EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
Proposal to the ISOLDE and Neutron Time-of-Flight Committee

Measurements of neutron induced capture and fission reactions on ^{233}U

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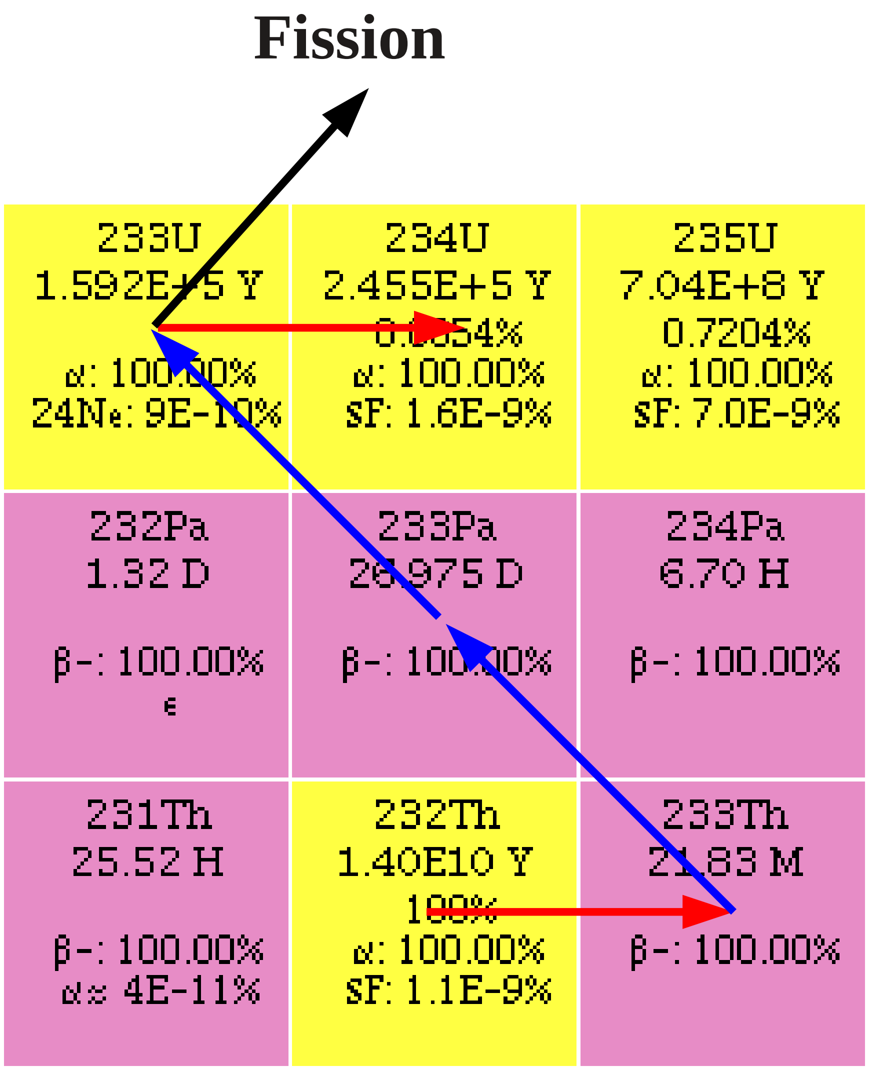
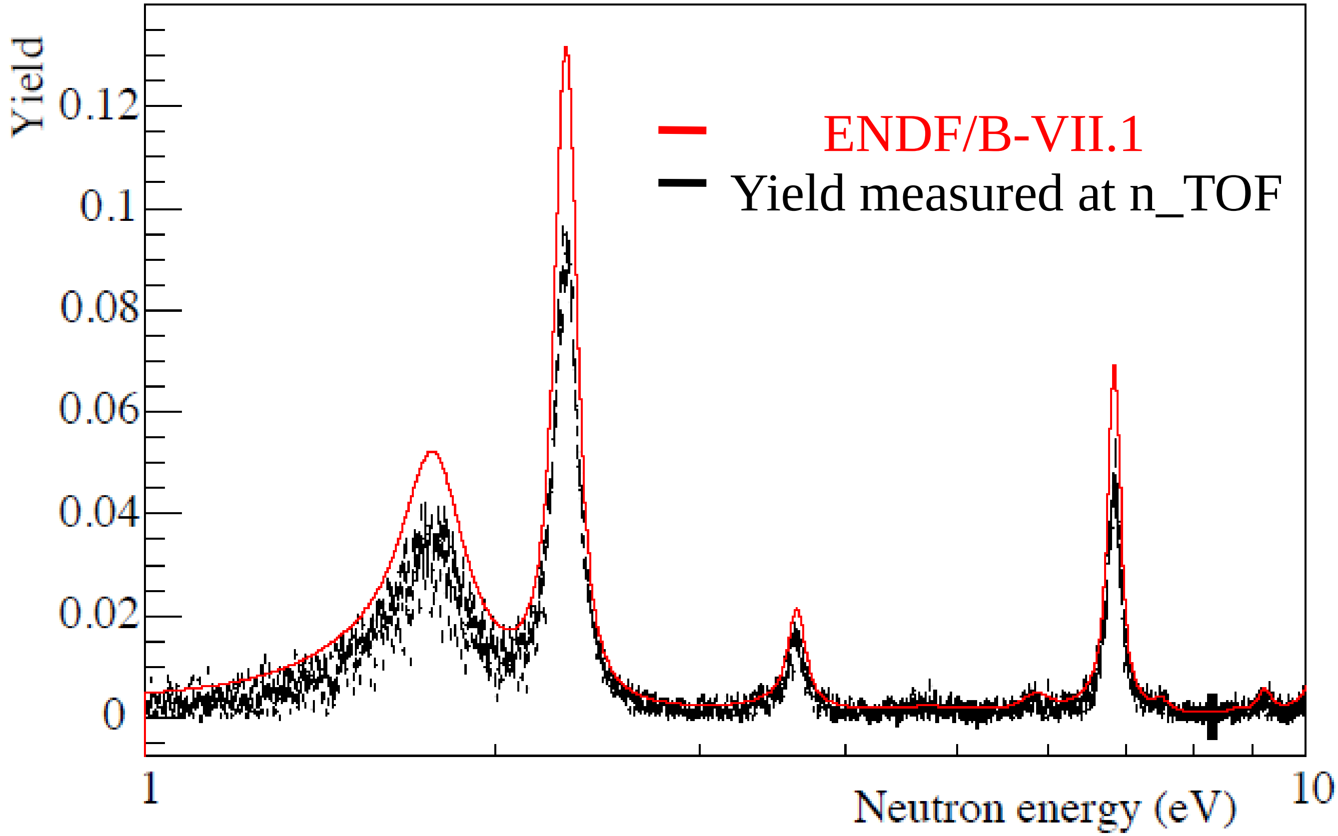
Motivation:
The Th-U Breading cycle



- Valid alternative to the U-Pu fuel cycle.
- Cleaner cycle in respect to the U-Pu.
- Radkowsky Thorium Reactor.
  - 29,000 effective full power hours
  - Availability factor of 76 %
  - Over 2.1 billion kWh
  - **1.39 % more fissile fuel present at the end of core life**.
- Sustainability.
- Scarce differential data to support the development of new reactor technologies.
- No integral data.

Motivation
Previous results: Capture Yield

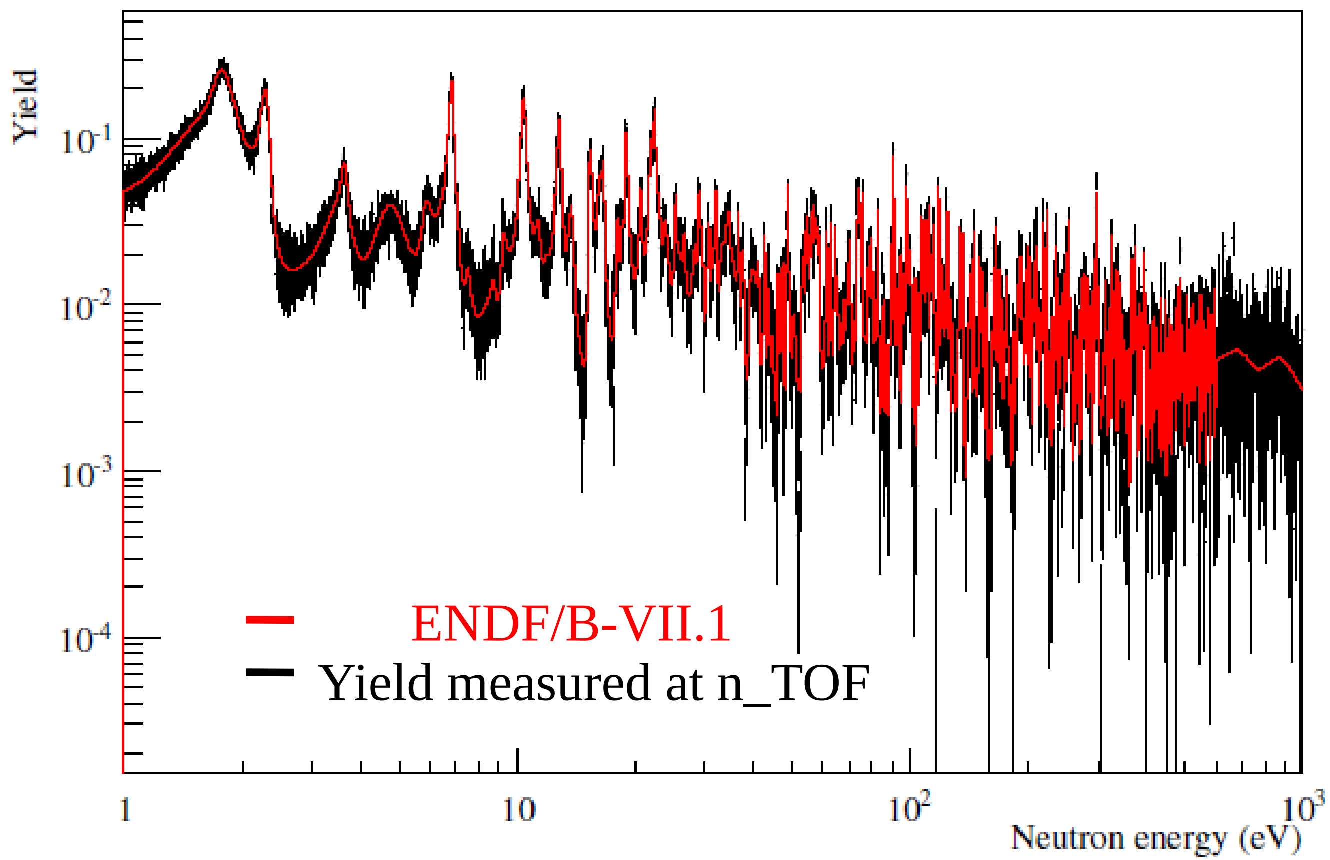


12.3% uncertainty in the capture yield.

~30% discrepancy in magnitude.

- **The assessed normalization doesn't agree with the data in the ENDF/B-VII.1 library.**
- **Data analyzed using the Calorimetric Shape Decomposition (CSD).**
- **Same analysis procedure used for capture and fission.**

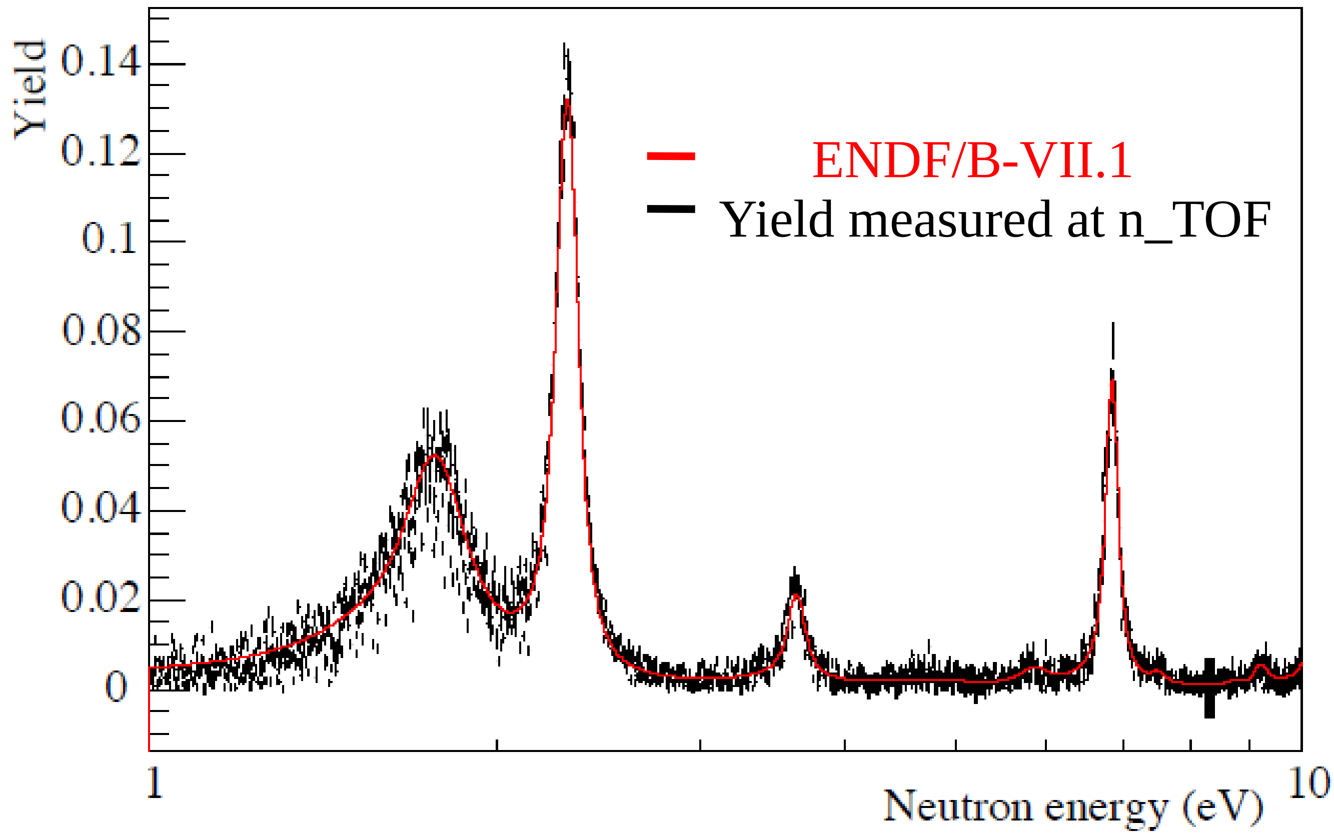
Motivation
Previous results: Fission Yield



6.6% uncertainty in the fission yield

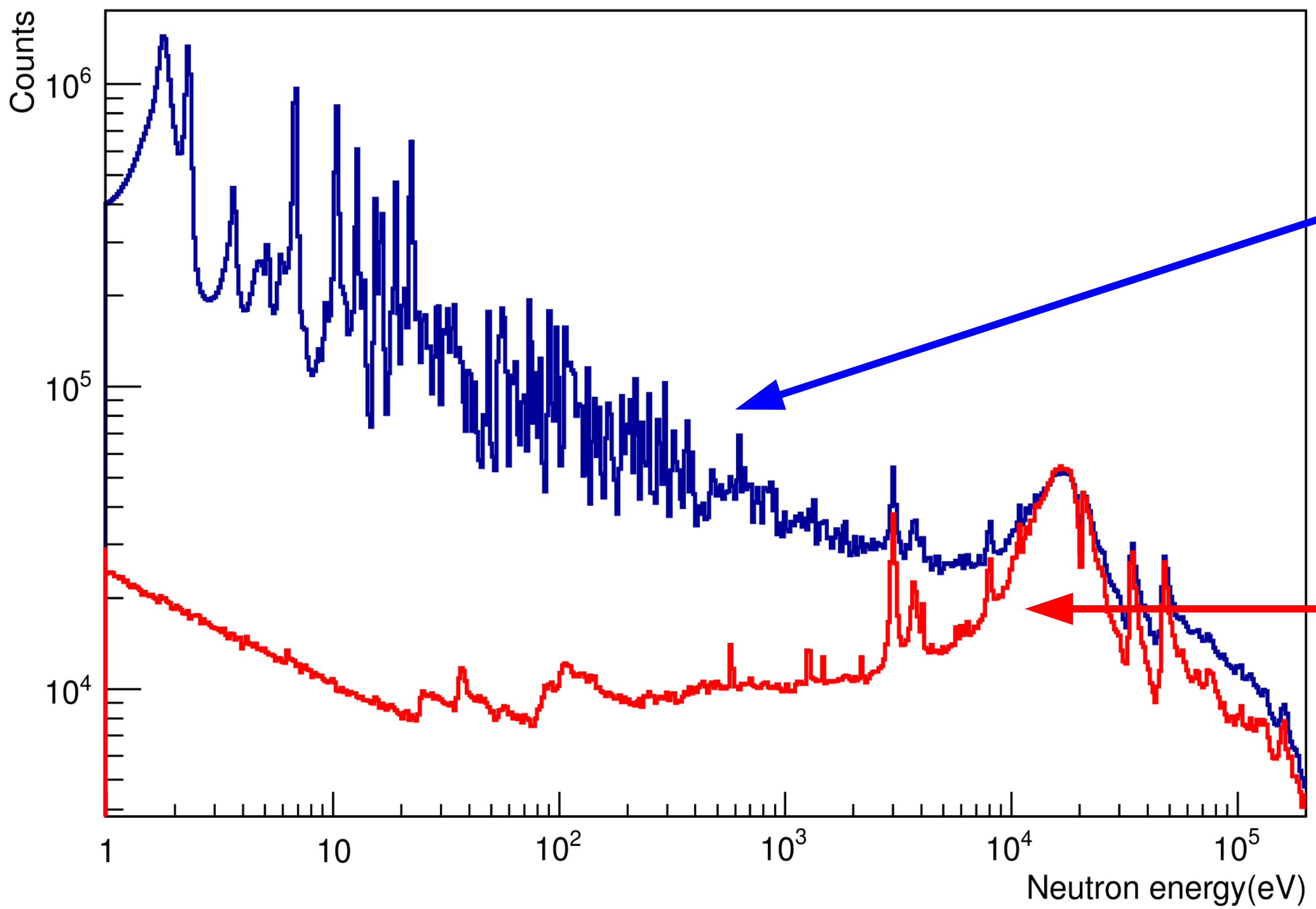
- **Data analyzed using the Calorimetric Shape Decomposition (CSD)**.
- Absence of a fission discrimination device.

Motivation
Previous results: Capture Yield



- **Good agreemen**t with the ENDF/B-VII.1 library **when using arbitrary normalization.**
- **We believe it points to a problem in current evaluations.**

Motivation
Removal of the sample's canning



91mg of ^{233}U

277.1 mg of Ti

High Priority Request List for the ^{233}U

Isotope	Reaction	Quantity	Energy range	Target Accuracy
^{233}U	**(n,γ)**	**σ**	**Thermal – 10 keV**	**5.0 %**
^{233}U	(n,γ)	σ	10 keV – 1 MeV	9.0 %

Goals of the measurement:

- Fulfill the demands on the High Priority Request List.
- Extend the Resolved Resonance Region (RRR).
- Confirm the neutron capture cross section magnitude.

Improvements: Samples

2003 sample and canning

Sample's isotopic composition:

^{233}U 99.01%

^{234}U 0.74%

^{235}U 0.22%

^{238}U 0.03%

Mass of ^{233}U 91 mg

Mass of Titanium 277.1 mg

Mass of Aluminum 70 mg

2014 sample

Better or equivalent isotopic purity.

Absence of titanium canning.

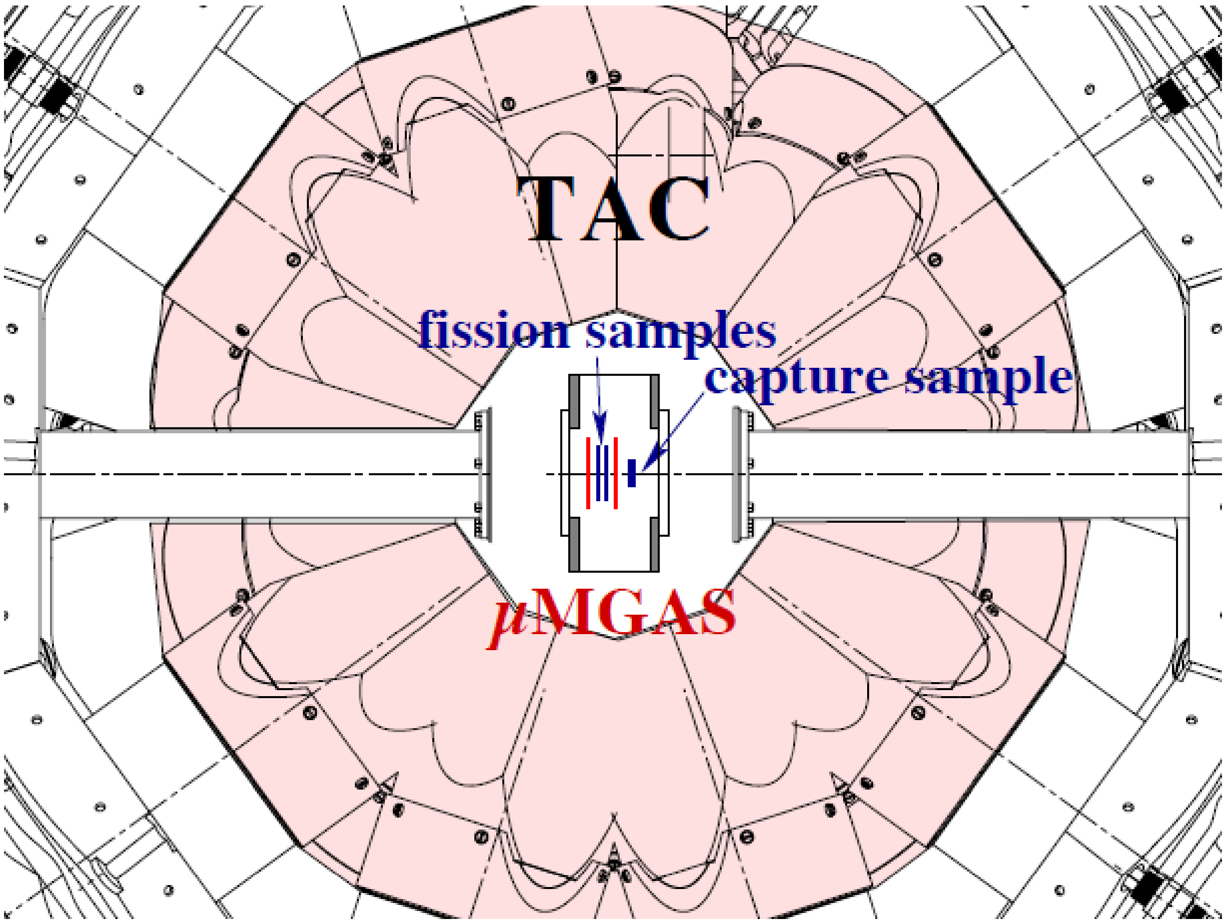
Measurement performed in a "Work Sector Type A".

Same mass of ^{233}U as in 2003.

2 thin samples (~4 mg/sample)

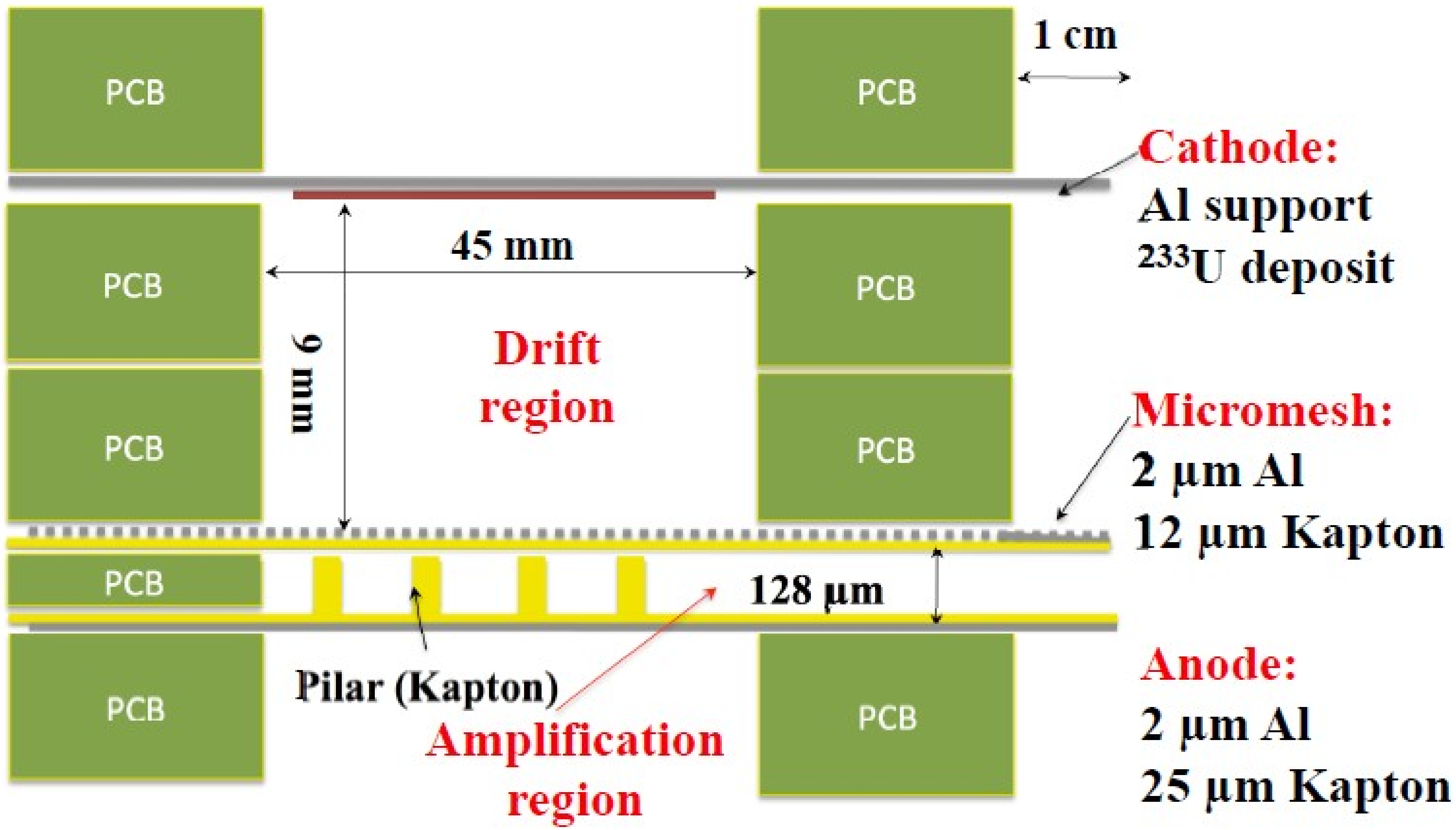
1 thick sample (~90 mg/sample)

Improvements: TAC + Al MicroMegas



- 4π array made of 40 BaF_2 crystals.
- High intrinsic and geometric efficiencies.
- Good energy resolution.
- Reconstruction and discrimination of nuclear reactions based on the calorimetric analysis.

Improvements: Al MicroMegas

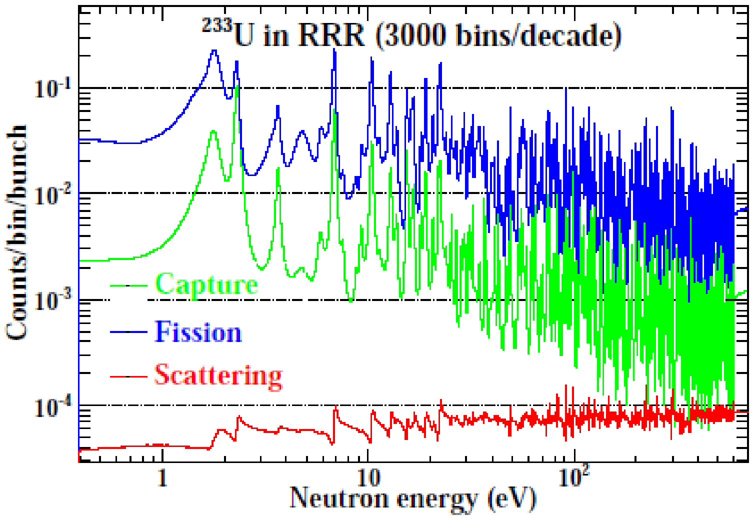


- Electrodes made of aluminum allow to measure at higher neutron energies.
- Good neutron and gamma transparency minimizing the background.
- High intrinsic detection efficiency for charge particles.
- Permits to measure in veto mode.

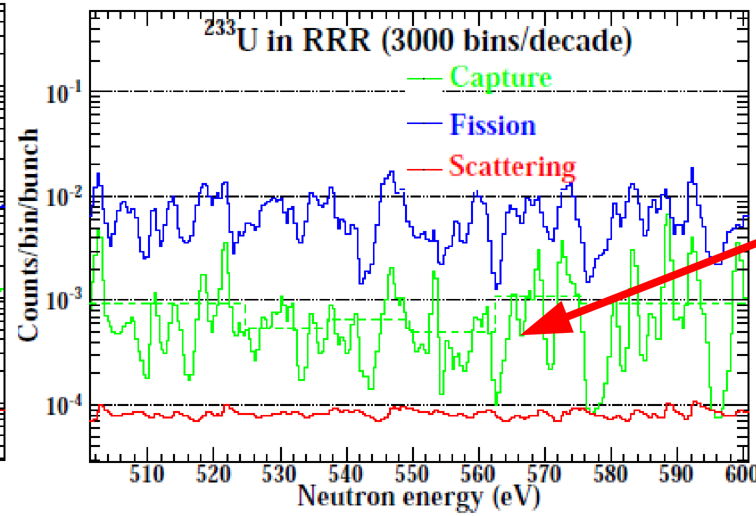
Improvements: Gated Photomultiplier

- **Commercially available technology.**
- **Using gated photomultiplier, the measurement can be extended up to 1 MeV.**
- **Nevertheless, its necessary to adapt the technology to the TAC's photomultipliers.**
- **A strong effort is being done by the n_TOF collaboration and by the CERN electronic team to produce custom made Gated Photomultiplier.**

Count rate estimates

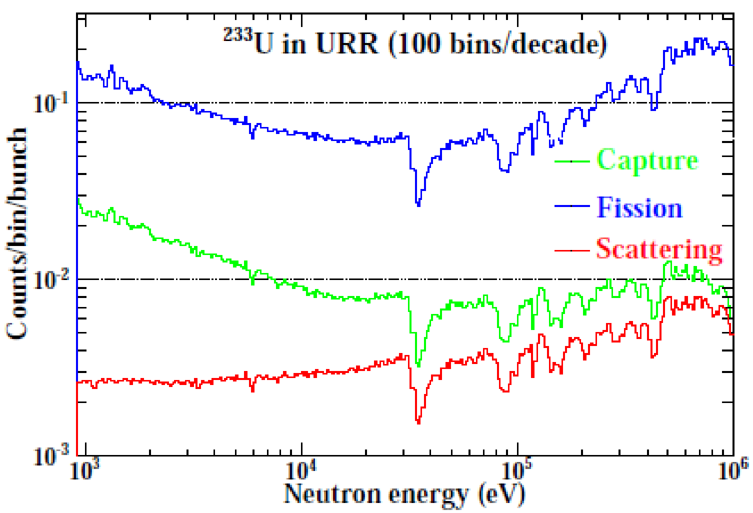


(a) Counts in the resolved resonance region

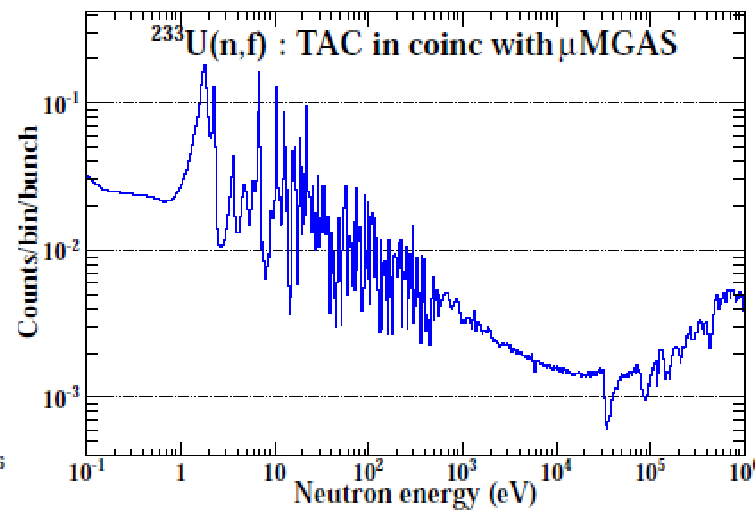


(b) Zoom around 500 eV

To obtain a 3% statistical uncertainty, $2.8 \cdot 10^{18}$ protons are needed.



(c) Counts in the unresolved resonance region



(d) Counts in TAC in coinc with μMGAS

Dedicated measurement to obtain an accurate shape of the fission events in the TAC.

Protons requested

Measurement	Number of protons
^{233}U capture and fission	**$2.8 \cdot 10^{18}$**
Coincidence measurement between TAC and fission fragment detection	$4.0 \cdot 10^{17}$
TAC response to neutron scattering using a carbon sample	$5.0 \cdot 10^{17}$
TAC response to the sample's canning for background subtraction	$5.0 \cdot 10^{17}$
Gold	$1.0 \cdot 10^{17}$
Total	**$4.3 \cdot 10^{18}$**

Special attention to the determination of:

- **The TAC's response to fission.**
- **And normalization.**

The protons necessary for the gated photomultipliers testing should be accounted in the EAR1 recommissioning.

Summary

- **Detection system development:**
  - **TAC: Ready**
  - **Al MicroMegas: Ready for production.**
  - **Gated photomultiplier: Ongoing adaptation to the TAC photomultipliers. (Not a show stopper)**

- **Samples availability:**
  - **Thick sample: Available from PSI plus 2003 sample.**
  - **Thin samples: Available from ILL Grenoble.**

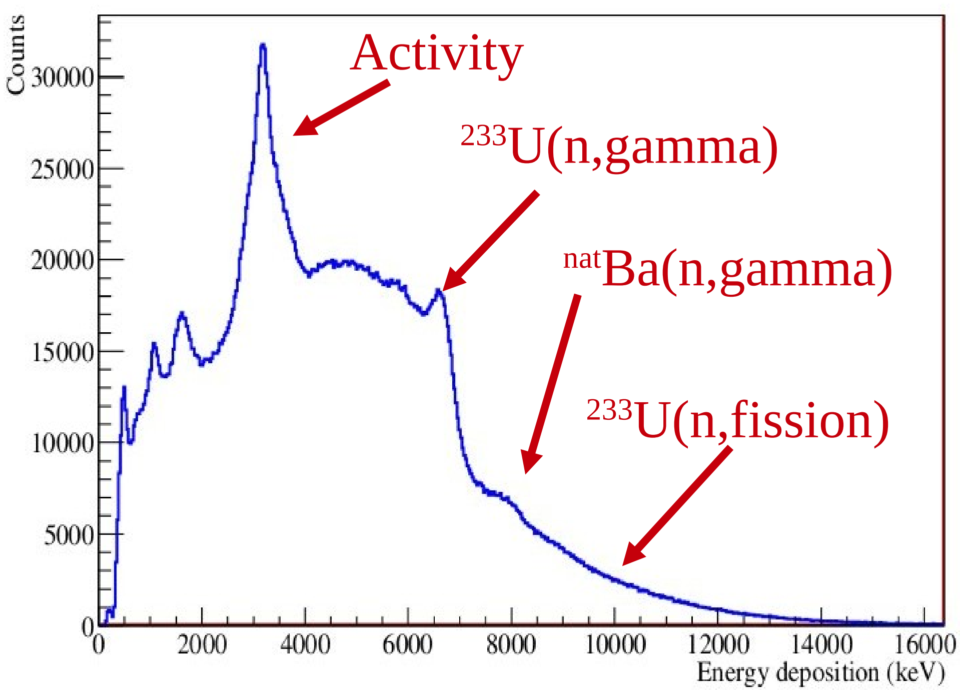
- **Data analysis:**
  - **Combination of Fission Veto and CSD techniques.**
  - **Experience obtained with the previous measurements (^{233}U and ^{235}U).**

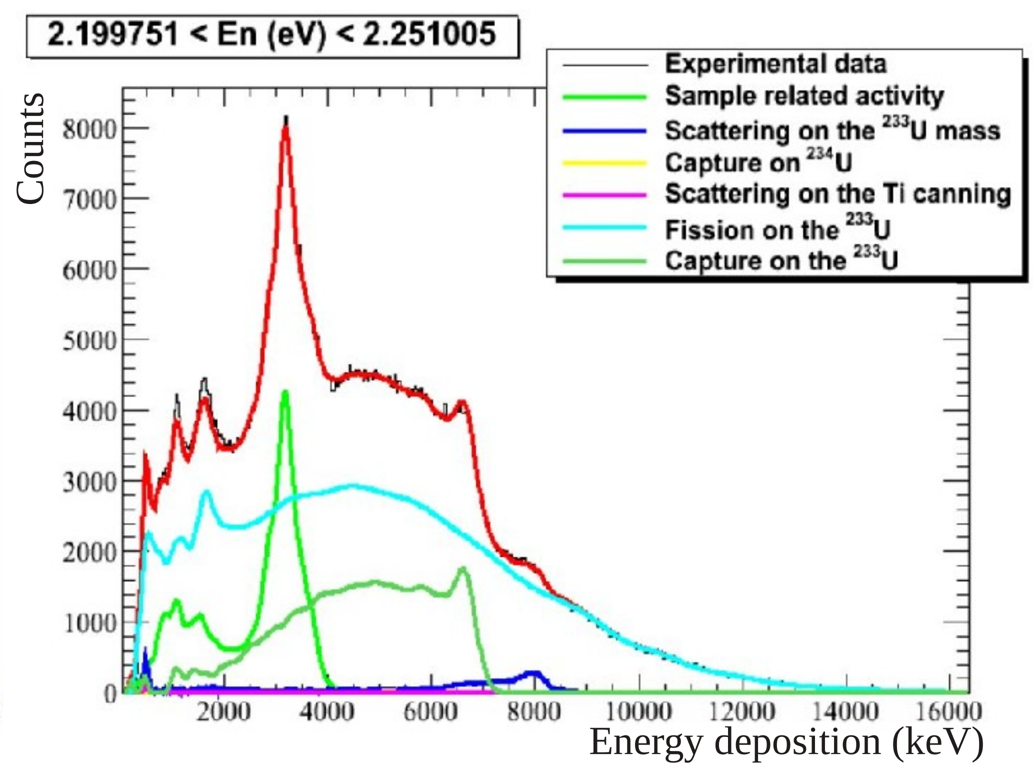
END

Thanks for the attention

^{233}U(n,γ) measurement: Calorimetric Shape Decomposition (CSD)

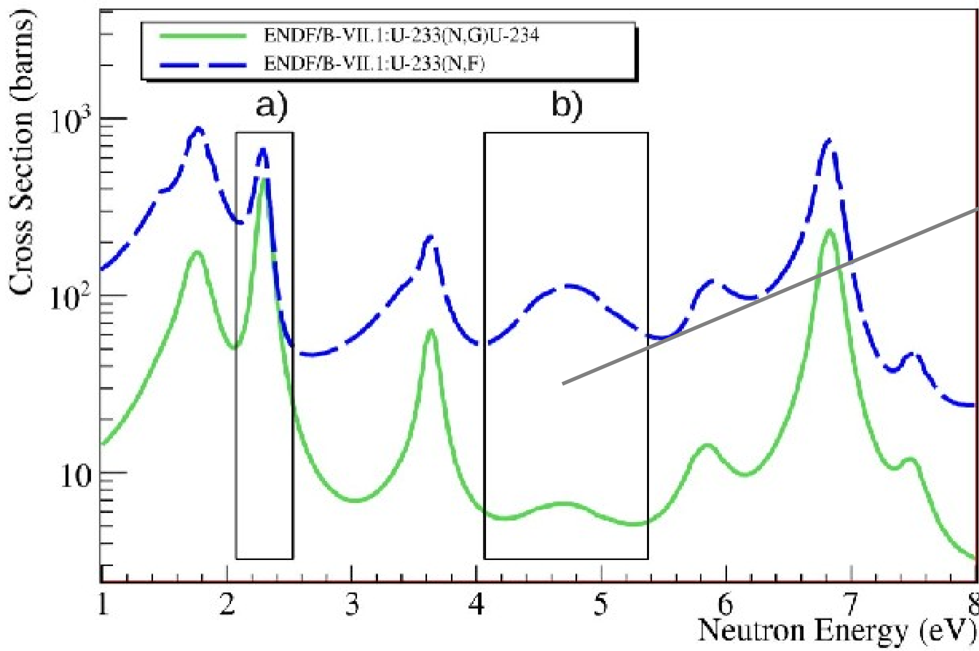
- Analysis of the TAC's energy response to each reaction
  - Isolate each reaction contribution.
  - Understand the TAC's energy and multiplicity response
  - Development of software to efficiently decompose the total energy spectrum.
  - Study the robustness of the software and the dependence of the TAC's energy responses assessed

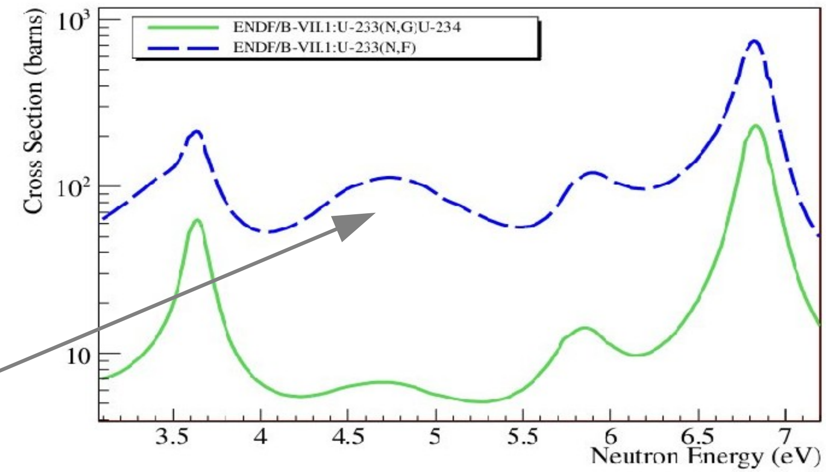


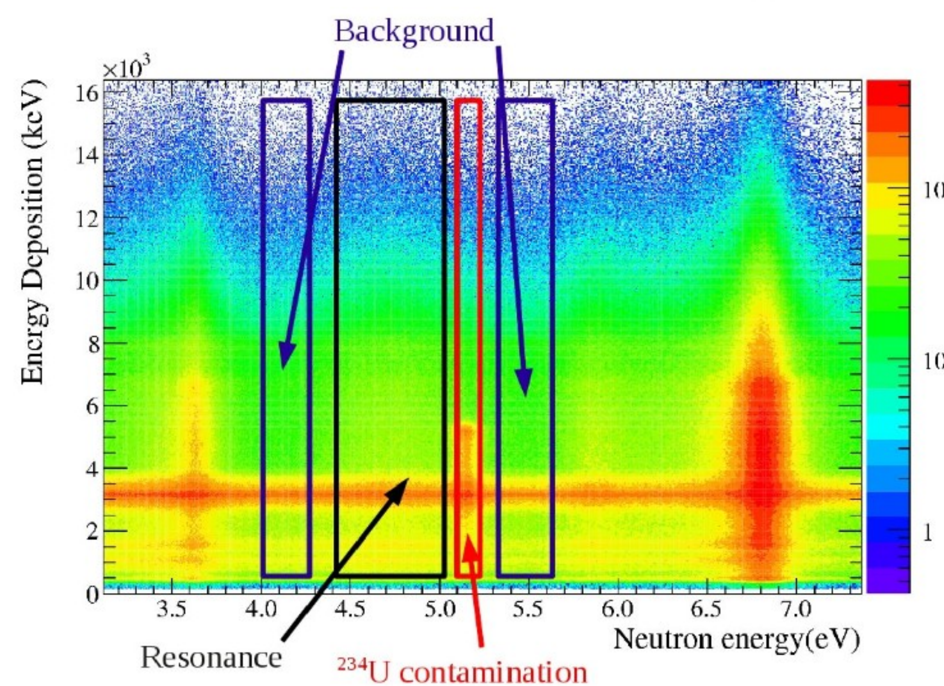


$^{233}U(n,\gamma)$ measurement: TAC response to Fission

To obtain the characteristic TAC energy response for each reaction, it is necessary to measure it alone or with a set of conditions that allows the discrimination.







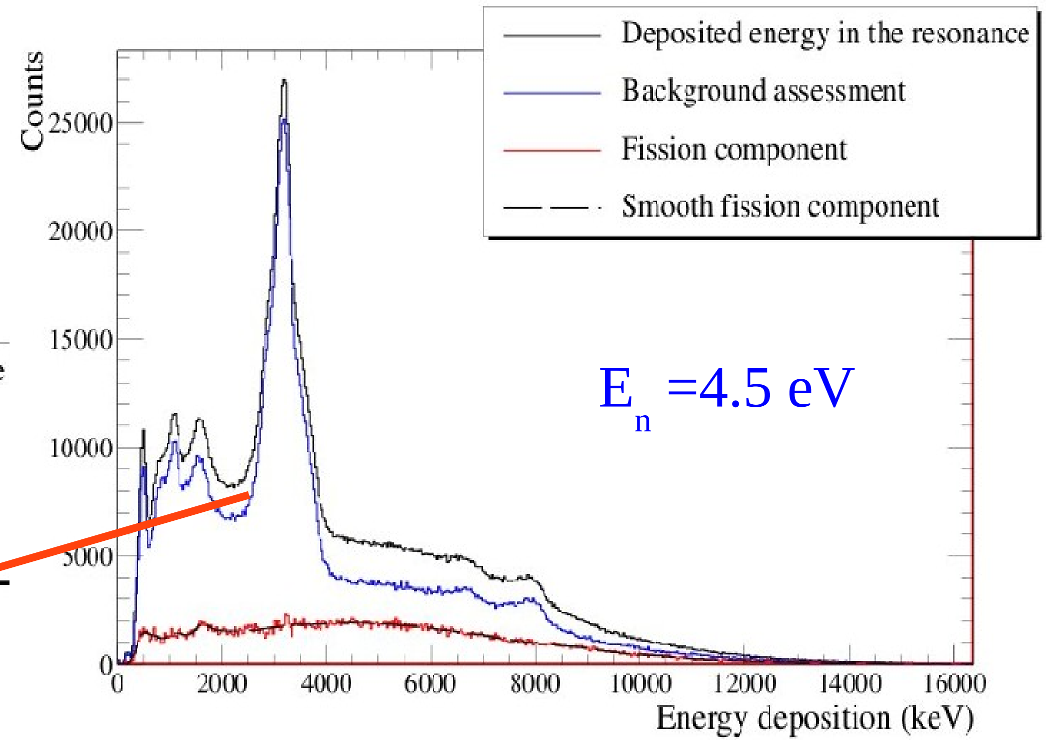
a) ***At 2.28 eV the ratio between capture and fission is 1***

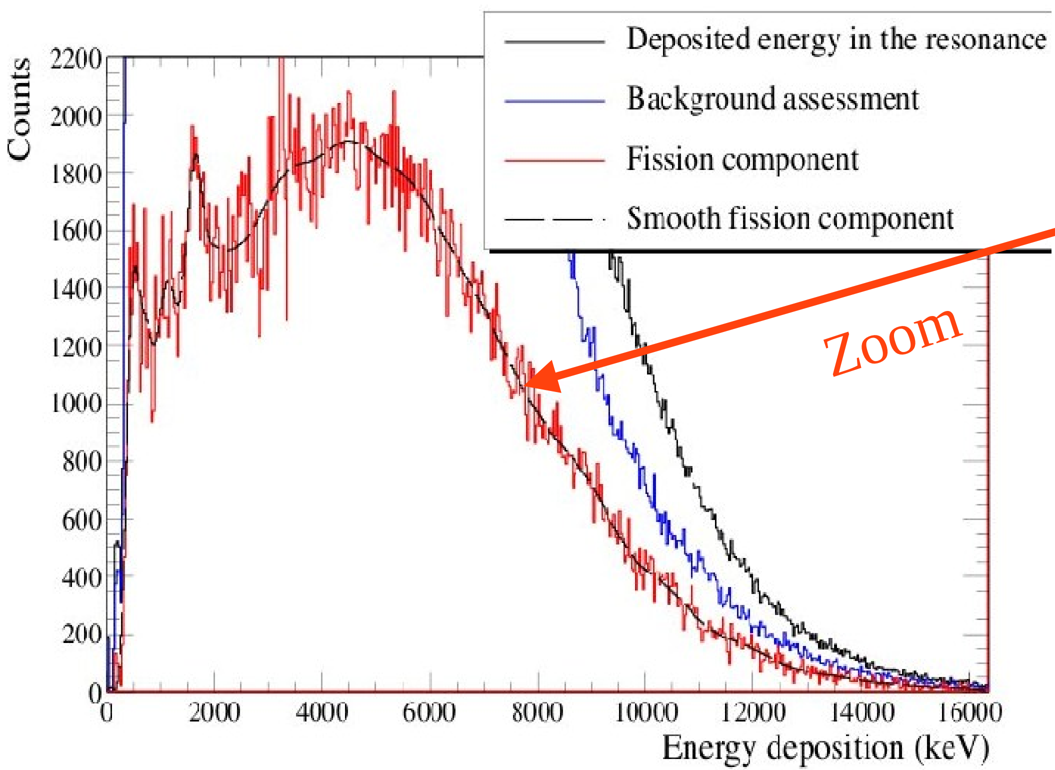
a) ***At 4.5 eV the cross section is dominated by fission.***

ENDF/B VII.1: Evaluated Nuclear Data File Library

$^{233}U(n,\gamma)$ measurement: TAC response to Fission

The counts in the resonance are due to fission events, superimposed by time-independent background from the sample related activity and other backgrounds.





It should be stressed that in the energy range of interest, the effect of sample-scattered neutrons belongs to this time-independent component.

MicroMegas with copper electrodes