^{233}U(n,γ) measurements at LANSCE

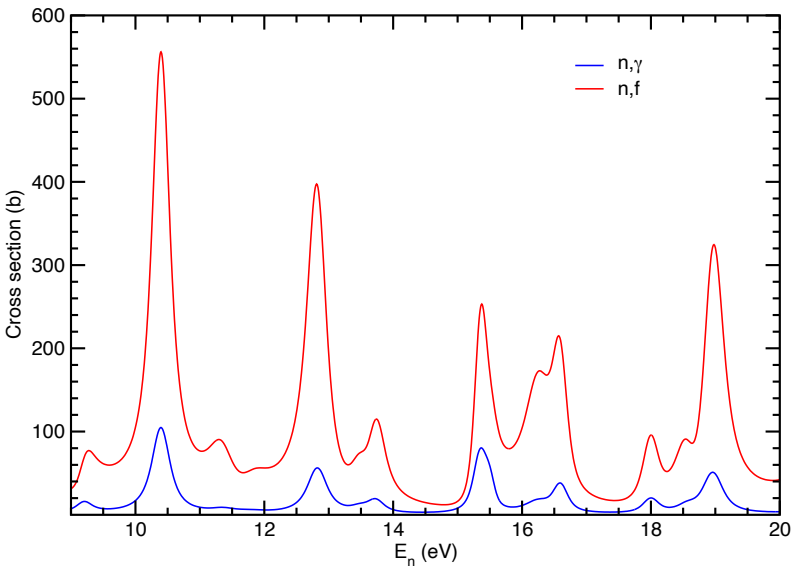
NDAG-2021

Esther Leal Cidoncha, Aaron Couture and
Gencho Rusev

19 November 2021

Motivation

- Th-U alternative to U-Pu fuel cycle due to its reduced amount of transuranium elements.
- Experimental ^{233}U(n,γ) cross section data in the literature are scarce and were measured decades ago.
- New report [1] suggests that a simultaneous measurement with capture would be useful.
- For ^{233}U fission is around one order of magnitude more likely than capture.
  - Good discrimination between gammas coming from capture and fission is required.
  - New measurement proposed at LANL combining NEUANCE and DANCE.



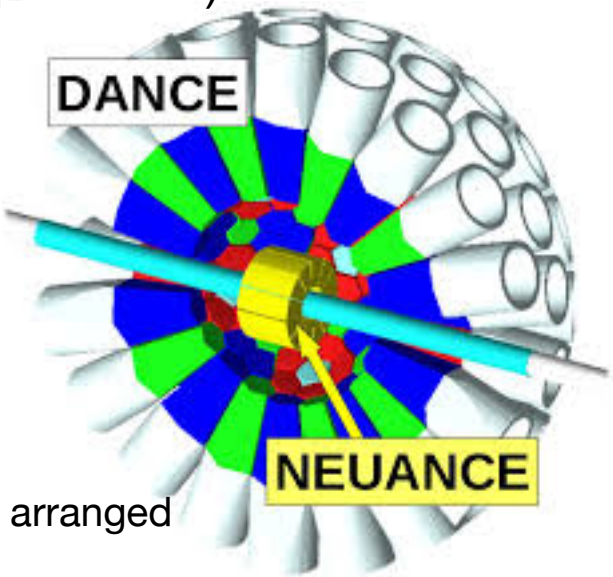
^{233}U(n,γ) and ^{233}U(n,f) cross sections from ENDF/B-VIII.

[1] M.T. Pigni, R. Capote and A. Trkov, Annals of Nuclear Energy **163** (2001) 108595.

DANCE and NEUANCE

DANCE (**D**etector for **A**dvanced **N**eutron **C**apture **E**xperiments)

- $4\pi BaF_2$ γ-ray calorimeter composed by 160 crystals with an inner cavity of 17 cm radius [2].
- Used to measure neutron capture cross section data on small quantities of radioactive isotopes.
- We can measure En, Esum, Ecl, and Mcl, providing more information than with C6D6 detectors.



NEUANCE (**NEU**tron detector array at d**ANCE**)

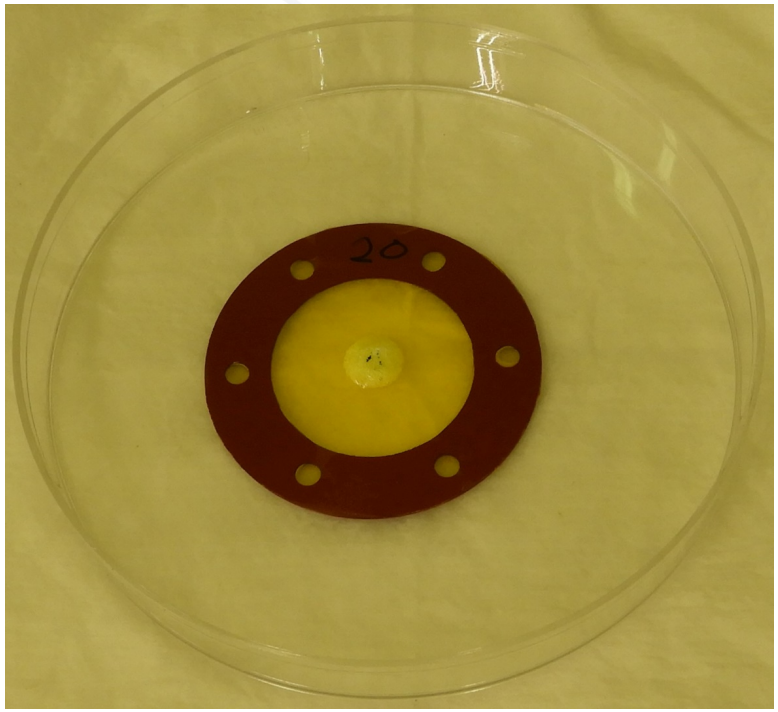
- Neutron detector array that consists in 21 stilbene crystals arranged in a cylindrical geometry around the beam pipe [3].
- Possibility to use a thick target.
- Used to detect neutrons coming from fission and determine by coincidence with DANCE, the gammas coming from fission.
- Those events are suppressed with a fission tag, and then the fission gamma shape is characterized with fission events to subtract the remaining fission background.

[2] M. Heil et al., Nucl. Instrum. Methods Phys. Res. A **459**, 229 (2001).
[3] M. Jandel et al. Nuclear Inst. and Methods in Physics Research, A **882** (2018) 105-113.

^{233}U targets

- The 30 mg of ^{233}U were supplied from Oak Ridge National Laboratory (ORNL).
- Material composition:

Isotope	Atom (%)
^{233}U	99.9843
^{234}U	<0.0002
^{235}U	0.0017
^{236}U	0.0004
^{238}U	0.0134



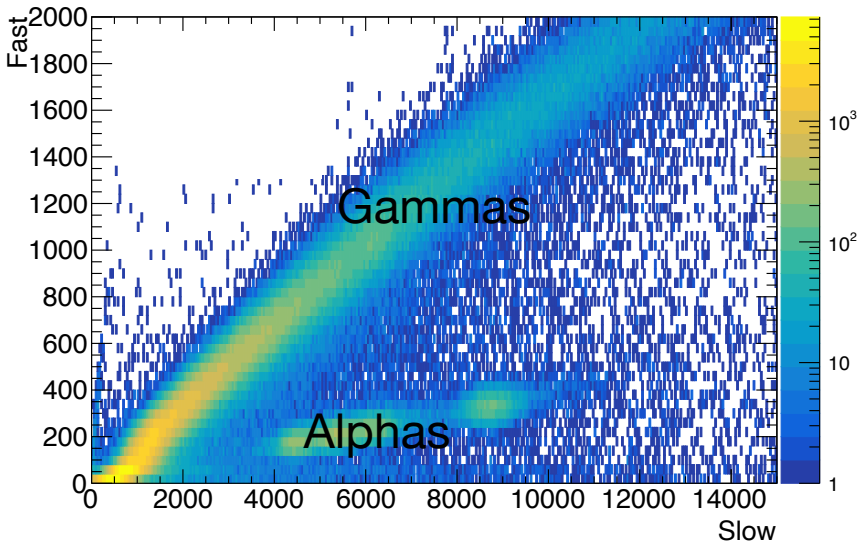
- Two samples have been prepared by Evelyn M. Bond at LANL.
  - 20 mg
  - 10 mg

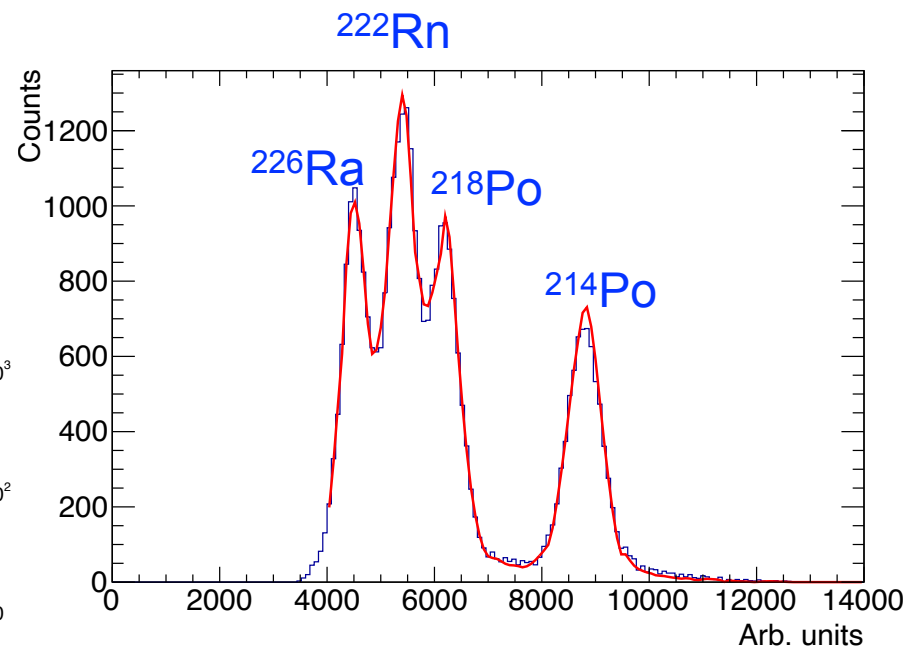
^{233}U experiment

- **DANCE & NEUANCE:**
- **Nov/Dec 2020**
  - Measurement limited by the sample construction.
  - 21 days of data taking.
  - 2 days of radioactive gamma sources for calibration.
- **June/July 2021**
  - Additional 19 days of data taking.
  - 3 days of radioactive gamma sources for calibration.
- **Neutron beam monitors:**
  - Fission chamber:
    - In parallel to measure ^{235}U(n,f) reactions during the whole data taking to calculate the neutron flux.
  - Si detectors:
    - In parallel to measure ^{6}Li(n,t) reactions to calculate the neutron flux.

DANCE calibrations

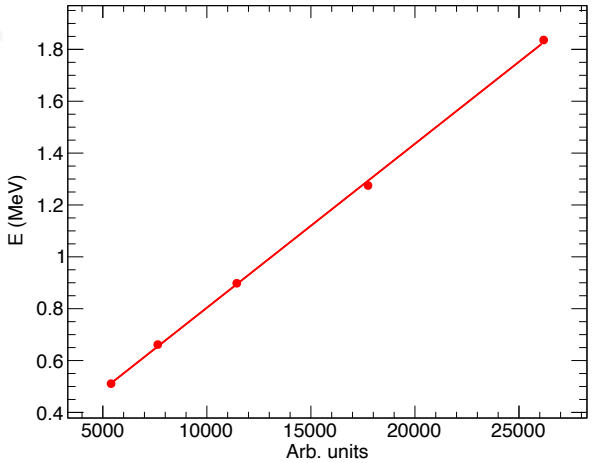
- Intrinsic radioactivity of BaF_2 used to calibrate the DANCE crystals.
- Using the Alpha-decay chain of the ^{226}Ra present in the BaF_2.
  - ^{226}Ra (4.8 MeV)
  - ^{222}Rn (5.5 MeV)
  - ^{218}Po (6.0 MeV)
  - ^{214}Po (7.7 MeV)

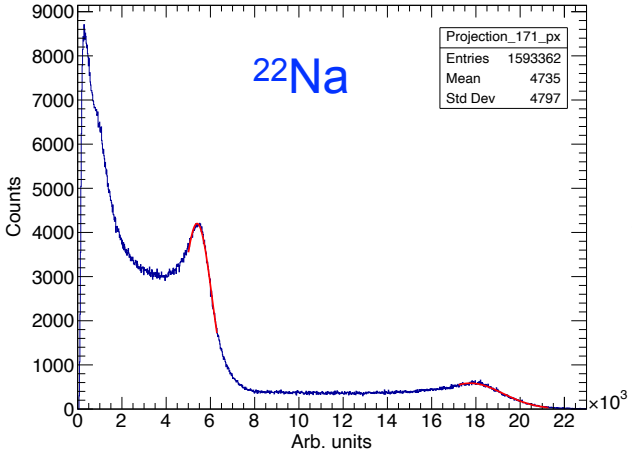


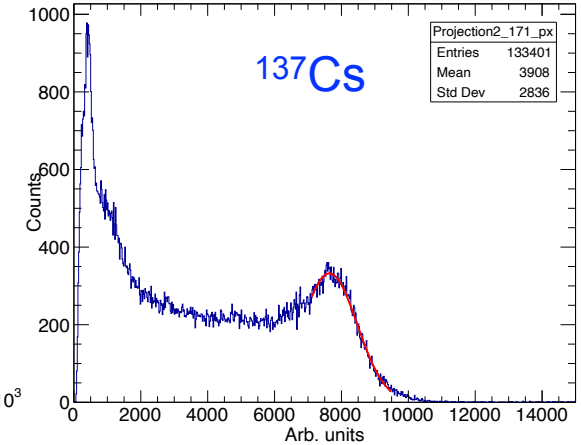


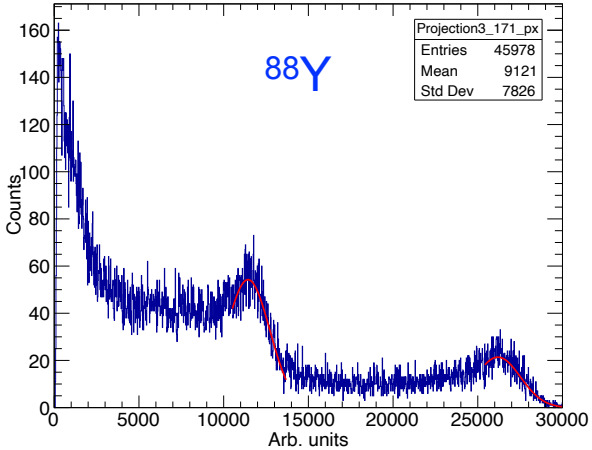
NEUANCE calibrations

- Calibration using gamma sources:
  - ^{22}Na (511 keV and 1274.537 keV).
  - ^{137}Cs (661.657 keV).
  - ^{88}Y (898.047 keV and 1836.090 keV).



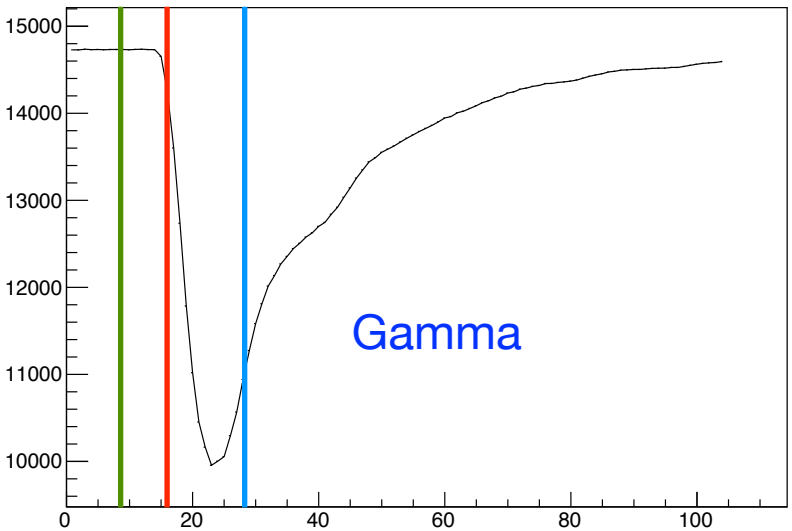


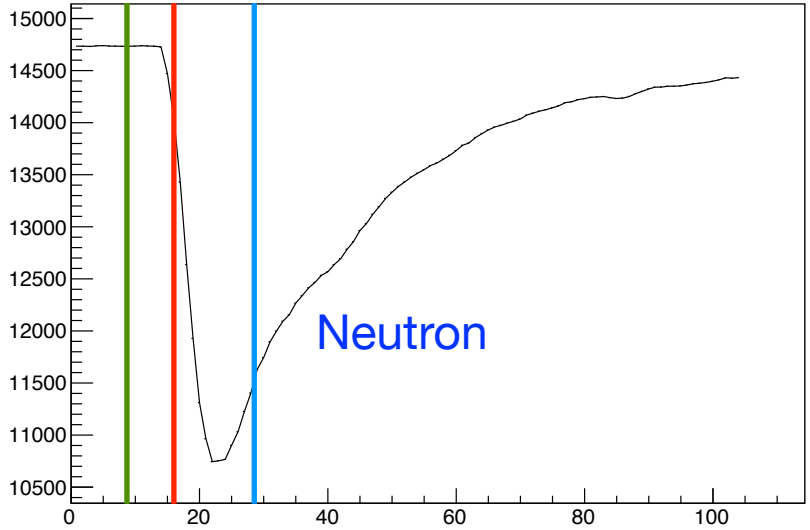




PSD NEUANCE

- Neutrons & gammas waveforms.





From the trigger:

Pretrigger gate = 16 samples

Offset gate = 8 samples

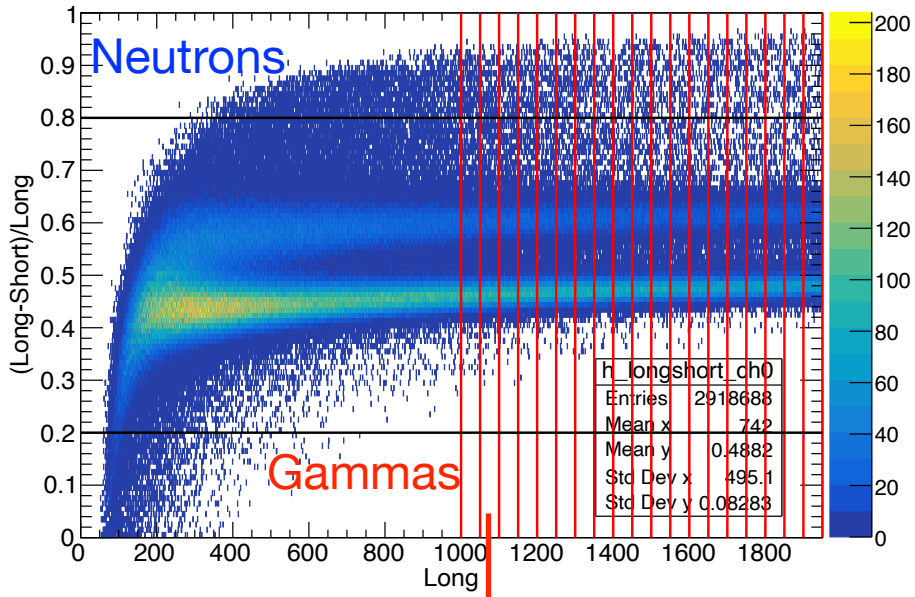
From the offset gate:

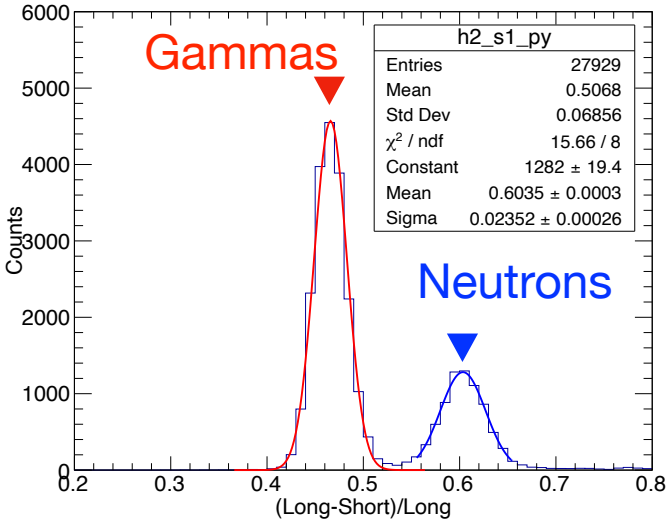
Short gate = 20 samples

Long gate = 250 samples

PSD NEUANCE

- Neutrons & gammas separation using the plot (long-short)/long vs long.

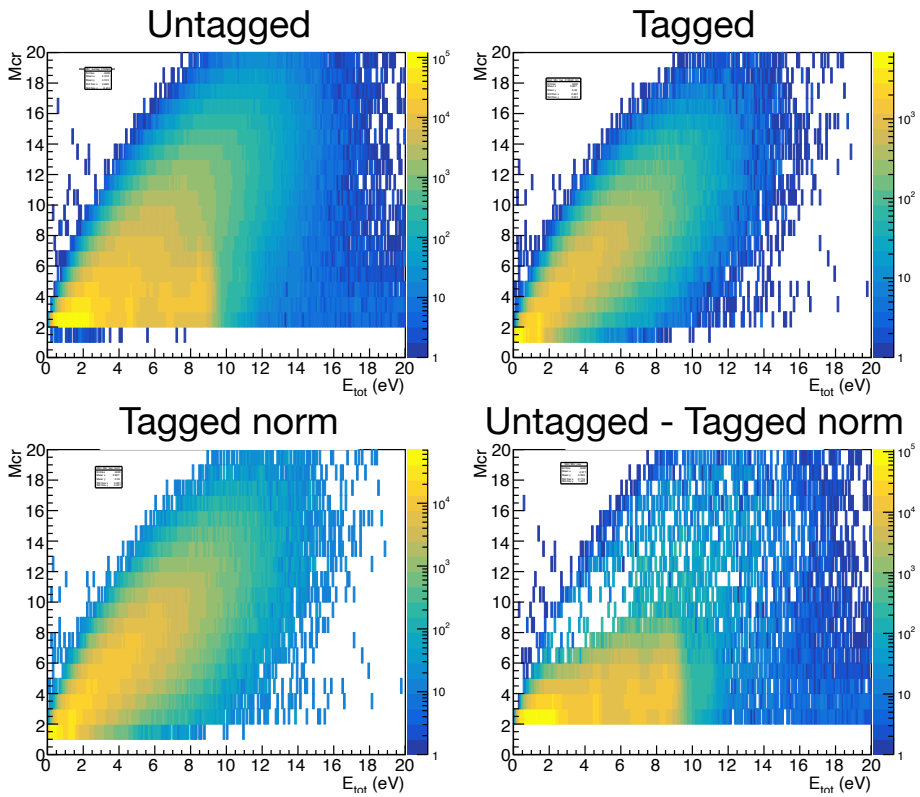




- Clear discrimination between fission neutrons and γ-rays.

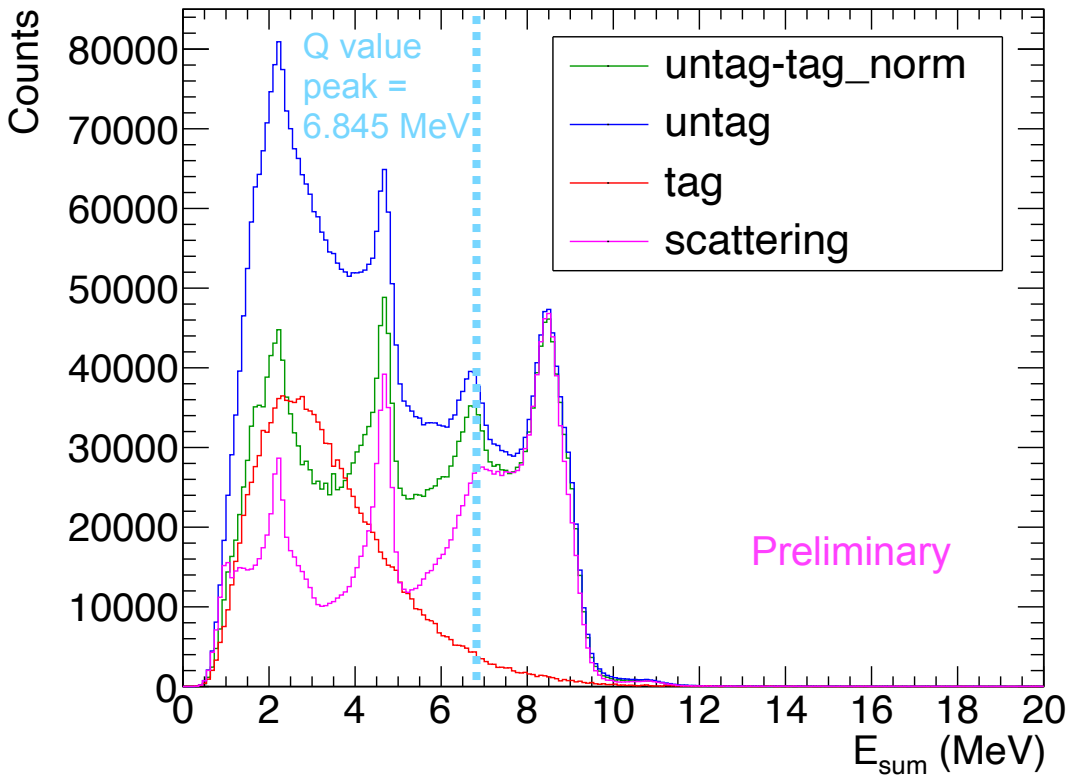
Fission tagging

- Search for coincidences between the two detectors.
- The DANCE gammas in coincidence with the NEUANCE neutrons are tagged as fission gammas.
- The purpose of tagging is to define the shape of the fission γ-ray spectrum that can be subtracted from the untagged spectrum.



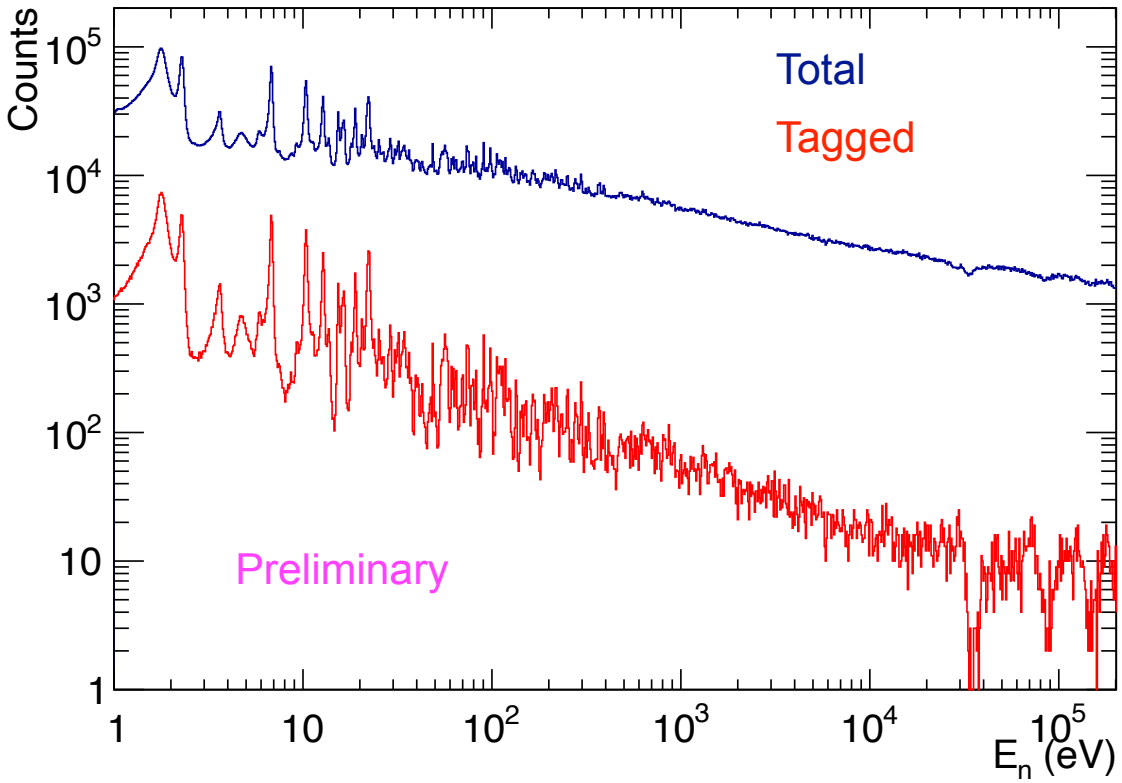
Fission tagging

- ProjectionX of the Mcr:Esum histogram for neutron energies from (1,100) eV and multiplicity from (3,6).
- The data correspond to 1h of data taking.



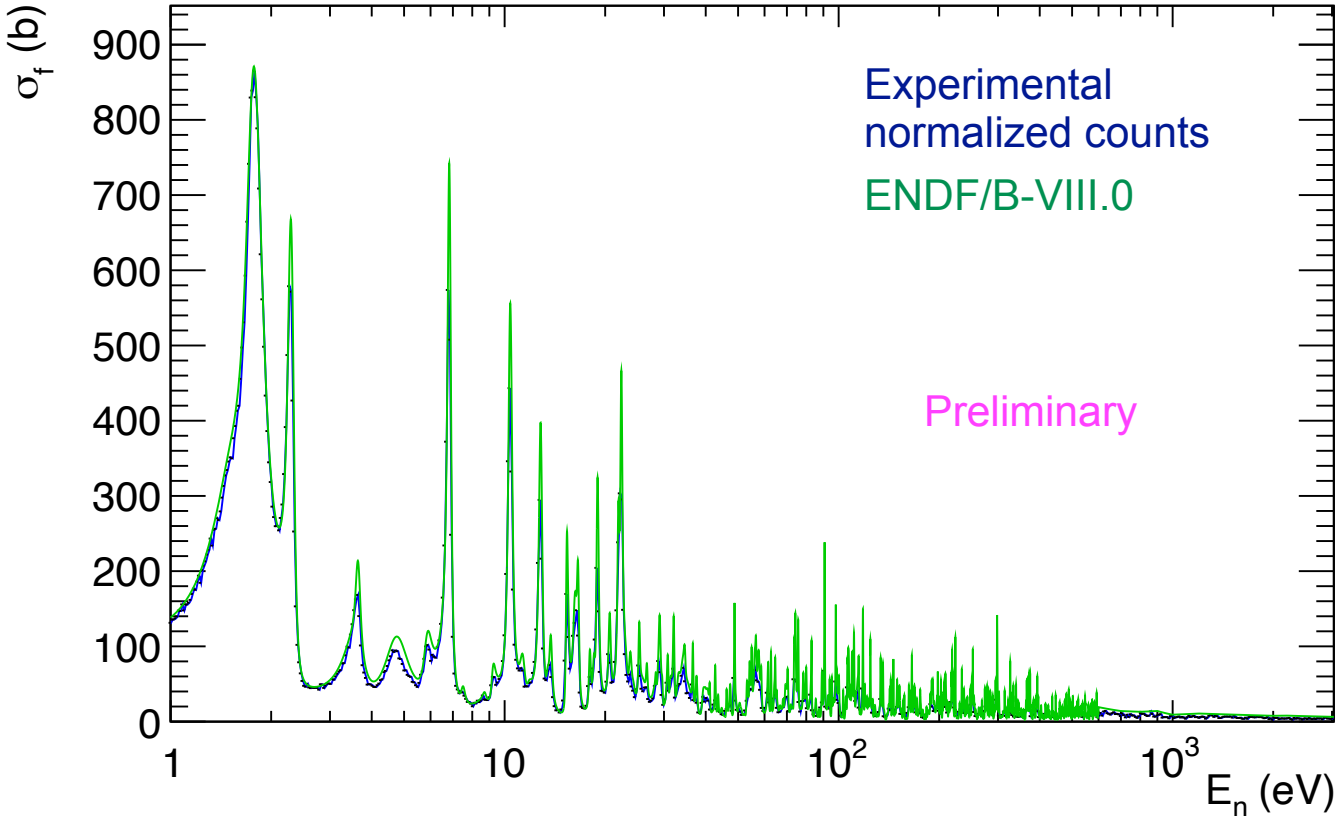
^{233}U (n,γ) DANCE spectrum

- Total and tagged raw counts of the ^{233}U(n,γ) reaction measured during 1h of data taking with DANCE.



^{233}U fission spectrum

- Comparison between the ENDF-VIII.0 evaluation and the shape of the raw fission data normalized to it.



Conclusions and next steps

- New measurement at LANSCE combining DANCE and NEUANCE at the end of 2020 and 2021.
- The ^{233}U material was provided by Oak Ridge National Laboratory (December 2020).
- Two samples of 10 mg and 20 mg of ^{233}U have been prepared at LANL by Evelyn M. Bond (December 2020).
- The experiment was performed in December 2020 and June/July 2021.
- Data analysis ongoing to extract capture data knowing fission.
- We are looking forward to deliver the capture/fission ratio from (1-300) keV by the end of the FY2022.

Acknowledgements

This work was supported by the Nuclear Criticality Safety Program, funded and managed by the National Security Administration for the Department of Energy.

The ^{233}U was supplied by DOE/SC Isotope Program.
Thanks to our collaborators John Ullmann (P-3), Cathleen Fry (P-3) and Todd A. Bredeweg (C-NR), to Oak-Ridge National Laboratory for providing the ^{233}U material and to Evelyn M. Bond for preparing it.