Nuclear research activities and open access program at JRC-Geel

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European Nuclear Physics Conference 2022

European Commission
Joint Research Centre

Joint Research Centre (JRC)

JRC

Policy neutral: has no policy agenda of its own

More than **50 large scale research facilities**
More than **110 online databases**

About **2 800 staff,** nearly **70 %** of whom are **scientific/technical staff**

83 % of core **research staff with PhDs**

Over **1 400 scientific publications per year**

European Commission

JRC sites

Headquarters in **Brussels** and research facilities located in **5 Member States:**

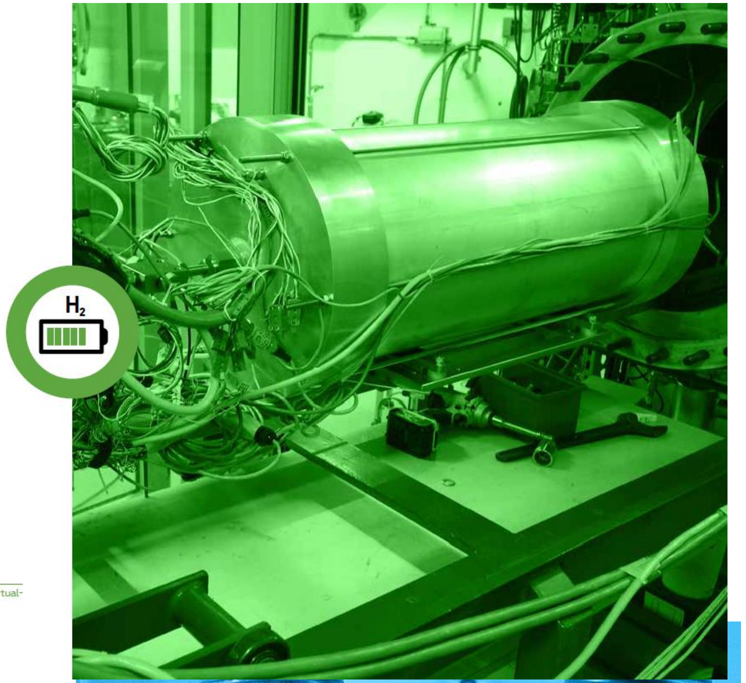
- Belgium (Geel)
- Germany (Karlsruhe)
- Italy (Ispra)
- The Netherlands (Petten)
- Spain (Seville)

European Commission

JRC research infrastructures

The JRC maintains 39 physical research infrastructures (RI) suitable for opening access to external users in the nuclear and radiological (Euratom Laboratories) fields, chemistry, biosciences/life sciences, physical sciences and ICT

JRC opens RI to Academia and SME in areas relevant to JRC’s strategic priorities (relevance driven mode)



JRC nuclear facilities under open access program

- Actinide User Laboratory (ActUsLab) in Karlsruhe
- Laboratory of the Environmental & Mechanical Materials Assessment (EMMA) in Petten
- European research infrastructure for nuclear reaction, radioactivity, radiation and technology studies in science and applications (EUFRAT) in Geel

European Commission

EUFRAT Open Access

Benefits of EUFRAT users for relevance driven mode

- Access to nuclear research facilities granted free of charge
- In-house JRC systems ready to use
- Local staff support in experiment design and setup
- Financial support to users for short term and long term visits
- Contribution to educational purposes, through training, data dissemination and strengthen collaborations at EU level

https://ec.europa.eu/jrc/en/research-facility/open-access

European Commission

JRC-Geel open access facilities

GELINA
150 MeV pulsed linear electron accelerator associated with a neutron time-of-flight facility for high-resolution measurements

MONNET
3.5 MeV tandem accelerator for high-intensity quasi mono-energetic neutron beams

TARGET
nuclear target preparation laboratories

RADMET
Radionuclide metrology laboratory with a wide range of detectors for measuring radioactivity

HADES
225 m deep underground laboratory for detection of low-level activities (sub mBq)

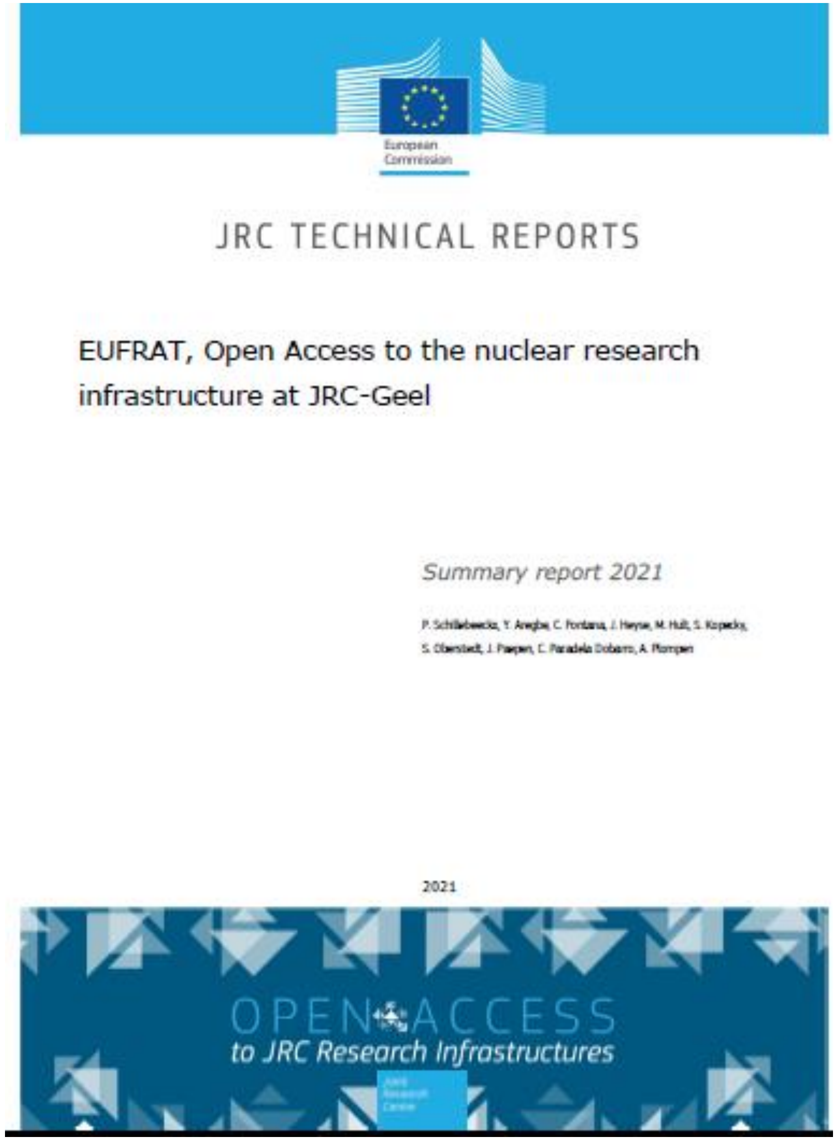
EUFRAT Open Access Eligibility

- User institutions from an EU MS, candidate or associated to EURATOM Research Programme
- Lead User Institution must be from a university, research or public institution, or a Small-Medium-Enterprise.

Table 3 Number of eligible (E) and accepted (A) proposals for the EUFRAT open access calls in 2017, 2018, 2019, 2020 and 2021.

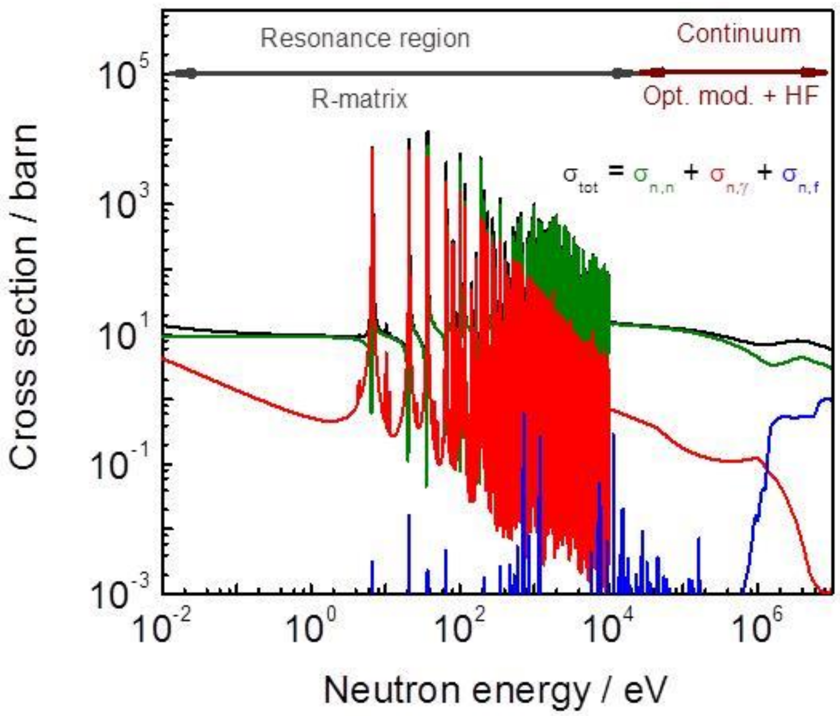
Year		GELINA	MONNET	HADES	RADMET	Total
2017	E	10	1	4	2	17
	A	8	1	4	2	15
2018	E	4	3	4	2	13
	A	3	3	4	2	12
2019	E	6		4		10
	A	6		4		10
2020	E	8	7	2	1	18
	A	8	7	2	1	18
2021	E	8	1		1	10
	A	7	1		1	9

64 accepted proposals



European Commission

Neutron interaction cross sections



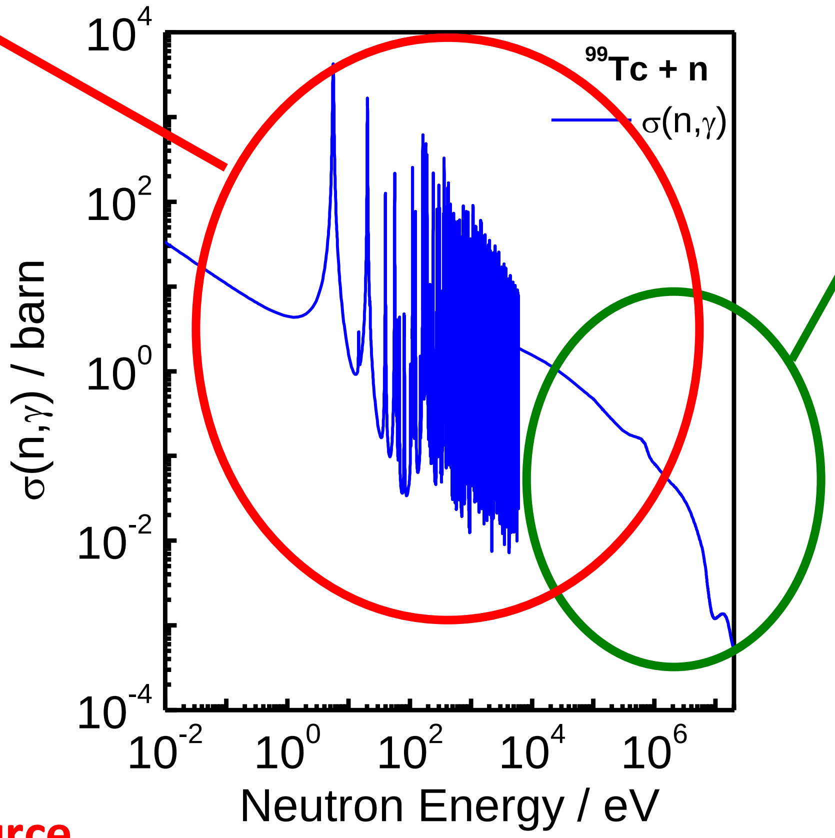
- Cross sections **cannot be predicted** by nuclear theory from first principles
- Cross sections **can be parametrized** by nuclear reaction theory (formalisms)
- Model parameters are **adjusted to experimental data**

$\Rightarrow$ **Experimental data are required**

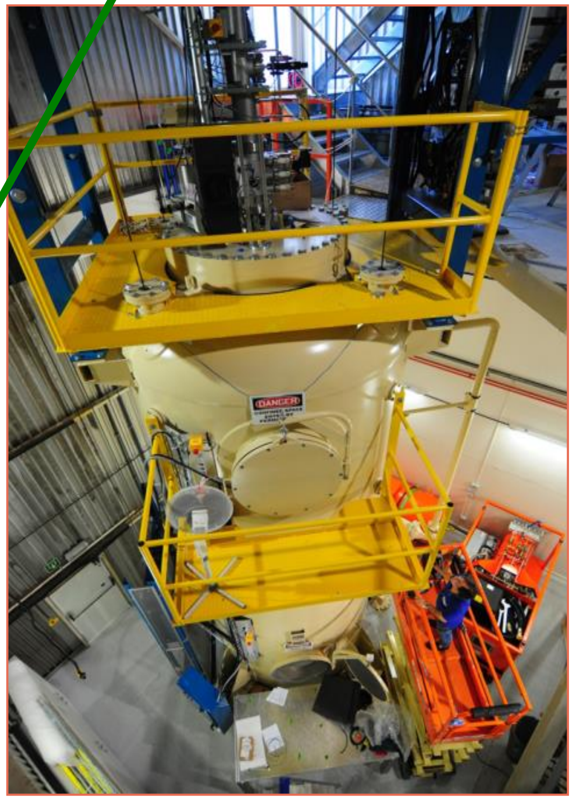
JRC - Geel Neutron facilities

GELINA

$^{99}Tc(n,\gamma)$ cross section



MONNET

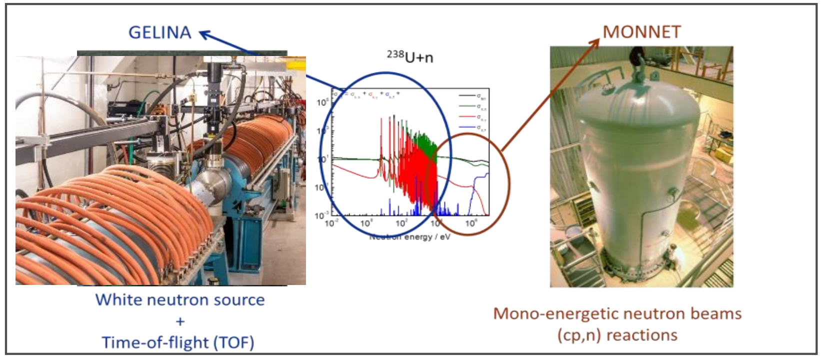


Pulsed white neutron source
+
Time-of-flight (TOF)

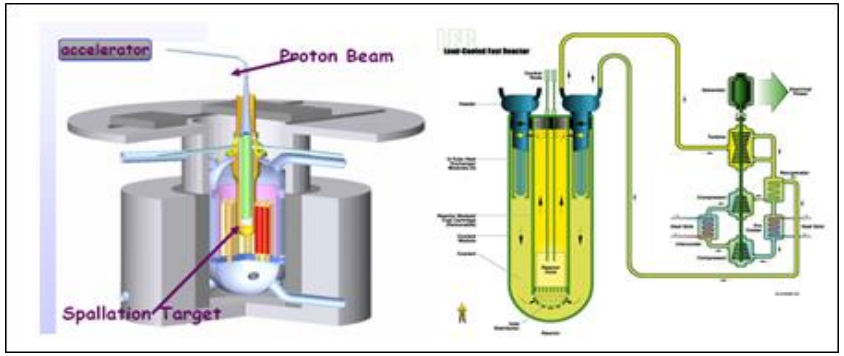
Quasi mono-energetic neutrons through (cp,n) reactions

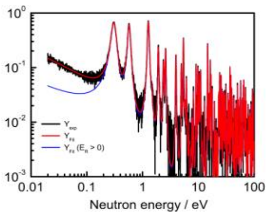
Nuclear data libraries for nuclear applications

NEA/OECD High Priority Request List
IAEA Coordinated Research Projects



New needs & Feedback





Microscopic data

Theory

Evaluation

Validation & Testing

Integral data

Evaluated Data Library

Industry

Regulatory bodies

Research & Development

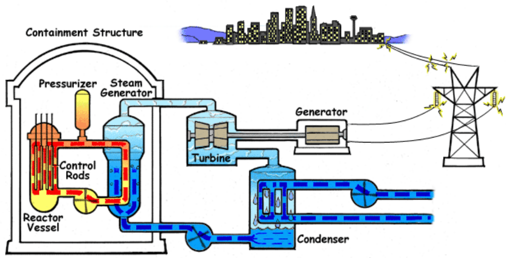
EXFOR library of experimental data

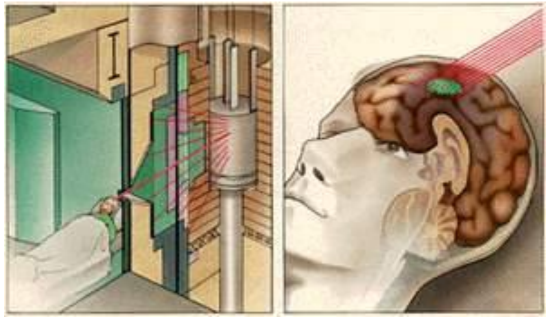
CENDL, ENDF/B, JEFF, JENDL, ROSFOND
and **NDS/IAEA (standards)**

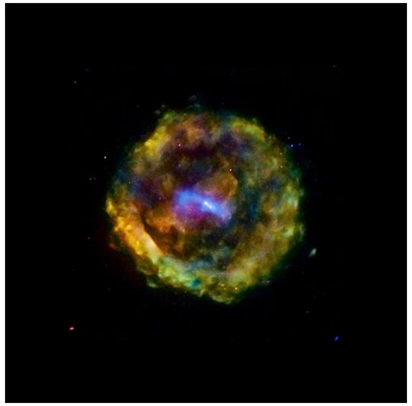
European Commission

Interest of neutron cross sections

- **Nuclear technology**
  - **Safety** assessment of existing nuclear systems
  - Development of innovative reactors (SMR, MYRRHA, etc.)
  - Storage, transport and final **disposal** of spent fuel
- **Nuclear medicine**
  - Radioactive isotopes for **imaging** and **therapy**
- **Nucleosynthesis**
  - *Understanding the **origin of nuclei** found in nature*
- **Nuclear astrophysics**
  - *Understanding nuclear processes in **stars** and in the **cosmos***
- **Neutron interrogation methods**
  - *Neutron activation analysis, neutron radiography, neutron resonance analysis…*







European Commission

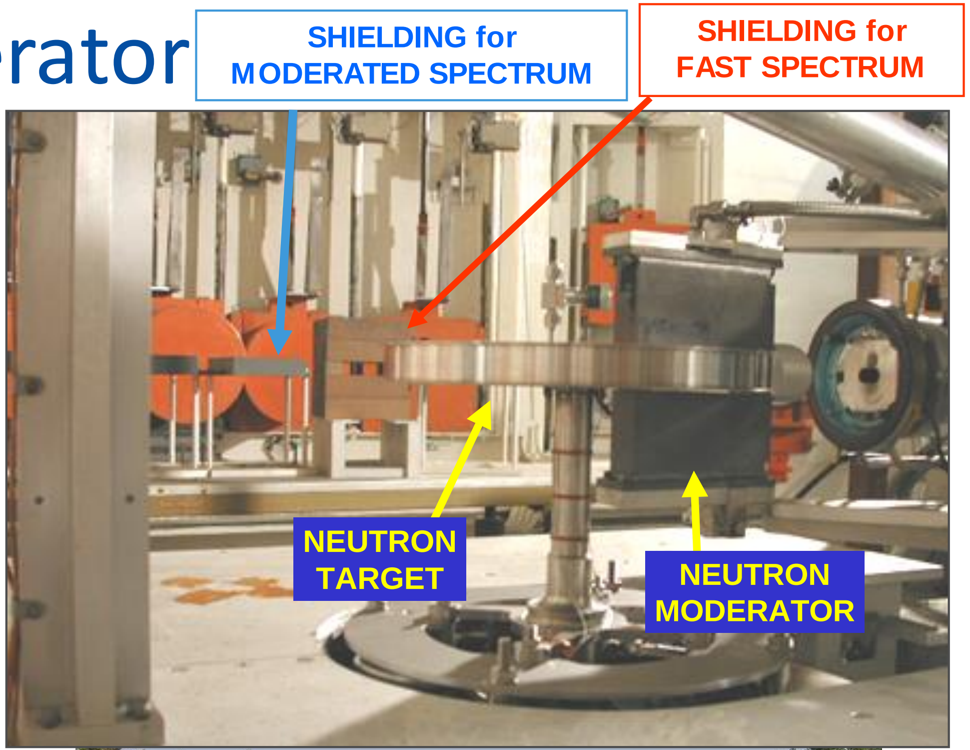
GELINA: **G**eel **E**lectron **LIN**ear **A**ccelerator

- **Electron linac** driven pulsed white neutron source
  (10 meV < En < 20 MeV)

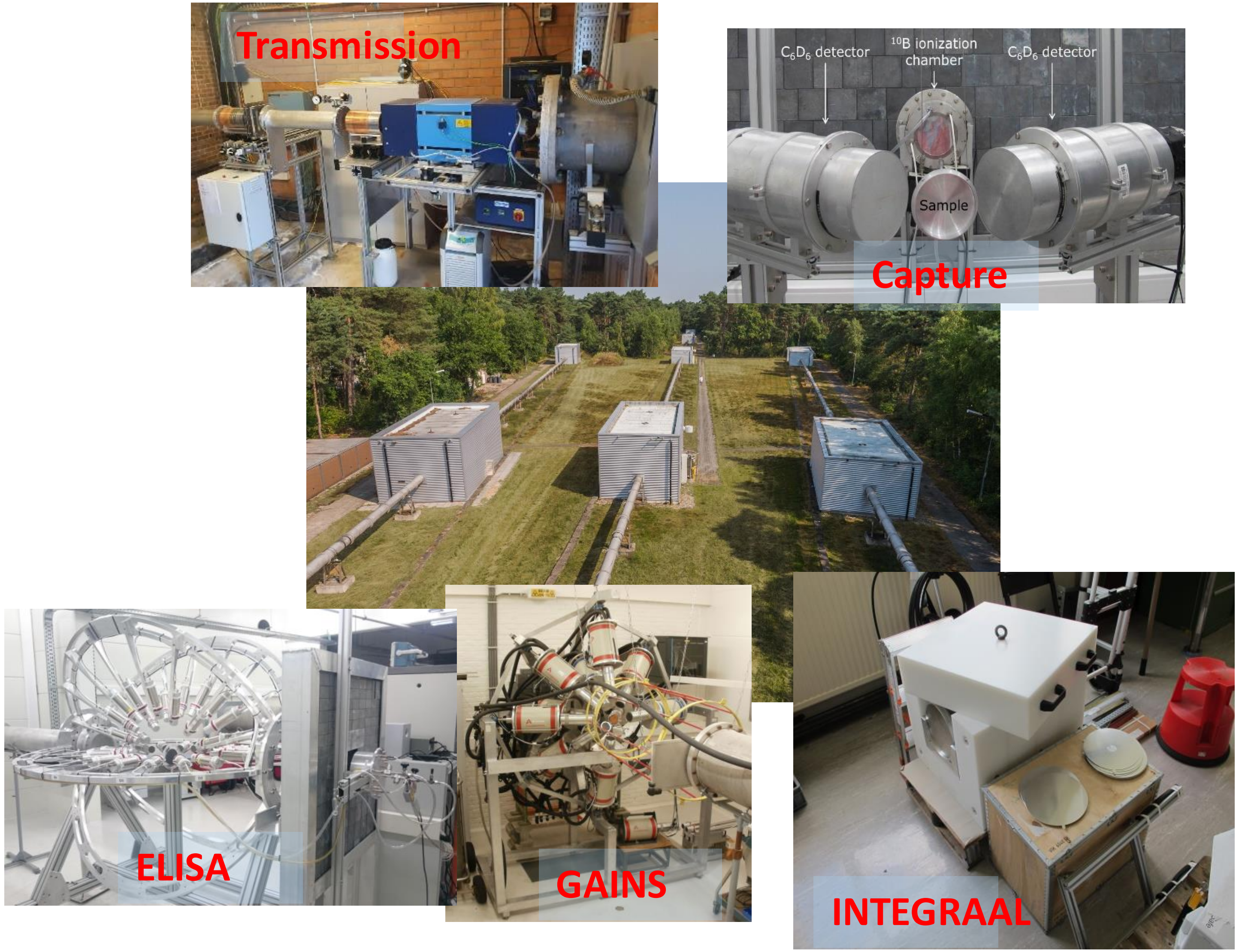
- Neutron energy : **time – of – flight** (TOF)

- **Multi-user facility**: 12 flight paths (10 m – 400 m)

- Measurement stations with **special equipment**:
  - Total cross section measurements
  - Partial cross section measurements



GELINA: Experimental set-ups



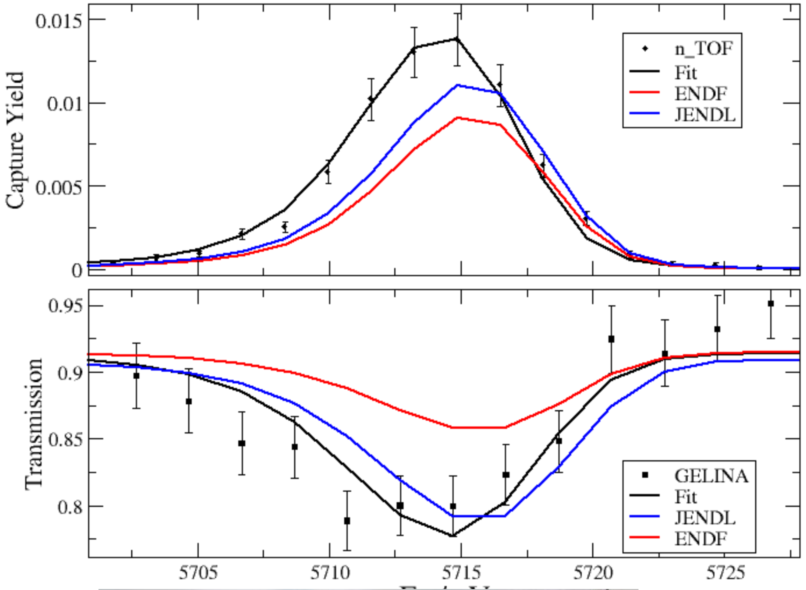
- Transmission
  - FP13-10 m, FP12-30 m, FP4-50 m
- Capture
  - FP5-10 m, FP15-30m, FP14-60 m
- Fission, (n,p), (n,α), …
  - FP2-10 m, FP17-10m
- Elastic, in-elastic scattering
  - FP1-30 m
- In-elastic scattering (n,n’γ)
  - FP16-30 m, FP3-100 m
- Target Hall

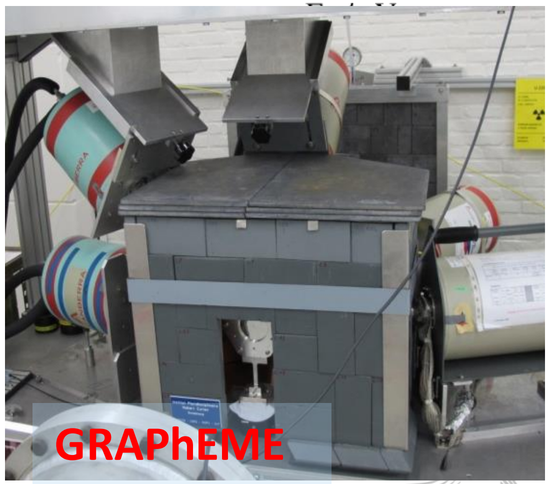
European Commission

GELINA Open Access Projects

Some EUFRAT projects at GELINA facility

- Bismuth_MYRRHA from SCK-CEN: Capture and transmission measurement for Bi at GELINA
- Y-XS from INFN and n_TOF Collaboration (see G. Tagliente's contribution on Wednesday 17:30 at Room 0)
- **MINERVE_NRTA from CEA: characterization of MINERVE samples by Neutron Resonance Transmission Analysis)**
- CHARPU: characterization of a new fission detector for ^{239}Pu(n,f) and α ratio at n_TOF (+target preparation)
- Punxn: ^{239}Pu(n,xn γ) with GRAPhEME setup from CNRS Strasbourg (+target preparation)
- **Oxygen_n_alpha : ^{16}O(n, α) cross section measurement from HZDR**

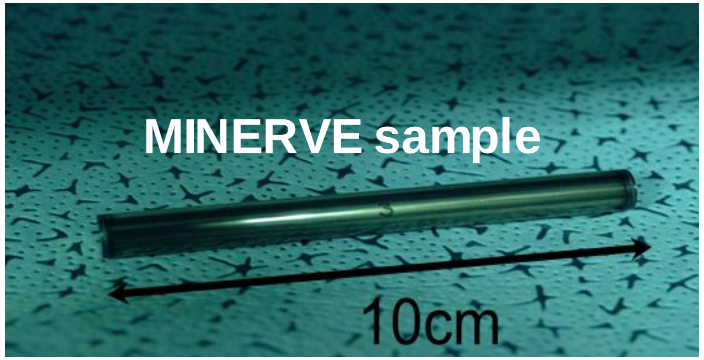


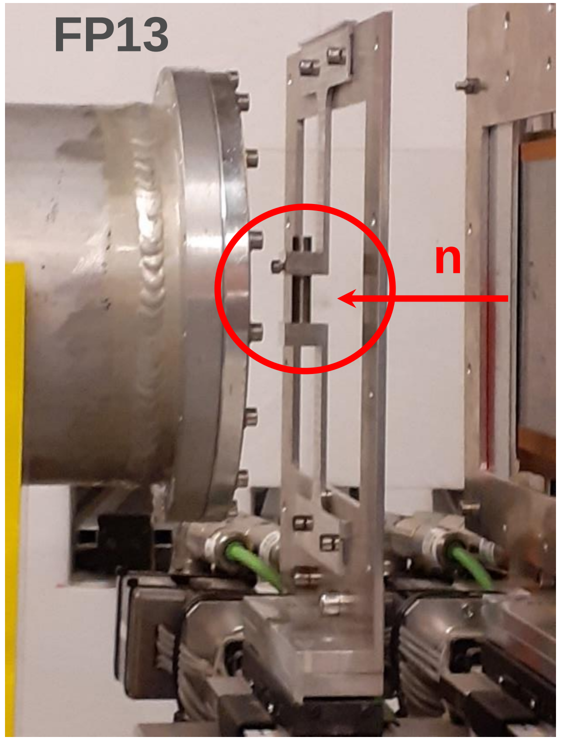


MINERVE_NRTA

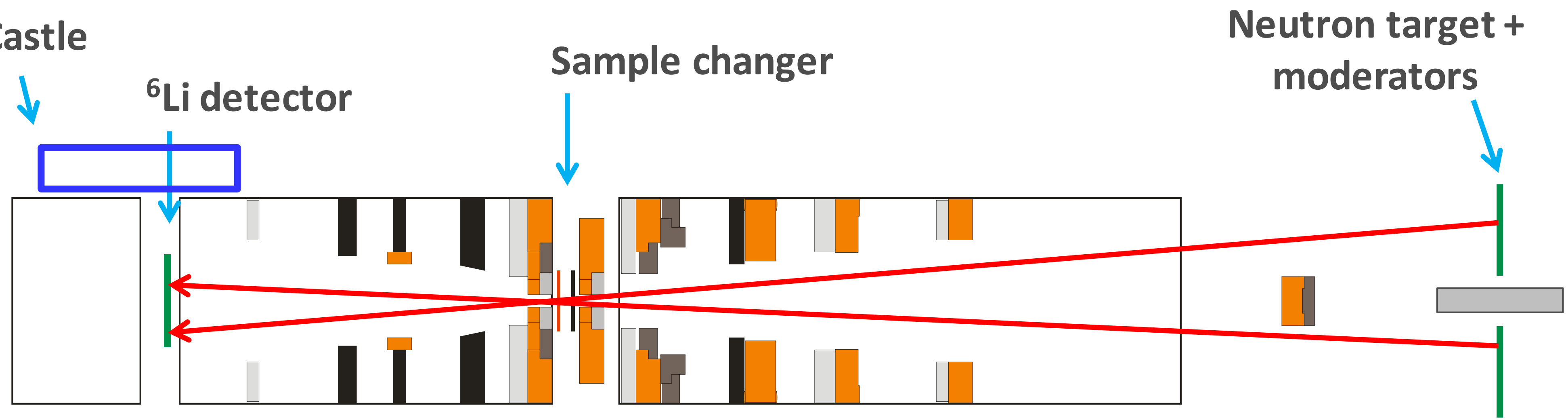
Characterization of samples used at MINERVE reactor by using Neutron Resonance Transmission Analysis

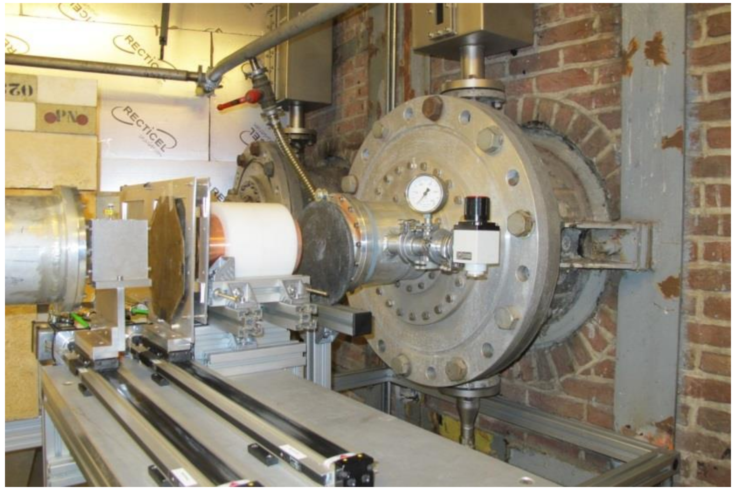
- MINERVE samples are cylindrical samples (4 or 10 cm height and about 1 cm diameter) containing different fission products in a UO_2 matrix
- EUFRAT proposal submitted in 2017 to study possible contamination in the samples and their quantification.
- Transmission measurements were performed at FP13-10 m station



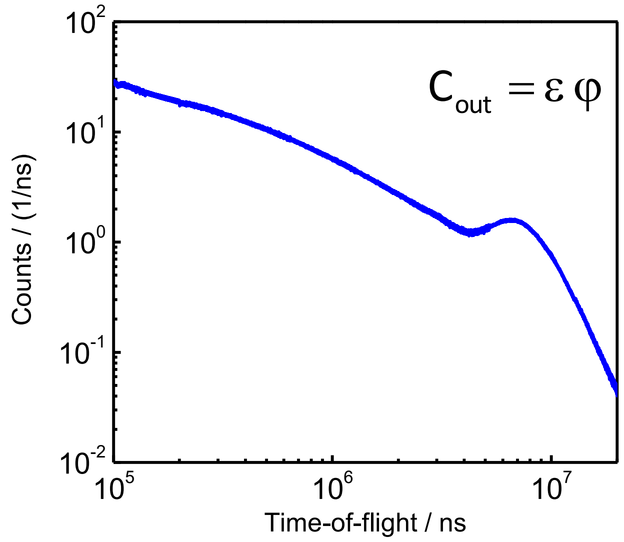


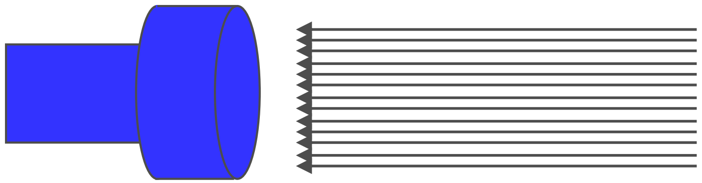
10 m flight path transmission station





Transmission measurements: σ_{tot}





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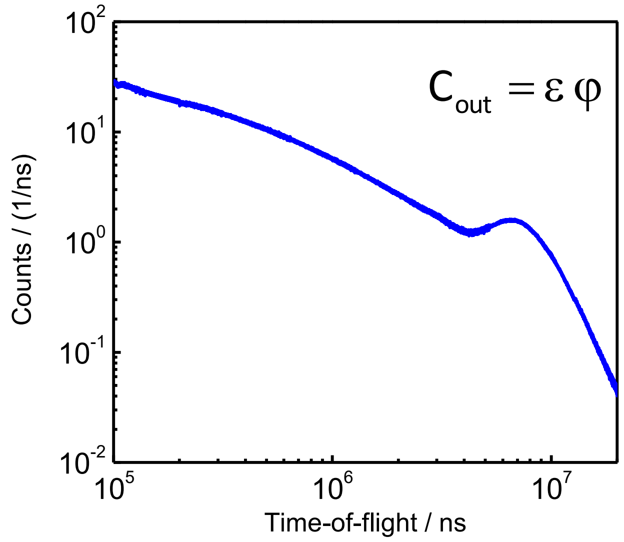

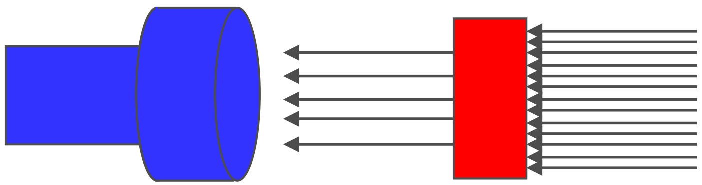

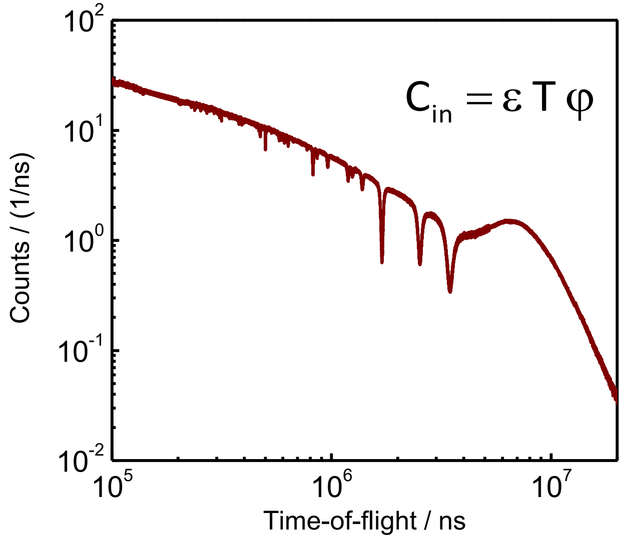

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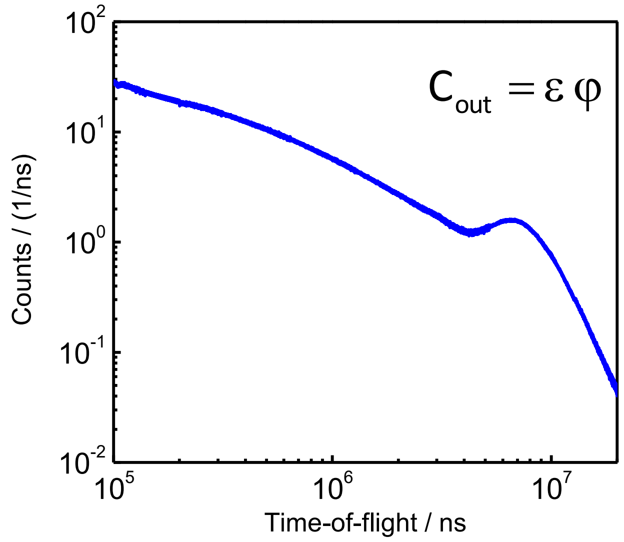
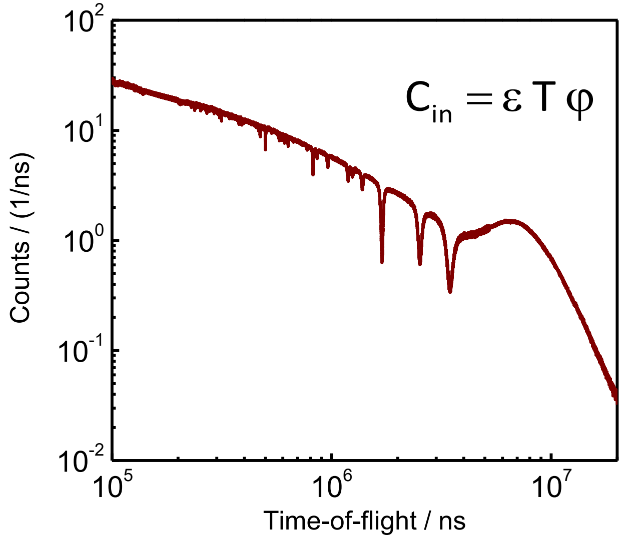
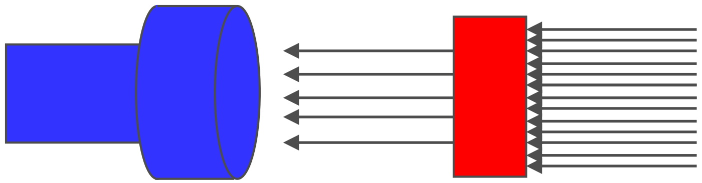
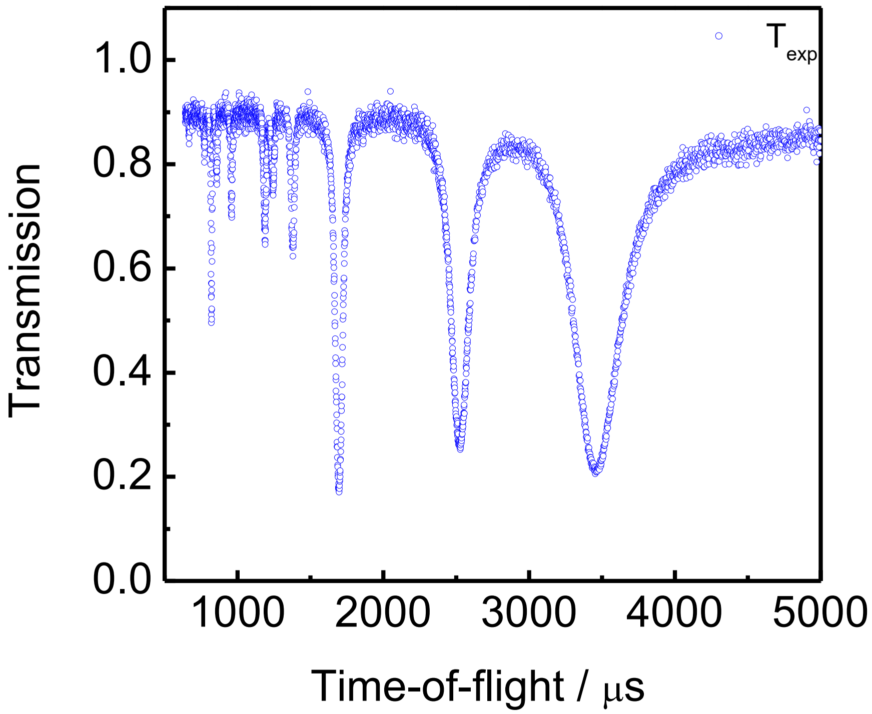


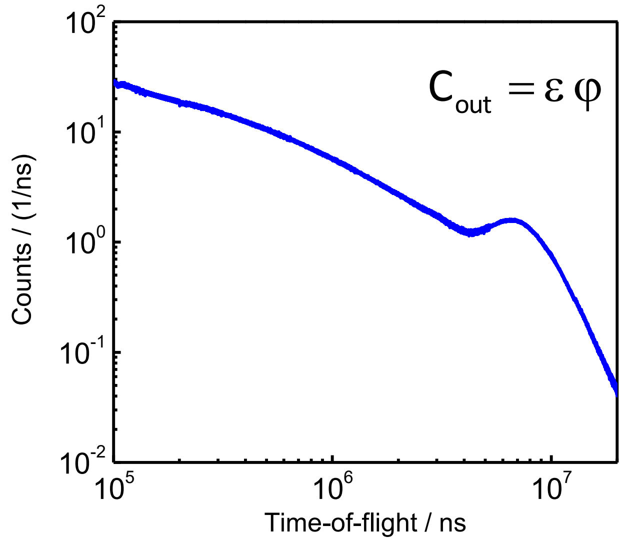


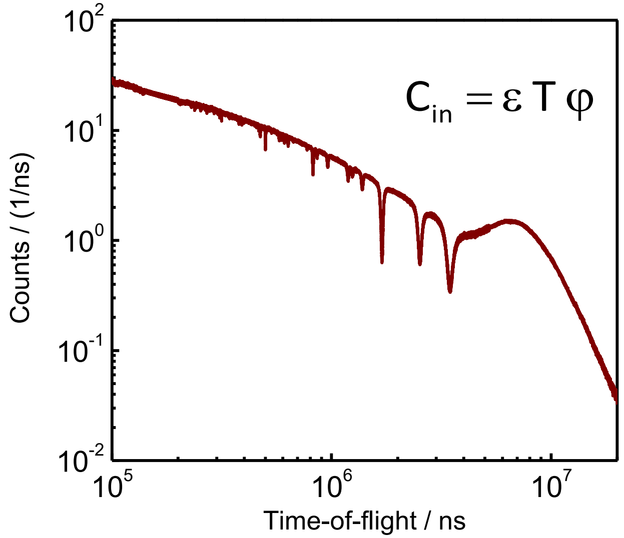
$$T_{exp} = \frac{C_{in}}{C_{out}}$$





Transmission measurements: σ_{tot}





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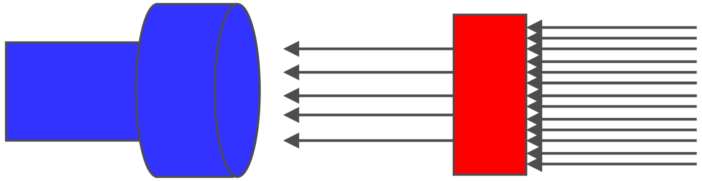


Total cross section

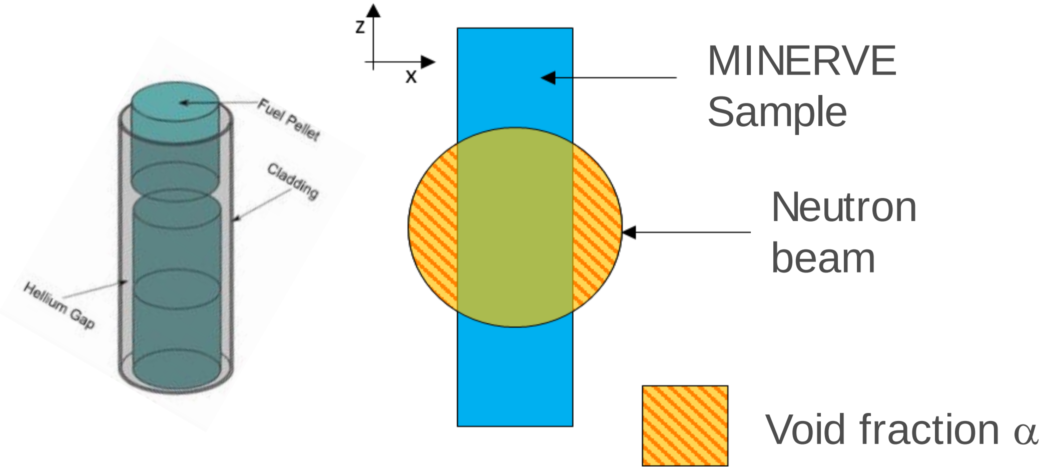
$$T \cong e^{-n\sigma_{tot}}$$

Well-characterised samples

n: areal density (total number of atoms per unit area) is well-known

accurate cross-sections can be determined

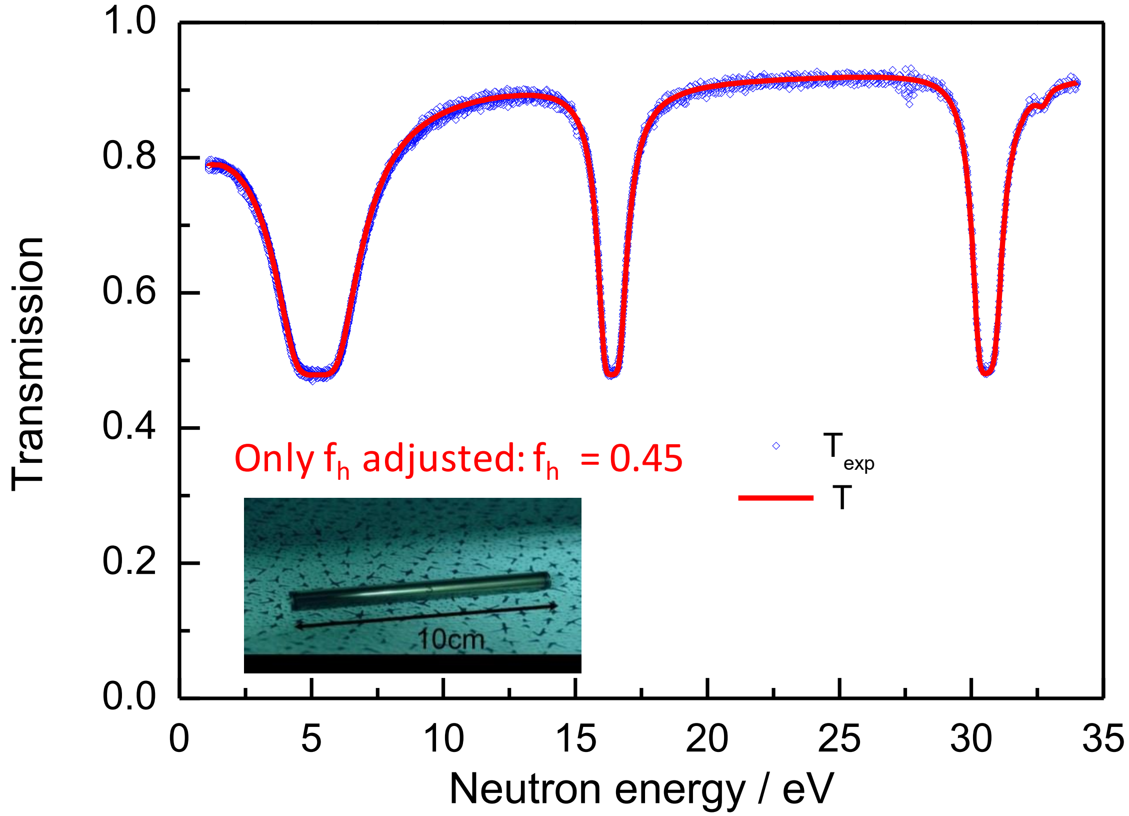
NRTA on pellet: dedicated model



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

- f_h : holes fraction
- ρ : number volume density
- x : track length (divided by 2R)
- R : radius

Implemented in Resonance Shape Analysis code (REFIT)

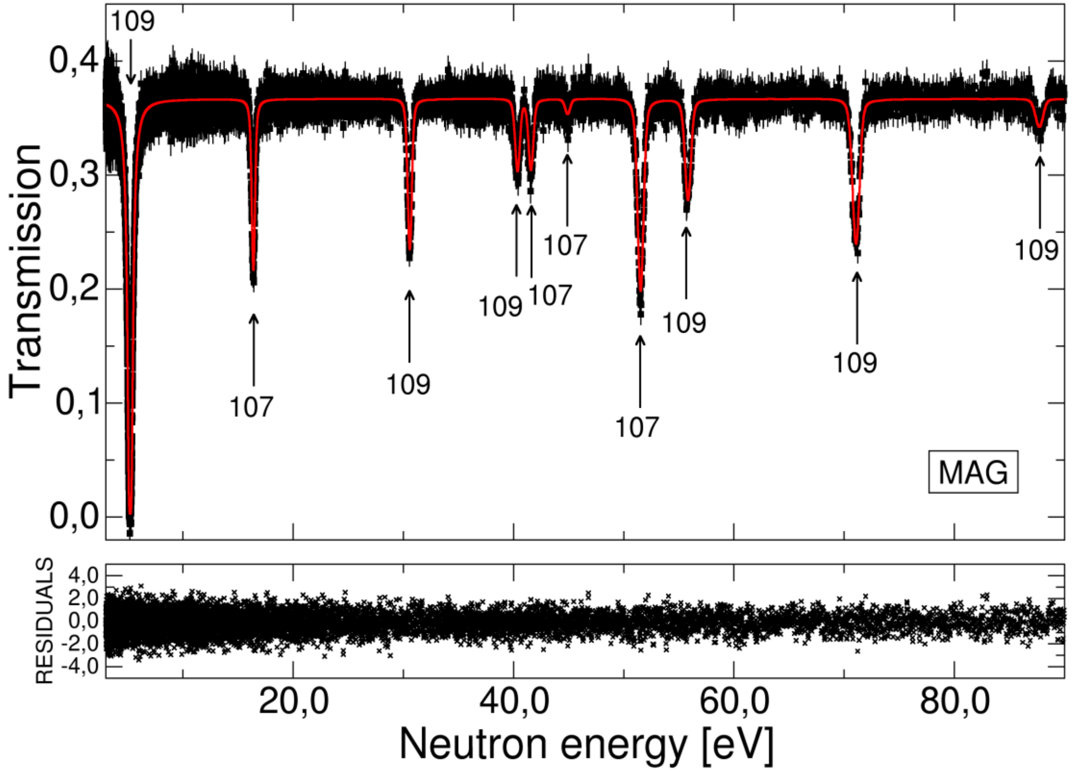


L. Salamon, PhD Thesis, AMU, University of Ljubljana, 2018

European Commission

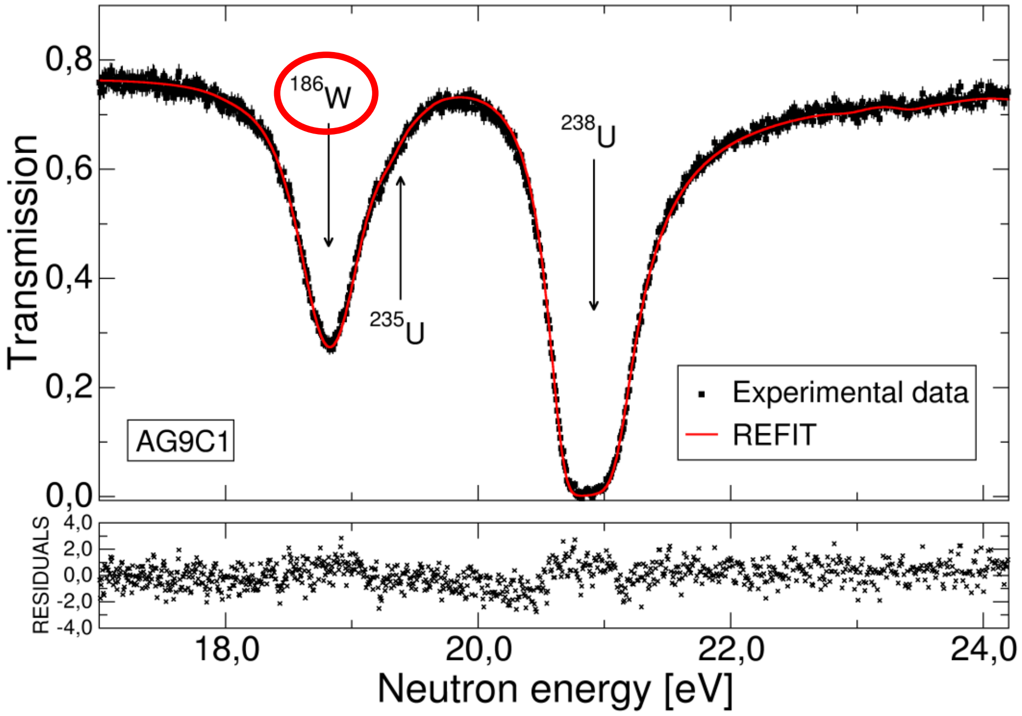
MINERVE_NRTA

Resonance parameters from ^{nat}Ag discs were used to analyse MINERVE samples with ^{109}Ag and ^{107}Ag and cylindrical pellets made of ^{nat}Ag



W presence not reported in the results of a chemical analysis. It comes from the fabrication process of the sample pellets

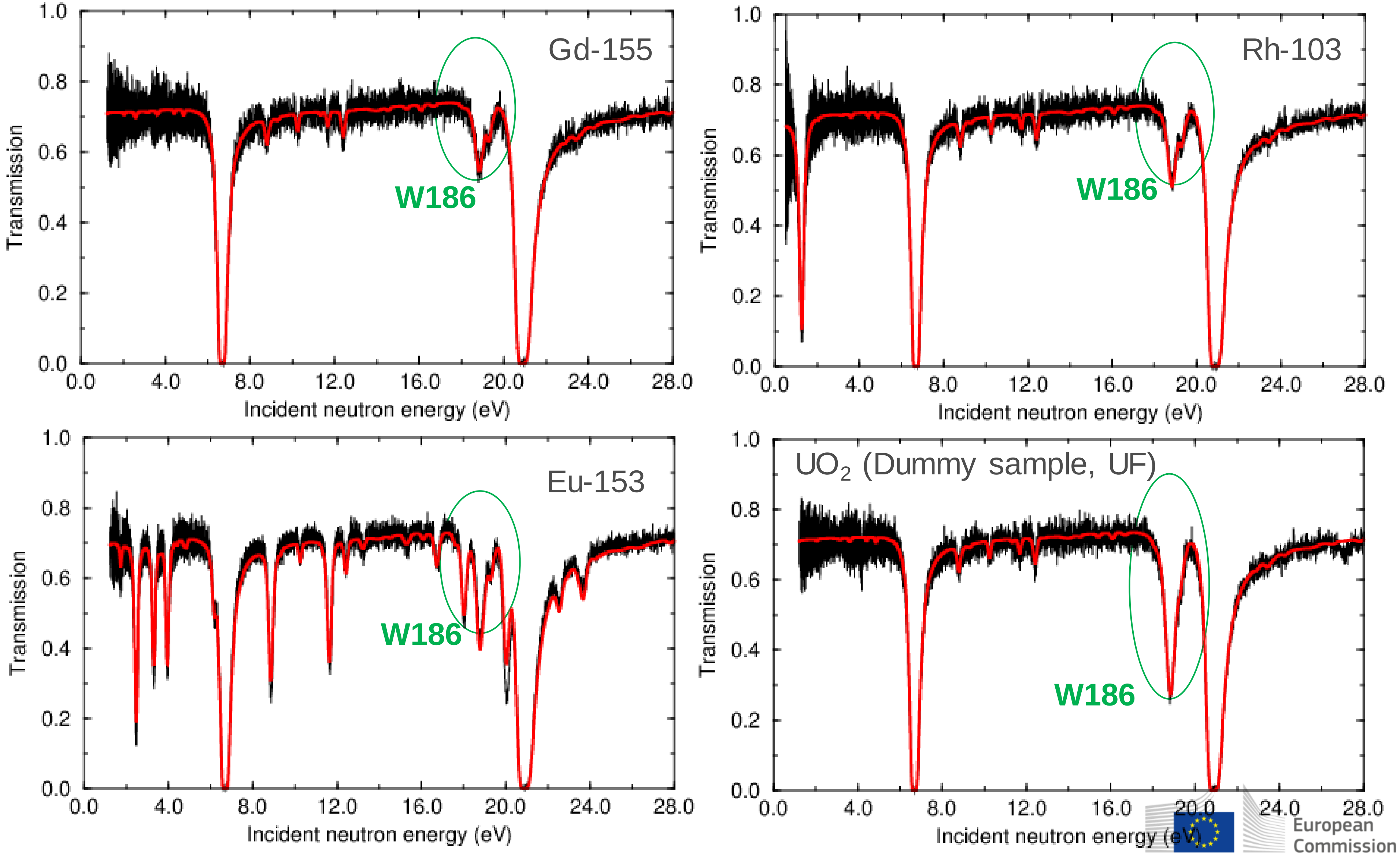
$\Rightarrow$ **grinding (tungsten carbid balls in grinder)**



L. Šalamon et al., NIMB, 446, 19 (2019)
L. Šalamon et al., J. Radioanal. Nucl. Chem., 321, 519 (2019)

MINERVE_NRTA

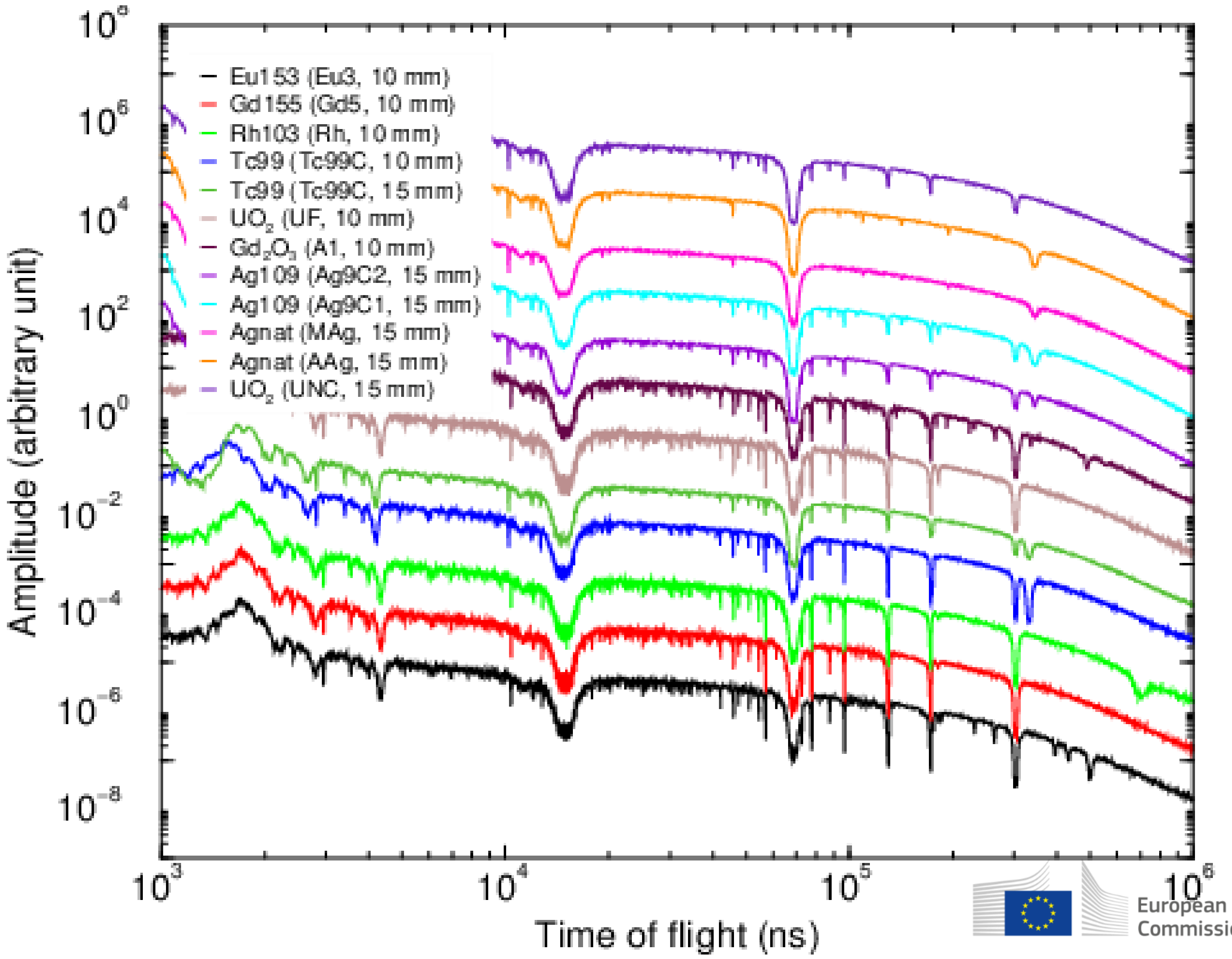
Large W contamination in the dummy sample (UO_2) will have a sizeable impact on the C/E results !



MINERVE_BUC

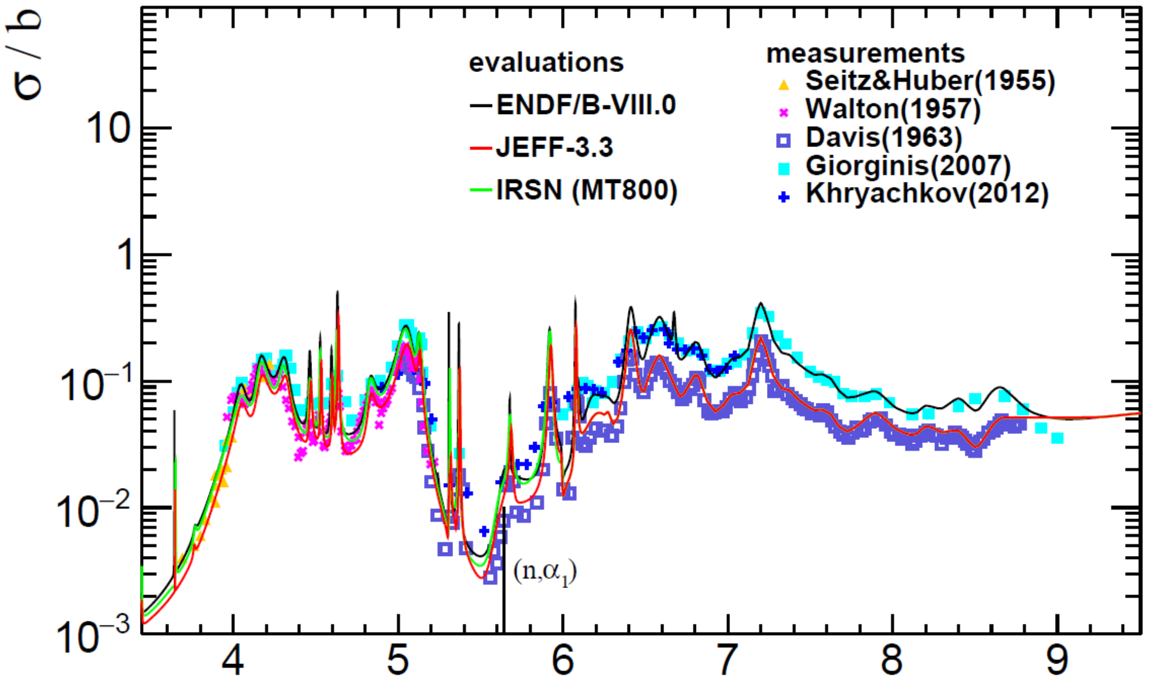
Follow up project:
- Continue MINERVE characterization
- Chance to evaluate nuclear data for Sm and Nd isotopes

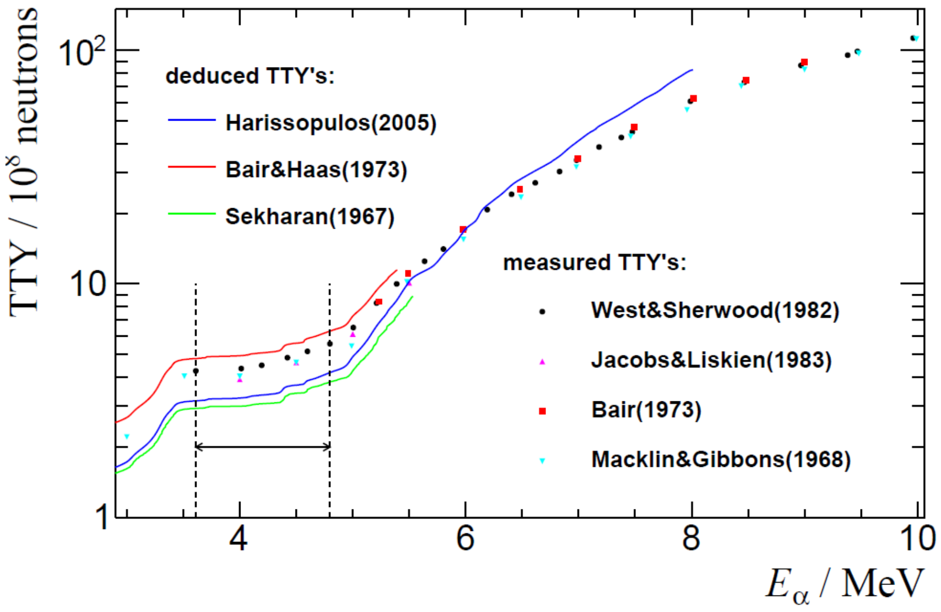
Programme	Type matrice	Dopant
CBU	UO2-nat	-
CBU	UO2-nat	Sm149
CBU	UO2-nat	Sm147
CBU	UO2-nat	Sm152
CBU	UO2-nat	Sm
CBU	UO2-nat	Nd143
CBU	UO2-nat	Nd145
CBU	UO2-nat	Nd
CBU	UO2-nat	Gd155
CBU	UO2-nat	Eu153
CBU	UO2-nat	Rh103
CBU	UO2-nat	Cs133
CBU	UO2-nat	Cs133
CBU	UO2-nat	Rh103
CBU	UO2-nat	Rh103



Oxygen_n_alpha

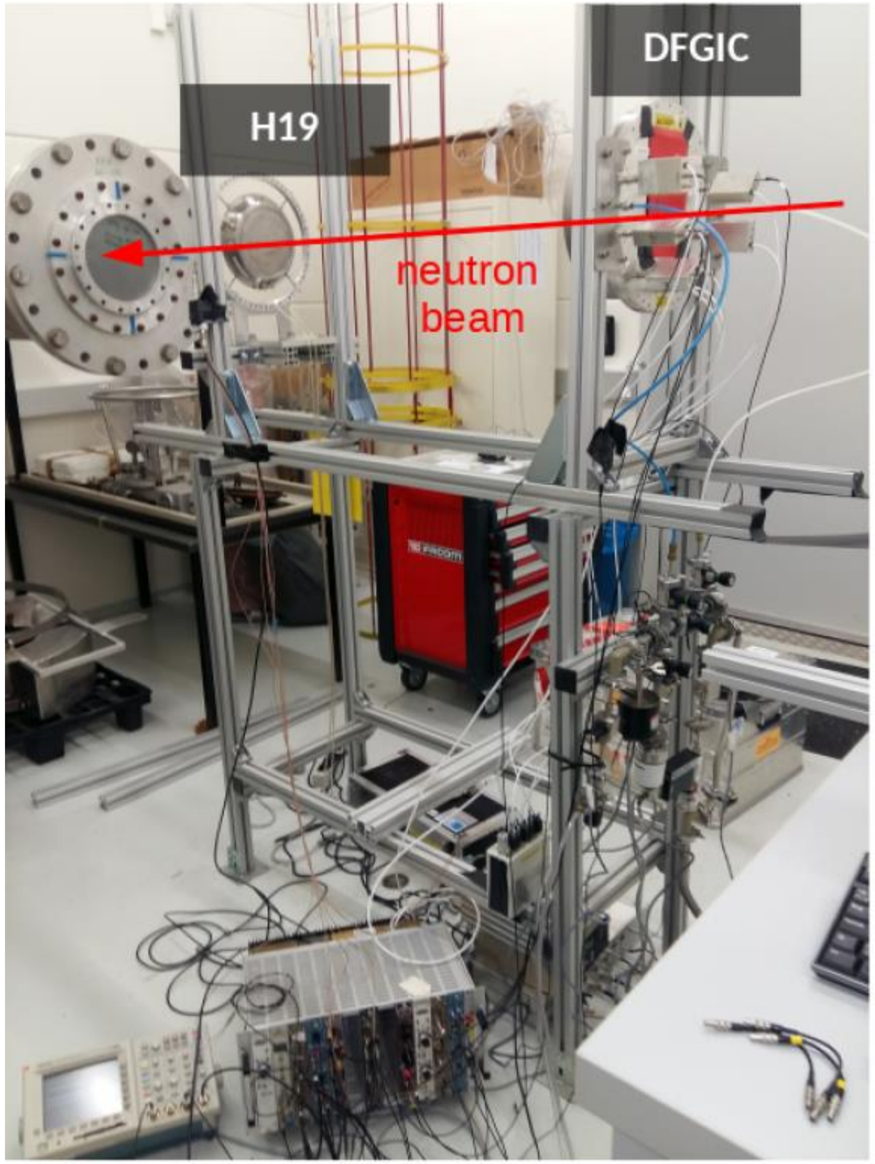
- ^{16}O neutron cross sections are highly relevant for nuclear technologies (CIELO project)
- Large discrepancies among experiments and evaluations of $^{16}O(n,\alpha)$
- Impact for s-process: $^{13}C(\alpha,n)^{16}O$ inverse reaction
- $^{13}C(\alpha,n)$ thin target experiments show discrepancies, while there is consistency among thick target experiments





$^{16}O(n,\alpha)$ measurement at GELINA

- Proposed by HZDR and supported by other n_TOF groups
- ^{16}O(n,alpha) reaction measured with a FGIC at 2 bar 95% Kr + 5% CO2
- Incoming neutron flux monitored by ^{235}U(n,f) H19 chamber from PTB (10 ^{235}U layers)
- FP16-60m during 2 weeks beam time
- Part of a PhD thesis (student visit to JRC supported by EUFRAT)



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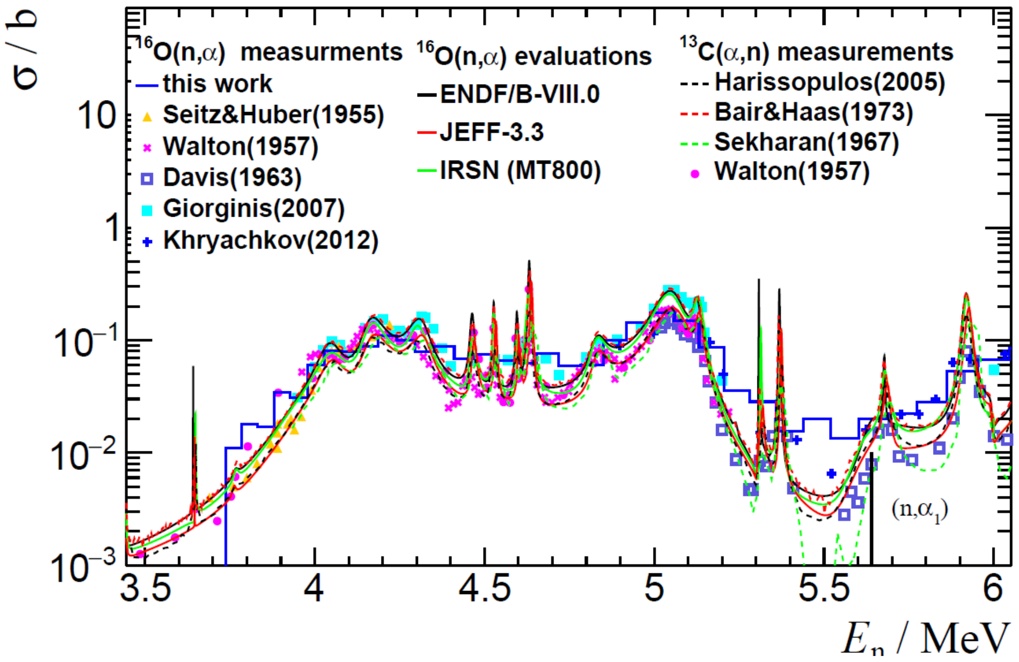
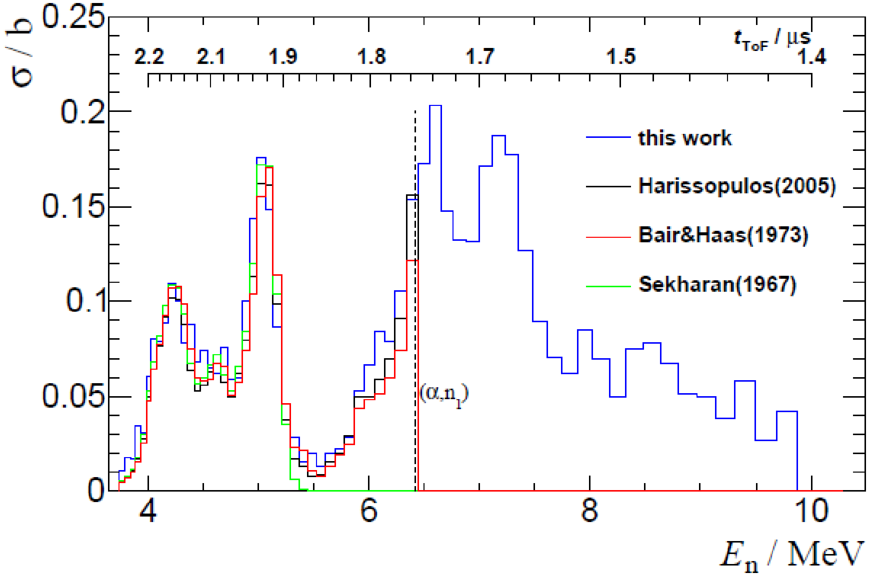
$^{16}O(n,\alpha)$ measurement at GELINA

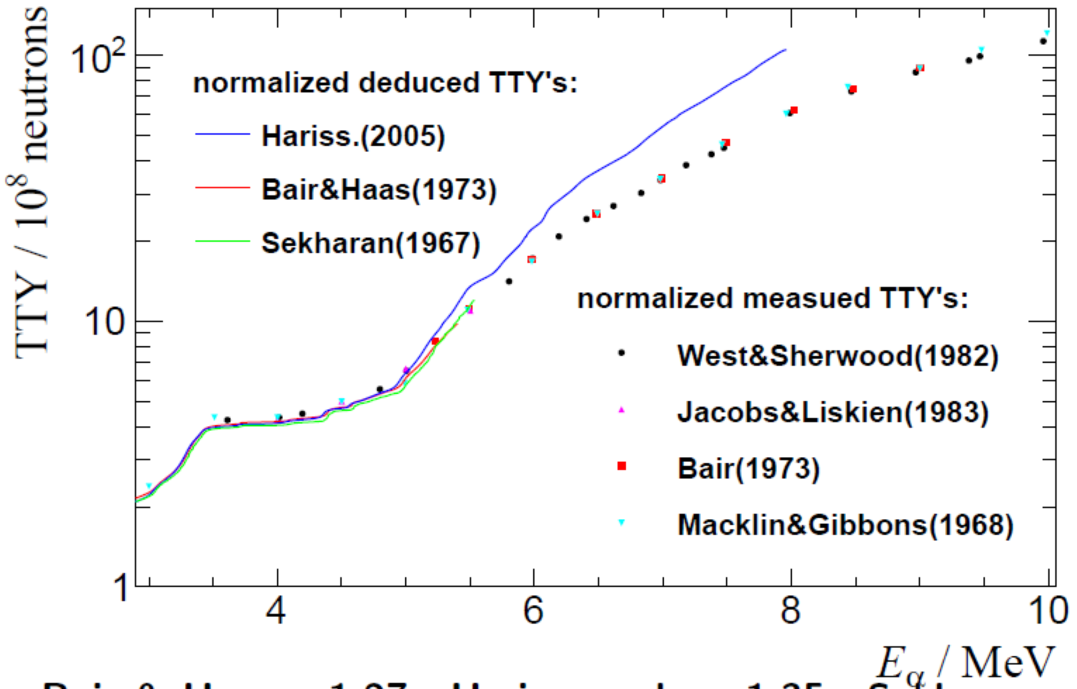
- Reduced TOF resolution (27 ns)
- Discrimination only for (n,α_0)
- Absolute measurement
  - ➢ Careful determination of areal density
  - ➢ Validation by C(n,n) reactions
- Comparison to converted data from $^{13}C(\alpha,n)\,^{16}O$





$^{16}O(n,\alpha)$ measurement at GELINA

The result agrees with Thick Target Yield (TTY) renormalization



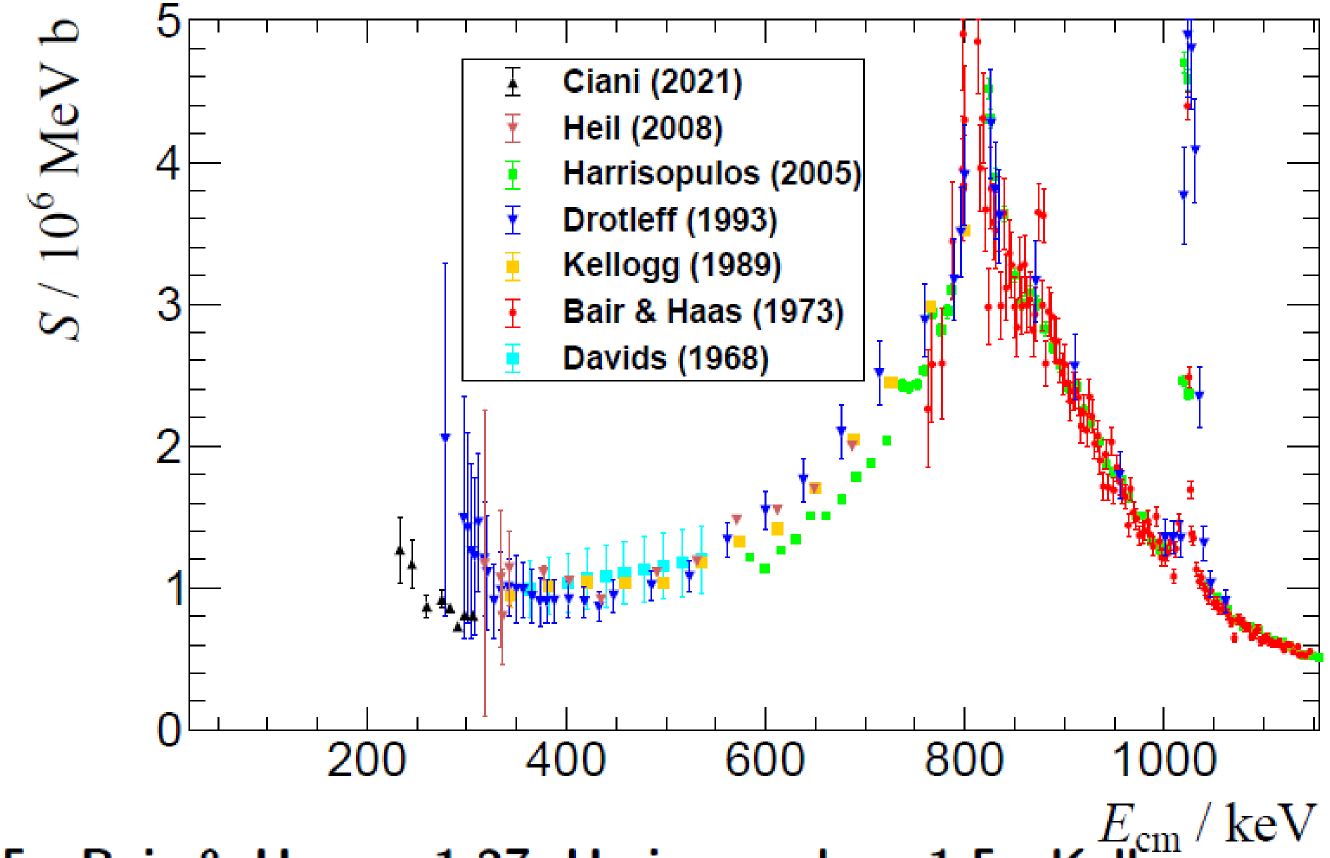
$0.85 \cdot$ Bair & Haas, $1.27 \cdot$ Harissopoulos, $1.35 \cdot$ Sekharan

	$^{16}O(n,\alpha_0)$ data (this work)	West and Sherwood TTY [3]	Pigni and Croft [4]	Ciani et al. [5]
main uncertainty	5% N_T^{16O} (^{16}O target)	8% ^{13}C abundance	8% ^{13}C abundance	8% detection efficiency
Bair and Haas [6]	0.87	0.85	0.8	
Harissopoulos [7]	1.30	1.27	1.15	1.37
Sekharan [8]	1.37	1.35		
IRSN [9]	1.02	1.00		
ENDF/B-VIII.0	0.92	0.89		
JEFF-3.3	1.26	1.25		

$^{16}O(n,alpha)$ cross section measurement

Implication for s-process stellar nucleosynthesis

- 800-1000 keV: agreement of Drotleff with Bair&Haas and Harissopoulus (renorm.)
- 300-800 keV: Drotleff, Heil, Davids



$0.85 \cdot$ Bair & Haas , $1.27 \cdot$ Harissopoulos, $1.5 \cdot$ Kellogg

- More information on open access

EU Science Hub: https://ec.europa.eu/jrc

MONNET: https://europa.eu/!Bk88rX

HADES: https://europa.eu/!qt66hJ

RADMET: https://europa.eu/!Fr78NG

GELINA: https://www.youtube.com/watch?v=cmq8KQ4Fe_8

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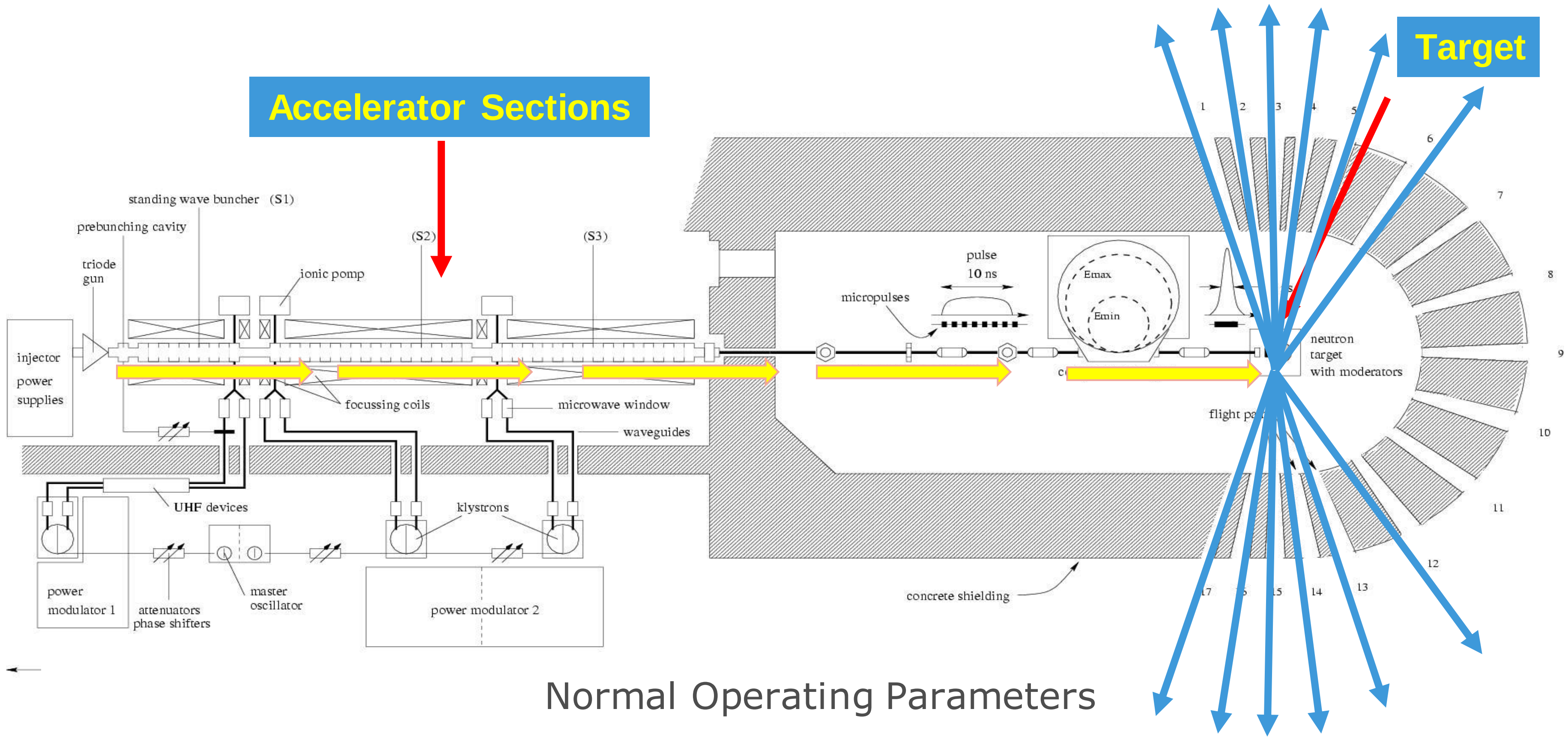
Back up slides

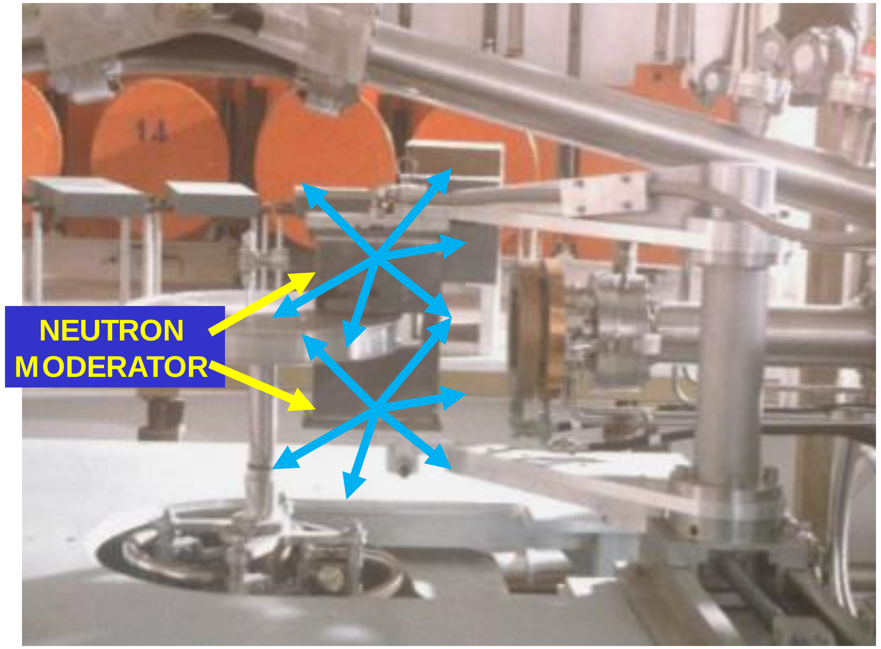
GELINA - Electron Linear Accelerator



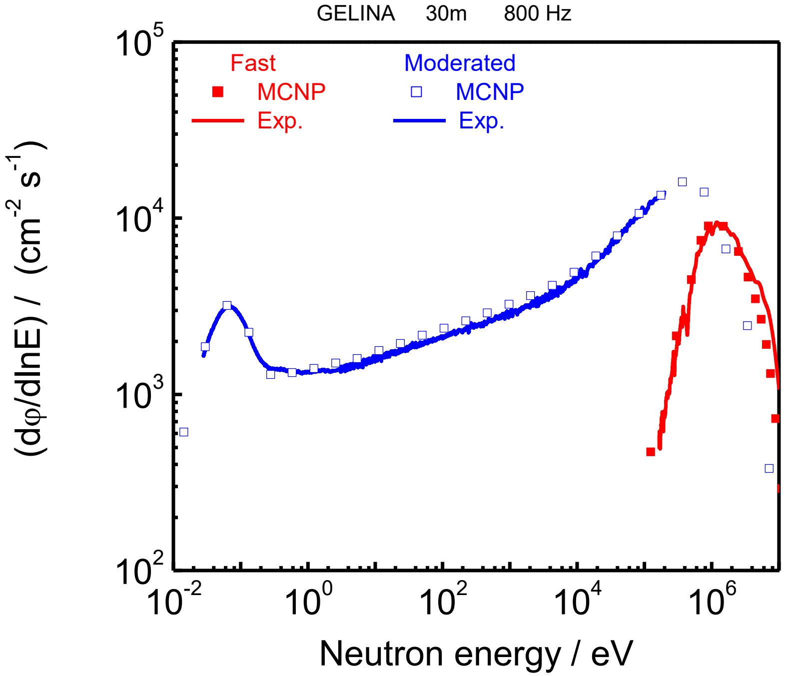
Normal Operating Parameters

Average Current	: 100 μA	Frequency	: up to 800 Hz
Maximum Electron Energy	: 150 MeV	Pulse Width	: 1-2 ns
Mean Power	: 10 kW	Neutron Flux	: 2 x 10^{13} 1/s

GELINA - Neutron Production

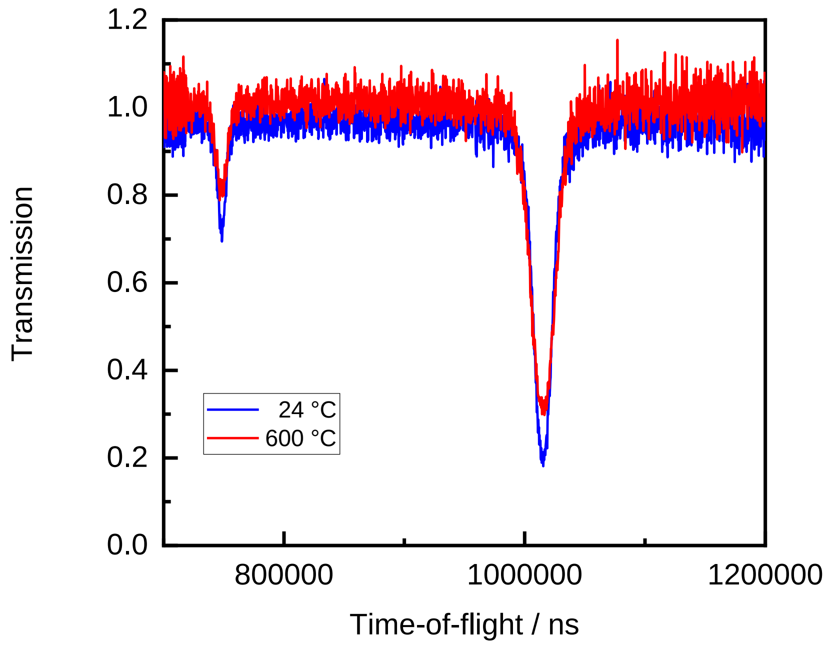


- e^- **accelerated** to $E_{e-,max} \approx 150$ MeV
- **Bremsstrahlung** in U-target (rotating & cooled with liquid mercury)
- **(γ,n), (γ,f)** in U-target
- Low energy neutrons by **moderation** (water moderator in Be-canning)



New experimental capabilities at GELINA

New transmission station for high temperature cross section measurements to study the Doppler effect



GELINA - Cross section measurements

Total cross section

$$T \cong e^{-n\sigma_{tot}}$$

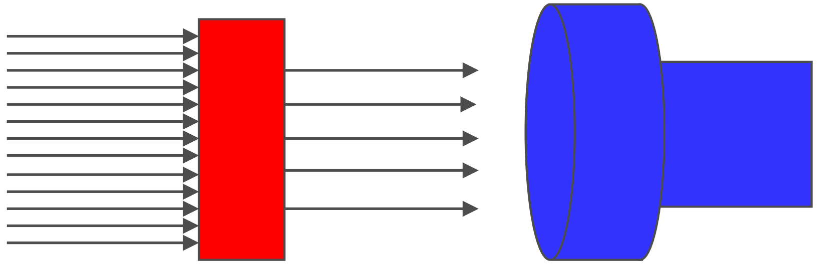
Reaction cross section

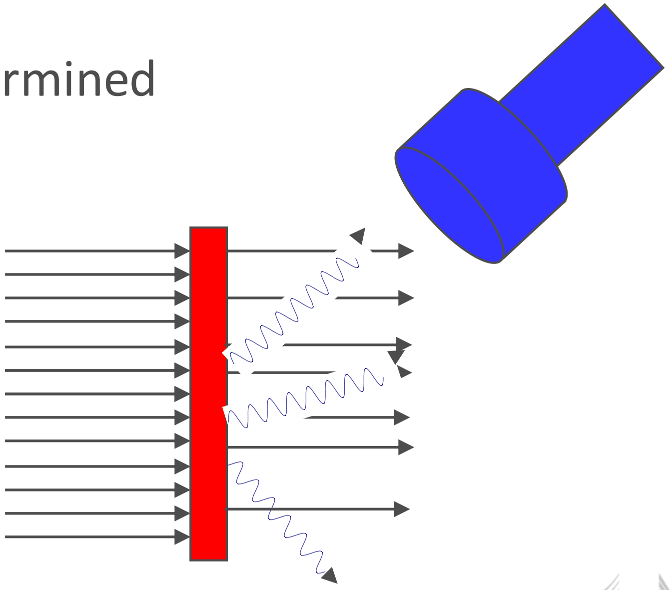
$$Y_\gamma \approx (1 - e^{-n\sigma_{tot}})\frac{\sigma_\gamma}{\sigma_{tot}}$$

Well-characterised samples

n: areal density (total number of atoms per unit area) is well-known

accurate cross-sections can be determined

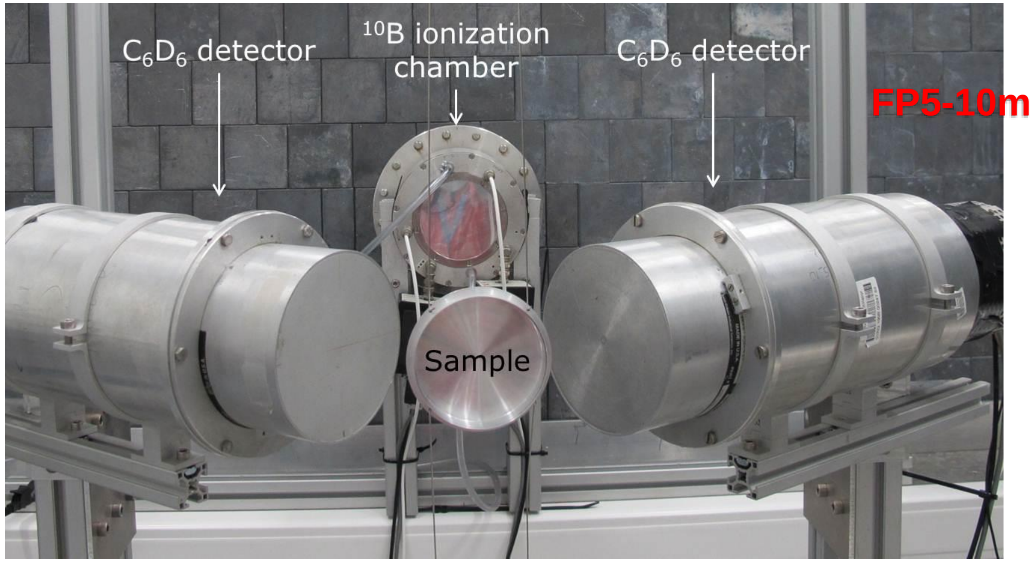


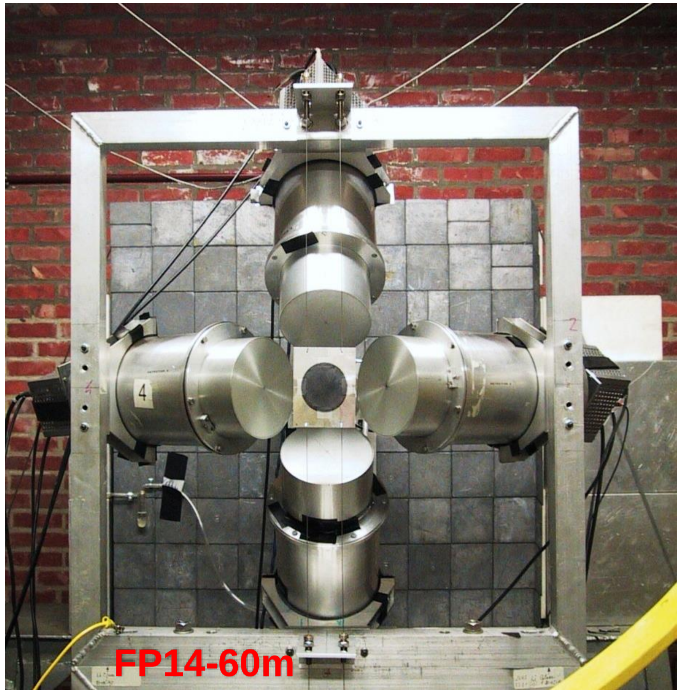


Capture cross section measurements

- Total energy detection principle
  - C_6D_6 liquid scintillators
  - Pulse Height Weighting
  - 125º
- Fluence rate measurements (IC)
  - $^{10}B(n,\alpha)$: $E_n <$ 200 keV
  - $^{235}U(n,f)$: $E_n >$ 200 keV

$$Y_{exp} = N \frac{C_w - B_w}{C_\varphi - B_\varphi} Y_\varphi$$





European Commission