Some considerations on the proper Monte Carlo simulation of neutron interactions

DESPEC Neutron Detector Working Group

Nuclear reaction cross sections at low energies (below 20 MeV) can not be calculated with nuclear models with enough ACCURACY. Example: in the simulation of a reactor, the criticality constant “k” should be determined with an accuracy of 1/1000 or better.

All possible reaction channels have to be **MEASURED** and **EVALUATED**:

- Comparison and weighting of available experimental data sets.
- Use of parameter dependent theoretical models for predicting the missing channels (possible at energies above a few hundred keV).
- Further adjustment of the cross sections with benchmarks and comparison of derived results to measurements in macroscopic nuclear systems .

The cross sections are then released in Evaluated Nuclear Data library Files (ENDF). In addition to the cross sections, also the secondary particles produced in a neutron reaction are tabulated.

(n,γ) reaction: sorting of gamma ray energies and multiplicity. No correlation between the energies, just mean values.

(n,f) reaction: sorting of fission fragments (A,Z), kinetic energies, sorting of neutrons (energy, multiplicity), sorting of gamma rays emitted by the excited fission fragments (energy and multiplicity)…

Table based Monte Carlo Simulation codes (MCNP, MCNPX and other well established codes) for neutron transport problems allow:

i. To use cross sections from any possible nuclear data library: ENDFB, JENDL, JEFF, CENDL, BROND. The data format is well known and well documented: ENDF
ii. The ENDF files are publicly available and can be downloaded from the web
iii. All isotopes for which data exist are in the libraries.
iv. Several processing tools for those files do exist (free or under license): PREPRO, NJOY…
v. Sorting of secondary particles , many times without the necessary correlations between them.

GEANT 4 neutron data library G4NDL:

i. No, cross sections are "God"-given and sometimes even wrong! In the past, compilation of different channels from different libraries thus violating the unitarily (sum of partial σ_i different from the total σ). No information of the format, but probably just pointwise cross sections.
ii. Files have to be requested and are sometimes not delivered.
iii. Only a "safe" selection of isotopes is present.
iv. No processing tool is available to the public. The user is forced to use the G4NDL file distributed.
v. Appropriate data missing or incorrect in many cases.

Proposals ordered by priority:

i. To **develop an interface between the ENDF files and GEANT 4 inside the NUSTAR collaboration**. Understand the G4 format (Temperature dependent pointwise cross sections?). Program an interface between the ENDF and G4 formats. Probably existing tools like PREPRO could be used for time-saving. In our opinion, it could be done in 6 months by one person with enough computing skills.

ii. **Patch GEANT 4 with** low energy **models for secondary particle production** which do include particle correlations. This has been done already for (n,γ) measurements by IFIC and CIEMAT.