



irfu

MINISTÈRE
DES ARMÉES
*Liberté
Égalité
Fraternité*

DGA

nTOF

European
Commission
JOINT RESEARCH CENTRE

APRENDE

EURO-LABS
EUROPEAN LABORATORIES
FOR NUCLEAR
BASED SCIENCES

Measurement of the ^{241}Pu neutron capture-to-fission cross section ratio at n_TOF

A. CAHUZAC, E. AUBERNON, J. AUPIAIS, Y. AREGBE, M. BACAK, D. BAUDIN, D. BERNARD, É. BERTHOUMIEUX, G. BÉLIER, E. DHAENE, M. DIAKAKI, M. DIETZ, E. DUPONT, F. GUNTING, J. HEYSE, C. LOISEAU, A. MANNA, L. MATHIEU, R. MUCCIOLA, G. NOGUERE, C. PARADELA, A. PLOMPEN, E. PIROVANO, P. SCHILLEBEECKX, O. SEROT, G. SIBBENS, J. TAIEB, G. TSILEDAKIS, D. VANLEEuw, R. WYNANTS, R. ZARRELLA & n_TOF collaboration

Table of contents

- 1. Project overview**
- 2. 2025 ^{241}Pu campaign on EAR1**
- 3. Preliminary analysis results**



Table of contents

- 1. Project overview**
2. 2025 ^{241}Pu campaign on EAR1
3. Preliminary analysis results

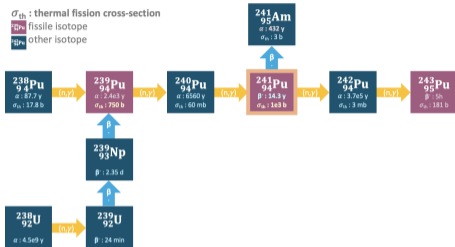




1 Project overview

■ Experiment context and organization

On ^{241}Pu



- (very) fissile
- Produced in uranium reactors
- Only 1 capture measurement (Weston&Todd, 1978)
- 14 years half-life, β - to ^{241}Am

Challenging measurement

- No Pu (241) enrichment since 70s
 - capture / fission of isotopes in sample
- Short $T_{1/2}$: fast production of ^{241}Am
 - increasing α activity
 - high $\sigma_{capture}$

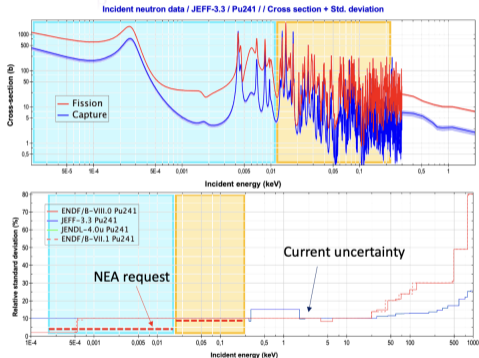
Neutron Capture and Fission Cross Sections of Plutonium-241

L. W. Weston and J. H. Todd
Oak Ridge National Laboratory, P.O. Box X
Oak Ridge, Tennessee 37830
Received July 20, 1977
Accepted September 19, 1977

Weston & Todd, in Nuclear Science and Engineering
65.3 (1978), p. 454-463.

Measurement project

Nuclear Energy Agency (OECD)
"High Priority Requests" on ^{241}Pu :



- material isolated at JRC-Geel
- few 10 mg of enriched Pu
- rare sample (possibly last in Europe)

^{238}Pu	^{239}Pu	^{240}Pu	^{241}Pu	^{242}Pu
0.09%	6.0%	23%	54%	17%

Pu total 10.9 mg α activity 29.6 MBq
 ^{241}Pu 5.9 mg β activity 22.6 GBq

Capture-to-fission ratio :

1. n_TOF EAR1 (fission-tagging)

Fission cross-section (wrt ^{235}U) :

1. n_TOF EAR1&2
 2. GELINA
- postdoc M. SPELTA

Table of contents

1. Project overview
- 2. 2025 ^{241}Pu campaign on EAR1**
3. Preliminary analysis results

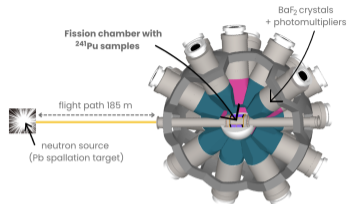




2. 2025 ^{241}Pu campaign on EAR1

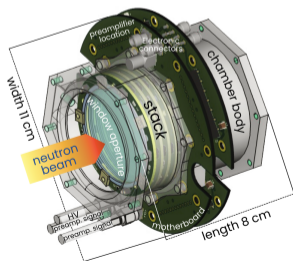
Setup, summary of the (long) campaign, some numbers

Detectors characteristics



n_TOF Total Absorption Calorimeter

The ^{241}Pu fission chamber



n_TOF Total Absorption Calorimeter (TAC)

- 40 BaF_2 crystals, close to 4π coverage
- on n_TOF EAR1 (flight path ~ 185 m)

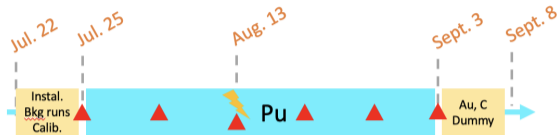
^{241}Pu fission chamber (FCPU)

- 8 pairs cathode (Pu on Al) - anode (plain Al)
- 1 preamplifier (CEA/DAM) for each pair
- 3 mm $\text{Ar}+\text{CF}_4$ at 300 mbar / voltage 77 V

Fission-tagging principle

- coinciding TAC+CaF signals \Rightarrow fission
- TAC signal alone \Rightarrow capture (+ bkg...)

Data taking



At CERN from Jul. 22 to Sept 18, 2025

- Pu + beam** main data
- Dummy + beam** scattering by FiCh
- Au + beam** beam interception factor (BIF)
- ^{12}C + beam** scattering by samples
- beam off Pu** FiCh+TAC background
- beam off Dummy** TAC ambient background
- calibrations** every week (few % drift in TAC)

Individual detectors :

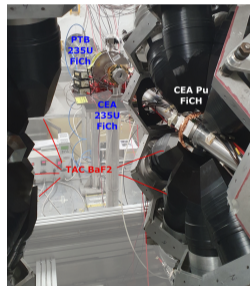
40 BaF2 crystals

2 FCU5 channels

8 FCPU channels

6 LMFC channels

1 PKUP



Data : ~2 PB raw (2 TB pre-processed)

Table of contents

1. Project overview
2. 2025 ^{241}Pu campaign on EAR1
- 3. Preliminary analysis results**



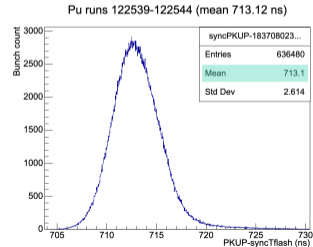
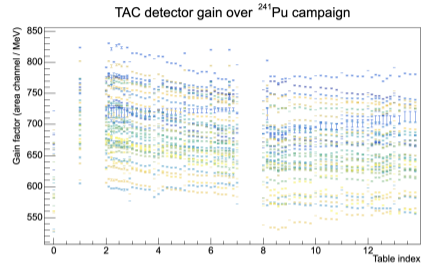
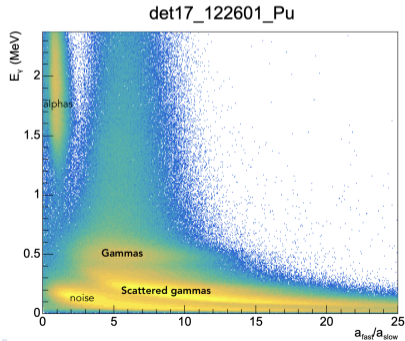


3. Preliminary analysis results

TAC data analysis

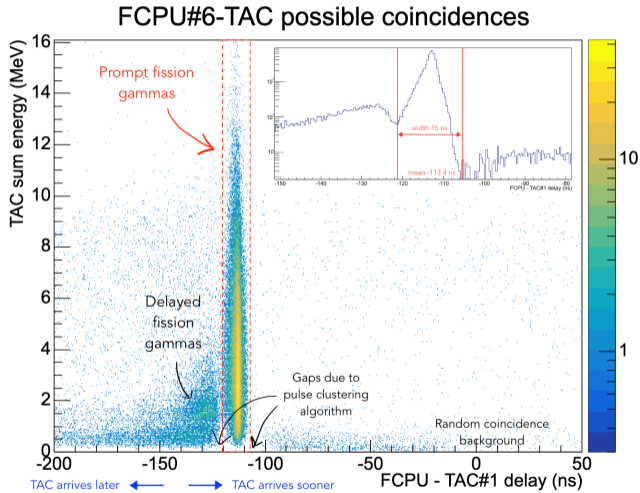
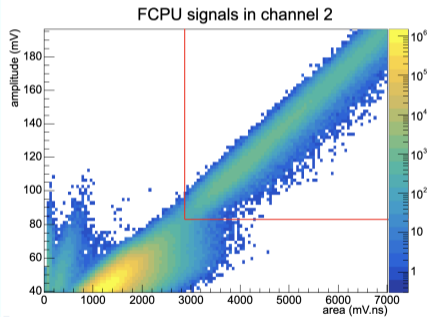
Data processing - TAC

1. Calibrate (high drift)
2. Synchronize between crystals
3. Synchronize with PKUP
4. Separate α and noise
5. Clusterize (pulses \rightarrow events)

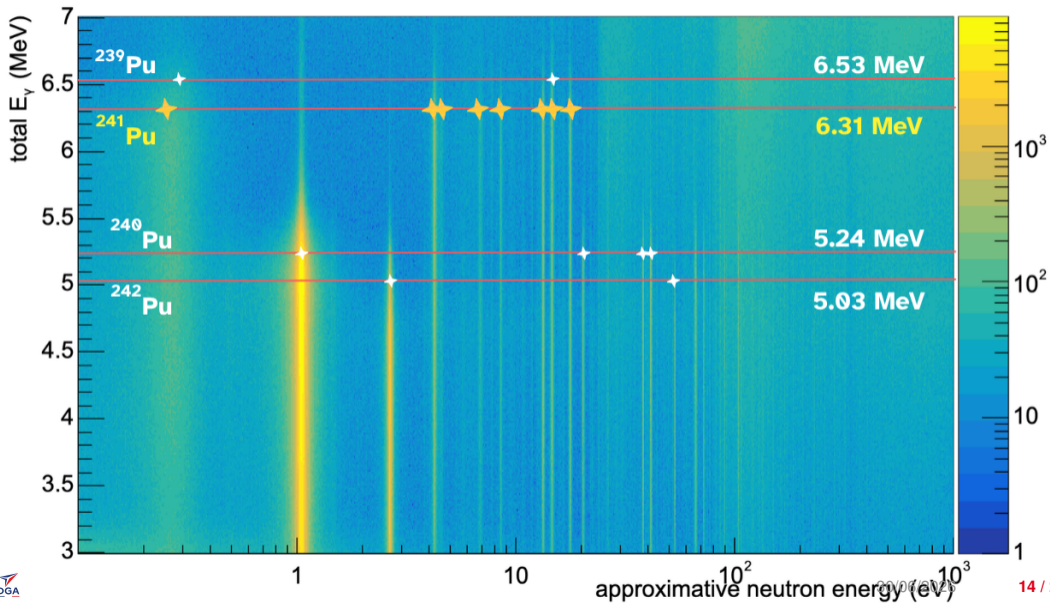


Data processing - FCPU & tagging

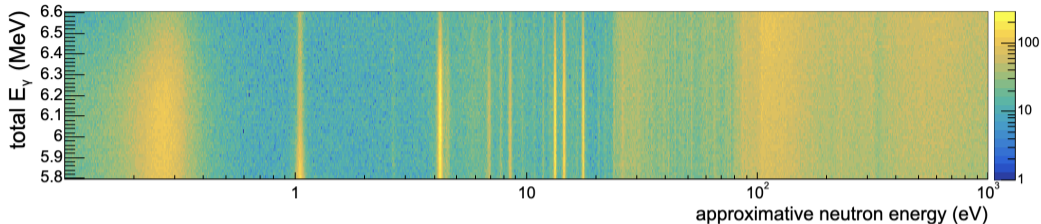
1. Separate alphas / FF
2. Synchronize FCPU - TAC
3. Tag γ events



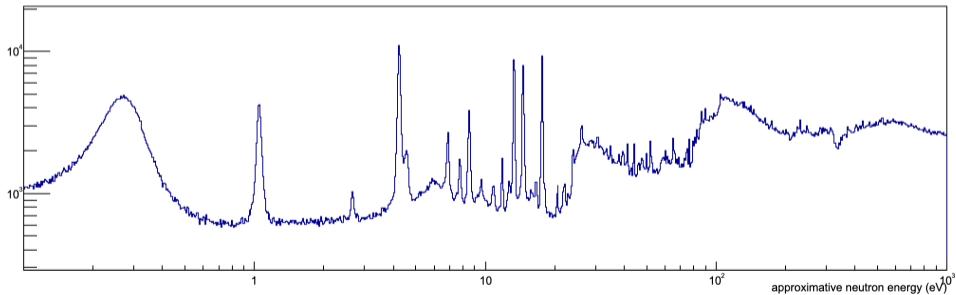
PuGamma events not in coincidence (multiplicity > 2)

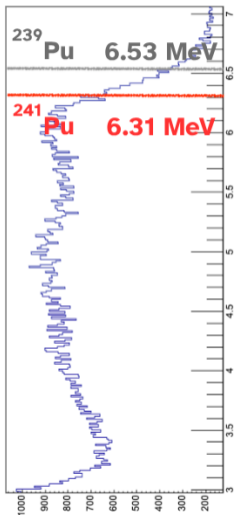


PuGamma events not in coincidence (multiplicity > 2)

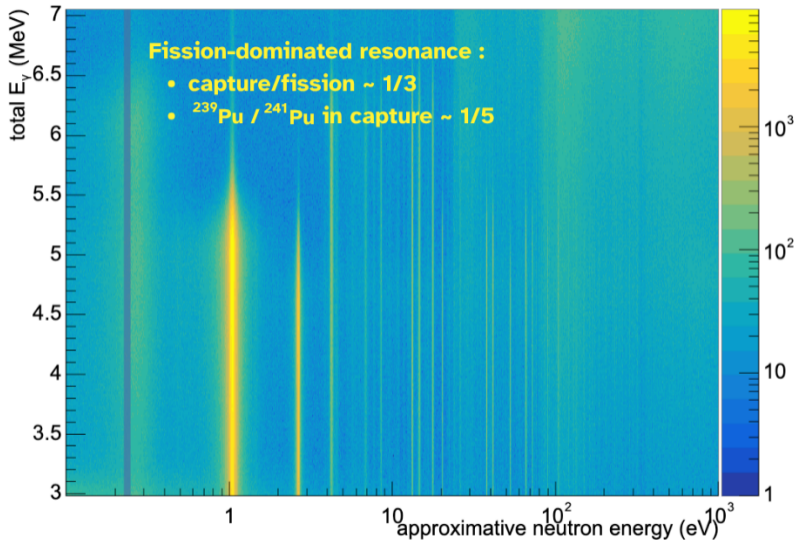


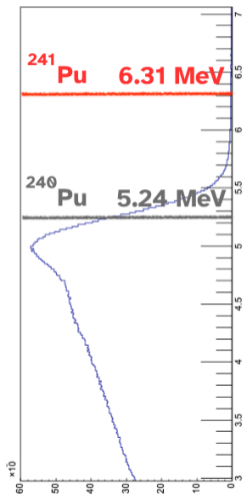
X projection bins [396 .. 481]



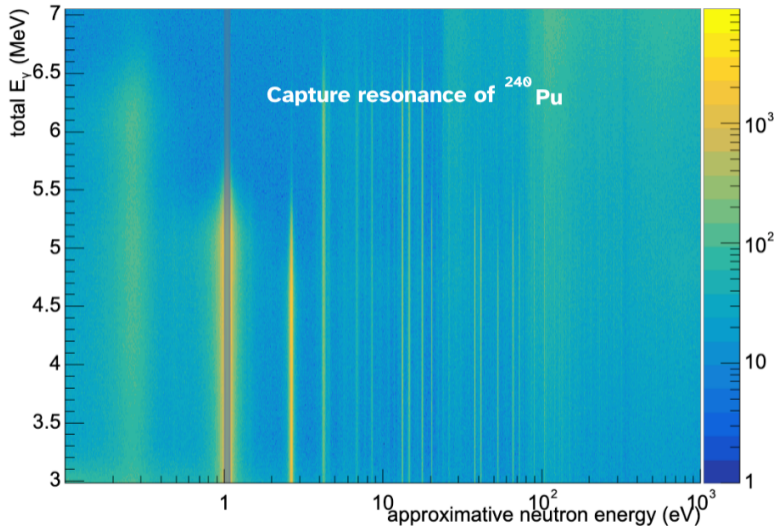


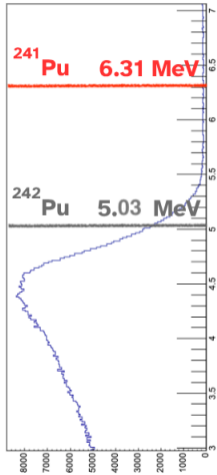
PuGamma events not in coincidence (multiplicity > 2)



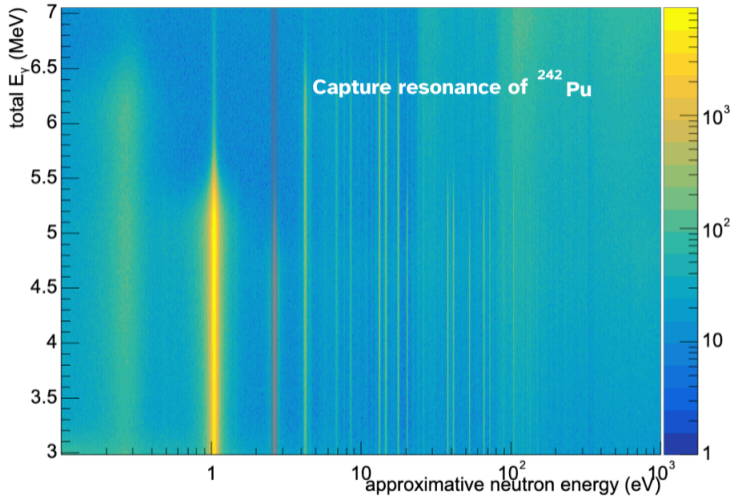


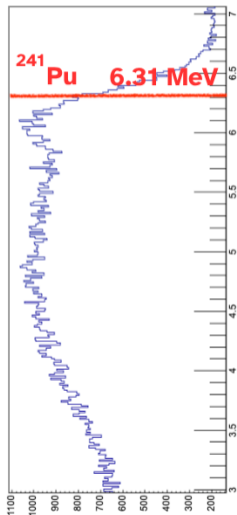
PuGamma events not in coincidence (multiplicity > 2)



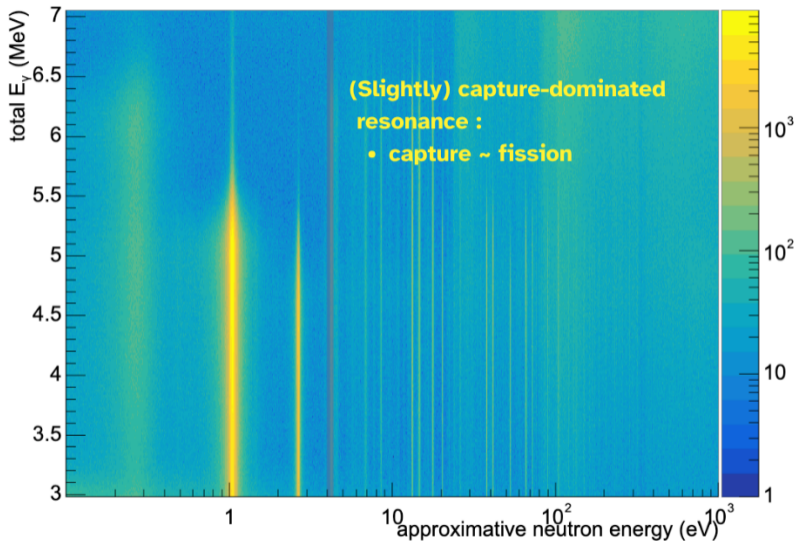


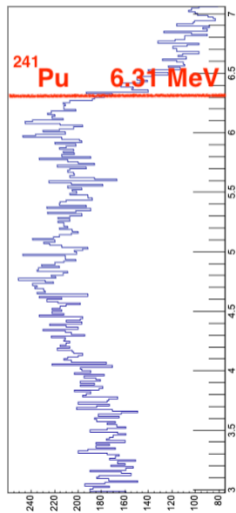
PuGamma events not in coincidence (multiplicity > 2)



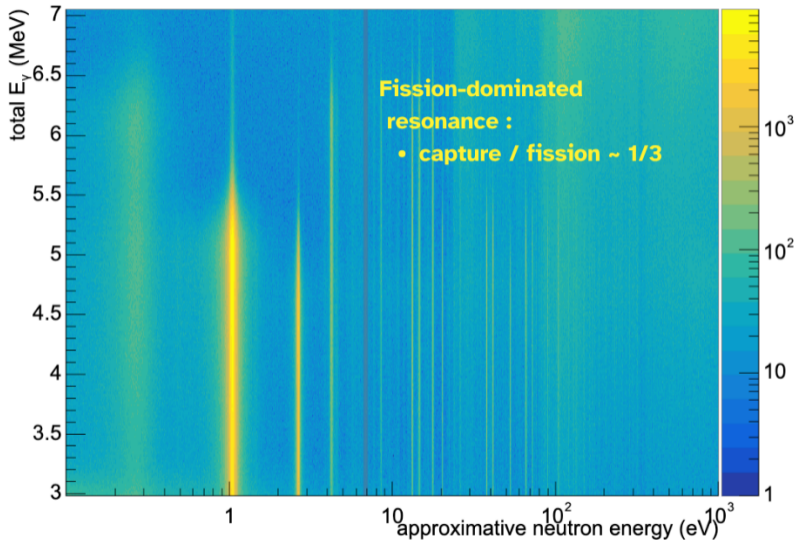


PuGamma events not in coincidence (multiplicity > 2)

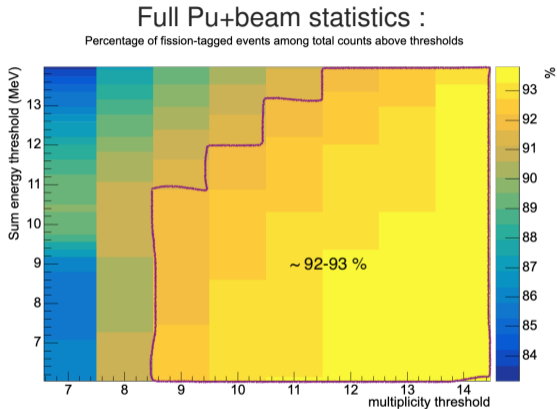




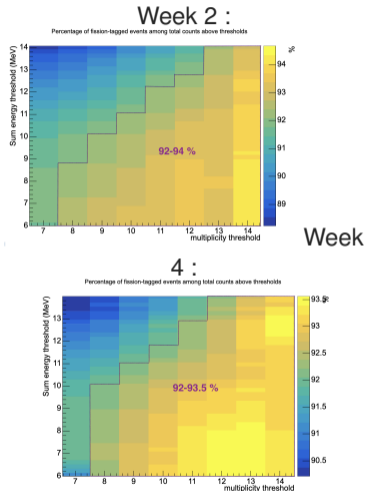
PuGamma events not in coincidence (multiplicity > 2)



Fission-tagging efficiency (very preliminary values)



Efficiency : 92.5 ± 0.5 % (to be confirmed).



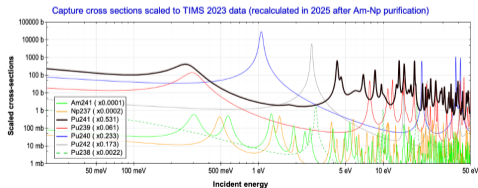
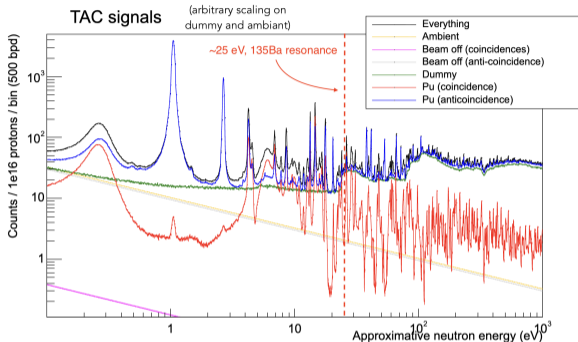
Further steps in the analysis

- TAC efficiency
- comparison to simulations
- background subtraction
- other Pu capture

Cuts :

Energy $2.5 \leq E_{sum} \leq 7$ MeV

Multiplicity $3 \leq M_{cr} \leq 7$



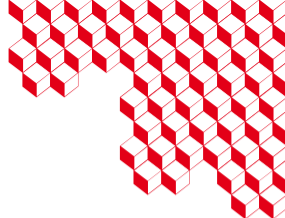


4. Summary

- experiment on a rarely measured isotope
- successful data taking campaign in S2 2025
- analysis of capture-to-fission ratio ongoing



irfu



Thank you for listening !

CEA Saclay
91 191 Gif-sur-Yvette Cedex
France
aline.cahuzac@cea.fr

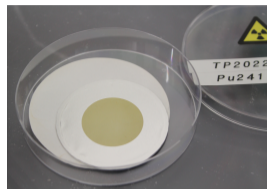
This project has received funding from the European Union's Horizon Europe Research and Innovation programme under Grant Agreement N°101057511 (EURO-LABS project).

This work was co-funded by the European Union under grant agreement 101164596 - APRENDE Project. Views and opinions expressed are however, those of the author(s) only and do not necessarily reflect those of the European Union or the European Atomic Energy Community (ECEuratom).

About the ^{241}Pu samples from JRC-Geel

Recovered from legacy material

- complex chemical procedures
- diverging estimations of isotopic content
- very active material



From (mass + α + γ) spectrometry, concluded Aug. 8th, 2025 (3rd week on EAR1) :

^{238}Pu	^{239}Pu	^{240}Pu	^{241}Pu	^{242}Pu
0.09%	6.0%	23%	54%	17%

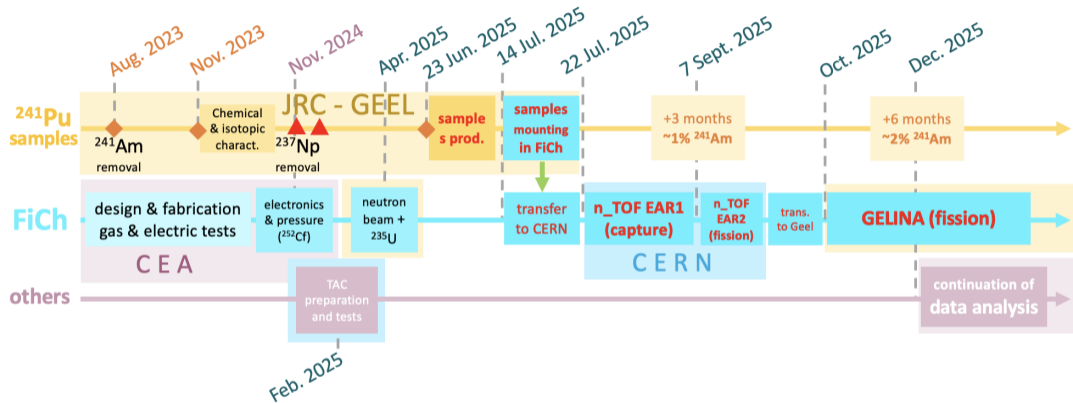
Fission chamber : 8 samples
→ content and activity

Pu total	15 10.9 mg	α activity	29.6 MBq
^{241}Pu	9.3 5.9 mg	β activity	22.6 GBq

Probably from the one and only (large and accessible) ^{241}Pu known stock :

- *enriched in the 70s (ORNL), characterized in 1974*
- *used by WESTON&TODD in the only existing measurement of $\sigma_{\text{capture}}(^{241}\text{Pu})$ (ORNL)*
- *few g bought by JRC in 1985*

Planning



2023-2024 Fission chamber design and prototyping, TAC simulations

2025 Experiment preparation and data taking

2025-2027 Data analysis (→ α ratio)