Intranuclear Cascade Model for Deuteron- and Alpha-induced Reactions at Intermediate Energies

モニラ，ジャナツル，コブラ

https://doi.org/10.15017/1931898

出版情報：九州大学，2017，博士（工学），課程博士
バージョン：
権利関係：

（様式２）

氏　　名　：モニラ　ジャナツル　コブラ

論 文 名　：Intranuclear Cascade Model for Deuteron- and Alpha-induced Reactions at Intermediate Energies
（中間エネルギー重陽子およびα誘起反応への核内カスケード模型の拡張）

区　　分　：甲

論 文 内 容 の 要 旨

The importance of particle transport codes is increasing in many fields such as nuclear transmutation, material science, and medical treatments. The intranuclear cascade (INC) model is utilized in the codes to calculate secondary particle production by nuclear spallation reactions. In recent years, INC is demanded to reliable estimation for cluster-induced reactions, because the late effect of low-dose exposure is a serious issue for childhood cancer treatment in carbon ion therapy. Fragments produced in carbon ion nuclear reactions are emitted to large angles with high-energies, and therefore healthy tissues far from the irradiation field suffer amounts of doses. It is known that the INC model and other non-perturbative reaction models including the quantum molecular dynamics (QMD) model give passably good accounts for nucleon productions, but large discrepancies for cluster production reactions in spite of great efforts by many authors over decades. It has been therefore suggested that unpreceded physics idea is needed to improve the INC model for cluster-induced cluster production reactions. The purpose of this work is to introduce into the INC framework an idea of virtual excited state, in which ground state wavefunction of incident cluster is expressed as a superposition of different cluster units. Model calculations are executed to validate the proposed model by comparison with experimental observations on deuteron- and α-induced reactions at intermediate energies, 20-100 MeV.

Chapter 1 is introduction. Firstly the need behind particle transport codes is explained in brief and the beneficiary applications are shortly listed. This is followed by the introduction of PHITS and other transport codes. Shortcomings of nuclear reaction models used in those codes are discussed. Lastly the purpose of the thesis is described.

Chapter 2 summarizes basic and important assumptions of the INC model. The INC model has been developed to explain nucleon-induced spallation reactions at high-energies. Since spallation reactions involve extremely high-degrees of freedom, interference disappears and the semi-classical approximation becomes appropriate. The relativistic kinematics of two-body collision is used with a phenomenological treatment of the Pauli exclusion principle to express antisymmetrized states of Fermionic system. Cross sections and angular distributions of nucleon-nucleon scatterings are parametrized to follow quantum mechanical features. In the present work, virtual excited states are assumed to express the interference, which plays an essential role in the cluster formation processes. The cluster break-up probabilities are calculated under an assumption of orthogonality, and are used in Monte Carlo calculations.

In Chapter 3, the validity of proposed model is discussed for the deuteron-induced nuclear reactions. Although the model needs a modeling of deuteron ground state, the potential depth of deuterons is controversial and ambiguities are discussed in terms of solutions of Schrödinger Equations. The search for ground state parameters as well as other parameters such as weighting factors of wavefunctions is detailed with the ^{27}Al(*d,px*) reaction at 70 MeV. Next, the validity of the proposed model is discussed by being compared with experimental data for (*d,d'x*), (*d,px*) and (*d,nx*) reactions on several targets from ^{27}Al to ^{181}Ta. Incident deuteron energies are 70-99.6 MeV for (*d,d'x*) and (*d,px*) reactions, and 22.3 MeV for the (*d,nx*) reaction. The model has succeeded in reproducing spectral shapes and magnitudes for all reactions at wide laboratory angle regions. In proton productions, the highest energy regions at forward most angles are underestimated. This discrepancy is attributed to the lack of one-nucleon transfer process in the model, which leads to excitation of shell model states.

Chapter 4 focuses on the α-induced nuclear reactions for all channels. The parameter search is executed as deuteron-incidence case in Chapter 3. The search for the maximum *b*-parameter is made carefully to fit the absolute cross sections of all reaction channels. To validate the proposed model, calculation results are compared with the experimental data for (*α*, *α'x*), (*α*, ^{3}He*x*), (*α*, *tx*), (*α*, *dx*), (*α*, *px*), and (*α*, *nx*) reactions on targets of ^{27}Al and ^{58}Ni for different laboratory angles from 20° - 135°. The alpha production spectra are predicted fairly well for all angles as well as energy regions. For ^{3}He and triton production spectra, the model successfully reproduces overall trends of spectra except underestimation at the highest energy region. This difference could be ascribable to the fact that the model ignores one-nucleon transfer reactions.

Chapter 5 draws a conclusion of this thesis. The effectiveness of the proposed model has been proved in terms of deuteron- and α-induced reactions. The inclusion of cluster induced reaction to the INC model will open the pathway to carbon-ion induced reactions for accurate dose calculations in cancer therapy.

〔作成要領〕

１．用紙はＡ４判上質紙を使用すること。
２．原則として，文字サイズ１０．５ポイントとする。
３．左右２センチ，上下２．５センチ程度をあけ，ページ数は記入しないこと。
４．要旨は２，０００字程度にまとめること。
（英文の場合は，２ページ以内にまとめること。）
５．図表・図式等は随意に使用のこと。
６．ワープロ浄書すること（手書きする場合は楷書体）。
この様式で提出された書類は，「九州大学博士学位論文内容の要旨及び審査結果の要旨」の原稿として写真印刷するので，鮮明な原稿をクリップ止めで提出すること。