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Uncertainty quantification in R-matrix analyses using Bayesian methods

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Bayesian methods provide a unifying and powerful framework to quantify uncertainties. Their recent application to R-matrix calculations of nuclear reactions has lent a new level of rigor to R-matrix analyses, accessing new information about R-matrix parameters and assessing the impact of experimental systematics on both estimates of those parameters and R-matrix predictions.

I will begin by reviewing Bayesian methods within the specific R-matrix context. I will argue, using examples, that sampling of the full Bayesian posterior for the R-matrix parameter vector $\vec{\theta}$ provides insights into the formulation of the R-matrix model that are difficult to obtain within a frequentist approach. I will then explain how, with that posterior in hand, it is straightforward to obtain predictions for as-yet-unmeasured reaction data.

Bayesian methods also permit straightforward modeling of experimental imperfections. I will show recent examples of Bayesian R-matrix analyses that treated experimental systematics such as acceptance effects at specific (lab.) angles [1], beam-energy shifts [2] and that examined the impact of inflating the point-to-point uncertainties of different data sets [3].

If time permits I will close by touching on the treatment of theory imperfections within a Bayesian approach.

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[3] D. Odell, C. R. Brune, D. R. Phillips, Phys. Rev. C 105, 014625 (2022).

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