Developments of simulation model describing both elastic and inelastic scattering

Yoshinori Fukui, Hiroki Iwamoto, Yusuke Uozumi
Faculty of Engineering, Kyushu University
Motooka 744, Nishi-ku, Fukuoka 819-0395, Japan
yoshinori@nucl.kyushu-u.ac.jp

Nuclear reaction simulations such as INC and QMD cannot calculate the nuclear elastic scattering. Based on stochastic quantization theory, we describe the wave motion of protons using particle motion, *i.e*, Newtonian mechanics, and then incorporate elastic scattering into the framework of intranuclear cascade model. The applicability of this model is verified.

１．**Introduction**

In recent days, the radiation dose estimation in various fields is increasing in importance. For instance, it is the particle radiation cancer therapy and the astronautical engineering. We utilize simulation the method to understand nuclear reaction for radiation dose estimation. Intranuclear cascade model (INC) model is commonly used to calculate nuclear reaction. INC model covers the domain of classical collision regime that inelastic reactions, and do not contain the nuclear elastic scattering. It is generally accepted that the elastic scattering must be described by the wave mechanics, and cannot be expressed from classical particle aspects. Therefore, the calculation result remains uncertainty about recoil nucleus momentum, deteriorate accuracy in case of light nucleus that have profound effect on recoil. In the present work, we study method in order to describe elastic scattering in the framework of one of the typical simulations, the INC model. We have two methods for calculating elastic scattering that uses the classical potential and introduces the stochastic quantization. Numerical calculations are made by using above two methods and each results are compared with experimental data.

２．**Theories**

The procedure is referred to the stochastic quantization. The trajectory displacement is described by introducing quantum fluctuation to the classical trajectory. The theory is based on the stochastic differential equation:

$$d\vec{r}(t) = \vec{b}(\vec{r}(t), t)dt + \sqrt{\frac{\hbar}{2m}}d\vec{w}(t) \quad , \tag{1}$$

where b is the mean for ward velocity, and dw corresponds to quantum fluctuation of Wiener process. In the present work, we are considered only with quantum fluctuation in order to simplify the calculation method. Specifically, the trajectory displacement is described by nonuniform random number based on empirical equation.

３．**Results and conclusion**

Fig.1 shows a comparison of angular distributions of $^{40}Ca(p,p)^{40}Ca$ reaction calculated by two methods. The solid line denotes the calculation result of introducing the stochastic quantization. The dashed line is the calculation result obtained by using the classical potential. And the close circles denote the experimental data.

It is shown that the method for using the classical potential cannot reproduce the experimental data in a region of large angle. On the other hand, the stochastic approach can roughly reproduce data in terms of angular distribution. However, it cannot describe wave interference effect. Consequently, we accept the stochastic quantization as more useful method than the another one.

In the future, we calculate momentum of recoil nucleus using the stochastic quantization. And we need to examine in the calculation result.

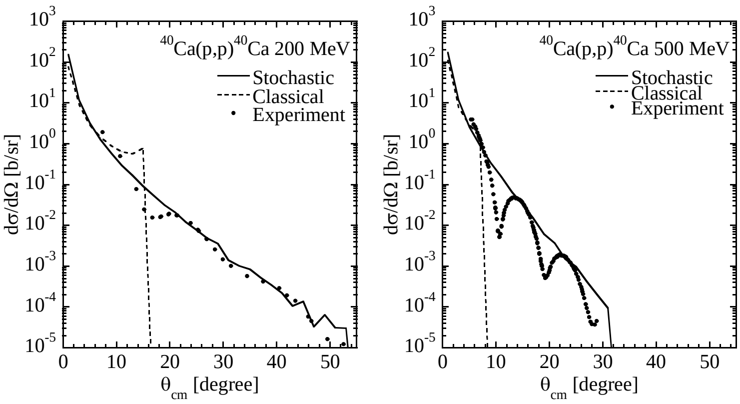

Fig.1. Angular distribution of $^{40}Ca(p,p)^{40}Ca$ reaction