

Nuclear Data Experiments at LANSCE: Highlights 2012

**Robert C. Haight for LANSCE-NS and colleagues
Los Alamos National Laboratory**

**Cross Section Evaluation Working Group Meeting
US Nuclear Data Program Meeting
Brookhaven National Laboratory
November 5-9, 2012**

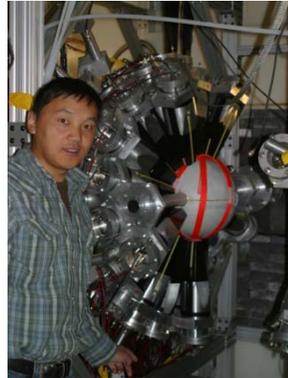
LA-UR-12-25988

Nuclear data measurements at LANSCE are made with several instruments

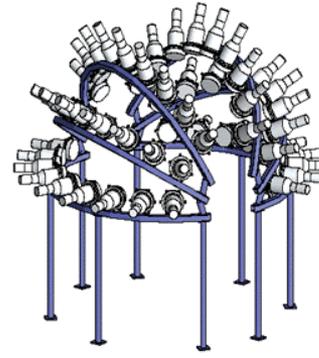
GEANIE (n,x γ)



DANCE (n, γ)



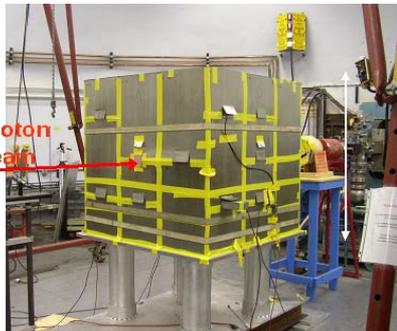
Chi-Nu (n,xn)



N,Z (Z= p, d, α)



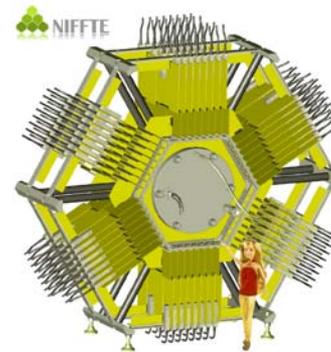
LSDS



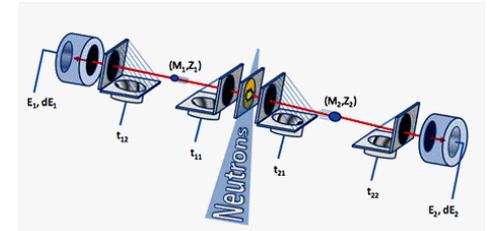
Ion Chambers



TPC

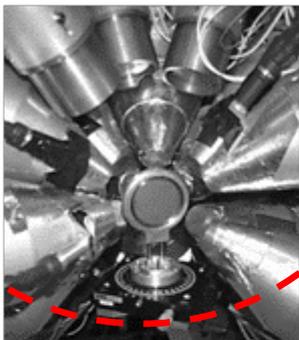


SPIDER

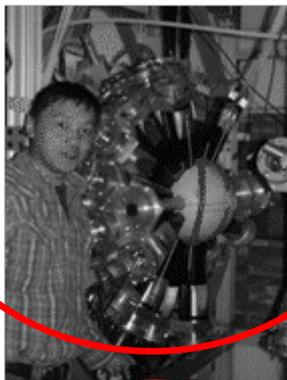


Experiments with actinides

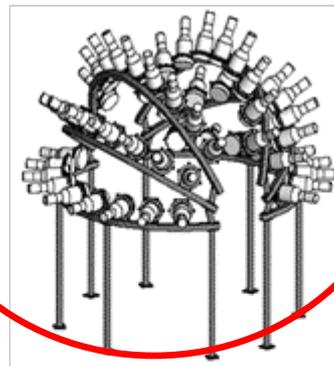
GEANIE (n,x γ)



DANCE (n, γ)



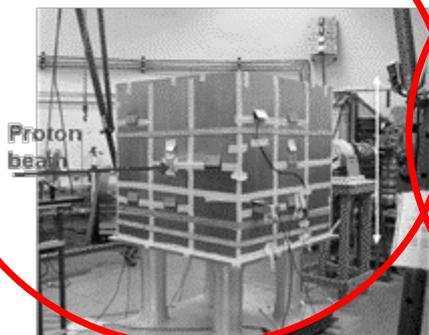
Chi-Nu (n,xn)



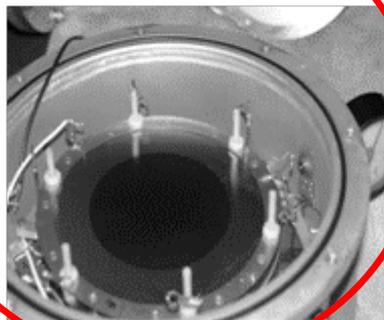
N,Z (Z= p, d, α)



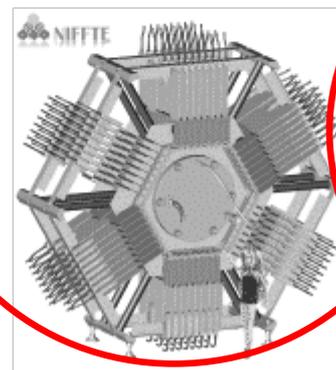
LSDS



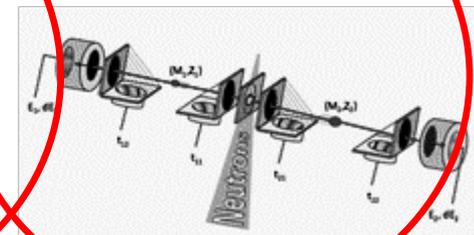
Ion Chambers



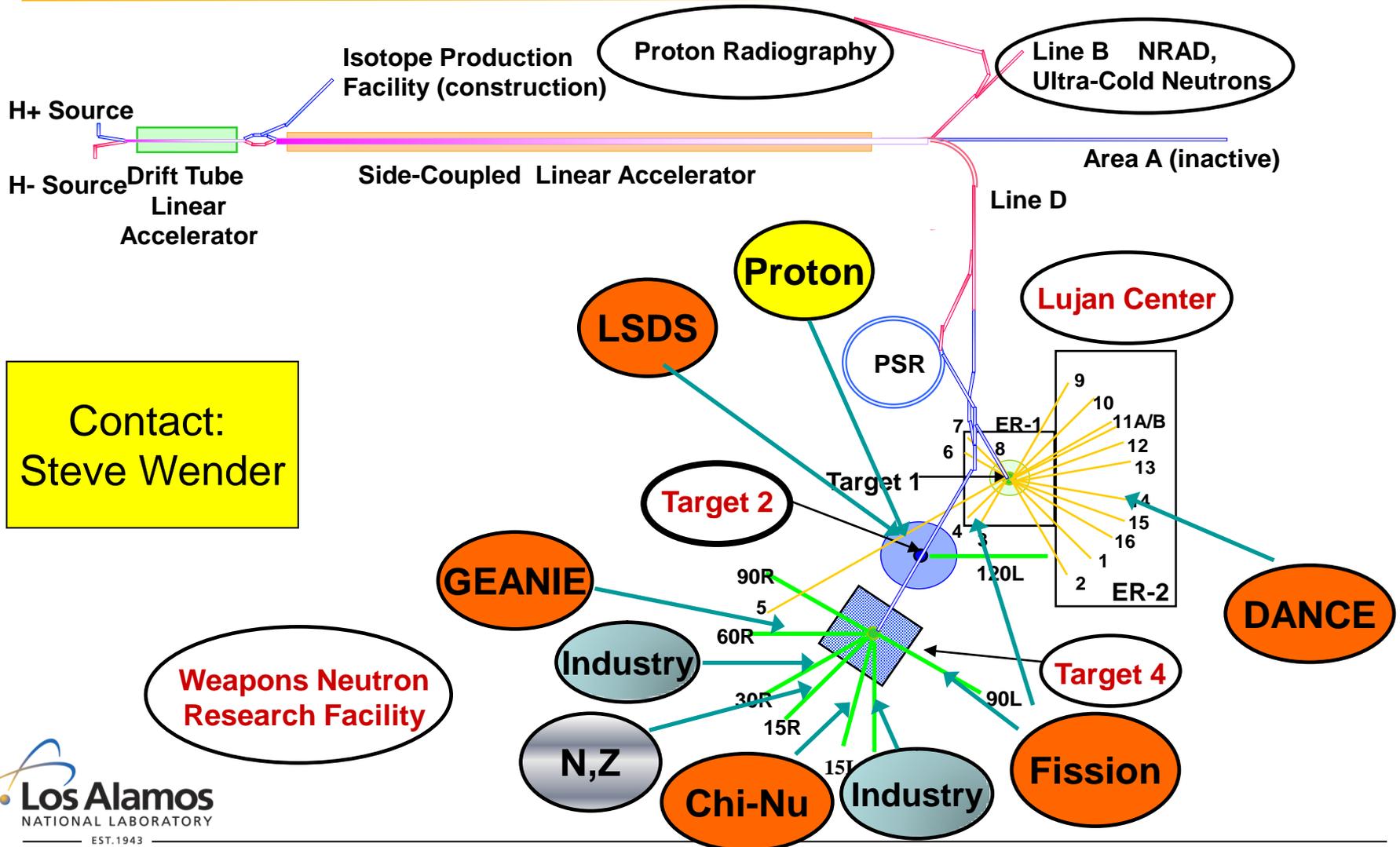
TPC



SPIDER



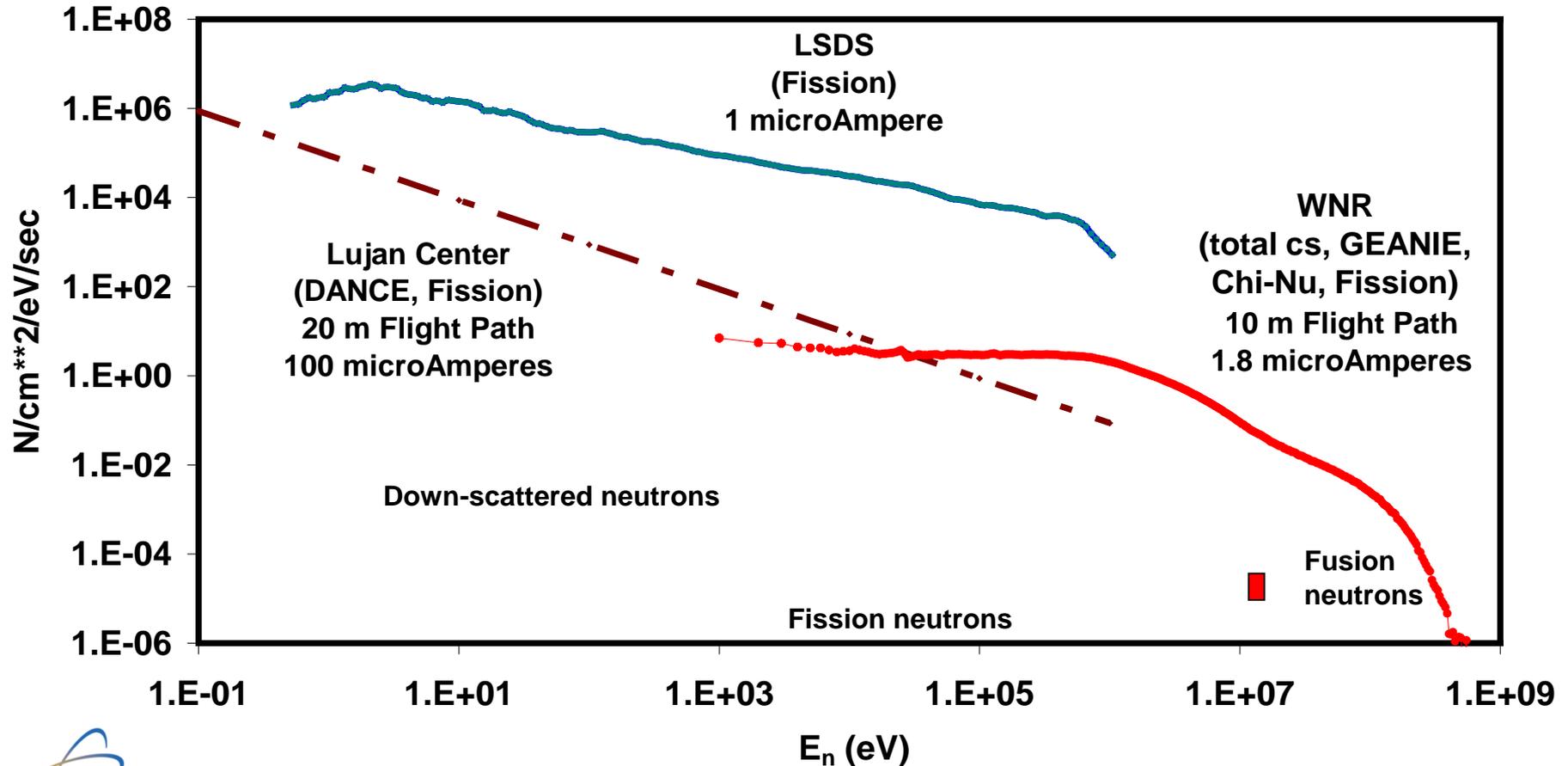
Nuclear data experiments at LANSCE use neutrons at the Lujan Center, Target 2 and Target 4



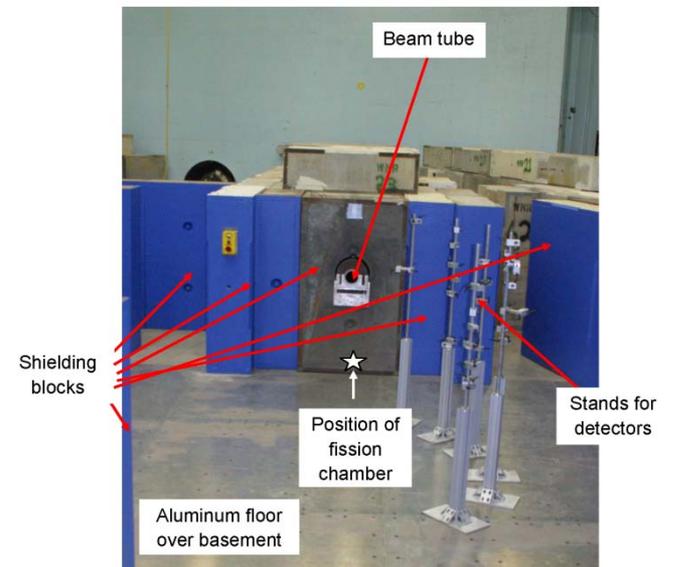
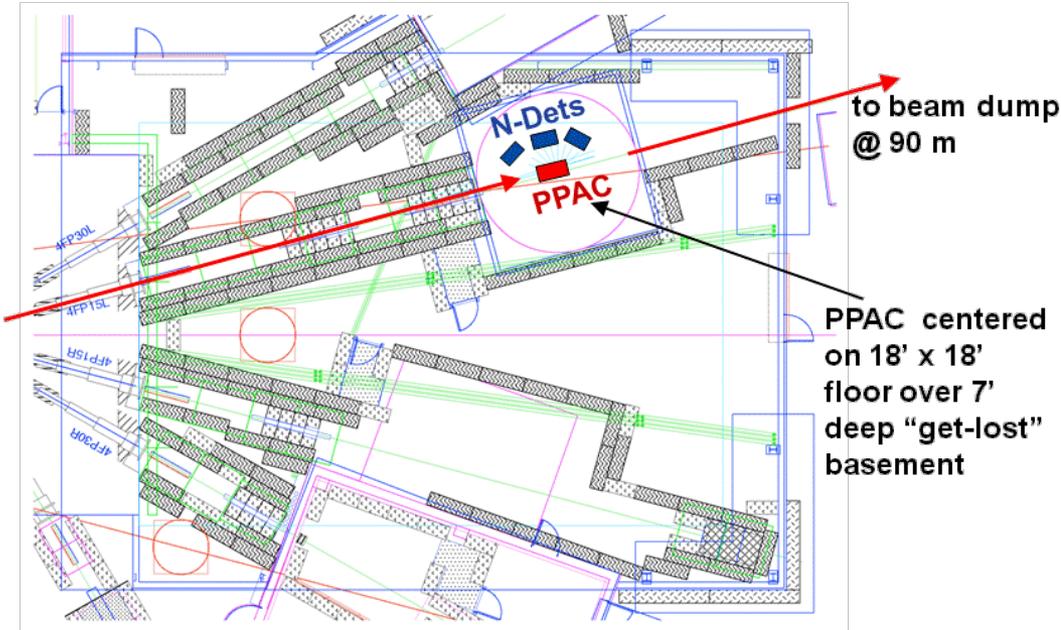
Contact:
Steve Wender

LANSCCE neutron sources cover the full range for fission and fusion applications

LANSCCE Neutron sources

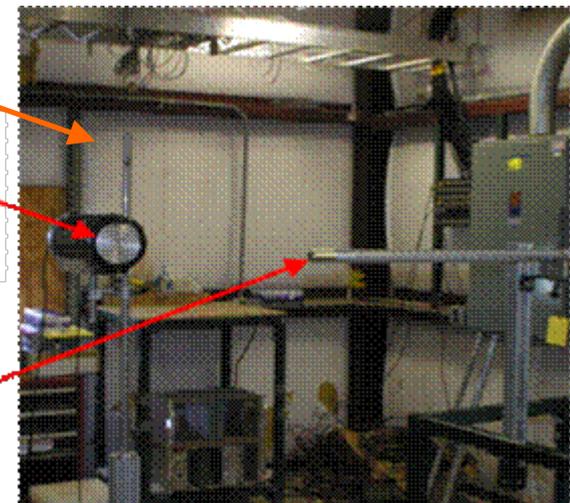
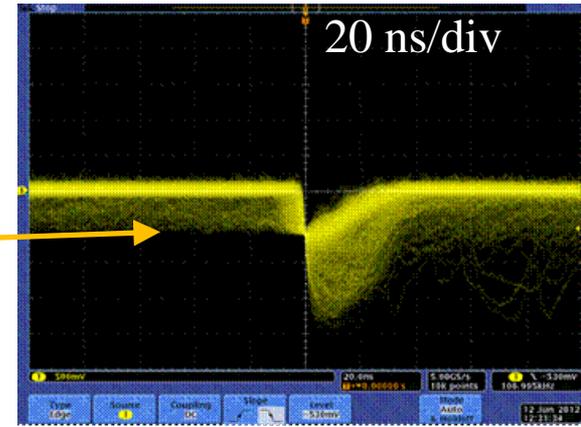


New building; new flight paths

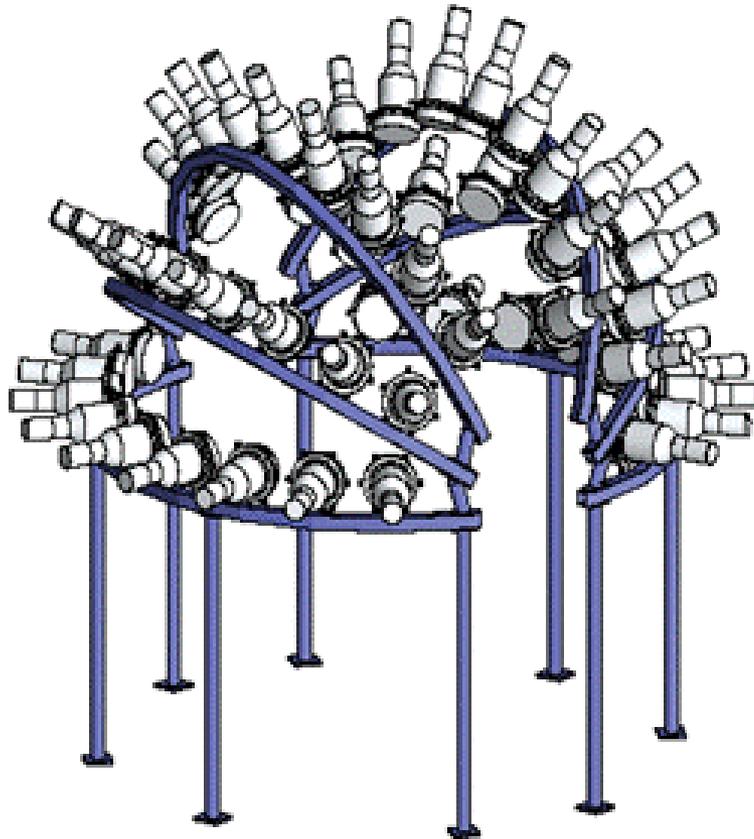


Test facility – ^{252}Cf fission chamber

- ^{252}Cf fission chamber from ORNL
- About $6.2 \text{ E}5$ fissions per second
- Good timing $\sim 1 \text{ ns}$
- Set up in MPF-34
 - 1.50 m above floor
 - Minimal scattering
- Signals sent to MPF17 for radiation protection
- Used for:
 - Detector characterization
 - DAQ development



Chi-Nu (aka FIGARO) ($n,fn + \gamma$)



Contacts:

LANL:

Bob Haight

Terry Taddeucci

Hye Young Lee

[Brent Perdue](#)

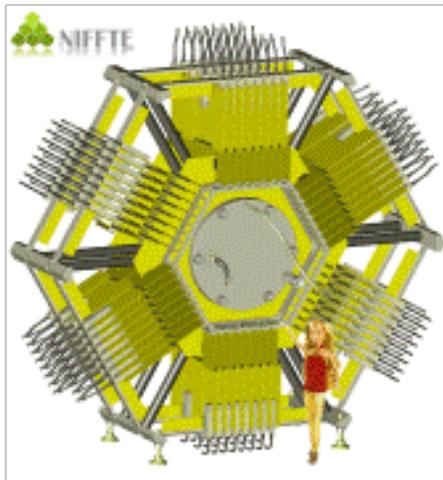
LLNL:

Ching-Yen Wu

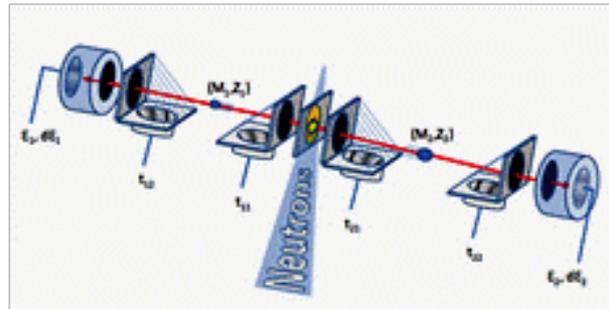
Elaine Kwan

Time-projection chamber (TPC) and SPIDER

TPC



SPIDER



Contacts:

LANL:

Rhiannon Meharchand

Fredrik Tovesson

Krista Meierbachtol

GEANIE (n,x γ)



Contacts:
Ron Nelson
Nik Fotiades
Matt Devlin

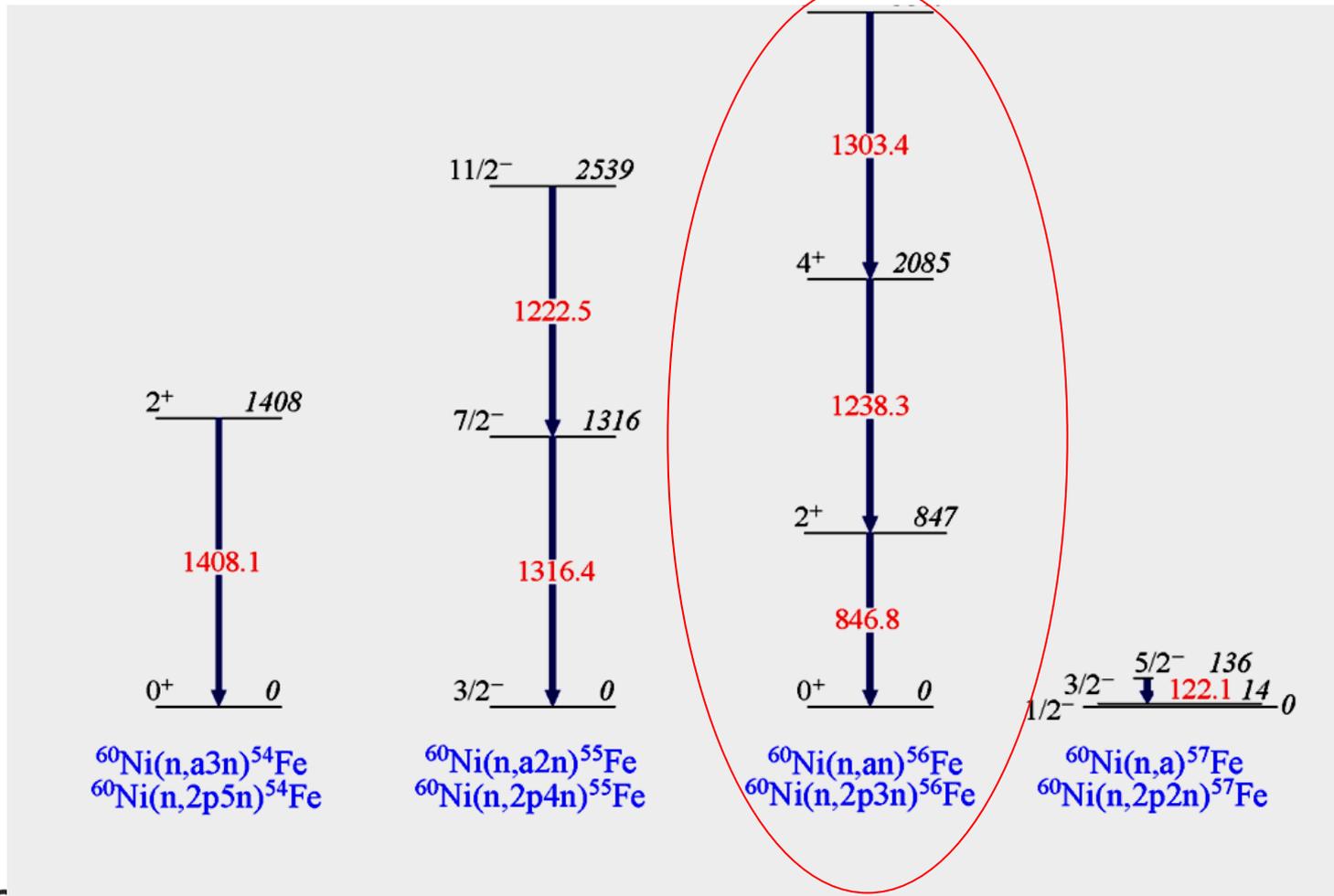
GEANIE measurements 2012 (1)

- **Sn → structure of $^{118,120,122,124}\text{Sn}$ -- N. Fotiades, et al.**
 - combine GEANIE and GAMMASPHERE experiments
 - “States built on the 10+ isomers in $^{118,120,122,124}\text{Sn}$ ”
 - Phys. Rev. C 84, 054310 (2011).
- **Measurements for double-beta decay experiments (Mitzi Boswell and Sean MacMullin (UNC))**
 - **Cu(n,xn γ), x = 1,2,.. – submitted to Phys. Rev. C**
 - **Ar(n,xn γ), x=1,2,... Phys. Rev. C 85, 064614 (2012)**
 - **Ne(n,xng), x=1,2,.. Submitted to Phys. Rev. C**
- **$^{86}\text{Kr}(n,xn\gamma)$, x= 1,2,... (M. Devlin) – data taken; structure and transitions**
- **Nal(n,xn γ) for data libraries (N. Fotiades) – data taken**

GEANIE measurements 2012 (2)

- **Isomer searches**
 - $t_{1/2} \sim$ tens of μs to 100 ms – e.g. ^{114}In (M. Devlin)
- **Various elements for a neutron-induced gamma-production reference cross sections (R. Nelson)**
 - $^7\text{Li} (n, n') ^7\text{Li}^*$ (LiF target – “optical window”)
 - Ti (n, $x\gamma$)
 - Cr
 - Fe
- **x-ray yield from n-induced fission (R. Nelson and Thierry Granier - CEA)**
- **$^{95}\text{Mo} (n, \gamma)$ – J. Cizewski et al. – extends neutron energy range of measurements made at Lujan Center last year into the 100’s of keV range; test of surrogate reaction approach**

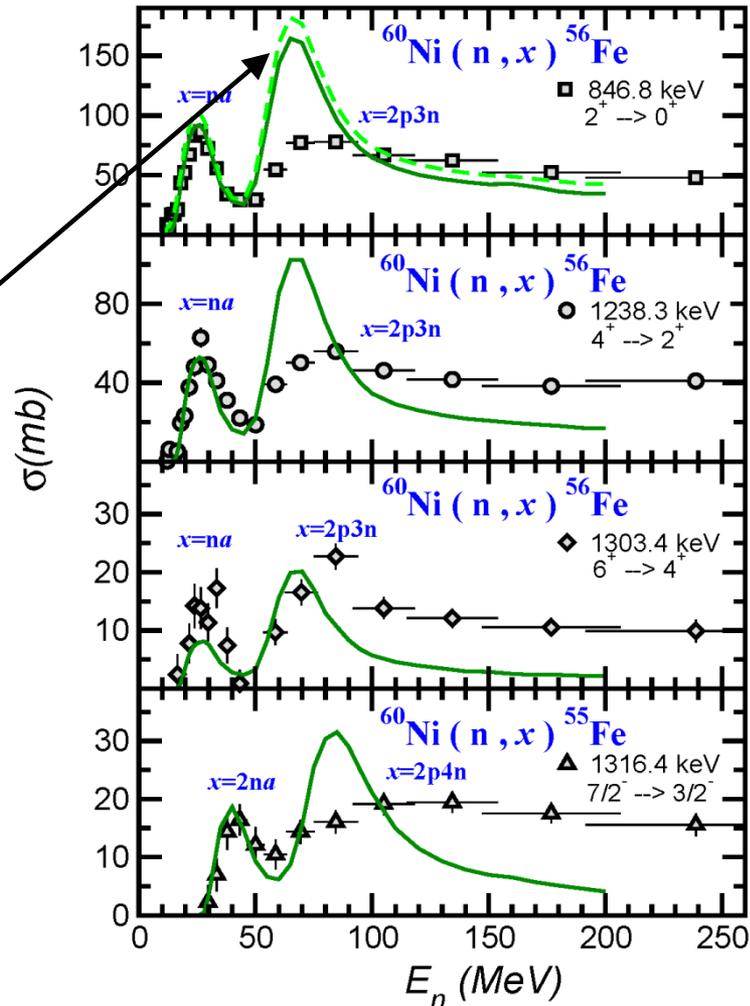
$^{60}\text{Ni}(n, x\gamma) - \text{c.f. } (n, x\alpha)$



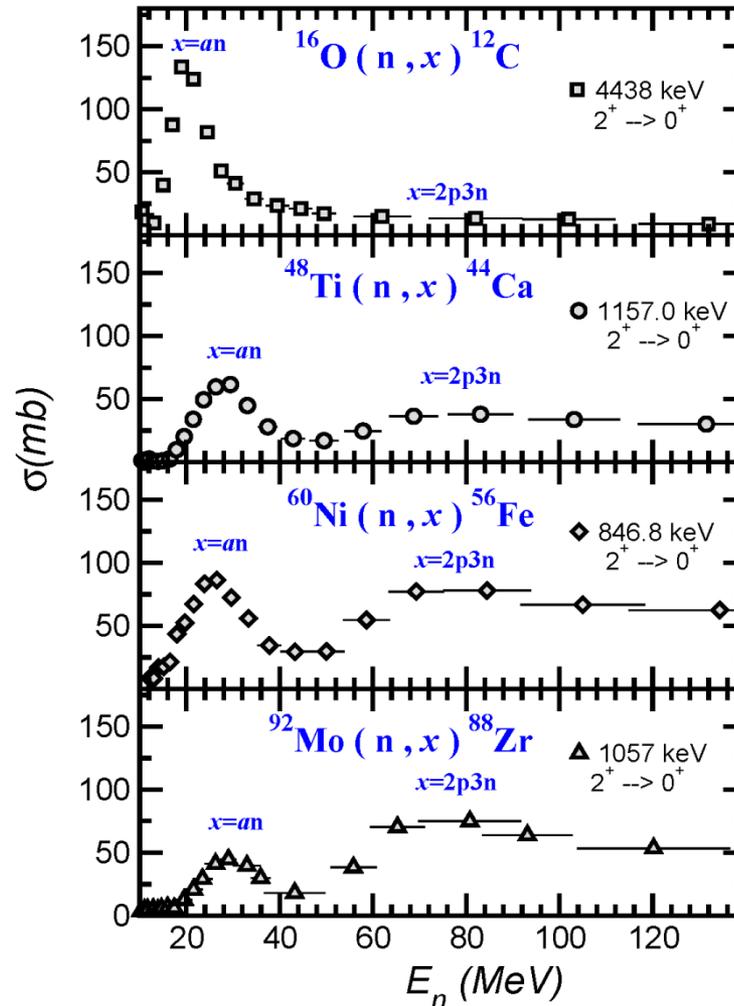
$^{60}\text{Ni}(n,x\gamma) - \text{c.f. } (n,x\alpha)$

- Calculations

- Hauser-Feshbach plus pre-equilibrium
- Dashed curve is for total ^{56}Fe production



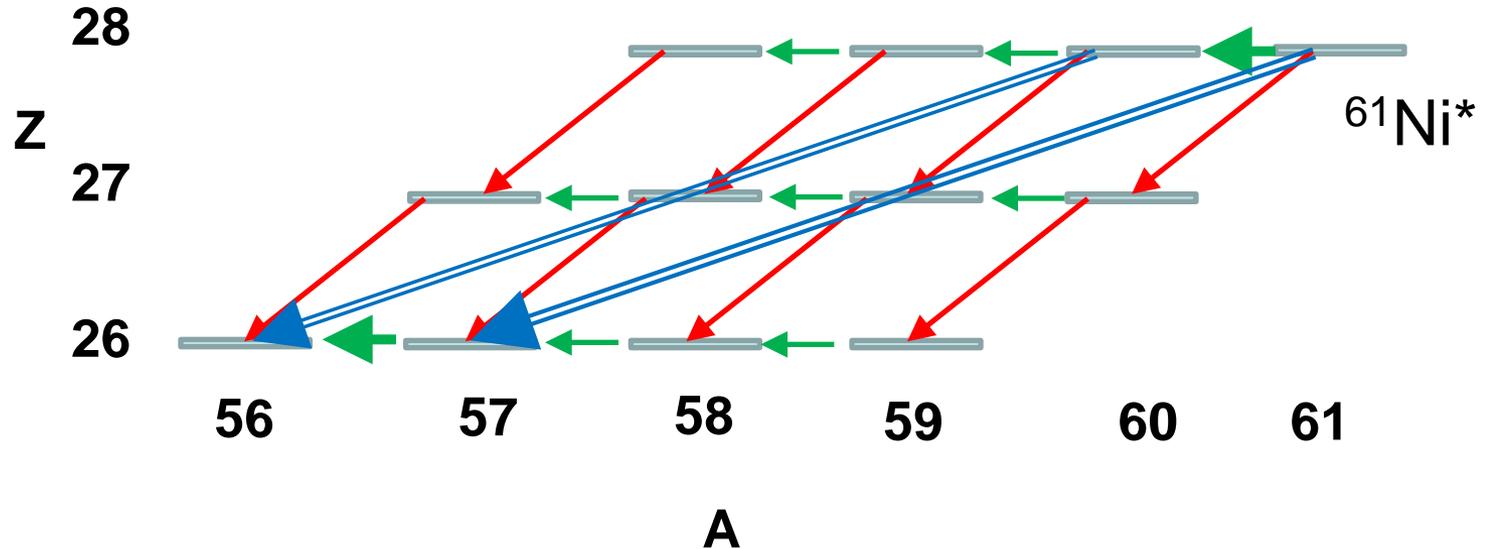
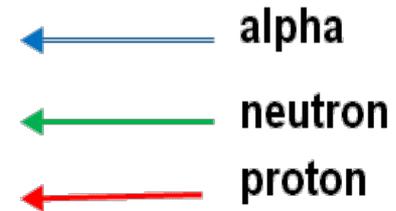
$^{60}\text{Ni}(n,x\gamma)$ – c.f. other targets



Many paths from $^{60}\text{Ni}+n$ to ^{56}Fe

- Most intermediate states are highly excited

Particle emitted





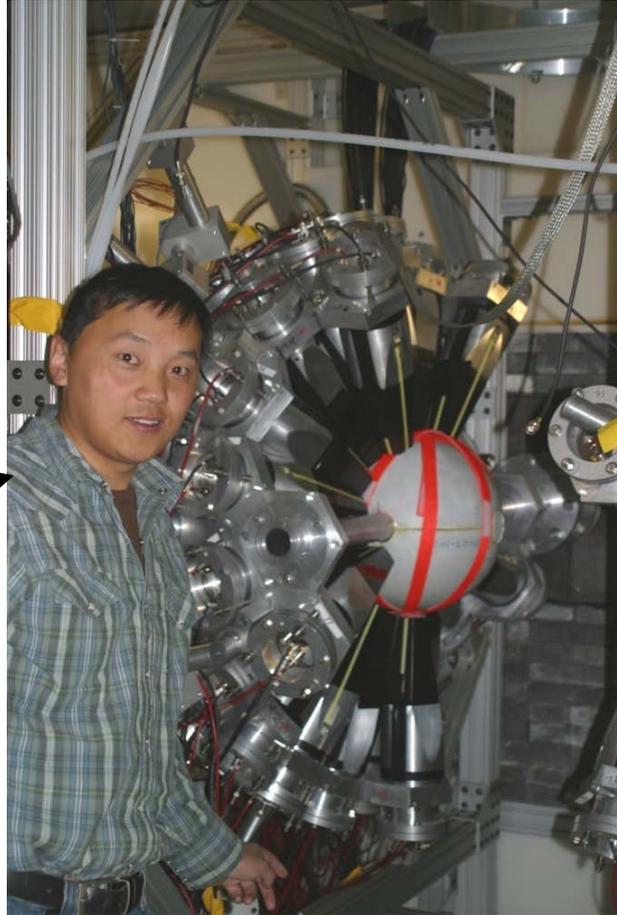
N,Z Reactions $Z = p, d, t, {}^3\text{He}, \alpha$

- **Last year: Cr, Fe, ${}^{58,60}\text{Ni}$ (Kunieda) for alpha-particle production cross sections**
- **This year: ${}^{60}\text{Ni}$ (n,xg)**

Contact:
Nik Fotiades
Bob Haight

DANCE (n, γ)

Bayarbadrakh
Baramsai
(NCSU)



Contacts:
John Ullmann
Aaron Couture
Marian Jandel

DANCE research in 2012 (1) – non actinides

$^{152,154,156,158}\text{Gd}(n,g)$

Bayarbadrakh Baramsai, NCSU/LANL
In progress.

^{97}Mo

Carrie Walker, NCSU PhD dissertation, in progress

$^{117,119}\text{Sn}$

Bayarbadrakh Baramsai, NCSU/LANL (In progress)

^{173}Lu

Capture. O. Roig (CEA) (In progress)

$^{184,186}\text{W}$

Capture, Marian Jandel LANL (in progress)

$^{191,193}\text{Ir}$

Capture; Todd Bredeweg, Charles Arnold LANL

DANCE research in 2012 (2) - Actinides

$^{233,235}\text{U}$, $^{239,241}\text{Pu}$

Capture to fission: LANL, LLNL In progress
 ^{235}U accepted by Phys. Rev. Lett.

^{235}U , $^{239,241}\text{Pu}$

Fission gamma ray multiplicity and spectra: LANL/LLNL (Prelim ^{239}Pu , ^{235}U reported)
Comparison Paper: submitted to Phys Rev C.
Detailed analysis of each: In preparation

^{238}Pu

Capture, capture/fission: LLNL

^{252}Cf

Fission gamma multiplicity and spectra: Phys Rev C

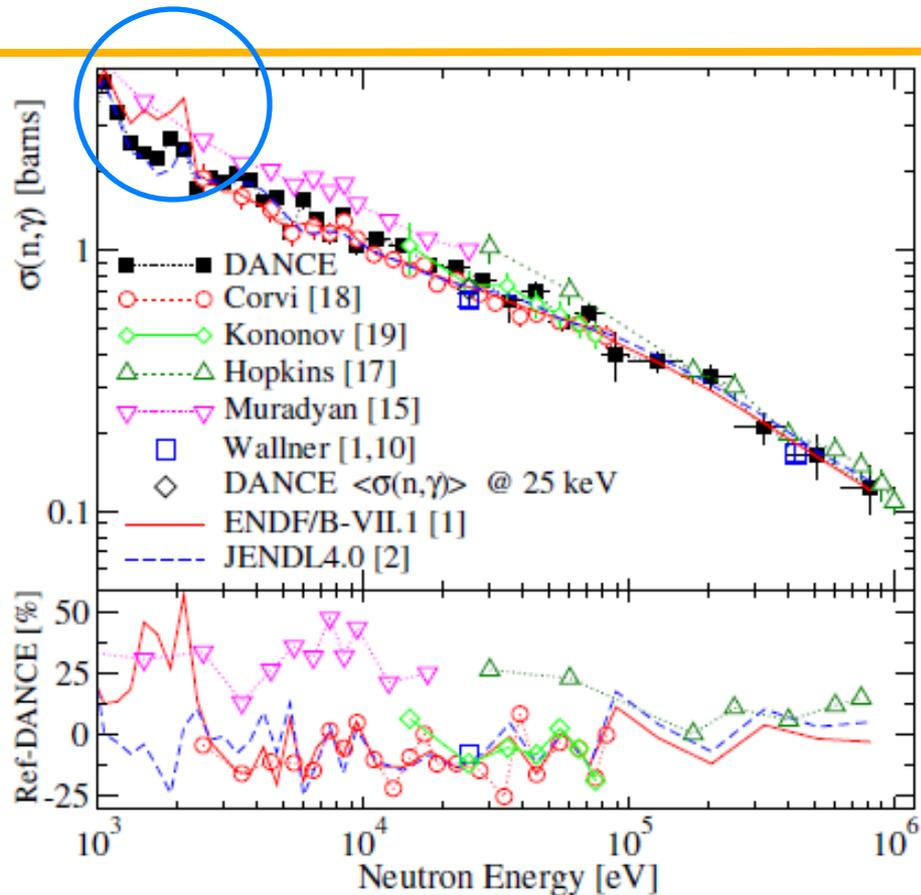
$^{242\text{m},243}\text{Am}$

Capture, Marian Jandel LANL (Prelim report)

^{238}U

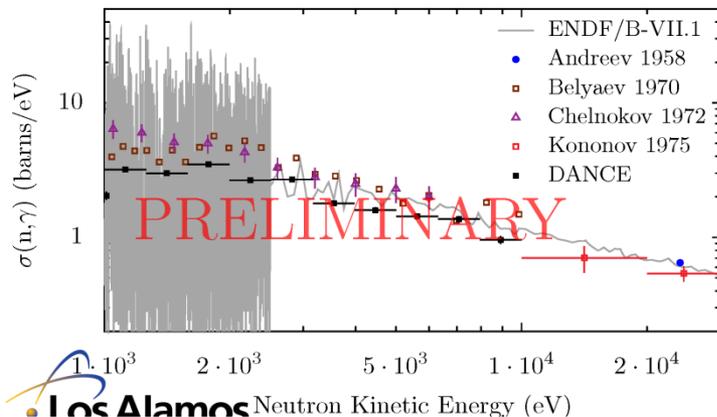
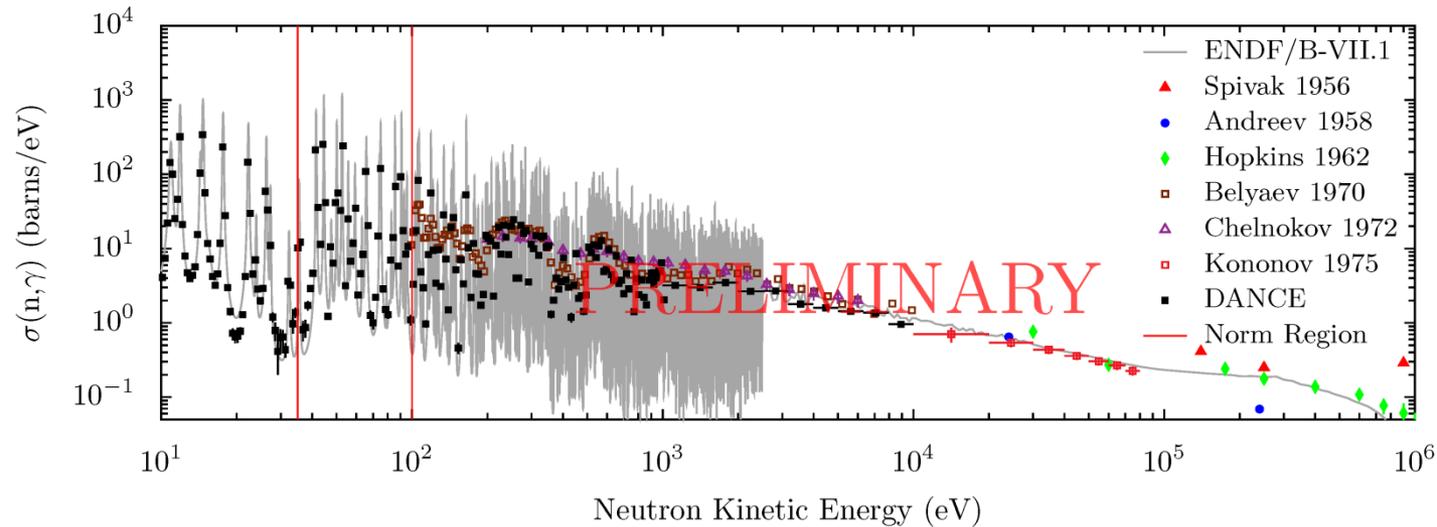
Capture xsec, gamma rays John Ullmann LANL (prelim. report)

New DANCE measurement of $^{235}\text{U}(n,\gamma)$



“New Precision measurements of the $^{235}\text{U}(n,\gamma)$ Cross Section.”
M. Jandel, et al., accepted by Phys. Rev. Lett.

^{239}Pu (n, γ) preliminary results



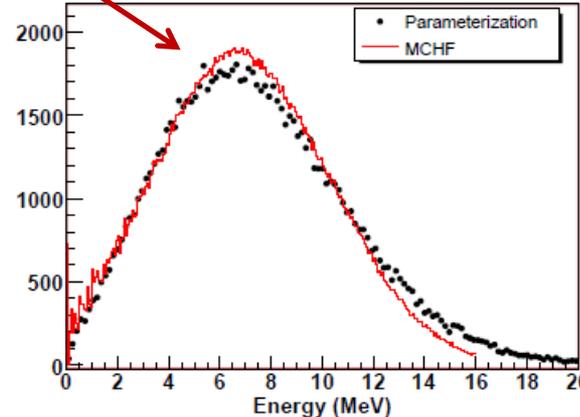
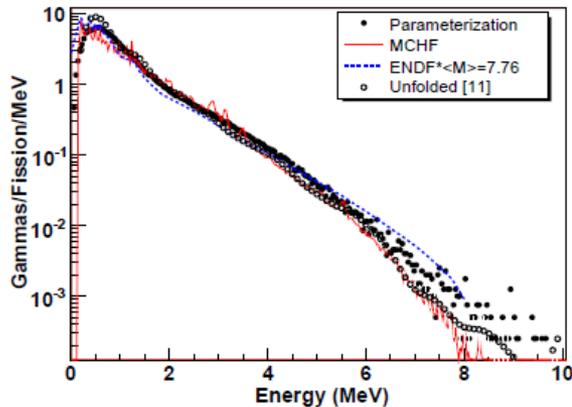
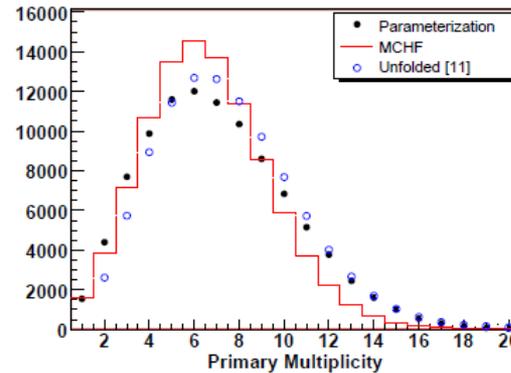
- Current Status: $^{239}\text{Pu}(n,\gamma)$ cross section measured from 10 eV to 10 keV
- 50 mg sample run pushed back - not run yet

Highly segmented DANCE array gives information on gamma multiplicity and spectra

$^{239}\text{Pu}(n,f)$ gamma emission spectra $1^+ 10.93$ eV resonance

- Multiplicity distribution
- Energy distribution of individual gamma rays

Total gamma energy distribution



Fission Cross Sections on small samples: Lead Slowing-Down Spectrometer

^{237}U (6.7 d) (n,f) from
thermal to ~ 5 keV



Contacts:
Marian Jandel
Matt Devlin
Bob Haight

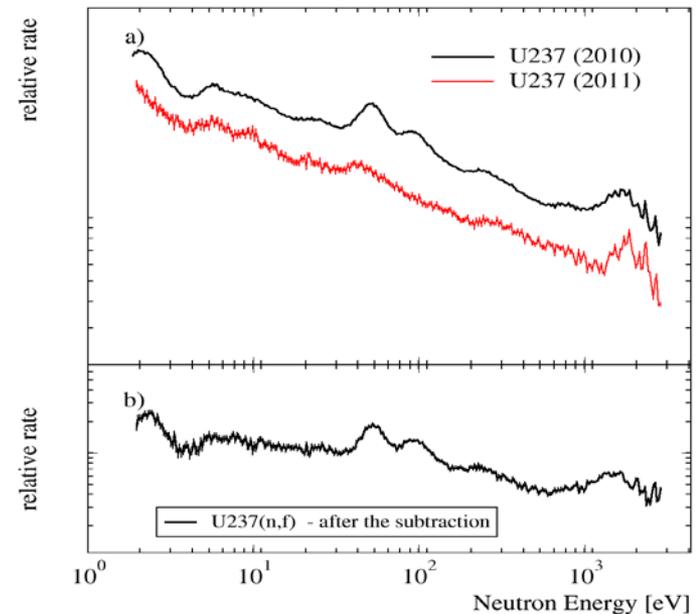
$^{237}\text{U}(n,f)$ cross section measurement

- A cube 1.2 m on a side from high purity Pb
- 800 MeV p + W \rightarrow neutrons + spallation products
- Allows for measurements with \sim ng targets
- 20-40 Hz repetition rate



Two Measurements: Dec 2010 and June 2011

- U-237: $M(t)=2\mu\text{g}(1-e^{-\lambda t})$
- U-236: 239 μg
- Preliminary results



Fission Cross Sections

Contacts:
Fredrik Tovesson
Alexander Laptev

LANSCCE fission cross section program status

EXFOR

#14130002 Np-237

#14271004 Pu-239

#14223002 Pu-240 ($t_{1/2}=6600$ a)

#14271007 Pu-241 ($t_{1/2}=14$ a)

#14223003 Pu-242

Completed

U-238

U-233

U-236

Am-243

U-234

Recently
completed

In progress

Measured in
2011-2012
run cycle

F. Tovesson, A. Laptev, T.S. Hill, *J. Korean Phys. Soc.* **59**, 1400 (2011)

F. Tovesson, A. Laptev, T.S. Hill, *AIP Proc.* **1336**, 598 (2011)

F. Tovesson, A. Laptev, T.S. Hill, *Trans. of the Amer. Nucl. Soc.* **102**, 490 (2010)

F. Tovesson, T. S. Hill, *Nucl. Sci. Eng.* **165**, 224 (2010)

F. Tovesson, T. S. Hill, M. Mocko, J. D. Baker, C. A. McGrath, *Phys. Rev. C* **79**, 014613 (2009).

F. Tovesson, T. S. Hill, *Nucl. Sci. Eng.* **159**, 83 (2008).

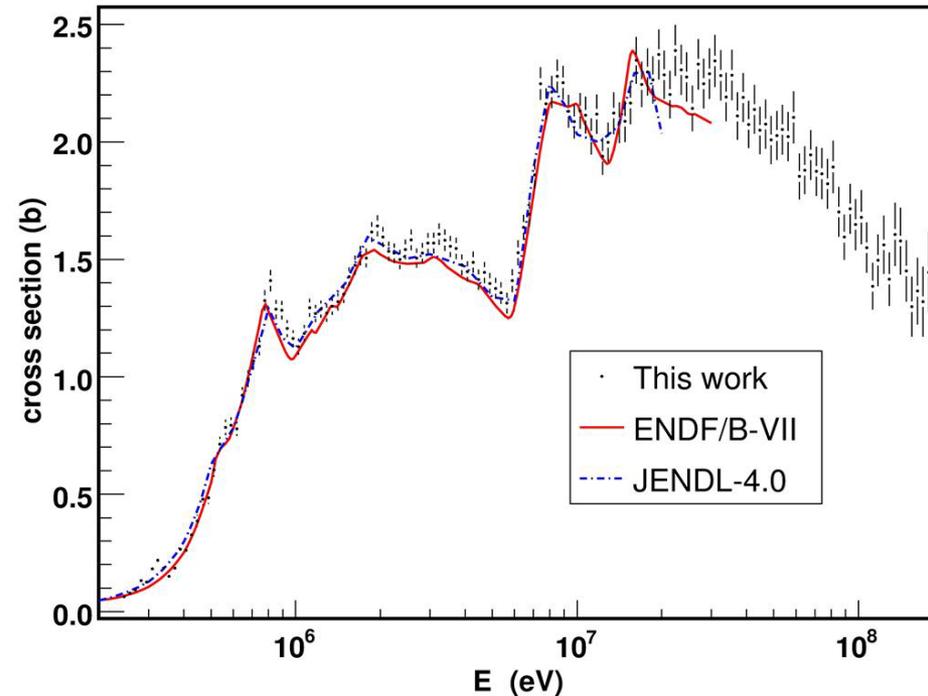
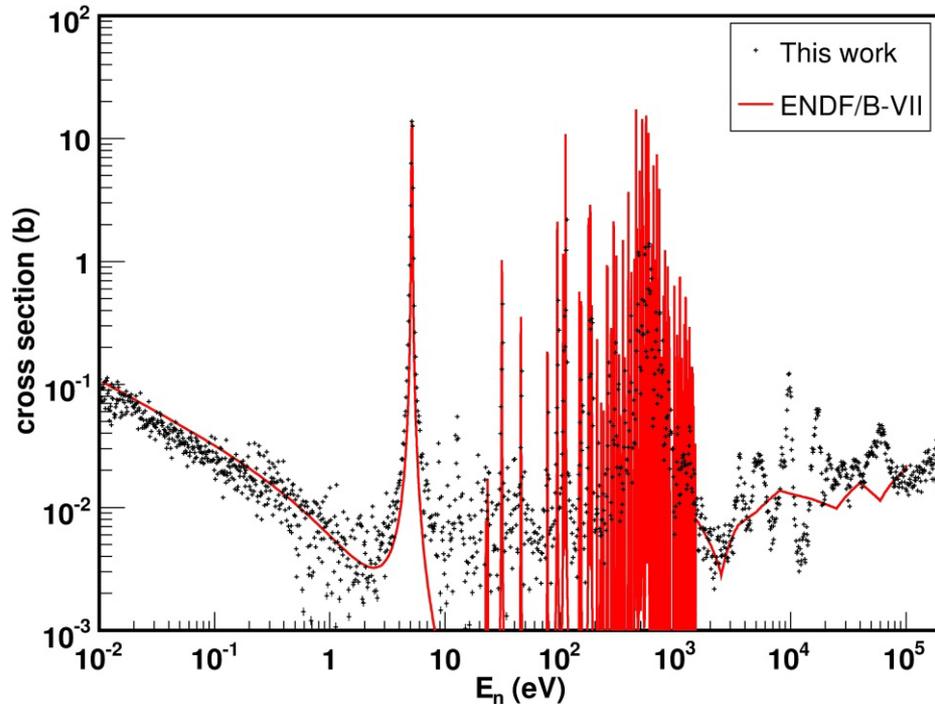
M. Mocko, G. Muhrer, F. Tovesson, *Nucl. Instr. and Meth. A* **589**, 455 (2008).

J. D. Baker, C. A. McGrath, T. S. Hill, R. Reifarh, F. Tovesson, *J. Radioanalytical Nucl. Chem.* **276**, 555 (2008).

F. Tovesson, T. S. Hill, *Phys. Rev. C* **75**, 034610 (2007).

F. Tovesson, T. S. Hill, K. M. Hanson, P. Talou, T. Kawano, R. C. Haight, L. Bonneau, *LANL report LA-UR-06-7318*, (2006).

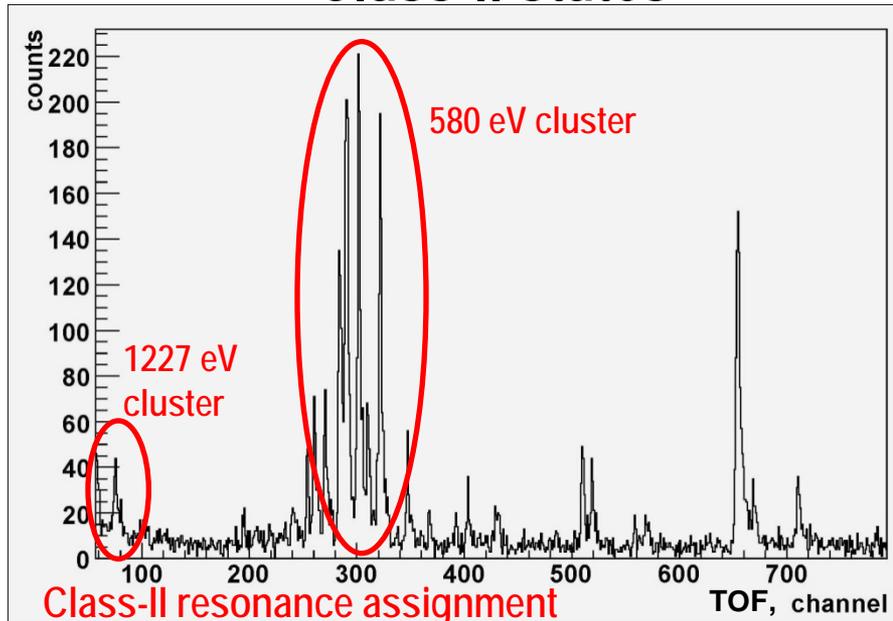
The U-234 neutron-induced fission cross section



- **U-234 completes the Uranium measurements. Full suite of Uranium data is a valuable data set for evaluators**
- **High statistics data for subthreshold fission**

Subthreshold fission of U-234

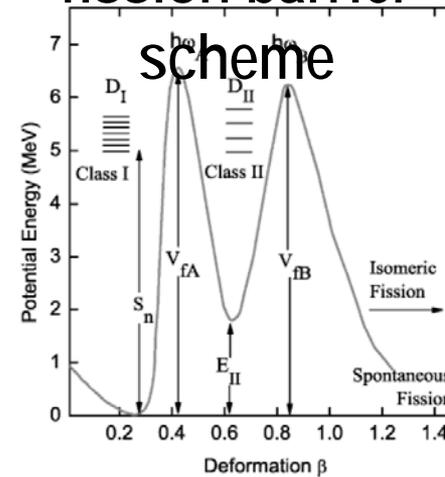
Class-II states



Class-II resonance assignment
based on G. James *et al.* data

- Gives unique information about fission barriers
- Average level spacing of class-II states can be estimated (in progress)

The double-humped fission barrier scheme

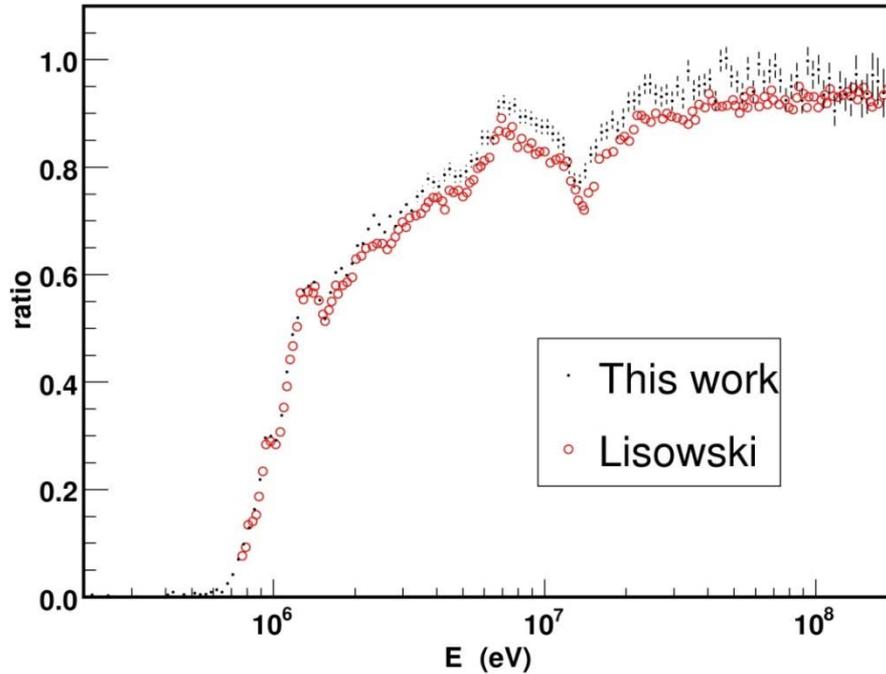


Mughabghab, Atlas of Neutron Resonances, 2006

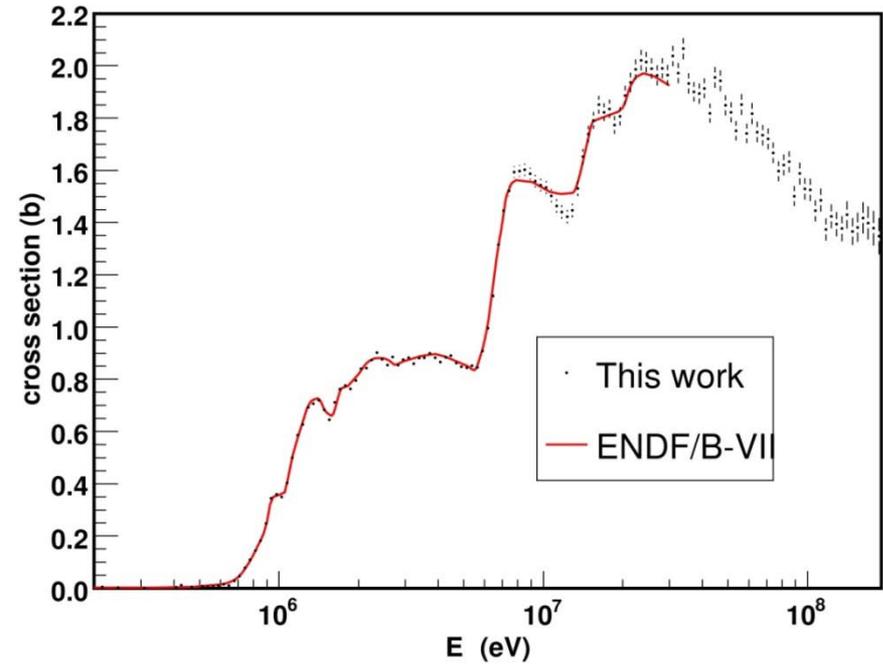
- Clear demonstration of the class-II resonances
- Clustering of subthreshold fission strengths is explained in terms of the double-humped fission theory
- First class-II resonance analysis was done by James *et al.*, PRC 15(1977)2083

The U-236 neutron-induced fission cross section and ratio to U-235

Ratio



Cross section



- The current result for U-236 ratio fairly good agrees with Lisowski *et al.* data
- Current evaluations are representing the data well

More on fission at LANSCE

Rhiannon Meharchand

TPC

SPIDER

Brent Perdue

**Prompt fission neutron spectra
("Chi-Nu")**

Collaborations

- LANL C-Division, P-Division, T-2
- LLNL
- INL
- ORNL
- NIST
- Universities
 - Rensselaer Polytechnic Institute
 - Rutgers University
 - North Carolina State University
 - Duke University
 - Notre Dame University
 - Ohio University
 - Abilene Christian University
 - Cal Poly San Luis Obispo
 - Colorado School of Mines
 - Georgia Institute of Technology
 - Idaho State University
 - Ohio University
 - Oregon State University
 - Univ. Michigan
 - Univ. Kentucky
 - Brigham Young
 - Texas A&M
 - Washington University
 - Yale University

- Foreign

- CEA France
- IRMM – JRC Geel Belgium
- Charles University Prague, Czech Republic
- Univ. Frankfurt Germany

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- **US DOE**
 - **NNSA**
 - **Nuclear Energy**
 - **Nuclear Physics**
 - **NEUP from DOE-NE**
- **LANL - LDRD**

Thank you!!!

Thank you for your attention!