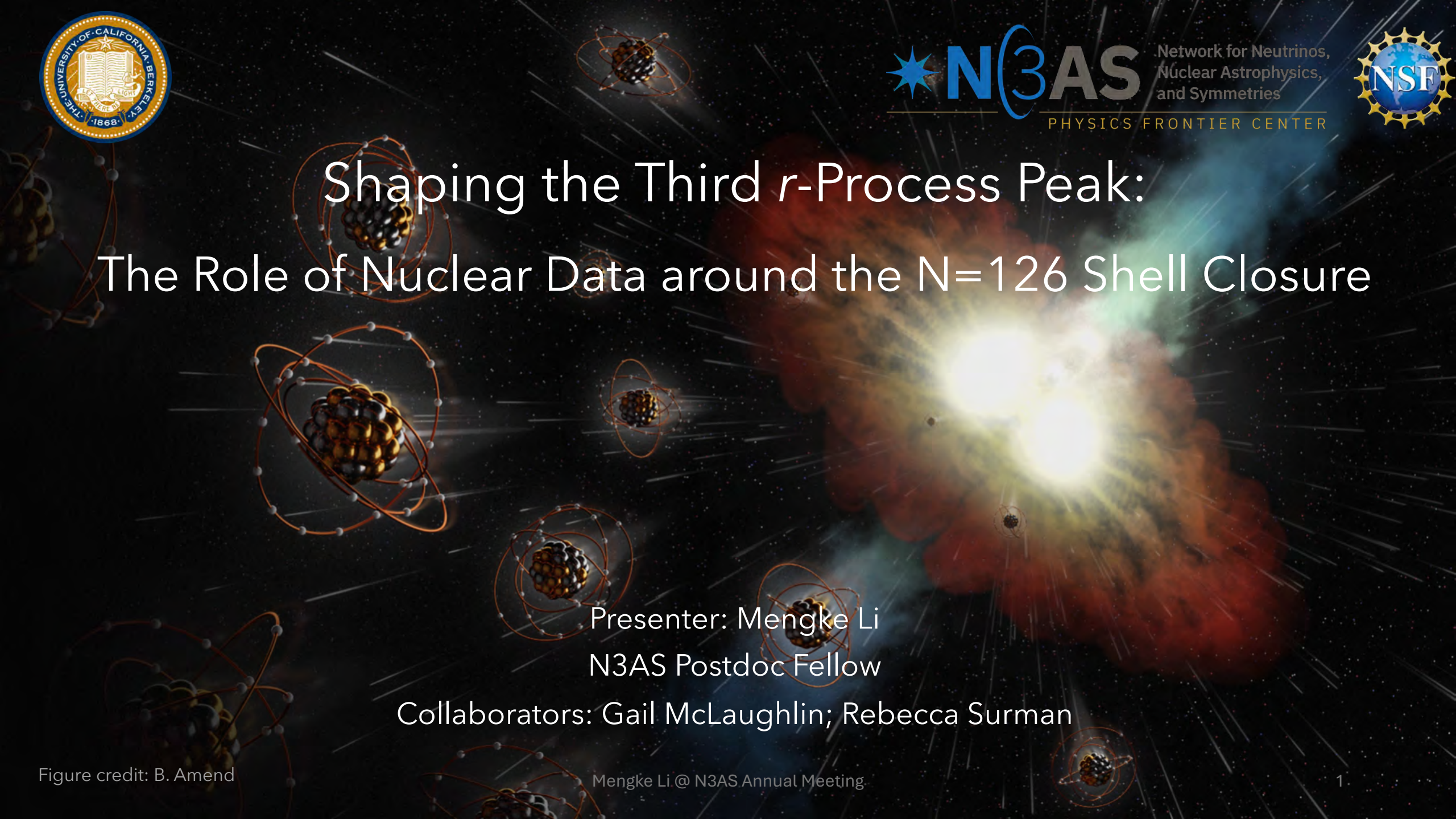


Shaping the Third *r*-Process Peak:

The Role of Nuclear Data around the N=126 Shell Closure

Presenter: Mengke Li

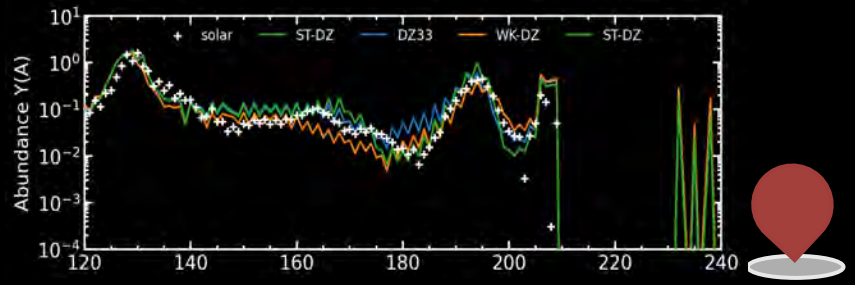
N3AS Postdoc Fellow

Collaborators: Gail McLaughlin; Rebecca Surman

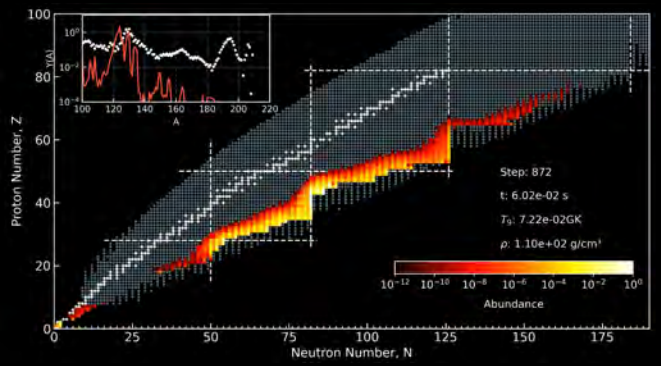
Figure credit: B. Amend

Road Map

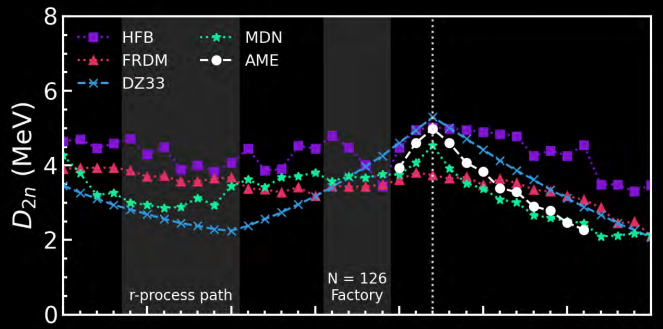
Impact on r-Process



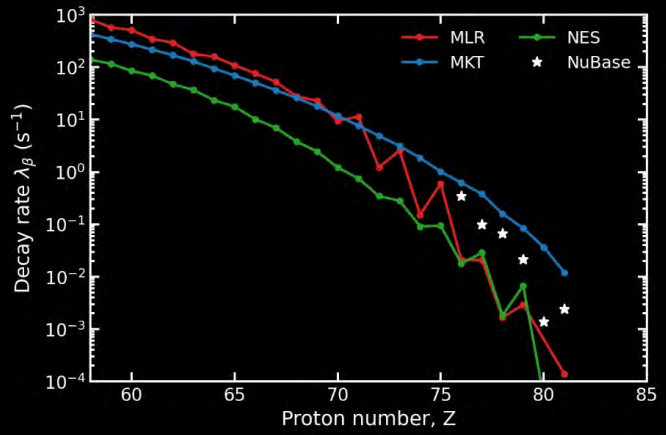
r-Process



N = 126 Closed Shell



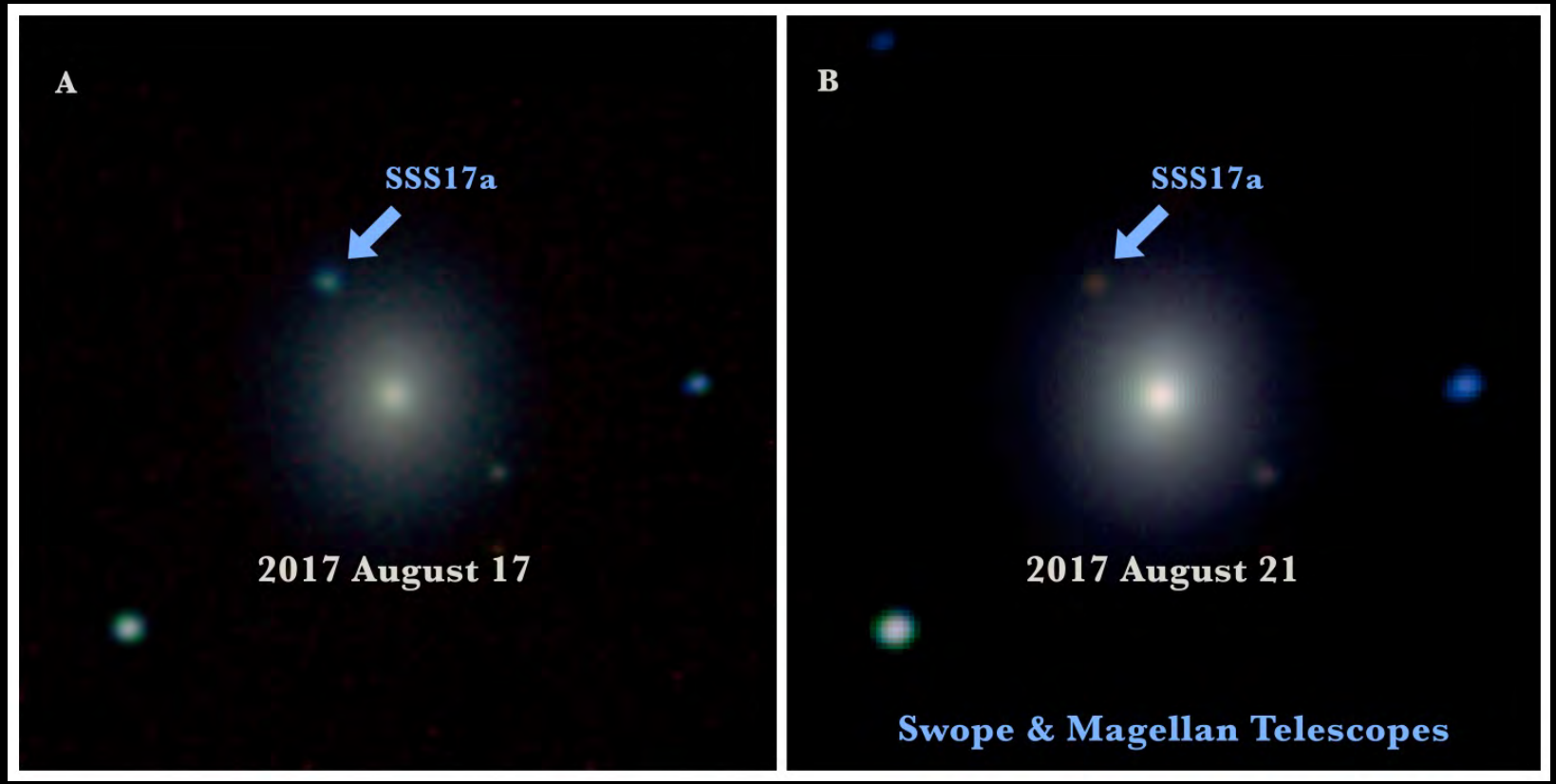
Role of Decay Rates



r-Process Sites

0.5 days after the merger

4.5 days after the merger



Pseudo-color images of SSS17a in the galaxy NGC 4993.

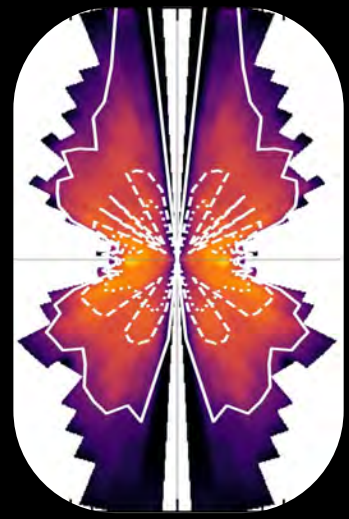
Drout et at. 2017

r-Process Sites

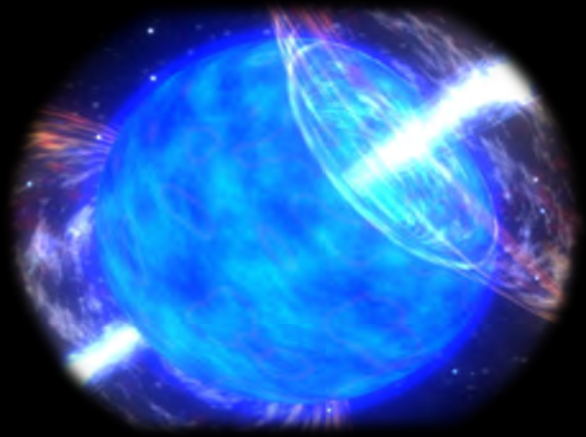
Neutron Star Merger
Drout et at. 2017

Magnetorotational Hypernova
D. Yong+2021

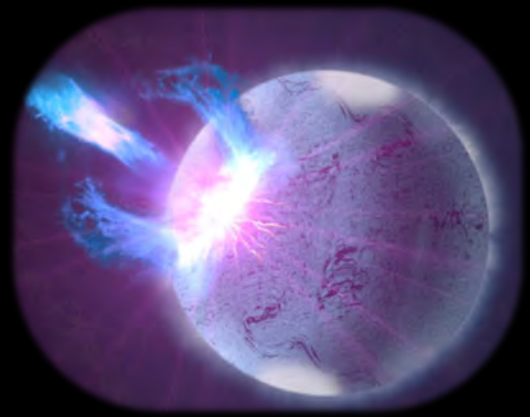
Accretion Induced Collapse
T. Pitik+ 2026



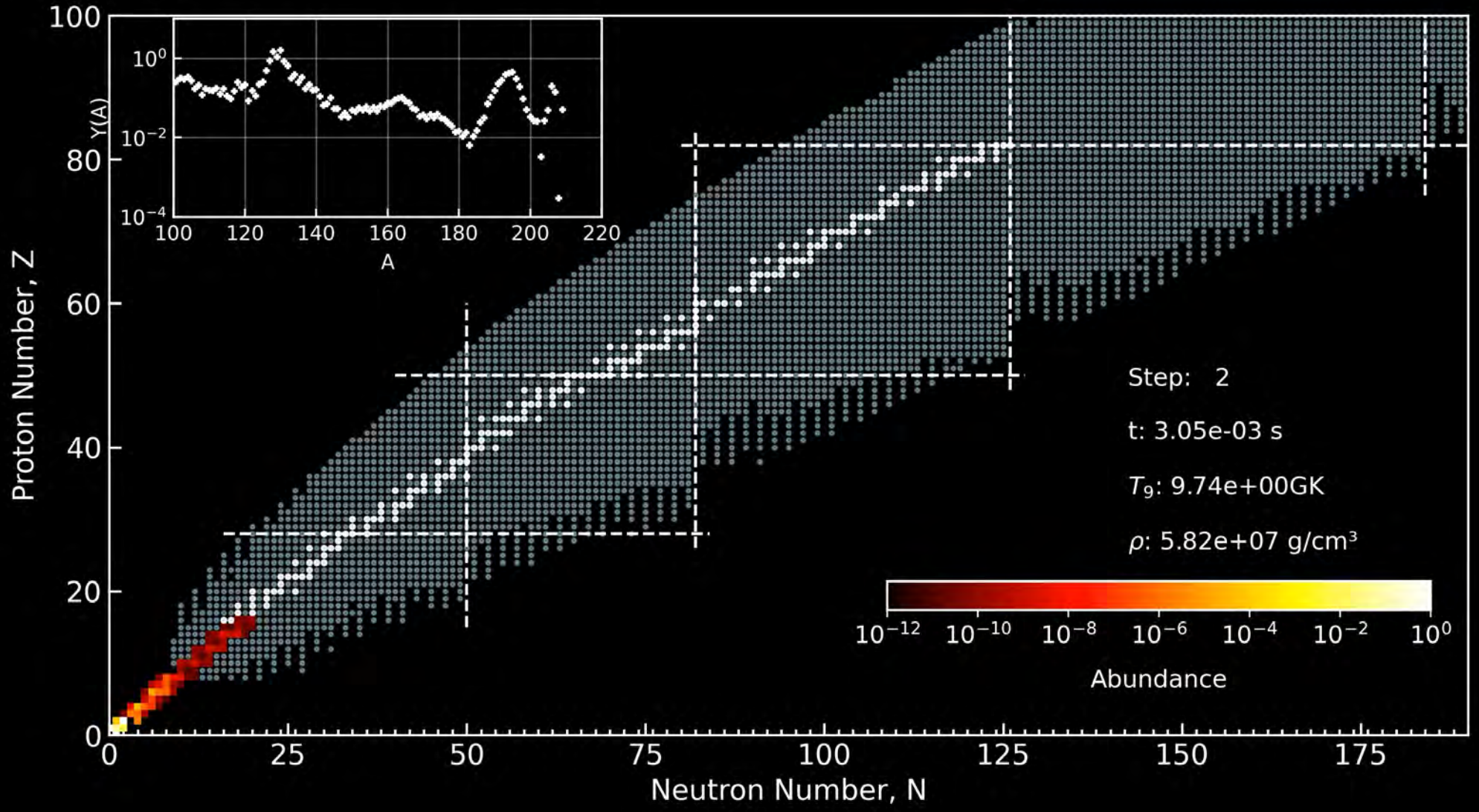
Collapsar
D. Siegel+2019



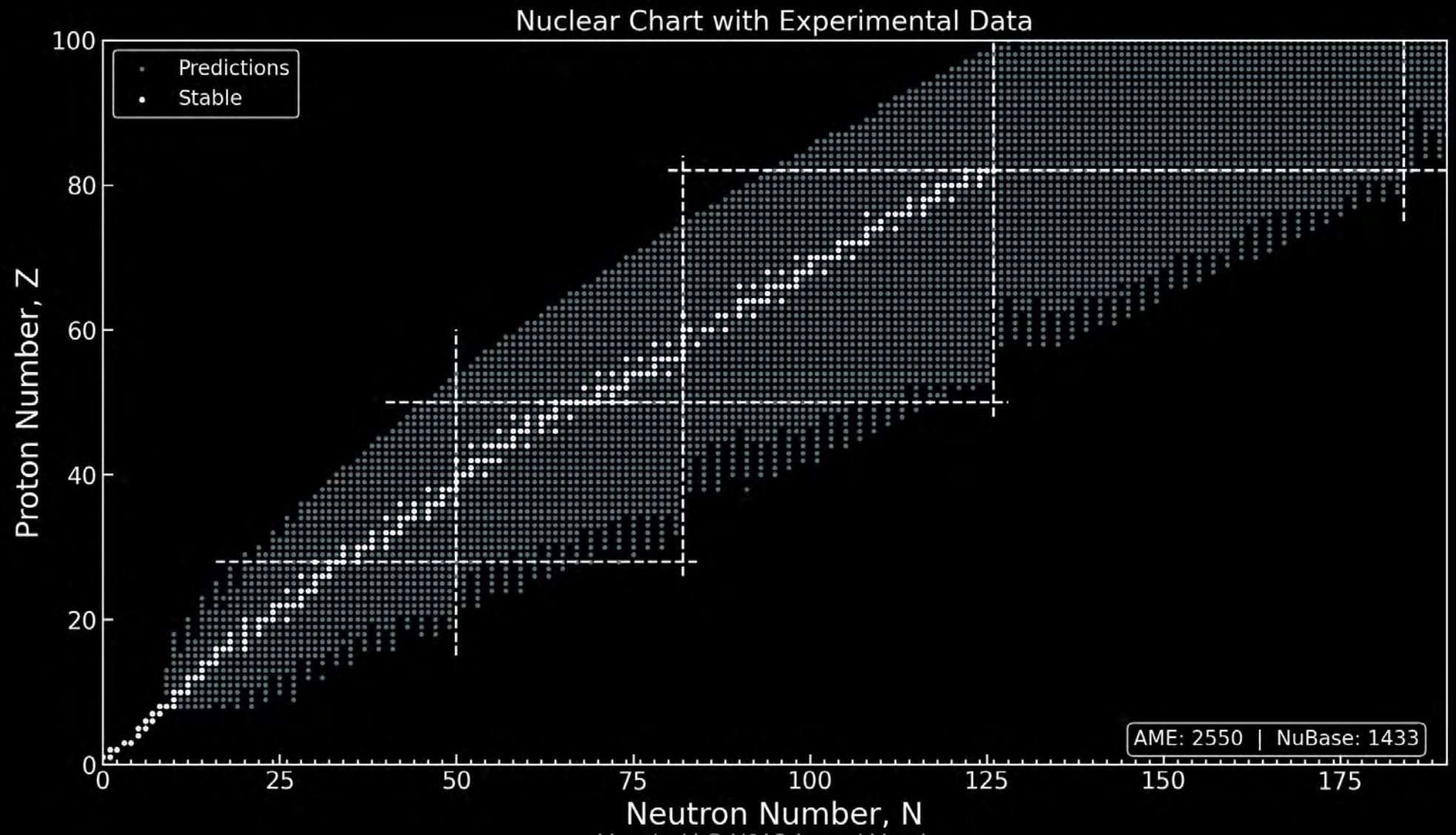
Magnetar Flares
A. Patel+ 2025



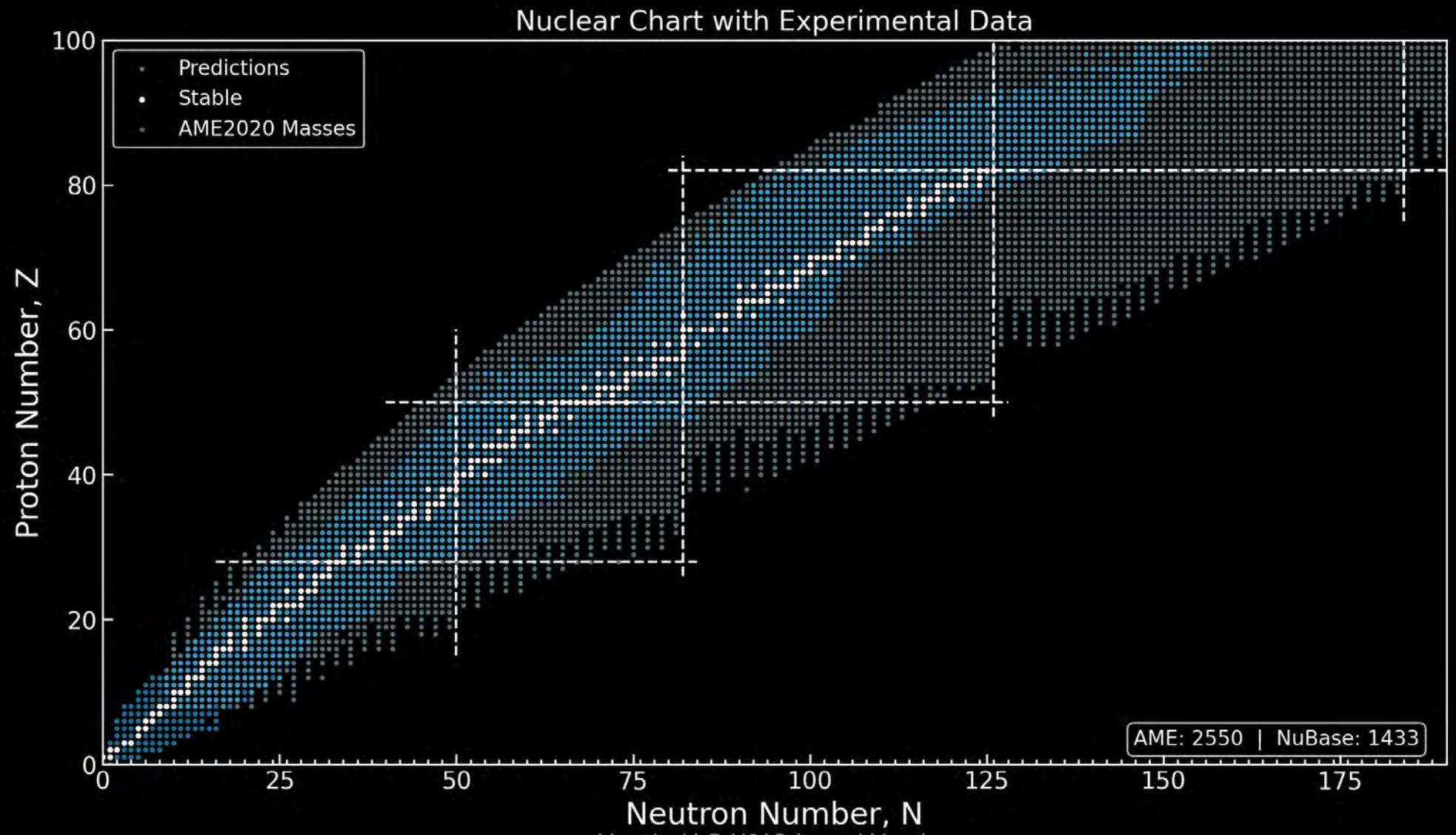
r-Process Simulations



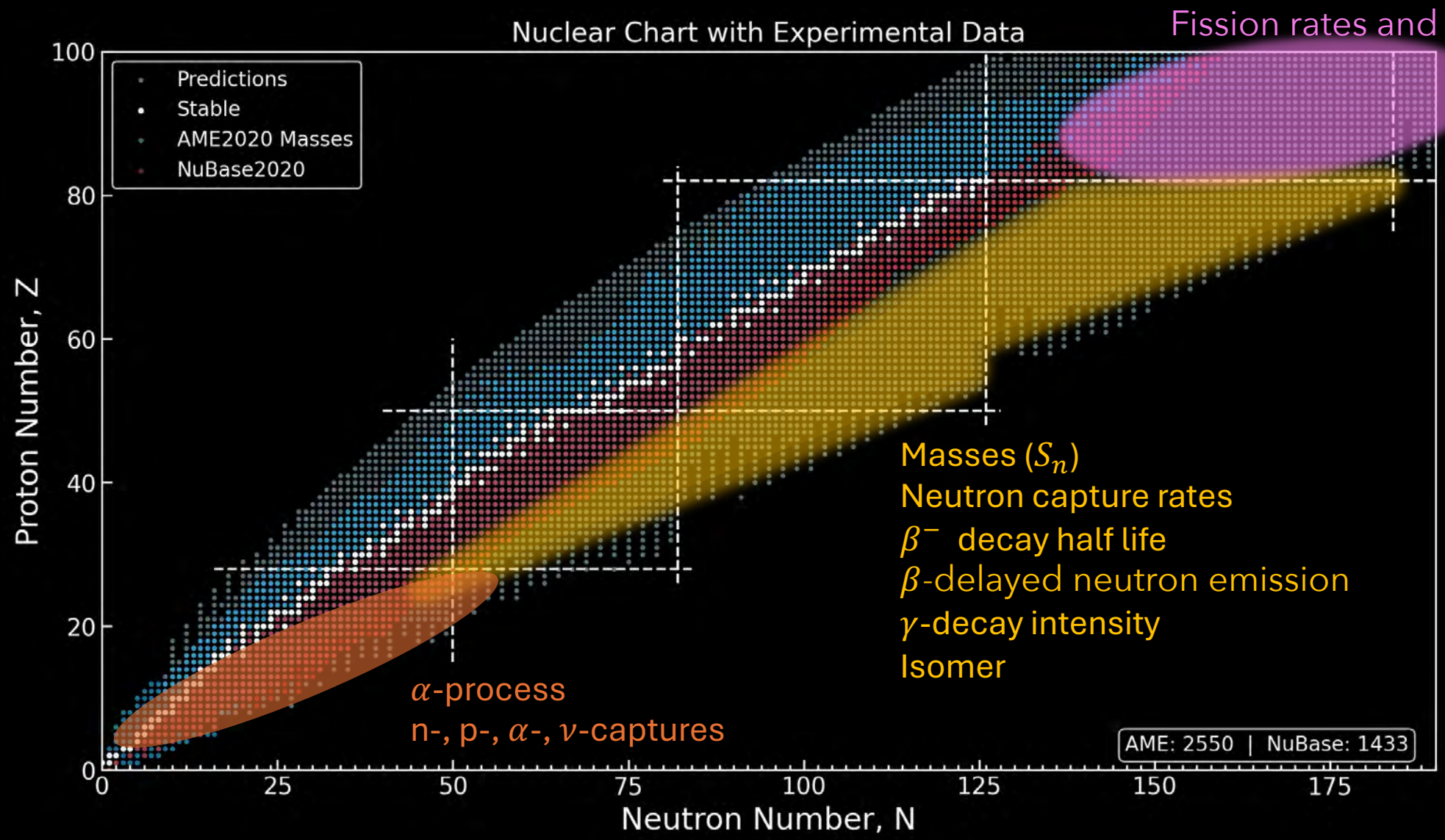
r-Process Simulations – available data



r-Process Simulations – available data



r-Process Simulations – nuclear data

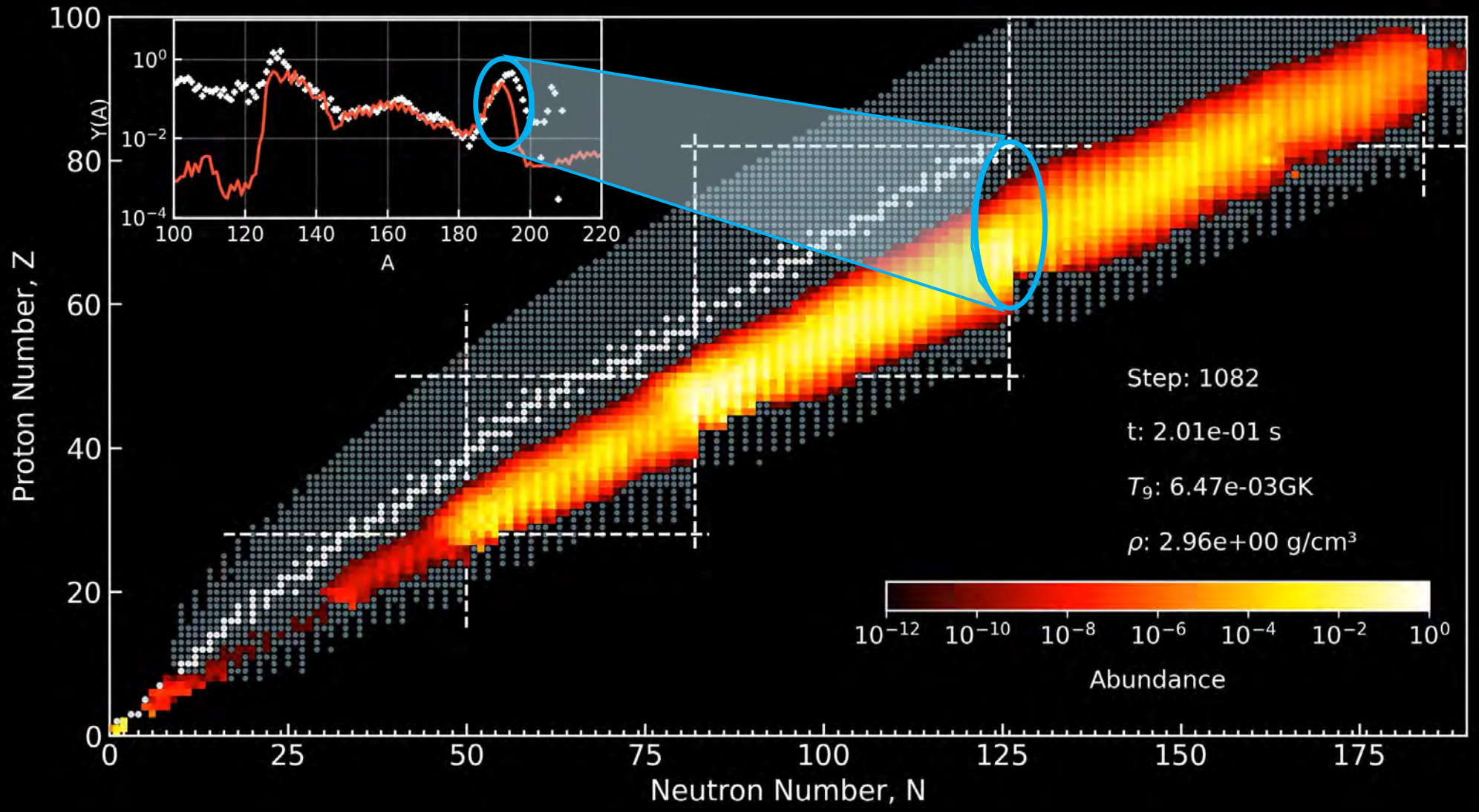


Fission rates and distributions:
n-induced
spontaneous
β-delayed

Masses (S_n)
Neutron capture rates
β^- decay half life
β-delayed neutron emission
γ-decay intensity
Isomer

α-process
n-, p-, α-, ν-captures

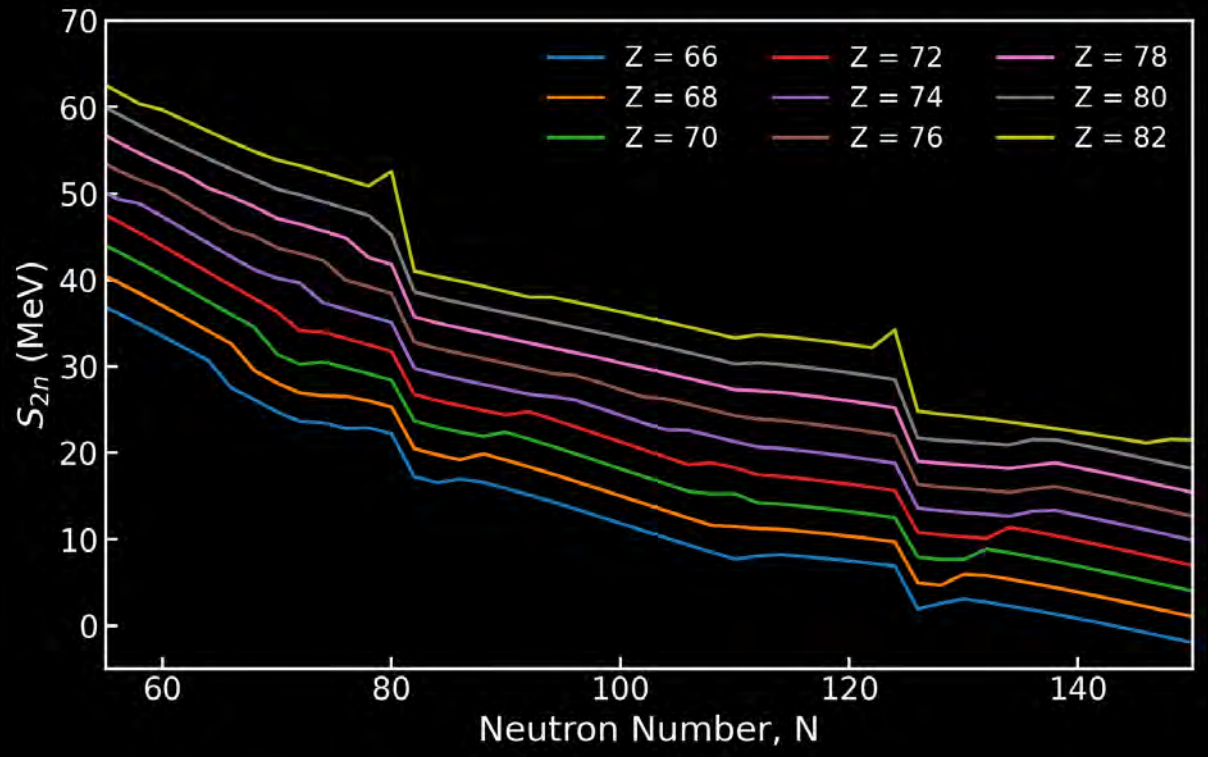
N =126 and the 3rd r-Process Peak



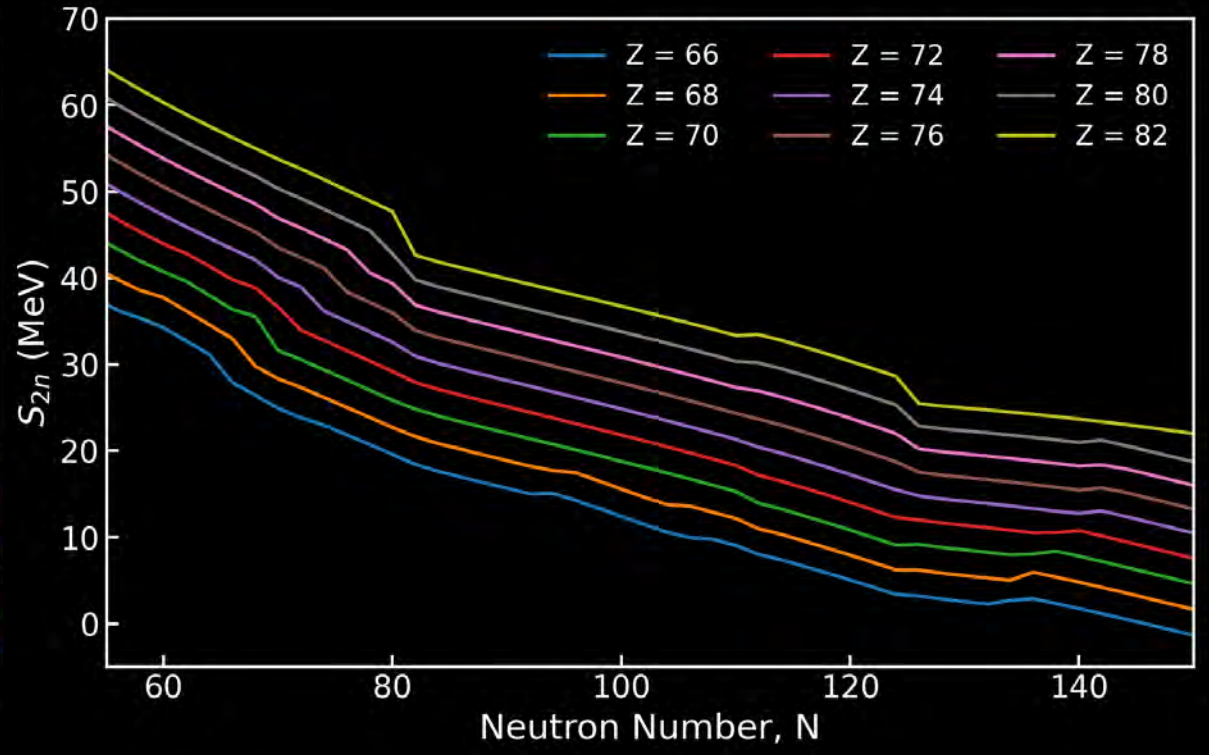
N = 126 Closed Shell Strength

Two Neutron separation energy: $S_{2n}(Z,A) = M(Z,N-2) + 2M_n - M(Z,N)$

Strong shell closure

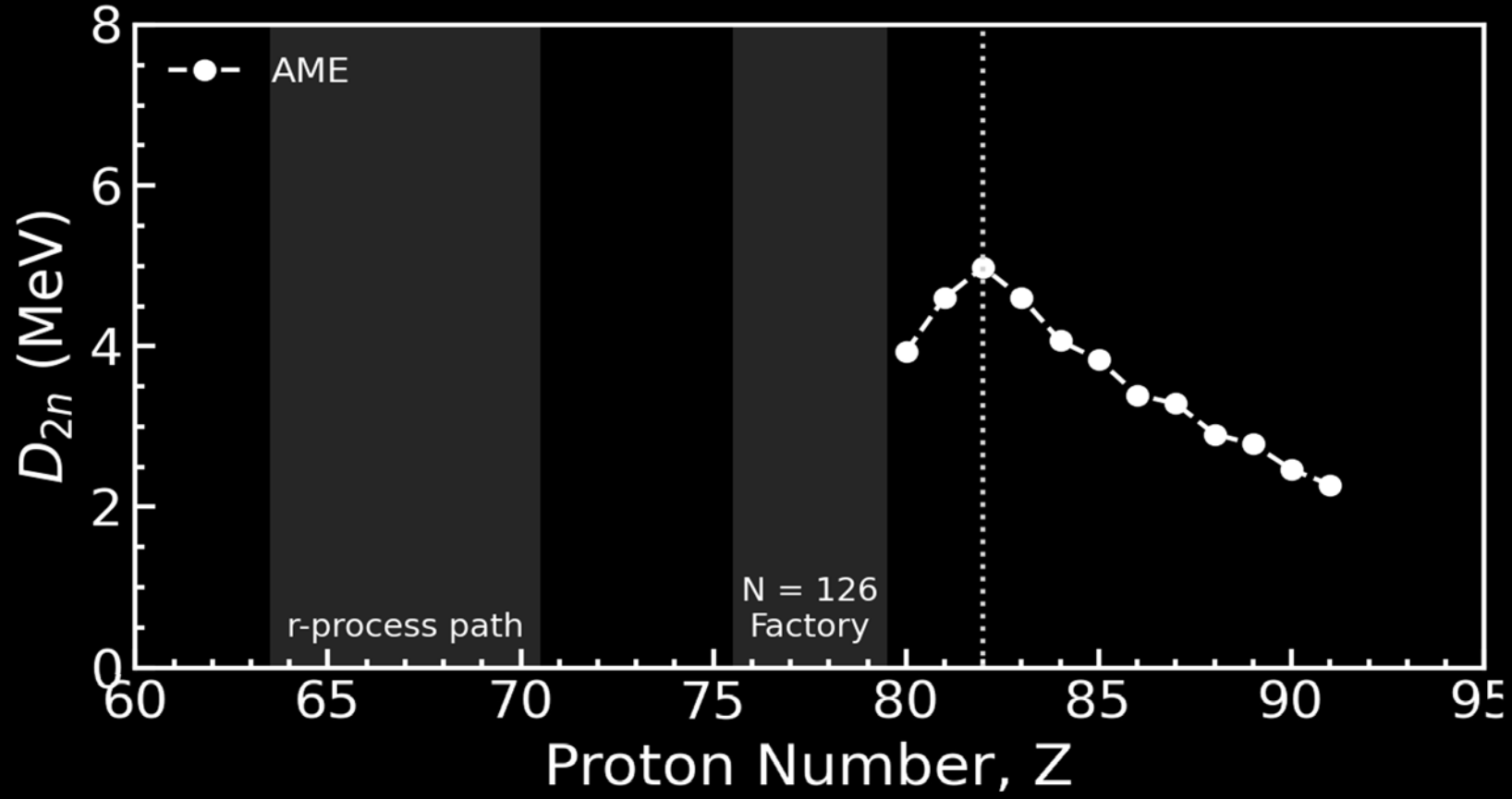


Weak shell closure



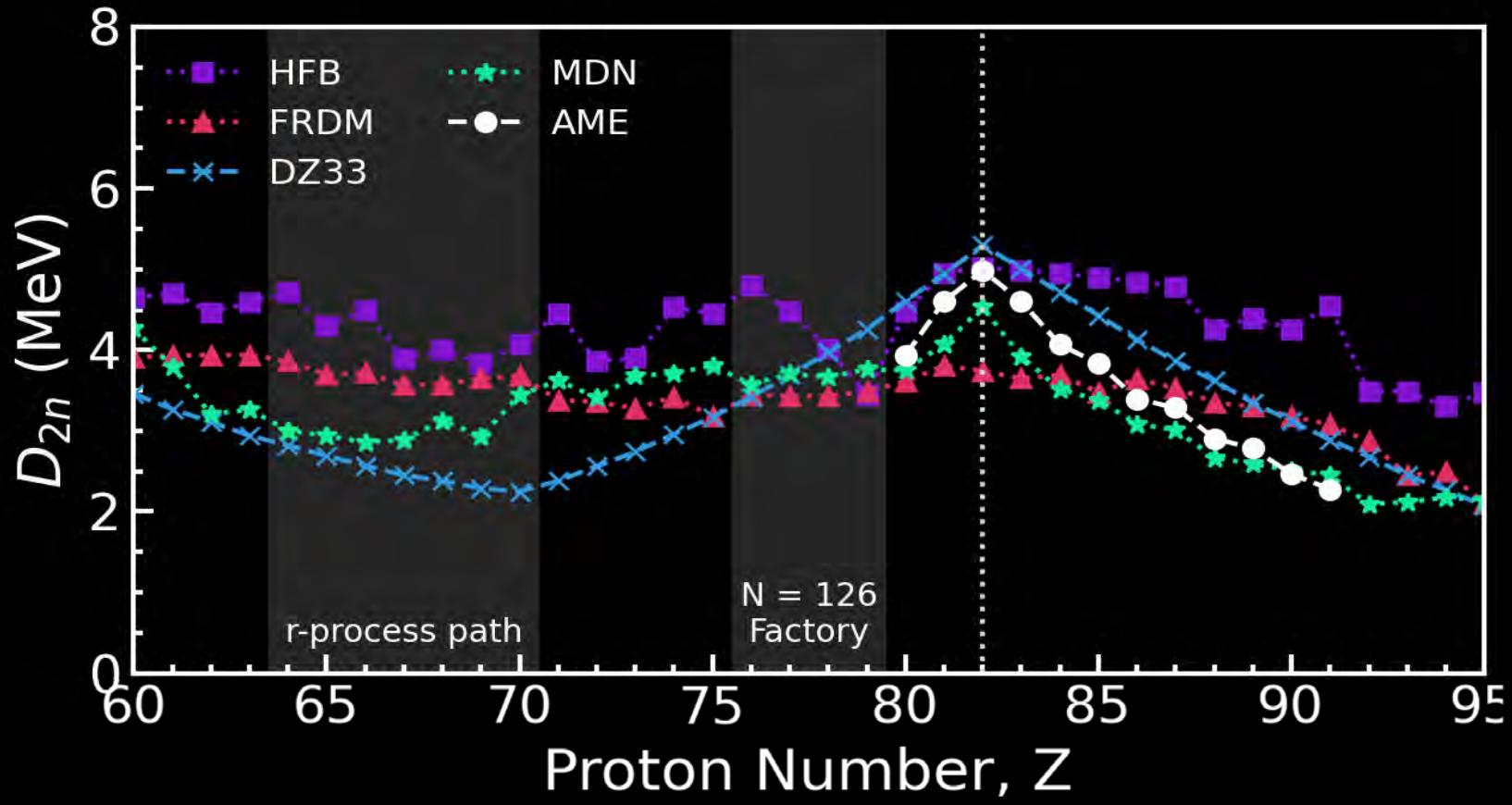
N = 126 Closed Shell Strength

$$D_{2n}(Z,N) = S_{2n}(Z,N) - S_{2n}(Z,N+2)$$



N = 126 Closed Shell Strength

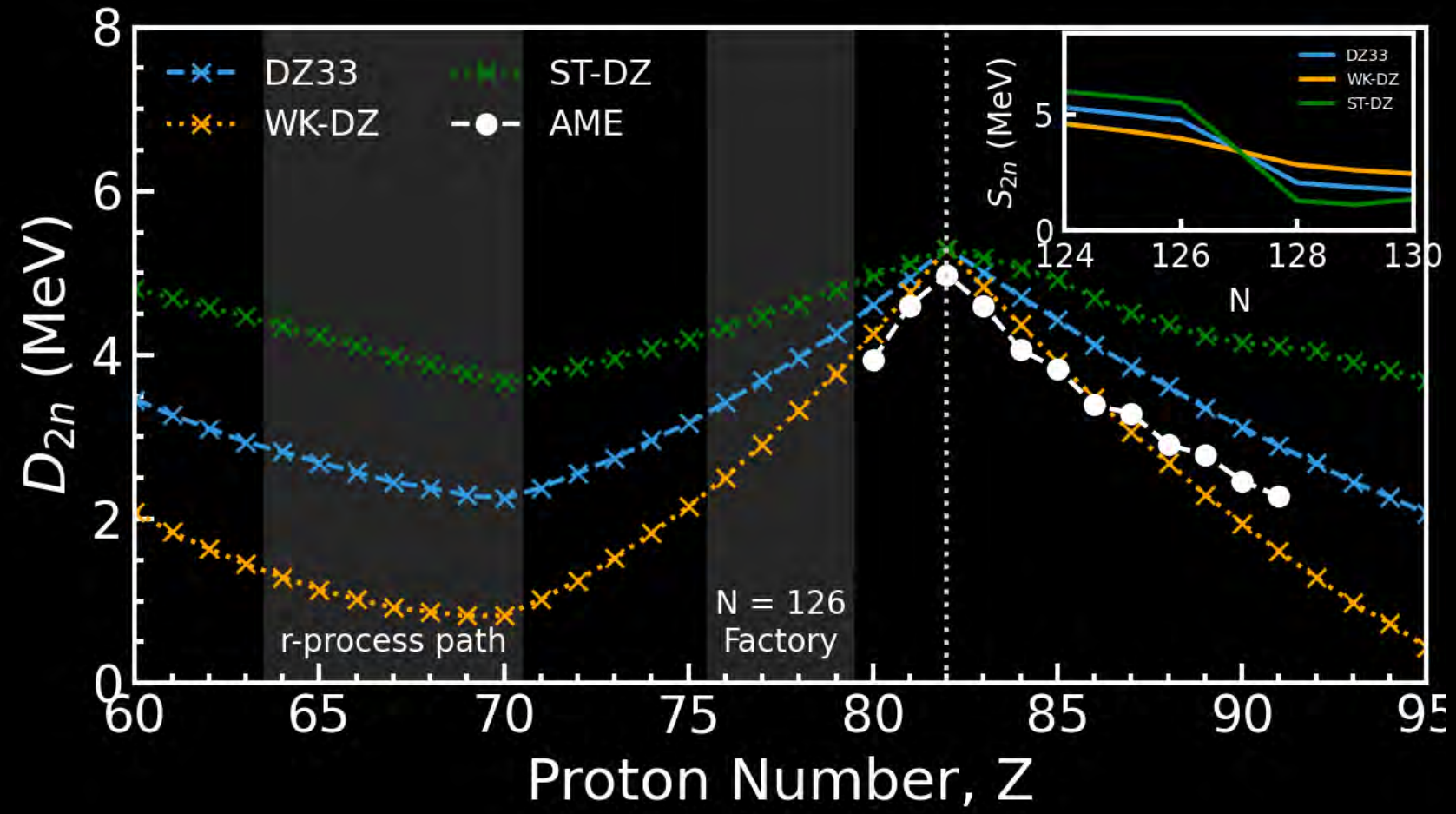
$$D_{2n}(Z,N) = S_{2n}(Z,N) - S_{2n}(Z,N+2)$$



Most global models miss the weakening trend seen in experiment.

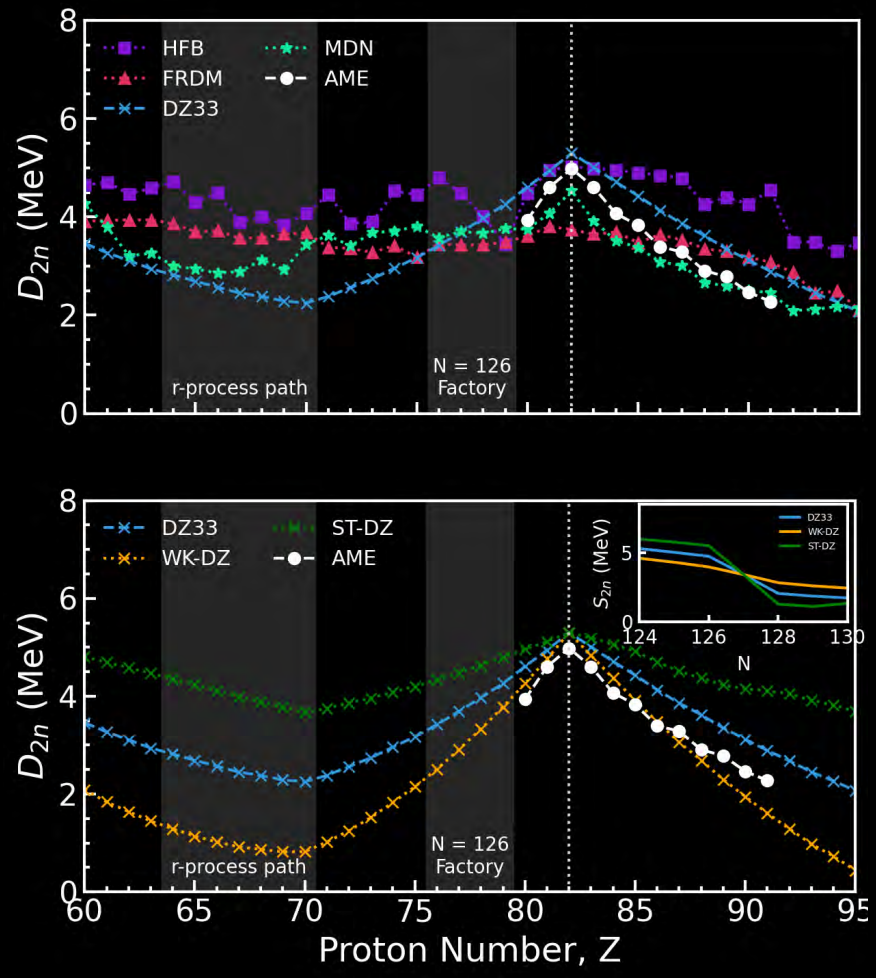
N = 126 Closed Shell Strength

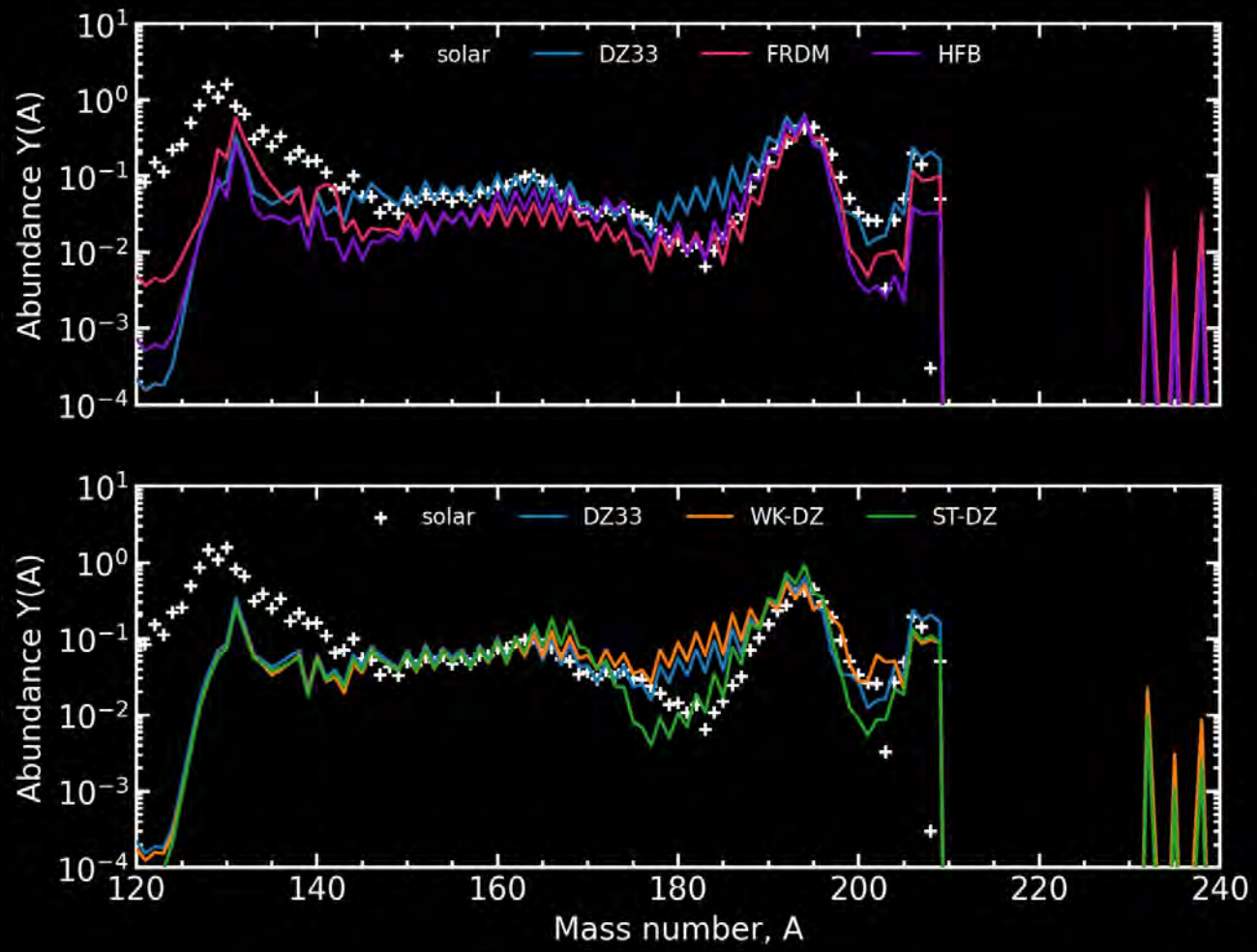
Modified DZ mass model to have either stronger or weaker closed shells



M Li, G McLaughlin, R Surman PLB, 2025

Simulated r-Process Abundance Pattern





M Li, G McLaughlin, R Surman PLB, 2025

The N = 126 Paradox

The Astrophysical constraint:

Observation:

Solar r-process pattern has a SHARP 3rd peak

Requirement:

Simulations need a STRONG shell to trap material.

VS

The Nuclear Physics constraint:

Observation:

AME measurements show a DECLINING trend.

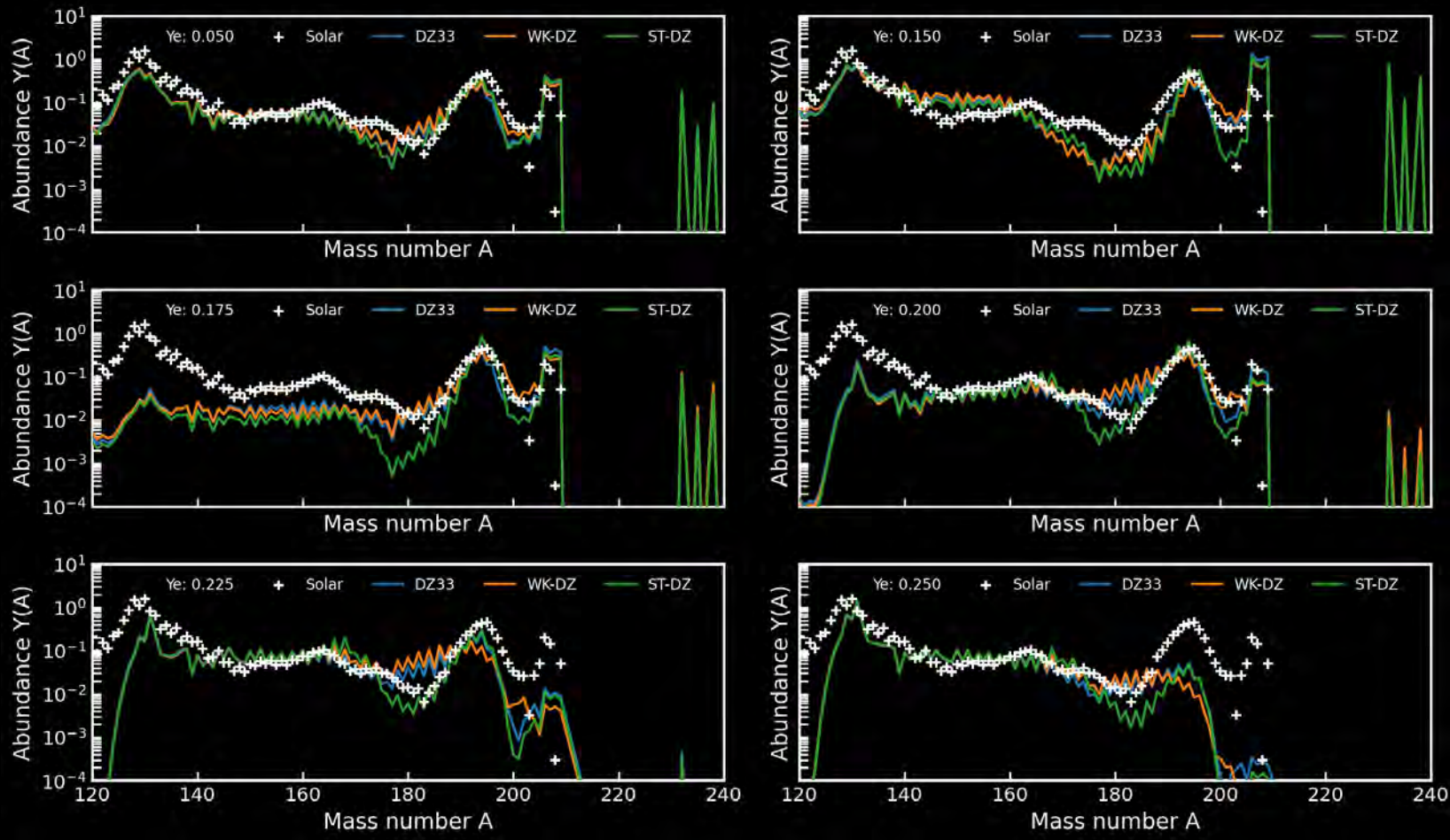
Implication:

The N=126 shell is WEAKENING. Will it continue?

Simulation Result: A Weak Shell → Flat Peak (Fails to match Solar).

How can we form a sharp peak if the shell is weak?

Simulating r-Process with Different Tracers

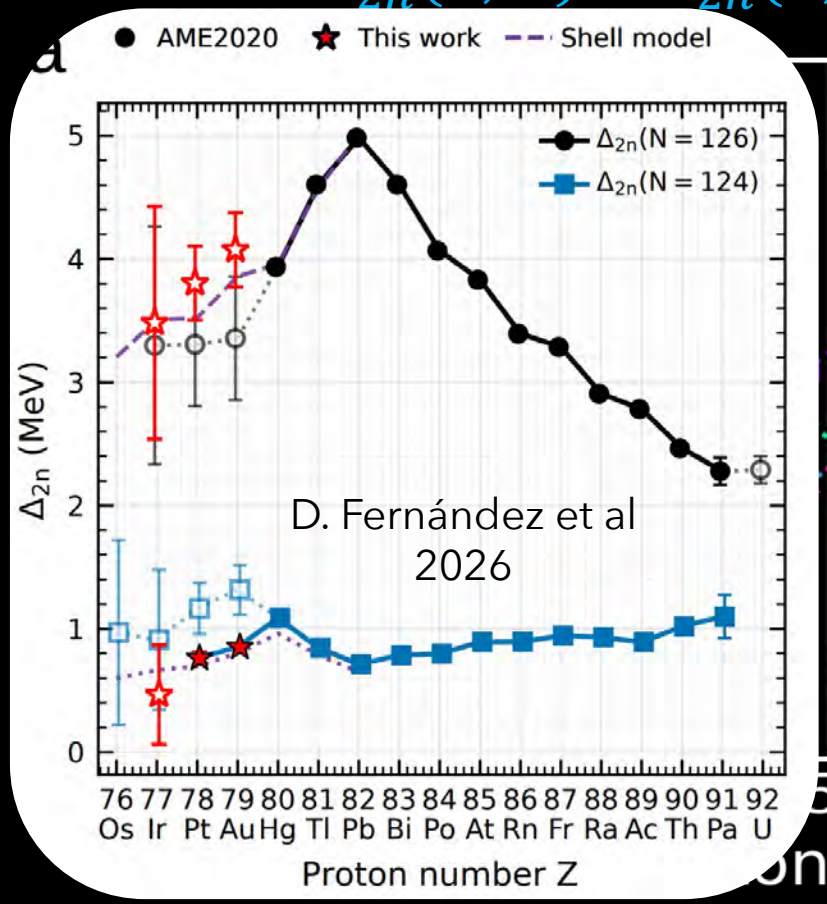


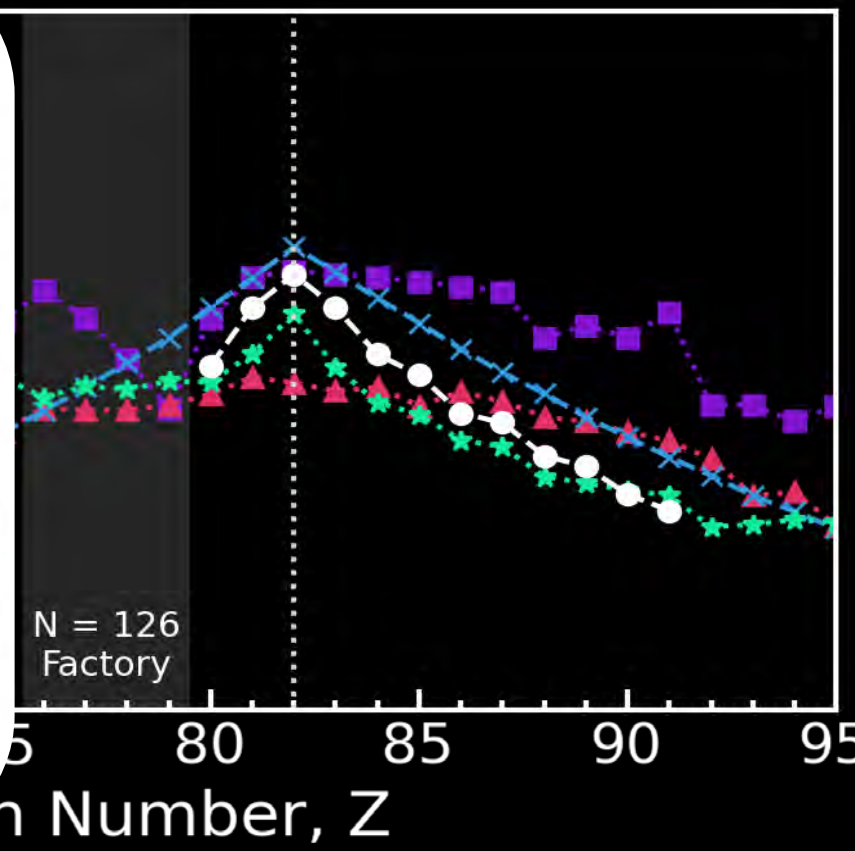
Low Ye conditions activate fission, providing extra neutrons to shift the peak to higher masses.

N = 126 Closed Shell (revisit)

$$D_{2n}(Z,N) = S_{2n}(Z,N) - S_{2n}(Z,N+2)$$

Waiting for more measurements:
FRIB
N = 126 Factory

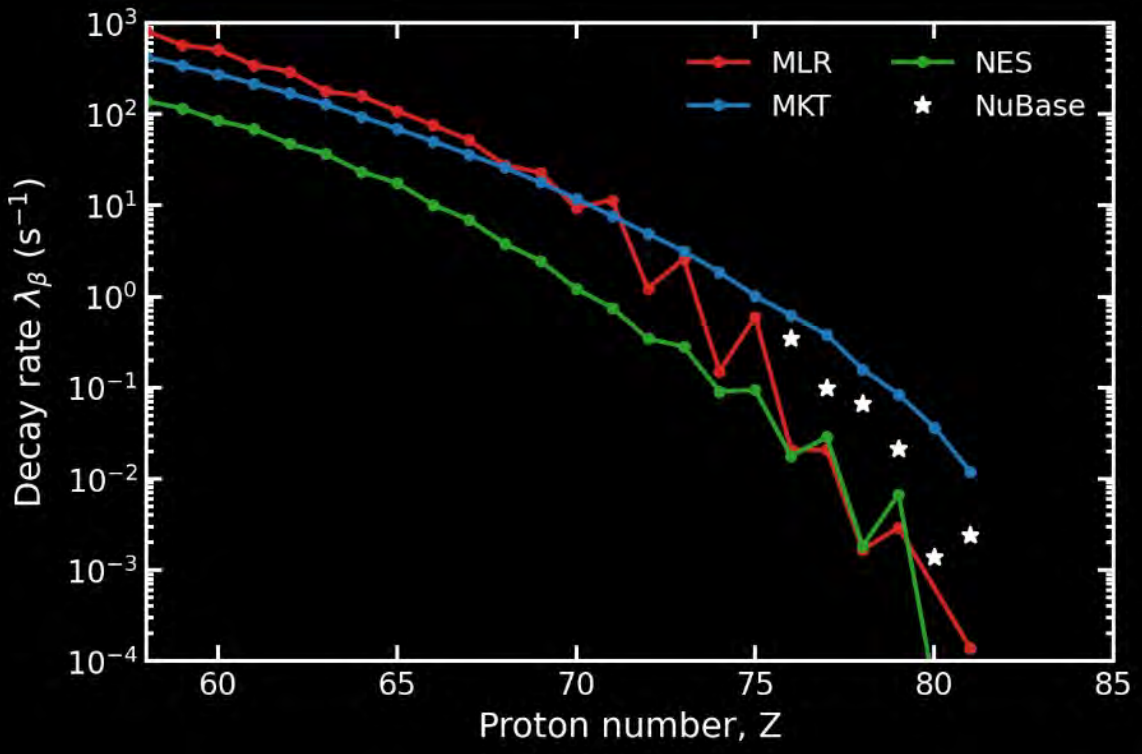




Most global models miss the weakening trend seen in experiment.

The Dependency on β^- Decay Rates

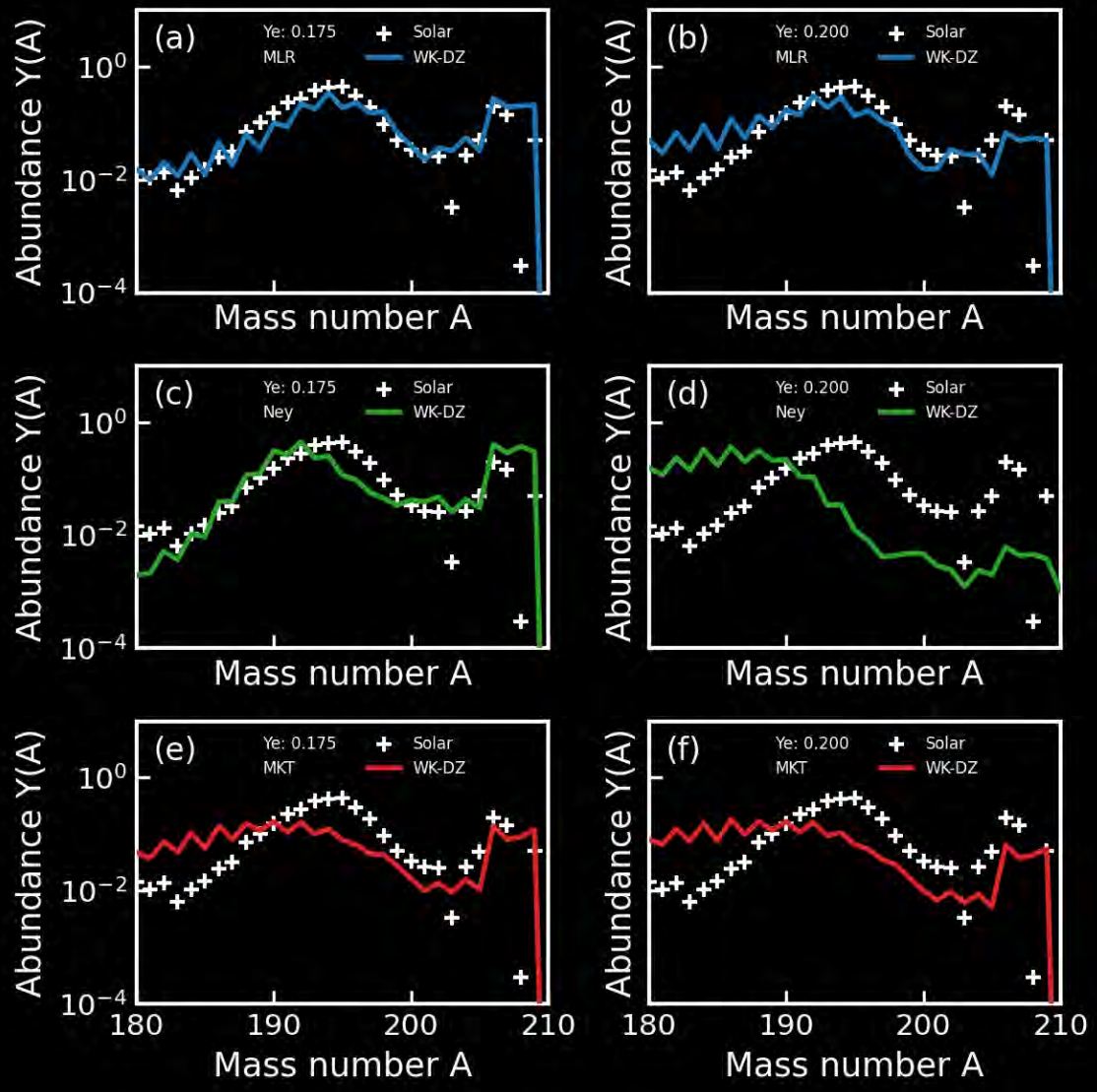
β^- Decay Rates along N = 126 closed shell



MLR

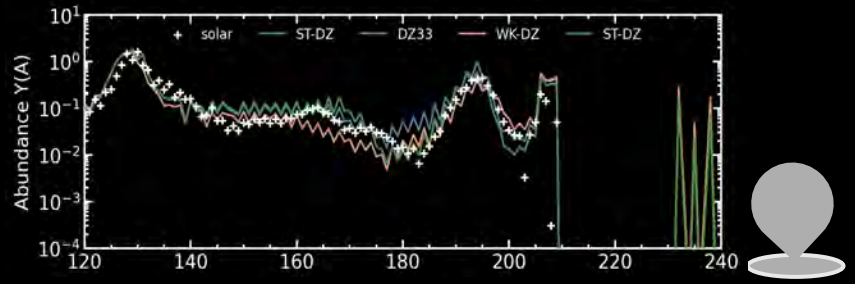
Ney

MKT

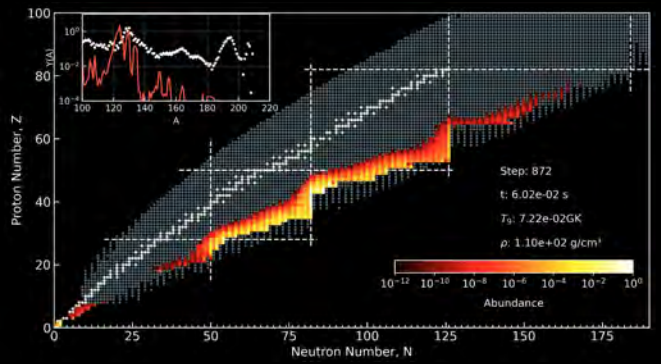


Road Map

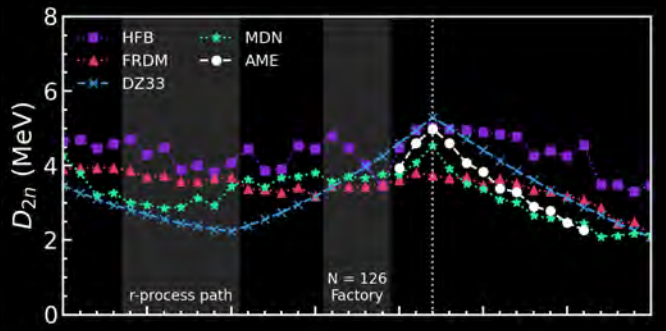
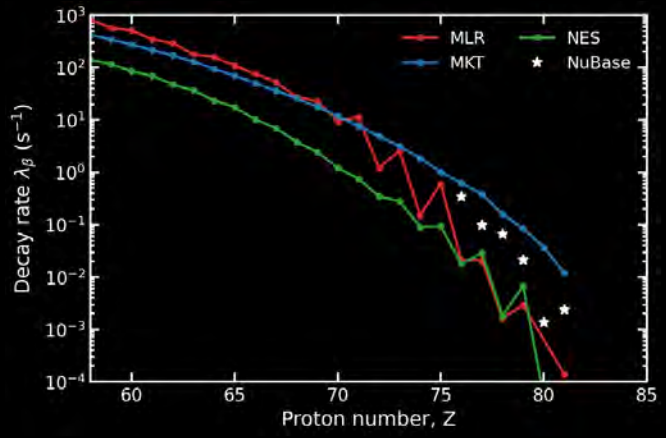
Impact on r-Process



r-Process



N = 126 Closed Shell



Role of Decay Rates