Thick target neutron and gamma yield distribution from 5.6 MeV proton induced reaction

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Introduction

Double differential neutron and photon yield measurements from thick targets constitute the source term for estimation of radiation field parameters in accelerators. This also helps to validate nuclear reaction model codes, use of which is indispensable in the absence of experimental data. Moreover, as the thick target measurements are superposition of thin target data, they provide insight into the reaction mechanism involved. Low energy proton induced reactions are studied in detail for various reaction parameters, but inclusive measurement of neutron and photon yield distribution is scarce. Nuclear reaction model code EMPIRE [1] is used for determination of inclusive as well as exclusive energy spectrum of neutrons and photons in reactions induced by protons upto 200 MeV. In this work we have measured the energy distribution of neutrons and gammas at some angles in 5.6 MeV proton induced reactions on Al and Ta. We also compare the measured data with the calculations of EMPIRE code.

Experiment

The energy distributions of neutron and photon yields from 5.6 MeV proton incident on thick Al and Ta targets were measured at 0^o, 30^o, 60^o, 90^o with respect to the incident beam direction. The experiments were carried out at Folded Tandem Ion Accelerator (FOTIA) at BARC, Mumbai. The targets are thick enough to stop the projectiles, but scattering of neutrons is negligible. This makes measurements in the extreme forward angles possible which allow a good test of the nuclear reaction model codes. Neutrons were detected with a NE213 liquid scintillator detector while gamma rays were detected with a BGO and a NaI detector. The detectors were kept at a distance of 1.0 m from the target. For the events recorded by the NE213 detector, pulse shape discrimination was employed to separate the neutrons from photons, and pulse height unfolding was used to measure the neutron energy [2].

EMPIRE Calculations

EMPIRE 2.19 [1] is a nuclear reaction model code which calculates preequilibrium emissions employing different models and evaporation using Hauser-Feshbach formalism. Emission of gamma ray, proton, neutron, alpha particle and one light ion can be considered. Level density of the residual nucleus can be calculated using different formalisms depending on the projectile type and energy. We have used Gilbert Cameron level density option.

Results and Discussions

We have compared the measured energy distribution of photons and neutrons with the calculations of EMPIRE. As EMPIRE gives energy distribution only for the emitted particles in the CM frame, we have assumed an isotropic emission in CM frame and then transformed the values to the laboratory frame. In figure 1, we have compared the experimental and calculated photon emission from p + ^{181}Ta at 60^o. Here we have shown the relative emission normalized at the peak value for the photon spectrum. From the comparison, we see that the low energy peak in the measured spectrum is at a lower energy by around 100 keV than that in the calculated spectrum. The higher energy peak is not reprodu-

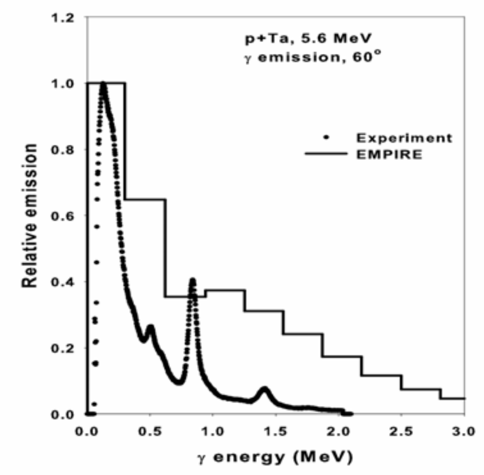

Fig. 1. Comparison of measured and calculated γ energy distribution in 5.6 MeV p + ^{181}Ta at 60^o.

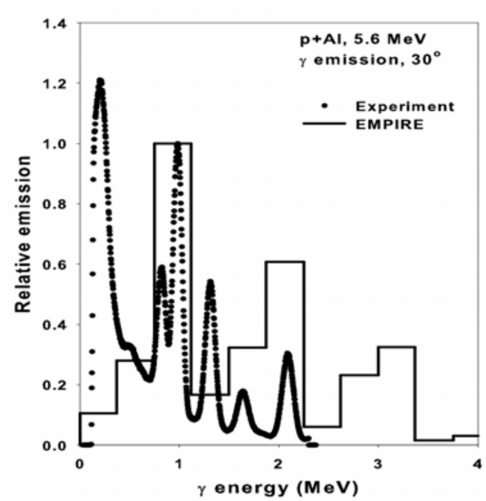

Fig 2. Comparison of measured and calculated γ energy distribution in 5.6 MeV p + Al at 30^0.

ced by EMPIRE. In figure 2 we have shown the comparison of measured and calculated relative photon emission at 30^o from p + Al at 5.6 MeV. Our comparison shows that the EMPIRE calculations do not reproduce the lowest energy peak at around 300 keV in the measured spectrum. At higher energies, the adjacent peaks are not resolved in the calculated spectrum.

In figure 3, measured and calculated energy distribution of neutrons at 30° from 5.6 MeV p+ ^{181}Ta reaction are compared. From the figure we see that the yield at evaporation peak is reproduced by the calculations, but at higher neutron energies measured yields are underpredicted. This discrepancy may be attributed to the statistical uncertainty in the measured counts and resolution of the detector. The level density also plays an important role.

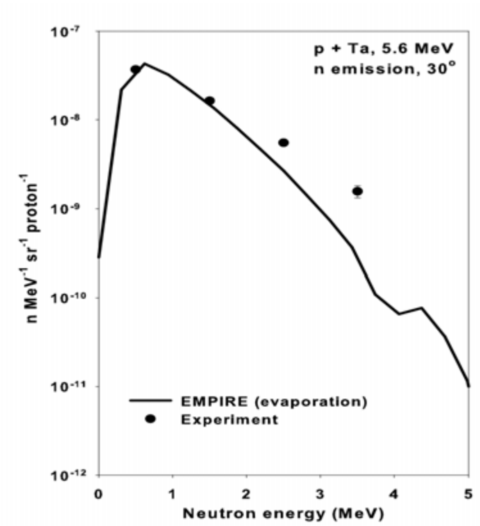

Fig.3. Measured and calculated energy distribution of neutrons in 5.6 MeV p + ^{181}Ta at 30^o.

Conclusions

Neutron and photon energy distribution at some specific angles from 5.6 MeV proton induced reactions on Al and Ta thick targets have been measured. The measured data are compared with the calculations of EMPIRE code. Our comparison shows that though it gives an approximate estimate, EMPIRE could not reproduce the data well at this incident energy.

Acknowledgement: The authors gratefully acknowledge all the support provided by the FOTIA group and others from NPD, BARC.

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