Gamma-ray Spectroscopy

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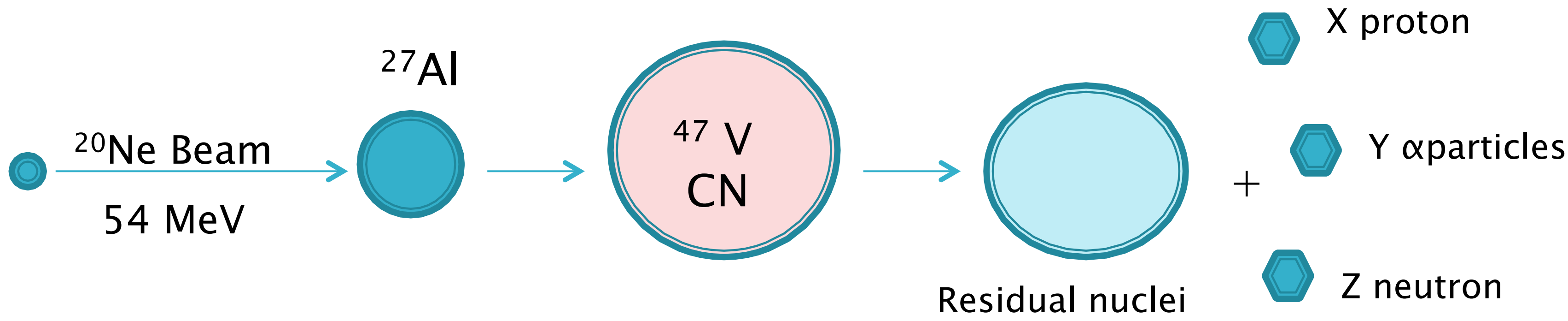
AGENDA

- Introduction
- Setup
- Target preparation
- Calibration
    - Energy calibration
        - Efficiency calibration
- Collecting data with installed target
    - Total gamma-ray spectrum
        - Identifying products of the reaction
            - gamma-gamma matrix
- Summary

INTRODUCTION

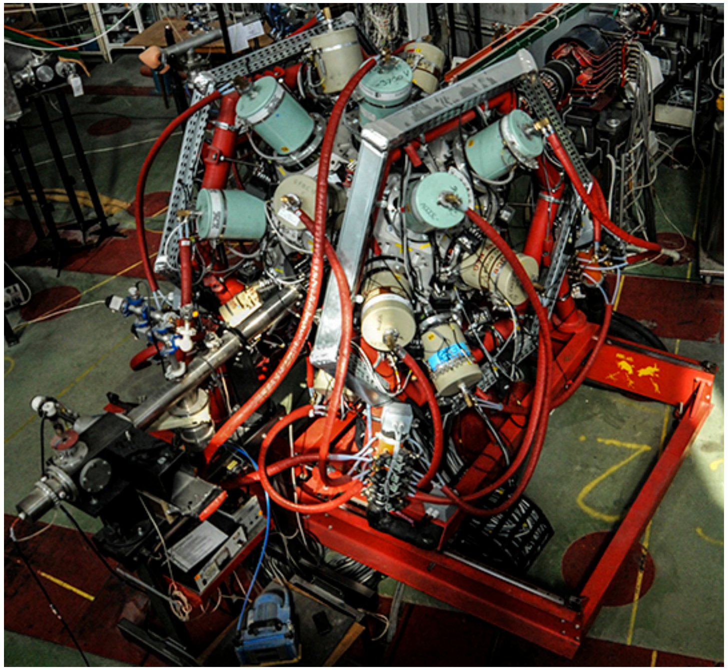
We used a ^{20}Ne beam with an energy of 54 MeV at target of ^{27}Al.
With this process, we produce a compound nucleus ^{47}V. Various combinations of particles p, n, alpha are emitted from CN leading to different residual nuclei.

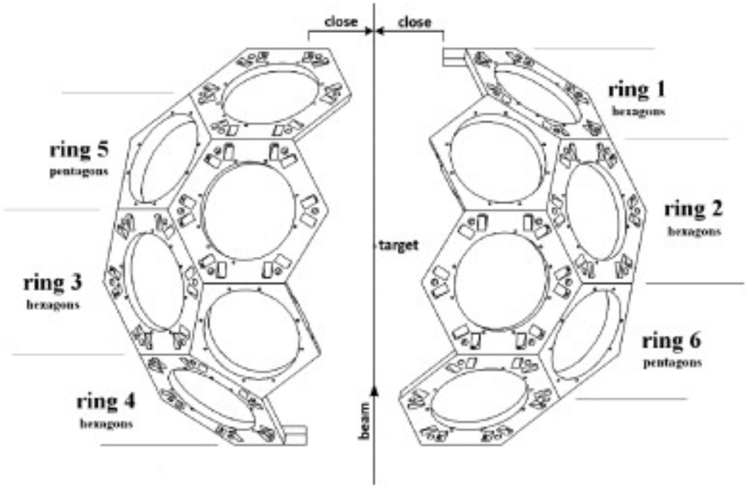


We register the gamma rays emitted from residual nucleus and in this way we determine properties of the excited states of the residual nuclei.

SETUP

The EAGLE array (European Array for Gamma Levels Evaluations) has been designed as a multi-configuration detector set-up for in-beam nuclear spectroscopy studies at the Heavy Ion Laboratory of the University of Warsaw. The array can accommodate a maximum of 30 Compton suppressed Ge detectors coupled to various ancillary devices.



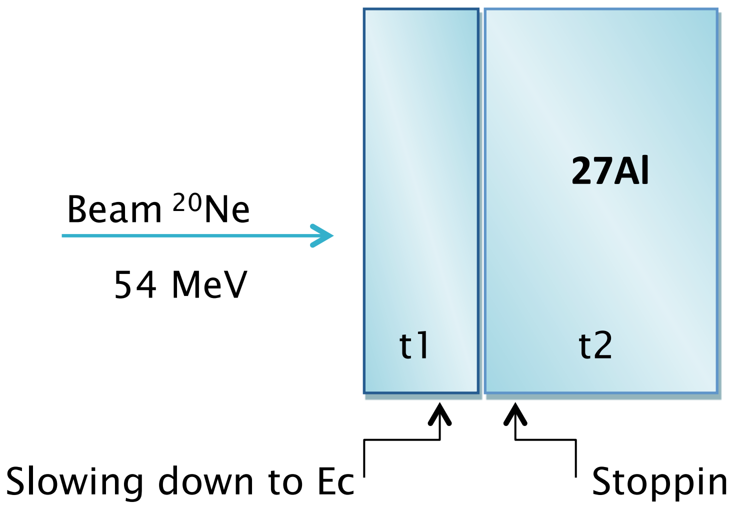


The shape of a truncated icosahedron with 20 regular hexagons and 12 regular pentagons was chosen for the frame for the Ge detectors.
We used 13 compton suppressed
Ge detectors

The major drawback of germanium detectors is that they must be cooled to liquid nitrogen temperatures to produce spectroscopic data. At higher temperatures, the electrons can easily cross the band gap in the crystal and reach the conduction band, where they are free to respond to the electric field, producing too much electrical noise to be useful as a spectrometer.

We check the resolution of one germanium detector with a source of ^{60}Co.
We connect it to an amplifier and get a result of FWHM (Full width at half maximum)= 2.79
Later , we connect the detector to EAGLE

TARGET



Reactions are take place above the Coulomb barrier.
Nuclei should be stopped in the target for studying their Gamma emissions. We don´t want Doppler effect to be visible at all.

Ec= 37,2 MeV (Coulomb barrier)
t1= 2.2 mg/cm^2
t2= 2 mg/cm^2
Thickness: 4.2 mg/cm^2 + 20% (safety)
=> Target thickness = 5 mg/cm^2
Best thickness was calculated.

Target 27Al

ENERGY CALİBRATİON

USED SOURCES

What is the purpose of energy calibration?

... so the purpose is translating channel numbers to true energy of gamma rays. $E = f(x)$,

x – channel

^{226}Ra

^{152}Eu

^{133}Ba

- We used three sources (^{152}Eu , ^{226}Ra , ^{133}Ba)
- We were looking at the spectrum of ^{152}Eu , took 2 strong peaks for preliminary calibration.

E_i *corresponds to* x_i *(channel$_i$), so we have to solve this linear system*:

$$E_1 = a_0 + a_1 . x_1$$

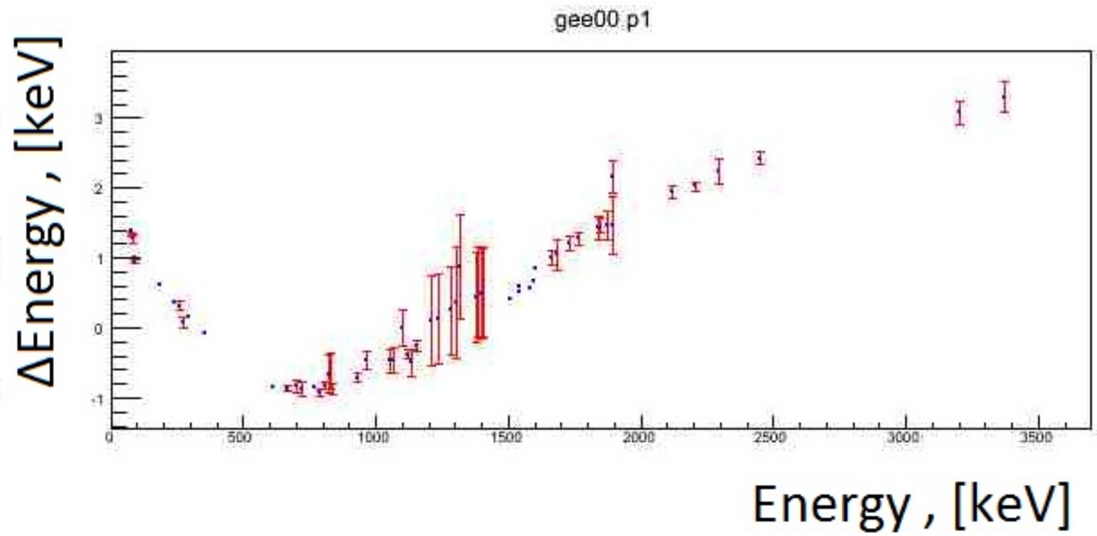
$$E_2 = a_0 + a_1 . x_2$$

to find the a_0 *and* a_1 *coefficients*

Now we know $E = a_0 + a_1 . x = f(x) \rightarrow$ *linear function*

- next source ^{226}Ra : detail energy calibration, fitting with more than 50 peaks for each detectors. For example detector number 00, the first one:

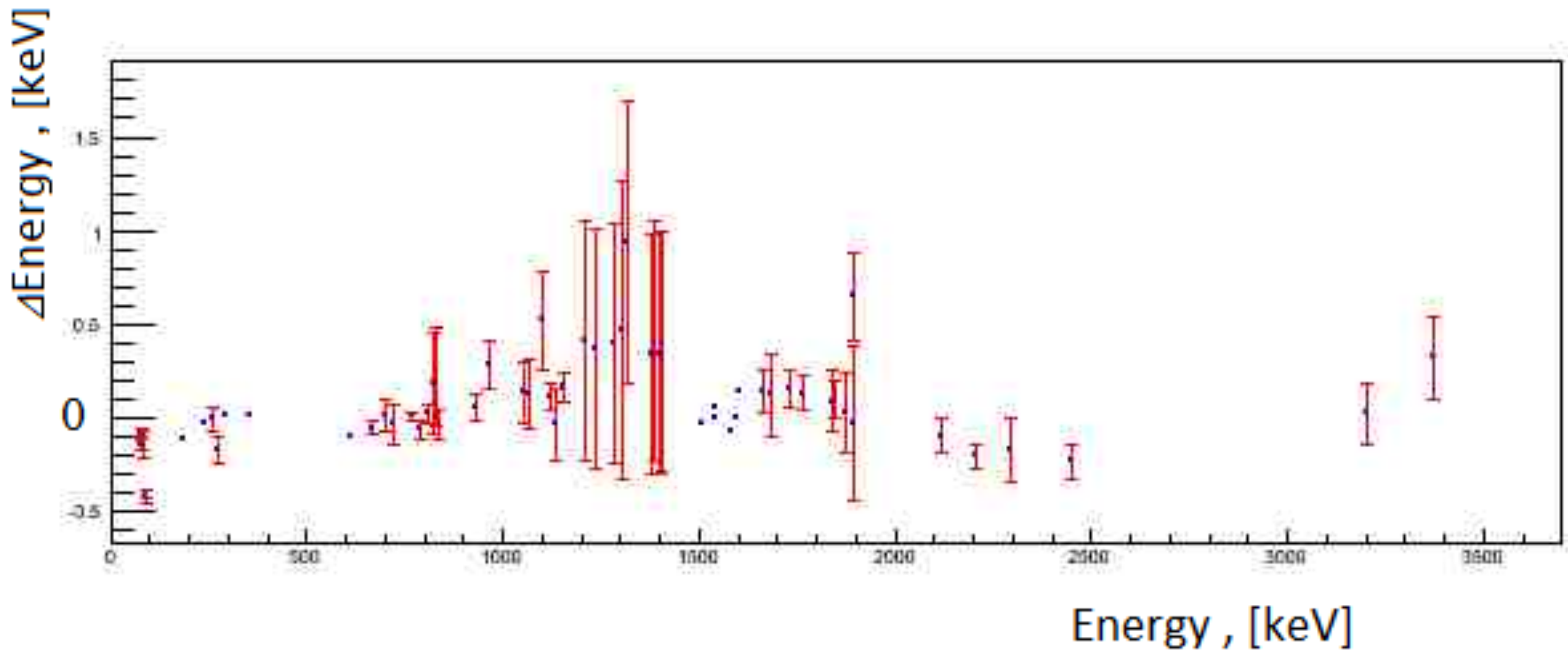
Deviation from linearity



The all detectors are not linear !!!

We tried to fit the data with 2,3,4 order polynomial, but the best fitting was 3rd order polynomial.

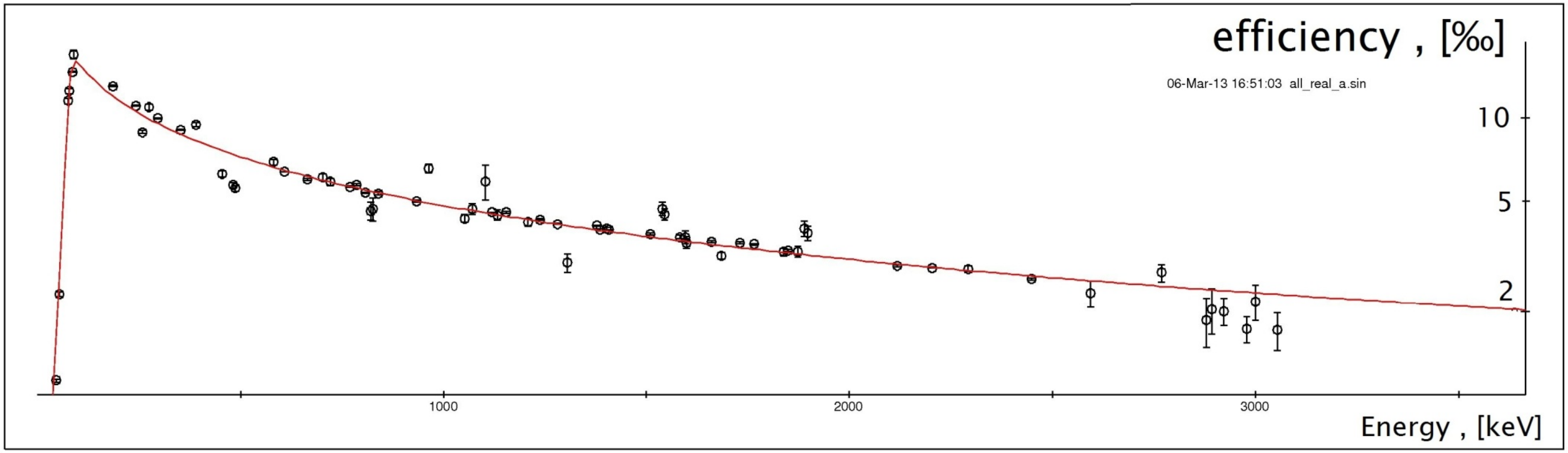
Difference between 3rd polynomial and actual positions



All detectors showed similar non-linearity

Efficiency calibration

Before collecting data with EAGLE (with installed target) we found the **<u>absolute efficiency</u>** calibration with ^{226}Ra , for all the detectors together (summed spectrum)



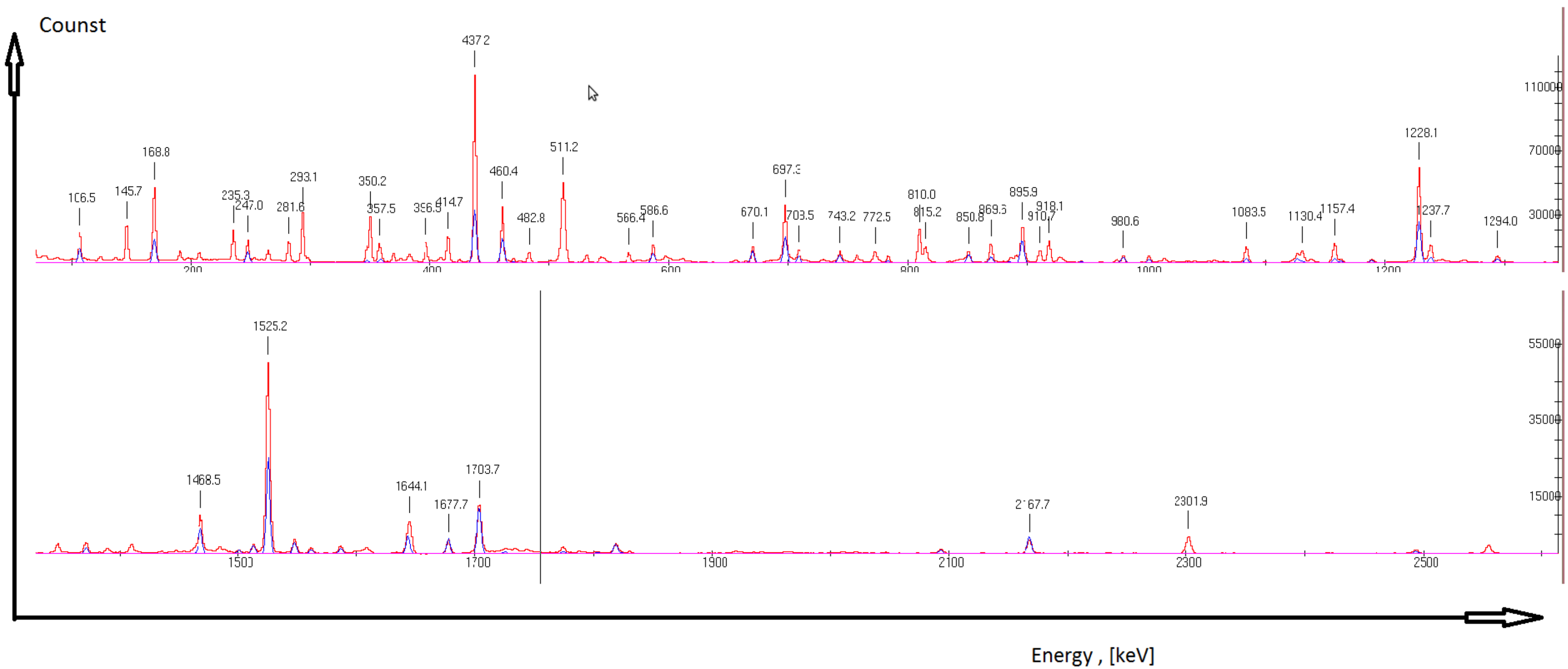
The curve above is sum of 2 parabolas, $eff = \{ A + Bx + Cx^2 \ , \ x = \ln(E/100) \ \ D + E$

$efficiency \to \ \epsilon(E_\gamma) = N_{detected}/N_{emitted} \ \ ; \ N - number\ of\ ga$

$dead\ time = 6{,}5\ \%$

Collecting data (event by event) with installed target for about 7 hours and a half

Total gamma-ray spectrum



Let’s start identifying products of the reaction

$${}^{20}Ne(\sim 54\,MeV) + {}^{27}Al \to {}^{47}V(compound\ nucleus) \to \to x.p + y.\alpha + z.n + residual\ nucleus$$

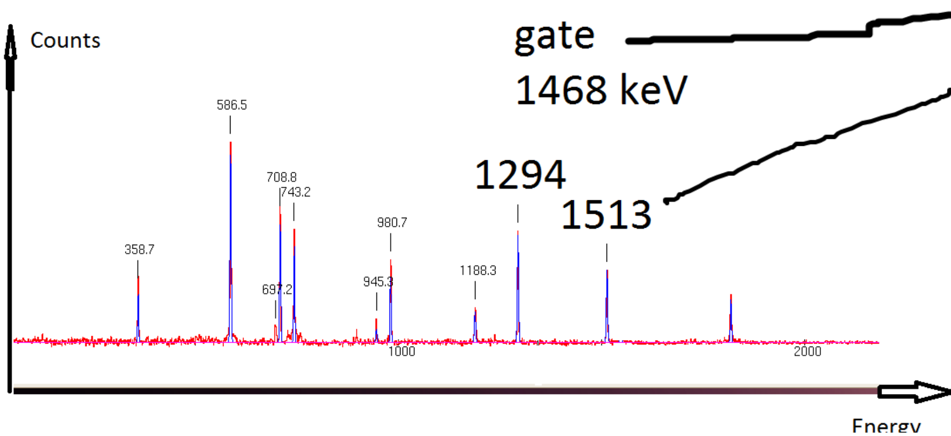
How did we do that?

1) We had the total single gamma ray spectrum

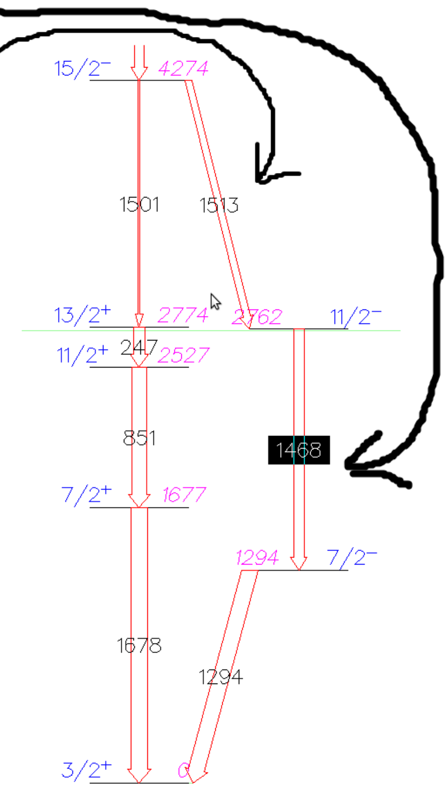
2) We had gamma-gamma coincidence data

3) We had information on gamma rays emitted by different nuclei from publications

So... It’s easy



- We produced the spectrum with the condition that in one of the detectors this gamma was observed

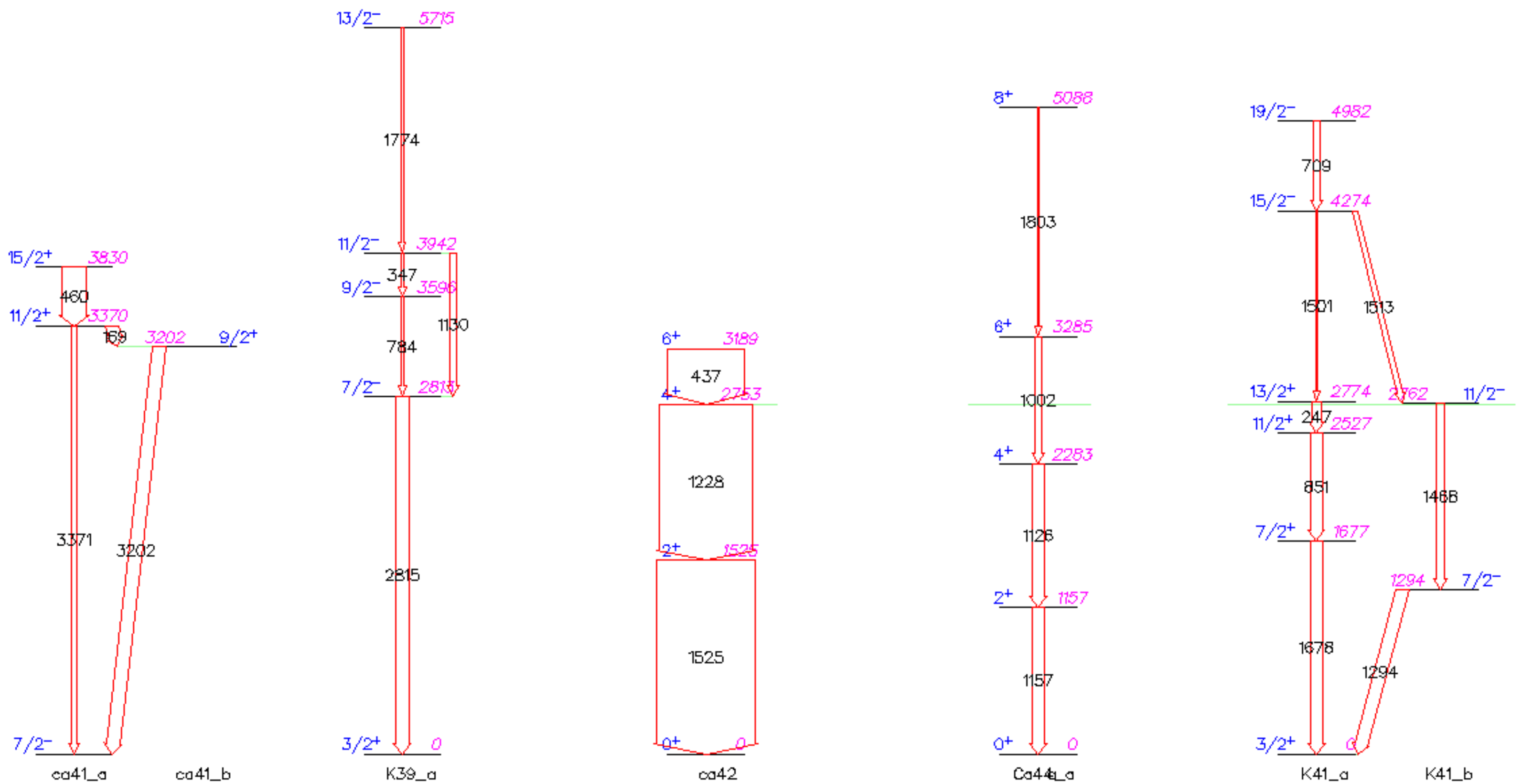


K41

This is only **a part** of the whole decay scheme

In this way We found the following residuals :

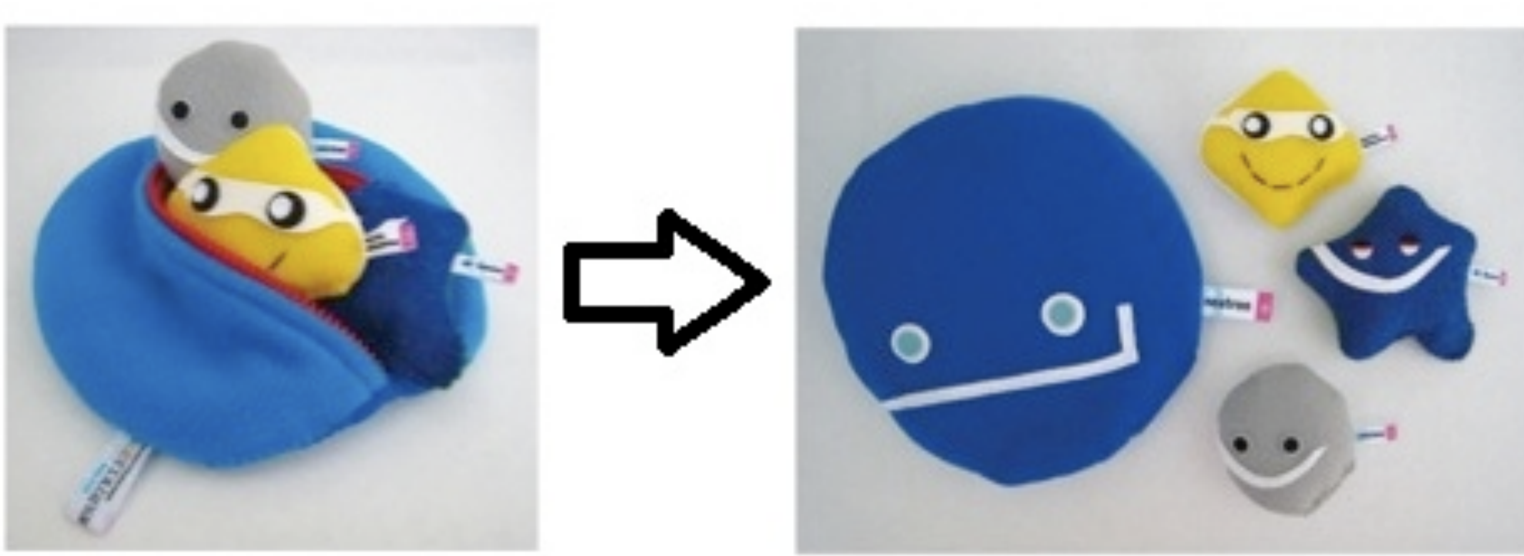
$^{38}Ar, ^{41}Ca, ^{39}K, ^{42}Ca, ^{44}Ca, ^{41}K, \; ^{44}Sc, ^{45}$



some of the decay schemes that we have found

Some examples of reaction channels :

$$ {}^{47}V(CN) \rightarrow {}^{41}K + \alpha + 2p $$
$$ {}^{47}V(CN) \rightarrow {}^{39}K + 2\alpha $$



$$ Compound\ nucleus \rightarrow Residual\ nucleus + p + n + \alpha $$

And again... “How did we do that” in more details

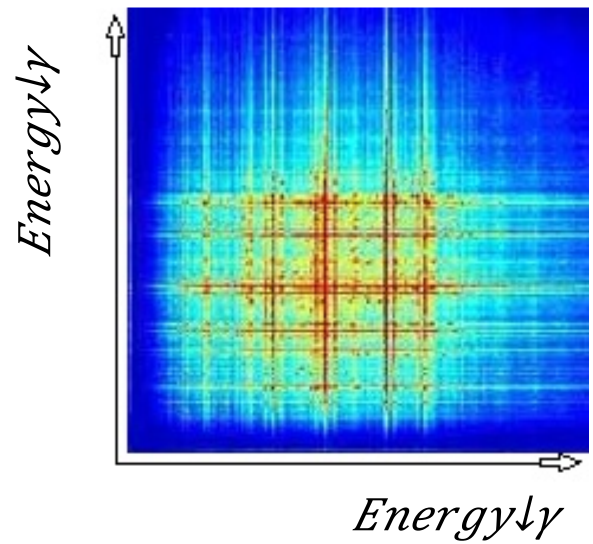
We collected data with EAGLE (with installed target):

1) for 21 minutes requiring that at least 1 gamma is detected ; $m_{\gamma} \geq 1, 2, 3, \ldots (\mathit{first\ trigger})$

2) for 7 hours requiring that at least 2 gammas are detected ; $m_{\gamma} \geq 2, 3, 4, \ldots (\mathit{second\ trigger})$

To create our gamma-gamma matrix we need events that contain at least two gamma rays. The events that contain only one gamma ray are uselles.The matrix looks like :

symmetric axes !



Summary

- We checked the resolution of one Ge detector
- We estimated the thickness of the target
- We used three sources for calibration
- We concluded that all the detectors are not linear
- We obtained the absolute efficiency calibration for all the detectors
- We we collecting data with installed target
- We studied the residual nuclei
- We created some decay schemes

Thank you
for your attention !