Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Legnaro

AGATA Week 2024

Improvements in the Post – PSA analysis

- *Neutron Damage correction*
- *Time dependent energy calibration*

Speaker: **Elia Pilotto**

September 2024

Neutron Damage correction - Introduction

- Neutron Damage (ND) from **fast neutrons** (E > 1 MeV) in HPGe detectors causes **charge trapping** and therefore **energy resolution degradation**
- The loss in signal amplitude is dependent on the **path length**, the **electric field** and the **trap density**
- In highly – segmented HPGe detectors, we can use Pulse Shape Analysis (PSA) to determine the **position of interaction** of the gamma – rays inside the crystal
- The current model is optimized for fast neutrons only and employs a 1st order Taylor expansion in its calculations

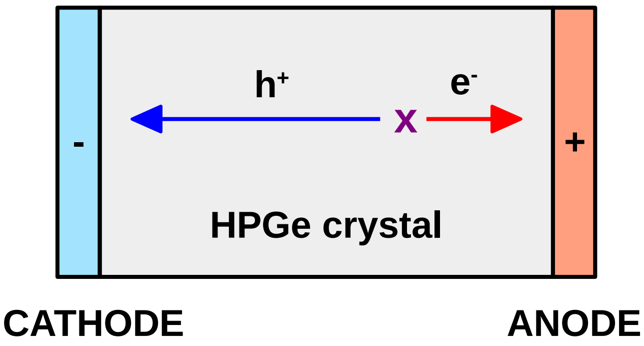
$$\frac{E_{meas}(x)}{E_{corr}(x)} = 1 + \frac{t_e(x)}{\lambda_e} + \frac{t_h(x)}{\lambda_h}$$

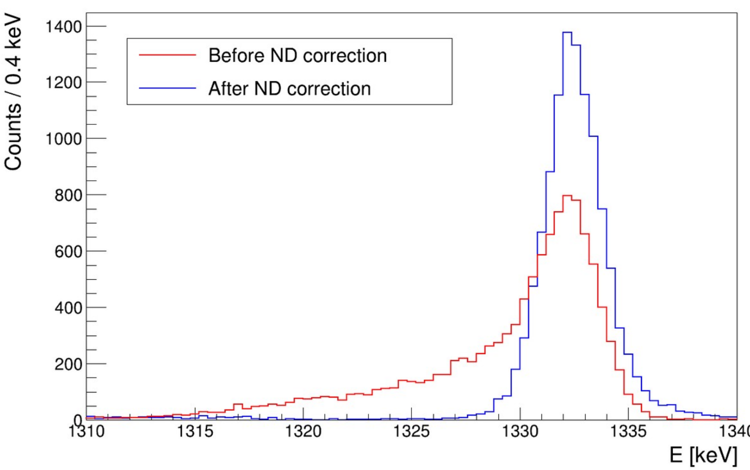
$\lambda_{e,h}$ = inverse electron / hole trap density

$t_{e,h}(x)$ = sensitivity to electron / hole trapping

B. Bruyneel et al, EPJ A 49 (2013)

Charge trapping





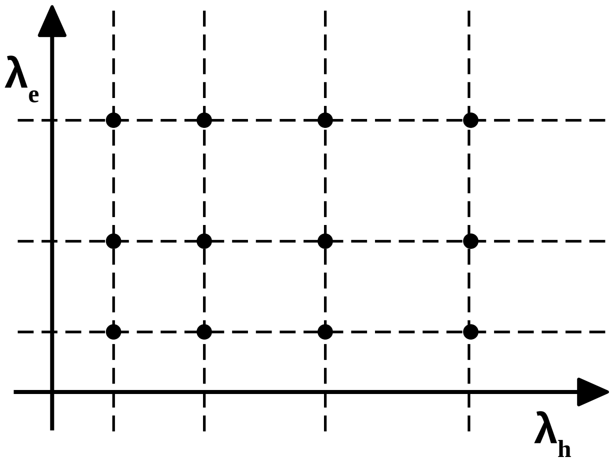
Critical for lineshape analysis in DSAM lifetime measurements

Neutron Damage correction – Current Algorithm

The objective is to obtain the $\lambda_{e,h}$ parameters that yield the best possible correction and therefore energy resolution

$$\frac{E_{meas}(x)}{E_{corr}(x)} = 1 + \frac{t_e(x)}{\lambda_e} + \frac{t_h(x)}{\lambda_h}$$

Algorithm code: https://gitlab.in2p3.fr/ip2igamma/agapro/-/blob/preprod/zPrograms/SortPsaHits.cpp



LOGARITMIC GRID – SEARCH

Fixed 50 x 100 grid

$$\lambda^n_{e,h} = -R\frac{\log_{10}\left(1 - \frac{n}{N_{e,h}}\right)}{\log_{10} N_{e,h}}$$

- Source data (usually ^{60}Co)
- Only segment multiplicity 1 events
- Optimization of SG, CC or SG+CC
- Estimation of a FOM
- Computation in each point of the grid, for each segment of each crystal

Ease of use, speed and robustness are key

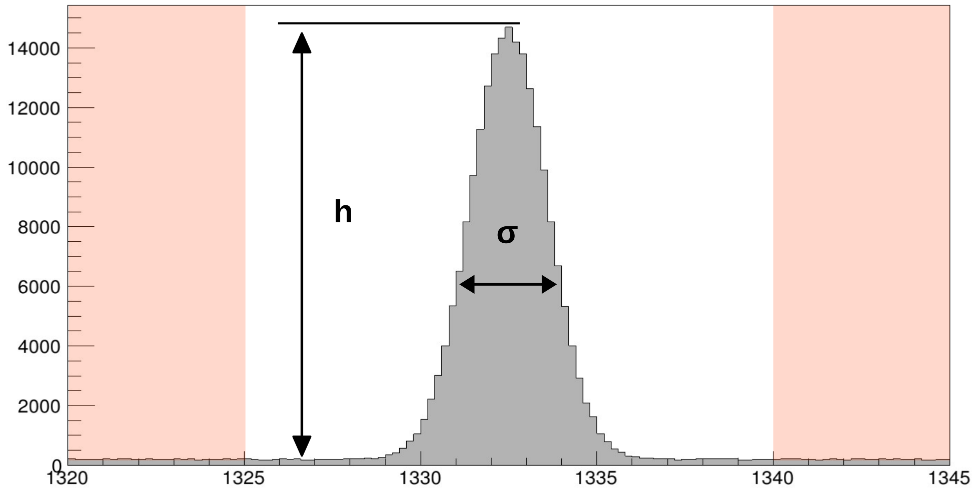
Neutron Damage correction – Current Algorithm

Various methods of estimating a FOM implemented

1. By fitting (Gaussian + tails): **amplitude** of Gaussian part
   - Slower, computation heavy
   - Less robust, works well with slightly damaged detectors
2. FOM = **h / σ**
   - Introduced recently (2023) as the "-std" option
   - Very fast
   - More robust, works with badly damaged detectors

OBS: for SG+CC, the algorithm just sums the FOMs of the two spectra

$$\sigma = \sum_{i=1}^{N} \frac{y_i (x_i - \mu)^2}{N - 1}$$



Issues:

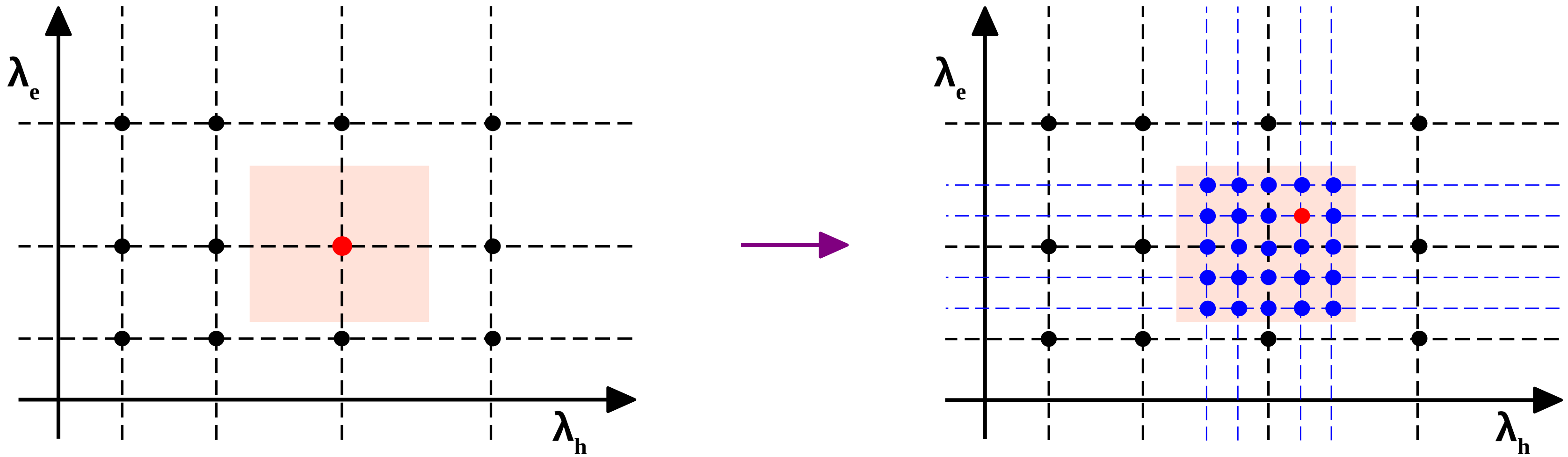
- **h** is the height of a single bin
  - Large statistical variance
  - Binning dependent
- **σ** is largely dependent on background
  - Not very significant
  - Range dependent

Neutron Damage correction – Improvements

We want to keep ease of use, robustness, speed and backwards compatibility.

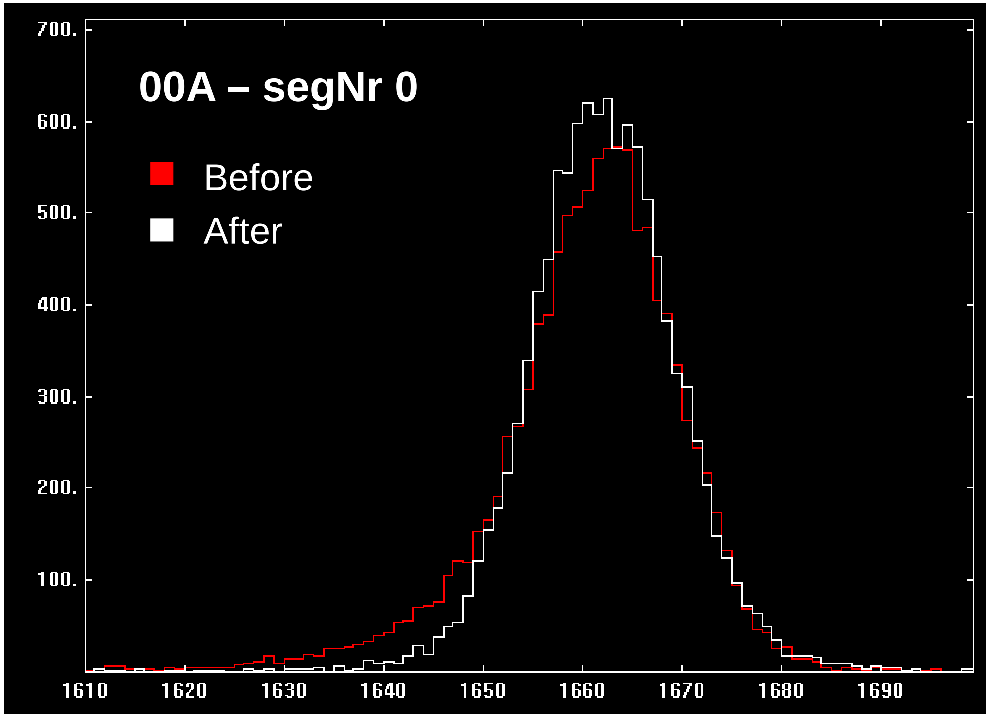
Two main improvements:

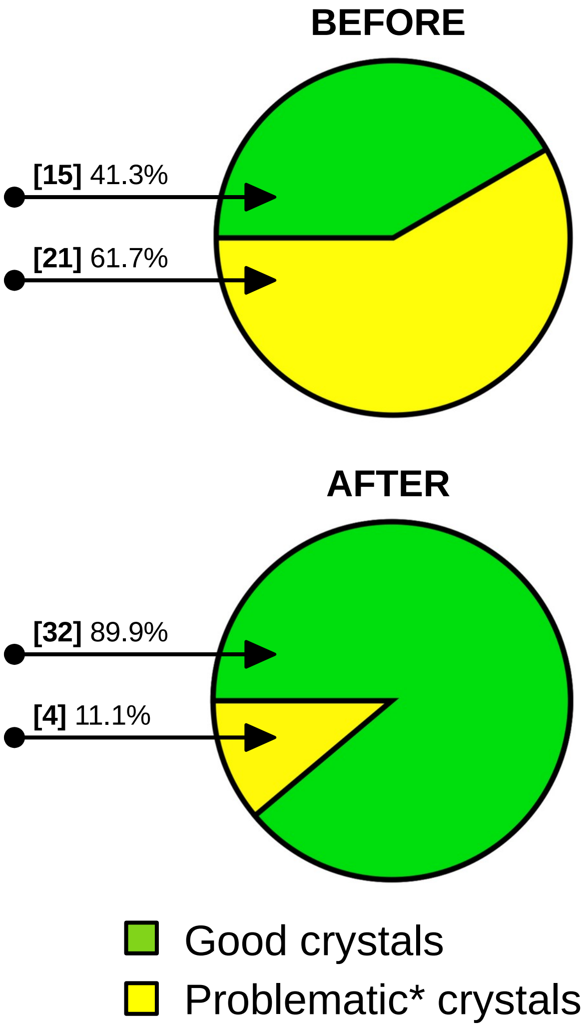
- For **SG+CC**, we employ a **normalization** of the whole grid of FOMs (such that the highest FOM has value 1) before calculating the average
- Implementation of an **Adaptive Grid – Search**
  - “-size” option: variable grid size, default is kept at 50 x 100
  - “-algo” option: user must choose which spectra to optimize (SG, CC or SG+CC) and number of iterations. Default is kept at 1 iteration only
  - “zoom” option: user can specify the magnification factor M between iterations. Default is 0.25



Neutron Damage correction – Improvements

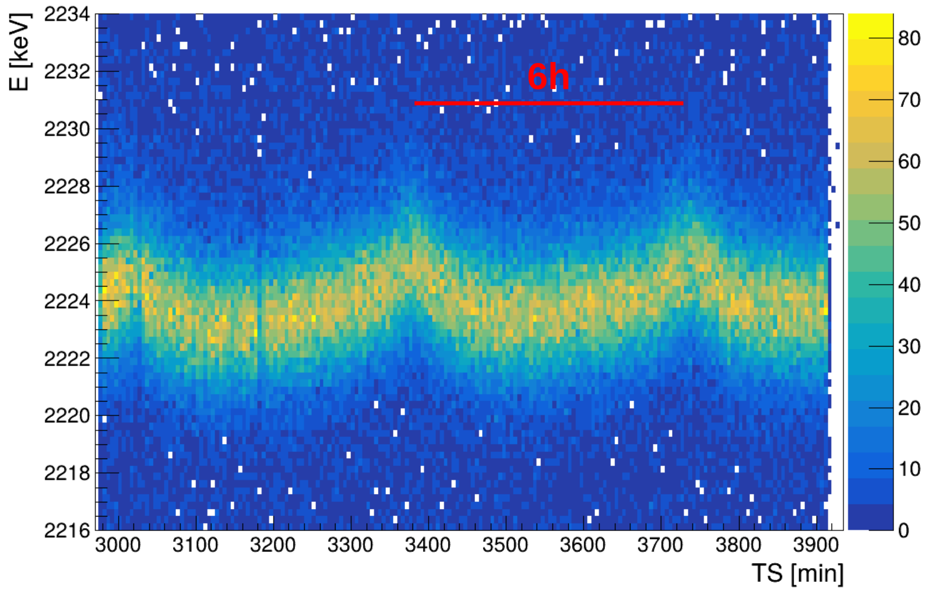
- ^{60}Co source data taken in November 2023
- Optimization of CC only with 3 iterations and 30 x 50 grid
- Better performance especially for badly damaged detectors and for front and back segments

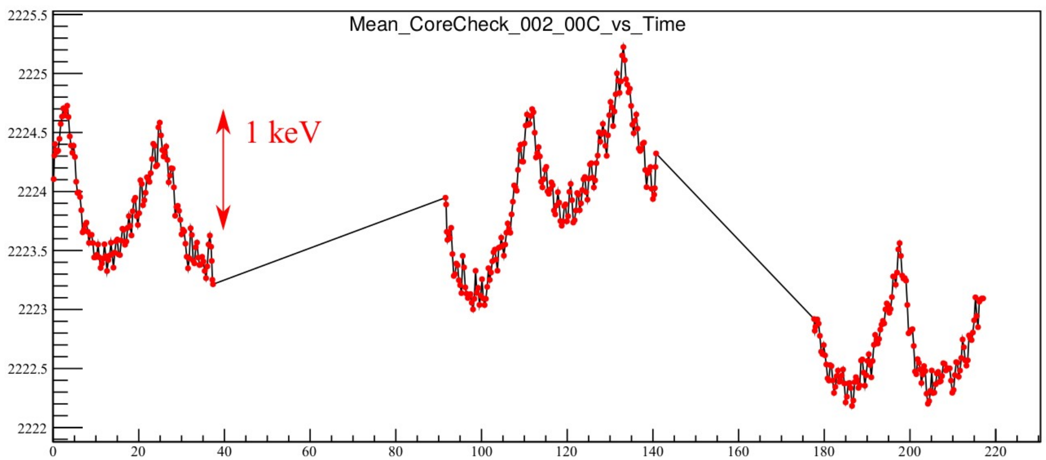




**crystals are defined “problematic” if at least one segment shows a visible tail in the CC spectrum after ND correction*

Time dependent energy calibration – Observation





From J. Dudouet – Rencontre Agata France 2016

- **Core energy obscillations** were observed in a long run taken with a high energy source
- Previously observed during the LNL Agata demonstrator campaign

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- Pseudo – periodic with 6h period
- More pronounced in detectors placed in the lower part of Agata, pointing upwards
- **Gain** obscillations up to **2.91‰**

↓

temperature effect

Time dependent energy calibration – Solution

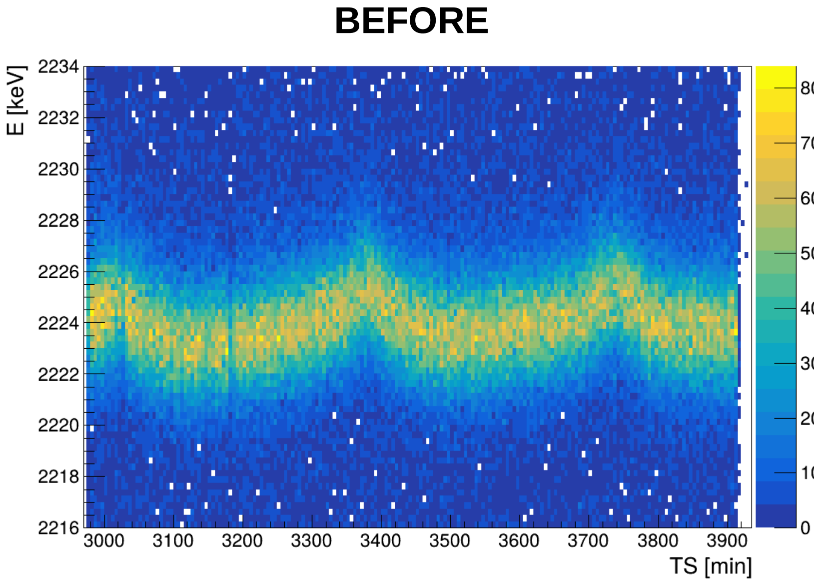
Implementation of time – dependent core gain correction before RecalCC

In configuration of PostPSAFilter

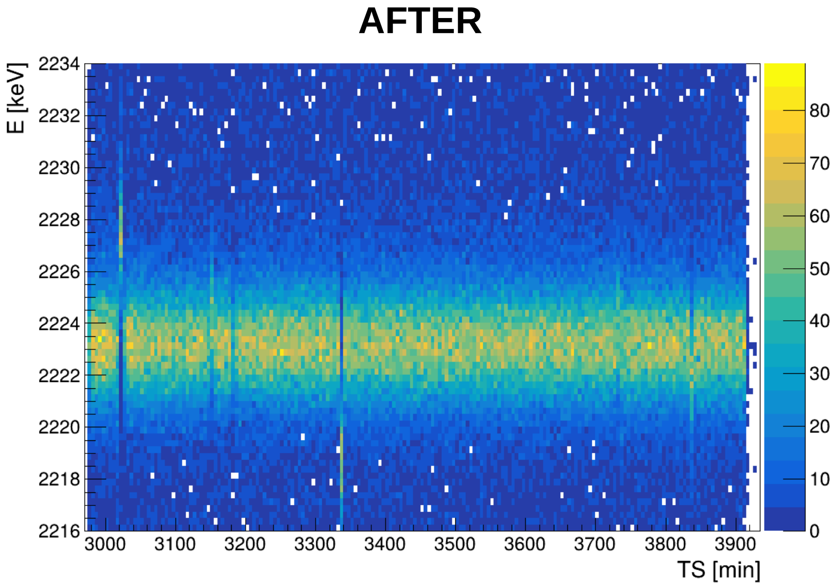
```
"TimeEvoCCFile        TimeEvoCC.conf", #file with time dependent gain...
```

TimeEvoCC.conf

```
#TS_start          TS_stop           gain
6150000000000      6210000000000     0.999948755522396
6210000000000      6270000000000     0.999887585155303
...
```



fwhm = 3.807(15) keV @ 2223 keV



fwhm = 3.525(17) keV @ 2223 keV

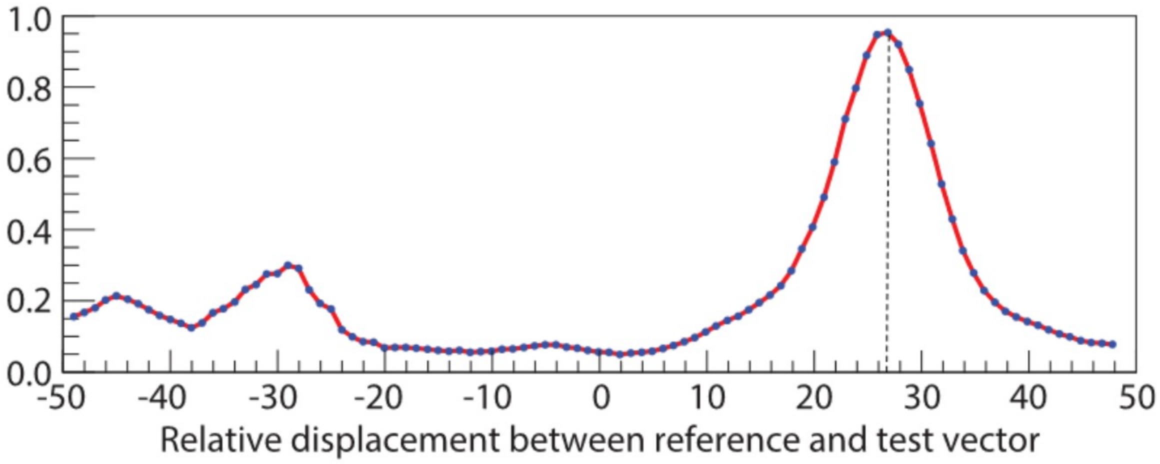
Time dependent energy calibration – algorithm used

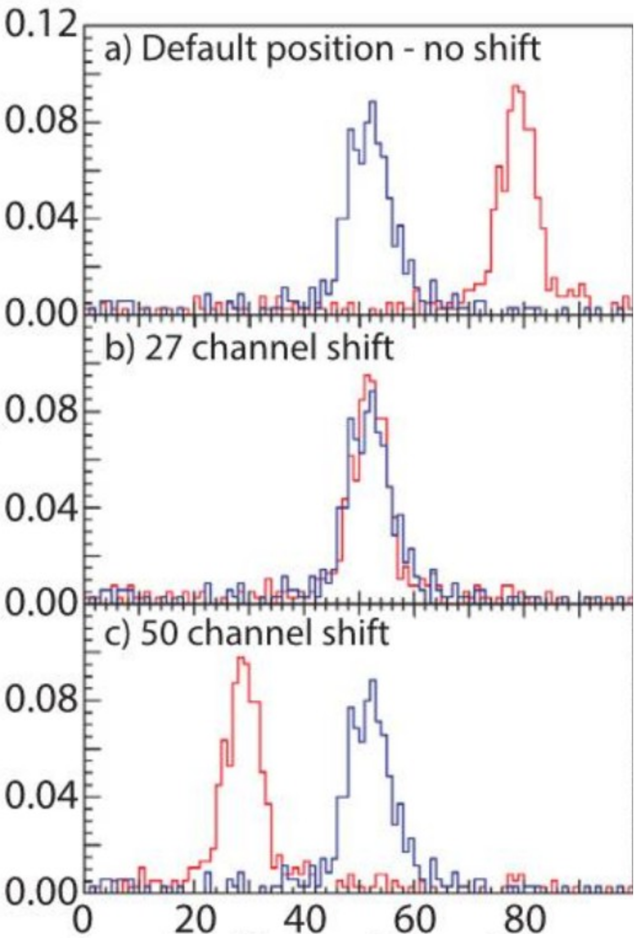
Cross – correlation Correction Method (CCM)

- Divide the matrix in slices, for each a projection
- Calculate dot product between a reference specturm and the shifted projection
- Perform a scan for each slice

Main characteristics

- Extremely fast and robust, no fitting involved
- No need for a peak, any feature can be used





Matus Balogh
NIM paper: https://doi.org/10.1016/j.nima.2021.165368
GitHub code: https://github.com/matLogh/CCM

AGATA ADVANCED GAMMA TRACKING ARRAY

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Thank you for your attention

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