Prompt Fission Neutron Studies at LANSCE

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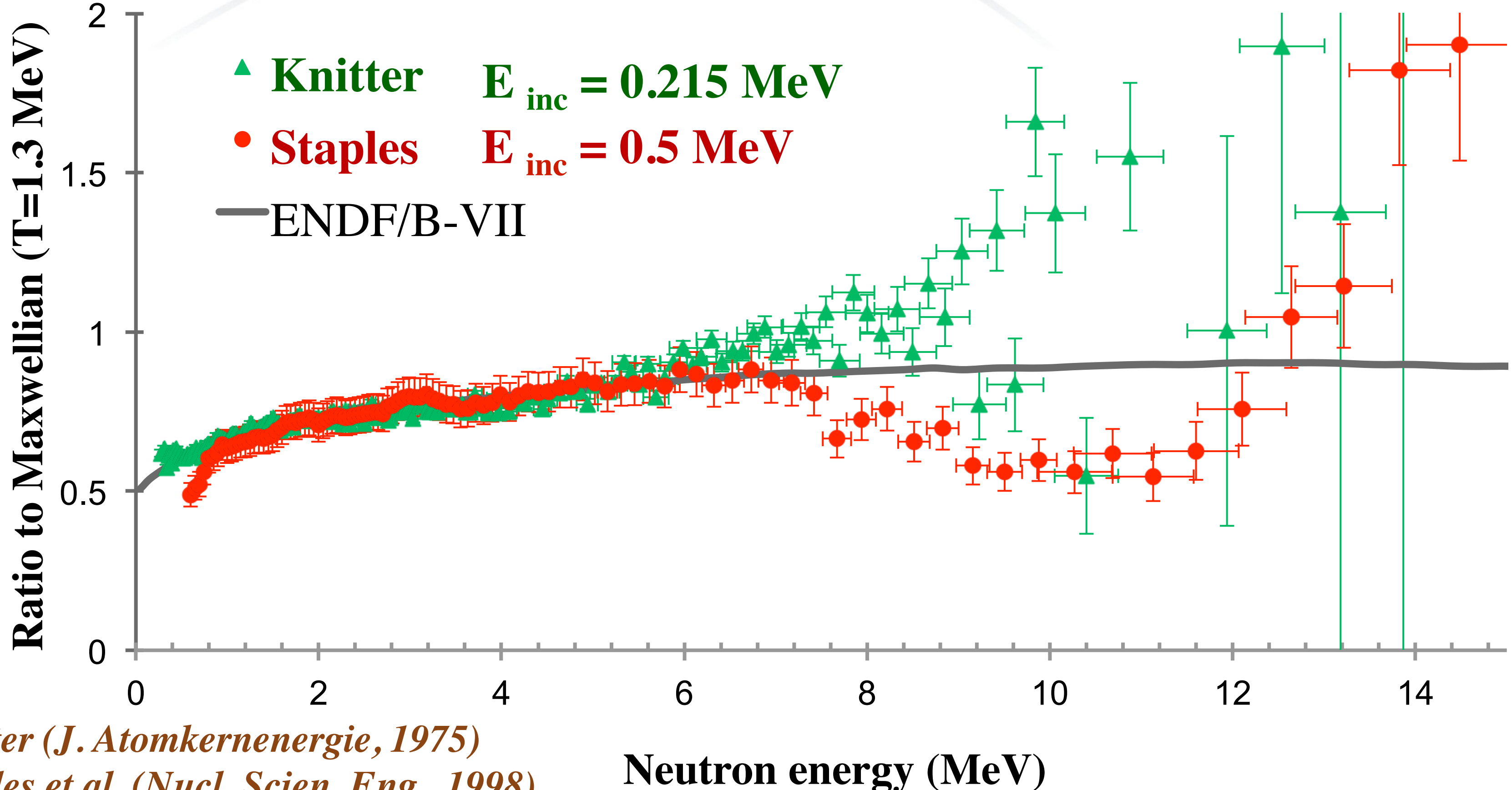
LANL FIESTA Fission School & Workshop, Sep. 8-12, 2014

Outline

- PFNS of $^{239}Pu(n,f)$: previous measurements tell us how to improve systematic uncertainties
- Experimental Efforts at ChiNu including MCNP calculations
- How to deduce PFNS using the ChiNu data
- Summary

PFNS of ^{239}Pu: High energy measurements

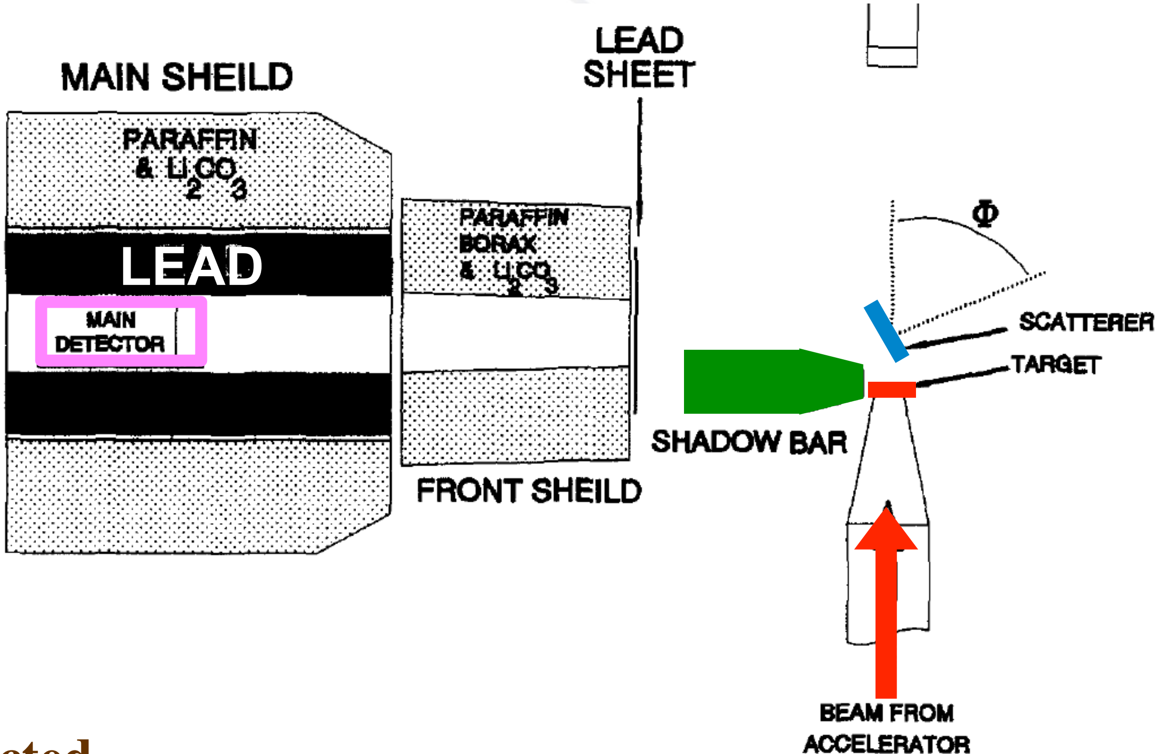
Current uncertainty : 20~50%



Knitter (J. Atomkernenergie, 1975)
Staples et al. (Nucl. Scien. Eng., 1998)

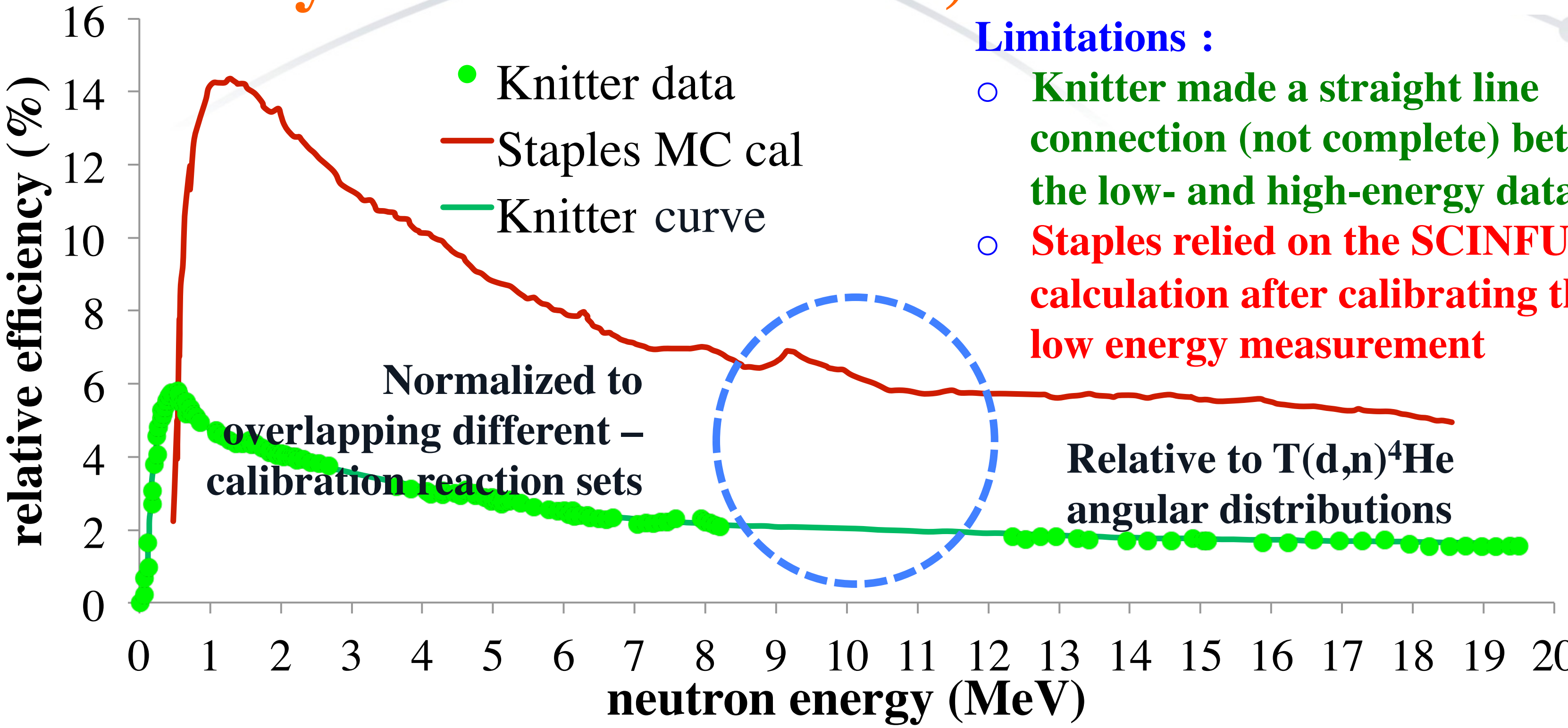
Measurement details on Staples vs. Knitter

1. Neutron source : $^{7}Li(p,n)$ with variable-energy and pulsed protons
2. Fissile samples
3. Neutron detector : liquid scintillators (BC501 vs. NE224)
4. Shadow bar to block direct neutrons



- TOF measurements
- No fission events detected
- Significant multiple scattering at thick targets and shielding materials
- Corrections & efficiency estimation using Monte Carlo calculations

Detector Efficiency (Uncertainty : 5-7 % and 2-5 %)



Limitations :

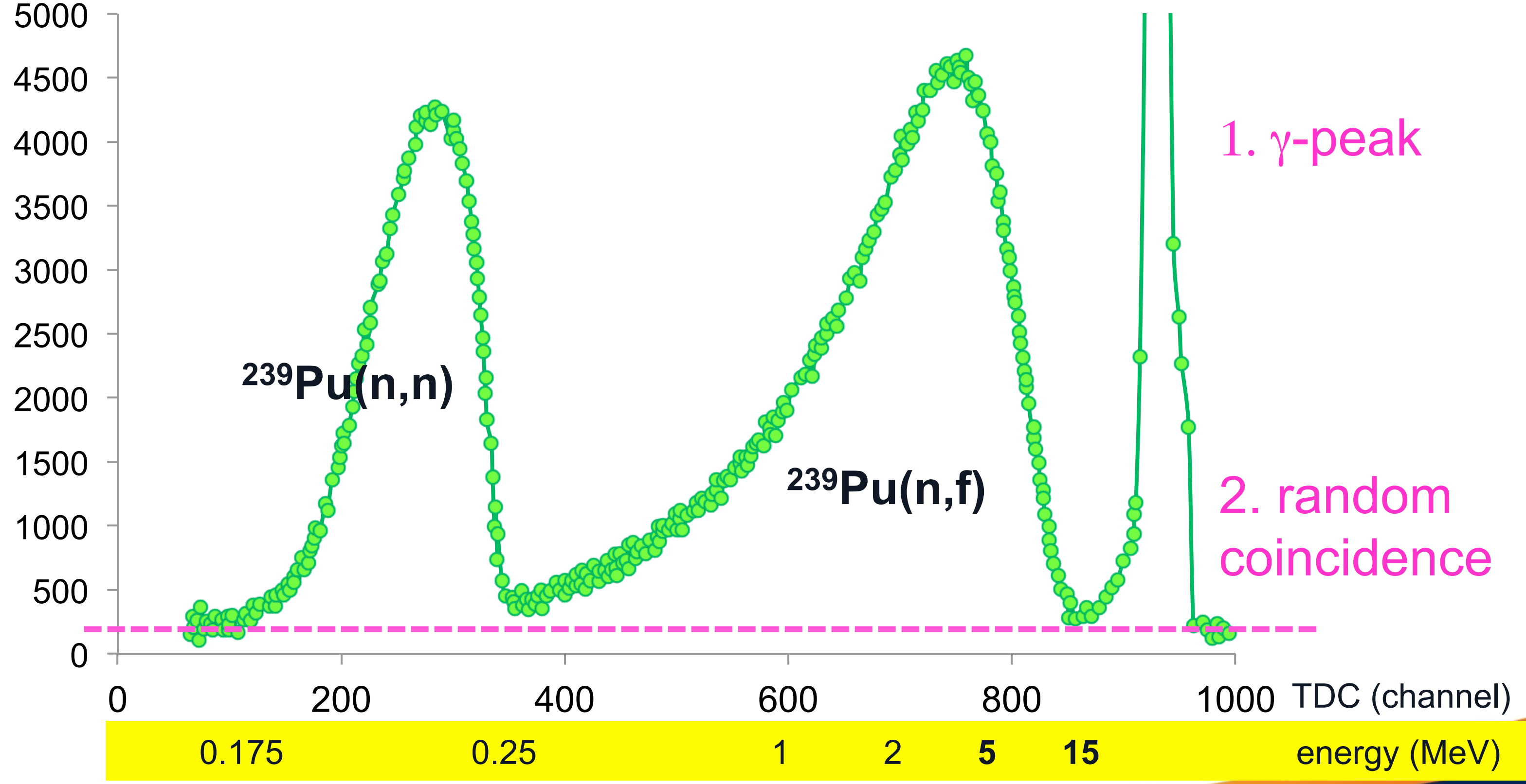
- Knitter made a straight line connection (not complete) between the low- and high-energy data
- Staples relied on the SCINFUL calculation after calibrating the low energy measurement

	Det. volume	Measurements	Calculation
Staples	117 cm^3	^{235}U fission counter (E<3.5 MeV)	SCINFUL for the rest energy
Knitter	75 cm^3	Multiple reactions (E<20 MeV)	Maggie for angular corrections

Systematic uncertainty in Knitter data

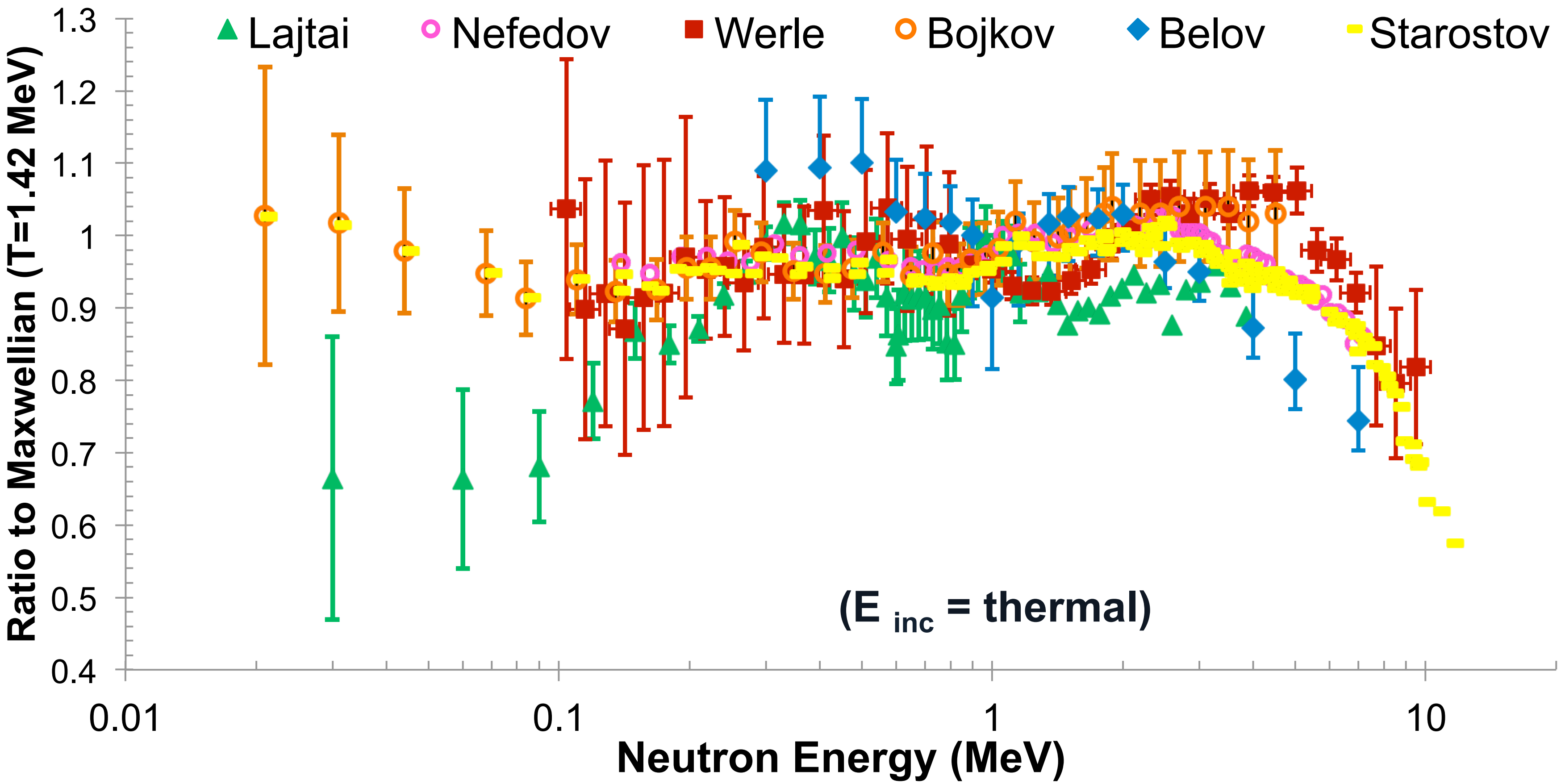
Knitter et al. Atomkernenergie (1973)

- correction for neutron inelastic scatterings
- constant background subtraction at ~15 MeV
- γ-peak correction influences the deduced shape of neutron spectrum at 5-15 MeV



PFNS of ^{239}Pu: Low energy measurements

Current uncertainty ~10% (compilation)



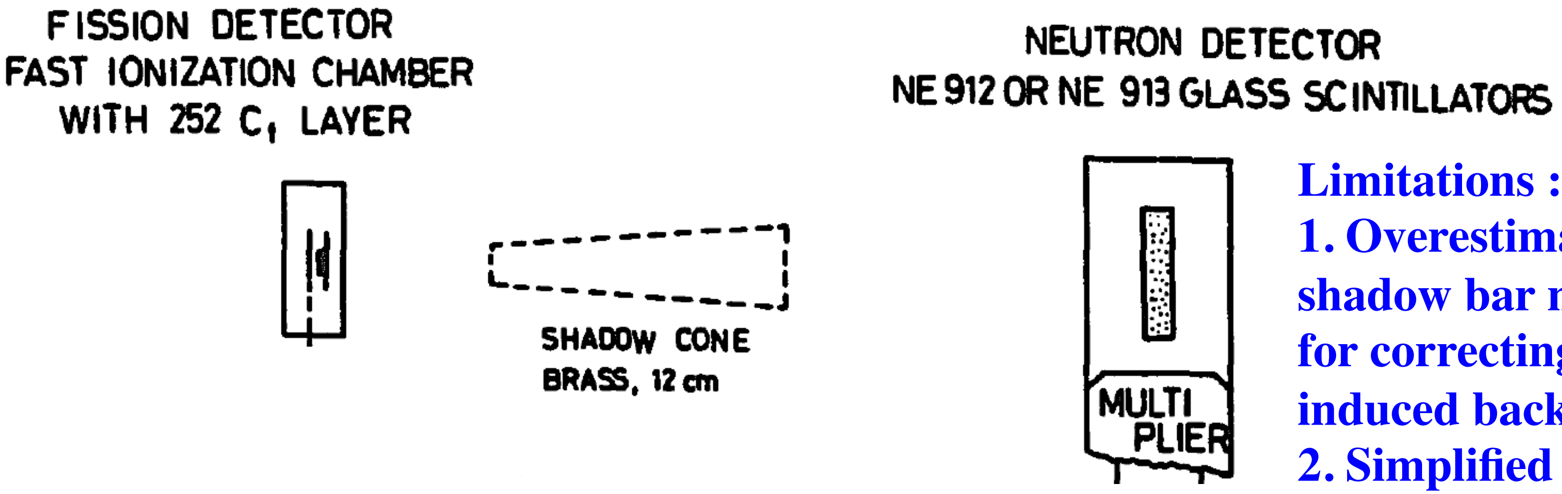
Bojkov-Nefedov (re-analysis) - **Starostov, Laitai,**
Werle (proton-recoil proportional counter), Belov (insufficient doc)

Starostov : notes on ^{239}Pu measurement

- Time of flight measurements
- Detector : 5 different neutron detectors + 2 different fission counters -
  $0.1 < E_n < 2$: Anthracene scintillator (ϕ=18mm, 4mm thick) at 51 cm
  -The absolute normalization for the efficiency is calculated using Monte Carlo calculation
  $0.01 < E_n < 5$: Gas scintillation ionization det. & IC at 10~40 cm
  -The efficiency was measured with a ^{252}Cf source
  - For the rest of detectors, used the complied ^{252}Cf shape (weighted average over Starostov, Blinov, Lajtai) to calculate the detector efficiencies
- After background subtraction, time spectra were corrected further due to multiple scatterings in the target room

Lajtai : notes on ^{239}Pu measurement

Lajtai et al. NIM A (1990)



Limitations :

1. Overestimation of shadow bar measurements for correcting neutron-induced background

2. Simplified detector response simulation especially near the resonance

- **^{6}Li-glass detector was used**
- **^{7}Li-glass detector to measure the delayed g-ray background**
- **Cu shadow cone to estimate neutron background**
- **Yield = Yield (^{6}Li detector w/o cone) – Yield (^{6}Li detector /w cone)**
  -Yield (^{7}Li detector w/o cone) + Yield(^{7}Li detector /w cone)

Chi-Nu project : Reduce unceratinty

- **Dedicated Flight Path at 4FP-15L**
  The 18' X 18' X 7' basement was built for reducing room-returned background at low energy

- **Fission Counter**
  Parallel Plate Avalanche Counter : 10 foils with ~ 400 μg/cm² thickness
  Timing resolution is ~ 1ns and light mass for low background

- **High Energy Measurement (E_n > 0.7 MeV) : n-γ separation**
  54 Liquid scintillators at 100 cm : EJ309, 17.8 cm dia., 5.08 cm thick

- **Low Energy Measurement (E_n < 1 MeV) : well-understood detector response function**
  22 ^{6}Li-glass detectors at 40 cm: Scionix10 cm diameter x 18 mm thick

R.C. Haight et al. (J. of Instr., 2012)

Chi-Nu project : Identify background

- **Time independent background**

  a. accidental coincidences with thermal neutrons – *$^{235}U(n,f)$ measurements*

  b. accidental coincidences with alpha decays – *$^{239}Pu(n,f)$ measurements*

- **Time dependent background**

  a. gamma flash from the neutron beam production – *beam energy gate*

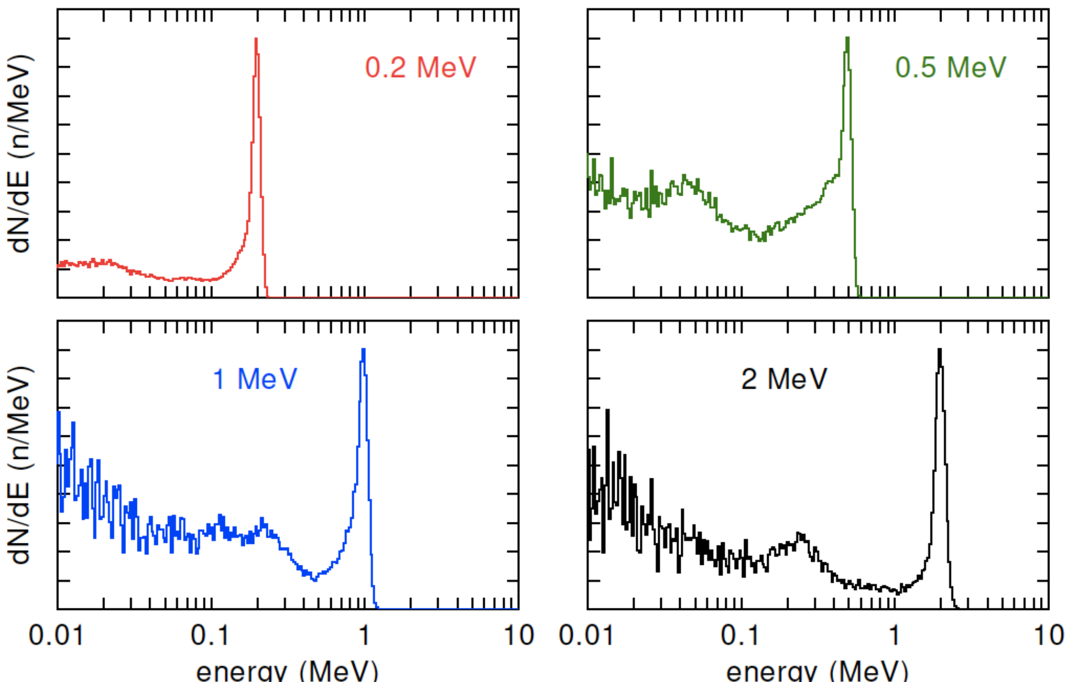
  b. incident fast neutron scattering on PPAC – *Li detector angle dependence and beam energy gate*

  c. gamma background from various reactions – *^{7}Li detector measurements*

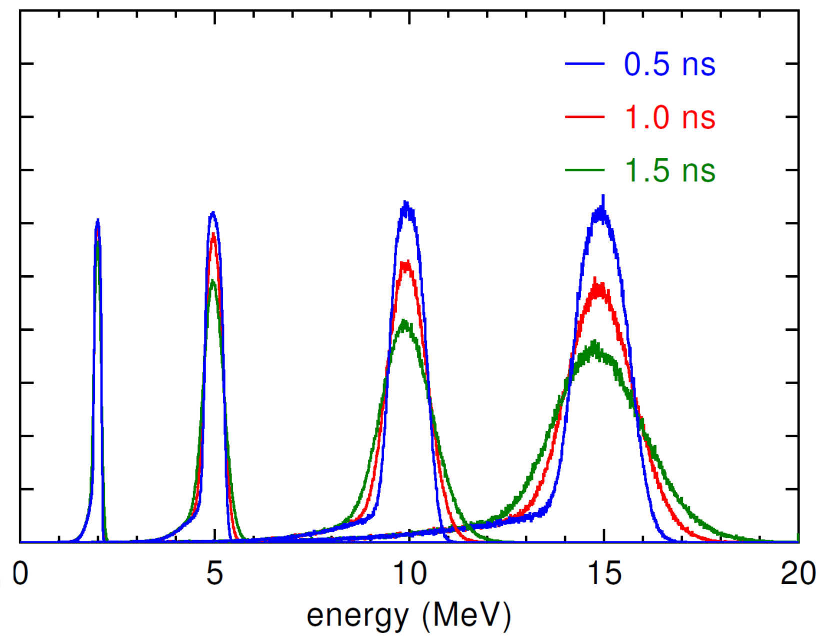
  d. neutron multiple scattering – *corrections obtained by MCNP calculation*

MCNP calculates detector response for monoenergetic neutrons

^{6}Li glass detector at different energies

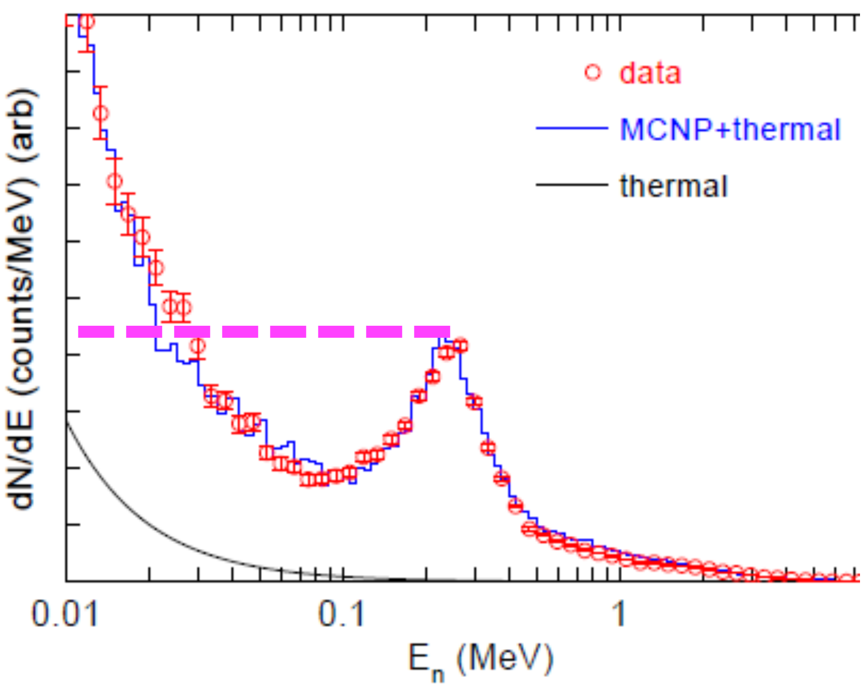


liquid scintillator with different timing resolutions

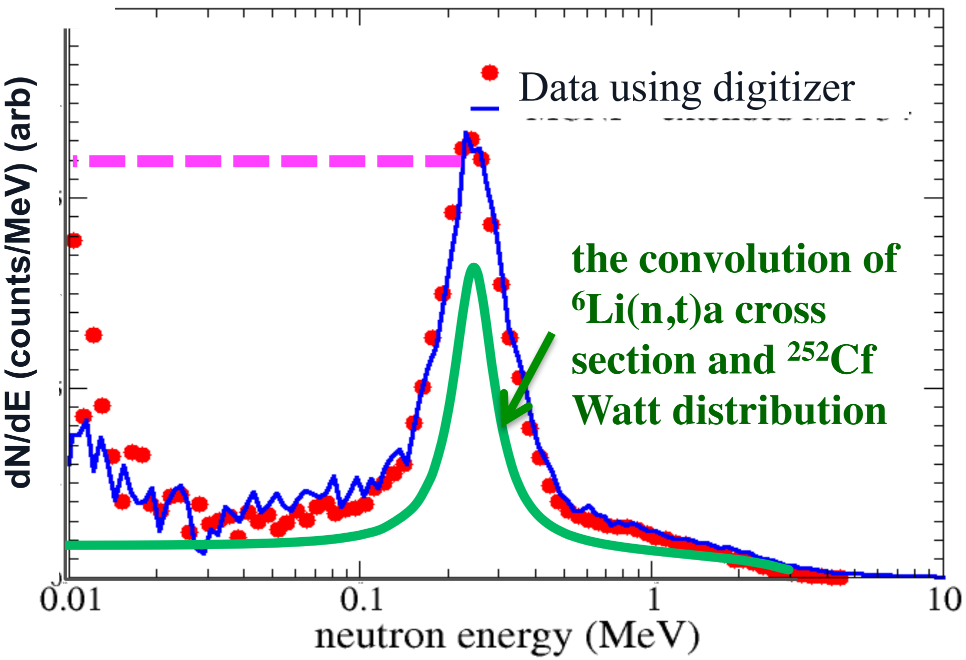


PFN yields of ^{252}Cf using a ^{6}Li-glass detector

PPAC-ver.1 in the FIGARO room



Fission chamber in the Calibration room

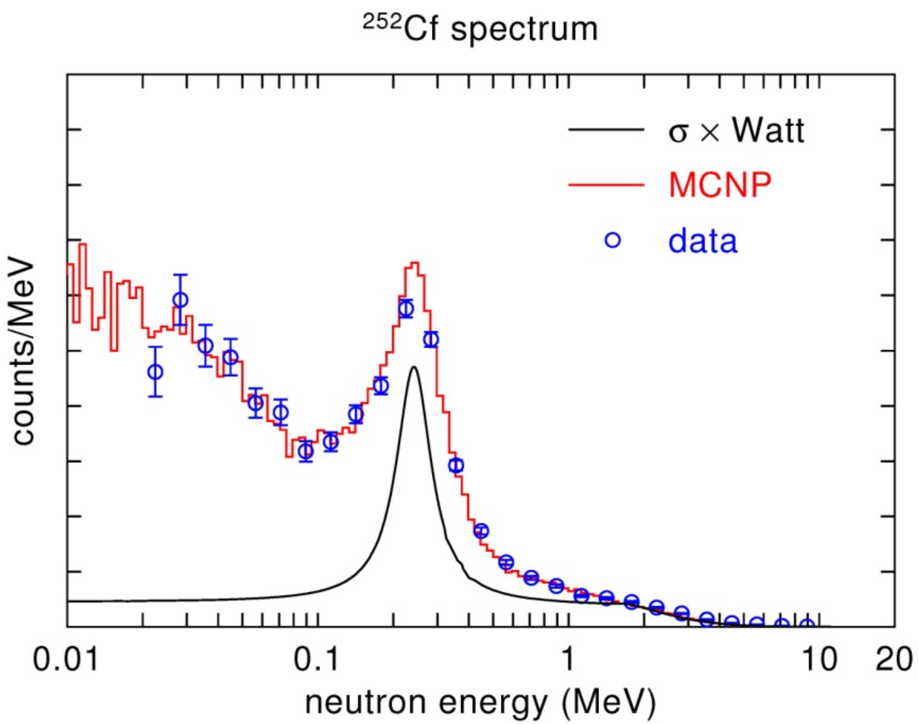


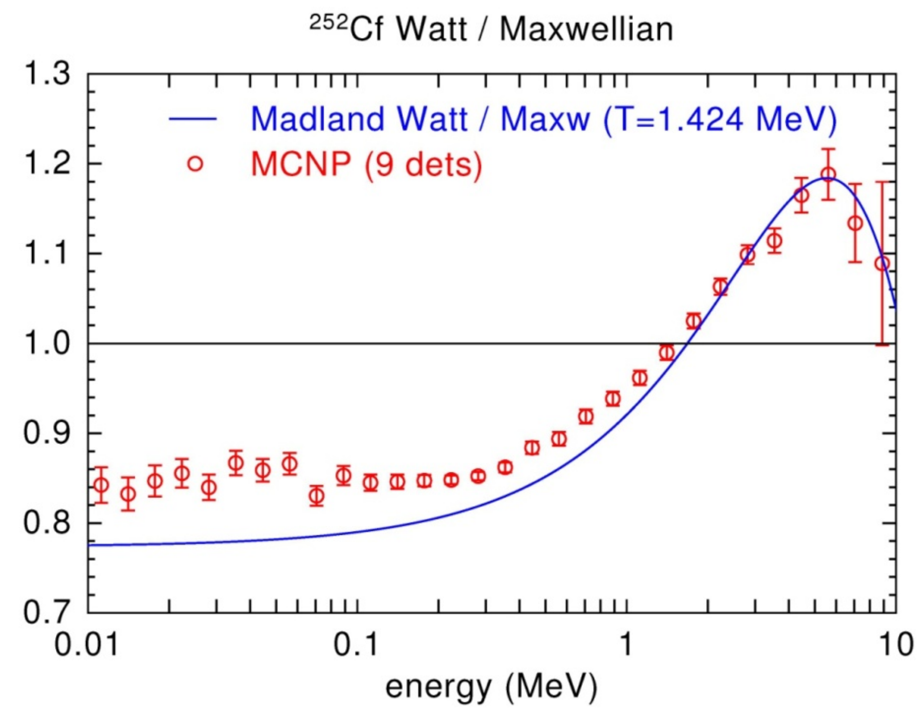
H.Y. Lee, T.N. Taddeucci, et al. (NIM A, 2013)

Low-energy tail is contributed by

- Any hydrogenated material near source and detector
- Multiple scattering on surrounding materials
- Distance between source and detector

MCNP shows that much of the difference between PFNS forms is preserved despite significant neutron scattering

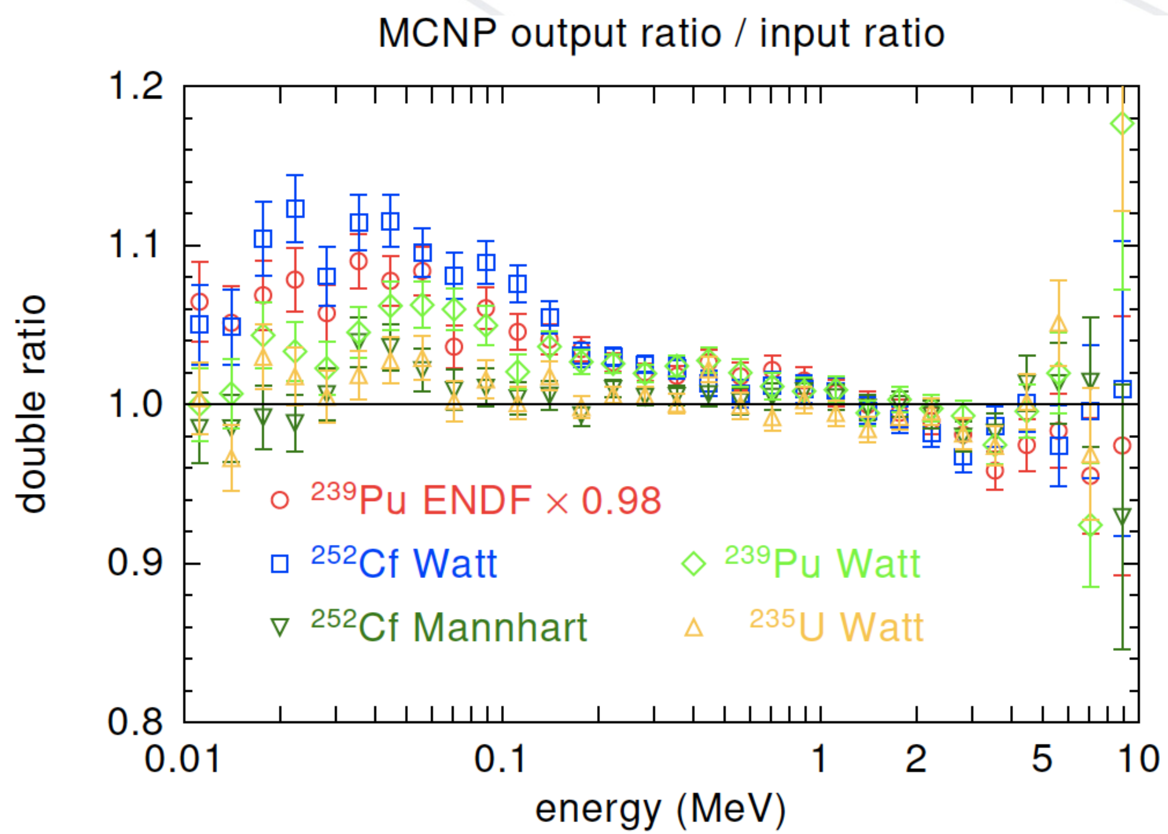




^{252}Cf PPAC-ver.1 at the ChiNu target room (PPAC+ 22 Li-glass detectors + array frame + target room components)

Unfolding vs. Integral approach to deduce PFNS from ChiNu data

- **Unfolding :**
  Using MCNP detector responses, the PFN yield can be deconvoluted to the PFNS
- **Integral – double ratio :**
  Using the spectrum shape-correction factor, the PFN yield can be corrected in bin-by-bin for deducing the PFNS



Double ratio = MCNP(PFNS)/MCNP(Maxw)/[PFNS/Maxw]

[PFNS/Maxw] = 1/double-ratio X [Measured ChiNu/ MCNP(Maxw)]

Summary

- For low energy measurements, any hydrogenated materials near the sample should be avoided
- Full MCNP Detector response needs to be studied at each setup
- Time-dependent background should be well understood and corrected
- Even with large multiple-scattering effects, ChiNu measurements still retain sensitivity to the PFNS
- Double-ratio method gives an answer with limited uncertainty, while the full unfolding will provide the PFNS with a target precision

Collaborators and Funding Agencies

LANL: R. C. Haight, H. Y. Lee, T. N. Taddeucci, J. M. O'Donnell, T. Bredeweg, M. Devlin, N. Fotiades, S. Mosby, R. O. Nelson, T. Seagren, S. A. Wender, J. L. Ullmann, D. Neudecker, M. White

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Kentucky U.
(M. Kovash, postdoc, student)
Brigham Young U.
(L. Rees, J. B. Czirr, students)
Texas A&M U.
(P. Tsvetkov, postdoc)

Commissariat à l'énergie atomique et aux énergies alternatives (CEA):
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DOE – NNSA
Nuclear Energy
Nuclear Physics
NEUP from DOE-NE