Nuclear Data Experiments at LANSCE: Highlights 2013

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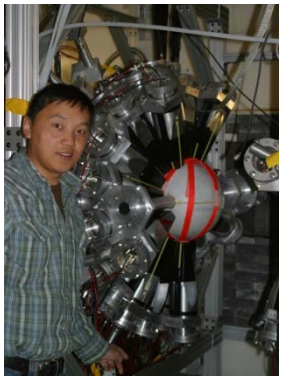
Los Alamos National Laboratory

Cross Section Evaluation Working Group Meeting
US Nuclear Data Program Meeting
Brookhaven National Laboratory
November 18-22, 2013

LA-UR-13-28836

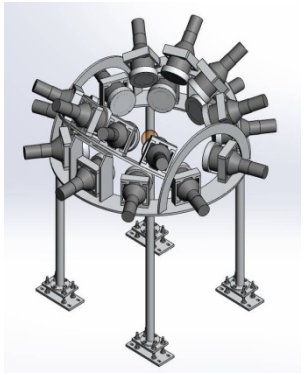
Nuclear data measurements at LANSCE are made with many different instruments

DANCE (n,γ)

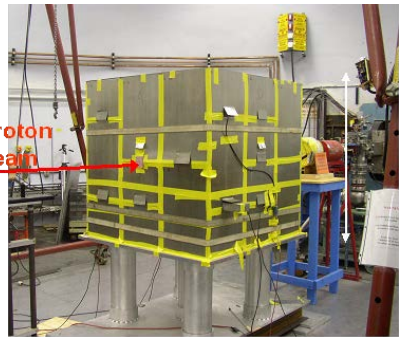


GEANIE (n,xγ)

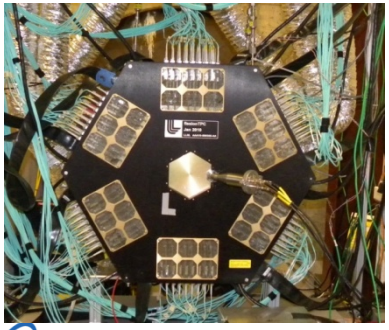
Chi-Nu (n,xn)



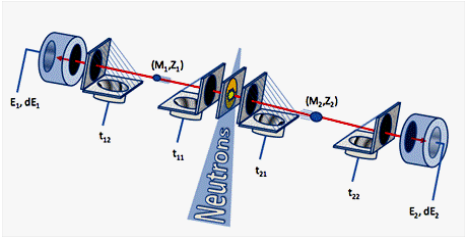
LSDS



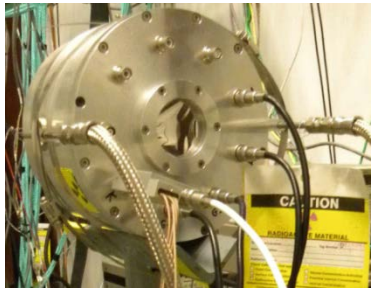
TPC



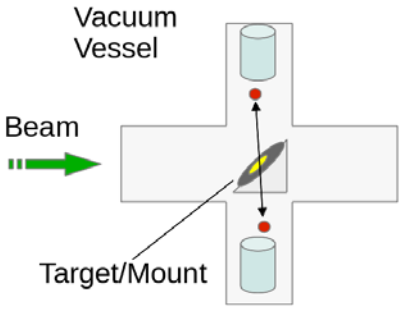
SPIDER



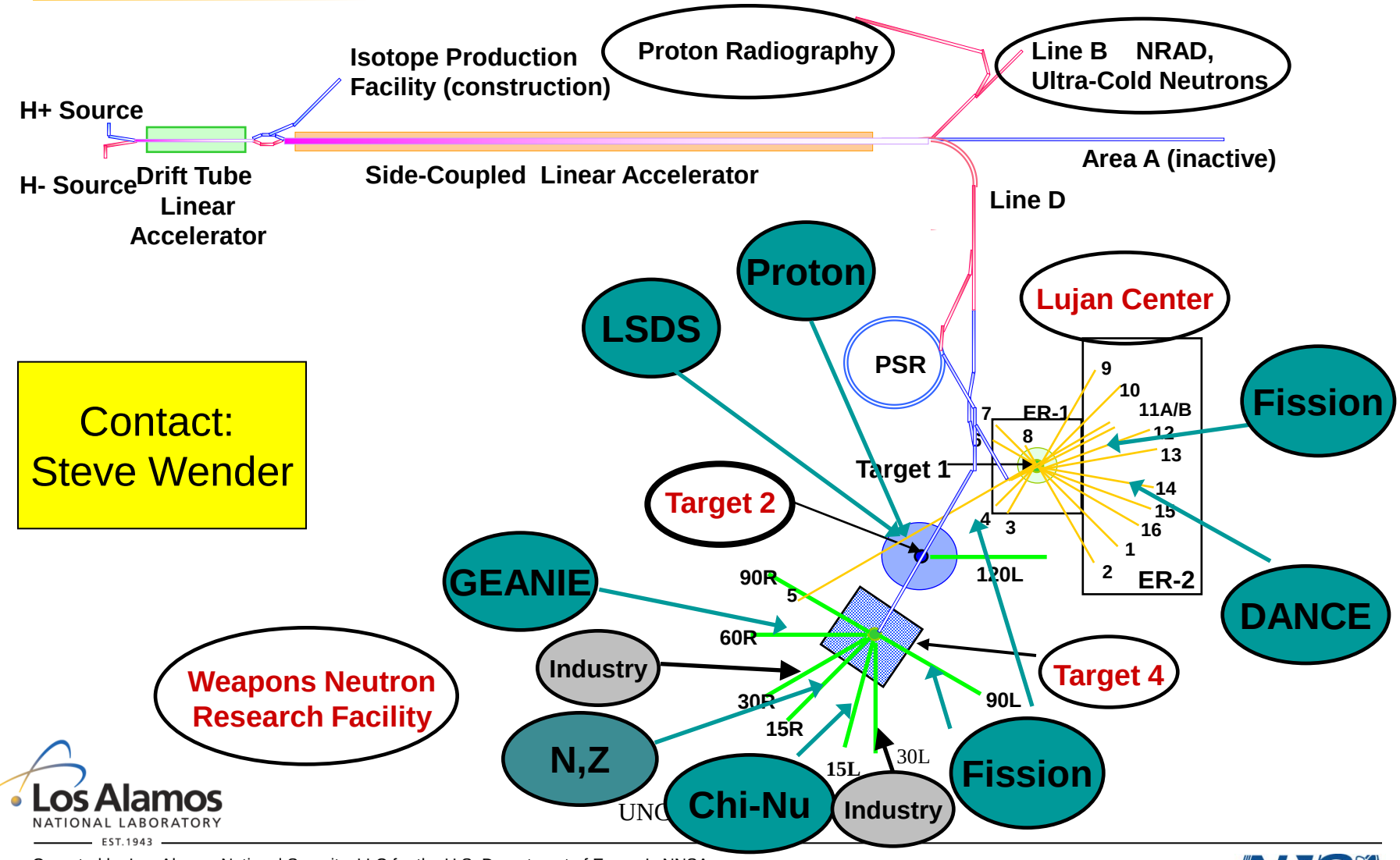
Double gridded ion chamber



Surface barrier detectors



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



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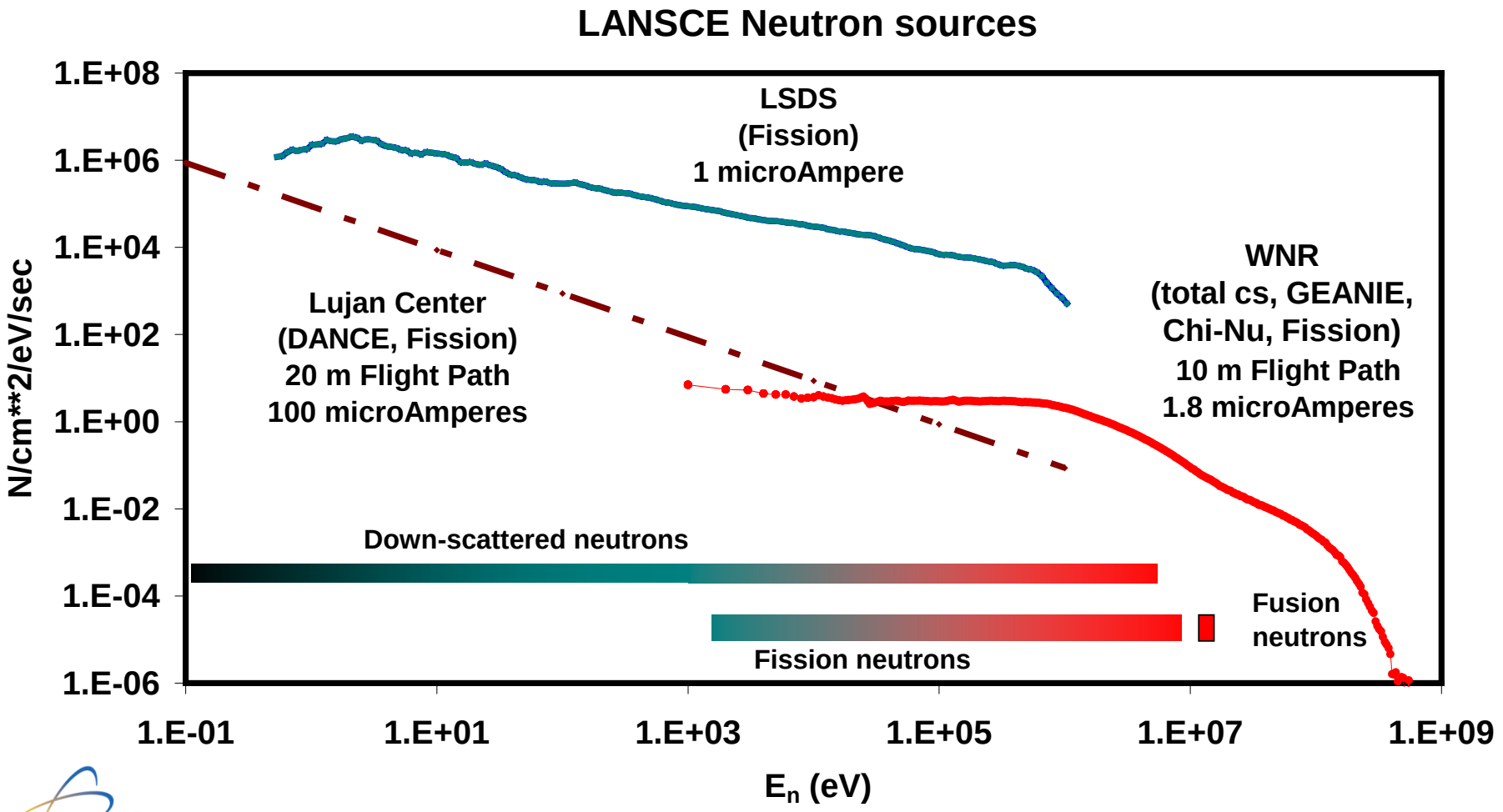
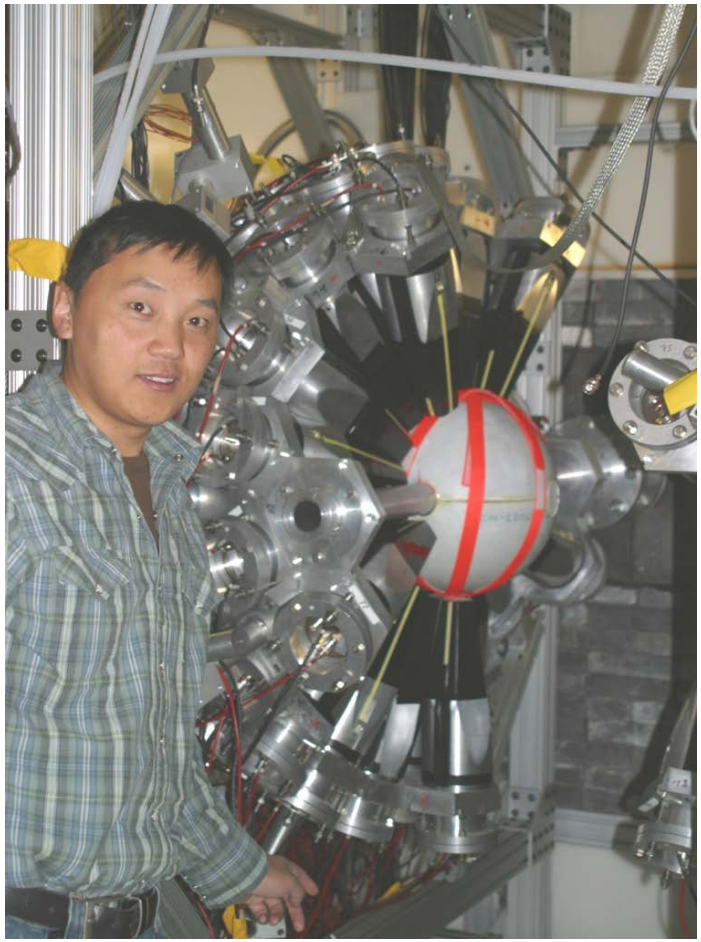
LANSCE neutron sources cover the full range for fission and fusion applications



DANCE (n,γ)



Contacts:
John Ullmann
Aaron Couture
Marian Jandel

DANCE research in 2013 (1) – non actinides

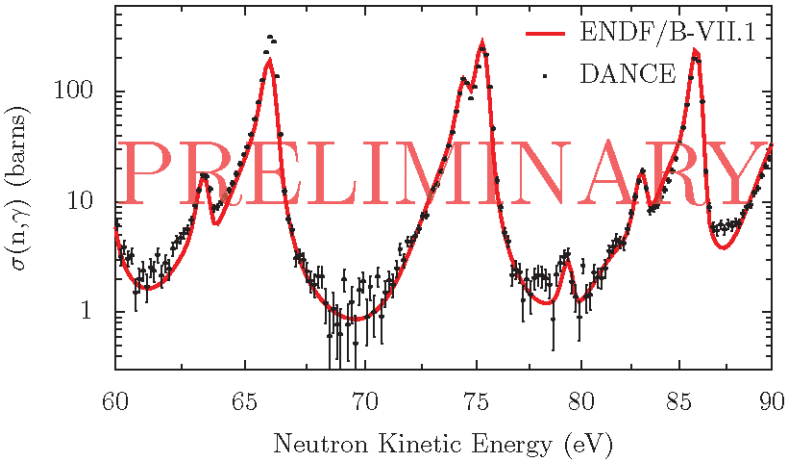
^{152,154,156,158}Gd(n,γ)	Bayarbadrakh Baramsai, NCSU/LANL; published
^{97}Mo	Carrie Walker, NCSU PhD dissertation; completed
^{117,119}Sn	Bayarbadrakh Baramsai, NCSU/LANL; in progress
^{173}Lu ($t_{1/2}$ = 1.37y)	Capture. O. Roig (CEA); in progress
^{184,186}W	Capture, Marian Jandel LANL; in progress
^{191,193}Ir	Capture; Charles Arnold LANL; in progress
^{136}Xe	Capture, gas target; data taken
^{161}Dy	Capture, data taken

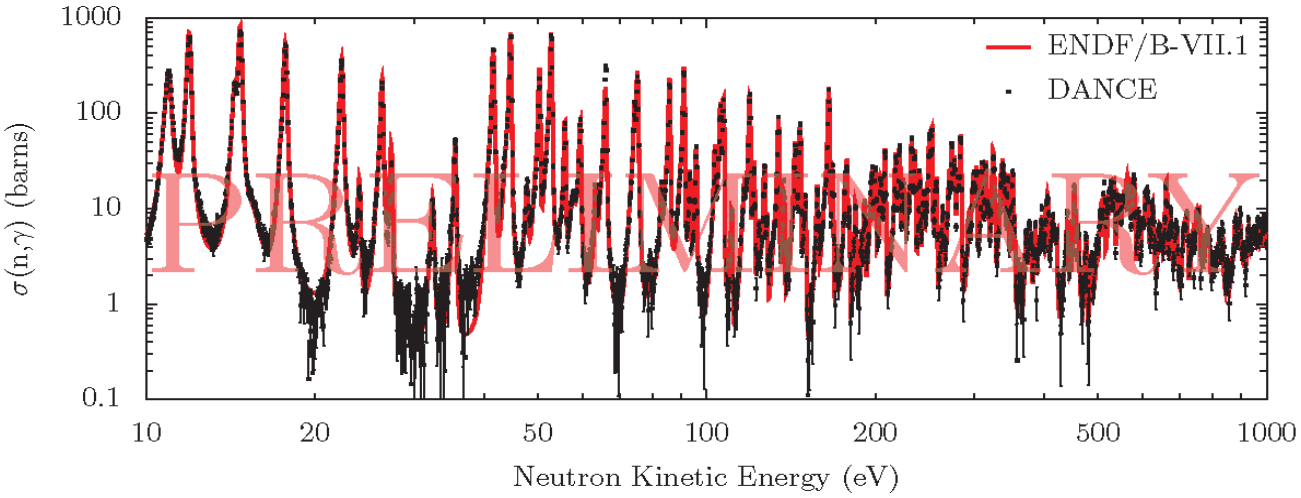
DANCE research in 2013 (2) - Actinides

$^{233,235}U,^{239,241,242}Pu$	Capture to fission: LANL, LLNL; in progress ^{235}U published in Phys. Rev. Lett. ^{239}Pu En < 1 keV; submitted for publication ^{242}Pu data taken (LLNL)
$^{235}U,^{239,241}Pu$	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; published (LLNL)
^{252}Cf	Fission gamma multiplicity and spectra; published (LLNL)
$^{242m,243}Am$	Capture, Marian Jandel LANL; prelim report
^{238}U	Capture xsec, gamma rays John Ullmann LANL; near completion

^{239}Pu(n,gamma) cross section from 10 – 1000eV

- **Generally good agreement with ENDF/B-VII.1; disagreements at a few resonances**
- **Good separation between gammas from capture and those from fission through observed multiplicity**
- **Measurement at higher incident energy in progress**





Fission gamma rays from 239Pu(n,f)

- **Gamma-ray spectra for several (cluster) multiplicities**
- **Previous works gave average energies and average multiplicities**
- **DANCE gives detailed energy-multiplicity data**

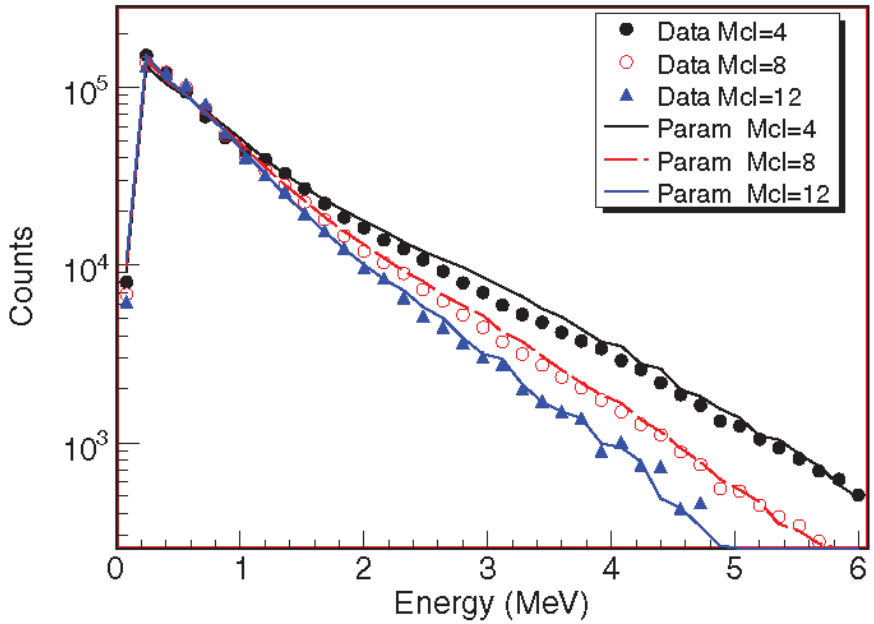
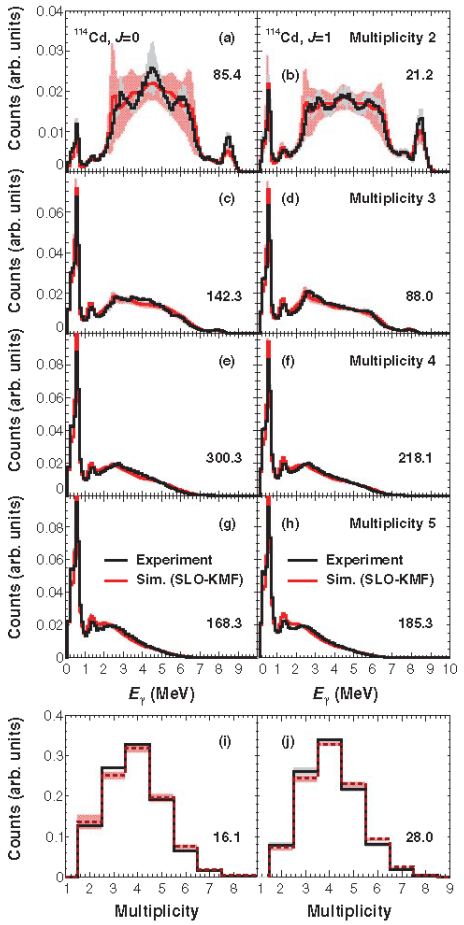


FIG. 2. (Color online) Measured gamma-ray cluster energy for cluster multiplicities (Mcl) 4, 8, and 12 compared with the spectra calculated with the best-fit parameters. For comparison, the spectra were all normalized to the Mcl = 4 data over the energy region 0.2–1.1 MeV.

Gamma rays from neutron capture by cadmium

- **Practical importance for neutron absorber**
- **Test of gamma-ray strength functions (SLO, KMF, pygmy resonances, etc.)**
- **DANCE provides a wealth of data on multiplicities, spectra**



DICEBOX, with chosen parameters, fits the gamma-ray data for ^{113}Cd(n,gamma)

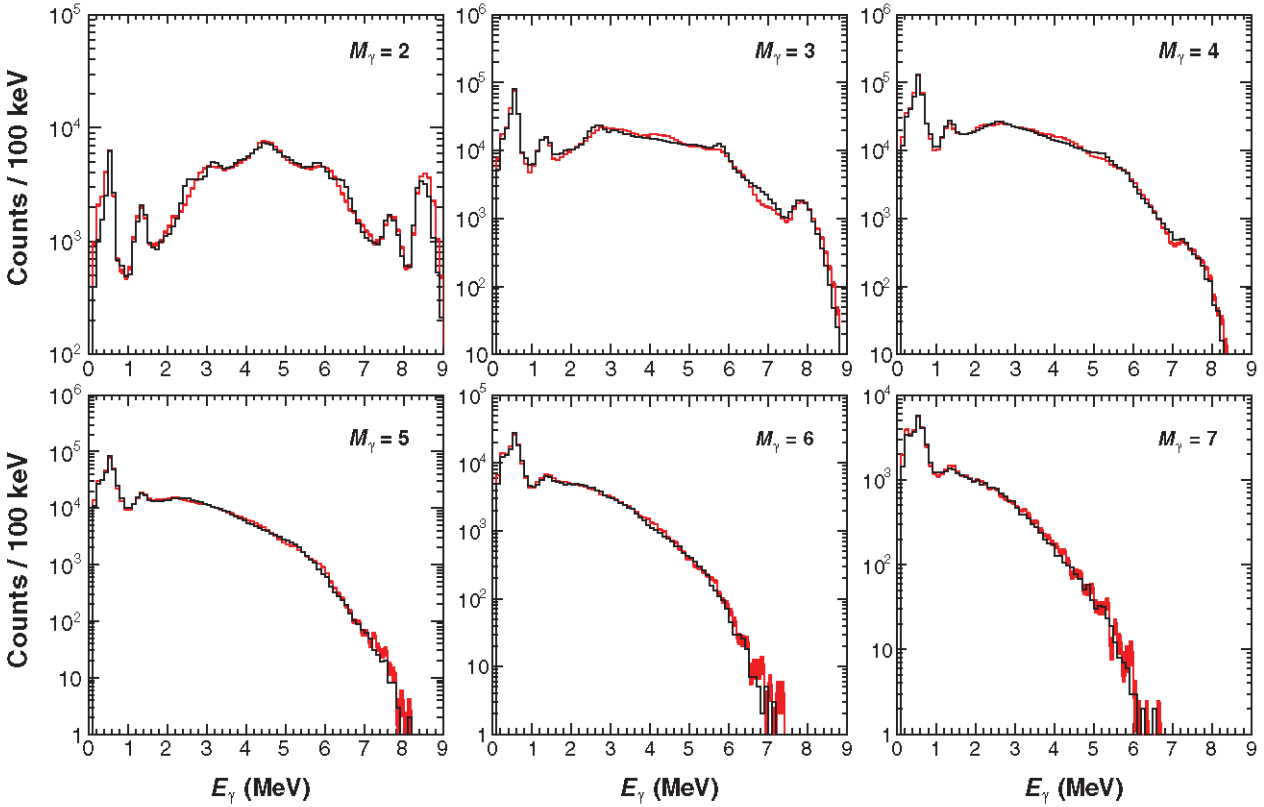


FIG. 1. (Color online) Measured γ-ray spectra with DANCE from the 0.178 eV resonance of the ^{113}Cd(n,γ) reaction for γ-ray multiplicities $M_\gamma = 2$ to 7. Predicted spectra corresponding to a DICEBOX realization which represents best the cascade transitions from the 0.178-eV resonance are shown in red.

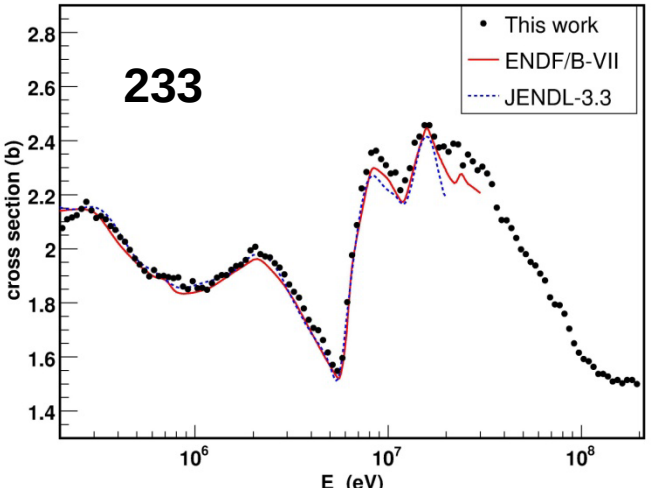
Fission Cross Sections
Fission Total Kinetic Energy
Fission Fragment Yields

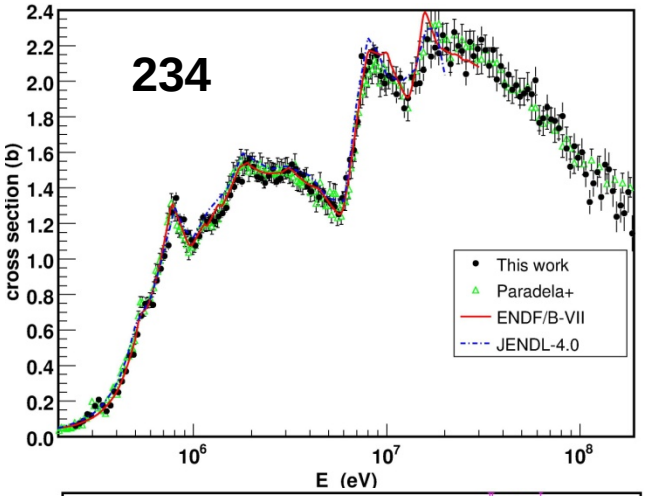
Contact:
Fredrik Tovesson

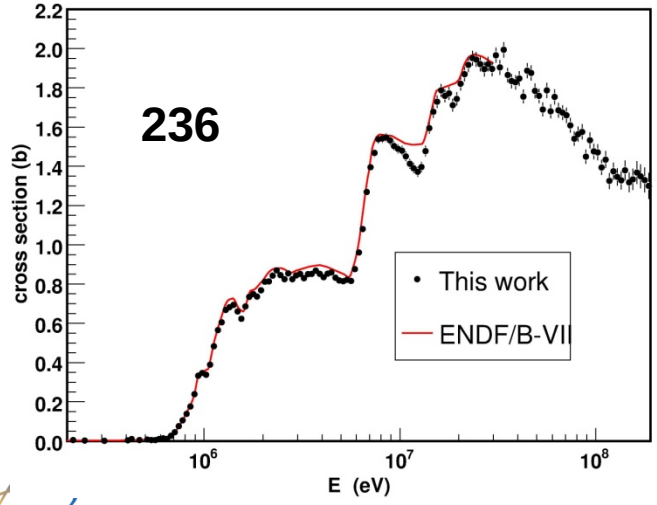
Status: fission cross sections and fragment properties

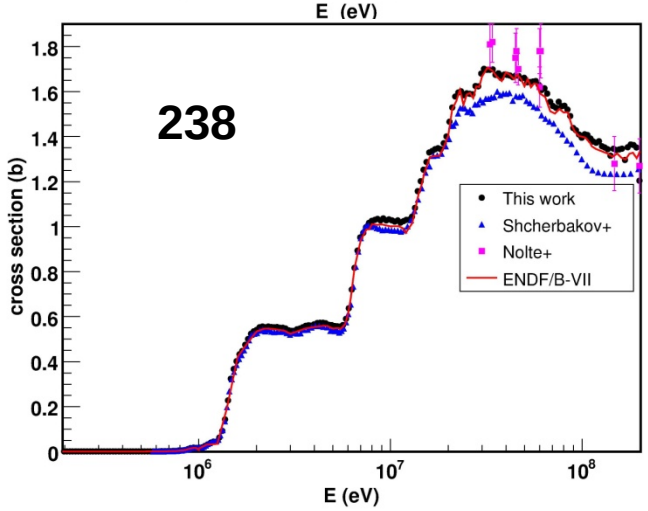
- Completed: U-233,234,236,238 (n,f) measured from 0.2-200 MeV
  - completed, submitted to Nucl. Sci. Eng.
- High precision cross sections with TPC
  - U-238(n,f) relative to U-235(n,f): Data collection and analysis in progress
  - Pu-239(n,f) relative to U-235(n,f): Production data collection in progress
  - Pu-239(n,f) relative to H(n,n)H: not yet started
- Total kinetic energy (TKE) release in fission
  - U-238: Data collection completed, analysis in progress
  - U-235: Data collection completed, analysis in progress
  - Pu-239: Experiment scheduled for Dec. 2013
- Mass yields of fission fragments
  - SPIDER: U-235(n,f) mass yields measured at thermal, analysis in progress
  - Gridded ionization chamber: same status as TKE

Fission cross sections of U-233,234,236,238 with standard ionization chamber







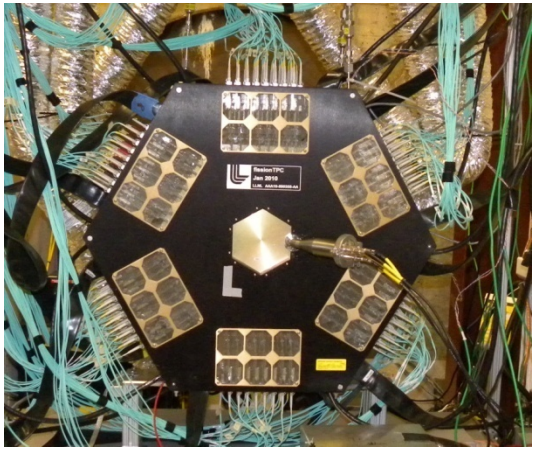


Studies of fission cross sections and fragment properties at LANSCE

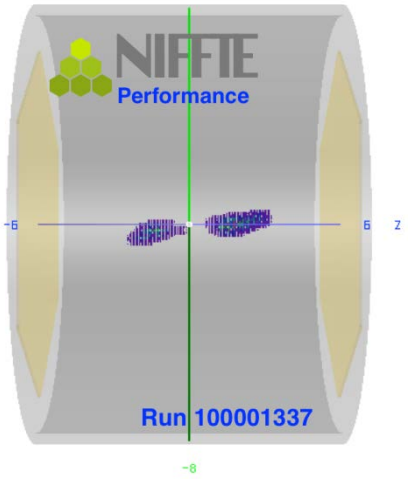
- Fission cross sections
  - Very High precision (~1%) with TPC
  - High precision with ionization chambers
- Total kinetic energy (TKE) release in fission
  - Frisch-gridded ionization chamber
  - SSBDs
- Mass yields of fission fragments
  - High mass resolution, low efficiency with SPIDER
  - Low mass resolution, high efficiency with Frisch-gridded ionization chamber

Time Projection Chamber (TPC)

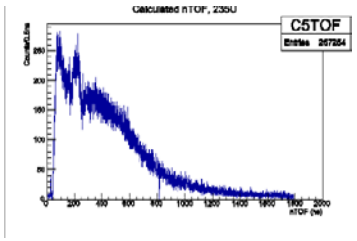
TPC on 90L



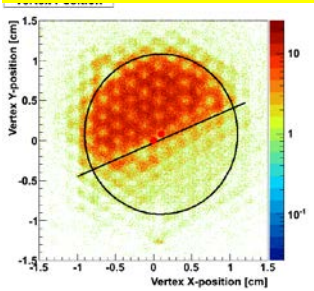
Fission fragment tracks



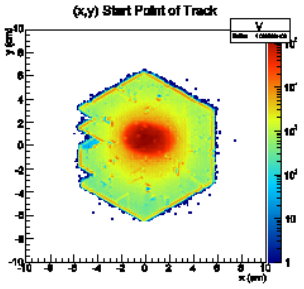
Neutron TOF



Target auto-radiograph

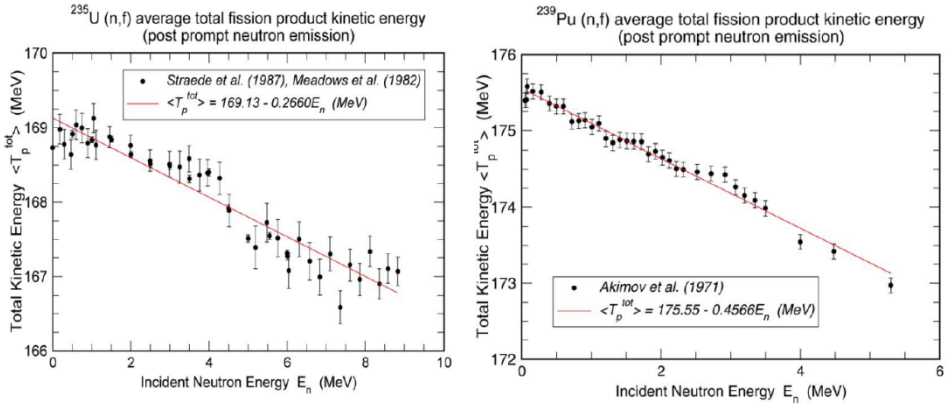


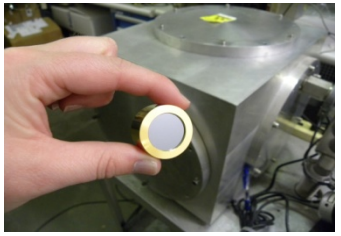
Beam profile imaging

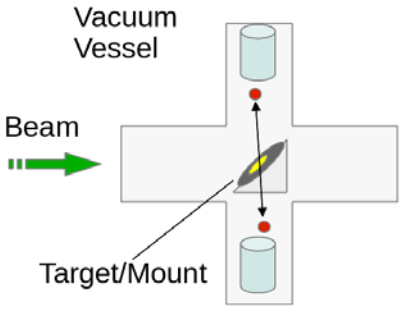


- Fully instrumented TPC was commissioned at LANSCE in August 2013
- Data on the U-238 (n,f) cross section were collected
- Currently taking production runs on Pu-239

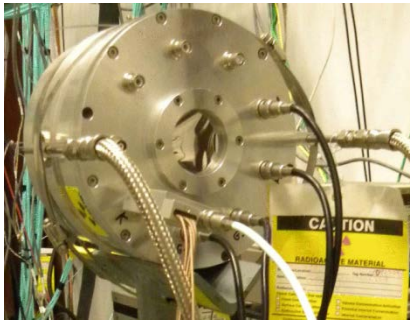
Total Kinetic Energy (TKE) release in fission

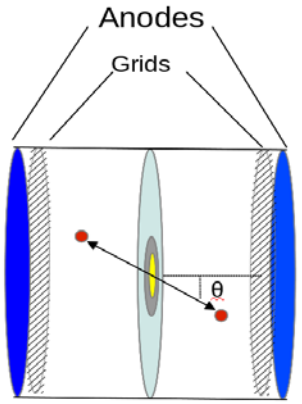




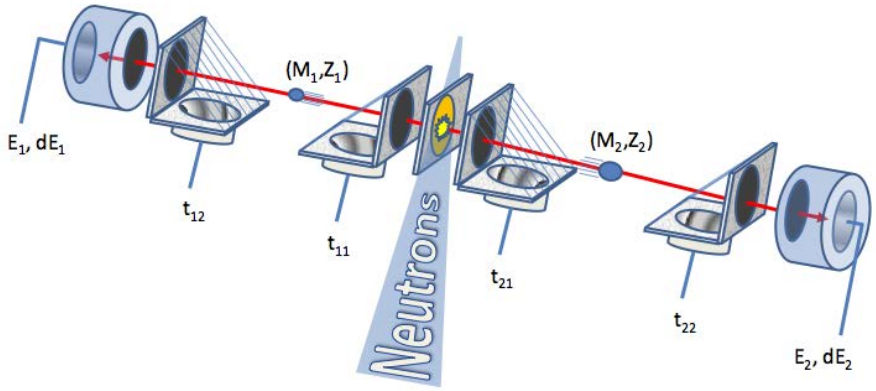


- **Madland has pointed out the need for new measurements of TKE in fission of U-235 and Pu-239 extending beyond 10 MeV**
- **Current measurements at LANSCE employ two detector types, Gridded IC and SSBD, to measure TKE at thermal and 0.2 – 100 MeV neutron energy**
- **Two detector types allow for better understanding of systematic effects**





Spectrometer for ion determination in fission research (SPIDER)

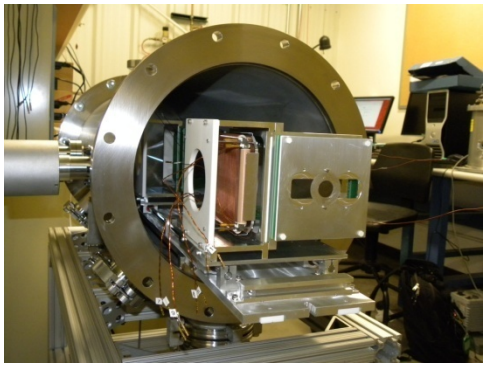


- New project at LANSCE to measure fission product yields
- Instrument based on the 2V-2E method for mass determination
- Bragg spectroscopy for charge measurements
- Goal is to achieve enough efficiency to measure energy dependent yields for fast neutrons

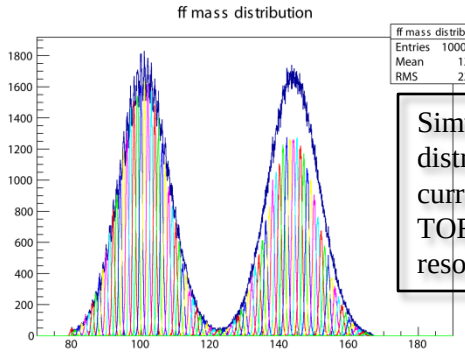
SPectrometer for Ion DEtermination in Fission Research

SPIDER

- New instrument for measuring independent fission yields
  - Fragment time-of-flight (TOF) spectrometer
    - Measures TOF and kinetic energy of both fragments in coincidence
    - Correlates fragment mass, charge and energy
  - Resolution
    - Mass: 1 amu for light fragments, 1.5 amu for heavy
    - Charge: 1 unit charge for light fragments (heavy fragment charge obtained from charge conservation)
    - Energy: 0.5-1.0%
  - Experiments at LANSCE
    - Incident neutrons ranges from thermal to several hundred MeV (moderated and un-moderated spallation targets)
    - Neutron time-of-flight to measure incident neutron energy
- Timeline
  - Thermal fission yields for U-235 and Pu-239
    - Beam experiments Sept.-Dec. 2013
    - Preliminary results March 2014
    - Collect more data Fall 2014
    - Finalized mass yields Dec. 2014
  - Fast-neutron induced fission yields for U-235 and Pu-239
    - Beam experiments in 2014 and 2015
    - U-235 mass yields (E = 1 - 15 MeV) in 2015
    - Pu-239 mass yields (E = 1 - 15 MeV) in 2016



Timing detector assembly for the SPIDER spectrometer



Simulated mass distribution based on currently achieved TOF and energy resolution

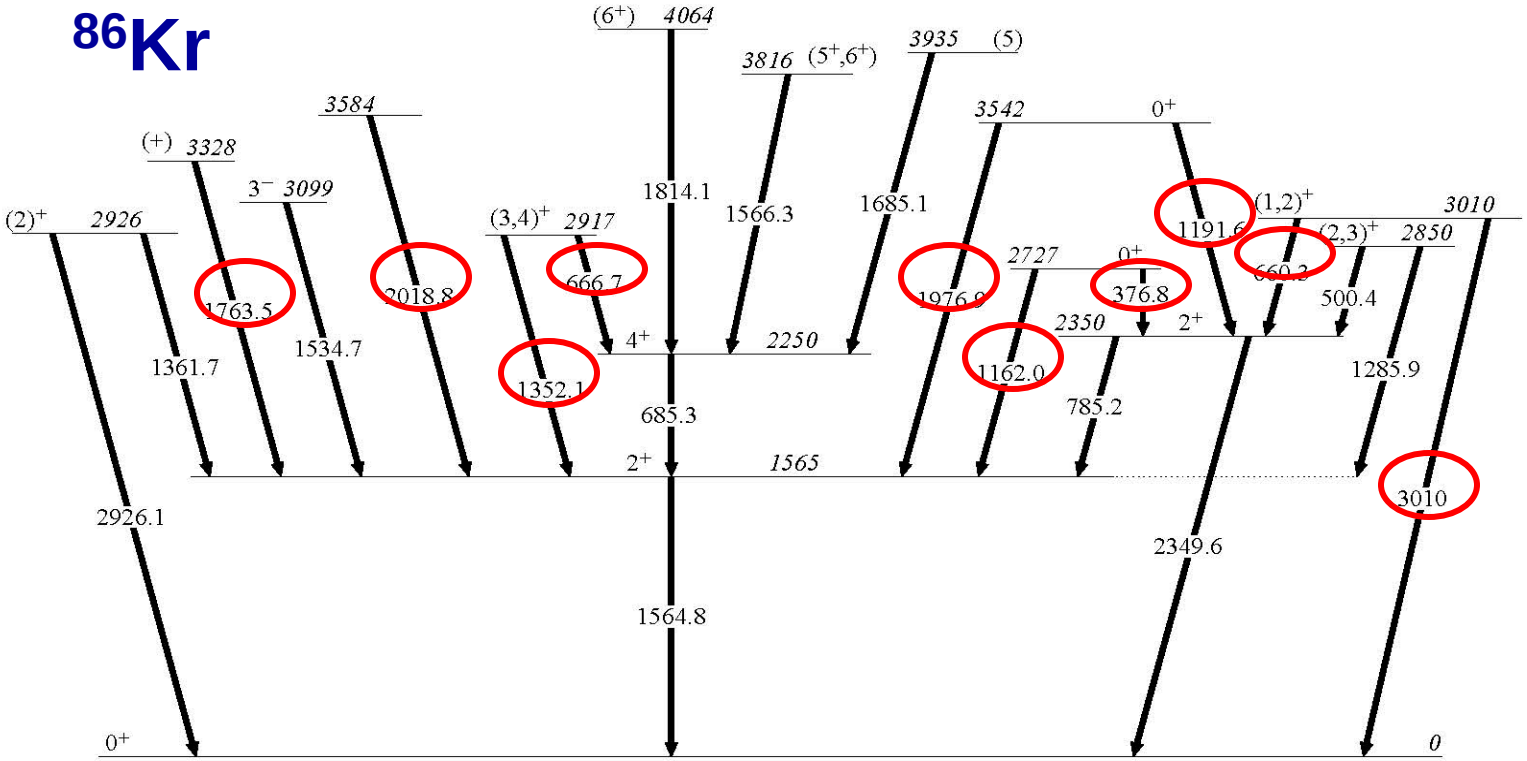
GEANIE (n,xγ)

Contacts:
Ron Nelson
Nik Fotiades
Matt Devlin

GEANIE measurements 2013

- ^{86}Kr (n, xn yp γ) - 10 new transitions (N. Fotiades ND2013)
- ^{109}Ag (n,xgamma) -- over 100 transitions in 12 reaction channels leading to Ag and Pd – in progress (N. Fotiades)
- ^{124}Xe, ^{176}Lu (n,xgamma) – in progress
- Millisecond isomers: ^{71m}Ge, ^{114m2}I, ^{208m}Bi, ^{88m1}Y, ^{88m2}Y, and ^{75m}As M. Devlin
- Various elements for a neutron-induced gamma-production reference cross sections (R. Nelson): ^{7}Li (n,n') ^{7}Li*, Ti, Cr, Fe
- x-ray yield from n-induced fission (R. Nelson and Thierry Granier - CEA) - published

New transitions in ^{86}Kr were observed



Ten new transitions (red circles) were observed. All previously known levels (from Ref. [1]: B. Singh, Nucl. Data Sheets 94, 1 (2001)) up to 3.7MeV excitation identified.

Our ^{86}Kr results are published in Ref. [2]: N. Fotiades et al., PRC 87, 044336 (2013)

Example of a millisecond isomer, ^{75m}As

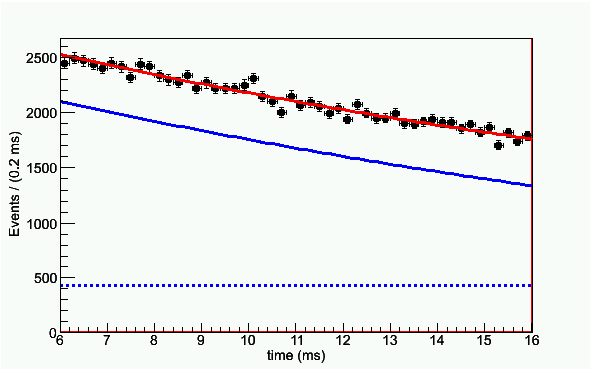


FIG. 7. Measured decay of the 280-keV transition from ^{75m}As as a function of time and a fit to the data (as in fig. 2).

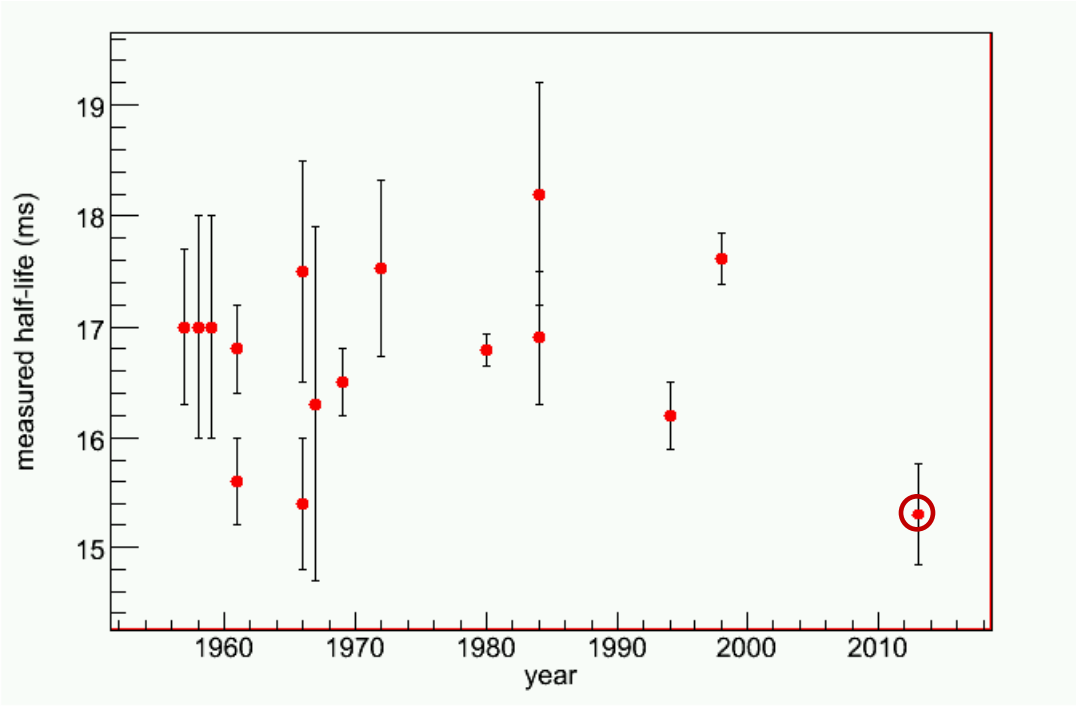
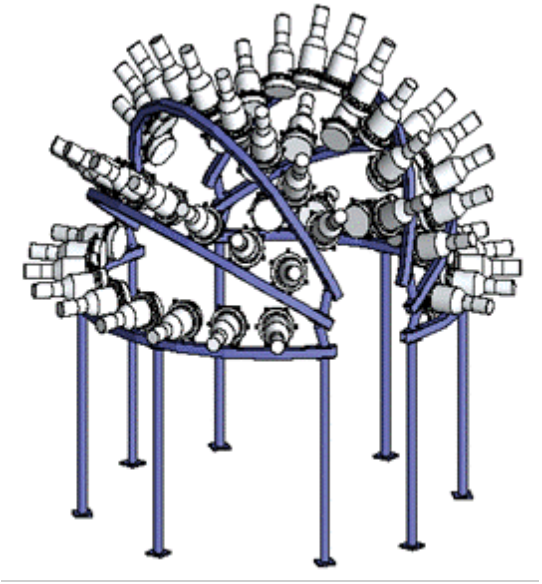
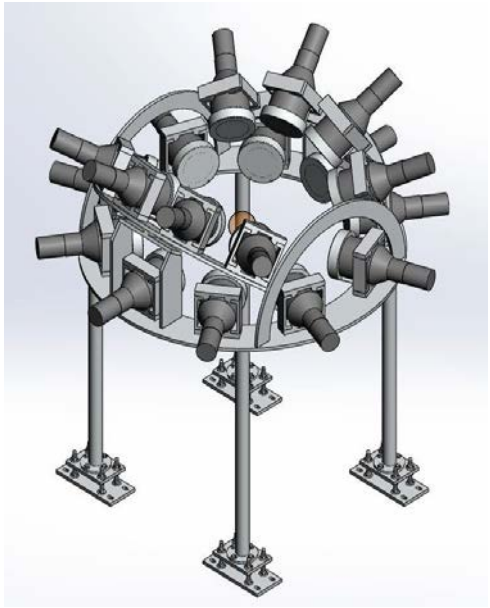


FIG. 8. Reported half-life measurements for ^{75m}As as a function of year, with the current measurement shown for 2012.

Chi-Nu - Prompt fission neutron spectra





Contacts:
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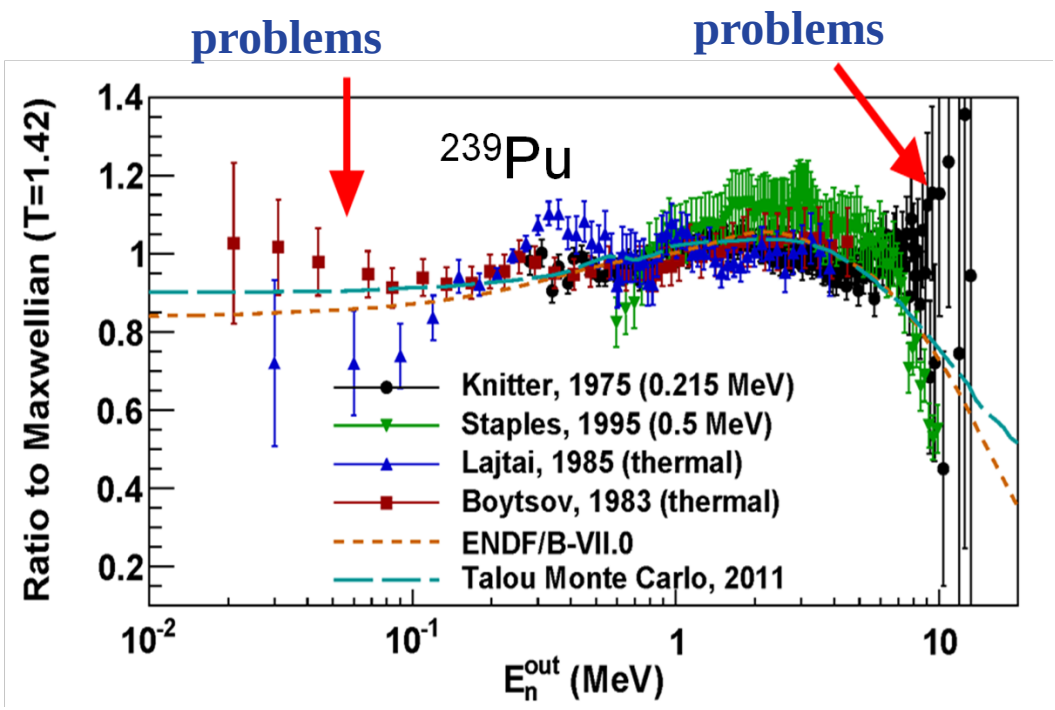
Bob Haight
Terry Taddeucci
Hye Young Lee
LLNL:
Ching-Yen Wu

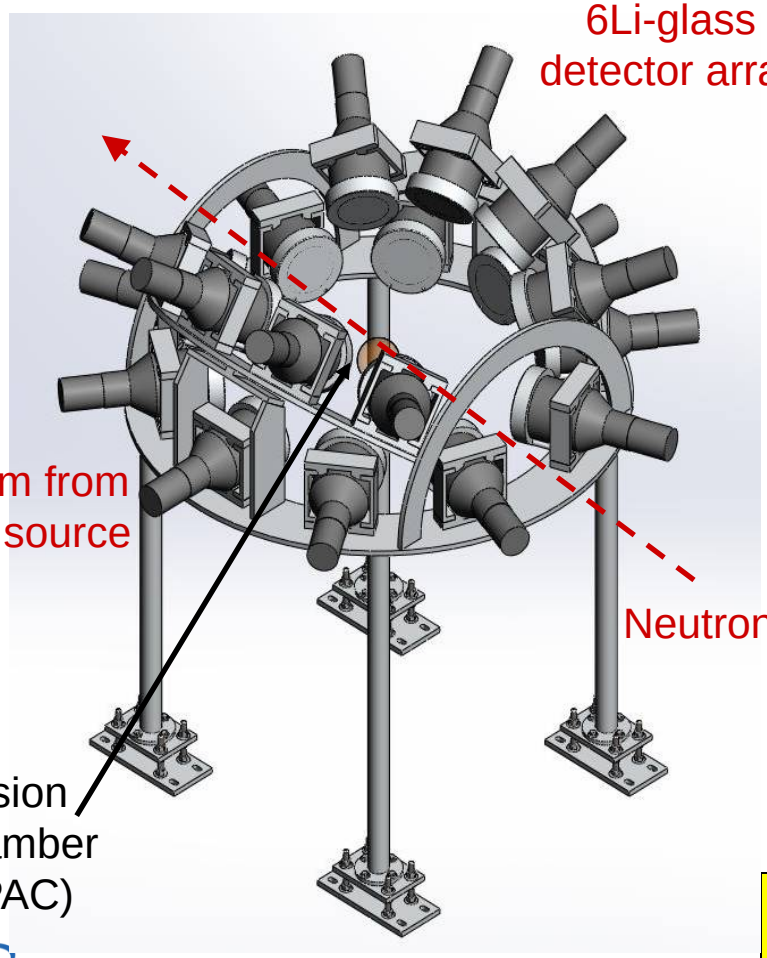
Literature data for ^{239}Pu(n,f) PFNS

- Issues to be addressed
  - Discrepancies in literature data
    - Low energy
    - High energy
  - Lack of data for MeV incident neutron energies

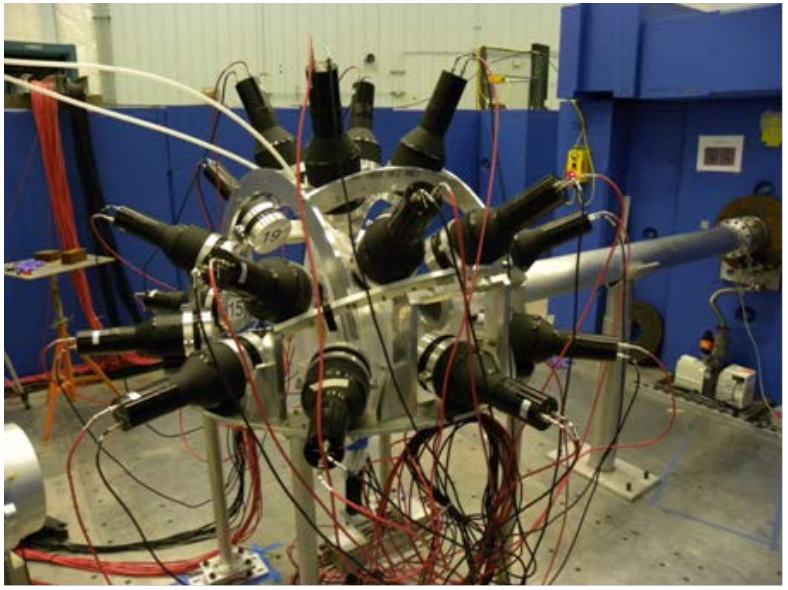


PHYSICAL REVIEW C 83, 064612 (2011)
Advanced Monte Carlo modeling of prompt fission neutrons for thermal and fast neutron-induced fission reactions on 239Pu
P. Talou,1,* B. Becker,2 T. Kawano,1 M. B. Chadwick,3 and Y. Danon2

Chi-Nu array of fast neutron detectors measures prompt neutron spectra emitted in fission



- **22 ^{6}Li-glass scintillation detectors - - or**
- **54 liquid scintillation neutron detectors**

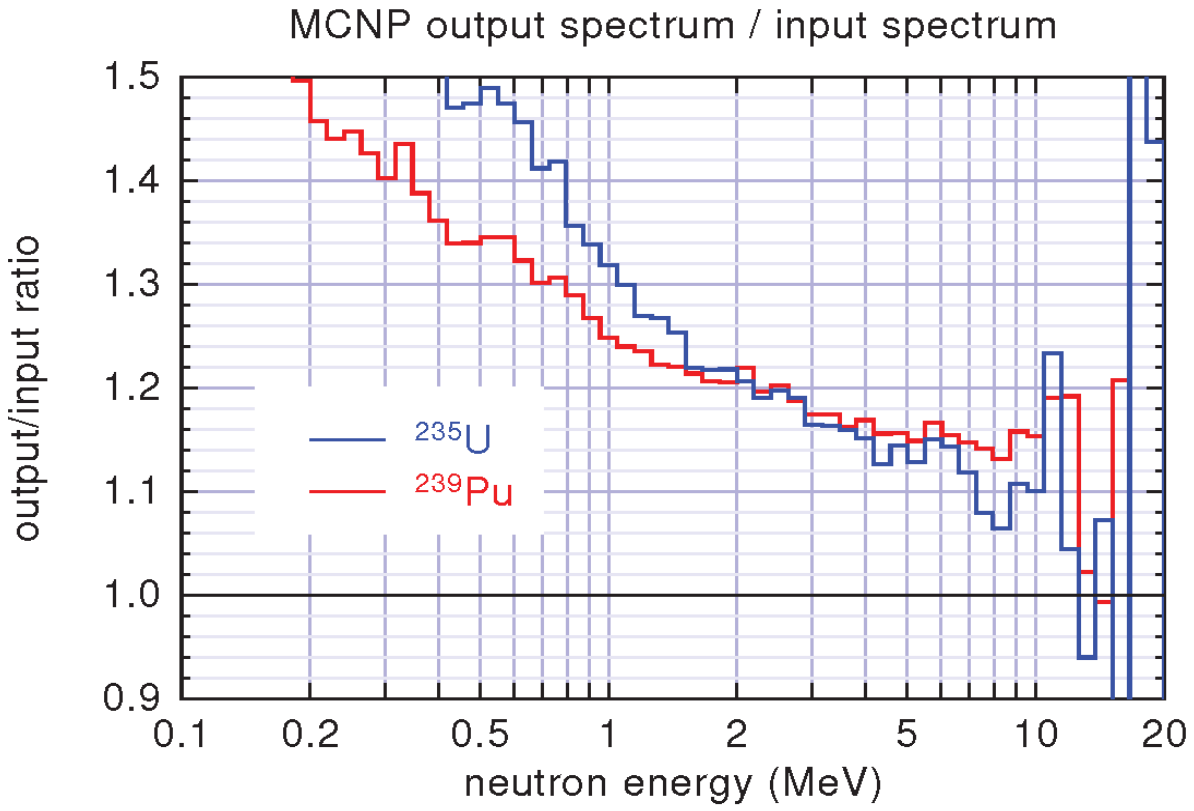


Double time-of-flight experiment

Progress in Chi-Nu

- Modeling
  - Previous measurements
    - Lack of neutron transport corrections
    - Problems at 30% level
  - Detector response
    - Multiple scattering
    - Scattering from photomultiplier tube
- Experiment
  - ^{239}Pu PPAC – 100 mg in 10 separate modules
  - 22 ^{6}Li-glass detectors
  - Digitizer Data Acquisition

Ratio of output to input clearly show how big the spectral distortions can be



MCNP input = Watt spectrum

MCNP output = flux at detector

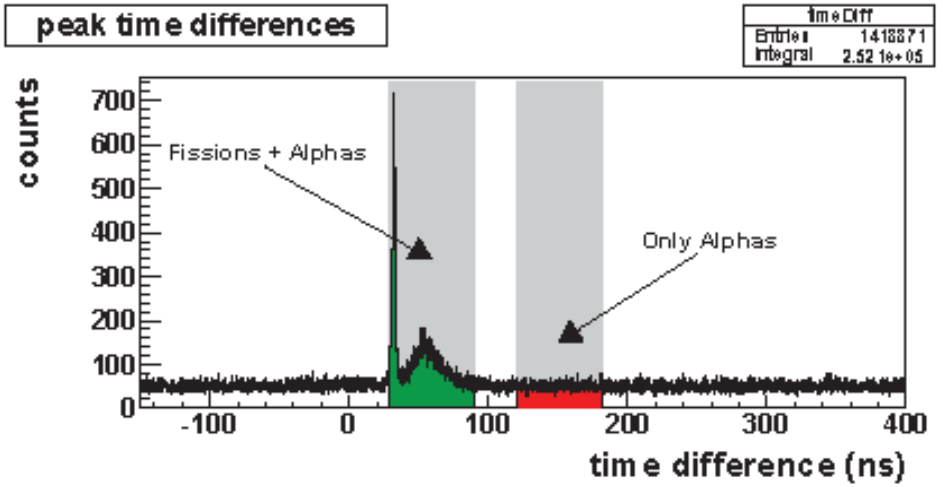
includes:

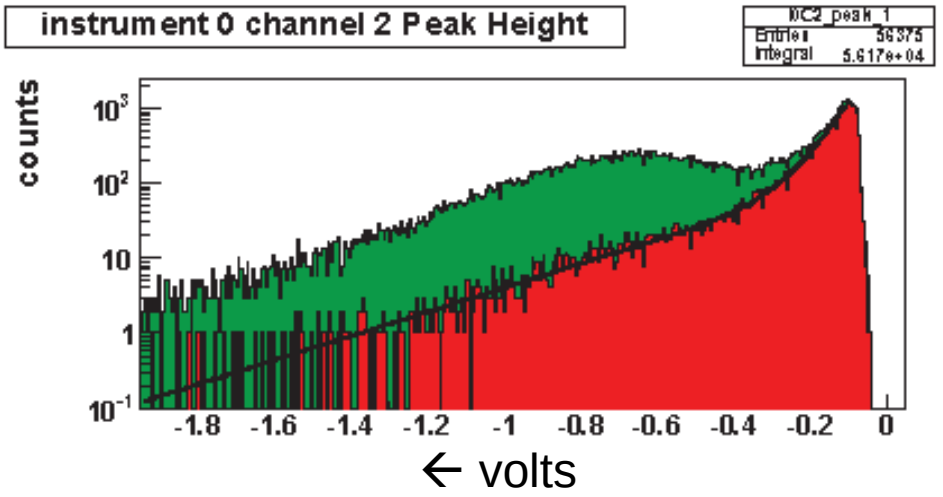
- n multiplication
- in-scattering

Corrections needed for PFNS measurement of ^{239}Pu(n,f) by Staples et al., Nucl. Phys. A591, 41 (1995)

Present challenge in PFNS of ^{239}Pu(n,f) is separating fissions from alphas in source

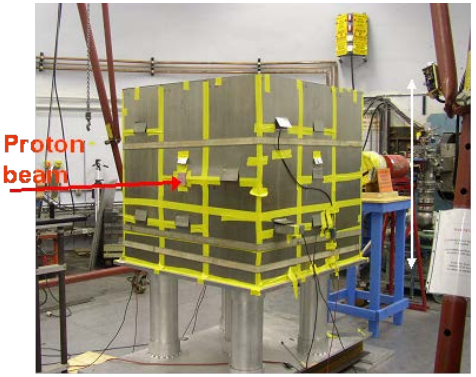
- ^{239}Pu fissions in PPAC
- EJ309 neutron detector
- Two cuts on TOF





Fission Cross Sections on small samples Lead Slowing-Down Spectrometer

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



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n + ^{3}He

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Collaborations

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- **INL**
- **ORNL**
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