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Neutron transmission and capture measurements for ^{241}Am at GELINA

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Outline

Motivation

existing data

GELINA facility

linac

experimental setup - sample

Measurements

analysis and results

Summary

Motivation

Nuclear waste management:
a major pressing and potentially costly environmental problem

Main components of waste from nuclear reactors

Component	Isotope	Half-life(years)	Quantity(kg/year)
Fission Fragments (39 ton/year)	^{135}Cs	2.3×10^6	400
	^{99}Tc	2.1×10^5	1000
	^{93}Zr	1.5×10^6	900
	^{129}I	1.0×10^7	200
	^{107}Pd	6.5×10^6	250
Plutonioum (11.4 ton/year)	^{238}Pu	88	190
	^{239}Pu	2.4×10^4	6500
	^{240}Pu	6.5×10^3	2500
Minor Actinides (1.1 ton/year)	^{237}Np	2.1×10^6	480
	^{241}Am	430	250
	^{243}Am	7.4×10^3	140
	^{245}Cm	$8.5\times 1-^3$	1

→ **Long term radiotoxicity and high volume makes geo-disposal not an optimum solution**

Resonance parameters for ^{241}Am+n in literature

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Transmission

- **Derrien and Lucas**
  - Saclay, LINAC (17 m and 53 m)
  - AmO_2 (4.5 10^{-4}, 1.6 10^{-4} , 4.7 10^{-4} at/b)
  - $^{10}B(n,\alpha_1)$, 478 keV with NaI

- **Kalebin et al.**
  - Chopper,
  - AmO_2 (3.3 10^{-3} and 6.3 10^{-3} at/b)
  - Collimation ~0.8 and 0.4 mm
  - BF_3 proportional counters

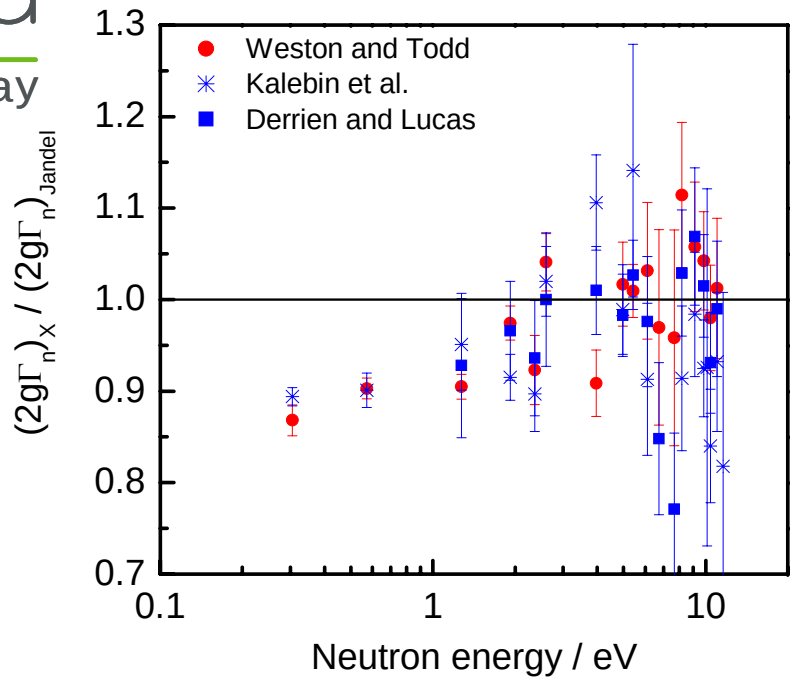
Capture

- **Weston and Todd** NSE 61 (1976) 356
  - ORELA (20 m and 85 m)
  - 1.1 10^{-4} at/b ^{241}Am, AmO_2 + S powder
  - Total energy + WF (C_6F_6)
  - E_d > 500 keV
  - Normalized at E_n = 0.0253 eV
    σ_γ^{th} = 582 b

- **Jandel et al.** PRC 78 (2008) 034609
  - LANSCE (20 m)
  - 1.7 10^{-6} at/b ^{241}Am (electroplated on Ti)
  - Total absorption (4π)
  - M_γ = 4 and 3.75 < E_γ^{tot} < 5.4 MeV
    $\varepsilon_{n,\gamma}$ = 12.5 ±1.0 %
  - Normalization at 4.9 eV of $^{197}Au(n,\gamma)$

$\Rightarrow$ **σ_γ^{th} = 665 ±33 b**

Literature data



Reference	Year	σ_γ(E = 0.0253 eV)
Jandel et al.	2008	665 ± 33
Nakamura et al.	2007	690 ± > 24
Fioni et al.	2007	696 ± 48
Maidana et al.	2001	672 ± 10
Shinora et al.	1997	854 ± 58
Evaluation Fröhner	1982	610 ± 19

⇒ **$A_\gamma \approx g\Gamma_n$ for E_r = 0.306 eV, 0.574 eV and 1.272 eV**

⇒ **Transmission: verify normalization of capture data of Jandel et al. and Weston and Todd**

⇒ **Capture to verify the thermal point and extend the energy range**

Homogeneous well characterized sample is required

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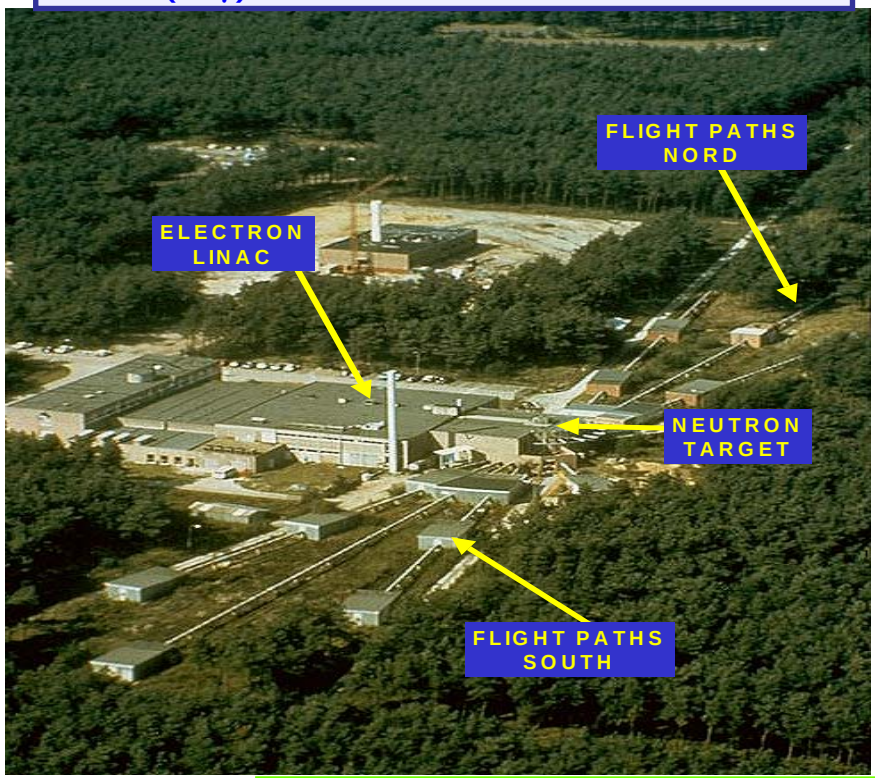
GELINA: dedicated to

- ∀ σ(n,tot)
- ∀ σ(n,f), σ(n,p), …
- ∀ σ(n,γ)



Time-Of-Flight facility

Pulsed white neutron source

(10 meV < E_n < 20 MeV)

Multi-user facility with 10 flight paths

(10 m - 400 m)

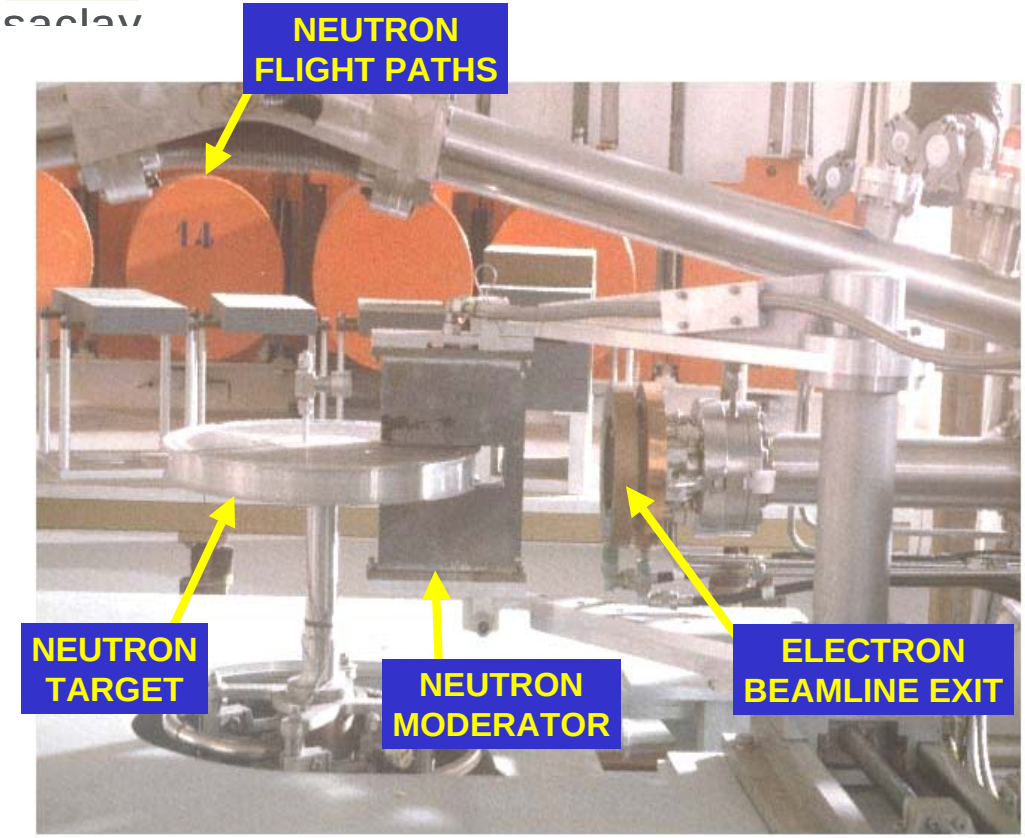
The measurement stations have equipment to perform:

Total cross section measurements

Partial cross section measurements

Pulse width	**: 1ns**
Frequency	**: 50 – 800 Hz**
Average current	**: 4.7 – 75 μA**
Neutron intensity	**: 1.6 10^{12} – 2.5 10^{13} n/s**

GELINA neutron source



- e^- accelerated to $E_{e-,max} \approx 140$ MeV
- (e^-, γ) Bremsstrahlung in U-target (rotating & cooled with liquid Hg)
- (γ, n), (γ, f) in U-target
- Low energy neutrons by water moderator in Be-canning

TOF - experiments at GELINA

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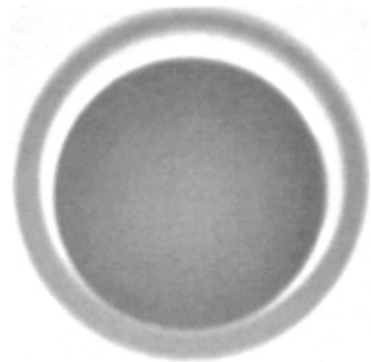
- **Sample**
  - AmO_2 in Y_2O_3 matrix (homogeneous)
  - Purification to reduce ^{237}Np
  - 40 GBq of ^{241}Am

    324.5 mg by γ - spectroscopy

    324.6 mg by calorimetry
  - Ø = 22.14 mm

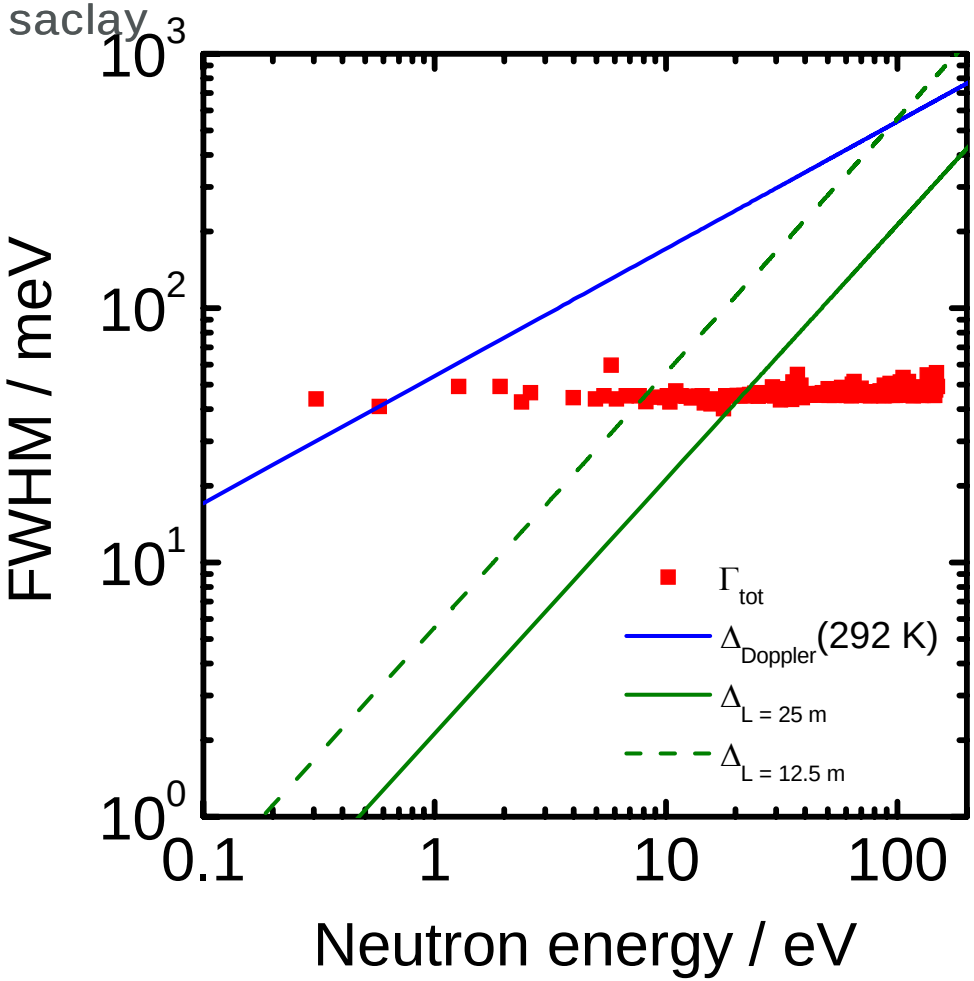
    verified by γ - radiography

    combined with non-contact electronic microscope



- **Transmisson at 25 m**
  - **^{6}Li-scintilllators**
- **Capture at 12.8 m**
  - **Total energy detection**
  - **C_6D_6 detectors + WF**
  - **Normalization**
    - Internal : Γ_n from transmission
    - External : 4.9 eV ^{197}Au+n

Experimental conditions



Capture and transmission

$\Rightarrow g\Gamma_n$

Doppler broadening dominates the observed width for E_r > 1 eV

Only for low energy resonances Γ can be determined from shape analysis

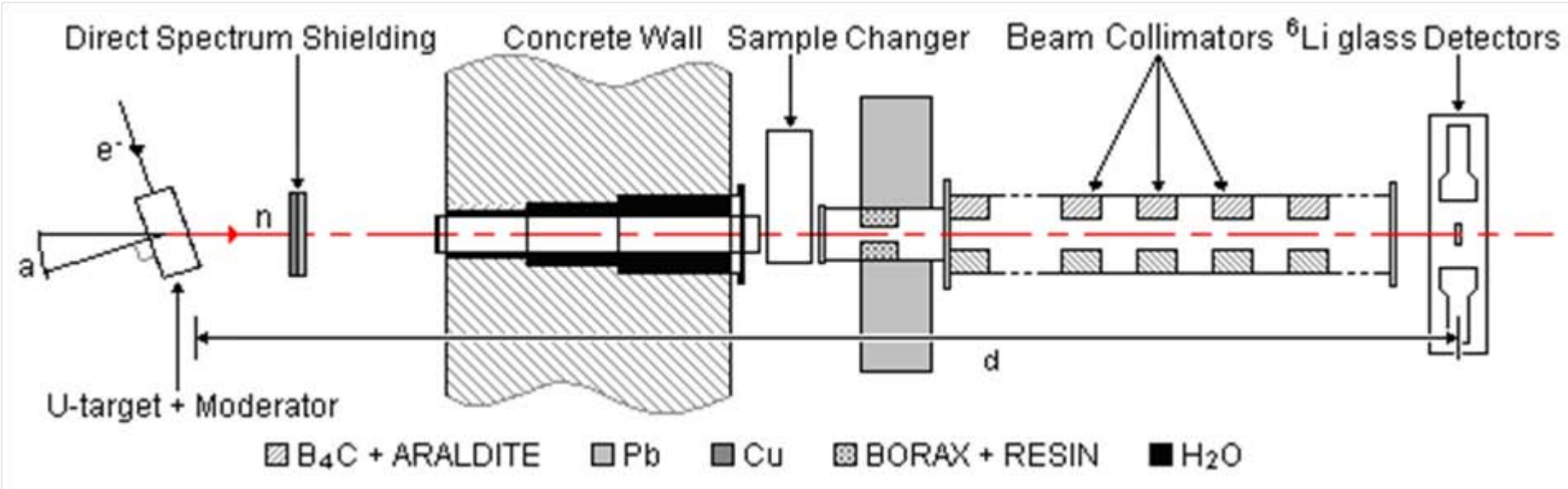
Experiments at GELINA

Measurement	Flight path	Frequency	Filters		
			Overlap	Fixed background	Additional background
Transmission	25 m	50 Hz		Co, Bi, Na	Ag, Cd
		50 Hz		Co, Bi, Na, Pb	Ag, Cd
		800 Hz	^{10}B	Na, Pb	Au, W, Co, Mn
Capture	12.5 m	50 Hz		Co, Bi, Na	Cd, Ag, W
		400 Hz	Cd	Bi, Na	Ag, W
		800 Hz	^{10}B	Na, S, Pb	Ag, W, Co

	Region	Overlap	Fixed background filters
50 Hz	< 100 eV	–	Co, Bi, Na
400 Hz	> 1 eV	Cd	Bi, Na
800 Hz	> 20 eV	^{10}B	Na, S

Transmission setup

Li-glass scintillator at 25 m

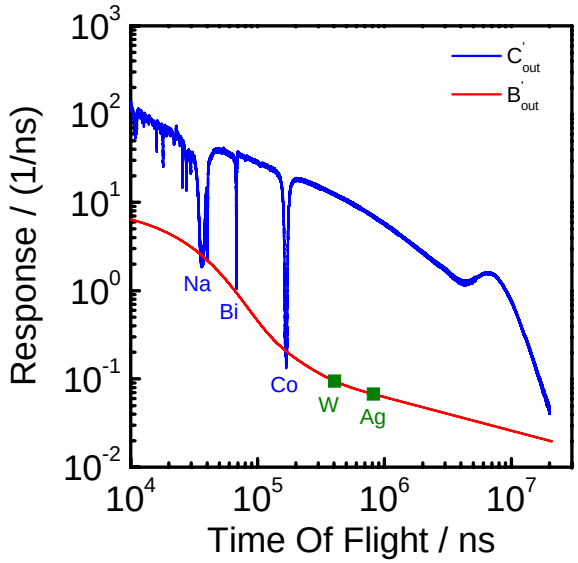


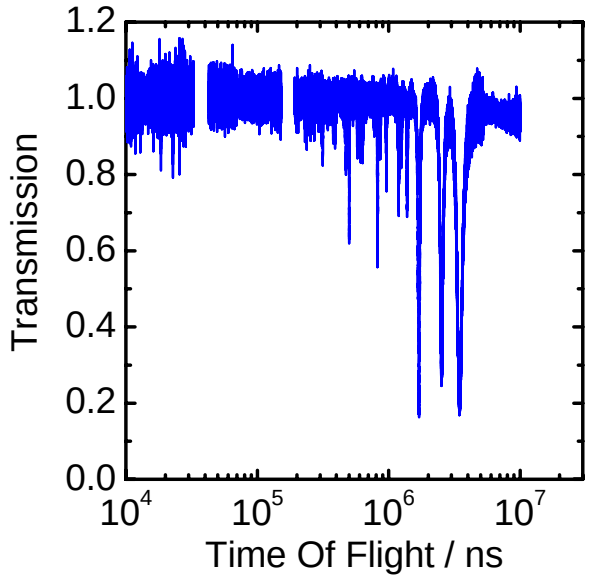
$$T_{\exp} = \frac{C_{in} - B_{in}}{C_{out} - B_{out}}$$

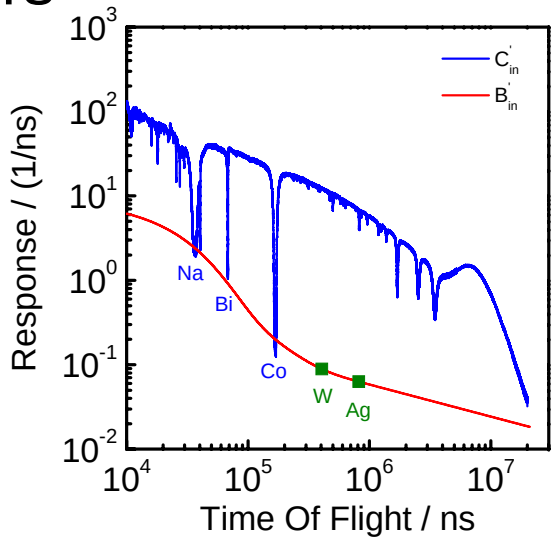
E_r = 6.6735 ± 0.0030 eV of ^{238}U+n
L = 26.444 ± 0.006 m

Transmission data

Fixed background filters







Capture measurements at GELINA

L = 12.8 m

Total energy detection

- **C_6D_6 liquid scintillators**
  - 125°
  - PHWT
- **Flux measurements (IC)**
  - $^{10}B(n,\alpha)$

$$Y_{exp} = N \frac{C'_w - B'_w}{C' - B'} Y \qquad N \frac{C'_w - B'_w}{C' - B'} \sigma$$

Borella et al., NIMA 577(2007) 626

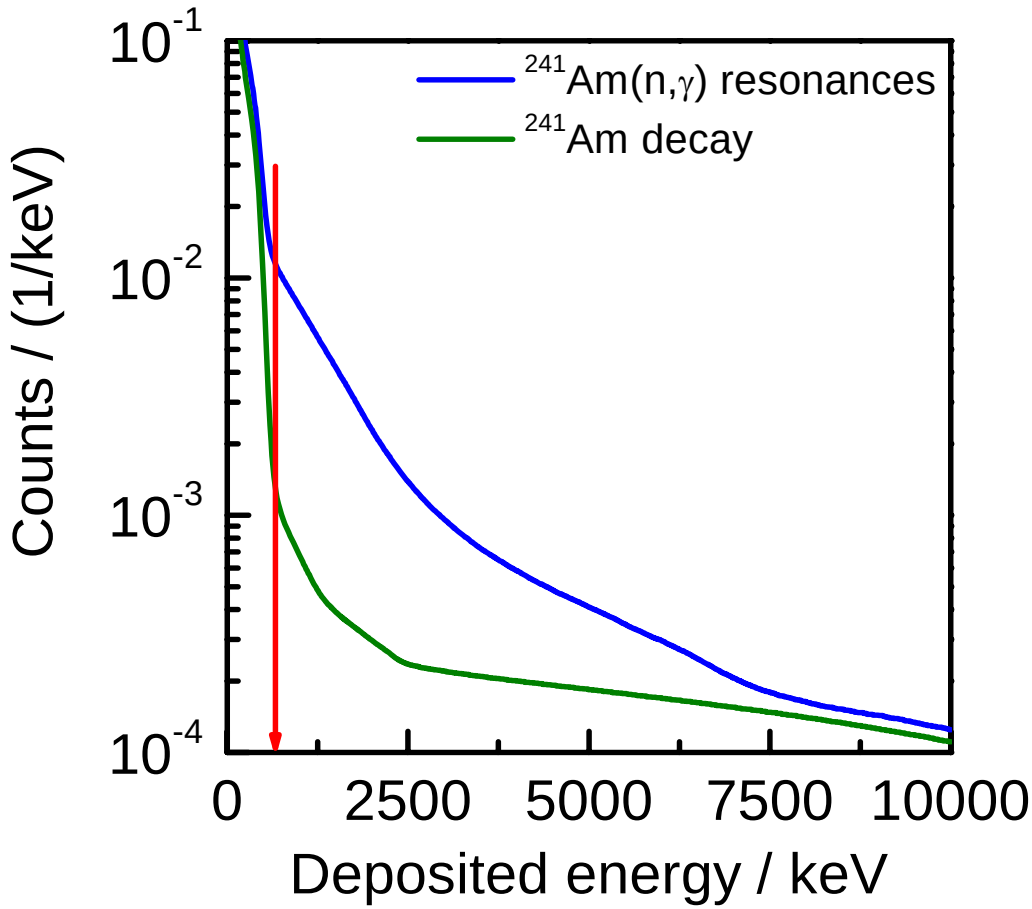
WF : from MC simulations

$$\int R(E_d, E_\gamma)\, WF(E_d)\, dE_d = kE_\gamma$$

$$C_w(T_n) = \int C_c(T_n, E_d)\, WF(E_d)\, dE_d$$

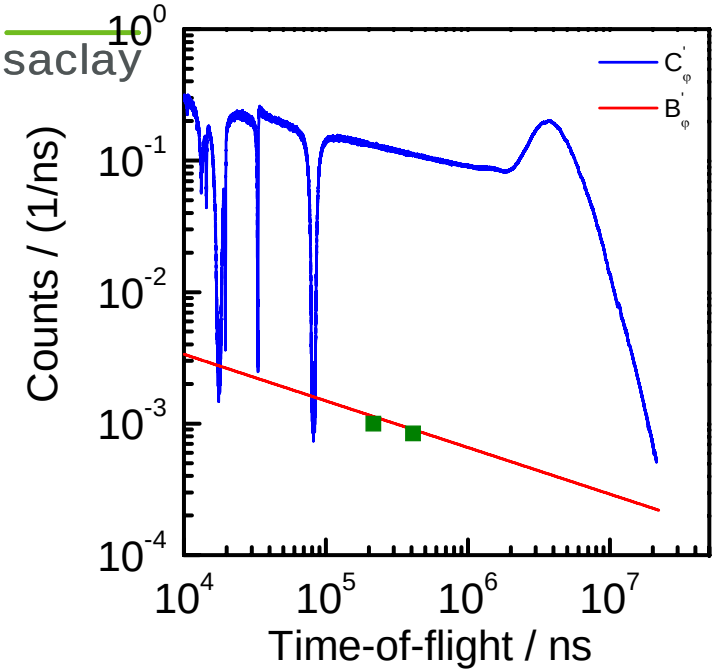
Pulse height spectra : threshold

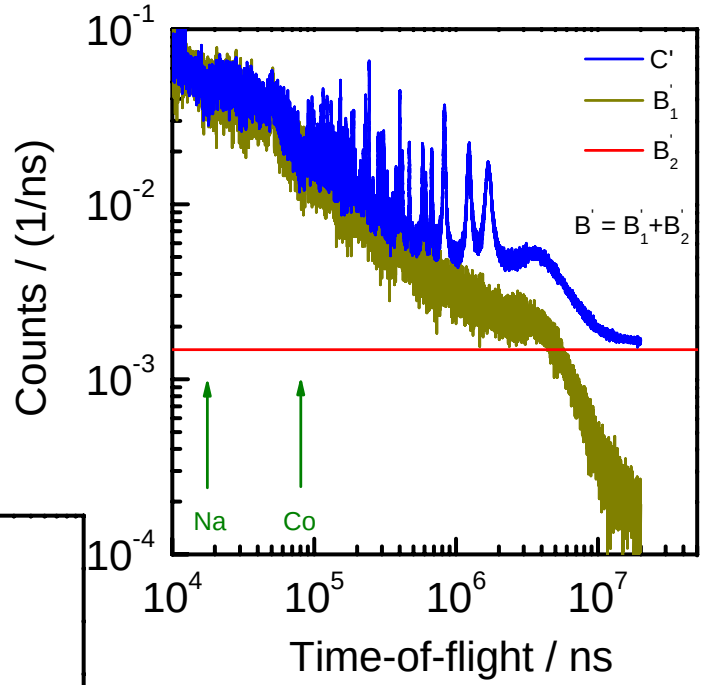
Choose optimum threshold conditions on detected gamma ray energy due to sample's activity

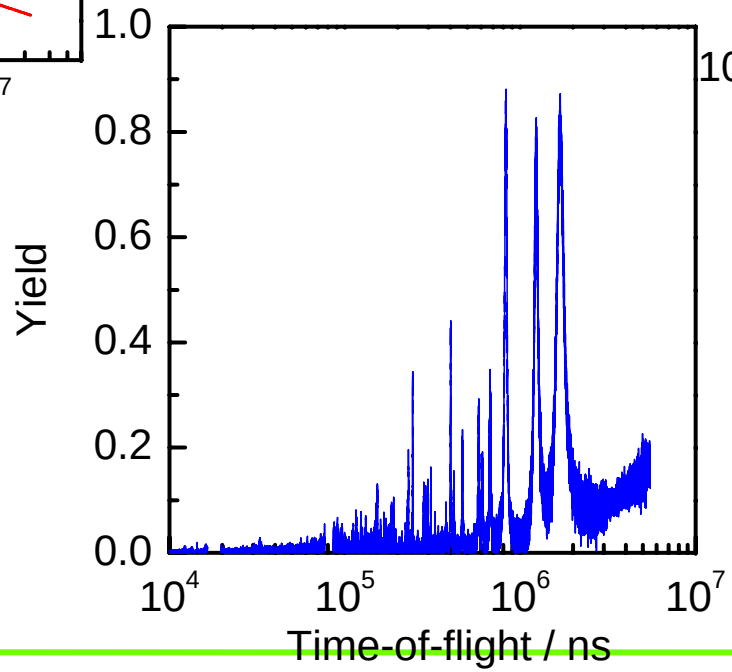


	Standard	^{241}Am
$E_d \approx$	160 keV	650 keV
$E_\gamma \approx$	300 keV	850 keV

Capture data (counts) for E_d > 650 keV

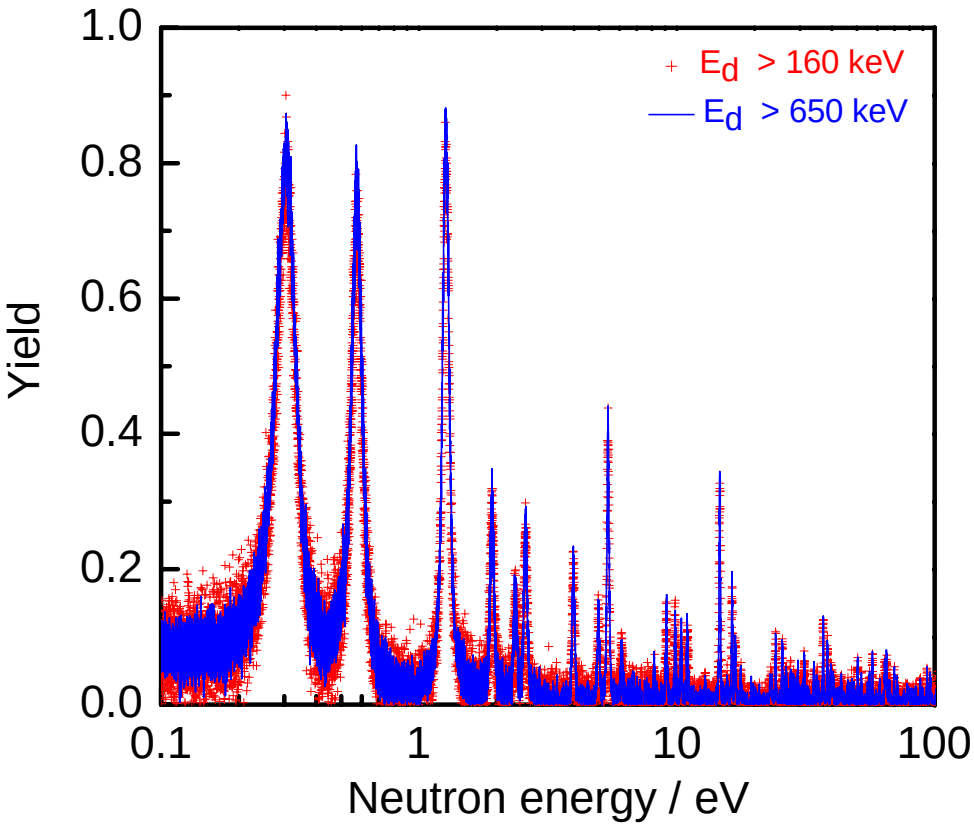


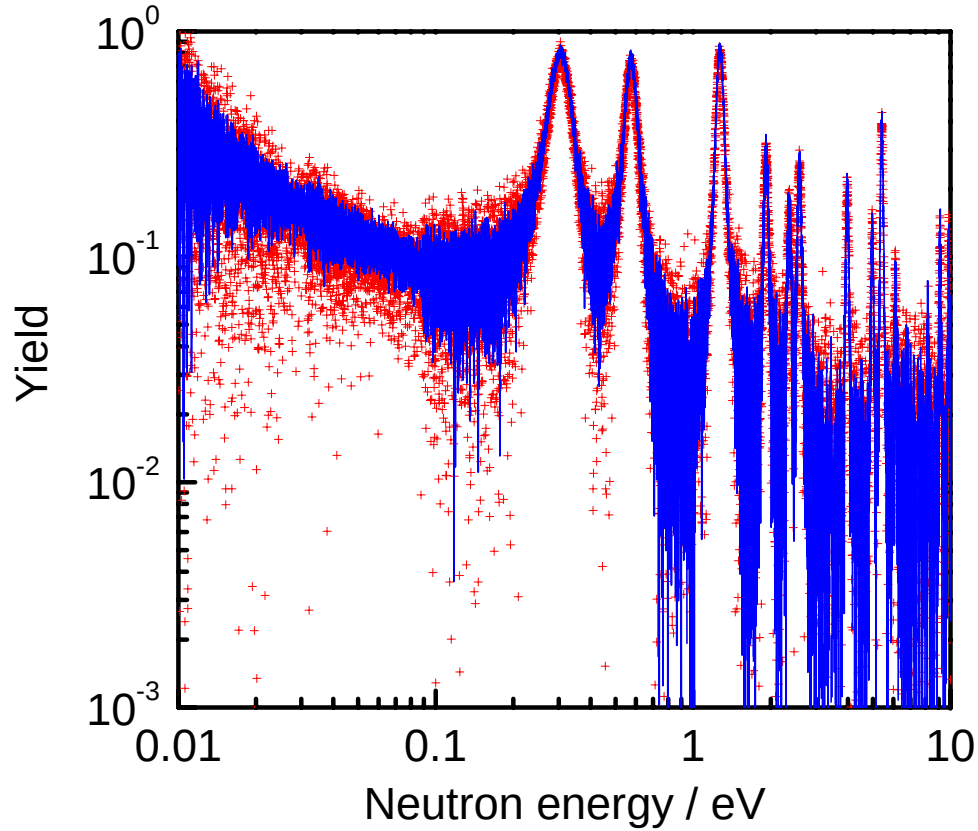




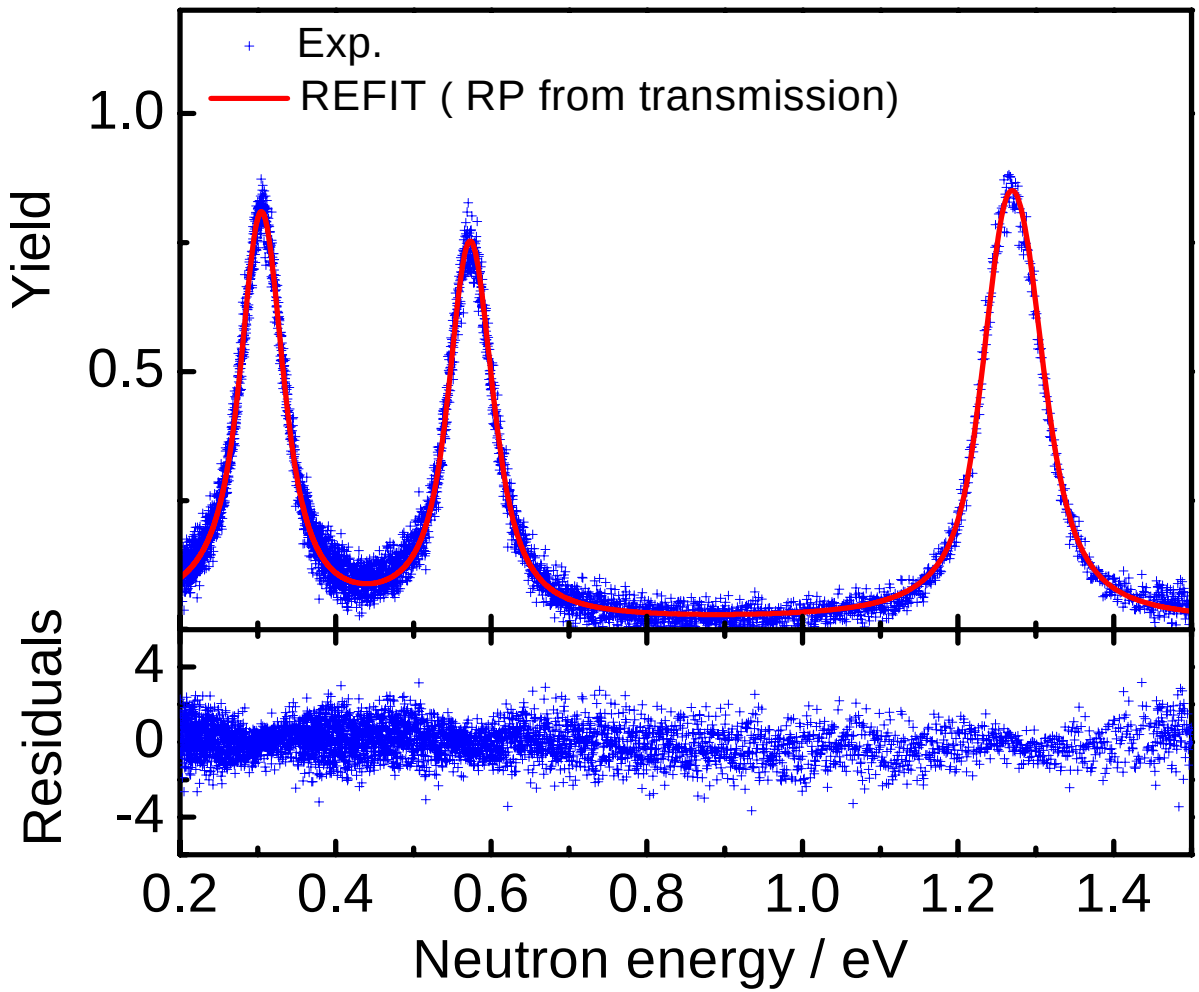
Time dependent background dominates

Capture data: impact of threshold

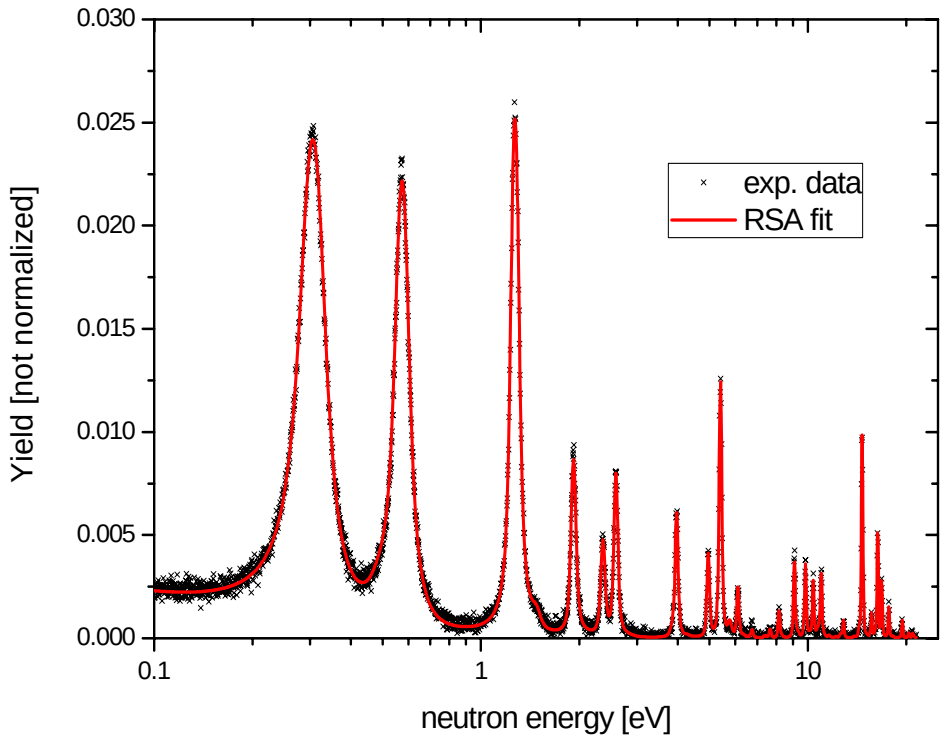


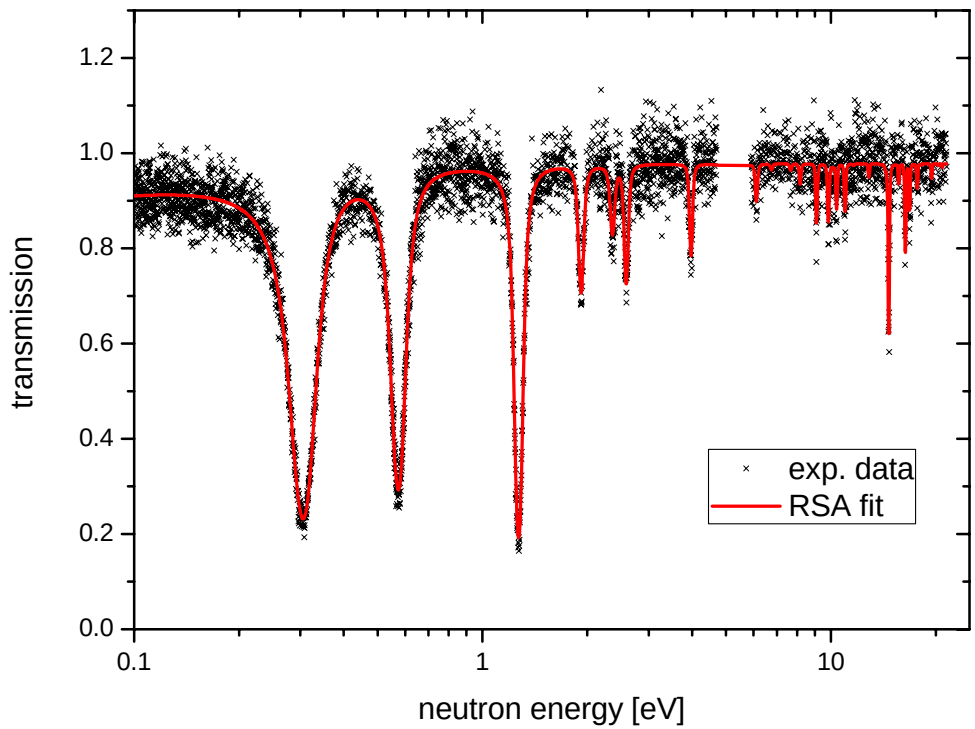


Capture and transmission data consistency



Capture and Transmission





Conclusions and output

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^{241}Am

Transmission and capture data are consistent

Characterisation of sample:

- ✓**Content by calorimetry at JRC/ITU**
- ✓**Area by radiography at IRMM**

Γ_{th} obtained

RP (E, $g\Gamma_{n,}$, < Γ_{γ}>) up to ~ 200 eV

Publication to be submitted within October 2012