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Identification of materials hidden inside a container by using the 14 MeV tagged neutron beam

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Abstract

The results of the experiments aiming to confirm the presence of explosive inside the container by using the 14 MeV tagged neutron beam are presented. Measurements were performed with paper, sugar, flour, fertilizer, tobacco and explosive (Semtex1a) as target material placed in the center of an empty container. Additional measurements were done with paper and explosive placed in the center of the container filled with the iron matrix of 0.2 gcm^{-3} density and with the paper target shielded by the 5.1 cm thick iron shield. The results of time of flight measurements and gamma ray spectra obtained by 14 MeV tagged neutron beam have showed that investigated materials could be well distinguished in the triangle plot with coordinates being the number of counts in the carbon peak, the number of counts in oxygen peak and the number of counts in transmitted neutron peak. By using such presentation we have been able to separate paper from Semtex1a, both hidden inside the 0.2 gcm^{-3} iron matrix. We have also been able to confirm the presence of 64.4 kg of paper behind the 5.1 cm thick iron shield corresponding to the range of 300 keV X-rays.

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Keywords: Explosive detection; Fast neutrons; Container inspection

1. Introduction

Method of inspection of cargo containers by using 14 MeV tagged neutron (TN) beam by detection of associated alpha particles has been recently discussed by several groups [1,2]. The aim of the proposed technique is to determine the chemical composition of the suspicious volume within the inspected container, which was previously identified by the X-ray imaging. Such a two sensors technique has been improved with the results promising it to become the powerful tool for container inspection ([3–5]). In the experiment presented, the 14 MeV tagged neutron technique has been used to confirm the presence of the explosive Semtex1a within the inspected container.

2. Methods and results

Fig. 1 shows the experimental set-up with the investigated target placed in the middle of the container. Target was the iron box dimensions $40 \times 40 \times 66\ cm^3$ and mass 9.2 kg, filled with the different materials in different measurements: 86.2 kg of graphite, 64.4 kg of paper, 78 kg of sugar, 75 kg of flour, 75 kg of fertilizer, 23.2 kg of tobacco, 100 kg of sand and 100 kg of Semtex1a. Four $3'' \times 3''$ NaI(Tl) were put at the transmission position in the cone of the tagged neutrons beam. Each detector was shielded with the 5 cm thick lead. The alpha detector (YAP:Ce) was 8 cm away from the tritium target. A quadratic collimator, 1.8 cm long, was placed in front of YAP:Ce

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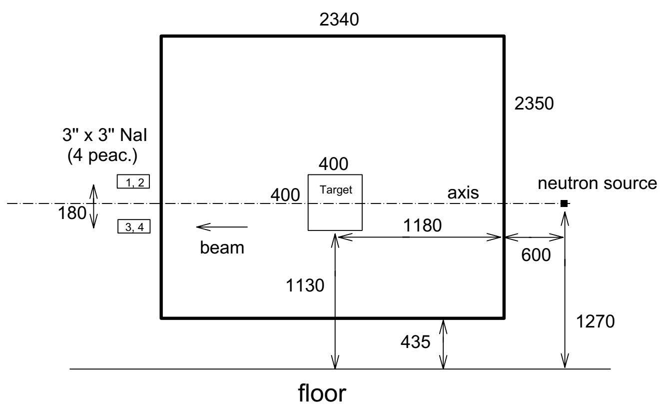

Fig. 1. Experimental set-up inside the container (all units are in mm).

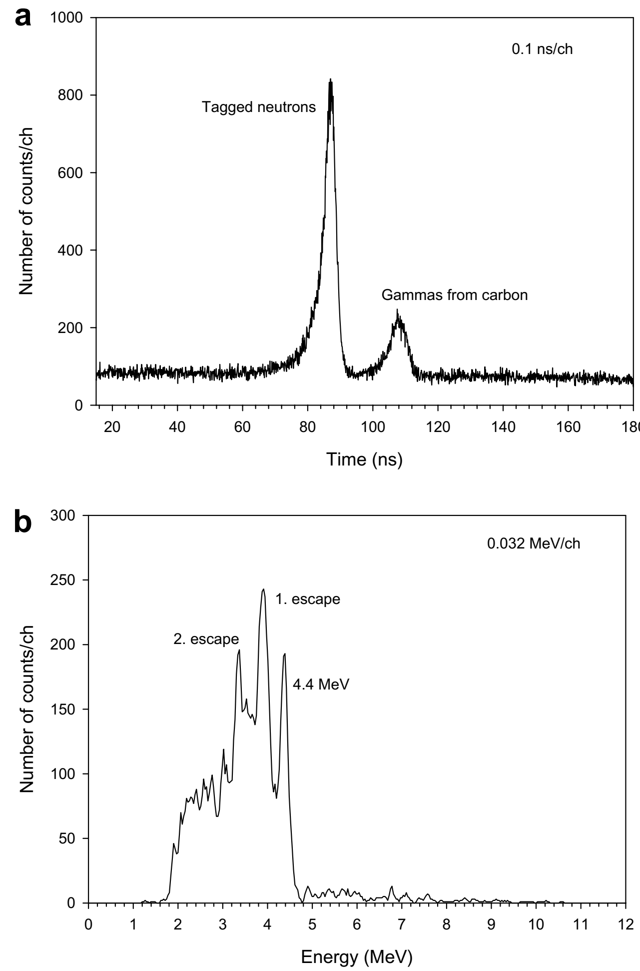

Fig. 2. The time spectrum (a) and the gamma ray spectrum (b) of the 86.2 kg of carbon. The gamma ray spectrum was obtained with the appropriate time window on gamma peak. (Target volume = $30 \times 40 \times 40$ cm^3, 2×10^8 tagged neutrons, Elapsed time = 17997 s, Average intensity = 0.3×10^7 n/s).

scintilator. For data processing, a standard NIM electronics was used. The four fast outputs from the 4-segmented PMT connected to the YAP were fed through the octal constant fraction discriminator and fan-in fan-out to the STOP of the time to amplitude converters (TAC). Outputs from the NaI(Tl) detectors were fed through the constant fraction discriminators and "or" logic units to the START of the TACs. Slow signals from the gamma detectors were fed through the amplifiers, quad linear gates and delay amplifiers to the acquisition system. Neutron beam intensity was kept low, 2.5×10^6 n/s in 4π, in order to avoid the problems experienced in previous experiments [6]. Iron matrix was made from iron boxes filled with the iron wire. The axis of the tagged neutron cone was directed through the container approximately parallel with the container bottom (see Fig. 1). Vertical and horizontal profiles of the tagged neutron beam were measured with the 7.62 cm times 7.62 cm NE-213 neutron detector in coincidence with the alpha counter. The experimental diameter of the neutron spot in the middle of the container was (37 ± 2) cm and (35 ± 2) cm for the horizontal and the vertical profile, respectively. As a QC/QA measures the carbon target was used. The 86.2 kg of graphite with the volume of $30 \times 30 \times 40$ cm^3 was put in the middle of the container. Fig. 2 shows the corresponding time spectrum (a) and the γ-ray spectrum (b) obtained with the appropriate time window and subtracted random background. The main peaks, corresponding to 4.4 MeV excited state as well as the first and the second escape peaks are clearly seen. Fig. 3 shows the time spectra from various materials taken with the same number of alphas. Integral number of the counts under the tagged neutron peaks gives the information on the densities of the various objects (and the surroundings matrices) while the time window set on the gamma peaks give the chemical compositions of the corresponding objects. All measurements with sand, sugar, tobacco, flour, paper, paper behind the 5 cm iron shield and fertilizer were done under the same conditions described in this article. The measurements with the explosive Semtex1a and paper in 0.2 g/cm^3 iron matrix were done under the similar conditions, described in [3], and appropriately scaled (scaling factor was found with the help of paper which was measured in both cases). Fig. 4 shows the dependence of integral numbers of TN on density for various materials. Density of the materials was found by dividing the mass with the volume of the iron box. Experimentally obtained data for empty iron box, tobacco, paper, fertilizer, flour, sugar and sand were fitted according to the following formula:

$$N = Ae^{-B\rho} \tag{1}$$

where A and B are fitting parameters, N is integrated number of the tagged neutrons and ρ is density. Appropriately scaled Semtex1a nicely follows the exponential fit. Semtex1a in iron matrix, paper in iron matrix and paper behind the iron shield does not follow the exponential fit as was expected. Fig. 5(a) shows the gamma ray spectra obtained for paper and paper behind the iron shield, respectively. Fig. 5(b) shows the gamma ray spectra obtained for sugar and sand, respectively. The gamma ray spectra obtained for flour and tobacco are shown in Fig. 6(a) and gamma