LA-UR-22-21762

Evaluation of Energy Dependent Fission Product Yields

Status Report 2022

T. Kawano, LANL

PIs: A. Sonzogni (BNL), L. Bernstein (LBNL),
L. Wood (PNNL), and N. Schunck (LLNL)

Energy-Dependent FPY Project Funded by NA22

Joint effort by 5 laboratories (LANL, BNL, LBNL, PNNL, and LLNL)

FY22 no cost extension at LBNL and PNNL

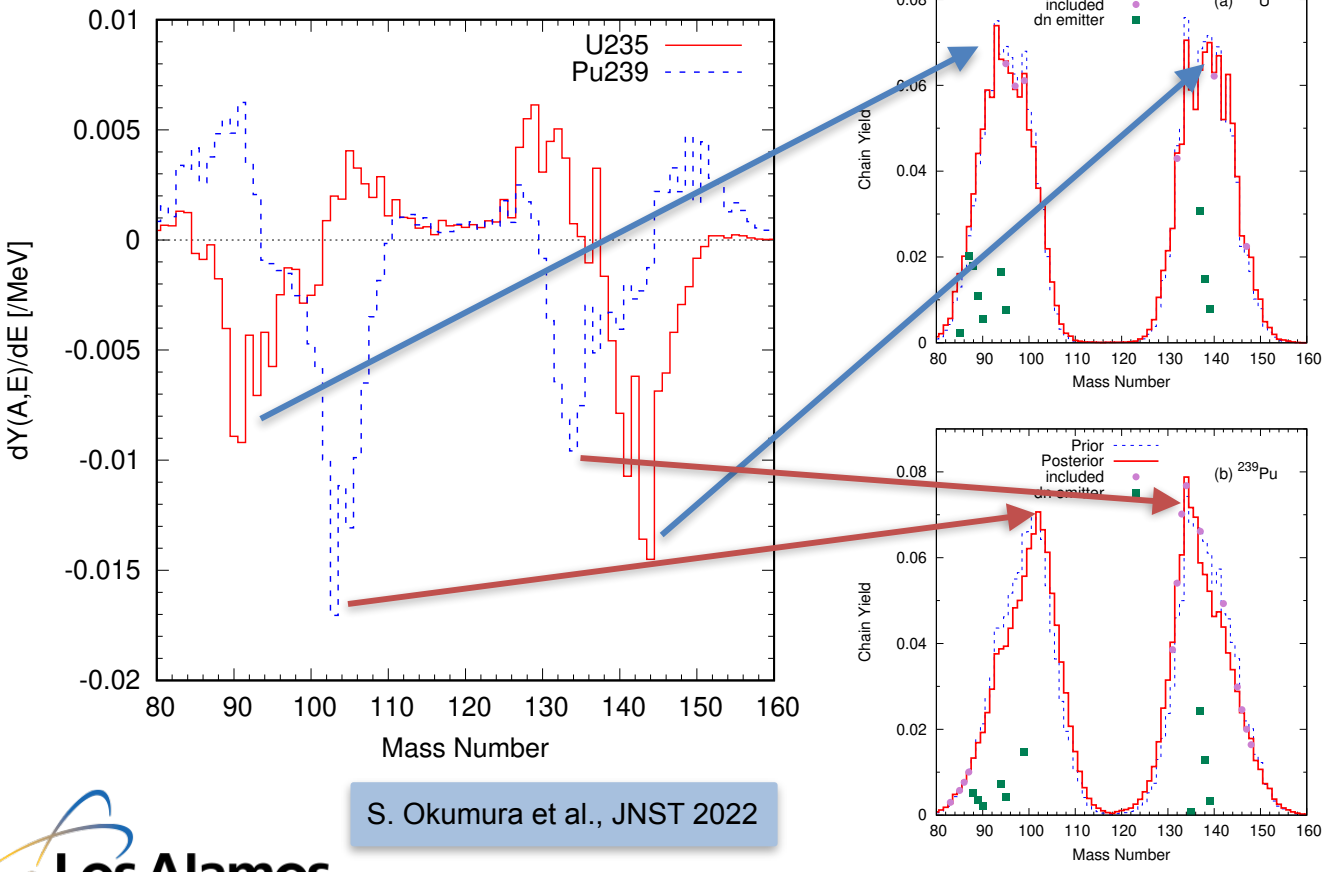
This report contributed by T. Kawano, A. Lovell, I. Stetcu (LANL), A. Sonzogni and A. Mattera (BNL), L. Bernstein and E. Matthews (UCB/LBNL), N. Schunck, M. Verriere (LLNL), S. Okumura (IAEA)

Recent Relevant Meetings

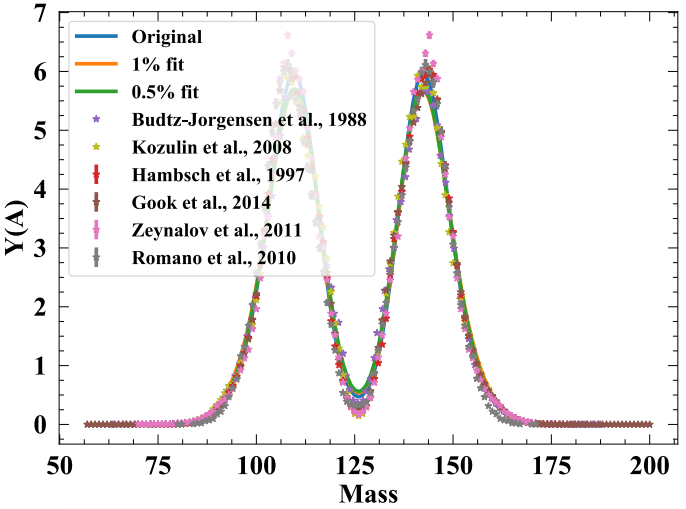
- Independent project review (5/20, 21), virtual event
  - T. Kawano and A. Lovell (LANL), A. Sonzogni and A. Mattera (BNL), L. Bernstein and E. Matthews (LBNL and UC. Berkeley), L. Wood and M. Moore (PNNL), and N. Schunck (LLNL)
- CSEGW (11/15 - 19, 2021), virtual event
  - A. Lovell helped organizing FPY session

LANL FPY Modeling for Energy Dependence

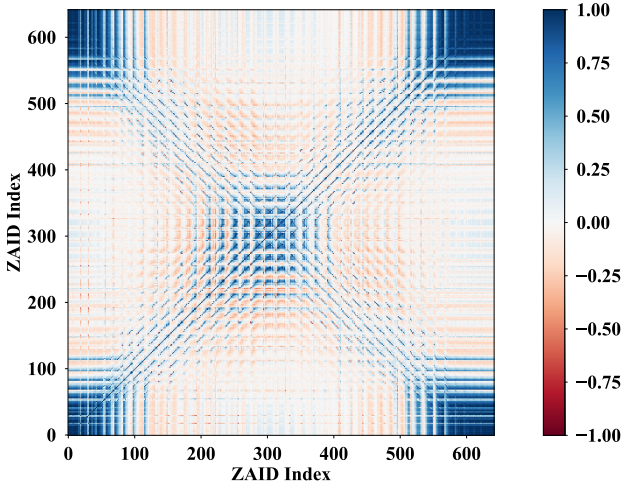
- Model parameter fitting by applying the KALMAN filter (Bayesian) technique
- Energy-dependent FPYs for ^{235,238}U and ^{239}Pu produced
- ^{252}Cf spontaneous fission, preliminary



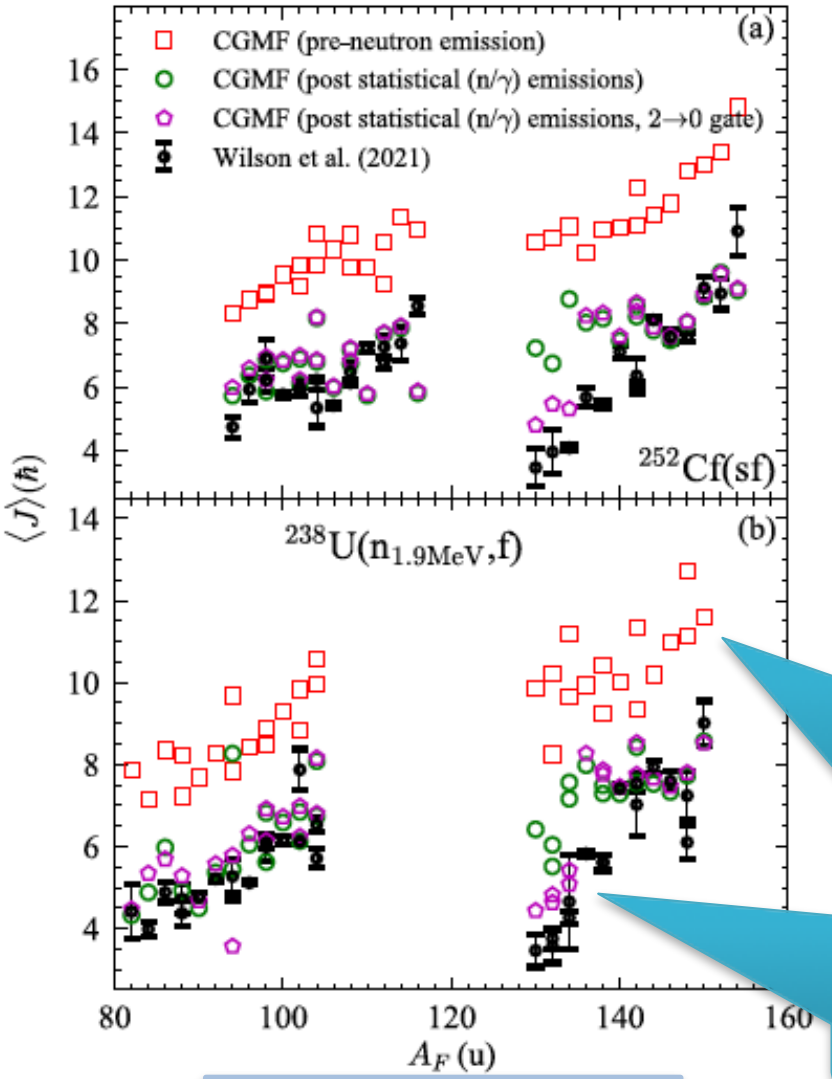
S. Okumura et al., JNST 2022



A.E. Lovell, under preparation for publication



Modeling Spin of Fission Fragments



I. Stetcu, PRL 127, 222502 (2021)

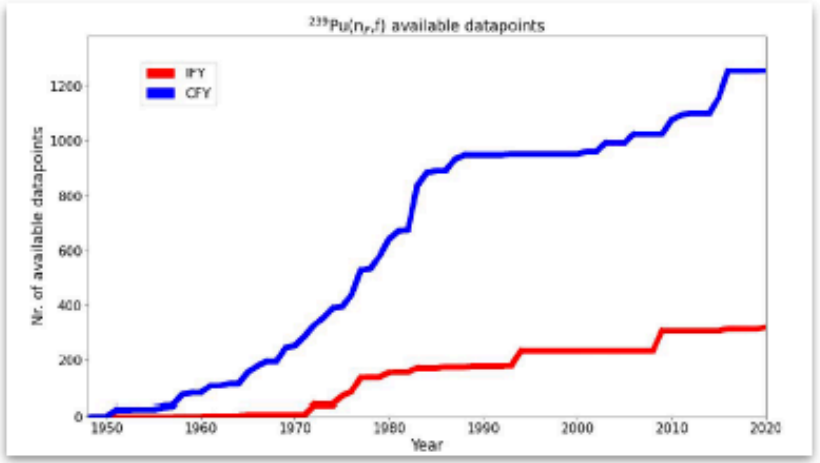
- Assumptions on the FF spin sensitive to many fission observables, FPY, nu-bar, fission gammas, etc.
  - Recent experimental data need to be interpreted properly
- So far we don't see any issues in our modeling/assumptions which conflict with experimental findings

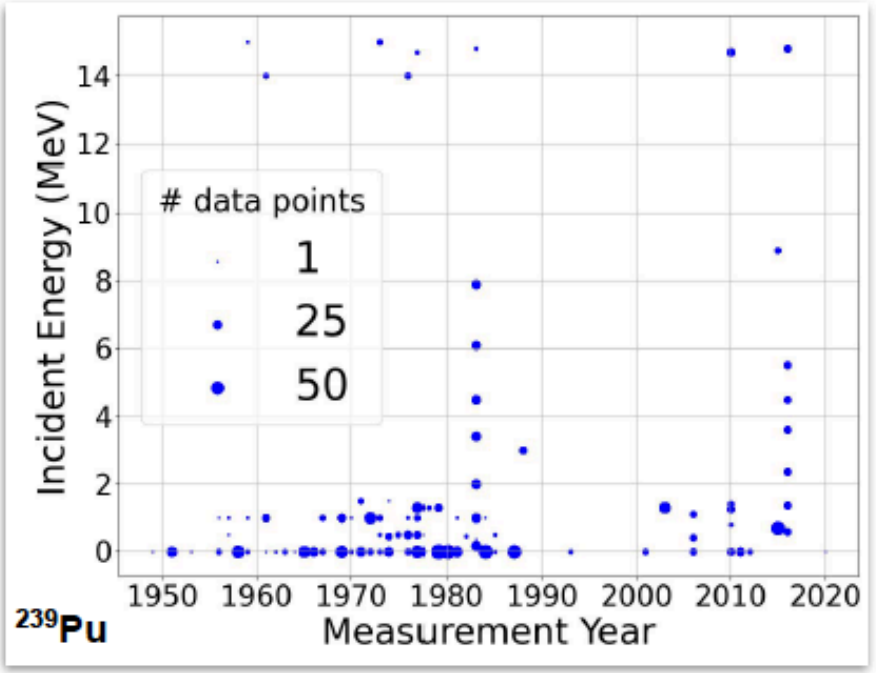
Fragments have higher spin

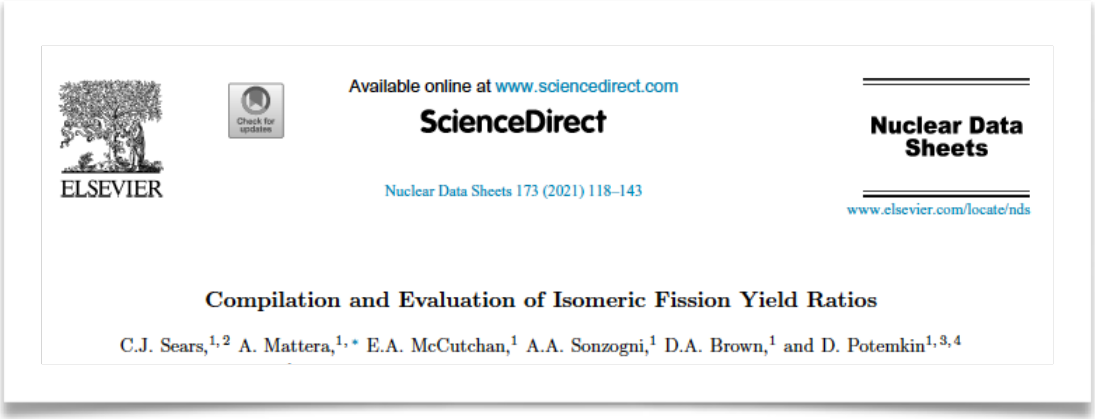
What we see are lower spin

BNL Evaluation of Experimental FPY data

- JSON-based database to store experimental FY values
- Compilation of ^{238}U, ^{239}Pu, and ^{241}Pu data updated with new decay data
- Study of the energy-dependence of ^{238}U experimental data
- Isomeric Yields compiled, corrected and new recommended experimental values







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Nuclear Data Sheets

Nuclear Data Sheets 173 (2021) 118–143

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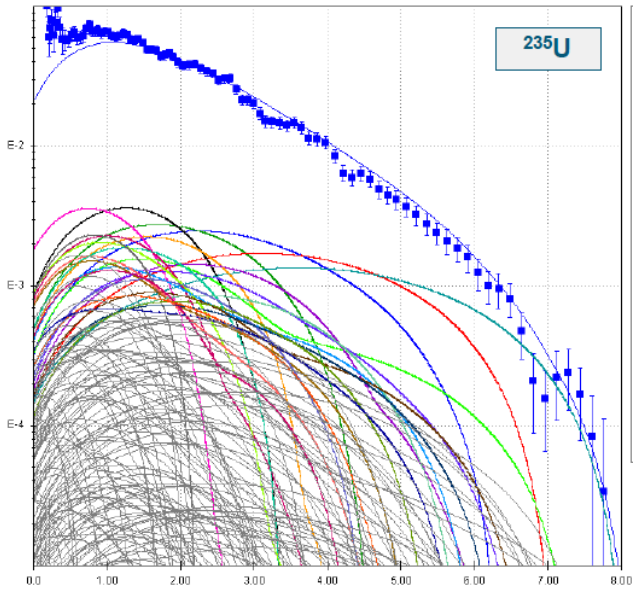
Compilation and Evaluation of Isomeric Fission Yield Ratios

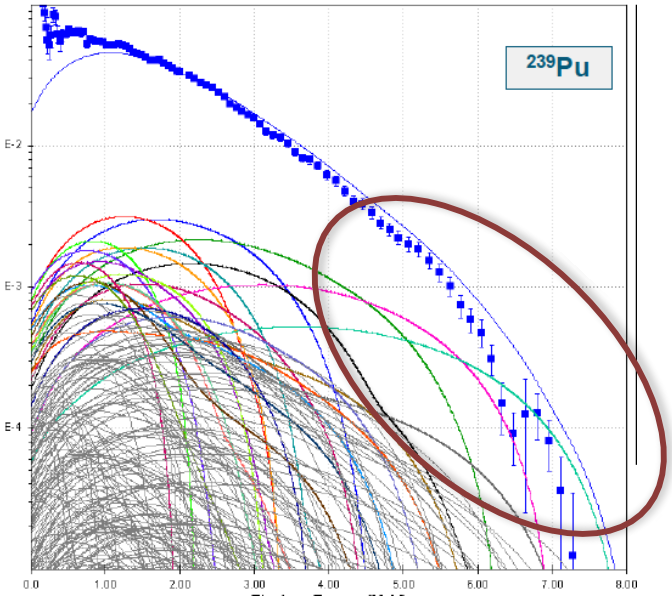
C.J. Sears,[1,2] A. Mattera,[1,*] E.A. McCutchan,[1] A.A. Sonzogni,[1] D.A. Brown,[1] and D. Potemkin[1,3,4]

BNL FPY Data Benchmarking by Beta-Delayed Electron

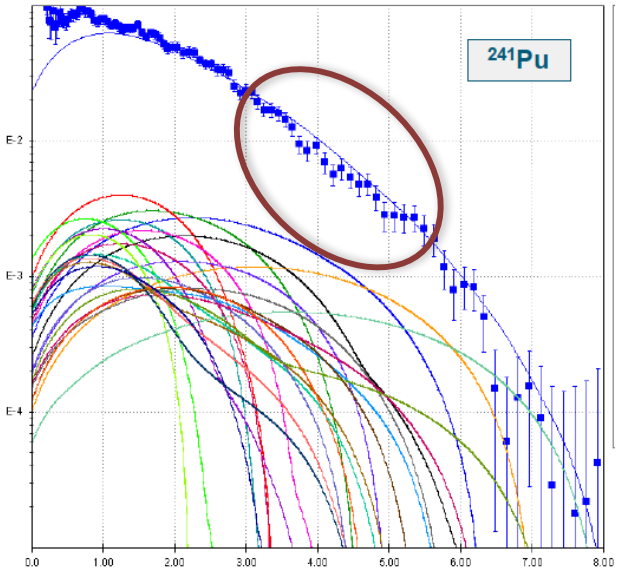
- Electron spectrum data in ORNL reports (J.K. Dickens, et al) digitized
  - ENDF/B-VIII.1b decay data JEFF-3.3 FPY data
  - 25 most important contributions identified



Electron Energy (MeV)



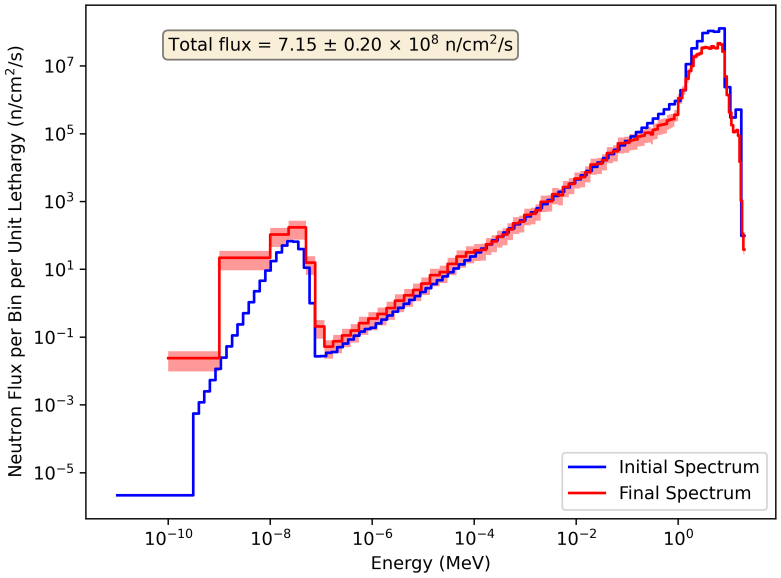
Electron Energy (MeV)

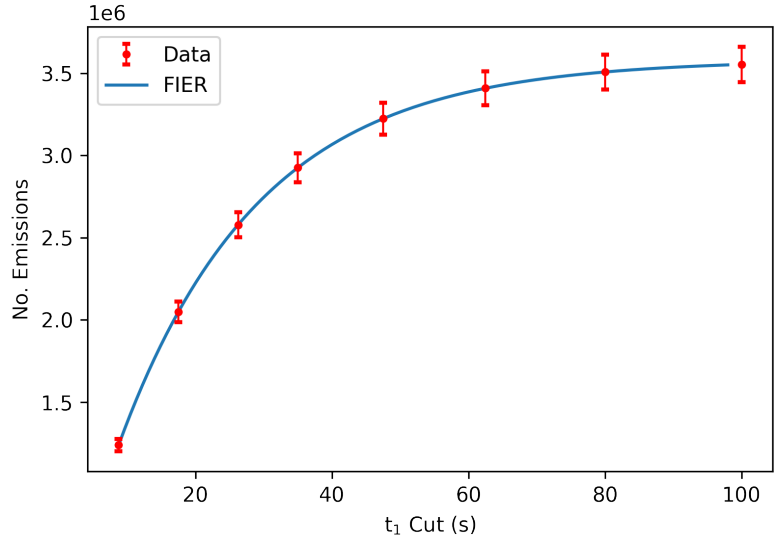


Electron Energy (MeV)

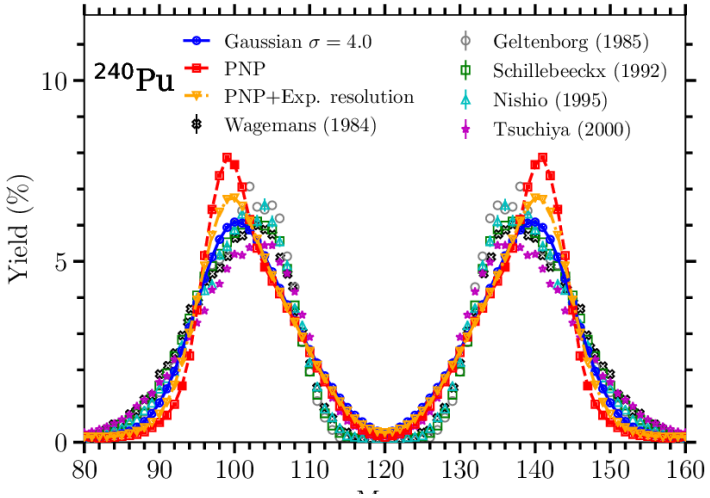
LBNL/UCB Measurements 2020 and 2021

- Fast Loading User Facility for Fission Yields (FLUFFY) at LBNL cyclotron
  - Transport times <0.75 sec allow observation of short-lived fission products
- July 2020 Experiment, ^{238}U, ^{235}U
  - 14 MeV deuteron breakup on graphite
  - FPY g-emission data analyzed by the FIRE code
  - A = 86, 98, and 136 mass chains reported in E. Matthews's dissertation
- May 2021 Experimen, ^{239}Pu
  - data analysis ongoing

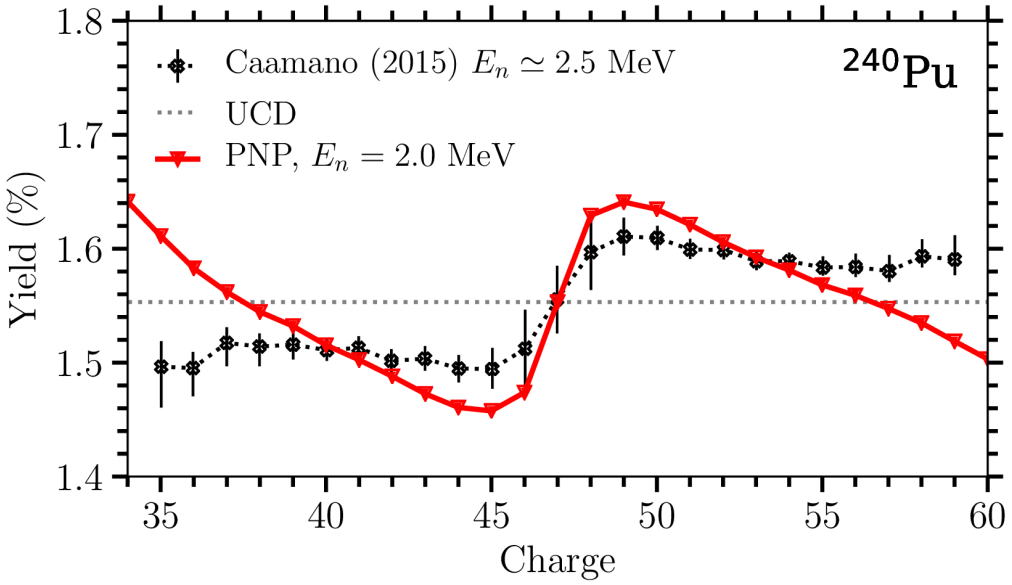




LLNL Primary Fission Fragment Yields

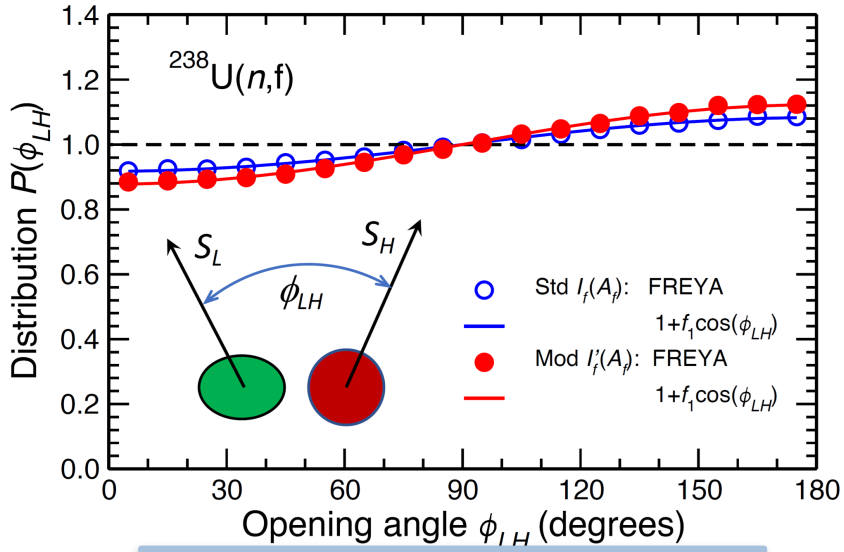


- Combining particle-number projection techniques with large-amplitude collective motion
- Particle number projection key to predict isotopic yields Y(Z,A) – including as a function of incident neutron energy
  - deviates from unchanged charge distribution (UCD)
  - good agreement with experimental data for major actinides

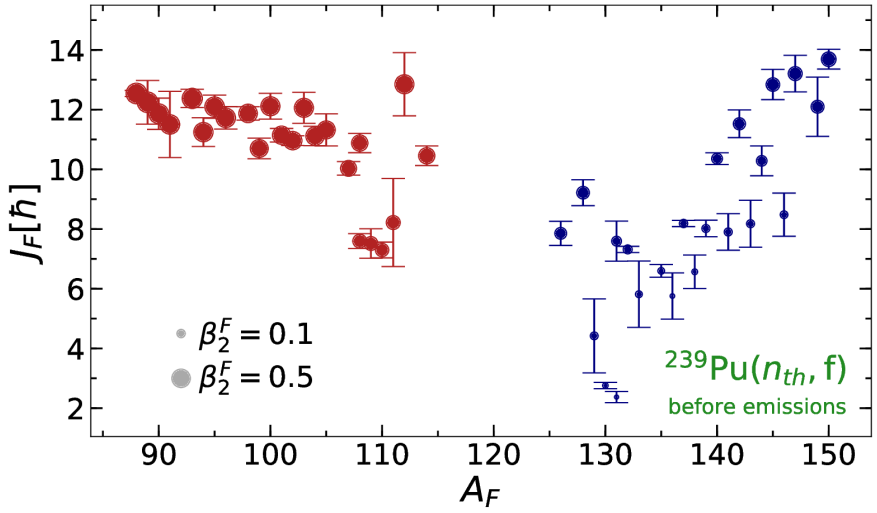


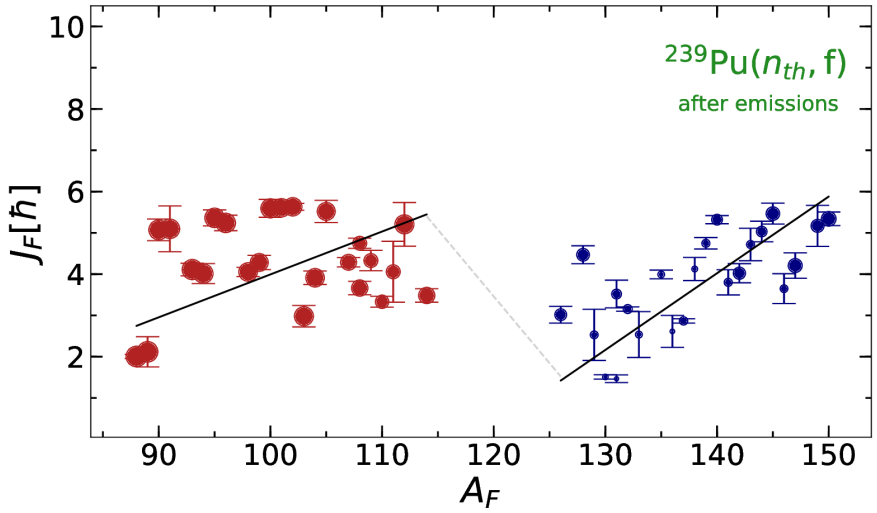
Fission Fragment Spin Distribution

- Angular-momentum projection technique gives the spin distributions of primary fission fragments
  - Importance of shell effects at scission
  - No adjustable parameters
  - Used as inputs in statistical decay code such as FREYA to determine photon spectrum



J. Randrup, R. Vogt, PRL 127 062502 (2021)





P. Marevic, et al. PRC 104 L021601 (2021)

Publications

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- Energy dependent calculations of fission product, prompt, and delayed neutron yields for neutron induced fission on 235U, 238U, and 239Pu, S. Okumura, T. Kawano, A.E. Lovell, T. Yoshida, J. Nucl. Sci. Technol. **59**, 96 (2022)
- Influence of non-statistical properties in nuclear structure on emission of prompt fission neutrons, T. Kawano, S. Okumura, A.E. Lovell, I. Stetcu, Phys. Rev. C **104**, 014611, (2021)
- Angular momentum removal by neutron and γ-ray emissions during fission fragment decays, I. Stetcu, A. Lovell, P. Talou, T. Kawano, S. Marin, S.A. Pozzi, A. Bulgac, Phys. Rev. Lett. **127**, 222502 (2021)
- Compilation and Evaluation of Isomeric Fission Yield Ratios, C.J.Sears, A. Mattera, E.A. McCutchan, A.A. Sonzogni, D.A. Brown, D.Potemkin, Nuclear Data Sheets **173**, 118 (2021)
- Stochastically estimated covariance matrices for independent and cumulative fission yields in the ENDF/B-VIII.0 and JEFF-3.3 evaluations, E.F. Matthews, L.A. Bernstein, W. Younes, At. Data Nucl. Data Tables **140** (2021) 101441.
- Advancements in the Nuclear Data of Fission Yields, E. Matthews's Ph.D. thesis,
- Microscopic calculation of fission product yields with particle-number projection, M. Verriere, N. Schunck, D. Regnier, Phys. Rev. C **103**, 054602 (2021)
- Angular momentum of fission fragments from microscopic theory, P. Marević, N. Schunck, J. Randrup, R. Vogt, Phys. Rev. C **104**, L021601 (2021)
- Fission Fragment Intrinsic Spins and Their Correlations, A. Bulgac, I. Abdurrahman, S. Jin, K. Godbey, N. Schunck, I. Stetcu, Phys. Rev. Lett. **126**, 142502 (2021)