Joliot-Curie School 2014

Nuclear Reactors, Evaluations, Library Development

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A nuclear data evaluation is often the result of an artful combination of experimental differential information, theoretical insight, model predictions, integral benchmarks as well as the "expertise" of the evaluator. In this lecture, I will review the full nuclear data evaluation process, through examples of interest to the nuclear reactor community and more generally to any nuclear application, from non-proliferation to astrophysics. I will also discuss the existing evaluation libraries, e.g., the U.S. ENDF/B-VII.1 and the European JEFF-3.1.1 libraries, their status, and how they can be used by the nuclear data community.

A nuclear data evaluation always begins with the search for available experimental data related to the particular isotopes and reactions of interest. A critical reading of experimental data and publications is required before analyzing and combining them through statistical techniques. The importance of uncertainties and correlations, of statistical and systematic nature, will be emphasized.

Theoretical nuclear reaction models are crucial to understand, validate, as well predict nuclear data that are often only partially measured. We will review some of the most general models used to describe nuclear reactions in the eV to MeV energy regions, of interest to nuclear reactors and other applications. Such models are at the core of several well-known nuclear reaction codes such as ECIS, GNASH, EMPIRE, TALYS or CoH. The statistical Hauser-Feshbach theory is commonly used to describe nuclear reactions in the keV-MeV region. Non-statistical effects, e.g., pre-equilibrium, direct or semi-direct reactions, etc, are also taken into account.

Bayesian statistical inference is ubiquitous in many scientific, technological, sociological studies, and is also commonly used in nuclear data evaluation works. It is used mostly to combine knowledge acquired from several sources, such as experimental data and model calculations. Bayesian updating schemes can be used to constrain the mean values and uncertainties of model input parameters, which in turn can be used to predict physical quantities where no experimental data exist. It is also commonly used by R-matrix fitting codes, e.g., SAMMY and CONRAD, in the resolved resonance region. I will provide a general introduction to the Bayesian technique, and how it is used in a nuclear data evaluation.

To be of broad and general use, an evaluated nuclear data file has to be as complete as possible. Transport codes, such as the well-known Monte Carlo MCNP code, use processed formatted evaluated libraries, and need physical processes to be fully described for a wide range of target nuclei, projectiles and reaction energies. General purpose libraries such as the U.S. ENDF/B-VII.1, the European JEFF-3.1.1, and the Japanese JENDL-4.0 libraries are relatively complete for incident neutrons, for example. Completeness does not equate quality however, and the quality of a particular evaluated file often reflects the importance of this particular isotope for specific nuclear applications.

I will conclude this lecture by discussing the recent International evaluation effort named CIELO, which represents an attempt at pulling together worldwide evaluation resources to establish a state-of-the-art evaluated nuclear data library.