New measurement of the ^{242}Pu(n, γ) cross section for MOX fuels at n_TOF-EAR1

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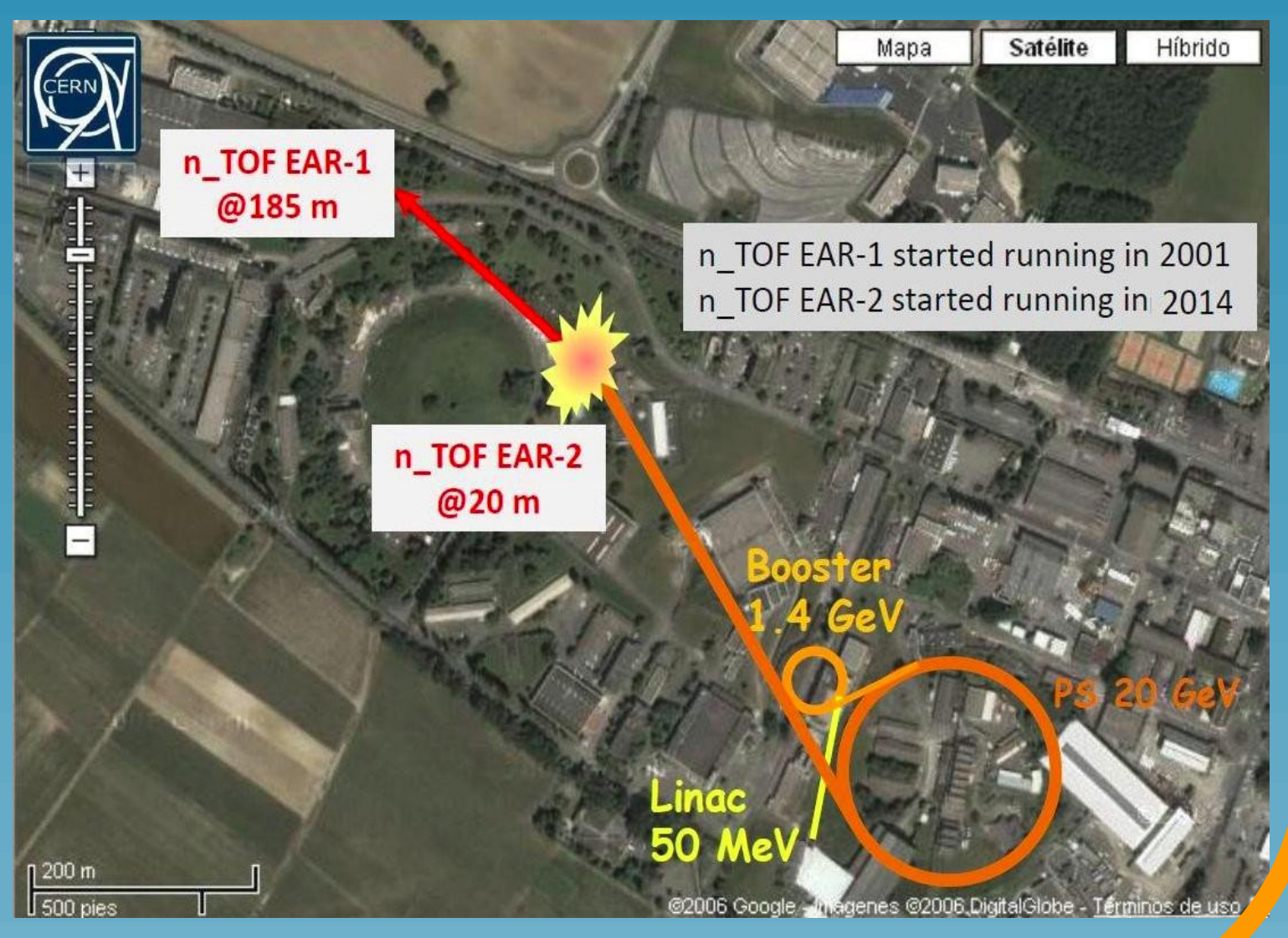
Introduction and motivation

The spent fuel from current nuclear reactors contains a significant fraction of plutonium, from which 66% are fissile 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 fuel in thermal power but even more effectively in fast reactors, calls for a **measurement of accurate capture and fission cross sections**. For the particular case of **^{242}Pu,** the first attempts to measure its **neutron capture** cross section were made in the 70's and the results indicate 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. In addition, an accurate measurement of the **Resolved Resonance Region** with enough resolution and statistics will allow to determine accurately the **average resonance parameters**. For all of the above, a **new measurement** of the ^{242}Pu cross section at the **n_TOF facility** [3] was **proposed and successfully performed.**

The n_TOF facility @ CERN

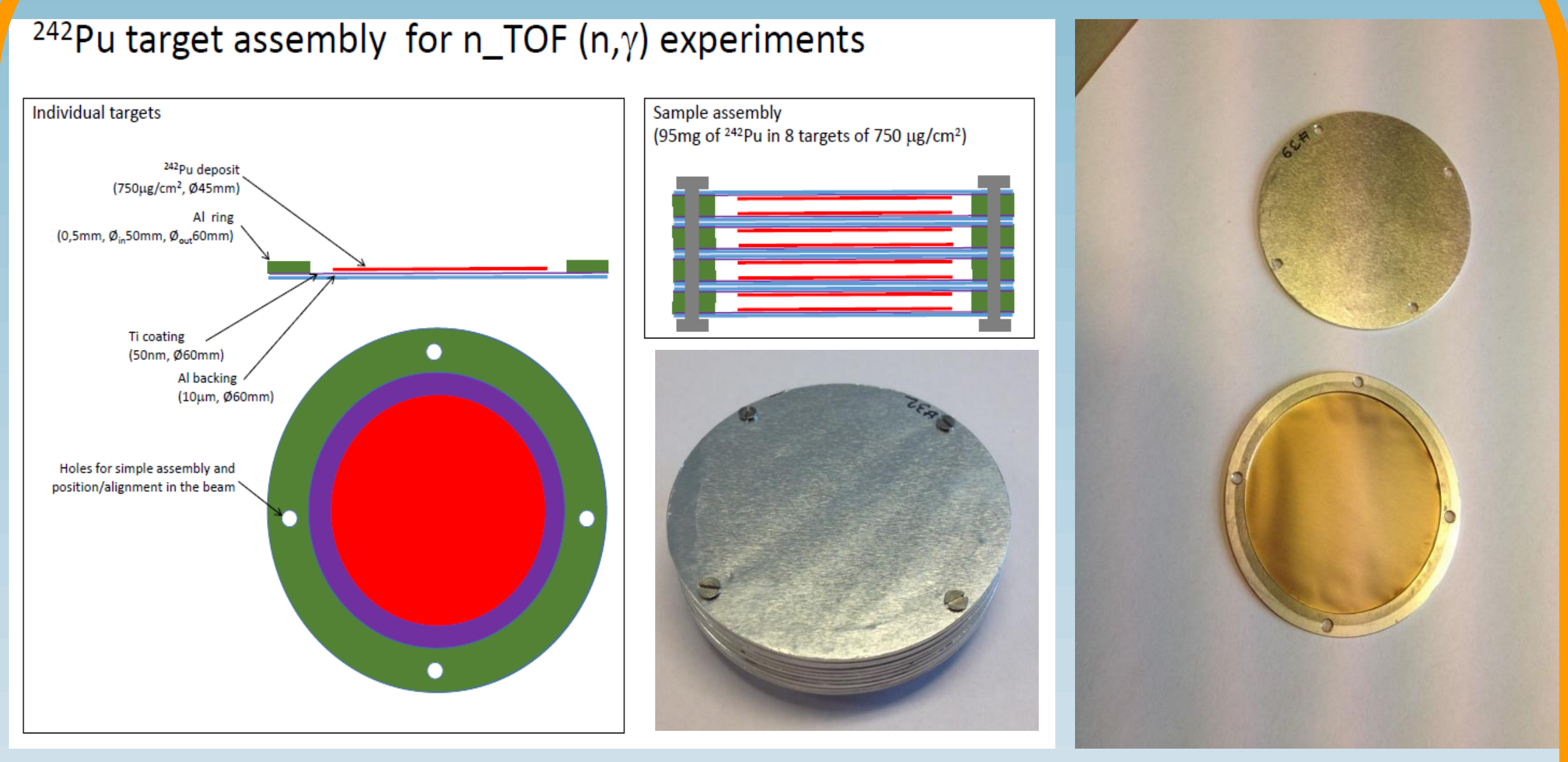
- Neutrons generated by spallation in Pb with a 7ns pulsed beam of 20 GeV/c protons
- Neutron Flux from thermal to GeV.



n_TOF EAR-1 started running in 2001
n_TOF EAR-2 started running in 2014

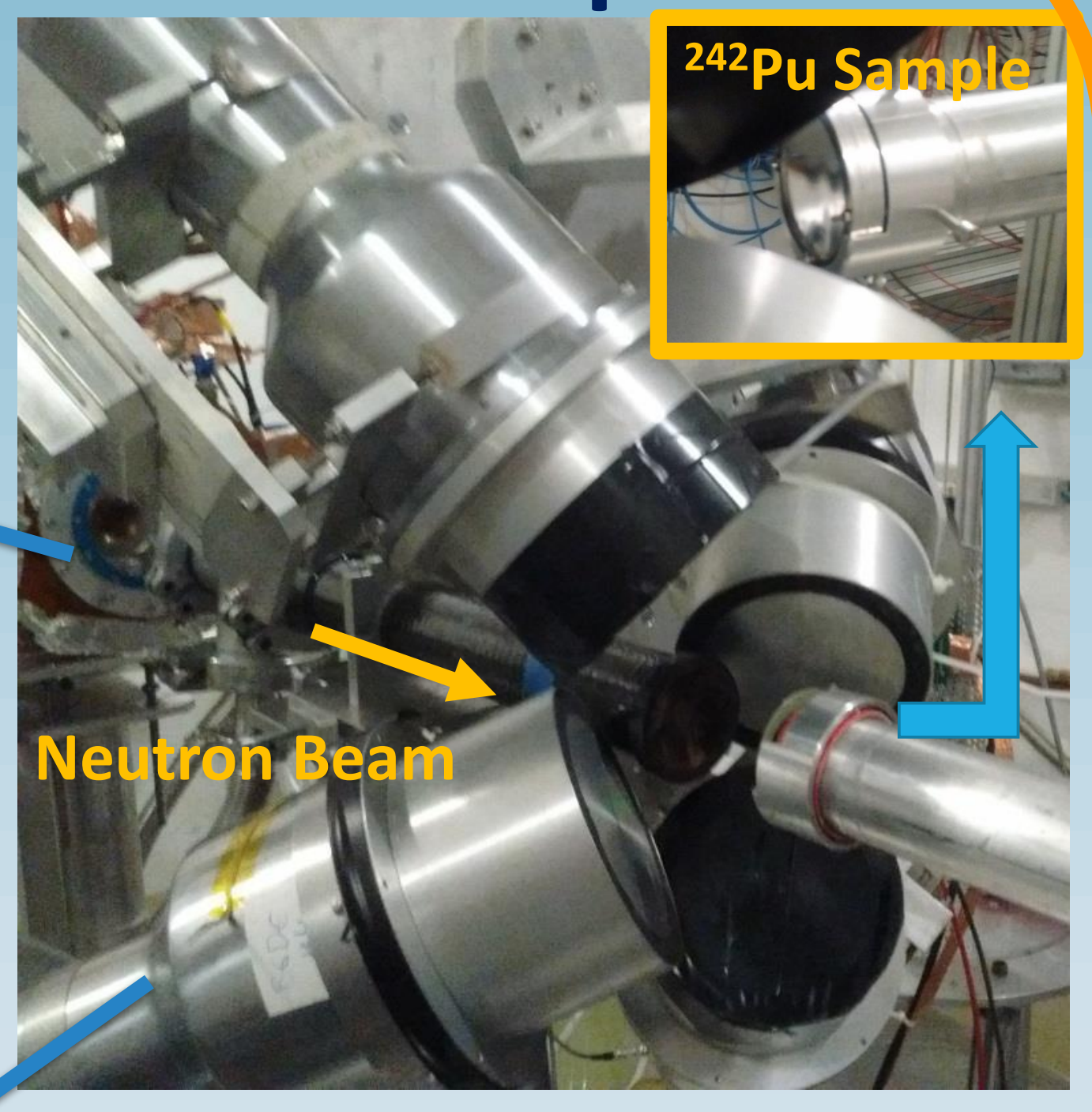
- **Experimental Area 1:**
  - @ 185m forward
  - Better energy resolution
- **Experimental Area 2:**
  - @ 19m upwards
  - Higher neutron flux

^{242}Pu Sample preparation


^{242}Pu target assembly for n_TOF (n,γ) experiments

- **Collaboration** with JGU Mainz and HZ Dresden-Rosendorf
- **95 mg of 99% pure** ^{242}Pu
- **Electrodeposition on 8** thin targets, 45 mm-diameter
- Thin backings 10 μm Al + Coating 50 nm Ti

Experimental setup



- **Neutron flux monitors**: charged particle Si detectors + Cross-section standards ^{6}Li (n,α)
- **Capture γ-rays:** Deuterized Benzene (**C_6D_6**) **scintillation detectors [4]**
  - Low neutron sensitivity
  - Total Energy Detection Technique

Total Energy Detection technique

The **Total Energy Detection principle [5]** requires the use of low efficiency detectors and it is based on:

I.- Just/at least one γ-ray per cascade detected:

$$\varepsilon_{\gamma i} \ll 1 \rightarrow \varepsilon_c = 1 - \prod_{\gamma i}(1-\varepsilon_{\gamma i}) \approx \sum_{\gamma i}\varepsilon_{\gamma i}$$

II.- Efficiency ∝ γ-ray energy :

$$\varepsilon_{\gamma i} = \alpha E_{\gamma i} \rightarrow \varepsilon_c = \sum_{\gamma i}\alpha E_{\gamma i} = \alpha E_c = \alpha(S_n + E_n)$$

ε_c is independent of the cascade path

Condition II needs manipulation of the response:

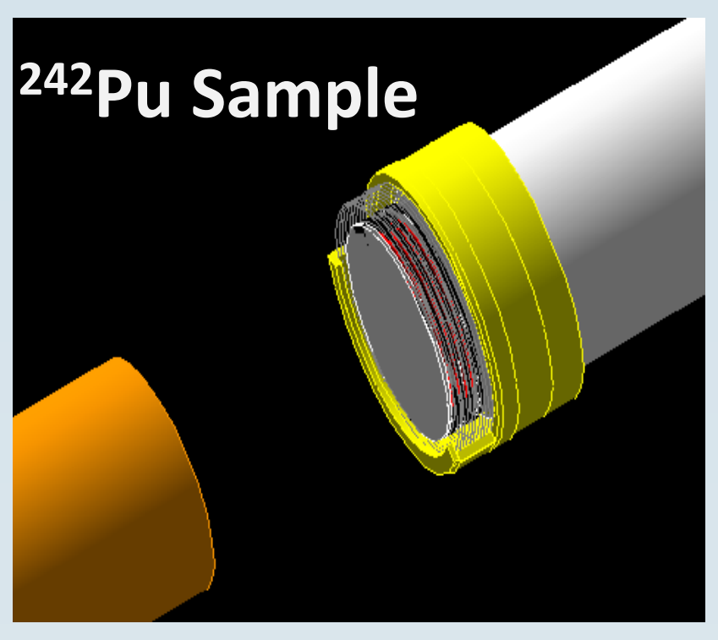
$$\varepsilon_{\gamma i} = \sum_j R_{\gamma i}(E_j) \rightarrow \sum_j W_i\, R_{\gamma i}(E_j) = E_{\gamma i}$$

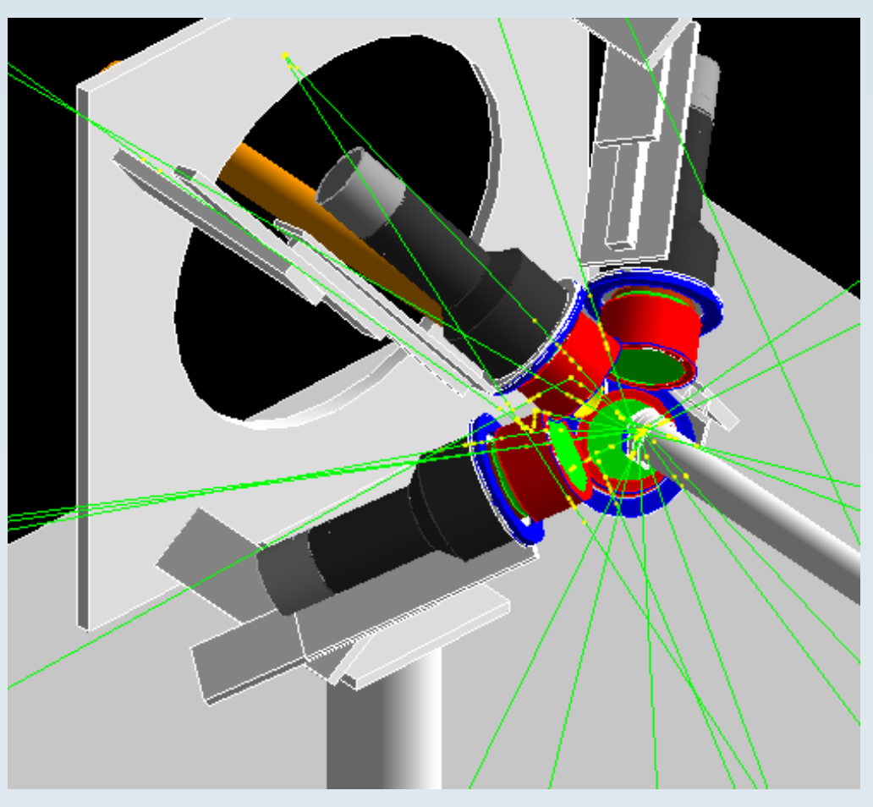
$W_i = W(E_j)$: Weighting Function (WF) depends on the **response** of the detectors **to each γ-ray energy $E_{\gamma i}$**

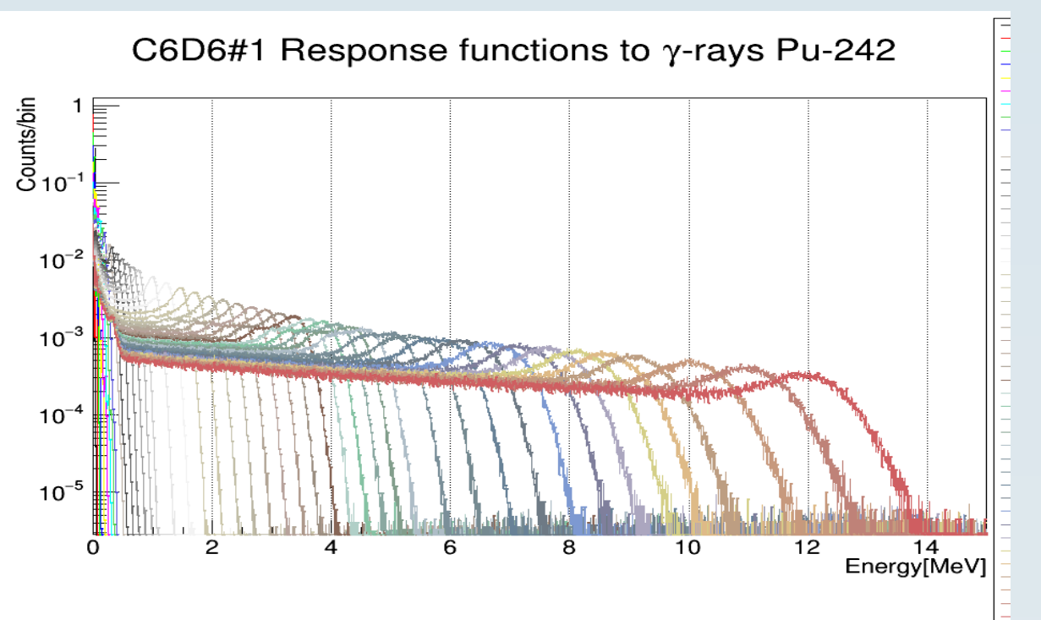
Response obtained from accurate Monte Carlo simulations (Geant4)

Factors affecting the response

- Detector geometry
- Effect of the γ-ray transport in sample, etc…



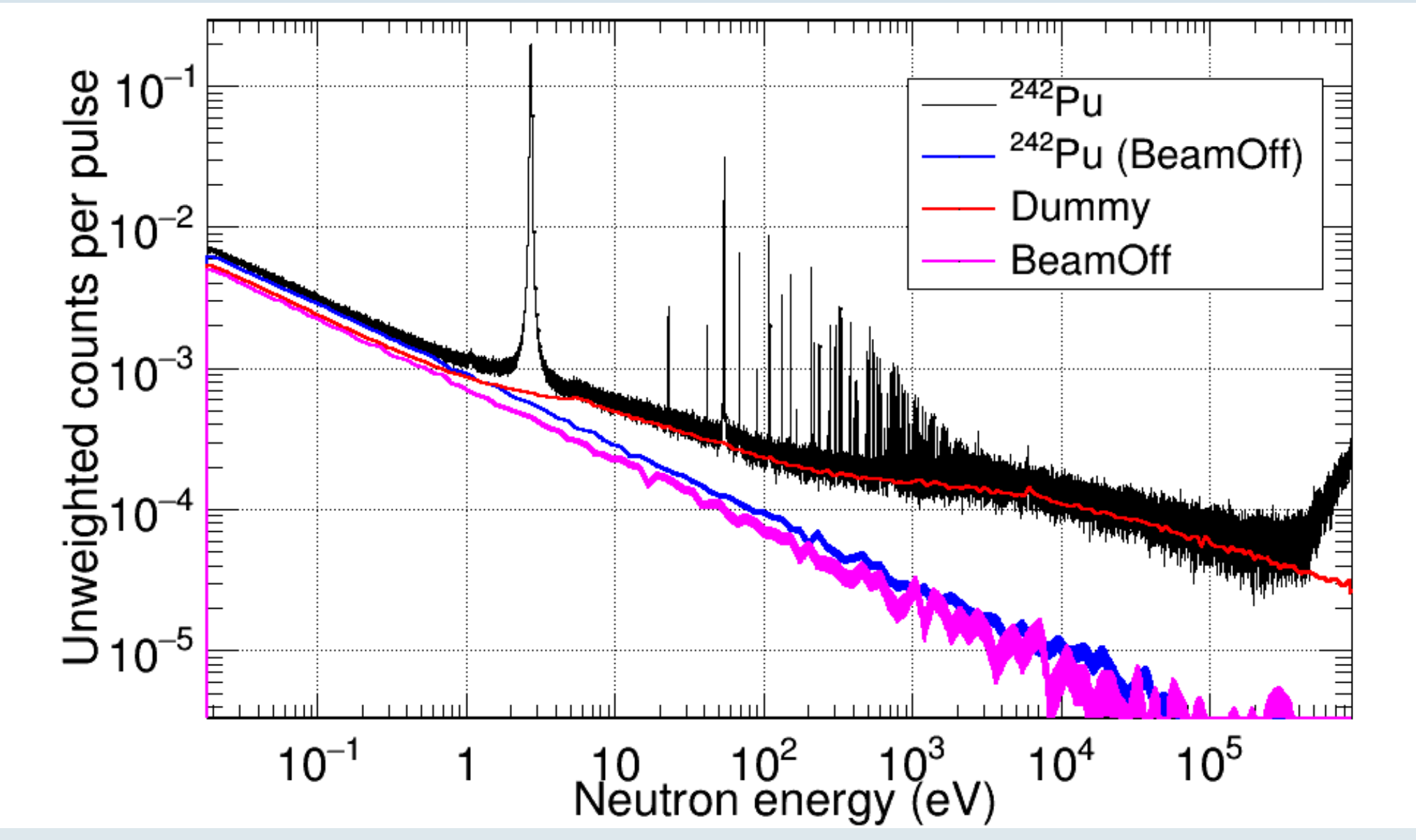




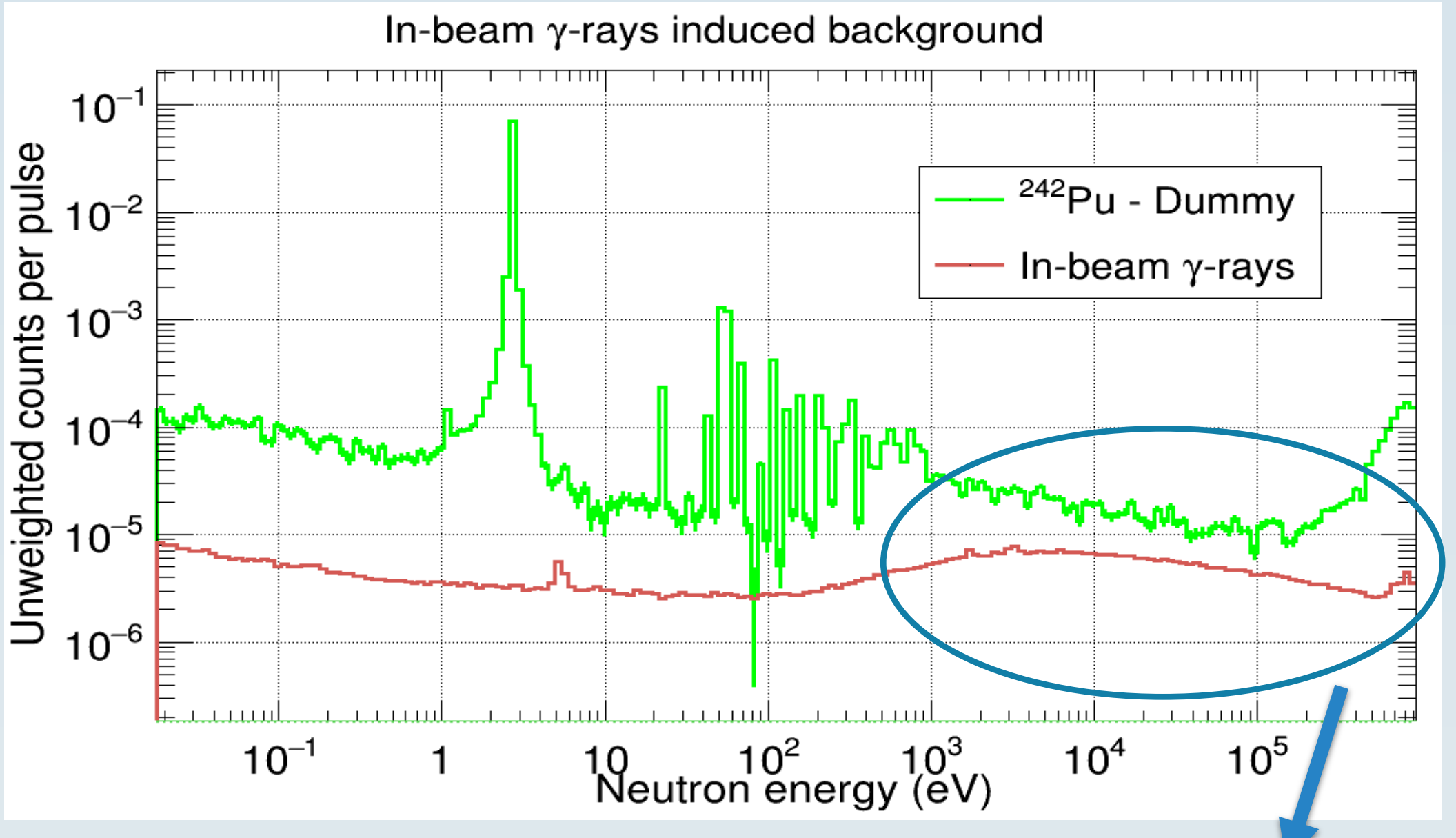
$R_j(E_i)$: Response distributions

Preliminary analysis and results

^{242}Pu and backgrounds



In-beam γ-ray background:



$$B_\gamma \propto Z^{\frac{3}{2}}.n(at/cm^2)$$

Up to 35% in the URR

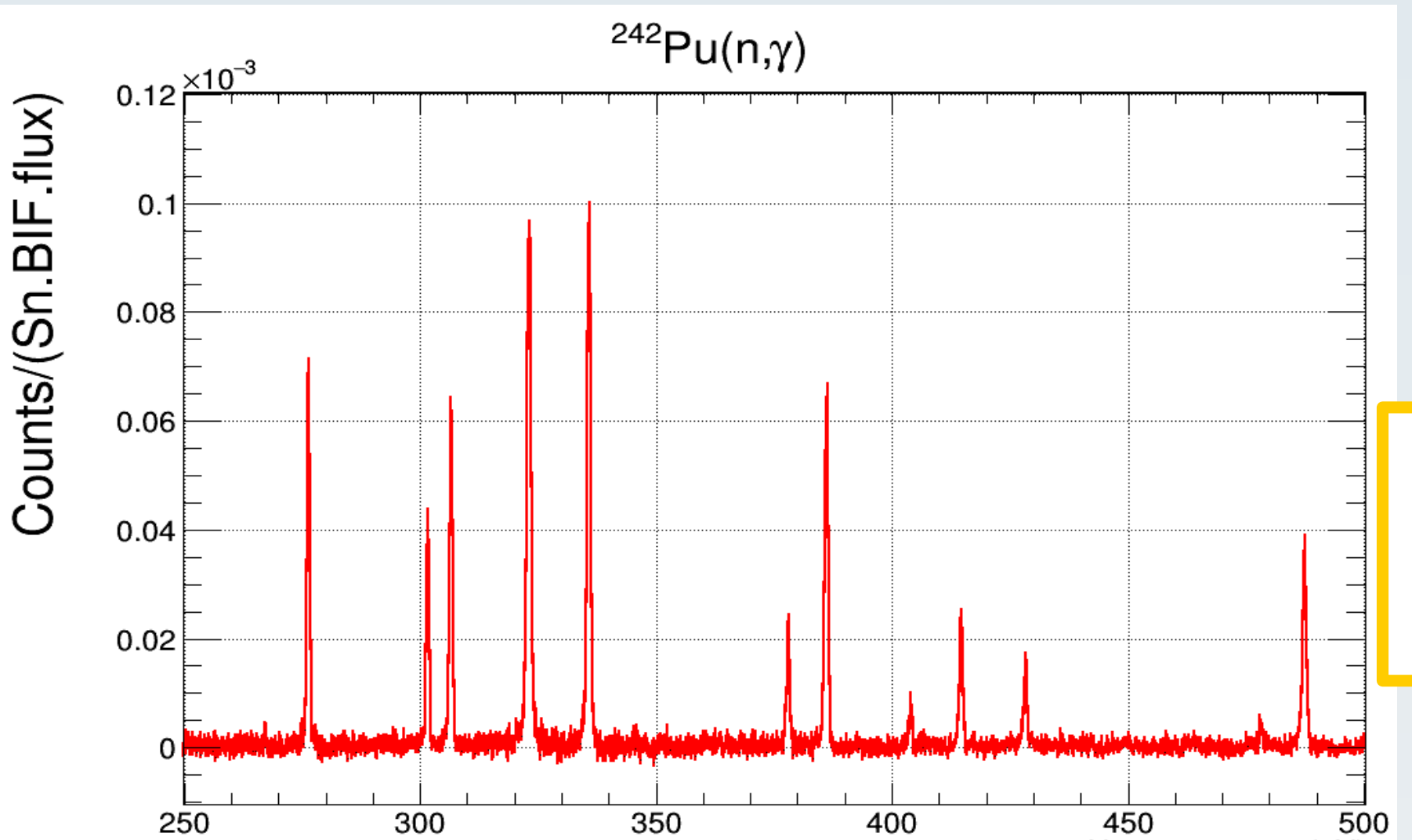
1. Time-of-flight to neutron energy:

$$E_n(eV) = \left(72.298\,\frac{L(m)}{ToF(\mu s)}\right)^2$$

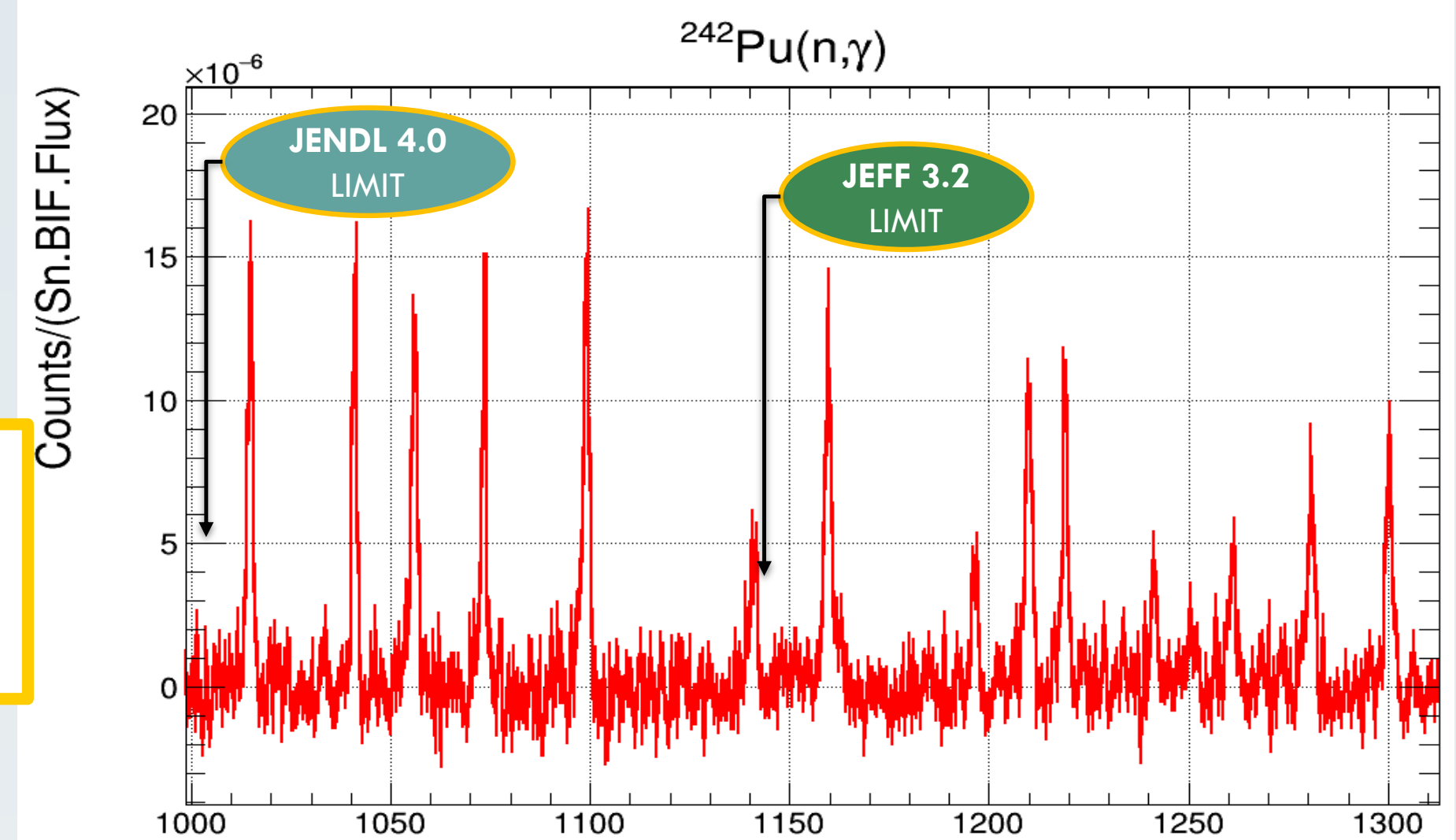
2. Background subtraction

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

3. Capture yield



High energy resolution and statistics



RRR: Resonance analysis up to ~1.5keV

References

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Acknowledgments

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Conclusions & outlook

The use of **MOX fuels in innovative nuclear systems** requires a better knowledge of the neutron **radiative capture cross section on ^{242}Pu**. Following the demands of the Nuclear Energy Agency the **new measurement** aims to reduce the current uncertainties in the 0.5 to 500 keV region down to 7-12% allow to reduce the current 10% deviations in the average resonance parameters. The 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 8 thin targets. cross section evaluation. The **first results** are **promising** and a final capture yield will be ready soon. After the resonance analysis we aim to **collaborate with evaluation groups** in order to include the new experimental data in the **upcoming release of the ^{242}Pu(n,γ) cross section.**

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