Nuclear Science Opportunities at LANSCE/Lujan Center

Mark Chadwick
Los Alamos National Laboratory

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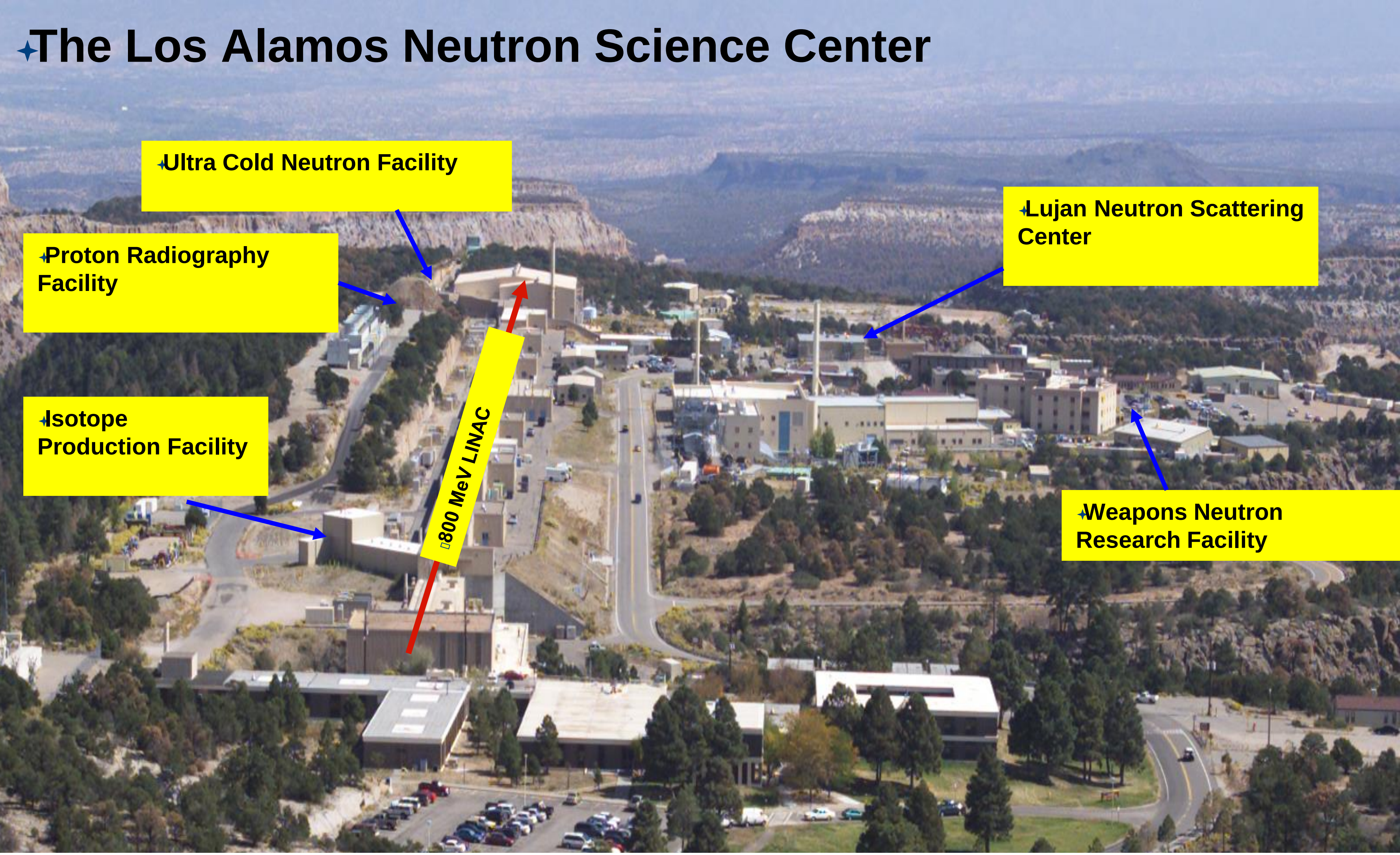
Abstract

A future research program planned for LANSCE/Lujan is described. This has been motivated by changes at Lujan following the DOE decision to end the materials science user program. We have an opportunity to design a new target, for improved measurements of nuclear cross sections in the 1-500 keV region. Possible future measurements are described.

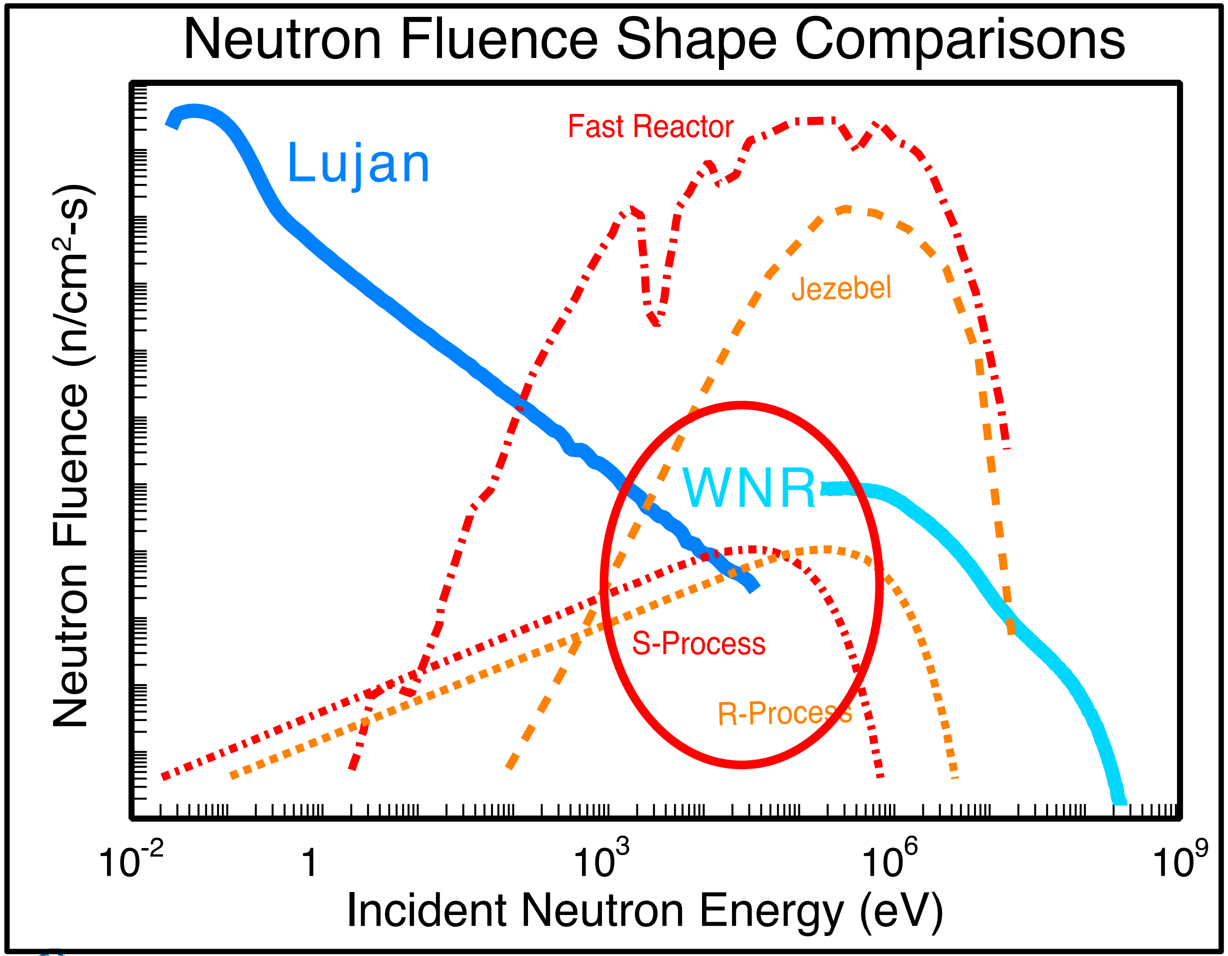
The Los Alamos Neutron Science Center



The issue:

- DOE/Office of Science pulled out of Lujan materials research
- Opportunity for LANL to rethink Lujan nuclear science, with a new target

Gaps in our understanding of intermediate energy nuclear reactions (~1 keV – 500 keV)



Redesign spallation moderation target to increase fluence in intermediate energy region

Optimization of a New Target at Lujan for Nuclear Science

- An opportunity now exists to optimize the present Lujan Center neutron spectrum to better cover the important intermediate neutron energy range between 100 eV to 2 MeV.

- Optimizations include:
  - Installation of a faster moderator which will enhance the neutron flux and energy resolution in this intermediate energy region
  - Changes to the pulse structure of the proton beam which includes producing a narrower proton pulse for better energy resolution and increasing the pulse repetition rate
  - Developing pulse stacking in the Proton Storage ring to increase the proton current. Initially, such a pulse-stacked pulse may be approximately 30 ns wide separated by 25 ms. If we store 4 pulses in the ring, the intensity will be approximately 95 uA with a pulse repetition rate of 160 Hz.

Objectives

Improved nuclear data for intermediate energy 1 keV – 500 keV neutrons, for:

- higher-fidelity neutronics simulations
- astrophysical applications
- fast reactor data needs

Historically we model intermediate energy criticality benchmarks more poorly than simple fast benchmarks

- They involve more scattering, a more complex transport, and are more sensitive to inelastic, elastic, reactions
- Neutron-incident reactions in the 1-500 keV region are often less well understood, *e.g*. actinide capture reactions, inelastic scattering
- Reaction rates (fission, n2n, …) modeled more poorly here too

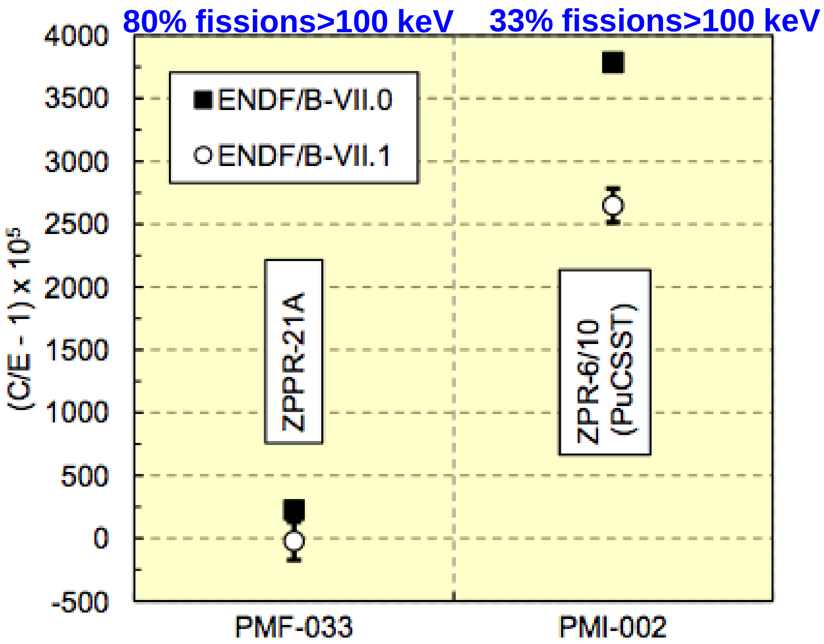


FIG. 24: MCNP Calculations with As-Built models for Pu metal FAST and INTER ZPR/ZPPR Assemblies.

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ENDF performs less well in intermediate energy spectra than in fast spectra, for reaction rates Flattop critical assembly

- Fission reaction rates, including threshold fissioners, measured by LANL radiochemists

- Fast discrepancy ~ 6%

- Intermediate discrepancy ~ 12%

Center region (fast)

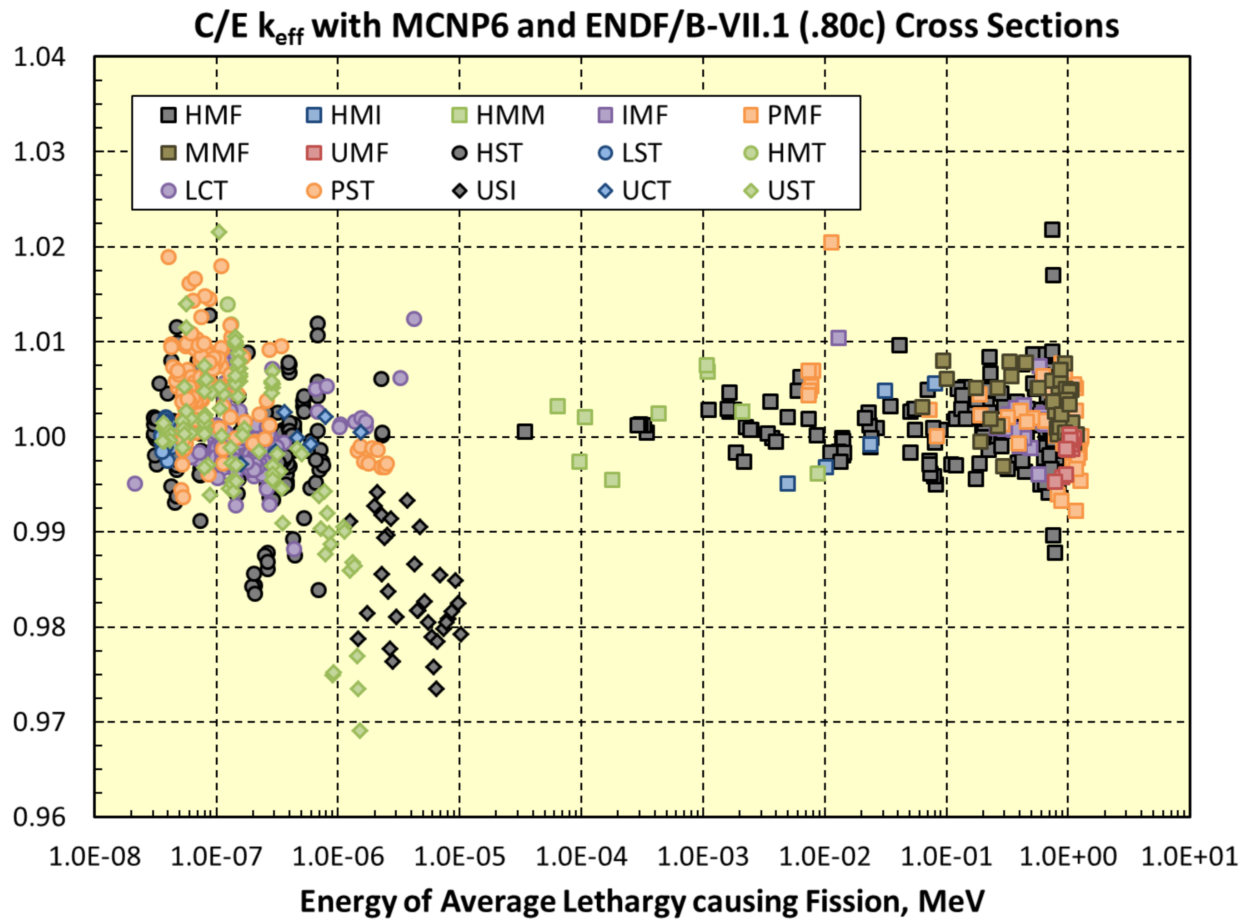
Outer region (intermediate)

TABLE XVI: Measured and Calculated Fission Rate Ratios for Selected Actinides in Flattop-25 by Barr *et al.* [15]. Data for the uranium isotopes and ^{239}Pu are ratioed to ^{235}U(n,f), the remaining results are ratioed to ^{239}Pu(n,f). The measurement location for those data given in the top half of the Table are near the center of the assembly (r=1.11 cm), data given in the bottom half of the Table are from the tamper region (r=13.97 cm). As these data have not been published previously, we also include the measured spectral indices in the second column of this Table. A generic 5% uncertainty is judged appropriate for these data, but the values tabulated are given to the precision used in internal LANL documents.

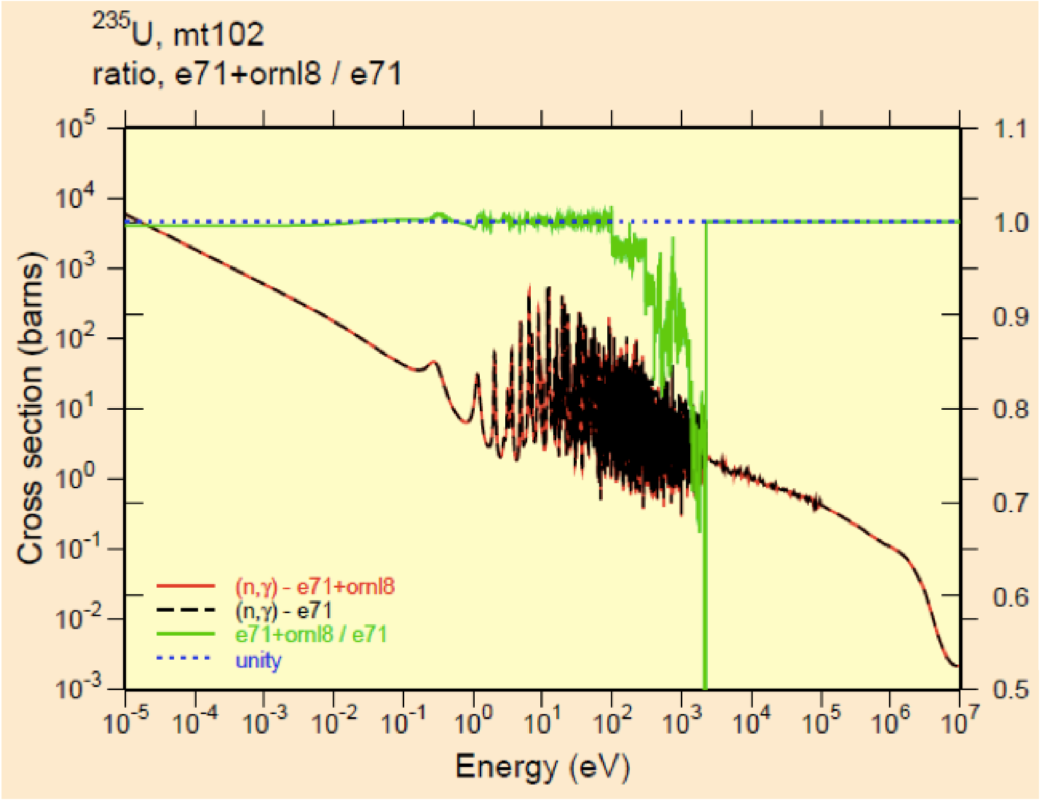
Reaction	Measured Spectral Index	ENDF/B-VII.0 C/E	ENDF/B-VII.1 C/E
^{233}U(n,f)	0.3155	0.921(46)	0.922(46)
^{237}U(n,f)	0.537	0.832(42)	0.892(45)
^{238}U(n,f)	0.1397	1.029(51)	1.030(51)
^{239}Pu(n,f)	1.307	1.039(52)	1.039(52)
^{238}Pu(n,f)	1.002	0.967(48)	0.950(47)
^{240}Pu(n,f)	0.549	1.043(52)	1.026(51)
^{241}Pu(n,f)	1.073	0.911(46)	0.911(46)
^{242}Pu(n,f)	0.482	0.961(48)	0.984(49)
^{241}Am(n,f)	0.577	0.918(46)	0.914(46)
^{233}U(n,f)	0.08	0.669(33)	0.672(34)
^{237}U(n,f)	0.391	1.018(51)	0.973(49)
^{238}U(n,f)	0.02487	0.832(42)	0.832(42)
^{239}Pu(n,f)	1.145	0.985(49)	0.985(49)
^{238}Pu(n,f)	0.708	0.968(48)	0.946(47)
^{240}Pu(n,f)	0.26	0.899(45)	0.870(43)
^{241}Pu(n,f)	1.251	0.954(48)	0.953(48)
^{242}Pu(n,f)	0.19	0.845(42)	0.871(44)
^{241}Am(n,f)	0.184	0.793(40)	0.784(39)

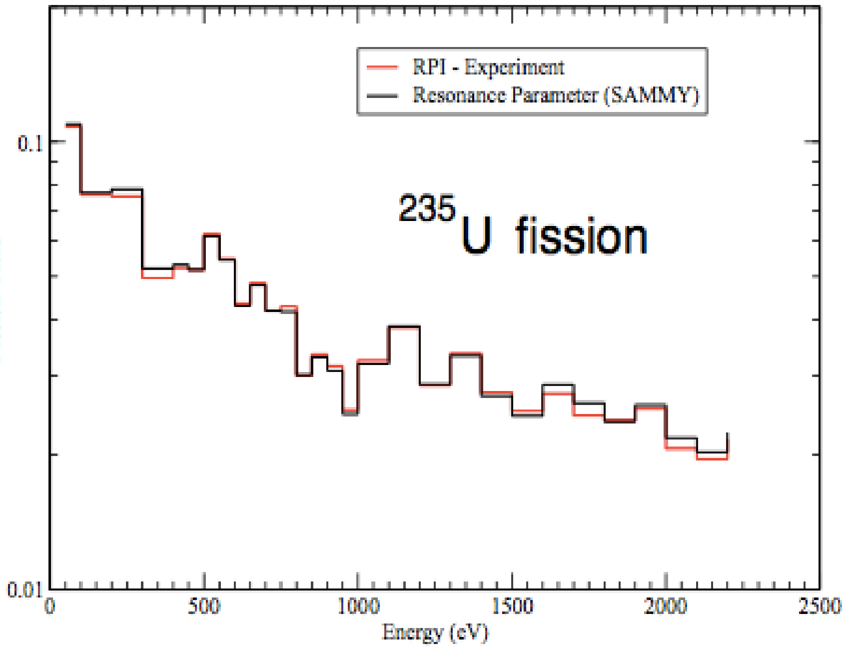
Survey of ICSBEP eigenvalue calculations (Kahler, LANL)

- Energy of Average Lethargy values below 1.0E-6 are largely “THERM” systems; values above 1.0E-1 are largely “FAST” systems.
- Fewer data exist the “INTERmediate” energy range.

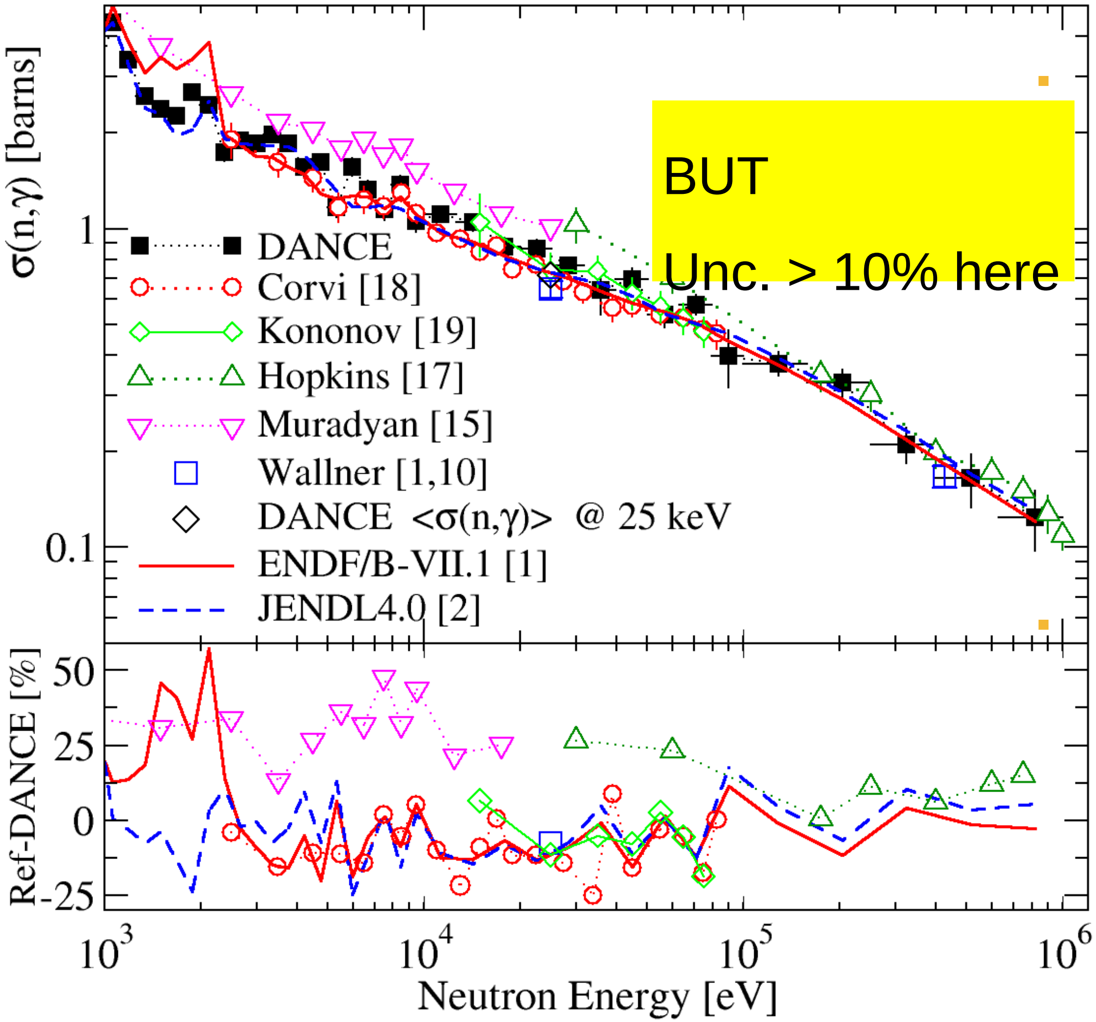


^{235}U capture: DANCE & RPI data solved the 0.5-2.5 MeV region questions (But questions above 2.5 keV still)





^{235}U capture: we need more accurate data in the 2.5 keV - MeV region



Jandel's ratio method helped

Precision <3% was achieved using simultaneous rate determination;

- Rates of U5(ng) and U5(nf)
- The same target → same n flux for both reactions

Being implemented for ^{239}Pu (S. Mosby et al.)

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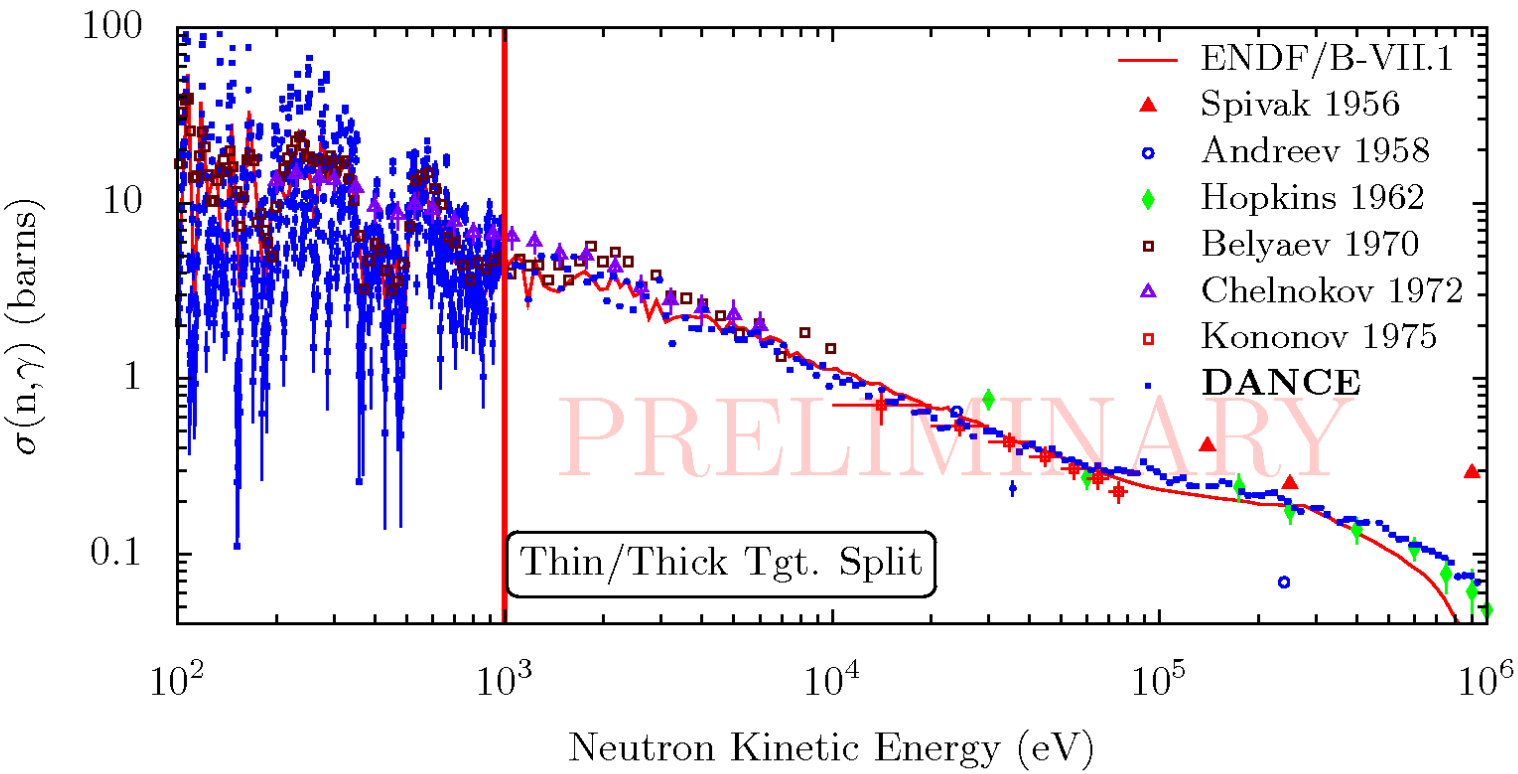
New Plutonium-239 Capture Cross Section Data. But More Accurate Data are Needed > 1 keV

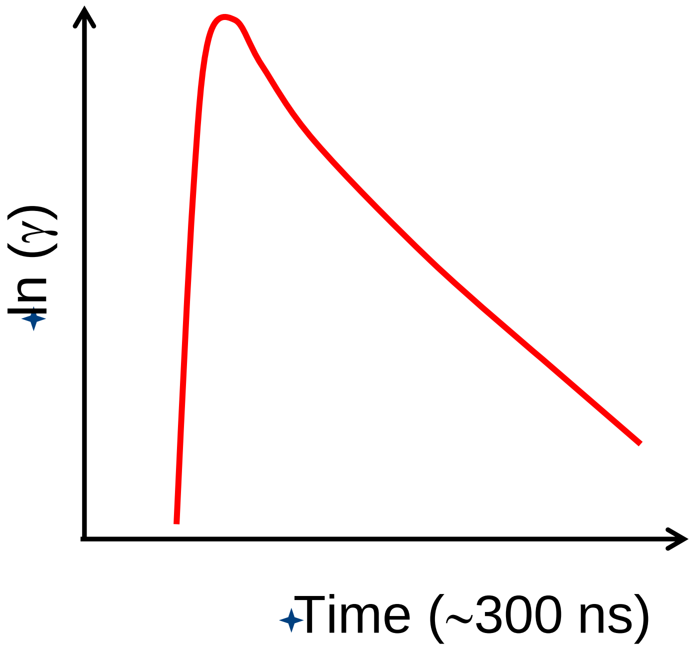


- Results up to 1 keV are published
- Experiment with thick target completed, analysis in final stages

Fission Decay Chain Measurements Motivate Prompt Fission Gamma-Ray Data at LANSCE/Lujan

Traditional approaches

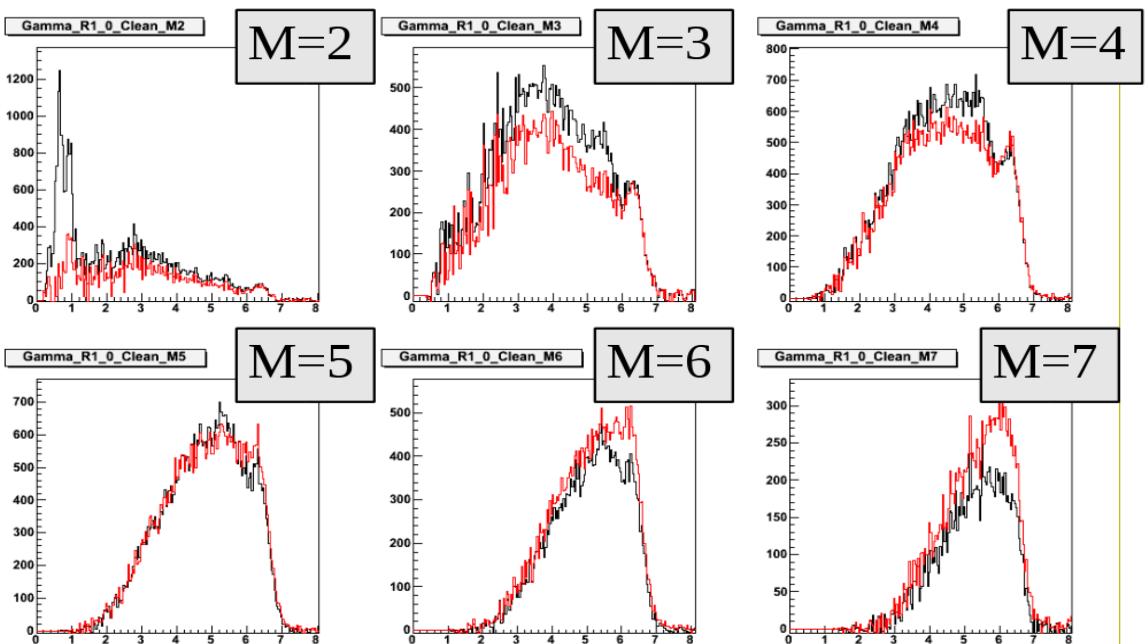
- 1/m plots (count rate v. control rod position, to identify asymptote & critical)
- Feynman variance of counts (doubles …) to infer multiplication and k-eff
- Decay of fission chain via fission-gamma-rays

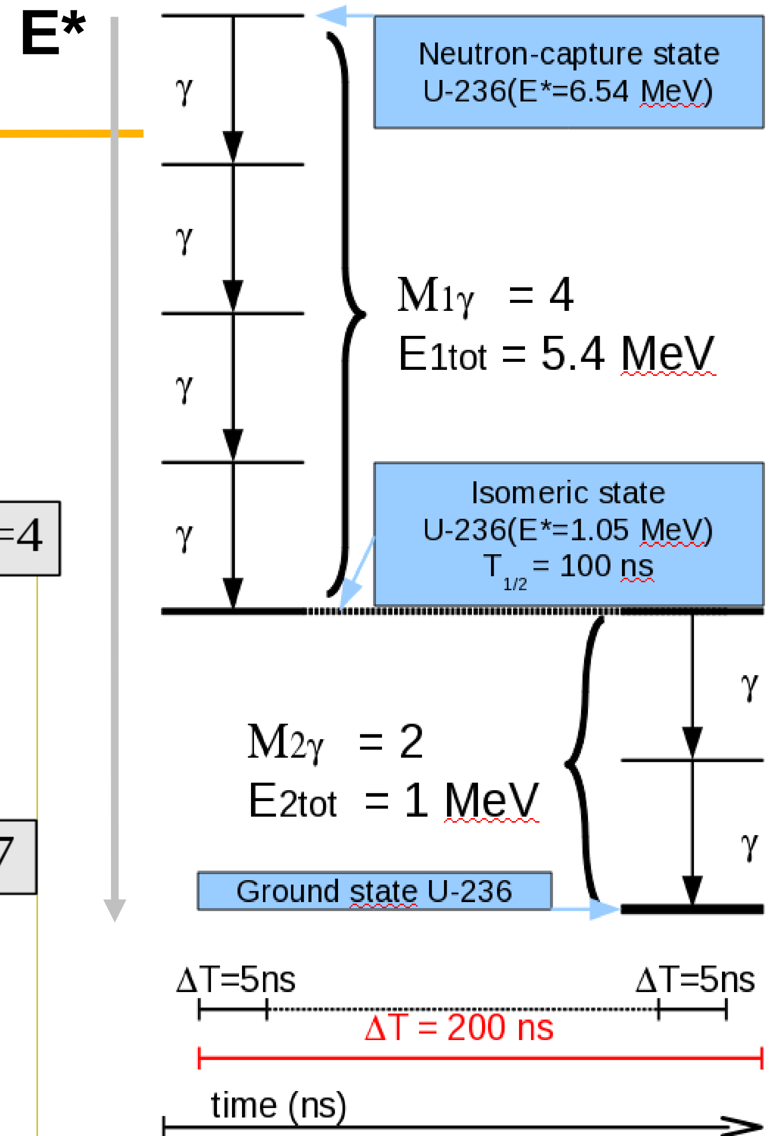


Short-Lived Isomeric states after U235+n

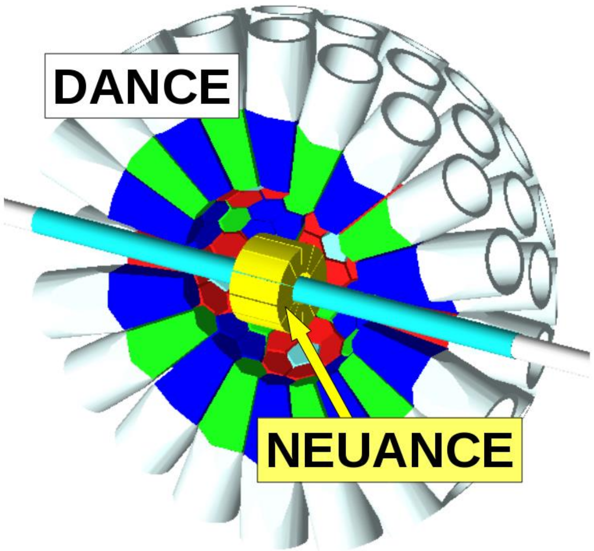
- During analysis of ^{235}U(n,□) cross section we have found structure in the total gamma-ray energy E_{tot} spectra

M. Jandel et al., Phys Rev Lett 109, (2012)





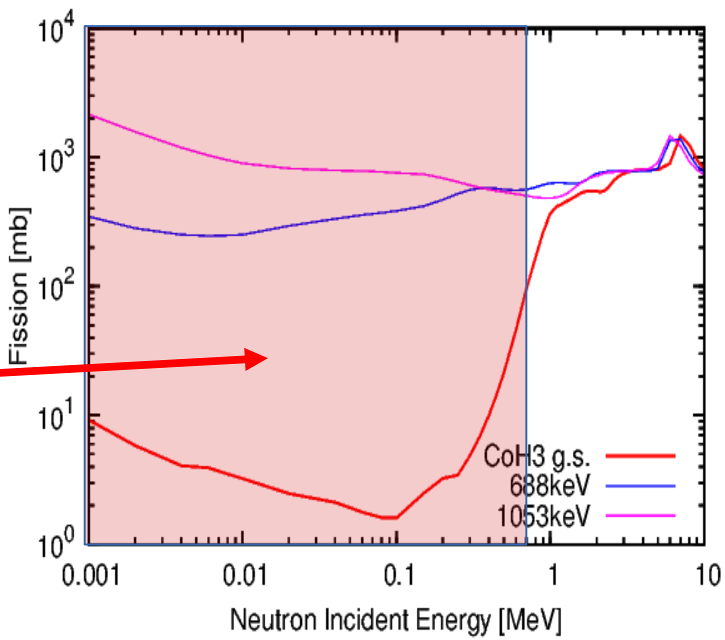
Isomeric states after U-235+n



- In high neutron fluence the secondary reactions can occur
- $^{236}U^*$: 1024 keV (4-) $T_{1/2}$ = 100 ns
- $^{236}U^*$: 678 keV (1-) $T_{1/2}$ = 3.7 ns
- Current work addresses resonance region

- What is the population of these states after ^{235}U+n ?
- What are the n-reaction cross sections on these states ?

A. **Future – unresolved region En> 1keV**



Conclusions

Future upgrades at Lujan are planned to address 1-500 keV advances:

- Precise capture & fission measurements
- Other reactions – inelastic, elastic scattering, e.g. with RPI staff
- Prompt fission gamma-ray data, isomers