Angular distribution neutron yield from 115 MeV ^{12}C incident on a thick ^{27}Al target

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Introduction

Neutron dose measurement in particle accelerators is non-trivial due to the presence of high energy mixed radiation components, anisotrpic emission, pulsed nature and the high fluence rate. The information however is important for radiation protection practices. In radiation therapy, the secondary particles generated during the treatment will further interact close to the tissue location and is now established as a cause for manifestation of latent cancer [1]. The study of the secondary particle yield is thus critical in treatment planning. Since heavy ions, (particularly carbon) are being widely used in therapy, such information becomes important.

FLUKA [2] Monte Carlo code is widely used for estimating the secondary particle emission and radiation treatment planning including heavy ion therapy. The secondary particle yield obtained from the code has been benchmarked at higher projectile energies. However, insufficient data at low incident energies has limited such exercises to just a few. The BME model [3], widely used to calculate the secondary particle emissions from pre-equilibrium (PEQ) reactions using heavy ion projectiles has been recently implemented in FLUKA using the Monte Carlo approach [4]. The implementation is expected to have considerable importance in various applications, including radiation protection and therapy.

In this work the angular distribution of neutron emitted from a thick Al target bombarded by carbon projectiles is studied. The results are expected to be a benchmark point for the FLUKA calculations. The preliminary results from the experiment, FLUKA simulations and PACE [5] calculations are presented.

Experiment

The experiment was carried out at the 15 degree beam line in the linac beam hall-1 of the BARC-TIFR Pelletron-linac accelerator facility at Mumbai. A 3 mm thick Al target was mounted on an electrically insulated 30 cm long drift tube for secondary charge collection and accurate current integration. The target was machined in the shape of a hemisphere to reduce the attenuation of neutrons emitted in the lateral directions. Five EJ-301® liquid scintillators (SCIONIX make) were placed at 1.5 m from the target at 0°, 30°, 60°, 90° and 120° with respect to the beam direction. The anode signal from the detector was fed to a Mesytec® MPD-4 n/γ discriminator module. The energy and a pulse shape discrimination outputs from this module were acquired as two parameters. The time of flight information was acquired as the third parameter. The RF signal from the buncher was used as the stop signal while the detector event was used as the start signal for the time of flight measurements. A separate BaF_2 detector was placed close to the target to derive the timing information of the beam bunch. A total of fifteen parameters from the five detectors were acquired in a list mode by the lamps data acquisition system. Since the measurements were singles in nature, the scattered component was estimated separately by means of shadow bar consisting of 30 cm iron followed by 30 cm of high density polyethylene.

Results and discussions

A typical n-γ pulse shape discrimination spectrum is shown in figure 1. Good discrimination (Figure of Merit = 1.3) was obtained as can be seen from the figure. In figure

2, a typical time of flight spectrum obtained is shown. The FWHM of the beam bunch as measured by the BaF_2 detector was 0.6 ns, which translates to an energy uncertainty of less than 10% at about 20 MeV of neutrons.

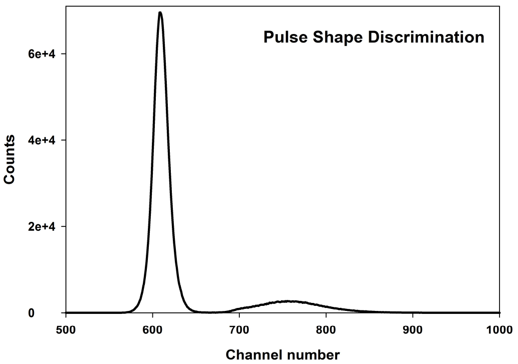

Fig. 1 A pulse shape discrimination spectrum obtained from the MPD-4.

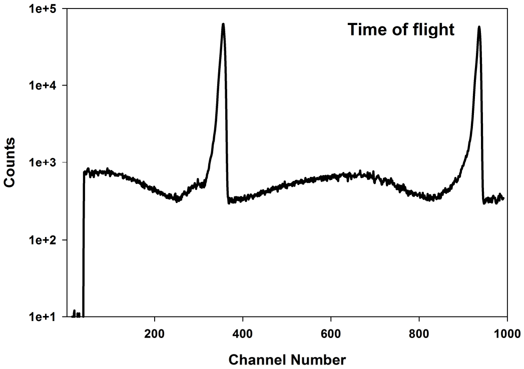

Fig. 2 A time of flight spectrum in a semi-log scale.

The energy integrated angular distribution of the neutron yield obtained is shown in figure 3. The experimental results (open circles) indicate an approximate exponential behavior. The closed circles are results obtained from FLUKA simulations with 120 MeV ^{12}C projectiles incident on a 5 mm thick Al target while the triangles are results obtained by PACE [5] calculations carried out for thick target [6]. The FLUKA results are higher than the experimental results by a factor of about 2 in the forward and about 3-4 times at the backward angles. The PACE calculations are lower than the experimental results by a factor of about 2 in the forward angles and about 3 times at the backward angles. Since the nucleus-nucleus interactions and the BME model are invoked only at 10 MeV/amu and above in FLUKA, the calculations were carried out at a projectile energy that was slightly higher than that used in the experiment. Thus the FLUKA results are higher than the experimental value. PACE on the other hand does not consider any pre-equilibrium (PEQ) effects and the results are based on evaporation calculations alone. At the projectile energy used in this work, some PEQ effects may also contribute to the total neutron yield and could be the reason for the lower values obtained by the PACE code.

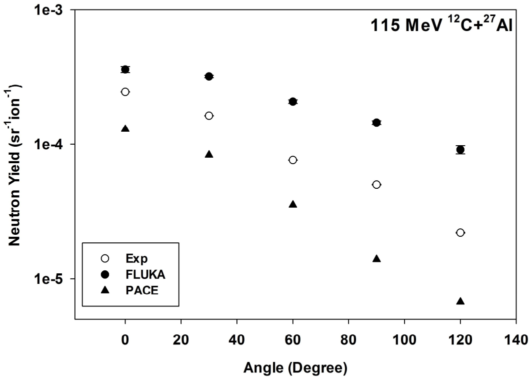

Fig. 3 The energy integrated angular distribution of the neutron yield obtained from 115 MeV ^{12}C projectiles incident on a thick Al target. The open circles are experimental data, closed circles are simulation by FLUKA and the triangles are PACE calculations.

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