Measurement of Neutron Yield and Angular Distribution for Thick ^{nat}Li(p, n+x) Reaction

H. Kumawat[1]*, R.G. Thomas[1], C. Yadav[1], R.K. Choudhury[1], S. Kailas[1], C. Sunil[2], S.P.C. Varma[3]
[1]*Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA*
[2]*Health Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA*
[3]*Center for Excellence in Basic Sciences, University of Mumbai, Mumbai-400098, INDIA*
** email: harphool@barc.gov.in*

Introduction

The low energy accelerators have been used to produce intense neutron flux for various applications employing lower threshold reactions involving light targets. Among those p+ ^{7}Li,^{9}Be,^{13}C, D+D,T are the popular ones. D+D and D+T can provide mono-energetic neutrons with hundreds of keV energy deuteron beams. Boron neutron capture therapy boosted the use of ^{7}Li as target material which has large cross-section at proton energy of 2.25MeV. Several designs were made to cool these kinds of targets at higher beam currents to fulfill the neutron flux requirements of ~10^9n/cm^2/s. With the availability of higher current in the accelerators this target can be used in several other applications like neutron induced cross-section measurement, neutron time of flight, isotope production for medical use, condensed mater research etc. In the present work we have measured the total neutron yield for thick Lithium target up to 5.5 proton energy using BF_3 counter. Angular distribution of the neutrons at 4.5 and 5.5 MeV also measured to investigate the feasibility of a neutron time of flight facility at FOTIA.

Experimental details and measurements

The details of the BF_3 neutron counter are given in one earlier paper in this symposium. The neutron yield for 5mm thick natural lithium target is measured and compared with the other experimental data [1, 2] as shown in Fig.1. The data are in close agreement and verifies the 3% efficiency of the detectors measured previously. The measured angular distribution of the neutrons is available up to 2.25MeV proton energy only where resonance occurs [3]. Although, data for partially thick targets also available for higher energies which are of no use because they are very different from that of the infinitely thick targets. Three cylindrical liquid scintillator detectors of dimension 5cm×5cm were used. The angular distribution up to 135° was measured in 15° interval.

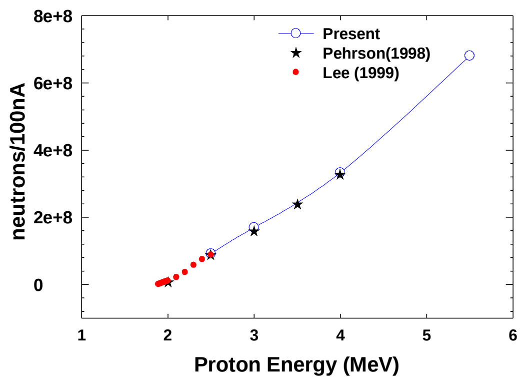

Fig. 1 Neutron yield from a 5mm thick natural Lithium target for proton energies from 2.5 to 5.5 MeV. The other experimental data [1, 2] are also plotted for comparison.

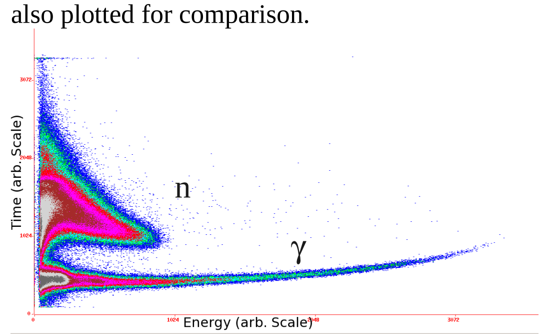

Fig. 2 Neutron gamma 2-D spectrum from 5.5 MeV proton beam interacting with thick lithium target.

The efficiency of the detector was close to 30% and threshold was around 150keV. The spectrum is shown in Fig.2 where clear separation of the neutrons with gammas is visible. In this experiment we have measured the relative yield of the neutrons and normalized it to the total neutron yield obtained from the BF_3 counter. The relative neutron yield for 4.5 and 5.5MeV proton energies are plotted in Fig.3. The neutron yield at 0° is one order of magnitude higher than the yield at higher angles.

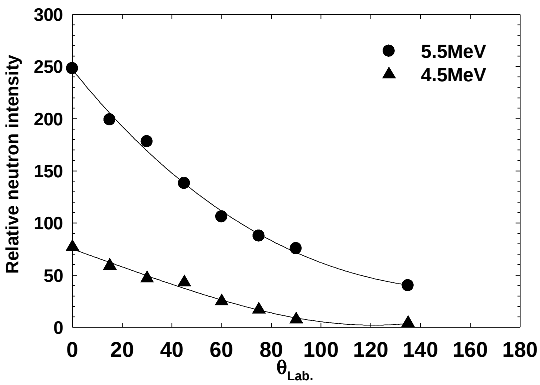

Fig. 3 Angular distribution of neutron yield from thick Lithium target from 4.5 and 5.5 MeV proton energies. The statistical error in the data is less than 0.1%.

Future plan

The neutron induced cross-sections are planned with thick lithium target neutron generator cooled with water. The feasibility of neutron time of flight at 0° is estimated as shown in Table 1. The neutron yield, flight time and resolution were calculated at 2m flight path. The bunching efficiency is assumed to be 60% with 2-harmonic buncher. The bunching period required is 200ns to cover neutrons from 500kev to 5MeV. The lower energy limit can be shifted to 0.2-0.3MeV to get the maximum neutrons. The bunch width is assumed to be 1ns and no electronic spread is assumed due to availability of sub-nano second electronic modules in the present time which might degrade the resolution by factor of two in the past time.

Table 1: Neutron flux, flight path and energy resolution

Total neutrons /500nC	Neutrons/cm2/s at 2m
3.40E+09	At 0 degree 5.4E+04
60 % efficiency	3.24E+04
E_n	500-5000 keV
Time of flight	204-65 ns
Energy resolution $\Delta E/E=2\Delta T/T$	0.98 – 3.1 ns (5 -155 keV) 70 keV for 1MeV

Internal recovery target inside a Fixed Field Alternating Gradient (FFAG) storage ring is partially worked out to increase current of the FOTIA by 1000 time. This will help to increase the neutron yield by similar factor and the TOF with other medical facility will be more feasible.

Conclusion

The neutron cross-section measurement is quite feasible with the water cooled lithium target. The neutron time of flight facility might be built in future with the available facility by placing a buncher just after the ion source at 10keV extraction point. Future facility can be also built using internal recovery target in a storage ring.

References

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