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Validation and application of the nuclear deexcitation simulator NucDeEx; For precise prediction of neutrino-nuclear interactions

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In recent years, neutron multiplicity associated with neutrino-nucleus interactions has become important observable in large neutrino detectors such as Super-Kamiokande, KamLAND, and JUNO. The neutron multiplicity can be measured by detecting gamma rays emitted by neutron capture by taking delayed coincidence. It is expected to improve the results of various physics analyses by using the measured neutron multiplicity to enhance flavor identification or signal-to-background ratio. However, predicting neutron multiplicity is challenging because neutrino-nucleus interactions involve highly uncertain nuclear effects.
Among the several processes involved in neutrino-nucleus interactions, nuclear deexcitation plays an important role in neutron multiplicity. This process emits particles, including neutrons, while transitioning to the ground state when the residual nucleus has exciting energy after the nucleon is knocked out. One issue is that most widely used neutrino interaction generators omit this process or describe it with a simplified model. Another issue is that the energy of deexcited particles is as low as a few MeV and, therefore, unobservable, i.e., un-constrainable, by most accelerator neutrino detectors due to higher detection thresholds. This feature of deexcitation requires us to rely on precise nuclear theory and experiments to verify it.
The author developed a dedicated nuclear deexcitation simulator, NucDeEx, based on the nuclear calculation software TALYS. Since TALYS contains sophisticated nuclear models and parameters, NucDeEx can precisely simulate the nuclear deexcitation process. In addition, NucDeEx can be easily integrated with the neutrino interaction generators and other hadron simulators, such as Geant4 and the hadron cascade model INCL. The source code of NucDeEx and the interfaces and build scripts necessary for use with the above software are available on the web. Thus, a wide range of applications are expected. In this poster, the author will present an overview of NucDeEx, validations with nuclear experiments, the impact of integrating NucDeEx into neutrino interaction generators, and its application to other particle simulators.

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NucDeEx GitHub: https://github.com/SeishoAbe/NucDeEx

Poster prize

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