TOTAL KINETIC ENERGY RELEASE IN THE FAST NEUTRON INDUCED FISSION OF ACTINIDE NUCLEI

HELLENIC INSTITUTE NUCLEAR PHYSICS CONFERENCE

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LANSCE

NNSA National Nuclear Security Administration

Los Alamos NATIONAL LABORATORY EST. 1943

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

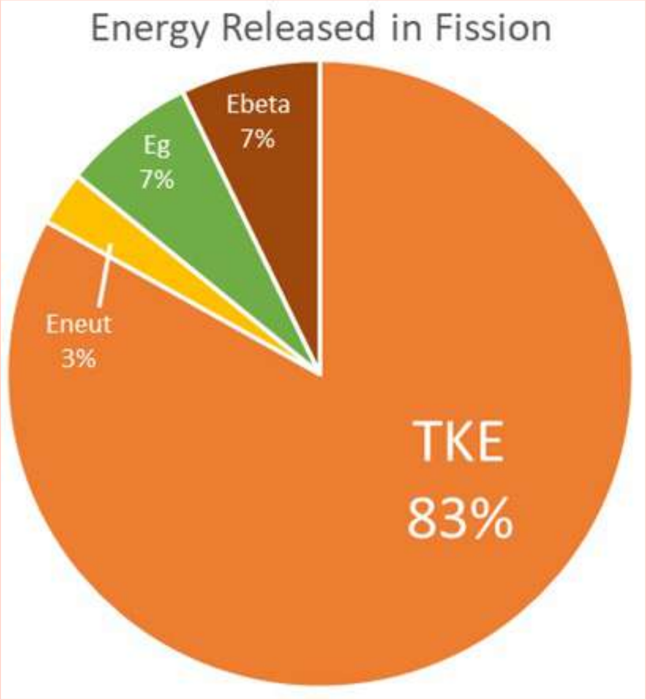
TKE Project Goals

Understanding the physics of the TKE release in fission and its variation with excitation energy of the fissioning system

Relative role of Coulomb and dissipative forces in this large scale nuclear collective motion

We started this project in 2016
Published 27 papers in the open, refereed literature
6 papers published last year

Energy Release in Fission



Total Energy Released in Fission = **TKE fragments** + TXE fragments + Prompt fission deexcitation.

- The fission process emits an enormous amount of energy per event, on the order of **200 MeV** per nuclei for the actinides.

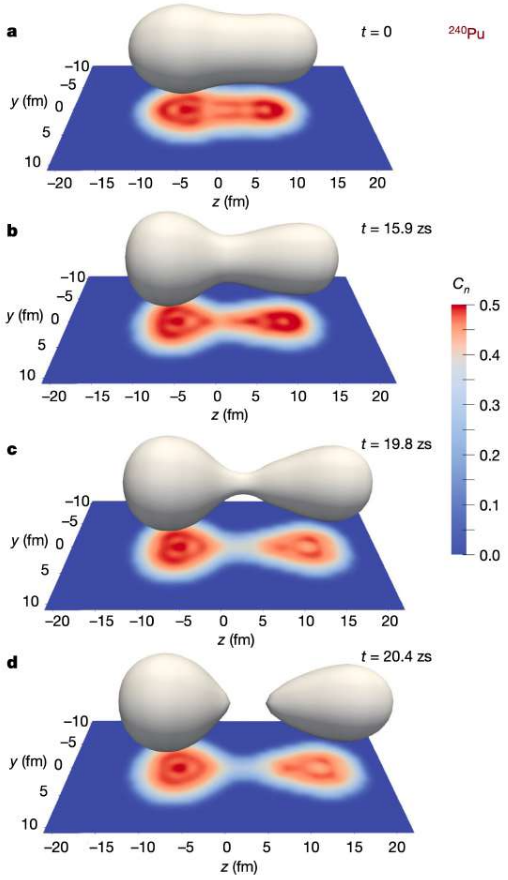
Recent Measurements

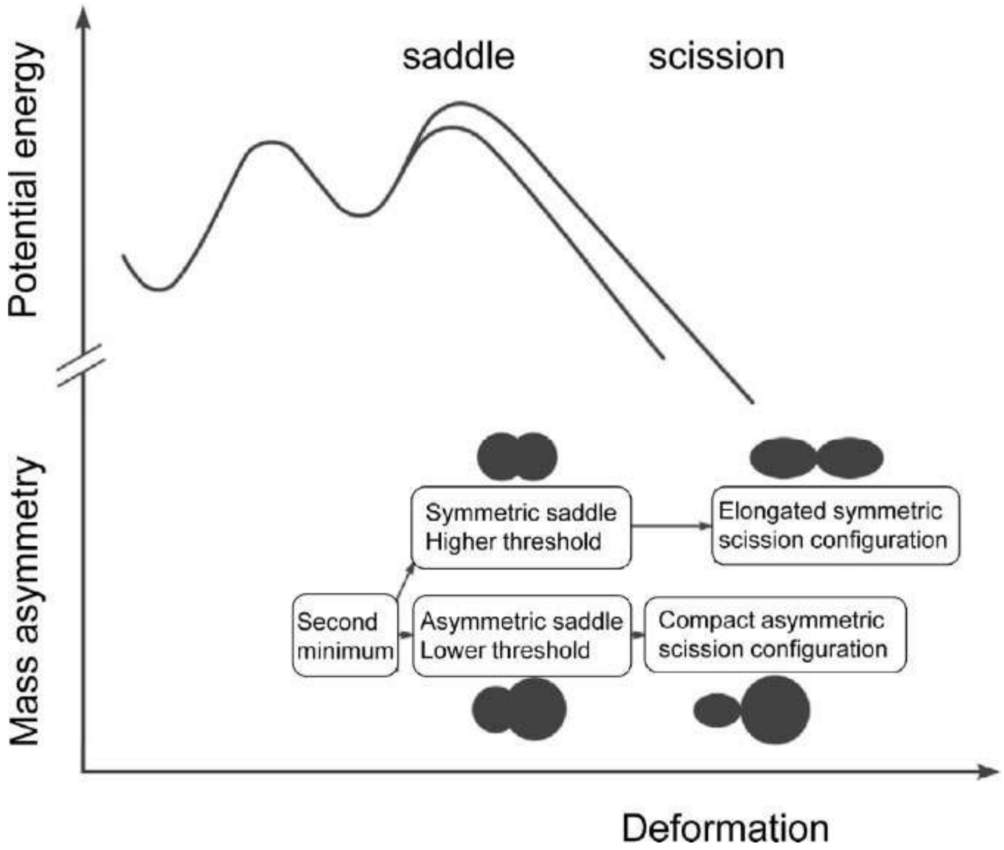
^{232}Th(n,f)

^{235}U(n,f)

^{237}Np(n,f)

Fission Evolution

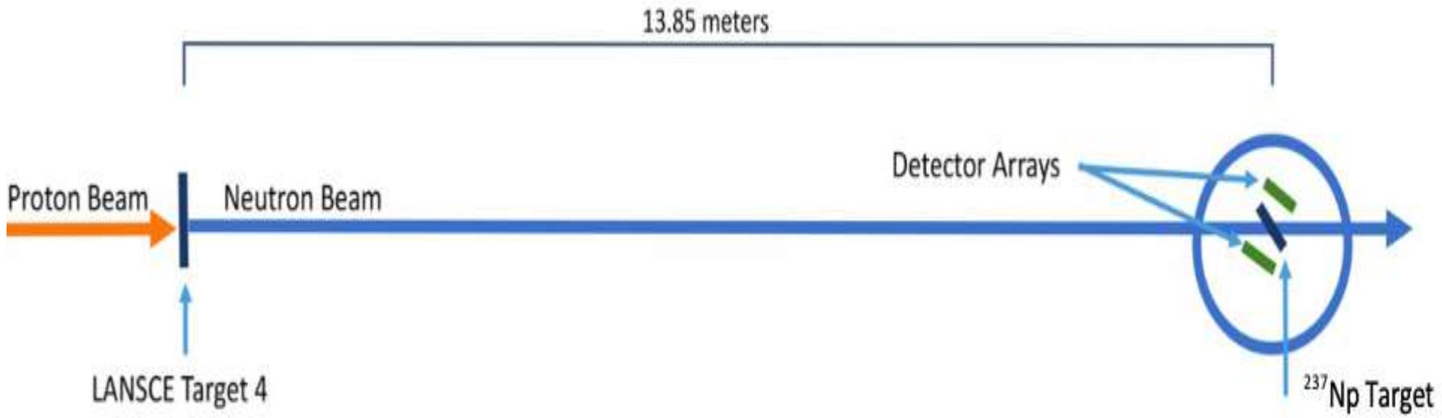




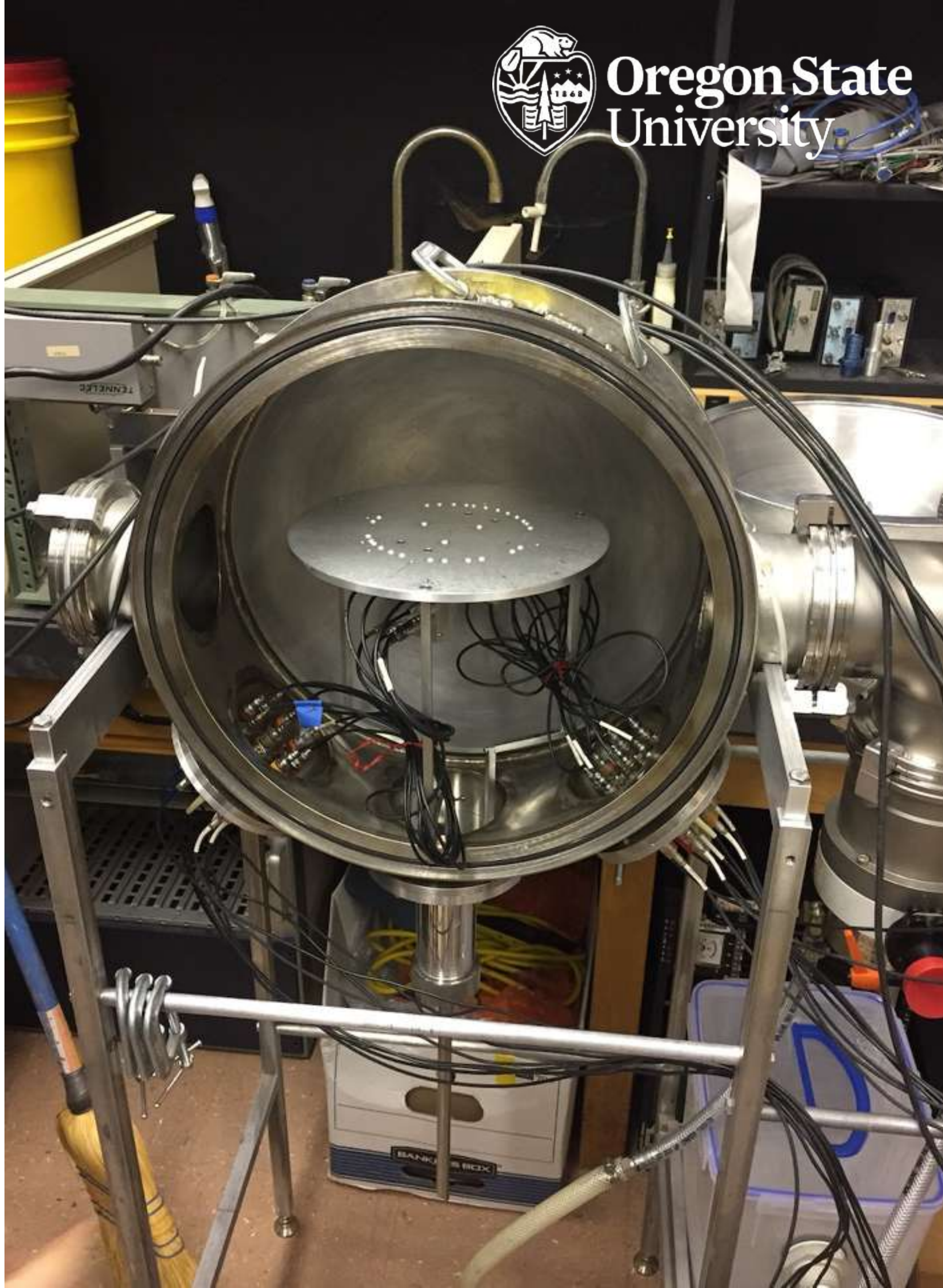
G. Scamps and C. Simenel. Nature 564, 382 (2018).

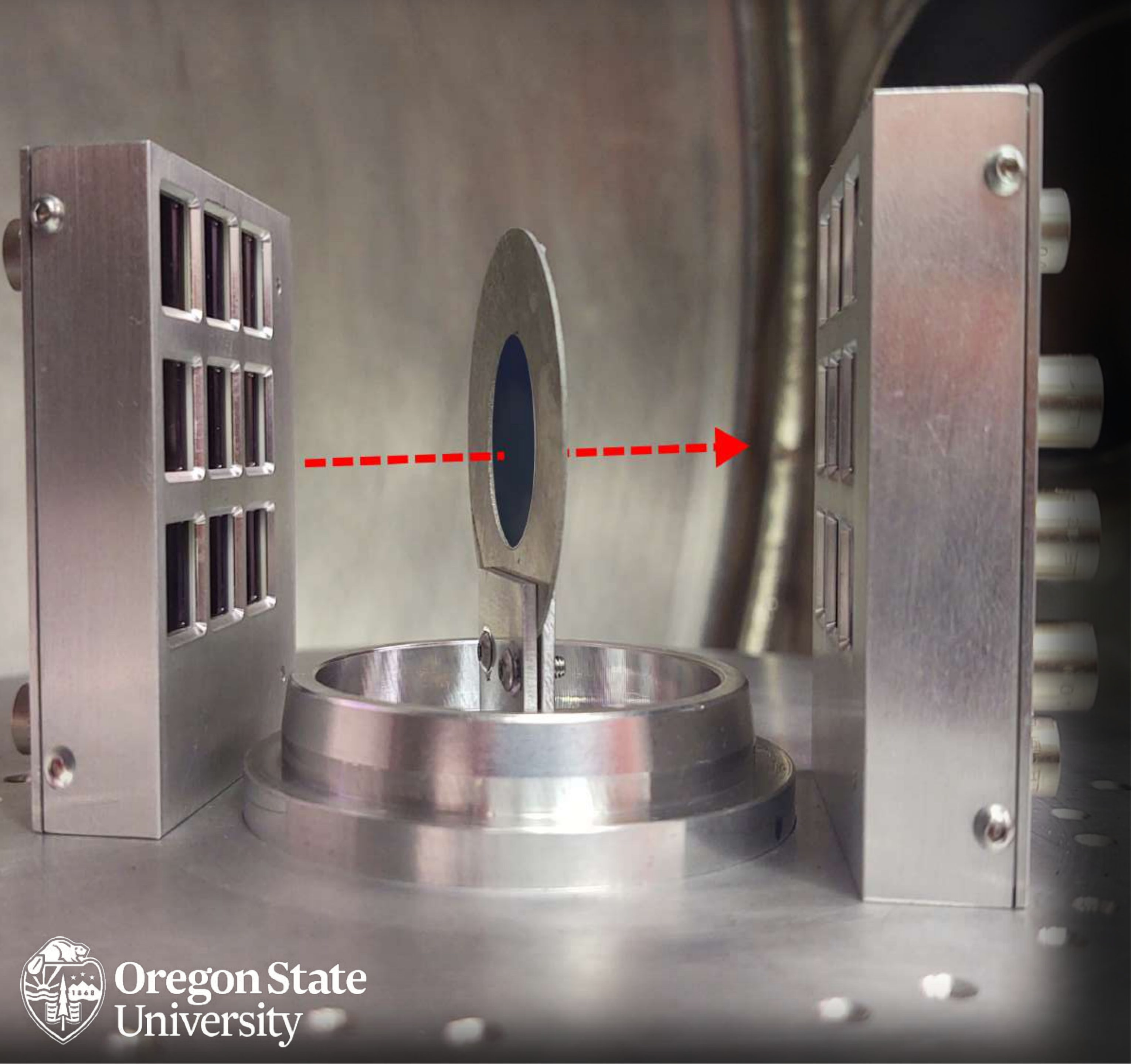
EXPERIMENTAL METHOD

- The LANSCE-WNR provides a high fluence of white spectrum neutrons produced from a W spallation target.



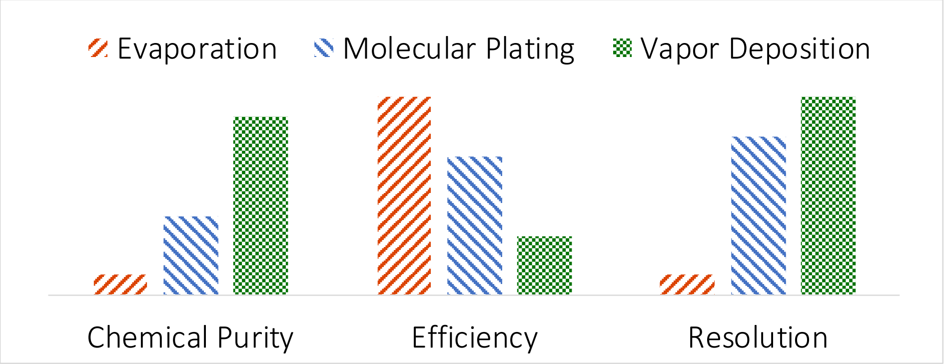
7-day irradiation period





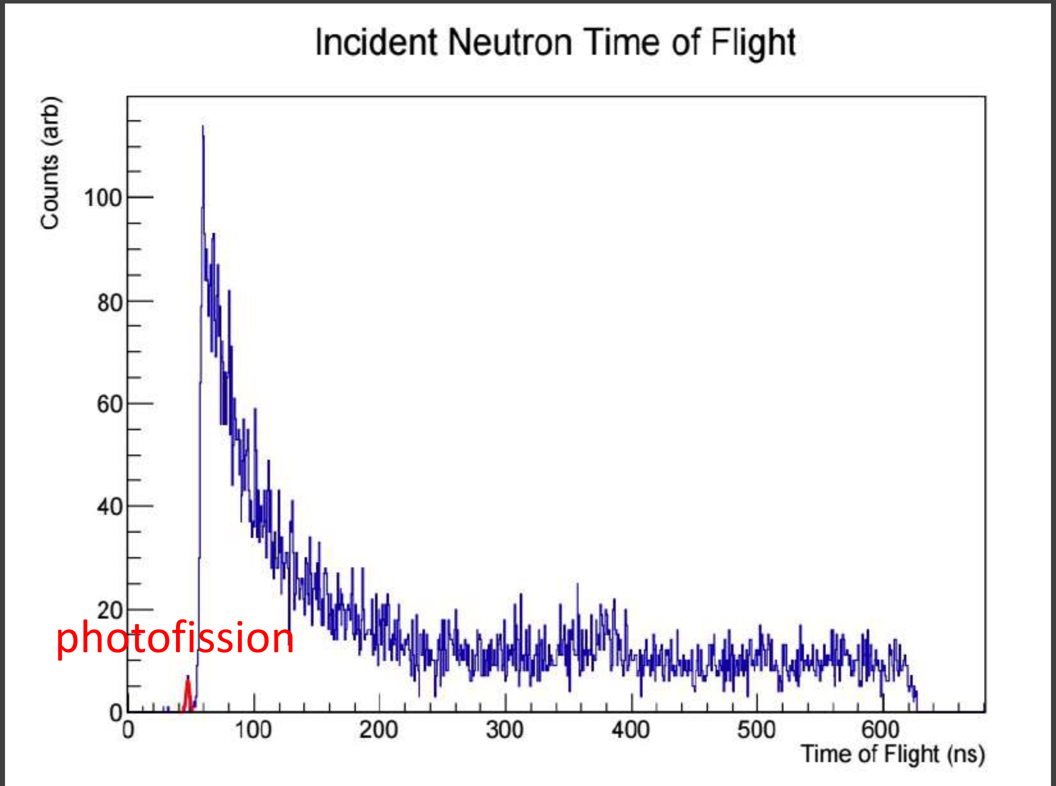
Experimental: LANL-LANSCE-WNR facility

Vapor Deposition



The 2E Method

- The calculation of fragment energy is based on the conservation of momentum and mass for the coincident fission products.



$$M'_H V'_H = M'_L V'_L$$

$$M'_L + M'_H = M_{CN}$$

$$M'_H E'_H = M'_L E'_L$$

$$M'_L = M_{CN} \frac{E'_H}{E'_H + E'_L}$$

Pre-neutron emission

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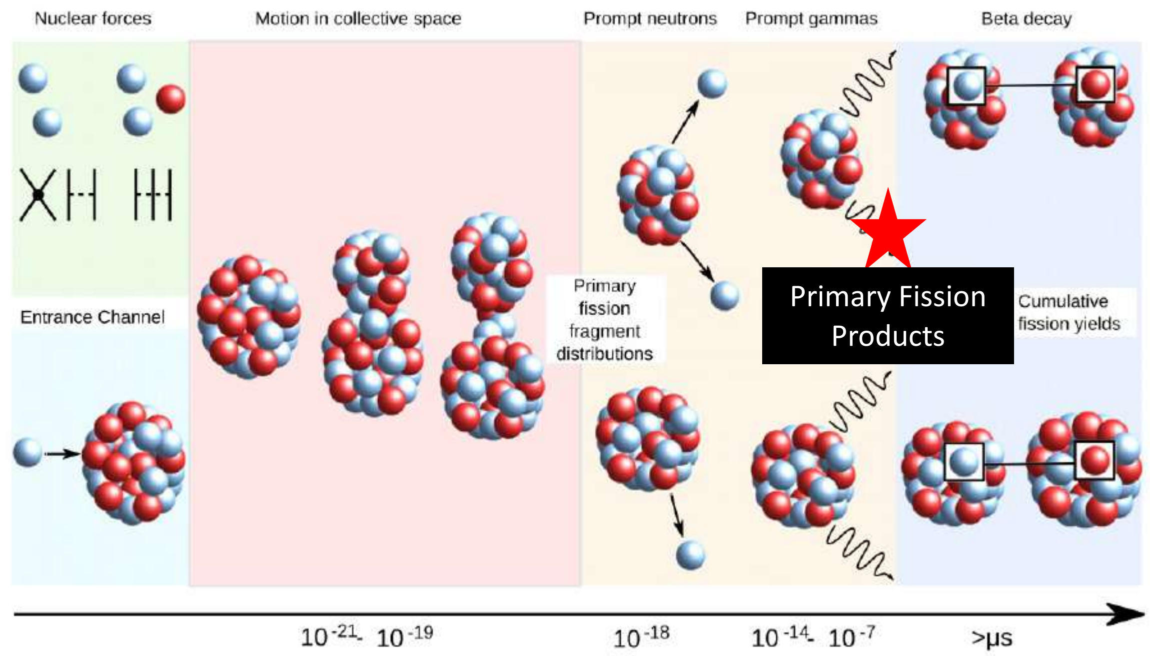
$$E'_{L,H} = E_{L,H}\left(1 + \frac{v_{post}(m'_{L,H})}{m_{L,H}}\right)$$

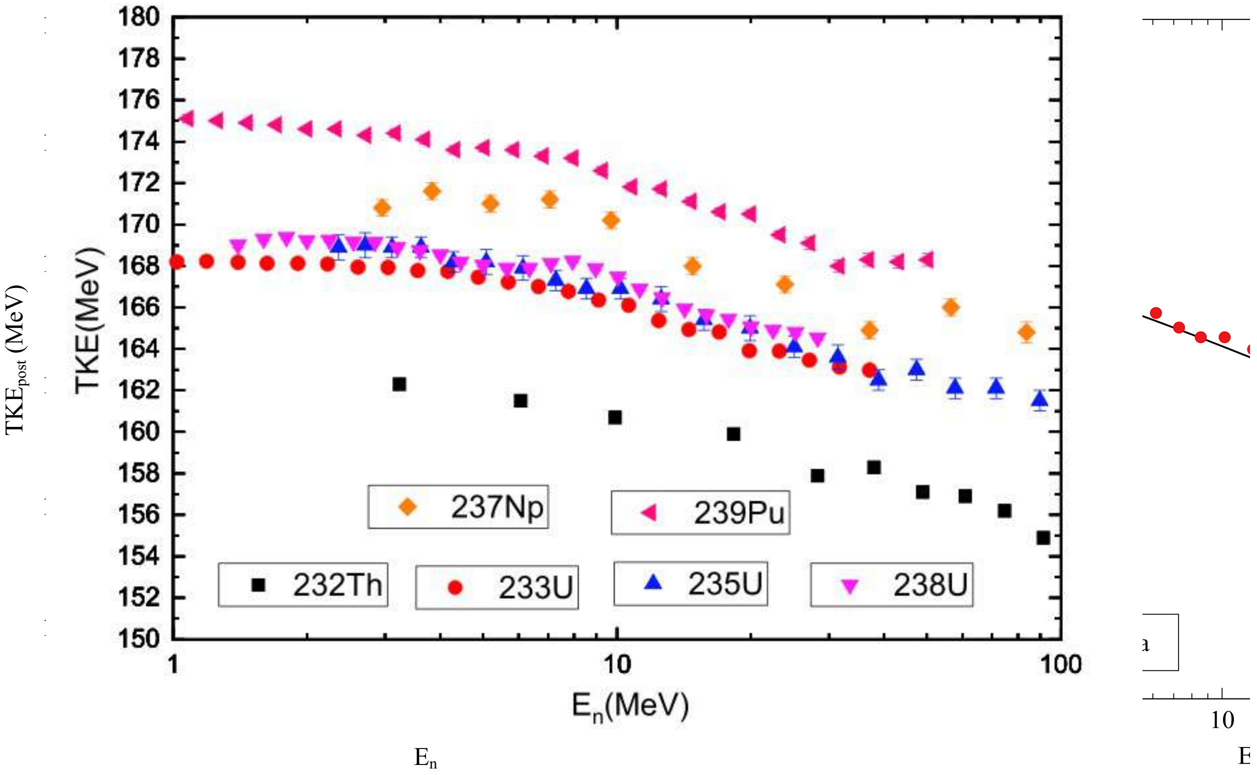
$$m_{L,H} = m'_{L,H} - v_{post\ L,H}(E_n, m'_{L,H})$$

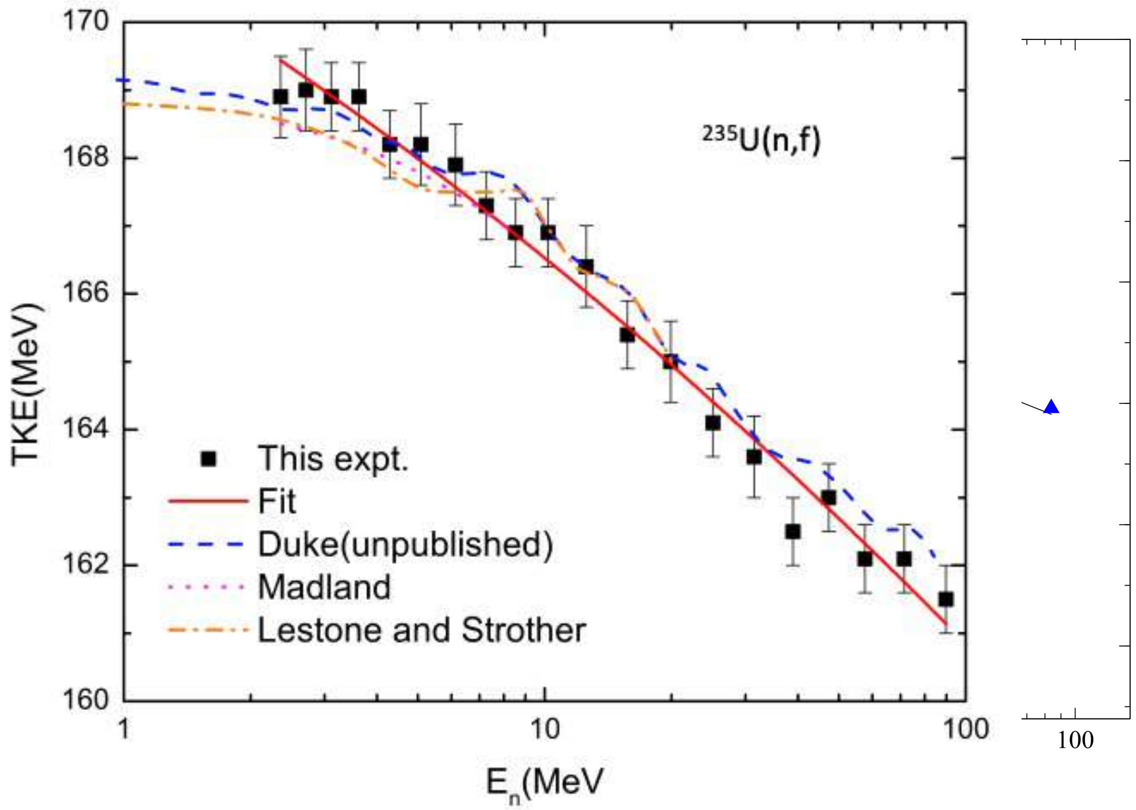
Neutron-emission correction



TKE RELEASE IN ACTINIDES

- The fading out of shell effects at high excitation energies (resulting in an increase of symmetric fission)
- The decrease of the total kinetic energy associated with asymmetric fission with increasing E_n.





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~ 6 MeV drop in TKE across the En = 1-100 MeV energy range

MASS YIELD DISTRIBUTIONS:

- Conservation of momenta dictates that the kinetic energies of the fission fragments are inversely proportional to their masses.

- In actinide fission, the fission fragment mass distribution is bimodal at low excitation energies. As E_n is increased the valley between the asymmetric fission peaks begins to fill.

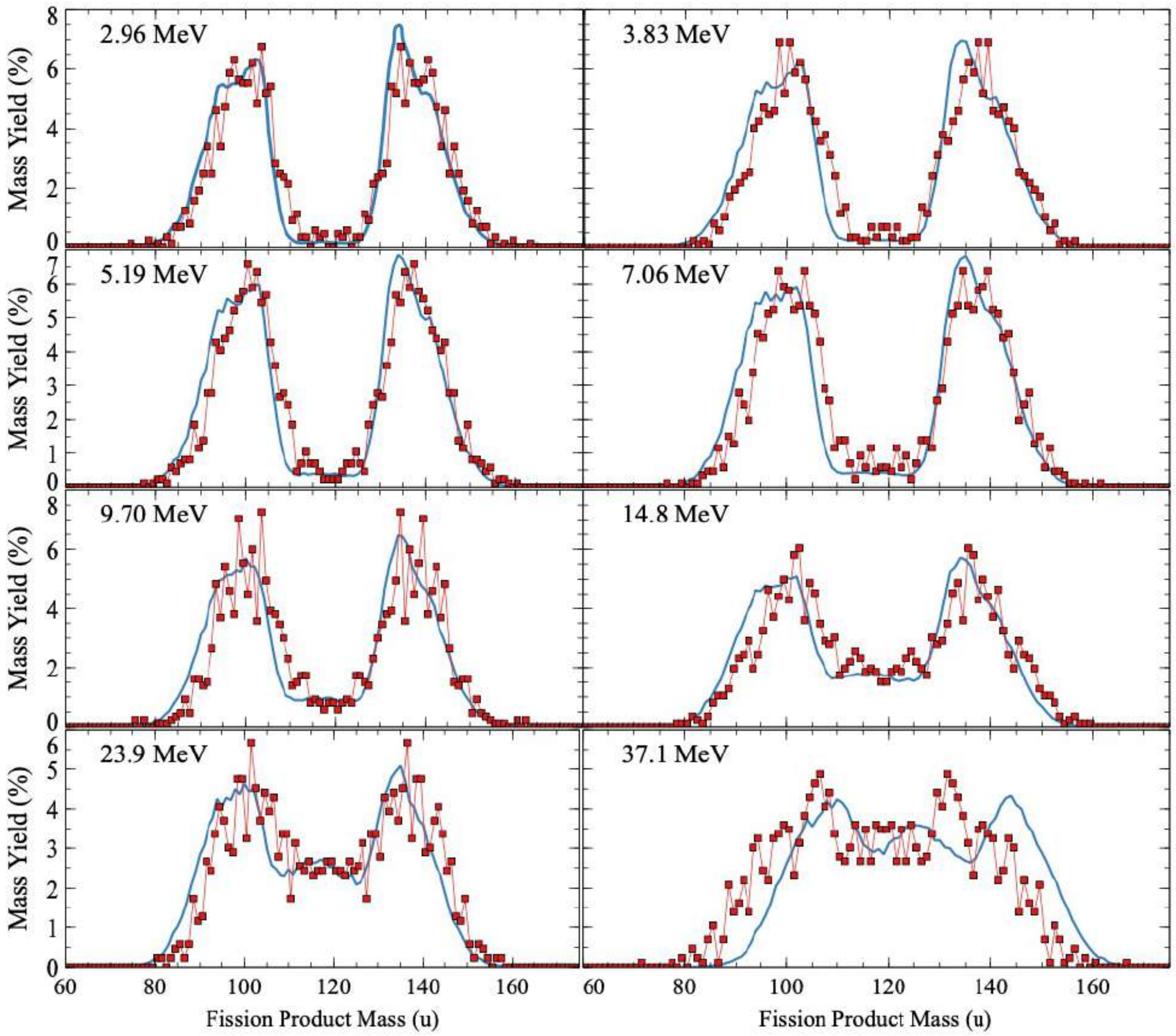

Figure: Comparison of the mass distributions measured in this work (red squares), normalized to 200%, and the predictions of the GEF_{post} model (blue line)

FISSION CHANNEL SYMMETRY:

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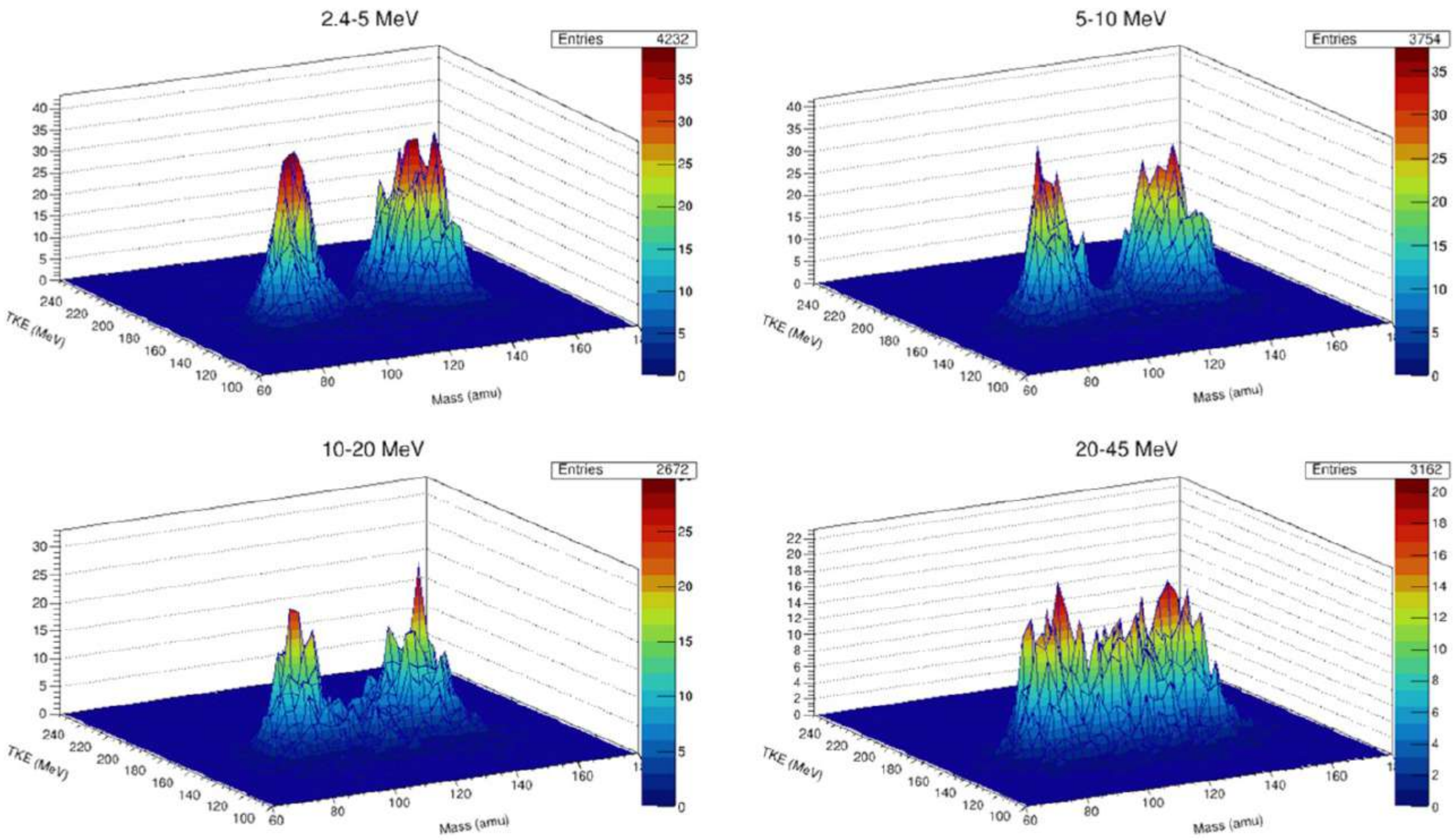
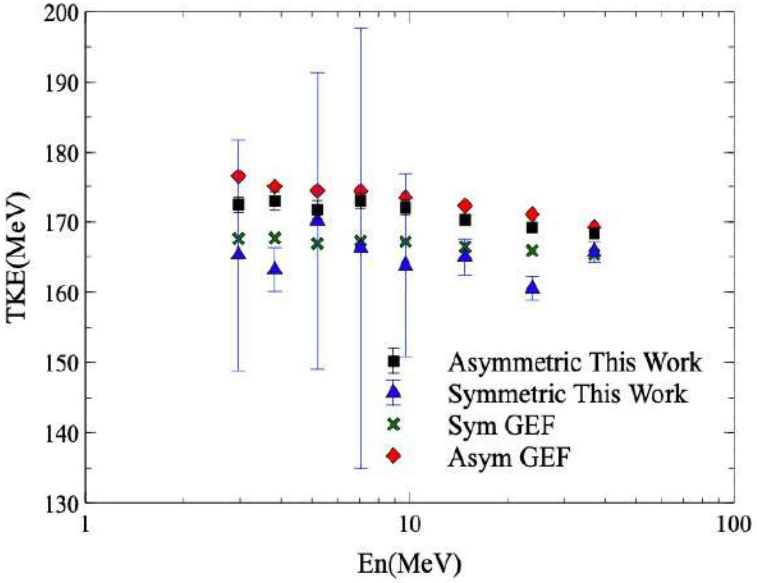
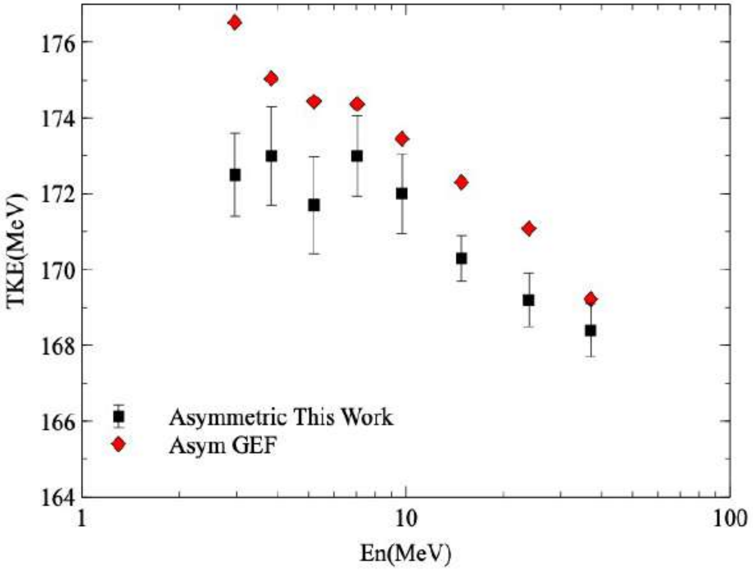


^{237}*Np (n, f) fission product mass distributions vs TKE at various incident neutron energies.*





TKE RELEASE IN ACTINIDES

- **The fading out of shell effects at high excitation energies (resulting in an increase of symmetric fission)**
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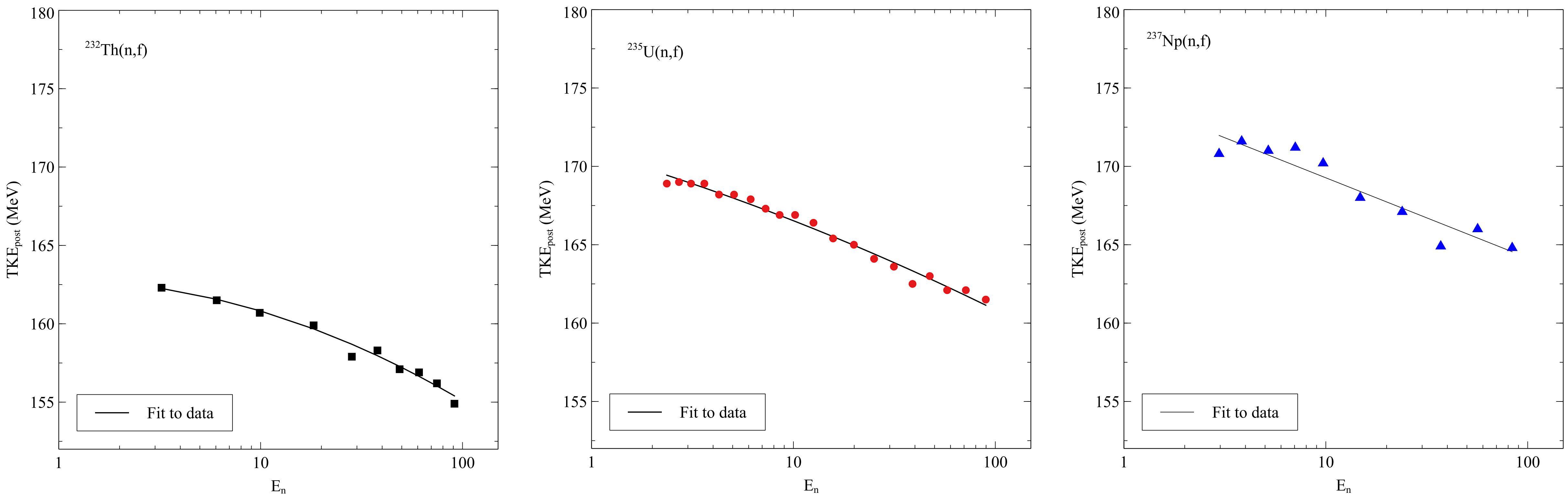

~ 6 MeV drop in TKE across the En = 1-100 MeV energy range

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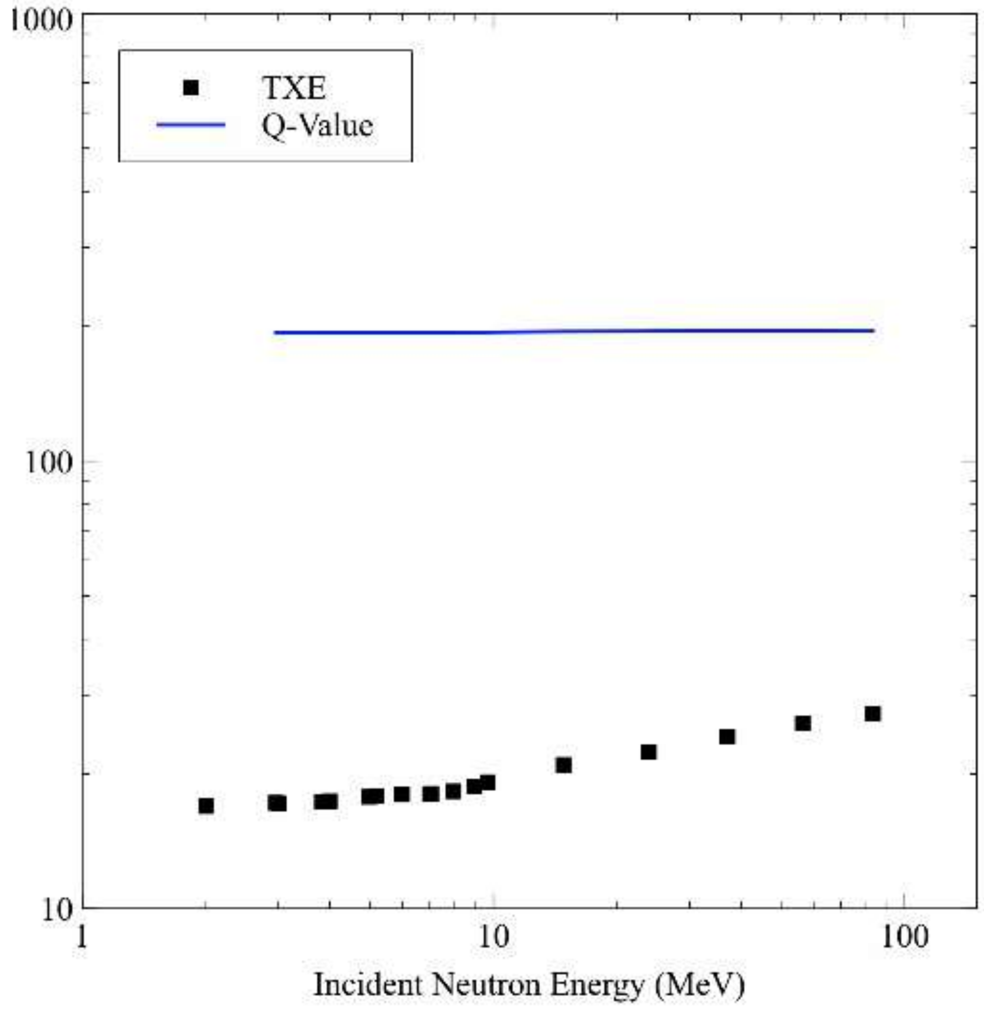
WHERE HAS THE ENERGY GONE?

- Q-values are virtually independent of $E_{n.}$
- TXE increases with increasing $E_{n.}$

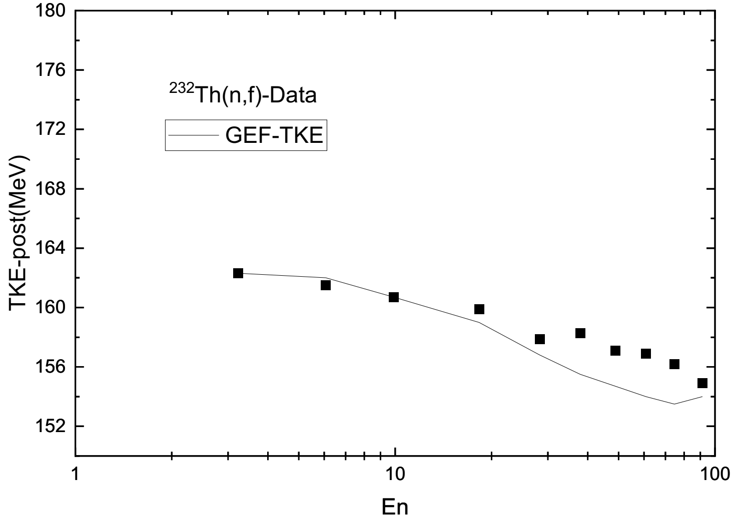
- Therefore, the energy brought by the incident neutron in appears in the fragment excitation energy, TXE.

$$Q = TXE + TKE$$

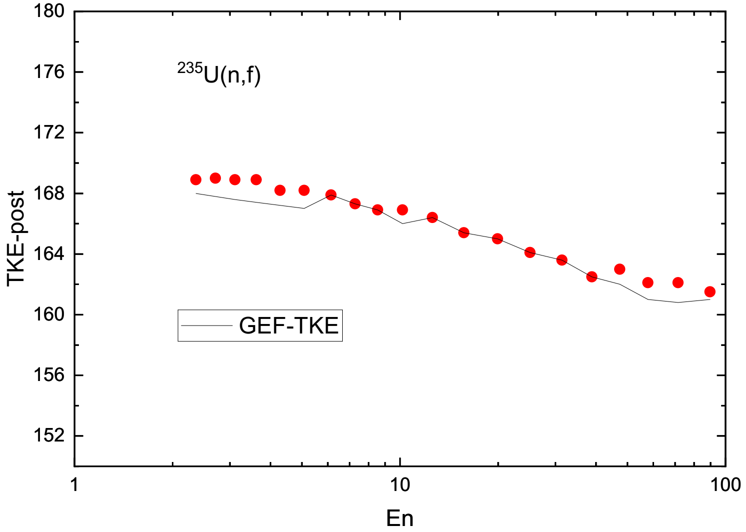


Models for TKE release in fission: GEF

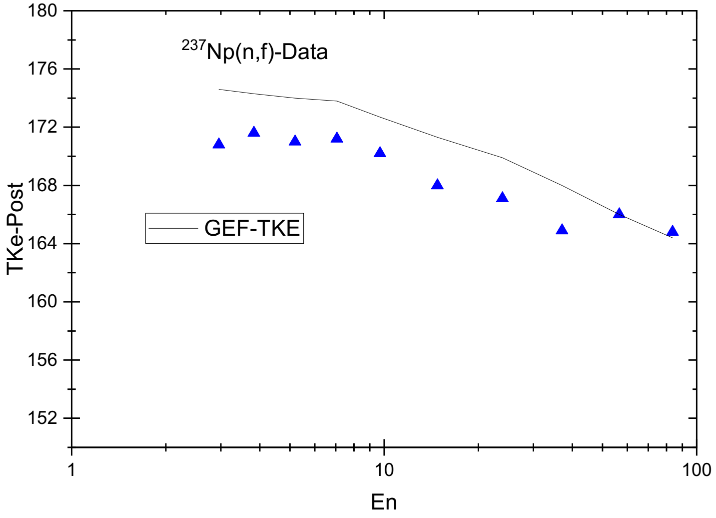
- **<u>Ge</u>neral Description of <u>F</u>ission Observables**
- 50 adjustable parameters



Not Good

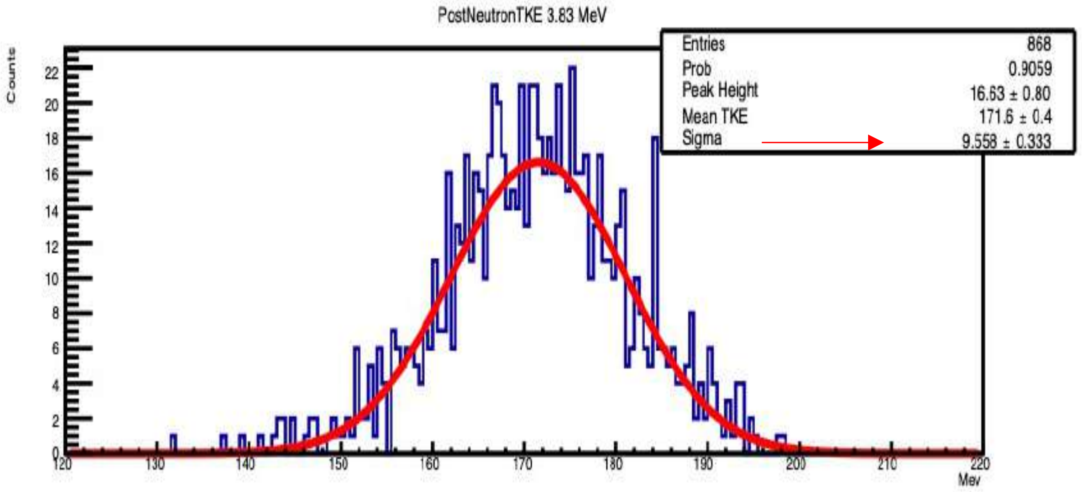


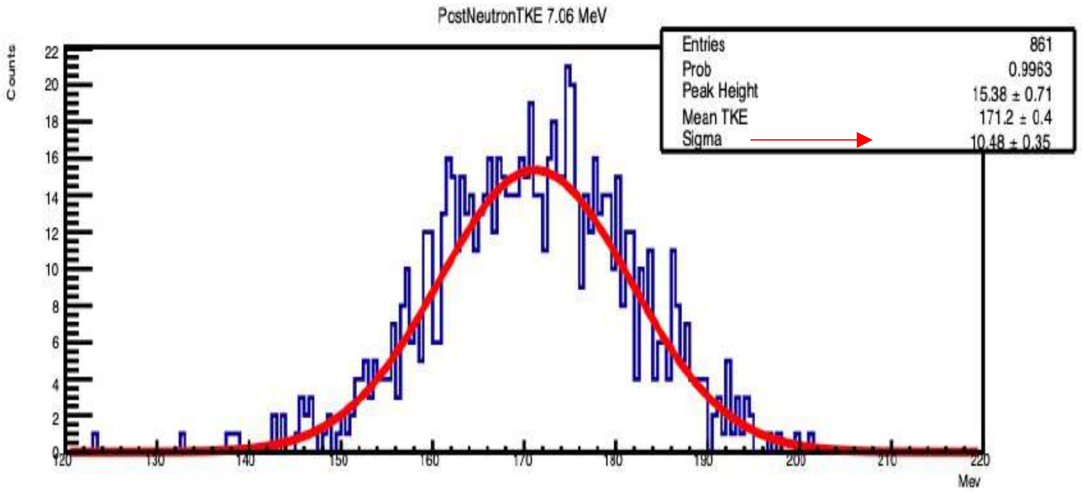
Good

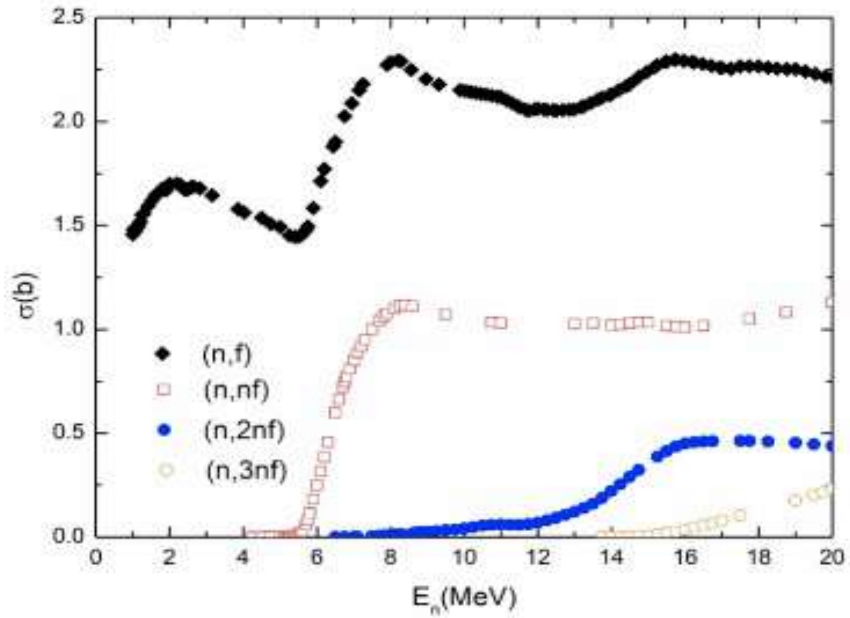


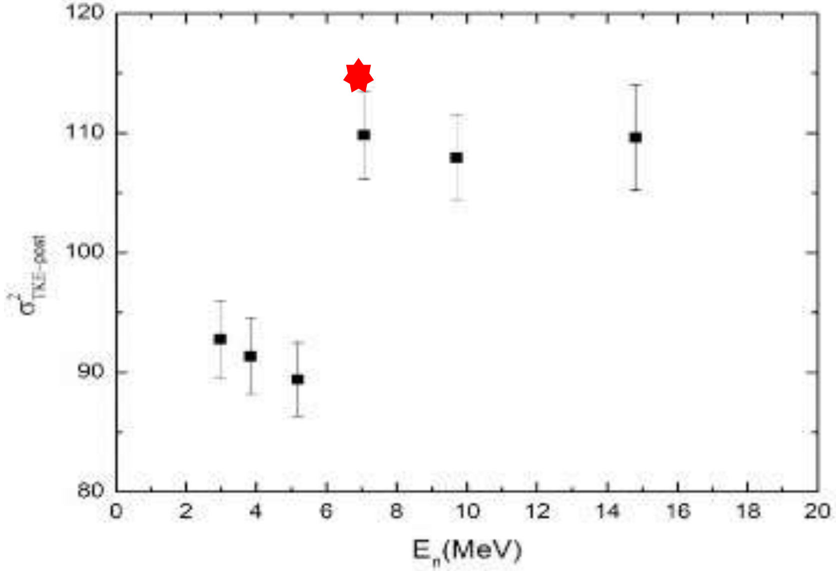
Abysmal

TKE Distribution Variances





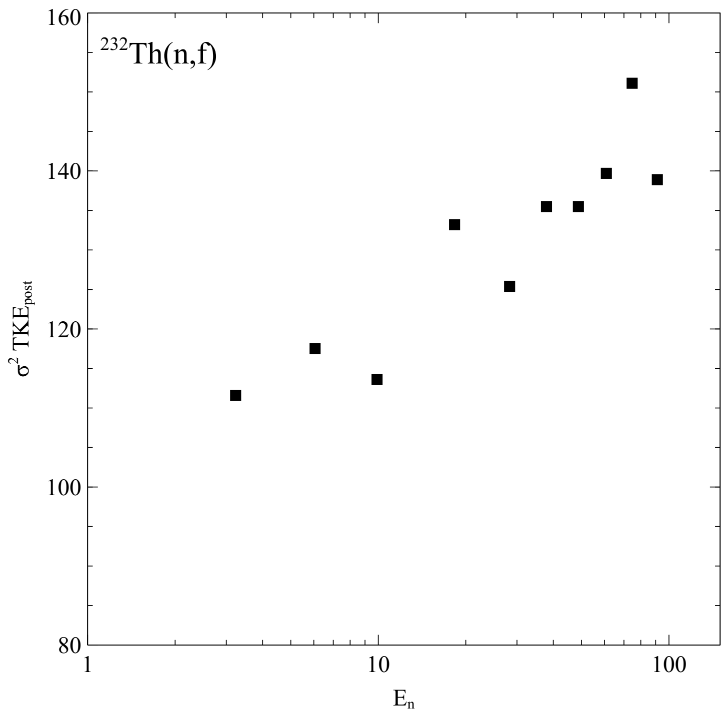


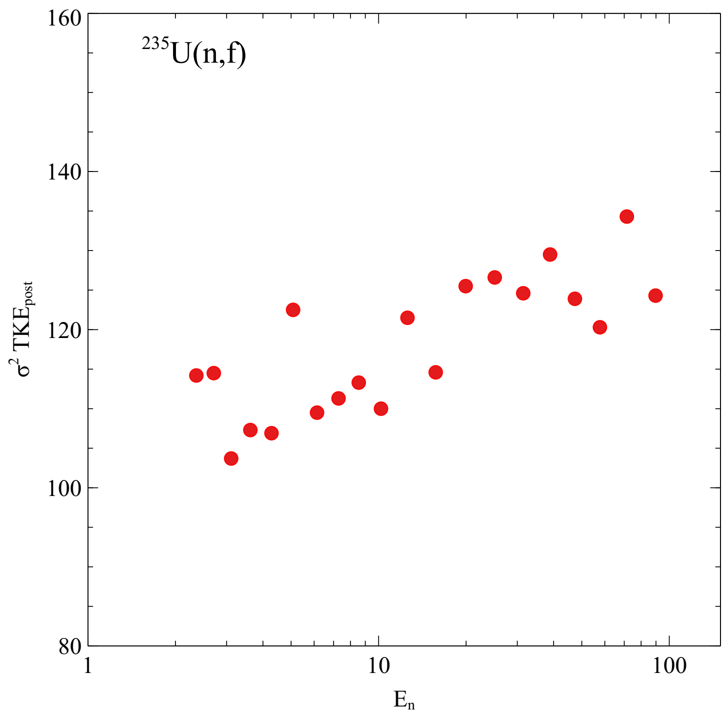


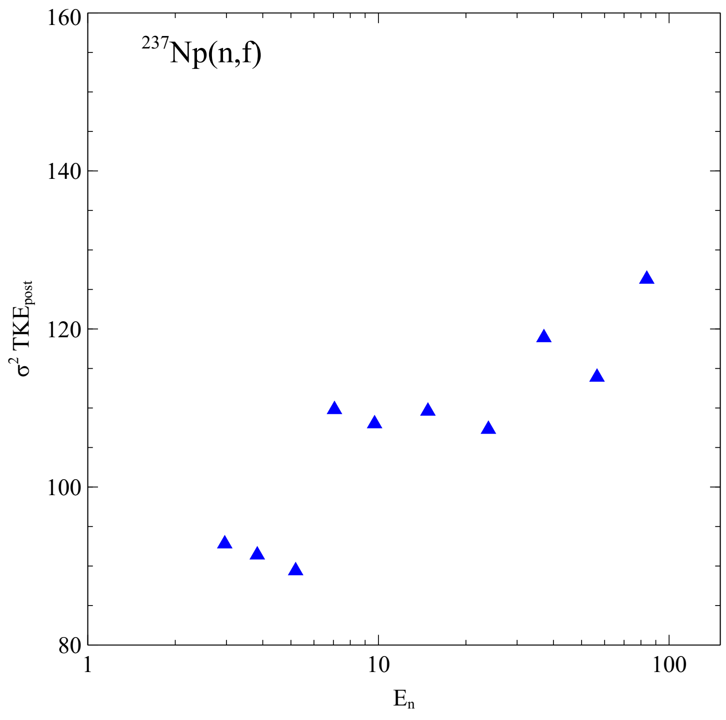
Top: cross section for ^{237}Np (n,f) from ENDF/B-VIII, ENDF/B-VI. Bottom: measured TKE σ^2 vs En for this study.

TKE Distribution Variances

- The variances become smaller as the Z,A of the fission system increases.





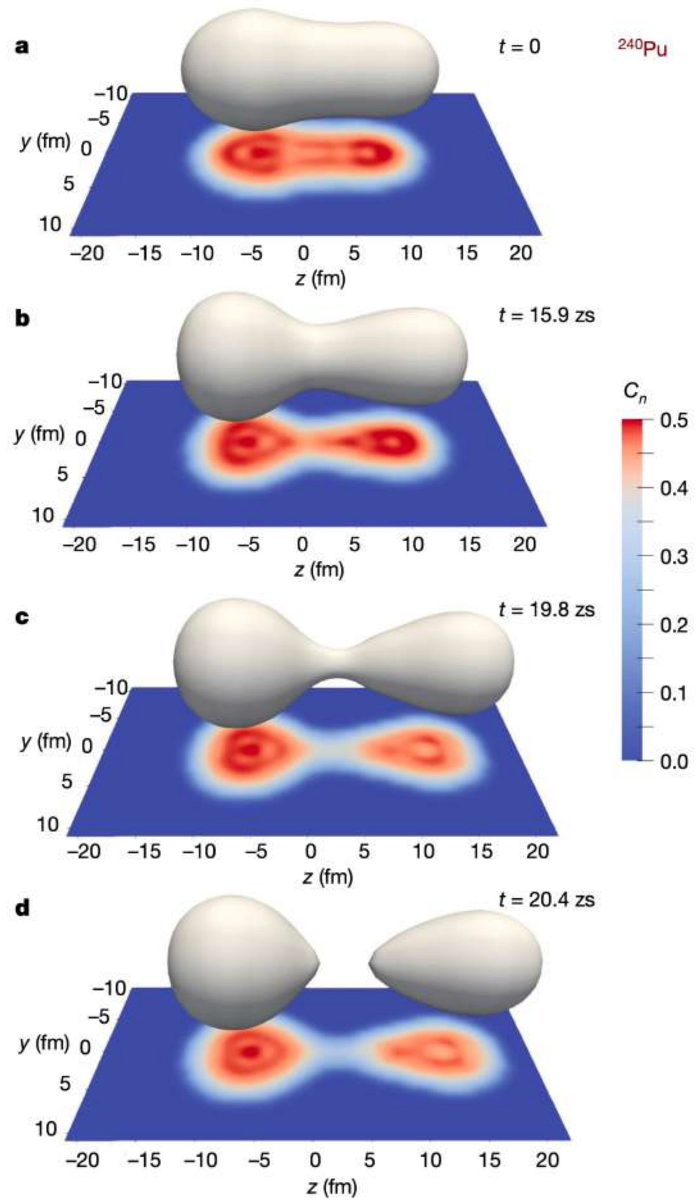


LESSONS LEARNED:

Most of the available energy of the incoming neutron does not go into collective motion in fission. The mean distance between the fragments at scission is nearly constant.

Decreasing TKE is due to the onset of symmetric fission AND a decrease in TKE_{asym} as E_n increases.

The variances of the TKE distributions reflect the onset of multiple chance fission and are constant for En = 20-90 MeV.



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Future Work

- Expanded measurement of late actinide (n,f) TKE, Pu-240, Pu-242, Am-241, and Cm-248

- Deployment of compact new DDAS with large dynamic range to measure fission-related observables, including ternary products

Thank you