Improvements of spallation models in view of more reliable predictions for RIB facilities.

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The recent intensive activities in production of Rare Isotope Beams and High Current Spallation Sources led to a revival of interest in reliable predictive modeling of collisions of hadrons with nuclei in the energy range of few tens MeV to few GeV. Owing to the complexity of the quantum-mechanical many-body problems, there is a need to develop tractable theories, using suitable approximations, to identify the conventional, non-exotic features of the processes for design of new experiments and identification of interesting new phenomena. Such computational tools, inplemented into transport codes (e.g. MCNPX, GEANT4) are also indispensable for characterization of the backgrounds in experimental setups and for the radio-protection evaluations.

Good candidates for such modeling are Monte Carlo implementations of Intra-Nuclear Cascade (INC) models followed by de-excitation models. They reproduce successfully wide variety of experimental data of hadron-nucleus reactions in the energy regime of few hundreds MeV to few GeV. They have a strong predictive power, since they use only a small number of adjustable parameters, most with clear physical meaning. They have been successfully implemented into the MCNPX transport code, bridging between the known experimental library data and the very high energy models.

The INC models treat the interaction of incoming hadron with the nucleus as a series of independent collisions using free particle-nucleon cross sections. The underlying assumptions for this approximation are: (1) The energy transferred into internal energy of the target is large in comparison with the binding energies of nucleons; (2) the mean free path (mfp) of the incident hadron is much larger than the de Broglie wave length; (3) the radius of the target nucleus is large with respect to mfp;(4) mfp is larger than the inter-particle distance. Though these assumptions limit the applicability of INC models to energies higher than few hundreds MeV and relatively heavy nuclei, it was found that the Liège Intra-Nuclear Cascade Model (INCL4 [1]), with some refinements, may be successfully used well outside this domain [2]. In the region of few tens MeV, it was also found that the calculated nucleon and light cluster spectra and the residual nucleus mass, energy and recoil momentum distributions are very sensitive to detailed modeling of the target nucleon momenta, Pauli exclusion principle and nuclear and Coulomb potentials.

Discrepancies between the calculations and the available data were carefully analyzed. A comparison between INCL4 and the older ISABEL code [3] was carried out, in order to identify discrepancies pertinent to the limitation of the INC method and those related to specific INC implementation.

The INCL4-ABLA model inside the MCNPX transport code is currently used by the EURISOL collaboration. Embedding of the new INCL version will improve and extend the predictive power of the transport code and make it useable also for lower energy facilities as SPIRAL2.

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