High accuracy measurement of the $^{235}\text{U}(n,f)$ reaction cross-section in the 10-30 keV neutron energy range in EAR1@n_TOF

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Why $^{235}$U(n,f) @ 10-30 keV?

- $^{235}$U(n,f) cross-section is often *(i.e. nearly always)* used as a reference in cross-section measurements of major and minor actinides.

- $^{235}$U(n,f) based detectors are widely used to measure neutron fluxes (MACS..).

- $^{235}$U(n,f) cross section in the energy range proposed can have a significant impact on fast critical reactor and sub-critical ADS.
The n_TOF Phase-2 neutron flux was accurately determined using 5 different detectors and 3 different converting reactions.

- The analysis of the neutron flux has revealed a discrepancy between results based on $^{235}$U(n,f) cross section and results based on $^6$Li(n,t)$\alpha$ and $^{10}$B(n,$\alpha$)$^7$Li, regardless of the detection system used (*).

- Also the comparison with the simulations shows such a discrepancy in the range 10-30 keV.

6-8% overestimation of the fission cross-section of $^{235}$U in database?

$^{235}$U(n,f) cross section not standard in that energy region, but declared known with <1% uncertainty (**)


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Only in this region, the uncertainties have been increased by a factor 4 in the latest release of ENDF/B-VII data library.
Status of evaluations and experimental data

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The $^{235}\text{U}(n,\gamma)$ cross section was “recently” measured at Los Alamos relative to $^{235}\text{U}(n,f)$ using DANCE+PPAC.

Between 10 and 30 keV, the DANCE cross sections are $\sim 10\%$ larger than both the ENDF/B-VII.1 and JENDL-4.0 cross sections. Significant discrepancies are observed among other measurements [14–18]. Neutron flux at

The 10% difference attributed to $^{235}\text{U}(n,\gamma)$ cross section could rather be explained by the overestimation of the fission cross section, consistent with our finding.
We measured (Aug-Sept 2016) in **EAR1** the $^{235}\text{U}(n,f)$ cross section together with the reference reactions $^6\text{Li}(n,t)$ and $^{10}\text{B}(n,\alpha)$.

- Detection at **forward and backward** directions
- Energy resolution

**Silicon detectors stack** (5x5 cm$^2$ and 200 μm thickness) **in the beam** (capture collimator)

- 500 μg/cm$^2$ $^6\text{LiF}$, 50 μm Al backing (Laboratori Nazionali del Sud)
- 80 nm $^{10}\text{BC}_4$, 18 μm Al backing (ESS, Linkoping- Chewbacca)
- 275 μg/cm$^2$ $^{235}\text{U}$, 250 μm Al backing (Institute for Reference Materials and Measurement)

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The setup

Lin/Log Mesytech preamp*

*Same setup in different areas → ~ same response

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Calculated transmission factor

Transmission Probability

Det#1
Det#2
Det#3
Det#4
Det#5
Det#6

Neutron Energy [eV]

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Preliminary Results

Amplitude spectra

SIFI 1

LiF

SIFI 3

10B

SIFI 6

235U

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Preliminary Results

SIFI 1

Forward direction

SIFI 2

Back direction

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Preliminary Results

Forward
Backward

energy (eV)

entries

10^4
10^3
10^2
10^1
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}

Preliminary Results

SIFI 1 / SIFI 2

Forward/Backward

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**Preliminary Results**

**Forward direction**

**Back direction**
Preliminary Results

Forward direction
Back direction

Figure: Distribution of entries as a function of energy (in eV). The data is shown for both forward (blue) and backward (red) directions. The graph illustrates the energy spectrum with a logarithmic scale for both axes, indicating the number of entries vs. energy.
Forward direction
Back direction

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Preliminary Results

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Preliminary Results

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SIFI 5 / SIFI 6

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Ancillary measurement

Study of pulse height defect in the silicons

LOHENGRIN recoil mass spectrometer for fission products @ ILL-Grenoble

Features

- Flux at target position: $5.3 \times 10^{14}$ n cm$^{-2}$ s$^{-1}$
- Solid angle $W$: $\leq 3.2 \times 10^{-5}$ sr
- Total length of main path: 23 m
- Mass dispersion for 1% mass difference: 3.24 cm
- Energy dispersion for 1% energy difference: 7.2 cm
- Mass resolution $A/dA$ (FWHM): 400 for target size 0.8 x 7.5 cm$^2$, 1500 for target size 0.16 x 4 cm$^2$
- Ionization chamber energy resolution: $E/\Delta E > 100$
- Nuclear charge resolution: $Z/\Delta Z \leq 36$

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Next steps

- Refine Time of flight to Energy conversion
- Refine cuts applied
- Increase statistic
- Extract the ratios of the standards