Online Monitoring of Fast Neutron (DT/DD) at Purnima Neutron Generator

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Introduction:

A neutron generator (NG) at Purnima Labs, BARC has been developed for DT accelerator driven zero power subcritical (ADSS) system. Subcritical core of ADSS will be coupled to the NG for benchmarking experiments. Kinetic parameters of ADSS such as K-source, flux, power etc depends on this external neutron source strength injected to the core. However the neutron emission rate of NG does not remain stable throughout its operation. In view of this a reliable, precise and online monitoring of NG's neutron emission rate is required.
An online neutron monitoring system based on associated particle method [1] has been designed, developed and installed at NG. The monitoring unit consists of an ion implanted planar silicon detector, placed inside the drift tube of NG at an angle with respect to D^+ beam direction. A series of experiments were carried out with increasing neutron yield to optimize the position of detector such that it has sufficient counting statistics and minimum pileup. A complementary calibration procedure for validating these results based on activation technique was also carried out with standard Cu foil. The reaction rate monitored with online monitor & foil activation technique were compared, their variations with the predicted (theoretical) results were within 16%.
This paper deals with the development and performance of online neutron monitoring system for DT and DD neutrons.

Keywords: Online neutron monitoring, DT/DD neutron, associated particle method,

Methodology:

In accelerator based neutron generator the neutron flux is critically dependent on its various operating parameters such as ion-source operating conditions, beam extraction potential, accelerating voltage, beam current, focusing, target aging etc, which tend to produce considerable drift. Unfortunately, direct measurement of the fast neutron (14MeV/2.5MeV)is difficult because of interference from sources like gamma rays due to interaction of neutrons with surrounding materials ,lower energy neutrons resulting from scattering or from the D(d,n)^{3}He reaction with the deuterons accumulated in the target. Associated particle technique (APT), is an alternative for online DT/DD neutron emission rate measurements in NG**.** In APT, integrated neutron output from the target (tritiated or deuterated) is determined by collecting the charge particle associated with neutrons emission (1) & (2) in a given small angle .In DT reaction alpha charge particle is counted

D + T = ^{4}He (3.5 MeV) + n (14.1 MeV) ------- (1)

The alpha counts accumulated during the irradiation period are normalized with time and solid angle, and then integrated over 4π to determine the total neutron yield [Benveniste and Zenger 1954].On the hand in case of DD mode two fusion reactions takes place within the target with equal probability:
D + D = ^{3}H (1.01 MeV) + p (3.02 MeV) ---------- (2a)
D + D = ^{3}He (0.82 MeV) + n (2.45 MeV) ---------- (2b)
The charged particles from both reactions (2) are collected with high resolution charge particle detector and the peak area under ^{3}He peak is measured for DD neutron yield calculation [1].

Experimental design and procedure:

The monitoring unit has been designed with passivated ion implanted planar silicon detector of 10x10 mm^2 active area and 300 μm depletion width. Silicon detector mounted on printed circuit board (PCB) was fixed inside a stainless steel (SS) cylindrical collimator of 10mm diameter. On active surface of detector a thin foil of B-10 (thick~ 1-2μm) or Al (~12um) was placed to eliminate the large background due to high yield of scattered deuterons. The detector assembly was installed inside the drift tube of PNG on a movable holder with a high vacuum (10^{-6} mbar) compatible connection. The geometrical lay-out of the system is shown in fig 1.

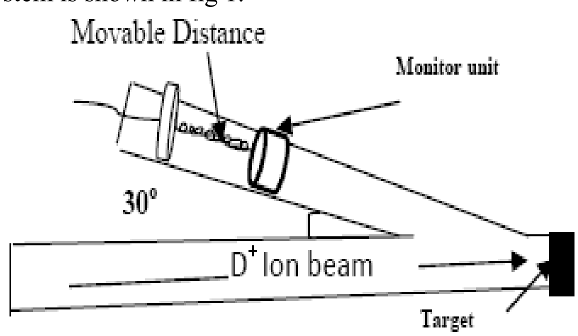

Fig1.Schematics of online neutron monitor

The signal from detector was processed through a charge-sensitive preamplifier to shaping amplifier to ADC/Counter with fixed bias voltage (25V). Pulse height spectra were recorded on MCA (4k) card (as shown in fig (2-5).

Performance of Monitor:

Detector was calibrated with Am-241 and Pu-239 alpha source before installing it with neutron generator. Charge particle spectrums were acquired with online monitor in DD/DT mode with varying neutron yield at various distances. Resulted spectrums are shown in fig (2-5).Total neutron yield was calculated [1, 2] with assumption of isotropic point neutron source. For comparison, neutron yield was also determined with the neutron activation technique using ^{63}Cu (n, 2n) ^{62}Cu /^{115}In (*n*, *n*')^{115m}In standard reaction[4] for DT/DD respectively. The results were found to be consistent with each other within the experimental uncertainties.

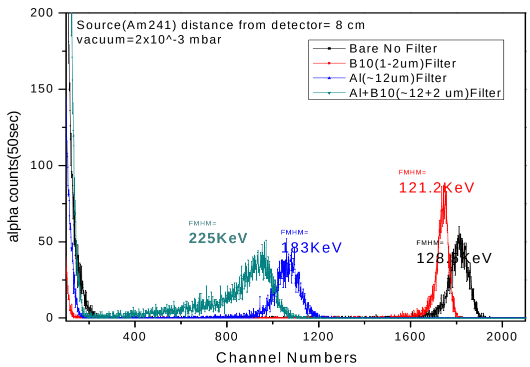

Fig2.Effect of different foil on alpha (Am241) energy as well as on detector resolution

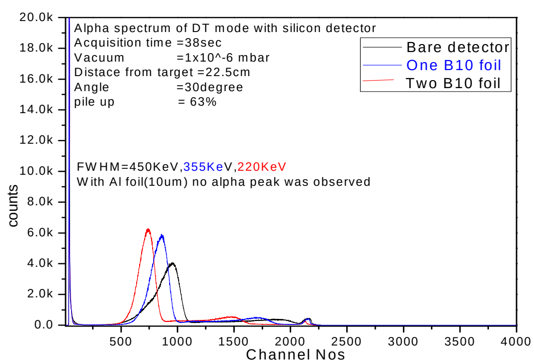

Fig3: Effect of different foils on DT alpha (3.45MeV) Energy

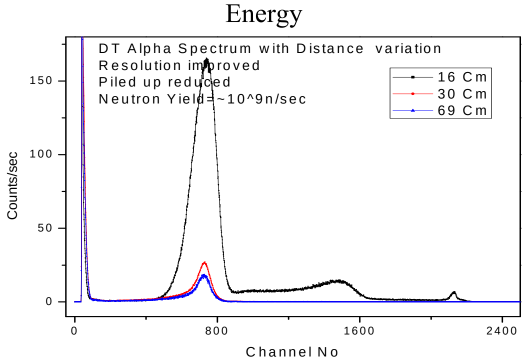

Fig4: DT Alpha spectrum with distance variation between target and monitoring unit

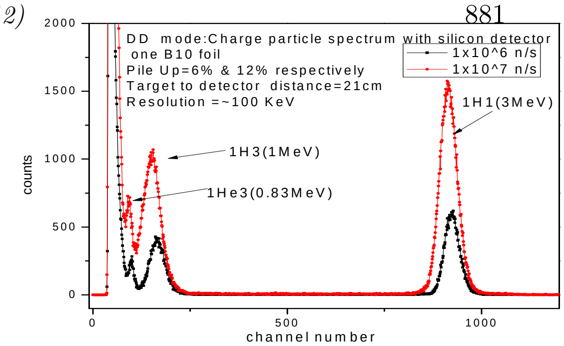

Fig5: Spectrum of charge particles produces in DD mode of NG

Result Discussion and Conclusion:

A neutron monitor based on associated particle technique (APT) was developed for online monitoring of DT/DD neutron emission rate (n/sec) at Purnima neutron generator (PNG) using ion implanted silicon charge particle detector. Performance of the monitoring unit was carried out successfully with increasing neutron yield of DT (10^5-10^9 n/sec) as well as with DD (up to 10^7n/sec). It was observed that increasing neutron yield increases the pile up of ~50% in counting. Hence monitor position was moved away from target till 69cm where monitor has measured sufficient counts and pile up has reduced to 10-16%. Acquired spectrums with monitoring unit shows clearly that DT alpha peak is far away from low noise signals and in case of DD mode all peaks of three charge particles are well resolved and distinguishable. Hence system can be used not only for DT but also for online monitoring of DD neutron. Such online monitoring system at PNG is useful and very important for ongoing project at department such as ADSS benchmark experiments, fast neutron radiography and for various other scientific applications. Also the system is independent of the neutron scattering due to surrounding or any experimental assembly set up near to NG system.
Further efforts are in progress to improve online neutron monitors' performance for higher neutron source strength (up to 10^{11}n/sec) measurement.

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