LANSCE Measurements supporting LLNL Nuclear Science Program

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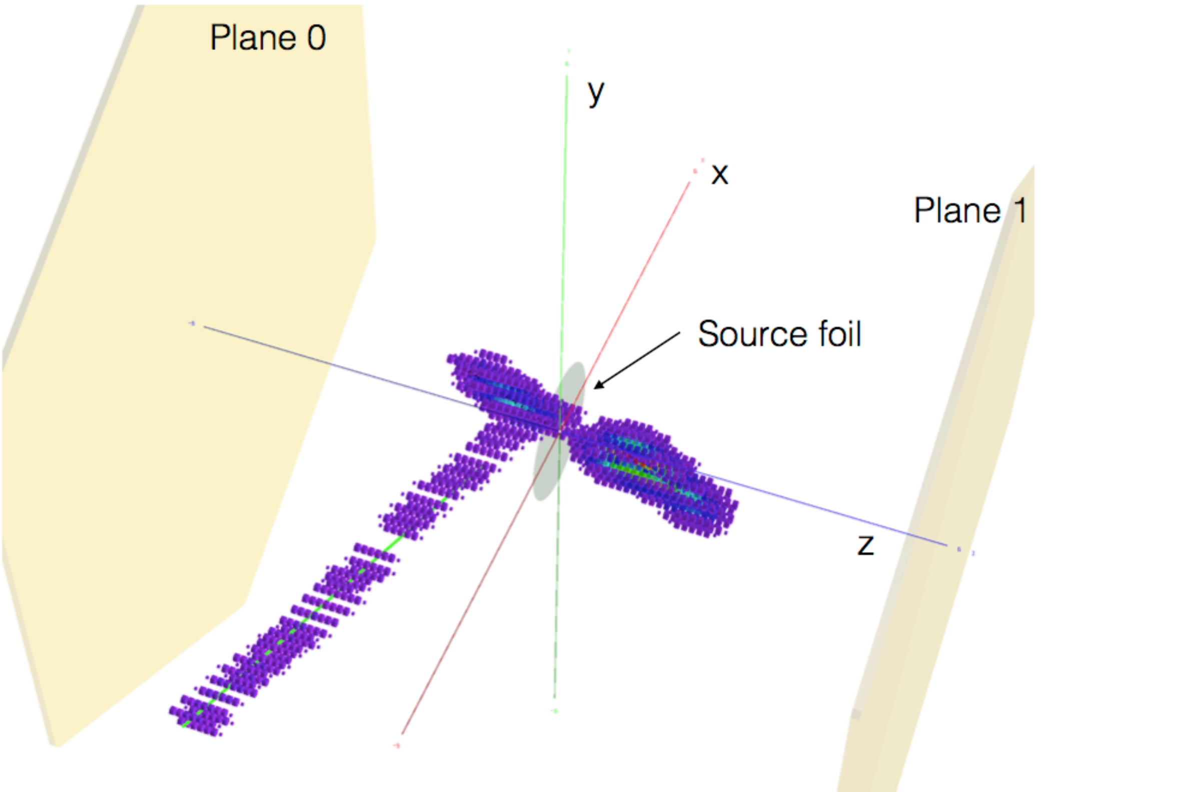
Lawrence Livermore National Laboratory



LLNL-PRES-678859
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

Nuclear Data Measuring using DANCE

Contact: Ching-Yen Wu
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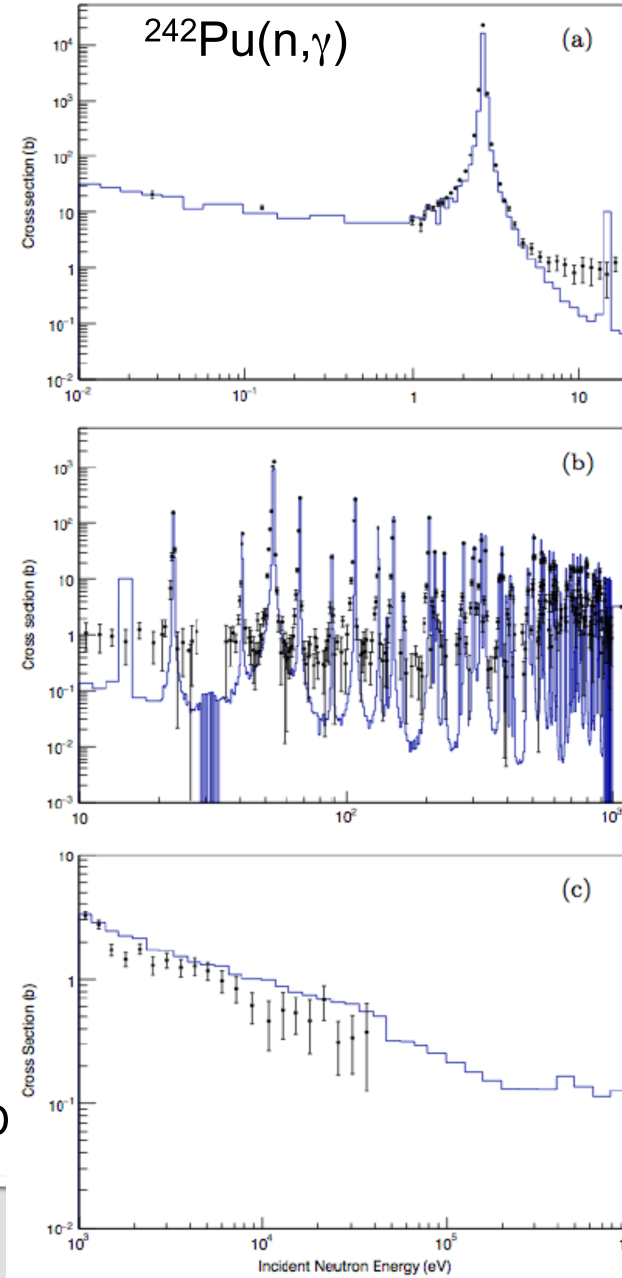
Absolute (n,γ) cross sections

- Improve the (n,γ) cross section on actinides; an effort to improve the network calculation of the Pu-Am RadChem diagnostic chain.
  - ^{238}Pu(n,γ); absolute scale set by ^{234}U(n,γ) resonance at En = 5.16 eV
    - **A. Chyzh, C.Y. Wu et al., PRC 88, 044607 (2013)**
  - ^{242}Pu(n,γ); absolute scale set by ^{239}Pu(n,f) resonance at En = 7.83 eV
    - **M Buckner, C,Y, Wu et al., to be published (2015)**
  - ^{242m}Am(n,g) in progress; absolute scale set by ^{242m}Am(n,f)

- A new compact parallel-plate avalanche was designed and fabricated at LLNL for this work.
  - **C.Y. Wu et al., NIMA 694,78 (2012)**



Support by NNSA Office of Defense Nuclear Nonproliferation R&D

Prompt γ emission in fission

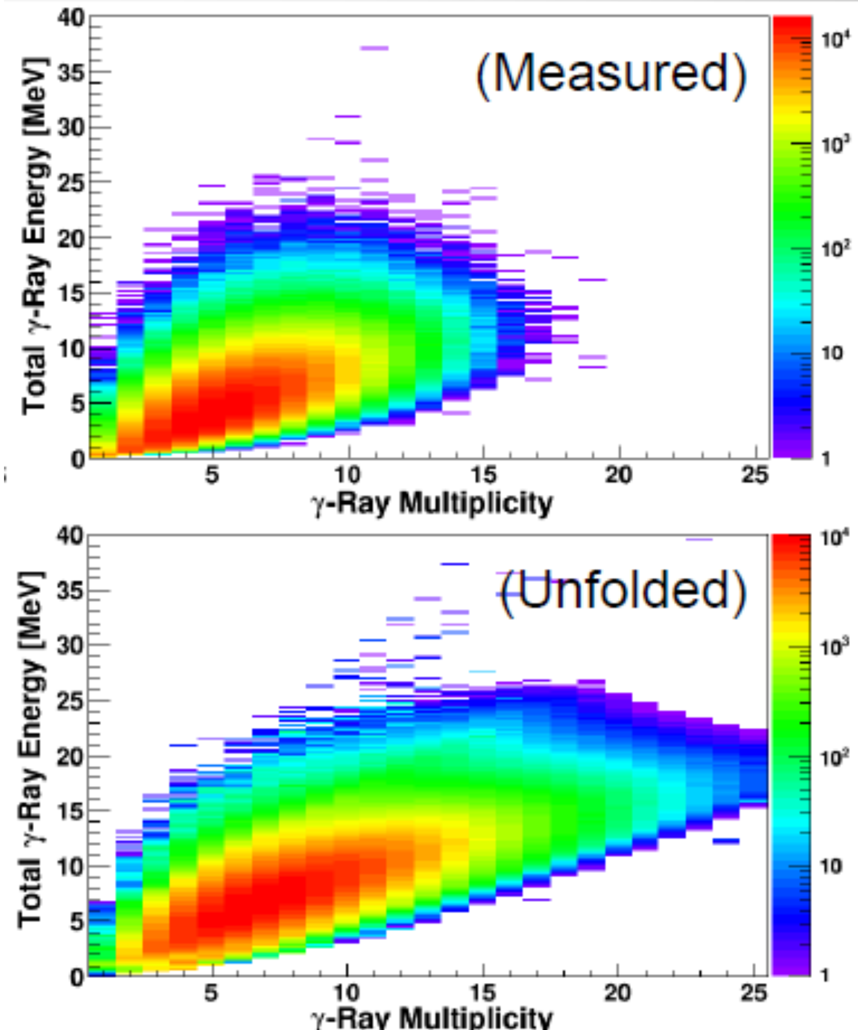
- Prompt γ emission was studied using DANCE for the neutron-induced fission of ^{235}U, ^{239}Pu, and ^{242}Pu, plus spontaneous fission of ^{252}Cf.

- The total prompt γ-ray energy vs multiplicity in fission was derived and unfolded
  - A. Chyzh, C.Y. Wu et al., PRC 85, 02160(R) (2012)
  - A. Chyzh, C.Y. Wu *et al*., PRC 87, 034620 (2013)
  - A. Chyzh, C.Y. Wu *et al*., PRC 90, 014602 (2014)

- The average total prompt γ-ray energy is about 20% higher than one derived from the product of average Eγ **and** Mγ
  - Serious concern raised for the equation below

$$? \langle E_{\gamma,tot} \rangle = \langle E_\gamma \rangle \times \langle M_\gamma \rangle$$

$^{239}Pu(n,f)$; En thermal to ~ 100 keV



Support by NNSA Office of Defense Nuclear Nonproliferation R&D

Neutron Radiography R&D

Contact: Brian Rusnak
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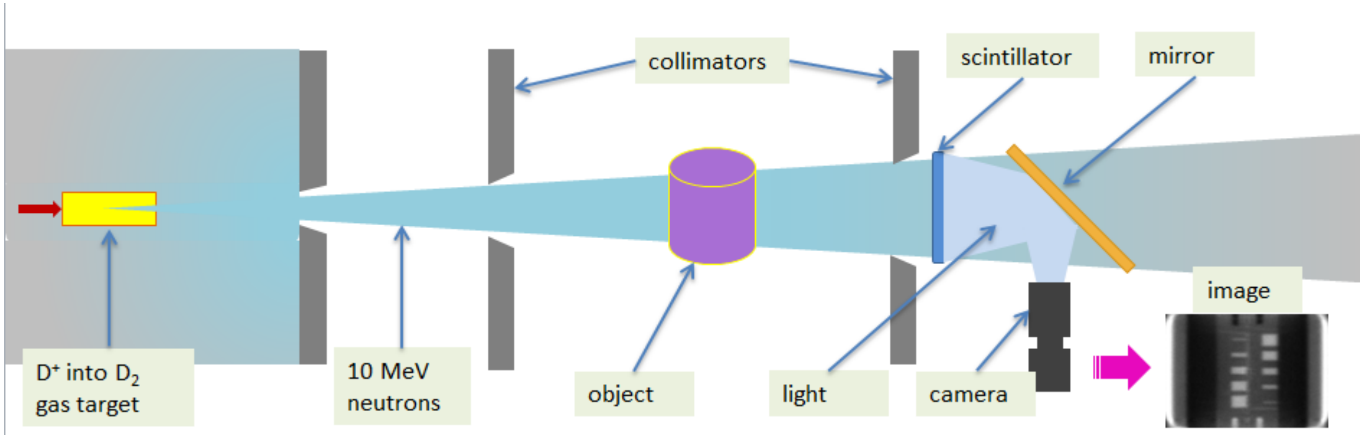
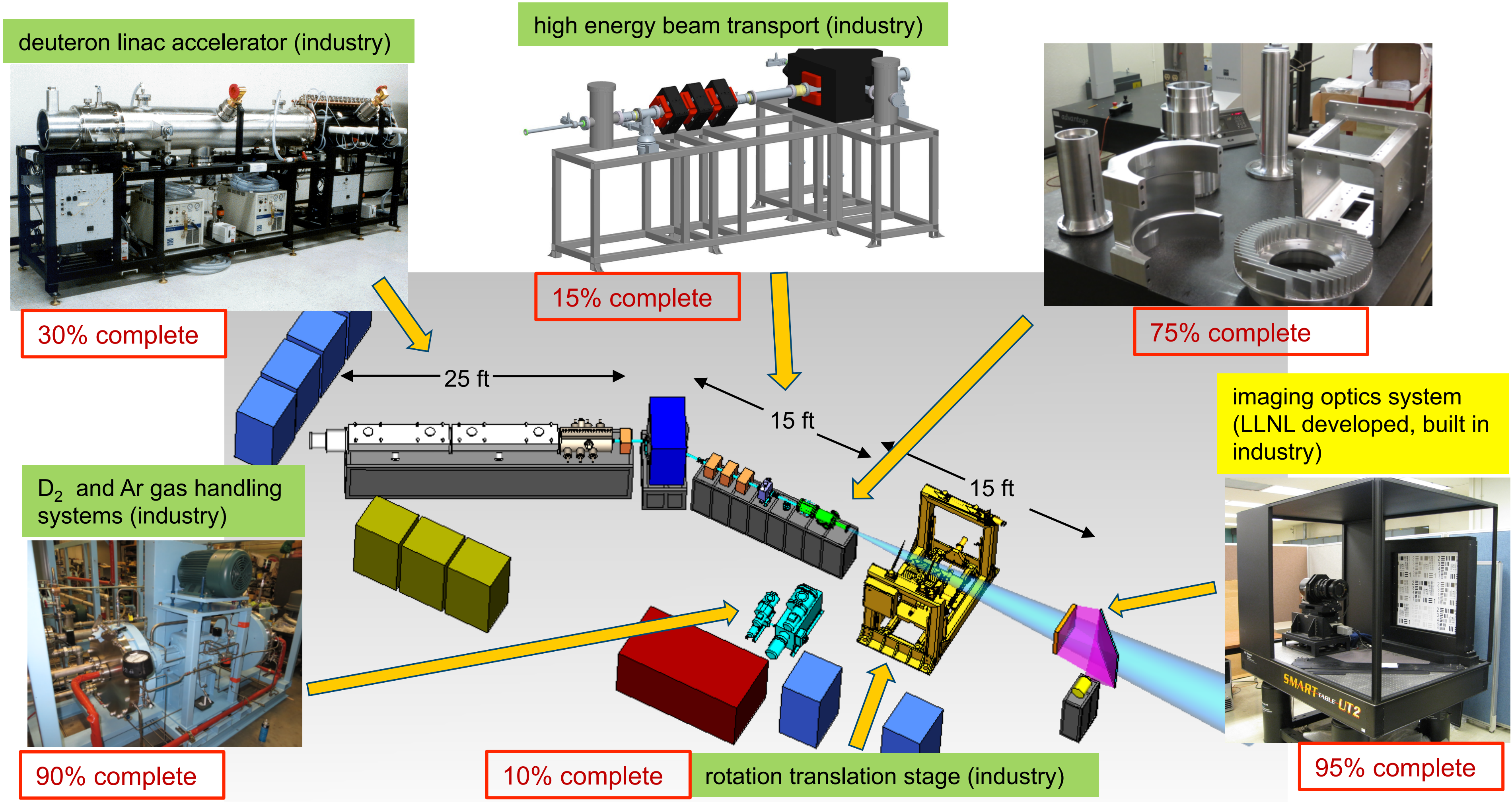
Fast Neutron Imaging Development for Enhanced Surveillance (ES) Aided by LANSCE Imaging Experiments

- ES fast neutron imaging (NI) development effort focused on building a compact system
- All components are commercially produced and supported – end machine not a physics experiment
- Technique relies on a high brightness, quasi-monoenergetic (3% FWHM) source at 10 MeV to optimize imaging signal to noise
  - Using 7 MeV D+ beam on D2 via D(d,n)3He
- NI at LANSCE employs poly-energetic fast neutron beam (~100 keV – 50 MeV tailing out to 700 MeV), providing analogous validation of approach
  - TOF (energy) gated imaging gets closer to QM
- Work continuing on quantifying differences in QM and PE imaging



Neutron imaging approach is comparable to x-ray imaging

Research approach used over the past 10 years worked on the higher-risk subsystem components first to reduce the overall technical risk



Conceptual layout of system using largely commercial components shows system can fit into a nominal 800 sq ft radiography vault

LLNL Contributions to Chi-Nu

Contact: Ching-Yen Wu
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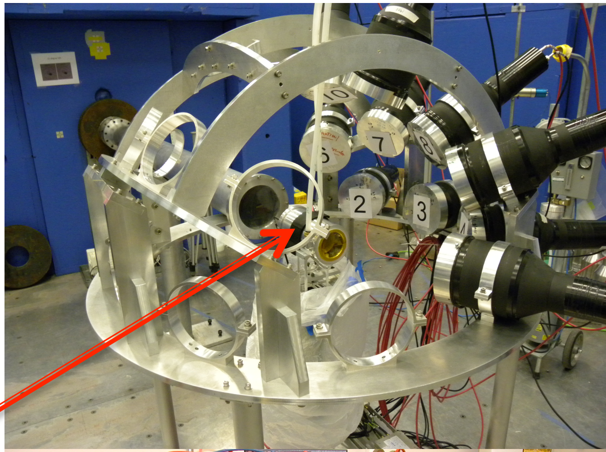
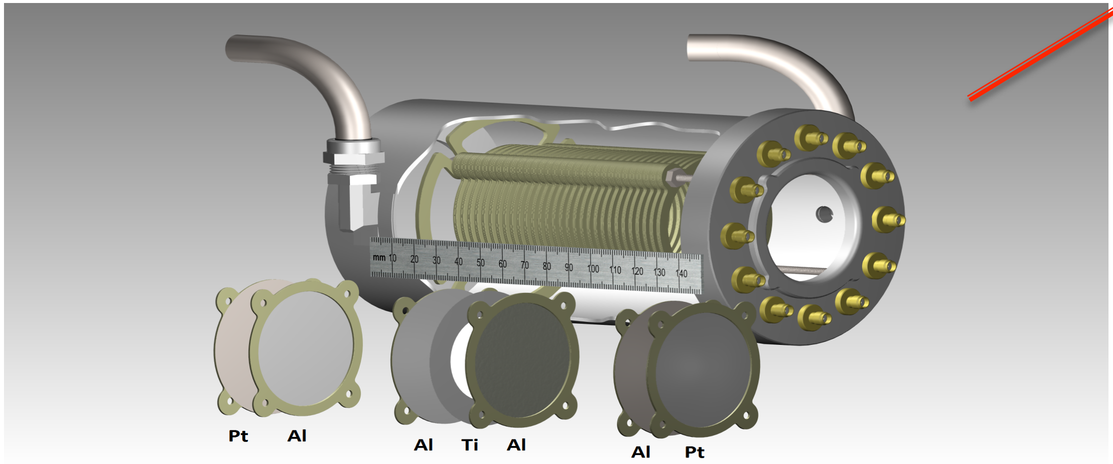
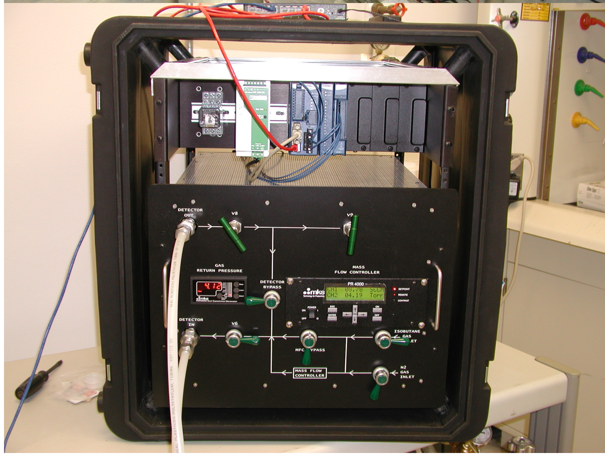
Fission PPAC particle ID and timing are key to measurement

- The cylindrical chamber has a wall thickness of 1/16 inch Al and consists of 10 target foils each with its own electronics.
- Target material is deposited on 3 micron Ti foil and then covered by 2.5 micron Al foils forming the anode, with a cathode of 2.5 micron Al and 5 micron Pt foil, all mounted on aluminum rings.
- Electron avalanche occurs in 4 Torr isobutane, regulated by a gas handling system, with ~400 V and resulting signal out to high-bandwidth, high-gain amplifiers.



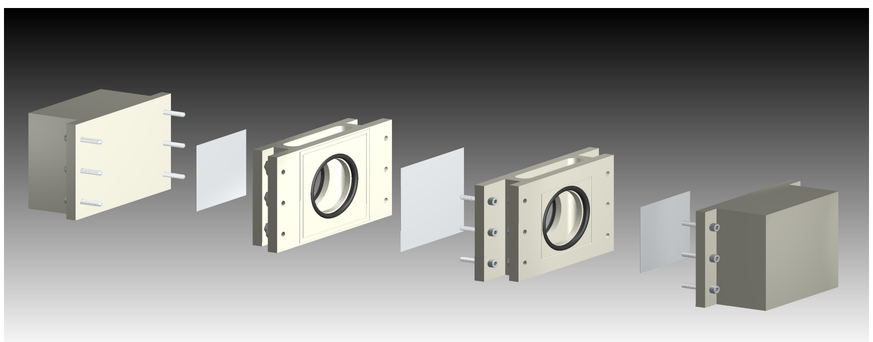




Details published in Wu *et al*., NIMA 794, 76 (2015)

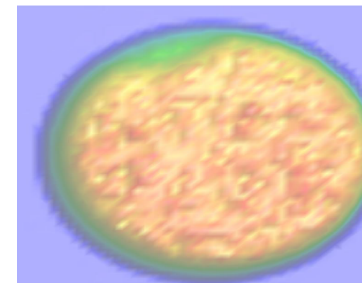
Achieving enough target mass while maintaining the necessary uniformity is a challenging fabrication task

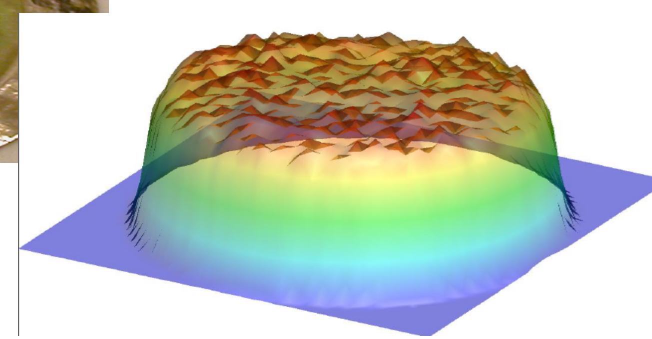
- Target fabricated in a parallel-plate double electrodeposition cell.
  - Fabrication process efficiency improved by two orders of magnitude.
  - Multiple target foils are required to achieve overall detector efficiency.
  - Uniformity better than 4% over an area of 4 cm diameter.



Newly designed electrodeposition cell.

Showing 9.71 mg of ^{239}Pu on 3 μm Ti foil





Details published in Henderson et al., NIMA 655, 66 (2011)

FissionTPC Project

Contact: Mike Heffner
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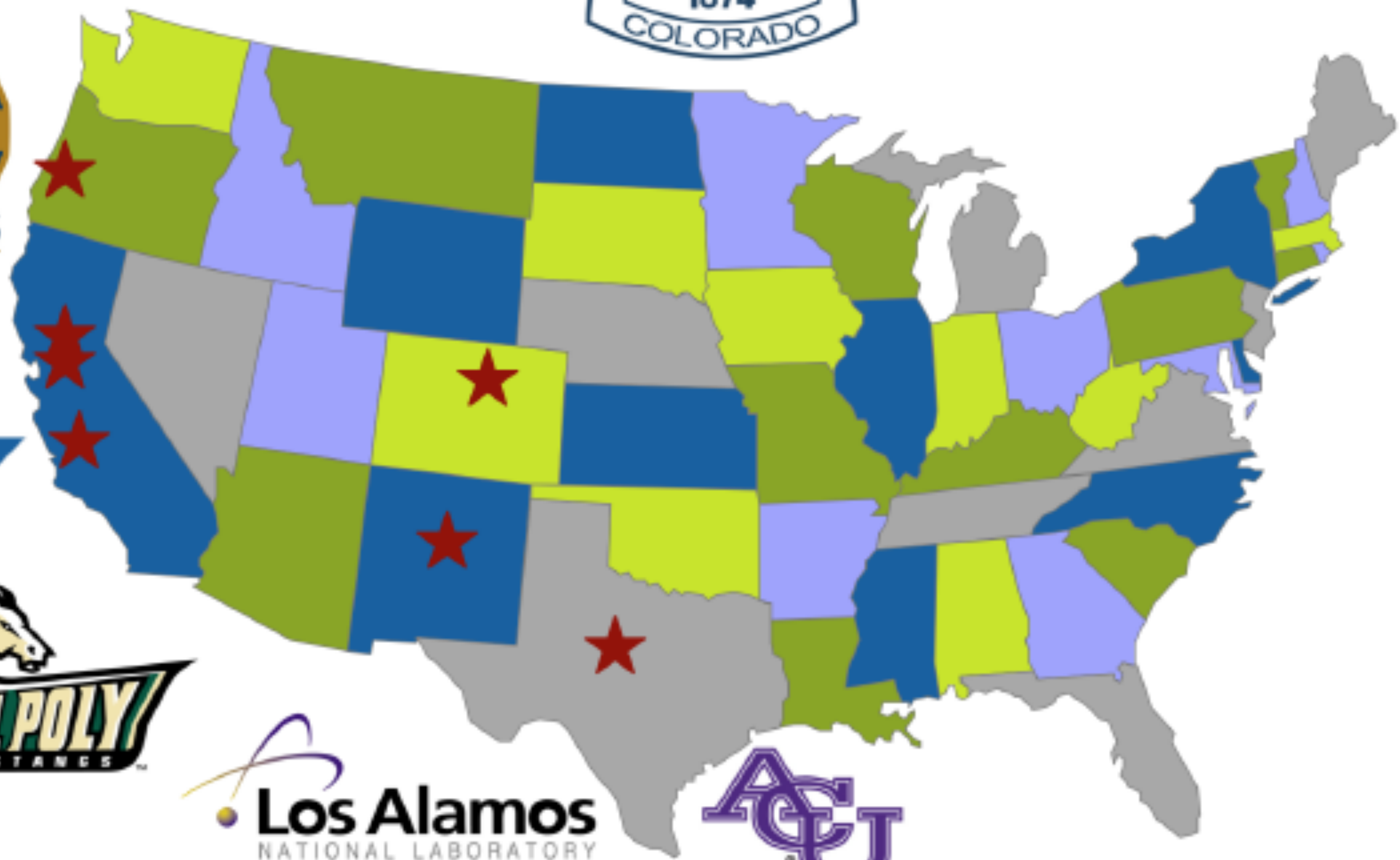
NIFFTE Collaboration

NIFFTE

OREGON STATE

SCHOOL OF MINES 1874 COLORADO

UC DAVIS AGGIES



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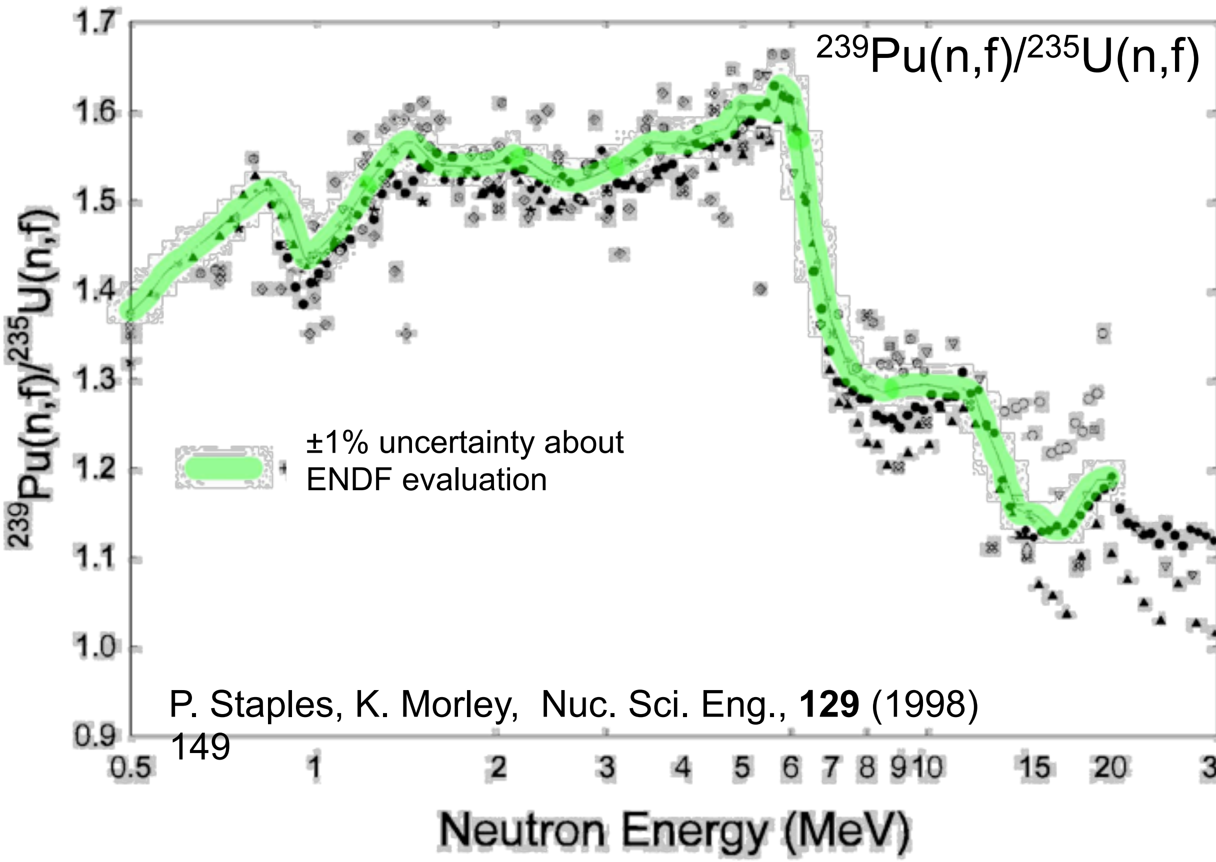
Motivation:
Study and Improve Cross-Section Ratio Systematics

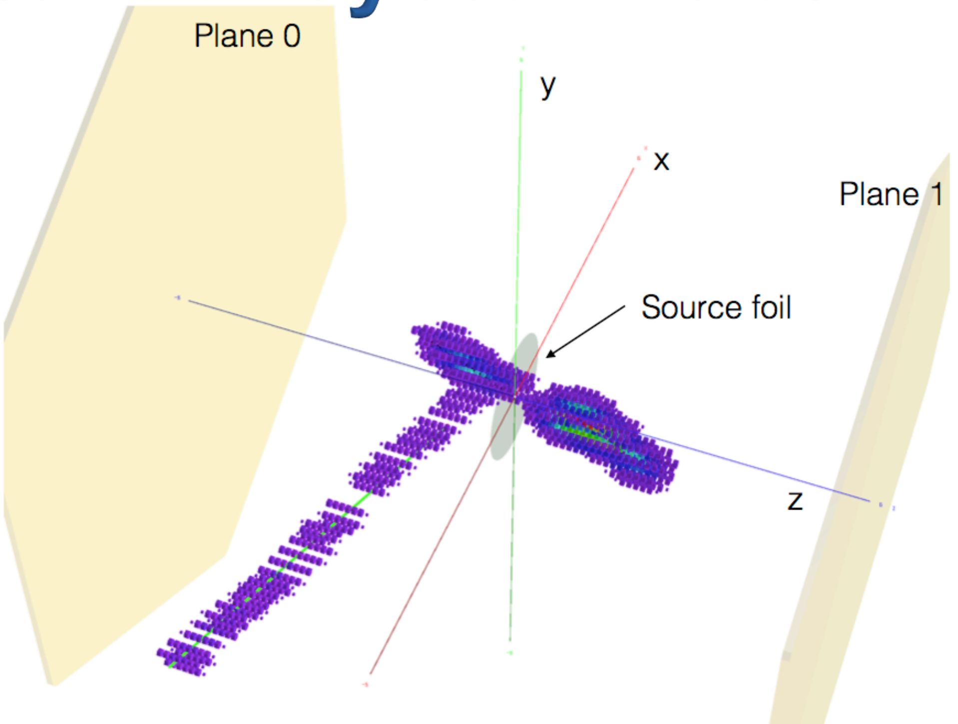
- Nuclear data uncertainties strongly influence design and operation margins in nuclear defense and energy applications

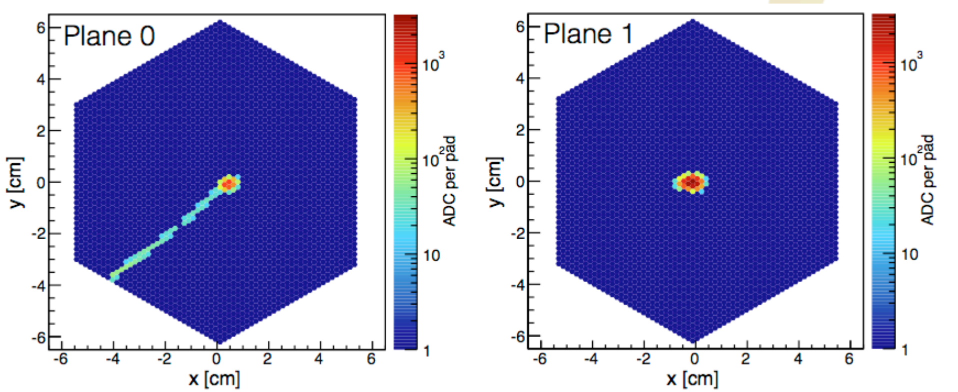
- Spread of existing data suggest uncontrolled and/or unrecognized systematic uncertainties



The NIFFTE fissionTPC will allow detailed study of potential systematics

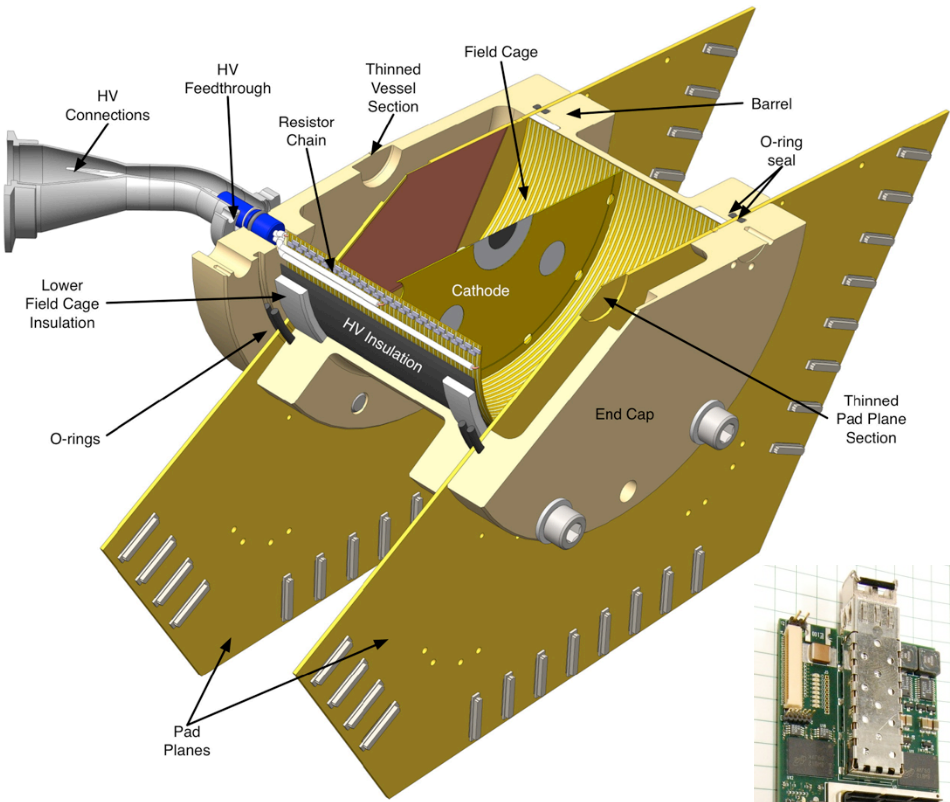
- Particle identification
  - Full track reconstruction, incl. dE/dx for PID
  - Reject alpha backgrounds
- Target/beam non-uniformities
  - In-situ beam profiling, target radiography
  - Multi-actinide targets
- Thin target backings
  - Minimize straggling losses
- Reference standards
  - Will use H bearing gas/target to measure (n,f) relative to $^{1}H(n,n')$

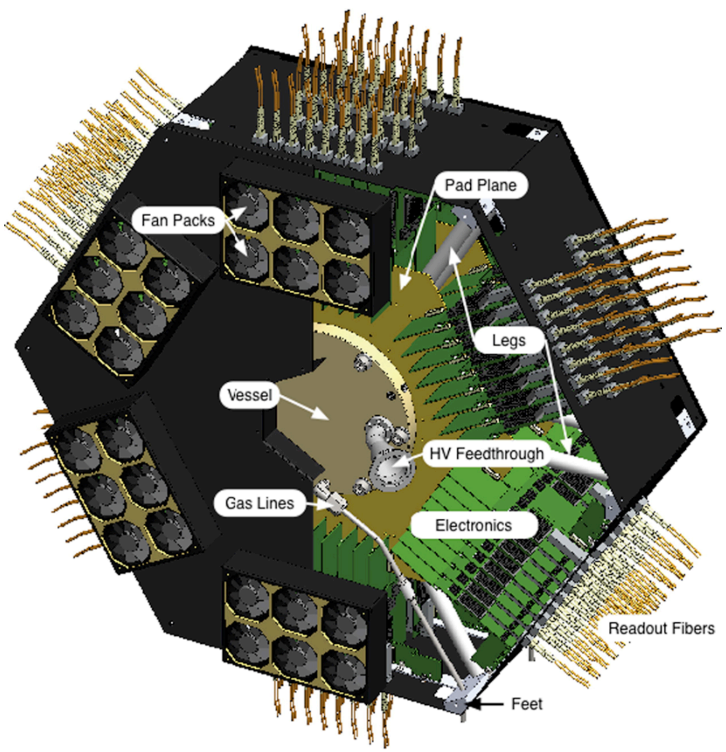




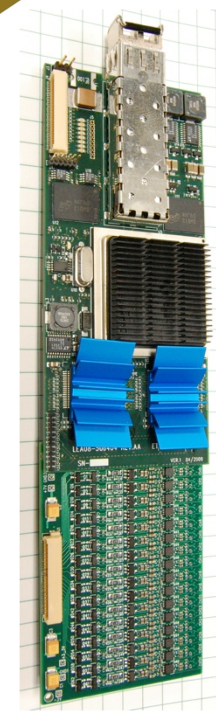
fissionTPC Design

- Dual volume MICROMEGAS TPC
- 2976 x 2 hex pads (2mm), 54mm drift length
- 95% Ar / 5% isobutane drift gas



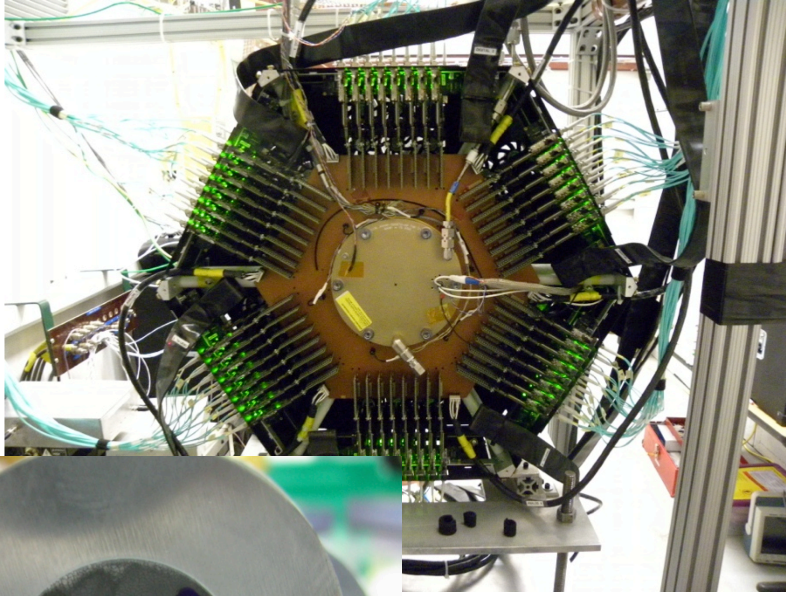


- Custom DAQ
  - Every pad recorded at 50MHz
  - Cathode recorded at 1GHz for neutron TOF measurement
  - $55 per channel

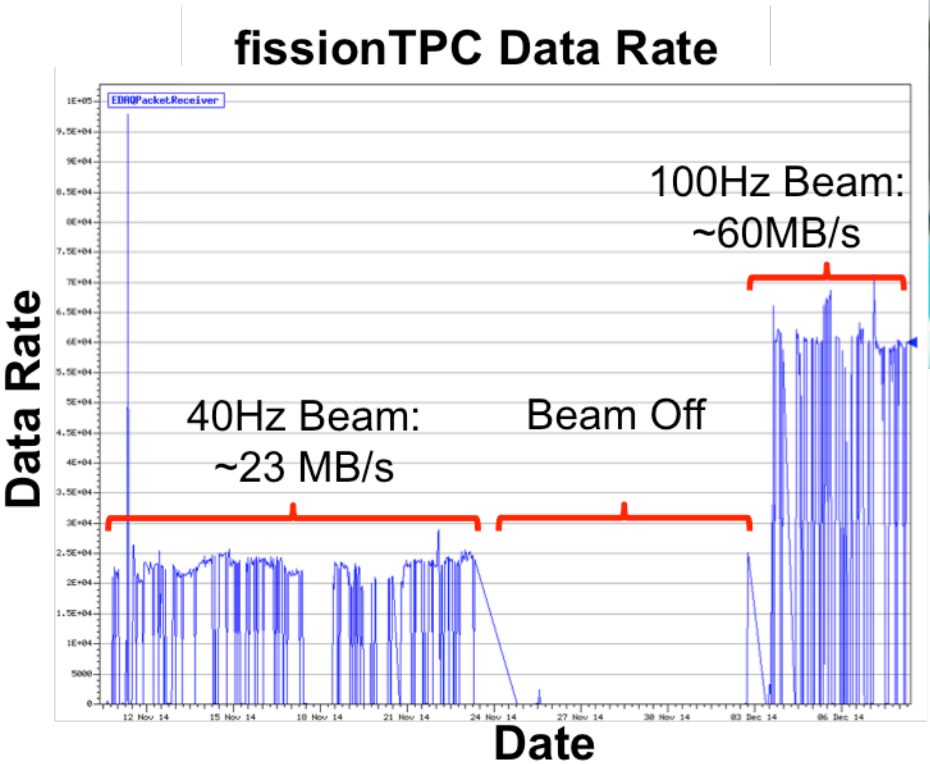


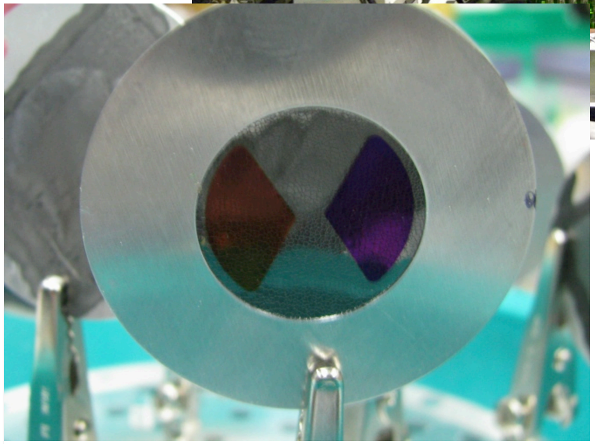
TPC description: M.Heffner, et. al., NIMA, 10.1016/j.nima.2014.05.057
DAQ design: M.Heffner, et. al., IEEE TNS **60** (2013) 2196

fissionTPC Operation



- Cross-section measurements performed at LANSCE 90L beamline
  - TPC fully instrumented since 2013
  - Data volume ~100MB/s, ~100TB/yr

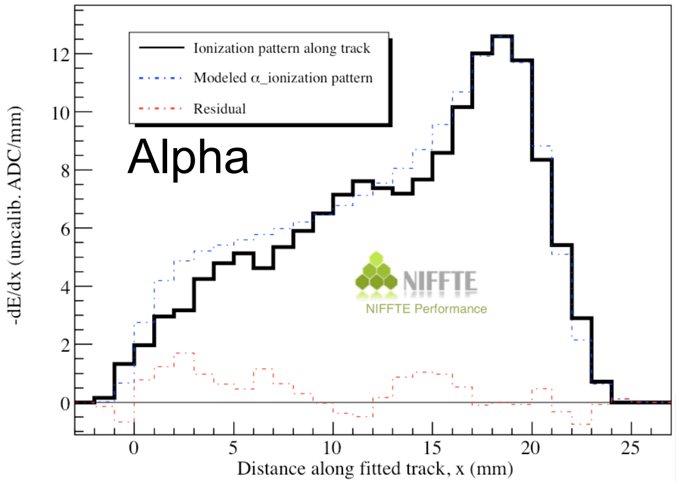


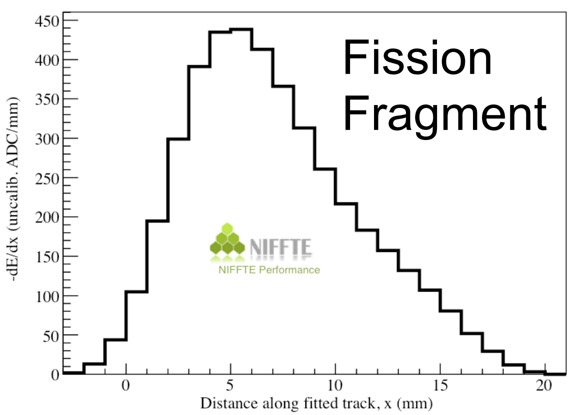


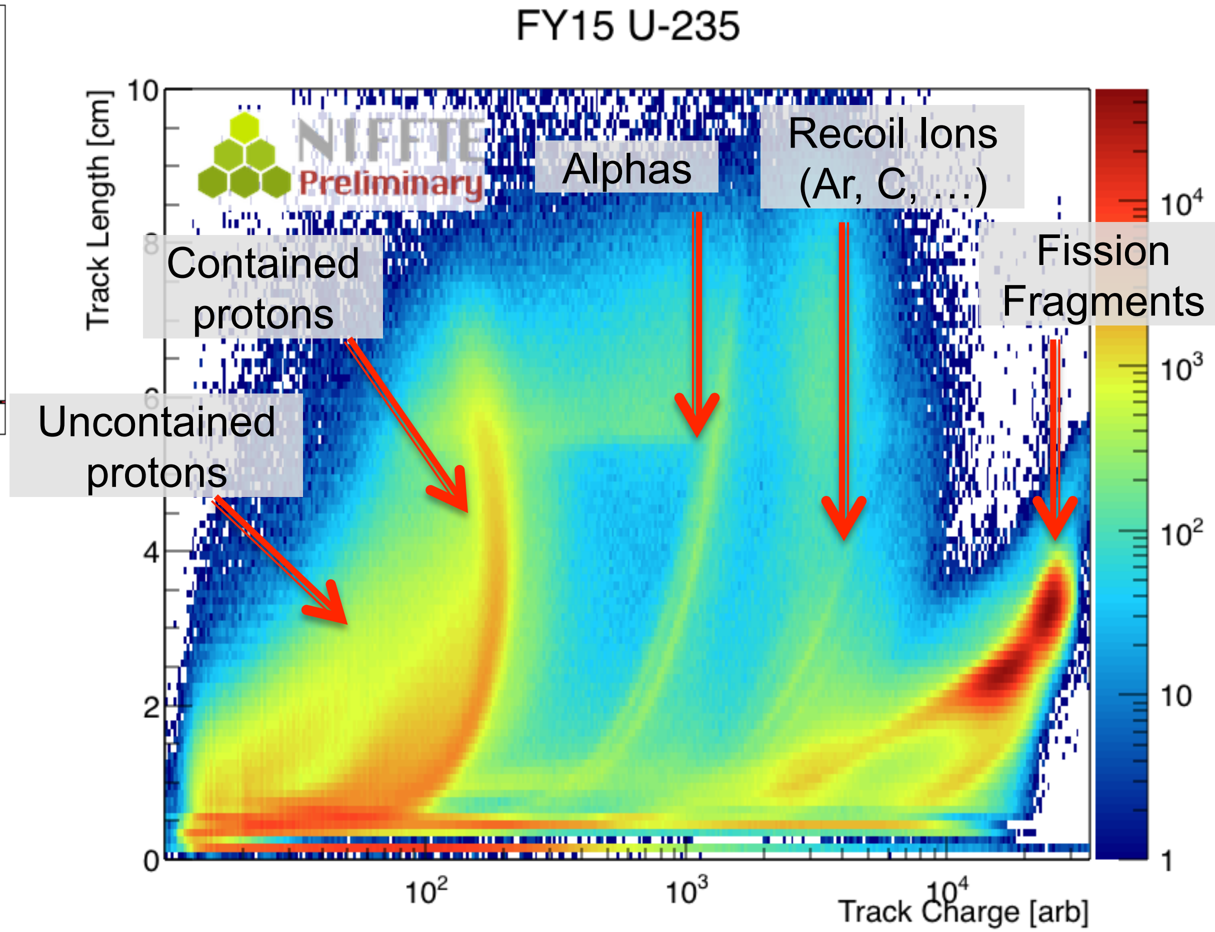
- Wide variety of targets used/planned:
  - ^{239}Pu, ^{235}U, ^{238}U, ^{252}Cf, ^{244}Cm
  - multi-actinide
  - thin & hydrogenous backings
  - activities as high as ~MBq

Event-by-event Particle ID based on Bragg 'curve' and track parameters

Direction of travel







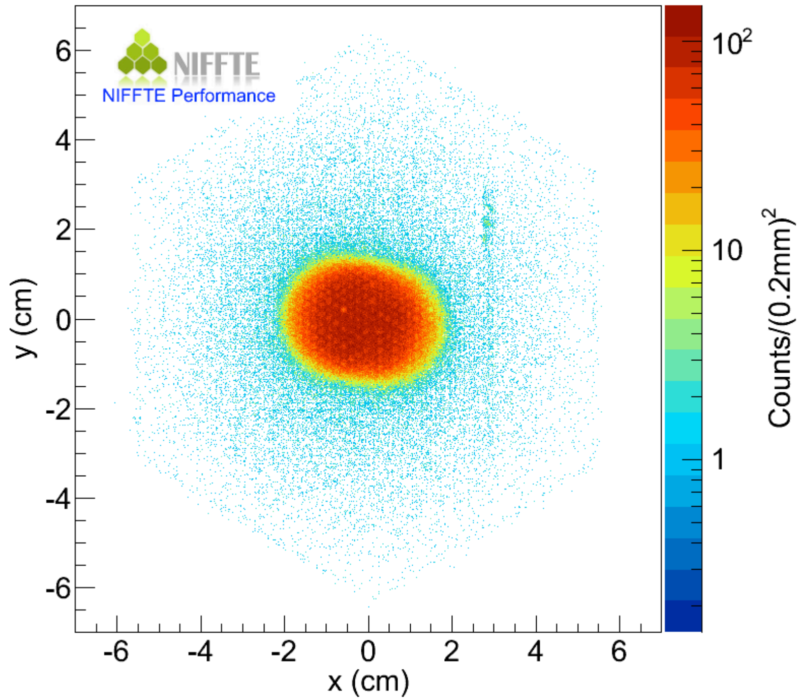
Example fissionTPC performance: Beam and target characterization

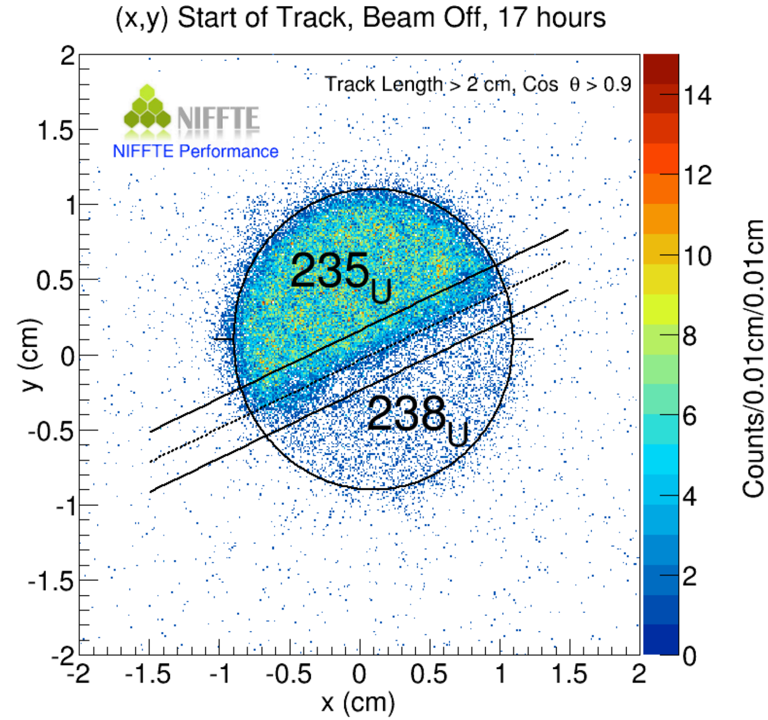
Neutron Beam Spatial Profile:

- Select recoil protons and examine start vertex
- Can study and account for any spatial variation

Target auto-radiograph:

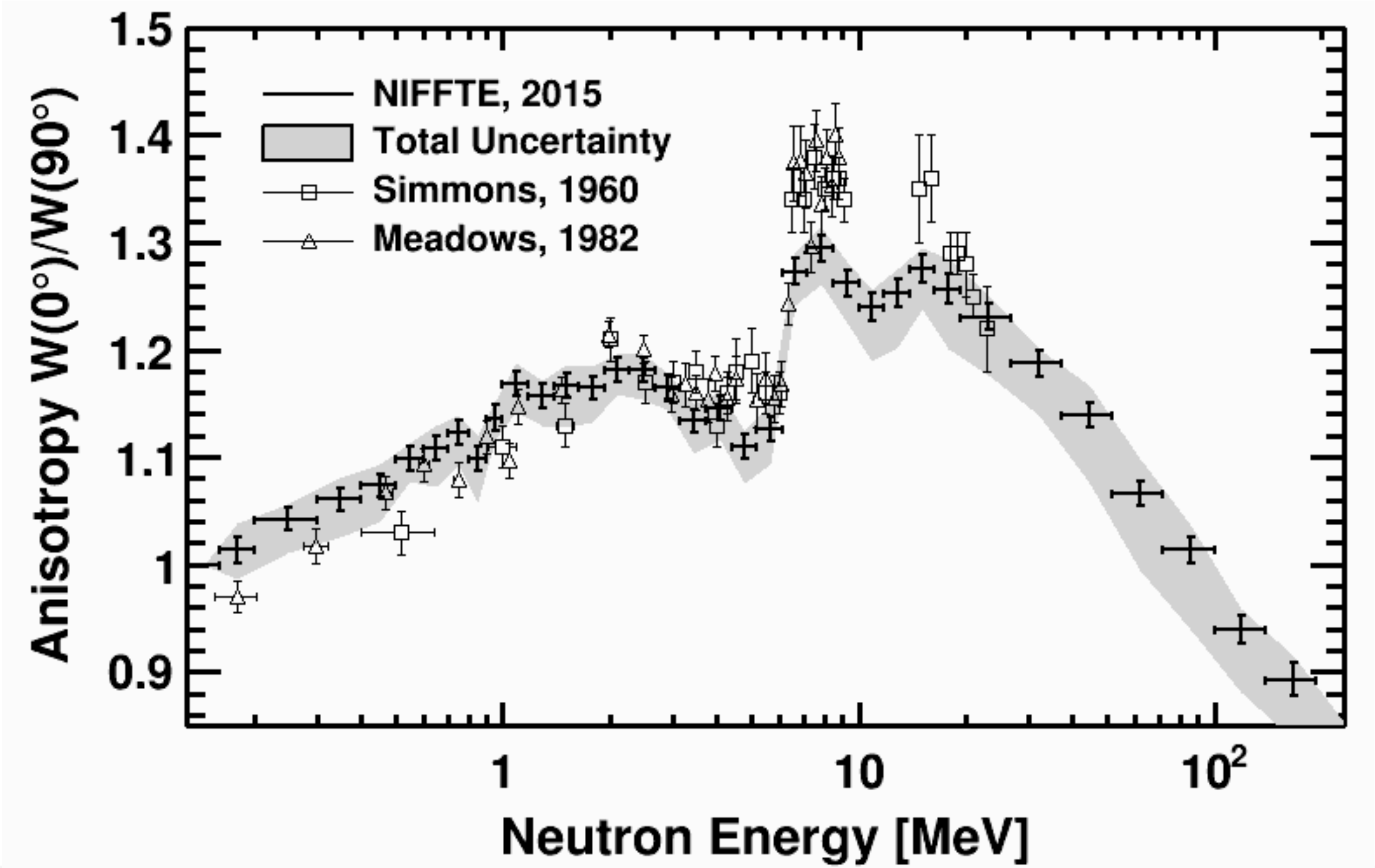
- Select fragments or alphas and examine start vertex
- Can study and account for target non-uniformity





First NIFFTE Physics Result: ^{235}U Anisotropy

PhD Thesis of Verena Kleinrath; publication expected in 2016



Current Status and Outlook

- Collected 'thick' target ^{239}Pu/^{235}U data set in FY, 'thin' target prepared for FY16 (now)
- Evaluating cross section with focus on uncertainties and correlations, correction terms enabled by TPC (e.g. non-uniformities)
  - To date, incomplete set of partial systematic uncertainties, focusing on fragment selection.
- Running hydrogenous target backings and performing gas system R&D in preparation for ^{239}Pu(n,f)/^{1}H(n,n') measurement
- Hope to complete full ^{239}Pu(n,f)/^{235}U(n,f) evaluation in 2016