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The Liège Intranuclear Cascade model. Towards a unified description of nuclear reactions induced by nucleons and light ions from a few MeV to a few GeV.

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The renewed interest in spallation reactions, driven by various applications (nuclear waste transmutation, neutron spallation sources, protection against space radiation, hadrontherapy, etc) has strengthened the idea that these reactions proceed through a two stage process, an intranuclear cascade (INC) stage followed by evaporation of a remnant, has established that this mechanism is dominant in nucleon-induced reactions from about 250MeV to a few GeV and has given an impetus to the improvement of the theoretical tools. We report here on the last developments of the Liège Intranuclear Cascade model (INCL). From a recent intercomparison, organized by the IAEA [1] two years ago, it appears that this model, when coupled to the Abla07 de-excitation model [2], provides the best global description of the various experimental quantities in the 150MeV-3GeV incident energy range. In particular, we here focus on the last developments of INCL that have been worked out afterward and that are embodied in the last version INCL4.6 [3] of the model. They bear on: (1) the production of clusters in the course of the cascade phase, which is made possible through a dynamic coalescence model, (2) the extension of the model below the putative low energy limit of validity of INC models (about 250MeV), (3) the extension of the model to reactions induced by light clusters (up to Carbon and Oxygen), managing complete and incomplete fusion, (4) the extension of the model to higher incident energy, up to 10-15 GeV, based on multipion production in nucleon-nucleon collisions. The validation of these improvements is provided by an extensive and successful comparison with relevant observables.

Two more fundamental points will also be illustrated. First, the validity of INC models well below the low energy limit alluded above will be discussed. The role of the Pauli principle will be shown to be crucial in that respect. It will also be shown that the introduction of an intermediate stage between cascade and evaporation is not necessary. Theoretical and circumstantial arguments supporting the neglect of this stage will be given, opening so the possibility of having a single and unified model for reactions, operating from a few MeV to a few GeV incident energy range. The second point deals with the recoil velocity of the residues. The distributions of the latter quantity display typical properties of a diffusion problem. The latter can be viewed as a direct consequence of the basis of INC model, namely the succession of independent binary collisions.

[1] http://www-nds.iaea.org/spallations
[2] A. Kelic , M. V. Ricciardi, and K.-H. Schmidt, in Joint ICTP-IAEA Advanced Workshop on Model Codes for Spallation Reactions, in IAEA INDC (NDS)-1530, edited by D. Filges et al. (IAEA Publications, Vienna, 2008), pp. 181–222.
[3] A. Boudard et al., accepted for publication in Phys. Rev. C [nucl-th]arXiv:1210.3498