Measurement of the ^{242}Pu(n, γ) cross section for MOX fuels at n_TOF-EAR1: Preliminary results in the RRR

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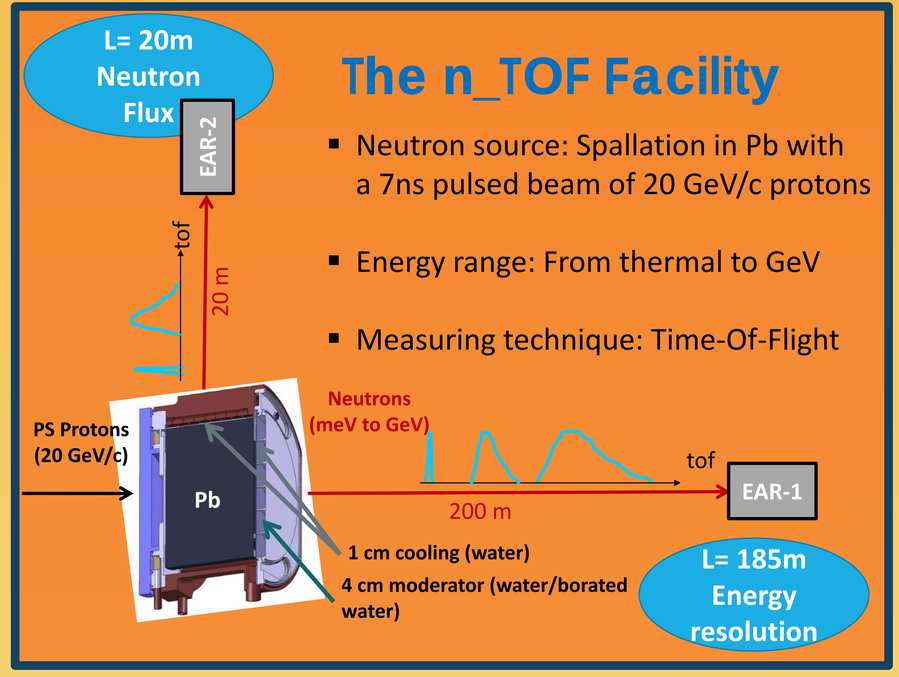
Introduction

The spent fuel of current nuclear reactor contains fissile plutonium isotopes that can be combined with ^{238}U to make **mixed oxide (MOX) fuel** [1]. In this way the Pu from spent fuel is used in a new reactor cycle, contributing to the **long-term sustainability of nuclear energy**. The use of MOX fuels in thermal and fast reactors requires **accurate capture and fission cross sections**. For the particular case of **^{242}Pu,** the previous **neutron capture** cross section measurements were made in the 70's, providing an uncertainty of about 35% in the keV region. In this context, the **Nuclear Energy Agency** recommends in its **"High Priority Request List"** [2] and its report WPEC-26 that the capture cross section of ^{242}Pu should be measured with an **accuracy** of at least **7-12%** in the neutron energy range between 500 eV and 500 keV. Furthermore, interpretations with JEFF-3.1 of two experiments carried out in the fast reactor PHENIX have shown an **overestimation of 14%** in the capture cross section and the **average resonance parameters** in the literature present **differences of more than 10%.** For all of the above, a **new measurement** of the ^{242}Pu cross section at the **n_TOF-EAR1 facility** [3] was **proposed and successfully performed.**

This work presents a brief description of the measurement, analysis and **first results of a TOF capture measurement** on this isotope in the last 40 years, providing **preliminary individual resonance parameters** beyond the current energy limits in the evaluations and **average resonance parameters**.



The n_TOF Facility

- Neutron source: Spallation in Pb with a 7ns pulsed beam of 20 GeV/c protons
- Energy range: From thermal to GeV
- Measuring technique: Time-Of-Flight

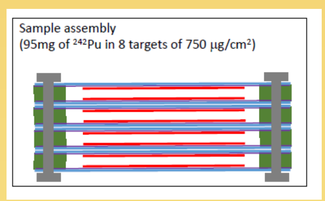
Measurement at n_TOF-EAR1: Detectors & ^{242}Pu Sample

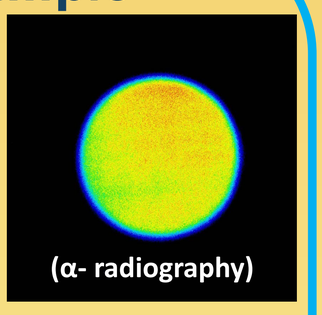
Neutron flux monitoring: Charged particle Si detectors + Cross-section standard ^{6}Li (n,α)

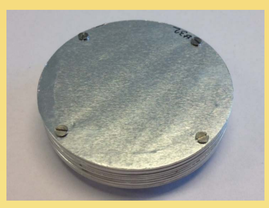
Capture cascades: C_6D_6 scintillation detectors [4]
- ✓ Low neutron sensitivity
- ✓ Simple Setup

Analysis with C_6D_6 :
Total **E**nergy **D**etection + **P**ulse **H**eight **W**eighting **T**echnique **[5]**

Stack of 7 thin targets: 45mm diam. on 10 μm Al + Ti Coating 50 nm

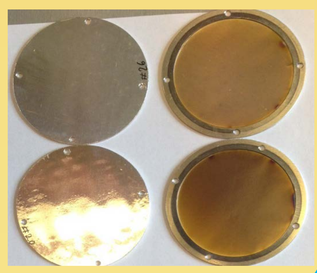






Final n_TOF target

Production: JGU Mainz and HZ Dresden-Rosendorf (***CHANDA***)
Mass: 95 mg 99% pure ^{242}Pu (α- counting)
Technique: Electrodeposition



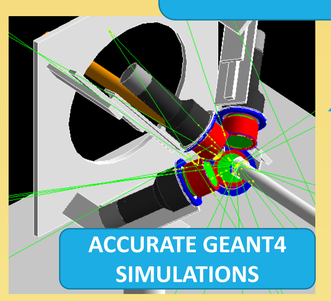
Individual targets

Data reduction

1. Time-of-flight to neutron energy:

$$E_n(eV) = \left(72.298 \frac{L_0(m) + \lambda(E_n)(m)}{ToF(\mu s)} \right)^2$$

RESOLUTION FUNCTION: Simulations neutron production [6]



2. Pulse Height Weighting Technique

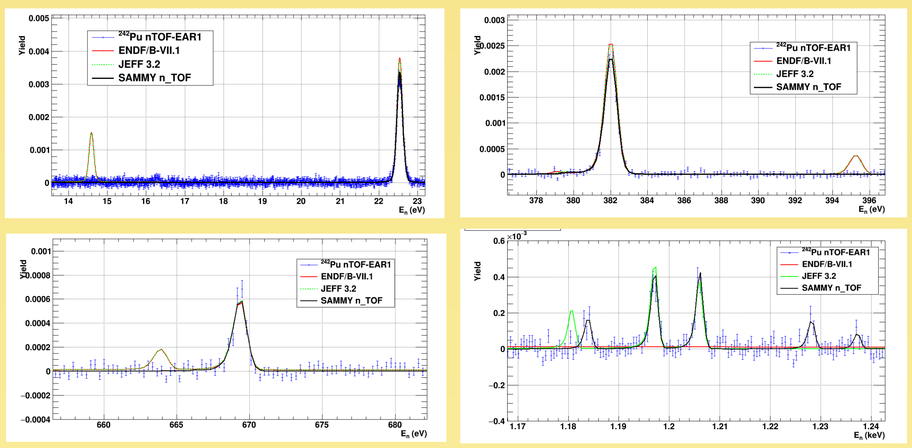
GOAL: Total efficiency for a cascade **proportional** to **total cascade energy**

$$\varepsilon_c = \alpha E_c = \alpha(S_n + E_n)$$

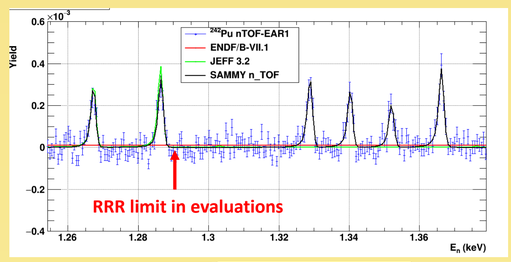
HOW: A different weight is given to each count **depending** on the **energy deposited**

Preliminary Resonance analysis (1eV - 2.4keV)

1) Confirm/reject + new resonances

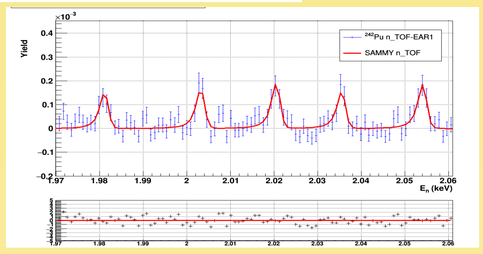


2) Extend current RRR energy range



Beyond JEFF 3.2

RRR extended up to ~2.5keV

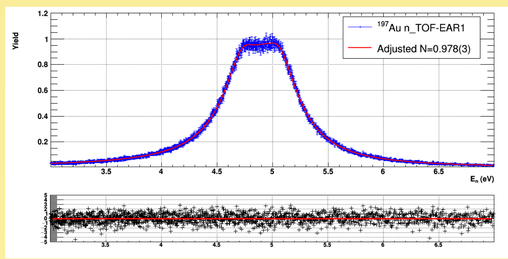


3) Preliminary average resonance parameters

	Reich NSE 162, (2009) 178-191	Mughabghab (2011)ENDF/VII	JEFF 3.1	RIPL	This work (preliminary)
$10^4 S_0$	0.91 ± 0.20	1.02	1.00	0.98±0.08	0.89±0.12
D_0 (eV)	16.8 ±0.5	13.6	15.3	13.5±0.15	14.8±0.7
$\langle\Gamma_\gamma\rangle$ (meV)	22±1	22.27	24.2	23±2	24±3

SAMMY code [7]

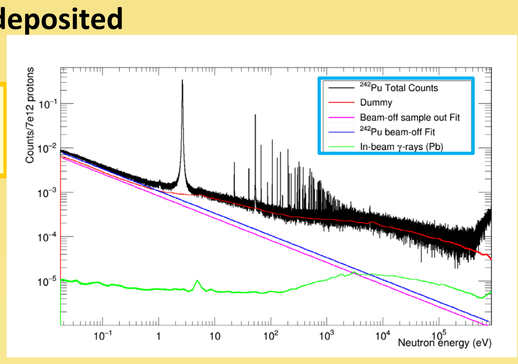
Fit ^{197}Au saturated resonance



Data reduction (continued)

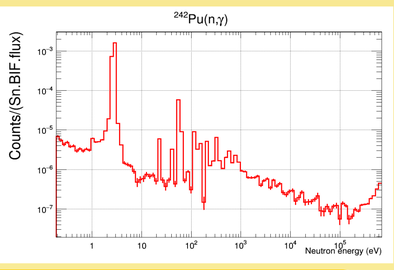
3. Background subtraction

Background components: Ancillary measurements

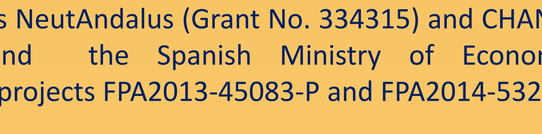


4. Capture yield

$$Y_{exp} = \frac{C_w}{\phi_n \cdot \varepsilon \cdot BIF}; \quad \varepsilon \equiv E_c = S_n + E_n$$



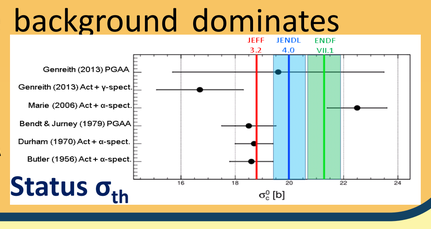
5. Normalization: Au Saturated Resonance Method



Outlook and complementary measurements

The TOF measurement has successfully taken place at **n_TOF-EAR1**, that features a **very high energy resolution**, using **95 mg of 99% pure ^{242}Pu** electrodeposited on 7 thin targets. Preliminary results of the final capture yield, resonance analysis and average resonance parameters up to almost 2.5keV have been presented. The analysis of the URR, where the background dominates over the capture signals, is ongoing.

The **TOF measurement** will be **complemented** soon with:
- **Thermal capture cross section** @ KFKI [8] (Budapest) : Activation + PGAA
- **MACS** measurement @ 30keV @ HISPANOS-CNA [9] (Sevilla): Activation



Status σ_{th}

"Int. Conf. on Nuclear Data for Sc. and Tech. 2016", 11th -16th September 2016, Bruges (Belgium)

References

[1] *Status and advances in Mox fuel technology*. IAEA Technical Reports Series, **415** (2003).
[2] *NEA High Request Priority List* http: www.nea.fr/dbdata/hprl
[3] C.Guerrero et. al, Eur. Phys. J. A, **49**, 27 (2013).
[4] R. Plag et al., Nucl. Instrum. Meth. A, **496**, 425 (2003).
[5] J.L. Tain et al., Nucl. Instrum. Meth. A, **521**, 454-467 (2004) .
[6] S. Lo Meo et al., Eur. Phys. J. A, **51**, 160 ,1-10 (2015).
[7] N. M. Larson, ORNL/TM-9179/R8, ORNL, Oak Ridge, TN, USA (2008).
[8] T. Belgya, Physics Procedia, **31,** 99-109 (2012) .
[9] J. Praena et al., Nucl. Instrum. Meth. A, **727**, 1-6 (2013).

Acknowledgments

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