CHARACTERISATION OF A SPECTROMETER FOR MEASUREMENTS OF ALPHA-PARTICLE AND X-RAY/GAMMA-RAY IN COINCIDENCE

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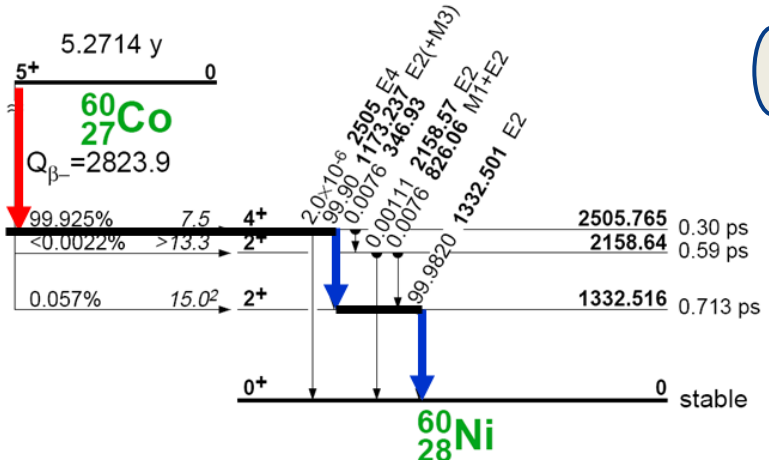
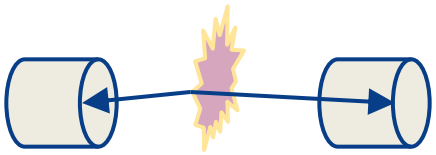
Why coincidence measurements ?

- **For study decay processes**
- **Reduce background (e.g. anti-Cosmic and anti-Compton Spectrometer)**
- **Study rare events**





Our ALPHA-PARTICLE AND X-RAY/GAMMA-RAY spectrometer setup

* Detectors

- Simple alpha detector placed in plastic vial to reduce attenuation of x-rays and gamma rays.

- Two types of Gamma/X-ray detectors tested:

  i) Si(Li) X-ray detector (10mm^2)

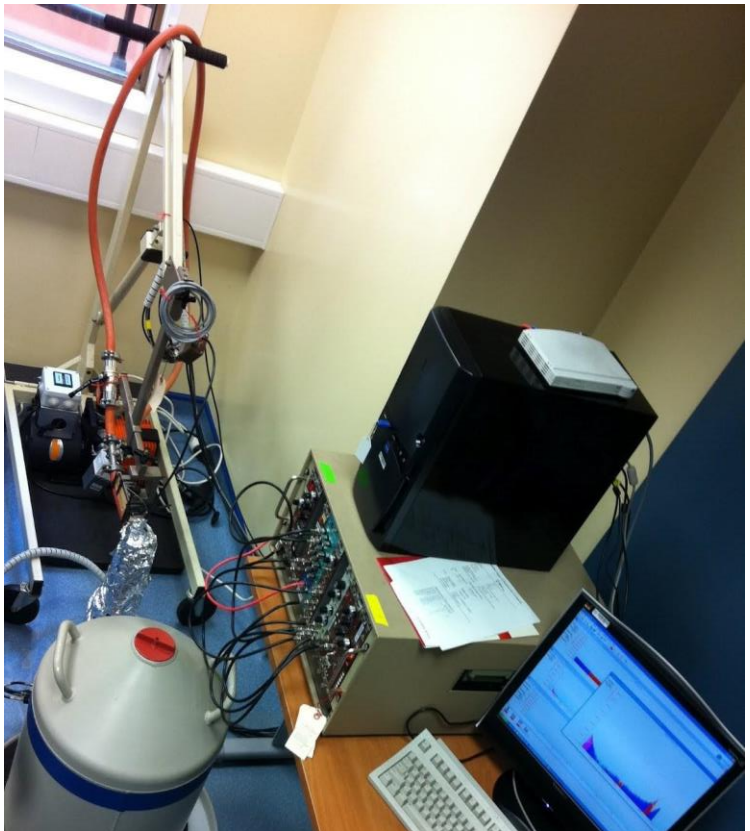
  ii) HPGe Sandwich detector

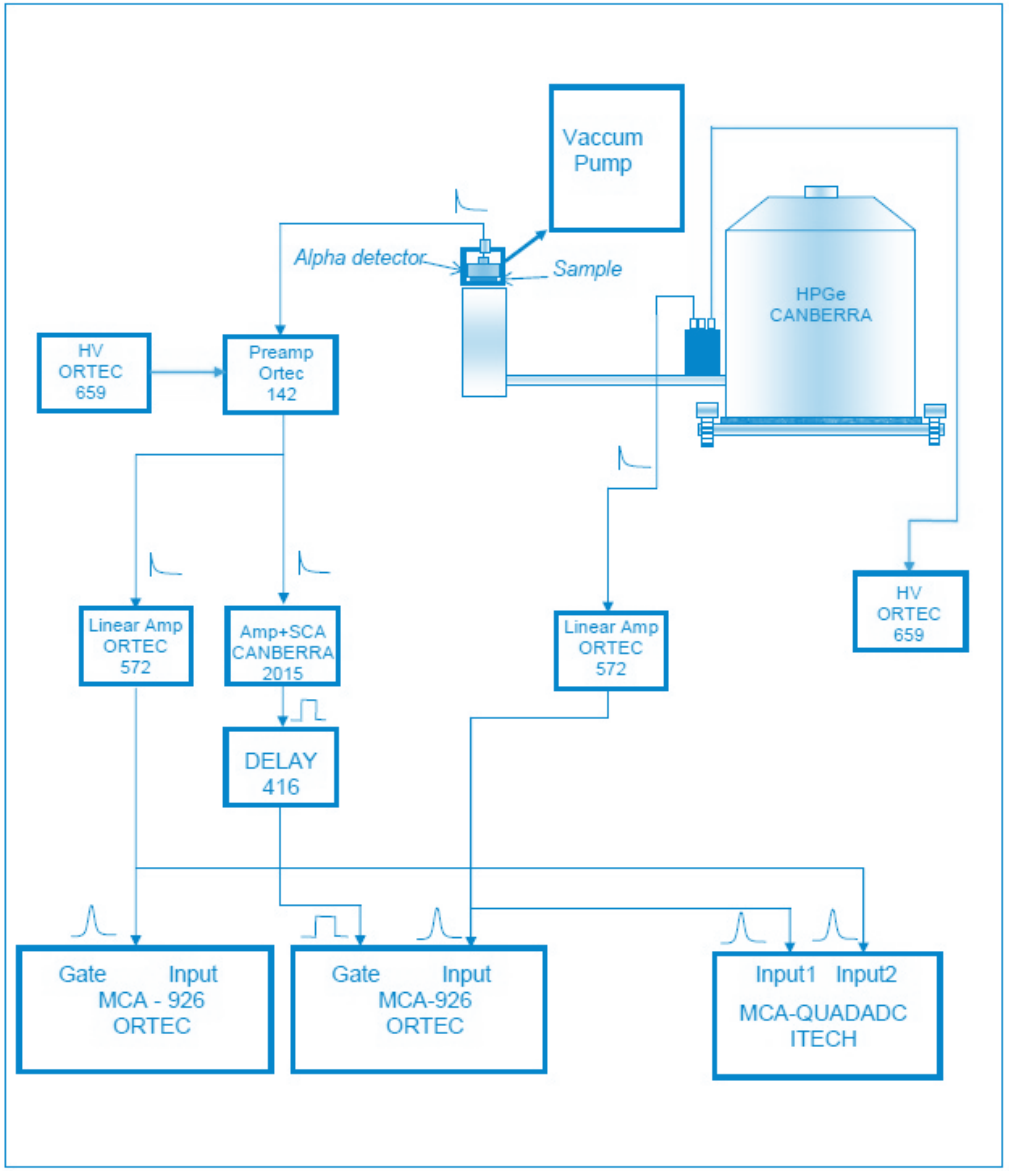
  (carbon epoxy window)

*The spectrometer is covered with Al-foil.

Our spectrometer setup

- Hardware set-up for analog and list-mode coincidence measurements





Our spectrometer setup

ITECH QuadADC

used in list mode acquisition

- combination of ADC and MCA
- 16K channels(64K for list mode)
- time stamp (0.5 µs timer resolution)

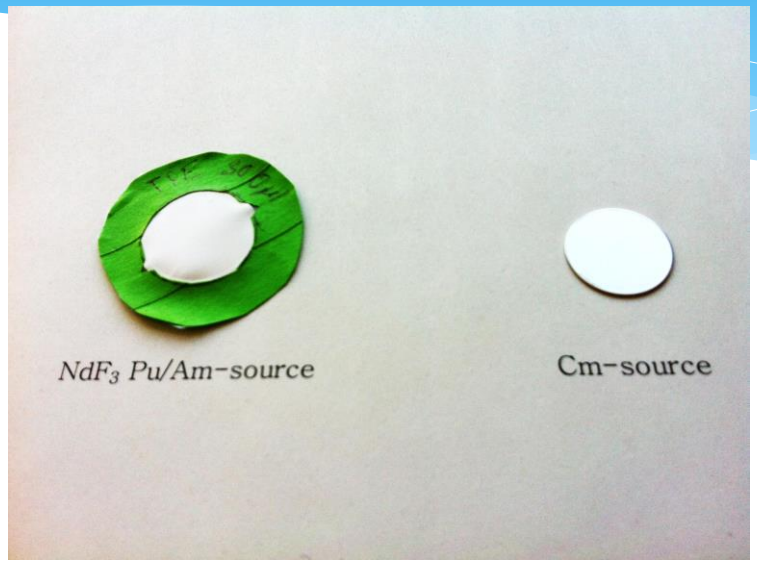
+ Data processing (No software for analysing the list mode data)

(2day Acquisition = ~ GB file)

- convert to ASCII
- "clean" the file
- Make analysing scripts
- Use R to process and analyse the data

Experiment / Examples

A



B

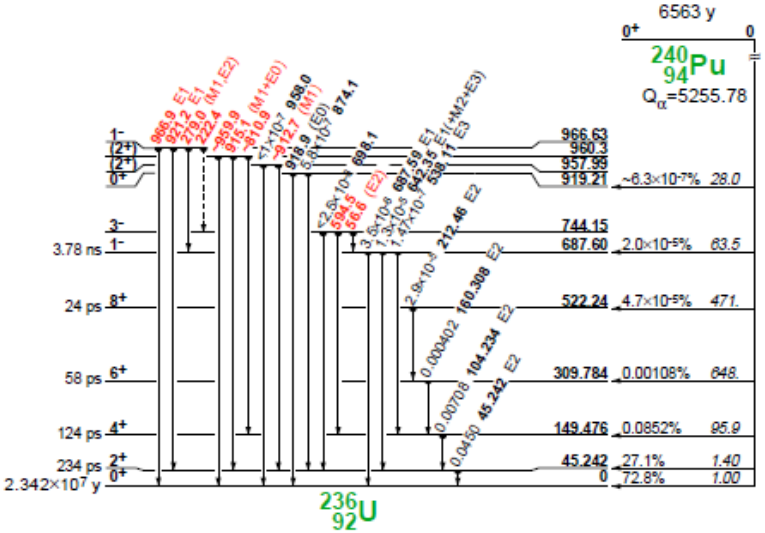
- Determination of $^{240}Pu/^{239}Pu$ in a weapon grade Pu and Am source
- **By studying the internal conversion process and the emission of characteristic uranium X-ray**
- **NdF_3-precipitation on membrane filter**

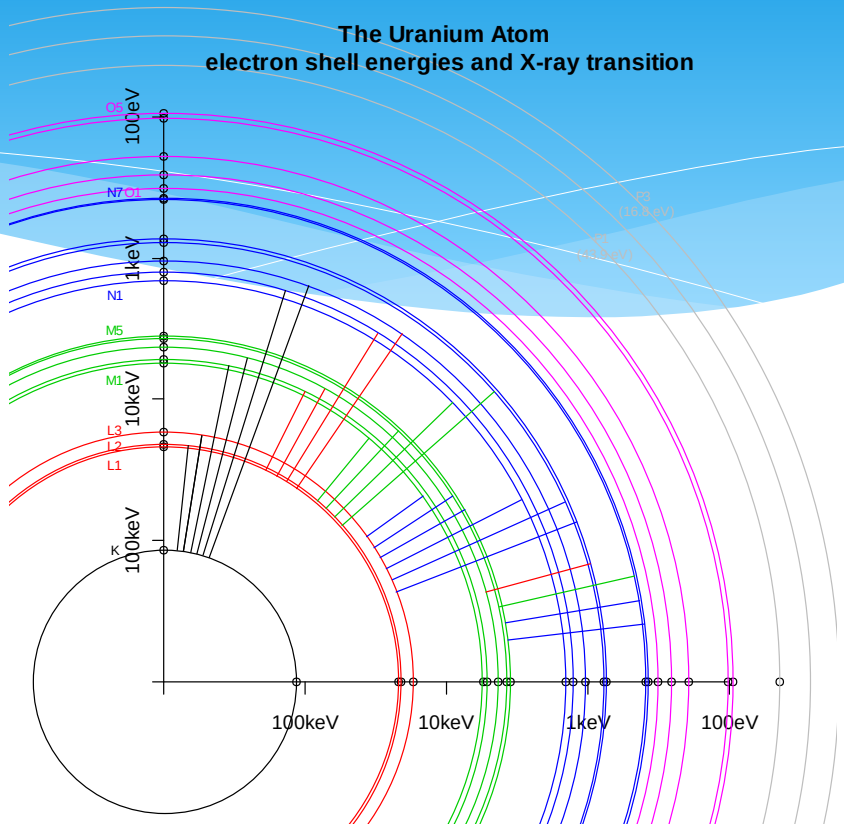
- ^{244}Cm standard with ^{243}Cm impurity
- **looking for rare gamma events, to identify the impurity.**
- **Micro-drop on stainless steel disc**

Experiment A

Determination of $^{240}Pu/^{239}Pu$ in a weapon grade Pu and Am source

- Study the internal conversion process and the emission of characteristic uranium X-ray





+ Alpha decay, leave the daughter in excite energy state

+ Internal conversion process competes with gamma decay

+ Emission of conversion electron may lead to characteristic X-ray or Auger electrons emission

Experiment

- Weapon grade Pu and Am source
- - Study the internal conversion process and the emission of characteristic uranium X-ray

$$\frac{P_1}{\varepsilon_{P_1}} = \eta_{238}^{P_1} \cdot A_{238} + \eta_{239}^{P_1} \cdot A_{239} + \eta_{240}^{P_1} \cdot A_{240} + \eta_{241}^{P_1} \cdot A_{241}$$

$$\frac{P_2}{\varepsilon_{P_2}} = \eta_{238}^{P_2} \cdot A_{238} + \eta_{239}^{P_2} \cdot A_{239} + \eta_{240}^{P_2} \cdot A_{240} + \eta_{241}^{P_2} \cdot A_{241}$$

$$\frac{P_3}{\varepsilon_{P_3}} = \eta_{238}^{P_3} \cdot A_{238} + \eta_{239}^{P_3} \cdot A_{239} + \eta_{240}^{P_3} \cdot A_{240} + \eta_{241}^{P_3} \cdot A_{241}$$

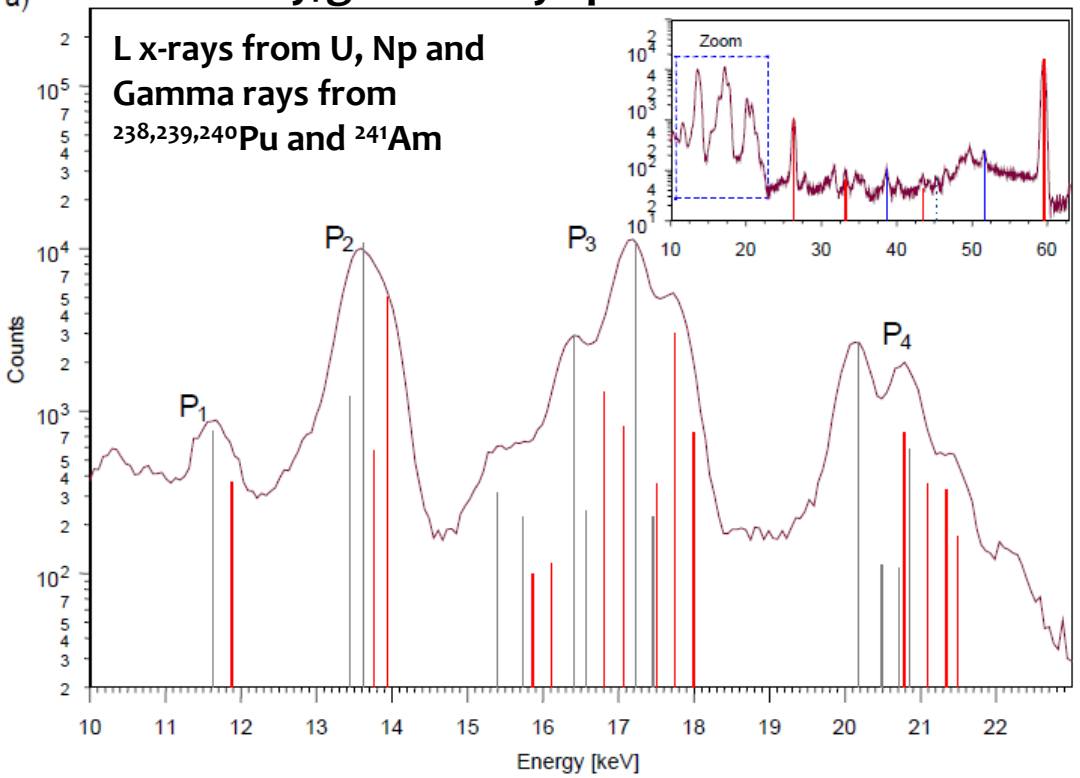
$$\frac{P_4}{\varepsilon_{P_4}} = \eta_{238}^{P_4} \cdot A_{238} + \eta_{239}^{P_4} \cdot A_{239} + \eta_{240}^{P_4} \cdot A_{240} + \eta_{241}^{P_4} \cdot A_{241}$$

$$\begin{pmatrix} \widetilde{P_1} \\ \widetilde{P_2} \\ \widetilde{P_3} \\ \widetilde{P_4} \end{pmatrix} = \begin{pmatrix} \eta_{238}^{P_1} & \eta_{239}^{P_1} & \eta_{240}^{P_1} & \eta_{241}^{P_1} \\ \eta_{238}^{P_2} & \eta_{239}^{P_2} & \eta_{240}^{P_2} & \eta_{241}^{P_2} \\ \eta_{238}^{P_3} & \eta_{239}^{P_3} & \eta_{240}^{P_3} & \eta_{241}^{P_3} \\ \eta_{238}^{P_4} & \eta_{239}^{P_4} & \eta_{240}^{P_4} & \eta_{241}^{P_4} \end{pmatrix} \begin{pmatrix} A_{238} \\ A_{239} \\ A_{240} \\ A_{241} \end{pmatrix}$$

$$\mathbf{P} = \eta \mathbf{A} \qquad solution \qquad \mathbf{A} = \eta^{-1} \mathbf{P}$$

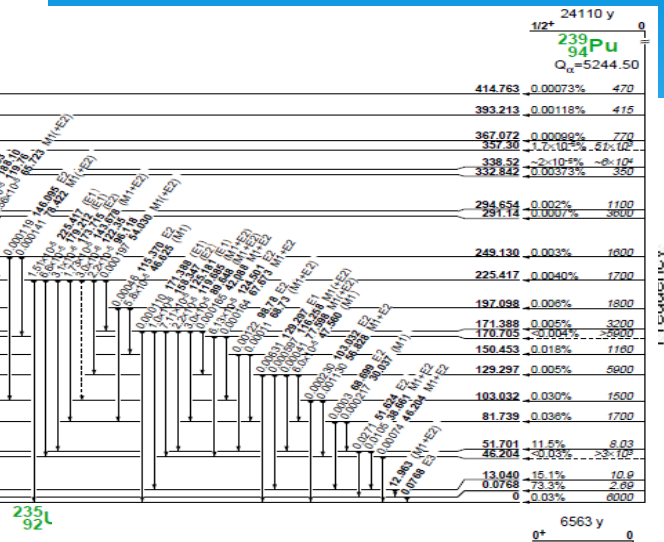
X-ray/gamma ray spectra in direct mode

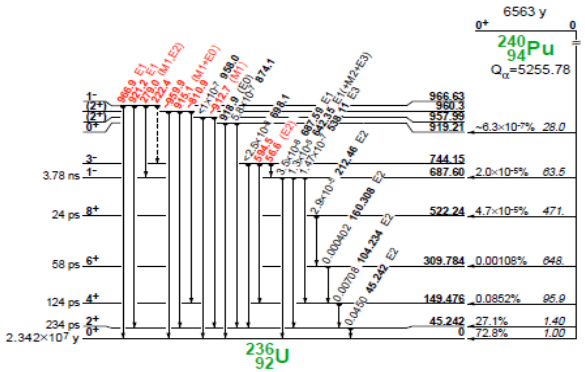
a)

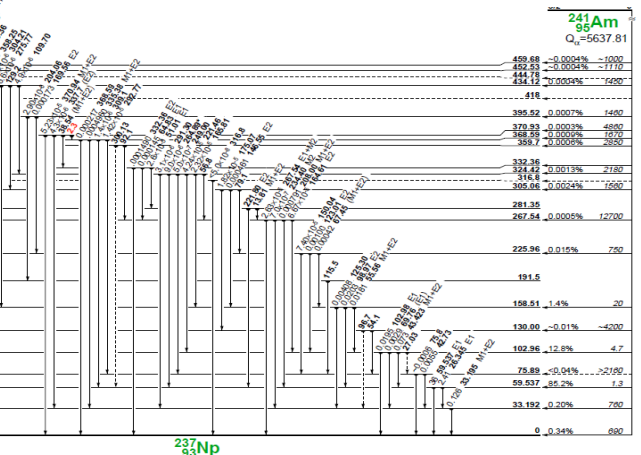


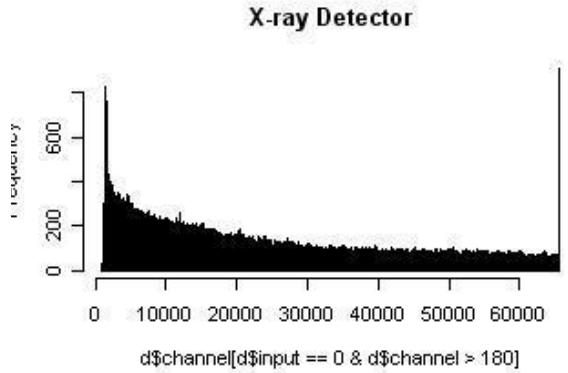
The solution gives the isotopic composition

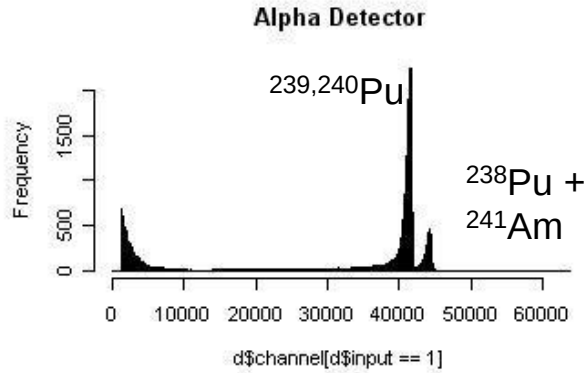
Results: Pu/Am source

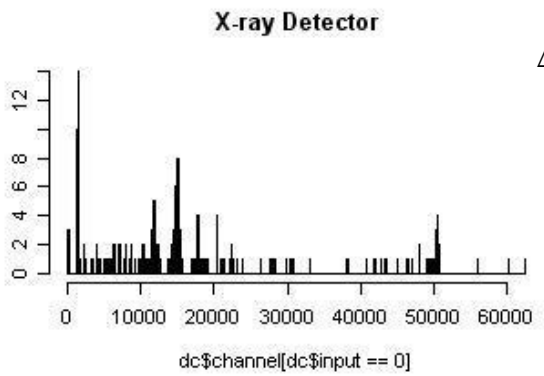




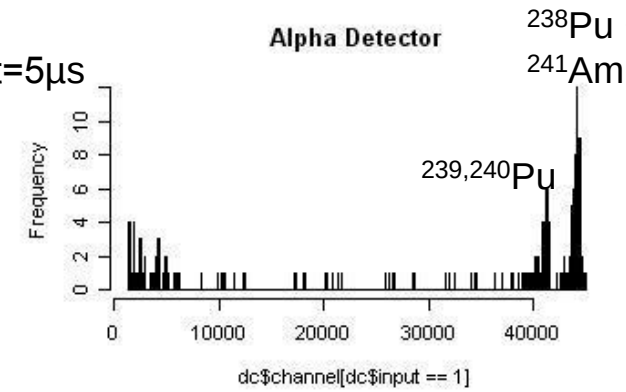


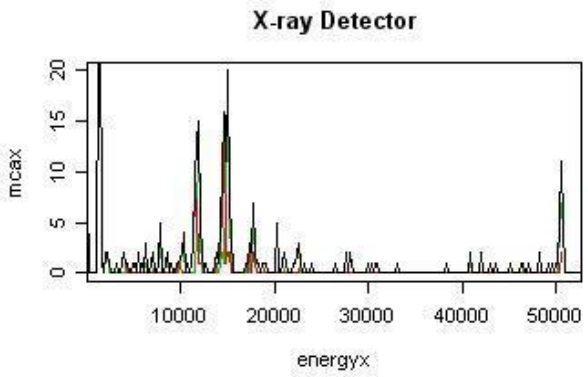


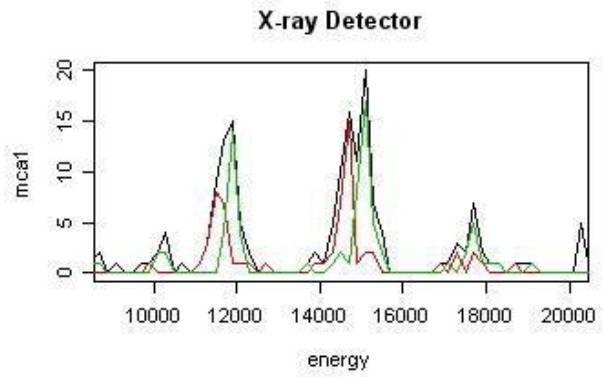


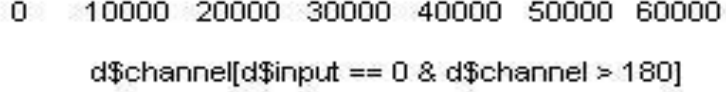


Δt=5μs

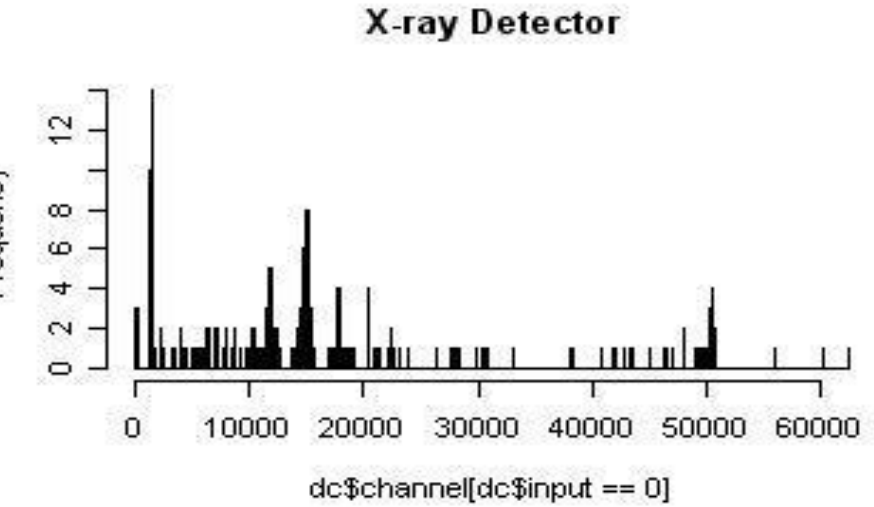




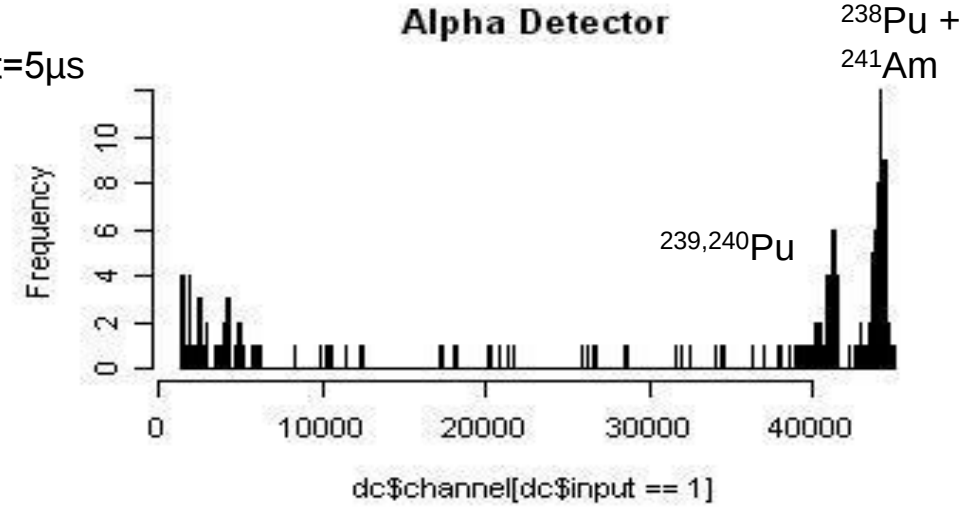


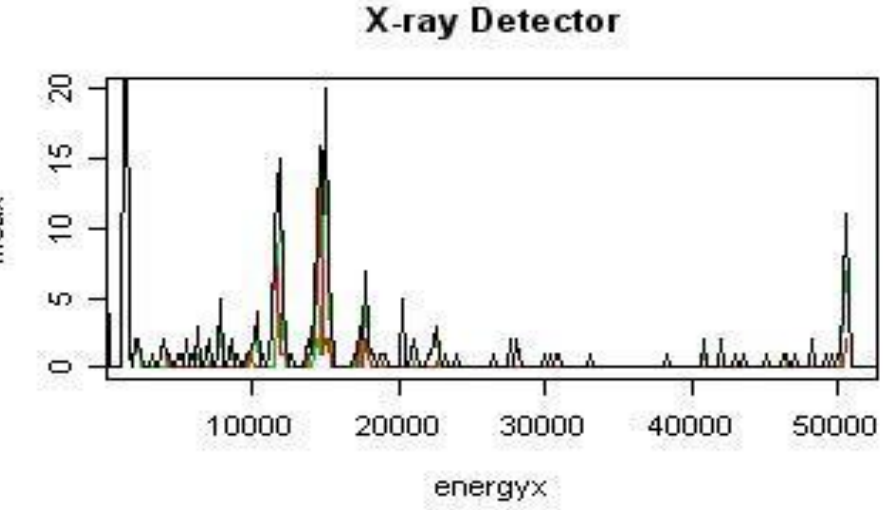

0 10000 20000 30000 40000 50000 60000
d$channel[d$input == 0 & d$channel > 180]

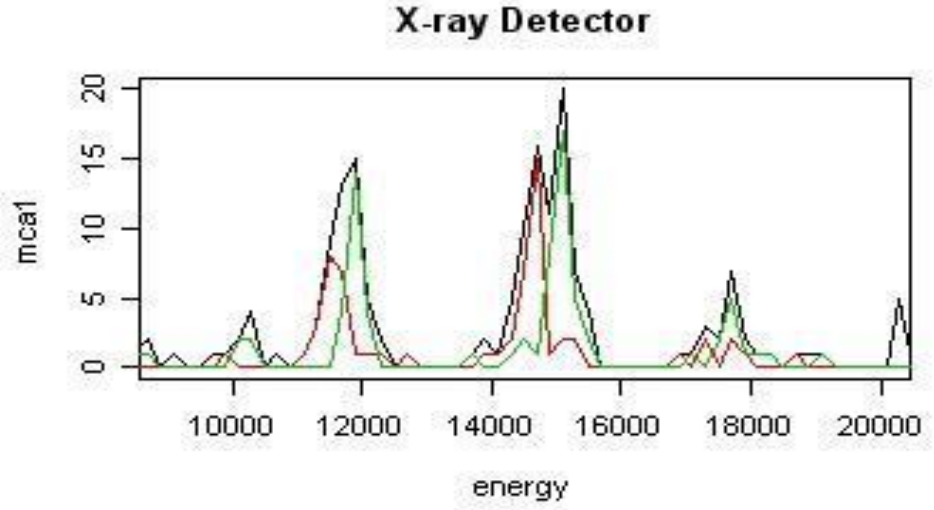

0 10000 20000 30000 40000 50000 60000
239,240Pu
d$channel[d$input == 1]


X-ray Detector
0 2 4 6 8 12
0 10000 20000 30000 40000 50000 60000
dc$channel[dc$input == 0]

Δt=5μs

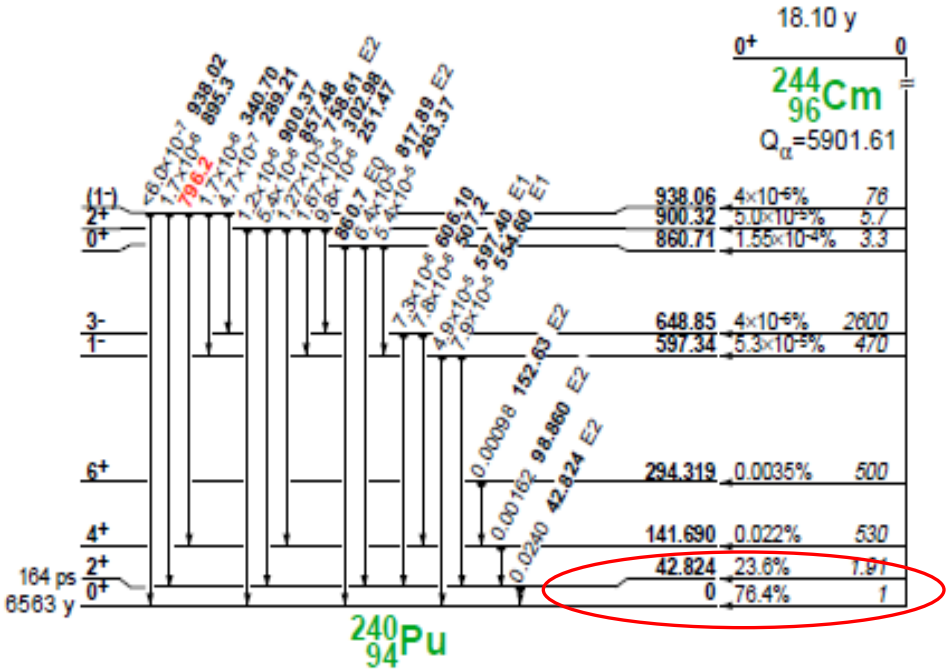

Alpha Detector
238Pu +
241Am
239,240Pu
Frequency
0 2 4 6 8 10
0 10000 20000 30000 40000
dc$channel[dc$input == 1]

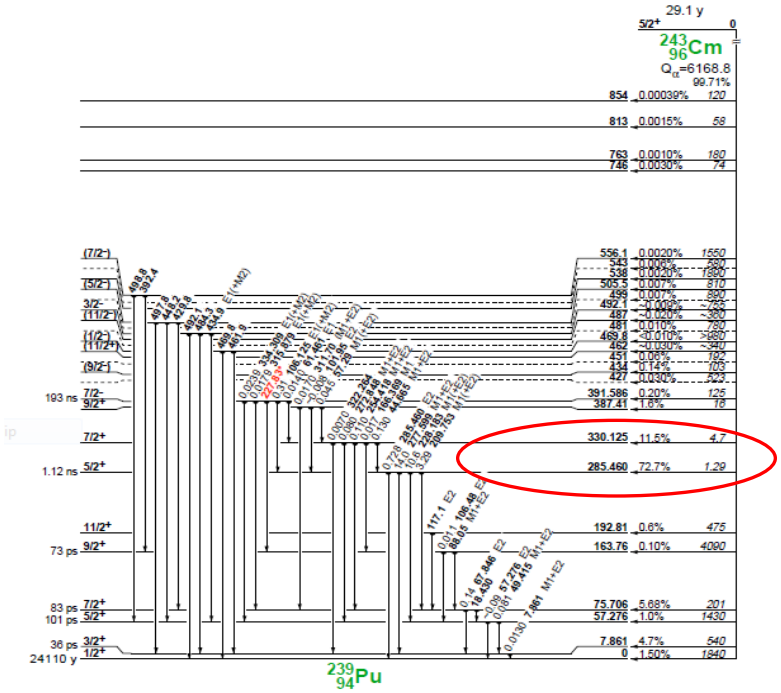

X-ray Detector
0 5 10 15 20
10000 20000 30000 40000 50000
energyx


X-ray Detector
mca1
0 5 10 15 20
10000 12000 14000 16000 18000 20000
energy

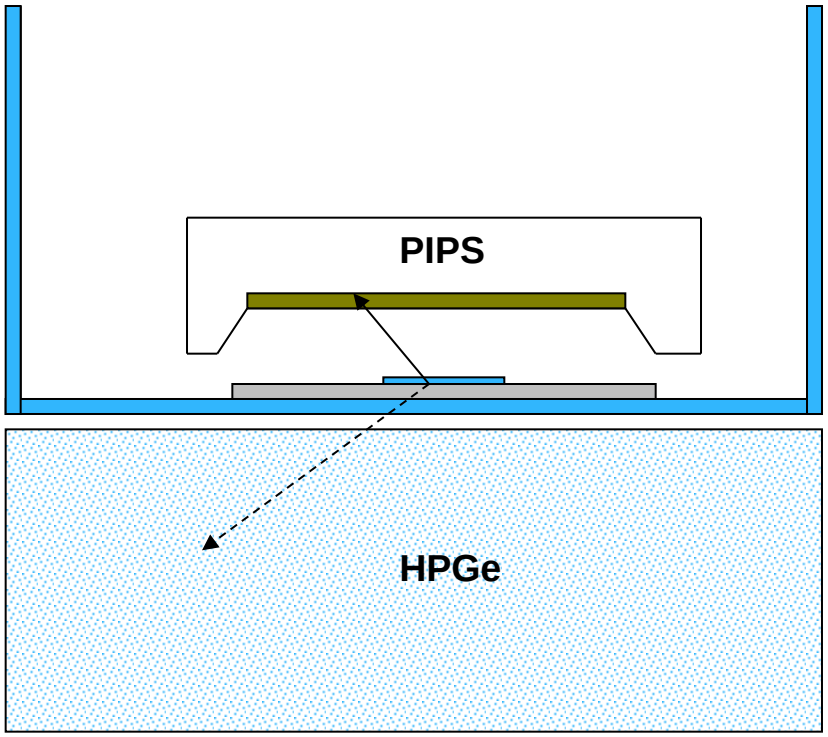
Experiment B

- **^{244}Cm standard with ^{243}Cm impurity**
- Challenge: the two radionuclide's have almost the same alpha ray energy
- Possibility:
  - i) study the x-rays of the impurity ^{243}Cm, as it is has a much higher internal conversion factor than ^{244}Cm
  - **ii) the impurity ^{243}Cm's alpha decay follows by gamma-ray's in coincidence**





Experiment/Example B
Cm-source
Efficiency estimate

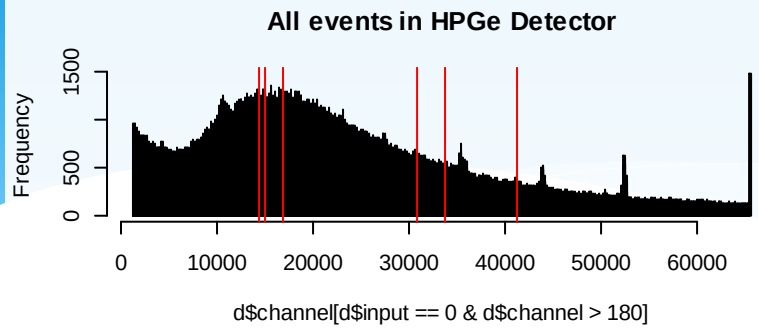


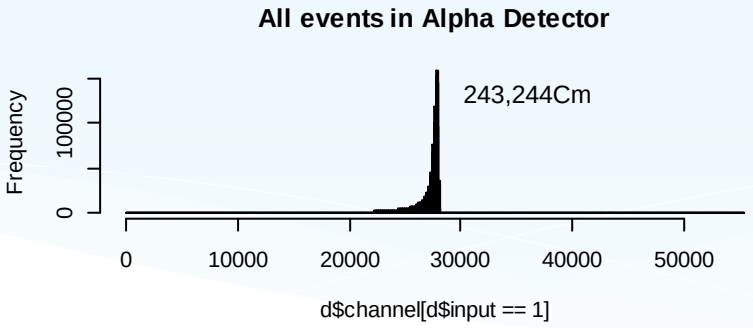
Alpha eff: ~ 0.3

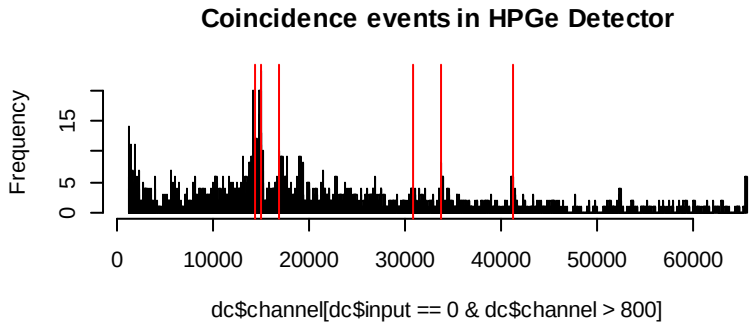
Gamma eff: ~ 0.1
(estimating the attenuation by the stainless steel disc,
@ 228.2 keV and 277.6 keV)

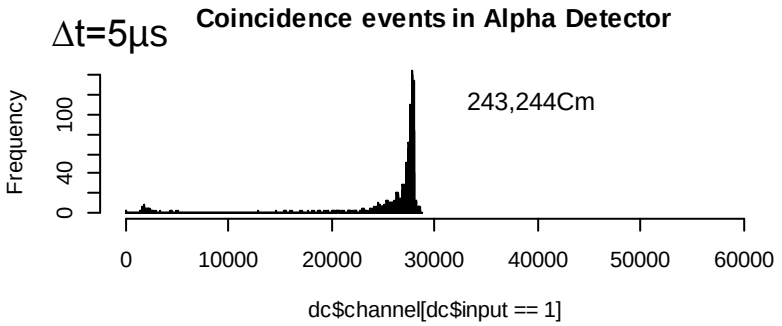
Coincidence geo eff: ~ 0.03

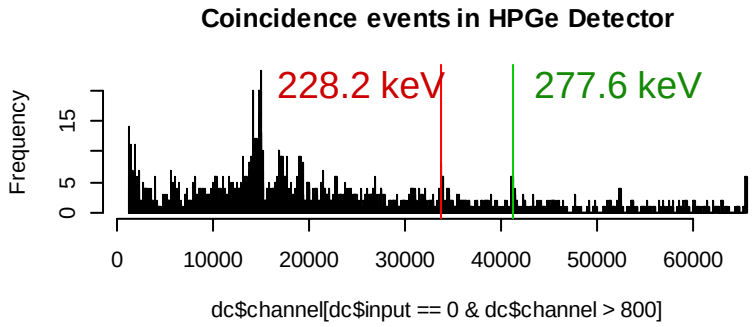
Results: Cm source

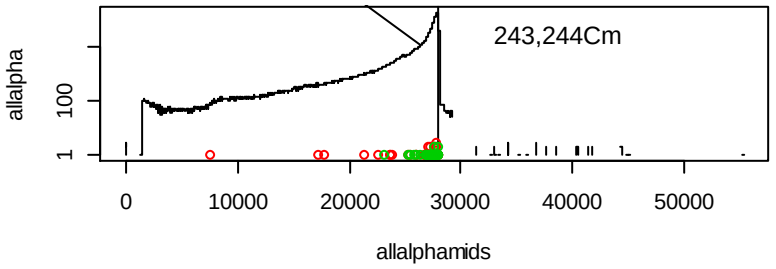












^{243}Cm impurity: Activity ratio ^{243}Cm/ ^{244}Cm ~ 0.0007

Conclusions

* In the coincidence spectrometer setup used, it is possible to **study rare events** from a source and to **reduce background** pulses in the spectra.
* Recording the acquisitions in **list mode** make the spectrometer **flexible** for alpha and X-ray/Gamma-ray coincidence **measurements (time and energy)** compared to electronically gated (analogic mode) coincidence events.
* Using the ITECH QuadADC for list mode acquisitions makes very large files (several Giga Byte) and no analysing software provided, experience in program scripting required
* Many software don't support large data files making them difficult to work with.
* Using R is an excellent way of processing the data.


http://www.r-project.org/