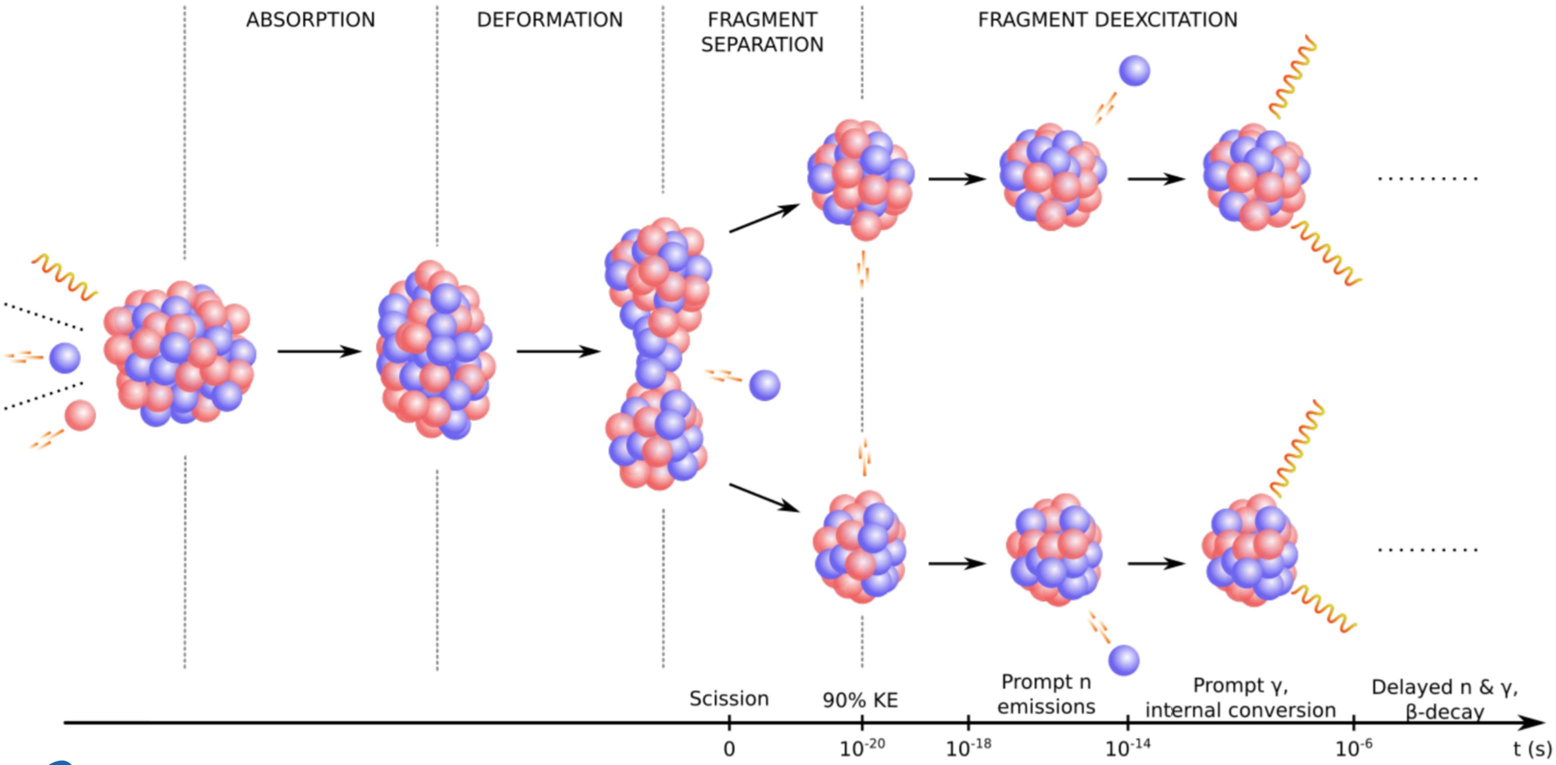
SIMULTANEOUS CALCULATION OF FISSION FRAGMENT CHARGE AND MASS YIELDS WITH THE eFRLDM



Los Alamos NATIONAL LABORATORY EST. 1943

LA-UR-21-30063

MATTHEW MUMPOWER

Fall DNP

Wednesday Oct. 13^{th} 2021

NDT

Nuclear Data Team

Theoretical Division

WHY DO WE NEED FISSION YIELDS?

Fission yields are needed for a variety of modern applications

Industrial applications: simulation of reactors, fuel cycles, waste management

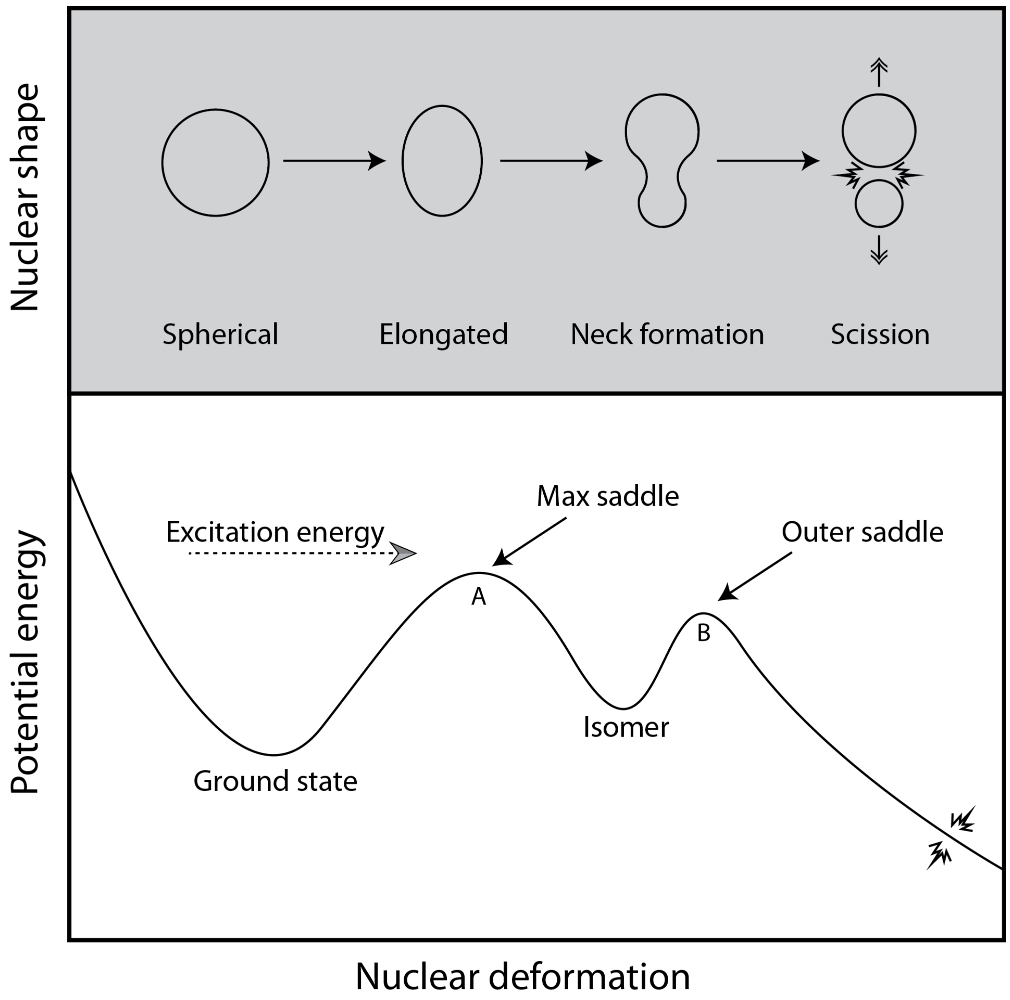
Experiments: backgrounds, isotope production with radioactive ion beams (fragmentation)

Science applications: nucleosynthesis, light curve observations

Other Applications: national security, nonproliferation, nuclear forensics

Figure: Chi-Nu detector (left), Reactor cooling towers (middle), Neutron star merger (right)

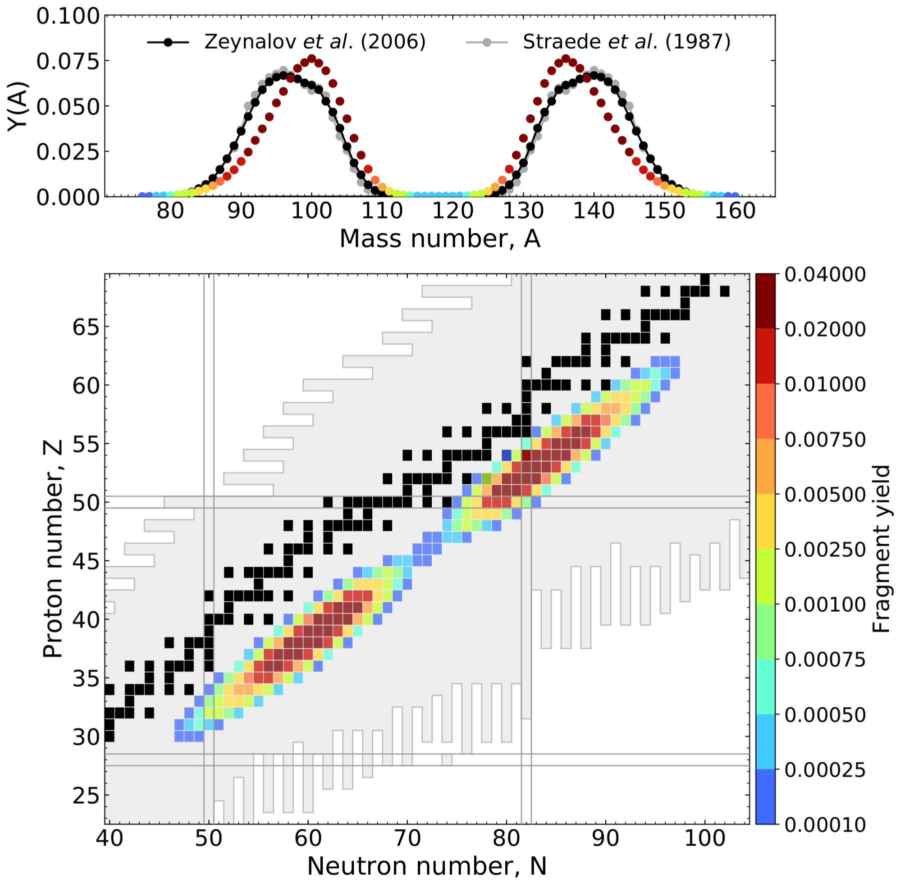
A BASIC PICTURE OF FISSION



Follow progression of the nucleus from compact to highly elongated shapes

Randrup *et al.* PRL (2011) • Randrup *et al.* PRC (2011) • Randrup *et al.* PRC (2013) • Figure from **Mumpower** *et al.* PRC 101 054607 (2020)

FRAGMENT YIELD CALCULATION (FRLDM)

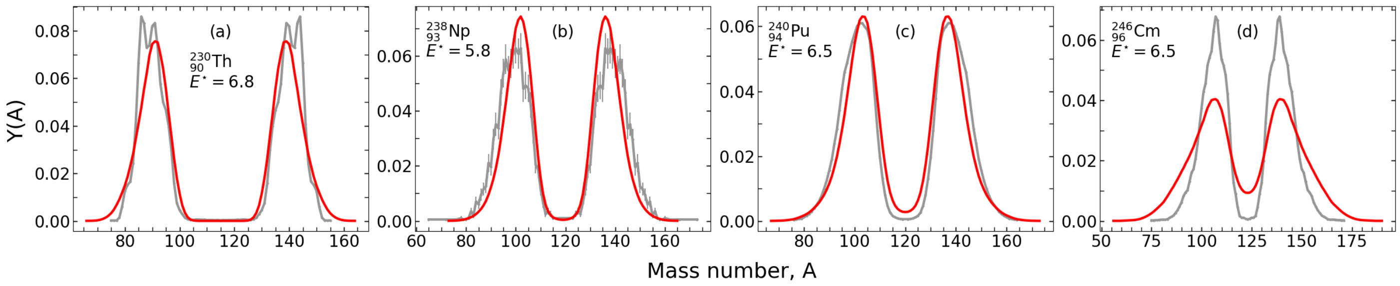


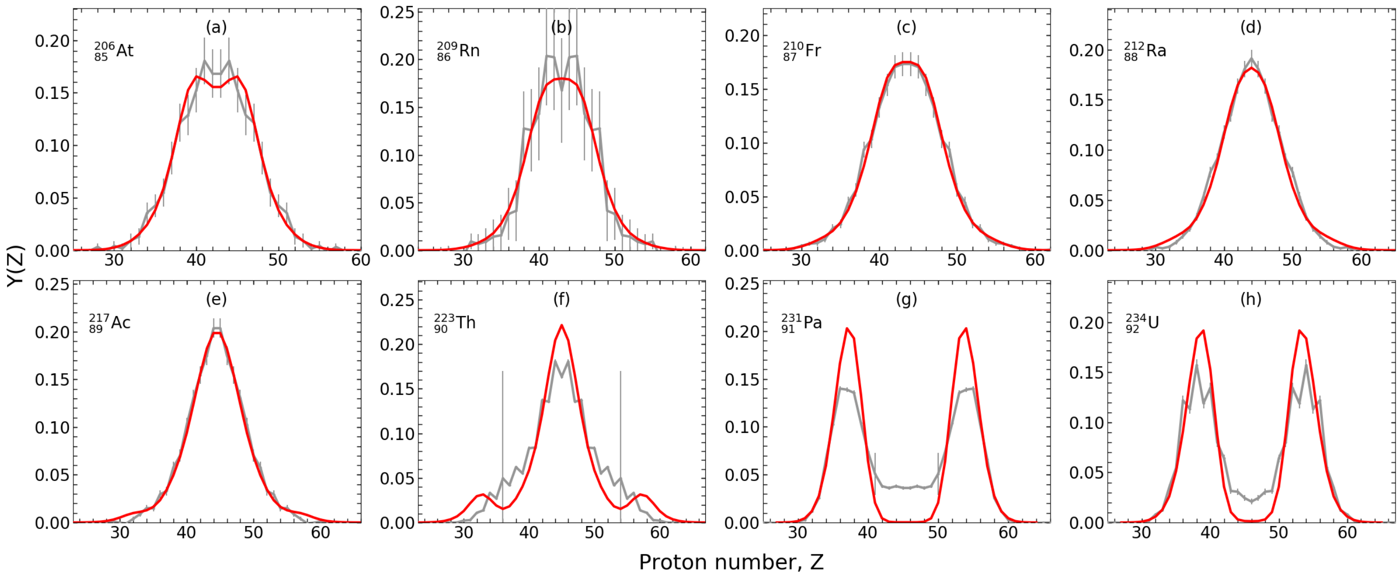
Ensemble of fission events leads to the cumulation of the yield curve (^{235}U + n_{therm})

Relies on geometric splitting argument for the scission configuration

Mumpower *et al.* PRC 101 054607 (2020)

MASS AND CHARGE YIELDS BOTH WELL REPRODUCED





However! We could not simultaneously predict both...

Mumpower *et al.* PRC 101 054607 (2020)

UPDATES TO OUR MODEL (eFRLDM)

Higher resolution of Harmonic Oscillator basis

Improved treatment of the Strutinsky procedure

New Potential Energy Surfaces (PES) on a finer-grained, larger grid

New technique for obtaining fission yields in the limit of overdamped motion

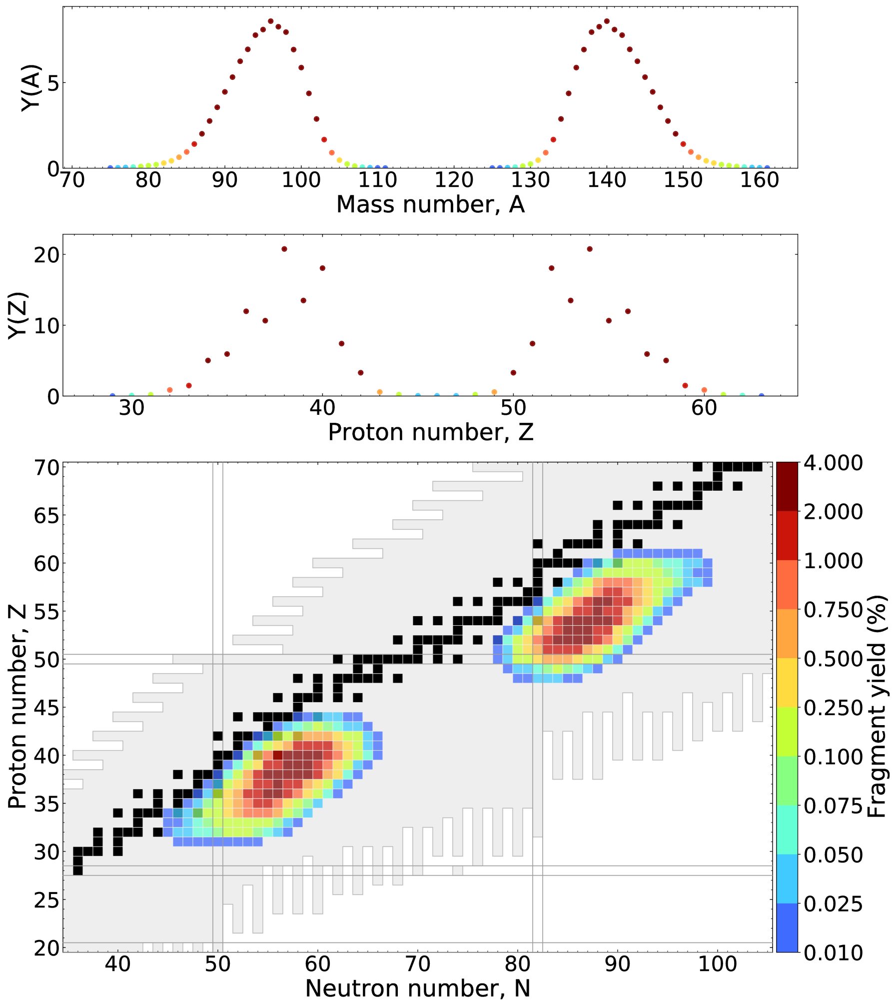
Consequences

M. Verriere: first theoretical prediction of odd-even staggering using a particle number projection technique

We also obtain the charge polarization of the nascent fragment distributions in agreement with experiment

Verriere *et al.* PRC 100 024612 (2019) • Verriere & **Mumpower** PRC 103 034617 (2020)

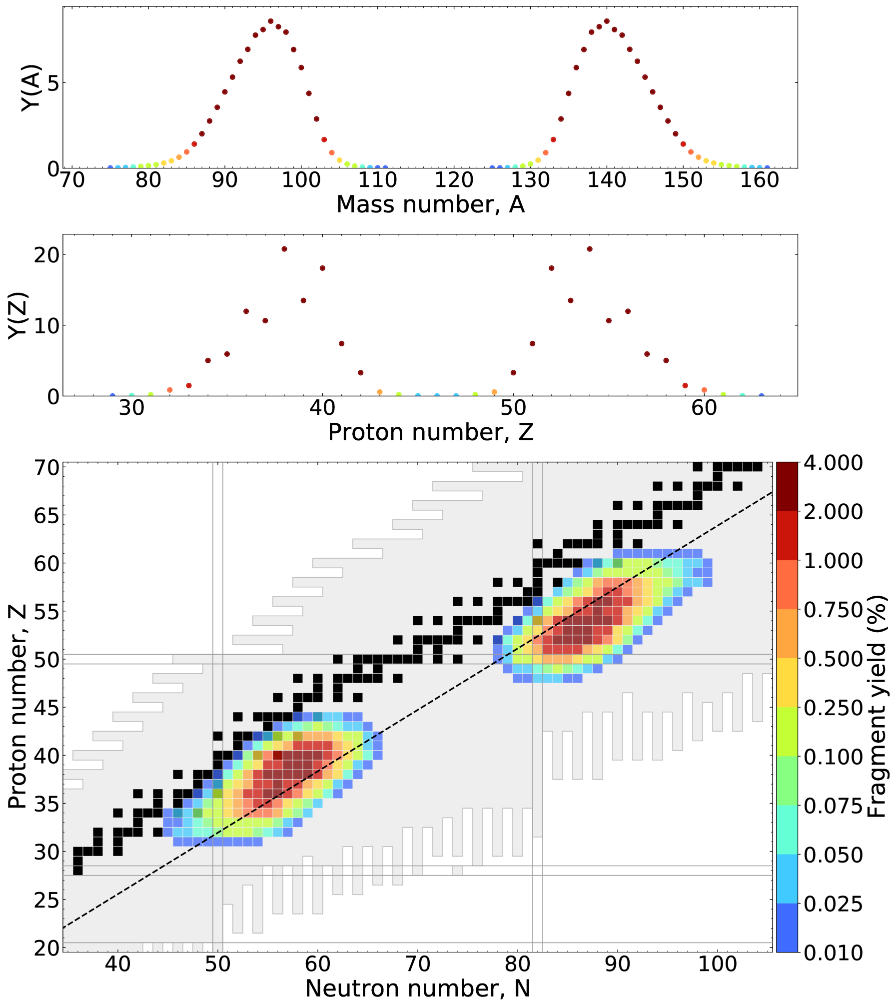
eFRLDM RESULTS: $^{235}U + n_{therm}$



We can now describe Y(A), Y(Z) and Y(Z,A) simultaneously

Verriere *et al.* PRC 100 024612 (2019) • Verriere & **Mumpower** PRC 103 034617 (2020)

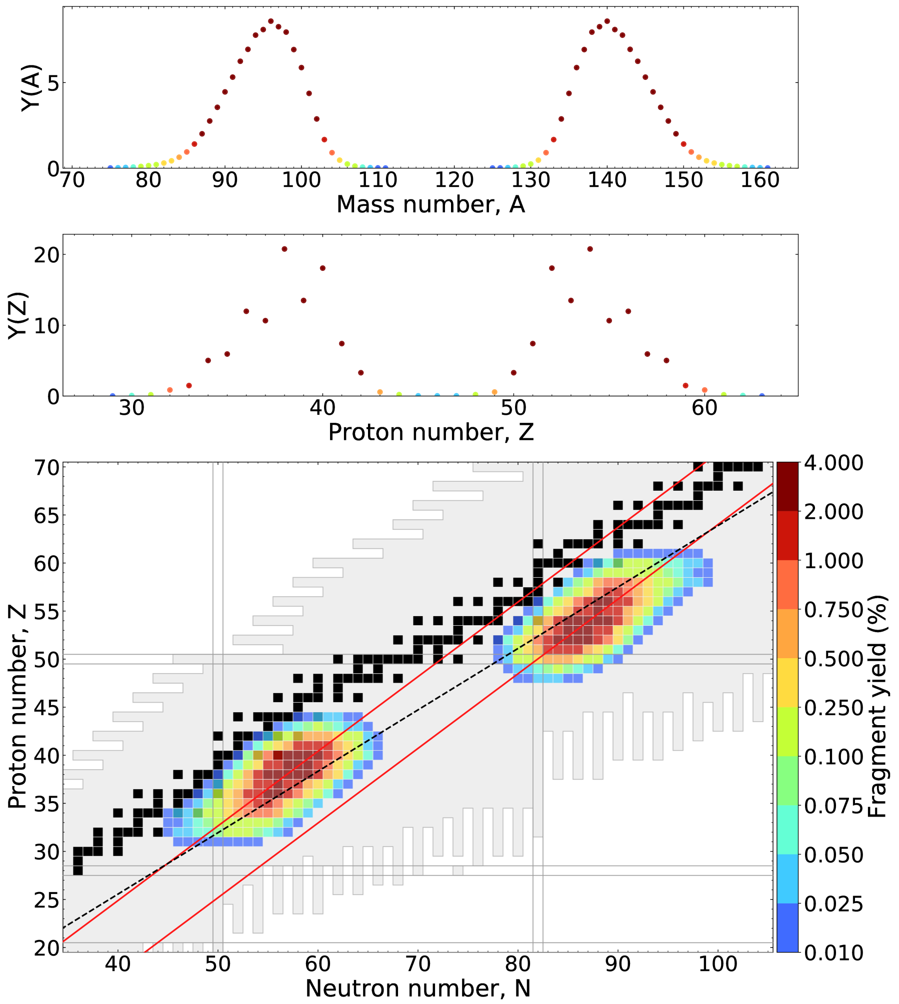
eFRLDM RESULTS: $^{235}U + n_{therm}$



Fragment yields no longer follow unchanged charge distribution (UCD) assumption (Blacked dashed line)

Verriere *et al.* PRC 100 024612 (2019) • Verriere & **Mumpower** PRC 103 034617 (2020)

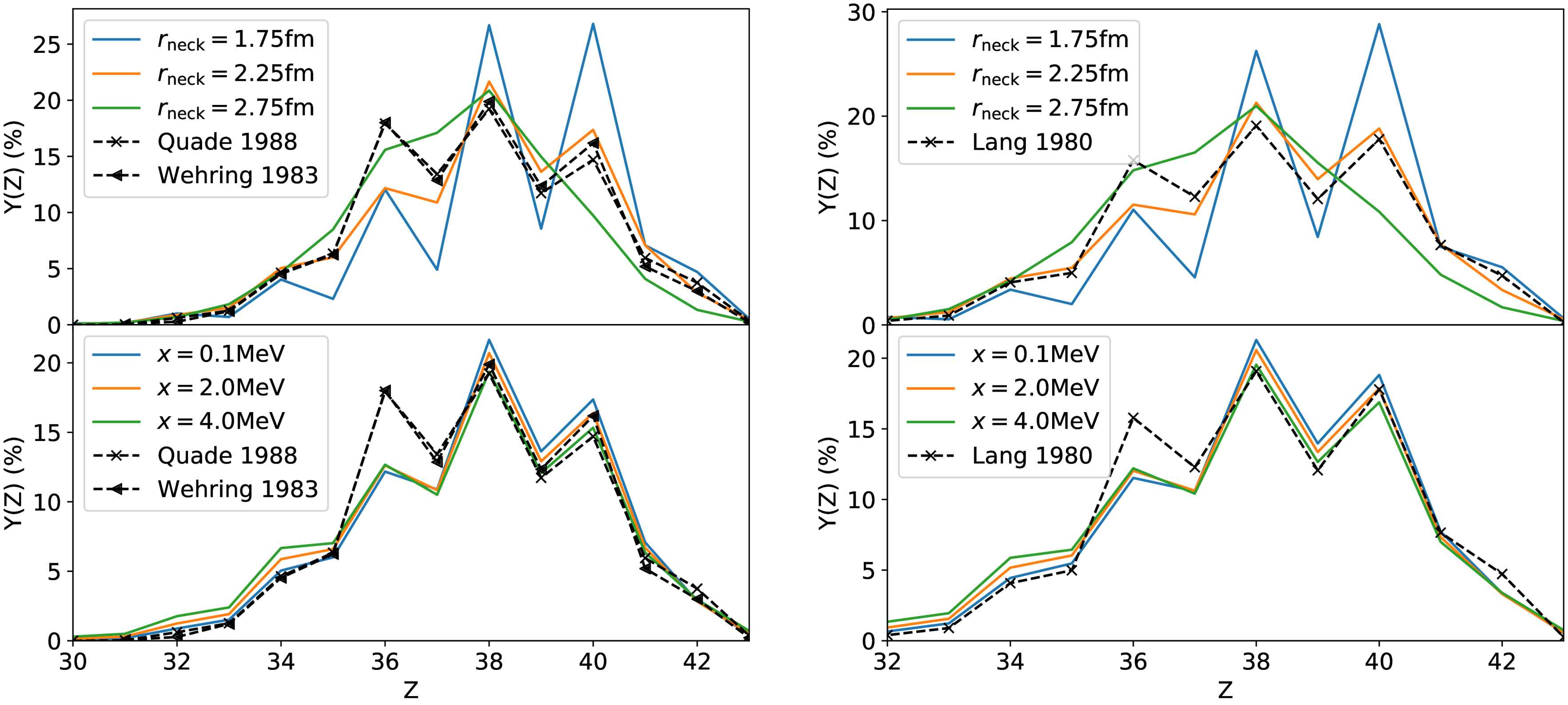
eFRLDM RESULTS: $^{235}U + n_{therm}$



Charge polarization offset predicted and in agreement with experimental measurements (red lines)

Verriere *et al.* PRC 100 024612 (2019) • Verriere & **Mumpower** PRC 103 034617 (2020)

ODD-EVEN STAGGERING IN CHARGE YIELDS



For the reactions (^{233}U + n_{therm}) [left] and (^{235}U + n_{therm}) [right]

First theoretical prediction of odd-even staggering using a particle number projection technique

Verriere *et al.* PRC 100 024612 (2019) • Verriere & **Mumpower** PRC 103 034617 (2020)

SPECIAL THANKS TO

My collaborators

P. Jaffke, T. Kawano, J. Randrup, N. Schunck, T. Sprouse,
I. Stetcu & M. Verriere

■ Postdoc

SUMMARY

Many modern applications require a *deep understanding* of fission

We have enhanced the FRLDM model to describe:

simultaneous fragment yields ▴ charge polarization ▴ odd-even staggering in charge yields

FRIB, etc. will help to constrain nuclear models, but the heaviest elements will remain relatively inaccessible

We therefore need to keep developing and studying theoretical models of nuclear physics, especially fission

Future upgrades to this type of fission modeling are in the works!

Results / Data / Papers @ MatthewMumpower.com