An Overview of Fission Measurements at LANSCE

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NNSA

LANSCE Fission Measurements.

- Precision cross section ratios

  Tony Hill, Fredrik Tovesson

- Fission cross sections on rare or radioactive nuclei with the lead slowing-down spectrometer (LSDS)

  R.C. Haight, D. Rochman, D.J. Vieira, Y. Danon . . . .

- Fission fragment production: GEANIE

  R. O. Nelson, M. Devlin, N. Fotiades, J.A. Becker, W. Younes, L. Bernstein, T. Ethvignot, T Grainier . . .

- Neutron and gamma-ray output: FIGARO

  R.C. Haight, M. Devlin, L. Zanini, T, Ethvignot, T. Granier. . .

- Capture to fission ratios: DANCE

  DANCE Collaboration

DANCE: *Many people have contributed.*

n

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P.E. Koehler

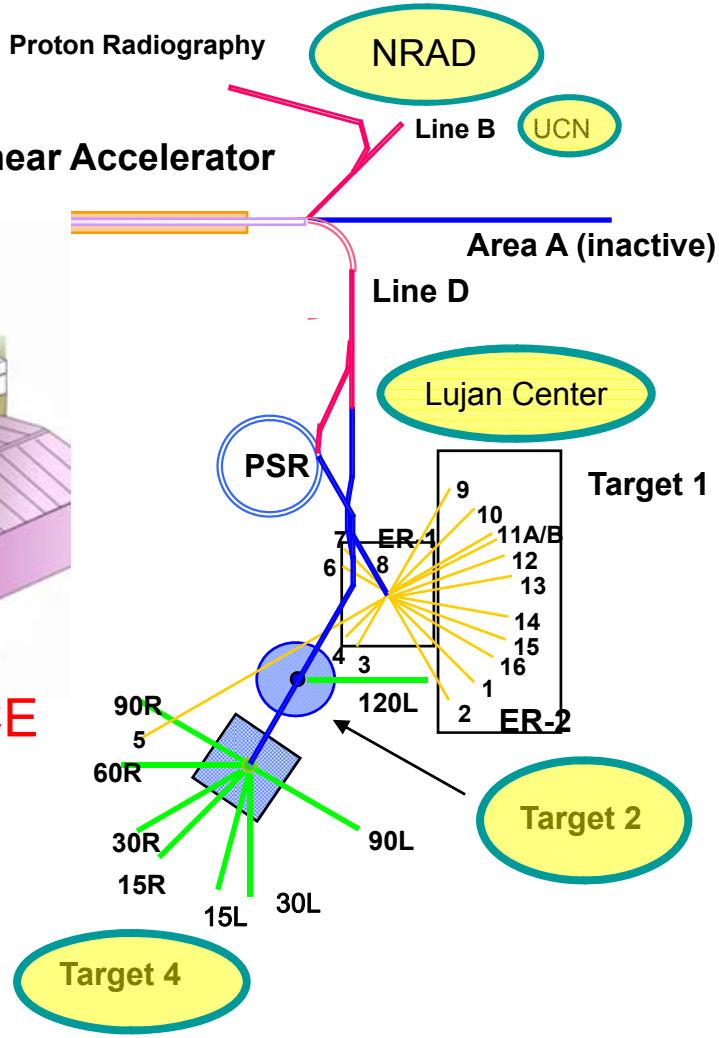
DANCE is located on FP14 at the Lujan Center

Weapons Neutron Research Facility

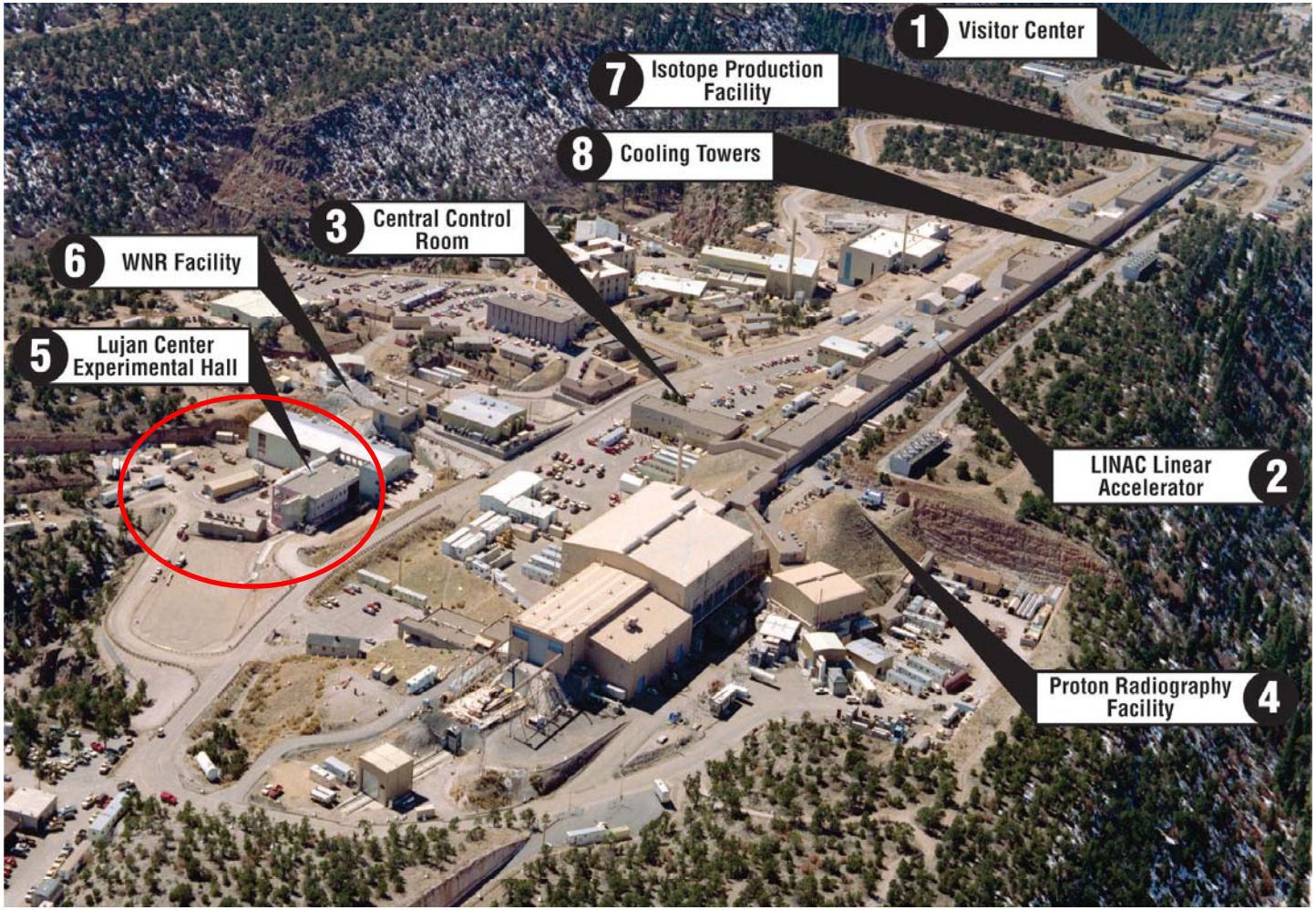
Target-4
High-energy neutron research

Target-2
- Proton-induced reactions
- Single-pulse experiments (Sandia)
- Lead Slowing-Down Spectrometer

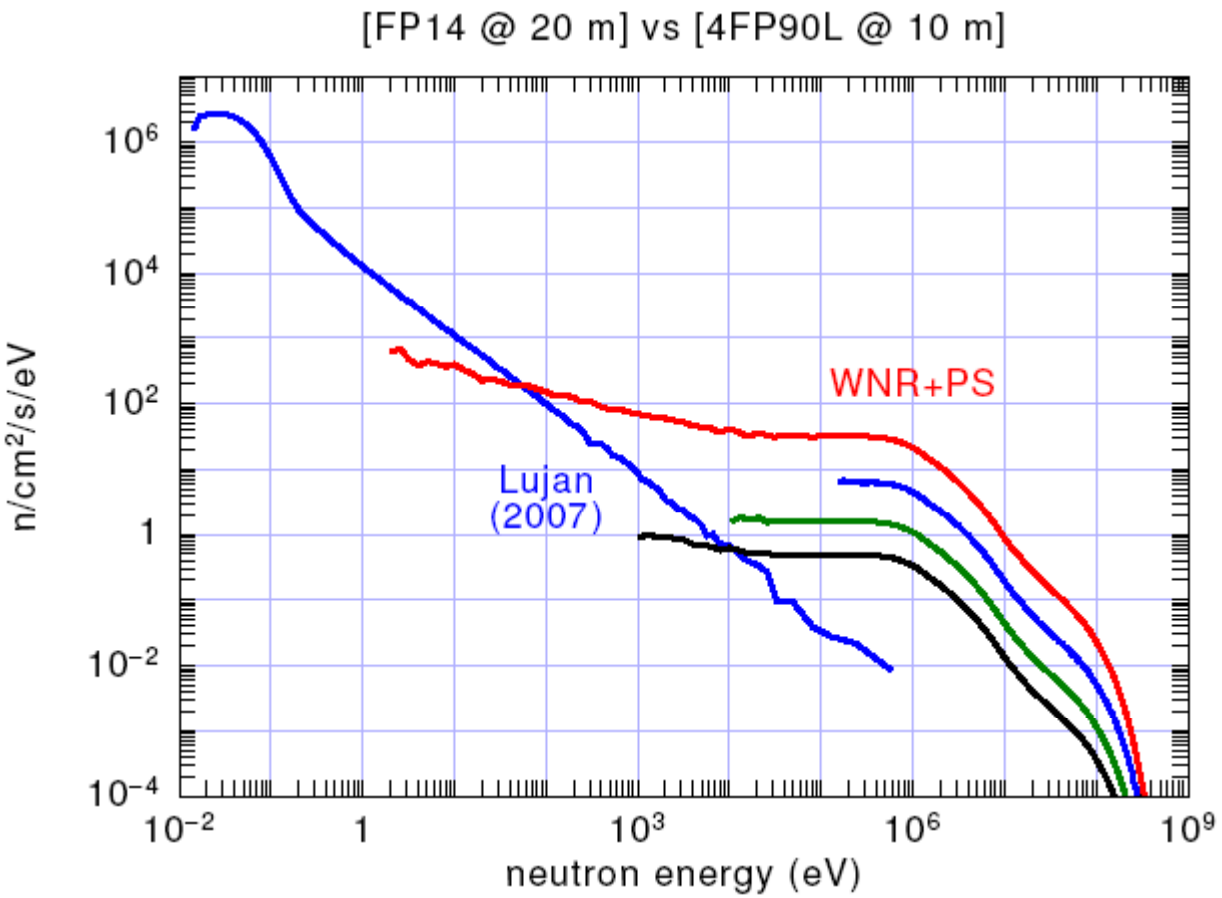
Lujan Center
Low-energy neutrons
- Material science
- Nuclear science



Los Alamos Neutron Science Center *(LANSCE)*



Neutron flux available at WNR and Lujan Center



20 μA WNR pulse stacking

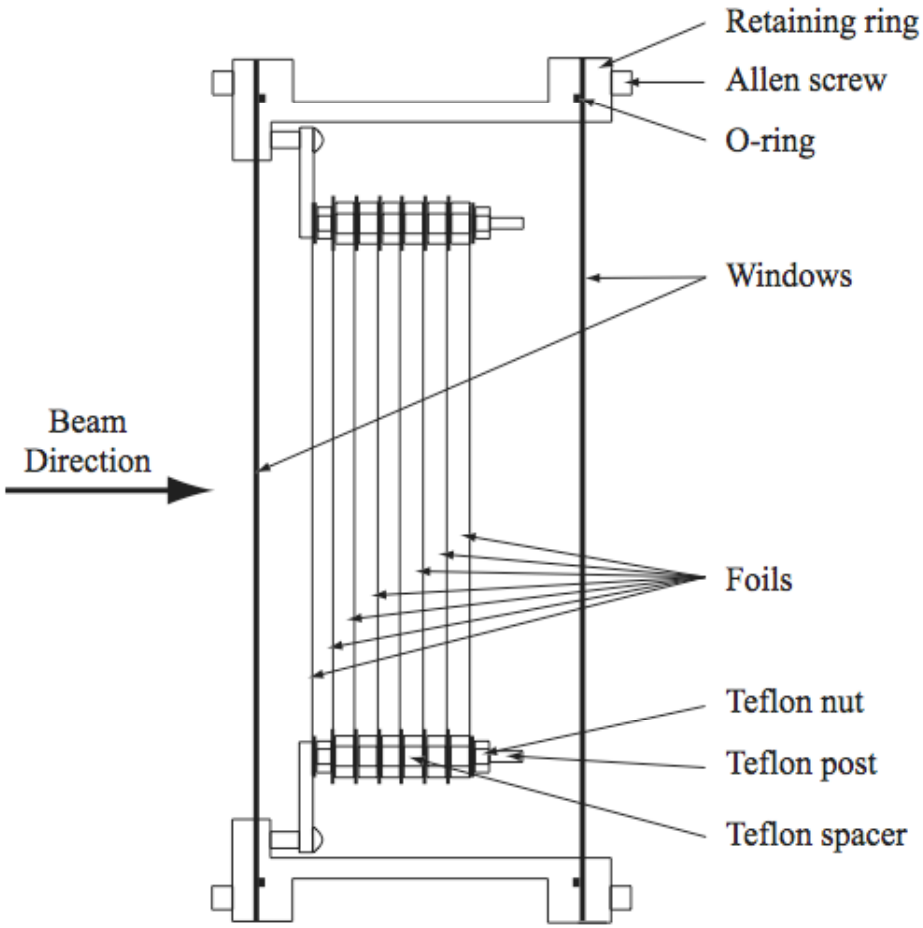
4 μA WNR 1.8 μs spacing

1 μA WNR 7.2 μs spacing

4/13 μA 23.4 μs spacing

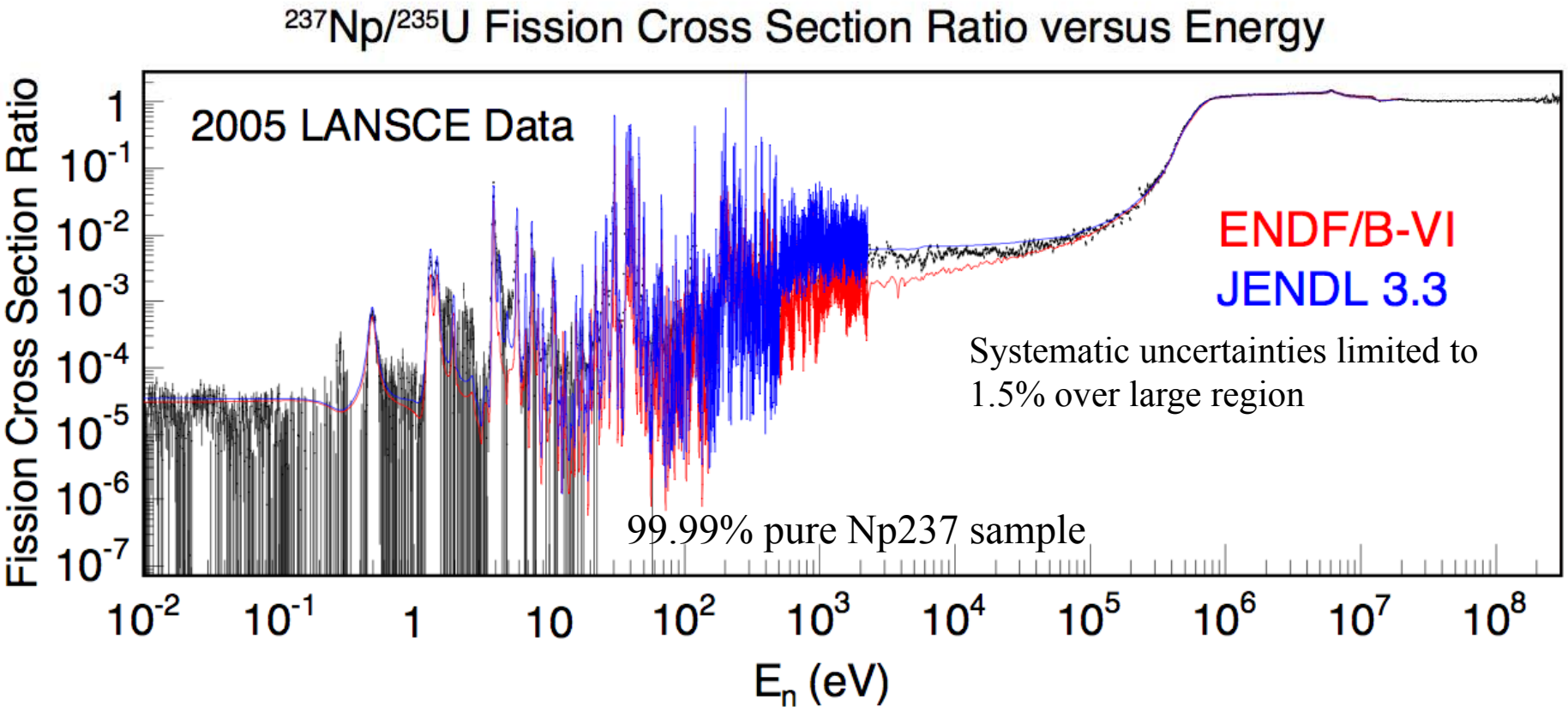
NOTE: Fluxes depend on experiment collimation!

Precision fission foil ratio measurements



- Compact gas-filled fission chamber, approx 12: dia X 6 in high
- Foils typically 200 μg/cm^2 X 15 cm dia
- Ratio measurements minimize systematic uncertainties, typically 1 – 2 %
- Easy to build, operate, instrument
- Cross section of interest inherits the uncertainties of the reference material
- Small enough to move from Lujan to WNR
- Usually contains ^{235}U, ^{238}U + sample of interest

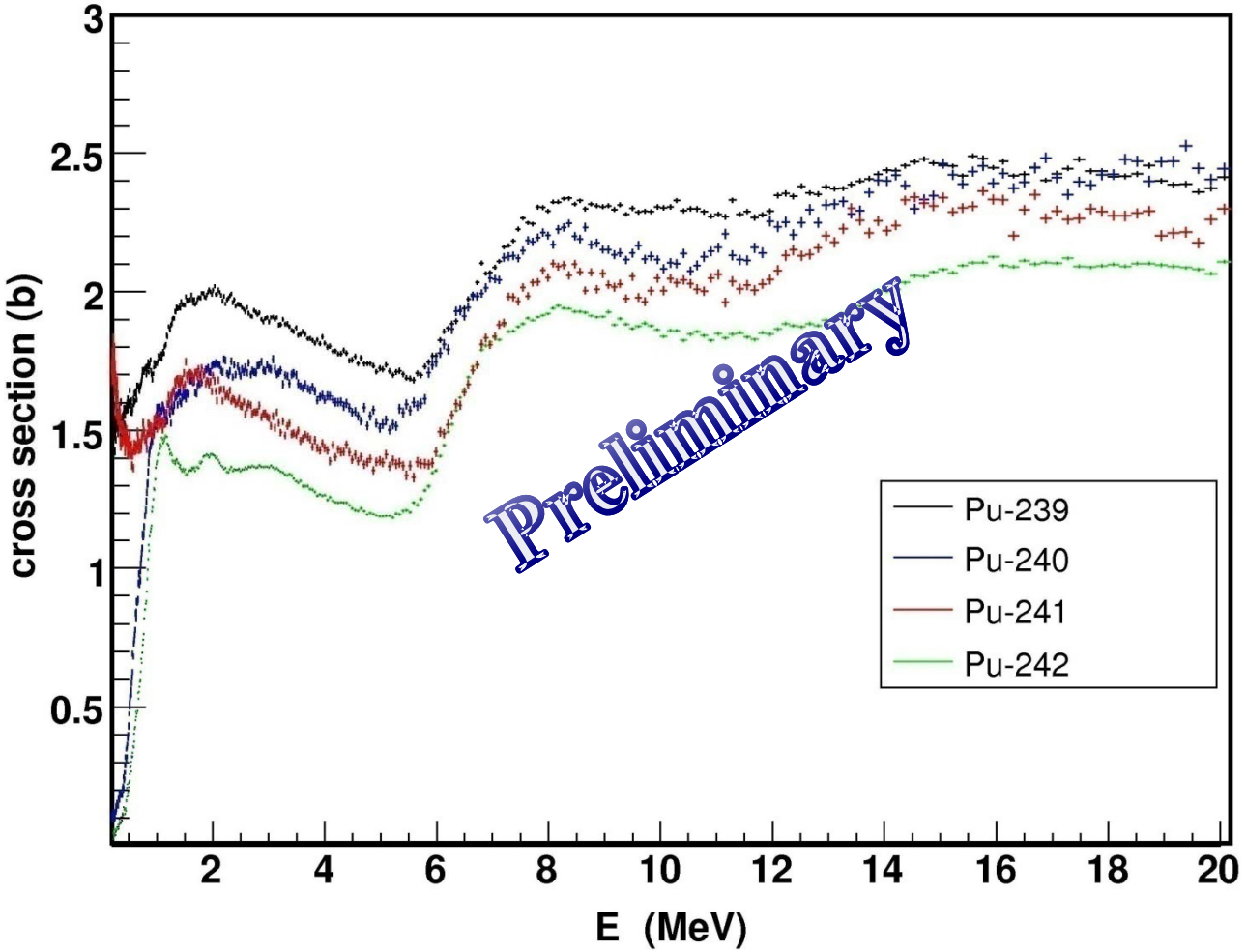
Np237 Fission Cross Section Ratio Measurement



AFCI measurement to resolve discrepancy between ENDF and JENDL

F. Tovesson, T. S. Hill, Phys. Rev. C **75**, 034610 (2007)
F. Tovesson, T. S. Hill, Nucl. Sci. Eng., in press

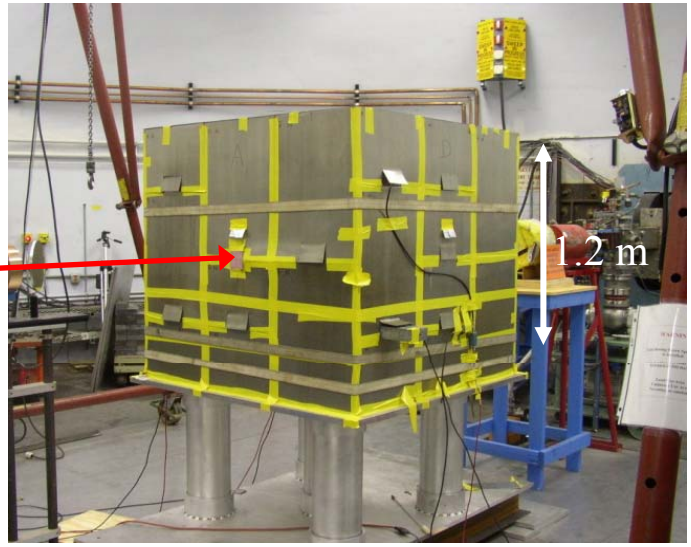
Fission cross sections of $^{239\text{-}241}$Pu



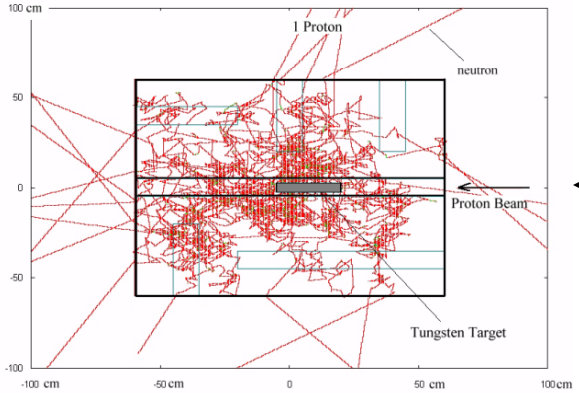
(Tovesson and Hill, private communication)

Lead slowing-down spectrometer at LANSCE

800 MeV Proton beam



Simulations

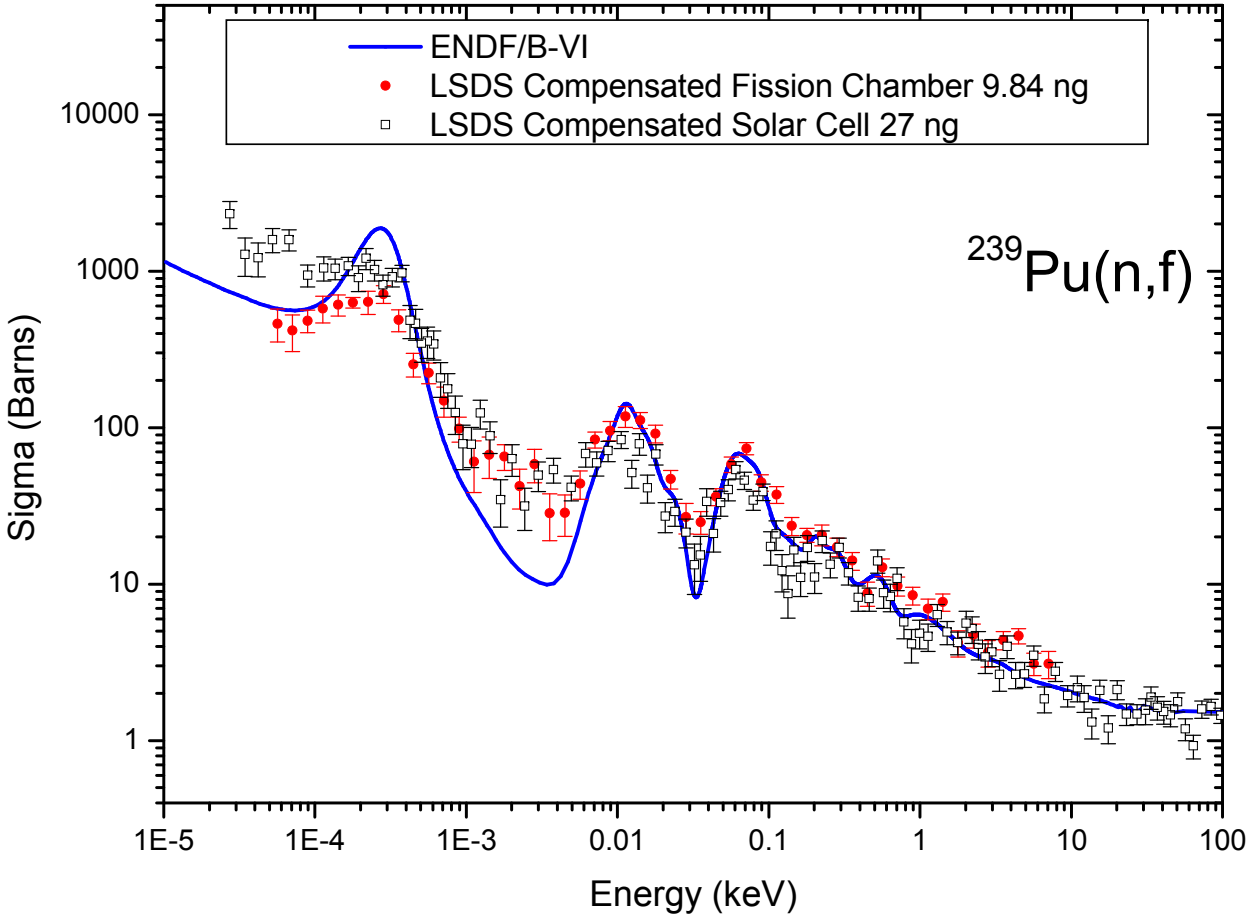


One proton

- 20 tons of high purity lead
- Pulsed proton beam → pulsed neutron source in center
- Fission chamber in one of the channels in the lead assembly
- Measure fissions as function of time

- For T_{neut} < 100 keV, $\langle T_{neut} \rangle$ = 165 keV-μsec^2 / (t-to)^2
- "Recycled" neutrons allows measurements on tiny samples
- Relatively poor energy resolution

With the LSDS, we measured the neutron-induced fission cross section on ^{239}Pu with sub-μg samples



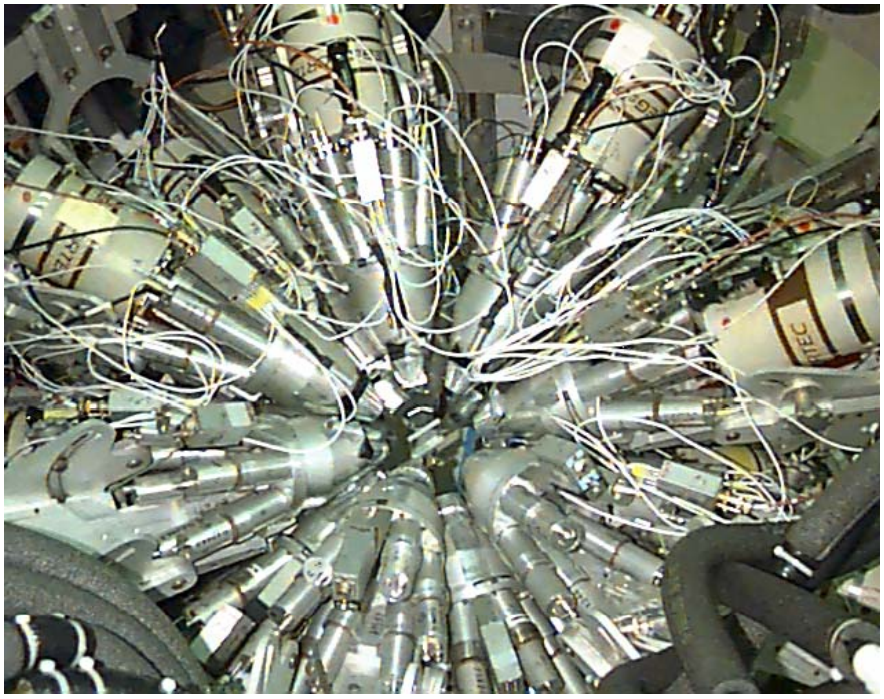
- Sample size of 9.87 ng can be studied
- Good results up to 100 keV
- This data, a few hours at 1 μA

• Cross Section Measurements for ^{239}Pu(n,f) and ^{6}Li(n,α) with a Lead Slowing-Down Spectrometer. D. Rochman, et al., Nucl. Instru. Meth. A 564, 400-404 (2006).
• Characteristics of a Lead Slowing-Down Spectrometer Coupled to the LANSCE Accelerator. D. Rochman, et al., Nucl. Instru. Meth. A 550, 397-413 (2005).

Fission fragment production using GEANIE

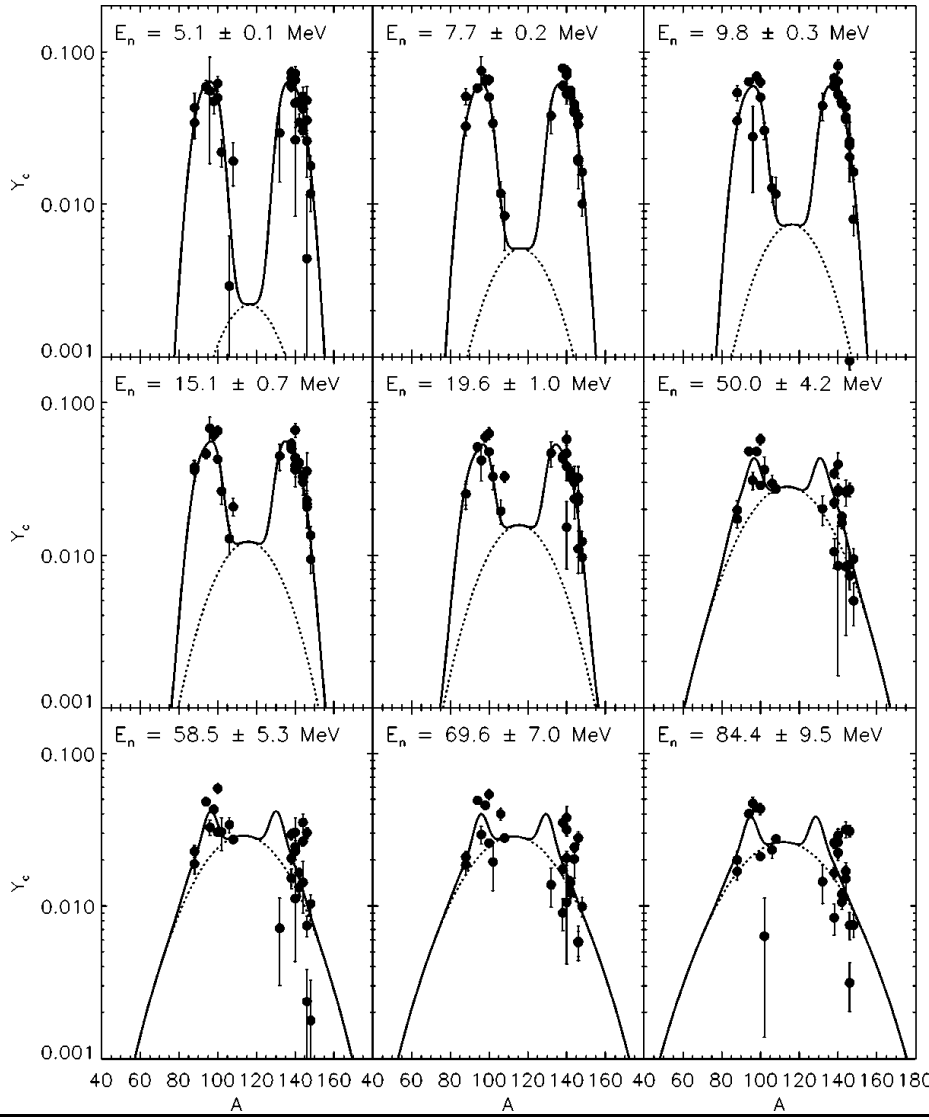
- Current Configuration
  - 26 Ge detectors (15 γ-ray & 11 x-ray)
  - 15 keV < Eγ < 9 Mev
  - ΔE/E ~ 1/1000
  - ε_{array} ~ 1% (Eγ=1.33 MeV)
- Upgraded Configuration
  - New frame (greater flexibility)
  - LEPS or Clover detectors
  - High rate DAQ

GEANIE γ-ray Spectrometer Array



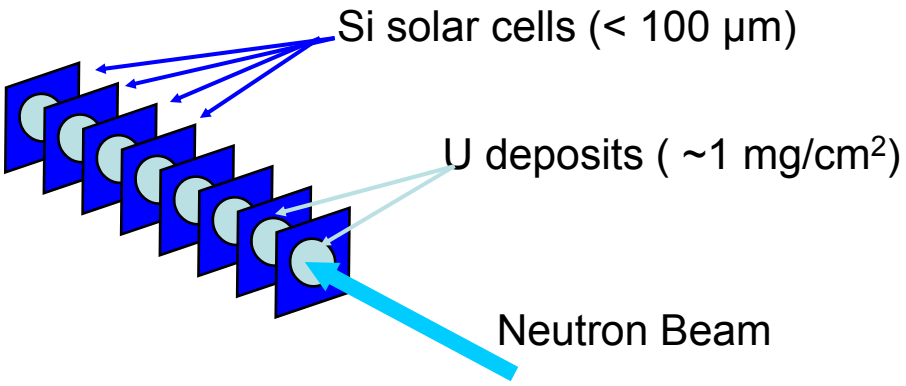
Asymmetric to symmetric fission in ^{235}U(n,f)

- Transition from asymmetric to symmetric fission in ^{235}U(n,f) studied by Younes, et al. (Phys. Rev. C **64**, 054613, 2001)
- 22 even-even fragments identified by single and coincident gamma rays
- Target foil: 0.617 mg/cm2, 93.2% enrichment

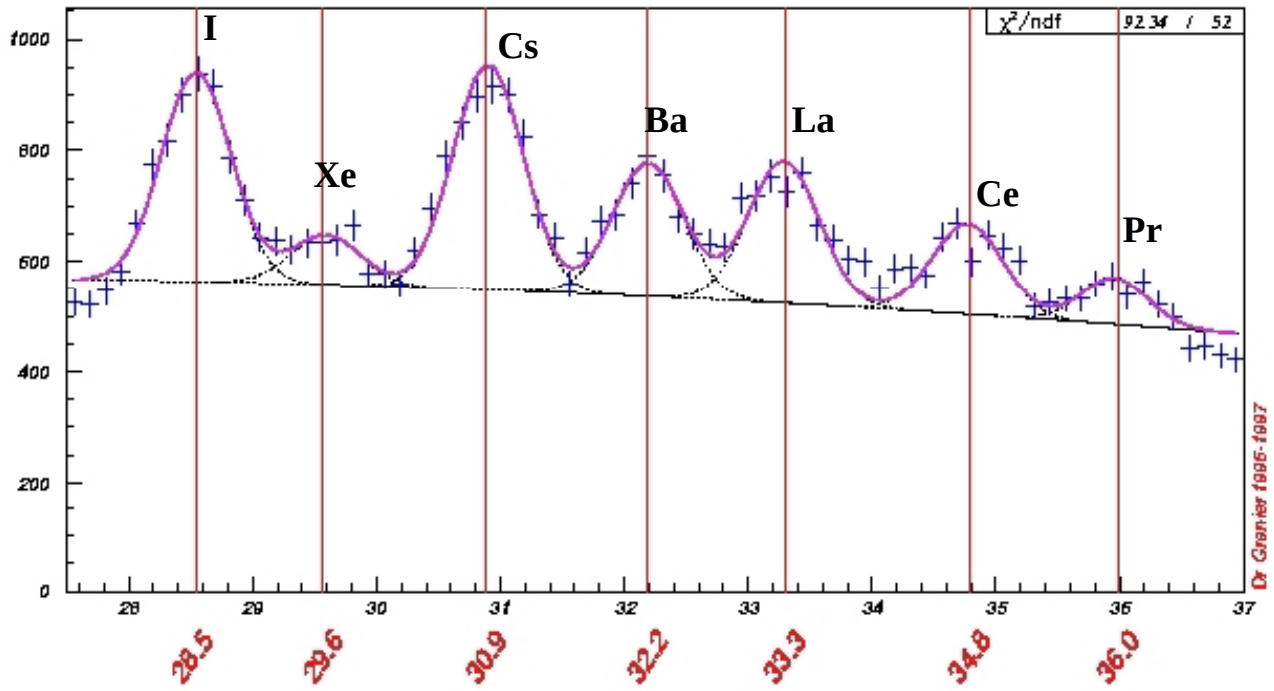


Fission-tagging to measure x-rays from ^{238}U(n,f)

- Determine x-ray yields from fission
- 11 low energy photon spectrometers for x-ray detection
- 15 coaxial Ge detectors for γ ray detection
- 8 ^{238}U deposits on thin solar cells in the WNR neutron beam as an active target
- Fission and photon coincidences required to eliminate high background at E_γ<50 keV
- Conversion coefficients are very sensitive to nuclear structure, and it is difficult to determine the charge distribution
- Collaboration with CEA BRC



Spectrum of x-rays from $^{238}U(n,f)$ for $10 < E_n < 20$ MeV

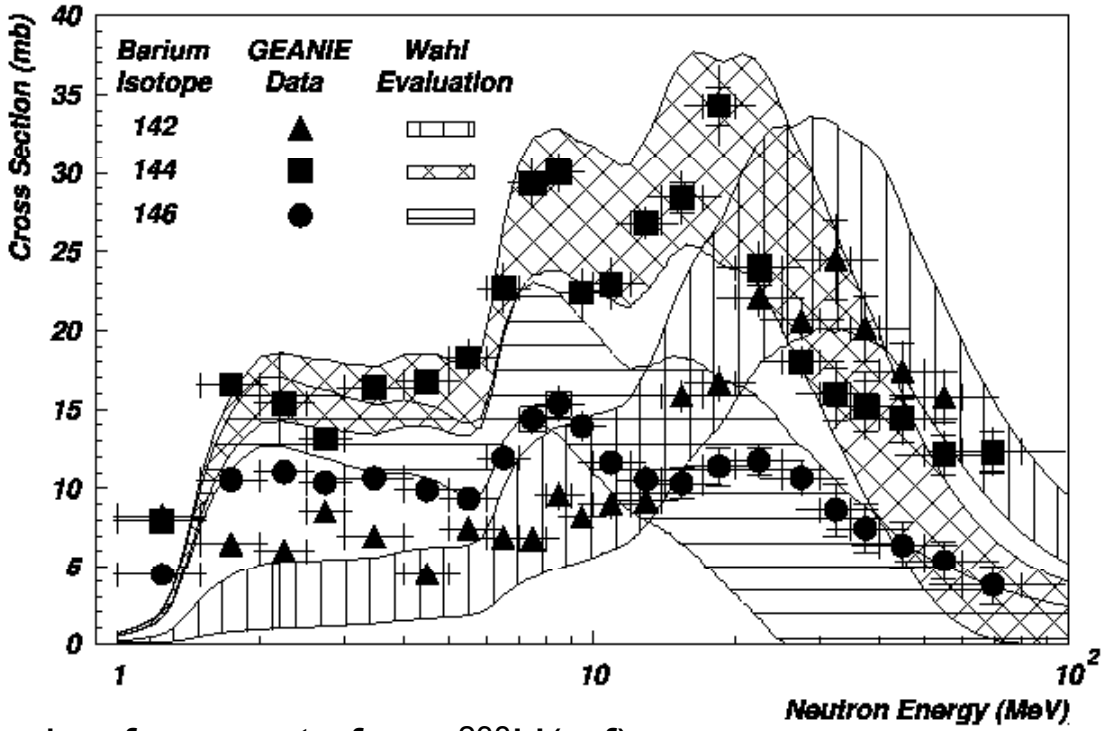


Photon Energy (keV)

GEANIE
LLNL/LANL

Los Alamos NATIONAL LABORATORY EST.1943

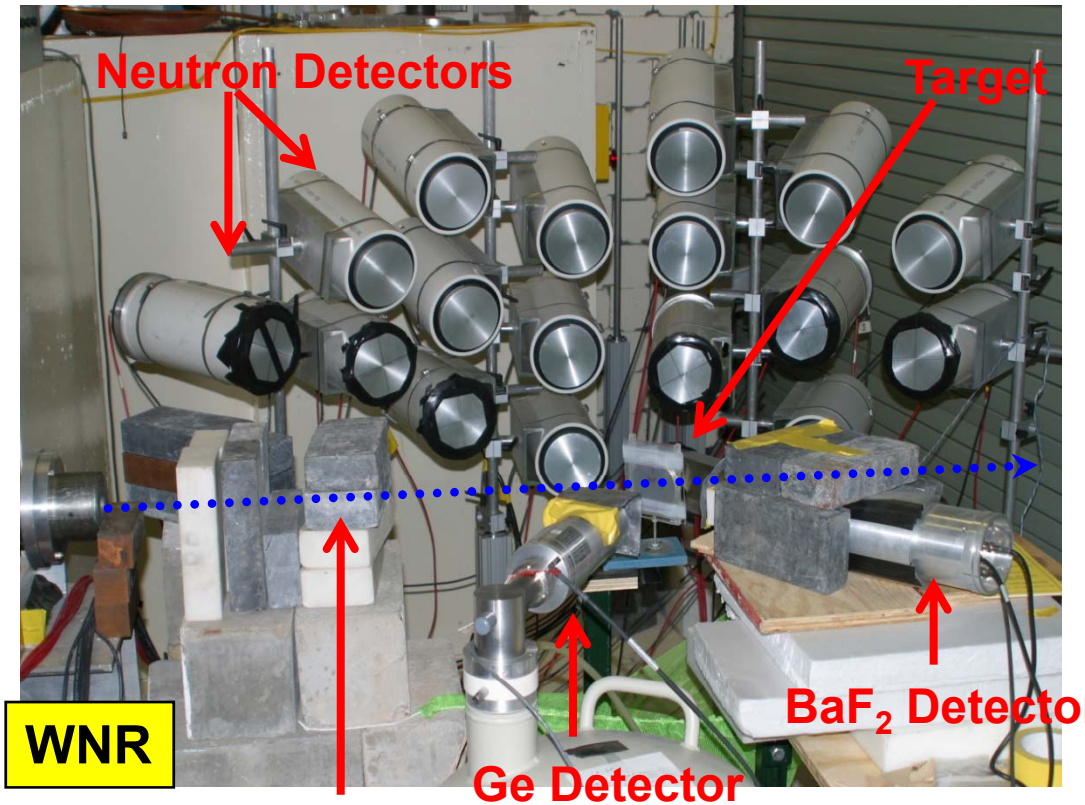
Excitation functions for fission fragments from ^{238}U(n,f)



- Fission fragments from ^{238}U(n,f)
- Approx. 100 fragments observed by γ – γ coincidences
- Excitation functions for individual fragment yields generally are in agreement with Wahl systematics (some exceptions)
- Pierre Casoli, PhD Thesis, U. Bordeaux, 2004

FIGARO Measures neutron and gamma output from fission

- Current configuration
  - Gamma-ray detectors
    - HPGe for good resolution
    - BaF2 for good timing and efficiency
  - 20 Neutron detectors
    - EJ301 liquid scintillators
  - Fission tagging detector
- Upgraded Configuration
  - greater fiducial coverage
  - Increased low energy sensitivity
  - High rate DAQ

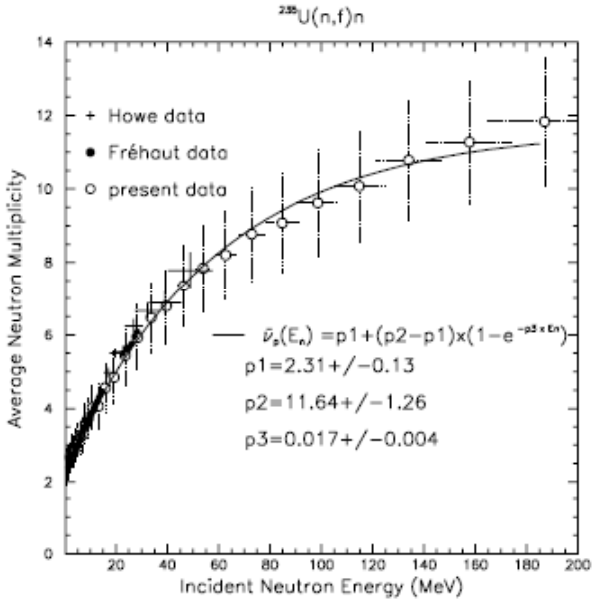


Double TOF technique

Average neutron multiplicity and energy using FIGARO

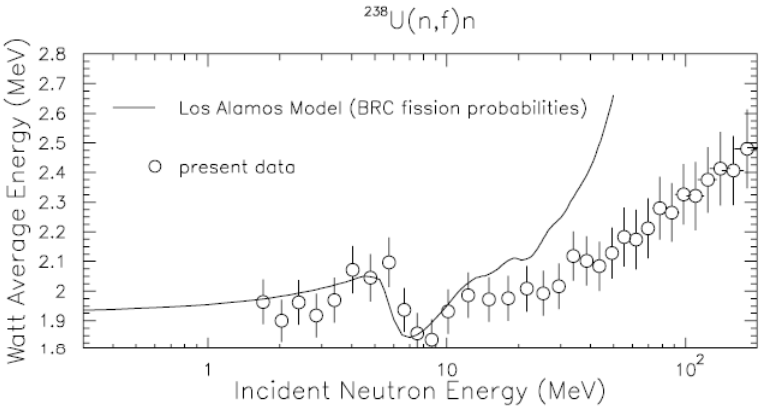
- LANL, CEA (Bruyeres-le-Chatel), Kyushu Univ.
- Data on ^{235,238}U published, ^{239}Pu recently acquired
- Average energy determined by fit of measured spectrum to a Watt function
- Multiplicity data normalized to unpublished work of J. Frehaut

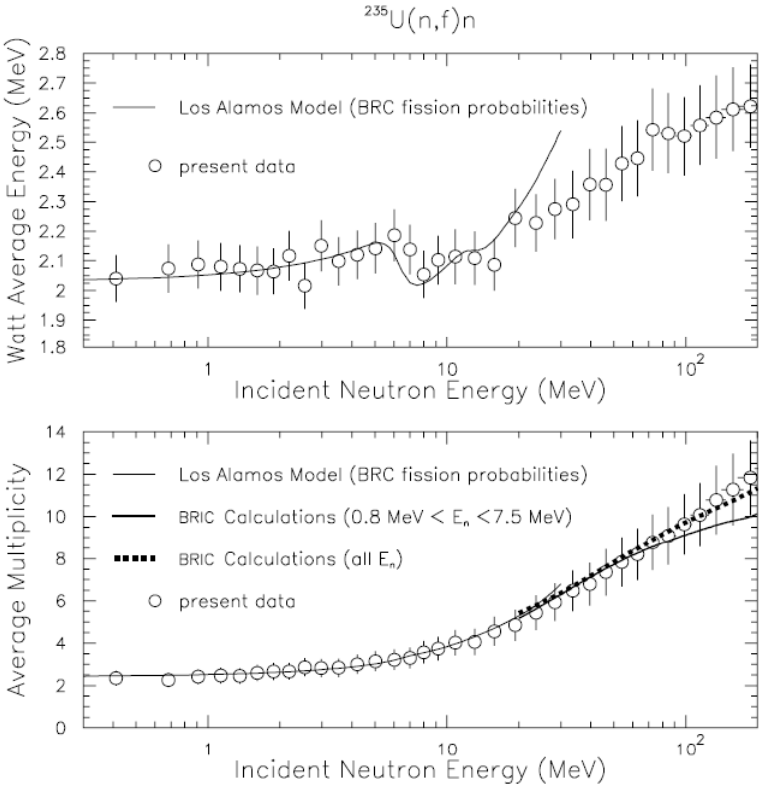
Fifty-plate fission chamber containing ^{235}U and ^{239}Pu samples for tagging fission events. This chamber was made at Bruyeres-le-Chatel



Average neutron multiplicity for ^{235}U(n,f) from FIGARO compared to earlier measurements of Frehaut and Howe. (T. Ethvignot, et al., Phys. Rev. Lett. **94**, 052701 (2005).

<v> and <E> for ^{235,238}U measured using FIGARO

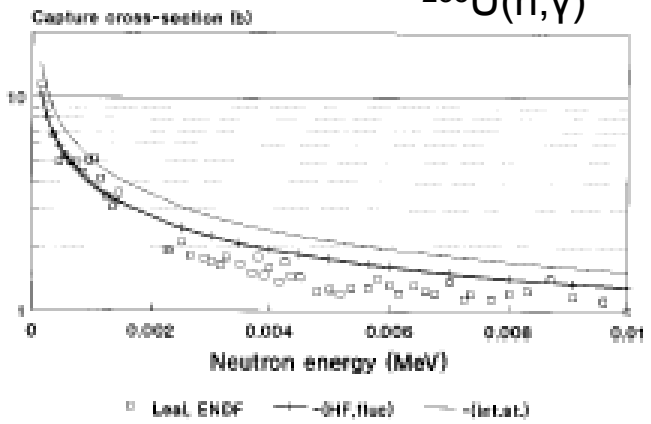




T. Ethvignot, et al., Phys. Rev. Lett. **94**, 052701 (2005).

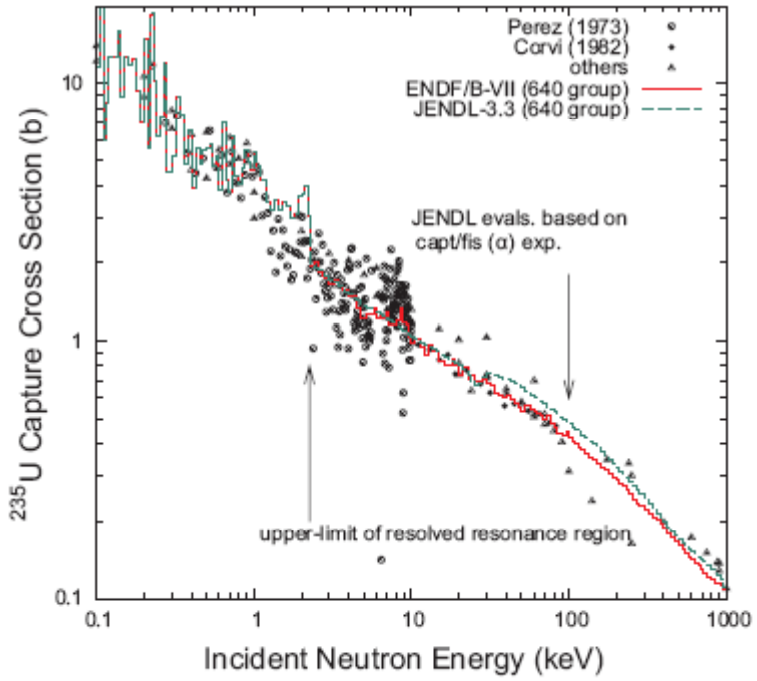
Capture to fission is not well understood.

$^{235}U(n,\gamma)$



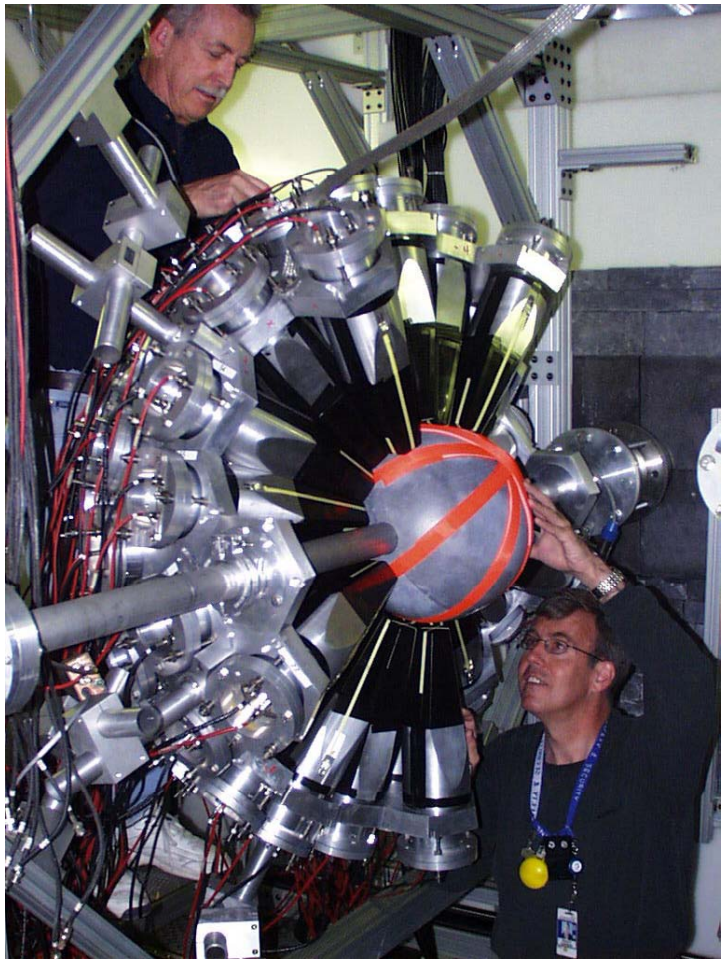
"If we compare with actual experimental data sets, however, we find there is a great deal of variation amongst these, and our calculations are in reasonable agreement with some of the sets with higher average values. . . . We conclude that new measurements of the capture cross section with one of the new generation of modern gamma-ray detectors such as DANCE at Los Alamos are highly desirable."

J.E. Lynn, International Conference on Nuclear data for Science and Technology (2004), R.C. Haight, et al, editors, Am. Inst. Phys. Conference Proceedings CP769 (2005).

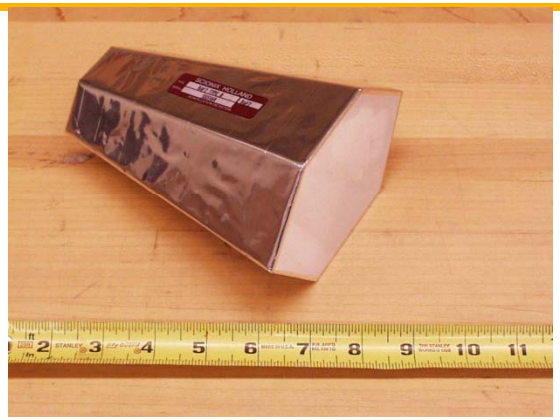


ENDF/B-VII .0. M.B. Chadwick, et al., Nuclear Data Sheets,107,2931 (2006).

DANCE crystals and assembly



Half of DANCE array with ^{6}LiH ball

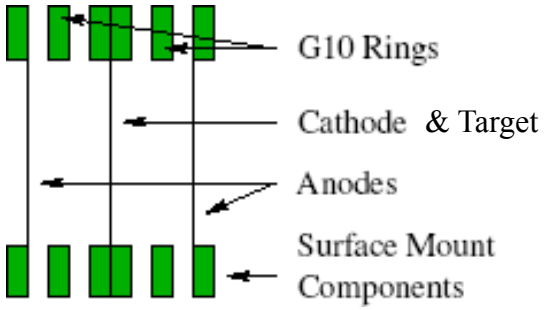


BaF_2 Crystal

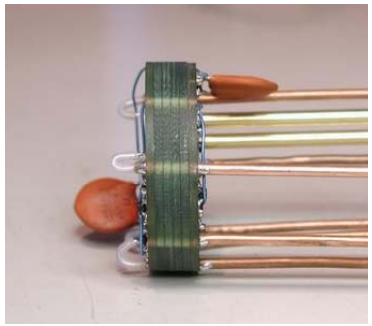
Crystal mounted on 75 mm phototube

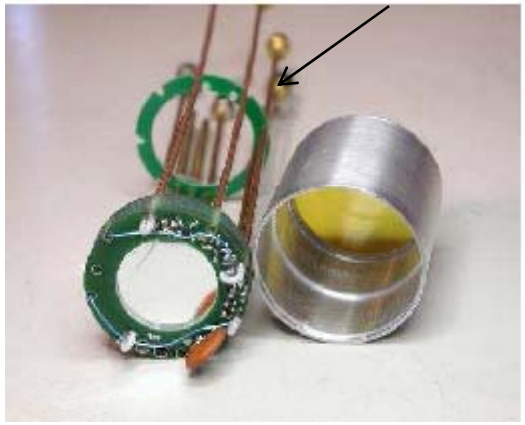
PPAC Detector for Capture and σ_g/σ_f Measurements at DANCE

- A double Parallel Plate Avalanche Counter (PPAC) was fabricated & tested (operated at 6 torr of isobutane @ ±200 V)



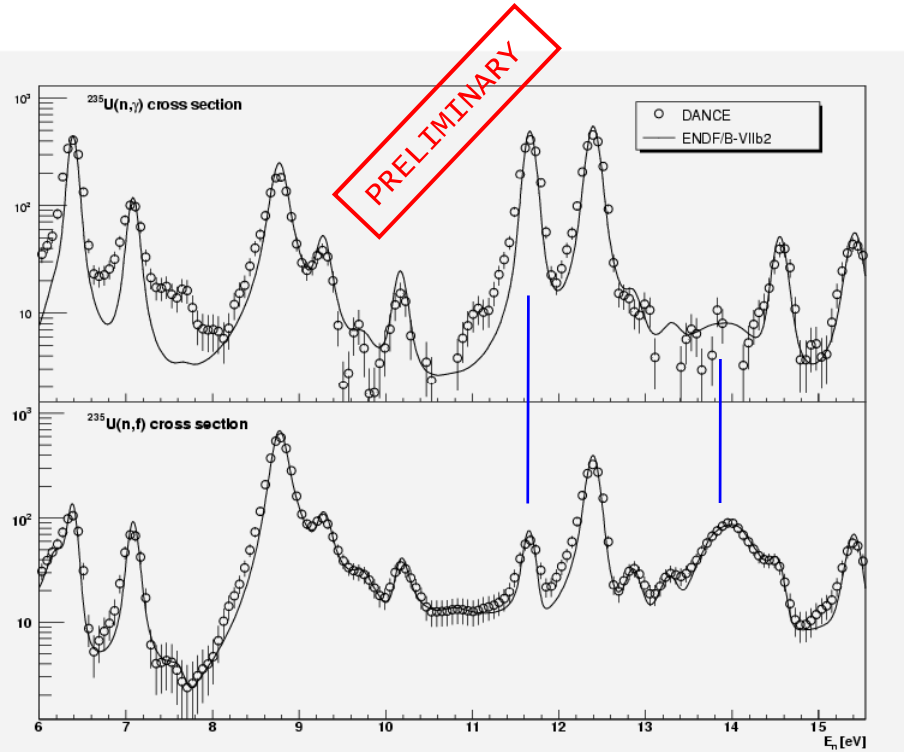
Close-up of PPAC showing removable cathode/target assembly





PPAC Assembly with gas lines and signal cables ready for insertion into DANCE center

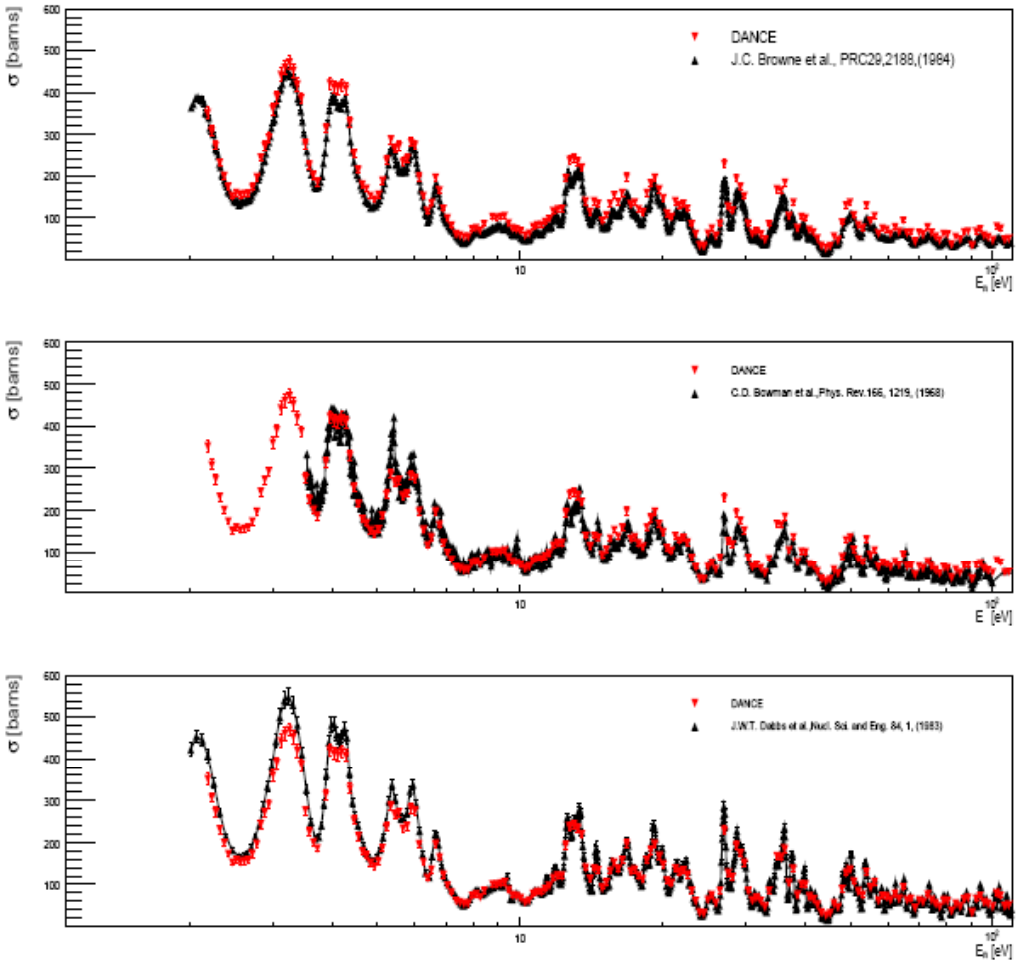
^{235}U Capture/fission ("α") w/ Fission Tagging



Reference:
T.A. Bredeweg,
M. Jandel

- Target: 460 μg ^{235}U(99.89%) in 0.7 cm deposit (1.2 mg/cm^2) electrodeposited on metalized mylar(flashed with 0.25 μg Ti on deposit side, 0.10 μg on other side)
- (n,γ) data has 5.5 < Esum(MeV) < 7.5, Multiplicity ≥ 4
- PPAC fission tag has 78% efficiency
- (n,γ) corrected for fission by subtracting 0.22 X fission spectrum
- Approximate normalization to ENDF/B-6 resonances

^{242m}Am(n,f) Measured at DANCE



- Preliminary measurement of ^{242m}Am(n,f) using a 44 µg sample
- Sample prepared by nuclear chemists (P. Wilk) at LLNL
- Larger sample preparation in progress (M. Stoyer) for capture and fission measurements

Targets for capture/fission measurements

Table 1: A partial list of planned actinide targets for neutron capture measurements at DANCE. The high neutron induced fission cross sections of these isotopes, relative to the corresponding capture cross sections, will require the use of fission-tagging. The thermal and resonance integral (number in parentheses) cross sections for fission (σ_f) and capture (σ_γ) are provided for each isotope.

Isotope	$t_{1/2}$ (years)	σ_f-th (Res. Int) (b)	σ_γ-th (Res. Int) (b)
^{229}Th	7.3×10^{3}	31 (500)	73 (280)
^{232}U	7.0×10^{1}	75 (380)	73 (280)
^{233}U	1.6×10^{5}	531 (760)	46 (140)
^{235}U	7.0×10^{8}	585 (275)	99 (140)
^{238}Pu	8.8×10^{1}	18 (33)	540 (200)
^{239}Pu	2.4×10^{4}	750 (300)	271 (200)
^{241}Pu	1.4×10^{1}	1010 (570)	361 (160)
^{241}Am	4.3×10^{2}	3 (14)	60 (150)
^{242m}Am	1.1×10^{3}	7000 (1800)	1700 (200)
^{243}Am	7.4×10^{3}	0.07 (0.06)	78 (1800)
^{243}Cm	2.9×10^{1}	610 (1600)	130 (220)

Todd Bredeweg, CAARI 2006

Future plans for fission at LANSCE

- **Beam time is a high priority for LANL**
- **Precision measurements**
  - Additional targets underway (^{240}Pu)
  - Time projection chamber
  - "Dual-arm" spectrometer
- **FIGARO**
  - Larger coverage for neutron detectors (bars?)
  - Fast acquisition
- **DANCE**
  - Improved fission tagging detectors
  - Active program
- **GEANIE, LSDS**
  - Available for proposals
- **WNR: Pulse Stacking**