DE LA RECHERCHE À L'INDUSTRIE

Preliminary results on $^{238}U(n,f)$ prompt fission neutron energy spectra at 2, 5.2 and 15 MeV measured using a p-terphenyl scintillator

A. Sardet

T. Granier, B. Laurent, A. Oberstedt, C. Varignon

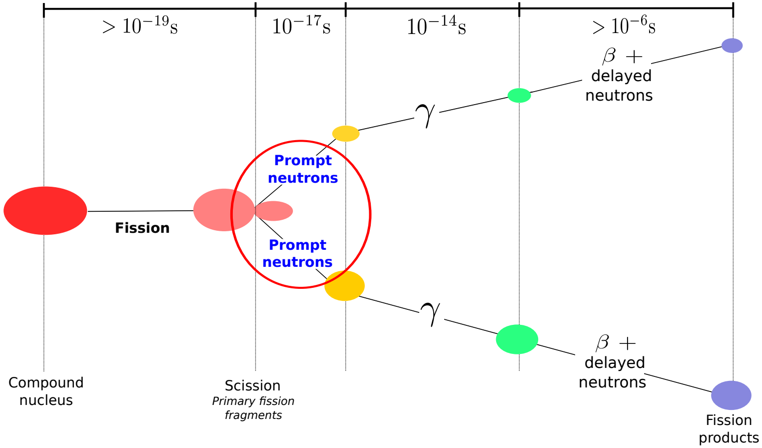
CEA/DAM/DIF

NEMEA-7/CIELO workshop - Geel

7 November 2013

Prompt neutrons

- Emitted mostly in flight by accelerated fission fragments

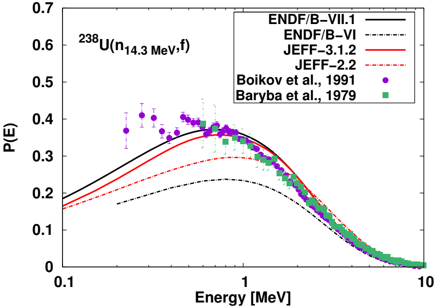


- Important role in many applications $\Rightarrow$ accuracy of nuclear criticality calculations
  - Conventional and advanced reactors
  - Non-proliferation applications

Prompt fission neutron energy spectra (PFNS)

- Important role in many applications $\Rightarrow$ accuracy of nuclear criticality calculations
  - Conventional and advanced reactors
  - Non-proliferation applications
- Theoretical description of prompt fission neutron energy spectra (PFNS) difficult

- Important role in many applications ⇒ accuracy of nuclear criticality calculations
  - Conventional and advanced reactors
  - Non-proliferation applications
- Theoretical description of prompt fission neutron energy spectra (PFNS) difficult
- Few experimental data
- Discrepancies between measured PFNS and evaluations [1]



[1] Baryba *et al.* EXFOR 40740 et Boikov *et al.* EXFOR 41110

Prompt fission neutron energy spectra (PFNS)

- Important role in many applications $\Rightarrow$ accuracy of nuclear criticality calculations
  - Conventional and advanced reactors
  - Non-proliferation applications
- Theoretical description of prompt fission neutron energy spectra (PFNS) difficult
- Few experimental data
- Discrepancies between measured PFNS and evaluations [1]
- 2009 : International program aiming at improving the adequacy and the quality of PFNS launched by the IAEA[2]

[1] Baryba *et al.* EXFOR 40740 et Boikov *et al.* EXFOR 41110
[2] INDC(NDS)-0541

Outline

1 Experimental

Experimental technique

Experimental tools

Data acquisition system FASTER

Fission chamber

P-terphenyl neutron detector

2 Prompt fission neutron spectra measurements

3 Conclusion and outlook

Outline

1 Experimental
Experimental technique
Experimental tools
Data acquisition system FASTER
Fission chamber
P-terphenyl neutron detector

2 Prompt fission neutron spectra measurements

3 Conclusion and outlook

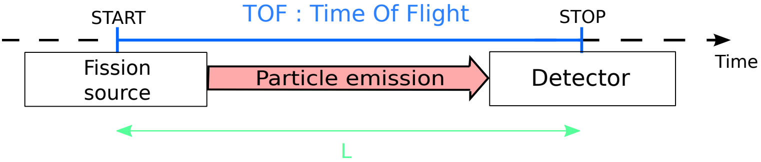
Measurement campaigns

- **CEA - Bruyères-le-Châtel - France** :
  - ^{238}U(n,f) induced by 2 MeV neutrons
  - ^{238}U(n,f) induced by 5.2 MeV neutrons
  - ^{238}U(n,f) induced by 15 MeV neutrons

DE LA RECHERCHE À L'INDUSTRIE
cea
DAM
ILE-DE-FRANCE

- **JRC-IRMM - Geel - Belgique**
  - ^{235}U(n,f) et ^{237}Np(n,f) induced by 500 keV neutrons

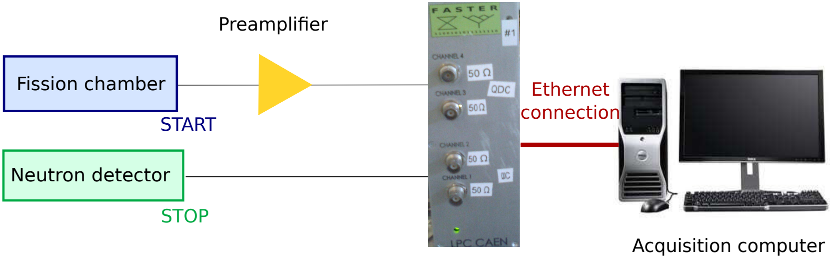
JRC
EUROPEAN COMMISSION
irmm
Institute for Reference Materials and Measurements



$$E_n = (\gamma - 1) m_n c^2 = \left(\frac{1}{\sqrt{1 - \frac{L^2}{TOF^2}\frac{1}{c^2}}} - 1 \right) m_n c^2$$

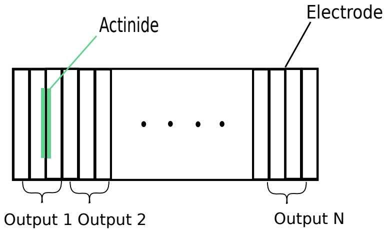
Data acquisition system FASTER

- Digital acquisition system Fast Acquisition SysTem for nuclEar Research (FASTER) currently being developed at the LPC Caen
- Programmable logic devices $\rightarrow$ Real time treatment of signals (0 % dead time)
- Module close to the detectors $\rightarrow$ optimization of the ratio $\frac{\text{signal}}{\text{noise}}$



Fission chamber : example of the ^{238}U chamber

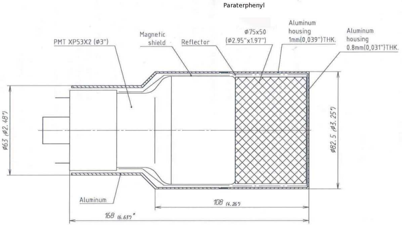
- Cylinder containing about 100 electrodes on which the actinides are deposited
- Ionization gas : P10 (10% methane and 90% argon)



Fission trigger (START signal)

P-terphenyl neutron detector : General points

- Organic crystal of doped p-terphenyl ($C_{18}H_{14}$) optically coupled to a photomultiplier

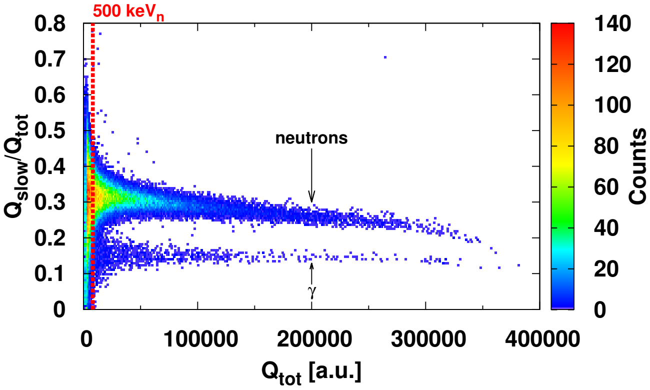


Crystal : $\varnothing 75 \times 50$ mm

STOP signal

P-terphenyl neutron detector : General points

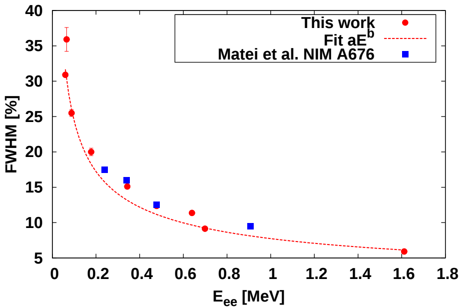
- Organic crystal of doped p-terphenyl ($C_{18}H_{14}$) optically coupled to a photomultiplier
- Excellent n-γ discriminations properties
- Good light output $\rightarrow$ detection in the low energy domain



P-terphenyl neutron detector : Characterization

1. Intrinsic timing resolution → (479.4 ± 15.3) ps

2. Deposited energy in the scintillator resolution

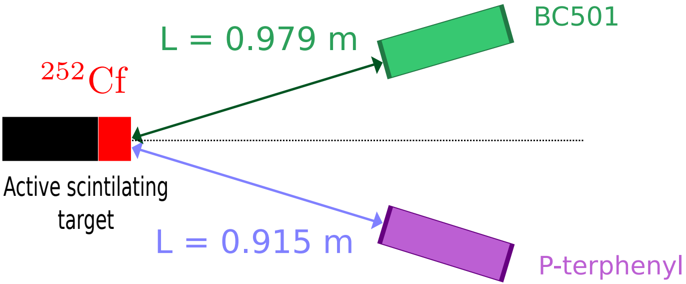


3. Neutron response using a ^{252}Cf scintillating active target

   a. Light output function

   b. Neutron detection efficiency

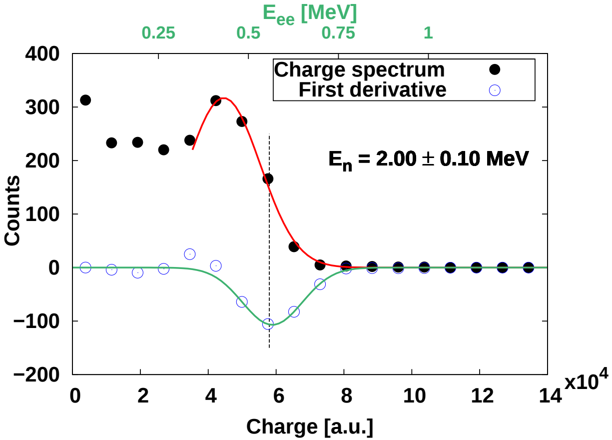
- Time-of-flight measurement using an active scintillating target[3] of ^{252}Cf(sf) above a pit



[3] G. Belier *et al.*, NIMA 664 (2012)

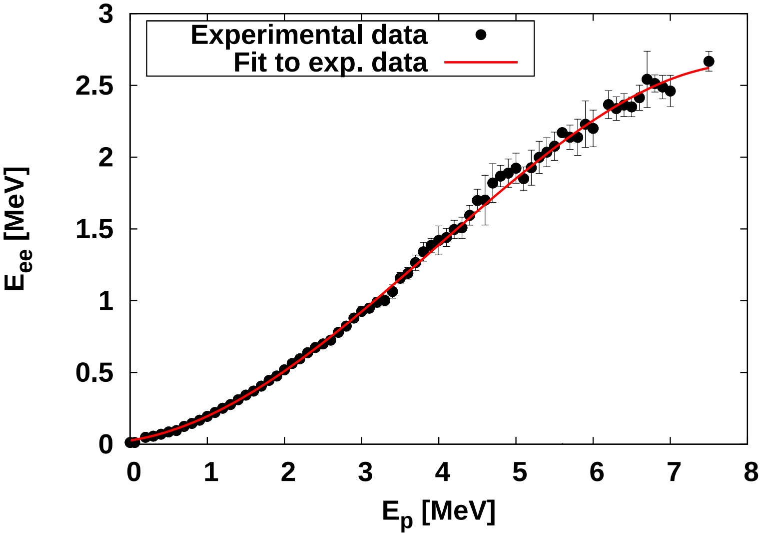
Neutron response

- Time-of-flight measurement using an active scintillating target[3] of $^{252}Cf(sf)$ above a pit
- Projection of the total charge for several energy bins



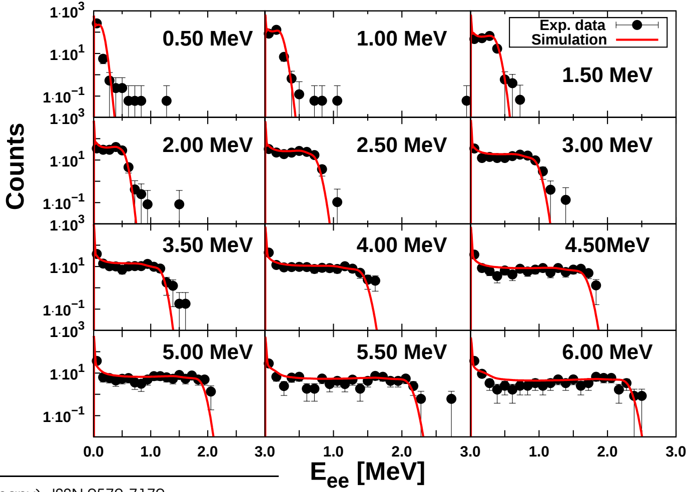
[3] G. Belier *et al.*, NIMA 664 (2012)

Light output curve



NRESP simulations

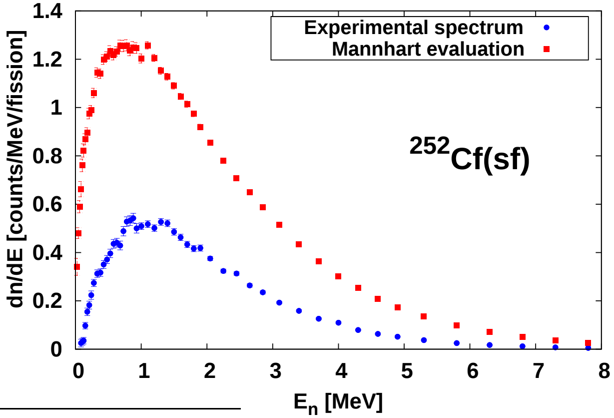
- Monte Carlo simulation code for the neutron response of liquid scintillators [4]
- Input parameters : detector geometry, detector composition and light output curve



[4](PTB, Germany). ISSN 0572-7170

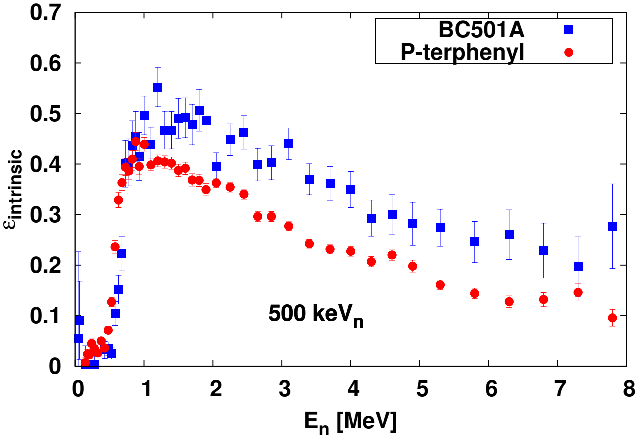
$$\varepsilon(E) = \frac{\text{detected neutrons}}{\text{neutrons emitted in fission}} = \frac{\Omega}{4\pi} \times \varepsilon_{\text{intrinsic}}(E)$$

- Experimental energy spectrum compared to Mannhart evaluation[5]



[5] Standard recommended by the IAEA

Neutron detection efficiency



Outline

1 Experimental

Experimental technique

Experimental tools

Data acquisition system FASTER

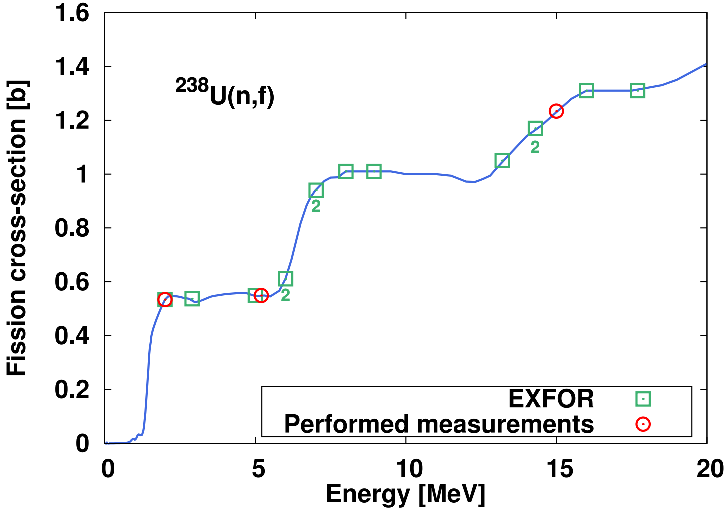
Fission chamber

P-terphenyl neutron detector

2 Prompt fission neutron spectra measurements

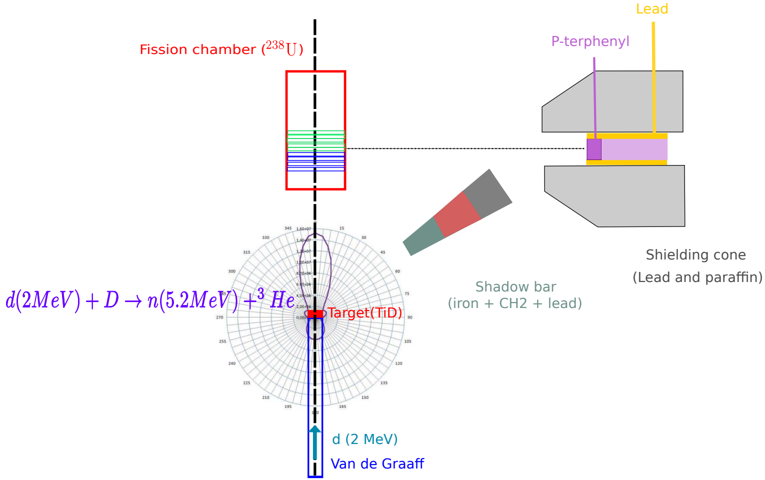
3 Conclusion and outlook

Fission cross-section[6] of ^{238}U

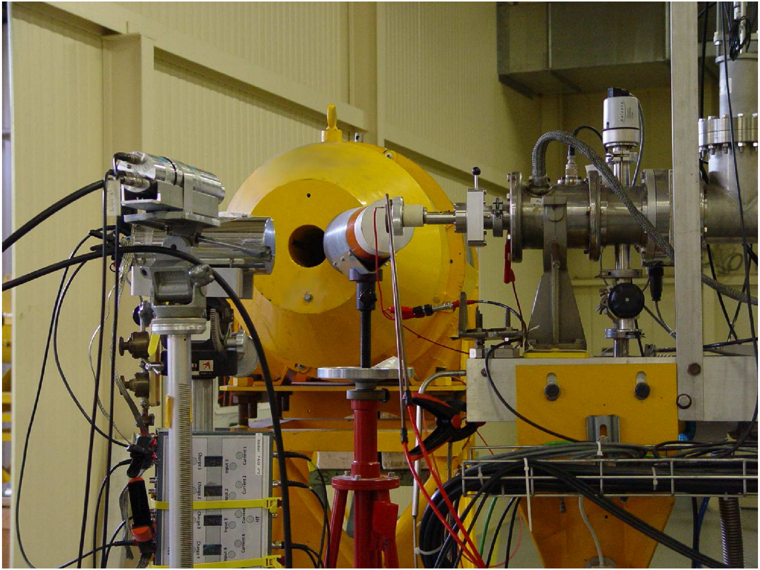


[6] ENDF/B-VII

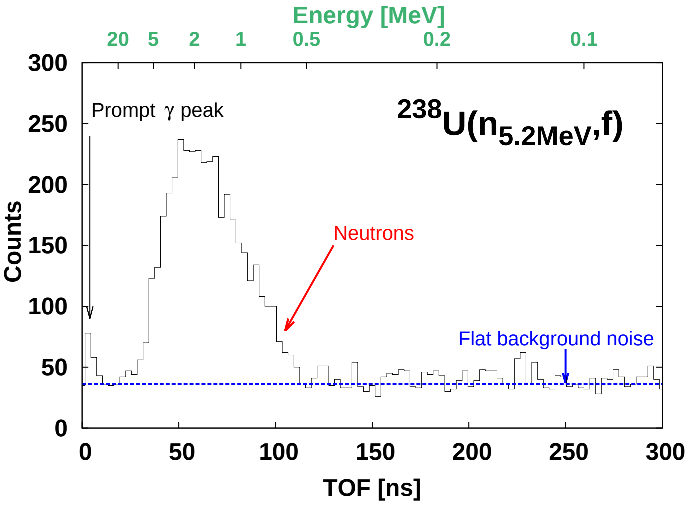
Experimental setup for ^{238}U at 5.2 MeV



Experimental setup for ^{238}U at 5.2 MeV

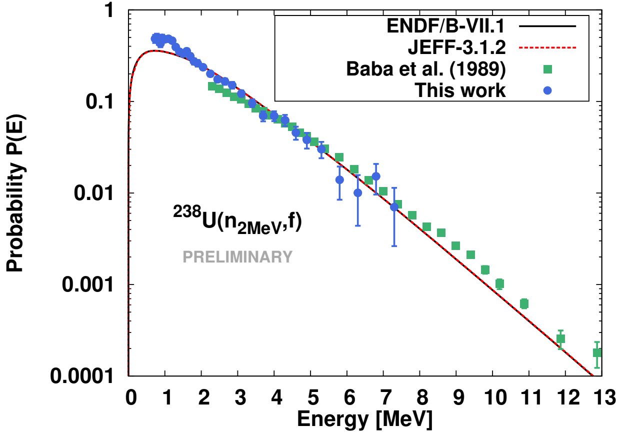


Example of a TOF spectrum for ^{238}U(n,f) at 5.2 MeV



- Remaining γ-peak : 5.9 %

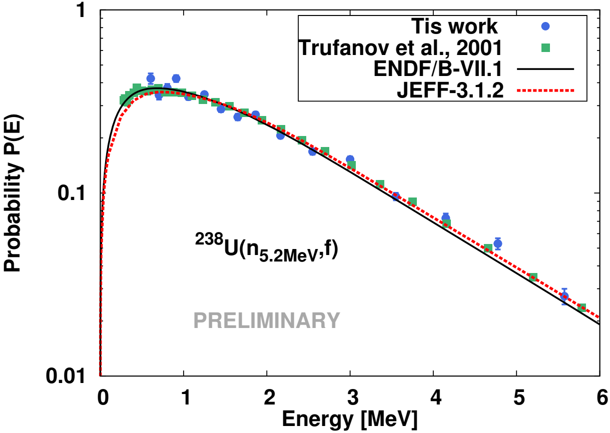
PFNS for $^{238}U(n,f)$ at 2 MeV



- Fit by a Maxwellian between 0.8 and 5.5 MeV

	T (MeV)
This work	1.50 ± 0.13
Baba *et al.*	1.18 ± 0.01

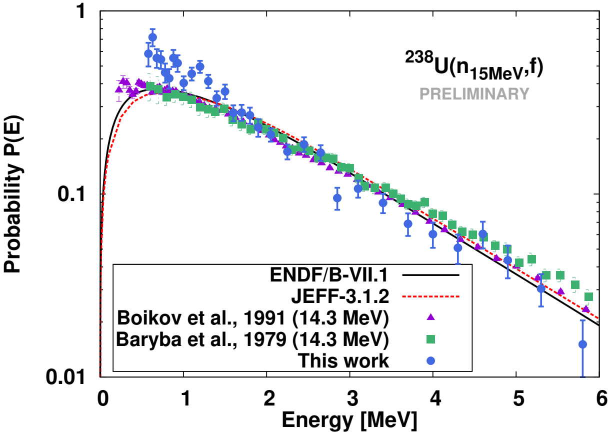
PFNS for $^{238}U(n,f)$ at 5.2 MeV



- Fit by a Maxwellian between 0.7 and 5.5 MeV

	T (MeV)
This work	1.23 ± 0.05
Trufanov *et al.*	1.34 ± 0.01

PFNS for $^{238}U(n,f)$ at 15 MeV



- Fit by a Maxwellian between 0.9 and 5.5 MeV

	T (MeV)
This work	1.15 ± 0.07
Baryba *et al.*	1.23 ± 0.04

Outline

1. Experimental
    - Experimental technique
    - Experimental tools
        - Data acquisition system FASTER
        - Fission chamber
        - P-terphenyl neutron detector
2. Prompt fission neutron spectra measurements
3. Conclusion and outlook

Conclusion and outlook

- Conclusion
  - P-terphenyl characterized
  - Preliminary results for ^{238}U at 2, 5.2 and 15 MeV
- Outlook
  - Simulations to study the distortion of the spectrum caused by shielding and the environment (MCNP)
  - Analysis of the measurements on ^{235}U and ^{237}Np at 500 keV
  - Comparison to models and evaluations
  - Other measurements at other energies and on other actinides