Covariances for Evaluated Cross Sections Derived from Nuclear Models

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The Issue

- The growing demand by applied users for covariances for evaluated cross sections, coupled with the fact that many contemporary evaluations are generated using nuclear models, suggests that a method is needed to provide such covariance information in a consistent way
- A new approach based on use of the Monte Carlo method is described here … it has been tested and shown to be a viable one by Arjan Koning (see separate presentation by Koning)

Basic Idea

- It is assumed that the uncertainties in the evaluated cross sections can be adequately determined by propagating suitable uncertainties in the nuclear model parameters employed in the nuclear model calculations
- A large collection of parameter sets is generated randomly with values chosen by Monte Carlo sampling within the specified uncertainty ranges
- A complete vertical evaluation of a particular isotope is performed for each of these sets
- Central values and their covariances for derived cross sections are generated from the results produced by this statistical sampling approach

Statistical Analysis

- Index "i" applies to evaluated quantity and index "k" applies to Monte Carlo history; "K" histories are traced in the exercise
- Vector $\mathbf{p}_k$ denotes a collection of model parameters selected at random for the kth history and $\sigma_{ik} = f_i(\mathbf{p}_k)$ are derived values
- $< \sigma_i > \approx (1/K) \text{ x } [\Sigma_{k=1,K} \sigma_{ik}]$
- $V_{ij} = (1/K) \text{ x } [\Sigma_{k=1,K} \sigma_{ik} \sigma_{jk}] - < \sigma_i > < \sigma_j >$

Interpretation

- The chosen nuclear model is used to generate a collection of “pseudo data” for all the quantities to be evaluated (including various reaction channels and energies)
- The evaluation itself corresponds to the averages of all these results and the covariance matrix elements for this evaluation are related to second moments derived from a statistical analysis of the accumulated Monte Carlo results

Technical Feasibility

- Such an approach is feasible because with modern computers a complete cross section evaluation for a particular isotope can be performed in a matter of seconds, or at most a few minutes … thus 1000 or more of such calculations can be performed readily within a few hours
- Arjan Koning (Petten) has demonstrated that this exercise can be done by applying his TALYS evaluation code system (see separate presentation by Koning)

Complications

- It can be argued with considerable merit that consideration of only the model parameter uncertainties overlooks the underlying (and usually imponderable) uncertainties attributable to deficiencies in the nuclear model (or models)
- It is probably unreasonable to randomly vary all parameters of the model independently since there are known parameter correlations to take into consideration … but, this is a technicality since once these correlations are established it is straightforward to take them into consideration in the Monte Carlo sampling procedure

What’s Next?

- Develop a “feel” for the appropriate model parameter uncertainties to use in such analyses based on experience gained by fitting data with models and by consideration of “systematics”
- Arrive at a consensus concerning reasonable assumptions for model parameter correlations
- Explore the feasibility of “covering” model deficiency uncertainties by the process of enlarging the uncertainties in certain key parameters of the existing nuclear models
- Develop efficient algorithms for performing Monte Carlo sampling exercises that involve complex model calculations