Setting up and characterization of 4π -BF_3 Neutron Counter

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

Introduction

Measurement of total neutron production cross-section along with neutron multiplicity is a subject of interest from the very discovery of neutron in 1932. Neutron induced reactions are important in nuclear and astrophysics research. Neutrons play an extremely important role in many applied fields ranging from condense matter research, boron neutron capture therapy [1], neutron radiography, cargo scanning to power production through fusion and fission reactions. Neutron being a neutral particle is detected mainly by passive techniques either by nuclear reaction or recoil energy measurement of the charge particles in elastic scattering. ^{3}He, ^{6}Li, ^{10}B and fissile materials are the candidate materials for their detection due to their large cross-section at low energies. The neutrons are first moderated and captured further. In the process of moderation the neutron energy information is lost because of this these detectors are basically called counters. Efficiency decreases as neutron energy increases. The proton recoil (pulse height) and time-of-flight are other techniques to get the energy information.

In this paper we describe the refurbishment and characterization of a 4π-BF_3 neutron counter. Almost flat efficiency of the outer set of detectors is observed. This counter was extensively used for the measurement of (p, n) [2] cross-sections in the 80's. The counter is made operational with making of new beam line and new electronics. Details are given in next section.

Experimental setup

The front and side view of the 4π-BF_3 neutron counter setup is given in Fig. 1. This counter consists of 12 cylindrical BF_3 gas (pressure ~ 0.8atm, 90% enriched) proportional detectors of 46cm long and 5cm dia. The outer brass wall works as cathode and the central tungsten wire of 50μm as anode. The detectors are mounted symmetrically in two concentric circles of dia. 16cm and 21cm inside a big block of paraffin. Each circle consists of equally spaced 6 detectors. The neutron background from outside is shielded with 7cm paraffin +1.25cm boric powder + 2mm cadmium. In this way, neutrons are first moderated and later captured by boric powder and cadmium. There is a 5cm hole up to the center of the counter for beam pipe entrance and 10cm hole from the target access side which has to be blocked by a paraffin plug after mounting the target.

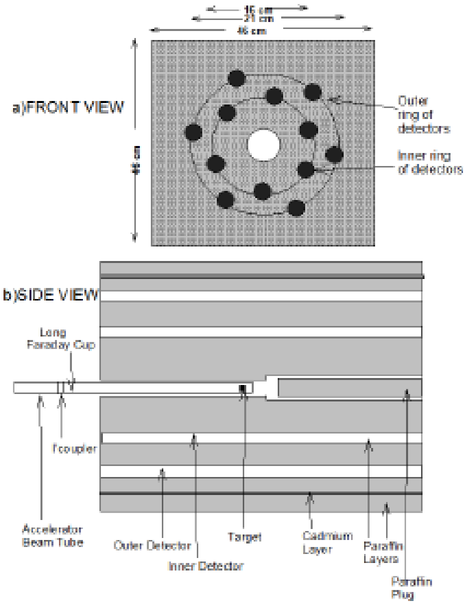


Fig. 1 A schematic diagram of 4π-BF_3 neutron counter setup a) front, b) side view.

The new beam line is constructed with three collimators of opening 2, 2, and 3mm dia. In the first stage, the collimators were made of steel which were replaced with Tantalum ones due to large background in steel. The thick tantalum backing of the target also gives significant neutron background due to this reason we have replaced the collimators and target backing with Aluminum which is having 5.8MeV threshold for neutron production compared to 0.92MeV for Ta. The neutron reaction with boron detector can be given as follows.

$$ {}^{10}_{5}B + {}^{1}n \longrightarrow {}^{7}_{3}Li + \alpha_0 + 2.794MeV $$

$$ {}^{10}_{5}B + {}^{1}n \longrightarrow {}^{7}_{3}Li^{*} + \alpha_1 + 2.314MeV $$

$$ {}^{7}_{3}Li^{*} \longrightarrow {}^{7}_{3}Li + \gamma + 480keV $$

Due to large 'Q' value, significant amount of ion pairs are formed which give quality signal to process further.

Characterization

All detectors were tested individually to get the operating voltage and pulse characteristics. It was observed that operating conditions were similar for all except 2 detectors. The outer set ring detectors were connected with common high voltage power supply through one pre-amplifier. Similarly the inner set was connected through one HV + pre-amp. unit. The operating voltage of 1800volts was set using plateau curve with the help of 10mCi Am-Be neutron source. The signal was processes through LAMPS data acquisition system. The spectrum is given in Fig. 2 which has a small kink of gamma ray at lower channels. The current was measured using ORTEC current integrator from a long (to count the emitted electrons) faraday cup to get the real counting of positive proton beam.

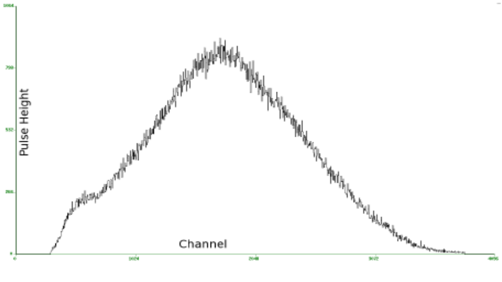


Fig. 2 Neutron spectrum from outer set of BF_3 detectors.

Efficiency measurement

The main aim of this kind of counter is to get integral neutron counts independent of neutron energies. The LiF target of thickness ~200µg/cm^2 on tantalum backing was irradiated with proton beam of energies from 1.8 to 5.8MeV from FOTIA accelerator facility. The measured cross-sections from EXFOR database were used to get the efficiency of the counter. An almost flat response was observed for outer set of detectors and the efficiency amounts to be ~3%. The efficiency curve is shown in Fig.3.

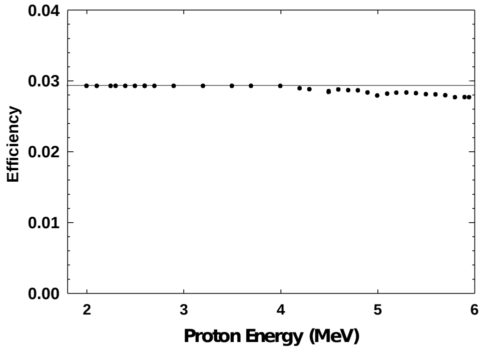
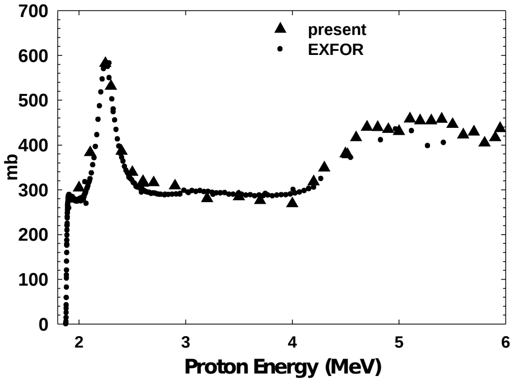


Fig. 3 Efficiency of the outer set of neutron detectors.

The excitation function for the ^{7}Li(p,n) is given in Fig.4 where resonance is observed at 2.25 proton energy.



The setup will be used for the integral neutron cross-section and neutron multiplicity measurements in near future.

References

[1] Y. Morii, Nucl. Instr. Meth. Phys. Res. A562, 591(2006).
[2] S. Kailas et al. Phys. Rev. C 12, 1789 (1975).