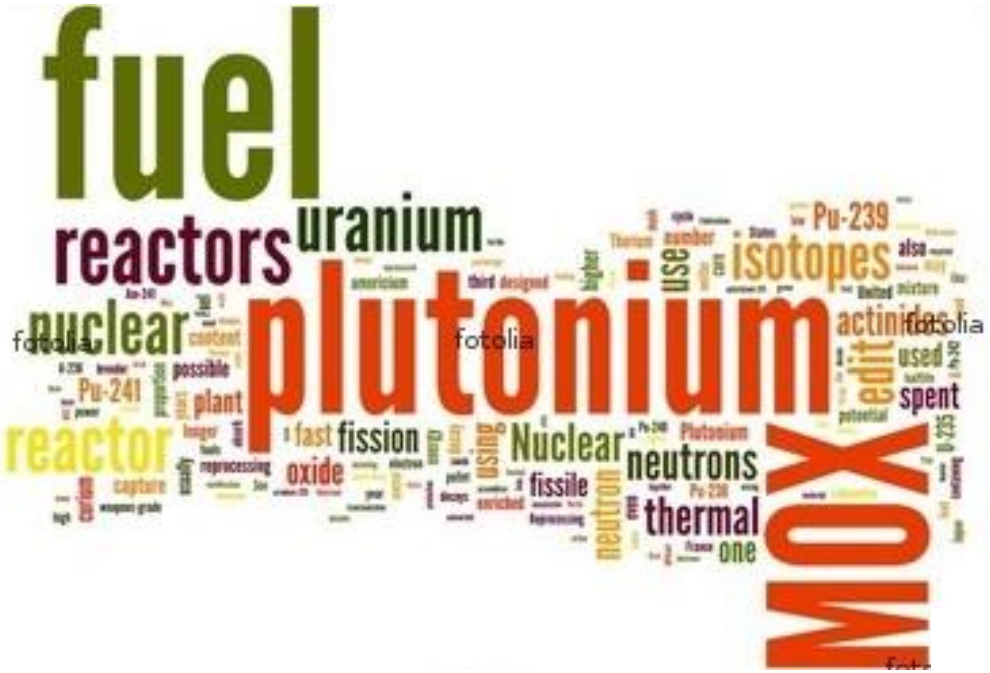
CERN-INTC-2013-027 (INTC-P-387):

Radiative neutron capture on ^{242}Pu for MOX fuel reactors

Spokespersons: C. Guerrero (US, CERN) and E. Mendoza (CIEMAT)



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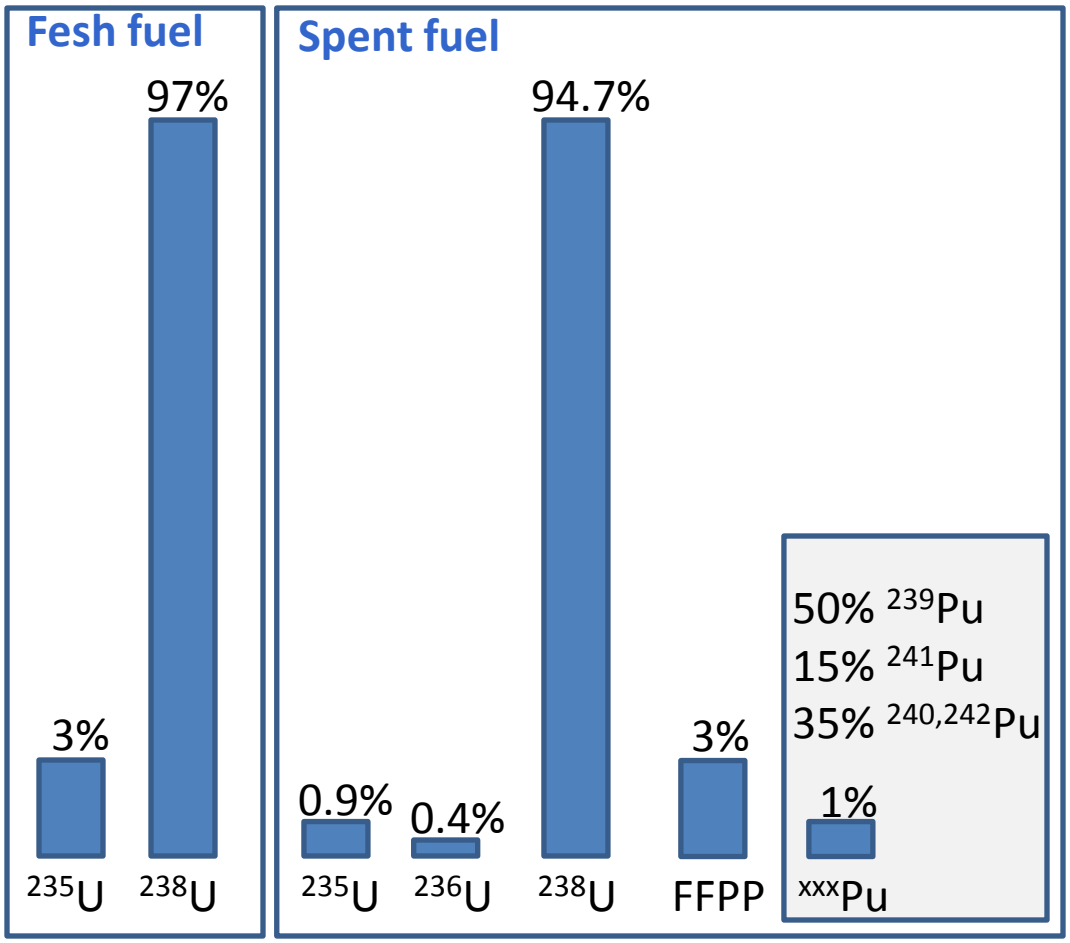
Motivation: Fresh and Spent nuclear fuel, the role of ^{242}Pu

The long term sustainability of nuclear energy calls for a more efficient use of the natural resources and management/reprocessing of the spent fuel.



Pu still a source of energy:

- ^{239,241}Pu are fissile, like ^{235}U
- ^{240}Pu is fertile!
- ^{242}Pu: neutron poison!
  (the door to Am and Cm)

Reprocess Pu/U to make MOX fuel:

(i.e. +22% energy outcome!)

- 30 reactors in Europe (+20 licensed)

(US interest in reprocessing Pu from weapons)

But:

- **Higher burn-up**
- **Fast neutrons for Gen-IV**
- **Fast neutrons for ADS**

Require a better known ^{242}Pu $\sigma(n,\gamma)$

Motivation: Nuclear data needs from International Agencies

- NEA/WPEC-26 *International Evaluation Co-operation:* **Uncertainty and target accuracy assessment for innovative systems using recent covariance data evaluations**
- **NEA High Priority Request List** (continuously updated)

	Energy range	Present accuracy (%)	Required accuracy (%)
SFR	2-500 keV	35	8
EFR	2-67 keV	35	25
GFR	2-183 keV	35	7-8
LFR	9-183 keV	35	11-12
ADMAB (ADS)	9-25 keV	35	10
PHENIX	0.5-2 keV	14	7
NEA/HPRL	0.5 2 keV	14%	8
Overall	**0.5-500 keV**	**14-35%**	**7-12**

Motivation: available data so far

PREVIOUS EXPERIMENTS:

Portmans et al., NPA 207, p.342-352 (**1973**)	(n,γ)@60 m below 1.3 keV
R.W.Hockenbury (C,75WASH,2,584,197503) (**1975**)	(n,γ)@RPI 6-87 keV
K. Wisshak and F. Kaeppeler, NSE 66, p.363 (**1978**)	(n,γ)@0.07 m 10-90 keV
K. Wisshak and F. Kaeppeler, NSE 69, p.39 (**1979**)	(n,γ)@0.07 m 50-250 keV

Reich et al., NSE 162 (2009) 178–191 (High E_n region): *Consistent s-wave strength function S_0, D_0 and $\langle\Gamma_\gamma\rangle$ are needed.*

PROFIL and PROFIL-2 are sample irradiation experiments carried out in the fast reactor PHENIX of CEA Marcoule, France. These experiments were designed to provide integral trends on a large variety of effective capture cross sections. For actinides, ***the largest discrepancy between the experimental and calculated results was observed for the ^{242}Pu(n,γ)*** *reaction. PROFIL and PROFIL2* ***suggest to decrease by at least 10% the capture cross section recommended in JEFF-3.1*** *(at high energy).*

Status on average resonance parameters: 10% differences in S_0, D_0 and $\langle\Gamma_\gamma\rangle$

	Reich NSE 162, (2009) 178-191	**Mughabghab (2011)ENDF/VII**	**JEFF-3.1**	**JENDL-4**	**RIPL**
$10^4 S_0$	0.91 ± 0.20	1.02	1.00	0.98	0.98±0.08
D_0 (eV)	16.8 ±0.5	13.6	15.3		13.5±0.15
$\langle\Gamma_\gamma\rangle$ (meV)	22±1	22.27	24.2	23.4	23±2

^{242}Pu is the next in the list of new evaluations by the CEA/ORNL collaboration

OBJECTIVES OF THE EXPERIMENT

Resolved resonance region (RRR)

Provide experimental data: 2nd in history, 1st in the last 40 years!

Extract individual and average resonance parameters up to at least 250 eV

Unresolved Resonance region (URR)

Provide ToF experimental data up to 25-67keV, hopefully up to 200-500 keV

2nd in history, 1st in the last 40 years!

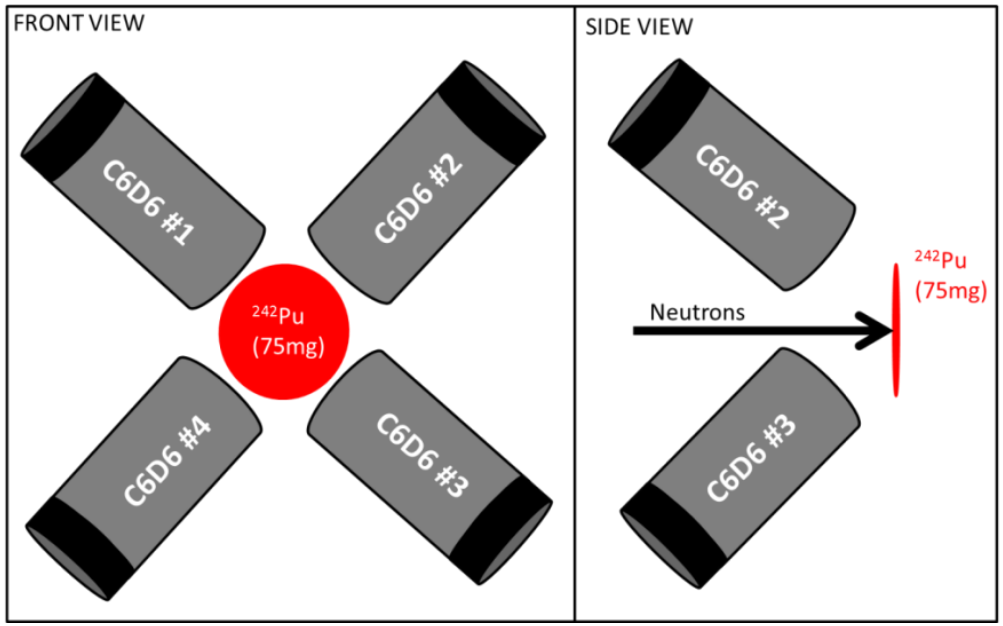
Test adequacy of Res. Par. from RRR for URR, and thus for higher energies.

Collaborate with the JEFF (CEA/Cadarache) and ENDF (ORNL) evaluators for a new release

Experimental set-up: new array of L_6D_6 @ EAR-1

Measurement in EAR-1 using 2 (better 4) of the new L6D6 detectors ($\varepsilon_{n,\gamma}$~7% each)

P. Mastinu et al., CERN-n_TOF-PUB-2013-002
"New C_6D_6 detectors: reduced neutron sensitivity and improved safety",



Why C_6D_6 low efficiency L6D6 detectors (the other option would be the 4π BaF_2 array)?

1. **Less affected by γ-flash** → higher energy limit at reach (goal is 500 keV)
2. **Lower neutron sensitivity** → background from scattering in the "many" backings reduced!
3. **Shorter dead-time** → less correction for the low energy "huge" resonances

Experimental set-up: ^{242}Pu Sample(s)

There are three possibilities:

a. Samples from the ^{242}Pu(n,f) n_TOF campaign in 2011/12
~3 mg distributed in 4 samples of 3 cm diameter
Backing 0.2 mm Al backing each (dominant in the URR)

b. New samples from the nELBE/U. Mainz collaboration (available by mid 2014)
~75 mg distributed in 8 samples of 7.6 cm diameter (x5 in atoms/barn wrt. **a**)
Backing 0.1 μm Ti [molecular elecroplating] each

c. Dedicated capture samples from nELBE/U. Mainz
Dedicated capture samples with 100 mg on 4 cm diameter (x5 in at/barn wrt. **b,** x25 in at/barn wrt. **a**)
Backing 0.1 μm Ti [molecular elecroplating] each

Option a would required to measured in EAR-2, except for the first resonance
Option b would allow to measure in EAR-1 up to ~25 keV (EAR-2 for E_n>25 keV)
Option c would allow to complete the measurement in EAR-1 (up to 600 keV)

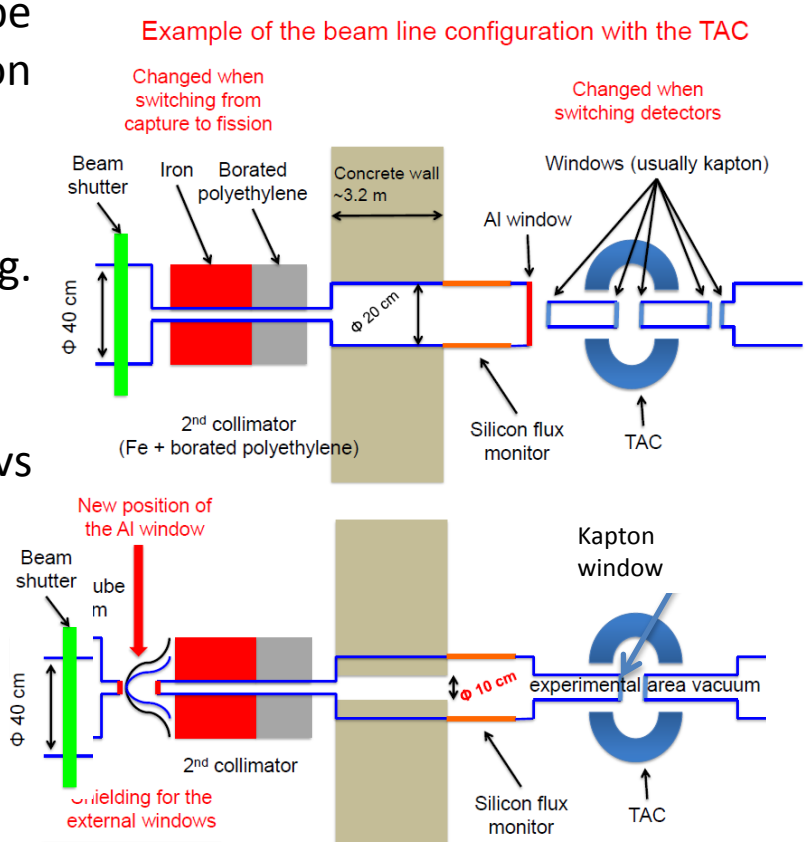
Experimental set-up: Background reduction in EAR-1

The beam line configuration in EAR-2 will be modified aiming for a sizable background reduction via:

1. New Al window: smaller diameter , thinner (e.g. 0.2 vs. 0.5 mm) and more upstream

2. Reduction of the free passage through wall: 10 vs 20 cm

3. Only Kapton windows in EAR-1



Expected counting rates (RRR)

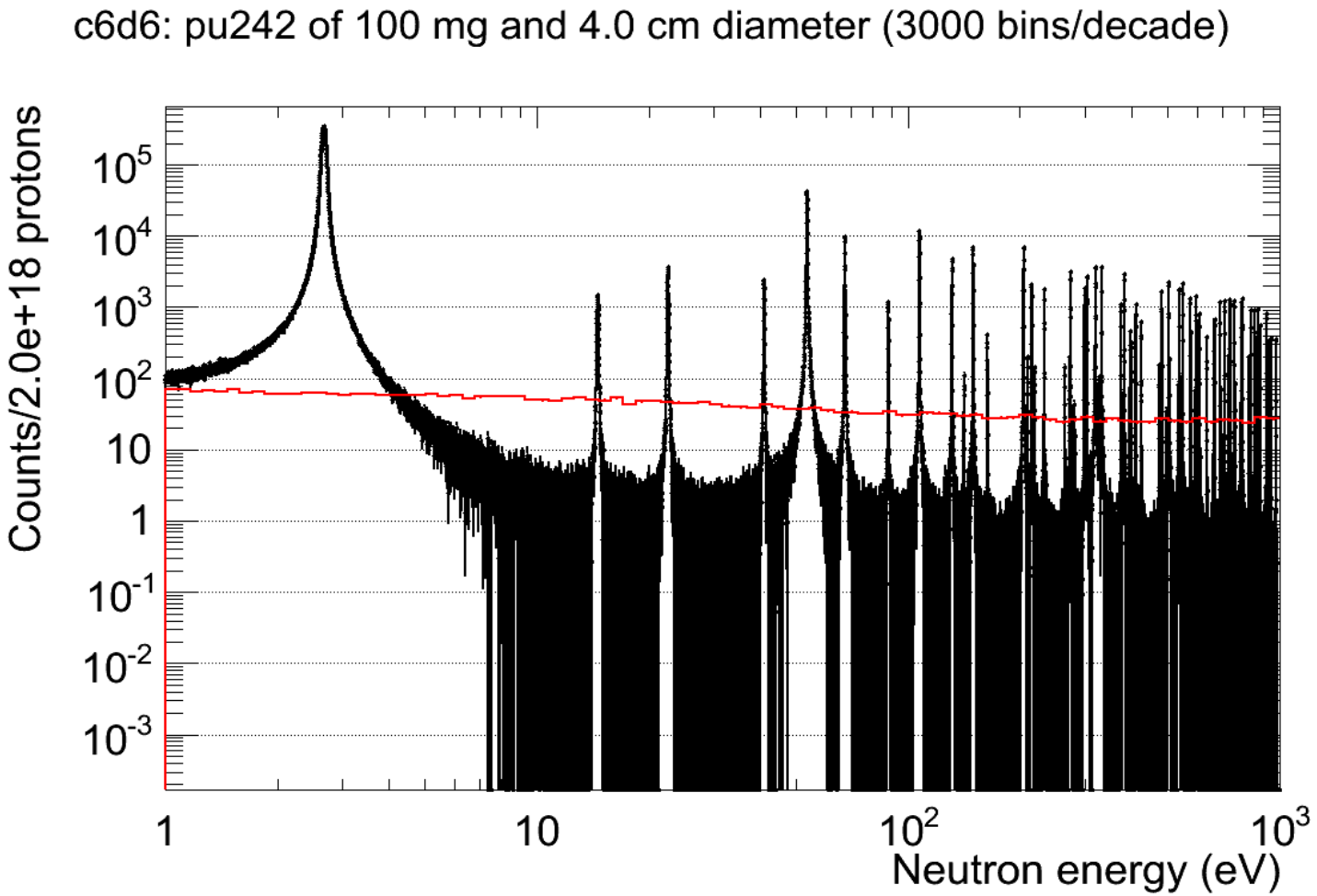


Figure 3. Expected counting rate for the ^{242}Pu(n,g) reaction under neutron irradiation with a total intensity of 2x10^{18} protons on target. 3000 bins/decade, needed to study the resolves resonance region. **The red line indicates the expected background level, considering the data available from 2012, that is before the improvements in the neutron beam lie that shall reduce the background significantly (see text for details).**

Expected counting rates (URR)

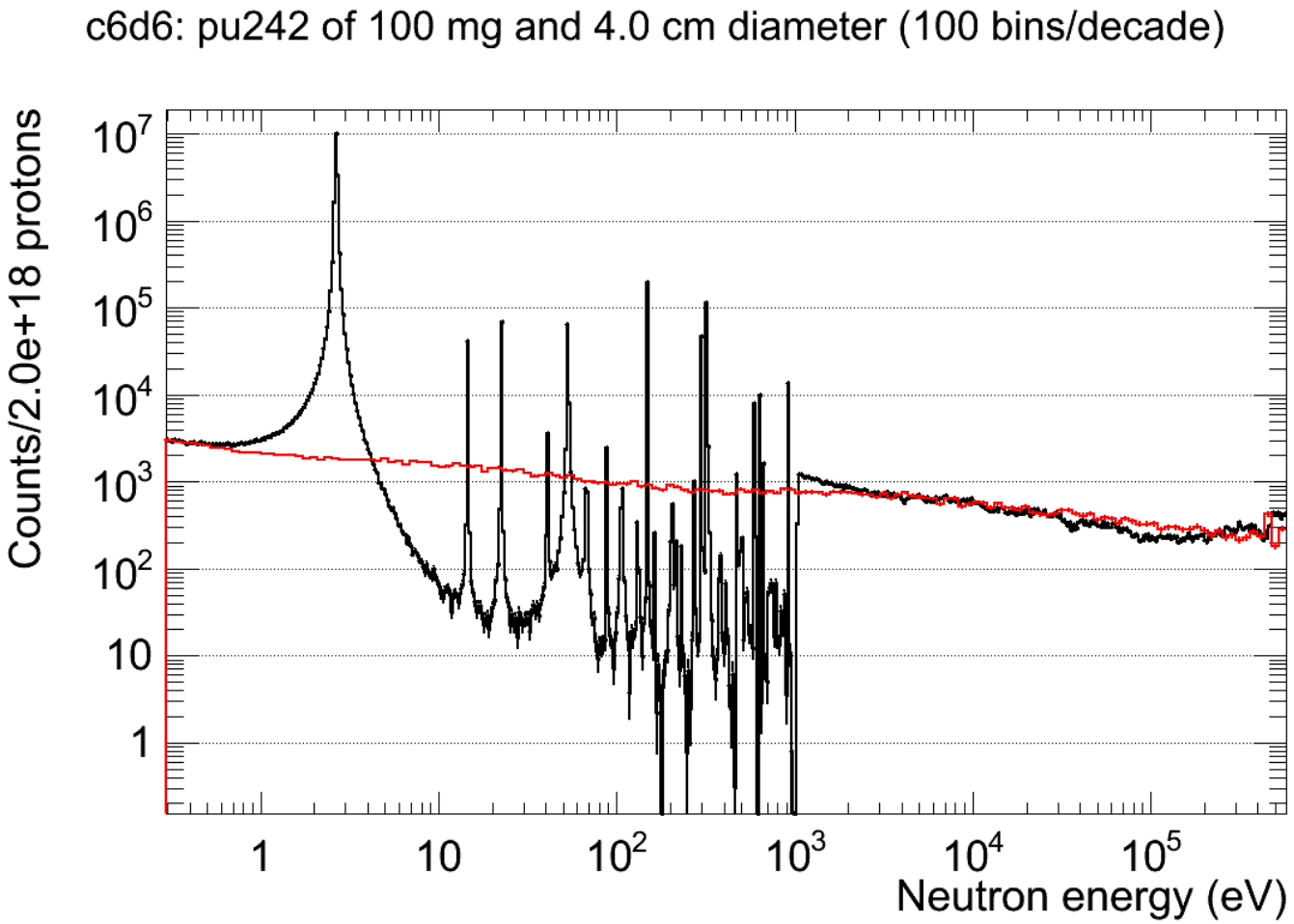


Figure 3. Expected counting rate for the ^{242}Pu(n,g) reaction under neutron irradiation with a total intensity of 2x10^{18} protons on target. 100 bins/decade, needed for the study of the smooth Unresolved Resonance Region. **The red line indicates the expected background level, considering the data available from 2012, that is before the improvements in the neutron beam lie that shall reduce the background significantly (see text for details).**

Conclusion and Proton Request

A new measurement of the ^{242}Pu $\sigma(n,\gamma)$ in the region up to 500 keV is proposed at EAR-1

- The aimed accuracy varies between 7% and 12% depending on the energy region and associated reactor type.
- The PHWT with a new array of L_6D_6 detectors will be used
- The measurement will take place in EAR-1 up to 200-500 keV.

Table 2. Number of protons requested for the measurement of the ^{242}Pu(n,γ) cross section and auxiliary samples.

SAMPLE	PURPOSE	PROTONS
^{242}Pu (100 mg, 40 mm diam.)	Capture Cross Section measurement	2.0×10^{18}
^{197}Au (1000 mg, 40 mm diam.)	Validation of the $\sigma(n,\gamma)$ measurement	0.4×10^{18}
Sample-out/Dummy*	Sample-independendt background*	0.8×10^{18}
^{nat}Pb/^{12}C	Sample-dependent background	0.3×10^{18}
Beam-off	Room background	-
TOTAL		3.5×10^{18}

* May change slighlty depending on results from comissioning of EAR-1 with reduced backgrounds