Angular distribution of neutron yield and dose from thick targets in energy range ~7.6 MeV/A - 10 MeV/A

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Introduction

Positive ion accelerators have gamma and neutrons as prompt radiation. Though neutron yield is less but due to high energy and penetrability it becomes of concern for radiation protection [1]. The information however is important for radiation protection practices. In radiation therapy, the secondary particles generated during the treatment are anticipated to further interact with the surrounding tissues and is now found to be a cause for manifestation of latent cancer. The study of the secondary particle yield is thus critical in heavy ion treatment planning. Since heavy ions, (particularly carbon) are being widely used in therapy, such information becomes important. Also, the data available on neutron yield from heavy ion interaction in thick targets is limited.

Organic scintillator detectors have been long recognized for their very good n-γ separation and are being extensively used in neutron measurements in positive ion accelerator facilities, which have mixed field where gammas are always present with neutrons. This work discusses the integrated neutron yield with its angular distribution and integrated dose from thick Al and C targets bombarded by C with kinetic energy ~ 10 MeV/A and F projectiles at ~ 7.6 MeV/A on thick Al target. The energy integrated yields from the different target projectile systems is compared and presented. Thick targets were studied as it represents any accidental or controlled beam loss situations in the accelerator component, drift tubes or beam dump. The thickness taken is such that the projectile particle loses its complete energy into the target before being completely stopped inside the target.

Experiment

The data used here is from three sets of experiments which were carried out at BARC-TIFR Pelletron-Linac accelerator facility. Thick targets of Al and C of thicknesses 3mm and 2mm respectively were used. The Al target was made in a hemisphere shape so as to reduce the degradation in energy of the neutrons emitted in the lateral direction. Time of flight technique was used to measure the neutron energy distribution, the details can be found elsewhere [2, 3]. Five 2″x 2″ EJ 301 (NE213 equivalent) detectors were placed at 150 cm from the target and covering angles 0º, 30º, 60º, 90º and 120º to obtain the angular distribution of the neutron yield. The RF signal from the buncher and neutron detection signal from neutron detectors were used as start and stop signal for the acquisition done using a VME based system. The target was electrically insulated for the secondary charge collection and current integration. Later the yield was normalized for the subtended solid angle and projectiles that bombarded the target.

The measurement was carried out in singles, thus the scattered component from the structural material was taken care using shadow bar technique [2, 3] for individual detectors.

Result and Discussion

A typical pulse shape discriminator output obtained from the MPD module is shown in Fig. 1. A good separation between the two radiation particles was obtained with a figure of merit ~ ~1.2. A typical time of flight spectrum obtained is shown in Fig. 2. , with two beam bunches falling in the time amplitude convertor settings. From the measured energy distribution of neutrons the energy integrated angular distribution of the emitted neutrons was obtained for all the studied target-projectile systems and is shown in Fig. 3. The neutron contribution was seen to be mainly through evaporation process.

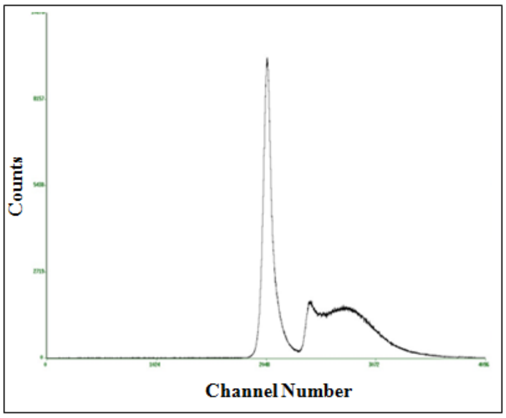

Fig1. Typical n-γ pulse shape discrimination spectrum obtained from multi-parameter discriminator module.

With nearly same projectile and similar kinetic energy incident on different target material the yield is seen as expected to be a function of the excitation energy and fusion cross-section. The neutron energy distribution being the primary physical quantity the neutron ambient doses were estimated by convoluting it with the ICRP fluence to dose conversion factors [4], for the radiation protection purposes. The integrated ambient neutron doses are given in the units of μSv/nA/h as presented in Table 1.

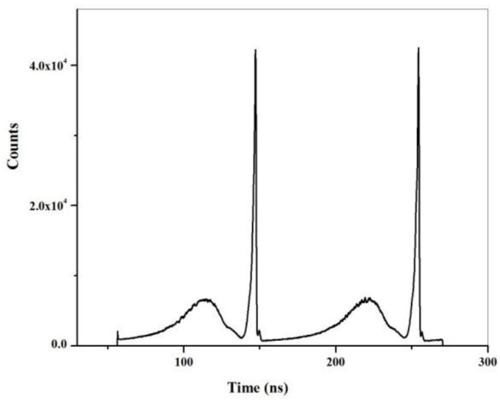

Fig2. A typical neutron time of flight spectra.

The energy integrated neutron yield indicates an approximate exponential behavior. The integrated yield and the ambient dose have similar forward peaking characteristics in the lab frame with a reduction by an order in the backward angles.

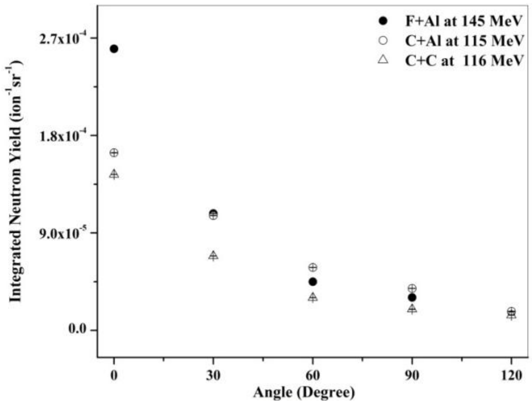

Fig3. Angular distribution of integrated neutron yield from the various systems

Table 1. Angular distribution of the neutron ambient dose from the various systems.

System / Angle	C+Al at 115 MeV (μSv/nA/h)	F+Al at 145 MeV (μSv/nA/h)	C+C at 116 MeV (μSv/nA/h)
0°	84.31	53.39	47.63
30°	34.73	34.23	22.30
60°	14.29	18.28	9.55
90°	9.56	12.08	6.11
120°	5.46	5.50	4.40

The integrated yield and the doses are the source term required for carrying out the shielding calculations for the accelerator facilities. The angular distribution is also important for optimizing the shielding.

References

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