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Triton-beam Induced Actinide Fission

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March 14, 2024
Triton 2024
Florida State University

LA-UR-24-22434

Outline

- Introduction
- Pommard $^{237}U(n,f)$ Measurement
- Issues with Pommard
- LSDS $^{237}U(n,f)$ Measurement
- Cost and issues with another direct measurement at LANSCE (for example)
- Surrogate Measurements of $^{237}U(n,f)$

Actinide fission reactions are important

- Major actinides ($^{235,238}U$ and ^{239}Pu) are well measured with direct techniques, and continue to be looked at
- Neutron-induced reactions are particularly important
- Longer lived minor actinides ($^{233,234,236}U$, $^{240,242}Pu$, ^{237}Np, etc) have also been studied directly as much as possible
- Even short-lived minor actinides have been studied (a long list)
- But, there are limits
- Where triton beams can help…

- I will be discussing ^{237}U and ^{239}U as examples
- And for background, $t_{1/2}$ for ^{237}U and ^{239}U are 6.75 d and 23.45 m, respectively

Pommard

- Nevada Test Site underground test used for (unclassified) nuclear data measurements

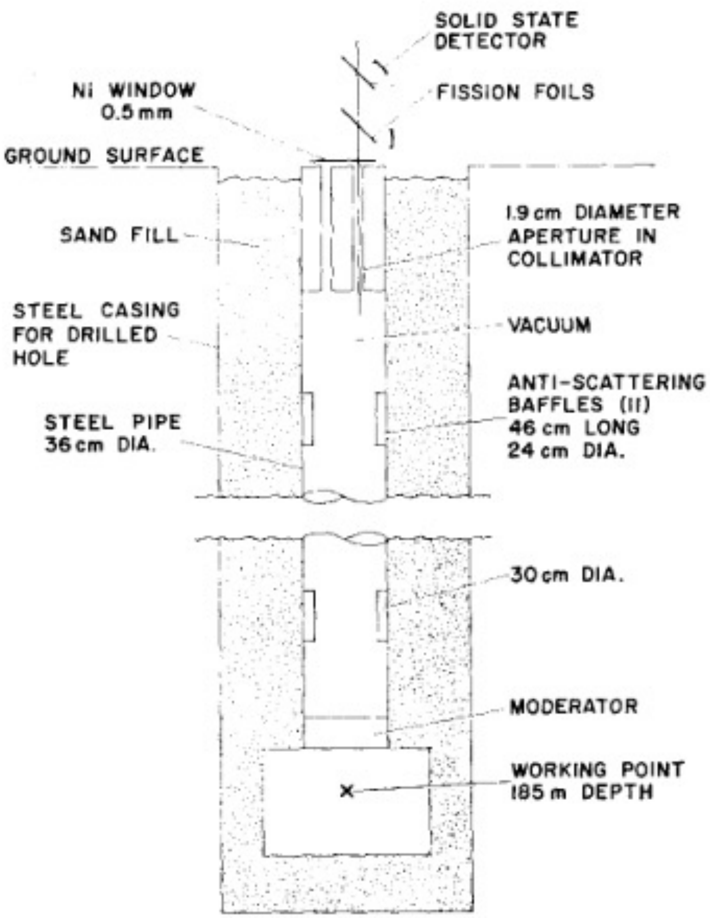
- LA-4220 *FISSION CROSS SECTIONS FRQM POMMARD, P Seeger (1970)*
- "Neutron-induced fission cross sections measured by LASL...on the Pommard event of March 15, 1968"
- The isotopes ^{232,233,235,236,237}U, ^{238,242}Pu, ^{243}Am and ^{243}Cm were measured
- Only ^{237}U(n,f) discussed here

PHYSICAL REVIEW C VOLUME 9, NUMBER 2 FEBRUARY 1974

Neutron-induced fission cross section of ^{237}U

J. H. McNally, J. W. Barnes, B. J. Dropesky, P. A. Seeger, and K. Wolfsberg
Los Alamos Scientific Laboratory, University of California, Los Alamos, New Mexico 87544
(Received 5 March 1973)

The Measurement (figures from Seeger, Hemmendinger and Diven)



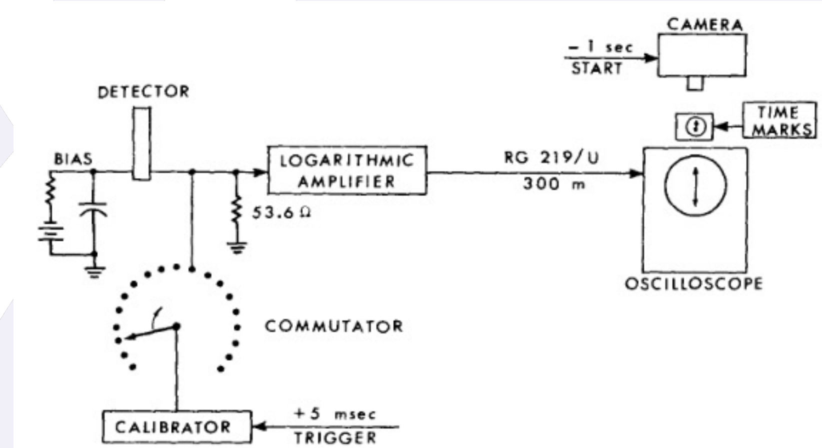
2.J

Nuclear Physics **A96** (1967) 605—616; © *North-Holland Publishing Co., Amsterdam*

FISSION CROSS SECTIONS OF ^{241}Am AND ^{242m}Am

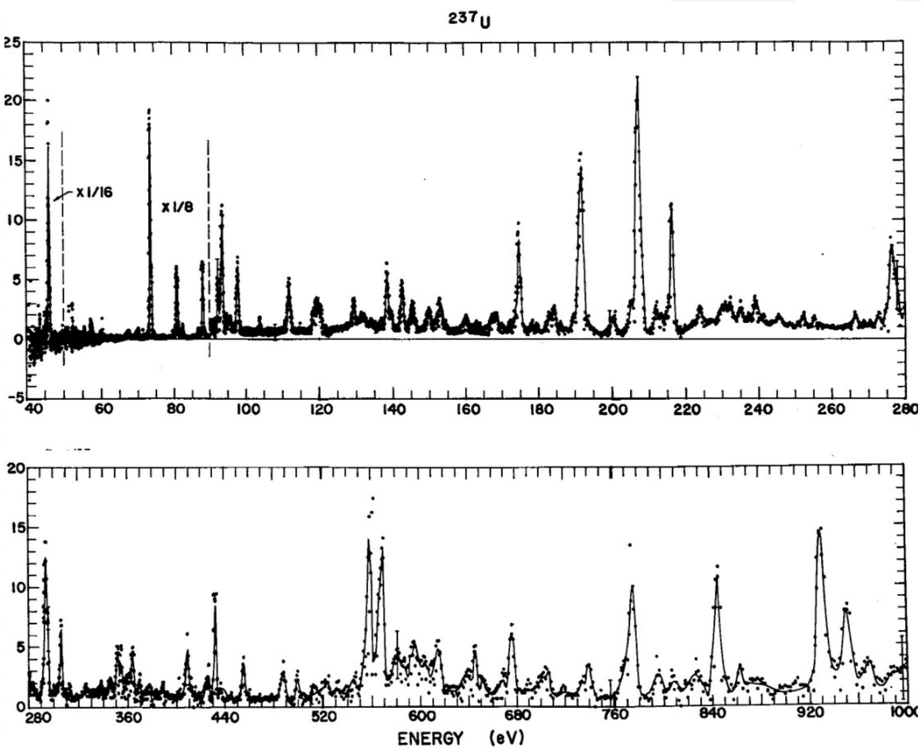
P. A. SEEGER, A. HEMMENDINGER and B. C. DIVEN
University of California, Los Alamos Scientific Laboratory, Los Alamos, N.M.[†]

Received 27 December 1966



^{237}U(n,f) from Pommard

- Technical difficulties during the measurement, causing a loss of data for some of the measurement time. Two separate incoming neutron energy ranges were reported.



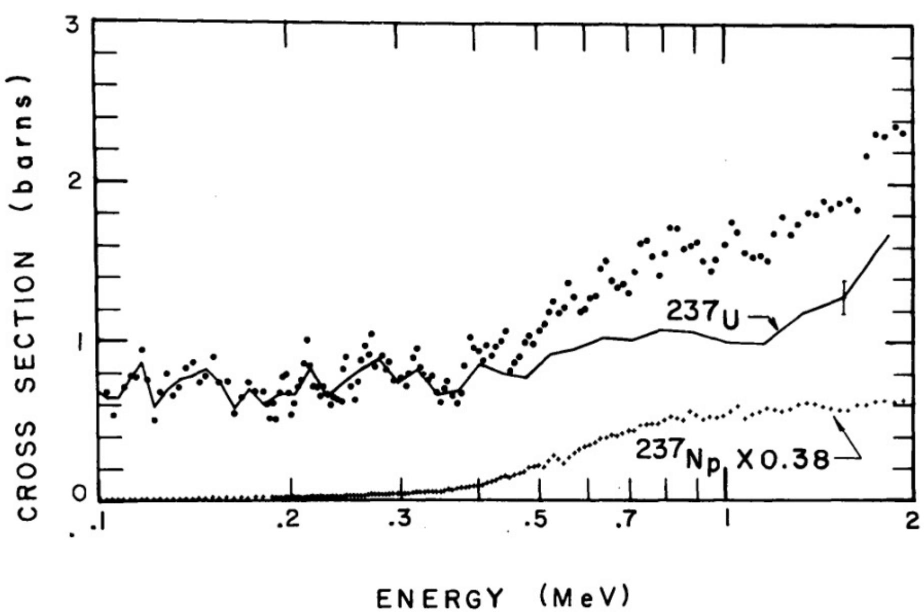


Fig. 12. Fission cross section of ^{237}U; data corrected for ^{237}Np content of target.

But Mcnally's Cross Section has issues in the Higher E_n Range: Systematics of (n,f) in the U Isotopes

NUCLEAR SCIENCE AND ENGINEERING: **116**, 213–217 (1994)

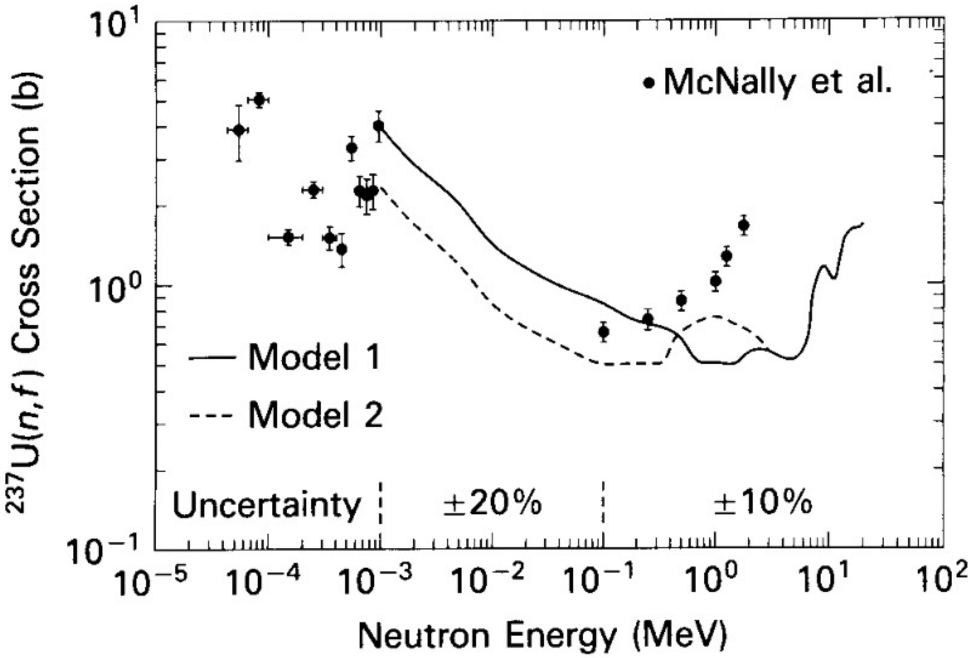


Fig. 4. Predicted $^{237}U(n,f)$ cross sections and the Pommard shot data of McNally et al.[4]

Statistical Model Calculation of the ^{237}U Fission Cross Section

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Los Alamos, New Mexico 87545

Received August 30, 1993
Accepted November 5, 1993

TABLE I. Target composition.

Nucleus	Amount
^{237}U	18.1 ± 0.5 μg
^{237}Np	6.9 ± 0.1 μg
^{236}U	0.5 ± 0.05 μg
^{238}Np	2.9×10^{10} atoms

What happened?

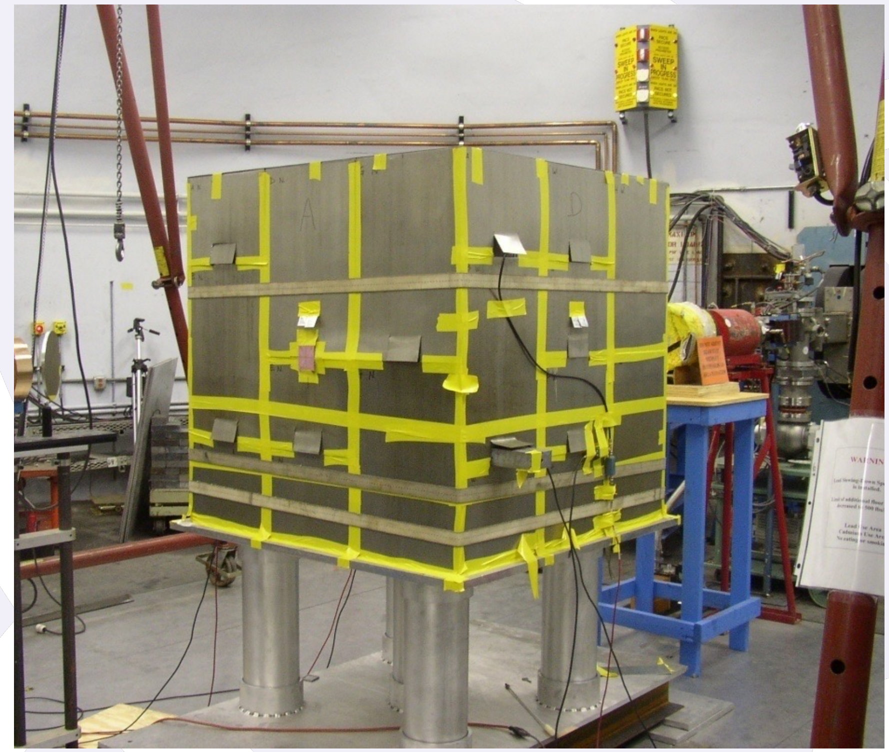
From the preface of the original report (LA-4220):

…The flight path for Pommard was 214.43m and recordings were made with resolutions of 0.2 and 1 μsec.

A malfunction of every amplifier at 50 μsec after the burst, presumably triggered by electro-magnetic noise, caused a calibration signal to be overwritten on every signal. For most amplifiers, there apparently was also a shift in the operating point of the amplifier input stage that led to considerable uncertainty in the base lines following this "catastrophe." Essentially all data from 100 keV to about 10 keV (the lower limit being different for each signal) were lost….

A retry at ^{237}U(n,f) at LANSCE

LSDS (partially assembled) and tungsten target

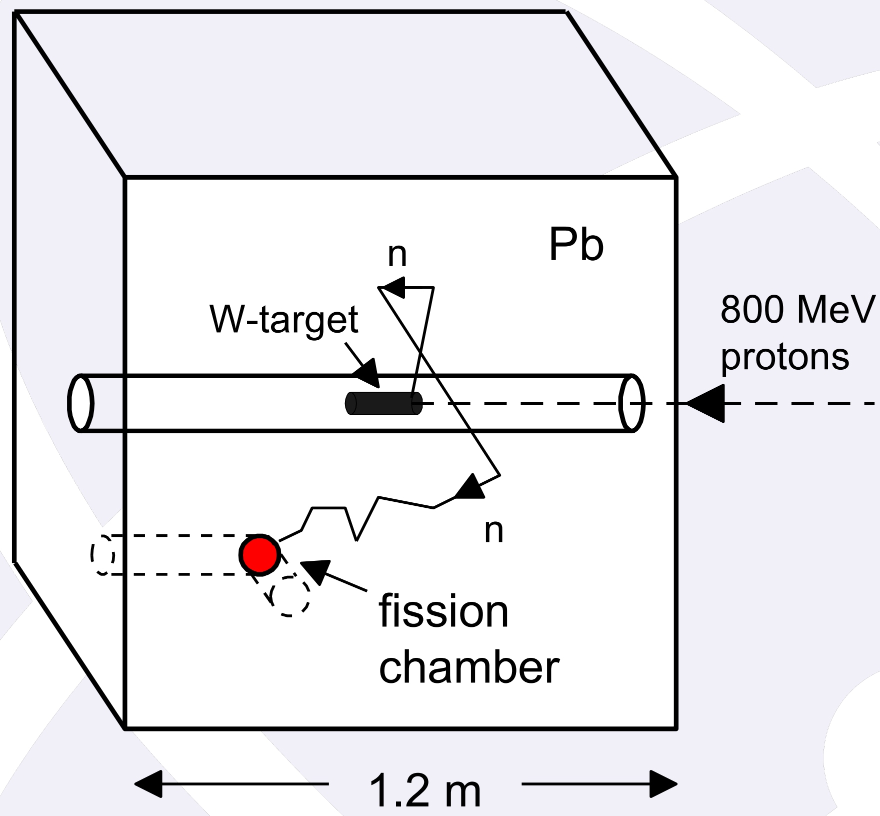


LSDS with Cadmium sheets

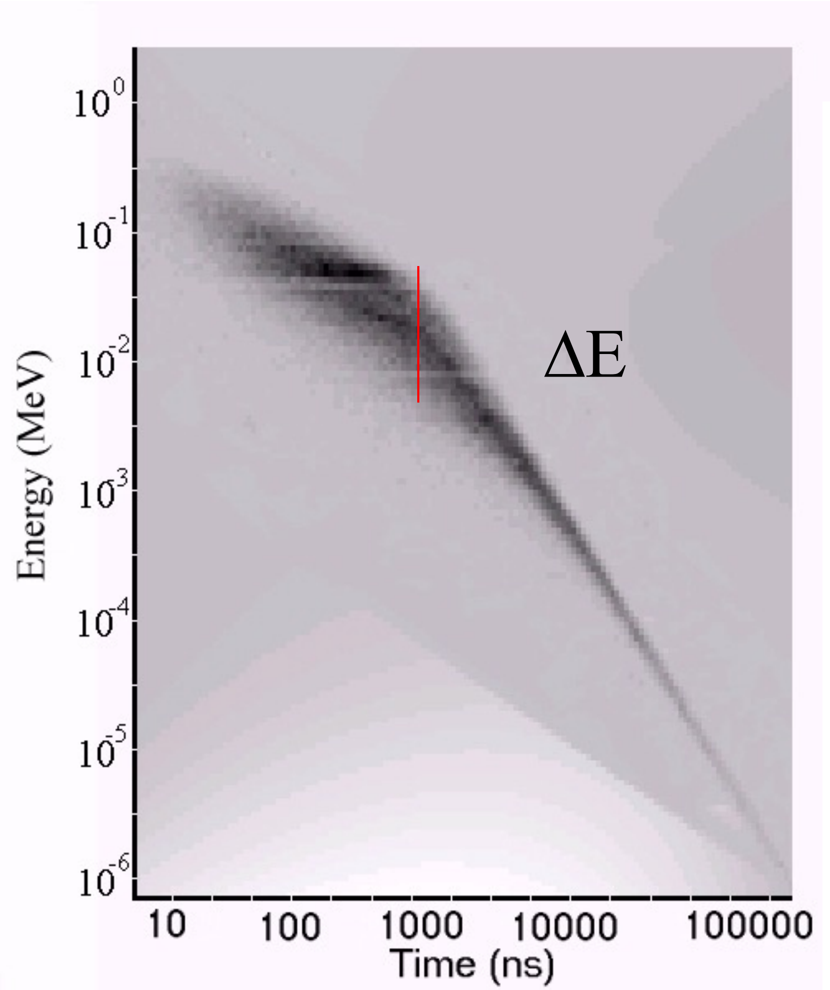
A Lead Slowing Down Spectrometer (LSDS)

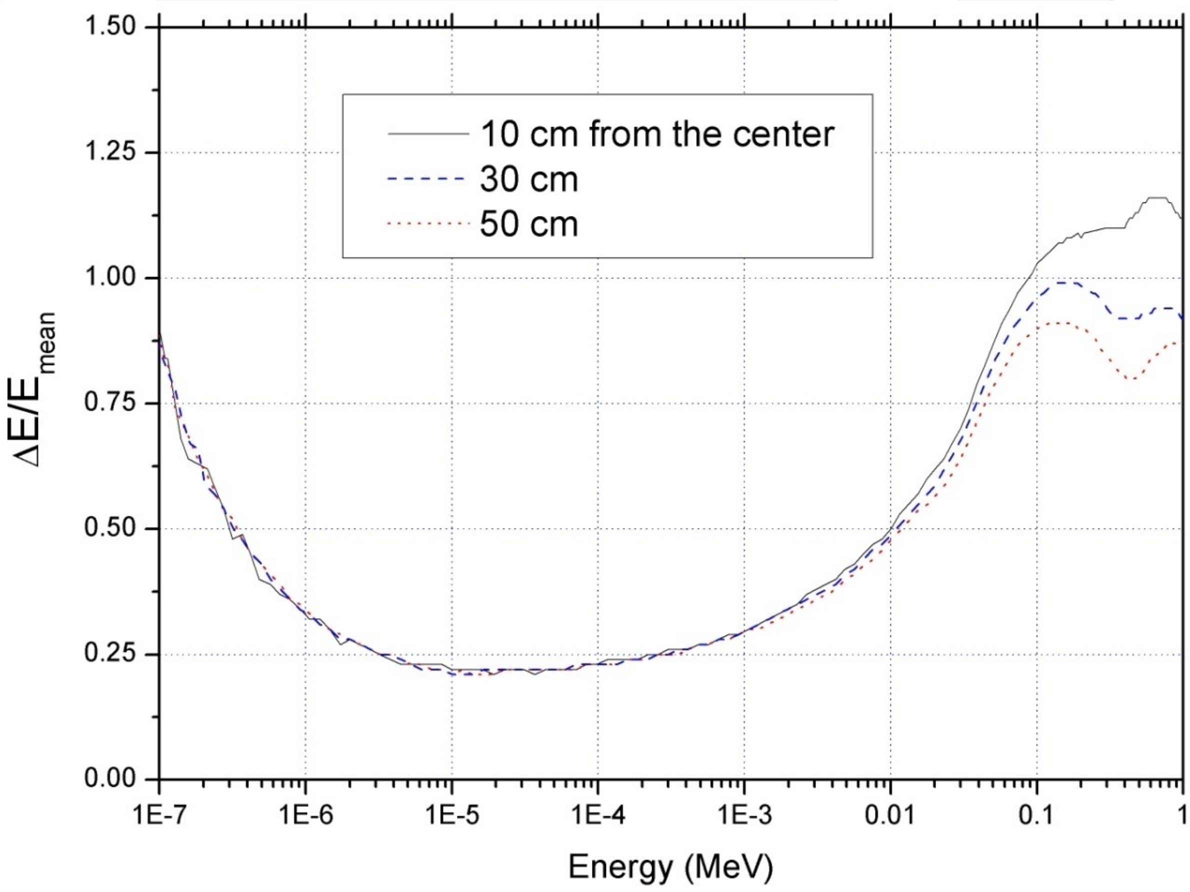
- Neutron source - pulsed
- Big lead cube
  - Lead has small absorption cross section
  - Lead has heavy nucleus → small energy loss for neutrons elastically scattered
  - Elastic scattering cross section approx, constant with neutron energy
- Measure reaction rate (e.g. fission) as a function of time
- For $E_n <$ 100 keV

$$< E_n > = K/(t + t_0)^2$$



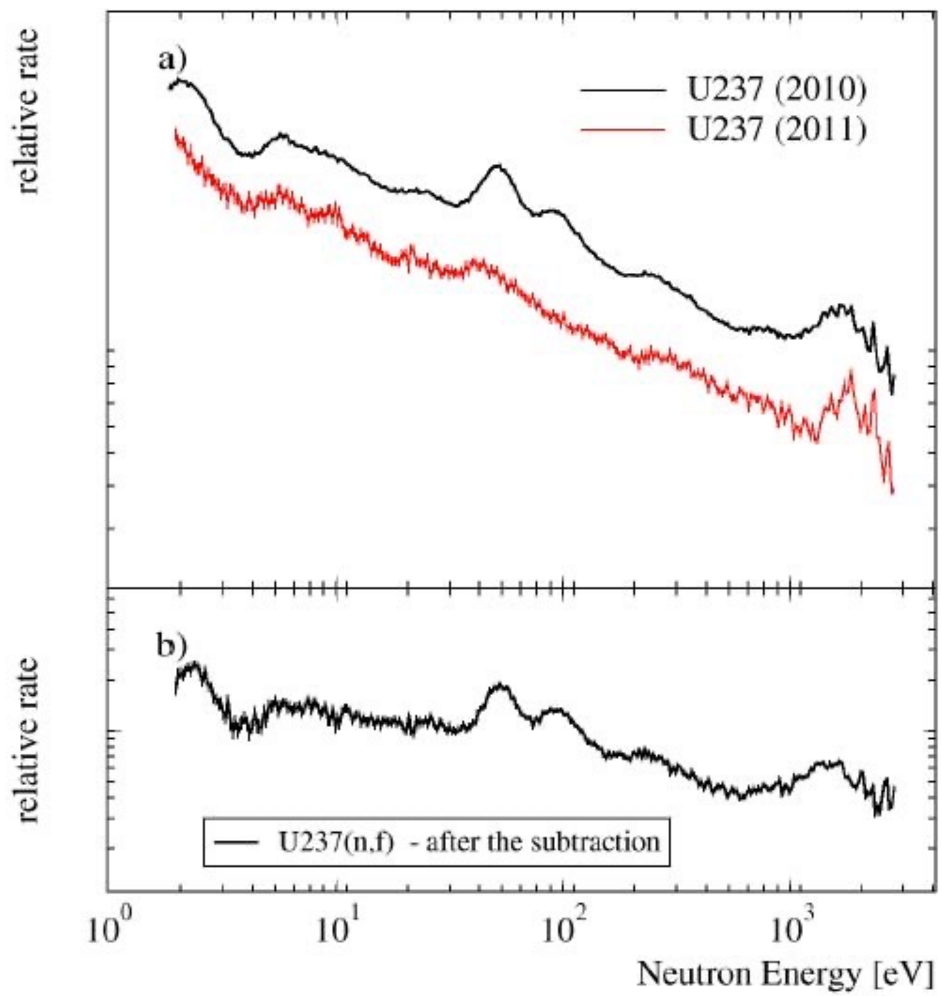
LSDS energy spectrum – time of flight in a Pb cube





Energy Dispersion > 25 %

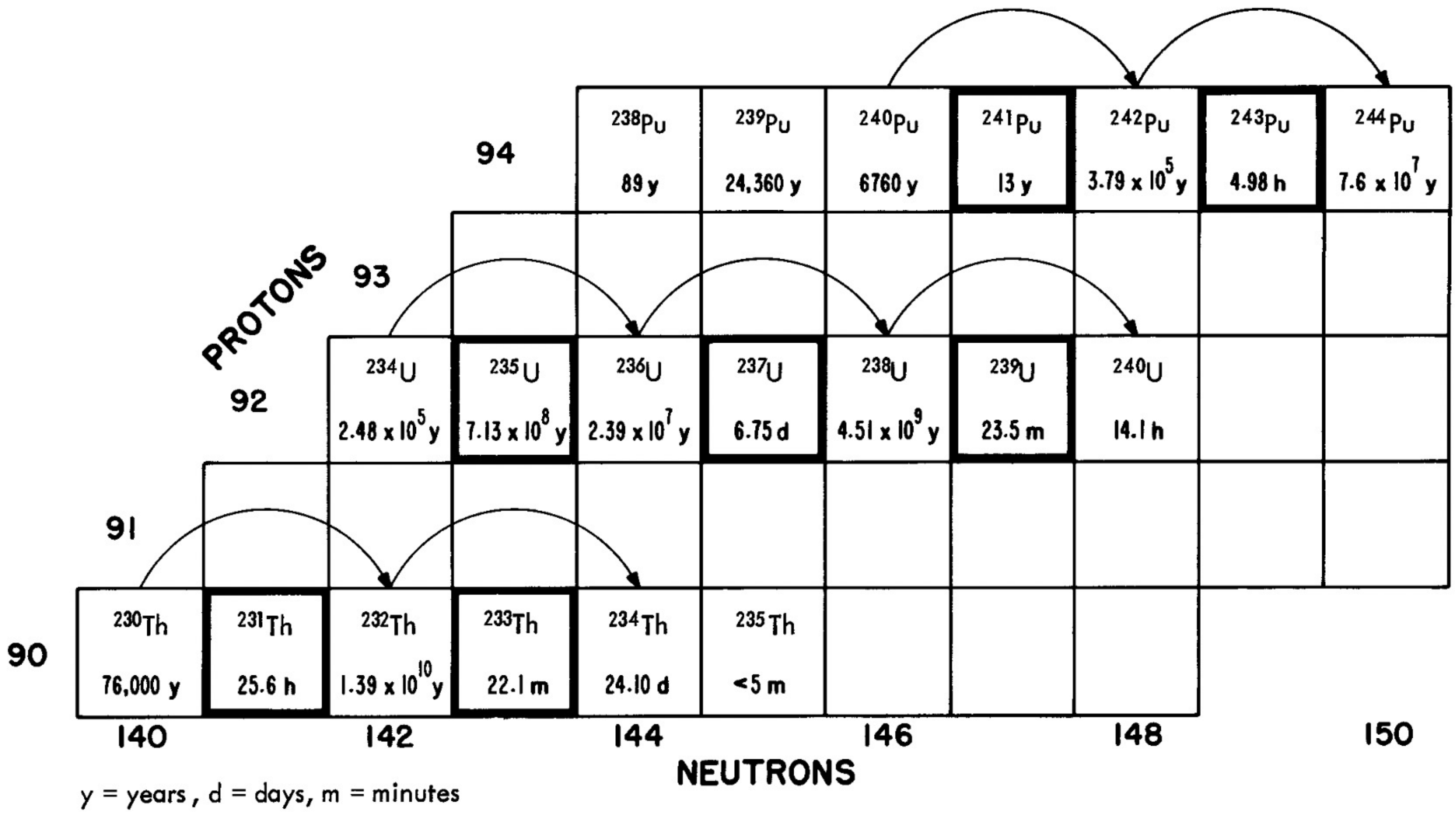
LSDS $^{237}U(n,f)$ Cross Section Result (Preliminary)



- The sample was 1% ^{237}U at the time of the measurement, and on the order of 1% ^{237}Np, and 98% ^{236}U
- Produced in a HFIR irradiation of ^{236}U
- Compensated fission chamber with the cell using 235U

M. Jandel, T. A. Bredeweg, E. M. Bond, M. B. Chadwick, A. Couture, J. M. O'Donnell, M. M. Fowler, R. C. Haight, A. C. Hayes-Sterbenz, R. S. Rundberg, *et al.*, *Fission and Properties of Neutron-Rich Nuclei*, Proceedings of the Fifth International Conference on ICFN5, Sanibel Island, Florida, USA , 416 (2013).

Why consider (t,pf)?



Prior Surrogate Work

NUCLEAR SCIENCE AND ENGINEERING: 41, 177-187 (1970)

Neutron Fission Cross Sections for ^{231}Th, ^{233}Th, ^{235}U, ^{237}U, ^{239}U, ^{241}Pu, and ^{243}Pu from 0.5 to 2.25 MeV Using (*t*, *pf*) Reactions

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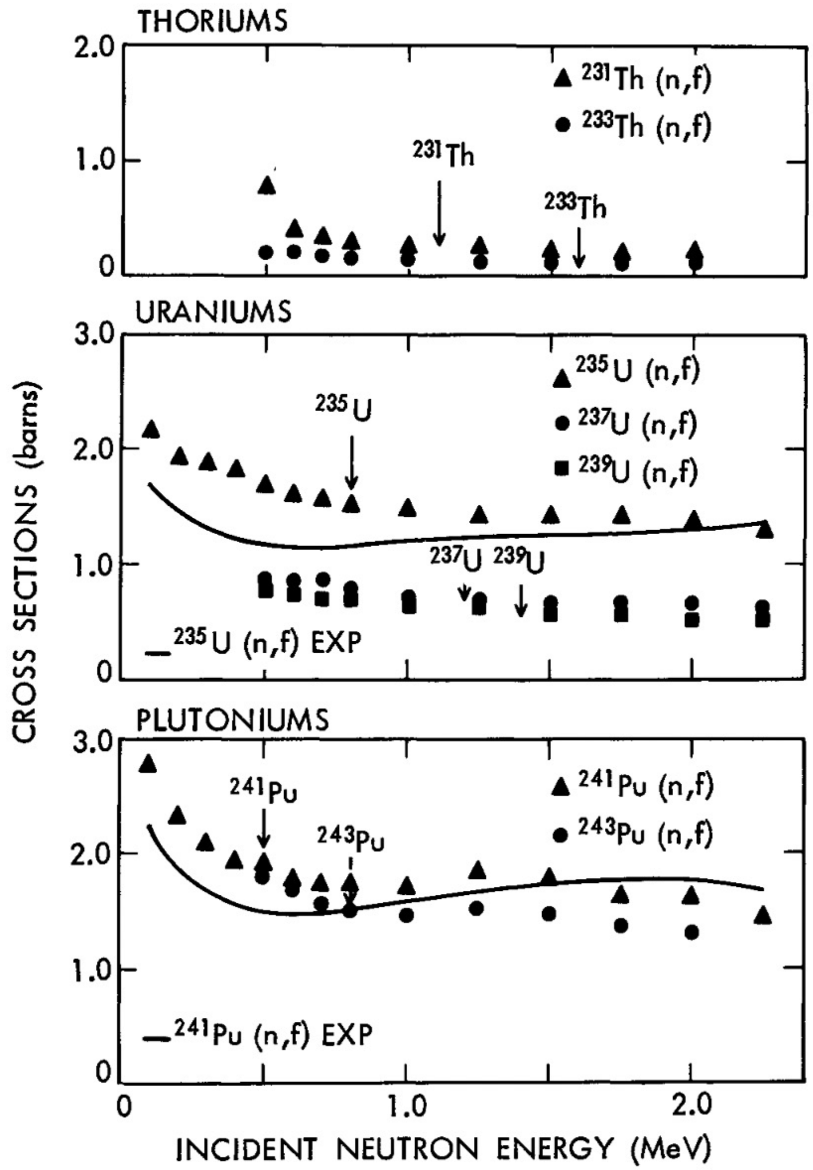
Received January 26, 1970
Revised March 23, 1970



PHYSICAL REVIEW C VOLUME 9, NUMBER 5 MAY 1974

Fission of doubly even actinide nuclei induced by direct reactions*

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Los Alamos Scientific Laboratory, University of California, Los Alamos, New Mexico 87544, and The Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark

H. C. Britt and J. D. Garrett†
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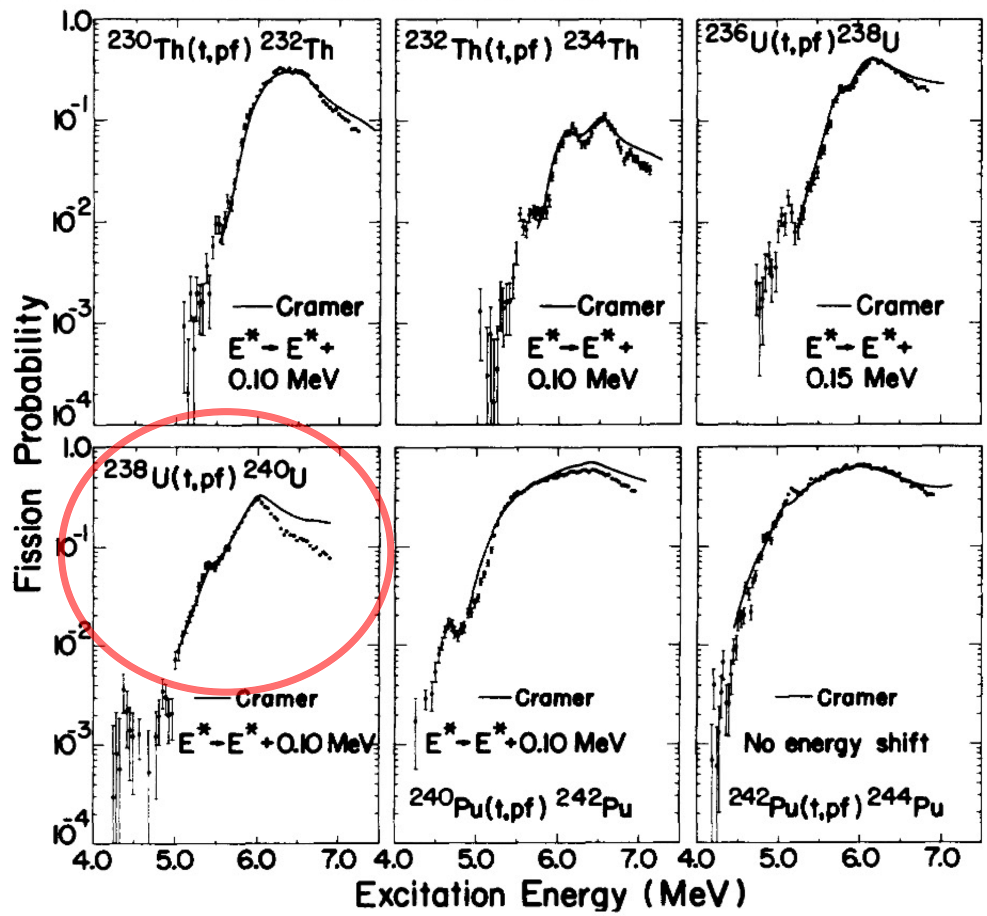
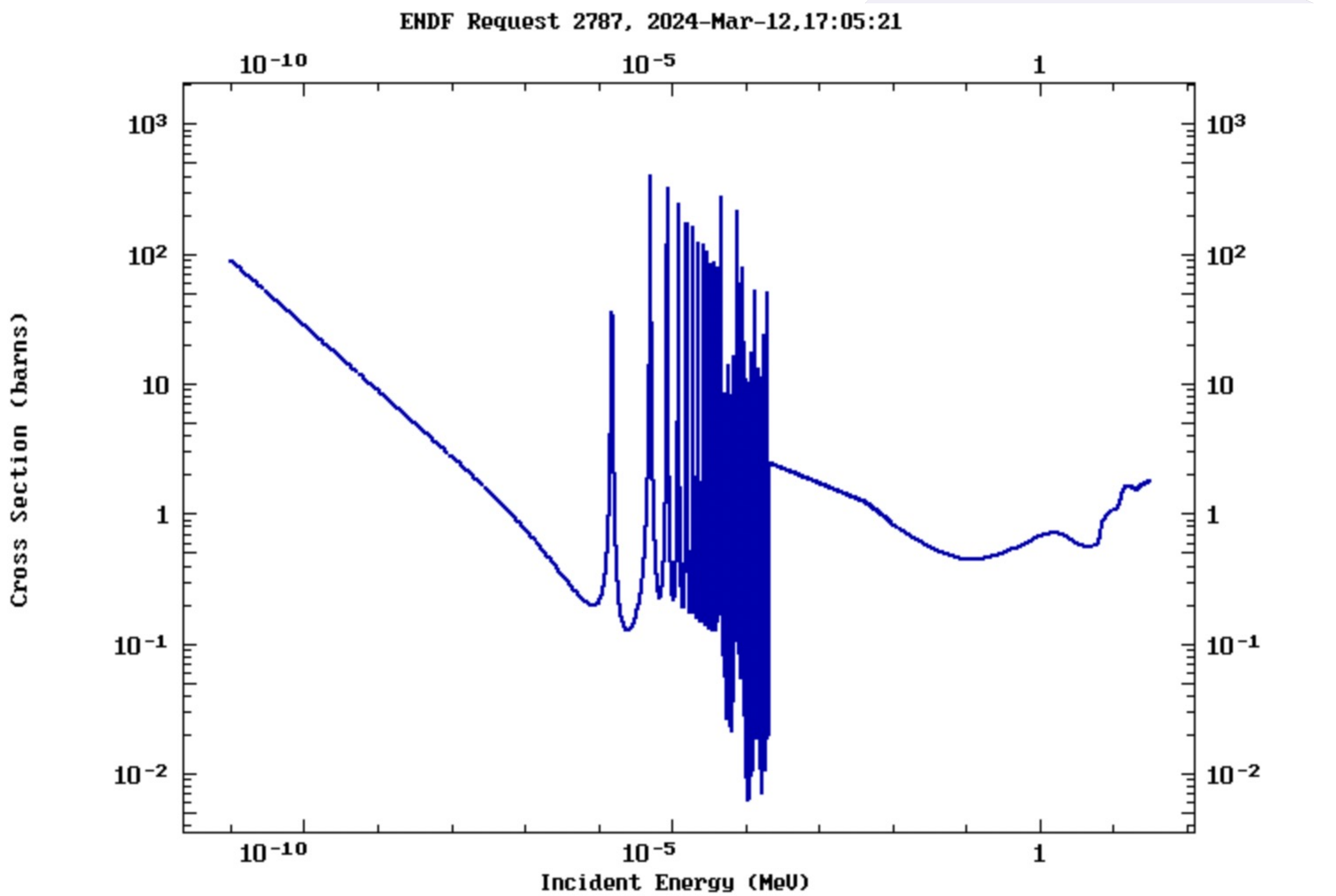
(Received 5 December 1973)

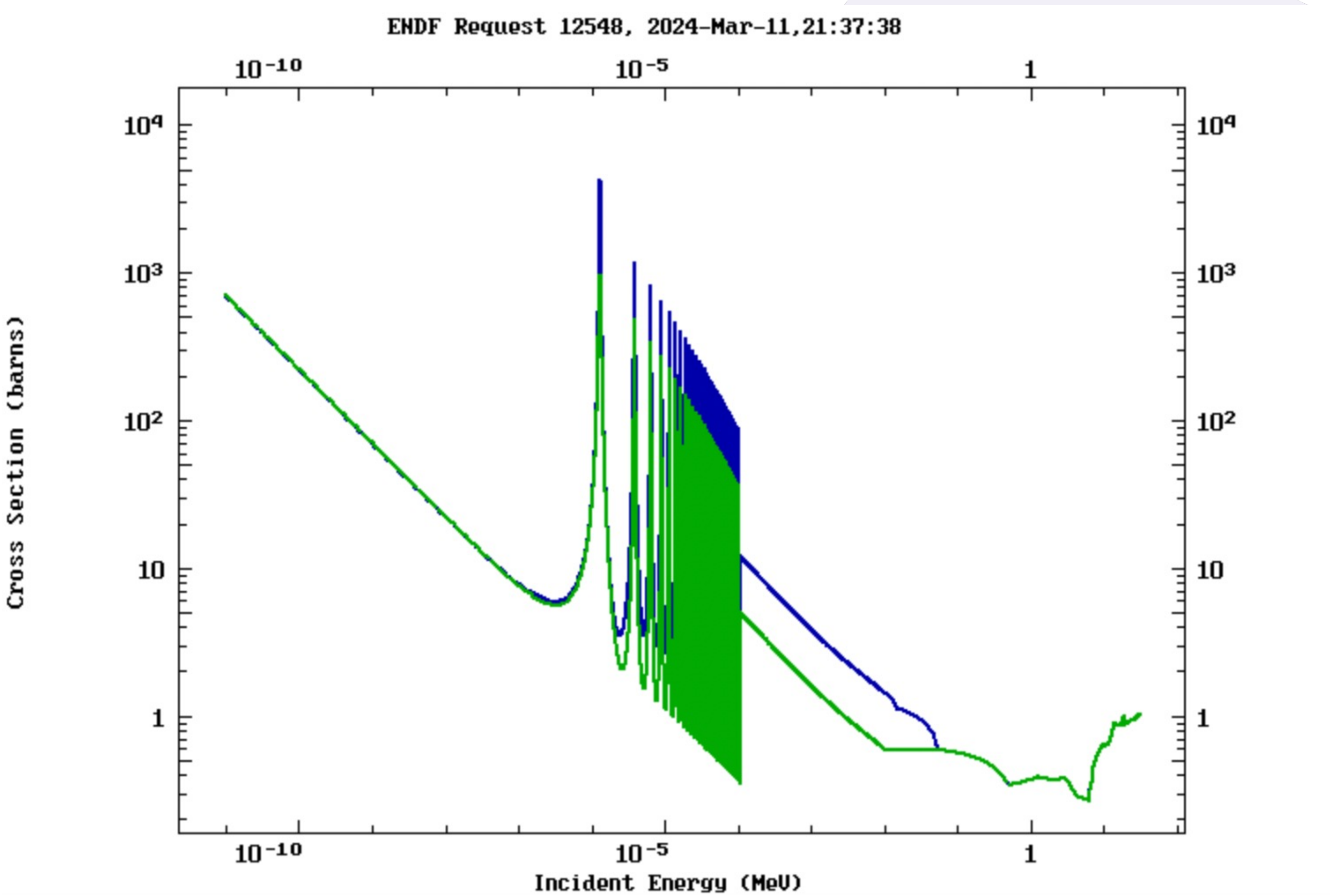


What is actually in ENDF/B: ^{237}U(n,f) Cross Section



- ENDF/B-V.III.0 in blue
- Model used where data does not exist

What is actually in ENDF/B: $^{237}U(n,f)$ Cross Section



- ENDF/B-VII.1 in green
- ENDF/B-V.III.0 in blue
- Only a model until higher energy

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Surrogate techniques and (t,pf) reactions are the best way to get some actinide fission cross sections

- (but I'm sure you already knew that)

Questions?