The Bayesian Analysis of Nuclear Dynamics CI Framework

https://bandframework.github.io/

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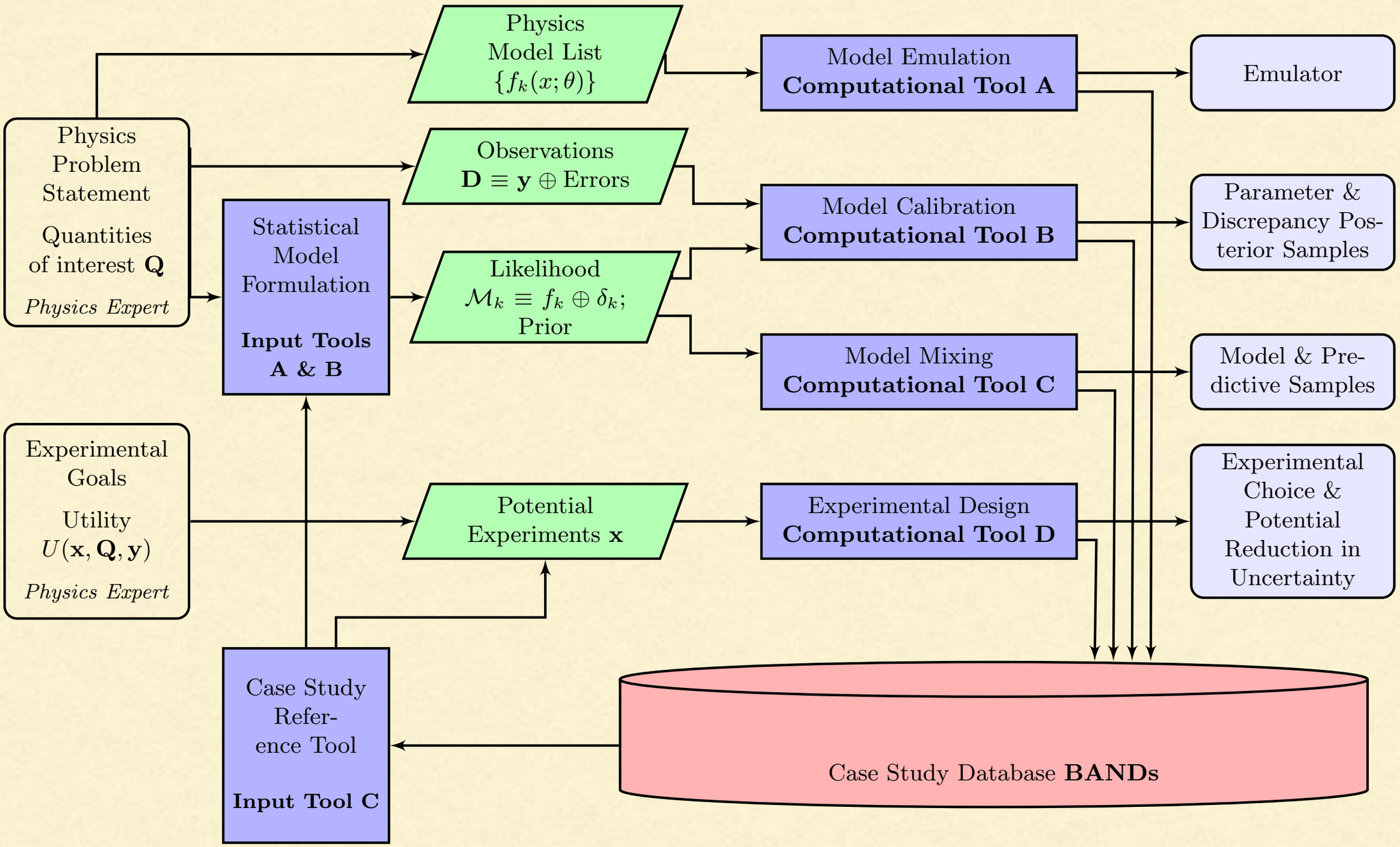
Bayesian Analysis of Nuclear Dynamics

- Much progress on Uncertainty Quantification in Nuclear Physics in last few years
- But still some inhibitions regarding use of Bayesian methods:
  - What prior should I choose?
  - Isn't MC sampling too computationally expensive a way to estimate the parameters I care about?
  - How do I use Bayesian methods to assess model uncertainty?
- BAND will provide solutions!
  - Guidance from experienced & expert statisticians and physicists on prior selection
  - Fast emulators for expensive physics models
  - Use "Bayesian Model Mixing" to provide error bars that reflect full error bar for a nuclear-physics prediction, based on best available Nuclear Physics knowledge
- Consistently calibrated and mixed nuclear-physics models can then be used for optimal design of experiments

The Framework



The Team

Senior Investigators

- Ohio U., Daniel Phillips: Nuclear Physics (PI)

OHIO UNIVERSITY

- Michigan State U., Taps Maiti, Frederi Viens: Statistics;
  Witek Nazarewicz, Filomena Nunes, Scott Pratt: Physics

- Northwestern U., Matthew Plumlee: Engineering/Statistics,
  Stefan Wild: Applied Math/Computer Science

- Ohio State U., Dick Furnstahl, Uli Heinz: Physics,
  Matthew Pratola, Statistics

MICHIGAN STATE UNIVERSITY

Northwestern University

THE OHIO STATE UNIVERSITY

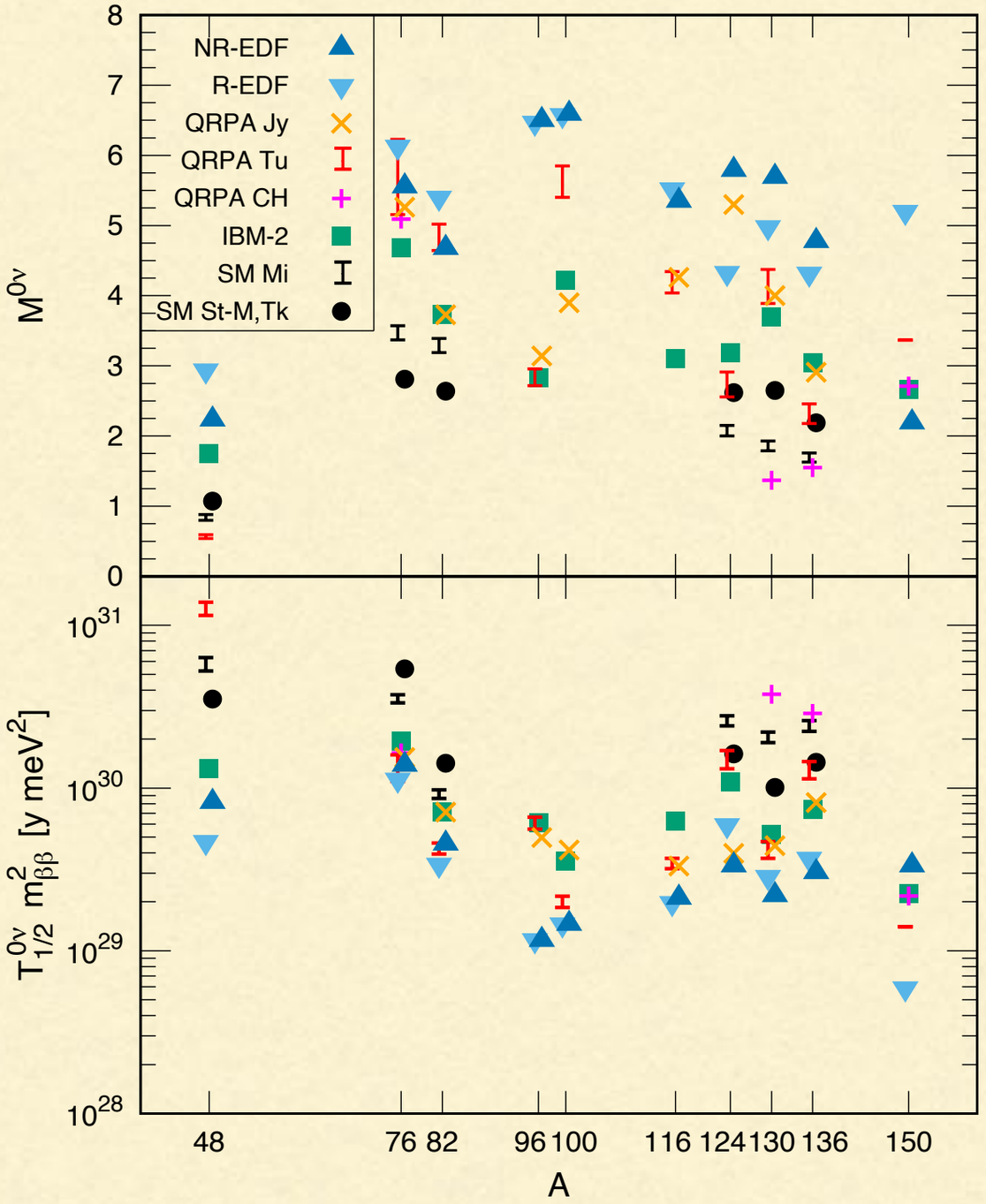
Nuclear Science motivation

- r-process: extrapolation to the dripline and beyond; ties in to other nuclear-structure issues
- Heavy-ion collisions: energy deposition; pre-hydrodynamic stage; conversion of hydrodynamic output to final-state particles
- Mixing different approaches to reaction dynamics→nuclear data evaluation with fully quantified uncertainties
- Neutrinoless double beta decay

Ultimate goal is to build framework that is *generally useful*

Some specific 0νββ context

- Wide range of predictions for $M^{0\nu}$ in experimentally relevant nuclei
- Should we just take an average?
- Or weight them somehow according to performance on other relevant observables?
- What if some approaches are better for small A and others for large A?
- Bayesian Model Mixing provides a way forward

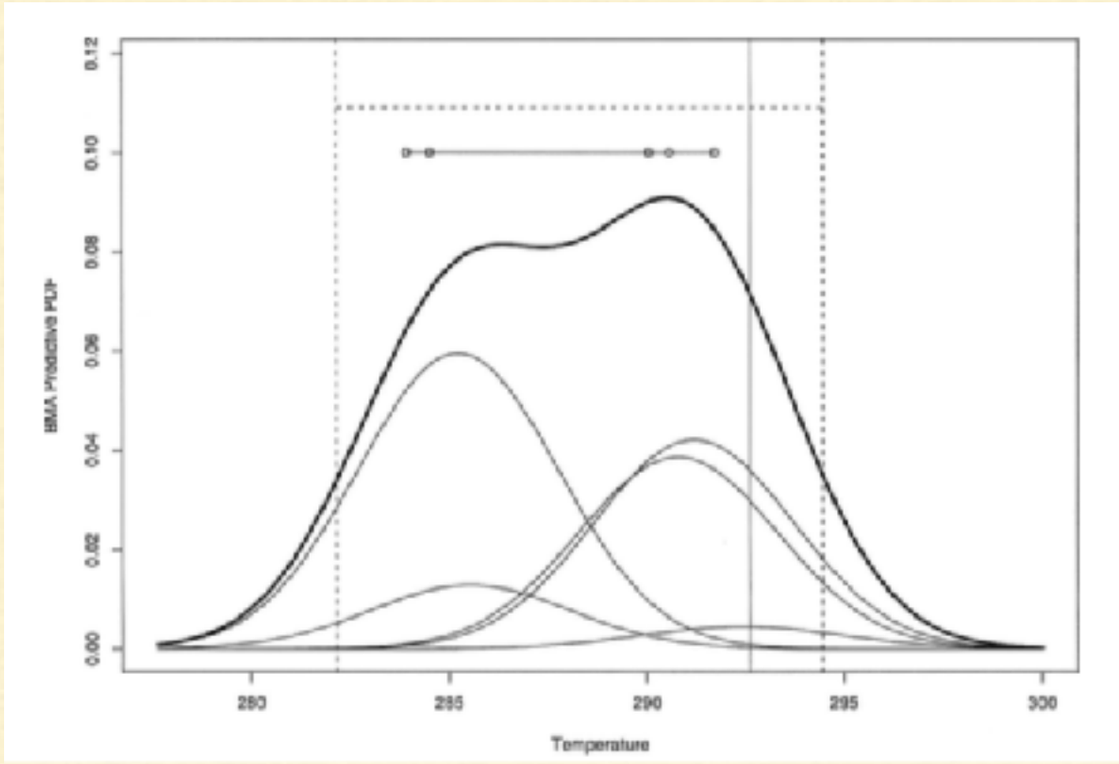


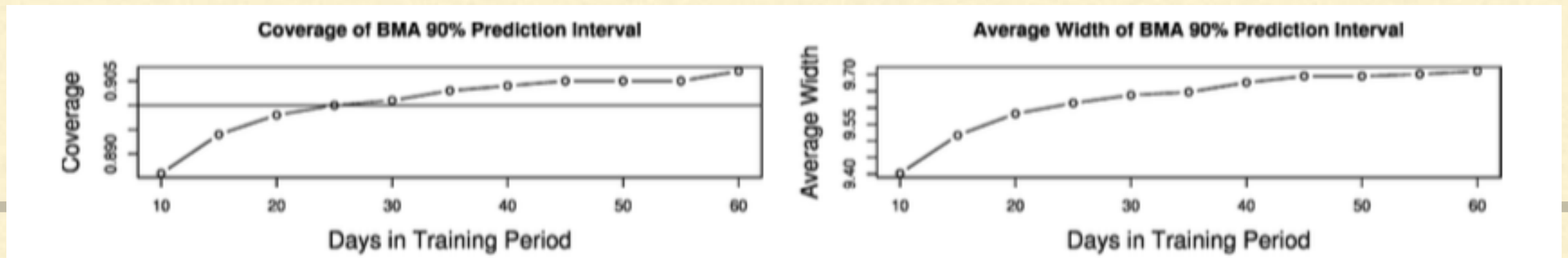
Bayesian Model Mixing

Simplest version is "Bayesian Model Averaging" (BMA)

$$\mathrm{pr}(Q \mid D, I) = \sum_M \mathrm{pr}(Q \mid M, D, I)\mathrm{pr}(M \mid D, I)$$

- Used in several other fields
- Improves predictive performance in weather forecasting — Raftery et al. (2005)
- Application to EDFs, proton-emission, etc. — Neufcourt et al. (2019-2022)
- Applied to EFT expansion in toy context — Connell, Billig, Phillips (2021)





Timeline

https://bandframework.github.io/

- Year 1: Release of BAND Manifesto; Nuclear-physics codes in repo
- Year 2: Version 1 demo released
- Year 3: Version 2 framework released
- Years 4 & 5: Mature version of BAND Framework released with database; POC demos for experimental planning and forefront nuclear theory; workshop for other disciplines
- Throughout: Roundtables with community, BAND camps, tutorials
- Collaboration & input welcomed