Nuclear Data Experiments at LANSCE: Highlights 2005

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Los Alamos National Laboratory

Cross Section Evaluation Working Group Meeting
US Nuclear Data Program Meeting
Brookhaven National Laboratory
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LA-UR-05-8366

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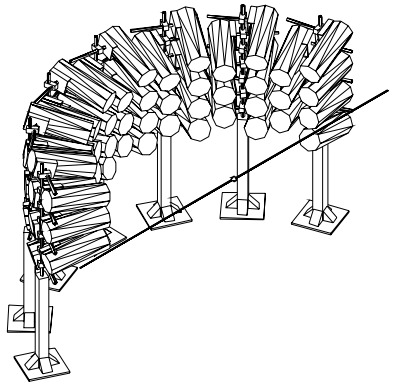
Nuclear data measurements at LANSCE are made with several instruments

GEANIE (n,xγ)

FIGARO (n,xn+γ)



DANCE (n,γ)

N,Z (n,charged particle)

Fission

LSDS

Double Frisch-grid fission chamber; also standard fission ion chamber

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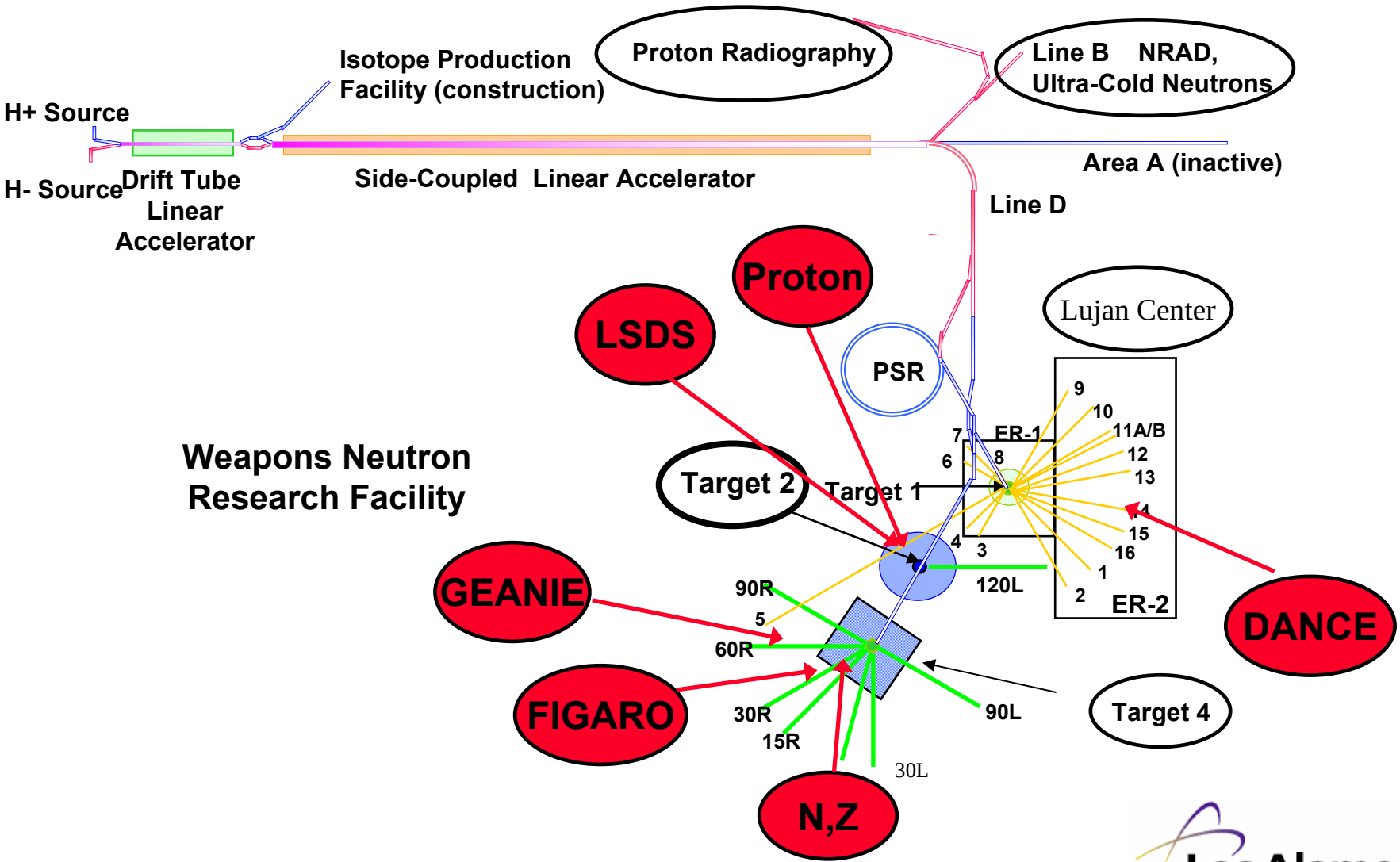
Nuclear data experiments at LANSCE use neutrons at three locations: Lujan Center, Target 2 and Target 4.



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GEANIE (n,xγ)

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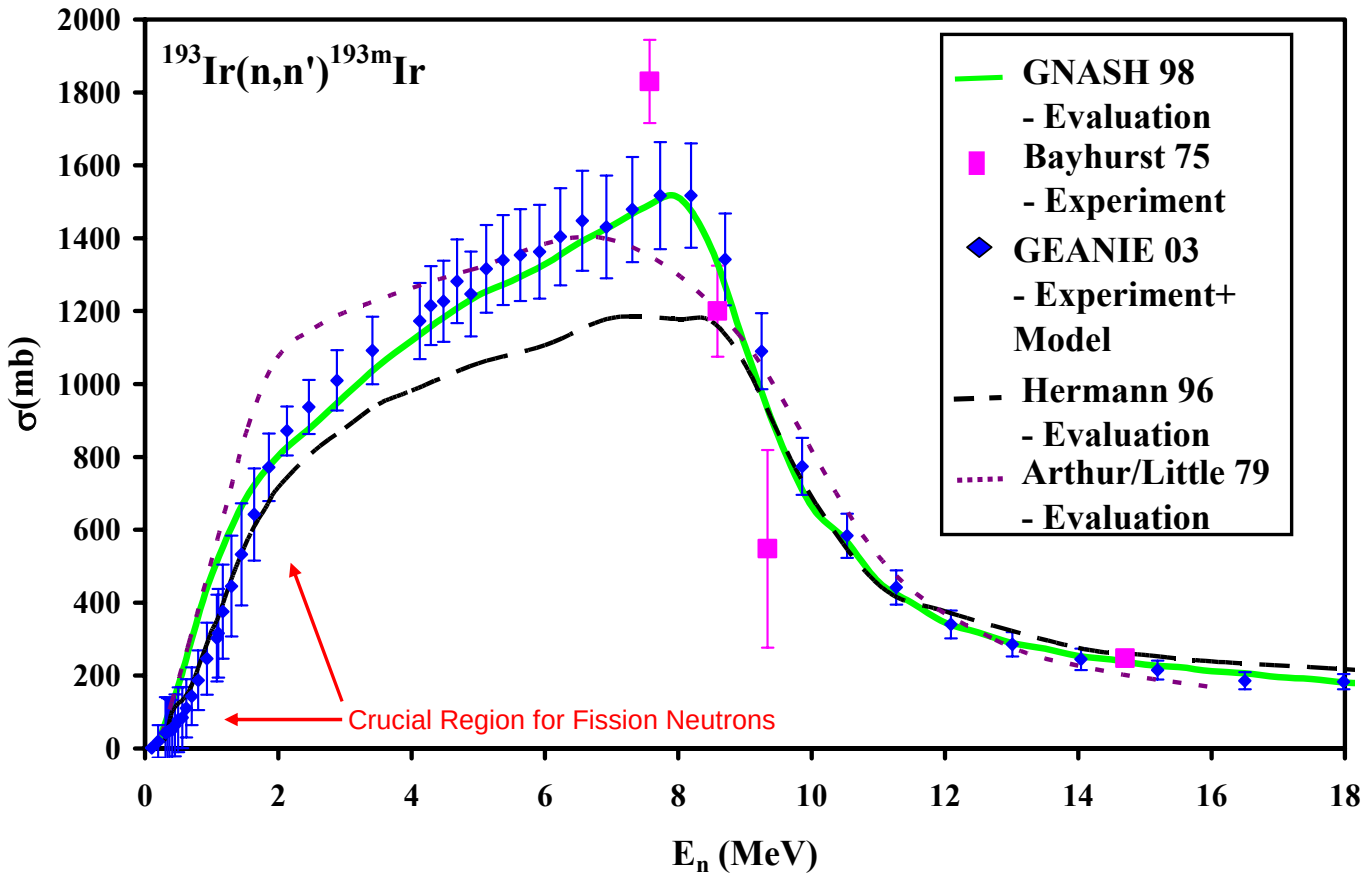
Recent & planned GEANIE neutron-induced gamma-ray cross-section measurements at LANSCE/WNR

~1 MeV < E_n < 200 MeV

- ^{191,193}Ir(n,n'γ), (n,xnγ), and (n,pxnγ) – results ND2004
- ^{197}Au(n,n'γ), (n,xnγ), and (n,pxnγ) – results APS DNP 10/2004
  - New levels and γ's obtained for ^{191,3}Ir and ^{197}Au
- ^{nat}Cr + ^{nat}V – relative, for secondary cross section standards
- ^{48}Ti(n,xγ) – dissertation - D. Dashdorj (NCSU/LLNL)
- ^{150}Sm(n,2nγ) – reported (UCRL-TR-205760)
- Planned analysis:
- ^{100}Mo(n,xγ),^{130}Te(n,xγ), ^{19}F(n,xγ)
- ^{70,72,74}Ge(n,xγ) – INL
- Planned measurements: ^{124}Sn, ^{138}Ba, ^{169}Tm, ^{186}W, ^{203}Tl, ^{233}U

New GEANIE data significantly improve the $^{193}Ir(n,n')^{193m}Ir$ cross section database



GEANIE
LLNL/LANL

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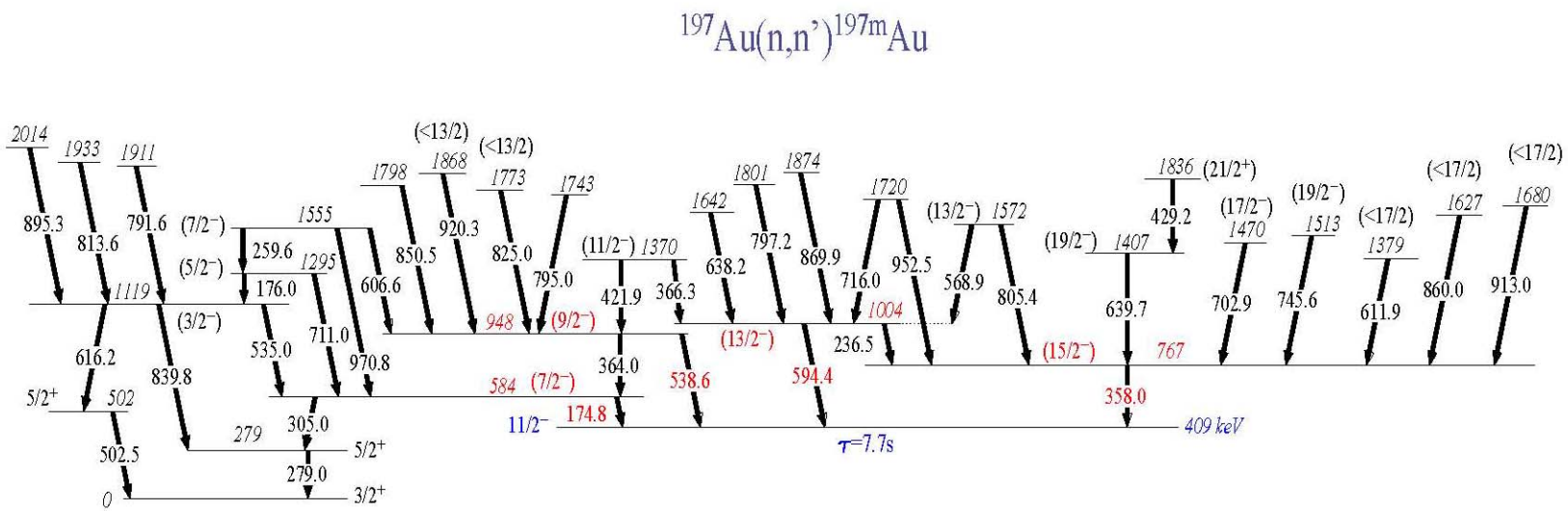
GEANIE data on 197Au(n,n') found 52 new gamma rays and 32 new levels

Level scheme above the 11/2- isomer



N. Fotiades et al., PRC 71, 064314 (2005)

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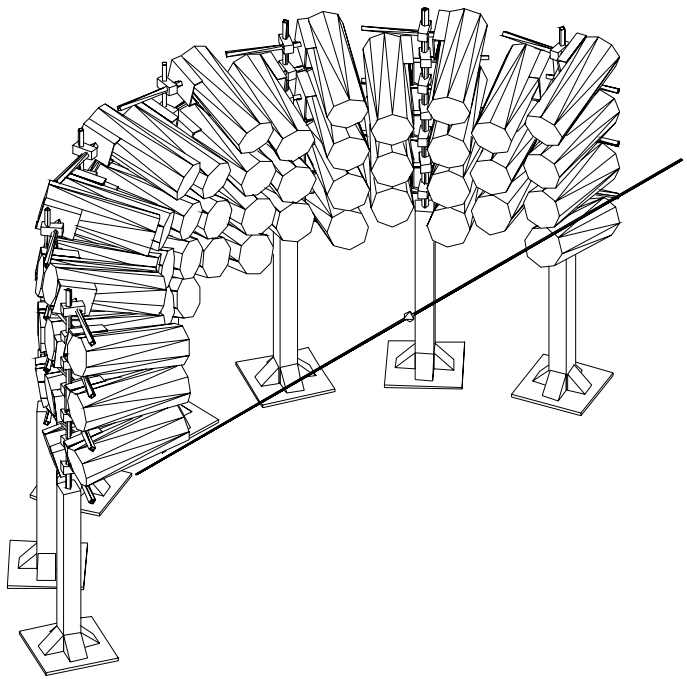
FIGARO (n,xn+γ)



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Present and future experiments at FIGARO/WNR: neutron-emission spectra and ν-bar in fission

1 MeV < E_n < 200 MeV

Fission Chamber in beam

- ^{235,238}U(n,f): E_{fn}, ν-bar — Ethvigot, Phys. Rev. Lett.
- ^{235}U(n,f): E_{fgamma} — R. Nelson, in progress
- ^{237}Np(n,f): E_{fn}, ν-bar — Data being analyzed
- 2.3 m flight path at 20-deg — Pre-equilibrium preceding fission

Gamma-ray trigger (HPGe or BaF_2)

- ^{99}Tc, ^{208}Pb, Ba — In progress

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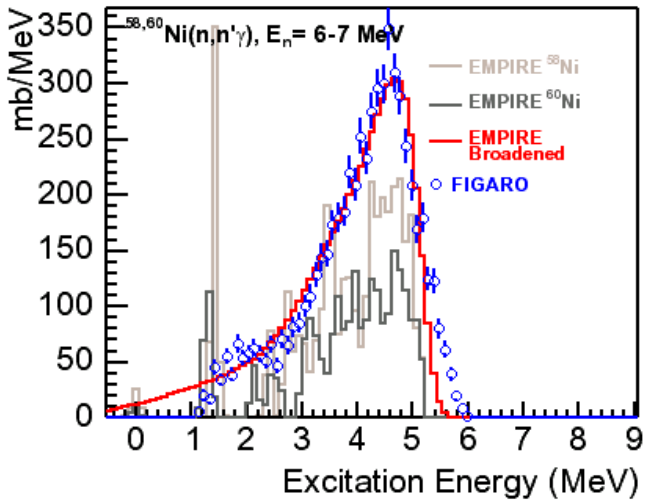
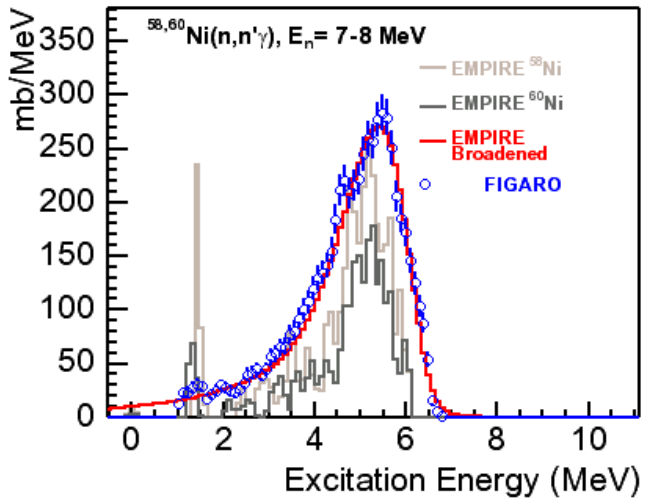
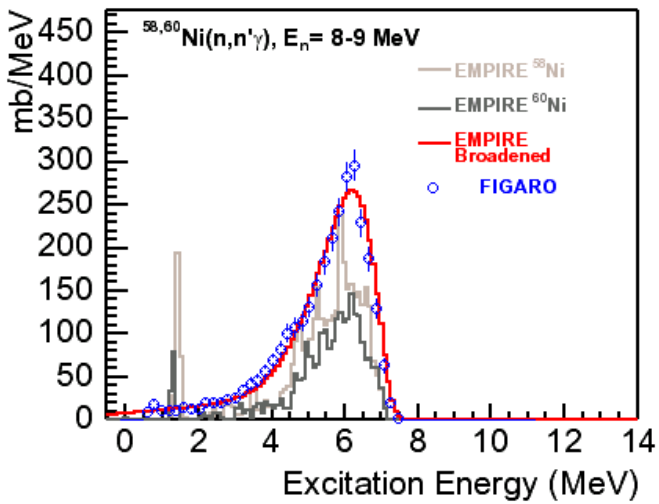
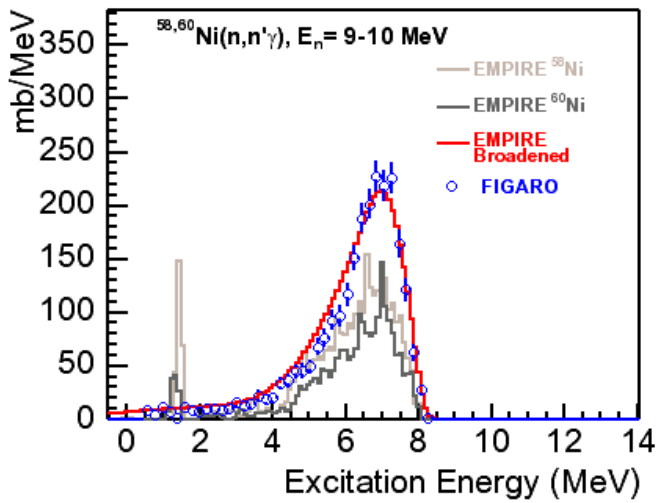
Model-Measurement Comparison for Ni(n,n'γ)









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N,Z = (n,charged particle) cross sections

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We measure proton, deuteron and alpha-particle production cross sections for the Advanced Fuel Cycle Initiative

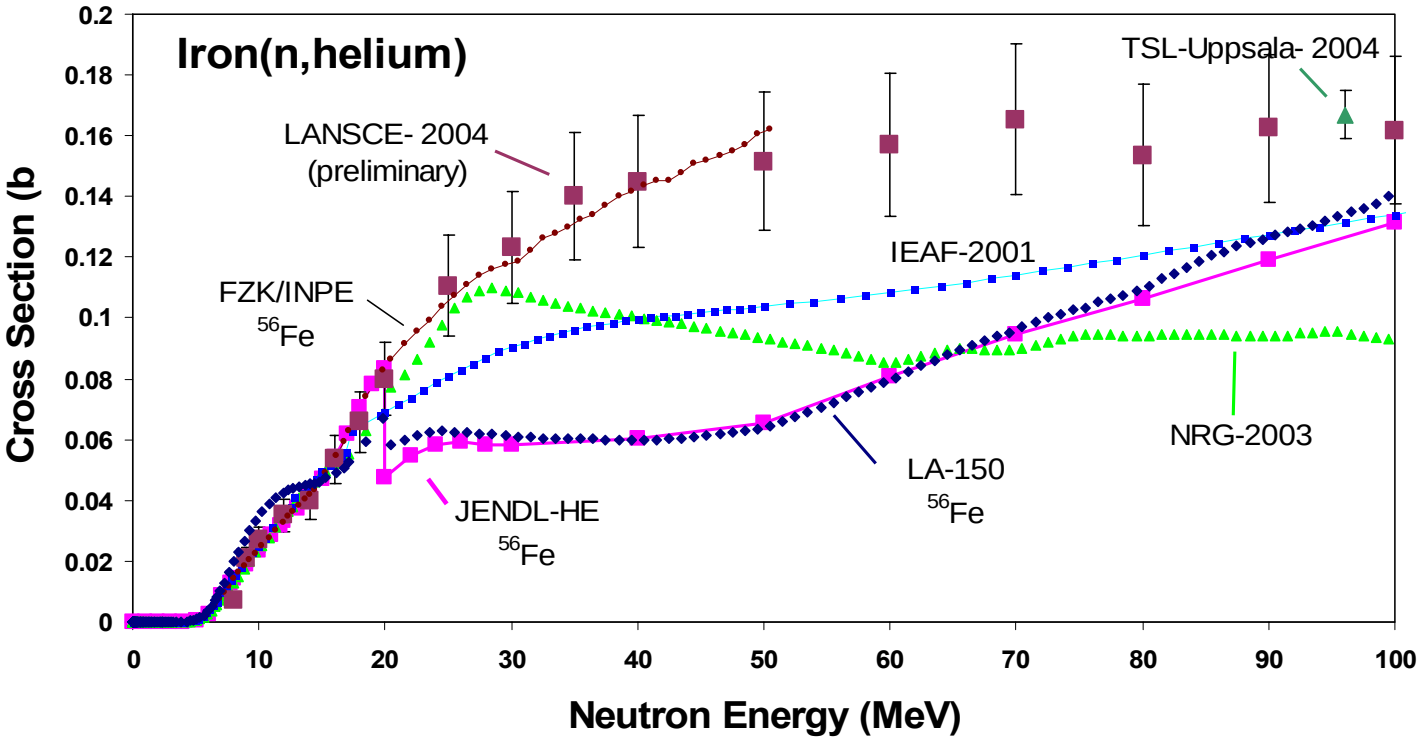
1 MeV < En < 100 MeV

- **Ta(n,xp) and (n,xα)**
- **Cr(n,xp) and (n,xα)**

- **Planned:**
  - **Zr(n,xp) + (n,xα)**

Goal is to determine, e.g. helium production / dpa for accelerated radiation damage analysis

New LANSCE data differentiate among evaluations



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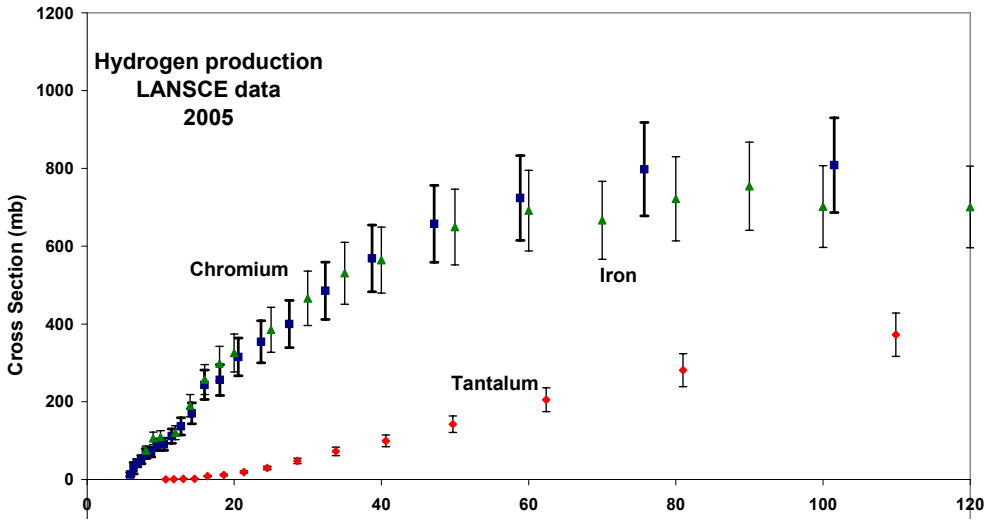
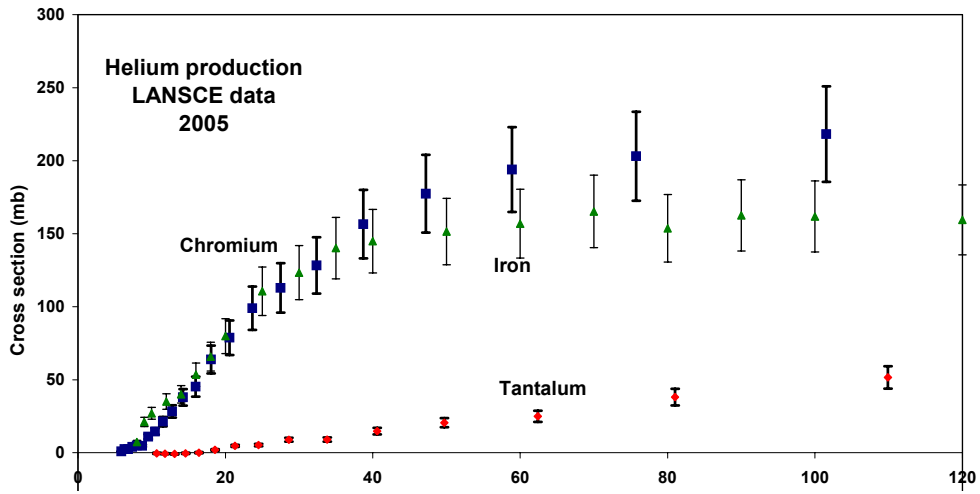
New data are for Tantalum and Chromium



Hydrogen



Helium

Future measurements:

Zr and Mo

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DANCE (n,γ)

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DANCE Progress 2004 - 2005

Stable Targets:

- ^{197}Au (well-studied standard)
- ^{139}La,^{45}Sc,^{55}Mn,^{59}Co,Cu,V,Rb,Sr (gaps in s-process)
- ^{102}Pd (p process)
- ^{62}Ni ("weak" s-process puzzle)
- ^{76,77,78,80}Se (s-process)
- ^{54,57,58}Fe (s-process)
- ^{94,95}Mo (γ-ray strength function)
- ^{152,154}Gd (radchem and s-process)
- ^{151,153}Eu (radchem)
- ^{147}Sm (spin assignments for resonances via multiplicities)

Radioactive Targets

- ^{237}Np -- AFCI
- ^{234,235,236,238}U -- known standards and defense programs
- ^{242}Pu -- AFCI and defense
- ^{151}Sm -- key s-process branch (largely completed)
- ^{241,242,243}Am (planned) -- AFCI and defense

Capture-fission ratio

- ^{235}U

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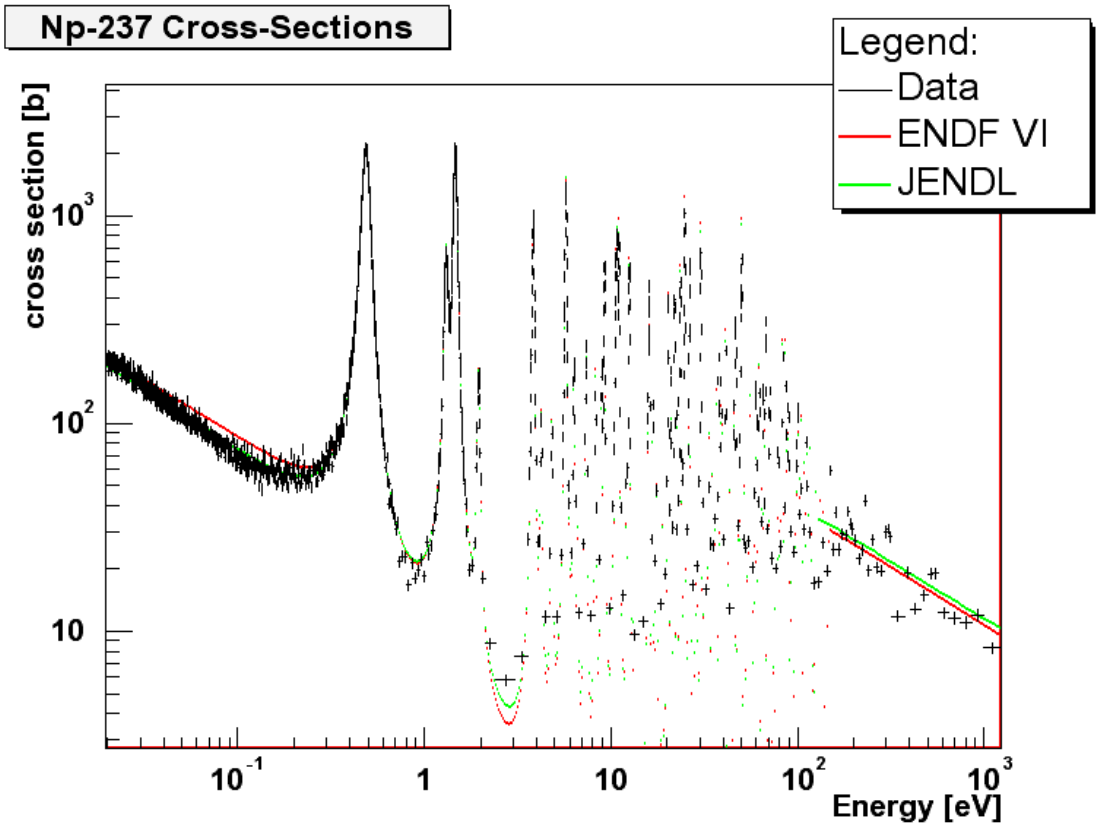
^{237}Np(n,γ)



Target: 0.44 mg ^{237}Np in 6.4 mm dia
(1.4 mg/cm^2)
Existing data above 1 keV discrepant

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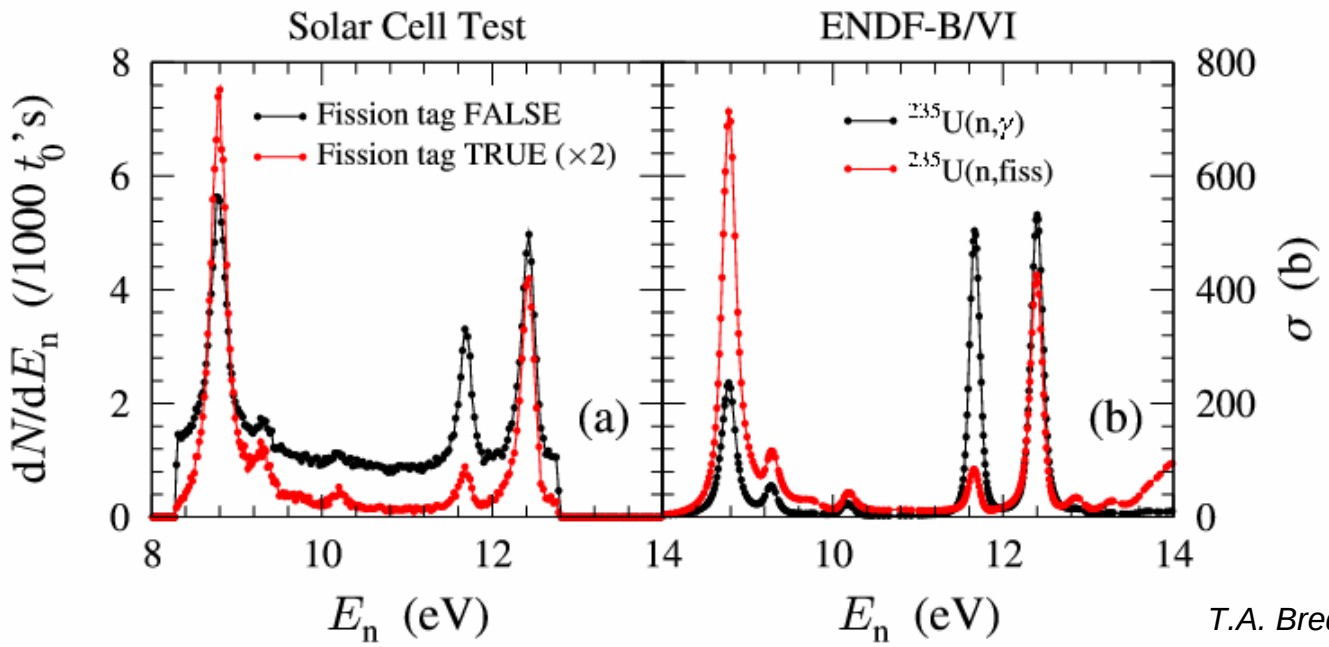
Test measurements with a fission-tagging detector



T.A. Bredeweg, et al.

- **Study:**
  - **Fission-to-capture ratios ("alpha")**
  - **Gamma emission following fission**
- **"Proof-of-principle" experiment used "thin" ^{235}U deposit on silicon solar cell (T. Ethvignot, et al.)**
- **Present: Thin gas fission chamber -- PPAC**

More on DANCE from Rene Reifarth

Lead Slowing-Down Spectrometer (n,f)

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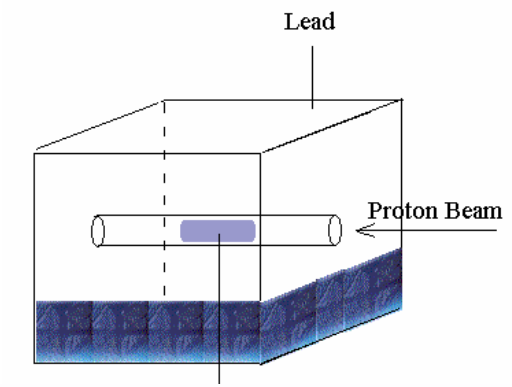
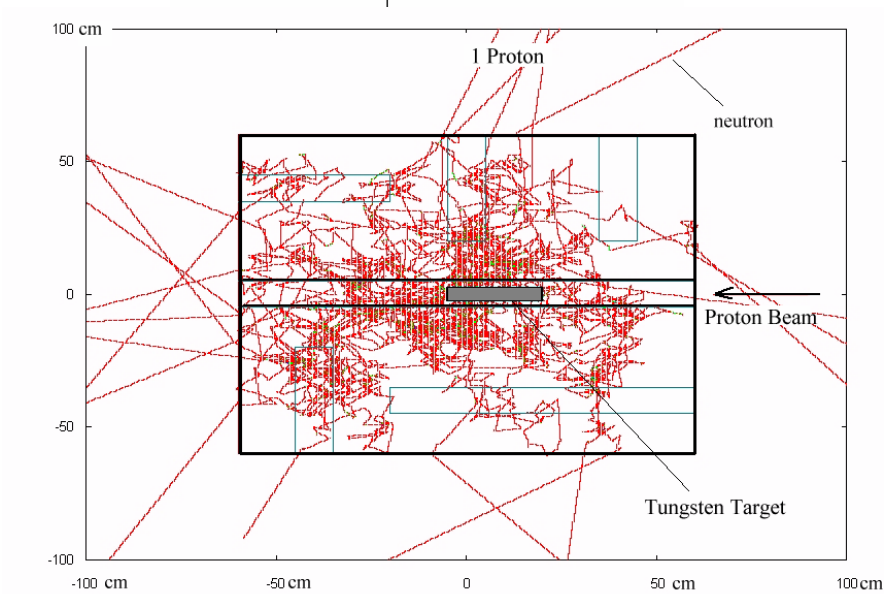
A Lead Slowing-Down Spectrometer is under development, driven by 800 MeV protons from the PSR





Neutron trajectories following the interaction of 1 proton with the tungsten target in the lead cube

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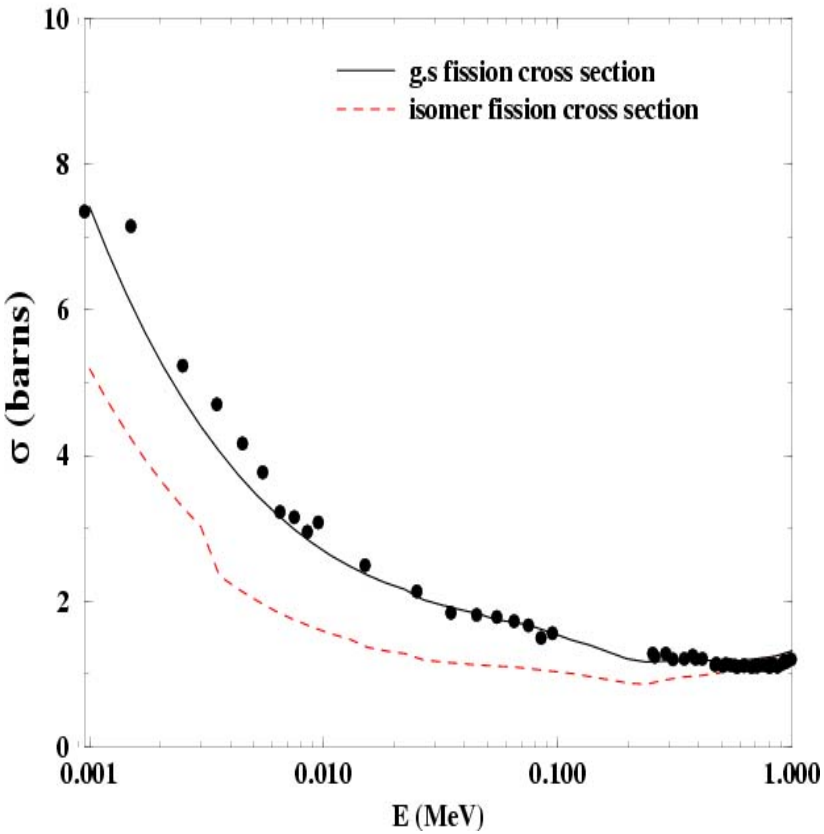
Lead Slowing-Down Spectrometer: To measure fission cross sections of ultra-small samples

- Effort motivated by interest in measuring the fission cross section of isomers and small samples of actinides
- Calculations show that cross section for ^{235m}U is significantly different than for ground state
- Experiments are in collaboration with LLNL, RPI and CEA/DAM

Fission cross section of ^{235}U and ^{235m}U



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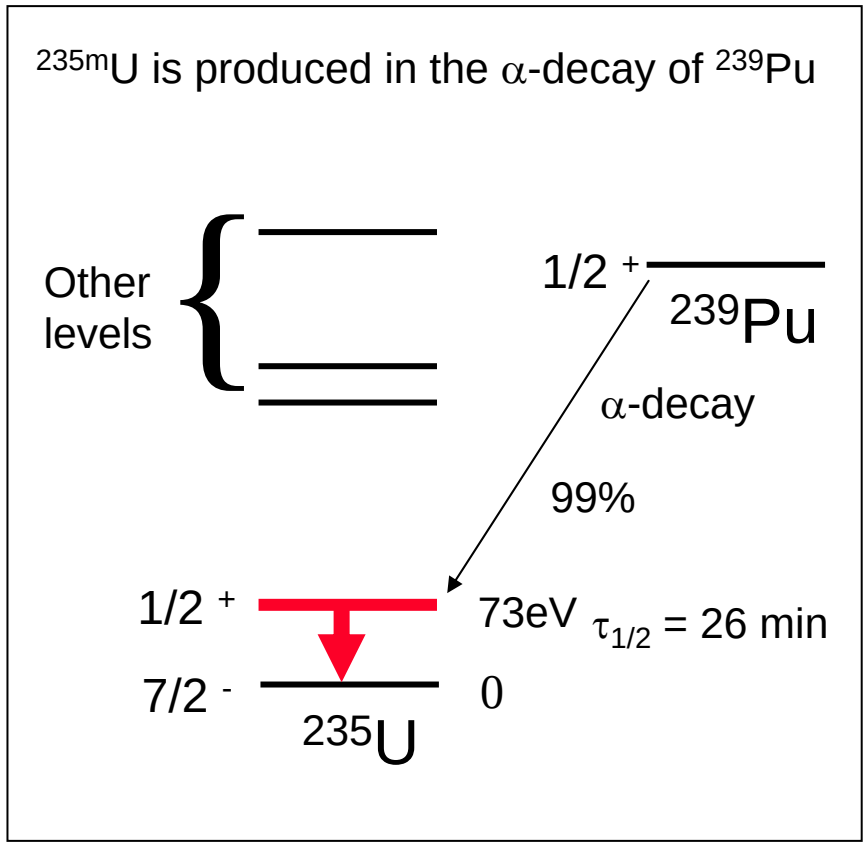
First excited state of ^{235}U is produced in decay of ^{239}Pu

- ^{235m}U
  - 26 min half-life
  - 73eV
  - Decays by internal conversion
  - 99% of 239Pu decays populate ^{235m}U
  - 5 gm of Pu will produce 10ng of ^{235m}U
- Fast extraction of ^{235m}U will be required
- To measure this small cross section, it is necessary to increase the neutron flux by using a lead-slowing down spectrometer (LSDS)



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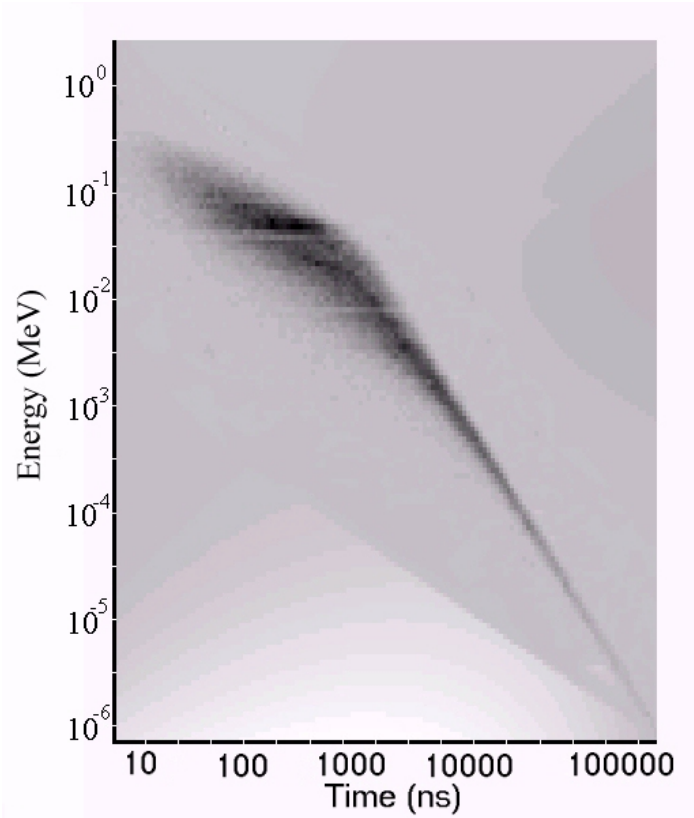
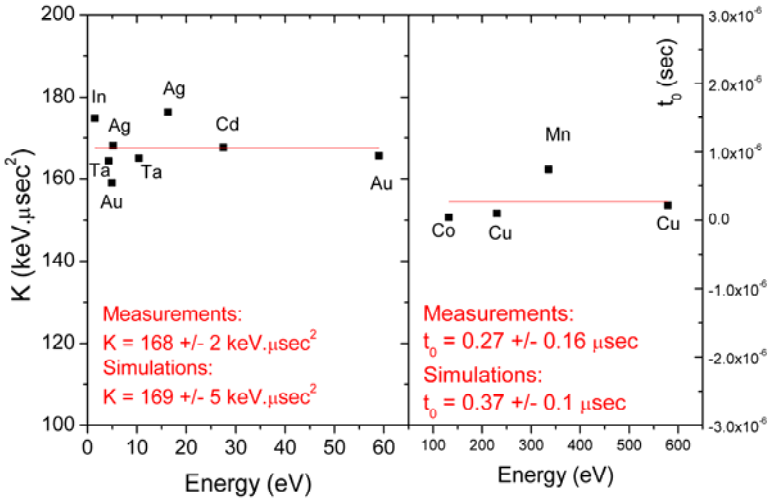
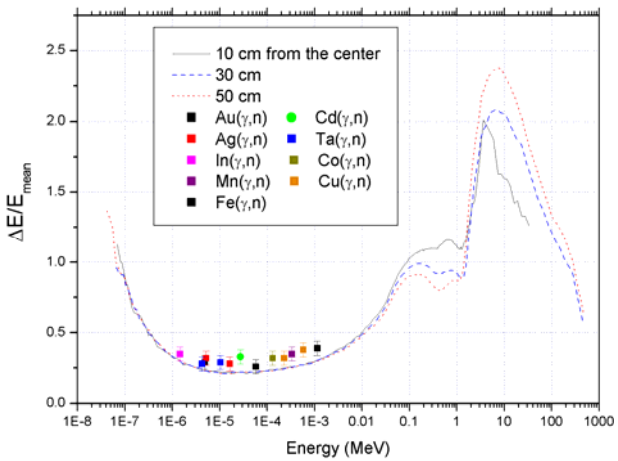
We have characterized the time-energy correlation and measured the resolution in capture resonances







Simulation: $\langle E_n \rangle = K / (t + to)^2$

with resolution, $\Delta E/E \sim 30\%$

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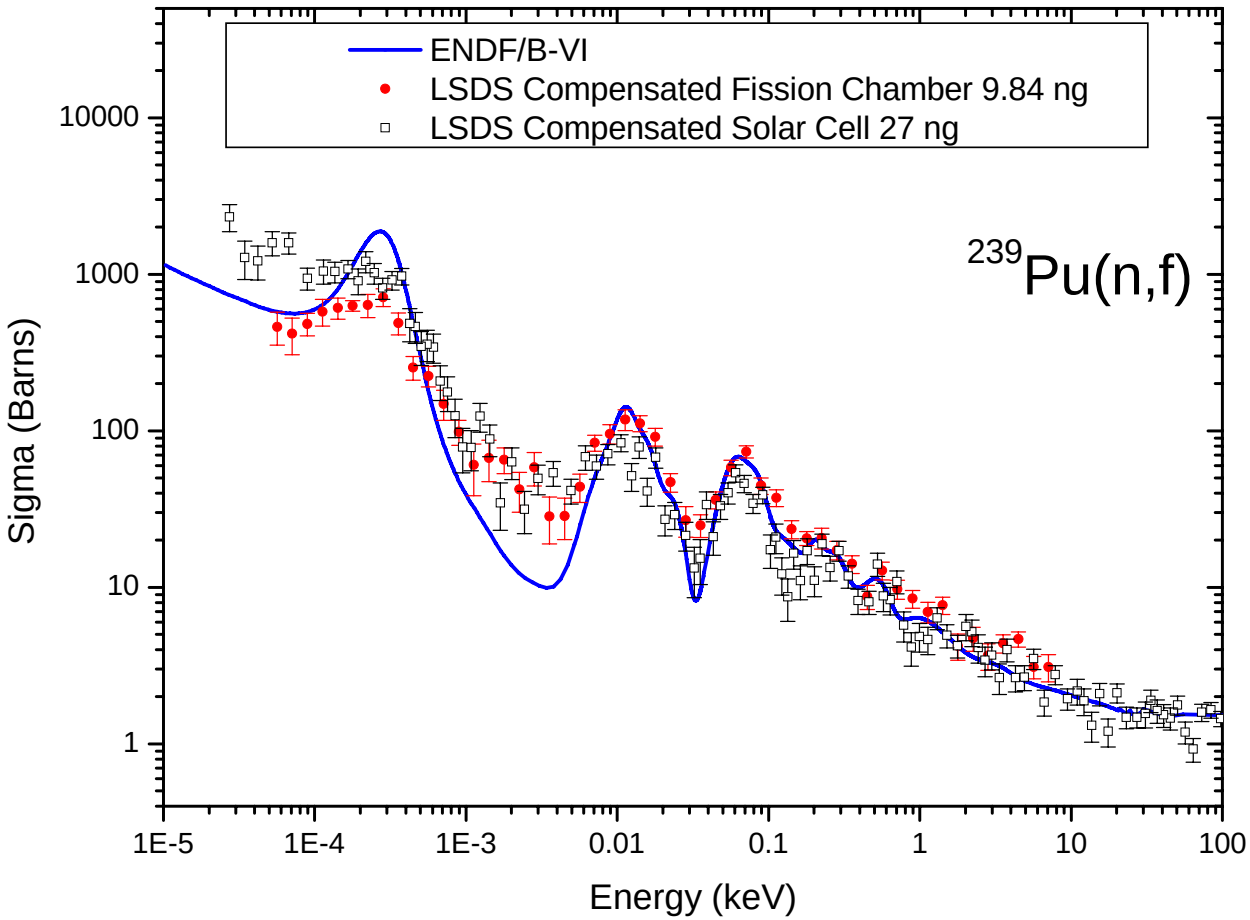
With the LSDS, we have measured the neutron-induced fission cross section on ^{239}Pu section with sub-μg samples



- Last year 27 ng

-This year 9.87 ng with higher current & higher rep-rate of PSR

- Good results up to 100 keV

- First planned ^{235m}U measurement 12/05

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Fission Cross Sections

Fission cross section measurements are being renewed at LANSCE

- Data for the Advanced Fuel Cycle Initiative
- New data ^{237}Np (standard fission chamber)
- FY-06: ^{237}Np, $^{240, 242}$Pu with Frisch-grid chamber
- FY-06-07: Precise ^{239}Pu fission cross section
- People:
  - Tony Hill
  - Fredrik Tovesson
  - F.-J. Hambsch
  - others

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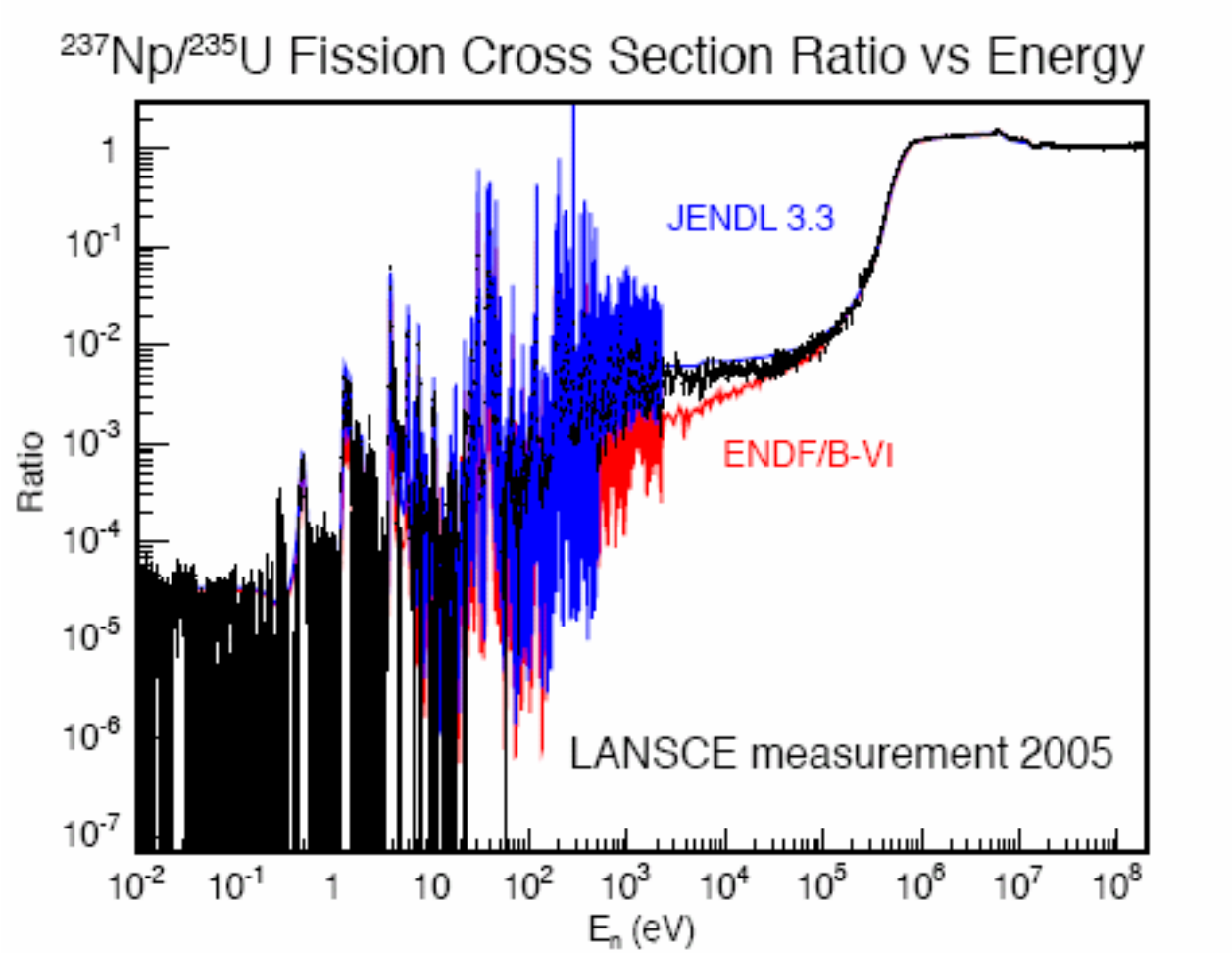
Comparison of this Np^{237}/U^{235} ratio measurement with evaluated data



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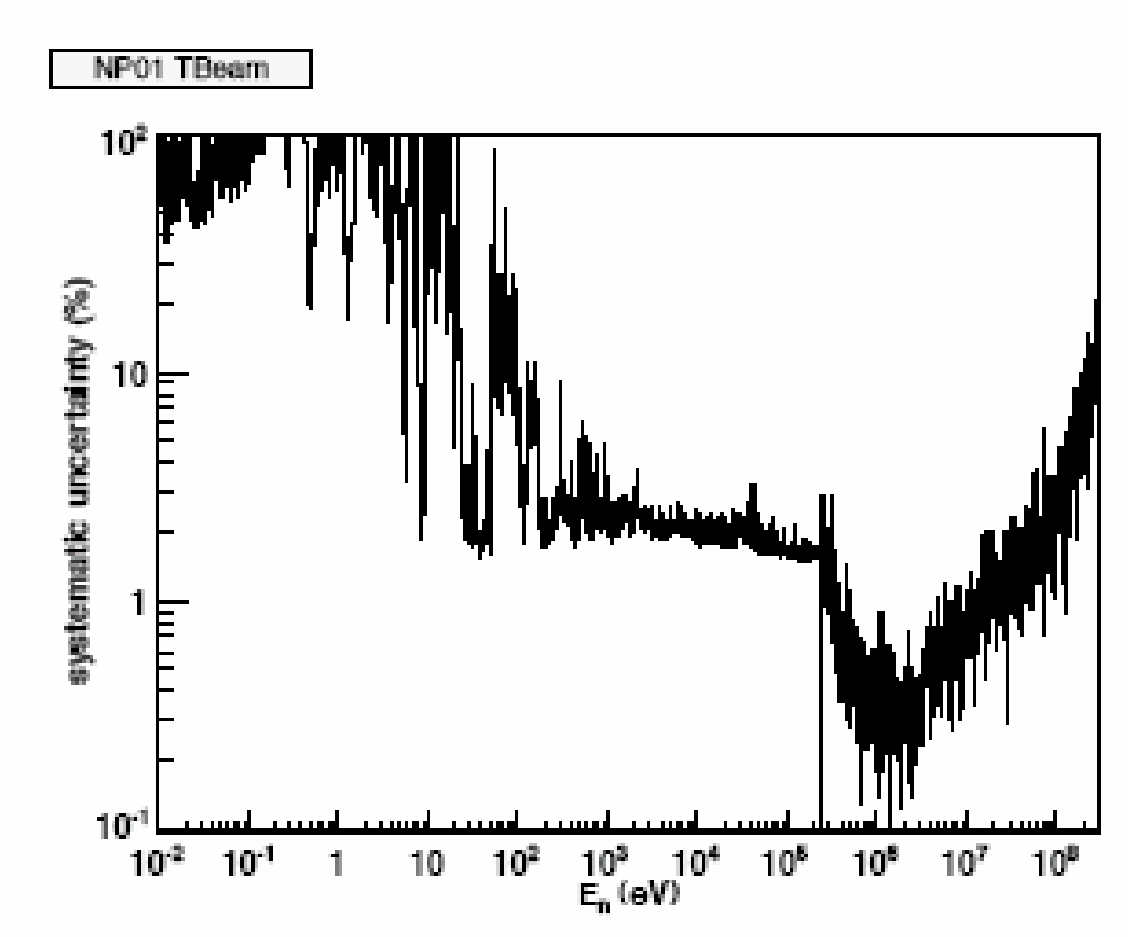
Uncertainties due to room background, frame-overlap, and time-dependent dark current are reported



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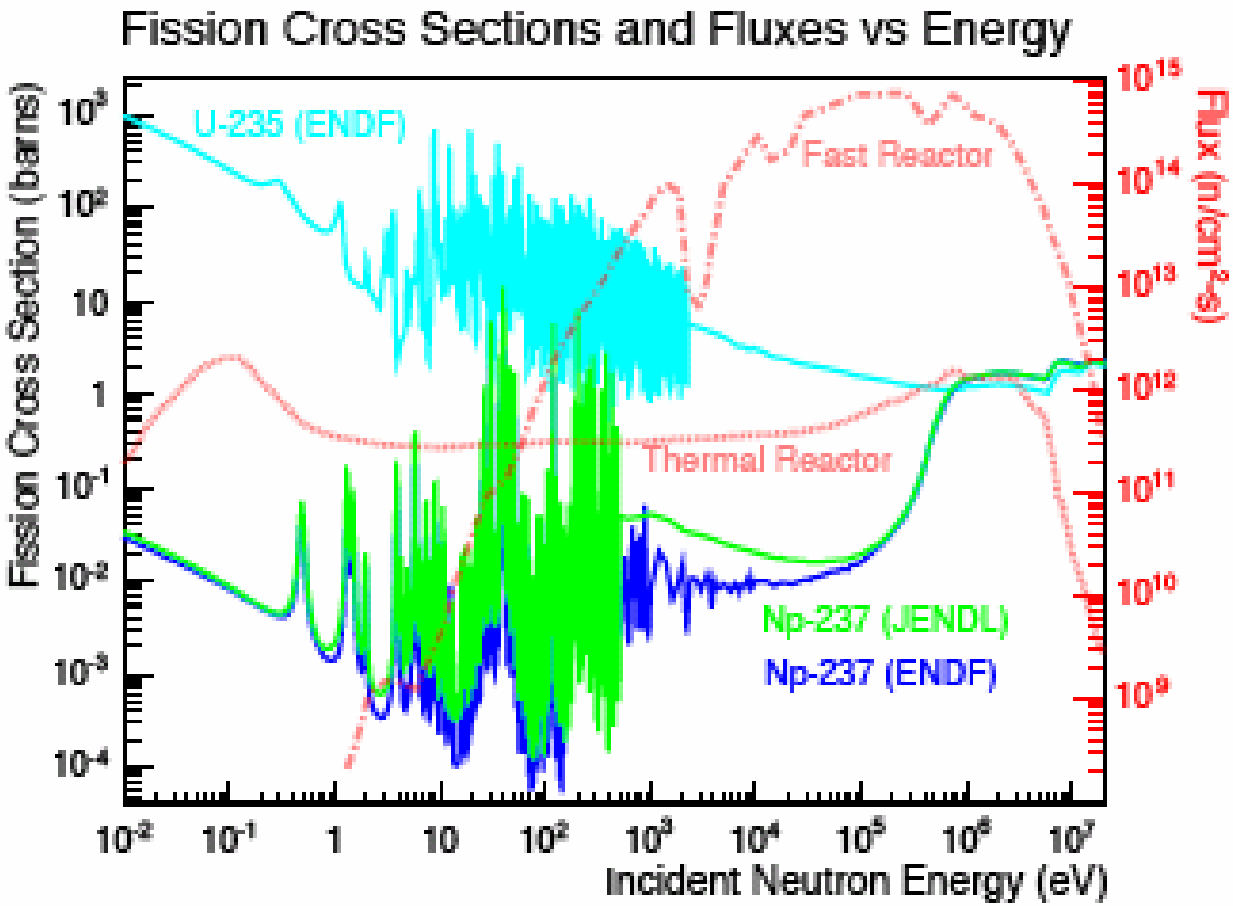
Fast reactors emphasize 1 keV – 5 MeV neutron energy range



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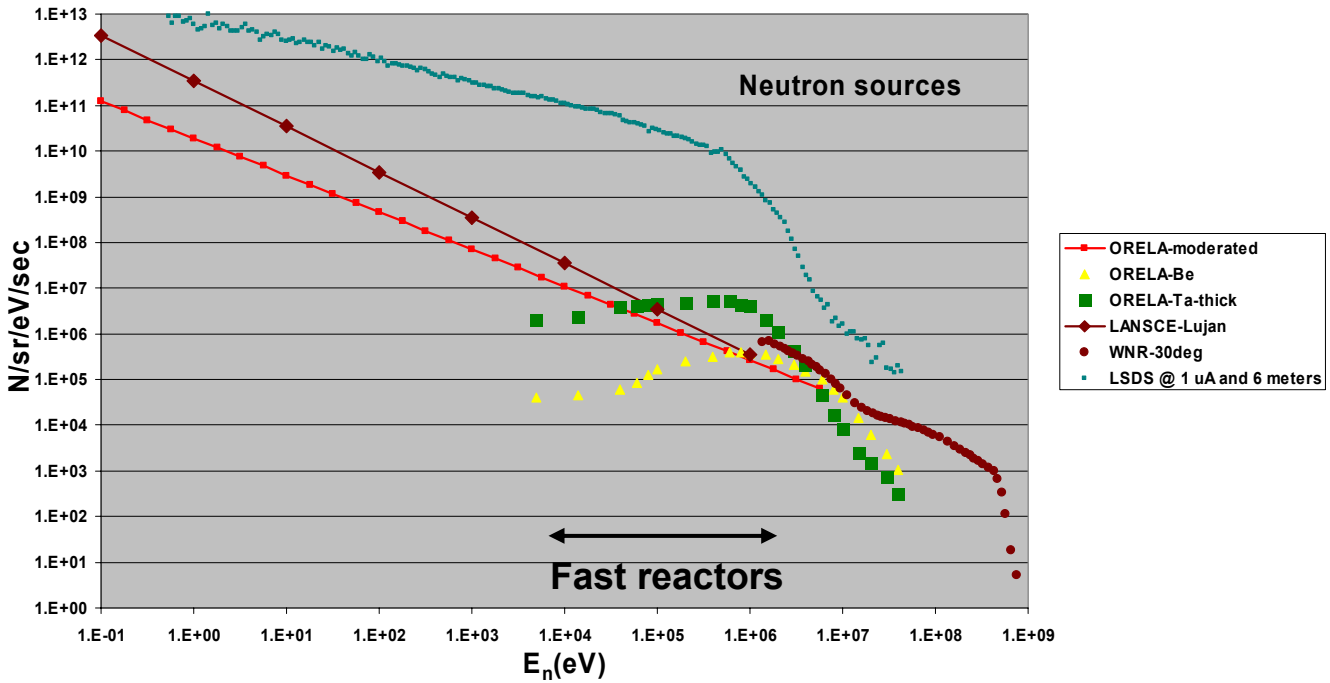
Two initiatives on the Horizon

Initiative on the Horizon – more neutrons in fast reactor energy region



- Need to improve flux in 1 keV – 5 MeV range
- Need a short pulse with better repetition rate
  - Lujan pulse is too long ~ 250 ns
  - WNR: 1.8 to 5 μs spacing is too small

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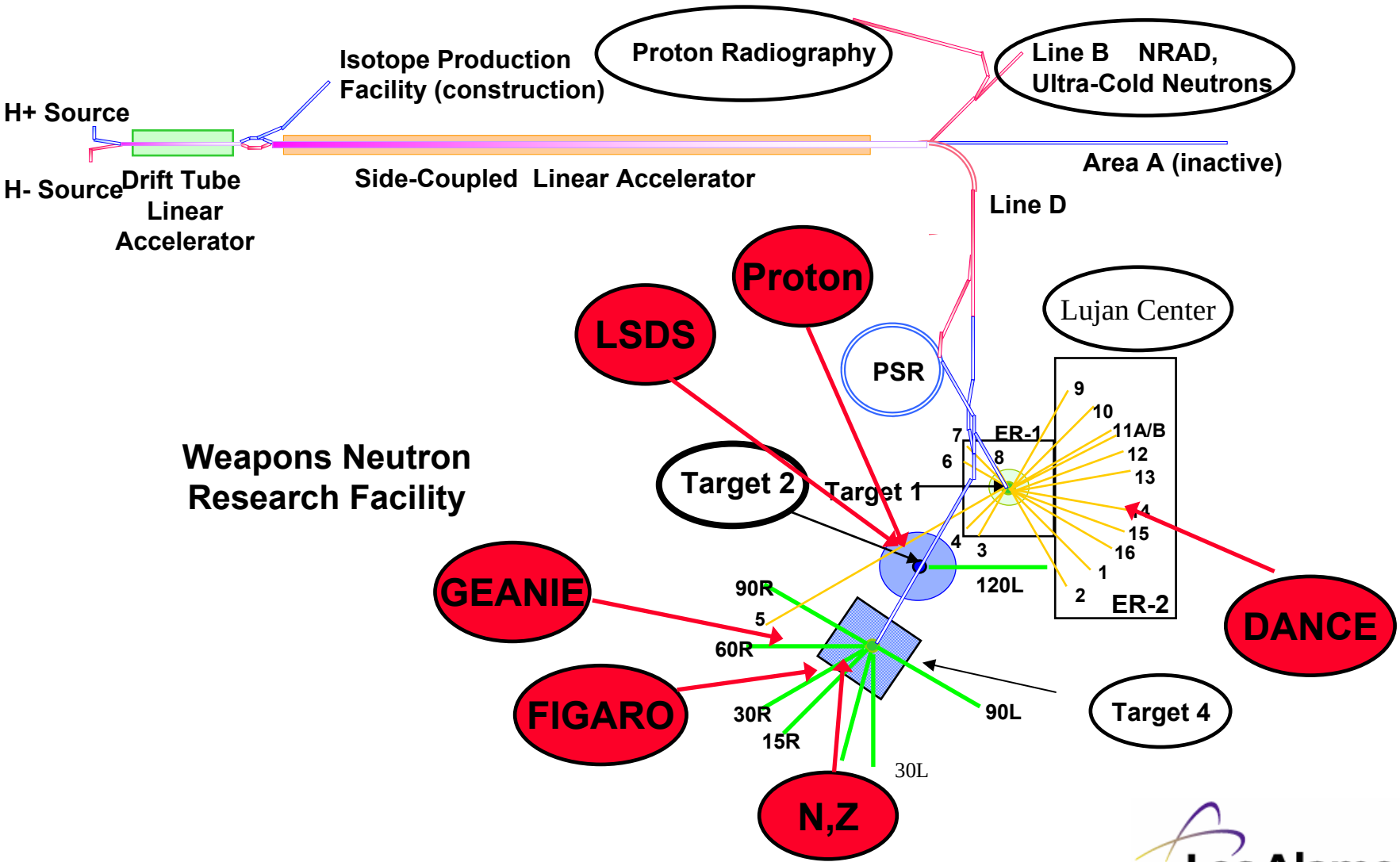
Nuclear data experiments at LANSCE use neutrons at three locations: Lujan Center, Target 2 and Target 4.



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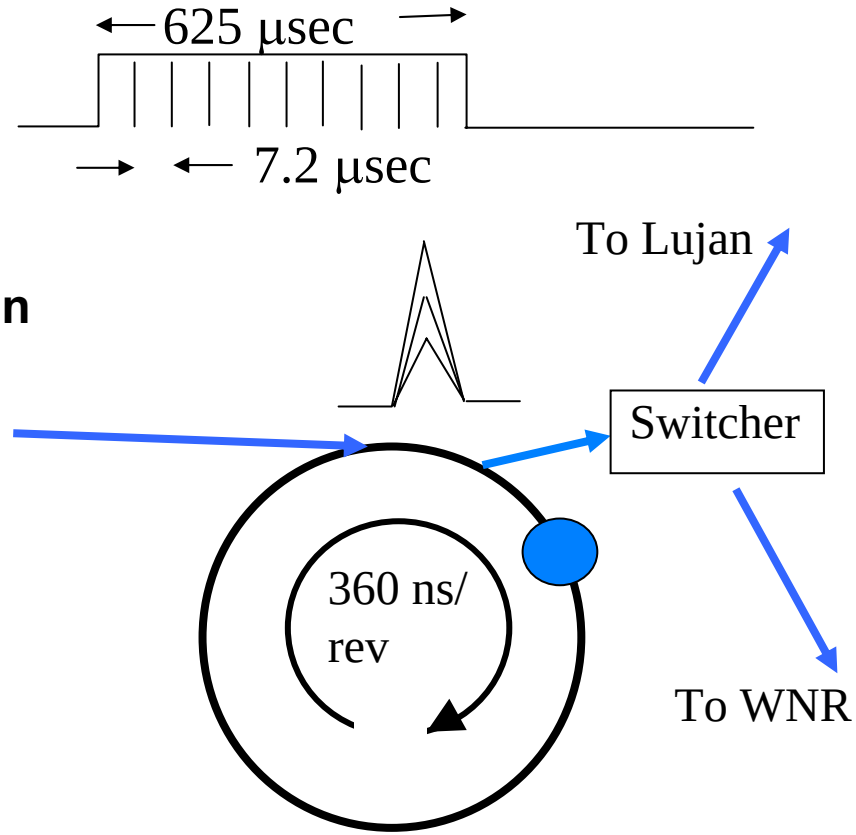
Stacking single micropulses in PSR will increase proton pulse

- Typical operation to Target-4 Δt=7.2 μsec Macropulse rate 100Hz
- Separate micropulses by 360 ns in macropulse. Get x20 increase in current/ macropulse.
- With 360 nsec separation, can have 1 pulse in PSR. Stack 1736 micropulses in PSR for width of Macropulse
- Dump pulse at 40 Hz to WNR and 20 Hz to Lujan. PSR operates at 60 Hz.
- Result (@40 Hz) 17 msec between pulses x 8 average beam compared 7.2 μsec at Target-4 + better neutron production target (additional x30?? Compared to Lujan Center)
- Miracles:
  - Operation of PSR at 60 Hz
  - Switcher to multiplex Lujan and WNR



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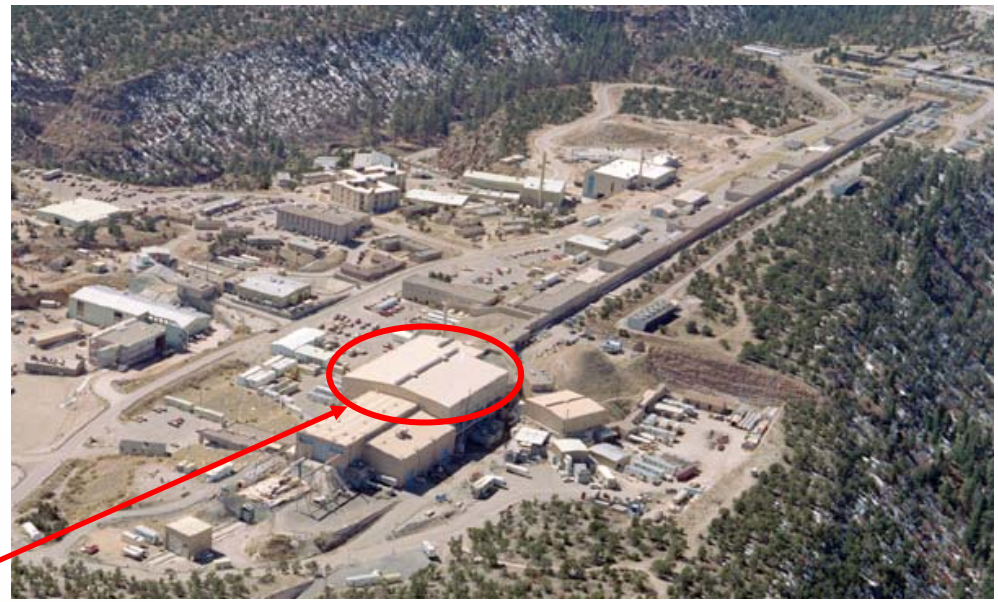
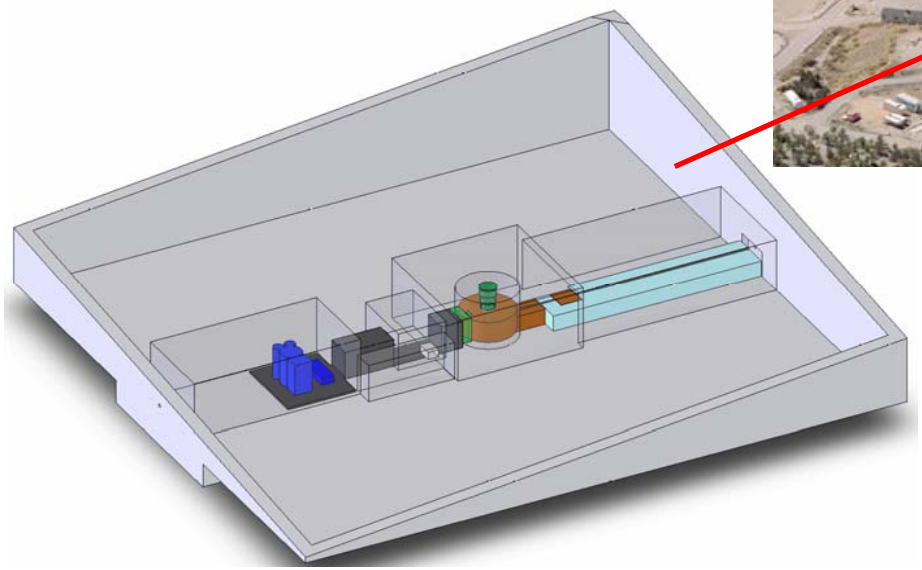
Initiative on the Horizon – Materials Test Station for DOE/NE

- Peak fast (>0.1 MeV) neutron flux of ≥1x10^{15} n.cm^{-2}.s^{-1}
- At least 1 kW/cm^3 volumetric heating in at least 30 fuel pellets
- Burnup rate of 3% per year in the peak flux region
- Displacement rate in iron of at least 10 dpa/y

MTS will be located in the 32,000-ft^2 LANSCE "Area A" experiment hall

Existing assets include:
800-MeV proton linac
30-T crane
Secondary cooling loops
Back-up generator
Shield blocks
Utilities





MTS will provide the first fast neutron irradiation capability in the USA since the shutdown of the FFTF and EBR-II

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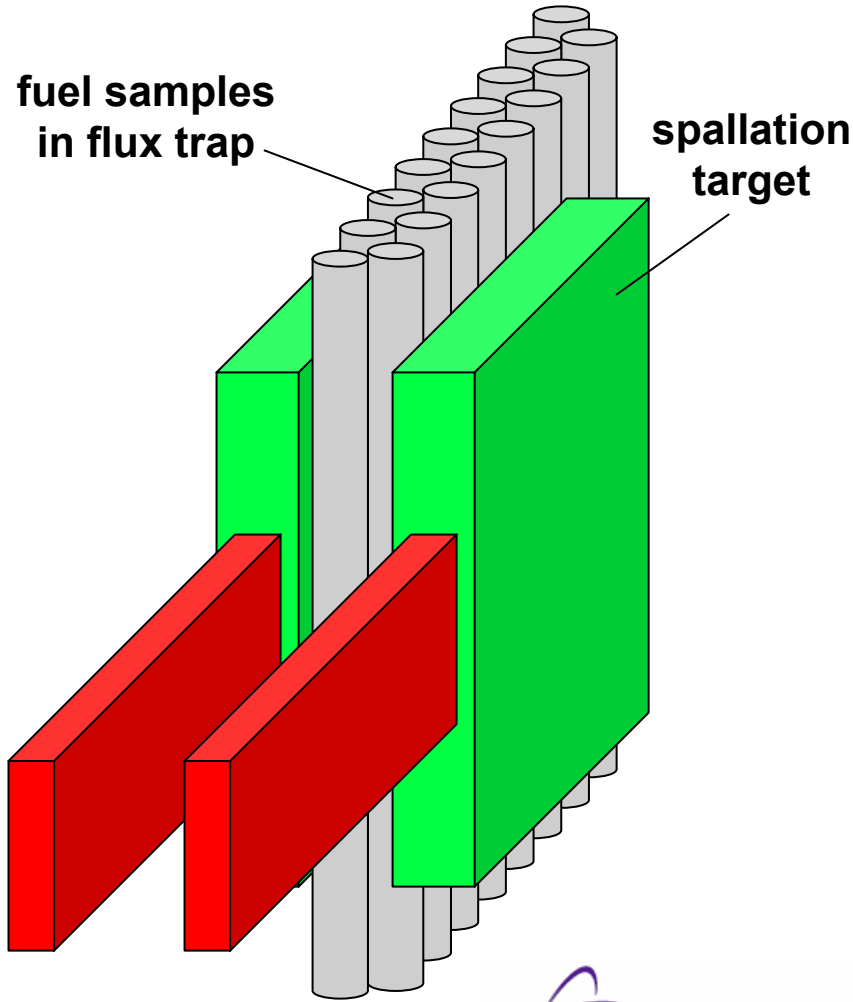
MTS capitalizes on the pulsed nature of the LANSCE beam to illuminate two target halves, thereby creating a “flux trap” in between

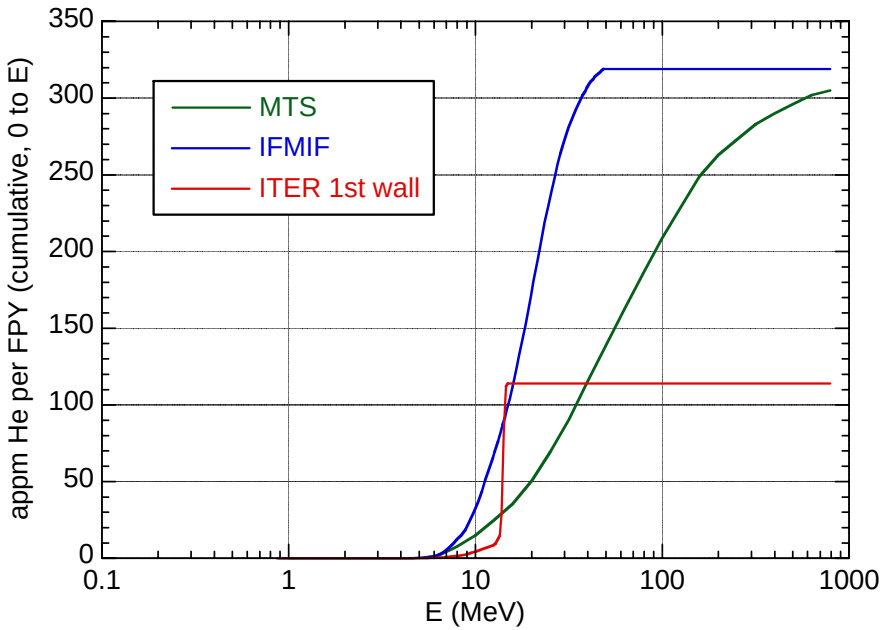
- The 1.5-cm-wide by 6-cm-high proton beam spot is directed on one target half during a 625-μs macropulse
- During the 7.5 ms that the proton beam is off, magnet polarities are switched
- The next beam macropulse is directed onto the other target half
- 50 macropulses hit each target half every second

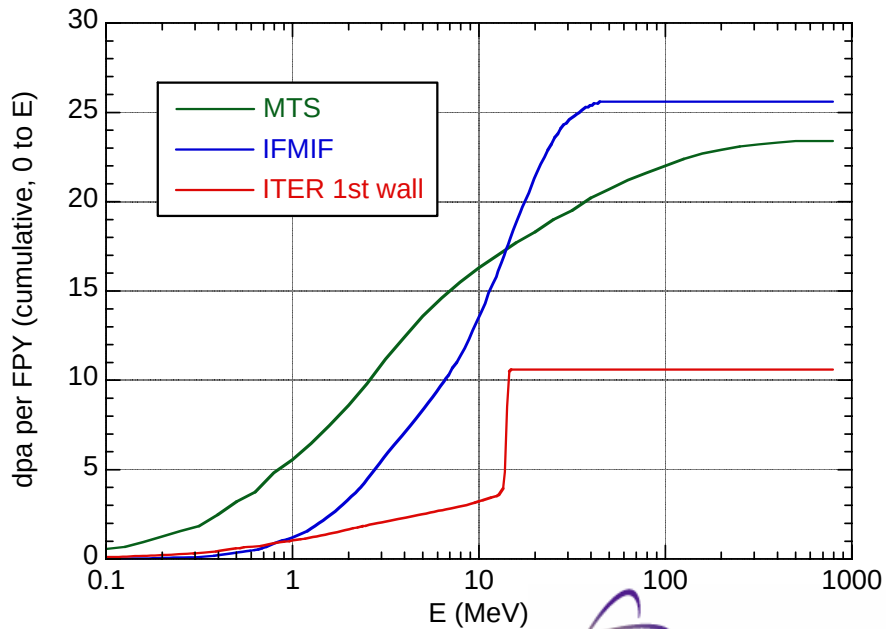


The damage rates for the MTS are similar to that predicted in IFMIF and roughly twice ITER

	appm He/FPY*	dpa/FPY*	He/dpa
ITER 1st wall	114	10.6	10.8
IFMIF HFTM	319	25.6	12.5
MTS peak	305	23.4	13.0
MTS (100 cc)	277	20.4	13.6

*FPY = full power year; MTS expected operation is 4400 hrs per year.





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Possible problems at LANSCE

- Technical issues
  - High power amplifier tube availability and quality (Burle 7835)→ limits WNR to 40 Hz (decrease in beam current by factor of ~ 2.5)
  - LANSCE-Refurbishment ("LANSCE-R")
- Funding problems (NNSA, LANL contract, sales tax, etc.) → 5 months of running in FY06 @ 20 Hz for Lujan (usual) and 40 Hz (down by factor of 2.5)
  - Electricity costs for WNR running
  - LANSCE-R
  - NNSA funding for nuclear data

We address the needs of LANSCE sponsors

- **National Nuclear Security Administration**
  - **Program in radchem cross section measurements**
    - » Neutron capture cross sections on radioactive targets (DANCE)
    - » Cross section measurements on high-order (n,2n), (n,xn) reactions (GEANIE)
  - **Program in neutron-induced fission measurements**
    - » Fission product distributions (GEANIE)
    - » Energy output in fission: neutron and γ-ray spectra (FIGARO)
    - » Nuclear properties of fission products and isomers (GEANIE and FIGARO)
- **Office of Nuclear Energy**
  - Measurements in support of the AFCI program include:
    - » Capture and fission cross section on actinides
    - » Gas production: (n,p), (n,α) reactions in structural materials
- **Office of Science**
  - Support of SNS in understanding pulsed radiation effects on liquid mercury targets
  - Fundamental physics experiments and nuclear data
- **National Resource**
  - Nuclear science User Facility for defense, basic and applied research
  - Industrial testing of semiconductor devices in neutron beams
  - University research in nuclear science

The LANSCE program in nuclear data involves many laboratories

- GEANIE – LANL, LLNL , INL, ORNL, Bruyères-le-Châtel, NC State
- FIGARO – LANL, Bruyères-le-Châtel
- N,Z – LANL, Ohio U
- DANCE – LANL, LLNL, ORNL, INL, Colorado School of Mines, FZK Karlsruhe
- LSDS – LANL, LLNL, Bruyères-le-Châtel, RPI
- Fission – LANL, IRMM, LLNL, INL
- Others – MIT, Kentucky, Kyushu, Harvard,…