# Tagging of D-D and D-T neutrons using Associated Particle Technique at Purnima Neutron Generator facility, India

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## Introduction

Illegal trafficking of narcotics, explosives and other illicit materials concealed in cargo is an issue of grave concern to homeland security. Presently, non-intrusive inspections of containers are mainly based on X-ray or gamma-ray scanners, which provide the shape and density of the transported goods. Neutron based detection system are being actively explored worldwide as a confirmatory tool for cargo inspection. Fast neutron based techniques are used to detect illicit material by detecting the neutron induced characteristic gamma-ray. However, due to presence of large surrounding matrix, the signal-to-noise ratio is poor. In order to overcome this problem, associated particle technique can be used. This technique improves the signal-to-noise ratio by selecting the signals only from a specific location inside a large matrix.

## Associated Particle Technique

In this technique [1], suspect volume is interrogated with fast neutrons as shown in Fig.1. In D(T,n)α reaction, each neutron is emitted simultaneously,at approximately 180 degrees ("back-to-back") with alpha particle. By detecting the alpha particle using a position sensitive multipixel alpha detector, the direction and timing of the neutron produced is determined. When the neutron strikes any material, gamma rays are emitted due to fast neutron induced reactions.

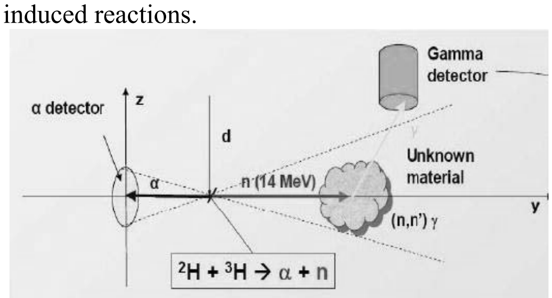


**Fig.1.** Schematic of Associated Particle Technique

The gamma ray detected in coincidence with the alpha particle allows the construction of time-of-flight (TOF) spectrum. The TOF allows to determine the position of the neutron interaction along the beam path, the 14 MeV neutron speed being approximately 5 cm/ns. If the gamma spectrum is properly analyzed or unfolded, then it reveals valuable informations about structure or chemical composition of the materials. The advantage of associated particle technique is that it can detect true signal in presence of large gamma background, thus increasing the signal-to-noise ratio.

In case of tritium there is only one associated charged particle while for deuterium target, two reaction channels occur with almost equal probability. Because of the presence of three charged particles it becomes very difficult to detect them separately and use associated particle techniques with D-D neutron by detecting only $^3$He.

D + D = T (tritium 1.01 MeV) + p (3.02MeV)

D + D = $^3$He (0.82 MeV) + n (2.45 MeV)

## Experimental set-up

Neutron tagging mechanism for D-D and D-T neutrons has been set up at the Purnima Neutron Generator[2] facility, BARC in collaboration with University of Padova, Italy. Accelerated deuterium ion beam is incident on Deuterium or Tritium target (target kept at 45° with respect to the incident beam).

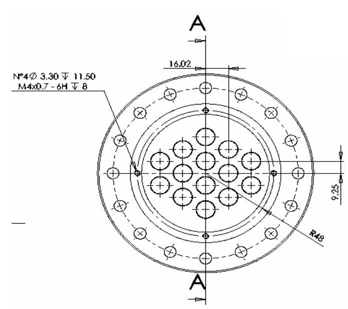


**Fig.2.** Schematic of YAP:Ce

In the experiment we used a plastic scintillator (2"x2") and a BGO detector (3"x3") for the detection of neutrons and gamma-rays respectively, and 14 YAP:Ce detectors for the detection of the associated particles.Each YAP:Ce crystal has a diameter of 13 mm and a thickness of 3 mm. The neutron detector was used to scan the correlated neutron beam profile; the BGO detector to acquire coincident gamma ray spectra. A 5-channel MCA card is used to see all spectra in the same window.

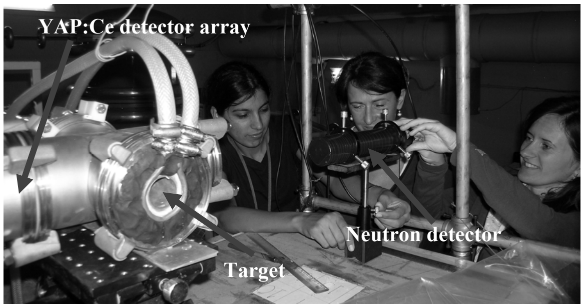


**Fig.3.** Experimental set-up showing the reaction chamber, YAP:Ce detector and the position of the neutron detector

## Results

Neutron beam profile was scanned (see Fig.4) corresponding to one of the YAP:Ce using neutron detector. The Full Width at Half Maximum (FWHM) of the tagged neutron beam at about 35 cm from the target is found to be of the order of 5 cm. The sample under investigation was subsequently placed at the position where the correlated neutron beam was maximum. The energy and time spectra for water sample with tagged 14 MeV neutron are shown in Fig. 5.The oxygen peak is visible ($E_\gamma$ = 6.13 MeV) in energy spectrum.

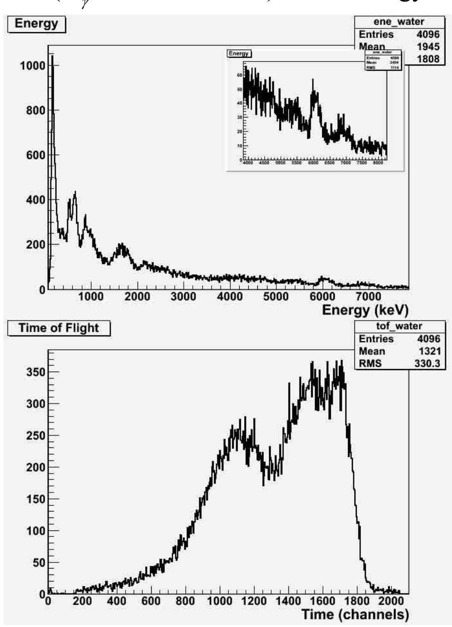


**Fig.5.** Energy and time spectra obtained with a sample of water

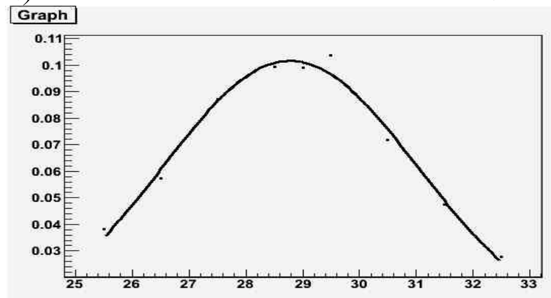


**Fig.4.** Neutron beam profile

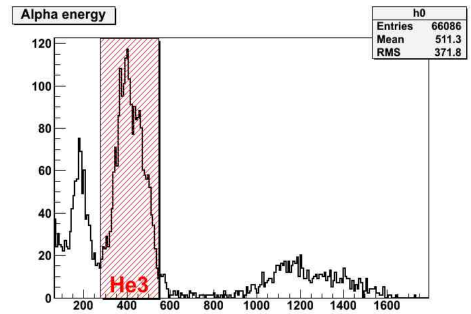


**Fig.6.** Associated particle energy spectra with D-D neutrons

In the case of the D-D reaction, the possible reactions are D(D,n)$^3$He and D(D,p)T. The energy of the reaction products are as follows:

$E_{neutrons}$~2.45 MeV, $E_{He\text{-}3}$~0.83 MeV, $E_{tritons}$~1 MeV, $E_{protons}$~3 MeV.

The energy spectrum obtained with a YAP:Ce detector is shown in Fig. 6. The response of YAP:Ce light yield depends on the different energetic particle. $^3$He is well distinguished from the other reaction products, by identifying the $^3$He peak in coincidence with the neutrons.

## Conclusion

We have successfully established associated particle technique experimentally with both D-T and D-D neutrons. We have presented some of the preliminary investigations in this paper. Our future work would concentrate on carrying out extensive experiments with different explosive simulants and illicit materials as well as benign materials.

## References

[1] B. Perot et al, NIM-B, Vol. 261, Issues 1-2
[2] T.Patel et al, NSRP-18, pg.91, 2009