

Ex fission ad astra: extending nucleon-nucleus interactions to the fission fragment region



2024 MTV Workshop

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Kyle Beyer

Facility for Rare Isotope Beams

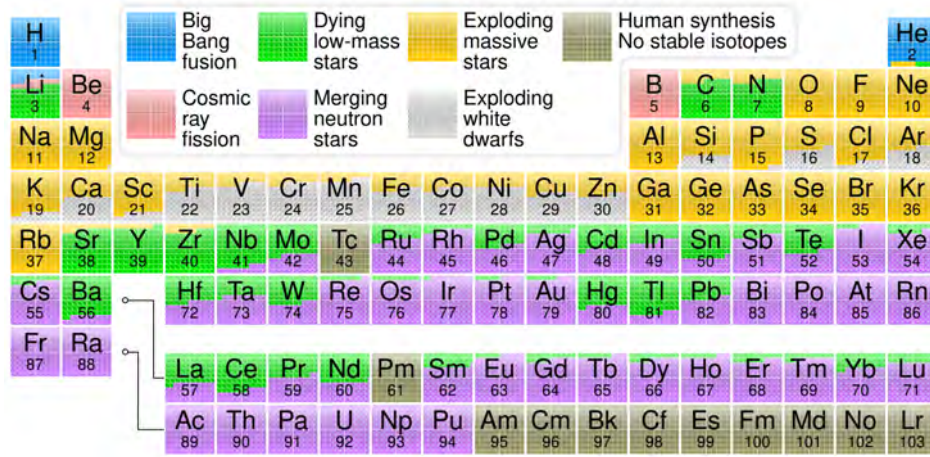
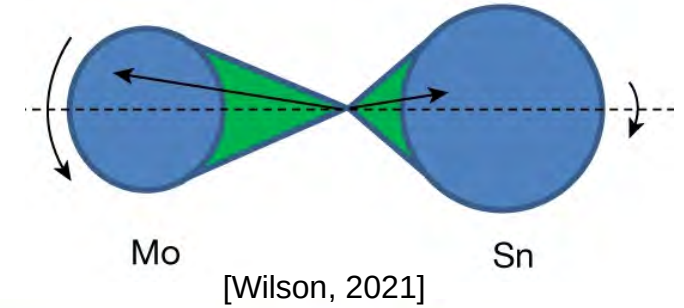
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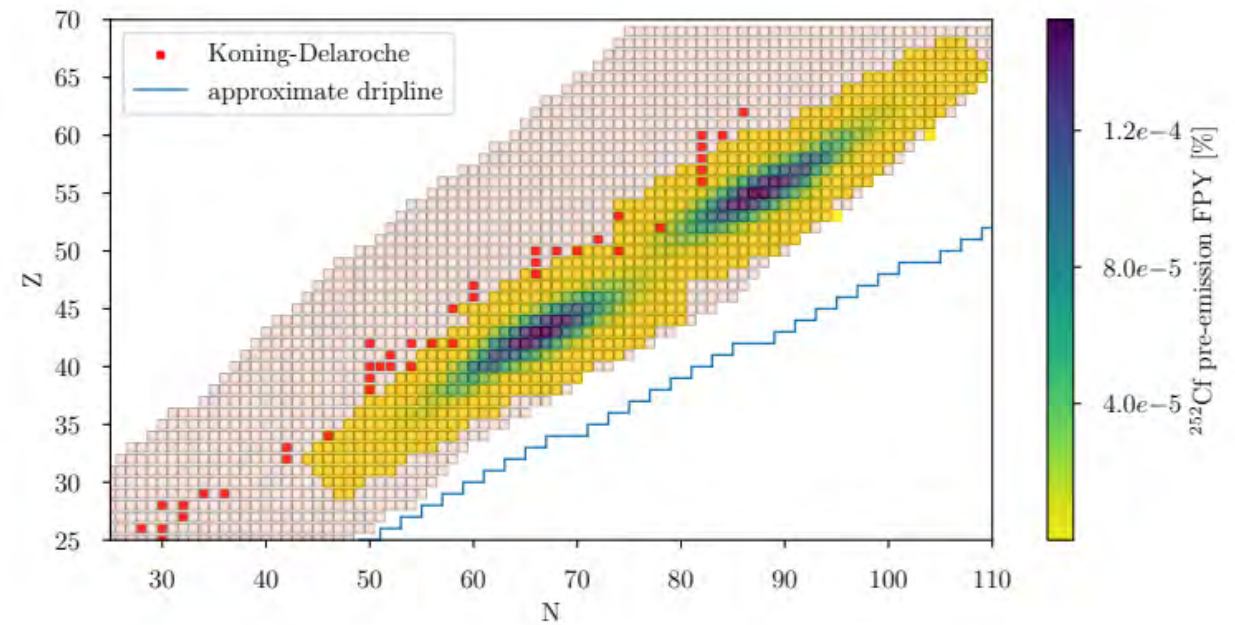


We want to accurately model reactions away from stability, with UQ

- prompt de-excitation of fission fragments: nuclear non-proliferation, open physics questions
- cross sections for fission products: spent fuel, depletion, forensics
- r-process nucleosynthesis

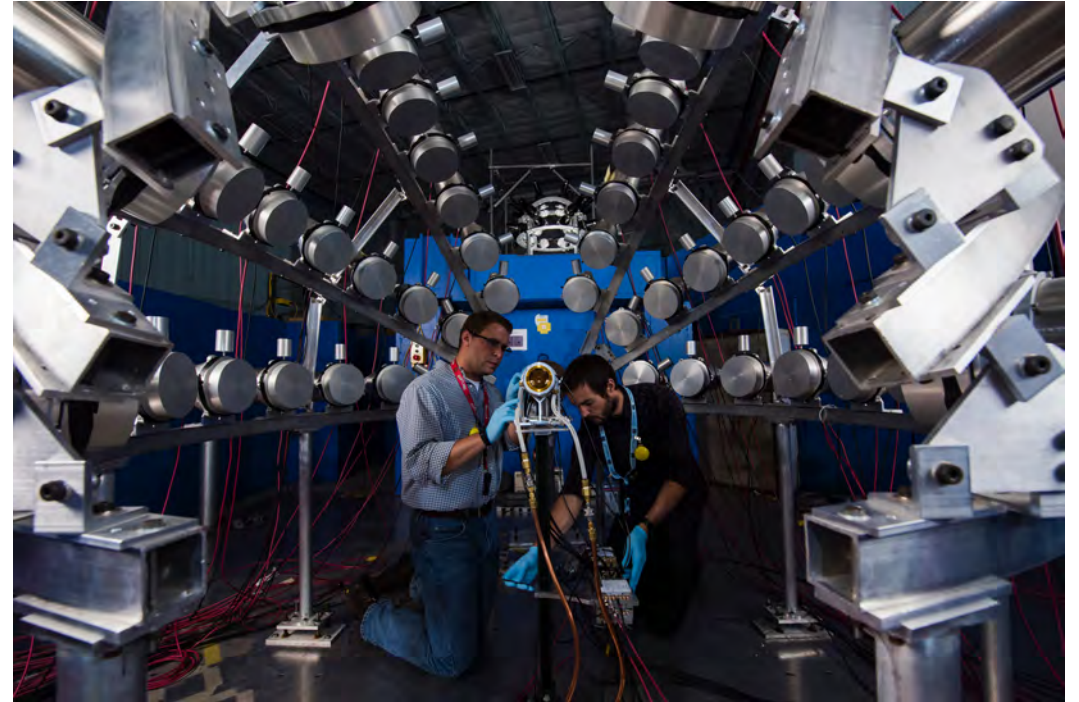


[wikimedia commons]



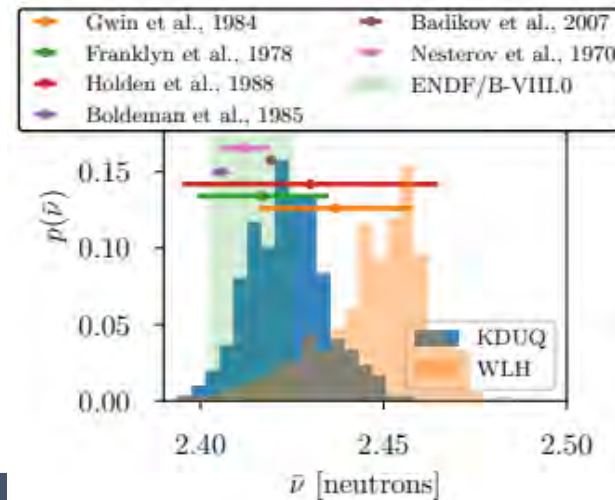
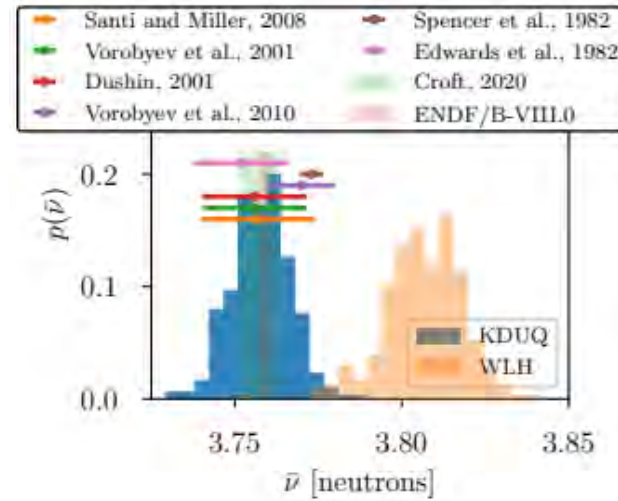
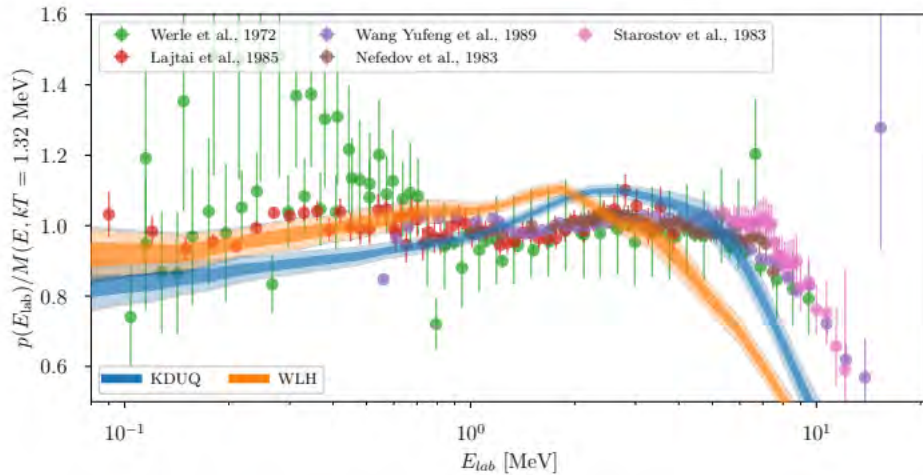
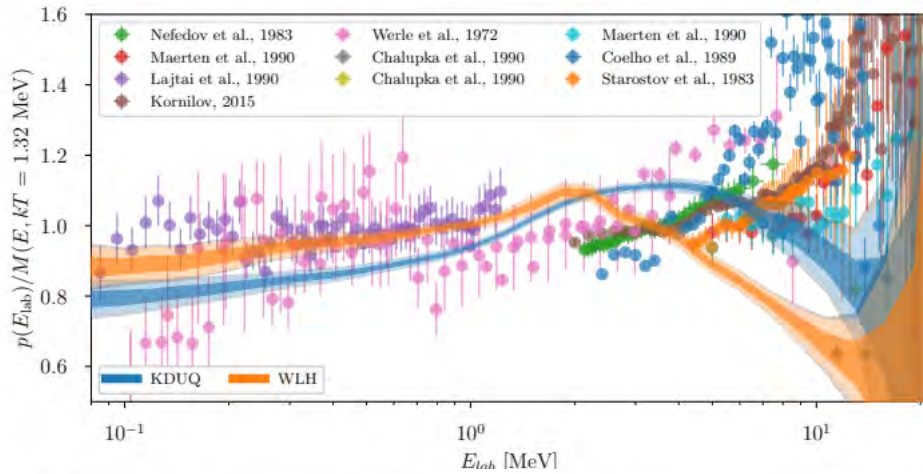
Mission relevance: nuclear data is “upstream” from nuclear applications

- significant cost and effort goes into measuring reaction observables
- resulting models only constrained for experimentally accessible A,Z
- **What are the uncertainties on observables relevant to non-pro and safeguards?**
- **What are the best measurements we can take to improve nuclear data?**



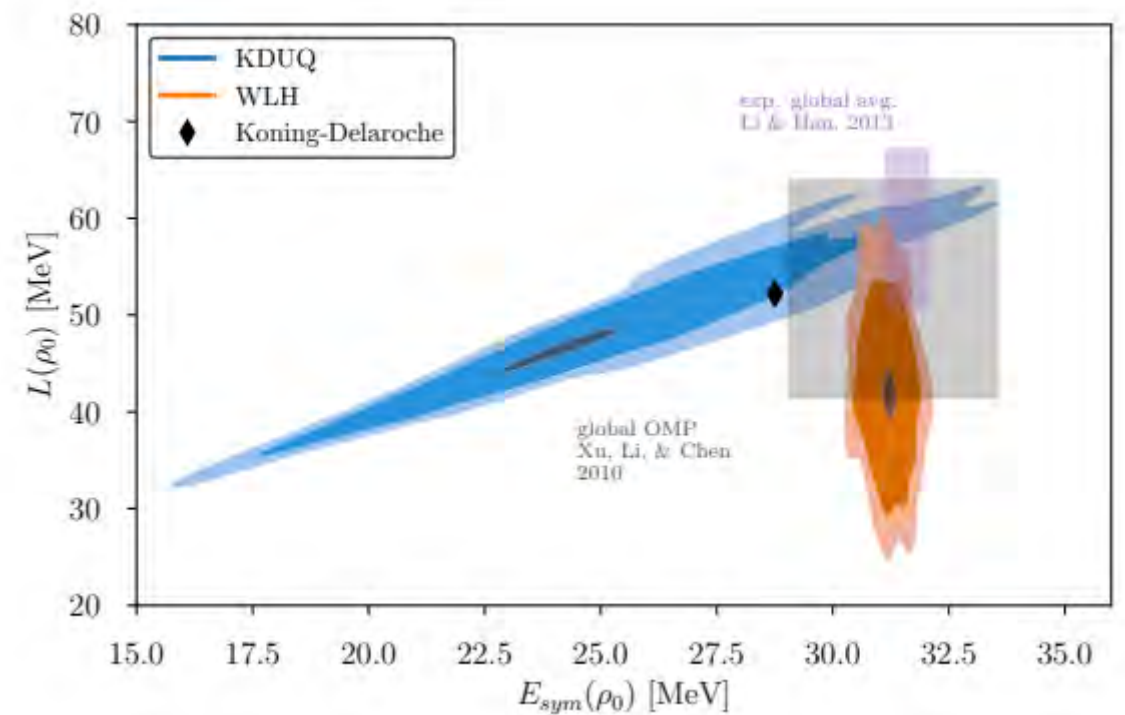
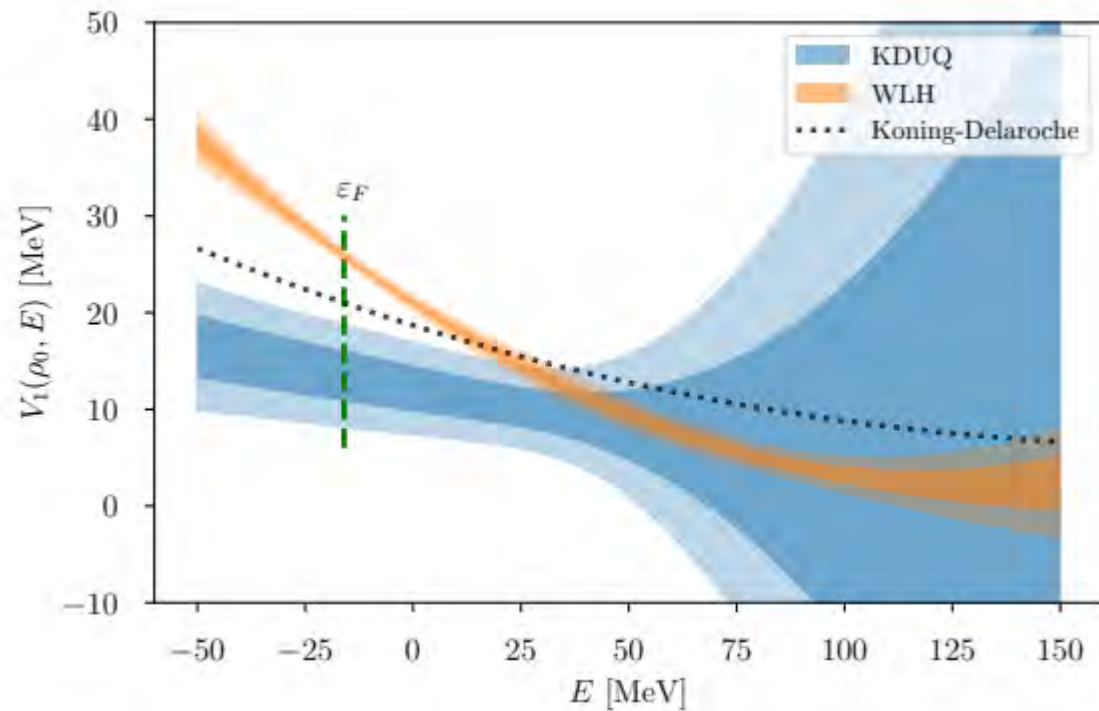
[courtesy of Matt Devlin]

Uncertainty quantification of fission observables in $^{252}\text{Cf}(sf)$ and $^{235}\text{U}(n,f)$



- **Significant uncertainties in important fission observables!**
- phenomenological: poor constraint of isovector dependence
- microscopic: truncation of self-energy diagrams

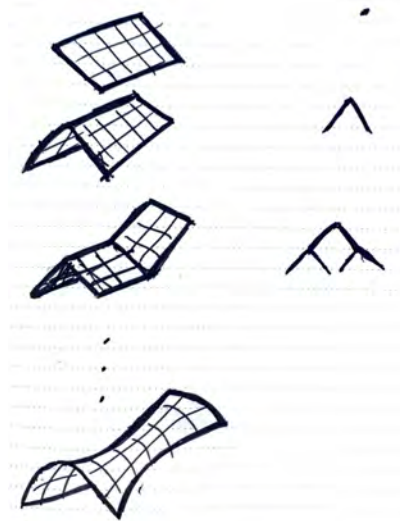
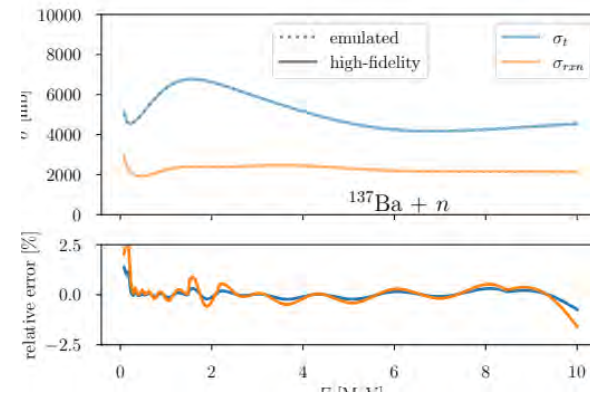
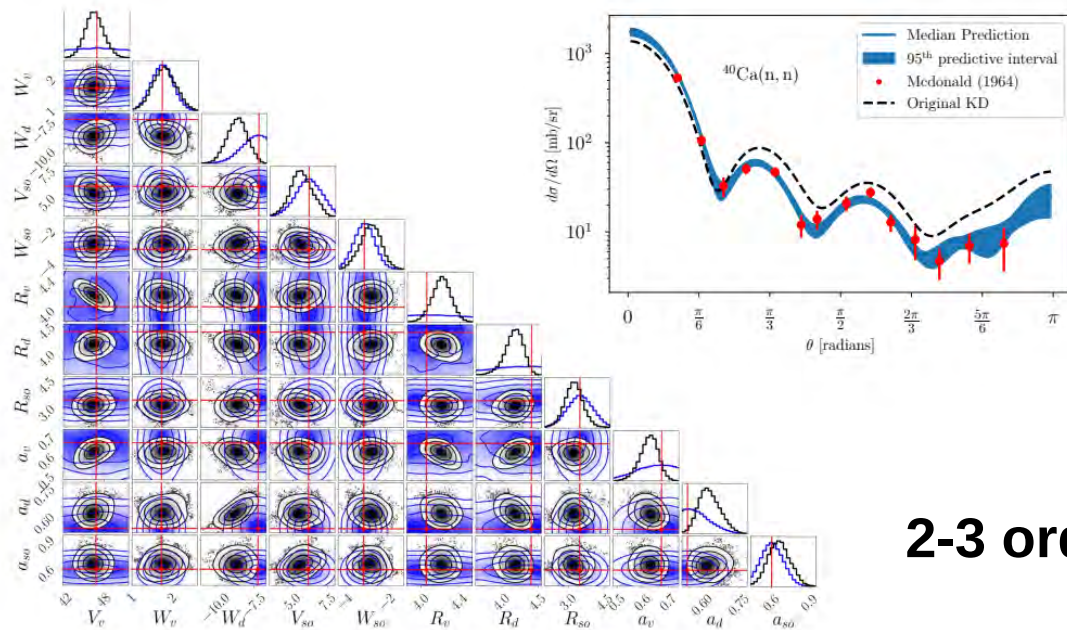
Uncertainty quantification for properties of nuclear matter



Projective model order reduction lets us do UQ on the personal computer...

Bayesian calibration of local optical potential using ~800k samples takes only 1 hour!

Extending to global potentials is possible using active subspace methods and local linear embedding



2-3 order of magnitude speedups!

... and opens up previously intractable problems on HPC

MTV involvement has lead to many fruitful collaborations



UQ

- ▶ Cole Pruitt

COSMOS++ team

- ▶ Peter Anninos
- ▶ Nathaniel Roth
- ▶ Tymothy K. Mangan
- ▶ Peter B. Robinson
- ▶ J. Luc Peterson
- ▶ Brooke Polak

- ▶ Amy Lovell
- ▶ Ionel Stetcu
- ▶ Toshiko Kawano

ROSE team

- ▶ Daniel Odell
- ▶ Pablo Giuliani
- ▶ Manuel Catacora-Rios
- ▶ Moses Y.-H. Chan,
- ▶ Edgard Bonilla
- ▶ Richard J. Furnstahl
- ▶ Kyle Godbey
- ▶ Filomena M. Nunes

- **publications:**

- ≈ PRC(x1)
- ≈ APJ (x1)
- ≈ 2 in progress!

- **conference talks:**

- ≈ DNP (x2)
- ≈ ISNET (x1)

- **visit to Los Alamos:**

- ≈ T-division

- **friends we made along the way:**

- ≈ priceless



Conclusions

- The first propagation of optical potentials uncertainties into fission observables and nuclear matter quantities
 - significant uncertainties
 - phenom better at fission, worse in NM
- 2-3 order of magnitude speedups in UQ using projective model order reduction techniques
 - negligible loss of accuracy
 - potentially transformative for UQ
 - extension to global potentials



Next Steps



- I have a big boy job now
- Continue work on constraining the isovector dependence of optical potentials using (d,p), etc.
 - ~ predictive theory out to the neutron dripline
- Continue development of projective model order reduction tools for nuclear physics
 - ~ cover the whole nuclear chart

Acknowledgements



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