Improved modelling of helium and tritium production for spallation targets

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Reliable predictions of light-charged particle (LCP) production in spallation reactions are important to correctly assess gas production in spallation targets. In particular, *He* production yield is important for assessing damage in the window separating the target and the accelerator vacuum, and tritium is a major contributor to the target radioactivity. Up to now, the models available in the MCNPX transport code, including the widely used default option Bertini-Dresner and the INCL4.2-ABLA combination of models, were not able to correctly predict light-charged particle yields. Here, we present the work done recently on both the intranuclear cascade model INCL4.5 [1] and on the de-excitation model ABLA07 [1] to improve the LCP prediction, in particular tritium and helium.

In LCP energy spectra, two different components are generally observed: a low-energy isotropic peak coming from the evaporation stage, and a high-energy forward-peaked tail, coming from initial reaction stage. The contribution of the latter in the production cross sections of tritium and ^{3}He is far from being negligible. This is why a coalescence mechanism leading to LCP emission has been implemented into INCL (first in ref. [2], later in ref. [1, 3]). The cluster emission mechanism is based on surface coalescence in phase-space i.e. on the assumption that a cascade nucleon ready to escape at the nuclear surface can coalesce with other nucleons close enough in phase space and form a cluster. All possible clusters up to a given mass number are formed and the priority is given to the one with the lowest excitation energy per nucleon. The selected cluster is emitted only if it succeeds to go through the Coulomb barrier. In INCL4.5 clusters up to mass 8 are considered.

In the original version of ABLA only nucleons and alphas could be evaporated. The new version [1] now allows the evaporation of all the types of light charged particles from p to ^{4}He and also of intermediate mass fragments. It uses improved parameterizations of inverse reaction cross sections and barriers of potential in order to better reproduce experimental particle energy spectra. A simultaneous break-up (multifragmentation) mechanism has been added for systems overcoming a certain limiting temperature. The fission part has also been modified.

In figure 1, the experimental light composite particle energy spectra [4] for the reaction p+Ta at 1.2 GeV are compared with the results obtained with INCL4.5-ABLA07. The dashed curve shows the contribution coming from the coalescence process in INCL4.5. It is evident that the combination of the two new models is rather successful and represents a definite improvement compared to the former models, which did not evaporate tritium and ^{3}He and were unable to account for the high energy tail of the particle spectra. A more detailed description of this work can be found in ref. [5]. Comparisons with many more experimental data and with other available models are also presented there.

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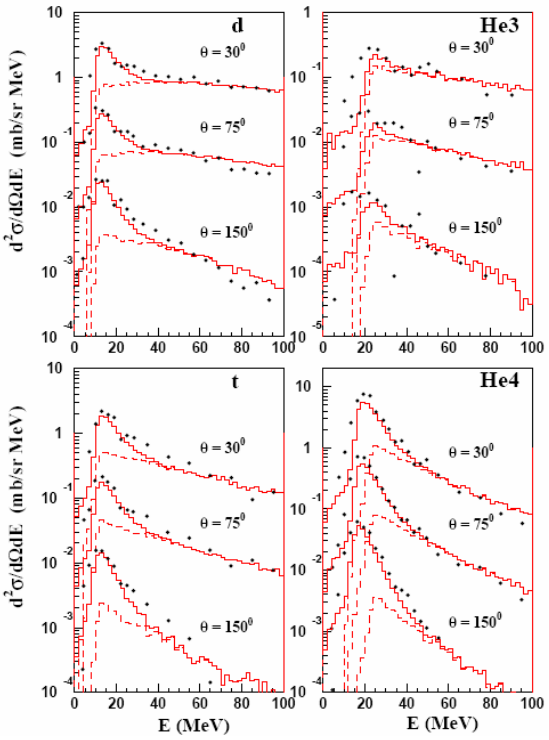

Figure 1: Light composite particle double-differential cross sections in the p+Ta reaction at 1.2 GeV [4] compared with the results of INCL4.5-ABLA07. Each successive curve, starting from the smallest angle, is scaled by a multiplicative factor of 10^{-1}. The contribution due to the coalescence process in INCL4.5 is given by the dashed line.

References

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