Study of a new crystal array detector to measure double differential cross sections of proton-actinide reactions in 600-MeV region

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Abstract. A new crystal array detector is proposed to conduct charged particle cross section measuremets with actinide targets for a study of accelerator transmutation of waste. The detector enables both the Time-of-Flight and the Pulse-Height measurements in an energy range around 600 MeV. From the simulation designs, it was revealed that the detector has great potential to realize a moderate energy resolution and a wide energy acceptance.

1 Introduction

The accelerator driven system (ADS) has been recognized as one of most attractive options for the nuclear transmutation of high level nuclear waste. One may expect ADS to reduce a hazard level of the waste dramatically, and to operate as an energy generator. Double differential cross section (DDX) data of nucleon-actinide reactions are of highly importance for the nuclear waste transmutation facilitated by ADS. In order to obtain high-quality nuclear data of DDX, one needs to use a detector that offers a moderate energy resolution of a few percent and a wide energy acceptance covering from almost zero up to the maximum emission energy. Moreover, detection efficiency should be high enough for the usage of a thin target. A crystal array detector is the most suitable one to these conditions, and the only solution above 100 MeV. However, there are some crucial problems when one uses it at energies of around/above 600 MeV.

In the present article are described a design study of a new crystal array detector that combines the Time-of-Flight (TOF) and the Pulse-Height (PH) measurement.

2 Crystal array detector for charged particles

2.1 Difficulties of present methods

When one applies a crystal detector to measure charged particle energies of several hundreds MeV, the particle identification (PI) analysis is most useful to deduce DDXs. However, the PI analysis is recognized to become insufficient in a high energy range. This is because the peak efficiency, the ratio of the number of full energy peak events to the total events, decreases to a level where the PI analysis is no longer applicable.

Although TOF is effective to detect high energy protons, its efficiency becomes very low due to a long flight path length that leads to an extremely small solid angle and a large portion of beam bunch thinning-out in cyclotrons. Moreover, it is impossible to realize a wide energy acceptance with a long flight path in charged particle measurements under atmosphere.

2.2 Proposal of new detector system used in 600-MeV range

In order to meet the criteria discussed above, we propose a new detector system which enables nuclear data measurement in a 600-MeV range. It utilizes both the pulse height and TOF in proton measurements. As the concept is illustrated in Fig.2, it consists of two sections; one is a crystal detector based on the ordinal dE-E method, and the other the TOF section following the crystal.

The crystal detector works as an E detector for low energy protons and an energy degrader for high energy protons. Since low energy protons stop in the crystal, one needs not the beam bunch thinning-out in cyclotron operations. The shorter flight path length, which is realized by the degrader, offers great advantages: the larger solid angle and easy preparation of a vacuum duct to cover the flight section which is essential for charged particle measurements. The detector proposed presently is expected to offer the best characteristics to fulfill required specifications, such as energy resolution and energy acceptance.

2.3 Energy resolution

The advantage of this method is demonstrated in Fig.2, which compares the time of flight with/without the degrader crystal under the flight path length of one meter. The effect of crystal degrader is significant, and helps to improve the energy resolution.

3 Conclusion

A new type of detector system was studied to measure double differential cross sections of proton productions from proton-actinide reactions at around 600 MeV. The detector system is based on a combination of dE-E and TOF measurements to realize a moderate energy resolution and an extremely wide energy acceptance. On the base of simulation calculations, the detector arrangement has been optimized in terms of crystal dimensions, TOF path length, and more.

References

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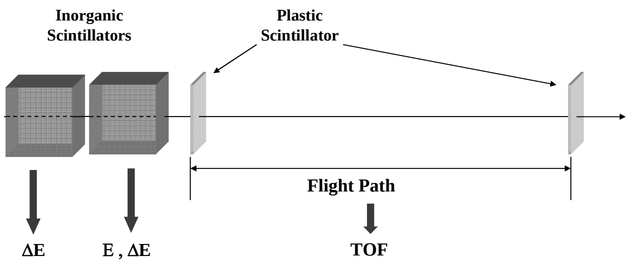

Fig. 1. The detector arrangement we decided.

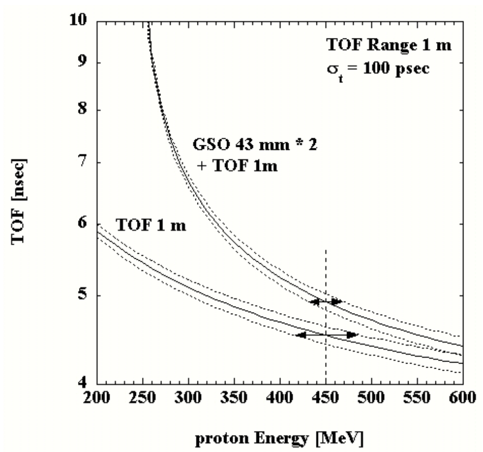

Fig.2. Estimated energy resolution as a function of proton energy compared with/without crystal as energy degrader.