
- Solar Orbiter

Detector and why Gamma Spectroscopy

- Caliste - CdTe semiconductor crystal
- First developments for astrophysical application
- Solar Orbiter

STIX Quick-look Light Curves



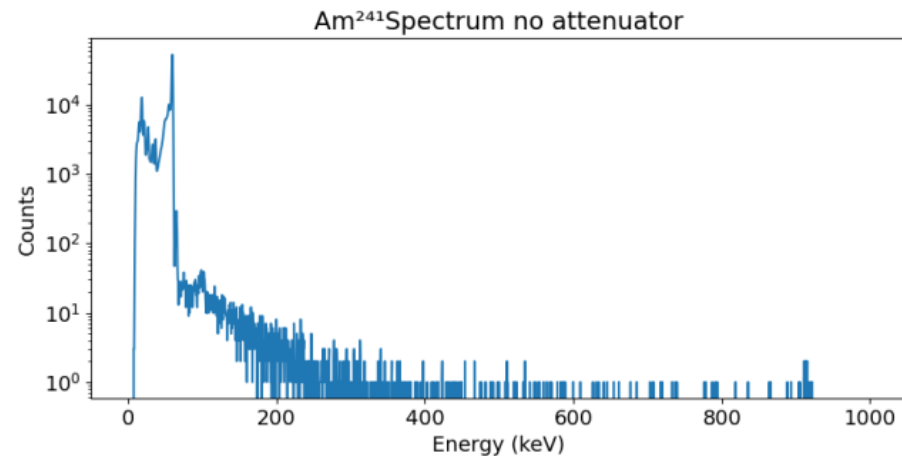
STIX Quick-look Light Curves

<https://datacenter.stix.i4ds.net/view/ql/lightcurves#>

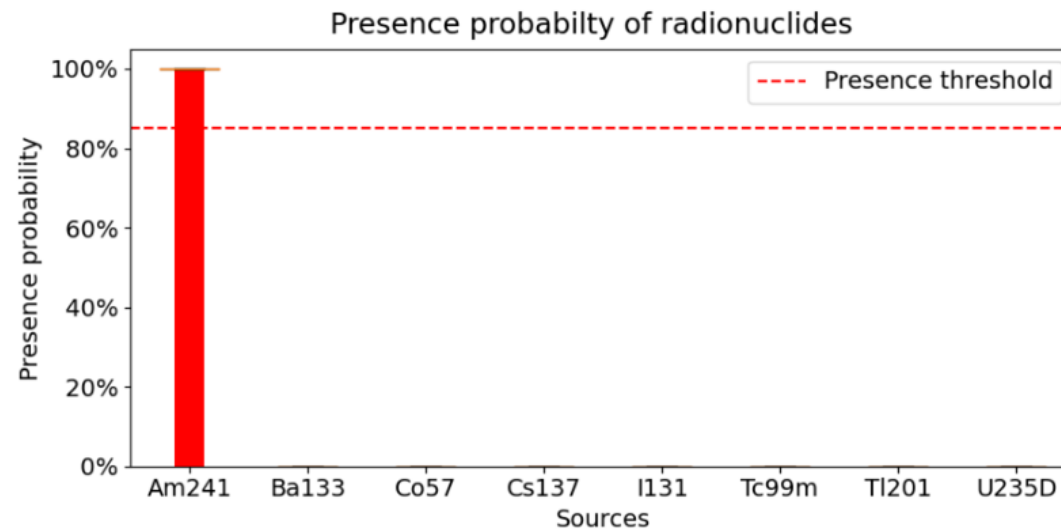
Detector and why Gamma Spectroscopy

- From space applications to industrial

Detector and why Gamma Spectroscopy

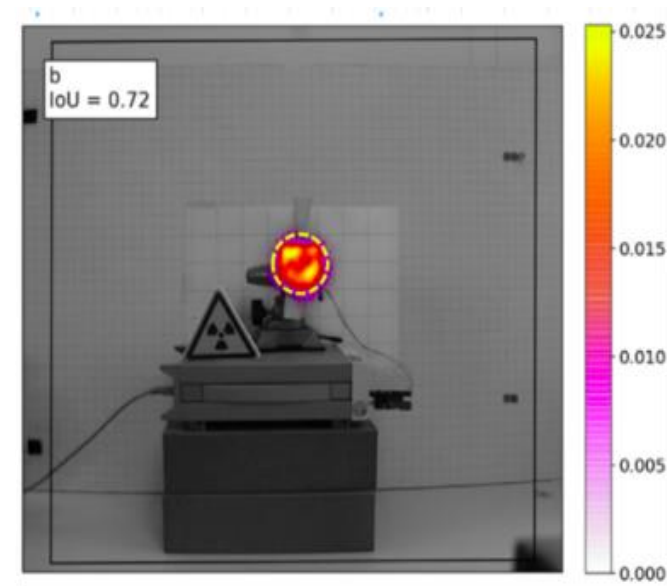
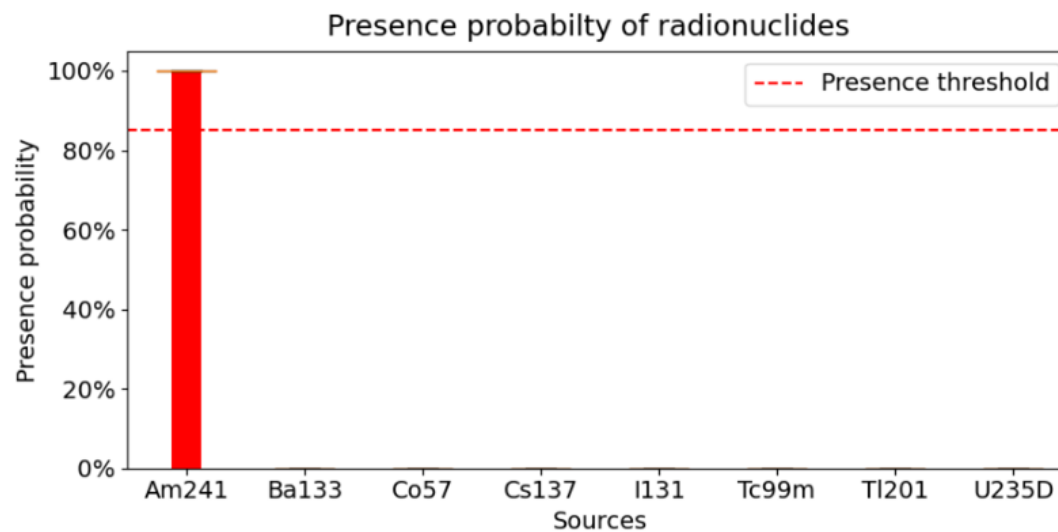
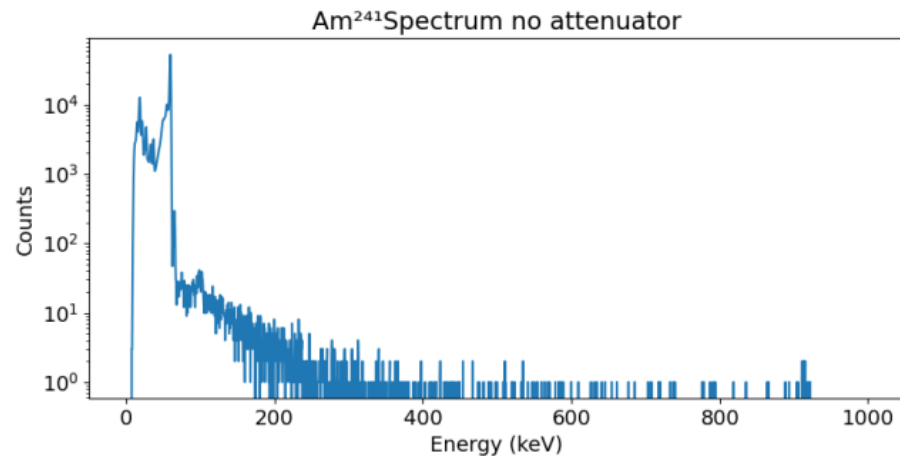


- From space applications to industrial



Detector and why Gamma Spectroscopy

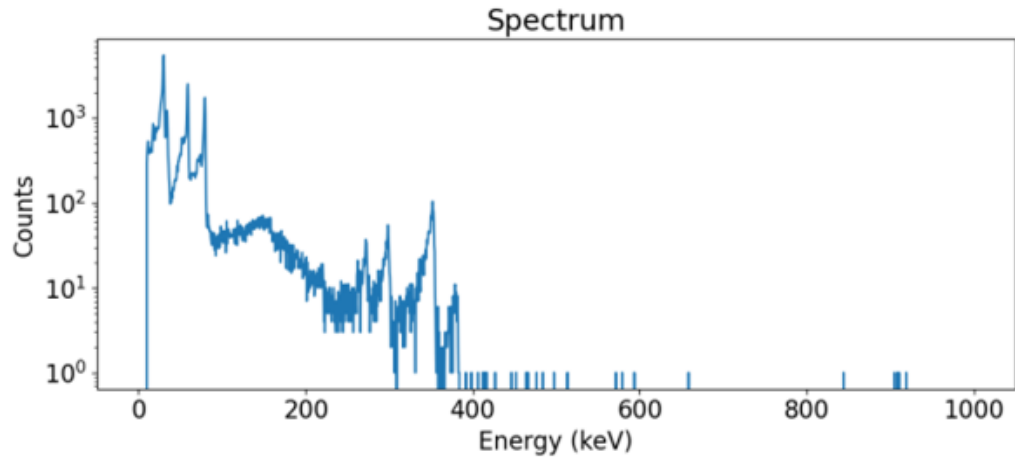
- Miniature pixelated spectro imager
- From space applications to industrial





3 ■ Where is AI?

Gamma Spectroscopy identification with CNN



Acquisition info

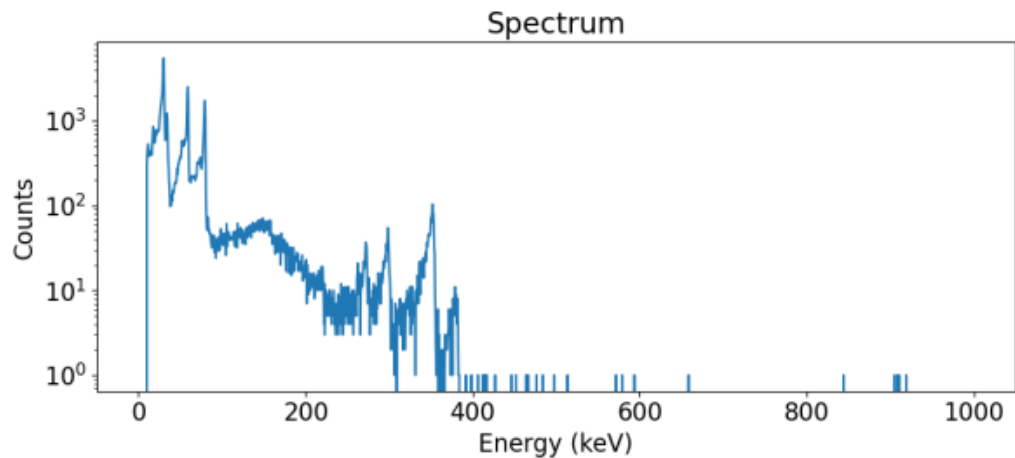
^{241}Am : 400 kBq

^{133}Ba : 3.7 MBq

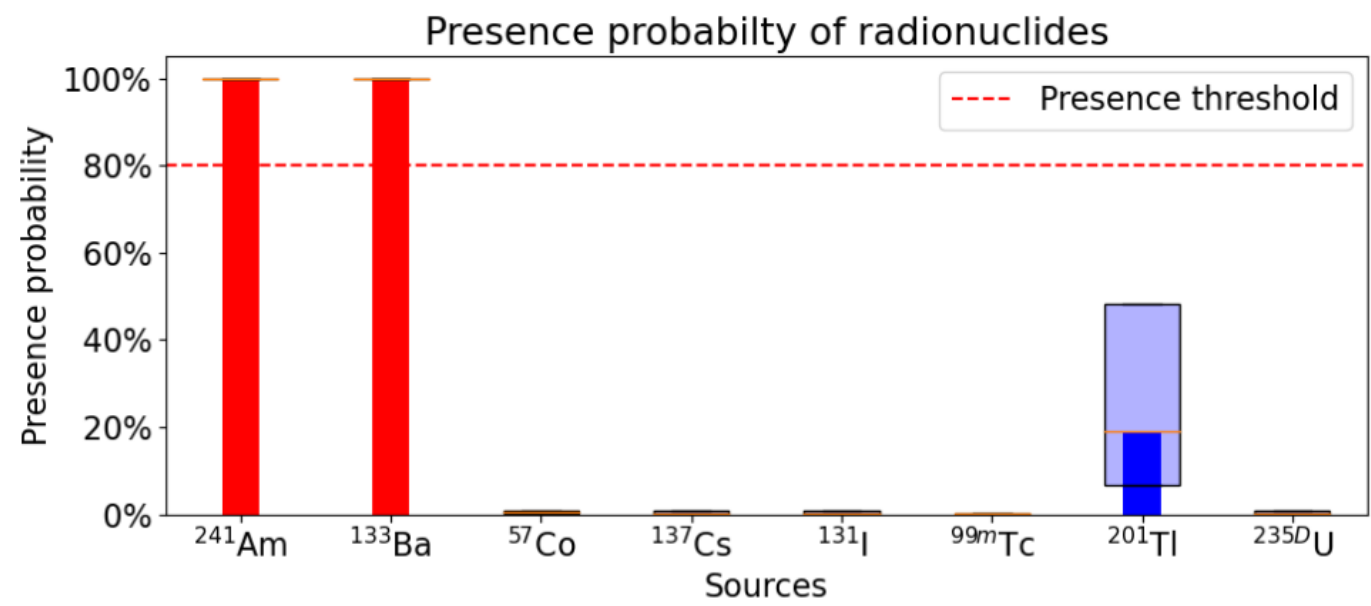
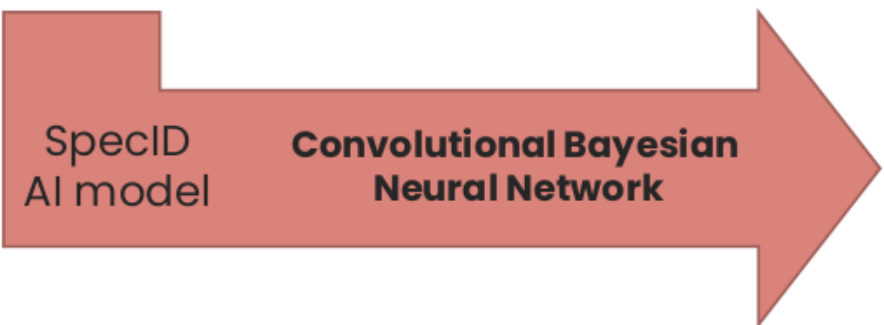
Distance from detector: ~2cm

Amount of photons: $7\text{E}+05$

Gamma Spectroscopy identification with CNN



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 ^{241}Am : 400 kBq
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Distance from detector: ~2cm
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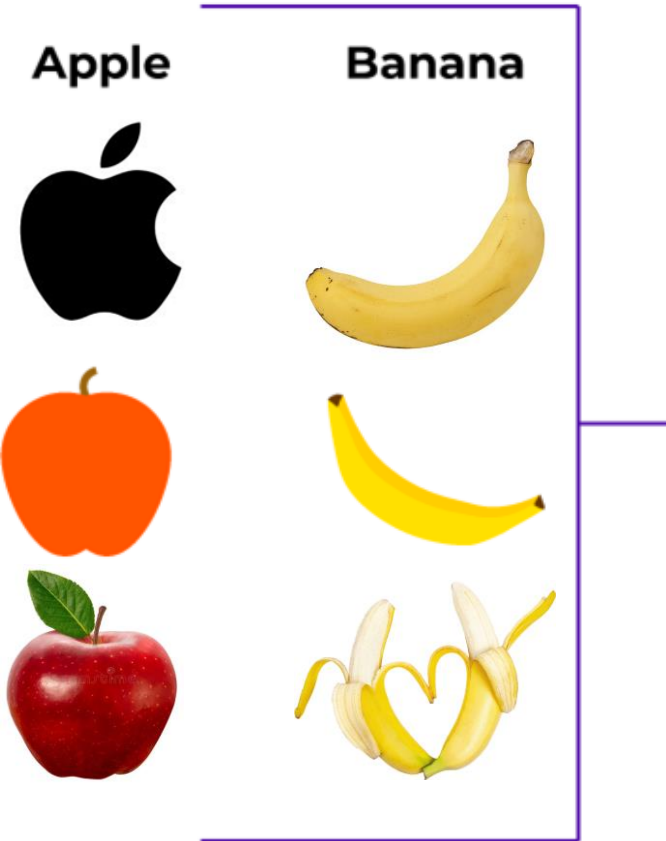


How?



Supervised - Classification

Training Data

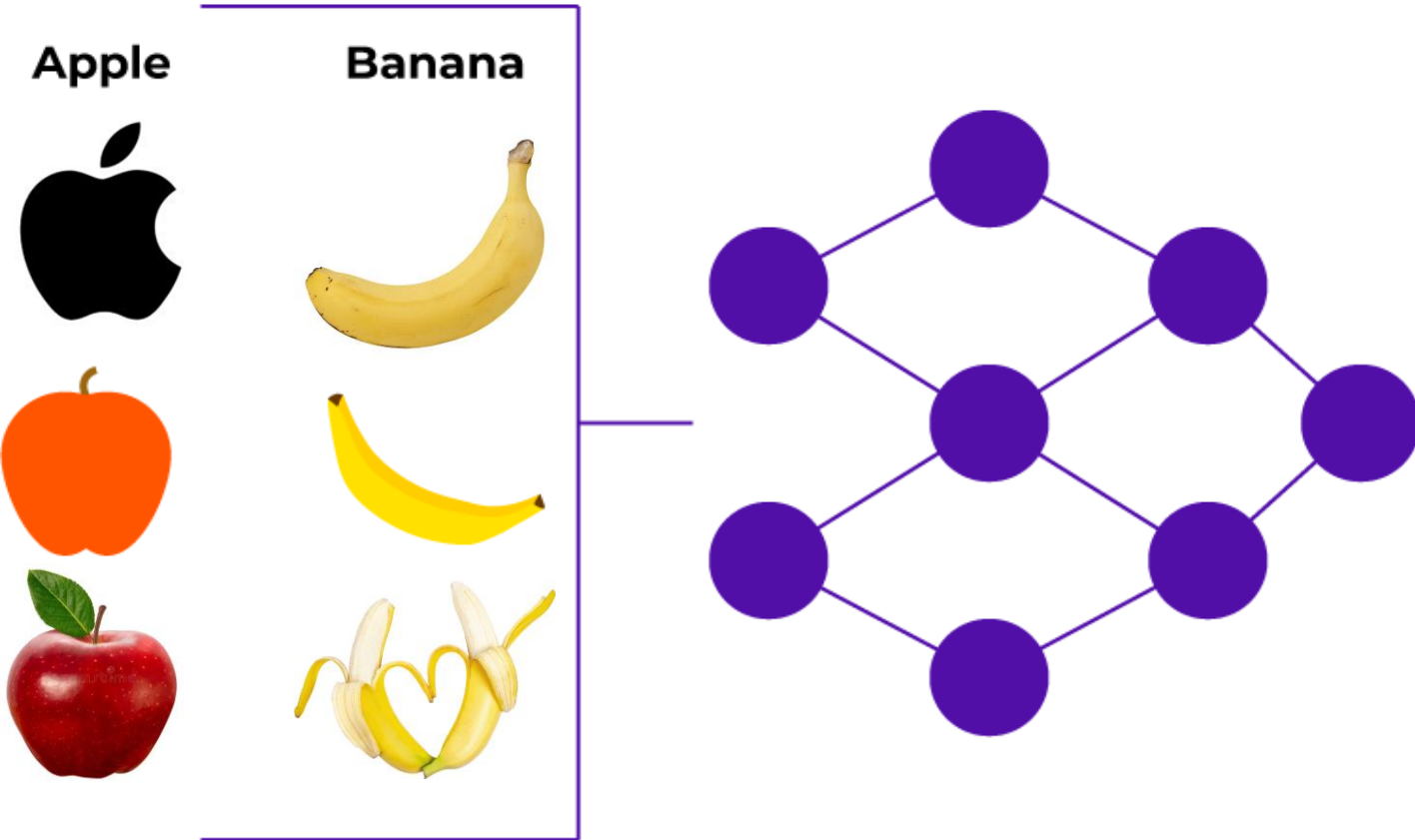




Supervised - Classification

Training Data

ML Algorithm



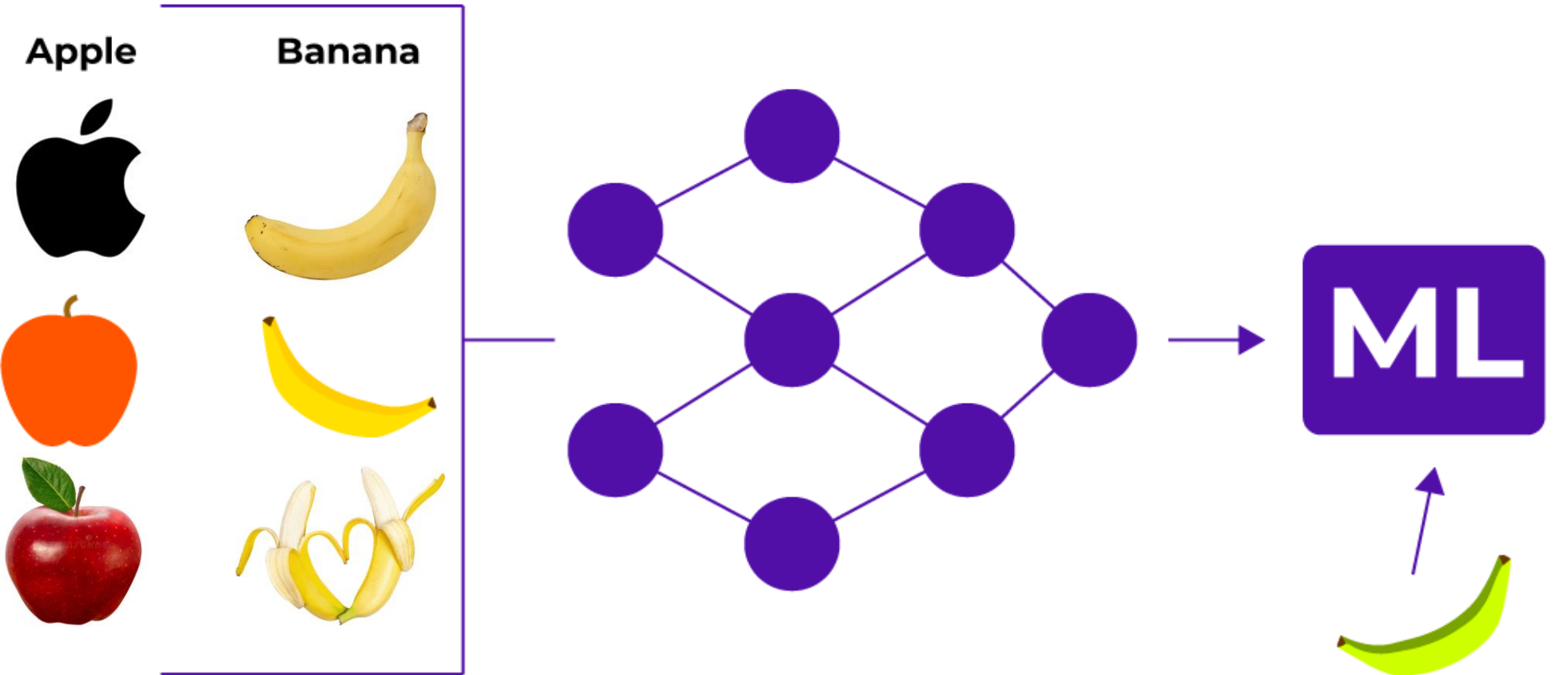


Supervised - Classification

Training Data

ML Algorithm

Model



Unseen and unlabeled data



Supervised - Classification

Training Data

ML Algorithm

Model

Prediction

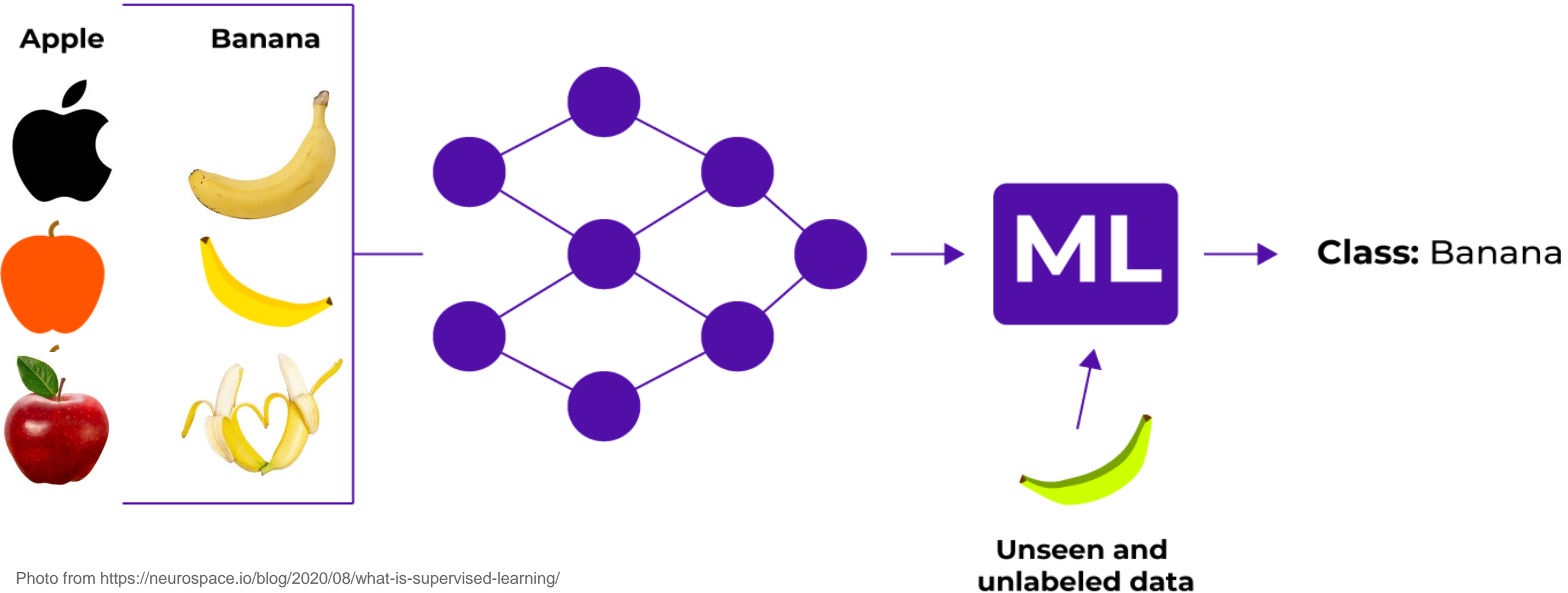


Photo from <https://neurospace.io/blog/2020/08/what-is-supervised-learning/>



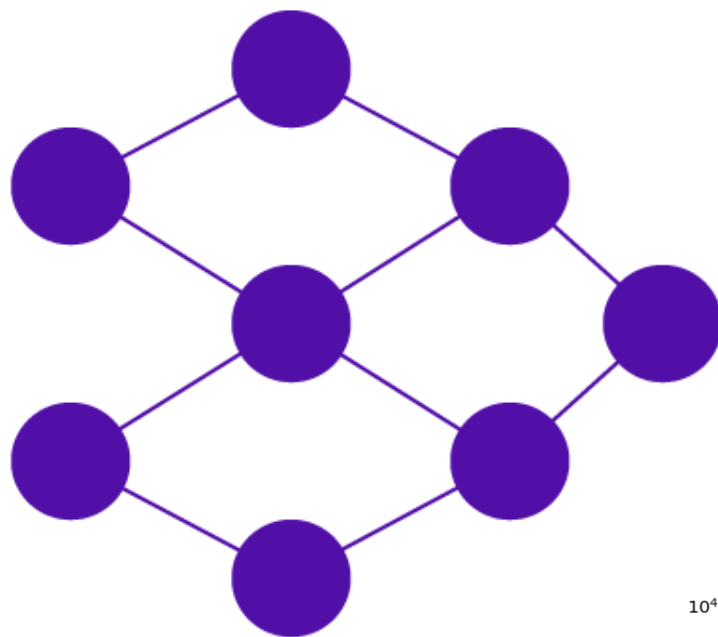
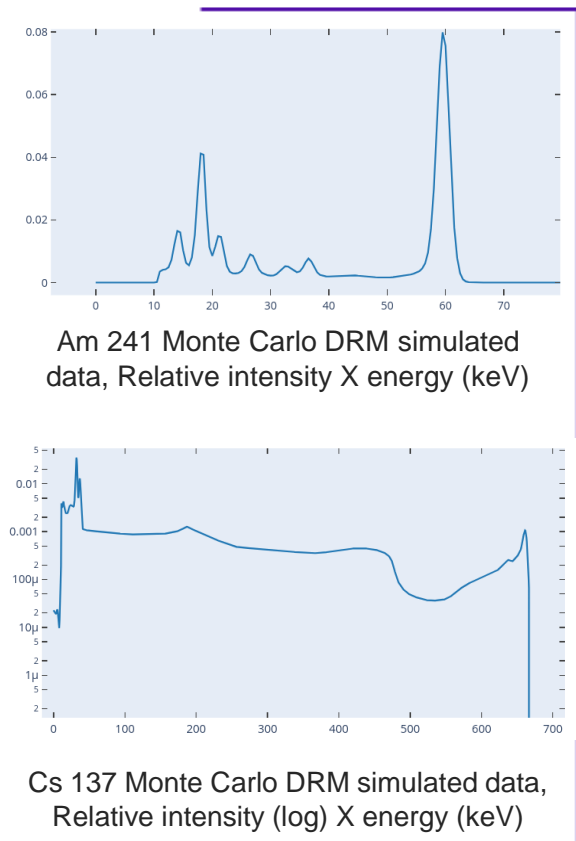
Supervised - Classification

Training Data

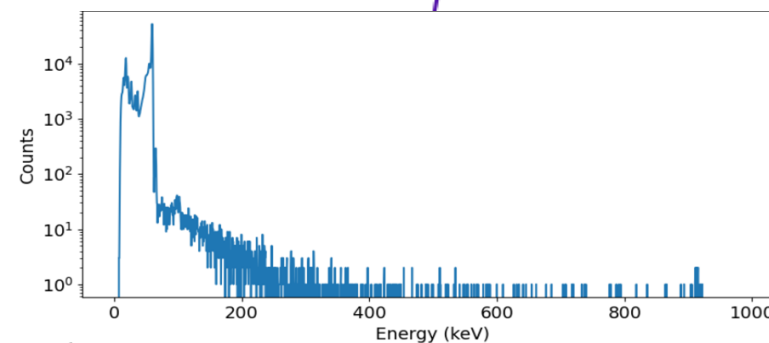
ML Algorithm

Model

Prediction



Class: Am 241



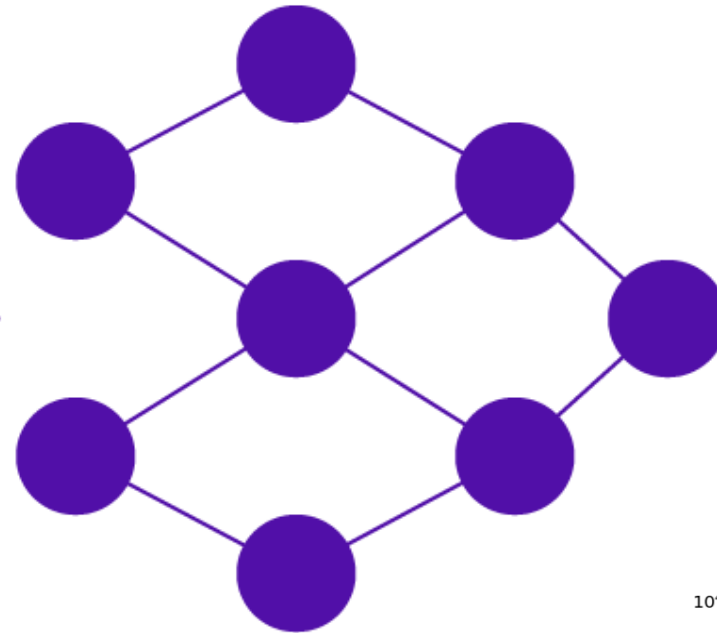
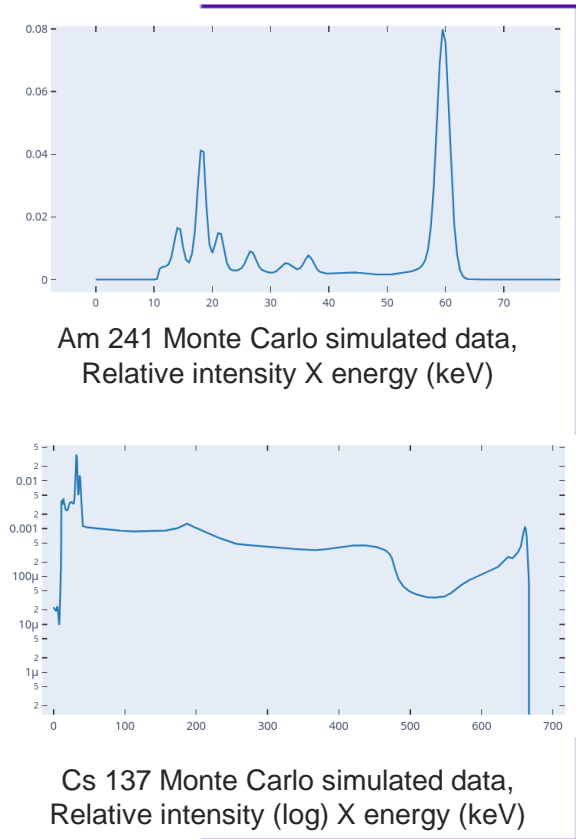
Supervised – Classification – Train data importance

Training Data

ML Algorithm

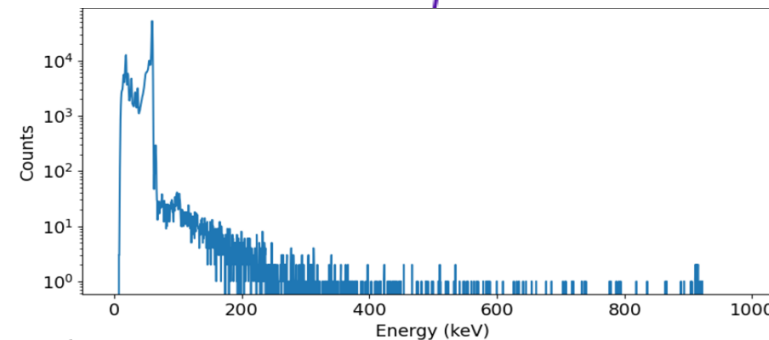
Model

Prediction



ML

Class: Am 241



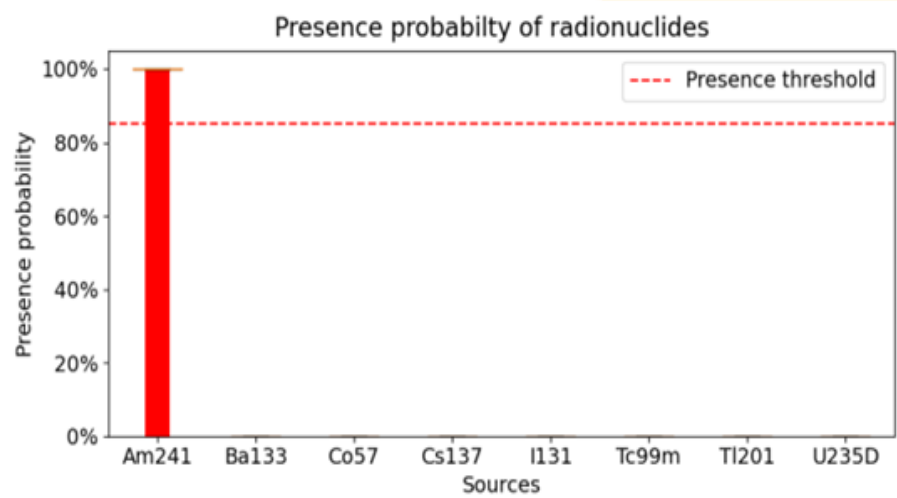
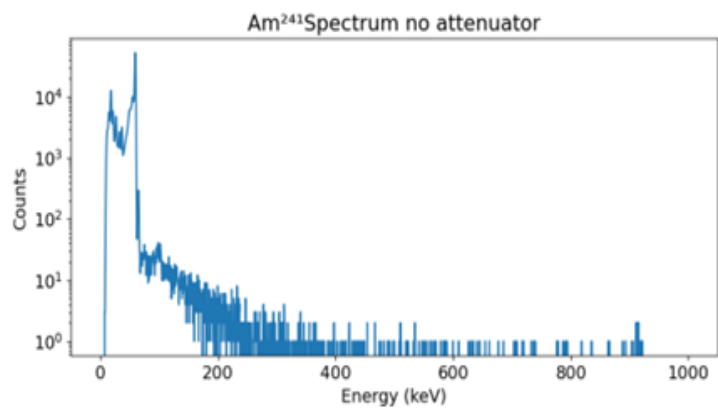
*"PDFs" MC generated -> Data Base creation by Poisson Sampling



4 ■ Complex environment issue

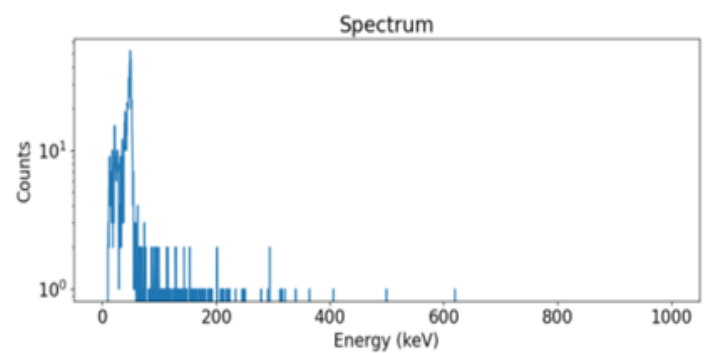
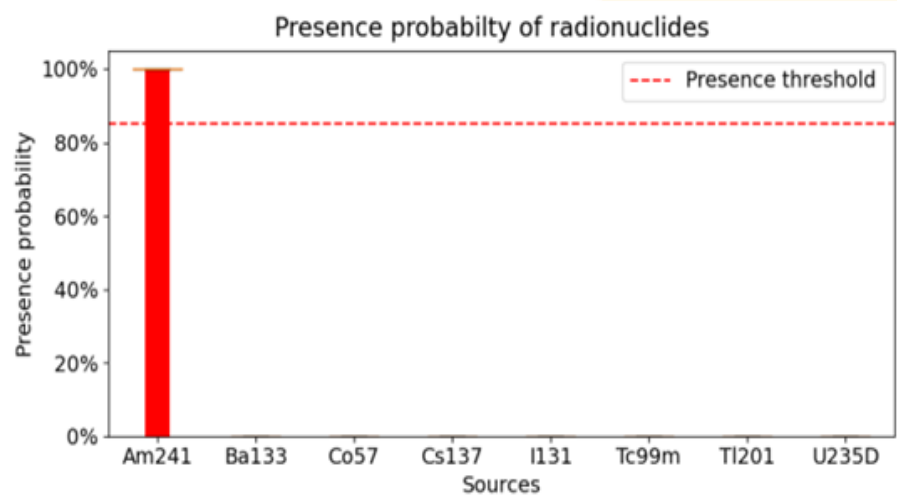
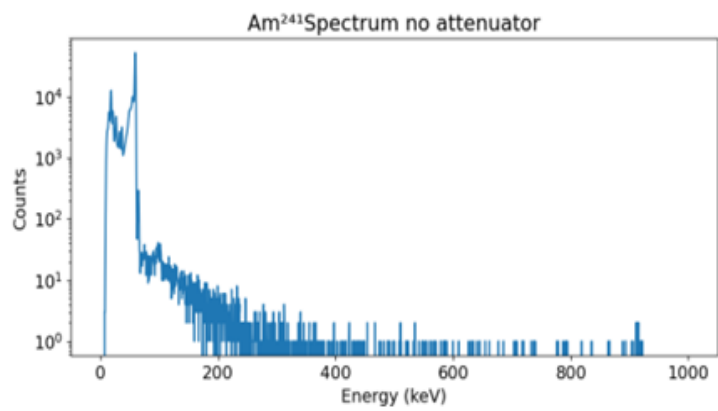
Issue of loss of accuracy in complex environments Shielded

Acquisition info
 ^{241}Am : 400 kBq
Distance from detector: ~2cm
Amount photons: $5.9\text{E}+05$ and $2.7\text{E}+02$

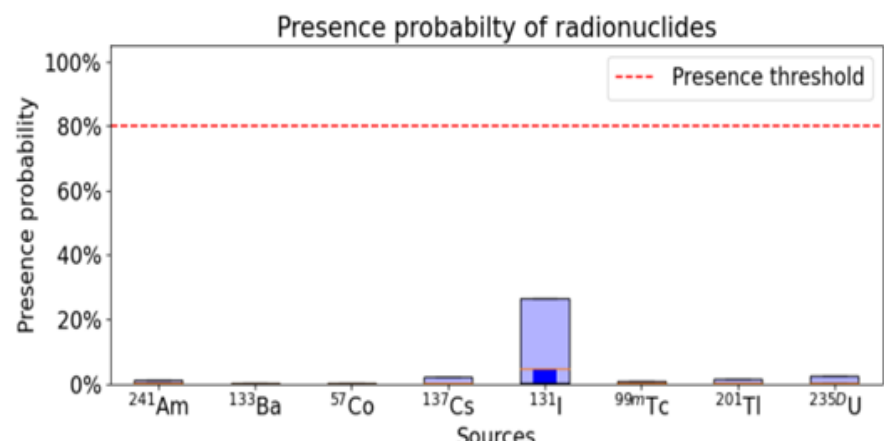


Issue of loss of accuracy in complex environments Shielded

Acquisition info
²⁴¹Am: 400 kBq
 Distance from detector: ~2cm
 Amount photons: 5.9E+05 and 2.7E+02



Attenuated by 2mm of lead

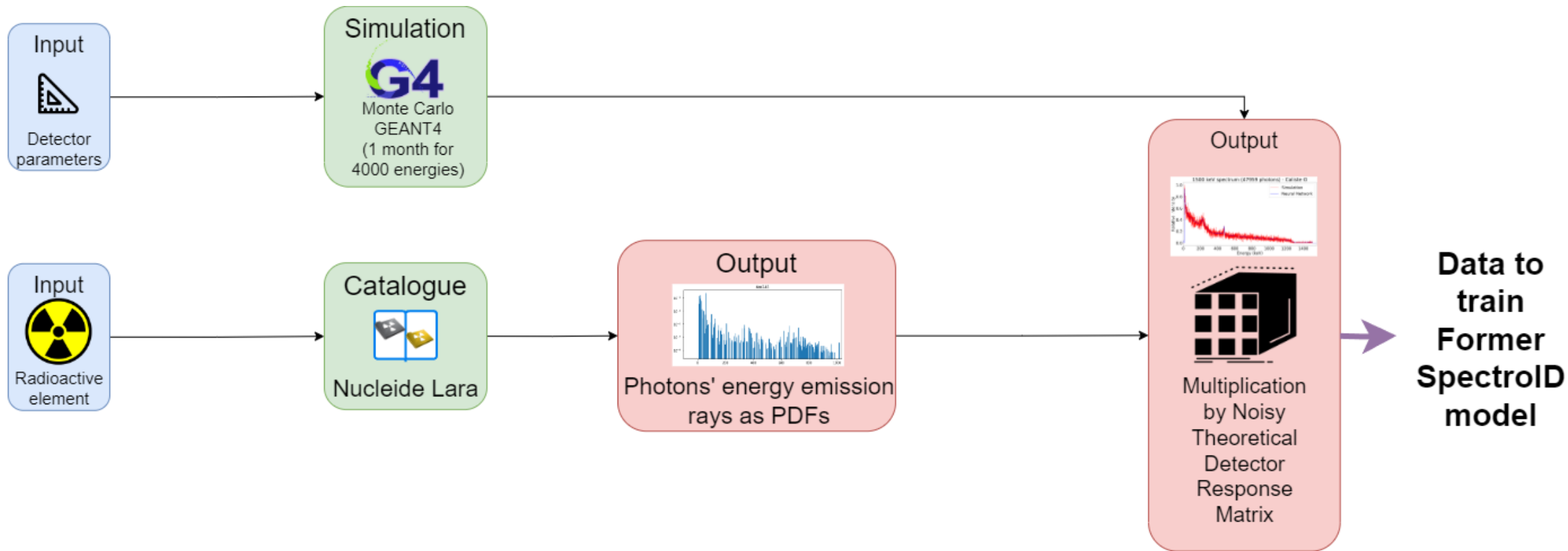




5 Proposed Solution?

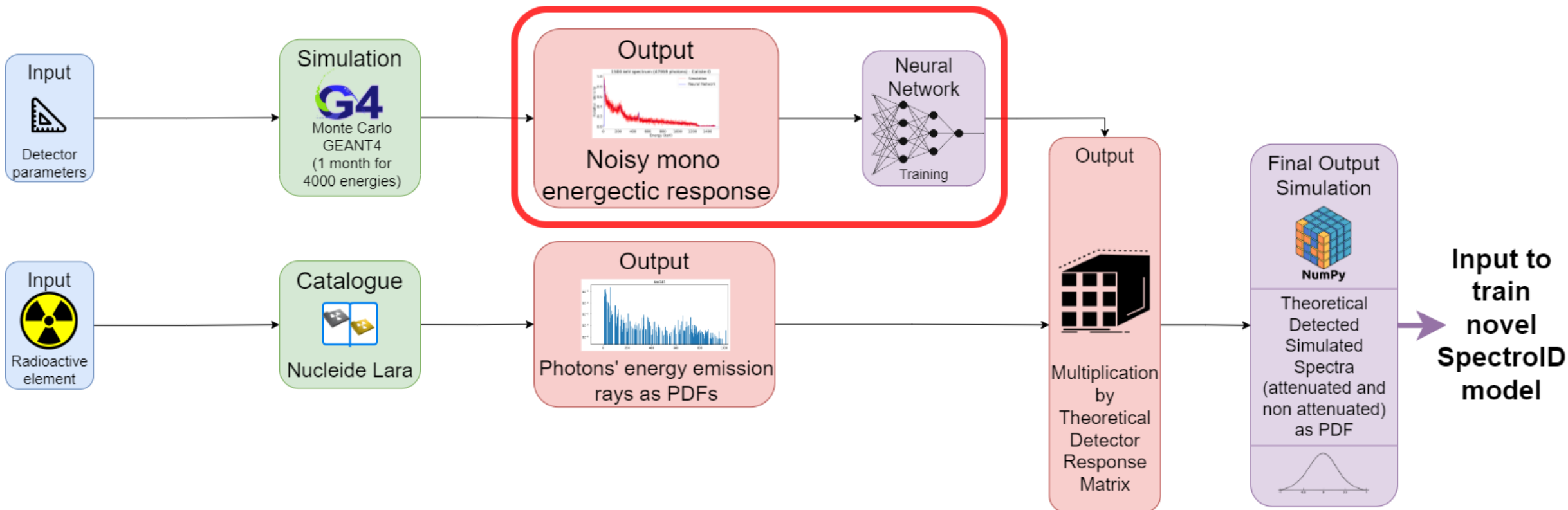
■ *AI - based advancements*
Data generation

Spectra construction – non shielded case



Proposed Solution

Mono energetic response accelerating and optimizing MC output



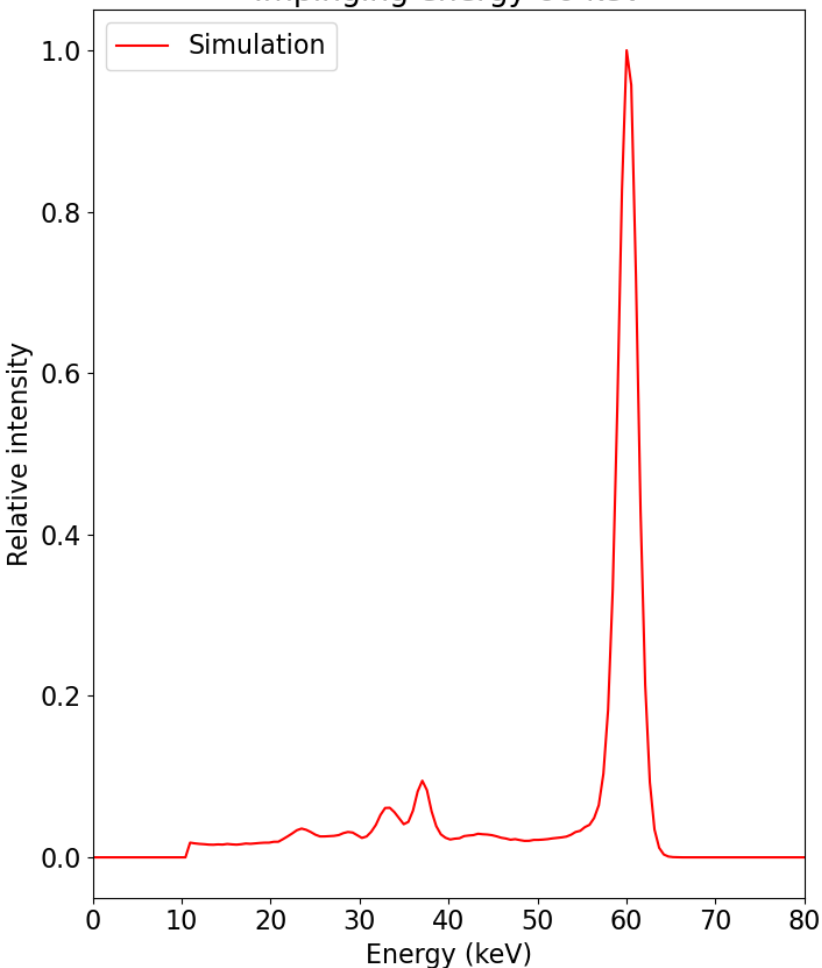
Proposed Solution

Mono energetic response accelerating and optimizing MC output

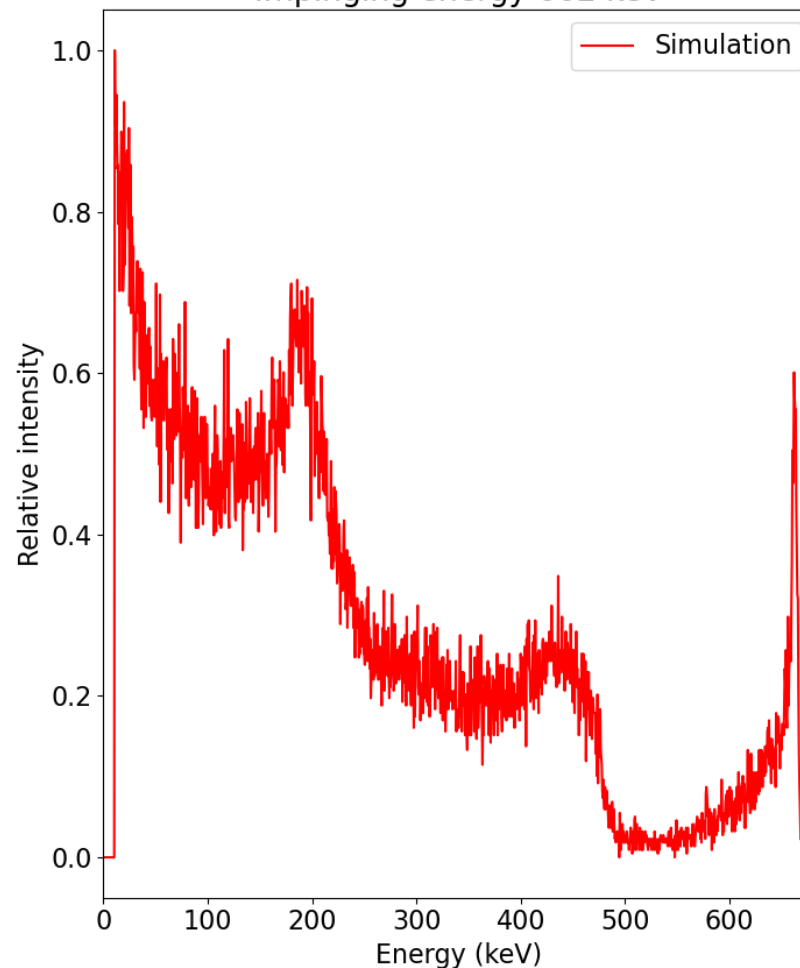


Simulation

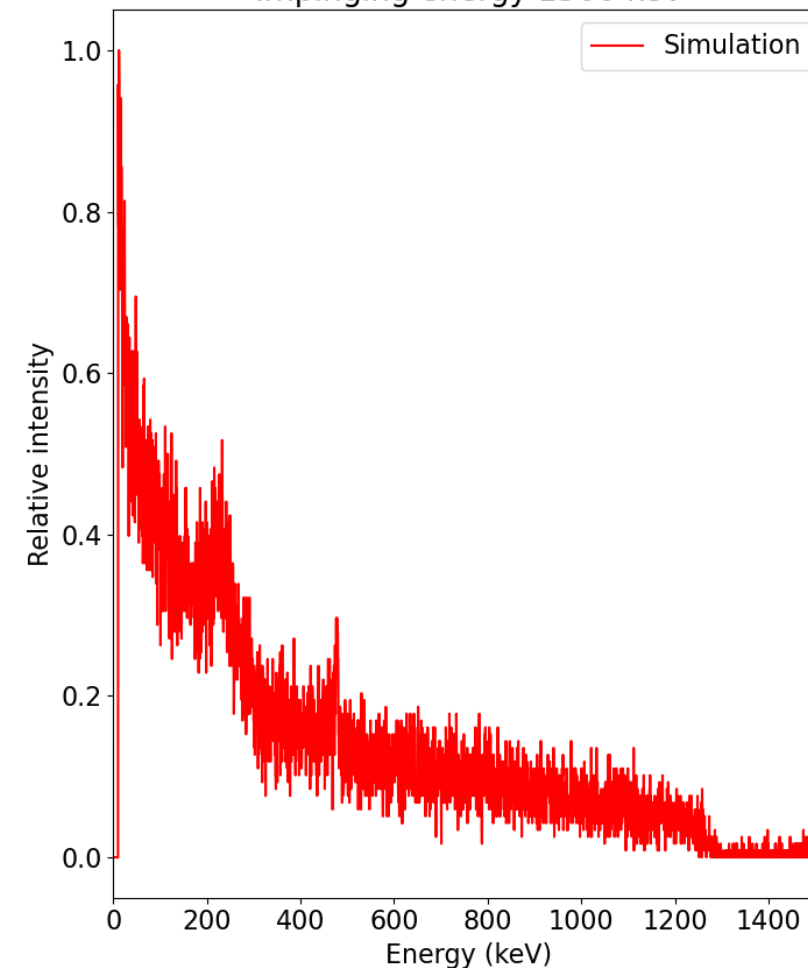
Impinging energy 60 keV



Impinging energy 662 keV



Impinging energy 1500 keV

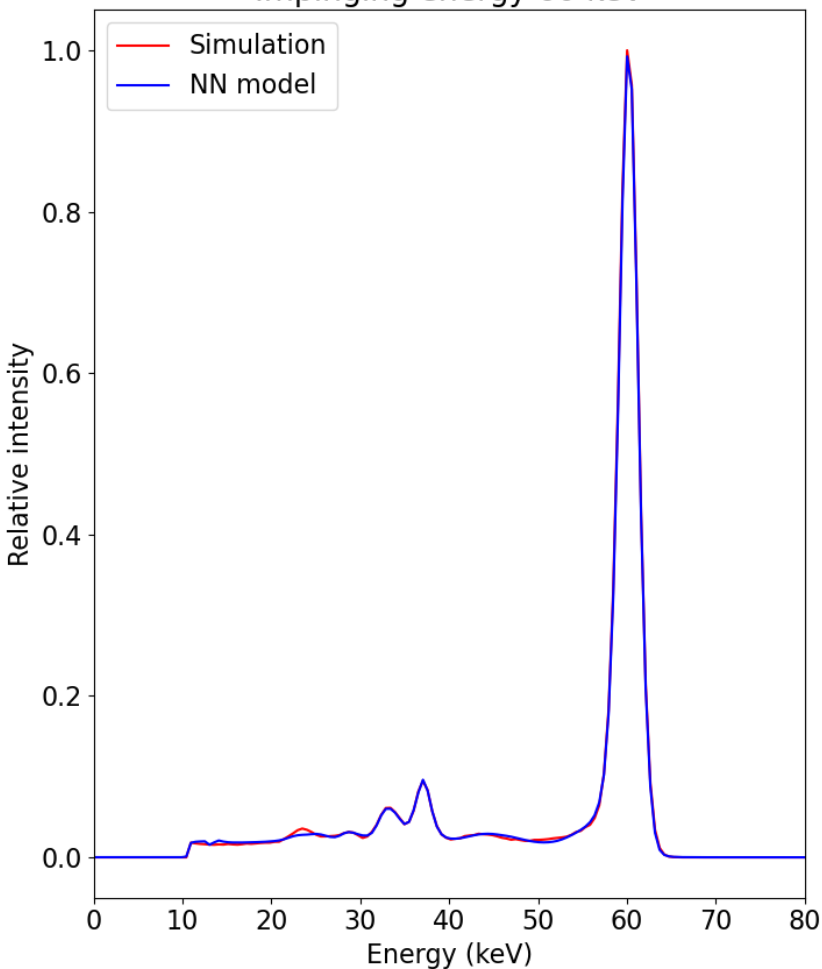


Proposed Solution

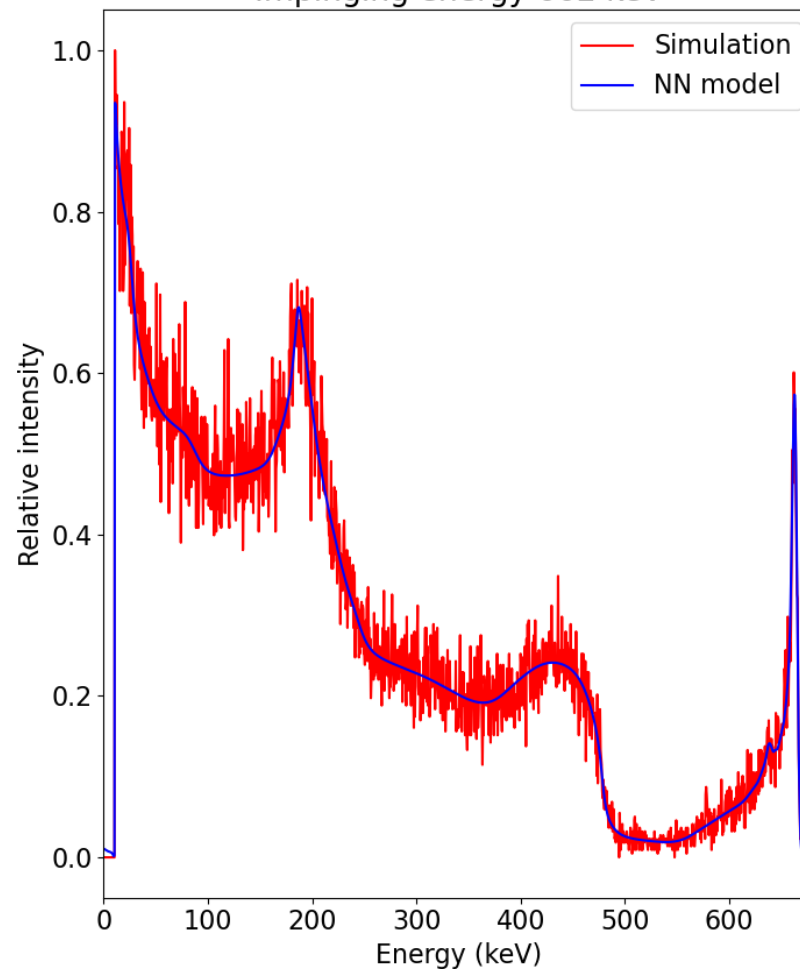
Mono energetic response accelerating and optimizing MC output

simulation

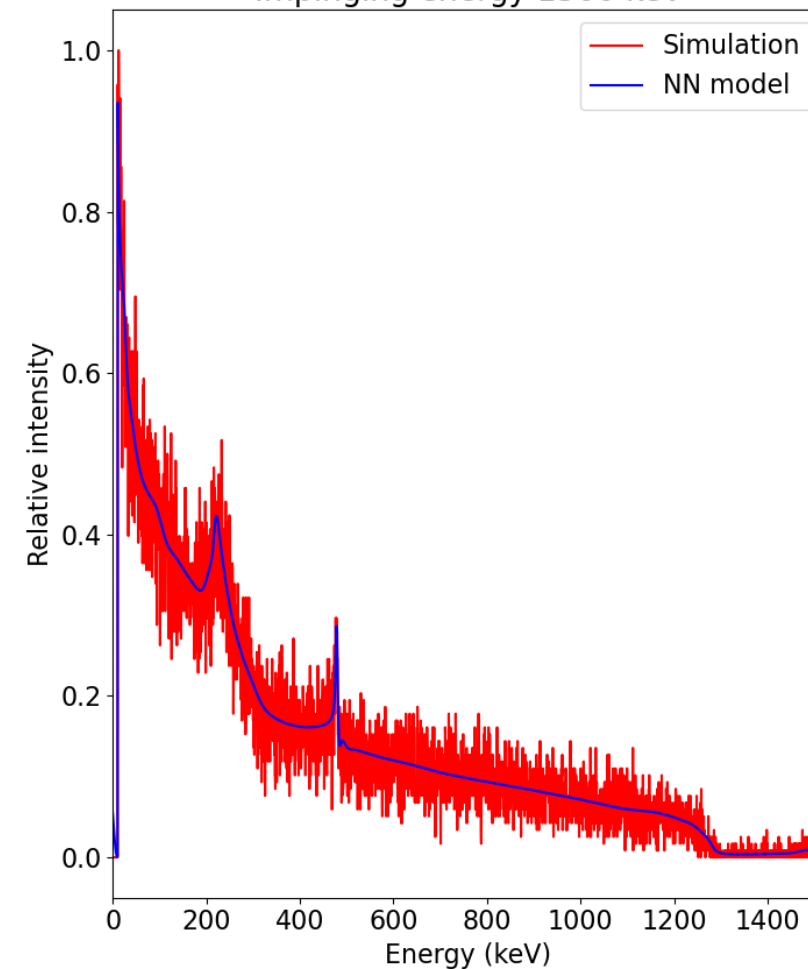
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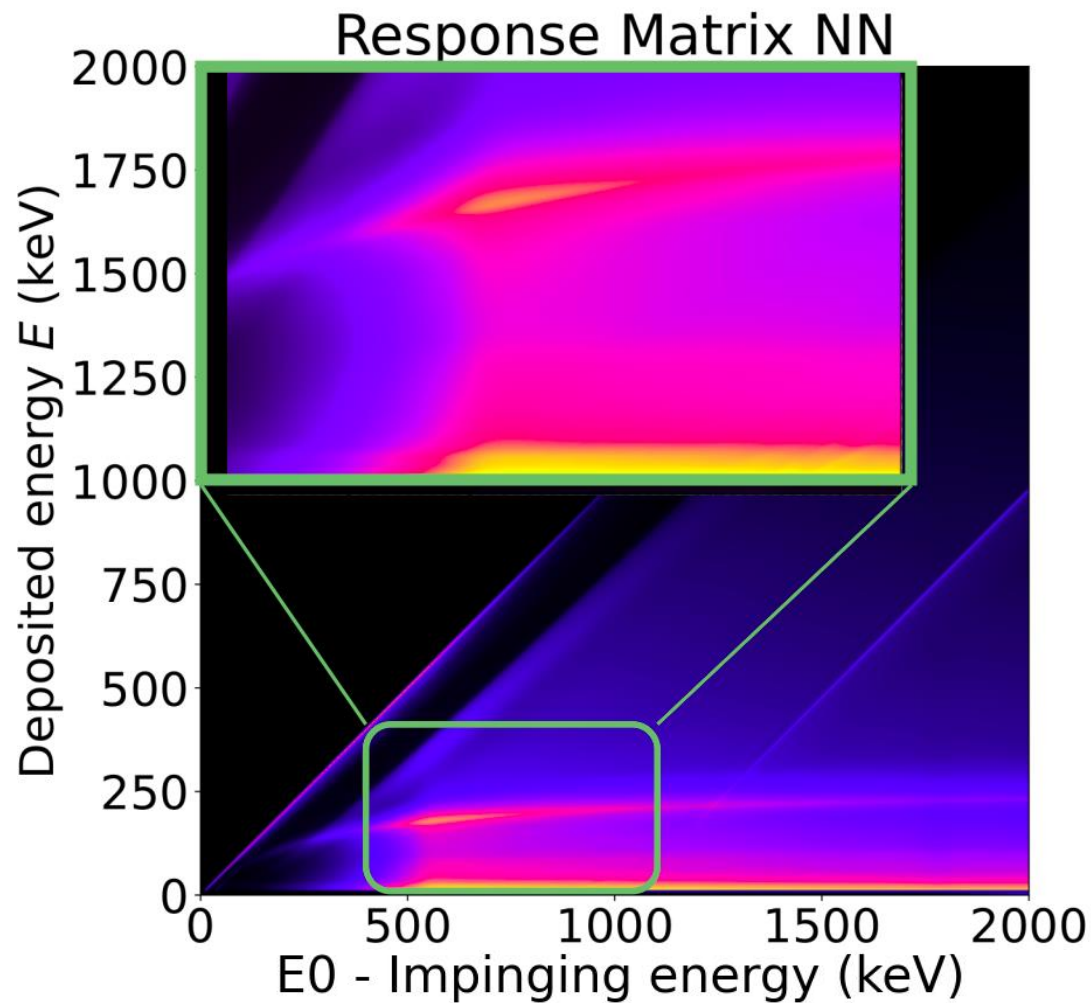
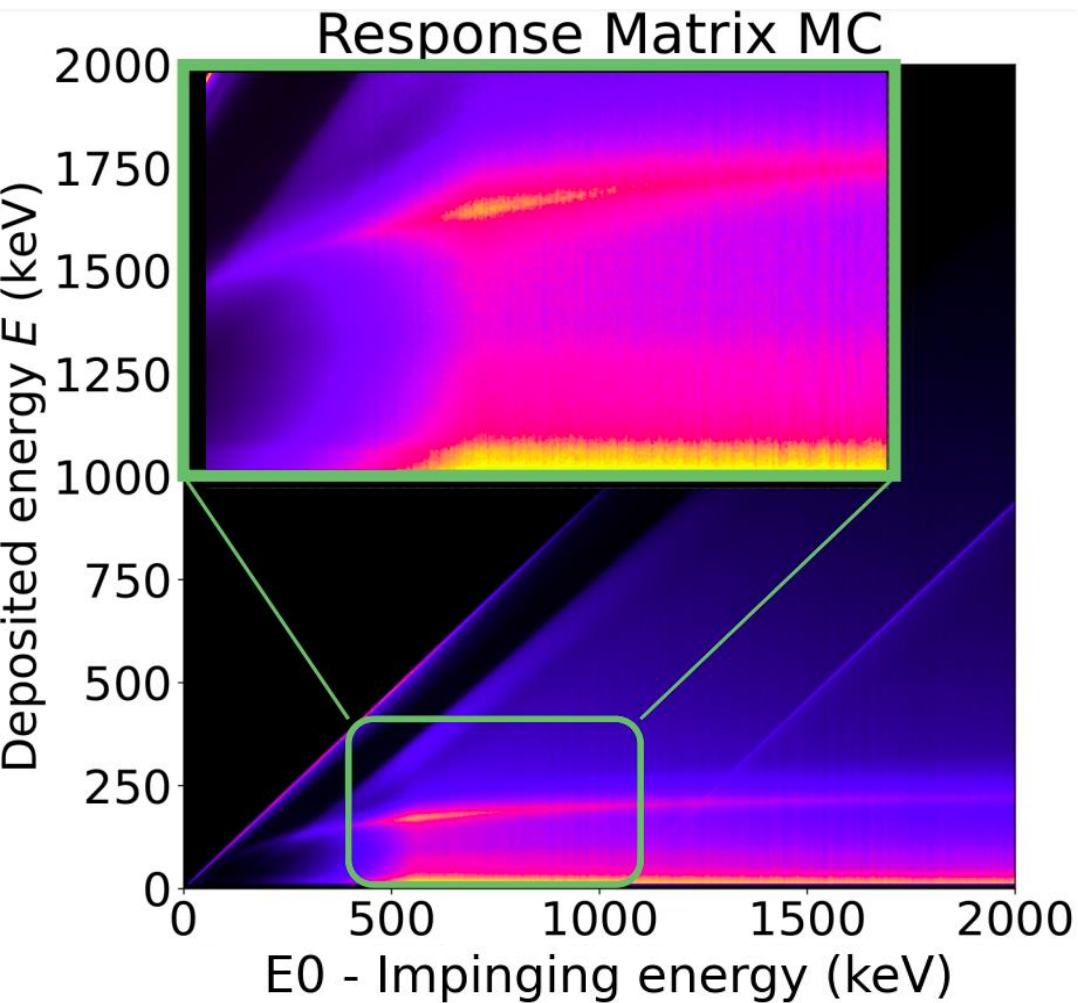
Impinging energy 1500 keV



Proposed Solution

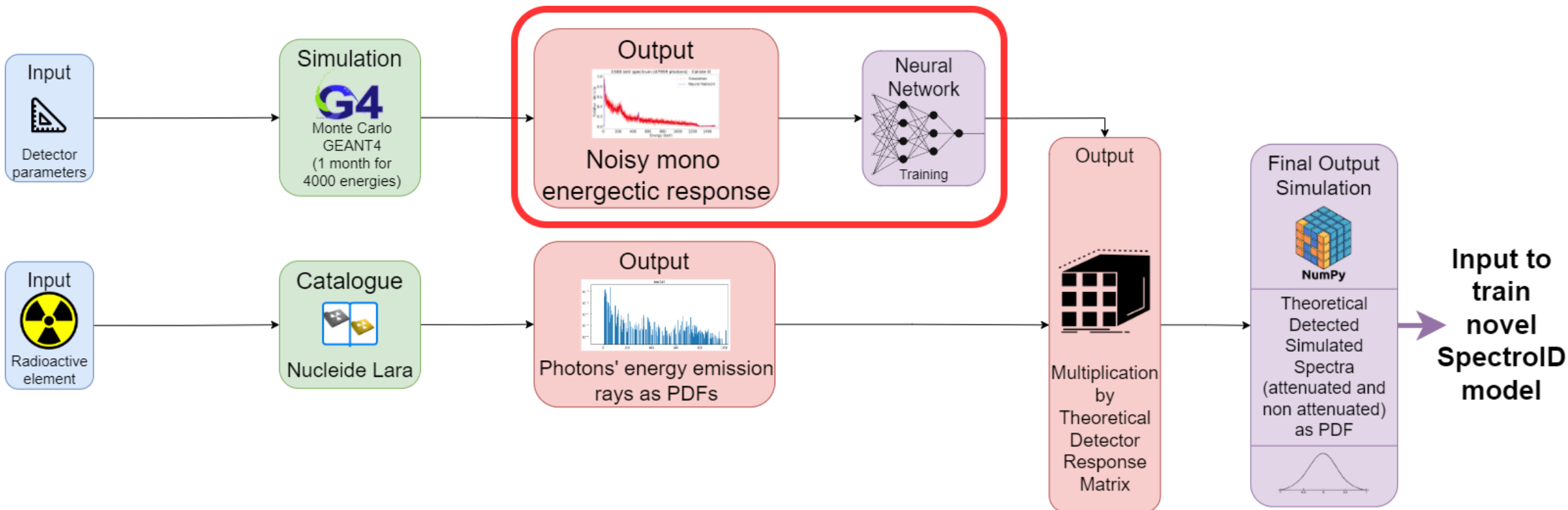
Mono energetic response – Response Matrix

simulation



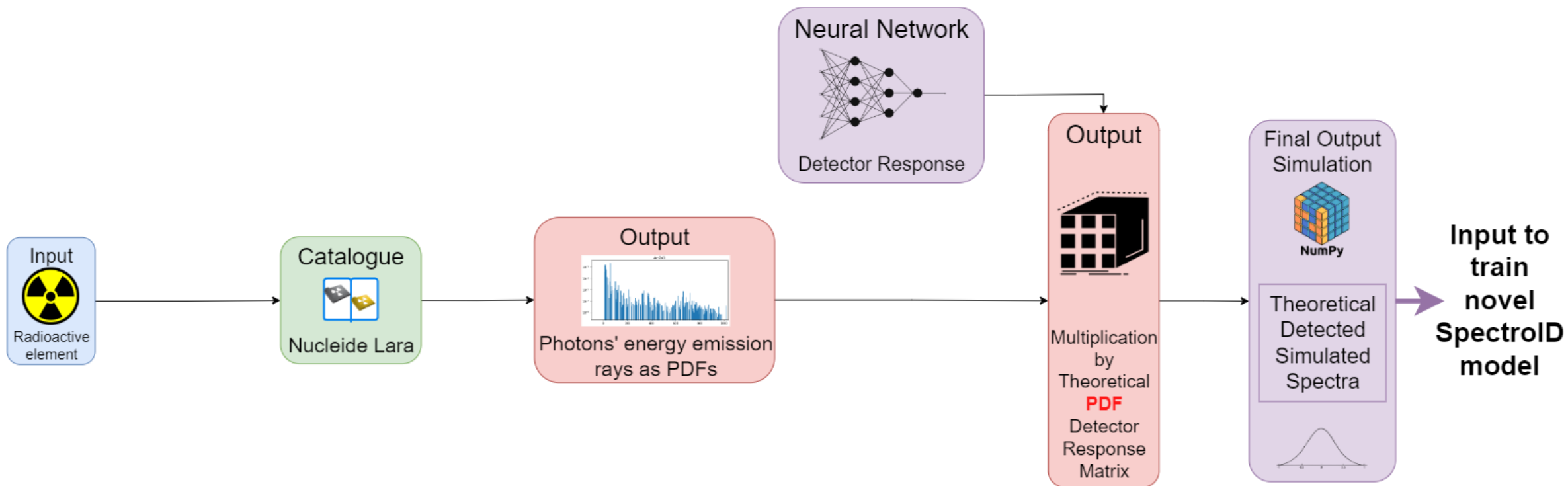
Proposed Solution

Mono energetic response accelerating and optimizing MC output



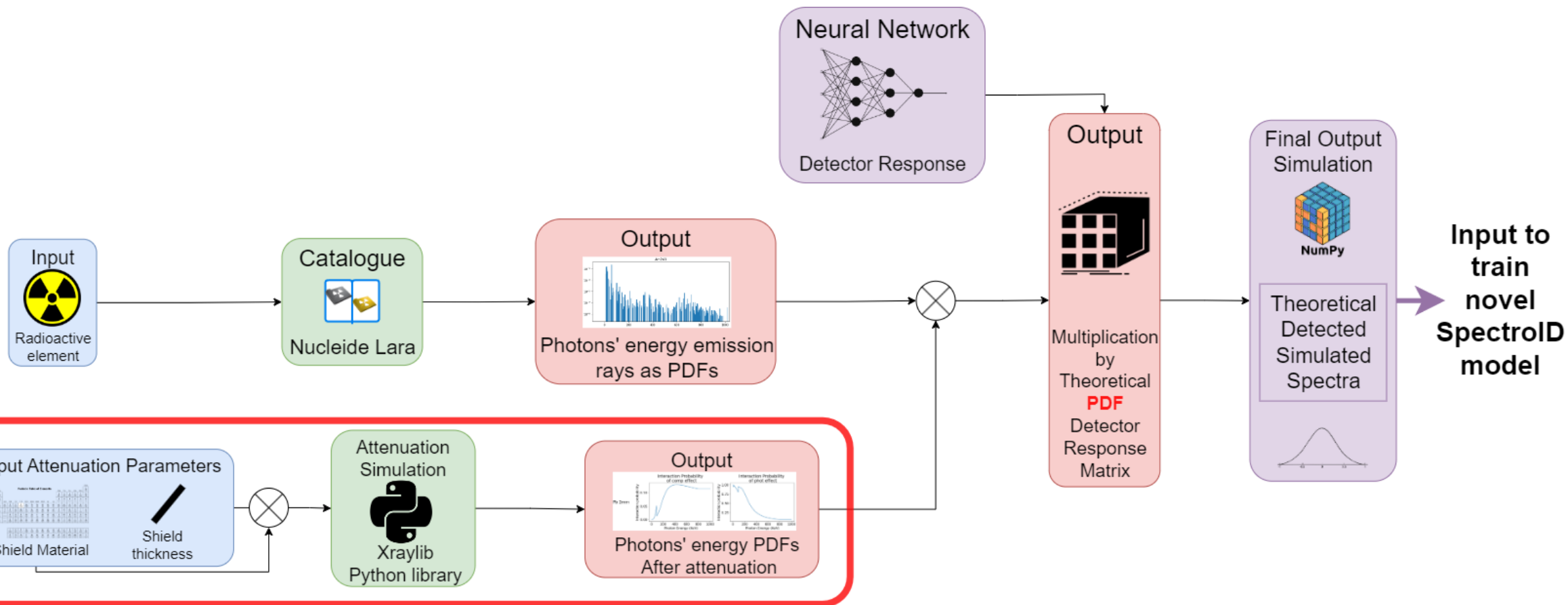
Proposed Solution

Mono energetic response accelerating and optimizing MC output



Proposed Solution

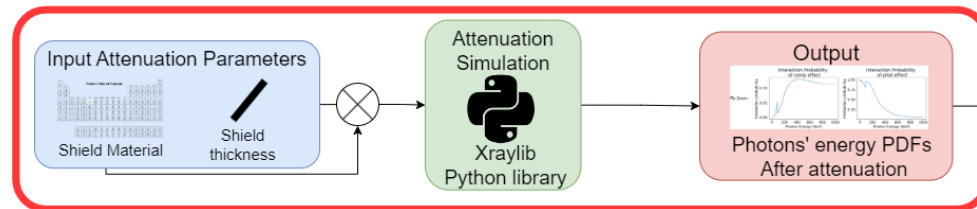
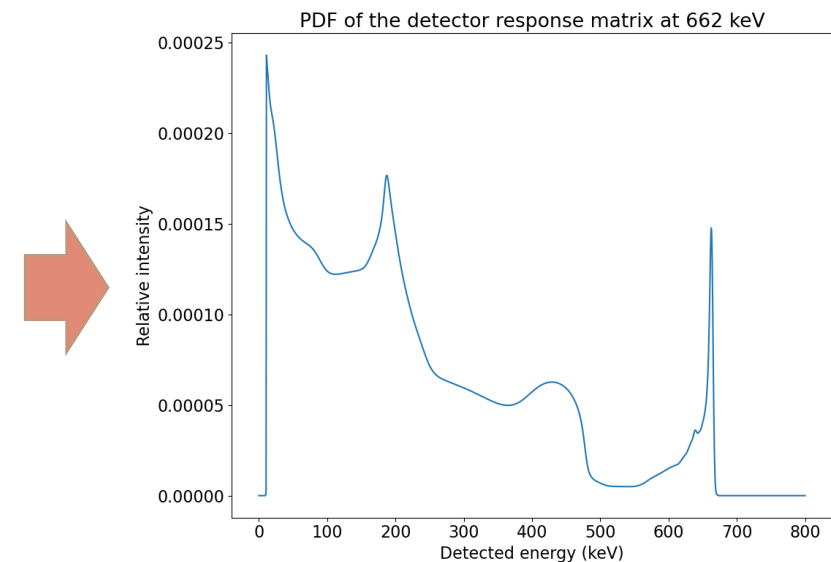
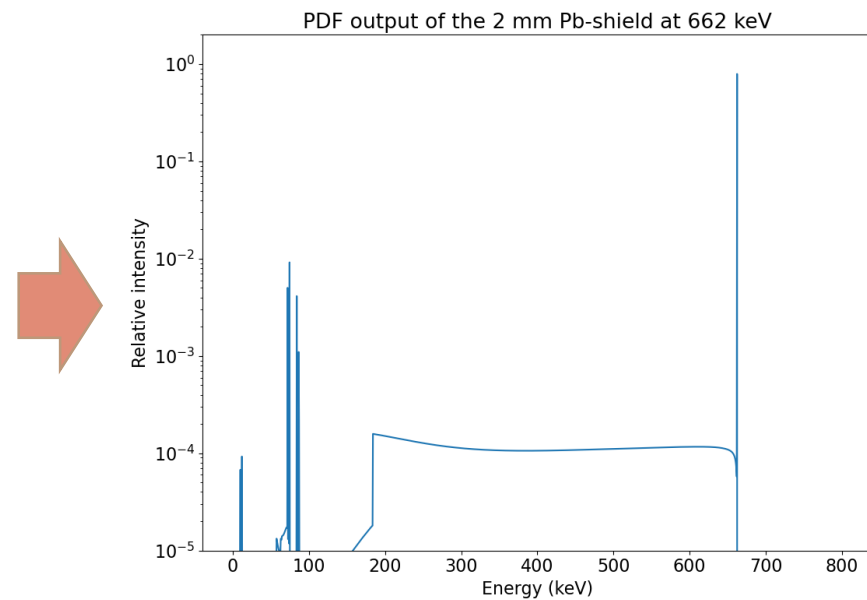
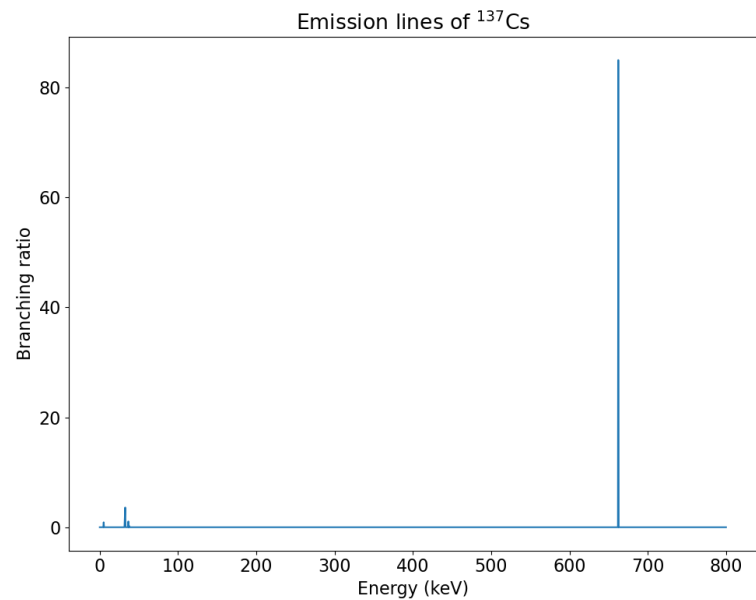
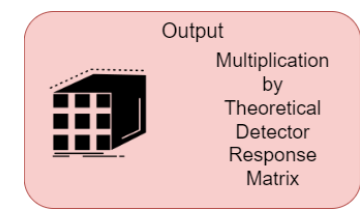
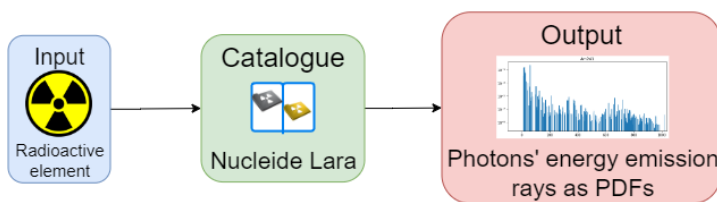
Physical modelization – Light matter interactions



Proposed Solution

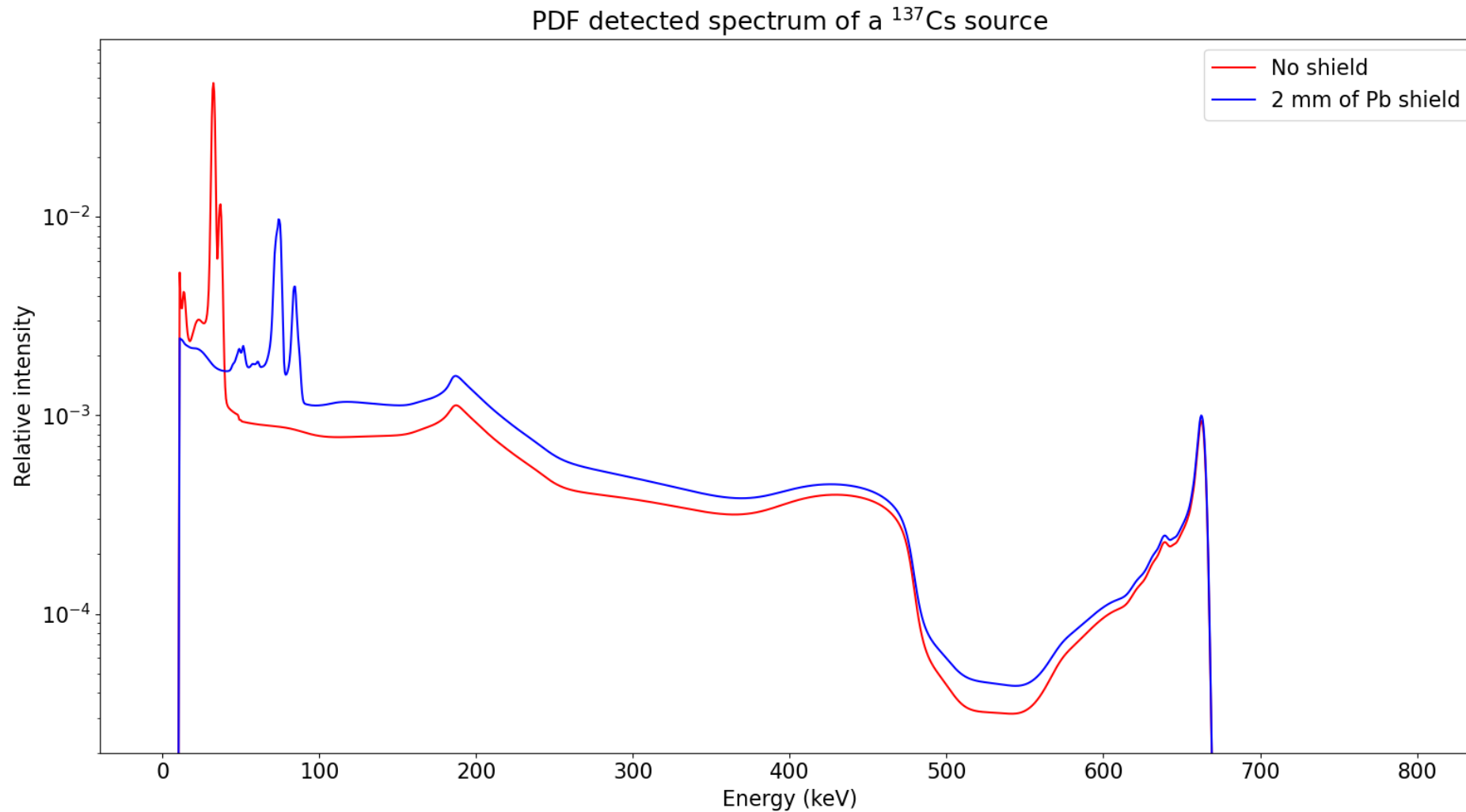
Physical modelization - Spectrum result

simulation



Proposed Solution

Physical modelization - Spectrum result



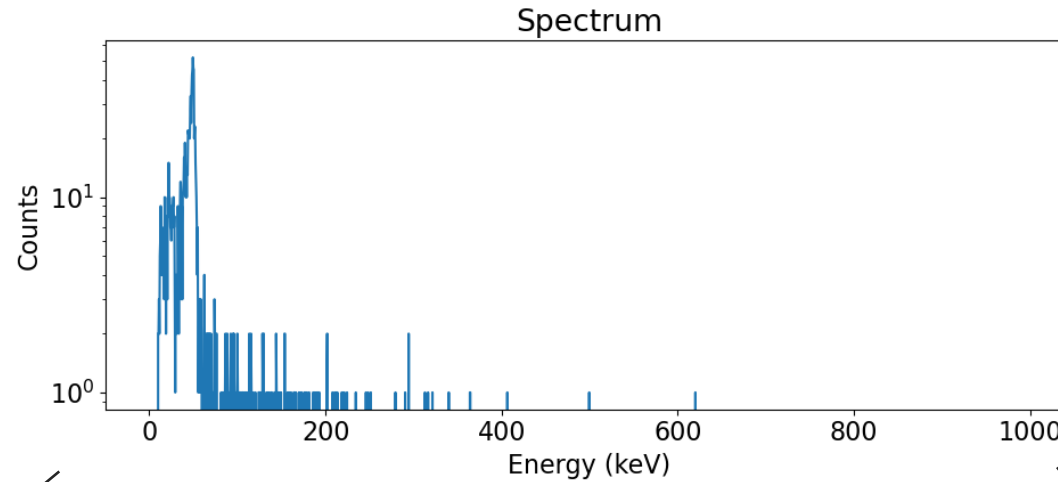


6 ■ Results after training

Results

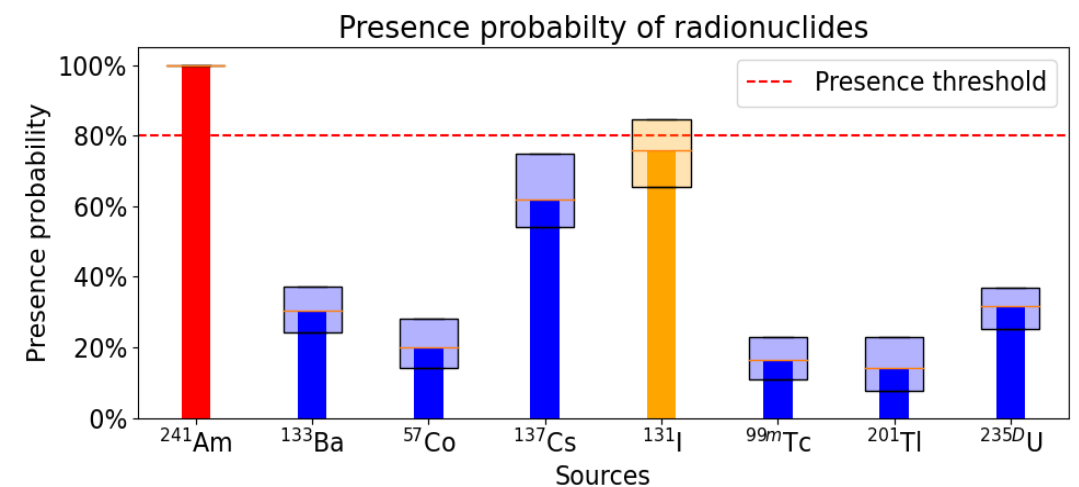
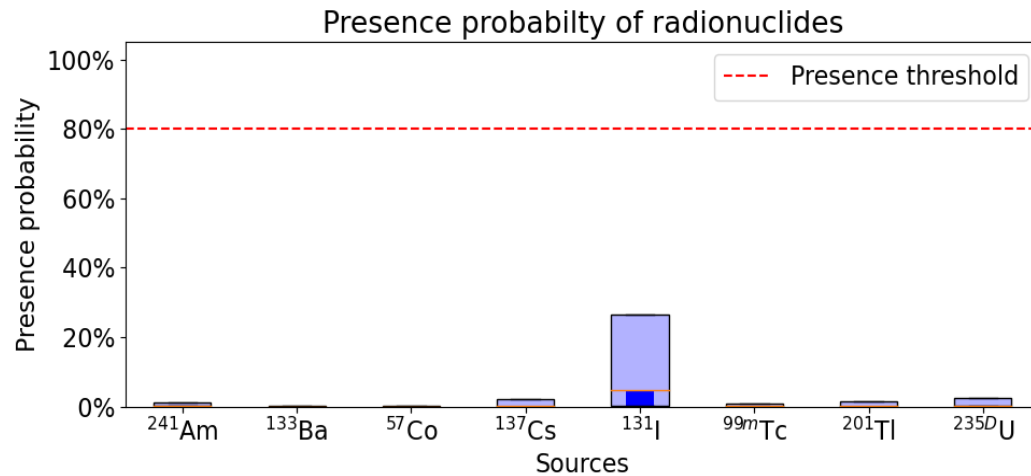
^{241}Am behind 2 mm of lead

Acquisition info
 ^{241}Am : 400 kBq
 Distance from detector: ~2cm
 Amount photons: $2.7\text{E}+02$



Non-shielded model

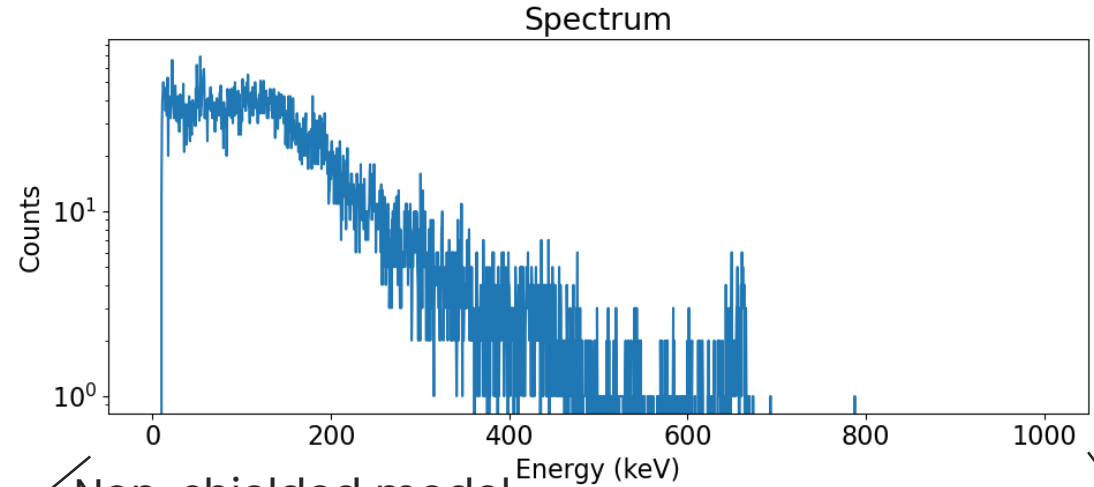
Shielded model



Results

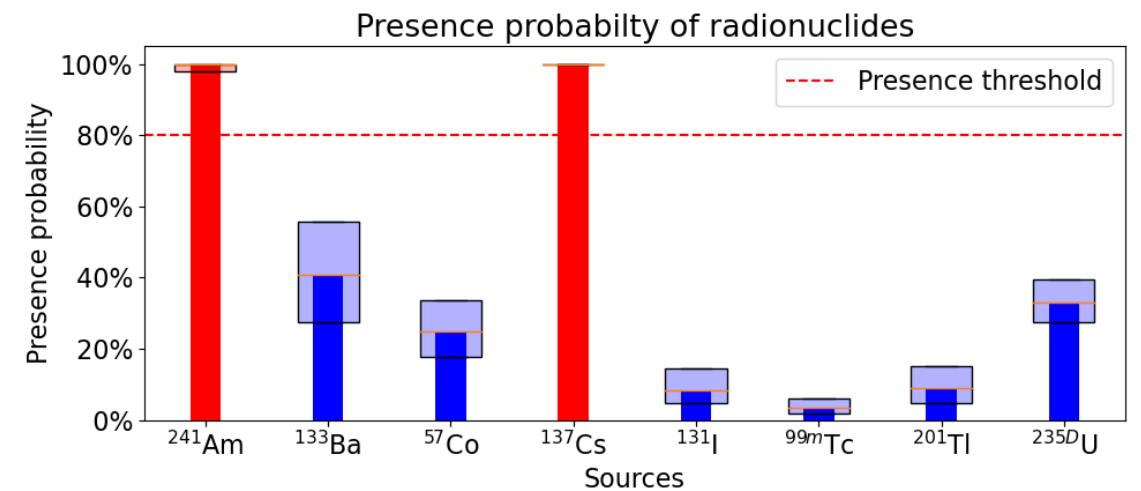
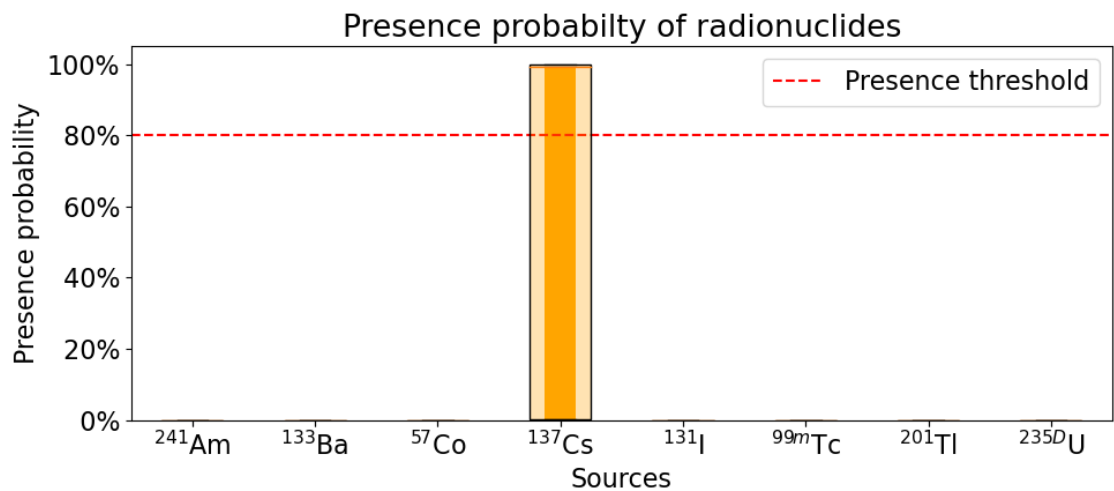
^{137}Cs and ^{241}Am behind 42 mm of copper

Acquisition info
 ^{241}Am : 400 kBq
 ^{137}Cs : 3.4 MBq
 Distance from detector: ~6cm
 Amount photons: $1.7\text{E}+04$



Non-shielded model

Shielded model





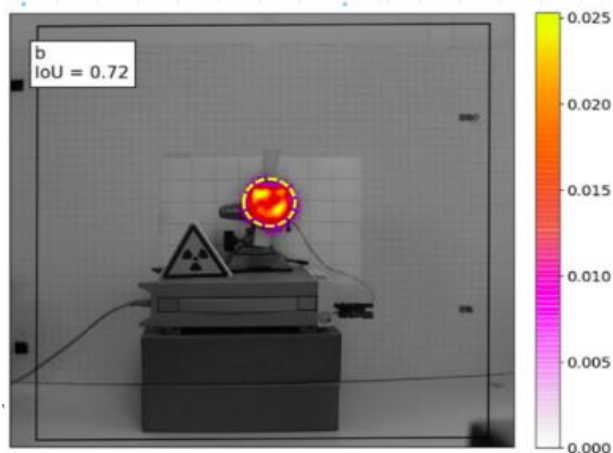
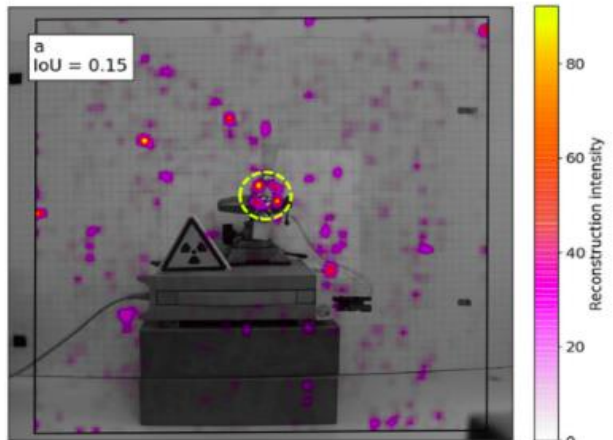
7 ■ Conclusions and further applications

Conclusions and further applications

- Training data proved to solve some attenuation issues
- No performance was lost
- Artificial data generation achieved prior objective

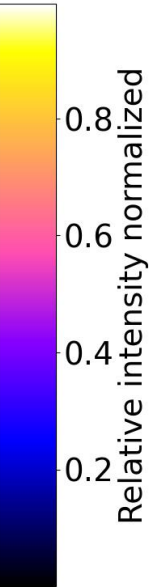
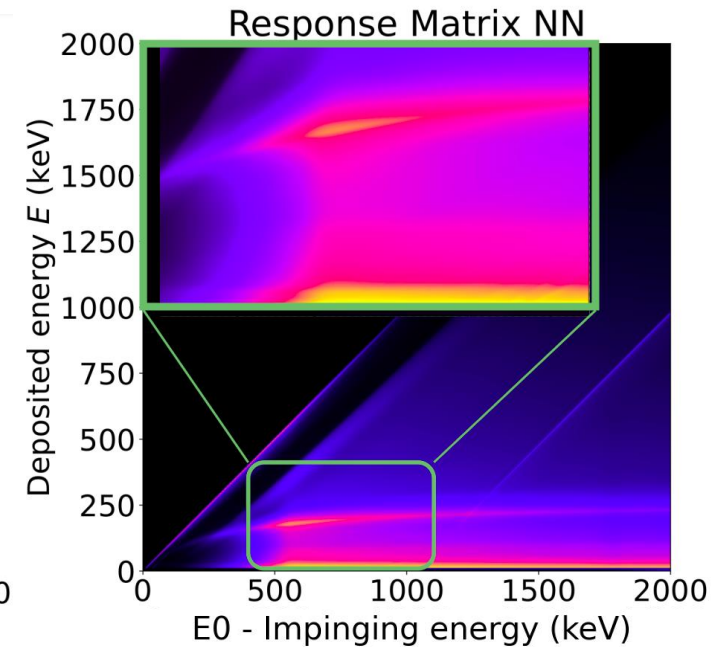
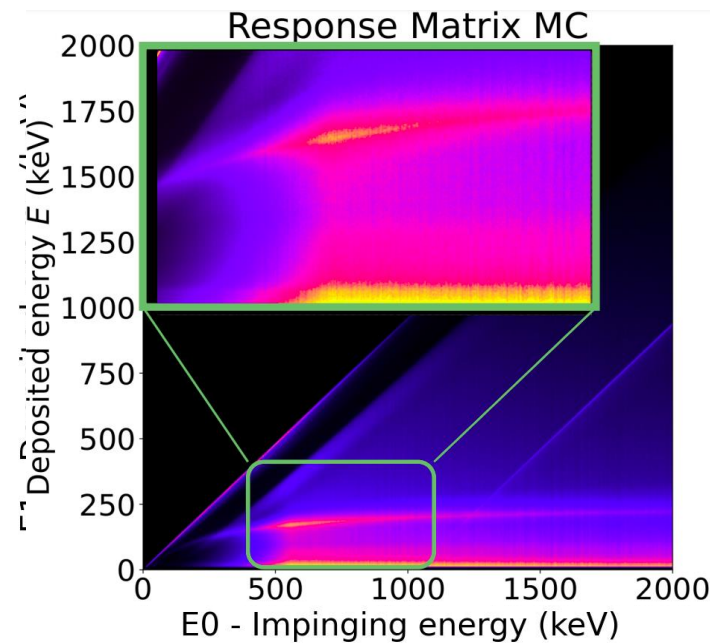
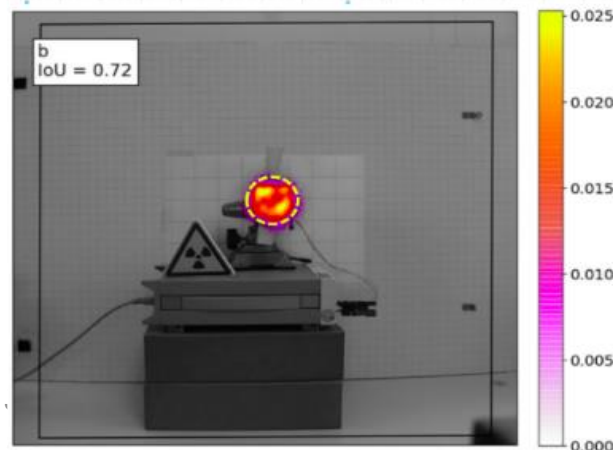
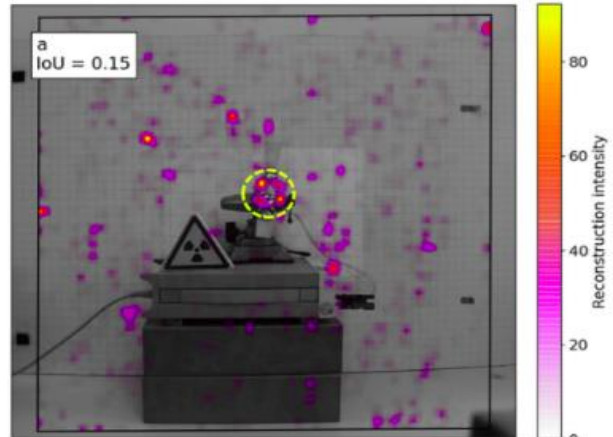
Conclusions and further applications

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- Artificial data generation achieved prior objective
- Other applications
 - Imaging



Conclusions and further applications

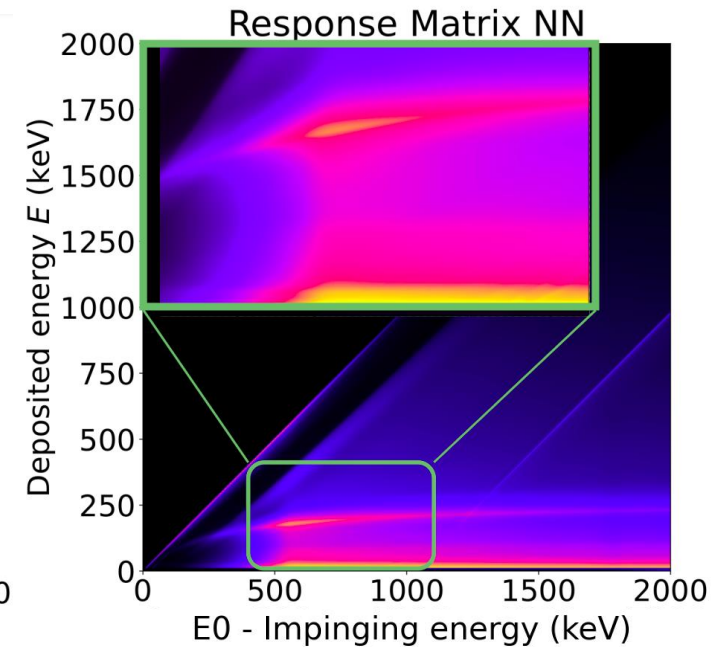
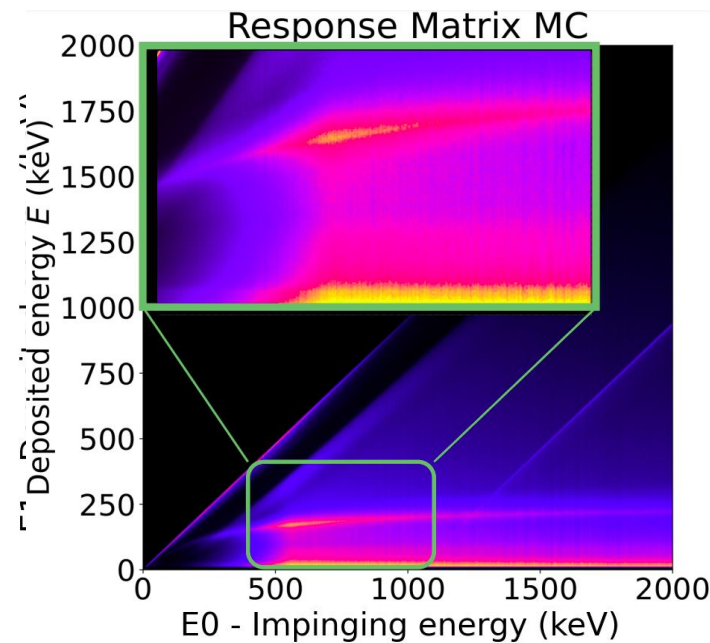
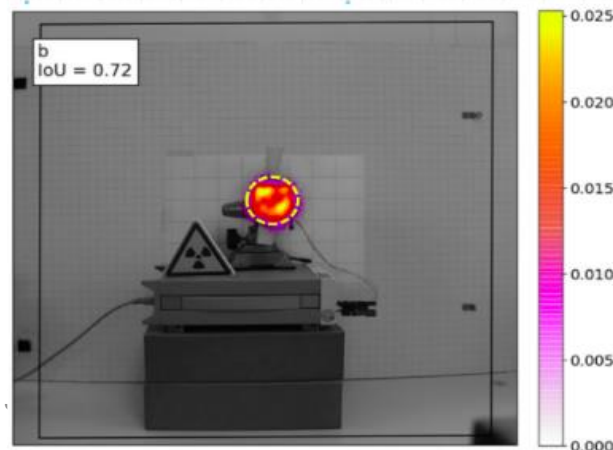
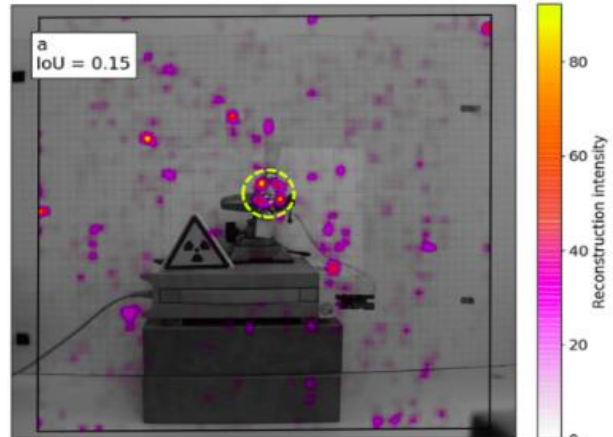
- Training data proved to solve some attenuation issues
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 - Imaging
 - Faster Detector Response Matrix compared with MC

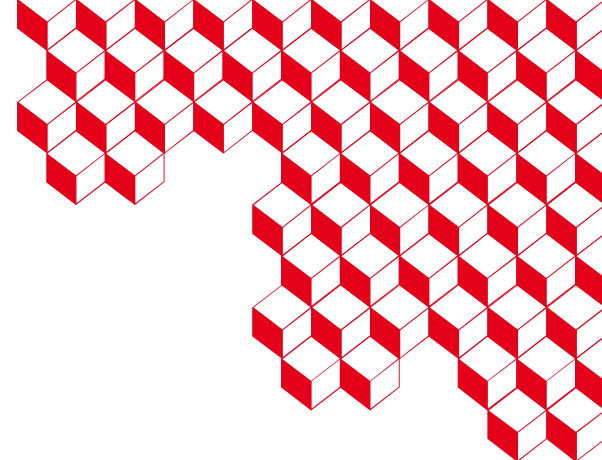


Conclusions and further applications

- Training data proved to solve some attenuation issues
- No performance was lost
- Artificial data generation achieved prior objective

- Other applications
 - Imaging
 - Faster Detector Response Matrix compared with MC
 - Spectrum Reconstruction
 - Etc...





Thank you

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