Detection of epithermal neutrons on Vesuvio

Erik Schooneveld

STFC, ISIS facility, UK

Neutrons Matter: International Workshop in Electron-volt Neutron Spectroscopy

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Content

- Introduction
- Pros and conns of detector types
- Detector choice
- Improvements

Introduction

- Vesuvio has plans to extend detector coverage + shift in science.

- Perfect time to reconsider detector suite.

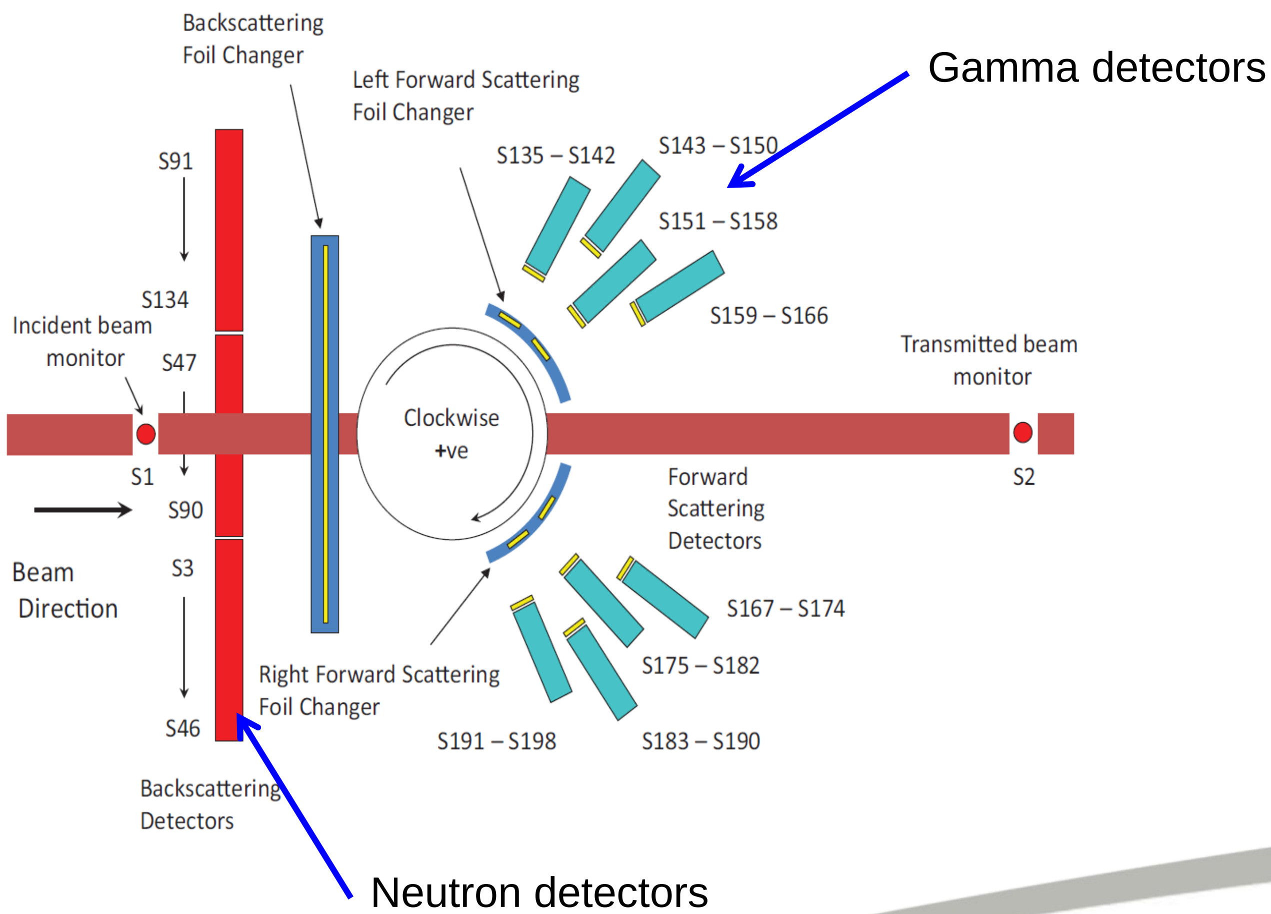
- Help from Italian colleagues is very much appreciated.

Introduction

- Detector requirements:
  - High detection efficiency $\Rightarrow$ solid state detectors
  - High count rate $\Rightarrow$ scintillators
  - Low sensitivity to background radiation (discrimination)
  - High stability (temperature)
  - Long life time and low maintenance
  - No absorption resonances ($E < 100eV$)
  - Available and affordable

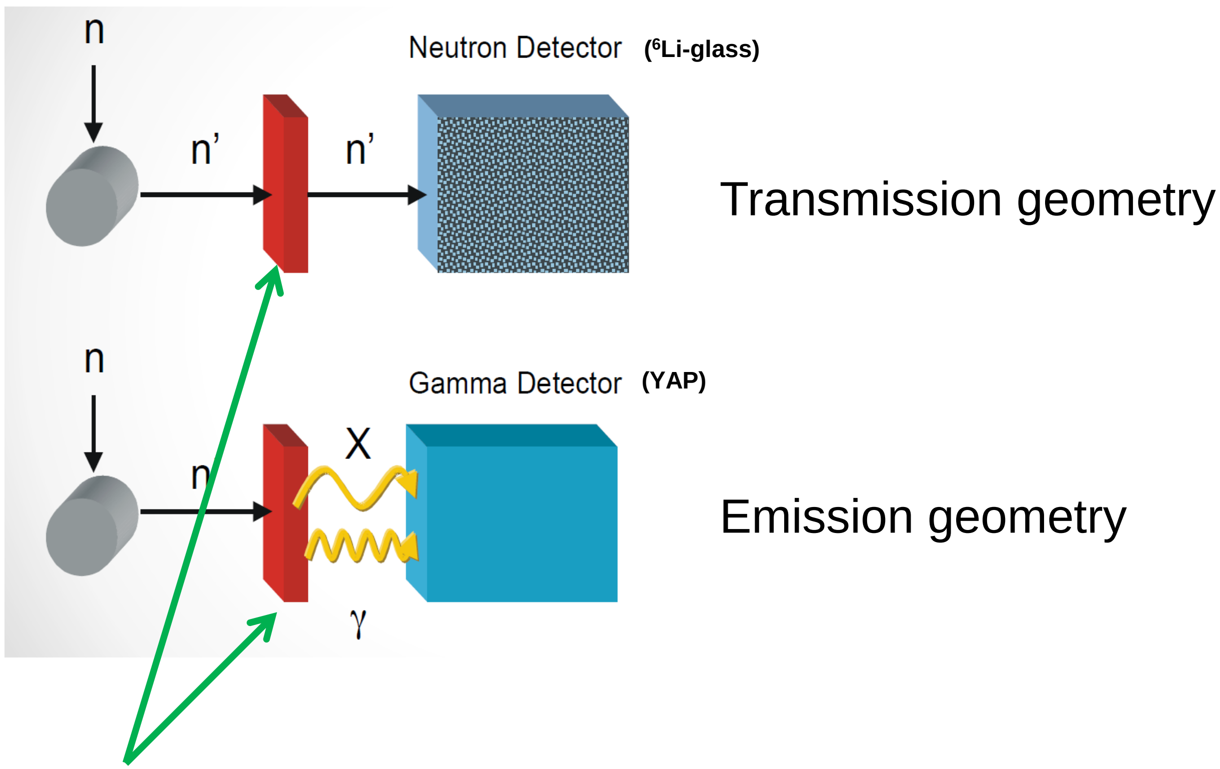
Introduction

- Vesuvio



Introduction

- Detector types:

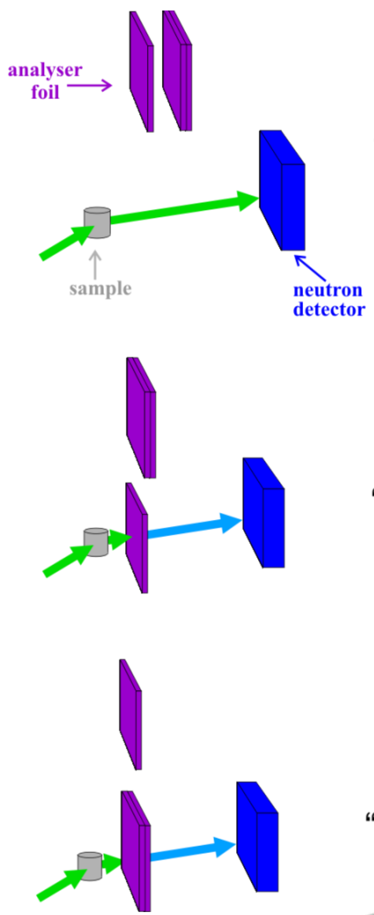


Au analyser foils (fix final energy)

Introduction

- Foil cycles

Neutron detector

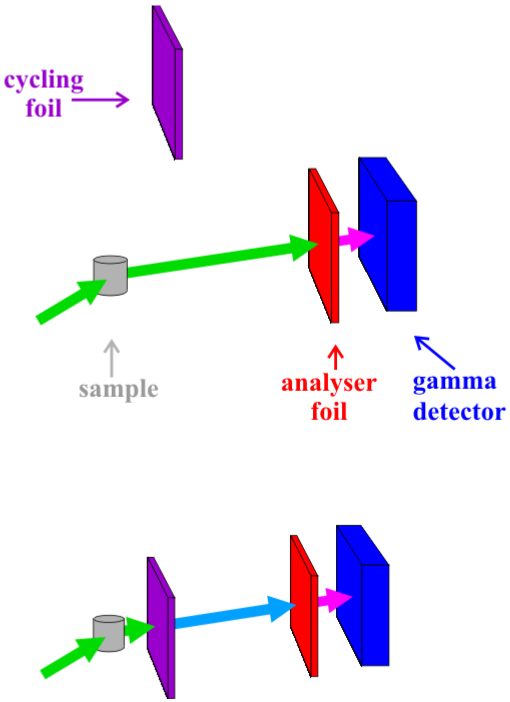


"Foil out"

"Thin foil in"

"Thick foil in"

Gamma detector

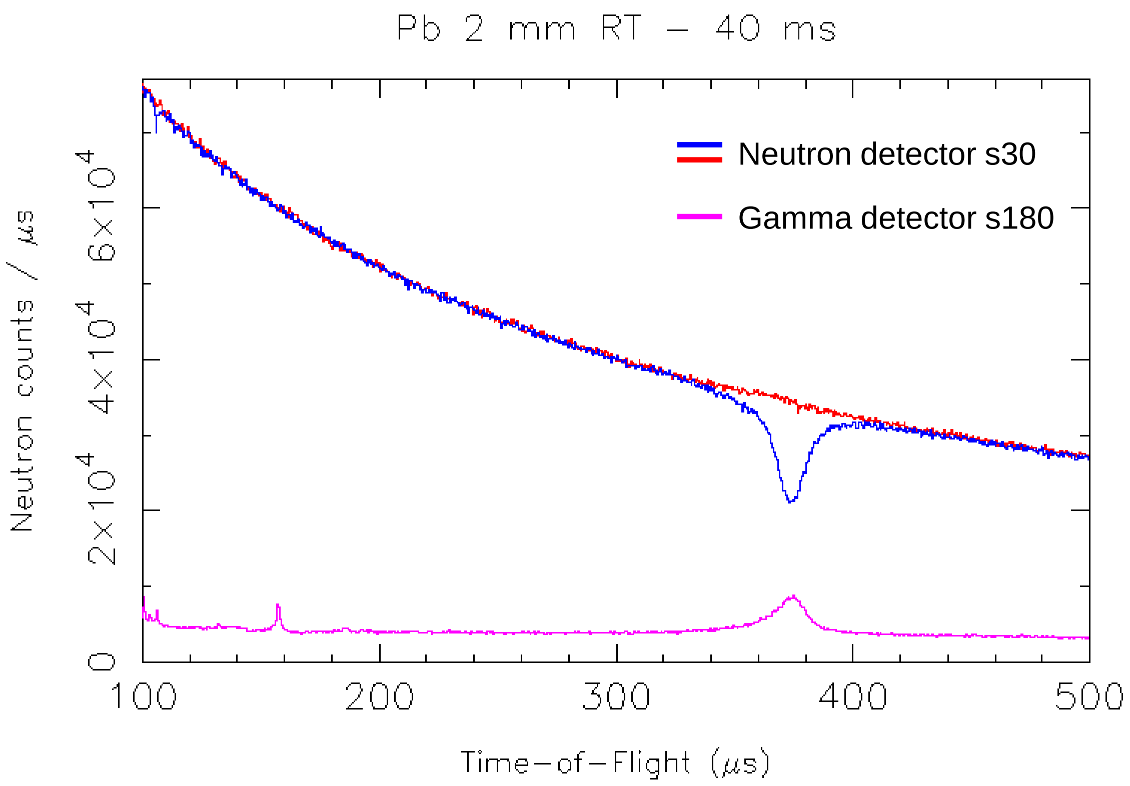


"Foil out"

"Foil in"

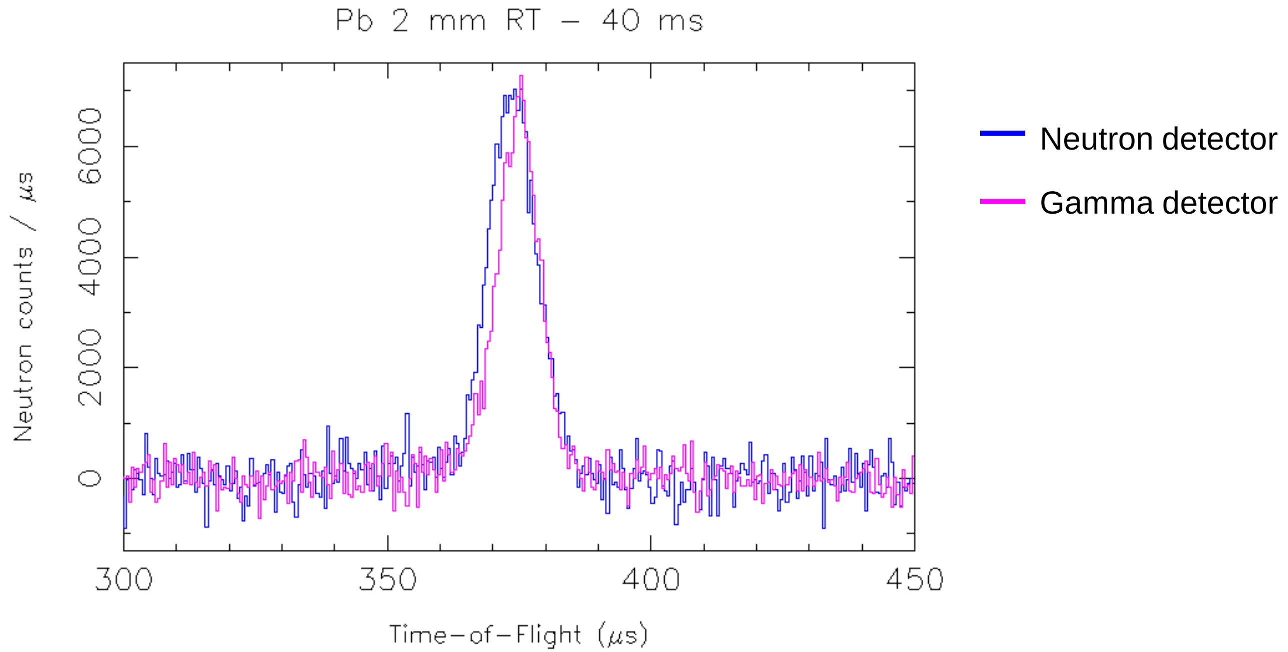
Introduction

- Very different response (signal-background).



Introduction

- Similar performance (resolution).



  - Neutron detector using double difference technique.
  - Gamma detector using foil cycling technique.
  - Gamma detector scaled by factor of 2.

- When to use each type?

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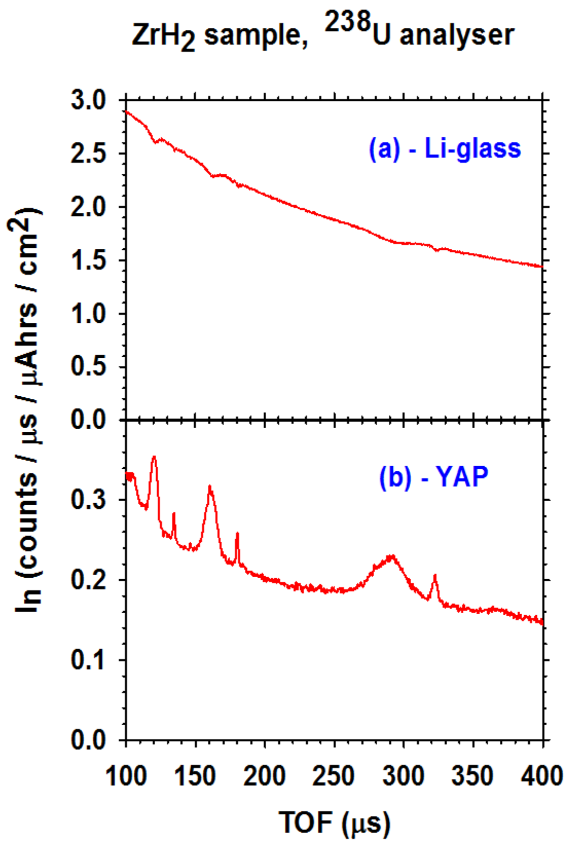
Neutron vs Gamma detector

Normalising foil in – foil out

- Tiny dips in Li-glass spectrum ⇒ need very good normalisation.

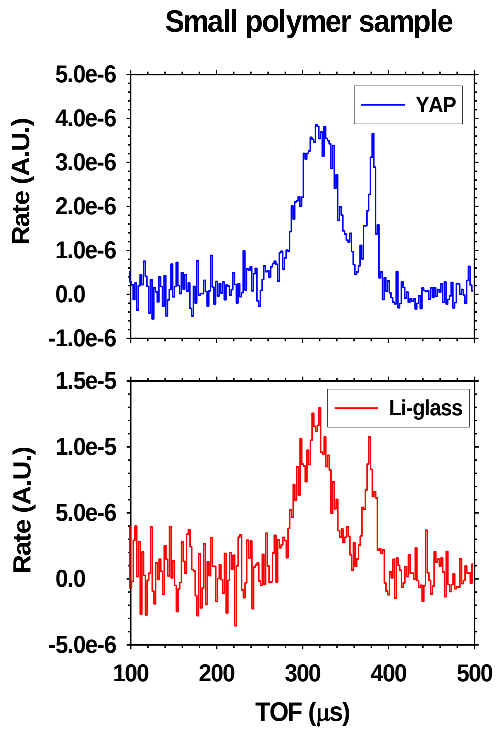
- High count rate of Li-glass detector ⇒ saturation issues.

➢ Normalisation much easier with gamma detector.



Neutron vs Gamma detector

Counting statistics



Double difference

➢ YAP gamma detector better than Li-glass neutron detector.

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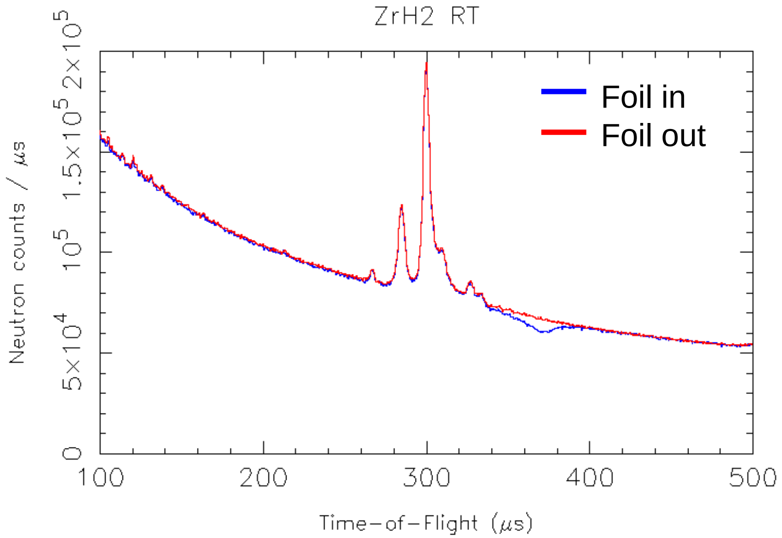
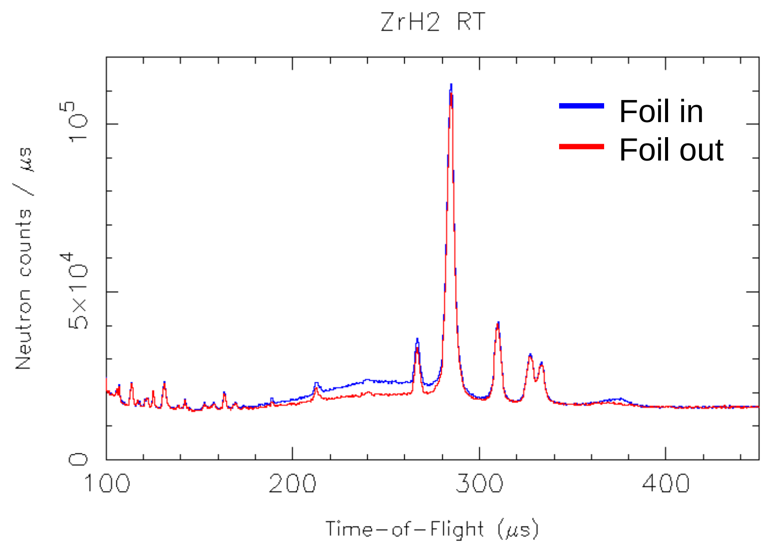
Neutron vs Gamma detector

Gamma emitted from ZrH sample (Hf impurities).

Neutron detector (backscattering)



Gamma detector (forward)



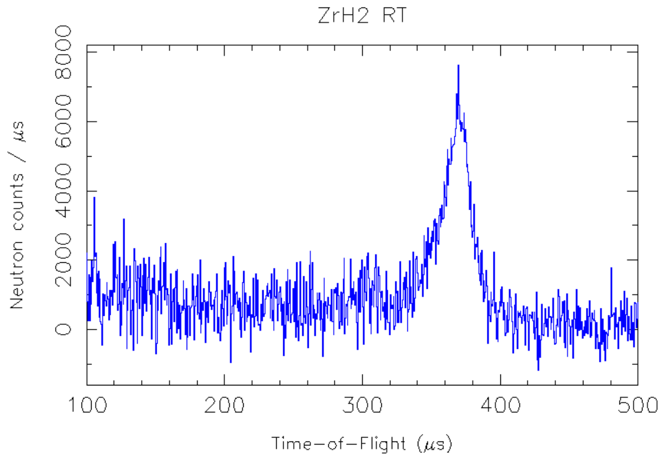
- Hf background/Pb peak: neutron detector: factor 13

  gamma detector: factor 80

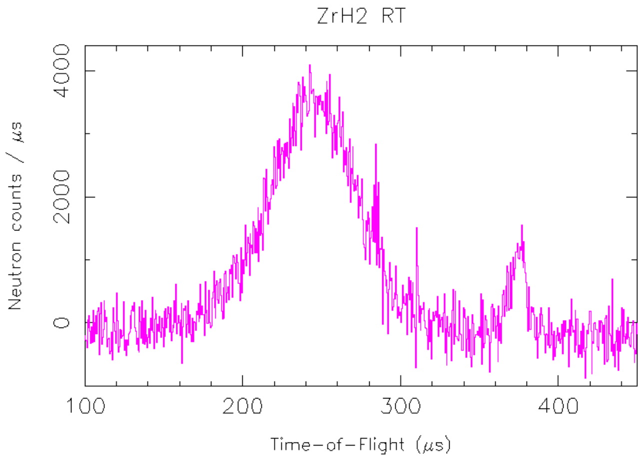
Neutron vs Gamma detector

- After taking foil differences:

Neutron detector single difference (backscattering)



Gamma detector (forward)



➢ Neutron detector: No problem

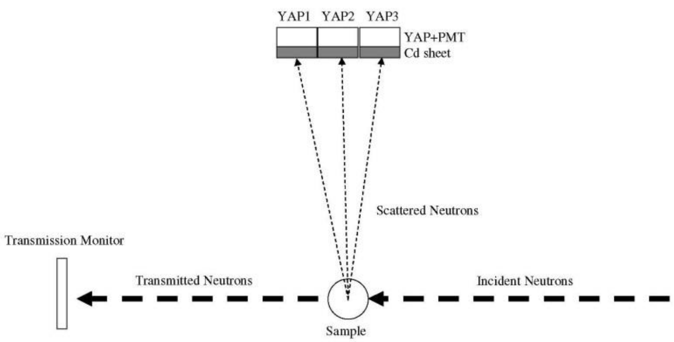
➢ Gamma detector: No serious problem.

Neutron vs Gamma detector

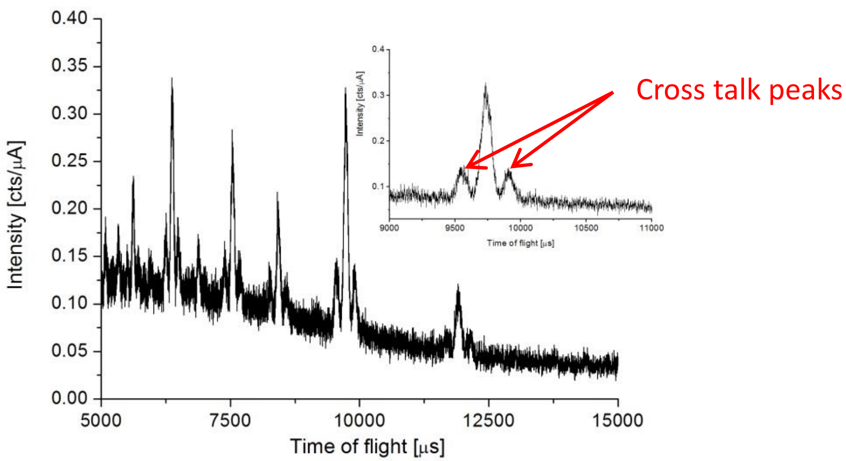
Cross talk between gamma detectors.

- Diffraction experiment on INES (Applied Radiation and Isotopes 130 (2017) 264–269).
- Closely packed detectors:

Setup



YAP2 diffraction data

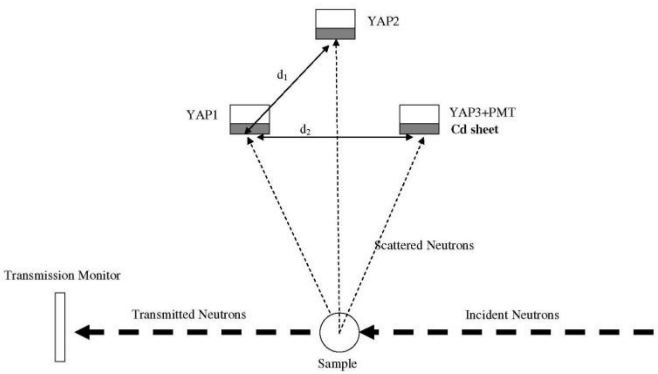


➢ Cross talk is 25%

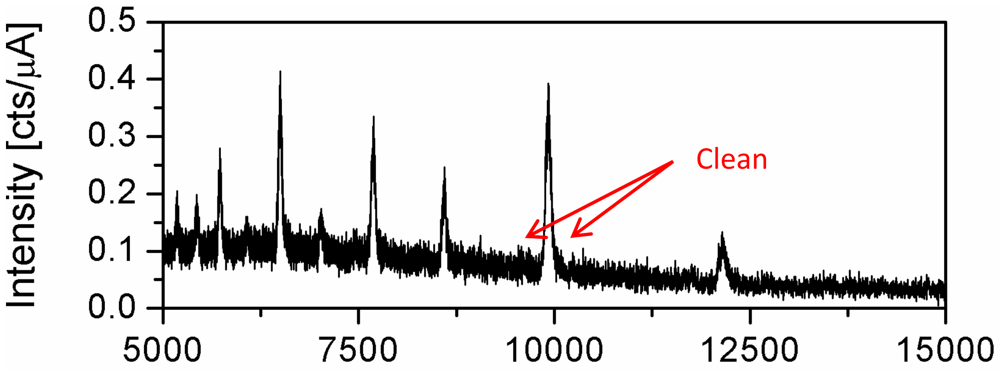
Neutron vs Gamma detector

- Spaced out detectors:

Setup



YAP2 diffraction data

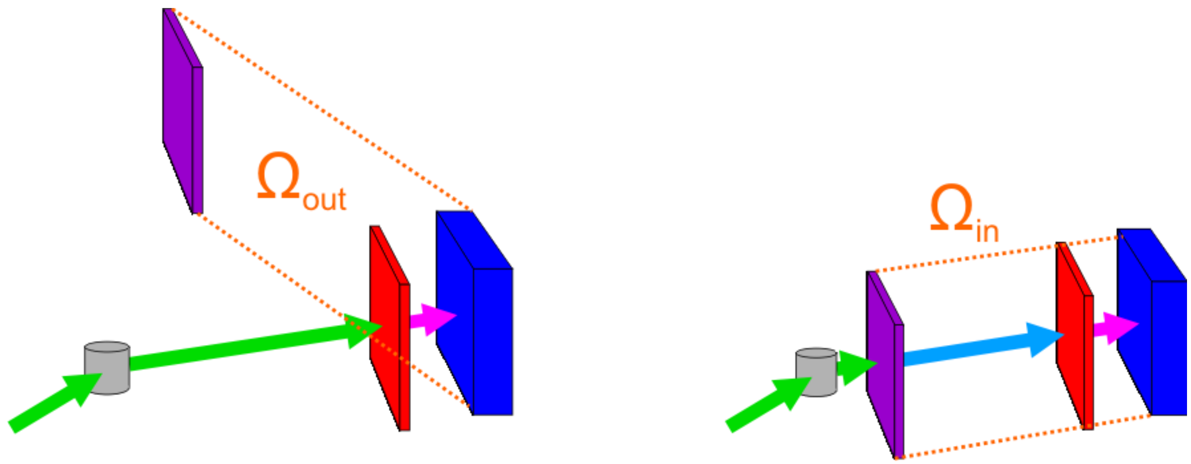


➢ Need sufficient space between detectors.

Neutron vs Gamma detector

Cycling foil gammas.

- Different solid angle for cycling foil in and out.

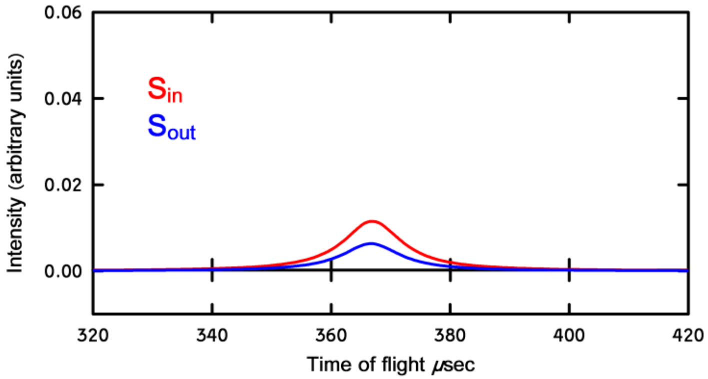


- $\Omega_{out} \neq \Omega_{in}$ ($\theta_{out} \neq \theta_{in}$) $\Rightarrow$ no perfect subtraction of gammas from cycling foil.

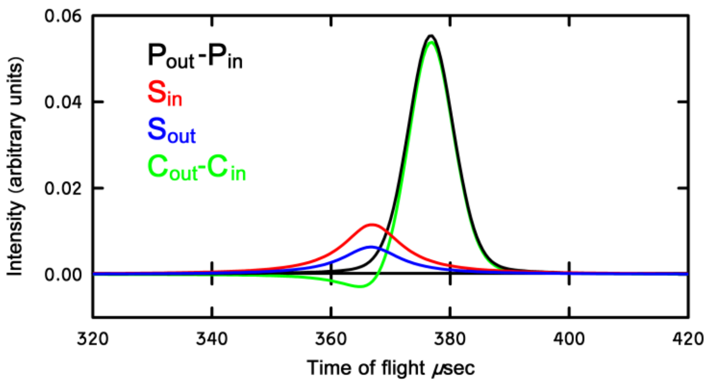
Neutron vs Gamma detector

- Mayers J 2011 *Meas. Sci. Technol.* **22** 015903.

Gammas from cycling foil



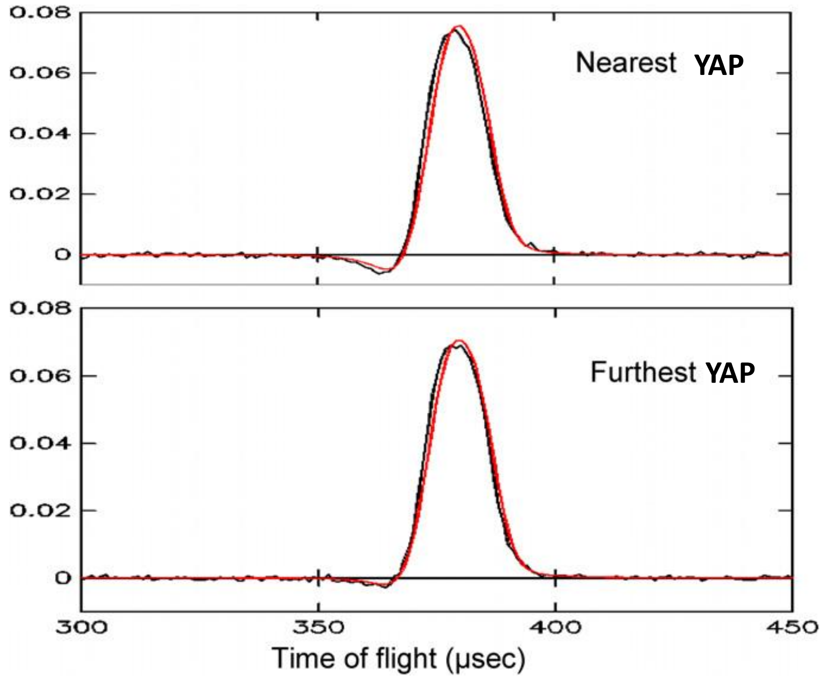
All spectra



- Mismatch in solid angles give undershoot before peak.

Neutron vs Gamma detector

- Correction: data and theory.



➢ Can correct for effect but introduces uncertainty.

Detector choice

- Neutron detector:
- ✓ Suitable for small spaces
- ✓ Collect diffraction data
- ✗ Higher rate $\Rightarrow$ prone to saturation
- ✗ Normalisation issues

- Gamma detector:
- ✓ Better signal-background for short TOF
- ✓ Efficiency doesn't decrease for higher final energy
- ✗ Requires more space inside block house
- ✗ Gammas from cycling foil

➢ Current Vesuvio configuration is optimal 🙂

Detector choice

- Backscattering:
  - Limited space
  - Diffraction
- ➢ Neutron detector in backscattering.

- Forward scattering:
  - Sufficient space
  - Better statistics + normalisation
- ➢ Gamma detector in forward scattering.

- ➢ Current Vesuvio configuration is optimal

Improvements

Other scintillators?

- No absorption resonance below 100eV or σ <= ~100 B.

	Scintillator composition	Density (g/cm^3)	Index of refraction	Wavelength of max.Em. (nm)	Decay time Constant (μs)	Scinti Pulse height[1)]
✓	YAP	5.50	1.9	370	0.030	70
	NaI(Tl) I	3.67	1.9	410	0.25	100
	CsI I	4.51	1.8	310	0.01	6
	CsI(Tl) I	4.51	1.8	565	1.0	45
	CaF_2(Eu) Eu	3.19	1.4	435	0.9	50
✓	BaF_2	4.88	1.5	190/220 310	0,0006 0.63	5 15
✓	BGO	7.13	2.2	480	0.30	10
	$CdW0_4$ Cd, W	7.90	2.3	540	5.0	40
	$PbWO_4$ W	8.28	2.1	440	0.020	0.1
✓	CeF_3	6.16	1.7	300 340	0.005 0.020	5
	GSO Gd	6.71	1.9	430	0.060	40
	LSO Lu	7	1.8	420	0.040	75

LaCl (La), LaBr (Br, La)

Gamma detector scintillators

➢ YAP still most suitable scintillator.

Improvements

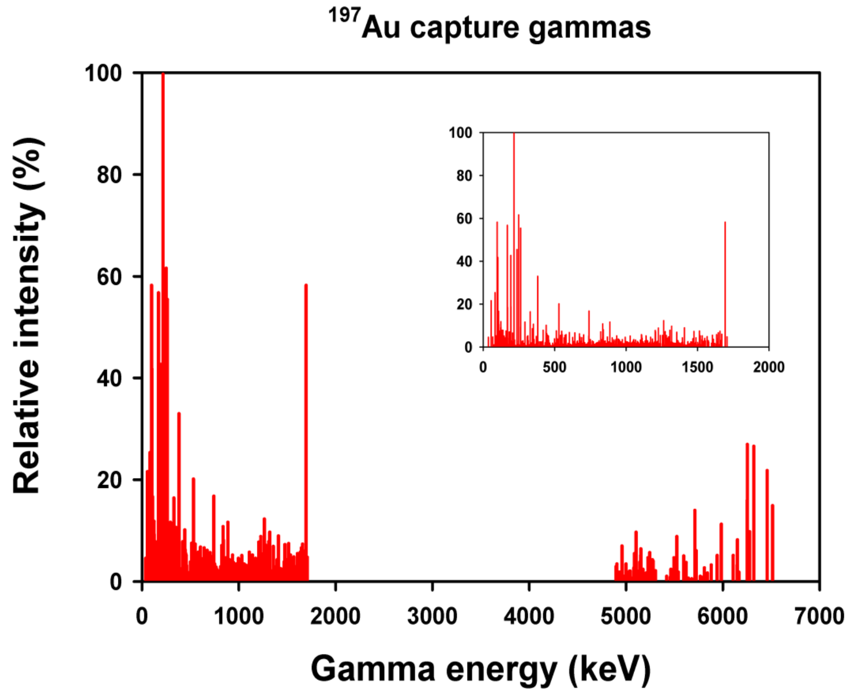
Neutron scintillators

- ✘ CLYC family contain Cs
- ✘ Iodides
- ✘ Eu doped scintillators
- LiCaF:Ce
  - ✓ Lower γ-sensitivity
  - ✓ ~2 times faster than ^{6}Li-glass
  - ✘ ~2 times less light
  - ✘ Emits at 270nm $\Rightarrow$ issue with (light) reflectors

➢ ^{6}Li-glass is still preferred

Improvements

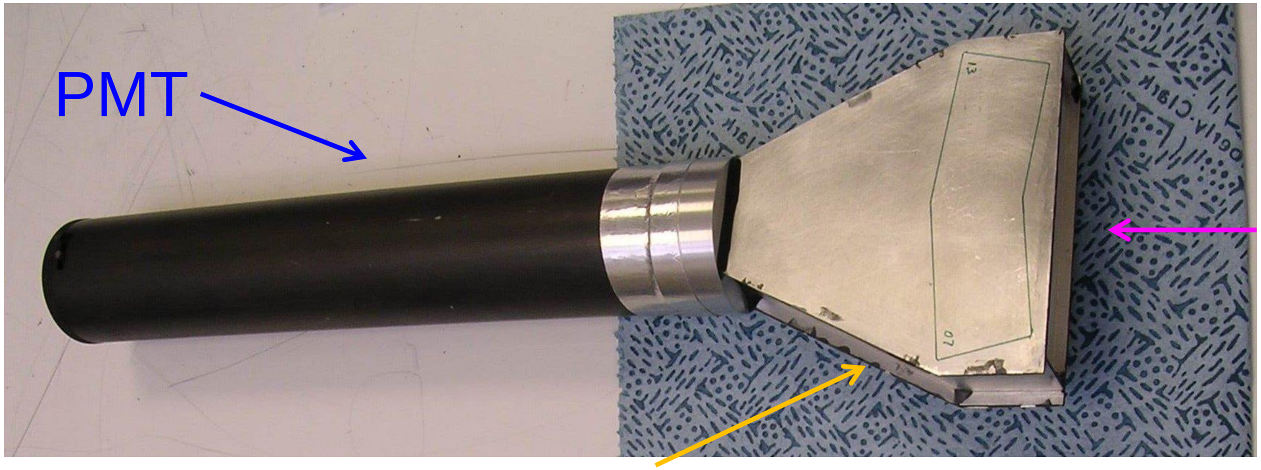
Optimise neutron detection threshold



- Most gammas below 600 keV (current threshold).
- Pierfrancesco's first results look promising.

Improvements

Much better reflector for light guide (Vikuiti)

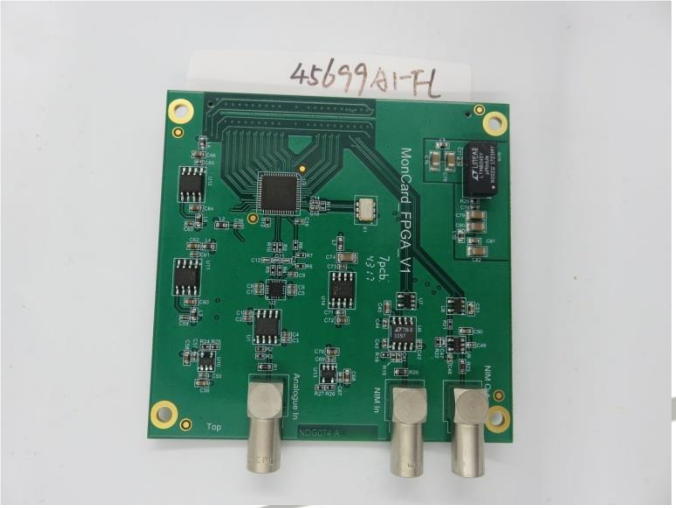


➢ Make detector faster and improve n-γ discrimination

Improvements

ADC based electronics

- Advantages:
  - Correct for amplitude variations (ageing, temperature variations).
  - Faster signal processing.
  - Collect biparametric data (pulse height + TOF) $\Rightarrow$ optimise data off-line.
  - Needs less maintenance $\Rightarrow$ improved reliability.

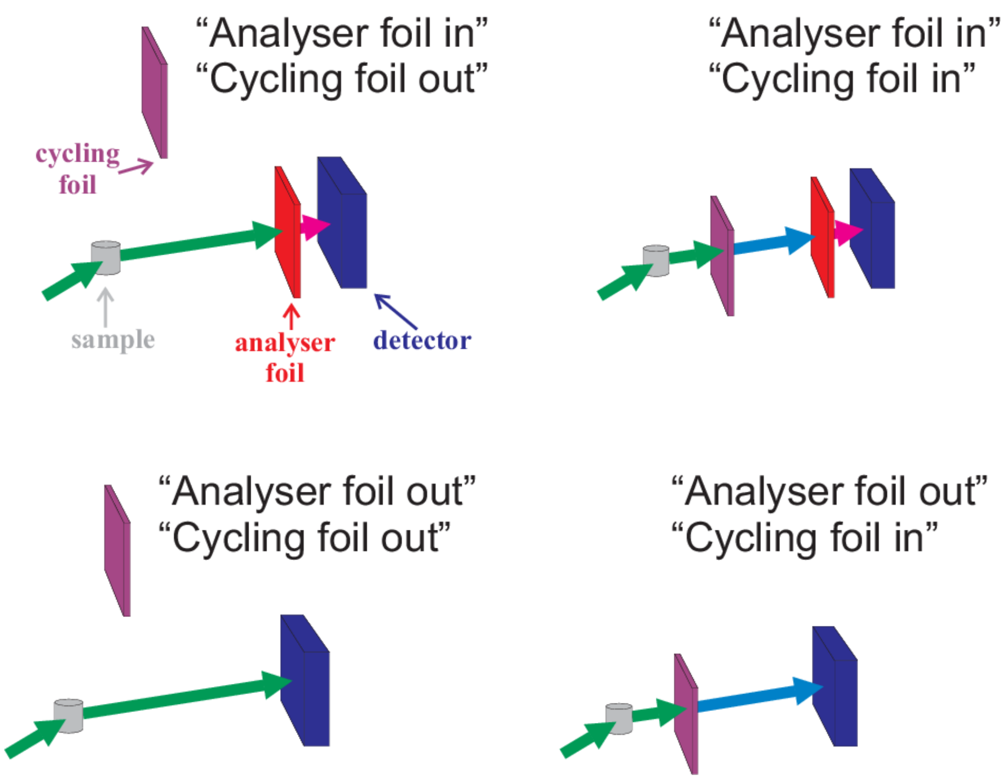


- At very early stages.

Improvements

Modified foil-cycling for gamma detectors?

- Reduce effect of gammas from cycling foil.

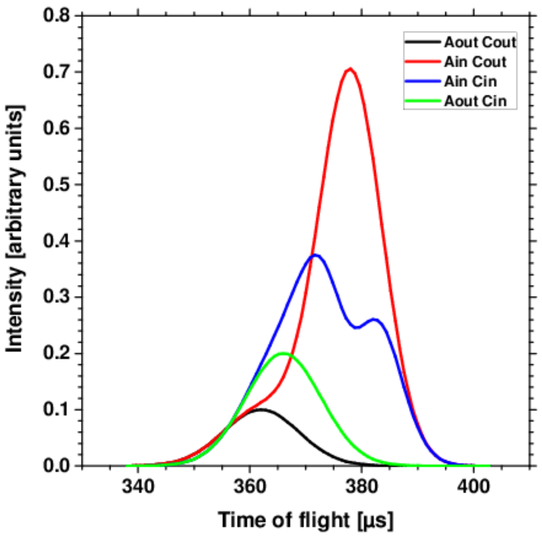


original FCT

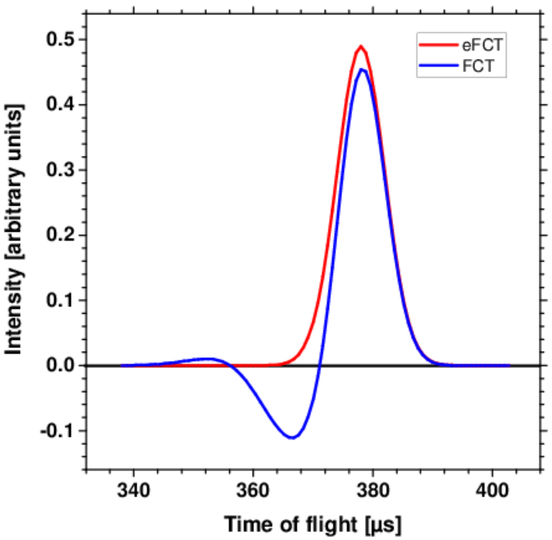
background measurement

Improvements

Raw spectra



Processed spectra



- Much worse statistics

- Could be worth if theoretical correction is unacceptable.

Summary

- Good time to reconsider detector choice for Vesuvio.
- Current Vesuvio detector configuration is optimal (neutron ⇔ gamma detector).
- No better scintillators available now.
- No progress at all after 15 years?
- No!: signal processing (threshold, new electronics) + reflector.

The end

Thank you very much for your attention

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