Measurements of Independent Fission Product Yields

Workshop on Applied Nuclear Data Activities (WANDA)

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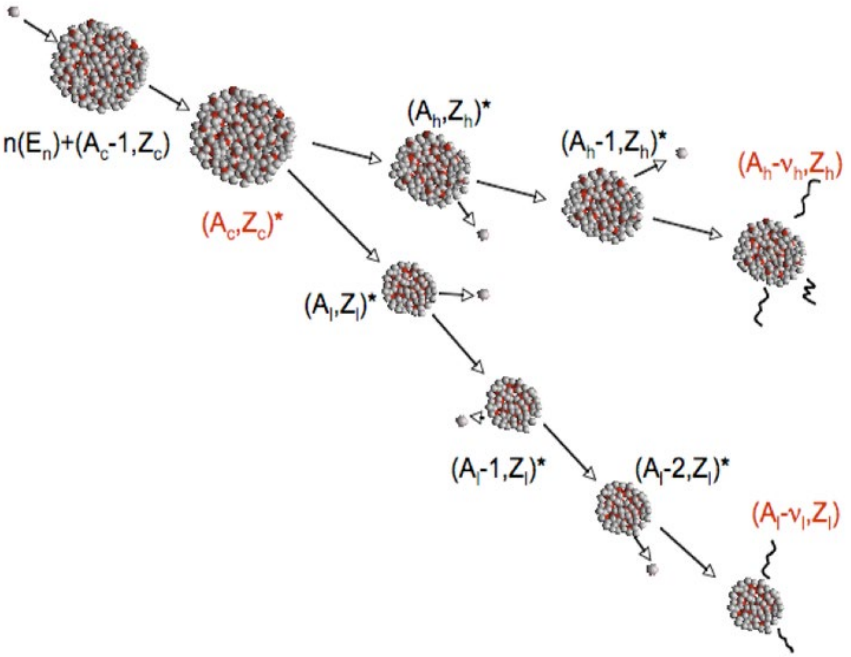
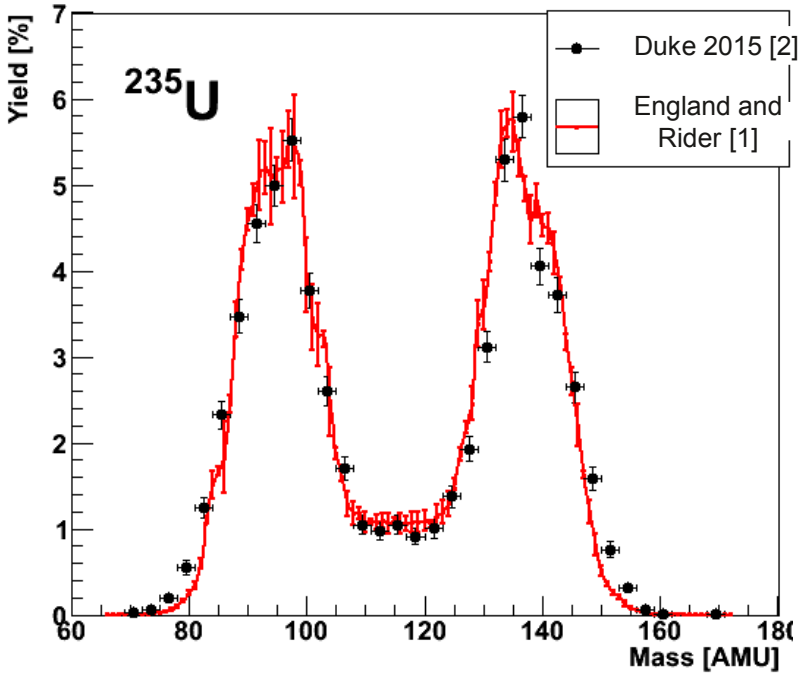
Introduction: The goal of this experiment is to improve IFPY nuclear data by minimizing and understanding uncertainty in new measurements.

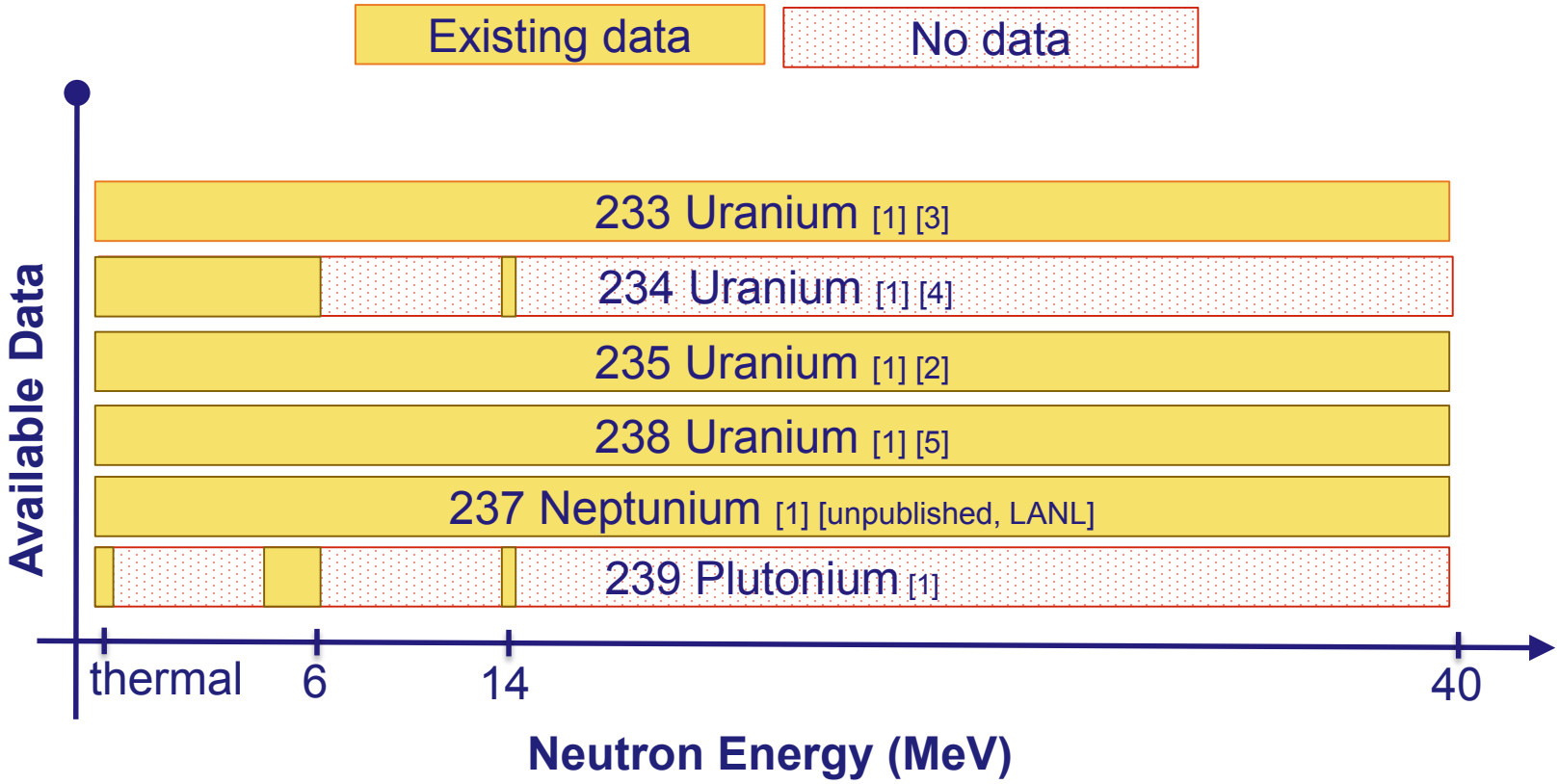
- We will accomplish this by leveraging existing and newly applied technologies: 2E Frisch Gridded Ionization Chamber (FGIC) and the fission Time Projection Chamber (fissionTPC)





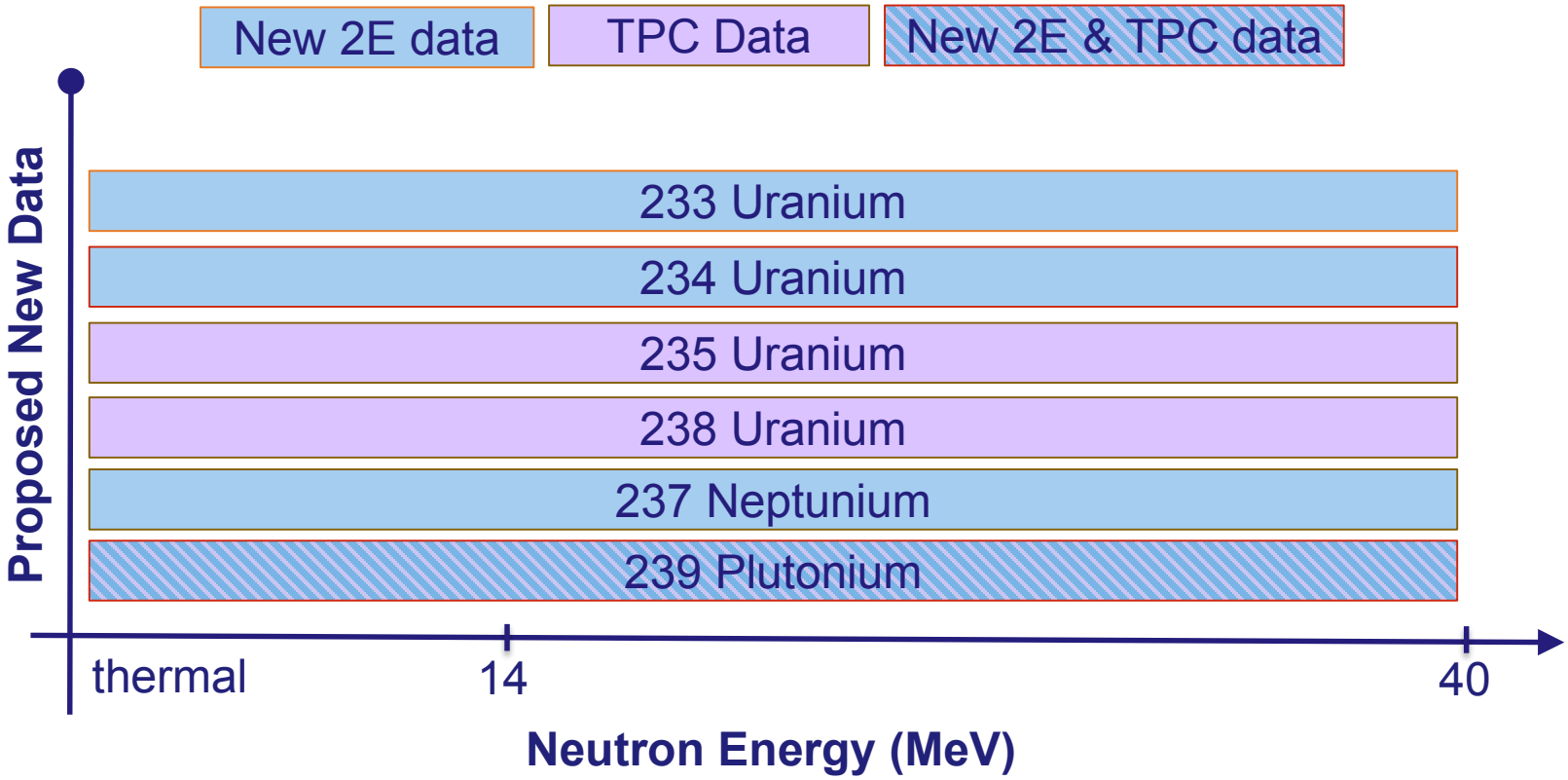
Motivation: As models of nuclear fission evolve, more independent fission product yield data (IFPY) are needed to support applications.

- The available data have gaps, especially at higher neutron energies, and needs improved uncertainty quantification.



Motivation: As models of nuclear fission evolve, more independent fission product yield data (IFPY) are needed to support applications.

- New data 2E will be added during this experimental program; the TPC data already exists and is awaiting analysis.

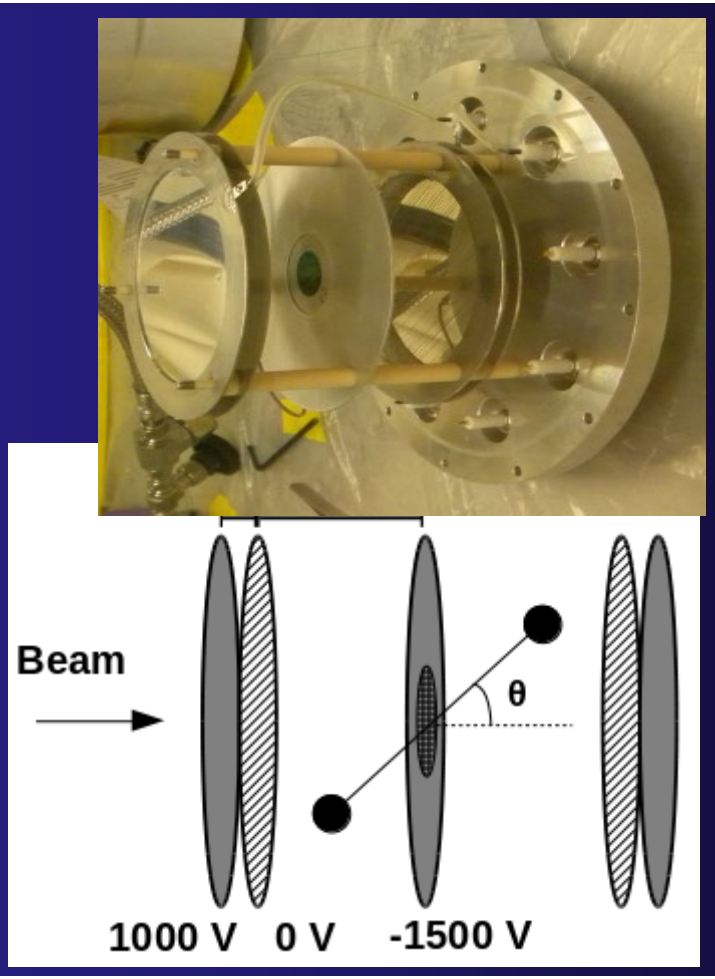


Experimental method: The method uses a three pronged approach to accomplish our goal.

1) Perform 2E measurements of 233-U, 234-U, 237-Np, and 239-Pu using the proven technology of the FGIC.
2) Perform an analysis that leverages existing TPC 235-U, 238-U, and 239-Pu data to produce FPY measurements and probe uncertainties related to energy loss, pulse height defect, and pile-up.
3) Develop a new Bragg curve based TPC analysis. This method has potential to provide fission product mass and charge distributions and place a constraint on prompt neutron emission.

1) FGIC's are a proven technology used to measure fission observables such as IFPY's, total kinetic energy release, and cross sections.

- The FGIC measures energies and emission angles of fission fragments, which are used to calculate masses in the 2E method.
- This detector type was used in most of the existing measurements, which provide about 4-5 amu mass resolution and have some systematic uncertainties.
- We will make new measurements of ^{233,234}U, ^{237}Np, and ^{239}Pu using a FGIC at the same facility as TPC.



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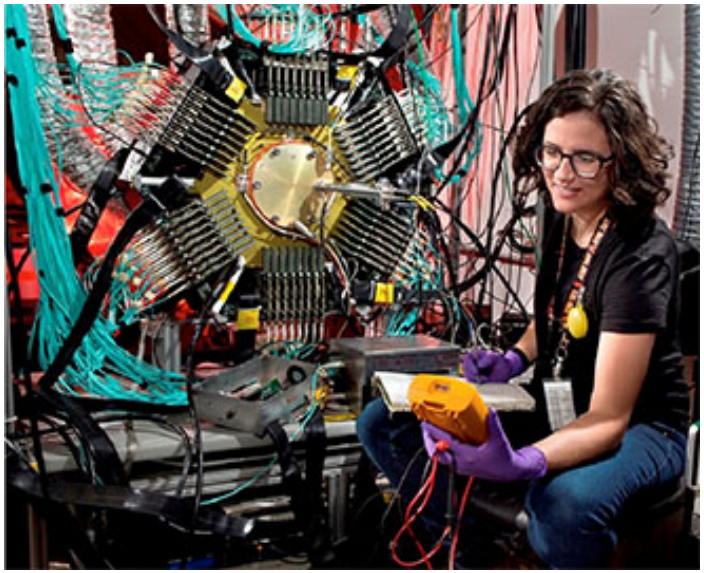
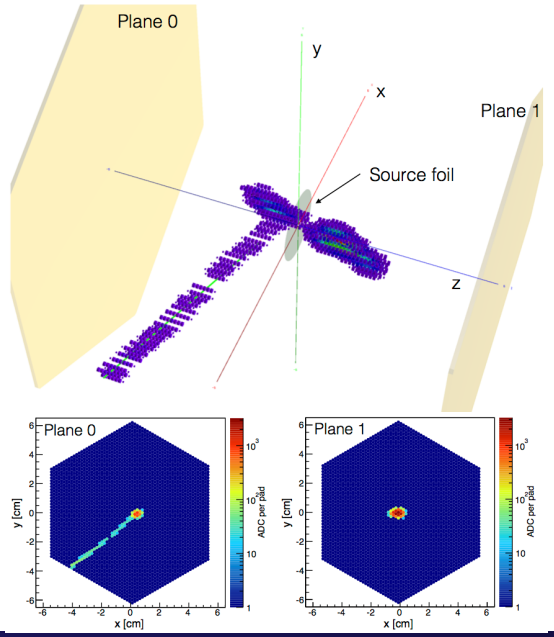
2) The TPC will use a 2E analysis technique on existing data to probe the uncertainties inherent in the method.

- The fissionTPC has been adding valuable precision cross section data to nuclear data libraries.
- A three dimensional reconstruction of the fission fragment track provides additional information that can be used to assess uncertainties in previous 2E measurements.
- Additional IFPY data for ^{235,238}U and ^{239}Pu will be added to evaluations using existing TPC data.





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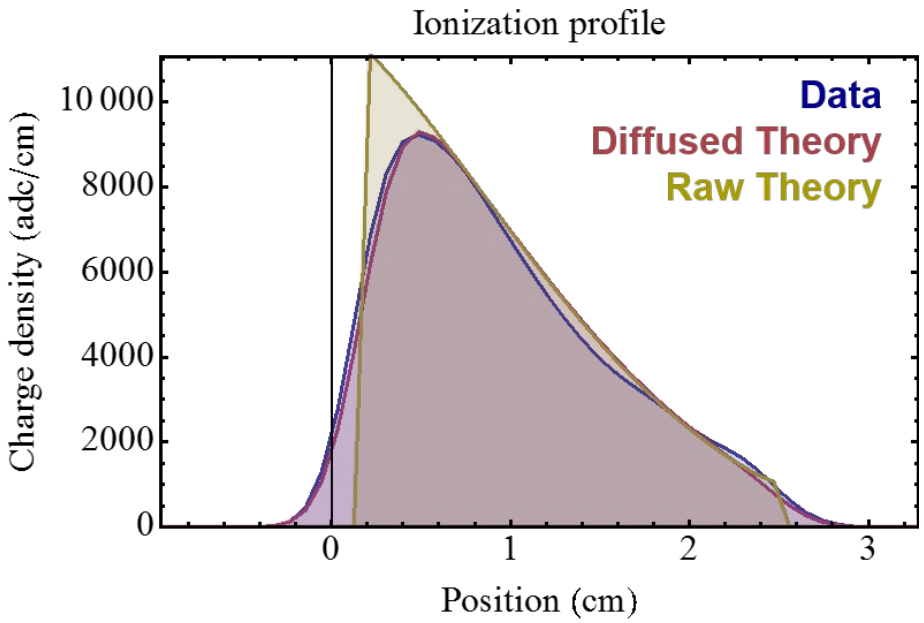
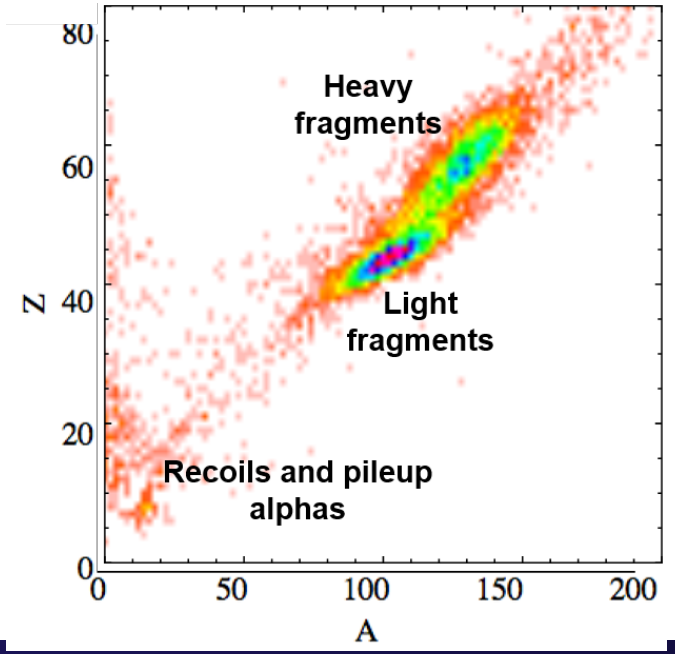
3) We will develop Bragg curve analysis and explore uncertainty reduction to IFPY's using the fissionTPC.

- Bragg curve spectroscopy can provide not only the mass (A) of the particle, but its charge (Z).
- Recent analysis suggest this may be possible using the fissionTPC.
- If A and Z of a fragment can be measured, it would have a lasting effect on the way that 2E analysis is performed because uncertainty from prompt-neutron emission could be significantly reduced.





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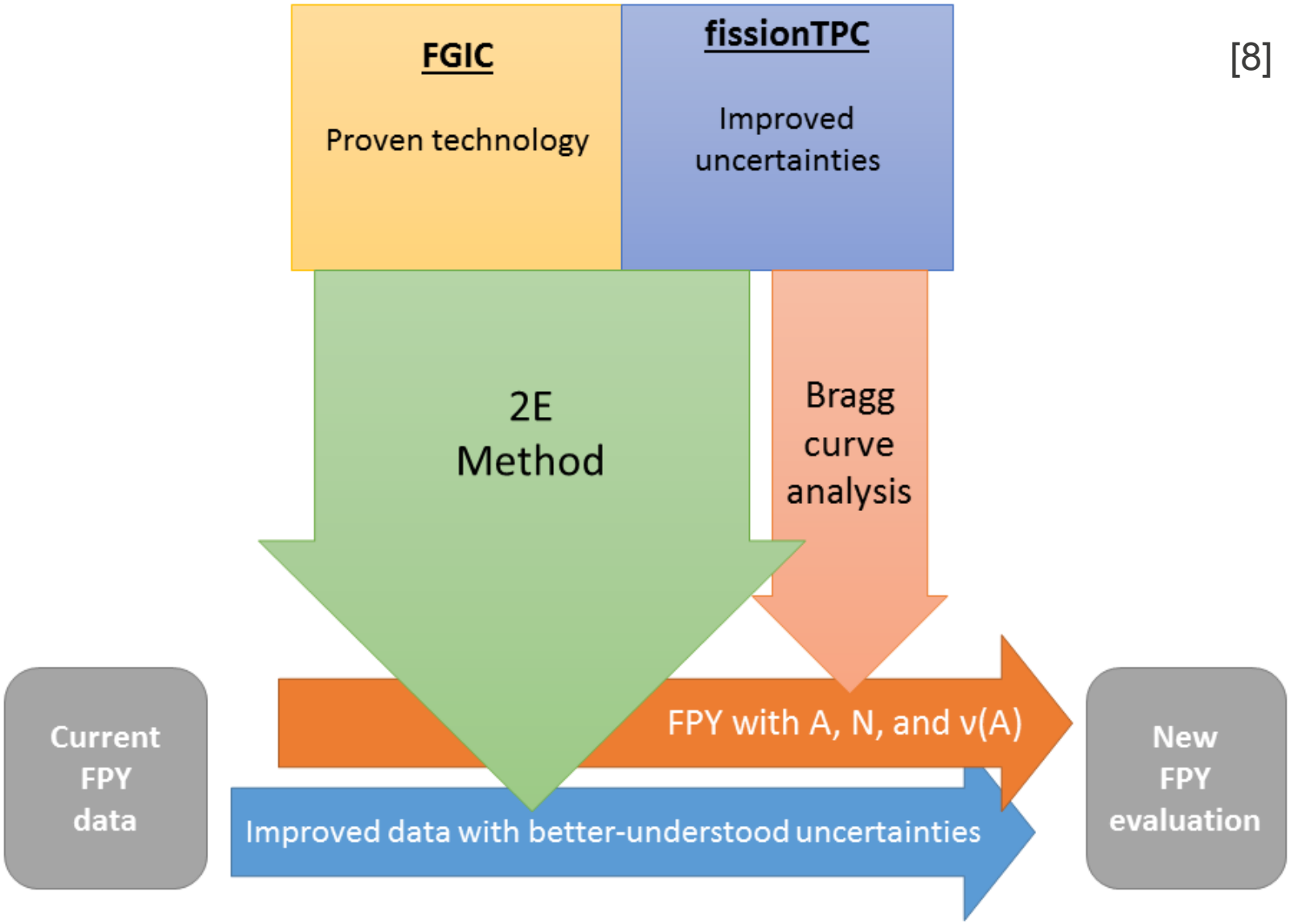

FGIC
Proven technology
fissionTPC
Improved uncertainties
2E Method
Bragg curve analysis
Current FPY data
FPY with A, N, and v(A)
Improved data with better-understood uncertainties
New FPY evaluation

Conclusion: The successful experiment will leverage the resources and strengths of both detectors to provide IFPY's with reduced uncertainty.

- The FGIC will collect new data and IFPY's will be analyzed with input from TPC on uncertainty analysis.
- Existing TPC data will be analyzed and provided additional IFPY's.
- By applying the TPC to measuring fission product yields, we will be able to better understand the uncertainties inherent in existing ionization chamber measurements, thereby improving the nuclear data libraries.

Progress (as of 1/11/19)

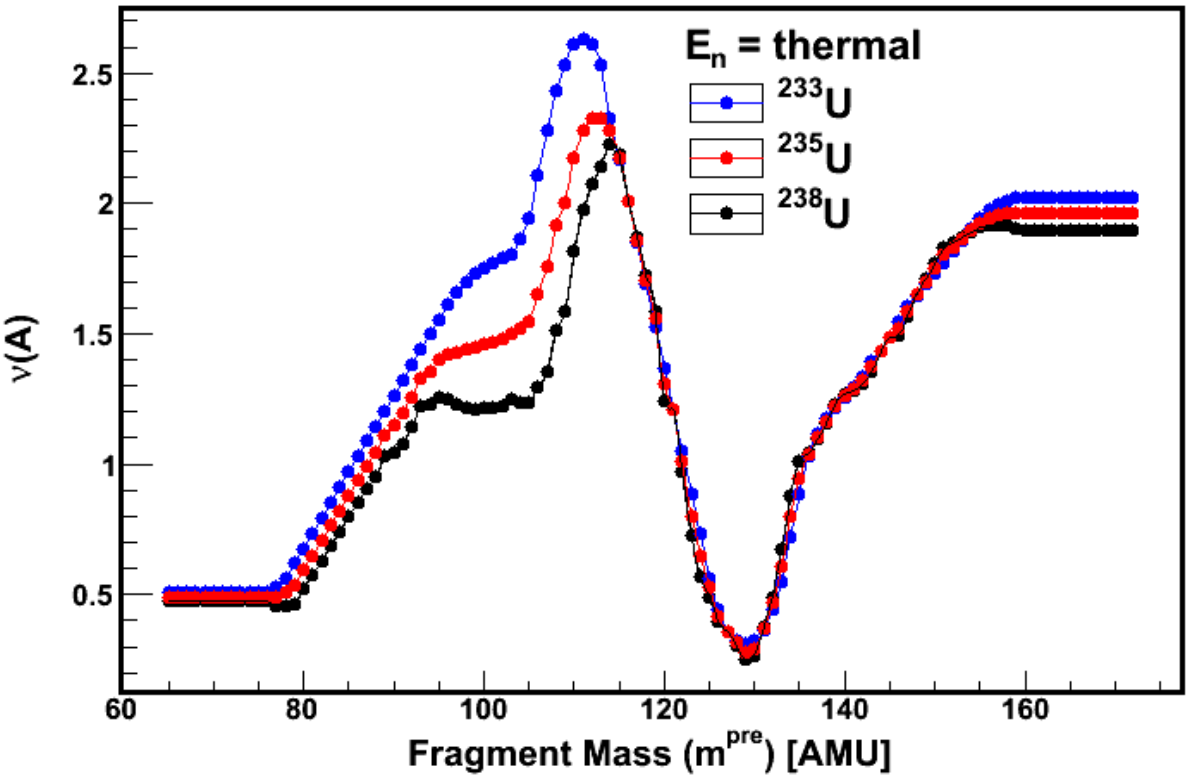
- Acquired new digitizers for FGIC
- Sourced U234
- Reprocessing archived fissionTPC data for U235, U238 & Pu239
- Developed saturation and diffusion corrections for improved fissionTPC energy resolution and tracking

Thanks for your attention!

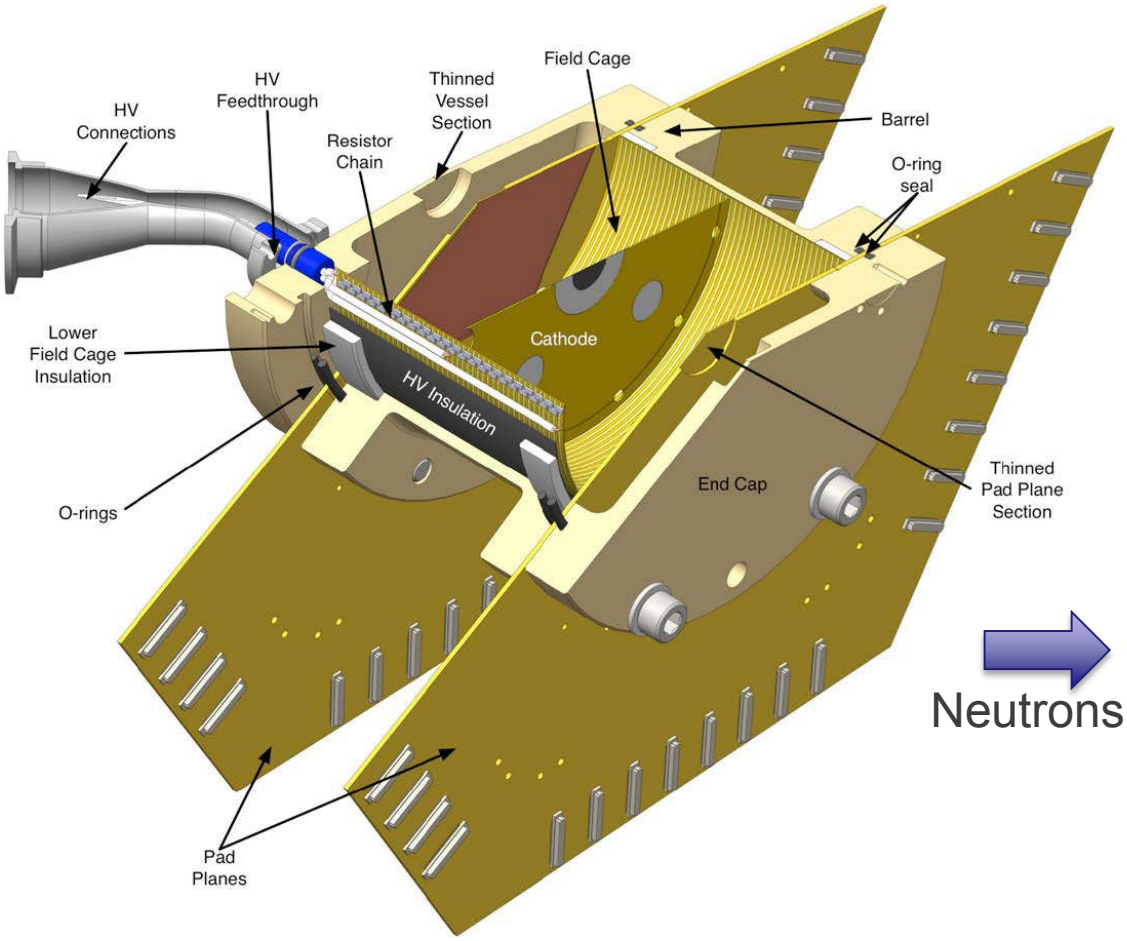
1) T. R. England and B. F. Rider. ENDF-349. 1993.
2) D. L. Duke. PhD Dissertation. Colorado School of Mines. 2015.
3) D. Higgins. PhD Dissertation. Colorado School of Mines. 2018.
4) A. Al-Adili et al. *Phys. Procedia.* 31:158-164. 2012.
5) D.L. Duke et al. *Phys. Rev. C.* 94:54-60 Nov. 2016.
6) S. Mosby et al. *Nuc. Inst. & Meth. A.* 757:75-81. Aug. 2014.
7) M. Heffner et al. *Nuc. Inst. & Meth. A.* 759:50-64. Sept. 2014.
8) D. Duke, L. Snyder, L. Wood. Measurements of IFPY's. LAB 18-1903.

Details on 2E analysis – using conservation of mass and momentum to calculate mass from two energies and two angles.

- Energies and angles of emission are measured, masses are calculated after correction for prompt-neutron emission
- Sources of uncertainty pulse height defect and prompt-neutron emission.



How does the fissionTPC work?



Neutrons