LA-UR-21-20718

Measurements of Independent Fission Product Yields

Workshop on Applied Nuclear Data Activities (WANDA)

Feb. 3, 2021

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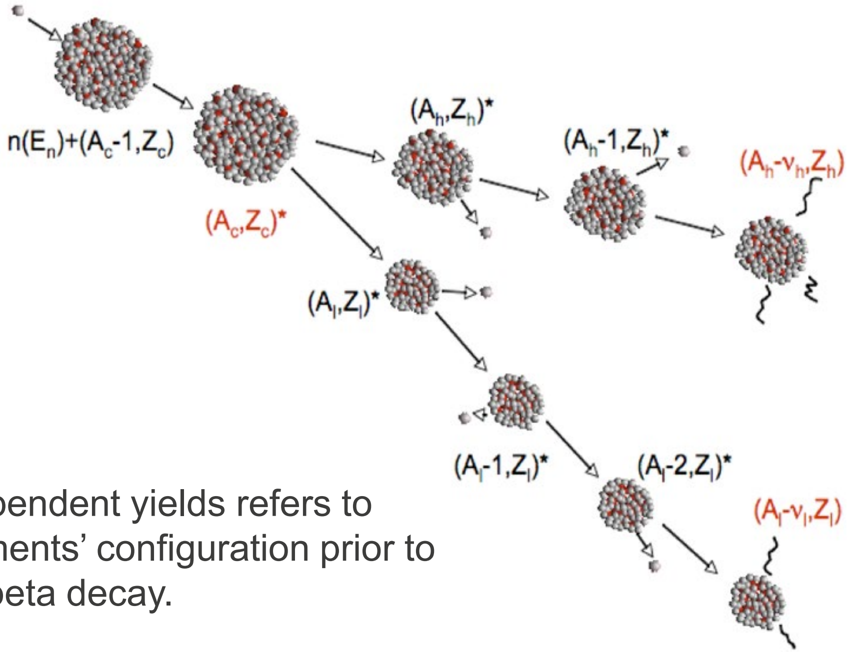
The goal of this experiment is to improve IFPY nuclear data by minimizing and understanding uncertainty in new measurements.

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



Independent yields refers to fragments’ configuration prior to any beta decay.

FGIC: ^{237}Np, ^{233}U, ^{234}U, ^{239}Pu
TPC: ^{235}U, ^{238}U, ^{239}Pu

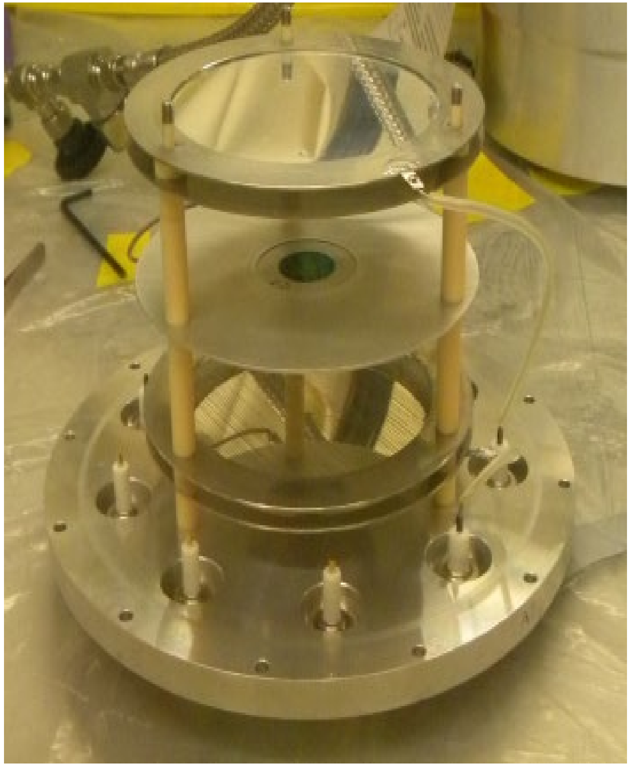
FOA Information: D. Duke, L. Snyder, L. Wood. Measurements of IFPY’s. LAB 18-1903

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

- **Goal: measure FPY for ^{233}U, ^{234}U, ^{237}Np, and ^{239}Pu**
  - ~100's of keV up to 40 MeV incident neutron energies
  - **^{234}U target is the first of its kind** – produced by Walt Loveland's team at Oregon State

- **Progress**
  - Data collection complete for ^{233}U, ^{237}Np, and ^{239}Pu (Oct-Nov)
  - Analysis underway on ^{233}U and ^{237}Np data sets collected in 2019, and processing for ^{239}Pu
  - ^{252}Cf calibration measurements are in the works

- **LANL access has been limited, but usable**
  - Submitting beam time proposal for ^{234}U

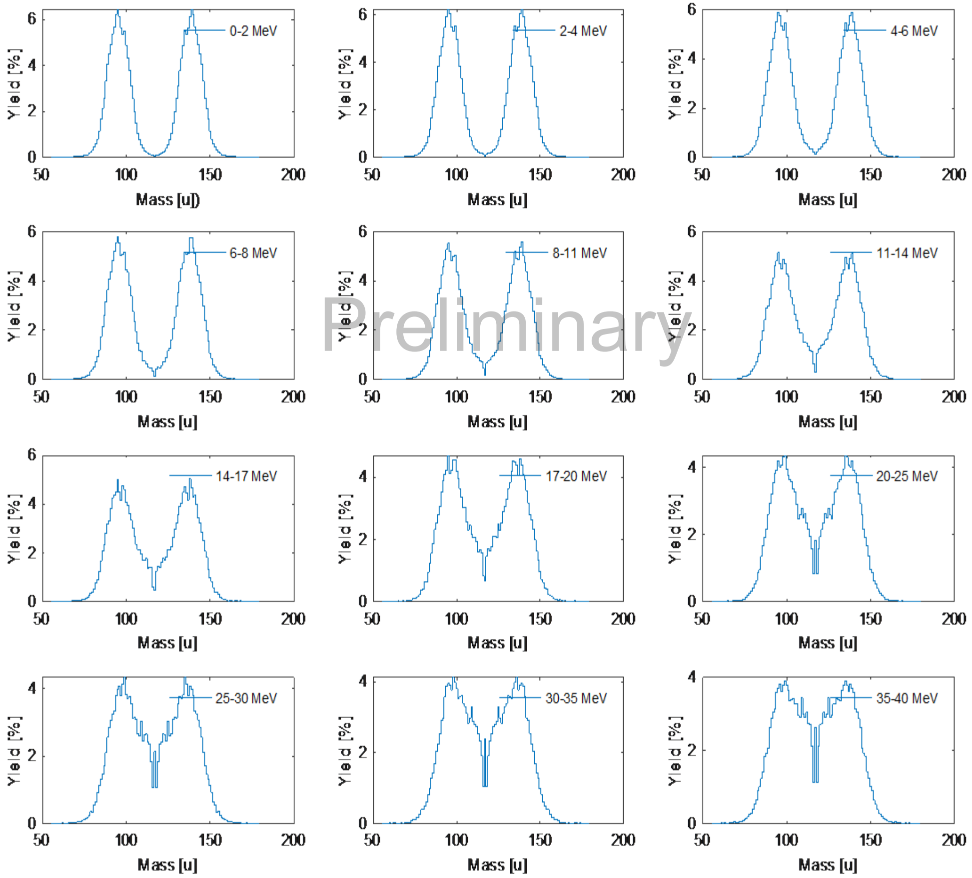


[1,2,3]

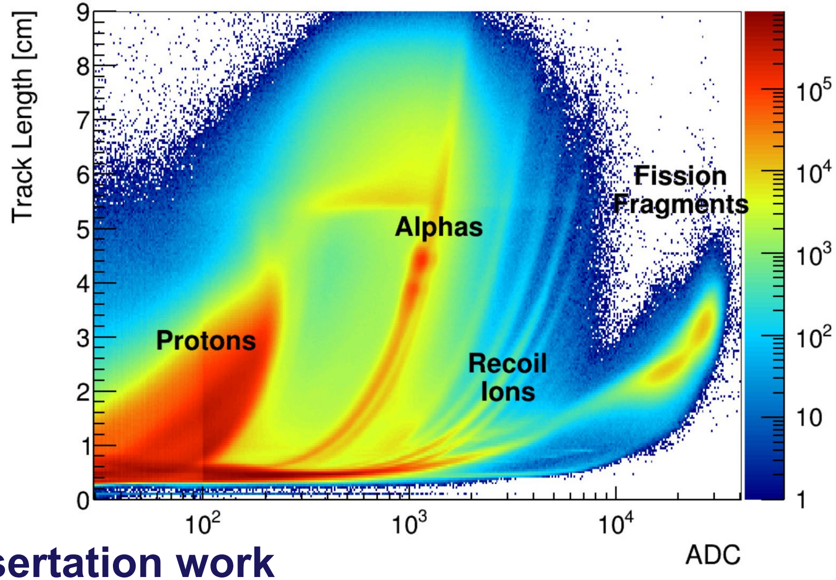
^{237}Np and ^{233}U data analysis is ongoing and preliminary data analysis of ^{239}Pu from 2020 is promising.

- **^{233}U data includes high-statistics FPY distributions up to 40 MeV**
  - Applying 2E method
  - Working with LANL's Theoretical Division to employ CGMF model outputs to correct from prompt neutron evaporation
  - Includes high-statistics FPY distributions seen at right

Analysis is part of CSM Ph.D. student K. Montoya's dissertation work



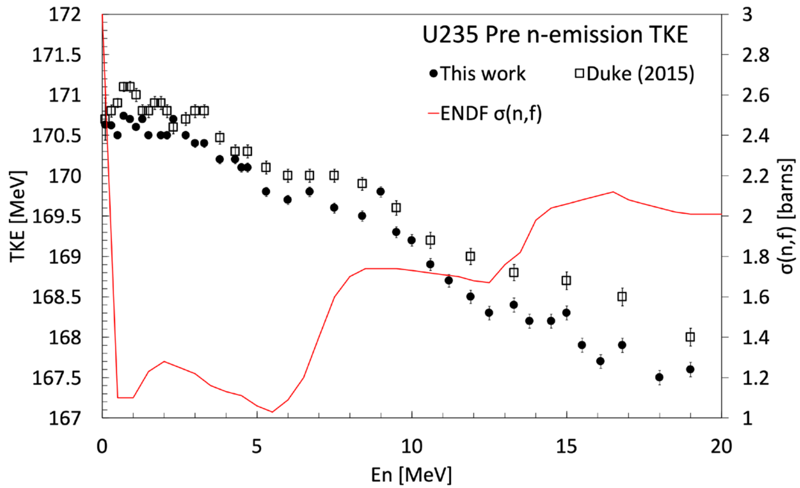
2) The fissionTPC has added valuable precision cross section data to nuclear data libraries, and the raw data can be mined for IFPY using a 2E analysis.

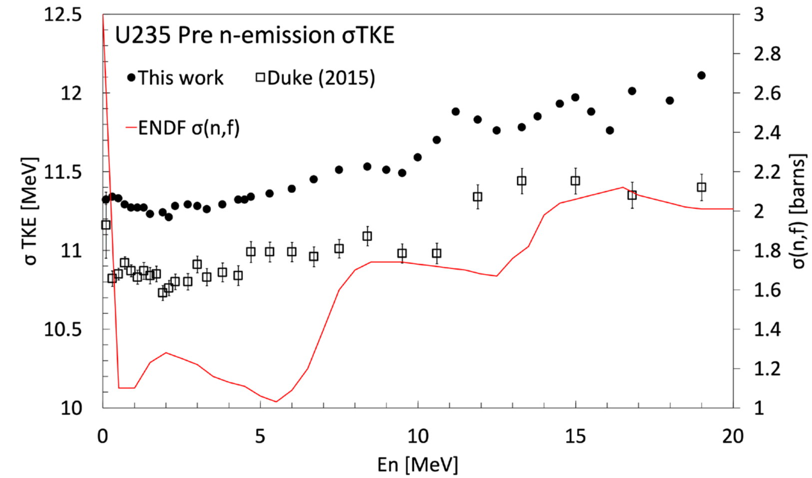


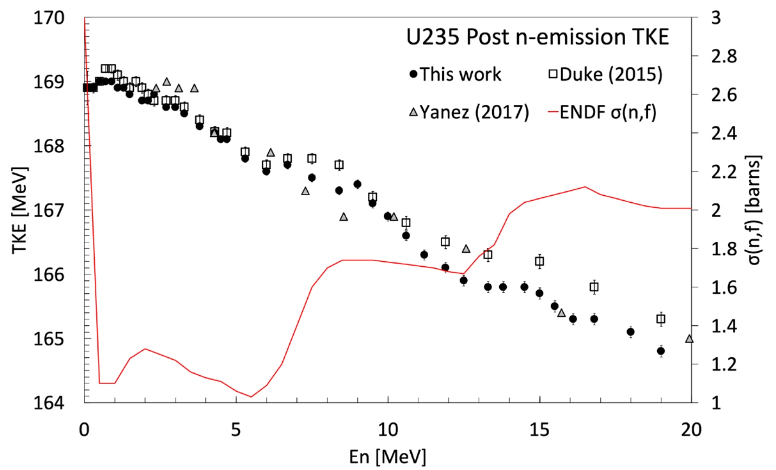
- **Goal: reanalysis of fissionTPC ^{235}U and ^{238}U data with 2E method**
- **Progress**
  - Preliminary 2E and TKE analyses of ^{235}U and ^{238}U are completed
  - **Part of CSM Ph.D. student J. Latta's dissertation work**
  - Current focus is on advancing an absolute energy calibration using spontaneous alpha decay data; **this would be a unique feature of fissionTPC data compared to standard FGIC 2E analysis**
  - Also working to finalize uncertainty quantification of the 2E analysis using methods developed for fissionTPC cross section ratio analysis, producing partial uncertainties and covariances.

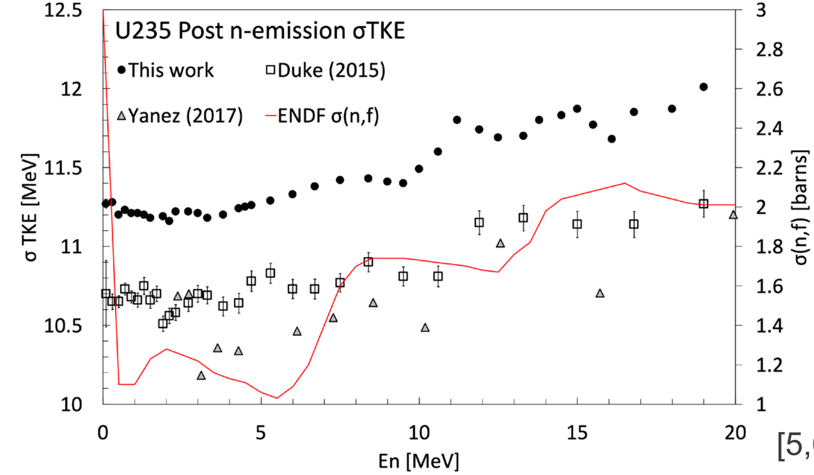
[4]

Preliminary TKE results from a 2E analysis on FissionTPC data.





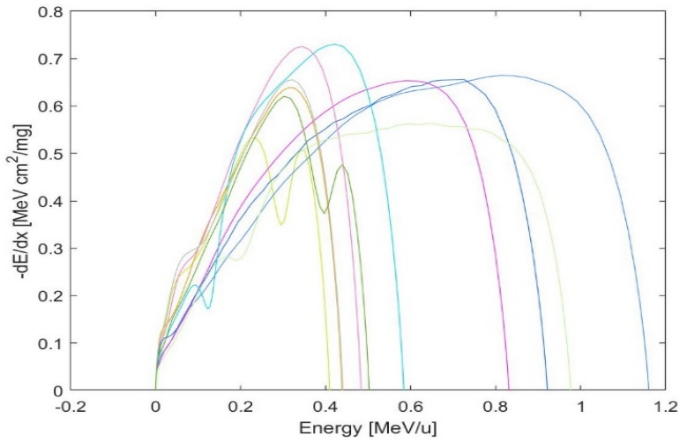




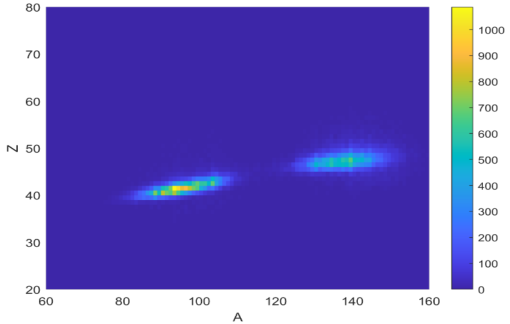
[5,6,7]

3) The goal of the Bragg curve fission fragment identification stopping power analysis is to reduce uncertainty in the A,Z discrimination

- **Working on extending parametrization to higher incident neutron energies**
  - Tracks with strong nuclear recoils tend to be erroneously identified as higher Z
  - Currently exploring methods of generalizing track data to include strong recoils
- Working with CSM to compare 2E results to this method
- **Currently preparing a submission to NIM B describing this methodology**



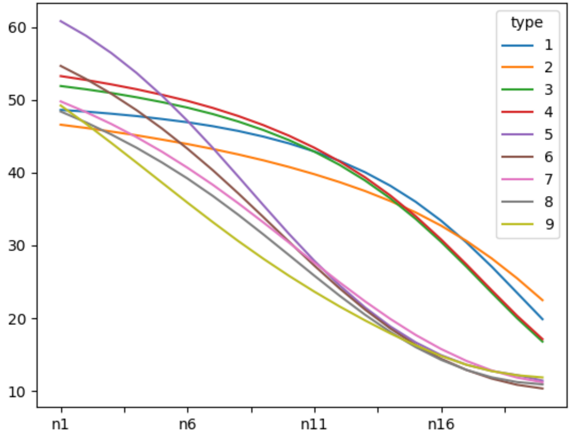
Areal density stopping power for 10 fissionTPC tracks

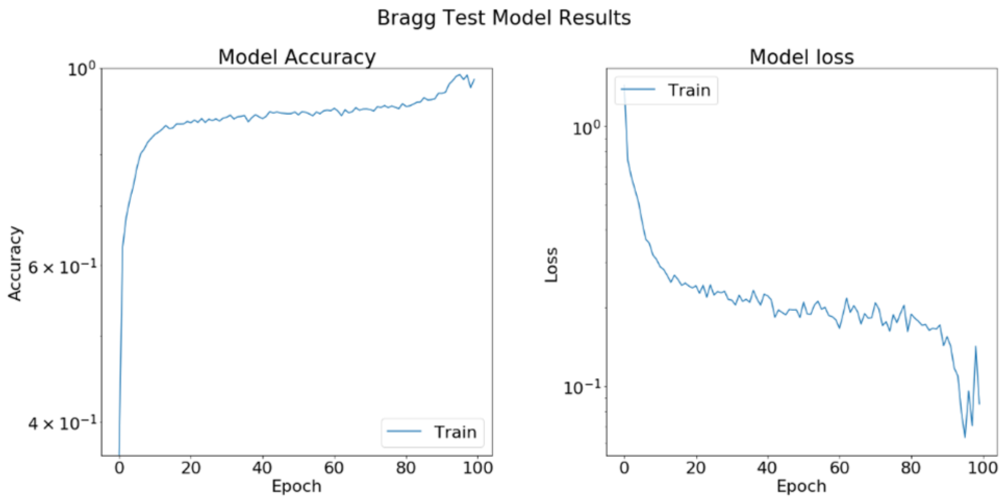


A,Z values for incident neutron energies of 400-500 keV

3) Machine-learning based Bragg curve identification of a small sample set showed potential and allowed initial model design.

- Discussed next steps with ML experts at PNNL, suggested more data and a look at methods that will allow combination of simulated (labeled) and experimental (unlabeled) data for training
- Currently generating a large TRIM data set: 50 isotopes,10k Bragg curves for each focused on the light fragment
- **Publication of methodology and results goal (NIM A)**

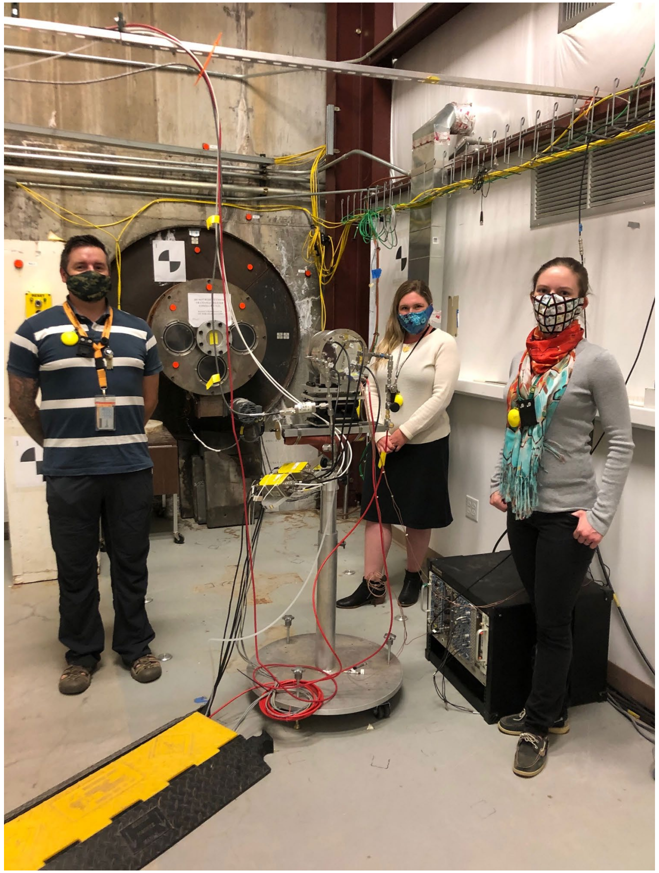




Conclusion: We are leveraging the strengths of both detectors to provide multiple IFPY's data sets with reduced uncertainty.

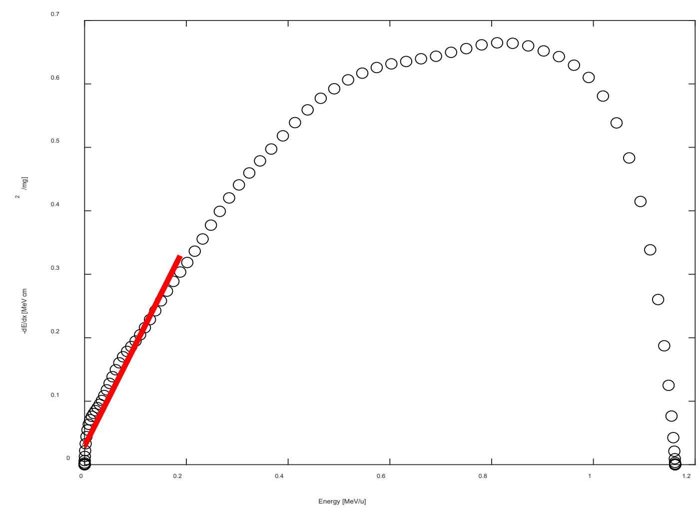
- **LANL**
  - ^{234}U data collection
  - Publication of ^{233}U, ^{237}Np, and ^{239}Pu results (plus dissertation)
  - Data submission to NNDC
- **LLNL/CSM**
  - Possible collection of ^{252}Cf data (requires travel, work at LANL)
  - Publication of ^{235}U, ^{238}U results (plus dissertation)
- **PNNL**
  - Publication of stopping power study method
  - Completion of machine-learning study with larger data set
  - Publication of machine-learning methodology and results

Thank for your attention!



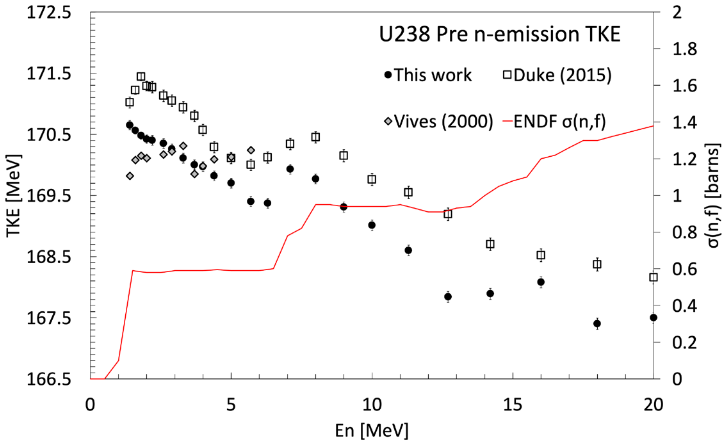
1) D.L. Duke et al. *Phys. Rev. C.* 94:54-60 Nov. 2016.
2) S. Mosby et al. *Nuc. Inst. & Meth. A.* 757:75-81. Aug. 2014.
3) Budtz-Jørgenson et al. *Nuc. Inst. & Meth. A.* 258.2:209-220 Aug. 1987.
4) M. Heffner et al. *Nuc. Inst. & Meth. A.* 759:50-64. Sept. 2014
5) D. L. Duke. PhD Dissertation. Colorado School of Mines. 2015.
6) Yanez et al. *Nuclear Physics A* 970:65-77, February 2018.
7) ENDF/B.VIII Nucl. Data Sheets 148(2018)1.

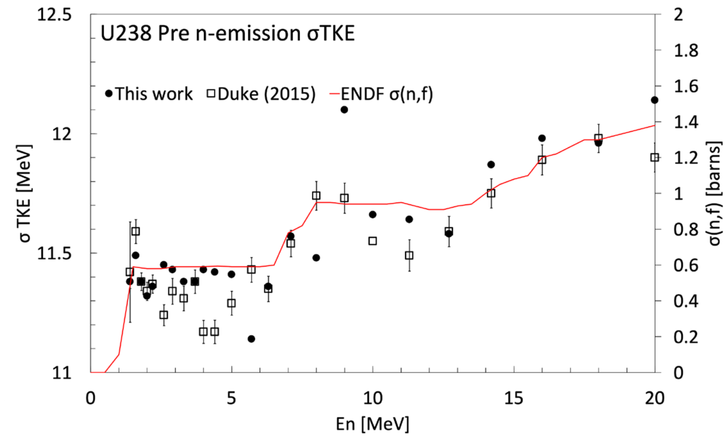
- **Looking at energy loss in MeV-cm^2/mg as alternative for improved discrimination**
  - Fitting low-order polynomial to energy-normalized tail of the areal density stopping power
  - Correlation of stopping to Z is well-known for ^{235}U for incident neutron energies of 100-500 keV

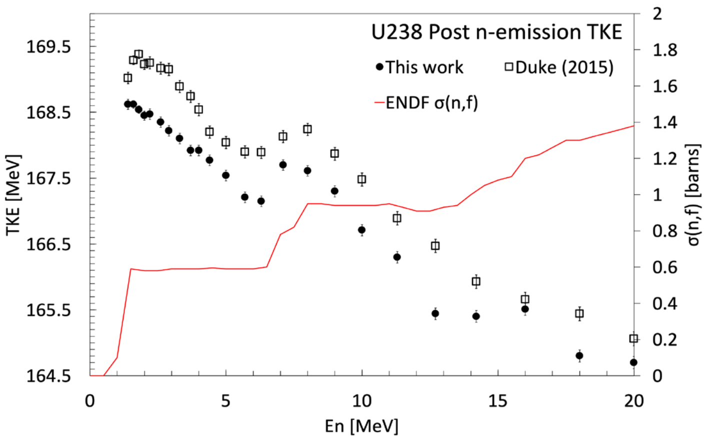


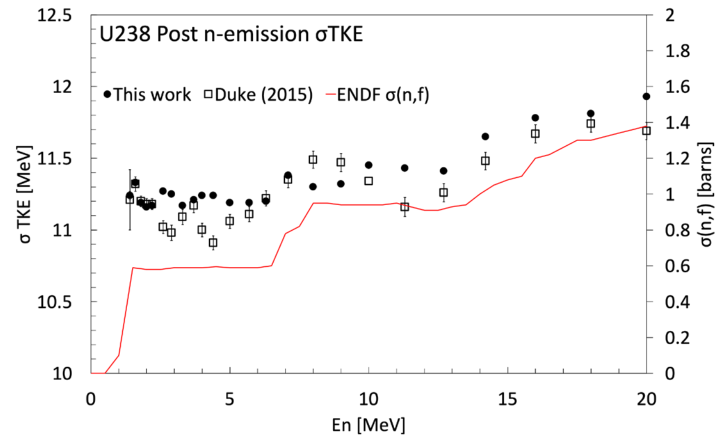
Stopping power fit for Z=40

2. Reanalysis of FissionTPC data with 2E method shows good agreement with previous measurements.



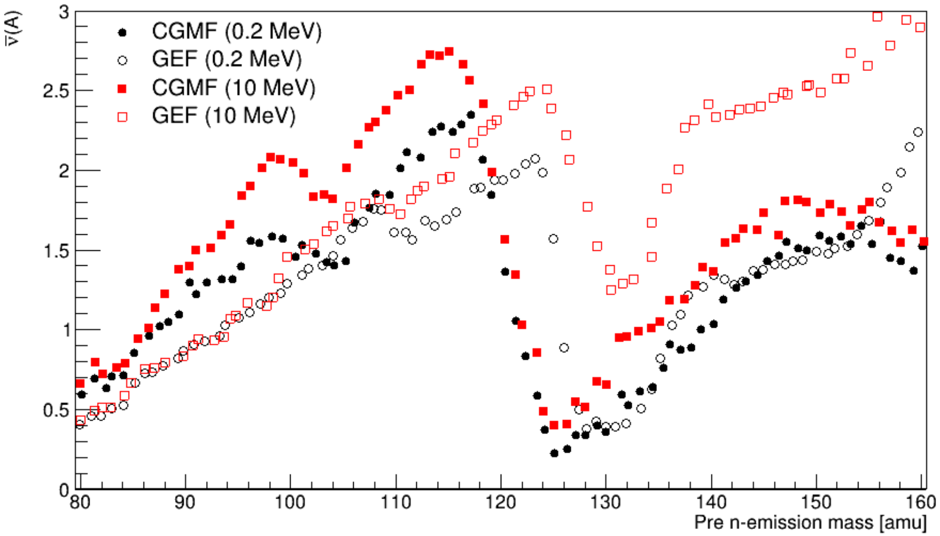


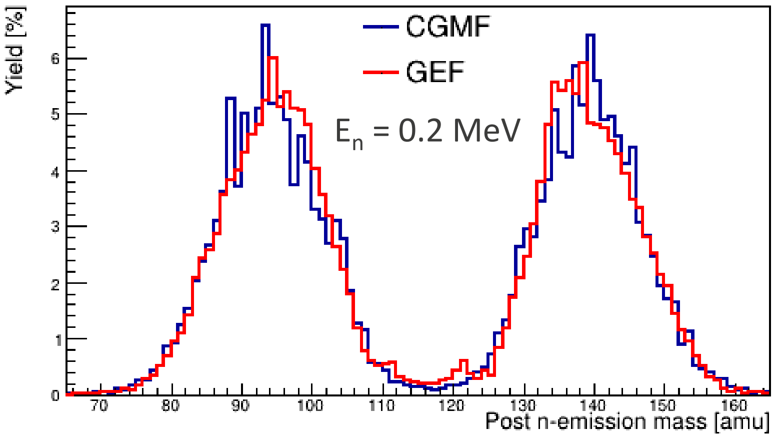


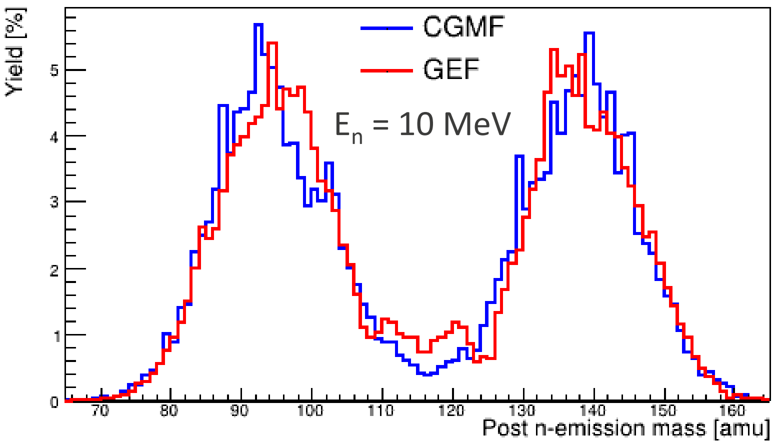


Effect of model inputs on 2E analysis

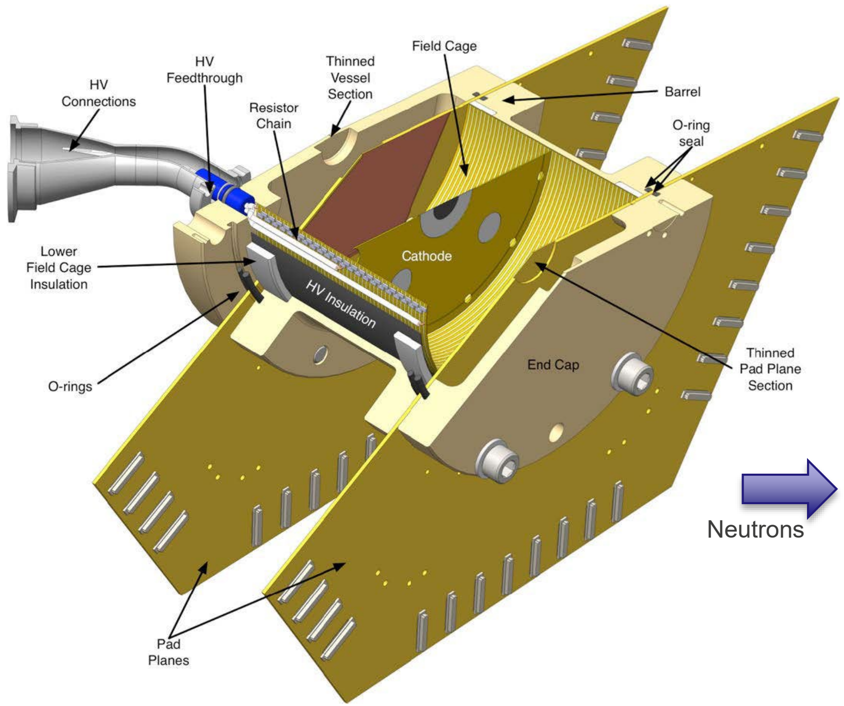
U235 Neutron multiplicity models

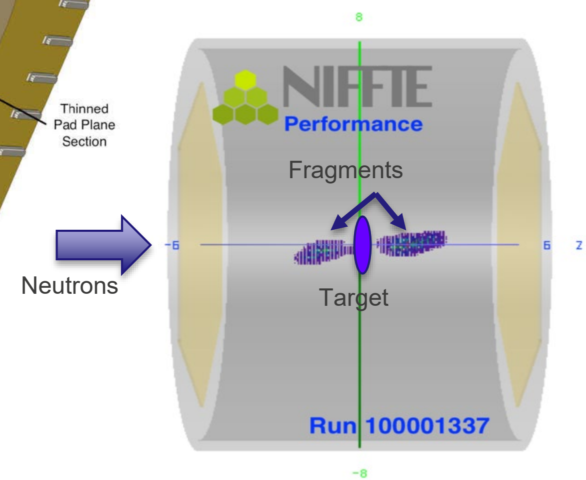






How does the fissionTPC work?





fissionTPC Data

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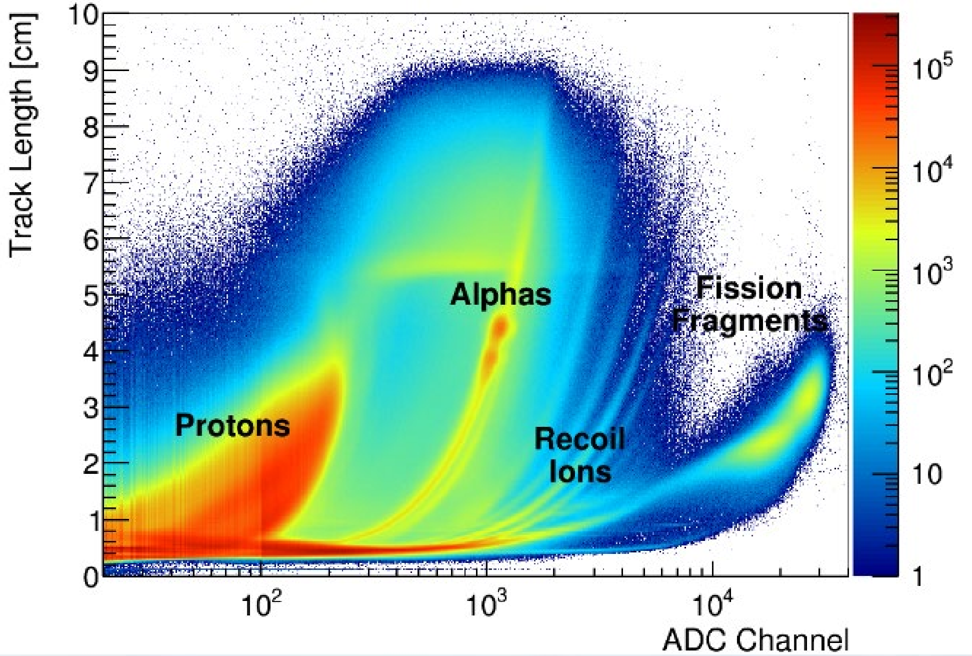

- Utilize advantages of fissionTPC such as measured track angle, 3D track reconstruction, track length and particle identification capability (address alpha pile-up in 239Pu data).
- Probe uncertainties related to energy loss in target/backing, v(A), and pulse height defect .
- Inform Bragg Curve Analysis