Nuclear data activities at JRC-Geel

P. Schillebeeckx

European Commission

Joint Research Centre, Geel (BE)

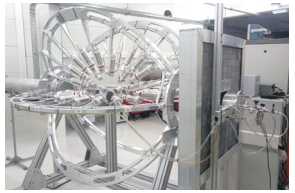
NCSP, 15 – 17 February 2022

ORNL

Nuclear facilities at JRC - Geel

Operated by JRC.G.2 Unit

- Nuclear data
- Radionuclide measurements
- Nuclear safeguards metrology



GELINA
neutron time-of-flight facility for high-resolution neutron measurements

MONNET
tandem accelerator based fast neutron source

TARGET
nuclear target preparation laboratories

RADMET
laboratories for standardisation of radionuclide activity

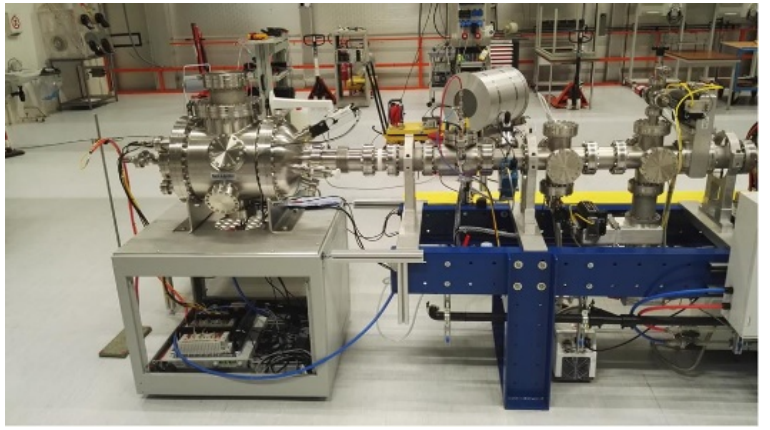
HADES
low-level gamma-spectrometry laboratory

METRO
nuclear reference material and measurement facility

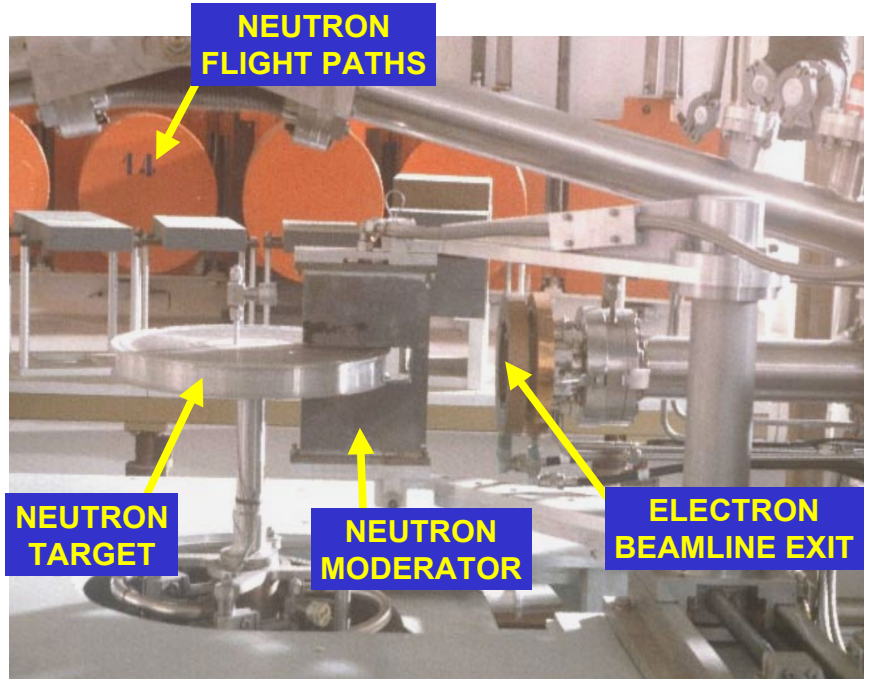
European Commission

MONNET

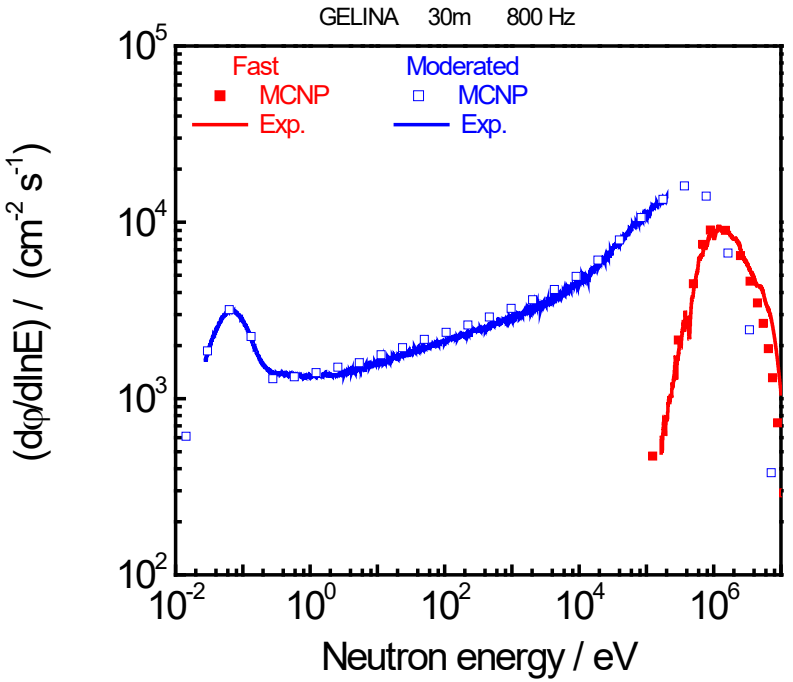
- irNANO – irradiation of NANO-particles
  - Medical radionuclide production with accelerators
  - Production of ^{99}Mo via the reaction ^{100}Mo(n,2n)^{99}Mo
  - Irradiation of nanoparticles with 15.5 MeV neutrons
  - Production yield of recoiled ^{99}Mo and separation efficiency determined by means of γ-ray spectrometry
- IB4N – ion beams for neutrons
  - Simulation of radiation damage with proton beams
  - Irradiation dose at 0.1 and 1 dpa @ T_S = (390±10) ^{o}C
- DUXISUN
  - Determination of the content of UXOs
  - Non-destructive method
  - Gamma/neutron interrogation following fast-neutron irradiation



GELINA : neutron production

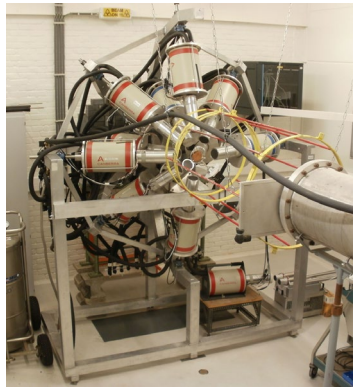


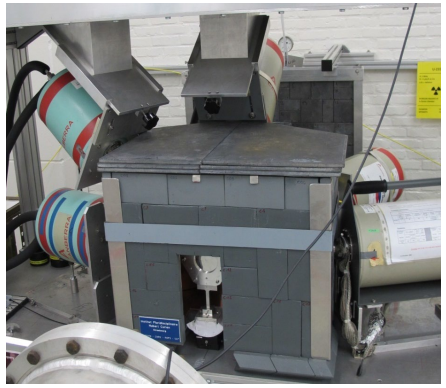
- e^- accelerated to $E_{e^-,max} \approx 140$ MeV
- Bremsstrahlung in U-target (rotating & cooled with liquid Hg)
- (γ, n), (γ, f) in U-target
- Low energy neutrons by moderation (water moderator in Be-canning)

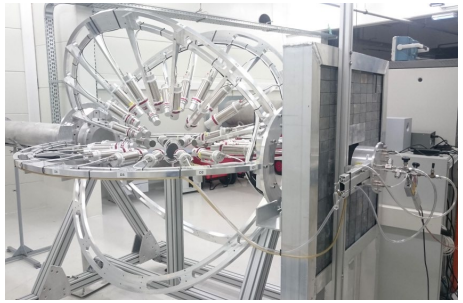


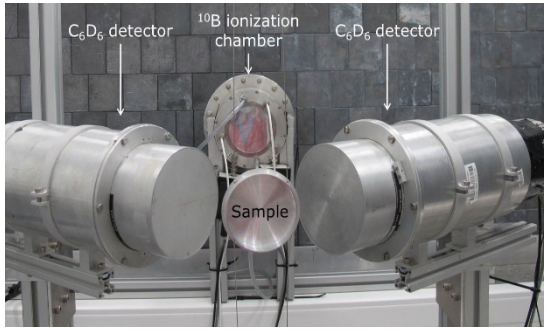
New Uranium target: NCSP- Y12

GELINA - Experimental set-ups







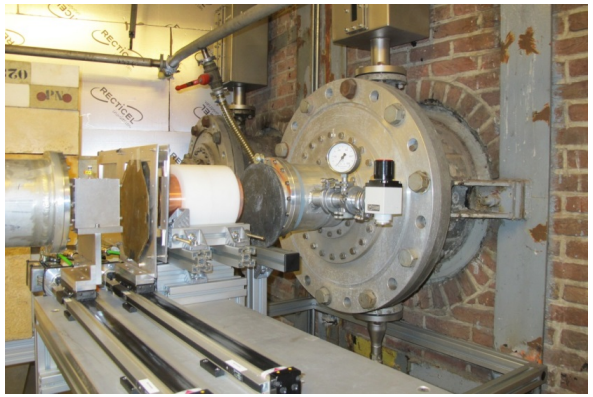


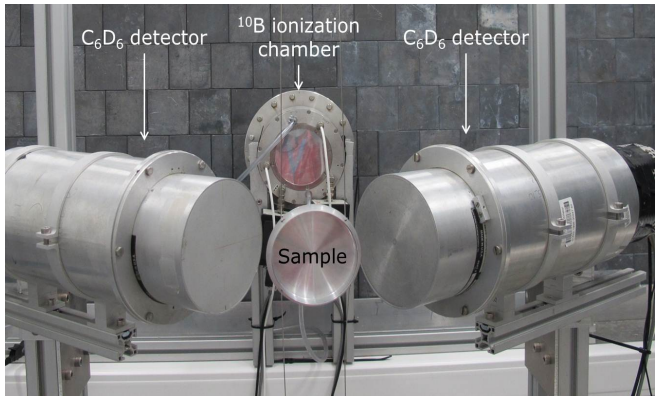
- Transmission
  - 10 m, 30 m, 50 m
- Capture
  - 10 m, 30m, 60 m
- Elastic, in-elastic scattering
  - 30 m
- In-elastic scattering (n,n'γ)
  - 30 m, 100 m
- Fission, (n,p), (n,α),
  - 10 m

JRC – ORNL : NCSP

	Start	Samples	(n,γ)	(n,tot)	Data Reduction & Analysis	Data Testing	Data Evaluation (NNDC)
W	2009	Metal disc $^{182,183,183,186,nat}W$	30 m, 60 m	50 m	X	X	X
Cu	2011	Metal disc $^{63,65,nat}Cu$	60 m		X	X	X
Ca	2013	Disc: ^{nat}Ca	60 m	50 m	X	X	X
Ce	2014	Metal: ^{nat}Ce	60 m	50 m	X	X	X
	2018	Oxide: ^{142}Ce	60 m	50 m	X		
V	2015	Metal disc: ^{nat}V	60 m	50 m	X	X	Ongoing
La	2017	Metal disc: ^{nat}La	60 m	50 m	X	X	Ongoing
Zr	2016	Metal disc $^{90,91,92,94,nat}Zr$	60 m	50 m			
Zr	**2021**	**Metal disc ^{90}Zr**	**60 m**	**50 m**			

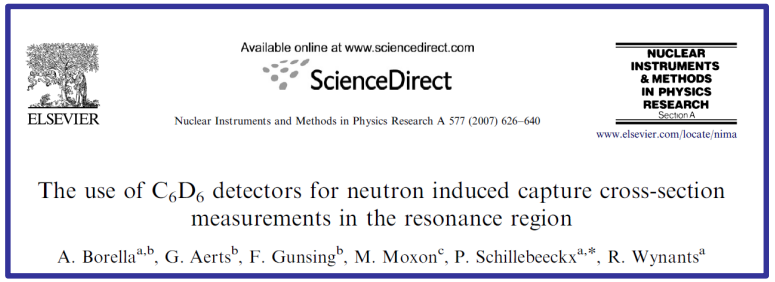
- Transmission at 50m
  - ^{6}Li-glass scintillator
  - Use of fixed background filters
- Capture at 30m and 60 m
  - Total energy detection principle
  - C_6D_6 detectors: PHWT





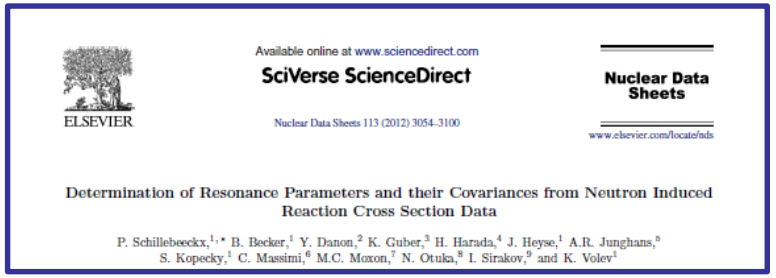
European Commission

Uncertainty evaluation and reporting


Available online at www.sciencedirect.com
ScienceDirect
Nuclear Instruments and Methods in Physics Research A 577 (2007) 626–640
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
www.elsevier.com/locate/nima

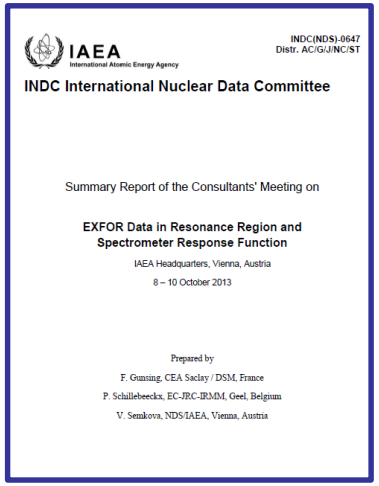
The use of C_6D_6 detectors for neutron induced capture cross-section measurements in the resonance region

A. Borella[a,b], G. Aerts[b], F. Gunsing[b], M. Moxon[c], P. Schillebeeckx[a,*], R. Wynants[a]


Available online at www.sciencedirect.com
SciVerse ScienceDirect
Nuclear Data Sheets 113 (2012) 3054–3100
Nuclear Data Sheets
www.elsevier.com/locate/nds

Determination of Resonance Parameters and their Covariances from Neutron Induced Reaction Cross Section Data

P. Schillebeeckx,[1,*] B. Becker,[1] Y. Danon,[2] K. Guber,[3] H. Harada,[4] J. Heyse,[1] A.R. Junghans,[5] S. Kopecky,[1] C. Massimi,[6] M.C. Moxon,[7] N. Otuka,[8] I. Sirakov,[9] and K. Volev[1]

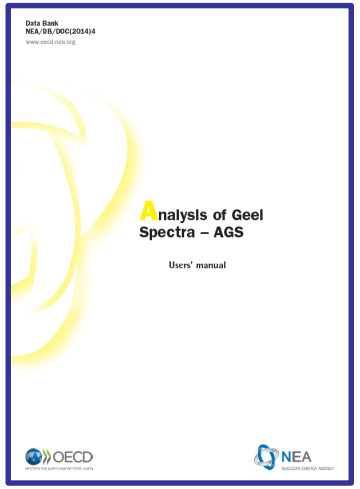

IAEA International Atomic Energy Agency
INDC(NDS)-0647
Distr. AC/G/J/NC/ST
INDC International Nuclear Data Committee

Summary Report of the Consultants' Meeting on

EXFOR Data in Resonance Region and Spectrometer Response Function

IAEA Headquarters, Vienna, Austria
8 – 10 October 2013

Prepared by
F. Gunsing, CEA Saclay / DSM, France
P. Schillebeeckx, EC-JRC-IRMM, Geel, Belgium
V. Semkova, NDS/IAEA, Vienna, Austria

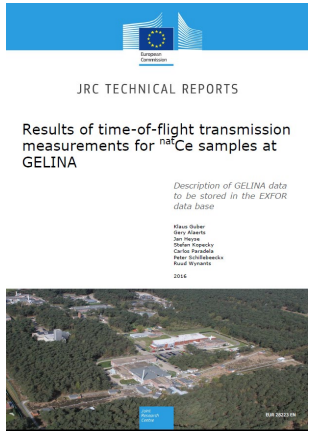

Data Bank
NEA/DB/DOC(2014)4
www.oecd-nea.org

Analysis of Geel Spectra – AGS

Users' manual

OECD NEA

- **Experimental procedures**
  including data reduction and analysis: **fully documented**
- **Uncertainty evaluation**
  - Identifying and quantifying uncertainties due **to systematic effects**
  - based on **dedicated experiments**
- **Reporting** in EXFOR
  - Full **experimental details** following **recommendations** in **INDC(NDS)-0647**
  - **AGS** concept:
    separation of **correlated** and **uncorrelated** uncertainty **components**


JRC TECHNICAL REPORTS

Results of time-of-flight transmission measurements for ^{nat}Ce samples at GELINA

Description of GELINA data to be stored in the EXFOR data base

Klaus Guber
Gary Alaerts
Jan Heyse
Stefan Kopecky
Carlos Paradela
Peter Schillebeeckx
Ruud Wynants

2016

European Commission

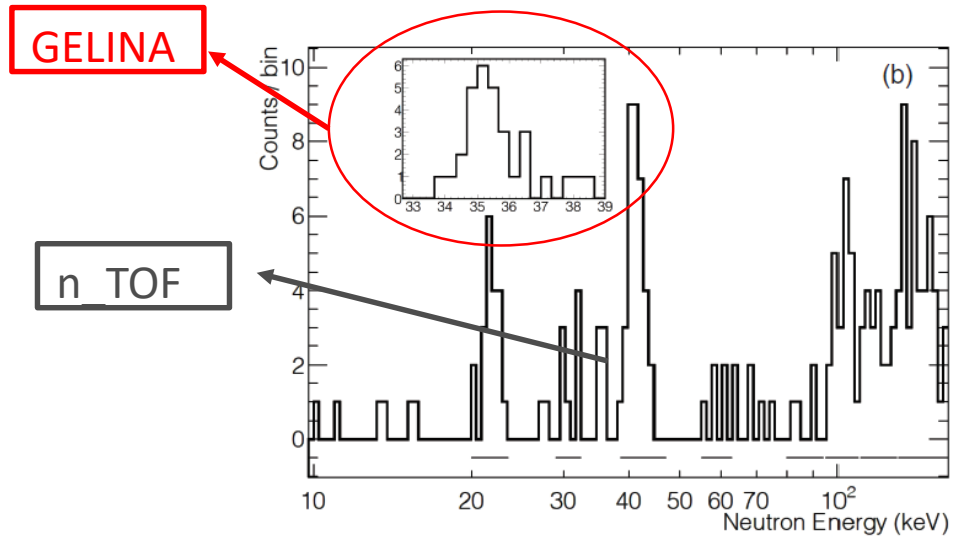
Experiments at GELINA

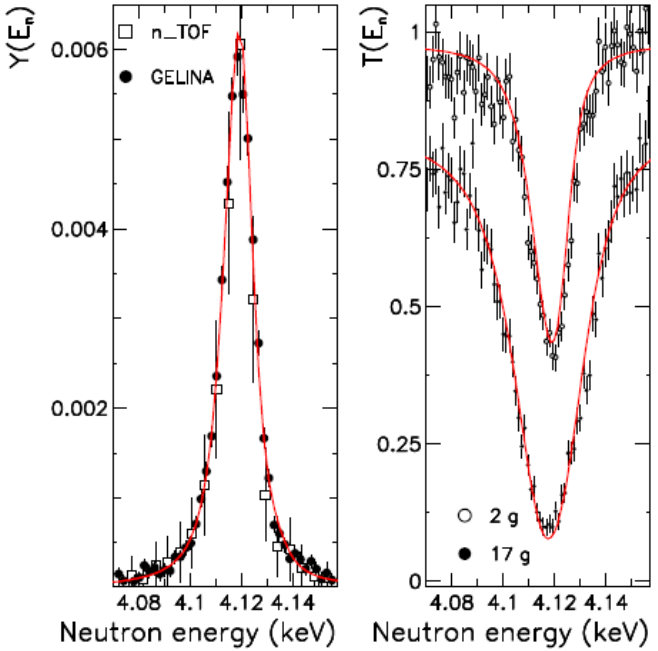
	2018	2019	2020	2021
(n,tot)	^{139}La ^{88}Sr ^{155,157}Gd	^{142}Ce ^{nat,154}Gd	^{209}Bi	^{90}Zr ^{nat}Mo
(n,γ)	^{139}La	^{142}Ce ^{nat}Gd	^{209}Bi	^{90}Zr
(n,xnγ)	^{57}Fe	^{19}F	^{40}Ca	^{40}Ca
(n,n)		^{54}Fe		^{23}Na
(n,α)		^{16}O		
(n,f)	^{239}Pu			

- JRC – ORNL : NCSP
- JRC – n_TOF collaboration
- Others: mainly through EUFRAT (open access projects)
  - CEA
  - CNRS (Strassbourg)
  - IFIN-HH
  - IRSN
  - SCK CEN

GELINA – n_TOF : examples

- $^{26}Al(n,\alpha)$ Lederer et al., Phys. Rev. C 104 (2021) L032893
  - n_TOF : (n, α_0+ α_1)
  - GELINA: (n, α_0) and (n,α_1)
- $^{154,155,157}Gd + n$ Mazzone et al., Phys. Lett. B 804 (2020) 1354; Mastromarco et al., Eur. Phys. J. A. 55 (2019) 9
  - n_TOF : $^{154,155,157}Gd(n,\gamma)$ at 185 m
  - GELINA:
    $^{155,157,nat}Gd(n,\gamma)$ at 30 m
    $^{154,155,157,nat}Gd(n,tot)$ at 50 m
- $^{92}Zr + n$ Tagliente et al., Phys. Rev. C accepted
  - n_TOF : (n,γ) at 185 m
  - GELINA:
    $^{92}Zr(n,\gamma)$ at 30 m
    $^{92}Zr(n,tot)$ at 50 m





European Commission

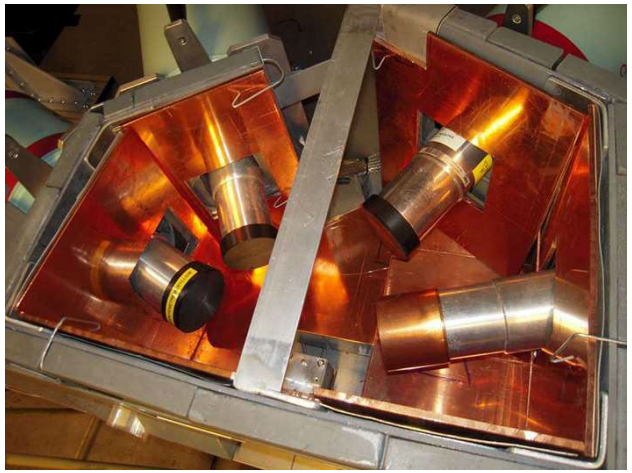
GELINA – GRAPhEME (Germanium array for actinides precise measurements)

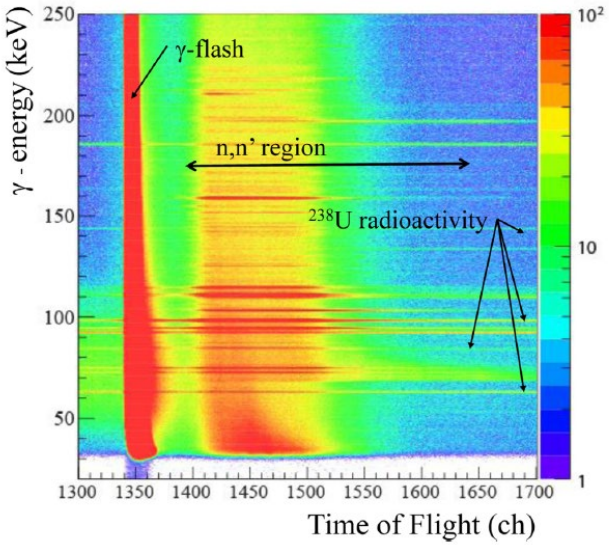
Kerveno et al., Phys. Rev. C 104 (2021) 044605

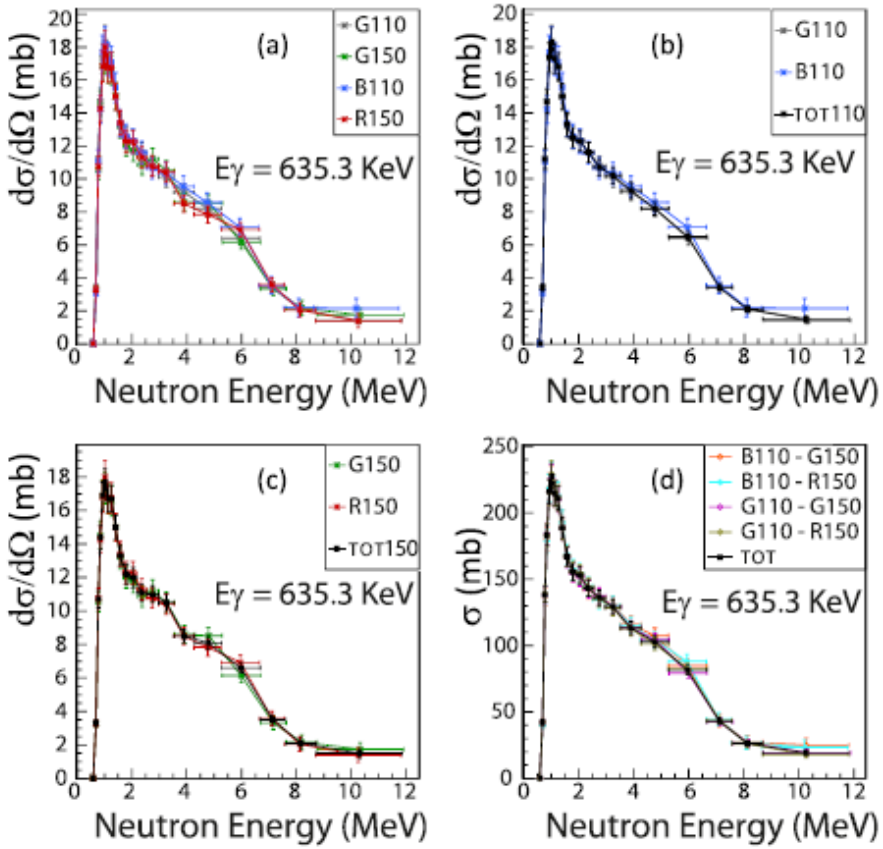
^{238}U(n,n'γ): **γ-ray production cross sections** at L = 30 m

Collaboration CNRS - JRC

- 5 planar HPGe detectors (1 segmented)
- Fluence rate measurements (IC): ^{235}U(n,f)

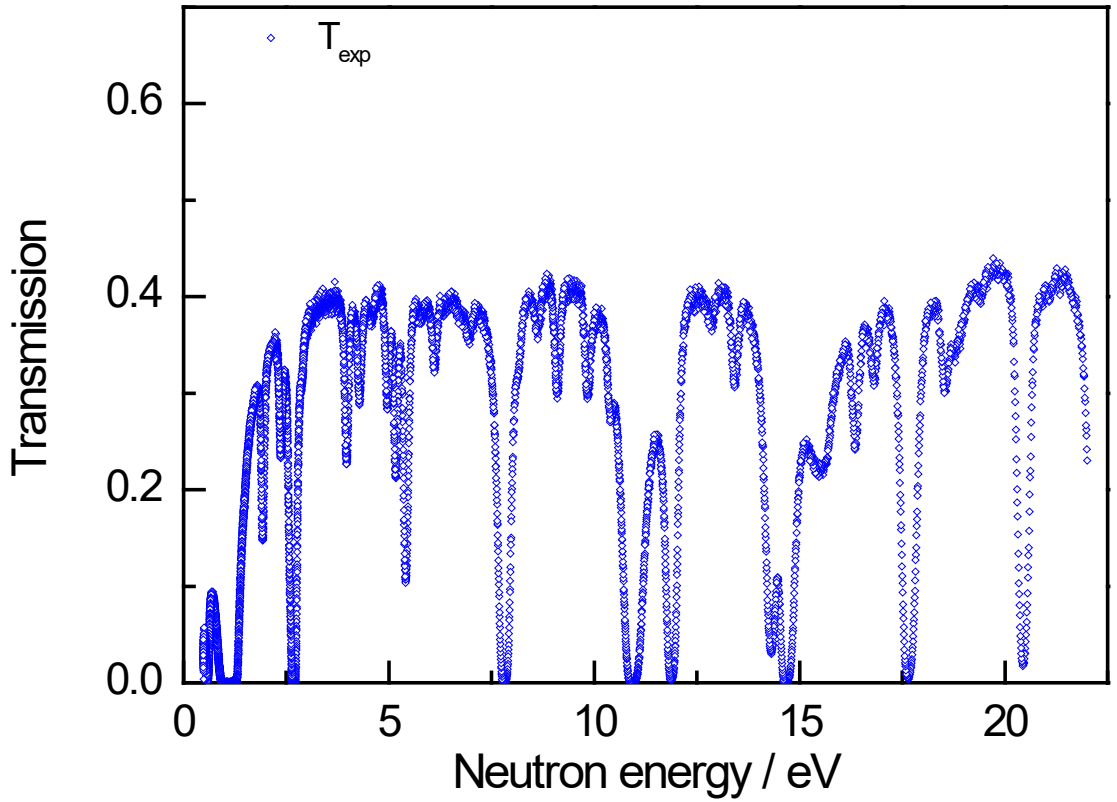


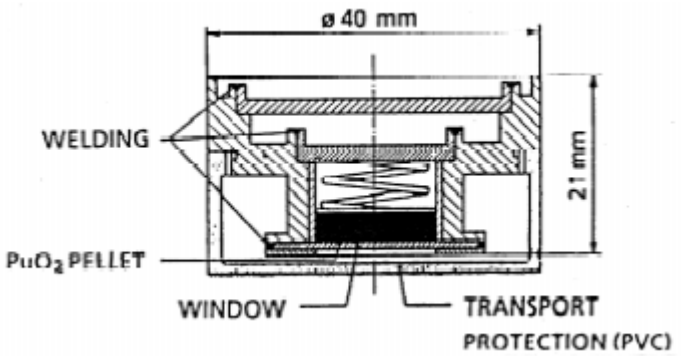




European Commission

NRTA of PuO_2 sample at GELINA (CBNM – 271)





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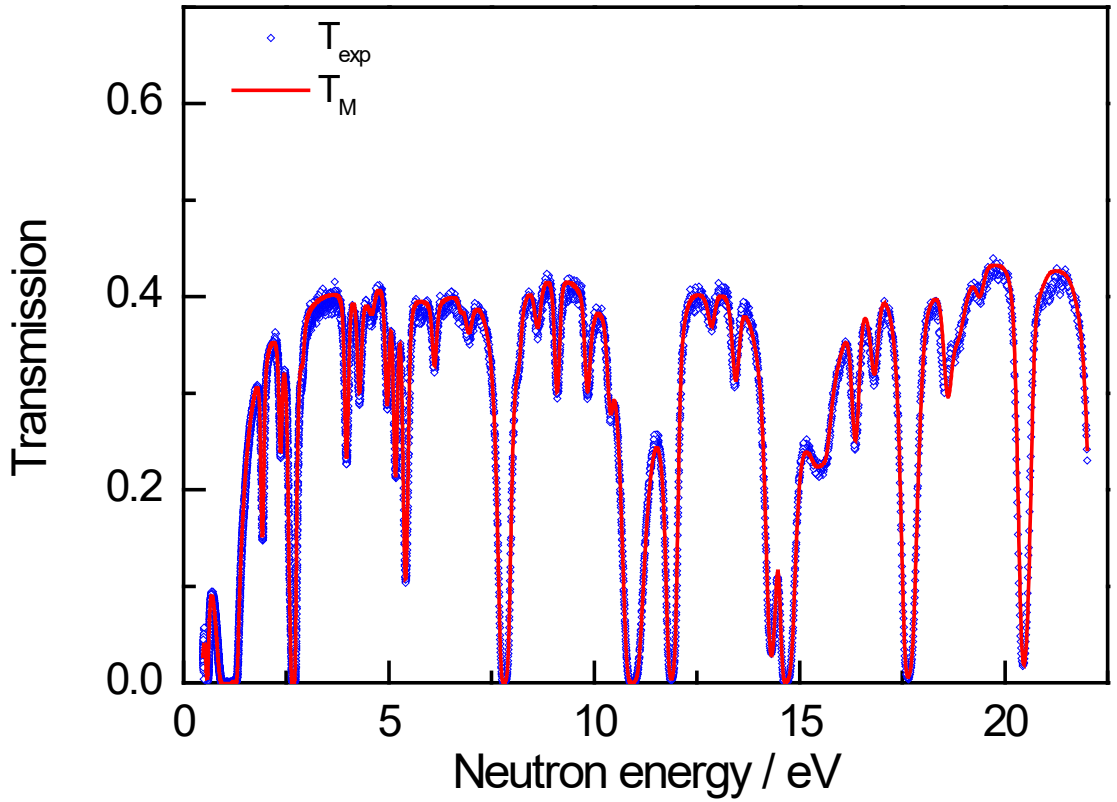

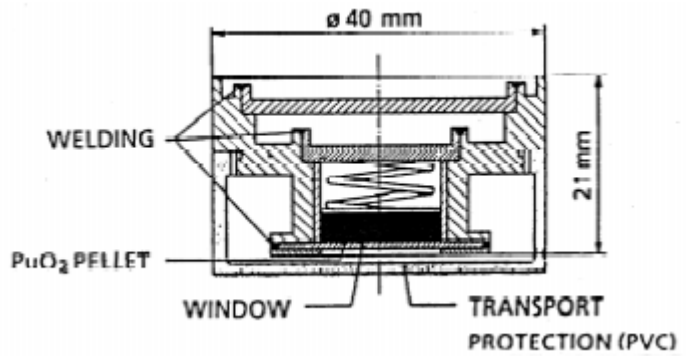

REFIT

$$T_M(t_m, n) = \int R(t_m, E)\, e^{-n\,\sigma_{tot}(E)} dE$$

$$\chi^2(n) = \left(T_{exp} - T_M(t_m, n)\right)^T V_{T_{exp}}^{-1} \left(T_{exp} - T_M(t_m, n)\right)$$

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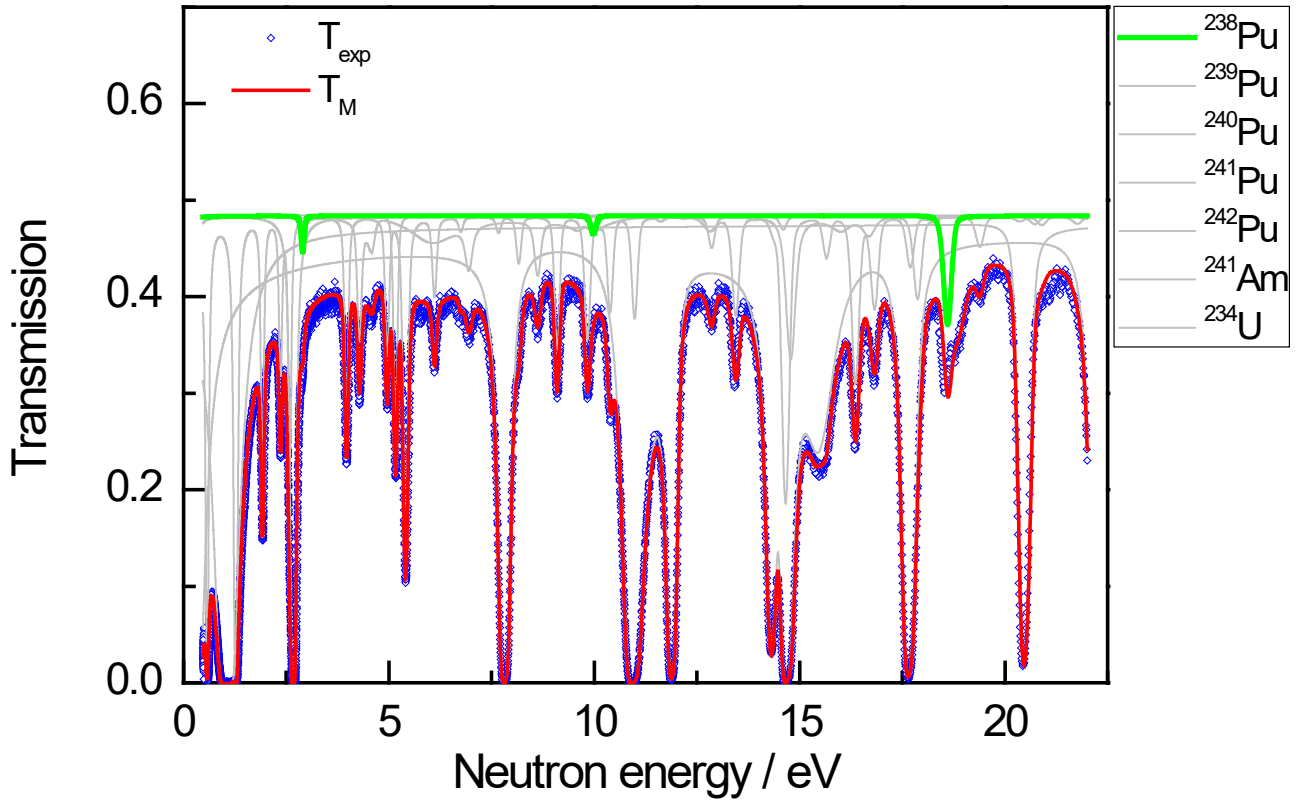

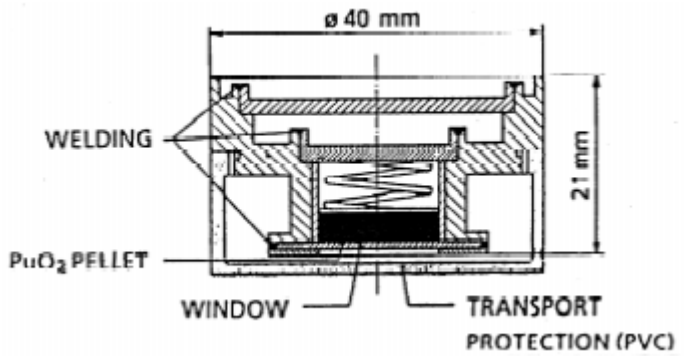

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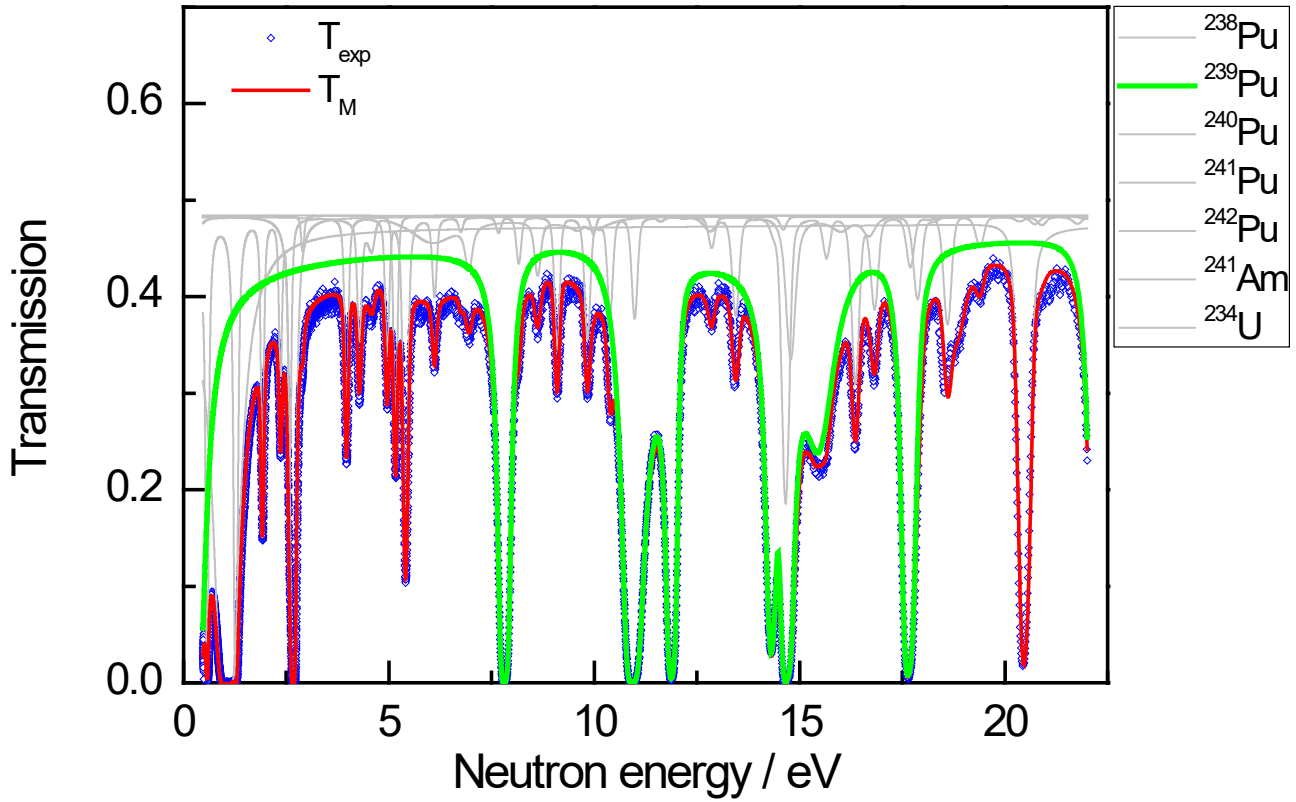

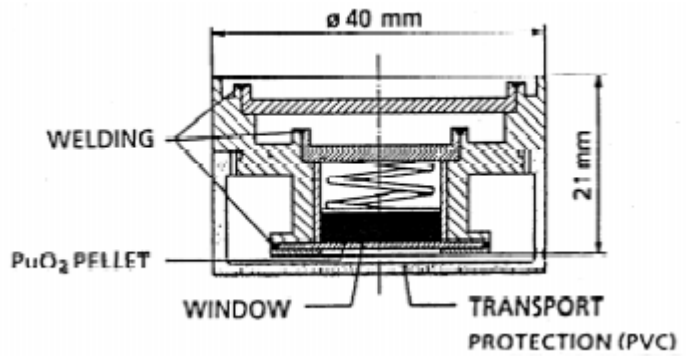

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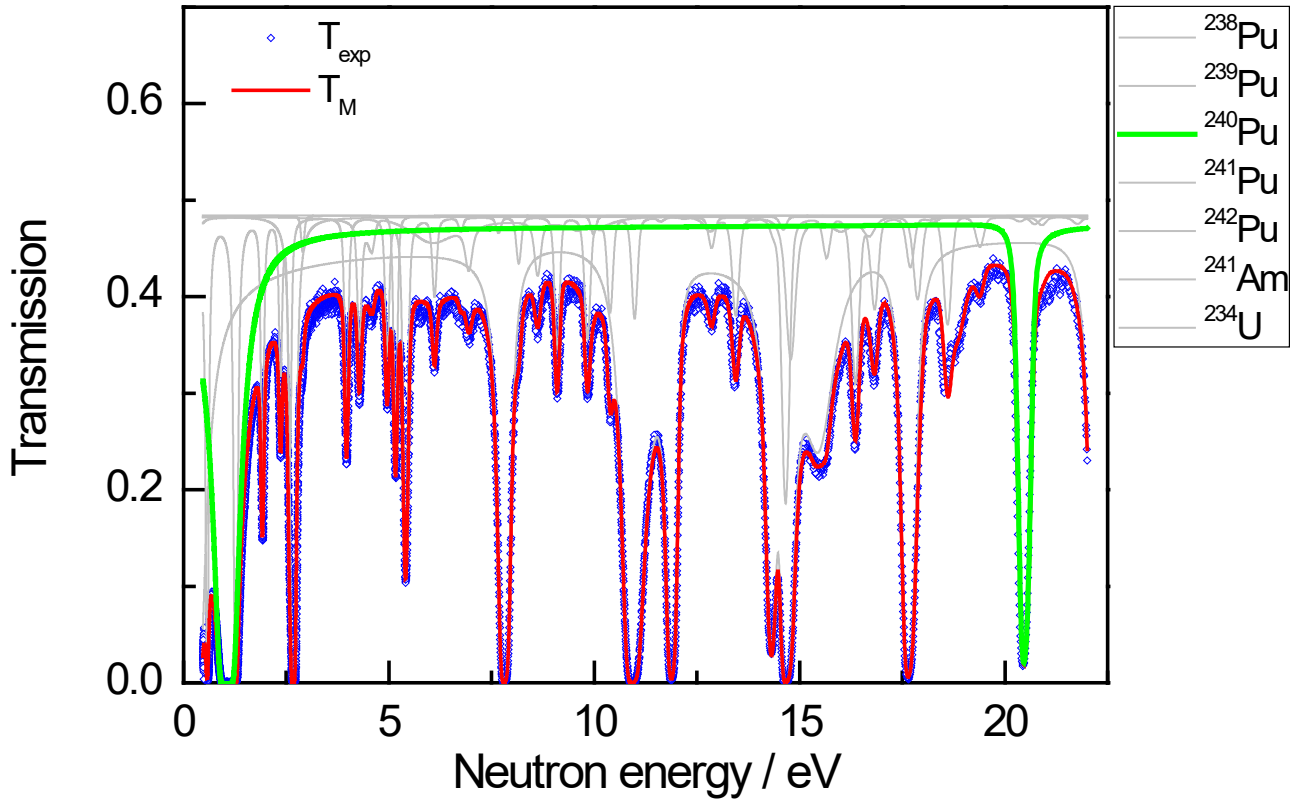

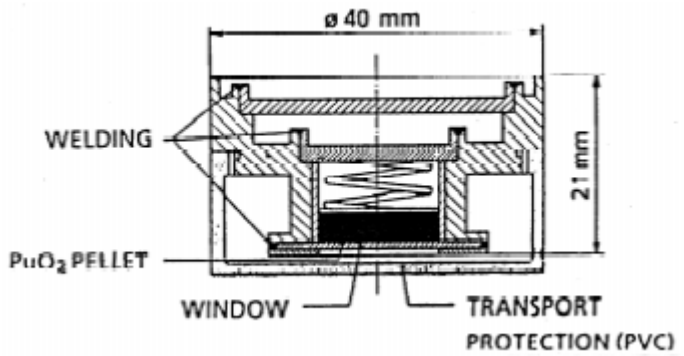

European Commission

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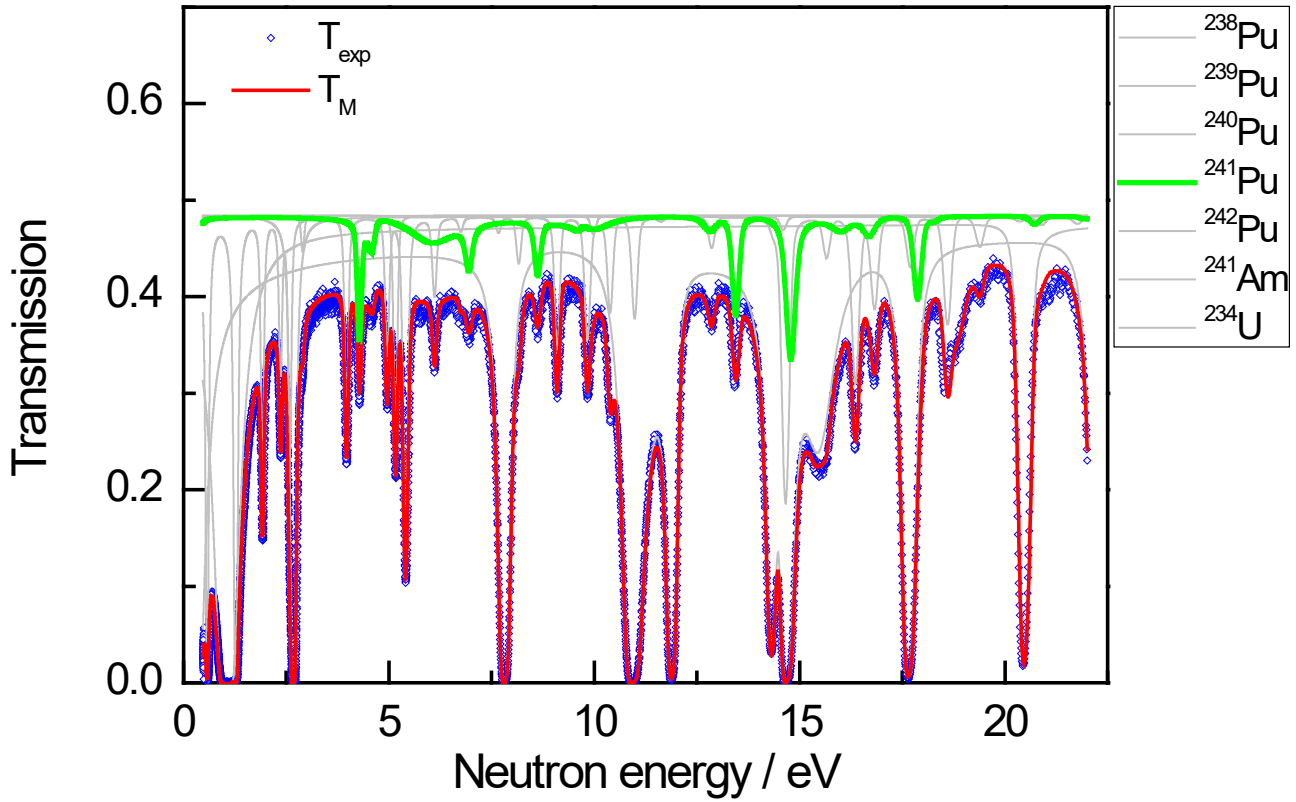

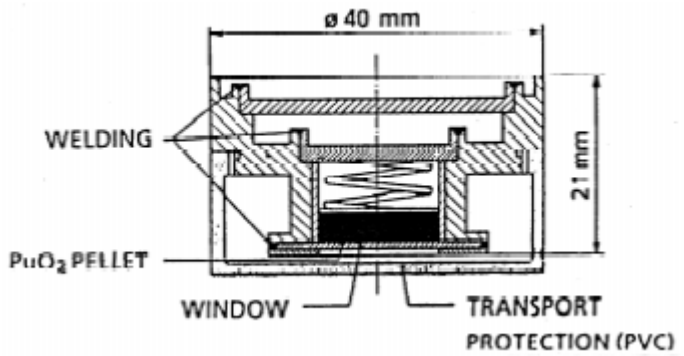

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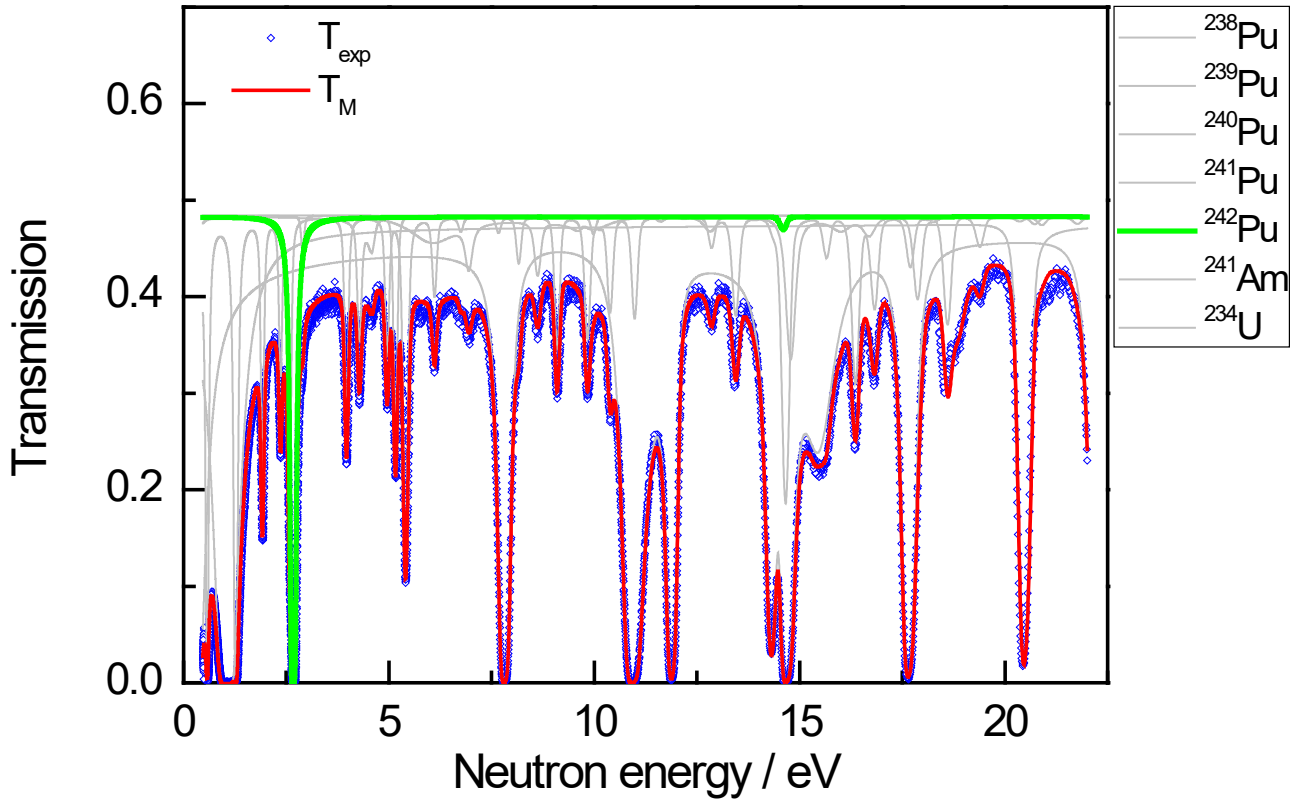

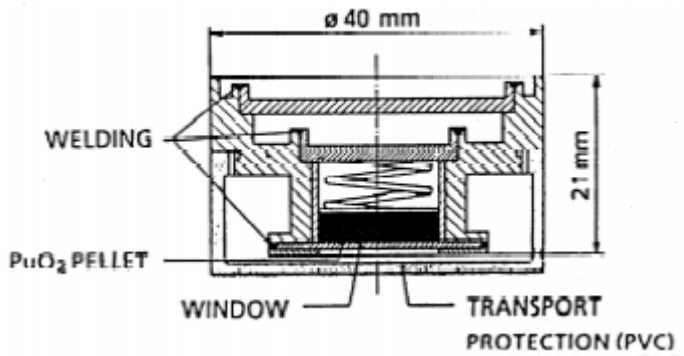

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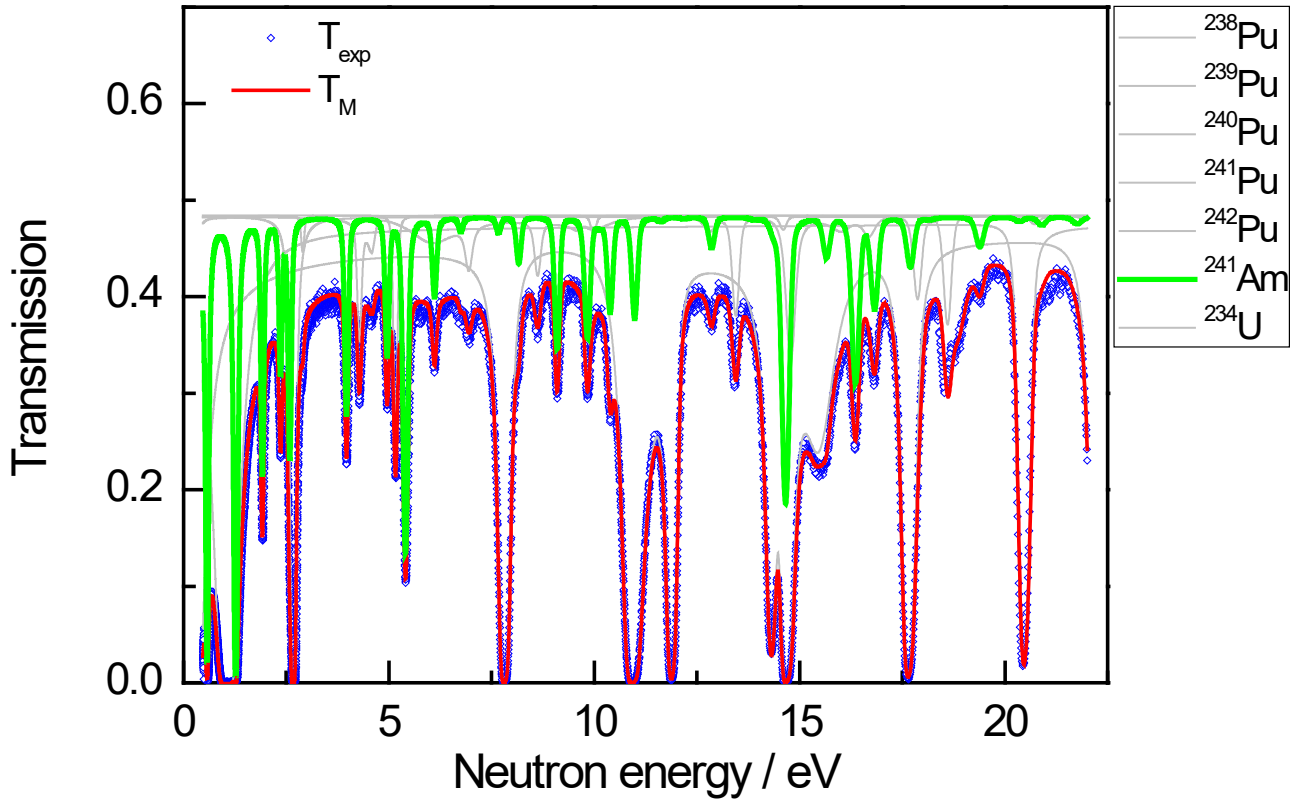
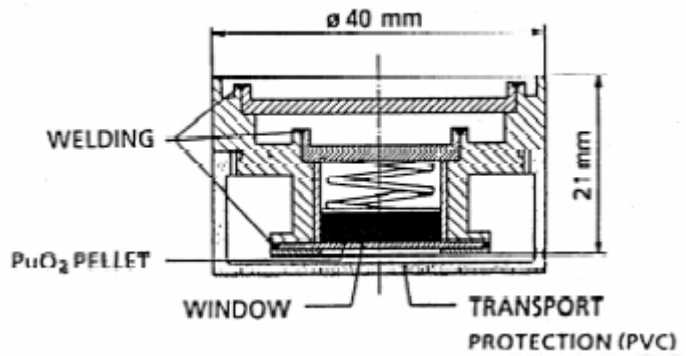
NRTA of PuO_2 sample at GELINA (CBNM – 271)





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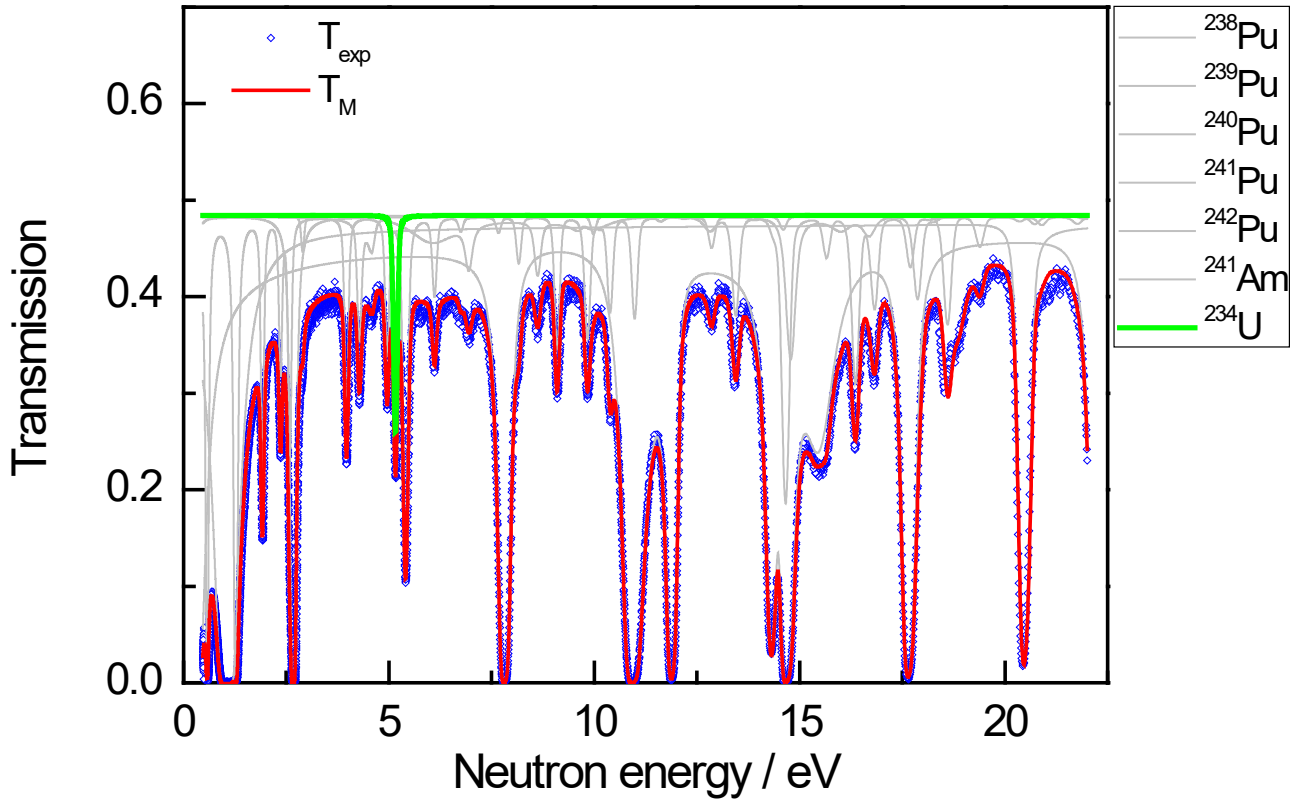
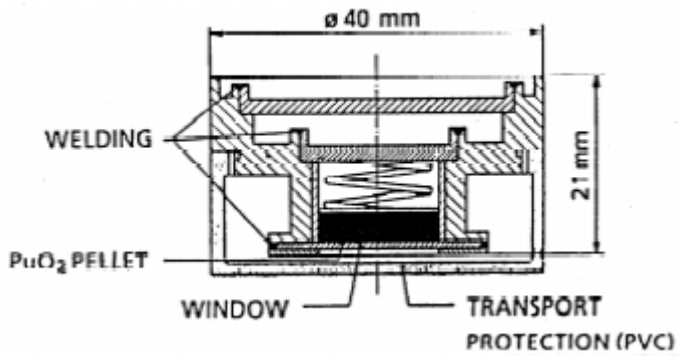
NRTA of PuO_2 sample at GELINA (CBNM – 271)





NRTA of PuO_2 sample at GELINA (CBNM – 271)

Nuclide	n_{REF}		n_{NRTA}				n_{NRTA} / n_{REF}			
			ENDF/B-VIII.0		JEFF-3.2		ENDF/B-VIII.0		JEFF-3.2	
^{238}Pu	0.009514	(20)	0.00783	(70)	0.00898	(70)	0.823	(74)	0.944	(74)
^{239}Pu	0.62603	(28)	0.62154	(90)	0.61530	(95)	0.9928	(14)	0.9829	(15)
^{240}Pu	0.25273	(24)	0.25699	(36)	0.26240	(32)	1.0169	(14)	1.0383	(13)
^{241}Pu	0.015697	(20)	0.01574	(10)	0.01577	(10)	1.0028	(64)	1.0045	(65)
^{242}Pu	0.041489	(60)	0.04334	(10)	0.04300	(10)	1.0447	(25)	1.0365	(24)
^{241}Am	0.06290	(63)	0.07236	(21)	0.06059	(20)	1.1503	(33)	0.9633	(32)
^{234}U	0.002918	(10)	0.00289	(10)	0.00287	(10)	0.989	(34)	0.982	(35)

n: atomic abundance relative to total Pu

NRTA uncertainties only due to counting statistics

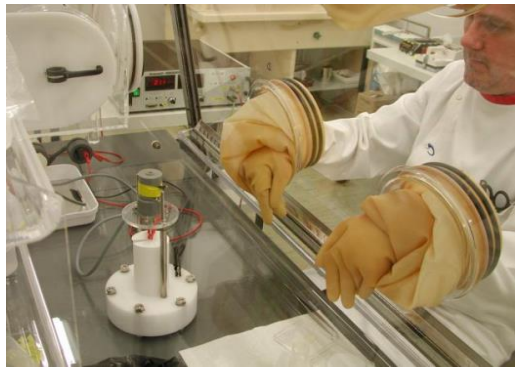
Planned activities of interest for NCS

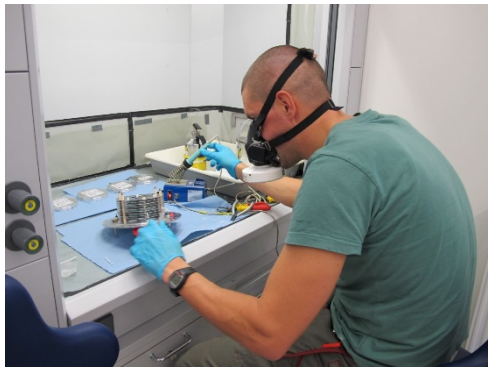
- ^{239}Pu + n
  - (n,n' γ) at GRAPhEME (CNRS)
  - (n,f) at GELINA (CIEMAT, Univ. Lodz)
  - (n,f) and (n,γ) at n_TOF

- ^{94,95,96,nat}Mo + n (INFN)
  - (n,tot) and (n,γ) at GELINA
  - (n,γ) at n_TOF

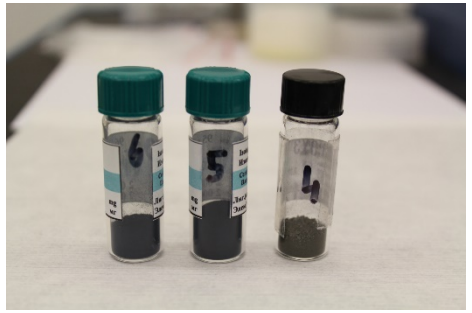
Targets prepared and characterised at JRC - Geel

^{239}Pu targets by electrodeposition





^{94,95,96,nat}Mo targets by pressing



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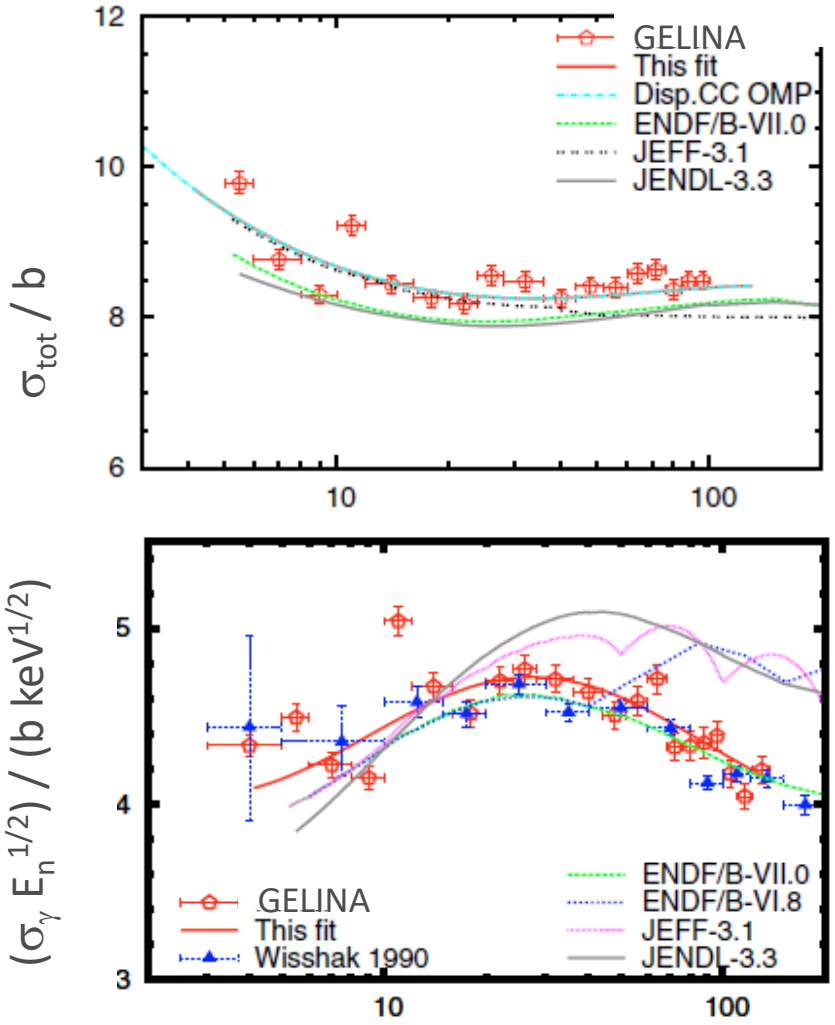
Planned activities of interest for NCS

- ^{103}Rh + n new evaluation in RRR and URR collaboration IRSN - JRC - IFIN/HH - INRNE
  - RRR

    CEA Saclay : (n,tot)
    GELINA : (n,tot) + (n,γ)
  - URR: methodology applied for ^{197}Au, ^{232}Th and ^{238}U

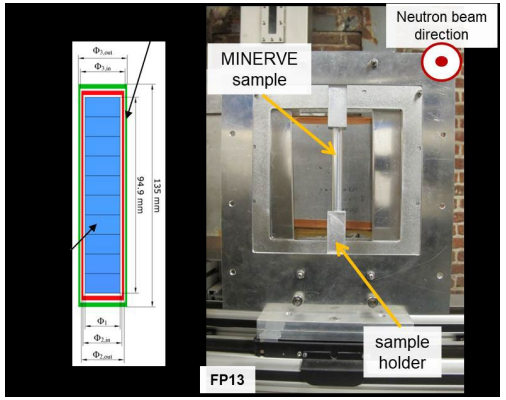
    HF + WF with link to OM transmission coefficients and phase shifts
    (see e.g. Sirakov et al., Eur. Phys. J. A. 53 (2017) 199)
- ^{238}U + n: review evaluation in RRR (CEA Cadarache)
  - (n,tot) at ORNL (Olsen et al. and Harvey et al.)
  - (n,γ) at GELINA and n_TOF

^{103}Rh + n

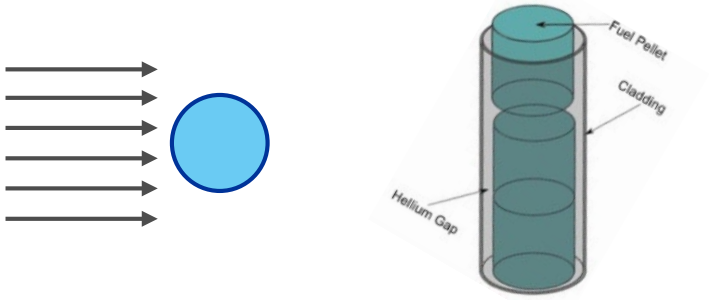


European Commission

Planned activities of interest for NCS



- NRTA of MINERVE pellet samples at GELINA
  (part of MAESRTRO)
  - Identification and quantification of impurities
  - Validation of resonance parameters of fission products
- Data analysis: improved transmission model in REFIT



$$T(E) = f_h + (1 - f_h) \int_0^1 \frac{x}{\sqrt{1 - x^2}} e^{-\rho \sigma_{tot}(E)\, 2Rx}\, dx$$

Fei Ma et al., J. Anal. At. Spectrom. 35 (2020) 478

Program	Sample	Dopant	Sample name	Dimensions
CBU	UO2-nat	Sm149	Sm9	10,6 x 101,5
CBU	UO2-nat	Sm147	Sm7	10,6 x 101,5
CBU	UO2-nat	Sm152	Sm2	10,6 x 101,5
CBU	UO2-nat	Sm	Sm	10,6 x 101,5
CBU	UO2-nat	Nd143	Nd3	10,6 x 101,5
CBU	UO2-nat	Nd145	Nd5	10,6 x 101,5
CBU	UO2-nat	Nd	Nd	10,6 x 101,5
CBU	UO2-nat	Cs133	CsC2	10,6 x 101,5
CBU	UO2-nat	Rh103	RhC1	10,6 x 101,5
CBU	UO2-nat	Rh103	RhC2	10,6 x 101,5
OCEAN	UO2-nat	Dummy fritté	UO2/O	10,6 x 101,5
OCEAN	UO2-nat	Eu151	Eu151	10,6 x 101,5
OCEAN	UO2-nat	Eu153	Eu153	10,6 x 101,5
OCEAN	UO2-nat	Hf180	Hf0	10,6 x 101,5
OCEAN	UO2-nat	Dy160	Dy0	10,6 x 101,5
OCEAN	UO2-nat	Dy161	Dy1	10,6 x 101,5
OCEAN	UO2-nat	Dy162	Dy2	10,6 x 101,5
OCEAN	UO2-nat	Dy163	Dy3	10,6 x 101,5
OCEAN	UO2-nat	Dy164	Dy4	10,6 x 101,5
OCEAN	UO2-nat	Er168	Er8	10,6 x 101,5
OCEAN	UO2-nat	Er170	Er0	10,6 x 101,5

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ORNL (US)

J. Brown, K. Guber, M. Pigni

NCSP for the Uranium target