Development of an active scintillating target for fission studies

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Fast neutron induced reactions are important for future nuclear plant generations, since most of the retained solutions are fast reactors. In this context fast neutron induced fission is of prime importance and one is faced to the lack of data together with incomplete understanding of the process.
Need for a new \((n,2n)\) reaction on \(^{239}\text{Pu}\)

- Passive target
  - Fission to be subtracted
  - High uncertainties

- Indirect measurement \((n, xn\gamma)\) with GEANIE/WNR
  - Model dependent
Count rates

→ Need for a very efficient fission veto
The neutron long counter CARMEN

BC521: Gd loaded (0.5%) scintillator ~1 m³
Detection efficiency: 85% for $^{252}$Cf SF neutrons

Prompt peak $\gamma,n \rightarrow$ trigger

$\rightarrow \Sigma E_\gamma$

$\rightarrow$ Stockastic captures $\rightarrow P_v$

Capture time probability distribution

Log(E) vs Capture time (μs)
Advantages

• «Ease» of fabrication.

• High mass concentrations → moderated volumes.

• Pulse shape discrimination.

• No specific electronic noise associated with high masses.

• Good time resolution.
Fission veto
α detection efficiency

- Isotope dissolved in active volume → high efficiencies
- Losses due to wall effects.

5 MeV α range ~ 50 µm

Simulations → 0.34 %
(energy loss 300 keV)
Measurement → 0.320 ± 0.058%
W.J.Dowell NAS-NS-3116
The fission case

Two cumulative effects:
- Shorter ranges
- 2 Fragments $\Rightarrow$ geometric effet

Light fragment range $\sim 30 \, \mu m$
Heavy fragment range $\sim 20 \, \mu m$

Losses estimated to $10^{-6}$
Principle

Scintillator:
- Toluene $\text{C}_7\text{H}_8$ 7.5 mol/L (solvent).
- Naphthalene $\text{C}_{10}\text{H}_8$ 1.5 mol/L.
- Scintillator PBBO $\text{C}_{25}\text{H}_{17}\text{NO}$ $10^{-2}$ mol/L.
- **Extractant HDEHP** $\text{C}_{16}\text{H}_{35}\text{O}_4\text{P}$ 0.2 mol/L.

For physicists: $\text{C}_{0.47}\text{H}_{0.52}\text{O}_{0.0054}\text{P}_{0.0013}\text{N}_{0.00007}$
Minimization of quenching

Procedure:
• Solution of An (up to 10 mg)
  0.1 M HNO₃
• Add hydroxylamine chlorhydrate
  10⁻² M (for elimination of NO₂)
• Add 1.2 mL Alphaex™
• Shaking 5 min
• Centrifugation 2000 rpm 5 min
• Sampling 1 mL Alphaex™
• Counting
Commercially available: Ordela 8100AB      NIM-3w

PERALS PhotoElectron-Rejecting Alpha Liquid-Scintillation

Pyrex tube
Pulse shape discrimination principle (PSD)

Response to fission unknown
First test with $^{252}$Cf

- α from $^{252}$Cf
- Spontaneous fission
- β

Number of counts vs Channel number
Bi-dimensional spectrum
Homemade system

Culture tube

PM : burle 8850
Optimization of PSD threshold
Bi-dimensional spectrum
Energy non linearity

$\alpha$ peak 6.118 MeV

$TKE=188$ MeV

78 MeV

$\sim 30$ MeV expected !!!!

$\beta$ suppressed spectra
Light absorption against actinide mass
Natural uranium α spectra with the PERALS system

Scintillator volume 1 cm³

Energy Resolution ~200 keV

50 mg

20 mg

10 mg

238U 4198 keV

234U 4774 keV

50 μg

574 keV
Tests with natural uranium

Natural uranium
10 µg/cm³; 1 mg/cm³; 10 mg/cm³
+ 7 Bq de $^{252}$Cf
Tests with thorium: representative of every actinide

Natural thorium (& Pu)
10 µg/cm³; 1 mg/cm³; 10 mg/cm³
+ 7 Bq de $^{252}$Cf

$^{232}$Th 10 µg/cm³

$^{232}$Th 10 mg/cm³
Dedicated cell + avalanche photodiode

- Compacity
Open questions on the maximum attainable mass

1. Radiolyse aging for high specific activities $\rightarrow$ isotope dependent

2. Quenching from chemical $\rightarrow$ specific to each isotope

3. Pile-up.
Perspectives

- Fission studies: calorimetry, $\gamma$ spectra, cross sections, $P_\gamma$
  1. Spontaneous fission – Bruyères le Châtel
  2. Neutron induced fission -- NFS 2012...
- Ultra-asymmetric fission: cluster disintegration $^{12}$C $\rightarrow$ $^{34}$Si (probability about $10^{-11}$)
- $(n,xn)$ reaction $\rightarrow$ CARMEN -- NFS 2012 ...