Nuclear Data Experiments at LANSCE: Brief Highlights 2014-2015

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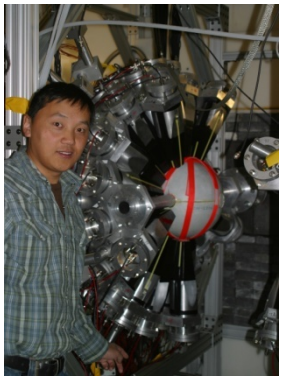
for P-27 and colleagues
Los Alamos National Laboratory

Cross Section Evaluation Working Group Meeting
"Mini-CSEWG"
Brookhaven National Laboratory
May 7-8, 2015

LA-UR-15-23446

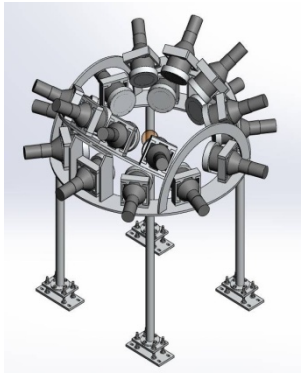
Nuclear data measurements at LANSCE are made with many different instruments

DANCE (n,γ)

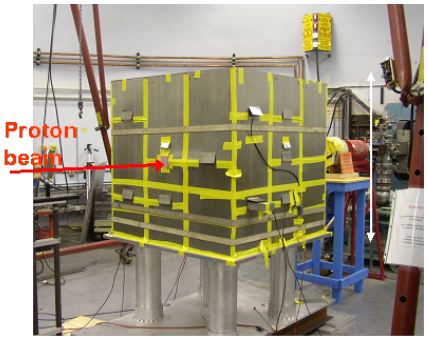


GEANIE (n,xγ)

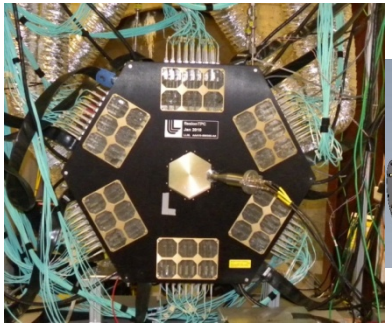
Chi-Nu (n,xn)



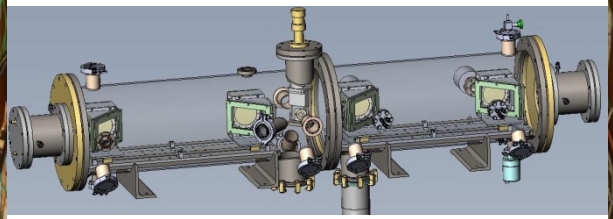
LSDS



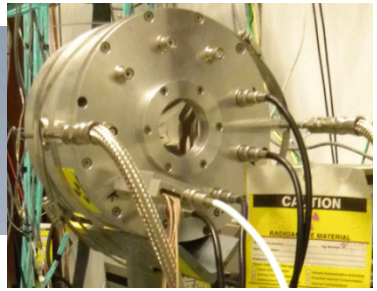
TPC



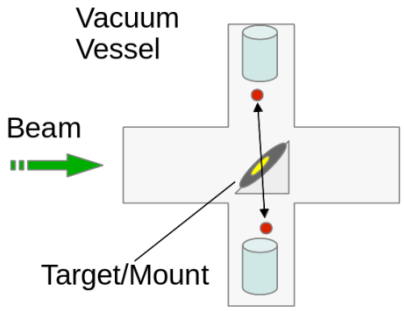
SPIDER



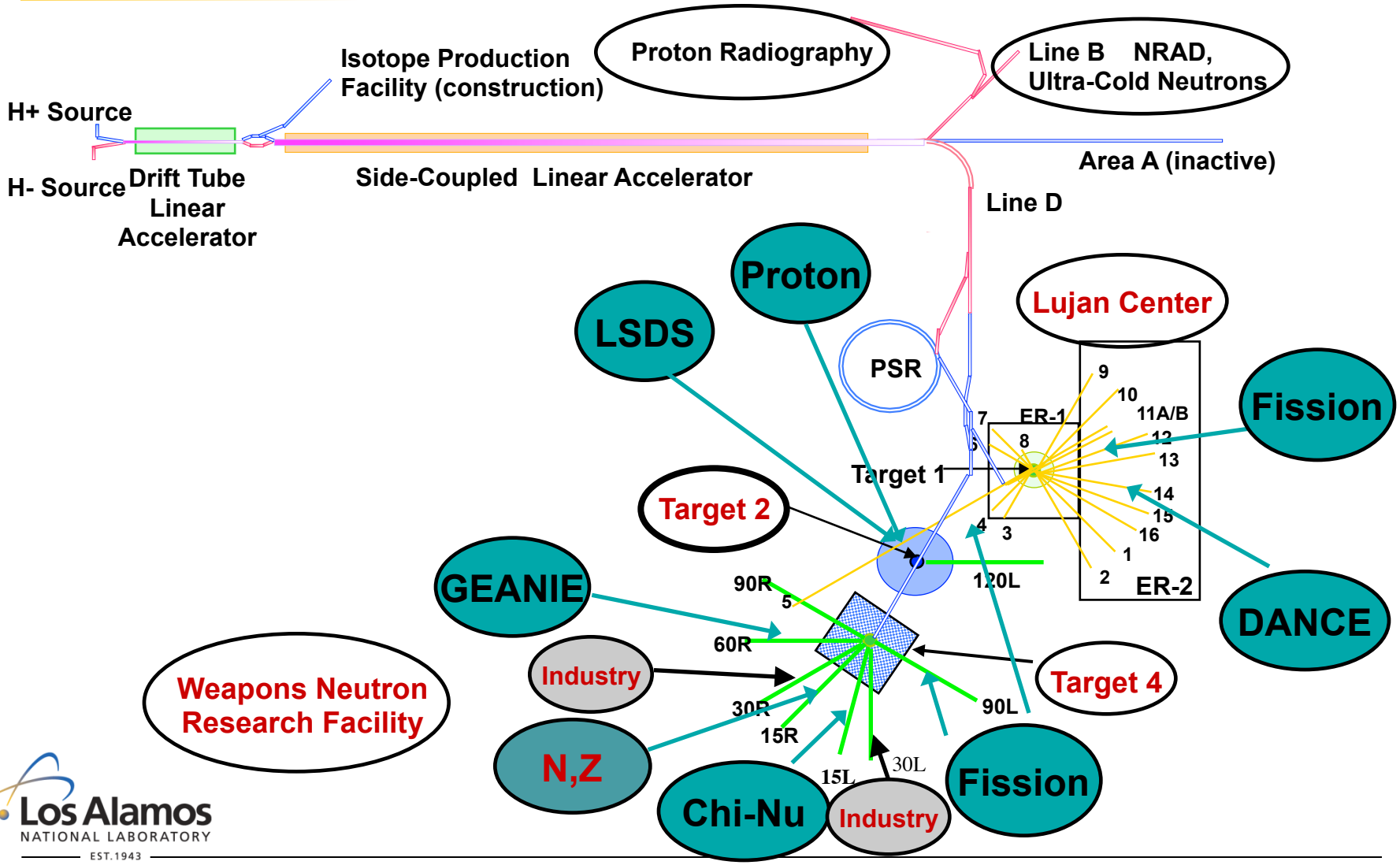
Double gridded ion chamber



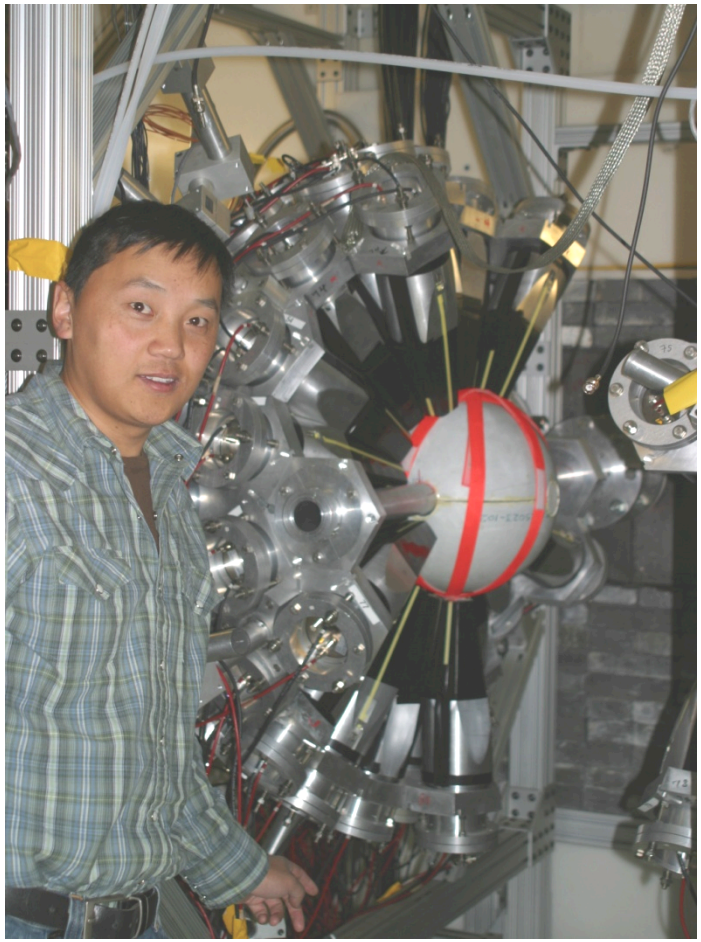
Surface barrier detectors



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



DANCE (n,γ)



Contacts:
John Ullmann
Aaron Couture
Marian Jandel

Major DANCE Experiments 2014/2015

- ^{236,238}U(n,γ) Relative to ^{235}U(n,f) – mixed target
  Data > 10 keV (M. Jandel DOE ECR)
- ^{67,68}Zn(n,γ) Astrophysics (with LSU)
- ^{173,174}Lu(n,γ) Radioactive samples! (With CEA)
- ^{242}Pu Spontaneous fission – gamma-ray spectra (with LLNL)
- ^{235}U(n,γ) Capture isomers (requires fission tagging)
- ^{161,162}Dy(n,γ) Strength functions and resonances (with NCSU, Charles U.)
- ^{136}Xe(n,γ) Double-Beta decay backgrounds and physics (With IU)
- ^{191}Ir(n,γ) Capture data > 10 keV

Recent Publications

Total prompt gamma-ray emission in fission of ^{235}U, ^{239}Pu,^{241}Pu, and ^{252}Cf. A. Chyzh, C.Y. Wu, E. Kwan, R. Henderson, T.A. Bredeweg, R/C/ Haight, A.C. Hayes-Sterbenz, H.-Y. Lee, J.M. O'Donnell, Phys. Rev. C **90**, 014602 (2014).

Improved Neutron Capture Cross Section of ^{239}Pu. S. Mosby, T.A. Bredeweg, A. Chyzh, A. Couture, R. Henderson, M. Jandel, E. Kwan, J.M. O'Donnell, J.L. Ullmann, C.Y. Wu, Phys. Rev. C **89**, 034610 (2014).

Cross Section and γ-ray spectra for ^{238}U(n, γ) measured with the DANCE detector array at the Los Alamos Neutron Science Center. J.L. Ullmann, T. Kawano, T.A. Bredeweg, A. Couture, R.C. Haight, M. Jandel, J.M. O'Donnell, R.S. Rundberg, D.J. Vieira, J.B. Wilhelmy, J.A. Becker, A. Chyzh, C.Y. Wu, B. Baramsai, G.E. Mitchell, M. Krticka, Phys. Rev. C **89,** 034603 (2014).

Cascade gamma rays following capture of thermal neutrons on Cd-113. G. Rusev, M. Jandel, M. Krticka, C.W. Arnold, T.A. Bredeweg, A. Couture, W. Moody, S.M. Mosby, J.L. Ullmann, Phys. Rev C **88**, 057602 (2013).

Precision measurement of the ^{238}Pu(n,γ) Cross section. A. Chyzh, C.Y. Wu, R.A. Henderson, T.A. Bredeweg, R.C. Haight, H.-Y. Lee, J.M. O'Donnell, J.L. Ullmann, Phys. Rev C **88**, 044607 (2013).

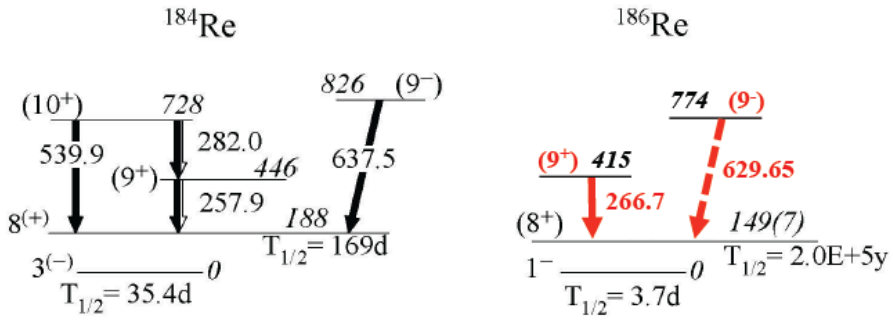
Strength of the scissors mode in odd-mass Gd isotopes from the radiative capture of resonance neutrons. J. Kroll, B. Baramsai, G.E. Mitchell, U. Agvaanluvsan, F. Becvar, T.A. Bredeweg, A. Chyzh, A. Couture, D. Dashdorj, R.C. Haight, M. Jandel, A.L. Keksis, J.M. O'Donnell, W. Parker, R.S. Rundberg, J.L. Ullmann, S. Valenta, D.J. Vieira, C Walker, C.Y. Wu, Phys. Rev C **88**, 034317 (2013).

GEANIE (n,xγ)

Contacts:
Ron Nelson
Nik Fotiades
Matt Devlin

GEANIE @ WNR/LANSCE: experiments in 2014
M Devlin, N Fotiadis, and RO Nelson

- ^{187}Re(n,xn) with Jeff Carroll (NRL) and David Matters (AFIT)



New g-rays feeding the isomer in ^{186}Re, observed with GEANIE from the ^{187}Re(n,2n) reaction. From D Matters, Master's Thesis, Air Force Institute of Technology (2015)

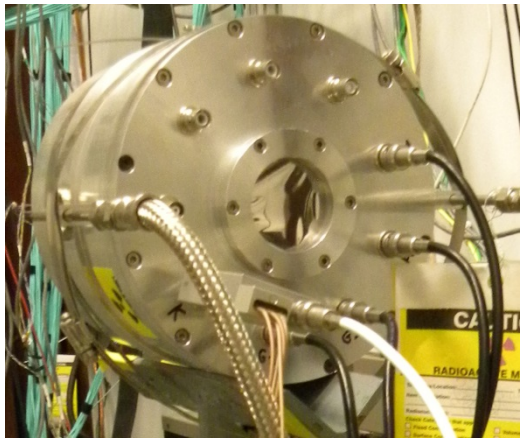
- ^{136}Xe(n,xn) for $0\nu\beta\beta$ backgrounds with Josh Albert, Lisa Hoffman, etc (IU)
- Neutron-induced γ-ray standard measurements: ^{56}Fe, Cr, B, Ti (n,n') γ-ray comparisons as a function of E_n
- Also: neutron scattering measurements with the UMASS-Lowell CLYC array (P Choudury, N D'Olympia, K Lister, et al.)

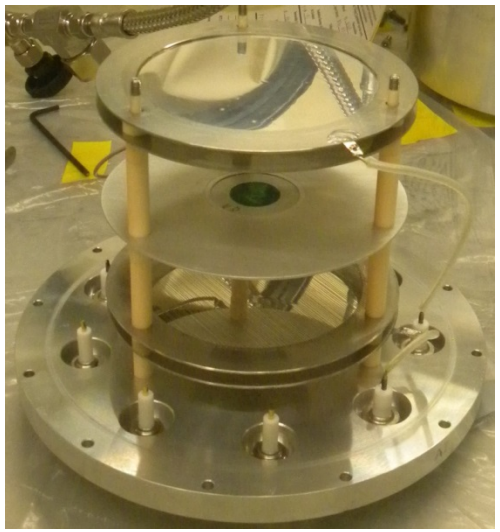
Fission Cross Sections
Fission Total Kinetic Energy
Fission Fragment Yields

Contact:
Fredrik Tovesson

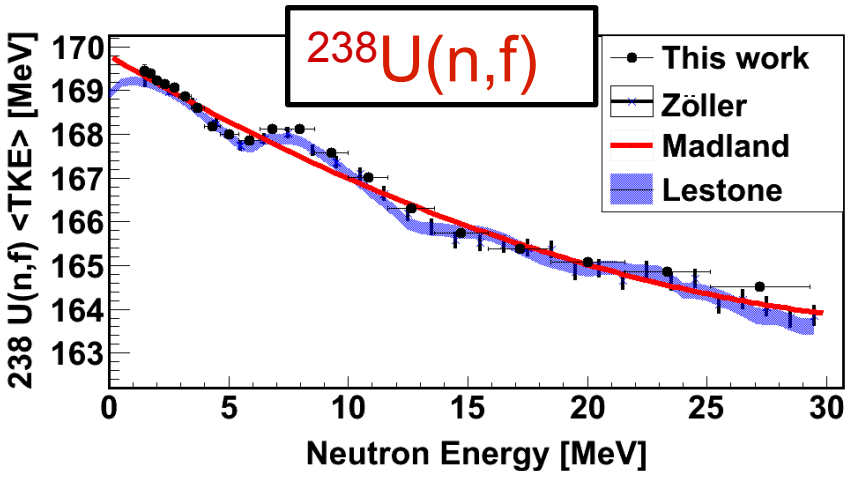
Frisch-gridded ionization chambers are used to measure fission fragment energy

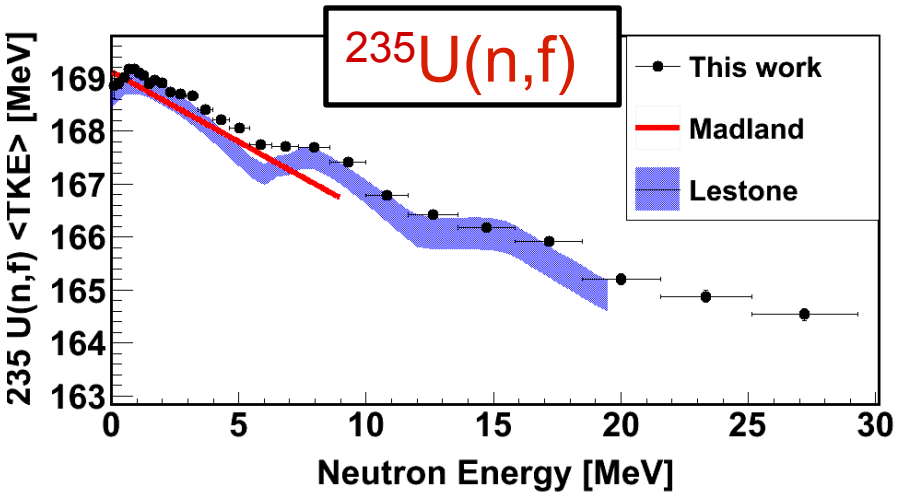
- **Provides excellent energy resolution for fission fragments**
  - Intrinsic resolution is 0.4-0.6%
  - Sample located inside active volume -> No energy loss through window
- **Collaboration with Joint Research Centers and Oregon State University**
  - Chamber built by Josch Hambsch at IRMM, Geel
  - Samples prepared by Walt Loveland at OSU
- **Three experiments at LANSCE with different isotopes**
  - 2012: U-238 measured with participation from IRMM
  - 2013: U-235 successfully measured, attempted Pu-239
  - 2014: Pu-239 successfully measured
- **Fission mass yields can also be calculated with low resolution using “2E” method**

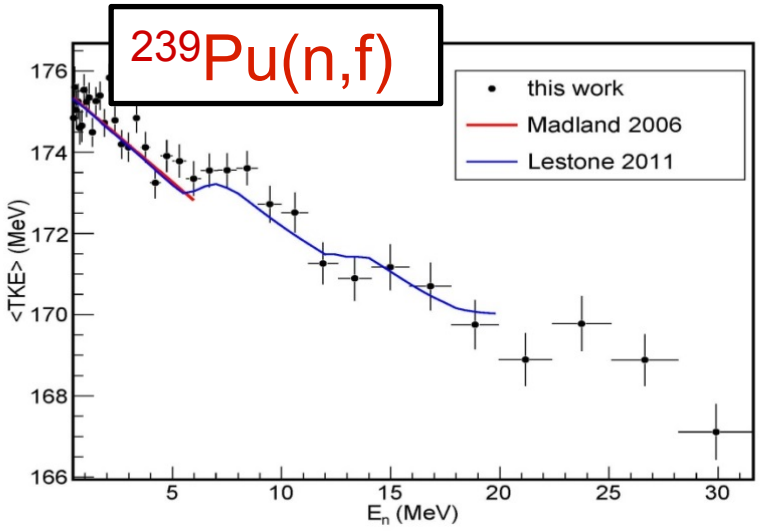




The experimental results are consistent with calculations by Lestone et al.

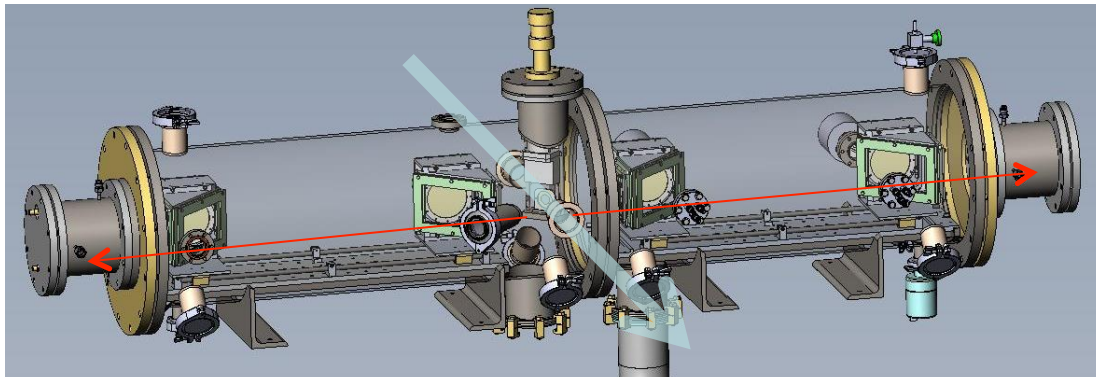




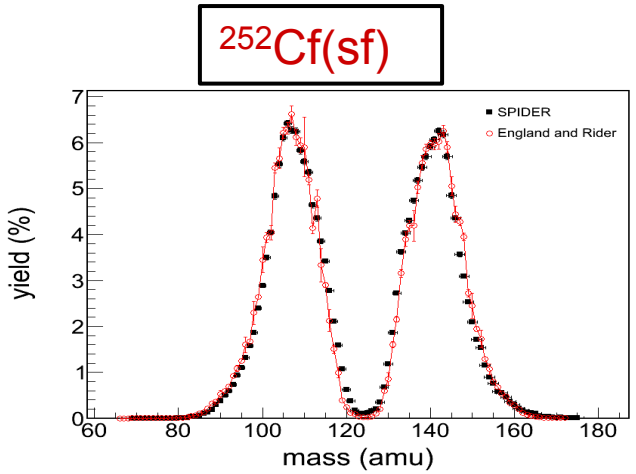


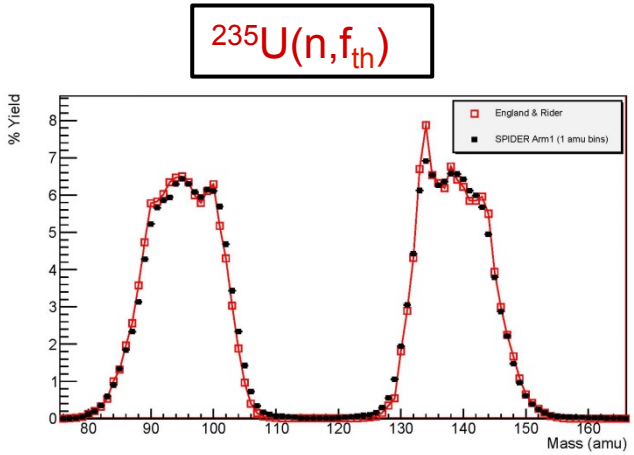
- **Zöller et al. data for U-238 extends beyond 30 MeV**
  - For U-235 no previous data above 9 MeV
  - For Pu-239 no data beyond 5 MeV
- **Madland evaluation is fit to experimental data**
  - Not intended for extrapolation
  - ENDF values for 14 MeV never the less are extrapolations
- **Semi-empirical modeling by Lestone et al. in close agreement with new data**
  - J.P. Lestone, T.T. Strother, Nuclear Data Sheets **118,** 208 (2014)

SPIDER measures fission product yields with high mass resolution



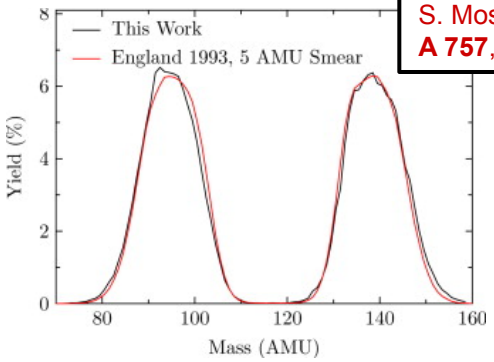
- The 2E-2v method can provide 1 amu resolution for light fragments
  - Demonstrated with Cosi-fan-Tutti at ILL
- SPIDER uses ionization chambers for energy measurement
  - 1% energy resolution for α-particles, 0.5% for fission fragments
  - Thin entrance window (Mylar or SiN)
- Fast, position sensitive TOF detectors
  - Micro-channel plates



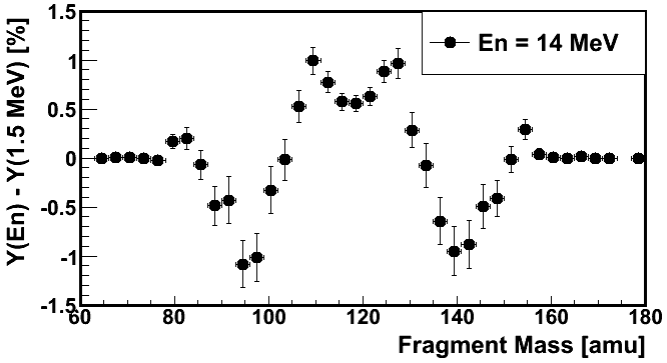


- K. Meierbachtol, F. Tovesson, D. Shields, *et al.*, *The SPIDER fragment spectrometer for fission product yield measurements*, Nucl. Instr. and Meth. A **788**, 59 (2015).
- C.W. Arnold, F. Tovesson, K. Meierbachtol, *et al.*, *Development of position-sensitive time-of-flight spectrometer for fission fragment research*, Nucl. Instr. and Meth. A **764**, 53 (2014).

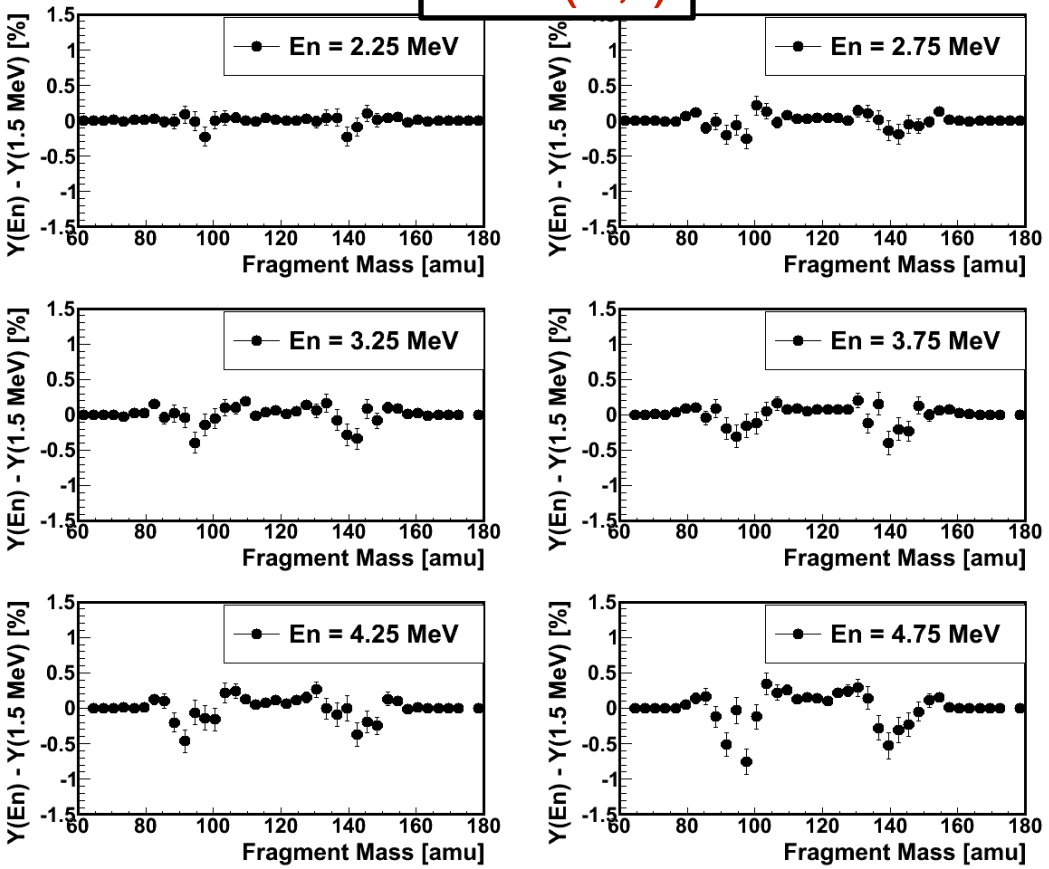
The 2E-method can be used to measure fission yields with low mass resolution



S. Mosby *et al.*, NIM **A 757**, 75 (2014).

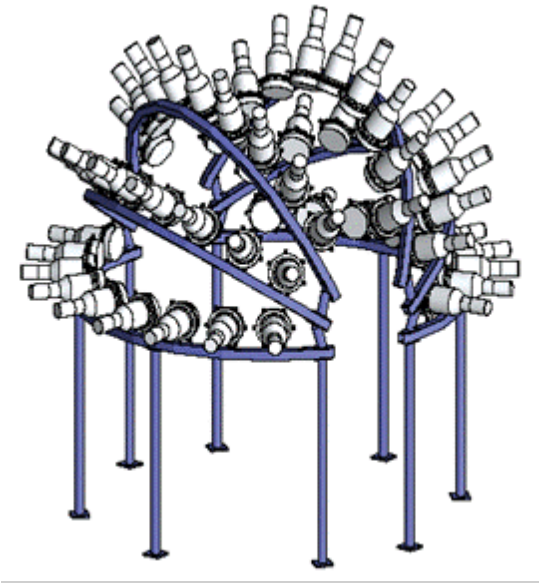


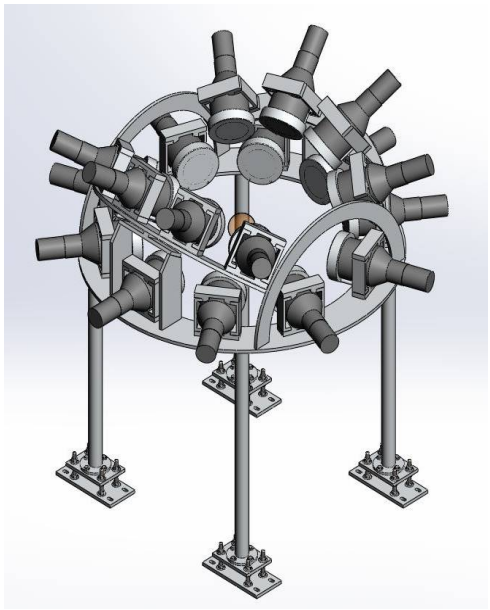
^{235}U(n,f)



- Fission product yields measured with TI chamber
  - ^{238}U: Completed
  - ^{235}U: Preliminary results
  - ^{239}Pu: Analysis in progress

Chi-Nu - Prompt fission neutron spectra





Contacts:
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Hye Young Lee
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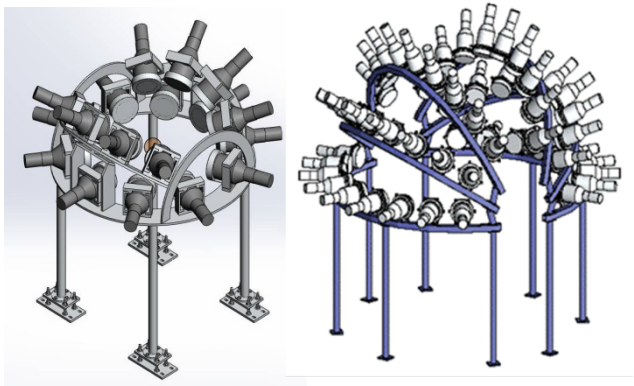
LLNL:
Ching-Yen Wu

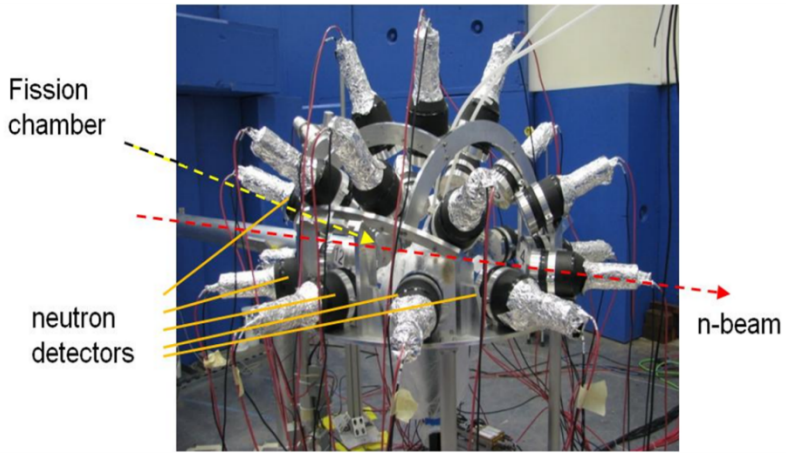
Approach – fast fission counter, two types of neutron detector arrays to cover fission neutron energy range

- WNR/LANSCE spallation neutron source – all neutron energies from 0.5 to 30 MeV and higher
- New building from LANS support
- Double time-of-flight
  - LANSCE spallation source to fission chamber → incident neutron energy
  - Fission chamber to neutron detector → fission neutron energy
- Multi-year project – thru FY2017
- Goal: a significant result for stockpile stewardship (i.e. with respect to the current nuclear data evaluations)

LLNL fission chamber

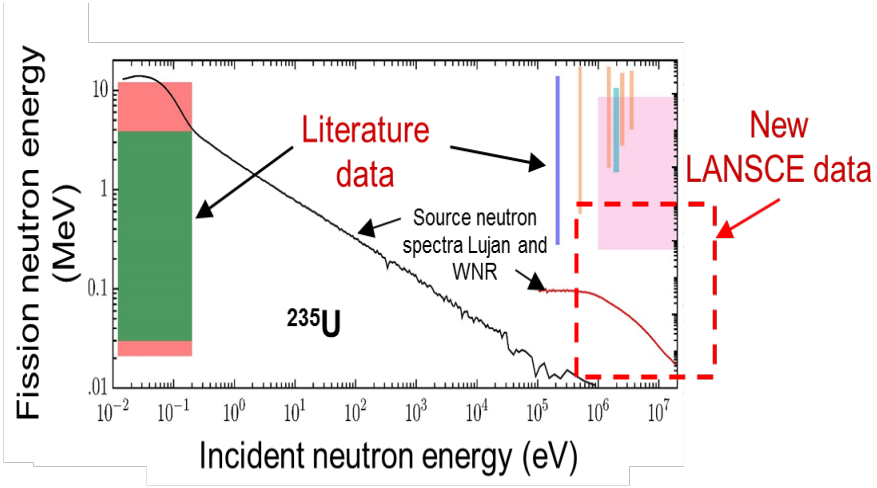
Two LANL neutron detector arrays

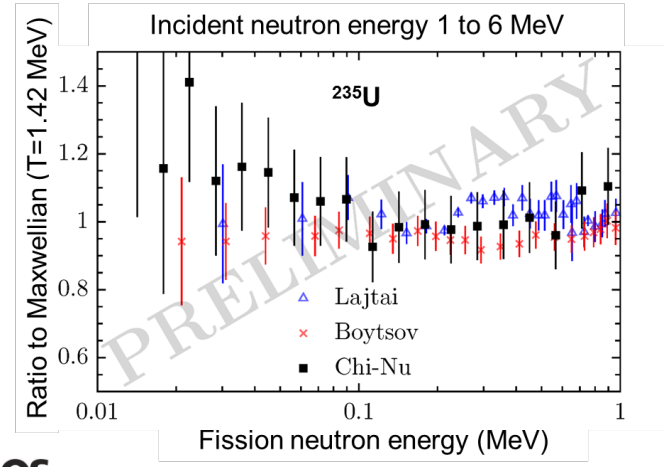




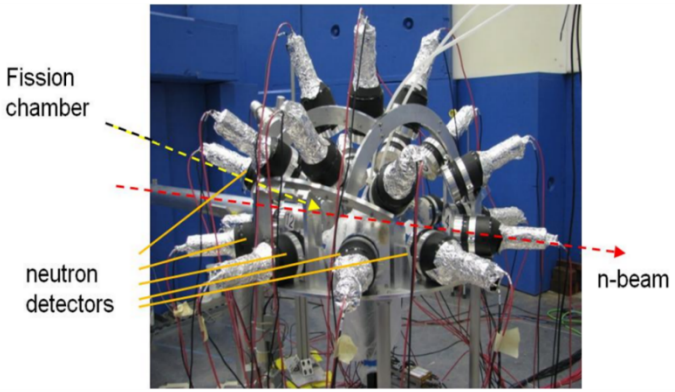
Prompt Fission Neutron Spectra Measurements at LANSCE obtain data in previously unexplored region

- New region of PFNS for fission induced by fast neutrons (above thermal) for ^{235}U(n,f).
- Measured PFNS ~ 50 keV to 1 MeV
- Preliminary analysis shows reasonable agreement with literature data obtained at thermal energy
- Next is full analysis of ^{235}U and then ^{239}Pu





^{6}Li-glass neutron detectors



Recent Publications

The LANL/LLNL Prompt Fission Neutron Spectrum Program at LANSCE and Approach to Uncertainties, D. Neudecker, P. Talou, T.N. Taddeucci, R.C. Haight, T. Kawano, H.Y. Lee, D.L. Smith, R. Capote, M.E. Rising, and M.C. White, R.C. Haight, C.Y. Wu, H.Y. Lee, T.N. Taddeucci, B.A. Perdue, J.M. O'Donnell, N. Fotiades, M. Devlin, J.L. Ullmann, T.A. Bredeweg, M. Jandel, R.O. Nelson, S.A. Wender, D. Neudecker, M.E. Rising, S. Mosby, S. Sjue, M.C. White, B. Bucher, and R. Henderson, Nucl. Data Sheets **123**, 130 (2015).

The LANL/LLNL Prompt Fission Neutron Spectrum Program at LANSCE and Approach to Uncertainties, R.C. Haight, C.Y. Wu, H.Y. Lee, T.N. Taddeucci, B.A. Perdue, J.M. O'Donnell, N. Fotiades, M. Devlin, J.L. Ullmann, T.A. Bredeweg, M. Jandel, R.O. Nelson, S.A. Wender, D. Neudecker, M.E. Rising, S. Mosby, S. Sjue, M.C. White, B. Bucher, and R. Henderson, Nucl. Data Sheets 123, 130 (2015).

Multiple-scattering Corrections to Measurements of the Prompt Fission Neutron Spectrum, T.N. Taddeucci, R.C. Haight, H.Y. Lee, D. Neudecker, J.M. O'Donnell, M.C. White, B.A. Perdue, M. Devlin, N. Fotiadis, J.L. Ullmann, R.O. Nelson, T.A. Bredeweg, M.E. Rising, S.K. Sjue, S.A. Wender, C.Y. Wu, and R. Henderson, Nuclear Data Sheets **123**, 135 (2015).

The need for new and precise experimental data on Prompt Fission Neutron Spectra from neutron-induced fissions of 239Pu, D. Neudecker,T.N. Taddeucci, R.C. Haight, H.Y. Lee, M.C. White, and M.E. Rising, Nuclear Data Sheets (invited, in preparation).

LANL-LLNL Chi-Nu Collaboration Team

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- US DOE
  - NNSA
  - Nuclear Energy University Programs
  - Nuclear Physics
- LANL - LDRD

Thank you!!!