Gamma-ray spectrometry of fission fragments : ML analysis of multi-dimensional spectra

Machine Learning workshop

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CEA / IRFU / DPhN / LEARN

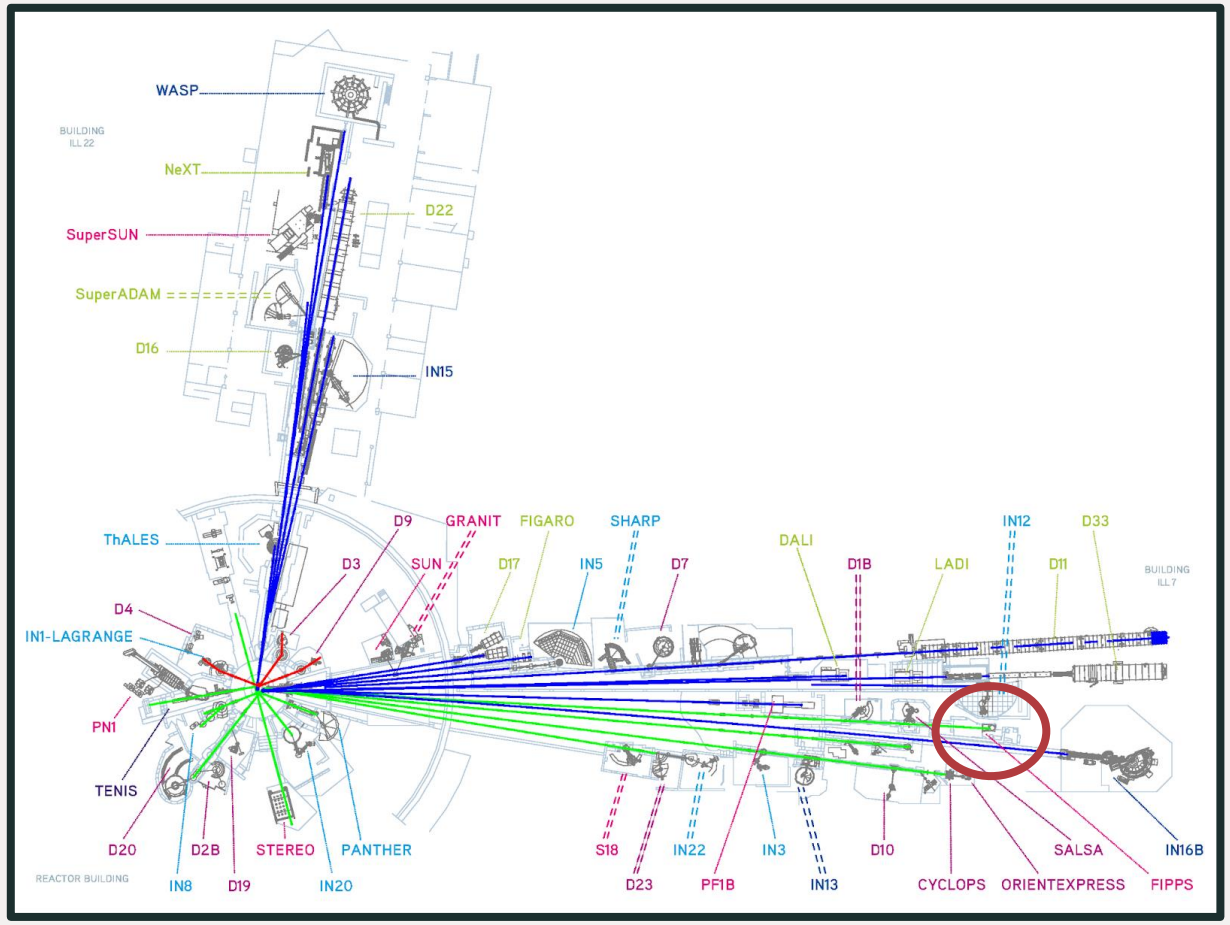
Outline

- Presentation of the experimental setup
- Data and analysis
- ML techniques

The experimental setup : ILL and FIPPS spectrometer

What do we measure, for what ?

The ILL (Institut Laue Langevin)



Neutron beams and the instruments at ILL

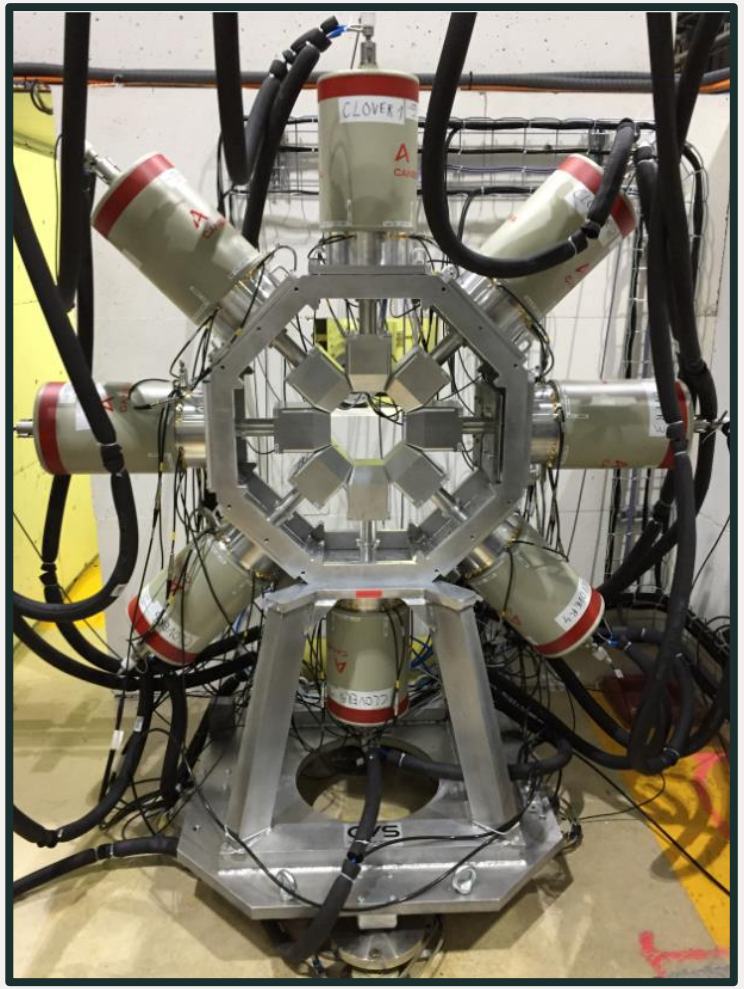
International research centre specialized on neutrons

High-flux research reactor (58 MW)

Provides one of the most intense neutron sources in the world
10^8 n/s/cm^2 at the target

40 instruments

Experimental setup



Spectrometers

FIPPS (FIssion Product Prompt γ-ray Spectrometer)

- 16 clovers, 64 crystals in total
- HPGe (High Purity Germanium) detectors with high energy resolution : ~ 1 ‰ at 1.2 MeV

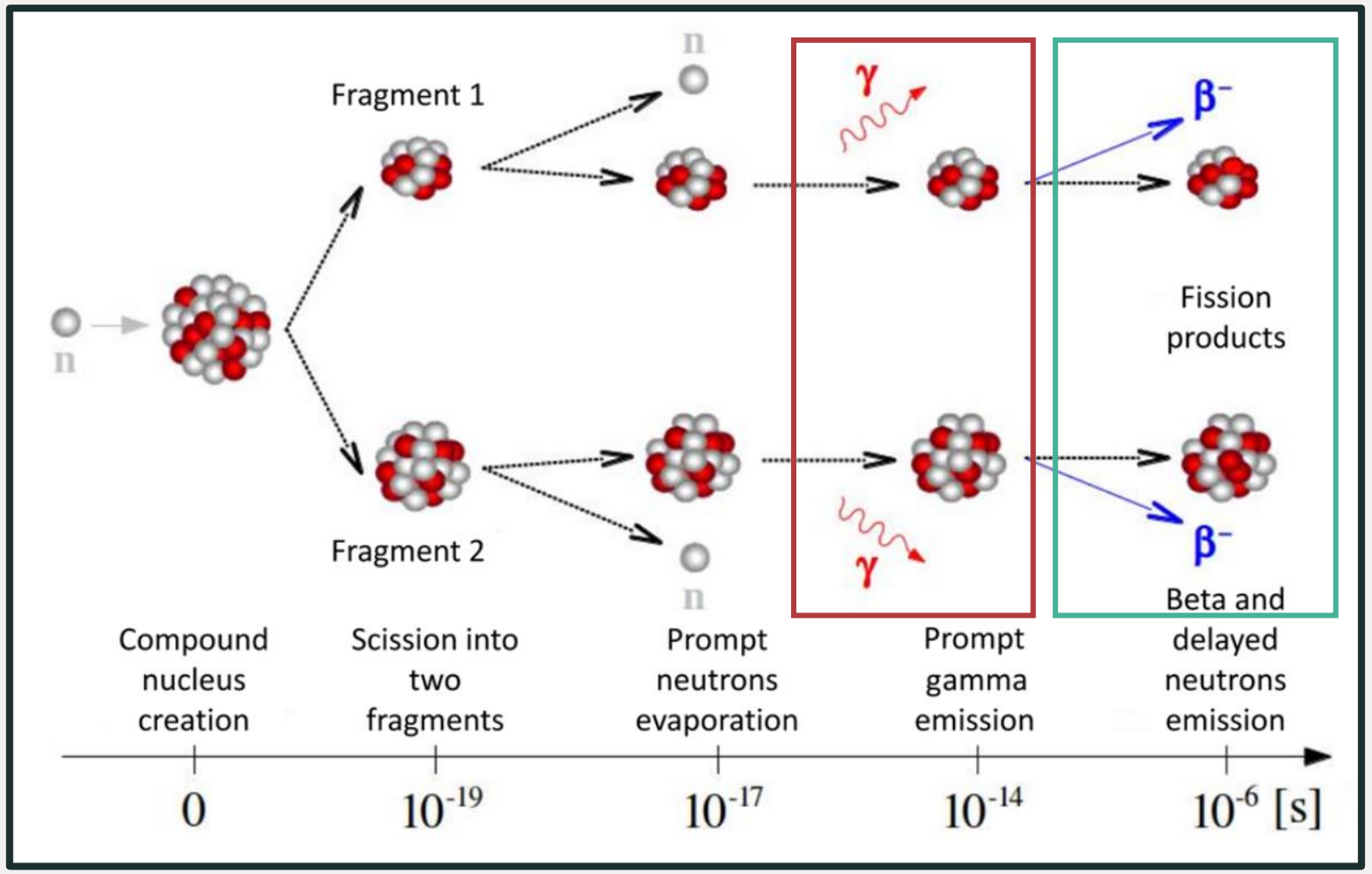
Fission tag

Active target in liquid scintillator + photo multiplicator (PM)

We can track the origin of a signal :

- Fisson fragments
- Beta decay

Neutrons induced fission and FIPPS



The steps of the fission induced by fission

Probe the intrinsic properties of the fission fragments

Study of the desexcitation of fission fragments throught gamma cascade

Comparaison with simulation code : FIFRELIN

Nuclear data

- Independent fission yield
- Cumulative fission yield

What has been done so far ?

- Measures with a calibration source (^{152}Eu)
- Measures with ^{235}U and ^{233}U in 2018 and 2019 (other experiments are planed, using ^{245}Cm)
- Pre-analysis has already been done
- Analysis of the data is ongoing (without machine learning for now)

Data and analysis

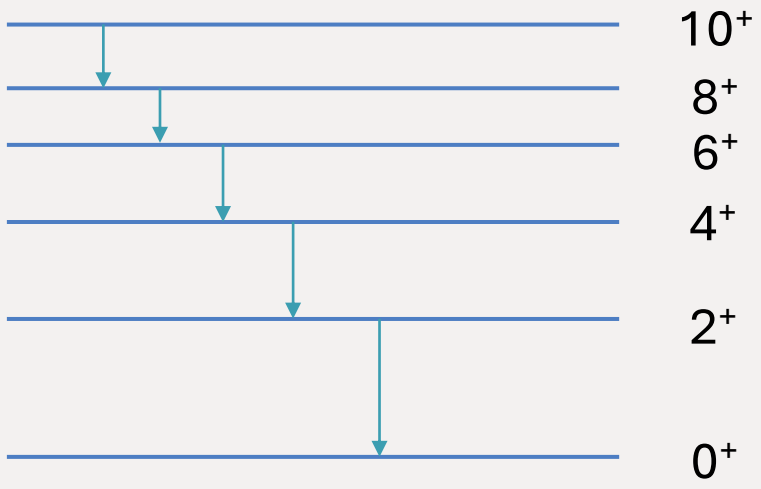
What the data are, what analysis do we perform on it ?

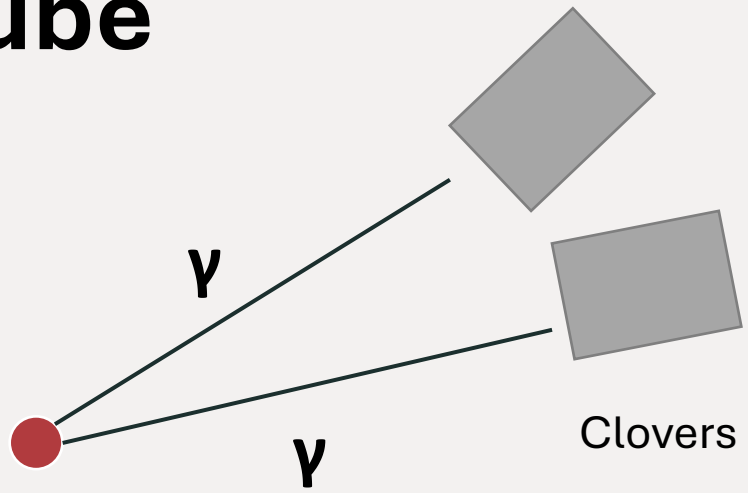
What are the issues ? What do we struggle with ?

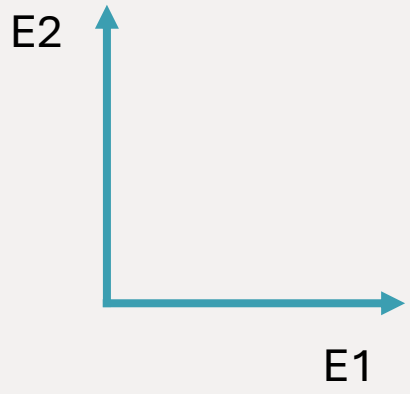
The γ – γ matrix and γ – γ – γ cube

Several gamma are emitted during a cascade

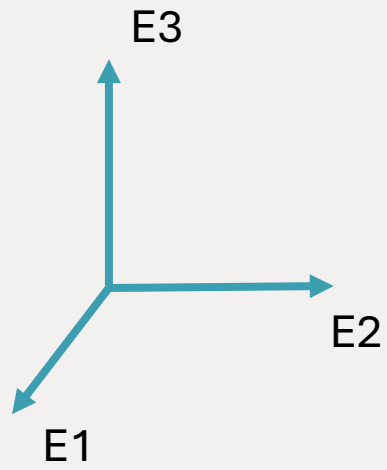
Around 9 for fission





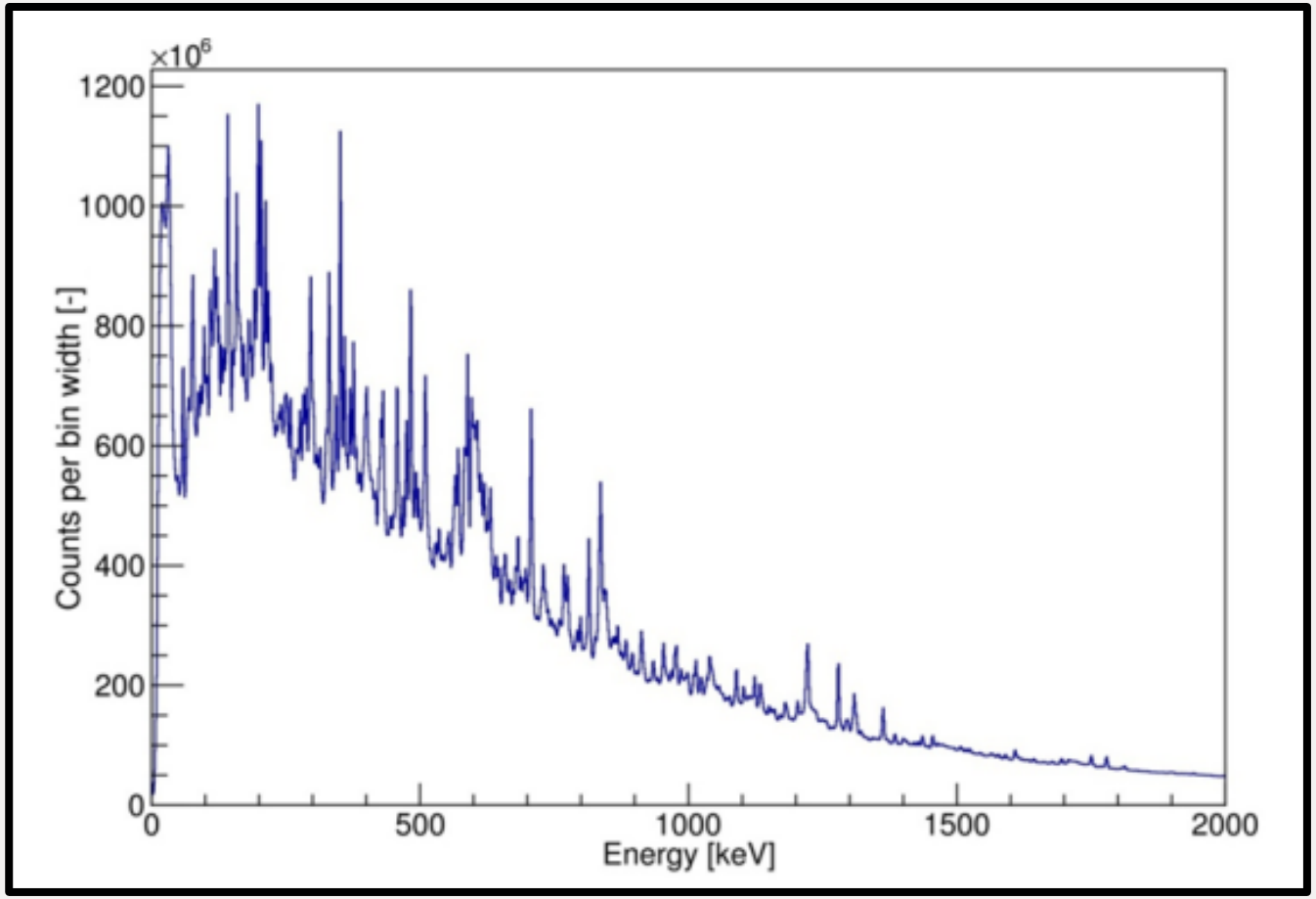


2D histogram



3D histogram

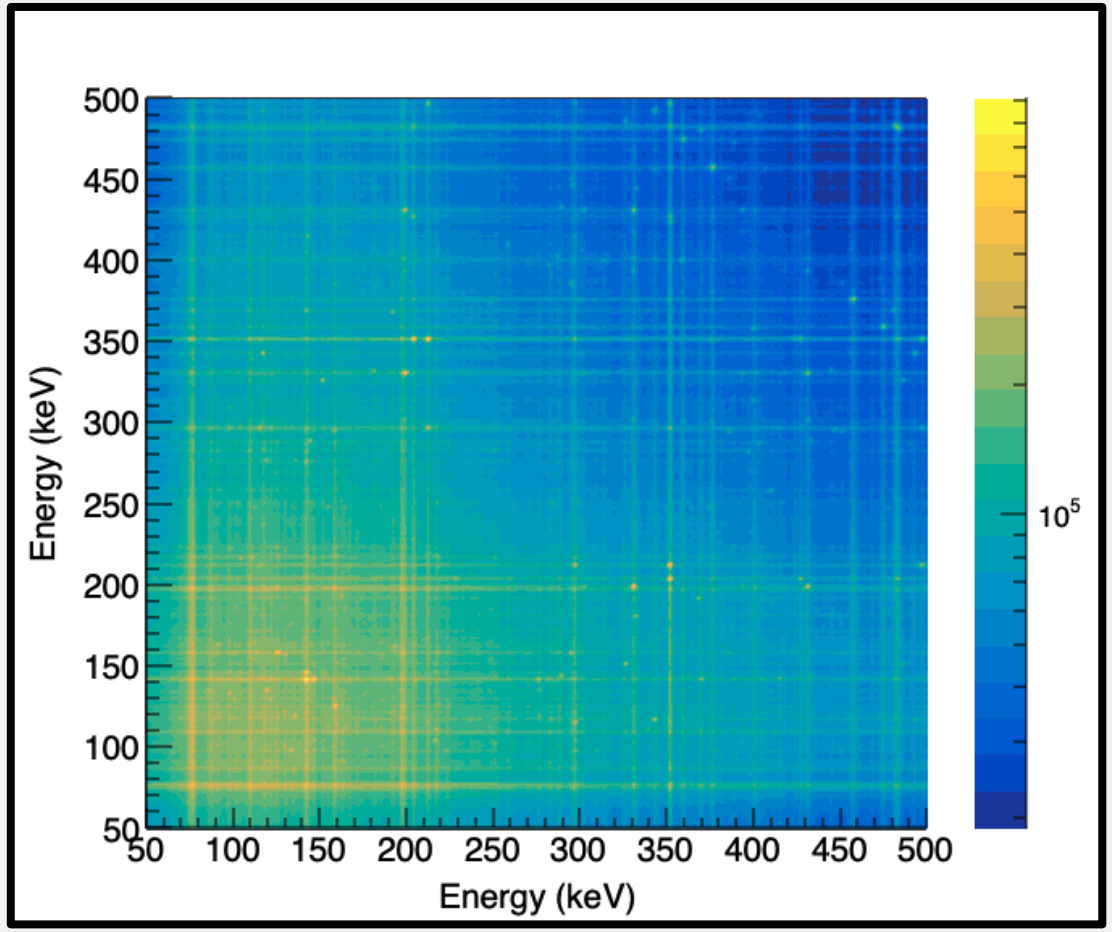
A closer look at the data



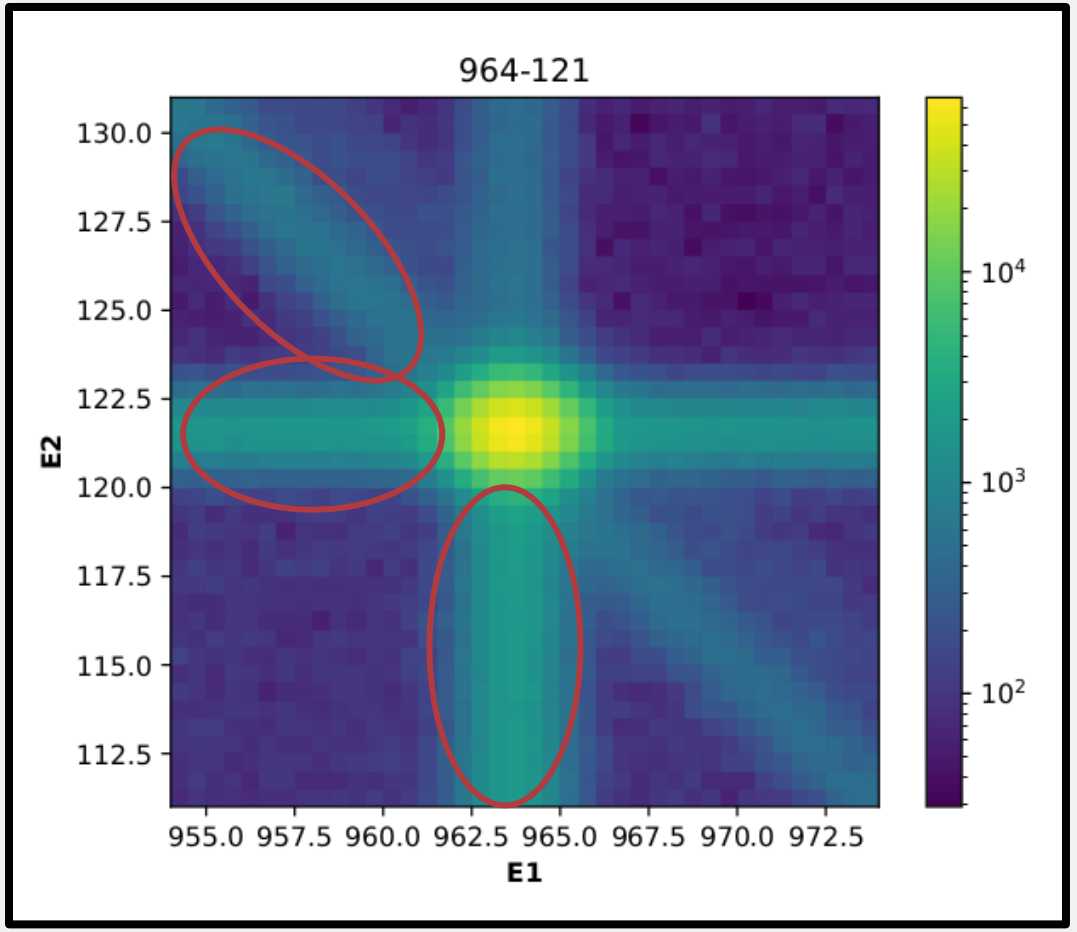
Spectrum obtained for (^{235}U, n_{th})

Unusable in practice :
too much overlapping between peaks

A closer look at the data



The γ – γ matrix for ^{235}U



A zoom on a peak from the data obtained with a source of ^{152}Eu

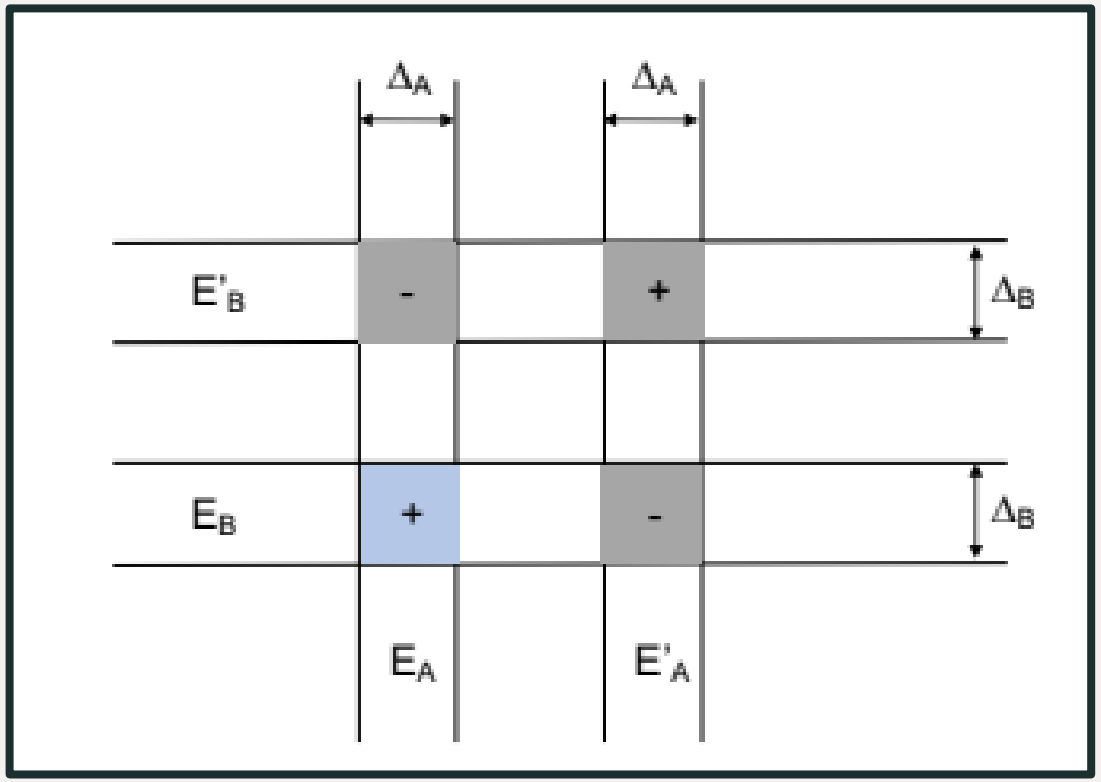
Data analysis

Main goal

Extract the intensities of the gamma rays in coincidence : fitting

How is it done ?

Fitting of peaks on 1D spectrum after dimensional reduction by gating, noise subtraction and projection

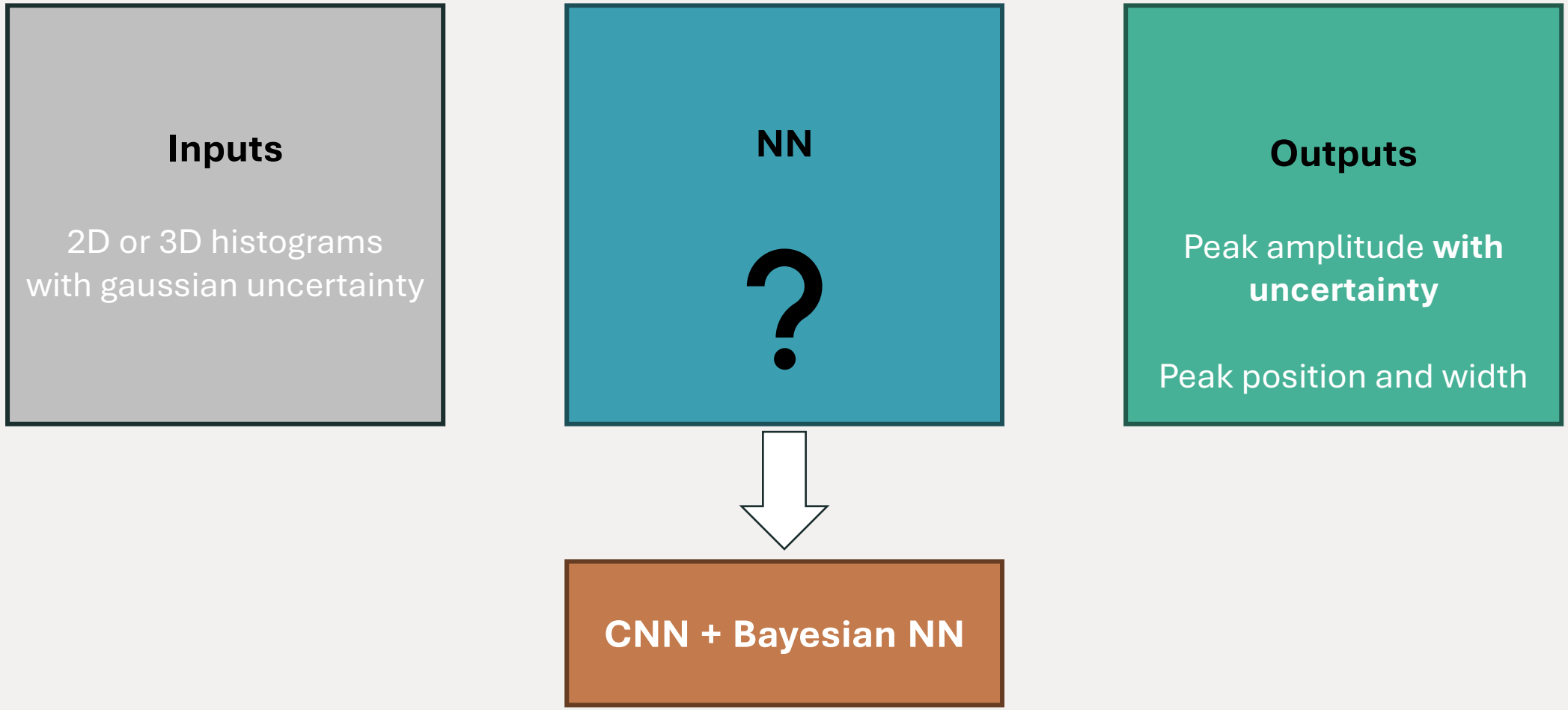


Gating procedure

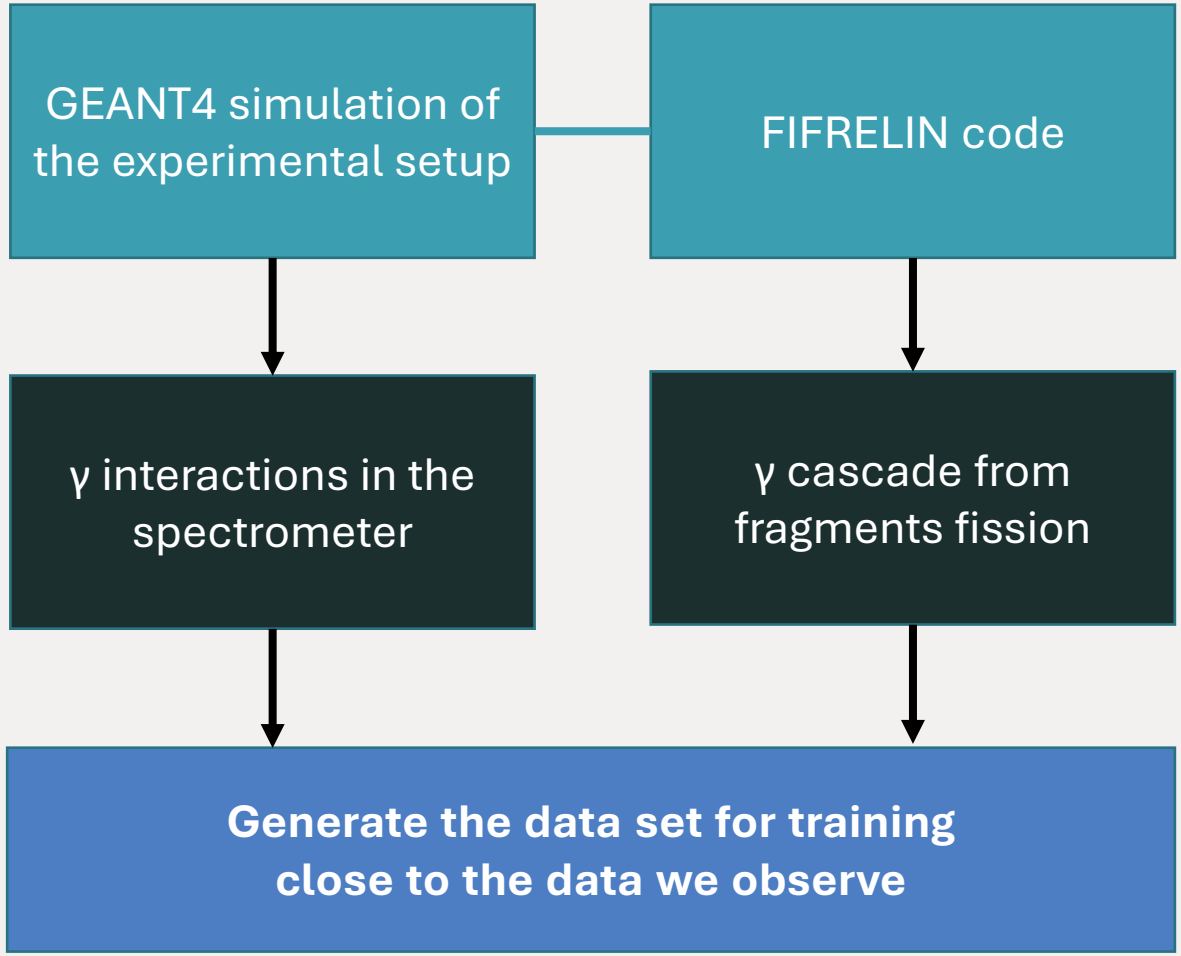
ML techniques

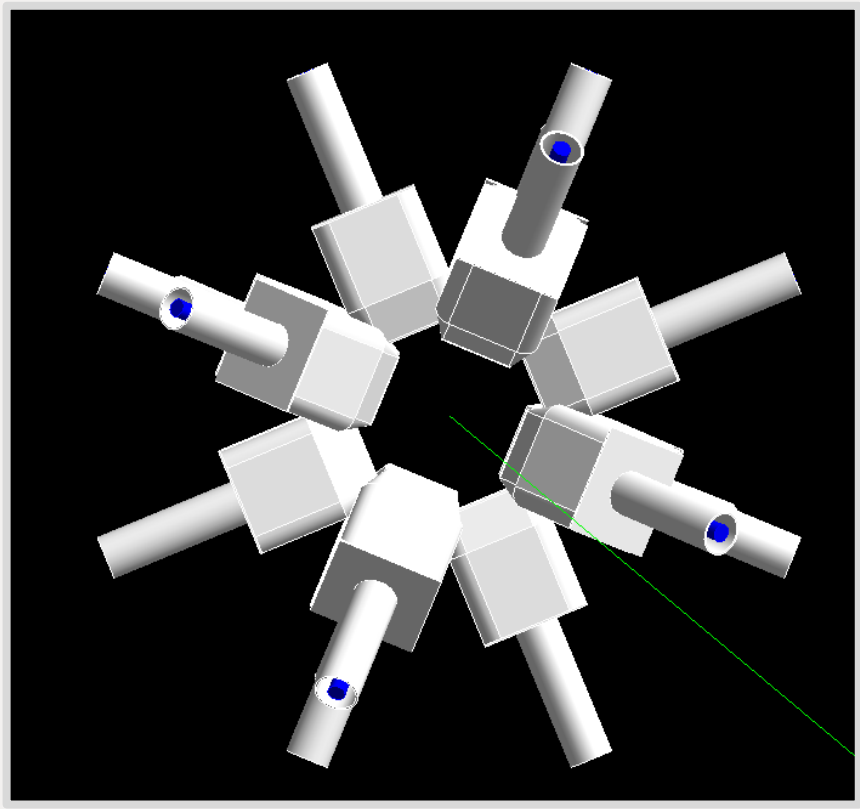
How ML can help us ? For what task exactly ?

What architecture for a neural network ?



Tools





Simulation of the clovers

in GEANT4, running on CCIN2P3

Conclusion

- Data with « pollution », hard to treat
- We want to automate the analysis process : ML seems promising
- How to take into account uncertainty on input data, prior knowledge ?
- For my thesis : developp a new analysis technique and compare it with the standard approach. Let’s code that !