

Nuclear Data Experiments at LANSCE: Highlights 2011

**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 15-17, 2011**

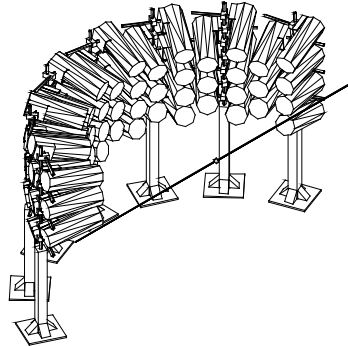
LA-UR-11-06216

Nuclear data measurements at LANSCE are made with several instruments

GEANIE (n, γ)



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



DANCE (n, γ)

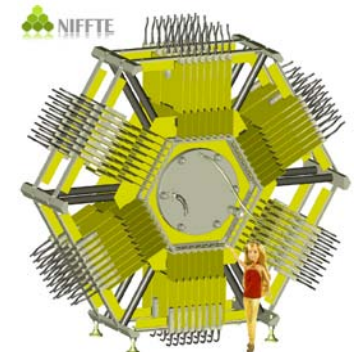
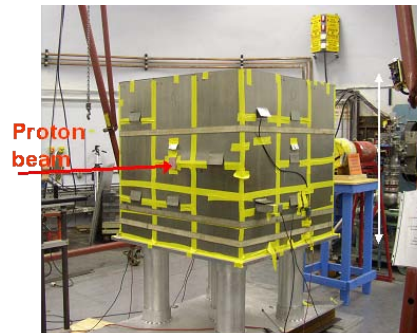


N,Z (n,charged particle)

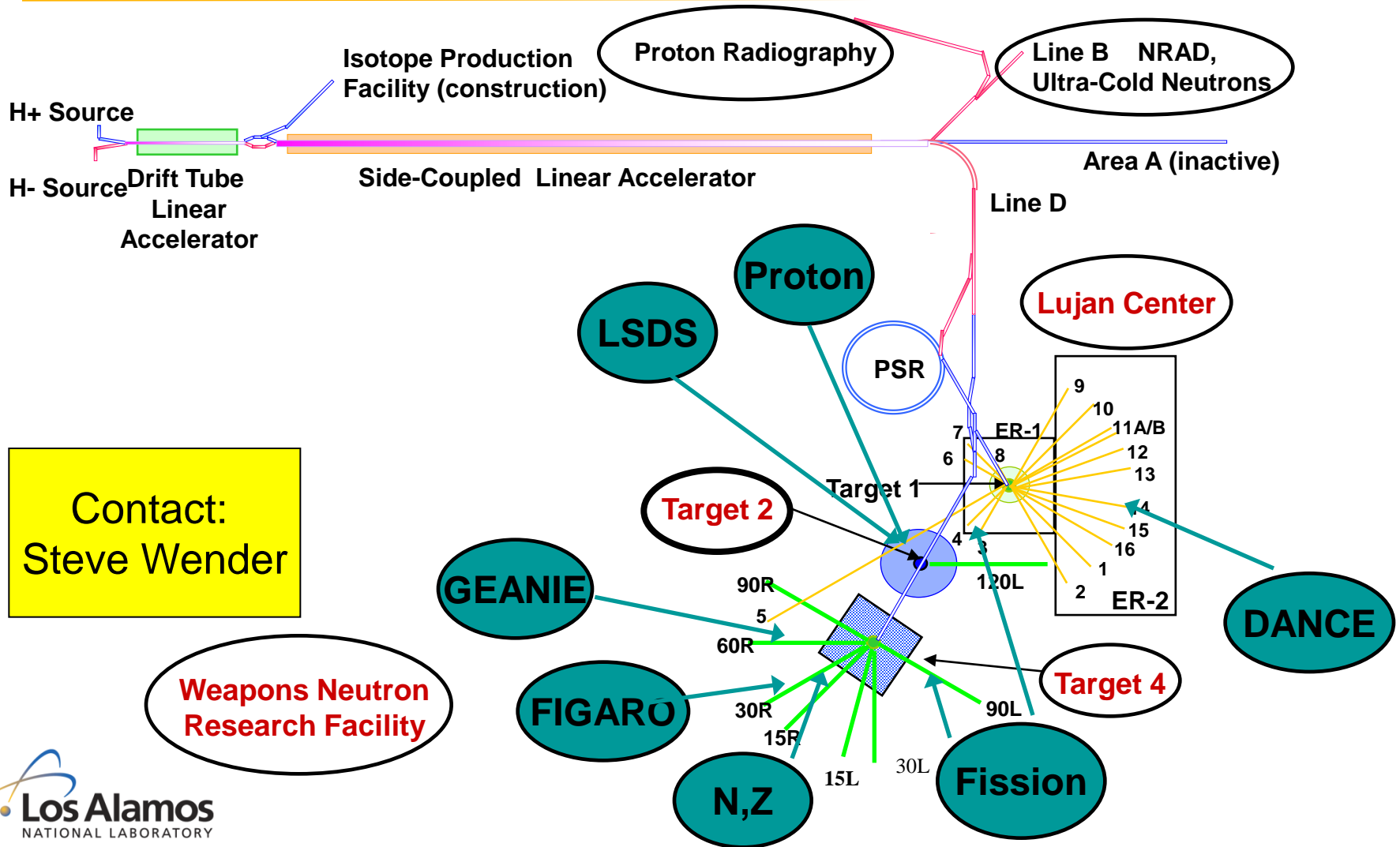


Fission

Double Frisch-grid fission chamber; standard fission ion chamber;
Time Projection Chamber; SPIDER; LSDS

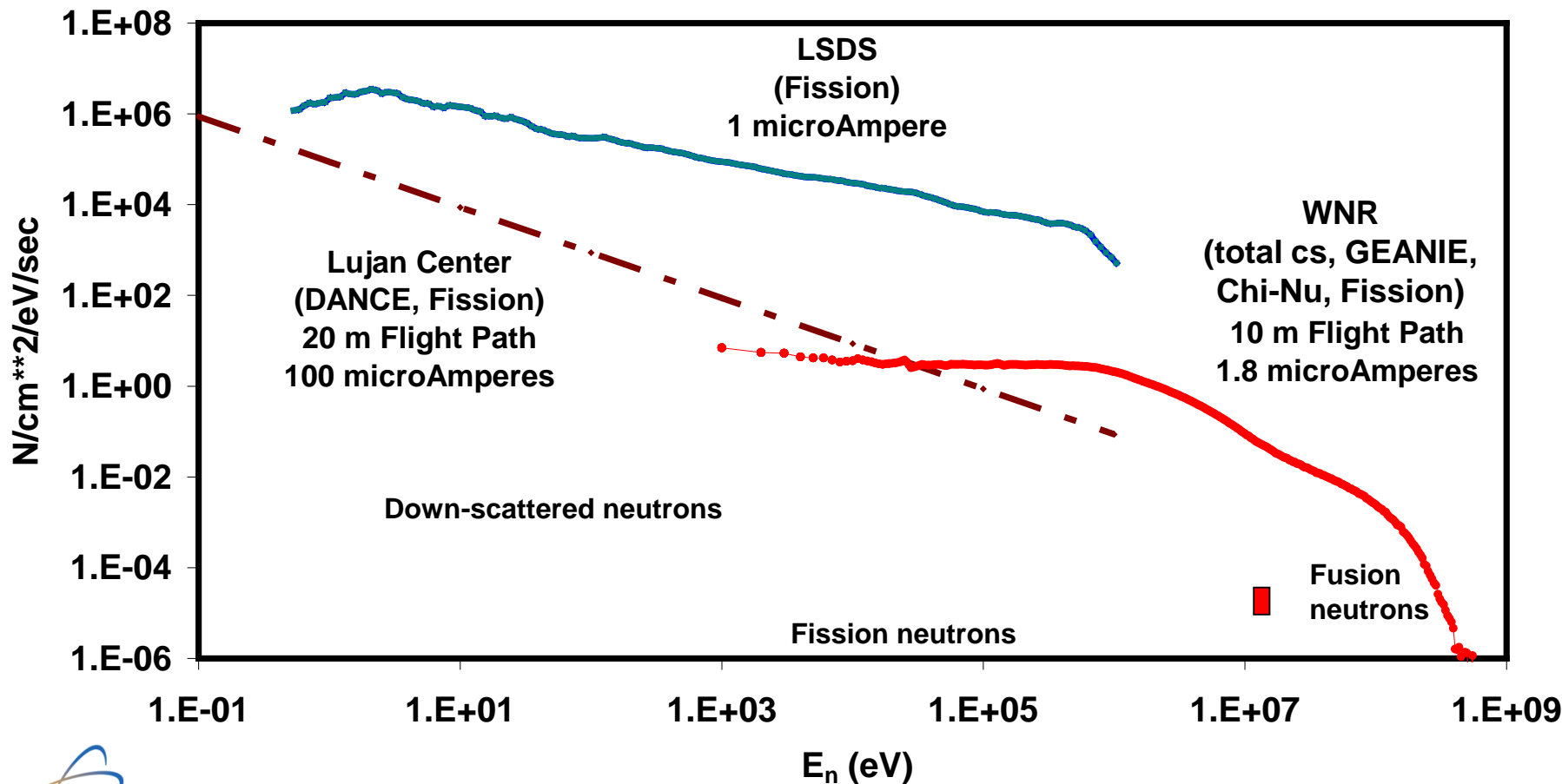


Nuclear data experiments at LANSCE use neutrons at the Lujan Center, Target 2 and Target 4

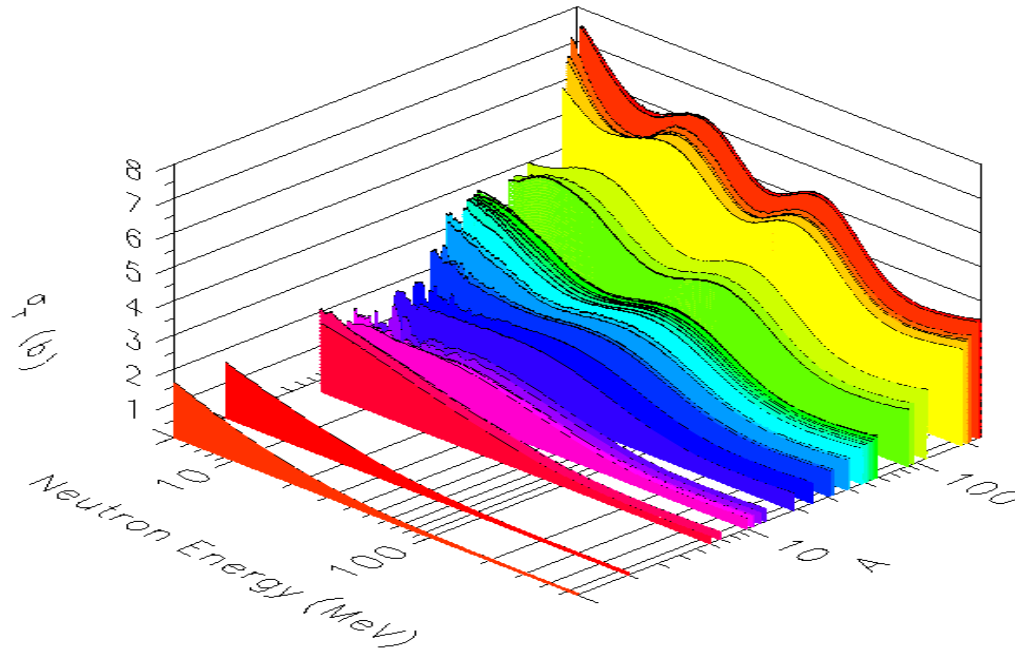


LANSCCE neutron sources cover the full range for fission and fusion applications

LANSCCE Neutron sources



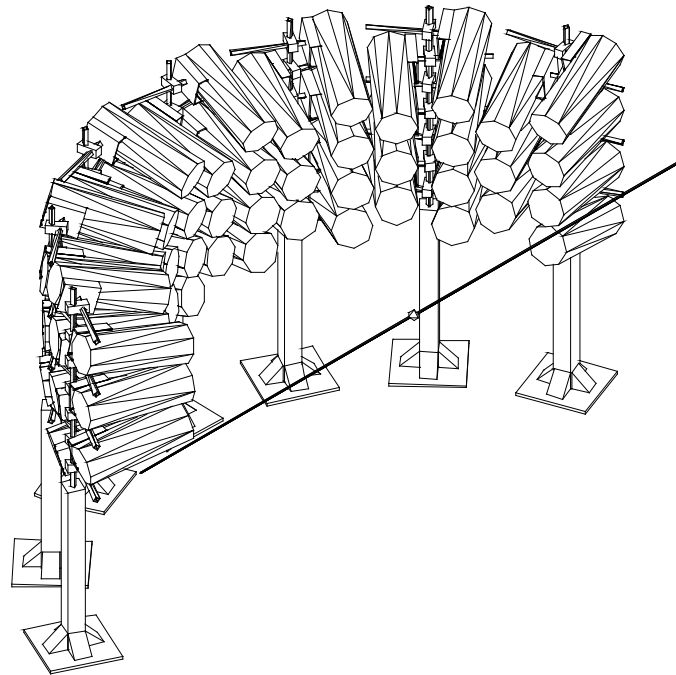
Total Cross Sections



Dormant this year; possible measurements with small samples in future – viz. 2.7 g samples of ^{48}Ca

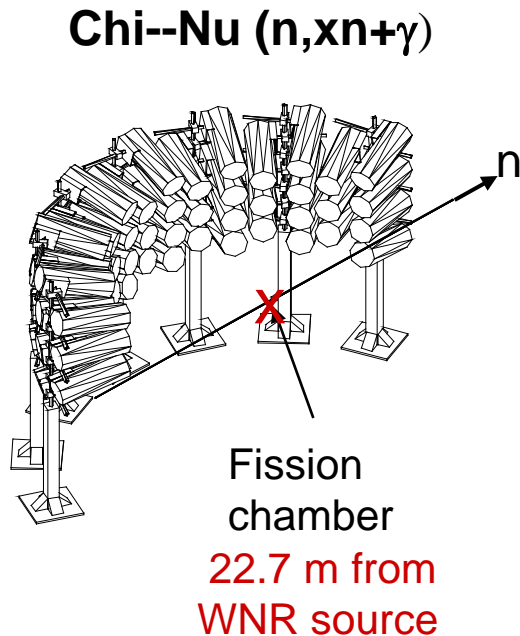
Contact:
Matt Devlin

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



Contacts:
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Terry Taddeucci
Hye Young Lee
Brent Perdue
Ron Nelson
Matt Devlin

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



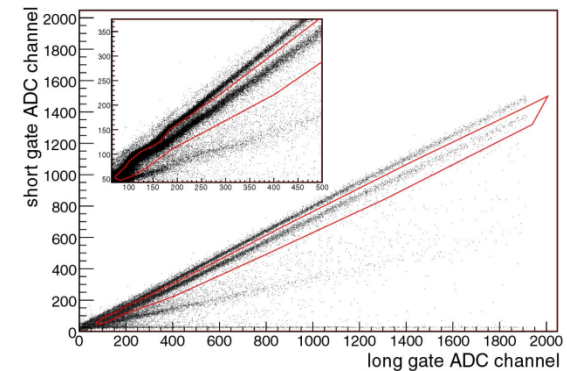
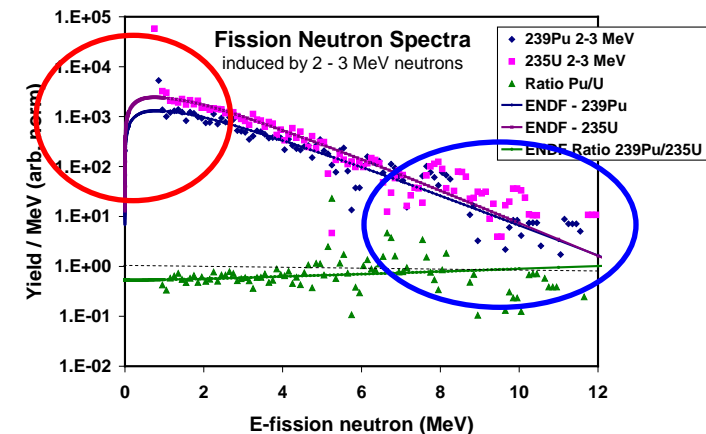
- 20 liquid scintillator neutron detectors
- 2 gamma-ray detectors

Double time-of-flight experiment

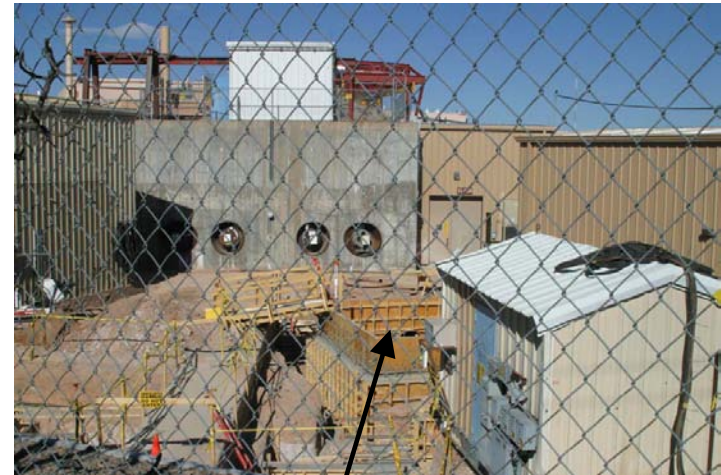
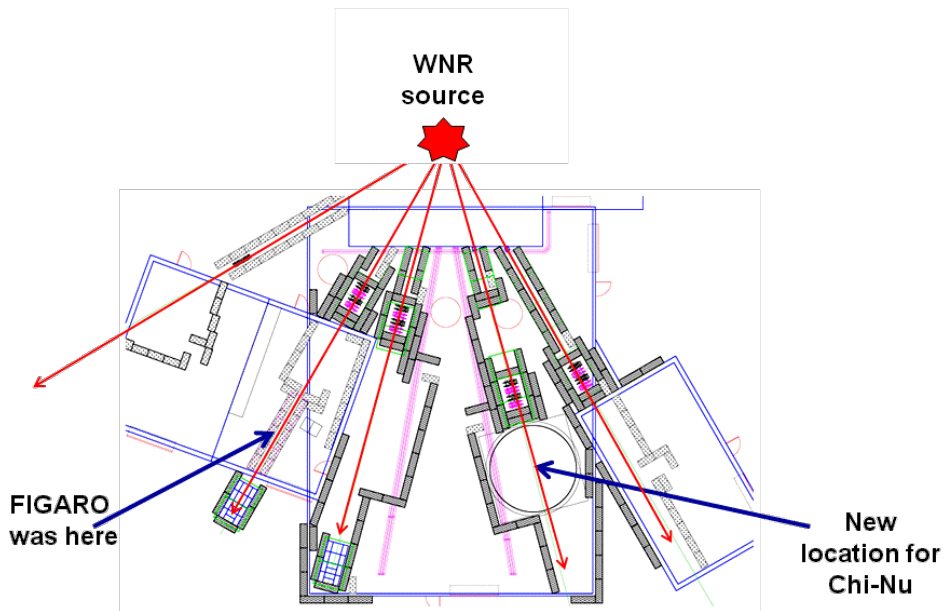
Program of fission neutron output measurements continues

- Measure fission neutrons below 0.6 MeV
 - ^6Li -glass detectors
 - Room-return is an issue → new flight path
- Measure fission neutrons better above 8 MeV
 - Better timing on fission chamber (LLNL-LANL collaboration)
 - More efficient neutron detectors (larger solid angle for detection)
 - Lower background
- Neutron detector efficiency
 - ^{252}Cf
 - Tagged neutrons
- Digitizer DAQ

S. Noda et al., Phys. Rev. C 83, 034604 (2011).



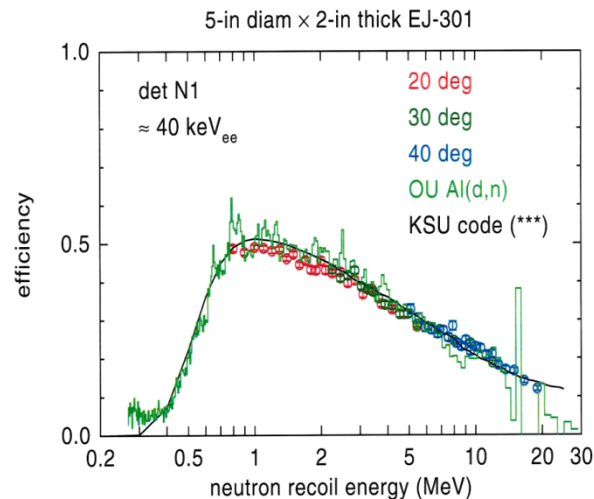
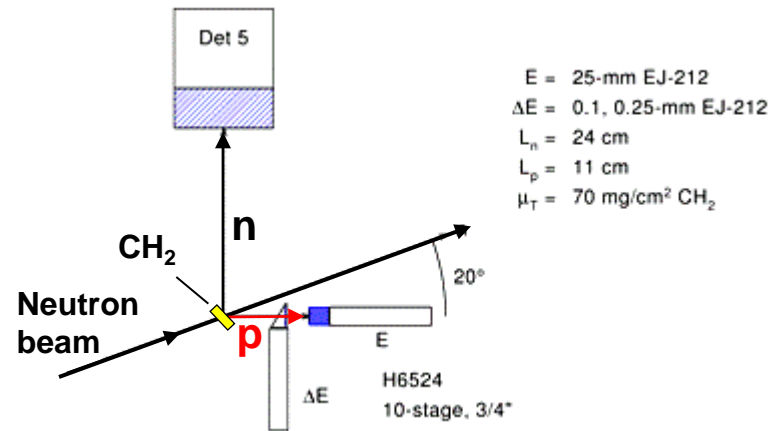
New flight path and building for measuring fission neutron spectra



2-meter deep pit under fission chamber to reduce scattering from floor

“Tagged neutrons” are used to measure detector efficiency for neutrons from 1 MeV to more than 20 MeV

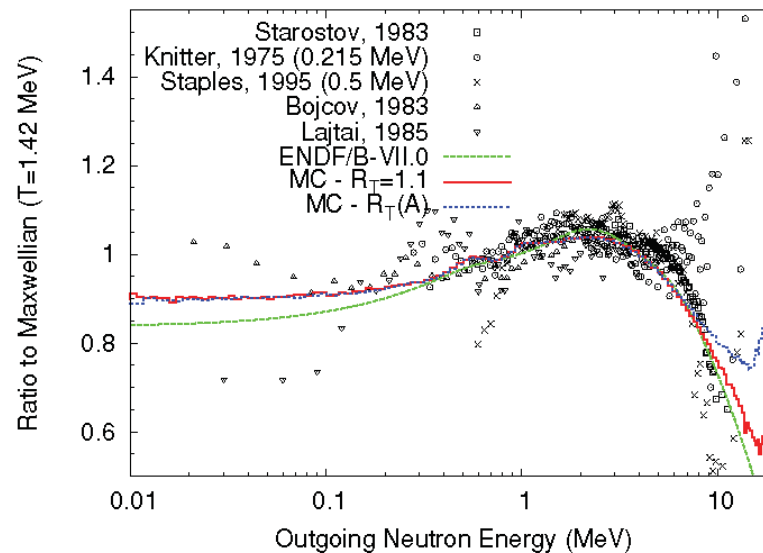
- Scatter neutrons from CH_2
- Detect recoil protons from n-p scattering
- Scattered neutrons go at the complementary angle on the other side of the beam
- For each detected proton, there is exactly one neutron incident on the detector



Target accuracy for PFNS is 5%

- Statistical and systematic errors assessed in LA-UR-11-05576
 - To assess contribution of background needs new building

ADVANCED MONTE CARLO MODELING OF PROMPT ...



P. Talou et al.,
PRC 83, 064612
(2011)

FIG. 11. (Color online) Same as Fig. 10 but shown as a ratio to a Maxwellian at temperature 1.42 MeV.

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

See results for Cr, Fe, ${}^{58,60}\text{Ni}$ (Kunieda)

Contact:
Bob Haight

GEANIE (n,x γ)

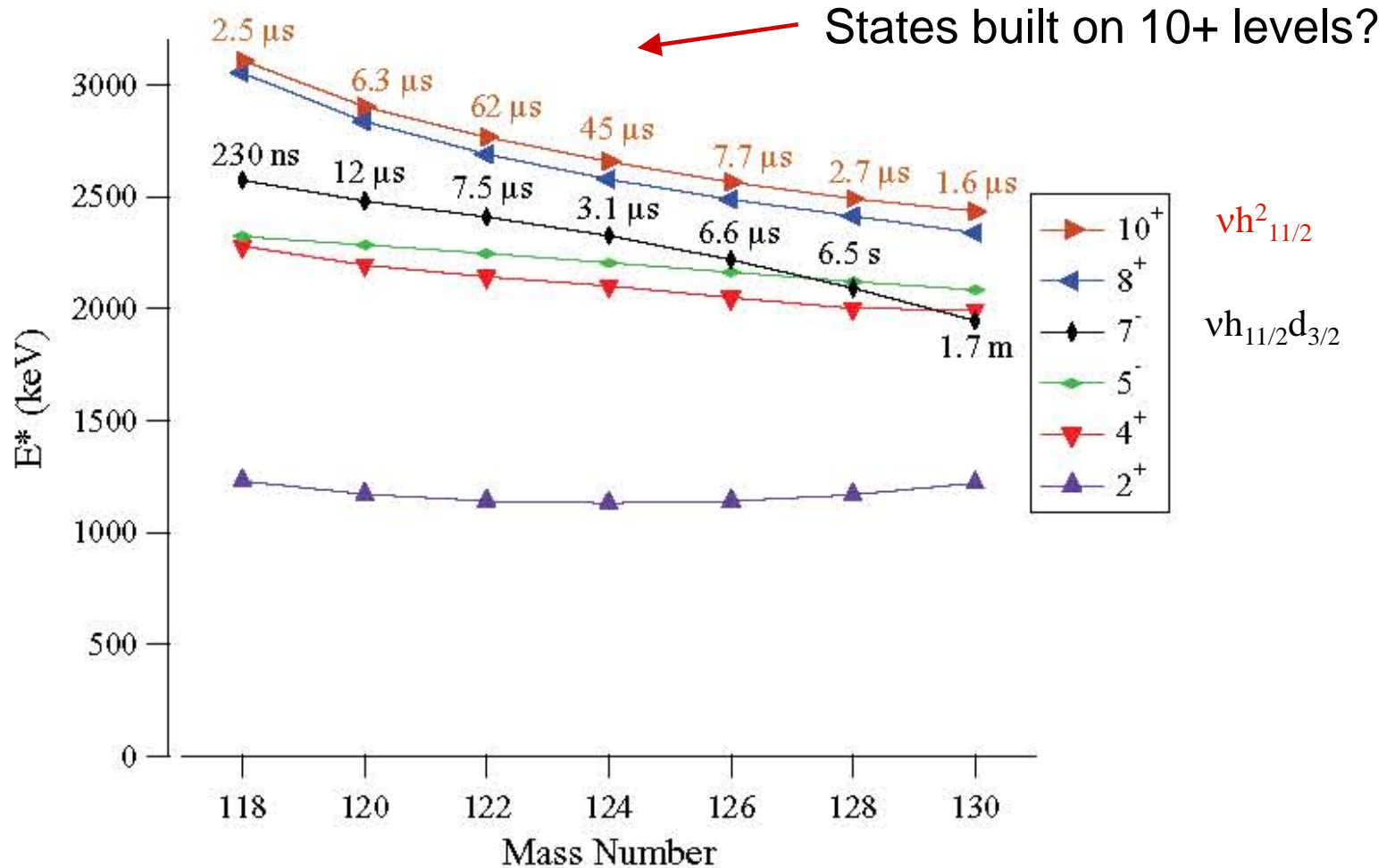


Contacts:
Ron Nelson
Nik Fotiades
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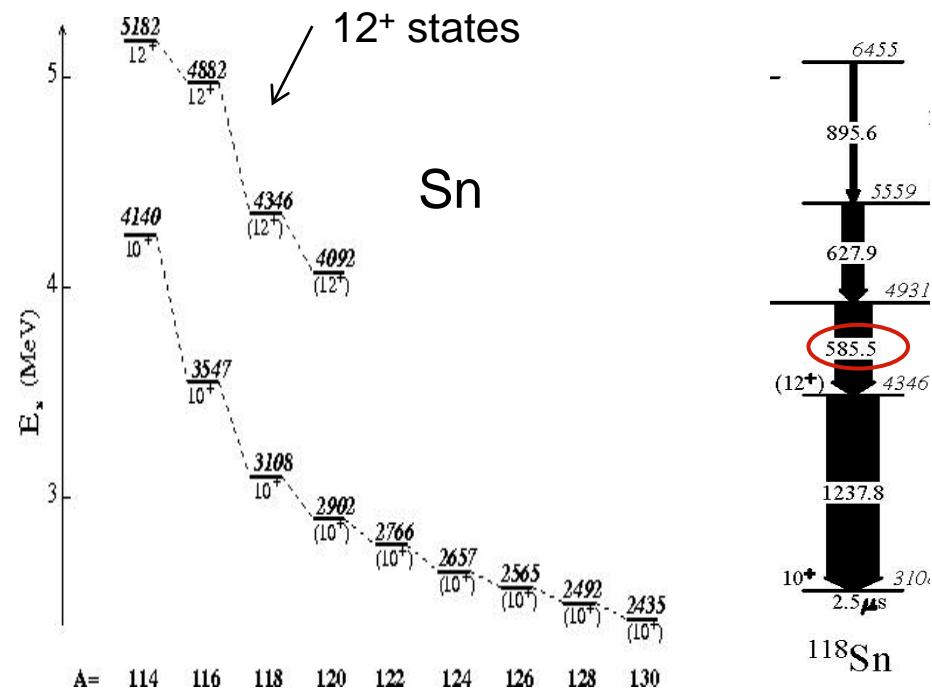
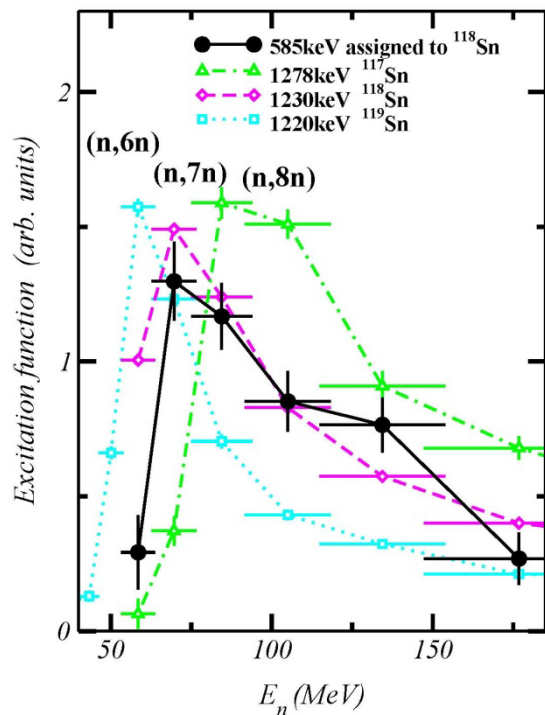
GEANIE measurements FY2011

- **Sn → structure of $^{118,120}\text{Sn}$**
 - combine GEANIE and GAMMASPHERE experiments
- **Cu(n,xn γ), x = 1,2,... and Ar(n,xn γ), x=1,2,... for double-beta decay experiments (Mitzi Boswell and Sean Macmullin (NCSU))**
- **$^{86}\text{Kr}(n,xn\gamma)$, x= 1,2,... (Matt Devlin)**
- **Nal(n,xn) for data libraries (Nikolaos Fotiades)**
- **Various elements for a neutron-induced gamma-production standards (Ron Nelson) and x-ray yield from n-induced fission (R. Nelson and Thierry Granier - CEA)**

Systematics in even-A Sn isotopes



γ -ray excitation functions from $^{124}\text{Sn}(n,xn)$ GEANIE experiment are used to identify residual nuclei



Excitation energies of the candidate 12^+ states in good agreement with shell model predictions from A. Insolia et al., Nucl. Phys. A 550, 34 (1992):

$^{116}\text{Sn} \sim 4.8\text{MeV}$, $^{118}\text{Sn} \sim 4.3\text{MeV}$, $^{120}\text{Sn} \sim 4.05\text{MeV}$

DANCE (n, γ)



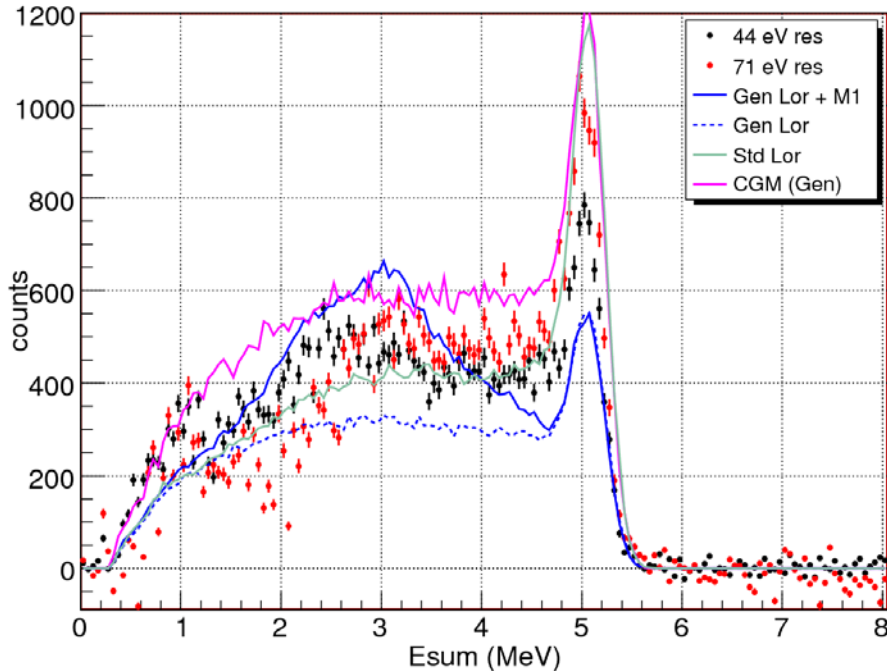
Contacts:
John Ullmann
Aaron Couture

DANCE research in 2011

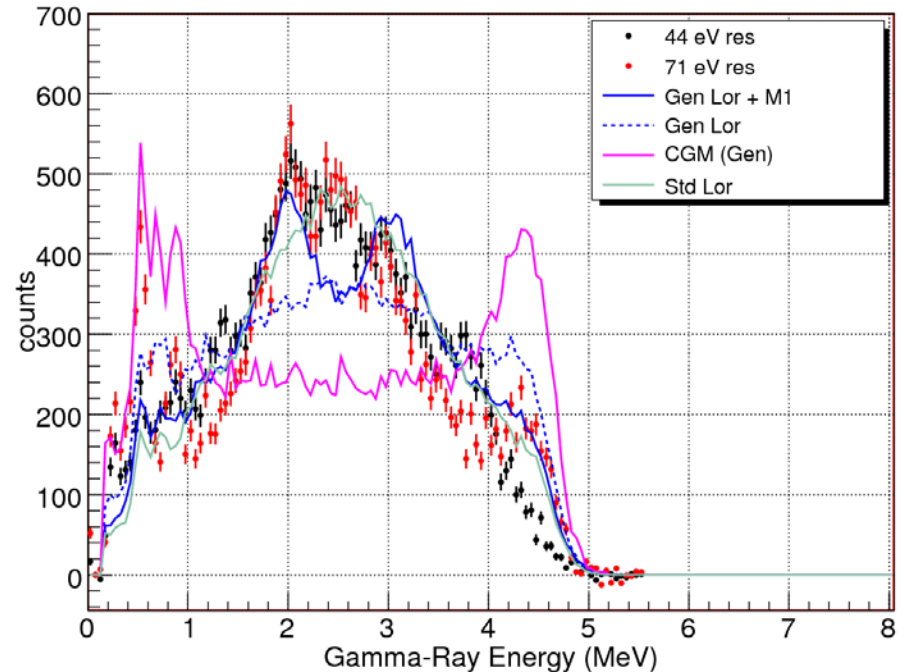
- 152,154,155,156,158Gd Bayarbadrakh Baramsai, NCSU/LANL - in progress.
- 97Mo Carrie Walker, NCSU PhD dissertation, in progress
- 184,186W Capture, Marian Jandel LANL (in progress)
- 191,193Ir Capture; Todd Bredeweg LANL
- 233,235U,239,241Pu Capture to fission: LANL, LLNL In progress
- 239,241Pu Fission gamma ray multiplicity and spectra: LANL/LLNL (Prelim 239Pu reported)
- 238Pu Capture, capture/fission: LLNL
- 252Cf Fission gamma multiplicity and spectra: LLNL
- 242m,243Am Capture, Marian Jandel LANL (Prelim report)
- 238U Capture xsec, gamma rays John Ullmann LANL (prelim. report)

Spectra – $^{236}\text{U}(n,\gamma) M_{\text{Cl}} = 2$

Summed Energy



Gamma-ray Energy



Spectra normalized to 44 eV resonance
Q value window: 5.13 ± 0.5 MeV
 E_{crit} in Dicebox Simulation: 0.600 MeV
Target: 1.29 mg/cm^2 ($r=0.35$ cm) 90%

Neutron capture gamma rays with HPGe to test surrogate reactions (non-DANCE)

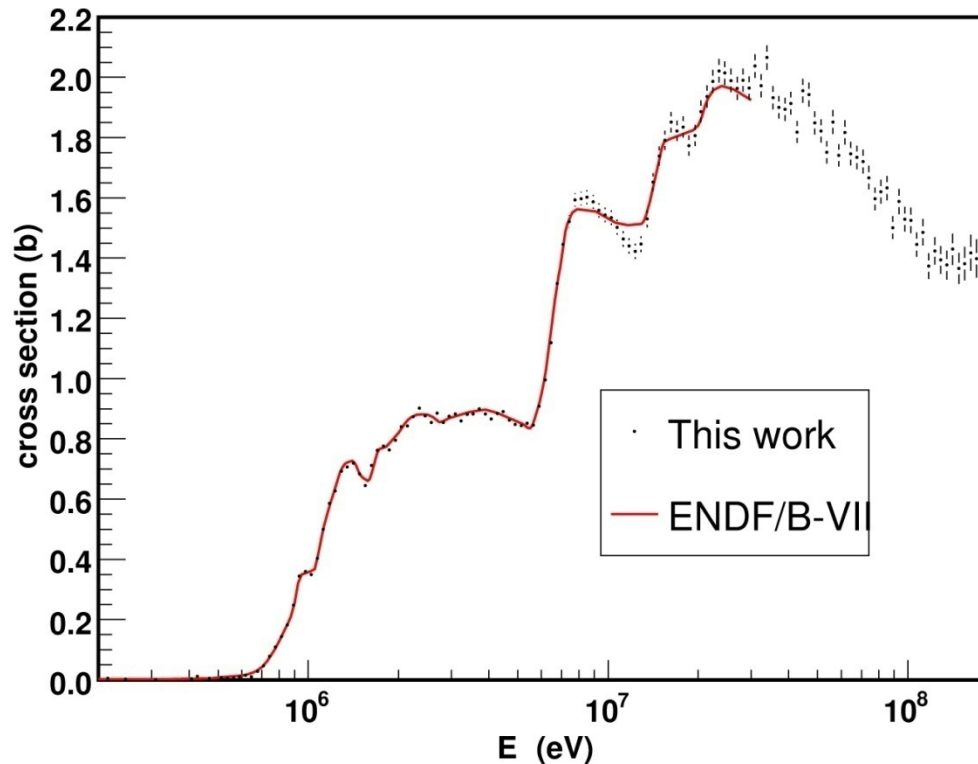
- $^{95}\text{Mo}(n,\gamma)$ for $E_n < 100$ keV
 - compare $^{95}\text{Mo}(d,p\gamma)$

J. Cizewski (Rutgers) et al.

Fission Cross Sections

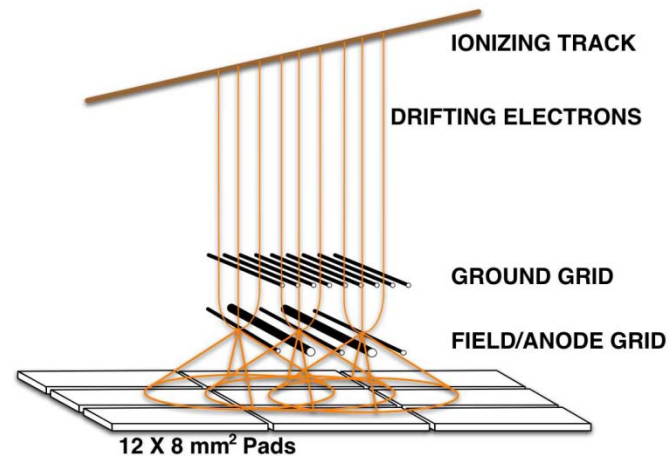
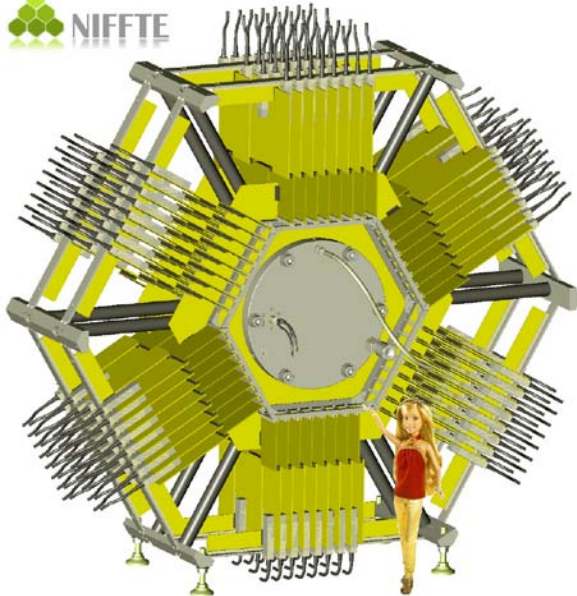
Contacts:
Fredrik Tovesson
Alexander Laptev

The U-236 fission cross section was measured from threshold to 200 MeV



- The U-236(n,f) was measured as part of a suite of uranium isotopes.
- U-233,238 were previously measured at LANSCE.
- U-234 is planned for FY12.

The Fission Time Projection Chamber (TPC) will provide cross sections with unprecedented accuracy



- **3D pictures of particle tracks**
 - sample uniformity
 - beam uniformity
 - efficiency
 - erases decay / light charged-particle background
- **“Absolute” fission cross sections**



FCR&D is funding 6 participating universities

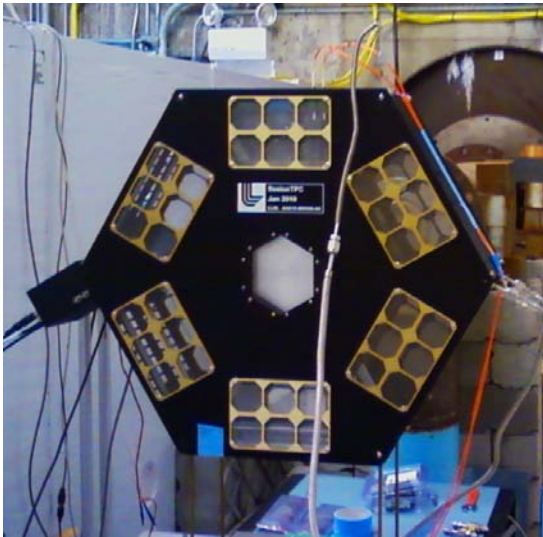
- Abilene Christian University (*Rusty Towell, Donald Isenhower*)
- Cal Poly San Luis Obispo (*Jenn Klay*)
- Colorado School of Mines (*Uwe Greife*)
- Georgia Tech (PI) (*Nolan Hertel, Eric Burgett*)
- Ohio University (*Tom Massey, Steve Grimes*)
- Oregon State (*Walt Loveland*)

FCR&D & NNSA provides lab funding

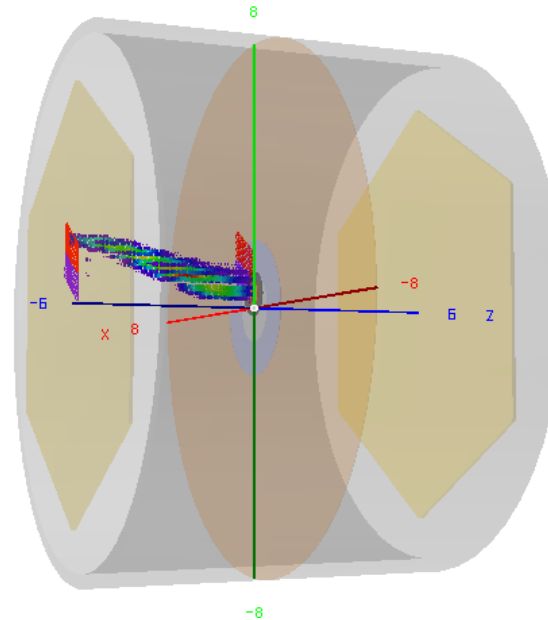
- Lawrence Livermore National Laboratory (*Mike Heffner*)
- Los Alamos National Laboratory (*Fredrik Tovesson, Alexander Laptev*)
- Idaho National Laboratory (*Tony Hill, Chris McGrath*)

First beam measurements with the fission Time Projection Chamber (TPC)

Prototype TPC on LANSCE flight path



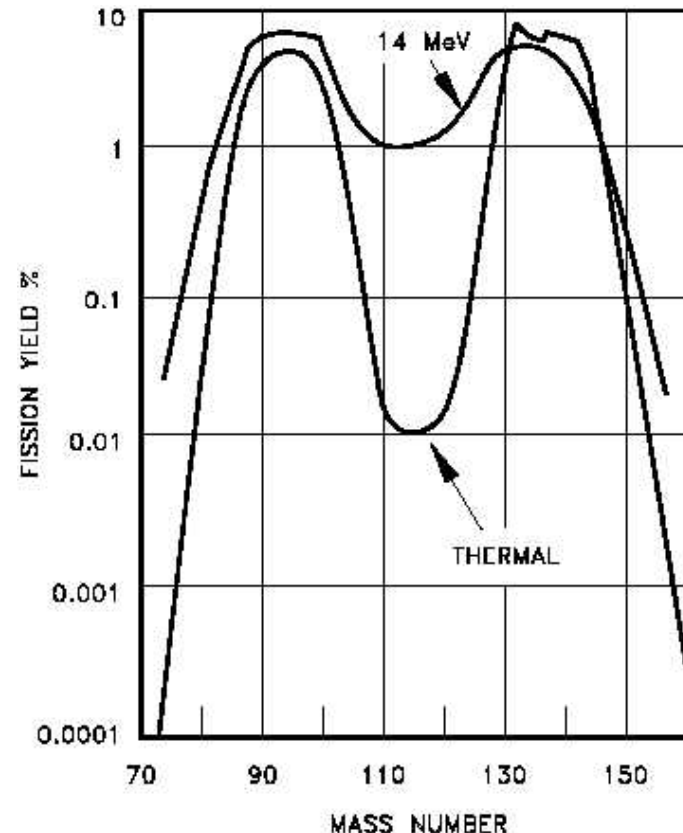
Fission fragment track from U-238 neutron induced fission



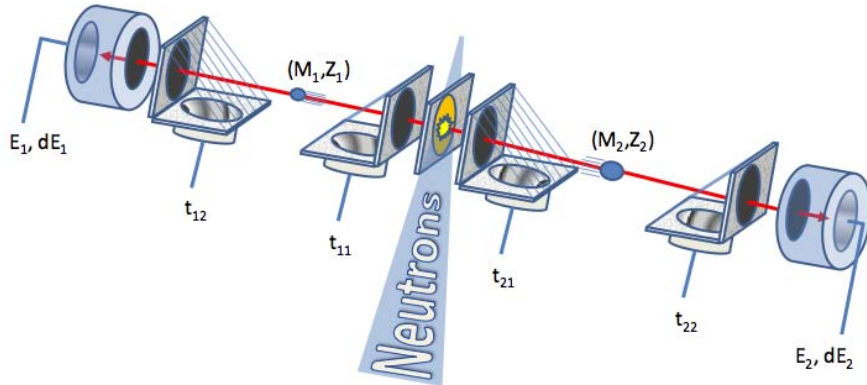
- First beam tests at LANSCE-WNR July-Dec. 2010
- 2 card (64ch) and 6 card (192 ch) data collected
- New measurements starting at LANSCE in Nov. 2011

A new approach to measuring fission product yields is being developed

- The LDRD program funded a feasibility study in FY2011 to investigate fission product yields. The projects includes scientists from the XCP, LANSCE ,T, and C divisions
- Most previous measurements of independent yields have were performed with low mass resolution.
- Only limited data exist for fast neutrons, and only a few isotopes were measured.
- Fission product yields are important for applications and basic science.
- The proposal includes a fission fragment spectrometer to be installed at LANSCE
- A full LDRD project is funded for FY2012

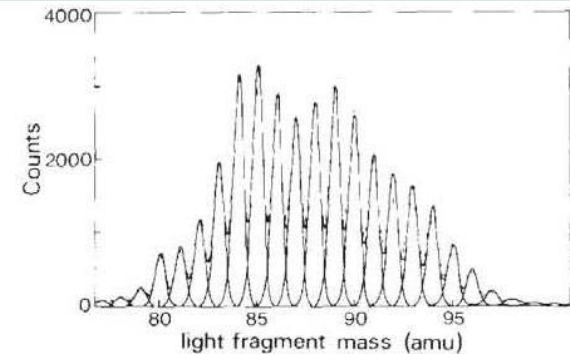


Spectrometer for ion species determination in fission research (SPIDER)

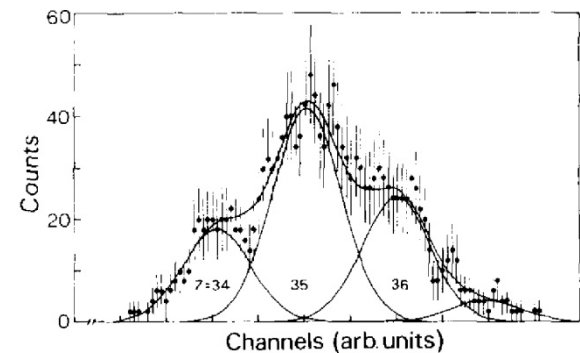


- New project at LANSCE to measure fission product yields
- Instrument based on the 2V-2E method for mass determination
- Bragg spectroscopy for charge measurements
- Goal is to achieve enough efficiency to measure energy dependent yields for fast neutrons

FPY measured with COSI-FAN-TUTTE



Nuclear charge distribution for A=87



Fission Cross Sections on small samples Lead Slowing-Down Spectrometer

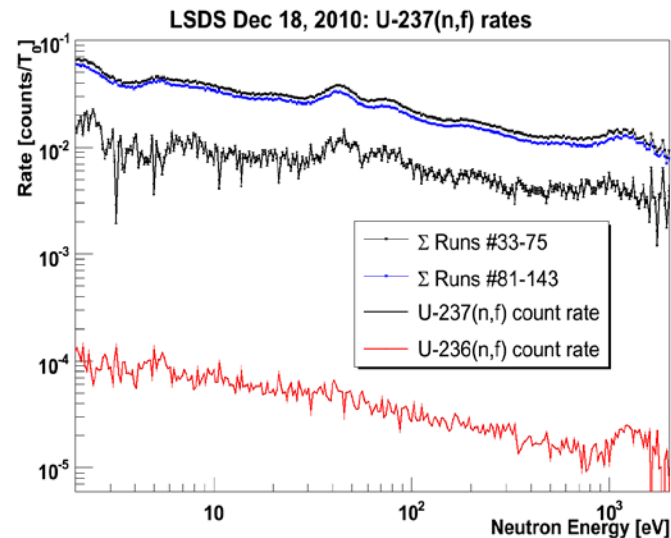
^{237}U (6.7 d) (n,f) from
thermal to ~ 5 keV



Contact:
Marian Jandel

LSDS – $^{237}\text{U}(n,f)$ measurement (in progress)

- ^{237}U – $T_{1/2} = 6.75$ days
- Preliminary results based on a difference count rate spectra
- U-236: 239 μg U6
- U-237: $M(t) = 2\mu\text{g}(1 - e^{-\lambda t})$
- Background run in 7/2011



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
 - 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!