Nuclear Data Experiments at LANSCE: Highlights 2010

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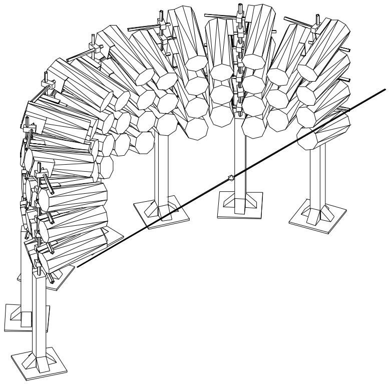
Cross Section Evaluation Working Group Meeting
US Nuclear Data Program Meeting
Santa Fe, NM
November 1-3, 2010

LA-UR-10-07331

Nuclear data measurements at LANSCE are made with several instruments

GEANIE (n,xγ)

FIGARO (n,xn+γ)

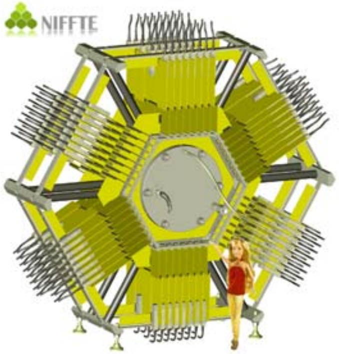


DANCE (n,γ)

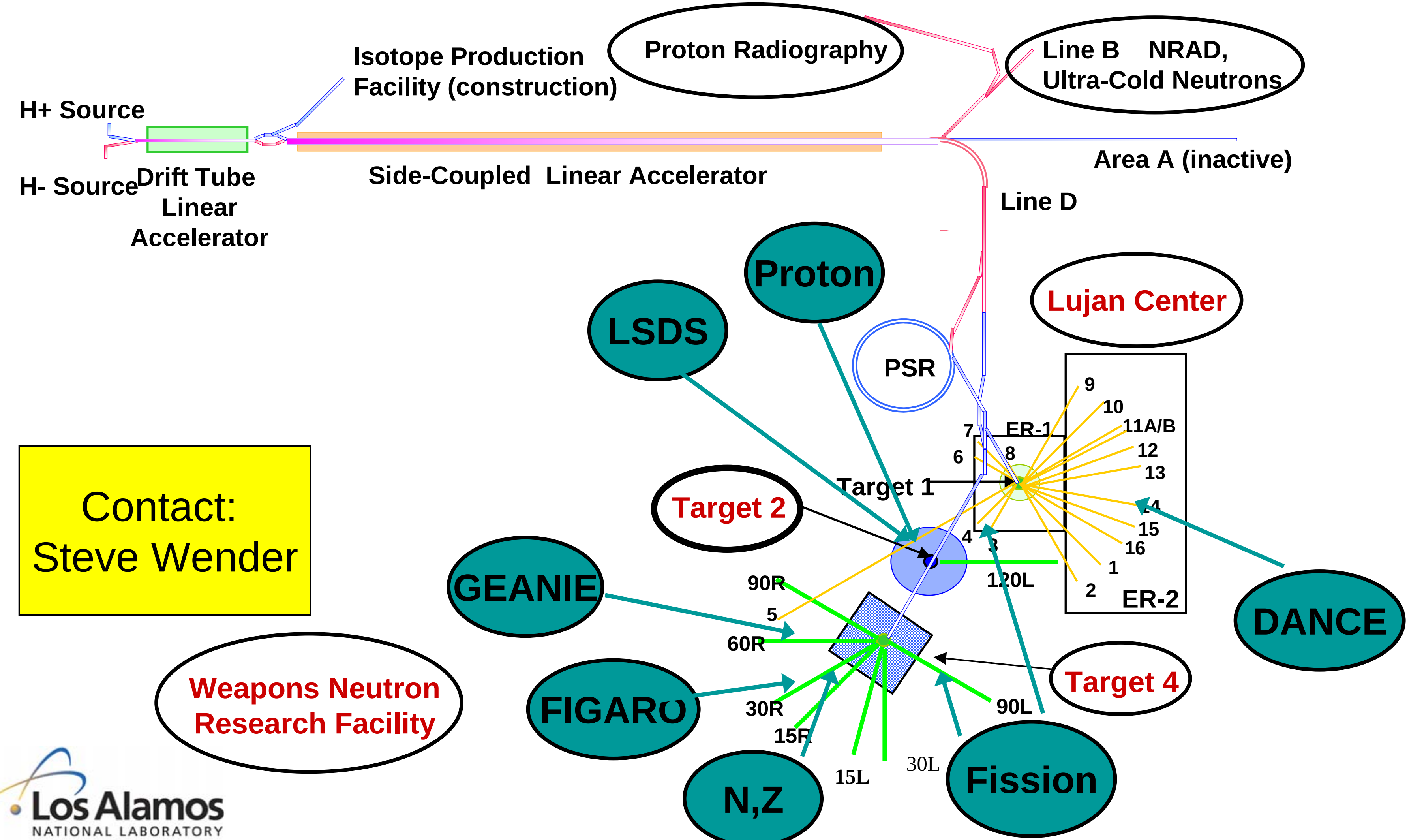
N,Z (n,charged particle)

Fission

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

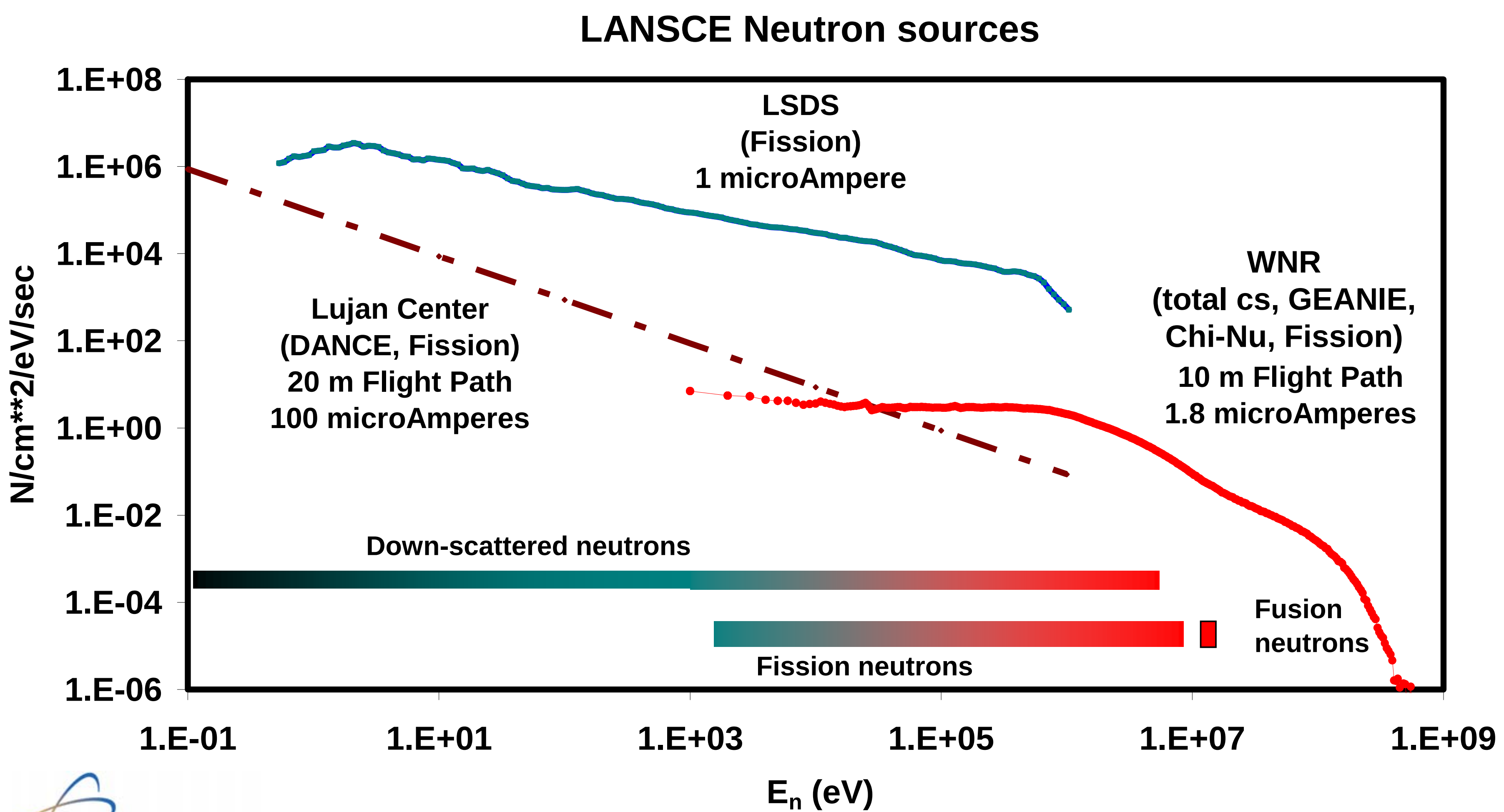


Nuclear data experiments at LANSCE use neutrons at the Lujan Center, Target 2 and Target 4

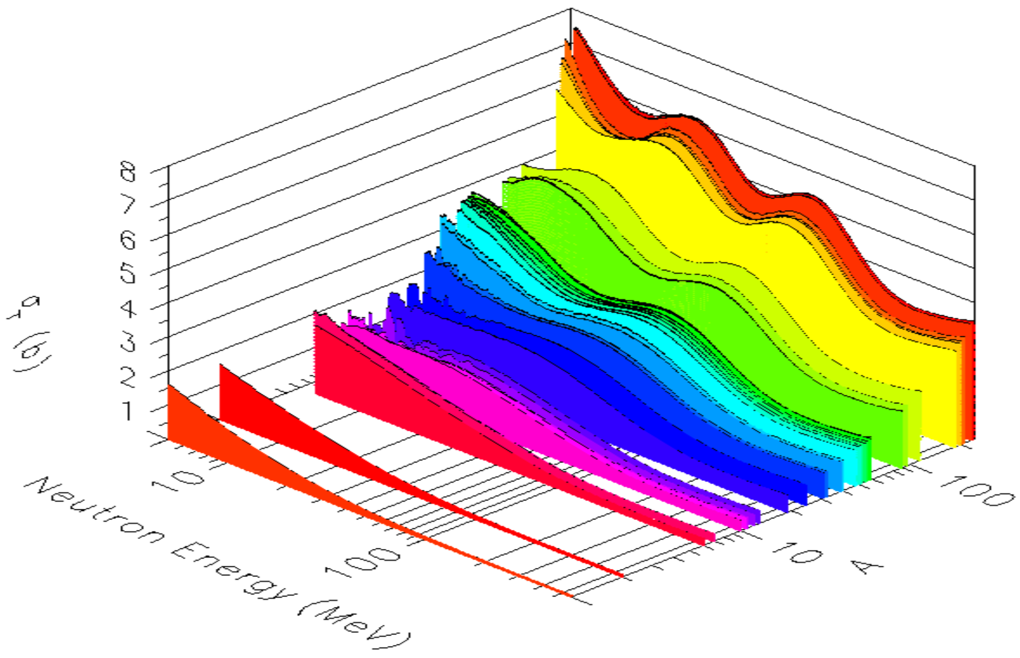


Contact:
Steve Wender

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



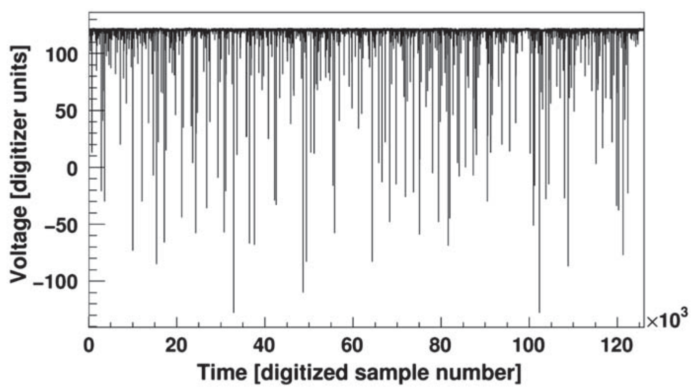
Total Cross Sections

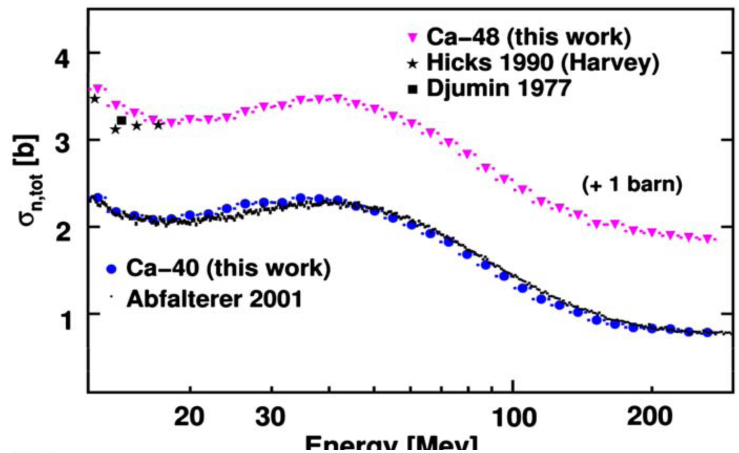


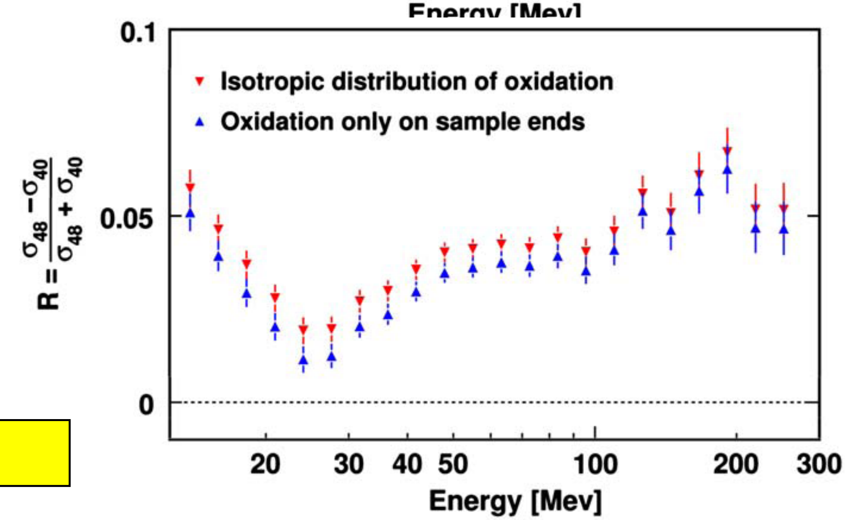
Contact:
Matt Devlin

Total cross section of ^{48}Ca

- 2.7 gram sample of ^{48}Ca
- Transmission experiment
- Digitizer data acquisition
- Washington U + LANL

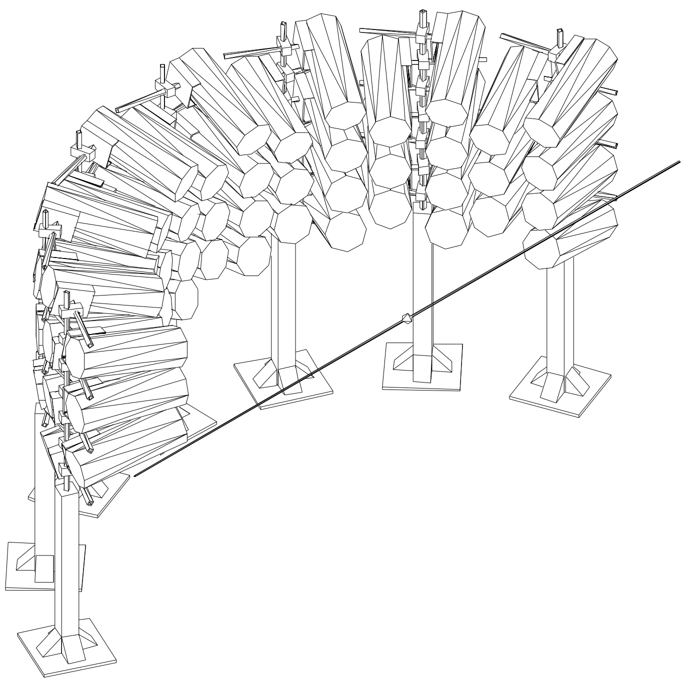






R. Shane et al., NIM A 614, 468 (2010)

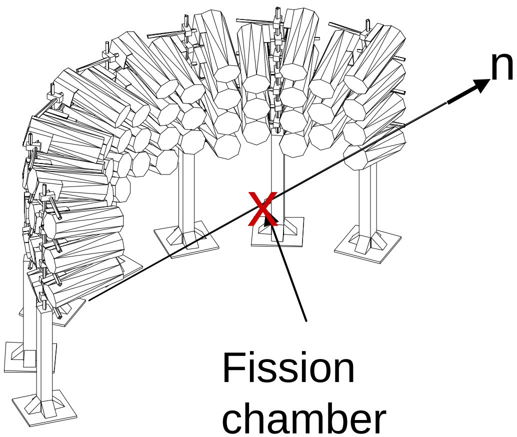
Chi-Nu (aka FIGARO) (n,xn+γ)



Contact:
Bob Haight
Hye Young Lee
Ron Nelson
Matt Devlin

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

Chi--Nu (n,xn+γ)



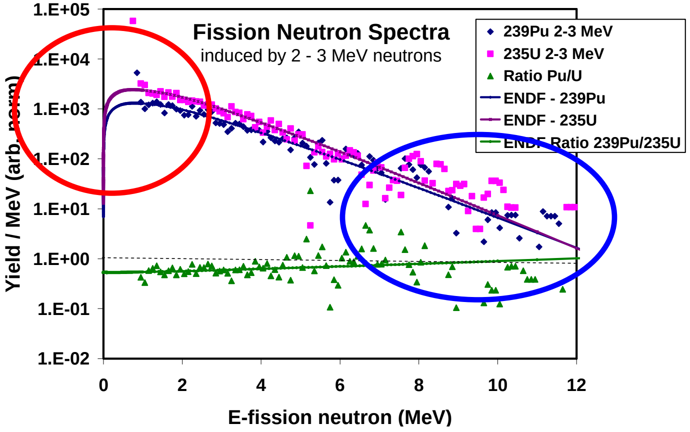
Fission chamber
22.7 m from WNR source

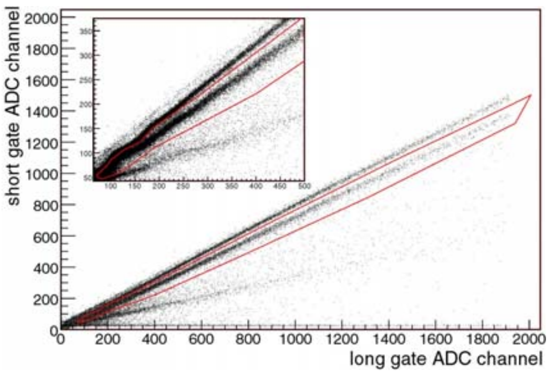
- **20 liquid scintillator neutron detectors**
- **3 gamma-ray detectors**

Double time-of-flight experiment

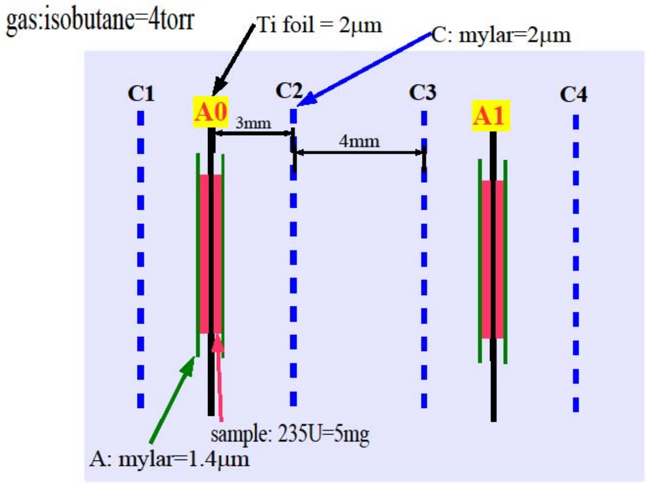
Program of fission neutron output measurements continues

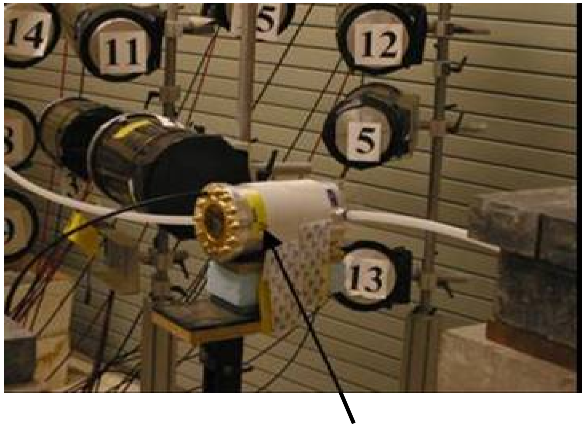
- Measure fission neutrons below 0.6 MeV
  - ^{6}Li-glass detectors
  - Room-return is an issue → new flight path
- Measure fission neutrons better above 8 MeV
  - Better timing on fission chamber (LLNL-LANL collaboration)
  - More efficient neutron detectors (larger solid angle for detection)
  - Lower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





Parallel-plate avalanche counter (PPAC) was used for first production runs June-September, 2010

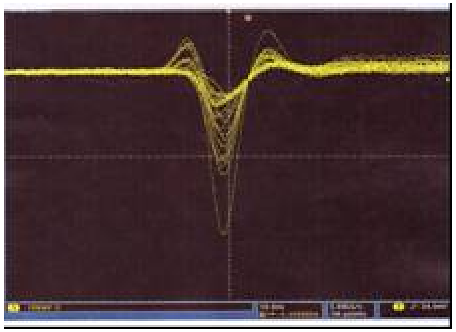




PPAC

Features of PPAC

- Gas gain for larger signal
- Fast (~ 1ns)
- Developed by LLNL



First production runs for $^{235}U(n,f)$ in 2010

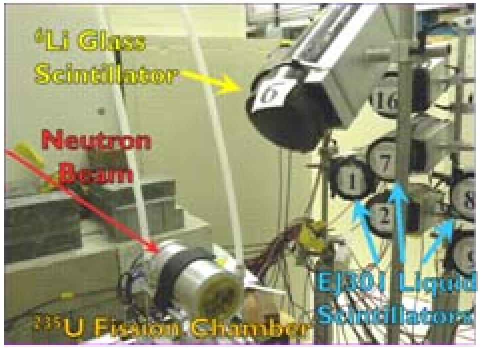
-- data being analyzed now

^{6}Li-glass scintillators were assembled, characterized and used in preliminary measurement in FY2010

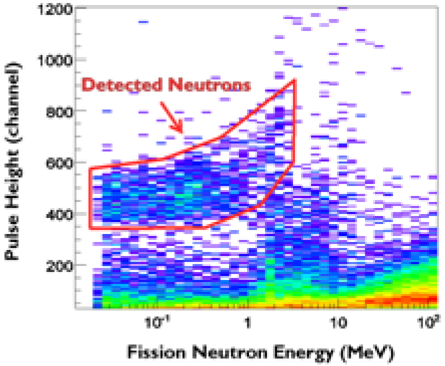
^{6}Li-glass on PM tube

Several types of reflector were tested

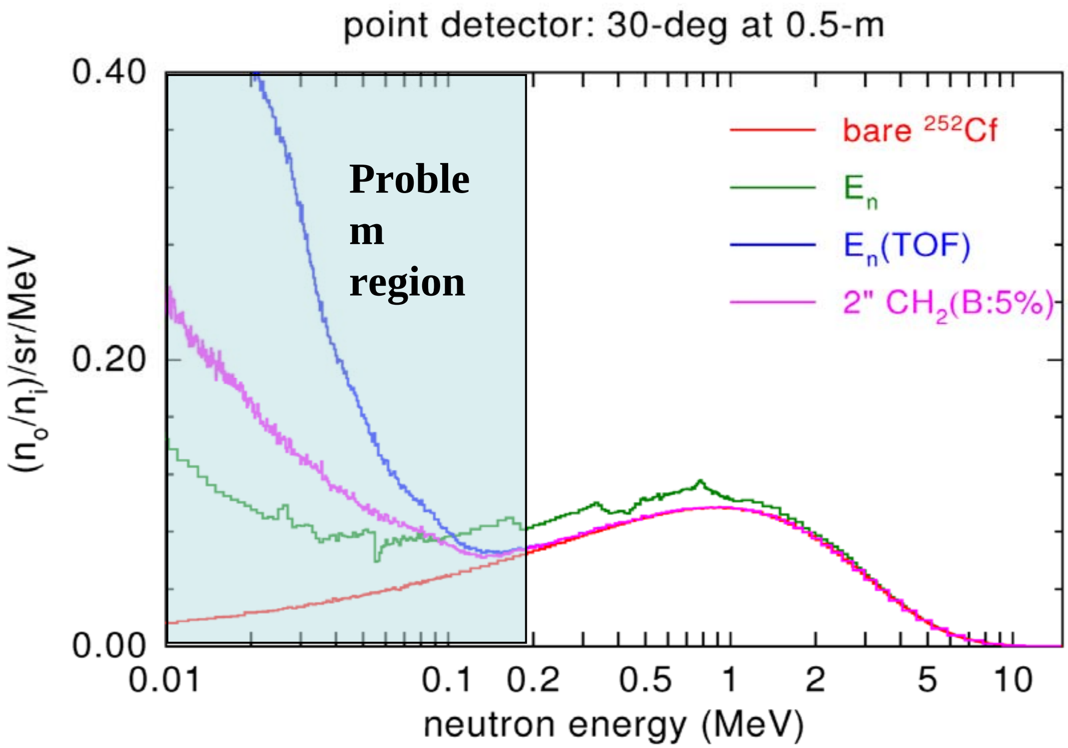
Setup in beam



Low energy neutrons are detected cleanly



Monte Carlo simulations for estimating the effect of “room-return” neutrons in ^{6}Li-glass detector

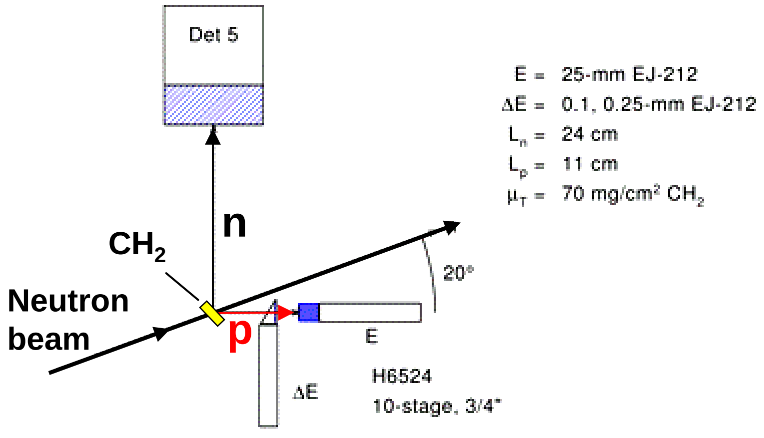


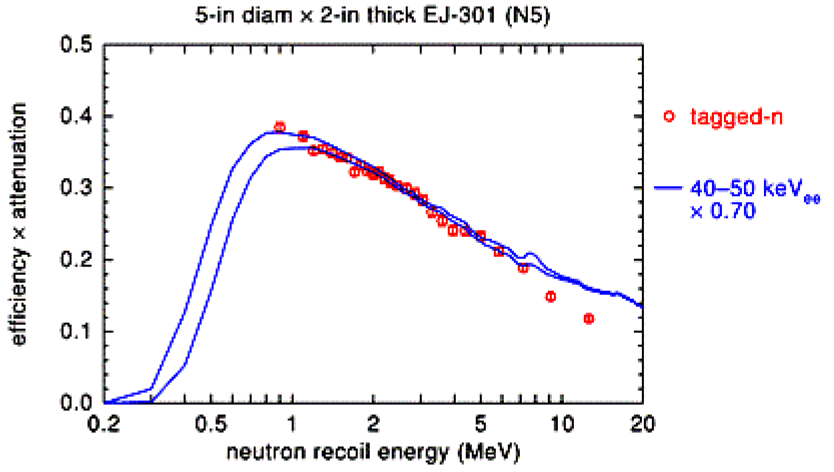
“Room-return” neutrons are caused by originally high energy neutrons bouncing around in the room, then being misidentified as low energy neutrons, due to the delayed time of flight at a detector. The simulation also reveals that the concrete floor and shielding blocks play the main contribution.

Bottom line → we need to be careful! New flight path should help

"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





N,Z Reactions

Z = p, d, t, ^{3}He, α

Dormant this year

Contact:
Bob Haight

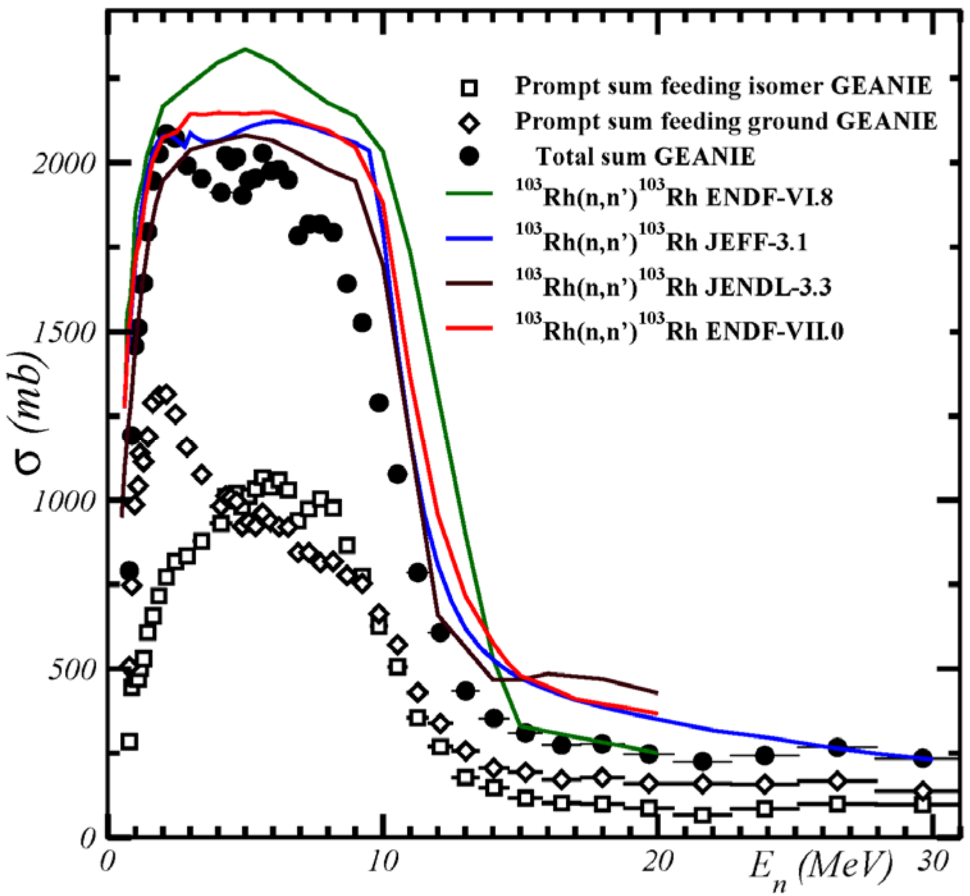
GEANIE (n,xγ)

Contact:
Ron Nelson
Nik Fotiades
Matt Devlin

GEANIE measurements

- ^{103}Rh(n,xnγ) analysis finalized, internal report written, cross sections obtained for 140 γ-rays in 15 reaction channels.
- ^{56}Fe(n,$\gamma\gamma$) published result on the first 3^- state of ^{56}Fe: PRC 81, 037304 (2010)
- ^{191,193}Ir and ^{197}Au isomer production published: PRC 80, 044612 (2009)
- From Gammasphere experiments: High spin states observed for the 1st time in ^{96,97}Nb (Fotiades et al., PRC 82, 044306,2010)

^{103}Rh – inelastic scattering cross sections



N. Fotiades et al.

^{56}Fe – looking for first 3$^-$ state

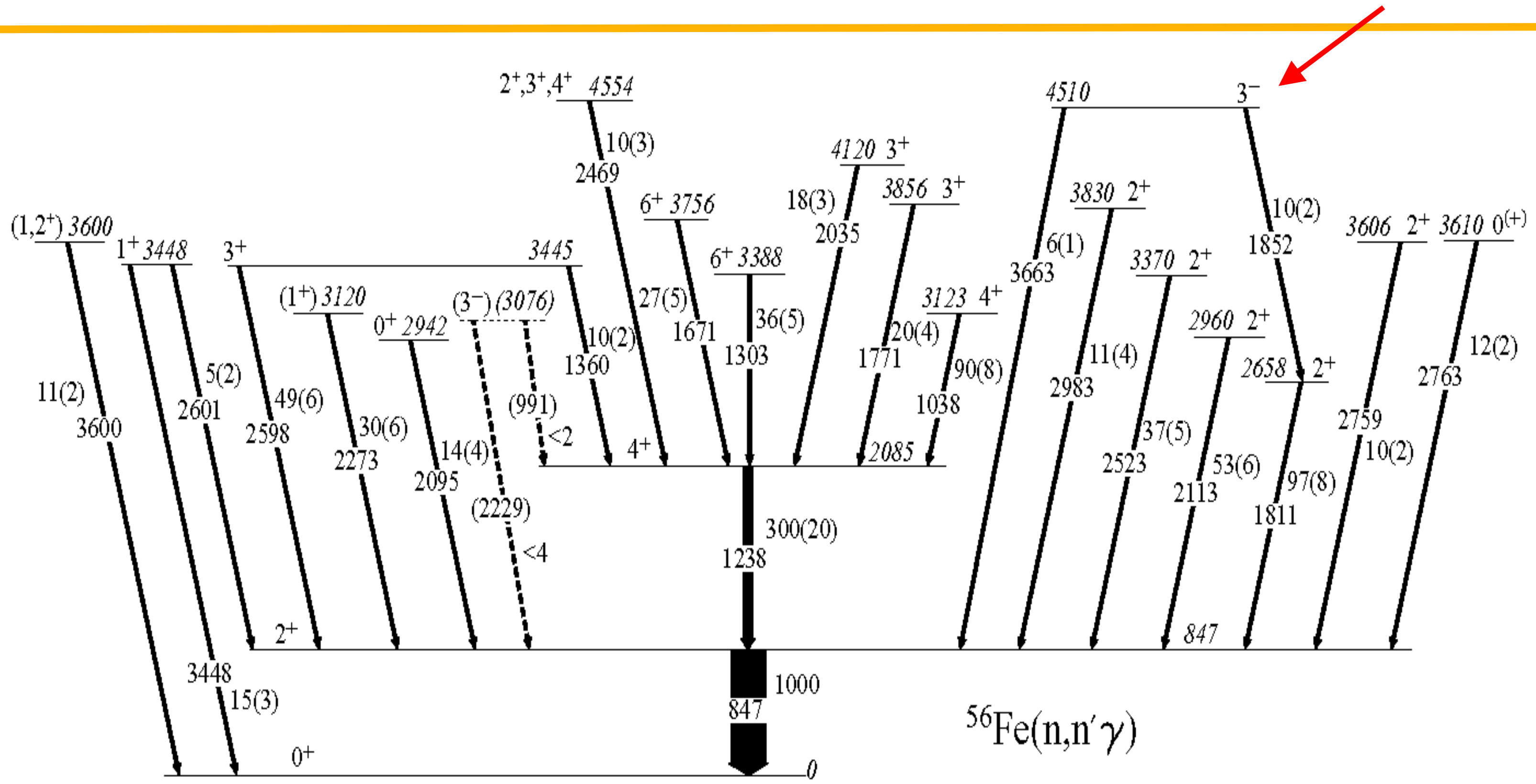


FIG. 2. Partial level scheme of ^{56}Fe as obtained in the present work. All γ-ray and level energies are given in keV. The observed intensities of each transition relative to that of the 847-keV, $2_1^+ \rightarrow 0_1^+$ transition (set arbitrarily to 1000) are also quoted. The 3076-keV level was not observed in the present work and is included in the level scheme only for comparison with the other levels.

^{56}Fe – looking for first 3- state -- conclusions

In summary, *γ* -*γ* coincidence data in the ^{56}Fe(*n*,*n'γ*) reaction was recorded with GEANIE in order to address the recently reported disagreement regarding the excitation energy of the 3_1^- state of ^{56}Fe. All previously known levels up to *Ex* = 3.6 MeV excitation energy were observed, by observation of at least one previously known transition from each level, except for the 3.076 MeV, (3^-) level. Moreover, no evidence for a 4370-keV, 3^- level was observed. The present experiment further supports the assignment of the 4509.6 keV level as the first 3^- state in ^{56}Fe.

DANCE (n,γ)

Contact:
John Ullmann
Aaron Couture

Analysis of DANCE neutron-capture data

^{89}Y, ^{157}Gd	Andrii Chyzh, NCSU/LANL: PhD thesis completed
^{152,154,155,156,158}Gd, ^{94,95}Mo	Bayarbadrakh Baramsai, NCSU/LANL: PhD thesis completed
^{97}Mo	Carrie Walker, NCSU, PhD Dissertation in progress
^{63}Ni	Aaron Couture, LANL: data taken; future run planned
^{233,235}U, ^{239,241}Pu	Capture to fission: LANL, LLNL
$^{239,\ 241}$Pu	Fission gamma-ray multiplicity and spectra: LANL/LLNL
^{191,193}Ir	Todd Bredeweg, LANL
$^{242m,\ 243}$Am	Marian Jandel, LANL – preliminary @ ND2010
^{238}U	John Ullmann, LANL – preliminary @ ND2010

Fission Cross Sections

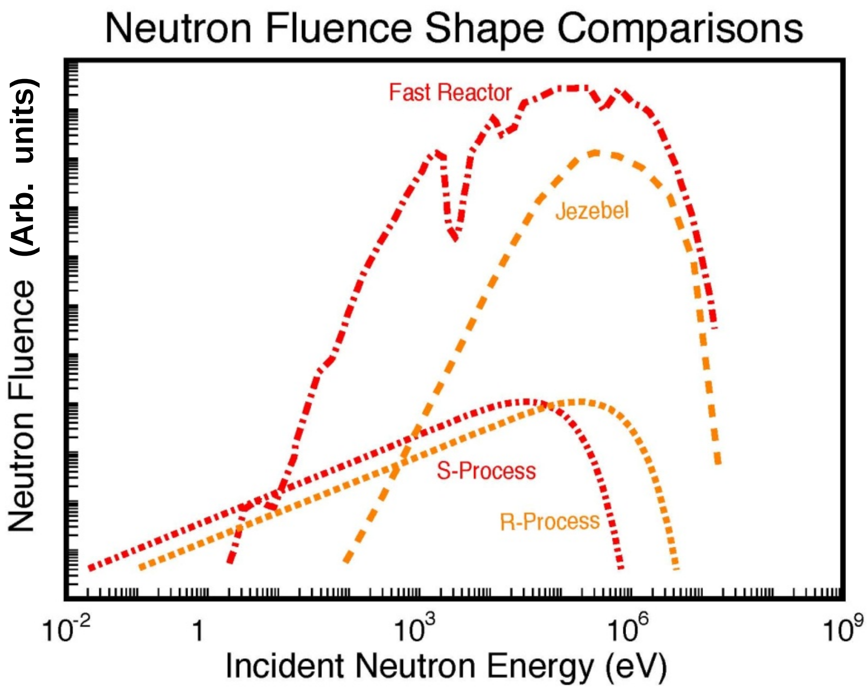
Fredrik Tovesson and
Alexander B. Laptev
Los Alamos National Laboratory

Introduction

- **Advanced nuclear reactors, weapons design, nuclear forensic and remote detection of SNM all rely on realistic *simulations*, which in turn require accurate *nuclear data* input.**
- **There are three sponsors for the fission work at LANSCE:**

  - DOE-NE is funding nuclear data sensitivity studies, measurements and evaluations in support of advanced reactor applications through the Fuel Cycle Research and Development (FCR&D) program.
  - Weapons Program is funding high precision fission cross section measurements. Sensitivity studies of nuclear weapons have shown the importance of improving the accuracy for Pu-239 fission. LANL and LLNL proposed using a Time Projection Chamber (TPC) to achieve the target accuracy, and this detector is currently being developed.
  - The Laboratory Directed Research and Development (LDRD) program is funding a new project in FY2011, aimed at improving the understanding of fission product yields and the fission process in general.

The energy range of interest is shared among different applications



- **Fast reactors, nuclear weapons and astrophysics have similar nuclear data needs**
- **For fast spectrum applications neutron cross sections keV to MeV energies are of particular interest**
- **The LANSCE facility covers this full energy range**

LANSCE fission cross section program status

Np-237
Pu-239
Pu-240 ($t_{1/2}$=6600 a)
Pu-241 ($t_{1/2}$=14 a)
Pu-242
U-238
U-233
Am-243

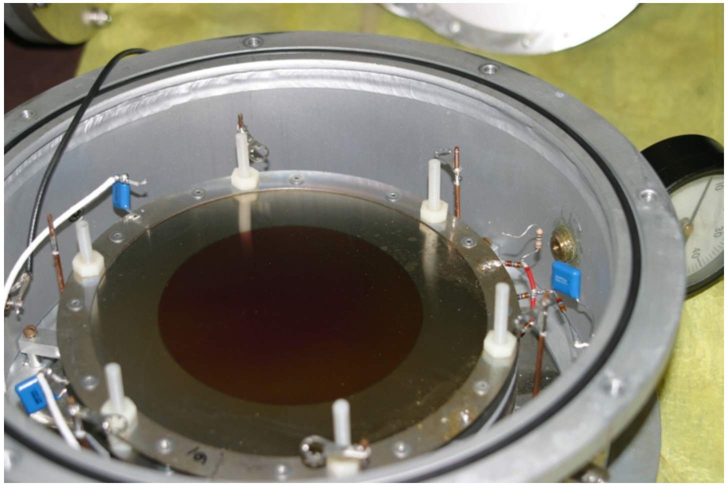
Completed

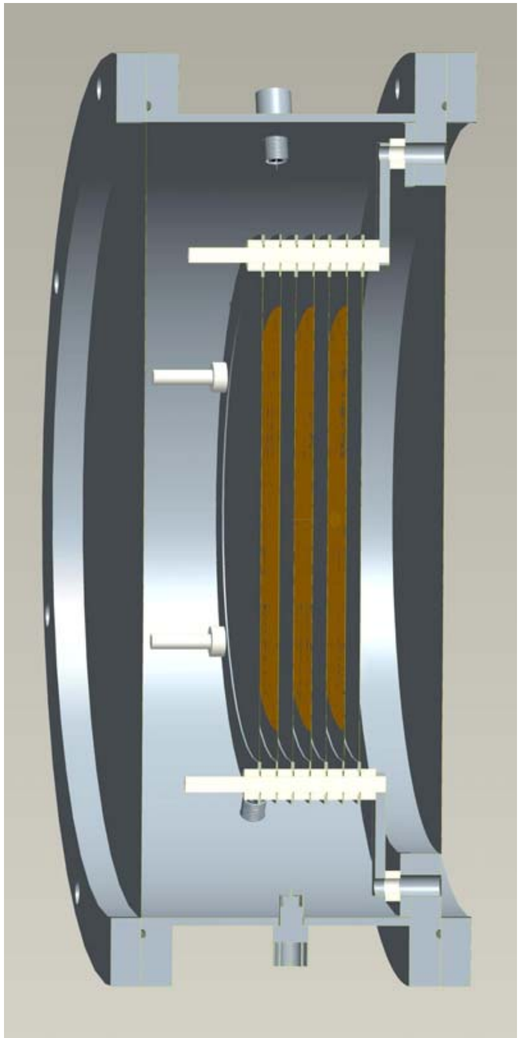
U-236 ← Finalizing in FY11
U-234 ← First data in FY11

- Developed techniques for precision fission cross section measurements, uncertainty reporting
- Close collaboration with theory, evaluators
- International collaborations with Joint Research Center (JRC) & Commissariat à l'énergie atomique (CEA)
- Extensive student participation **(1 full time & 4 summer students in 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. Reifarth, **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).

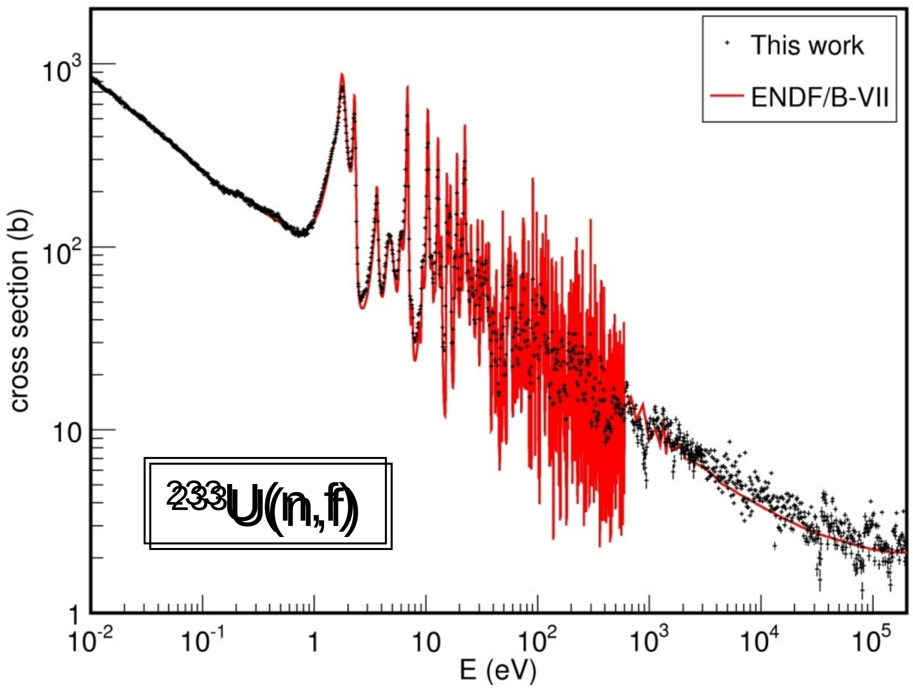
The current technology for fission cross section measurements uses parallel-plate ionization chambers

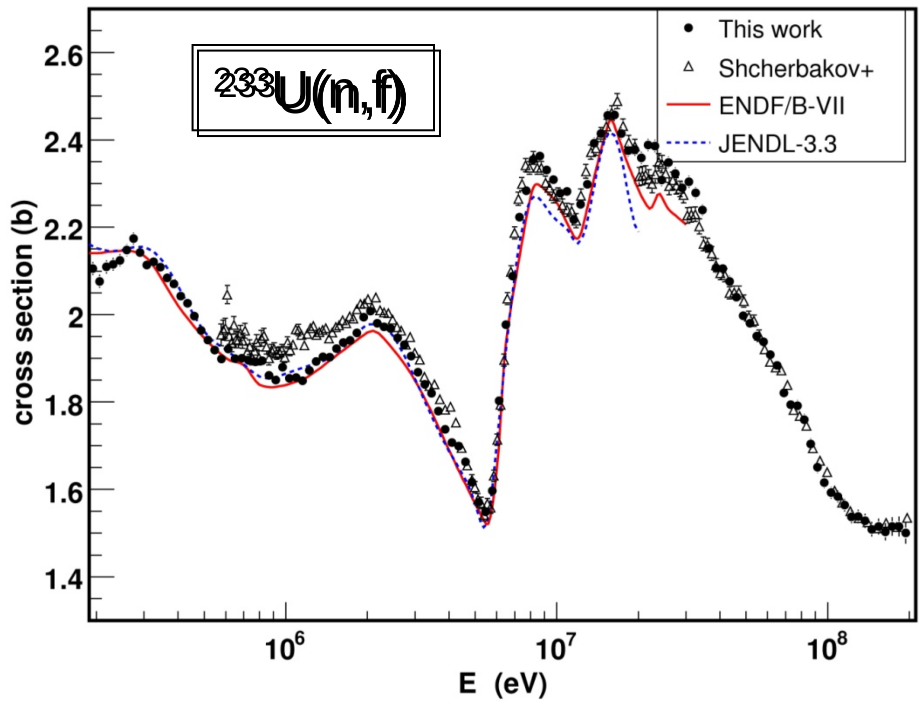




- **Parallel-plate ionization chambers are the currently used fission detectors**
- **High efficiency**
- **Fast timing properties**
- **Reasonable fission identification**
- **Easy to operate and insensitive to radiation damage**

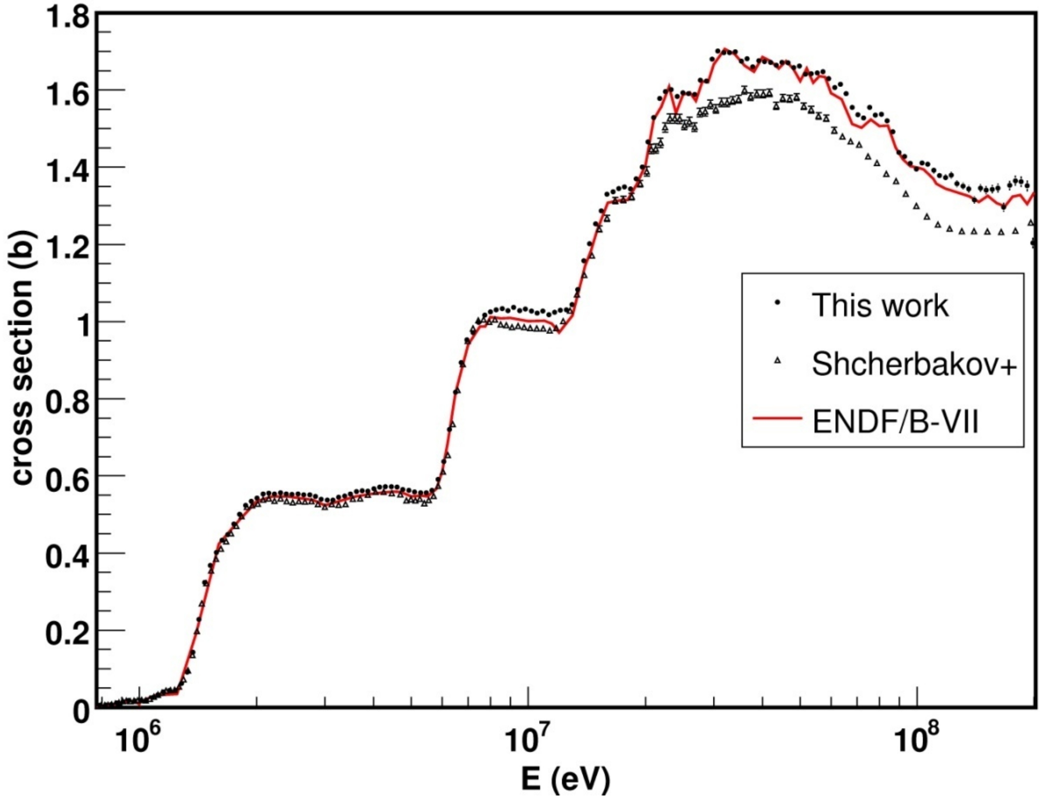
The U-233 fission cross section was finalized in FY2010





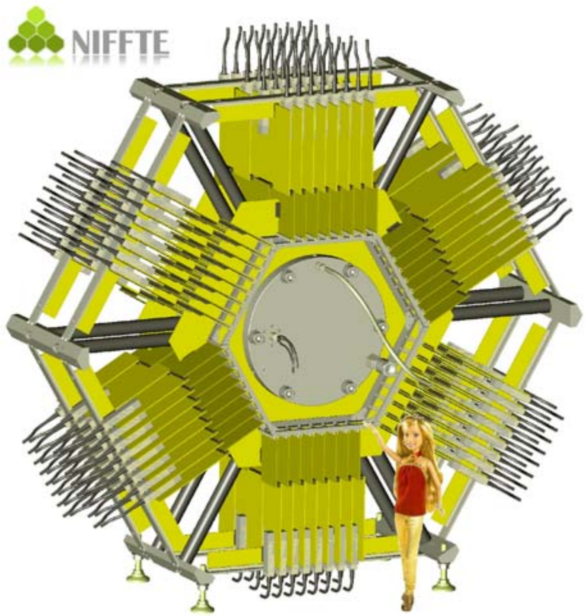
- **The neutron energies below 200 keV are measured at Lujan Center. Structures in the unresolved resonance region observed, missing from the evaluation.**
- **The data set extends to 200 MeV. The only other measurement extending beyond 20 MeV is from PNPI (Shcherbakov et al.)**

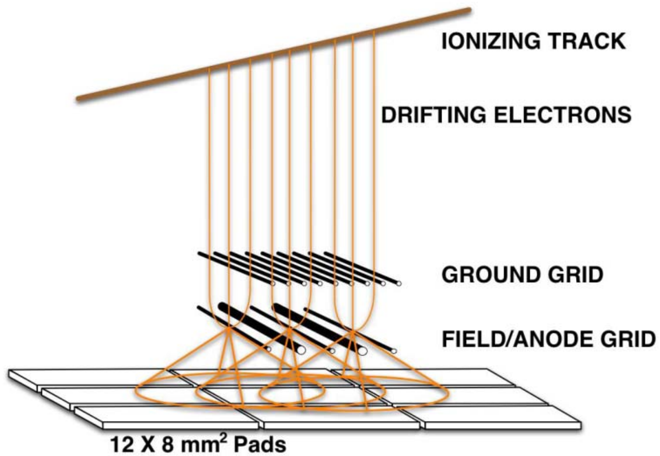
The U-238 (n,f) cross section was measured from 0.2 to 200 MeV



- U-238 (n,f) is a standard up to 200 MeV. The standard evaluation above 20 MeV is mainly based on one experimental data set (Lisowski et al.)
- The new data agrees with Lisowski, and does not support the lower cross section measured by Shcherbakov et al.

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





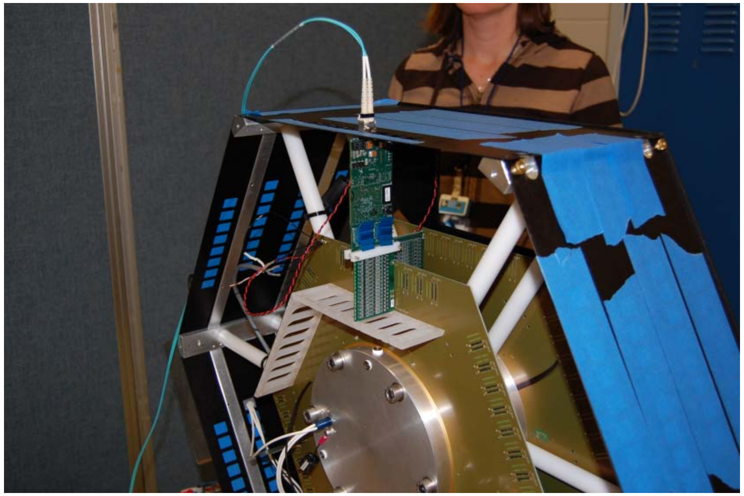
- **3D pictures of particle tracks**
  - sample uniformity
  - beam uniformity
  - efficiency
  - erases decay / light charged-particle background
- **"Absolute" fission cross sections**

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)*

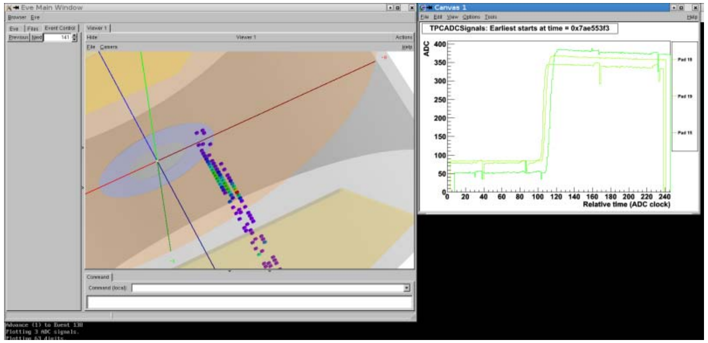
FCR&D & NNSA provides lab funding
– **Lawrence Livermore National Laboratory** (*Mike Heffner)*
– **Los Alamos National Laboratory** (*Fredrik Tovesson, Alexander Laptev)*
– **Idaho National Laboratory** (*Tony Hill, Chris McGrath)*

The TPC will address virtually all sources of systematic uncertainties in fission cross section measurements

- **TPC will provide 3D "pictures" of the charged particle trajectories**
  - Alpha backgrounds removed
  - Sample auto-radiograph (α particles)
  - Beam non-uniformities
  - Multi-actinide targets
- **TPC will use thin backing foils (<50μg/cm^2)**
  - Minimize beam interaction backgrounds
  - Maximize efficiency
  - Minimize multiple scattering of fragments
  - H_2 drift gas will also minimize scattering
- **TPC will provide data on both fission fragments simultaneously**
  - Random backgrounds removed (vertex requirement)
  - Fission vertex with <100 μm resolution (fission radiograph)
- **Fission measurements relative to n(H,H)n scattering**
  - Removes remaining ~2% ^{235}U(n,f) liability

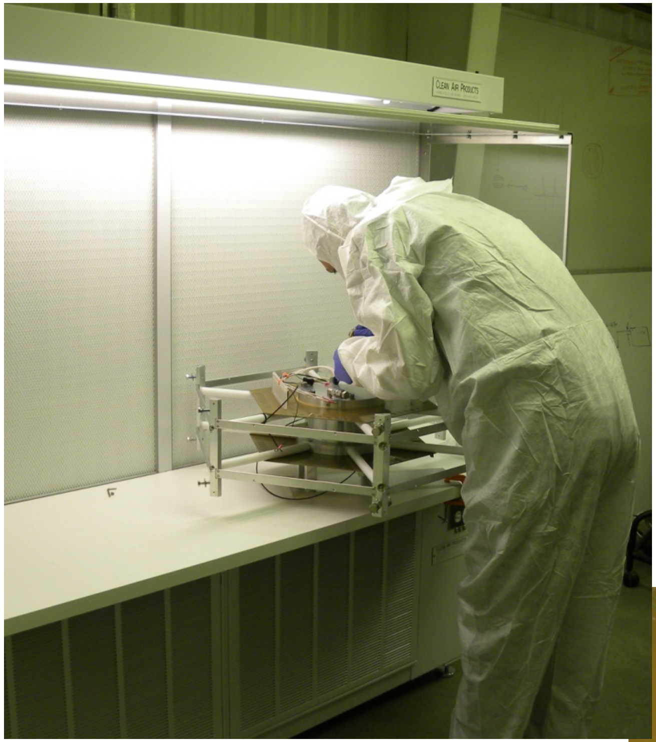


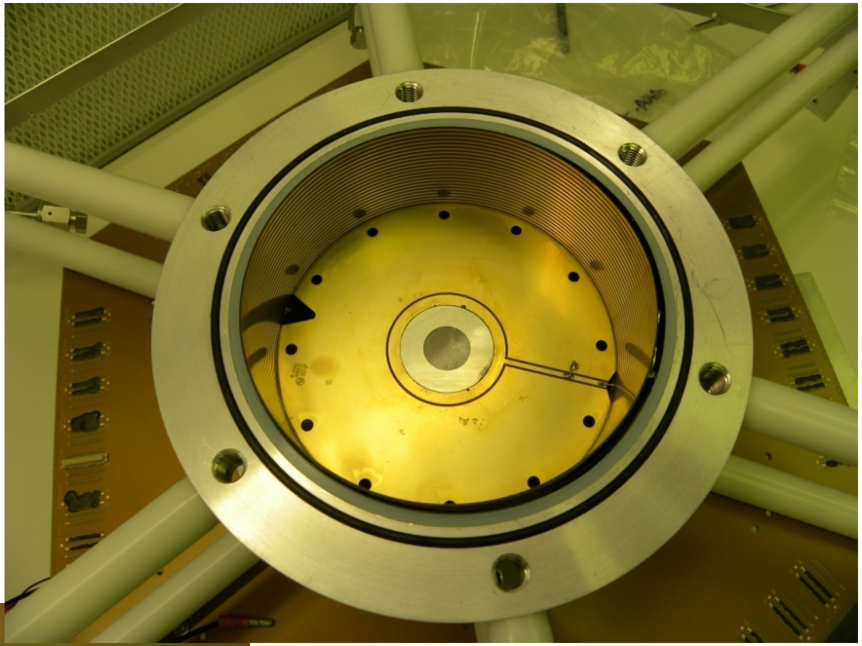
Prototype TPC with one electronic chain connected

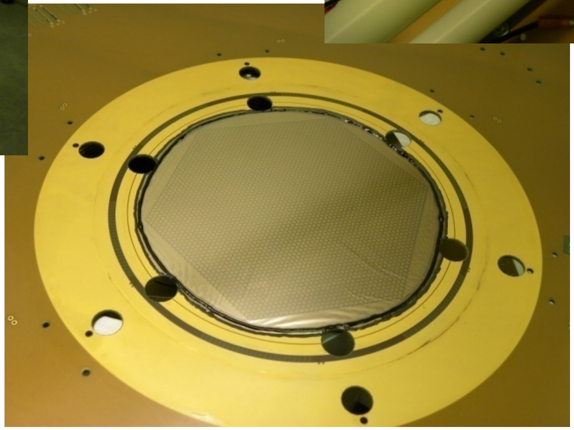


Track reconstruction for alpha-particle radiation in first tests at LLNL

The prototype TPC was delivered to LANL July 28

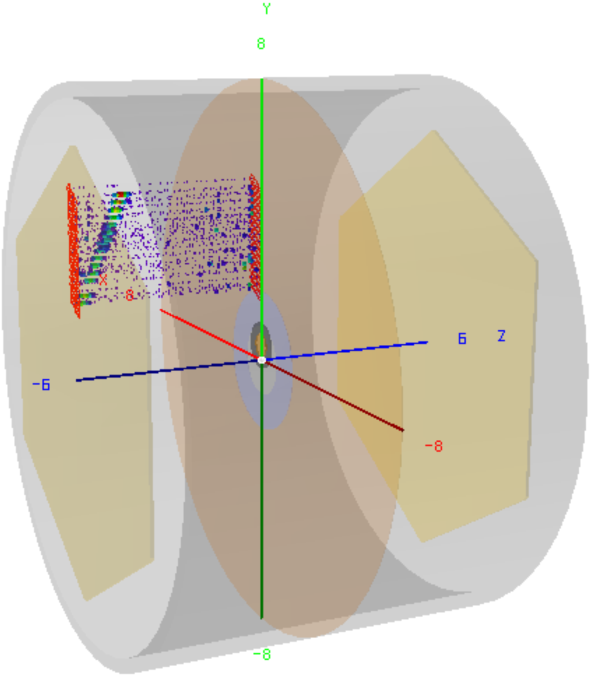






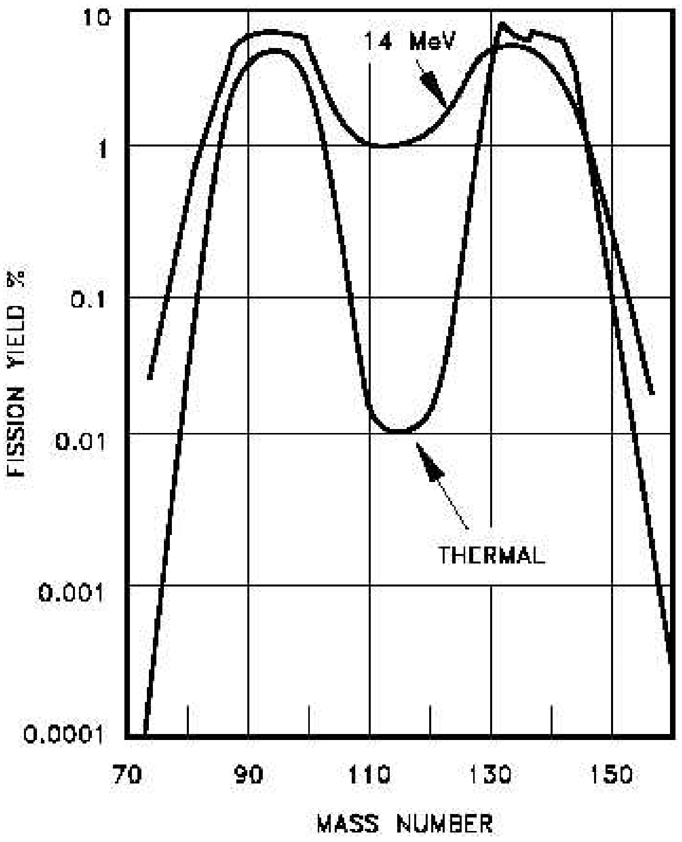
The TPC is installed and collecting data at LANSCE

- **The prototype TPC uses 2 out of 192 preamp and digital cards**
- **A level 2 milestone for the weapons program was met when the prototype TPC took first neutron beam data in August/**
- **Engineering data is being collected with a U-238 sample**

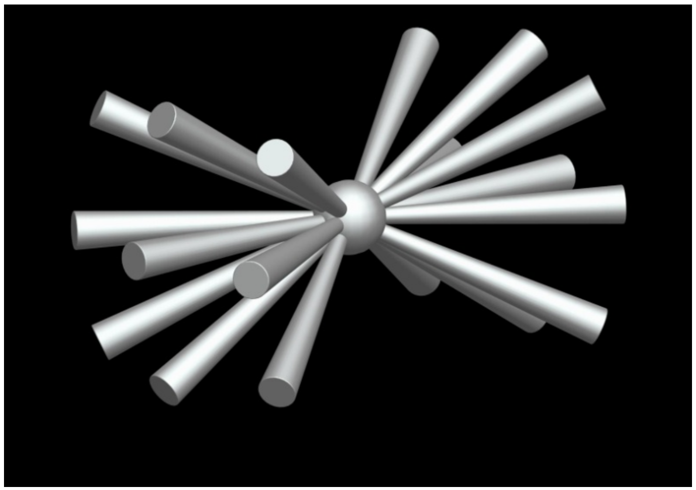


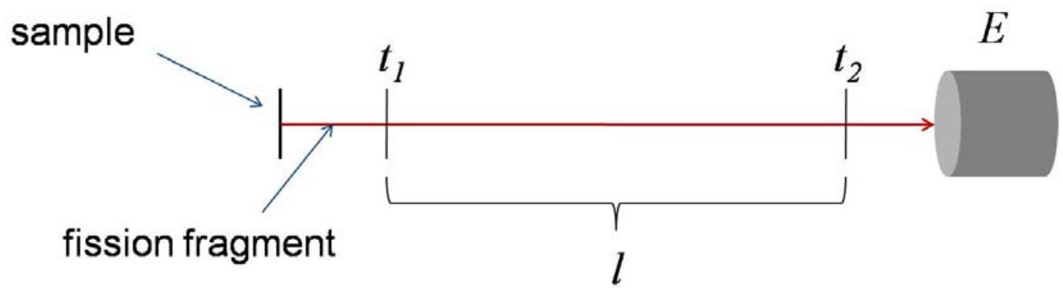
A new approach to measuring fission product yields is being developed

- 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



Spectrometer for ion detection in fission experiments (SPIDER)

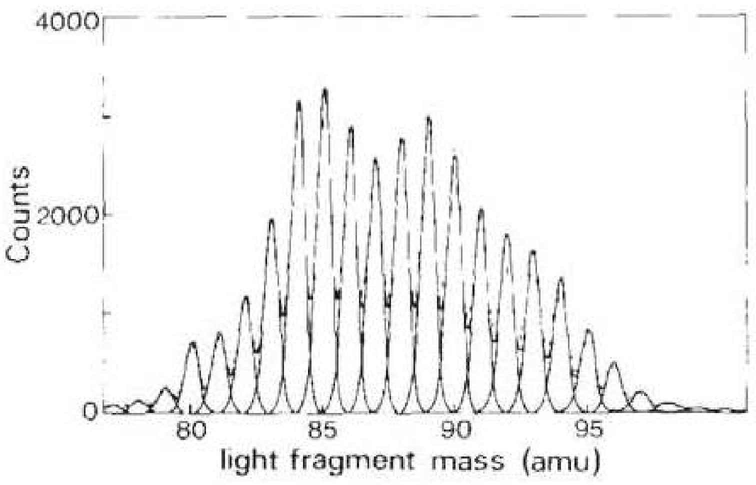




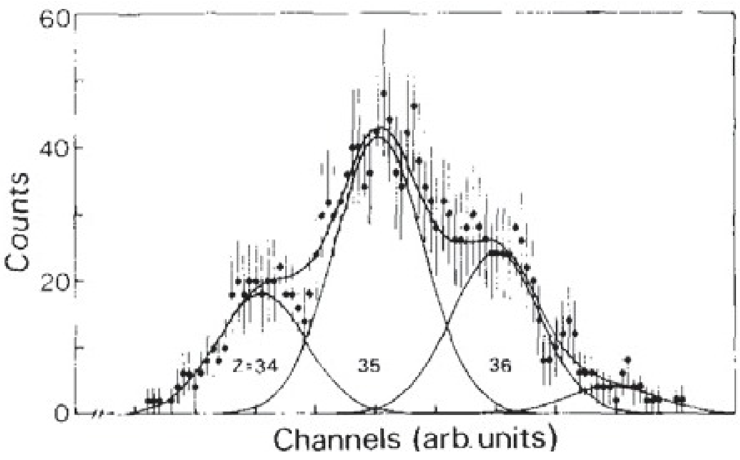
- A spectrometer based on the 2E-2v method could provide FPY data with ~1 amu resolution
- Approach was successfully demonstrated in the 80's at the ILL reactor, but no data exists for fast neutrons.
- Technical challenges are achieving ultra fast timing and high energy resolution for heavy ions, as well as minimizing energy loss in windows, and maximize efficiency.

The COSI-FAN-TUTTE spectrometer demonstrated excellent mass and charge resolution

Fragment mass yield



Charge yields for A=87



Conclusions

- The fission cross section program has delivered to FCR&D for the last few years, and is continuing with a multi-year plan.
- The TPC will provide improved accuracy for cross sections, and provide new capabilities for fission research. A level 2 milestone was met in FY10 when the prototype TPC was installed at LANSCE.
- Ongoing efforts are aimed at measuring fission product yields in collaboration with XCP, T and C. Will provide crucial data for applications, and improve understanding of the fission process.

Thank you for your attention!