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Fission Data Experiments at LANSCE: SPIDER, TKE, and fissionTPC

CSEWG2016 Contribution

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On Behalf Of SPIDER, TPC, and TKE collaborations
(LANL PI – Fredrik Tovesson)

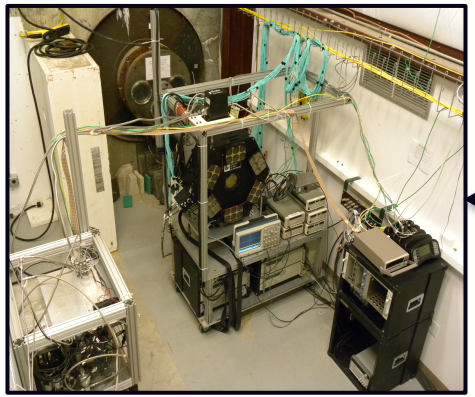
Nov. 14th, 2016

Operated by Los Alamos National Security, LLC for the U.S. Department of Energy's NNSA

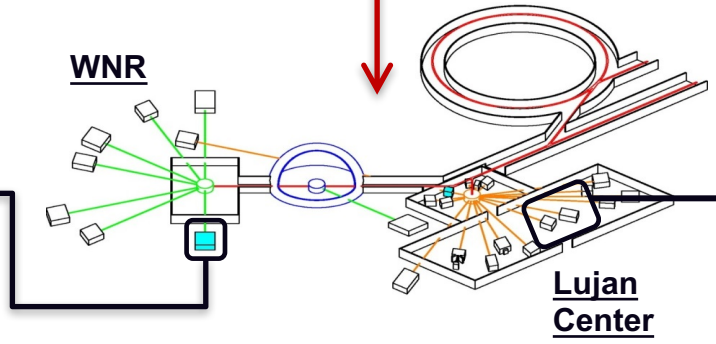
Experimental Facilities – Lujan Center and WNR

- LINAC accelerates protons to 800-MeV
- Pulsed beam allows for nToF determination
- Target 1 – moderated neutron source
  - Lujan Center (E_n - cold to thermal)
- Target 4 – unmoderated spallation target
  - WNR (E_n - fast up to 600 MeV)

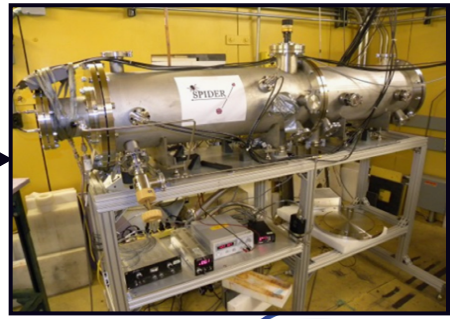
TA-53, LANSCE



TPC and TKE



SPIDER



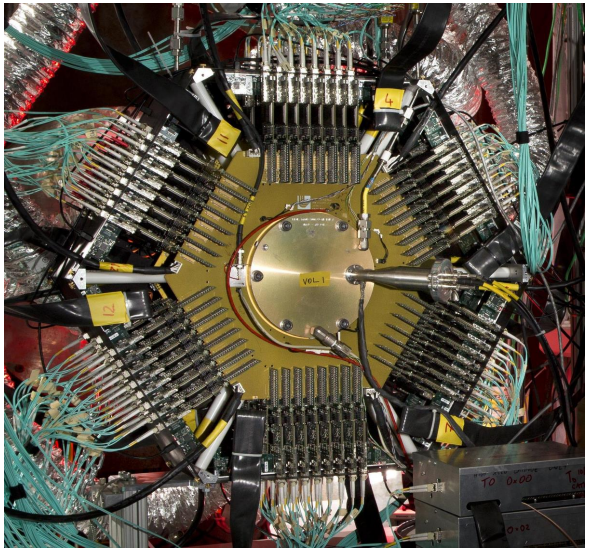
NIFFTE Time Projection Chamber

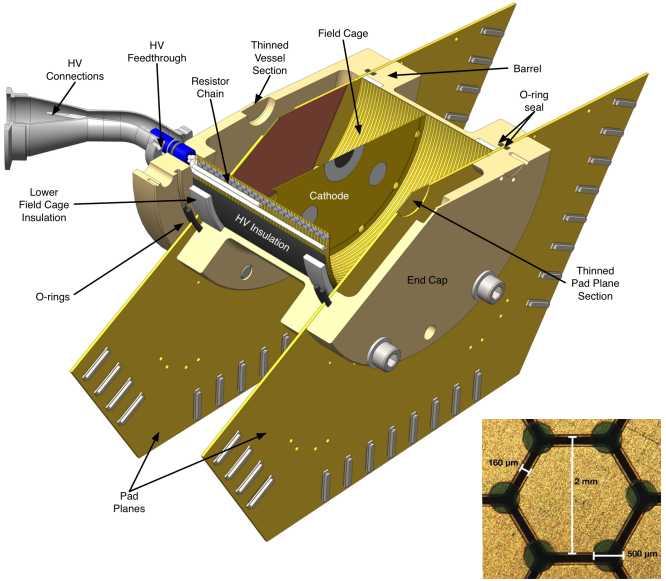
(Neutron-induced Fission Fragment Tracking Experiment)

NIFFTE fissionTPC – Time Projection Chamber

- Cross section datasets have uncertainties of 3-5%in the fast region
- Uncertainties of <=1% are needed for applications
- NIFFTE seeks to study sources of uncertainties effecting prior works

Sources of uncertainty
Particle ID, alpha/fission fragment separation
^{235}U reference
Energy loss in target
Neutron beam profile
Neutron beam energy-position correlations
Beam spreading and attenuation
Neutrons scattering back in (room return)
Target contamination
Non-uniform density (target and backing)
Complete fragment loss (detector efficiency)

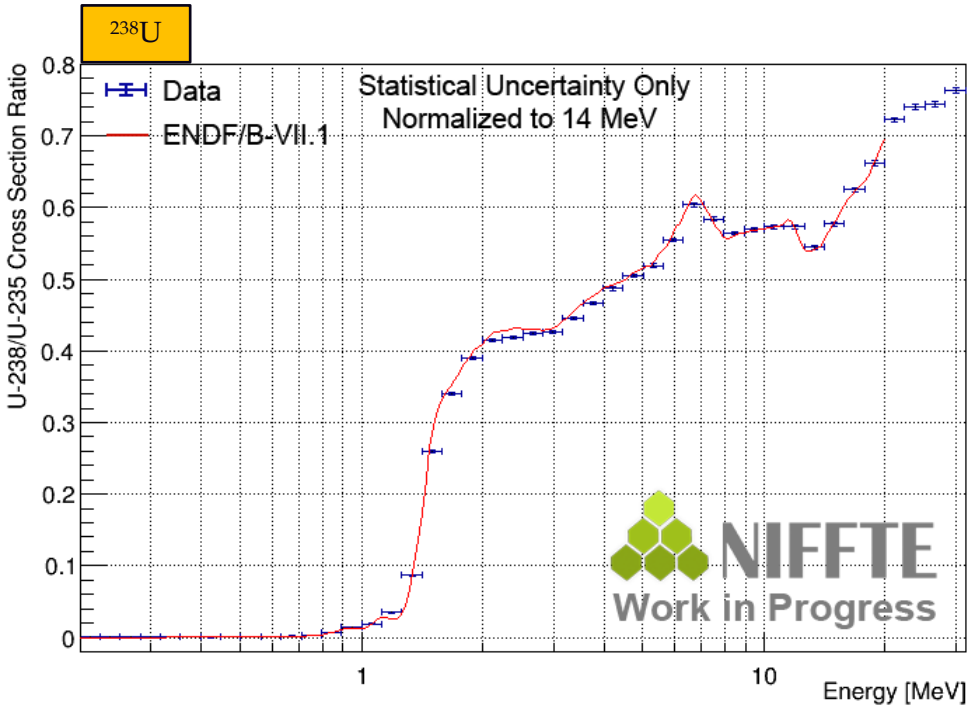


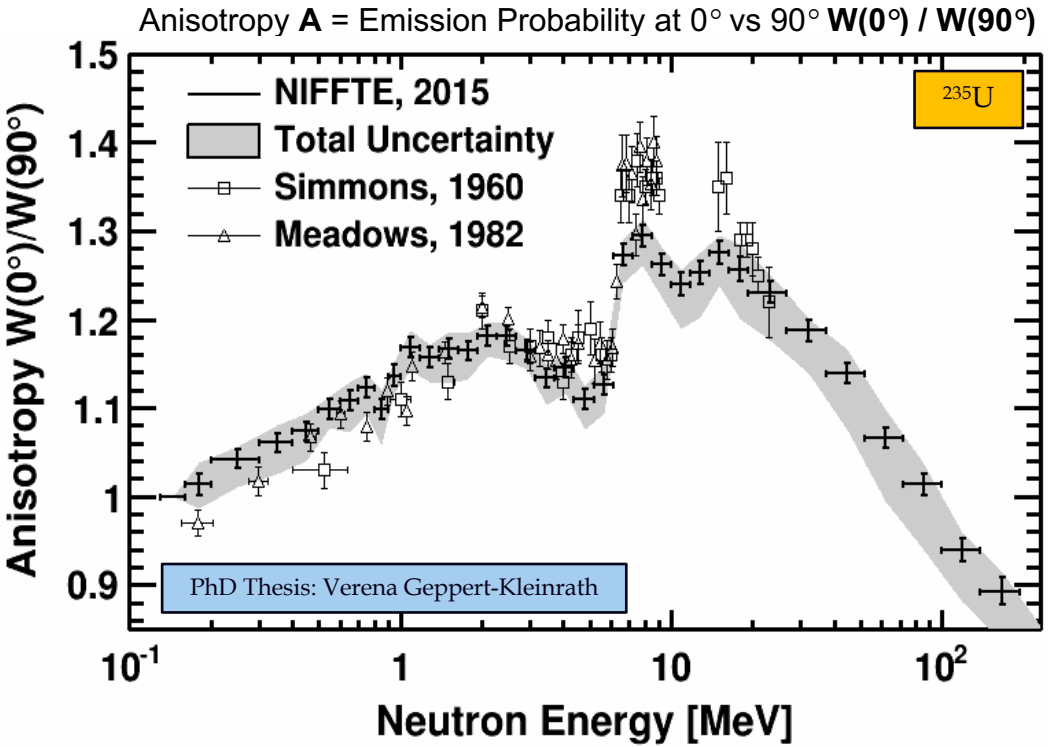


fissionTPC Features:

- Two-chamber design
- Compact, 4π Detector
- Particle tracking
- Segmented MicroMegas
- ~6000 independent channels

NIFFTE fissionTPC – Time Projection Chamber





- Analysis of ^{239}Pu/^{235}U cross section ratio in progress

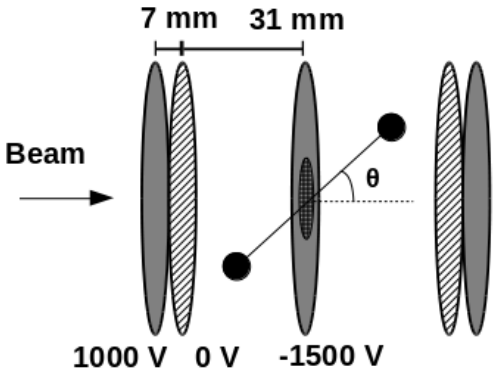
Heffner, M. *et al.*, NIMA **759**, 50 (2014)

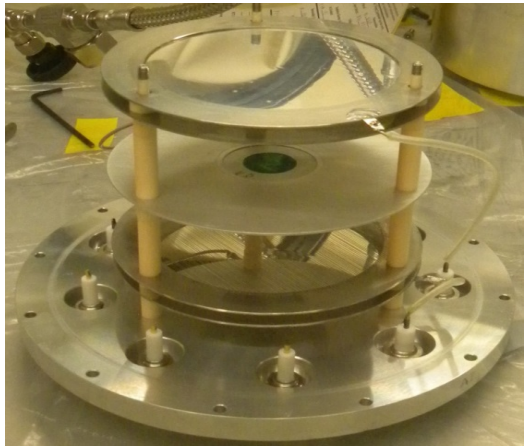
Dual Frisch-gridded Ionization Chamber

(TKE - Total Kinetic Energy)

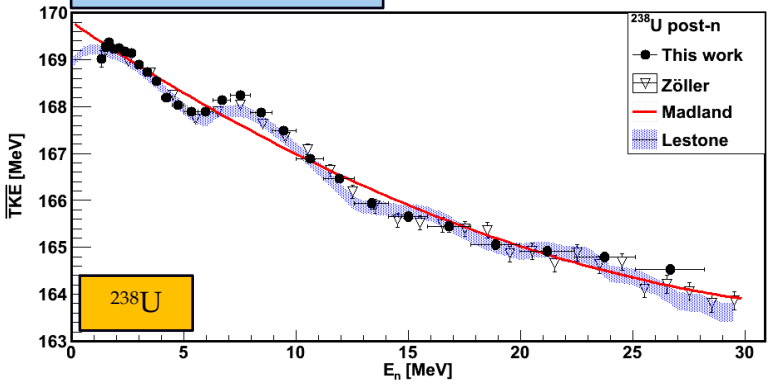
Dual Frisch-gridded Ionization Chamber

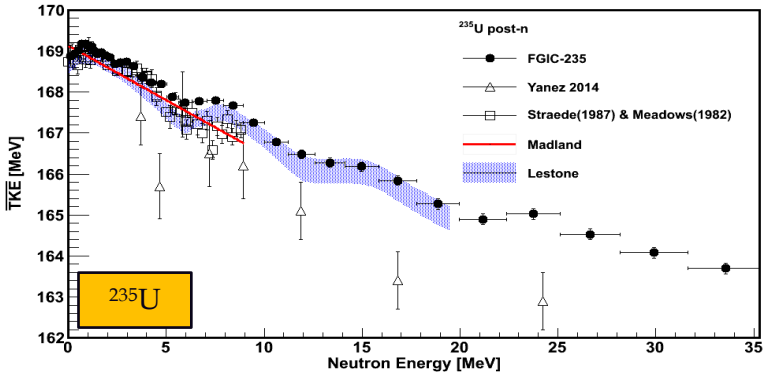
- TKE represents most of the energy released in fission
- A key observable to model and application communities
- Evolution of fission observables with increasing E_n
  - Benchmark for state-of-the-art fission models





PhD Thesis: Dana Duke



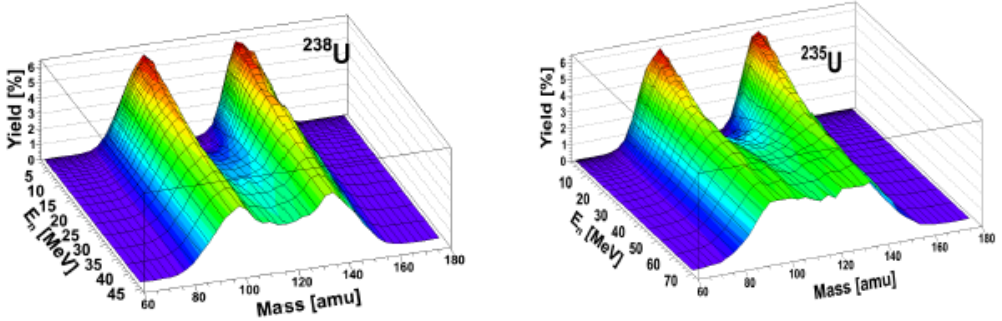


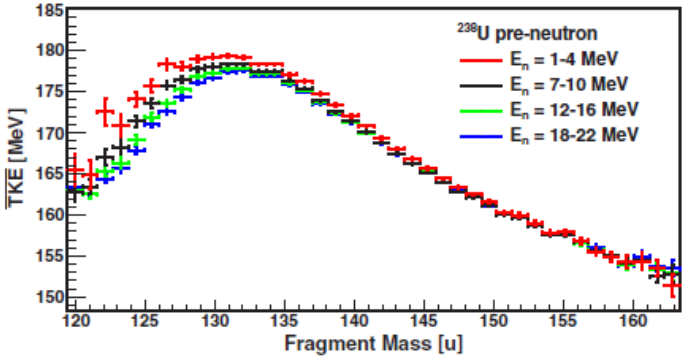
Duke, D. *et al.*, PRC **94,** 054604 (2016);

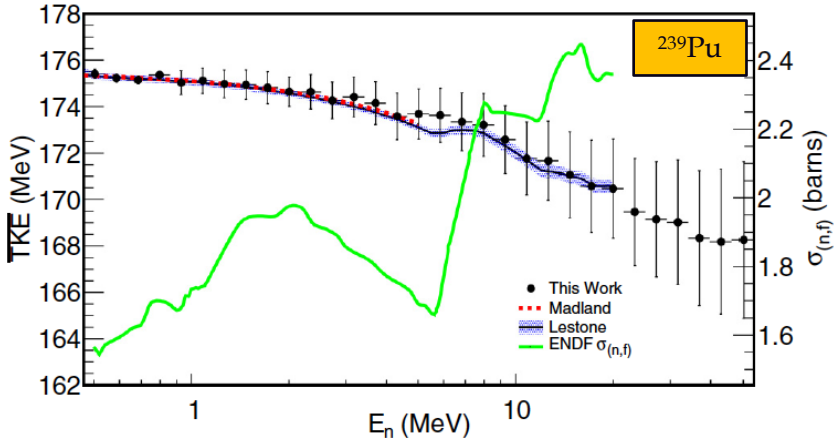
Dual Frisch-gridded Ionization Chamber Experiment

FPYs (E_n)

Resolution: 3-5 amu







Run Cycle 2016 Data

→ ^{232}Th (collected)

→ ^{233}U (in progress)

→ ^{237}Np (planned)

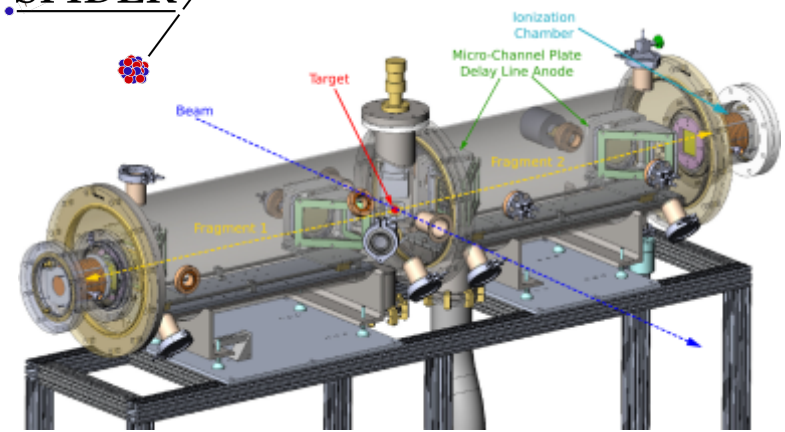
Meierbachtol, K. *et al.*, PRC **94,** 034611 (2016); Duke, D. *et al.*, PRC **94,** 054604 (2016);

SPIDER – 2*v*2*E* Mass Spectrometer

(Spectrometer for Ion Determination In Fission Research)

SPectrometer for Ion DEtermination in fission Research

SPIDER



CAD of Dual-arm SPIDER

- Mirrored mass spectrometer for event coincidences

$$E = \frac{1}{2} m \left(\frac{\vec{l}}{t}\right)^2 \leftrightarrow m = 2E\left(\frac{t}{\vec{l}}\right)^2$$

- Velocity detectors kept at high-vacuum ($10e^{-5}$ to $10e^{-7}$ torr)
- Energy detectors use *i*-butane as active medium

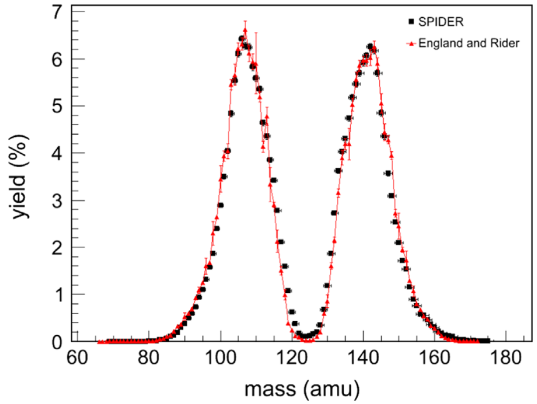
Instrument mass resolution given by

$$\frac{\partial m}{m} = \sqrt{\left(\frac{\delta E}{E}\right)^2 + 2\left(\frac{\delta t}{t}\right)^2 + 2\left(\frac{\delta l}{l}\right)^2} \approx 0.01 \rightarrow 1 \text{ amu}$$

0.5% (≤ 500 keV) ☆

0.5% (≤ 250 ps) ✓

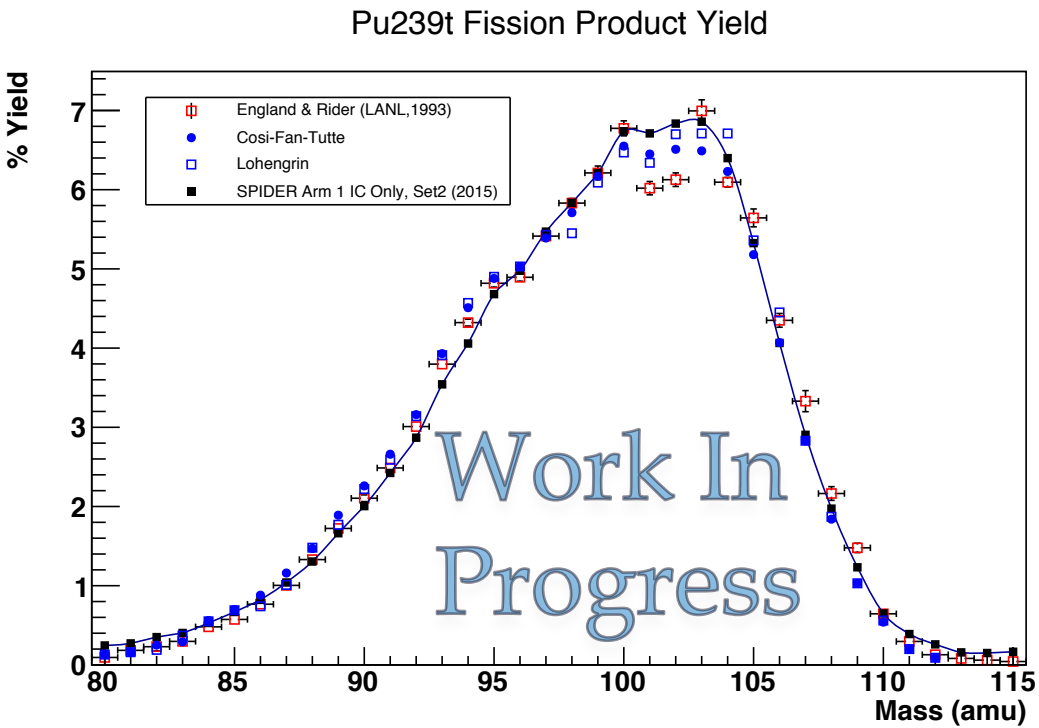
0.5% (≤ 0.3 cm) ✓

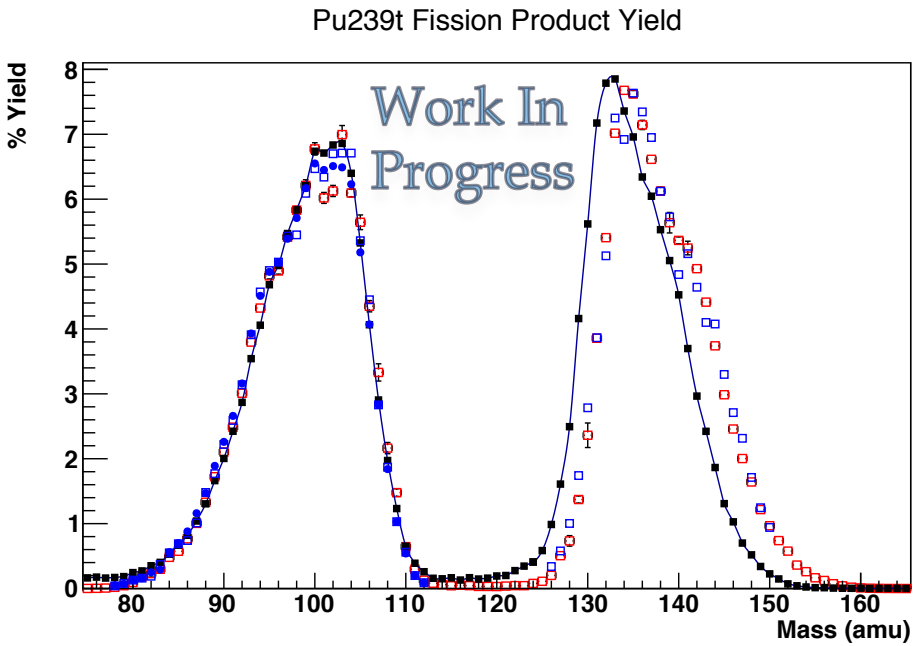


LANSCE Los Alamos Neutron Science Center

Meierbachtol, K. *et al.*, NIMA, **788** 59 (2015); Arnold, C.W. *et al.*, NIMA, **764** 53 (2014).

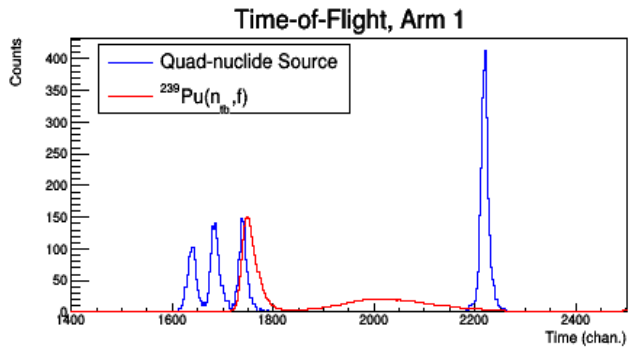
SPIDER Results: ^{239}Pu Thermal Fission (*1v1E*)

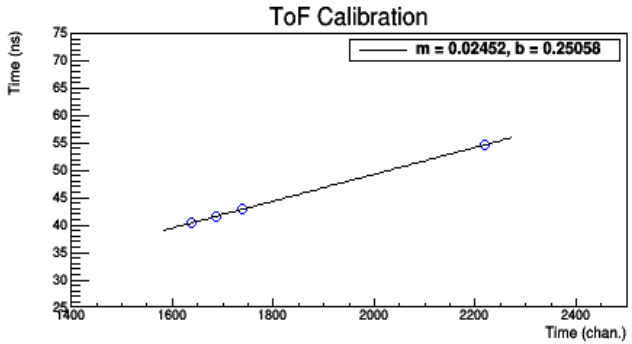




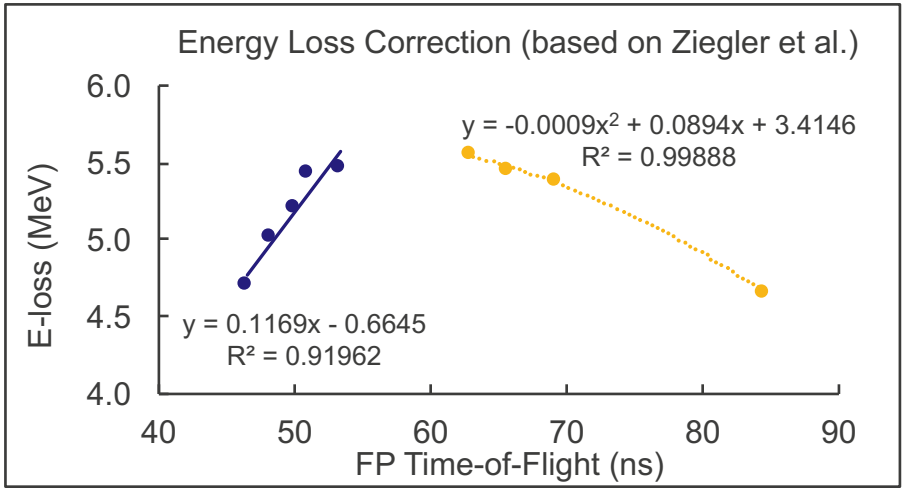
SPIDER Results: ^{239}Pu Thermal Fission (*1v1E*)

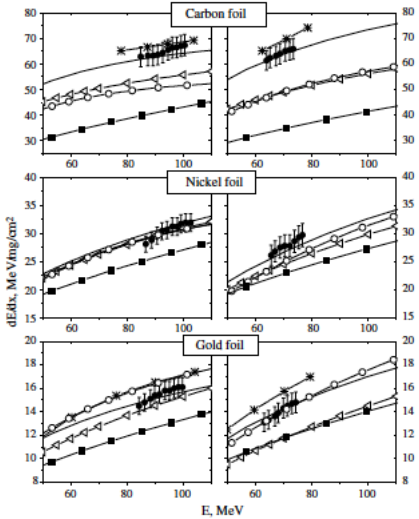
Time (Velocity)





Energy



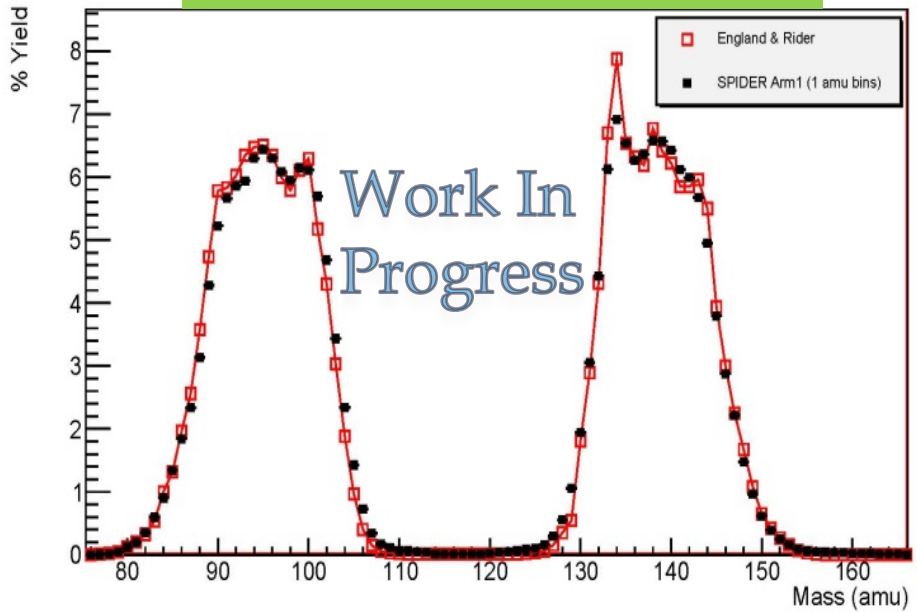


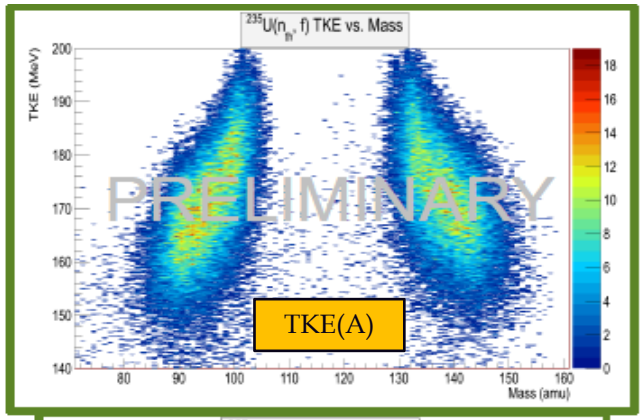
- Correction for energy loss separate for light and heavy fragments
- Uncertainties in energy loss estimates can reach up to 30%
- The heavy fragment are most affected by the uncertainty and pulse-height defect (PHD)

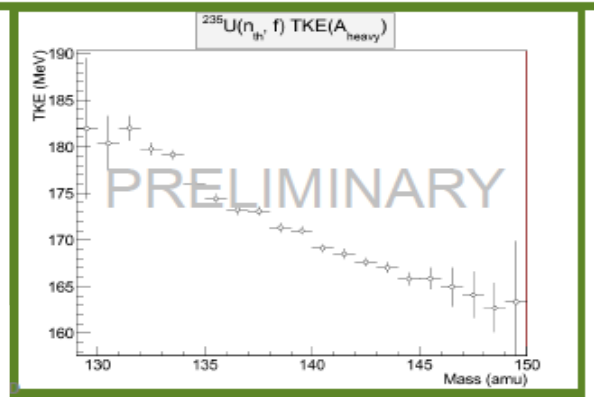
Knyazheva, G. *et al.*, NIMB **248**, 7 (2006).

SPIDER Results: ^{235}U Thermal Fission (*2v2E*)

Data Courtesy of D. Shields (CSM)







- ^{235}U FPY distribution exhibits pronounced features
- **Preliminary** data, but demonstrates high-resolution

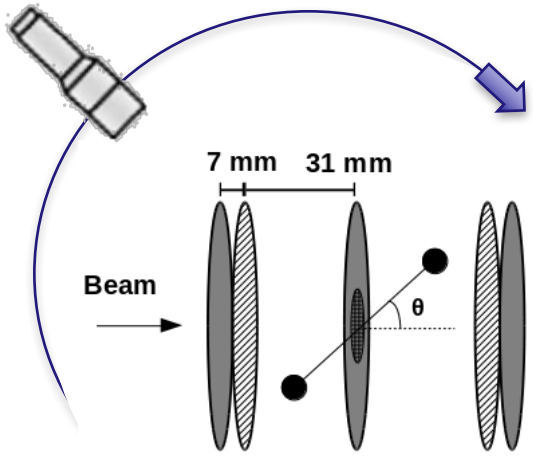
LANSCE Los Alamos Neutron Science Center

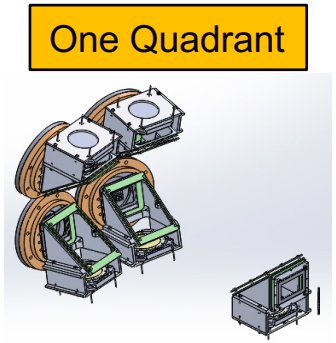
SPIDER

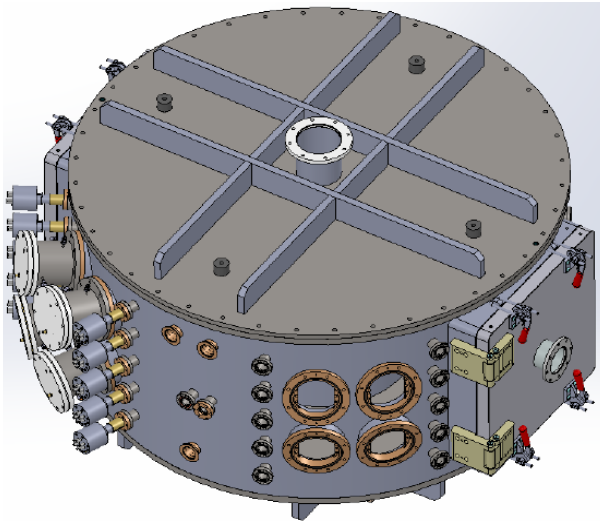
Future Plans

Summary and Future Plans

- Experimental nuclear data efforts at LANSCE include several complementary approaches
- These aim to help improve understanding of the fission process and to validate models
- Furthermore, the data collected at LANSCE may help to improve nuclear data libraries
    - This latter point is particularly interesting in light of the reactor anti-neutrino anomaly







- ≈ 8x gain in solid angle coverage
- 16 ICs and 20 MCPs (1 start for 4 stops)
- Main chamber to be completed in early 2017
- Offline ^{252}Cf planned after assembly
- Challenges: Gas-vacuum interfaces / Thin foils

Acknowledgements

SPIDER

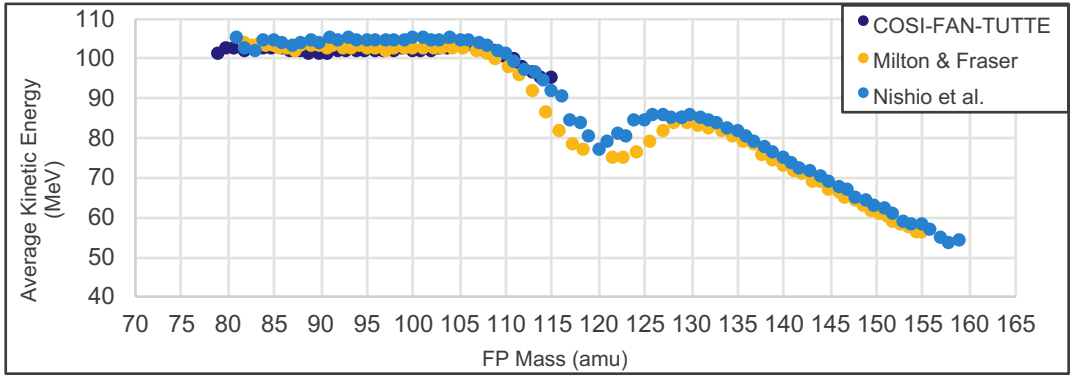
FGIC (TKE)

fissionTPC

Additional LANL Support (Partial List)
Arnie Sierk, T-2, TKE and SPIDER
Denise Neudecker, XCP-5, fissionTPC

Thank you for your attention!

Back-up Slides


COSI-FAN-TUTTE
Milton & Fraser
Nishio et al.
Average Kinetic Energy (MeV)
110
100
90
80
70
60
50
40
70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150 155 160 165
FP Mass (amu)