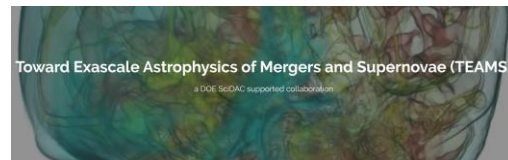


Following fission products in explosive astrophysical environments

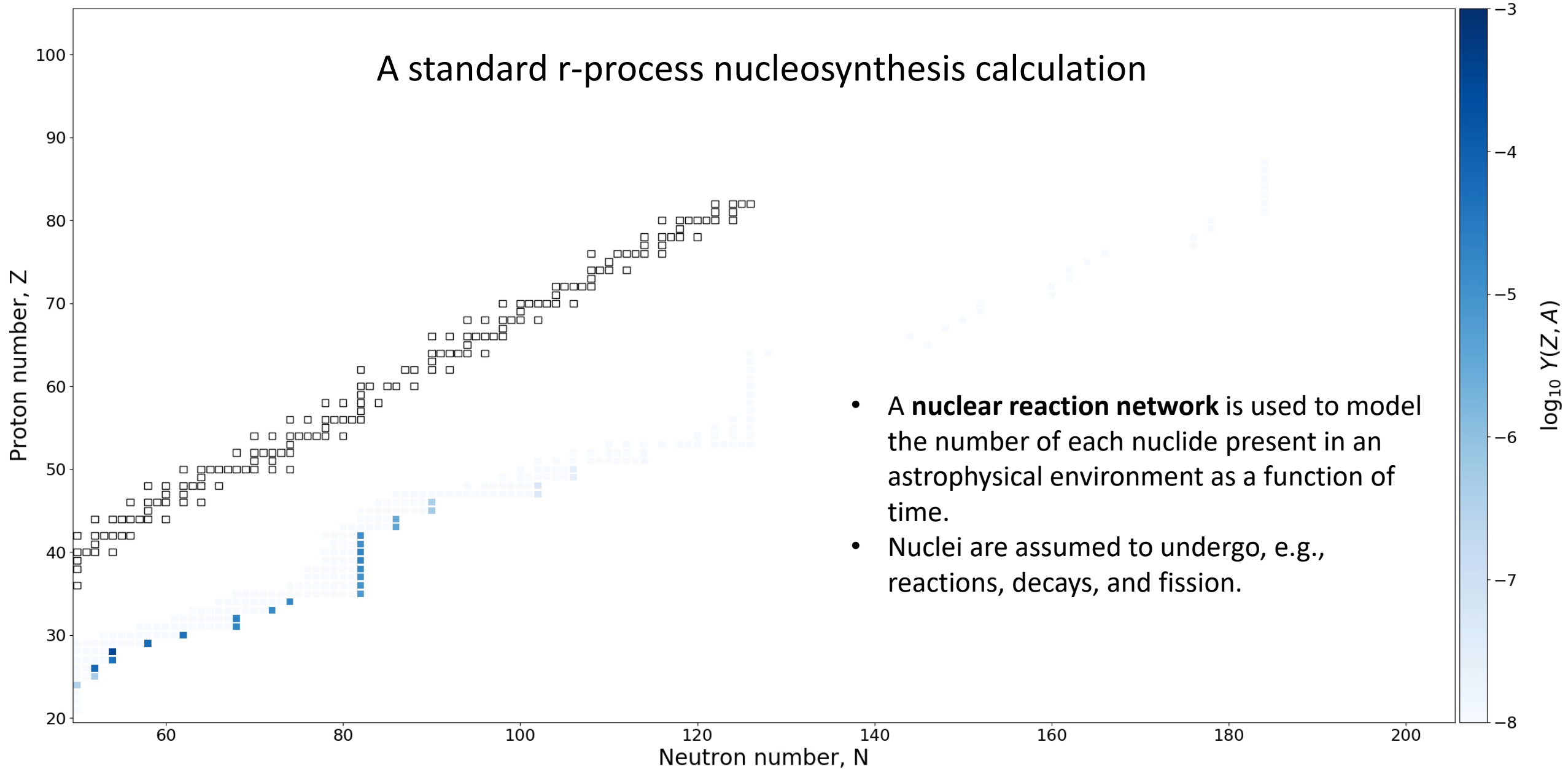
Trevor Sprouse · Matthew Mumpower · Rebecca Surman

FIRE Collaboration Meeting - 2020

1 July 2020

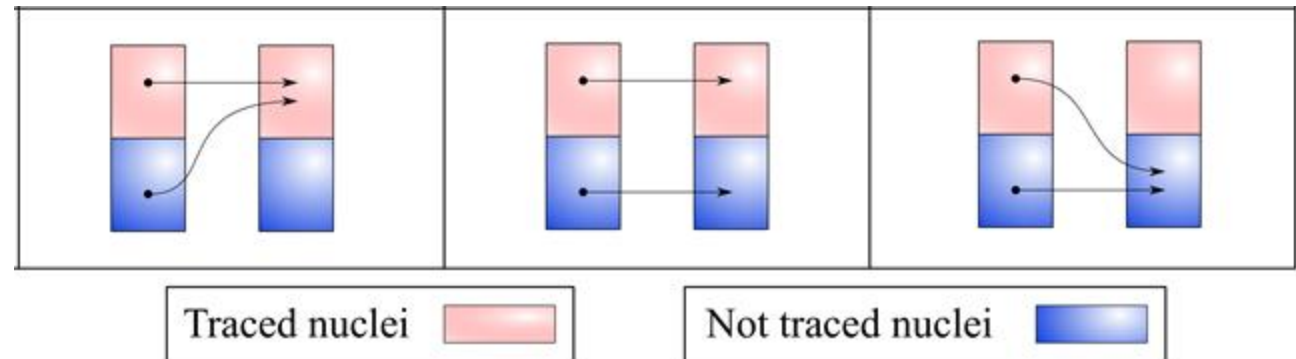


A standard r-process nucleosynthesis calculation

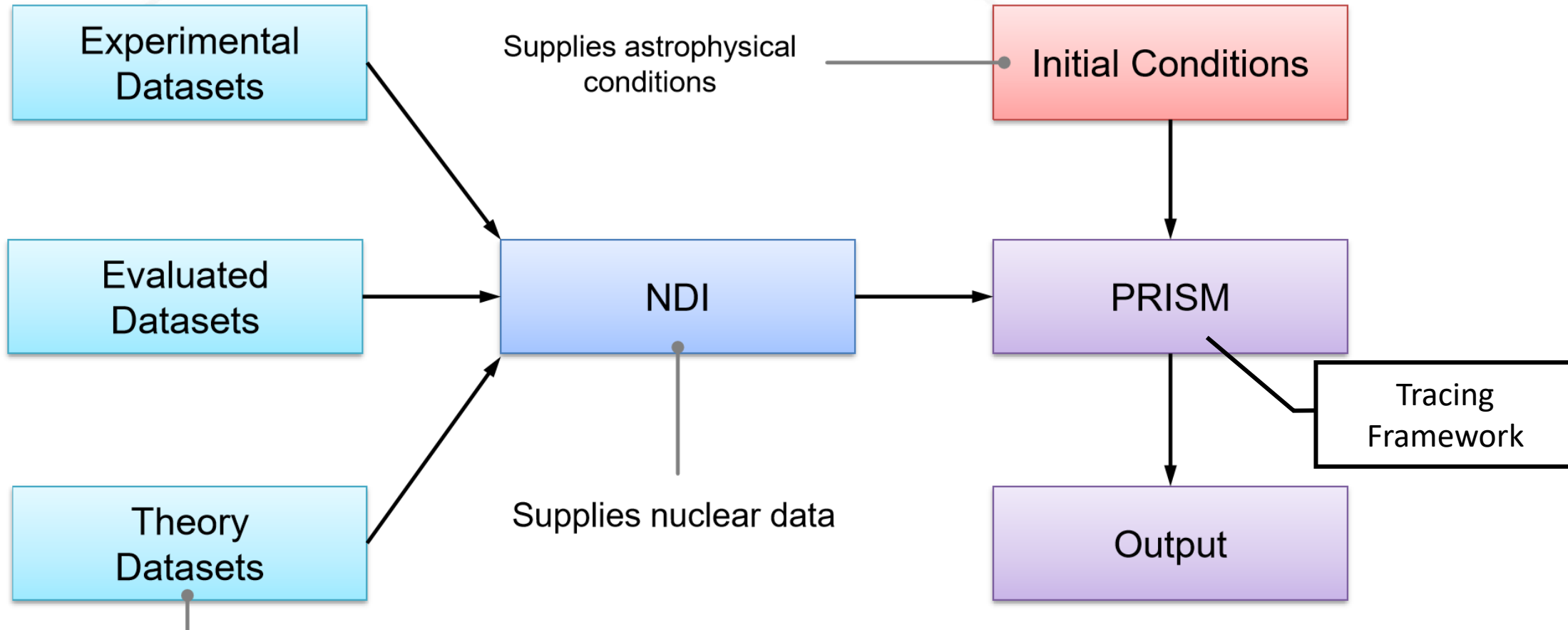


- ***Every nucleus following an r process has a complex and unique history involving many reactions, decays, and fission events.***
- Traditional nuclear reaction networks fail to capture these histories.

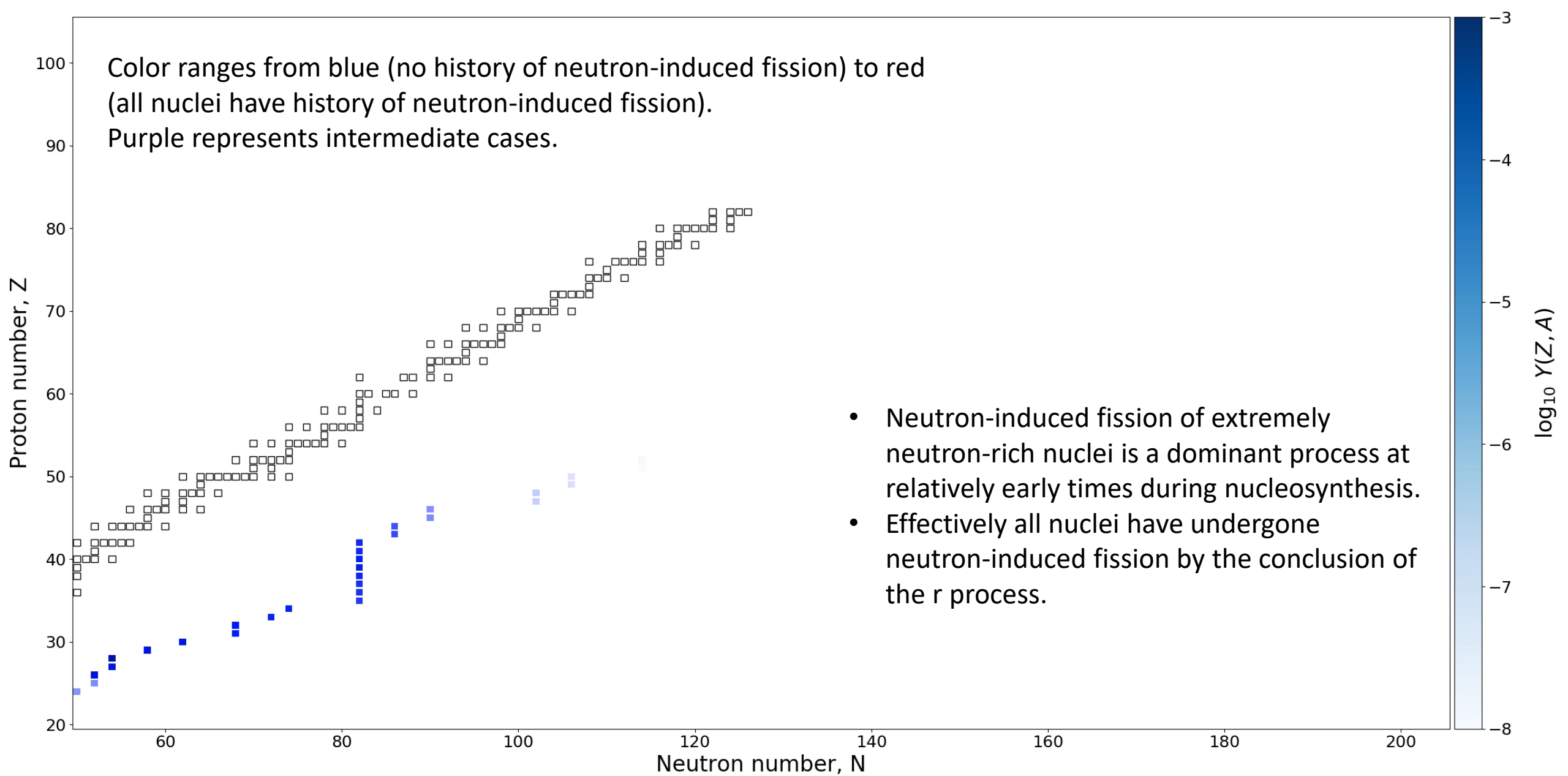
- We have developed a **nucleosynthesis tracing framework** that begins to study, for the first time, the full nucleosynthetic history of *all* nuclei during nucleosynthesis.
- This tracing framework allows us to robustly quantify which nuclei have undergone a particular reaction, decay, or fission process *at any point* in their history.

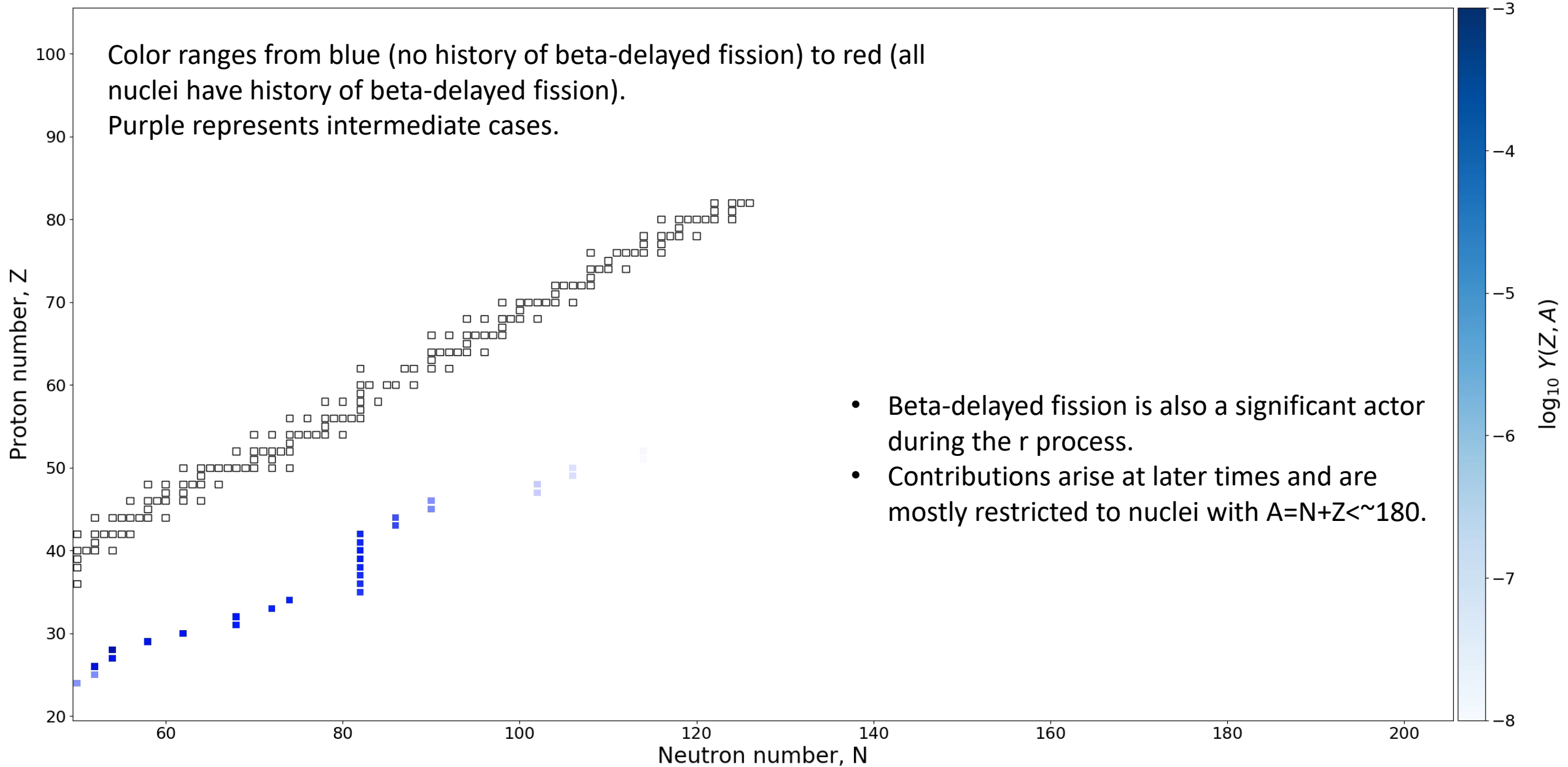


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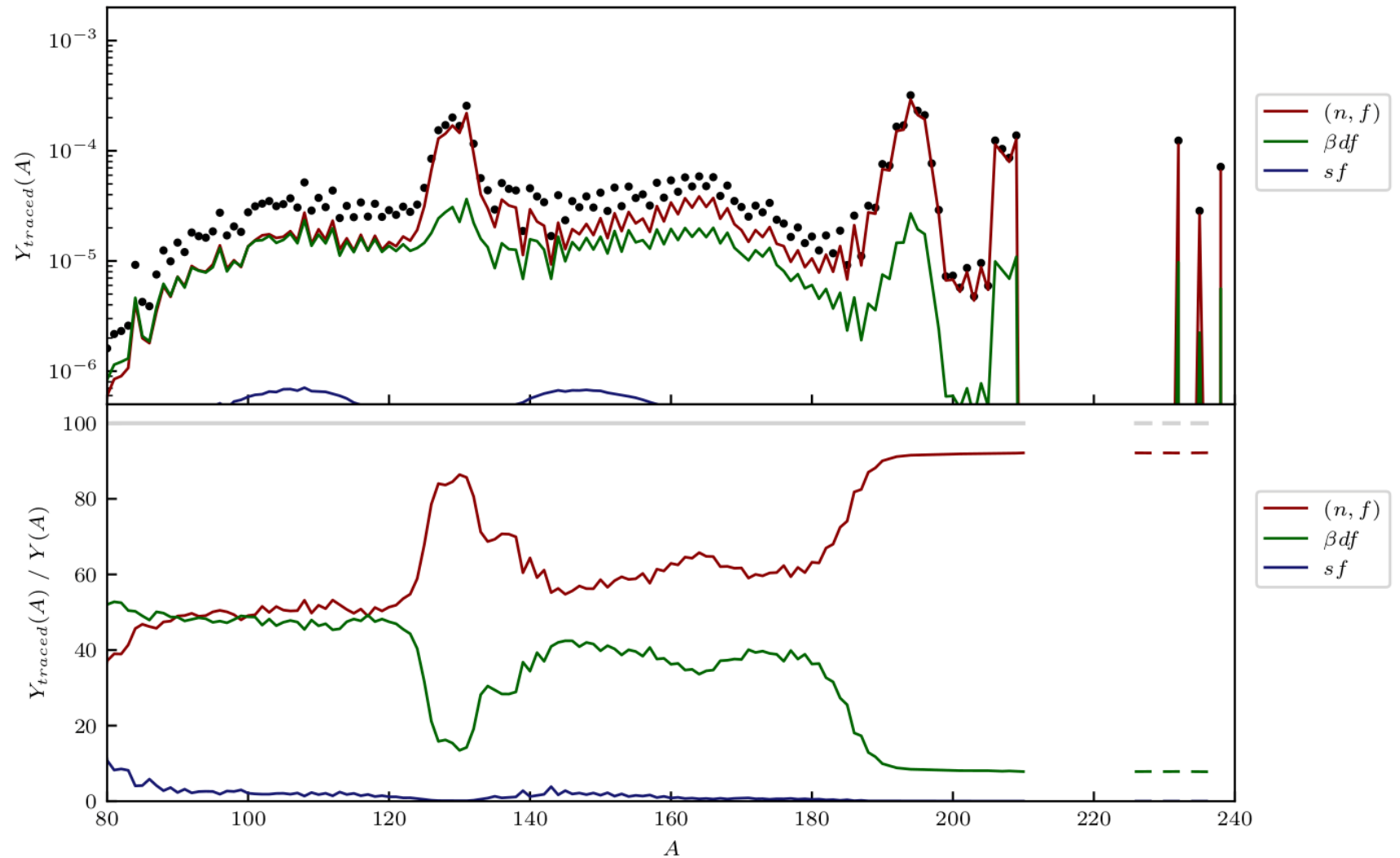


Our tracing framework was implemented as an extension to our **PRISM** reaction network code, and it remains fully integrated with our existing pipeline for nucleosynthesis studies.

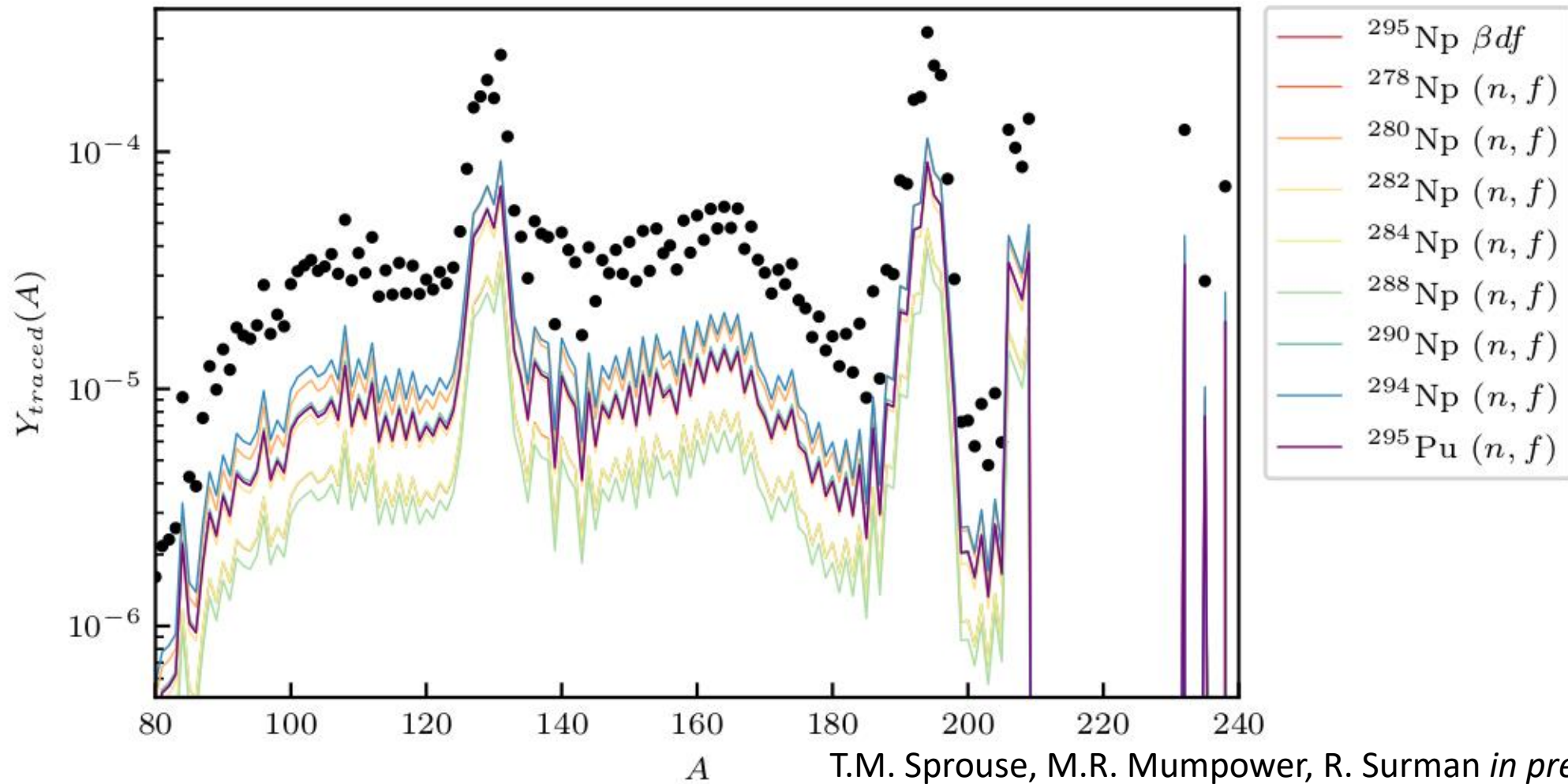




- Here, we consider only the very last fission process in which each nucleus has participated after 1 billion years following an r process.
- For these astrophysical conditions, all nuclei have fissioned at least once.
- Both neutron-induced and beta-delayed fission are important for the r process.

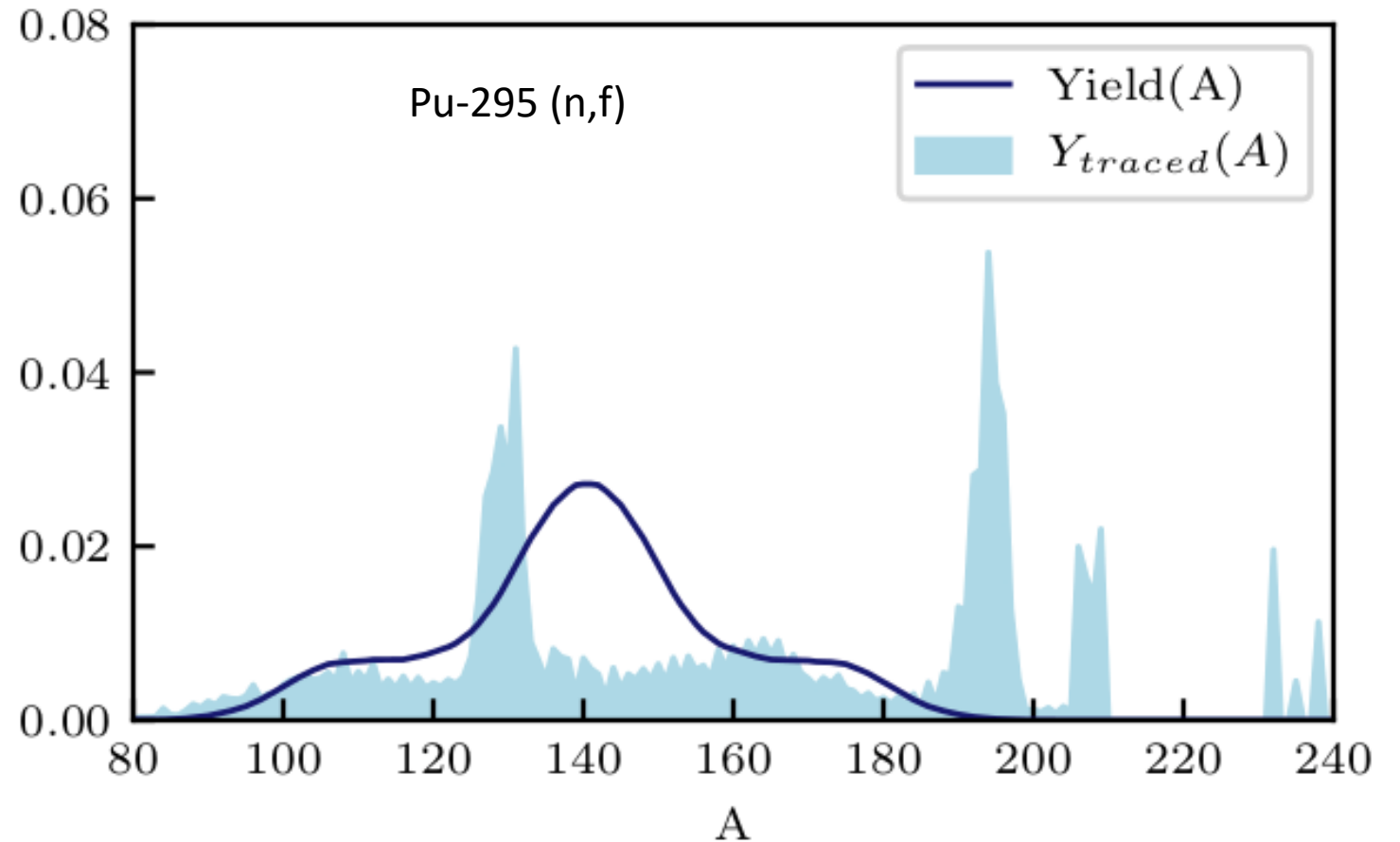


T.M. Sproue, M.R. Mumpower, R. Surman *in prep.* (2019)



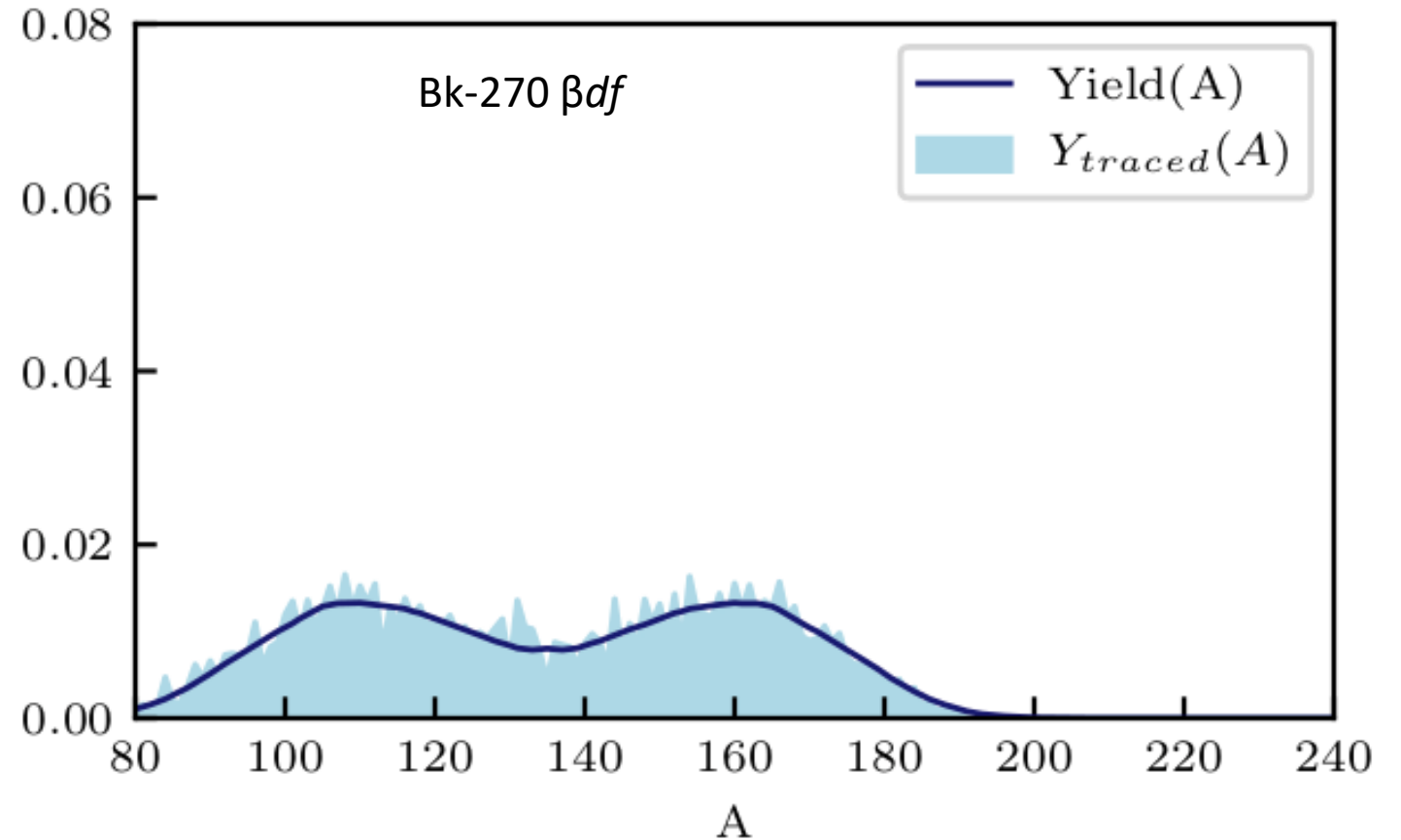
Nucleosynthesis tracing can also be applied to the fission of **individual nuclides** and their corresponding **fission products**.

- For fission that occurs relatively early-on in the r process, fission products are significantly redistributed by follow-up nucleosynthesis.



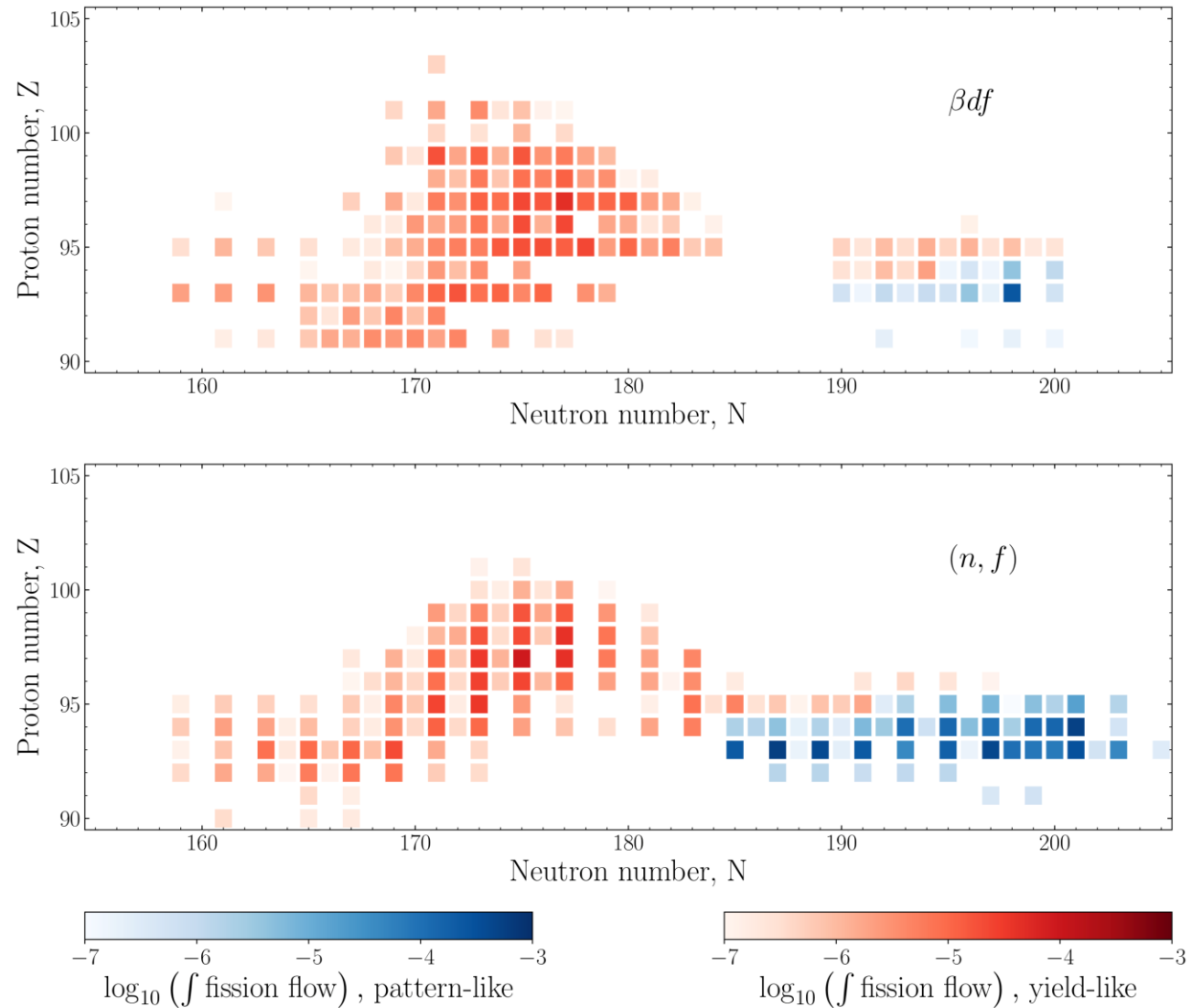
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- For fission that occurs relatively late in the r process, fission products remain mostly fixed (as a function of mass number, A).
- These contributions to r process abundances are closely related to the fission product yields.

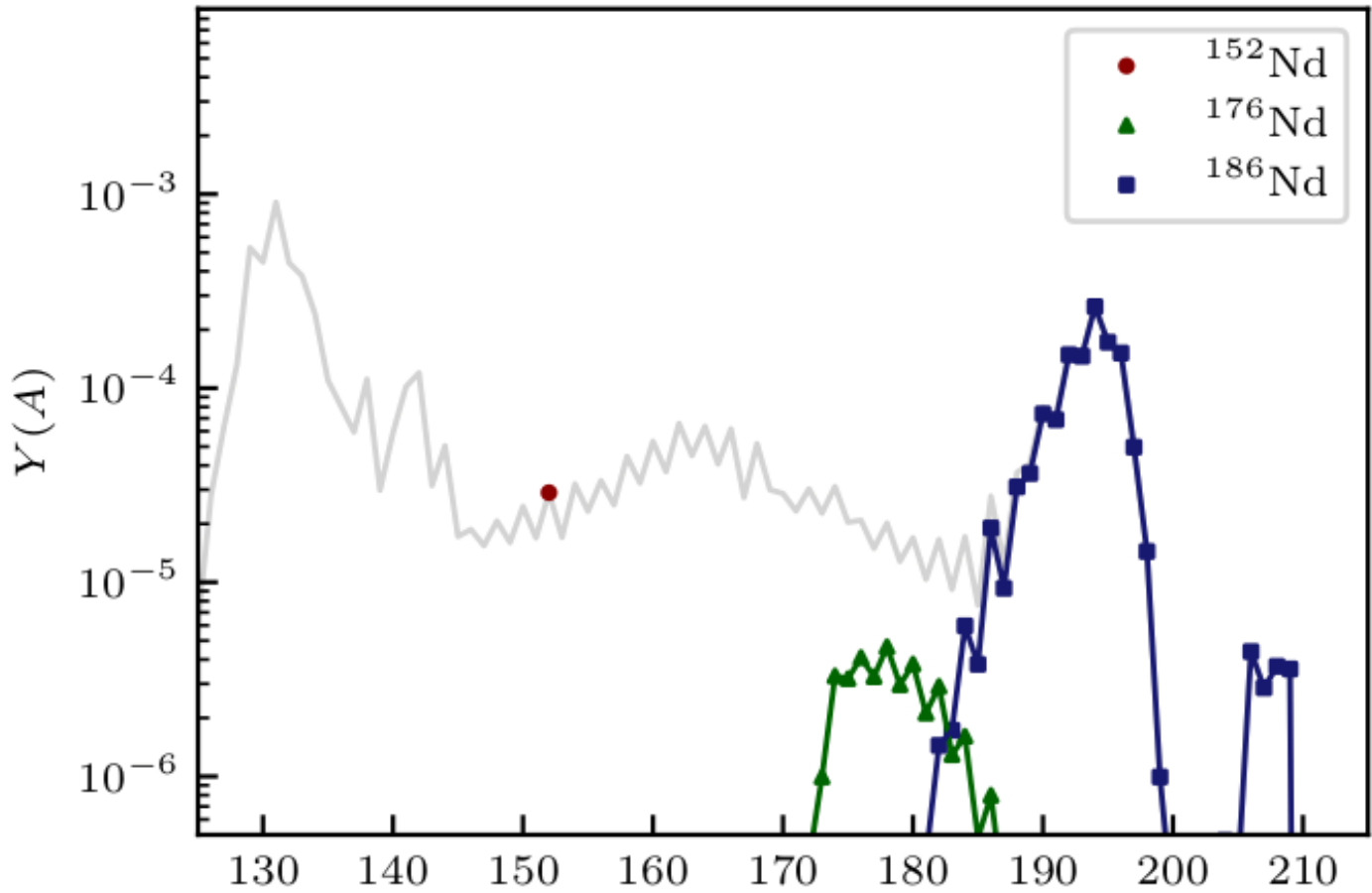


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- We have systematically performed a comprehensive set of tracing calculations for the beta-delayed (top) and neutron-induced (bottom) fission of individual r process nuclides.
- Nuclides colored red indicate that r process contributions closely reflect the fission product yield's distribution in A.
- Nuclides colored blue indicate that r-process contributions are significantly re-processed by nucleosynthesis.



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Nucleosynthesis tracing has other applications; here, we have applied it to the beta decay of individual Neodymium isotopes.

Conclusions

- We have developed an extension of traditional reaction networks to carefully and precisely isolate the role of individual nuclear reactions, decays, and fission in nucleosynthesis modeling.
- Fission products will undergo varying degrees of additional nucleosynthesis during the r process.
 - If we are to utilize r-process observations as a path towards understanding fission product yields for extremely neutron-rich nuclei, these effects **must** be considered.
 - We are finally able to quantify these effects using the nucleosynthesis tracing framework.
- Our nucleosynthesis tracing framework, combined with our pipeline for implementing experimental and theoretical data, can be used to immediately evaluate the specific role of, e.g., future fission experiments and theory calculations in r-process nucleosynthesis.
- Applications for this framework are many and varied, and they extend well beyond studies of fission in the r process.

Thanks!

