Advances in Radioactive Isotope Science

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Quantifying Uncertainties for Optical Model Parameters and Cross Sections

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While uncertainty quantification has been applied to many fields within nuclear theory, it is still relatively unstudied in reaction theory. There are many sources of these uncertainties, including but not limited to the effective potentials used, model approximations and simplifications, and structure functions. Many of these have been investigated [1], however, they have not been systematically studied. For instance, the uncertainties from optical model parameterizations are often calculated by computing the difference between the cross sections that result from two parameterizations used within the same reaction framework. Although this gives a relative error between the two, it does not give a systematic way to quantify the uncertainty from a given parameterization.

To begin to quantify the uncertainties coming from these optical model parameterizations, chi-square fitting to elastic scattering data is used to constrain the depth, radius, and diffuseness of each term in the optical model potential. From these fits, 95% confidence bands can be constructed around cross-section calculations from the best-fit parameterizations. Correlations between the parameters can also be explored. Correlations within the model itself can be taken into account using a correlated chi-square fitting function, which produces lower chi-square values, larger confidence bands, and a more physical description of the data. We will discuss results from this process as applied to 12C-d elastic scattering and transfer, as well as 45Fe-n elastic and inelastic scattering. [2]

This fitting procedure, however, only explores the parameter space around a given minimum and does not provide a way to include knowledge about the physical constraints on the parameters. As an alternative, a Bayesian analysis can be performed, using a Markov Chain Monte Carlo to explore the parameter space – constrained by the elastic scattering data and physical limits on the optical model parameters. Results from this first exploration will be shown, along with comparisons to the chi-square fitting procedure. Finally, possible future developments will be discussed.

References:

[1] A.E. Lovell and F.M. Nunes, J. Phys. G: Nucl. Part. Phys. 42 034014 (2015)

[2] A.E. Lovell, F.M. Nunes, J. Sarich, and S.M. Wild, arXiv:1611.05126v1 [nucl-th] 4 Nov 2016

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